Development of a Storm Surge Classification Scale for Brazil's Coast Using Wave Energy Flux

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4th Workshop on Waves, Storm Surges and Coastal Hazards

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Overview

The "ressaca" phenomena

(Storm surge, but not quite it...)

What is Ressaca?

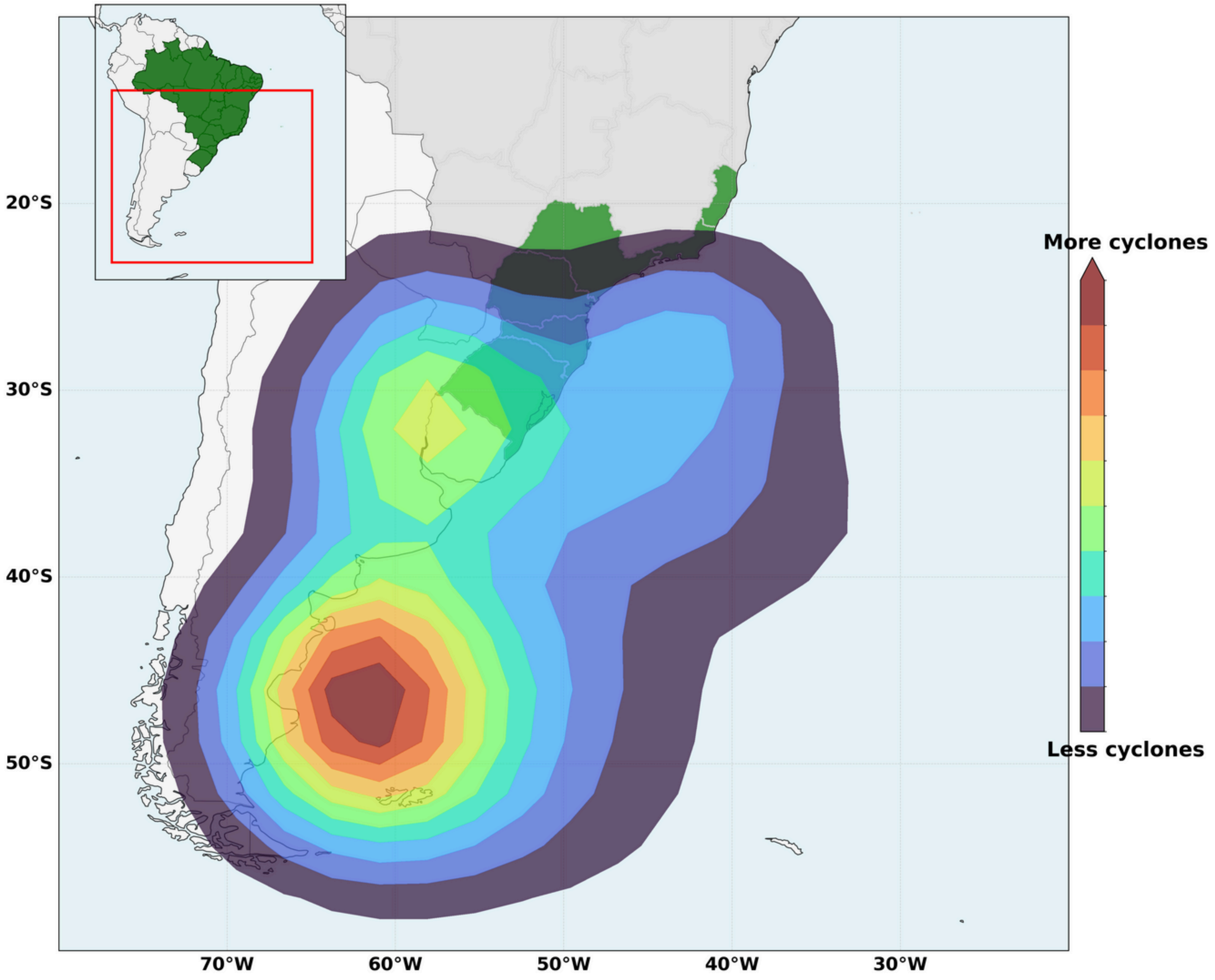
- Brazillian Navy → Large waves > 2.5m

Storm surge

- Sea level rise caused by storms (no wave setup)

In Brazil...

- Cyclogenesis close to the coast
- Often cause both large waves and storm surge



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Objectives

Objective 1

Devise a storm surge classification scale for the southern/southeastern Brazil based on Wave Energy Flux (Pw)

Objective 2

Validate the Brazilian Navy "ressaca" definition by comparing the devised scale with the reported occurrences

