Tropical Atlantic Variability And Fluctuations of Small Pelagic Fish off Angola: The Remotely-forced Upwelling Scenario

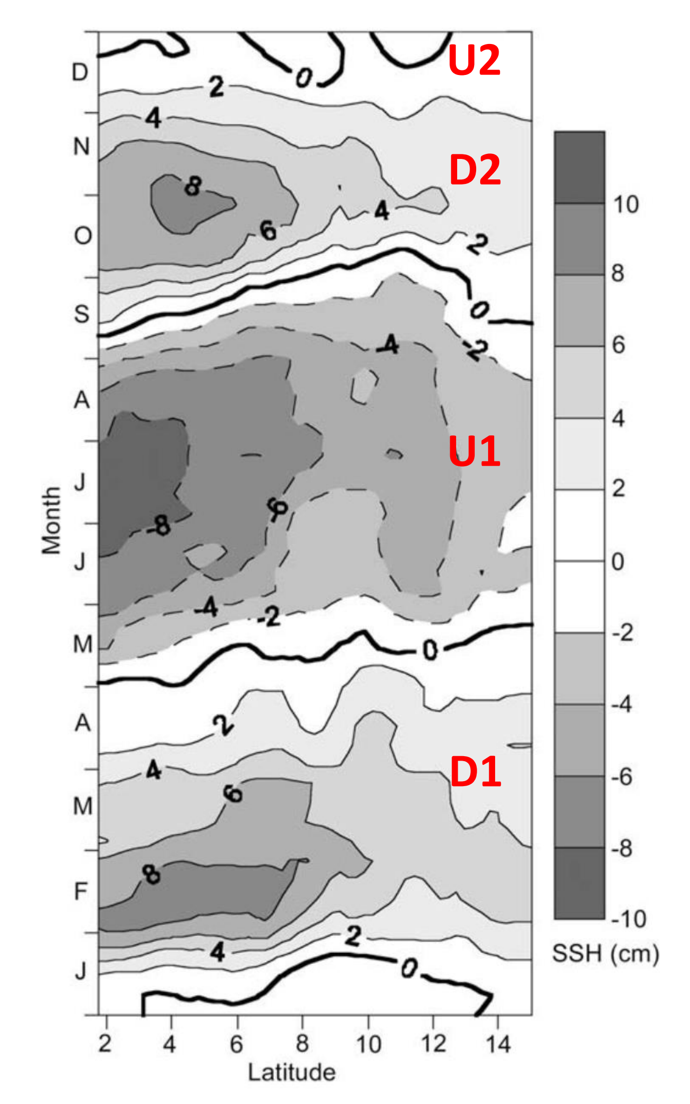
Marek Ostrowski[1] and Antonio Barradas[2]

PREFACE-PIRATA-CLIVAR Tropical Atlantic Variability Conference
November 28th-December 1st 2016, Paris

[1]Institute of Marine Research
Bergen, Norway

[2]Instituto Nacional de Investigaçaõ
Pesqueira Luanda, Angola

Path towards understanding the role of TAV in controlling the coastal upwelling off the tropical Angola sector.



Hutchings et al. (2009)

Picaut (1983): the first experimental evidence of remotely forced propagations as the source of the Angolan upwelling.

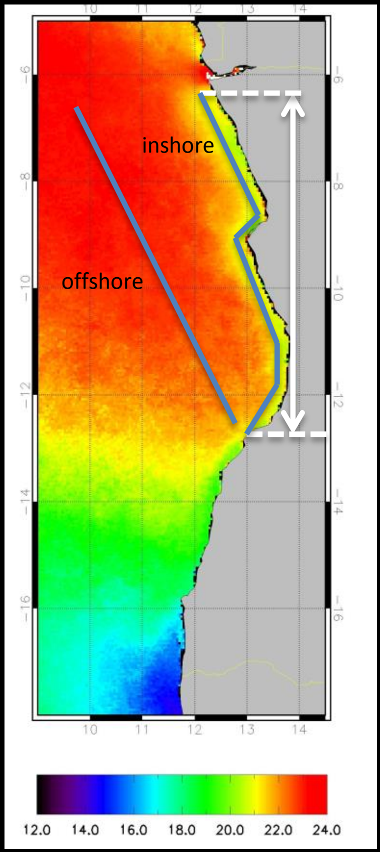
Schouten et al. (2005): description of the semi-annual cycle of upwelling and downwelling propagations along the Angolan coast from altimetry.

Florenchie et al. (2004): connection of 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): formulation of the remotely forced Angolan upwelling 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 seasonal cycle (by canonical averaging of the weekly data)

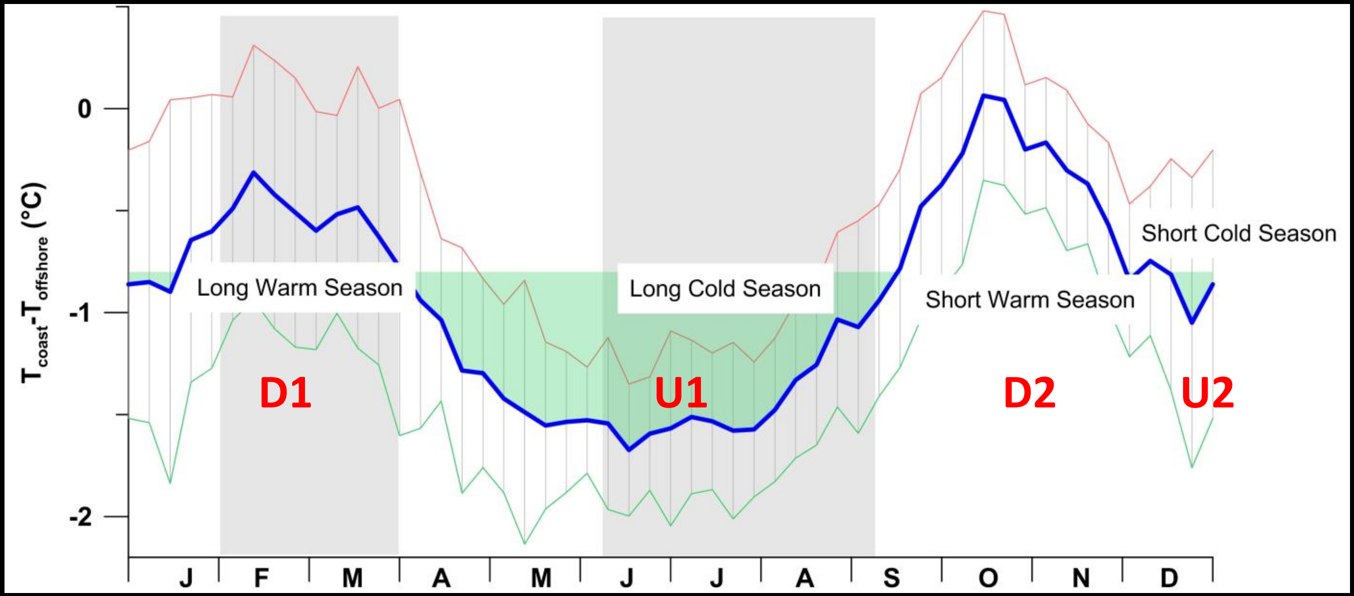


$T_{inshore}$: Sea surface temperature from the Pathfinder v.52 (1981-2012) Modis Aqua (2002-2015)

UI ($T_{inshore} - T_{offshore}$): temperature contrast between the inshore and offshore lien

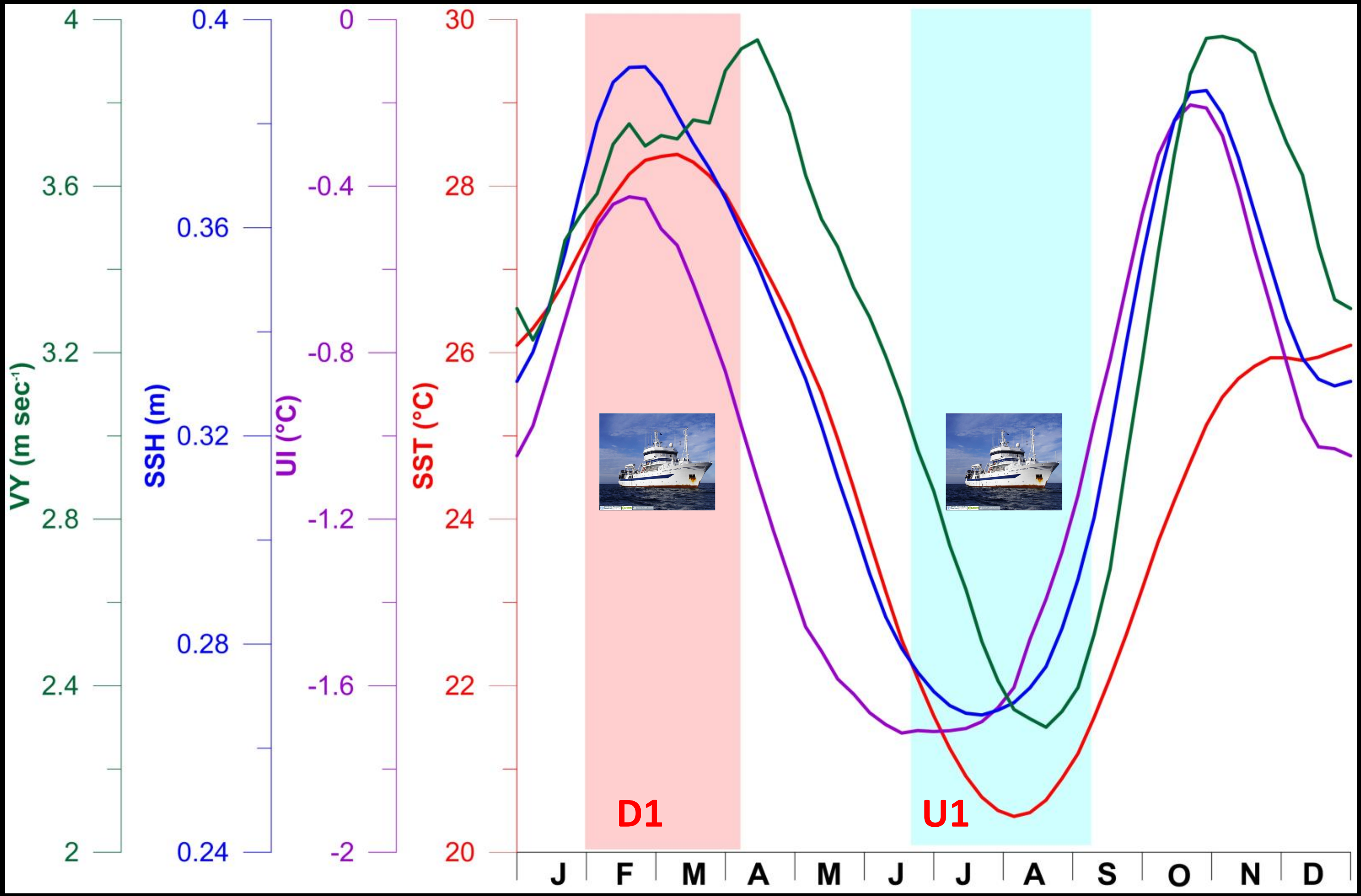
$SSH_{inshore}$. : Merged Absolute Dynamic Topography - Aviso

Vy: meridional wind from the QwikSCAT (1999-2009) and ASCAT (2007-2015) sensors



The satellite derived variability nearest the Angolan coast, averaged over the latitude range 6°30’-12°30’S:

