4TH INTERNATIONAL WORKSHOP ON WAVES, STORM SURGES, AND COASTAL HAZARDS
Incorporating the 18th International Waves Workshop

Relating Wave Energy and Shoreline Change: A Uruguayan Case Study

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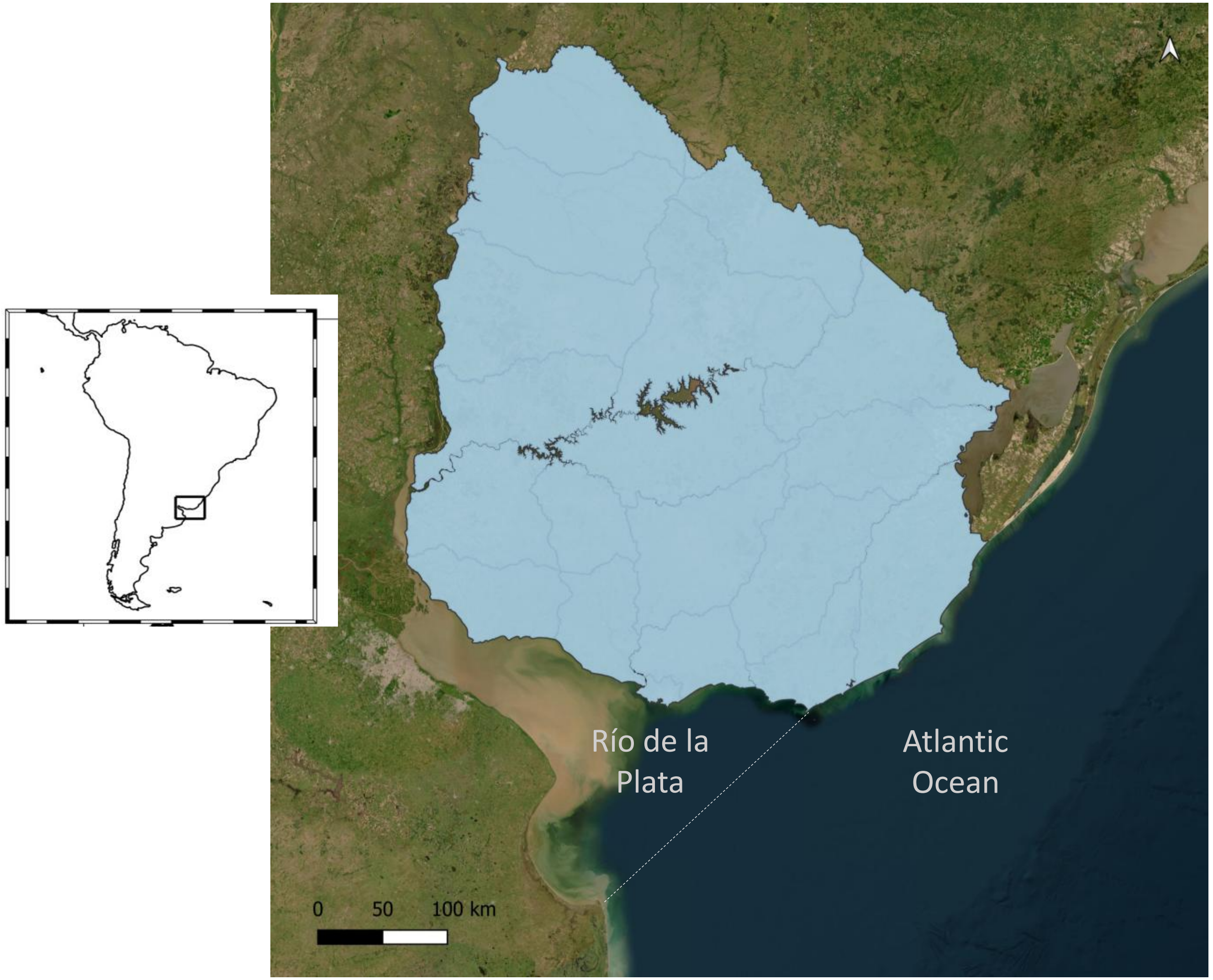


Uruguayan Coast

- 700 km long aprox.

  Río de la Pata (~465 km) + Atlantic (~ 235 km)

- Mostly composed of sandy beaches.

  Micro-tidal

  Wave-dominated morphology

- Different wave climates between the two extremes.

  Atlantic: Swell dominated

  (Mostly Multimodal spectra).

  Inner Río de la Plata: Wind sea dominated

  (Mostly fetch limited).

Motivation

Previous work

To support a knowledge-based coastal management, two nationalwide, high resolution and long-term databases were developed:

Local wave hindcast

Remote monitoring of shoreline position

Ongoing work

Analyze relationships between waves climate and shoreline variability

This presentation

Focus on inter-annual scale

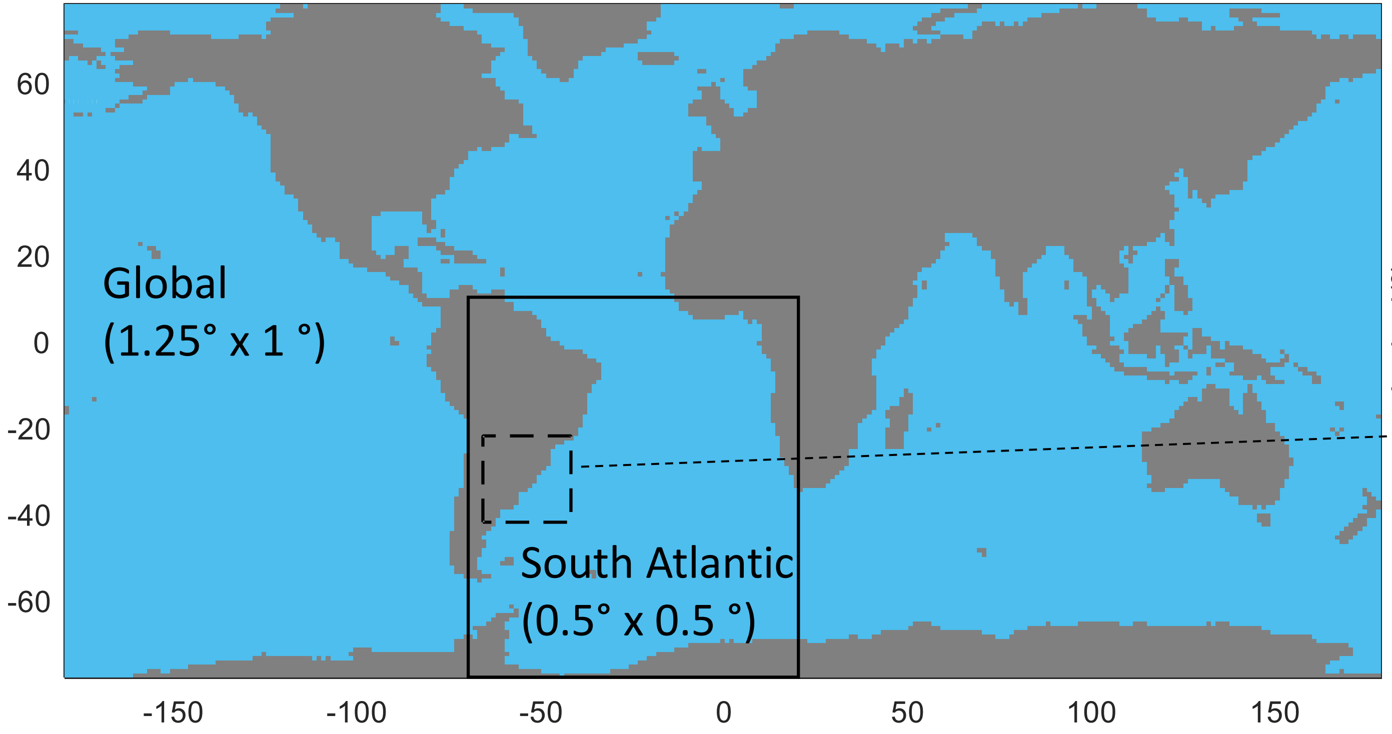
Wave hindcast

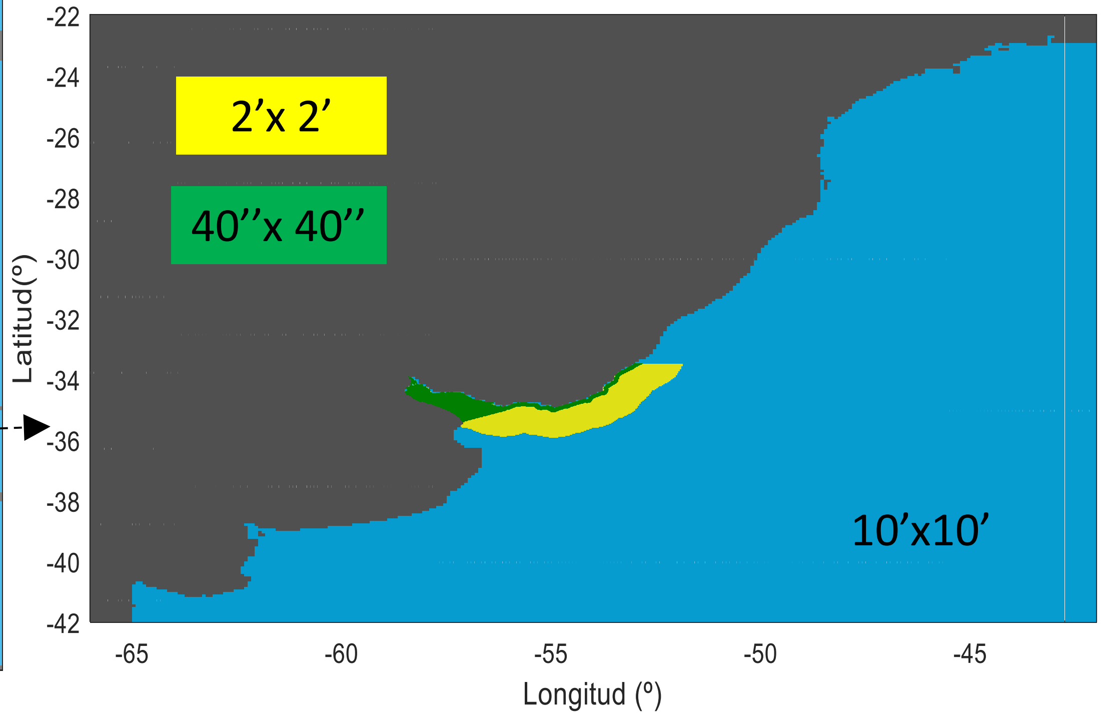
Configuration

WAVEWATCH III ® 5.16. Multi-grid mode. Two-way nesting. 5 regular grids.

