MERCATOR OCEAN INTERNATIONAL

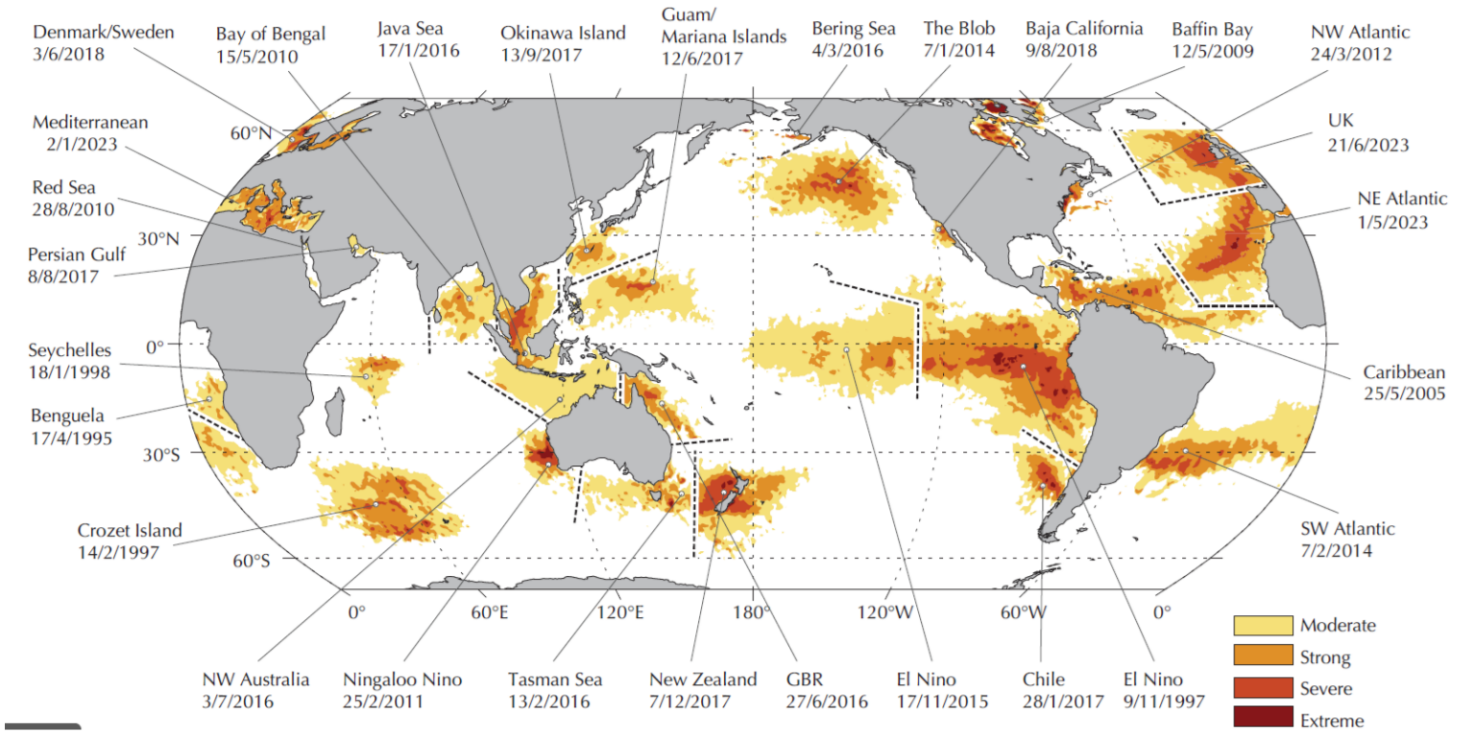
Monitoring & Forecasting Marine Heatwaves at MOi

UEF2026 – Reading, UK

Amélie Loubet
loubeta@mercator-ocean.fr

Introduction & Outline

Marine Heatwaves (MHW): prolonged period during which the **temperature is abnormally high** (above a threshold)



Main historical MHW events since 1995. (Smith et al., 2020 ; marineheatwaves.org)

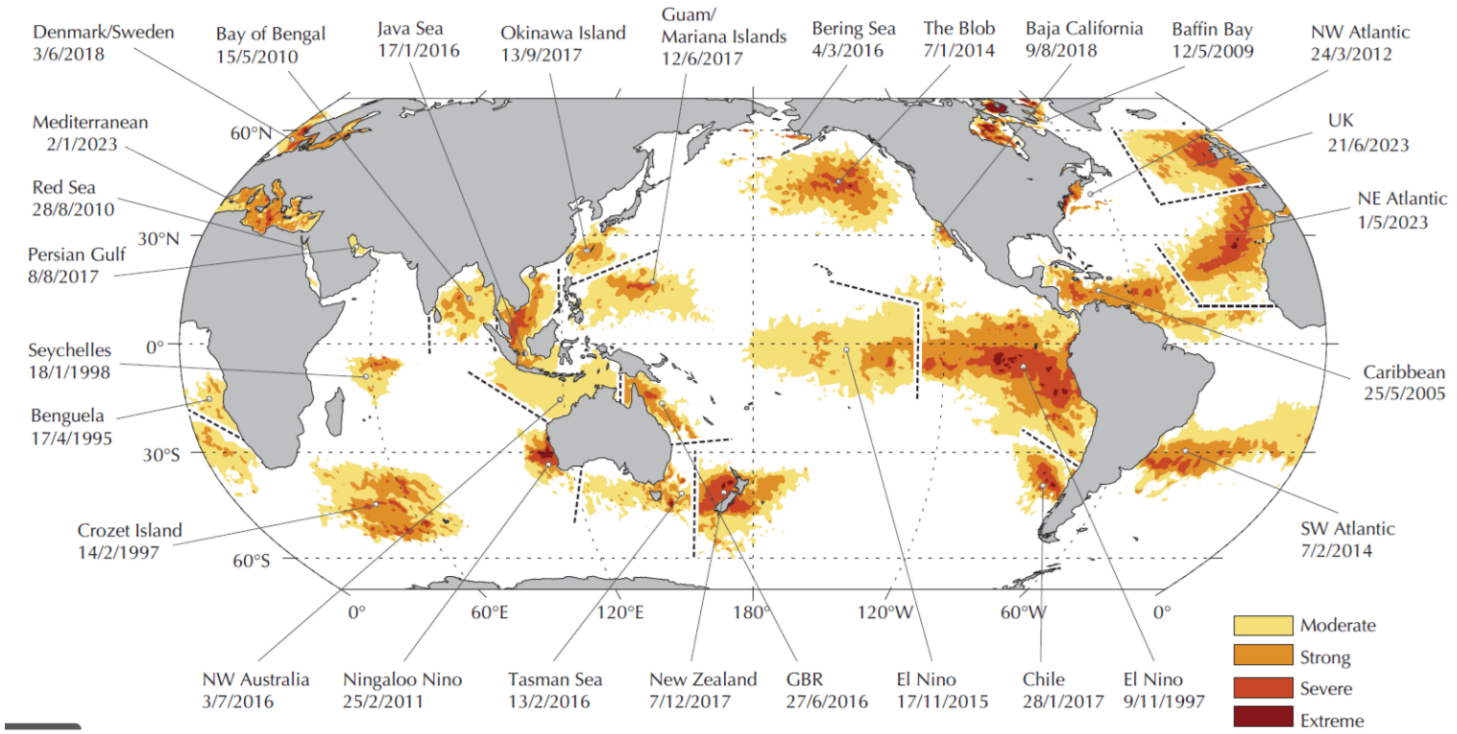
→ Becoming **longer**, **warmer** and **more frequent** in our changing climate

→ Have **strong impacts** on **biology**, **marine ecosystems**

=> Need to monitor and forecast them

Introduction & Outline

Marine Heatwaves (MHW): prolonged period during which the **temperature is abnormally high** (above a threshold)



Main historical MHW events since 1995. (Smith et al., 2020 ; marineheatwaves.org)

→ Becoming **longer**, **warmer** and **more frequent** in our changing climate

→ Have **strong impacts** on **biology**, **marine ecosystems**

=> Need to monitor and forecast them

Outline

- Understanding marine heatwaves
- Operational marine heatwaves monitoring & forecasting at MOi
- Extend to subsurface

