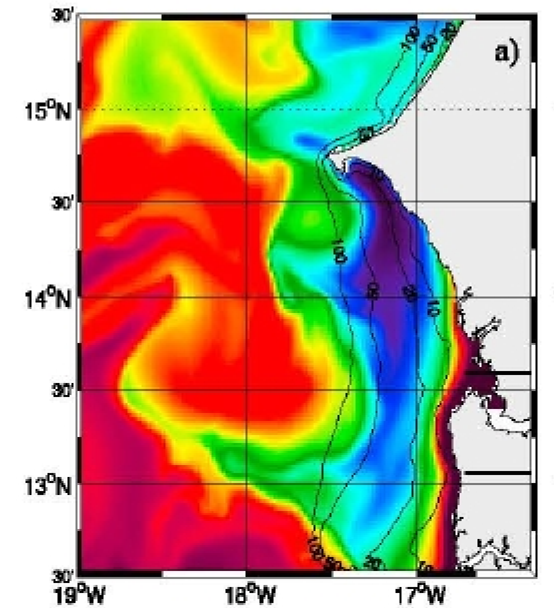
Recent glider deployements in the Senegalese upwelling system

V. Echevin, N. Kolodziejczyk, A. Piétri,
A. Lazar, P. Testor, S. Ndoye et al.



ECLAIRS
Etude du Climat en Afrique de l'Ouest et de ses Interactions avec l'Environnement Régional

Institut de Recherche pour le Développement
FRANCE

division technique de l'INSU

LOCEAN

LPAO-SF
Université Cheikh Anta Diop de Dakar

LOPS

AWA

PREFACE

lefe

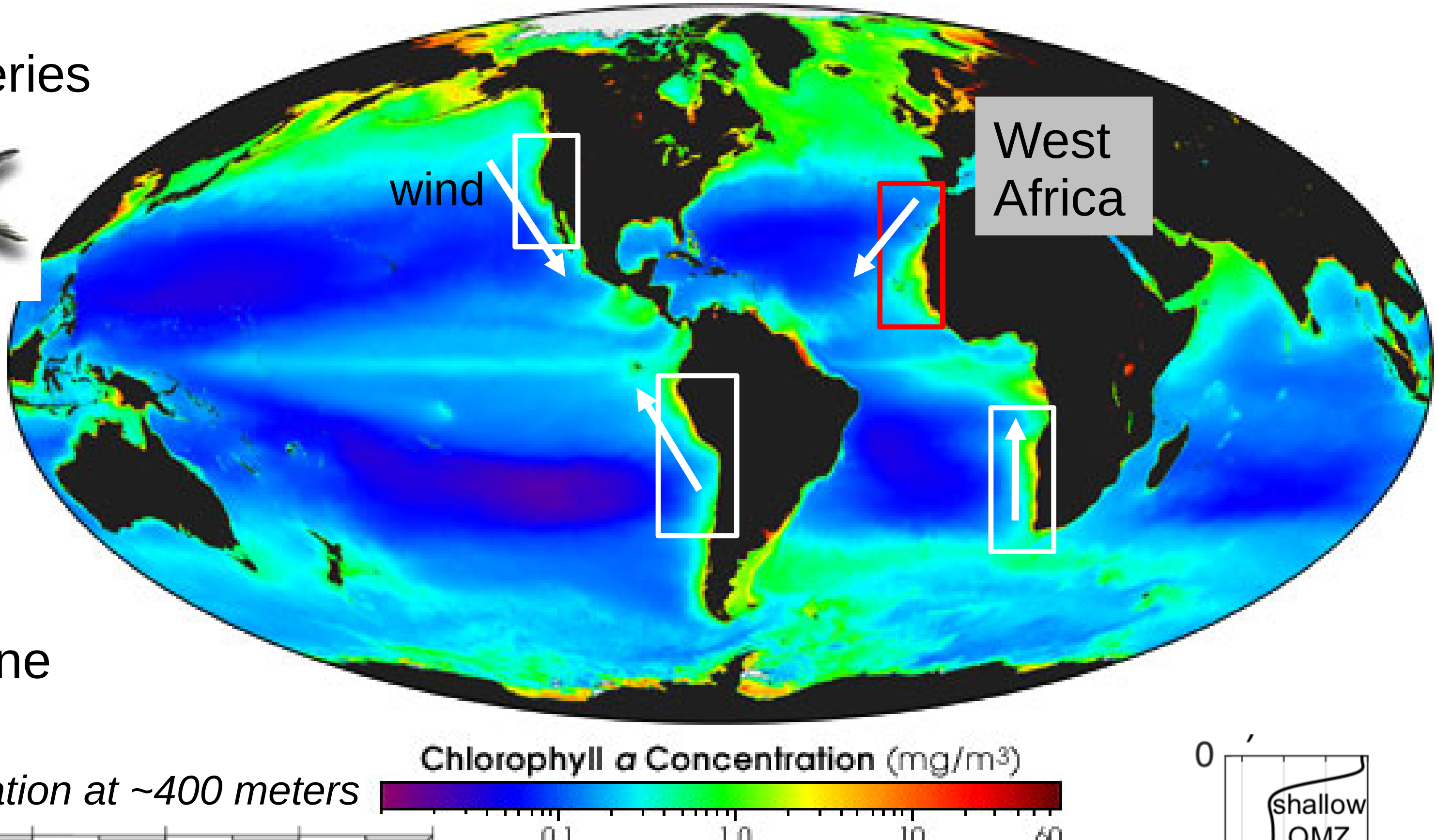
The west-african upwelling system

- important artisanal fisheries

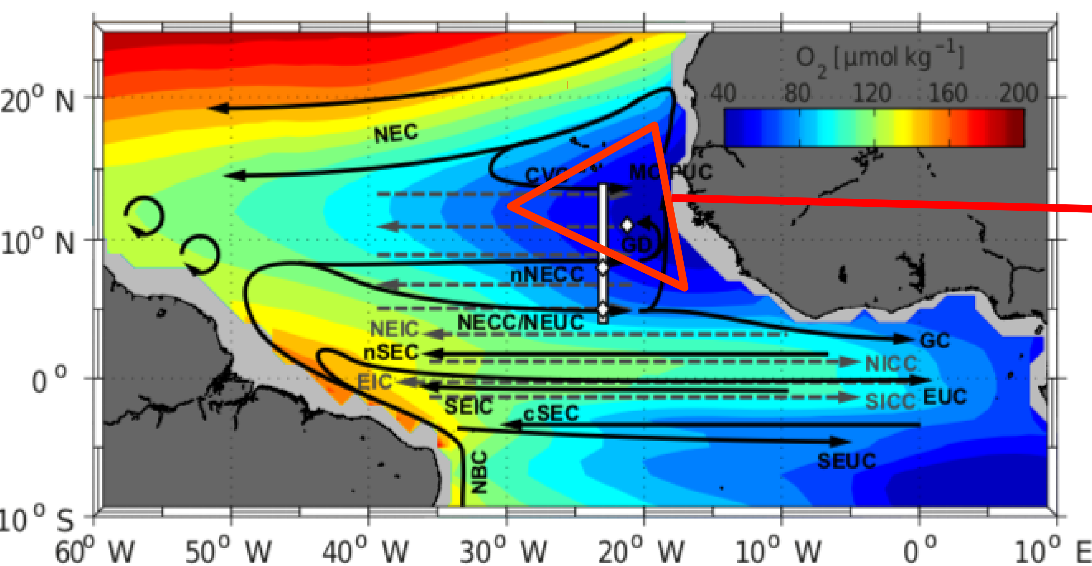
Sardinella auritae

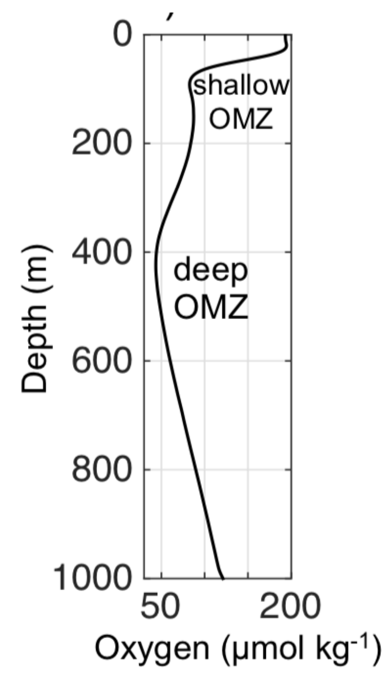
- oxygen minimum zone

Seawifs surface chlorophyll



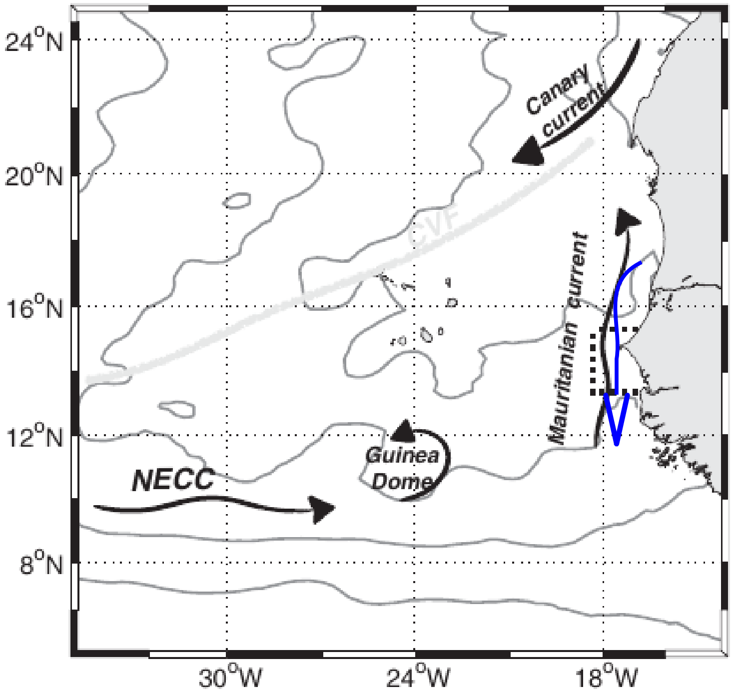
Hahn et al. 2017, O2 concentration at ~400 meters



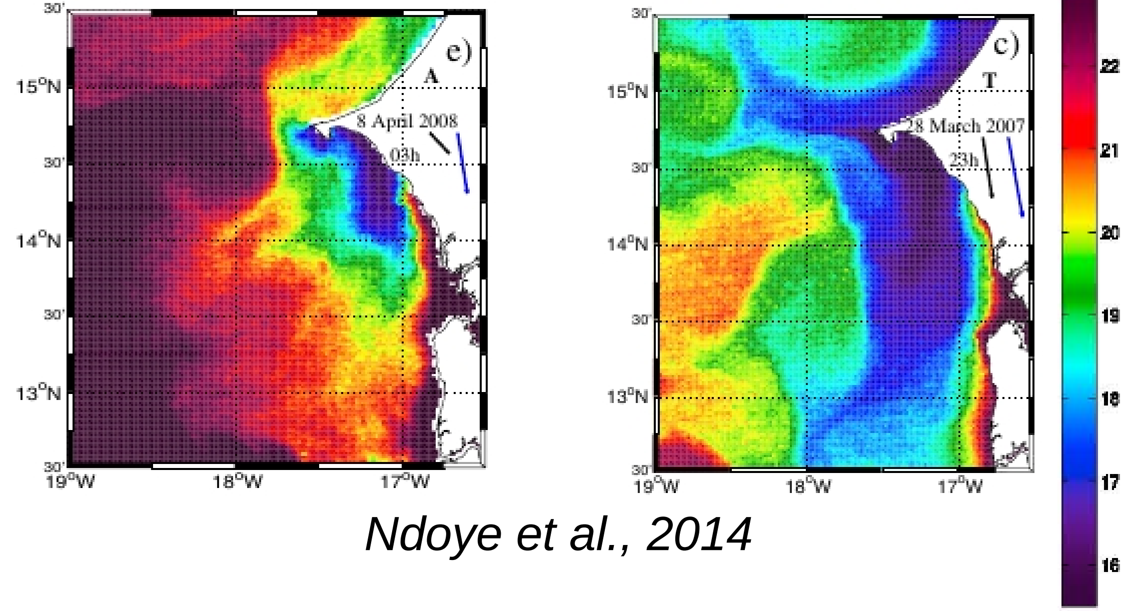


The west-african upwelling system: Senegal sector

Circulation sketch

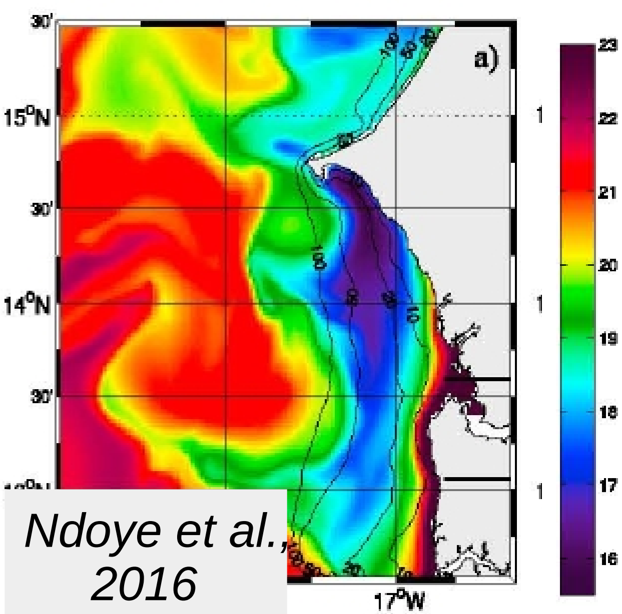


SST SST



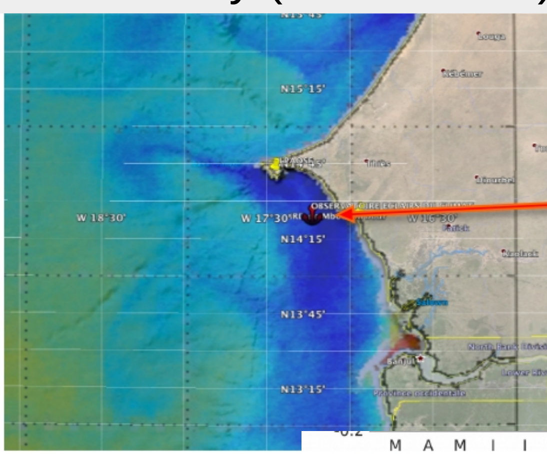
Ndoye et al., 2014

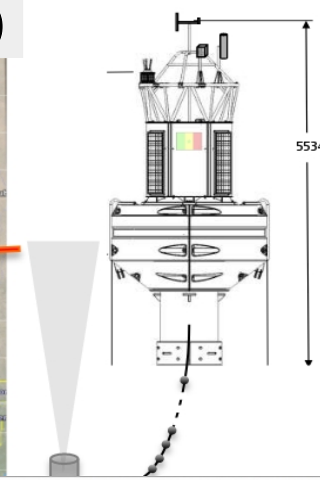
Croco model (2km) SST



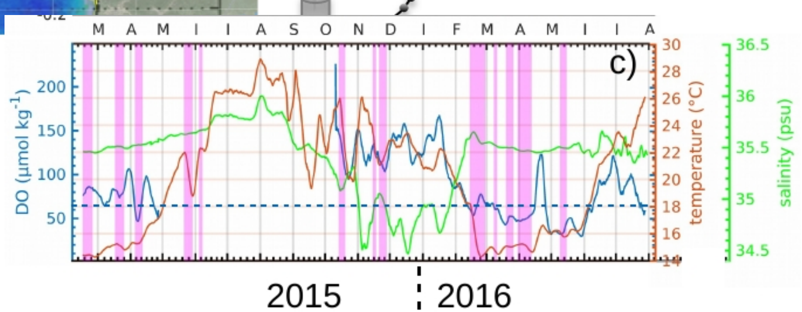
Ndoye et al., 2016

Melax buoy (P.I. A. Lazar)





Temperature
Salinity
Oxygen



3 deployments between 2011 and 2016 (P.I. A.Lazar, LOCEAN)

1) **Hannon glider** (SENEGLIDE project, LEFE & IRD funding)
- 8 february → 17 march 2011
- ~ 0-50 km off Dakar (14-15°N / 17.5-18°W)
- 975 profiles from surface to 1000m depth
- temperature, salinity, oxygen, fluorescence, CDOM, backscatter

=> ongoing exploitation of the data (slow since 2015 but plans to continue)

2) **Campe glider** (GLISEN1 project, LEFE-GMMC & EU PREFACE funding)
- 12 march → 13 may 2014
- Long section offshore of Dakar, completed with GEOMAR glider
- 412 profiles from surface to 1000 m depth
- temperature, salinity, oxygen, fluorescence, turbidity

=> data analysed and published : Kolodziejczyk et al., JGR, 2018

3) **Bonpland glider** (GLISEN2 project, LEFE-GMMC & EU PREFACE funding)
- 5 october → 25 November 2016
- Long section offshore of Dakar (~ GLISEN1) + triangle
- temperature, salinity, oxygen, fluorescence, CDOM, backscatter

=> data not yet exploited (but some plans to do it)