Forcings

CFSR winds ~0.31° for all the grids.
TELEMAC water levels and currents 2’ for high rank grids (Green and yelllow)

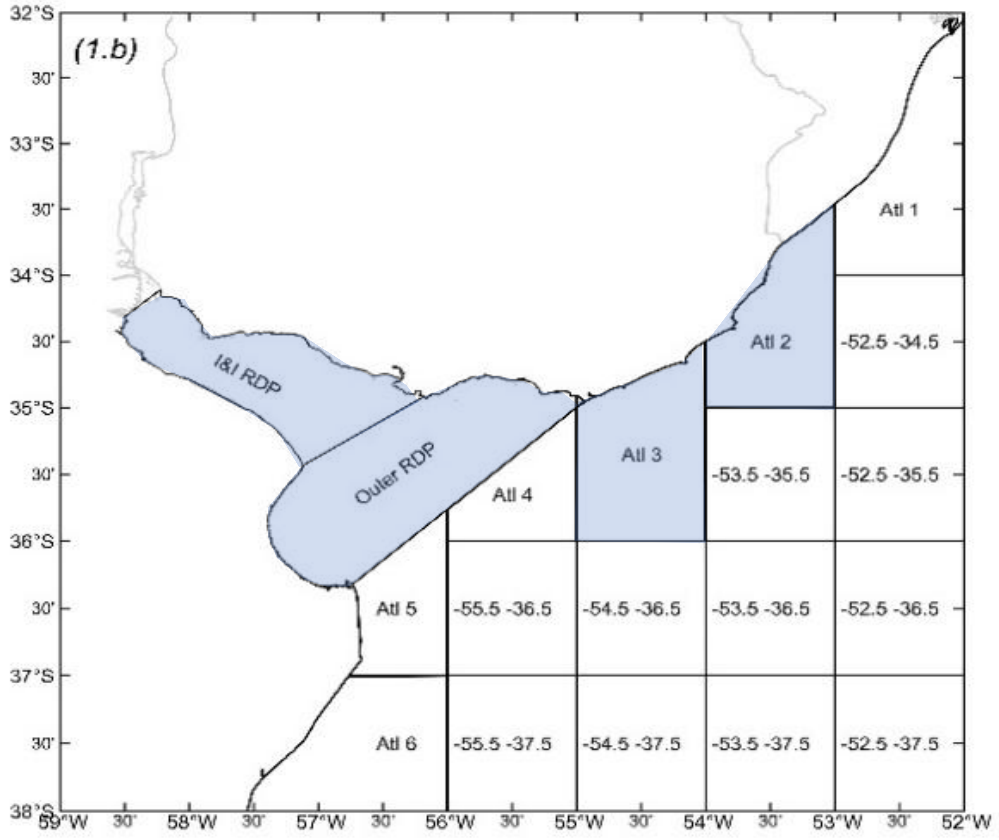


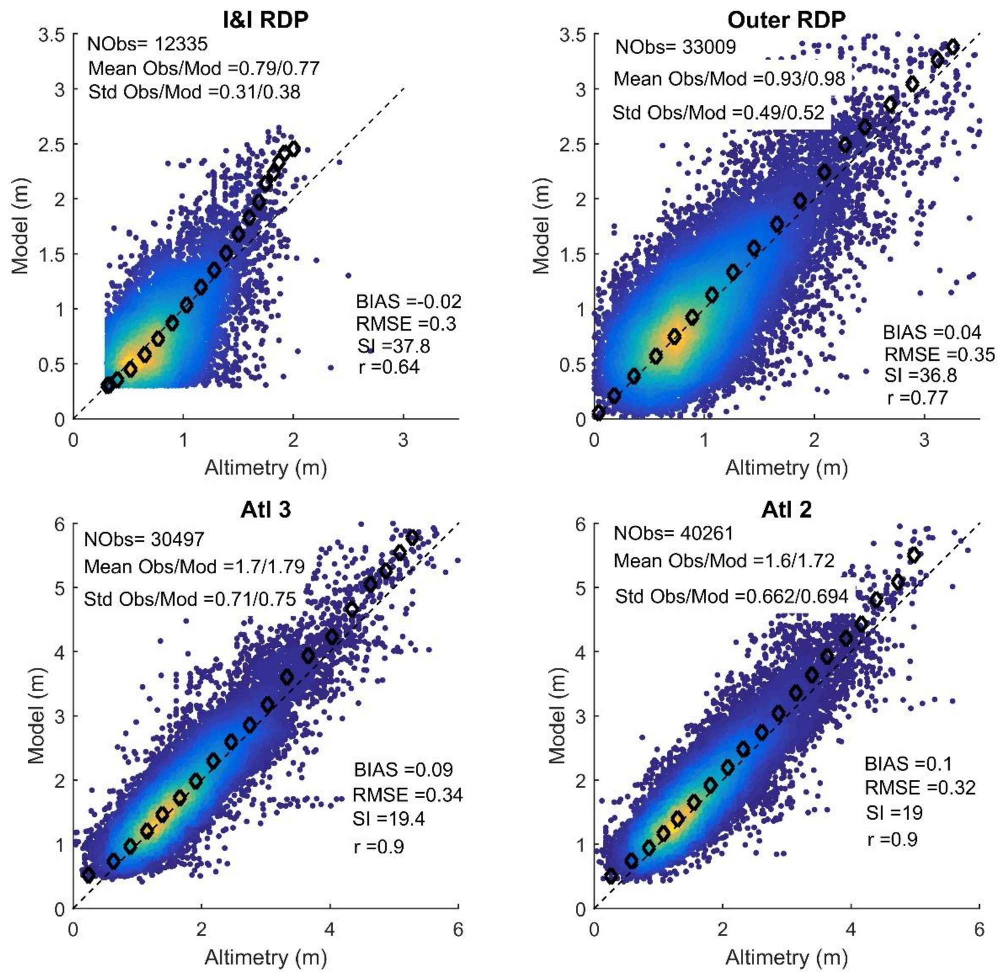


Wave hindcast

β_{max} (ST4)=1.55 , $\Gamma(S_{bot})$=-0.012 m^2s^{-3}

Calibrated with altimetry

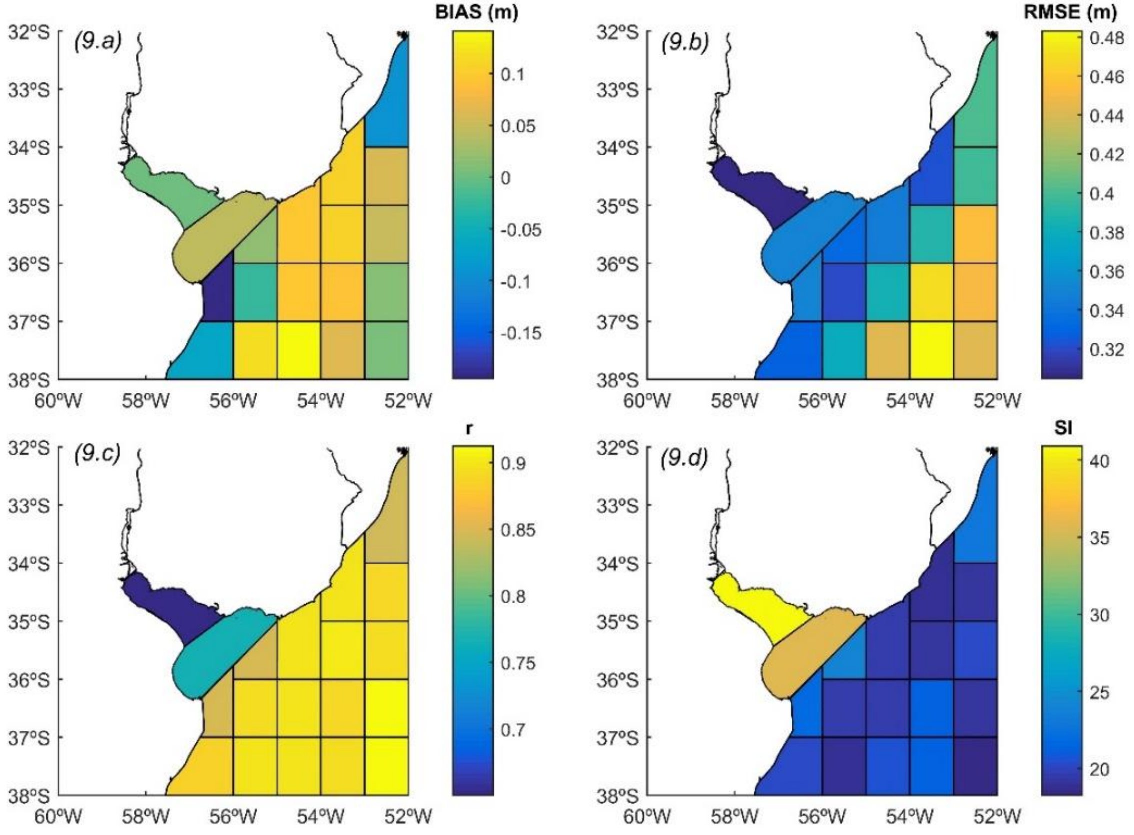




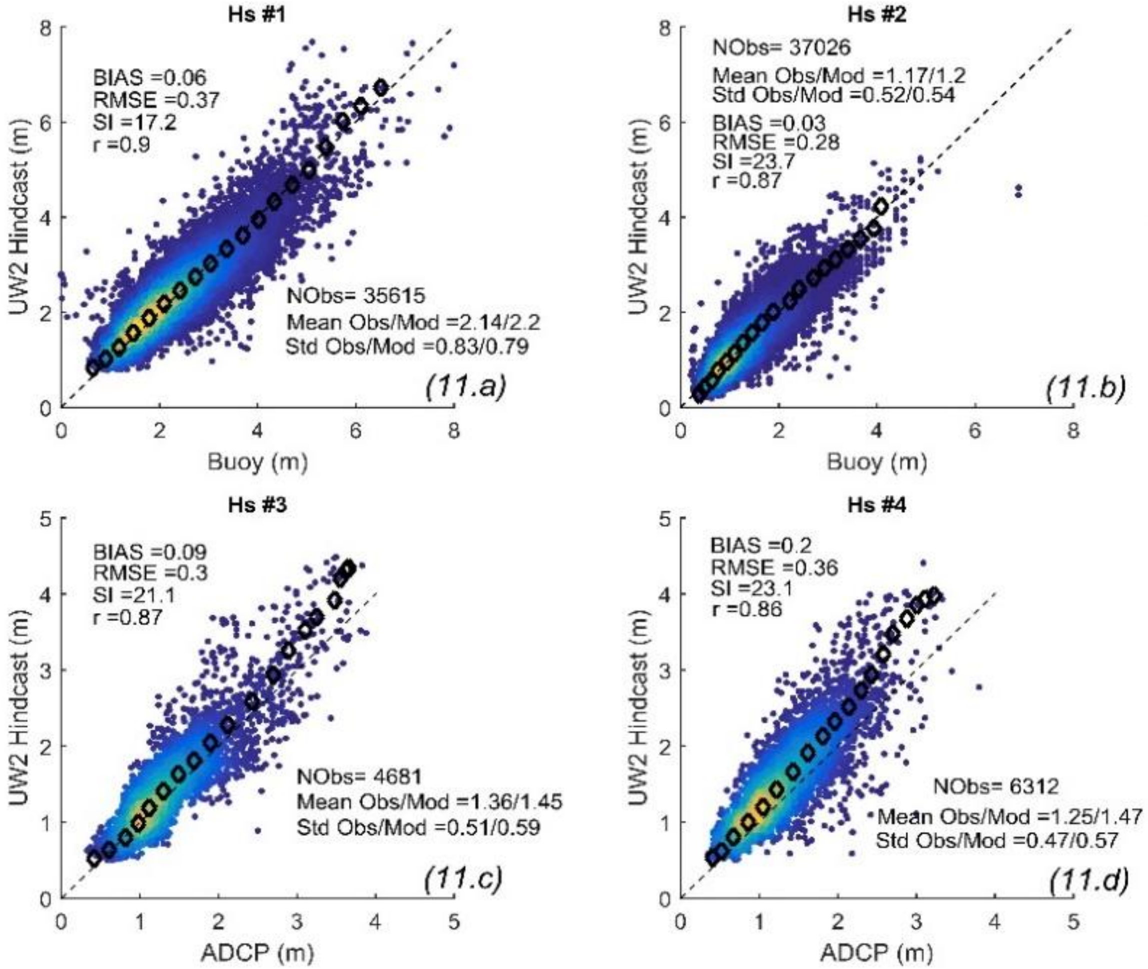
Wave hindcast

Validation

Altimetry



In-situ



Wave hindcast

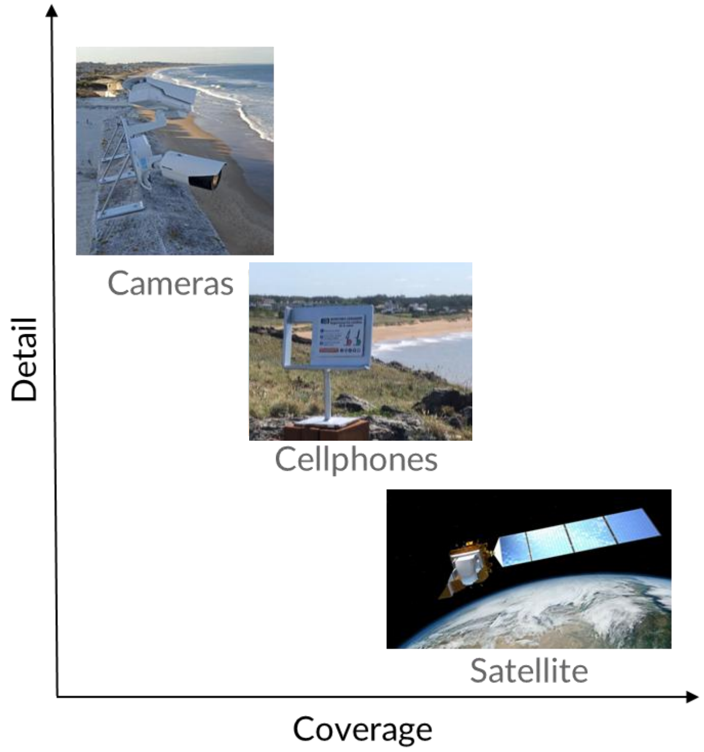
Products

- ❖ Gridded integral parameters
- ❖ 68 Virtual Buoys: Directional spectra (25 freq. X 36 dir.)