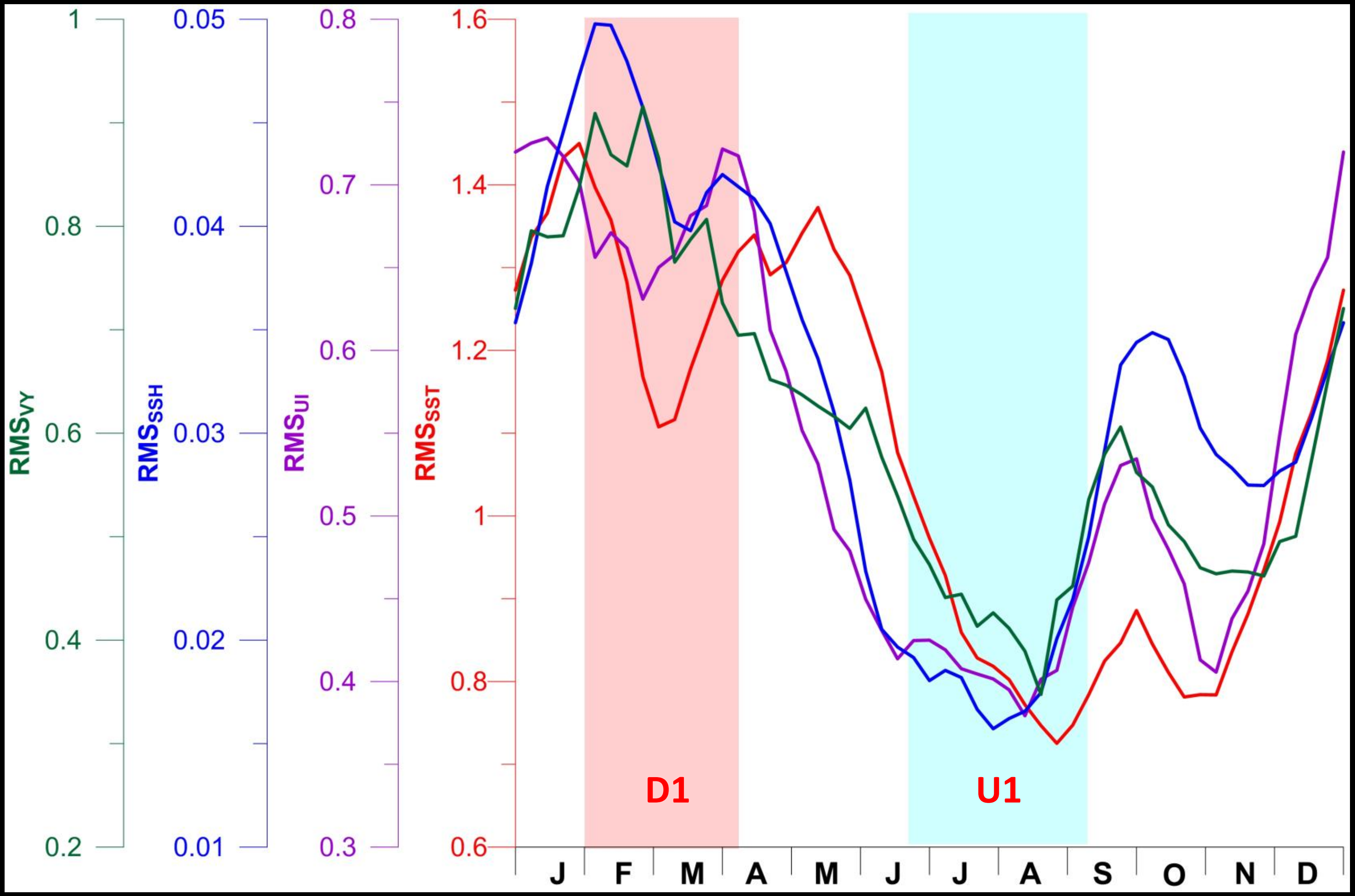
Comparing the seasonal cycles: SST (blue), UI (violet), SSH(blue), Meridional wind (green)



The Annual Minimum of SST, UI, SSH and coastal wind coincides with U1 propagation

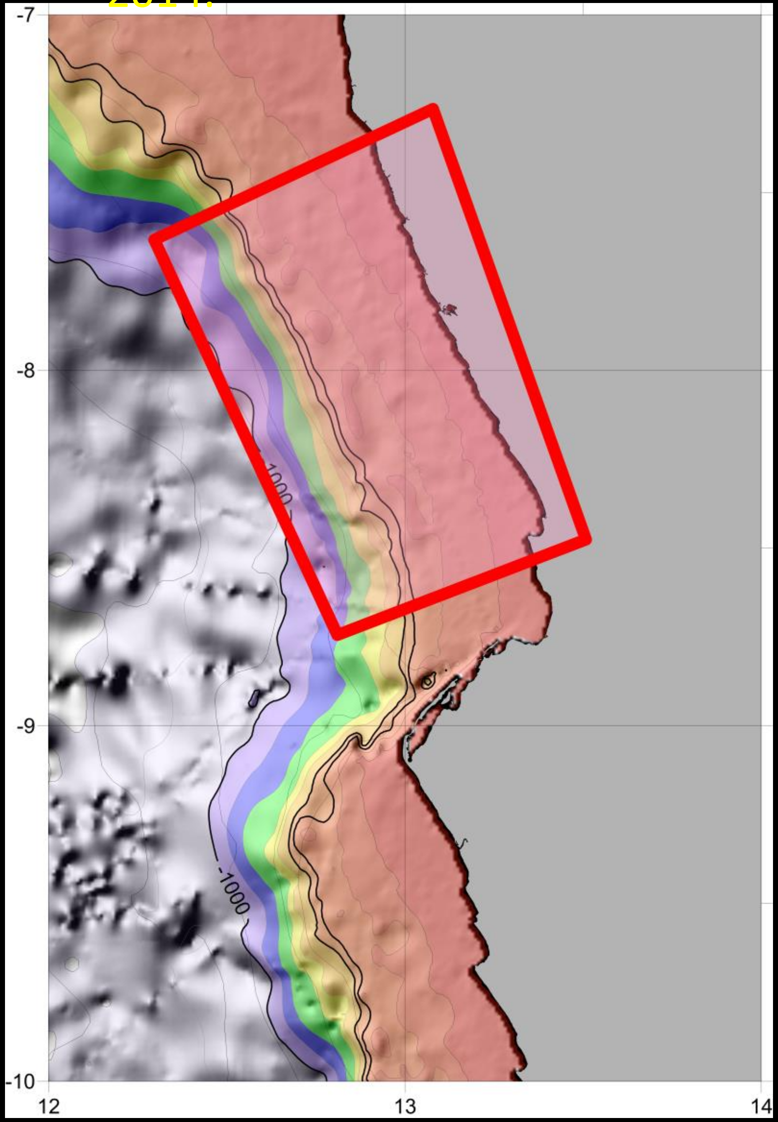
Satellite derived variability nearest the Angolan coast, averaged over the latitude range 6°30'-12°30'S:

Comparing the RMS of the interannual variability : SST (blue), UI (violet) – both 1982-2016;
SSH(blue) 1992-2016, meridional wind (green) 1999-2016.



The maximum of RMS of the variability is during D1, the minimum during U1

The features of the long warm and long cold season regimes off the Ambriz Shelf (7°15’-8°30’S) as estimated from the Angola’s EAF Nansen database 1985-2014.

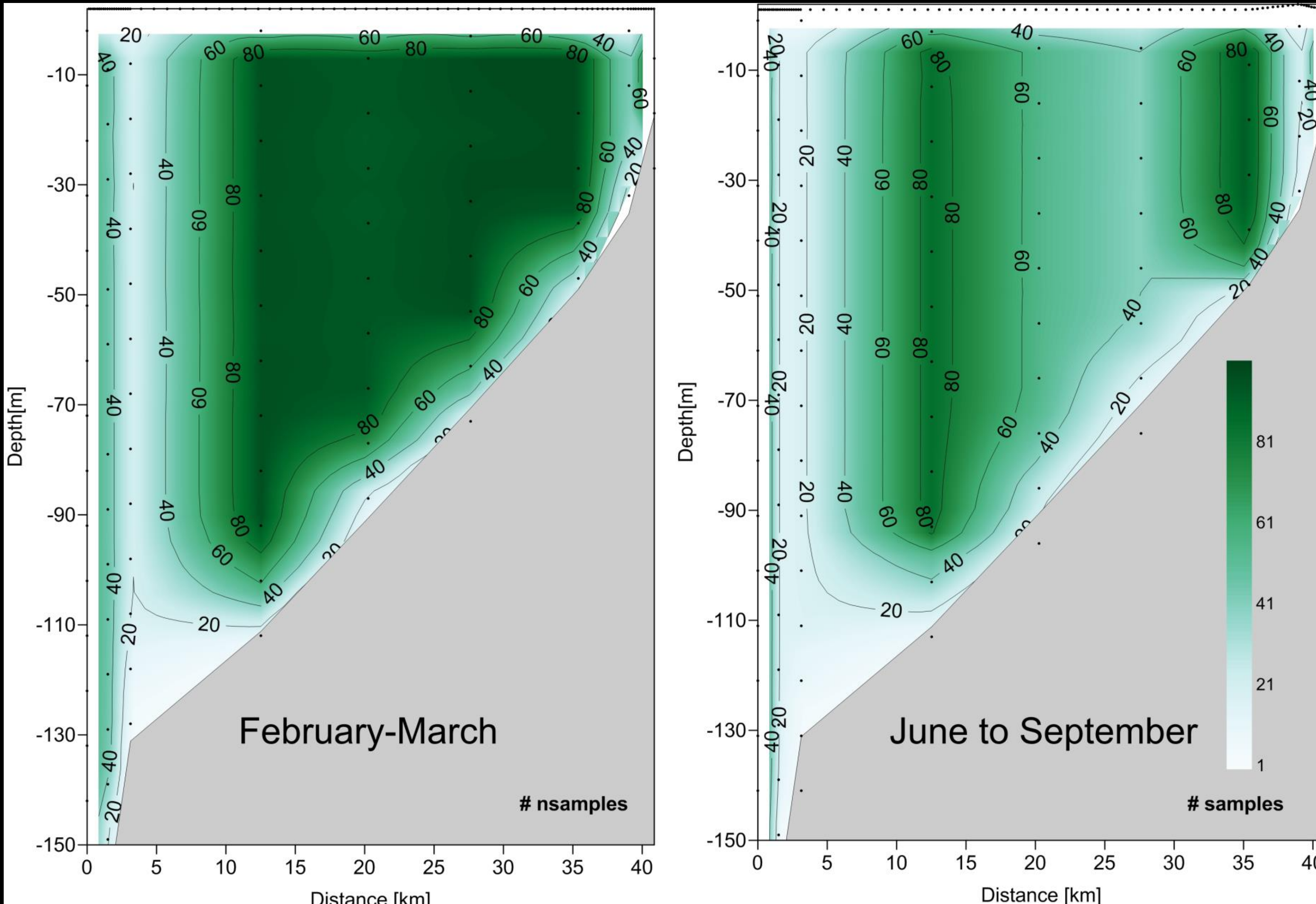


The region is characterized by a uniform bathymetric profile and absence of major rivers. It is sufficiently distant from the Congo River as well as from the bathymetric threshold of Luanda.

