Interannual variability of ocean surface waves in the Southeast Pacific

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Motivation

- Several global studies have shown that the interannual variability of the wave climate and the occurrence of extreme wave events are associated to large-scale climate oscillations, as the Southern Annular Mode (SAM) and El Niño Southern Oscillation (ENSO), among others (e.g. Izaguirre et al., 2011, Stopa et al., 2014, Kumar et al., 2016).

- Few studies have assessed regional wave climate in the Southern Hemisphere (e.g. Hemer et al., 2010) and the Southeast Pacific remains poorly studied.

- Recently, the first Chilean Wave Atlas database was generated and validated (Beyá et al., 2017, https://oleaje.uv.cl/), and the wave climatology of the Southeast Pacific was described (Aguirre et al., 2017). Nevertheless, the Southeast Pacific coast still lacks a detailed description of the interannual variability of wind waves.

- Here, we analyze the interannual variability of waves at the Southeast Pacific related to ENSO and SAM, using a model hindcast.
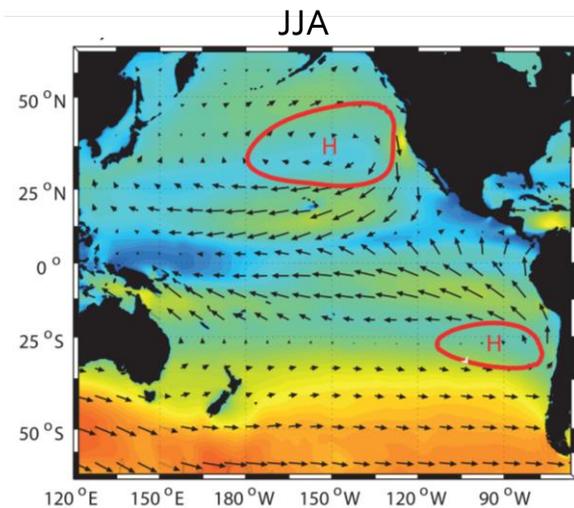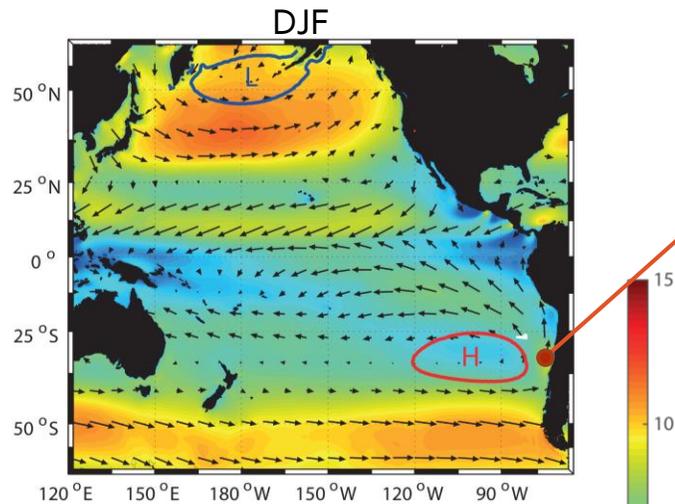
Datasets

MODEL DATA

- A 38-yr hindcast was carried out for the period between 1979 and 2016 for the Pacific Ocean using the Wavewatch III v4.18

- To force the model, we used sea ice concentration and wind fields from the ECMWF atmospheric reanalysis ERA-Interim (Dee et al., 2011).

- Maps of wave parameters and spectral data along the coast of the Southeast Pacific were saved each 2° of latitude.
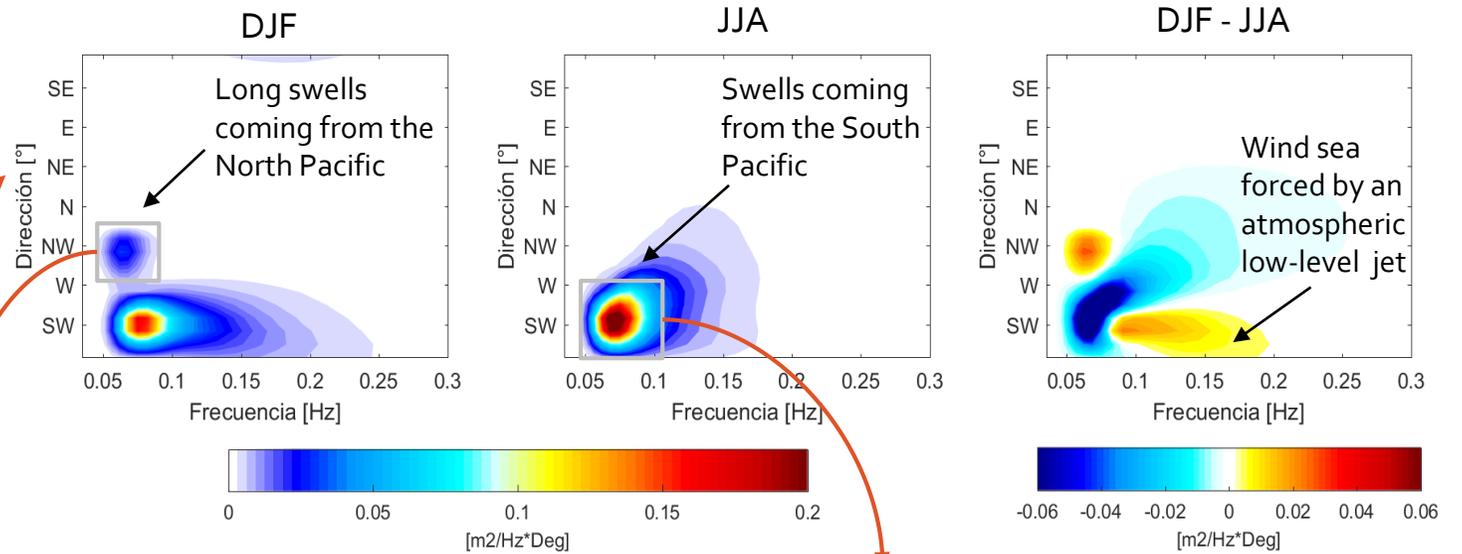
CICLONE TRACK

