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Understanding Eastern Tropical Atlantic Ocean Dynamics in Relation to Climate Indices

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Motivation & objectives

- <u>Eastern tropical ocean basins</u>:

  ➞ Low-energy regions

  ➞ Received less attention than their western counterparts, where the strongest currents flow

  ➞ Regions where significant atmosphere-ocean interaction occurs

  ➞ Encompass the major areas of permanent upwelling (enhanced primary production)

- Focusing on the <u>Eastern Tropical Atlantic Ocean</u> (ETAO)

  - $3°N \leq \varphi \leq 30°N$; $40°W \leq \lambda \leq 0°$

  - considering a study period of 28 years (1993-2020)

this study aims to:

1. **Investigate the space-time variability of satellite altimetry derived oceanographic fields**
2. **Understand how these variables correlate with climate indices, either being forced by them or acting as their forcing mechanisms**

Study Area

Eastern Tropical Atlantic Ocean

- Interaction of several ocean currents
- Intense trade winds induce coastal circulation and upwelling
- One of the world's major upwelling regions

Currents in the study area :

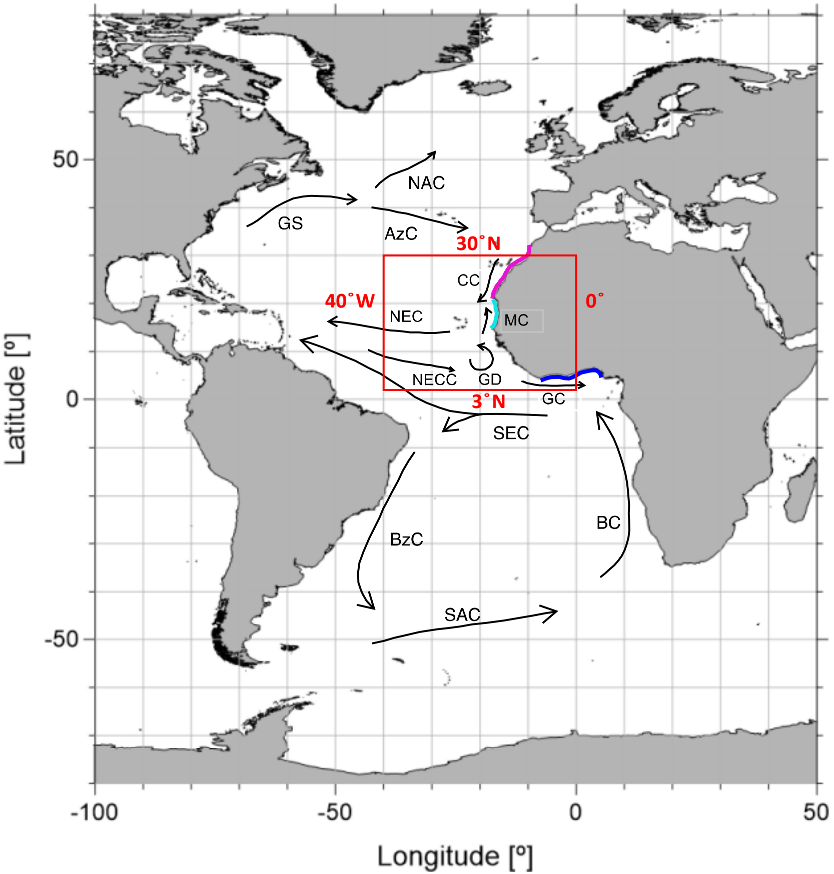
CC	Canary Current
MC	Mauritania Current
NEC	North Equatorial Current
NECC	North Equatorial Counter Current
GC	Guinea Current
SEC	South Equatorial Current

Upwelling systems:

- Pink - Continuous (wind-driven)
- Light blue - Seasonal (wind-driven)
- Dark blue - Seasonal (unclear mechanism)
- GD Guinea Dome (wind-driven)

Other main currents in the Atlantic Ocean:

GS	Gulf Stream
AzC	Azores Current
NAC	North Atlantic Current
BzC	Brazil Current
SAC	South Atlantic Current
BC	Benguela Current



