



**IH cantabria**  
INSTITUTO DE HIDRÁULICA AMBIENTAL  
UNIVERSIDAD DE CANTABRIA



# 3RD INTERNATIONAL WORKSHOP ON Waves, Storm Surges, and Coastal Hazards

A worldwide coastal analysis of the  
climate wave systems

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Menéndez Melisa

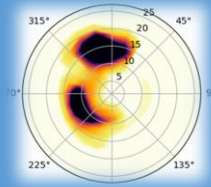
1

Motivation



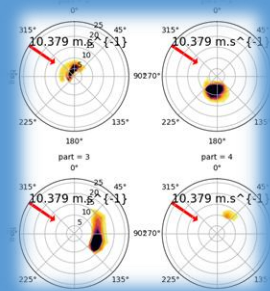
2

Data



3

Methodology



Spectral Partitions  
Wave Systems

4

Results



Spectral Partitions  
Wave Systems

5

Conclusions



# MOTIVATION

1

2

3

4

5

# Motivation

## Wave climate characterization

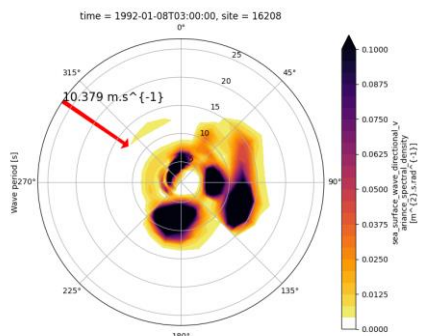
- Hs [m]
- Tp [s]
- MWD [°]
- Tm02 [s]

These parameters allows the computation of some theoretical spectra, such as Pierson-Moskowitz, Ochi-Hubble, JONSWAP, etc..

$$JONSWAP(f) = \alpha * H_s^2 * T_p^4 * f^{-5} * exp\left(\left(-1.25 * (T_p * f)^{-4}\right)\right) * \gamma * exp\left(\frac{(-T_p * f - 1)^2}{2 * \sigma^2}\right)$$

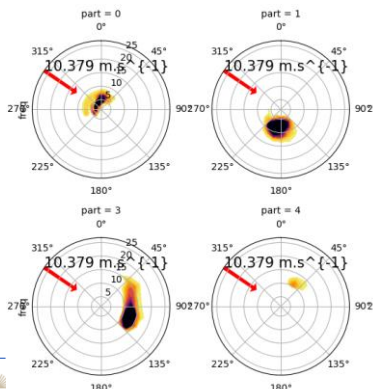


## Directional wave spectrum (E(f,θ))

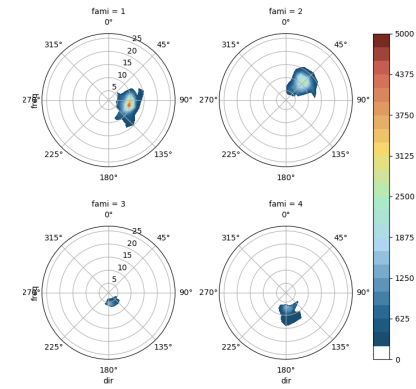


Hanson and Phillips (2001);  
 Hanson (1997);  
 Portilla et al. (2009);  
 Portilla-Yandun et al.(2015);  
 Rodrguez and Soares(1999),  
 Gerling, (1992)  
 Hasselmann et al., (1996)  
 Lobeto et al. (2022)

## Classification in WS and SWs



## Wave Systems



the long-term conditions prevailing over a frequency-direction wave energy area of the spectrum collecting similar environmental and physical characteristics.

**MOTIVATION**

1

2

**DATA**

3

4

5

GOW2 wave hindcast: (Perez et al. 2017)

GOW directional wave spectrum validation (Mazzaretto, et al 2021)

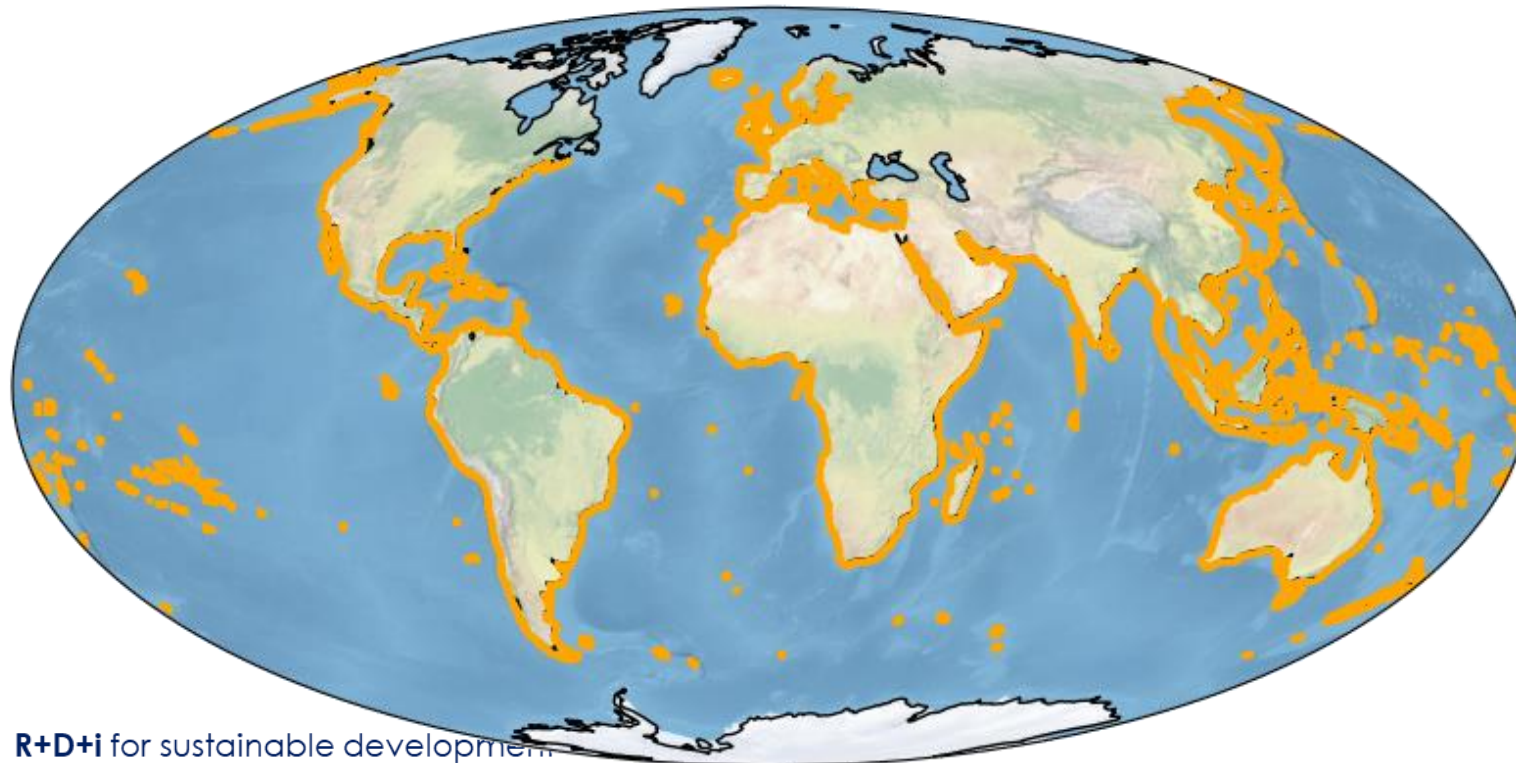
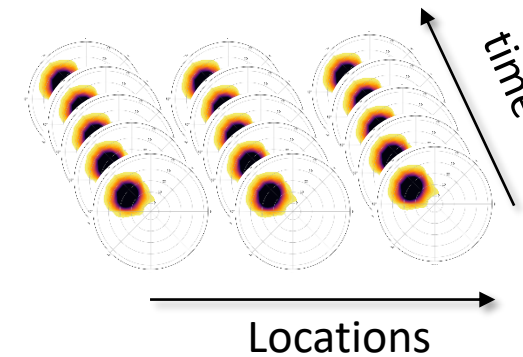
total locations worldwide: #36455

time resolution: 3h (1979-present)

