CAREHeat

deteCtion and threAts of maRinE Heat waves

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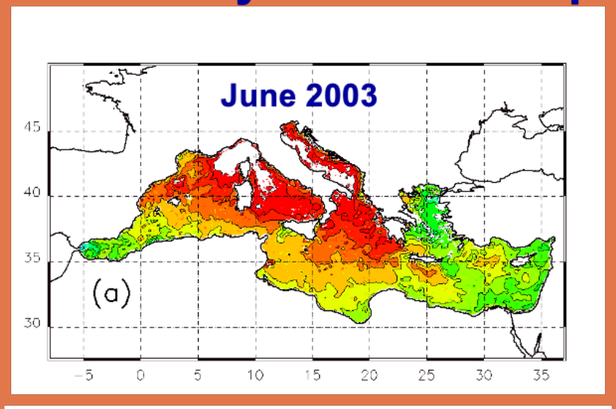
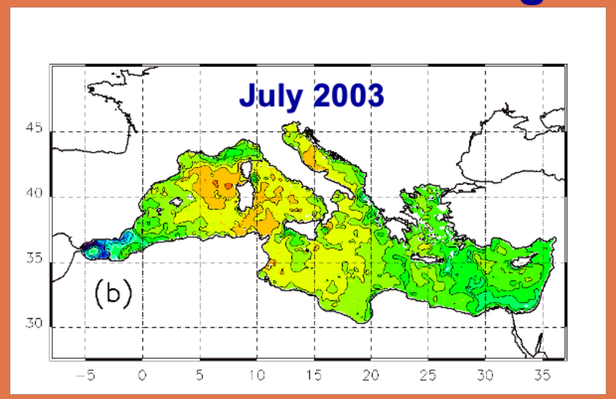
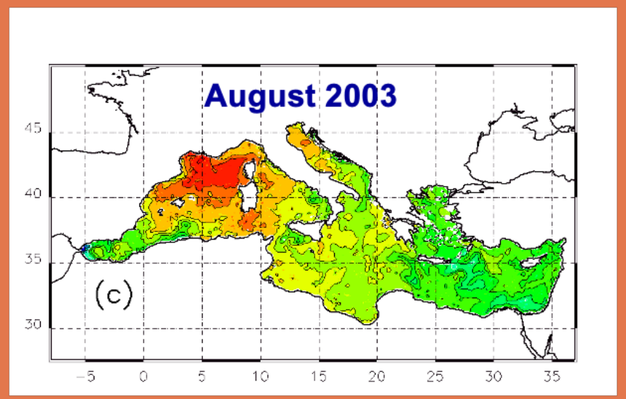
Marine Heath Waves (MHW)

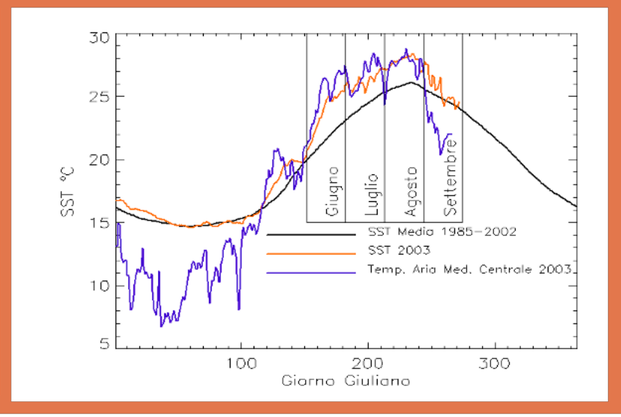
Definition: Abnormal warm seawater temperature events

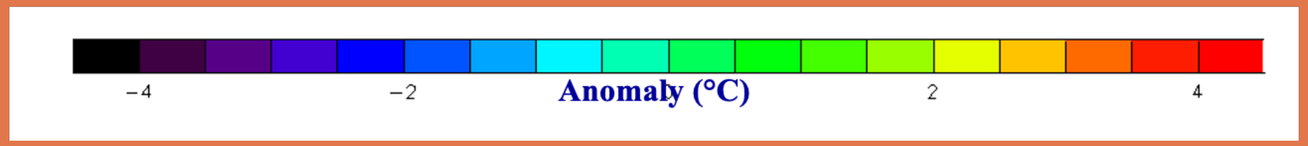
The warm summer of 2003 observed in NRT: SST anomaly 2003 with respect to 1985 – 2002 average











