Diagnosis of the atmospheric conditions associated with the arrival of sargassum to the coasts of Quintana Roo, Mexico.

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Motivation

The massive arrival of sargassum generates adverse environmental, social, and economic impacts in the Quintana Roo coast.

Sargassum fluitans. Credit: A. N. S. Siuda

As it floats, part of the sargassum is exposed to the surface wind.

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Motivation

Since 2011, the arrival of sargassum has increased through a belt in the Atlantic that extends from West Africa to the Gulf of Mexico: The Great Atlantic Sargassum belt (GASB).

https://cigom.org/noticias/

The spatial distribution of this belt is driven by oceanic and atmospheric circulation among oth

https://cigom.org/noticias/

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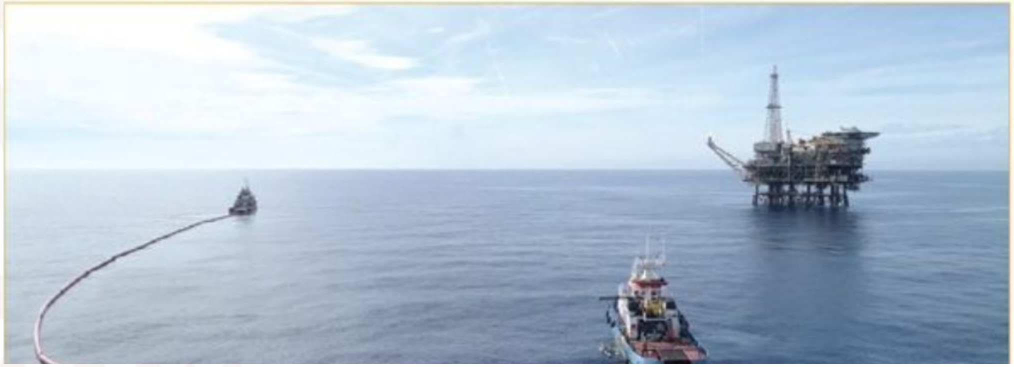
Motivation

Airports on Mexico's Caribbean coast reported more than 35 million visitors in 2025.

Approaches

There are three main approaches to analyzing the arrival of sargassum on the coasts of Quintana Roo:

- Sargassum population dynamics
- Ocean surface dynamics
- ✔ Atmospheric surface dynamics



https://cigom.org/noticias/

https://www.jornada.com.mx/noticia/2025

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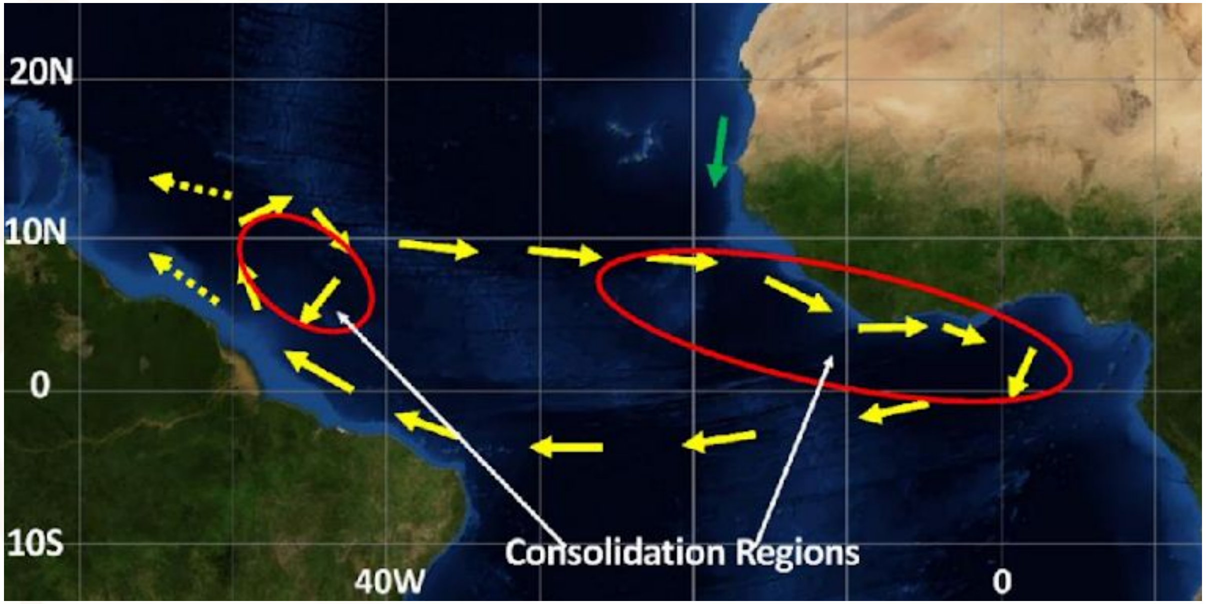
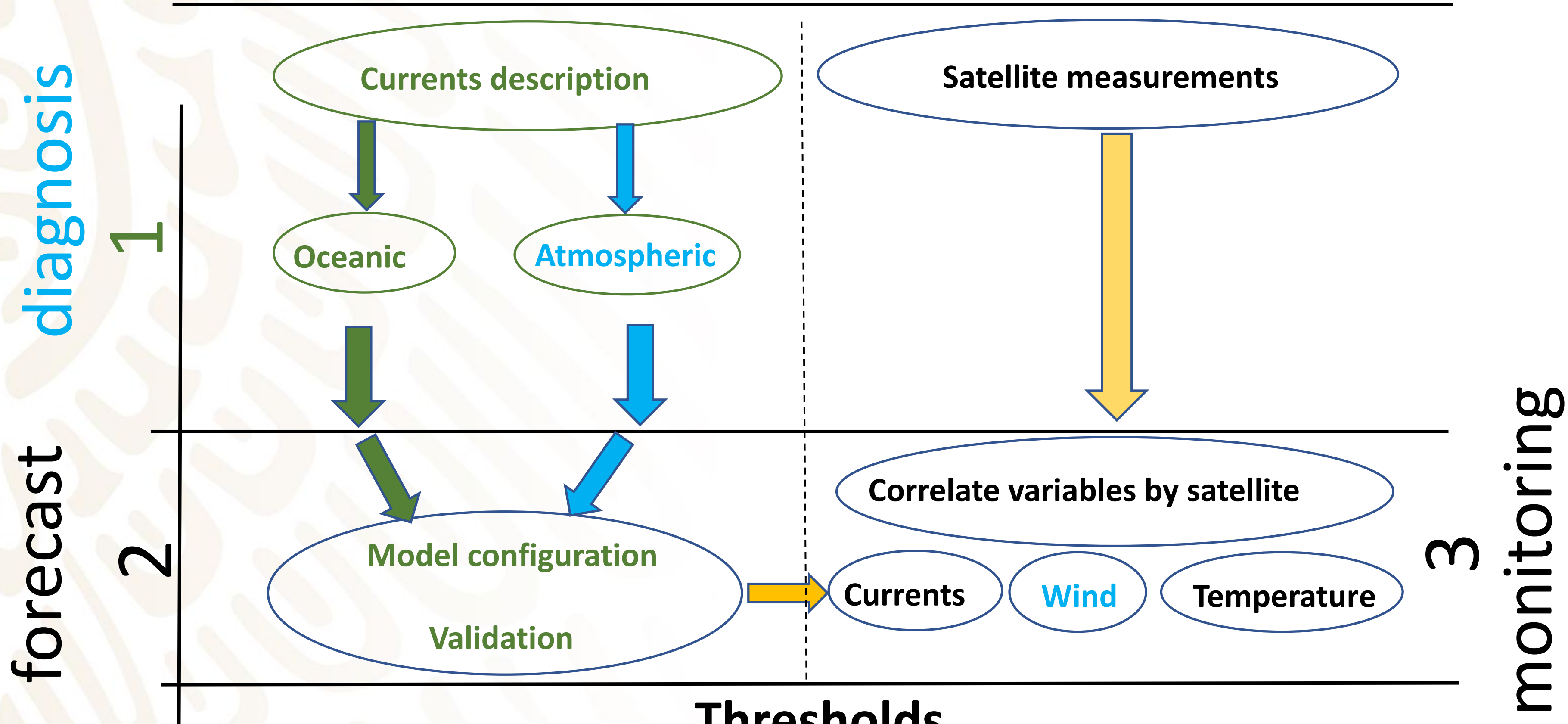
Sargassum transport pathways

$$\nabla \cdot u = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$



Schematic of proposed Sargassum transport pathways using drifting buoy experiments. (Franks et al. 2016)

