

## 45th Session of the WCRP Joint Scientific Committee (JSC)

27-30 May 2024

### **DEADLINE: 1 May**

#### **Instructions**

**Overarching content/goal:** *To provide an update on progress made during the last year, as well as your future plans, and highlight any aspects that you want to bring to the attention of the JSC.*

- *The length of the report should be kept to around 4 pages if possible (appendices and links can of course be used).*
- *Include the topics indicated below.*
- *Work with the WCRP secretariat responsible for your activity, in the preparation of the report and/or presentation.*
- *Discuss any points you would like to raise with the JSC with your JSC liaison(s), keeping the WCRP Secretariat focal point informed.*

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### **Report to the WCRP Joint Scientific Committee**

#### **CLIVAR: Climate and Ocean - Variability, Predictability and Change**

**1. Highlights for Joint Scientific Committee** (including high-level publications, new achievements/products, and capacity building activities – **in particular anything you feel should go into a WCRP annual achievement report or brochure**)

- CLIVAR has produced several publications in 2023 and 2024 associated with activities in 2023, and four reports (see publication list). Six high-level publications are mentioned below with one currently in press in *Nature* (Watanabe et al.).
- As a major outcome of the CLIVAR Pacific Region Panel (PRP), the Tropical Pacific Decadal Variability (TPDV) working group published a review paper in *Nature Reviews Earth & Environment* (**Capotondi et al. 2023**), that evaluates our understanding of the governing processes behind TPDV which has important ramifications on climate and environment across the globe. This review paper is a product of rigorous discussions at several virtual meetings over the span of two years since the working group's establishment in May 2021. A Science Highlight was published on CLIVAR website.
- The PRP has just initiated a new WG on Atmospheric Teleconnections in a Warming Climate (ATAC) to synthesize the present understanding of how the large-scale atmospheric circulation, linked with changes in the tropical Pacific, drives changes in weather patterns and affects other regions globally, and how they might change in a warming future. The WG, involving other panels (Tropical Basin Interaction Research Foci (TBI RF), Climate Dynamics Panel (CDP)) will explore the interaction across spatial-time scales, i.e., ranging from changes in large-scale interannual variability to regional synoptic patterns and local impacts with a focus on effects over land through extreme events such as heatwaves, floods, and droughts. The working group is about to commence their work.
- CLIVAR Climate Dynamics Panel and Pacific Region Panel established the **"TROPICS" working group** in 2023 to bring communities together to resolve the important issue of model-observation

discrepancy in the tropical Pacific sea surface temperature trend pattern. The core leadership consists of representatives from CDP, PRP, and WCRP CFMIP, with 19 working group members. A subgroup gathered in person at the 2023 CFMIP meeting and led the breakout session on TROPICS WG activities. The TROPICS WG submitted a perspective paper to *Nature* on the recent tropical Pacific warming pattern (**Watanabe et al. 2024**).

