

CLIVAR Pacific Region Panel

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Panel overview

The PRP general objectives cover a wide range of science issues. This includes efforts to develop a coordinated international strategy for a sustainable Pacific observing system (e.g. Tropical Pacific Observing System, North Pacific Ocean Circulation Experiment) and a better understanding of (1) the internal dynamics of the Pacific variability (including ENSO and Decadal Variability), (2) the impact of external forcing on the Pacific (including greenhouse gases, aerosols, volcanic eruptions and solar insolation), (3) how Pacific climate variability generates remote impacts through teleconnections and interacts with climate variations external to the Pacific, (4) the dynamics that control the multi-scale variability in Western Boundary Currents (WBCs), the influence of WBCs on the Pacific climate and their oceanic connection to the Indian Ocean through the Maritime Continent and (5) the predictability of Pacific climate. Given the breadth of topics in scope and the current members' expertise, the PRP is presently focusing most of its attention on four main activities: ENSO conceptual models, ENSO metrics, decadal variability in the tropical Pacific, and continuing interactions with the TPOS2020 committee to provide scientific guidance during their implementation phase. Some of the activities planned for 2019-2020, like the ENSO Summer School in Trieste, Italy, did not take place due to the COVID-19 pandemic. Most of the PRP activities and interactions have occurred virtually. While progress has been made on the panel's main objectives, the lack of in-person interactions, and the cancellation of in-person events during 2020, have limited some of the expected achievements.

Achievements for 2019-2020

1. Conferences/Workshops/Meetings

ENSO Summer School. The PRP has been heavily involved in the organization of the 3rd Summer School on "Theory, Mechanisms, and Hierarchical Modeling of Climate Dynamics: Tropical Ocean, ENSO, and their Teleconnections", which was proposed by the PRP, and was scheduled to take place at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy, from 3 to 14 August 2020. Several current and past PRP members (Mike McPhaden, Andrew Wittenberg, Antonietta Capotondi, Matthieu Lengaigne, and Agus Santoso) were scheduled to give lectures at the school together with other ENSO and Interbasin Interactions experts. Due to safety concerns associated with the COVID-19 pandemic, the event was canceled for this year. The possibility of rescheduling the school in 2021 or 2022 is being discussed at the ICTP center, but there are still uncertainties about its feasibility due to the ongoing pandemic concerns.

AGU sessions. PRP members have been actively involved in the organization of two sessions at the AGU Fall meeting in San Francisco in December 2020:

- El Niño Southern Oscillation in a Changing Climate. Conveners: Agus Santoso, Mike McPhaden, Andrew Wittenberg, Antonietta Capotondi. Other PRP members (Kug, Luo, and Vialard) will help chair the virtual live sessions.
- Tropical Pacific Decadal Variability, Drivers, Predictability and Impacts. Conveners: Shayne McGregor, Yu Kosaka, Sam Stevenson, and Jing-Jia Luo.

PICES meetings. As co-Chair of the Joint PICES/CLIVAR working group on “Climate and Ecosystem predictability”, A. Capotondi has represented the PRP at the virtual working group meeting in the context of the PICES 2020 annual meeting. A. Capotondi has also participated in the PICES Physical Oceanography Committee (POC) meeting, which was also attended by members of the CLIVAR leadership. Interest for a continuing collaboration between the two organizations was expressed by both sides. The PRP will play a major role in this CLIVAR/PICES collaboration as PICES focuses on the North Pacific.

CLIVAR-GOOS meeting. A. Capotondi is representing the PRP in the organization of the CLIVAR-GOOS Pan-Panel meeting planned for early May 2021 in Trieste, Italy. Due to uncertainties in the safety of a large international in-person meeting, the pan-panel meeting has been postponed to 2022. Since a big focus of this meeting was the involvement of developing countries and capacity building, efforts will be made during 2021 to start planning for this aspect of the meeting. In particular, representatives of developing countries will be identified, and virtual presentations and discussions will be held in preparation for the in-person meeting in 2022.

2. Scientific results from activities

AGU Monograph “ENSO in a changing climate”. The PRP very actively contributed to several chapters of an AGU monograph written for the AGU Centennial titled *ENSO in a Changing Climate*. This book, edited by A. Santoso (former PRP member), W. Cai (SSG co-chair and former PRP co-chair and ENSO RF member) and M. McPhaden (PRP ex-officio), provides a comprehensive review of ENSO and the effect of climate change on its dynamics, predictability, and impacts. The PRP members involved with the book have finalized their chapters during 2020. The book is in the process of being published.

