Comparison of wave power throughout South America using models with and without CFOSAT data assimilation

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Introduction

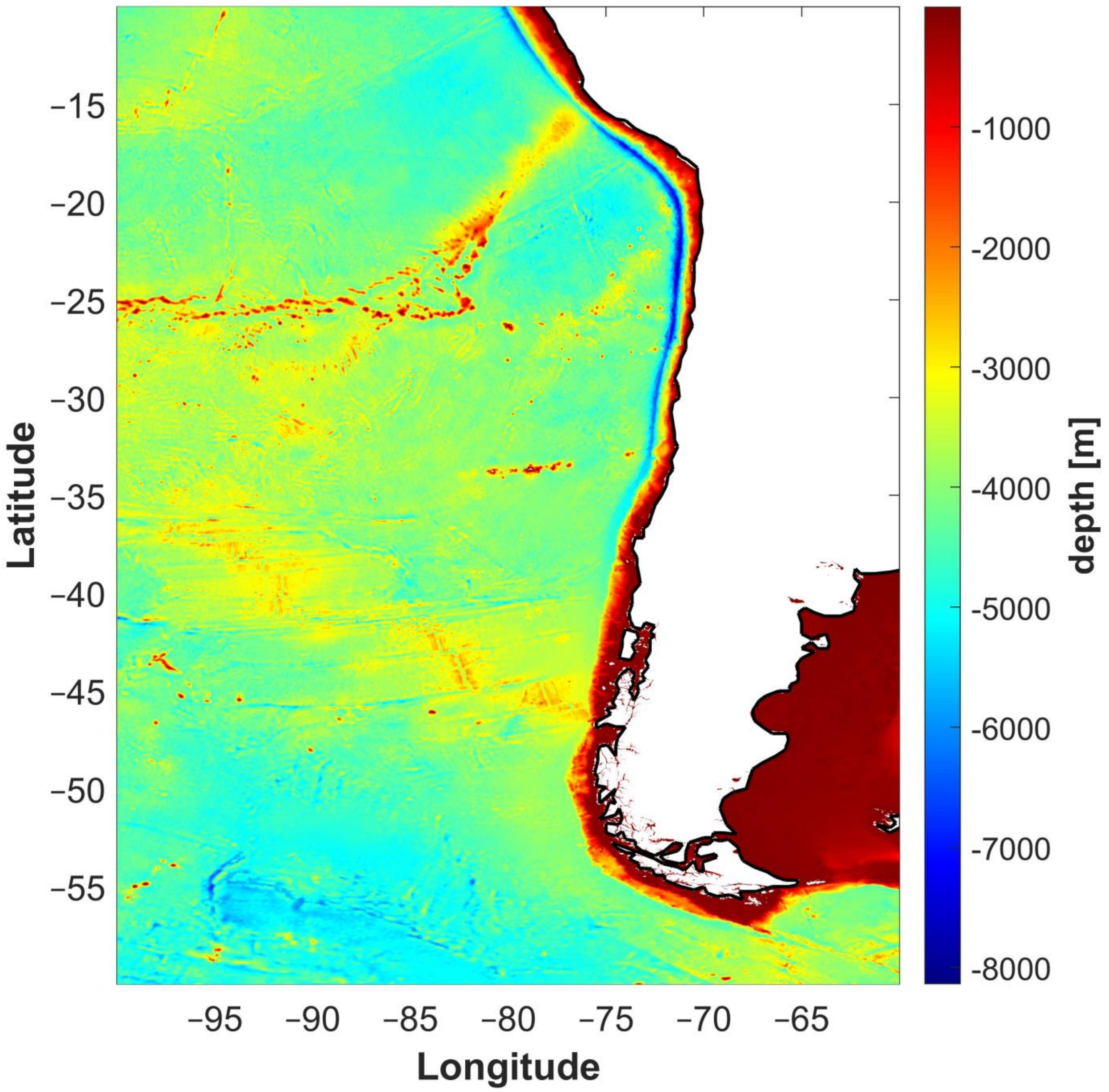
- Integrating renewable energy sources into the energy mix is increasingly vital for reducing greenhouse gas emissions.
- Planning and controlling the renewable energy supply that goes into the grid is a significant concern.
- Ocean waves are an essential resource. It’s been estimated that the world wave power is around 2.11 TW.
- Wave energy converters are not designed to extract energy all the time; it is particularly harmful to have extreme events that affect the survivability of the devices.