Towards a sargassum warning system



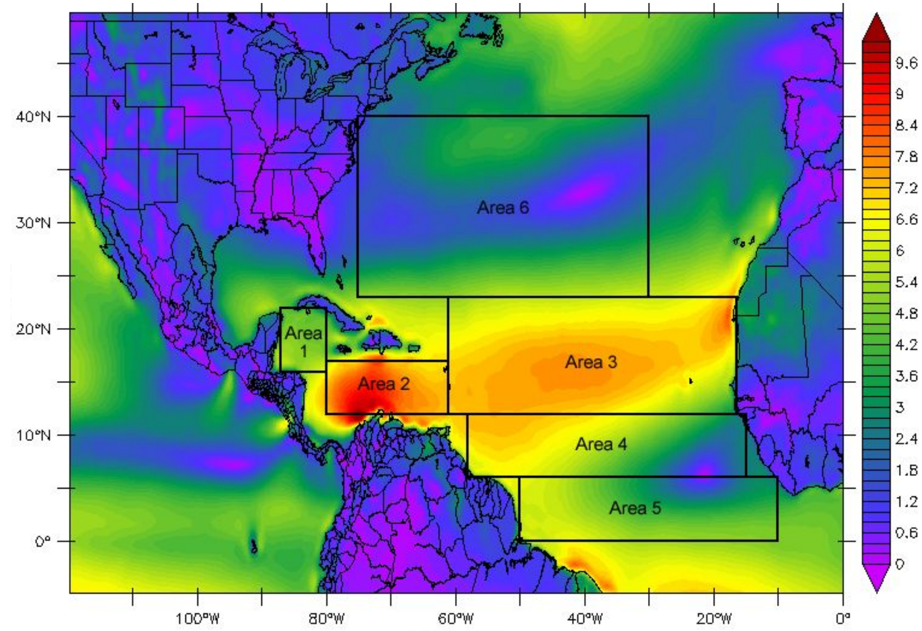
Goal

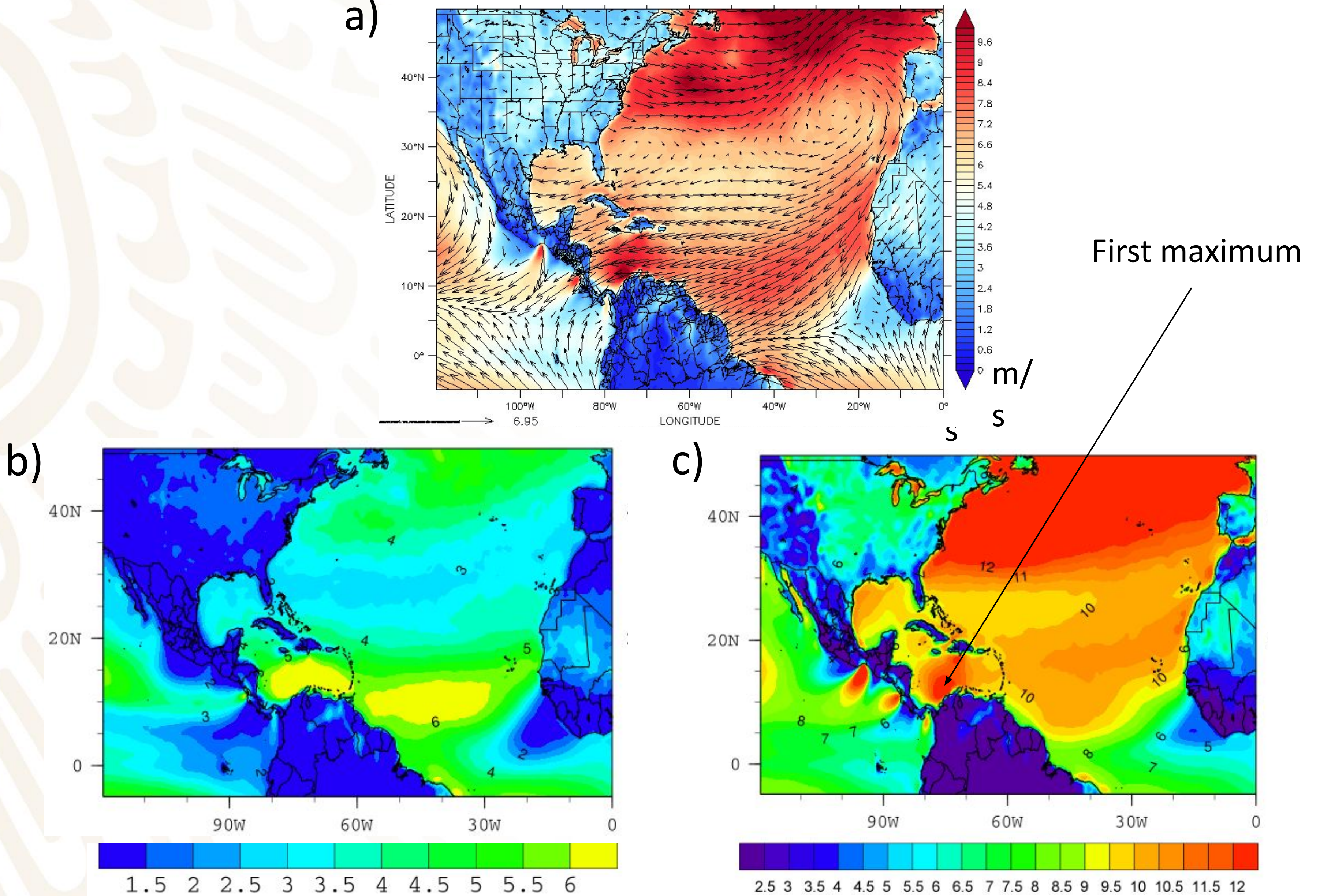
To contribute to an early warning system through a diagnosis of seasonal, annual, and interannual atmospheric circulation patterns in the Atlantic and Caribbean Sea.

Data and methodology

- 30 years (1989 to 2018) of wind data at 10m from NCAR's Climate Forecast System Reanalysis (CFRS). Temporal resolution of 6 hrs. Spatial resolution of 0.31° (40 Kms. aprox.)

- For each zone, its seasonal, annual, and interannual variability, as well as its extreme values, were estimated.





Wind at 10 m, **winter** 1989-2018. a) Wind direction and magnitude. b) 10th percentile of speed wind. c) 90th percentile of speed wind.

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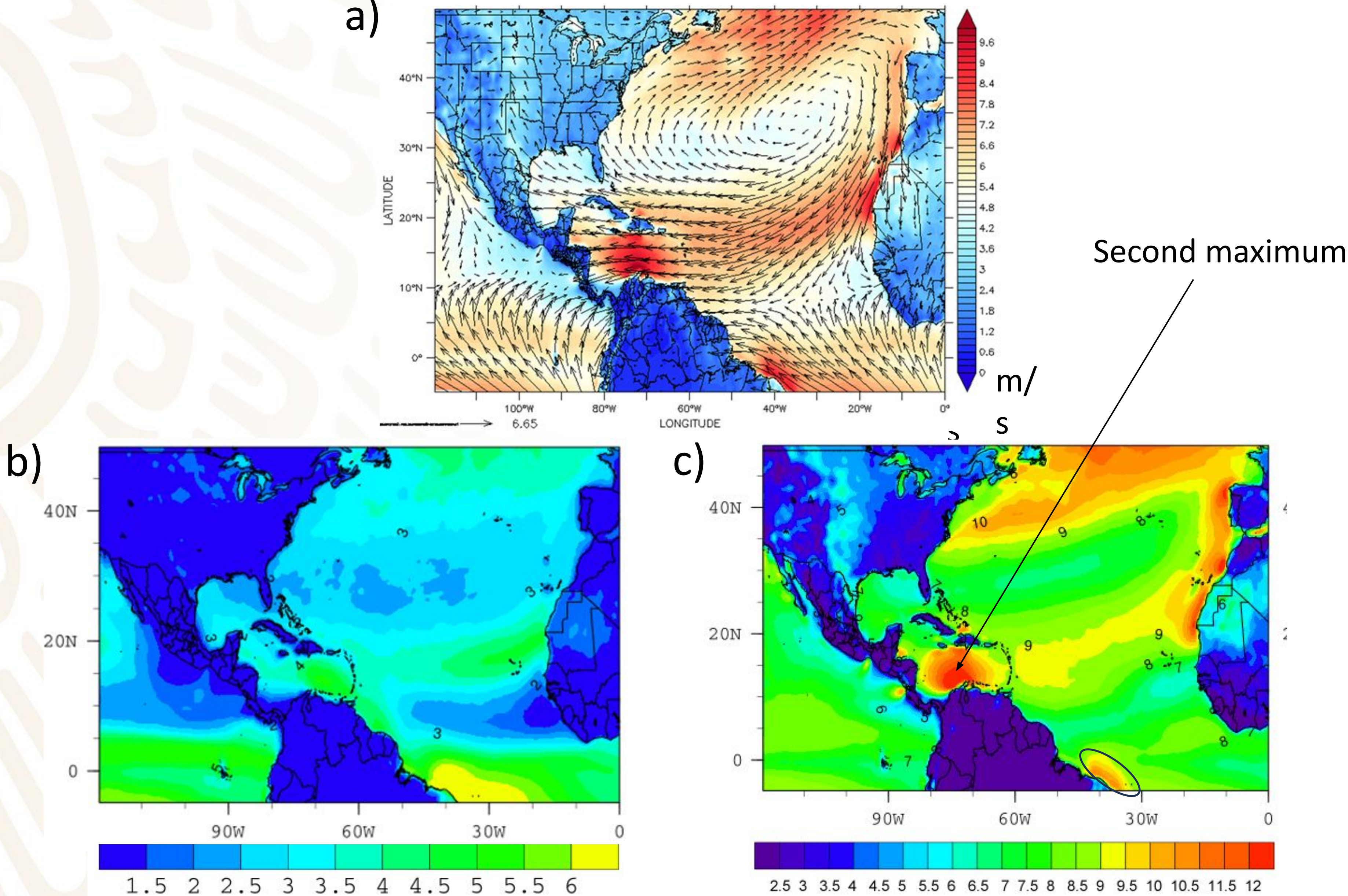