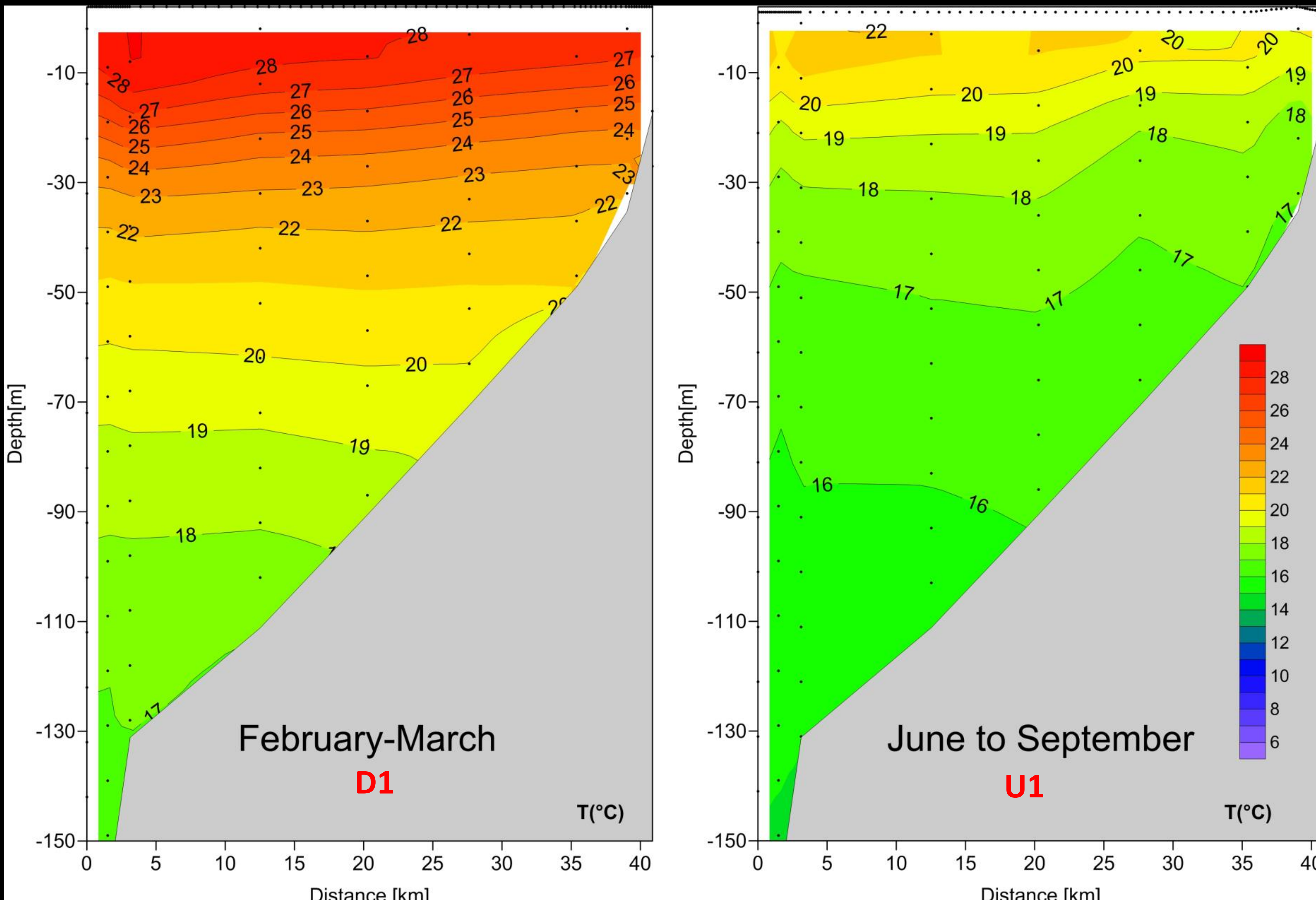
The Nansen survey design served fisheries purposes where station positions are not fixed. For this reason a set of fixed depth strata was selected and a time—series of CTD stations was constructed for each of these strata:

- < 30m
- 31 – 40 m
- 41 – 60 m
- 61 – 80 m
- 81 – 100 m
- 101 – 120 m
- 121 - 140 m
- 141 – 180 m
- 180 – 230 m

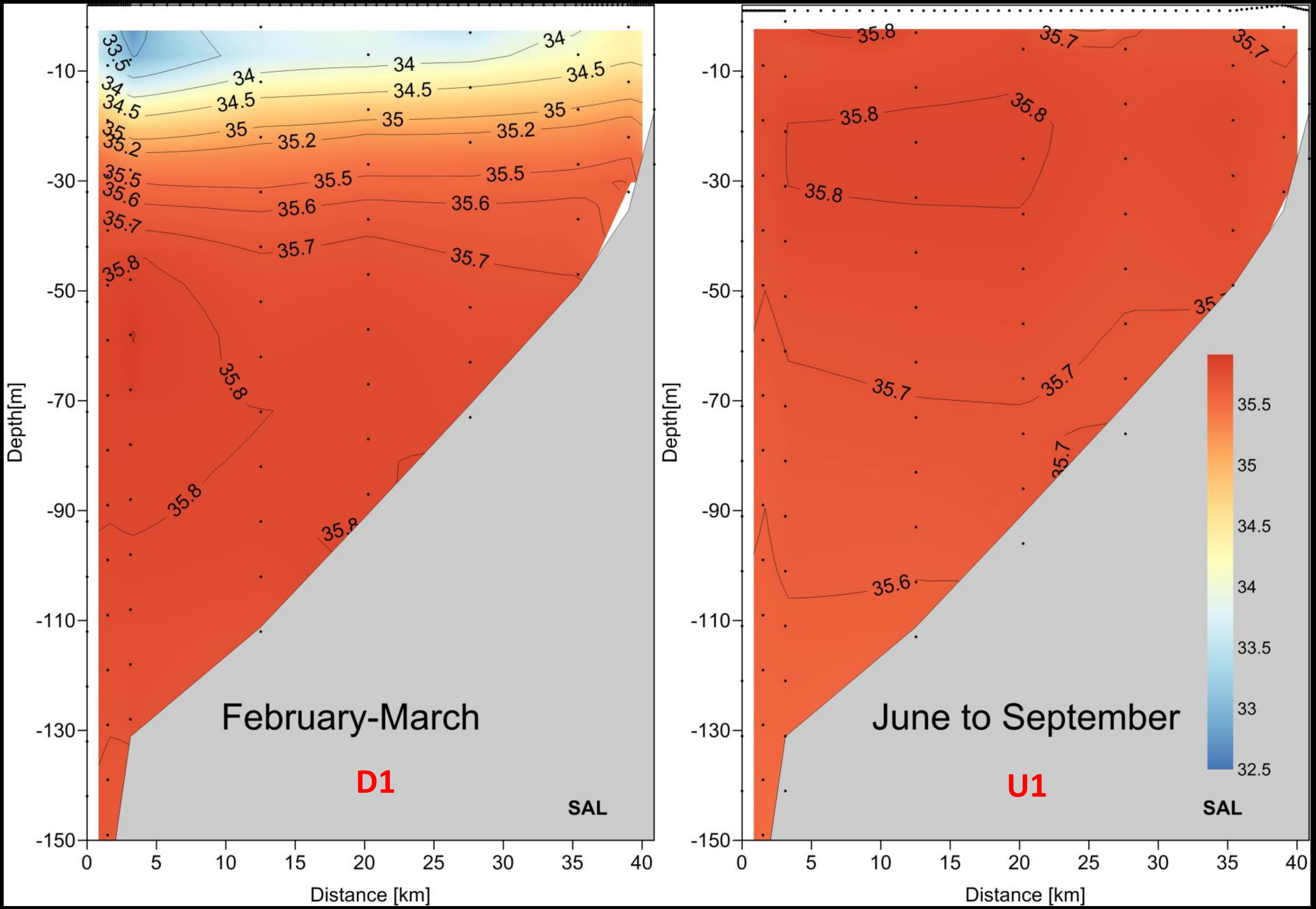
Number of CTD data cycles contained in the Angola's EAF Nansen Database 1985-2014 for the strata analyzed.



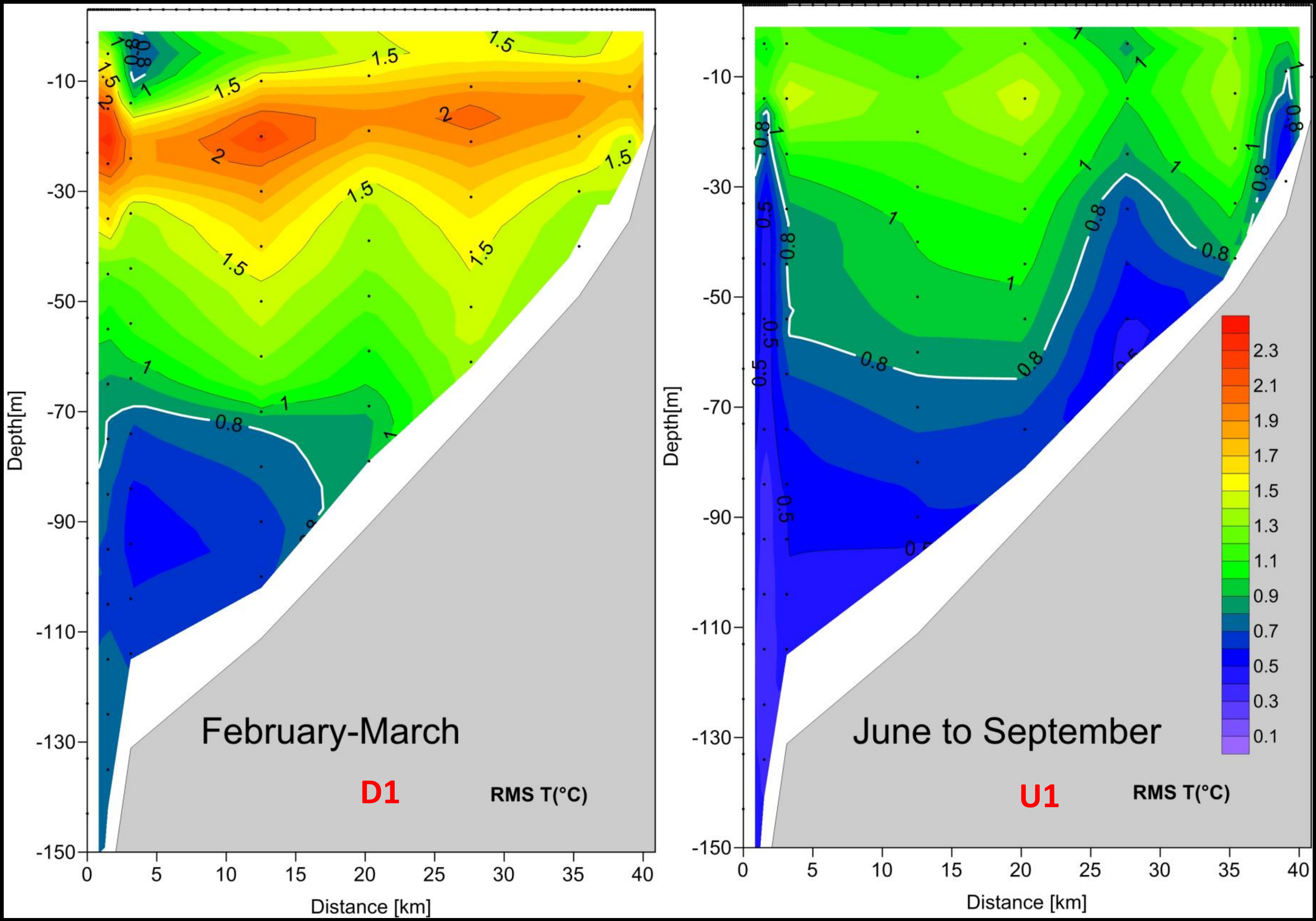
Mean temperature off the Ambriz Shelf (7°15’-8°30S) estimated from the Angola’s EAF Nansen database 1985-2014.