- A cyclone tracking software developed at The University of Melbourne was used (Murray and Simmonds 1991; Simmonds et al., 1999).

- Cyclones were identified using the sea level pressure data of the ERA-Interim dataset with spatial and temporal resolution of 2.5° and 6 hours, respectively.

- Sea level pressure, trajectory, duration and density of extratropical cyclones were obtained.
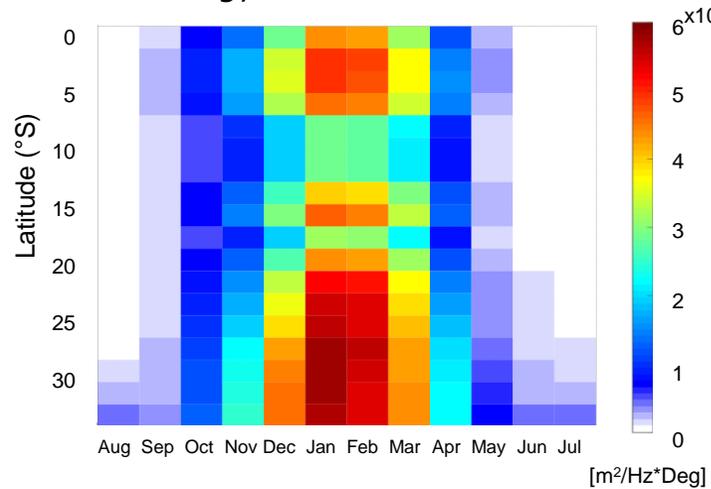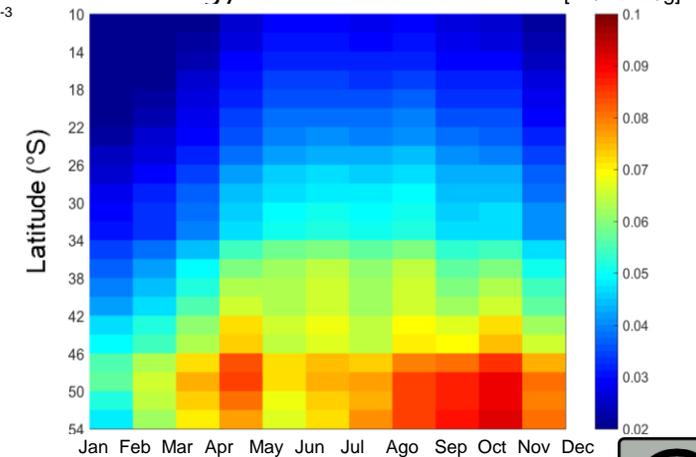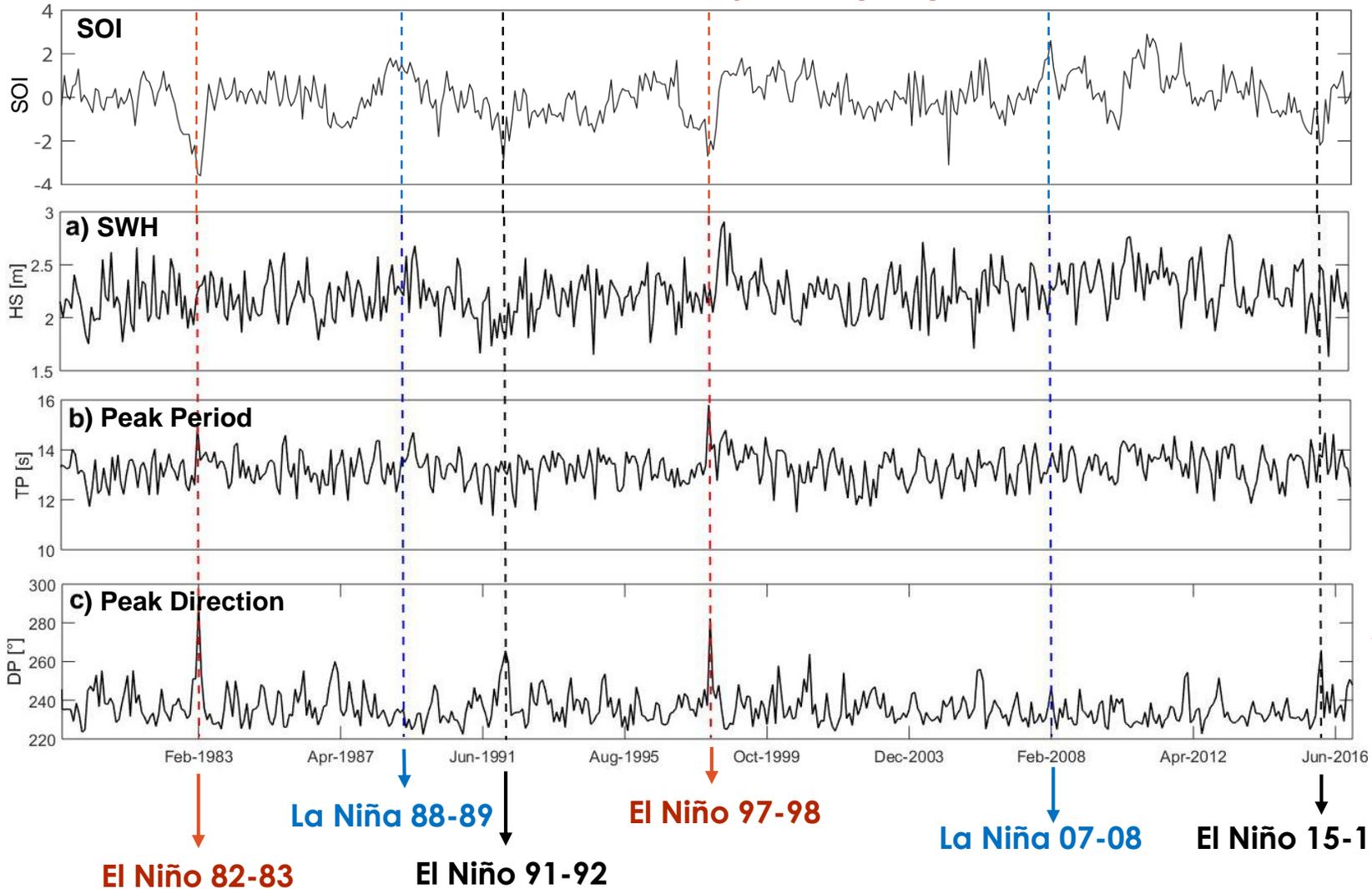
Seasonal Cycle

