

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, Tropical Pacific Decadal Variability (TPDV), ENSO metrics, Pacific observing systems, including the implementation phase of TPOS2020, and the North Pacific Circulation Experiment (NPOCE). The PRP has also interacted with the North Pacific Marine Science Organization (PICES) to provide climate expertise for advancing understanding of the predictability of marine ecosystems in the North Pacific. During 2021-2022, like in the previous two years, most of the PRP activities and interactions have occurred virtually due to COVID-19. While progress has been made on the panel's main objectives, the lack of in-person interactions, and the cancellation of some in-person events during 2022, have somewhat limited expected achievements.

Achievements for 2021-2022

1. Conferences/Workshops/Meetings

ENSO School in Trieste. The 3rd Summer School on "[Theory, Mechanisms, and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO, and their Teleconnections](#)", originally scheduled to take place in August 2020, was held at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy, during July 18-29, 2022. The first week of the school focused on El Niño Southern Oscillation (ENSO), while the second week was devoted to far-field tropical teleconnections. A. Capotondi was involved in the design of the scientific program of week 1, together with colleagues at ICTP, and with input from other panel members. The school was sponsored by WCRP and CLIVAR. Lecturers and students from the U. S. were supported by US CLIVAR through funding from the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF).

The first week of the school covered key aspects of the ENSO phenomenon, including observations (Dr. **Mike McPhaden**), ENSO-mean state interactions (Dr. Alexey Fedorov), theory (Dr. Fei-Fei Jin), predictability (Dr. Ben Kirtman), diversity (Dr. **Antonietta Capotondi**), modeling (Dr. **Eric Guilyardi**), prediction (Dr. Michelle L'Heureux), societal applications (Dr. Andy Robertson), ENSO decadal modulations (Dr. **Andrew Wittenberg**) and ENSO future projections (Dr. **Agus Santoso**). Several of the lectures were delivered by current and former members of the PRP and “ENSO in a changing climate” Research Focus group (names in bold). The school was conducted in hybrid format, with over 100 students from countries on all six continents, including about 35 students on site and up to 70 participants on line on any given day.

Ocean Sciences sessions. PRP members were actively involved in the organization of three sessions at the Ocean Sciences meeting that took place virtually during February 27-March 4, 2022:

- *El Niño in a Changing Climate.* Conveners: **Jerome Vialard**, **Samantha Stevenson**, Malte Stuecker, **Andrew Wittenberg**
- *Toward Predictive Understanding of Pacific Decadal Variability and its Global Implications.* Conveners (after merging with another similar session): **Antonietta Capotondi**, Cristian Proistosescu, Sara Sanchez, Malte Stuecker.
- *Marine Climate Extremes: Part 1 Mechanisms, Predictability and Coastal Impacts.* Conveners: Emanuele Di Lorenzo, Steven Bograd, Nadia Pinardi, Gerald Meehl, **Antonietta Capotondi** (invited to participate as CLIVAR representative)

PICES meeting. The PICES annual meeting was held in Busan, South Korea, September 23 – October 2, 2022 in hybrid format. A. Capotondi attended the session of the meeting focused on the development of a new PICES working group (WG-49) entitled “Ocean extremes and coastal impacts” whose goal is to better understand and predict ocean extremes, i.e., marine heatwaves and their biogeochemical impacts, and assess the socio-economical consequences of these extremes. This working group is of great relevance to CLIVAR and some of the WCRP Lighthouse Activities (LHAs), e.g., “My Climate Risk”, and “Explaining and Predicting Earth System Change”, and is intended to be joint with CLIVAR and other organizations ([news link](#)). Capotondi was invited to be part of the WG-49 leadership as a CLIVAR Pacific panel representative.

CLIVAR-GOOS workshop ‘From global to coastal: cultivating new solutions and partnerships for an enhanced Ocean Observing System in a decade of accelerating change’ was held in August 15-17 in Trieste, Italy, in hybrid format. PRP members I. Montes and S. Cravatte were members of the organizing committee, and attended part of the workshop virtually. The 3-day agenda of the workshop covered: (Day-1) Ocean observing systems and the way forward; (Day-2) From observations to predictions, applications, and end-users; and (Day-3) New technologies and frameworks for ocean observing systems. Main achievements of the workshop include: 1) understand how and where the scientific and societal priorities of regional (Indian, Atlantic, Pacific) ocean observing systems and national near-coastal observing systems align; 2) facilitate an exchange of goals, challenges, and ideas between CLIVAR / GOOS scientists and invited speakers from rim nations and small island states that can lead to new solutions and partnerships for an enhanced global ocean observing system; 3) outline opportunities for developing rim nations to increase their oceanographic and forecasting capabilities in partnership with the regional ocean observing systems; and 4) to promote a CLIVAR and GOOS contribution

to the UN Decade of Ocean Science for Sustainable Development 2021-2030. Recommendations/outcomes included:

- To develop a mentoring program (OceanMATCH), where global community (seniors and non-senior scientists with abilities/skills to give/share or get/win) can be connected, e.g., for helping to use/develop technology and to develop research papers, etc. This goal can be addressed through an app or website where funding opportunities can also be included. Of course, it is necessary to review what is already available and present it as a mini proposal to, e.g., CLIVAR (Lighthouse activities), GOOS/INCOIS/Ocean Decade Early Career Network among other possibilities.
- To implement/create a pilot collaborative study in data poor regions to illustrate the value of a new technology/approach and show how this adds capacity to the observing system. Two projects can be envisioned in the short-term: using turtles to observe ocean heat waves and using fishing vessels user-observer pilots.
- To create a user community network/forum that can assist in using the technology, making it accessible and easy to use,
- To ensure that instrument developers/manufacturers are invited to workshops and meetings so that they have a better view of the interests and needs of the scientific community,
- To improve communication between the ocean observing scientists and end-users, policymakers, stakeholders (including coastal indigenous communities) in all countries to better understand the needs to be addressed. This can be done by exploring existing communication mechanisms (IOC, WMO, POGO, CLIVAR), organize workshops/forums/summer schools/hackathons on science communication and build a partnership with coastal indigenous community which can be addressed as a pilot project to support the implementation.

4th NPOCE Open Science Symposium on “Western Pacific Ocean Circulation and Climate”. The Symposium was successfully held during 24-27 Oct. 2022 in a hybrid format, onsite in Xiamen, China, and online through the zoom platform. The four-day-long meeting received about 1400 attendees from 10 countries in five sessions, which strengthened the communication and cooperation among the scientists on physical and biogeochemical studies in the western Pacific Ocean and adjacent seas. PRP member Dr. F. Wang was one of the leading organizers of the Symposium. S. McGregor and A. Capotondi participated remotely in the symposium as invited speakers.

2. Scientific results from activities

ENSO Conceptual Model working group. The working group, led by Jerome Vialard, includes several current and past members of the PRP (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). It also includes some early career scientists (S. Gangiredla, Soong-Ki Kim, Shineng Hu, Xiang-Hui Fang). Since its inception in June 2020, the working group has met 13 times through teleconferences, which were alternatively scheduled on eastern and western-hemisphere friendly timings. The meetings were always recorded and the recording + meeting slides made available on the WG digital repository. In 2022, these teleconferences included both discussions about a

synthesis paper (work in progress, to be discussed in the “Plans for 2023” section) and talks on topics relevant to the WG:

- February 2022: An overview of panel activities since the beginning of the WG, with a proposed outline for a synthesis paper (Vialard) + discussion on the outline
- April 2022: one hour discussion on the review paper outline + talk by X. Huang (Extension of the Recharge Oscillator concept to a 3-box model in order to account for ENSO diversity)
- September 2022: talks by S. Thual (The role of spatial shifting in El Niño/Southern Oscillation complexity) and S-I. An (An overview of the basin mode potential importance for ENSO)

The synthesis paper outline and contents are now agreed upon, and lead authors have been nominated for each chapter, with a deadline for a first draft in early December. We will plan a new videoconference in early 2023 to discuss the status of the draft, but mainly rely on the face-to-face meeting in Melbourne, Australia in February 2023 to make progress on the writing (see plans for 2023 section).

Tropical Pacific Decadal Variability (TPDV) Working Group. The TPDV working group, led by A. Capotondi, includes several current and past panel members (S. Cravatte, Y. Imada, K. Karnauskas, Y. Kosaka, J.-J. Luo, S. McGregor, M. McPhaden, S. Stevenson, A. Taschetto, F. Wang, X. Zhang), several experts from the broader scientific community (K. Cobb, R. Farneti, N. Holbrook, F. Kucharski, M. Mayer, B. Qiu, A. Santoso, J. Sprintall, M. Stuecker, C. Ummenhofer), and seven early career scientists (Giorgio Graffino, Ryan Holmes, Shijian Hu, Nicola Maher, Sara Sanchez, Arnold Sullivan, Mathias Zeller). Launched in May 2021, the working group has met virtually quasi-monthly during 2021, and 5 times during 2022. The meetings, intended to critically review this topic from both oceanographic and atmospheric perspectives, have typically included one or two presentations on different aspects of TPDV followed by a discussion.

