Exacerbation of Coastal Erosion along the Equatorial Pacific due to Oceanic Anomalies like ENSO

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CNR   ISMAR

ESCUELA POLITÉCNICA NACIONAL

Mode Mat

4th International Workshop on Waves, Storm Surges and Coastal Hazards

Incorporating the 18th International Waves Workshop

UC | Universidad de Cantabria

IH cantabria

- In several places along the Pacific coasts beaches are being progressively lost.

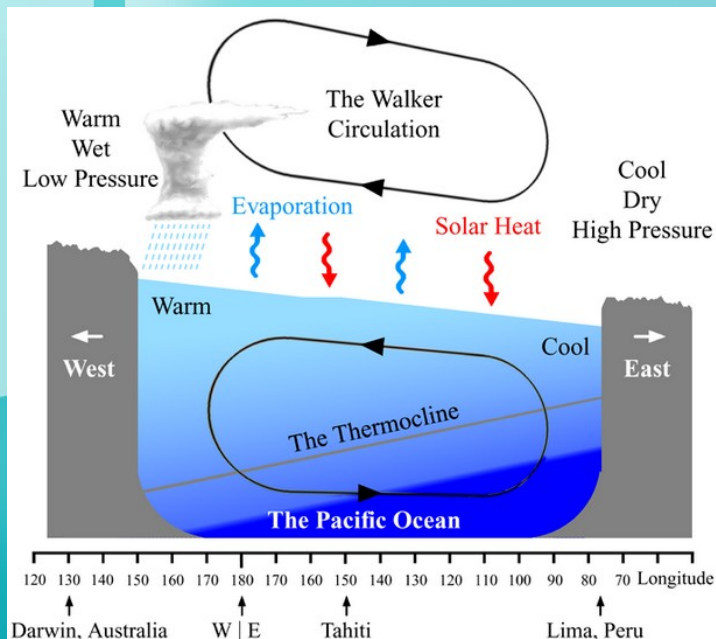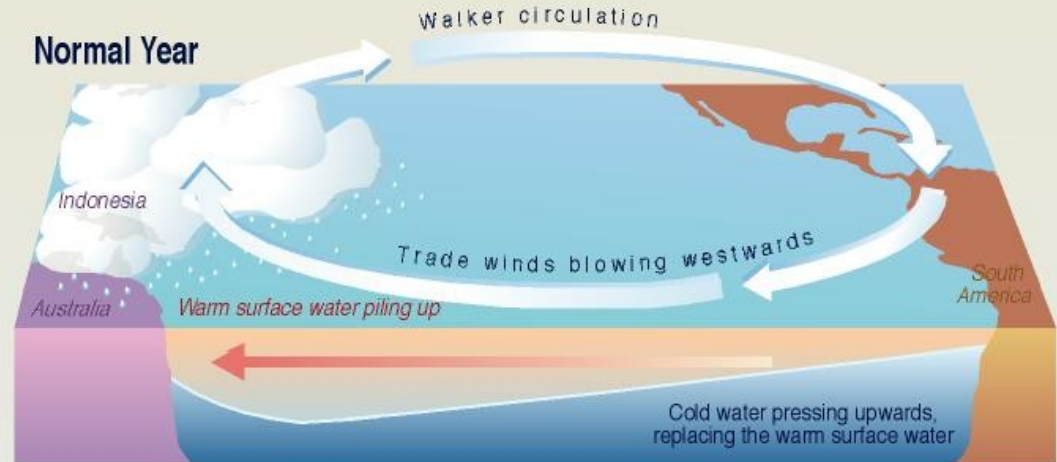- Exceptional ENSO conditions were forecasted by NOAA due to extreme SST in 2023

- El Niño phenomenon

is an anomaly originally detected by high SST and excess rainfall along the Ecuadorian and Peruvian coasts.

Currently it is recognized that its consequences are global


El Niño Phenomenon (ENSO)

1) Trade Winds

are the prevalent winds in the tropical and temperate zones. They are moderate but play an important role in the regional climate.

2) Convergence Zones (Atmospheric Circulation)

- Zones where two atmospheric systems get together.

- They are characterized by low wind speeds and high cloudiness.

The Inter-tropical convergence zone **(ITCZ)**, establishes the confluence of the trade-winds from North and South.
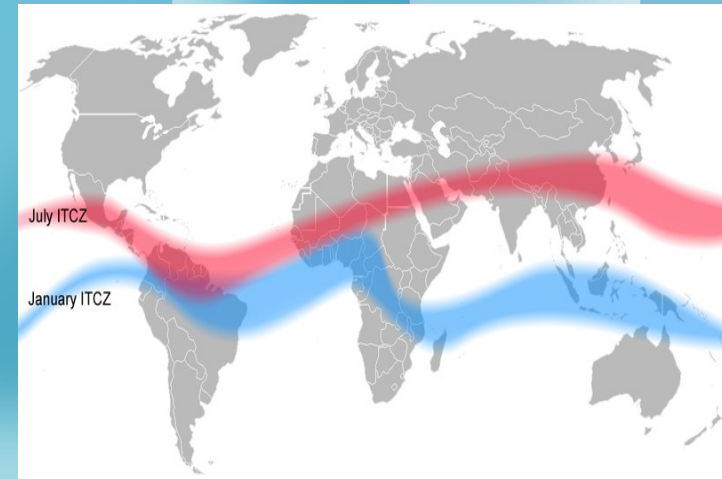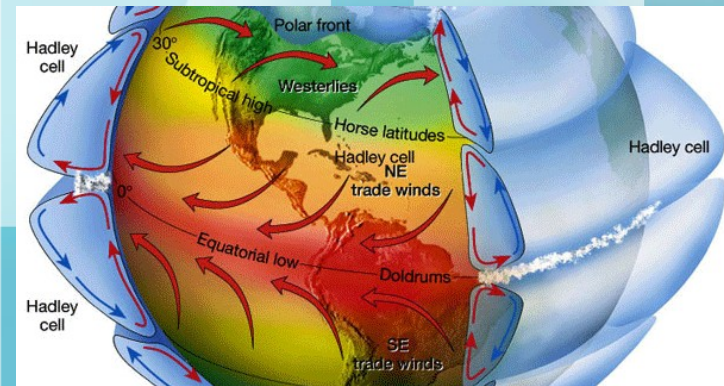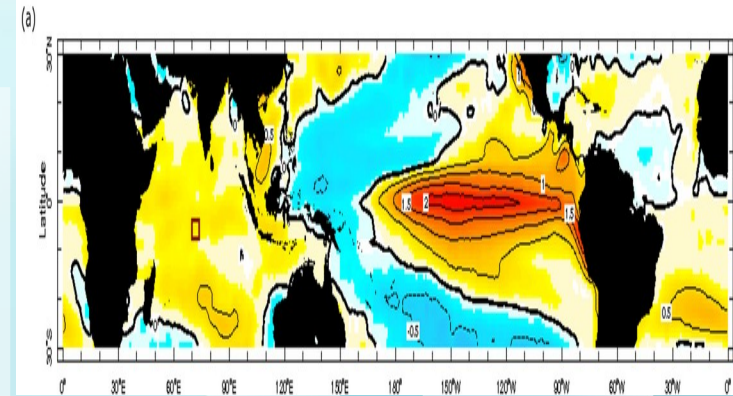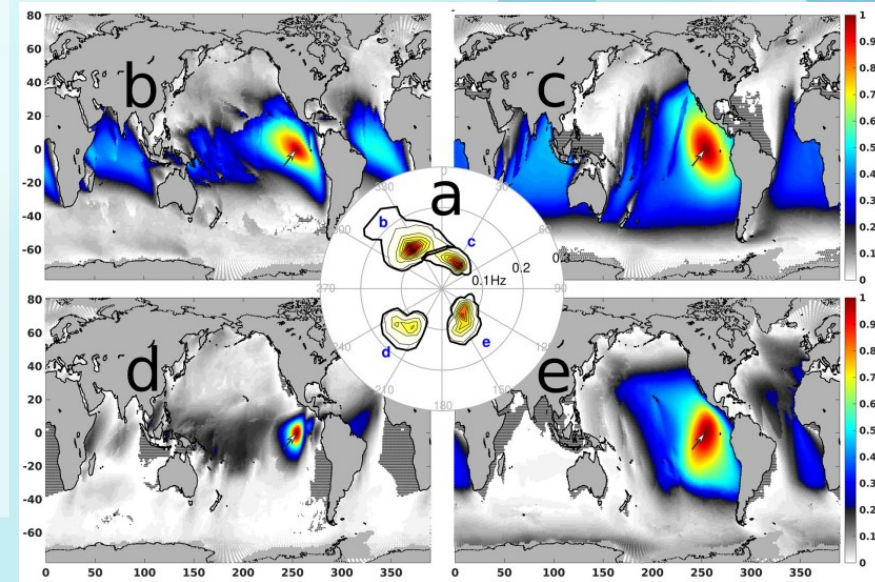
Approach and General Context

