Marine Heatwaves (MHWs) in the Global Oceans

A New CLIVAR Research Focus Group

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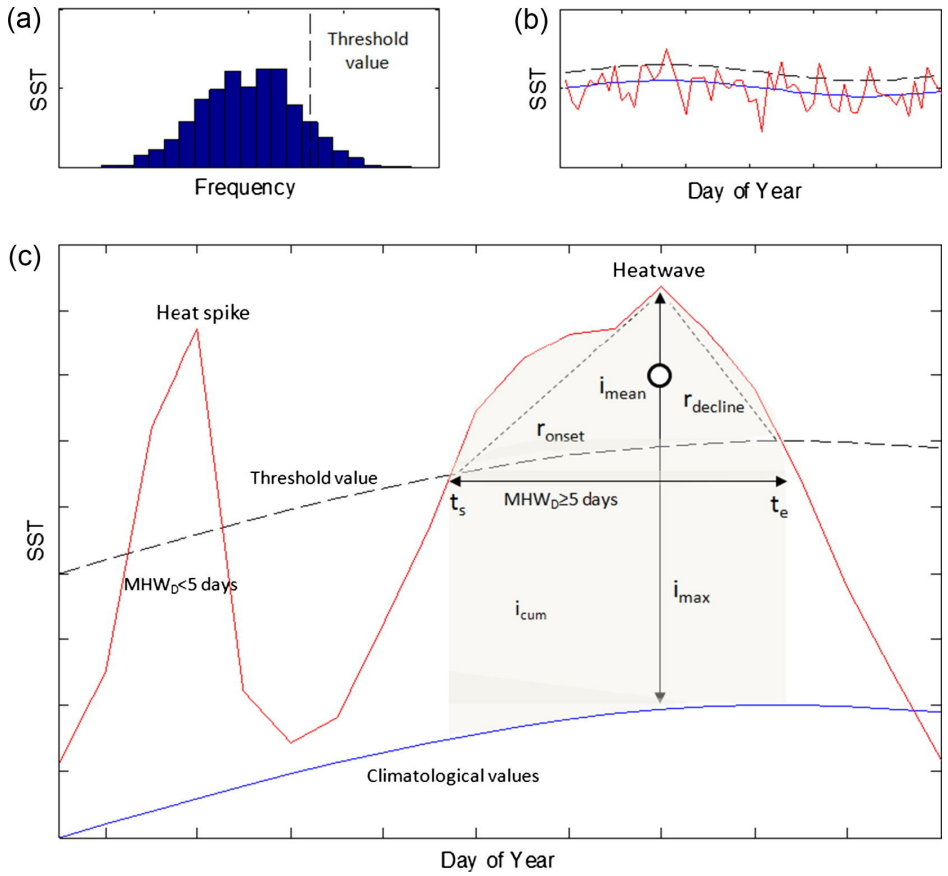
- Motivation for this RF by reviewing the status of MHW research, and scientific challenges
- Present the objectives and membership of this RF

What are MHWs?

