

## Coastal Ocean Circulation Experiment off Senegal (COCES - II)

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### LONG-TERM GOALS

To investigate the dynamics of coastal areas dominated by buoyancy input and wind forcing, influenced by complex topography and interacting with the deep ocean. To improve the understanding of coastal marine environmental evolution, with particular emphasis on eddy dynamics.

### OBJECTIVES

The general objective of COCES-II is to investigate the coastal dynamics off the coast of Senegal, a region strongly dominated by coastal upwelling. Specific goals are: 1. to construct unbiased statistics of near surface circulation; 2. to describe the upwelling circulation features; 3. to simulate the coastal circulation with a numerical model and 4. to train local Senegalese oceanographers (capacity building). COCES-II is the continuation of the COCES project. It aims to consolidate the longer term cooperation between US, European and Senegalese scientists to study the North Atlantic off the west African coast.

### APPROACH

Surface drifters are deployed off the coast of Senegal on a continuous monthly basis for at least a year, with an intensification period in winter/spring to better sample the upwelling circulation features. The drifter data are analyzed in conjunction with ancillary *in-situ* data (ship-based CTD and ADCP) and satellite images of sea surface temperature (SST), chlorophyll concentration (<Chl>) and sea level height (SSH). Numerical model simulations are performed with ROMS and are compared to the observations.

The project includes the following specific tasks:

- Procurement and deployment of Surface Velocity Programme (SVP) drifters with Argos data telemetry and positioning. Regular monthly deployments off the Senegal coast and specific releases of drifters in the vicinity of filaments during the upwelling season (winter).
- Drifter data management in both near-real time (processing and posting on the web) and delayed-mode (creation of a database updated every three months).

## Report Documentation Page

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- Statistical analyses using the drifter velocity data: mean circulation and eddy variability maps. Qualitative description of the circulation using drifter and satellite data (creation of images and animations with dynamic topography (SSH), <Chl> and SST overlaid with drifter tracks).
- Numerical simulations for the upwelling season (winter/spring 2012) and comparison with drifter and satellite data.
- Training and capacity building activities to teach Senegalese people to operate drifters, to process their data, and to analyze the scientific results obtained from them.

## WORK COMPLETED

### *Drifter deployments and drifter data processing*

Deployments of SVP drifters off the Senegalese coast continued in FY13 with the help of local oceanographers. In total, 28 drifters were released between October 2012 and June 2013 (see Table 1 for details on the deployment episodes), including 1 drifter kindly provided by the Global Drifter Programme (GDP) and 27 drifters acquired as part of this ONR project. The SVP drifters were manufactured in the USA by Pacific Gyre (PG) and Data Buoy Instrumentation (DBI). In total, about 3000 drifter-days worth of data were collected between 1 October 2012 and 26 September 2013.

***Table 1. Chronology of drifter deployments off Senegal in the tropical Atlantic Ocean between October 2012 and June 2013.***

<b>Date</b>	<b>Drifters deployed</b>	<b>Ship</b>
October 2012	2 DBI ONR	Rented boat / Fishermen
November 2012	2 DBI ONR	Rented boat / Fishermen
December 2012	3 DBI ONR	Rented boat / Fishermen
January 2013	2 DBI ONR	Rented boat / Fishermen
February 2013	3 DBI ONR	Rented boat / Fishermen
March 2013	2 DBI ONR + 1 PG GDP	Rented boat / Fishermen
April 2013	8 DBI ONR	COCES-II Campaign
June 2013	5 DBI ONR	Rented boat / Fishermen
<b>Total</b>	<b>28 SVP (1 GDP + 27 ONR)</b>	

Most drifters were deployed off Cap Vert (Dakar), with the help of local fishermen. In April 2013 8 drifters were deployed during the COCES oceanographic campaign in the coastal waters between Dakar and Saint Louis (see more details below).

