Discerning the world ocean wave fields from long-term spectral wave data

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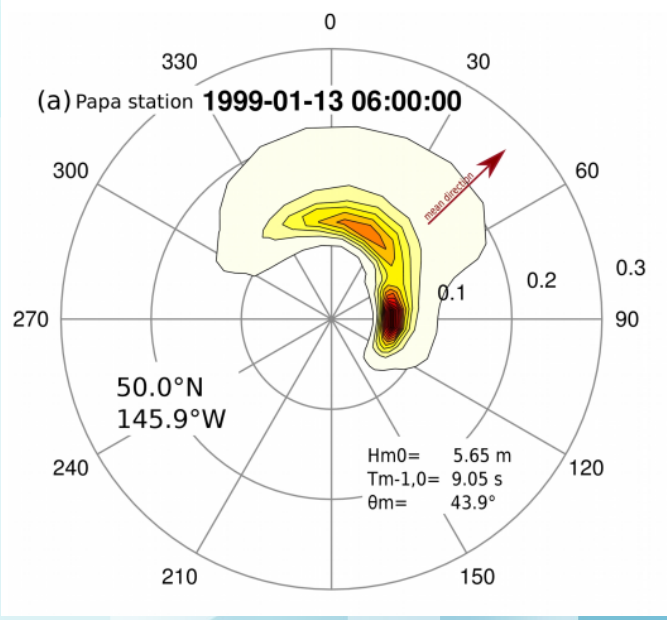
Motivation

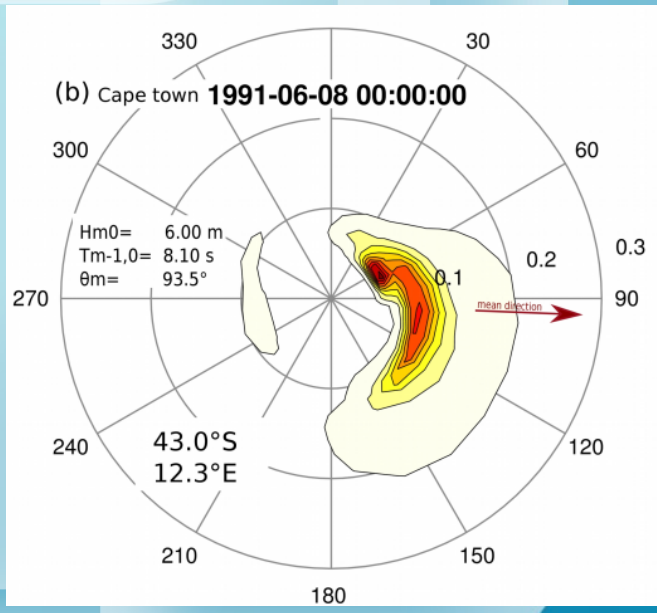
- The wave spectrum contains a lot more information than what is typically used in most applications (e.g., H_s, T_m, θ_m).

- Wave spectral statistics allow to gain insight into local wave conditions by extracting essential information.

- Long-term wave spectral features are physically (meteorologically) very consistent.

- Global spectral statistics are available in the GLOSWAC atlas (https://modemat.epn.edu.ec/nereo)





Method

1 **Partitioning:**
ERA-I spectra data (37 years)
27.900 wet points
54.000 spectra/point

2 **Spectral statistics:** at each point, all partitions are collected into a f,θ density function (PDS)

3 **Spectral clustering:** local wave systems are defined as different clusters within the PDS

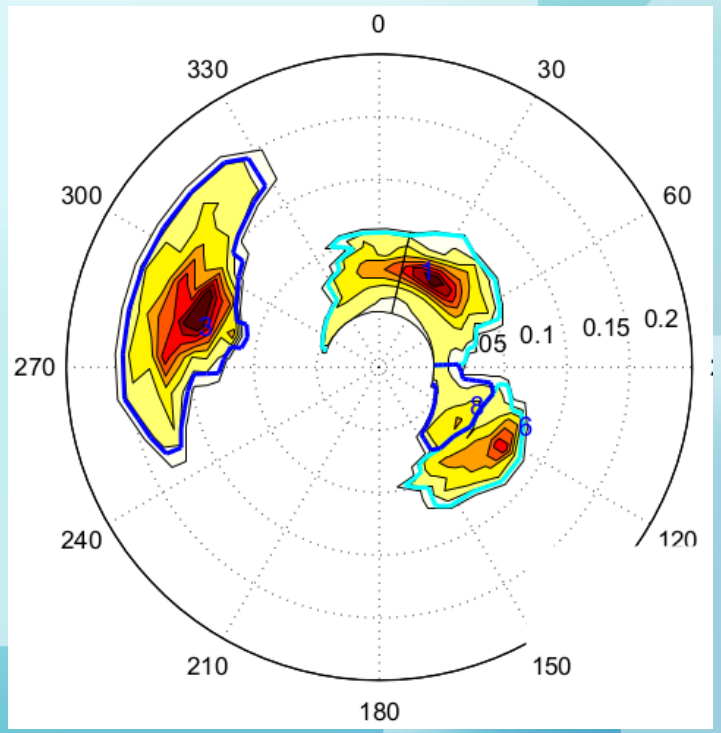
4 **Spatial correlations:** for each point, and each wave system, the point-partial spectra (pps) are compared to all other pps's

5 **Spatial clustering:** spatial correlations reveal the structure of the wave fields (WF), which are delimited via clustering

6 **Conciliation:** spectral control of redundancy and consistency are used to conciliate point WF into Ocean WF's

7 **Characterization:** the properties of the identified WF are computed, i.e., magnitude, interannual and seasonal variability, among others

Method



Partitioning:
ERA-I spectra data (37 years)
27.900 wet points
54.000 spectra/point

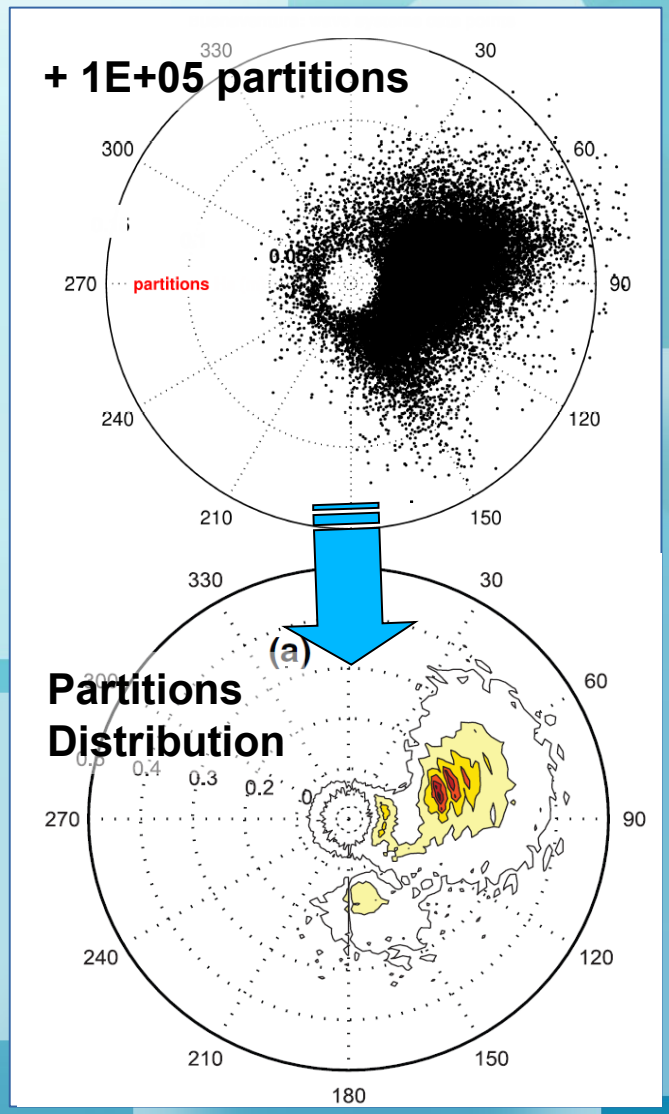
- Spectral partitioning

- Allows identifying all the individual wave components
- Represent wave systems by their integral parameters (more meaningful)
- Derive spectral statistics

Spectral partitioning and identification of wind sea and swell. (2009)
Portilla, J., Ocampo & Monbaliu, J. of Atmospheric and Oceanic Technology, 26(1), 107–122.