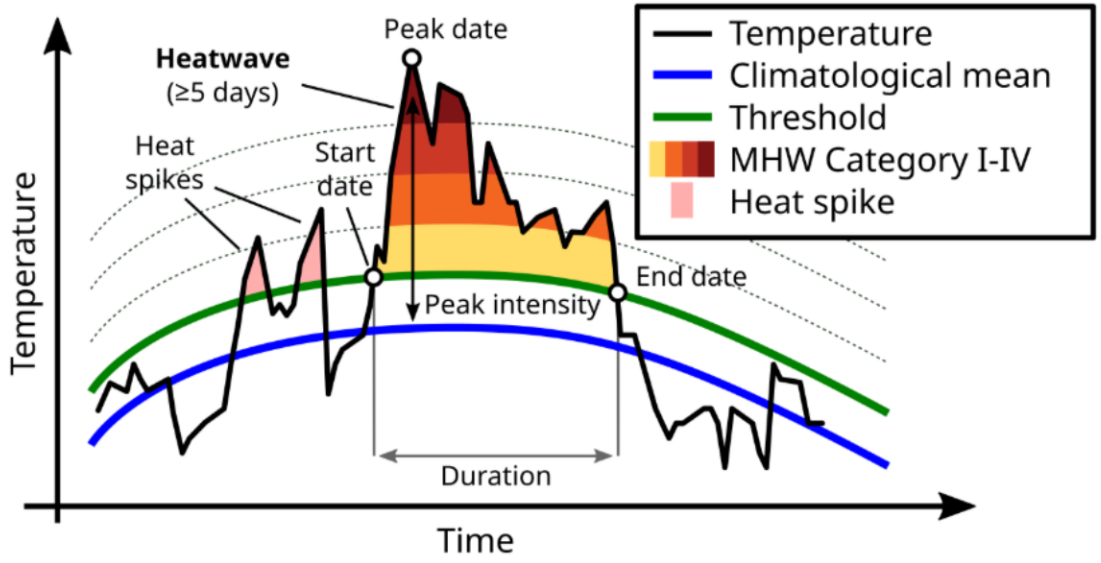
MERCATOR OCEAN INTERNATIONAL

Understanding Marine Heatwaves

What are Marine Heatwaves?

Marine Heatwaves (MHW): prolonged period during which the **temperature is abnormally high** (above a threshold)

- Comon definition (Hobday et al. 2016): at least **5 days** above **90th percentile** of 30-year climatology
- **4 categories** (Hobday et al., 2018):
  - **Moderate** (yellow)
  - **Strong** (orange)
  - **Severe** (bright red)
  - **Extreme** (dark red)

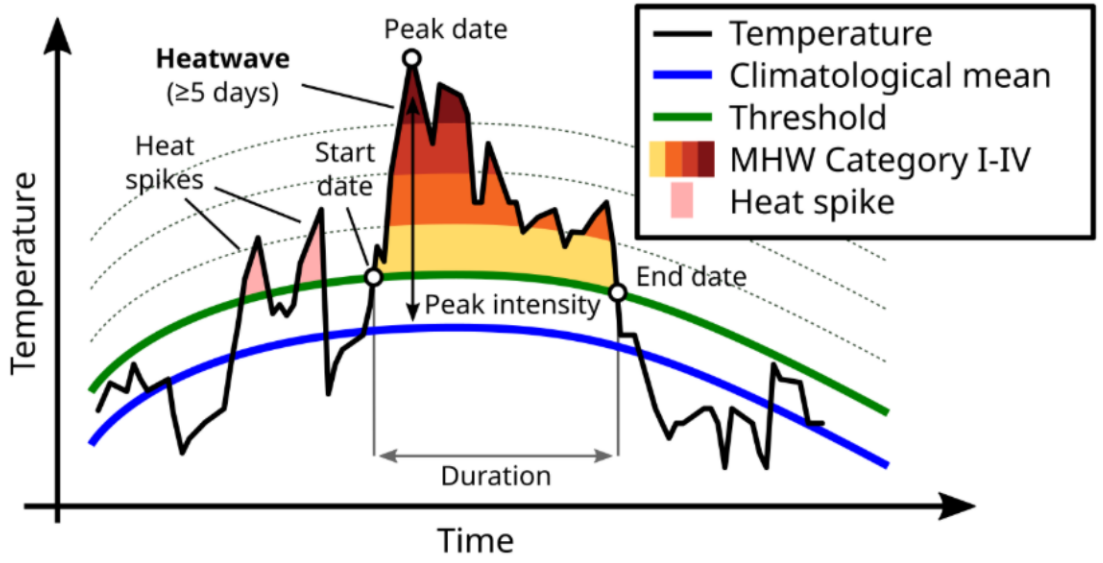


SST Temporal evolution and MHW thresholds (marineheatwaves.org)

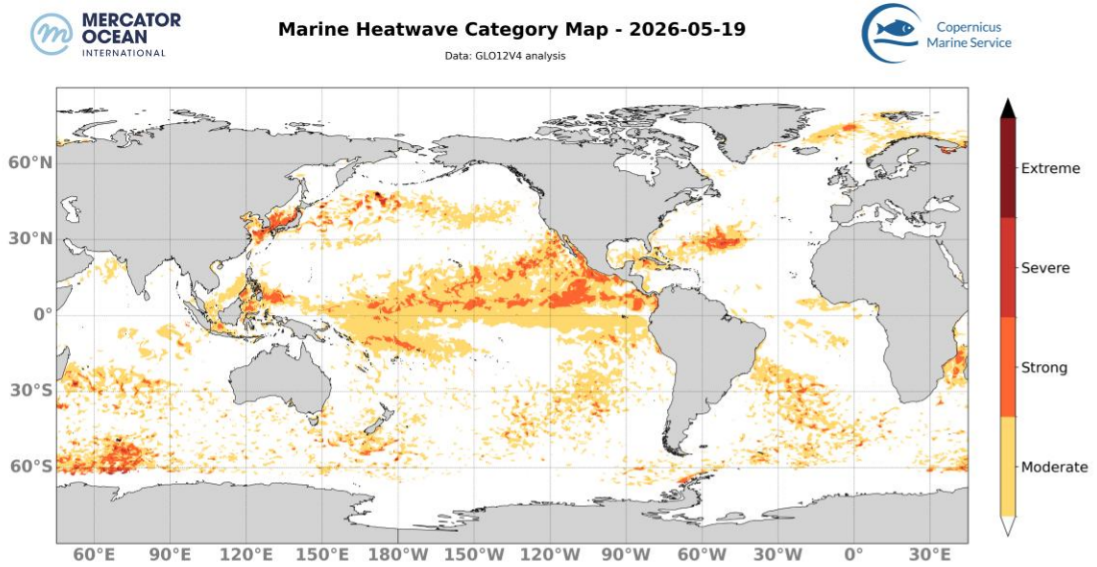
What are Marine Heatwaves?

Marine Heatwaves (MHW): prolonged period during which the **temperature is abnormally high** (above a threshold)

- Comon definition (Hobday et al. 2016): at least **5 days** above **90th percentile** of 30-year climatology
- **4 categories** (Hobday et al., 2018):
  - **Moderate** (yellow)
  - **Strong** (orange)
  - **Severe** (bright red)
  - **Extreme** (dark red)



SST Temporal evolution and MHW thresholds (marineheatwaves.org)