The COCES web pages were updated. They provide basic information on the project, near real time (updated on a daily basis) products such as graphs with drifter trajectories and with times series of position (latitude and longitude, speed, sea surface temperature, battery voltage, drogue presence parameter, etc.). A status table is also included to monitor the drifter array. The drifter positions have also been implemented in Google Earth. The URL address of the COCES main page is:

[http://nettuno.ogs.trieste.it/sire/drifter/coces/COCES\\_main.html](http://nettuno.ogs.trieste.it/sire/drifter/coces/COCES_main.html)

All the drifter data were processed (editing, optimum interpolation, low-pass filtering, sub-sampling every 6 h) and archived in a database. This web-based database includes final descriptions of the observational work, final graphical representations and statistical summaries of the processed data, and data files in MATLAB binary format (<http://nettuno.ogs.trieste.it/sire/drifter/database/COCES/>).

### *Oceanographic campaign COCES-II*

An small oceanographic campaign onboard R/V Hermès (Fig. 1) was organized by Senegalese collaborators on 23-25 April 2013. The main objective of the cruise was to deploy drifters and Argo floats and collect CTD observations in the coastal waters between Dakar and Saint Louis (Grande Côte). The CTD station and drifter/float deployment locations are shown in Fig. 2. In total, 8 drifters and one Argo float were deployed. Twelve CTD casts were performed. Details about this cruise can be found in Wade and Cheikh M'baye (2013).



***Figure 1. Photo of R/V Hermès being prepared for the COCE-II campaign.***

### *Capacity building*

A Senegalese graduate student (Mr. Saliou Faye) was supported to come to Trieste, Italy for the entire year 2013 in order to work with the P.I. and local collaborators on COCES data analysis, their interpretation and the publication of the most salient results. Besides, Mr. Faye has worked on the comparison between the COCES drifter data, satellite altimetry products of surface geostrophic circulation and numerical simulations produced by French colleagues.



**Figure 2. Ship track of R/V Hermès and locations of CTD casts and deployments of SVP drifters and an Argo float during the COCES-II campaign off the “Grande Côte” of Senegal (23-25 April 201).**