Topics covered this year include:

- February 2022: The talk entitled “*Paleo Tropical Pacific Decadal Variability*” by Sara Sanchez provided an overview of the insights that can be gained from the paleo archive.
- May 2022: A. Capotondi provided a summary of the material presented in previous meeting to assess the degree of completeness of the working group review of TPDV, and identify areas in need of further review and discussion. This summary presentation led to the preparation of a document that will be used for the preparation of the review paper.
- June 2022: The meeting was dedicated to the discussion of the summary paper to assess its suitability as review paper on the topic.
- September 2022: M. Stuecker presented some of his recent results on the potential role of oceanic nonlinear dynamical heating associated with ENSO in TPDV phase transitions.
- November 2022: S. McGregor presented a literature review of the influence of Atlantic and Indian Ocean variability on tropical Pacific variability at interannual and decadal timescales, and A. Capotondi discussed the role of tropical wind fluctuations in driving the transport of the Subtropical Cells (STCs), a key component of the ocean circulation at decadal timescales, along the same latitude. Both topics are important for identifying which winds are most effective in forcing the oceanic processes relevant for TPDV.

The TPDV working group has been invited to prepare a review paper by the Editor of *Nature Reviews Earth & Environment*. Activities are underway to prepare an initial draft of the paper by

mid-December, which is expected to be finalized during the meeting in Melbourne in 2023. Apart from its scientific goals, the working group has also demonstrated an impactful way to include Early Career Scientists in CLIVAR activities.

Collaboration with PICES. CLIVAR and PICES have had long-time successful interdisciplinary cooperation, through the CLIVAR participation in several PICES Working Groups (WGs). In particular, the recently ended [WG-40 on Climate and Ecosystem Predictability](#) was a joint Working Group of CLIVAR and PICES. This working group, which included CLIVAR members A. Capotondi from PRP, S. Minobe from CDP, and Ryan Rykaczewski from the Eastern Boundary Upwelling System Research focus group, leveraged the international expertise of both organizations, and produced a research topic in *Frontiers of Marine Science* on “[North Pacific Climate and Ecosystem Predictability at seasonal to decadal timescales](#)”, as a final product of the working group. A [perspective paper](#), and an Editorial were published this year as part of the research topic by the CLIVAR representatives. The perspective paper discusses how climate model predictions can be used for marine ecological forecasting. This is an important avenue to be explored, involving collaborations across physical climate science and marine biological science.

ENSO Metrics. The PRP hosts the activities of the ENSO metrics group, initiated by the [CLIVAR Research Focus on ENSO in a Changing Climate](#) (2013-2018). This project has coordinated international experts on ENSO to develop and apply a community diagnostic package to automatically evaluate, compare, and explore the ENSO performance, teleconnections, and processes in climate simulations. The open-source [ENSO Metrics Package](#) documentation and Python code are publicly available via a [GitHub code repository](#) and [wiki](#), together with an [interactive metrics browser for the CMIP5 and CMIP6 models](#). The project members, who met via teleconference in 2021-2022, achieved several new milestones over the past year. A. Wittenberg, former co-chair of the CLIVAR ENSO RF, is the liaison scientist of PRP to ENSO Metrics.

1) The metrics package was used to assess the **robustness of ENSO behavior**, using datasets from CMIP6 and the [US CLIVAR Large Ensemble Working Group](#) to estimate the **ensemble sizes** needed to quantify and compare ENSO simulations against observations and other models ([Lee et al. 2021](#); also [presented](#) at the 2021 Fall AGU). This study, building upon the work of [Planton et al. \(2021\)](#), found that larger ensembles are needed to robustly characterize ENSO’s baseline characteristics and physical processes, than to characterize the tropical Pacific background climatology and ENSO teleconnections. Another study (Planton et al., submitted to *J. Climate*) used the metrics package to determine the ensemble sizes needed to robustly detect the **time of emergence** of model-projected future changes in ENSO behavior.

2) The ENSO Metrics Package played an important role in the [CLIVAR/ICTP ENSO Summer School](#), held in Trieste, Italy in July 2022. Y. Planton developed and presented **student tutorials** on using the package to analyze CMIP data for student research projects. This training, which included numerous participants from developing countries, was in direct support of the [WCRP Academy](#) (a WCRP Lighthouse Activity).