Objective 3

Compare the devised scale with real occurences of coastal extreme events

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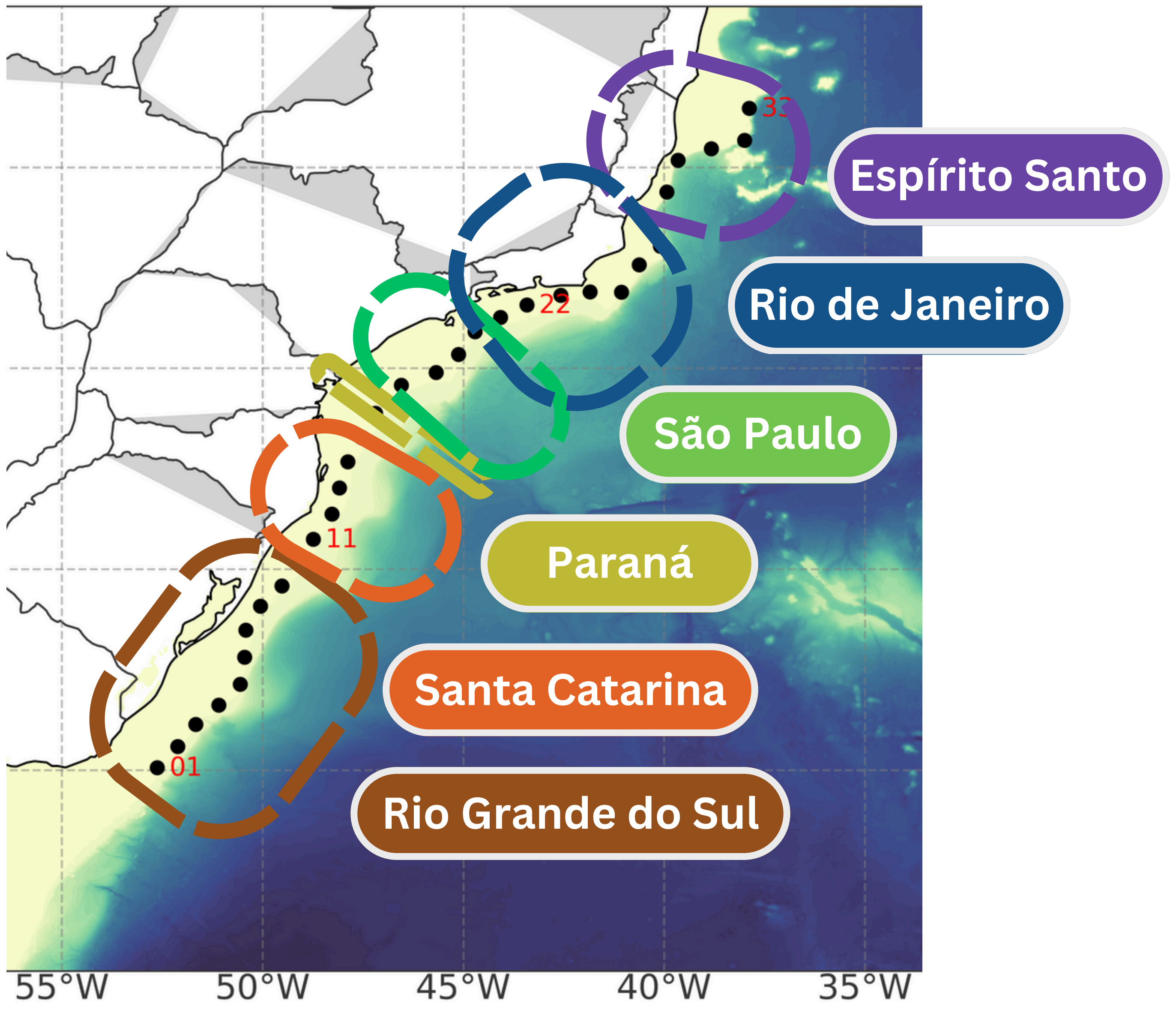
Data

- Waverys Reanalysis: 1993-2021
- 33 points along the 100m isobar



Variables

- Maximum Wave Energy
- Event total integrated energy
- Energy mean direction

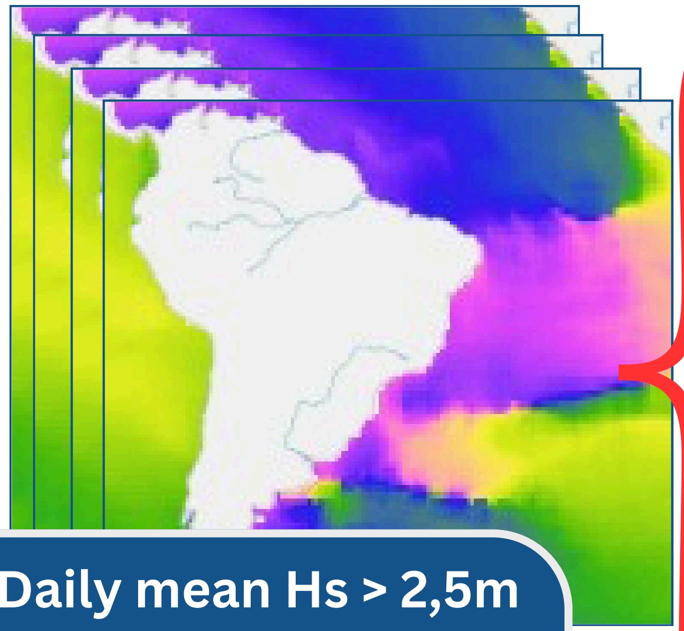
Wave Energy Flux

$$P_W = \frac{\rho g H_S^2}{16T}\left[\frac{\lambda}{2} + \frac{2\pi h}{\sinh\left(\frac{4\pi h}{\lambda}\right)}\right]$$

- Wave height (Hs)
- Peak period (T)
- Wavelength (λ)

