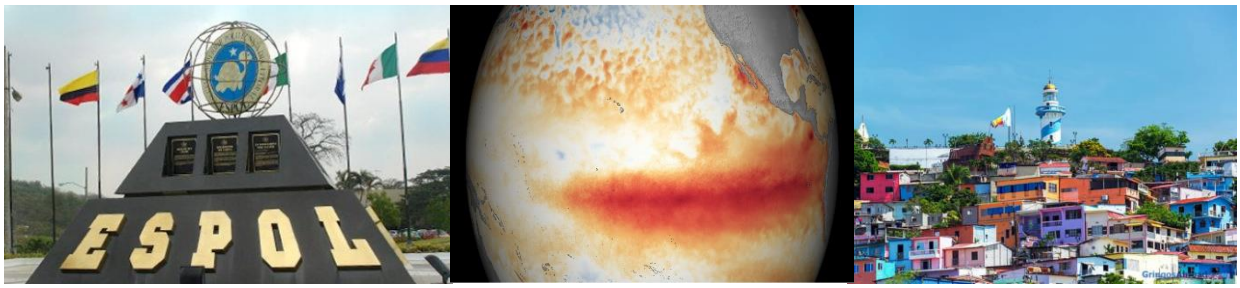

IV INTERNATIONAL CONFERENCE ON ENSO Guayaquil 2018

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Session 1. ENSO Observations

Oral presentations

Session 1. ENSO Observations
Keynote, 10:30 – 11:00, Oct. 16

The 2015-16 El Niño and Climate Change

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Key words: El Niño, Climate Change

An El Niño of surprising intensity developed in 2015-16, affecting patterns of weather variability worldwide. The event rivaled the 1997-98 El Niño, the strongest on record, in its magnitude and impacts. El Niño-related drought, flooding, extreme weather, and wild fires affected far reaching parts of the globe in 2015-16, with consequences for agriculture, power generation, economic development, and human health. The 2015-16 El Niño also affected Pacific marine ecosystems and fisheries, most notably contributing to record coral bleaching event that affected approximately 40% of the world's coral reefs. This presentation will describe the evolution of the 2015-16 El Niño, the physical mechanisms that gave rise to it, how it compared to previous El Niño events, and how well it was predicted by various forecasting centers. The question of whether anthropogenic greenhouse gas forcing is having an effect on the El Niño/Southern Oscillation (ENSO) cycle of warm El Niño and cold La Niña events will also be addressed.

Session 1. ENSO Observations
Keynote, 11:00 – 12:00, Oct. 16

Advances in paleo-ENSO: a past to future perspective

Kim M. Cobb[1], Pamela M. Grothe[1], Alyssa Atwood[1,2], Hussein R. Sayani[1], Nick Hitt[1], Gemma O'Connor[1], Giovanni Ligori[1], Niko Westphal[3], Chris C. Charles[3], Antionetta Capotondi[4], Jean Lynch-Stieglitz[1], Emanuele Di Lorenzo1, Larry Edwards[5], Hai Cheng[5], Daniel Deocampo[6], Tianran Chen[1], John Southon[7]

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Key words:

Earth system models project a shift towards enhanced hydrological extremes associated with ENSO variability under anthropogenic greenhouse forcing, but such a trend is not yet evident in instrumental records of ENSO temperature and rainfall patterns. The detection of a potential trend in ENSO properties is complicated by the short instrumental records of oceanic and atmospheric ENSO variations, especially given the high level of intrinsic variability in the tropical Pacific ocean-atmosphere coupled system. A variety of new paleoclimate reconstructions of ENSO reveal significant trends in ENSO-related variance from the pre-industrial era to the present, providing tantalizing evidence that ENSO properties may have already changed under anthropogenic forcing. Here we present one such reconstruction comprised of monthly-resolved modern and fossil coral oxygen isotope records from Kiritimati Island (2N, 157W), stretching discontinuously back to 7,000 years before present in segments of 9-316yrs in length (Cobb et al., 2013; Grothe et al., submitted). In this presentation, we focus on its interpretation in the context of i) output from long simulations of statistical and dynamical ENSO models, ii) output from an isotope-enabled version of the Regional Ocean Modeling System (iso-ROMS; Stevenson et al., 2015, 2018), and iii) an intensive observational campaign at Kiritimati across the very strong 2015-2016 El Niño event (O'Connor et al., in prep). Combining these tools to provide context for the observed shift in ENSO variance from the pre-industrial to present, we infer that one or both of the following two scenarios are reflected in the data: 1) that there has been an intensification of ENSO-related SST anomalies, and/or 2) that the hydrological impacts of ENSO-related SST anomalies have increased from the pre-industrial to the late 20 th and early 21 st centuries. The statistical significance of our findings rest on the inclusion of the 1997/98 very strong El Niño event in the late 20 th century ensemble of ENSO extremes – in that sense it is fair to say that the detection of a potential anthropogenic signal on ENSO properties requires the development of additional paleo-ENSO reconstructions data from other sites, as well as the inclusion of future ENSO extremes as they occur. Nonetheless, the available data, and associated findings, represent a compelling avenue for investigation with isotope-enabled coupled climate model simulations of historical and future climate change.

Session 1. ENSO Observations
Oral, 11:30 – 11:50, Oct. 16

ENSO complexity: a monitoring and forecasting perspective

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Key words: observing system,monitoring,prediction

A sustained and improved observing system the pillar for advancing the science of ENSO, the routine monitoring and the prediction capabilities. The integration of observations in ocean and atmospheric reanalyses has contributed to our ability to monitor and predict ENSO, which in turn has that has led to the awareness of its complexity. The events over the past few years clearly demonstrate that ENSO is a very varied phenomenon, modulated by decadal variability and climate change, triggered by subseasonal variability, connected with other ocean basins, and with a complex behaviour regarding its impact on the atmosphere. Capturing this complexity is a challenge for the current seasonal forecasting systems and for the ENSO forecasters alike. A forensic examination of forecast performance requires the separation between forecast error (model or initial condition) and intrinsic predictability limit. The lack of long observational records is one of the main handicaps for the correct attribution of errors in probabilistic forecast. The value of coupled data assimilation and century-long reanalyses for further understanding and prediction of ENSO will be discussed, as well the associated observational needs. Improved earth system reanalyses also provide the basis for additional observational metrics of ENSO, which should assist the identification of different events. Along this line, recent efforts to characterize the energetics of ENSO events based on reanalyses will be presented.

Session 1. ENSO Observations
Oral, 11:50 – 12:10, Oct. 16

El Niño diversity, cross-equatorial winds, and the intertropical convergence zone

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Key words: El Niño diversity, Intertropical convergence zone, Cross-equatorial winds, Decadal climate change

Over the past two decades, El Niño events have weakened on average and the corresponding sea surface temperature (SST) anomalies shifted westward towards the central Pacific. What has caused these El Niño changes remains uncertain and intensely debated. Furthermore, the intertropical convergence zone (ITCZ) that is ordinarily located north of the equator ceased to cross the equator during El Niño events, even during the extreme event of 2015, unlike in the 1980s and 1990s. Another prominent change in the tropics, largely overlooked before, is the strengthening of cross-equatorial winds in the eastern Pacific, which is robust across in-situ, satellite, and reanalysis wind data. We combine observational analysis with coupled model simulations, and show that cross-equatorial winds can effectively modulate tropical Pacific mean state and variability, contributing to El Niño diversity and affecting ITCZ shifts. Further implications for past and future climate change will be also discussed.

Session 1. ENSO Observations
Oral, 12:10 – 12:30, Oct. 16

ENSO variability in Galápagos corals: New insights on variability and trends

Julia Cole[1], Gloria Jimenez, Diane Thompson, Sandy Tudhope, Lael Vetter, Jessie McCraw, Emma Reed, Anson Cheung, Larry Edwards,

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Key words:

Paleoclimate records from tropical corals offer new views of Pacific climate variability that complement insights from instrumental data and models. Because they often originate from regions where direct observations are extremely sparse, coral records can fill gaps in our knowledge of recent ENSO-related variability, including trends and changes in spatial and temporal patterns. Here we present initial paleoclimate results from recent work in Galápagos, based on modern and fossil corals. We find a warming trend since 1940 in the northern islands that stands in contrast to more stable temperatures in the central archipelago; this pattern implicates the competing effects of increases in upwelling and wind strength versus radiative forcing. The northern islands host the only remaining, persistent coral reef ecosystems in Galápagos, and the identification of warming in this region highlights potentially unrecognized vulnerabilities to future climate change. A longer SST reconstruction from the northern Galápagos reflects stress-induced variations, along with substantial decadal variability that is expressed at sites throughout the equatorial Pacific. Finally, using fossil corals, we have developed geochemically based temperature reconstructions from multidecadal intervals centered near the years CE 1600 and CE 1740. These are generally comparable in range to modern analogs from similar sites; we are exploring whether these records indicate changes in seasonally constrained processes (e.g. upwelling). A larger, yet unanalyzed, suite of fossil coral cores from Galápagos offers the chance to develop records dating back over the last 4000 years and evaluate ENSO variability across several millennia. This site also provides an eastern Pacific counterpart to published central Pacific records that will enable us to evaluate past changes in the longitudinal SST gradient and assess changes in the spatial fingerprint of ENSO.

Session 1. ENSO Observations
Oral, 13:30 – 13:50, Oct. 16

Impacts of the Pacific Equatorial Undercurrent on the Northern Peruvian Coast

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Key words: EUC southern coastal branch, Southeast Pacific water mass, ENSO

In this study, the relationship between the Equatorial Undercurrent (EUC) along the Pacific equatorial line (0°N) and the oceanographic conditions along Paita Line (5°S) off Northern Peruvian Coast, are investigated during autumn season from 2000 to 2015. The results from the analyses along the equator suggest that the analyzed period can be separated into two regarding the EUC strength, the weak EUC period during 2002-2006, and the strong EUC period during 2007-2014. The former period is dominated mostly by the weak El Niño trend, whereas the latter is mostly in La Niña trend (ONI). During the strong EUC period, the 15°C isotherm and isopycnal at σ_θ=26.0 deepen off Northern Peruvian Coast, with stronger stratification, higher salinity and oxygen concentrations found in the subsurface layers compared to the weak EUC period. The lagged correlation analyses suggest that these EUC modulations, and their pulses that propagate eastward through EUC, are associated with ENSO and reach Northern Peruvian Coast from central equatorial Pacific (170°W) about 10 months later. Comparing the probability density functions of density and salinity between equatorial Pacific and off Northern Peruvian Coast, we propose a new definition of the EUC Southern Coastal branch (EUCSCb) water mass with the density range of σ_θ=25.25-26.5, and salinity range of 34.86 – 35.20.

Session 1. ENSO Observations
Oral: 13:50 – 14:10, Oct. 16

The impact of global warming on ENSO is clearer now than ever before

Scott Power[1], Christine Chung[1], Francois Delage[1], Sarah Perry[2], Shayne McGregor[2]

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Key words: ENSO,global warming,projections,consensus

Given that further human-forced changes in the Earth's climate system seem inevitable, the possibility exists that the character of ENSO and its impacts might change over the coming century. Although this issue had been investigated many times during the past twenty years, there has been very little consensus on future changes in ENSO, apart from an expectation that ENSO will continue to be a dominant source of year-to-year variability. Recent research, however, has revealed that projected changes in some aspects of ENSO-driven variability appear more robust than previously thought. For example: • There are robust projected changes in the spatial patterns of year-to-year ENSO-driven variability in both surface temperature and precipitation in both CMIP3 and CMIP5 models under various scenarios in which CO 2 concentrations increase during the 21st century. • The projections include an intensification of both El Niño-driven drying in the western Pacific Ocean and rainfall increases in the central and eastern equatorial Pacific. • Precipitation variability in the equatorial Pacific associated with ENSO is projected to intensify and move east, and the area of the globe with statistically significant ENSO teleconnections is projected to increase. • ENSO-driven variability in many regions around the world tends to increase by order 15-20%. An increase of this size, although important, is easily masked at the regional level by internally-generated multi-decadal variability. • The projected changes in ENSO-driven precipitation and surface air temperature variability are typically much smaller than projected changes in their mean-state values. • The frequency with which major disruptions to Pacific rainfall caused by ENSO is projected to increase over the 21 st century under RCP8.5, and humans may have contributed to the major disruption that we have already witnessed. • Although marked and sustained reductions in 21 st century anthropogenic greenhouse gas emissions can greatly moderate the likelihood of future major disruption, an elevated risk of occurrence appears locked in now, and for at least the remainder of the 21st century, and beyond. All of the above are projected despite the presence of continuing high uncertainty in projected changes in the amplitude of ENSO-driven SST variability. This apparent inconsistency arises because projected changes in ENSO-driven precipitation variability is primarily determined by a nonlinear response to surface global warming. Uncertain projected changes in the amplitude of ENSO-driven surface temperature variability play a surprisingly minor role.

Session 1. ENSO Observations

Posters

Session 1. ENSO Observations
Poster

The 1877-1878 Mega Niño and its social impact in Costa Rica, Central America

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Key words: ENSO, Social Impact, Central America, El Niño, Locusts

This work analyzes the social impact of the 1877-1878 Mega-Niño event in Costa Rica, through the comparison of data about droughts, rains, locust plagues and epidemics, collected from documentary sources of that time, with analysis of meteorological data. During the years 1877-1878, Central America was dominated by drier, warmer and windier conditions, like the ones observed during a warm El Niño event in the eastern equatorial Pacific. That scenario did not favor the formation of mesoscale convective systems on the Central American Pacific slope, nor the formation of tropical cyclones in the Atlantic basin, what is in agreement with the drier observed conditions. The present research also establishes the relationship between the plague of locusts that took place in Costa Rica between 1877 and 1878 with the Mega-Niño described (one of those that caused the greatest impacts on a planetary scale during the 19th century) from the analysis of the historical sources and the meteorological information corresponding to the period of study. According to the reports of that time, mainly contained in documents of the Congress, Governance and Municipal Funds of the National Archive of Costa Rica, this plague began to manifest itself in 1876 in the province of Guanacaste and in the following months it was largely extended of the Costa Rican territory, affected several populations within the Central Valley, the Pacific coast, the Northern Plains and to a lesser extent the Comarca de Limón. The atmospheric conditions prevailing with the presence of the 1877-1878 Mega-Niño favored the gregarization of these insects, which expanded the clouds of locusts that caused significant effects for agriculture due to the invasion of agricultural lands, so measures were taken to combat the presence of locusts and mitigate their impact on the Costa Rican society.

Session 1. ENSO Observations
Poster

What makes Protracted El Niño to last longer than Canonical El Niño?

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Key words: ENSO, Temporal evolution

Behavior and teleconnections associated with canonical El Niño event (~18-24 months;CE) and protracted El Niño event (~greater than three years; PE) is revisited in the present study. A careful look at seasonal mean of SST anomalies averaged over Niño3.4 region for the period 1980-2010 shows that El Niño episodes in the boreal winter of 1991 and 2002 do not turn into La Niña as CE events (1982-83, 1986-88, 1997-98, 2006-07, 2009-10). Unlike phase transition in canonical cases of El Niño followed by a neutral or La Niña event, El Niño episode in the year 1991 and 2002 continued as weak El Niño for another three years. In general drying associated with El Niño events over tropical landmass is stronger in PE events compared to CE events. A relatively weaker SST anomaly in PE events in equatorial Pacific Ocean (PO) leads to subdued convection compared to CE cases. A typical signature of CE events in tropical Indian Ocean (IO) is basin wide warming which is highly localized and relatively weaker in magnitude in PE events. PE events are found to be associated with almost no subsurface ocean propagation in equatorial PO. PE events are linked to more frequent westerly wind bursts of weaker intensity and smaller timespan compared to CE cases. Strong IO warming during CE events generates easterlies in the equatorial western PO which extend further towards eastern PO as upwelling Kelvin waves. This upwelling Kelvin waves shoals thermocline through Ekman divergence and cools the SST during decay phase of El Niño. Whereas in PE cases, Indian Ocean warming is insufficient to generate any atmospheric response in terms of easterlies and frequent WWBs in PE cases helps in maintaining positive SST anomalies in eastern PO.

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Insights into ENSO activity during the last two millennia from archaeological bivalve isotopic records from Peru.

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Key words: paleoclimate, Eastern Pacific, Bivalve, ENSO

In the context of anthropogenic global warming, it is essential to assess the current activity of ENSO in regard to its multicentennial pre-industrial history. In the south-eastern Pacific, where ENSO accounts for ~85% of the inter-annual variability of sea surface temperature and of coastal climate, observations are still extremely scarce, and virtually inexistent before the 16th century and the first historical documents. Here we extend the instrumental and historical record back to ca. A.D. 700 using shells of Mesodesma donacium from a long accumulation sequence of the Pachacamac archaeological site (12.3°S), combined with shell samples from three additional archaeological sites of the Inca period, located between 14 and 16°S. These sites are located on the coast south of Lima, within the influence of the intense Peruvian coastal upwelling. A modern shell sample was used as a reference to evaluate climate changes relatively to modern conditions. The sclerochronological and isotopic analysis of these shells provide us with estimates of SST, seasonality and ENSO activity from A.D. 700 to A.D. 1530. This dataset complements reconstructions based on historical documents and marine sediments to offer a more comprehensive view of ENSO multicentennial variability in the eastern Pacific that may constrain model simulations. It provides us with a reference baseline of ENSO behavior in Peru prior to anthropogenic impact on global climate.

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Balance of Moisture Transport in the North Coast during El Niño

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Key words: moisture flow, low level jet

In recent years it has been shown that the warming of the sea surface temperature (SST) in El Niño 1 + 2 region influences rainfall on the coast and northern highlands of Peru significantly. The increase in moisture content in this area is not only due to the arrival of Kelvin waves to South America but is also influenced by the evaporation and the entry of flows from the western Pacific Ocean and even by winds from the Caribbean, such as it was observed in the El Niño Coastal 2017 event, increasing significantly the moisture content at low levels of the atmosphere in the equatorial Pacific. In the present study, the El Niño 1982-83 and 1997-98 extreme events were analyzed in El Niño 1 + 2 region, which ranges from -10 ° S to 0 ° latitude and from 90 ° W to 80 ° W longitude, to determine the temporal and spatial variation of the moisture content in the lower levels of the atmosphere as well as to evaluate the transport of moisture in El Niño 1 + 2 region. To do this, data from the NCEP-NCAR Reanalysis 2.5 ° Lat / Lon were used. The results showed the presence of the Caribbean Low Level Jet in 925 hPa during the summer months and suggest the influence of this system in the increase of moisture content in El Niño 1 + 2 region. Likewise, a relationship was observed between the highest values of the ICEN coastal index and the moisture content in the atmosphere over the Niño 1 + 2 region during the months of December (Niño 1997-98) and April (Niño 1982-83).

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Presence of oceanic Kelvin waves during the 2017 coastal El Niño event

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Key words: Coastal El Niño, Oceanic Kelvin waves

In contrast to the El Niño events of 1982-1983 and 1997-1998, the coastal El Niño of 2017 was characterized, mainly, by the sudden increase in the Sea Surface Temperature (SST) in the Far East in mid-January 2017. The first investigations and reports related to this event rule out the presence of Kelvin waves as "triggers" of the event, although it is considered, according to information observed and simple models, that these waves were present during the summer of 2017 contributing to the increase in SST. In this study, we review the altimetry data (DUACS product) in the equatorial belt and the temperature data (ARGO floats) near to the north coast of Peru during coastal El Niño 2017 to verify the presence of Kelvin waves. The preliminary results show, three important cores of subsurface temperature anomaly off the Piura coast (approx.) with values above 6°C between the first and second week of March. Moreover, the intra-seasonal anomaly of sea level clearly shows the arrival of four waves Kelvin to the coast of the continent between January 2017 and September 2018 with anomalies of 3cm. Although the weakening of the trade winds had an important roll during coastal El Niño 2017, the contribution of oceanic Kelvin waves can not be ruled out. An analysis of the dynamic and/or numerical simulations near the coast is necessary to accept or discard the role of the oceanic Kelvin waves in this event.

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Is El Niño current part of the equatorial current system?

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Key words: El Niño begins, El Niño current

El Niño current was often mentioned in Peruvian historical documents dated in 1892, as a warm flow that appeared around Christmas time that, and brought a significant increase in sea surface temperature and precipitation in northern of Perú cost. This denomination of the current gave a name to what later would be recognized as a global ocean-atmospheric event of greater connotation in the equatorial Pacific, known as El Niño-Southern Oscillation (ENSO). Some contemporary authors, analyzing the ocean circulation in the eastern equatorial Pacific, mention a warm flow coming from the Panama Basin. This flow remains from December to April, when the southeasterly winds diminish, and northeasterly trades, or winds from the Caribbean, are more frequent and intense. A consequence of this wind pattern is the decrease of the pressure gradient between Central America and the equatorial zone. However, there are few references explaining the characteristics of this flow, namely its temporal or spatial variability, location, direction and the way it is integrated into the equatorial current system. Additionally, the name of "El Niño current" is rarely used when describing the equatorial circulation. Daily data series of absolute dynamic topography, SST, and winds, obtained from AVISO, OISSTV2, and ASCAT/QUICKSCAT respectively, were used in the study presented here to compute zonal and meridional geostrophic velocities and analyze the dynamics of El Niño Current. The time frame investigated is from 1993 to 2017, with a spatial resolution of ¼°. Preliminary results show that a monthly climatology of sea current speed gives evidence of a seasonal southern current of about 50 cm/s, appearing between December and April, and centered at 83 °W between 7°N and 2° N. This region is part of the cyclonic circulation of the Panama Basin. We have detected changes in intensity and length of this current with variability of wind, pressure gradient and sea temperature in scales lesser than monthly. In addition, El Niño current also shows a clear spatial and temporal variability on an interannual timescale. Acknowledgements: SSALTO/DUACS DELAYED-TIME LEVEL-4 SEA SURFACE HEIGHT AND DERIVED VARIABLES MEASURED BY MULTI-SATELLITE ALTIMETRY OBSERVATIONS OVER GLOBAL OCEAN DISTRIBUTED BY COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE (CMEMS). WIND PRODUCT IS OBTAINED FROM THE FTP SERVER OF INSTITUT FANC¸AIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER (IFREMER), FRANCE. IT IS DAILY AVERAGED WIND FIELDS AT A SPATIAL RESOLUTION OF 0.258 IN BOTH LONGITUDE AND LATITUDE.

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On the possible cause of distinct El Niño types in the recent decades

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Distinct El Niño types have been observed in the recent decades with warm anomalies in the eastern Pacific (Canonical El Niño, EL) and central Pacific (El Niño Modoki, EM). Among these, a basinwide tropical Pacific (TP) warming is seen during 2009 and recently during 2014. We carried out data analysis and numerical simulation experiments to understand the possible cause for different El Niño flavours. The results reveal that the co-evolution of ocean-atmospheric conditions are critically important. Stronger boreal spring (Mar-May) through summer (June-September) westerly wind anomalies (WWA), with relatively stronger ocean pre-conditioning can lead to EL, weaker ocean preconditioning and weaker WWA can generate EM, while stronger ocean preconditioning and weaker WWA can lead to basinwide warming pattern. The strength of the WWA is crucial in determining the strength of the ocean dynamic response and the thermocline displacements in the Pacific. The study has important implications for understanding the nature of El Niño in advance.

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Variability of Barrier Layer in the Equatorial Pacific associated with ENSO

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Key words: barrier layer, El Niño

We investigate the variability of the barrier layer (BL) associated with This study investigates the seasonal-to-interannual variability of the barrier layer (BL) associated with El Niño/Southern Oscillation (ENSO) using in situ temperature-salinity observations and simple ocean assimilation data (SODA). The comparisons with the BL derived from the in situ observations show that SODA successfully captures the variability of the BL in the Pacific warm pool. On seasonal timescale, based on the empirical orthogonal function (EOF) analysis, we identify that three seasonal leading modes of the BL along the equatorial Pacific are closely associated with the transition, resurgence and onset of ENSO, respectively. We also confirm that two interannual leading modes of the BL are related to different flavors of ENSO events. EOF1 mainly embodies a combined response to the central and east Pacific ENSO events while EOF2 is related to the central Pacific ENSO events. We especially focus on the contrast of the BL between east Pacific El Niño (EPEN) and central Pacific El Niño (CPEN). During EPEN, the abnormally thick BL appears in the east of the dateline. It follows the sea surface salinity front to shift zonally with the evolution of EPEN event, and propagates toward the central Pacific. It can be attributed to horizontal ocean advection, heavy precipitation and the downwelling Kelvin waves. In contrast, during CPEN, the abnormally thick BL is confined to the region between 160°E and 180°E around the SSS front without significant west–east displacement. It is mainly dominated by the local processes including Ekman pumping, precipitation, and zonal ocean advection. Different from the BL in the EPEN events, it has no evident basin-scale propagating signal. (ENSO) using in situ temperature-salinity observations and simple ocean assimilation data (SODA) in this study. The comparisons with the BL derived from the in situ observations show that SODA successfully captures the variability of the BL in the Pacific warm pool. On seasonal timescale, based on the empirical orthogonal function (EOF) analysis, we identify that three seasonal leading modes of the BL along the equatorial Pacific are closely associated with the transition, resurgence and onset of ENSO, respectively. We also confirm that two interannual leading modes of the BL are related to different flavors of ENSO events. EOF1 mainly embodies a combined response to the central and east Pacific ENSO events while EOF2 is related to the central Pacific ENSO events. We especially focus on the contrast of the BL between east Pacific El Niño (EPEN) and central Pacific El Niño (CPEN). During EPEN, the abnormally thick BL appears in the east of the dateline. It follows the sea surface salinity front to shift zonally with the evolution of EPEN event, and propagates toward the central Pacific. It can be attributed to horizontal ocean advection, heavy precipitation and the downwelling Kelvin waves. In contrast, during CPEN, the abnormally thick BL is confined to the region between 160°E and 180°E around the SSS front without significant west–east displacement. It is mainly dominated by the local processes including Ekman pumping, precipitation, and zonal ocean advection. Different from the BL in the EPEN events, it has no evident basin-scale propagating signal.

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External and internal origins of ENSO modulation revealed by Holocene corals and climate model simulations

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Key words: Holocene ENSO, coral paleoclimatology

El Niño-Southern Oscillation (ENSO) is the main driver of Earth's interannual climate variability. Paleoclimate records indicate reduced ENSO variance during the middle Holocene; however, the extent to which external forcing has driven past changes in the magnitude and characteristics of ENSO are matters of considerable debate. Here, we combine coral oxygen isotope (d18O) data from central Pacific corals with a suite of forced and unforced simulations conducted using the CSIRO Mk3L and GFDL CM2.1 climate system models. On millennial timescales, the coral data reveal a statistically significant increase in ENSO variance over the past 6,000 years. This trend is not reproduced by the unforced model simulations, but can be reproduced once orbital forcing is taken into account. Analysis of the forced simulations reveals that the increasing NINO3.4 SST variance arises from a weakening of the Asian summer monsoon circulation, and an associated weakening of the Pacific Walker Circulation, in response to decreased summer insolation. The picture is less clear on shorter time scales, and we explore further ENSO multi-decadal variations focusing on the apparent ENSO amplitude minimum at 3,000-5,000 years ago. We combine a 175-year-long coral d18O ENSO record from a 4,300-year-old coral with new d18O results from a ~300-year-long Porites sp. coral microatoll. Both corals were discovered on Kiritimati (Christmas) Island, an optimal ENSO 'centre of action' in the central tropical Pacific, and radiometric dating indicates that the corals have a 25-year overlap. Together, the unprecedented contiguous ~450 year-length of the combined results shows interdecadal modulation of ENSO amplitude. The results provide a robust baseline of intrinsically-generated ENSO modulation, against which to quantify the response of ENSO to past and future external forcings.

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Sea surface temperature inter-annual variability in the northeastern tropical Pacific and its relationship with El Niño and La Niña conditions

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Key words: El Niño and La Niña phenomena,Northeastern tropical Pacific

The analysis, monitoring, and prediction of the extreme phases of inter-annual variability of the tropical Pacific have been focused in the equatorial channel, in the Niño 1+2, Niño 3, Niño 3.4 and Niño 4 sectors. However, some situations with remarkable anomalies have been observed south and north of this channel in the tropical eastern Pacific, that have induced climate anomalies in several regions of South and Central America. In fact, southern of this channel, in front of the coast of Perú, it was detected special situation, which called El Niño-costero. As observed in the second half of 2014, it is possible that similar situations have been observed in the northeastern tropical Pacific, which may be the cause of climatic anomalies in Central America and northern South America that are not attributable to the phenomena of El Niño and La Niña recognized until now. To corroborate this hypothesis, the behavior of anomalies in the sector between 5°N-15°N and 80°W-120°W was analyzed. This article summarizes the results of this exploration.

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ENSO Indices for a Changing Climate

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Key words: index, climate change

The El Niño-Southern Oscillation (ENSO) is a complex, coupled, multi-dimensional phenomenon. In the face of this complexity, there is value in quantifying ENSO's strength and potential impacts by a single index. At present, many such indices are in use, ranging in complexity from mean temperature anomalies in a single patch of tropical water to the leading principal component of the coupled climate system. This variety of indices makes it difficult to compare the results from different studies. Also, none of the common indices simultaneously capture the effects of ENSO and the background climate state in driving atmospheric responses such as drought and flood in diverse areas of the globe. Most fundamentally, none of the indices in common use are robust to large-scale changes in the climate system.

This presentation describes a simple ENSO index based upon the difference in sea surface temperature beneath those portions of the tropical Pacific that are most subject to interannual ENSO-driven variations in outgoing longwave radiation and precipitation The specific index definition is based on optimizing the magnitude and robustness of the large-scale atmospheric response to the specification of the geographical areas used to define the index. The index is more suitable for historic ENSO time series than conventional indices because it is less sensitive to changes in the observing system. We compare the magnitude of correlations with and nonlinear responses in remote climate variability when ENSO is defined using the new index versus existing indices. We also investigate the applicability of this index to the ENSO-like phenomena simulated in global climate models in different climate states.

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Assessment of twentieth century reanalyses to represent ENSO impacts over the Tropical Atlantic and Ceará rainy season

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Key words: reanalyses, ENSO, Tropical Atlantic, Ceará

The use of long time series can provide a significant number of ENSO events giving more confidence in the representation of the main circulation patterns characteristic of this phenomenon. In this context, the role of reanalyses is paramount. Although reanalyses are very attractive to the climatic studies, it is necessary to know beforehand if they can represent the observed patterns. The present work aims to evaluate the climatic variability over the tropical north Atlantic (TNA) associated with ENSO and its influence over the precipitation extremes in Ceará, using the twentieth-century ERA 20C and NOAA 20CR reanalyses.

The study presents comparisons of atmospheric patterns associated with ENSO events between the period of 1979-2010. For each phase of ENSO, the anomaly composites of atmospheric and oceanic variables were constructed using ERA 20C, NOAA 20CR, satellite-era reanalyses (ERA Interim and NCEP-Reanalysis 2) and data based on observations (ERSST v.5, OiSST v.2 and Funceme).

As an important result, both twentieth-century reanalyses are able to capture, as the satellite-era reanalyses, the main features in the tropical Pacific representing the climatic system during ENSO years as well as its impact in the Tropical Atlantic, in agreement with previous studies. However, some differences were noted, as: 1) the NOAA 20CR differs from the other reanalyses in the representation of the 850 hPa wind anomalies intensity over the equatorial Pacific, since it indicates the existence of stronger anomalies over the central-west of the basin for both El Niño and La Niña composites; 2) over the tropical Atlantic, all the reanalyses indicate the existence of a omega anomaly dipole between 10°N and 10°S for both phases of ENSO, although this dipole is weaker in the NOAA 20CR; 3) in the ERA 20C 850 hPa wind anomalies composite of El Niño years, the weakening of the North Atlantic Subtropical High is less intense than in other reanalyses. Regarding the SST anomalies, ERA 20C proved to be a reliable reanalysis tool for climatic studies since it was able to reproduce its main spatial patterns over the tropical Atlantic when compared to the products based on observations. At last, the precipitation over Ceará during ENSO years was also well reproduced by ERA 20C, providing interannual variability similar to the observed and a small dry bias compared to the observed precipitation from Funceme. On the other hand, the NOAA 20CR had a poor representation of the interannual variability of the precipitation for ENSO phases and a dry bias greater than that of the ERA 20C.

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Spatial and temporal analysis of daily precipitation during the coastal El Niño 2017 in Peru

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Key words: Coastal Niño, Precipitation

The coastal El Niño 2017 can be defined like a climatic extreme event or hydrological extreme event, which triggered torrential rains in the basins of the central and northern coast, from Ica (-15 ° S) to Tumbes (-3 ° S), with daily accumulations comparable to El Niño 1982-1983 and 1997-1998. These rains generated 268 660 people affected and 1 229 461 victims, as well as the destruction of infrastructures and the interruption of communication routes in all regions.

Precipitations occurred during this event had a spatial displacement from south to north and temporary from January to March, which was due to the variation of the spatial position of the warm water pool and the prevailing meteorological factors during the occurrence of rains. In this research, three important rainfall periods were defined: the first one occurred in Ica region during the second half of January, where rains exceeded its 99th percentile threshold and even historical records of the last 40 years. The second one occurred from February to the first days of March in the regions of Lima and Ancash (central coast), where there were also extraordinary rains favoring the occurrence of continuous landslides, increasing in the flow of rivers and recovering dry rivers. These two periods of heavy rains were associated with the weakening of the trade winds of the south, the increasing of the north winds in the low and middle levels, intensification of the positive anomalies of sea surface temperature (SSTA), high precipitable water content in the atmospheric column parallel to the Peruvian coastline, high instability associated to SSTA and therefore an intensification of the sea breeze in the afternoon. Finally, the third period was located in the north of La Libertad to Tumbes, where heavy frequent rains occurred during March. These were highly influenced by the position of the second band of the Intertropical Convergence Zone, the wide SSTA (e.g. La Libertad recorded +10 °C of anomaly) and the divergent phase of the Madden- Julian in short periods.

According to the analysis of stations data from National Service of Meteorology and Hydrology (SENAMHI), it was found that the effect of the coastal El Niño was progressive, and it had three important moments according to where and when happening the most important daily accumulations. In turn, it was related to the oceanic conditions and atmospheric conditions typical of the rainy season.

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Enso Influence on the Precipitation Pattern along the Ecuadorian Coast

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Key words: ENSO, Ecuador, El Niño 1982-83, El Niño 1997-98, Oceanic Niño Index (ONI), El Niño Coastal Index (ICEN)

El Niño-Southern Oscillation (ENSO) refers to the warm (El Niño) and cold (La Niña) phases of an ocean-atmospheric event that originates in the tropical Pacific. ENSO events occur every two-seven years on average, each phase can cause changes in several oceanic and atmospheric parameters including temperature, precipitation and wind patterns. ENSO events originate in the equatorial Pacific Ocean, but their impacts are also felt in other regions of the planet through atmospheric teleconnections. ENSO events are linked to periods of drought in some areas and to heavy rains in others, affecting agriculture, and therefore, food security. In Ecuador, the most documented and well-known impacts of the El Niño phenomenon correspond to the episodes of 1982-1983 and 1997-1998 where there was an increase of 200-300% in the normal amount of total precipitation for the rainy season along the coast of Ecuador; with significant socio-economic impact: about 50% of losses in the fisheries and agriculture sectors and damage to infrastructure (transport, roads and bridges).