spatial resolution:  $0.25^\circ \times 0.25^\circ$

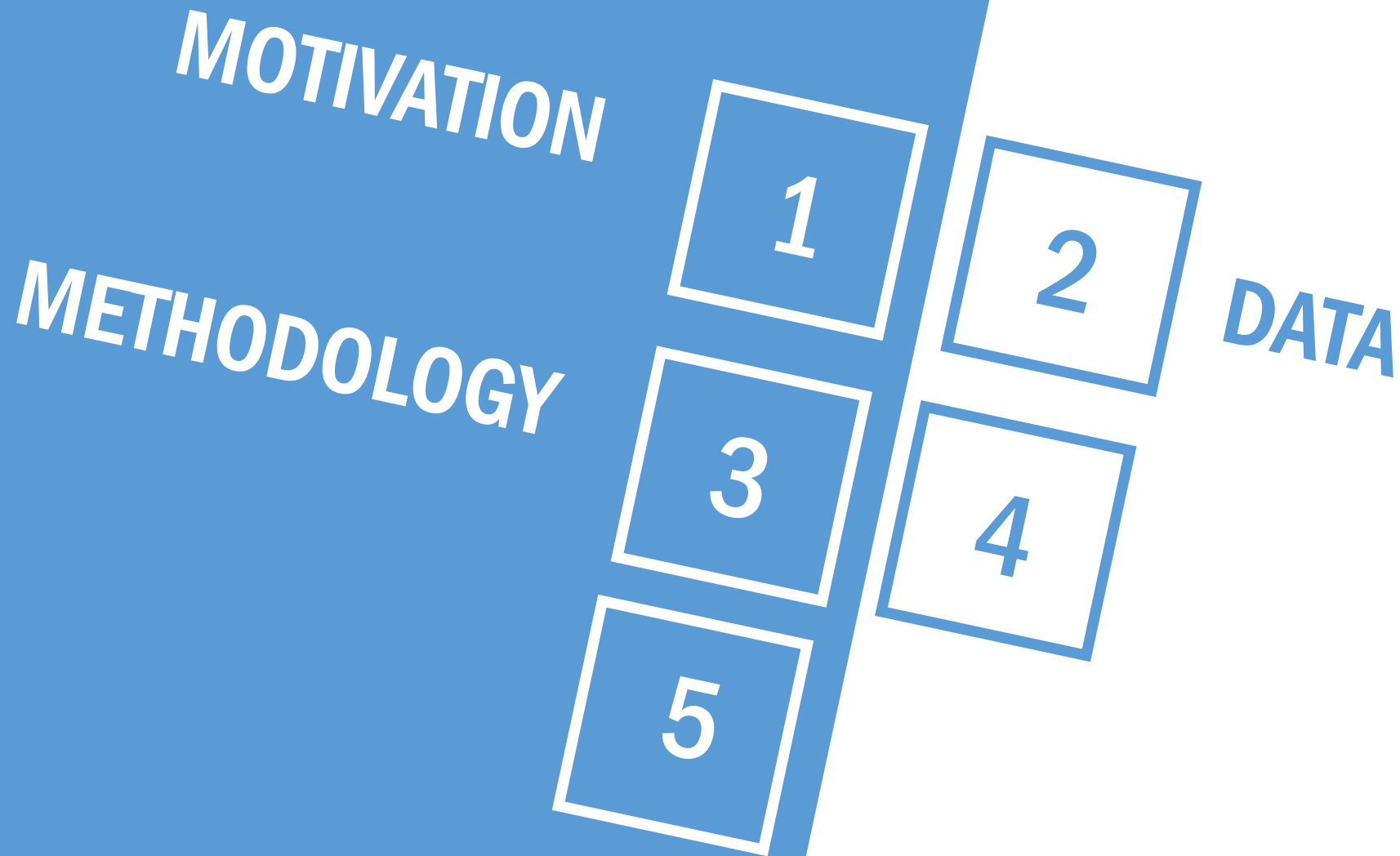
frequency resolution: 0.0373 - 0.7159 Hz

directional resolution:  $15^\circ$



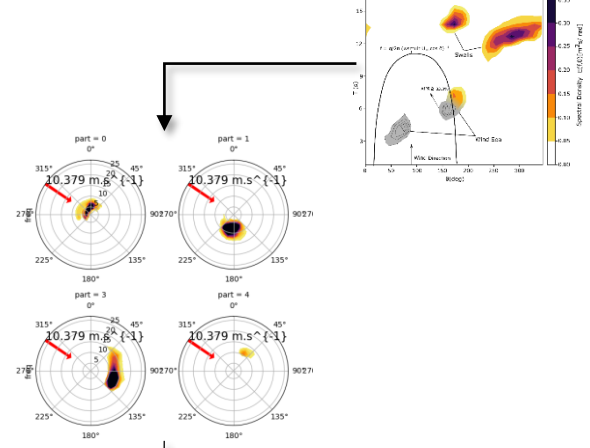
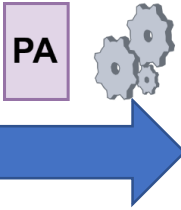
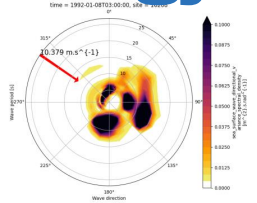
## ANALYSED DATA:

- **Locations: 10238**
- **Time Resolution: 3h**
- **Time range: 1989-2020 (32 years)**
- **Total of data: ~7 TB**

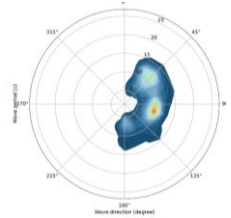
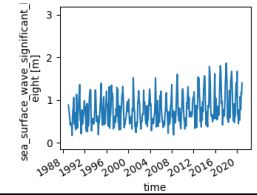
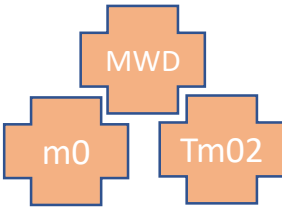


# Methodology

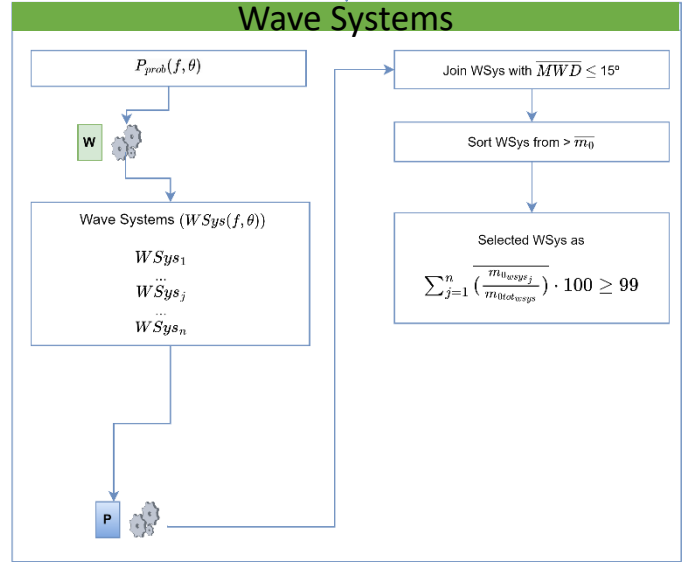
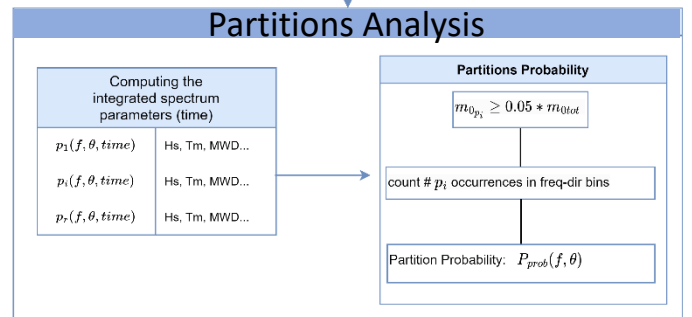
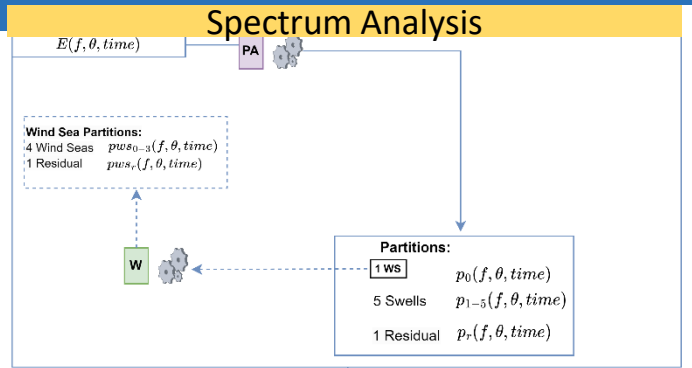
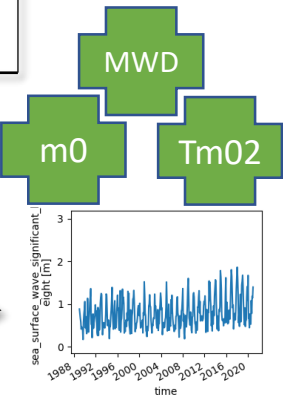
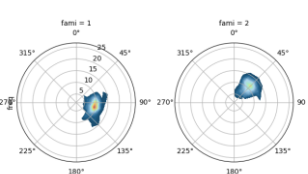
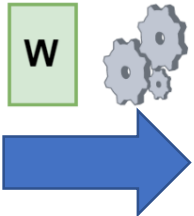
## Spectrum Analysis



## Partitions Analysis



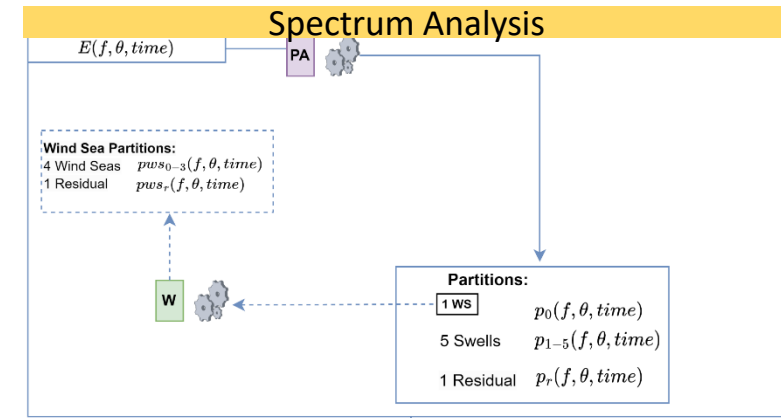
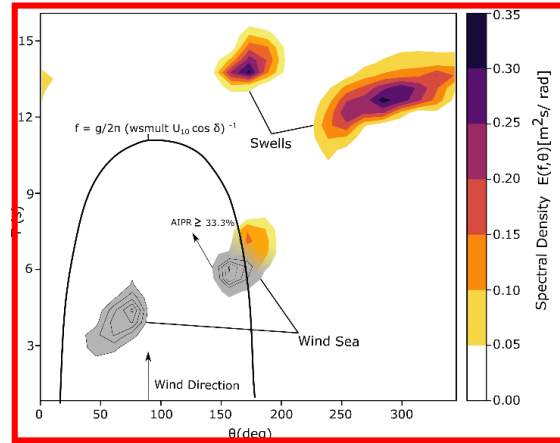
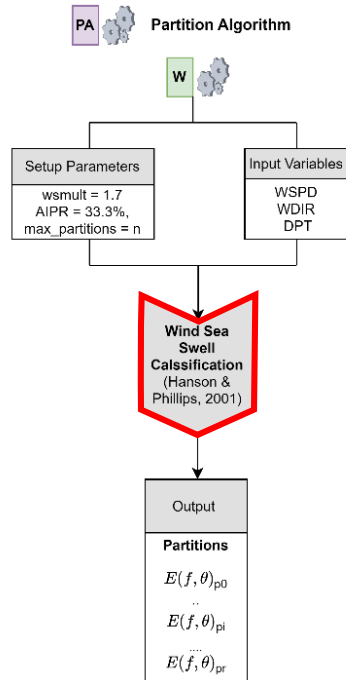
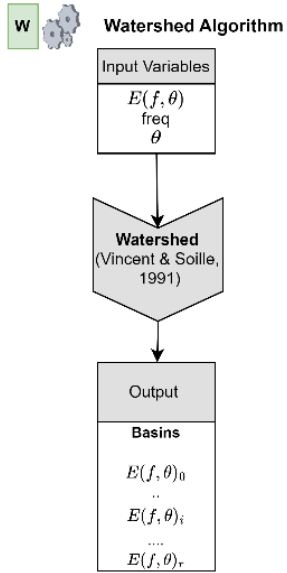
## Wave Systems