ENSO metrics. The PRP has hosted the activities of the ENSO metrics group over the last two years, which continues the efforts of the former CLIVAR Research Focus on ENSO in a Changing Climate (2013-2018). This project has been coordinating a large international group of ENSO experts to develop a community metrics and diagnostics package to automatically evaluate, compare, and explore the ENSO performance, teleconnections, and processes in climate simulations. To support model developers and users, the package is written in Python and designed to plug into widely-used community diagnostic tools (including ESMValTool, CliMAF, and the PCMDI Metrics Package). A. Wittenberg presented updates on the ENSO metrics project, at the October 2019 PRP Meeting (Victoria, BC) and the September 2020 teleconference of the PRP Working Group on ENSO Conceptual Models. A paper describing this package and applying it to the CMIP5 and CMIP6 models has recently been published in the Bulletin of the American Meteorological Society (BAMS), with several PRP members as co-authors (Planton et al. 2020; see publication list at the end of this report). To accompany that paper, the group also created an

interactive graphical web browser to view all of the ENSO metrics and diagnostics products applied to the CMIP5 and CMIP6 historical simulations:

<https://pcmdi.llnl.gov/research/metrics/enso/>

ENSO Conceptual Model working group. As planned during last year’s PRP meeting, the “ENSO conceptual model” working group was started at the beginning of 2020. The working group, led by Jerome Vialard, includes several PRP current and past members (Capotondi, Kug, Lengaigne, Luo, McGregor, McPhaden, Stevenson, Vialard, and Wittenberg) as well as several other ENSO experts (Soon-Il An, Dietmar Dommenges, Alexey Fedorov, Fei-Fei Jin, Malte Stuecker, Eli Tziperman, Chunzai Wang) as well as some early-career scientists (S. Gangiredla, Soong-Ki Kim, Shineng Hu, Sulian Thual). The main objectives of the Working Group are: 1) Define ENSO conceptual models; 2) Define ENSO fundamental properties that should be accounted for by an ENSO conceptual model, and metrics of these properties; 3) Conduct a literature review to examine existing ENSO conceptual model families and core hypotheses, and identify physical mechanisms that need to be accounted for; 4) Investigate the ability of existing conceptual models to reproduce key ENSO properties and mechanisms in observations and CMIP class models; 5) identify ENSO properties that are not well-captured by existing conceptual models, and devise a way forward; and 6) Develop a “Community Conceptual Model” for ENSO. Expected outcomes of this working group are a review paper, an improved conceptual framework for ENSO, and possibly other research papers resulting from collaborations among the Working Group members. The group has already held several teleconferences with presentations from its members, including Jerome Vialard (Introduction, terms of reference, timeline), Andrew Wittenberg (Essential ENSO properties and corresponding metrics), and Fei-Fei Jin (Existing ENSO conceptual models, and research on the recharge oscillator and ENSO seasonality).

Tropical Pacific Decadal Variability paper. The review paper on Tropical Pacific Decadal Variability promoted by the PRP, and led by Scott Power was submitted to Science in December 2019. From recent communications with the Science Editors, we know that the paper is in review.

Integration of low-latitude western boundary current and maritime continent observations into a unified multi-platform observing system. During 2019-2020, the North Pacific Ocean Circulation Experiment (NPOCE) made substantial progress in monitoring the Pacific Low-Latitude Western Boundary Currents (LLWBCs) and their connections with the Indonesian Throughflow (ITF) by organizing and conducting 7 cruises in the western Pacific Ocean and the Indonesia Seas. The NPOCE Scientific Steering Committee (SSC) 2019 annual meeting and the NPOCE 2020 Ocean Science Meeting side meeting were successfully held. An observation training proposal for young scientists and students from developing countries with a joint sponsor of POGO and the Institute of Oceanology, Chinese Academy of Sciences (IOCAS) in 2020 has been submitted to POGO. Through comprehensive cooperation, 77 scientific papers and 5 books associated with the western Pacific Ocean circulation and climate variability were published, including a review paper “Review on observational studies of western tropical Pacific Ocean circulation and climate”. The paper highlighted many important achievements in observational studies of western tropical Pacific Ocean circulation in the recent 20 years and proposed future focus. The paper is led by the NPOCE Chair, Dunxin Hu, and the two vice-chairs, Fan Wang and Janet Sprintall, with about 20 scientists from the international oceanographic community (Hu et

al., 2020). It was published in the Journal of Oceanology and Limnology as one of the contributed papers to celebrate the 70th anniversary of the IOCAS.