3) Ocean surface wind waves

Wind driven ocean waves constitute the coupling interface between the atmosphere and the ocean.

The waves signal has a longer memory

The thermal equivalent of most of the atmosphere (troposphere = 10 km), is about 3m of ocean water column

In this project...

We investigate the relationship between the ITCZ and ENSO

Is is known that during ENSO, the southern trade-winds in the Pacific Ocean become weaker.

¿How ENSO and the trade-winds are related?

¿What happens to other wind systems?
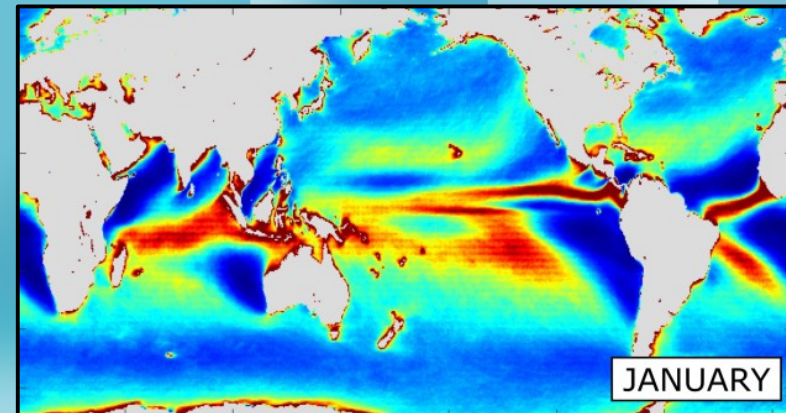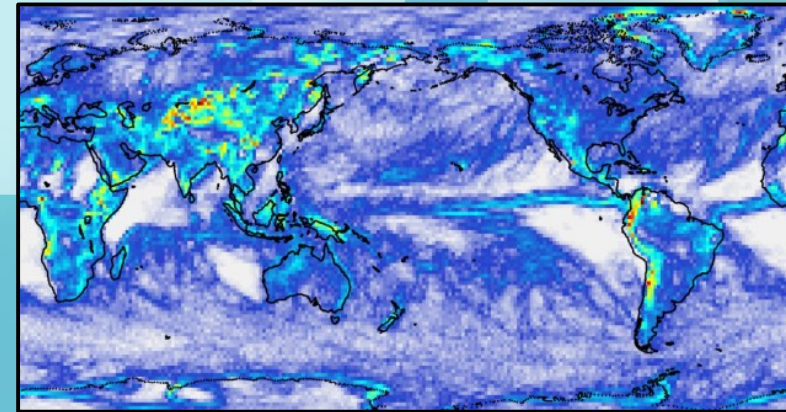
¿Why is the ITCZ relevant?
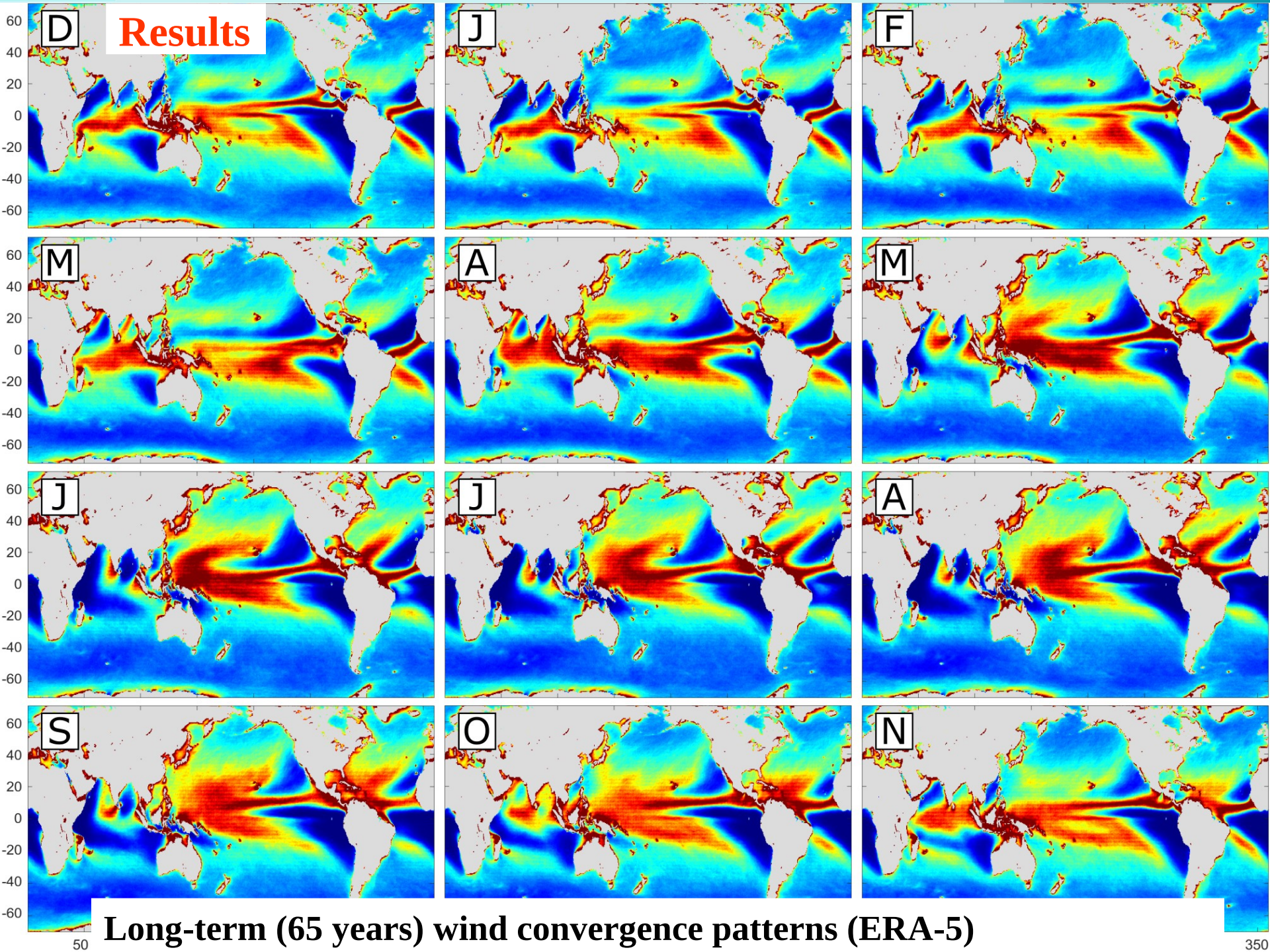
Based on pattern identification methods