Introduction

- Wave models are great options for studying large areas, as they must correctly represent most sea states.
- Knowing the waves with high precision allows us to reduce the uncertainty associated with integrating wave energy into the electrical grid.
- This study will compare wave models with and without using CFOSAT data to show this importance in marine power calculation.

Data

- Location: Southeast Pacific
- Two years of comparison (2020-2021)
- ERA5: without CFOSAT data, spatial resolution X, time resolution: 1 hour
- MFWAM: with CFOSAT data, spatial resolution X, time resolution: 3 hours.



Wave power

- The wave power per unit of wave crest can be estimated:

$$P = \frac{1}{64\pi} \rho g^2 H_s^{\,2} T_p$$

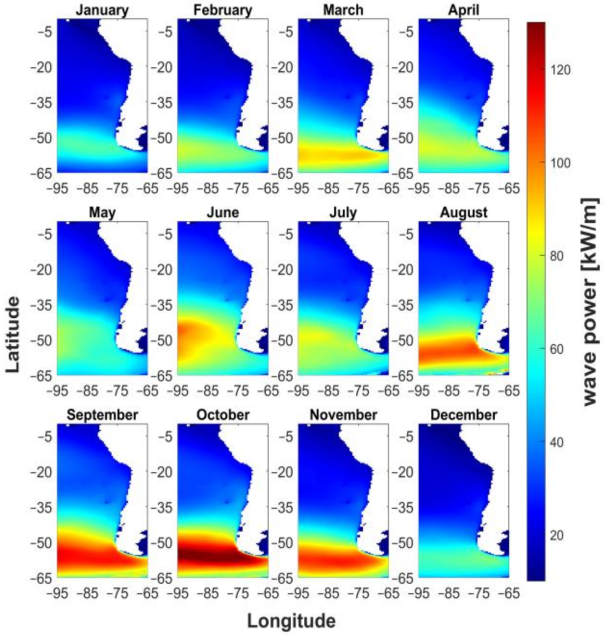
ρ : sea water density $\left(\frac{kg}{m^3}\right)$

g : acceleration due to gravity $\left(\frac{m}{s^2}\right)$

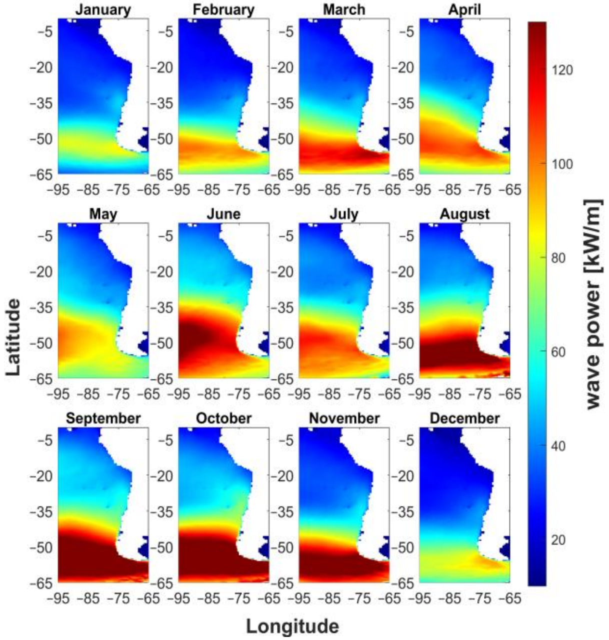
H_s: Significant wave height (m)