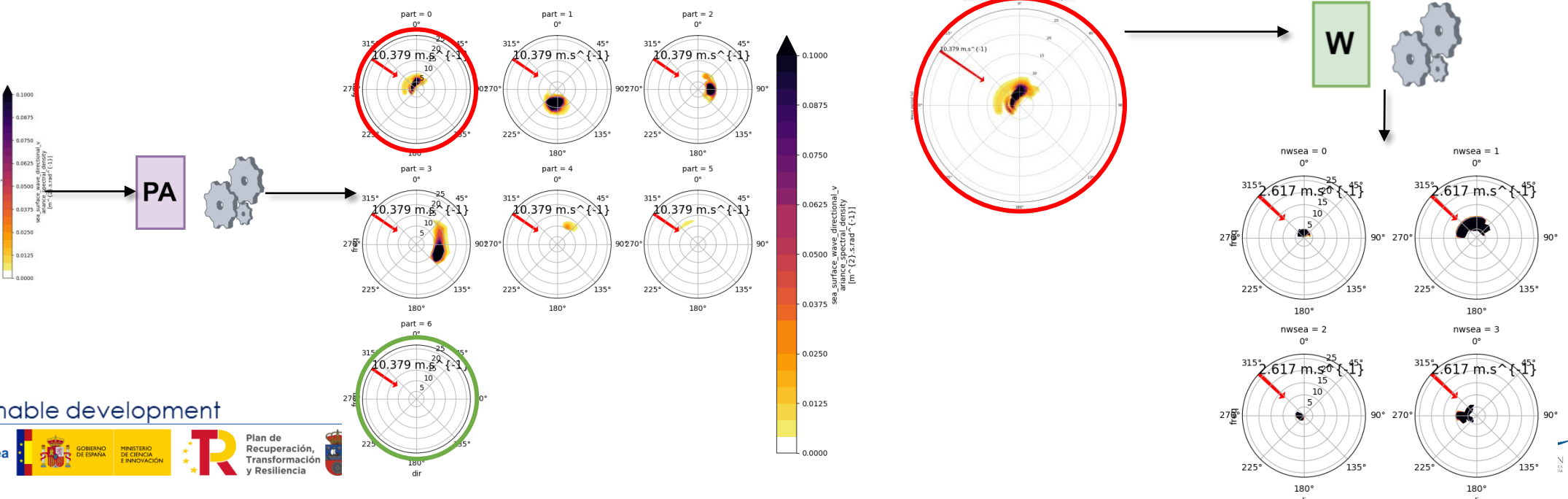
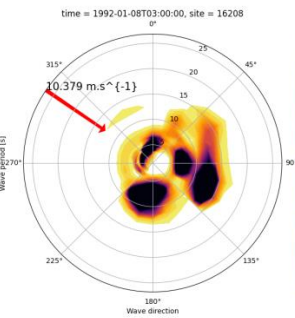
R+D+i for sustainable development



# Methodology



How many Wind Seas in the WS Partition?



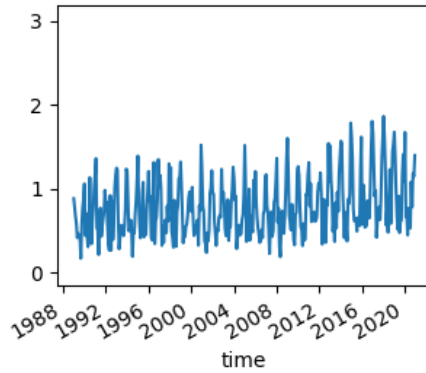
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# Methodology

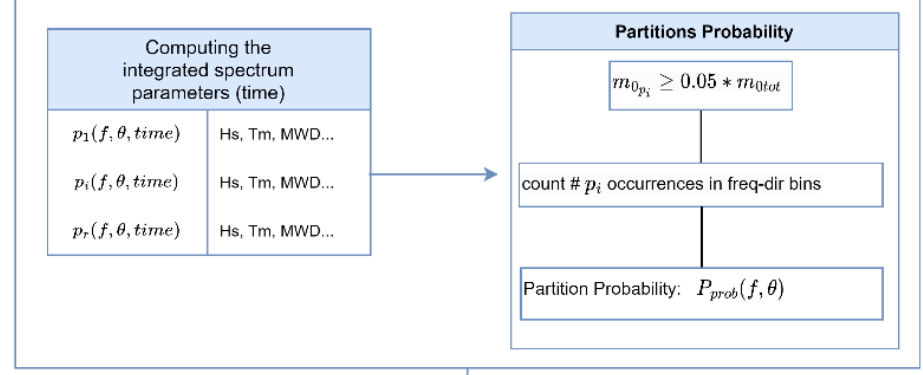
## Wind Sea and Swells dominance

5 Sws + 1Res

Example of time series Hs value for partition 1 in a grid point

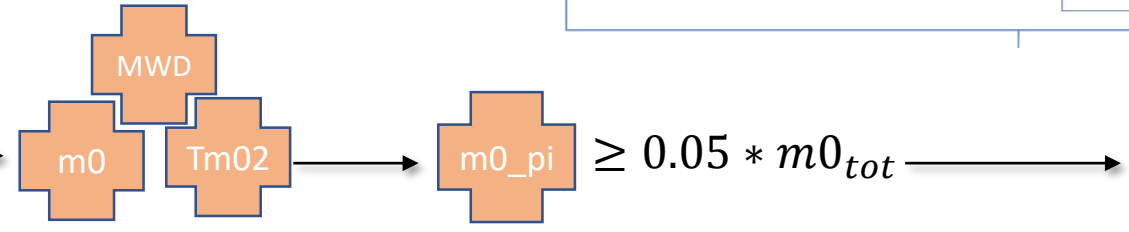
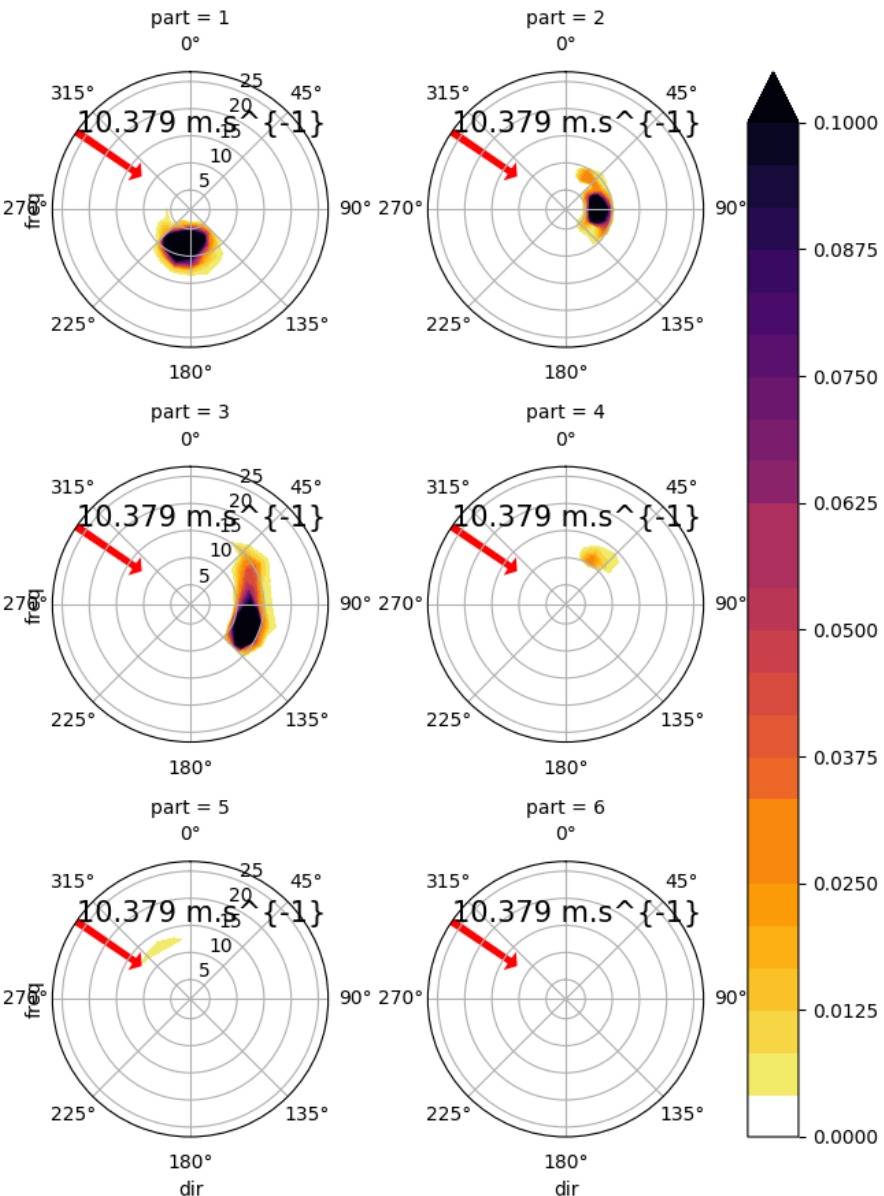
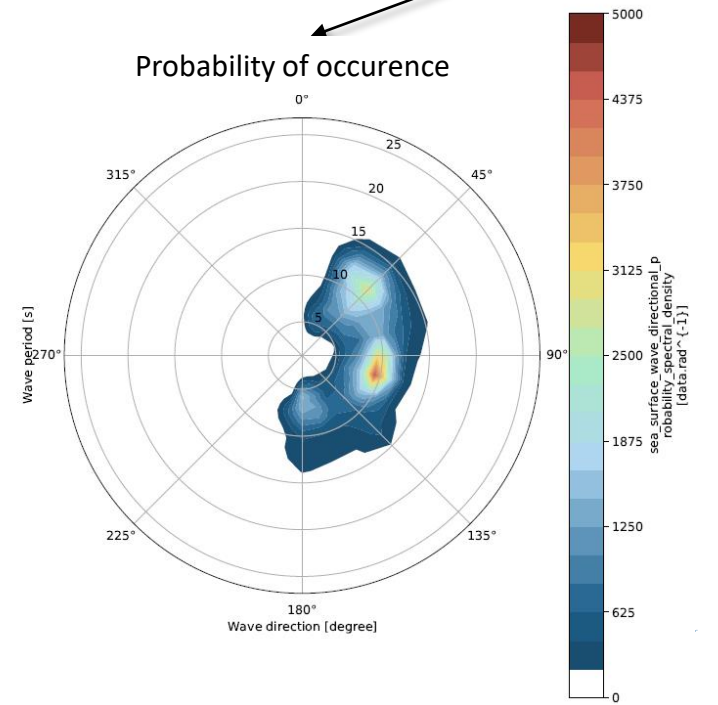