- We first identify wind convergence points (from its N-S direction change). **single time-step**

- We then collect these convergence points for a single **month-year period**.

- Then climate statistics are obtained about convergence zones (**monthly global**)
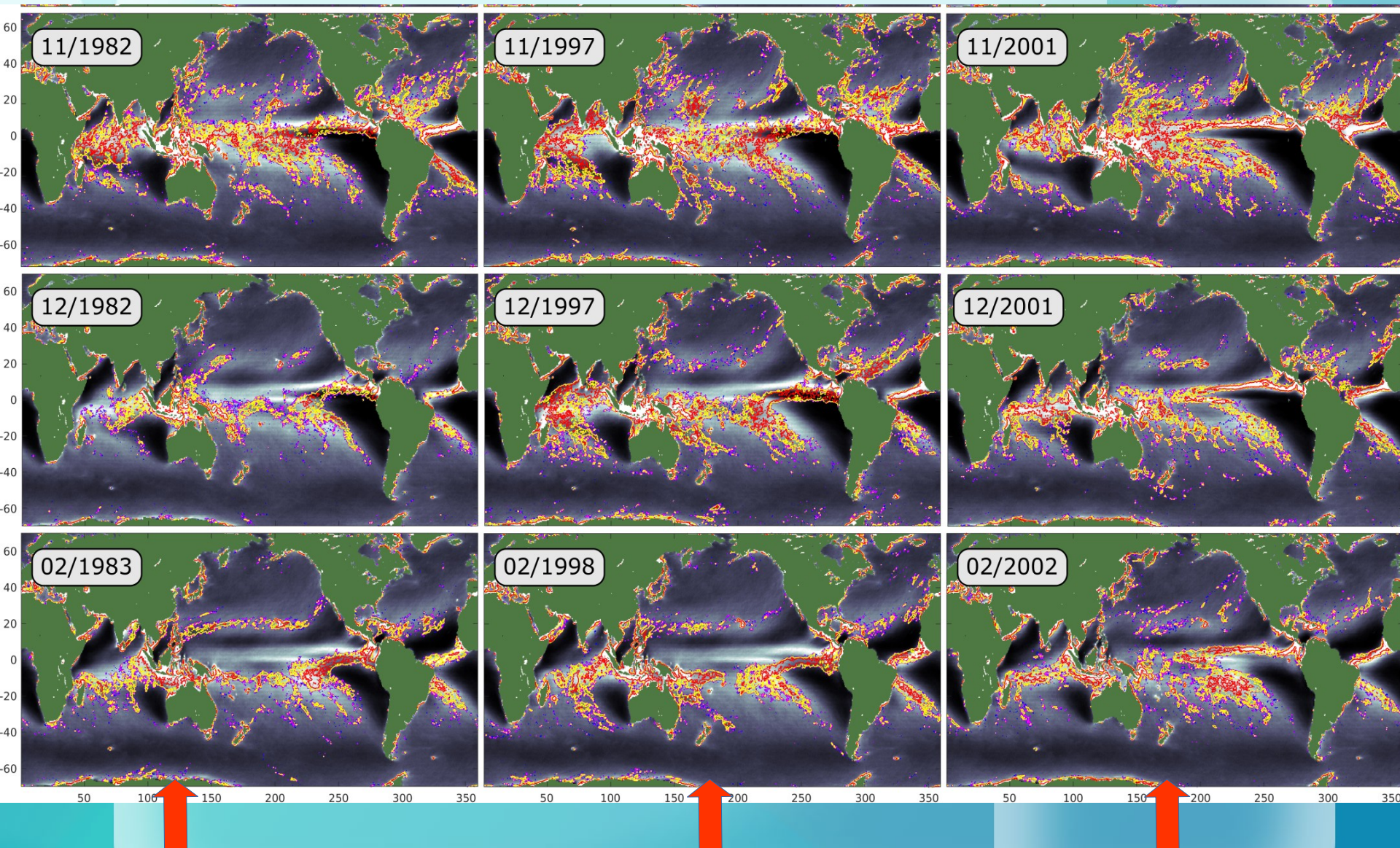
Data from ERA5 (ECMWF)
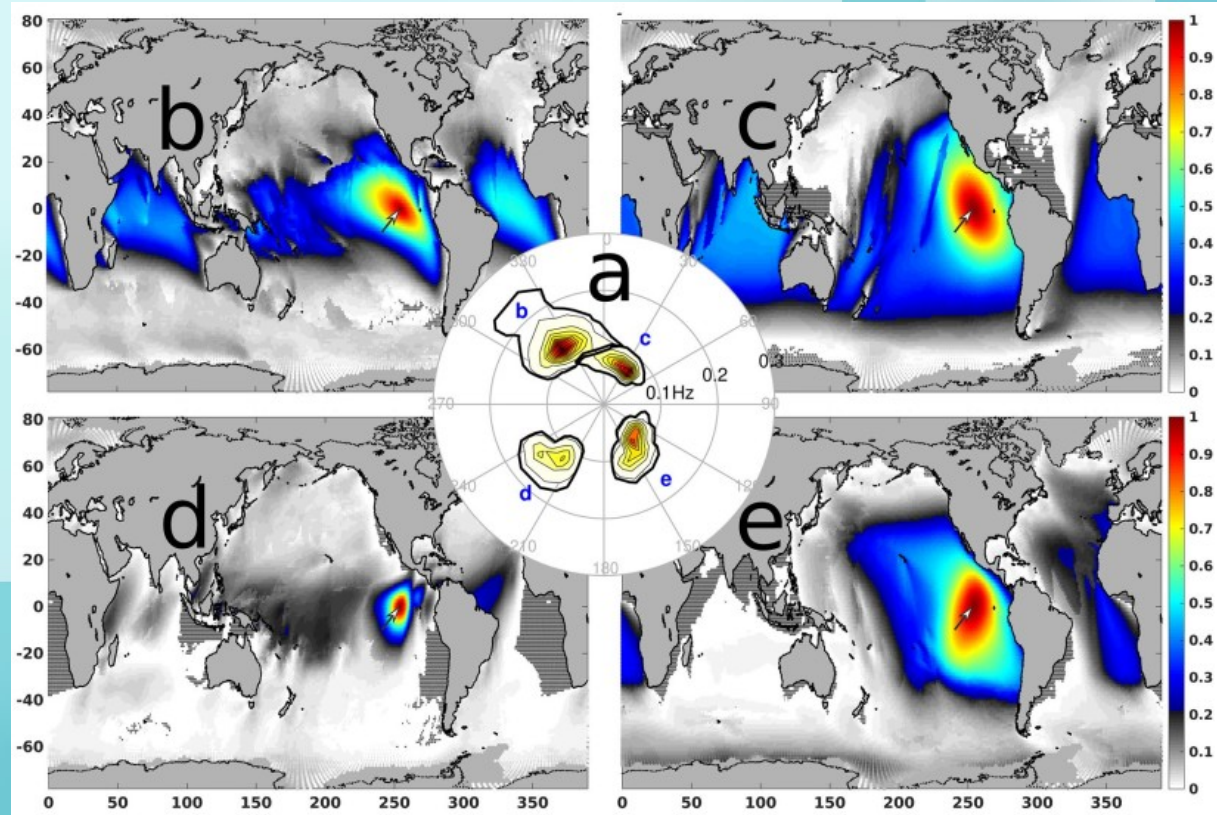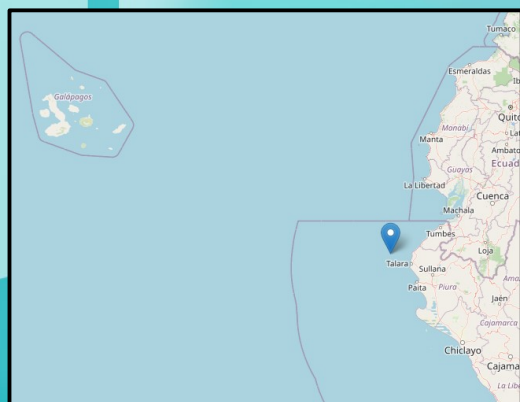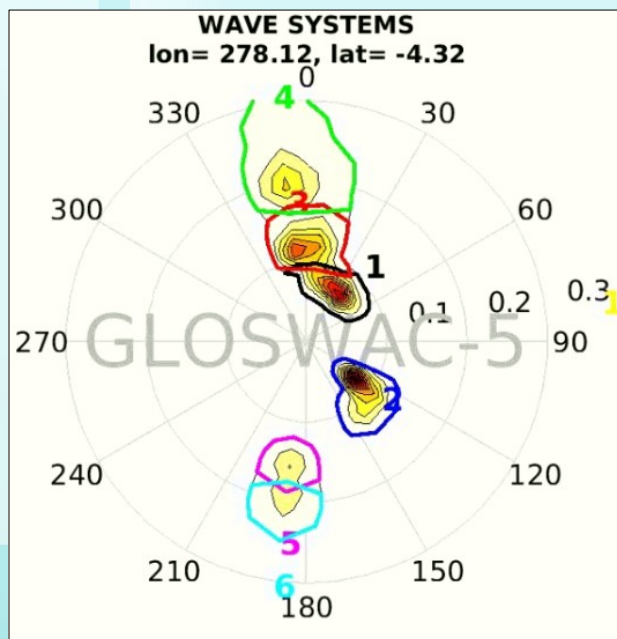
Wind: 1959-2025

Waves: 1969-2023

JANUARY

Results

Long-term (65 years) wind convergence patterns (ERA-5)

Results

11/1982   11/1997   11/2001

12/1982   12/1997   12/2001

02/1983   02/1998   02/2002

1983 – STRONG ENSO YEARS – 1998   **NEUTRAL**

The waves point of view

1. southern swells
2. northern swells
3. trade winds
4. local trade winds
5. extremes of the Panama jet
6. Panama jet