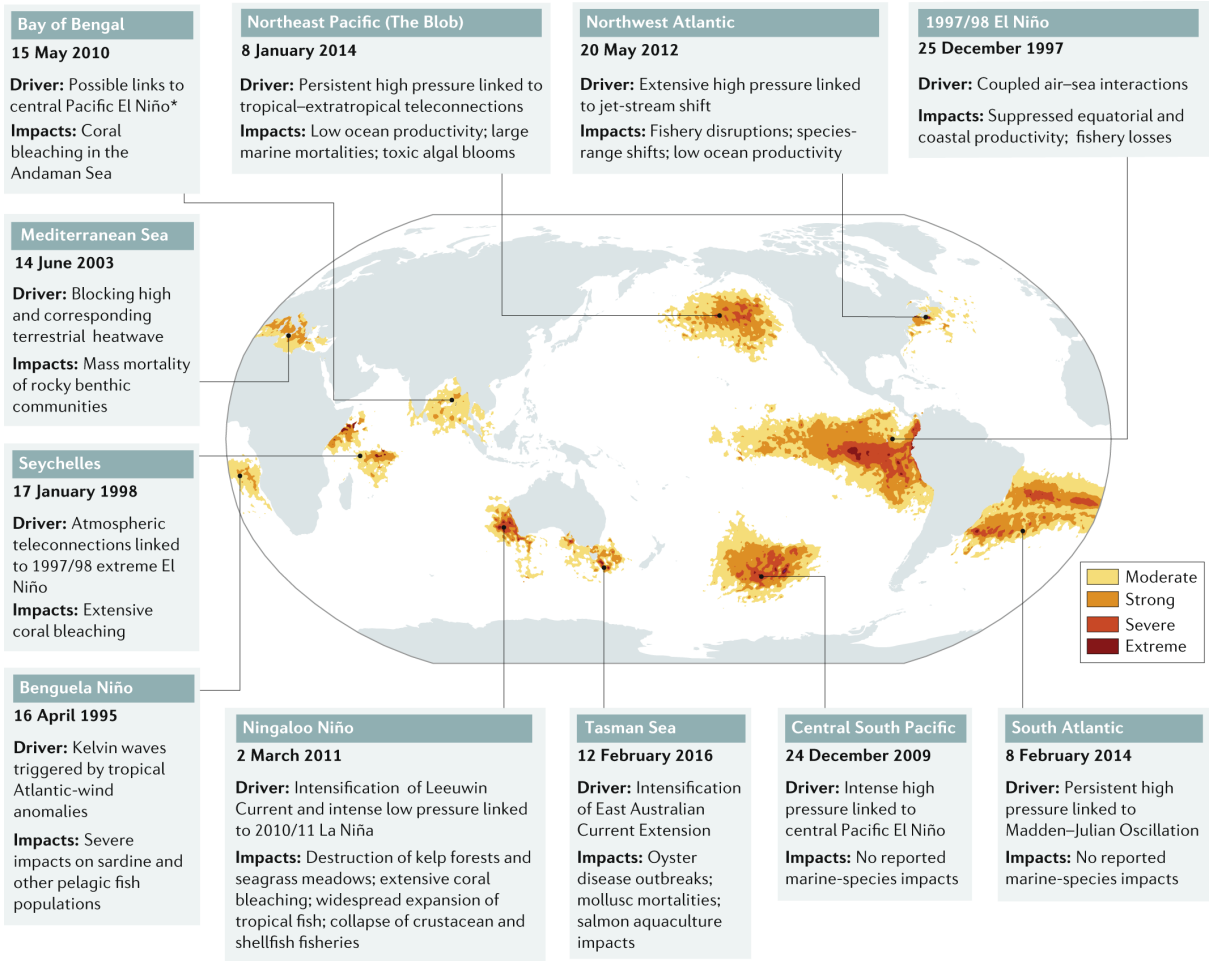


MHWs are extreme and persistent ocean warm events

A more precise definition was proposed by Hobday et al. 2016: A MHW is a warm event above the 90th percentile, lasting for at least 5 days.

Hobday et al. Progr. Oceanogr. (2016)

Where did MHWs occur?



MHWs have occurred in many parts of the world over recent decades with devastating ecological and economical impacts.

