Request to US CLIVAR For Workshop Sponsorship

1. **Requesting Panel, Working Group, or person/s:**

Dr. Janet Sprintall
co-chair, Summer School Scientific Organizing Committee
member, CLIVAR/IOC-GOOS Indian Ocean Regional Panel
Scripps Institution of Oceanography, CA

Dr. Antonietta Capotondi
member, Summer School Scientific Organizing Committee
co-chair, CLIVAR Pacific Region Panel
member, US CLIVAR Process Study and Model Improvement Panel
NOAA Physical Sciences Laboratory, CO

2. **Title of workshop or meeting:**

CLIVAR/ICTP Summer School on Marine Heatwaves: Global Phenomena with Regional Impacts

3. **Venue:**

International Center for Theoretical Physics (ICTP), Trieste, Italy

ICTP has already agreed to host the school. This venue has adequate space for anticipated attendance, including plenary, breakout, and poster sessions as well as infrastructure for supporting remote attendance.

4. **Dates:**

Six (6) days (Monday-Saturday) potentially in July 2023

5. **Scientific Organizing Committee (include affiliations):**

Shikha Singh, (co-chair), Indian Institute of Tropical Meteorology *(member, CLIVAR Indian Ocean Regional Panel)*
Janet Sprintall, (co-chair), Scripps Institution of Oceanography, CA, USA *(member, CLIVAR Indian Ocean Regional Panel)*
Antonietta Capotondi, NOAA Physical Sciences Laboratory, CO, USA *(member, US CLIVAR PSMI; co-chair, CLIVAR Pacific Ocean Regional Panel)*
Juliet Hermes, South African Environmental Observation Network, South Africa *(co-chair, CLIVAR Indian Ocean Regional Panel)*

Roxy Mathew Koll, Indian Institute of Tropical Meteorology, India
(co-chair, CLIVAR Indian Ocean Regional Panel)
Cristian Martinez Villalobos, Universidad Adolfo Ibáñez, Chile *(member, CLIVAR Pacific Regional Panel)*
Regina R. Rodrigues, Universidade Federal de Santa Catarina, Brazil *(co-chair, CLIVAR Atlantic Ocean Regional Panel)*

6. Proposed attendees, include estimate number (indicate if open or by invitation):

We anticipate approximately that 35-40 Early Career Researchers (ECRs) such as students and postdocs will attend in person, as well as potentially 35-40 remote participants, and approximately 10-15 lecturers.

ECR attendees will use an open application while selected Lecturers will be sent specific invitations (see below).

7. Aims and objectives:

Marine Heatwaves (MHWs) are extreme climatic events that impact all ocean basins and can persist from weeks to months and spread over hundreds to thousands of kilometers. MHWs have devastating impacts on marine habitats and ecosystems and influence regional weather systems such as the monsoons and extreme weather events like tropical cyclones. Large subsurface warming with more frequent and longer MHWs have been observed in the past two decades, a trend that is expected to continue in a warming climate (IPCC SROCC 2019). Paleo data from corals suggest that higher amplitude events than captured by instrumental data likely occurred in the past. Yet only recently have we begun to understand some of the climate drivers impacting the intensity and persistence of these extreme events.

MHWs lead to major economic losses through declines in fish catch, they are killers of seabirds and marine mammals, and they force relocation of species because of inhospitable conditions. Reported economic costs of individual MHW events exceed US$800 million in direct losses related to fisheries and habitat closures and >US$3.1 billion in indirect losses of ecosystem services over multiple subsequent years (Smith et al. 2021). Clearly given their significant ecosystem and economic impact there has been a heightened interest by governments and society concerning the climate community's ability to detect and, most importantly, to forecast MHWs in a timely fashion.

The global annual number of MHW days has risen by 54% over the past century, with 8 of the 10 most extreme MHWs ever recorded occurring since 2010. Climate change is clearly responsible for increasing the frequency of these events but open questions remain about the internal variability that drives these extreme events above the slowly evolving background warming. Thus, despite the widespread occurrence of MHWs across the global oceans, the large-scale and local processes driving MHWs, as well as the full extent of their impacts in different regions are just emerging. In-situ and in-depth observations of MHWs are also challenging but gradually evolving to improve our understanding.

This summer school will introduce the participants to the criteria used to identify and monitor MHWs. It will discuss our state-of-knowledge on the mechanisms responsible for MHW development in different parts of the global ocean, and whether such mechanisms can lead to some degree of predictability. The skill of current prediction activities will also be discussed. The lectures will be structured in a way that will allow hands-on experience and provide tools for a wide spectrum of participants, from early career to established researchers, particularly in under-resourced countries and large ocean states, wanting to better track MHWs and understand their impacts.

