Tropical Atlantic climate variability: insight from interannual sea surface chlorophyll-a

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LEGOS

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How do climate modes shape the chlorophyll-a interannual variability in the tropical Atlantic?

Submitted to GRL in April 2021

➡ **Focus on the equatorial Atlantic**

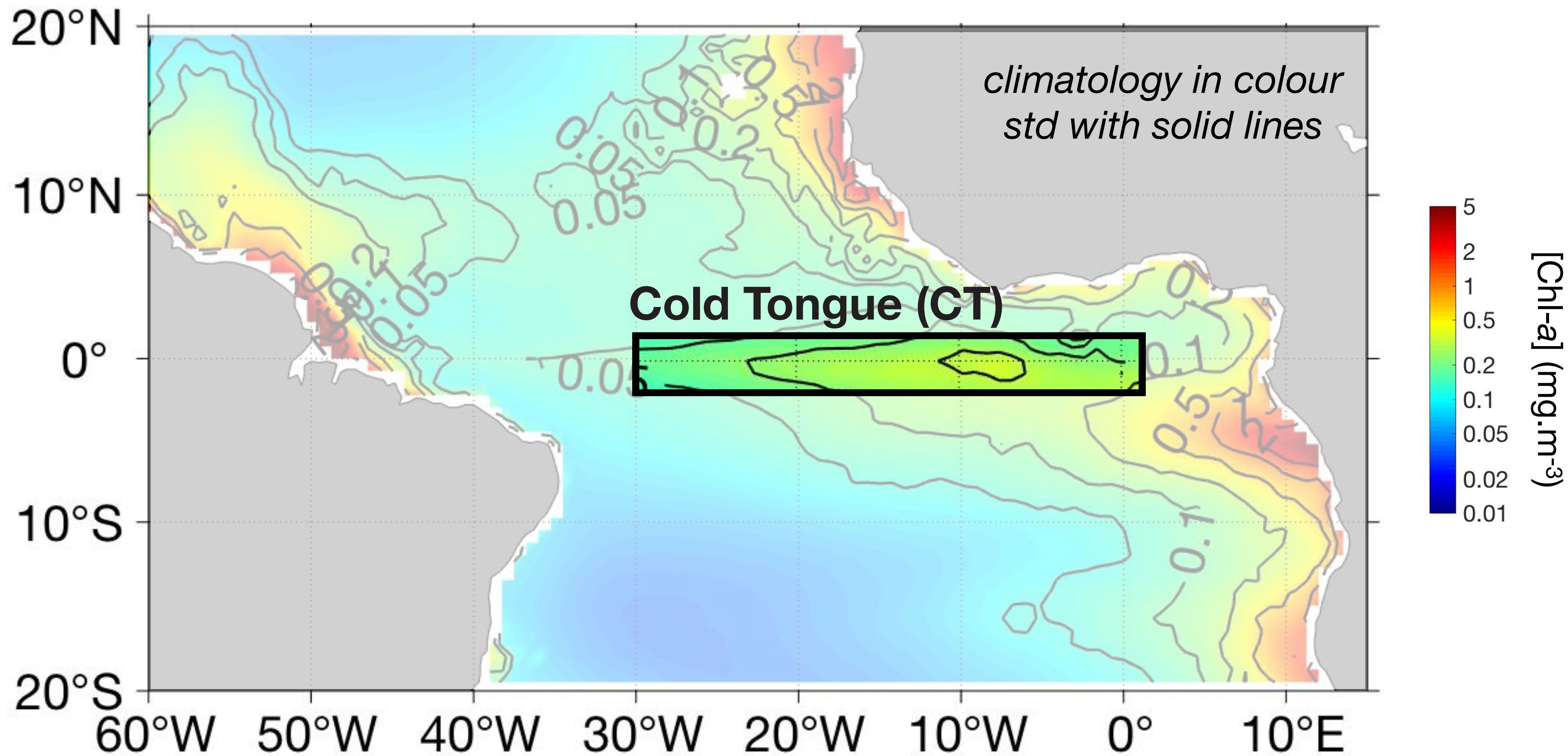
➡ **Observation approach:**

Sea Surface Chlorophyll-a (Chl-a): monthly ocean-color satellite data, from E.U. Copernicus Marine Service Information CMEMS - cloud-free Chl-a maps, L4 product.	**Sea Surface Height (SSH)**: monthly remote-sensed data from Aviso Ssalto/Duacs, provided by CMEMS.	**Sea Surface Temperature (SST)** and **surface winds**: monthly data from European Center for Medium-Range Weather Forecasts ERA-Interim reanalysis

Period: 1998-2018
Area: Atlantic, [20°S-20°N]
Preprocessing: linear trend removed, monthly interannual anomalies estimated relative to the climatology.

INTRODUCTION: What do we already know about chlorophyll-a variability?

Remote-sensed sea surface chlorophyll-a (1998-2018)



➡ Focus on the **equatorial band / Cold Tongue**: [3°S-3°N;30°W-3°E]

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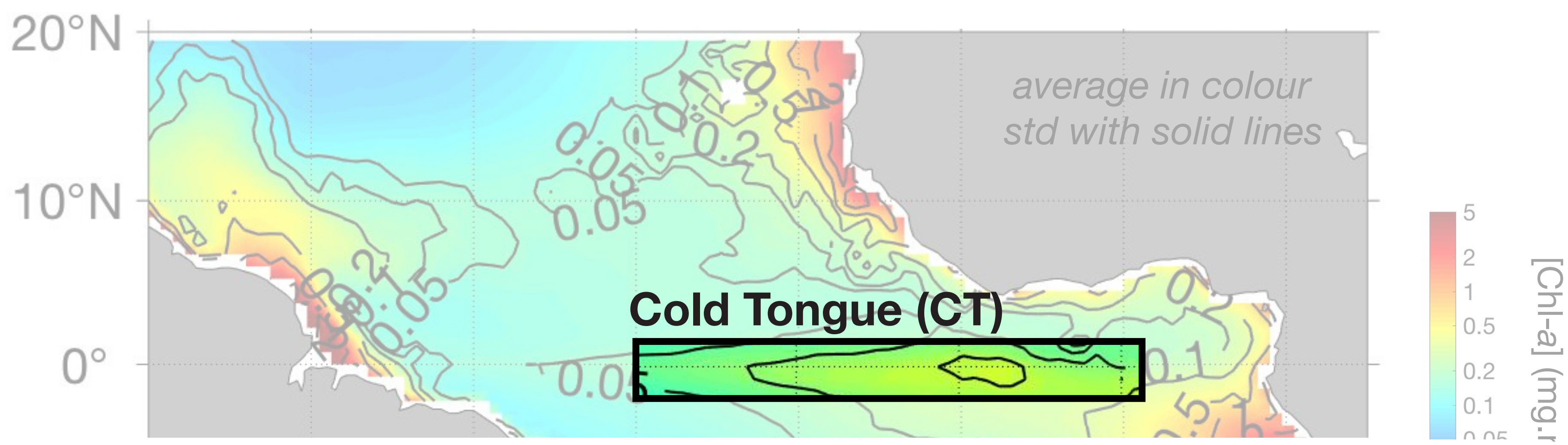

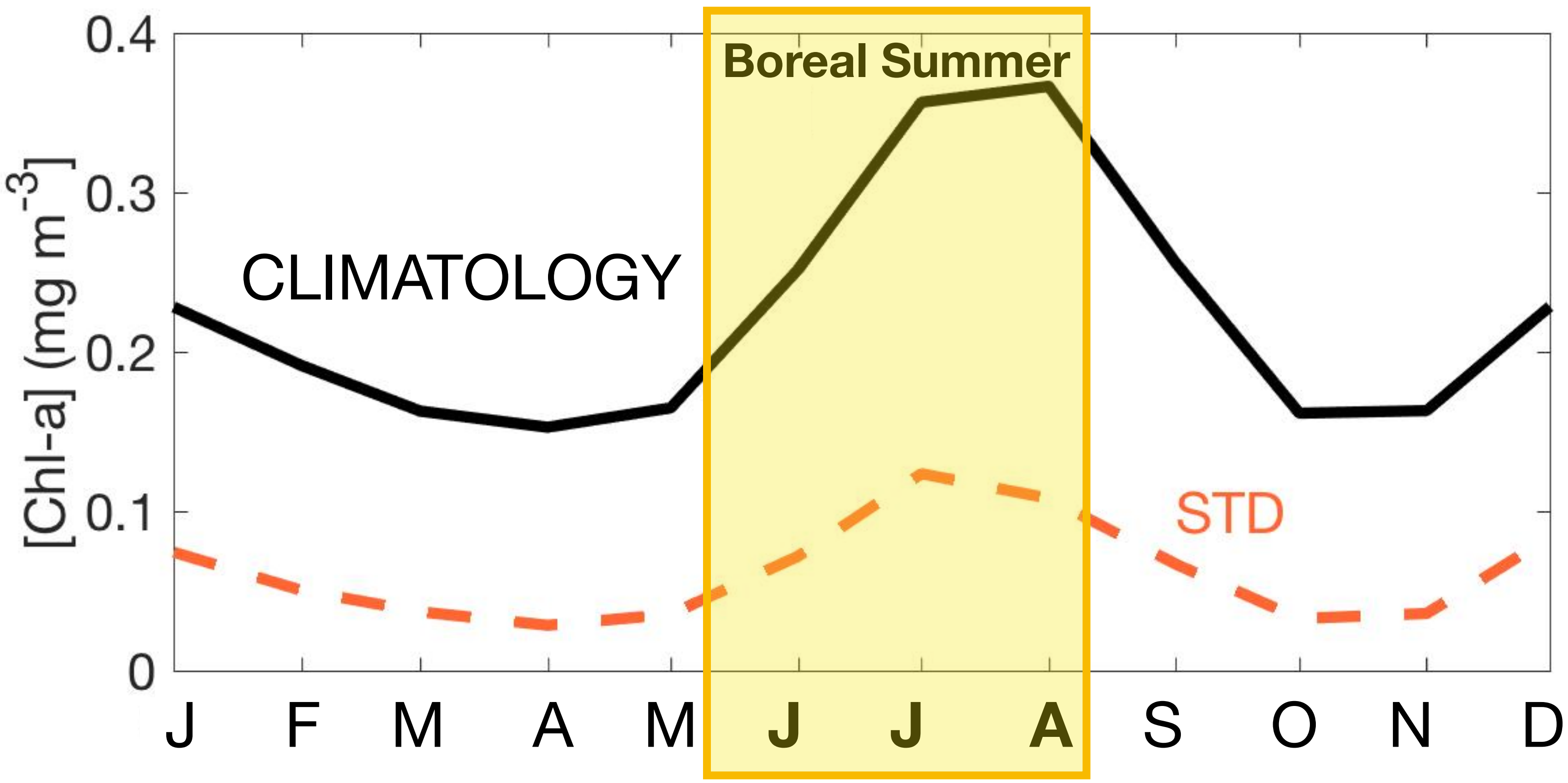

- ➡ Max Chl-a in the CT peaks at 10°W
- ➡ Max Chl-a in boreal summer (JJA)
- ➡ Max variability of Chl-a in summer (JJA)