Spectrum off Valparaíso (33°S)

10-m Winds

DJF

JJA

DJF

Long swells coming from the North Pacific

JJA

Swells coming from the South Pacific

DJF - JJA

Wind sea forced by an atmospheric low-level jet

[m2/Hz*Deg]

[m2/Hz*Deg]

Energy from North Pacific

Energy from South Pacific

[m²/Hz*Deg]

[m²/Hz*Deg]

ENSO-related interannual variability of waves

Time series off Valparaíso (33°S)

SOI

a) SWH

b) Peak Period

c) Peak Direction

El Niño 82-83
La Niña 88-89
El Niño 91-92
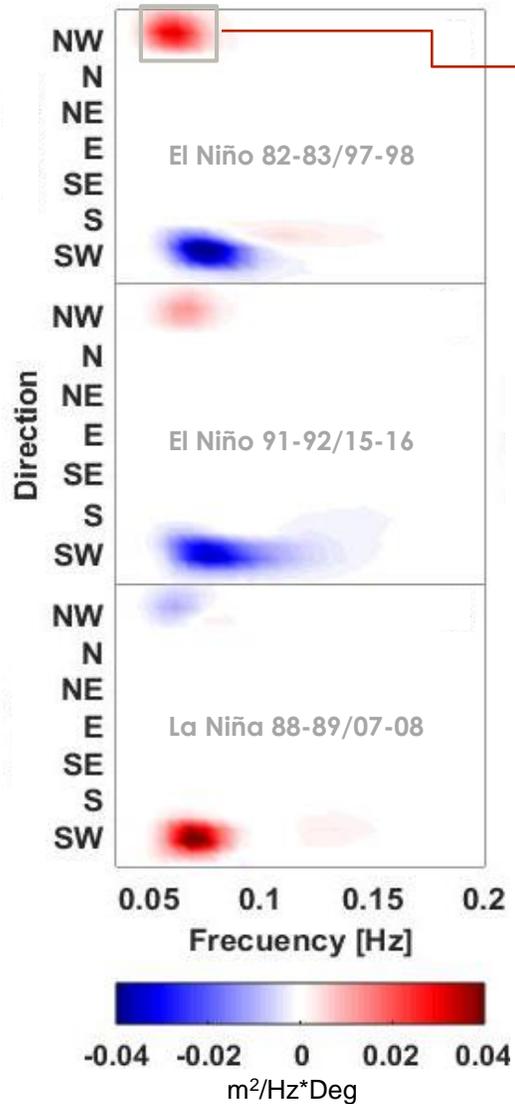El Niño 97-98
La Niña 07-08
El Niño 15-16
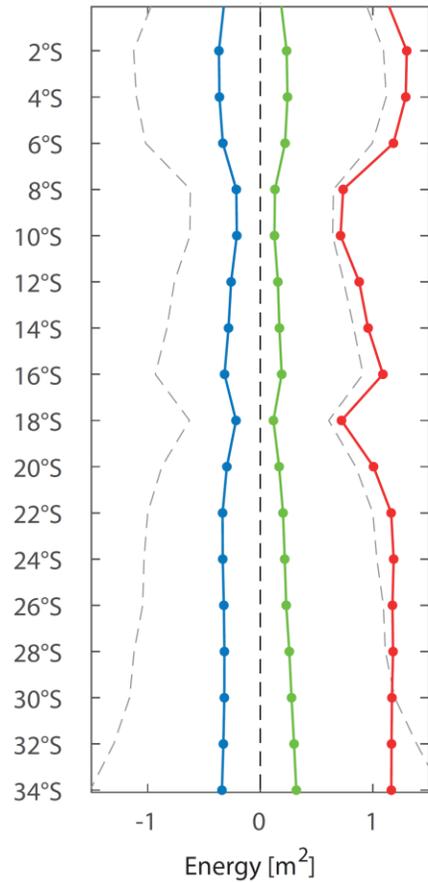
Correlation SWH-SOI