The objective of this work is to evaluate the influence of ENSO events on rainfall patterns along the Ecuadorian coast during the 1975-2016 period using the Oceanic Niño Index (ONI) and the El Niño Coastal Index (ICEN, acronym in Spanish). The study was conducted in the five most populated cities along the Ecuadorian coast: Esmeraldas, Manta, Salinas, Guayaquil and Machala. These cities were negatively impacted by the El Niño events of 1982-83 and 1997-98. The meteorological data was collected by the National Institute of Meteorology and Hydrology of Ecuador, anomalies and Sea Surface Temperature (SST) values were obtained through the website of the National Oceanic and Atmospheric Administration and the Geophysical Institute of Peru. In the five cities the correlation between precipitation and SST was evaluated.

The normal precipitation pattern for the period (1975-2016) was calculated and compared to Warm and Cold events that occurred within that interval using both ONI and ICEN indexes. A moderate positive correlation was observed between monthly total precipitation and SST (Region 1.2). It is concluded that the pattern of average precipitation during the period 1975-2016 in the Ecuadorian cities studied is different than the precipitation pattern during ENSO events as characterized by the ONI and ICEN indexes the reason is because these indexes use different ranges for the categories that define the intensity of the event and the warm/cold geographical conditions from which each of these indices arises. The precipitations under warm thresholds characterized by the ONI and the ICEN presented a behavior above the normal Ecuadorian pattern, while the precipitations under cold thresholds showed a behavior below the normal pattern.

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Uncertainty estimation of rainfall anomalies during ENSO in Colombia

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Key words: Uncertainty, Anomalies, ENSO, Tropical rainfall

Estimating uncertainty in hydro climatic anomalies (HyAns) is an understudied topic in Earth System sciences. In hundreds of studies, calculation of HyAns is taken for granted, and does not consider diverse error sources or the bias-induced error owing to interdependence in analysis of climate time series and, consequently, the ambiguity of the physical explanation of results. Here we quantify precipitation anomalies over Colombia (in terms of their sign, timing, and magnitude) and their interdependence with El Niño – Southern Oscillation (ENSO). Overall, the hydro-climatic variability in Colombia at inter-annual timescales is mainly controlled by the two phases of ENSO system: El Niño (warm phase) and La Niña (Cold phase).

We use four methods to estimate HyAns including: (a) HyAns based on the Traditional Annual Cycle or constant climatology (HyAns-TAC), (b) HyAns using F-filtering of the Annual Cycle by moving averages (HyAns-FAC), (c) HyAns by means of Singular Spectrum Analysis to determine the Annual Cycle (HyAns-SSAC) and, (d) HyAns by extraction of the Modulated Annual Cycle or variable climatology (HyAns-MAC) based on Ensemble Empirical Mode Decomposition (EEMD). Furthermore, we use Canonical Correlation Analysis (CCA) to illustrate the impact of HyAns' methods on the interdependence analysis of time series. We compare HyAns' methods as well as the differences in CCA by mean of Minkowski distances.

To that end, we use data from a reanalysis performed by Hurtado and Mesa [2014], which produced monthly precipitation fields for Colombia, spanning the period from 1975 to 2006, at a spatial resolution of 5 arc-minutes, in the region 5°S – 15°N and 80°W – 65°W.

Our results reveal manifold important aspects such as: (i) During the warm phase of ENSO (El Niño), the traditional HyAns-TAC method overestimates up to 80% the magnitude of precipitation anomalies in comparison with the most modern method (HyAns-MAC). In addition, all HyAns' methods coincide in sign and timing (the most impacted month) during El Niño. (ii) During the cold phase of ENSO (La Niña), HyAns' methods exhibit high differences in magnitude (until 250%) and timing (no coincidence in the most impacted month) although they are coincident in sign. (iii) CCA between the ENSO signal (in the tropical Pacific Ocean) and precipitation anomalies evidences that the geographical areas with significant statistical correlation are strongly dependent on the HyAns' method used. We find the most significant difference between HyAns-TAC and HyAns-MAC. The geographical areas of statistical significance decrease (or increase) until 20% depending on the used HyAns method. (iv) Significant differences among the HyAns' methods induce high-biases to interdependence analysis of climate time series, which generate ambiguities regarding the physical interpretation of results.

In general, our results point out the need of quantifying the uncertainty of HyAns in terms of magnitude, sign, timing, and phase of ENSO. In addition, it is pertinent to revise the theoretical basis behind the diverse HyAns methods, which are not necessarily supported on physical grounds. Moreover, high induced-bias to interdependence analysis of time series is a fundamental issue for future research, which should be considered in relation to the sophisticated non-linear methods reported in the literature. Our results evidence the need to tackle this fundamental overlooked problem regarding the effects of ENSO in hydro climatic processes.

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Spectral Analysis of Sea Surface Temperature on the Equatorial Pacific from 1950 to 2014

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Key words: sea surface temperature, wavelet analysis, equatorial Pacific

In this study we identified and analysed the spatial and temporal patterns of spectral oscillation ranges of monthly sea surface temperature, SST, over the Equatorial Pacific region, from 1950 to 2014, through wavelet analysis. The strategic steps considered the variance analysis, obtained from the wavelet computation, for each single grid point instead of the analysis for a spatial mean variance, as is commonly assumed, allowing visualise the spatial distribution of SST variance during time periods. In order to summarise the findings, results show the SST variance in the Niño areas, Nino1+2, Niño3, Niño3.4 and Niño4, mainly oscillating within the 2-4 and 4-8 years spectral ranges. The strongest El Niño events present their main oscillation in the 2-4 and 4-8 years spectral ranges while weaker El Niño events show more association with the 1-2 years spectral range. Stronger El Niño events of 2-4 and 4-8 years oscillations have the beginning of the respective increased variance several months before their maximum variance, ranging from 24 to 47 months, by e.g., for the 2-4 years spectral range. This precedent information can be considered as potential predictor of stronger El Niño events. On the other hand, the peaks of the strongest El Niño events are almost always preceded by moderate and weaker El Niño events, what possible means that weaker events provide energy for the strongest ones. This result is in accordance with theoretical approaches postulated in previous studies, which discussed the genesis of strong events. La Niña events are overall associated with higher frequency oscillations, for the 1-12 months and 1-12 years spectral ranges.

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Seasonal Variation in Microclimates and the Role of Regional Weather and Environmental Factors

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Key words: Microclimate, Temperature, Relative humidity

Microclimates are an important component of our ecosystem, and can impact human health through heat-related injuries or by affecting disease vectors. Research on microclimates can be difficult; our understanding of the temporal and environmental variation of microclimates is limited. Microclimate data (temperature and relative humidity) were collected over a twelve-month period in a small community in Ecuador, and summarized for over each 24-hour collection period. Using generalized linear models with generalized estimating equations, we assessed the variability of microclimate variables across time and environmental variables, including urbanicity, elevation and vegetation coverage. With local weather station and remotely-sensed climate data, we assessed the relationship between regional weather and microclimates. Two-hundred and eighty-seven log-days of data were collected; the absolute maximum temperature was in July, and the absolute minimum occurred in August. Relative humidity of 100% occurred frequently during the sampling period; the absolute minimum occurred in March. Some microclimate variables were more temporally stable than others (mean, median, and minimum temperature and maximum relative humidity); urban sites had higher temperature variability ($p=0.0169$) and rural sites had higher mean relative humidity ($p=0.0137$), compared to suburban areas. Microclimate temperature variables were associated with remotely-sensed surface temperature ($p=0.047$). Miicroclimate minimum ($p=0.0001$) and mean ($p=0.045$) temperature were associated with climate station temperature minimum and mean measures, respectively. Relative humidity mean ($p<0.0001$), median ($p<0.0001$), minimum ($p=0.038$), and maximum ($p=0.0018$) were associated with the number of days with precipitation at the climate station. These data demonstrate the need for climate and health researchers to reconsider the meaning and impact of climate variables across spatial scales.

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Distribution of functional groups of phytoplankton in the Pacific Equatorial Post El Nino 2015-2016

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Key words: Phytoplankton, El Nino, Ecuatorial Front, Upwelling, Galápagos

Phytoplankton, are microscopic vegetal cells that live in the photic surface layer of the oceans, are responsible for approximately half of the global marine production and have a great potential to be used as indicators of hydro-climatic change, can experience high or low densities algae during oceanographic events such as El Niño-La Niña. In the Southeast Pacific Ocean, the oceanographic event of El Niño-Southern Oscillation (ENSO) is developed in its warm (El Niño) and cold (La Niña) phases, such as the recent El Niño event 2015-2016.

The National Committee for the Study of the El Niño Phenomenon of Ecuador (ERFEN-Ecuador), has developed two cruises in September 2016 and October 2017. The study area includes the Equatorial Front (EF) from continental Ecuador to Galapagos (2 ° N to 3 ° S) subdivided into 4 sections (92 °, 89 °, 86 ° and 82 ° W). The environmental parameters, such as temperature, salinity, and chlorophyll were obtained from CTD sets; Samples were collected for nutrients and phytoplankton in standardized depths in the layer from 0 to 75m, following standardized methodologies. The objective of this study was to characterize the phytoplankton in functional groups and species in response to the physicochemical variables in both cruises post an El Niño event.

The results in 2017 showed a higher density of phytoplankton in relation to 2016. The maximums were located in the upwelling centers at E31-27 west of Galápagos at 1 ° S (17.63 ° C) in 2016 and at 0 ° (19.64 °). C), continuing towards the continent south of the Equatorial Front. The main functional groups of phytoplankton were centric and pennate diatoms, dinoflagellates and ciliates. 98 species were recorded (2016) and 117 (2018), only 12 species were frequent throughout the study area. In the upwelling area of the Galapagos, it was characterized by the dominance of Pseudo-nitzscchia delicatisima, P. seriata, Nitzschia longissima. Centric diatoms were scarce in 2016. Gyrodinium sp. and Gymnodinium sp. were the dominant dinoflagellates in 2017, as well as the ciliate M. rubrum and flagellates (unidentified) also increased in 2017. The maximum levels of phytoplankton were correlated with the larger nitrate and phosphate concentration toward the south of EF and mínimum temperature. In September 2016 and October 2017, these dates corresponded to a cold phase of El Niño 1-2, associated to the upwelling system of the currents of Humboldt and Cromwell. The physical oceanographic conditions presented slight differences in both cruises, in both cases the equatorial upwelling west of the Galapagos was strengthened, with less production of phytoplankton in 2016 while in 2017 it increased, mainly due to the contribution of nitrate and phosphate that favored high productivity.

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Insights Into ENSO and Paleo-ENSO From Short-Lived Bivalves

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Key words: Paleoclimate, Bivalves, Peru

Recent events like the 2017 coastal El Niño highlight the spatial variability inherent within El Niño-Southern Oscillation (ENSO). While most monitoring for prediction occurs in the central Pacific Ocean, the existence of events that are centered in, and primarily impact, the eastern Pacific Ocean and coastal Peru has been known for some time. While marine sediment cores provide long-term perspectives on ENSO variability in the eastern Pacific, their temporal resolution is usually not high enough to capture seasonal variability or individual events, especially going farther back in time. Sclerochronology, or the study of time from the hard parts of living organisms, can provide higher temporal resolution for paleoclimate and ENSO reconstructions. However, the longer lived (>50 years) organisms that are usually used in sclerochronological reconstructions, such as corals, sclerosponges, or certain bivalves, are unavailable in much of the tropical eastern Pacific Ocean and western coastline of South America. Previous research has highlighted the utility of short-lived (<5 years) intertidal bivalves from archaeological sites in reconstructing ENSO variability along coastal Peru. The species Mesodesma donacium, a cold-water intertidal bivalve, has been successfully used in several such reconstructions. However, M. donacium is vulnerable to die-offs during El Niño events, biasing reconstructions from its shell geochemistry towards La Niña and Neutral conditions. M. donacium is also functionally extinct north of ~14°S, limiting the geographic range of modern studies. As a complement to M. donacium, we present results from Donax obesulus, another short-lived intertidal bivalve species extant along most of the modern coastline of Peru. D. obesulus, unlike M. donacium, survives the warmer sea surface temperatures (SST) associated with El Niño events, though it may experience mass mortalities during stronger La Niña events. We collected live D. obesulus from beaches along the Nepeña Valley, Ancash, Peru in 2012, 2014, and 2016 (La Niña, Neutral, and El Niño years) to test its suitability as a paleoclimate proxy. We obtained D. obesulus and M. donacium shells excavated from the archaeological site of Caylán (dated ~2300 ±100 BP) in the same valley. Using archaeological shells allows us to look not only at the strength of ENSO during this time period, but also how local human populations may have responded to changing oceanographic conditions. Shell δ18O, which is a proxy for both SST and water δ18O, matches well with both annual and monthly SST averages. Modern D. obesulus record an annual SST range of ~8.4°C and mean of ~22.4°C, similar to modern satellite-derived SST records. Archaeological D. obesulus records an annual SST range of ~7.4°C and mean of ~19.0°C. Archaeological M. donacium compare similarly to previous studies, recording an annual SST range of ~4.0°C and mean of ~13.0°C, as compared to an annual SST range of ~2.9°C and mean of ~16.9°C.

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Oceanic and atmospheric variability of the eastern Pacific associated with El Niño Costero 2017

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Key words: El Niño, temperatura del mar, lluvias

During the austral summer of 2017 off the coasts of Ecuador and Peru there was a climatic event called El Niño Coastal. This event is recurrent, lasts a few months and is characterized by the warming of the sea and the excess of precipitation, mainly, along the coast of Ecuador and Peru. This event is motivated by the weakening of the South Pacific anticyclone and, consequently, by the weakening of the trade winds that travel from south to north along the western coast of South America.

At the same time, during this event, the winds coming from the north travel to the south more easily and intensely; they cross the equatorial line and promote the transequatorial circulation, from north to south, of the warm superficial waters contained in the Panama basin, which increases the sea temperature on the coast of Ecuador to the central coast of Peru.

This climatic event has been described and baptized by the fishermen of northern Peru, who noticed that in most of the years, towards the end of December, near Christmas, there was an increase in seawater temperature. They attributed this warming to the arrival from the north of a marine current of warm waters, which they called: the "current of El Niño Jesus". At the end of the 19th century, in a Bulletin of the Geographic Society of Lima, it was documented about the heavy rains and the warming of the waters that occurred in the coasts of northern Peru during the summer months of the southern hemisphere.

This type of event, currently called El Niño Costero, is based on the original El Niño concept. The Coastal Child differs from the Oceanic Child, whose operational definition given by the NOAA of the United States, is based on the surface temperature of the sea in the Niño 3.4 region and is related to the ENSO cycle (El Niño and Oscillation). of the South), being El Niño its positive phase.

This work analyzes the variability of the superficial thermal structure, the atmospheric circulation, the zonal and meridional component of the wind, the atmospheric pressure and the precipitation during the occurrence of coastal El Niño 2017. The analysis reveals a certain alteration in the circulation of the winds in the Hadley cell, which would justify the strong presence of north winds in southern latitudes, which favored the displacement of the warm waters of the Panama basin towards the north coast of Peru accompanied by heavy rains in the region.

On the other hand, the oceanic and atmospheric indices used to monitor the evolution of ENSO did not explain the development of El Niño Costero 2017.

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Description of La Niña 2007-08 event in the Eastern Tropical Pacific

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Key words: Eastern Pacific, ENSO, Local warming, Niño Costero

Sea surface temperature (SST), altimetry, winds and precipitation data in the Eastern Tropical Pacific were used to describe the oceanic and atmospheric conditions of La Niña| 2007-08. This event was characterized by negative SST anomalies of -0.5°C (Oceanic El Niño Index) around June-2007, which continued to intensify in the following months, reaching their lowest value around December-2007 and January-2008 (-1.6°C) in the Niño 3.4 region.
Despite the generalized cold conditions in the Central Equatorial Pacific, there was an abrupt local warming in the Far Eastern Tropical Pacific, with a maximum SST developed in March-2008 (over 27°C in the Niño 1+2 region); been this warming the precursor of a weak development of the second branch of the Intertropical Convergence Zone, and heavy rainfalls in the coastal regions of Ecuador and the north of Peru during early austral fall of 2008. The processes that determined this warming could be linked with the collapse of Trade winds off Peruvian coast, and the oceanic response to the Panama and Papagayo jets in the Panama basin developed during these months. In addition, this event is put in perspective with the concepts of El Niño-Southern Oscillation (cold phase) and Carnival Coastal Warming event (so-called El Niño Costero).

Session 2. ENSO dynamics

Oral presentations

Session 2. ENSO dynamics
Keynote, 14:30 – 15:00, Oct. 16

El Niño in the far-eastern Pacific: Concepts, impacts and dynamics

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Key words:

El Niño was originally defined in terms of anomalously warm ocean water in the far-eastern Pacific, off the northern coast of Peru, replacing the cold water associated with coastal upwelling. This concept was then incorporated into the large-scale El Niño-Southern Oscillation (ENSO), although warm ENSO events and the original El Niño do not always coincide. From the perspective of the original definition, the strongest El Niño events produce severe impacts along the coastal desert of Peru, primarily associated with heavy precipitation and flooding, and can be classified in two major types: an extreme warm ENSO phase or "global El Niño", such as in 1982/1983 and 1997/1998, and a "coastal El Niño", such as in 1925 and 2017. The two types of event differ in that the warming in the case of the former extends west into the central Pacific, while the latter is confined only to the far-eastern Pacific, with neutral-to-cool conditions in the rest of the equatorial Pacific, but deeper differences can be found in the underlying dynamics. The extreme "global El Niño" events are governed by the well-established ENSO dynamics, with non-linear processes such as the activation of deep atmospheric convection in the otherwise stable eastern Pacific amplifying the feedback processes that allow El Niño events to become extreme. On the other hand, the development of the "coastal El Niño" is not associated with the basin-scale ocean-atmosphere Bjerknes feedback but with the reversal of the north-south climate asymmetry in the far-eastern Pacific facilitated by the feedback between cross-equatorial northerly winds, the strengthening of the southern branch of the ITCZ and the ocean warming off the northern coast of Peru. It is locked to the austral fall, when the southern branch of the ITCZ is seasonally strongest, and since it involves the warming of a much shallower ocean layer than associated with extreme ENSO events, its onset occurs in a few weeks. The two types of events similarly lead to severe rainfall and flooding in the coastal desert of Peru and impacts in the coastal marine ecosystem. However, due to their different central Pacific signature and associated teleconnections, the extreme "global El Niño" can lead to droughts in the central Andes and Amazon, while during the "coastal El Niño" the rainfall in the Andes can be enhanced.

Session 2. ENSO dynamics
Keynote, 15:00 – 15：30, Oct. 16

Understanding ENSO event precursors

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Key words: El Nino, Warm Water Volume

The build up of equatorial Pacific warm water volume (WWV) prior to an El Niño event is considered a necessary precondition for event development, while the event initiation is thought to be triggered by bursts of westerly wind. However, in contrast to the view that warm water slowly builds up years before an El Niño event, the volume of warm water in the equatorial Pacific doubled in the first few months of 2014 reaching values that were consistent with the warm water build up prior to the extreme 1997/1998 El Niño. Here, a wind forced ocean model is used to decompose the equatorial Pacific warm water volume (WWV) between 1980 and 2016 into two components: the (i) adjusted wind response, which is found by letting the model evolve unforced for three months, and (ii) instantaneous wind response, which are the instantaneous WWV changes due to Ekman transports. Our results suggest that roughly half of WWV variability is due to this instantaneous change, which contradicts existing accepted theory. This also suggests that at least this component of WWV is only as predictable as the winds that drive the instantaneous change. Separate examinations of pre-2000 and post-2000 periods reveal (i) nearly equal importance of instantaneous and adjusted responses for the pre-2000 period and (ii) dominance of the instantaneous response during the post-2000 period, which is most apparent during the recharge phase prior to an El Niño event. This increasing instantaneous contribution prominence explains the post-2000 reduction in WWV/El Niño-Southern Oscillation sea surface temperature lead times (from six to nine months pre-2000 down to three months post-2000) and is consistent with the reduction in post-2000 El Niño-Southern Oscillation prediction skill.

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Oral, 16:00 – 16:20, Oct. 16

A hierarchy of models for ENSO diversity in past, present and future

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Key words: ENSO diversity, ENSO flavors

Climate model skill in simulating ENSO diversity and the physical mechanisms that govern it is critical not only for accurate simulation of ENSO-flavor global impacts in past and present climates but may also be used as a tool to constrain future climate model projections. To this end, I will show that in models that exhibit strong ENSO diversity, the projected tropical Pacific sea surface temperature warming pattern is closely linked to the projected ENSO response, highlighting that ENSO simulation biases may lead to potentially biased projections in long-term SST and precipitation trends, with great significance for regional climate adaptation strategies.

Motivated by the demonstrated significance of a faithful simulation of ENSO diversity, I will present a hierarchical model study to explore the factors affecting the existence of ENSO flavors or regimes under different forcing scenarios. First, I will discuss a nonlinear version of the recharge-discharge model, which focuses only on ENSO diversity associated with the strength of the warming and not the pattern. In this parsimonious model, the nonlinearity in the Bjerknes feedback associated with the activation of deep convection in the cold eastern Pacific is sufficient to produce a bimodal distribution of peak ENSO SST anomalies, similar to the observed. Second, moving up the hierarchy of models to include the spatial expression of ENSO diversity, I will use a modified version of the Zebiak-Cane model which simulates two ENSO modes with SSTa patterns reminiscent of ENSO flavors. I will show that orbitally-induced changes in the cold tongue annual cycle lead to a response of the two ENSO modes towards opposite directions, in agreement with global climate model simulations. To further explore the complexity of ENSO-flavor response to external forcings, I will then use a suite of Community Earth System Model (CESM) simulations that span the last deglaciation (23ka to 0 BP) to show systematic changes in the distribution of ENSO peaks and the dynamics of the two ENSO flavors in response to seasonally modulated feedbacks and their respective growth rates.

To conclude, I will discuss how the insights into ENSO-flavor response to external forcings gained from this hierarchical study apply to the interpretation of paleoclimate proxy records. As an example, I will show that a potential dominance of the Central Pacific flavor in the midHolocene would lead to an approximate threefold reduction of convective precipitation in a region of high-elevation lakes in the Ecuadorian Andes (eastern Pacific), and thus a potential threefold reduction of events of high clastic sediment flux into the lakes, which is consistent with the interpretation of paleoclimate records from the region.

Session 2. ENSO dynamics
Oral, 16:20 – 16:40, Oct. 16

A Stochastic Skeleton Model for the MJO and ENSO

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Key words: ENSO, MJO

A broad range of random atmospheric disturbances in the tropics may be considered as possible triggers to the El Niño Southern Oscillation (ENSO), such as for example westerly wind bursts, easterly wind bursts, as well as the convective envelope of the Madden-Julian Oscillation (MJO). Here a simple dynamical stochastic model for the tropical ocean-atmosphere is proposed that captures those processes as well as their multiscale interactions. Realistic features include for the first time altogether the MJO wavenumber-frequency power spectra, eastward propagation, structure and confinement to the warm pool region and similarly for atmospheric Kelvin and Rossby equatorial waves, in addition to the ENSO intermittency, power spectrum and non-Gaussian statistics of sea surface temperatures, among others.

Importantly, intraseasonal atmospheric disturbances such as the MJO are here solved dynamically which renders more explicit their upscale contribution to the interannual flow as well as their modulation in return. First, the background red noise spectrum of atmospheric disturbances rather than their individual characteristics is shown to be most important for the triggering of the ENSO. Second, the onset, strength and demise of El Niño events is linked to the increase and eastward expansion of atmospheric disturbances eastward of the warm pool region. The present framework serves as a prototype for general circulation models that solve similar dynamical interactions on several spatial and temporal scales.

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Oral, 16:40 – 17:00, Oct. 16

Decrypting the nonlinearity in ENSO observations: potential for skillful predictions

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Key words: Nonlinear Map, Phenomenology, Prediction Skill, Spring Predictability Barrier

The skill of the statistical as well as physics-based coupled climate models in predicting the El Ni{\~n}o-Southern Oscillation (ENSO) is limited by their inability to represent the observed ENSO nonlinearity with fidelity. A promising alternative, namely a deterministic nonlinear dynamical model derived from an observed ENSO time series, however, has so far remained elusive. To this end, we discover, exclusively from ENSO observations, a phenomenological nonlinear dynamical map that embodies known physical processes responsible for the self-sustained quasi-oscillatory character of the ENSO and its observed spectrum of variability. High predictive potential of the map is demonstrated and the intrinsic nonlinearity of ENSO is shown to be critical for overcoming the Spring Predictability Barrier to a large extent. The unique methodology presented here has the potential for constructing similar maps for other geophysical systems.

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Oral, 17:00 – 17:20, Oct. 16

ENSO modes-annual cycle interaction and ENSO complexity

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Key words: ENSO complexity, theoretical ENSO modes, bimodal interaction, annual cycle, ENSO regime shift

In observations and model simulations, ENSO manifests as two main flavors differing in their spatial patterns, periods and triggering mechanisms. Many attempts have been made to explain such diversity and complexity. Here, using a modified Zebiak-Cane model, we present a new nonlinear theory for this issue based on two co-existent intrinsic ENSO modes: a quasi-quadrennial (QQ) eastern Pacific (EP) mode and a quasi-biennial (QB) central Pacific (CP) mode. The two theoretical modes are reminiscent of the observed ENSO flavors. We found that the nonlinear interaction between the two modes is essential for ENSO complexity in this model. Neither single mode nor cascades with annual cycle (AC) can cause ENSO complexity. When there is nonlinear bimodal interaction, diverse ENSO patterns appear and spectral energy peaks can be found in both of the QQ and QB bands, as in observations. In these cases, the dominances of ENSO spatial patterns and periods depend on the linear instabilities of the two modes. However, AC can modulate the ENSO bimodal interaction: it enhances the EP mode but suppresses the CP mode. Therefore, AC shifts an EP-CP coexistent ENSO regime to an EP dominant ENSO regime, but shifts a CP dominant regime to an EP-CP coexistent ENSO regime. The interactions between the two ENSO modes and between ENSO modes and annual cycle provide a "hybridization" theory to understand ENSO complexity.

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Oral, 17:20 – 17:40, Oct. 16

The Role of the Western Pacific Heat Buildup in the Development and Prediction of El Niño

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Key words: western Pacific, heat buildup

The buildup of heat in the subsurface western tropical Pacific is one of the most characteristic features of the growing and recharge phases of an El Niño event. This process begins early on in its formation and has important implications about the timing and intensity of the event during the later stages. We have explored the sensitivity of the El Niño timing and intensity to the magnitude of the heat buildup in the ocean subsurface 21 and 9 months ahead of the peak of an event, by using specially designed numerical experiments with the fully coupled Community Earth System Model. Within the setup of the experiments, the coupled ocean-atmosphere system compensates any initial decrease in heat content at 21 months lead time, and evolves towards a new recharge phase, with a possible delay of one year in the occurrence of a warm event. A different scenario occurs if the heat content is adjusted during the recharge phase (at 9 months lead time). The timing and magnitude of the event is not largely affected by a substantial increase of the heat content, but it is sensitive when a considerable decrease is prescribed. The results point to a non-linear dependence between the intensity of the subsurface heat buildup, the phase of a sudden increase or decrease in the heat content, and the strength and time of occurrence of the El Niño.

We have also incorporated this dynamically very relevant process in a flexible statistical dynamic components model by adding temperature at different depths and regions of the tropical western and central Pacific Ocean as predictor variables. Applying this strategy rather than the traditional integration of upper ocean heat content has allowed us to extend in time the predictive capacity of our model. We have performed hindcasts of the Niño3.4 Index in the period 1970-2016, and it successfully predicts all the major EN episodes, including the recent extreme 2015/16 El Niño event beyond the spring barrier. Importantly, our findings point out that the events are predicted much more accurately after the completion of the observational array in the tropical Pacific in 1994. Therefore, our results also confirm the usefulness of the Tropical Pacific Observing System and stress the benefits of expensive monitoring system initiatives such as the Tropical Ocean Global Atmosphere Program derived some decades later.

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Posters

Session 2. ENSO dynamics
Poster

ENSO under greenhouse warming: the impact of model biases

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Key words: ENSO, Model biase, Greenhouse warming

El Niño-Southern Oscillation (ENSO) affects ecosystems, agriculture, and extreme weathers worldwide. How ENSO will change under greenhouse warming is a long-standing scientific issue. Recent progress shows that events with extreme impacts will increase in frequency under greenhouse warming, but how SST variability may change is still unclear. The projected increase in frequency of events with extreme impact is underpinned by a mean state change, which facilitates movement of atmospheric convection as occurred during such events. However, models are plagued with systematic biases, and their impact is not well-known. We present an assessment showing the biases could have a significant impact on the projected ENSO change.

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ENSO diversity and global warming

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Key words: ENSO, Global warming, CESM-LE

The frequency of occurrence of extreme El Niño events is predicted to double in the future in response to the increase in greenhouse gases based on the CMIP3 and CMIP5 data bases. Such projections rely however on state-of-the-art models that still present mean state biases and do not simulate realistically key features of El Niño events such as its diversity as related to the existence of at least two types of El Niño events, the Eastern Pacific (EP) El Niño and the Central Pacific (CP) El Niño events. Here we take advantage of the Community Earth System Model (CESM) Large Ensemble (LE), that provides 40 realizations of the climate of the 1920-2100 period with a combination of both natural and anthropogenic climate forcing factors, to investigate the mechanisms associated to the higher frequency of occurrence of extreme events in the warmer climate. The CESM-LE simulates realistically many aspects of the ENSO diversity, in particular the non-linear evolution of extreme Eastern Pacific events, and exhibits an increase in the frequency of occurrence of extreme El Niño events in a warmer climate comparable to the CMIP5 data base, although the magnitude of the changes can vary among different definition of El Niño events. It is shown that the seasonal evolution of El Niño events is modified from the present to the future climate, with in particular a shift in the peak season of Eastern Pacific events from boreal winter to early spring in the warmer climate, which explains the increase of precipitation-related extreme El Niño events in the eastern Pacific. The ENSO non-linearity is also showed to increase, which is interpreted as resulting from the increased stratification based on the analysis of the a mixed-layer heat budget. Implications for understanding processes associated to changes in ENSO in a warmer climate are discussed.

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Tropical lower stratospheric ozone link to El Nino Southern Oscillation dynamics

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Key words: ENSO dynamics, lower stratospheric ozone, Equatorial Pacific Ocean Heat Content, Ultra Violet solar radaition (UV-B)

In this study we use reanalysis and observational data to demonstrate the link between lower stratospheric ozone regulation of solar ultraviolet radiation (UV-B) to ENSO modulation. It is shown that the lower stratospheric ozone absorption of UV-B leads to the inverse association between the air temperatures of the lower stratosphere and upper troposphere especially in the eastern tropical Pacific. In this region the lower stratospheric ozone is also inversely related to the Ocean Heat Content. Related geopotential height changes which occur in the tropical south Pacific in turn influences the South Pacific High circulation whose equatorward region has a strong bearing on the eastern Pacific upwelling including the strength of the equatorial easterlies. We conclude that the ozone regulation of UV-B in the lower stratosphere of the tropical Pacific should play a dominant role in the ENSO dynamics that cascade downwards to the ocean's tropical and equatorial surface and subsurface.

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A plausible atmospheric trigger for the 2017 coastal El Niño

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Key words: Coastal El Niño, Ocean-atmosphere interaction

The coastal El Niño during the austral summer 2017 has been the strongest on record and caused torrential rains along the west coast of tropical South America, with hundreds of fatalities and significant economic losses in Perú and Ecuador. After the very intense, basin-wide El Niño 2015/2016 the surface ocean in the far eastern Pacific remained about 0.5°C warmer than average and experienced an extra 1.5°C warming in a series of week-long episodes in January, February and March of 2017. The behavior of the ocean-atmosphere system during this event differs substantially from the canonical ENSO dynamic, contributing to the lack of predictability of this event.

Climatologically, the blocking of the free tropospheric westerlies impinging the tall subtropical Andes results in subsiding equatorward flow and cools the surface of the tropical/subtropical eastern Pacific through enhanced evaporation and cloud feedbacks. On this basis, we posit that episodes of substantial lessening of the westerlies leaded to a relaxation of the SE trades off the coast, even reversing the flow at some times. The association between mid-level westerlies in the subtropics and near-surface flow over the far eastern Pacific at low latitudes was evident during the summer of 2017. The variability of the westerly flow aloft was driven by geopotential height anomalies at about 35°S, which at least in one case was part of Rossby wave train across the Pacific emanating from northern Australia. The second part of our conceptual model is the connection between the SE trades relaxation and the warming of the eastern Pacific through the weakening of upwelling in a near-coastal band and the lessening of the evaporative cooling farther offshore. Local ocean-atmosphere feedbacks may amplify this initial wind/SST perturbation.

Probing the mechanisms suggested here offers an opportunity to understand coastal El Niño and, hence, contribute to preparedness efforts to face strong events in the future.

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On the physical interpretation of the lead relation between Warm Water Volume and the El Niño Southern Oscillation

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Key words: El Niño Southern Oscillation (ENSO), Warm Water Volume (WWV), ENSO recharge oscillator, ENSO predictors, ENSO conceptual models, CMIP5 climate models, equatorial Kelvin and Rossby waves

The El Niño Southern Oscillation (ENSO) is the leading mode of interannual climate variability on Earth. The warm water volume (WWV), a proxy for the Pacific heat content over the entire equatorial band, is the most widely used precursor of ENSO. The standard interpretation of this lead relation in the context of the recharge oscillator theory is that anomalous easterlies during, e.g. a La Niña, favour a slow recharge of the equatorial band that will later favour a transition to El Niño. Here we show that WWV is only the best predictor of the upcoming ENSO peak amplitude during boreal spring, in both observations and CMIP5 models. At longer lead times, heat content in the western Pacific (WWVw) is the best ENSO predictor, as initially formulated in the recharge oscillator theory. Using idealised experiments with a linear continuously stratified (LCS) ocean model, we demonstrate that the WWV in spring mostly reflects the fast Kelvin wave response to wind anomalies during the early months of the year, rather than the longer-term influence of winds during the previous year. It is hence not an appropriate index of the slow recharge invoked in the recharge oscillator. The WWVw evolution before spring is dominated by the forced Rossby wave response, with little contribution from reflection at meridional boundaries. As a result, WWVw can be approximated from the integral of equatorial Pacific wind stress anomalies over the previous ~10 months, hence involving a longer-term recharge than WWV. We hence recommend to use WWVw rather than WWV as an index for the slow recharge before the spring predictability barrier. We will finally suggest an improved WWVw index with a wider meridional extent, and discuss the physical processes by which a WWVw build-up in autumn can affect SST in the central/eastern Pacific during the following spring (i.e. the ENSO onset), to explain the observed/modelled lead relation between this parameter and following year's ENSO amplitude.

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The influence of volcanic forcing on Pacific Ocean inter-annual to decadal variability over the last centuries

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Key words: ENSO decadal variability, Last millennium, role of external forcing

Direct observations of sea surface temperatures over the historical period and reconstructions from natural archives such as corals in the Pacific Ocean now provide windows of observations covering several centuries. These observations indicate a wide range of El Nino–Southern Oscillation (ENSO) amplitude modulations at inter-annual to decadal timescales that can persist for decades. Yet, there is no clear consensus today about the underlying processes, whether they are linked to internal variability or result from the influence of natural external forcing. The last millennium provides a promising time frame constrained by climate reconstructions to explore the interactions between external forcings and the internal dynamics of climate. It is indeed relatively long and reasonably well reconstructed and modelled. For the period preceding the nineteenth century, volcanic eruptions have been shown to be the dominant cause of externally forced climate variability. Although the effects of volcanic eruptions on climate are largest in the 2 years following a large stratospheric injection, recent work reveals extended volcanic impacts via long-term memory of the ocean heat content and sea level. This contribution investigates the links between tropical explosive volcanism and ENSO in a suite of externally forced and unforced ensemble simulations using the IPSL coupled climate model for the last millennium. As suggested by observations, and independently of initial states, all simulations tend to produce persistent transient cooling in the tropical Pacific during the 13th and 14th centuries and higher decadal variability of ENSO amplitude consistent with paleoclimate reconstructions. Our results indicate that large volcanic eruptions can alter trade winds, modulate ENSO at decadal scale, can drive transient global cooling (hiatus-like) and alter ocean heat uptake.

