IH cantabria
INSTITUTO DE HIDRÁULICA AMBIENTAL
UNIVERSIDAD DE CANTABRIA
I+D+i PARA UN DESARROLLO SOSTENIBLE

3rd International Workshop on
Waves, Storm Surges, and Coastal Hazards

A global assessment of the projected changes in wave climate from wind-wave directional spectra

Hector Lobeto[1] (lobetoh@unican.es), Melisa Menendez[1], Iñigo J. Losada[1], Mark Hemer[2]

[1]Instituto de Hidráulica Ambiental de la Universidad de Cantabria (IHCantabria)
[2]CSIRO Oceans and Atmosphere, Hobart, TAS, Australia

Summary

- ❑ Introduction
- ❑ Wave climate data
- ❑ Added value of directional spectra
- ❑ Global assessment of wave climate projected changes
- ❑ Conclusions

How is the effect of climate change on wind waves assessed?

Assessment of the **projected changes** in different wave climate indicators.

1. Integrated wave parameters { H_s, T_p, T_m, Dir_m } e.g., Mori et al., 2013, Hemer et al., 2013, Semedo et al., 2013, Lemos et al., 2019, Casas-Prat et al., 2018, Morim et al., 2018, 2019, 2020

Standard approach

2. Projected changes in variables that integrate several parameters: e.g. energy flux (e.g., Mentaschi et al., 2017, Reguero et al., 2020, Lemos et al., 2020)

3. Projected changes in **wave partitions**: Swells and sea components (Lemos et al., 2021, Amores & Marcos, 2020, Fan et al., 2014)

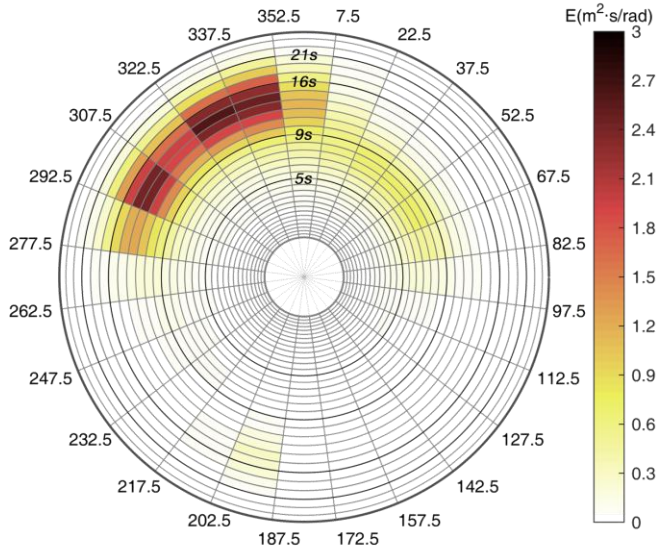
What is the most complete way to describe the wave climate?

The frequency-direction wave spectra fully characterizes the wave climate at a certain location.

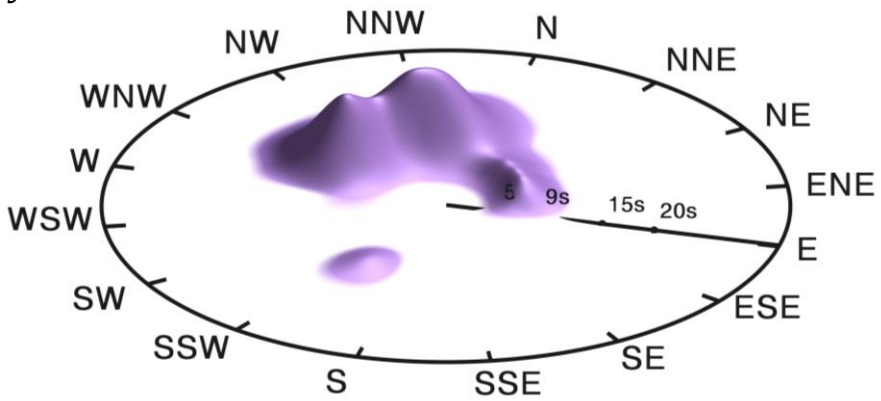
- Storage demand affordable
- Global information available

Introduction

- At any point on the ocean surface, the wave field results from the **superpoistion of wave systems** of different characteristics.
- The future **behavior** of **wave systems** with a different origin under **climate change** scenarios is expected to be **different**.
- **Multimodal** wave climates are frequent in **tropical** latitudes.
- Integrated wave **parameters** cannot describe wave system **individual changes**.