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Part 2

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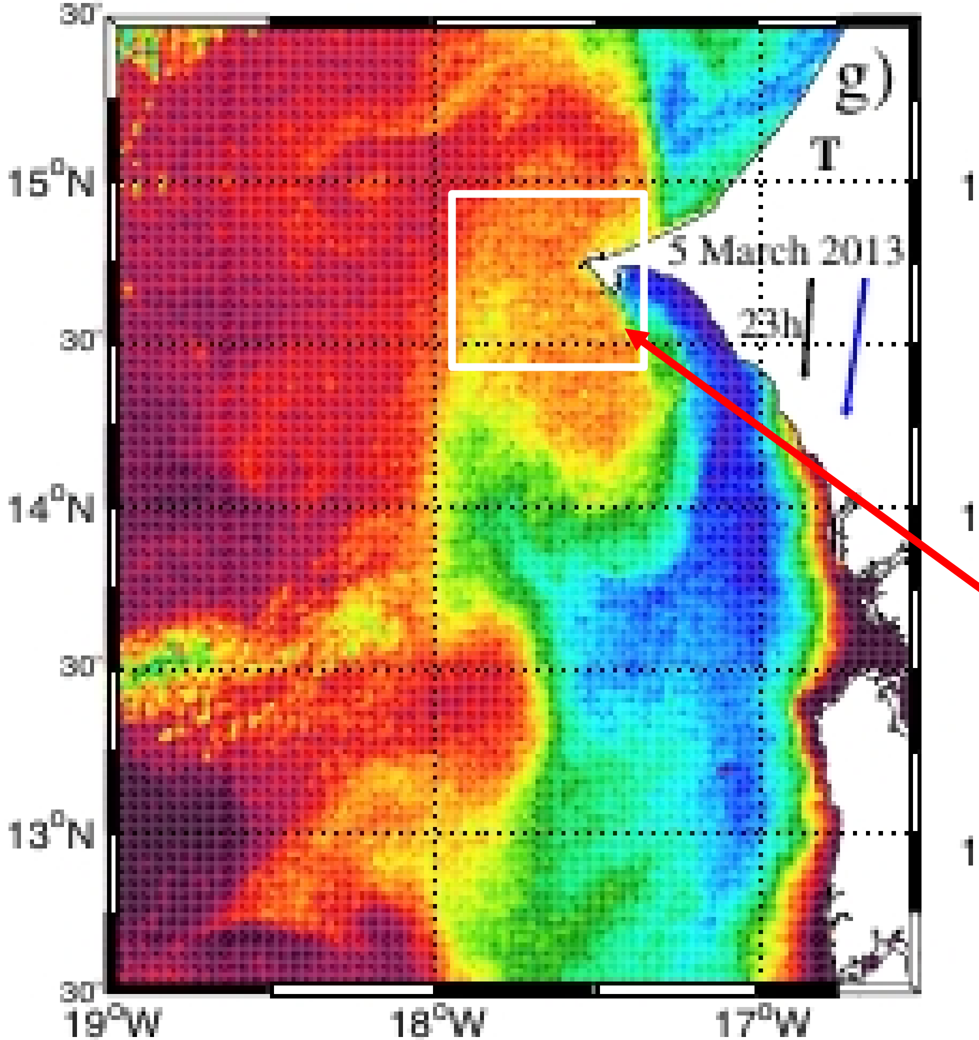
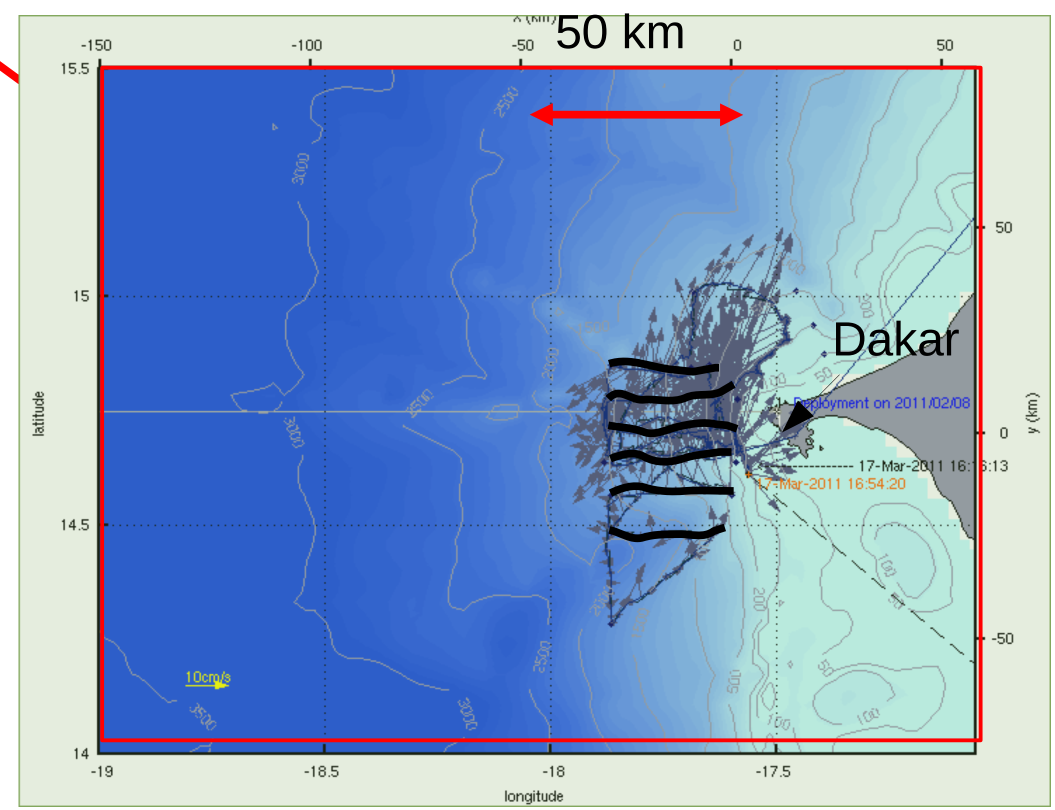
=> data not yet exploited (but some plans to do it)

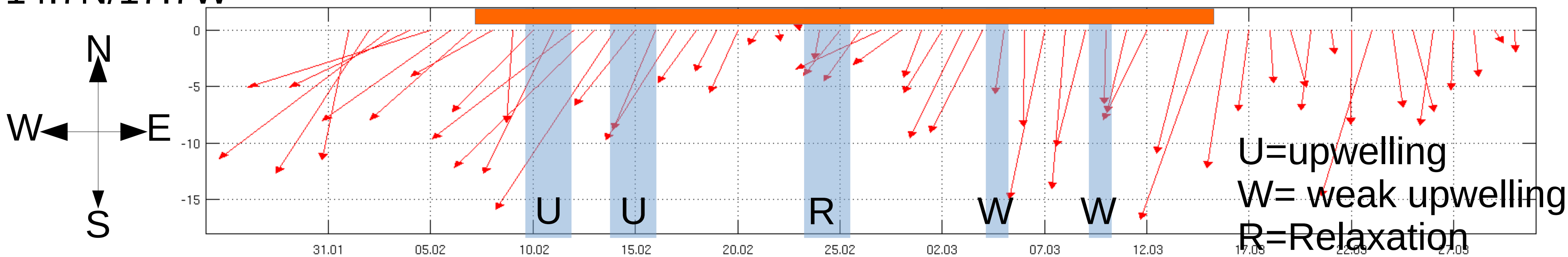
SENEGLIDE deployement (8 february-17 march 2011)



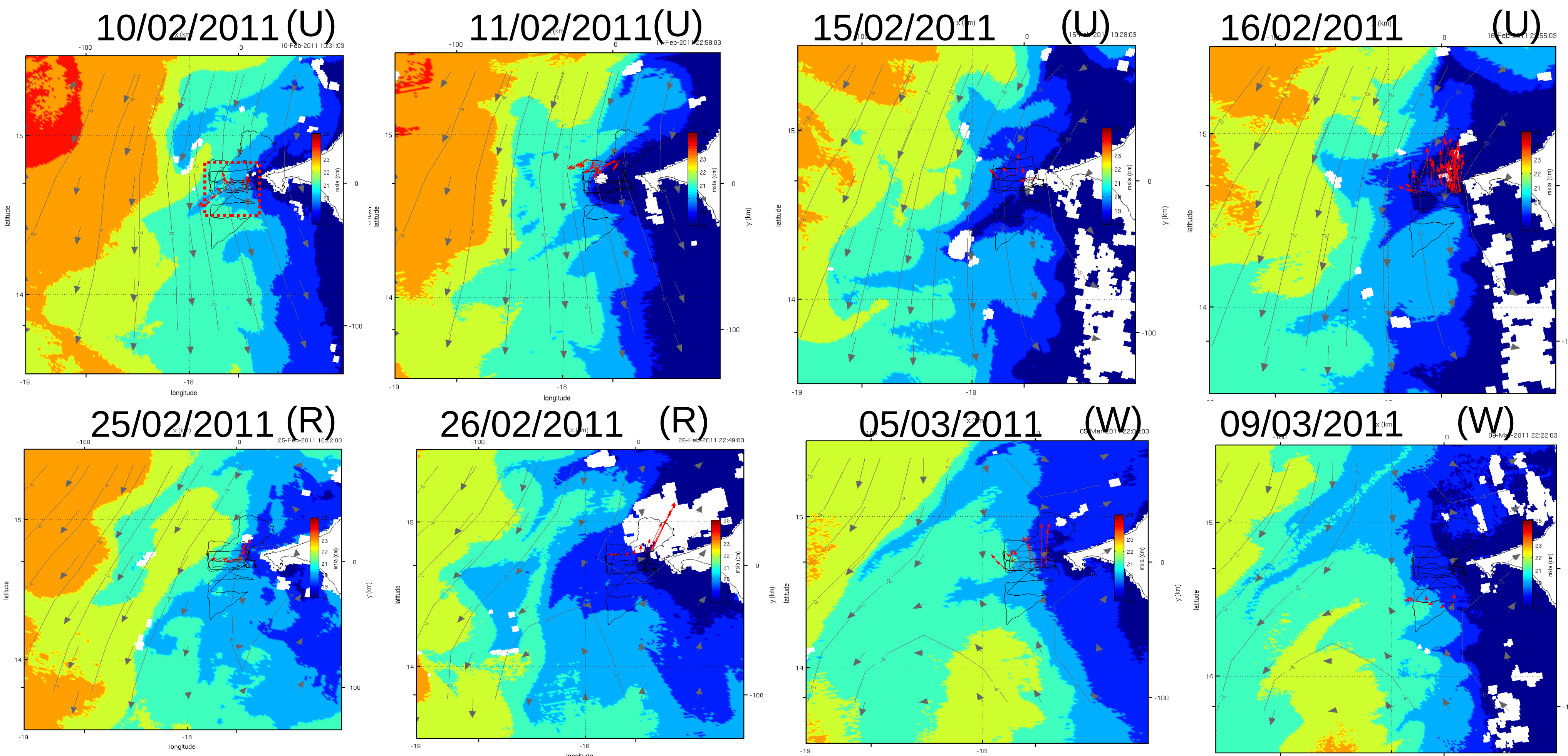


Upwelling phase during SENEGLIDE (8 February-17 march 2011)

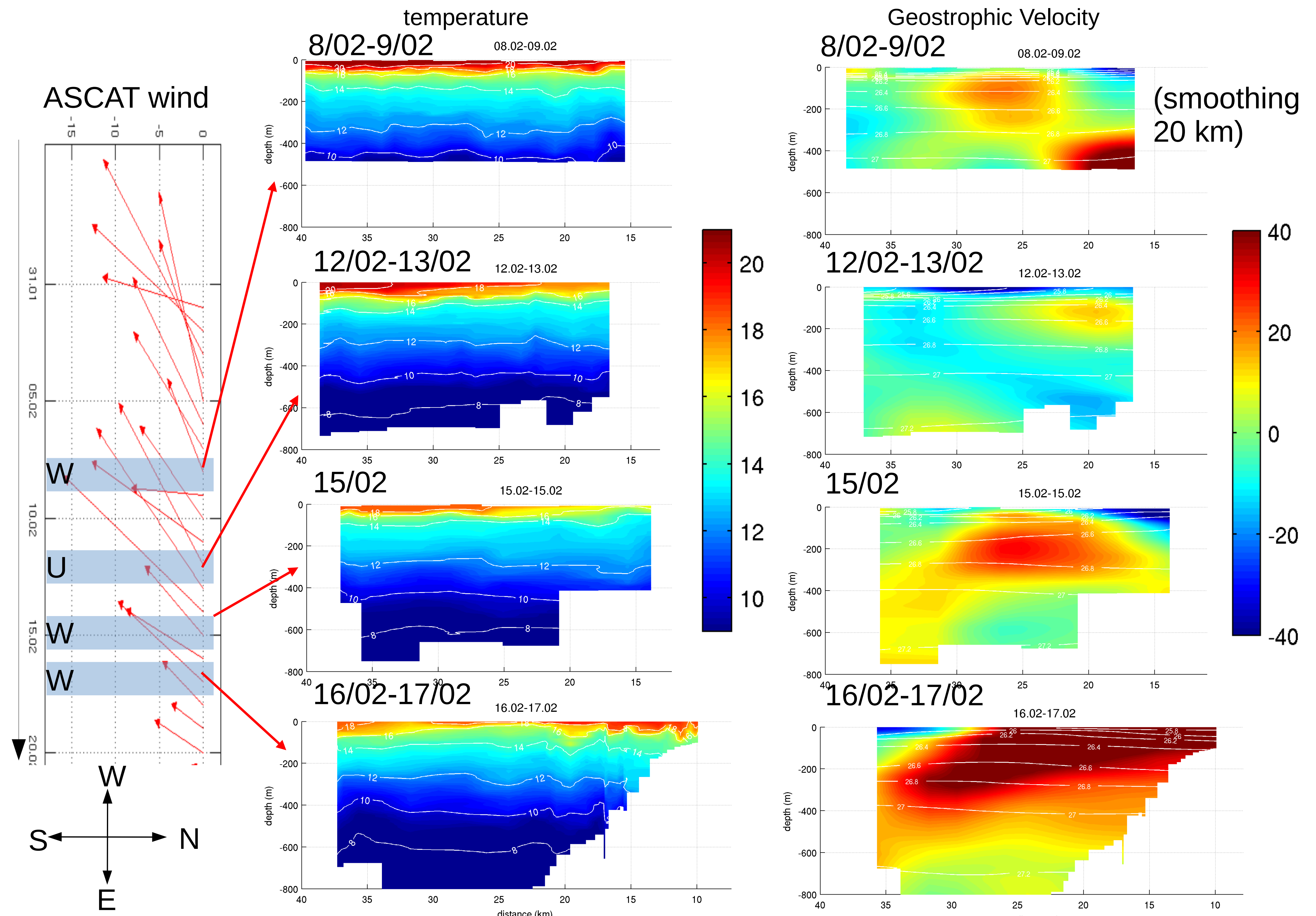
ASCAT wind
14.7N/17.7W



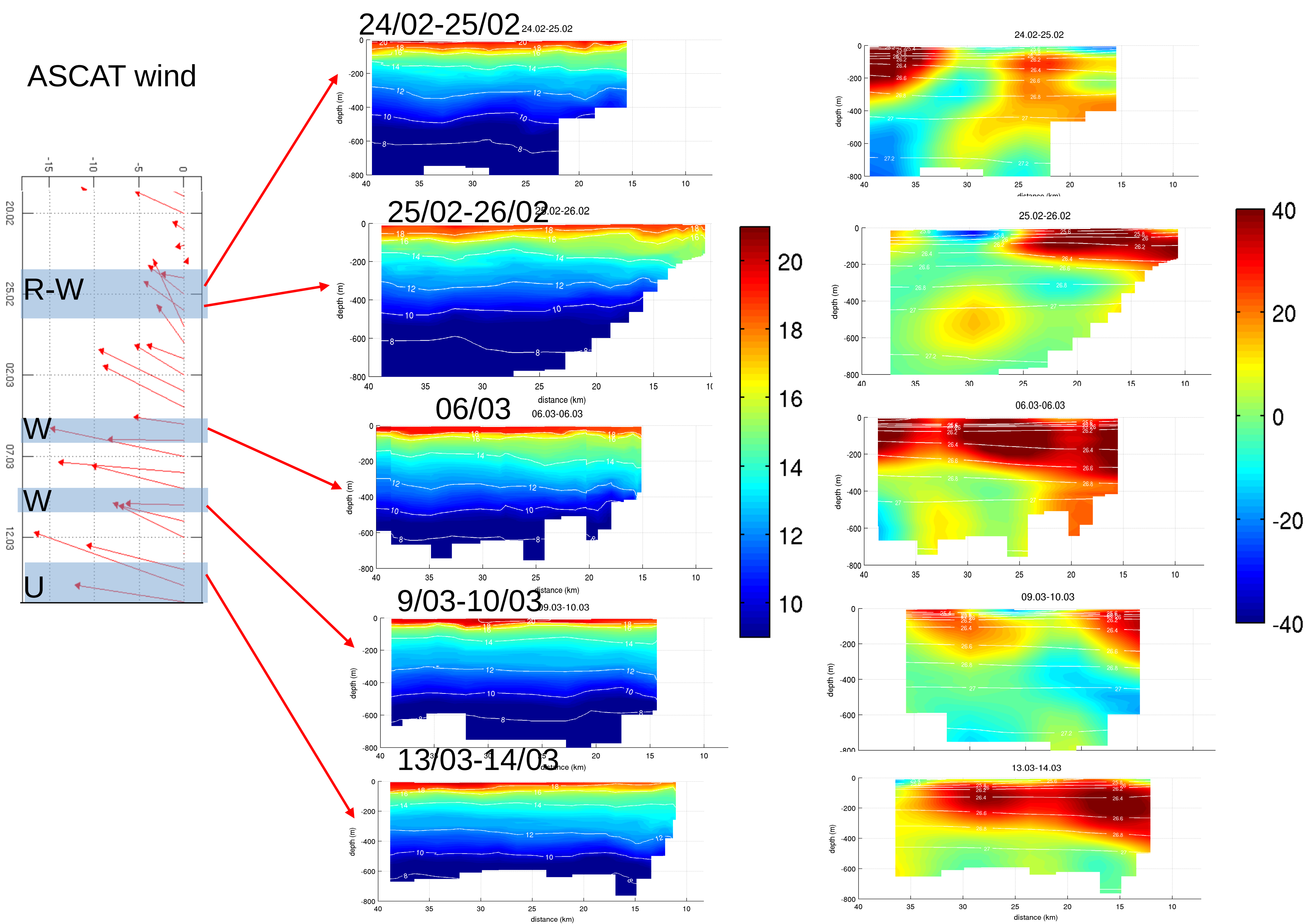
SST & AVISO currents



Temperature and geostrophic velocity (February)