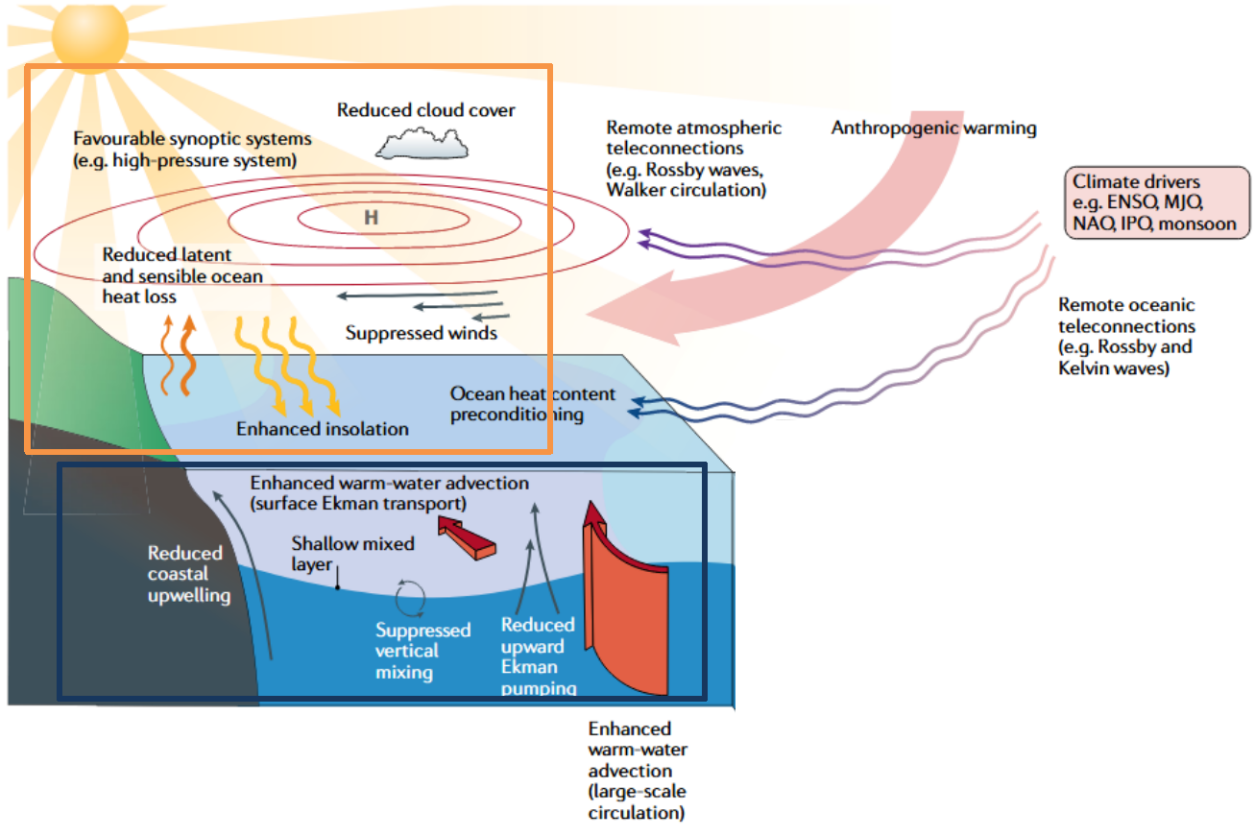
MHW Category Map for 19th may 2026 (Mercator Ocean International, Copernicus Marine Service)

Drivers & Impacts

- **Main Drivers**

Atmospheric drivers

Oceanic drivers



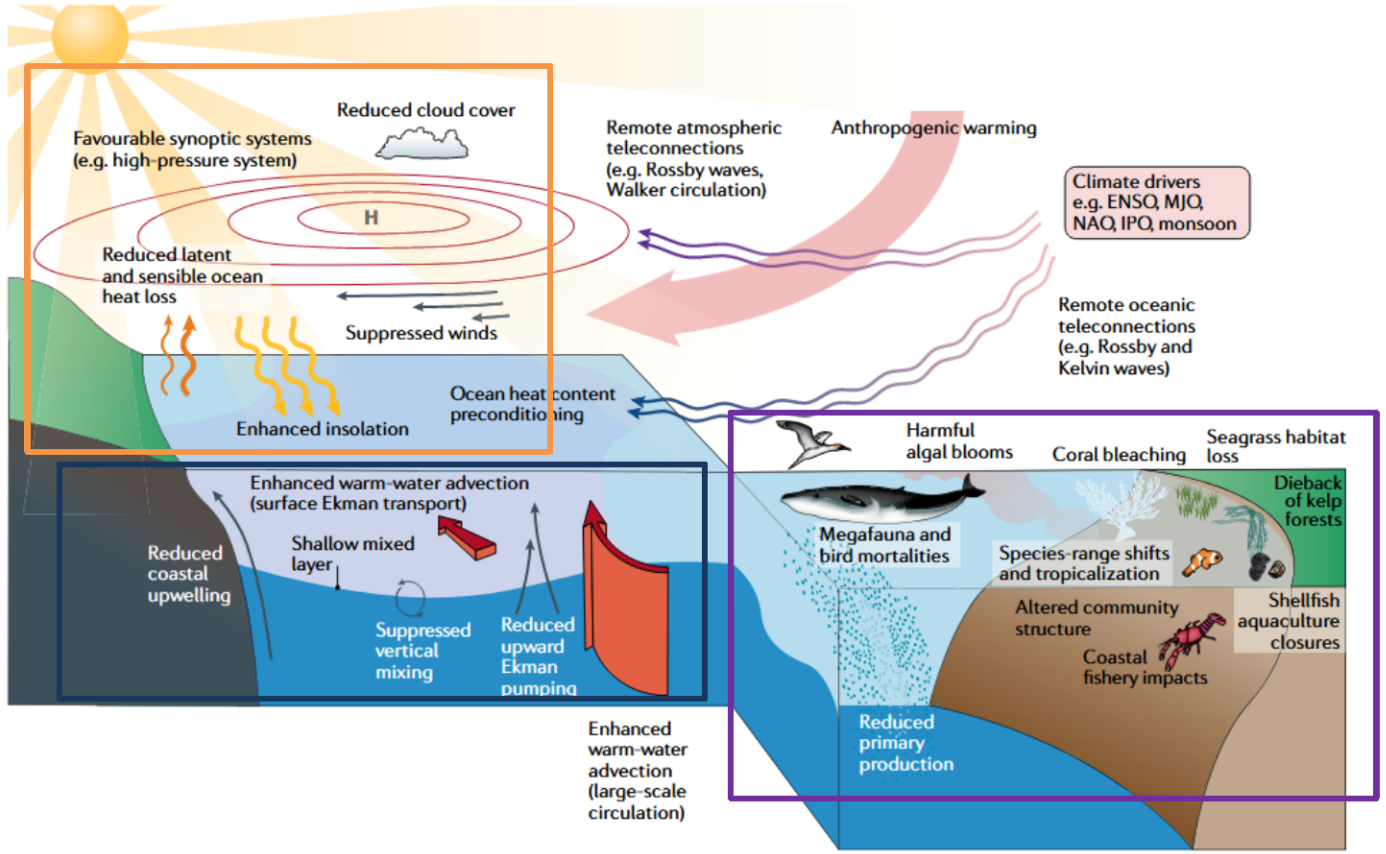
MHW drivers and impacts (Holbrook et al., 2020)

Drivers & Impacts

- **Main Drivers**

Atmospheric drivers

Oceanic drivers



MHW drivers and impacts (Holbrook et al., 2020)

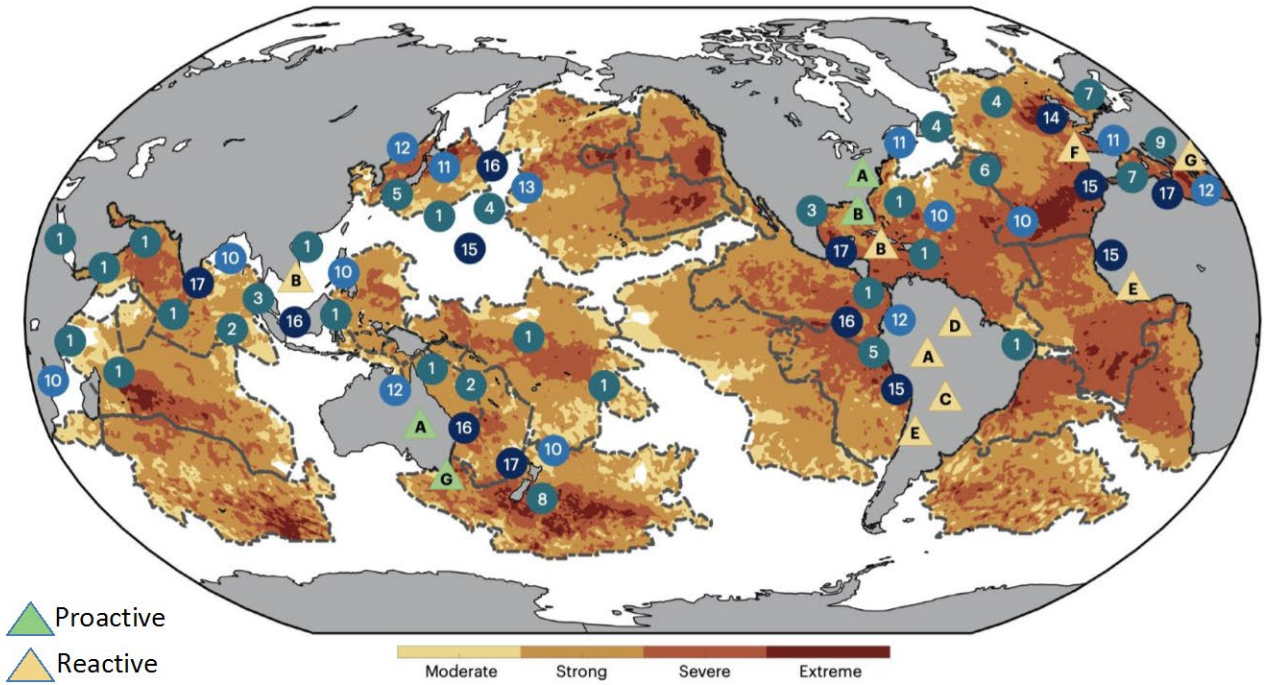
- **Main Impacts**

Impacts on oceanic and coastal ecosystems

+ Extreme Weather (enhance cyclone, hurricane, heatwaves …)