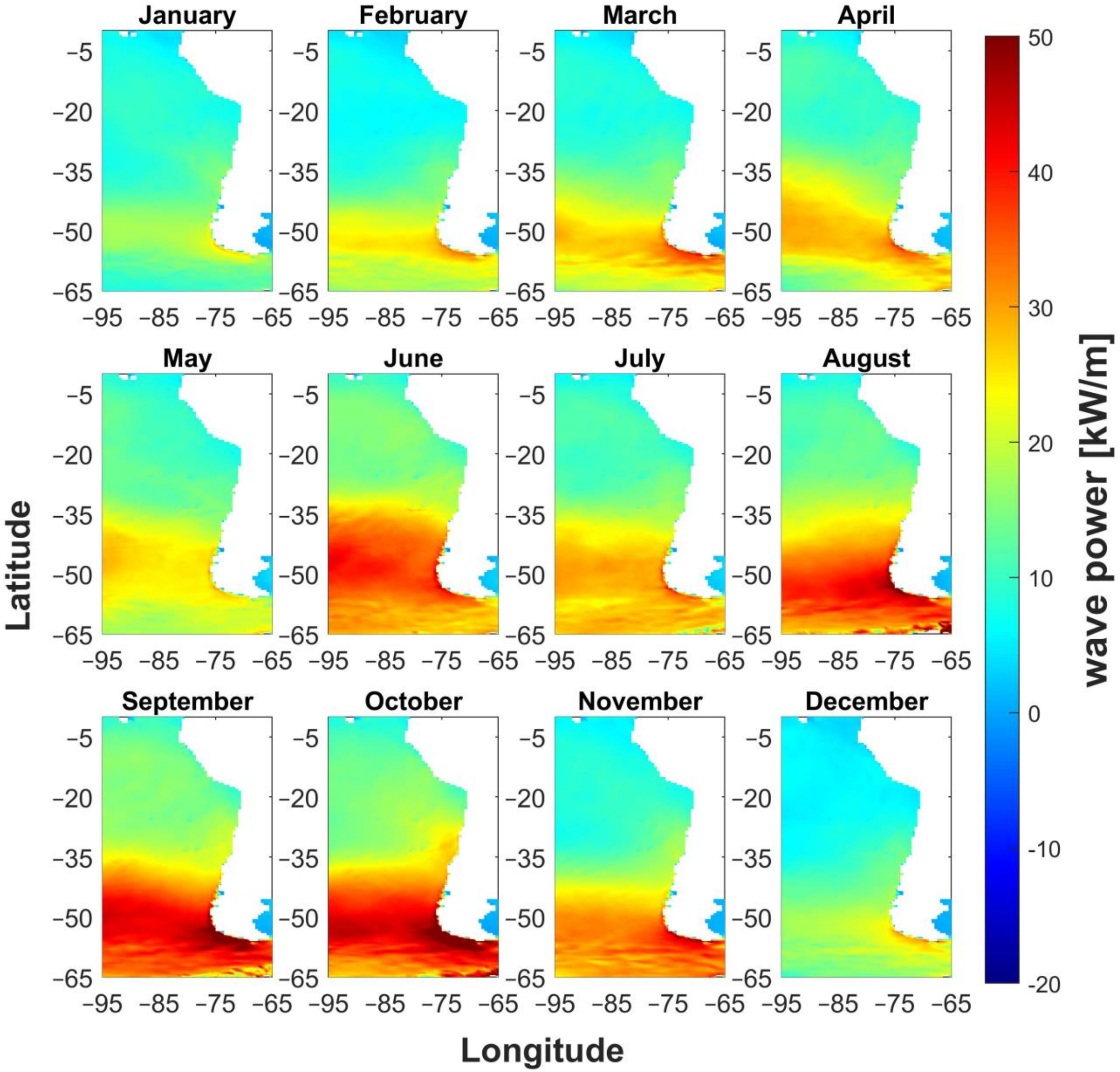
T_p: Peak period (s)