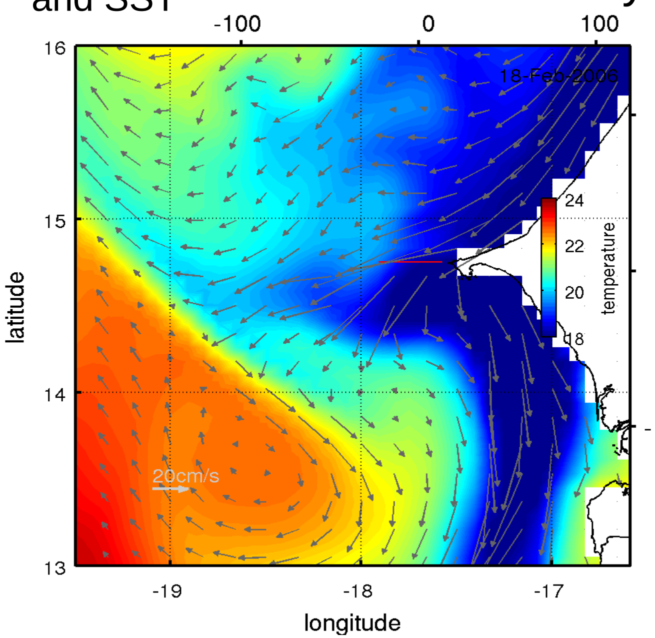
Temperature and geostrophic velocity (end of February-March)



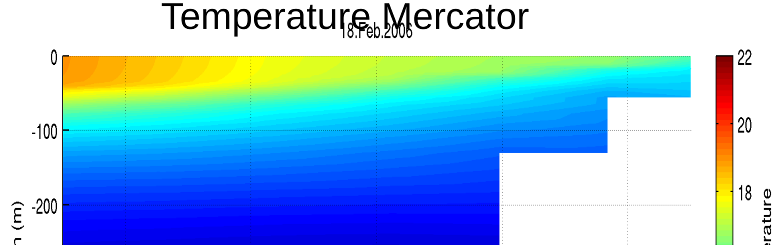
Comparing to Mercator model (~10 km resolution)

surface current and SST

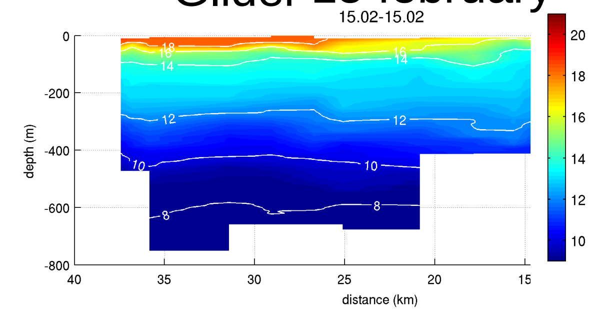
18 february



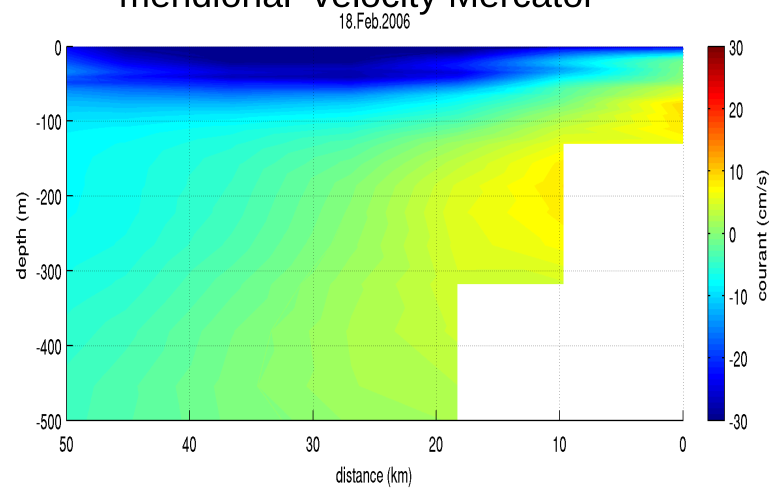
Temperature Mercator

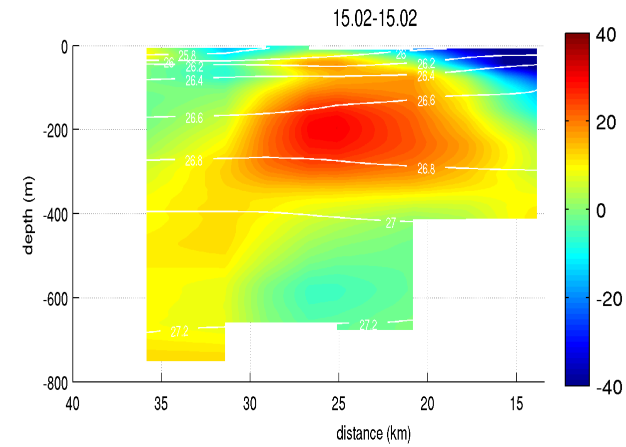


Glider 15 february



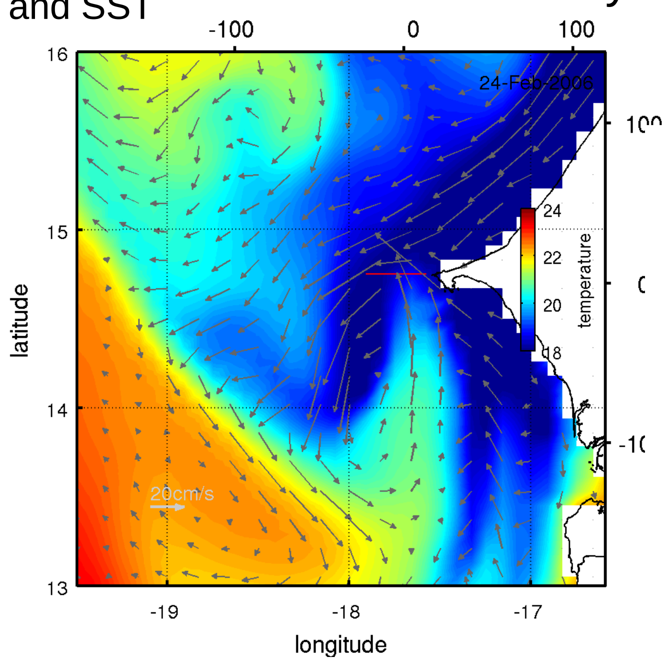
meridional velocity Mercator



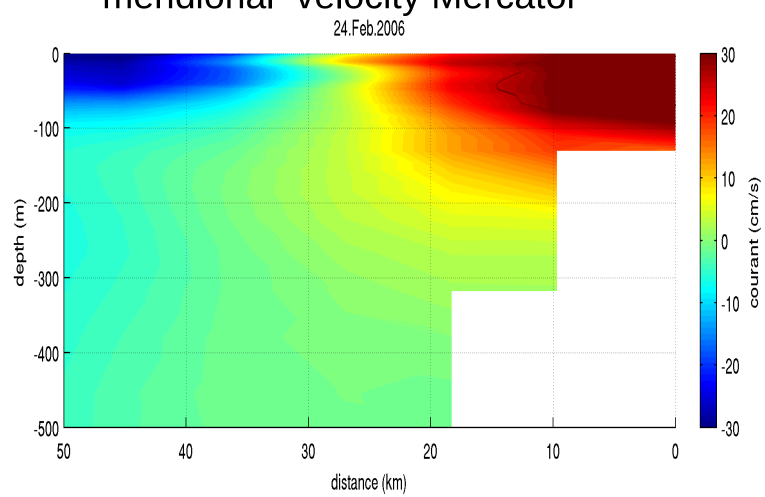


surface current and SST

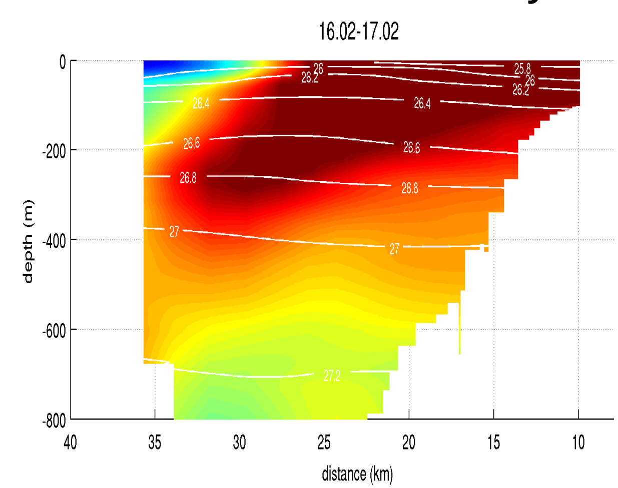
24 february



meridional velocity Mercator

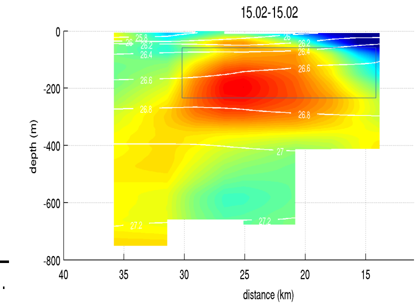


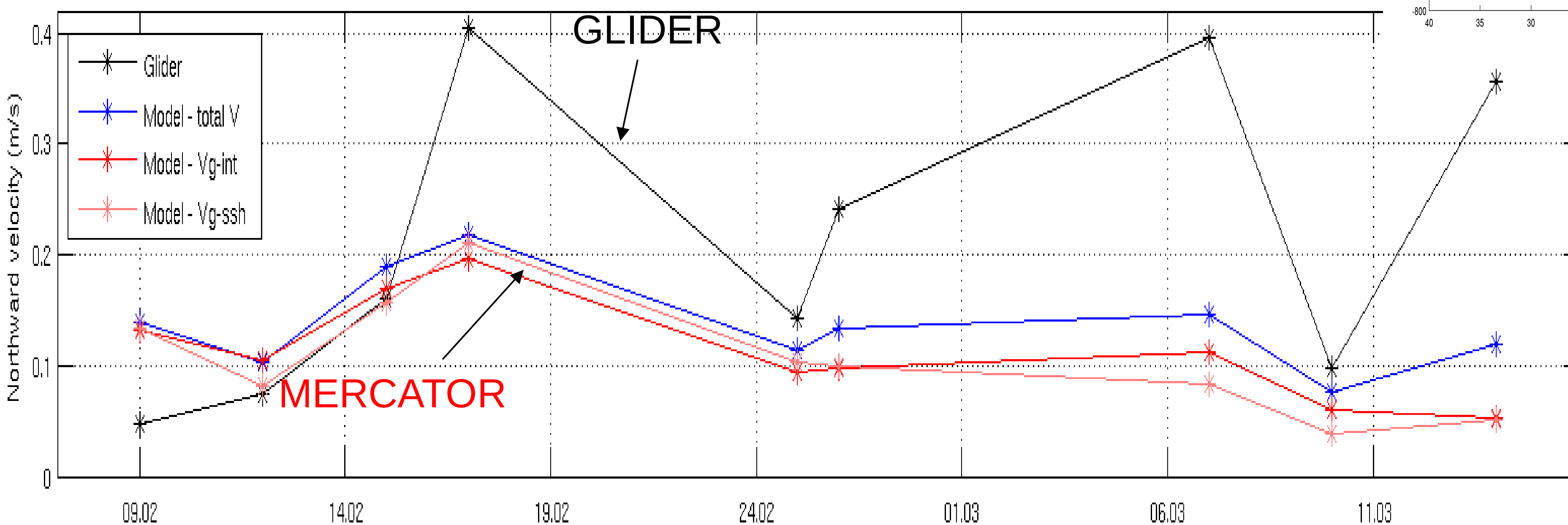
Glider 18 february



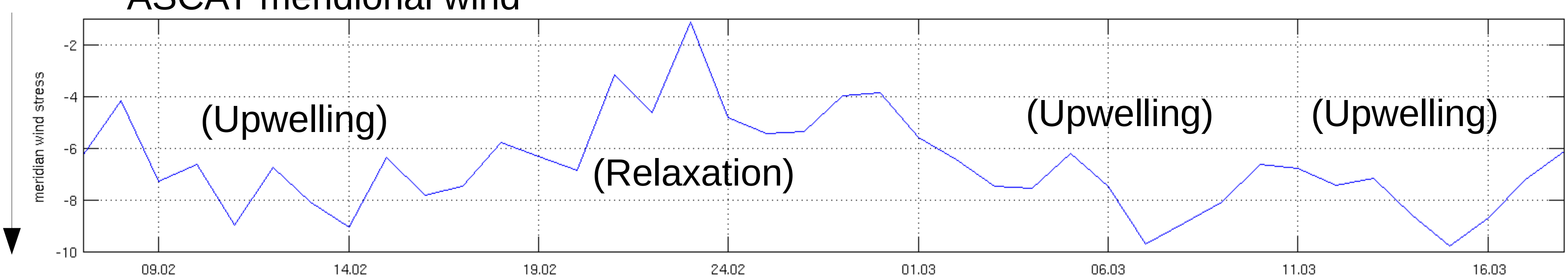
Comparing to Mercator model (~10 km resolution)

Northward transport in coastal box (15-30 km from coast, 100-200 m depth)





ASCAT meridional wind

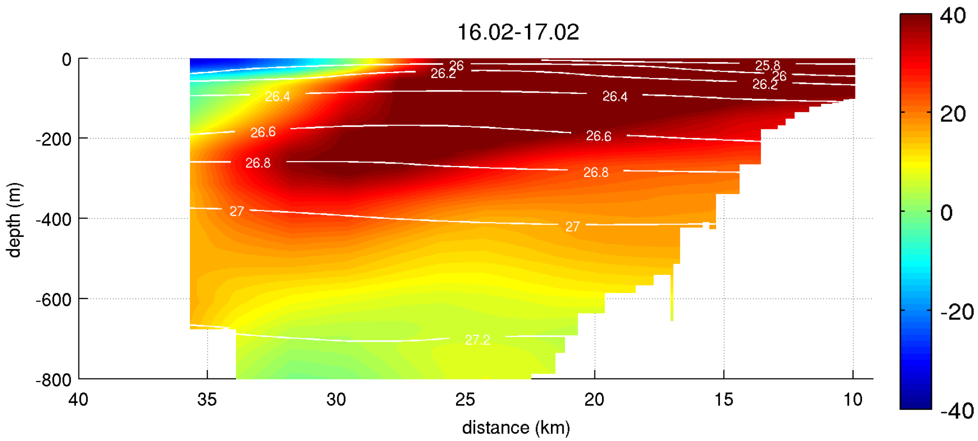


=> no clear relation between undercurrent intensity and meridional wind

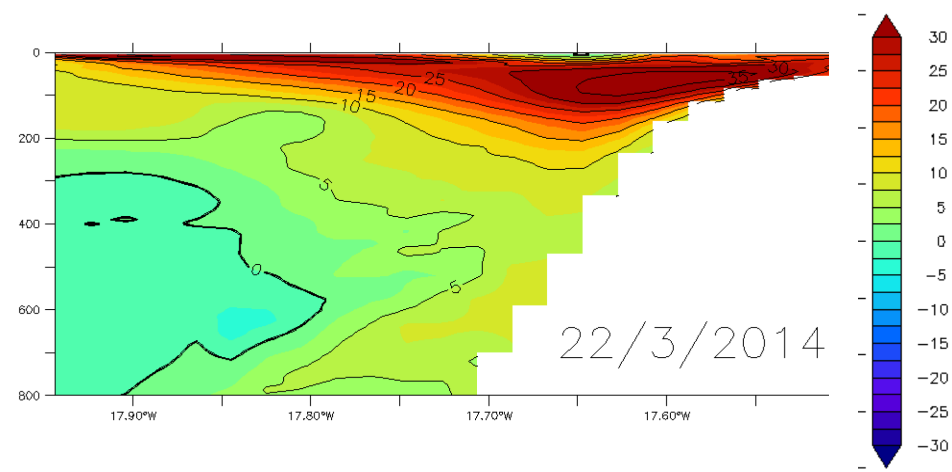
=> coastal waves?