Remote monitoring of shoreline position

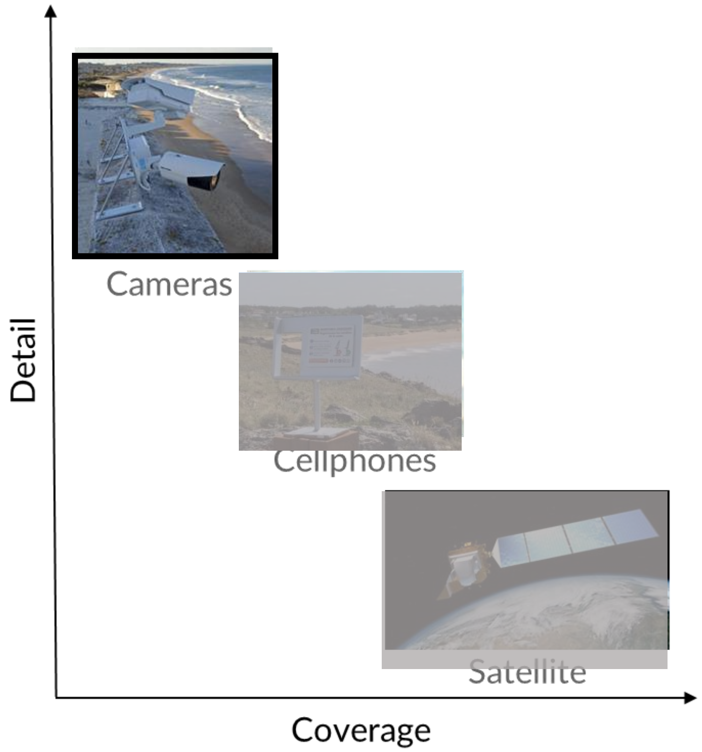
Ministerio de Ambiente

- 3 sources of information



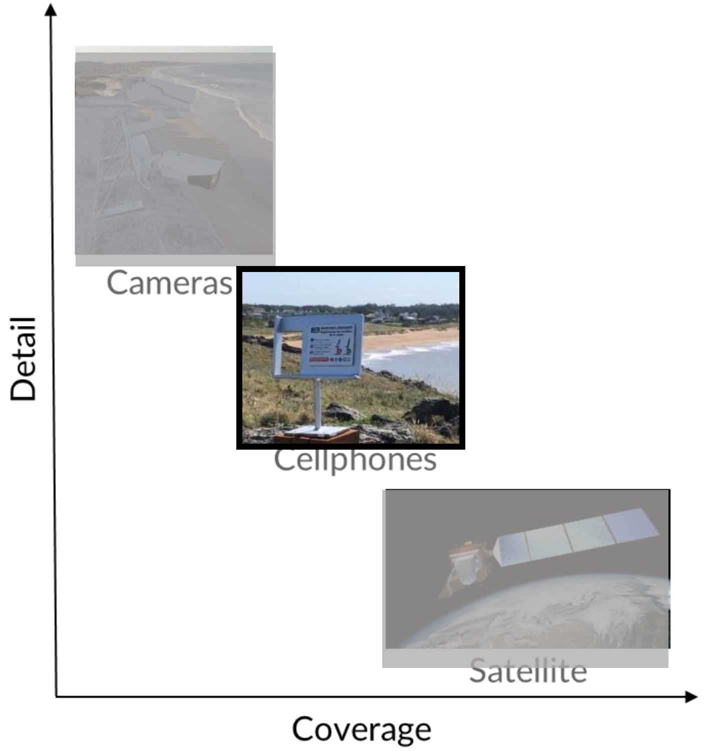
Remote monitoring of shoreline position

- 3 sources of information



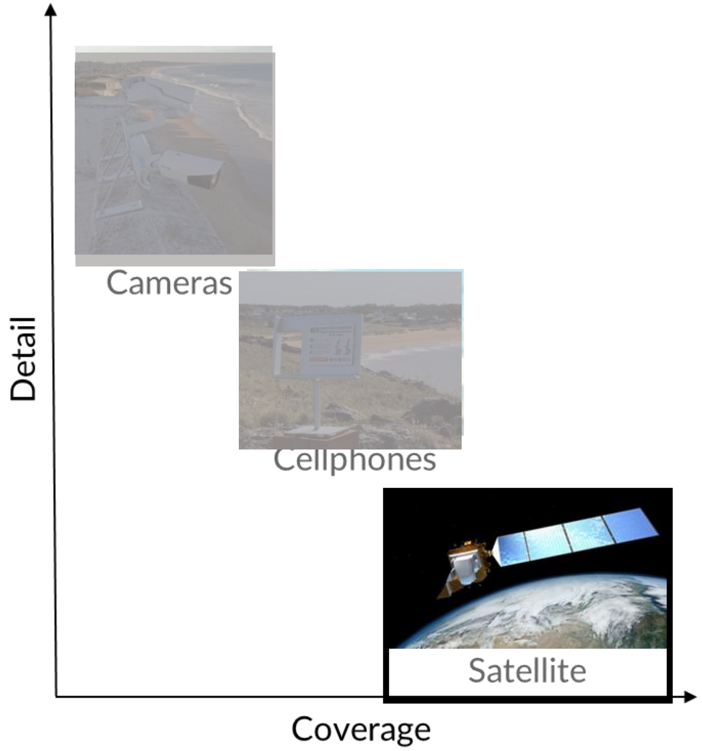
Remote monitoring of shoreline position

- 3 sources of information



Remote monitoring of shoreline position

- 3 sources of information



- Based on the toolkit CoastSat (Vos et. al 2019) https://github.com/kvos/CoastSat.
- Uses satellite imagery available at Google Earth Engine (Landsat and Sentinel missions).
- The algorithm was adapted and applied to 90 beaches covering the entire national shoreline.
- Post-processing tools were developed to analyze results.
- Results were generated in transects each 100 m (alongshore).

Databases:

Remote monitoring of shoreline position

I) Pair beaches with the nearest vitural buoy.

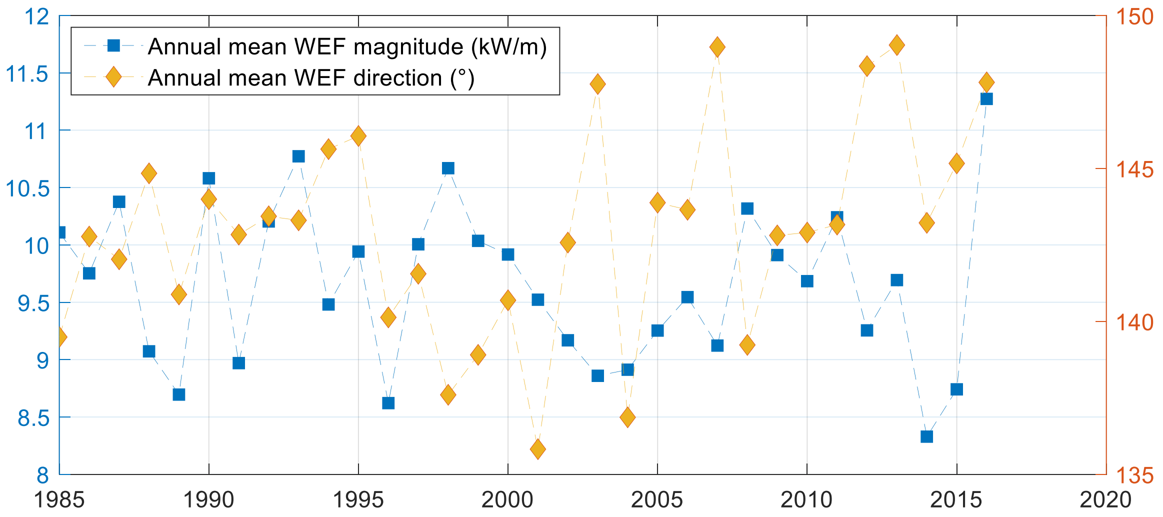
II) 2D spectra → WEF

$$WEF_x = \int_0^{2\pi}\int_0^{\infty} \cos(\theta)\, S(f,\theta).C_g(f,h)\,df\,d\theta$$

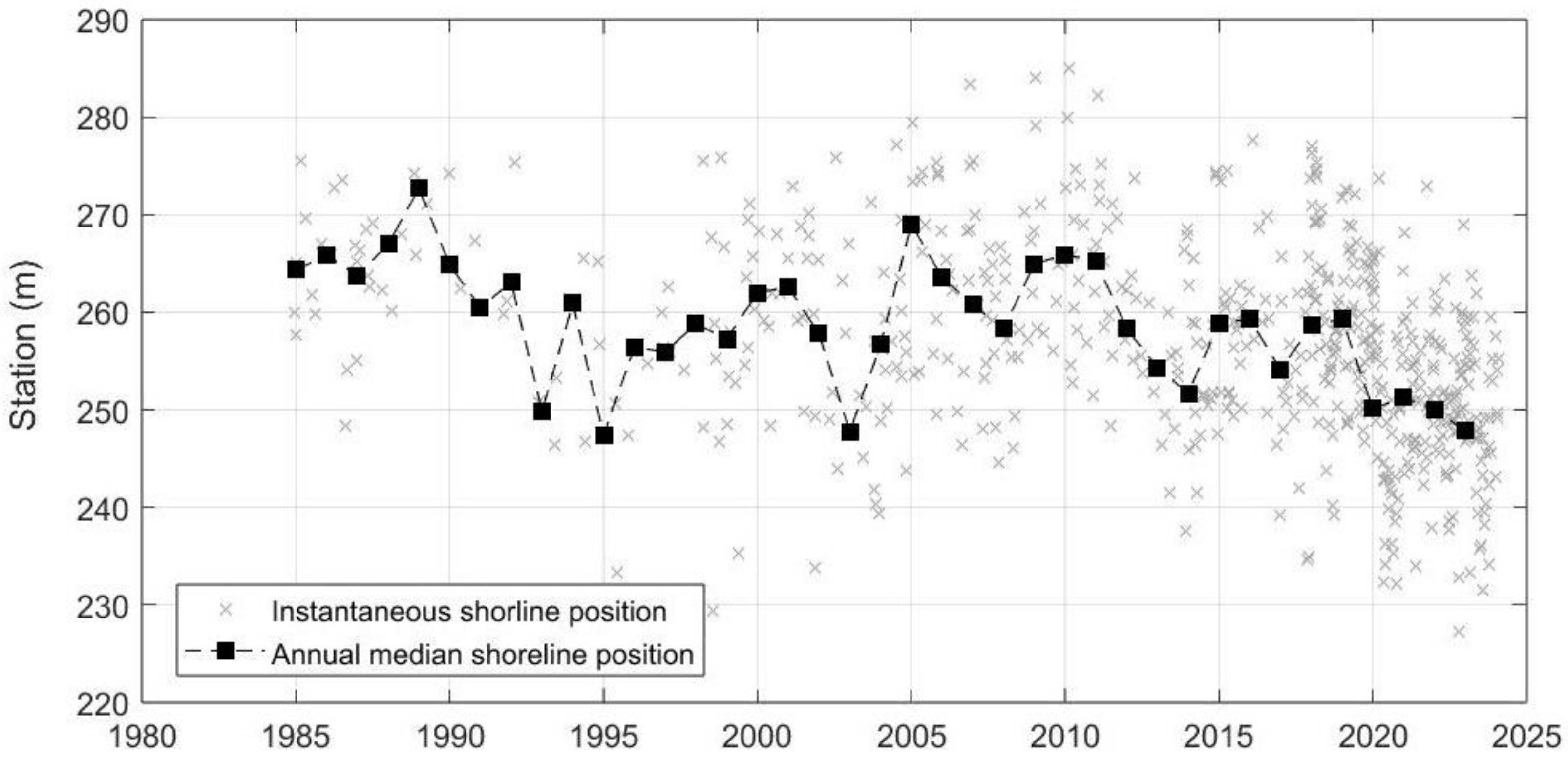
$$WEF_y = \int_0^{2\pi}\int_0^{\infty} \sin(\theta)\, S(f,\theta).Cg(f,h)\,df\,d\theta \;;$$