+ Socioeconomics (fisheries, aquaculture, tourism …)

Importance of forecasting for effective preparation



MHW category		
Impacts		**Interventions**
Biological	**Physical**	**Proactive** / **Reactive**
1. Coral bleaching 2. Harmful algal bloom 3. Mass mortality event 4. Species range shift 5. Habitat loss 6. Reduced primary productivity 7. Reduced growth and reproduction 8. Increased cetacean stranding 9. Disease	10. Tropical cyclones or storms 11. Atmospheric heatwaves 12. Flooding 13. Oceanic currents **Societal** 14. Tourism 15. Fisheries 16. Aquaculture 17. Infrastructure	A. Warnings issued B. Coral conservation C. Commercial fisheries cancelled/quotas issued D. Government subsidies provided E. New/increased commercial fisheries F. Increased tourism opportunities G. Species collected/monitored for conservation

2023-2024 MHWs impacts and interventions (Smith et al., 2025)

Lack of

- MHW forecast for many regions
- Good communication briefs

Need for:

- improved forecast accuracy for greater confidence for proactive decision-making,
- longer-range forecasts will extend the preparation window

MERCATOR OCEAN INTERNATIONAL

Operational MHW monitoring & forecasting at MOi

Mercator's systems

Copernicus Marine Service

- Climatology & Historical MHWs :

GLORYS12

Global Reanalysis

- 1993 to 2026 **daily data**
- 1/12 degree-50 vertical layers
- Assim (OSTIA SST, In-situ T(z) S(z), SLA, CERSAT SIC)
- Atmospheric forcing: ERA-Interim (1993-2019) & ERA5 (since 2019)

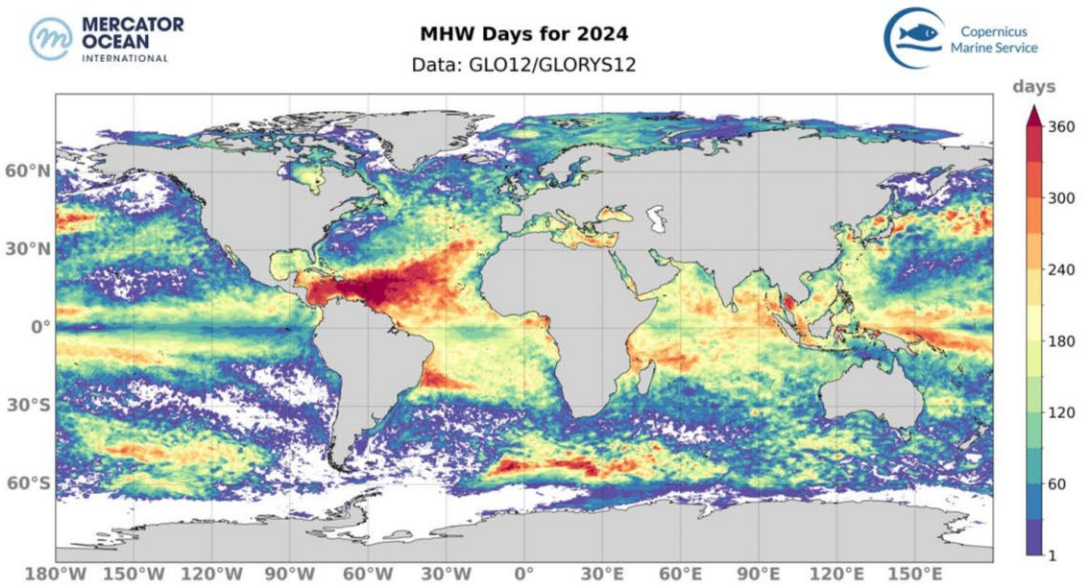
- NRT & forecasted MHWs :

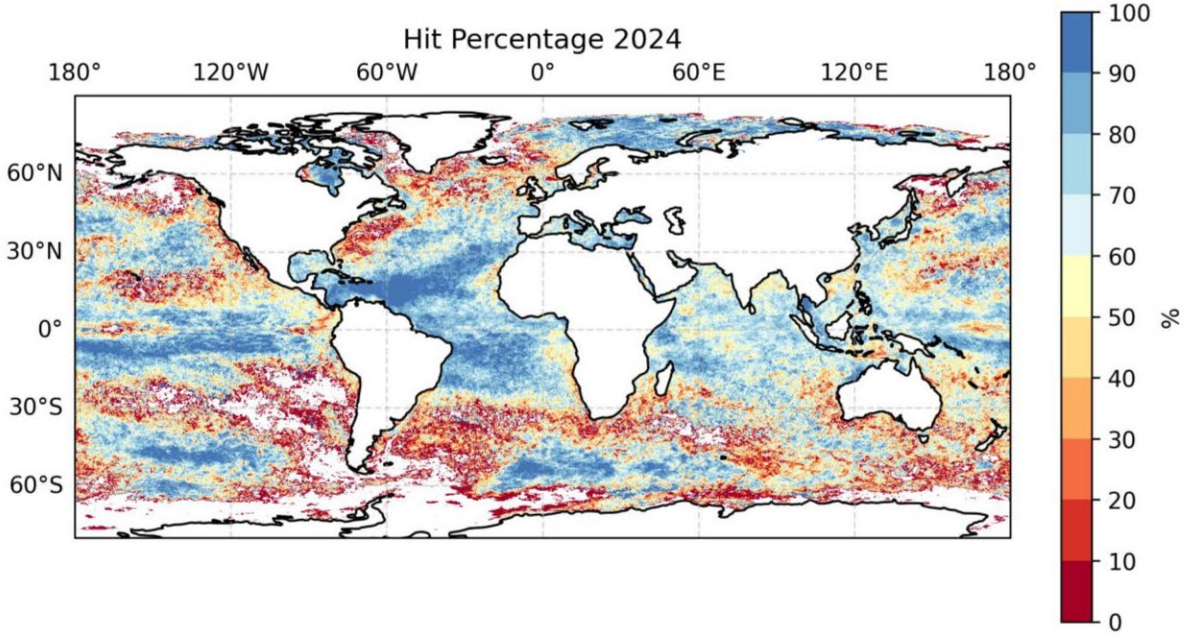
GLO12

Global Analysis and Forecast

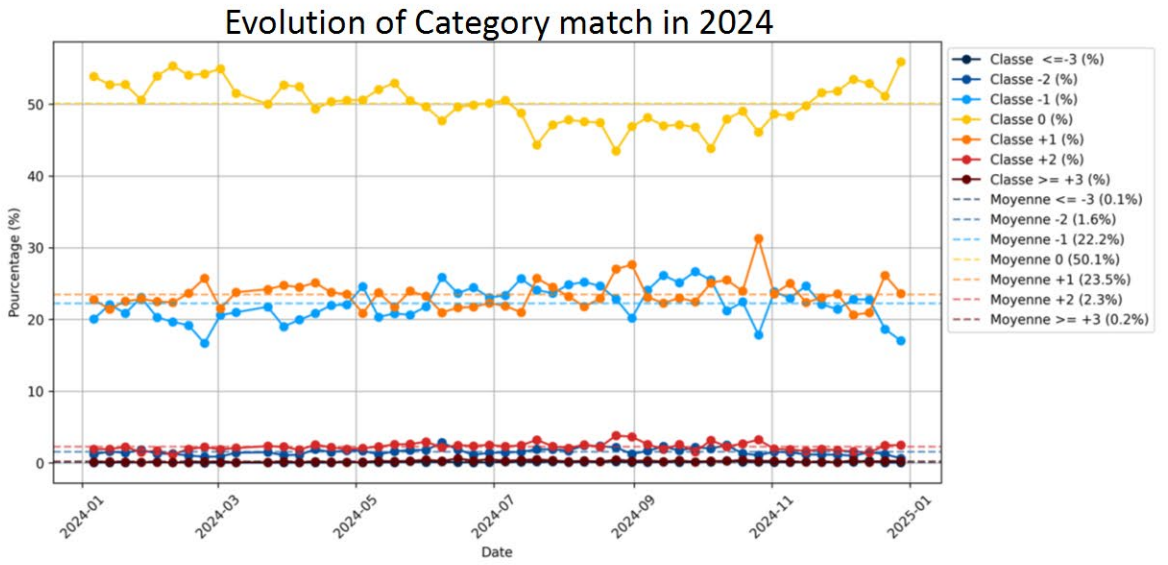
- **10-day** daily forecast
- 1/12 degree-50 vertical layers
- Assim NRT from CMEMS (In-situ T(z) S(z), SST-ODYSSEA, SIC-OSISAF), SLA-AVISO
- Atmospheric forcing: ECMWF IFS HRES