Comparison to cross-shore sections in croco model (2013-2017 period)

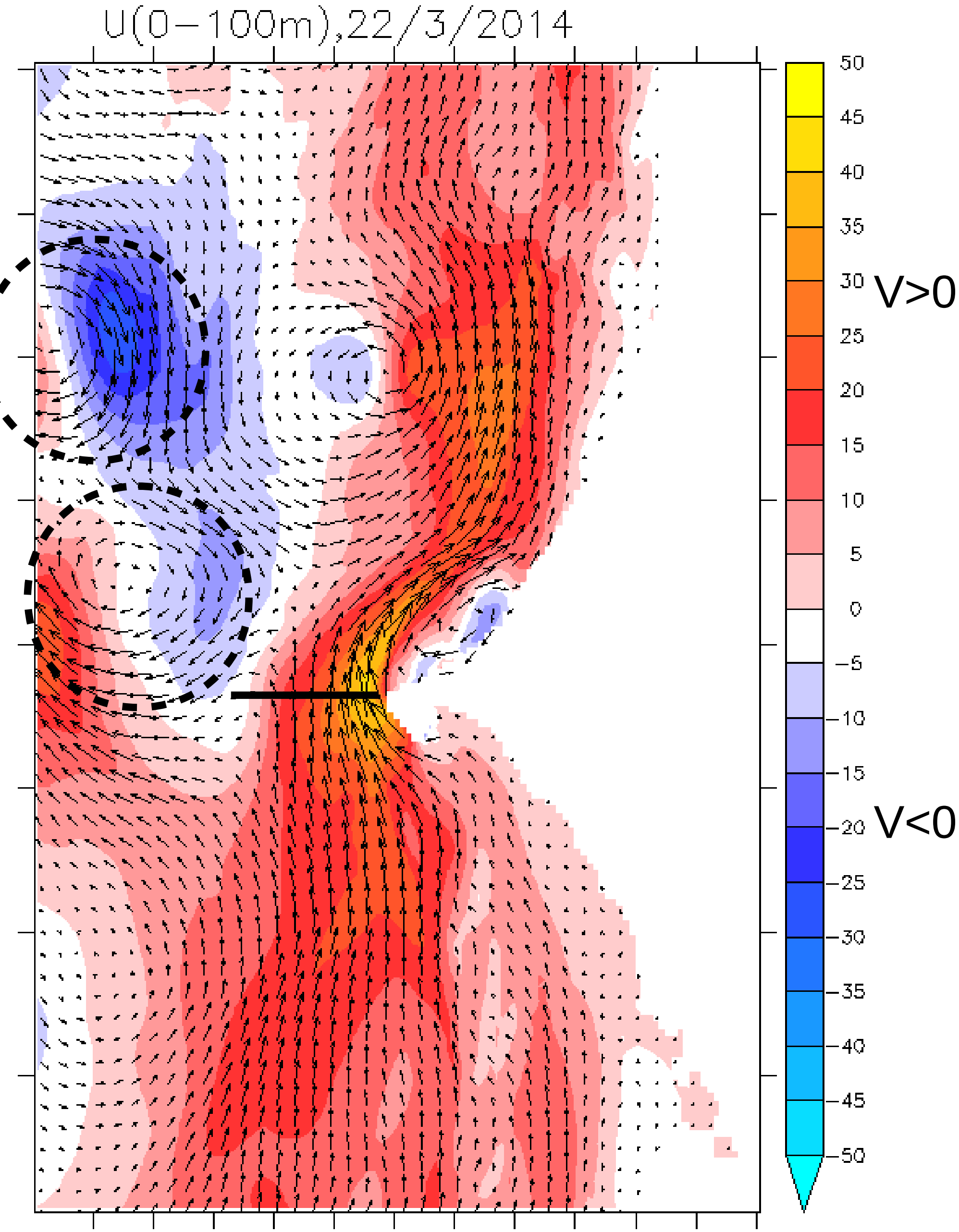
Glider current (16-17/02/2011)



Croco model (2km) current, 22/03/2011



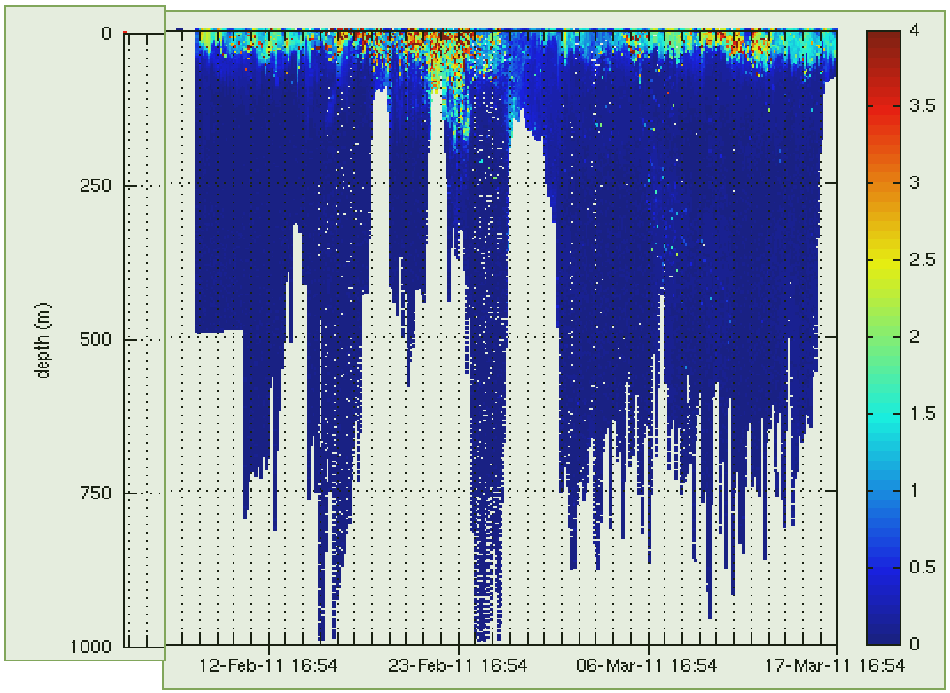
Depth averaged circulation (0-100m)



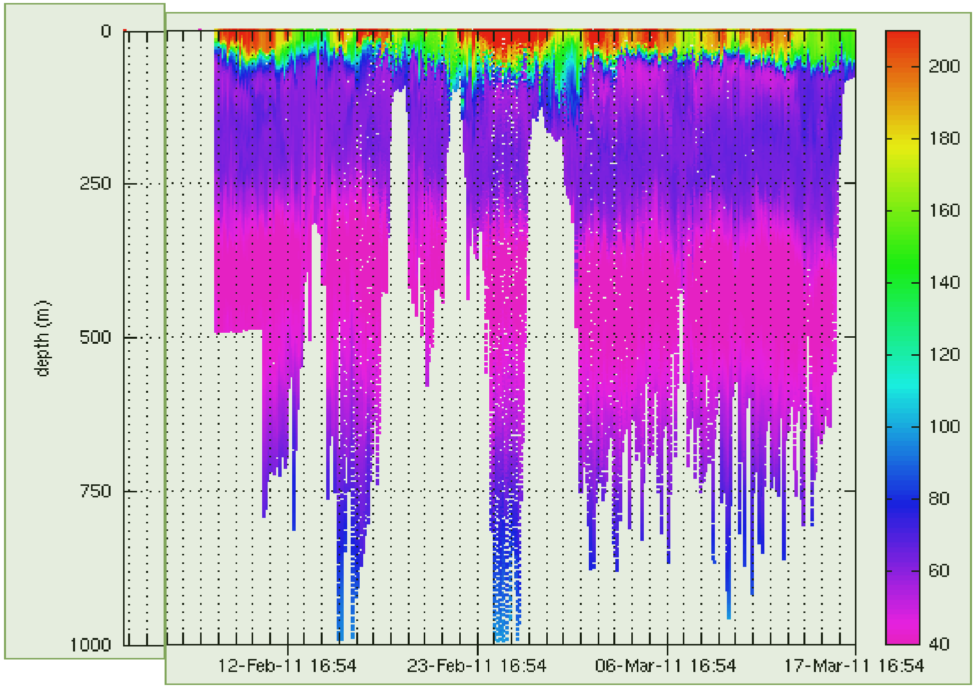
More SENEGLIDE data to exploit

Salinity sections + ...

Fluorescence ($mgChl/m^3$)



Oxygen (µmol/l)



(raw data, to be processed)

Conclusions and perspectives (part 1)

- cross-shore sections revealed complex surface/subsurface current structures

  Open questions: what explains the short-term (~daily) variability of these jets?

  → meanders due to instabilities?

  → interactions between offshore eddies and the coastal jets?

  → remotely-forced coastal trapped waves?

- a lot of data remains to be analyzed : salinity (water mass characteristics), oxygen, fluorescence

- regional model: useful tool to help interpreting the data

  (2011 glider period needs to be simulated)

Part 2: glider measurements in a anticyclonic mesoscale eddy and embedded fine scales structures offshore of the upwelling system

AGU100 ADVANCING EARTH AND SPACE SCIENCE

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE
10.1029/2018JC014135

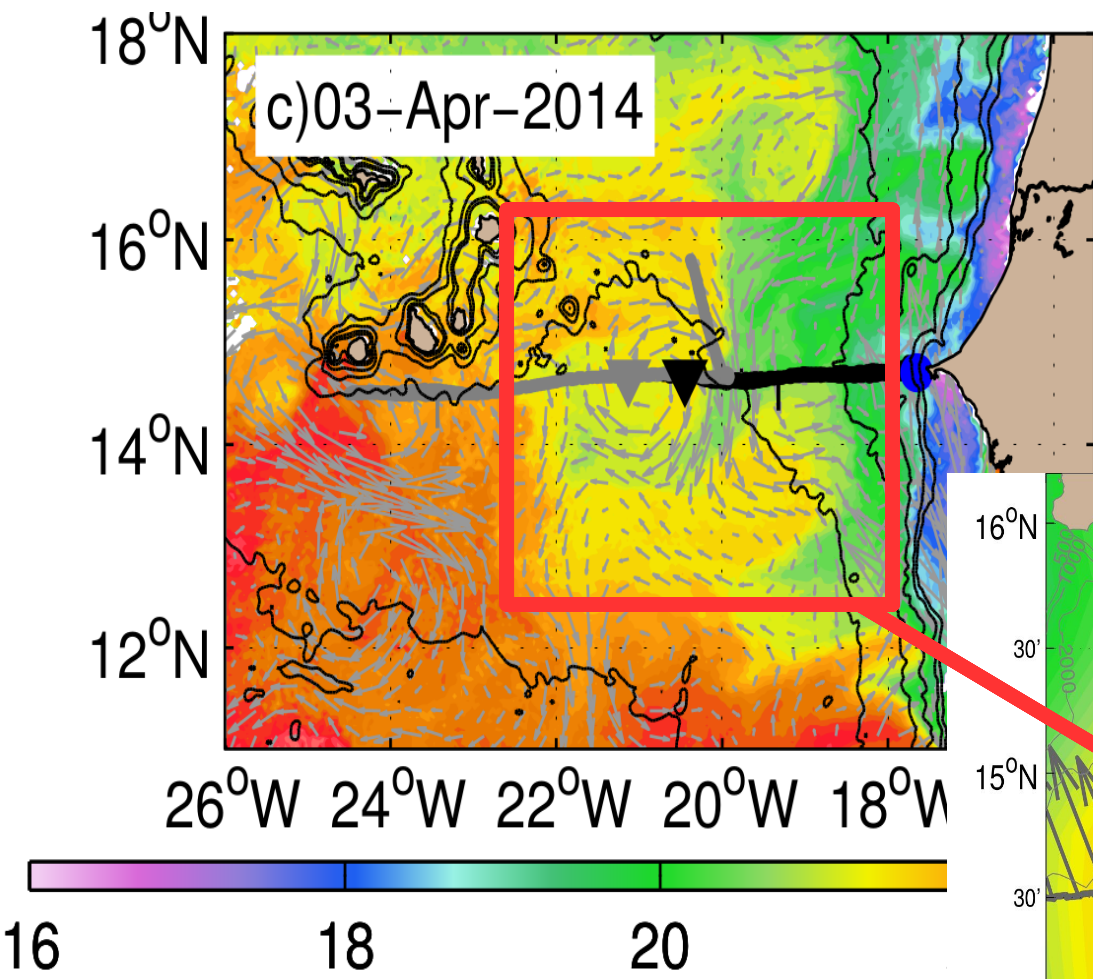
Key Points:
- Anticyclonic near surface eddy is observed from high-resolution gliders measurements in the Eastern Tropical Atlantic
- Fine-scale thermohaline and dissolved oxygen features are observed in the anticyclonic eddy
- This fine-scale feature are likely related to stirring by the mesoscale eddy

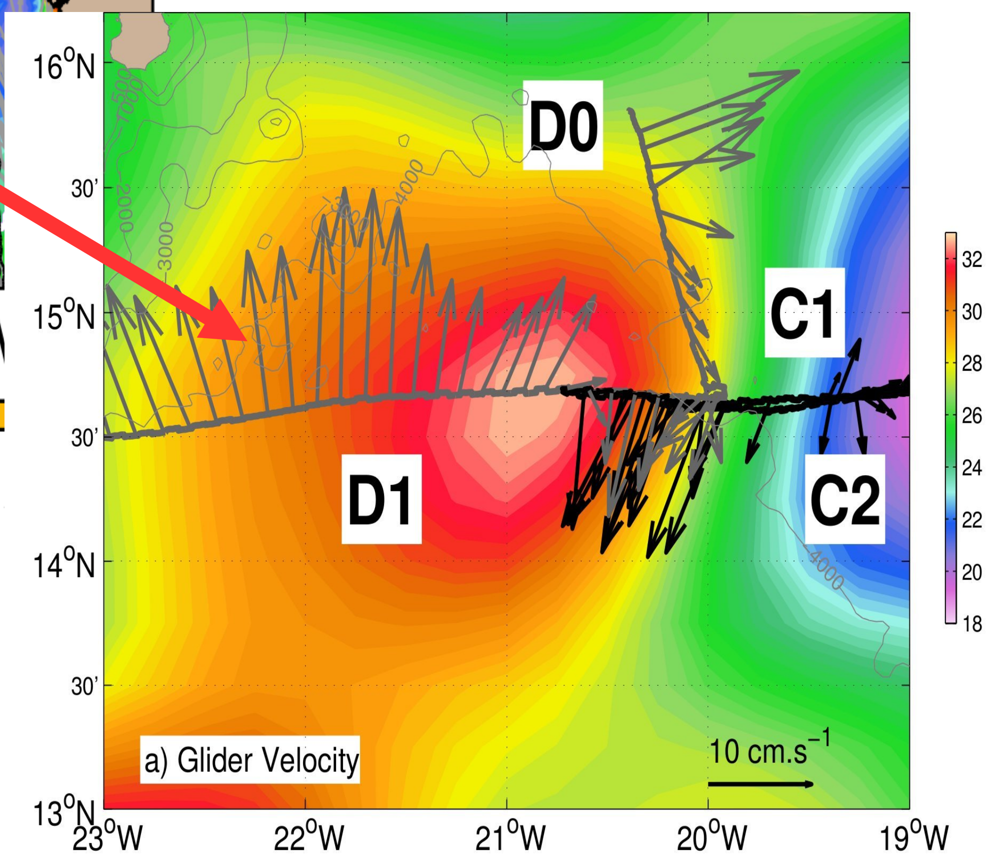
Subsurface Fine-Scale Patterns in an Anticyclonic Eddy Off Cap-Vert Peninsula Observed From Glider Measurements

Nicolas Kolodziejczyk[1,2], Pierre Testor[1], Alban Lazar[1], Vincent Echevin[1], Gerd Krahmann[3], Alexis Chaigneau[4], Claire Gourcuff[1], Malick Wade[5], Saliou Faye[6], Philippe Estrade[7], Xavier Capet[1,8], Laurent Mortier[1], Patrice Brehmer[8], Florian Schütte[3], and Johannes Karstensen[3]

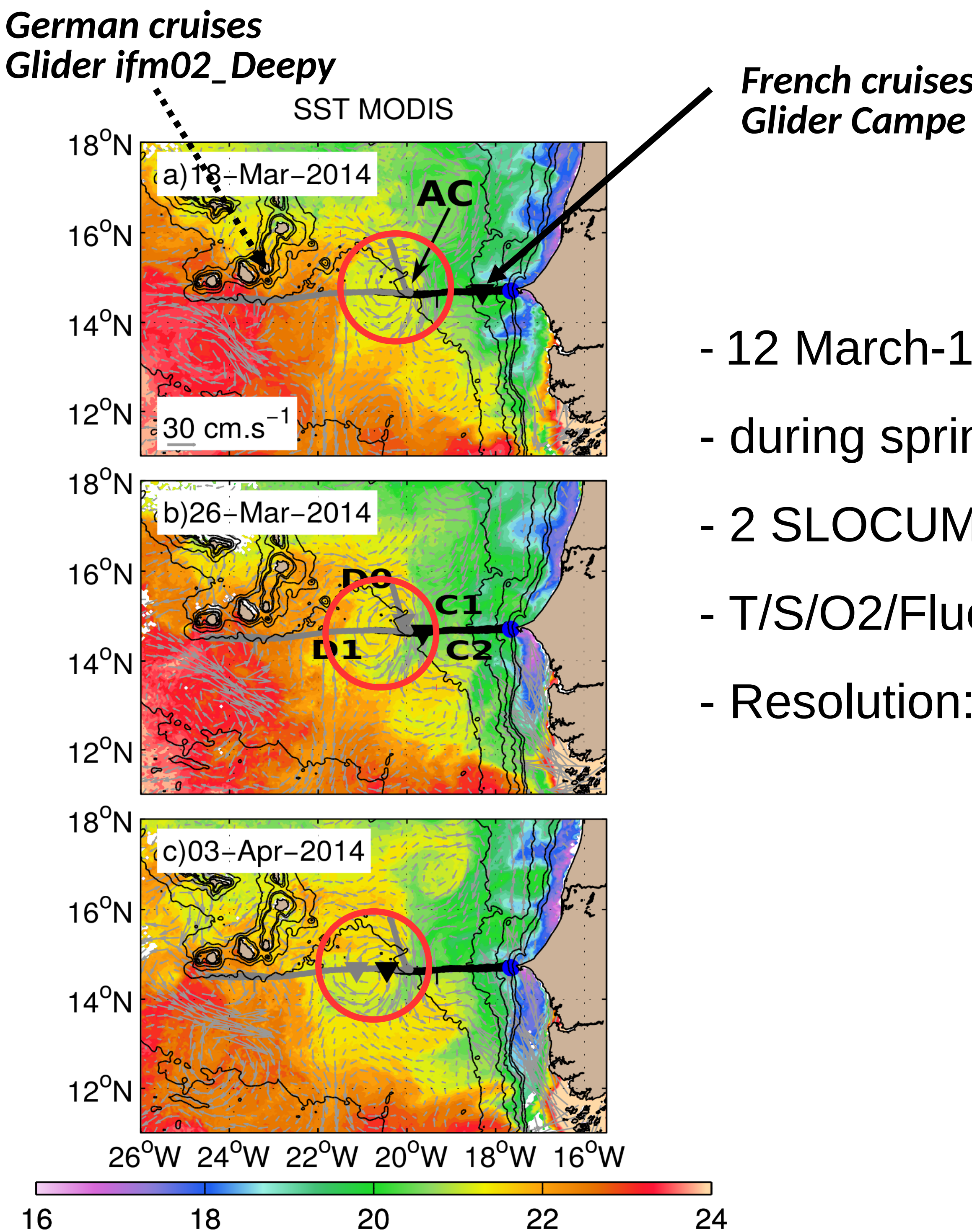
[1]Sorbonne University (UPMC, Univ Paris 06)-CNRS-IRD-MNHN, LOCEAN Laboratory, Paris, France, [2]University of Brest, CNRS-IRD-Ifremer, LOPS Laboratory, IUEM, rue Dumont d'Urville, Plouzané, France, [3]Helmholtz Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany, [4]LEGOS, Universite de Toulouse, CNES-CNRS-IRD-UPS, Toulouse, France, [5]Laboratoire des sciences de l'Atmosphère et de l'Océan, Université Gaston Berger, Saint-Louis, Sénégal, [6]Institut Sénégalais de Recherches Agricoles, Centre de Recherche Océanographique de Dakar-Thiaroye, Dakar, Sénégal, [7]IRD, UCAD/LPAOSF, Dakar, Sénégal, [8]Institut de Recherche pour le Développement, Dakar, Sénégal

