From Physical Mechanisms to Natural Fluctuations of Small Pelagic Fishes: The Angolan Upwelling Scenario

by

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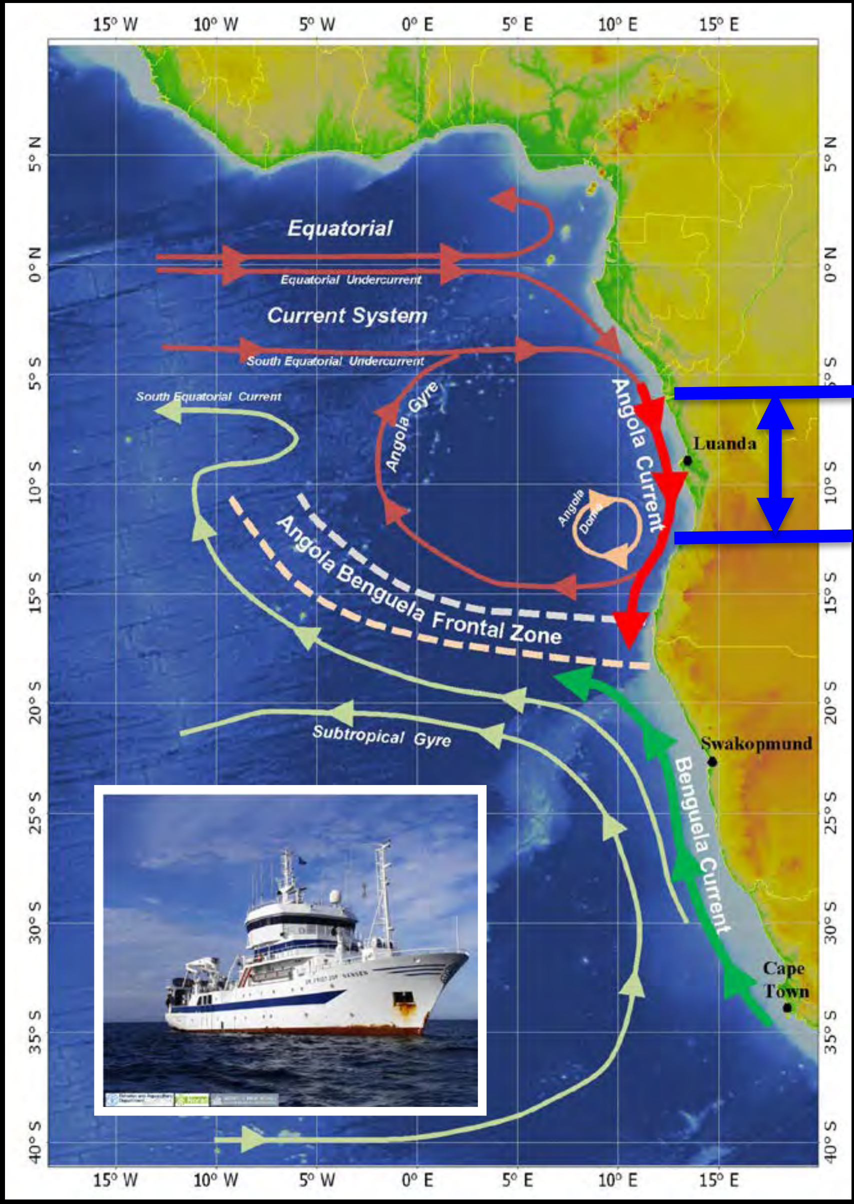
IFM-GEOMAR



NANSEN PROJECT

Outline

Upwelling mechanisms

1) What type of upwelling dominates in the tropical sector off Angola 6°-12°30'S?

2) The annual cycle of oceanography and SPF habitats inferred from satellite and in situ data

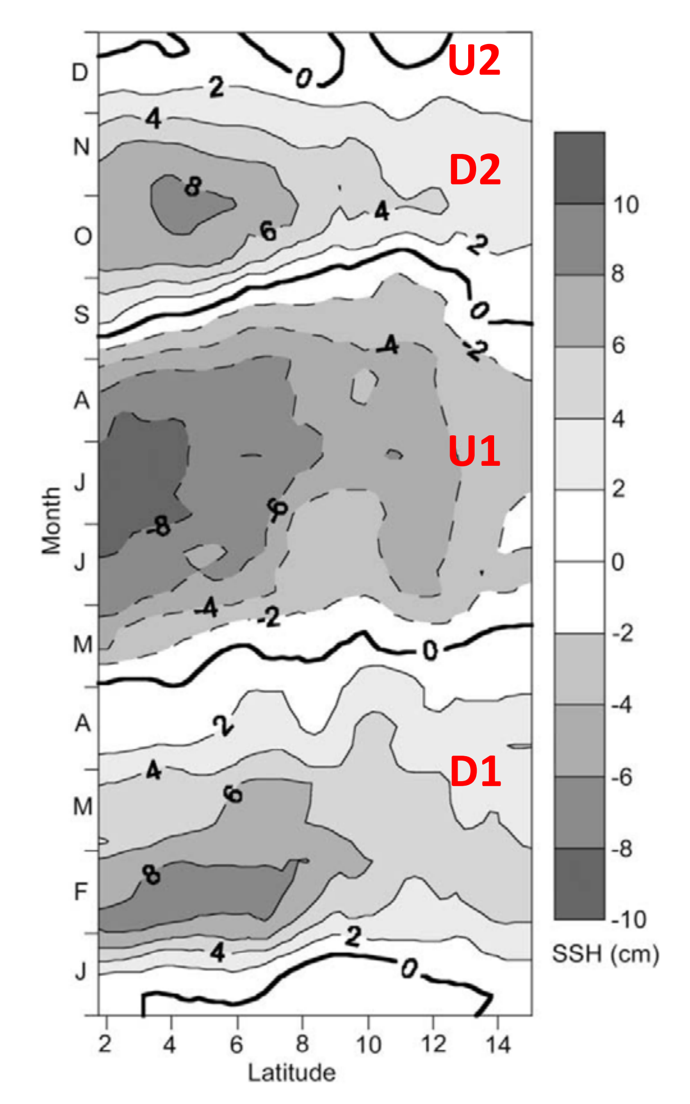
Angolan Sardinella and Climate

3) Warming of the coastal climate and interannual events 1982-2014 inferred from satellite data

4) The changes in the distribution pattern and length structure *of sardinella spp.* from acoustic surveys 1991-2014

5) Strength of the interannual warm events, the Benguela Niños vs. changes to the southern range of the sardinella stock. Is there a correspondence?

Towards understanding the role of Tropical Atlantic Variability (TAV) and Coastally Trapped Waves (CTW) in controlling the coastal upwelling in the ATUR.



Hutchings et al. (2009)

Picaut (1983): the first observational evidence of remotely forced propagations as the source of the Angolan upwelling (pressure sensors and bucket temperature at coastal stations).

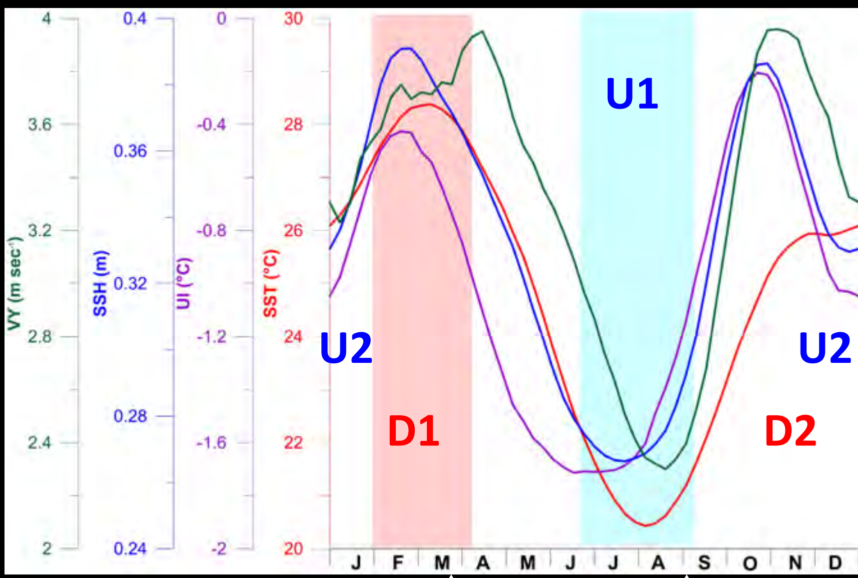
Schouten et al. (2005): description of the semi-annual cycle of upwelling and downwelling propagations along the Angolan coast from altimetry.