Mean spectrum – South Canary Islands

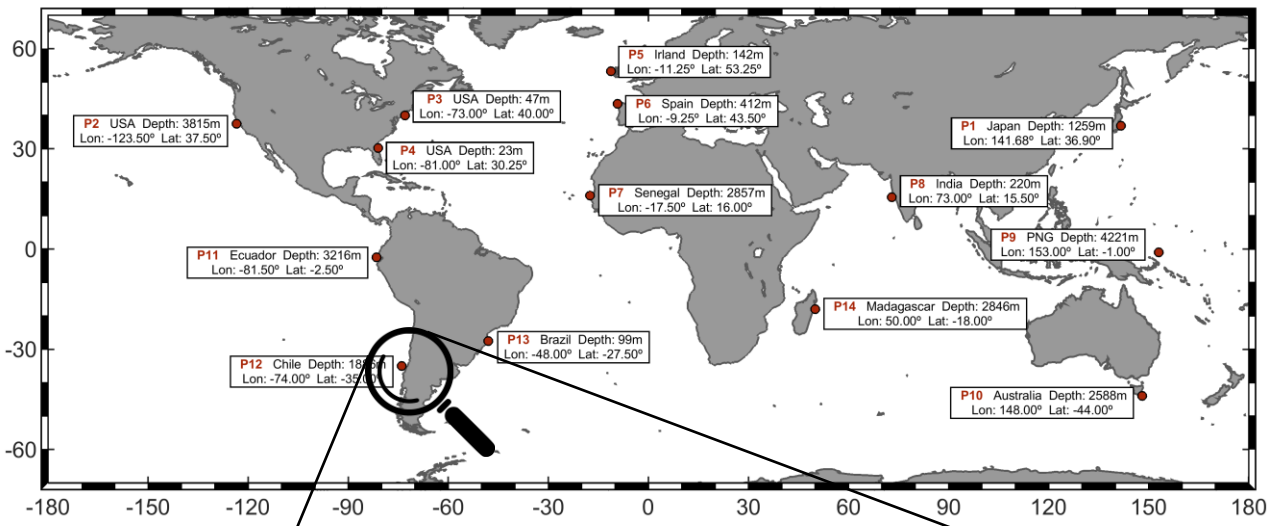


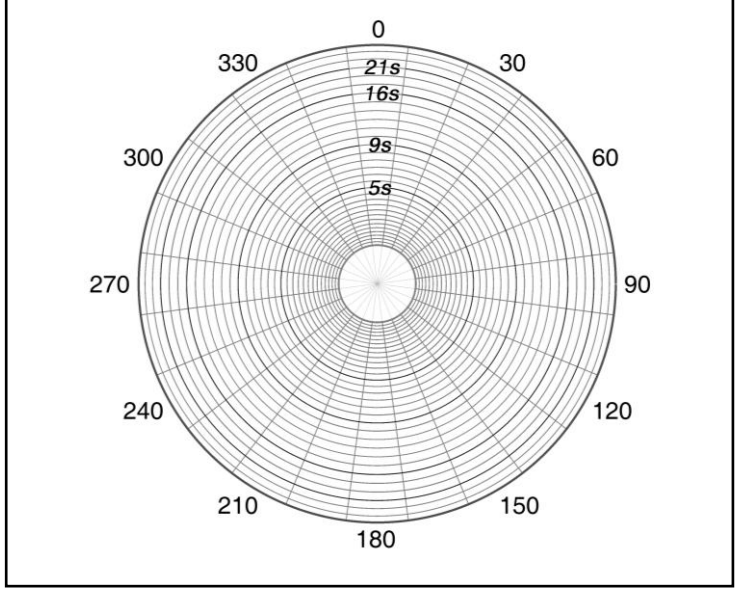
Main goals:

- Assess the added value of directional spectra to analyze the effect of climate change on wind waves.
- Assess the projected changes in wave climate from directional spectra globally.

Wave climate data

- Global wave climate projection ensemble of **seven members**
- Future GHG emission scenario: **RCP8.5**
- Present-day reference period: **1986-2005**
- Projected period: **2081-2100**

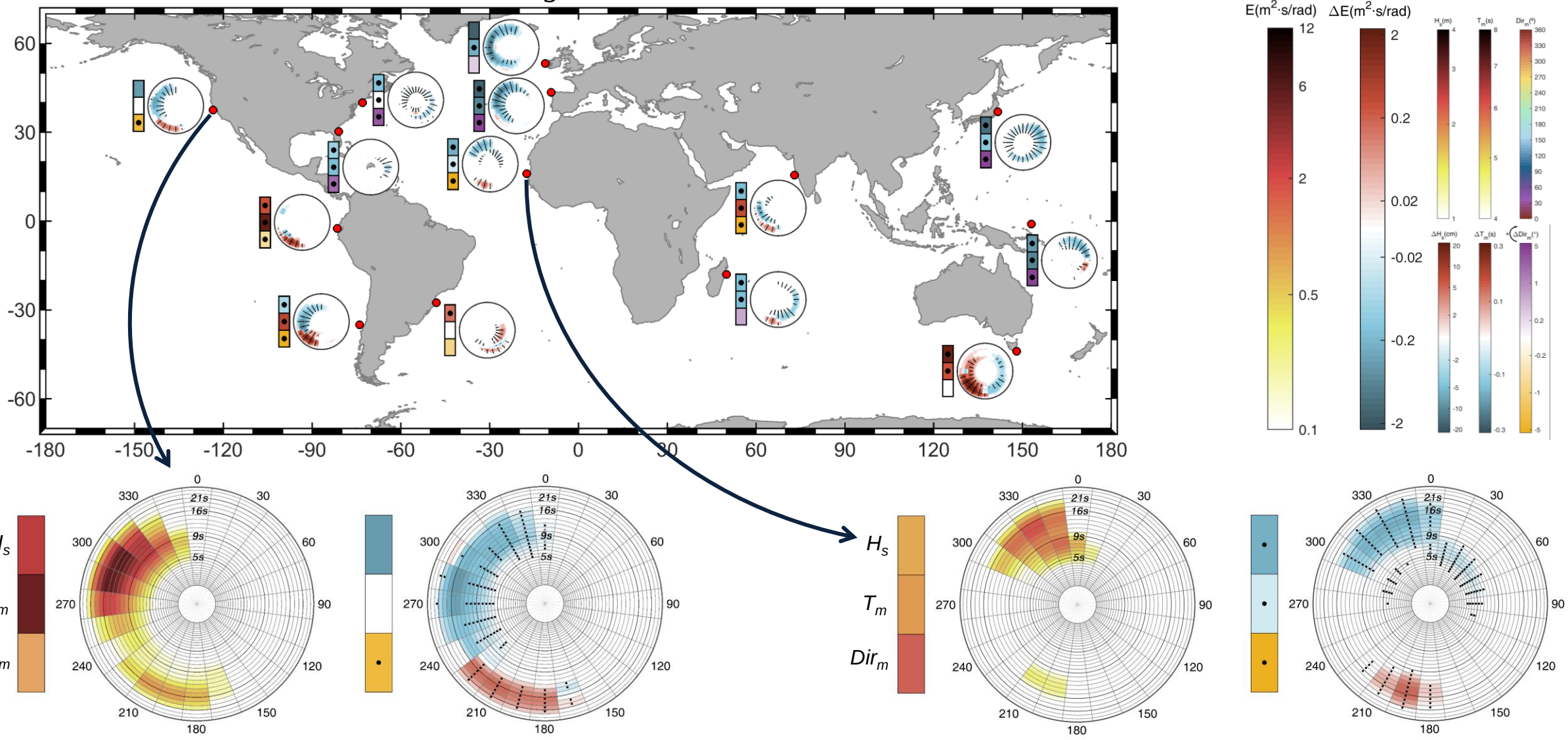




- Outputs:
  - **Spectral wave data**
    - **Full directional spectra** at 14 locations (map).
    32 frequencies x 24 directions
    Hourly time series
    - **Spectral partitions**: 2 swells + 1 wind sea
    1-degree global resolution
    3-Hourly time series
  - **Integrated wave parameters**: H_s, T_m, Dir_m
    Hourly time series