Mesoscale context





Sampling using 2 gliders



- 12 March-13 May 2014
- during spring : coastal upwelling season
- 2 SLOCUM gliders (french & german)
- T/S/O2/Fluo. (0-900 m depth)
- Resolution: ~5 km/4 hours

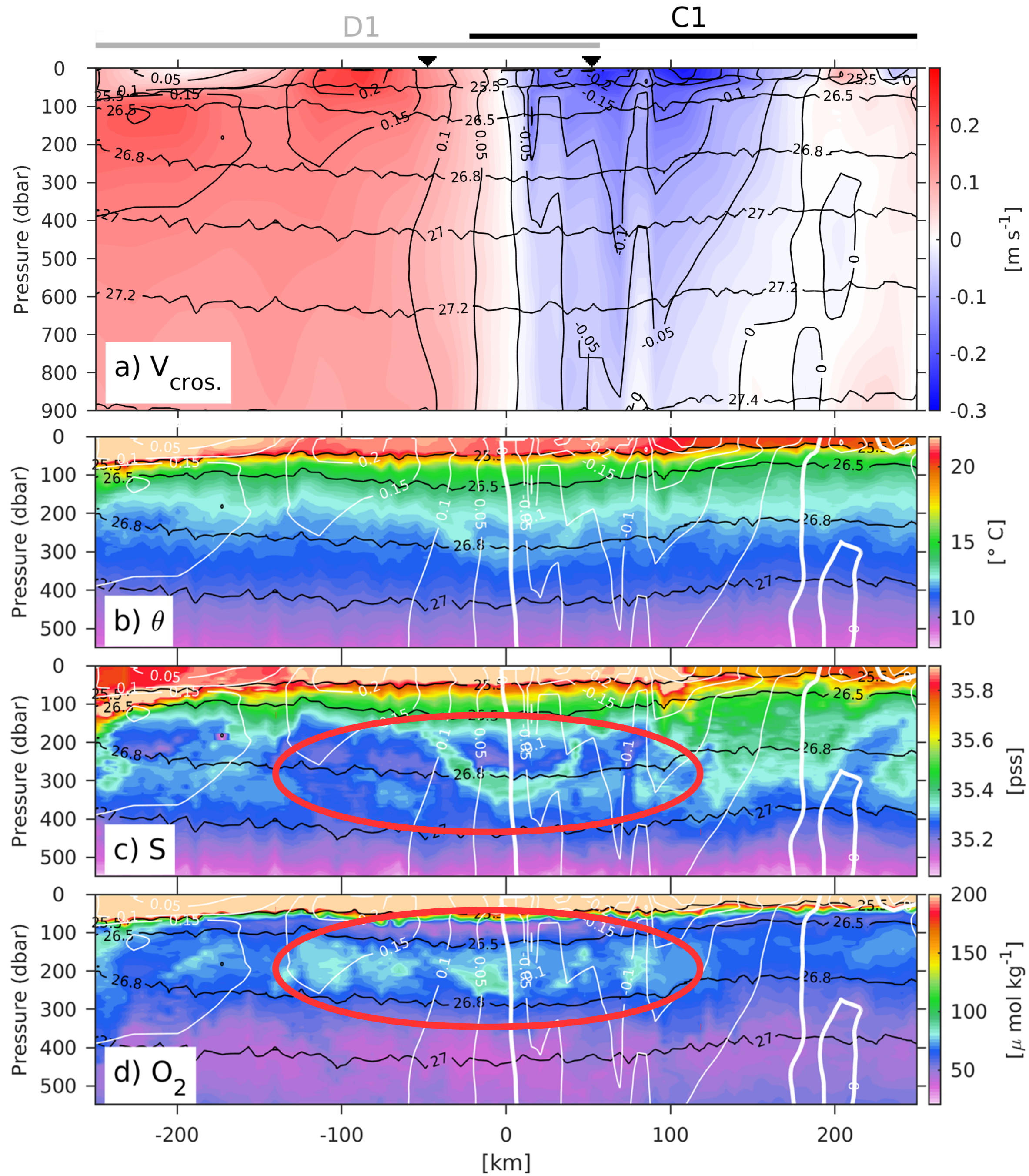
Merging of the 2 glider sections

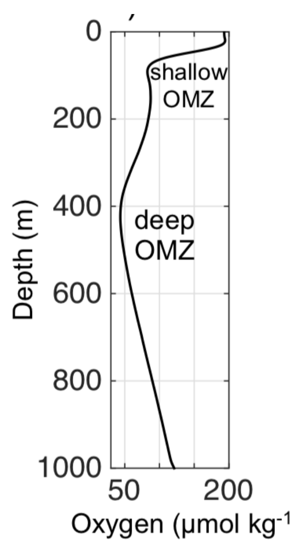
Geostrophic meridional speed

Temperature

Salinity

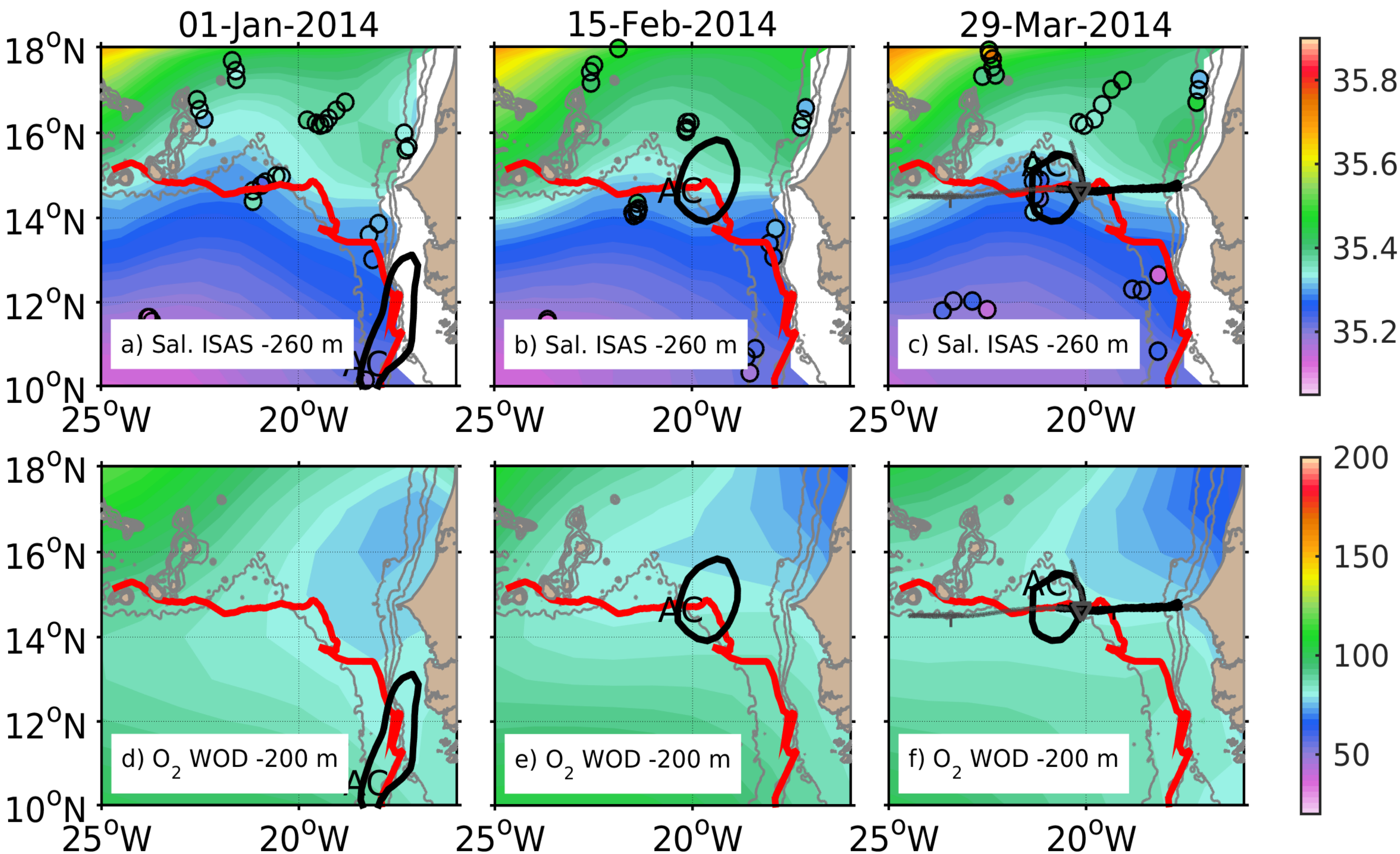
Oxygen





Tracking of the eddy and its water masses

AVISO altimetry + ISAS salinity



- Eddy tracking method : *Chaigneau et al.* (2008)

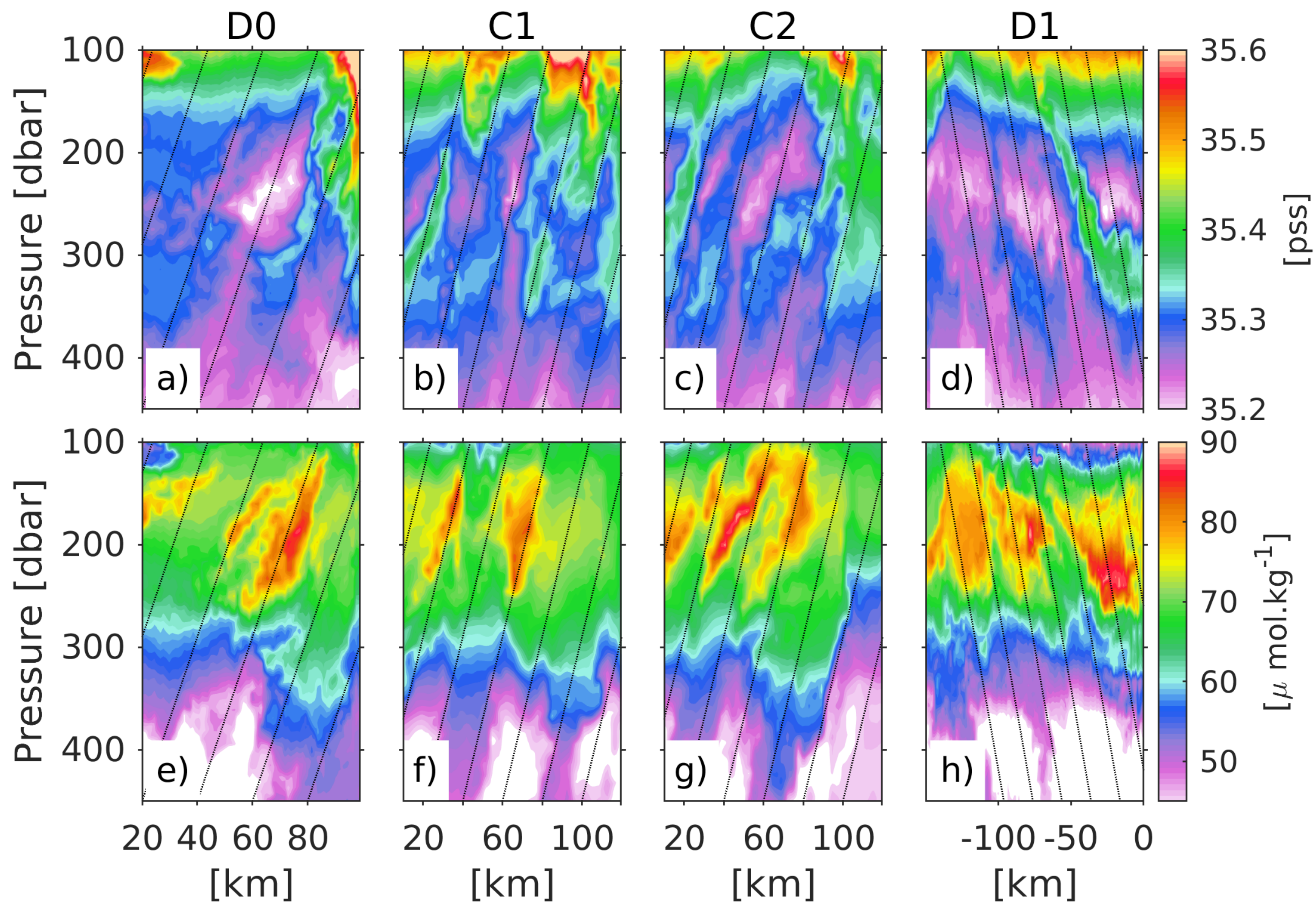
→ South-eastern origin

→ Low salinity/high oxygen region

Fine-scale salinity and oxygen structures

Salinity

Oxygen

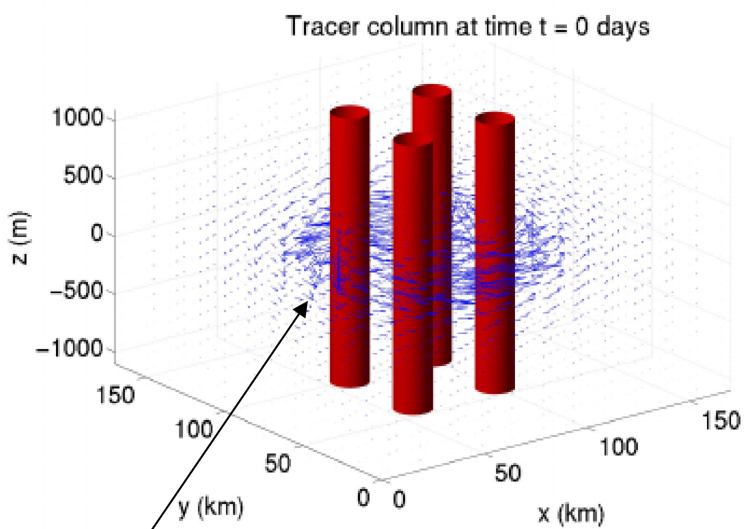


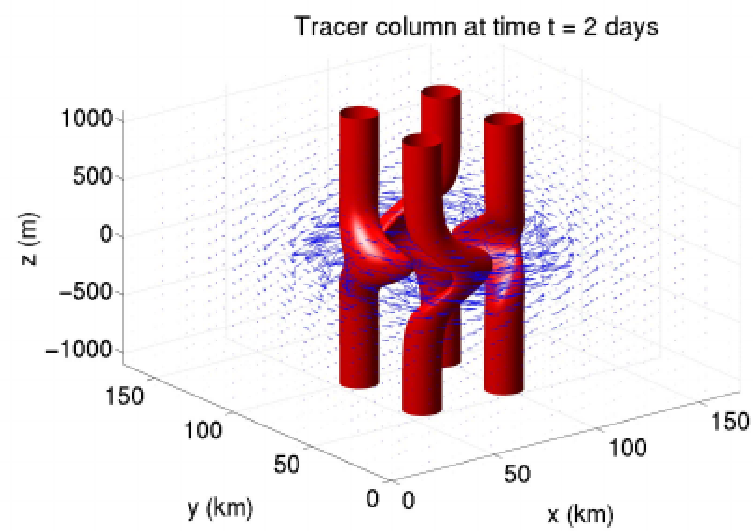
→ weak salinity/ high oxygen → water mass from south of the eddy

→ fine-scale structure slopes are close to f/N (Smith and Ferrari, 2009)