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The warm water volume, a better predictor of La Niña than of El Niño

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Key words: El Niño – La Niña asymmetry, ENSO recharge oscillator

El Niño – Southern Oscillation (ENSO) is the dominant mode of interannual climate variability, with large environmental impacts at the global scale. With anomalous warming of up to 4°C in the eastern equatorial Pacific, extreme El Niño events, such as in late 1982, 1997 and 2015, involve a complete re-organization of tropical convection with outsized societal impacts relative to moderate El Niño events. Despite an improved understanding of ENSO dynamics over the past decades, predicting the amplitude of ENSO events remains a challenge, especially at long lead-times. The “recharge-discharge oscillator” theory highlighted the role of the oceanic heat content averaged over the western equatorial Pacific as a robust precursor of ENSO. This theory is however essentially linear and does not account for the potential asymmetries existing between El Niño and La Niña events. Yet, observations suggest that the ocean preconditioning is a more efficient predictor for La Niña than for El Niño events. Because of large uncertainties related to the short observational record, we analyse this asymmetry in a set of pre-industrial control experiments from eleven coupled models, selected for their capability to simulate observed ENSO variability. As suggested by observations, the discharge one year before ENSO peak in these models is a significantly better precursor of La Niña occurrence and amplitude than the recharge for El Niño. This asymmetry likely arises from (1) the asymmetry of the ocean preconditioning that promotes a larger influence on La Niña (larger discharge) than on El Niño (weaker recharge) and from (2) a nonlinear Bjerknes feedback that promotes the growth of El Niño rather than La Niña. These results are used to define sensitivity experiments in order to further investigate the mechanisms and predictability of ENSO events.

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La Niña 2010 originated in the Amundsen and Bellingshausen Seas

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Key words: La Niña, South Pacific High, Sub Polar Low, Amundsen Sea, Ferrel Cell

La Niña or the cold phase of the ENSO is referred to an anomalous inter-annual cooling of SST in the central Equatorial Pacific. In such an event the easterly trade winds accelerate which in turn strengthen the Equatorial Upwelling, which lifts deeper and colder water to the surface. The velocity of the trade winds is determined by the pressure gradient at sea surface between the South Pacific High (SPH) and the Indonesian Low (IL), meaning that an extraordinary intense SPH is needed to initiate a strong La Niña event. This additional air mass is ought to be supplied by the IL by means of the Southern Oscillation (SO). This century's strongest La Niña scenario with maximum SST anomalies < -1.5°C initiated in June 2010.

Monthly mean sea level atmospheric pressure from the ERA INTERIM 1979-2016 reanalysis project on a 0.75 x 0.75° Longitude/Latitude grid were employed in this study to scrutinize how the SPH gained momentum in 2010. The IL here is constraint by the northern and southern 12° Parallel and the 130° and 183° eastern Meridian; the SPH resides between 18° and 42°S and extents from 228° to 285°E. Time series of monthly mean air pressure from January 2009 to December 2011 were computed for the IL and the SPH as well. Air pressure registered more than 2 hPa above the long-term monthly means from May 2010 to February 2011. This intensification coincided, with the onset of the 2010 La Niña event. The IL, however, remained about at its climatological mean during 2010, which implies that the observed intensification of the SPH during this year was not supplied via the SO.

In this paper, air pressure at each grid cell and for each month first was replaced by the total air mass which lies above it owing to the geometry of the Eastern South Pacifc which is much wider at the Equator than at high latitudes. Secondly at each grid cell the 38 year mean of total air-mass of this very same grid cell was subtracted thus resulting in time series of air mass deviations from the mean state, the principal variable employed here.

Here it is shown that the air-mass needed to intensify the SPH in 2010 and consequently the trade winds as well, which initiated the La Niña event at the end of this year was supplied by the Sub Polar Low, located in the Amundsen and Bellingshausen Seas, most likely via the Ferrel Cell which connects the Polar Cell with the Hadley Cell.

The Sub Polar Low lost 342 Trillions kg of air mass during 2010 while the SPH gained 308 Trillions kg of air mass in the very same time. A drop in air pressure accompanied the loss of air mass in the Sub Polar Low by 9.8 hPa whereas the SPH intensified by only 2.7 hPa thus emphasizing that this about equal meridional air exchange could only be detected by employing time series of air mass deviations. We conclude that the Ferrel Cell should be considered in ENSO dynamics.

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Pole tide in the Pacific Ocean can trigger El Niño

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Key words: Chandler wobble, Earth's pole motion, pole tide, El Niño prediction, strange nonchaotic attractor

El Niño is, perhaps, the most known to general public almost periodically (rhythmically) repeating phenomenon in the global climate system. The periods of El Niño's rhythms are well measured as equal to about two, three, four or five years, and numerous theories exist which try to explain the origin of El Niño. However all these badly help to predict El Niño. The following El Niño usually turns out to be unexpected.

We emphasize that the main periods of El Niño's rhythms are similar to subharmonics (2.4, 3.6 and 4.8 years) of the so-called Chandler wobble (of the ~1.2 year period) in the Earth's pole motion. Using satellite data on altitudes and temperature of the sea surface we show that a wave (called the oceanic Pole tide) in the Pacific ocean which is generated by this wobble can trigger El Niño. This tide propagates eastward within a temperate latitude belt. Its period is equal to about 14 months. Reaching the North America coast, the tide transforms into a surf, and the wave of this surf moves in the direction of the Panama Isthmus. Combined with the simultaneous strengthening of the north-eastern trade winds that occurs during the autumn shift of the Intertropical Convergence Zone to the south, this surf wave excites the El Niño anomalies. The further westward movement of the surf wave is traced in the AVISO SLA and NOAA OI SST data up to the coasts of Indonesia archipelago. It is found that some secondary waves alternately brake away from the surf wave and move to north- and southward. These secondary waves are capable to affect the equatorial upwelling that is important for the El Niño - Southern Oscillation processes.

Some other periods of El Niño's rhythms are seen at the super-harmonics of the Luni-Solar nutation (of the ~18.6 year period), and combinational harmonics of the Schwabe's (Hale's) solar activity cycle. Because of the incommensurability of their periods all these forces affect the ocean-atmosphere system in inappropriate time moments. It is proven that the power spectra of the ENSO indices are not continuous but discrete in their character. As a result, the ENSO dynamics can be described as strange but nonchaotic attractor (SNA) in the quasi-periodically forced dynamical systems. Thus, one can conclude that the dynamics of ENSO is predictable with no limit in principle.

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Nonlinear Walker Circulation feedbacks on El Niño diversity in CMIP models

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Key words: Walker Circulation, ENSO Flavors, nonlinear Bjerknes feedback, Pacific ITCZ, RCP8.5 scenario, precipitation

The Walker Circulation (WC) has an important role in the formation of the El Niño spatial and strength diversity in the equatorial Pacific. To assess the nonlinear WC feedbacks associated with El Niño diversity, we investigated the changes of surface circulation and zonal equatorial circulation, averaged between 5°S and 5°N, in all tropospheric levels associated with the Central and Eastern Pacific El Niño indices of Takahashi et al (2011; C and E, respectively) through regression and composites analysis in observational and model data. We used ERA-Interim and multi-mean ensemble of AMIP, historical, and representative concentration pathway 8.5 (RCP8.5) simulations from phase 5 of Coupled Model Intercomparison Project (CMIP5).

The observational results verify the existence of a nonlinearity in the Bjerknes feedback, with an enhancement of the response at higher temperatures with both El Niño indices. With central Pacific warming, there is a westward shift and enhancement of the upward branch (170°E) while the downward branch enhances its intensity in the far-eastern Pacific (FEP) (80°W). Conversely, eastern Pacific warming is associated with two anomalous upward branches located over the central western Pacific (170°W) and FEP. The second upward branch is induced by strong positive surface sea temperature (SST) anomalies over FEP. With extreme El Niño in the eastern Pacific, the two anomalous upward branches merge and the WC experiences an eastward shift of 45°. As the warming increases, the WC becomes more shifted towards the east.

Among the CMIP models, we only found this nonlinearity in 8 out of 23 models, although the general underestimation of the values of E in the coupled runs could be a limitation for the empirical determination. Under the RCP 8.5 scenario, for the 2071-2100 period, the weakening of WC during El Niño is observed for both indices, with weakening of vertical velocity over western tropical Pacific and FEP between 500- and 200-hPa. When restricted to eight of the climate models with the best representation of the nonlinear feedback, the WC response to El Niño is projected to be weakened for both indices, but maintaining the current structure.

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Mid-Holocene ENSO teleconnections to the Indian Summer Monsoon : A PMIP3 narration

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Key words: Mid-Holocene, Indian Summer Monsoon Rainfall, ENSO-ISMR teleconnections

The time period of early to mid-Holocene (~6 kyr ago) has been recognized as a period of anomalously warm climate in the Northern Hemisphere. The Indian Summer Monsoon Rainfall (ISMR) is typically thought to have been stronger during this period, based on sparse observational proxy data. However, on a larger scale, it is still unclear how the ISM and El Niño-Southern Oscillation (ENSO) teleconnections were during the mid Holocene period. Our analysis using 7 PMIP3 model outputs suggests stornger ISMR during the mid-Holocene as compared to present day. The EOF analysis shows weaker amplitudes of ENSO in the mid-Holocene in all models. Further, correlation analysis of ENSO and ISM rainfall shows weaker magnitudes in all models. Our analysis present a a possible mechanism responsible for the strengthening of ISM and weakening of its ENSO teleconnections, during the mid-Holocene.

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The response of the equatorial Pacific Ocean to the winds during 2014-2015

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Key words: ENSO, Equatorial waves

The equatorial wave dynamics of interannual sea level variations between 2014/2015 and 2015/2016 El Niño events are compared using the LICOM forced by the NCEP reanalysis Ⅰ wind stress and heat flux during 2000-2015. And the LICOM can reproduce the interannual variability of D20 anoamlies and sea level anomalies (SLA) along the equator over the Pacific Ocean in comparison with the D20 anomalies data and the AVISO altimeter SLA data well. The equatorial wave coefficients are extracted from the LICOM simulation to study the role of the propagation and reflections of the equatorial waves in the evolution of SLA during El Niño events. During 2014/2015 El Niño event, upwelling equatorial Kelvin waves from the western boundary in April 2014 reach the eastern Pacific Ocean, which weakened SLA in the eastern Pacific Ocean induced by the downwelling equatorial Kelvin waves. However, no upwelling equatorial Kelvin waves from western boundary in the Pacific Ocean can reach the eastern boundary during 2015/2016 El Niño events. Linear wave model results also demonstrate that upwelling equatorial Kelvin waves in both 2014 and 2015 from the western boundary can reach the eastern boundary. However, stronger westerly-wind-burst-forced downwelling equatorial Kelvin waves overwhelmed the upwelling equatorial Kelvin waves from the western boundary in 2015. Therefore, the western boundary reflection and weak westerly wind burst inhibit the growth of 2014/2015 El Niño event. The disclosed equatorial wave dynamics are important to the simulation and prediction of ENSO event in future study.

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Definition of Extreme El Niño and Its Impact on Projected Increase in Extreme El Niño Frequency

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Key words: Extreme El Nino, Definition

During extreme El Niño events, the Intertropical Convergence Zone moves to the normally cold and dry east equatorial Pacific, resulting in a nonlinear rainfall increase with sea surface temperature in the region. An arbitrary threshold value of boreal winter total rainfall (e.g., 5 mm d−1) in the east equatorial Pacific was used by previous studies to capture this feature. Under greenhouse warming, the frequency of extreme El Niño events is projected to increase, so is the mean east equatorial Pacific rainfall. Is the projected frequency increase a consequence of the mean rainfall increase? We show that the projection is not significantly influenced by the increased mean rainfall. Instead, the increased frequency accounts for approximately 50% of the mean rainfall increase. Using upward atmospheric vertical velocity for defining extreme El Niño reaffirms the conclusion that the increased frequency results from increased probability of atmospheric deep convection, as the eastern equatorial Pacific warms faster than the surrounding regions.

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What controls ENSO-amplitude diversity in climate models?

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Key words: ENSO-amplitude diversity, CMIP5, Bjerknes stability index

Climate models depict large diversity in the strength of the El Niño/Southern Oscillation (ENSO) (ENSO amplitude). Here we investigate ENSO-amplitude diversity in the Coupled Model Intercomparison Project phase 5 (CMIP5) by means of the linear recharge oscillator model which reduces ENSO dynamics to a two-dimensional problem in terms of eastern equatorial Pacific sea surface temperature anomalies (T) and equatorial Pacific upper ocean heat content anomalies (h). We find that a large contribution to ENSO-amplitude diversity originates from stochastic forcing. Further, significant interactions exist between the stochastic forcing and the growth rates of T and h with competing effects on ENSO amplitude. The joint consideration of stochastic forcing and growth rates explains more than 80% of the ENSO-amplitude variance within CMIP5. Our results can readily explain the lack of correlation between the Bjerknes Stability (BJ) index, a measure of the growth rate of T, and ENSO amplitude in a multi-model ensemble.

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Mechanism of the weakened ENSO amplitude during mid-Holocene

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Key words: ENSO amplitude, feedbacks, mid-Holocene

The mechanism of El Niño-Southern Oscillation (ENSO) amplitude change during the mid-Holocene (MH) is investigated by the Bjerknes stability (BJ) index through the model simulations from the Paleoclimate Modelling Intercomparison Project Phases (PMIP) 2 and 3. Results show that the weakening of thermocline (TH), zonal-advection (ZA) and Ekman (EK) feedback terms are the major drivers for the weakened ENSO amplitude in MH. And then we go one step further to discuss the key factors in regulating the above drivers and reveal that the weakening of TH, ZA, and EK terms are attributed to the weakened thermocline response to zonal wind stress anomaly in MH compared to PI. Such changes are due to the flattened meridional structure of ENSO-related interannual anomaly field (e.g, zonal wind stress anomaly field) in MH. The meridional structure change of ENSO-related anomaly field results from the strengthening of mean surface poleward meridional current (or mean subtropical cell). Quantitative diagnosis of PMIP simulations shows that the mean STC change might be a key factor, which plays an essential role in determining the changes of TH, ZA, and EK feedback terms, and thus the change of ENSO amplitude in MH.

Session 3. ENSO and Other Modes of Climate Variability

Oral presentations

Session 3. ENSO and Other Modes of Climate Variability
Keynote: 9:00 – 9:30, Oct. 17

The role of intraseasonal variability in ENSO

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Key words:

High frequency atmospheric can promote the development and/or initiation of El Niño events. In the equatorial Pacific, this high frequency atmospheric forcing mostly occurs under the form of synoptic short-lived Westerly Wind Events (WWEs), characterized by westerly wind anomalies lasting between 5 and 30 days. In this talk, I will review some observational and modelling aspects of WWEs and their influence on El Niño. WWEs warm the equatorial cold tongue through downwelling Kelvin wave propagation and shift the eastern edge of the warm-pool eastward through the generation of a locally forced eastward surface jet. They are therefore important processes for the central and eastern Pacific warming during the onset and development phase of El Niño. WWEs cannot however be considered as external stochastic forcing of ENSO, but must be instead be considered as a noise forcing that depends on the mean state: WWEs indeed occur more frequently when the western Pacific warm pool is abnormally shifted to the east. This state-dependent WWE forcing can be viewed as an intraseasonal component of the Bjerknes feedback and is an essential contributor to El Niño diversity, in terms of timing, magnitude and spatial pattern. It also raised hopes for the potential to improve ENSO prediction but some of the WWEs activity remain stochastic, which could still strongly limit the predictability of El Niño. I will finally illustrate the competing role of the deterministic vs. stochastic WWEs in the contrasted evolution of the Pacific in 2014 and 2015. The important role played by WWEs in the evolution and amplitude of recent El Niño events may therefore strongly limit the predictability of El Niño.

Session 3. ENSO and Other Modes of Climate Variability
Keynote: 9:30 – 10:00, Oct. 17

Decadal Variability of ENSO

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Key words: Decadal Variability, Linear Inverse Modeling

Both observations and long climate model simulations show decadal variations in the amplitude, dominant timescale, and spatial pattern of ENSO events. The origin of these decadal variations, whether driven by deterministic changes in dynamics, or occurring purely by chance has been the subject of many investigations. Changes in dynamics can be expected to be mediated by low-frequency variations in the background state of the tropical Pacific, through changes in the dominant ENSO feedbacks. However, it is still unclear whether these background changes are driven by extra-tropical Pacific influences, or due to the rectification of the ENSO variability itself. In this talk, I will first examine the nature of the decadal ENSO changes, focusing on the 1976/77 "climate regime shift" as an example. Using a multi-variate linear inverse modeling technique, I will provide evidence that the changes in ENSO characteristics during this climate shift did not happen by chance, but were related to changes in the system dynamics. Possible mechanisms underlying these dynamical changes, including variations in the strength of the Pacific Subtropical-Tropical Cells, as well as the possibility of nonlinear rectification processes will be reviewed, and outstanding open questions outlined.

Session 3. ENSO and Other Modes of Climate Variability
Oral: 10:30 – 10:50, Oct. 17

Extreme El Nino events and 21st century climate change: attributing inter-model differences in future projections

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Key words: Climate change, Extreme El Nino, Climate modeling

Constraining the response of the El Nino/Southern Oscillation (ENSO) to 21st century climate change is a fundamental problem in climate research which remains unsolved. Future projections of ENSO strength differ across models, making the estimation of future risks associated with extreme El Nino events highly uncertain. Here we analyze results from two large (30+ member) ensembles with the CESM and ESM2M, to demonstrate strong linkages between 21st century projections of extreme El Nino and mean 20th century Pacific climate and its response to warming. Inter-model differences are large, with the frequency of extreme El Nino rainfall in the eastern equatorial Pacific (EEP) increasing in CESM and decreasing in ESM2M under RCP8.5. Although this reduction in ESM2M relates to the weakening of El Nino SST anomalies, in CESM the dominant influences are the increased EEP mean rainfall and a stronger sensitivity of rainfall to SST. Change to the global-mean hydrological cycle and the zonal gradient of equatorial Pacific SST are shown to drive these influences, and are in turn dependent on the 20th century mean state. This implies that increasing the accuracy of extreme El Nino projections is intricately linked with understanding both mean biases in present-day climate and future base-state changes. The potential for reductions in present-day model bias to narrow spread in future projections will be discussed.

Session 3. ENSO and Other Modes of Climate Variability
Oral: 10:50 – 11:10, Oct. 17

Decadal modulation of ENSO and the linkage to tropical Pacific decadal variability

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Key words: decadal modulation of ENSO, tropical Pacific decadal variability

Observational data and paleoclimate proxy records suggest that the amplitude of El Nino-Southern Oscillation (ENSO) varies considerably on decadal-multidecadal time scales, in association with changes in the background state of tropical Pacific climate. To advance our understanding of ENSO modulation and its relation to tropical Pacific decadal variability (TPDV), we analyzed a 1300-yr control simulation of the Community Climate System model version 4 (CCSM4), which reproduces important features of tropical Pacific mean climate and variability. The ENSO simulated in CCSM4 exhibits distinct decadal modulation that is closely related to the two leading modes of TPDV. Systematic modulation is found not only in the amplitude, but also in the frequency, duration, and pattern of ENSO events. The frequency and duration of El Nino vary with the leading mode of TPDV, which resembles the interdecadal Pacific Oscillation (IPO) in observations. The amplitude and asymmetry of El Nino and La Nina, on the other hand, modulate with the second leading mode of TPDV that represents changes in the zonal and meridional contrast of tropical Pacific climate. Diagnostic analysis suggests that the occurrence and evolution of El Nino are more sensitive to decadal changes in the background state compared to La Nina. The resultant changes in El Nino, in turn, affect the occurrence and evolution of La Nina that often follows El Nino.

Intriguingly, the patterns of TPDV in CCSM4 have resemblance to those simulated by its atmospheric component coupled to a slab ocean model through local surface heat fluxes. In both models, atmospheric circulation anomalies associated with TPDV project onto known teleconnection patterns over the North and South Pacific that arise from internal atmospheric dynamics. To test the hypothesis that low-frequency variability of these internal atmospheric modes drives TPDV and modulates ENSO, we conducted a suite of CCSM4 experiments by prescribing the associated surface heat flux anomalies. Despite the surface heat flux forcing confined to the South or North Pacific, the time mean response shows a global pattern of ocean-atmosphere anomalies. In particular, the forcing related to the Pacific-South American pattern induces an anomaly pattern similar to the observed IPO and significantly alters the frequency of El Nino, in agreement with the analysis of the CCSM4 control simulation. This experiment also suggests that oceanic teleconnections from the South Pacific provide a delayed negative feedback to the IPO. The internal atmospheric modes, however, have weak impacts on the second leading mode of TPDV, indicating that the equatorial ocean dynamics plays a more important role.

Session 3. ENSO and Other Modes of Climate Variability
Oral: 11:10 – 11:30, Oct. 17

Atlantic Impacts on Multi-decadal ENSO diversity and Amplitude Variability

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Key words: ENSO multidecadal variability, ENSO diversity, Tropical teleconnections

Multidecadal shifts in ENSO variability have been observed, but it is unclear if this variability is just a random variation in the ENSO cycle or whether it is forced by other modes of climate variability. Recent studies have suggested that the observed mean state differences in the tropical Pacific from the first decade and a half of the new millennium were driven by changes in the Atlantic SSTs. Here, we will show that the impact of Atlantic SST forcing on the tropical Pacific mean state are expressed as asymmetric changes to the annual cycle. The asymmetric changes in the tropical Pacific annual cycle creates a distinct signature in the relationship between the ENSO and the tropical Pacific annual cycle that we observe in the multidecadal ENSO variability in reanalysis and proxy records and that this variability follows the Atlantic Multidecadal Variability. The multidecadal forced changes to ENSO also manifest in the variability associated with diversity of El Niño. We further find that there are concurrent changes in the location of the tropical Pacific ITCZ on multidecadal timescales. The shifts in location of the ITCZ in response to a warmer north Atlantic are consistent with the predictions of an ITCZ shift forced by an enhanced interhemispheric energy gradient. Targeted coupled model experiments are then used to confirm the impact of Atlantic Multidecadal Variability on the tropical Pacific multidecadal variability and explore the impact of SST changes in different regions of the north Atlantic.

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Oral: 11:30 – 11:50, Oct. 17

The role of interannual ENSO events in decadal timescale transitions of the Interdecadal Pacific Oscillation

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Key words: ENSO, Interdecadal Pacific Oscillation

The build-up of decadal timescale upper ocean heat content in the off-equatorial western tropical Pacific could provide conditions for an interannual El Niño/Southern Oscillation (ENSO) event to produce a decadal timescale transition of tropical Pacific SSTs to the opposite phase of the Interdecadal Pacific Oscillation (IPO). Evidence is presented from a set of initialized hindcasts with CCSM4 and CESM1 to show this role for El Niño in the 1970s transition to positive IPO, and for La Niña in the late 1990s transition to negative IPO. Decadal predictions with these models that were initialized in 2013 show that Niño3.4 SSTs qualitatively tracked the observations through 2017, including the El Niño event of 2015-2016. The year 3-7 average prediction (2015-2019) from the 2013 initial state shows a transition to the positive phase of the IPO from the previous negative phase, and a resumption of larger rates of global warming over the 2013-2022 period consistent with a predicted positive IPO phase. As in the previous decadal transition to positive IPO, off-equatorial western Pacific heat content has notably decreased since 2015. A long pre-industrial control run with CESM1 is analyzed to study these proposed interactions between interannual ENSO timescales and decadal IPO timescales.

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Oral: 11:50 – 12:10, Oct. 17

Effect of increasing atmospheric resolution on Prediction Skill of ENSO in Coupled Forecast System (CFS)

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Key words: ENSO, CFS

The effect of increasing atmospheric resolution on prediction skill of El Niño southern oscillation (ENSO) phenomenon in climate forecast system (CFS) model is explored in this paper. Improvement in prediction skill for sea surface temperature (SST) and winds at all leads compared to low resolution model in the tropical Indo-Pacific basin is observed. High resolution model is able to capture extreme events reasonably well. As a result, the signal to noise ratio is improved in the high resolution model. However,spring predictability barrier (SPB) for summer months in Nino 3 and Nino 3.4 region is stronger in high resolution model, in spite of improvement in overall prediction skill and dynamics everywhere else. Anomaly Correlation Coefficient (ACC) of SST in high resolution model with observations in Nino 3.4 region targeting boreal summer months when predicted at lead times of 3-8 months in advance decreased compared its lower resolution counterpart. It is noted that higher variance of winds predicted in spring season over central equatorial Pacific compared to observed variance of winds results in stronger than normal response on subsurface ocean, hence increases SPB for boreal summer months in high resolution model.

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Impact of Multiple Large-Scale Climate Modes on Northern Equatorial African Precipitation Variability

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Key words: Northern equatorial Africa, Rainfall Variability, Ocean-atmosphere Association

Improving the predictive understanding of Northern Equatorial Africa (NEA) (lat 5oN-10oN and lon 10oE-30oE) boreal summer (JAS) rainfall variability is important for rain-fed agriculture. The study investigated the impact of evolution of multiscale global climate modes on the dominate modes of rainfall variability on seasonal timescales. 58 years of data, comprising Climate Research Unit (CRU) precipitation data with 0.5 x 0.5 degree resolution (1951-2008), National Oceanic and Atmospheric Administration (NOAA) Extended Reconstructed Sea Surface Temperature (ERSST) 2.5o lat x 2.5o lon and selected climate indices from 1950/51 to 2007/08. The principal analysis techniques employed were empirical orthogonal function (EOF), composites analysis and multiple linear regression model (MLR). Three dominant modes of rainfall variability were revealed accounting for 42.7% of the total explained variance with EOF 1, 2, and 3 explaining 24.1%, 10.2% and 8.5%, respectively. Spatial loadings showed positive monopole mode for EOF 1, dipole mode for EOF 2 and EOF 3 with interannual variability temporal for all three modes. The grid point correlation between the rainfall modes and global ocean demonstrated EOF 1 was linked to Atlantic meridional feature and negative correlation with equatorial Pacific Ocean for most time steps. The EOF 2 showed negative correlation with North Atlantic Ocean whereas EOF 3 was linked directly to global warming signature over tropical equatorial Ocean. The results of the MLR suggested, on lagged boreal winter to spring time steps, Atlantic Multidecadal Oscillation (AMO) had positive impact on EOF 1 rainfall mode. The simultaneous association indicated positive (negative) link to Tropical North Atlantic (Niño 4 and Tropical South Atlantic (TSA)) indices. TNA and AMO showed varied impact on EOF 2 and EOF 3 rainfall modes. The R-square for the model ranged from 40% to 60% . The outputs of the analysis are significant for subseasonal to seasonal timescale climate prediction.

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Influence of ENSO Events on Intraseasonal Rainfall Oscillations in Central Africa

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Key words: ENSO, MJO

This study addresses the interannual modulation of MJO activity by ENSO events, in Central Africa. In the tropics, the Madden-Julian Oscillation(MJO) and El Niño Southern Oscillation (ENSO) are dominant atmospheric and oceanic variability, respectively. Then in this study, we investigated the relationship between the interannual modulation of MJO activity and the ENSO cycle, in the central Africa's complex climatology. Central Africa extends from 15oS to 15oN and 0-50oE mainly over the land and part of Atlantic and Indian oceans on its edges, and the topography of the region is quite varied, including highlands, mountains, and plateaus. Spatial gradients exist between the western and eastern parts of the region. The western part consisted of zones of intense precipitation, especially over the Congo Basin. The Congo Basin which is imbedded in the western part of the region was proven to experience one of the world's most intense thunderstorms and highest frequency of lightning flashes. The eastern part is characterized by widely diverse climates ranging from desert to forest over relatively small areas. We began the study by extracting the main modes of intraseasonal oscillations in Central Africa. The spatial and temporal structures of the intraseasonal atmospheric variability over central Africa has been investigated using 2.5-degree x 2.5-degree Daily outgoing longwave radiation (OLR) and Nino3.4 SST indices.

The result of the empirical orthogonal functions (EOFs) analysis has shown that the three leading EOF modes explain about 45 %of total intraseasonal variability. The power spectra of all the three corresponding principal components (PCs) peak around 45–50 days, indicating a Madden–Julian Oscillation (MJO) signal. The first mode exhibits high positive loadings over Northern Congo, the second over Southern Ethiopia and the third over Southwestern Tanzania. The PCs time series revealed less interannual modulation of intraseasonal oscillations for the Congo mode, while Ethiopian and Tanzanian modes exhibit strong interannual variations.

An index of MJO strength was built by averaging the 30–50 day power for each day. A plot of MJO indices and El Niño Southern Oscillation (ENSO) cycle confirm a strong interannual modulation of MJO over Eastern central Africa partially linked with the ENSO events (El Niño and La Niña). Strong MJO activity is observed during La Niña years or during ENSO-neutral years, while weak or absent MJO activity is typically associated with strong El Niño episodes.

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El Niño event of 2015-16 and its impact on vulnerable communities of Tharparkar, Pakistan

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Key words: drought, Tharparkar, health, impacts, Pakistan

The prevailing unusually intense El Niño conditions during 2015-16 have created severe drought in Thaparkar (known as Thar) region in southeastern Pakistan. The outbreak of different diseases has posed serious health and life threat to the vulnerable population including children aged less than 5 years and women. Most of the deaths in Thar region have been reported during October 2015 to January 2016. The higher number of deaths have been repeatedly reported due to malnutrition and lack of food. The average lowest minimum temperature was recorded higher than the climatology, creating a challengeable situation for the policy makers and concerned authorities. Future El Niño events may bring similar conditions and cause threat to health and life of the people creating a drought over Thar region however, the intensity of the drought may depend on the intensity of an El Niño event.

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Influence of El Niño Southern Oscillation and Contemporary Climate Change on wave conditions of the Pacific Ocean and the Colombian Pacific

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Key words: Pacific ocean, Ocean waves, Antartic Oscilation, El Niño Southern Oscillation

This research quantitatively indicates the influence of the El Niño Southern Oscillation (ENSO), as well as other oscillations of interannual and decadal scale (Antarctic Oscillation and Pacific Decadal Oscillation) in the wave conditions of the Pacific Ocean and its incidence in the Colombian Pacific. This research constitutes as a tool for the optimization of operational wave forecasts, as well as in the identification of the effect of Contemporary Climate Change and the interaction with ENSO-type events in its dynamics. For this purpose, reanalysis data (1979-2012) generated by the Australian Weather and Climate Research Collaboration (CAWCR), validated with on-site records from a wave buoy located in Buenaventura in the Colombian Pacific were used. The response of the reanalysis to wave trains from the southern hemisphere was evaluated, using retrospectively simulated data for eight geographical positions located in the maritime jurisdiction of the countries of Ecuador and Chile.

Considering the complexities of the ocean swell of the Pacific Ocean in terms of its interannual nature, the description of the swell and swell climate was made through the application of Self-Organizing Maps (SOM) from a temporal and spatial, spectral and statistical analysis. The mean multiannual and monthly mean wave height (Hs) regime was obtained in the Pacific Ocean and the Colombian Pacific, identifying the main patterns of variability existing in this variable through the application of Empirical Orthogonal Functions, as well as analysis SOM as a tool for the identification of the spatial distribution of variability patterns in the geographical area of study. The adoption of these last two techniques for the analysis of the patterns of variability proved to be very efficient to understand the behavior of the waves in the areas of interest. This same methodology was applied to the flow of wave energy, with which the changes produced by ENSO in the directional component were analyzed.

As a result, the level of linear association between ENSO and the prevailing wave conditions in the areas of interest was identified, finding that El Niño produces a decrease in the significant wave height in specific regions, and an opposite behavior during La Niña. The spatial distribution of the patterns that have the greatest influence on wave conditions is evidenced by the SOM analysis. In the same way, it was found that the significant wave height presents a delayed response of five months in front of an ENSO type event, with great impact on its dynamics. On the other hand, it was found that the Antarctic Oscillation has an important influence in the wave conditions of the Pacific Ocean, as well as in the prevailing conditions in the Colombian Pacific. The research also shows the importance of these results in the optimization of operational forecasts of wave conditions, and how these results contribute to the knowledge of Contemporary Climate Change.

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The Pacific Decadal Oscillation modulation of ENSO influence on the precipitation in Ecuador

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Key words: PDO-ENSO relation, Ecuador precipitation

El Niño 97-98 had devastating effects worldwide in the economic and human dimension. Likewise, in Ecuador, this event produced important economic loses and damages to infrastructure, plus delays in diverse sectors of the economy. Previous studies on the influence of ENSO in Ecuador, demonstrated the relation between precipitation in the costal plains (PCP) with the sea surface temperature of region Niño 1+2 (SST 1+2), assuming that such relation is stationary. However, the changes in ENSO from the early 2000s until the present make urgent questioning if the influence of ENSO on the precipitation has changed. In the present study the relation of ENSO and the PCP of Ecuador is analyzed with non-stationary techniques on the time and frequency domain, e.g. cross wavelet analysis. We show that the coherence between SST Niño1+2 and PCP from 1980 to early 2000s was high (e.g >0.8) across 1 to 8 years periods, indicating a strong link between both variables. However from 2003 to 2011, and prior to the early 80s, we show that the coherence between SST 1+2 and PCP lowered considerably across several time frequencies. This is a clear indication of a climatic shift. Interestingly, the coherence between Trans El Niño Index and PCP keep high (e.g. > 0.8) from the 60's to 2011. We attribute the change in the ENSO-PCP relation to the Pacific Decadal Oscillation (PDO) influence. PDO positive phase from the late 70s to early 2000s might be determinant for a stronger relation ENSO-PCP thus increasing precipitation. During PDO negative phase this relation is much weaker, thus more frequent droughts may be expected. Therefore, questions arise towards the water availability during different PDO phases as well as the impacts on diverse ecosystems. In addition a revision of currently used ENSO predictors in Ecuador may be required.

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Analysis of the variability of water levels of Titicaca Lake

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Key words: Titicaca Lake, ENSO, PDO

The purpose of this study is to compare the variability of the Titicaca Lake (TL) water level to the Pacific Decadal Oscillation (PDO) between 1914 and 2014 and relate it was compared to El Niño - Southern Oscillation (ENSO) between 1969 and 2014 to evalute the hydrological cycle and perform rainfall forecast. Results show that the Lake Titicaca water level decreases (increases) in the positive (negative) phase of the PDO. Likewise, the negative phase (positive) of ENSO generates patterns of positive anomalies (negative) of precipitation. Therefore, the positive (negative) phase of PDO, with greater probability of positive phase ENSO events (negative), precipitation anomalies shows negative (positive) which can be associated with the decrease (increase) in Titicaca Lake water level.

