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Impact of intra-seasonal coastal Kelvin waves on SST in the eastern boundary upwelling systems of the Tropical Atlantic : a composite analysis of boreal winter

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1. Introduction and objectives

Our study focuses on the impact of intra-seasonal coastal Kelvin waves on the SST along the northern West African coast and especially in the Senegalese upwelling zone. Matsuno in 1966 described for the first time theoretically the Kelvin waves, followed by (Moore, 1986): They describe the equatorial band as a wave guide propagating eastward (Kelvin waves) and westward (Rossby waves). They can also be the result of the reflection of a non-dispersive Rossby wave on the west coast of the basin. Kelvin waves propagate along the equator, which acts as a dynamic barrier due to the absence of Coriolis force.

Following the method of Polo, Lazar et al 2008, we will study the impact of intra-seasonal coastal Kelvin waves on the SST in the Senegalese upwelling system [20°W-10°E and 5°S-30°N] by making a composite analysis of the winter season.

The results obtained show a very strong link between the SST and the SLA in the Senegalese upwelling. The intra-seasonal variability of the SLA anomaly reveals that clear and continuous propagations similar to the intra-seasonal Kelvin wave signatures that are present for all years are accompanied by a response of the SST anomaly and propagating up to about 26°N. Phase velocity estimates range from 1 to 3.4 m/s along the equator and the West African coast. The wave appears to be generated by a zonal wind creating an impact on the SST of about 0.2 °C/cm in the upwelling system.

The objectives of this presentation are to investigate the SST anomalies that impact the artisanal fishery at the intra-seasonal scale during the winter season (DJF) and to compare the satellite SLA anomaly with the MELAX buoy anomaly for the period 2015-2017.

2. Data, Methods and Study area

Data: Satellite:

SLA OSTM/JASON-2, SST OISST NOAA and Wind ERA5 for a period of 1993-2018 with a spatial resolution of 0.25° and daily temporal resolution.

In-situ: MELAX buoy:

The MELAX buoy is located in the heart of the Senegalese upwelling 40 km south of Dakar on the continental shelf in 35 meters of water (14°20'N, 17°14'W). In our case, we will focus on data collected in the ocean (pressure) by the Acoustic Doppler Curent Profile (ADCP) from 11 February 2015 to 09 September 2017.

Methods:

- Implementation of tracks and Study Zone
- Application of an intra-seasonal tape filter: retain periods between 20 and 90 days
- Composite waves: average of a large number of events impacting the Senegalese upwelling.