Florenchie et al. (2004): connecting the subsurface temperature fluctuations along the Angolan coast to the Benguela Niños – the remotely forced interannual events that outcrop to the surface at the ABF.

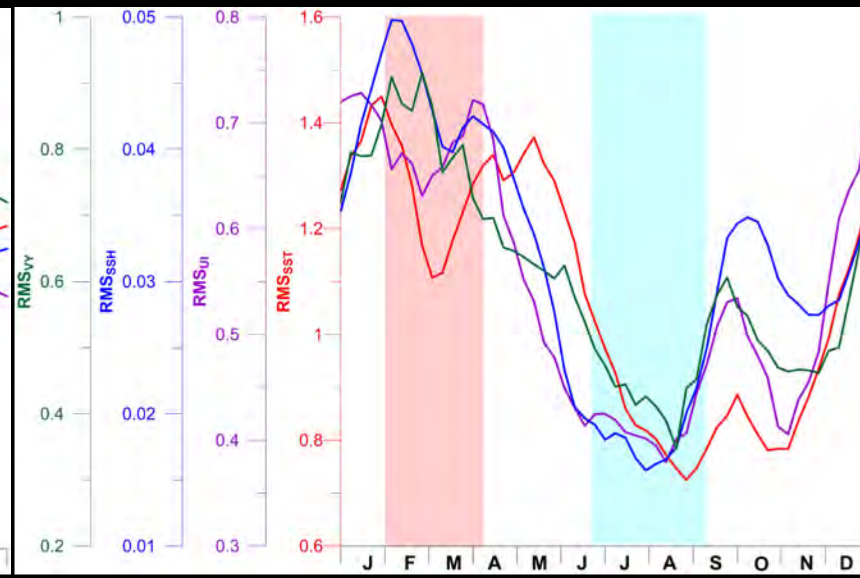
Hutchings et al. (2009): identifying the remotely forced Angolan upwelling area as a distinct component within the Benguela Ecosystem.

The satellite derived variability nearest the Angolan coast, averaged over the latitude range 6°30’-12°30’S:
The mean seasonal cycle and its interannual variability: SST (blue), UI (violet), SSH(blue)
, meridional wind (green)

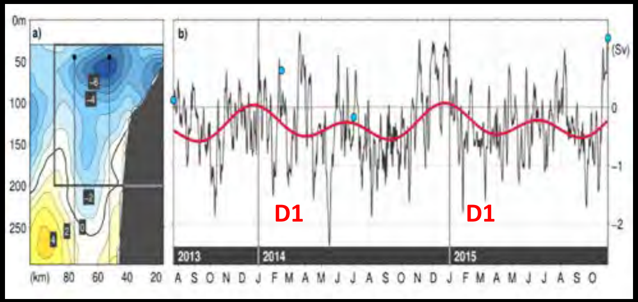
The mean seasonal cycles



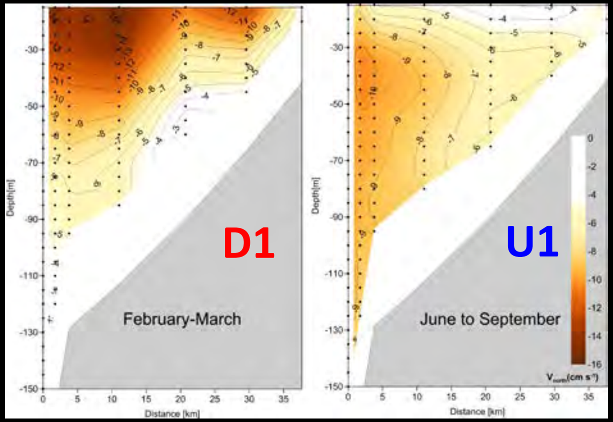
The interannual variability (RMS of seasonal cycles)



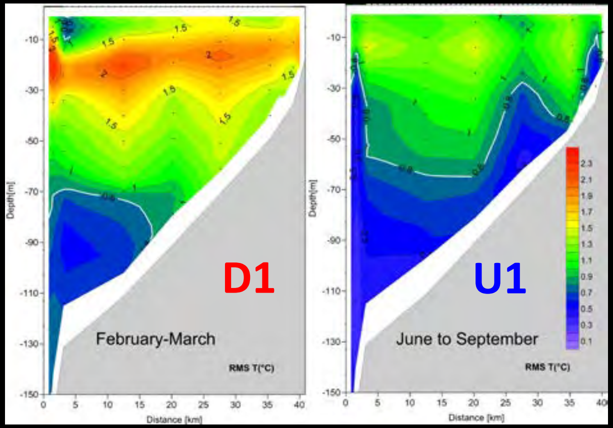
The time series of in situ oceanographic data collected with the RV Dr. Fridtjof Nansen – **the EAF Nansen Oceanographic Dataset** – covers D1 and U1 CTD during 1985-2015, ADCP 2005-2015, fluorescence 2008-2015.



Transport across 11°S, 2013-2015 (Kopte et al. 2017)



Mean alongshore current 2005-2015, during D1 and U1



RMS of temperature 1985-2015, during D1 and U1

Transport estimate at 11°S, across the shelf from a combined mooring result (2013-2015) and a repeated ADCP section data

- Southward transport dominates
- Intraseasonal and semiannual variability
- D1, D2 southward Angola current (AC) accelerates
- U1, U2 AC subsides or reverses

Kopte et al. 2017

Cross-shelf structure of the current (average of 2005-2014 ADCP):

- D1 Surface intensified "El Niño-like" current extends inshore
  Northward undercurrent along the cont. slope.
  Vertical shear very strong

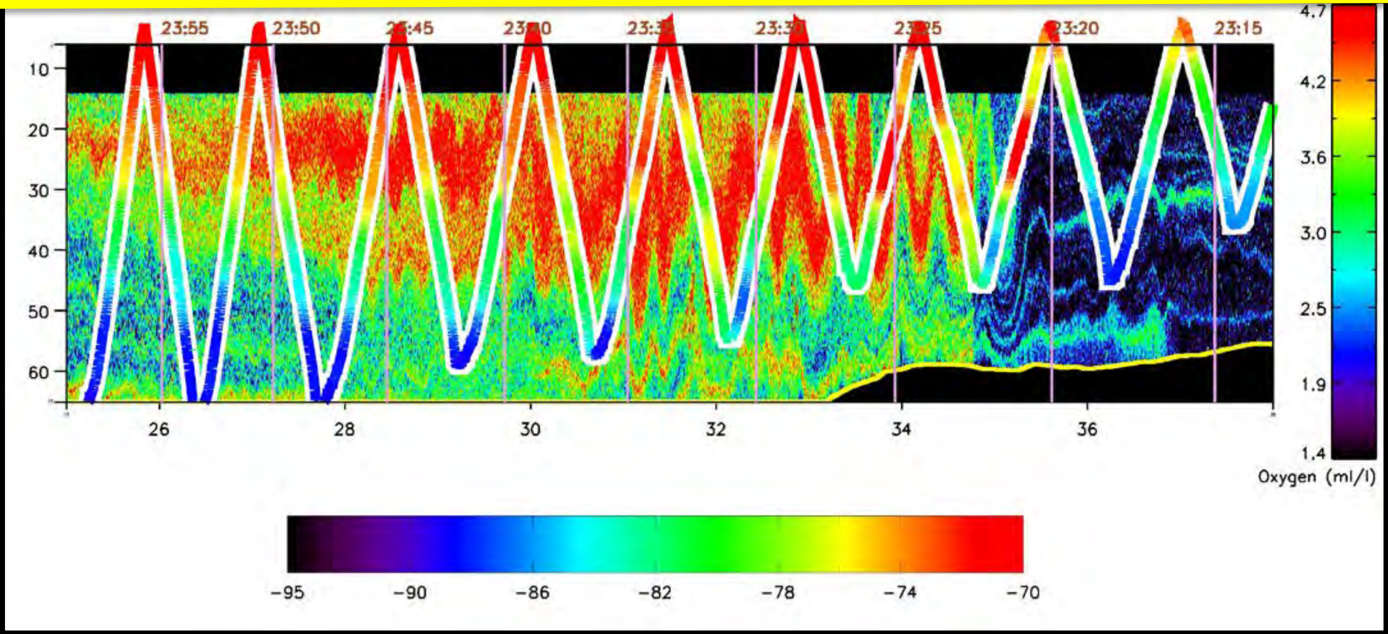
- U1 The core of the AC above the shelf break.
  Weak southward or reversed (northward) current inshore
  Vertical shear weak