10-day MHW forecasting skills (2024)





- Weekly 10 -day forecast compared with analysis
- **High level of skills in regions most exposed**
- Intensity of events well captured



Communicating on MHW: Moi's Bulletin

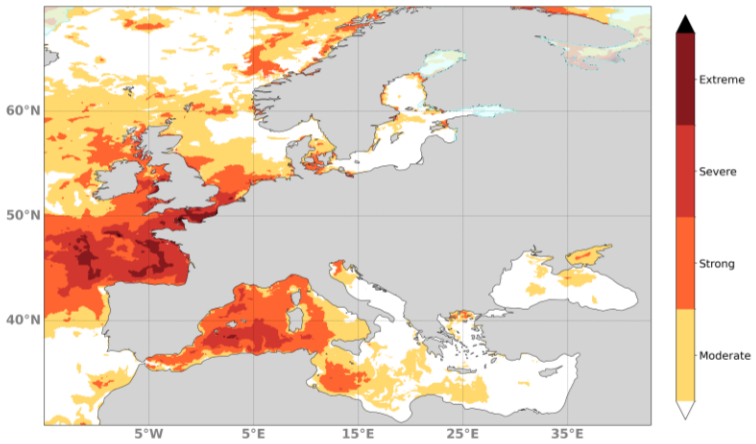
Monthly, Seasonal and Annual synthesis:

→ What has just happened in terms of MHW and how it fits compared to previous years

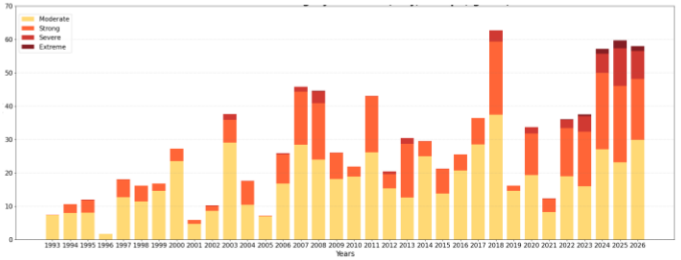
→ Global and regional scale

Highest MHW Categories reached in May 2026

Data: GLO12/GLORYS12



Extent of May maximum categories



3rd largest MHW extent in May since 1993

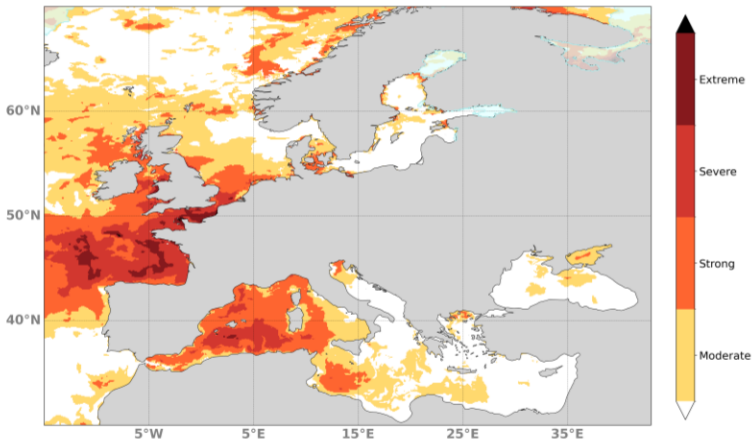
Communicating on MHW: Moi's Bulletin

Monthly, Seasonal and Annual synthesis:

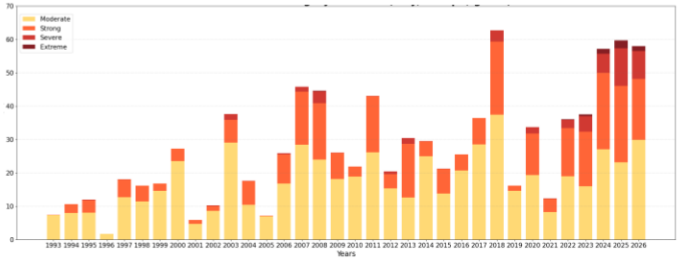
→ What has just happened in terms of MHW and how it fits compared to previous years

→ Global and regional scale

Highest MHW Categories reached in May 2026



Extent of May maximum categories

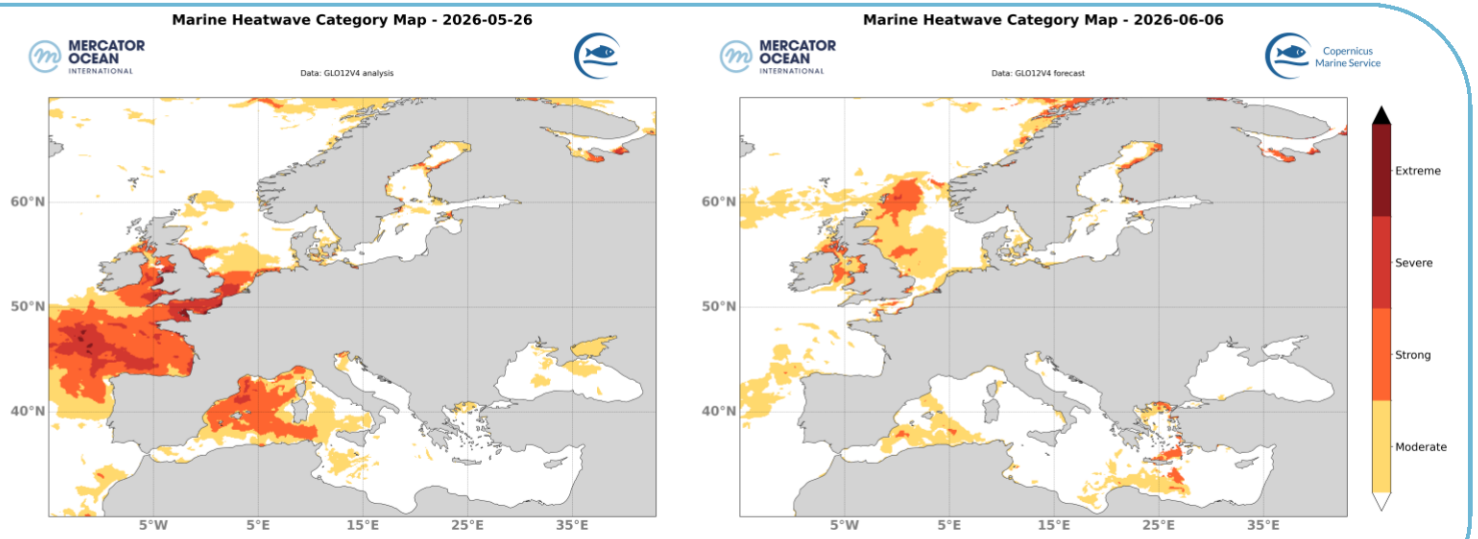


3rd largest MHW extent in May since 1993

Weekly 10-day forecast:

→ MHW evolution over next 10d

Users feedbacks: Need for longer term forecast to better anticipate the event



Forecast weakening of MHW conditions over Europe in early June

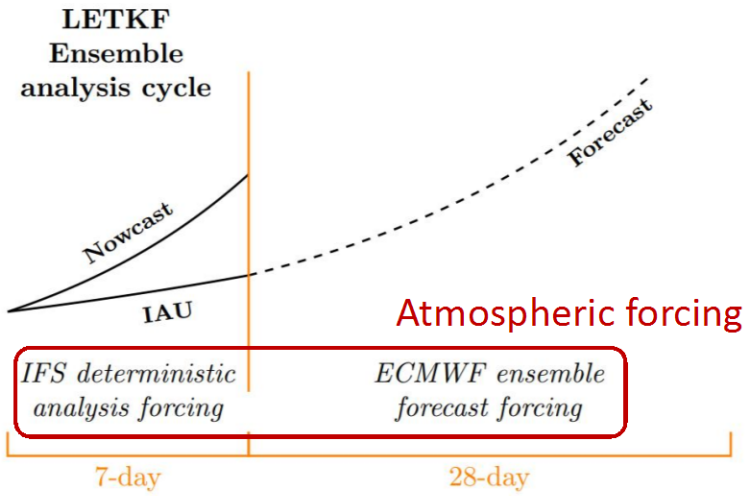
Extend forecasting horizon: the GLO4Ens system

GLOENS

50 members 3D 28-day forecast on EDITO

- ¼ degree-75 vertical layers/SI3 5 categories
- 50 members + Ctl (unpert.+assim cov-ens)
- Assim (SST-OSTIA, In-situ, sea level anomaly, SIC-OSISAF)

GLO4Ens weekly cycle scheme



- MHW detection: Use of OSTIA climatology

Longer probabilistic forecast:

- Enables **better anticipation**
- Why? Better for decision making - contains info of **uncertainty** and **dispersion** of the forecast
- Testing of method, qualification, and relevant metrics

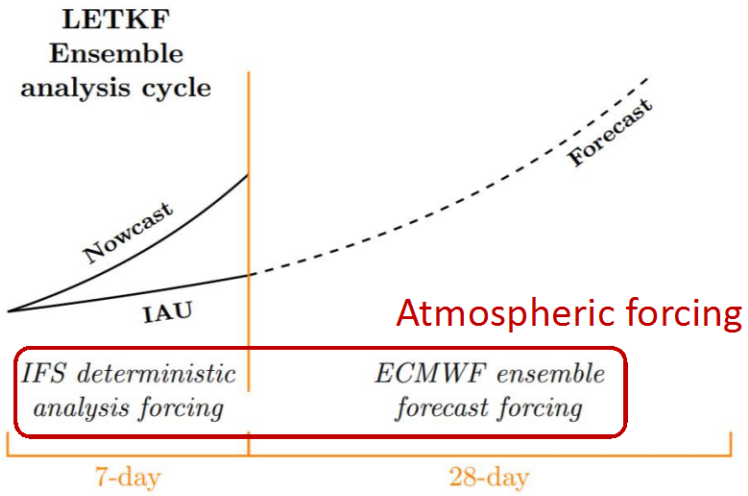
Extend forecasting horizon: the GLO4Ens system

GLOENS

50 members 3D 28-day forecast on EDITO

- ¼ degree-75 vertical layers/SI3 5 categories
- 50 members + Ctl (unpert.+assim cov-ens)
- Assim (SST-OSTIA, In-situ, sea level anomaly, SIC-OSISAF)

GLO4Ens weekly cycle scheme

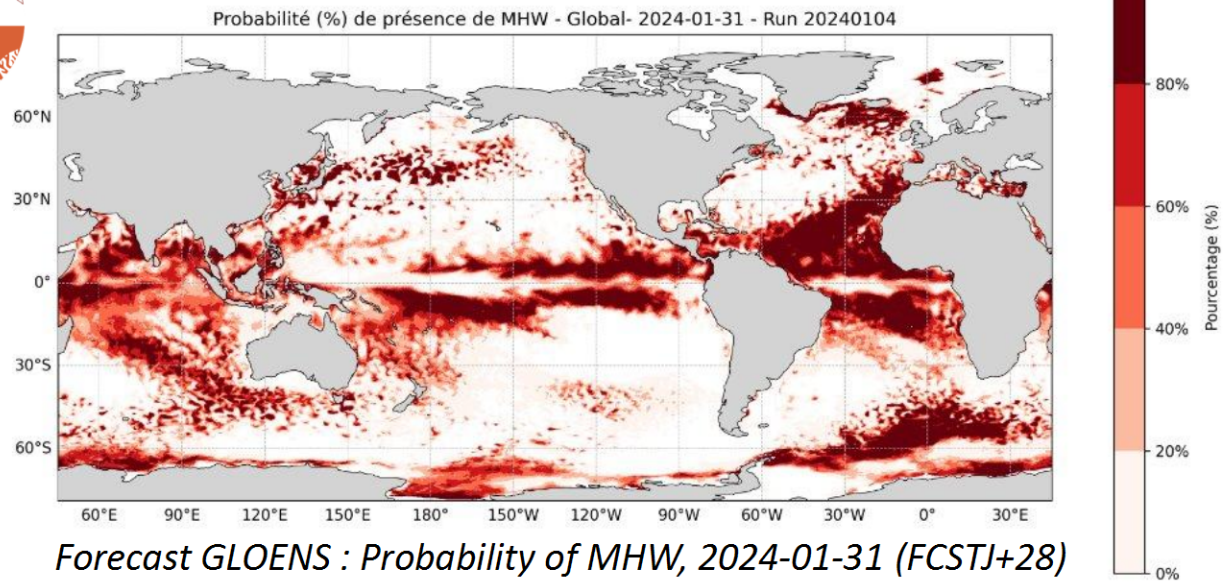


- MHW detection: Use of OSTIA climatology

Longer probabilistic forecast:

- Enables **better anticipation**
- Why? Better for decision making - contains info of **uncertainty** and **dispersion** of the forecast
- Testing of method, qualification, and relevant metrics

→ Weekly 28-day forecast : MHW probabilities



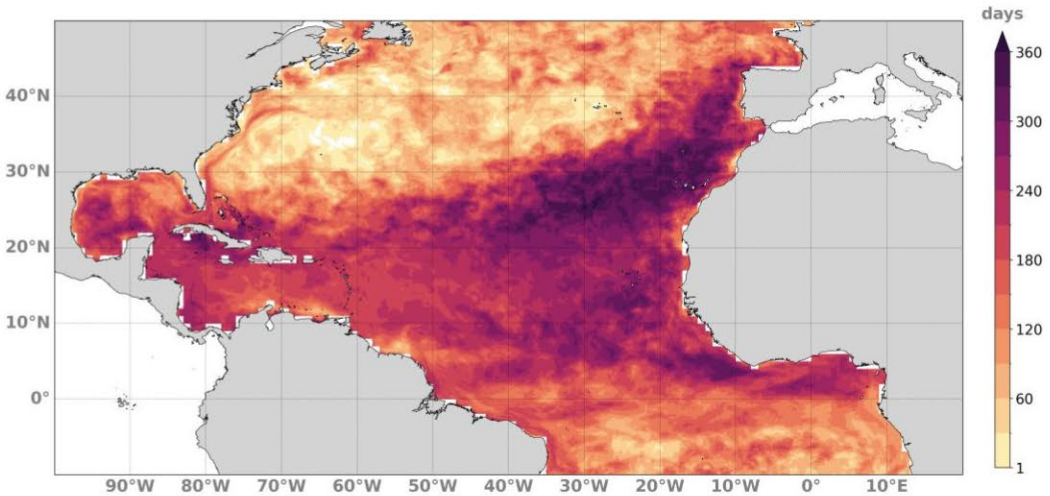
Forecast GLOENS : Probability of MHW, 2024-01-31 (FCSTJ+28)