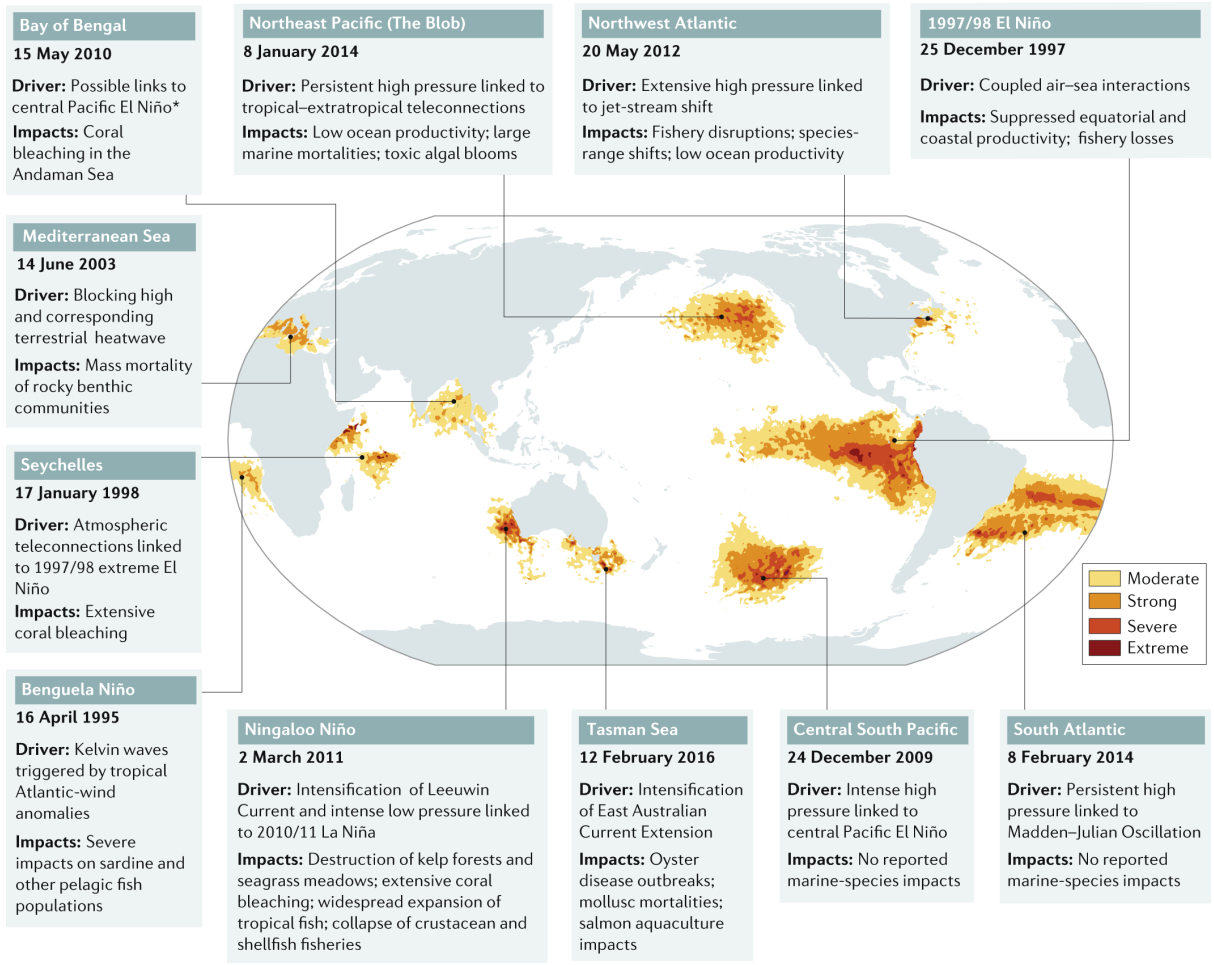
Holbrook et al. NREE (2020)

Problems with definition

- The duration threshold is arbitrary, and may be too short in the marine environment.
- The requirement of daily SST data is often impractical. Limited observational datasets or model output at this resolution.
- The use of a fixed (present-day) climatology confounds separation of internal processes and climate change impacts, especially regarding projections.

As a result, different groups around the world have used alternative definitions and approaches to study MHWs -> Need to create a common framework among different groups

Mechanisms (important for predictability)



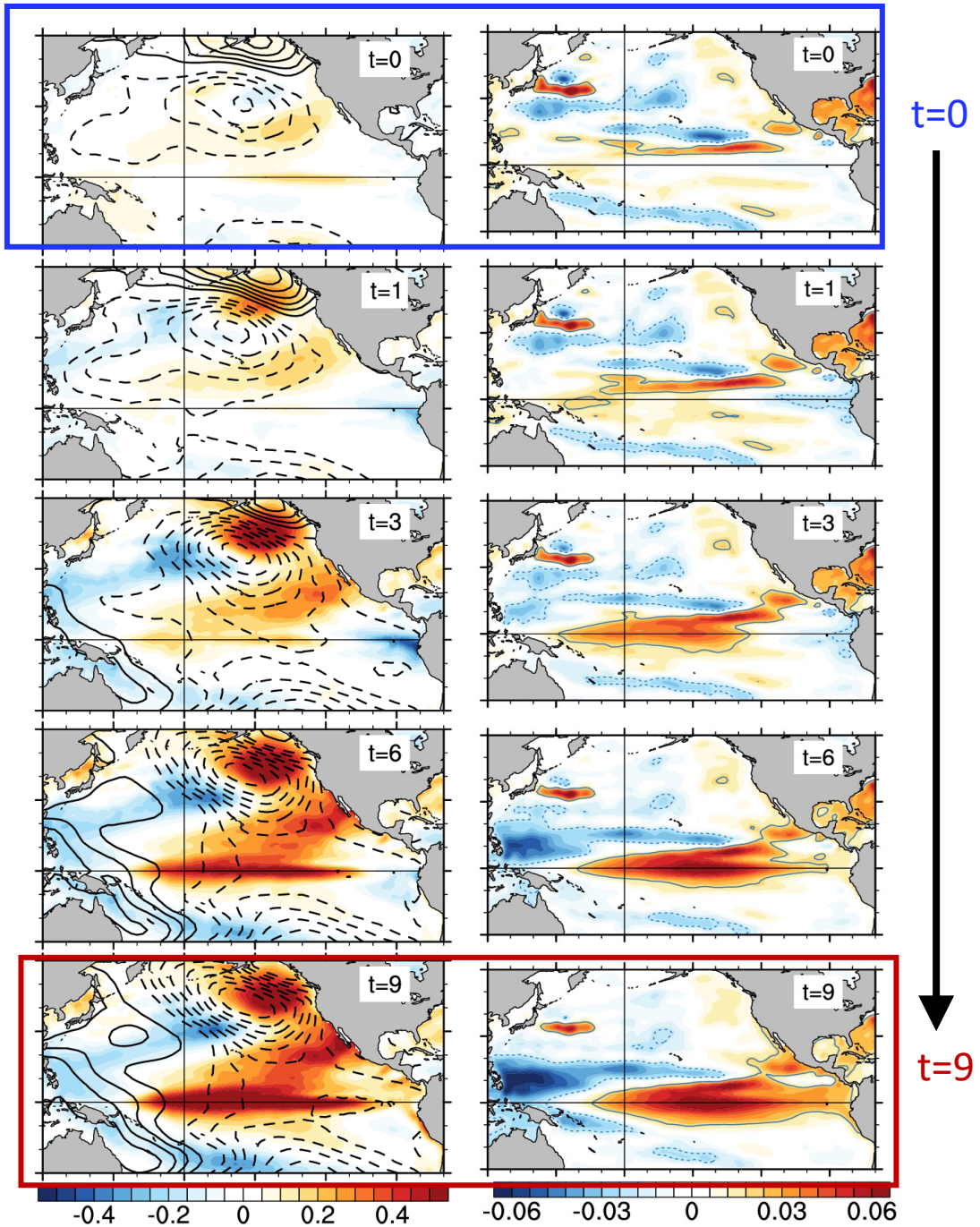
Holbrook et al. NREE (2020)