Interannual variability (IV – RMS of 1985-2014, CTD data):

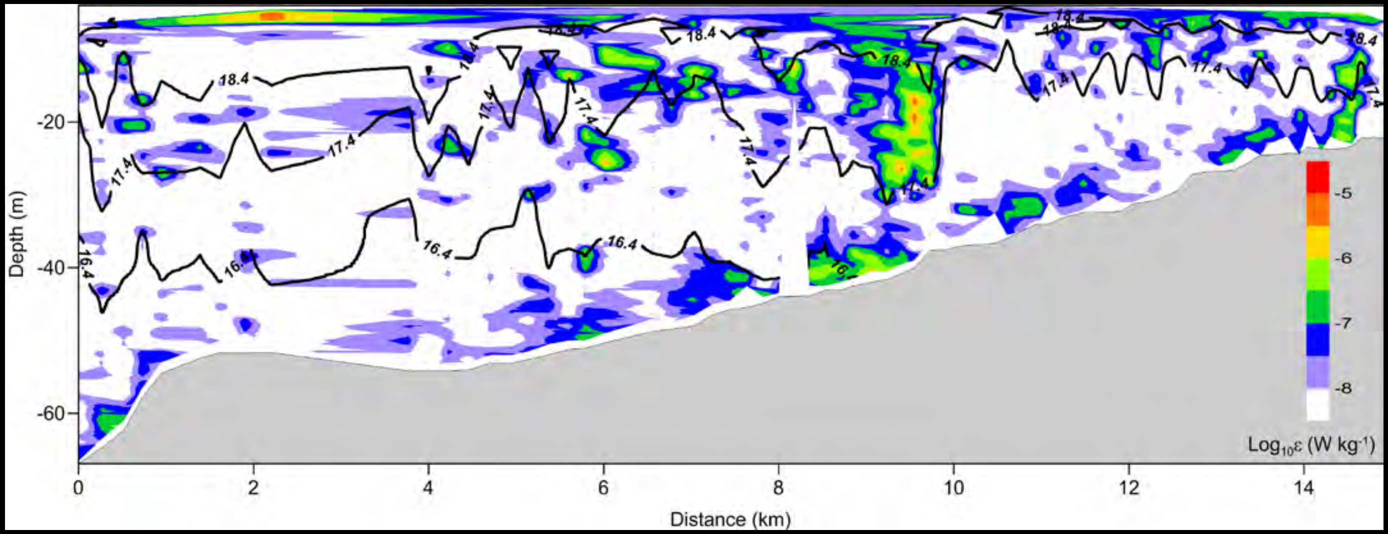
- D1: the strongest IV the thermocline – due to the IV the first mode baroclinic CTW: the cause of the Benguela Niños; the lowest IV is below the 70 m depth of SACW during that season.

- U1: low IV near the bottom expands to a 30 m depth range due to the upwelling CTW induced uplift of SACW. This results in low oxygen and high nutrient concentrations near the bottom without the wind action.

An enrichment mechanism observed on the inner shelf: persistence of internal waves (IW) during U1, enrichment in regions of their IW breaking.



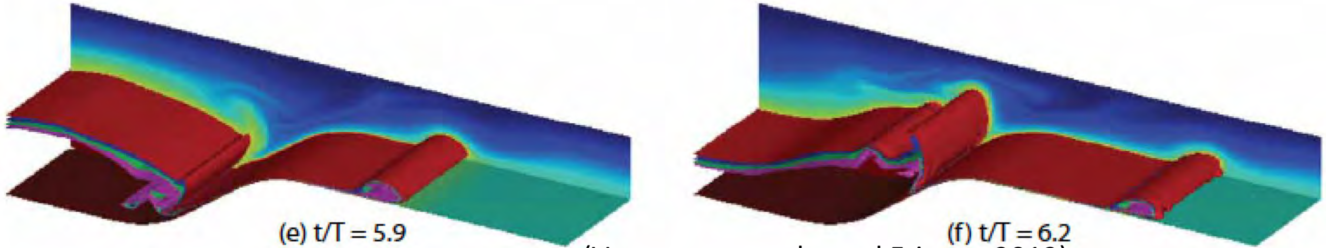
An acoustic record (in the background) showing an internal wave train breaking with a trace of an undulated CTD showing oxygen concentration. At the IW breaking front a larger portion of the column is occupied in with with low in oxygen (and rich in nutrients) SACW.



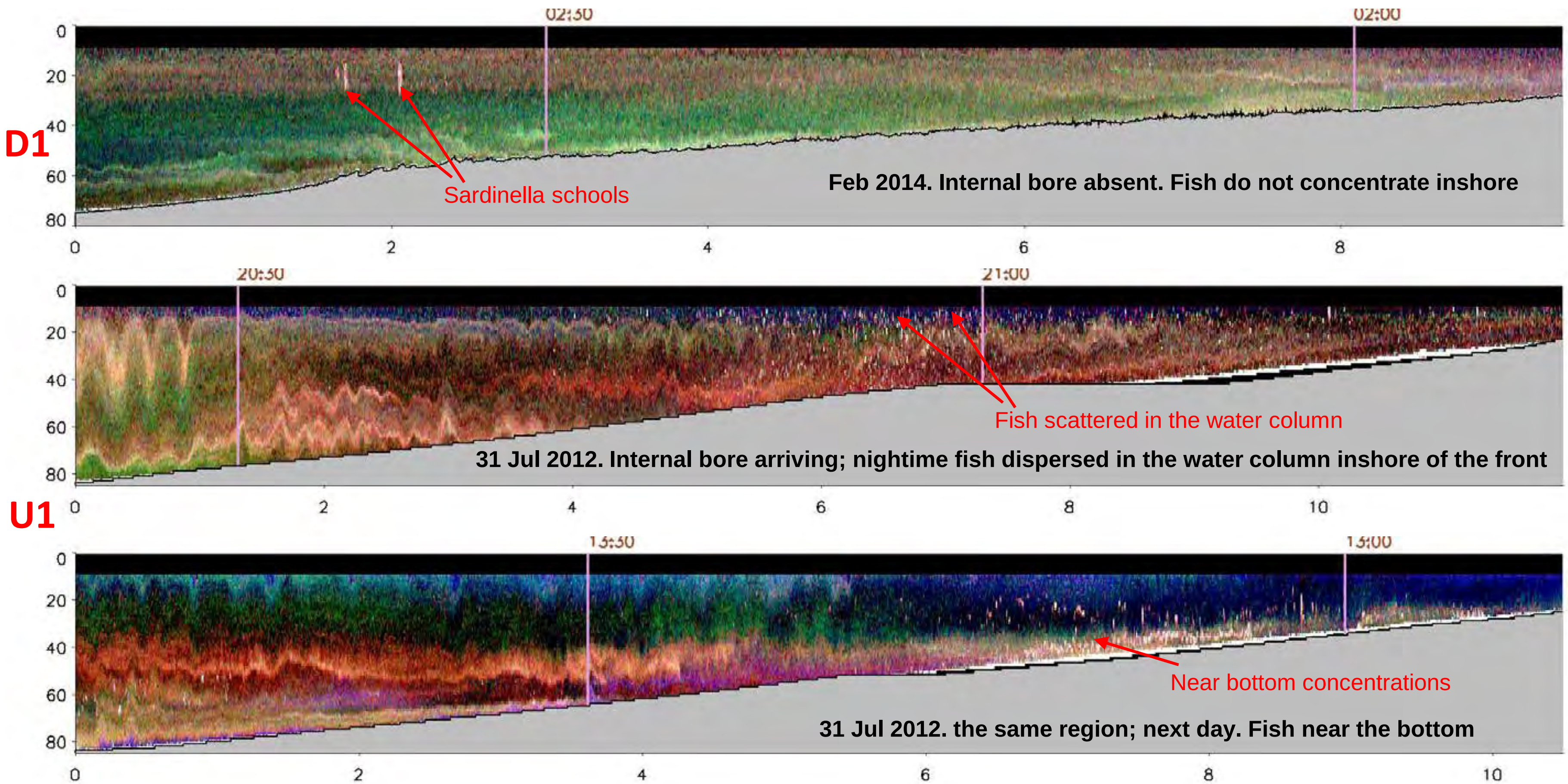
Kinetic energy dissipation rates averaged over several microstructure casts increase to 10^{-5} W kg^{-1} suggest an intense mixing at the region of IW breaking