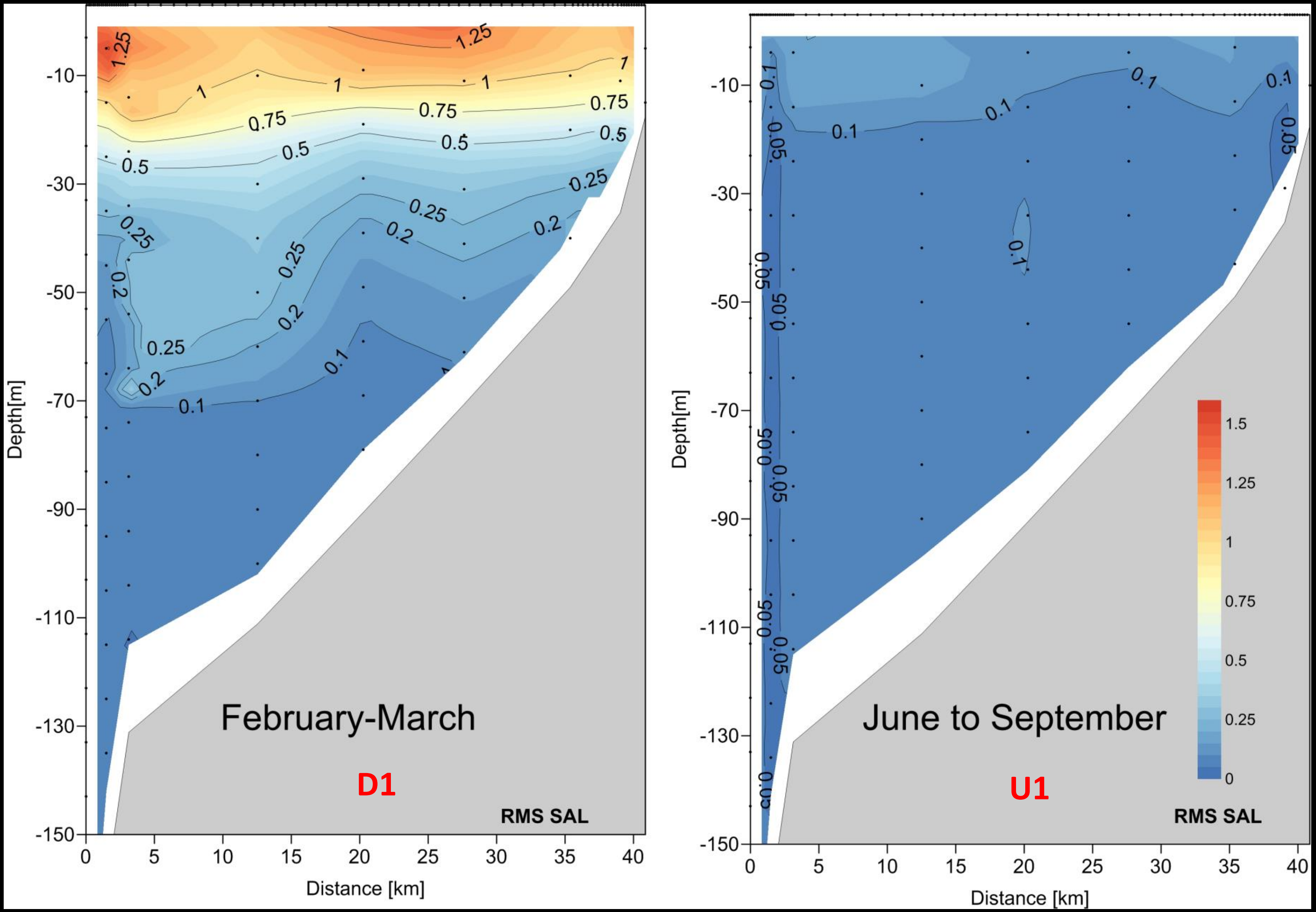
Mean salinity off the Ambriz Shelf (7°15'-8°30S) estimated from the Angola's EAF Nansen database 1985-2014.



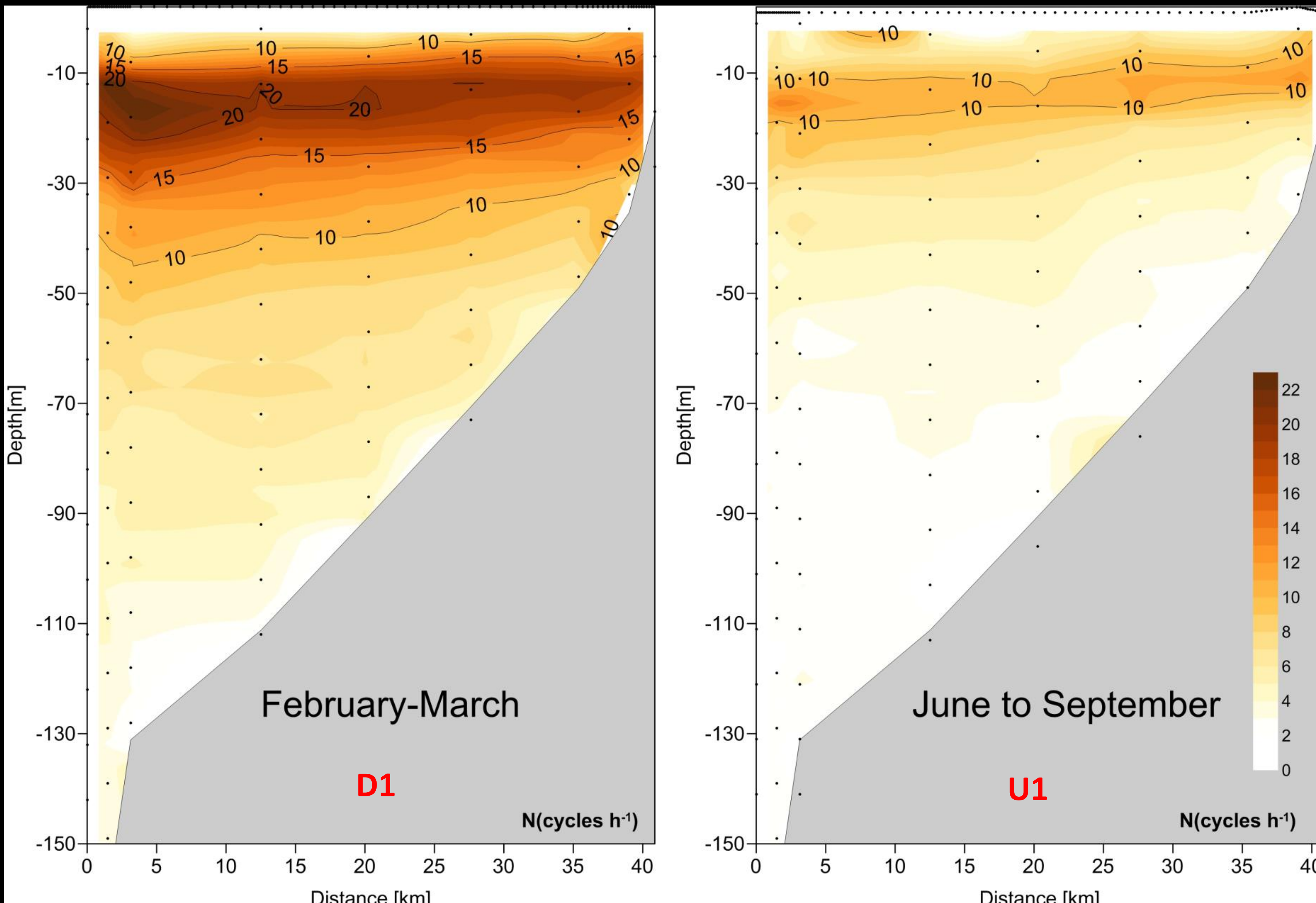
RMS Temperature off the Ambriz Shelf (7°15’-8°30S) estimated from the Angola’s EAF Nansen database 1985-2014.



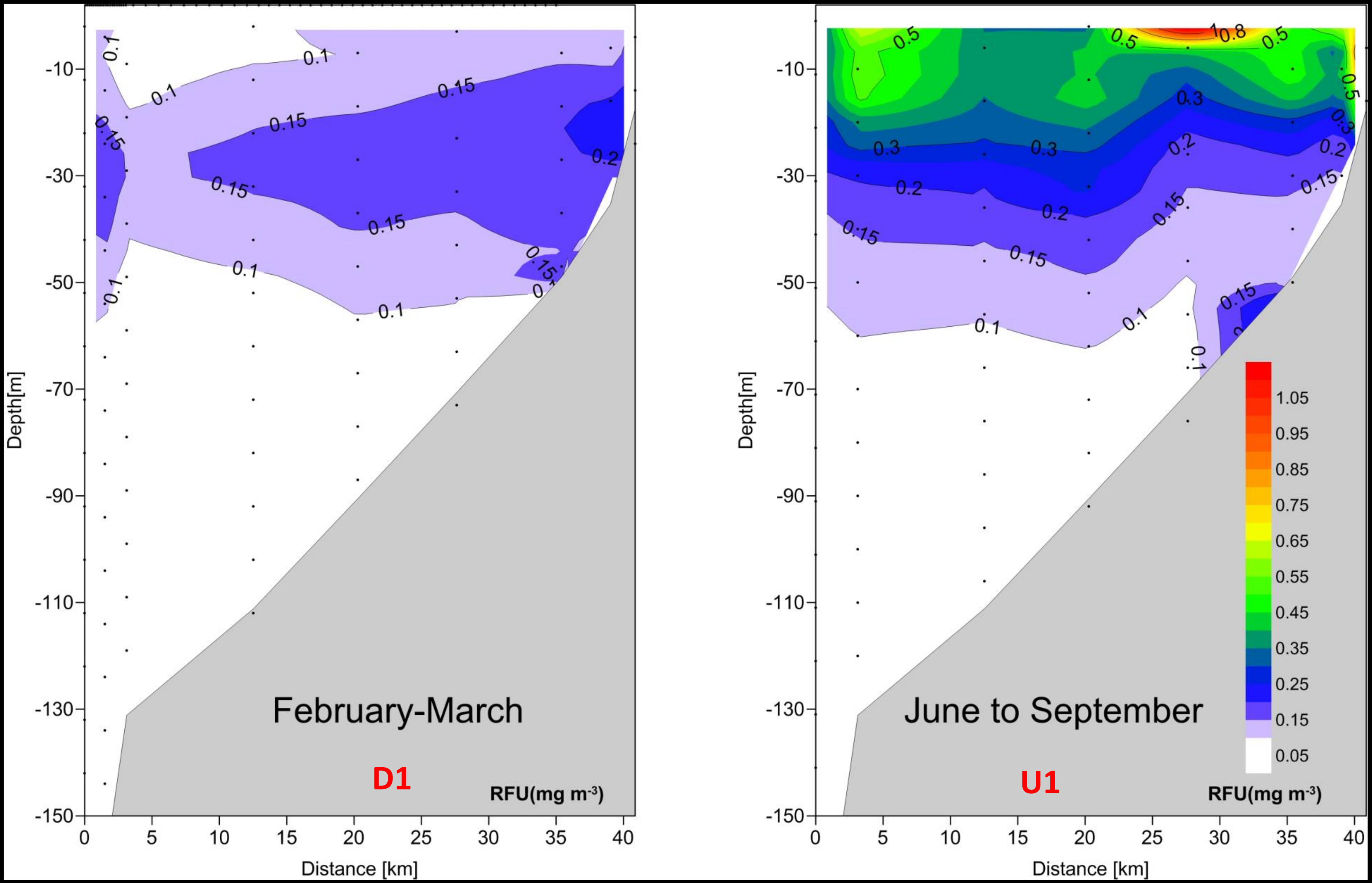
RMS Salinity off the Ambriz Shelf (7°15’-8°30S) estimated from the Angola’s EAF Nansen database 1985-2014.