Different drivers have been identified for MHWs in different regions, e.g.:

- Western Australia: Intensification of the Leeuwin current due to the the 2010/11 La Nina
  Which La Nina events are most impactful?
- Northeast Pacific: Persistent high-pressure linked to tropical-extratropical interactions
  Which specific interactions are most important?
- Tasman Sea: Intensification of East Australian Current Extension
  What caused the EAC intensification?

We need to better isolate the local processes from the large-scale drivers to clarify and exploit sources of predictability.

"Optimal precursor of the "Blob"



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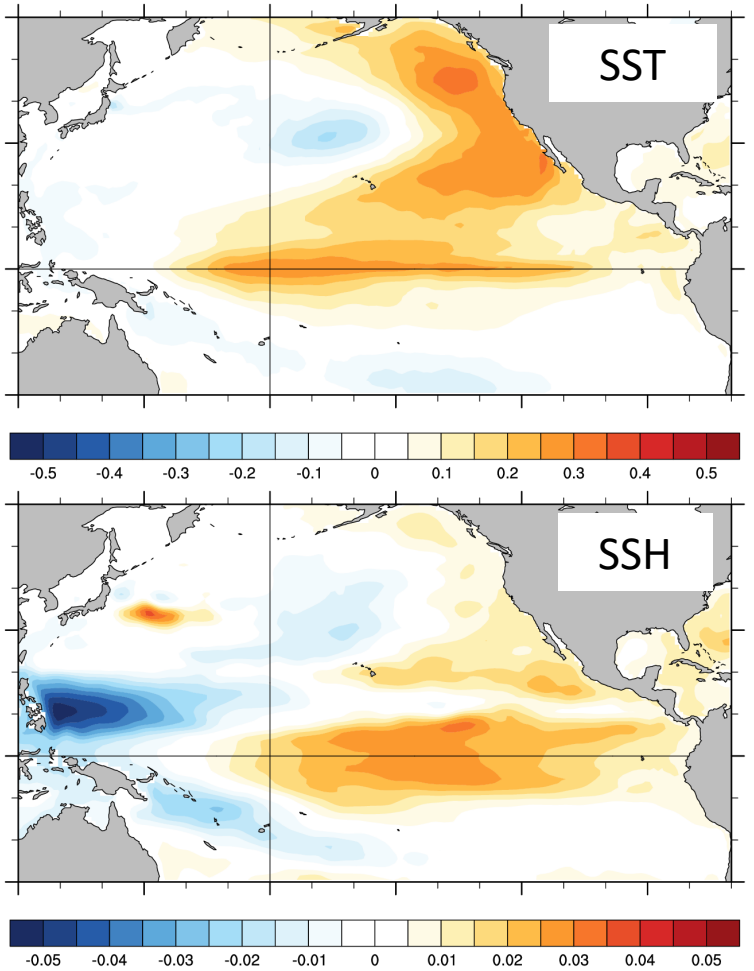
Example:
Northeast Pacific MHW 2013-2016