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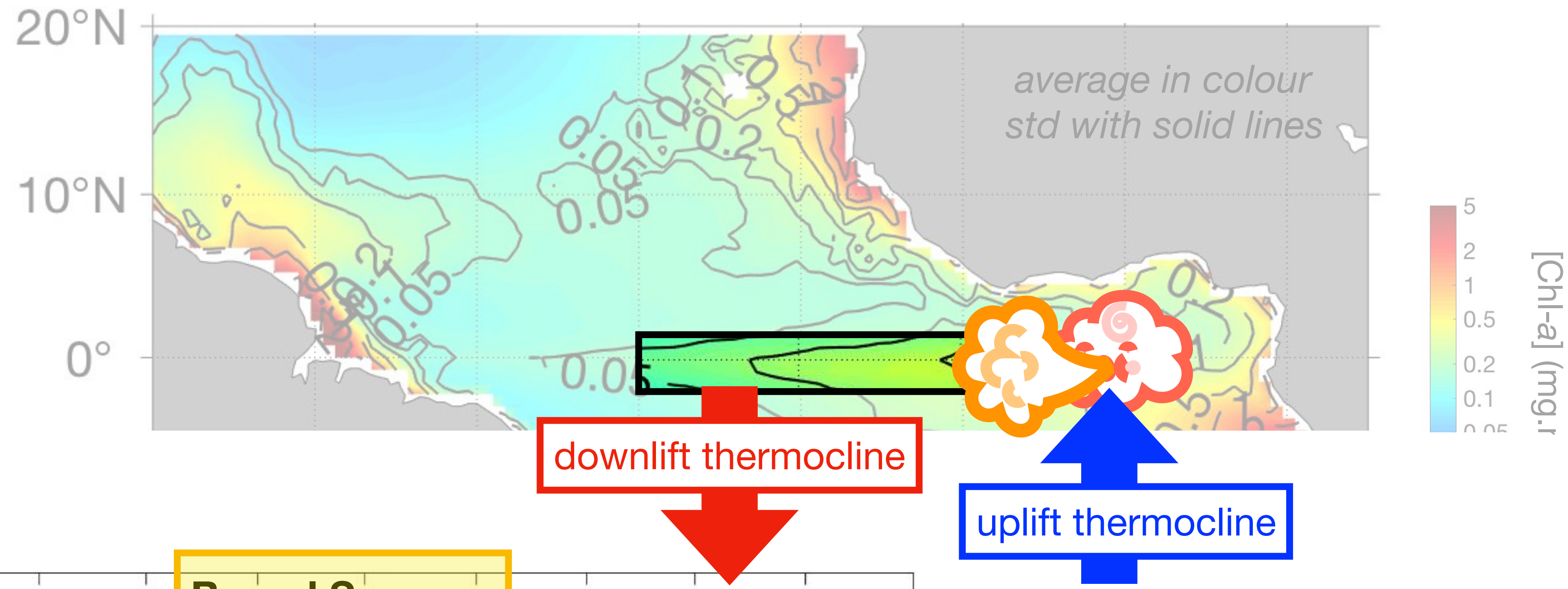

