# Decadal variability of the Benguela upwelling system with global warming

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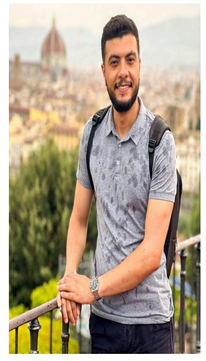

## 1 INTRODUCTION

- Benguela upwelling system **(BUS)** is one of the most productive marine systems in the world.
- Global warming may increase the land-sea atmospheric pressure gradient, intensifying upwelling winds and changing the upwelling process, which could significantly impact the BUS's productivity **(Figure 1)**.

**Aim of the work: Investigating the physical and biogeochemical changes in the BUS over the past 4 decades of global warming.**

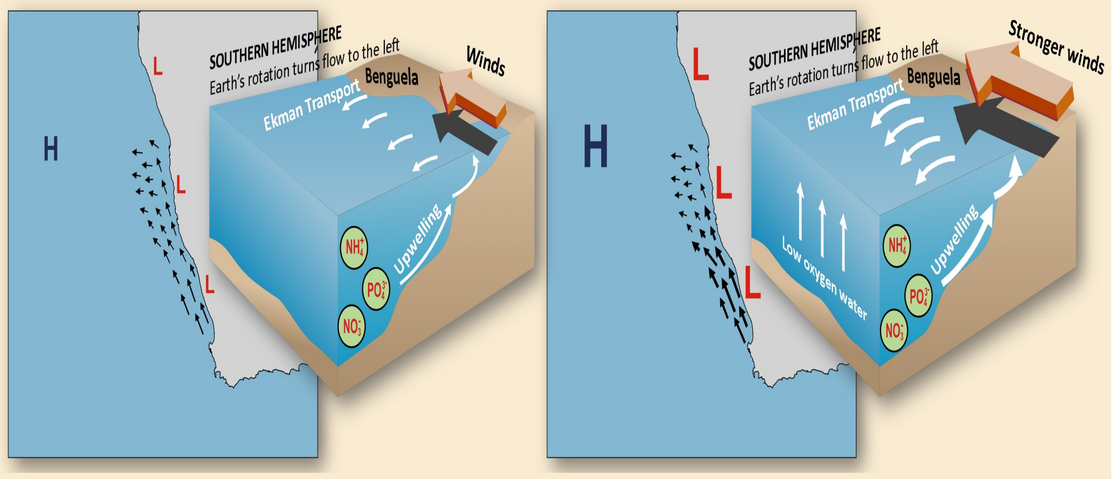


**Figure 1:** Illustrates the potential impacts of global warming on the BUS.

## 2 MODEL SETUP

- A coupled 3D physical-biogeochemical model has been developed based on **NEMO** (Nucleus for European Modelling of the Ocean) and **BFM** (Biogeochemical flux model).
- The model applies an online nesting approach, in which the BUS domain's grid with a resolution of (1/4°) is being nested from a global ocean grid (1/16°) using the nesting tool **AGRIF**.
- **Upwelling indices** were computed, to measure the strength of the upwelling process.

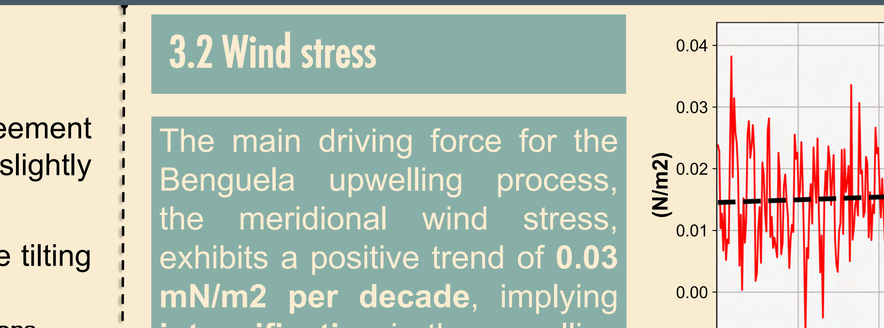


**Figure 2:** Nesting (parent) and nested (child) domain grids

| Parameter | Description |
|---|---|
| Grid | ORCA025 Tripolar grid |
| Vertical grid | 75 Layers |
| Surface Boundary conditions | ERA5 reanalysis |
| Bottom boundary conditions | (Goutorbe et al., 2011) |
| Initial conditions | World Ocean Atlas 2018 |
| Terrestrial runoff | Global Flood Awareness System (GloFAS) |

**Table 1:** Model's configuration

## 3 RESULTS

### 3.1 Model Validation

- Temperature and salinity comparisons demonstrate that there is good agreement between model and observations, although the simulated salinity values were slightly higher than the observed values **Figure 3**.
- The efficient simulation of the upwelling process was evidenced by the noticeable tilting of **isopycnals** in the vertical transect plots.