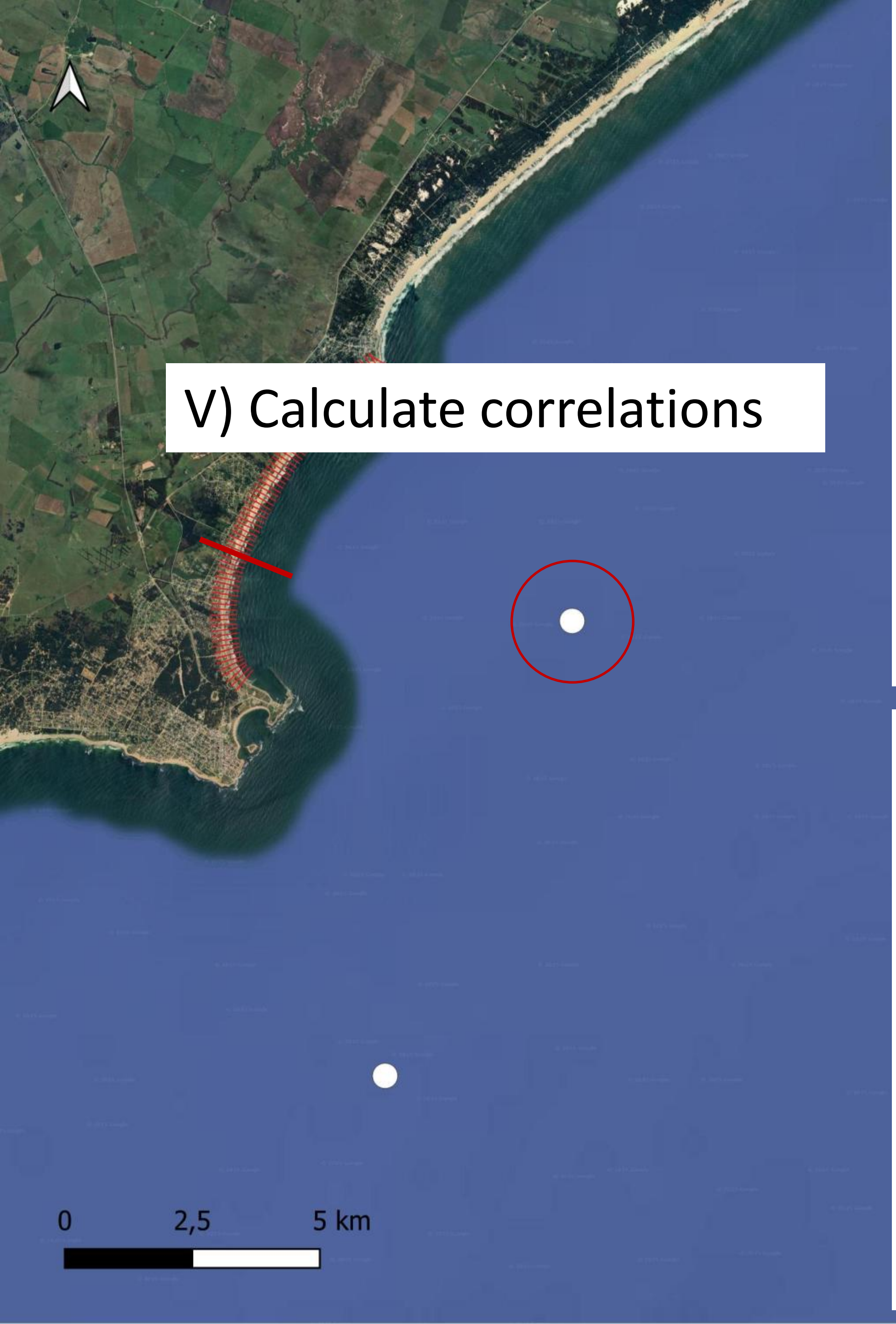
$$\|WEF\| = \sqrt{{WEF_x}^2 + {WEF_y}^2},\ \theta_{WEF} = \tan^{-1}\left(\frac{WEF_y}{WEF_x}\right)$$