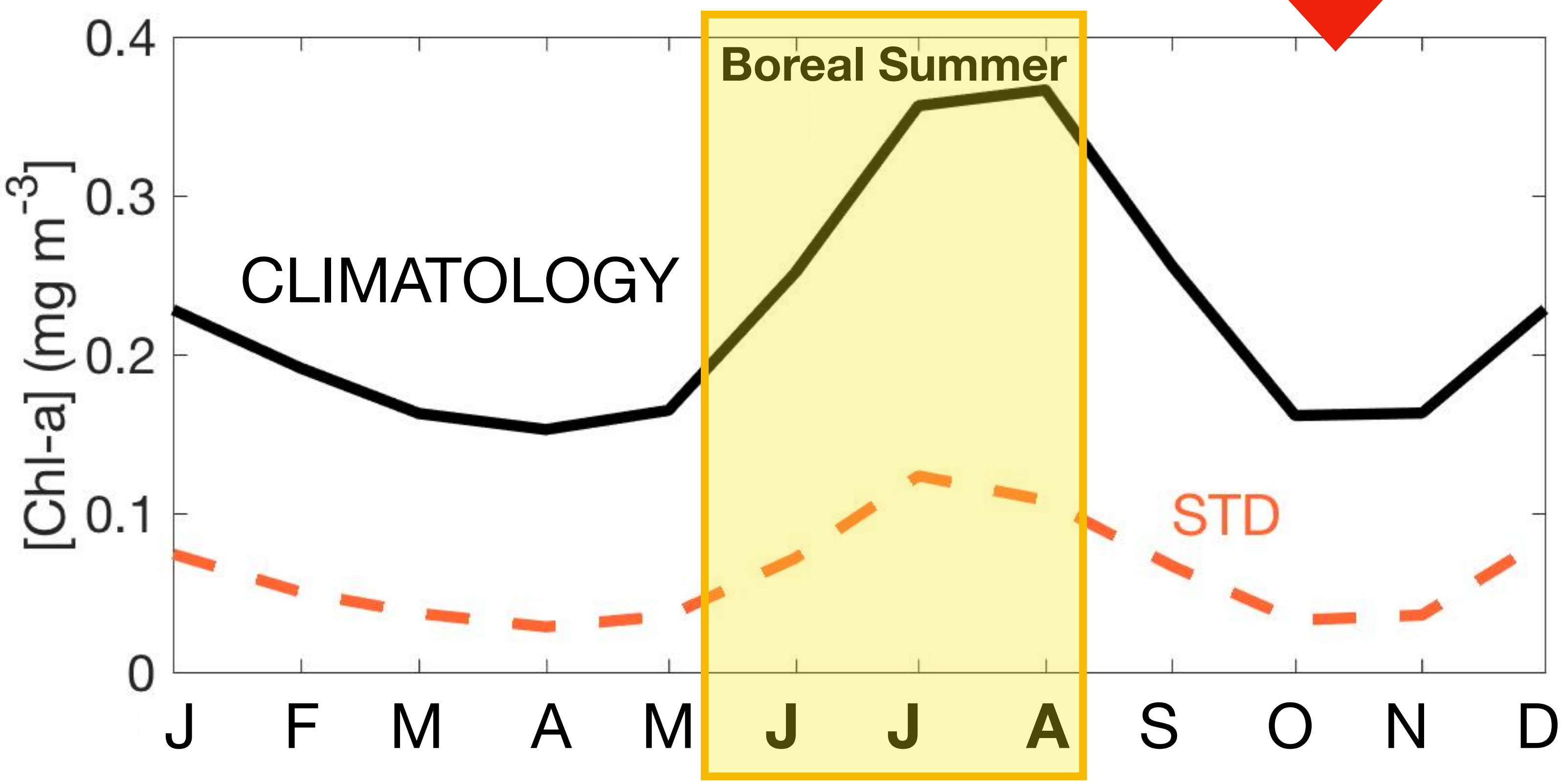

- ➡ Max Chl-a in the CT peaks at 10°W
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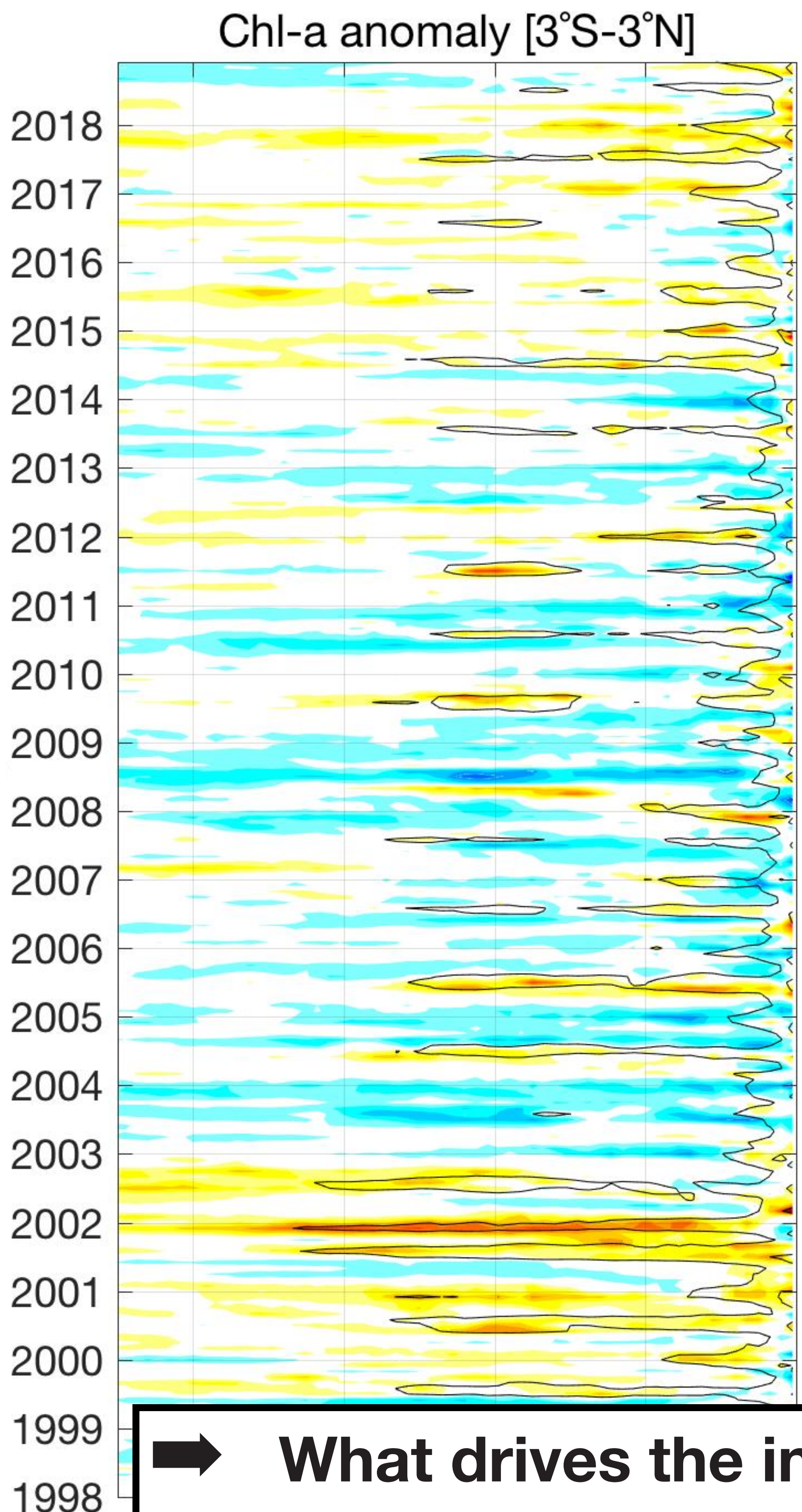
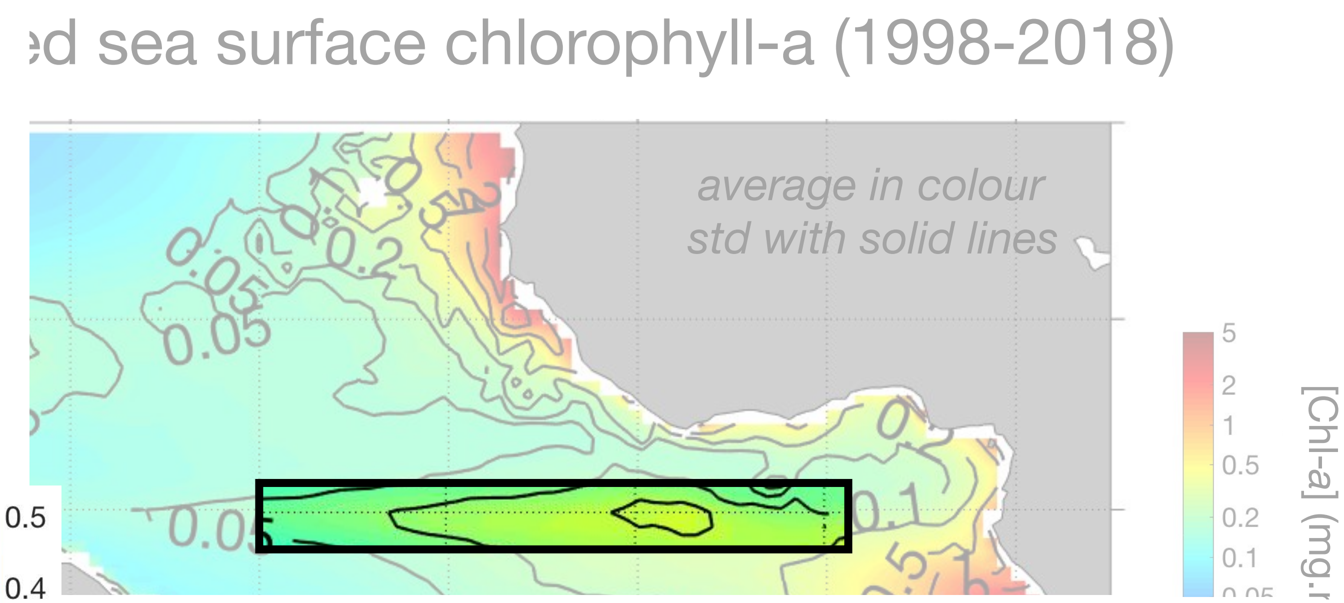
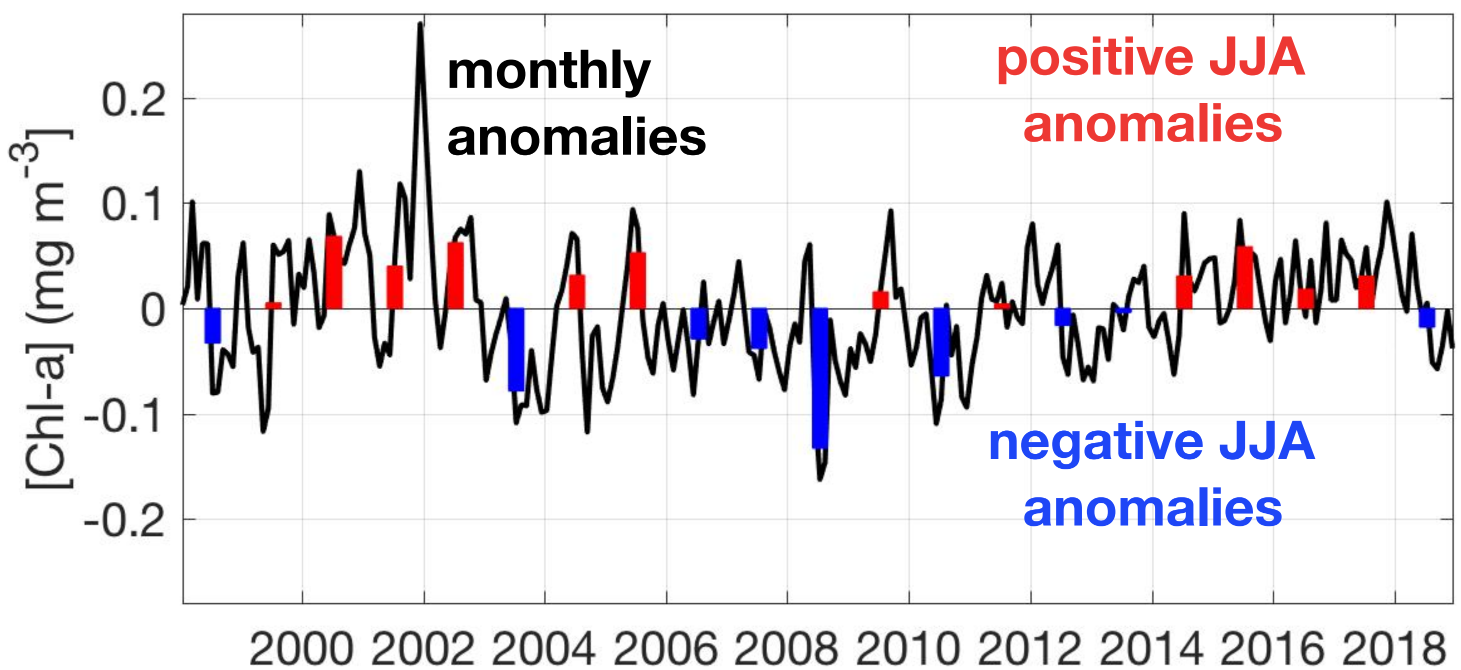
- ➡ Max variability of Chl-a in summer (JJA)

- **Intensification of easterlies** in JJA induces an **uplift** of the thermocline/ nutricline in the **east** and **deepening** it in the **west**.

(Signorini et al.,1999; Perez et al 2004; Grodsky et al., 2008; Radenac et al., 2020)







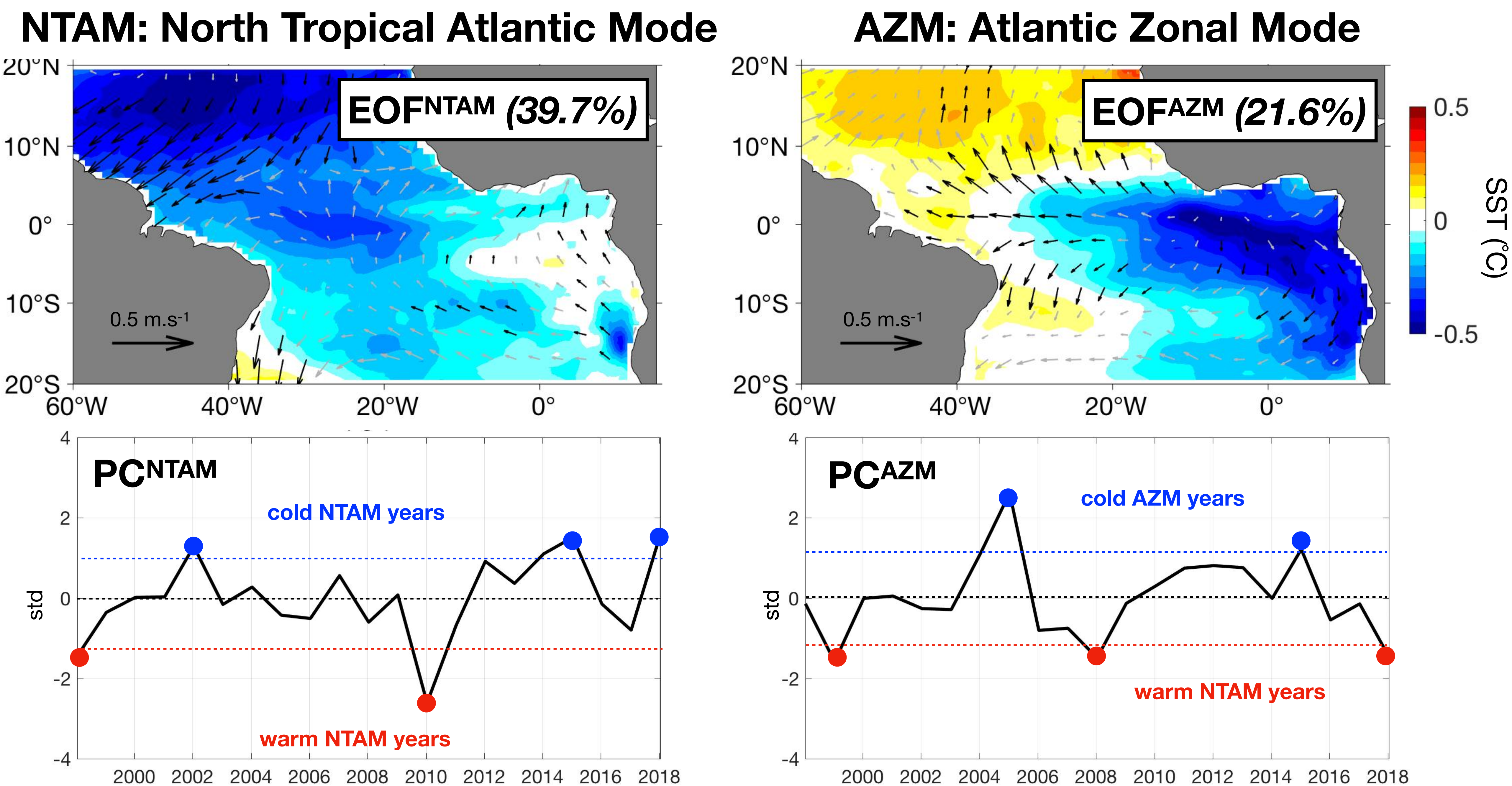
- ➡ Strong interannual variability: up to +/- 30% for JJA.
- ➡ Westward extension of the JJA bloom in some years.