Enhancing the Chilean Climate Ocean Observing System (ECCOOS). During 2020, the PRP endorsed the Chilean project ECCOOS. Many Chilean observational field programs are conducted by individual universities, without much coordination among institutions. The goal of the ECCOOS program is to augment the existing 4 buoys currently operating along the Chilean coast with two additional buoys that will be deployed further offshore and will provide vertical profiles of various quantities as well as surface meteorological observations. The observational program is planned for 5 years. A proposal for this project was submitted to the Chilean government, and the PIs are still awaiting to hear whether the project will be funded.

TPOS2020. The last TPOS2020 Steering Committee meeting was held on 5-7 November, 2019, in Hangzhou, China. Since then, the TPOS 2020 Steering Committee and Task Teams members, among them several current or former PRP members (S. Cravatte, S. McGregor, J. Sprintall, A. Wittenberg) worked (remotely) to articulate recommendations for missing elements of the observing system. These include proposed enhancements to TMA meridional extensions, salinity sampling, ocean velocity and near-surface measurements, biology and ecosystem. They worked on the draft of the Third (final) Report, whose main goal is to serve as a hand-off document for implementers and as a report to project sponsors. The TPOS 2020 project will terminate when this report is complete, but we recognize the continued need for scientific oversight and for coordination among the implementers.

The final report aims to provide a summary of the progress, and a self-evaluation of the TPOS 2020 project's successes and failures. It will provide recommendations on future governance past the end of the project. Finally, it will provide additional information on modelling studies, and an evaluation of the pilot and process studies linked to the TPOS 2020 project. This Third Report had been expected to be open for public review early September, but the process has been delayed. In addition, 2020 should have seen the start of the Implementation of the plans by the stakeholders, both on the Chinese and NOAA sides. Intercomparison experiments of moorings, both on land and at sea were planned. However, the COVID-19 crisis hindered the TPOS 2020's momentum. Similarly, the last Steering Committee meeting, which was planned for November 2020 to complete the project, is postponed to an unknown date in early 2021.

Ocean Isotopes. The PRP continues to support the efforts of the US CLIVAR working group on Observations and Modeling of Water Isotopes in the Climate System. PRP member Stevenson is a member of this US CLIVAR effort, and presented an update on working group activities to the PRP at the Fall 2019 meeting in Victoria. This included a summary of the US CLIVAR-hosted workshop held in October 2019 in Boulder, CO, designed to evaluate the state of water isotope science in relation to climate model validation, tracing of the modern hydrological cycle, and paleoclimate applications. Since then, the water isotopes working group has continued to hold regular teleconferences, as well as organizing a session at the upcoming AGU Fall Meeting. Additionally, working group members (including Stevenson) are working on a review paper on the importance of water isotopes as climate system tracers, with a likely publication date of late 2021. The working group is also in the process of identifying 'legacy' activities to provide momentum for water isotope science after the working group sunsets: example activities include

coordinating inter-comparison efforts for isotope-enabled climate models, and facilitating long-term sustained isotope observations through coordination with ‘ship of opportunity’ programs.

3. Scientific Capacity Building and Career Support

- During 2020, A. Capotondi and S. Stevenson have served as mentors for the US program “Mentoring Physical Oceanography Women to Increase Retention” (MPOWIR). This program involves one conference call per month to support young women at the Ph.D. and Post-Graduate level in successfully navigating the field of Physical Oceanography and finding appropriate and fulfilling roles.
- The ENSO conceptual model working group involves early career scientists and provides them with opportunities to participate in discussions and activities that can support their scientific and professional development.

4. Knowledge exchange

The joint PICES/CLIVAR working group has allowed continuing interactions between the two communities.