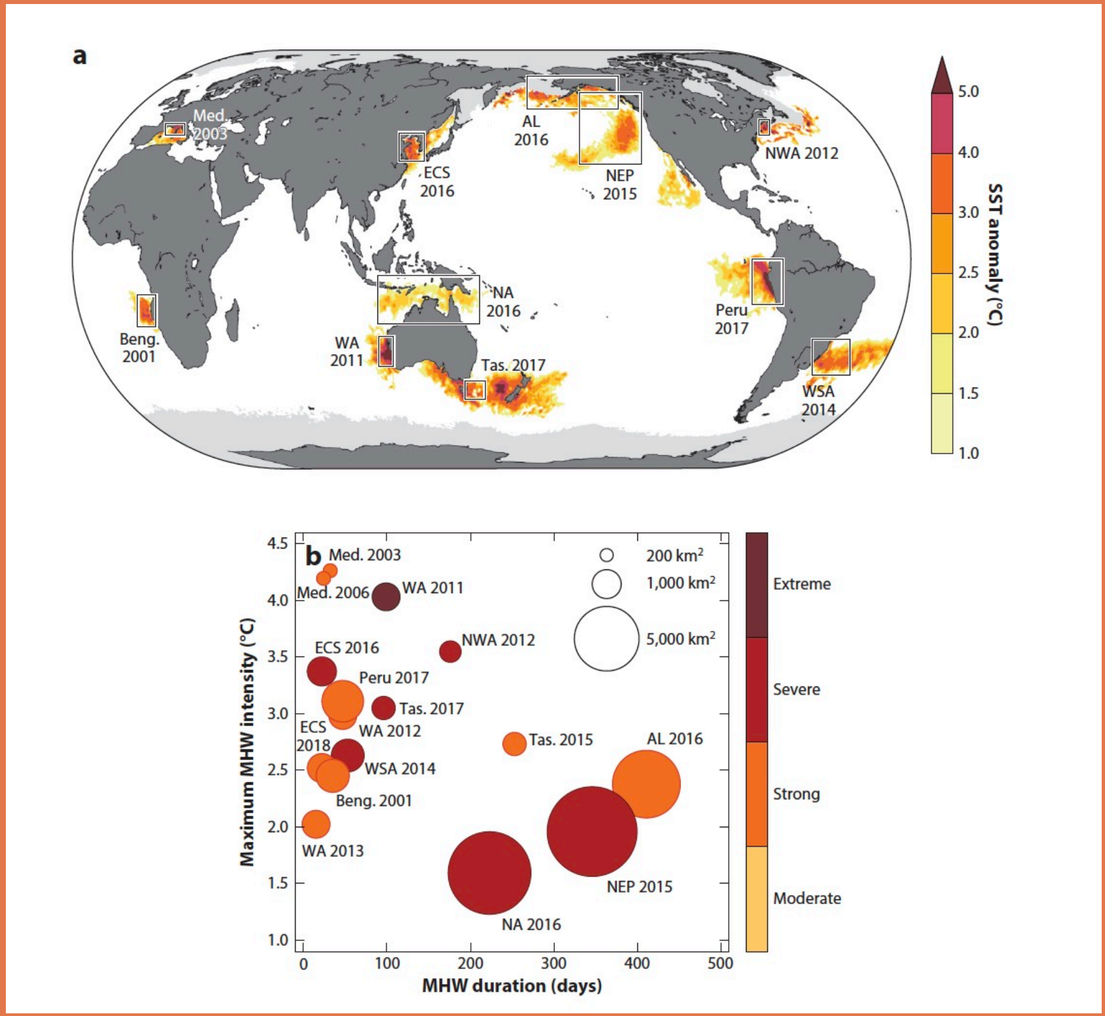
First evidence of MHW in Summer 2003 in NRT durng Summer 2003

SST 4-5 °C > climatology
2003 MHW lasting 2-3 months

From Marullo & Guarracino 2003

Marine Heath Waves (MHW)

frequently observed in any region of the ocean



From Oliver et al. Annu. Rev. Mar. Sci. 2021.

Prominent MHWs have been reported to have a devastating impact on marine ecosystems

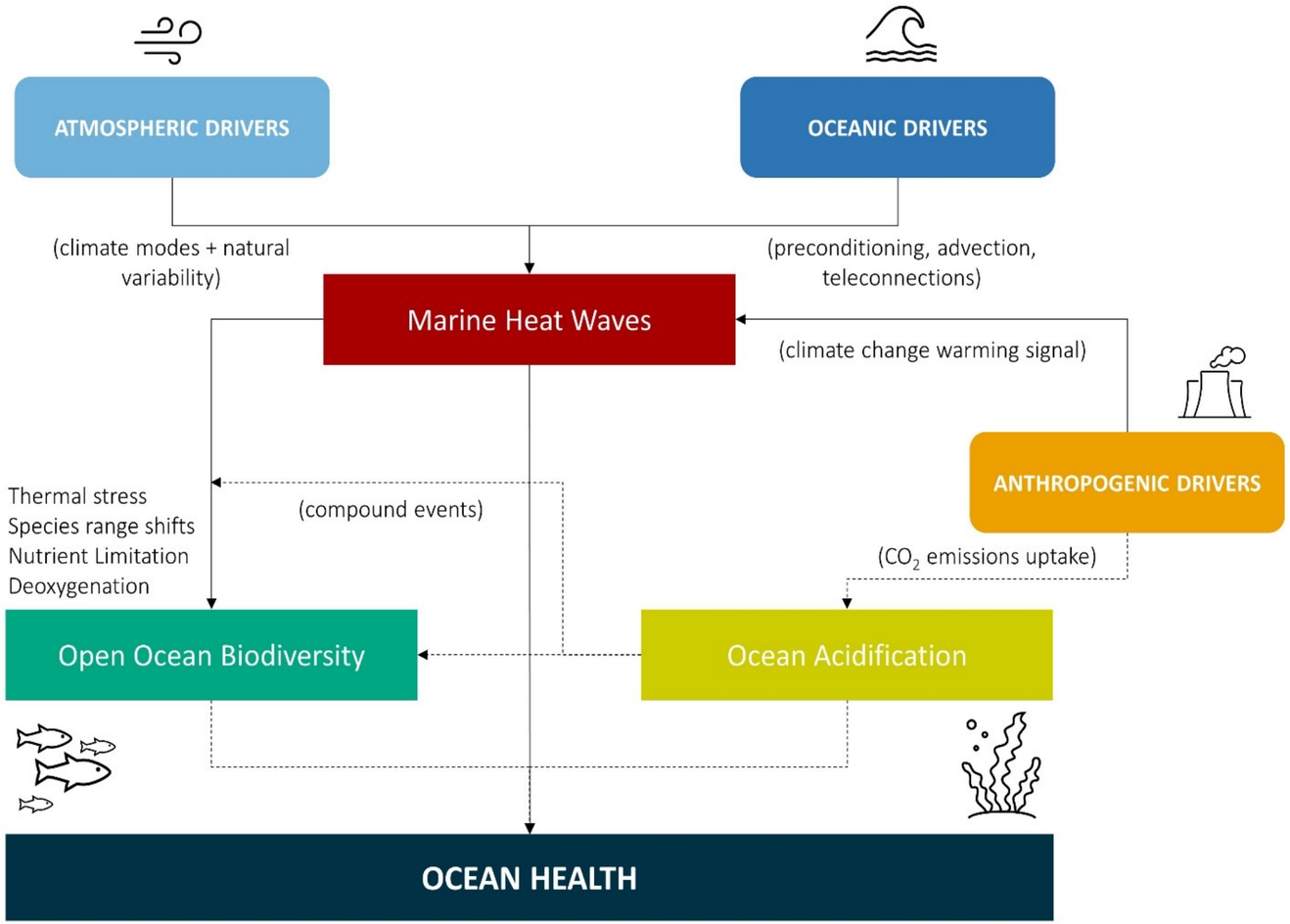
Marine Heath Waves (MHW) –
abnormal warm seawater temperature events –
THREATH living organisms and marine ecosystems and planetary health