Valparaíso

C
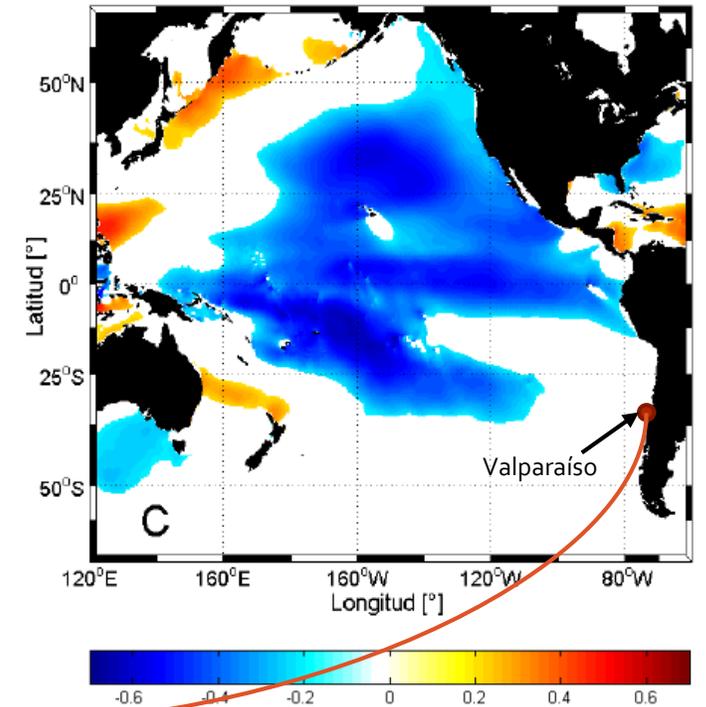
Correlation map of monthly mean SWH with the Southern Oscillation Index (SOI). Only significant correlations (at 95% confidence level) are showed.

Wave Energy anomalies

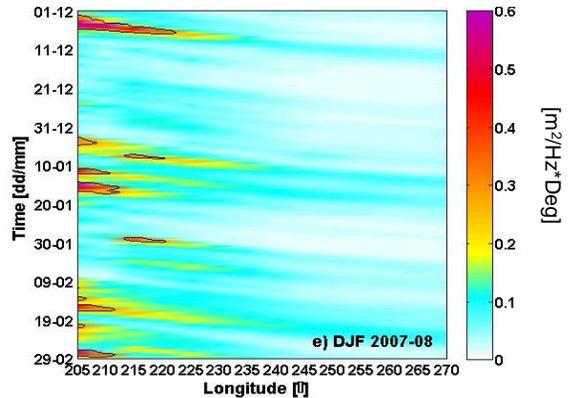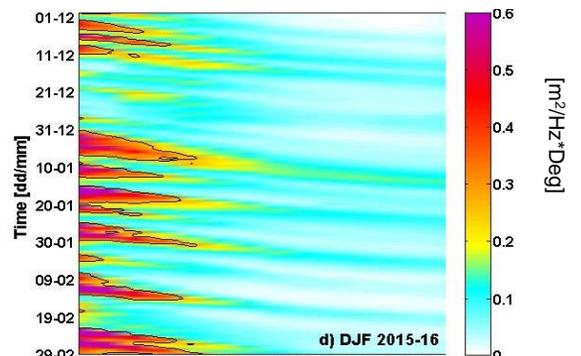Spectrum off Valparaíso (33°S)
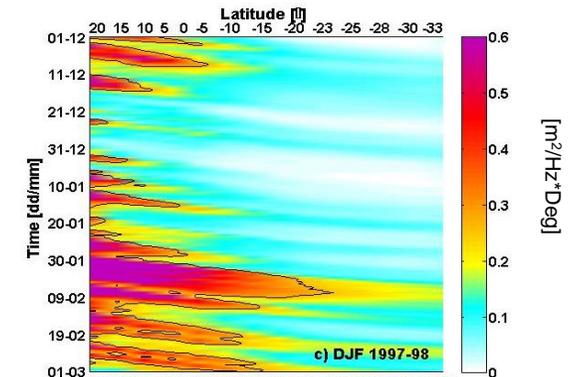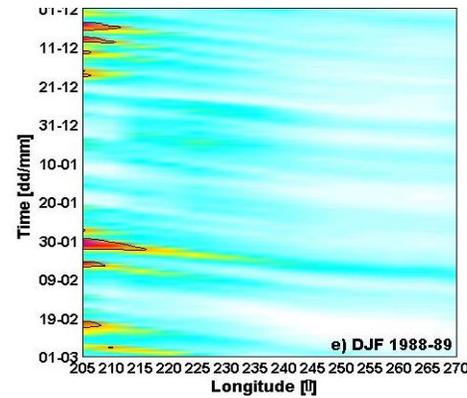