➡ What drives the interannual variability of the sea surface Chl-a?

➡ Do climate modes explain such interannual variability?

 Let's introduce interannual modes of variability in the Equatorial Atlantic

Method: Empirical Orthogonal Functions (EOFs) on boreal summer (JJA) **SST** then boreal summer (JJA) **surface winds** regression on Principal Components (PCs)

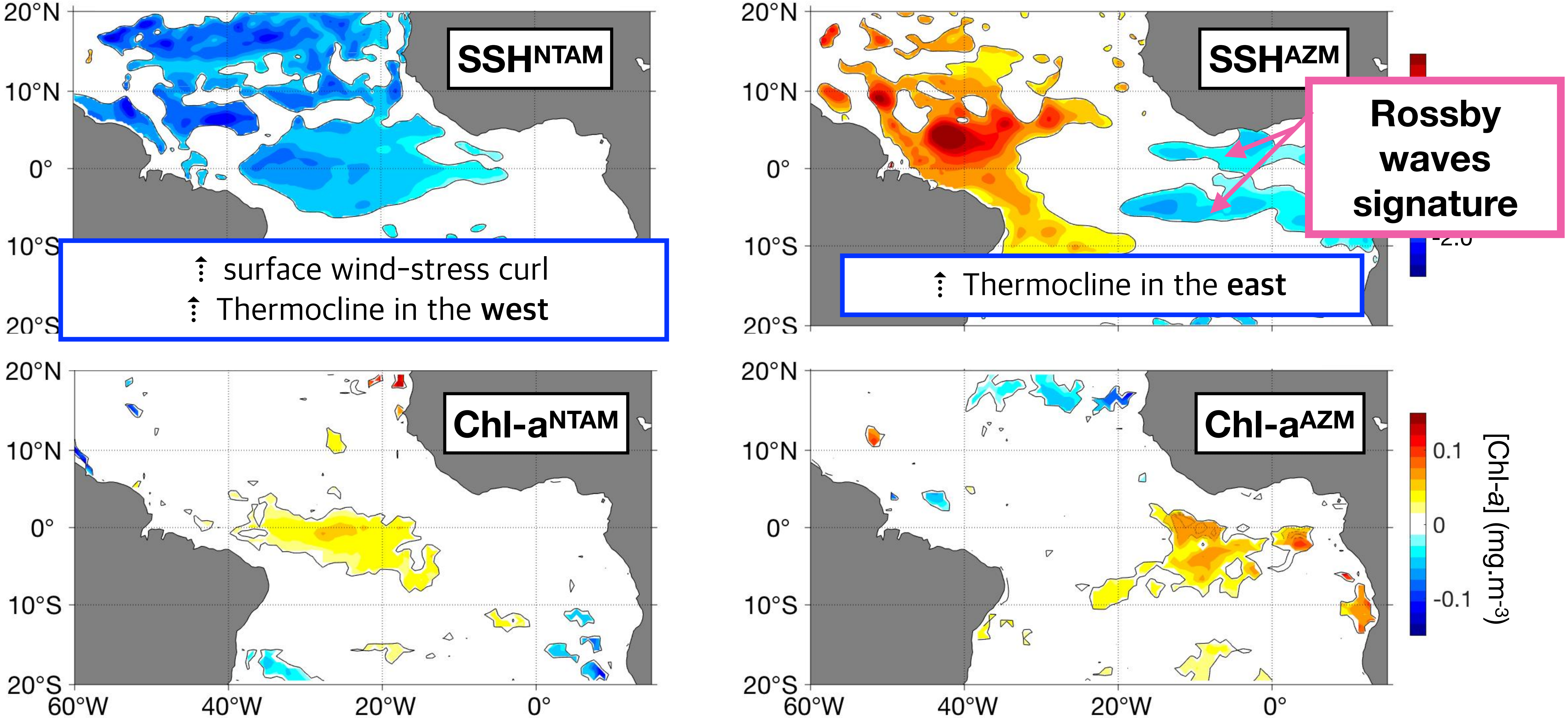


➡ These two modes are **typical of a AMO+** (1998-2018) *Martin-Rey et al. (2018)*.

RESULTS #2 What are the SSH and Chl-a signatures associated with the modes?

Method: Regression of boreal summer (JJA) SSH and surface Chl-a on PCs

NTAM: North Tropical Atlantic Mode   AZM: Atlantic Zonal Mode

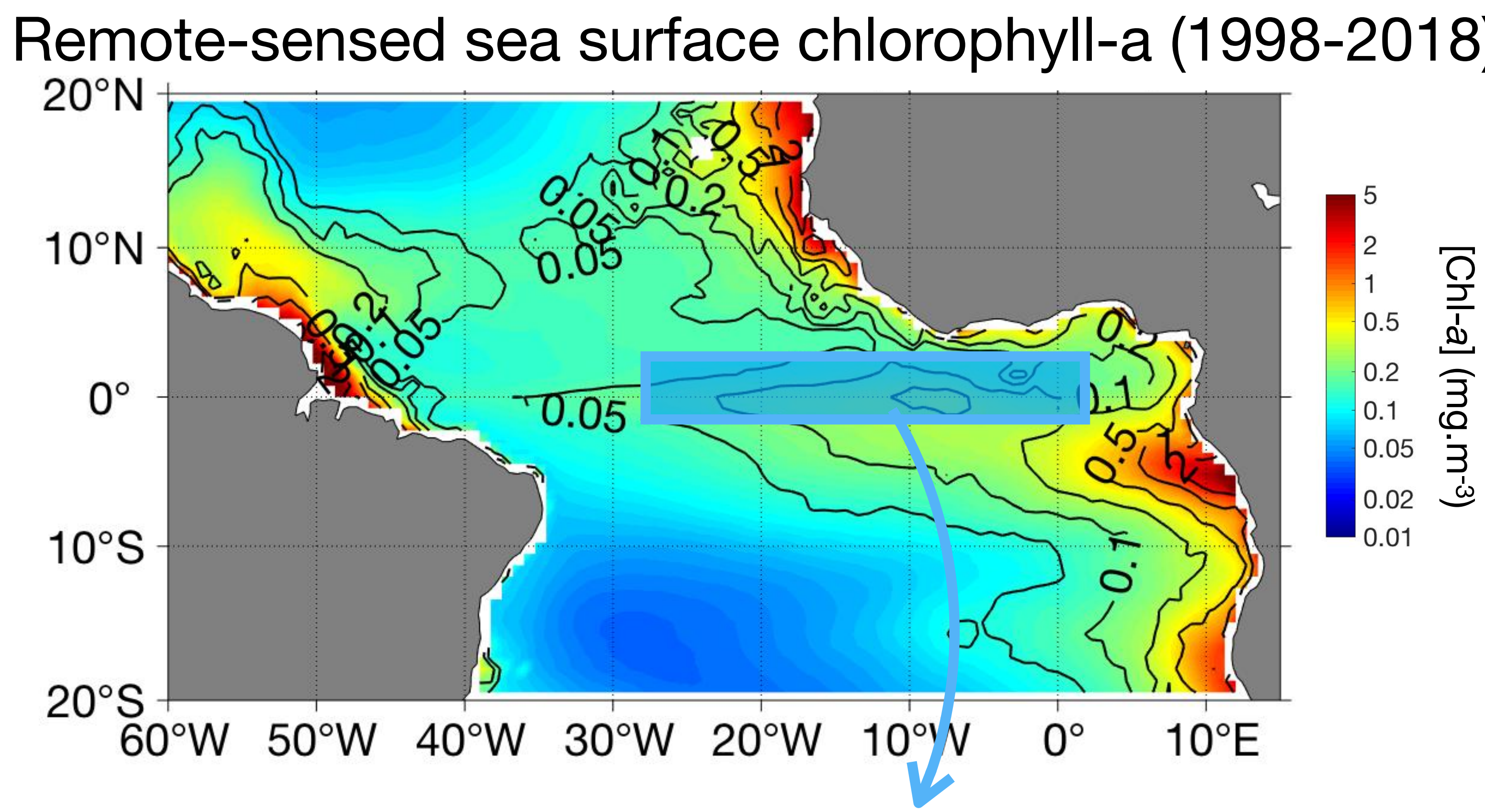


➡ **Western** signature of **NTAM** on SSH and Chl-a, promoted by **local** Ekman pumping