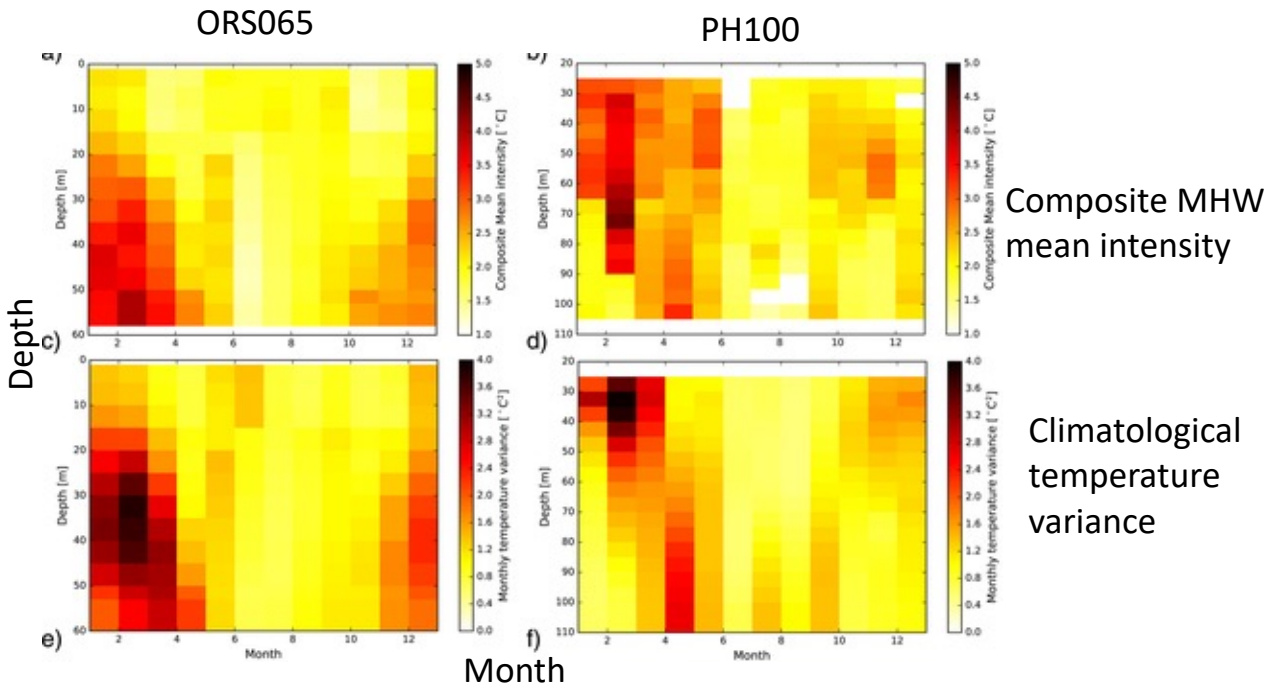
"NP-CP" Eigenvector (phase of maximum amplitude)



Capotondi, Newman, Xu & Di Lorenzo, GRL, 2022

Subsurface characteristics

Tasman Sea



Shaeffer & Roughan, 2017

While MHWs are defined based on SST, their subsurface characteristics are very important for marine ecosystems and ocean biogeochemistry.