Added value of directional spectra

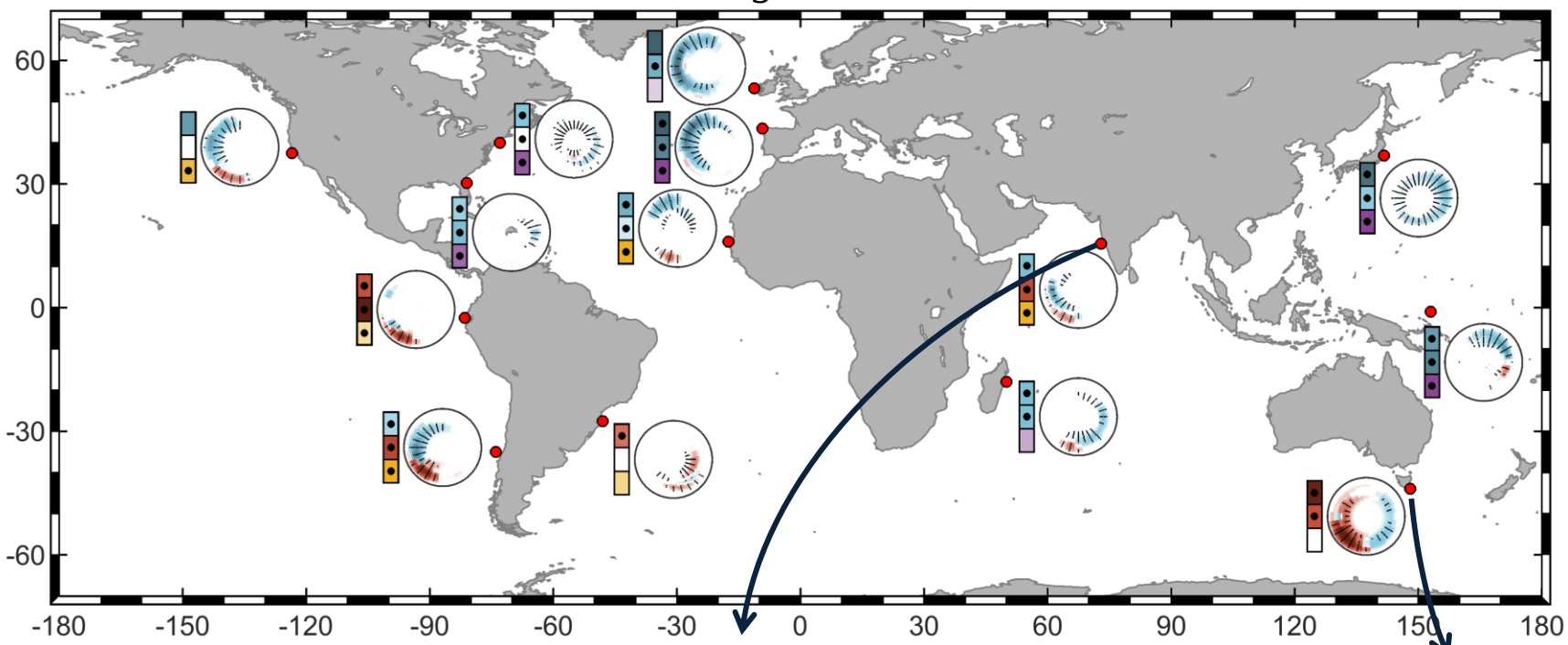
Ensemble mean change under RCP8.5 scenario

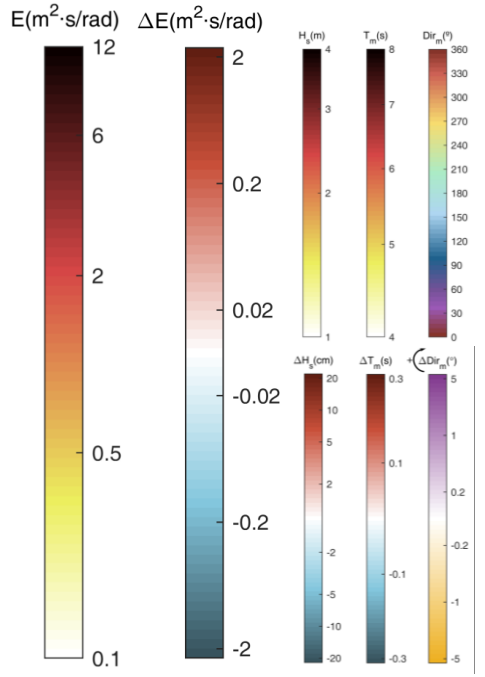


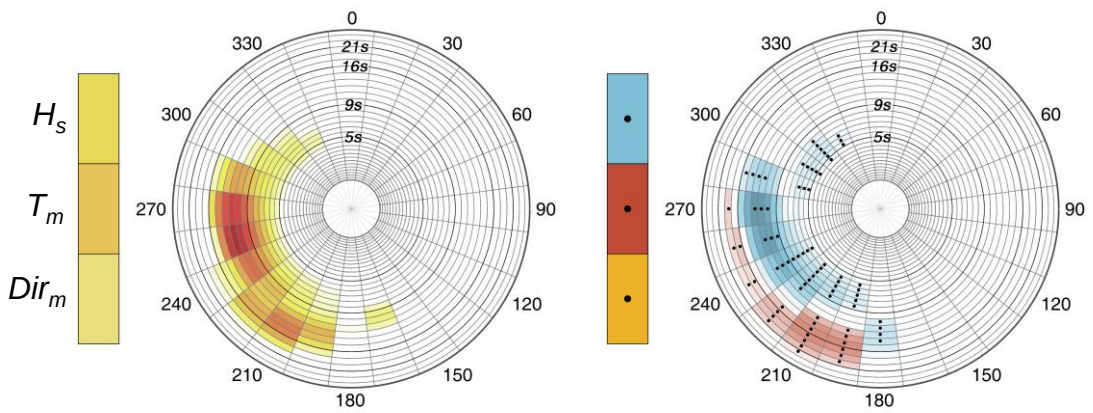
Lobeto et al. (2021).