Workflow

Storm surge classification scale from clustering the 3 computed variables



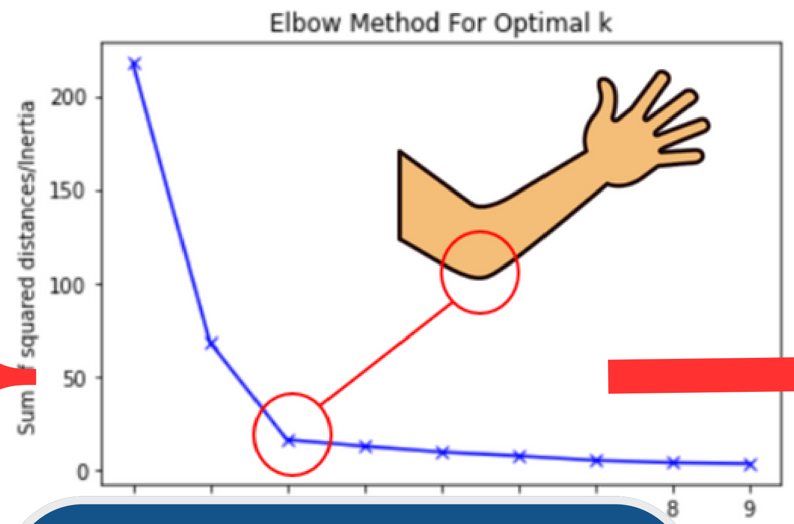
🌊 Daily mean Hs > 2,5m
⏱️ Duration > 24h

(for each point)

💻 Integrated Pw

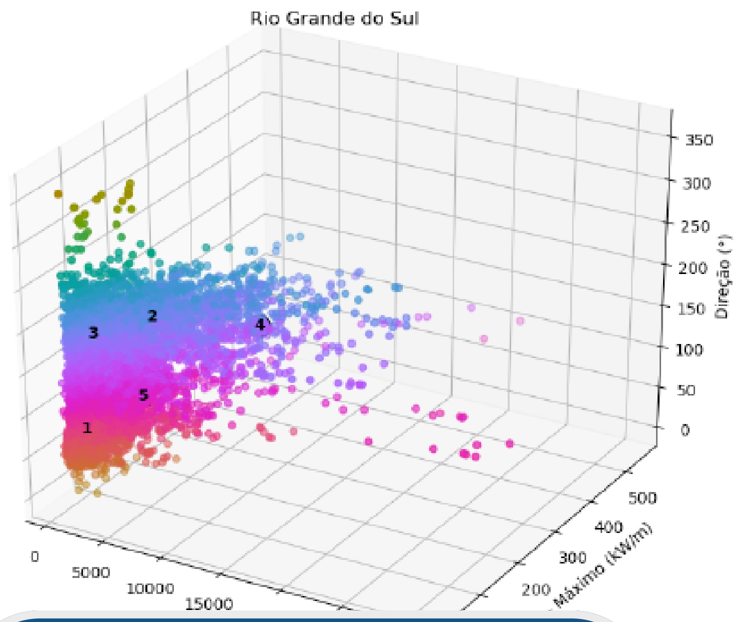
💻 Pw max.

💻 Mean energy direction



📉 Elbow method

(determining optimal number of clusters)



✅ K-means

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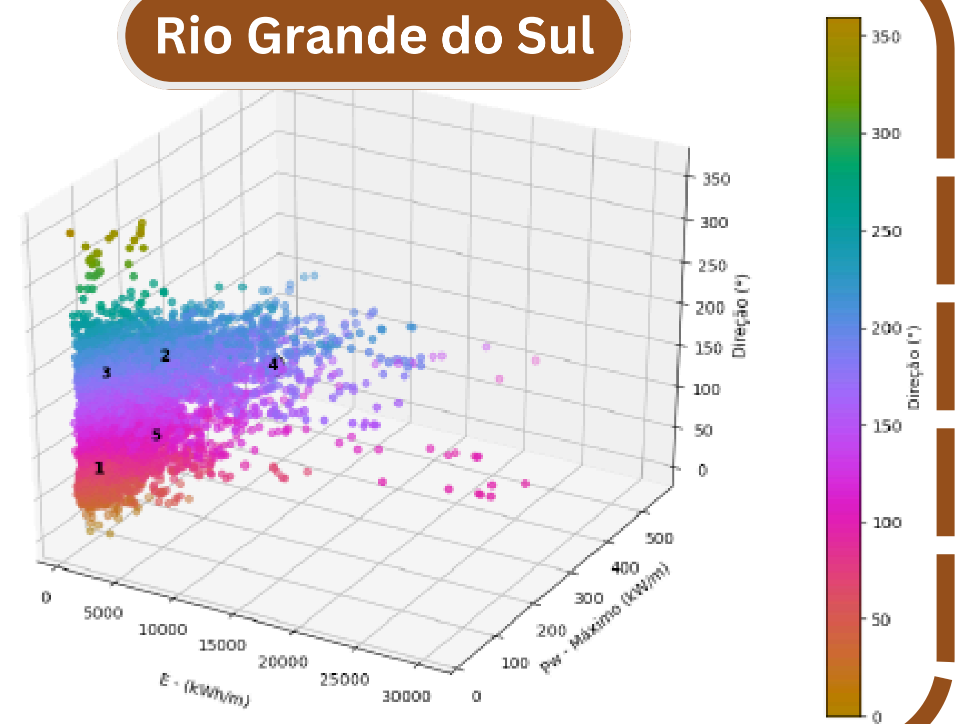
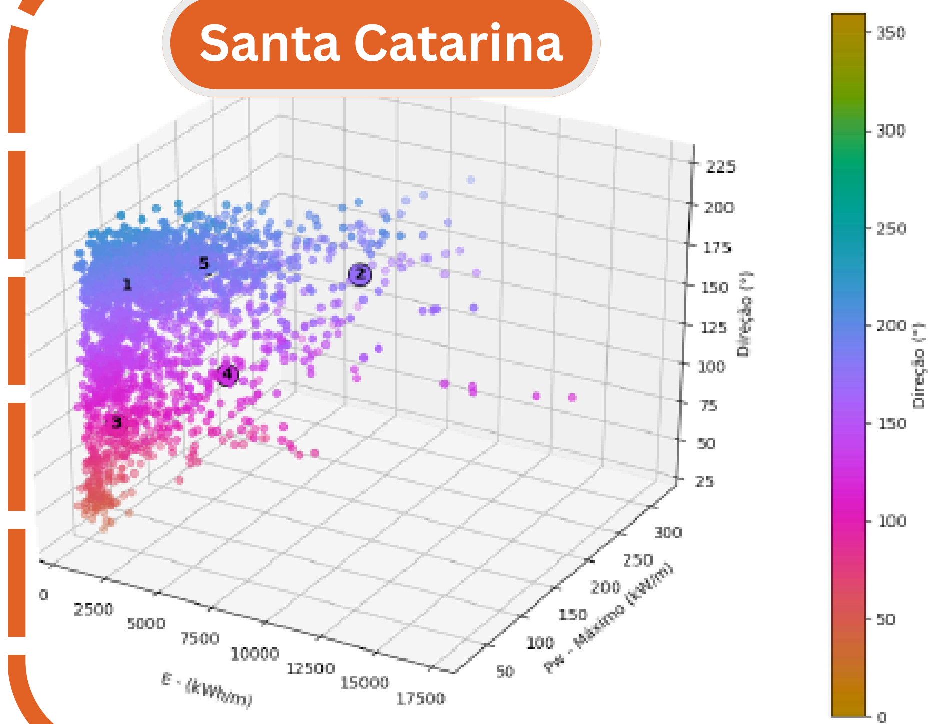
Storm surge scale