Generation of submesoscale structures by stirring

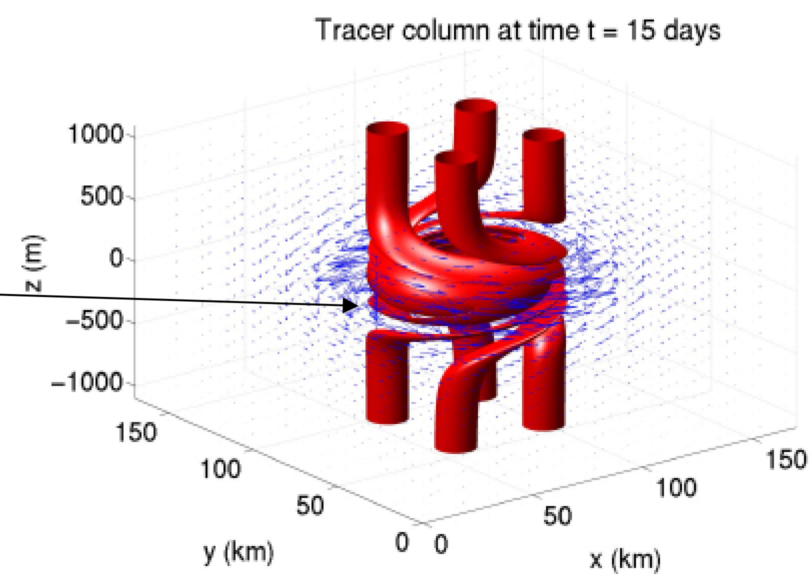
Visualization of mesoscale stirring





Eddy velocity field

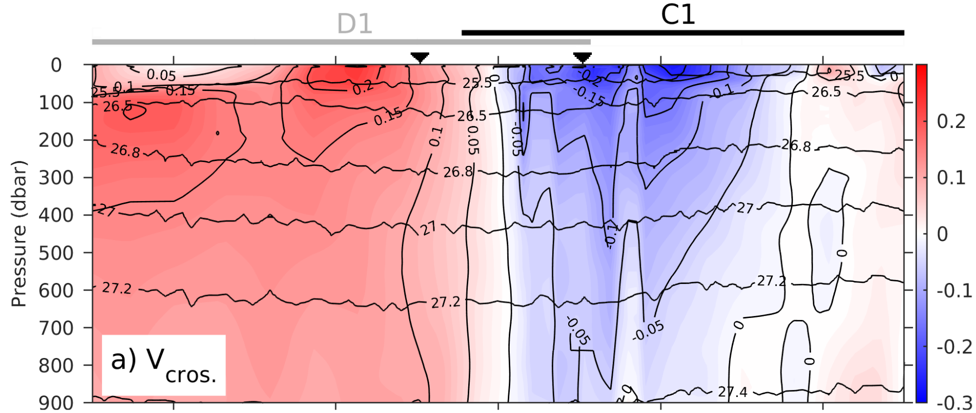
Layering



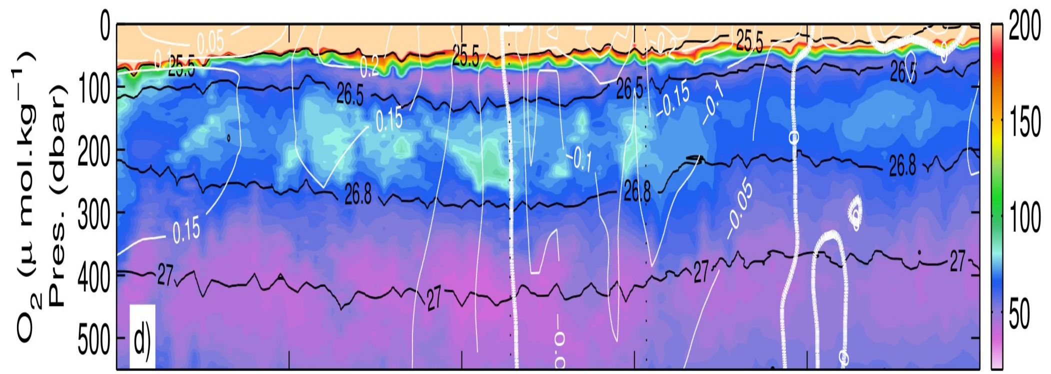
Meunier et al.,2014

Comparison with model (croco-pisces, 2 km)

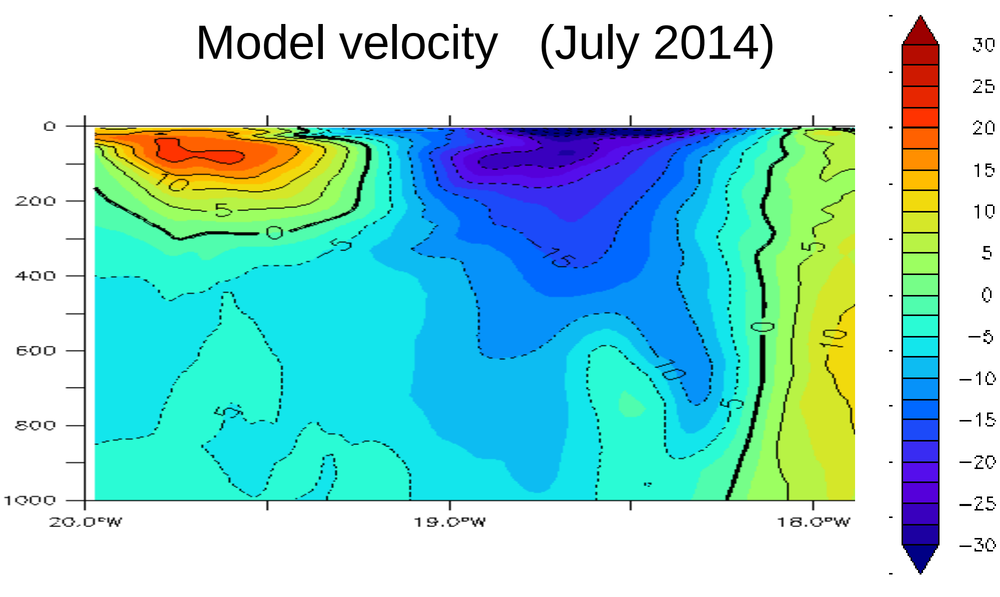
Geostrophic velocity (March-April 2014)



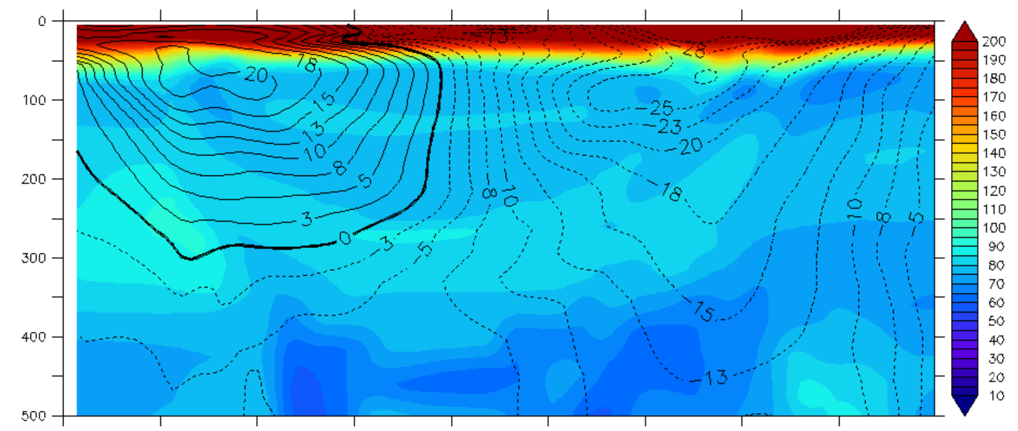
Oxygen



Model velocity (July 2014)



Model oxygen (July 2014)



Part 2 Conclusions & perspectives

→ anticyclonic eddy sampled with 2 Gliders off Cap-Vert penisula

→ eddy transported low salinity and low oxygenated waters from south senegal coast

→small scale thermohaline and oxygen features likely associated with of the stirring of the surrounding water masses

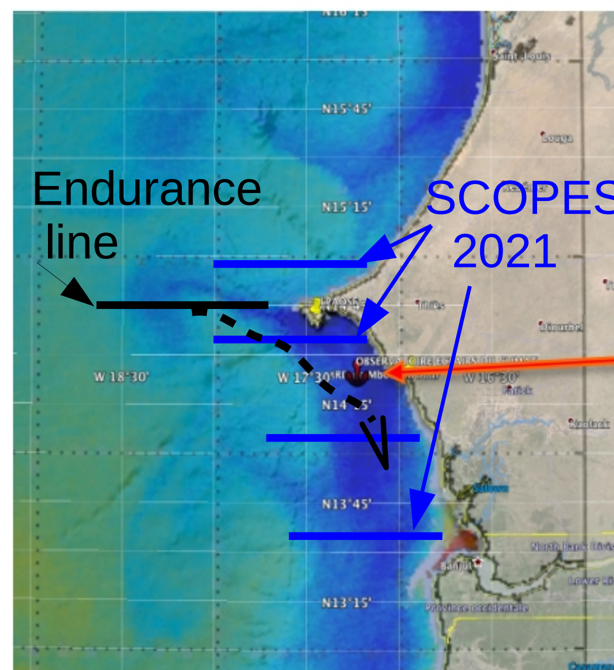
Perspectives:

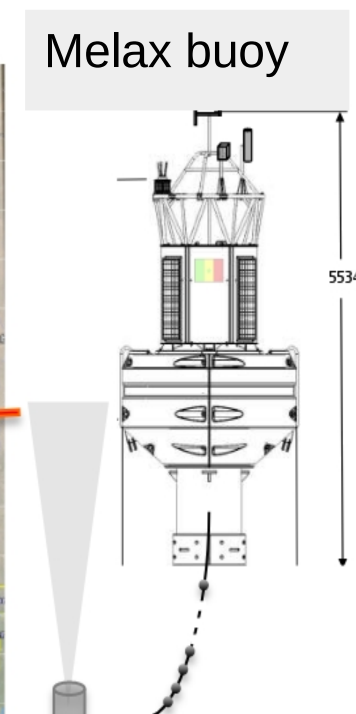
→ resume data analysis of SENEGLIDE and begin GLISEN2 (M2 training period in 2020 in LOPS)

→ future glider deployments:
Context: MELAX buoy (2015→)
and SCOPES/SOLAB cruises in 2021

→ Endurance line off Dakar:

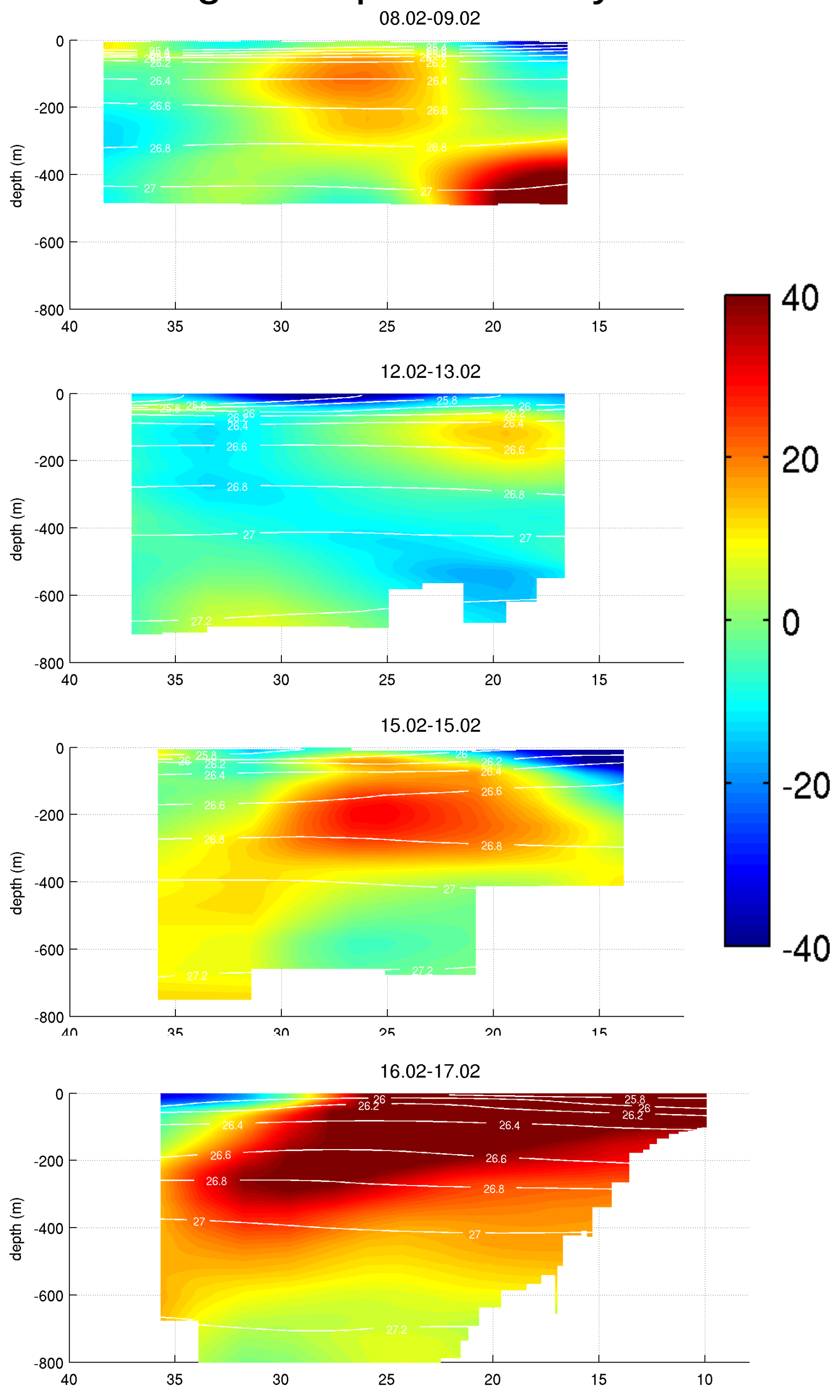
- alongshore currents unknown in warm season (no upwelling)
- monitoring of oxygen conditions
  → source waters for the shelf



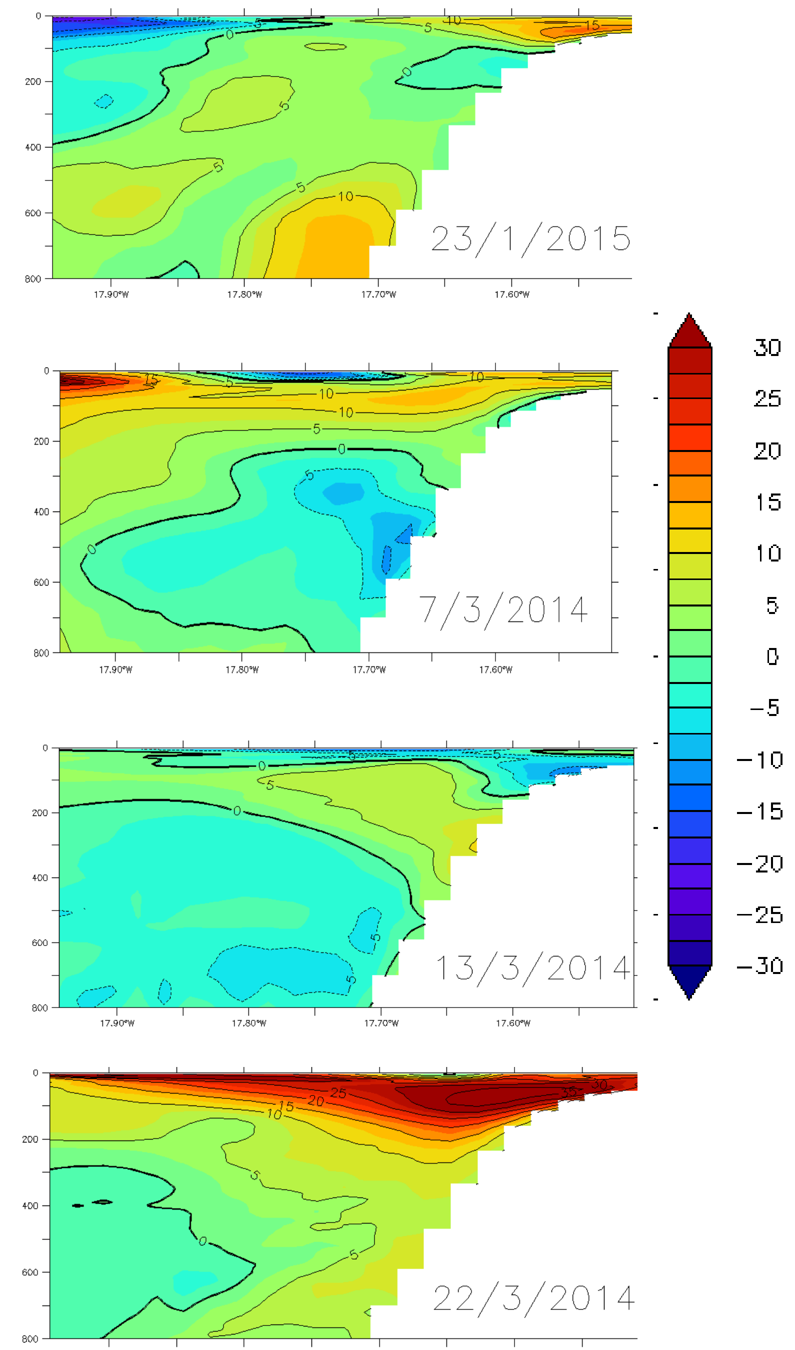


Comparison to cross-shore sections in croco model (2013-2017 period)