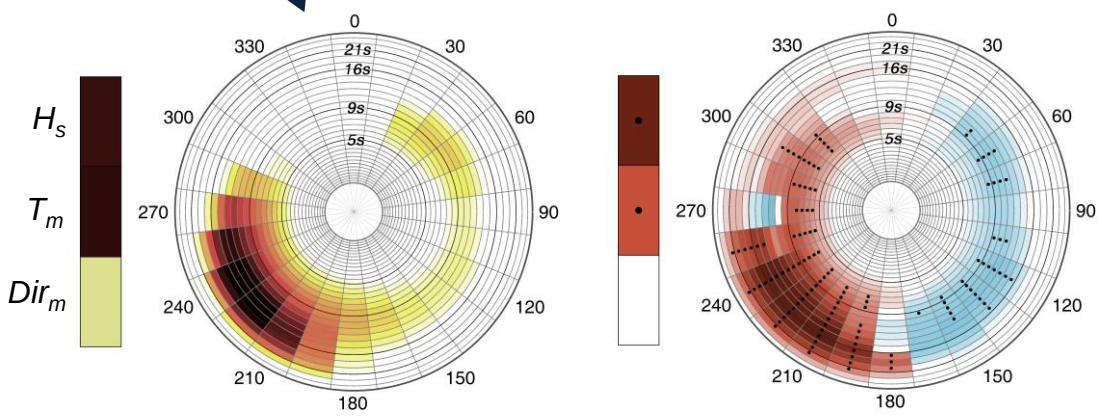
Added value of directional spectra

Ensemble mean change under RCP8.5 scenario





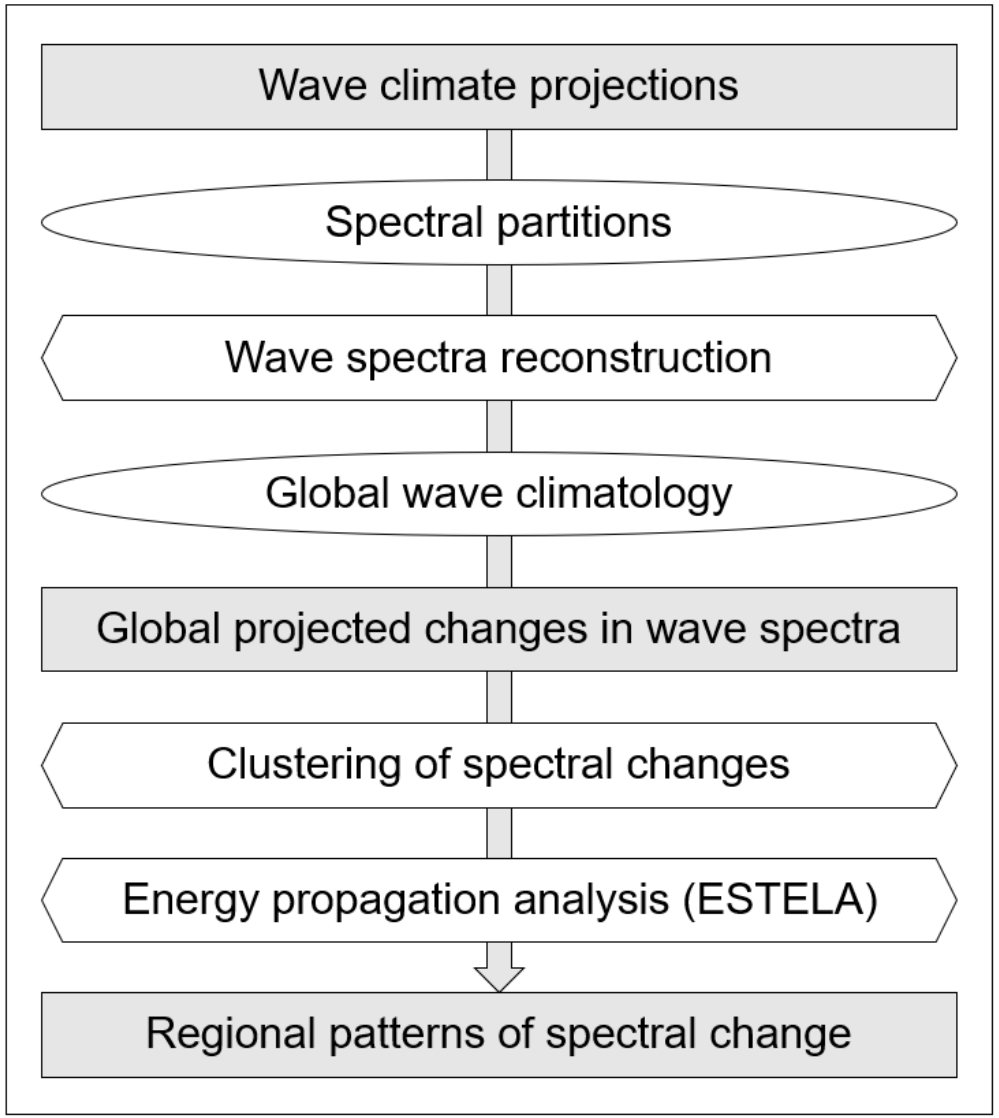




Lobeto et al. (2021).

Global projected changes

Methodology overview



Lobeto et al. (2022).

Global projected changes

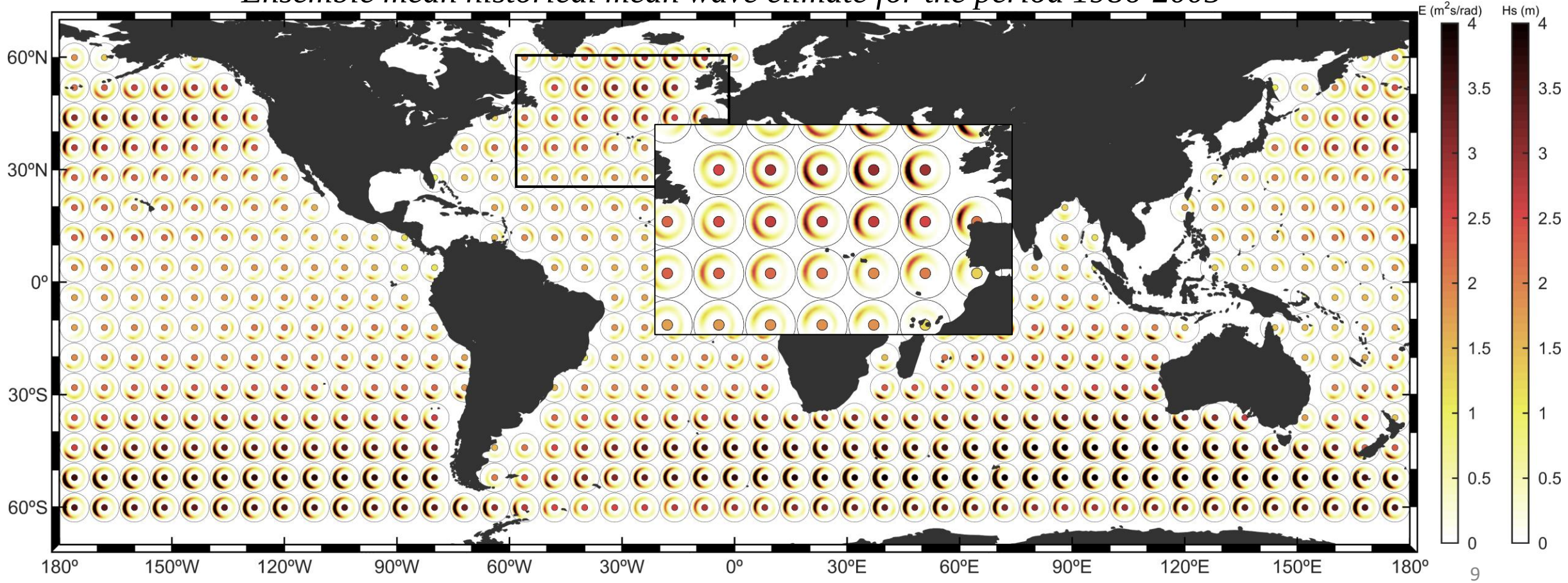
Spectral partitions
Hs_i, Tp_i, Dir_i, Spr_i