3) The ENSO metrics package was used to diagnose the **impacts of Andes topographic heights on ENSO** ([Xu et al. 2022](#)). This study found that elevating the Andean topography to more realistic levels in a coupled GCM improved its simulated tropical Pacific climate and ENSO.

4) The ENSO Metrics Package was expanded to include several **new observational reference datasets** for a variety of ocean-atmosphere fields, and was used to assess the robustness of ENSO metrics to the choice of observational dataset. [Planton et al.](#) presented this work at the 2021 Fall AGU (December 2021), and a manuscript is currently being prepared.

5) **Pre-calculated ENSO metrics for the CMIP5 and CMIP6 models** were [provided to the public](#) in convenient formats (JSON, Excel), to aid researchers in evaluating and comparing their models.

5) **New ENSO process metrics** were developed and applied to three leading U.S. climate models ([Chen et al. 2021](#)), as a testbed for inclusion into the ENSO Metrics Package. These results were further used to develop a new funding proposal (Jin, Wittenberg, et al., 2022; submitted to [NOAA MAPP](#)) to build a dynamically-constrained framework for reducing uncertainties in multi-decadal ENSO projections, and to deliver new metrics in coordination with the ENSO Metrics effort and the **PRP Working Group on Conceptual Models of ENSO**. Another new project ([Wittenberg et al. 2022](#)), recently funded by [NOAA CVP](#), would develop metrics for tropical Pacific upwelling, mixing, and the upper-ocean heat budget associated with the equatorial Pacific climate and ENSO, enhancing the CLIVAR ENSO Metrics Package and informing the **TPOS Pacific Upwelling and Mixing Physics (PUMP)** process study. Prototype scripts to assess **ENSO event evolution and forecast skill**, using a data-mining model-analog technique ([Ding et al. 2018](#); [Ding et al. 2020](#)), were tested in 2022 for eventual incorporation into the ENSO Metrics Package.

NPOCE. The NPOCE activities during the past year included several scientific achievements as well as significant community activities and service:

Scientific Achievements. Two cruises were successfully conducted in the western Pacific Ocean by the IOCAS from Nov. 2021 to Jan. 2022 and from Feb. to Apr. 2022. During these two cruises, 6 moorings were retrieved and 9 moorings were deployed with 161 CTD stations and water samples being conducted. These recent observations extended the NPOCE western Pacific observational network of CAS to 12 years, and provided a valuable database for a better understanding of the western Pacific Ocean circulation and its climatic effects. A multi-platform observation in the Philippine Sea (13°N, 137°E) maintained by JAMSTEC has collected meteorological and oceanographical data for more than 5 years.

Community Activity and Service. In Jan. 2022, the new term of NPOCE Scientific Steering Committee (SSC) membership was announced at the annual SSC meeting, which includes 14 members from 6 countries. Dr. Fan Wang serves as the chair of the SSC, and Dr. Janet Sprintall and Dr. Fei Chai serve as the vice chairs. To strengthen scientific communications and promote cooperation among NPOCE SSC members and early-career scientists during the pandemic of COVID, NPOCE initiated a series of [NPOCE webinars](#) in 2022. Five webinars including 16 talks on the five themes of NPOCE scientific foci were successfully held, which attracted over 500 attendees from all over the world. In addition, as detailed above, the 4th NPOCE Open Science Symposium on “Western Pacific Ocean Circulation and Climate” was organized and held in hybrid format during 24-27 Oct. 2022. The NPOCE is actively involved in other international projects such as the 2nd Cooperative Study of the Kuroshio and Adjacent regions (CSK-2) program, the GOOS Ocean Observations Physics and Climate panel (OOPC) Boundary Currents and Shelf Sea

Interactions Task Team (BS-TT), the CLIVAR Tropical Pacific Decadal Variability Working Group, and others, under the joint efforts of all NPOCE SSC members.

TPOS2020 Updates. The final TPOS2020 Steering Committee meeting was held virtually on May 17, 2022. It served as the conclusion for the TPOS2020 Project, and as a handover for the new TPOS governance. The CLIVAR PRP co-chairs were invited and joined the meeting. The meeting focused on discussions concerning the top issues that will require the attention of the new TPOS, looking both in hindsight and forward to the future scientific and technical horizons. Regarding the new TPOS governance, as recommended in the third TPOS2020 report, the new TPOS governance consists of two primary groups: the Scientific Advisory Committee (SAC), led by Drs. Fei Chai and Billy Kessler, and the new Implementation Coordination Group (ICG), led by Drs. Iwao Ueki and Karen Grissom. These groups are still being populated. Please refer to Annex A in this report for more detailed information about the priorities of TPOS, the terms of references of the two governing groups (SAC & ICG), as well as the implementation status of TPOS, and etc. The new website is available and contains many information on the observations, and on-going projects (<https://tropicalpacific.org/>). Dr. S. Cravatte and Dr. I. Montes are the liaison scientist within PRP to TPOS.