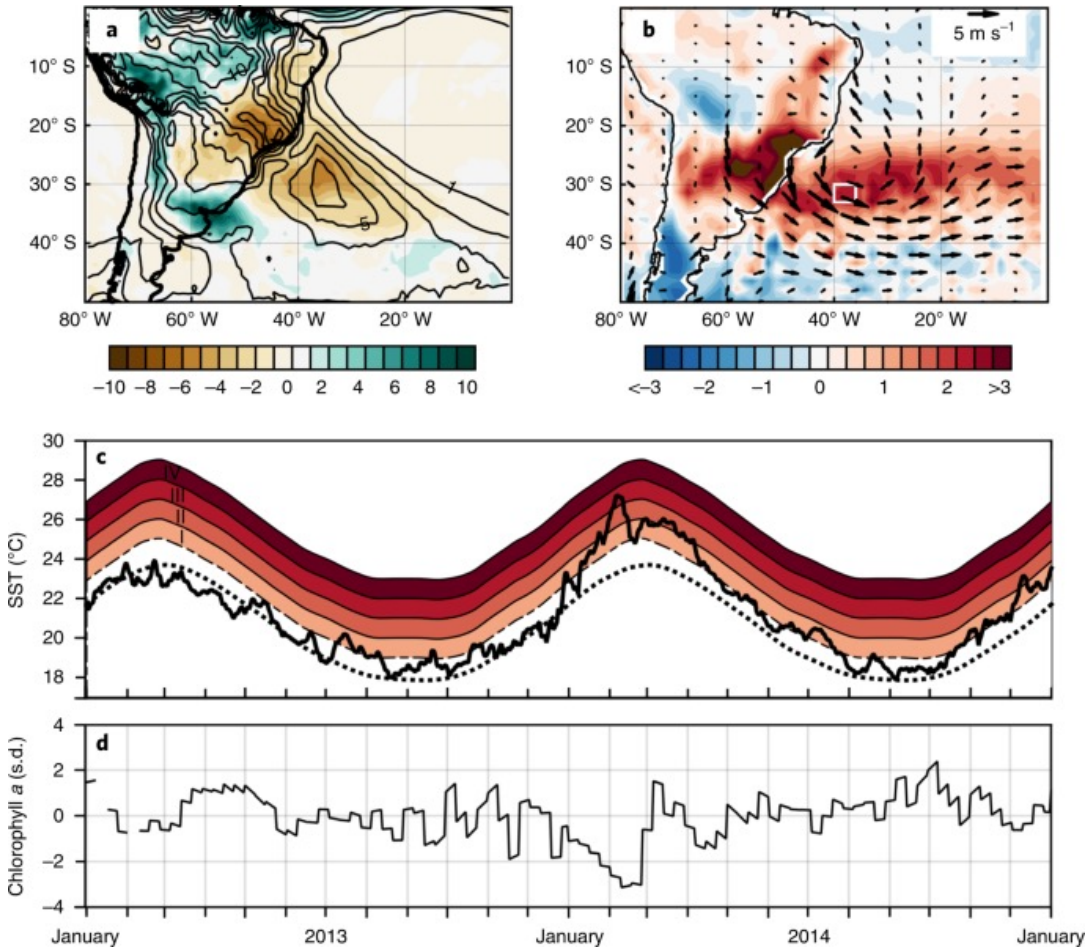
In some regions, MHWs achieve their largest intensity at depth

Subsurface anomalies can be more persistent than at the surface

Improved understanding of the subsurface signature of MHWs, including amplitude and persistence, is needed