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Interdecadal Change in the Precipitation Anomaly over Peru's Central-Southern Andes

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Key words: Interdecadal Change, Precipitation, Teleconnection

In the present study, it was employed a rainfall datasets of 166 stations over Peru's central-southern Andes, spanning the period 1964-2016. The year-to-year precipitation anomalies averaged over this region indicate a notable change around late-1990s. It was seen that, on contrast to the precipitation during 1983-1998, precipitation during 1999-2012 revealed a notable increase. This feature of the interdecadal change was displayed more clearly using a 10-year-running-mean precipitation anomaly. Moreover, the variability is stronger in stations located in western of the Andes. It is believed this change was associated with circulation anomalies in the middle/upper troposphere over South America. In order to analyze the atmospheric circulation changes which accompanied this interdecadal change of precipitation, it was used the ERA-INTERIM reanalysis dataset. Result suggested that, during 1999-2012 there was a significant enhancement of middle tropospheric moisture convergence over eastern Andes and western Amazon basin and this would be related to northeasterly wind anomaly. In upper troposphere, an anticyclonic circulation anomaly, whose center is located in 20°S/62°W, provided with high level divergence over Peruvian Andes. At the same time, ascending motions were detected during this same period over the eastern Andes, so is very likely that changes in zonal flow induced ascent over Peruvian Andes. On the other hand, during 1983-1998, results showed a southwesterly wind anomaly in upper troposphere which had brought about cold advection over Andes. These findings emphasize the of the middle/upper troposphere zonal and meridional flow changes on the interdecadal precipitation change around the late-1990s. Considering that variability of precipitation is influenced by the sea surface temperature (SST) anomaly in tropical Pacific through teleconnections, it is suggested that interdecadal change of precipitation is closely associated with a distinctive sea surface temperature decadal variability over tropical Pacific.

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Network properties of the Sea Surface Temperature field in reanalyses and in the CESM Large Ensemble

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Key words: Climate network, Enso teleconnections

Earth's climate is a complex dynamical system. The underlying components of the system interact with each other (in a linear or non linear way) on several spatial and time scales. Network science provides a set of tools to study the structure and dynamics of such systems. Here we propose an application of a novel network inference method, -MAPS, to investigate sea surface temperature (SST) fields in reanalyses and models. -MAPS first identifies the underlying components (domains) of the system, modeling them as spatially contiguous, potentially overlapping regions of highly correlated temporal activity, and then infers the weighted and potentially lagged interactions between them. The SST network is represented as a weighted and directed graph. Edge direction captures the temporal ordering of events, while edge weights capture the magnitude of the interaction between the domains.

We focus on two reanalysis datasets (HadISST and COBE) and thirty members of the Community Earth System Model (CESM) Large Ensemble. The datasets have monthly resolution and all networks are computed using linearly detrended anomalies. The analysis spans in detail 35 years, from 1980 to 2015, during which we have satellite data, and expand for a longer period, 1920-2100 for some model integrations.

We use four different metrics to explore similarities and differences between the observed and modelled climate networks in the period 1980-2015. The spatial extent and shape of the identified domains is consistent between observations and models. According to our analysis the largest SST domain always corresponds to the El Niño Southern Oscillation (ENSO) while most of the other domains correspond to known climate modes. The largest biases are in the network structures. One of the largest sources of biases is found to be a robust overestimation of the thermodynamic response of tropical SST to El Niño events. Also the standard deviation of the ENSO domain is found to be often overestimated in the ensemble. The autocorrelations of the modelled time series are always found to be larger than observed.

To every ensemble member we remove its individual linear trend and ensemble mean trend. Individual linear trends in CESM appear closely related to modes of variability, while the ensemble mean trend is linked to the increased concentration of greenhouse gases.

We then investigate changes in the modelled network structure depending on the detrending method. On average domains are found independent of the trend removed. Larger changes are seen in the network structure. Here, the significance of some connections depends on the method of detrending. This is true especially for members with a ENSO/PDO shaped trend in the Pacific: when this pattern is subtracted, the Pacific variability is modified and fewer links from the ENSO domain are found. By removing the ensemble mean trend, positive correlated links are restored.

Finally, we explore similarities and differences between reanalyses and models in terms of their time evolution. The focus is on the mean strength of tropical domains, dominated by ENSO activity. We find positive trends in both reanalyses and models. This translates in a steady increase in the dominance of ENSO in the climate network in both the observed and modelled world.

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The impact of Pacific Japan pattern on Indian summer monsoon rainfall

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Key words: Pacific Japan pattern, Indian summer monsoon rainfall, El Nino Southern Oscillation, Tropical Indian Ocean

This study discusses the impact of the Pacific-Japan (PJ) pattern on Indian summer monsoon (ISM) rainfall and its possible physical linkages through coupled and uncoupled pathways. Empirical orthogonal function analysis of 850 hPa relative vorticity over the western North Pacific (WNP) is used to extract the PJ pattern as the leading mode of circulation variability. The partial correlation analysis of the leading principal component reveals that the positive PJ pattern, which features anticyclonic and cyclonic low-level circulation anomalies over the tropical WNP and around Japan respectively, enhances the rainfall over the southern and northern parts of India. The northwestward propagating Rossby waves, in response to intensified convection over the Maritime Continent and reinforced by low-level convergence in the southern flank of westward extended tropical WNP anticyclone, increase rainfall over southern peninsular India. Meanwhile, the anomalous moisture transport from the warm Bay of Bengal due to anomalous southerlies at the western edge of the low-level anticyclone extending from the tropical WNP helps to enhance the rainfall over north India. The atmospheric general circulation model forced with climatological sea surface temperature confirms this atmospheric pathway through the westward propagating Rossby waves. Furthermore, the north Indian Ocean (NIO) warming induced by easterly wind anomalies along the southern periphery of the tropical WNP-NIO anticyclone enhances local convection, which in turn feeds back to the WNP convection anomalies. This coupled nature via inter-basin feedback between the PJ pattern and NIO are confirmed using coupled model sensitivity experiments. These results are important in identifying new sources of ISM variability/predictability on the interannual timescale.

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High Resolution Remote Sensing Study Of ENSO Energetics , Sea-level Variability Mechanism , Sub-Mesoscale Dynamics and their Correlation with Climate Variability Over Pacific Transitional Areas (TAs)

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Key words: Correlational Climate Variability ENSO Forecasting Model (CCVEFM), HPC

The El Niño Southern Oscillation (ENSO) originates in the tropical Pacific Ocean TAs & are source of year-to-year climate variability. (TAs) are strong gradients ares in the physical environment associated with Sea-level Variability Mechanism, Sub-Mesoscale Dynamics over the Oceanic areas impacting the Climate change & are the potential oceanic regions of early detection of Climate variability.

The study examines the ENSO Energetics, Sea-level variability mechanism on time & Space Scales through SSTs, dynamics of sub-mesoscale systems by making use of High Resolution Satellite imageries, data access assimilation; HPC and cloud computing for real-time analysis ; with emphasis on the large scale kinematic and thermodynamic behavior of selected sub-mesoscale Systems over Pacific Transitional Areas(TAs).

The kinematic & thermodynamic characteristics, e.g. lifetime, distribution, trajectories, size and three dimensional structure, i.e., vertical extent of these systems would be computed in order to develop a Correlational Climate Variability ENSO Forecasting Model (CCVEFM) over tropical Pacific Ocean

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Effects of Climate Forcing Parameters on Coastal Regions due To Maritime Aerosols

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Key words: Radiative Forcing, Cloud Condensation Nuclei, aerosol, climate

The total marine trading is concentrated in the maritime states. Since they are the facilitated by the port and harbours for the marine transport. It is essential to provide the safety for the major population from the maritime aerosols.

An aerosol is a colloid of fine solid particles or liquid droplets, in air or another gas. The excessive range of aerosol in the particular region will affect the health of the living organism and affect the regional climate. Therefore, in-depth study on the aerosol over the coastal regions is pre-requisite in the climate change projections. The particulate analyzer is used to find out the level of aerosol. In order to analyze the aerosols, the particulate analyzer kept in upper deck of ship and analyzed the aerosol concentration over the atmosphere of south Indian coast. The aerosols concentration is used to analyze the optical property of aerosol and to find the radiation budget in the region. Residence time of CO2 is longer about five years, whereas Sulphur residence time is about 10 days. The radiation data gives the detail of aerosol formation by which the level of forcing on climate is analyzed.

The emissions of CO2, NOX and SOX from atmospheric pollutant affect cloudiness, and accelerate climate impact ‘Radiative Forcing’ (RF). Positive RF produces warming and Negative RF produces cooling effect. They also indirectly affect weather patterns through the Cloud Condensation Nuclei (CCN). The overall effect is Negative Radiative Force. Increase in Sulphur could result in reduced Negative RF.

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Enso Influence On The South American Atmospheric Circulation And Precipitation At Different Phases Of The Pacific Decadal Oscillation Between 1970 And 2003

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Key words: Pacifil Decadal Oscillation, Atmospheric circulation, South America

The present study has investigated ENSO events occurring in each phase of the Pacific Decadal Oscillation, as well as the description of the atmospheric patterns and the influence of the El Niño and La Niña events on the mean PDO signal in South America. The rate of occurrence of EN and LN phenomena was calculated during the three PDO subperiods between 1970 and 2003 (1970-1976, 1977-1996 and 1997-2003) for wind at 850 hPa and sea surface temperature, based on NCEP-NCAR reanalysis I, and precipitation data of GPCC. The results indicated five LN events (0,6%) and two EN events (0,2%) during the first subperiod, negative phase of PDO. For the second subperiod, positive phase of the PDO, six EN events (0,3%) and four LN (0,1%) events were identified. For the 1997-2003 period, negative phase of PDO, two events of EN (0,3%) and three events of LN (0,4%) were observed. The occurrence of cold and warm ENSO events are associated with the PDO phases. The positive phase of the PDO was determined by warmer ENSO events. Similarly, the negative phases of PDO are more associated with ENSO colder events. The results showed positive SST anomalies over the equatorial Pacific during the positive phase of the PDO and the reverse phase in the negative phase of the PDO. Furthermore, based on calculations and linear trend, it has been found that the SST of the third phase of the PDO is appreciably larger than the SST of the first phase of the PDO, both negative phases. Although Pacific general warming occurs in the western areas, Pacific warming differences were observed for the central-east equatorial region in the last period, indicating that when there are EN events, such areas are becoming warmer by the comparison of PDO negatives phases. In relation to precipitation it occurs as dipole in the center-east part of South America. We identified more influence of PDO in the northeast region than the southeast part. LN events presented similar precipitation anomalies to the average observed in South America, while EN events showed differences in two periods of occurrence. The detailed analysis of the annual wind anomalous circulation allowed us to verify the years that contributed most to determine the average pattern of the PDO subperiods. In general, negative PDO phases are associated with stronger meridional winds over continental central areas and stronger zonal winds over the northeastern areas of South America. For both the zonal and the meridional component anomalies, every year from 1970 to 1976 follow the average pattern of the first subperiod. In the second subperiod, it can be observed that for the two wind components, the years from 1977 to 1984 - years of successive LN events, except 1978, are the ones that move away from the average spatial pattern. For the third subperiod, the years 1997, 2002 and 2003 are the ones that deviate more from the average, contributing more for weaker meridional and zonal winds over central and northeastern areas.

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The relationship between Indian summer monsoon rainfall and tropical variability

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Key words: ENSO, IOD, Indian summer monsoon rainfall

El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) tend to exert an offsetting impact on Indian summer monsoon rainfall (ISMR), with an El Niño event tending to lower, whereas a positive IOD tending to increase ISMR. However, the effect from ENSO and the IOD on ISMR shows inter-decadal variations, such as the weakening relationship between ENSO and ISMR and the increasing relationship between IOD and ISMR since 1980s. The dynamics are not fully understood. Here we show that a post-1980 weakening in the ENSO-IOD coherence plays a key role. During the pre-1980 high coherence, ENSO drives both the IOD and regional rainfall, and the IOD's influence cannot manifest itself. During the post-1980 weak coherence, a positive IOD leads to increased Indian rainfall, offsetting the impact from El Niño. Further, simulation of these relationships in Phase Five of the Coupled Model Inter-comparison Project has not been fully assessed, nor is their impact on the response of ISMR to greenhouse warming. Here we show that the majority of models simulate an unrealistic present-day IOD-ISMR correlation due to an overly strong control by ENSO. As such, a positive IOD is associated with an ISMR reduction in the simulated present-day climate. This unrealistic present-day correlation is relevant to future ISMR projection, inducing an underestimation in the projected ISMR increase. In conclusion, ENSO, the IOD and their relationship with ISMR are crucial to ISMR simulation and projection.

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MJO and ENSO interaction on the modification of rainfall impacts over the Northwest of South America

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Key words: MJO, ENSO

El Niño Southern Oscillation (ENSO) has direct effects on rainfall on the Northwest of South America (NWSA). ENSO-related impacts vary over the region, but generally the warm episode is associated, for example, with floods in Ecuador and Peru and droughts in Colombia. In addition, the Madden-Julian Oscillation (MJO) is the leading driver of intraseasonal rainfall variability in the tropics. Previous studies have shown that MJO can modulate ENSO-related impacts in the extra-tropics and in the tropics. The present study aims to better understand the impacts of rainfall associated with the interaction between ENSO and MJO.

We performed a diagnostic analysis on rainfall impacts in the Northwest of South America when there is an ENSO condition defined by the Oceanic Niño Index (ONI) and an active MJO by using the operational Real-Time Multivariate MJO index (RMM). Composites of zonal winds at the surface and at the upper-tropospheric level, outgoing long-wave radiation (OLR) and rainfall are made using data derived from reanalysis and satellite datasets from 1981 to 2016. These variables are the average of the intraseasonal anomaly fields occurring during the days that fall within the RMM phases during El Niño and La Niña years, respectively.

We found a systematic association between ENSO, MJO phases, and rainfall impacts for the area of study. Results show that rainfall anomaly patterns can be strengthened or weakened when ENSO and MJO happen simultaneously. When there are El Niño conditions and MJO is in phase 2 (convective Indian Ocean), strong negative OLR anomalies appear over the coast of Ecuador, and negative anomalies overall emerge in the NWSA. Meanwhile, in phase 7 (convective western Pacific), there are positive OLR anomalies over Colombia and Ecuador, but negative OLR anomalies over Peru. Understanding the dynamical mechanisms between ENSO and MJO could give insight about the potential for seasonal-to-seasonal forecasting on the region.

Session 3. ENSO and Other Modes of Climate Variability
Poster

Reconstructing late Pleistocene to Holocene glacial advances to assess the fast warming of the northern Andes

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Key words: freezing level height, Holocene climatic reconstruction, northern Andes, SST main modes

There is still limited knowledge of how fast the northern Andes warmed up since the Last Glacial Maximum. One way of deducing such changes is by inferring variations in the height of the freezing level. Two complementary approaches were merged to reconstruct late Pleistocene to Holocene glacial advances in a particularly challenging glacierized setting: the northwestern flank of the Ruiz-Tolima volcanic massif, one of the most extensively glacier-covered massifs in the northern Andes. Activities included geomorphological mapping and time-series reconstruction of changes in the altitude of the 0°C isotherm. High-resolution satellite images were used to identify geological landforms that may keep a record of the timing and magnitude of past glacial advances. Cartographic maps were validated and complemented during field campaigns. ~30-kyr paleo-reconstructions of eastern tropical Pacific sea surface temperatures (SSTs) and sea level changes were combined with reconstructed and observed present-day Indo-Pacific and tropical Atlantic SST data, as well as with ECHAM4.5, ERA-Interim reanalysis and ground-truth air temperature data to infer fluctuations of the 0°C isotherm. Gridded datasets of SST anomalies were decomposed into combinations of orthogonal spatial patterns. SST data were also used to analyze the probability distribution of air-sea temperature differences and the spatial distribution of grid points with temperatures above the minimum threshold necessary to initiate deep convection. ECHAM4.5 grid points along the axis of the Andes Cordillera were selected to assess the main modes of spatio-temporal variations of temperature gridded datasets. ERA-Interim reanalysis and ground-truth data were processed to assess normal environmental lapse rates (ELRs), whose values were compared with Indo-Pacific and tropical Atlantic first eigenvalues. Correlation coefficients and slope parameters were plotted on radar charts to assess year-to-year changes in monthly conditions. Potential ranges of past ELRs were inferred by comparing present-day moist adiabatic lapse rates with current, observed ELRs. Fluctuations in ELRs were based on extrapolations of present-day relationships from scatter diagrams of ERA-Interim ELRs vs. equatorial Pacific and tropical Atlantic eigenvalues, for a bulk of the distribution of SST anomalies in the range from -2.8 to -1.7°C. Maps of glacial landforms and reconstructed Freezing Level Heights provided well-founded reconstructions of past glacier advances, narrowing down the coarse resolution of previously-suggested glacial advances. They also refined assumptions and extrapolations proposed for both flanks of the massif under study. This research fills the gaps in the understanding of past climatic changes in the region of interest, provides some insights into the analysis of the signals of natural and anthropogenic climate change, and open doors to further studies on the ongoing and forthcoming warming of the northern Andes.

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North Pacific Coastal oscillation

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Key words: California Current, Aleutian Low, Northeast Pacific High, East Pacific Warm Pool, Cold Surge, Mountain-gap winds

During the last decades, numerous patterns of natural climate variability have been described at different temporal and spatial scales. This work characterized two dominant modes of ocean variability arising from coastal analysis of sea surface temperature anomalies from Ecuador to Alaska. The first costal mode is present throughout the Pacific basin and corresponds to interannual warming and cooling events with “El Niño” like shape over the Equatorial Pacific and along the American coast. At temporal scale this mode was related to the interannual warming and cooling events present in the two main climate variability patterns described for the Pacific basin: El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation. The second mode was a novel dipole of coastal variability exclusive of the Northeast Pacific, with one pole in the California Current System (CCS), and the other pole in the East Pacific Warm Pool (EPWP). We called this pattern as North Pacific Coastal Oscillation (NPCO), and it was not associated with any of the climate patterns referred to the Pacific and Atlantic basin. The NPCO represented opposites warming-cooling events at interannual scale over the CCS and the EPWP; it was not related to ENSO, but the interaction between both patterns seems to modulate the intensity of warming-cooling events over the tropical and extratropical coasts of the Northeast Pacific. The NPCO was the result of the oceanic and atmospheric variability over the North Pacific Ocean and North American Continent; and especially with the interaction between the Aleutian Low and the Northeast Pacific High. The NPCO represents changes in the flow of surface currents and in the upwelling wind patterns along the coast in the CCS; and changes in the southern movements of cold air masses over the North American continent and the Gulf of Mexico that activatesmountain-gap wind jets over the EPWP. Besides, the analysis showed that the focus on certain fractions of the system can be providing useful information to understand the dynamics of particular regions.

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ENSO as a Component of the Global Atmospheric Oscillation

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Key words: ENSO, Global Atmospheric Oscillation, temporal rhythms of ENSO, ENSO in the CMIP5-models, long-term El Niño prediction

The main target of the study is to show our recent finding of the interannual Global Atmospheric Oscillation (GAO) and its climatic features. The GAO was found to form an X-shaped spatial structure of the negative sea-level pressure (SLP) anomaly centered in the tropical Pacific. Its four branches border a vast domain of positive SLP anomalies that develop in tropics from the Atlantic coast of South America up to the west part of the Pacific Ocean. Another two domains of significant positive SLP anomaly incorporate a north part of Northern America and far south-east of the Pacific. Thus, GAO is a global-scale phenomenon which shows itself by different atmospheric processes, both intra- and extratropical ones. The work presents our recent disclosure the ENSO as incorporated element of the GAO as well.

To characterize GAO we define an index presented by a combination of the SLP anomalies corresponding to ten local minima and maxima of GAO at specific geographical locations. Cross-correlating this index with an El Niño index we find out a strong relationship between GAO and ENSO. Having shifted the locations westward, we develop the GAO index that can be used to predict El Niño with the lead-time of about one year. Such selection of contributing regions is motivated by the facts that high-latitude domains of nonzero-GAO values are represented by certain waves in the SLP that propagate from west to east. Thus, GAO appears useful when trying to forecast El Niño with the lead-time longer than the well-known spring predictability barrier of ENSO.

To better understand why the present-day long-term El Niño forecasts are not always successful we compute spatial structures of anomalies corresponding to GAO with CMIP5-models. We find out that some of these models reproduce the spatial structure of GAO fairly well. However, as it is seen in power spectra of observed and modeled GAO indices, temporal variations of the modeled GAOs differ substantially from it's observed variations. All main peaks in the modeled spectra correspond to periods of some subharmonics of the annual period. Opposite to this, the observations-based GAO spectrum reveals a certain decrease in the spectral density near these periods. Instead, the main peaks of the observed spectrum are seen near the subharmonics 2:1, 3:1, and 4:1 of the so-called Chandler wobble in the Earth's pole motion, the superharmonics 1:2, 1:3, and 1:4 of the Luni-Solar nutation of the Earth axis and the ~11-year cycle of the Sunspots. This difference in position of main spectral peaks in the observed and modeled spectra is a consequence of the fact that the present-day models do not take into consideration impacts of afore-mentioned external periodicities on the interannual climate dynamics. As a result, although the best of the present-day climatic models are capable of forecasting El Niño events in principle, they usually fail to properly forecast these in time.

This study was supported by the Russian Science Foundation (grant no. 14-50-00095).

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Fingerprint of Volcanic Forcing on the ENSO-Monsoon Coupling

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Key words: ENSO, Monsoon, Coherence, Volcano

The coupling of ENSO and the Indian Monsoon is an important source of predictability of the seasonal monsoon rains which directly impacts the lives of millions of inhabitants in the region. While it is recognized that the radiative effects of aerosols injected into the stratosphere by strong volcanic eruptions can potentially influence the evolution of ENSO, detecting the signatures of volcanic forcing on ENSO-Monsoon coupling has remained challenging. Here we use a non-linear approach for identifying phase relationships of oscillatory systems and show that volcanic forcing can induce phase-locking of the ENSO and Monsoon phenomena, as evidenced from instrumental records, paleo-climatic reconstructions and the Paleoclimate Modelling Intercomparison Project Phase III (PMIP3) model simulations. Proxy-based paleo-climate reconstructions allow us to detect signatures of ENSO-Monsoon coupling induced by 9 major volcanic events that occurred during the last millennium. While very strong volcanic eruptions seem necessary for triggering El Nino events, our analysis suggests that the phase synchronization of El Nino and Monsoon droughts over South Asia tends to critically depend on the state of the tropical atmosphere-ocean coupled system.

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Changing Climate Cycles of ENSO and PDO Intensified Sea Level Swings in the Pacific

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Key words: Climate cycles, Intensified sea-level swings

Over the past 60 years, sea level changes in the tropical Pacific have been intensified, particularly in the last 30 years [Moon and Song, 2013]. It is puzzling how long this pattern of regional sea-level changes has been gone, what is the dynamic cause, and how these can be predicted for future decades. These intensified sea-level swings, when superimposed on the global trend of sea level rise, could have profound implications for coastal communities, the health of marine and estuarial habitats. Combining recently reconstructed long-term sea level data products, upper-ocean measurements, recent satellite data, and a general ocean circulation model [Song and Colberg, 2011], we show that the multi-decadal sea-level swings are the consequence of upper-ocean heat changes, closely related to the Pacific Decadal Oscillation (PDO)-induced ocean circulations, and the modulation of the dueling climate cycles, PDO and ENSO, may have intensified the sea level swings in the tropical Pacific since 1980s [Moon et al., 2015]. The implications of this finding suggest that the combined effect of ENSO and PDO is the key to predict future sea level changes in the tropical Pacific. The underling dynamic mechanisms will also be discussed.

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Influence of ENSO Flavors in the interdecadal atmospheric teleconnection between North Atlantic Oscillation and rainfall in the Central Andes (Peru-Bolivia)

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Key words: Rainfall, Central Andes (Peru-Bolivia), Wavelet coherence technique, ENSO flavors, North Atlantic Oscillation, interdecadal variability, Eastern El Niño, Central El Niño, Mantaro Basin, Bolivian Altiplano

Interdecadal forecasting of the rainfall is one of the significant challenges of the scientific community. This challenge is higher in the Mountains regions such as Central Andes (Peru-Bolivia) where few rainfall stations have a long record. The North Atlantic Oscillation (NAO) is a seesaw of atmospheric mass which alternates between the polar and subtropical regions. The NAO is a large-scale seesaw in atmospheric mass between the subtropical high and the polar low. Few studies have shown the existence of a relationship between NAO and rainfall in the central Peruvian Andes (Nickl 2007; Silva et al., 2008) while it has not documented for the Bolivian Altiplano yet. Therefore, the primary goal of this study is to describe the relationship between NAO and rainfall in the Central Andes on interdecadal timescales as well as ENSO flavors impacts this relationship. We use monthly rainfall of the stations of Huayao (central Peruvian Andes) and San Calixto (Bolivian Altiplano) from 1917 to 2010. We use the monthly series of Central El Niño (C) and Eastern El Niño (E) for the same period. Our analysis is a focus in the austral spring (September-October-November, SON) and summer (December-January-February, DJF). To examine the relationship in time-frequency space between rainfall of Huayao and San Calixto, NAO, and ENSO flavors, we use Wavelet coherence technique.

Wavelet coherence shows an in-phase link between 17-19 year period between NAO and Central EL Niño while opposite phase is observed between NAO and Eastern El Niño during the austral spring (SON) for the 1918-2010 period. Conversely, Wavelet coherence also shows a reverse phase between NAO and Eastern El Niño during the austral summer (DJF) for periods higher than 17 years, while NAO and Central El Niño do not register a link in this season. Wavelet coherence features the existence of an in-phase link between 15-17 year period between NAO and rainfall of the central Peruvian Andes during the austral spring for the 1918-2010 period whereas this relationship does not occur during the austral summer. Similarly, the precipitation of the Bolivian Altiplano registers an in-phase link with NAO for periods higher than 14 years during the austral spring while this same in-phase link only is observed between 17-19 year for the 1918-1980 period during the austral summer.

In conclusion, Central El Niño has a negative relationship with the NAO between 18-20 year period while the opposite case occurs with Eastern El Niño for the same 18-20 year period. On the other hand, NAO modulates in phase between 15-17 year period the spring rainfall of the Central Andes (Peru-Bolivia) while the NAO only modulates the summer rainfall of Bolivian Altiplano between 1918 and 1980.

Session 3. ENSO and Other Modes of Climate Variability
Poster

The role of noise forcing in generating ENSO diversity

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Key words: ENSO Diversity, Stochastic Forcing, Meridional Mode, Westerly Wind Burst

The role of noise forcing in generating ENSO diversity is explored using linear inverse model (LIM) and numerical model approaches. First, a LIM is developed using historical or modeled sea surface temperature (SST) and thermocline depth, and is used as a dynamical filter to separate the deterministic tendency of the multivariate state of the Tropical Pacific from the non-deterministic (i.e. noise) multivariate forcing. The temporal structure of noise forcing with CP and EP characteristics is obtained by projecting the multivariate noise time series onto optimal initial conditions for ENSO events with CP and EP characteristics. Finally, the noise time series are related to other variables (e.g. sea level pressure, low-level winds, surface heat fluxes, and outgoing longwave radiation) to better characterize phenomena within the noise that lead to ENSO events with CP or EP characteristics. The analysis is applied to observed variability and to modeled variability in the NCAR Community Earth System Model (CESM).

The noise forcing is then investigated to evaluate structures that lead to ENSO events with CP vs. EP characteristics. Two analyses are presented: (i) analysis of the evolution of individual ENSO events in the historical record as a check on the technique and as a method to infer specific structures in the noise forcing, and (ii) designed numerical model experiments (using the CESM) in which an individual element of the noise forcing is applied as an external forcing in an ensemble of NCAR CESM experiments. Results confirm the well-established finding that ENSO events with CP characteristics are strongly related to the seasonal footprinting mechanism. ENSO events with EP characteristics are less clear: observational analyses indicate that EP events appear to be related to both westerly wind burst activity and forcing from the South Pacific Meridional Mode, but ENSO events with EP characteristics are not reproduced by the numerical model experiments. Results will be discussed with implications for understanding past and future mechanisms for generating ENSO diversity.

Session 4. Modeling and Prediction

Oral presentations

Session 4. Modeling and Prediction
Keynote: 14:30 -15:00, Oct. 17

ENSO in climate models: Progress and Opportunities

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Key words: ENSO, climate modeling, coupled GCMs, seasonal forecasts, air-sea interaction, tropical Pacific, climate prediction

Coupled general circulation models (CGCMs) are indispensable tools for forecasting ENSO, illuminating ENSO dynamics, and projecting the future of ENSO in the context of a changing climate. Recent advances in CGCMs have led to improved understanding of ENSO's precursors, impacts, nonlinearities, spatiotemporal diversity, and interdecadal modulation, and will soon enable seamless subseasonal-to-decadal predictions. Yet despite this impressive progress, several major challenges remain for CGCMs: persistent biases in the tropical Pacific mean climate, displaced patterns of ENSO's variability and teleconnections, altered feedback loops, and insufficient diversity, asymmetry, and seasonal synchronization of ENSO. Such model biases can then degrade historical climate reanalyses, generate initialization shocks and conditional biases in forecasts, and undermine confidence in model projections of ENSO's future. I will discuss community-wide efforts to tackle these problems, supported by strengthening connections among observations, theory, and numerical models. I will also highlight recent progress at NOAA GFDL toward simulating and understanding ENSO, offering exciting new avenues to further improve predictions of tropical Pacific climate variations and their global impacts.

Session 4. Modeling and Prediction
Keynote: 15:00 -15:30, Oct. 17

Consensus climate model evaluation for end users: an example with ENSO metrics

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Key words:

Evaluating ENSO in climate models has occupied the community for decades. Initially this activity has been mostly driven by ENSO experts trying to improve ENSO properties. As climate models are increasingly used for climate impacts and by more distant end users, model evaluation is evolving. This wider use opens new opportunities for community climate model evaluation, in particular defining question-driven metrics, in addition to the more classical performance or process-based metrics. We will here review these issues and propose to organise a consensus model evaluation approach for the benefit of non-expert end users, with a first proof of concept using ENSO metrics. Software infrastructure requirements for such an organisation are also addressed.

Session 4. Modeling and Prediction
Oral: 16:00 16:20, Oct.17

A Bird's Eye View of Operational ENSO Prediction: Methods, Challenges, and Paths Forward

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Key words: predictions, operations

Once a month, the NOAA Climate Prediction Center updates its ENSO status and forecasts through the ENSO Diagnostic discussion (and climate.gov ENSO Blog), which are disseminated through social and formal media. The core of our product suite is the categorical probabilities for El Niño- Neutral–La Niña based on a consensus interpretation of a large number of deterministic and probabilistic model-based forecasts of the Niño-3.4 index. However, many users request information on the potential strength of an upcoming ENSO event, for which these three category outlooks fall short. Recent developmental work has focused on expanding the number of probabilistic categories that would provide more resolution on the Niño-3.4 intensity. The skill of nine-category outlooks is compared against the probabilities provided by one subset of models, the North American Multi-Model Ensemble. We will also provide some ideas (or requests) in order to continue to move our ENSO outlooks forward and maximize benefits for a diverse user community.

Session 4. Modeling and Prediction
Oral: 16:20 – 16:40, Oct. 17

Does the equatorial recharge/discharge increase ENSO predictability?

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Key words: ENSO predictability, equatorial recharge/discharge

El Niño and La Niña events, together referred to as the El Niño – Southern Oscillation (ENSO), drive large-scale changes in weather patterns, generating recognizable alternations in seasonal climate across the globe. As such, predicting ENSO events many months in advance is of particular interest. Despite decades of scientific research on the dynamics of ENSO, our ability to predict the amplitude of ENSO events 10-12 months in advance remains limited. This long lead-time forecast challenge is often attributed to internal variability of the climate system that influences the triggering and subsequent evolution of events. An open question is, how much does this internal variability hinder our ability predict ENSO events? This study introduces an idealized state-of-the-art climate model methodology to model perturbation growth that hinders ENSO predictability. The goal is to quantify how much random disturbances, like weather, contribute to increasing the range of possible outcomes in ENSO forecasts. The details of the initial condition are also investigated, particularly whether the recharge/discharge (i.e., the buildup of heat content in the equatorial Pacific subsurface) increases the predictability of events by reducing the range of possible outcomes and/or enhancing the signal we hope to predict. The idealized framework is also used to identify the minimum processes necessary to simulate ENSO events in NCAR CCSM/CESM. A key finding is that the recharge is a necessary condition to simulate extreme El Niño events, whereas the discharge does not generate any type of La Niña event that random disturbances kicking off coupled instabilities cannot.

Session 4. Modeling and Prediction
Oral: 16:40 – 17:00, Oct. 17

Improved skill in North American multi-model ensemble for the Americas

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Key words: NMME, weighted ensemble, SST biases

We use knowledge of the performance of individual GCM contributing to the North American multi-model ensemble (NMME) system to improve the interpretation and ensemble construction of surface temperature and precipitation seasonal forecast. Relevant process-based linkages of the remote and coastal SST anomalies and associated biases, as well as local precipitation and temperature biases, are used to diagnose model performance and assign weights of the ensemble members. In general, the weighted ensemble forecast improved the skill of the NMME forecast products relative to the unweighted ensemble. The proposed ensemble member weighting approach help improve NMME forecasting skill throughout the year, especially during the summer and fall. We demonstrate how the information regarding individual model's structural errors help improve the overall ensemble skill during the whole retrospective period and and show the impact during individual ENSO episode forecast. Further, we show the spatial patterns highlighting the regions benefiting from this blending approach. In all, we highlight the readiness of the NMME seasonal forecast products for operations purposes focused in the Americas.

Session 4. Modeling and Prediction
Oral: 17: 00 – 17:20, Oct. 17

Characterizing tropical Pacific SST predictability

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Key words: ENSO predictability, forecast skill, empirical models

The predictability of seasonal anomalies worldwide is largely due to the predictability of tropical sea surface temperature (SST) anomalies. Despite several decades of model improvements, however, the tropical SST forecast skill of the operational North American Multi-Model Ensemble (NMME) system, which combines forecasts from eight state-of-the-art coupled nonlinear atmosphere-ocean models (CGCMs), remains close both regionally and temporally to that of a vastly simpler Linear Inverse Model (LIM) derived from the observed covariances of SST, sea surface height (SSH), and wind fields, over the years 1982-2009. Additionally, the regionally and temporally varying potential forecast skill estimated using the LIM's forecast signal to noise ratios also closely tracks the NMME and LIM skill, and is only slightly higher. The closeness of both LIM realized and predicted skill to that of the NMME-mean suggests that the predictable SST dynamics may be characterized as effectively linear, with the strong nonlinearities in the coupled tropical Pacific ocean-atmosphere acting primarily as noise forcing that increases ensemble spread rather than enhancing the predictable signal. The exception is the Niño1.2 region, where LIM skill significantly below the NMME-mean for leads greater than about 3 months points to some predictable nonlinearity there.

This conclusion is tested in a second analysis, where hindcasts for 1982-2009 are initialized directly on a CGCM's own attractor, using an analog approach in which model states close to the observed initial state are drawn from a library obtained from prior uninitialized CGCM simulations. The subsequent evolution of these "model-analogs" yields a forecast ensemble, without additional model integration. This technique is applied to half of the NMME CGCMs, selecting from prior long control runs those model states whose monthly tropical IndoPacific SST and SSH anomalies best resemble the observations at initialization time. Hindcasts are then made for leads of 1-12 months. Deterministic and probabilistic skill measures of these model-analog hindcast ensembles throughout the equatorial Pacific are comparable to and slightly higher than those of the initialized NMME hindcast ensembles. Despite relatively large initial ensemble spread, model-analogs also reproduce each CGCM's perfect-model skill, consistent with a coarse-grained view of tropical predictability. Finally, the linearity of model-analog (and hence CGCM) skill is assessed by reversing the analog sign and then repeating the hindcasts. To first approximation, skill patterns and amplitudes are largely similar, consistent with effectively linear skill, particularly in the central equatorial Pacific, northwestern tropical Pacific, and Indian ocean. However, again all four models show substantial Niño1.2 skill differences, supporting potential predictable nonlinearity there that is captured by the CGCMs (and even better by the model-analogs) but not by the LIM.