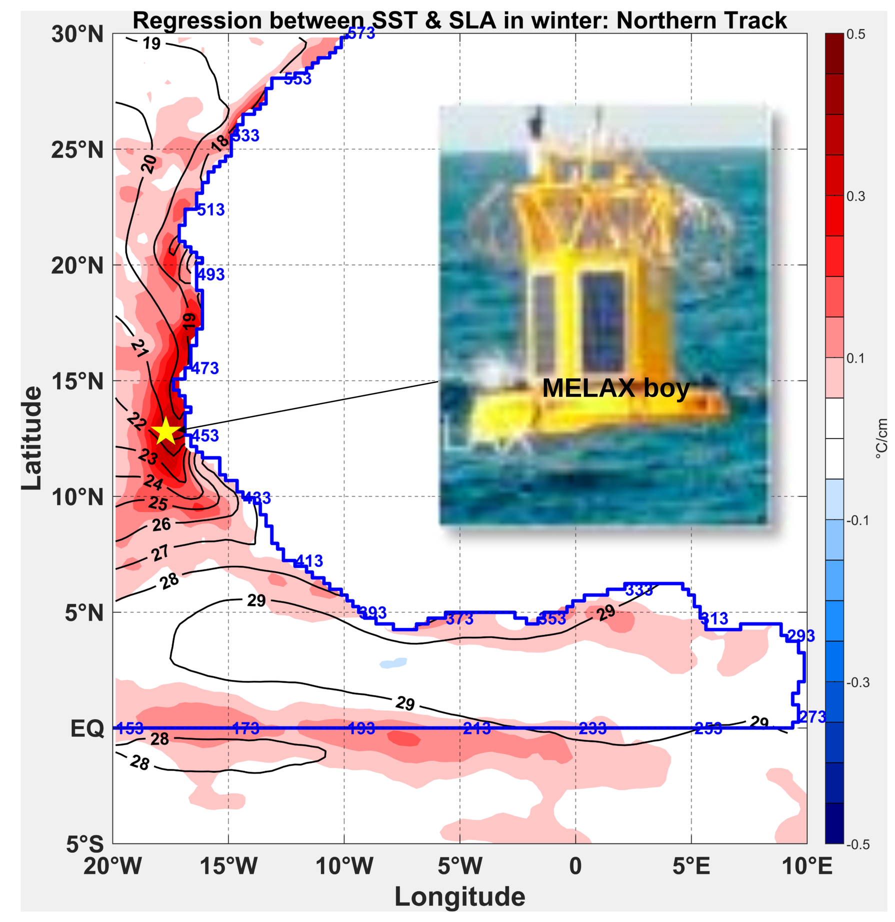

Figure 1 : March-April-May regression map of the SST on the SLA for the period 1993-2018 and represents our study area. The blue line materializes the path followed by the Kelvin waves along the equator and the northern West African coast. The black contours, represent the climatology of the SST. The yellow image is the MELAX buoy represented by the yellow star.

3. Results

3.1. Intra-seasonal variability of the dynamic height of the sea level anomaly (SLA) along the northern track

- Signals similar to Kelvin wave propagation appear clearly from the equator to the African coast along the GG and the northern coast
- 1-2 events per year all year round
- From 0.5 cm to 5 cm: larger amplitude at the coast
- Speeds vary according to the season: change of stratification or wind forcing
- Propagation up to 26°N