The nonlinear internal waves are a ubiquitous physical feauture in the ATUR during U1: Ostrowski et al. 2009

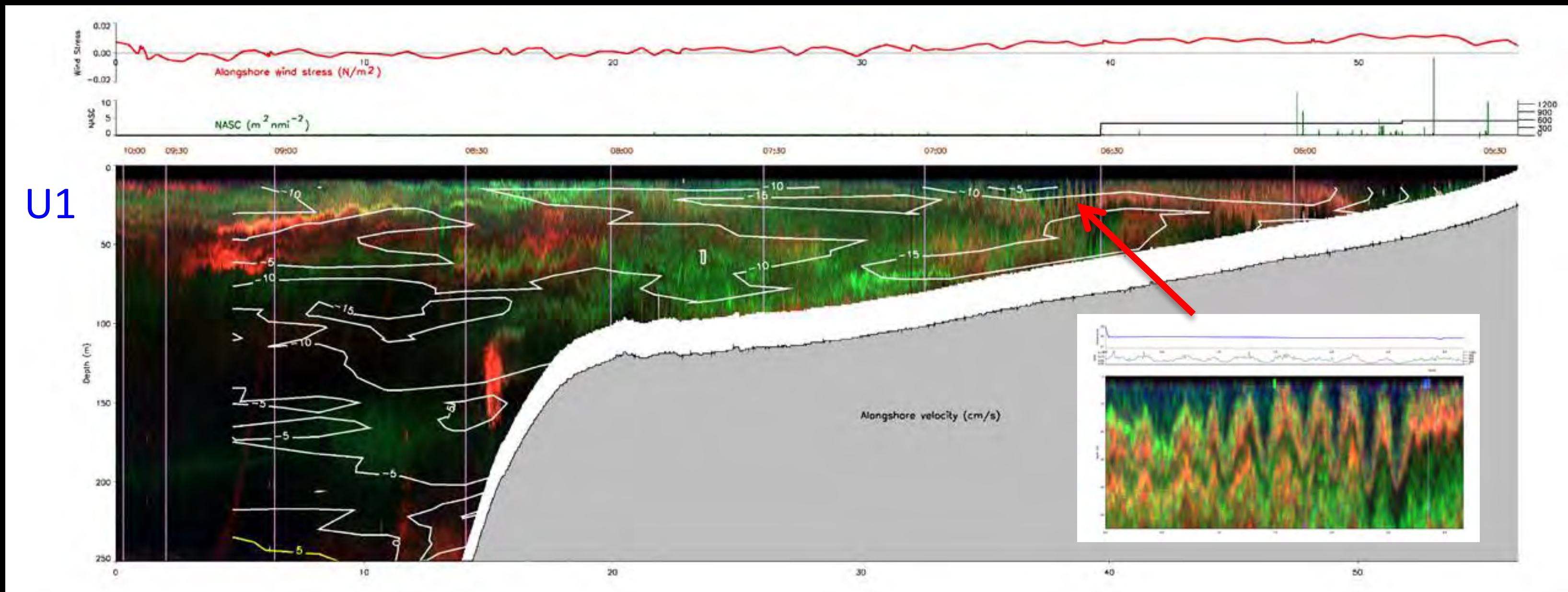
Concentration of small pelagic fishes at the front associated to a collapsing internal bore as visualized by multi-frequency acoustics



(Venayagamoorthy and Fringer, 2012)



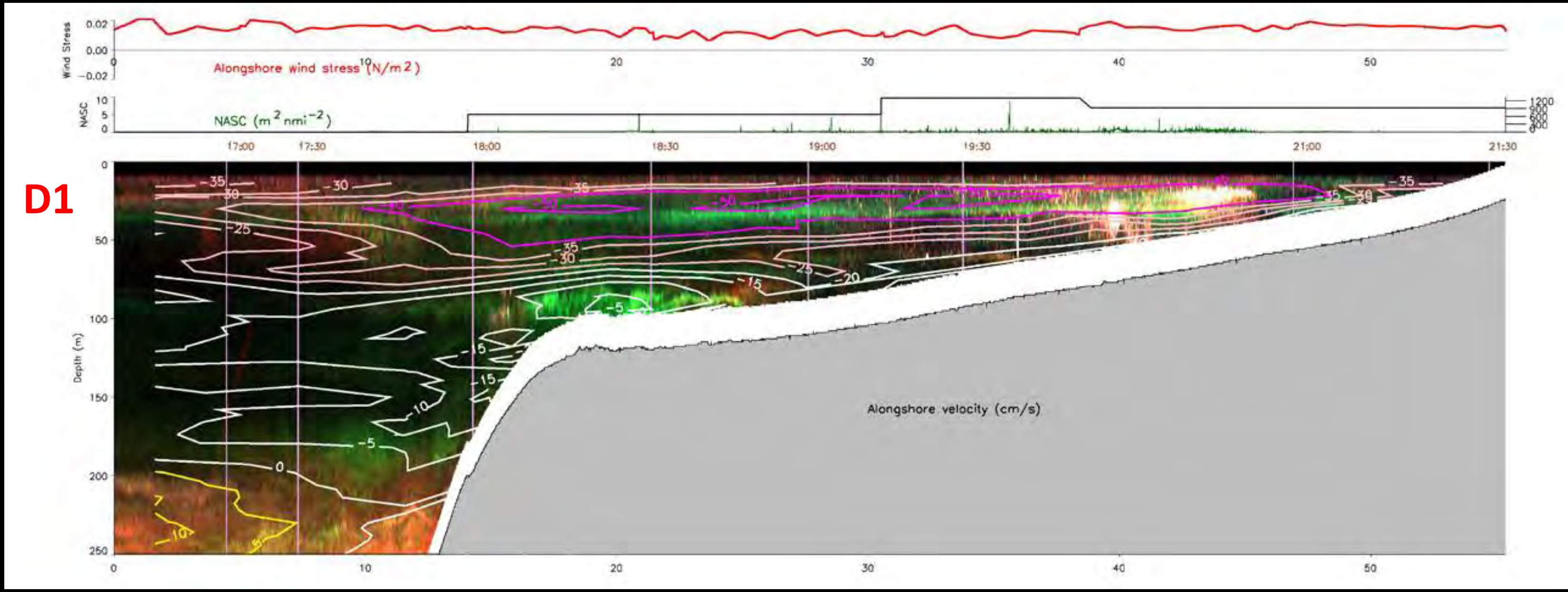
Macro-zooplankton, micronecton and fish responses to the ISWs driven regime during U1



Thin scattering layers are entrapped within the strongly fluctuating thermocline and entrained in ISWs propagations.