Session 4. Modeling and Prediction
Oral: 17: 20 – 17:40, Oct. 17

Tuning ENSO in a Climate Model

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Key words: equatorial cold SST bias, atmospheric feedbacks, Walker Circulation, ENSO dynamics

Despite improvements in simulating El Niño/Southern Oscillation (ENSO) in the last decades, current climate model still suffering in simulating important ENSO properties of ENSO, like the amplitude, the frequency, the phase locking to the annual cycle or the asymmetry between El Niño and La Niña (e.g. Bellenger et al. 2014). In a recent study of Bayr et al. (2018) the equatorial cold sea surface temperature (SST) bias in the tropical Pacific could be highlighted as one large contributor to biased ENSO dynamics in climate models. The cold equatorial SST bias, a common problem in climate models, causes a La Niña-like mean state with a too westward position of the rising branch of the Walker Circulation (by up to 30°), resulting in an erroneous convective response during ENSO events. This in turn biases the two most important atmospheric feedbacks, the positive (amplifying) wind-SST and negative (damping) heat flux-SST feedback, with error compensation between these two.

Bayr et al. (2018) also give some indications how ENSO is tunable, as the study shows that it is possible to reproduce the same spread in cold SST bias and atmospheric feedback strength as seen in a CMIP5 multi-model ensemble with a perturbed physics ensemble of the Kiel Climate Model (KCM). This was achieved by changes in the cloud and convection parameters which are usually used to tune the climate models. Here we present a more detailed and systematic analyses of the influence of the tuning parameters on ENSO simulation in the KCM which employs ECHAM5 as the atmospheric component. We show the impact of the tuning parameters on the cold SST bias, the ENSO atmospheric feedbacks and important ENSO properties and demonstrate the possibility to tune ENSO and important global climate properties at the same time.

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Posters

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Poster

Long term Holocene trends, change in seasonality and ENSO variability

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Key words: earth system model, model-data comparisons

Improved understanding of the relationship between interannual variability and the mean climate state is an important issue for anticipating the changes due to the current global warming. Past climate simulations offer a unique opportunity to test the possible influence of long term climatic trends on ENSO characteristics and to test the realism of climate simulations. Here we focus on the late Holocene, considering both a small multi-complexity ensemble of mid-Holocene (6ka BP) to present-day climate simulations with the IPSL model and a pan Pacific reconstruction of seasonality and interannual variability from coral and mollusks records. The simulations allow testing different model configurations in terms of land surface and resolution. They all include the carbon cycle and one of the simulations also deals with dynamical vegetation. The analyses both assess the similarities in the respond of the different model versions and differences in term of pattern, magnitude and timing of major events. A particular focus will be put on the relative evaluation of trends and variability between the East Pacific, the Central Pacific, the Western Pacific and the SPCZ region where the high resolution records spanning the mid to late Holocene are more numerous. The large variability of ENSO events will be discussed, as well as methodologies to properly compare model results with climate reconstructions.

Session 4. Modeling and Prediction
Poster

Evaluation of ENSO Diversity on CMIP3 and CMIP5 Models

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Key words: ENSO, CPW - EPW, CMIP3, CMIP5

Given the importance of El Niño Southern Oscillation (ENSO) and its socio-economical impacts, its representation on global coupled climate models is relevant, particularly because these models are used for climate projections and to study the effects of climate change not only on tropical climate but also globally. The representation of ENSO on both CMIP3 and CMIP5 models is studied, focusing on the two different flavors of ENSO, namely the central (CP) and eastern Pacific (EP)warming. Different authors have performed an evaluation of the representation of ENSO flavors on CMIP models and have concluded that even though 50% of the models still failed to show the intensity of strong CP and EP events, there are some improvements in the CMIP5 models in terms of spatial patterns.

In this study we will focus on the representation of different characteristics of ENSO events in the models. These include the frequency/periodicity, length of the events, evolution of surface and subsurface anomalies and also their relationship with the seasonal cycle. Preliminary results show that most of the models with a good representation of the EP events capture the duration of these type of warming but most of them failed to represent the duration of the CP. As for the periodicity of the events, in general most of the models capture the interannual peak of the EP and CP events according to observations but not the 8 yr CP peak found in observations.

Regarding the evolution of SSTa, most models capture the December peak found in observations but there are differences in the evolution with some models having shorter periods of warming and others showing extended warming periods. This is more evident for the CP events.

As for the subsurface anomalies there's still debate on whether thermocline variability plays a key role on CP events as it has been show for EP (thermocline feedback vs local processes). However, the performed analyses have not shown consistent evidence among the models that support either one or the other hypothesis. Further analyses will be performed to address this question.

Session 4. Modeling and Prediction
Poster

Dynamics, predictability, and prediction of 2-year La Niña

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Key words: La Nina, Prediction

Historical observations show that one in two La Niña events have lasted for two consecutive years. Despite their outsized impacts on drought and flooding, little is known about the predictability of these 2-year La Niña events. We addressed this question using a hierarchy of simulations performed with the Community Earth System Model Version 1 (CESM1) – a model that simulates realistic 2-year La Niña. We find that strong El Niño events drive a disproportionally large initial thermocline discharge requiring 2 years of La Niña conditions and relatively weak thermocline recharge for the Pacific to return to a neutral state. This nonlinearity increases the predictability of 2-year La Niña after strong El Niño in "perfect model" forecasts.

We applied these results to the prediction of the recent 2-year La Niña event of 2016-18, which was preceded by the record-breaking El Niño of 2015/16. We used a suite of ensemble forecasts performed with the same version of CESM1 initialized on every November since 1954. The ensemble initialized in November 2015, at the peak of the El Niño of 2015/16, was used to predict the evolution of the subsequent La Niña. CESM1 predicted La Niña conditions lasting for 2 years, i.e. until the winter of 2017/18 with a probability of 60%. An empirical model based on the magnitude of the observed thermocline discharge gives a 80% probability of returning La Nina conditions. Together these results demonstrate that, under specific initial conditions, La Niña events can be predicted two years in advance.

Session 4. Modeling and Prediction
Poster

ENSO Influence on the Predictability and Forecast Skill of Drought Events over the Amazon Basin

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Key words: Drought predictability, Forecast skill, Standardized Precipitation Index

Past several droughts over the Amazon have led to massive number of impacts in water availability for human consumption, agriculture, ecosystem processes and hydropower production. Increases of these extreme events have been particularly intense in the Southwestern Amazon since 1979; however, the understanding of the mechanism and predictability is still limited.

In this study, we aim to assessed the predictability and skill forecast for droughts over the Amazon basin, based on 30 year ensemble hindcasts from multiple climate model, which have been seldom analyzed up to now for this region and the evaluation in the rate of change for the predictability in ENSO years. Contrasting with GPCP grid (1°x1°) as an observed database. Focus on meteorological droughts, the 3 months standardized precipitation index (SPI3) was used as a drought index, evaluated from both model hindcasts and observations. Otherwise, the anomaly correlation (AC) mean of the SPI3-drought, was used as measure of predictability skill in all years, with special focus on El Niño-Southern Oscillation (ENSO) events.

Drought predictability and forecast skill are well correlated in general, with higher values on the northeastern of the Amazon at seasonal time scale, ENSO has a substantial impact on drought over the Amazon basin. The impact is more significant in southeastern Amazonia. Predictability and forecast skill for drought is higher over the northern of the Amazon basin, due to the capability in capturing ENSO teleconnection. The outcomes of this study serves as an indicator for forecast skill in areas which there is not in-situ instruments and remote sensing techniques are considered unreliable.

Session 4. Modeling and Prediction
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Do we project a frequency change of robustly classified El Niño types?

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Key words: El Niño frequency, classification

Many studies have quantified an increase in the Central Pacific or Mokoki type Niños post-1990 (Ashok et al, 2007, Kao & Yu, 2009, Kug et al, 2009, Lee & McPhaden, 2010). This increase is important as Mokodi type Niños have different global impacts than Canonical Niños (e.g. Wang & Hendon, 2007, 2007, Kim et al 2009). This increase was initially attributed to increasing greenhouse gases (Yeh et al, 2009). However, thirty years is too short to observe such a trend, with internal variability likely responsible for the observed increase (Mc Phaden et al, 2011, Yeh et a, 2011, Neuman et al, 2011).

We investigate whether the frequency of different types of ENSO events (Modoki, Canonical and Strong El Niños) are projected to change in the future. We use large ensemble simulations to determine whether changes are due to internal variability or are forced. The 100-member Max Planck Institute Grand Ensemble (MPI-ESM-GE) for 4 forcing scenarios, combined with one forcing scenario from the 40-member LENS ensemble and 10-member CESM ensemble from ETH are used in this study. We identify each type of El Niño event using two different classification methods. The first classification system is based on three factors: the sea surface temperature pattern, ENSO evolution between May and January and the Niño3.4 index. Secondly we apply a deep learning algorithm, namely the random forest classifier. When the two classifications are applied to observations, we are able to automatically classify the majority of ENSO events correctly.

The variability in the frequency of each type of ENSO event is higher over a short time period, in agreement with previous studies, which indicate that the recent increase in Modoki Niño events is likely due to internal variability. Preliminary results show that when we consider multiple future scenarios, there is no change in the mean frequency of each type of ENSO event, although there is high internal variability between members. We then subset the MPI-ESM-GE into members which have projected El Niño-like, La Nina-like and uniform Pacific warming. Here, we evaluate whether the projected frequency of each type of El Niño is due to the background warming. We find that the frequency of events in each scenario are unaffected by this subset.

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Poster

El Niño-La Niña asymmetry in a Linear Inverse Model Framework

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Key words: El Niño - La Niña asymmetry, Linear Inverse Model, Stochastic Model, Nonlinearity, Data Model

One of the defining aspects of the El Niño-Southern Oscillation (ENSO) during the observed record is the asymmetry between its positive (El Niño) and negative (La Niña) phases. Large El Niño events tend to be more intense than large La Niña events, while La Niñas tend to persist longer. Although several mechanisms have been proposed (e.g., nonlinear dynamical heating, asymmetry in thermodynamic damping, nonlinear response of wind stress, etc), the cause for this asymmetry is still under debate. While the primitive equations governing the dynamics of the Tropical Pacific are undoubtedly nonlinear, the resulting system is not immune to "aggregational gaussianity" arising from consideration of the central limit theorem. Following this line of thought, for monthly or longer timescales, it can be argued that rapid nonlinear effects average out, in which case the Tropical Pacific can be well represented by a deterministic linear system, with the remaining nonlinearity treated as noise.

An approach that has been very useful in terms of understanding and also forecasting Tropical Pacific anomalies, is the employment of linear inverse models (LIMs). Here, an empirical description of the Tropical Pacific sea surface temperature anomalies (SSTAs) is calculated from the system's covariance statistics. In this kind of approach SSTAs evolution is given by a linearized, stable dynamical operator forced by weather noise. This approach naturally explains ENSO irregularity, and the (non-normal) cycle of ENSO decay and growth. For simplicity, the noise operator is usually taken as state-independent (i.e., the noise statistical properties are insensitive to whether the system is in a neutral, positive, or negative state), in which case the resulting long-term statistics are Gaussian. In this case a LIM approach cannot explain the observed El Niño-La Niña asymmetry. In general, LIMs are not restricted to be forced by state-independent noise, but inclusion of noise state-dependence has remained limited due to lack of estimation methods in the multivariate case. In this work we calculate, in a simplified setting, the noise-state dependent component forcing the Tropical Pacific SSTAs and incorporate this noise state-dependence into an SST LIM. Results show that the state- dependent noise forcing part of the system has a larger amplitude during positive ENSO phases compared to negative phases, behavior that is reminiscent of what is expected from the coupling of westerly wind bursts to convection. In this case large positive amplitudes can be generated without invoking nonlinearity of the dynamical operator. In general, we show that noise state-dependence alone can explain the observed El Niño-La Niña asymmetry in amplitude and duration, showing that this asymmetry is consistent with linear theory at a monthly timescale.

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Simulation of deep moist convection and rainfall in cut-off lows over South Africa

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Key words: cut-off lows, simulation, deep moist convection

Out of all rain-producing weather systems, cut-off lows (COLs) are linked with the occurrence of extreme impact rainfall and in some cases flash floods which can last for 24 hours. This study intends to simulate areas of deep moist convection and rainfall during the occurrence of COLs over South Africa. Investigations of deep moist convection and rainfall during COLs over southern Africa are more focused over the winter than summer rainfall regions. Furthermore, anomalous weakening of the Southern Annular Mode (SAM) is associated with the shifting of the COL events from southern (32°S) towards northern parts of the country. Areas of deep moist convection during the occurrence of COL events are expected to be shifting towards the northern parts of the country. The National Centers for Environmental Prediction (NCEP/NCAR) Reanalysis will be used to develop a 36-year (1980-2016) climatology of COLs over South Africa. This study will objectively investigate the accuracy of the regional numerical Unified Model (UM) in simulating deep moist convection and rainfall in COL events which occurred between 2015 and 2016. UM with a grid spacing of 4km is capable of producing two years maximum amount of data for small weather events. The accuracy of UM will be validated through the use of Global Precipitation Measurement (GPM) and Outgoing Longwave Radiation (OLR) satellite data. Furthermore, COL events are expected to be one of the major rainfall contributors to the overall rainfall over South Africa. This will be complemented by the use of rainfall station data from South African Weather (SAWS) stations.

Session 4. Modeling and Prediction
Poster

Modelling study of 2017 Coastal El Niño

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Key words: Coastal, Niño

The aim of this study is to understand the physical mechanisms that gave rise to the high precipitation rates in the 2017 boreal spring over the far Eastern Pacific and which were related to the event known as Coastal El Niño (Coastal EN). For this purpose, an investigation of the 2017 event was done with reanalysis data and complemented by a modelling investigation with the OpenIFS Atmospheric General Circulation Model (AGCM).

The analysis of the 2017 event revealed the similarity of the event with the one occurred 92 years before (with much less observational data available). It generated rates of precipitation over the far Eastern Pacific only comparable to the ones observed before during the 1982-83 and 1997-98 extreme El Niño events. But a particular characteristic of the Coastal EN events are the abruptness of the warming and precipitation changes.

For the modelling study we first documented model biases and determined that the OpenIFS was suitable for the study of this phenomenon. Then, some model experiments were set up to study the most relevant physical atmospheric processes of Coastal EN events that cause the high increments of precipitation and the role of the coastal warming on that. From them we could determine that the coastal warming plays an essential role in the observed precipitation changes. Also, we show that the source of moisture for the anomalously high precipitation rates was the moisture flux convergence over the zone.

Thus, given the the scarcity of research on Coastal EN events and limited data availability (only one case with full observational data available), this study provides a useful source of information to better understand this phenomenon in light of the new available data for the 2017 event and the further data generated by the modelling study. However, how these events are initiated and what conditions lead to their development are still issues that requires further study.

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Poster

ENSO Conditions at the Eastern Equatorial Pacific Ocean Using a High Resolution Regional Ocean Modeling System

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Key words: ENSO, ROMS model, Ocean Modeling, SODA Reanalysis, C20Rv2

The eastern Tropical Pacific Ocean plays an important role in global climate variability and the interaction between ocean and atmosphere in the Pacific basin, mainly through seasonal and interannual variability. Under normal conditions, SST has maximum values during the northern spring due to the relaxation of the southeast trade winds [*Philander*, 1981]. By contrast, minimum SST values occur during the northern summer and autumn when the easterly trade winds intensify. ENSO conditions in the Eastern Equatorial Pacific Ocean are explored using a high resolution ocean model. The model domain covers the coast of South America to 96°W, including the Galapagos Islands, and from 15°S to 15°N. An experiment based on a run from January 1990 to December 1999 is conducted using the Simple Ocean Data Assimilation version sparse input.2 (SODAsi.2) 5-day data sets for the initial and boundary conditions. For surface forcing the 20CRV2 (20th Century Reanalysis version 2) daily data set is used. The period from 1990 to 1999 is used in order to configure a model to able to detect main changes related to seasonal cycle, annual and interanual variability, and the most relevant features related to a prominent ENSO event, that is from 1997-98. The results show strong anomalies of sea surface temperature (SST) and sea surface height (SSH) during El Niño. Changes in conditions at the surface and subsurface demonstrate the strength of the 97-98 El Niño event, especially when compared with the weaker 1991-92 event. The results are also used to explore changes in circulation around the Galapagos during El Niño. According to the variation in SST from ROMS output at the equator in the eastern Equatorial Pacific during the period between 1990 and 1999, the annual change shows a period of warm SST that rises recurrently at the beginning of each year.

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Poster

Conciliating tropical Atlantic impacts on ENSO

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Key words: ENSO, tropical Atlantic, ENSO prediction

El Niño phenomenon has been found to be predictable from the tropical Atlantic. On the one hand, some authors have found in observations predictability from boreal spring and from the north tropical Atlantic. On the other hand, other authors put forward the equatorial Atlantic in boreal summer . The mechanisms involved in each of the teleconnections are different and induce different periodicities to ENSO. Using CMIP5 simulations in PI configuration, the present work conciliates both perspectives proposing a mechanism by which , multidecadal ocean variability act as a swhich that enhaces one mechanims or the other. The results of this study have important implication in the s2d forecast system.

Session 4. Modeling and Prediction
Poster

Tropospheric Water Vapor as a Predictor to ENSO Intense Rain Phase

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Key words: Intense rain, ENSO, Continuous Phase Transitions, power laws, change point

Intense rain is one of the most difficult natural phenomena to predict, even more into an ENSO regime. Recent theories from complex systems and continuous phase transitions physics suggest a changing point in the precipitation when the system gets a critical value of tropospheric water vapor. Therefore, is proposed a phase transition from a state of light rain into a state of heavy rain, which can be described by a power law behavior, with long-range correlations. Notwithstanding, this model has not been proven in extreme rain conditions, as the presented during some warm ENSO phases. Thus, this research evaluates the effectiveness of this theory into opposite ENSO phases. For this purpose, Niño 2-3 region (4.8 x 106 km2) was studied, during warm (2009-2010) and cool (2010-2011/ 2011-2012) ENSO occurrence, using high-resolution TRMM satellite data of superficial rain and tropospheric water vapor; of 5 km and 1.6 seconds. Although the coefficients of the model depend on the climatic characteristics of the ENSO phase, a unique exponent of the power law was found. These results show the ability of the power law relation to describe the extreme rain events, even during opposite ENSO conditions. In addition, it agrees with the observed increase of intense rain events, due to climate change warming and therefore, water vapor accumulation.

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Dynamical Seasonal Prediction of ENSO and Monsoon

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Key words: ENSO prediction, Monsoon Prediction

Dynamical seasonal prediction of ENSO and summer monsoon rainfall over India in the past 57 years (1957-2014) has been carried out using NCEP Climate Forecast System. As a case study, it is found that if the modern day coupled climate models were available during the 1970's, even with the limited ocean observations at that time, it should have been possible to make skillful prediction of the 1972-73 ENSO event and the associated severe monsoon drought. It is also found – somewhat surprisingly – that in spite of enhanced ocean observing systems during 1979-2014, the skill of ENSO prediction is not significantly different from that for the previous period of 1957-1978. This result has implications for research on ocean data assimilation.

After more than 50 years of climate modeling, the present generation of climate models have some skill in prediction of monsoon rainfall over India. However, this skill is almost entirely due to skill in prediction of ENSO. Factors limiting the predictability of ENSO and the Indian monsoon rainfall, and suggestions for future research will be briefly discussed.

Session 4. Modeling and Prediction
Poster

ENSO Potential Predictability from its Seasonal Teleconnections

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Key words: potential predictors, tropical and extratropical predictors

Using a linear relationship we explore systematically the seasonal potential of a variety of indexes for the predictability of the ENSO state, represented by the Niño3.4, the Niño4 and Niño1+2 Indexes for 1950-1979 and- 1980-2012 periods. We consider tropical and extratropical predictors associated with the classical teleconnection patterns in the Northern and Southern Pacific. Our study shows that the number of potential predictors in the recent period has increased with respect to the previous one. We found that a new index named the South Tropical Pacific Zonal Gradient (STZG) Index shows a significant difference statistical comparing the study periods.

Session 4. Modeling and Prediction
Poster

Comparison of the Niño3.4 Index Longer Lead Predictability Skills Scored by Linear and Nonlinear Statistical Models

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Key words: modelling, predictive skill, ensue predictability

In the first part of this work we use some linear seasonal statistical model that include variables representing the interactions between the Niño3.4 Index and others from tropical and extratropical regions. We focus on the analysis of the skill sensitivity to the different choices of the variables when the target of predictions is the summer and autumn Niño3.4 conditions. We perform a comparative analysis of the predictive skill gained by including in the model, a particular variable that represents processes and regions identified as longer lead ENSO precursors. We have found that for the hindcast with target winter and spring Niño3.4 conditions, it suffices with equatorial variables to obtain useful skill values. Predictions from summer initial conditions are the most sensitive to the introduction of extratropical variables. Models using indexes built from atmospheric temperature anomalies integrated from the surface up to the midtroposphere shows higher scores.

In the second part, we compare the results obtained previously with those achieved by models that include nonlinear interactions among their variables.

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Evaluation of the zonal wind stress response to SST in the CMIP5 AMIP simulations

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Key words: Feedback, CMIP

Zonal wind stress plays an important role in the evolution of El Niño–Southern Oscillation (ENSO) events; however, a comprehensive comparison and analysis in terms of model performance and related bias in the interannual variability of zonal wind stress across the tropical Pacific has yet to be performed. In this study, the authors evaluate how well the individual atmospheric models participating in phase 5 of the Coupled Model Intercomparison Project simulate zonal wind stress. It is found that the wind stress anomalies simulated by the multi-model ensemble are weaker than those in the observation in both El Niño and La Niña events, with a larger bias in the former. Further analysis indicates that the bias associated with El Niño events may be mainly attributable to the weaker negative precipitation anomalies in the AMIP simulations, compared with observations, over the eastern Indian Ocean. Through the Gill-like responses in atmospheric circulation, the rainfall bias over the eastern Indian Ocean results in an easterly wind stress anomaly in the western and central equatorial Pacific, which to some extent offsets the westerly wind stress anomalies associated with El Niño events. Consequently, the responses of zonal wind stress anomalies to warm SST anomalies are much underestimated in AMIP simulations during El Niño events.

Session 5. Impacts and Regional Processes

Oral presentations

Session 5. Impacts and Regional Processes
Keynote: 09:00 -09:30, Oct. 18

Air-sea interactions off Peru and Ecuador and the development of Eastern Pacific El Niño events

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Key words: air-sea interaction, ENSO diversity

Since the study by Rasmusson and Carpenter (1982) that provided for the first time a description of the evolution of the so-called “canonical” El Niño, our understanding of ENSO dynamics has very much improved. Still forecasting and simulating ENSO has remained a challenge. Recent progresses in ENSO research led to the notion of ENSO diversity that suggests the existence of two regimes of ENSO, one associated to moderate events and the other one to extreme events that can grow through the non-linear dynamics of the tropical Pacific system. The reasons for which moderate El Niño events do not evolve as extreme El Nino event despite sometime favourable conditions have remained unclear. Here, based on observations and Reanalysis products, we investigate the inter-event variability among moderate to strong El Niño events in order to identify key processes altering the Bjerknes feedback. We show that warm conditions off the coast of Ecuador and Peru in Austral fall are associated with an equatorial westward-propagating air-sea mode that yields the development of Eastern Pacific (canonical) El Niño events, but also to the emergence of equatorial easterlies east of 130°W in Austral summer that prevents them to develop as extreme events. The analysis shows that these easterlies have been particularly active during the 2015 El Niño event. In particular, the equatorial Kelvin wave during the development of the 2015 El Niño is shown to experience a strong dissipation in the far eastern Pacific compared to the 1997/98 El Niño event. We show that global climate models (GCMs) do not adequately account for the diversity in the evolution of the moderate El Niño events. Implications for modelling ENSO in the eastern tropical Pacific are discussed.

Session 5. Impacts and Regional Processes
Keynote: 09:30 -10:00, Oct. 18

ENSO teleconnections and impacts on North America during La Niña summers

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Key words: ENSO teleconnections, boreal summer, ENSO transition, Multi-year La Nina, North America

El Niño – Southern Oscillation (ENSO) has well-known impacts on seasonal weather anomalies and interannual climate variability across the globe from boreal winter to early spring. The summer ENSO teleconnections, though relatively weak and less-established, can also drive significant impact on crop yields over North America during summer growing season. This study focuses on the characteristics and impacts on North America during the developing season of La Niñas.

There are two types of developing La Niñas for the summer season: one transitioning from El Niño winters (12 out of 21 La Niñas during 1950-2016) and one persistent from La Niña winters and becoming a multi-year La Niña (9 out of 21 La Niñas). These two types of La Niñas have distinct differences in the oceanic and atmospheric features during the developing summer. Our results show that during the summer with La Niña conditions transitioned from an El Niño, the tropical Pacific shares the characteristics of both the decaying El Niño and the developing La Niña: The central to eastern tropical Pacific shows La Niña state with negative sea surface temperature (SST) anomalies and reduced deep convection activities, while the western tropical Pacific shows negative precipitation anomalies due to the previous El Niño. The teleconnections triggered by these depressed deep convective activities result in a significant anomalous ridge over Northeast North America, together with a robust warming signal over the Midwest, one of the predominant crop regions in the US, imposing threat on the maize and soybean yields. It is noted that this unique warm anomaly happens only during the El Niño to La Niña transition summer. For the persistent La Niña, where only the central and eastern tropical Pacific cooling and the accompanied reduced convection are present, the responses in North America are much weaker and insignificant. These results suggest that it is necessary to separate the transitioning and persistent La Niñas as their features and impacts are essentially different, which could provide useful information for improving the skill of seasonal temperature and precipitation prediction – and subsequently agricultural managements – over North America.

Further work, using an idealized AGCM - the dry dynamical core, on the sensitivity of circulation to the anomalous tropical Pacific deep convection during the ENSO transition summer will be conducted to confirm the hypothesis based on the observational analysis.

Session 5. Impacts and Regional Processes
Oral, 10:30 – 10:50, Oct. 18

Oceanography, total alkalinity and pCO_2 levels during El Niño 2015-16 in a subtropical coastal upwelling area of Humboldt Current.

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Key words: El Niño 2015-16, Humboldt Current, Sub-tropical upweeling, Oceanography, Total alkalinity, pCO_2

Oceanographic signals observed during the year 2016-17 at the Equatorial Pacific zone portended one of the most intense El Niño events since that observed between the years 1997-98. However, poleward propagated oceanographic perturbations were not such intense, challenging our understanding and prediction capabilities. Here we presented a weekly-to-synoptic time series of temperature, salinity, oxygen, size-fractionated chlorophyll (Chl), and total alkalinity measurements, as well as pCO_2 estimates performed during a year (January 2015 to 2016) in the upper layer (30 m) of the subtropical coastal upwelling area off Antofagasta (23°S), in the Humboldt Current system. Total alkalinity was determined using thermal regulation and the open-cell titration method (all samples were analyzed at 25± 0.1° C). Analysis' accuracy was controlled against certified reference material (A. Dickson, USA), whose uncertainties of alkalinity and pCO_2 measurements and estimates were 3 µmol kg-1 and 11 µatm, respectively. Whole period was composed by three different stages of variability. First quarter was dominated by synoptic upwelling events which along with temperate (17°C) and stratify the water column, were characterized by relatively lower oxygen (<3.5 mL L-1), salinity (<34.8), TA (<2300 µmol Kg-1) and pCO_2 (<500 µatm) values. During this time period, relatively high phytoplankton biomass ($\geqslant$ 3 mg Chl m-3) was dominated by the large-sized fraction. At the end of this period the stratification ceased, salinity (~35), TA (>2300 µmol Kg-1) and pCO_2 (500-900 µatm) increased, while phytoplankton biomass decreased (<3 mg Chl m-3), becoming dominated by the small-sized fraction. This period lasted around 3 months and was followed by a continuous thermal and oxygen decreasing of the whole water column (<16 °C and $\leqslant$ 2mL L-1), and while TA decreased (<2300 µmol Kg-1) the pCO_2 reached its maximum (>900 µatm) in despite of phytoplankton biomass increased ($\geqslant$4 mg Chl m-3) upon the dominance of large-sized fraction. The observed oceanographic and carbonate (i.e. TA and pCO_2) conditions suggest that although the very essence of the upwelling was a common feature, especially during the first quarter of the study period, seasonal transition from Summer-Fall-Winter was atypical for local climatology. Pulsatile upwelling episodes prevail year round at this latitude, providing cold and oxygen poor waters to surface. This scenario changed markedly at beginning of winter period when positive deviations from annual means where observed. Thus, the upper layer became warm (>16°C), salty, very well oxygenated (>4 mL L-1), and showing relatively high values of TA and pCO_2. These positive deviations from annual means, which lasted for around 3 months when also phytoplankton biomass was largely supported (>60%) by small-size phytoplankton fraction, configure oceanographic symptoms associated with remotely forced oceanographic perturbations. Independent on temporal variations in phytoplankton biomass, the upper layer was permanently CO2–supersaturated, while temporal pCO_2 variability was significantly correlated with salinity. Salinity values >34.6 and pCO_2 levels > 400 µatm have been associated to Equatorial Sub Surface Waters, suggesting poleward Kelvin waves associated with El Niño 2015-16, decoupled the upwelling-driven synoptic repositioning of water masses and its impact on phytoplankton biomass.

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Oral, 10:50 – 11:10, Oct. 18

How relevant is ENSO to global crop production?

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Key words: food security, corn, maize, crop yield, soy, wheat, drought, agriculture, teleconnection, El Niño, La Niña, ENSO

Modes of climate variability, particularly the El Nino Southern Oscillation (ENSO), are often posited as a risk to regional and global food security. But what fraction of crop yield variability do they actually account for? Here, for the first time, we estimate the relative contribution of major modes of climate variability to crop yield variability at the global scale. We find that past studies have overemphasized the importance of modes of climate variability for globally aggregated soy and wheat production, but that ENSO does, in fact, pose a significant correlated risk to maize yields capable of forcing globally synchronous crop failures. To illustrate this point, we demonstrate that the largest synchronous crop failure in the post-1960 historical record is directly attributable to ENSO.

We consider the influence of not only ENSO, but also the Indian Ocean Dipole (IOD), tropical Atlantic variability (TAV) and the North Atlantic Oscillation (NAO). We find that modes of climate variability account for 4% and 8% of globally aggregated soy and wheat production variability, respectively. For maize, however, ENSO accounts for a staggering 41% of global production variability, with minor additional variability (2%) attributable to the IOD and TAV. The low fractions of global-scale soy and wheat production variability attributable to climate doesn't preclude significant regional impacts, it is instead a result of offsetting ENSO-induced yield anomalies in major production regions. ENSO-forced maize production anomalies do not offset at the global scale because production is concentrated in regions with same-sign yield anomalies, notably the United States, Brazil and southeast Africa. Our results highlight how the distribution of global cropland in relation to ENSO teleconnections contributes significantly to the presence or absence of synchronous global crop failures.

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Oral: 11:10 – 11:30, Oct. 18

The role of buoy and Argo observations in ENSO in two SST analyses

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Key words: ENSO,SST,Observations

The monthly Extended Reconstructed Sea Surface Temperature version 5 (ERSSTv5) and Daily Optimum Interpolation Sea Surface Temperature version 2 (DOISST) are frequently used for El Nino, La Nina, and Southern Oscillation (ENSO) monitoring and assessment. ERSSTv5 uses in situ observations from ships, buoys, and Argo floats. DOISST uses observations from ships, buoys, and satellites, while biases of satellite observations are corrected according to in situ observations. Therefore, in situ observations (both number and area coverage) are critical to these sea surface temperature (SST) analyses.

The relative roles of buoy (moored and surface drifting buoy) and Argo observations on two SST analyses are studied in the tropical Pacific over 2000–16 using monthly ERSSTv5 and DOISST. Our study suggests that the impact by buoys is large over 2000–2005 when the number of Argo floats was low, and becomes smaller over 2010–2016 when the number and area coverage of Argo floats increased. The magnitude of El Niño and La Niña decreases when observations from buoys, Argo floats, or both are excluded, suggesting the importance of observations in ENSO monitoring. The impact by the Tropical Atmosphere Ocean (TAO) and Triangle Trans-Ocean Buoy Network (TRITON) is small in normal years and during El Niño events. The impact by TAO/TRITON buoys on La Niña events is small when Argo floats are included in the analysis systems, but becomes large when Argo floats are not included. The reason for the different impact of TAO/TRITON on El Niño and La Niña events is that the drifting buoys are more dispersed from the Equatorial Pacific region by stronger trade winds during La Niña events.

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Oral: 11:30 – 11:50, Oct. 18

Impact of Tropical Atlantic variability on Tropical Pacific predictability

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Key words: Tropical Atlantic variabiity, Seasonal predictions

Previous studies indicate the influence of Atlantic variability on ENSO frequency and variability. Rodriguez-Fonseca et al (2009) shows that summer equatorial Atlantic anomalous SSTs are highly anticorrelated with the equatorial Pacific in the next winter months.

The mechanism of the Atlantic/Pacific teleconnection involves an anomalous Walker circulation triggered by the anomalous SST over the eastern Tropical Atlantic, which results in anomalous easterly winds over western Pacific and thermocline perturbations that propagate eastward thus favoring the development of ENSO conditions (Losada et al., 2010; Polo et al., 2015).

Here, we use the NMME and EUROSIP multi-model seasonal prediction systems for the period 1981-2014. In order to investigate the impact of the summer Atlantic variability on the predictability of ENSO, we compare retrospective forecasts initialized in February to forecasts initialized in June. We find that the June initialized forecasts have consistently higher skill in predicting ENSO than the February initialized at longer lead times, indicating a source of ENSO predictability in the initialization of June. We further find that models with high prediction skill over the summer Tropical Atlantic tend to both better reproduce the connection between the summer Tropical Atlantic SST and the winter Tropical Pacific SST, and also have higher skill in predicting the winter Tropical Pacific SST. Given that the Tropical Atlantic is an area of large and systematic biases and poor prediction skill (i.e. Richter et al., 2017) this study emphasizes the importance of correctly representing the Tropical Atlantic mean state and variability in order to improve Tropical Pacific predictability.

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Oral: 11:50 – 12:10, Oct. 18

Impacts of different ENSO flavors and tropical Pacific convection variability (ITCZ, SPCZ) on austral summer rainfall in South America, with a focus on Peru

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Key words: rainfall, atmospheric teleconnections, ENSO, SPCZ, ITCZ, South America, Andes, Peru

The impacts of the El Niño in the eastern and central Pacific in the rainfall of South America, and the atmospheric pathways through the South Pacific Convergence Zone (SPCZ) and Inter-Tropical Convergence Zone (ITCZ) are poorly understood. To address this, we performed linear regression analysis of E (eastern Pacific) and C (central Pacific) indices of sea surface temperature (SST), as well as precipitation indices for the SPCZ and ITCZ, with gridded precipitation and reanalysis datasets during the austral summer (December–February) for the 1980–2016 period.