The Summer School was selected for support by the CLIVAR SSG in September 2022 and subsequently approved by the venue host ICTP as the biannual CLIVAR-ICTP summer school for 2023. Note that the US CLIVAR supported ENSO Summer School was held in 2022 only because of the delay from the original proposed dates in 2020 due to COVID.

8. Relevance and/or benefits to US CLIVAR:

The relevance and benefit to US CLIVAR is clear: ensuring that the next generation of climate scientists are well-informed and have the tools and knowledge at their disposal to implement observational infrastructure and modeling systems in their home countries to better understand regional MHWs and their impacts. This aim is particularly pursuant to the US CLIVAR mission *"to serve the climate community and society through the coordination and facilitation of research*" and the science goal "*fostering collaboration with research and operational communities that develop and use climate information*." The topic of this school strongly projects onto the US CLIVAR "Climate and extreme events" Grand Challenge by directly addressing marine extremes. Given that some of the most intense, long-lasting, and devastating marine heatwaves occur in coastal

environments, the activities of this school will also address some aspects of the "Climate at the Coast" Grand Challenge.

Clearly the summer school would have cross-panel interests for US CLIVAR teams. In particular, we note that the US CLIVAR Predictability, Predictions, and Applications Interface (PPAI) Panel has hosted a number of webinars that were focused on MHWs along the US coast and also had a dedicated session at the 2022 PPAI panel meeting on understanding and predicting climate extremes.

Finally, the summer school aligns with a number of global initiatives such as the Global Ocean Observing System (GOOS) co-design 'exemplar' project "*Monitoring marine heatwave impacts on biodiversity and economies*" and also generated pan-CLIVAR interest with cross-panel representation on the organizing committee (see Section 5). Once dates and other logistical efforts are finalized, the Summer School will be proposed for endorsement as a UN Ocean Decade Activity.

9. Format of meeting:

The summer school will be organized over a 6-day period as primarily an in-person event. Should Covid-related safety considerations limit some participants to travel to Trieste, plans will be made to enable their participation virtually. The ICTP facility is well set-up to host virtual meetings including equipment and IT support. The school will include not only lectures on the current state of knowledge on the topic of MHWs, but also practical sessions with the development of student projects to provide a hands-on approach to the understanding of the material presented in the lectures. In particular, analysis tools for the detection and diagnosis of these extreme events in observations and climate model output will be made available to the students prior to the school, so that they can be readily applied to small research projects during their time in Trieste. Presenters will make pre-recorded lectures available so that ECR participants in different time zones can watch them at their own pace. We also plan to have short presentations given by the students to share their research and give them an opportunity to be able to organize and share their science findings with all other participants.

We will work closely with the WCRP Academy Lighthouse Activity (https://www.wcrp-climate.org/academy), which forms the research training advisory and coordination arm of the WCRP. Their mission is to *"equip future climate scientists with the knowledge, skills and attributes required to tackle the world's most pressing and challenging climate research questions*" with a specific

goal to connect the people who need climate science training with people and institutions that can provide that training. Engagement with the WCRP Academy will ensure that the course is well archived and permanently available so as to improve global access of all ECRs from the climate research community to the workshop materials. Dr. Antonietta Capotondi, a member of the Summer School Scientific Organizing Committee, also served on the WCRP Academy Science Plan Development Team.

The school will cover the following topics concerning MHWs, that will be divided into four primary themes – detection, mechanisms, impacts, and future projections. For detection, we will cover definitions of MHW and their identification using readily-available online data sources and global forecast models. For mechanisms, lectures will discuss the current state-of-understanding of formation of MHWs in different parts of the world and identify where there are gaps in our understanding. For impacts, lectures will cover how MHWs influence ecosystems and climate, and additionally discuss what observing systems could be put in place - especially in developing countries - to fill the gaps in global marine observational networks and improve advanced warning by prediction and potential mitigation options. Finally for future projections, we will use global climate models to cover how MHWs will change in a warming world, as a result of both the climate change trend and internal variability.

It is expected that each theme would be allotted one day, to include invited lectures, hands-on training and student presentations, with the remaining 2 days dedicated to a synthesis of each theme, including an overall recap of the theme and student project presentations that stem from their hands-on sessions at the school.

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. Tentative list of invited speakers/participants:

The summer school will bring together experts from many disciplines: atmospheric scientists and oceanographers, observationalists (in situ and satellite), data assimilation experts, and modelers. Lecturers will be selected keeping in mind gender, career stage and geographical diversity. Ensuring effective communication among attendees will be tantamount to the summer school success. The scientific organizing committee will proactively facilitate this communication by 1) tailoring lecturer invitations to address the areas of

research we would like discussed aligned with the four summer school themes; 2) holding a virtual meeting with all lecturers well in advance of the workshop to discuss presentation topics, shape a coherent narrative, and emphasize the need to avoid the use of jargon; 3) intervene as needed during oral presentations to ask for clarification on the use of technical definitions that may not be familiar to all participants; and 4) tailoring discussion questions to engage all students in the discourse.