Wave System 1

Southern swells

The waves point of view

Wave System 2

Northern swells

Wave System 3

Trade winds (long fetch)
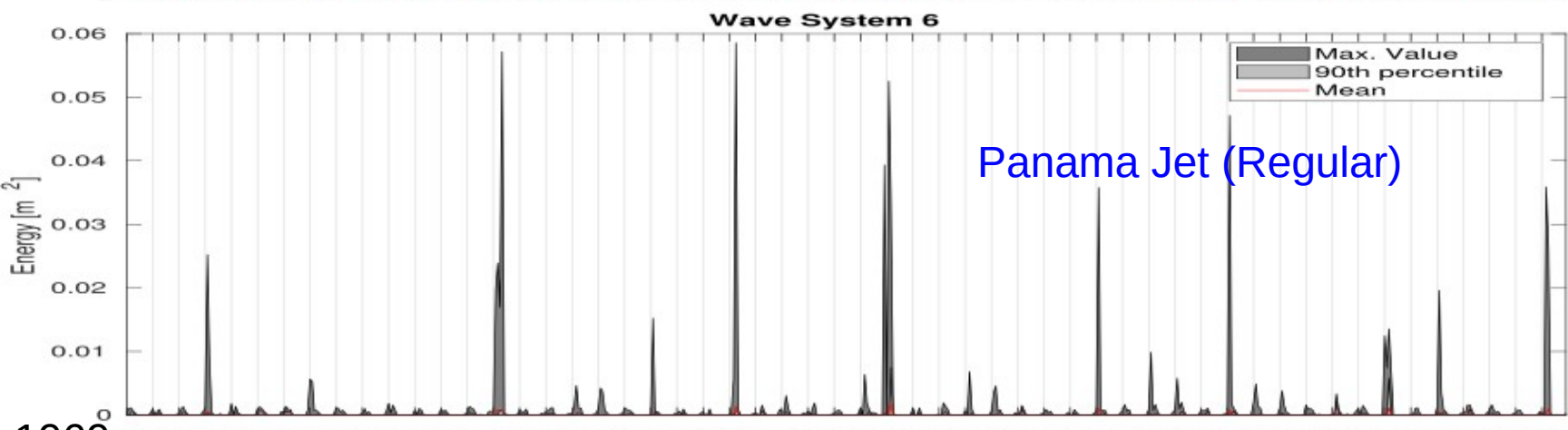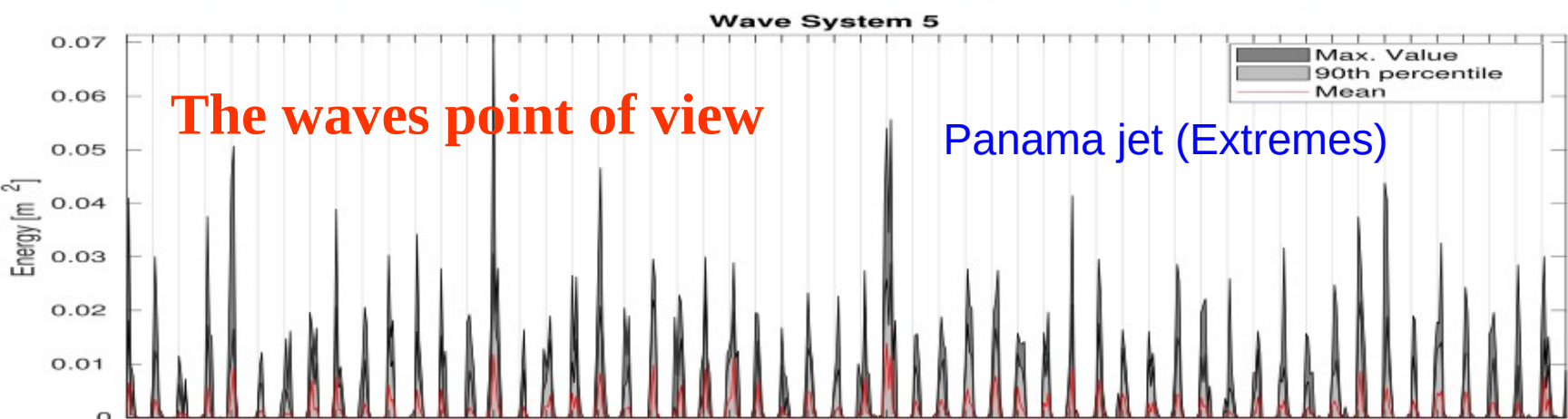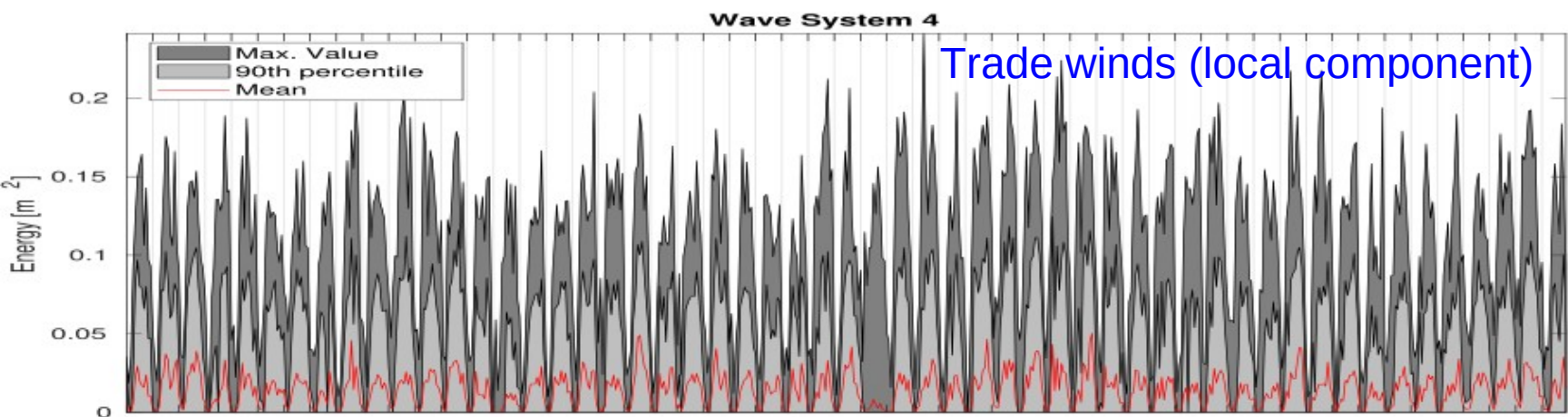
1969   2023

Wave System 4

Trade winds (local component)

Max. Value
90th percentile
Mean

Wave System 5

The waves point of view

Panama jet (Extremes)

Max. Value
90th percentile
Mean

Wave System 6

Panama Jet (Regular)