The results show that positive C induces dry conditions along the tropical Andes and northern South America (NSA), while wet conditions prevail over southeastern South America (SESA). Moreover, it produces wet anomalies in the northwestern Peruvian Amazon. Contrary, positive E induces wet anomalies along the coasts of Ecuador and northern Peru associated with the southward displacement of the eastern Pacific ITCZ and at the same time induces dry conditions in the Altiplano, Amazon basin, and northeastern Brazil (NEB). Both El Niño Southern Oscillation (ENSO) indices are associated with anomalous upper-level westerly flow over Peru, but it is more restricted to the central and southern Peruvian Andes with positive E.

The results also show that both SPCZ indices, the zonal position of the SPCZ and its latitudinal displacement, suppress rainfall along western Peruvian Andes when are positive, but the latter also inhibits rainfall over the Bolivian Altiplano. They are also linked to upper-level westerly wind anomalies overall of Peru, but these anomalies do not extend as far south in the first. The southward displacement of the eastern Pacific ITCZ also induces wet anomalies in SESA while dry anomalies prevail over NEB, the western Amazon basin, and Bolivia. Oppositely, the southward displacement of the central Pacific ITCZ induces dry anomalies in NEB and along the northern coast of Peru; while wet anomalies occur mainly in eastern Brazil, Paraguay, and Bolivia through an enhancement of the low-level jet.

This work will present part of the results documented in Sulca et al. (2018) that was published in the International Journal of Climatology.

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Pacific El Niño and the Frequency of Inertia Gravity Waves over Tropical Africa: Filling the Gap Between Cause and Event

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Key words: ENSO Dynamics, Inertia Gravity Waves, Kalahari Transect, Tropical Africa

The relationships between Pacific El Niño and rainfall over tropical Africa have been documented by atmospheric scientists over a period of about four decades. For example, the general trend for the October, November, December (OND) rainfall in Botswana from 1961 to 1980 indicates that the relationship between Pacific sea-surface temperature (PSST) and rainfall is negative; that is, when PSST increases, there is less rainfall and a decrease in temperature results in more rainfall, except for the 9 months lag correlations for Francistown (21°07'S, 27°33'E) and Maun (19°58'S, 23°25'E), which are not yet understood. This trend is in agreement with the conclusions that El Niño episodes result in less rainfall over southern Africa while the opposite is true for La Niña events. Secondary relationships in the context of agriculture, energy and health have also been the subject of a few discourses. However, not much has been documented on the intermediary stages of these teleconnections namely, the effects of El Niño on the dynamics and frequencies of inertia gravity waves, which are known as the main rain-producing systems; especially over tropical Africa. These inertia gravity waves are known to initiate the mesoscale systems, which bring much moisture to different parts of Africa. The “travelling” equivalent of these waves in Sahelian Africa is the squall lines. The intermediary stage between El Niños and rainfall regimes over tropical Africa is presented with the aid of a linearised inviscid form of the hydro-dynamical equations solved in shear for a two-layer model of the atmosphere. It is shown that El Niños have a modulating effect on mid-tropospheric instabilities that trigger inertia gravity waves. An offshoot of the modulating effect is the influence on the frequency of these waves. The largely unexplored dynamics of these waves within the Kalahari transect of southern Africa is discussed.

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Interannual variability and predictability of precipitation over Northwestern South America and its relationship with ENSO

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Key words: ENSO, Precipitation, Northwestern South America, Forecast Skill

Precipitation over the Andean and coastal regions of Northwestern South America (NWSA) exhibits a strong interannual variability. This variability has been related to ENSO phenomenon, via teleconnections, which explain the reduction (increase) on precipitation over these regions that occurs typically during El Niño (La Niña) episodes.

In this research, the relationship between ENSO and precipitation over the NWSA is analyzed through a probabilistic approach, which allows measuring changes on precipitation exceedance probabilities under different phases and intensities of ENSO. Additionally, the physical mechanisms that explain the observed teleconnection with ENSO are analyzed by compositing the behavior of omega, velocity potential and the zonal and meridional mass stream functions. The results show that the physical pathways in which precipitation is impacted over the NWSA occurs through coherent modulation of the Hadley and Walker circulation cells.

The ability of seasonal forecasts from the Climate Forecast System version 2 (CFSv2) to simulate the outlined teleconnection patterns is examined by regressing precipitation and forecasted sea surface temperature (SST). However, CFSv2 simulated precipitation only shows reasonable skill for the first 1 to 2 months forecast windows, whereas SST forecasts over the central-eastern Tropical Pacific and Tropical North Atlantic are significantly more skillfull and correlate well with observed precipitation even in the 9 months forecast window.

To take advantage of the higher skill of SST forecasts over Tropical Pacific and Atlantic and their strong teleconnections with precipitation over NWSA, a novel hybrid “statistical-dynamical” model is proposed. Through statistical schemes, the hybrid model combines the CFSv2 forecasts of different oceanic and circulation indices, including ENSO and other Atlantic ocean interannual anomalies, with dynamical precipitation forecast. The results show that the proposed hybrid models improve the predictive capacity of seasonal precipitation anomalies over NWSA even beyond the 6-month window.

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Warm ENSO Impact on climatologic variables of Bioclimatic Ecoregions in Central Africa

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Key words: Central African BCERs, ENSO and lagged correlation

The purpose of this work was to assess the relationship between the El Niño Southern Oscillation (ENSO), rainfall, photosynthetic activity of vegetation and temperature over Central African Bioclimatic Ecoregions (BCERs) and the timing of these climatologic variables in response to the different warm ENSO events. The study was carried out using NDVI data set (NDVI3g) from AVHRR-NOAA (Advanced Very High Resolution Radiometer-) processed by the GIMMS, rainfall data from GPCP and temperature data from UDEL. The method of Standardization were used for our analysis, annual variables were generated to assess the impact of warm ENSO on BCERs climatologic variables and data were deseasonalized for lagged correlation computation. Results brought out that El Niño and La Niña events represent an important factor affecting rainfalls and vegetation and temperature over Central African BCERs. Lagged correlation analysis between the signal of El Niño and BCERs climatologic variables displayed time lags by several months. The response of NDVI/rainfall peak to the warm phase of ENSO is found between 6-16/6-15 months throughout BCERs. The time lags of temperature stand by 4-16 months overall. NDVI variability of BCERs showed a clear response to rainfall variability and ENSO signal.

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The role of moisture transport in the relationship between ENSO and precipitation in Central Chile

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Key words: ENSO, IVT, Atmospheric river

The role played by tropical teleconnections in the precipitation of Central Chile through Rossby waves propagating over the Pacific basin has been long recognized in studies since the early 1980s. The main source of internannual variability is connected to ENSO through the teleconnections along the Pacific South American sector. The vision we have of this teleconnection involves the existence of a blocking high and and diffluence of the flow around it that would divert the flow of middle latitudes to lower latitudes during warm episodes of ENSO.

As a consequence of this teleconnection, the central zone of Chile experiences an increase in rainfall. This explanation, although it considers the aspects of dry dynamics in the teleconnection, like intensity of the blocking high, equatorial displacement of the baroclinicity or storm-track, does not give the due importance to the transport of water vapor (defined as Intregral Vapor Transport, IVT) from the tropics to the mid-latitudes of South America . This transport has been studied and considered an important factor in winter storms in central Chile in a synoptic-scale, since the Pacific coast of southern South America has low climatological amount of precipitable water.

In this work, using information from reanalysis and satellite-derived precipitable water, anomalies of IVT are studied during warm and cold episodes of ENSO. It is observed that the IVT from the equatorial Pacific towards central Chile increases during warm episodes of ENSO favored by positive anomalies of the zonal component of the wind, while in cold episodes the transport becomes unfavorable. This is also evident when analyzing a database of atmospheric river frequency and location, the atmospheric rivers towards the coast of Chile from the equatorial Pacific are more frequent in warm episodes of ENSO and less frequent on cold events.

It is postulated that these positive anomalies of IVT, as also more frequent atmospheric rivers, are a direct consequence of the teleconnection and the semi-estacionary Rossby wave, in particular the transport of water vapor in the equatorial branch of an anomalous cyclone in the Central Pacific, which ends up increasing the availability of water vapor in the systems of precipitation in the coast near Chile in El Nino years.

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Precipitation Anomalies in the South of Colombia and Associated Features to the El Niño Southern Oscillation (ENSO)

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Key words: El Niño Southern Oscillation-ENSO, Precipitation, Wavelet Analysis , South of Colombia

The El Niño Southern Oscillation (ENSO) is the main variability mode climatic of the coupled ocean-atmosphere system, has strong disturbances on the global climate system and affects the balance of societies and ecosystems in much of the world. Understanding this phenomenon and its variations in different Earth's regions is essential to reduce the vulnerability of the affected elements. One of the most affected regions in American is the South American tropics, where the orographic complexity established by the Andes mountain range and the climatic variability suppose a greater complexity for understanding the ENSO. Therefore, we explored the connections between monthly rainfall recorded in 44 climatic stations of Colombian Pacific's southern region (Nariño) and sea surface temperature anomalies (SST) in the Tropical Pacific Ocean for 34 years (1983-2016).

Homogeneous climatic zones were established by cluster analysis (CA) and the first principal components (PC) for each climate zone were estimated. Subsequently, with this information, were identified the main associations with ENSO through the analysis of wavelet transform and correlation fields with SST and sea level pressure (SLP). The results of AC indicate that Nariño has two homogeneous climatic zones: i) Pacific Zone (PZ) and ii) Andean Zone (AZ). Two and three CPs were found for PZ and AZ, respectively. These CPs explain the rainfall's variance of each climate zone in 58.3% and 67.1%. Moreover, the results of the wavelet transform indicate that the PZ exhibits the highest values of the global wavelet spectrum (GWS) on the interannual scale of 4-6 years. Furthermore, a nonsignificant decadal scale of 8 to 15 years, results that are to the GWS of the first CP of the AZ, and that is statistically significant with a confidence level of 95%.

The 4-6 years' band was used for atmospheric field correlation analyzes, and indicate significant relationships with the SST of the Niño 1+2 region (0-15 S, 110-80 W). The correlation fields in the PZ and the SST showed significant positive correlations higher than 0.44 for CP1 and 0.55 for CP2, while the correlations between the AZ and the SST of the Pacific Ocean showed significant values lower than -0.39 for CP1. In the framework of this research, we continue advancing in the search for associations between precipitation and the SST of the Pacific Ocean using neural networks. This methodology will eliminate the linearity's restriction and reduce the uncertainty in the association between rainfall and SST of the Tropical Pacific Ocean.

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Categorical predictability of precipitation in the Ecuadorian coast and Galapagos islands using Support Vector Machines

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Key words: Precipitation, Ecuador, El Niño, SVM

This work propose the use of Support Vector Machines (SVM) for tercile-based categorical prediction of precipitation (PRE) in the Ecuadorian coast and Galapagos, a region whose rainfall is strongly modulated on interannual scale by El Niño-Southern Oscillation, and on the intraseasonal scale by Madden Julian Oscillation. The predictor variables are Sea Surface Temperature (SST) and Outgoing Longwave Radiation (OLR) of South Pacific ocean. The response variable is monthly precipitation, with data corresponding to 15 station of study area. The training and test periods of SVM were defined between December 1981 to June 2010, and from December 2010 to June 2018, respectively. The accuracy of SVM model was evaluated using continuous and categorical metrics (total error and Receiver Operating Characteristic -ROC curves).

The preliminary results indicates (1) the generally good relation between PRE and SST in the El Niño 1+2 region (as reported by other authors), and OLR in the equatorial Pacific (due to the descent of Intertropical Convergence Zone during austral summer-fall). Particularities have been identified in the basis of precipitation variance: the greater the variance, the smaller the area of SST-PRE 90th percentile correlation off Peru, and the atypical the area of OLR-PRE 10th percentile correlation; (2) the SVM model based on these index (SST and OLR) is capable to predict the categoricals precipitation in the Ecuadorian coast and Galapagos with a precision of up to 75%, approximately.

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ENSO and the Indian Summer Monsoon: mid-Holocene to present relationship in transient global simulations

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Key words: transient simulations, Indian summer monsoon, ENSO

An ensemble of five fully-coupled transient simulations run with the IPSL model is utilized to document changes in the relationship between the Indian Summer Monsoon (ISM) and the El Niño Southern Oscillation (ENSO) from mid-Holocene onward. These simulations differ according to the horizontal resolution, the hydrological model (IPSLCM5A versus IPSLCM6 hydrology), the way vegetation is parameterized (static versus dynamic) and the length of the integration (-6000 to preindustrial for the longest and -6000 to -3000 for the shortest).

The ISM mean state depicts a robust linear-like trend towards drier conditions from mid-Holocene onward in the five simulations. The ISM drying is associated with changes in both the occurrence and the intensity of extreme ISM seasons, with the 10% driest seasons getting drier and more frequent and the 10% wettest seasons getting drier and less frequent. Such a drying is interpreted as a response to decreased inter-hemispheric temperature gradient during summer forced by eccentricity and obliquity changes.

Unlike the ISM mean state, the ISM year-to-year variability does not clearly relate to changes in orbital forcing since the sign of the trend varies within the ensemble. More interestingly, this trend is far from linear regardless the simulation, with alternation of periods of increasing variability, periods of constant variability and periods of decreasing variability.

Here, we investigate the extent to which such an alternation in the ISM variability is induced by changes in ENSO characteristics. Are periods of increasing ISM variability associated with increasing ENSO variability, and reversely for periods of decreasing ISM variability? Is the control of ENSO straightforward through changes in the Walker circulation or indirect through interfering with remaining coupled modes of variability known to affect ISM variability (e.g. the Indian Ocean Dipole)?

Thanks to available reconstructions of changes in monsoon indices and ENSO variability we also discuss the realism of the simulated changes. Our modelling exercise offers an original framework to better understand high-to-low fluctuations of the ENSO–ISM relationship, hence may provide useful information for gaining confidence in future projections.

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Are the impacts associated with TCs in Mexico exacerbated by local vulnerability and ENSO conditions?

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Key words: Climate Action, Disaster Risk Reduction

Tropical Cyclones (TCs) are well-known for their destructiveness power and their relationship with the ENSO conditions over the North Atlantic Ocean. However, the local impacts associated with TC tracks haven't been explored by taking into account local vulnerability as the damage produced by the existence of droughts, level of rivers, population and their salary or even, types of housing mostly affected by TCs, for example: high vs low income housing. All these aspects should be considered while evaluating impacts associated with TC passage in Mexico.

Three tropical cyclones both from the North Atlantic Ocean (Alex 2010, Ingrid 2013 and Earl 2016) and the Eastern Pacific Ocean (Pauline 1997, Manuel 2013 and Patricia 2015) were examined to assess the impacts produced by TC translational speed, size, rainfall and category on the type of housing, population and their salary. Physical and social vulnerabilities were gathered to widely explore how TCs can affect different Mexican regions and determine the role of the ENSO conditions in increasing or diminishing local impacts.

Local aspects indicated that regions of low-income housing and a large number of inhabitants were more affected by the size, rainfall and TC translational speed than the TC category. ENSO plays an important role in determining climatological conditions, as droughts and soil moisture, and the level of rivers prior to the existence of TCs. These pre-conditions can make worse TC impacts depending on the ENSO phase and Mexican region.

The future research will be focused on developing the understanding of how ENSO needs to be evaluated. The past three main events: 1982-1983, 1997-1998 and 2015-2016 provided useful information about the creation of new social indicators and techniques to monitor ENSO events and their impacts. The main goal of the future research is to greatly contribute to the Sustainable Development Goals (SDG's) and Sendai Framework targets.

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Impact of the ENSO phenomenon on the glaciers of the Cordillera Blanca

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Key words: Cordillera Blanca, ENSO, Mass Balance, El Niño 3.4 SST Index

Considering the impact of the ENSO phenomena "El Niño" and "La Niña" on the Peruvian tropical glaciers, for the first case, "El Niño", there is clearly an accentuated process of reduction of the glacier mass, since the increase of unusual warm temperature on the surface of the Pacific Ocean generates losses of significant amounts of water from the glaciers. The passage from one extreme phenomenon to the other is influenced by a close relationship between the temperature of the sea surface and the prevailing winds.

The second case, "La Niña" is considered as the cold phase, where cold temperatures are present with intense and lasting winds. With regard to the aforementioned considerations, it is necessary to take into account that the interval of occurrence is from 2 to 7 years, discounting "normal" and "neutral" periods (neither "Niño" nor "Niña"), with varying intensity and duration. El Niño usually reaches its maximum level in December, a month which, despite rainfall, is the period of greatest losses of glacial mass. The analysis of the mass balance of the Peruvian glaciers in the Cordillera Blanca shows a clear relationship with the values of "El Niño 3.4 SST Index" [anomalies in the Niño 3.4 region that is above (below) the threshold of +0.5°C (-0.5°C). This standard of measure is known as the Oceanic Niño Index (ONI)]. It is evident that the cold phase has also had a direct influence on the behavior of these glaciers.

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Reliability of installing oceanic thermal energy sources around South America

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Key words: thermal energy, renewable energy

Formerly, human being was searching sources of renewable energy, due to the fact that our World has many kinds of energy sources that we could transform into another types of energy. One of the most recent sort of energy is arriving from the Oceans, even difficulties of transportation. Is South America an advantageous continent, because it is border by two open Oceans and most of its lands have tropical weather, which represent the main condition required to obtain thermal energy from the Ocean?

This project analyzes buoys from TAO Project from Pacific Marine Environmental Laboratory (PMEL) of National Oceanographic and Atmospheric Administration (NOAA) located near the South American continent to determine possibilities of installing thermal energy sources placed on the Pacific or Atlantic Ocean. One second question will be how to install thermal machines down the Ocean; will be an idea analyzing gradients of temperatures upon these Oceans to approach them to Carnot Machines for example? The only problem will be to rule if these machines will be appropriated for our waters to do, due to their contamination. Is there any solution to solve problems of human contaminations, maybe this form of energy can allow us to reduce contamination without losing water quality? Or it is better to avoid operate this kind of machines. So, the first thing we need to do is to arbitrate if it is possible obtaining this kind of energy in South America.

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Monitoreo, evaluación y pronóstico de sequías meteorológicas e hidrológicas en el Organismo de Cuenca Pacífico Norte, México y su relación con El ENSO. Monitoring, evaluation and forecasting of meteorological and hydrological droughts in the North Pacif

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Key words: Droughts, ENSO, Monitoring and Forecast, Drought indices, North Pacific Basin

Droughts recurrently occur in any part of the world, with strong economic, social and environmental impacts. Hence the importance of the results obtained with the development of the doctoral thesis Determination of scenarios by drought through temporal multivariate analysis using neural networks in Mexico, defended recently at the National University of Córdoba (UNC), Córdoba, Argentina, whose methodology was implemented can serve as a model for other basins. The application was carried out at the OCPN, located in the northwest of Mexico, with a total extension of 152,007 km ². Analysis and determination of drought scenarios were carried out in the period 1978-2016. They addressed the temporal and spatial monitoring of meteorological droughts, using point indices (SPI and PDSI) and satellite (NDVI); and hydrological conditions using monthly runoff volumes (Q), Streamflow Drought Index (SDI) and Dams Status (Ie) indexes, in the main streams and dams of the OCPN. Scenarios for 1, 2 and 3 months, based on the temporal multivariate analysis and use of neural networks, climatological and basin variables. Results show that the most accurate prognosis for Q was obtained by the two-layer Perceptron Multilayer neural network model. In addition, the analysis of climatic variation in relation to El Niño phenomenon shows that there is very low correlation and low predictability of its effects at the local and regional scales. The probability of its occurrence increases only when it is in the negative phase (La Niña) with intensities lower than -1.07 °C. However, the possibility of developing a line of research to predict hydrological droughts through neural networks is opened, considering as one of the variables (far pivot) the ENSO index in the 3.4 region of the Equatorial Pacific. This will contribute to the integrated management of basins for prevention, mitigation, adaptation and response to drought.

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Short term prediction of Ecuadorian rainfall from macroclimatic variables: A transfer function model approach

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Key words: Ecuadorian rainfall, oceanic and atmospheric variables, predictors, climate, transfer function model

The rainfall in Ecuador is produced by the interactions of many atmospheric and oceanic systems. The understanding of these processes and the applications of modelling tools are necessary for better performance precipitation predictions.

Because of these interactions, it is necessary to identify which variables and spatial domains have the most important signal contributions for rainfall on the Coast and Insular regions. For this purpose, linear transfer functions models have been used for predicting the four monthly regional rainfall regimes, which have been identified according to the main pluviometric regions. The K-mean cluster method was applied to all point historical precipitation values for classification purposes. The resulting clusters, called Pluviometric Groups (PG), are PG I as the first group representing the stations closer to the ocean; PG II which refers to the stations in the Guayas River Basin; PG III composed by the stations located at the Andes highlands and PG IV located in the Galapagos Islands.

These PGs are expressed by its first principal component (CP1), which accounts for over the 70% of the total rainfall variability.

On the other hand, results show that the best predictor for the PGs are sea surface temperature (SST), potential velocity (PV), specific humidity (SP), outgoing longwave radiation (OLR) and Geopotential height (GH), leading precipitation by 1 to 4 months. Significant correlations values ($p < 0.001$) ranging from 0.7 to 0.8 were found between CP1 and SST, 0.4 between CP1 and PV, -0.6 to -0.7 between CP1 and specific humidity, -0.6 to -0.8 between CP1 and OLR and 0.5 to 0.6 between CP1 and HGT, using a lag 0 between predictors and the CP1.

Results show that the models proposed can reproduce moderately well the overall rainfall variability of Ecuadorian rainfall, with model accuracy of 0.71, 0.60, 0.62 and 0.58, for pluviometric groups I, II, III, and IV, respectively. Finally, we can conclude that the ensemble of predictors (15 found in total) have great potential for rainfall prediction in Ecuador.

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Modelling of tidal propagation and currents velocity for the Gulf of Guayaquil during the El Niño 2015 vs normal conditions, using Delft3D model

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Key words: sea level, tides, Delft3D, coastal flooding, numerical modelling

El Niño events are considered one of the most influential factors in natural climate variability. During this phenomenon, a sea level rise occurring in the Eastern Pacific can cause higher than usual tides in coastal areas such as the Gulf of Guayaquil. As a consequence, Pacific coastal regions may become vulnerable to flooding and severe erosion processes that effect touristic beaches, piers, ports and many coastal structures. In Ecuador, the Gulf of Guayaquil is an area of great economic and ecological relevance, as well as home to several coastal populations that are vulnerable to the effects of high tides during El Niño. To increase the knowledge of these potential effects in the Gulf, tidal propagation and current velocity magnitude was analyzed through a simulation performed using Delft3D hydrodynamic model.

The study aims to compare tidal and current velocity magnitude during the 2015-2016 El Niño event with those measured in 2014, a year with normal conditions. The simulated time periods for both years include the months of April (wet season) and June (dry season). Additionally, the simulated area covers the outer estuary, from the Sprig of Santa Elena up to Estero Salado and the north of Mondragon Island in the Guayas River corresponding to the inner estuary. Temporal resolution was applied at 10 min intervals and the spatial resolution range was 500 m - 1 km in the inner Gulf and less than 4 km in the outer Gulf. The model was calibrated and validated with tide gauge measurements from the Ecuadorian National Oceanographic Institute of Navy (INOCAR) tidal stations.

It was found that tides in the Gulf of Guayaquil were higher in April (30-55 cm higher) and June (20 cm higher) during El Niño conditions in 2015, and during spring and neap tides dates analyzed, compared to tidal height in 2014 with normal conditions. When spring tides or extreme high tides coincide with high sea levels generated by El Niño, coastal cities are more exposed to severe impacts. The coastal province of Guayas, which surrounds most of the Gulf, was the second province with the largest affected population (3703 people) by El Niño 2015. Historically, the low-lying areas of the Guayas basin have been impacted by large floods affecting communities and fishing, shrimp and agricultural industry during extreme El Niño events. In addition, greater current velocity magnitudes were also found during 2015 El Niño conditions, in contrast to velocity magnitudes in 2014. This may be associated with the largest freshwater flows discharged into the Gulf recorded in April and June 2015 during El Niño, in contrast to 2014, as reported by the Ecuadorian National Institute of Meteorology and Hydrology (INAMHI).

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Cause of severe droughts in Southern Peru during 1965 - 2010

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Key words: Rainfall, Drought, South Peru, The Tropical Pacific

The cause of severe droughts over the Southern Peru (SP) during the local wet season is investigated on the station rainfall data of the Peruvian Meteorology and Hidrology National Service and the Japanese 55-year Reanalysis (JRA-55) data during 1958-2010. The droughts are in general consistent with local anomalous descent in the middle troposphere and strong zonal westerlies winds across the Andes. The diagnosis of the vertical motion (omega) equation indicates that the local descent is primarily maintained by the anomalous anticyclonic vorticity processes and minor action by cold temperature advection. A composite analysis shows the cyclonic circulation anomaly offshore and nearby the SP is induced by an anomalous jet off the coast of Peru which is controlled by remote forcing from the tropical Pacific. In this configuration, the SP zone is in the jet equatorward exit region, where downward motion is expected. During

El Niño years, enhanced heating over the Equatorial Pacific Ocean (EPO) induces an strong upper-level tropospheric divergent dipolo that enhances the moisture flux convergence to the east EPO alongside the anomalous equatorial Jet which in turn interacts with the Peruvian Andes increasing vertical anticyclonic vorticity between 500-200 hPa in balance with mostiure flux divergence and subsidence over the SP where severe droughts ocurred. Another possible route is through the South Pacific teleconnection, in which downstream Rossby wave energy propagation plays a crucial role blocking the normal eastern wind flow pattern across Southamerica.

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Empirical statistical modeling of March-May rainfall prediction over southern nations, nationalities and people's region of Ethiopia

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Key words: Seasonal rainfall, Statistical, Hierarchical clustering, Teleconnection,, Linear regression

Statistical predictive models were developed to investigate how global rainfall predictors relate to the March-May (MAM) rainfall over Southern Nations, Nationalities and People's Region (SNNPR) of Ethiopia. Data utilized in this study include station rainfall data, oceanic and atmospheric indices including El Nino Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD). Because of the spatial variations in the interannual variability and the annual cycle of rainfall, an agglomerative hierarchical cluster analyses were used to delineate a network of 20 stations over study area into three homogeneous rainfall regions in order to derive rainfall indices. Time series generated from the delineated regions were later used in the rainfall/teleconnection indices analyses. The methods employed were correlation analysis and multiple linear regressions. The regression modes were based on the training period from 1987-2007 and the models were validated against observation for the independent verification period of 2008-2012. Results obtained from the analysis revealed that sea surface temperature (SST) variations were the main drivers of seasonal rainfall variability. Although SSTs account for the majority of variance in seasonal rainfall, a moderate improvement of rainfall prediction was achieved with the inclusion of atmospheric indices in prediction models. The techniques clearly indicate that the models were reproducing and describing the pattern of the rainfall for the sites of interest. For the forecast to become useful at an operational level, further development of the model will be necessary to improve skill and to determine the error bounds of the forecast.

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Evaluation of the influence of ENSO on the tropical cyclonic activity and its pluviometric contributions in the province of Camagüey, Cuba

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Key words: Tropical Cyclones, ENSO Phenomenon, pluviometric contribution.

The great influence exerted by the ENSO phenomenon on global climatic variability, coupled with the occurrence of important changes in the frequency and intensity of extreme hydrometeorological phenomenon, such as Tropical Cyclones (TC) is well known. Due to its impacts, the uncertainty associated with its greater or lesser frequency of occurrence and trajectory, obliges to deepening in the knowledge of the peculiarities of the interactions between the ENSO and TCs. Knowing the way in which the phases of this event influences cyclonic activity in the province of Camagüey, the management of territorial water resources can be improved, as well as preventing negative repercussions. To achieve that, it is done the study of the regime, the anomalies and the temporal and spatial variability of the Tropical Cyclonic Activity (TCA) that affected the province during 50 cyclonic seasons (1961-2010). By other side the study of the ENSO phenomenon, was carried out by analyzing and comparing the thermal anomalies of the sea surface (ATSM), taking as reference the data of the Niño 3.4 zone, as well as the field of atmospheric pressures through the Southern Oscillation Index (IOS). From the analysis of the correlations it was possible to determine that 79% of the impacts by CT are under the influence of non-El Niño events. The 73% with longitudinal trajectories were which provide the greatest rainfall. Due to its efficiency in the rainfall contribution is the cross-sectional trajectories, which predominate at the beginning and end of the season. To that period the relative rainfall contribution of the TC relay on ranges between 15.9% in June and 85.2% in November. Additionally the probability that Camagüey is affected by intense hurricanes is very low and during studied period did not exceed 6%.

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Precursors of severe and sustained drought in the Central America Dry Corridor

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Key words: drought, drylands

Although the hydric stress in Central America is generally low, there is a region relatively drier and prone to drought known as the Central America Dry Corridor (CADC). The area of interest is located mainly in the Pacific slope of Central America, from Chiapas in southern Mexico, to the Nicoya Peninsula in the Costa Rican North Pacific. Most of the region has experienced significant warming trends (1970-1999). On the contrary precipitation and the Palmer Drought Severity Index (PDSI) have mainly displayed non-significant trends. Analysis using the Standardized Precipitation Index (SPI) and PDSI in the CADC, suggests a significant periodicity of severe and sustained droughts of around 10 years. The drought response has been associated with tropical heating that drives an atmospheric response through strengthening of the Hadley cell, which in turn produces higher pressure in the subtropical highs, and intensification of the trade winds (indexed by the Caribbean Low Level Jet). It is important to determine the commonness of severe and sustained droughts in the CADC to improve water resources planning, as this is a region that depends on subsistence agriculture and presents high social and economic vulnerabilities

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Observed Precipitation variability induced by ENSO

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Key words: Teleconection, low frequency variation

The Argentinian Chaco region (ACR) is highly sensitive to precipitation variability because of water scarcity during dry season. The work aims at clarifying the hemispherical/global climate forcing that drives precipitation in the region at inter-annual scale. The precipitation data was acquired from the network provided by the Chaco Province Water Authority, consisting in 64 gauge stations over the ACR in the period 1954-2010. The annual precipitation cycle was statistically divided into two seasons: a wet season (from October to April) and a dry season (from May to September). A spatial cluster analysis was performed by means of Principal Component Analysis technique, yielding four subregions in ACR. For every subregion a representative precipitation index for each season (dry and wet) was calculated and further examined. First, trends were estimated and removed if significant. Secondly, a spectral analysis was computed, reveling periodicities that could be related to the low and high frequency variability of the El Niño-Southern Oscillation (ENSO) and the Indian Ocean Dipole. The Yamamoto test for climatological jumps was calculated for each precipitation index and the running correlation between the precipitation index and climatological indices were compute to determine different periods of potential changes in teleconnections. For those specific periods, composite anomalies of atmospheric and oceanic variables were computed for high index values and low index values. The composites revealed that high and low values of precipitation are directly associated with ENSO, showing high inter-El Niño variability. Particularly, most of dry years in western ACR are linked to La Niña events. The El Niño signal is less noticeable in eastern ACR.

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Distribution and composition of the main small pelagic fish in Gulf of Guayaquil during La Niña event (March 2018)

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Key words: fishery, small pelagic fish, hydroacoustic, biomass, Gulf of Guayaquil, ENSO

The fishery of small pelagic resources in Ecuador constitutes an important socioeconomic income. Therefore, the monitoring of the distribution and composition of these resources becomes necessary in the face of extreme climate events like ENSO.

In the period from March 12th to 23rd, 2018, a hydroacoustic and monitoring fishing survey INP-SRP-CNP 18-03-01PV was carried out. It was obtained information on biomass and abundance of the main small pelagic species of commercial interest: frigate tuna (Auxis spp.), chub mackerel (Scomber japonicus), shortfin scad (Etrumeus teres), pacific thread herring (Opisthonema spp.), scad mackerel (Decapterus macrosoma) and pacific anchoveta (Cetengraulis mysticetus).

This study is based on the information obtained from the Gulf of Guayaquil. Additionally, catch data of the sardine purse-seine fleet from October 2017 to April 2018 were included in the analysis. Subsequently, using GIS tools, the areas of spatial distribution (horizontal and vertical) were determined for each species. Finally, the results were correlated with oceanographic parameters through a multivariate statistical analysis.

The highest concentration of biomass was located at coastal levels, mainly between Chanduy and Playas and also between Puerto Bolívar and Puná Island. In addition, a high biomass core was found at 2.85 ° S 80.6 ° W. In general, the vertical distribution of small pelagic fish was between 7-260 m of depth, prevailing mostly from 50 -100 m. The most representative species in terms of biomass was frigate tuna, with an estimate of 631 771 tonnes, followed by chub mackerel with 265 714 tonnes, constituting 64% of the total estimated biomass. Among the species assessed, none correlated significantly with sea surface temperature anomalies (SSTA) in the Niño 1+2 Region. However, the frigate tuna showed a positive correlation of 0.3, which is high from a biological point of view.

The pattern in the distribution of these species is considered unusual for the period of study, because the schools were not grouped or near the surface. Besides, according to ONI index of NOAA, in the Central Pacific negative anomalies were observed for more than five consecutive months. This could mean that the behavior of these species would be a consequence of a cold episode on the Ecuadorian coasts which would modify their spatial distribution.

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Evaluation of RCA4 Seasonal Variability of Precipitation Associated with ENSO Forcing over Central Africa

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Key words: ENSO, Precipitation, RCA4

This study assesses the ability of the fourth version of Rossby Center Atmospheric Model (RCA4) forced by nine different GCMs in replicating the impact of ENSO forcing on seasonal rainfall patterns over Central Africa. The mean climatology, annual cycle and interannual variability of RCA4 outputs have been assessed over four (4) sub-regions against four (4) observational datasets. The Oceanic Niño Index allowed us to select ENSO occurring years and then a composite analysis allowing to a better observation of rainfall variability during one of the two seasons of peak ENSO activity. This analysis reveals some differences in spatial distributions and intensity of rainfall depending on boundary conditions and significant biases from one sub-region to another. We also note a decrease in precipitation during the active phase of ENSO (El Niño) and an increase in precipitation during the passive phase (La Niña) in certain countries but the model failed in representing it with the same intensity. Generally, the model follows the migration of ITCZ and hence, seasonal variability of precipitation is fairly well reproduced, but with an underestimation of precipitation by the model. In the same way also, the model failed in detecting the peaks and minima of precipitation due to ENSO.

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The role of ENSO flavors in recent droughts over Amazon forests

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Key words: Amazonia, drought, warming

The recent 2015-2016 El Niño (EN) event was considered as strong as the EN of the century in 1997-1998. Given such magnitude it was expected to result in extreme warming and moisture anomalies in the tropical land. Here we characterize the spatial patterns of drought over the Amazon tropical forests during the course of the 2015-2016 EN event, and also during the occurrence of other EN events in 1982-1983, 1997-1998, 2005-2006, 2009-2010. The link between the spatial patterns of drought during EN events and sea surface temperature anomalies in the Central and Eastern Pacific (CP, EP) is also explored. We found distinct spatial patterns of drought during the different EN events, although a characteristic drought pattern over Amazonia was observed in 2009-10 and 2015-16 EN events, both characterized by a high CP anomaly. This study aims to explore the regional distribution of drought linked to the different contribution of EP and CP anomalies.