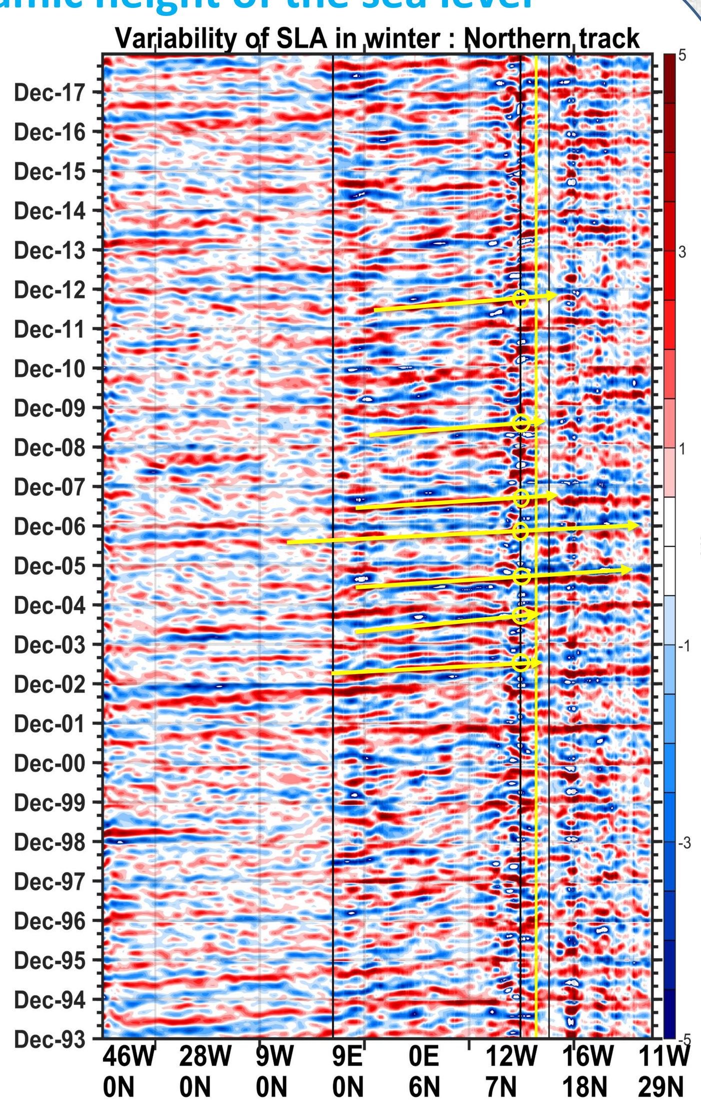

Figure 2: Hovmûllers diagrams of the intra-seasonal variability of SLA (cm) for the DJF season for the period 1993-2018 along the northern track. We have concatenated only the months of December, January and February for the period 1993-2018. The first black line represents the separation between the equator of the coast. The second black line represents 12 °N. The third line black represents 16 °N. The yellow arrows materialize the wave's propagation speeds. The yellow line represents the position of the MELAX buoy

3.2. Winter season composite along the North track

- Maximum SST anomaly of ~0.3°C @lag 0d&5d
- Propagation of the average wave from -25 days in the GG and along the Senegal-Mauritanian coast
- A wave with two propagation speeds:
  - In the GG: v1= 1 m/s
  - -Along the Senegal-Mauritanian coast: v2=3.4 m/s
- Constructive wind anomaly (the meridional component decrease amplifies the downwelling wave)