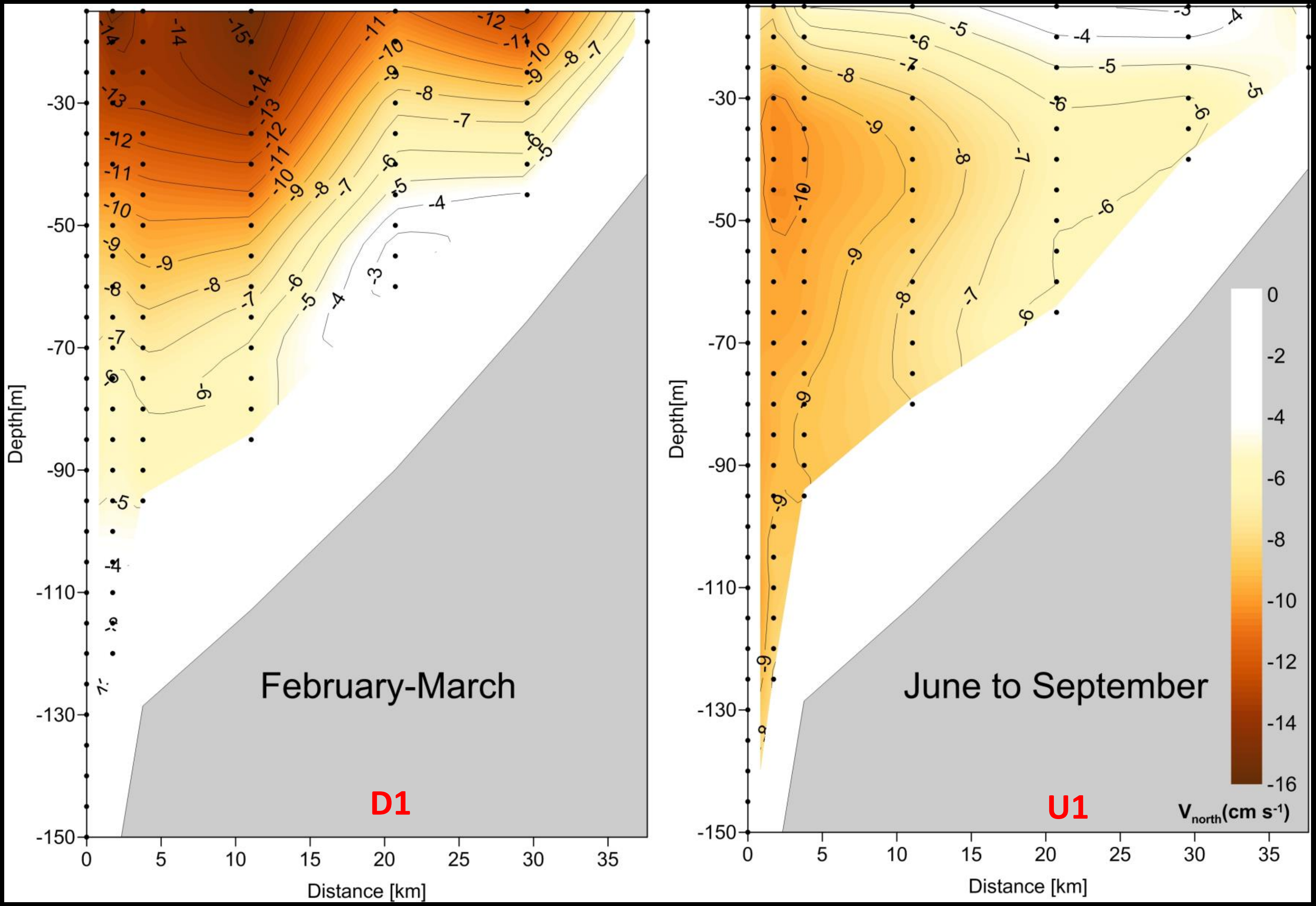
Buoyancy frequency off the Ambriz Shelf (7°15'-8°30S) estimated from the Angola's EAF Nansen database 1985-2014.



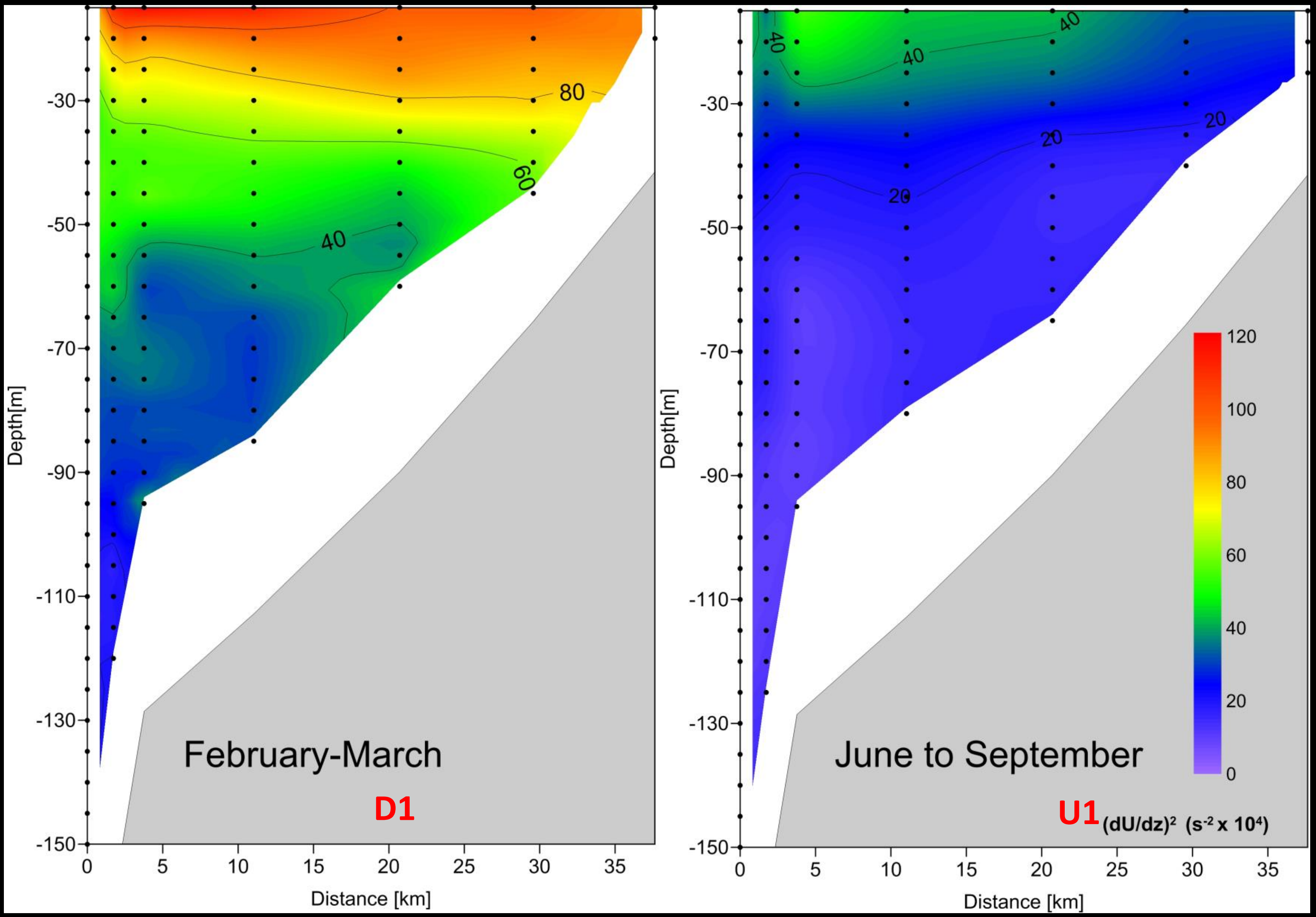
Mean fluorescence off the Ambriz Shelf (7°15’-8°30S) estimated from the Angola’s EAF Nansen database 2008-2014.



Mean alongshore current (-21.8° T) off the Ambriz Shelf (7°15’-8°30S) estimated from the survey data of R/V Dr. Fridtjof Nansen collected 2005-2011 and 2013, 2014.



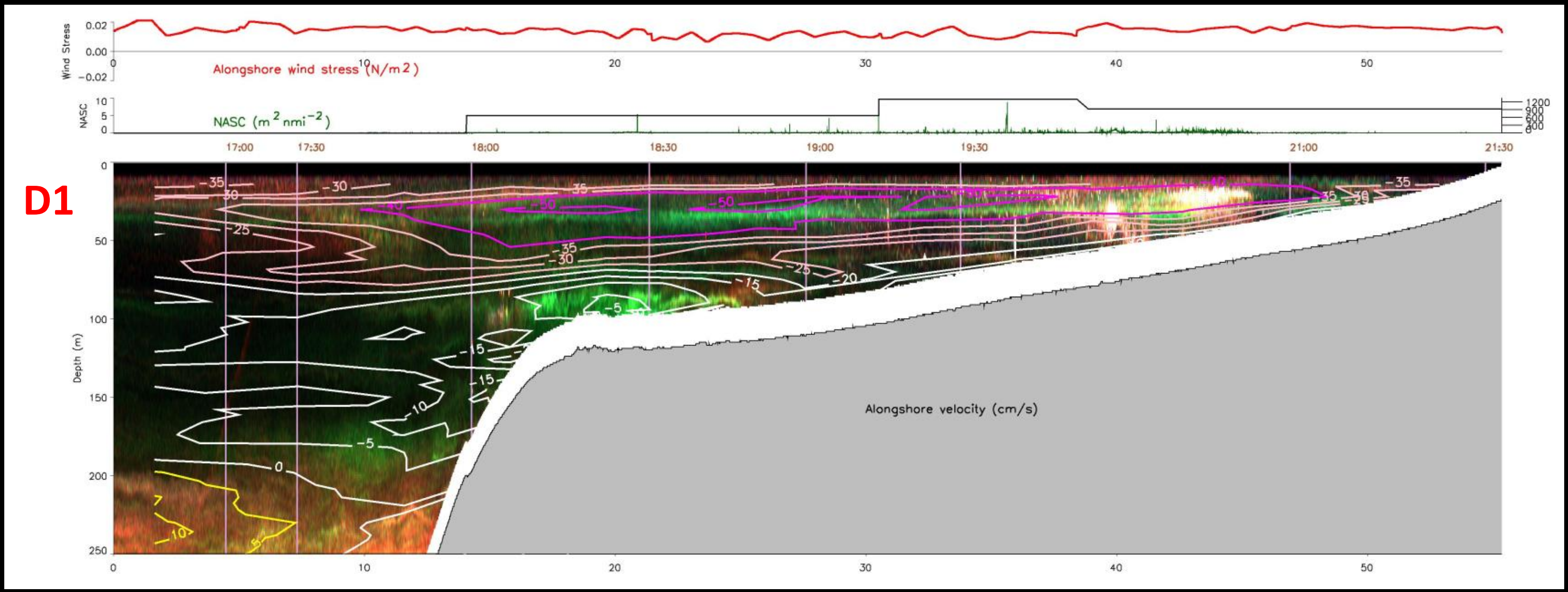
Mean vertical current shear off the Ambriz Shelf (7°15’-8°30S) estimated from the survey data of R/V Dr. Fridtjof Nansen collected 2005-2011 and 2013, 2014.