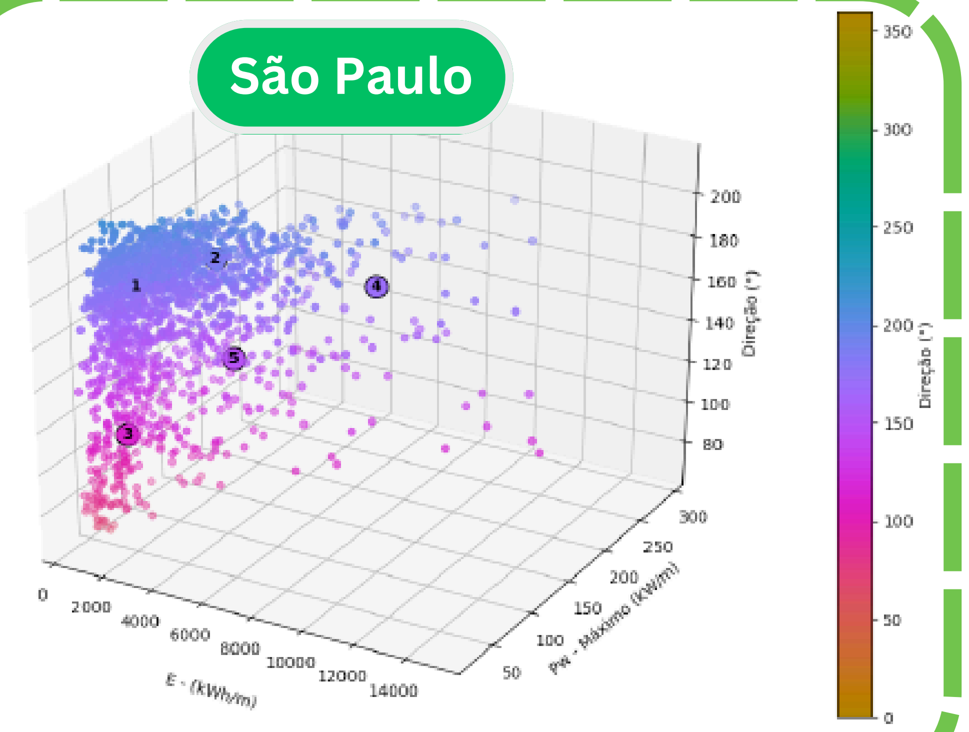
Rio Grande do Sul



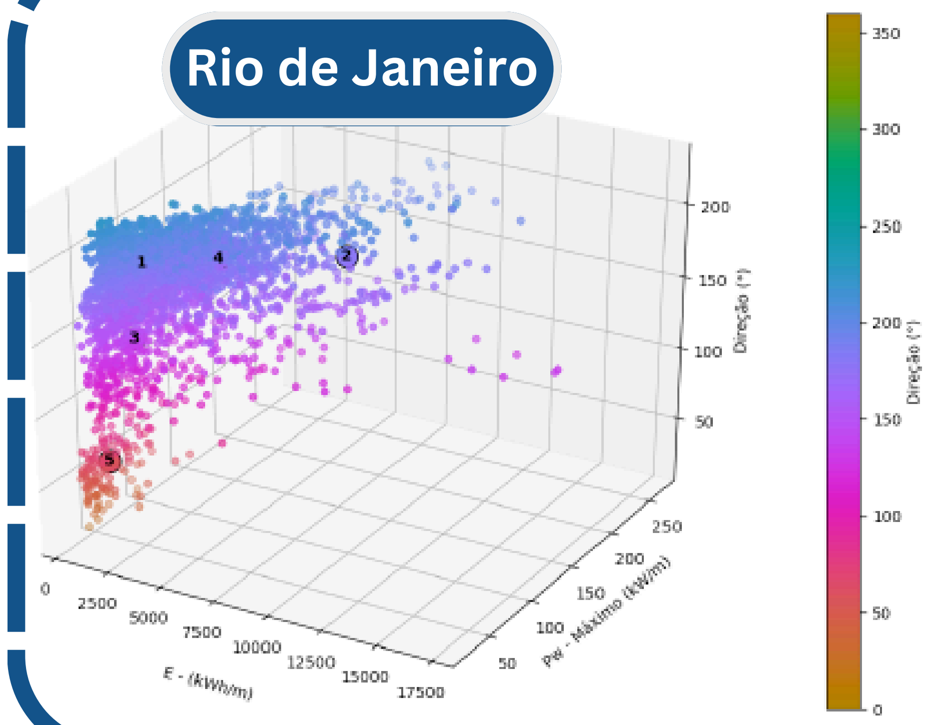
Santa Catarina

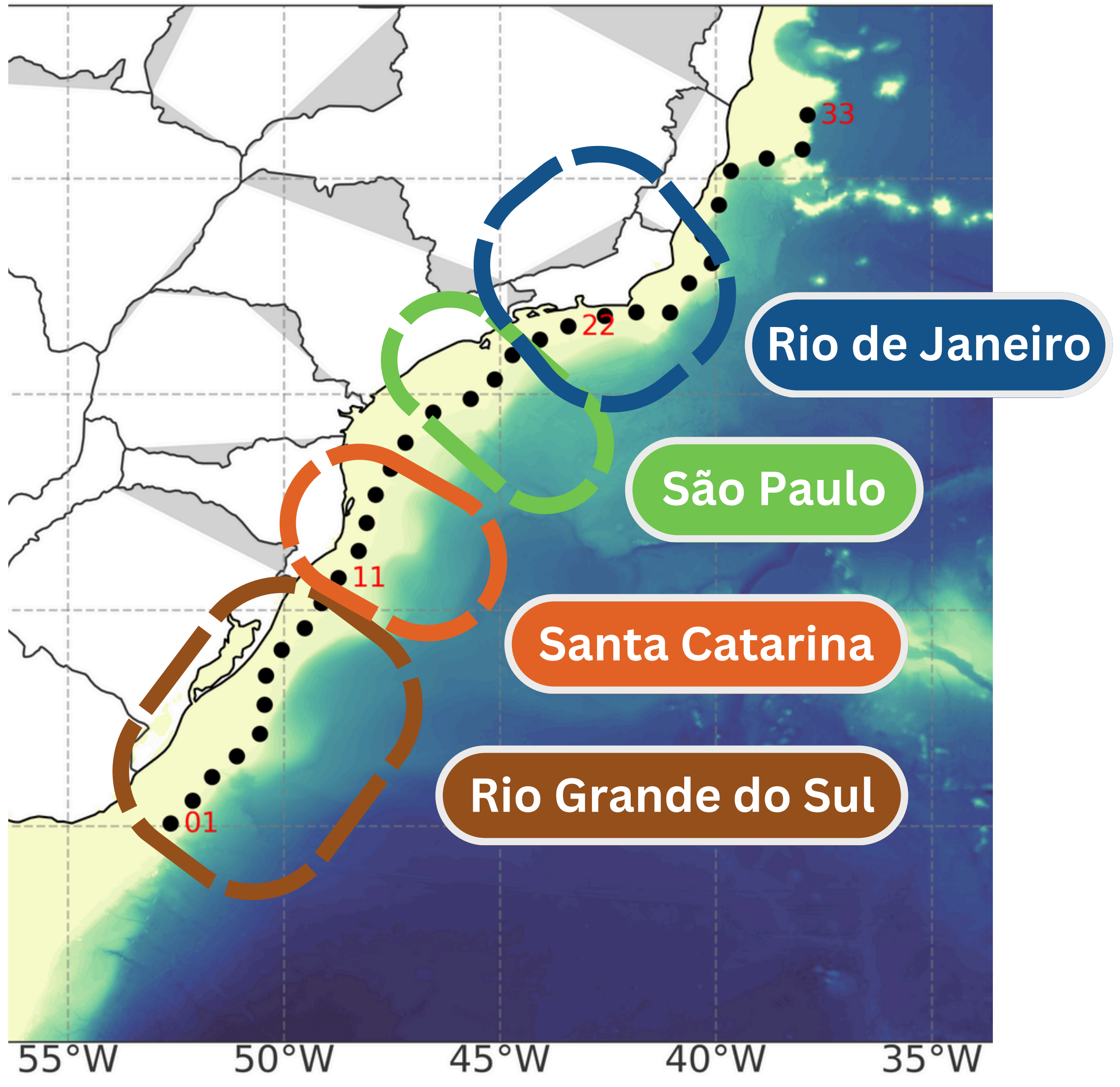


São Paulo



Rio de Janeiro





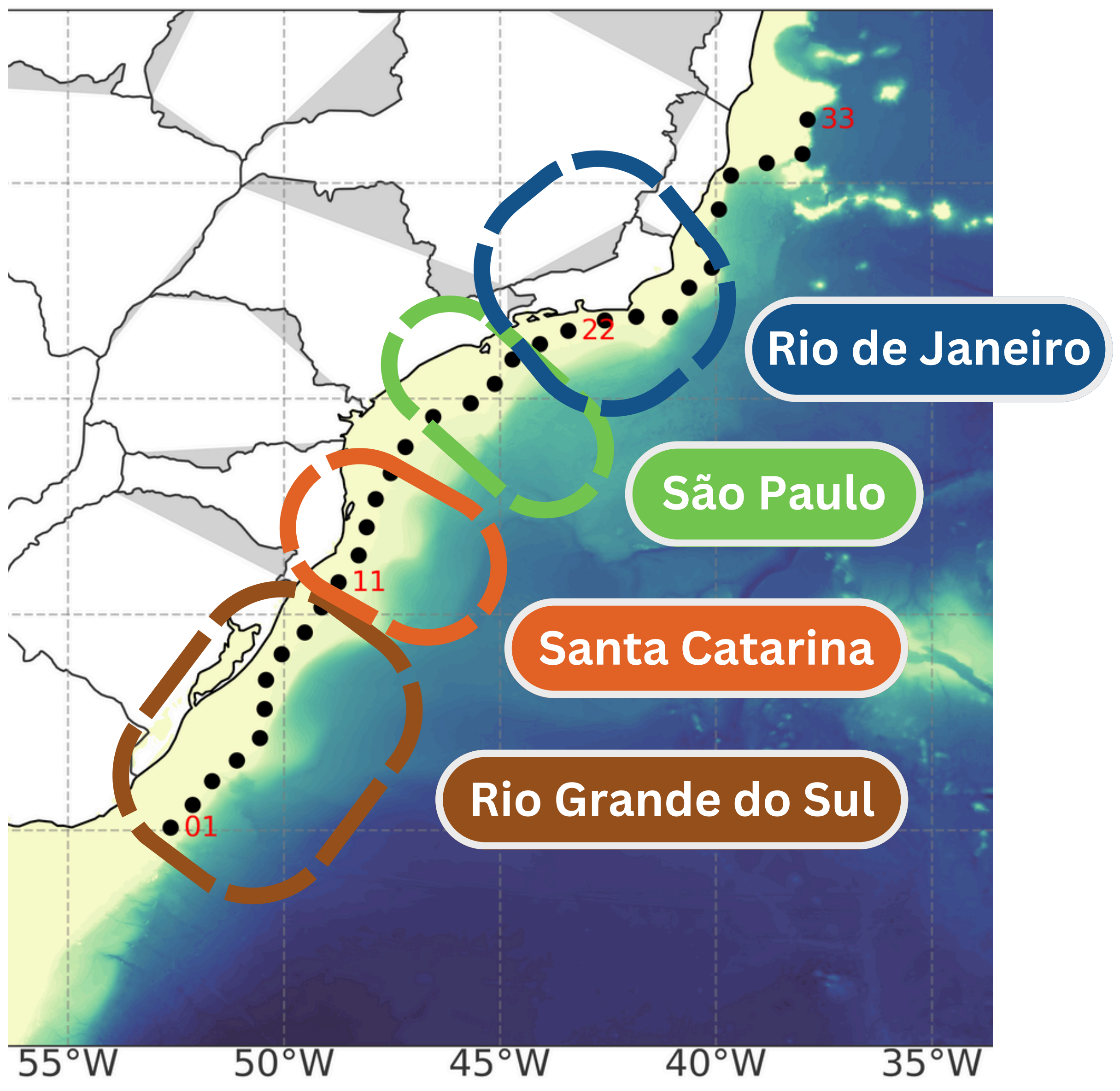