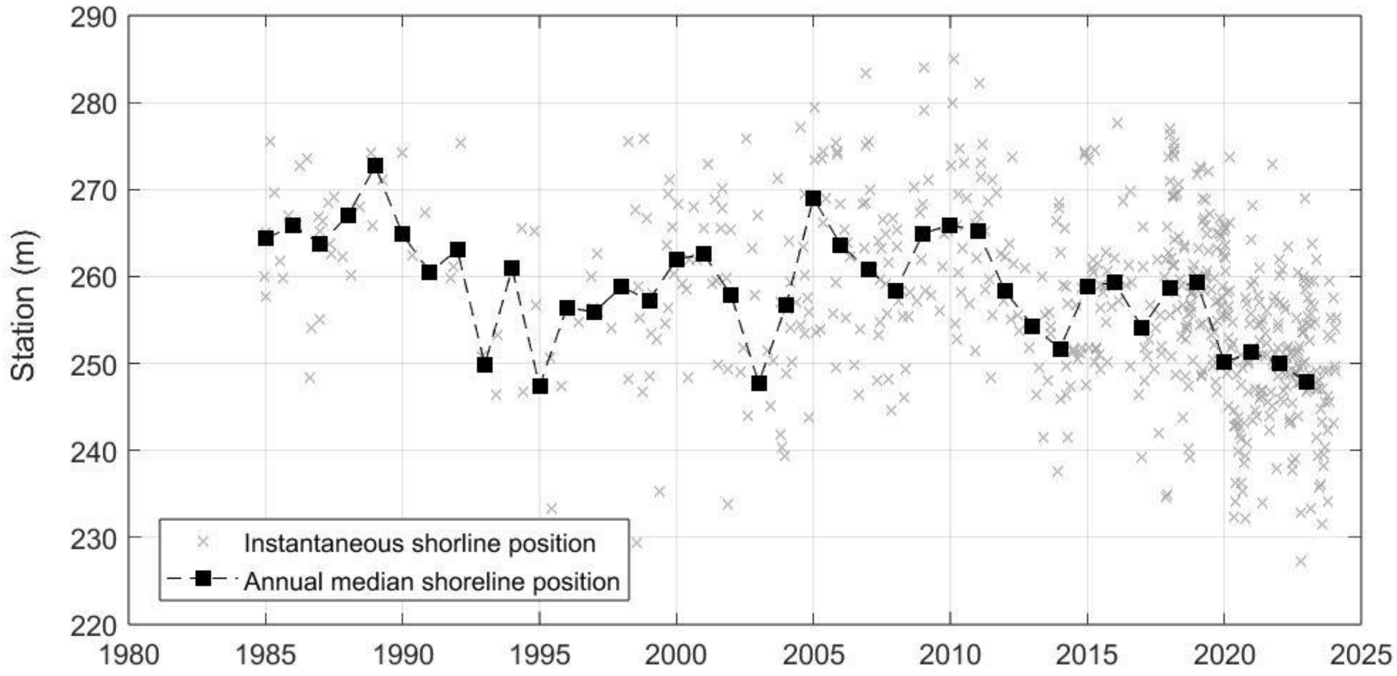
III) Annualize WEF

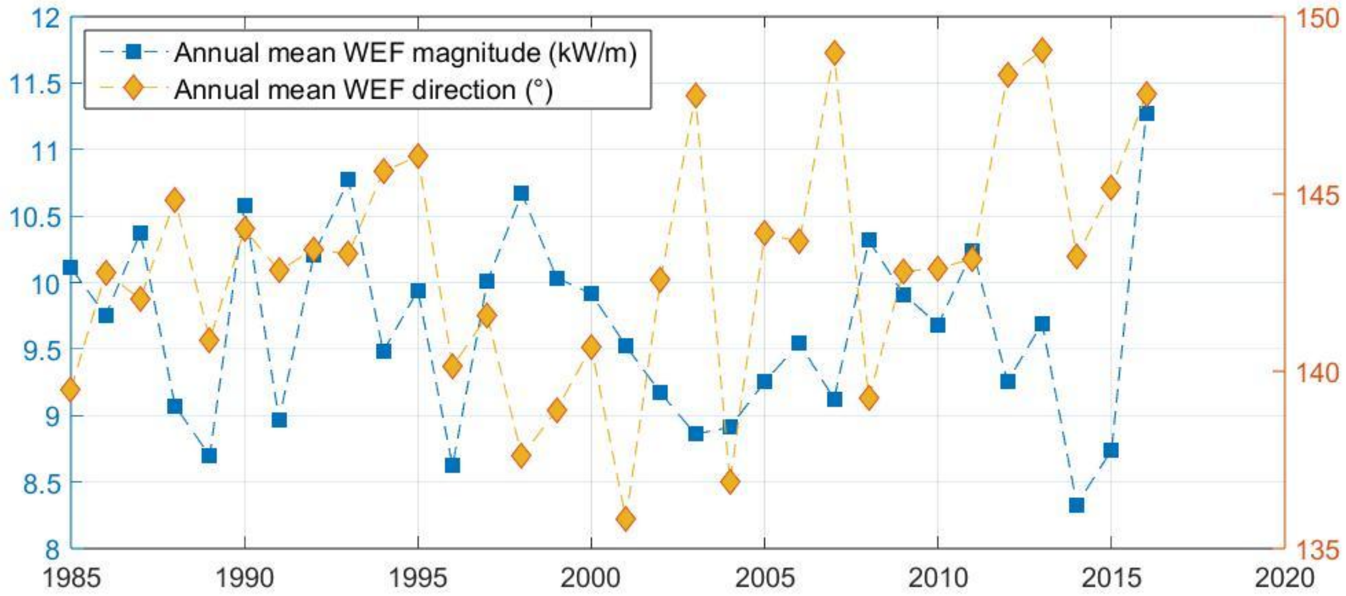


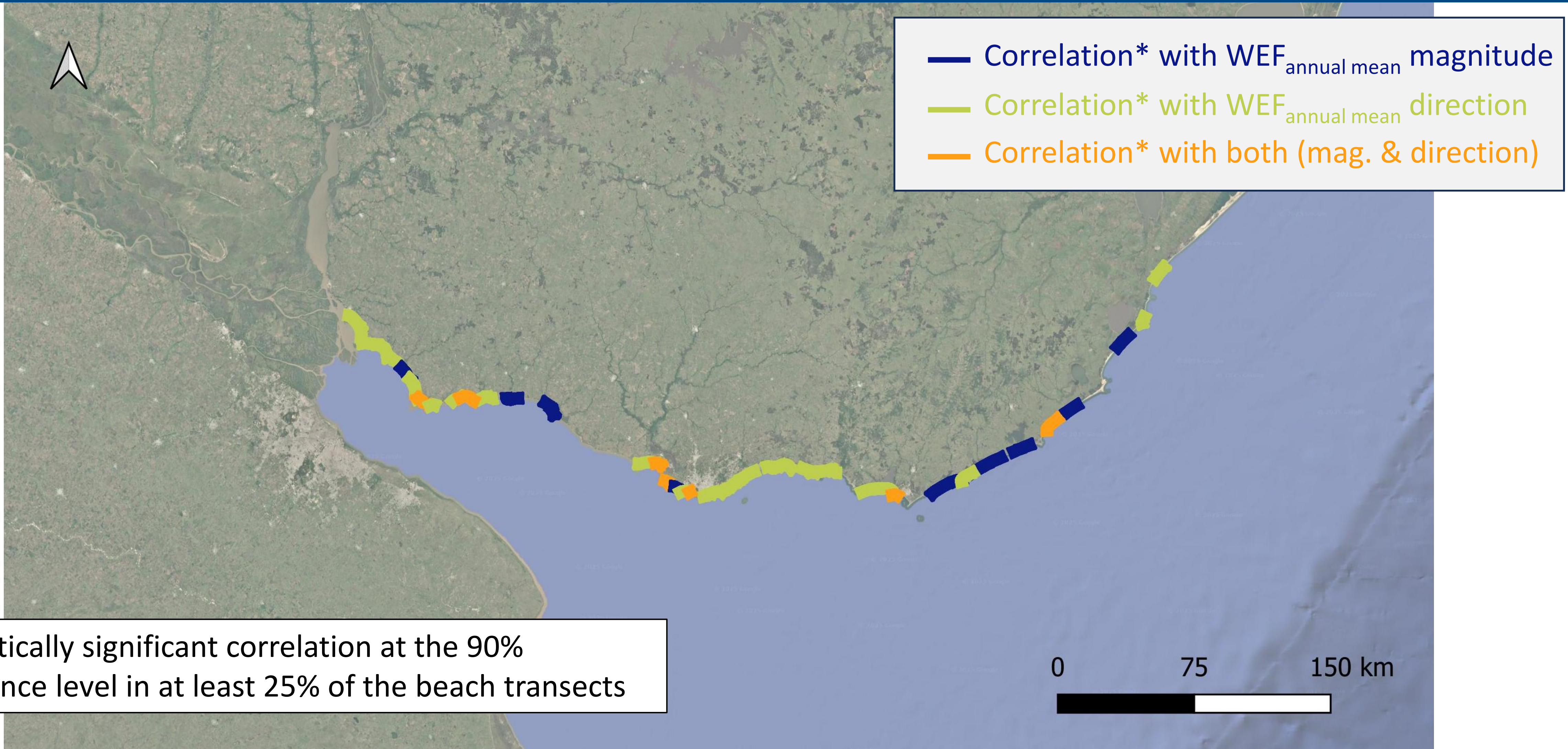
IV) Shorelines detected are traduced to stations along transects and the annual median is calculated.




V) Calculate correlations
0
2,5
5 km

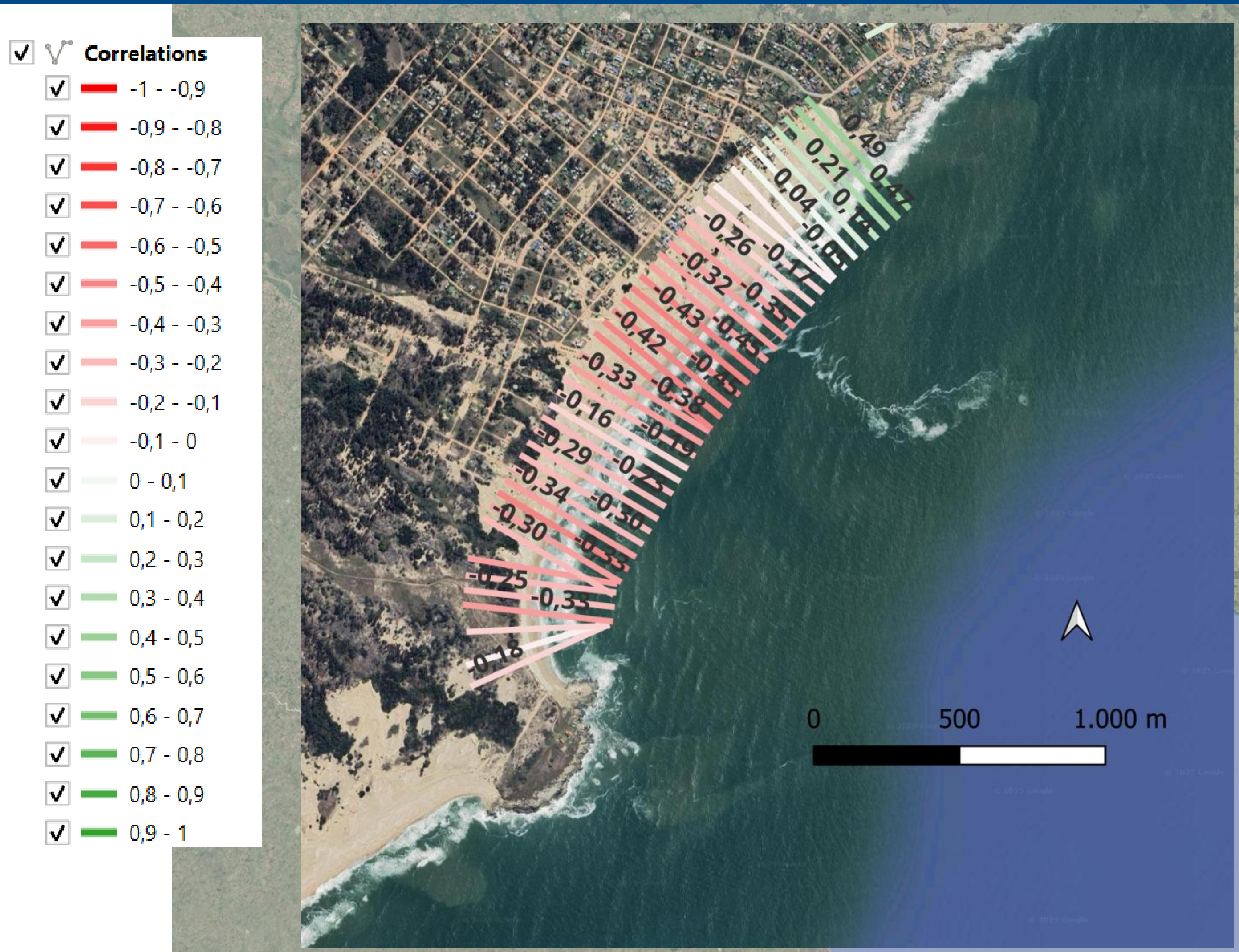

Station (m)
Instantaneous shoreline position
Annual median shoreline position
290
280
270
260
250
240
230
220
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025


Annual mean WEF magnitude (kW/m)
Annual mean WEF direction (°)
12
11.5
11
10.5
10
9.5
9
8.5
8
150
145
140
135
1985
1990
1995
2000
2005
2010
2015
2020

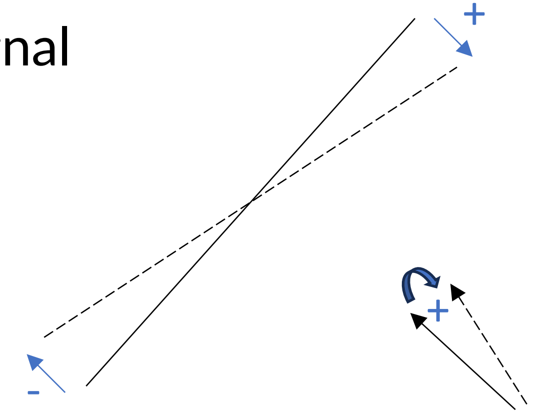


* Statistically significant correlation at the 90% confidence level in at least 25% of the beach transects