Wind at 10 m, **summer** 1989-2018. a) Wind direction and magnitude.
b) 10th percentile of speed wind. c) 90th percentile of speed wind.

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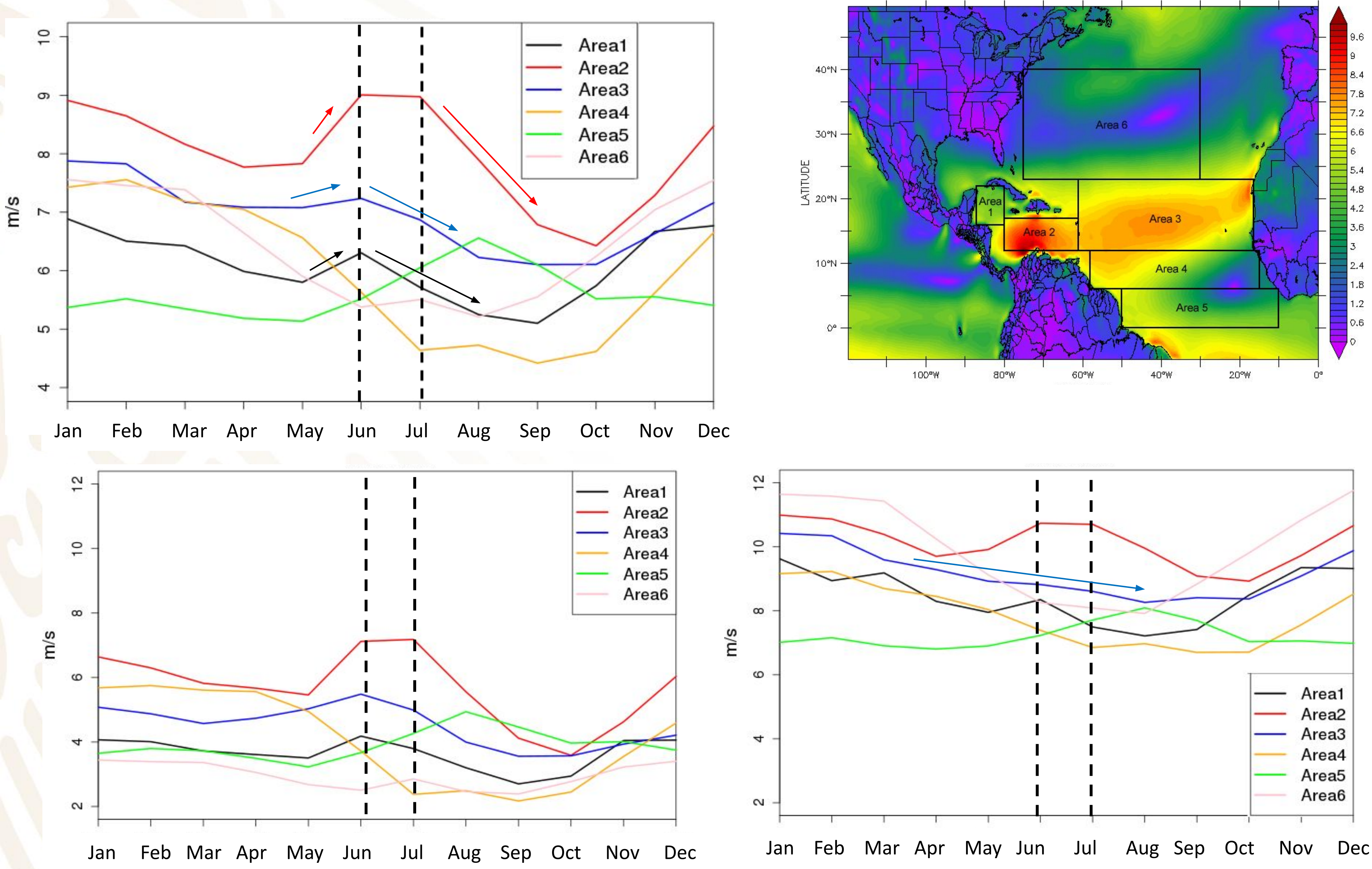
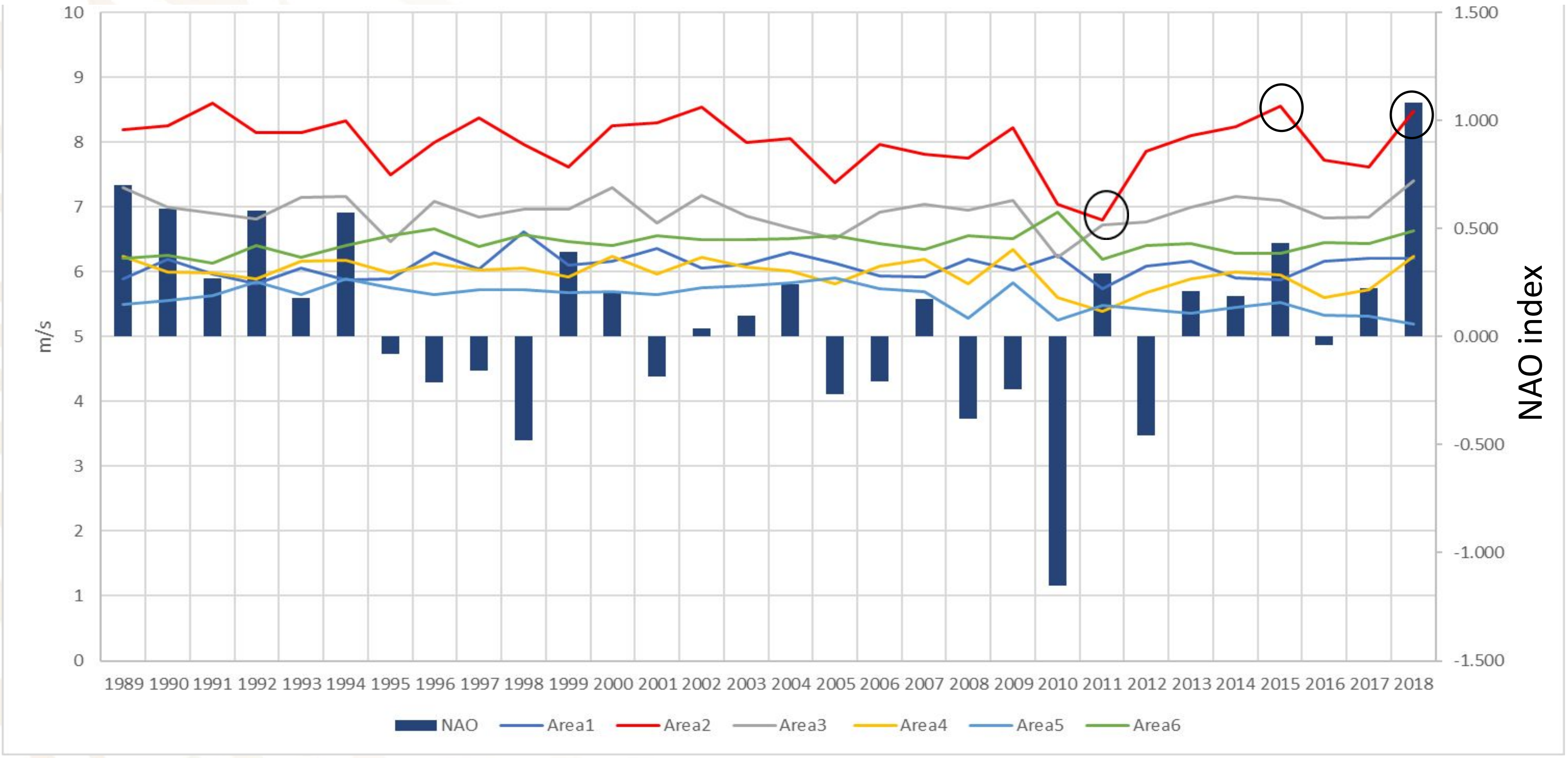
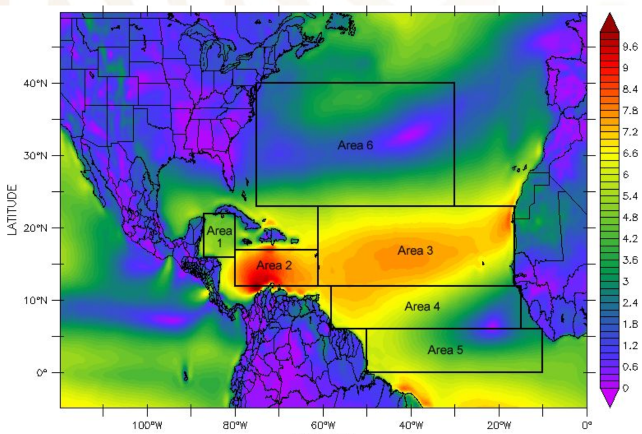