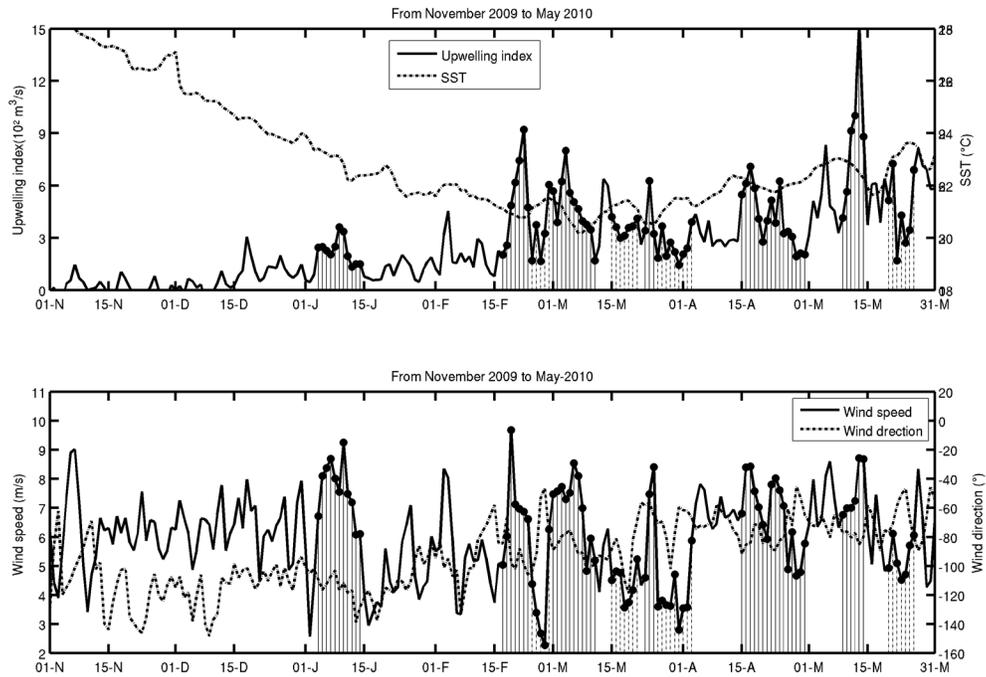
## RESULTS

### *Coastal upwelling off northwest Africa*

The COCES drifter observations, satellite data (images of sea surface temperature) and ocean surface winds were used to describe the upwelling dynamics off northwest Africa during 2009-2012. Cold and nutrient-rich coastal near-surface waters are upwelled and transported offshore (westward) by means of energetic filaments rooted at specific locations along the coasts the Mauritania (e.g. off Cap Blanc) and Senegal (e.g., off Cap Vert). These jets can evolve into, or interact with, eddy structures to form convoluted frontal patterns and complicated surface circulation features. The filaments show an offshore extension of about 500 km, half way to Cape Verde Islands. Coastal upwelling occurs from November to May and maximum values of upwelling index are observed in February, April and May. Relaxation episodes between trade wind events are identified during the upwelling seasons 2009-2012. As an example, the upwelling and relaxation events between November 2010 and May 2012 are described in Figs. 3 and 4.

### *Drifter trajectories and surface circulation in the northeastern tropical Atlantic*

The low-pass filtered and kriged drifter trajectories of the COCES-II drifters between October 2012 and September 2013 are shown in Fig. 5. The drifters deployed off Cap Vert (Dakar) generally moved westward, after an initial drift towards the north along the coast of Senegal and Mauritania for some units (especially in Oct./Nov. 2012 and Apr. 2013). The drifters sampled the westward-flowing North Equatorial Current between 10°N and 22°N and the North Equatorial Counter Current south of 10°N. The drifters revealed complex mesoscale and submesoscale eddy motions mostly between the Cape Verde Islands and the African coast.