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Analysis of the Relationships between Precipitation, Vegetation, Streamflow and ENSO Phenomenon in Andean Basins

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Key words: ENSO, SPI, NDVI, STREAMFLOW

The Southern El Niño Oscillation (ENSO) affects the global climate especially in countries located in low latitudes that border the Pacific Ocean. There are many investigations of the relationship of the ENSO phenomenon with some hydrometeorological variables in several regions, however there are few studies in Andean areas, even the literature on the relationships of the ENSO phenomenon with biodiversity is very scarce. This study explores the relationships of the ENSO phenomenon, precipitation, vegetation and streamflow in Andean watersheds analyzing the information in the time and frequency domains (using spectral analysis). We used indexes that characterize the ENSO phenomenon, such as the El Niño Oceanic Index (ONI), the Southern Oscillation Index (SOI), the Trans-Niño Index (TNI) and the Sea Surface Temperature (SST) anomalies of the Pacific Ocean of the Niño 1 + 2, 3, 3.4 and 4 regions over a period of 16 years (2000-2015). In addition the relationship analysis used the river flows, the Standardized Precipitation Index (SPI) and the Normalized Difference Vegetation Index (NDVI). The Tomebamba and Machángara river basins were chosen to analyze the different relationships. Cross correlations were performed with a maximum delay of 24 months between ENSO-SPI, ENSO-NDVI and ENSO-STREAMFLOW. The streamflows of Machángara and Tomebamba river basins in the time domain showed a significant relationship with the indexes and SST anomalies, reaching correlations of +- 0.50 in different time lags. In the frequency domain these correlations increased, reaching values of +- 0.90 with various harmonics and lags. The division of the time series into different signals of the SPI (frequency domain) of Machángara and Tomebamba river basins show correlations close to unity (+- 0.90) with the indexes and anomalies of the ENSO phenomenon in different time lags and taking into account several harmonics. Meanwhile, the NDVI did not have very high values in its correlations with the ENSO phenomenon, in the two domains of analysis. Precipitation and streamflow are the variables that most relate to the ENSO phenomenon in the two domains (time and frequencies). When the ENSO phenomenon occurs in its positive phase, precipitation and streamflow are reduced in the two basins, the opposite occurs when the ENSO phenomenon occurs in its negative phase. The analysis also showed that the frequency domain has a higher number of relations in some lags (0-24) while the time domain has relations between the lags 0 and 13. All these relationships could serve to build alert and preparation indicators for the times of excess and deficit of water in the Machángara and Tomebamba river basins.

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Evolution, vulnerability and the economic and social impacts of El Niño 2015-2016 in Latin America

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Key words: El Niño, Vulnerability, Latin America, Risk management, Socioeconomic impacts

This article documents in detail the evolution of the most relevant oceanic and atmospheric variables during the warm phase of El Niño 2015-16, as well as its manifestations on Latin America in relation to precipitation, temperature and extreme events. EFbl Niño 2015-16 is comparable to those of 1997-1998 and 1982-1983, and it has been one of the most powerful since 1950. It affected millions of people, mainly in Latin America. During 2015-16 the global climate experienced an unprecedented combination of El Niño, the Pacific Decadal Oscillation and the hottest period on the planet, since records began. Official sources and press reports were compiled to pinpoint the most consequential social and economic impact on Latin America, in particular with regard to the agricultural sector and food security. Although it had a wide range of repercussions in the countries, the most significant effects of El Niño 2015-16 were mainly associated with the exacerbated drought in the region, the extreme precipitation events and the subsequent flooding.

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Impact of the ENSO on the Behavior of Fruit Trees in the North Coast of Peru

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Key words: agriculture, ENSO, PHENOLOGY

The phenomenon of El Niño, understood as a planetary climate event whose impacts have a global impact, is also one of the most inter-annual events (Lagos & Silva, 2008), which means that its impacts on the territory vary between one and another event, changing the patterns of their effects. Particularly in South America, numerous studies have been carried out that reveal the impacts it has had on the continent (Nouvelot & Pourrut, 1984). Among the economic activities that generate impacts is agriculture, which is a relevant activity in northern Peru (Piura Region) where climatic variability acts as an exogenous factor and has a significant impact on crop production and yield. The present study represents an analysis on the impact of extreme temperatures and rainfall related to the El Niño event of 2016-2017, followed by a La Niña period on the phenological behavior of crops, especially in fruit trees of economic importance for the region. : mango, lemon, vine, banana at the same time to have an answer to the following questions: is the yield of the crop linked to the behavior of temperature and precipitation variations?

A decadal analysis was made with meteorological information from the meteorological observation network of the National Meteorological and Hydrological Service SENAMHI. The results allowed to determine the influence of the minimum temperature on the reduction of up to 30% in the flowering of the mango in child conditions, 60% on the mango setting in girl condition, 100% on the flowering of the lemon and grape influenced by the precipitations and temperatures in child conditions.

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Export Fluctuations of Merluccius Gayi Associated to El Niño Southern Oscillation (ENSO)

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Key words: Hake, ENSO, Chorophyll-a, Ecuador, Merluccius gayi

In Ecuador the Merluccius gayi has been present as an associated fauna in the landings of artisanal and industrial fisheries since the 1980s, however since 2010 the small-scale fishery has targeted this specie as a substitute for trawling fisheries. Fishing grounds are mainly located on the coasts of Manabí, Santa Elena, El Oro and the Gulf of Guayaquil from the equatorial line to 3.2 S. Time series from 1997 to 2017 for three-month running average of Sea Surface temperature (SST3m), Multivariate ENSO (MEI) and Oceanic Niño (ONI) indexes as well as chlorophyll-a , used as an indicator of cold or warm surface currents, upwelling systems and ocean primary productivity, were correlated to the exportation data of Merluccius gayi as 79% of the hake caught is exported. The non-linear correlation showed that at SST3m, ONI and MEI are inversely correlated (r2) up to 0.15, 0.22, and 0.26 respectively with a p-value < 0.05, in the case of chlorophyll a there was a correlation up to 13% but the p-value > 0.05 is not statistically significant. Results suggest that during La Nina years with anomalies of -1.5C and temperatures range 22 - 27°C tend to register higher exports of Merluccius gayi. On the other hand, during the very strong EL Niño the catch of Merluccius gayi decrease rapidly; this is related to the increase of temperature to 29 °C, water column stratification, and reduction of primary productivity, which in turn is extended to higher trophic levels, therefore impacting the fisheries.

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How High and Low Frequency Events Could be Affecting Bigeye Tuna Fishing in the Eastern Pacific

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Key words: Bigeye, ONI, MEI, PDO, tuna

Bigeye (Thunnus obesus) is one of the main species of Ecuadorian tuna industry. Its catches seemed to be affected by El Niño or La Niña (97–98, 00 - 02). Bigeye catches (87-17) in the Eastern Pacific Ocean being as total (purse seine -PS plus long line-LL gears) were correlated to: SST of regions Niño 1+2, 3 and 3.4; additionally, to other indexes: ONI, MEI and PDO as well. Linear regression curves had a negative slope; viz., in lower temperatures ranges, 22.5 - 24 C in 1+2, 25 - 26.5 C in 3, and 26 - 27.5 ^{o}C in 3.4 catches would increase, and vice versa. The correlation coefficients (R^2) of SST series for Niño 1+2, 3 and 3.4 and the volume catches were 0.18, 0.16 and 0.15 respectively. Captures were also correlated to SST series from TAO/TRITON stations at the longitudinal transects 95W and 110° W, from 0°, 2°, 5°, 8° N and 2°, 5°, 8° S; the R^2 were: 0.221, 0.188 and 0.138 at the transect 95W (0, 2S and 8S), where the highest total catches generally occur. Correlations of PS catches with ONI, MEI and PDO were 0.286, 0.365 and 0.178 respectively; with LL: 0.168, 0.162 and 0.098 in the same order; bot series with a lag time of 12 months. Different lag time responses were evaluated. Linear regression slopes with PS captures were negative whilst for LL positive. PS catches are more affected by surface temperature than LL ones, as their fishing operation occurred in surface water. The results demonstrate the no less important impact of oceanographic conditions on bigeye fishing.

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Coastal Kelvin waves associated with El Niño phenomenon and its impact on the Central and South America coast

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Key words: coastal Kelvin waves, El Niño and La Niña phenomena, Eastern tropical Pacific

Using sea level data from South and Central America gauging stations in sub-monthly resolution, the evidences of the passage of the coastal Kelvin waves along the western coast of the American continent are presented. Also, the socio-economic impacts these waves cause in the region is showed. It was established that after the arrival of the equatorial Kelvin wave to the South American coast, the coastal waves propagate along the coast and a rise of the sea level is observed sequentially in several localities to the north along the coast of the American continent up to the coast of North America. In the tropical sector, when the maximum phase of the waves coincides with those of syzygy (in boreal spring or autumn), tides and waves move deeper into the littoral, causing disasters in the small settlements located on the coast. Evidence presented in this article can serve as a basis to strengthen the systems of surveillance and warning systems established for the management of disaster risk by this type of events in the countries of the region.

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ENSO signal on the distribution of precipitation, improving seasonal information for stakeholders

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Key words: seasonal precipitation, impact on yields, remote forcing

El Niño- Southern Oscillation (ENSO) is one of the most important modes of inter-annual climate variability taken into account for predicting seasonal rainfall, useful information for decision makers. In the monthly meetings of the Argentine National Weather Service (scientists, technicians, decision makers, users, etc), this information is supplied as the probability of seasonal accumulated rainfall, separated in terciles. However, for certain users, it is also necessary to know how rainfall is distributed through the season. For agriculture planning, moderate rainfall at first stages of summer crops and during vegetative growing, represent benefit for the yields.

The objective of this study is to analyze the probability of occurrence of seasonal rainfall under different ENSO phases and to explore whether the distribution through the season supplies water demand from different phenological stages of summer crops.

Daily rainfall was used from 30 meteorological stations in Southeastern South America for the period 1970-2010. Three ENSO phases were discriminated based on Oceanic Niño Index. Firstly, from the terciles of rainfall, it was calculated their probability of occurrence under ENSO phases. Secondly, since seasonal rainfall is not necessarily equally distributed through the season, it was calculated if monthly rainfall was higher than the third part of its seasonal total. This study was performed during summer when high evapotranspiration can reduce or reinforce the impact of high and low rainfall, respectively.

The probability of reaching the 3rd tercile is between 40% and 60% in most of the stations under El Niño. It is noticeable that some stations near the southern border of the study region present lower probability, between 20% and 40%. The probability is lower under La Niña, between 20% and 30% in the center and 30% to 40% in the rest of the study region. For the 1st tercile, under La Niña, the probability is 30% to 50% in most of the stations whereas it is below 30% in most of them under El Niño.

Additionally, the probability of exceeding a threshold -third of seasonal rainfall accumulation- was evaluated in December (maize and soybean sowing stage), and January (vegetative growing stage). In December, the probability of exceeding the threshold is between 50% and 70% to the east and northeast and 70% to 80% in the rest of the region, under El Niño. Lower probabilities with higher spatial variability are presented under La Niña. When December is rainy, the probability of exceeding a threshold in January is above 50% in almost all the stations under the three phases. This result is relevant for short-term planning in agricultural systems.

Finally, it is worth mentioning the two most relevant ENSO events in the recent years. During 2011´ La Niña event, 13 out of 30 stations reached the third tercile but only 3 of them presented high rainfall during December. More recently, during 2015´El Niño event, 17 stations reached the third tercile and 10 of them presented high rainfall during December.

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Identifying the Periodic Inclusive Droughts and Wet Years of Iran in Southwest Asia and their temporal Adaptation to Southern Oscillation Index (SOI)

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Key words: Drought, Southern Oscillation Index, spectral analysis, Iran

The most important goal behind each study to identify periodic of droughts is to provide an appropriate scientific tool for predicting their occurrence in the future. In this research, two datasets were used to detect the periodic of inclusive droughts and wet years of Iran in Southwest Asia, and their temporal adaptation to Southern Oscillation Index tele-connection (SOI) cycles. In the first place the data on the monthly rainfall of 63 synoptic stations of Iran during the period of 1988-2015 is obtained from the Iran Meteorological Organization; secondly the values of the Southern Oscillation Index (SOI) of teleconnection pattern were achieved, which for the same period of time were inferred from National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) and Climate Prediction Center dependent on US National Oceanic and Atmospheric Administration.

Standardized Precipitation Index (SPI) was used to identify the frequency of different degrees of droughts. The main purpose of this index is to assign a numerical value to each rain event on a monthly scale. After computing the standardized precipitation index (SPI) for all stations under study, based on following three spatial indices the drought and wet years of Iran were divided into three categories: local droughts (or wet years), they are those droughts for about 25% or less of which the stations under study in Iran have declared drought (or wet year). Semi-inclusive droughts (wet years): those droughts (or wet years) for which the stations under study have declared about 25-75% of drought (or wet year). Inclusive droughts (or wet years): droughts (wet years), for which the stations under study have declared about 75% and more of drought (or wet year). Spectral analysis by Fourier method was used to identify the dominant periods in the time series of droughts and wet years, as well as for identifying the dominant periods in the time series of Southern Oscillation Index (SOI) of teleconnection pattern. In spectral analysis by the Fourier method, Radix-2 Fast Fourier Transform was used. Finally, the adaptation of the periodic obtained from two time-series was compared with together.

The results of spectral analysis showed that the periodic in the drought and wet year time series of Iran were very diverse. During the different periodic, the four main periodic with the highest potentials were 2.7, 2.1, 10 and 4.3 years, respectively. So, the periodic of droughts in Iran has been short-term. But the results of the spectral analysis of the Southern Oscillation Index (SOI) of teleconnection pattern showed that the four main periods based on the highest potentials were: 11.1, 12, 8.4, and 8 years. It is therefore clearly determined that the periodic of this index was the midterm periodic. Therefore, it can be concluded that there is no adaptation in terms of time between the inclusive droughts and wet years of Iran and Southern Oscillation Index (SOI) of teleconnection pattern.

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Weather and climatic controls of rainfall extremes fluctuations in the Western Andes of Ecuador and northen Peru

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Key words: rainfall extremes, weather types, El Niño

Weather and climatic characterization of rainfall extremes fluctuations in the Western Andean Ridge (WAR) of Ecuador and Peru (0-6ºS) is both of scientific and societal value for hydrometeorogical risk management. Here, we use ground data from the second half of the 20th century along the WAR, and an analysis framework based on signal-enhancement methods and extreme value modelling to discriminate, for the first time, the weather and climate (El Niño-driven) controls of rainfall extreme occurrences.

We found that north of 2.5ºS, catchments are found more influenced by large-scale organized convection, in which oceanic moist given by the El Niño (EN) development is primary distributed by terrain-blocked low-level flows. The advection drivers are essentially southerlies which convey weak/moderate EN-SST moist to the WAR's northernmost edges. Strong EN-SST anomalies signals only appear in the central WAR (~1.5-2ºS); their associated moisture seems locally advected at lowlands. This somehow redefines the long-standing idea that strong SST anomalies influence is topographically bounded by the WAR's relief. South of ~2.5ºS, the WAR seems detached of regional ocean-atmospheric patterns. There, local-to-meso-scale forcing dominates and shows a twofold pattern. Overall, we show that the meridional component of the tropical airflow is what matters for moist convection distribution leading to high rainfall intensities alongside the WAR, and that the zonal wind component of the EN types (e.g. the reversal of the Walker circulation), which has been traditionally stressed in several EN event based studies, is not evidenced in the inland continent. Moreover, the southern WAR seems to dampen meridional airflows rather than favouring pathways for zonal large-scale moisture transport, leaving local hygrothermal gradients to control rainfall extremes anomalies.

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The role of ENSO in the seasonal prediction of daily precipitation extremes in the Pampas region (Argentina)

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Key words: Extreme daily precipitation, Seasonal forecast

The extreme precipitation events are a distinctive climatic characteristic in the Pampas region, being precisely there where the different phases of the ENSO generate a greater impact in the extreme rain in comparison with any other region of the south of South America (Grimm and Tedeschi, 2009). These events have large social and economic impacts, given that the Pampas region is a highly populated area and concentrates most of the agricultural-livestock activities as well as the port, hydrological and tourist activities.

There is a growing need for studies of extreme precipitation events in the region and their relationship with climate forcings. In addition, the low predictability of summer precipitation together with the lack of predictions of extreme precipitation on a seasonal scale are still a big challenge to face. In this context, the objective of this work was to explore and identify predictors of extreme daily summer rainfall on a seasonal and monthly time scales in the Pampas region of Argentina, with the aim of moving towards the inclusion of these relationships in statistical forecast models.

Extreme daily precipitation indices, called FREQUENCY and DIER, were defined from data of 30 meteorological stations located in the Pampas region in the period 1960-2012. Daily extreme precipitation events were identified as those rainy days that exceeded the daily 75th percentile of the precipitation distribution. On a monthly scale, the FREQUENCY was defined as monthly series of the number of daily extreme precipitation events whereas the DIER as the monthly series of the average daily intensity of extreme precipitation events. Averaging monthly information, seasonal indices were obtained. These indices were the predictands. Among the potential predictors, different climatic indices (including those related to the ENSO phenomenon) and regional circulation indices were considered. In addition, indices that enabled the study of the effect of SST of the Atlantic Ocean in regions close to the area of interest and local moisture conditions were built. The relationship between predictors and predictors was studied from the Pearson and Spearman correlation coefficients, considering a lag of up to 6 months in advance. From the relationships found, the statistical forecast model was developed by means of the canonical correlation analysis and the cross-validation technique.

Different intra-seasonal signals were found depending on the predictor considered. The ENSO showed the strongest signals especially when considering the FREQUENCY during December and the summer season, while in January and February it considerably weakened and indices related with local moisture conditions prevailed. The validation of the developed statistical model was showed good performances, so that it was considered among the models used by the National Weather Service of Argentina for the last summer seasonal prediction.

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Mutual Spectral Analysis ENSO Index and Surfase Air Temperature on the Antarctica Stations

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Key words: ENSO index, surface air temperature, Antarctic region

The purpose of the study was to detect the connection between the surface air temperature of the Antarctic stations and the ENSO index. For spectral analysis data of the 33 Antarctic stations were used: the 14 stations of East Antarctica, 6 Western Antarctica and 13 stations of the Antarctic peninsula. Mutual spectral analysis was carried out between the ENSO index and the surface air temperature (at 2 meter the level).

The ENSO index (El Niño and La Niña indexes) is determined by the anomalies of the temperature of the ocean surface. Although originally, the terms El Nino and La Niña was related to the anomalies of the temperature of the ocean surface, currently as ENSO studies, called El Nino and La Niña, are understood not only as surface temperature anomalies in the equatorial region of the Pacific, but also the corresponding anomalies the circulation of the atmosphere and precipitation in this region, that is, the climatic anomalies in the ocean-atmosphere system.

The interconnection between periodic components in time series of the average monthly values of the ENSO index and the surface air temperature was carried out by means of a mutual spectral analysis. The algorithm for the investigation of stationary random processes was implemented using the computer program "Spektr". The statistical estimations of the mutual spectral density of the ENSO index and the average monthly temperature of air for 33 stations in Antarctica were obtained. The probability of statistical estimates of mutual spectral density was determined by coherence equal 0.9 and more.

The analysis of the results showed that in the spectral density of the ENSO index there is a seasons of oscillation with a period of 2.1, 2.3, 2.4 and 2.5 months, half a year - 5.6, 6.0, 6.7 months, year - 11, 1-14.6 months and fluctuations with a period of 42.7 months (3.6 years), as well as 170.7 months (14.2 years).

The spectral density of the average monthly air temperature during the same period of research for the stations of East, Western Antarctica and the Antarctic Peninsula also has a fluctuation season of 2.2, 2.4, 2.5, 2.6 months, and half a year - 5.8-6.1 month, yar - 10.7 and 11.6 months, and fluctuations with a period of 42.7 months (3.6 years).

The analysis showed that there is a close correlation between the periodic components in the time series of the ENSO index and the air temperature at the stations in Antarctica. Namely - the dependence of the air temperature of the from the ENSO index with a shift of synoptic scale, from three days to two weeks. There is also often a shift with a period of 1 month, which corresponds to annual harmonics, as well as seasonal shifts (about 2 months). For dome stations and stations located on shelf glaciers, the dependence of the air temperature on the ENSO Index with a displacement of 2.5 to 7 months was detected.

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Modulation of Winter Precipitation Dynamics Over the Arabian Gulf by ENSO

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Key words: Middle East Precipitation,ENSO Dynamics,ENSO Modulation

The Arabian Gulf (Gulf) and the surrounding regions are centres of intense economic activity. The precipitating weather systems that form over the Gulf are important for this predominantly arid region. It is suggested that El Niño–Southern Oscillation (ENSO) influences the Middle East precipitation variability through an equatorward shift of the subtropical jet. Here we present compelling evidence to illustrate the role of ENSO in modulating the local dynamics and moisture transport in initiating precipitation during different ENSO phases using satellite and reanalysis data. It is found that the moisture transport from the Red and Arabian Seas toward the Gulf is stronger during El Niño years. The pattern and strength of moisture transport toward the Gulf are weakened during La Niña and neutral years, with most of the transport directed toward the northern Gulf. Using a 120 h back trajectory analysis, it is found that while the air parcels coming toward the Gulf from the Arabian and Red Seas side originate at lower tropospheric levels, the air parcels from the Mediterranean originate at middle and upper tropospheric levels during El Niño years. In contrast, upper tropospheric air parcels originating over the southern Arabian Sea plays a dominant role on Gulf precipitation during La Niña and neutral years. The seasonal mean transients of zonal winds show a robust ENSO signature over the Gulf, indicating a favorable (less favorable) condition for the penetration of midlatitude eddies over the region during El Niño (La Niña) winters.

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Linkages of ENSO Variability and Declining Rice Productivity in Bihar, India

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Key words: ENSO, Climate Variability, El Niño, Rice Productivity

Climate change brought various negative results to the environment around us and area under rice crop in Bihar has also faced a lot of negative impacts due to variability in temperature and rainfall variables. Location of Bihar in Northern Plain of India automatically makes it prime location for agriculture and therefore variability in climatic variables brings highly sensitive results to the agricultural productivity (especially Rice). In this study, rainfall, temperature and soil moisture along with different climate indices are considered to look into the climatic teleconnection and its impact on Rice producing area resulting into decline in Rice productivity .Change in climate variable with the passage of time is prevailing since the start of geological time scale. How the variability in climate variables has affected Rice productivity? It is an interesting point for inquiring into that does there exists direct relation between climate variability and productivity Rice? How many important variables directly signals toward the change in productivity of Rice? These entire questions are answered with respect to change in productivity under rice cultivation of Bihar State of India. Temperature, rainfall and ENSO oscillation are a good indicator with respect to Rice cultivation in the Indian subcontinent. Ocean Niño Index, Niño3 and Southern Oscillation Index are highly correlated with the decline in the Rice productivity of the state. Therefore, forecast of the scenario of these indices with an appropriate lead period can help policy makers to take the precautionary measures to manage the production.

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Rainfall along the coast of Peru during strong El Niño events

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Key words: strong El Niño events, rainfall anomalies variability, rainfall anomalies modes, rainfall, highlands, Peruvian Pacific coast

While, climatologically, most areas of the Peruvian Pacific region do not experience precipitation, they can be affected by heavy rain and flooding during strong El Niño events with severe socio-economic impacts. Only four strong El Niño events took place within the last five decades (1972/1973, 1982/1983, 1997/1998 and 2015/2016) which led to significant rainfall events in the northern part of Peru. Here a detailed analysis of the evolution of precipitation during these events was performed using gauge records from 1964 to 2016 from a network of 145 meteorological stations located along the Peruvian Pacific region. Through empirical orthogonal function analysis, the rainfall anomalies variability is interpreted as resulting from the combination of a meridional see-saw mode (North–South) (Ep mode) and a zonal see-saw mode (East–West) (Cp mode) that represent, respectively, 34 and21%of the explained variance. It is shownthat the extreme 1982/1983 and 1997/1998 El Niño events have a dominant projection on the Ep mode that has a strong loading in the northern region, while the 1972/1973 and 2015/2016 El Niño events have a relativelyweak projection onto the Ep mode (about ten times less at the peak rainy season than the extreme events) and mostly project onto theCpmode.Also, it is shown thatwhile all events are associated with positive rainfall anomalies in the northern part of Peru which is accounted for by the Epmode, the evolution of rainfall anomalies along the Cpmode exhibits a significant dispersion. This suggests that the impact of strong El Niño events on the highlands along the coast cannot solely be inferred from the magnitude of the sea surface temperature anomalies in the central equatorial Pacific. Overall, our study illustrates the nonlinearity of the ENSO teleconnection on the rainfall along the coast of Peru during strong El Niño events.

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Rainfall and moisture patterns associated with strong El Niño events in the eastern Pacific region

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Key words: Moisture transport, Convergence of moisture transport, Extreme rainfall, Strong El Niño events

We studied how vertically integrated water vapor transport (Q) (and its convergence, -∇·Q) associated with large-scale and regional atmospheric circulation can explain the different patterns of rainfall over the Eastern Pacific basin (EPB) during the last three strong El Niño events: 1983, 1998 and 2016 with focus in Ecuador and northern Peru. This study uses 37 years (1979-2016) of monthly data from the ERA-Interim reanalysis. Although these three events recorded as strong in the Niño 3.4 region, singularly El Niño 2016 presents an atmospheric response opposite to the first two events that are similar experiencing an out-of-phase -∇·Q pattern regarding those two events. El Niño 2016 also exhibits moisture transport from the Amazon opposite to the Amazonian subsidence that dominates in 1983 and 1998. However, in 1998 a weakened subsidence allows moisture transport from 600 to 400 hPa towards highlands. While the topography stops the -∇·Q concomitantly the amount entering the EPB is influenced by regional atmospheric circulation of upper level southerly or northerly winds (100 to 300 hPa) that can induce strengthening (or weakening) of subsidence allowing lower (greater) income from -∇.Q characterizing different enhanced -∇.Q transported by the EPB which are reflected in the different rainfall patterns. This enhanced transport in El Niño 1983, 1998 and 2016 reached about 10°S, 14°S and 6°S, founding the extremes and weak rainfalls anomalous, respectively in the North-Centre EPB. This study illustrates link of upper level regional mechanisms on the large-scale moisture transport in determining different rainfall patterns during these El Niño events.

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The El Niño role in the interannual variability of the South Atlantic Subtropical Mode Water

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Key words: Mode water, El Niño, variability

Mode waters are characterized as distinct volume in the ocean with a picnostad, a low density gradient layer, trapped between the seasonal and the main thermoclines most of the year. Their major characteristic is the homogeneity of properties (T, S, density, O^2, potential vorticity, among others). Subtropical mode waters (STMW) are a specific kind of mode water generated in the poleward edge of the subtropical gyre, near the boundary currents. Their formation occurs from winter to spring, when harsh atmospheric conditions induce a buoyancy decrease of the surface waters by means of latent heat loss from the ocean to the atmosphere. This convective mixing process is a mechanism that increases vertical mixing, by subducting the surface water to just above the permanent thermocline. Notably during the summer, when seasonal thermocline is formed, this homogeneous layer is isolated from the surface.

The detection of the subtropical mode water in the South Atlantic is done by examining temperature and salinity profiles from outputs of the Global Ocean Assimilation System (GODAS) reanalysis model. For detection of mode water we used the following parameters: T between 13.0^{o}C and and 18.0^{o}C, S between 35.0 and 36.5, and potential vorticity smaller than 1.5x〖10〗^(-10) m^(-1) s^(-1)and/or a vertical temperature gradient less than 0.01^o〖Cm〗^(-1).

The interaction between the ocean and the atmosphere is crucial for the formation of mode water. Therefore, atmospheric teleconnections with remote processes such as the El Niño-Southern Oscillation (ENSO) may modify local patterns and influence the amount of mode water formed during one winter and subsequent ones in the South Atlantic. We examine the correlation between the STMW volume formed relative to El Niño and La Niña events by using the climate index of the East Central Tropical Pacific SST (Niño 3.4). The influence of the teleconnection patterns in the mode water formation is assessed through two methodologies: cross-correlation and composite analysis. For these analyses, all time series are expressed in terms of anomalies, total minus (mean plus trend plus annual cycle). The annual cycle is estimated by fitting a sinusoidal curve by linear regression. From the cross-correlation we can determine the lag when the maximum correlation between the climate index anomaly and the mode water volume anomaly occurs.

In the composite analysis an El Niño (La Niña) event is considered when the threshold of 0.5ºC (−0.5ºC) is found in the anomaly of Niño 3.4. The composites of STMW during El Niño and La Niña year events are compared with the prior and subsequent ones to examine the effect of ENSO on the presence of STMW.

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Seasonality of Dengue Fever in Rural Ecuador: 2009—2016

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Key words: dengue, seasonality

Season is a major determinant of infectious disease rates, including arboviruses spread by mosquitoes, such as dengue, chikungunya, and Zika. Seasonal patterns of disease are driven by a combination of climatic or environmental factors, such as temperature or rainfall, and human behavioral time trends, such as school year schedules, holidays, and weekday-weekend patterns. These factors affect both disease rates and healthcare-seeking behavior. Seasonality of dengue fever has been studied in the context of climatic factors, but short- and long-term time trends are less well-understood. With 2009—2016 medical record data from patients diagnosed with dengue fever at two hospitals in rural Ecuador, we used Poisson generalized linear modeling to determine short- and long-term seasonal patterns of dengue fever, as well as the effect of public holidays. With a second model, we also examined the effect of climate on diagnosis patterns. In the first model, the most important predictors of dengue fever were annual sinusoidal fluctuations in disease, long-term trends, day of the week, and hospital. Public holidays were largely not significant predictors of dengue fever diagnoses, except for a spike in diagnoses on the day after Christmas ($p=0.0015$). Compared to an average day, cases were 25% ($p=0.012$) and 26% ($p=0.033$) more likely to be diagnosed on Tuesdays and Sundays, respectively, and 20% ($p=0.063$) and 26% ($p=0.016$) less likely to be reported on Thursdays and Fridays, respectively. Seasonal trends showed single peaks in case diagnoses, during April, with long-term trends showing an overall decrease in case diagnoses and suggested inter-epidemic periods every two or three years. In the second model, important climate variables included the Oceanic Niño Index ($p=0.0085$), an interaction between monthly total precipitation and monthly absolute minimum temperature ($p=0.0335$), and three-way interaction between minimum temperature, total precipitation, and precipitation days ($p=0.0198$). This is the first report of long-term dengue fever seasonality in Ecuador, one of few reports from rural patients, and one of very few studies utilizing daily disease reports. These results can inform local disease prevention efforts, public health planning, as well as global and regional models of dengue fever trends.

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Features of the formation of the surface air temperature and atmospheric pressure fields in the western sector of the Southern Hemisphere and their relation to the ENSO

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Key words: main component, anomaly, atmospheric pressure, ENSO

The main attention in study is paid to revealing the degree of the El Niño-La Niña phenomenon impact on the formation of the fields structure of near-surface air temperature and atmospheric pressure in the middle and low latitudes of the western sector of the Southern Hemisphere.

To achieve this goal, we used methods of multivariate statistical analysis (cluster, correlation, component and regression analysis), methods of the theory of random processes.

The South Pacific region, consisting of four regions, was investigated. Region № 1 - is the water area of the Southern Ocean west of the coasts of Australia with coordinates 150 ° - 210 ° E, 10 ° - 30 ° S, is characterized by elevated temperature anomalies. This region is also represented in the work of Peterson and White (). Regions № 2 - 210 ° to 280 ° E, 10 ° to 40 ° S, № 3 - 190 ° to 285 ° E, 40 ° to 60 ° S , № 4 - 310 ° E - 10 ° E, 30 ° - 60 ° S, cover the circumpolar Antarctic current and its branches.

A component analysis of the fields of the near-water air temperature and atmospheric pressure in these regions showed that for each of the regions more than 60% of the total dispersion of the initial fields is caused by the first two eigenvalues. The time series of these main components contain information about their dynamics. Fourier analysis showed that the hidden periods in the time series of the first two main components of the atmospheric pressure fields in the selected regions are characterized by periods of 4-5 years.

A feature of periodicity hidden in the time series of the first two main components of the temperature fields in the selected regions of the Southern Hemisphere is that oscillations with high amplitudes have periods of 6-8 and 10 years. In addition, the first major component in the selected regions is characterized by 4-year periodicity. Most of the extrema in the time series of the main components of the air temperature and atmospheric pressure fields in region № 1 coincide with the El Niño and La Niña phenomena, respectively. In addition, there is a consistent relationship between the structure of the time series of the main components in region № 1 with regions № 3 and 4.

The characteristics of the correlation between the main components of the pressure fields in certain regions are more diverse than in the temperature fields. The results of the studies make it possible to conclude that the warm and cold phases of the El Niño phenomenon have an unconditional influence on the structure of atmospheric pressure fields in the low and moderate latitudes of the South Atlantic Ocean and adjacent land surface. In this case, the realization of the warm phase leads to the formation of positive pressure fields with respect to the average long-term values of the anomalies. With the realization of the cold phase of the phenomenon, fields of negative pressure anomalies are connected. The formation of such fields can be explained by a change in the intensity of cyclonic activity under the influence of the phases of the El Niño phenomenon in the western sector of the Southern Hemisphere.

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Changes in winter precipitation in Chile associated with different El Nino transitions

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Key words: Planetary Wave, Teleconnection, Winter rainfall, Chile

Many works have shown a link between El Niño-Southern Oscillation (ENSO) and precipitation in Chile, using SST anomalies over the Central Equatorial Pacific as modulator of winter rainfall. The major problem related with this methodology is the self-nature of ENSO. Analyzing the 3 month-running mean of ONI index among April and September, it is clear that during most of years,Tropical Pacific evolves into a cold or warm phase during this time period, reaching to stable El Niño or La Niña condition during the next Austral summer, when the rainy season is over.

Considering this, we decided to classify each year (among 1950 and 2016) according to how the ONI index changed during the Austral winter rather than as the customary absolute value of ONI. We then compute rainfall anomalies in rain gauges on weather stations among 29 and 43°S for each transition of ONI, to compare with composite of oceanic and atmospheric fields from Reanalysis data. This methodology allows to classify winters in 9 potential scenarios that we called “transitions”.

Results indicates during transitions from neutral to El Niño and Stable El Niño conditions, a wet pattern is found in most of the stations analyzed. Synoptic features are related with the PSA teleconnection mode over the Southern Pacific. However, during Neutral to El Niño winters, the anomalous wet pattern is better defined compared to Stable El Niño years, especially in central-north and central Chile (29-35°S). This seems to be produced due to an enhancement of the PSA teleconnection: a more intense blocking over Bellingshausen sea, a weaker subtropical high and the apparition of a blocking over Weddell sea. During stable El Niño winters, we even found a couple of years that showed dry conditions in most of the country, unlike during transition from Neutral to El Niño winters, where no dry years were found. For both transitions, positive precipitable water vapor anomalies are advected from Tropical Pacific toward South America, which could be related with the higher than normal precipitation anomalies during the winter.

Previous studies has shown that La Niña conditions can be considered as dry-winters generator, specially for Central Chile. Our paper suggest stable La Niña produces slightly dry or even normal rainfall anomalies. The driest pattern among all nine potential transitions correspond to El Niño to La Niña. This situation has only happened in three occasions and only during the last 20 years: 1998, 2010 and 2016. In fact, during these years it is possible to appreciate that all weather stations presents the highest negative anomalies of total winter rainfall, even in the South of the country, where linear relationship with ENSO are very weak during this time of the year. This situation seems to be caused due to a reversed PSA-like structure in the Southern Hemisphere Troposphere, weakening the subtropical jet, reinforcing the subtropical high and producing deep trough anomalies over Bellingshausen sea.