Sardinella tends to be confined within the inshore productivity areas where ISWs break

Macro-zooplankton, micronecton and fish responses to the vertically sheared regime during D1



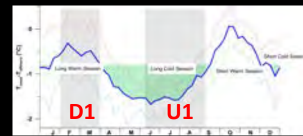
Thin zooplankton layers associated with the shear of the current

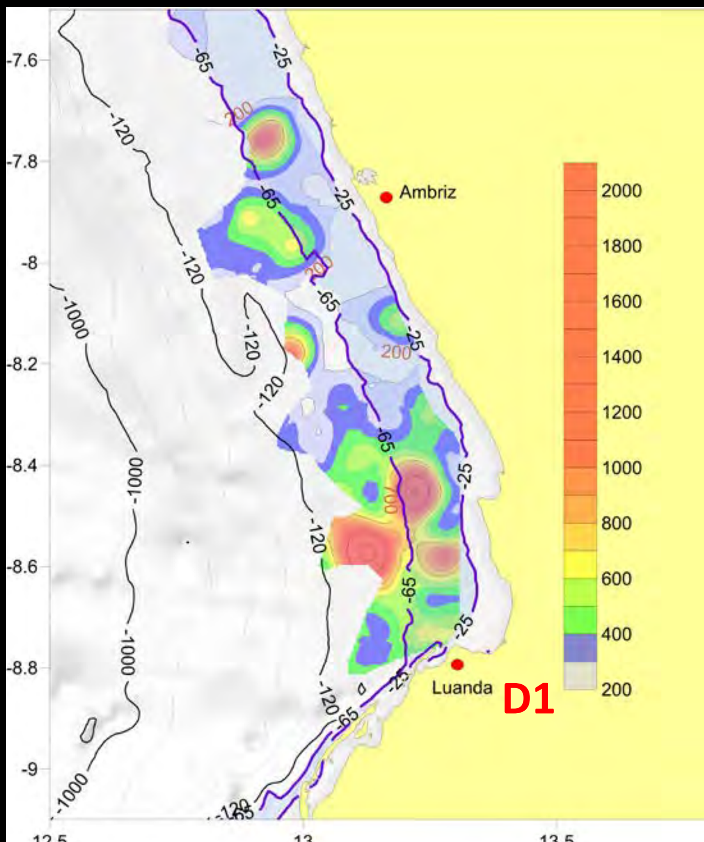
Stacey et al. 2007

Sardinella tends to to be widely distributed across the shelf

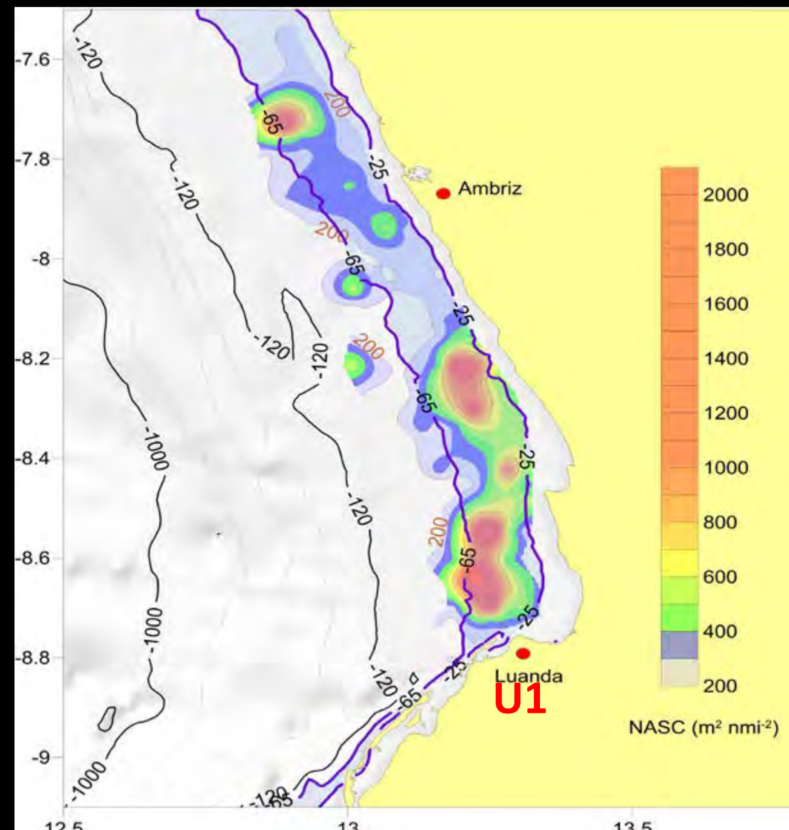
Ambriz on 3 Feb 2014

The offshore ranges of the acoustically derived distributions of *Sardinella spp*. respond to the the D1 and U1 regimes





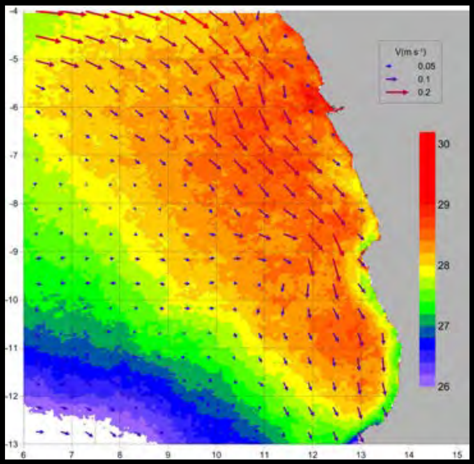
February-March



June-August

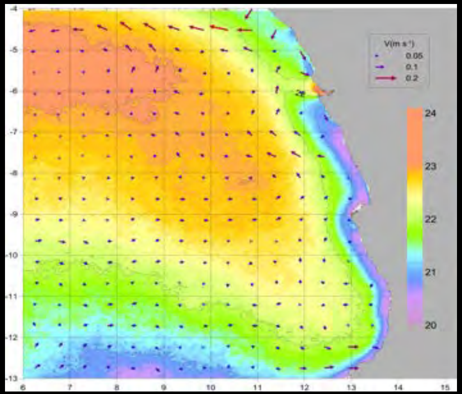
SUMMARY 1: The annual scenario of the SPF habitat in the CTW controlled Angolan Tropical Upwelling Region

D1, D2:

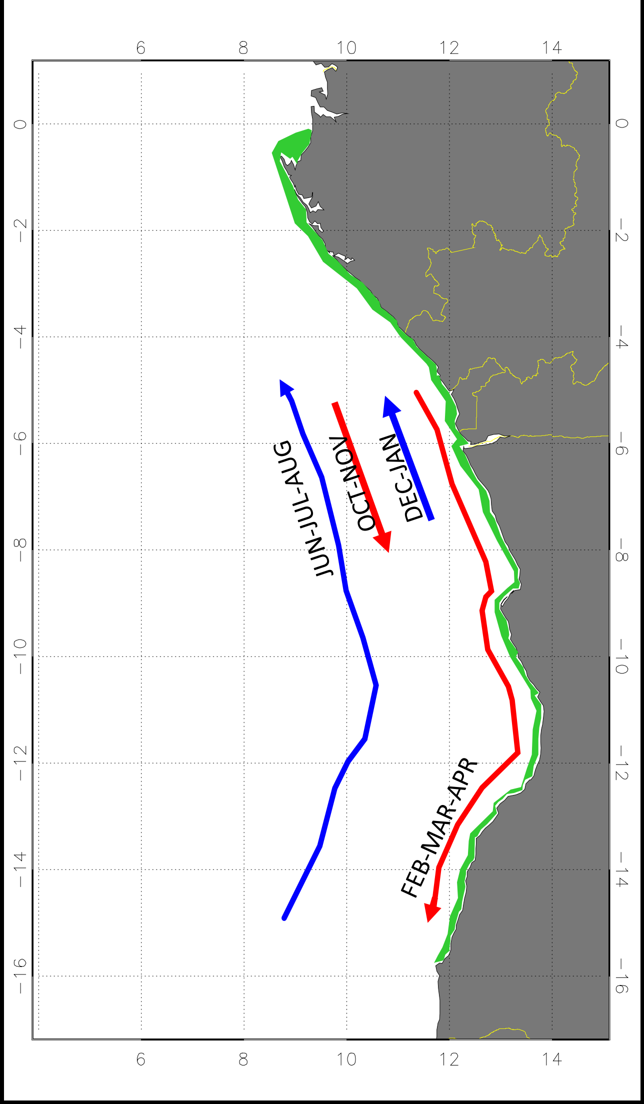


Favors transport habitat; offshore foraging, larval transport and adult fish migration with the persistent current to the south.