MERCATOR OCEAN INTERNATIONAL

Extending to subsurface

The 2023 MHW in the North Atlantic tropical ocean

2023 MHW Days

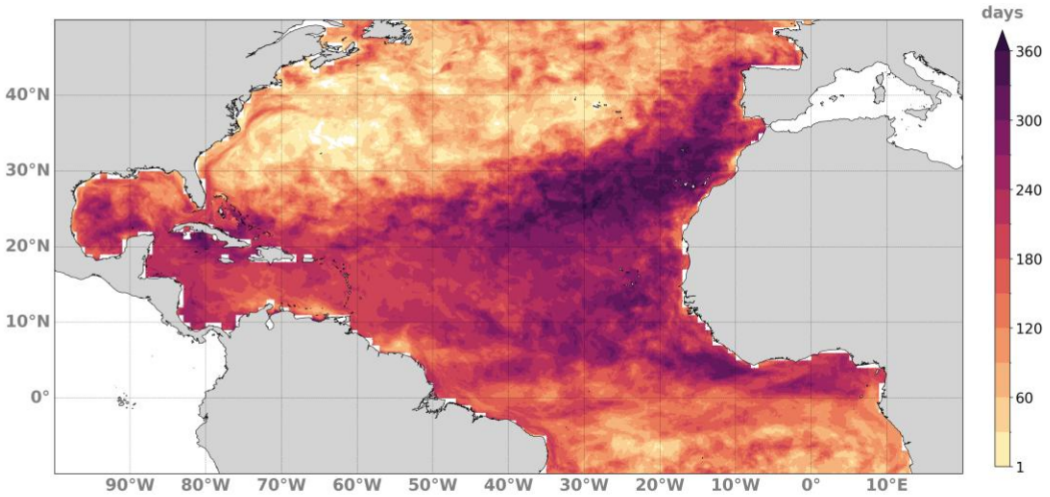


- Entire basin affected by MHW
- 50% of the basin > 180 days

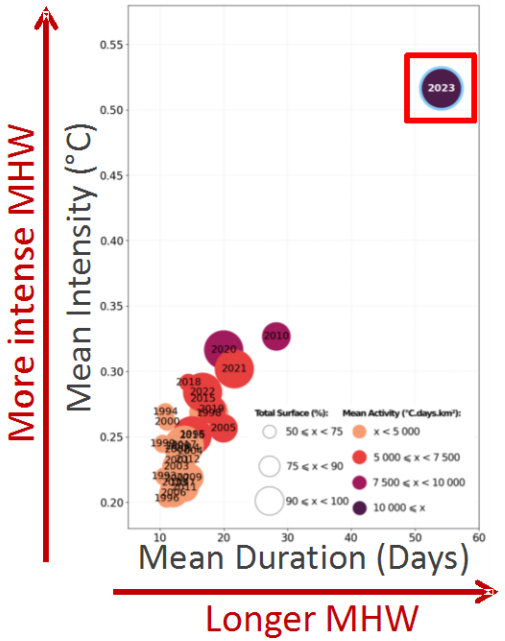
Loubet et al. (Ocean State Report 9, 2025)

The 2023 MHW in the North Atlantic tropical ocean

2023 MHW Days



MHW Characteristics



- Entire basin affected by MHW
- 50% of the basin > 180 days

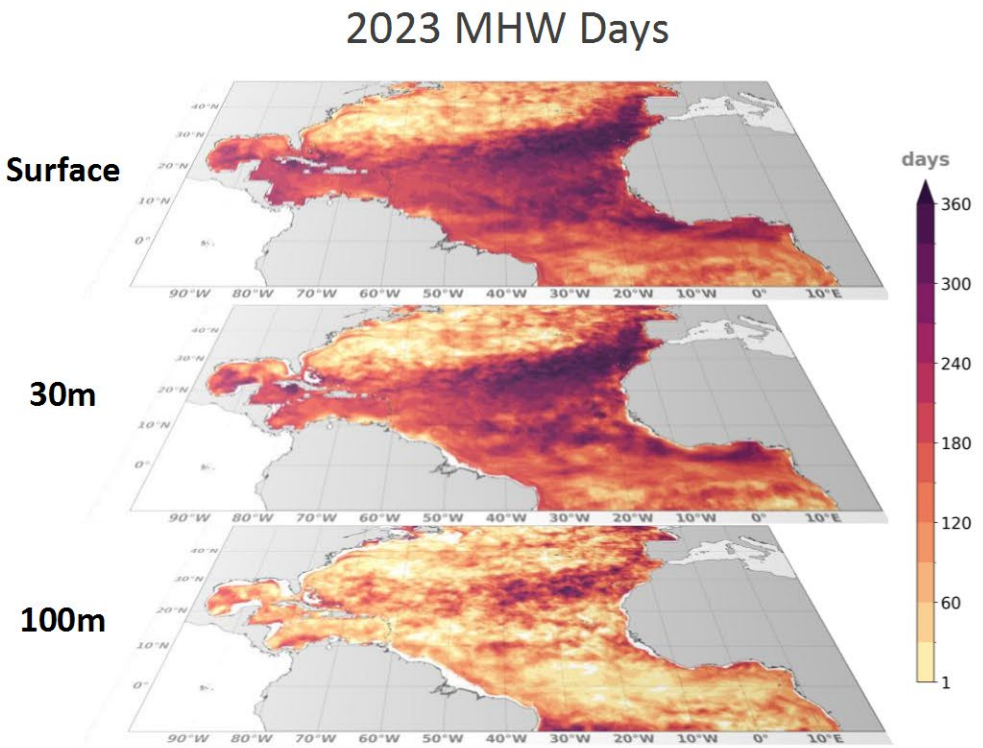
- 2023: **most intense (x2), longest (x2) and most widespread** MHW of the past 3 decades at the surface

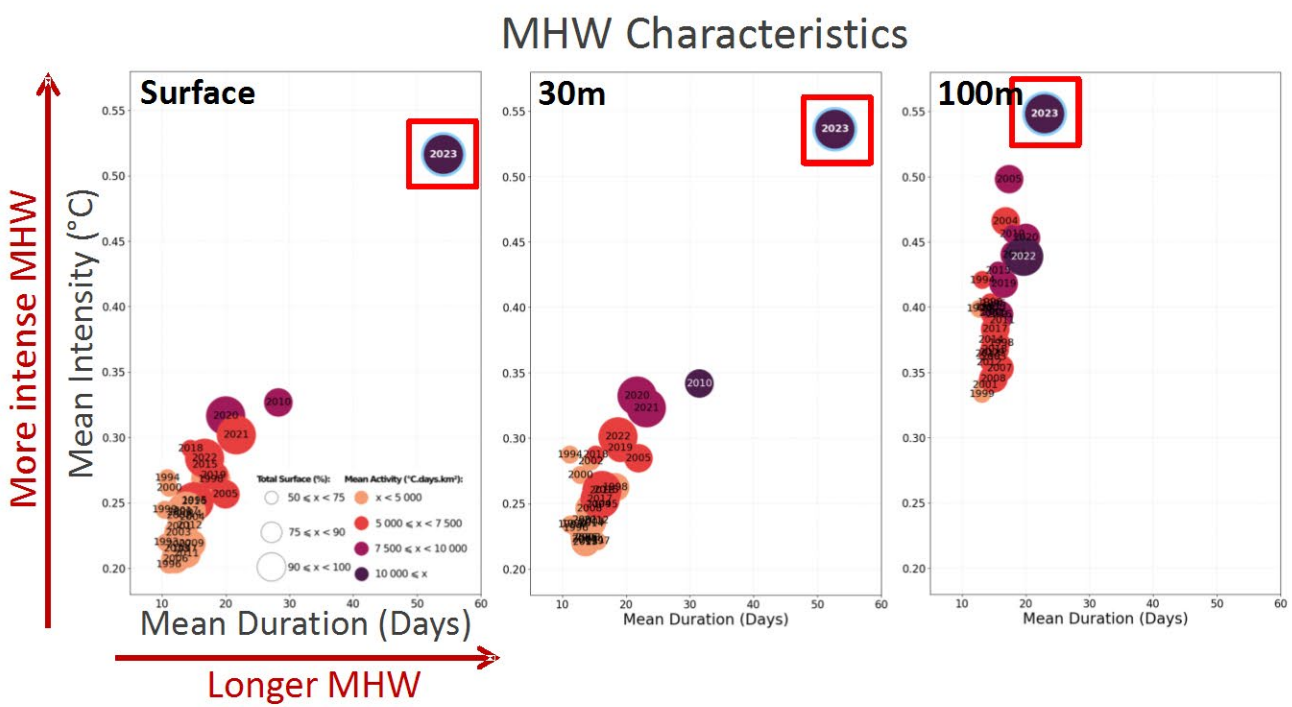
2023: unprecedented MHW at the surface: **what about subsurface?**

Loubet et al. (Ocean State Report 9, 2025)

Need to go beyond the surface

- **Subsurface**





- 2023: **most intense, longest and most widespread** MHW of the past 3 decades at the surface **and at depth**