Plans for 2021 and beyond

NPOCE. In the following years, NPOCE will promote multi-institutional cruises to overcome the EEZ issue in some key regions of field experiments, and strengthen in-depth cooperation among SSC members and with other projects based on the scientific foci of NPOCE during 2021-2025. Other efforts, from various countries, are also made to observe the LLWBCs transport and heat transport in the southern hemisphere, and the ITF transport. An integrated approach, and a stronger coordination among these various efforts should be the ultimate goal to build a coherent international sustained observing system in these regions. To make further progress in our understanding of the importance of LLWBCs variability for the Pacific climate, simultaneous measurements of both the north and south LLWBCs heat transports (together with that of the ITF) may be envisioned. The 4th OSS (Open Science Symposium on Western Pacific Ocean Circulation and Climate) is planned to be held in 2021 in Xiamen, China.

The CLIVAR PRP might decide to foster dialogue between the partners working on the 3 systems, to see how projects intersect, and encourage a coordinated experiment.

ECCOOS. The PRP will continue to communicate with the PIs of the project, and provide scientific support and guidance.

TPOS2020. Past 2020, after the end of the TPOS 2020 project, the project will be transitioning toward implementation, and the need for oversight bodies is recognized. Two groups should be created, although the details and terms of reference of these groups are not final. The first would be an “Implementation Coordination Group”, responsible for TMA planning and coordination, data management, profiling floats coordination, and interfacing with international higher level bodies. The second group would be a “scientific advisory committee”, tasked to provide ongoing

scientific oversight, ensure a scientific and technological watch to evolve the TPOS, considering new technology and pilot study results, and to refine the design if needed, as the TPOS must stay open to evolution.

Initiatives that the PRP might undertake include:

- Provide feedback to the Third TPOS2020 Report when open to public review
- Participate in the international cooperation, especially with eastern and western Pacific regional coordination, with small Island Developing States, and ensure data sharing. Despite great efforts, the TPOS 2020 project did not succeed in engaging multiple countries into the observational efforts, and in motivating effective participation in implementation.
- Advocate for a coordinated experiment for the northern and southern LLWBCs and ITF, fostering dialogue between the partners working on these connected systems.
- Keep connection with the new TPOS groups (e.g. members of the new Scientific Advisory Committee), to help with implementation plans, ongoing assessments, and evaluating new technologies.
- PRP members could also engage in discussions with their agencies regarding the recommended pilot projects, and the numerical experiments such as OSSEs.

ENSO conceptual model working group. The activities of the working group will continue during this coming year with monthly 2-hour conference calls, each featuring two speakers. The presentations, each of which will be prepared by a team of three scientists, will discuss specific aspects of ENSO with focus on the main open questions, including, e.g., ENSO phase locking, asymmetry, stochastic forcing, diversity etc.

ENSO metrics. Work on ENSO metrics will continue during this coming year, and will benefit from the interactions with the ENSO conceptual models working group, particularly with regard to process diagnostics. Efforts will also be made to incorporate the ENSO metrics package into community tools like the PCMDI Metrics Package (PMP) and the Earth System Model Evaluation Tool (ESMValTool), to support future model development and analysis internationally. The metrics will be applied to a broader set of CMIP5 and CMIP6 simulations, to investigate impacts of climate change on ENSO, and to identify emergent constraints toward reducing projection uncertainties and clarifying future ENSO risks.

Tropical Pacific Decadal Variability (TPDV) Working Group. The PRP is planning to start a new working group on oceanic mechanisms of tropical Pacific decadal variability. This working group stems from the open questions highlighted by the PRP-led review paper on TPDV, and will try to assess the impact and relative importance of different mechanisms of TPDV involving ocean dynamics. It will also investigate the influence of inter-basin interactions on TPDV. The working group will benefit from the expertise of several PRP members who have agreed to participate in this initiative (Capotondi, Imada, Kosaka, Luo, McGregor, McPhaden, Stevenson, Wang, Zhang) as well as other experts in the fields, who will be invited to participate. Early career scientists will also be included in the working group, as they have been in the ENSO conceptual models working group.