Glider geostrophic velocity

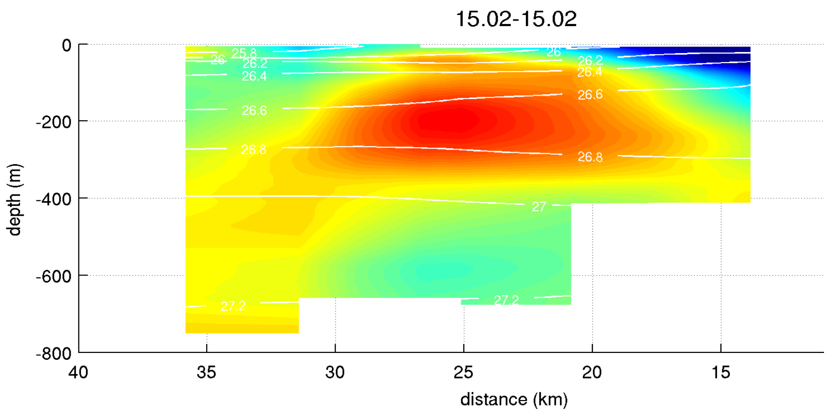


Croco (2km) meridional velocity

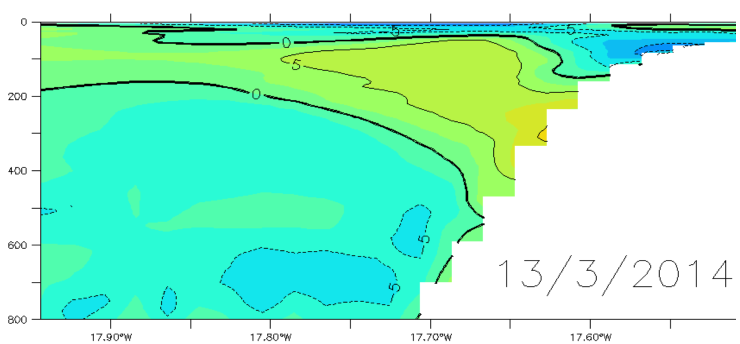


Comparison to cross-shore sections in croco model (2013-2017 period)

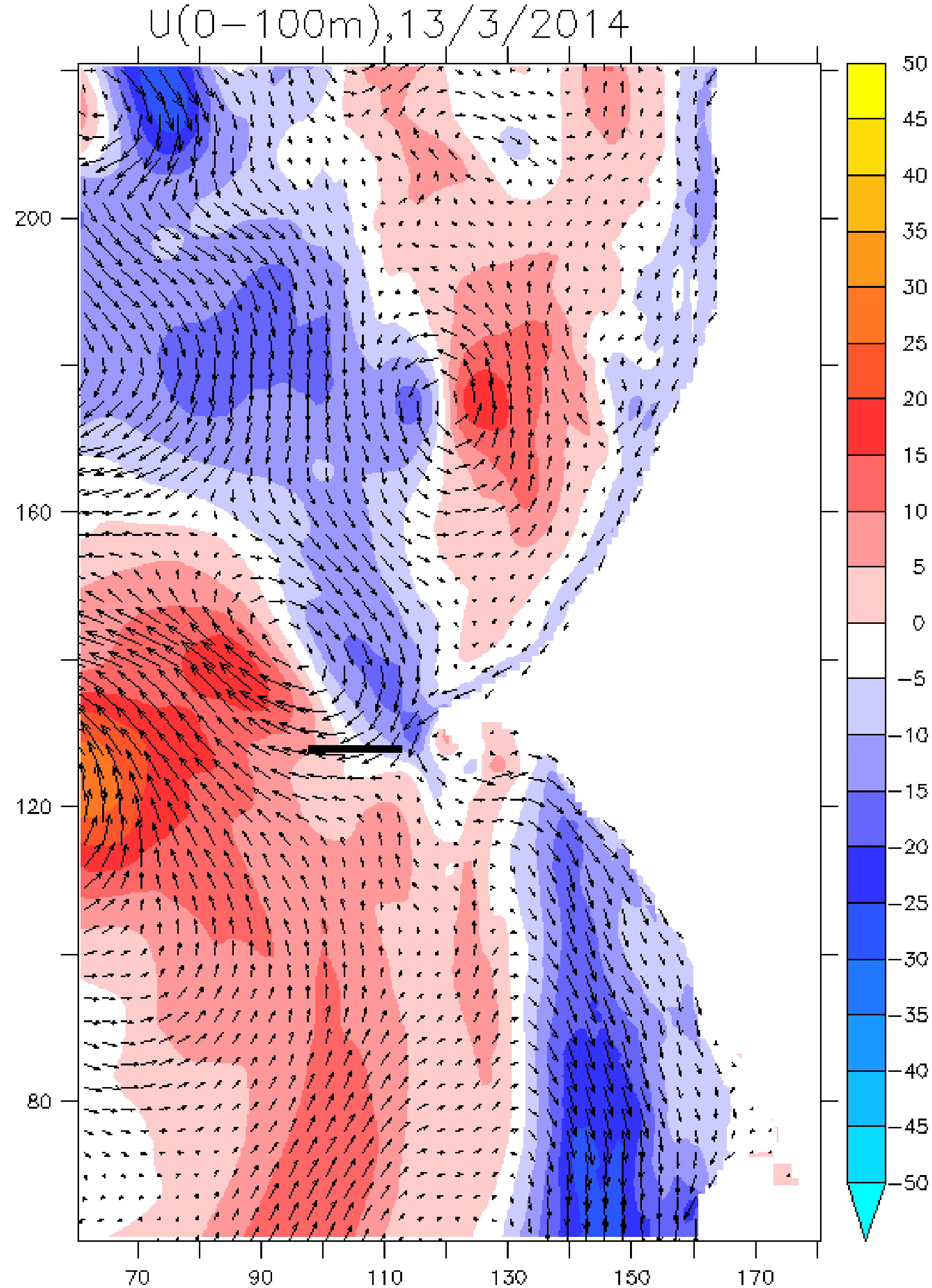
Glider current



Model current



Depth averaged circulation (0-100m)



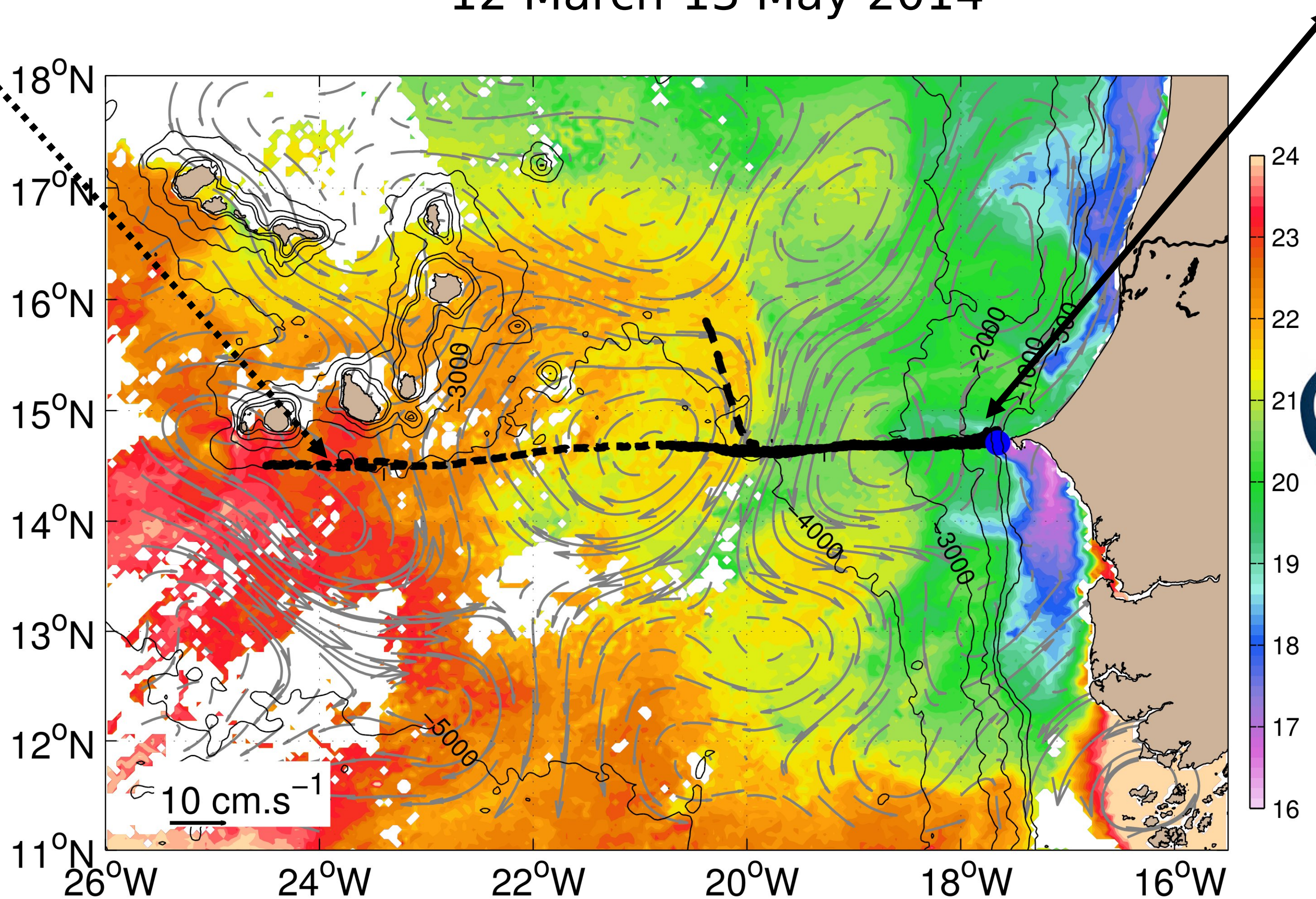
V>0

V<0

GLISEN Glider Campaign
GLISEN/DEPL21/AWA
12 March-13 May 2014

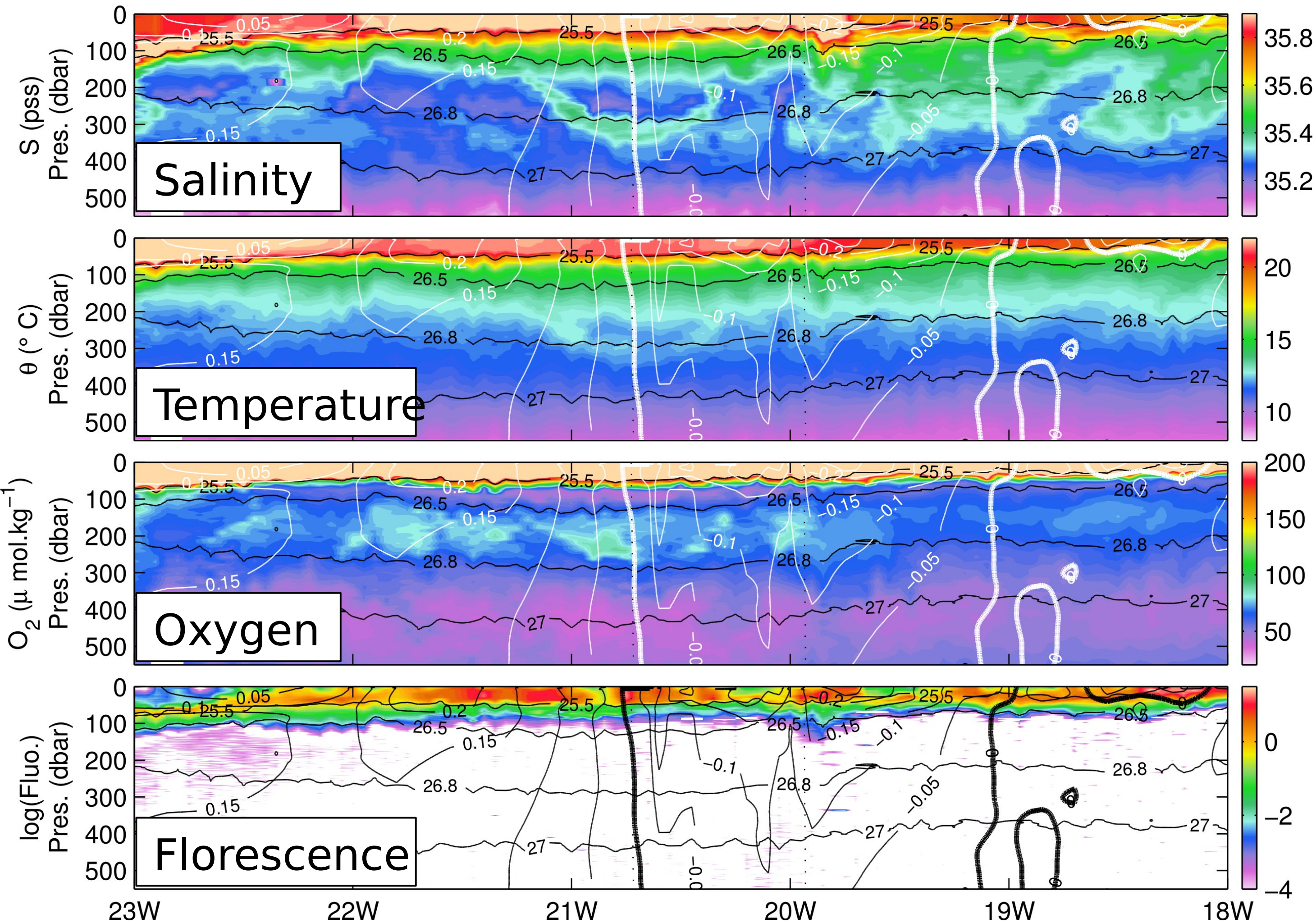
German cruise
Glider ifm02_Deepy

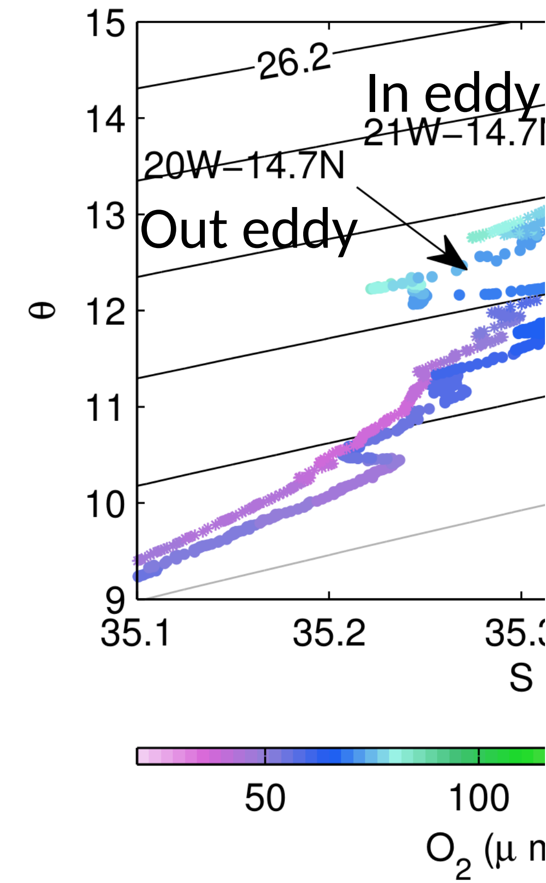
French cruise
Glider Campe



<u>Motivations</u>:
- Increase the sampling of the GD
- Description of upper hydrology and circulation
- Ventilation of the Guinea Dome region
- Coastal off-shore exchanges (currents/eddies...)