Method

Spectral statistics: at each point, all partitions are collected into a f,θ density function (PDS)



- **Long-term Wave Spectral Statistics**
  - Several indicators are possible
  - We use the Empirical distribution of spectral partitions (f_p, θ_p)

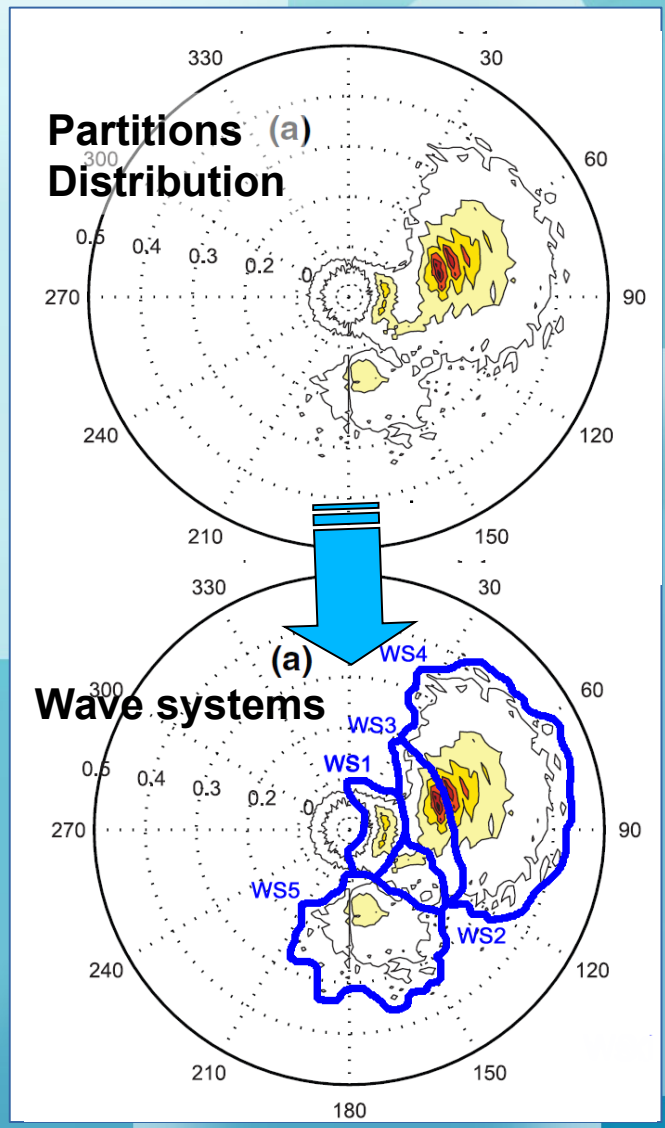
Wave spectra partitioning and long term statistical distribution, (2015)
Portilla J., Cavaleri L., Van Vledder G. J. Ocean Modelling, 96 , pp. 148-160.

Method

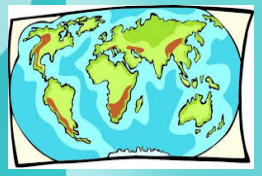
3

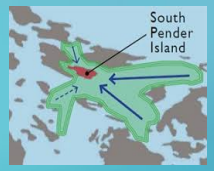
Spectral clustering: local wave systems are defined as different clusters within the PDS

- **Spectral clusters (GLOSWAC)**
  - Represent different wave systems (WS)
  - WS are physically consistent, they are associated to waves with different origin and characteristics.



https://modemat.epn.edu.ec/nereo





The global signature of ocean wave spectra. (2018)
Portilla Yandún, J. Geophysical Research Letters, 45, 267– 276.

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https://modemat.epn.edu.ec/nereo

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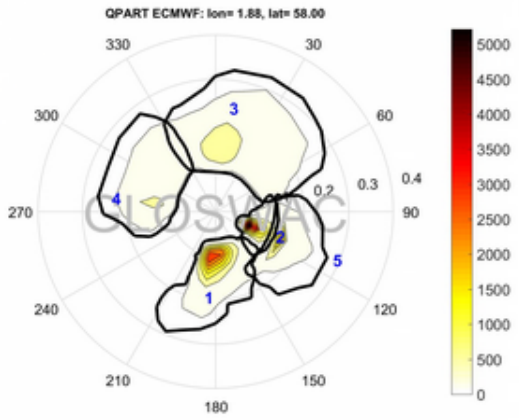
GLOSWAC

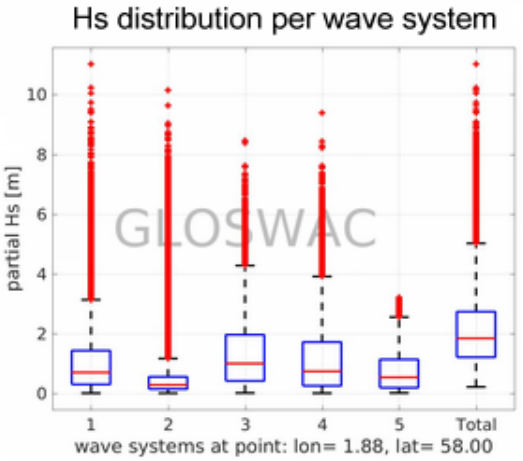
GLOSWAC is an interactive atlas that provides information about the spectral wave conditions at global scale. GLOSWAC goes beyond the standard integral parameters such as Hs (Significant Wave Height) or Tp (mean or zero crossing period). At any specified point, GLOSWAC provides information of the wave energy distribution in frequency and direction. This characterization is made using long-term spectral wave statistics.

The Global Signature of Ocean Wave Spectra

Global Spectral Wave Climate (GLOSWAC)

Lat: 57.58 Lon: 1.72 Search





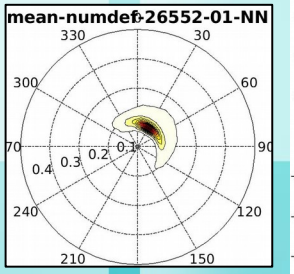
Method

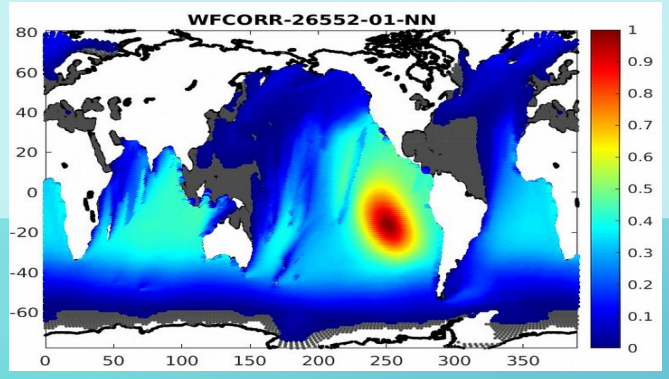
$$\left(R^m_{i,j}\right)^2 = 1 - \frac{\int_\theta \int_f \left[S^m_{j,estimate} - S^m_{j,true}\right]^2 df\, d\theta}{\int_\theta \int_f \left[S^m_{j,true} - \overline{S^m_{j,true}}\right]^2 df\, d\theta}$$

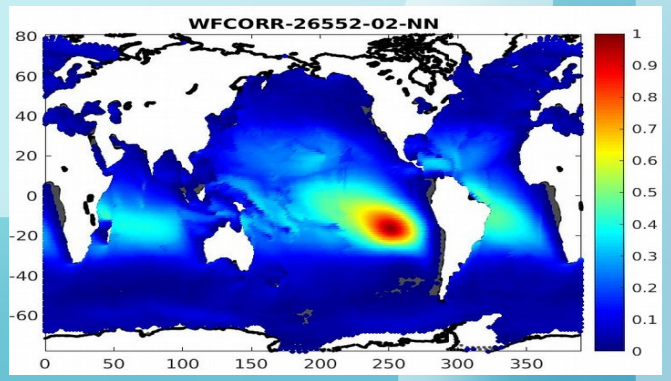
4

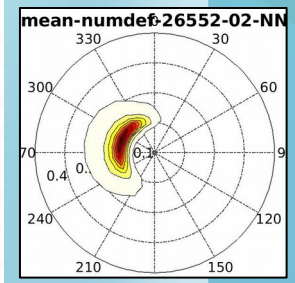
Spatial correlations: for each point, and each wave system, the point-partial spectra (pps) are compared to all other pps's

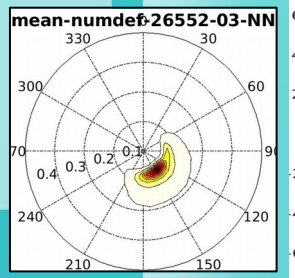
- Spectral correlations are computationally expensive but very robust.
- Redundancies help to reduce the number of computations.