Articles published in 2019/20 as part of panel activities

AGU Monograph: El Niño Southern Oscillation in a Changing Climate, McPhaden, Santoso, Cai (Eds), Wiley, 2020, ISBN: 978-1-119-54812-6

Chapters with PRP contributions:

- [1] Cai W., G. Wang, L. Wu, M. Collins, A. Timmermann, **S. Power**, **M. Lengaigne**, 2020: ENSO response to greenhouse forcing, <https://doi.org/10.1002/9781119548164.ch13>
- [2] **Capotondi, A., A. Wittenberg, J.-S. Kug**, K. Takahashi, and **M. McPhaden**, 2020: ENSO Diversity. <https://doi.org/10.1002/9781119548164.ch4>
- [3] Fedorov, A., S. Hu, **A. T. Wittenberg**, A. Levine, and C. Deser, 2020: ENSO low-frequency modulation and mean state interactions. <https://doi.org/10.1002/9781119548164.ch8>
- [4] Guilyardi E., **A. Capotondi, M. Lengaigne**, S. Thual, and **A. Wittenberg**, 2020: ENSO modelling: history, progress and challenges, <https://doi.org/10.1002/9781119548164.ch9>
- [5] Holbrook, N. J., D. C. Claar, A. J. Hobday, K. L. McInnes, E. C. J. Oliver, A. S. Gupta, M. J. Widlansky and **X. Zhang**, 2020: ENSO-driven ocean extremes and their ecosystem impacts, <https://doi.org/10.1002/9781119548164.ch18>
- [6] Karamperidou, C., M. F. Stuecker, A. Timmermann, K.-S. Yun, S.-S. Lee, F.-F. Jin, A. Santoso, W. Cai, and **M. J. McPhaden**, 2020: ENSO in a changing climate: Challenges, paleo-perspectives, and outlook. <https://doi.org/10.1002/9781119548164.ch21>
- [7] **Kug J.-S., J. Vialard**, J.-Y. Yu, Y.-G. Ham, **M. Lengaigne**, 2020: Remote forcing: Influence of climate variability outside the tropical Pacific. <https://doi.org/10.1002/9781119548164.ch11>
- [8] **McGregor, S., Khodri, N. Maher, M. Ohba, F. S. R. Pausata**, and **S. Stevenson**, 2020: The Effect of Strong Volcanic Eruptions on ENSO. <https://doi.org/10.1002/9781119548164.ch12>
- [9] **McPhaden, M. J.**, A. Santoso, and W. Cai, 2020: Introduction to El Niño Southern Oscillation in a Changing Climate, AGU Monograph, ISBN: 978-1-119-54812-6
- [10] **McPhaden, M. J.**, T. Lee, S. Fournier and M. A. Balmaseda, 2020: ENSO Observations. <https://doi.org/10.1002/9781119548164.ch3>
- [11] Sprintall, J., **S. Cravatte**, B. Dewitte, Y. Du, A. Sen Gupta, 2020: ENSO Oceanic Teleconnections, AGU monograph, <https://doi.org/10.1002/9781119548164.ch15>

CLIVAR-endorsed Workshop Reports:

- [12] Hagos, S., G.R. Foltz, C. Zhang, E. Thompson, H. Seo, S. Chen, **A. Capotondi**, K. Reed, C. DeMott, A. Protat, 2020: Atmospheric Convection and air-sea interactions over the tropical oceans: Progress, challenges, and opportunities. *Bull. Amer. Meteor. Soc.*, 101, E253-E258.

ENSO metrics:

- [13] Planton, Y., E. Guilyardi, **A. T. Wittenberg**, J. Lee, P. J. Gleckler, T. Bayr, **S. McGregor**, **M. J. McPhaden**, **S. Power**, R. Roehrig, **J. Vialard**, and A. Voldoire: Evaluating climate models with the CLIVAR 2020 ENSO metrics package. *Bull. Amer. Meteorol. Soc.*, in press. doi:10.1175/BAMS-D-19-0337.1

NPOCE:

- ^[14] Hu, D., F. Wang, **J. Sprintall**, L. Wu, S. Riser, **S. Cravatte**, A. Gordon, L. Zhang, D. Chen, H. Zhou, K. Ando, J. Wang, J.-H. Lee, S. Hu, J. Wang, D. Zhang, J. Feng, L. Liu, C. Villanoy, C. Kaluwin, T. Qu, Y. Ma, Review on observational studies of western tropical Pacific Ocean Circulation and Climate, JOL, DOI:10.1007/s00343-020-0240-1

Budget and other needs for 2021

Please keep in mind that the overall budget of CLIVAR is limited and this needs to be distributed between all activities and the SSG meeting.