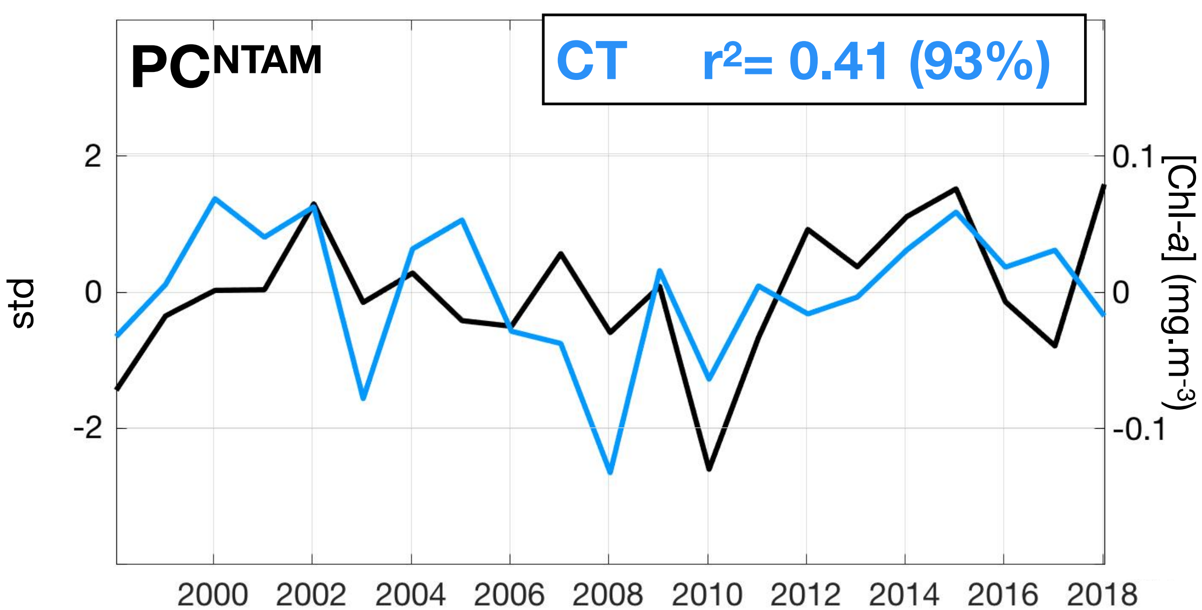
➡ **Eastern** signature of **AZM** on SSH and Chl-a, driven by **remotely**-forced wave propagations

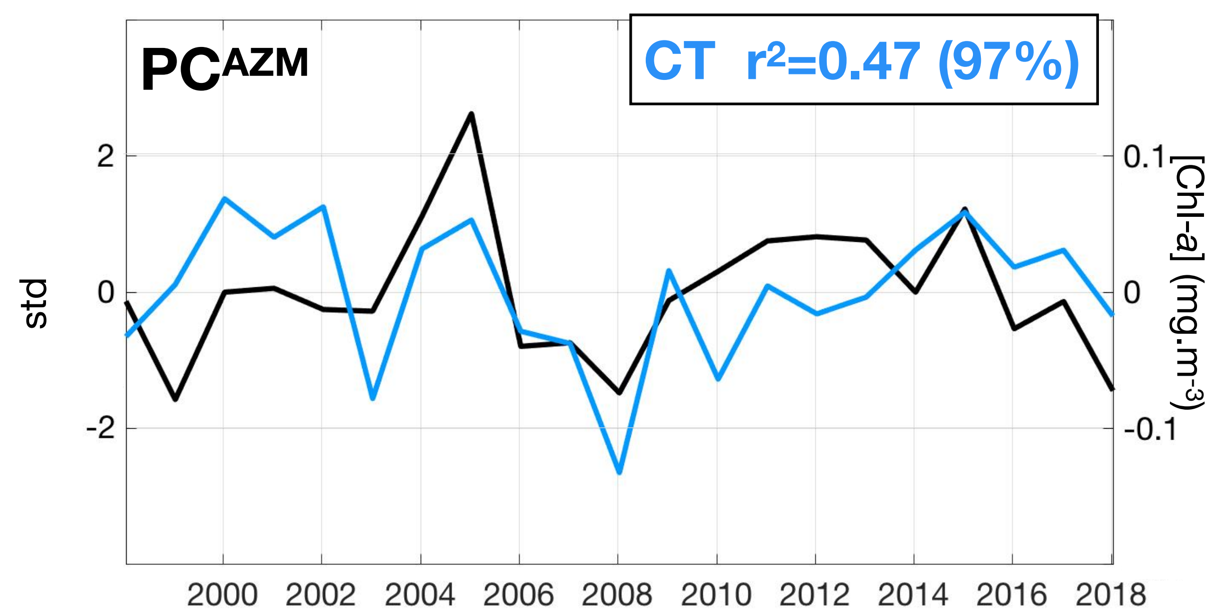
➡ **Zonal modulation** by each mode of variability.

RESULTS #3 How these two modes of variability modulate temporal Chl-a signature?

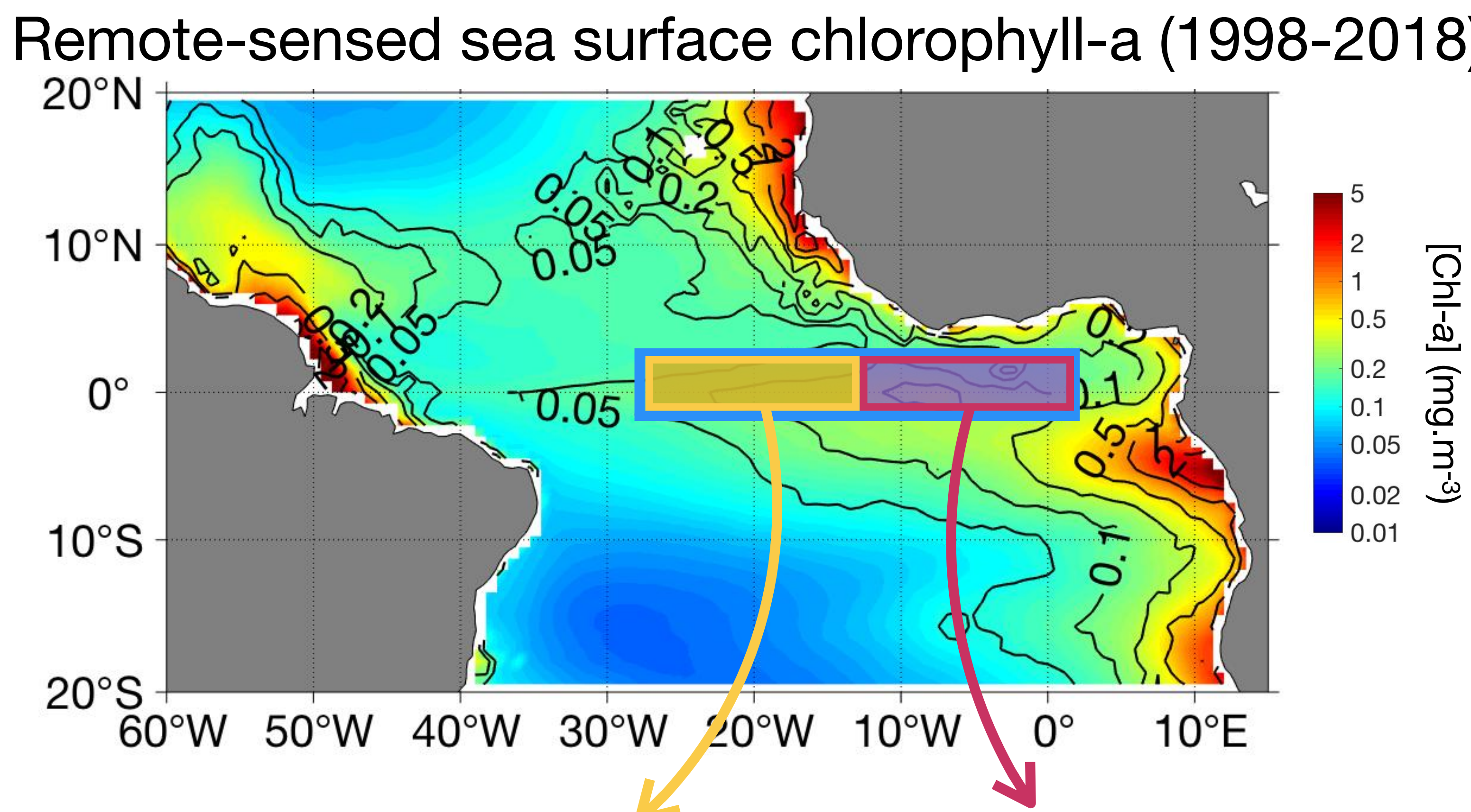


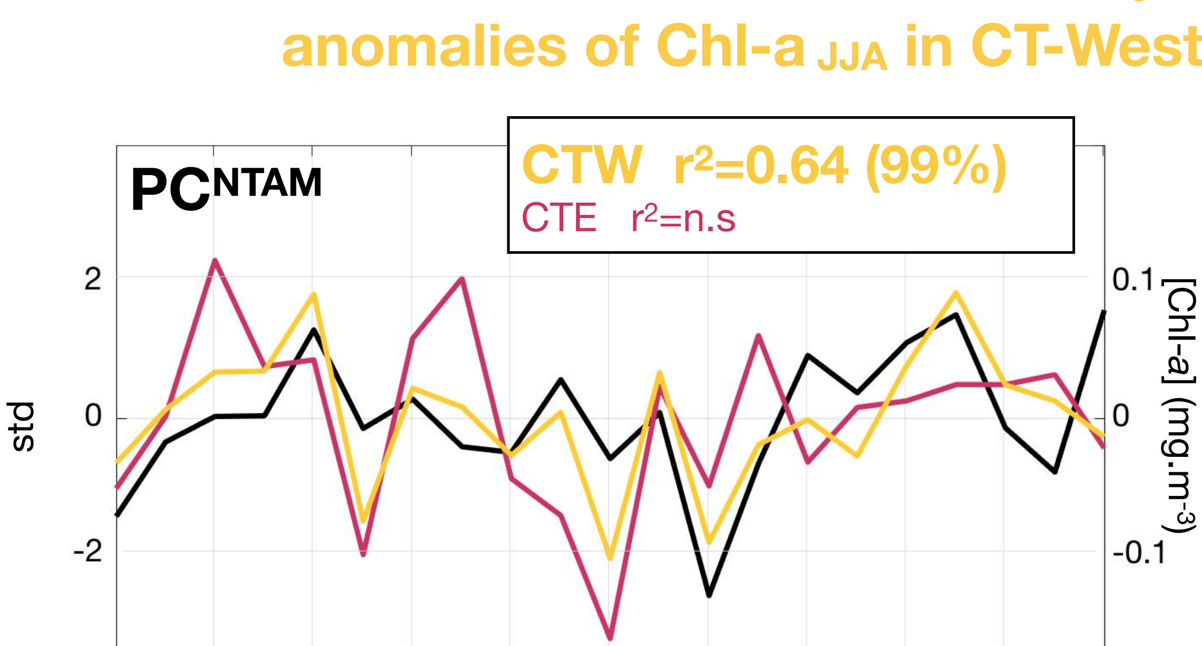
anomalies of Chl-a $_{JJA}$ in the Cold Tongue