Ocean Isotopes. The PRP continues to support the development and maintenance of long-term water isotope records. PRP member Stevenson has maintained involvement with the former members of the US CLIVAR working group on [Observations and Modeling of Water Isotopes in the Climate System](#), which has culminated in the writing of two review papers on the use of water isotopes in paleoclimate and modern contexts for evaluating modes of climate variability and the magnitude of climate sensitivity, as well as applications of water isotopes in process-based evaluation of climate models. The first of these review papers will be submitted to *Environmental Research Letters - Climate* in December 2022, with the second shortly to follow. Stevenson is also maintaining dialogue with the National Center for Atmospheric Research in Boulder, CO, regarding the development and use of water isotope-enabled climate models, facilitated by her position as the Community Earth System Model Paleoclimate Working Group Co-Chair.

A new Research Focus Group proposal. A. Capotondi, as a representative of the PRP, has prepared a proposal for a new Research Focus (RF) Group on Marine Heatwaves (MHWs), in collaboration with R. Rodrigues (ARP) and with input from Roxy M. Koll and J. Hermes (IORP). Thus, this proposal can be viewed as a joint effort among three of the regional CLIVAR panels. The proposal was prepared in response to the CLIVAR call for new Research Foci, and was motivated by the compelling need to improve our understanding of the drivers and predictability of MHWs and their impact on ocean biogeochemistry and ecology. This new RF, if approved, will support the CLIVAR's mission "to understand regional climate phenomena" and "to identify factors and mechanisms that determine the location, intensity, and frequency of extreme events". Given the devastating ecological and societal impacts of MHWs, especially in coastal areas, the goals of this RF will also strongly project on the activities of the WCRP "My Climate Risk" Lighthouse Activity.

3. Scientific Capacity Building and Career Support

- During 2022, 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 3rd Summer School on “[Theory, Mechanisms, and Hierarchical Modeling of Climate Dynamics: Tropical Oceans, ENSO, and their Teleconnections](#)”, which was held at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste, Italy and online, during July 18-29, 2022, recruited over 100 students from countries on all six continents, including about 35 students on site and up to 70 participants online on any given day. The school was an important training opportunity for students all over the world after the hiatus due to the pandemic. It also provided the students on site with the opportunity to interact with experts in the field and build community.
- The ENSO conceptual model and the Tropical Pacific Decadal Variability working groups include several early career scientists and provide them with opportunities to participate in discussions and activities that can support their scientific and professional development.
- The ICTP-CLIVAR Summer School on “Marine Heatwaves: Global Phenomena with Regional Impacts”, planned to take place at the International Center for Theoretical Physics (ICTP) in Trieste, Italy in July 2023 (see below) will emphasize the involvement of Early Career Researchers (ECRs). Indeed, Dr. Shikha Singh (co-chair of the Summer School Scientific Organizing Committee) is the ECR representative on the CLIVAR Indian Ocean Regional Panel and has developed SDA² (Skill Development, Awareness and Application), a process designed to help better engage ECRs in broader CLIVAR activities. The SDA² framework will be implemented as part of the Summer School to help ECRs better understand the subject of MHWs and collaborate on a project leading to a publication. Prior to the Summer School, participants will be organized in groups, and will be given assignments to be completed as a pre-school exercise. The results will be reviewed during the school and may lead to the development of a practical product such as the tools to detect and define the characteristics of MHWs in their particular region. Further, each group will be provided a problem to work on during the school and advised by a mentor from the group of lecturers/organizing committee, giving a presentation on the status of their effort at the end of the summer school. It is envisaged that the group will stay active after the Summer School and work on the problem to write-up their results and analysis. In addition, the mandate of ICTP is to support and include participants from developing countries, so we envision the participation of several students from the Global South.
- NPOCE has invited several ECRs as speakers in their webinar series during the past year, and is planning to increase the number of ECRs invited to speak in the upcoming year.

4. Knowledge exchange

The joint PICES/CLIVAR working group has allowed very valuable interactions between the two communities. The new working group on ocean extremes can be expected to provide continuing interactions and collaborations.