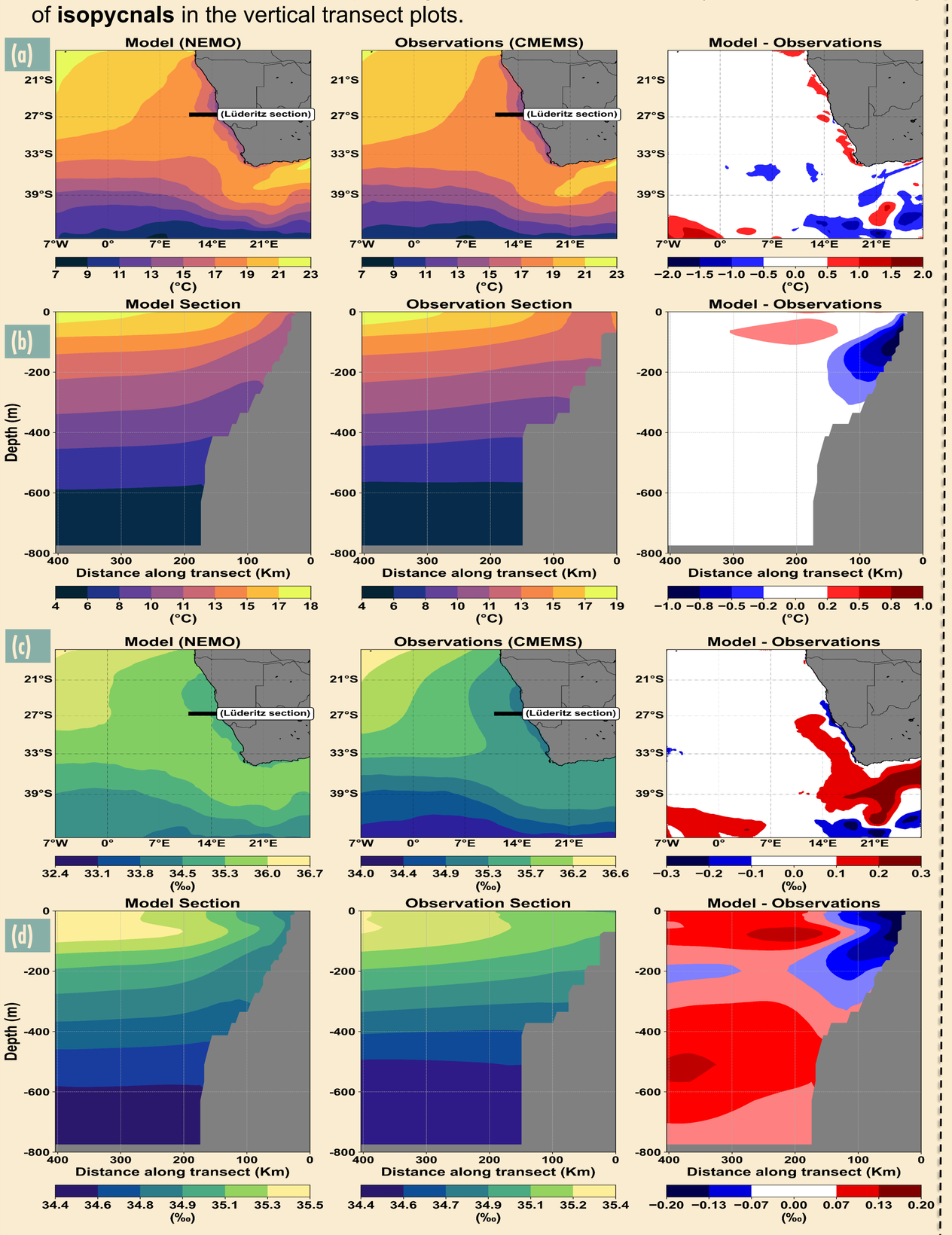


**Figure 3**: Annual climatology of model and observation (**temp and salinity)** over surface **(a and c)**, and over a longitudinal transect **(b and d)** at **(-26.64°S**) and (**11.28°E** and **15.34°E**) and their difference.

