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Large-scale atmospheric influence on the physical and biogeochemical properties of the Benguela upwelling system

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The Namibian upwelling region is one of the four Eastern Boundary Upwelling Ecosystems and among the most productive areas in the World Ocean.
Here, upwelling indices have been defined in three ways.
First, by performing EOF analyses of Sea Surface Temperature (SST) observations HadlSST1 and high resolution ocean model simulations (MPI-OM (STORM) and MOM4), driven by meteorological reanalysis. Second, water vertical velocity of STORM and MOM4. Third, the area between the 13°C isotherm and the coastline was used to indicate the intensity of the upwelling.
Correlations with observed atmospheric variables (NCEP reanalysis) over the whole southern Atlantic show which conditions favour upwelling: higher than normal South Atlantic anticyclone, strong and southerly wind/wind stress and pressure and air temperature contrast between ocean and land. Separating the coastal area off southern Africa at Lüderitz (28°S) depicts the differences between the northern and southern Benguela upwelling region. Northern Benguela is characterised by a negative trend in upwelling over the last 60 year, Southern Benguela by a positive one. Furthermore, Northern Benguela upwelling seems to be influenced strongly by the conditions described above while the wind field correlated with the upwelling south of 28°S do not show stronger southerly winds. Additionally, the southern upwelling index of MOM4 is not reflected properly in the corresponding SST field. A reason for this could be an overlaying signal, possibly the advection of warm air from the Indian or the central Atlantic Ocean.
The sea level pressure (SLP) gradient between land and ocean of NCEP reanalysis provide a opposite trend to the one postulated by Bakun ([1]). We did not find an indication for a stronger pressure contrast between land and ocean.
Correlations with indices of El Niño Southern Oscillation (ENSO), the Antarctic Oscillation (AAO) and an index of the tropical Atlantic SST variability. None of these correlations is strong enough to claim a detection of a main driver of upwelling. However, a significant relationship between the summer upwelling and ENSO can be found. The SST-based index is also significantly correlated with the tropical Atlantic. In contrast, the upwelling indices of the vertical velocities show significant correlations with the AAO.
Spectral analysis of the vertical velocity index (STORM) shows especially in summer a clear peak at timescales of 5 years. The longer series of HadlSST1 additionally displays decadal variability.

The oxygen minimum zone in the Benguela region has an important impact on the ecosystem and local fisheries. The content of South Atlantic Central Water (SACW) on the shelf drives the intensity and extension of the oxygen minimum zone. Therefore, the water masses with the STORM and MOM4 simulations have been analysed. The STORM simulation does not contain biogeochemistry and the MOM4 simulation is too short. Thus, the analysis of the water masses, their origin and pathways through the South Atlantic will be analysed with a longer MOM simulation and the MPI run of the Climate Model Intercomparison project 5.

([1]) Bakun, A. (1990). Global climate change and intensification of coastal ocean upwelling. Science, 247:198-201.