a) Annual cycle of wind speed at 10 m. 1989-2018.
b) 10th percentile. c) 90th percentile.





NAO index and annual wind speed

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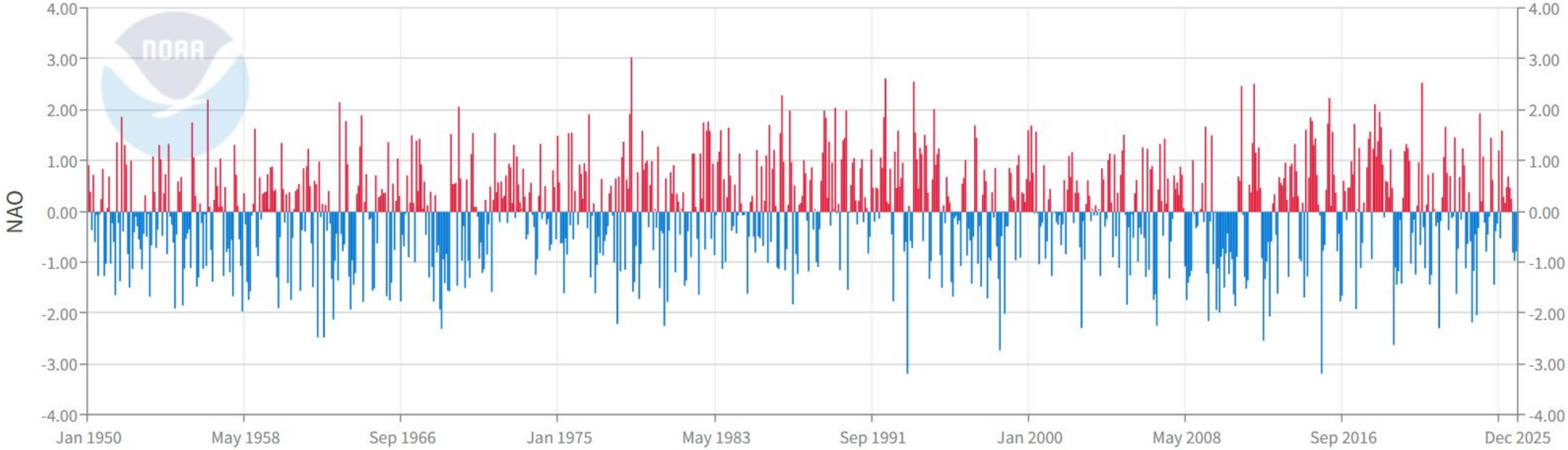
North Atlantic Oscillation (NAO)

January 1950-December 2025



Source: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/norm.nao.monthly.b5001.current.ascii.table

Powered by ZingChart

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	1.79	1.32	1.45	0.73	0.15	-0.07	-3.18	-0.76	-0.65	0.44	1.74	2.24
2016	0.12	1.58	0.73	0.38	-0.77	-0.43	-1.76	-1.65	0.61	0.41	-0.16	0.48
2017	0.48	1.00	0.74	1.73	-1.91	0.05	1.26	-1.10	-0.61	0.19	-0.00	0.88
2018	1.44	1.58	-0.93	1.24	2.12	1.09	1.39	1.97	1.67	0.93	-0.11	0.61

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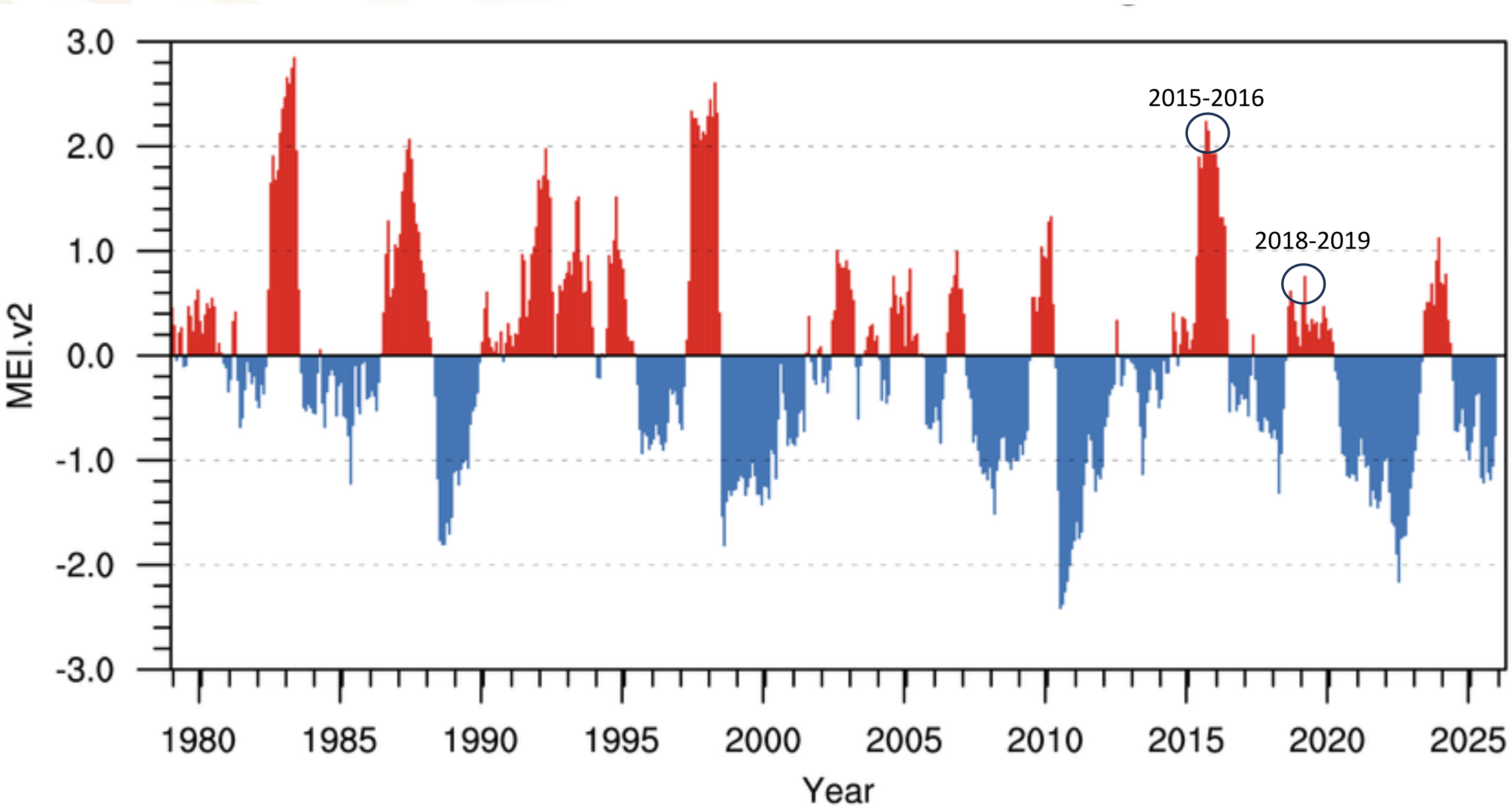
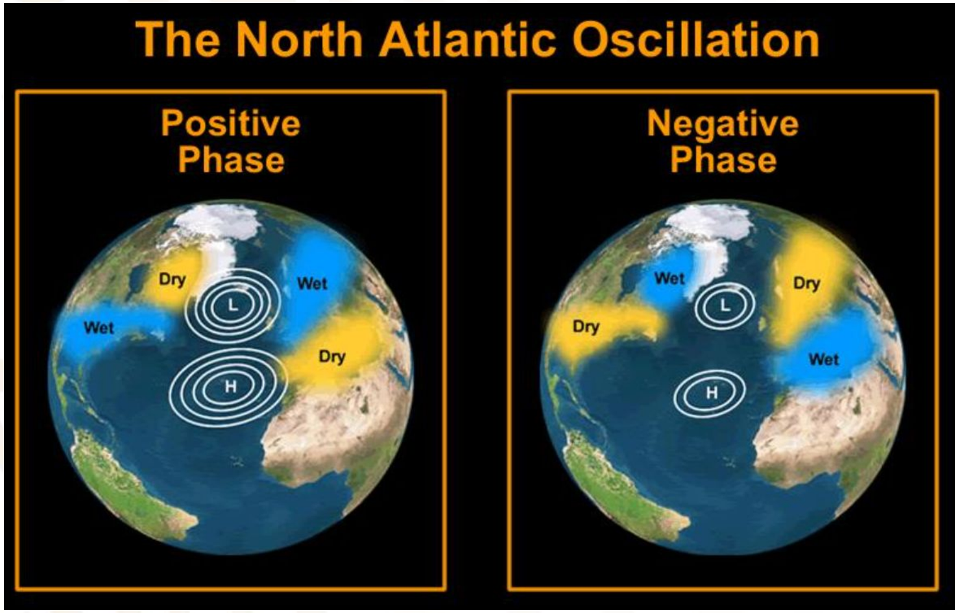
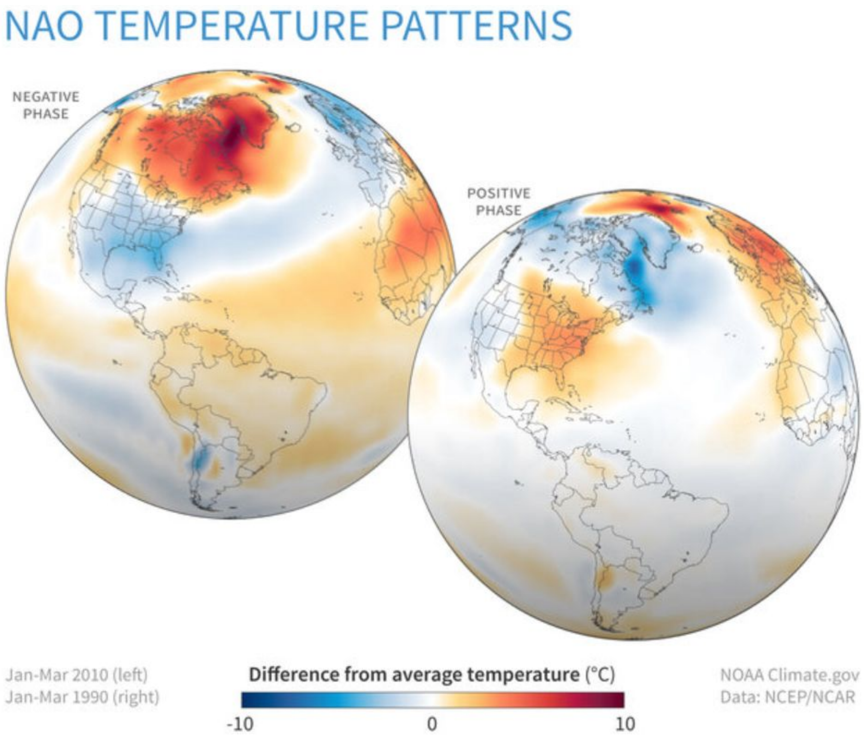