Hydrological sections

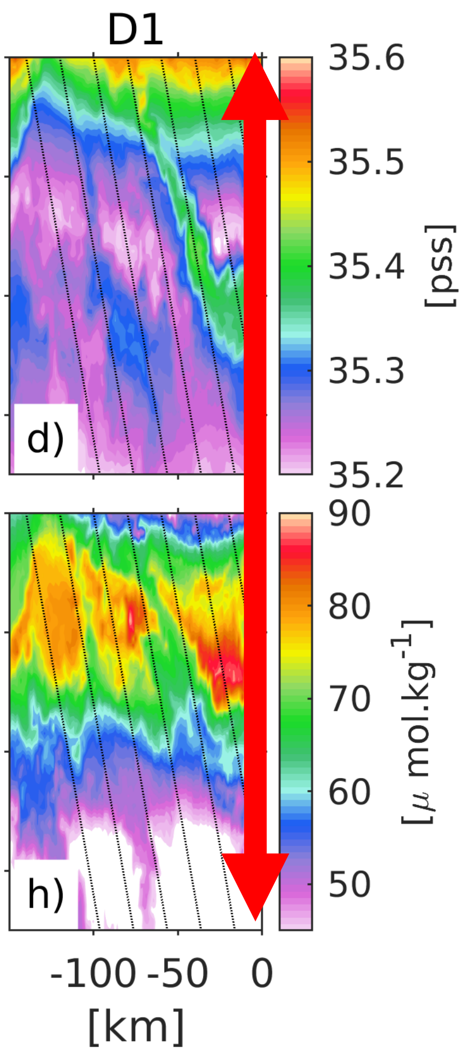




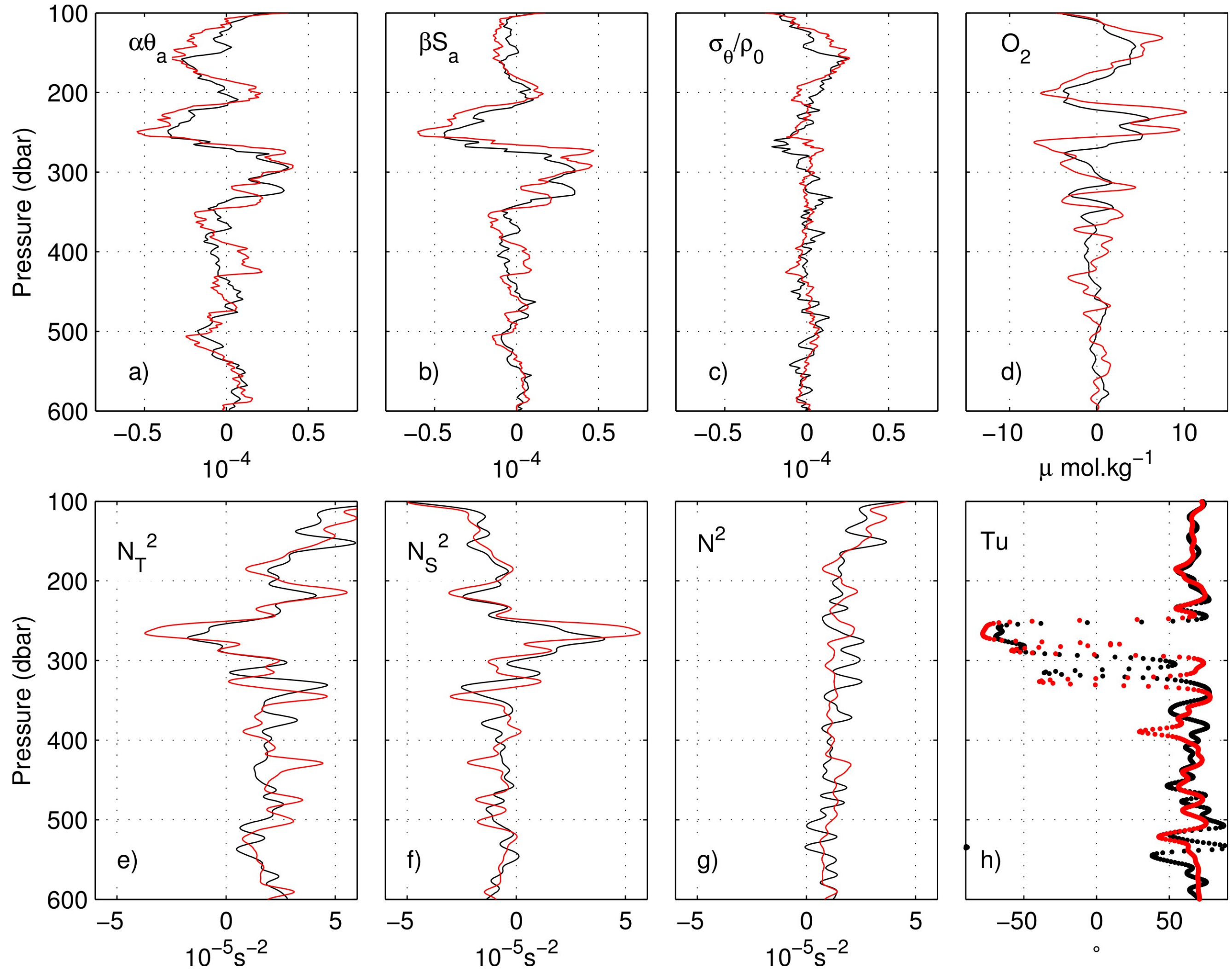
→ Between σ_θ=26.5-27.0, anticyclone cooler, fresher and oxygenated / surrounding water masses

→ Between the shallow and deep OMZ

Fine scale features : Vertical structures

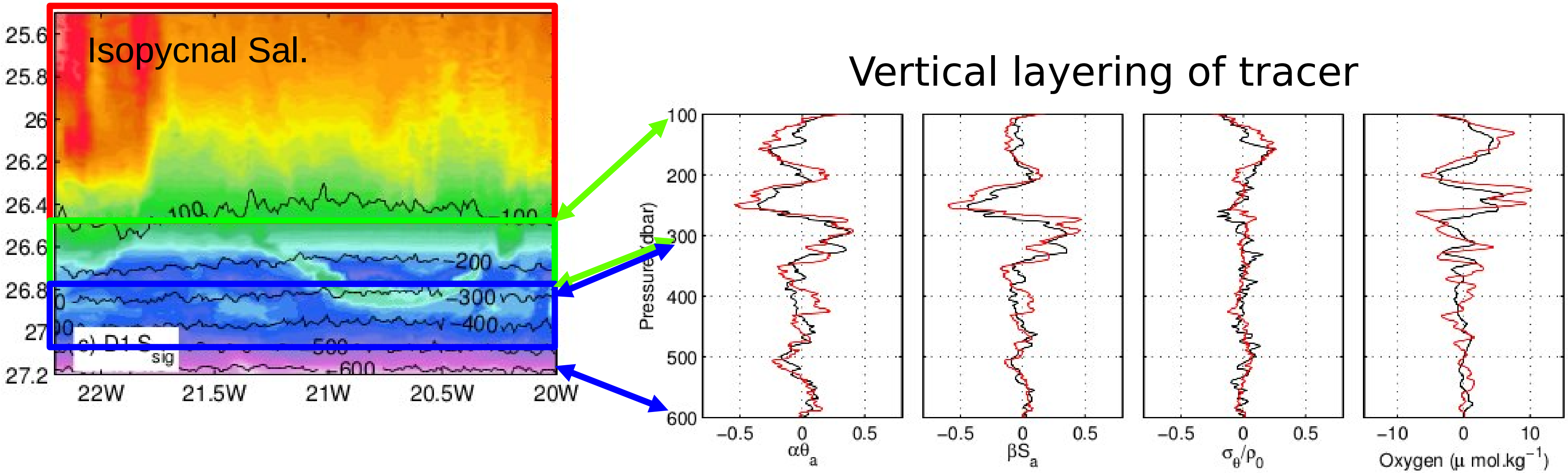


High pass filter > 100 m



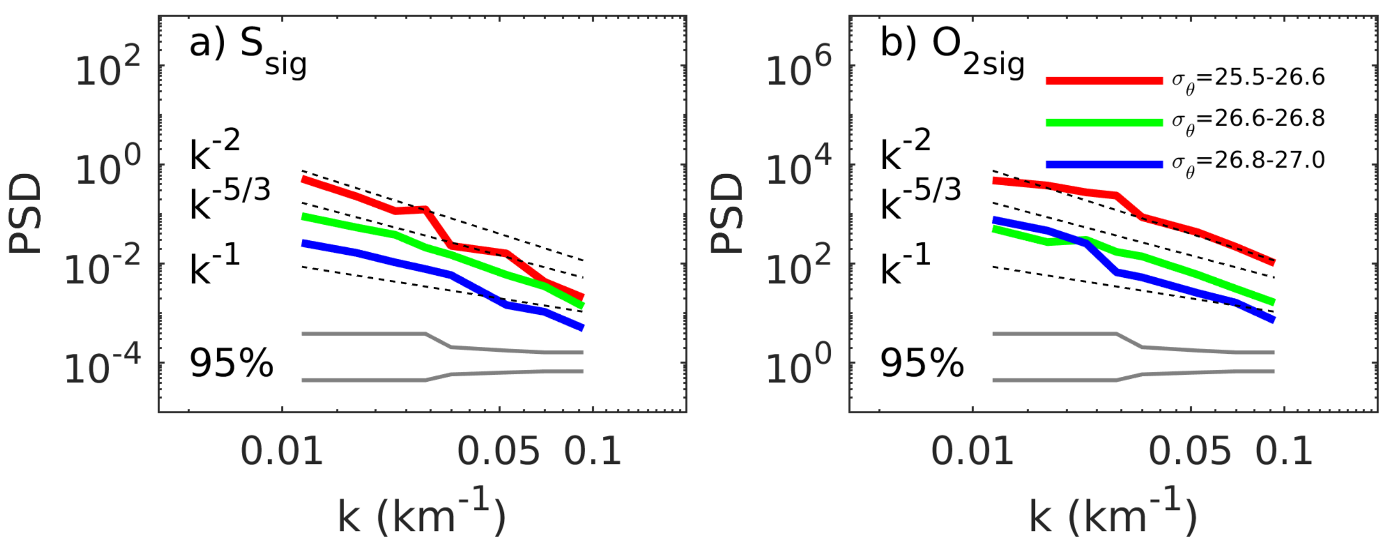
- Thin layers of T/S/O2 anomalies → thickness = 100-15 m
- Tu → +/- 70-80° ~ vertical density compensation
→ Double diffusion?

Fine scale features : horizontal structures



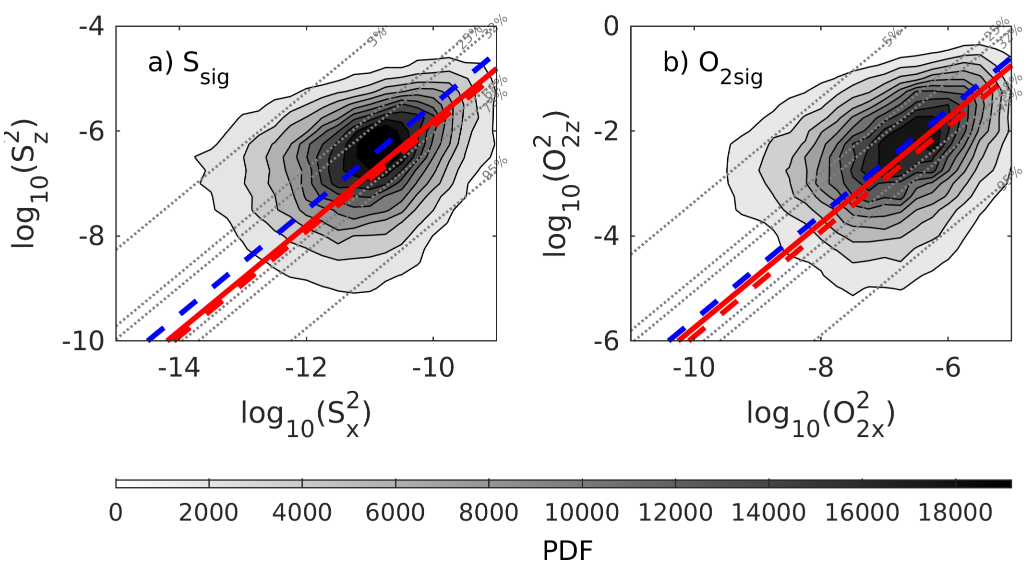
- Horizontal isopicnal tracer spectra (≠ gravity waves)
- Slopes around ~ k_h^{-2}]

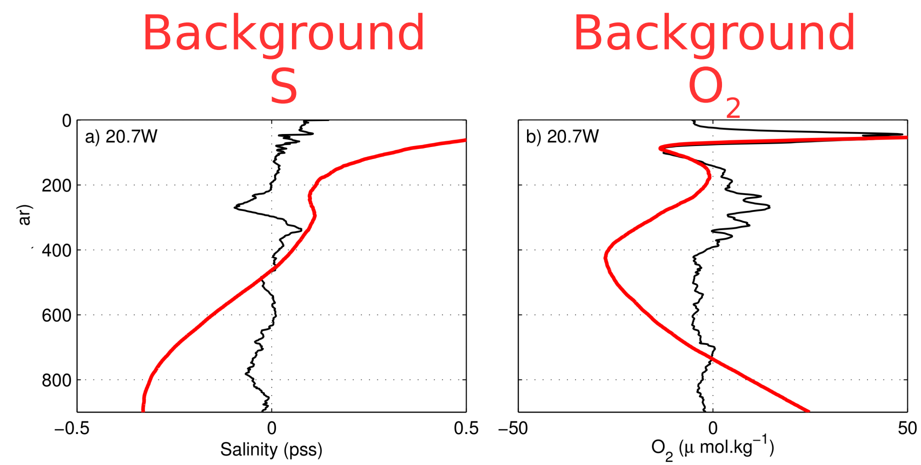
→ Compatible with stirring in QG turbulence if advection field is compact (f/N~0.01) (*Gilbert*, 1988; *Hua et al.*, 2013)



Fine scale feature : horizontal/vertical aspect ratio

- Aspect ratio f/N (100-400 m) of tracer S and O2 (Smith and Ferrari, 2009)
→ not exactly compatible with QG stirring



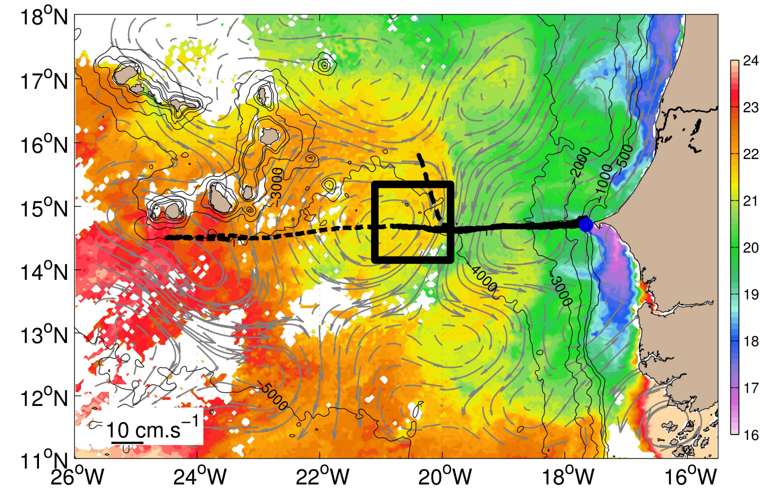


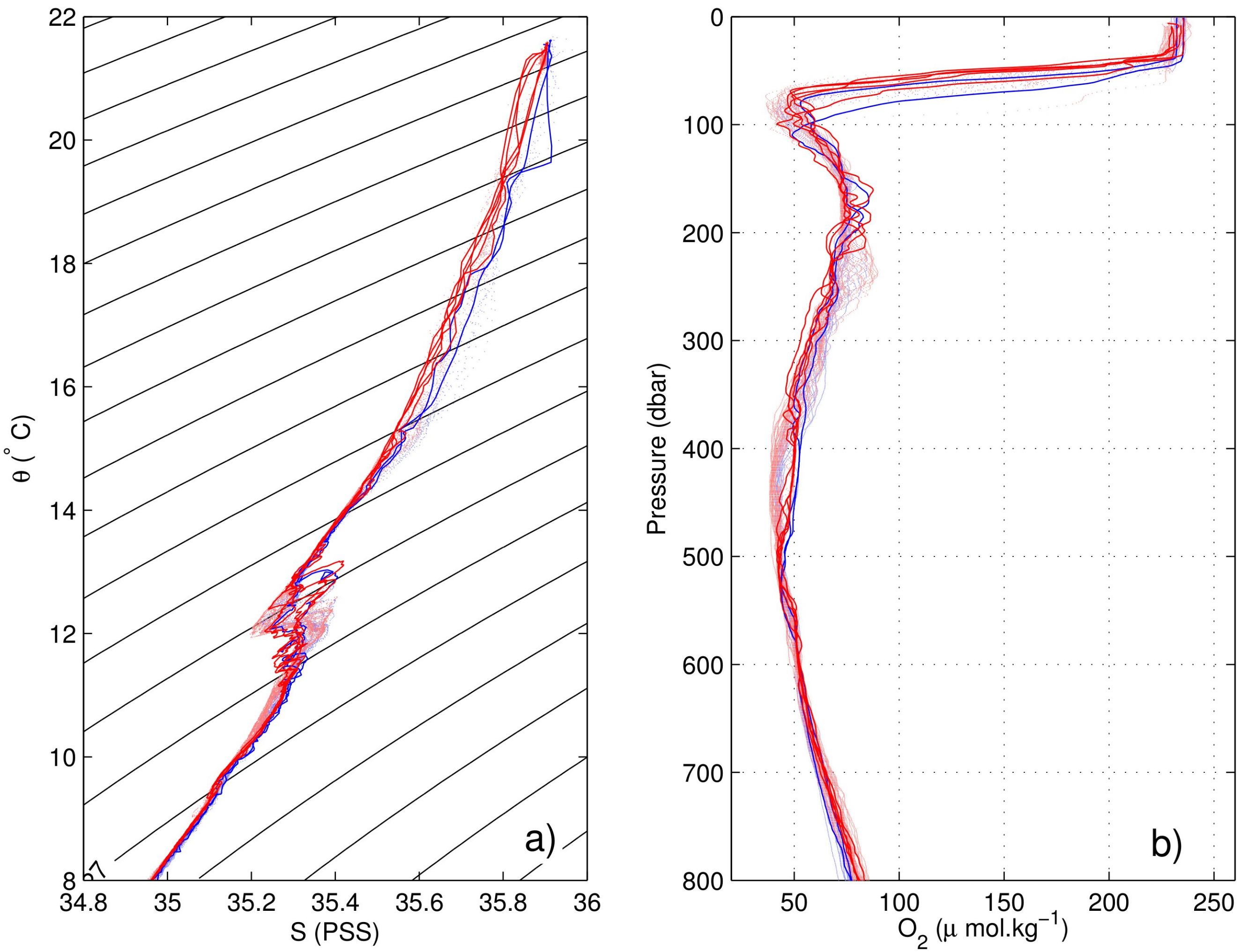
Background /filament

$$\frac{\left(|\partial_z \tilde{\Phi}|\right)^2}{\left(|\nabla \tilde{\Phi}|\right)^2} = \left(\frac{d\Gamma/dz}{\Gamma}\,\frac{\Phi}{\partial_z \Phi}+1\right)^2 \frac{|\partial_z \Phi|^2}{|\nabla \Phi|^2} \quad \sim f/N$$

$$\mu = |1 + h_{fialment}/h_{background}|$$

Data processing : Lag correction





<u>Correction T/S :</u>

- Campe
  - + correction offset
  - + Garau et al. (2011)
- Ifm02
  - + no offset
  - + Krahmann

(~ Garau et al., 2011)

<u>Correction O_2 :</u>

- Ifm02
  - + Calibration in situ
- Campe
  - + Linear fit on Ifm02

(Takashita et al., 2013)

→ Overlap section : good match

→ Base of mixed layer : not perfect