Compound events

Average Precipitation and SST in 2013-2014 in the southwest Atlantic

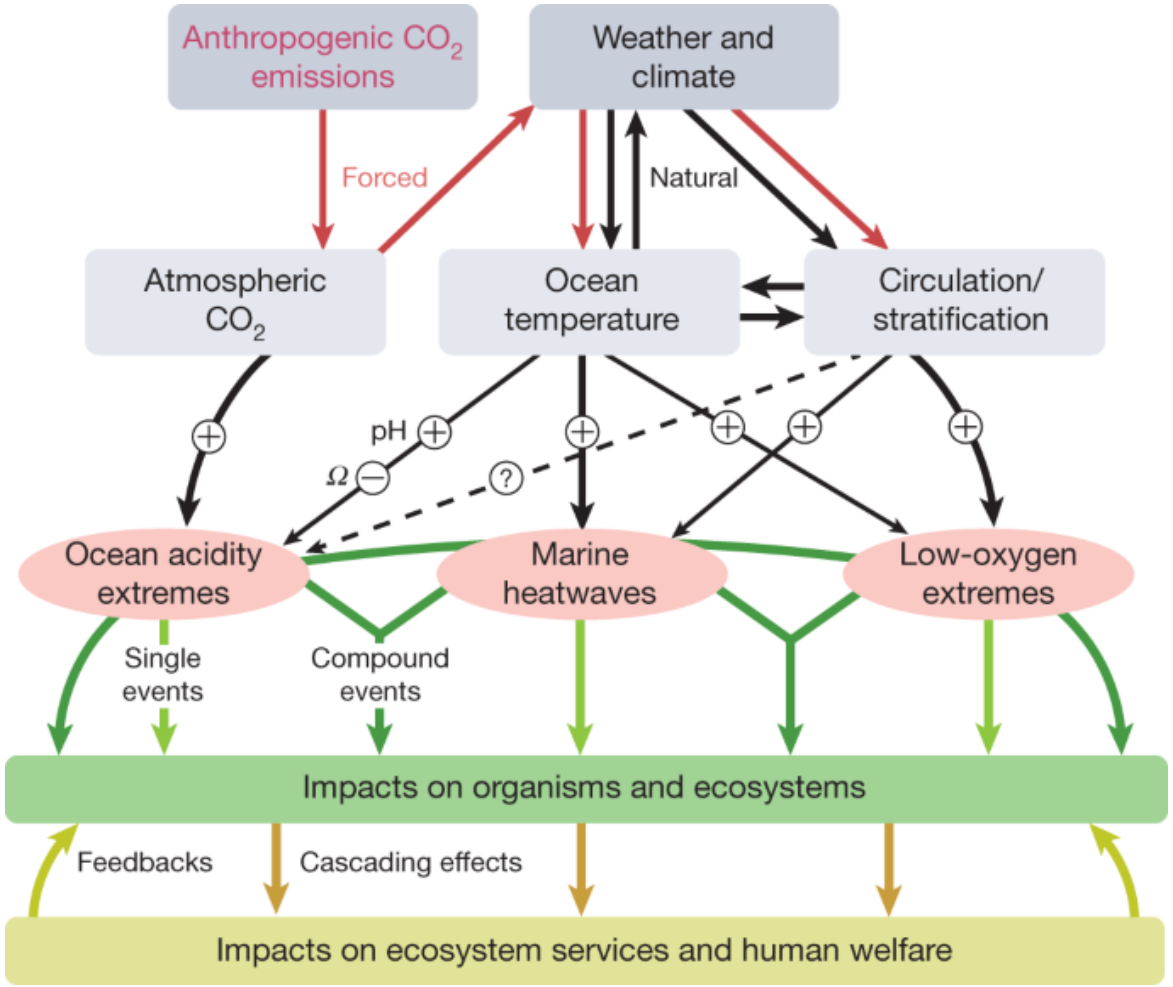


Rodrigues et al., 2019

Marine heatwaves do not often come alone, but may be associated with other extremes, which pose additional threats to society.

MHWs in the Southwest Atlantic were concurrent with severe drought conditions over the adjacent land, due to the same meteorological forcing. Ocean primary production was also reduced.

Biogeochemical extremes



MHWs can also cause or occur in conjunction with other biogeochemical extremes (e.g., ocean acidity and low-oxygen events), giving rise to compound events that can interact synergistically and can be exacerbated by climate change.