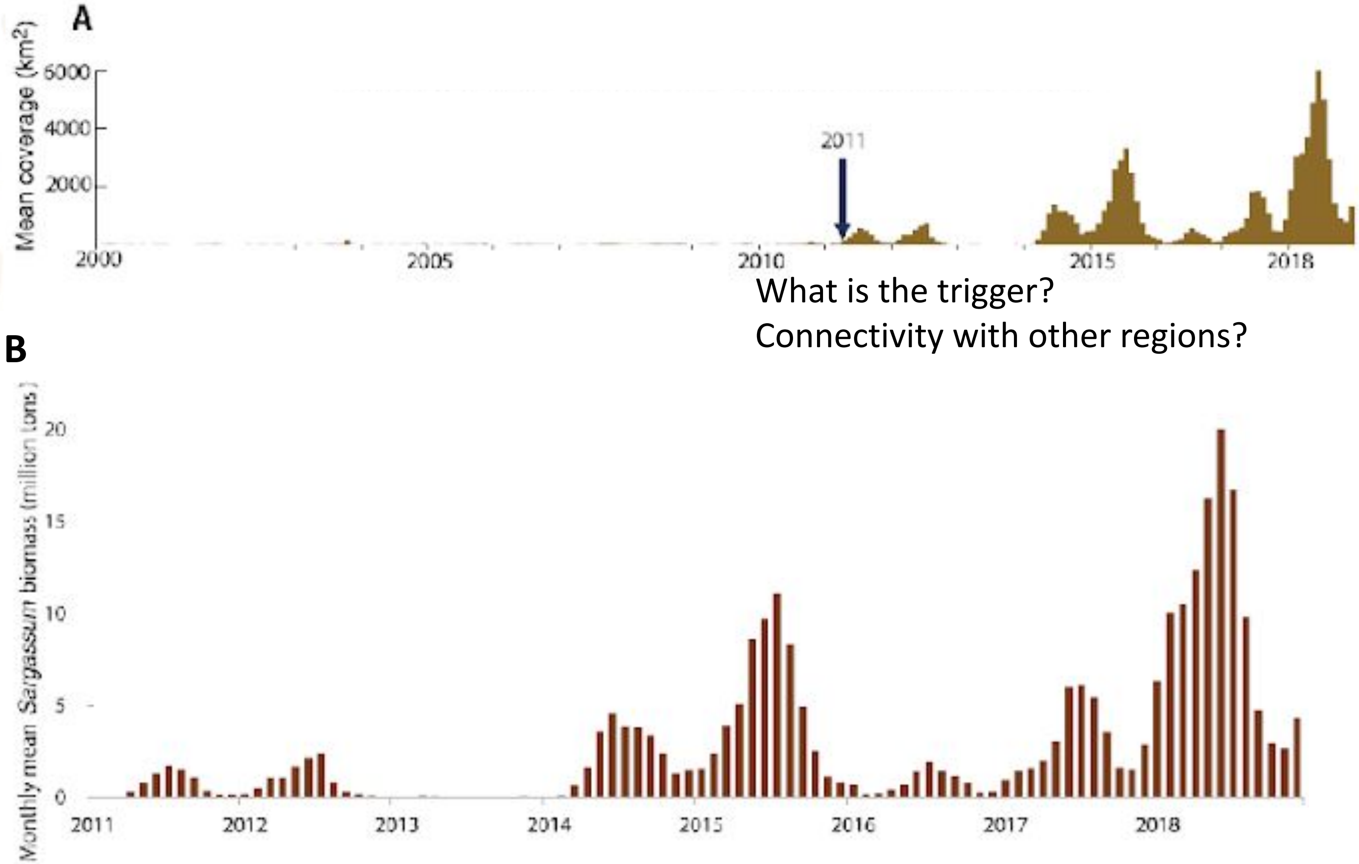
Multivariate ENSO Index using Japanese Reanalysis for Three Quarters of a Century (JRA-3Q)

https://psl.noaa.gov/enso/mei/


The North Atlantic Oscillation
Positive Phase
Negative Phase
Dry
Wet
L
H
Wet
Dry
Wet
Dry
Dry
Wet
L
H


NAO TEMPERATURE PATTERNS
NEGATIVE PHASE
POSITIVE PHASE
Jan-Mar 2010 (left)
Jan-Mar 1990 (right)
Difference from average temperature (°C)
-10
0
10
NOAA Climate.gov
Data: NCEP/NCAR

Case studies



What is the trigger?
Connectivity with other regions?

(A) Monthly mean Sargassum areal coverage in the Caribbean Sea and the central Atlantic Ocean. (B) Monthly mean Sargassum density (% cover) in January, April, July, and October. (Wang et al., Science 365, 83–87, 2019).