Storm surge scale

Classes

- 5 storm surge classes.
- Three main classifications: Class I (Mild), Class II (Moderate), Class III (Severe).
- Classes I and II have two subcategories based on average wave direction.

Spatial variability

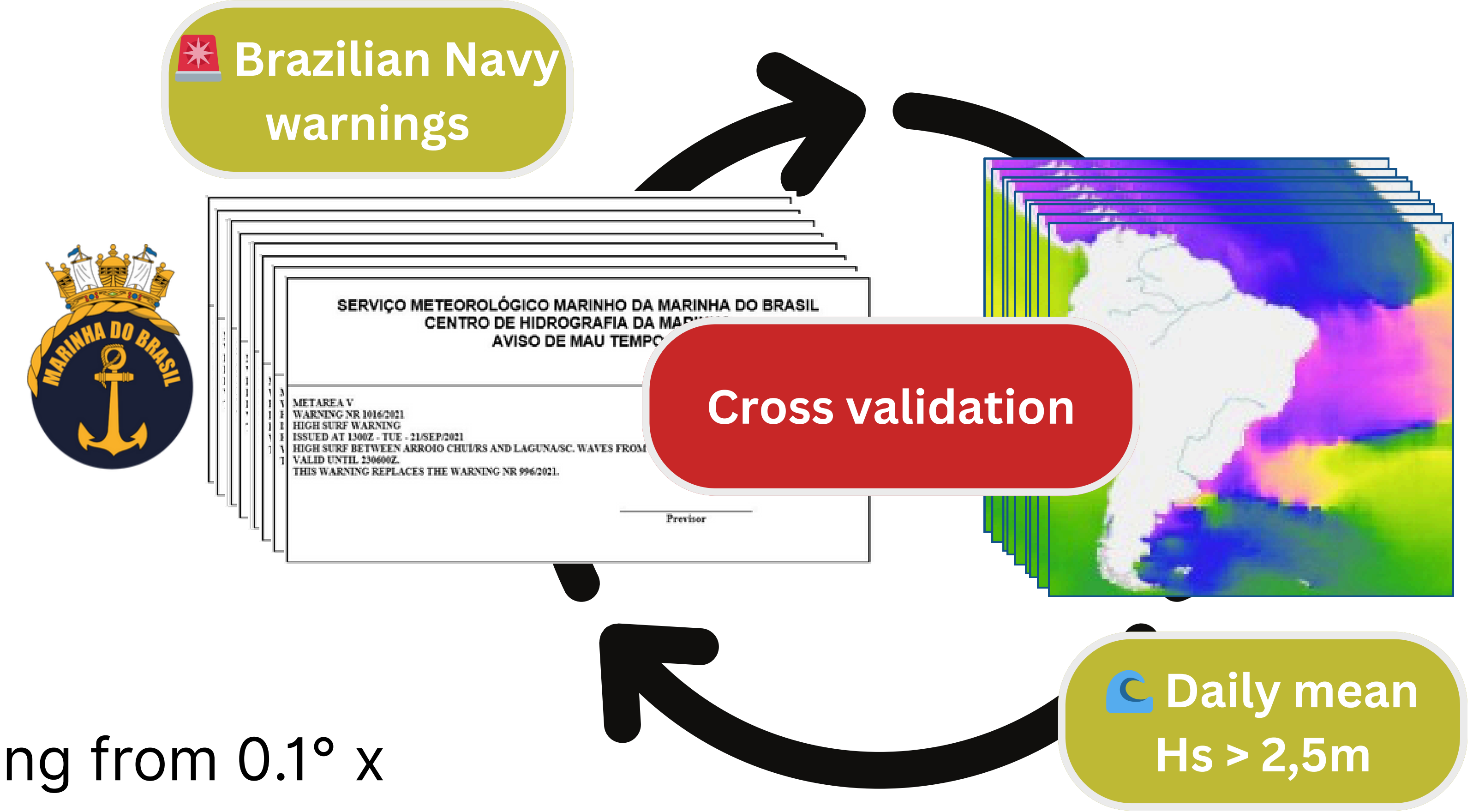
- Most surges → **Rio Grande do Sul** (50%) of surge cases
- Following → **Rio de Janeiro** (17%) and **Santa Catarina** (14%)
- Most severe cases → **Rio Grande do Sul** (7%), followed by **São Paulo** (6%)