Climate Indices influencing the ETAO

- Global or regional-scale climate variables fluctuate almost regularly (**oscillations**)
- **Climate Indices (CI)**

  - Scalar values resulting from the combination of several climate variables (Sea Surface Temperature (SST), Sea Level Pressure (SLP), Wind speed, Rainfall)

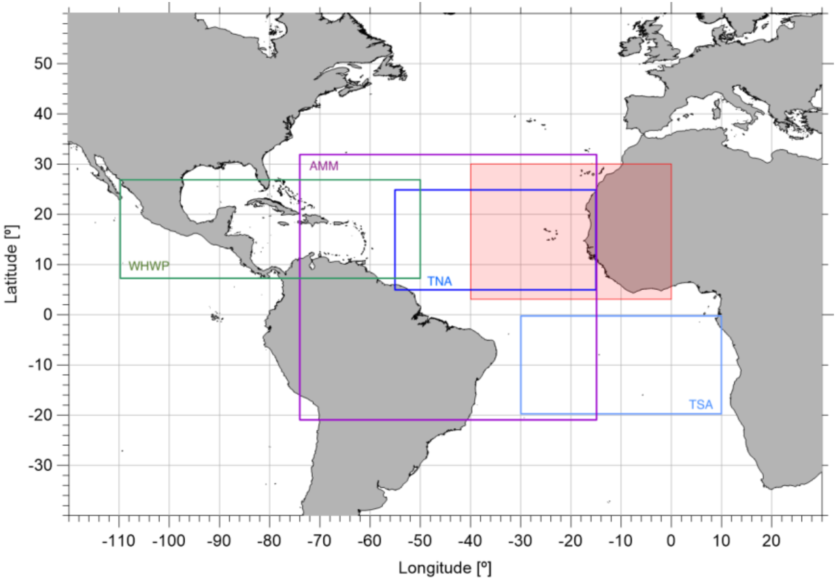
  - Used to monitor these oscillations

Tropical North Atlantic (TNA)

Tropical South Atlantic (TSA)

Atlantic Meridional Mode (AMM)

Western Hemisphere Warm Pool (WHWP)



North Atlantic Oscillation (NAO)

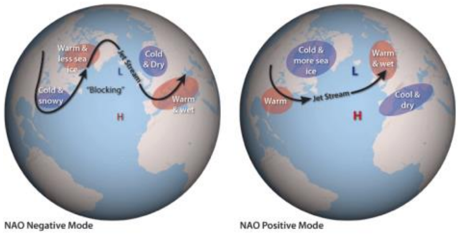


Image source: https://www.climate.gov/sites/default/files/NAO_Schematic_0.png

Southern Oscillation Index (SOI)

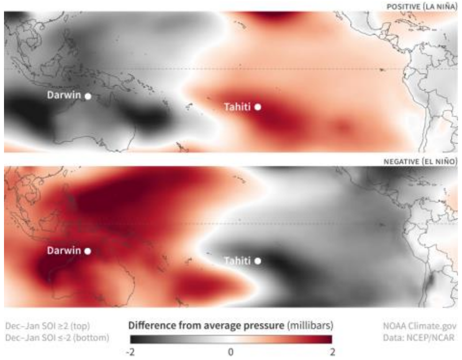


Image source: https://www.climate.gov/sites/default/files/NAO_Schematic_0.png

Data

Satellite altimetry:

- Copernicus Climate Change Service (C3S): Sea Level Anomaly (SLA) daily grids, global, 1/4° spatial resolution (vDT2021)
- Climate-oriented products

Climate indices:

- NOAA Physical Sciences Laboratory (PSL): monthly time series

NAO standardized 3-month running mean index

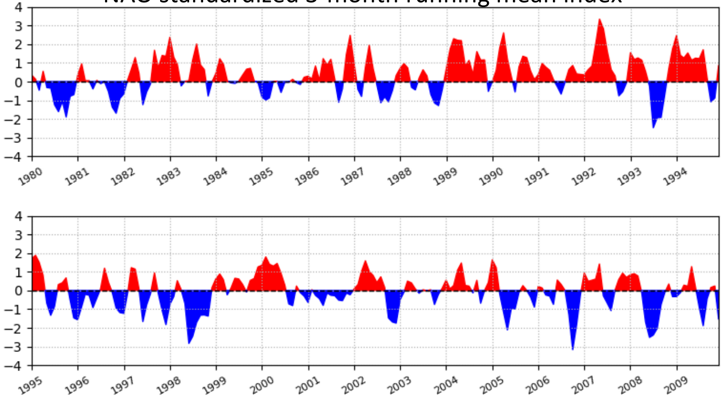


Image source: *https://www.cpc.ncep.noaa.gov/data/teledoc/nao_ts.shtml*

SLA (cm) for 01/09/2020 (vDT2021)

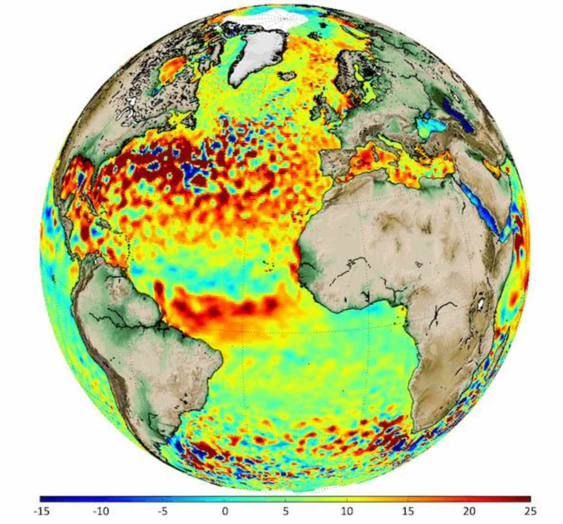


Image source: *https://cds.climate.copernicus.eu/cdsapp#!/dataset/satellite-sea-level-global?tab=overview*

Data

Sea Surface Temperature (SST):

- NOAA Extended Reconstructed SST V5 data provided by the NOAA PSL: monthly 2.0°×2.0° global grids

SLP & Wind:

- NCEP-NCAR Reanalysis-1 data provided by the NOAA PSL: monthly mean SLP, uwnd.10m and vwnd.10m, 2.5°×2.5° global grids

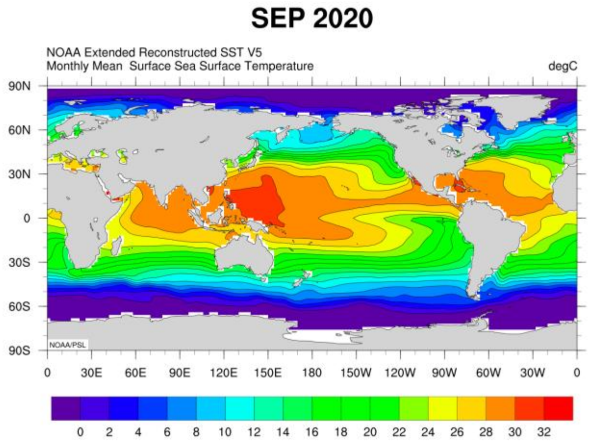
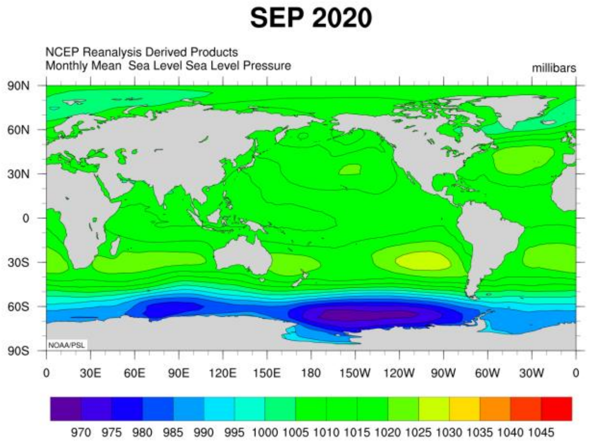