## Partitions Analysis

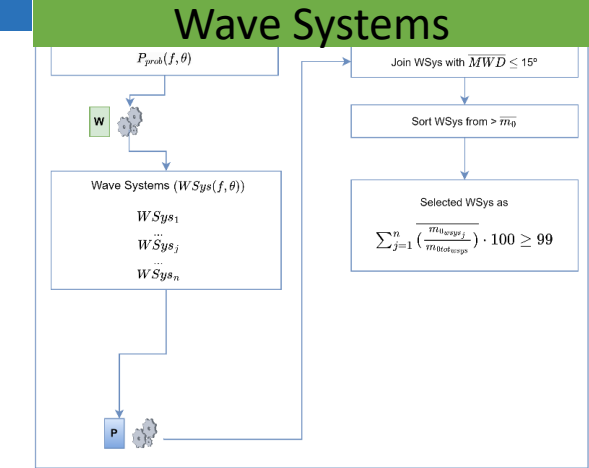


Count # p\_i occurrences in freq-dir bins

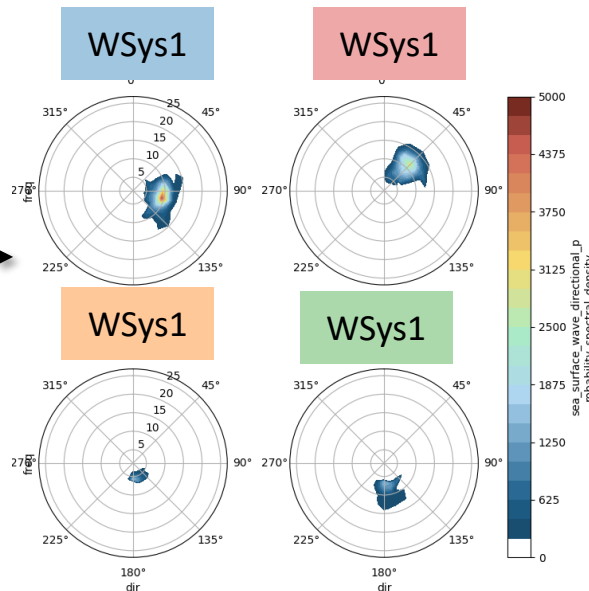
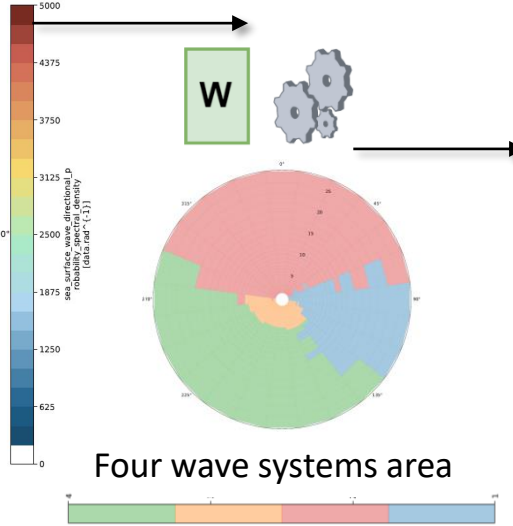
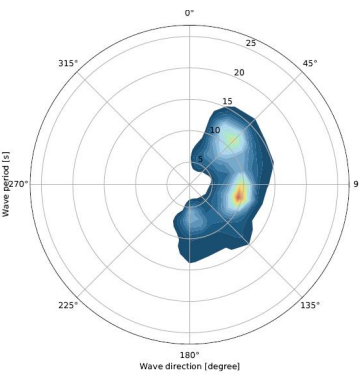
Probability of occurrence



# Methodology



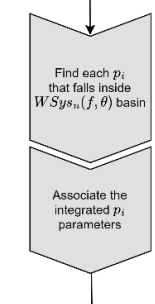
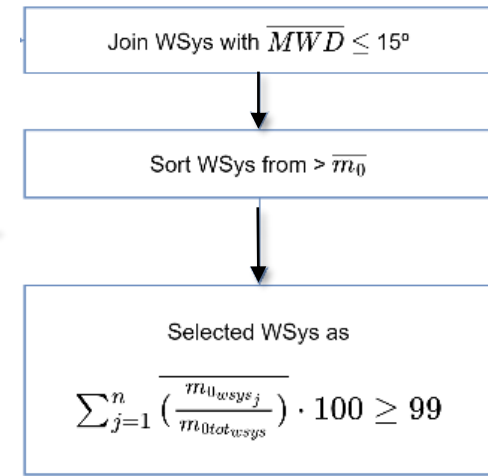
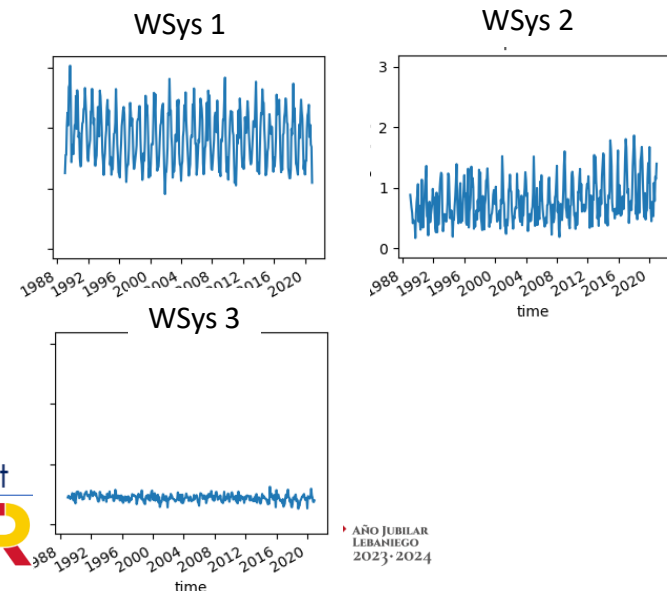
Probability of occurrence



**P** WSys Integrated Spectral Parameters

Input Variables	
Integrated spectral parameters [time]	
$p_1(f, \theta, time)$	Hs, Tm02, MWD...
$p_i(f, \theta, time)$	Hs, Tm02, MWD...
$p_n(f, \theta, time)$	Hs, Tm02, MWD...
$P_{prob}(f, \theta)$	Dimensions
$W_{Sys1}$	$P_{prob}(f, \theta)_{W_{Sys1}}$
$W_{Sysj}$	$P_{prob}(f, \theta)_{W_{Sysj}}$
$W_{Sysn}$	$P_{prob}(f, \theta)_{W_{Sysn}}$
	$f$
	$\theta$

Example of temporal series of Hs for the Wave Systems



OUTPUT: Integrated spectral parameters [time]

$W_{Sys1}(f, \theta)$	Hs, Tm02, MWD...
$W_{Sysj}(f, \theta)$	Hs, Tm02, MWD...
$W_{Sysn}(f, \theta)$	Hs, Tm02, MWD...