Max. Value
90th percentile
Mean
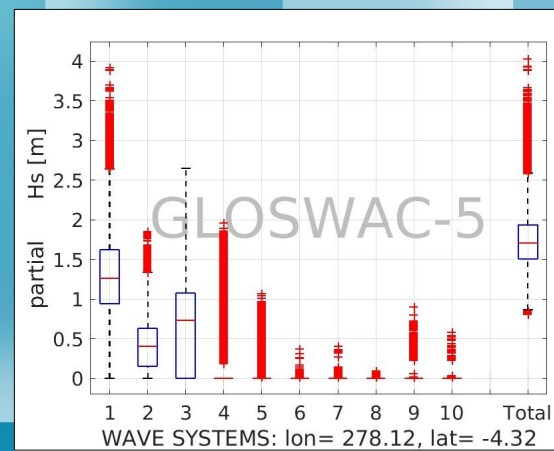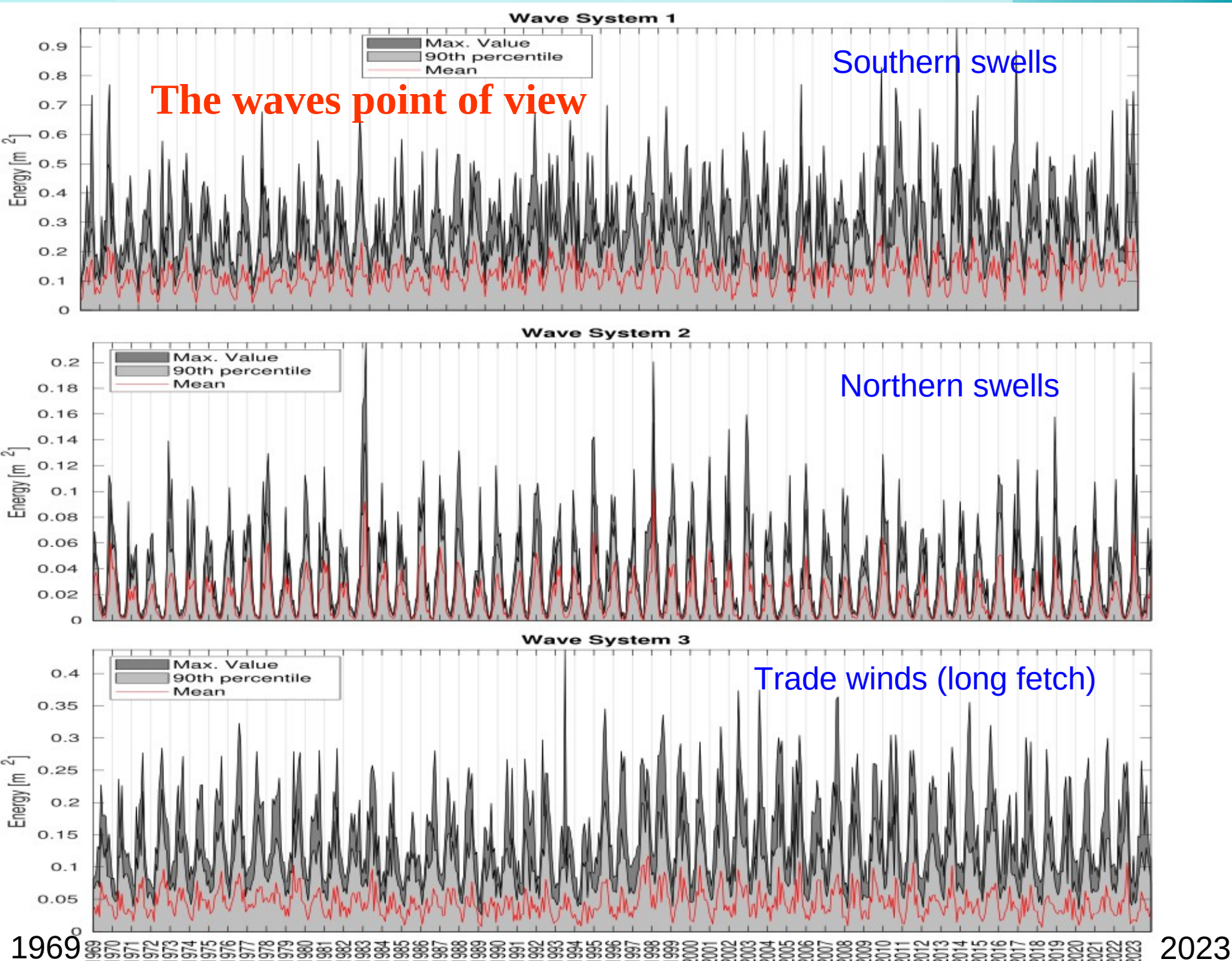
1969   2023

So what happened in 2015, 2023? ... ¿Godzilla El Niño?
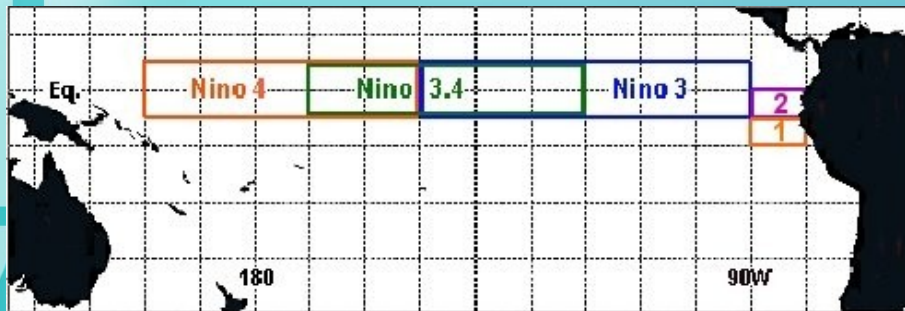

2015

2015

Experts Warn of 'Godzilla El Nino' Storm That Could Rock West Coast Dangerous storm and flash floods hit Las Vegas as the West braces for a possible monster storm.

2023

The Washington Post
Democracy Dies in Darkness

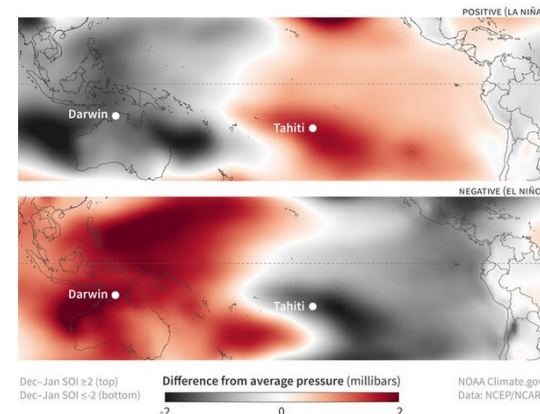Extreme Weather   Weather   Climate   Capital Weather Gang   Environment   Climate Lab