U1, U2:

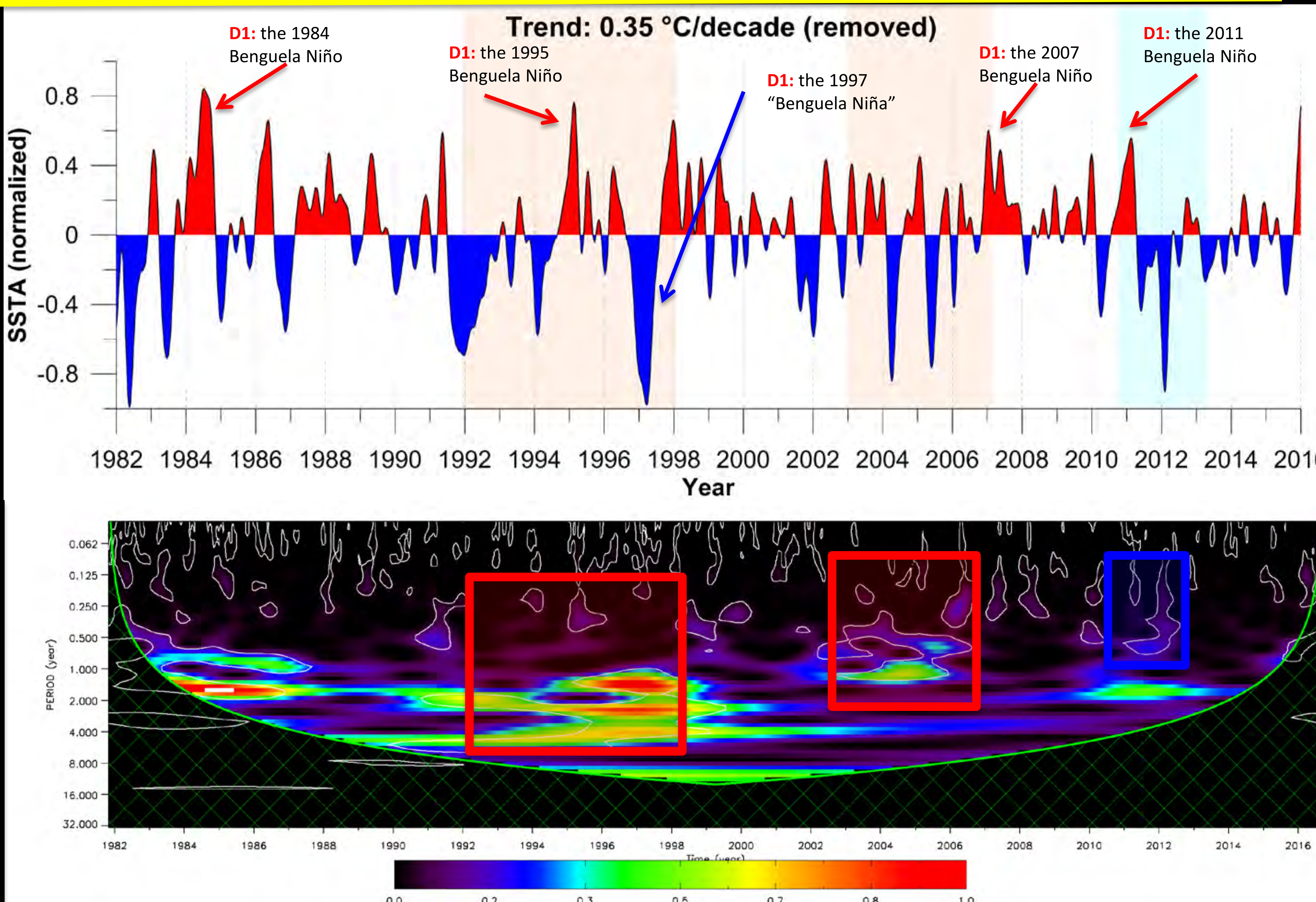


Favors spawning habitat; Inshore foraging, retention of spawning products within The inshore areas. Weak southward to northward currents, particularly inshore, are favorable to natal homing migration of the adults towards the north



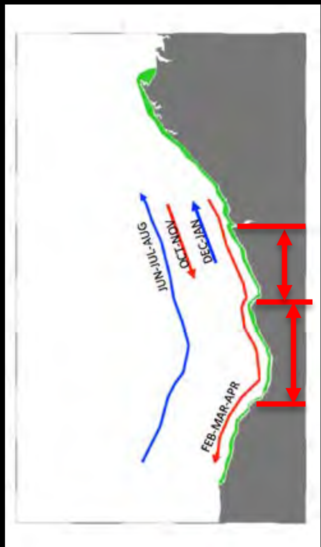
Adapted from Boley and Freon 1980, after Ghéno and de Campos Rosario, 1972

Evolution of the weekly SST anomaly nearest to the Angolan coast (8-16 km), 6°-12°30'S and periods of largest disturbances



the method: Torrence and Compo (1998)

The synchrony between the strength of remotely forced circulation and intensity of the seasonal migration of sardinella along the the Angolan coast was observed in 1970s to 1990s.