- CLIVAR/IOC-GOOS Indian Ocean Region Panel (IORP) spearheaded effort in understanding the challenges in sustaining the Indian Ocean observing system (IndOOS) due to the global pandemic, leading to an article published in *BAMS* (**Sprintall et al. 2024**). The article documents how huge losses in the implementation of the observing arrays have left a permanent gap in the observation record that is critical to future climate predictions; and provides insights on the way forward. To address how these gaps impact forecasting and data-assimilation systems, the IORP has initiated a new Task Team to understand the impact of COVID-induced degraded observing systems over the Indian Ocean.
- **CLIVAR Research Focus (RF) on Marine Heatwave in the Global Ocean** was launched at the start of 2023. The RF is a cross-panel activity whose goal is to achieve a better understanding of marine heatwaves globally, including detection, surface and subsurface characteristics, mechanisms, and connection with climate change and biogeochemical extremes.
  - The RF is currently preparing a review paper for one of *Nature* journals as part of a special collection on marine heatwaves.
  - At the February 2024 AGU Ocean Sciences meeting in New Orleans, the MHW RF led a session on “Marine heatwaves in a changing world”, with 5 oral sessions and a large poster session.
  - One major activity in 2023 involving the Marine Heatwave RF and other CLIVAR panels (Indian Ocean, Pacific, and Atlantic Region Panels) was the organization of a Summer School on “*Marine Heatwaves: Global Phenomena with Regional Impacts*” held at ICTP in Trieste, Italy, July 24-29, 2023<sup>footnote2</sup>.
  - An important part of the summer school was the implementation of an innovative approach known as SDA2 (Skill Development, Awareness & Application) that provided a framework to help the early career researchers (ECRs) build long lasting and fruitful collaborations both among themselves and with their mentors. A Summer School report has been published in *BAMS* (**Singh et al. 2024**).
  - The Marine Heatwave RF and some members of the Atlantic Region Panel issued a [statement on ocean warming](#) which was published simultaneously by WCRP and WMO in September 2023. The statement outlined the potential reasons for the severe warming of the global ocean in 2023, particularly in the North Atlantic, and provided more accurate information amid speculations in the media.
- The CLIVAR Research Focus on Tropical Basin Interaction (TBI) that is due to conclude in 2024 has been granted an extension to the end of 2025, to complete important activities of its four working groups (WG) that were delayed during the pandemic and for them to collectively write a synthesis review paper:
  - WG1 on *Coordinated GCM experiments (CoEx)* is actively working on experiments based on 5 models (CESM2, NorCPM, SINTEX-F2, MIROC6, ACCESS-CM2) that are planned to be completed and analyzed in 2024, with output to be published on ESGF. A paper on the experiment design is in preparation for GMD journal. A townhall event was held at the Ocean Sciences 2024 in New Orleans to inform the community of the status of the experiments.
  - WG2 on *Conceptual and Intermediate Complexity Models and statistical approaches* is making their experiments (idealized GCM) and codes (linear inverse model, interbasin recharge oscillator) available to the community.
  - WG3 on *Observations* is writing a review article on pantropical observing system, and plans to engage OOPC on this topic.
  - WG4 on *Paleo proxies* will collaborate with WG3 on their review article to include a section on seawater  $\delta^{18}\text{O}$  observations in coordination with former members of US CLIVAR Water Isotope Working Group.