More Frequent lately …. but **Many Unknowns**

Are MHW well identified? How frequent are MHW?
What are the Drivers and the Triggers of these extreme events ?
What are the Effects on Ecosystems and their Services?
Do they Co-Occur with other Hazardous events?

CAREHeat **AIM**

- IMPROVE current MHW **Detection** and **Characterization** methodology
- ADVANCE the understanding of the physical processes involved in **MHW Development**
- ASSESS MHW impact on marine **Ecosystems and Biogeochemistry**
- ASSESS the impact of MHW on **Ecosystem Services**



CAREHeat Project starting soon

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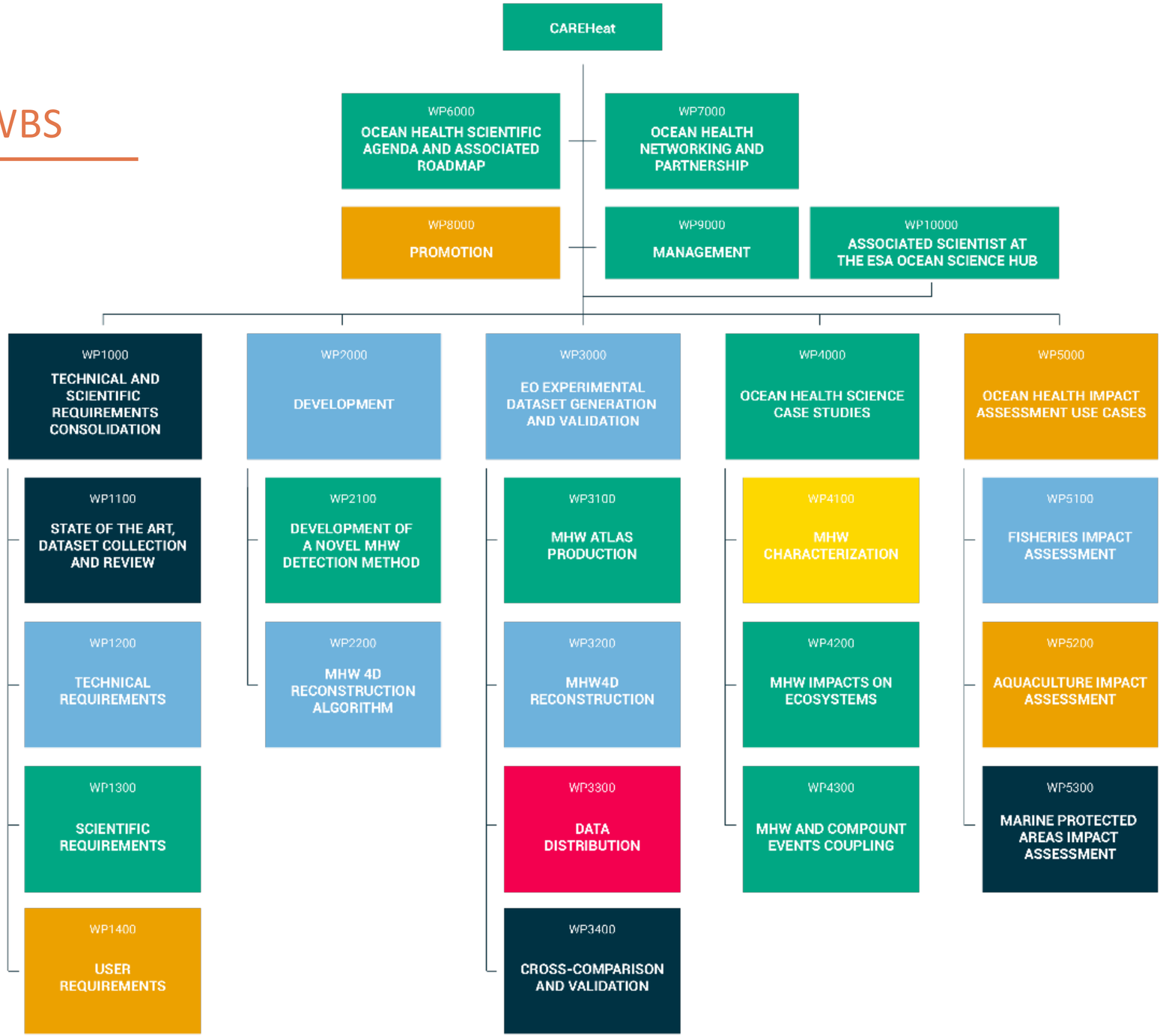
The CONSORTIUM & WBS