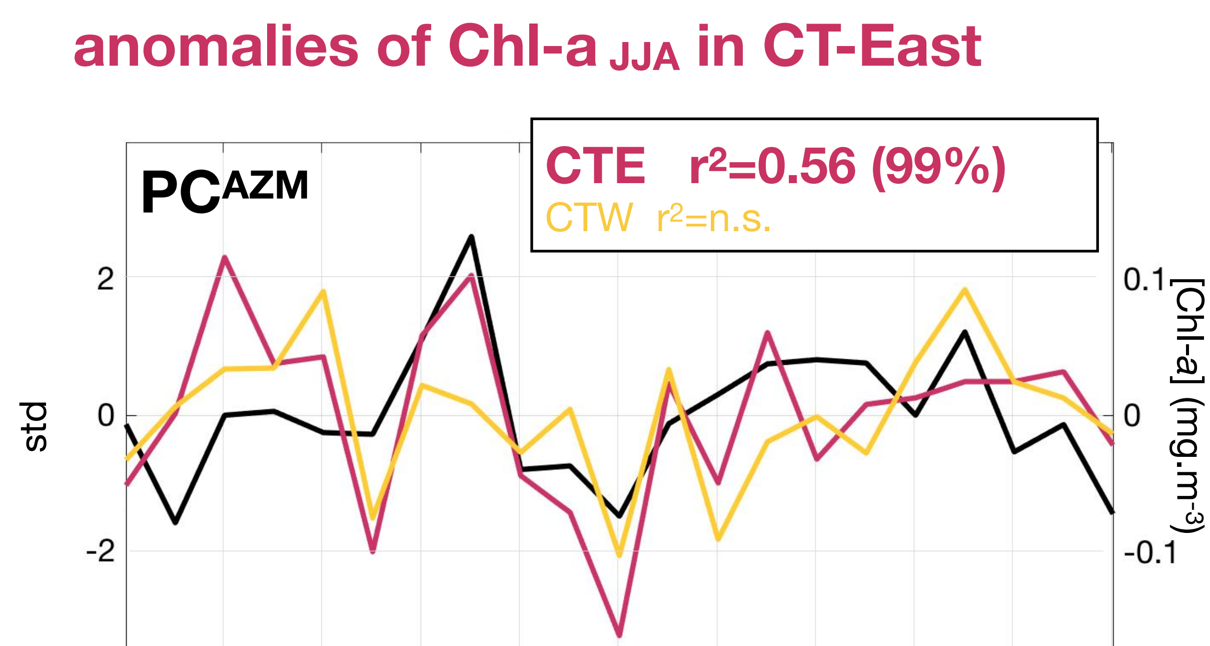




RESULTS #3 How these two modes of variability modulate Chl-a signature?







➡ **NTAM** significantly explains Chl-a interannual variability in the **western** CT

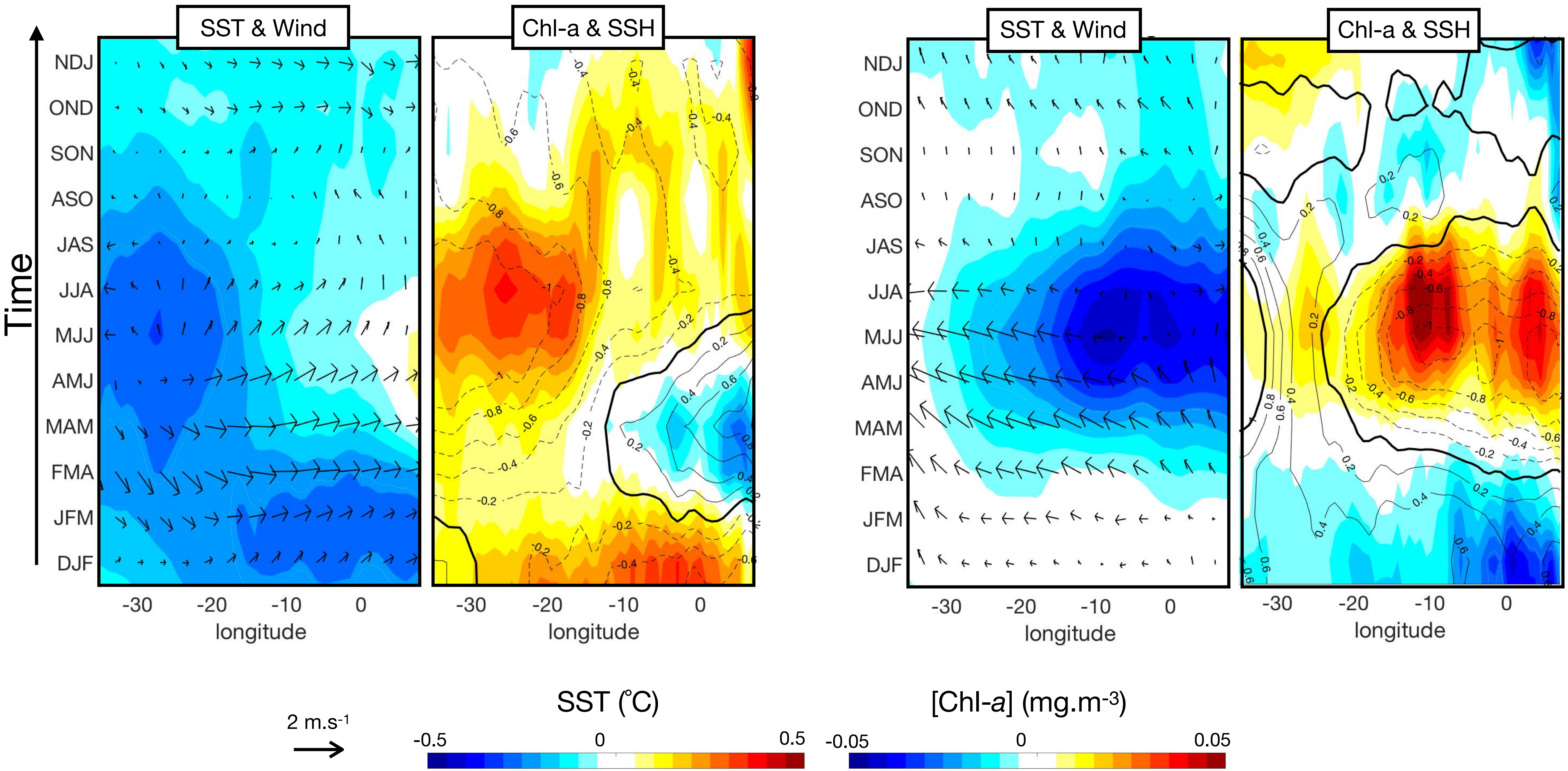
➡ **AZM** significantly explains Chl-a interannual variability in the **eastern** CT

➡Boreal summer **Chl-a** interannual variability is **zonally modulated** by each mode of variability.

RESULTS #4 What is the seasonal influence of these two modes of variability?

Method: Regression of the 3-month running-mean of SST, surface wind, SSH, and Chl-a interannual anomalies onto the PC^{NTAM} and PC^{AZM}, then averaged over [3°S-3°N]

NTAM: North Tropical Atlantic Mode | **AZM: Atlantic Zonal Mode**



➡There is a clear **spatio-temporal modulation** of the surface properties by the two leading climate modes.

How do climate modes shape the chlorophyll-a interannual variability in the equatorial Atlantic?

Take home messages:

Both modes significantly drive the interannual surface Chl-a variability in the equatorial Atlantic, with a clear zonal signature :

NTAM:
- in the **western** Cold Tongue (CT),
- **from boreal spring to fall**, peaking in summer,
- in response to **locally-forced pumping**
- modulates the western extension of the CT.

AZM :
- in the **eastern** Cold Tongue (CT),
- during **boreal summer,**
-involving **remotely-forced wave propagations**
- modulation in the core of the CT (10°W).

The challenge now: understand how these climate modes impact the interannual spatio-temporal variability of the **planktonic ecosystem**, their consequences on the **biological carbon pump** and the **higher trophic levels**.

Next step: analyses of a **coupled physical-biogeochemical model** to diagnose processes.

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- TRIATLAS post-doc until September 2021: looking for opportunities
- Applying for a permanent position for IRD on a similar thematic on the Gulf of Guinea

Thank you!

Interannual variability of biogeochemical properties in the tropical Atlantic Ocean

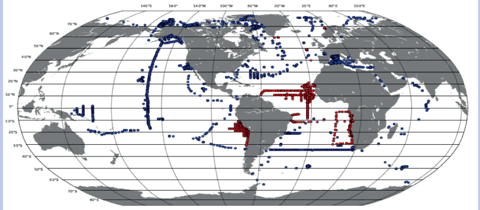
WP6

TRIATLAS South and Tropical Atlantic climate-based marine ecosystem prediction for sustainable management

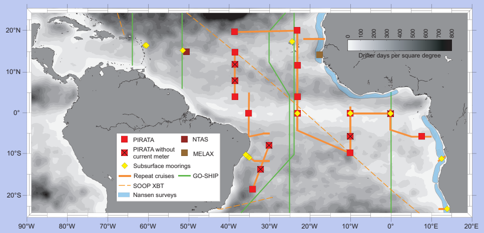
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 817578

CT1 Current state of the marine ecosystems

TRIATLAS will focus on physical, ecological and social factors to understand the mean state and seasonal cycle.