- The Southern Ocean Freshwater release model experiments Initiative (SOFIA)<sup>footnote1</sup> – a task team of the CLIVAR/CLIC/SCAR Southern Ocean Region Panel (SORP) that was launched in October 2021, has been recently registered as a Community MIP under CMIP (“SOFIAMIP”) as of November 15, 2023. To date, SOFIA has 11 different participating models, with Tier 1 model experiments completed which aim at understanding model uncertainty in freshwater release of 0.1 Sv from Antarctica under pre-industrial climate. Tier 2 experiments will then cover the historical period and future scenarios. A protocol paper was published last year in *Geoscientific Model Development* (**Swart et al. 2023**), and a first science paper in *Geophysical Research Letters* (**Chen et al. 2023**). Monthly SOFIA meetings are growing to become a notable exchange platform for ocean and climate modelers on issues surrounding ice-ocean interaction, in particular ocean-driven melt of the Antarctic Ice Sheet.
- Special Collection “Ocean Science in the South Atlantic” was published in *Communications Earth & Environment* in January 2023 and highlighted a Review Paper on the “South Atlantic Meridional Overturning Circulation (SAMOC)” and a Comment on “Inclusive Science in the South Atlantic”, both pieces are co-authored by many former and current members of the CLIVAR Atlantic Region Panel.
- CLIVAR holds seminar series by panels. The Southern Ocean Region Panel (SORP)’s quarterly seminar series “PROS4SORP” aims to build a more coherent community and raise awareness of SORP activities. The first seminar was held in October 2023 (70 participants), with Sharon Stammerjohn presenting on Antarctic sea ice changes. The Monsoons Panel holds WCRP/WWRP Webinar Series (“Global Monsoon” on 13 September 2023 with 175 attendees; “Asian-Australian Monsoon” on 30 November 2023 with 120 attendees). More seminar series are planned by other panels (e.g., ENSO webinars by PRP).
- Several activities at the *WCRP Open Science Conference in 2023*, including the SSG’s 28<sup>th</sup> session, CLIVAR/GEWEX Monsoons Panel’s 5<sup>th</sup> session, with many panel members were actively involved at the conference; e.g., members of the Monsoons Panel and its working groups led several sessions with 9 presentations and 18 posters<sup>footnote3</sup>. MP Co-chairs are the Co-Lead authors of the Concept Paper on Regional and Global Monsoons for the OSC Kigali Declaration with WG members as co-authors. There were also Poster Clusters (“Marine heatwaves in the world oceans”, “Changes in sea surface temperature patterns in the Tropics”).
- CLIVAR has been active in capacity building efforts, through organizing training schools, e.g.,:
  - *Summer School on “Marine Heatwaves: Global Phenomena with Regional Impacts* (Trieste, 24-29 July 2023);
  - *The 4th Summer School on Theory, Mechanisms and Hierarchical Modeling of Climate Dynamics: Atlantic Variability and Tropical Basin Interactions at Interannual to Multi-decadal Timescales* (Trieste, Italy, 31 July – 11 August, 2023),
  - *CLIVAR-FIO Summer School on Biogeochemical processes in Earth System Models* (Qingdao, China, 15-20 July 2024),
  - *ICTP-SORP-NORP Summer School and Workshop on Polar Climates: Theoretical, Observational and Modelling Advances* (Trieste, 22-31 July 2024).
- CLIVAR has organized workshops that involve cross-activity/panel interactions:
  - *CLIVAR workshop on the tropical Pacific and its interbasin interactions* (Melbourne, Australia, 14-17 Feb 2023),
  - *Workshop on Meeting AMOC Observation Needs in a Changing Climate* (Hamburg, Germany, 18-20 July 2023),
  - *Workshop on Atlantic Variability and Tropical Basin Interactions at Interannual to Multi-decadal Timescales: Mechanisms, Drivers, and Impacts* (Trieste, Italy, 9-11 August 2023),
  - *The 2024 CFMIP Meeting and CLIVAR Climate Dynamics Panel 3rd Annual Workshop* (Boston, USA, 3-6 June 2024) on Clouds, Precipitation, Circulation, and Climate Sensitivity, with additional theme on tropical warming pattern formation mechanisms,
  - *Workshop on “Interaction among the tropical basins: observations and simulation”* (Seoul, Korea, 22-23 June 2024),

- *OMDP-COMMODORE Workshop 2024* (Boulder, USA, 9-13 September 2024).
- CLIVAR supported and participated in two satellite events at the 2024 Ocean Decade Conference in Barcelona: 1) Co-designing ocean observing system for better societal services – Pan tropics and basin use areas; 2) Ocean-based solutions to mitigate climate change impacts with Africa as a demonstration.
- The [Atlantic Blog](#) was launched in April 2023 with the first post by Dr Eleanor Frajka-Williams on “The great ocean conveyor - what has it been doing lately?” followed by another post by Dr Ingo Richter on “Atlantic Niños aren’t what they used to be”. The blog requires more contribution from the community.