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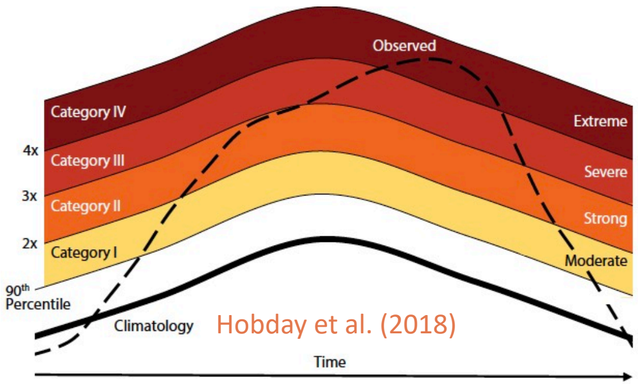
Improving the MHW detection method

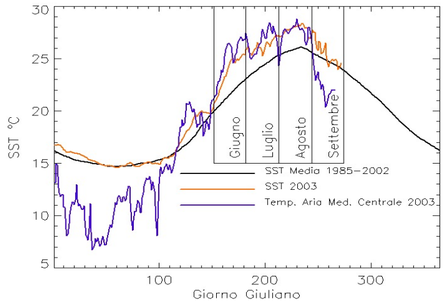
MHW detection

Widely used MHW detection method is Hobday et al. (2016). This method is based on local temperature anomalies exceeding a given climatology percentile threshold.



Hobday et al. (2018)

FIGURE 2. Categorization schematic for marine heatwaves (MHWs) showing the observed temperature time series (dashed line), the long-term regional climatology (bold line), and the 90th percentile climatology (thin line). Multiples of the 90th percentile difference (2× twice, 3× three times, etc.) from the mean climatology value define each of the categories I–IV, with corresponding descriptors from moderate to extreme. This example peaked as a Category IV (extreme) MHW.

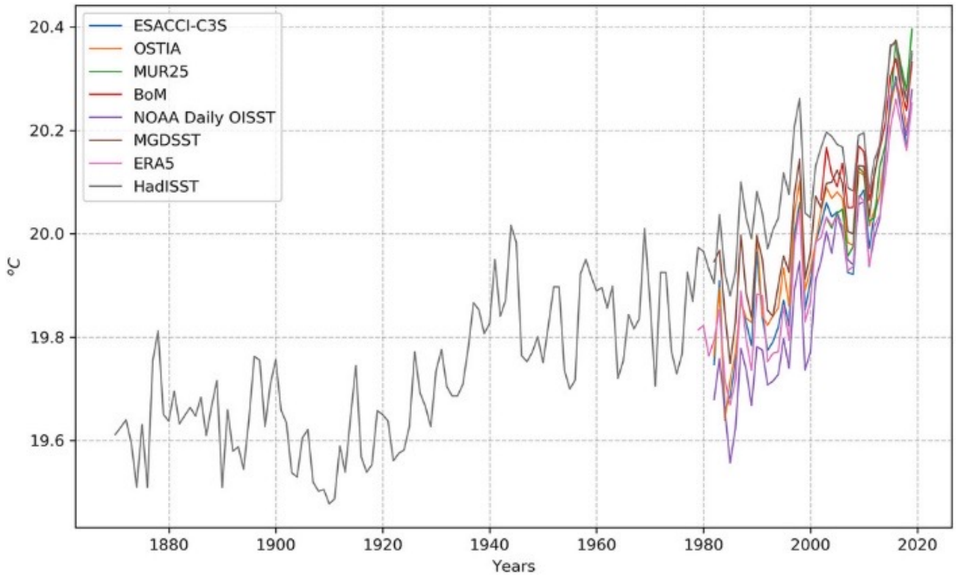


Marullo & Guarracino (2003)

Aims

What is the effect of SST trend on MHW detection?

What is the contribution of natural mode of variability?



Yang et al 2021: Global monthly mean SST time series for all the ensemble members for the whole covered period originally obtained in each SST product.

Method Improvements

- SST TRENDS and impact of CLIMATE MODES on the statistical thresholds at regional and global scale
- Sensitivity of MHW detection with respect to the baseline climatology definition (e.g., moving versus fixed climatology)
- Effects of DIURNAL WARMING
- Disentangling the main drivers of MHW development

Extensiive use of all available satellite datasets (

Validation

Novel MHW products will be compared with well-known MHW events

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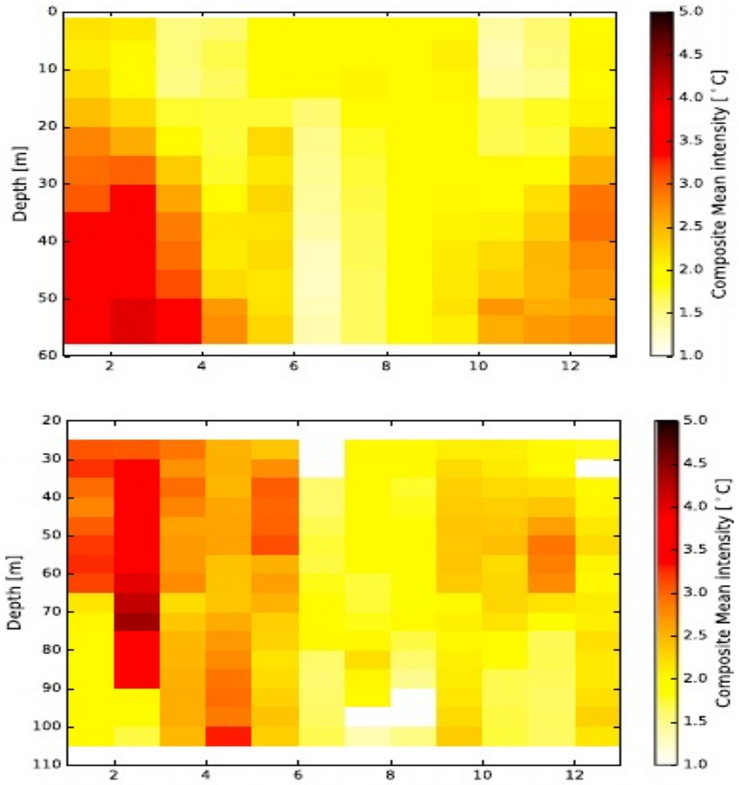
4D MHW reconstruction