	D1 FEBRUARY to MARCH	U1 JUNE TO SEPTEMBER
SST	27-29°C	19-21°C
SSS	< 34, higher inshore	oceanic (> 35.8)
stratification	extreme	Strong, but conducive to molecular diffusion
SACW	below shelf-break	to inner shelf (40-60m)
Algal blooming	in DCM	inshore and in top layer
Angola Current	strong across the shelf	intensifies at shelf break
Vertical shear	strong across the shelf	less intense

Zooplankton and fish responses to the vertically sheared regime prevailing during D1

D1



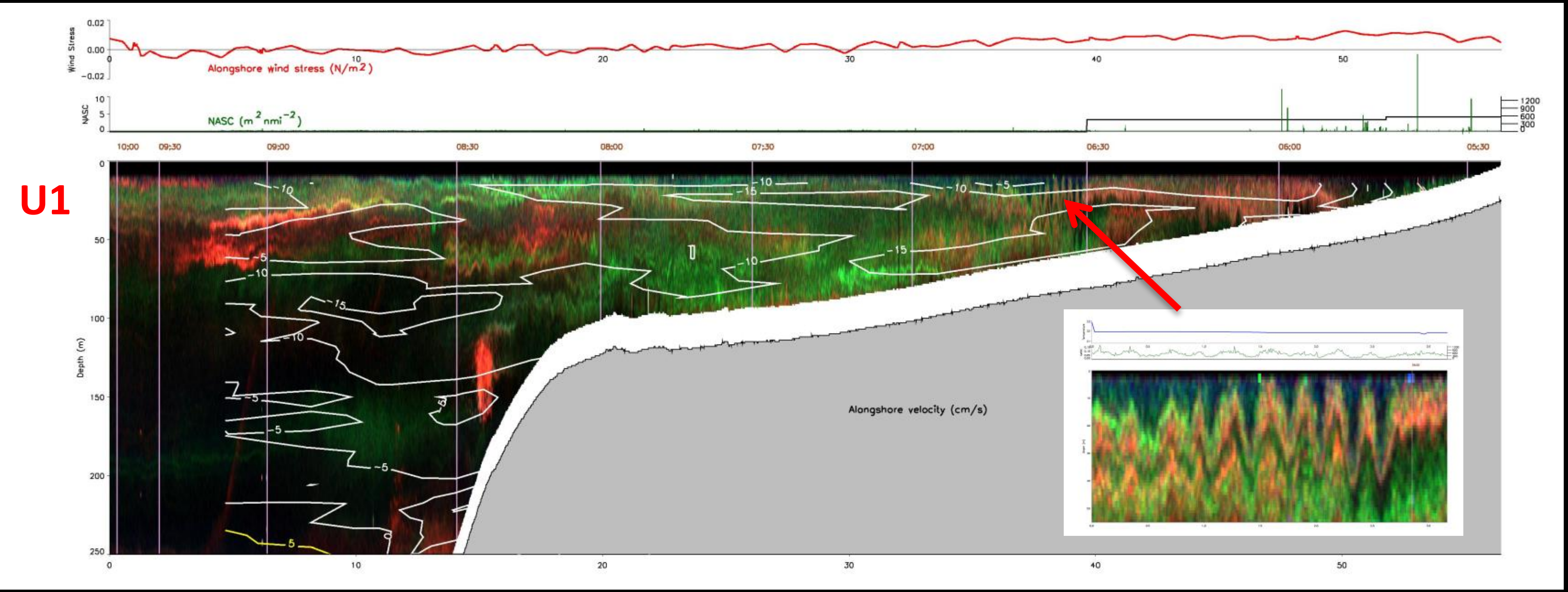
Thin zooplankton layers associated with the shear of the current

Stacey et al. 2007

Sardinella tends to to be widely distributed across the shelf

Ambriz on 3 Feb 2014

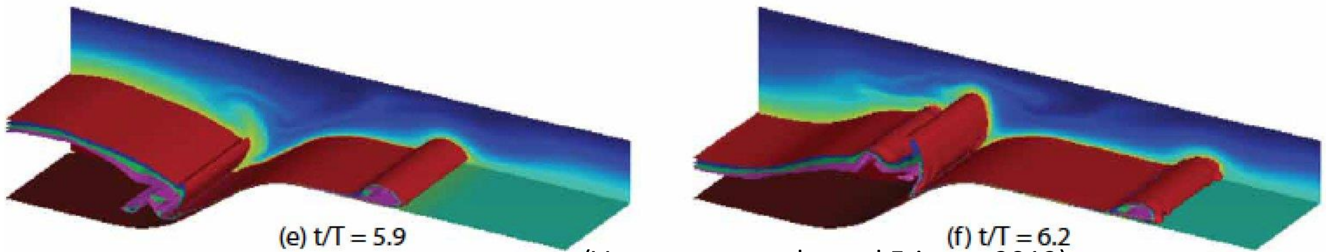
Zooplankton and fish responses to the ISWs driven regime during U1



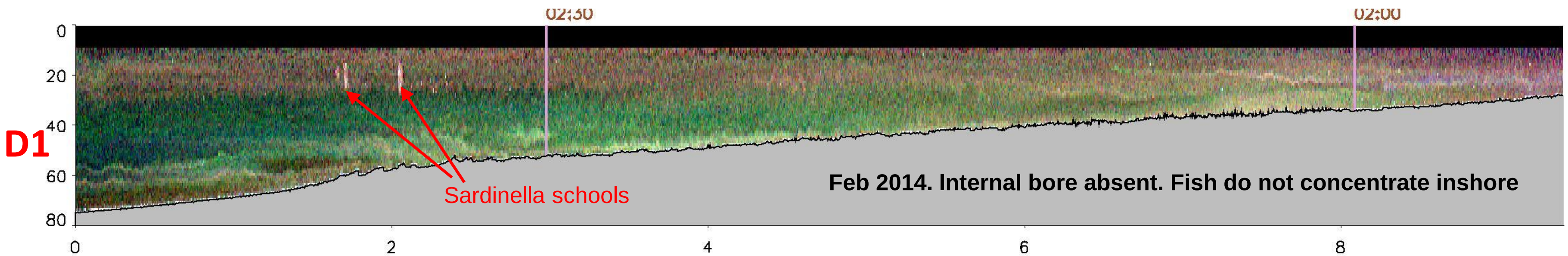
Thin zooplankton layers are entrapped within the strongly fluctuating thermocline and entrained in ISWs propagations.

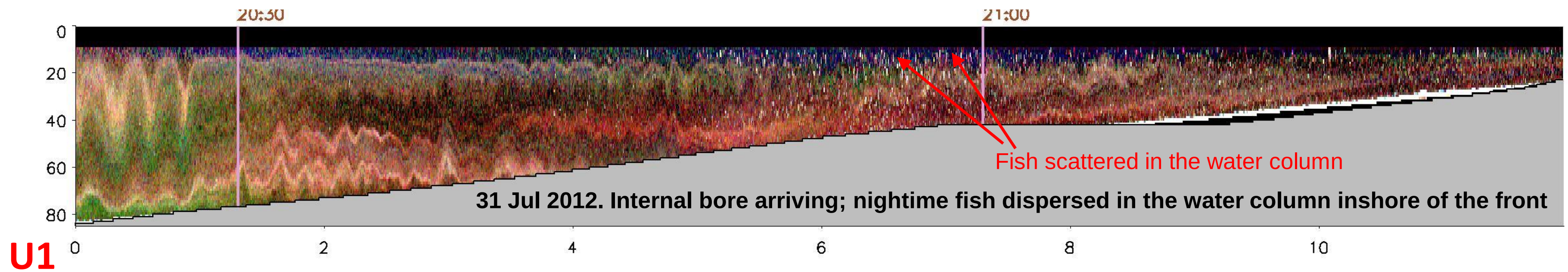
Sardinella tends to be confined within the inshore productivity areas where ISWs break

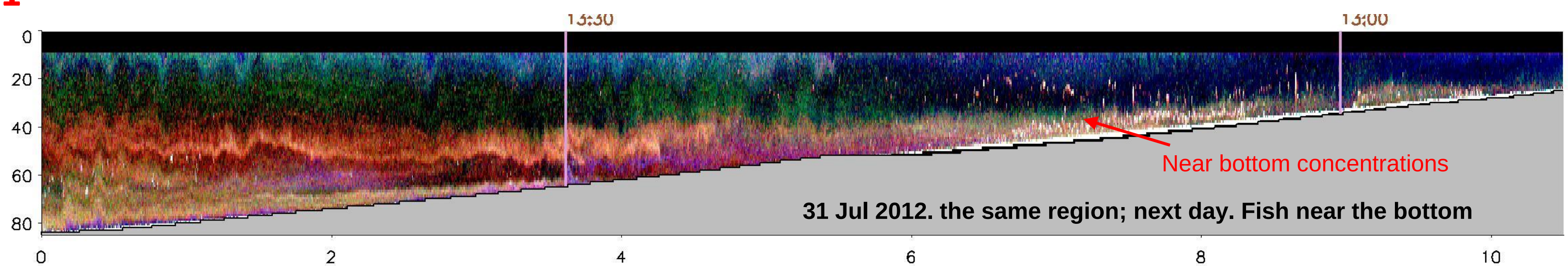
Concentration of small pelagic fishes at the front associated to a collapsing internal bore as visualized by multi-frequency acoustics



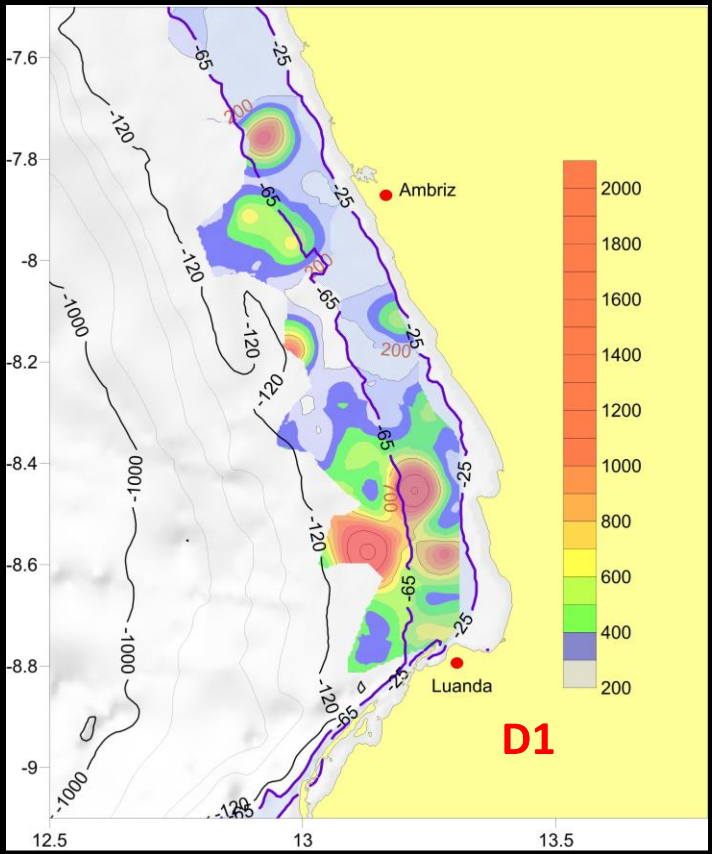
(Venayagamoorthy and Fringer, 2012)



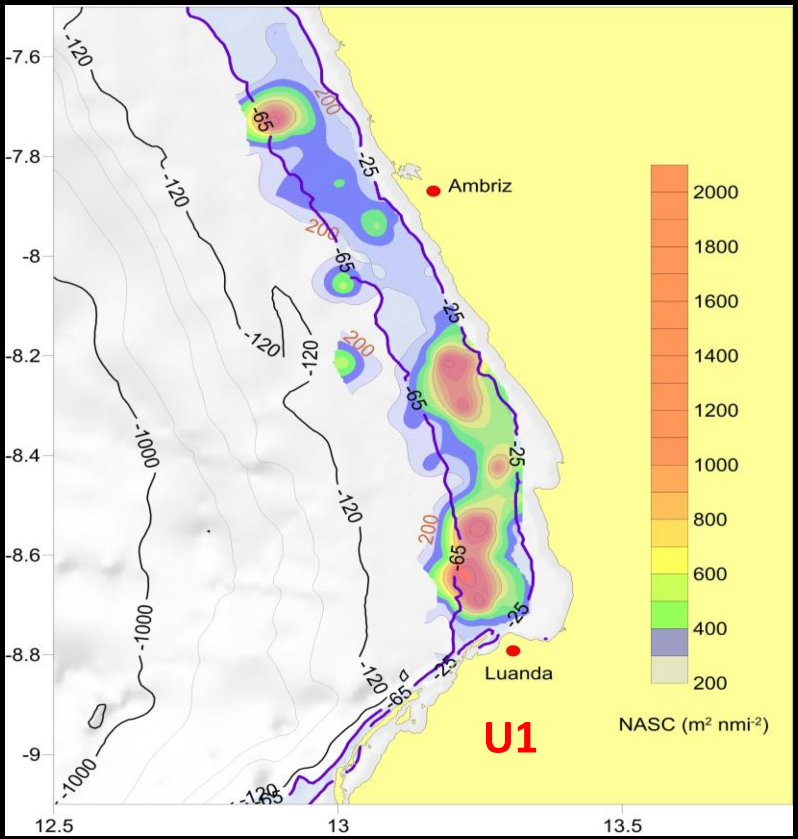




The observed behavioral responses of sardinellla to the D1 and U1 regimes is reflected in the acoustic fisheries distribution data.