## **2. Planned science initiatives and major events (over next 1- 5 years)**

- *Science initiative 1: High-resolution modeling.* One issue raised at the last JSC session was a gap in CLIVAR’s activities on coastal modelling and coastal science given the increasing emphasis within WCRP on climate information for society. In response to this, CLIVAR is now venturing into activities associated with high-resolution modelling. For example, the OMDP is pursuing downscaling climate projections with regional models; they had Angelique Melet (Mercator Ocean) joining their panel meeting on 24 April 2024 to initiate activities on this topic. The Climate Dynamics Panel is organizing a workshop in early 2025 to catalyse effort towards high-resolution modelling activities.
- *Science initiative 2: Biogeochemistry.* Another issue raised was links of CLIVAR activities to biogeochemistry including the carbon cycle. CLIVAR has a few members with some biogeochemistry expertise in the Indian Ocean, Southern Ocean, Northern Oceans, Atlantic, and Pacific Region Panels, that can be leveraged to expand into this topic. This year, the Southern Ocean Region Panel specifically entrained members with biogeochemistry expertise. The PRP, at their panel meeting on 22 April 2024, discussed avenues in exploring ocean biogeochemical dynamics in the tropical Pacific in relation to air-sea interactions, ocean dynamics, and climate variability, with consideration of forming a working group. Some of PRP members will deliver lectures at the [CLIVAR-FIO Summer School](#) on Biogeochemical Processes in Earth System Models.
- *Science initiative 3: Understanding the impact of COVID-induced degraded observing systems over the Indian Ocean.* The new IORP task team will undertake observing system simulation experiments to assess the impact of observational gaps in IOD and ENSO prediction.
- *Science initiative 4:* NORP plans to meet with representatives of Arctic data centers, comparing Arctic Ocean reanalysis products with respect to specific science questions and engage with northern (local) communities.
- *Science initiative 5:* NORP and OMDP aim to explore potential collaboration on Arctic water mass analysis and processes in OMIP runs, and engage with respect to CMIP7.
- *Science initiative 6: Metrics for assessing synthesis products.* GSOP identified a weakness in the synthesis community, which is the wide adoption of basic metric for evaluation of systems. The panel plans to establish a task team, comprising of panel members from CLIVAR GSOP, OOPC, OceanPredict, and SynObs.
- *Science initiative 7:* The follow-on OMIP for CMIP ocean diagnostics specification project successfully led by OMDP for CMIP6 is planned to be repeated for CMIP7. Several subgroup activities toward this goal are ongoing (outlining paper defining updates data request for CMIP7; preparing a new dataset for driving ice-ocean models; planning a revised protocol for OMIP experiments).
- *Science initiative 8:* Development of intermediate complexity model of TBI (“TBI Cane-Zebiak model”) as well as theoretical studies on the dependence of TBI on the mean state are planned to be conducted by the TBI RF.

- *Major event 1:* CLIVAR will organize a **Pan-CLIVAR Meeting** in late 2025<sup>footnote4</sup>. The meeting will bring together members of all CLIVAR panels, research foci, and the scientific steering group to: 1) foster cross-panel interactions through facilitating internal coordination among activities across different CLIVAR panels and research foci; 2) evaluate progress, formulate future priorities, and enhance members cohesion within each panel and research focus group; 3) develop ideas and input for new CLIVAR science and implementation plans for the next 5 to 10 years.
- *Major event 2:* The Pacific Region Panel is planning “**The Wyrтки Symposium and ENSO Winter School**” in early 2025 to be held at the University of Hawaii at Manoa<sup>footnote5</sup>. The three-day symposium is to honor the scientific legacy of Klaus Wyrтки, to showcase the transformative advances that have taken place in the past 50 years in observing, understanding, and predicting ENSO, and to highlight research challenges in the context of a changing climate and the urgency of addressing them. The symposium is to be followed by a 1-week winter school to inspire, educate, and empower the next generation of ENSO researchers.
- *Major event 3:* The Climate Dynamics Panel is organizing their 4<sup>th</sup> annual workshop in Australia early 2025 with the theme “Weather & Climate Interactions – observations, theory, and modelling”, to catalyse effort towards high-resolution modelling activities.
- *Major event 4:* Northern Oceans Region Panel (NORP), Southern Ocean Region Panel (SORP) and Ocean Model Development Panel (OMDP) plan to host a joint workshop in early 2025 on the topic of ocean heat fluxes in polar regions. Seasonal freshwater variability and its relation to heat as well as connections to lower latitudes will also be a focus. The workshop will produce a review paper, to be submitted in late 2025.