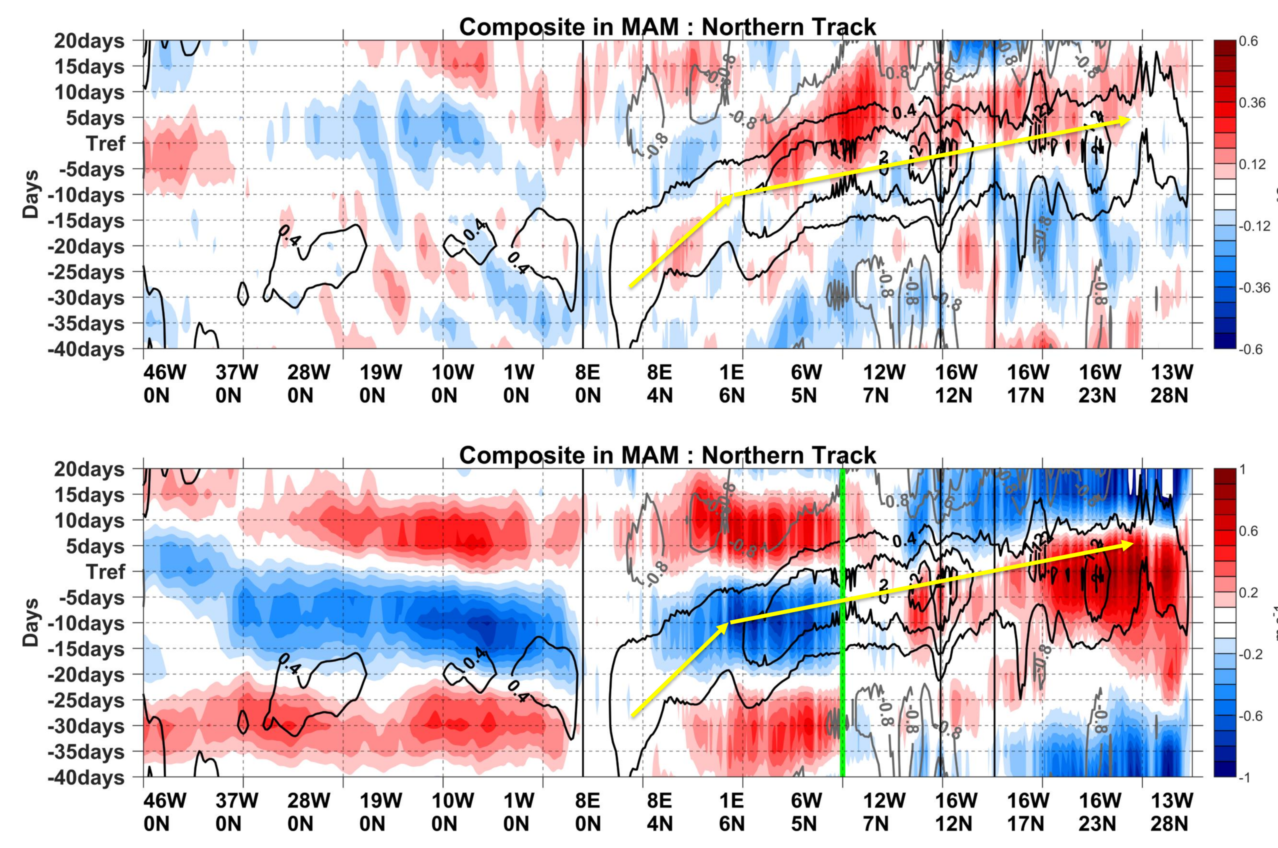

Figure 3: Hovmûllers diagrams of the average SLA composite in DJF for the period 1993-2018 on the right along the northern track. The first black line on the two panels represents the separation between the equator of the coast. The second black line represents 12 °N. The third line represents 16°N. The black arrows materialize the wave's propagation speeds.

3.3. Comparison of the satellite SLA and the MELAX buoy SSH anomaly

The hovmûller diagram shows the arrival of the waves and the time series highlight the comparison between the ADCP SSH and the satellite SLA at the MELAX buoy off Mbour, Senegal, over the period 2015-2017.

In 2015:

Many events are lagging with a delay of 5 to 10 days of the satellite SLA peak (SAT SLA) compared to the buoy SSH peak (ADCP SSH).

In 2016:

SAT SLA and SSH ADCP in phase for 5 days to a month with underestimation of SSH ADCP amplitude compared to SAT SLA amplitude. The phase shift observed during this year between the buoy SSH and SAT SLA peaks is at most 15 days.

In 2017:

SSH ADCP and SLA SAT events are in agreement at the beginning and end of the year but also a 5 day phase shift was noted the SSH and SLA SAT.