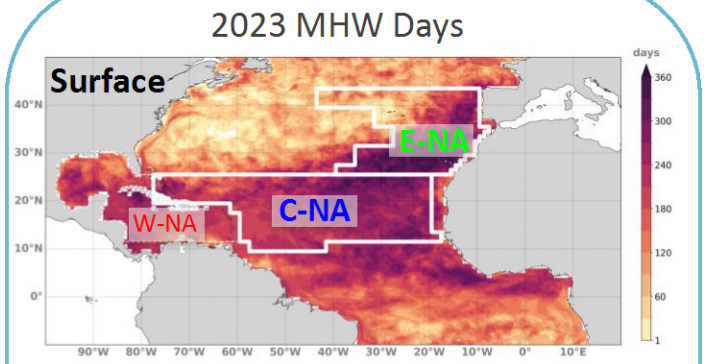
2023: unprecedented MHW at the surface and **subsurface**

Loubet et al. (Ocean State Report 9, 2025)

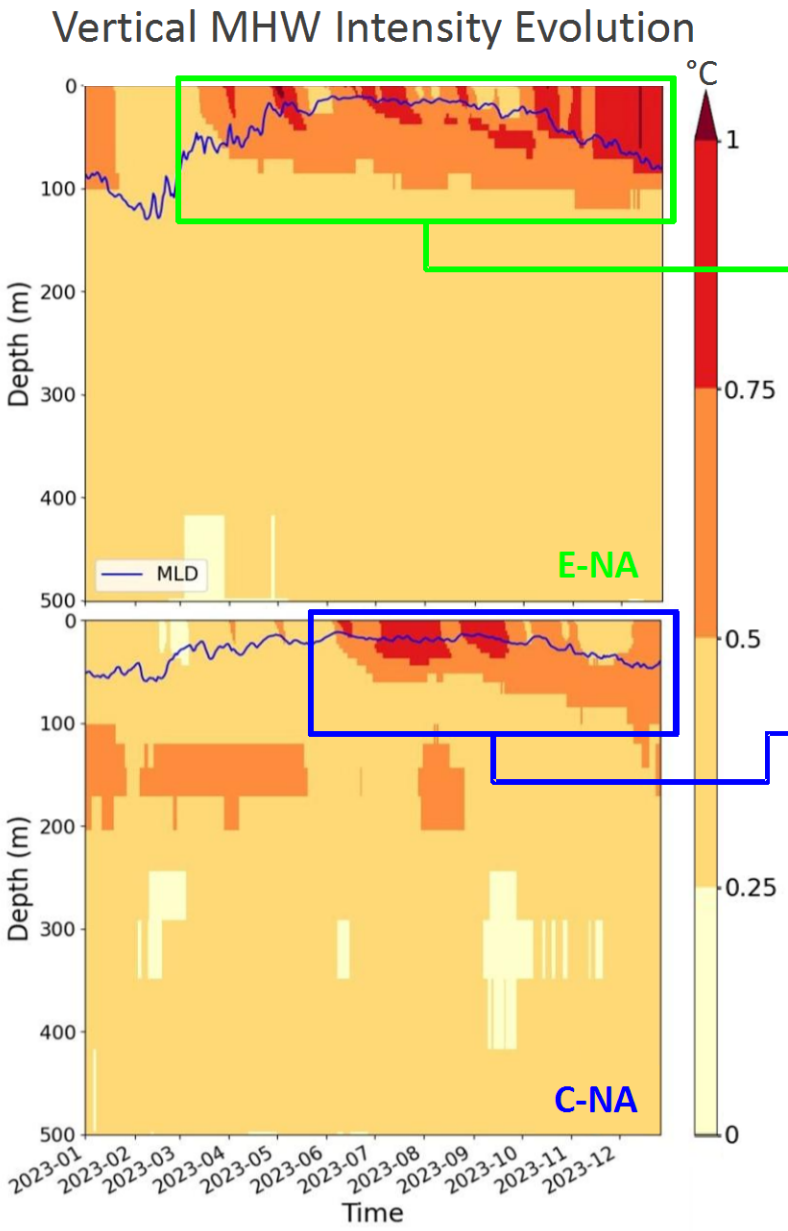
Regional Vertical Structure of MHW

- **Eastern & Central Basin:**

Longhurst Provinces:



- **E-NA:** Eastern tropical North Atlantic
- **C-NA:** Central tropical North Atlantic
- W-NA: Western tropical North Atlantic



Strong variation across the year

↓

Atmospheric forcing

Longer-lasting surface event, later in the year

MHWs develop at the surface and expand **below the MLD**

Loubet et al. (Ocean State Report 9, 2025)

Conclusion

Conclusion

Marine Heatwaves (MHW):

- Becoming **longer, more intense, and more frequent**
- **Reliable forecasts** are essential to support mitigation and adaptation

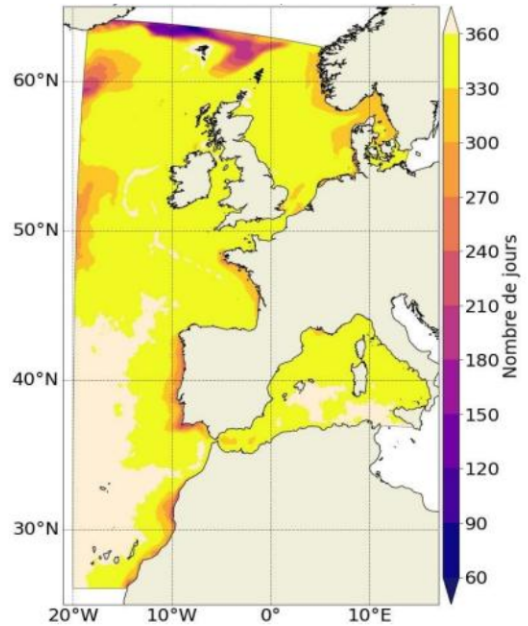
At MOi:

- **Regular MHW bulletins**
- Weekly MHW **10-day forecast**
- Developments toward **longer-term forecasts: 28 days**

Extend to subsurface:

- MHW can extent to subsurface
- 2023 NA event highlighted the impotance of subsurface monitoring and forecasting

MHW in projections



Projected Mean Number of annual MHW days between 2076 and 2100 (IBI-CCSv2, CNRMH, SSP5-8.5)

→ **MHW definition becomes challenging under near-permanent conditions**

References

Hobday, A. J., Alexander, L. V., Perkins, S. E., Smale, D. A., Straub, S. C., Oliver, E. C. J., Benthuysen, J. A., Burrows, M. T., Donat, M. G., Feng, M., Holbrook, N. J., Moore, P. J., Scannell, H. A., Sen Gupta, A., and Wernberg, T.: A hierarchical approach to defining marine heatwaves, Progress in Oceanography, 141, 227–238, https://doi.org/10.1016/j.pocean.2015.12.014, 2016.

Hobday, A. J., Oliver, E. C. J., Gupta, A. S., Benthuysen, J. A., and Burrows, M. T.: Categorizing and Naming Marine Heatwaves, Oceanography, 31, 162–173, https://doi.org/10.5670/oceanog.2018.205, 2018.

Holbrook, N. J., Sen Gupta, A., Oliver, E. C. J., Hobday, A. J., Benthuysen, J. A., Scannell, H. A., Smale, D. A., and Wernberg, T.: Keeping pace with marine heatwaves, Nat Rev Earth Environ, 1, 482–493, https://doi.org/10.1038/s43017-020-0068-4, 2020.

Loubet, A., van Gennip, S. J., Bourdallé-Badie, R., and Drevillon, M.: The 2023 marine heatwave in the North Atlantic tropical ocean, State of the Planet, 6-osr9, 1–11, https://doi.org/10.5194/sp-6-osr9-11-2025, 2025.

Smith, K. E., Burrows, M. T., Hobday, A. J., Sen Gupta, A., Moore, P. J., Thomsen, M., Wernberg, T., and Smale, D. A.: Socioeconomic impacts of marine heatwaves: Global issues and opportunities, Science, 374, eabj3593, https://doi.org/10.1126/science.abj3593, 2021.

Smith, K. E., Sen Gupta, A., Burrows, M. T., Filbee-Dexter, K., Hobday, A. J., Holbrook, N. J., Malan, N., Moore, P. J., Oliver, E. C. J., Thomsen, M. S., Wernberg, T., Zhao, Z., and Smale, D. A.: Ocean extremes as a stress test for marine ecosystems and society, Nat. Clim. Chang., 15, 231–235, https://doi.org/10.1038/s41558-025-02269-2, 2025.