2-year climatology ERA5



2-year climatology MFWAM





Difference in wave power between MFWAM and ERA5 to show the changes when using or not using CFOSAT numerical models

Wave resource estimation

$$COV = \frac{\sigma(P)}{\overline{P}_{annual}}$$

$$SV = \frac{\left(P_{S_{max}} - P_{S_{min}}\right)}{\overline{P}_{annual}}$$

$$MV = \frac{\left(P_{M_{max}} - P_{M_{min}}\right)}{\overline{P}_{annual}}$$

$P_{M_{max}}$: Median wave power for the more energetic month

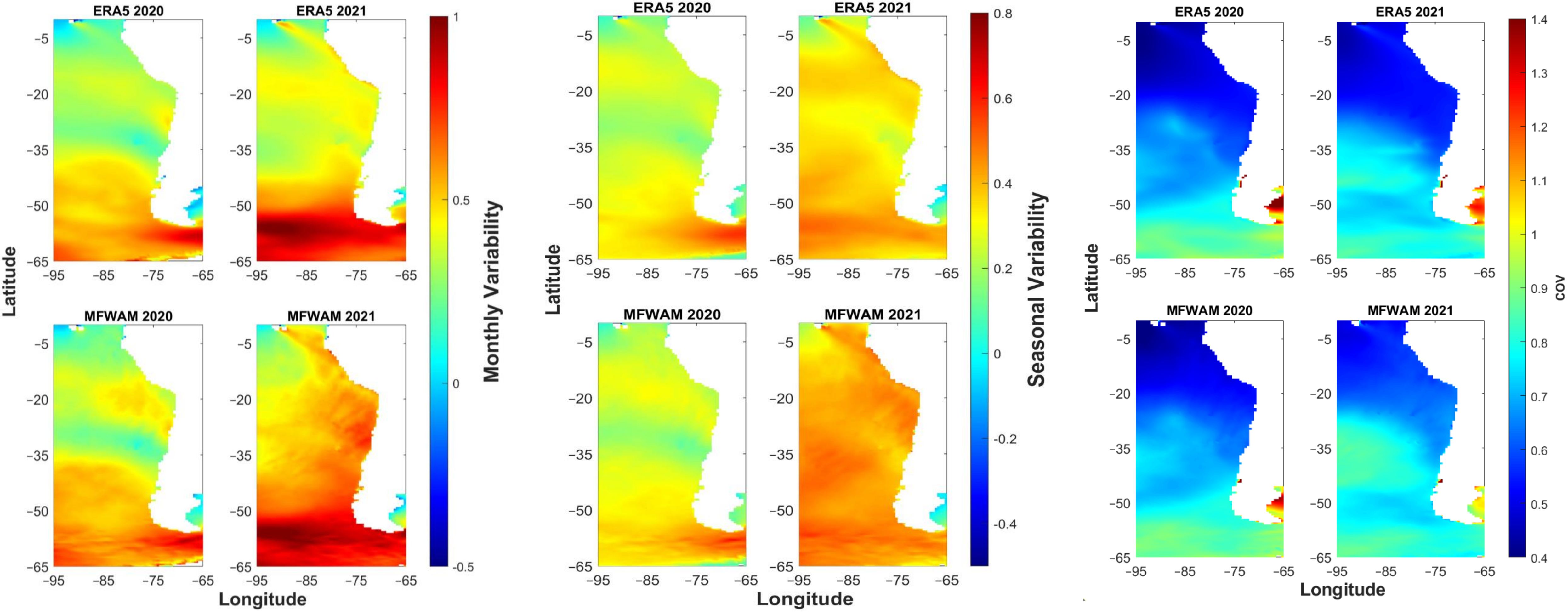
$P_{M_{min}}$: Median wave power for the less energetic month