Image source:
https://psl.noaa.gov/mddb2/makePlot.html?variableID=2783



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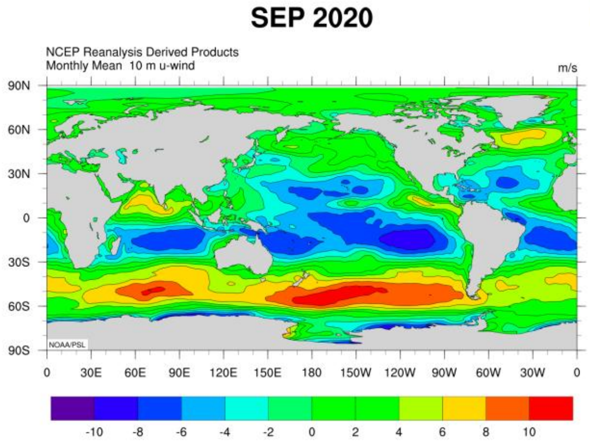


Image source:
https://www.psl.noaa.gov/mddb2/makePlot.html?variableID=155961

Methodology

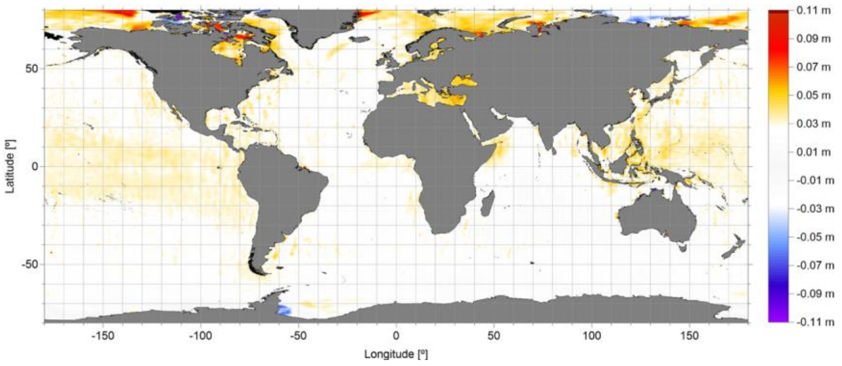
<u>SLA calculated w.r.t. the 1993-2020 period</u>

- SLA grids corrected for the 28-year reference period
- Time-varying components of the geostrophic currents (*u′* and *v′*) and Eddy Kinetic Energy (EKE) per unit mass computed using the corrected SLA grids
- Magnitude of the surface geostrophic currents (u and v) ➞ original C3S grids

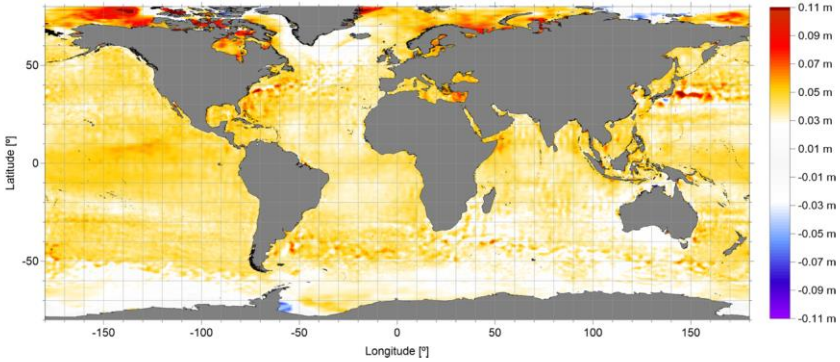
<u>Seasonal time series of SLA (for each grid pixel) and each CI</u>

- **Winter** (wtr): December, January and February
- **Spring** (spr): March, April and May
- **Summer** (sum): June, July and August
- **Autumn** (aut): September, October and November

Mean overall SLA for the period 1993-2012



Mean overall SLA for the period 1993-2020 (no correction applied)