Reconstructing the information related to MHW events in the subsurface of the ocean is crucial for our understanding of MHW and their impact on ecosystems.

- Over the last 30 years, extremely hot sea surface temperatures (SSTs) have become more common in one third of the world's coastal areas ([Lima and Wethey, 2012]
- Different studies demonstrated an intensification of MHW at depth as well as a deeper penetration of the signal (e.g. Schaeffer and Roughan, 2017).
- The characteristics of subsurface events can differ from the ones at the surface: Darmaraki & al (2019) shown that in the MED Sea, subsurface events are seasonally shifted and appear, on average, longer and more intense but less frequent and less extended in space than surface MHW
- The propagation of surface events to depth can strongly impact benthic organisms and ecosystems => In response to the unusual thermal stress, marine communities have to either acclimatize or track more suitable habitat farther poleward or deeper. This includes shallow communities and benthic species, coral communities and seaweed below the surface mixed layer. Habitat-forming species are dying and are not able to recover after the MHW has subsided (Wernberg et al.,2016)

MHW intensity as a function of depth– 2 sites along the Australian coast



Schaeffer and Roughan, 2017

Unfortunately, little is known about temperature extremes at depth due to the lack of long-term in situ measurements.

CAREHeat: better characterize the subsurface MHW events through the reconstruction of a dedicated 4D MHW dataset

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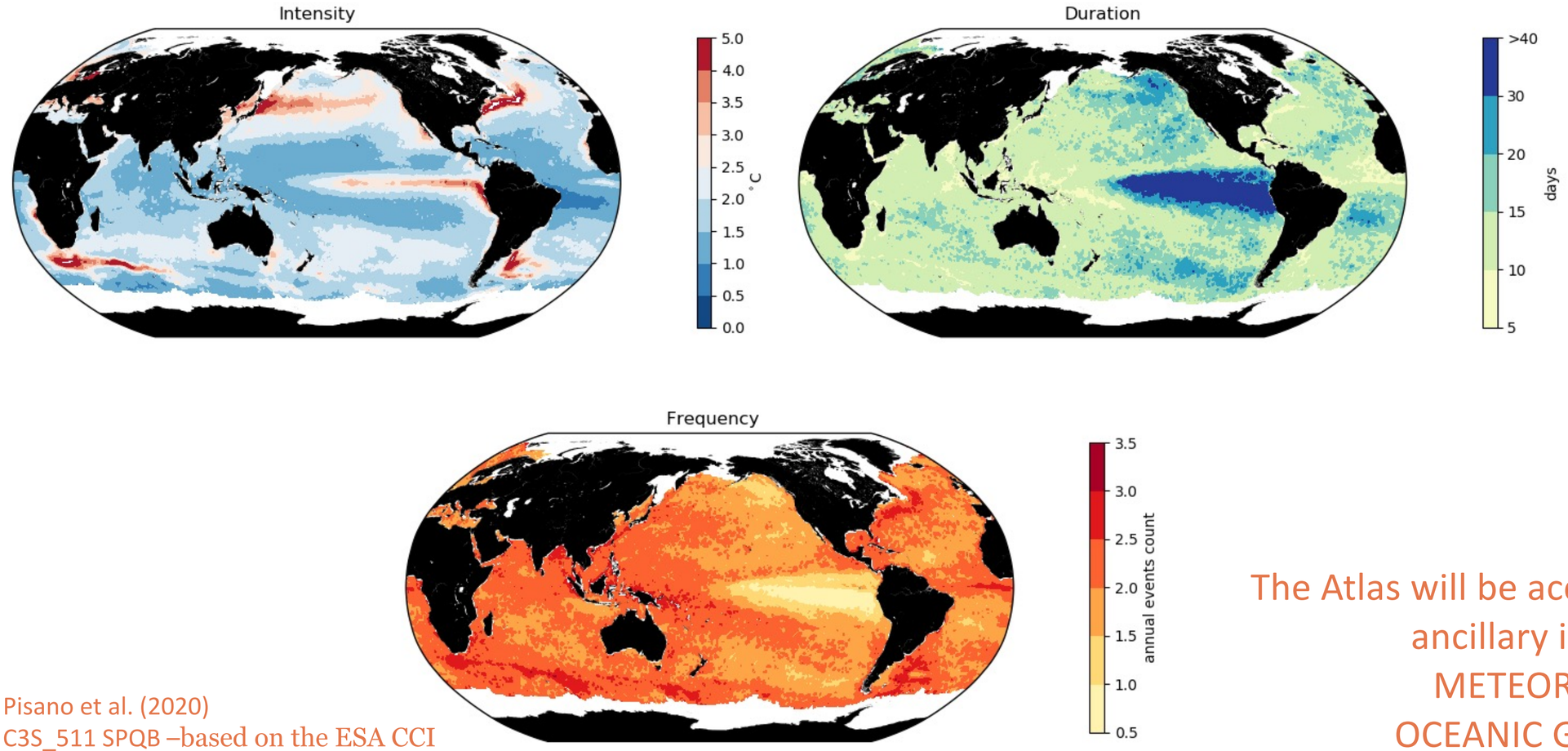
MHW Surface Global Atlas