Number of Significant Wave Systems

**MOTIVATION**

1

2

**DATA**

3

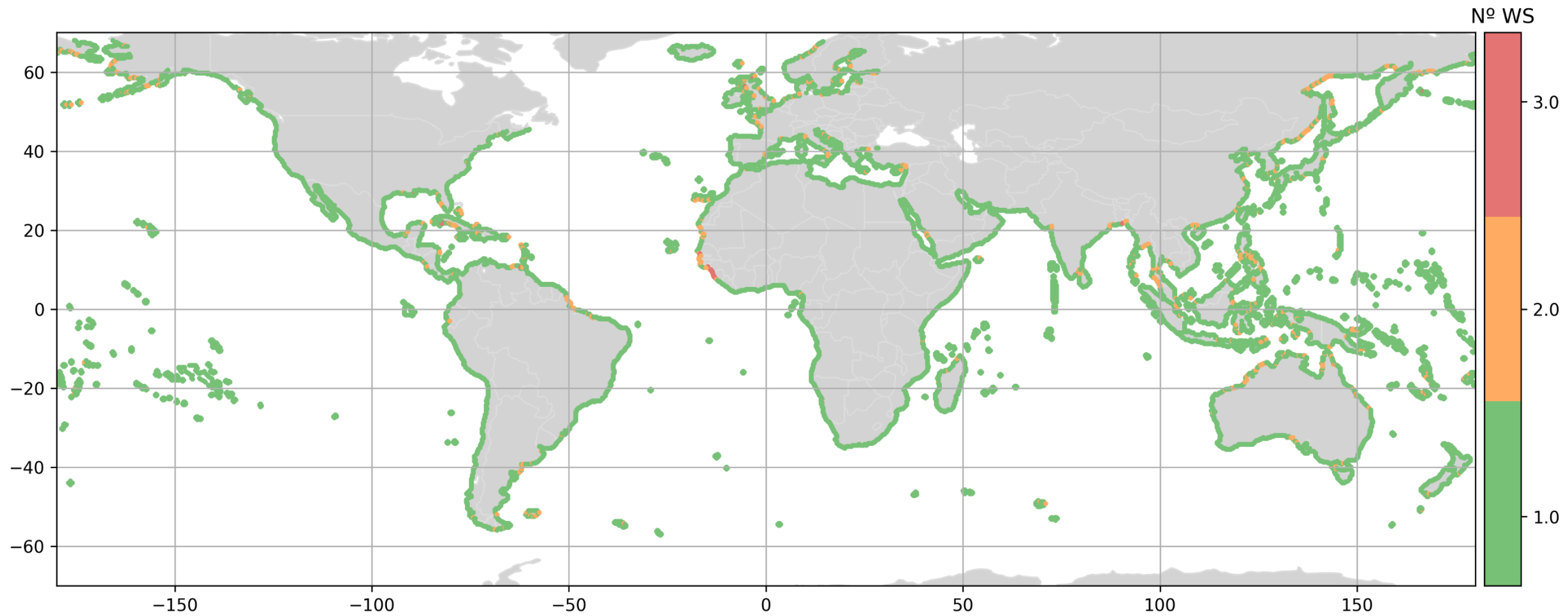
4

**RESULTS**

**METHODOLOGY**

5

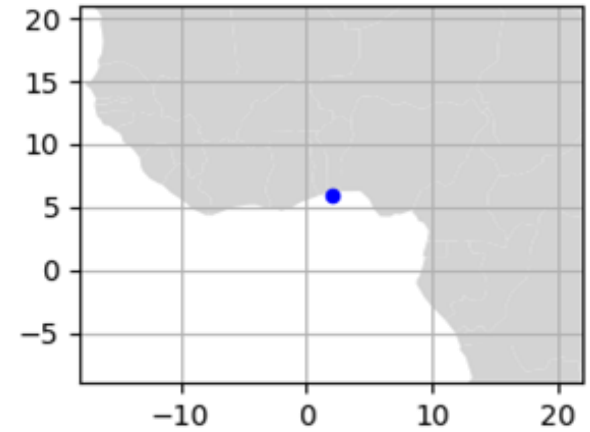
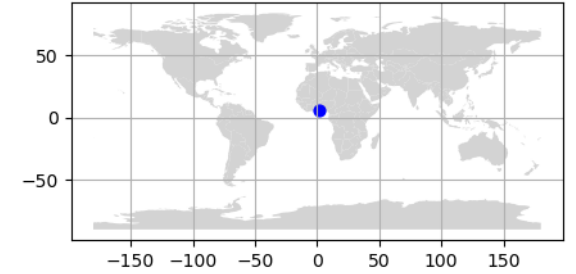
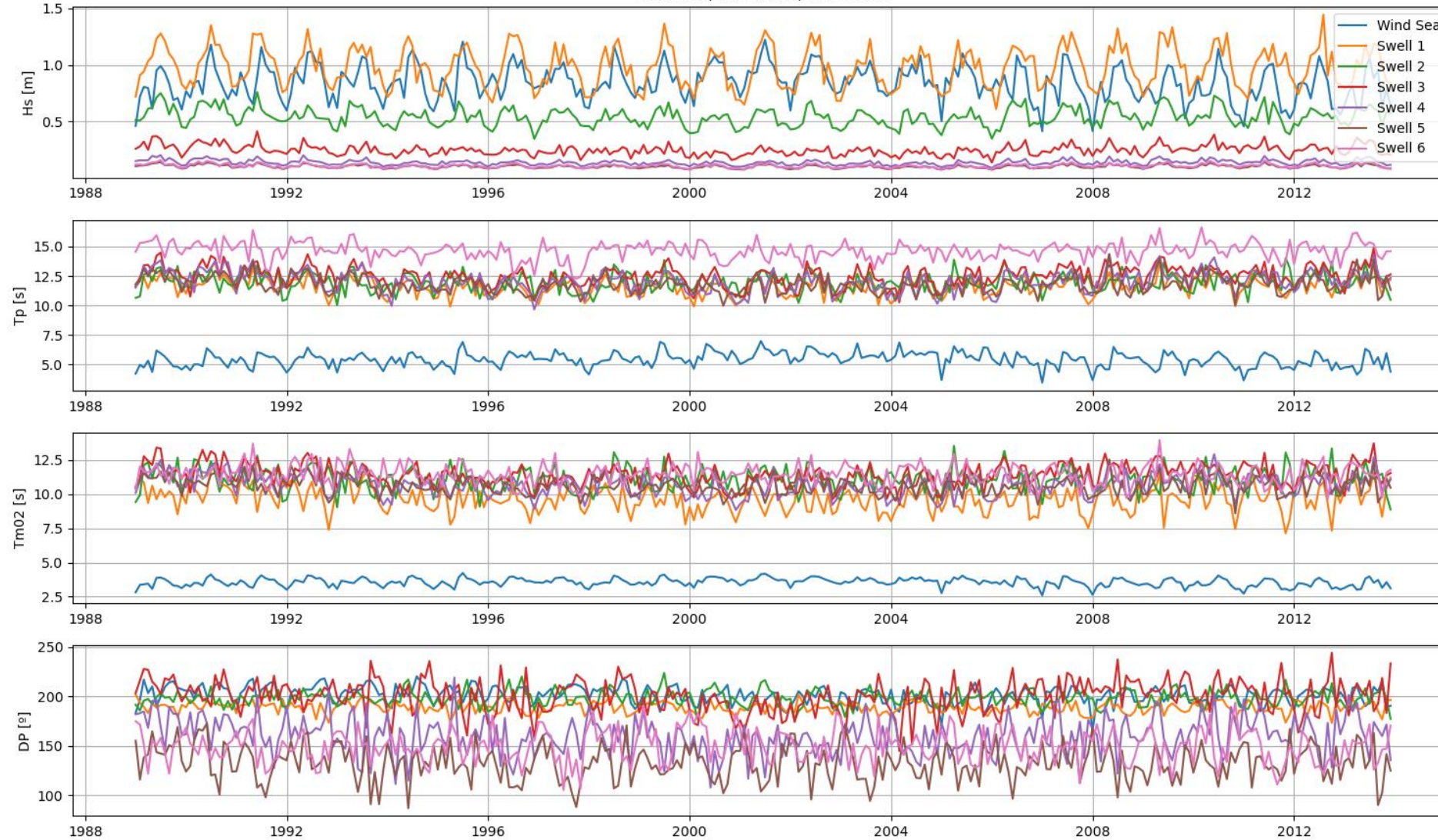
$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( \sum_{iws=1}^{N_{WS}} \frac{m_{0iws}}{m_{0WS_{tot}}} \right)_{it} \cdot 100 > 99$$



# Results-Partitions

## Partitions Analysis

site: 200, lat: 6.000, lon: 2.000

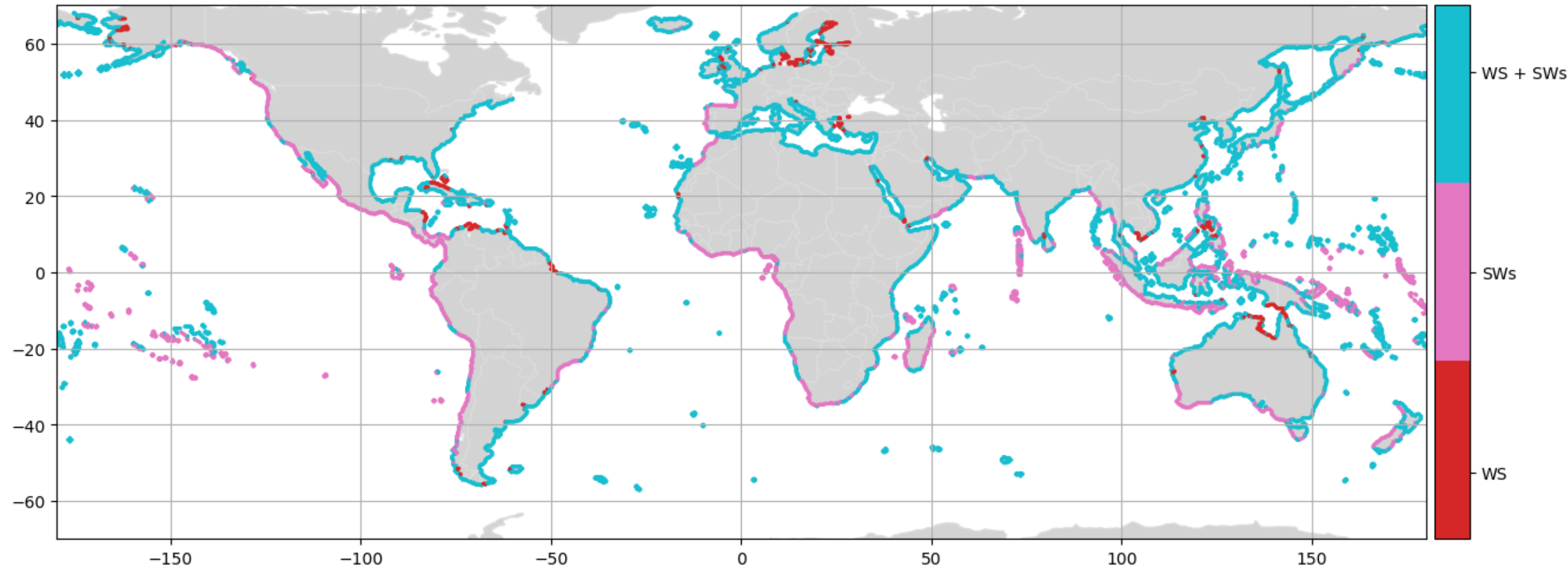


# Results-Partitions: Dominance

$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( \frac{m_{0WS}}{m_{0tot}} \right) > 75 \rightarrow \text{Dominant WS}$$

$$25 \leq \frac{1}{N_t} \sum_{it=1}^{N_t} \left( \frac{m_{0WS}}{m_{0tot}} \right) \leq 75 \rightarrow \text{WS and SWs}$$