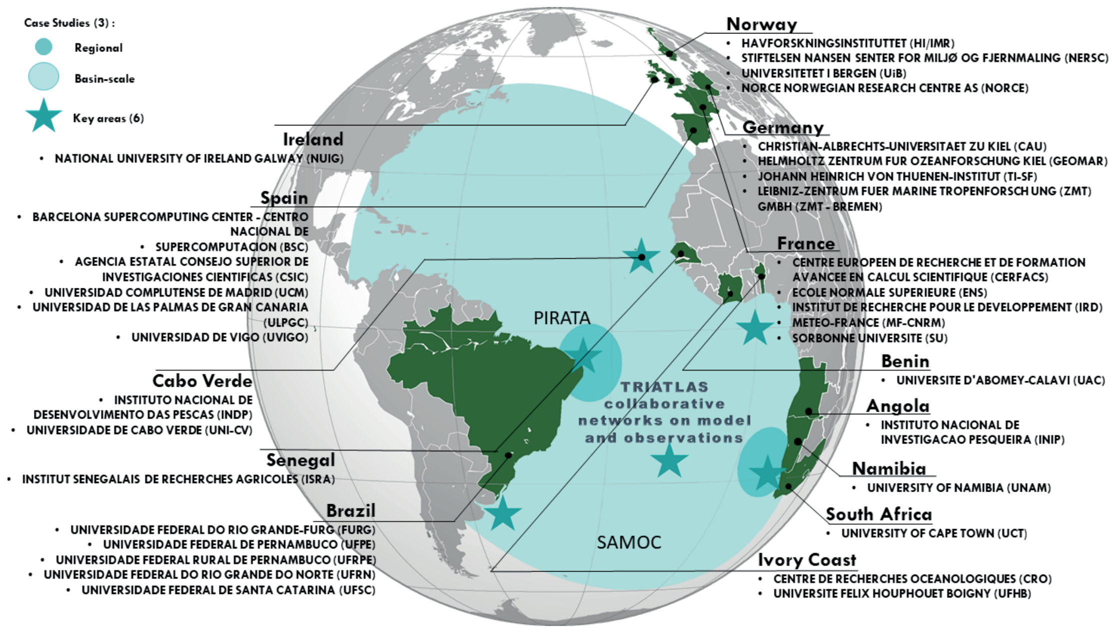


Global data set of Underwater-Video-Profiler observations (red - source TRIATLAS partner GEOMAR) comprises information on POM and plankton distribution and size spectra. Source: GEOMAR



TRIATLAS is based on the existing sustained observing system and will contribute to maintain and extend the observing system by including additional moorings and sensors and contributing to seagoing experiments.

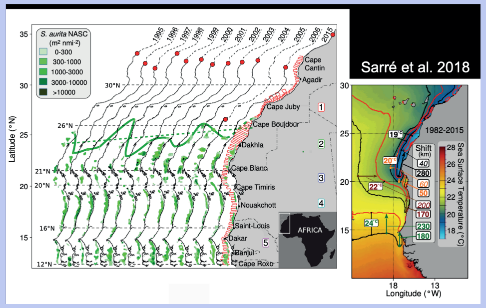
34 partners across the world



CT2 Ecosystem changes

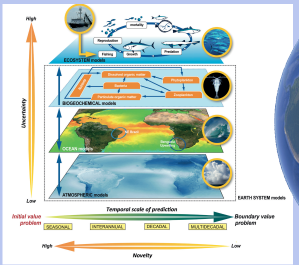
TRIATLAS will deliver an improved understanding of ecosystem changes focusing on key case study regions, considering environmental and anthropogenic factors, and investigating extremes on interannual and decadal timescales.

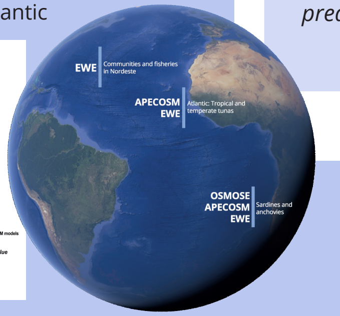
Annual shifts of biomass of Sardinella derived from hydroacoustic surveys.



CT3 Climate and marine-ecosystem prediction

TRIATLAS will provide an assessment of seasonal to decadal predictability and climate change scenarios simulations of ecosystems & fisheries in the South and Tropical Atlantic





We will develop end-to-end predictions based on three different earth system models (NorESM, EC-EARTH, CNRM) and three different ecosystem models (APECOSM, EWE, OSMOSE).

The TRIATLAS key challenge

To develop the understanding and the capacity (observational, modelling, and human) to best predict changes in the tropical Atlantic marine ecosystem and its societal impacts

Overall objective and plan

To assess the status of the South and Tropical Atlantic marine ecosystem and develop a framework for predicting its future changes, from months to decades, and thus to contribute to the sustainable management of human activities in the Atlantic Ocean as a whole.

This will be achieved by combining observations, climate-based ecosystem prediction and information on future socio-economic and ecosystem service changes.

Coordinator: Noel Keenlyside
University of Bergen and Bjerknes Centre for Climate Research

Co-coordinator: Heino Fock
Thünen Institute

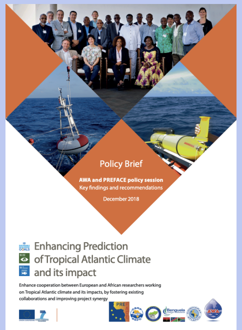
TRIATLAS.W.UIB.NO

Project manager: Nilgun Kulan
Communications manager: Andreas H. Opsvik

CT4 Knowledge exchange and societal impacts

Science to policy

TRIATLAS will engage stake holders from fisheries and other sectors through open forums, such as in the AWA and PREFACE projects.



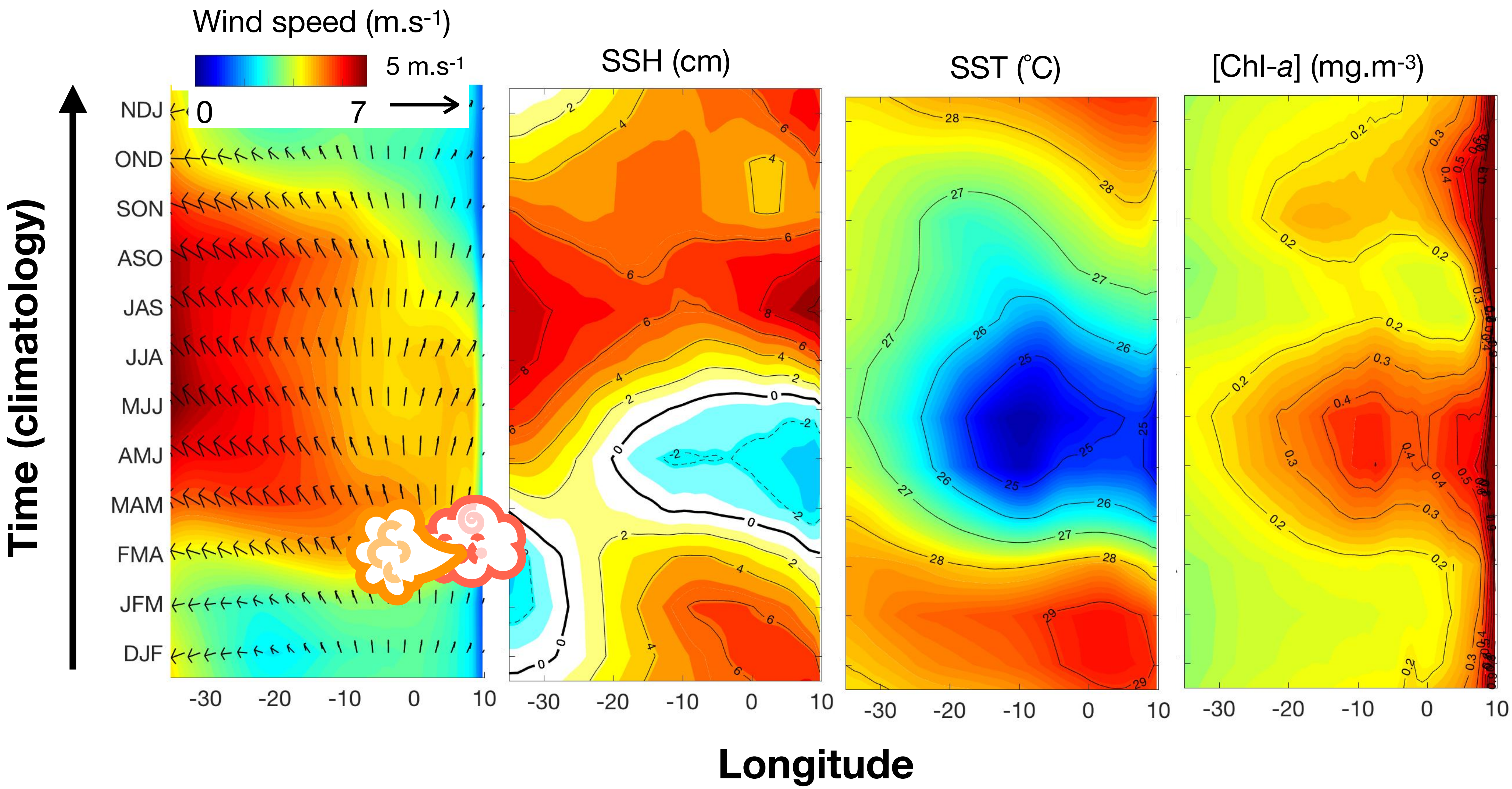
tinyurl.com/prefacepolicybrief

Cross-Atlantic Network of Excellence in Marine Science (CANEMS)

TRIATLAS will train a new generation of researchers to work on the tropical Atlantic ocean, ecosystem, and climate prediction.