One of the most intense El Niños ever observed could be forming

An experimental forecast from scientists at the National Center for Atmospheric Research calls for a 'super' El Niño by winter
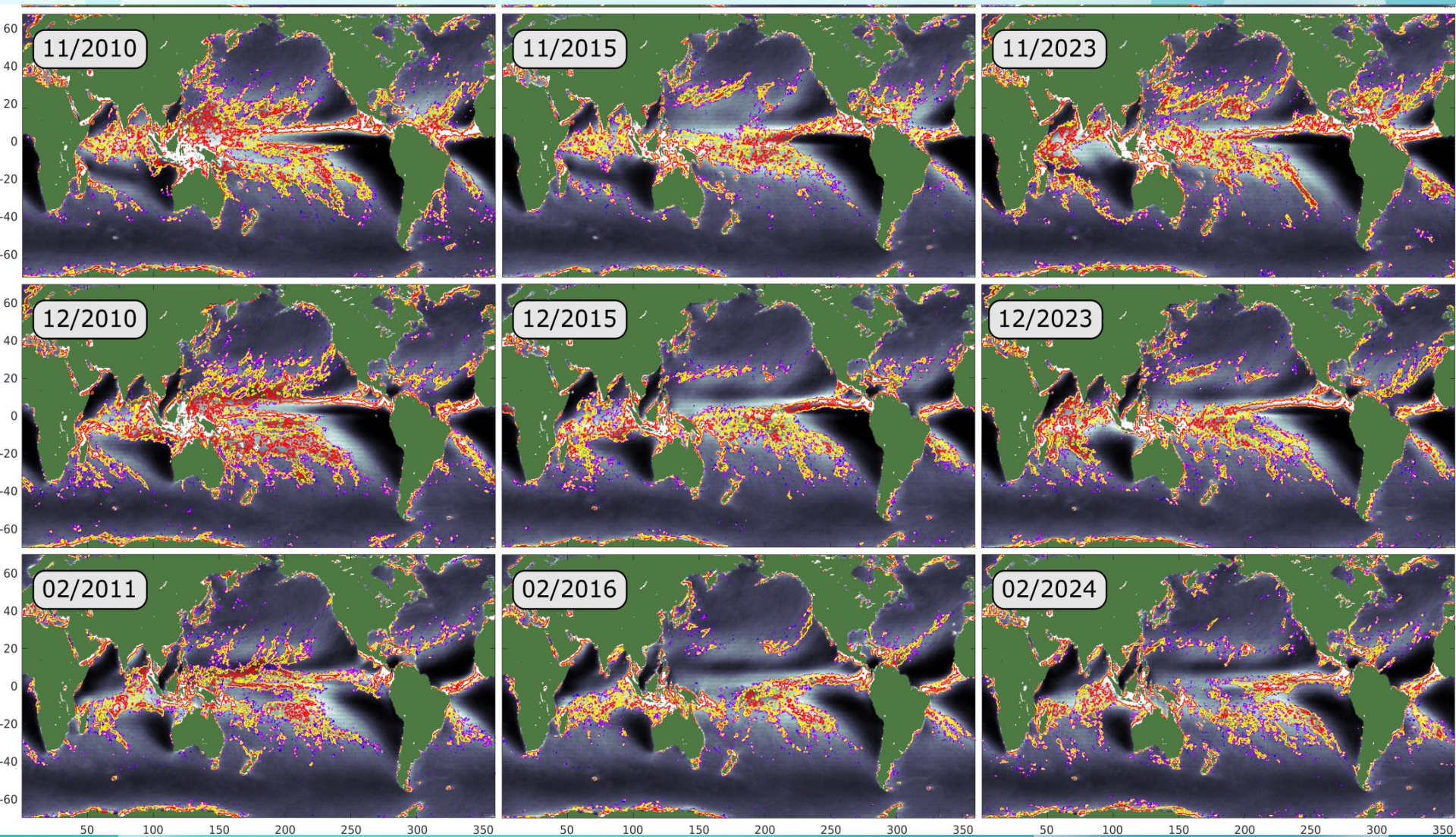
September 26, 2023

- Extreme ENSO conditions were forecasted due to extreme SST

- Why is ENSO prediction so unreliable?

- Are there other variables that bear complementary prediction skills?

Results

Despite extremely high SST, trade winds patterns were normal

Conclusions

- The 2015 and 2023 events, are not consistent with typical wind and wave ENSO patterns.

- The main current ENSO indexes are based on SST (ONI) and atmospheric pressure differences (SOI), which are more close to the consequences.

- The ENSO phenomenon is very complex and implies intricate feedback mechanisms involving atmosphere and ocean at global scale.

- We believe that waves and winds are more close to the causes and therefore it is worth looking at their signals.

- The anomalous behavior of the ITCZ (position and structure) seems consistent with the development of ENSO (at least in the available record).

- Coastal erosion seems to be more related to anthropogenic effects (not shown).
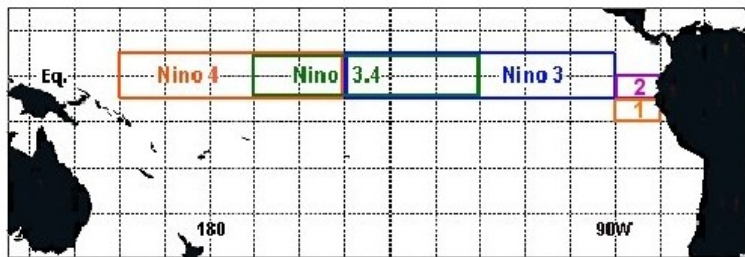
Thanks for your attention

Motivation

- Why is ENSO prediction so unreliable?

- Are there other variables that bear enhanced prediction skills?

ENSO Indices

NOAA Oceanic Niño Index (ONI)
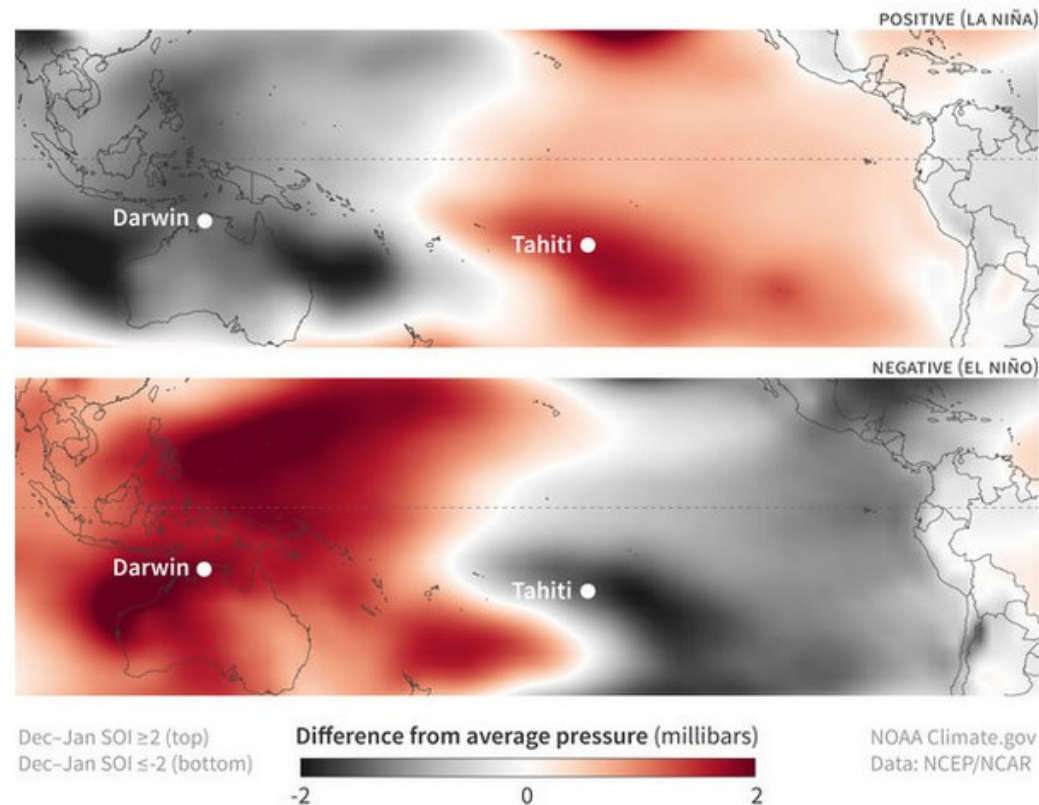sea surface temperature anomaly index for Niño 3.4 (5°N to 5°S, 170°W to 120°W)