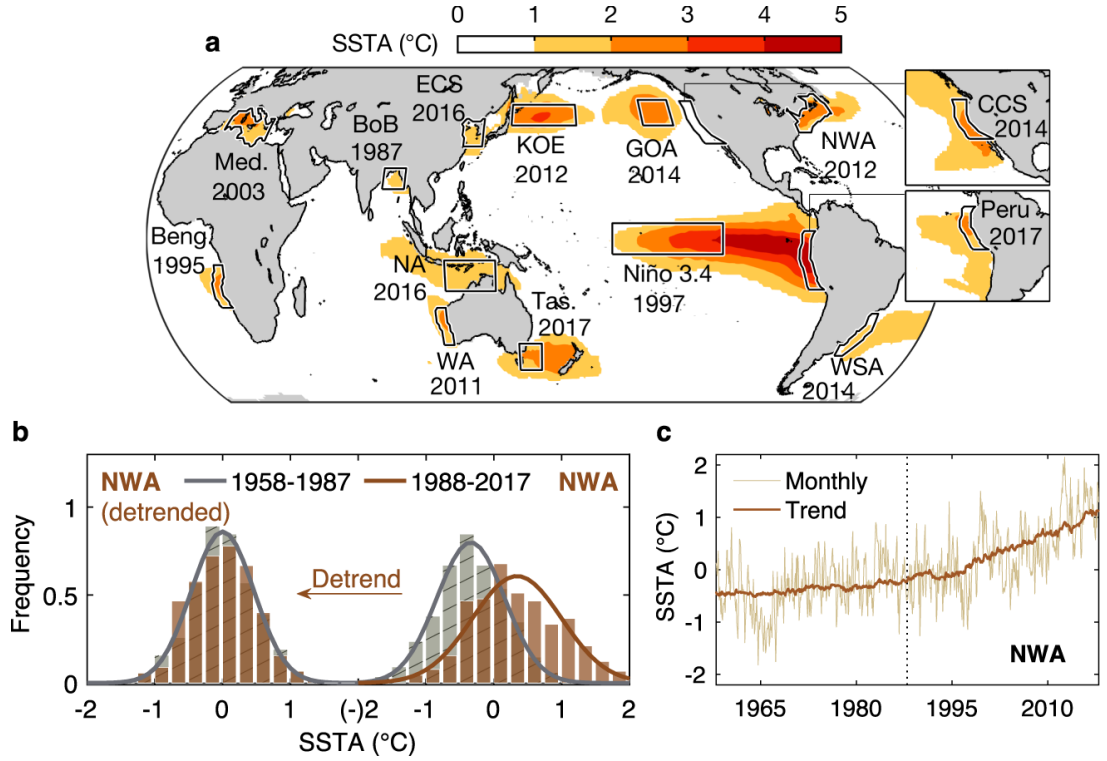
Gruber et al. Nature 2021

MHWs in a changing climate

MHWs have often been defined based on a fixed baseline ->

-> frequency, intensity and spatial extent are increasing in a warming world

Important to separate impact of climate change from internal variability



Xu et al. *Nat. Comm*. 2022

This study uses a Linear Inverse Model to separate the trend from the internal variability. In the Northwest Atlantic, for example, the variability does not change, but the increase in MHWs intensity and duration is due to the nonlinear trend.

Similar analyses should be systematically extended to climate models

Terms of Reference

- **To establish approaches and definitions** that properly characterize MHWs and compound extreme events for diverse applications, and develop the software and tools needed to implement those definitions as a community resource
- **To characterize the subsurface expression of MHWs** and compound extreme events in different regions and the relationship with their surface signatures as a function of season.
- **To investigate the leading mechanisms responsible** for the development of surface and subsurface MHWs in different regions and seasons. Mechanisms will include local processes, typically diagnosed through heat budget analysis, and remote influences from large-scale climate modes of variability.
- **To examine the fidelity of climate models and operational prediction systems** in simulating MHWs with the observed characteristics and resulting from the same mechanisms as in observations.
- To assess the **relative contribution of climate change and internal climate variability** in the occurrence of historical and future MHWs in different regions of the world.
- To **provide guidance to the GOOS/Ocean Observing Co-Design Program of the UN Ocean Decade**.
- To **train the next generation of climate scientists** on this topic of high societal relevance.

Membership

- **Antonietta Capotondi** (Co-Chair) PRP and University of Colorado, CIRES, USA
- **Regina Rodrigues** (Co-Chair) ARP co-Chair and Federal University of Santa Catarina Brazil
- **Dillon Amaya**, NOAA/PSL, USA ECS
- **Jessica Benthuysen**, Australian Institute of Marine Science, Australia
- **Clara Deser**, National Center for Atmospheric Research, USA
- **Thomas Frolicher**, University of Bern, Switzerland
- **Juliet Hermes**, IORP co-chair and South African Environmental Observation Network, South Africa
- **Neil Holbr**ook, University of Tasmania, Australia
- **Roxy Koll**, Indian Institute of Tropical Meteorology, India
- **Nicole Lovenduski**, University of Colorado, ATOC, USA
- **Cristian Martinez Villalobos**, PRP, Universidad Adolfo Ibañez in Peñalolén, Chile ECS
- **Simona Masina**, Istituto Nazionale di Fisica e Vulcanologia (INGV) and Centro Mediterraneo per i Cambiamenti Climatici (CMCC), Italy
- **Amandine Shaeffer**, University of New South Wales, Australia
- **Robert Schlegel**, Institut de la Mer de Villefranche, France
- **Alex Sen Gupta**, University of New South Wales, Australia
- **Kathryn Smith**, Marine Biological Association of the United Kingdom, UK ECS
- **Chunzai Wang**, South China Sea Institute of Oceanology, China

Deliverables

- A **summer school** to train and engage Early Career Scientists while promoting dialogue and knowledge exchange among experts in the field (**Trieste, Italy, July 24-29, 2023**).
- Develop a **set of tools** for detecting and diagnosing surface and subsurface MHWs in observations and models.
- Special **sessions at international conferences** and meetings to stimulate research on this topic.
- A **workshop** to discuss advances in our understanding of MHWs mechanisms and biogeochemical/ecological impacts, with the participation of GOOS/Ocean Observing Co-Design Program members, and representatives from the North Pacific Marine Science Organization (PICES).
- A **special collection of papers** to describe advances in our characterization of surface and subsurface expressions of MHWs, their physical mechanisms (including both local and remote influences) in different regions, and their biogeochemical impacts.
- **Review or group papers** on mechanisms in different regions, models' representation of MHWs and future projections over the global ocean.
- **Input to observational groups**, in particular, the UN Ocean Decade GOOS Program MHW Exemplar, as well as to **PICES WG-49** on "Ocean extremes and coastal impacts"