February-March

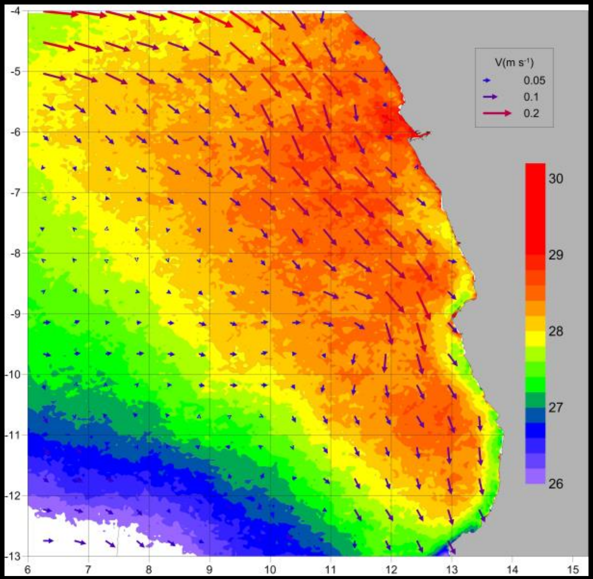


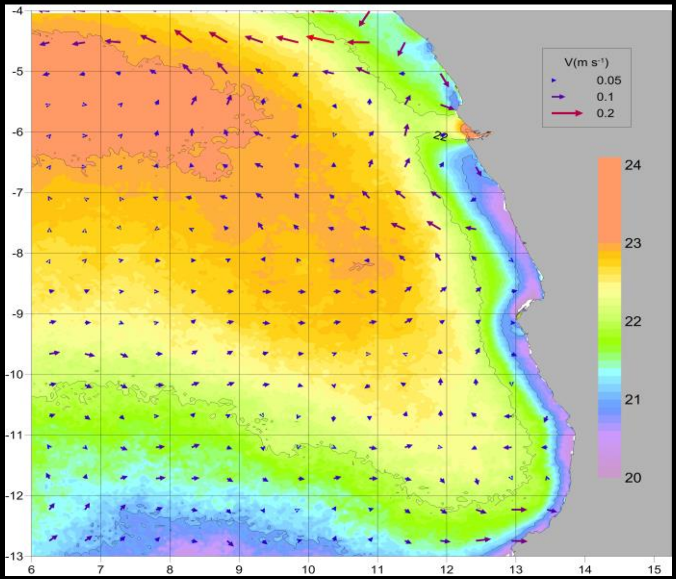
June-August

Summary: The Kelvin wave controlled seasonal regimes and and the life cycle of sardinella in the Angolan waters

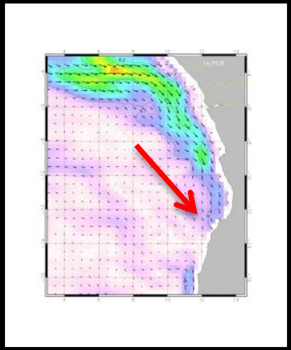
D1: Favors transport habitat; offshore foraging, adult fish migration and larval transport to the south.

U1: Favors spawning habitat; Fish concentration and larvar retention in inshore waters



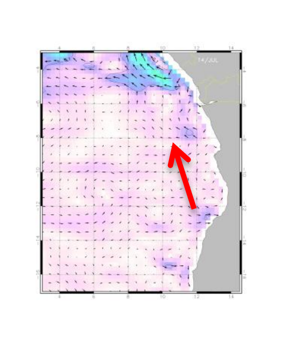


Summary: The correspondence between the Kelvin wave controlled flow patterns along the Angola coast and the annual migration cycle of sardinella



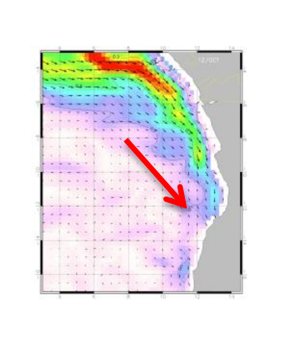
D1: FEB-MAR

Adult migration
and
transport of
spawning products
to the south.



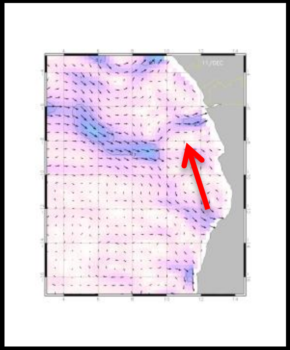
U1: MAY-AUG

Reverse migration
to spawning areas
in the north



D2: SEP-NOV

Adult migration
and
transport of
spawning products
to the south



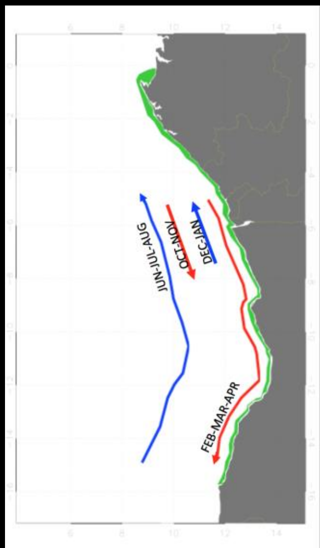
U2: DEC-JAN

Reverse migration
to spawning areas
in the north

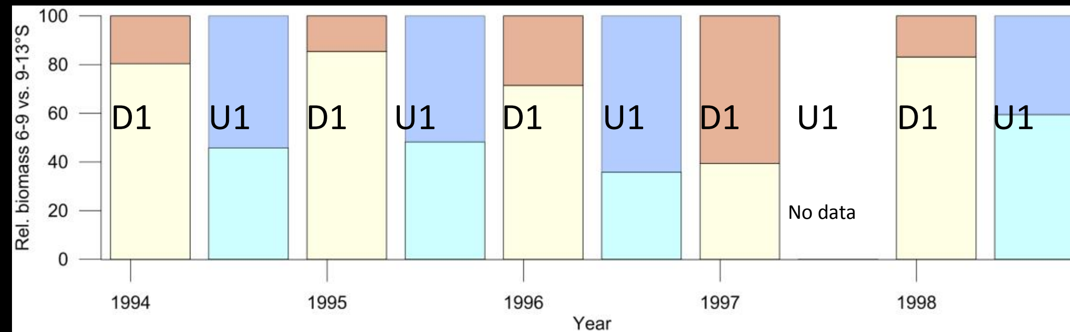
Suggested by the patterns in the climatology of the altimetry derived geostrophic currents

Now this suggestion is strengthen by the results of the PREFACE mooring observations (Kopte et al. 2016)

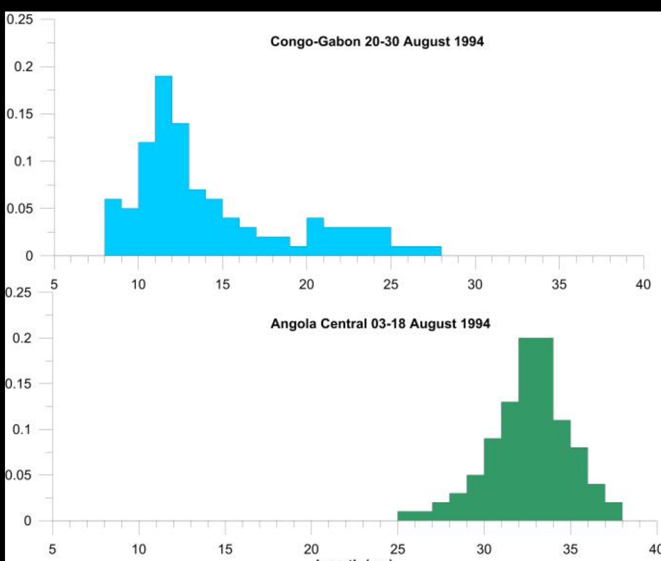
The synchrony between the strength of remotely forced circulation and intensity of the seasonal migration of sardinella along the the Angolan coast was observed in 1970s to 1990s.