Potential invited lecturers that align with the primary research themes of MHWs include:

1) Technical aspects*: Definitions and methodologies used to estimate extremes.*
Michael Jacox (M; NOAA Fisheries, USA)
Eric Oliver (M; Dalhousie University, Canada)
Hillary Scannell (F; Jupiter Intelligence, USA; ECR)
Robert W. Schlegel (M; Sorbonne Universite, France; ECR)

2) Drivers of marine heatwaves*: Atmospheric and oceanic mechanisms.*
Dillon Amaya (M; NOAA Physical Sciences Laboratory, USA; ECR)
Antonietta Capotondi (F; NOAA Physical Sciences Laboratory, USA)
Neil Holbrook (M; University of Tasmania, Australia)
Regina R. Rodrigues (F; Federal University of Santa Catarina, Brazil)
Amandine Schaeffer (F; University of New South Wales, Australia)

3) Impacts of marine heatwaves*: Cyclones, ecosystems, societal costs.*
Nicolas Gruber (M; ETH Zurich, Switzerland);
Roxy Mathew Koll (M; Indian Institute of Tropical Meteorology, India)
Kathy Mills (F; Gulf of Maine Research Institute, USA)
Kathryn E. Smith (F; The Marine Biological Association, UK; ECR)

4) Future projections, attribution and forecast: *trends vs internal dynamics.*
Clara Deser (F; NCAR, USA)
Charlotte Laufkotter (F; Bern University, Switzerland; ECR)
Tongtong Xu (F; University of Colorado, USA; ECR)

We will similarly aim for gender and global geographic diversity when selecting students and ECR participants for the summer school. We will widely advertise using the global CLIVAR network to reach out to potential student participants. As noted above, we expect to invite ~35-40 ECRs to participate in-person at the school.

11. Deliverables:

A number of deliverables are expected as part of the summer school.

1. A summary report of the summer school will be prepared and key highlights from the school will be summarized in a short report for publication, for example, in BAMS.
2. A special edition of "CLIVAR Exchanges" is also planned, providing a summer school summary and in particular showcasing selected research presented by the ECR participants.

In addition to these short-term deliverables, the previous experience of the organizers of summer schools has consistently shown the profound impact that summer schools can have on the ECR participants, by exposing them to cutting-edge research, instilling in them the curiosity and passion for science, and thus fostering the development of a new global generation of talented climate researchers. The connection that often emerges between the ECR participants with their future colleagues and exposure to a strong professional network enables them to forge professional relationships that will help facilitate their future research and academic careers.

12. Approaches to address diversity, equity, and inclusion:

The organizers of the summer school have a strong commitment to principles of equity, diversity and inclusion. The summer school will be executed ensuring diversity in gender, region, expertise, and career for participants and lecturers/trainers. Our international Science Organizing Committee will promote and encourage participation from across the globe, and special focus will be given to ECRs of low-to-middle income nations where capacity building is essential. Our goal is to improve global access to high-quality climate science training and professional development.

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 SDA^2 (Skill Development, Awareness and Application), a process designed to help better engage ECRs in broader CLIVAR activities. We will implement the SDA^2 framework 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. This article will either be submitted to CLIVAR Exchanges or, if at a more advanced stage, to a peer-reviewed journal. This will be an extended endeavor beyond the period of the Summer School itself to help build long term collaborations.

13. Budget request from US CLIVAR:

Funding is requested to support travel (airfare, ground transportation, per diem, accommodation) of 15 USA participants including two (2) members of the Scientific Organizing Committee, 6 invited speakers, and 7 early career participants.

Travel for 15	$39,274
Travel Staff Time	1,873
Indirect Costs	659
Total	$41,806

14. Other sources of funding:

ICTP: The venue host ICTP is committed to providing lecture rooms, IT, and administrative support. ICTP funds will also be made available to support participants from developing countries (lodging, travel expenses, meals) who will be granted free accommodation and meal coupons. The ICTP application will include a request for a sufficient number of rooms in the economical ICTP guesthouse (~US$70/night) to cover the majority, if not all, of the other participants.

CLIVAR: Funds for this Summer School will also be requested by the CLIVAR Panel co-chairs from the ICPO. The request will be submitted as part of the Indian Ocean Regional Panel annual request (November 2022) and we have been informed by the ICPO they would provide ~US$10K. These funds would be used to support travel expenses of the organizing committee, invited lecturers, and early career participants.

References:

Smith, K. E., M. T. Burrows, A. J. Hobday, A. Sen Gupta, P. J. Moore, M. Thomsen, T. Wernberg, and D. A. Smale (2021). Socioeconomic impacts of marine heatwaves: Global issues and opportunities, *Science*, 374: 6566, 10.1126/science.abj3593.