Improved methodology will be use to produce a new MHW Atlas covering the satellite era (> 10 years)

Spatial distribution of average properties of MHW
C3S_511



Pisano et al. (2020)
C3S_511 SPQB –based on the ESA CCI SST Level-4 dataset v2.0
Detection with current methodology applied to ESA CCI SST Level-4 dataset (v2.0)

The Atlas will be accompanied by a list of ancillary information:
METEOROLOGICAL
OCEANIC GEOPHYSICAL
BIOLOGICAL

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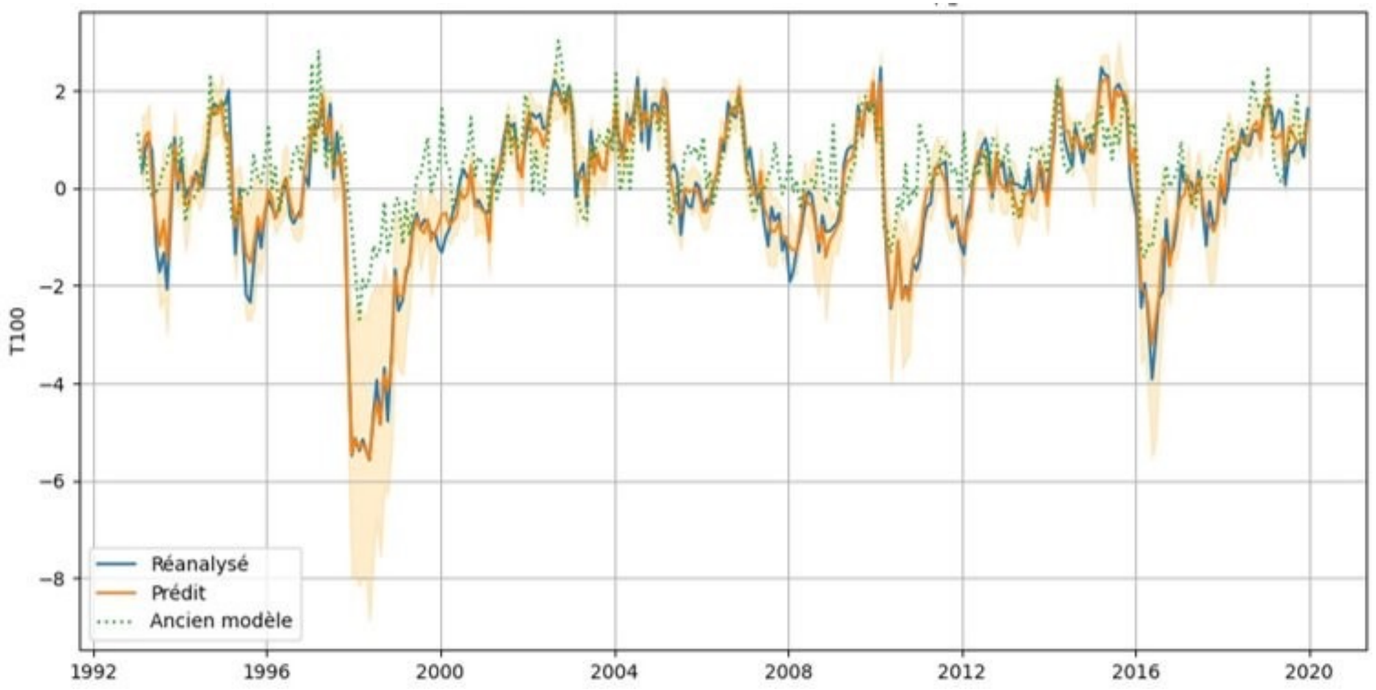
4D time series reconstruction

Optimize the AI approach to reconstruct Marine Heatwaves (MHW) in the subsurface for past events over a recent 10-year period

Output 4D

A 4D MHW dataset for several areas of interest



Random Forest model at 0°N – 180°E

Schaeffer and Roughan, 2017

Optimization

Choose the right oceanic and atmospheric predictors to reconstruct the 4D field & prepare these data (detrending, denoising (e.g.: EOFs, interpolation, …).

This task relies on the preliminary study about the MHW drivers.

Target some MHW events (based on MHW Atlas computed) on test sites to guide this optimization

Select the best performant supervised ML-based approach (Random Forest (RF) or Neural Network(NN), other...) to reach the target. Iterative tests.

Validation

In situ data are the truth. Independent reference observations

The estimation of MHW requires time series, so moorings will be preferred

Intercomparison with other subsurface temperature products (dynamic models, CMEMS), statistical models based on combined earth observations such as ARMOR3D (Guinehut et al., 2012), other reconstructed products with ML approach if available on the test sites (Buongiorno Nardelli, 2020)

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Drivers and precursors of MHW