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Methodology

For each season:

Correlation between SLA and CI

- Pearson correlation coefficient and Student’s t-test for statistical inference at 95%
- All time series previously detrended/normalized

Identification of the periods of +/- CI phases

- Threshold value for positive/negative CI phases:

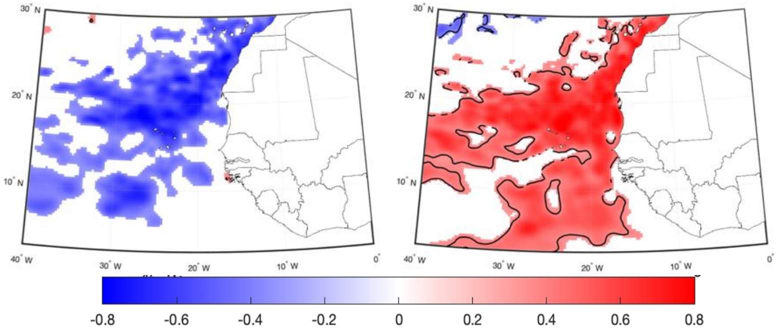
+/- 0.5×σ, σ - std w.r.t. the mean for that particular season

SST, SLP and wind anomalies computed for +/- CI phases:

- Climatological seasonal mean removed at each grid pixel
- Composite maps: SSTA (colour), SLPA (contours) and surface wind stress anomalies (vectors)

SLA differences w.r.t. climatological seasonal mean during +/- CI phases mapped

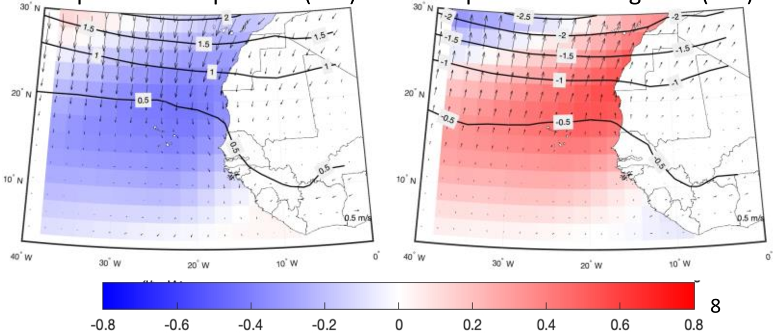
SLA/NAO correlation (wtr) SLA/TNA correlation (wtr)



NEGATIVE CORRELATION:
Index ⇩ => SLA ⇧
Index ⇧ => SLA ⇩

POSITIVE CORRELATION:
Index ⇧ => SLA ⇧
Index ⇩ => SLA ⇩

Composite: NAO positive (wtr) Composite: NAO negative (wtr)

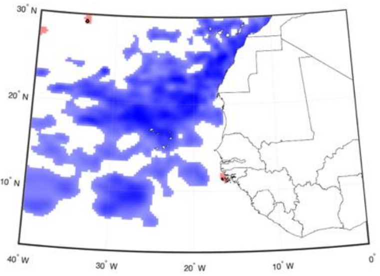


Correlation and composite maps: NAO

WINTER

- Only negative correlations
- Along the coast, north of 20°N, the correlation areas coincide with the area of continuous upwelling
- North of around 20°N, all the climate variables contribute to the negative correlations
- South of 15°N, only SST seems to influence the SLA fluctuations in the regions of strong correlations