Plans for 2023 and beyond

ENSO Conceptual Model working group. The main objective for 2023 will be to submit a review paper to *Reviews in Geophysics*. The previous extensive review chapter on ENSO theory, in the “El Niño Southern Oscillation in a Changing Climate” book did focus on presenting the existing recharge oscillator models. On the other hand, it did not extensively summarize how studies using the RO contribute to our current knowledge of ENSO, and how they complement, for example, observational studies or studies with more elaborate models. That will be the first objective of our review paper. Also, the previous chapter only had a short section on the “way forward”. That will be the main goal of our WG review paper, where we want to summarize how 1) the RO can address “hot” ENSO topics such as interactions with other basins, ENSO response to climate change, ENSO representation in models or decadal ENSO modulation; 2) how the Recharge Oscillator should be generalized in order to account for ENSO diversity.

An outline and section lead authors have been agreed on. The target is to have a first draft and figures proposals ready by December. This material will then be revised by the WG during a videoconference in January (with various lead authors reviewing other lead authors sections). We plan to use the face-to-face meeting in February in Australia as an opportunity to make further progress on the paper (2 1h30 sessions dedicated to paper reviews by WG members and 4 1h30 breakout writing sessions). The plan is to submit the paper in 2023, and to organize an ENSO dedicated conference session to present its outcomes in late 2023 or early 2024.

TPDV working group. The working group first goal in 2023 will be to complete a review paper to be submitted to *Nature Reviews Earth & Environment (NREE)*. This review paper will provide a critical summary of our current state of knowledge on this topic, based on the review and discussions conducted during the TPDV meetings in the past year. Despite the existence of a large body of literature on TPDV, there is no consensus on which of the processes that have been proposed are the most relevant sources of decadal variability. In addition, the nature of the atmospheric forcing of those processes, whether stochastic or part of a decadal feedback loop, is still under debate.

After describing the main components of the ocean circulation and the observed characteristics of decadal variability, the paper will review evidence for the leading oceanic mechanisms proposed for TPDV, followed by an examination of the most likely sources of wind forcing involved in TPDV. Possible sources include: 1) atmospheric response to sea surface temperature anomalies in the tropical Pacific; 2) Influences from the Pacific extratropical regions; and 3) Tropical basin interactions.

A paper synopsis has already been approved by the Editor of *NREE*, and the Lead Authors for each section have been selected. We anticipate having a draft ready in December, and use the hybrid meeting in Melbourne in February to discuss open questions and finalize the various sections. It is anticipated that new research projects, involving collaborations among TPDV working group members, will be spurred by the review conducted to date and summarized in the *NREE* paper by the working group. The WG goal of achieving an improved understanding of decadal variability in the tropical Pacific, an area that has been shown to affect the global climate, can be expected to significantly contribute to the activities of the “Explaining and Predicting Earth System Change” Lighthouse Activity.

Collaboration with PICES. During the recent PICES Physical Oceanography and Climate Committee (POC) meeting, which was held in Busan, Republic of Korea and online on 25 and 28 September 2022, mutual interest was expressed for continued and strengthened interactions and cooperation between CLIVAR and PICES, building on the legacy of existing efforts. One possibility for this continuing collaboration is offered by the newly established PICES [WG-49 on Climate Extremes and Coastal Impacts in the Pacific](#). A. Capotondi will be part of WG-49 as a representative of CLIVAR, and in particular of the Pacific Panel. In addition, the upcoming ICTP-CLIVAR Summer School on “Marine Heatwaves: Global Phenomena with Regional Impacts” (July 2023, Trieste, Italy, described below) is also a potential opportunity to cooperate under this broader theme of climate extremes.

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. Work will further proceed to incorporate the ENSO metrics package into community tools like the [PCMDI Metrics Package \(PMP\)](#), [Earth System Model Evaluation Tool \(ESMValTool\)](#), and [CliMAF](#), to support model development and analysis internationally. We may also leverage [ES-Doc](#) (which aims to systematically document models, e.g., their [Comparator](#)) to enable grouping models by resolution, lineage, and parameterization schemes. The metrics will be applied to a broader set of CMIP5 and CMIP6 simulations to investigate: (a) impacts of climate change on ENSO (Planton et al., submitted); (b) the robustness of ENSO to the choice of observational datasets (Planton et al., in prep.); (c) model-analog diagnostics of ENSO event evolution and predictability (Ding, Wittenberg, et al., in prep.); (d) roles of upwelling and mixing processes (Wittenberg et al., funded NOAA CVP/TPOS project); and (e) identify emergent constraints toward reducing projection uncertainties and clarifying future ENSO risks (Jin et al., project proposed to NOAA MAPP). As it matures, the ENSO Metrics project could benefit from any available CLIVAR resources — especially in the form of postdoctoral support — to accelerate community uptake via research and development, documentation, tutorial-building, training, and website curation.

