Recent glider deployments in the Senegalese upwelling system

The west-african upwelling system

- important artisanal fisheries

*Sardinella auritae*

- oxygen minimum zone

*Hahn et al. 2017, O2 concentration at ~400 meters*
Characteristics of the West African EBUS

The West African upwelling system: Senegal sector

Ndoye et al., 2014

Circulation sketch

Croco model (2km) SST

Ndoye et al., 2016

SST

Ndoye et al., 2014

SST

Melax buoy (P.I. A. Lazar)

Temperature

Salinity

Oxygen

Ndoye et al., 2016

Temperature graph for 2015 and 2016
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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SENGLIDE deployment (8 February-17 March 2011)
Upwelling phase during SENEGLIDE (8 February-17 March 2011)

ASCAT wind
14.7N/17.7W

SST & AVISO currents

10/02/2011 (U)
11/02/2011 (U)
15/02/2011 (U)
16/02/2011 (U)
25/02/2011 (R)
26/02/2011 (R)
05/03/2011 (W)
09/03/2011 (W)

U = upwelling
W = weak upwelling
R = Relaxation
Temperature and geostrophic velocity (February)

ASCAT wind

Geostrophic Velocity

8/02-9/02

(smoothing 20 km)
Temperature and geostrophic velocity (end of February-March)

ASCAT wind

24/02-25/02

25/02-26/02

06/03

9/03-10/03

13/03-14/03
Comparing to Mercator model (~10 km resolution)

18 February

Temperature Mercator

Glider 15 February

15 February

Surface current and SST

18 February

Glider 18 February

16 February

Surface current and SST

24 February

Meridional velocity Mercator

Temperature Mercator

Glider 15 February

15 February

Surface current and SST

24 February

Meridional velocity Mercator

Glider 18 February

16 February

Surface current and SST
Comparing to Mercator model (~10 km resolution)

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

=> 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)

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 an anticyclonic mesoscale eddy and embedded fine scales structures offshore of the upwelling system

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

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Key Points:
- Anticyclonic near surface eddy is observed from high-resolution glider 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
Mesoscale context
French cruises
Glider Campe

German cruises
Glider ifm02.Deepy

- 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
Eddy tracking method: *Chaigneau et al.* (2008)
→ South-eastern origin
→ Low salinity/high oxygen region
→ weak salinity/ high oxygen → water mass from south of the eddy

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

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

→ small scale thermohaline and oxygen features likely associated with 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)

Depth averaged circulation (0-100m)

Glider current

Model current
Motivations:
- 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 $\sigma = 26.5-27.0$, anticyclone cooler, fresher and oxygenated / surrounding water masses
→ Between the shallow and deep OMZ
Fine scale features: Vertical structures

- 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 isopycnal tracer spectra (≠ gravity waves)
- Slopes around ~ $k_h^{-2}$

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

![Vertical layering of tracer](image)
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

$$\mu = \left| 1 + \frac{h_{filament}}{h_{background}} \right|$$
Data processing : Lag correction

Correlation T/S :
- Campe
  + correction offset
  + Garau et al. (2011)
- Ifm02
  + no offset
  + Krahmann
  (~ Garau et al., 2011)

Correction O$_2$ :
- Ifm02
  + Calibration in situ
- Campe
  + Linear fit on Ifm02
  (Takashita et al., 2013)

→ Overlap section : good match
→ Base of mixed layer : not perfect