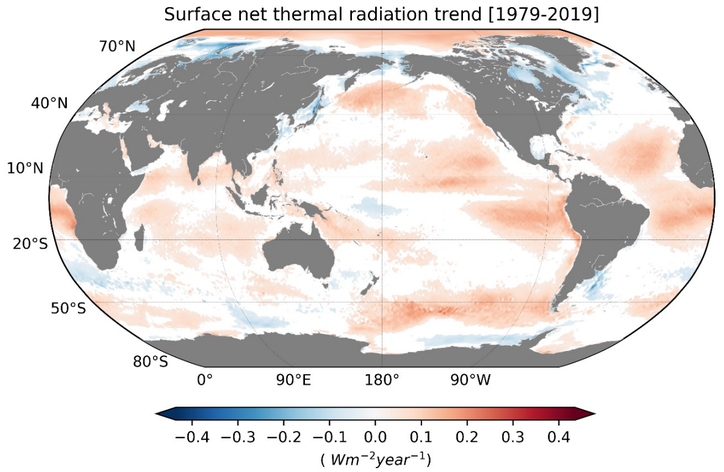
CHARACTERIZE MHW variability, **drivers and precursors** that are responsible for MHW occurrence and evolution

Strategy

- Evaluate global 10 year time and space variability of MHW
- Investigate via statistical tools the relationships between MHW events and key oceanic and atmospheric variables

Validation

Exploit ocean model analysis and reanalysis to investigate (e.g., using tools for advanced time series analysis) the effects of forcing and eligible precursors occurring during observed MHW events



MHW impact on biodiversity and biogeochemistry

Assess the IMPACT of MHW on marine **biodiversity** and **biogeochemistry** along the water column

Strategy

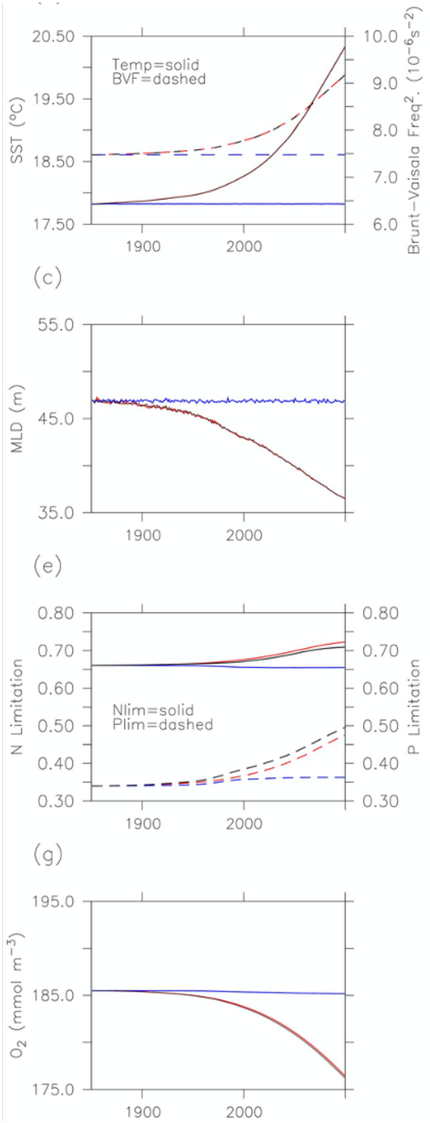
- Use MHW4D products
- Assess EFFECTS of MHW during and after the event
- Exploit synergies between Ocean Colour satellite observations, BGC-Argo floats and biogeochemical models
- Capitalize on open carbon products (e.g., C_{phyto} and POC) within the ESA Ocean Science Cluster

Key questions to address

1. How MHW impact on Chl concentration?
2. Do biomass or physiology affect Chl changes?
3. Impact on phytoplankton community structure?
4. Impact on ocean biogeochemistry - nutrients and oxygen?
5. Impact on higher trophic levels?
6. Impact and sensitivity on pH and air-sea CO_2 fluxes during MHW events?

MHW and compound events

IDENTIFY **compound events and** ASSESS impacts and links with oceanic biological productivity



Strategy

- Use MHW4D products
-Identify the co-occurrence of MHW with extreme anomalies in CMEMS-biogeochemical model output

Key questions to address

1. Identification and Frequency of compound events
2. Identify cumulative impact on ocean productivity
3. Identify positive feedbacks driving compound events

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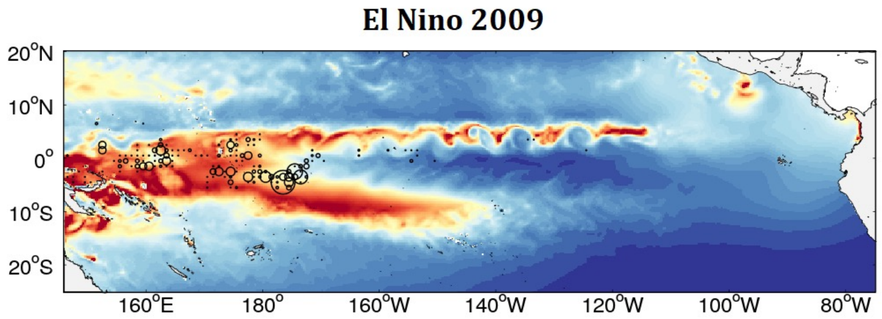
Fisheries

Two species of tropical Tunas

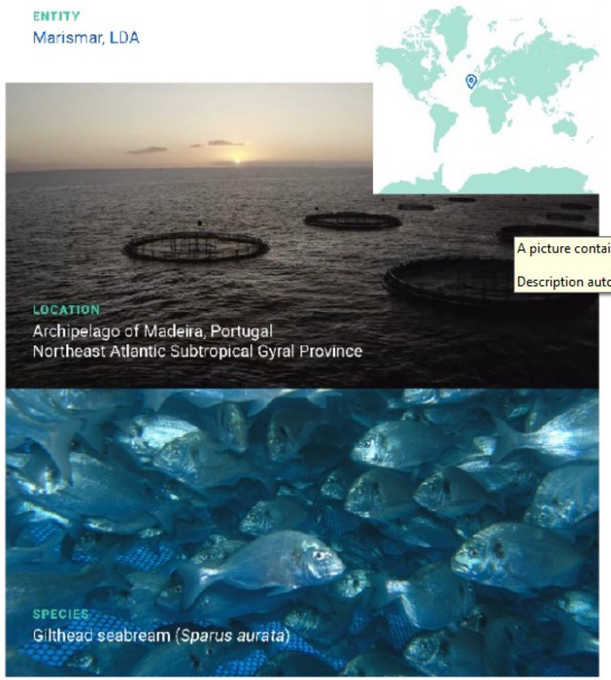
Evaluate short-term impacts of MHW on larvae, juveniles, immature and mature tunas