$P_{S_{max}}$: Median wave power for the more energetic season

$P_{S_{min}}$: Median wave power for the less energetic season

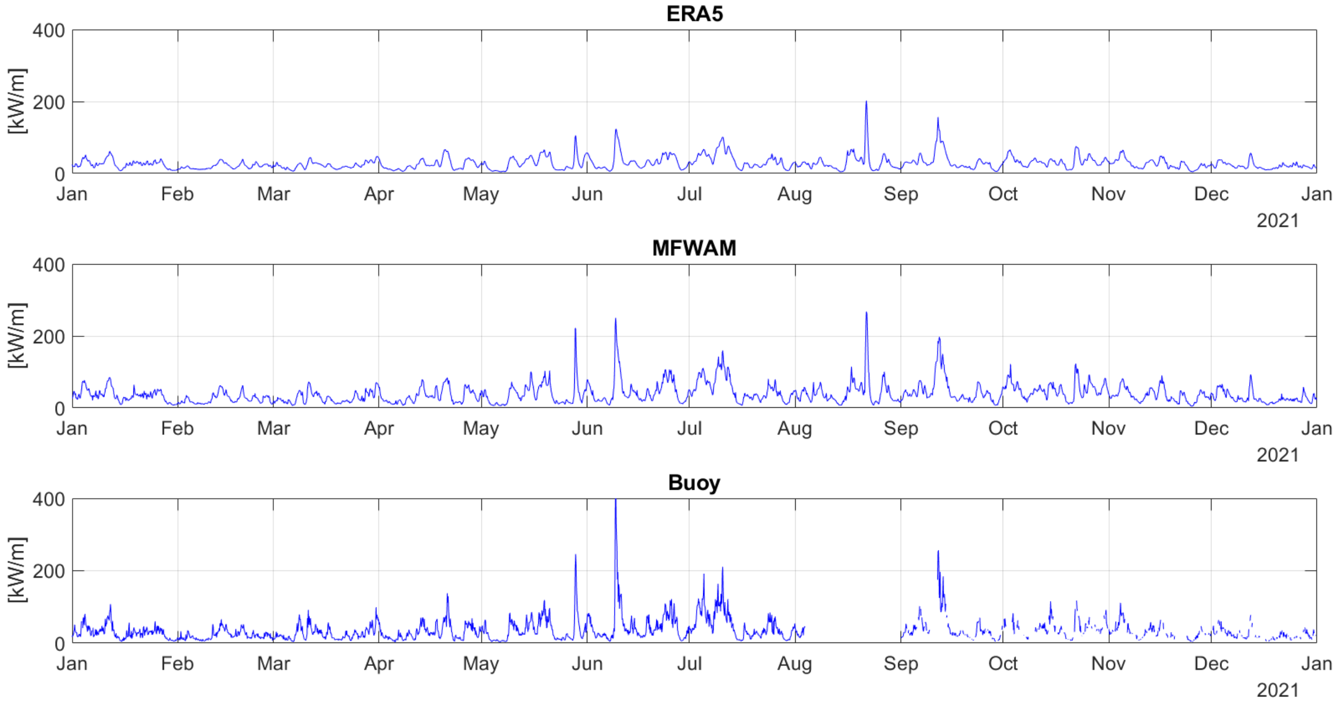
$\overline{P}_{annual}$: Annual median wave power

Wave resource estimation



Variability index: seasonal (SV), monthly (MV) and Coefficient of Variation (COV)

Case study (Talcahuano, Chile)