Energy anomalies from NW

Extreme El Niño

El Niño

La Niña

El Niño 82-83/97-98
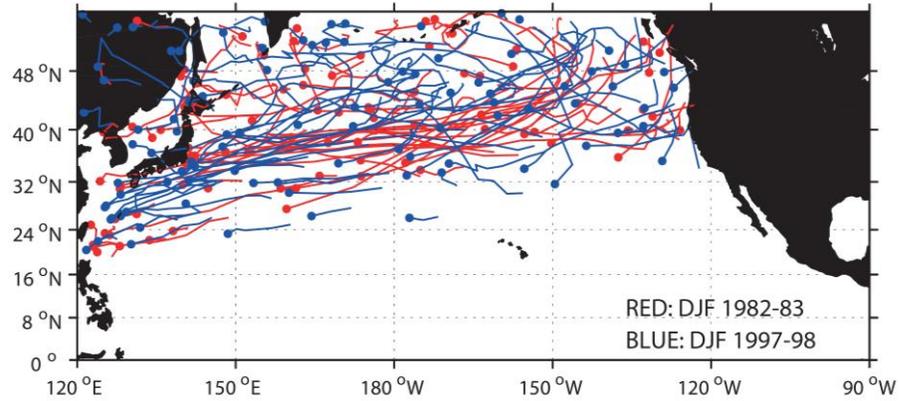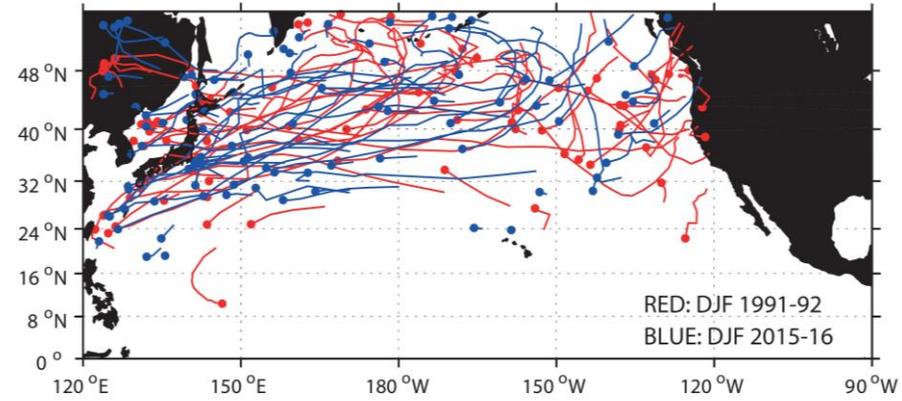El Niño 91-92/15-16
La Niña 88-89/07-08
Montecarlo test (90%)
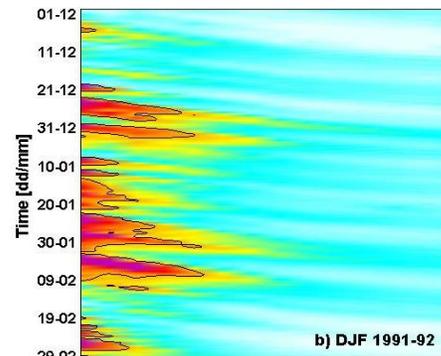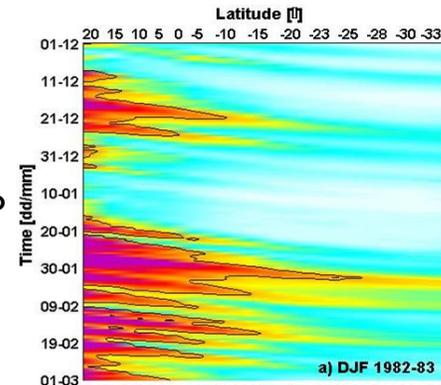
Hovmoller diagram of the wave energy with NW direction during austral summer of ENSO selected events

Cyclone Tracks

El Niño 82-83/97-98

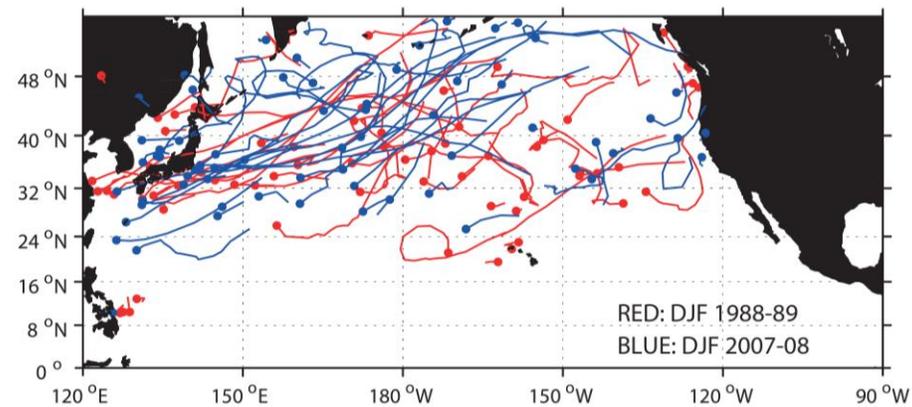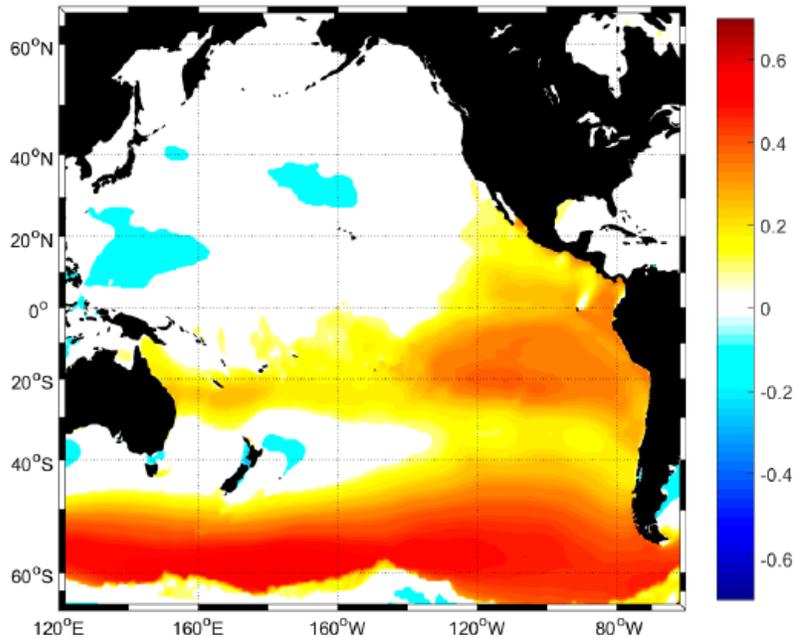RED: DJF 1982-83
BLUE: DJF 1997-98