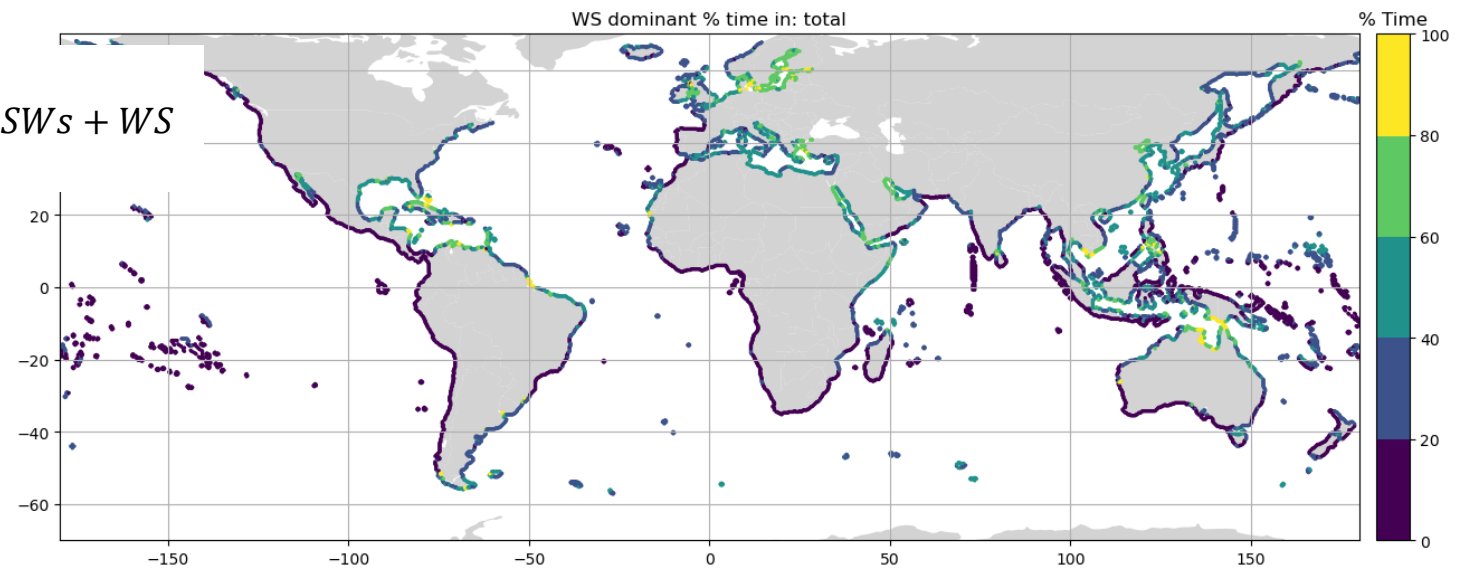
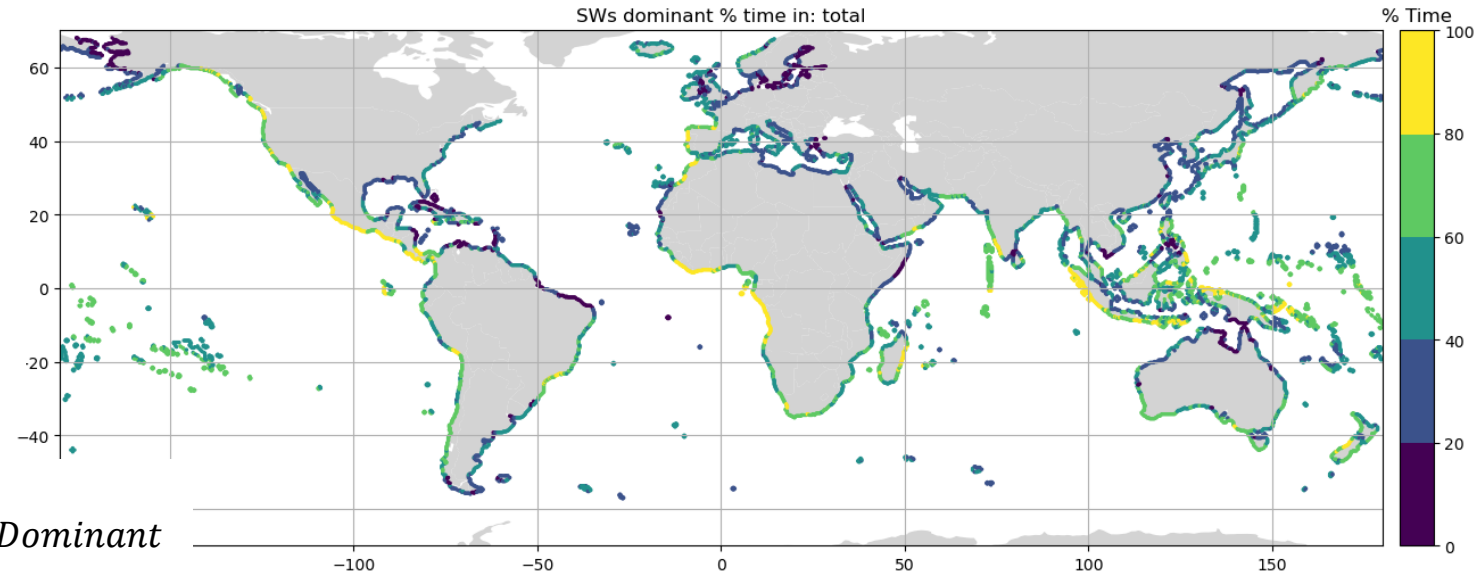
$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( \frac{\sum_{iSW=1}^{N_{SWs}} m_{0isw}}{m_{0tot}} \right) > 75 \rightarrow \text{Dominant SWs}$$



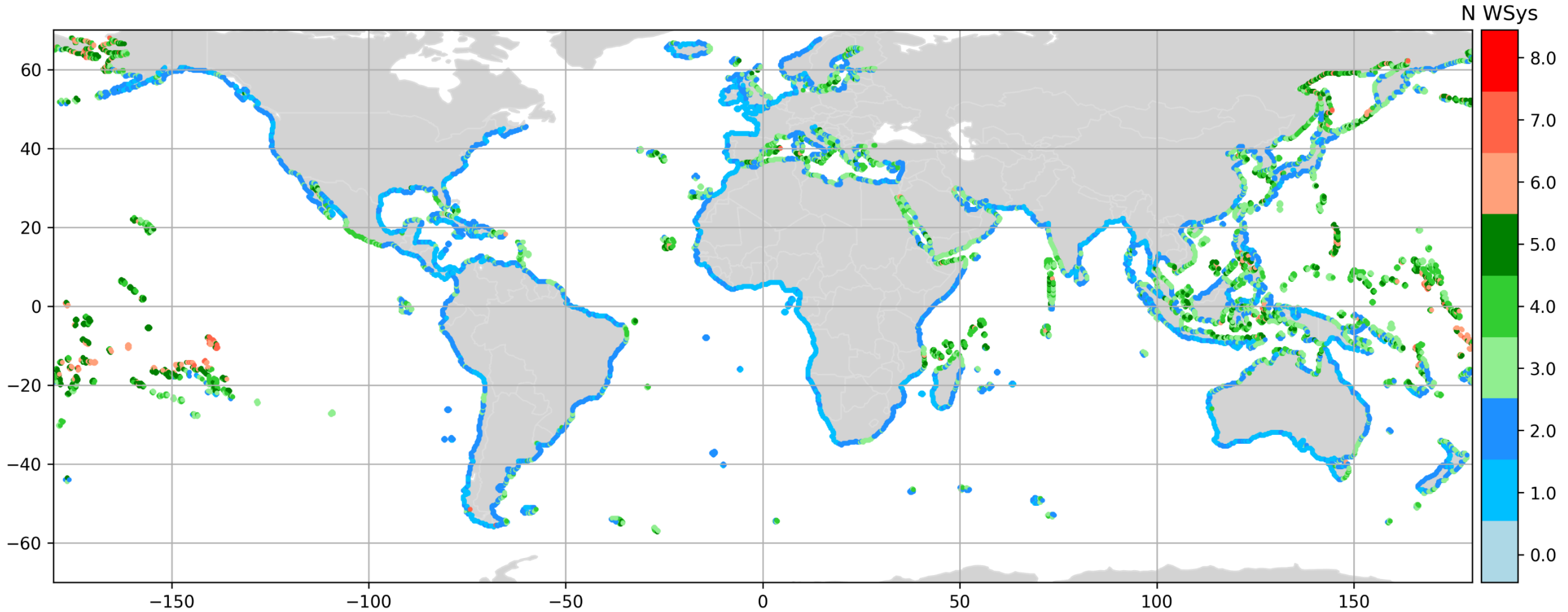
$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( m_{0_{WS_{it}}} > m_{0_{tot}} \cdot 0,75 \right) \cdot 100 \rightarrow \% \text{ of time } WS \text{ Dominant}$$

$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( \sum_{isw=1}^{N_{SWs}} m_{0_{isw}_{it}} > m_{0_{tot}} \cdot 0,75 \right) \cdot 100 \rightarrow \% \text{ of time } SWs \text{ Dominant}$$

$$\frac{1}{N_t} \sum_{it=1}^{N_t} \left( m_{0_{tot}} \cdot 0,25 \leq m_{0_{WS_{it}}} \leq m_{0_{tot}} \cdot 0,75 \right) \cdot 100 \rightarrow \% \text{ of time } SWs + WS$$