### **3. Planned Products, high-level assessments or other key outputs/publications**

- The Pacific Region Panel (PRP) Working Group (WG) on ENSO Metrics has produced a software package to evaluate, compare, and explore ENSO performance, teleconnections, and processes in climate simulations and diverse observations<sup>footnote6</sup>. New metrics continue to be added and developed through several institutional projects funded by NOAA.
- The PRP WG on ENSO Conceptual Models is working on a review paper for *Reviews in Geophysics* and the reproduction of the Python reference version of the ENSO Recharge Oscillator which will be made available.
- The MHW RF was invited by one of the Nature Editors to prepare a review/perspective paper as introduction to a special collection on MHWs organized by some of the Nature journals.
- The OMDP, in collaboration with NCAR, is working on a new dataset that will replace the JRA55-do datasets that are used as the canonical forcing for the OMIP2 protocol which have been discontinued.
- TBI RF WG2 will make output of idealized GCM experiments (idealized continental outlines and basin configuration) available once the first paper has been published. Code for interbasin recharge oscillator and a Linear Inverse Model (LIM) to study interbasin interaction will soon be made available to the community, potentially on CLIVAR website.
- The TBI RF plans to write an integrated review of the outcome of all research activities of their four WGs, as well as publishing a paper on the experimental design of the TBI Coordinated Experiments (CoEx). They will also archive the CoEx Tier 1 simulations model output, jointly analyze the model output, and write a synthesis paper on the CoEx.
- A review article on pantropical observing systems is in preparation led by TBI RF WG3.
- The Southern Ocean Region Panel has compiled 8 articles for the *CLIVAR Exchanges* on research highlighting emerging Southern Ocean and Antarctic programs, in particular to feature programs developed in the Global South. The manuscripts are currently being edited by the chief editor.
- Members of MP and the WGs will be involved as Guest Editors/Contributors for a special issue of *Advances in Atmospheric Sciences* on global monsoons, including Asian monsoon, American monsoon, African monsoon, and Australian monsoon.

- The WG-AAM will aim to complete an article on the unusual characteristics of the past two years' Asian-Australian monsoons.
- ENSO Special Collection has been proposed to the *Journal of Climate* to focus on the unusual ENSO behavior observed in the past decade. This is a joint initiative from the CLIVAR Pacific Region Panel, Research Foci on Marine Heatwaves in the Global Ocean and Tropical Basin Interaction, and CLIVAR Scientific Steering Group.