El Niño 91-92/15-16

RED: DJF 1991-92
BLUE: DJF 2015-16

La Niña 88-89/07-08

RED: DJF 1988-89
BLUE: DJF 2007-08

SAM-related interannual variability of waves

Wave Power relative change

Correlation SWH-SAM

Correlation map of monthly mean SWH with the Southern Annular Mode (SAM). Only significant correlations (at 95% confidence level) are showed.

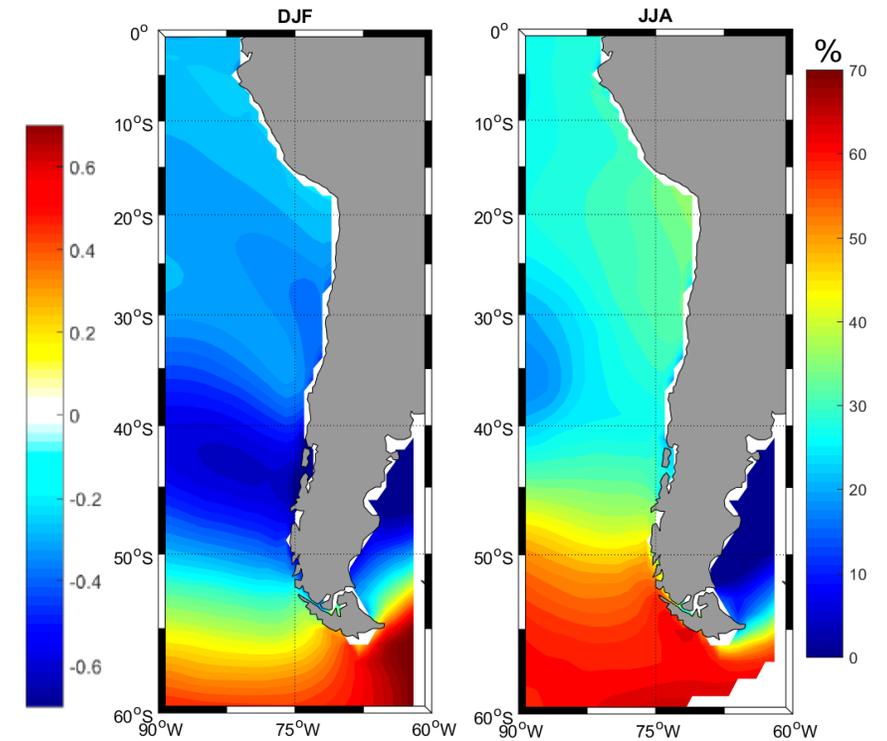**Correlation Mean period-SAM**
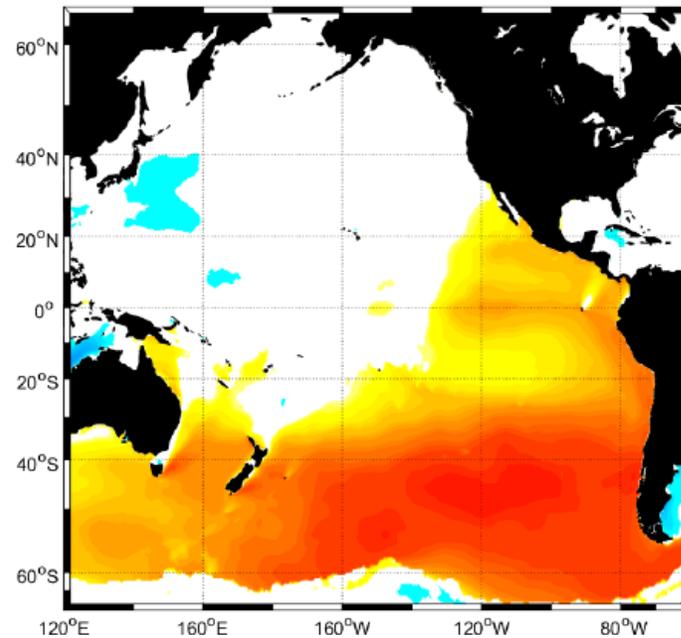
Correlation map of monthly mean period with the Southern Annular Mode (SAM). Only significant correlations (at 95% confidence level) are showed.