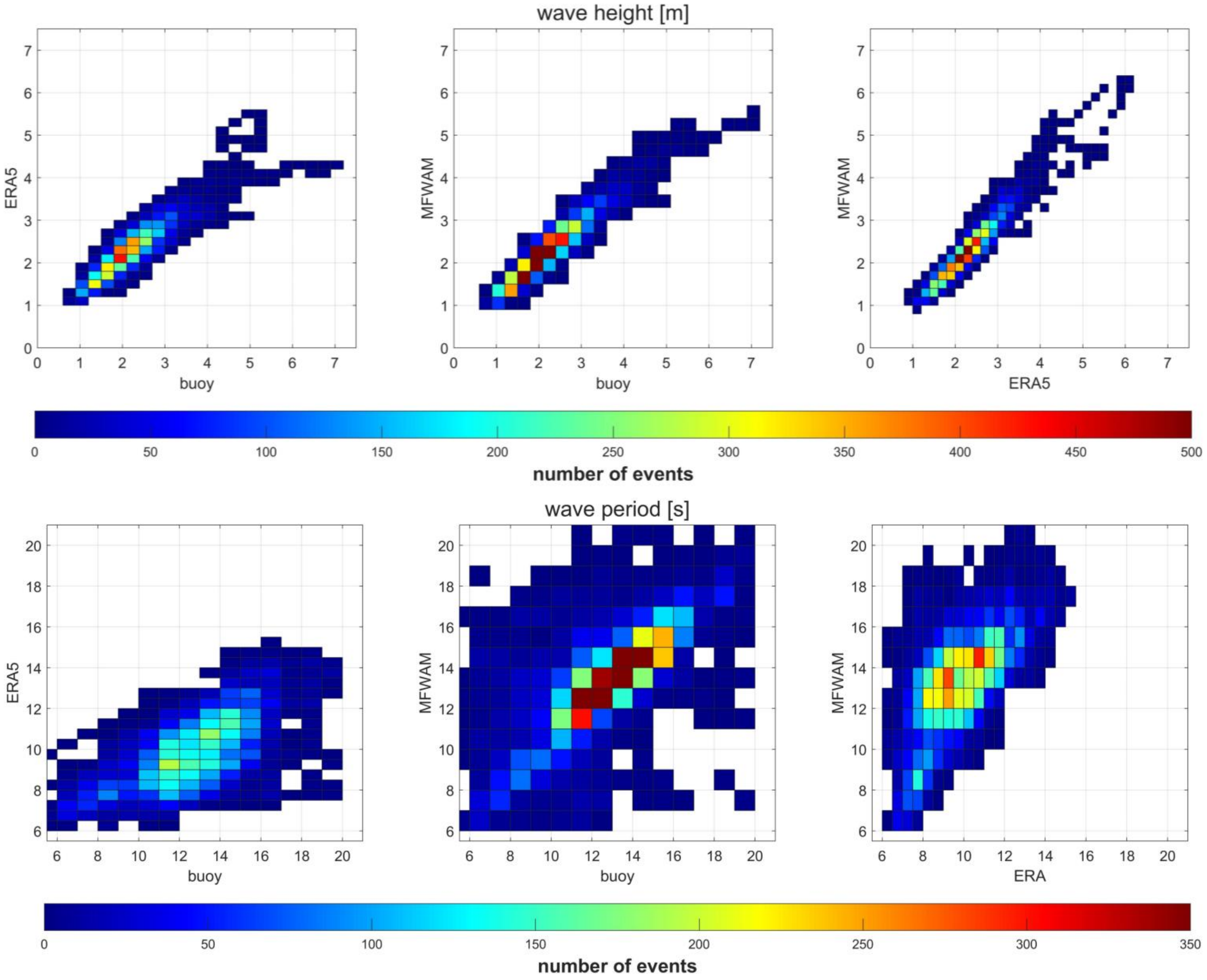


Time series of wave power from buoy measurements and models (ERA 5 and MFWAM)