NPOCE. NPOCE will continue the effort to address its collective research needs on field experiments and data sharing in the Western Pacific Ocean (WPO) and its ambient oceans/seas. With the help of the Research Organization for Earth Sciences and Maritime-National Research and Innovation Agency (RO EAM-BRIN), the IOCAS-BRIN Indonesian sea joint cruise will be conducted during Nov.–Dec. 2022. In addition, two field programs, the Equatorial Line Observations (ELO) and the Measuring and Modeling the Indonesian Throughflow International Experiment (MINTIE) funded by NSF in the Indonesian Seas are expected to proceed in early 2023. Given the good feedback of the 2022 webinar series, NPOCE will continue the webinars in 2023 and invite more young scientists to share their research and ideas.

TPOS. The PRP will maintain a close interaction with TPOS in its implementation plan through members S. Cravatte and I. Montes, and provide input as needed.

CLIVAR/ICTP School. An ICTP-CLIVAR Summer School on “Marine Heatwaves: Global Phenomena with Regional Impacts” is being planned to take place at the International Center for Theoretical Physics (ICTP) in Trieste, Italy in July 2023. A. Capotondi is part of the organizing committee, and will represent the PRP in this initiative. The school emphasizes the involvement

of Early Career Scientists and capacity building, in the spirit of the principles advocated by the [UN Decade of Ocean Science for Sustainable Development](#) (2021-2030) and in line with the goals of the “WCRP Academy” Lighthouse Activity..

Articles published in 2021/22 as part of panel activities

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Budget and other needs for 2023

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. (Already approved).

Annex A: TPOS Updates

1) The final TPOS2020 Steering Committee meeting was held virtually on May 17, 2022.

It served as the conclusion for the TPOS2020 Project, and as a handover for the new TPOS governance. The CLIVAR PRP co-chairs were invited and joined the meeting. The meeting focused on discussions concerning the top issues that will require the attention of the new TPOS, looking both in hindsight and forward to the future scientific and technical horizons. These priorities include:

- a) Traceability and inter-operability, that will be critical. Assessing the changes during transition is key, and securing the funding for dedicated intercomparison studies (between different buoys, and between buoy/Uncrewed Surface Vehicles (USVs)) is of high priority. Developing tools to assess impacts of the changes in mapped products and prediction systems also appear as key.
- b) Taking care of data flow and data quality, and incorporation the FAIR data principles. The future TPOS should put a high priority in data streams, data QA and QC, liaising with expert groups working on data quality and best practices. The most demanding application will be to detect the climate change signal, especially in winds and air-sea fluxes.
- c) Keeping track of the whole of the observing system: advocate and monitor all of its components, including Argo doubling, which is a key piece of the plan, interacting with Argo national groups for coordination among various nations, and including ship sampling, which is key for biogeochemistry (BGC).
- d) Ensuring a scientific and technologic watch to evolve the TPOS, taking into account progress in emerging technology and assessing readiness of pilots.
- e) Greater entrainment of ecological observations. For that, ensure further consultation with international panels (GOOS Biology and Ecosystem Panel, Pacific Fisheries Commission)
- f) The need to work toward greater engagement of more partners/stakeholders. For that, more support from high-level intergovernmental organizations is needed as well as help from the CLIVAR Pacific Region Panel regarding coordination efforts for the eastern and western Pacific, and with the island states. More workshops should also be conducted in South America and the Pacific Islands to increase participation and stakeholder engagement in those regions.

2) New TPOS governance:

As recommended in the third TPOS2020 report, the new TPOS governance consists of two primary groups: the Scientific Advisory Committee (SAC), led by Drs. Fei Chai and Billy Kessler, and the new Implementation Coordination Group (ICG), led by Drs. Iwao Ueki and Karen Grissom. These groups are still being populated. The Terms of Reference for the SAC and ICG components of TPOS are listed here below for reference.