Spectrum reconstruction

JONSWAP (γ = 3.3) + Mitsuyasu

Full directional spectra (24x32)
8-degree resolution

Ensemble mean historical mean wave climate for the period 1986-2005

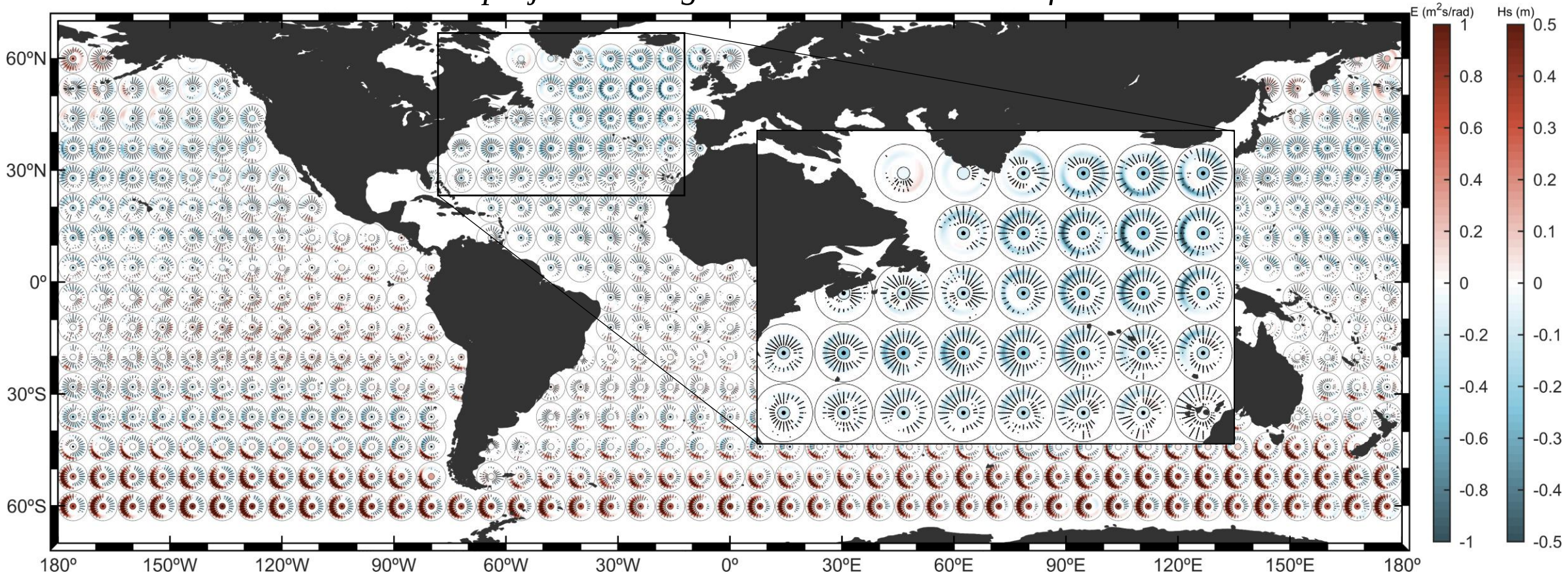


Lobeto et al. (2022).

Global projected changes

- **Projected changes** in wave climate from directional spectra (***future – historical***)
- Projected change **robustness**: 50% models statistically robust change + 80% models agree sign of change

Ensemble mean projeced changes in mean wave climate for RCP8.5

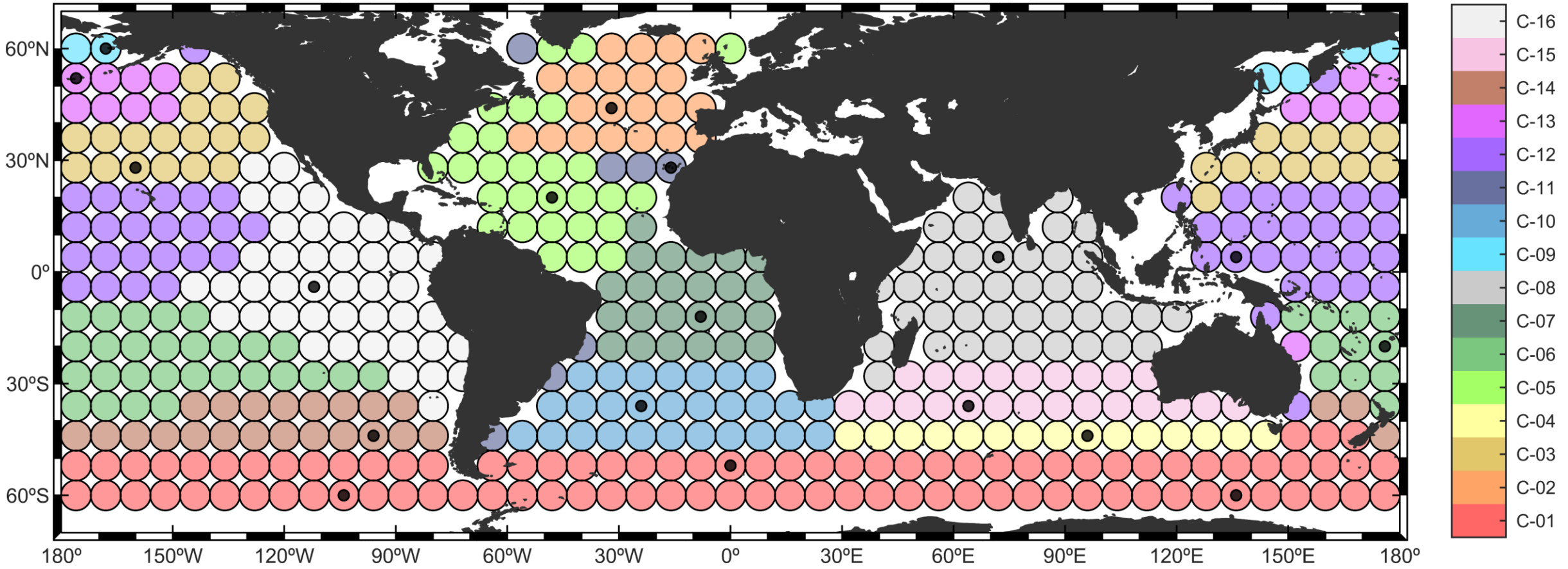


Lobeto et al. (2022).

Global projected changes

- **Clustering** of spectral changes → Selected clustering technique: **k-means**
- Sixteen patterns of spectral change