Validation of the Navy alerts

Cross validation results

- Proven alerts: ~75% (percentage of alerts that correctly matched events)
- Coverage of events: ~50% (percentage of events with Hs > 2.5m covered by alerts)
- Highest false alarm ratio in **Santa Catarina** and **Espírito Santo** (31%)
- Lowest false alarm ratio in **São Paulo** and **Rio de Janeiro** (19%)



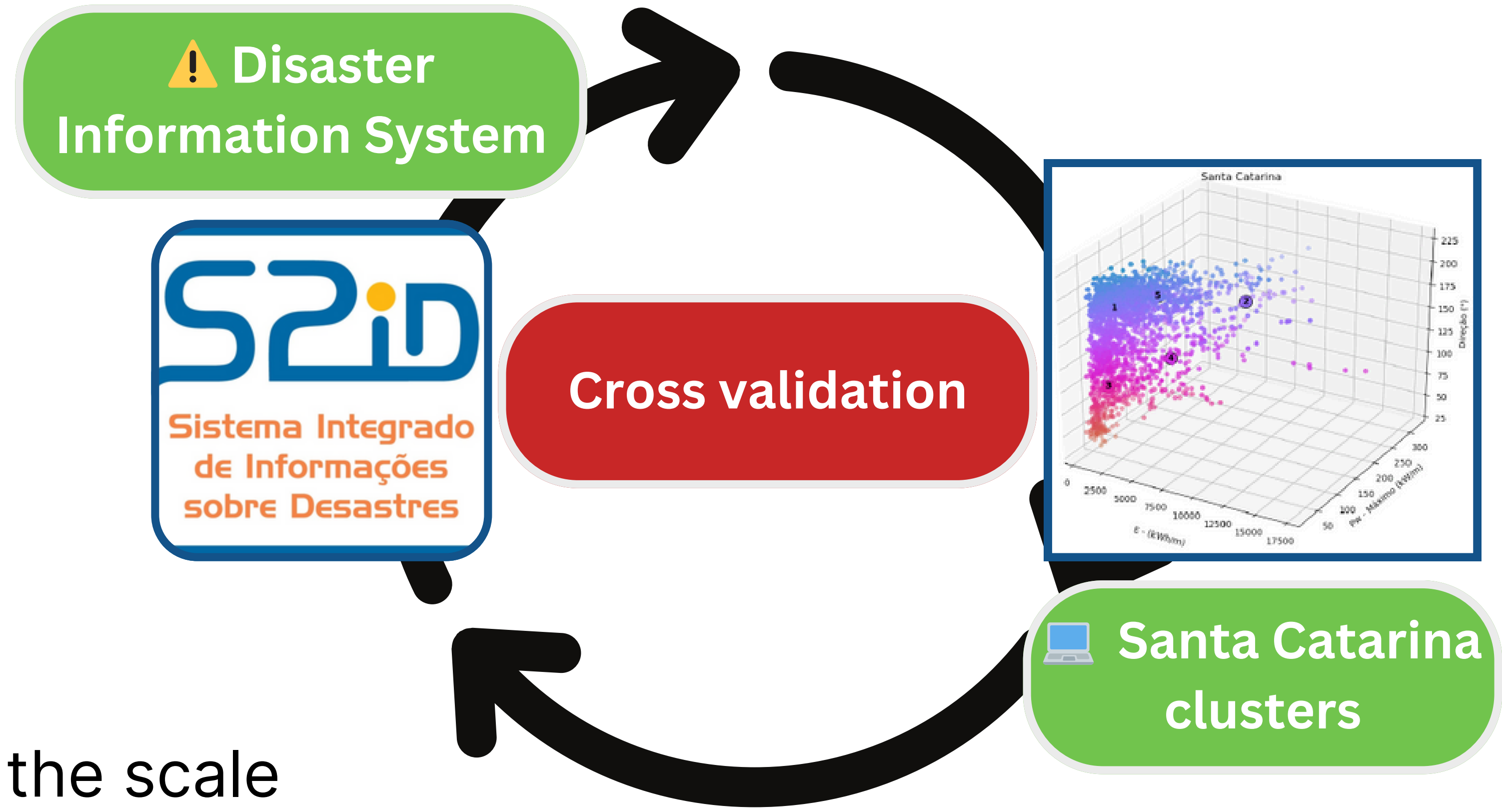
Future directions

- The Navy's WW3 forecast model improved grid spacing from 0.1° x 0.1° to 0.08° x 0.08° in 2023
- This change may reduce false alarms and increase event coverage
- Further research is needed to explore these developments