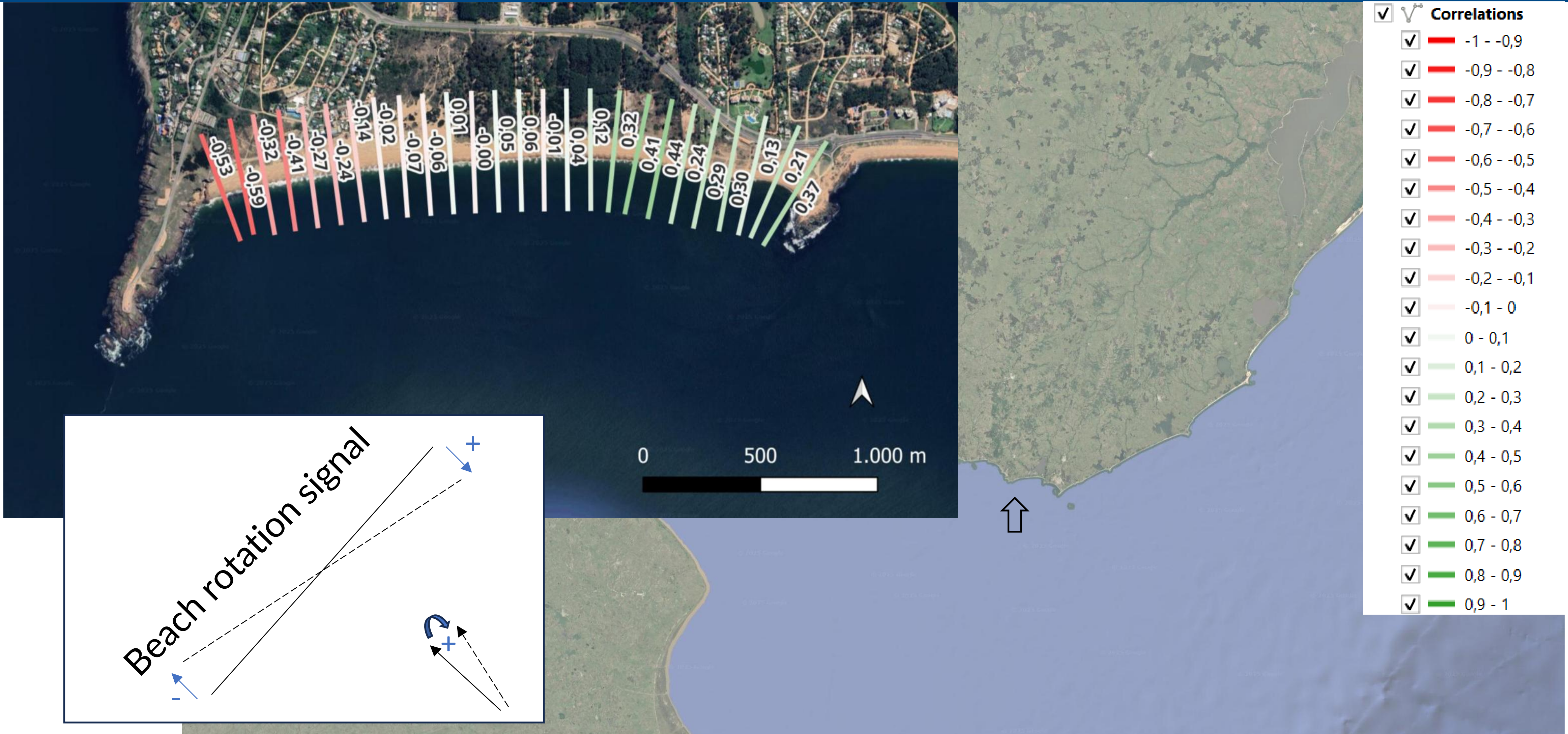
Correlation with $WEF_{\text{annual mean}}$ direction