#### **4. Linkages with other Core Projects, Lighthouse Activities, Academy etc.**

- The work of CLIVAR panels has significant connection with WCRP LHAs and CPs. Three CLIVAR's panels are co-sponsored by other WCRP CPs: CliC co-sponsors NORP and SORP; GEWEX co-sponsors the Monsoons Panel. These partnerships have enhanced the capacity of the panels to organize activities on a larger scale that have allowed a wider participation (e.g., from developing countries). Cross-CP/LHA interactions are also facilitated through membership of CPs in CLIVAR panels (e.g., SPARC's chair Amanda Maycock is a new member of the ARP); and vice versa (ARP's co-chair Regina Rodriguez is chair of My Climate Risk LHA).
- The ARP's Ocean Risk Working Group with LHA My Climate Risk, as well as IORP and PRP, is creating [regional Hubs on Ocean Climate Risk](#) – last year successfully implemented 2 hubs: Indian Institute of Meteorology and South African Environmental Observation Network to foster connection to regional observation and marine prediction activities. Currently, the WG is liaising with the Pacific Region Panel to implement a hub at an institution bordering the Pacific Ocean.
- CLIVAR's training schools, such as the MHW Summer School, are to be catalogued in the WCRP Academy.
- The Monsoons Panel has active interactions with other CPs and LHAs: SPARC and CliC (developing partnerships between global north and south), as well as My Climate Risk and Safe Landing Climates LHAs through their WG-AFM members. MP and WGs will provide ideas/activities for GPEX LHA which will be useful for the monsoon community.
- There is a potential synergy with CORDEX and GEWEX in relation to OMDP's plan on downscaling climate projections on regional ocean models. In addition, CLIVAR's planned work on biogeochemistry will potentially form linkage with GEWEX, associated with coastal processes (e.g., impacts of riverine freshwater inputs at the coasts, connecting particular basin panel activities to the regional hydrology).
- There are plans to establish more solid interactions with LHAs: ARP's AMOC Task Team is to reach out to EPESC WG2 members; regional panels, GSOP, and OMDP to connect with EPESC WG1; CDP has established synergies with CFMIP and APARC through panel membership and event organization, and along with TBI RF, is to further interact with SLCs. CDP's plan to promote high-resolution modelling as well as PRP's new task team ATAC should develop synergy with GEWEX on topics such as atmospheric rivers and modes of variability which influence precipitation.
- GSOP will look to engage with other WCRP core projects such as APARC (on reanalysis intercomparison project), and ESMO.
- IORP is to engage with My Climate Risk and RfS to expand Indian Ocean science to include policy and society.

#### **5. Partnerships with entities outside of WCRP**

- The IORP is co-sponsored by the IOC-GOOS, and has continued engagement with the scientific community and observational programmes, e.g., OOPC, GOOS, SIBER, SOLAS, IOCINDIO, TRIUMPH, EKAMSAT, RAMA, Ocean Decade activities, including at the IIOSC-2024. The IORP has ongoing

interaction with SIBER on development of Coastal Observations Lab in a Box (COLaB) – a low cost technological development for under-resourced countries, and has been encouraged to form closer links to promote the panel’s involvement in ocean biogeochemistry activities

- Besides CliC, the SORP is co-sponsored by SCAR (Scientific Committee on Antarctic Research). SCAR was a co-sponsor of NORP-SORP workshop on polar fresh water: Sources, Pathways and Impacts of fresh water in northern and southern Polar oceans and seas (SPICE UP). SORP interacts with Antarctic InSync an endorsed UN Ocean Decade Action which is proposing synchronous observations of the Southern Ocean and Antarctica.
- Partnership with OOPC continues to develop, e.g., joint meeting with OOPC (GCOS Joint Panel Meeting) in Bonn, Germany (23-30 June 2023) to discuss the opportunity for a more coordinated implementation strategy using the tropics as an example given the observing systems are reasonably well developed. There was a recommendation to include OOPC representatives on the TBI WG3 on Observations to coordinate the Pacific (TPOS), Atlantic (TAOS), and Indian (IndOOS) Ocean observing systems in terms of tropical basin interactions, possibly expanding the remit to include biogeochemistry and carbon cycle themes. This coordination may also involve NPOCE and TPOS via the PRP.
- The PRP, and in synergy with MHW RF, is to continue interactions with PICES through Antonietta Capotondi (MHW RF co-chair, PRP ex-officio) who is involved in PICES WG-49 on ‘Ocean extremes and coastal impacts’ and is organising a session on marine extremes (physical and biogeochemical) at the next PICES annual meeting in Honolulu, October 2024. The MHW RF will interact more with UN Ocean Decade GOOS Program MHW Exemplar.
- Linkage with UN Decade project [SynObs](#): The Monsoons Panel will get involved in the SynObs Project for the evaluation of Ocean Observing System as a cross-panel activity. IORP’s new Task Team will be coordinated with SynObs.
- There is a potential partnership with the Ocean University of China, the host of the International CLIVAR Project Office, in terms of organizing events, such as summer schools and conferences.
- A closer [partnership with CLIVAR-endorsed programme OSF](#) (Ocean to Climate Seamless Forecasting System) is also possible.