Validation of the storm surge scale

Cross validation results

- Data pertains only to Santa Catarina.
- From 2011 to 2021, 81 storm surge cases were recorded, with 40 matching the proposed scale.
- Of the 40 classified events, **15 were Class III** (severe), **14 Class I** (mild), and **11 Class II** (moderate).
- 33 events led to significant financial losses, totaling US$ 6,789,102.51 for the public treasury.



Influence of Spring Tides

- Analysis revealed that many damaging events, not meeting the scale criteria (HS > 2.5m for 24h), were influenced by spring tides.
- Spring tides can amplify the effects of swells, even if waves are not significantly high for long.

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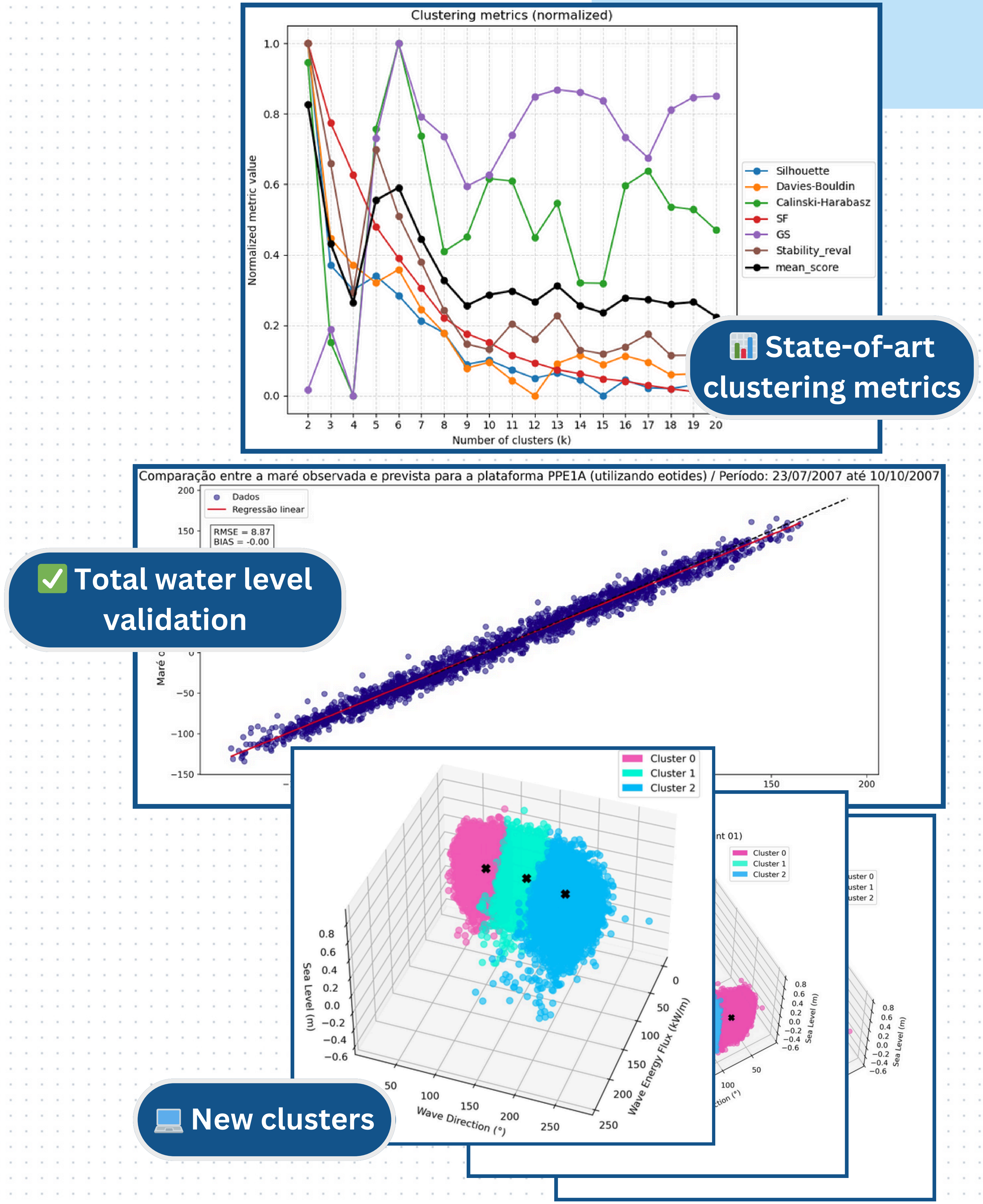
Next steps

New sea-states clustering

1. Total water level = BRAN (meteorological component) + FES (astronomical tide)
2. Hourly wave energy flux and direction
3. Segregate day-to-day states and extreme cases



Thank You

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