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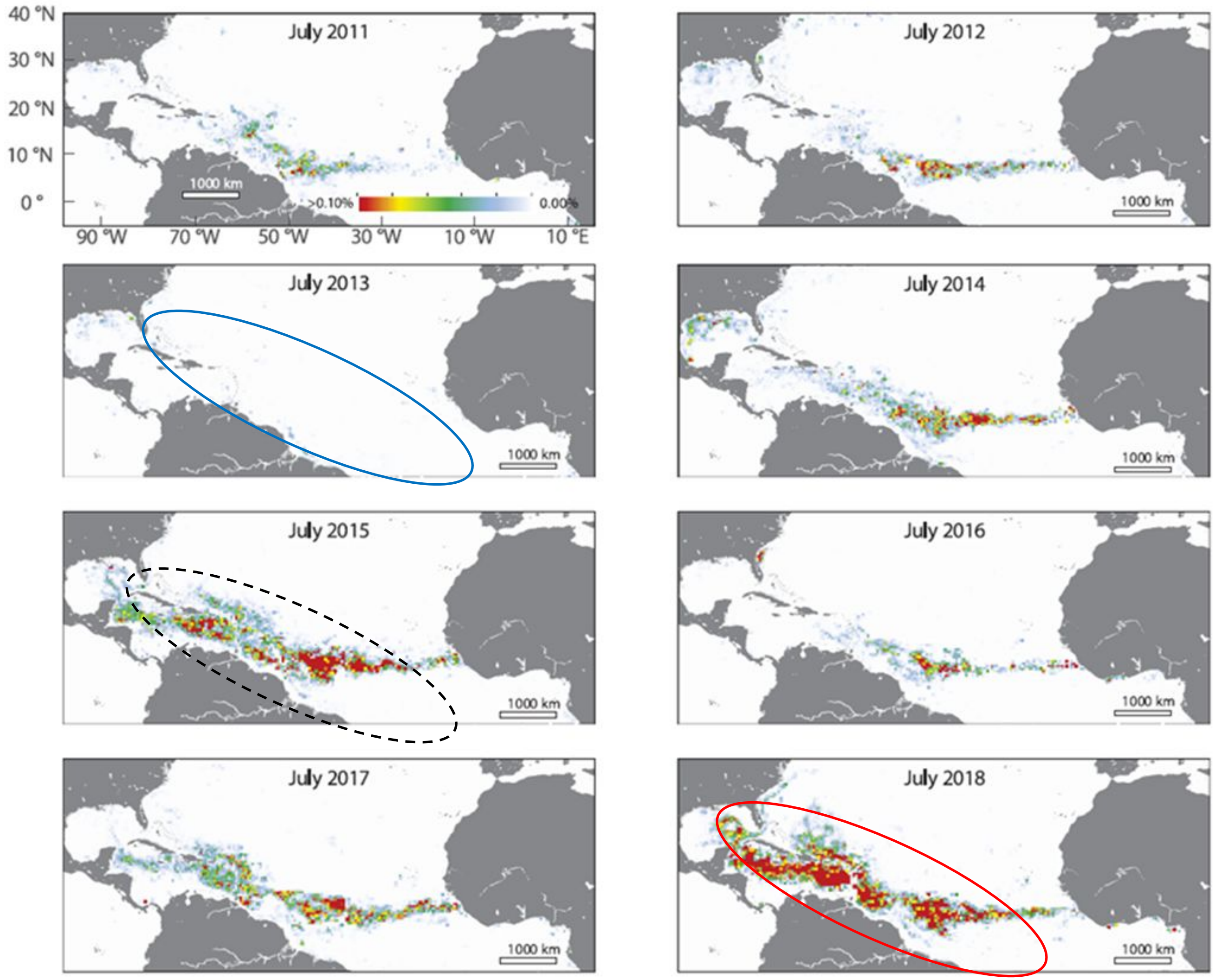

Monthly mean Sargassum density. (% of area covered). (Wang et al., Science 365, 83–87, 2019).

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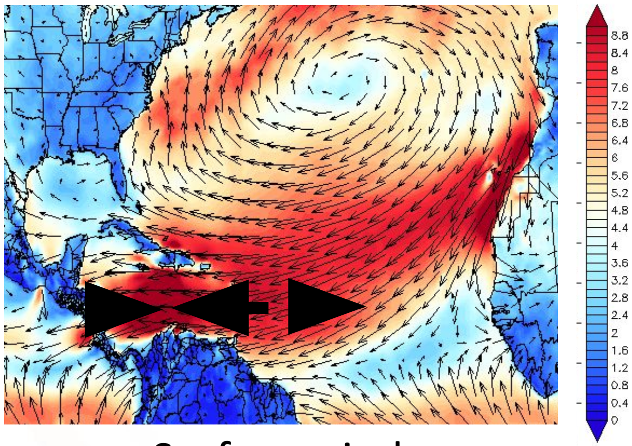
Physical processes of sargassum accumulation