Annex A

Proforma for CLIVAR Panel requests for SSG approval for meetings

Note: If your group has approved funds in 2020 that were not used because of Covid19, and you propose to use them in 2021, they should be included again in this request, in addition to any new request.

Carry over from 2020 to 2021:

1. **Panel or Working Group:** Pacific Region Panel
2. **Title of meeting or workshop:** 3rd Summer School on Theory, Mechanisms and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO and their Teleconnections
3. **Proposed venue:** Trieste, Italy at the Abdus Salam International Centre for Theoretical Physics (ICTP)
4. **Proposed dates:** 3-14 August 2020 (original); **TBC in 2021 (ICTP's decision will be made in November 2020)**
5. **Proposed attendees, including likely number:** Approximately 50 participants (mainly early career scientists) from around the world and 18 lecturers (senior scientists, with expertise on ENSO and its global teleconnections). The summer school will be advertised using multiple channels, and a selection committee will be established to select the participants who will get financial support to attend the Summer School, while other participants will be invited to attend the course at their own cost.
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:** ENSO understanding, modeling and forecasting have been major foci of research within International CLIVAR, given the impacts of ENSO in many areas very important for society. The proposed Summer School will build on the achievements of the ENSO Diversity Working Group, and extend its legacy with the inclusion of new advances in inter-basin interactions and tropical teleconnections. These recent advances will allow us to broaden the discussion on the topics that were identified as outstanding issues and key research priorities: Causes of ENSO diversity regime changes; Precursors and Triggers; Sustained and enhanced ocean observations for ENSO; Teleconnections and impacts; Assessment of climate model performance in simulating and predicting ENSO diversity. Thus, the goals of the proposed Summer School are fundamentally aligned with and support those of CLIVAR PRP research, including the PRP's planned activities on ENSO metrics, ENSO conceptual models, and the tropical Pacific observing system.

The proposed summer school will contribute to CLIVAR science: this topic is very relevant to the tropical climate dynamics and predictability, a core science topic in the new CLIVAR science plan. It is also relevant to WCRP Grand Challenge on "Near-term Climate prediction".
7. **Specific objectives and key agenda items:** The El Niño Southern Oscillation (ENSO) is a naturally occurring phenomenon in the tropical Pacific, and it is a strong driver of significant weather and climate anomalies across the globe. The global teleconnections related to ENSO and its diverse expressions continue to be an area of very active research,

and include not only effects on the circulation over the mid-latitudes (Europe, Asia and North America), but also the strong influence on the Indian Monsoon. The Indian Monsoon (as well as other monsoons) also have their own set of teleconnections, not all of which are related to ENSO. In recent years, there have been significant advances in the understanding of the regions that affect the monsoon and of the regions the monsoon interact with, including the tropical ocean basins, the adjoining land masses, mid-latitudes and the stratosphere. Recent research developments also include inter-basin interactions, and their influence on ENSO, its decadal modulation, and global teleconnections.

The proposed summer school on Tropical Oceans, ENSO and their teleconnections, is aimed to share the latest advances in the understanding of ENSO dynamics, diversity, modeling, predictability, and decadal modulation, as well as its associated broad range of teleconnections. The summer school is extremely relevant to scientists (particularly for early career scientists and students) from developing countries, because many economies (in particular in monsoon affected countries) depend on the accuracy of seasonal to longer-term prediction of agricultural production.

The lead organizers and many invited speakers for the summer school have participated in the organization of relevant activities led and coordinated by the CLIVAR Pacific Region Panel and former Research Focus on ENSO in a Changing Climate (2015-2018) in the past years, including:

- ENSO Complexity Workshop (Busan, Korea, 2017), which produced a paper entitled 'El Niño–Southern Oscillation complexity' published in Nature in 2018;
- IV International Conference on El Niño Southern Oscillation: ENSO in a warmer Climate (Ecuador, 16-18 October 2018);
- Two workshops on Tropical Pacific Decadal Variability (Ecuador, 2018 & Paris, France 2019), whose outcomes are being summarized in a paper to be submitted shortly to Science;
- A paper on 'Pantropical climate interactions' published in Science (2019).
- A standard ENSO evaluation protocol of CMIP models (ENSO Metrics)

Several of the organizers and speakers have also been involved as contributors to the new Wiley book entitled "El Niño Southern Oscillation in a Changing Climate" (McPhaden, Santoso, Cai, Eds.) that is in production now and will be published early next year. That book will be available to students as part of the summer school and will be a major source of material for the curriculum.