The TPOS SAC Terms of references:

1. *Oversee the design and assessment of the TPOS backbone and ensure better integration across the value chain;*
2. *Report on the state of TPOS relative to its aims by maintaining responsiveness to sponsor and stakeholder needs and be responsible for developing measures that demonstrate impacts of TPOS activities in response to the Stakeholders Forum;*
3. *Ensure a smooth transitioning of the functions of the TPOS 2020 Steering Committee into the SAC and the ICG;*

4. *Initiate and oversee activities of task teams*, including the development of appropriate work plans and their sunseting;*
5. *Provide advice and consultation to stakeholders and agencies so they can effectively direct their investments to guide future improvements of the system;*
6. *Work closely with the Implementation Coordination Group;*
7. *Develop and foster ties to regional partners who could leverage TPOS efforts to better meet regional needs;*
8. *Establish and maintain relationships to intergovernmental structures including the WMO and IOC; reports to GOOS Steering Committee*

The TPOS ICG Terms of references:

1. *Focus on implementation of the TPOS by addressing observational recommendations from TPOS 2020 and advancing integration of new capabilities (e.g. technologies, regional efforts) and activities (e.g. pilot studies);*
2. *Work closely with the Scientific Advisory Committee (SAC) on the implementation of the observing system;*
3. *Monitor and advocate for adequate maintenance and reporting for the entire observing system;*
4. *Develop a) common core mooring configuration, b) implementation procedures (e.g., intercomparison studies), and c) data management principles and dissemination. The array should remain a seamless backbone;*
5. *Assist with inter-agency collaboration to facilitate the smooth operation of the observing system (e.g., EEZ clearances, ancillary observations) for the network operators/contributors as appropriate*
6. *Liaise with the SAC in developing the expectations for the relationship with intergovernmental bodies (e.g., IOC-GOOS, WMO).*

3) Implementation to date:

Moorings: NOAA has accepted TPOS2020 recommendations for TAO almost entirely. Beyond refocused sampling, TAO is being rebuilt: improvements to all systems are beginning this year. In addition, the Chinese Ministry of Natural Resources (MNR)'s Ding array has begun initial mooring deployments. Unfortunately, no moorings west of 165°E are currently transmitting data. Argo: MNR deployed 28 new Argo floats in the west in 2021, along with 8 new BGC floats. More floats are coming from MNR. NOAA is also increasing its Argo work, including both core and BGC floats. Other countries (Australia, France) also contributed some floats.

NOAA and JAMSTEC funded **pilot studies** with useful results. Process studies are under way: Pre-field modeling is happening now, and fieldwork is expected in 2025.

Joint International assimilation/evaluation experiments are being developed (ECMWF-NOAA-JMA) in addition to several funded data assimilation studies in operational centers (NCEP, JMA, CSIRO, Mercator-Ocean, etc.)

Nations in western South America are also stepping up towards better cooperation in regional initiatives. In particular, the SEPICAF project (led by Boris Dewitte <https://www.ocean-ops.org/reportcard2021/>) aims at improving the current observing system in the Southeast Pacific via the deployment of a total of 17 ARGO-type floats off the coasts of Peru and Chile, which were

released in 2021. The first 3 floats were released off the central-northern region of Chile thanks to the collaboration with the TARA Oceans Foundation Scientific Expedition which, aboard a sailboat equipped with oceanographic equipment and populated by a scientific crew, had been analyzing the marine microbiome to contribute to the understanding of the impact of climate change on the oceans and to contribute to the development of capacities to adapt and mitigate its effects. The second launch was carried out during a cruise financed by the CEAZA's CLAP project (Research program for Climate Action Planning) off the central Chilean region in collaboration with IMO (Millennium Institute of Oceanography, University of Concepcion) and the Universidad Católica del Norte in Coquimbo. In Peru, SEPICAF was developed in the context of the IGP (Institute Geofísico del Perú) - IRD (Institut de Recherche pour le Développement) collaboration framework agreement, and has been implemented under the IGP-TASA (Tecnología de Alimentos S.A.) collaboration framework agreement, allowing the launch of 9 ARGO floats distributed off the coast (north, center and south) of Peru. The launches were made during the spring of 2021 by the crew of the fishing vessels TASA 314 and TASA 419, each with 04 and 05 floats, respectively, without scientific personnel on board. Due to the restrictions imposed by the sanitary emergency, the crew in charge of the fishing boats was prepared only by receiving virtual training and graphic instructions included in each box that contained the float. All the launches were successful and the methodology used for the launches was highlighted by Argo France (https://twitter.com/argo_france/status/1453382594045911045). The data collected from the floats off Peru are being used for local monitoring of El Niño (<http://met.igp.gob.pe/variabclim/argo2.html>).