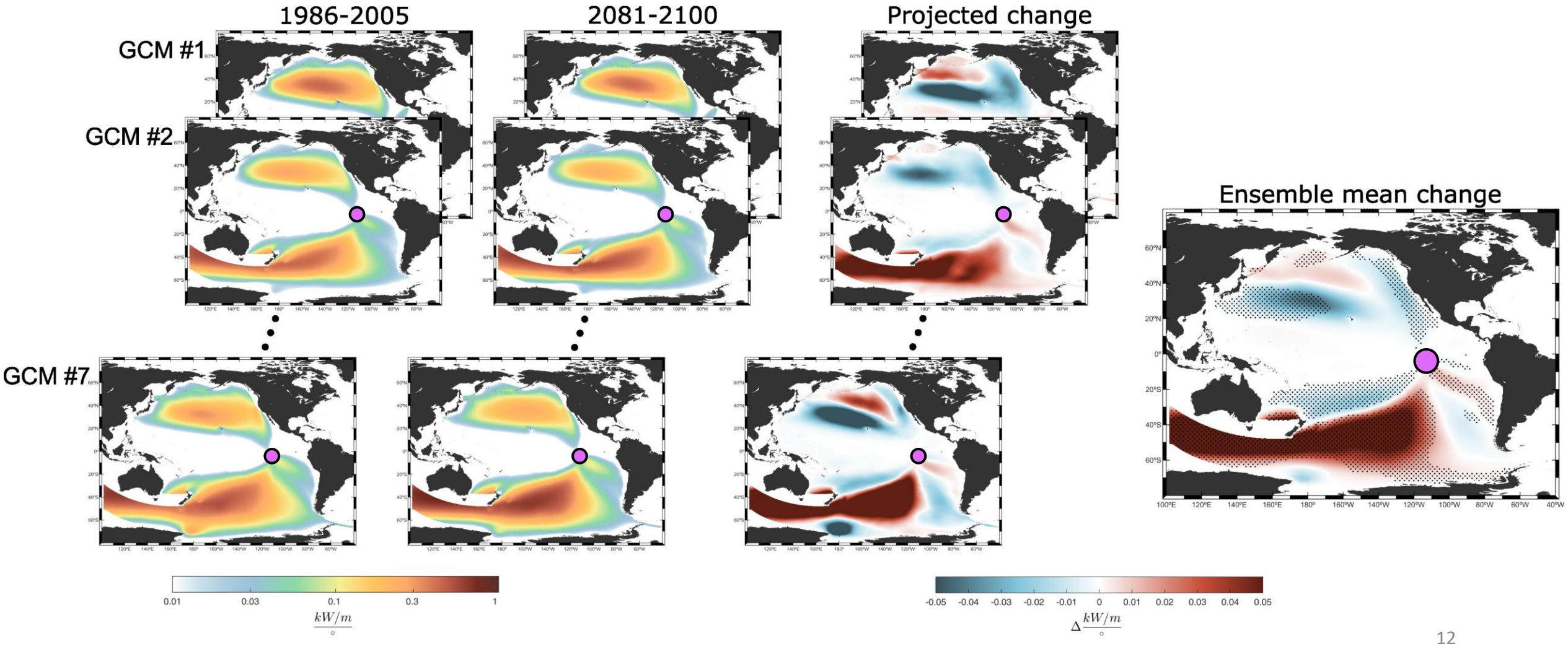
Regional patterns of spectral change



Lobeto et al. (2022).

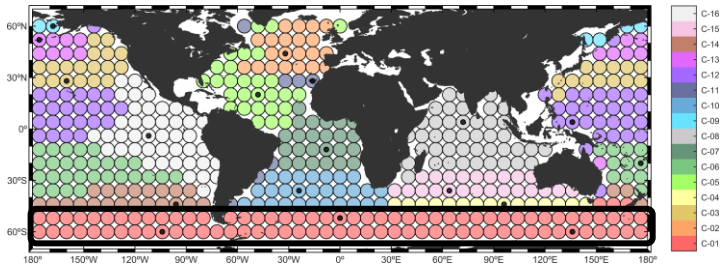
Global projected changes

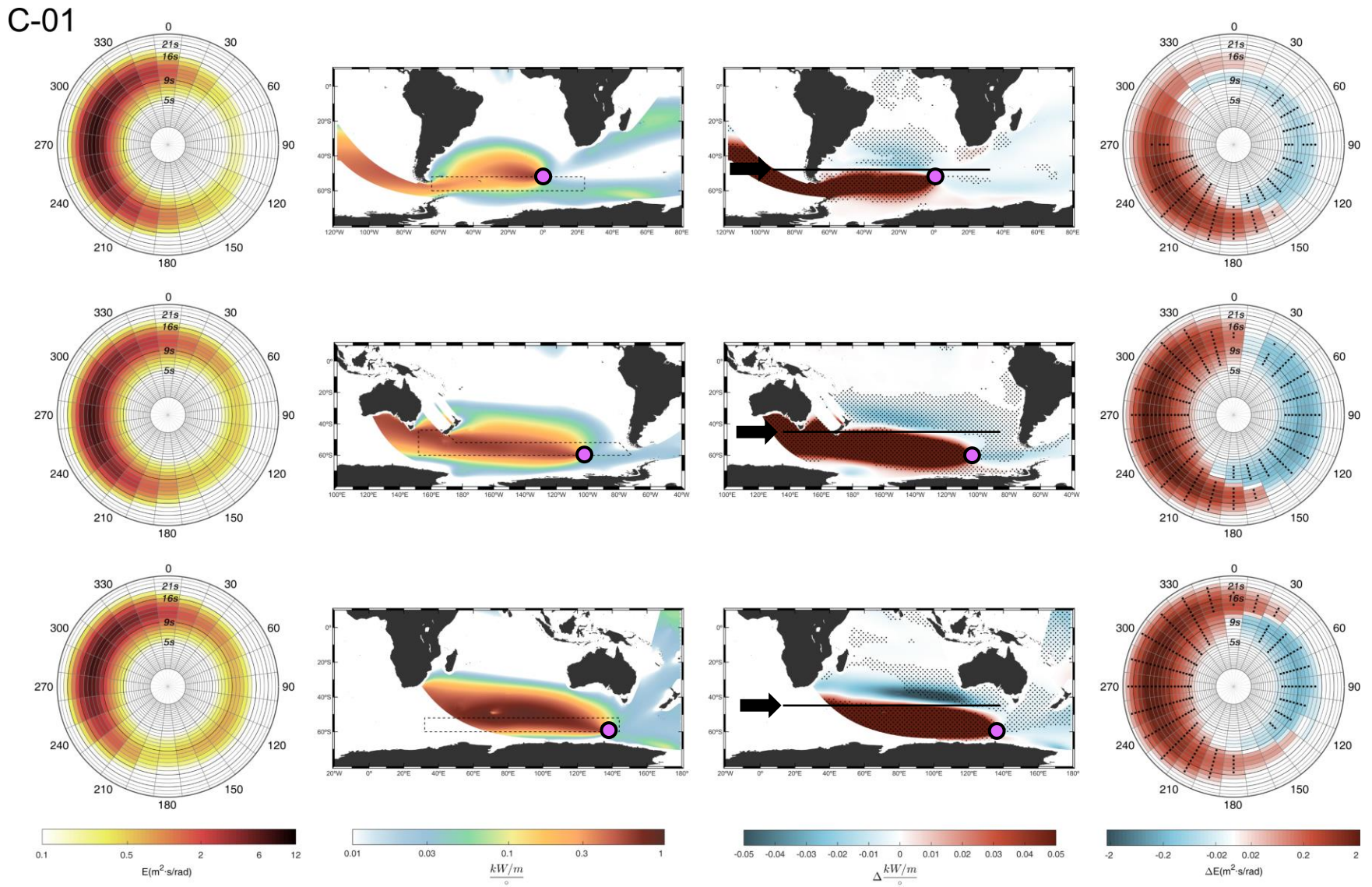
- Analysis of the **wave energy** propagating (Perez et al., 2014) toward the centroid of each identified cluster
- Assessment of the **projected change in wave energy** to complement the spectral analysis



Lobeto et al. (2022).