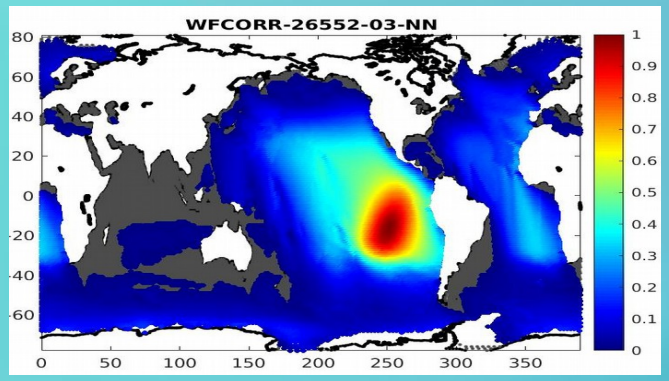


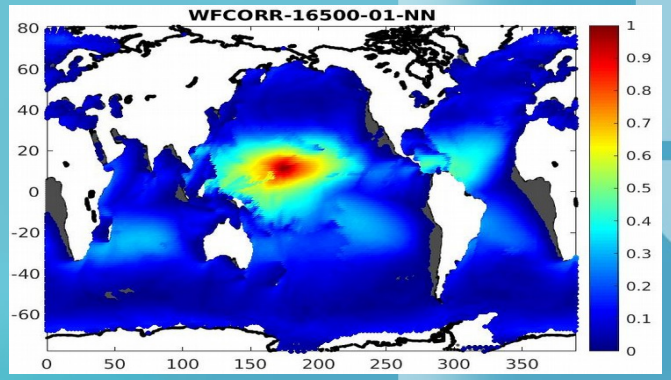


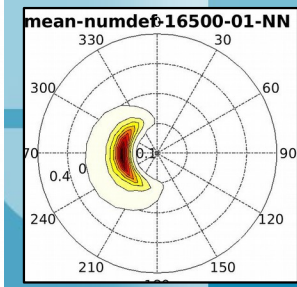






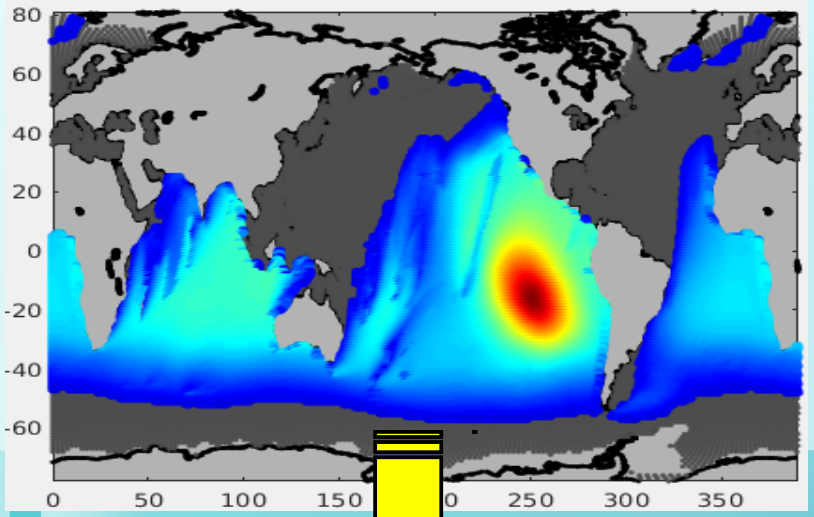


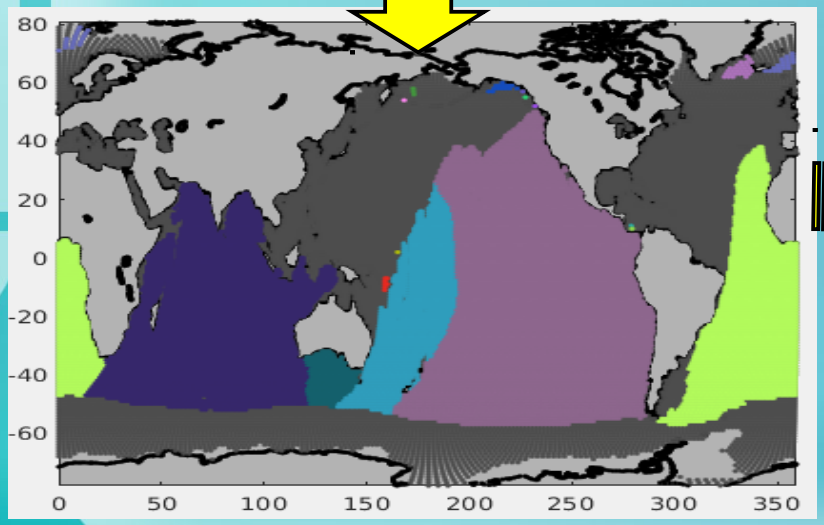


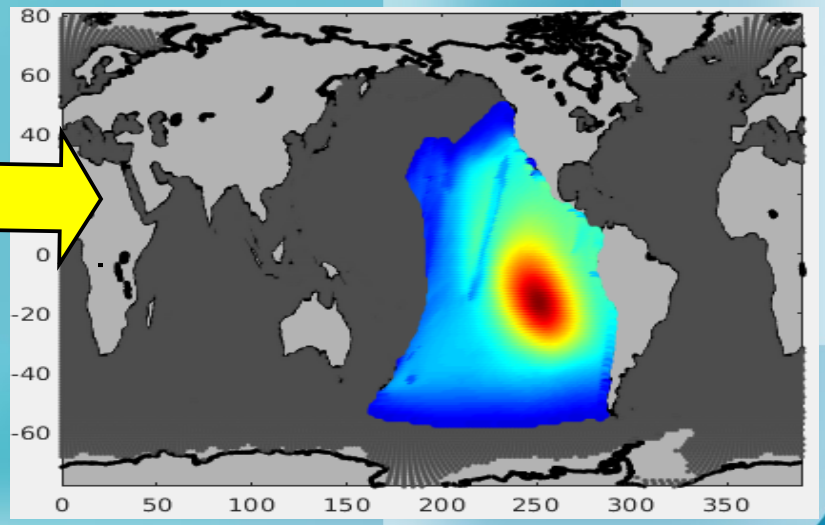


On the specification of background errors for wave data assimilation systems. (2016) Portilla-Yandún, & Cavaleri, L. Journal of Geophysical Research: Oceans, 121, 209–223.

Method





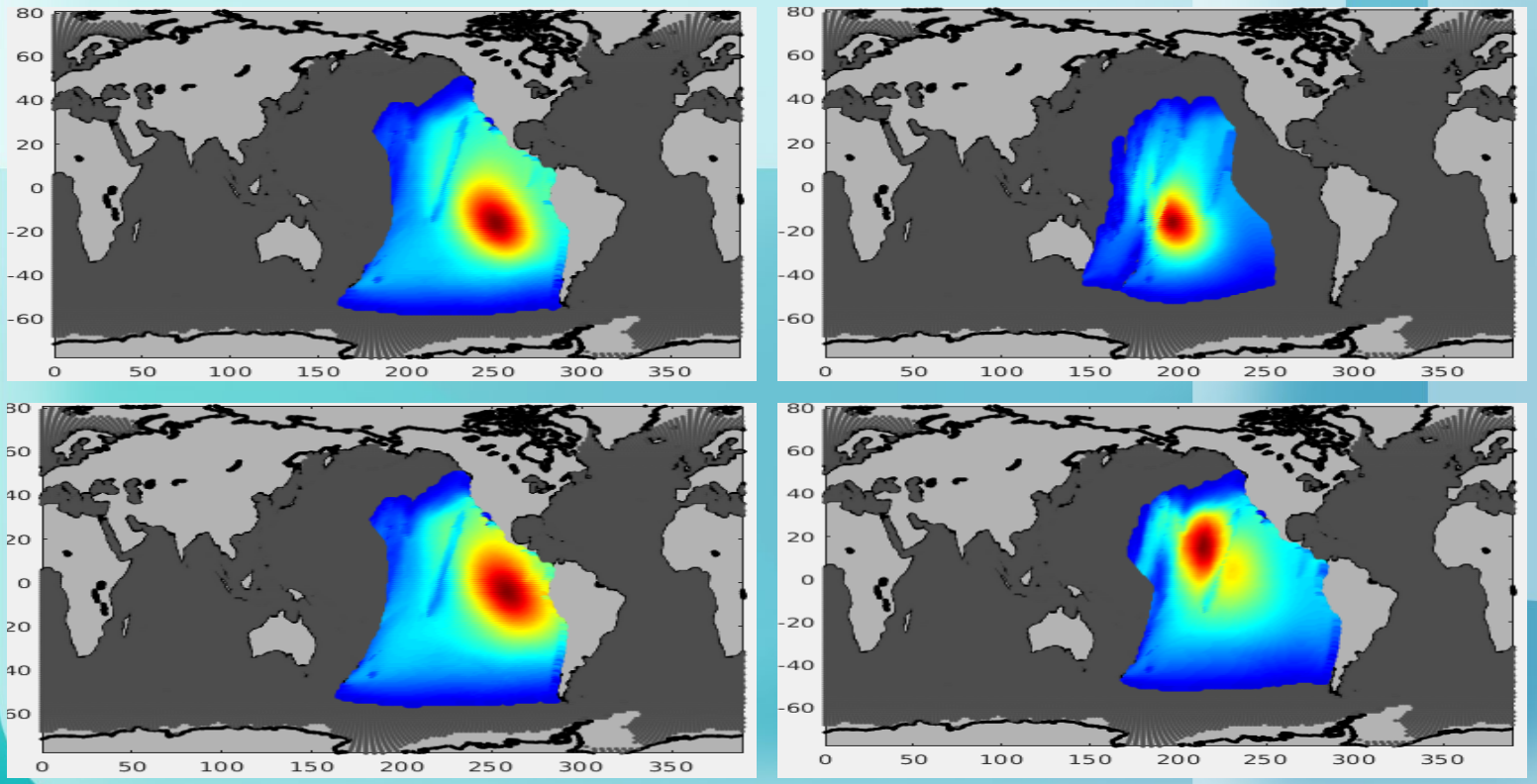


Spatial clustering: spatial correlations reveal the structure of the wave fields (WF), which are delimited via clustering