Adapted from Boley and Freon 1980,
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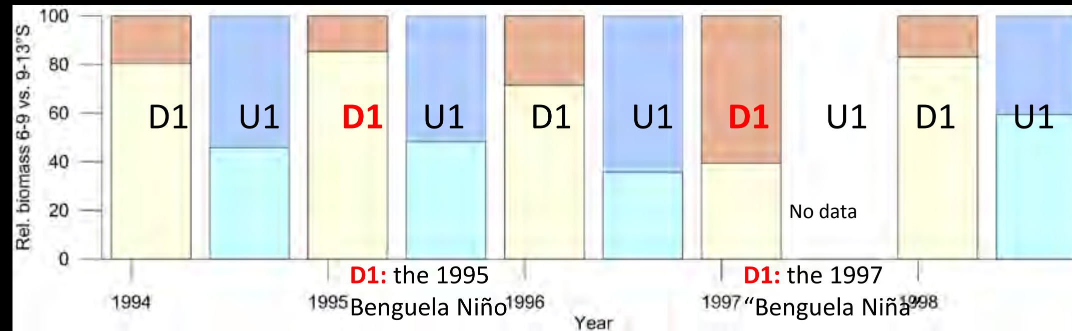
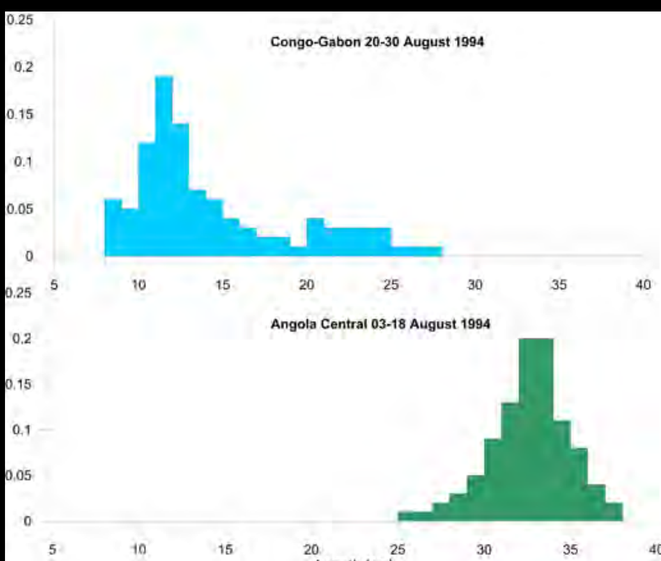
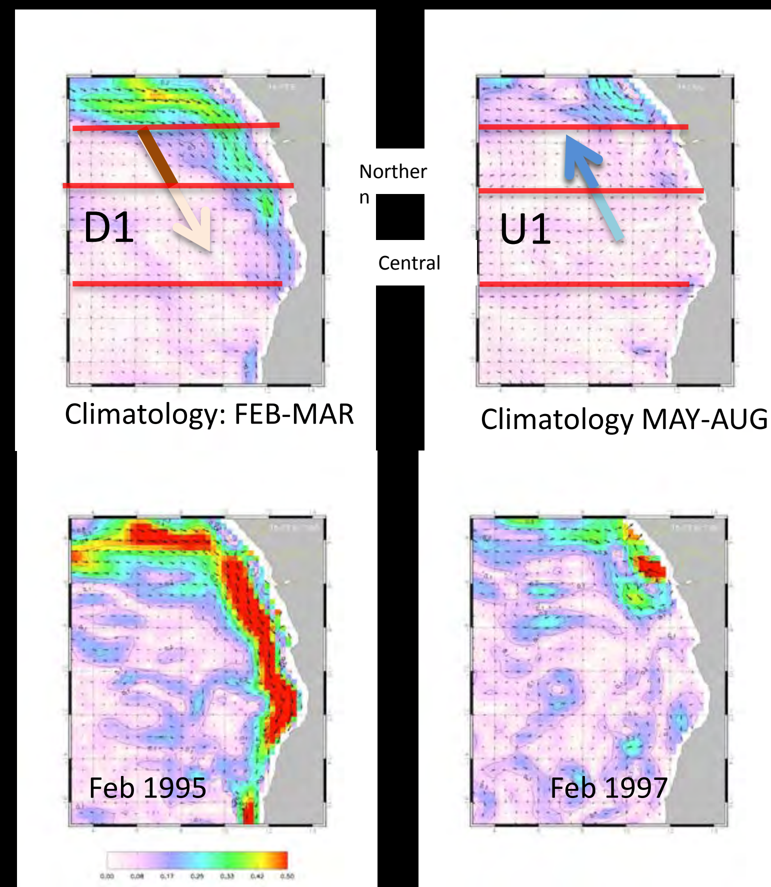
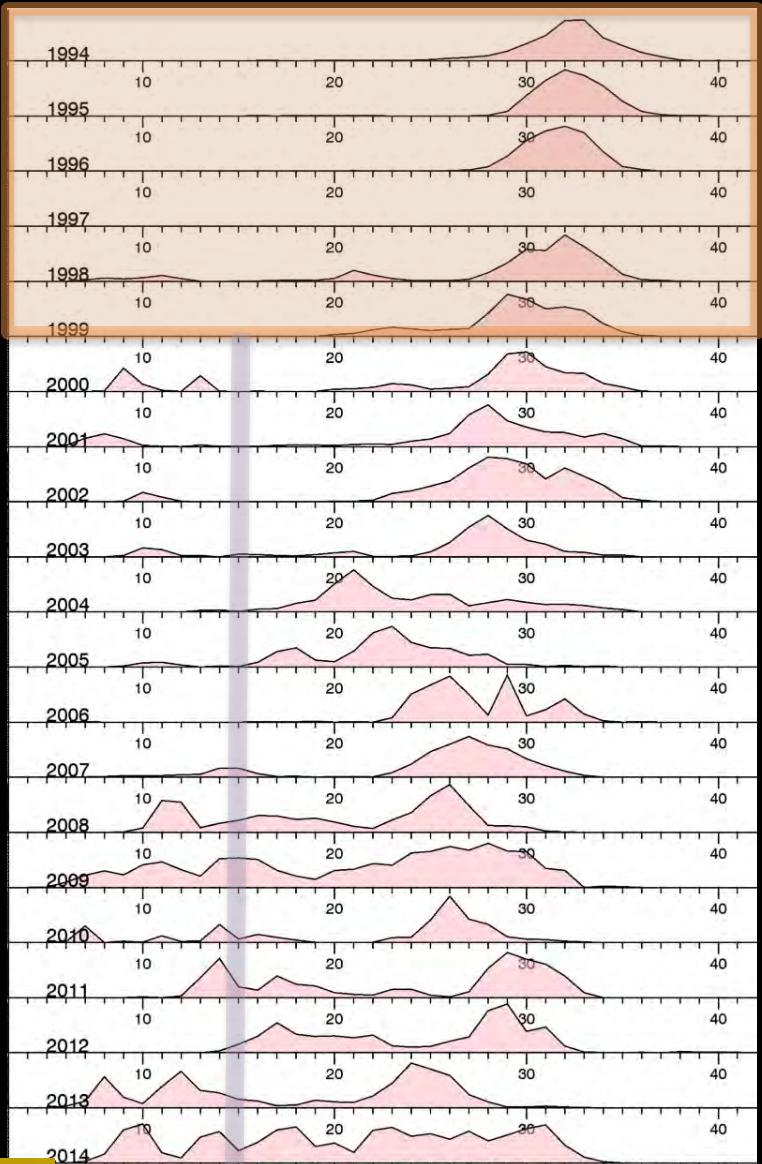


The percentage of sardinella biomass to the north (top) and south of Luanda(bottom) regions during D1 and U1 surveys, with Dr. Fridtjof Nansen 1994-1998

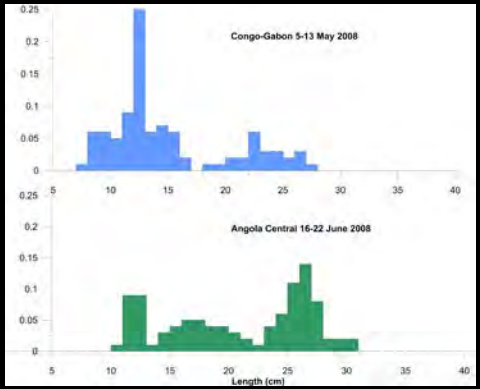


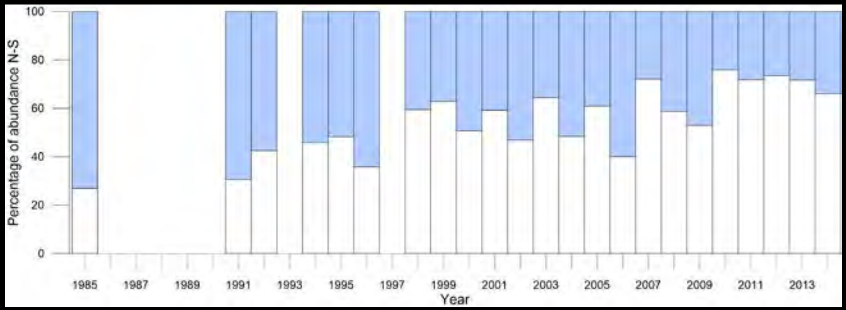


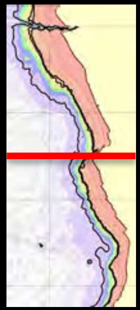
Following 1998 , the Dr. Fridtjof Nansen trawls started to record juvenile sardinella species in Angolan waters, suggesting a decrease in the spawning migration to the Gabon-Congo region and development of local spawning areas off Angola, particularly for flat sardinella to the south of Luanda.



Comparing the length structure between fish caught off the Gabon Congo region with those caught of Angola between the 1990s and more recent surveys indicate that following the late 1990s warming the Angolan upwelling region has become a new spawning/nursery area for the southeastern Atlantic stock of flat and round sardinella.