### 3.2 Wind stress

The main driving force for the Benguela upwelling process, the meridional wind stress, exhibits a positive trend of **0.03 mN/m2 per decade**, implying **intensification** in the upwelling process over the last **4** decades

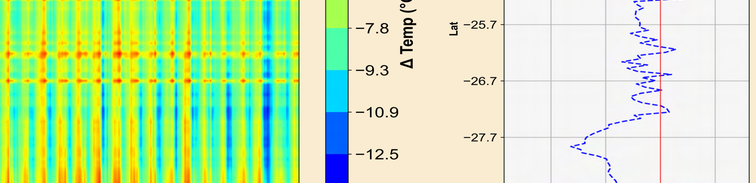


**Figure 3**: timeseries of spatially averaged meridional wind stress over the BUS.

### 3.3 SST upwelling index

Negative trend in the SST upwelling index ΔSST ($SST_{coast} - SST_{ocean}$) indicate a strengthening of the upwelling process, due to the fact that intensified upwelling brings more deep cold water to the surface and lowers SST values.

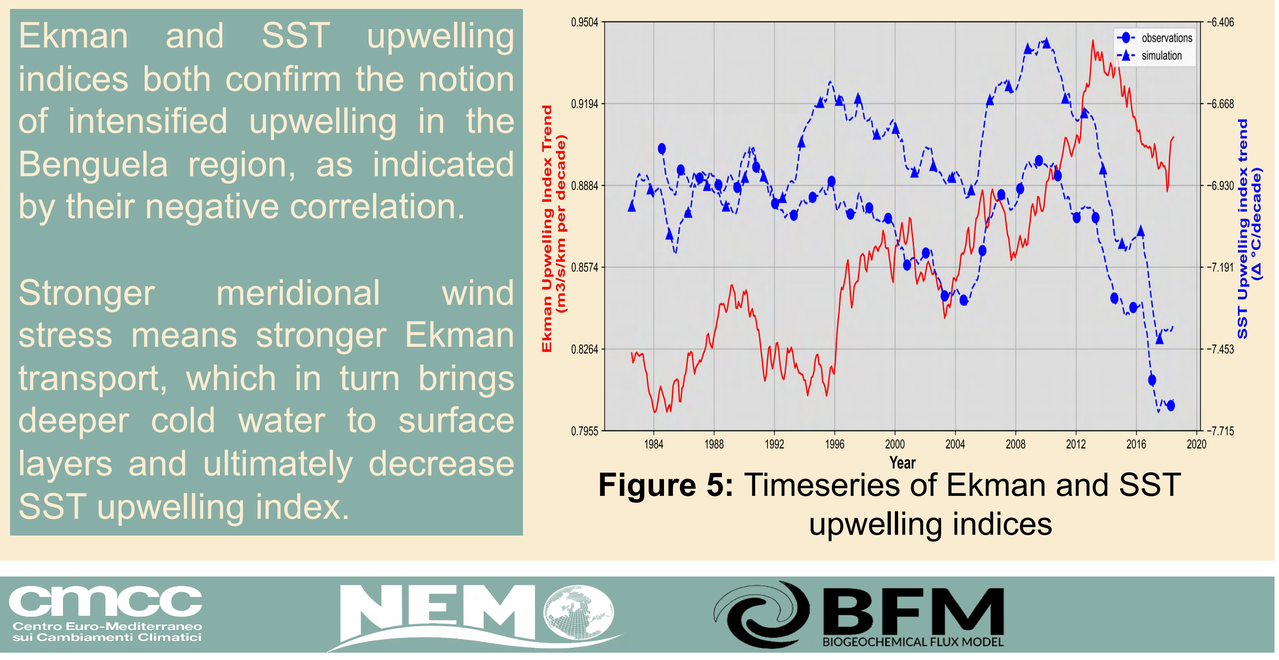


**Figure 4**: **Left** : Zonal Hovmöller diagram of SST upwelling index. **Right** : Trend of the zonal SST Upwelling Index (dashed blue) (1980 – 2020) over the BUS domain.

## 4 CONCLUSION

Ekman and SST upwelling indices both confirm the notion of intensified upwelling in the Benguela region, as indicated by their negative correlation.

Stronger meridional wind stress means stronger Ekman transport, which in turn brings deeper cold water to surface layers and ultimately decrease SST upwelling index.




**Figure 5:** Timeseries of Ekman and SST upwelling indices