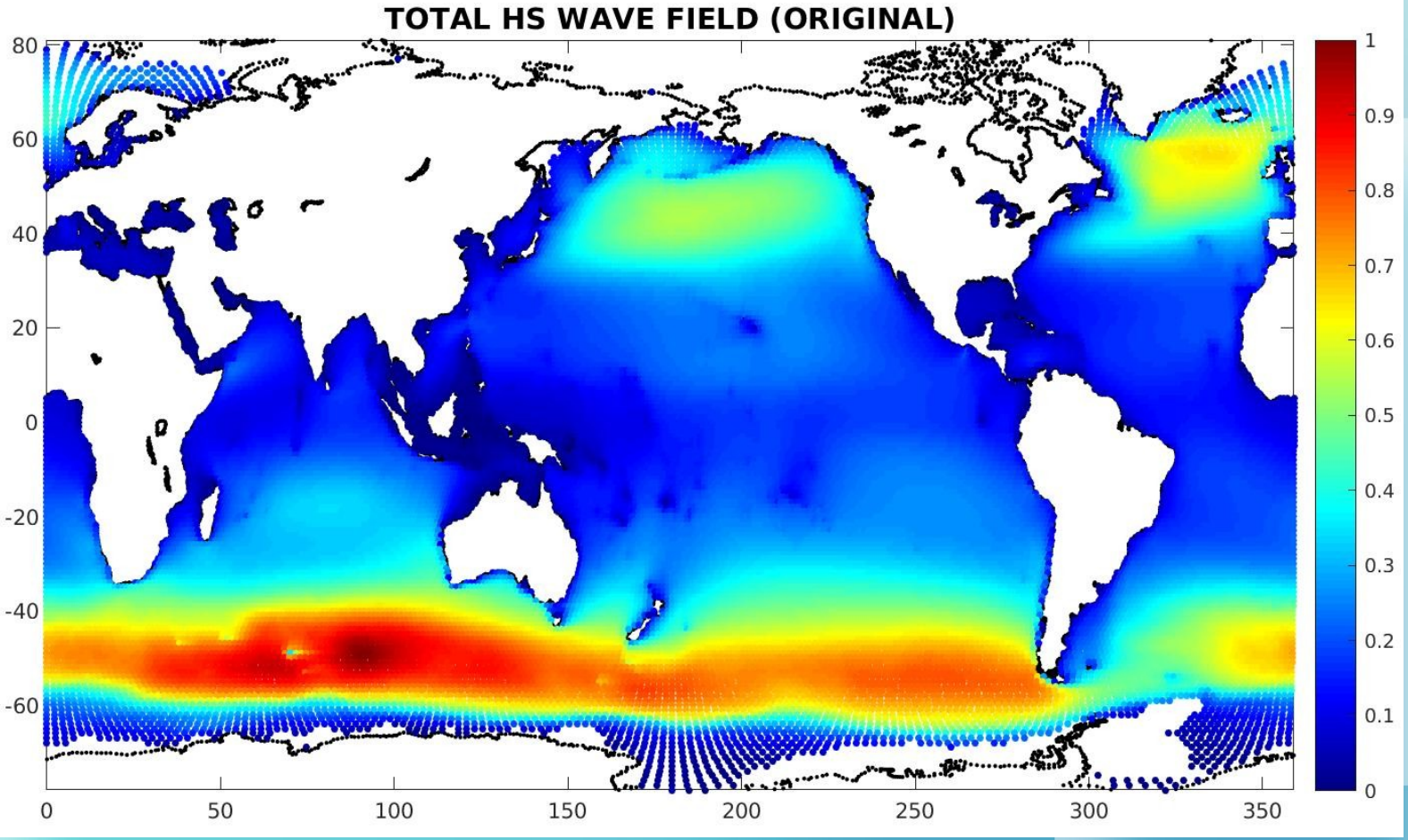
Method

6 **Conciliation:** spectral control of redundancy and consistency are used to conciliate point WF into Ocean WF's

The same WF is "seen" differently from different locations.
Redundancies help integrate all these fields into a single one.

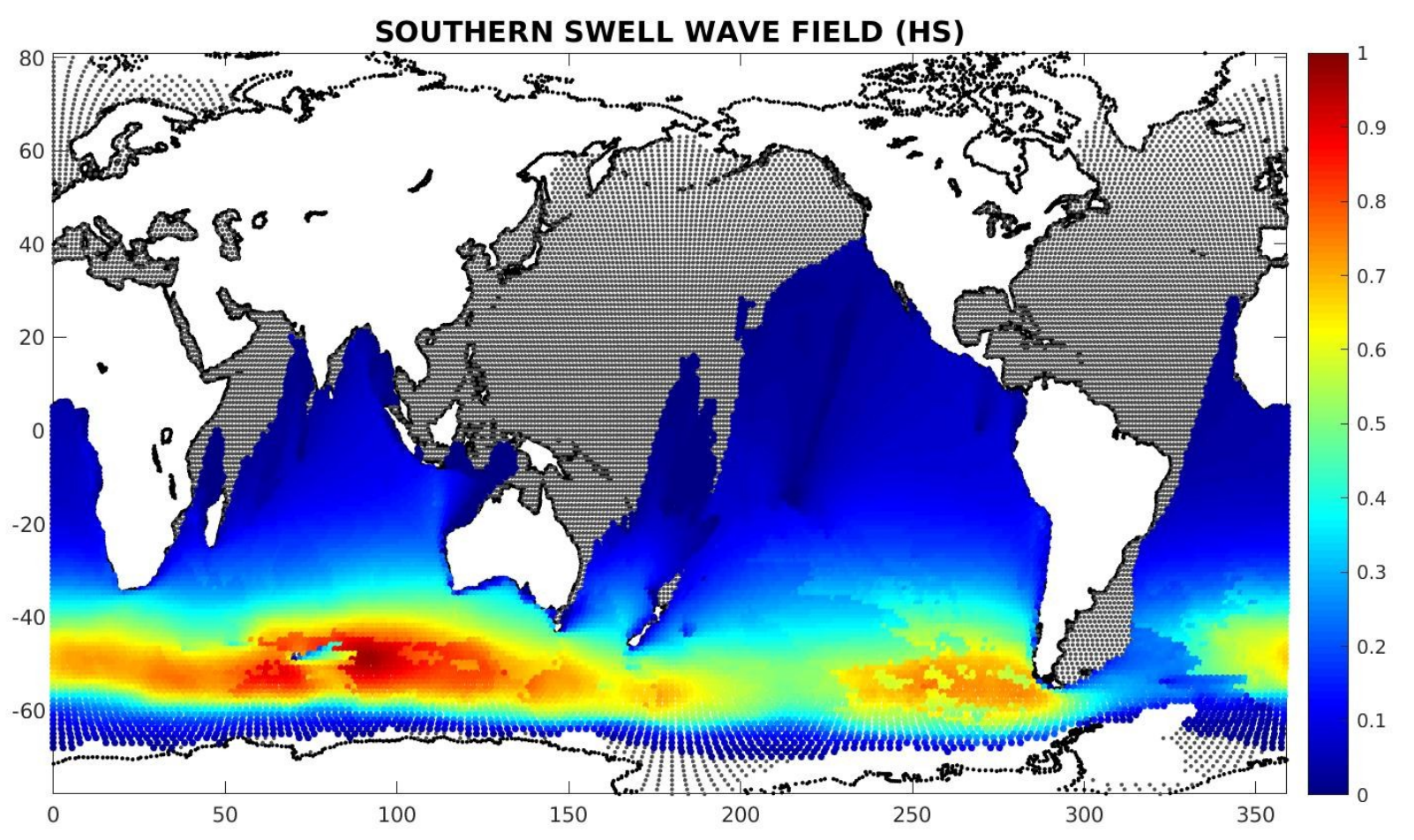


Results (preliminary: focused on the Pacific Ocean)