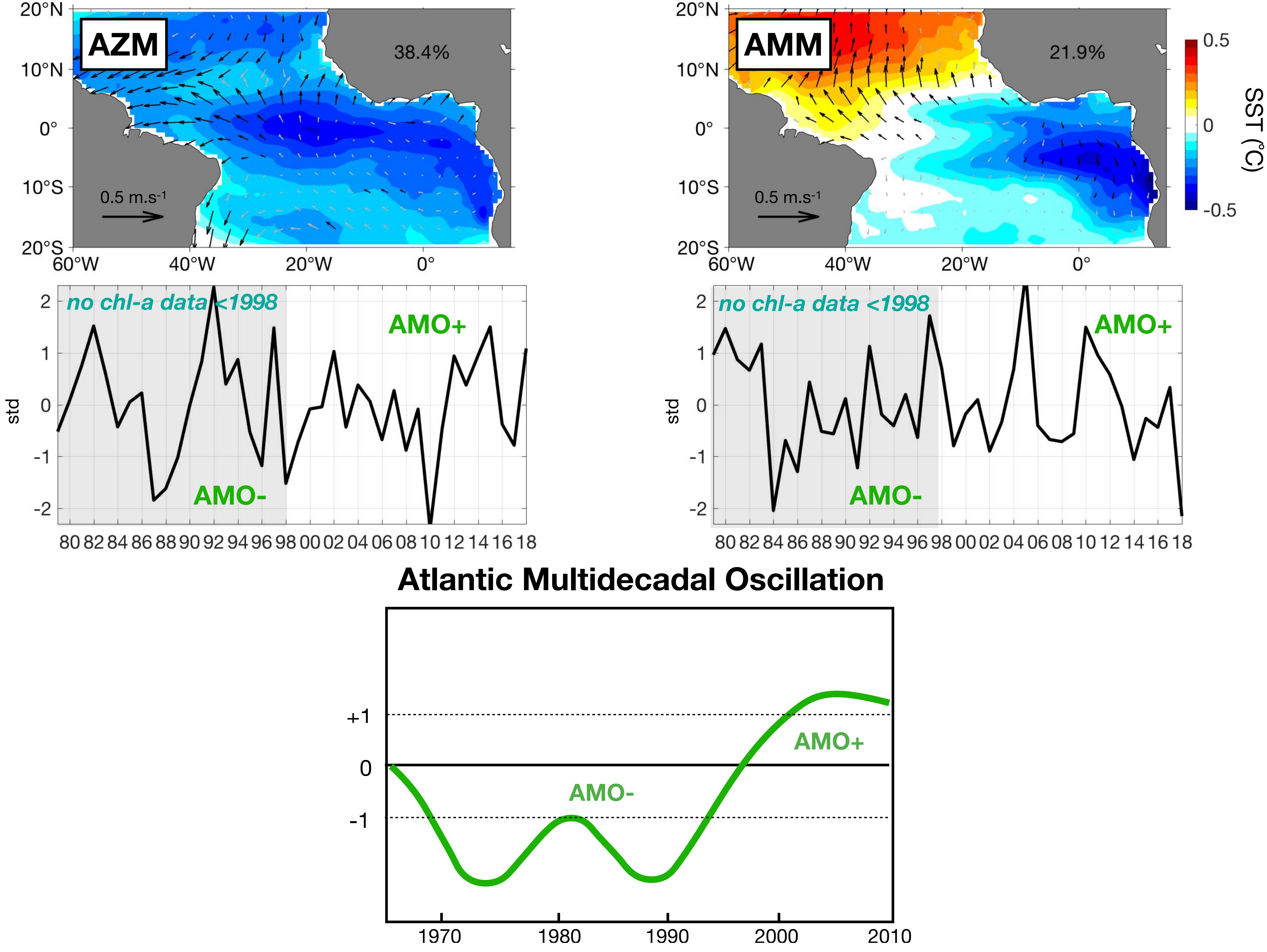
What do we already know about chlorophyll-a variability?

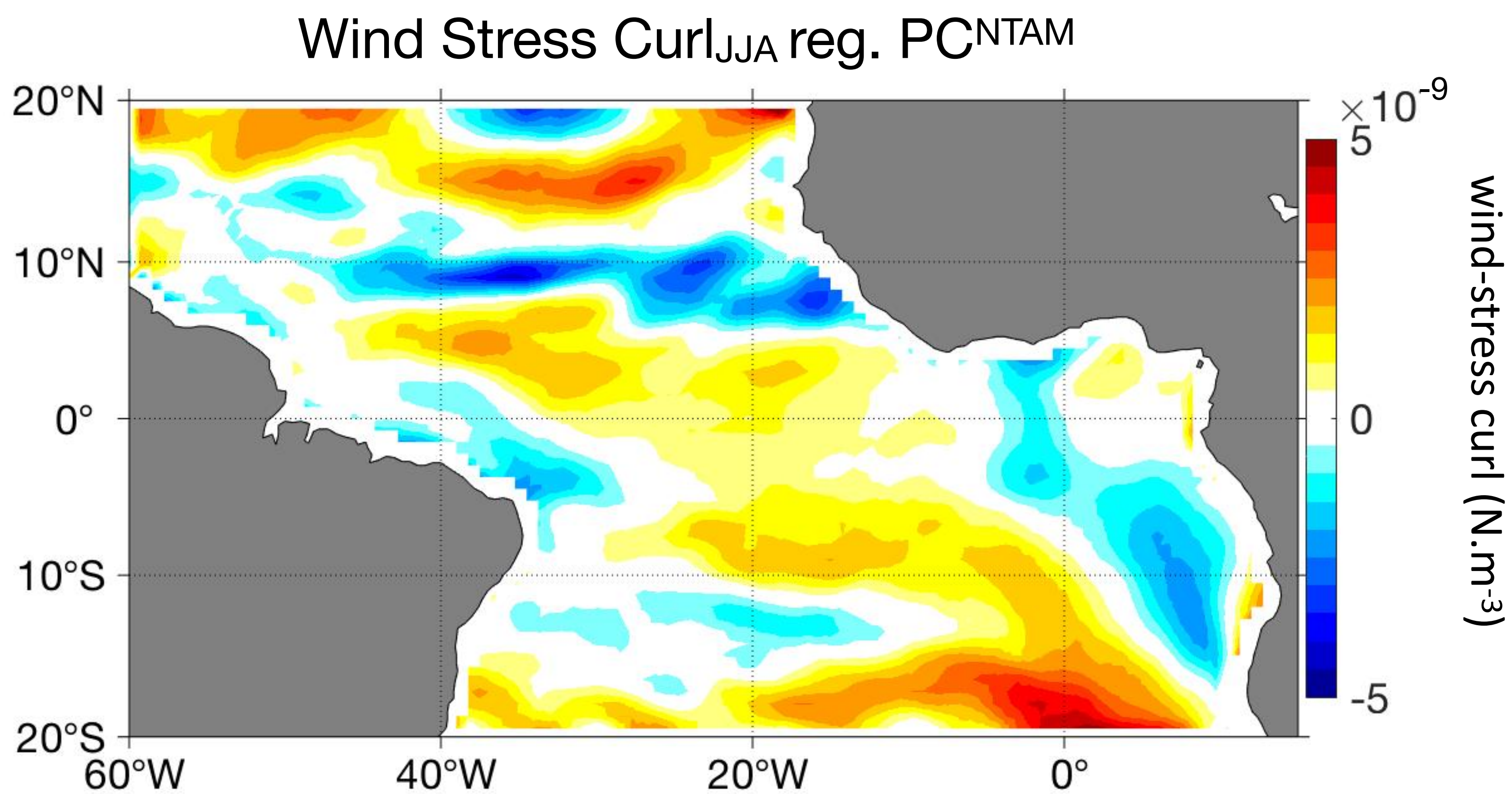
Climatological phenology in the Cold Tongue?



Data ***ERA-Interim*** ***AVISO*** ***ERA-Interim*** ***CMEMS Copernicus*** ***(1998-2018)***

Canonical modes of variability in the Equatorial Atlantic: AZM & AMM

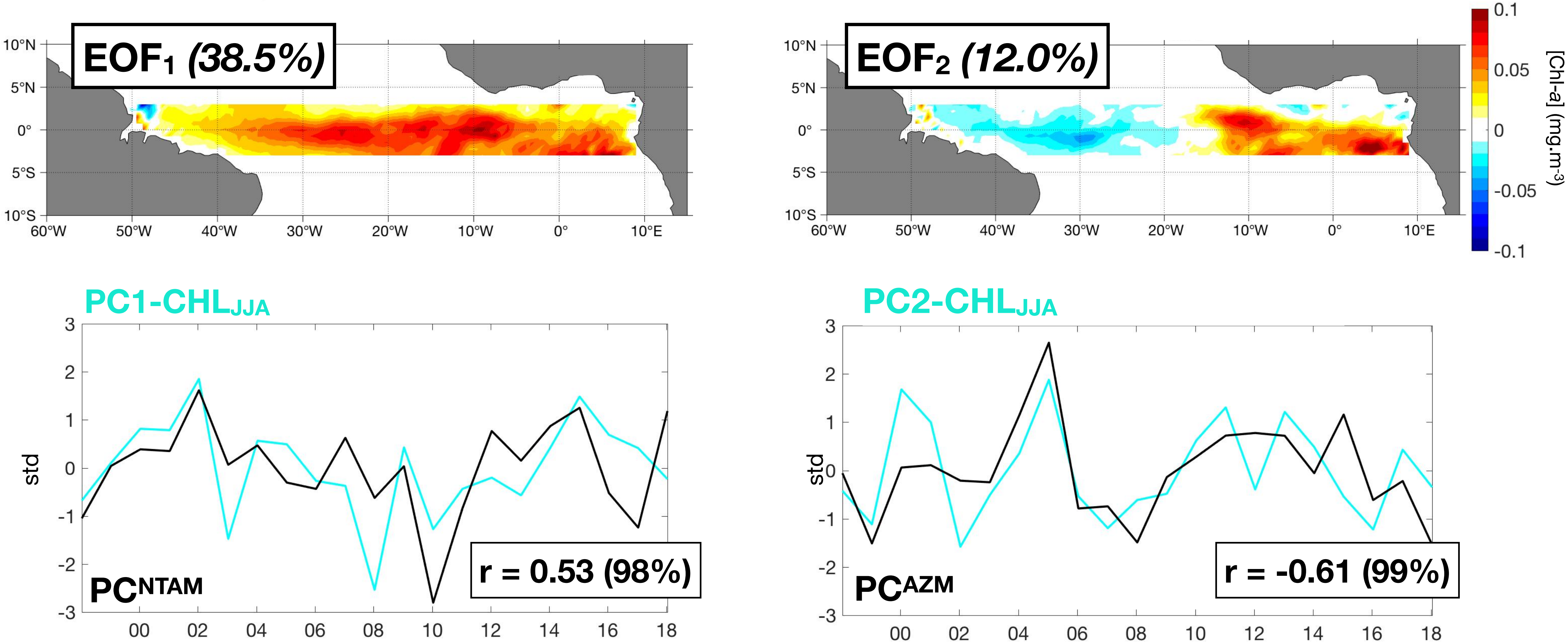




Surface wind-stress curl regressed on PC^{NTAM}. As for Fig.3a, we regressed maps of JJA surface wind-stress curl interannual anomalies ($N.m^{-3}$) onto the standardized PC^{NTA} (shown in panels e, black line).

How Chl-a signature is modulated by these two modes of variability?

<u>Method</u>: Empirical Orthogonal Functions (EOFs) on boreal summer (JJA) **Chl-a** on 3°S-3°N



➡**Chl-a** patch over the **entire CT** extends **westward**

➡Significantly explained by **NTAM**

➡**Chl-a East/West dipole**

➡Significantly explained by **AZM**