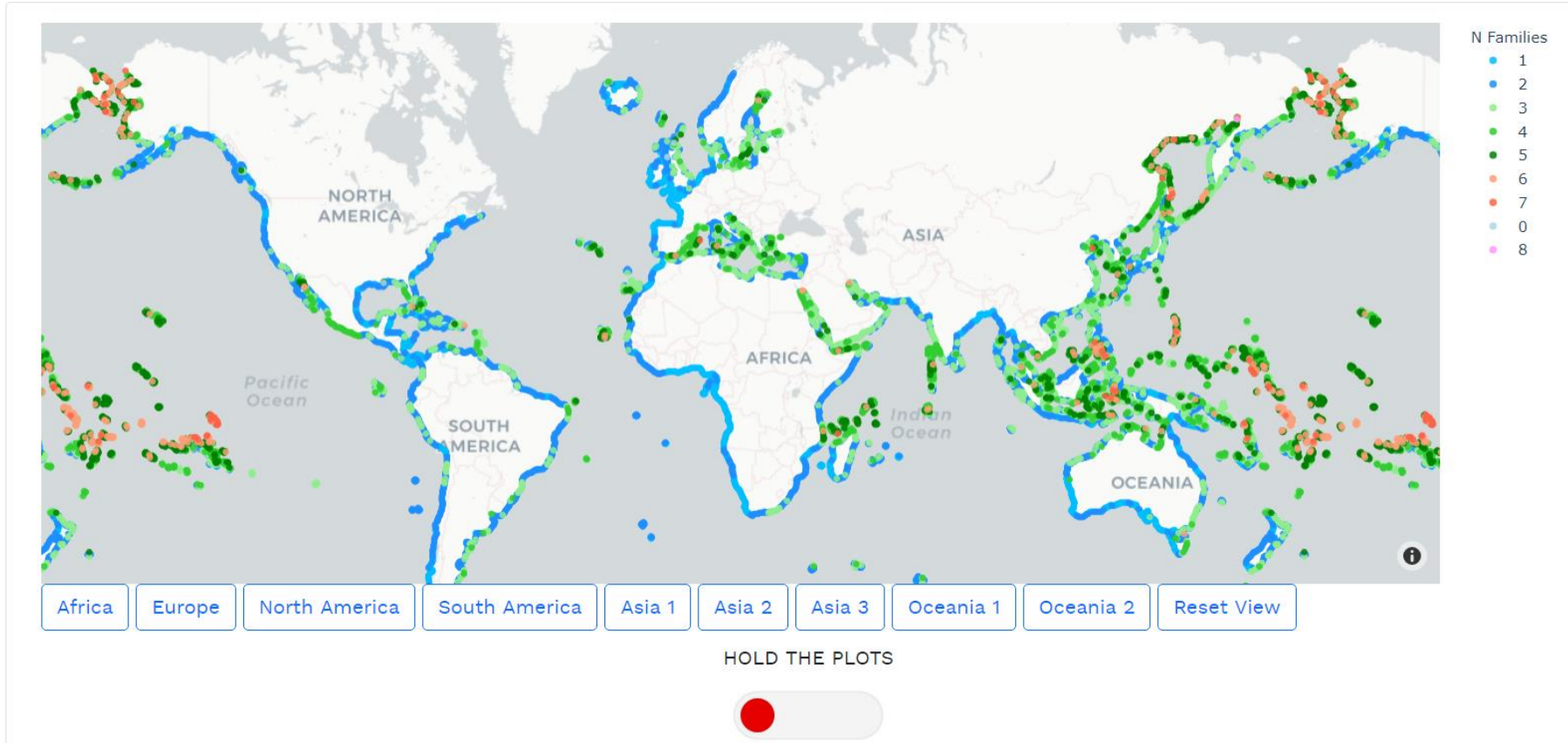




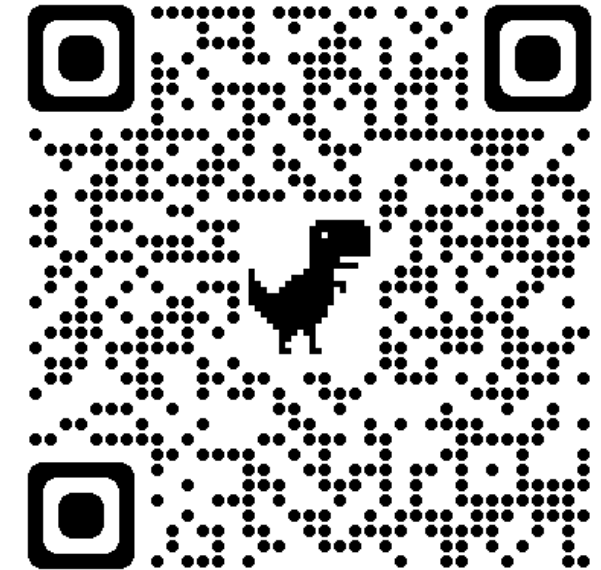
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## Wave Systems