$$\nabla \cdot u = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

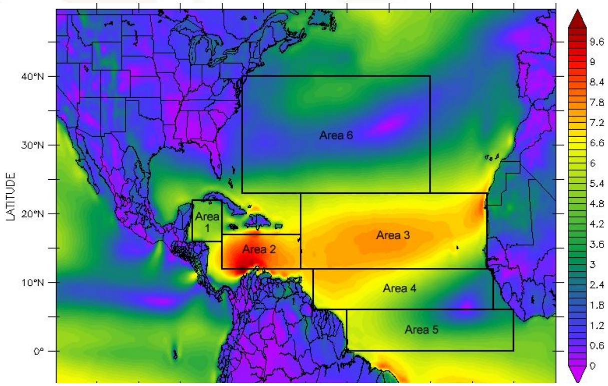

Surface wind

convergence

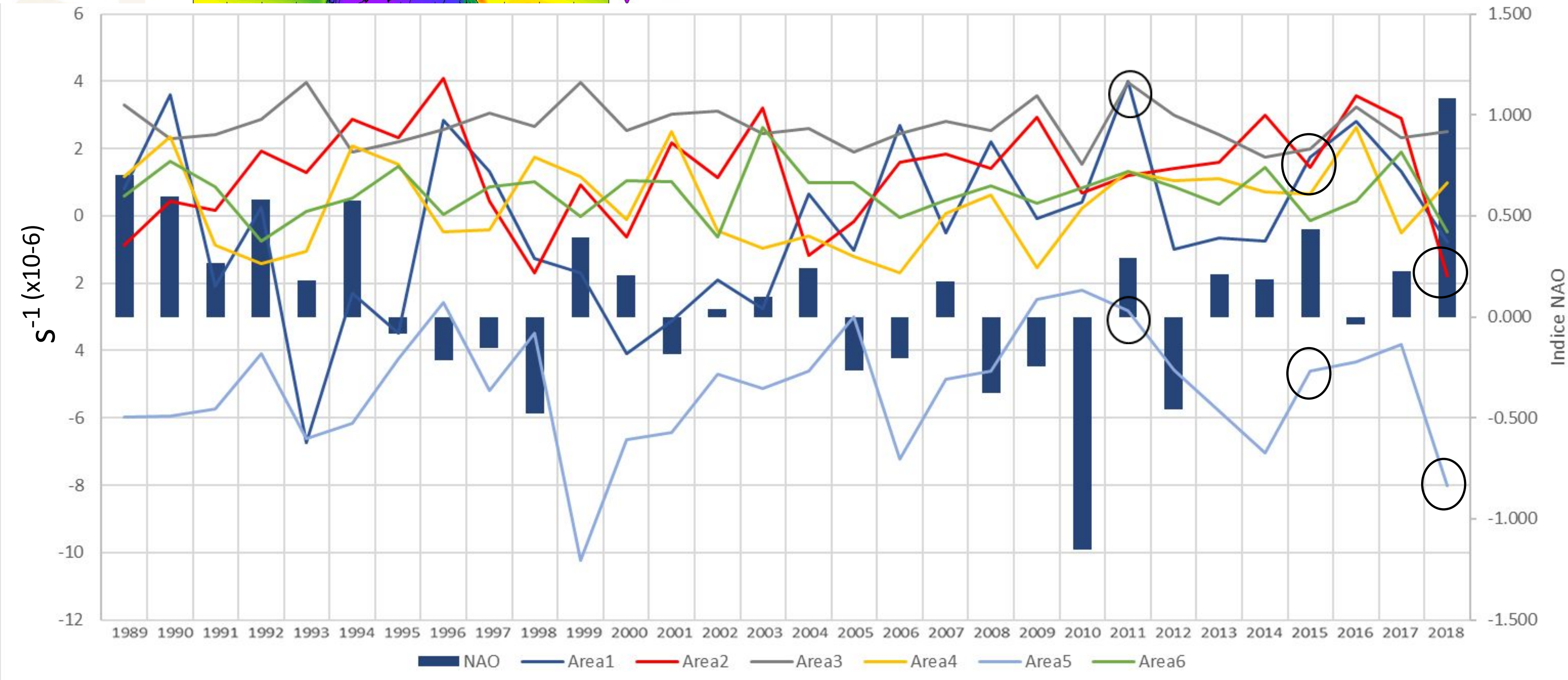
divergence

deceleration convergence

acceleration divergence



$$\nabla \cdot u = \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}$$

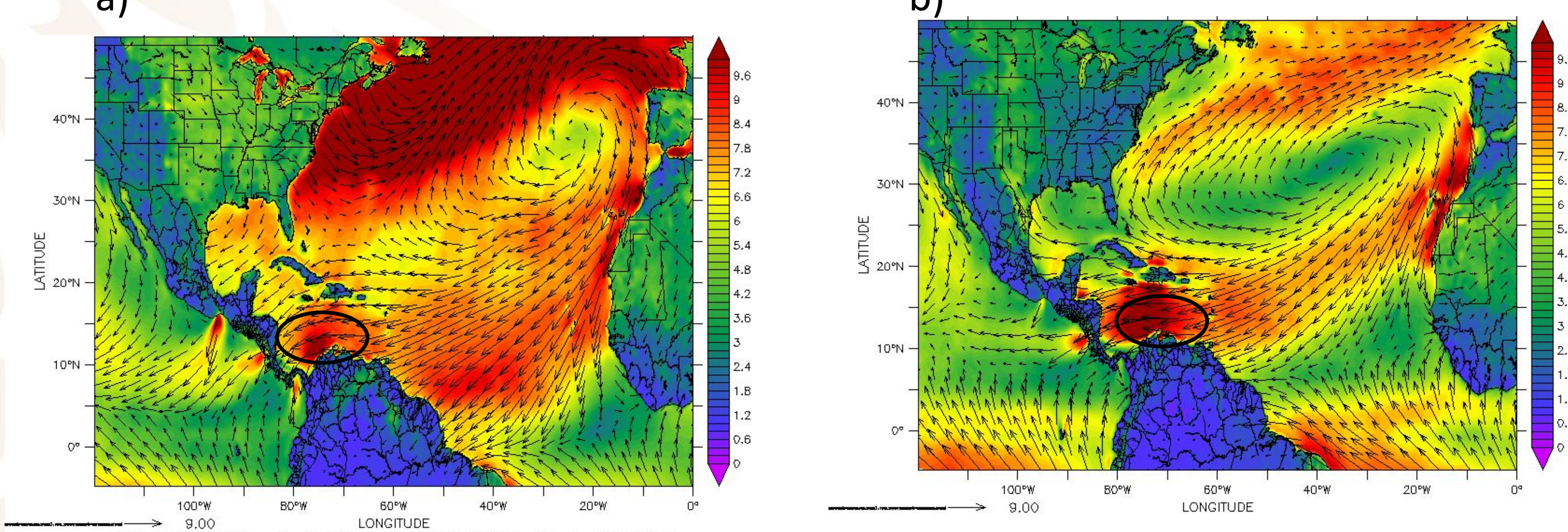


NAO index and annual wind divergence (s^{-1})