8. **Anticipated outcomes (deliverables):** A summary report of the summer school will be prepared. Key highlights from the school will be summarized in a report for BAMS.

We are also planning to publish a special edition of "CLIVAR Exchanges" providing a summer school summary and showcasing selected research presented.

Apart from these short-term deliverables, experience from previous summer schools that some of the organizers/lecturers participated in has shown the profound impact these schools have had on the early career scientists who attended them, by exposing them to cutting-edge research, instilling in them the curiosity and passion for science, thus fostering the development of a new generation of talented climate researchers.

9. **Format:** The summer school will be organized over a two-week period (10 working days plus one Saturday). The school will include not only lectures on the current state of knowledge on ENSO and the associated broad range of teleconnections, but also practical sessions and the development of student projects to provide a hands-on approach to the

understanding of the material presented in the lectures.

The school will cover the following topics

Week 1: ENSO dynamics

- ENSO phenomenology
- ENSO theory
- ENSO modeling
- ENSO decadal modulation
- ENSO prediction

Week 2: ENSO teleconnections

- Pathways for tropical influence on the extra-tropics
- Remote impacts of the Indo-Pacific on Europe
- Global teleconnections with the Asian monsoon
- Decadal variations of interannual ENSO teleconnections
- Inter-basin teleconnections

Poster sessions will be organized during the summer school to give more opportunities for early career scientists and students to share their works among peers.

Sessions will also be planned to introduce the participants to the relevant activities and research interests of both US and International CLIVAR, which will provide opportunities for networking, as well as help identify possible pathways by which US and International CLIVAR can support early career scientists.

10. **Science Organizing Committee (if relevant):** Antonietta Capotondi (University of Colorado and NOAA/ESRL, USA), co-chair of the International CLIVAR Pacific Region Panel; David Straus (George Mason University, USA); Jagadish Shukla (George Mason University, USA); Fred Kucharski (ICTP, Italy); Mike McPhaden (NOAA/PMEL, USUSA); Eric Guilyardi (IPSL/LOCEAN, Paris, France); Andrew Wittenberg (NOAA/GFDL, USA)
11. **Local Organizing Committee (if relevant)**
12. **Proposed funding sources and anticipated funding requested from WCRP:**
 - ICTP: 32,000 US\$** (including venue, facilities, lodging and meals for 68 attendees)
 - US CLIVAR: 30,000 US\$** (including travel for US lecturers and students) – **Funding proposal has been approved by US CLIVAR through it 2019 Fall Open Call for Workshops (Funds will be carried over to 2021 if the school could occur in 2021, decision should be made by 13 November).**
 - ICRP: 4,000 CHF** (travel support for non-US lecturers and students).

Annex A

Proforma for CLIVAR Panel requests for SSG approval for meetings

New request:

1. **Panel name:** Pacific Region Panel
2. **Title of meeting or workshop:** 15th session of the PRP meeting
3. **Proposed venue (Or indicate if online):** San Francisco, USA, alongside the 2021 AGU Fall Meeting.
4. **Proposed dates:** 12 or 18 December 2021
5. **Proposed attendees, including likely number:** PRP members + 5 invitees (~20 people)
6. **Rationale, motivation and justification, including: relevance to CLIVAR science & WCRP Grand Challenges, and any cross-panel/research foci links and interactions involved:** Opportunity to hold our meeting back to back with the 2021 AGU Fall Meeting, to foster our collaboration with US CLIVAR, reduce carbon footprint and travel costs for the several PRP members participating in the AGU meeting, and share the cost of the venue.
7. **Specific objectives and key agenda items:** ENSO conceptual models, Tropical Pacific Decadal Variations
8. **Anticipated outcomes (deliverables):**
9. **Format:**
10. **Science Organizing Committee (if relevant)**
11. **Local Organizing Committee (if relevant)**
12. **Proposed funding sources and anticipated funding requested from WCRP:**
4k CHF (travel expenses for 2 PRP members)