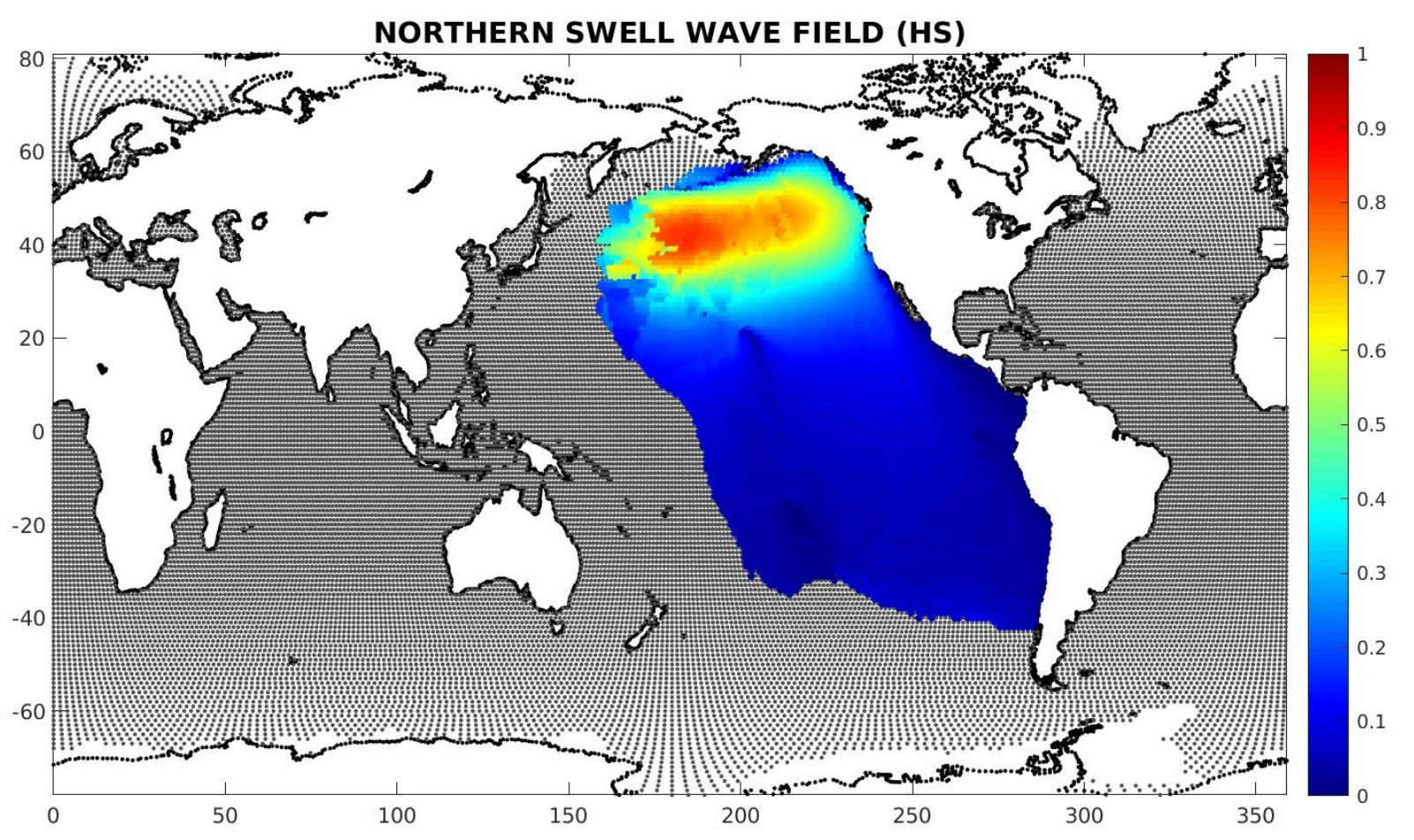
Hs factor: 1

Results (preliminary: focused on the Pacific Ocean)



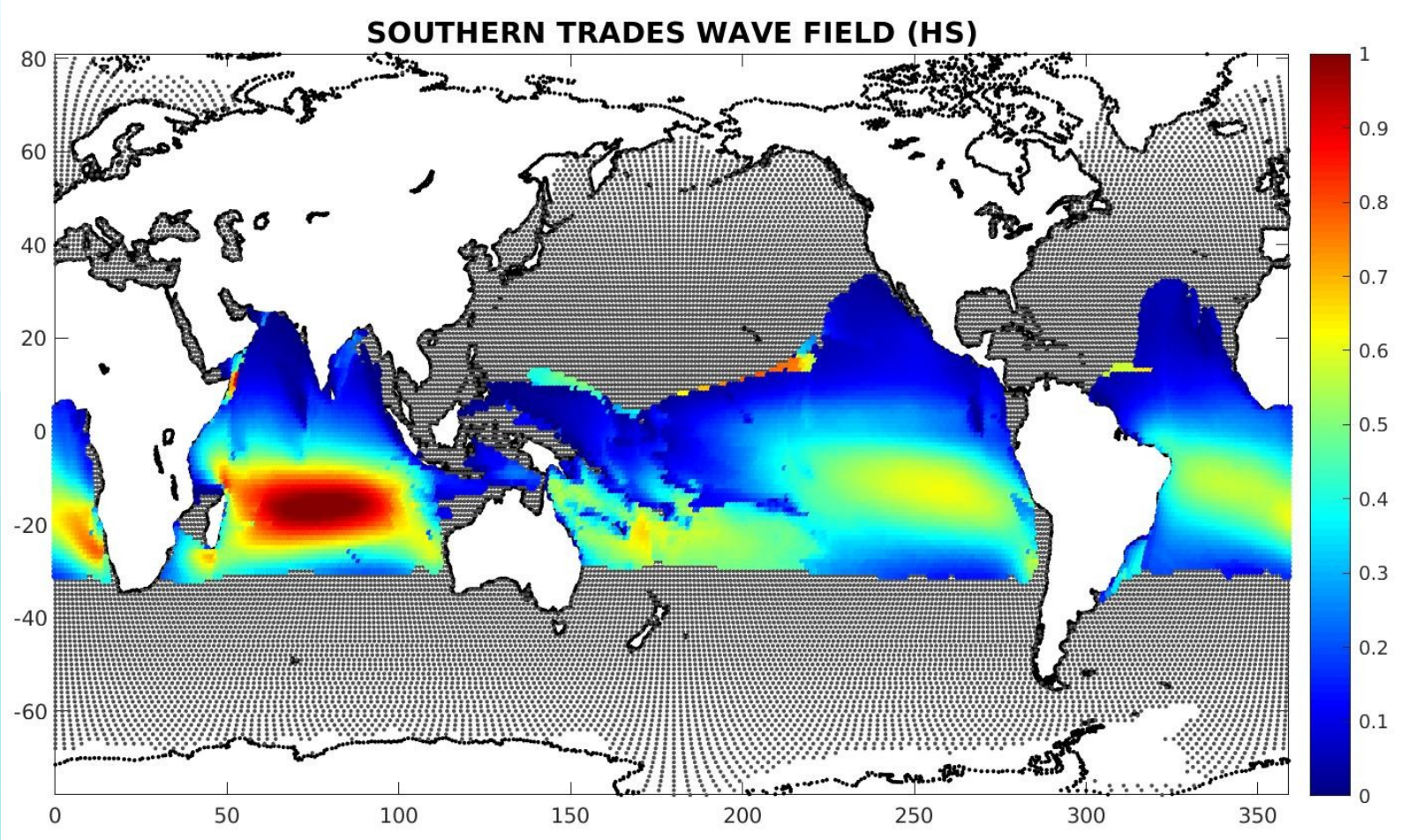
Hs factor: 1

Results (preliminary: focused on the Pacific Ocean)



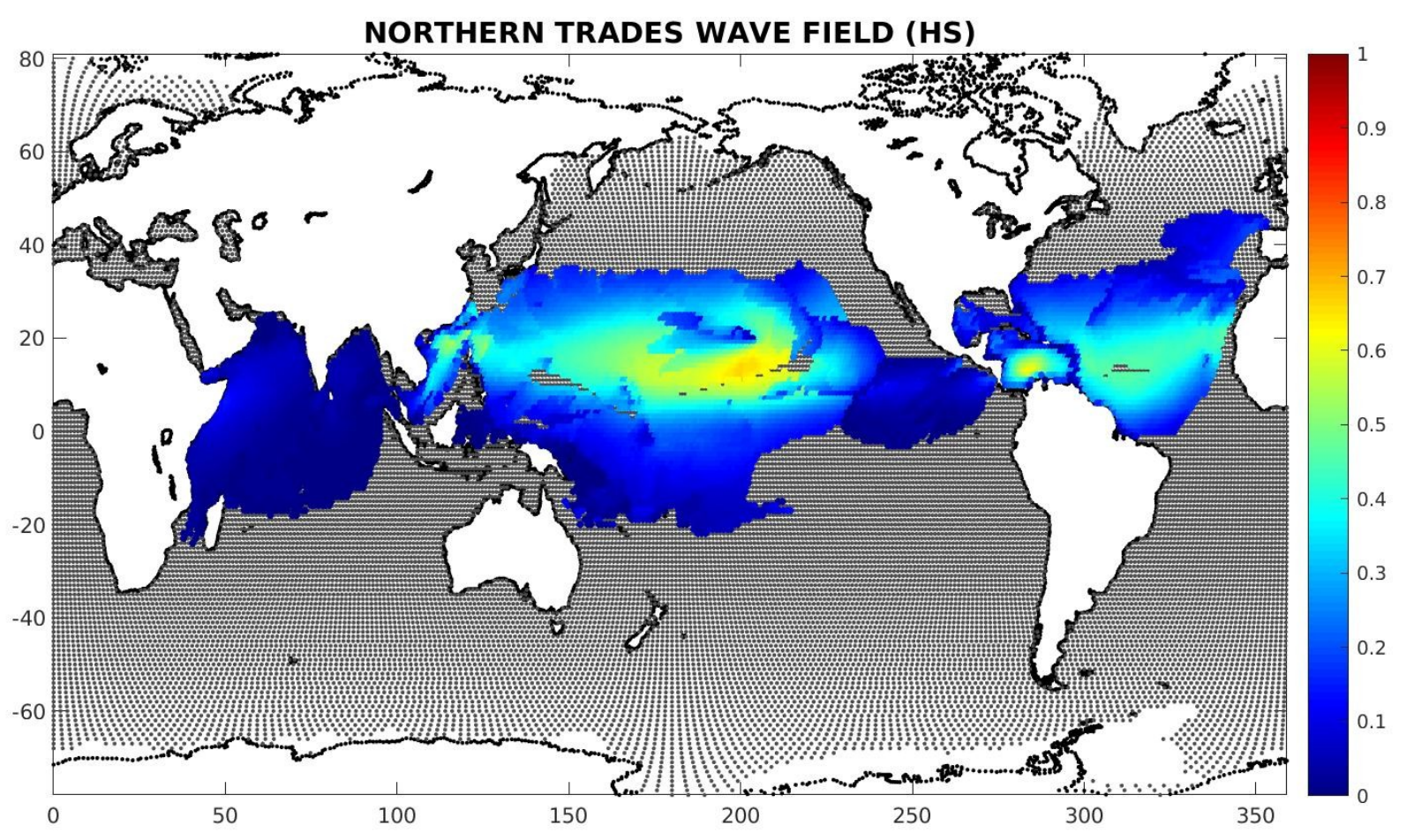
Hs factor: 2

Results (preliminary: focused on the Pacific Ocean)