## **6. Suggestions, issues or challenges:**

- *Issues/challenges 1:* The International CLIVAR Project Office underwent a transition in early 2023, moving from the previous host First Institute of Oceanography to the current host Ocean University of China, along with departure of its director and two staff members. A senior staff scientist remained until July 2023 as a deputy manager. The ICPO was left completely unstaffed until 5<sup>th</sup> of December 2023 when a new director arrived. The ICPO is still currently understaffed, requiring further recruitment of two staff scientists and an administrative assistant. Although interviews for the staff scientists have recently been completed, it may take several weeks before staff will assume their posts due to complex paperwork. Until then, the project office has focused largely on basic operations and services such as supporting the SSG, finalizing budget and memberships, handling travel requests, supporting certain activities that require substantial assistance and planning (e.g., CLIVAR-FIO summer school, TBI Workshop, Pan-CLIVAR Meeting, and setting up meetings for certain panels and RF).
- *Issues/challenges 2:* The CLIVAR Global Synthesis and Observations Panel (GSOP) has not been active since 2023, with little engagement between the co-chairs and members. The SSG met with the GSOP co-chairs on February 2024, offering feedback and advice. The panel finally met for the first time recently on 2<sup>nd</sup> of May 2024, and is currently in the process of sorting out their membership. Eight panel members have their terms already expired in December 2023, and one co-chair (Nathalie Zilberman) intends to rotate off.

*Footnotes:*

<sup>1</sup>The motivation of SOFIA is that the vast majority of global climate models do not represent ice sheet and ice shelves, and thus require an application of freshwater forcing to emulate the effect of ice-sheet melting in a warming climate. However, the solutions vary across models, and SOFIA aims to reconcile these by conducting freshwater release experiments using various models. The group has been having discussions more broadly about freshwater forcing in CMIP.

<sup>2</sup>The MHW summer school was jointly organized by CLIVAR and the International Centre for Theoretical Physics (ICTP) with additional support from the World Climate Research Programme (WCRP), US-CLIVAR, and US agencies NASA, NOAA and NSF. The summer school had the primary goal to educate and share current understanding of the mechanisms, predictability and impacts of MHWs, as well as to provide hands-on experience and tools to enhance the capacity of early career researchers (ECRs) from under-resourced countries for detecting and predicting marine heatwaves. The Summer School had 42 students and ECRs from 13 countries who attended in person, with another 27 participating on-line. 50% of the participants were from developing countries. The 12 lecturers invited to the Summer School were RF members, and reflected the gender, career stage and geographical diversity of the RF membership.

<sup>3</sup>(Theme 2: Human Interactions with Climate", "S24: Attribution of changes"; "S03: Global and Regional Monsoons"; "S28: Regional Information – Data and Methods"), and delivered talks and keynotes ("Cascading multi-model sub-seasonal predictions from global to regional and local scales", "Major issues and challenges for the American monsoons", "Major issues and challenges for the African monsoons", "The objective seasonal forecasting approach over Eastern Africa: Benefits, challenges and future prospects", "A zonal contrast in future changes in Sahel precipitation).

<sup>4</sup>The meeting will serve as a forum to develop new ideas towards the new S&I plan, which include biogeochemical processes, high-resolution ocean modelling and downscaling, coastal modelling and predictions, as to link CLIVAR science more closely to societal/regional community needs and enhance interactions with ESMO, Rifs, Digital Earths, and My Climate Risk. As many of our panels have synergies with other WCRP core projects and external partners, including CLIVAR-endorsed projects (e.g., OSF), we intend to invite partner representatives to attend the Pan-CLIVAR meeting; e.g., GEWEX, CliC, SCAR, IOC-GOOS, as co-sponsors of the CLIVAR Monsoons, Northern Oceans Region, Southern Oceans Region, and Indian Oceans Region Panels, respectively. We also intend to invite ex-officio/emeritus members of panels/RF who have a longer-term perspective of panels/RF's progress, and thus would be able to provide valuable input for the plan forward. The venue is to be located in the Global South, to encourage attendees from developing countries.