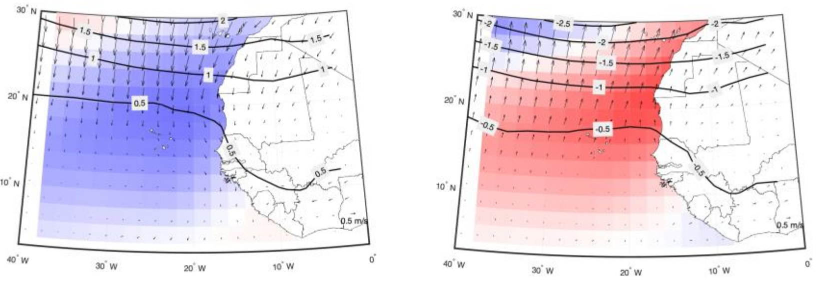
Correlation map

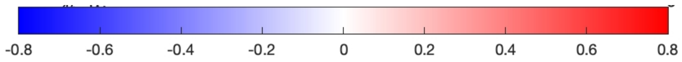


Composite maps

NAO positive

NAO negative

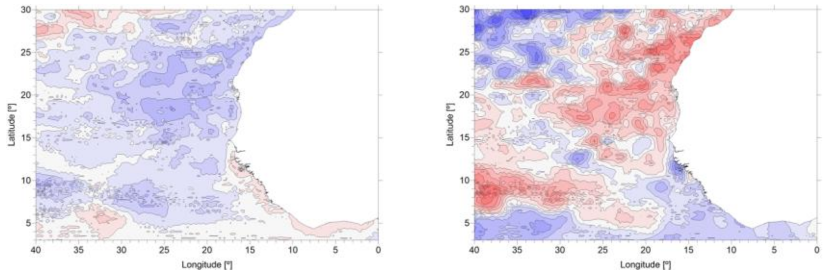




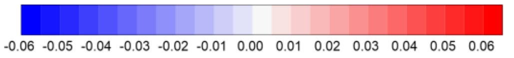
Significant correlations (95% confidence) between SLA and NAO

SSTA (°C, colour), SLPA (hPa, contours) and wind stress anomalies (m/s, arrows) during NAO positive and negative phases

SLA anomalies



SLA anomalies (m) during NAO positive and negative phases



Correlation and composite maps: TNA

WINTER

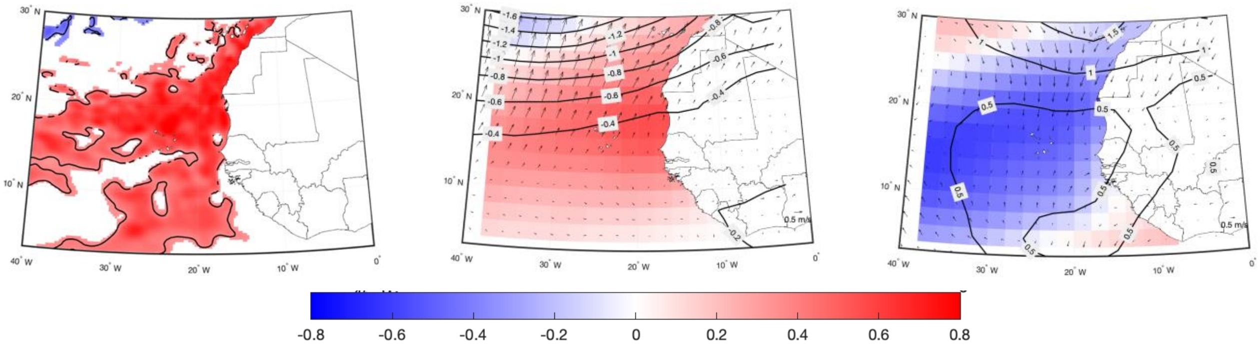
- Mostly positive correlations
- Highest correlation values located along the western African coast (permanent and seasonal upwelling regions), and extending south and spreading west at around 20°N following the NEC, NECC and MC paths
- North of 15°N, all the climate variables contribute to the positive correlations
- South of 15°N, SSTA is the main forcing factor

Correlation map

Composite maps

TNA positive

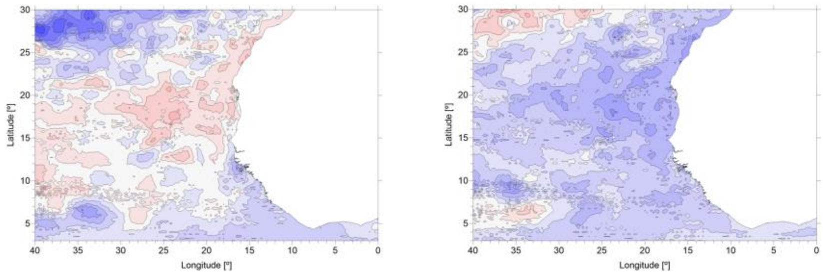
TNA negative



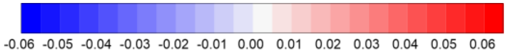
Significant correlations (95% confidence) between SLA and TNA