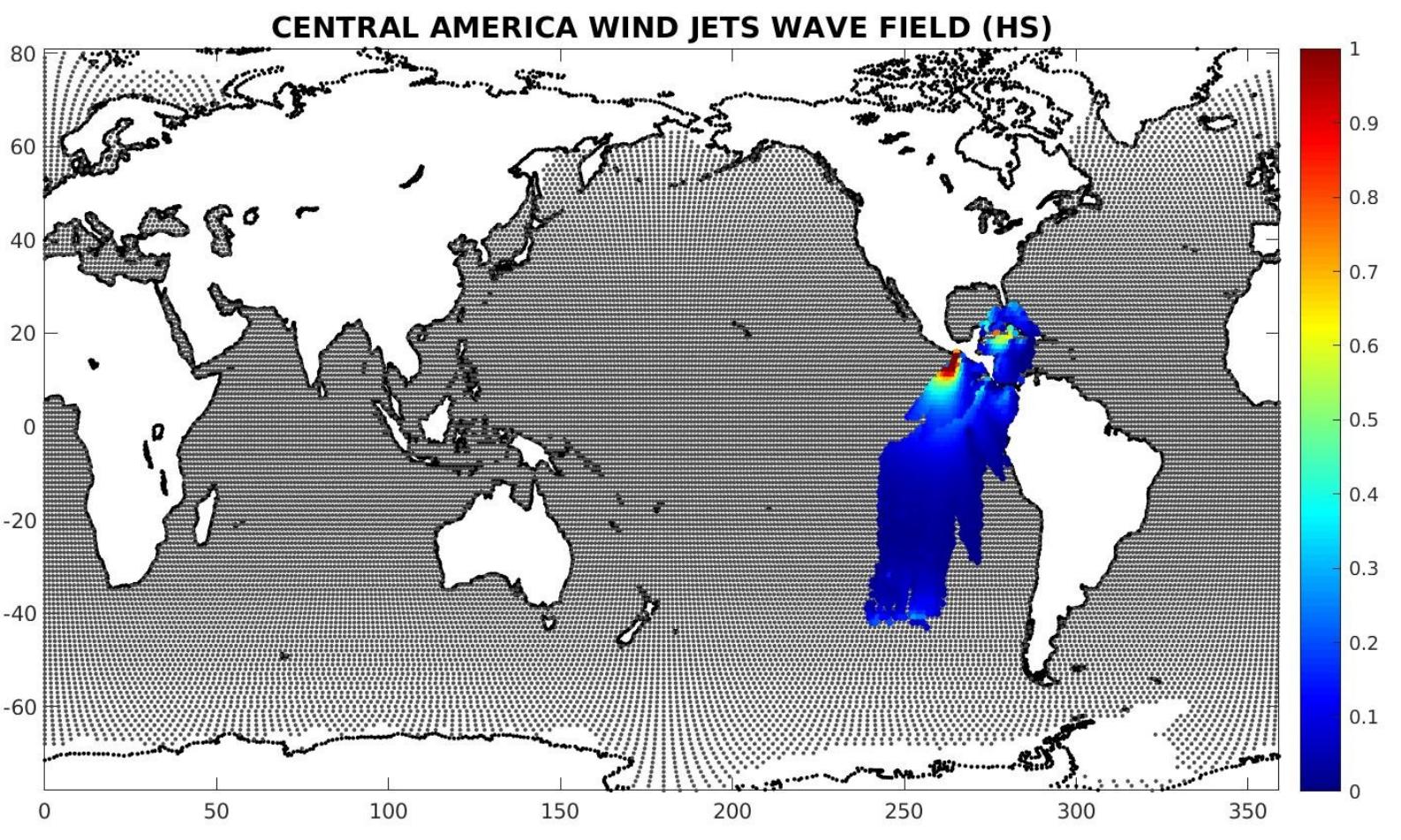
Hs factor: 4

Results (preliminary: focused on the Pacific Ocean)



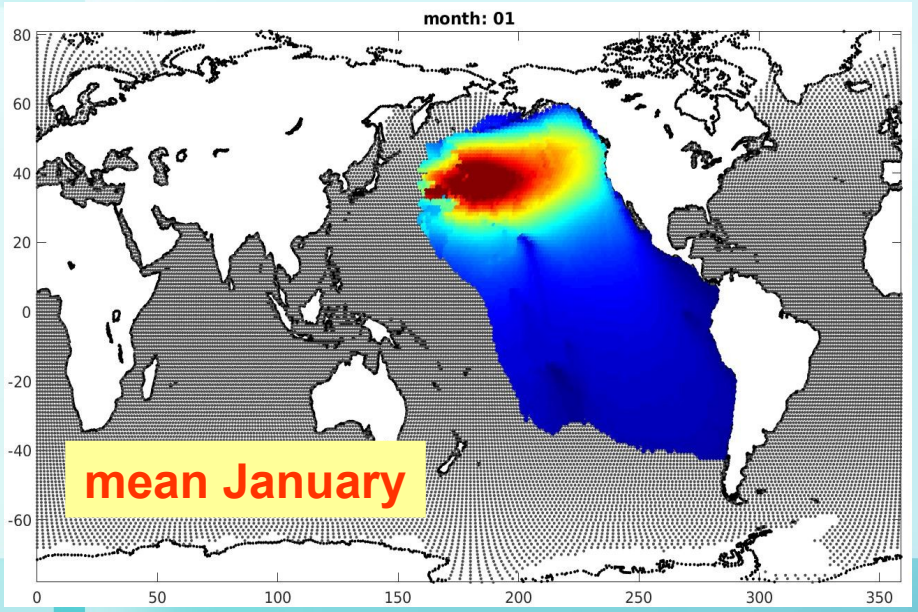
Hs factor: 4

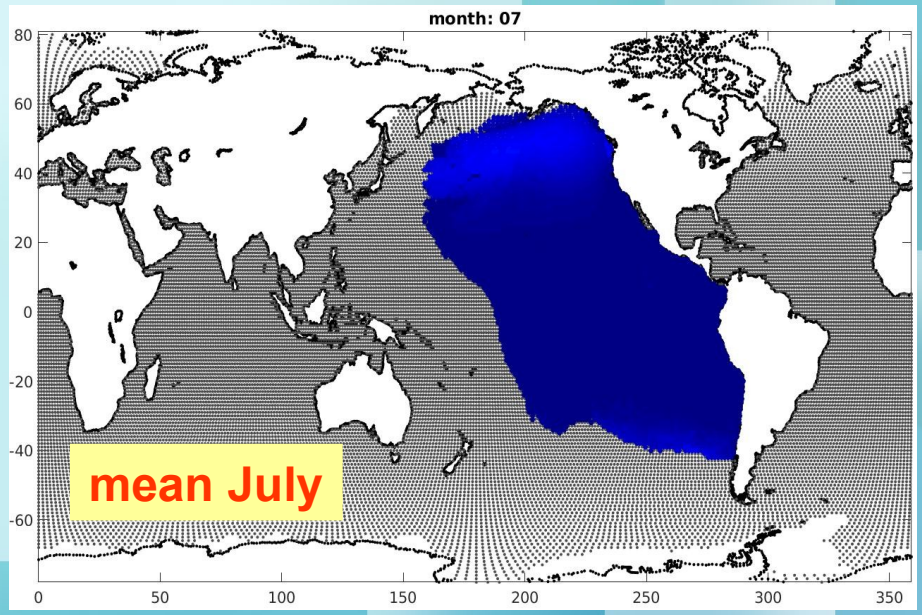
Results (preliminary: focused on the Pacific Ocean)