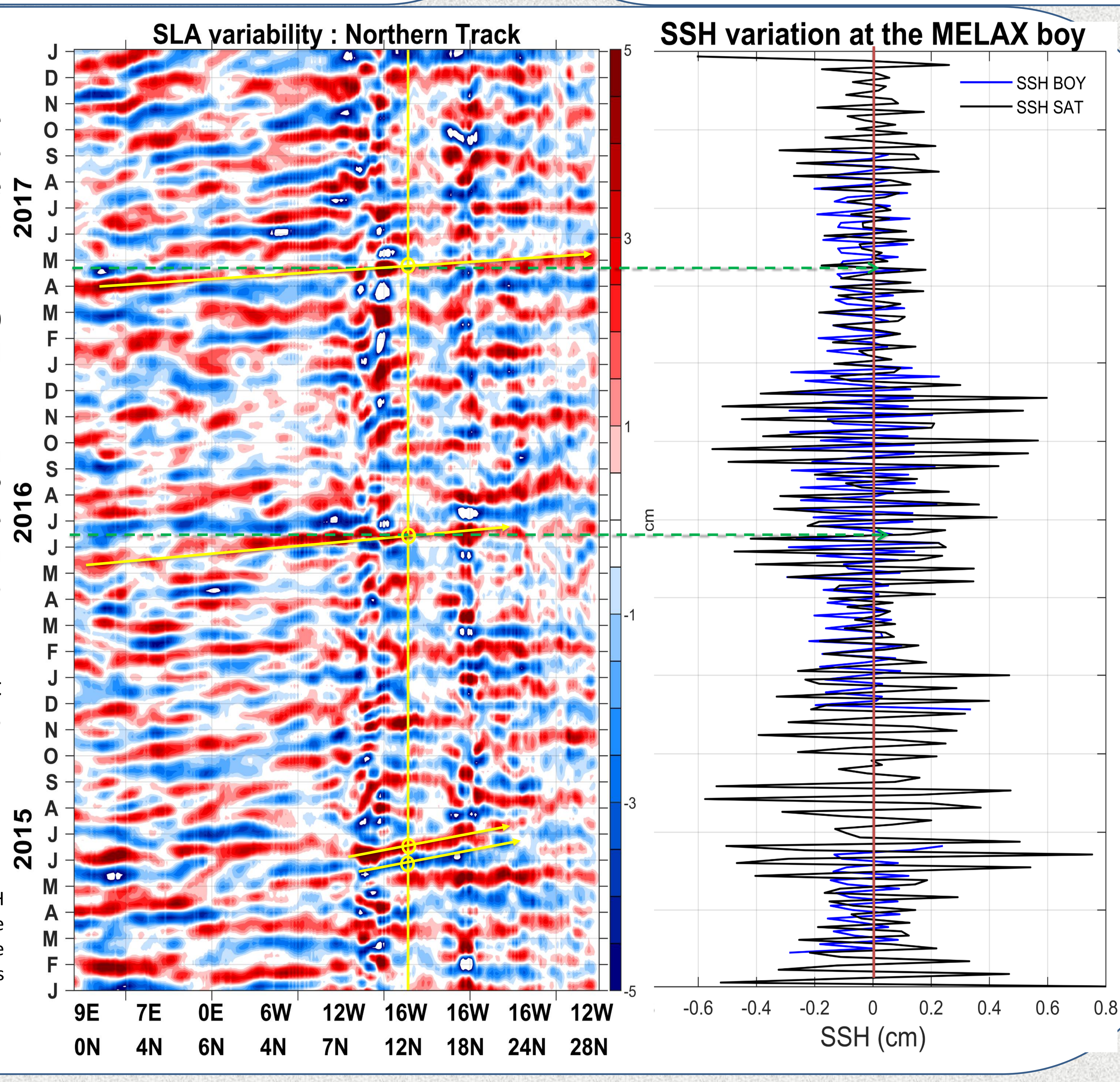

Figure 4: Comparison of the satellite SLA with the buoy SSH anomaly measured by ADCP over the period 2015-2017. The yellow line represents the position of the MELAX buoy and the green arrows respectively highlight the arrival of the waves captured by the buoy and materialize the propagation speed.

4. Conclusion

This presentation focused on intra-seasonal Kelvin waves and their impact on SST in the tropical Atlantic coastal upwelling areas by performing a composite analysis of the boreal winter. This study is performed using satellite observational data for SLA, OISST NOAA, zonal and meridional winds from the ERA5 reanalysis for the period 1993-2018. To study intra-seasonal coastal Kelvin waves, we filtered data such as sea level, sea surface temperature, and finally zonal and meridional wind over the bandwidth in the 20-90 day period. In addition, the regression map allowed us to quantify the relationship between SLA and SST during the winter season at wave passage in the upwelling systems and along the northern coast. Indeed, we note a very strong link between SST and SLA in the upwelling areas with regression coefficients between 0.05 and 0.3 °C/cm. During the propagation of the wave, differences in propagation speed between 1 and 3.4 m/s are observed depending on the season. However, the comparison between the satellite SLA and the ADCP SSH, shows that the MELAX buoy picks up well some intra-seasonal coastal Kelvin wave signals sometimes with an offset of 5 to 7 days up to a maximum of 15 days of offset.

Acknowledgements:

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