<sup>5</sup>The year 2025 marks the 50th anniversary of two milestone events that involved Klaus Wyrtki, a pioneering oceanographer at the University of Hawaii who made groundbreaking contributions to our understanding of El Niño/Southern Oscillation (ENSO): 1) the publication of his seminal Journal of Physical Oceanography 1975 paper which identified the importance of the collapse of trade winds thousands of kilometers to the west of the eastern equatorial Pacific on the onset of El Niño; 2) the launch of the El Niño Watch Expedition to verify the first ever El Niño forecast.

<sup>6</sup>Open-source Python code and documentation are made publicly available via a GitHub code repository and wiki, together with an interactive metrics browser for the CMIP5 and CMIP6 models. The ENSO metrics package has been fully incorporated into the PCMDI Metrics Package (PMP), and documented as a component of the PMP (Lee et al., in prep for Geoscientific Model Development). This has enhanced access to the Earth System Grid Federation (ESGF) database, enabling rapid analysis and exploration of the CMIP5, CMIP6, and other community datasets like those from the US CLIVAR Large Ensemble Working Group.



## Publications:

### Atlantic Region Panel

- Chidichimo, M.P., Perez, R.C., Speich, S., Kersalé, M., Sprintall, J., Dong, S., Lamont, T., Sato, O.T., Chereskin, T.K., Hummels, R. and Schmid, C., 2023. Energetic overturning flows, dynamic interocean exchanges, and ocean warming observed in the South Atlantic. *Communications Earth & Environment*, 4(1). <https://doi.org/10.1038/s43247-022-00644-x>
- Perez, R., Garzoli, S., Hummels, R. and Ansorge, I., 2023. Inclusive science in the South Atlantic. *Communications Earth & Environment*, 4(1). <https://doi.org/10.1038/s43247-022-00646-9>

### Pacific Region Panel

- CLIVAR 2023, 'The 15<sup>th</sup> Session of CLIVAR Pacific Region Panel', CLIVAR Report No. 04/2023.
- Capotondi, A., McGregor, S., McPhaden, M.J. et al. Mechanisms of tropical Pacific decadal variability. *Nat Rev Earth Environ* 4, 754–769 (2023). <https://doi.org/10.1038/s43017-023-00486-x>

### Climate Dynamics Panel

- Watanabe, M., S M. Kang, M. Collins, Y.-T. Hwang, S. McGregor, and M. F. Stuecker, 2024: Possible Shift in Controls of the Tropical Pacific Surface Warming Pattern. *Nature*, in press.

### Southern Ocean Region Panel

- Chen, J.-J., N. C. Swart, R. Beadling, X. Cheng, T. Hattermann, A. Jüling, Q. Li, J. Marshall, T. Martin, M. Muilwijk, A. G. Pauling, A. Purich, I. J. Smith, and M. Thomas, (2023), Reduced Deep Convection and Bottom Water Formation Due to Antarctic Meltwater in a Multi-Model Ensemble, *Geophysical Research Letters*, <https://doi.org/10.1029/2023GL106492>.
- Swart, N. C., T.orge Martin, R.ebecca Beadling, J.ia-J.ia Chen, C.hristopher Danek, M.atthew H. England, R.iccardo Farneti, S.tephen M. Griffies, T.ore Hattermann, J.udith Hauck, F. A.alexander Haumann, A.ndré Jüling, Q.ian Li, J.ohn Marshall, M.orven Muilwijk, A.ndrew G. Pauling, A.riaan Purich, I.nga J. Smith, and M.ax Thomas, 2023: The Southern Ocean Freshwater Input from Antarctica (SOFIA) Initiative: scientific objectives and experimental design. *Geosci. Model Dev.*, 16, 7289-7309, <https://doi.org/10.5194/gmd-16-7289-2023>

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