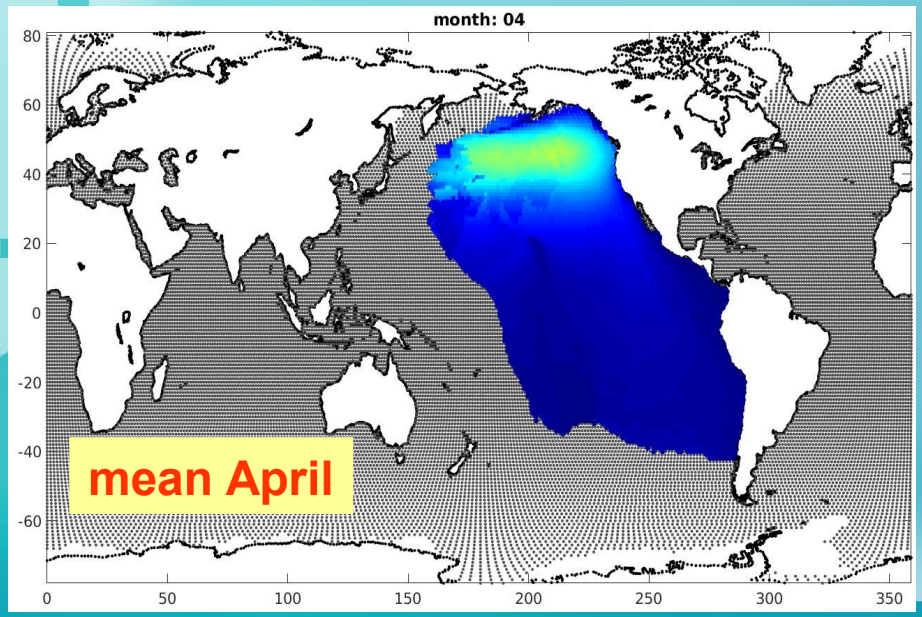


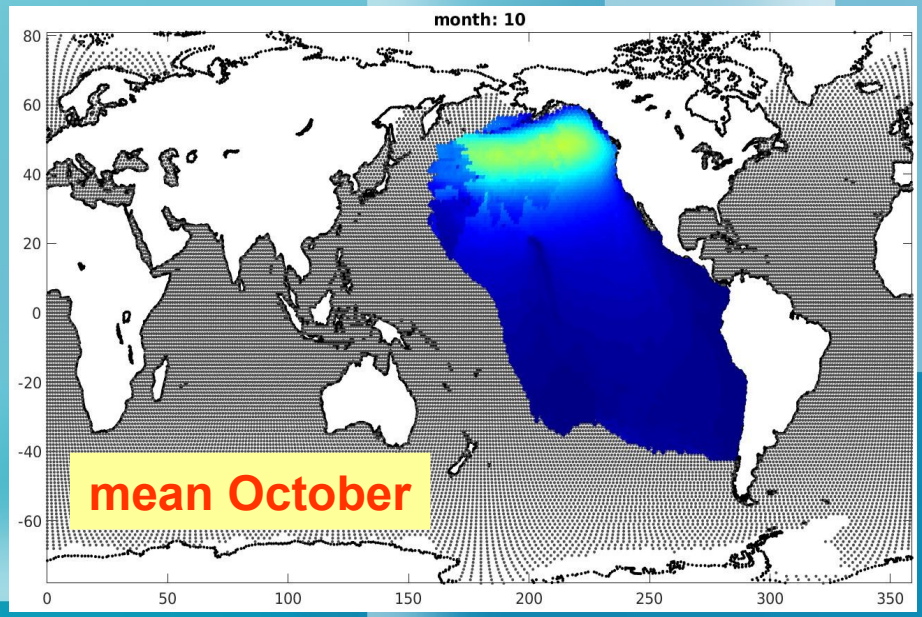
Hs factor: 4x5

Results (year and month variability)

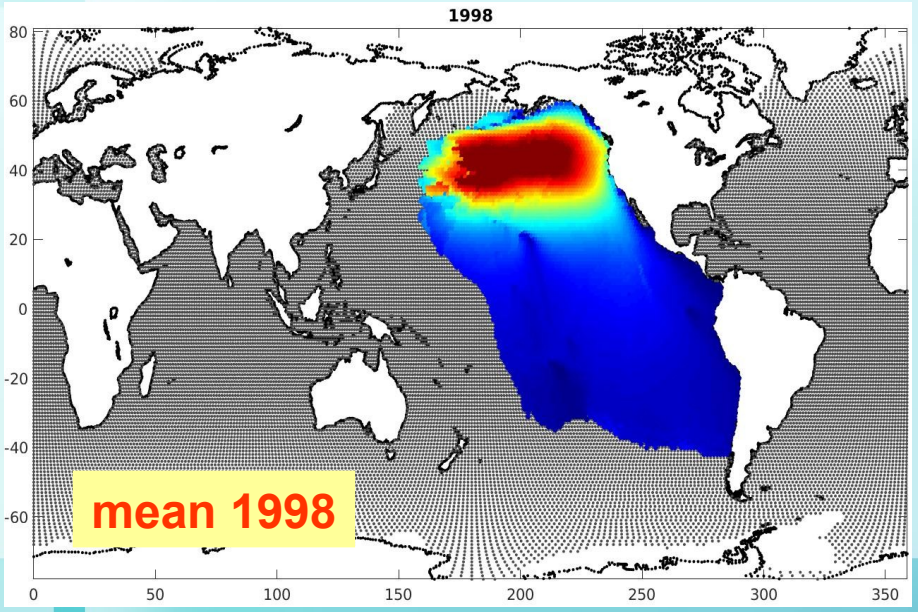


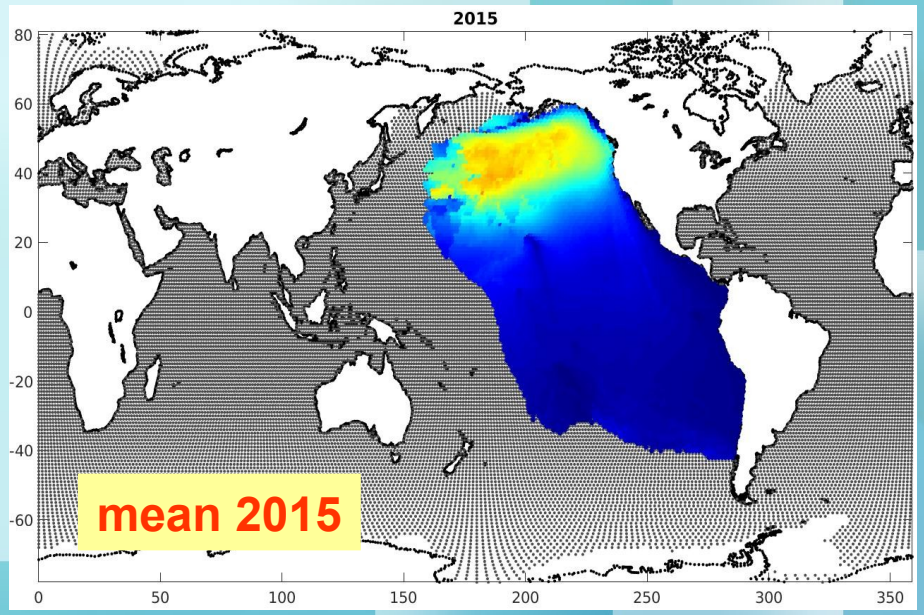


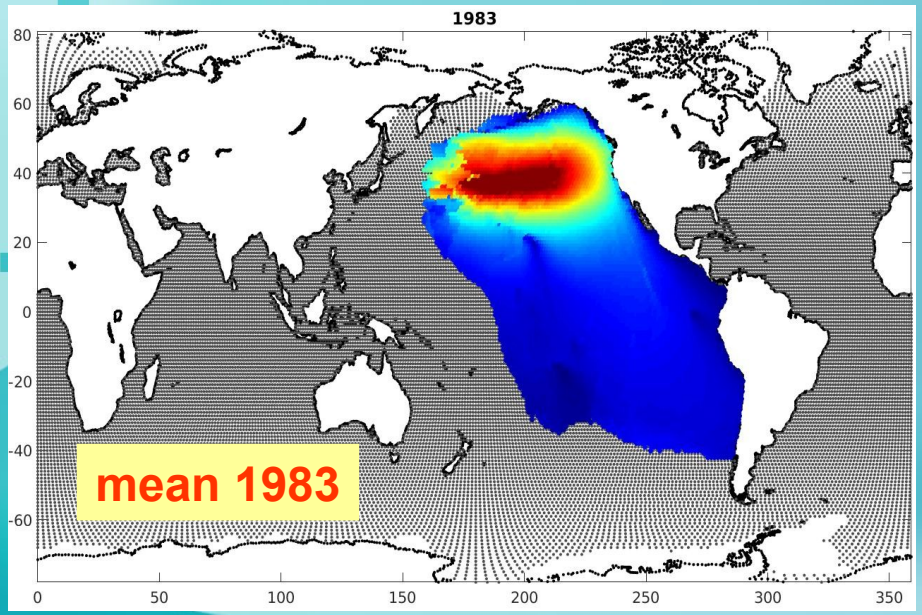




Results (year and month variability)