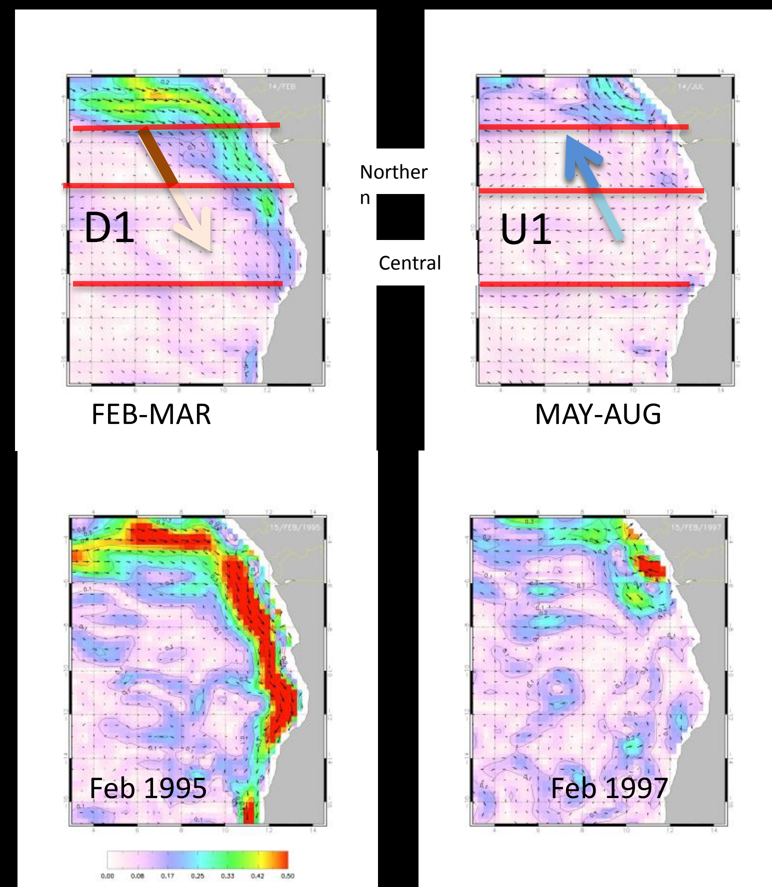


Adapted from Boley and Freon 1980,
after Ghéno and de Campos Rosario, 1972

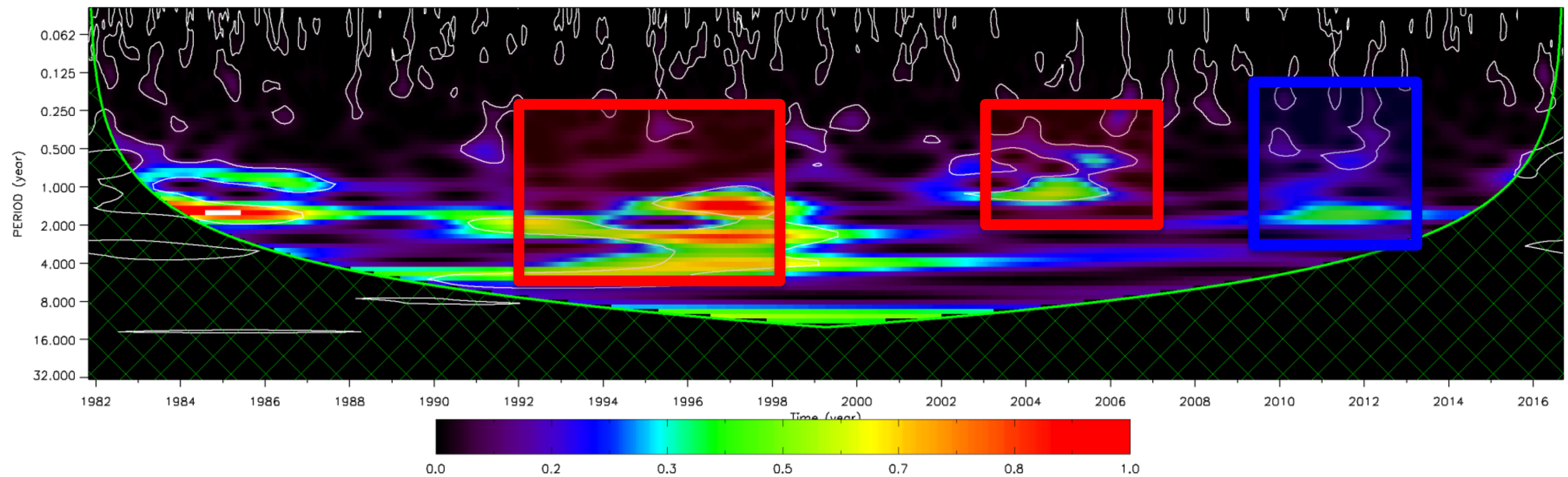


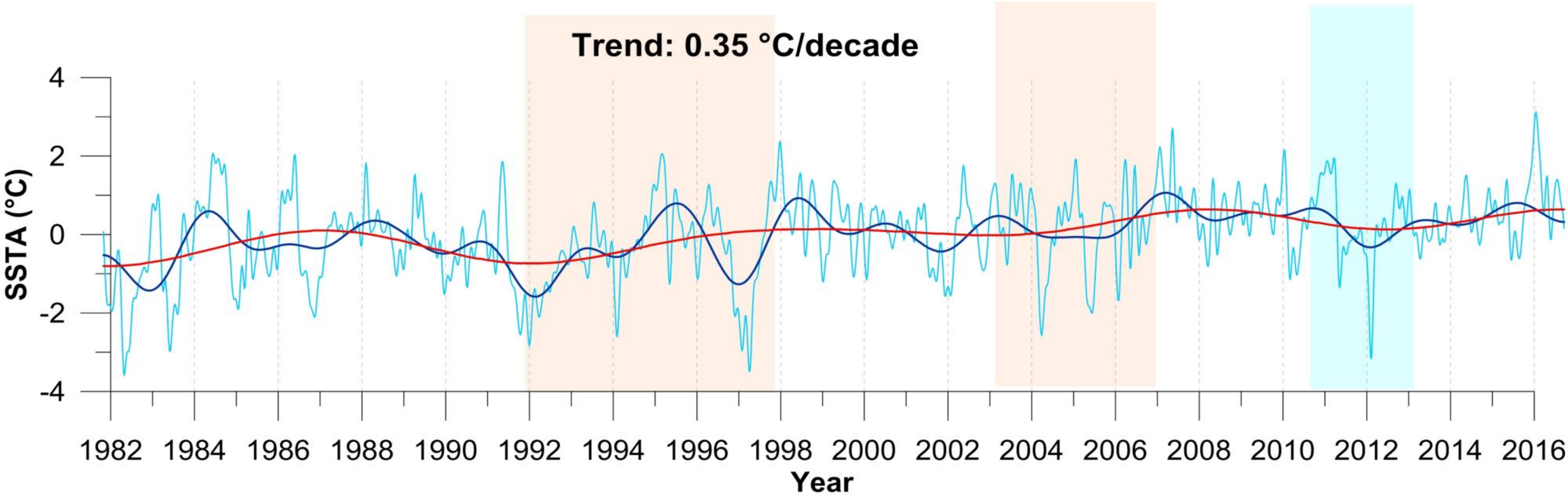
The percentage of sardinella biomass to the north (top) and south of Luanda(bottom) regions during D1 and U1 surveys, with Dr. Fridtjof Nansen 1994-1998



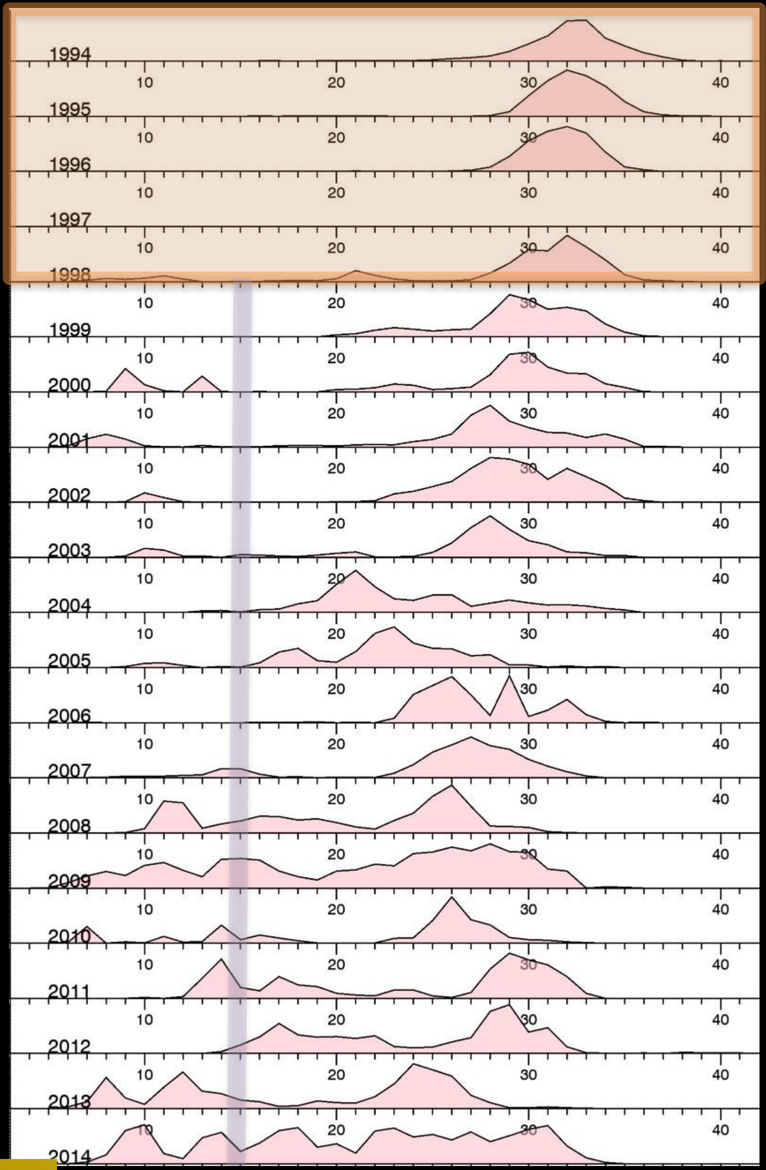


However, since early 1990s until present the Angolan coastal ocean is subject to a systematic warming. A particularly strong warming period occurred between 1992 to 1998.

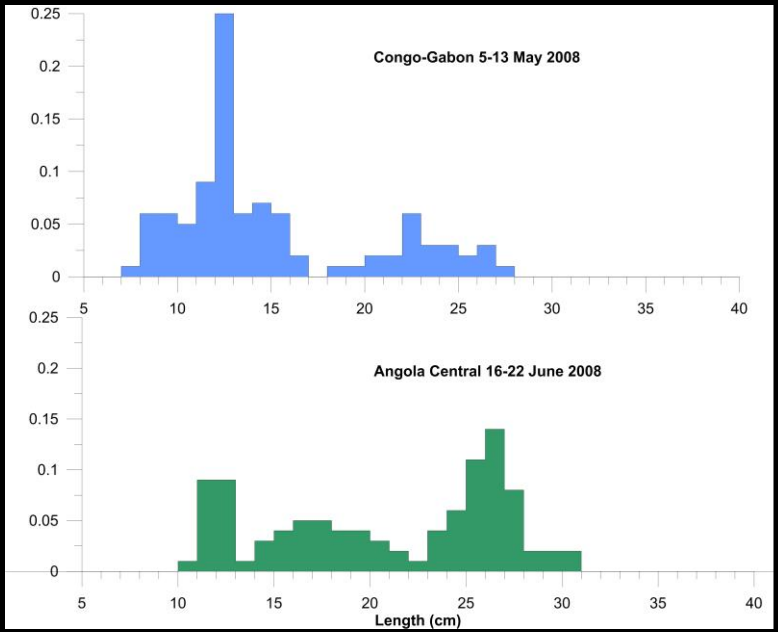




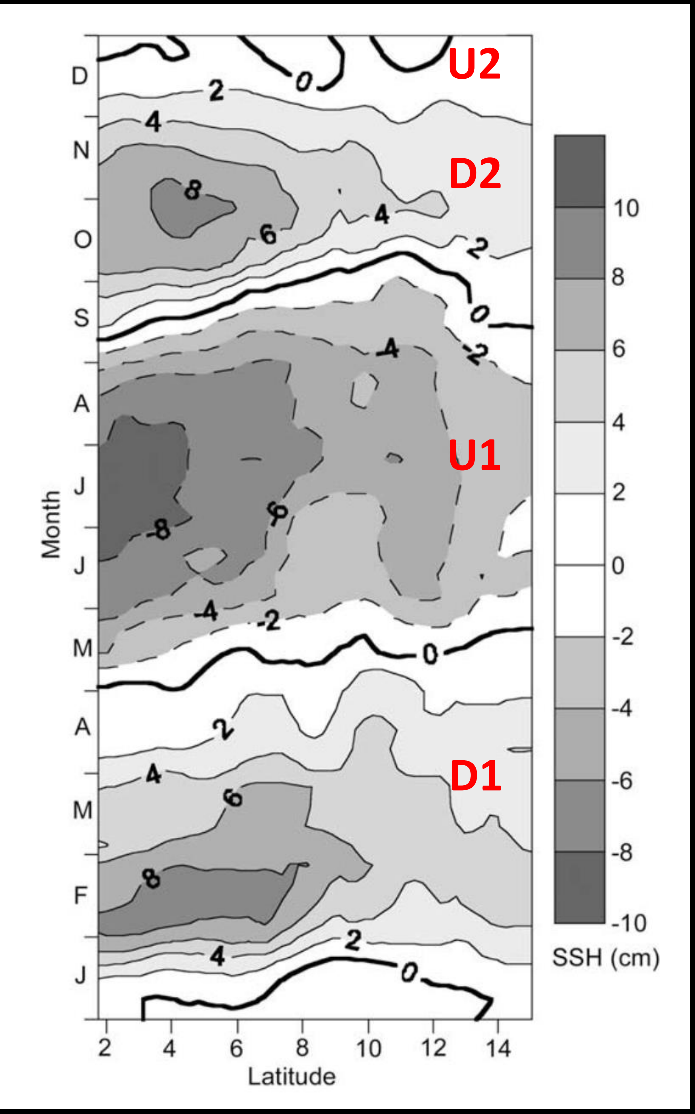
Following 1998 , the Dr. Fridtjof Nansen trawls started to record juvenile sardinella species in Angolan waters, suggesting a decrease in the spawning migration to the Gabon-Congo region and development of local spawning areas off Angola, particularly for flat sardinella to the south of Luanda.



Comparing the length structure between fish caught off the Gabon Congo region with those caught of Angola between the 1990s and more recent surveys indicates 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.



Summary



Passage of coastally trapped trapped propagations 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 acting on much more regular seasonal time-scales.

Sardinella exhibits similar adaptations to those observed in small pelagic species in the Humboldt Current upwelling upon a passage of El Niño/La Niña events. Schooling behavior, distance from the coast and alongshore migration pattern (e.g. Bertrand et al. (2008) are affected, but those are the part of the regular life-cycle, not the survival strategies.

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


THANK YOU