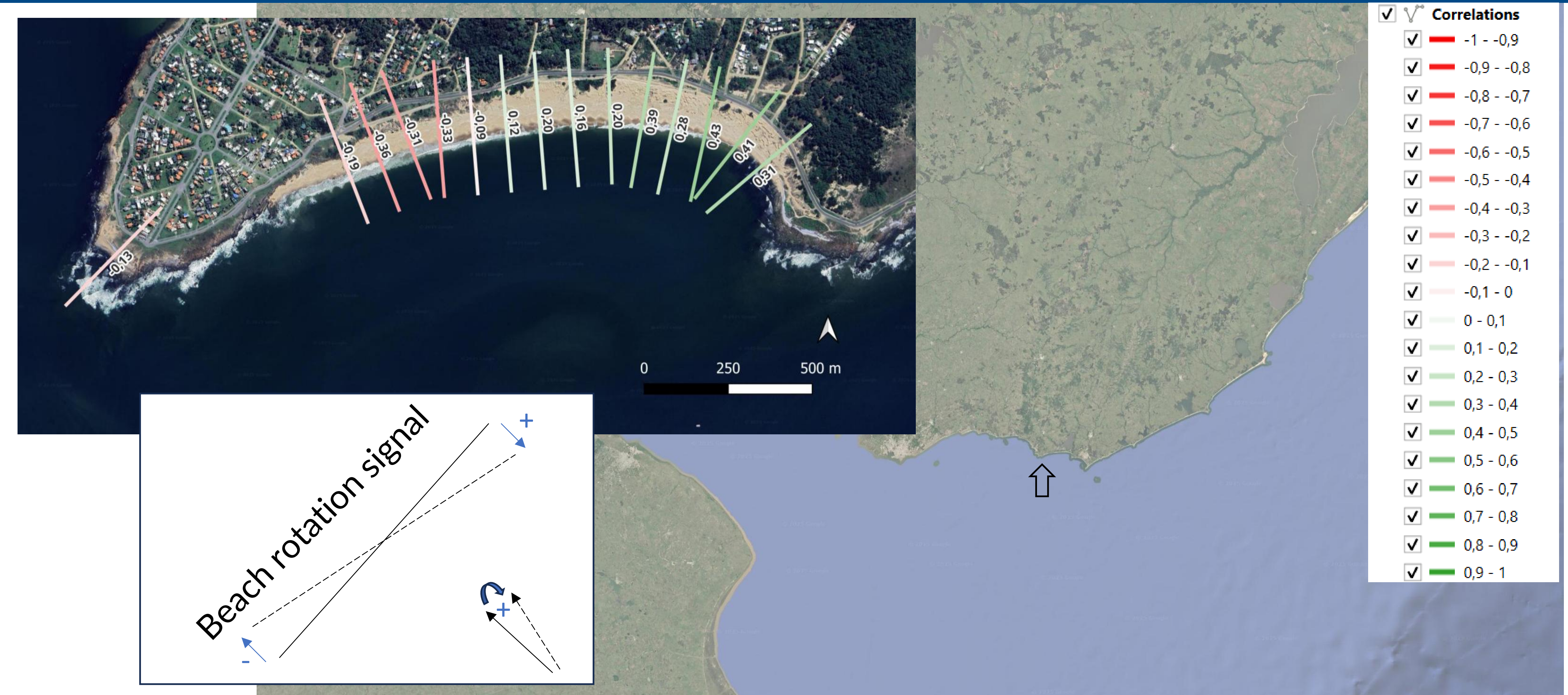
Beach rotation signal



Correlation with $WEF_{\text{annual mean}}$ direction

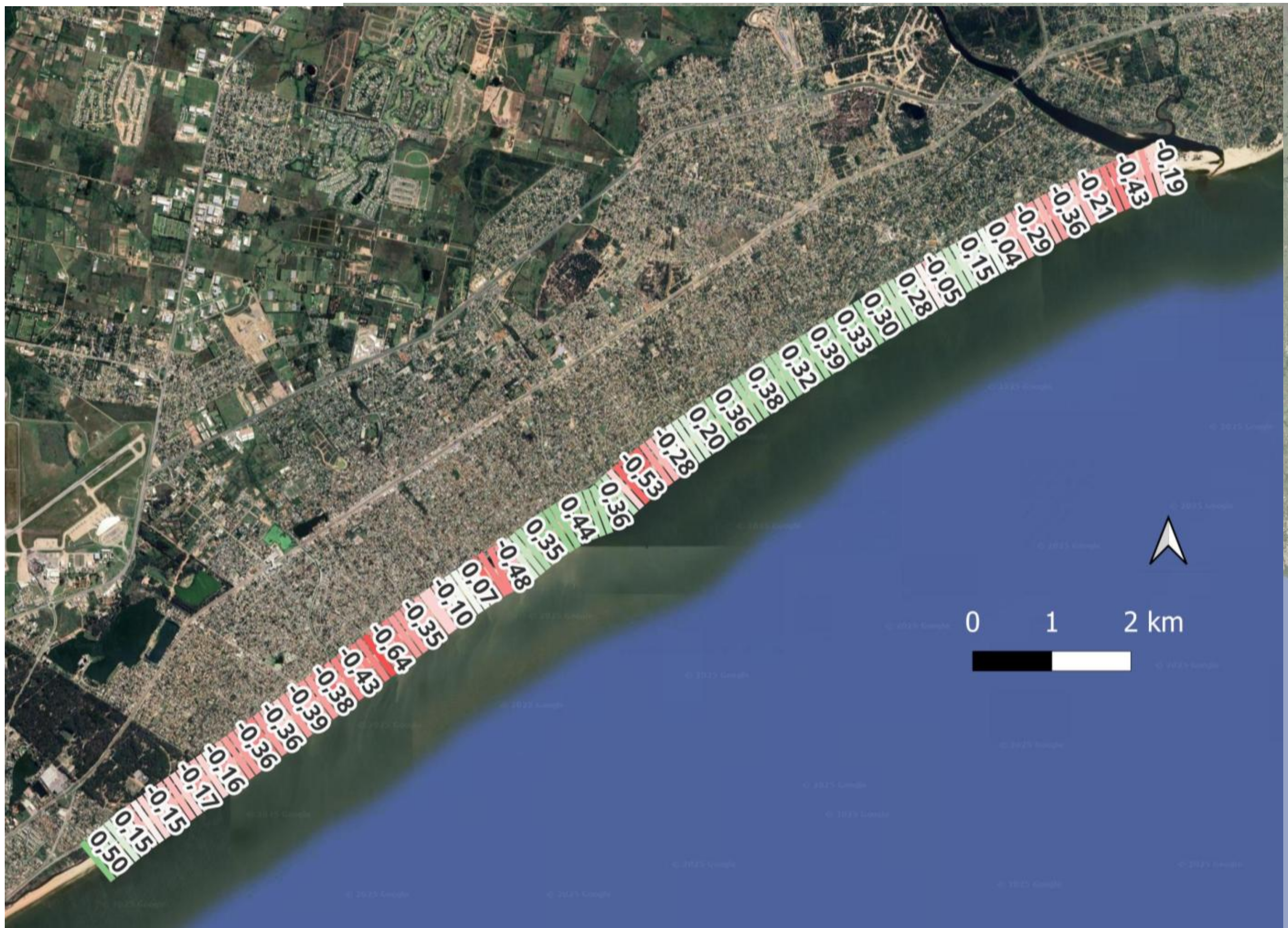


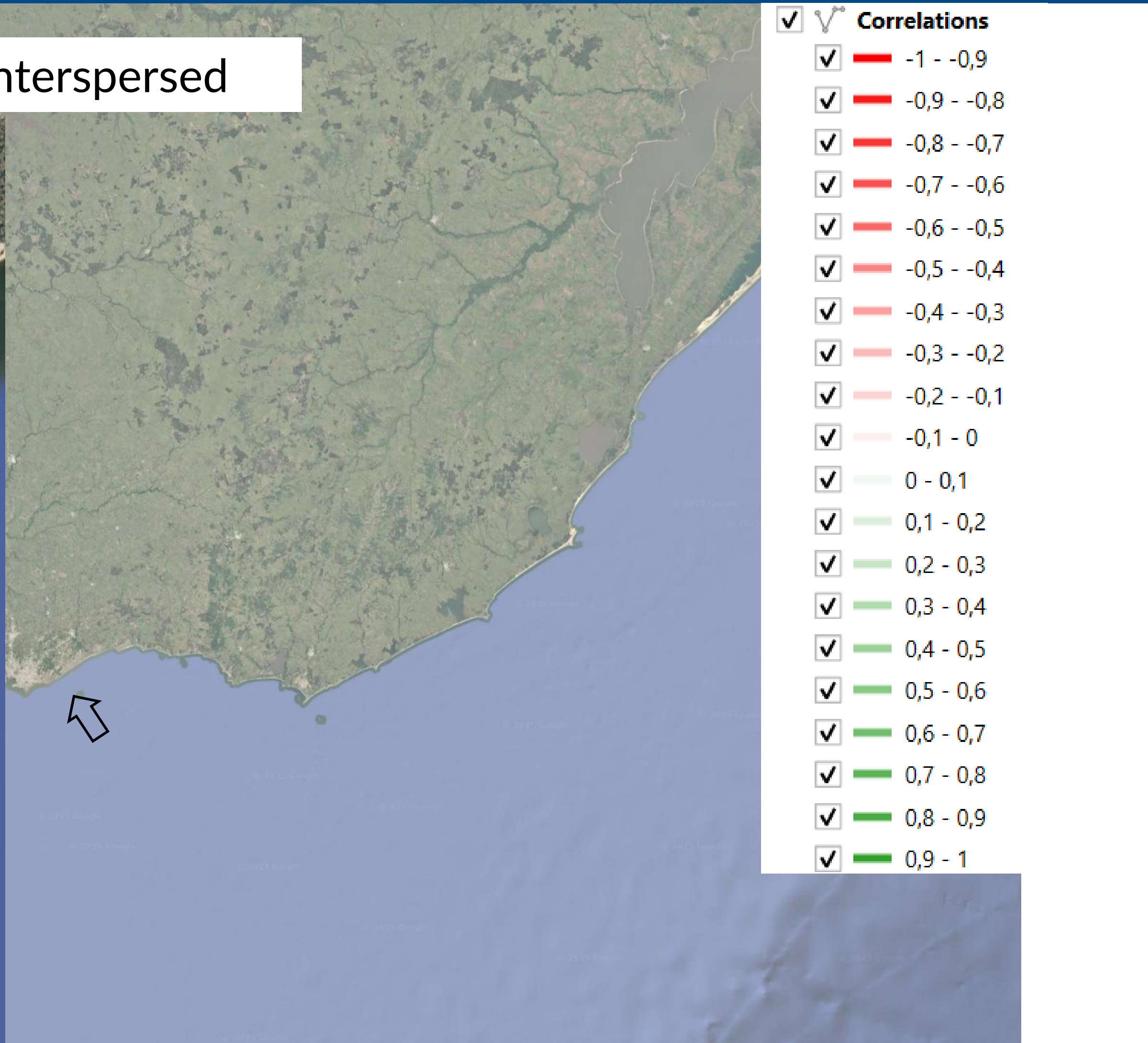
Correlation with WEF$_{\text{annual mean}}$ direction



Correlation with $\mathrm{WEF}_{\mathrm{annual\ mean}}$ direction

Straigth beaches where positive and negative correlations are interspersed





Correlation with $WEF_{annual\ mean}$ direction

Straigth beaches where positive and negative correlations are interspersed

Correlations
- -1 - -0,9
- -0,9 - -0,8
- -0,8 - -0,7
- -0,7 - -0,6
- -0,6 - -0,5
- -0,5 - -0,4
- -0,4 - -0,3
- -0,3 - -0,2
- -0,2 - -0,1
- -0,1 - 0
- 0 - 0,1
- 0,1 - 0,2
- 0,2 - 0,3
- 0,3 - 0,4
- 0,4 - 0,5
- 0,5 - 0,6
- 0,6 - 0,7
- 0,7 - 0,8
- 0,8 - 0,9
- 0,9 - 1

Correlation with $\text{WEF}_{\text{annual mean}}$ magnitude

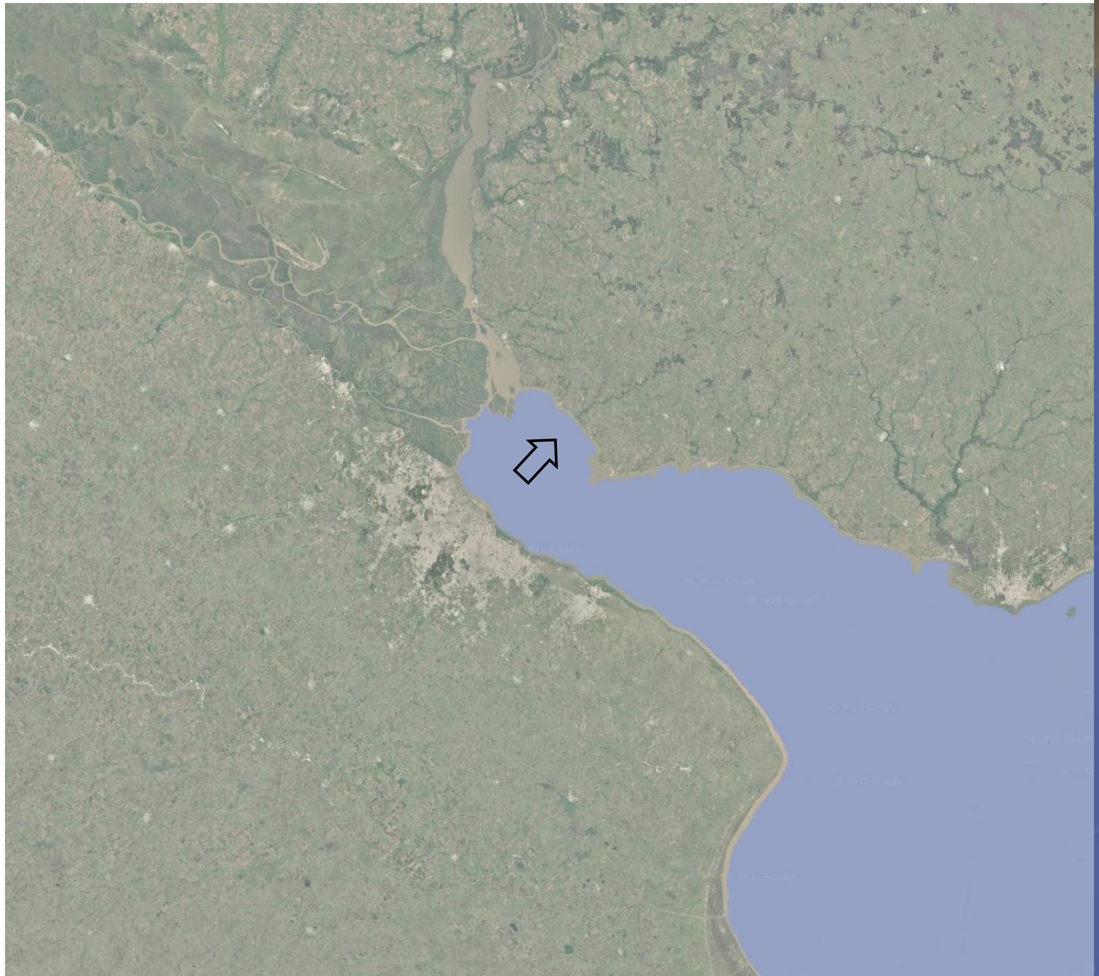
Negative correlation on the most exposed beaches

Correlation with $WEF_{\text{annual mean}}$ magnitude

Positive correlations on the less exposed beaches

Correlations

- -1 - -0,9
- -0,9 - -0,8