Evaluate long-term impacts of MHW on tuna recruitment



Density distribution of biomass for tunas as predicted by the model SEAPODYM

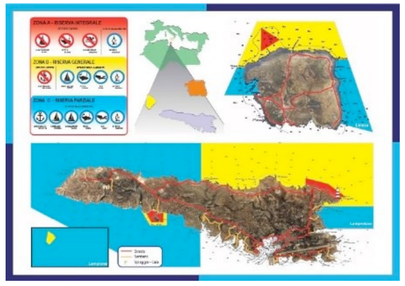
Aquaculture



Assess how two economically important marine species (Sea Breams and Sugar Kelp), from different trophic levels respond to acute thermal stress during events of MHW, in Portugal and Norway. Analysis of impacts on life cycle and mortality, distribution and productivity

Marine Protected Areas

MPA Isole Pelagie (Lampedusa)



Corals

Sea urchins

Marine birds

Assess MHW impact on fertility and reproduction, nesting, mortality, and behaviour

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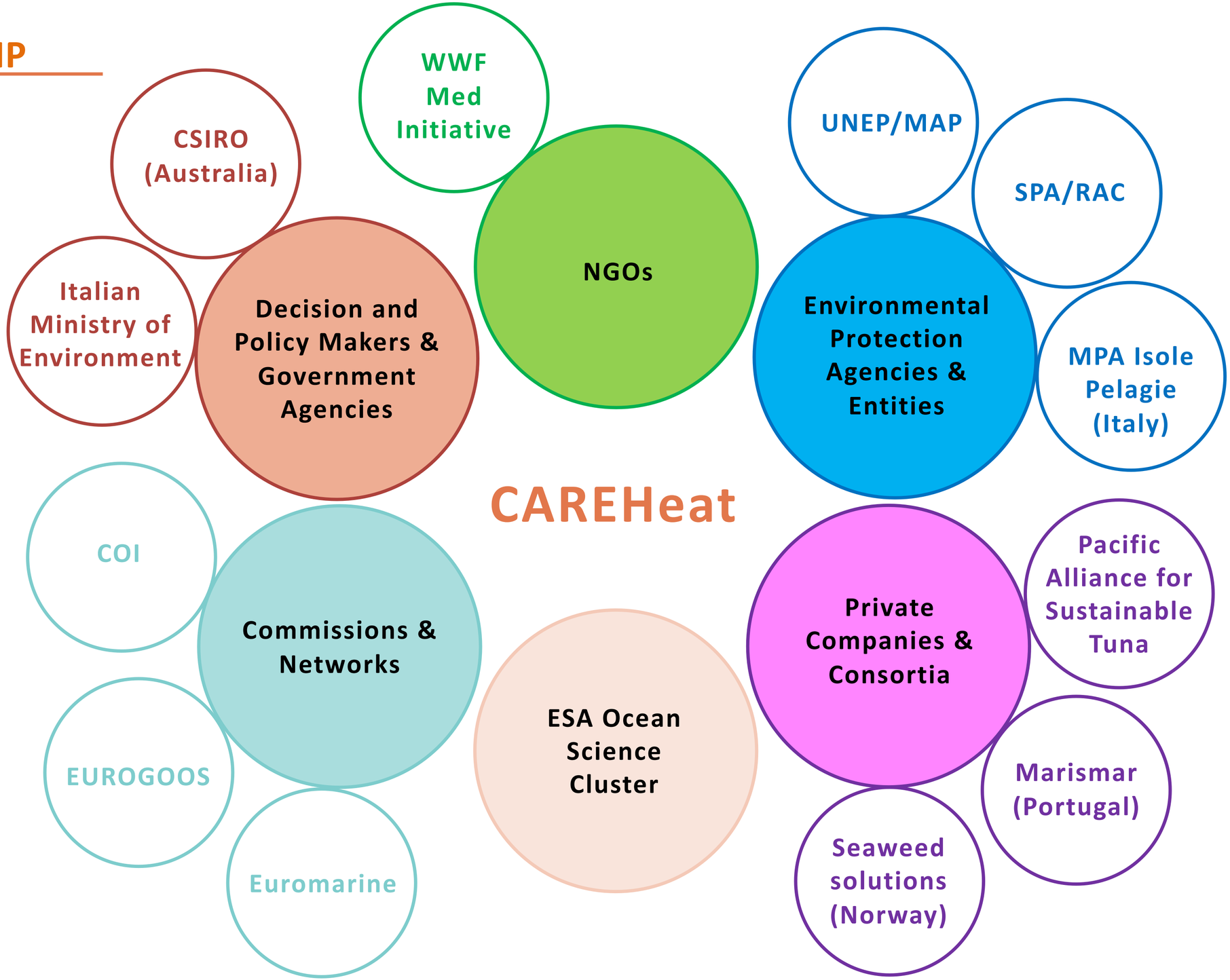
PARTNERSHIP

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Thanks for your attention
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