The seasonal oceanographic and primary productivity regimes in an upwelling system by remotely forced uplift of the thermocline at the eastern boundary of the tropical Atlantic

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INTRODUCTION

Uplift of the thermocline near the coast induces upwelling of nutrient-rich central waters; and it is this supply of nutrients, which boosts biological productivity.

Upwelling driven by alongshore wind and Ekman transport is the most known upwelling mechanism.

However, near the equator the uplift of the thermocline may also be remotely forced, without a wind action.

This presentation demonstrates that the latter mechanism applies to the Angolan upwelling and describes the associated oceanographic and productivity regimes observed in the water column.
Monthly sea surface chlorophyll climatology for May between 4° and 13°S

Peru

Angola

Chl a mg m⁻³

Modis A mission 2002-2012
http://oceandata.sci.gsfc.nasa.gov
The annual cycle of SST (top) meridional wind (bottom) between 4° - 13°S along the coast

Data source: Risien, C.M., and D.B. Chelton, 2008:
The SST-Wind seasonal covariation patterns in the Peruvian and Angolan upwelling
Equatorial oceanic teleconnection controls the seasonal variability along the tropical southeast Atlantic
The time-latitude plot of the annual cycle of sea level anomaly along the Peruvian and Angolan coasts 

Derived from AVISO merged SLA product 1992-2012

http://www.aviso.oceanobs.com/
The climatology of the Angolan upwelling

Derived from the SST Pathfinder product 1982-2010
Oceanographic and productivity regimes dominating the upper water column in response to downwelling and upwelling propagations.
1) The current regime; A – conditions during downwelling propagation

Depth 26 m

Depth 110 m

Palmerinhas
Kwanza
C. Ledo
C. São Braz
Rio Longa
Tres Pontas
Porto Amboim
1) Current regime; B – conditions during upwelling propagation
2) Current regime: vertical and cross-shelf structure of the current

![Graphs showing current regime](image)
3) Current regime: front between the tropical intrusions and resident waters
4) Thermocline depth and mixed layer structure; A - downwelling conditions
4) Thermocline depth and mixed layer structure; B - upwelling conditions
Productivity regime: (5) Depth of the low oxygen layer
(6) Spatial structure of primary production
6) Spatial structure of primary production
An algal bloom observed on MODIS A image off the Quicombo Bank on 8 May 2008
Productivity regime: (8) patchiness in vertical and cross-shelf zooplankton distribution

March 1998

August 1998

Ostrowski et al. 2009
### Summary of the oceanographic and productivity regimes characterizing the downwelling and upwelling propagations

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<th>Patterns</th>
<th>Downwelling (D1)</th>
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<td>Current regime</td>
<td>Poleward unidirectional flow</td>
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<td>Vertical flow structure</td>
<td>Velocity shear</td>
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<td>Southernmost range low-salinity tropical water intrusion</td>
<td>Large interannual variability</td>
<td>N/A</td>
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<td>Depth of low oxygen layer</td>
<td>50 m +</td>
<td>~20 m</td>
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<td>Chlorophyll max. location</td>
<td>At the thermocline</td>
<td>At the surface In the surf zone</td>
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<td>Thin layers</td>
<td>ISWs-following or random clouds</td>
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THEMA 2

Changes in oceanographic and productivity patterns in response to the variability in the coastal climate
Evolution of sea level anomaly along the Peruvian and Angolan coasts, 1997-2012

PERU

ANGOLA
Wavelet spectra of sea level anomaly along the Peruvian and Angolan coasts, 1997-2012

YEAR	Power(Y,P)/P_{max}

PERIOD (Year fraction)
Variability of downwelling (D1) and upwelling (U1) regimes off Angola 1993-2011

![Graph showing variability of downwelling (D1) and upwelling (U1) regimes off Angola 1993-2011.](image_url)
Conclusions

The Angolan upwelling is induced by the seasonal thermocline departures controlled by an oceanic teleconnection with the equatorial variability.

Periods of downwelling and upwelling propagations are associated with distinct oceanographic and productivity regimes.

The upwelling regime is very stable interannually, in contrast to the downwelling regime, subjected to strong interannual variability controlled acute (1-2 month long lasting and typically warm) events that recur every few years.

Changes in distributional patterns and biomass of coastal tropical fish unlikely to vary with environmental conditions observed during an upwelling, as those are very stable each year; but, rather, will depend on conditions the stock endured during downwelling events preceding such an observation.