- -0,8 - -0,7
- -0,7 - -0,6
- -0,6 - -0,5
- -0,5 - -0,4
- -0,4 - -0,3
- -0,3 - -0,2
- -0,2 - -0,1
- -0,1 - 0
- 0 - 0,1
- 0,1 - 0,2
- 0,2 - 0,3
- 0,3 - 0,4
- 0,4 - 0,5
- 0,5 - 0,6
- 0,6 - 0,7
- 0,7 - 0,8
- 0,8 - 0,9
- 0,9 - 1



Conclusions

Primary results from the cross-referencing of a wave hindcast and shoreline position databases were presented.

It is observed:

- Most of Uruguay's beaches (~65%) show a correlation between the inter-annual variation of shoreline position and the annual mean wave energy flux (magnitude, direction or both).
- Straight beaches with a pattern of alternating positive and negative correlations with $WEF_{annual\ mean}$ direction.
- Negative (positive) correlation with $WEF_{annual\ mean}$ magnitude were observed in the most (less) exposed beaches.

Future work:

Include other hindcasts, focus on higher frequency scales (e.g. seassonal), and explore other wave climate parameters (e.g. storminess).

Thanks for your attention !!!

Ackonowledgments:

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E INNOVACIÓN

Proyecto FMV_1_2023_1_176595