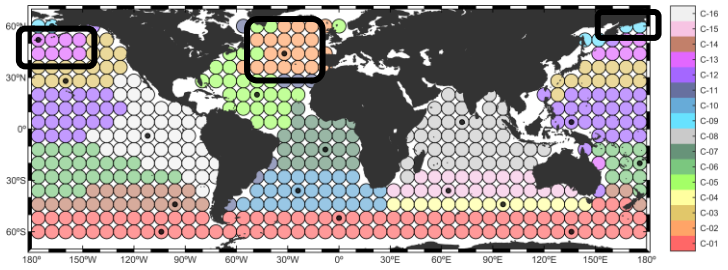
Global projected changes

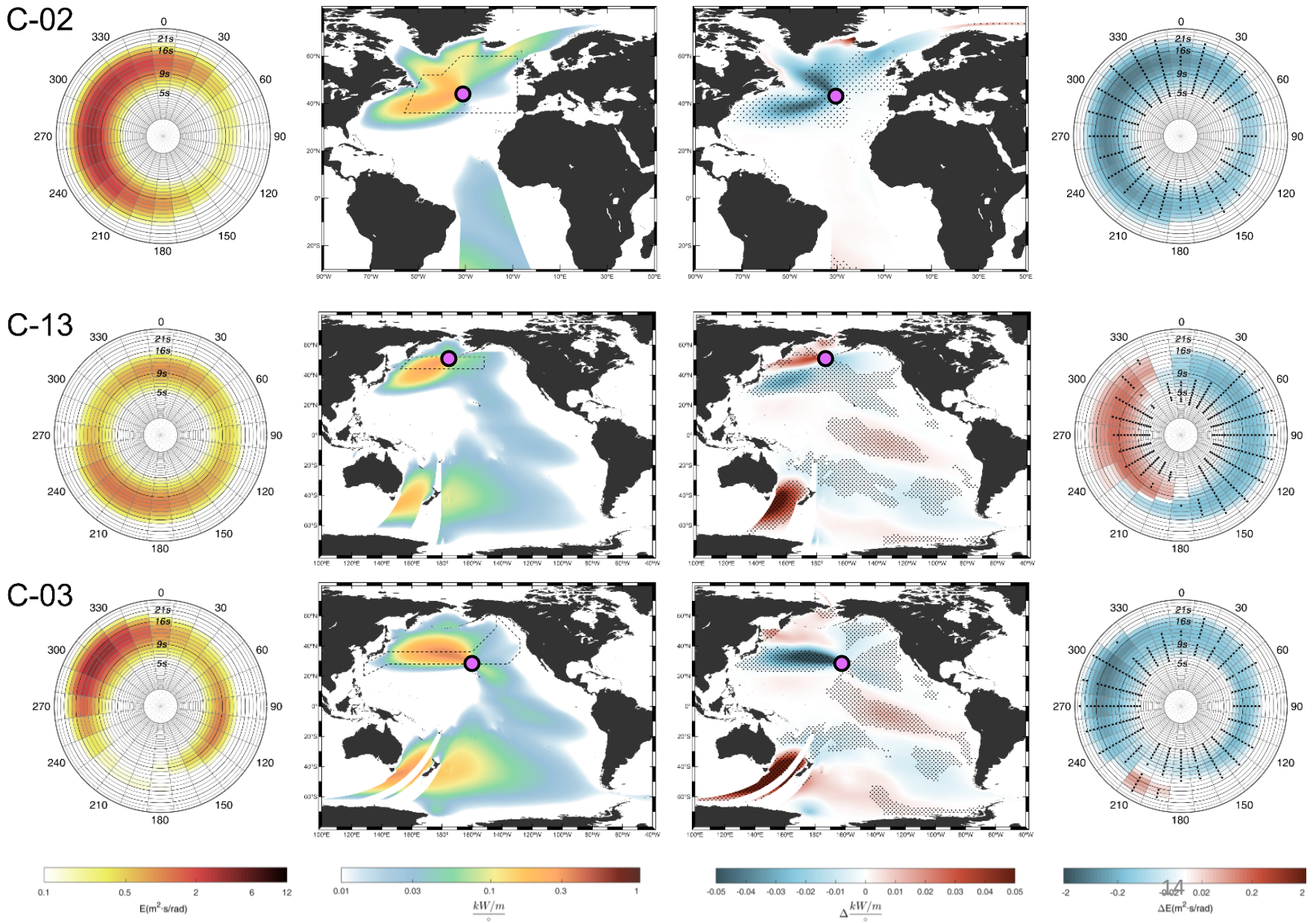




Lobeto et al. (2022).

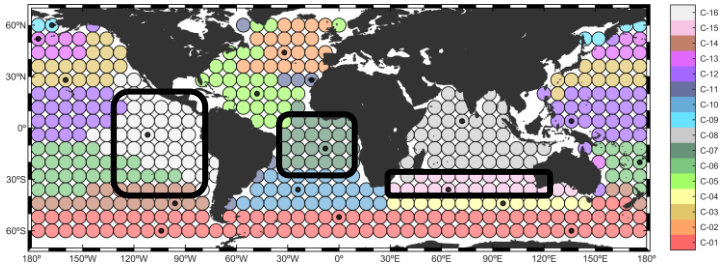
Global projected changes



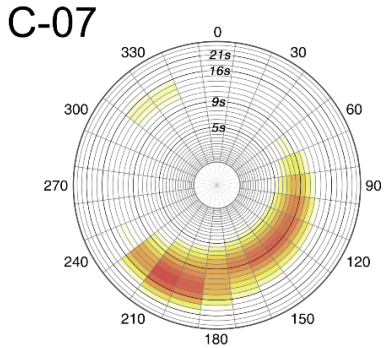


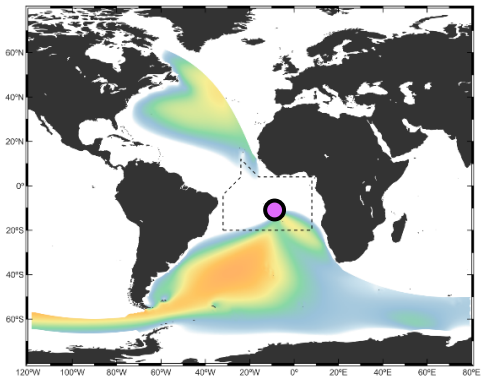
Lobeto et al. (2022).