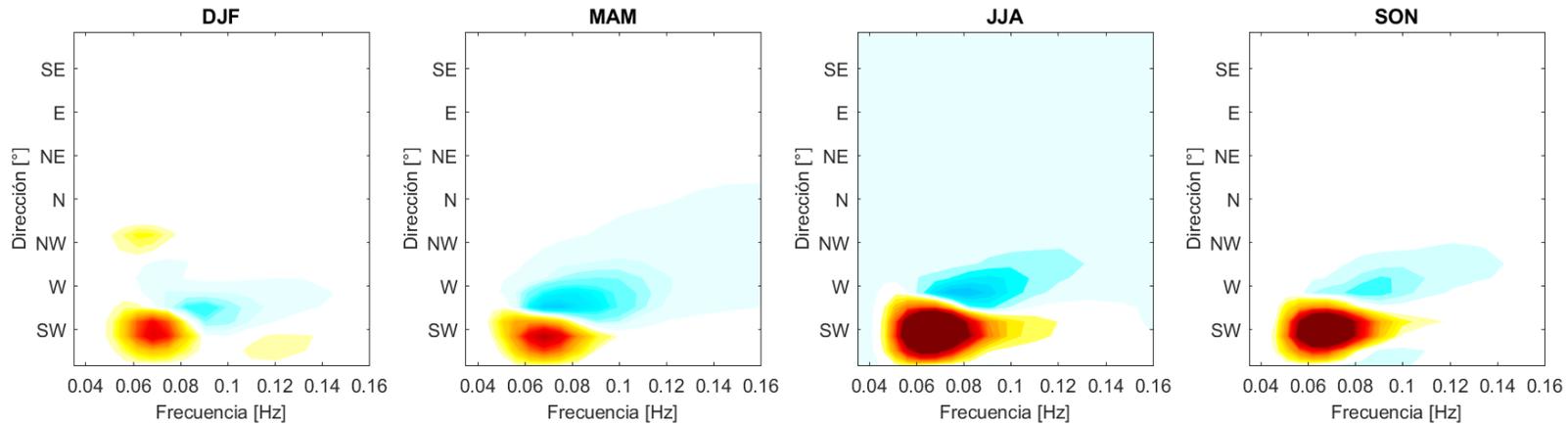Wave power (WP) relative change calculated using the upper and lower quintiles of the SAM.
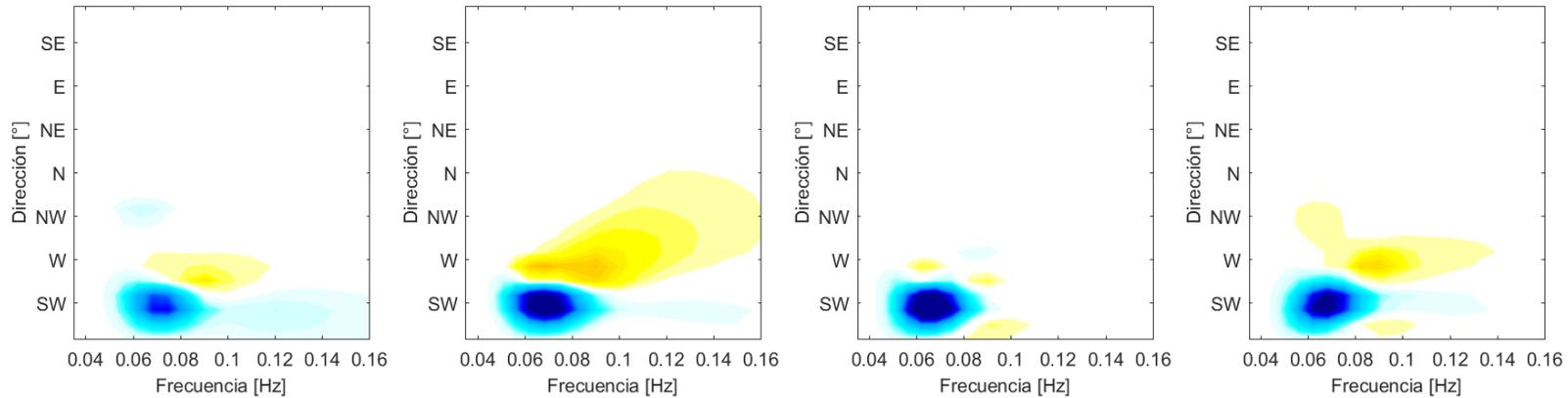
$$(WP_{SAM+} - WP_{SAM-}) / WP_{MEAN}$$

Wave Energy anomalies

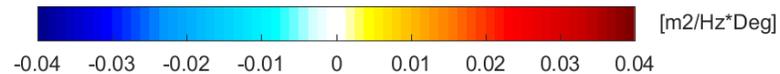## Wave energy anomalies off Valparaíso (33°S)

Upper quintile of the SAM (positive phase)

Lower quintile of the SAM (negative phase)

Composites of the wave energy calculated using the upper and lower quintiles of the SAM index.

SAM-driven SWH trends

Simple linear regression framework to estimate SWH changes congruent with the SAM