SSTA (°C, colour), SLPA (hPa, contours) and wind stress anomalies (m/s, arrows) during TNA positive and negative phases

SLA anomalies



SLA anomalies (m) during TNA positive and negative phases



Correlation and composite maps: WHWP

SPRING

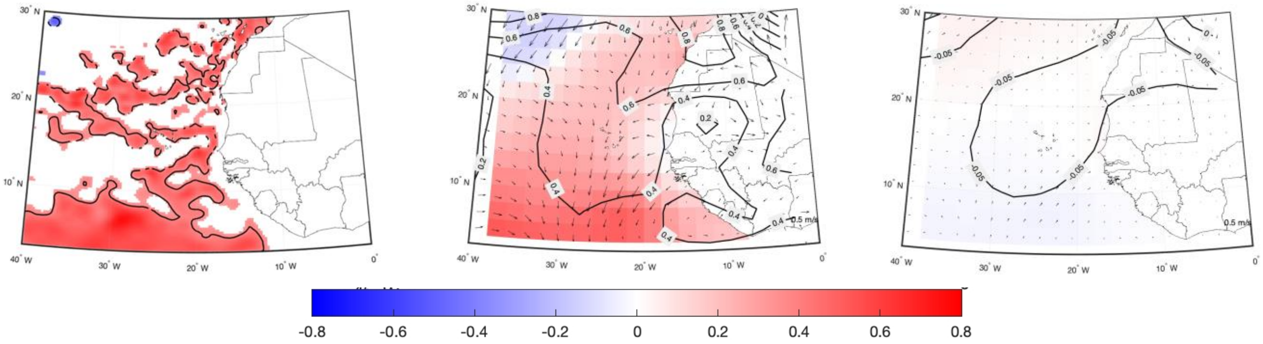
- Mostly positive correlations
- Highest SSTA values are found south of 10°N where the correlations are stronger and the NECC develops
- During WHWP positive phases, all climate variables exhibit increased intensity, while during WHWP negative phases, they nearly dissipate. Despite this, their remaining strength is sufficient for signal inversion, enabling the positive correlations.

Correlation map

Composite maps

WHWP positive

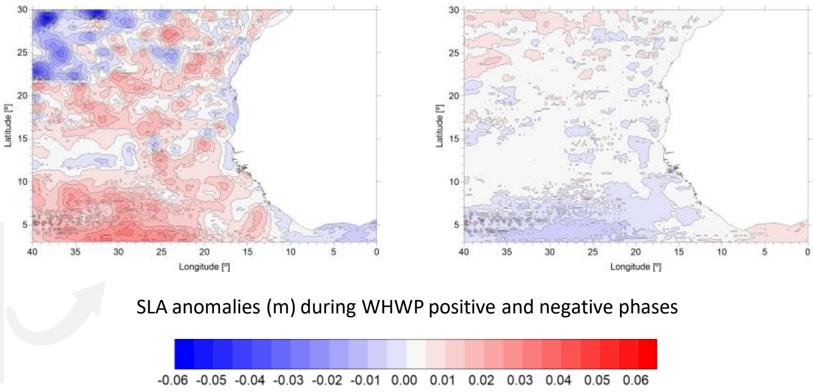
WHWP negative



Significant correlations (95% confidence) between SLA and WHWP

SSTA (°C, colour), SLPA (hPa, contours) and wind stress anomalies (m/s, arrows) during WHWP positive and negative phases

SLA anomalies



SLA anomalies (m) during WHWP positive and negative phases

Opposite states of SLA differences w.r.t. climatological seasonal mean during +/- CI phases have an impact on e.g. the NECC, EKE and surface geostrophic currents