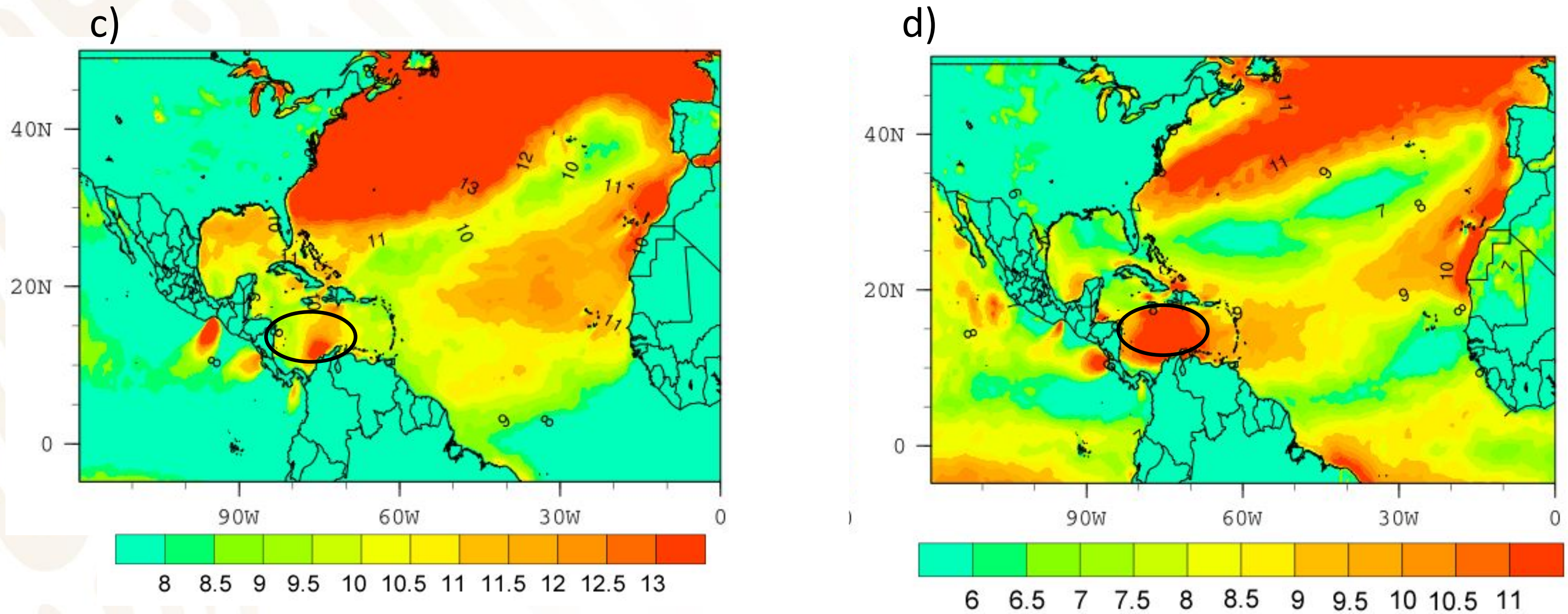
Highlighted cases

a) July 2015
b) July 2018

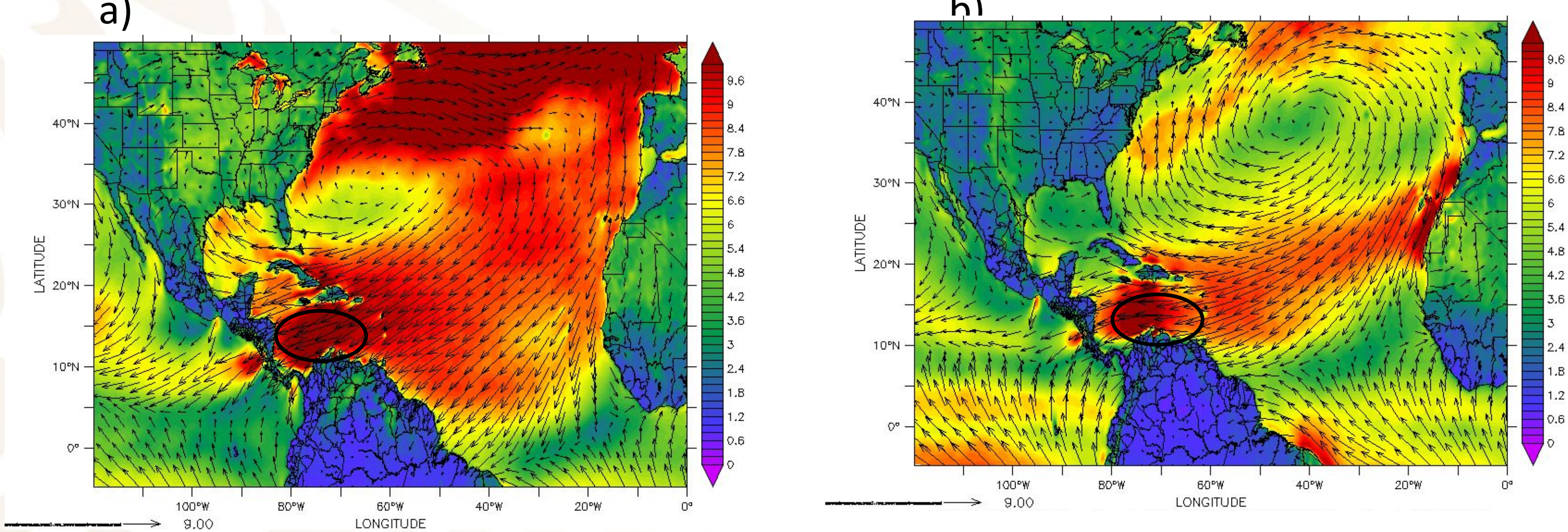
c) February 2015
d) February 2018



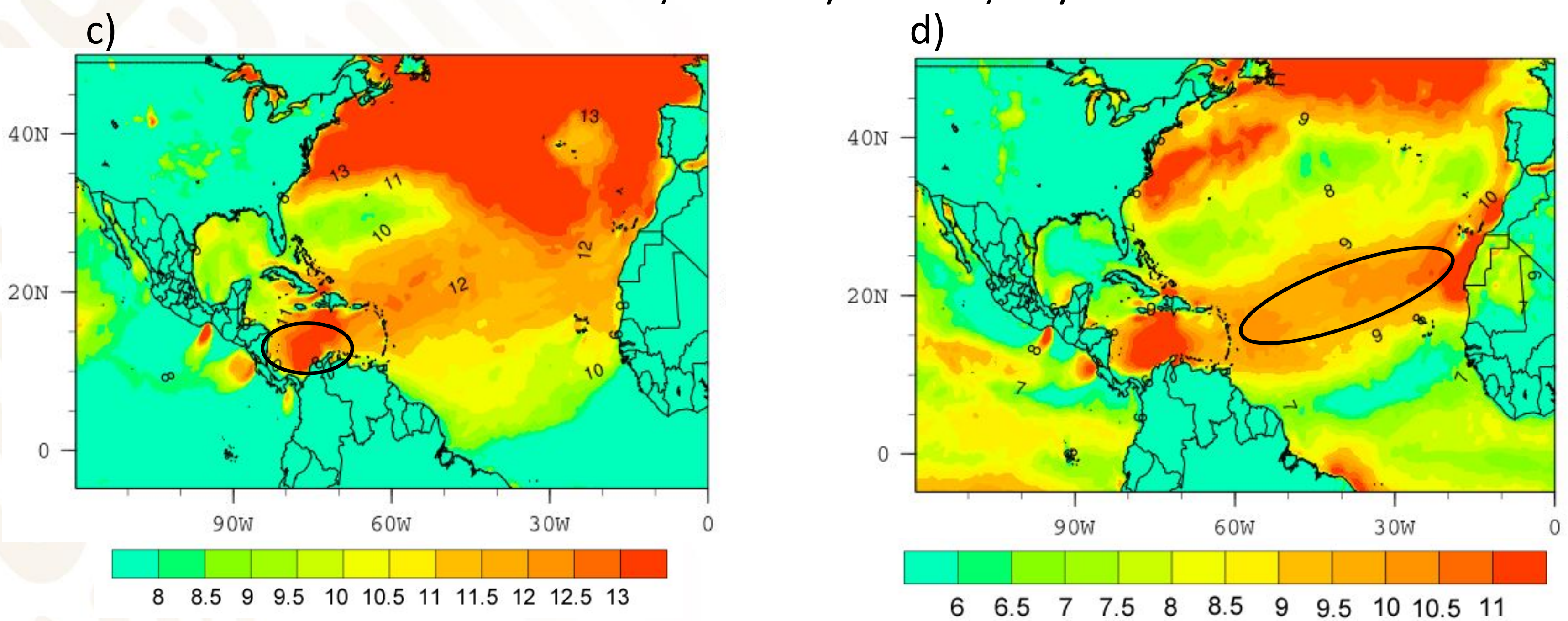
Wind at 10m. a) February **2015**. b) July **2015**



90th percentile of wind at 10m. c) February **2015**. c) July **2015**



Wind at 10m. a) February **2018**. b) July **2018**



90th percentile of wind at 10m. c) February **2018**. c) July **2018**

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Discussions

1. Atmospheric conditions for transporting sargassum to the coasts of Quintana Roo are **more favorable in summer** than in winter.

2. The highest extremes (90th percentile) in the Caribbean modulates sargassum transport in both winter and summer; however, **connectivity** with other regions makes summer more favorable.

3. The case studies were identified in the recent years 2015 and 2018, specifically in February and July. In 2018, the 90th percentile was higher than in 2015, but the average for the Caribbean was not.

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Towards a wind warning system

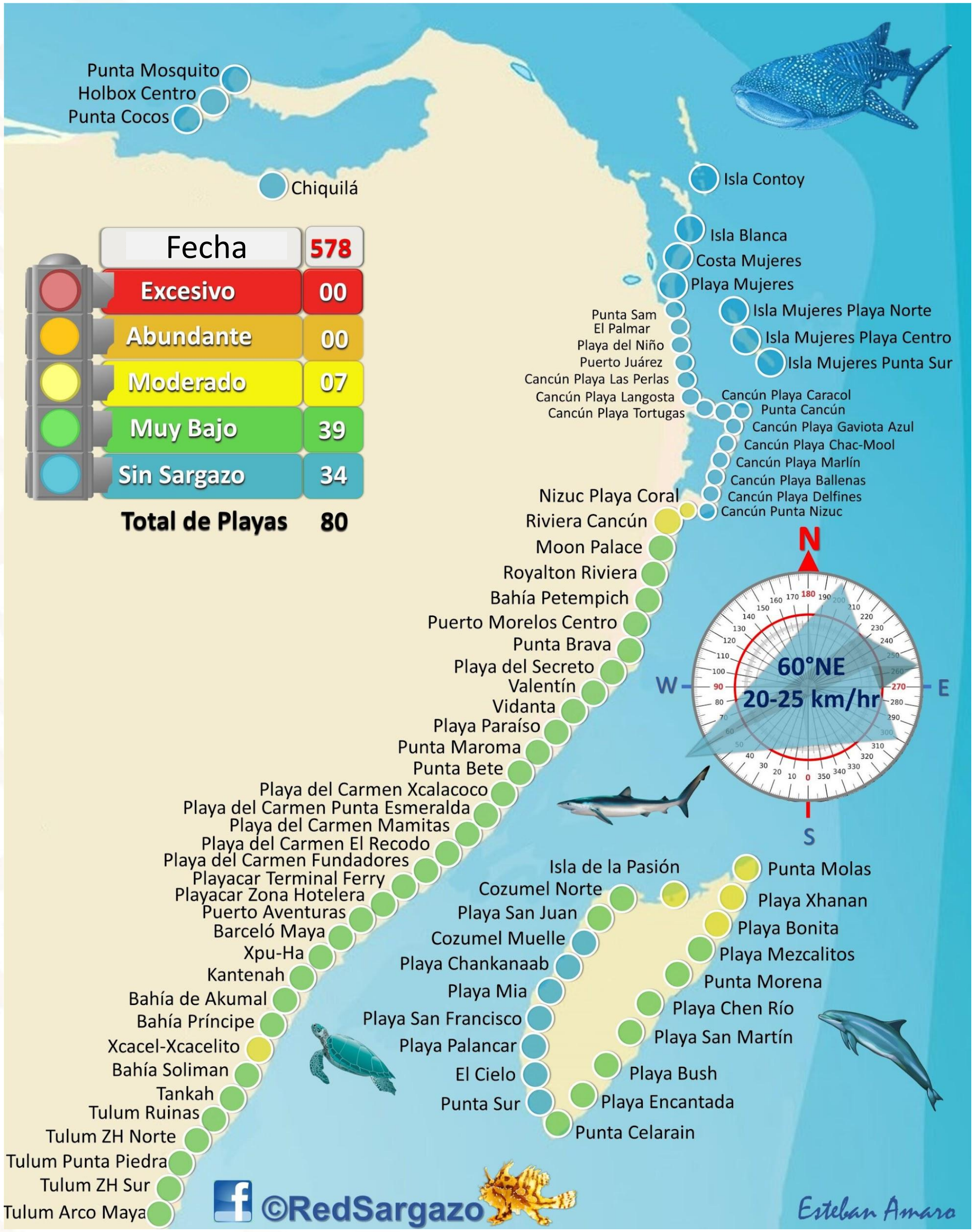
Alert levels that relate the degree of danger and colors that will be displayed on a map.

ALERT LEVEL AND COLOR. GENERAL RECOMMENDATIONS		
AZUL	MINIMAL DANGER. ALERT	Conditions actors and actions.
VERDE	LOW HAZARD. PREVENTION	Conditions actors and actions.
AMARILLO	MODERATE DANGER. PREPARATION	Conditions actors and actions. .
NARANJA	HIGH DANGER. ALARM	Conditions actors and actions.
ROJO	MAXIMUM DANGER. IMPACT	Conditions actors and actions.

Wind speed (m/s)	**SST**	**Ocean current speed (cm/s)**	**Distance to the point of interest (km)**	**Mass or volume of sargassum (tons or m^3)**	**8 to 3 days**	**48 to 42 hrs**	**42 to 36 hrs**	**36 to 30 hrs**	**30 to 24 hrs**	**24 to 18 hrs**	**18 to 12 hrs**	**6 to 0 hrs**

Alert matrix for the potential arrival of sargassum

The activation of the stages will depend on the conditions estimated in a diagnostic study of the environmental conditions under which the sargassum arrives (wind, currents, times, geographical area and mass).



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Future work

Second stage:

- Estimation of wind thresholds, ocean currents and surface temperature of the Caribbean Sea and their temporal and spatial evolution that trigger a dynamic early warning traffic light.

Third stage:

Validated numerical forecast of circulations (atmospheric and oceanic) and their correlation with sargassum trajectories.

Fourth stage:

Automated early warning system based on a dynamic traffic light system for easy consultation and interpretation.