- The SAM-driven SWH trend is estimated as

$$\delta_{\text{SWH-SAM}} = \beta \times \delta_{\text{SAM}}$$

δ_{SAM}: linear trend of the SAM index

β : regression slope computed between the time series of the SAM index and simulated SWH
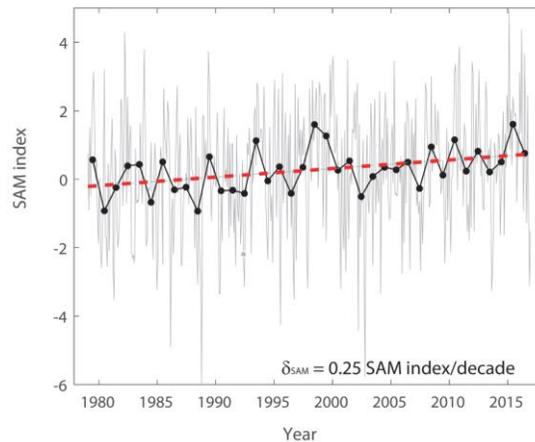
Time series of the SAM index (we use the index of Marshall et al. [2003], https://legacy.bas.ac.uk/met/gjma/sam.html
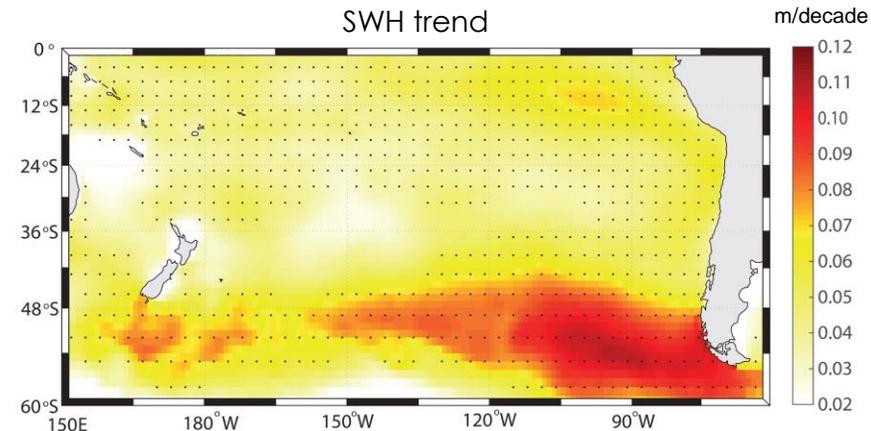
SWH trend

Black dots indicate values that are statistically significant according to the Mann-Kendall test.

SAM-driven SWH trend ($\delta_{\text{SWH-SAM}}$)

$[(\delta_{\text{SWH-SAM}})/\text{SWH trend}]*100$
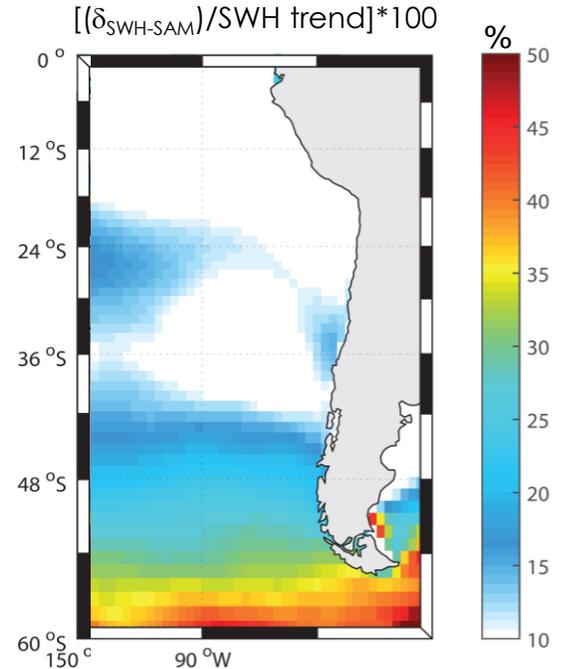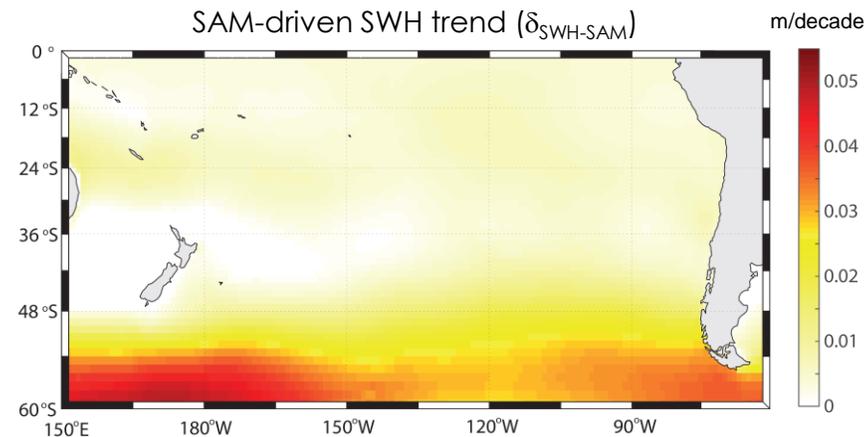
Over the SE Pacific, SAM-congruent SWH trend explains less than 50% of the simulated SWH trend.

Conclusions

- Although no significant relationship is found between SWH and ENSO at the Southeast Pacific, the wave energy coming from the North Pacific is significantly higher during the austral summer of the extreme ENSO events occurred during 82/83 and 97/98.

- The SWH and mean period exhibit a relationship with the SAM at the Southeast Pacific, which strongly impact the wave power, particularly at the southern tip of Chile.

- Directional spectra show an increase (decrease) of wave energy coming from SW during the positive (negative) phase of the SAM. But, spectra also indicate increased (decreased) energy coming from W-NW during the negative (positive) phase of the SAM.

- The simulated SWH shows a positive trend in the Southeast Pacific, which can be only partially attributed to the observed trend in the SAM index. While the SAM-congruent SWH trend can explain more than 50% of the simulated SWH trend in the Southern Ocean, over the Southeast Pacific, SAM-congruent SWH trend explains less than 15% of the simulated SWH trend.

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