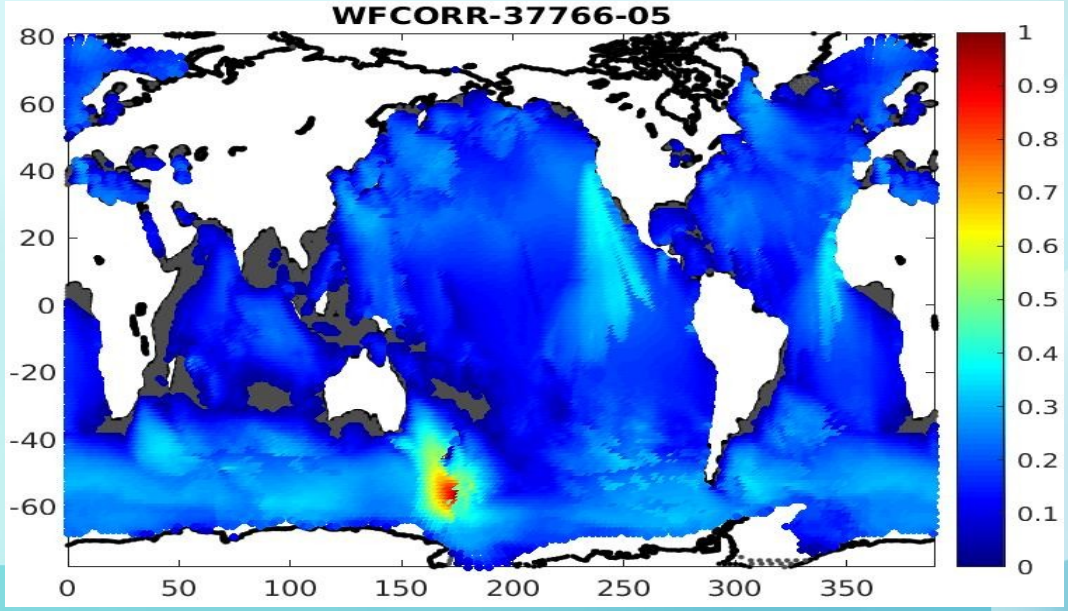


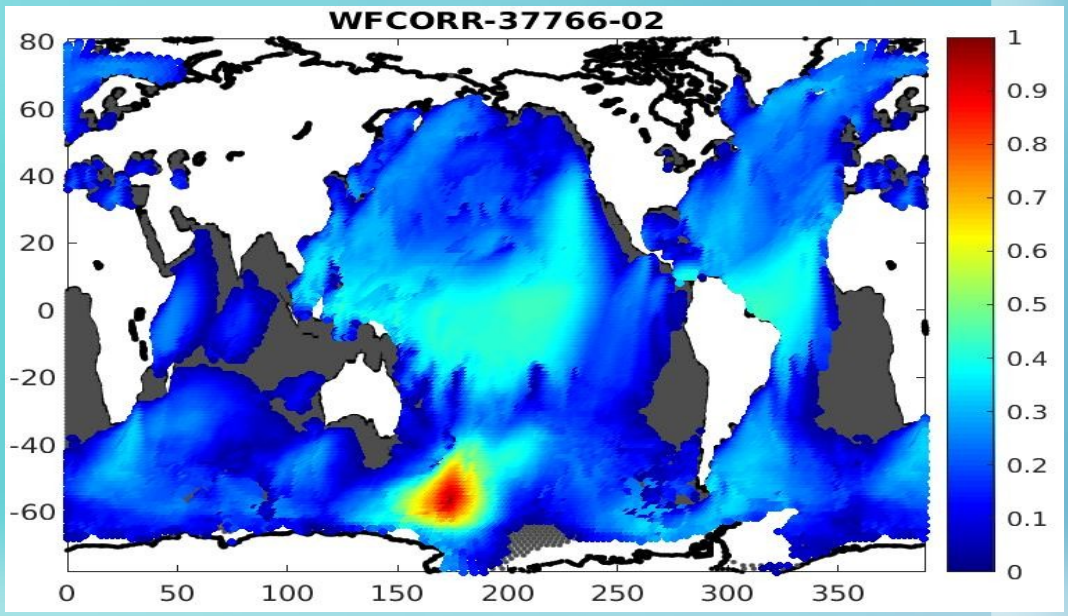




The 2014–16 El-Niño phenomenon, according to the WMO, is one of the three strongest since 1950.

Results (other specific features and interrelations)





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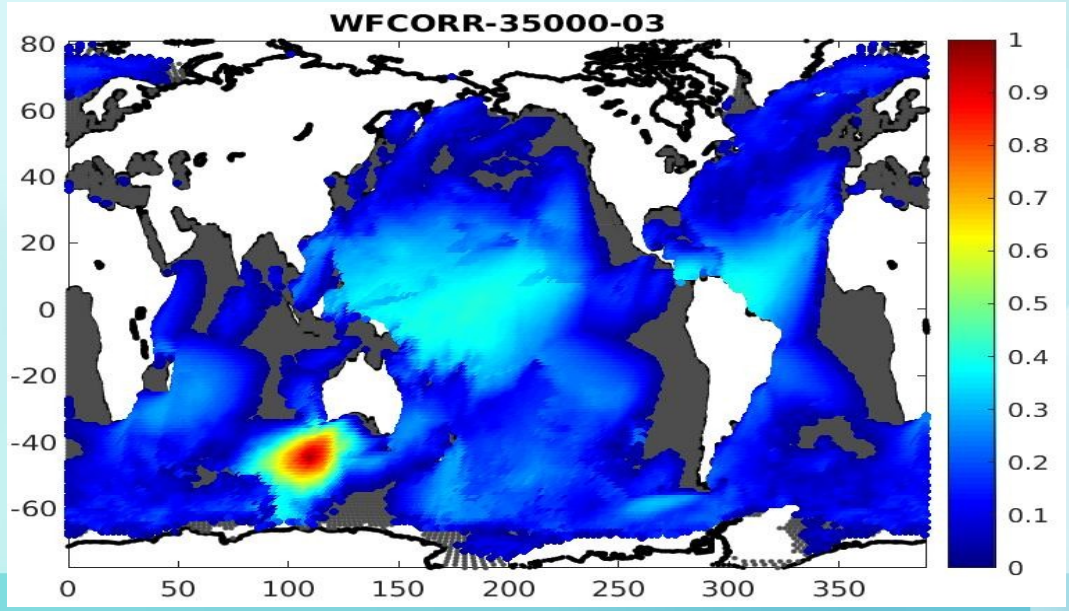

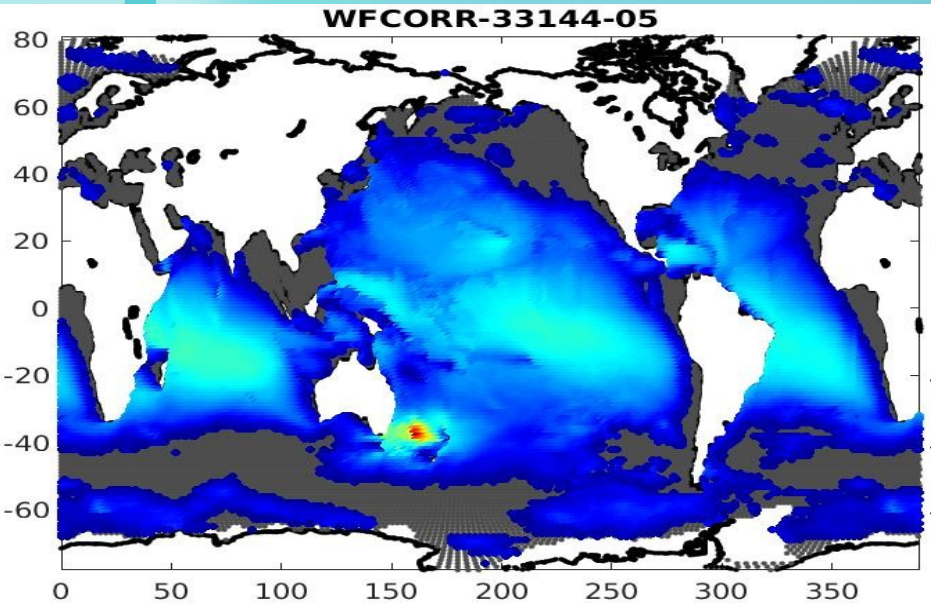

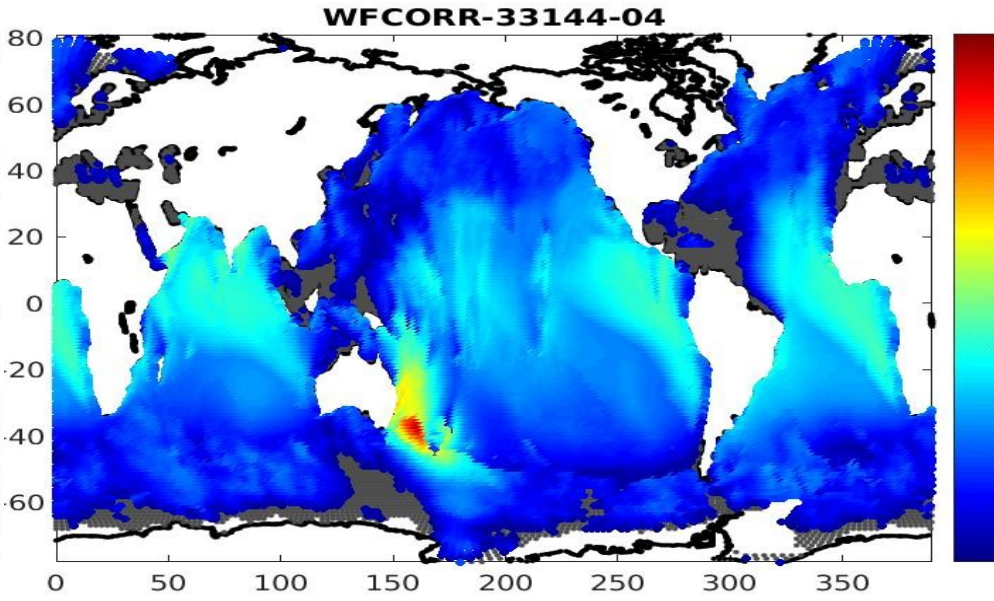

SUMMARY, PERSPECTIVES, and FURTHER WORK

- Wave spectra (due to superposition) have a better memory and contain more details of the driving wave fields (than integral parameters or wind data).

- Spectral correlations strongly point out to the spatial structure of wave fields, these are used here as departure information.

- Discerning and extracting the individual wave fields is useful for:

  - Studying the dissipation rate of swells under different conditions
  - Climate analysis (variability, tele-connections, trends)
  - Assessing and processing Remote Sensing Data (e.g., SAR)
  - Consistent Wave Data Assimilation (using spectra)
  - Wave model evaluation at spectral level


Thanks for your attention