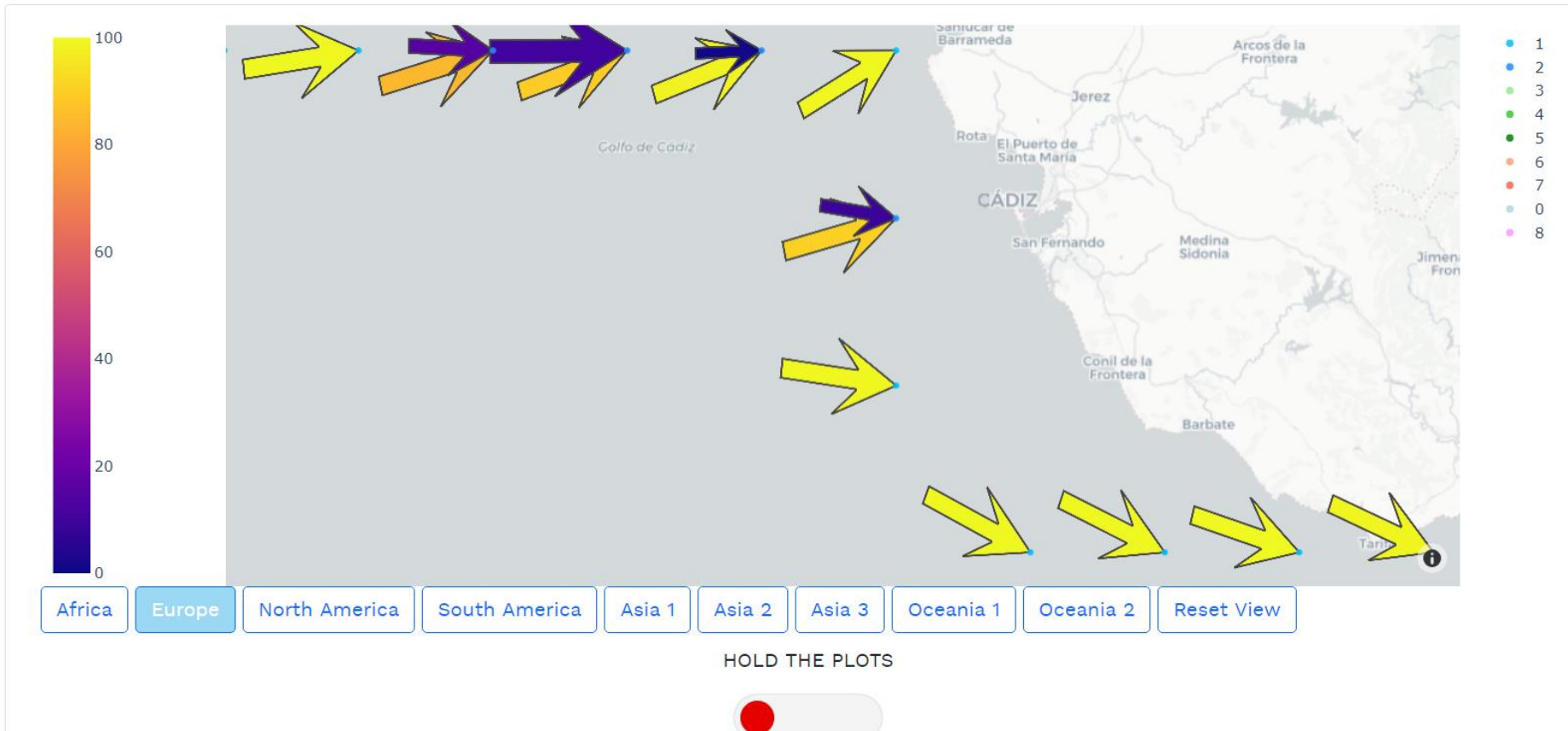


<https://ottaviom.github.io/>

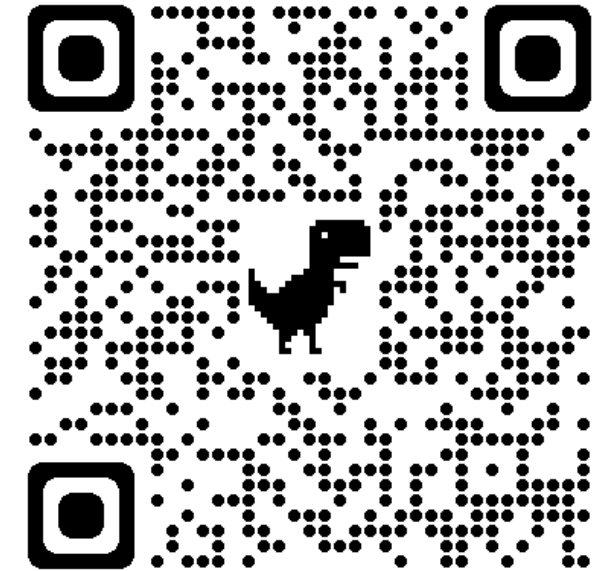


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## Wave Systems



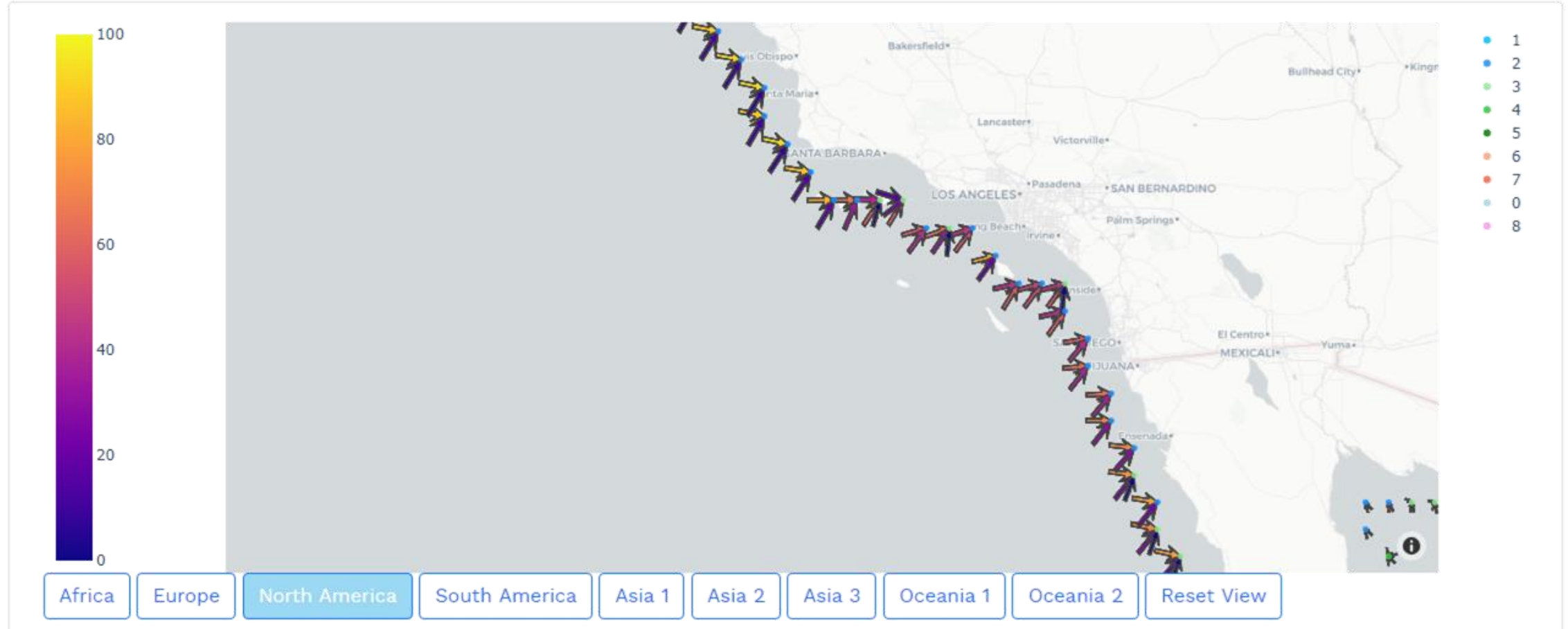
<https://ottaviom.github.io/>



The color identifies the relative energy of each family, it is expressed in percentage,  $\frac{m_{OW Sys_i}}{m_{OW Sys_{tot}}}$ . The size of the arrow represents the time averaged  $T_p$ , whereas the number of the arrow are the number of wave systems that exist in that location, the direction of the arrow represent the time averaged  $MWD$  where the wave systems come from.

<https://ottaviom.github.io/>

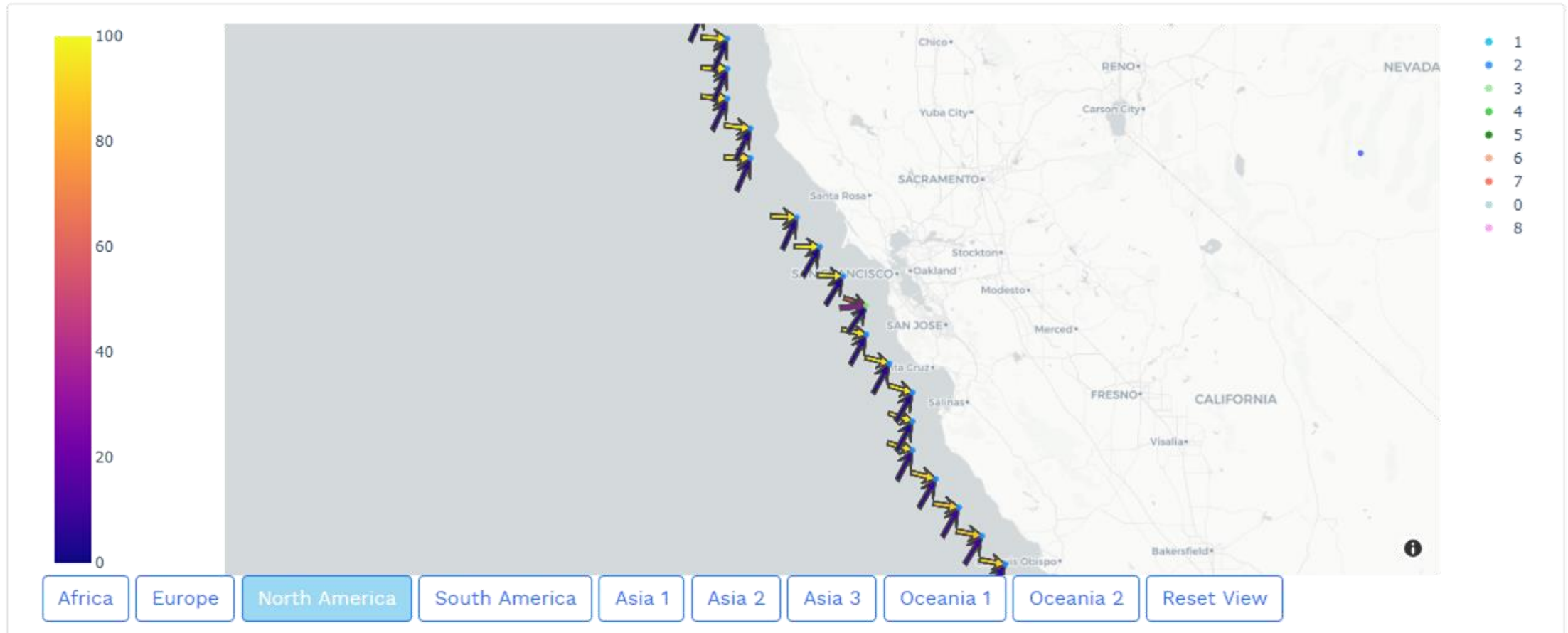
# Wave Systems



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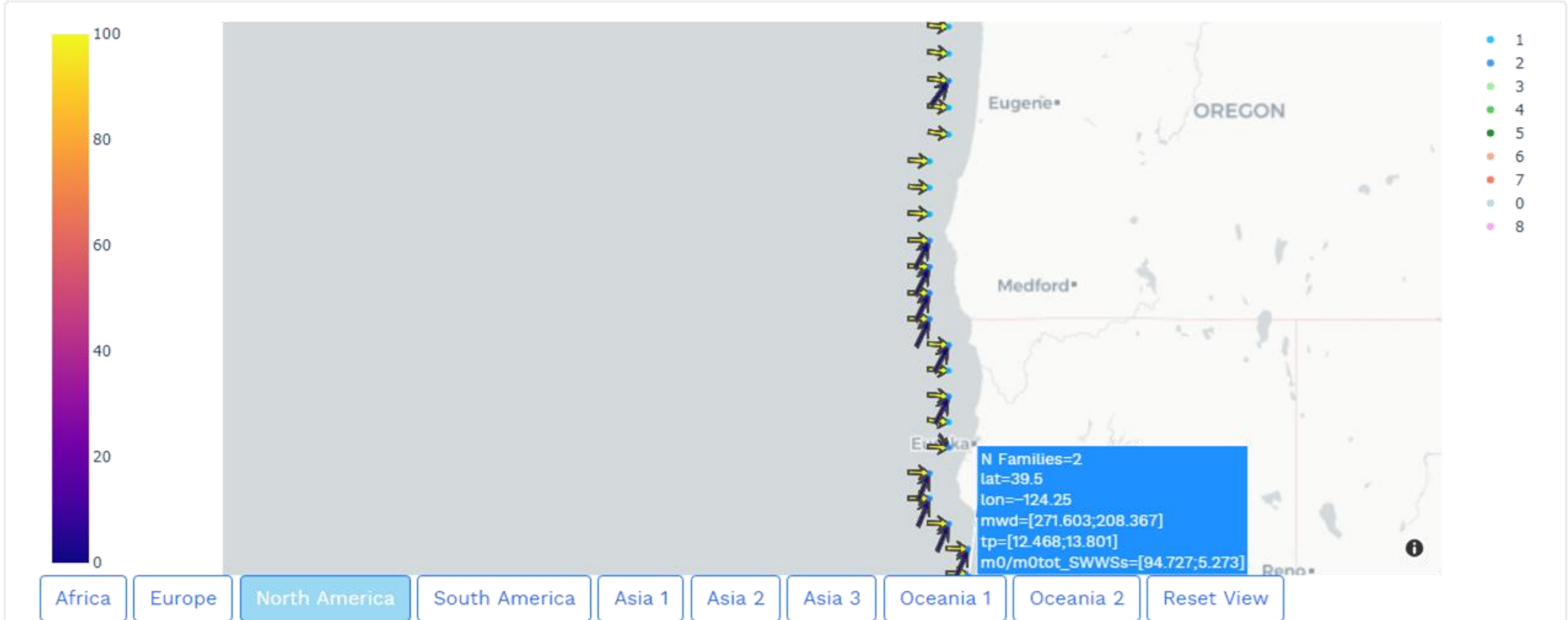
## Wave Systems



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## Wave Systems



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**MOTIVATION**

1

2

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**METHODOLOGY**

3

4

**RESULTS**

**CONCLUSIONS**

5

- Partitioning the directional wave spectrum gives a more comprehensive understanding of the wave climate
- Review the wind sea definition in those areas in which more than one WS partitions fall inside the parabolic region defined by [Hanson and Philips 2001](#)
- Dominance of Swells and Wind Sea:
  - 70% of the global coast → WS + SWs
  - 25% of the global coast → SWs
  - 5% of the global coast → WS
- Clustering of the swell wave partitions has facilitated the identification of distinct wave systems: the long-term conditions prevailing over a frequency-direction wave energy area of the spectrum collecting similar environmental and physical characteristics.
- Existence of significant wave systems:
  - 1 wave system → 18%
  - 2 wave systems → 33%
  - 3 wave systems → 24%
  - 4 wave systems or more → 25%



# Thank You For Your Attention

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Menéndez Melisa: [melisa.menendez@unican.es](mailto:melisa.menendez@unican.es)

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