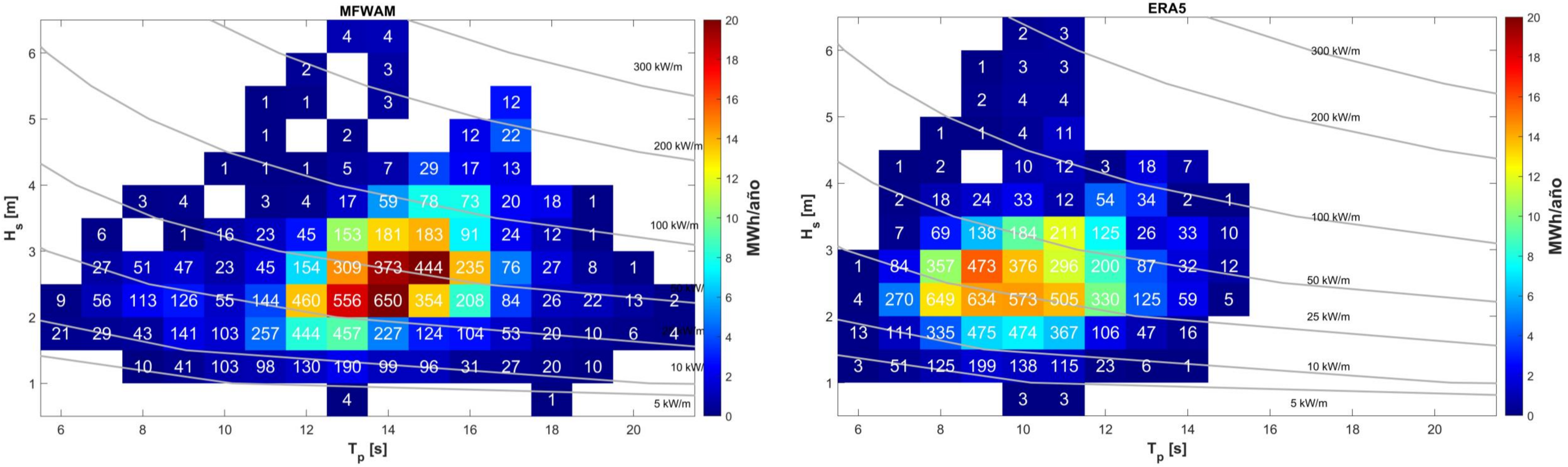
	case	NRMSE	NBIAS	SI	Slope	R
Hs	MFWAM	0,11	0,041	0,1	1,01	0,942
	ERA5	0,15	0,044	0,14	1	0,892
Tp	MFWAM	0,165	0,054	0,146	1,037	0,62
	ERA5	0,26	-0,24	0,144	0,766	0,674
P	MFWAM	0,27	0,0741	0,3193	0,949	0,9196
	ERA5	0,4172	-0,1741	0,4643	0,6473	0,8889

Evaluation of significant wave height (Hs), period (Tp) and wave power (P). Model using CFOSAT data (MFWAM), without CFOSAT data (ERA5) and buoy.

Bivariate histogram



Bivariate distribution



Histogram of probability and energy distribution for case study in Talcahuano from models with and without CFOSAT assimilation. The sea-states are represented in the significant wave height and energy period. Colors represent the cumulative energy for one year (2021) in each bin. Digits are the number of occurrences of each sea-state for each bin, in hours per year.

Summary

- Wave power increases with higher latitudes. Going from 10 kW/m in the equator to over 150 kW/m in the southern ocean.

- The most significant differences in power are found in the higher latitudes, which also correspond to the zones with the highest variability indices. This difference reaches values of 40 kW/m

- MFWAM represents in a better way extreme wave heights than ERA5. Since wave power is calculated using the squared of the wave's height, the discrepancies can be considerable.

Summary

- Model evaluation versus buoy observation of significant wave height shows slightly better performance in MFWAM (CFOSAT) than in ERA5. However, when comparing peak periods, MFWAM is significantly better.

- Having a correct bivariate distribution is essential when studying energy, as it gives relevant information on prevalent sea-states that could guide WEC selection.

- CFOSAT is a vital asset to wave models as it reproduces a more reliable sea-state to study wave energy.