- onset of El Niño declared when Niño 3.4 anomaly exceeds +0.5°C for 3-month period
- to be "full-fledged" El Niño (or La Niña), onset conditions must be met for 5 consecutive 3-month periods
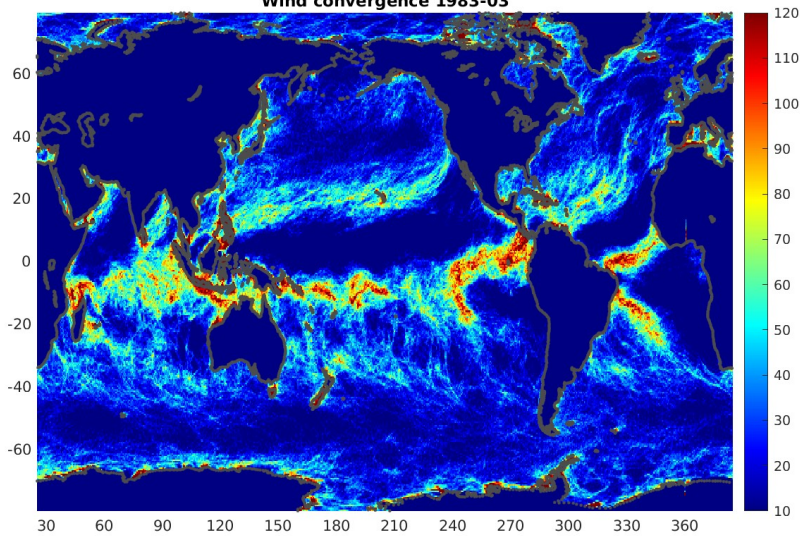
Multivariate ENSO Index (MEI)
weighted anomaly average of 6 meteorological variables in the tropical Pacific

- sea surface temperature
- sea level pressure
- surface air temperature
- components of surface wind
  - zonal component
  - meridional component
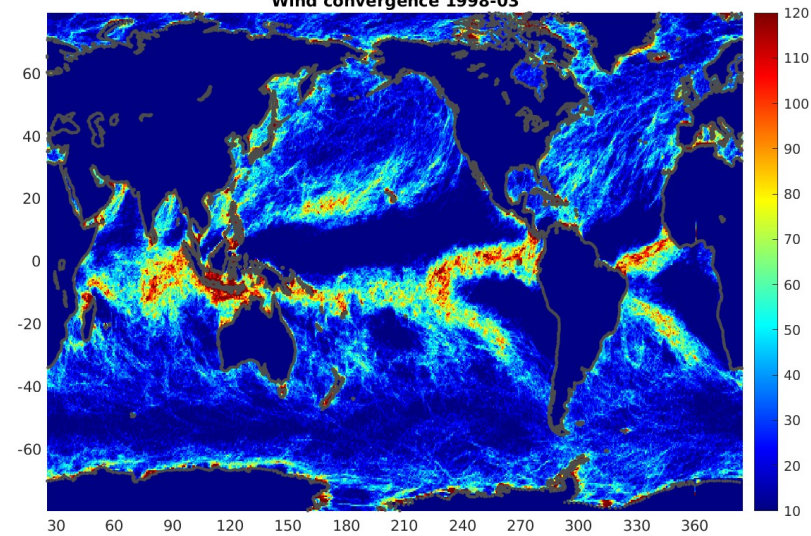- total cloudiness fraction of the sky

SOI PRESSURE PATTERNS

POSITIVE (LA NIÑA)

NEGATIVE (EL NIÑO)

Dec–Jan SOI ≥2 (top)
Dec–Jan SOI ≤-2 (bottom)

Difference from average pressure (millibars)

-2   0   2
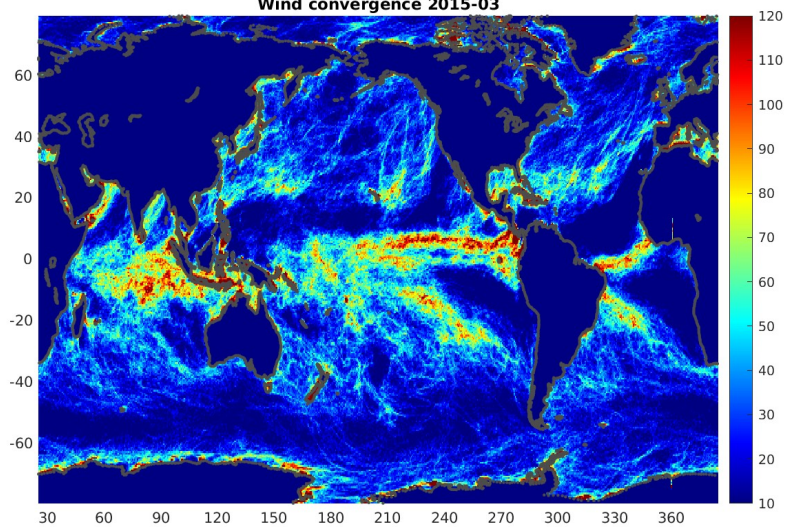
NOAA Climate.gov
Data: NCEP/NCAR

Wind convergence 1983-03

Wind convergence 1998-03

Wind convergence 2015-03

Wind convergence 1968-03