Correlation and composite maps: SOI

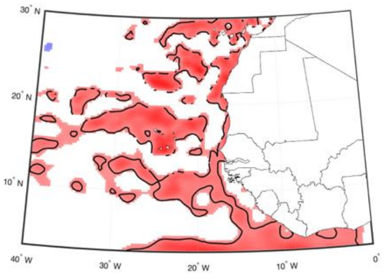
SUMMER

- Positive correlations along the African coast, including the paths of Mauritania and Guinea currents

- North of 15-20°N, SLP and wind contribute to the positive correlations

- South of 15-20°N: correlations explained by both different-than-average SST and SLP

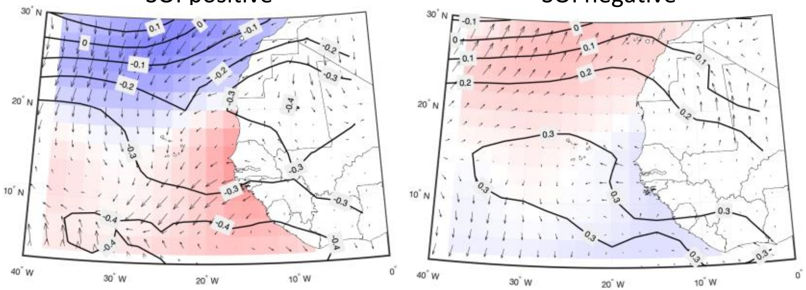
Correlation map

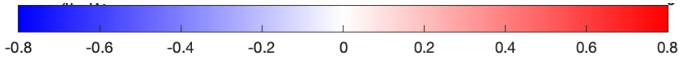


Composite maps

SOI positive

SOI negative

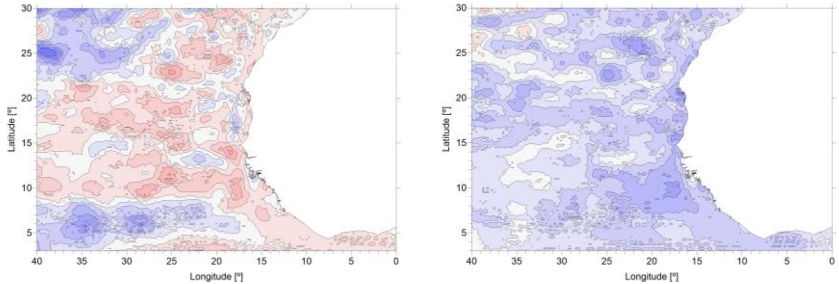




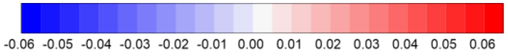
Significant correlations (95% confidence) between SLA and SOI

SSTA (°C, colour), SLPA (hPa, contours) and wind stress anomalies (m/s, arrows) during SOI positive and negative phases

SLA anomalies



SLA anomalies (m) during SOI positive and negative phases



Summary

- SLA and CI:

  - NAO is the only CI that presents negative correlations with SLA

  - SST appears to be the primary variable explaining the correlations between SLA and CI

  - Wind also explains the correlation between SLA and some CI but its primary influence is confined to the northernmost area of the study region

  - SLP contribution to the correlations seems to be negligible, explaining correlations only for some indices and during limited seasons (e.g., NAO in winter, TNA winter, SOI summer)

- EKE/ Magnitude of surface geostrophic currents and CI (not shown):

  - In general, EKE anomalies for +/- CI phases across different seasons align with SST variability

  - The magnitude of surface geostrophic current anomalies appears to be strongly influenced by the dominant current in the region (NECC)

Future Work

- Consider temporal lags between oceanic variables & CI → Effects of the variations may only be apparent after a significant time delay
- Investigate cross-interference between different CI → e.g., NAO interference with WHWP has been suggested by previous studies
- Investigate EKE and surface geostrophic currents regional change → Characterize mesoscale activity and phenomena influencing results north and south of latitude 10°N

Thank you for your attention!