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Impact of Two Types of El Niño on Tropical Cyclones over the Western North Pacific: Sensitivity to Location and Intensity of Pacific Warming

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Key words: Two Types of El Niño, Tropical Cyclones, Location and Intensity of Pacific Warming, Monsoon Trough

The present study investigates the impact of various central Pacific (CP) and eastern Pacific (EP) warming on tropical cyclones (TCs) over the western North Pacific (WNP) for the period 1948-2015 based on observational and reanalysis data. Four distinctly different forms of tropical Pacific warming are identified to examine different impacts of locations and intensity of tropical Pacific warming on the WNP TCs. It is shown that WNP TC activity related to ENSO shows stronger sensitivity to the intensity of CP SST warming. The locations of TC genesis in an extreme EP El Niño featuring concurrent strong CP and EP warming (CEPW) display notable southeastward shift that is generally similar to the CP El Niño featuring CP warming alone (CPW). These influences are clearly different from the effects of moderate EP El Niño associated with EP warming alone (EPW). The above influences of Pacific warming on TCs are possibly via atmsopheric circulation variability. Anomalous convection associated with CP SST warming drives anomalous low-level westerlies away from the equator as a result of Gill-type Rossby wave response, leading to an enhanced broad-zone, eastward-extending monsoon trough (MT). Anomalous Walker circulation in response to EP SST warming drives an increase in anomalous equatorial westerlies over the WNP, leading to a narrow zone, slightly equatorward shift of the eastward-extending MT. These changes in MT coincide with a shift in large-scale environments and synoptic-scale perturbations, which favor TC genesis and development. In addition, during weaker EP SST warming (WEPW) with similar intensity to CPW, local SST forcing exhibit primary control on WNP TCs and atmospheric circulation.

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Searching for mesoscale processes in ENSO influenced tree ring proxies

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Key words: Ecuador, mesoscale processes

Ecuador is one of the countries that is, due to its proximity to the equatorial Pacific, strongly affected by ENSO events. This results in the region being promising for reconstructing ENSO events of the past. Tree ring proxies are an important tool for this purpose, but still have a considerable amount of unexplained variance. We suggest that taking mesoscale processes into account will increase the amount of explained variance. Mesoscale processes are an important component of the climate of Ecuador due to strong climate gradients arising from the mountainous landscape. To identify these processes, we use a high-resolution regional atmospheric model for our study site within the protected 'Laipuna Conservation and Development Area' located on the western flank of the Andes in Southern Ecuador. We chose this study site because two in situ measurements at different altitudes for the model evaluation are available. Moreover, it is a protected area within a semi-wet forest with a distinct wet and dry season, which allows trees to form distinguishable annual tree rings. As a first step, prior to analysis of collected tree ring proxy data, we attempt to differentiate the local effects of the general circulation, ENSO and mesoscale processes on the study site. This should provide a better understanding of the involved processes by comparing and correlating the high-resolution regional atmospheric model output with a global reanalysis dataset.

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ENSO-related Global Ocean Heat Content Variations

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Key words: ENSO, Global ocean heat content, heat redistribution, heat budget

The El Niño-Southern Oscillation (ENSO) is the most energetic climate variability on interannual timescales (2-5 years). ENSO's impacts on both global and regional ocean heat contents have been studied before, but the underlying mechanisms are less well understood. Moreover, most existing works focus on the upper tropical oceans only, and have not addressed ENSO's impact in the deep ocean and mid- to high-latitudes. In this study, we aim to establish a dynamical connection between global and regional ocean heat content anomalies during ENSO events. A thermodynamically consistent ocean state estimate (ECCOv4) is utilized to investigate global and regional integrated heat budget anomalies during ENSO events. The global ocean heat content (GOHC) exhibits a cooling tendency during the peak and decaying phases of El Niño. This is mainly a result of negative Surface Heat Flux (SHF) anomalies in the tropics (30ºS-30ºN), which are partially compensated by positive SHF anomalies at higher latitudes. ENSO's perturbation on ocean heat content is mostly confined to the upper 440 m where heat is redistributed towards the 0-100 m of the tropics during the developing and peak phases of El Niño. This internal heat redistribution is a key mechanism in generating the ENSO-related GOHC variations via its modulation on the SHF anomalies in the tropics. The heat redistribution occurs in both meridional and vertical directions. The meridional redistribution is mostly driven by velocity anomalies, while the vertical redistribution across 100 m is controlled by multiple processes. In addition, heat advection accompanied with a net volume transport and that due to different types of circulations (e.g., meridional overturning cell) are quantified separately. Results presented here have implications for monitoring planetary energy budget, and provide a quantitative benchmark for evaluating ENSO's imprints in global and regional heat content across different estimates.

Session 6. Climate Information and Sustainable Development and Future of Climate and Ocean Science

Oral Presentations

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Keynote: 14:30 – 15:00, Oct. 18

Keeping climate science fundable: Challenges and opportunities from the 2030 Agenda for sustainable development

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Key words: Climate, International funding, WMO, WCRP

At the present, climate change is highly positioned in the international agenda. For first time, “Climate action” is one of the Sustainable Development Goals agreed by the United Nations. The Paris Agreement on Climate Change and the Sendai Framework for Disaster Risk Reduction are in force. However, at the same time, severe cuts on climate staff and decrease of operational budgets have occurred in several climate centers around the world. The National Meteorological Services from developing countries struggle with reduced resources and more demands from their governments and the general public. The sustainability of the climate observing system is threatened by reduced resources for maintenance; long term records could be discontinued, mainly ocean data. International climate research programmes are facing the deviation of funds to other initiatives, affecting the continuity of essential climate research, which could lead to significant impacts worldwide but more in developing countries. There are an increasing number of National Adaptation Plans around the world which have been developed and implemented with any scientific basis about how present and future climate can impact in human and natural systems.

In this article some key elements are analyzed to ensure that climate funding can support fundamental climate research at global, regional and national level: 1) To enhance the synergy between operational and research communities by creating common spaces to co-design a collaborative system. 2) To enable the ways to connect global climate science with the regional level, to address research gaps specially in developing countries. 3) To take opportunity of existent structures within the World Meteorological Organization (WMO) such as the global production centers (GPC), regional climate centers (RCC), world climate research programme (WCRP) and its panels. 4) To foster the adequate connection between risk management and adaptation to climate change communities, to assure better climate services and tangible social and economic benefits.

Finally some specific recommendations are suggested to change the traditional way to mobilize funding from existent financial sources and keep the climate science fundable.

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Keynote: 15:00 – 15:30, Oct. 18

Towards an ENSO Early Warning System in Ecuador: Lessons learned

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Key words: ENSO impacts, Climate Information

The presence of El Niño Southern Oscillation (ENSO) Events can be felt in two ways: a) through alterations on the normal pattern of both the atmosphere and ocean systems, and b) through their impacts on natural ecosystems (both marine and terrestrial) and on societal and economic sectors (like fisheries, health, and agriculture).

It is widely known that ENSO events have to main phases (El Niño/La Niña) that produce changes in several physical parameters including: sea temperature and salinity, sea level and wave activity, air temperature and amount of ultra violet radiation reaching the surface of the earth, and alterations in the rainfall and evaporation patterns; changes that depend on the region of the world and the phase of ENSO.

However ENSO is far from a binary system oscillating within two distinct phases (Warm-El Niño and Cold-La Niña), it is recognized that ENSO has different “flavors” that are capable to contribute to climate variability and long-term trends in unique ways.

For this reason, as evidenced in previous ENSO events in Ecuador (one of the countries in the western coast of South America that is usually most heavily impacted when ENSO strikes) it is not easy to make an "average" pattern of ENSO impacts for a variety of reasons: the impacts depend greatly of factors like geographical extent and position of the oceanic anomalies, and intensity and timing of the anomalies; also the influence of social, economic and political structures determines whether climate anomalies caused by ENSO in a particular region will lead to severe societal and economic impacts.

The scientific community also plays a potential role in the extent of the impacts that ENSO can produce, if scientists can provide information on the impact of the presence of ENSO by identifying and focusing on its precursors, intervention could be taken early enough. There is however, something to be said against that: information can be misleading, target inappropriate at-risk groups, or generate a false sense of security.

The presence and reaction upon the occurrence of past ENSO events in Ecuador has given us valuable lessons that we need to keep in mind if we are to develop an effective early warning system for this region. In this work we make an overview of some of the considerations that need to be taken to achieve that goal.

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Oral: 16:00 – 16:20, Oct. 18

Differences between ENSO 2014- 2017 and another strong ENSO events

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Key words: ENSO, water mass, biological indicators

Accurate prediction of strong El Niño Southern Oscillation (ENSO) events is very difficult; such as was observed during the beginning and specially during the end of ENSO 2014-17 regarding its intensity and duration along South American Coast. The oceanographic-meteorological and biological indicators variation in the latest ENSO and its comparison with ENSO 1982-83 and 1997-98 will be discussed. El Niño 2014-17 began in February - March 2014 while strong west winds from the western Equatorial Pacific area blew over the huge warm pool, such as those occurred in 1982 and 1997. Before the winds blew, anomalous thermocline deepened with a higher dynamic height in the west was detected. As part of the mechanism, eastward kelvin waves are formed and started to move through the Pacific deepening the thermocline and reaching off South American Coast. Then, the warm pool eastward movement begin, however, it was stopped in July 2014. Progressively, the warming continued toward the east in 2015, 2016 and finished during the summer 2017, when Subtropical Surface Waters with high temperatures and salinities were observed off the Peruvian Coast. It could be attributed to the strong trade winds meridional component. After summer 2017, the weak La Niña developed until summer 2018, being this behavior completely different from those strong La Niña events observed from the end of 1983 and 1998. In 2014, notorious variations in the pelagic and demersal species distribution along the Peruvian Coast were also observed. In resume, ENSO 2014-17 was characterized by a poor intrusion of Tropical and Equatorial Surface Waters. Although, an important intrusion of the Subtropical Surface Waters from the west was detected. Coincidentally, trade winds meridional component intensified.

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Oral: 16:20 – 16:40, Oct. 18

Impacts of ENSO and summer monsoon rainfall on riverine flooding in Upper Indus Basin of Pakistan

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Key words: riverine flooding, Upper Indus, Pakistan, monsoon, land cover

Pakistan has experienced severe floods over the past decades due to climate variability. Among all the floods, the flood of 2010 was the worst in history. This study focuses on the assessment of 1) riverine flooding in the district Jhang (where Jhelum and Chenab rivers join, and the district was severely flood affected) and 2) south Asiatic summer monsoon rainfall patterns and anomalies considering the case of 2010 flood in Pakistan. The land use/cover change has been analyzed by using Landsat TM 30 m resolution satellite imageries for supervised classification with maximum likelihood algorithm, and three instances have been compared i.e., pre flooding, flooding, and post flooding. The water flow accumulation, drainage density and pattern, and river catchment areas have been calculated by using Shutter Radar Topography Mission digital elevation model 90 m resolution. The standard deviation of south Asiatic summer monsoon rainfall patterns, anomalies and normal (1979-2008) have been calculated for July, August, and September by using Era interim 0.75o resolution. El Niño Southern Oscillation has also been considered for its role in prevailing rainfall anomalies during the year 2010 over Upper Indus Basin region. Results show the considerable changing of land cover during the three instances in the Jhang district and water content in the rivers. Abnormal rainfall patterns over Upper Indus Basin region prevailed during summer monsoon months in the year 2010 and 2011. The El Niño (2009-2010) and its rapid phase transition to La Niña (2011-2012) may be the cause of severity and disturbances in rainfall patterns during the year 2010. The combined techniques of GIS and reanalysis climatic data can be used to develop a monitoring tool in flood management.

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Oral: 16:40 – 17:00, Oct. 18

Climate Services for Public Health: the use of El Niño and other climate modes for arbovirus forecasting in Latin America and the Caribbean

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Key words: early warning systems, arbovirus modeling, climate services, El Nino

Climate variability and change are associated with the burden and spatial distribution of arboviruses of major public health concern (i.e., dengue fever, zika, chikungunya). El Niño-Southern Oscillation (ENSO) may trigger episodes of infectious disease epidemics regionally through its impact on local climate conditions, which interact with socio-ecological factors to impact the risk of disease transmission. The World Meteorological Organization (WMO) has led the development of a Global Framework on Climate Services (GFCS) to provide tailored climate information to policy-makers in key sectors, including health. There is a body of research on using information on El Niño and other climate modes as potential predictors of arboviruses. However, climate-based seasonal forecasts of arboviruses are not fully integrated into mainstream public health services and decision-making. In this paper, we will assess the challenges and opportunities to enhance climate services as an operative approach for an arbovirus early warning system in the Latin America and Caribbean (LAC) region.

We conducted a literature review in the LAC region to identify the gaps between research products and operational dengue early warning systems (EWS). We assessed efforts to develop a dengue EWS using the pillars of the GFCS, including communication and partnership with stakeholders, capacity building, and avenues for mainstream climate services for health operations. Modeling results suggest that the effect of El Niño or La Niña on local meteorological conditions potentially influences interannual variability in dengue transmission. Even though there is abundant observational evidence of the effects of meteorological variables on changing disease patterns, climate alone does not account for a large proportion of the overall variation in dengue cases as in some examples of Brazil as well in Ecuador. In both places, the inclusion of specific information about vectors and circulating viruses, and other non-climate factors can improve the skill of the dengue forecasts and a better understanding of the contextual risk factors and public health interventions.

Regional-level climate-arbovirus probabilistic models have been developed to identify a hot spot for potential risk of arbovirus transmission. In the GFCS the research component needs to be accompanied by strong communication and partnership with the health operations staff, some specific examples are presented. However, to ensure health sector participation, climate services should be linked to the existing health priorities and Ministry of Health agendas. The successful implementation of climate-driven early warning systems will require strong collaboration with the operational, policy and technical support mechanisms of both the climate and health sector.

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Climate System Interactions for Climate Risks Management in Developing Countries

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Key words: Climate System, Risk management, El Nino

In a context of Climate Change, owing to the increase of anthropogenic greenhouse emissions, social systems in developing countries are seriously affected due to perturbations generated in the physical-

biogeochemical state of the climate. The particular case of the Latin-American countries shows that more than 70% of the emergencies and disasters reported are related to extreme hydro-meteorological events which generate losses of millions of dollars every year. Although threats like these affect developed countries with losses in the order of magnitude of billions of dollars per event, the Global Resilience Index positions them on top of the ranking while developing countries are ranking last.

Therefore, it is evident the necessity of a disaster risk management strategy to counteract the dramatic effects of climate change in developing societies. In this study, a multi-scale approach using a scale diagram is used to describe the mode of interaction of the physical and social components of the climate system. The tool is intended to describe how the nature and spatial extent of phenomena

are related with the potential human-response capacity. Thus, socio-political efforts in a local and regional extent can be combined with national socio-economic strategies to mitigate the side effects of a physical phenomenon in a changing climate.

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Ocean and climate models improvements by including the surface wave

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Key words:

For ocean models, to accurately simulate and forecast the vertical structure of the upper ocean such as temperature and salinity remains a challenge; the forecast ability on Typhoon intensity has no progress during the past several decades while the Typhoon track forecast ability is much improved; for regional and global climate models, the tropical biases and southern ocean simulation errors remain in climate models. To overcome the above barriers, new generation ocean, Typhoon and climate models are urgently needed. The inclusion of the surface wave-induced vertical mixing can overcome the common problems faces by ocean models including overestimated sea surface temperature, underestimated subsurface temperature and too shallow mixed layer depth in the upper ocean for POM, ROMS, HIM, POP, MOM, NEMO, and FESOM etc; The inclusion of sea spray due to wave breaking can much change the air-sea fluxes, heat flux can be 3 times larger, and the forecast of Typhoon intensity can be improved; The inclusion of surface wave in global climate model can alleviate the tropical biases, which are common problems for all climate models.

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Posters

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Poster

Remote data acquisition for ENSO (RENSO): A low budget locally developed approach

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Key words: low budget, Remote data acquisition

Current ocean in-situ equipment for sensing and understanding El Nino can be difficult to acquire by an Ecuadorian government institution such as ESPOL. This is mainly due to its high cost, long purchasing process times as well as obtaining permission for patient use in national waters. Therefore, RENSO proposes a technique to acquire remote data in real time using local built open source technology. The aim is to offer the researcher a low-budget nationally-developed technology as a way to empower our own engineers as well as to involve the general community in its development. Having access to self developed technology not only is a way to avoid lead times but it also gives the opportunity to customize it to our own water properties in Ecuador.

RENSO concept consists of a low budget buoy which serves as a modular platform for pressure (wave and tide-sea level data) and telemetry sensors. RENSO is first-guessed to sense these two variables because there are strongly modulated by ENSO (for example, during El Niño, the incident waves are more energetic, modifying littoral processes in some beaches). It is moored strategically in one point to prove a working concept. Scientific sensors will be underwater and will gather data during specific periods of time. Data acquisition times will be pre configured using open sources software. Data will be stored in a micro-controller which will also be based on open source software. Using SMS technology, data will be transmitted to a land station at specific pre configured times.

It is expected to obtain real time measurements of ENSO relevant data like pressure, temperature etc remotely. The data will be displayed in relevant graphs which will then be made available to local researchers for analysis, validation and feedback

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Algae Blooms and oceanographic drivers at the coast of Ecuador during La Nina and El Nino events (1997-2017).

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Key words: Harmful Algae Blooms (HABs), remote sensing, Gulf of Guayaquil, La Nina

The eastern tropical Pacific, within South America, is a region dominated by the trade wind circulation, the eastern upwelling system on the South Pacific, and the El Nino Southern Oscillation. Those oceanographic and climate drivers together with ecological strategies of phytoplankton interact in a complex dynamic to produce Harmful Algae Blooms (HABs). In this study we develop a synoptic and inter-annual analysis of Chlorophyll a and phytoplankton taxonomic groups associated to potentially Harmful Algae Blooms in four stations to 10 miles away of the coast of Ecuador sampled by the Oceanographic Institute of Ecuador (INOCAR); Esmeraldas, Manta, La Libertad, and Puerto Bolivar from the north to the south of Ecuador.

A multi-correspondence analysis (MCA) is developed, using an assemblage of 6 atmospheric ocean variables (from 1997 to 2017) for Sea Surface temperature (SST), Chlorophyll a concentrations (CHL) as a proxy of productivity, Wind Stress (WS) as an indicator of stratification, phytoplankton absorption (GIO), Photosynthetic active radiation (PAR), and precipitation (PREC), is related with the abundance of Phytoplankton taxonomic groups, and the indexes El Nino 1+2 and the Multi ENSO Index (MEI). It was explored the seasonal patterns of the taxonomic groups: dinoflagellates (DINO), centric (DIATC) and pennate (DIATP) diatoms potentially associated to HABs.

Main findings reveal a greater production of phytoplankton (biomass), associated to high levels of chlorophyll a, at the southern coastal station of Puerto Bolivar in the Gulf of Guayaquil, and followed with La Libertad at the center of the coast. At the stations, Esmeraldas, Manta y La Libertad, higher concentrations of the phytoplankton taxonomic groups diatoms (centric and pennate) and ciliates, are associated with higher levels of CHL, SST, PREC, and GIO, with significant correlations between CHL and GIO (62 and 82) during La Nina weak conditions.

At the station of Puerto Bolivar in the Gulf of Guayaquil, there are high concentration of the phytoplankton taxonomic groups dinoflagellates and diatoms (centric and pennate) associated to high levels of SST, PREC, GIO with significant correlations between CHL vs SST, PREC, GIO of (0.43, 0.74 0.66), under La Nina weak conditions. The maximum levels of chlorophyll a peak in March associated to the Guayas watershed runoff and another lower peak in September associated to the upwelling system of Humboldt Current.

On the other hand, during algae blooming dinoflagellates are the dominant taxonomic group, associated to medium levels of photosynthesis activity and Chl a, suggesting that dinoflagellates have strategies that enhance their productive capacity during warmer ocean conditions and water column stratification associated to moderate El Nino and weak La Nina events.

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Poster

Ecosystem-based adaptation to El Nino Impacts in Peru

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Key words: El Niño, floods, droughts, ecosystem-based adaptation

Peru is often struck by hydro-meteorological hazards during an El Niño event, and recent strong El Niño episodes (1982-83, 1997-98, and 2016-17) have led widespread significant negative impacts on human populations. While capacities to monitor and predict climate-related events have improved over the years, climate projections for adaptation purposes that account for El Niño-related impacts are still missing. Moreover, the current high-cost adaptation measures based on infrastructure have failed to mitigate the extreme weather impacts in Peruvian communities, which bring the necessity to introduce other feasible and cost-effective adaptation options. This study proposes Ecosystem-based adaptation options to El Niño impacts in Peru, build upon the regulating services of ecosystems to buffer the impacts of extreme events such as floods and droughts while providing benefits at socio-economical level. To do so, the Max Planck Institute Earth System Model (MPI-ESM) is used to construct El Niño-related hazards maps for floods and droughts for past and future scenarios. Along with it, a climatically and economically optimized model is used to assess Ecosystem-based adaptation alternatives over the affected regions shown by the maps. The aim is to propose an interdisciplinary way of translating climate knowledge into practical and beneficial adaptation outcomes for the Peruvian communities most affected by the negative effects of El Niño, using the valuable services ecosystem provide.

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Poster

Evolution of Relative Humidity over the Pacific Ocean

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Key words: Relative Humidity, Correlation functions, Probability Density function, Moisture

Our Oceans should be plenty of moisture on their surface, but it really does or it is reduced by radiation? Analyzing data of Relative Humidity from TAO Project from Pacific Marine Environmental Laboratory (PMEL) of National Oceanographic and Atmospheric Administration (NOAA), will improve our knowledge of this matter over the Pacific Ocean along the equatorial line. Even the Pacific Ocean is very big, ranges of Air temperatures increase little by little from East Pacific Ocean to West, and it is well known that humidity varies with temperature; but also, vapor water from the ocean should increase with temperature. So, high temperatures upon the Ocean will dry its atmosphere or maybe will increase its wet: it is a thing that we could find out processing data from Tao Project. It could be expected that in the warmer latitudes, near the 0° N, where temperatures must be higher, there will be the summit of higher or lower humidity, despite, how it does according to their longitudes? Are the waters from the western side cooler than Easter's? Really, there is a specific behavior of the weather parameters or they behave randomly?

The present work deals with temperatures and relative humidity on the Pacific Ocean, analyzing the data mention above means probability density functions and lag correlations, comparing the more than 60 buoys of this project (TAO) since the year 1980. Comprehension of the atmosphere-ocean interaction can help us to understand many phenomena that happen around the World and we can find several impressive occurrences.

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Behavior phytoplankton in the Eastern Equatorial Pacific, in relation to environmental variations caused by the presence of warm events

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Key words: Multi-way, Eastern Equatorial Pacific, Phytoplankton, Niño 1+2, warm conditions.

Eastern Equatorial Pacific, known for its phytoplankton richness and for containing the Niño 1+2 region, characterized by its sensitivity to detect variations in sea surface temperature, makes it an area of great interest for this research. The data are from 4 fixed stations 10 miles from the coastal profile of Ecuador Continental (3 located in Niño 1+2), from the 2013-2015 period, by standard depths classified by season, 7 environmental variables and the abundance of 23 species of Diatoms (granted by the Oceanographic Institute of the Navy-Ecuador (INOCAR)). The aim of this research is to identify the behavior of diatoms exposed to environmental variations by the presence of warm conditions. For each year there are two data tables (biological and environmental) of three-way, with the dimensions: standard depths by season (rows), environmental variables/species (columns) and space-sampling stations (conditions), forming two paired cubes for each year. The tables are analyzed jointly with the STATICO multivariate method (Simier, et al., 1999, Thioulouse, 2004,) to identify the stable part between the species-environment relationship; later, the commitment matrix obtained (structure in common species-environment) is interpreted from a perspective BIPLOT (Gabriel, 1971) using the HJ-BIPLOT (Galindo, 1986). The result of the commitment showed a relationship between groups of environmental variables except nitrite and phosphate (normal conditions), however, in extreme warm conditions a better covariation is observed between them. Some species associate their high abundance with the average values of environmental variables (normal conditions), but when were exposed to warm conditions they show an association with a particular environmental variable, such as Skeletonema costatum with Nitrite and Lauderia borealis with Oxygen.

The species were associated according to climatic conditions, because in the presence of extreme warm conditions the association patterns are different, for example Navicula sp., further of showing a low quality of representation of the abundance of the species. These results are related to what was mentioned by Torres (2017) that associate the low algal densities by warm conditions of the El Niño 2015, González-Narváez (2016) who observed a lower species-environment correlation in the first superficial layers in 2015; Barber and Chavez (1983) associate the decrease in plankton to high sea temperatures, and higher productivity at cooler temperatures, with a more shallow mix and thermocline layer; Tapia and Naranjo (2004) agree that the variability, composition and abundance of plankton depend on the seasonal season, the environmental conditions.

The multivariate statistical methods showed that the presence of hot events of great importance alter the structure of phytoplankton species.

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Impact assessment in the Great Horn Of Africa, a case study of Kenya

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Key words: MAM, Onset, GHA

In the Great Horn of Africa (GHA), the March to May (MAM) long rains season of 2018 was characterized with an early onset over much of Uganda and Belg-rains benefiting regions of Ethiopia during February. The rain belt further expanded to bring early onset of the rains in late February to early March in the equatorial regions of GHA covering much of Kenya, Rwanda and Burundi. Seasonably dry conditions prevailed over much of central and northern Somalia.

Satellite rainfall estimates for the third dekad of February and first dekad of March 2018 as per the forecast models indicated a likelihood of above to near normal rainfall across the western and central parts of the GHA including western Ethiopia, southern to central South Sudan and western Uganda. Depressed rainfall was expected over eastern Kenya, southeastern Ethiopia, and much of Somalia. The rest of the GHA is expected to have largely normal rainfall. The month of April was characterized with above to near normal rainfall with a lot of massive flooding and landslides leading to loss of lives, property and environmental degradation over central and eastern Kenya.

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Using ENSO forecast information to estimate dengue epidemics in El Oro Province, Ecuador

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Key words: ENSO forecasts, dengue estimation

The El Niño-Southern Oscillation (ENSO) is a high-impact climatic phenomenon that causes extreme weather worldwide, damages agriculture and marine ecosystems, and increases the risk of certain infectious diseases. Due to its effect on the local meteorological conditions, it potentially influences the interannual variability of dengue transmission in southern coastal Ecuador. El Oro province is a key dengue surveillance site there, due to the high burden of dengue, year-round transmission, co-circulation of all four dengue serotypes (DENV 1-4), and the recent introduction of chikungunya and Zika viruses in the region. In this study we explored the sensitivity of large dengue epidemics in El Oro to long-lead ENSO forecasts from a recently developed dynamic components ENSO prediction model.

The model uses state space methodology and incorporates predictors relevant to the evolution of El Niño events. It is specifically tailored to forecast warm events at long-lead times beyond the traditional spring barrier limit in predictability.

The ENSO forecast information was used in a Bayesian hierarchical mixed model designed to predict dengue in El Oro. A modelling framework was developed where the dengue and the ENSO models were coupled together. The predictive capacity of this framework was demonstrated in another study where a similar approach was utilized in combination with seasonal climate forecasts to predict in real time the dengue incidence in the city of Machala in El Oro in 2016 at a lead time of up to 11 months.

Here we build upon these results by testing the sensitivity of the dengue model to long-lead El Niño forecasts by using them at increasing lead times up to 21 months to simulate dengue incidence during 1998 and 2010 when large dengue epidemics occurred in the region. The dengue model correctly estimated the dengue incidence even at the very long simulation lead times of 2 years. Thus, information was successfully passed from the ENSO forecasting domain into the dengue estimation domain. The results confirmed the sensitivity of large dengue epidemics to the ENSO forecast information, and hold promise for a potential increase in the dengue predictive lead time in an operational framework. This demonstration study and exploratory analysis could be further extended to other infectious diseases transmitted in a similar way in other subtropical countries suffering the severe impacts of ENSO on local temperature and precipitation extremes.

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Multisite Downscaling of Seasonal Predictions to Daily Rainfall Characteristics over Pacific–Andean River Basins in Ecuador and Peru

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Key words: Sesonal Forecasting, Predictability, Rainfall, Hydrology

The seasonal predictability of daily rainfall characteristics is examined over 21 hydrologic units in the Pacific–Andean region of Ecuador and Peru (PAEP) using a nonhomogeneous hidden Markov model (NHMM) and retrospective seasonal information from general circulation models (GCMs). First, a hidden Markov model is used to diagnose four states that play distinct roles in the December–May rainy season. The estimated daily states fall into two wet states, one dry state, and one transitional dry–wet state, and show a systematic seasonal evolution together with intraseasonal and interannual variability. The first wet state represents regionwide wet conditions, while the second one represents north–south gradients. The former could be associated with the annual moisture offshore of the PAEP, thermally driven by the climatological maximum of sea surface temperatures in the Niño-1.2 region. The latter corresponds with the dynamically noisy component of the PAEP rainfall signal, associated with the annual displacement of the intertropical convergence zone. Then, a four-state NHMM is coupled with GCM information to simulate daily sequences at each station. Simulations of the GCM–NHMM approach represent daily rainfall characteristics at station level well. The best skills were found in reproducing the interannual variation of seasonal rainfall amount and mean intensity at the regional-averaged level with correlations equal to 0.60 and 0.64, respectively. At catchment level, the best skills appear over catchments south of 4°S, where hydrologically relevant characteristics are well simulated. It is thus shown that the GCM–NHMM approach provides the potential to produce precipitation information relevant for hydrological prediction in this climate-sensitive region.

Reference:

Pineda, L.E. and P. Willems, 2016: Multisite Downscaling of Seasonal Predictions to Daily Rainfall Characteristics over Pacific–Andean River Basins in Ecuador and Peru Using a Nonhomogeneous Hidden Markov Model. J. Hydrometeor., 17, 481–498, https://doi.org/10.1175/JHM-D-15-0040.1

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El Niño and probabilistic dengue outbreak prediction in Ecuador

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Key words: dengue, climate services, seasonal climate forecasts, early warning system

Introduction: El Niño and its impact on local meteorological conditions influences interannual variability in dengue transmission in southern coastal Ecuador. El Oro province is a key dengue surveillance site, due to the high burden of dengue, seasonal transmission, co-circulation of all four serotypes, and the recent introduction of chikungunya and Zika. In this study, we used ensemble climate forecasts to predict the evolution of the 2016 dengue season in the city of Machala, following one of the strongest El Niño events on record.

Methods: We incorporated precipitation, temperature and Niño3·4-index forecasts in a Bayesian hierarchical mixed model to predict dengue incidence. The model was initiated on 1 January 2016, producing monthly dengue forecasts up to eleven months ahead. We accounted for misreporting due to the introduction of chikungunya in 2015, using active surveillance data to correct reported dengue case data. We then evaluated the forecast retrospectively with available epidemiological information.

Results: The predictions correctly forecast an early peak in dengue incidence in March 2016, with a 90% chance of exceeding the mean dengue incidence for the previous five years. Accounting for the proportion of chikungunya cases that had been incorrectly recorded as dengue in 2015 improved the prediction of the magnitude of dengue incidence in 2016.

Discussion: The main advantage of this dengue prediction framework is the use of seasonal climate and El Niño forecasts, which permits dengue prediction to be made at the start of the year for the entire season. Combining active surveillance data with routine dengue reports improved not only model fit and performance, but also the accuracy of benchmark estimates based on historic seasonal averages. This study highlights the need to combine climate information and active surveillance data to strengthen early warning systems for arboviruses in Ecuador and other El Niño-sensitive areas with arboviral disease circulation.

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Towards responsible small pelagic fish consumption and alternatives in a changing climate

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Key words: Fishmeal, Climate change, SustainabiSustainability

Background: Aquaculture expanded around 8.6% per year during the period 1980–2012. It is the fastest growing food producing sector. The intensification of fish production from aquaculture has made its demand for fishmeal from small pelagic fishes as an increasingly important issue. Recognizing the vulnerability of small pelagic fishes to challenges of climate changes is serious. It will have consequent challenges in terms of ensuring economically, socially and environmentally responsible fishmeal production practices. The possibility of replacing fishmeal with nutritionally comparable feedstuffs would diminish stress on prices of feed inputs resulting from captured fisheries. Diverse types of alternative (plant, animal, fishery by-products and novel foods) protein sources have been experienced in a variety of aquaculture feeds.

Objectives: This review aims to appraise the different kinds of fishmeal alternatives and the most proper substituent in fish diets. The paper in hand proposed that some of the described fishmeal alternatives could leads to a considerable drop in small pelagic fishes utilization, but still they might be more cost-effective than fishmeal. Studies should take into account both economic and biological assessment of dietary protein sources as fishmeal substituents. On the other hand, the environmental impacts of such alternatives should be evaluated in order to guarantee sustainability of fish feed industry.

Conclusion: It is concluded that the idea of managing dynamic ecosystems throughout elastic, adaptive, ecosystem based management systems is getting enormous support (Garcia and Cochrane, 2005). Sustainability of natural resources and ecosystem services rely on how community can responds to ecosystem alterations resulted from mutual climatic and utilization patterns, rather than on their individual effects per se. In this respect, finding different types of novel sustainable protein sources has grown to be a major drive in the aquaculture industry consecutively to decrease dependence on fishmeal as the foremost protein component in aqua feeds (Hardy, 2010).

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Tracking the variability of marine productivity in the Gulf of Guayaquil throughout 2016: local evidences of ENSO events?

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Key words: Phytoplankton, chlorophyll, Gulf of Guayaquil, ENSO, sea surface temperatures

The Gulf of Guayaquil is the biggest tropical estuary of the Pacific coast of South America, and a complex transitional coastal-marine environment where fresh and cold waters converge. It receives nutrient-loaded fresh waters from the Guayas river, the main hydrographic system in the Ecuadorian coast, furthermore, it is also under the influence of the cold and rich-nutrient Humboldt current that flows further offshore and within the eastern Pacific upwelling system, such confluence makes the area one of the most productive within the Ecuadorian coast. 2016 has been a peculiar year in terms of oceanographic conditions according to the Oceanic Niño Index (ONI). In the first half of 2016, the ONI presented positive sea surface temperature anomalies during five consecutive overlapping seasons and authorities declared a state of emergency due to an El Niño event. On the other hand, the second half of 2016 presented ONI values below normal SSTs along five seasons too, and was classified as a La Niña event. The present study aims at assessing the marine primary productivity and the seasonal variability of the phytoplankton productivity in the Gulf of Guayaquil during 2016 as well as identifying and quantifying evidences of ENSO local events. With this purpose, a total of 4 ocean samplings were performed in-situ throughout 2016 with an average frequency of 3 months. The methodology included the use of CTD in order to register profiles of temperature, salinity and dissolved oxygen along the water column up to 30 meters depth, being remarkable the increase of temperature recorded in January and March 2016, with values around 28ºC. These abiotic data were correlated with the abundance and composition of the phytoplankton assemblage that was sampled through a Van Dorn bottle. The samples for chlorophyll a were taken at the water surface and subsequently analyzed in the laboratory by spectrophotometry (SM 10200H). The results indicate a minimum of chlorophyll and phytoplankton in January 2016 associated to a strong El Niño episode. In March 2016, surface salinity reaches its annual minimum below 30 ppt, and the peak of chlorophyll a in surface waters fully matches with the remarkable increase in microalgae abundance and diversity. This has been linked to a large riverine nutrient input. By mid-2016, an intermediate productivity was registered linked to conditions of transition. The higher phytoplankton abundance in subsurface waters of September 2016 was related to a weak La Niña. The taxonomic identification of species was performed using an optical microscope, within the phytoplankton, the diatoms dominate the assemblage under normal circumstances followed by dinoflagellates. However, the abundance of the dinoflagellates increases significantly at the beginning of 2016, reaching the 43.3 %, in particular, the genus *Protoperidinium sp.* This is a response to a change to environmental conditions that favors the proliferation of this group, i.e higher sea surface temperatures and less turbulence in the surface waters.