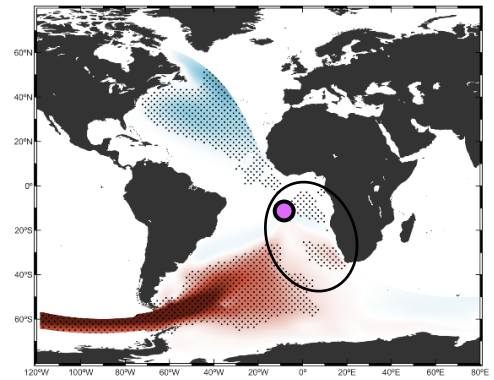
Global projected changes

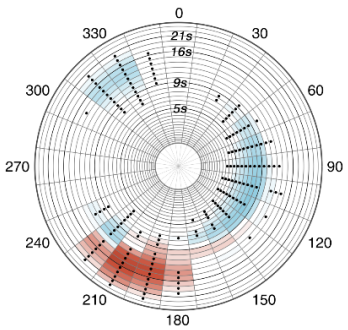


C-07

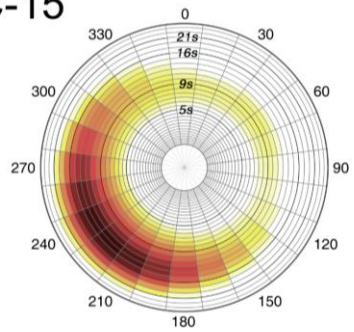


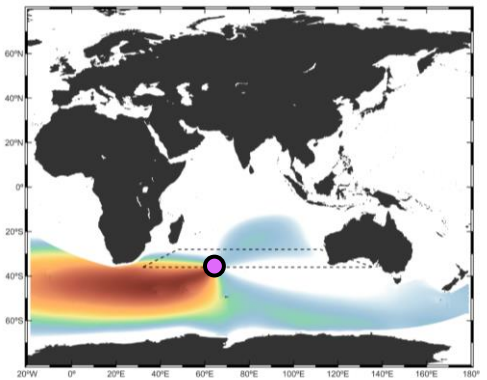


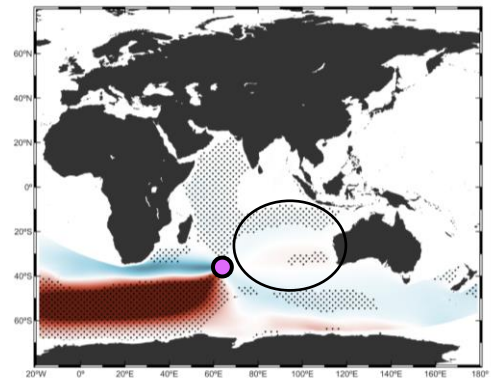


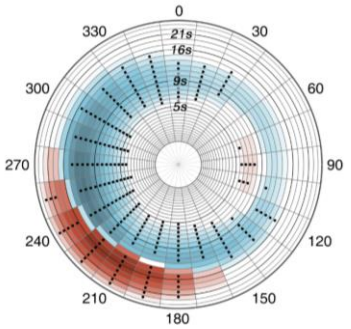


C-15

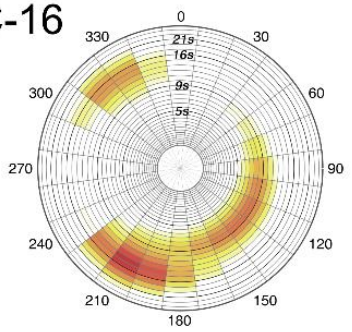


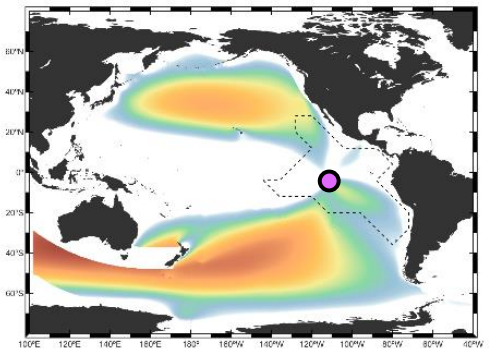


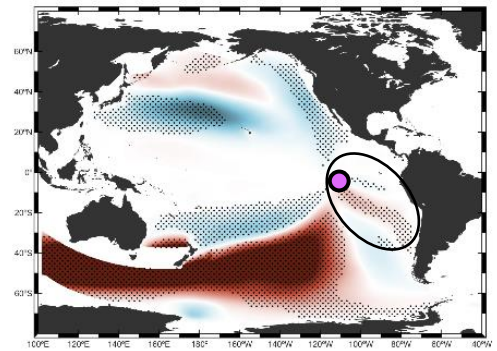


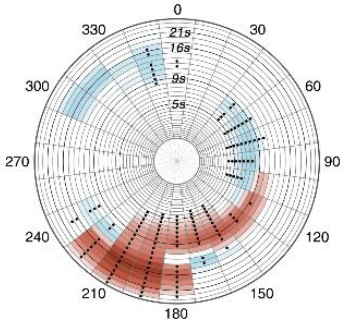


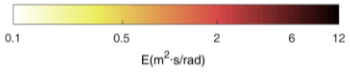
C-16

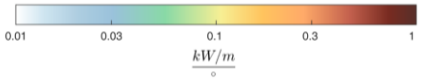


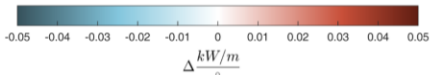


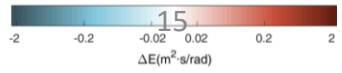












Lobeto et al. (2022).

Conclusions

- The assessment of projected wave climate changes from **directional spectra** provides information that cannot be obtained from the commonly used approach based on **integrated wave parameters**.
- Each wave system shows its **individual change signal**, which propagates with it and converges with those from other wave systems at any point of the ocean.
- Wave **parameters mask** relevant information about the **magnitude** and **sign of change** of the changes of **individual wave systems** due to the integration of changes with opposite sign from different wave systems.
- The assessment of wave climate projected changes leads to the following conclusions:
  - A **robust sign of change transition** in Southern Ocean westerly swells is observed around **45°S**.
  - The **increasing signal** found in the **southernmost swells** propagates north beyond 30°N, **contributing** to the changes in **tropical regions** such as the tropical S Atlantic and tropical SE Pacific.
  - There is a **great complexity of the Pacific Ocean** due to the convergence of multiple wave systems. In the **northern Pacific** basins, the combined effect of the **ice melting** and a **poleward shift** of the storm track drives an **increase** of the northernmost **westerly swells**.
  - A poleward shift of trade-induced waves due to the **Hadley cell expansion** can also be observed globally, causing a clear **dipole change pattern** in the tropical S Atlantic and tropical Indian oceans.

References

- Lobeto, H., Menendez, M., & Losada, I. J. (2021). Projections of directional spectra help to unravel the future behavior of wind waves. *Frontiers in Marine Science*. DOI.

- Lobeto, H., Menendez, M., Losada, I. J., & Hemer, M. (2022). The effect of climate change on wind-wave directional spectra. *Global and Planetary Change*. DOI.

Thank you for your attention

Hector Lobeto (lobetoh@unican.es), Melisa Menendez, Iñigo J. Losada, Mark Hemer