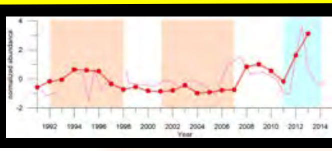




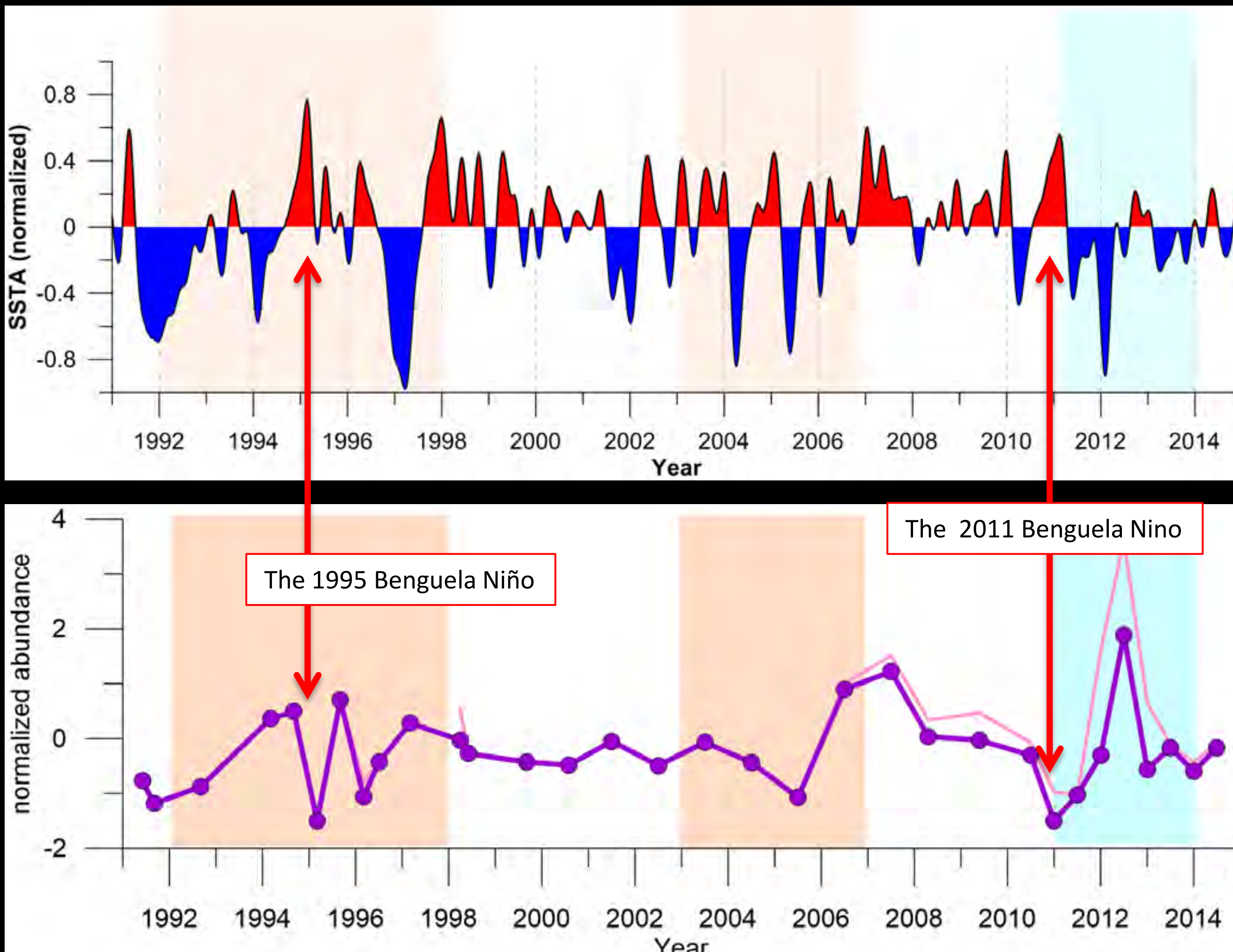


Changes in relative biomass between the north and southern region of the ATUR, 1985-2014 , winter surveys only

Patterns of correspondence between SSTA 8-16 km from the Angolan coast and evolution of *sardinella spp*. biomass index by acoustic surveys with RV Dr. Fridtjof Nansen 1992-2014



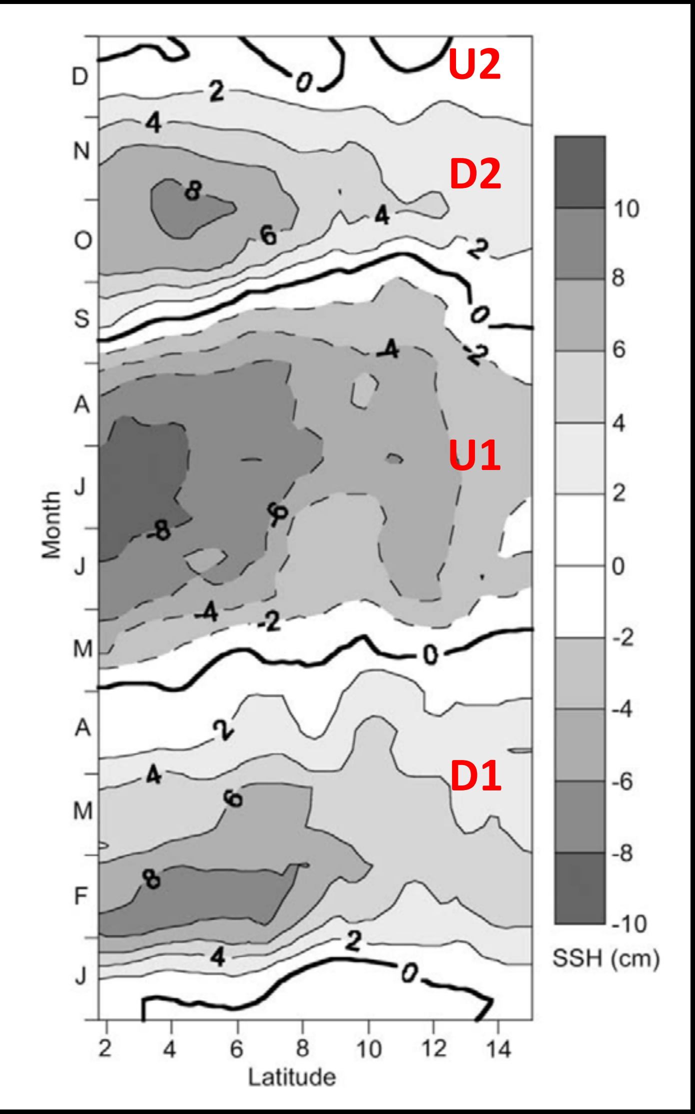
Biomass index by acoustics vs. landings by the Angolan industrial fleet



Benguela Niños

- drop in the estimated biomass
- For 1995 BN the estimate returned to the previous level the half year later
- For 2011 BN it took it one year to rebound.
- A huge increase in the estimated biomass in the wake of the 2011 BN. It coincided with a prolonged cooling 2012-2014.
- Long term effect: Juvenile sardinella started appearing in the Nansen trawls after 1999, coincident to a strengthening of the annual cycle in SST.

Summary 2: Benguela Niños and evolution of sardinella



Passage of coastally trapped propagations (CTW) along the Angolan coasts induces the similar warm and cold water column scenarios to those known from the passage of El Niño/La Niña scenarios along the Pacific Coasts, e.g. Huyer et al. (2002), Kosro (2002) but the difference is that off Angola these scenarios are locked to the seasonal time-scales.

The largest interannual variability falls on the austral summer and autumn. Warm events, the Benguela Niños, affect the SPF habitat of Angola by inducing particularly strong downwelling and southward current episodes that shut down productivity from the inshore fish habitats, enforce the alongshore poleward transport.

Benguela Niños episodes are found to affect biomass estimates of sardinella by acoustic surveys. Southward shifts of its distributional range and drop in the estimated biomass were observed. However, these changes were transient, rebound to the previous state within one season or year. The population structure was not affected.

Both flat and round sardinella did well in connection to the warming observed in the Angolan waters during the last two decades. Its biomass increased, while spawning and nursery grounds were expanded to the south of the Congo River.


THANK YOU