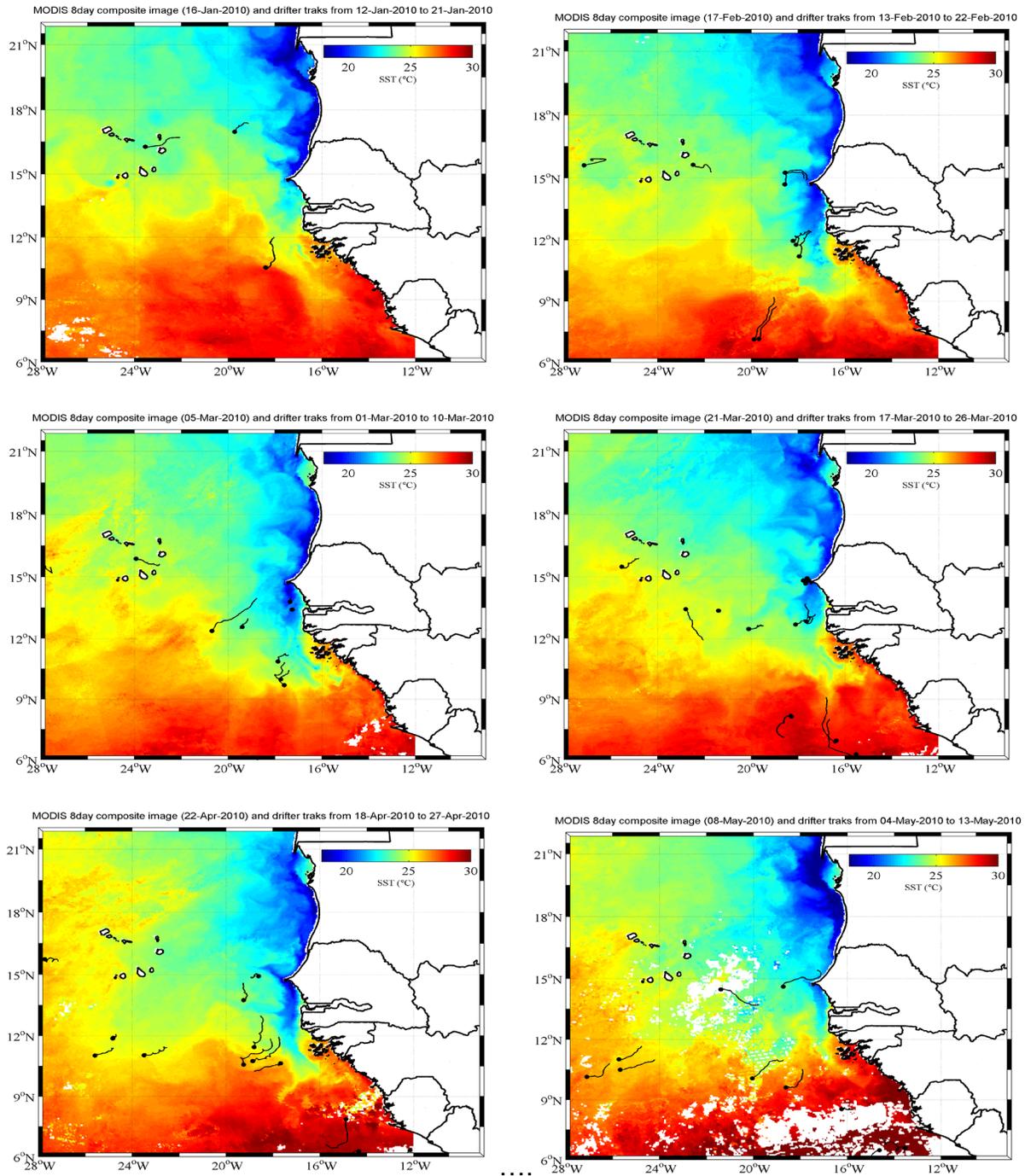


**Figure 3. Time-series of SST and upwelling index (top) and of the wind speed and direction (bottom) spatially averaged in an area off Cap Vert (Dakar) . The time periods characterized by the main upwelling and relaxation events are emphasized with vertical continuous and dashed lines, respectively.**

*Comparison between COCES drifter data, satellite altimetry products and numerical simulations*

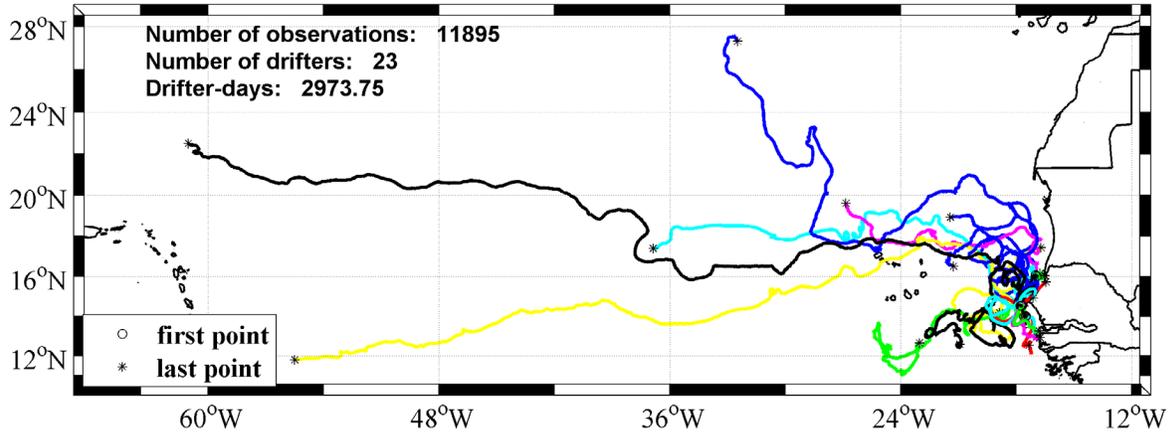
The COCES drifter trajectories and velocity timeseries (averaged over 5-7 day intervals) were compared qualitatively with the absolute surface geostrophic circulation maps derived from satellite altimeter data and with numerical simulations:

1. Gridded products ( $1/8^\circ$  resolution) of absolute surface geostrophic currents in the northeastern tropical Atlantic obtained from AVISO (SEE PAPER MILENA) were obtained and were compared quantitatively with the drifter tracks. Agreement is good, except in very coastal areas where it is known that the gridded products are less accurate.
2. Numerical simulations using the NEMO (Nucleus for European Modelling of the Ocean) model configured for the tropical Atlantic, with a horizontal resolution of  $1/12^\circ$  and forced by the ERA-Interim winds and fluxes, were compared both qualitatively and quantitatively with the COCES drifters data. Five-day-long drifter tracks were superimposed on the map of surface geostrophic currents produced by the model. An example is shown in Fig. 6 for February 2010. In general the comparison is satisfactory. To be more quantitative, the model was sampled at the drifter locations and drifter/model velocities and kinetic energies were compared. This work is still in progress at the end of September 2013.

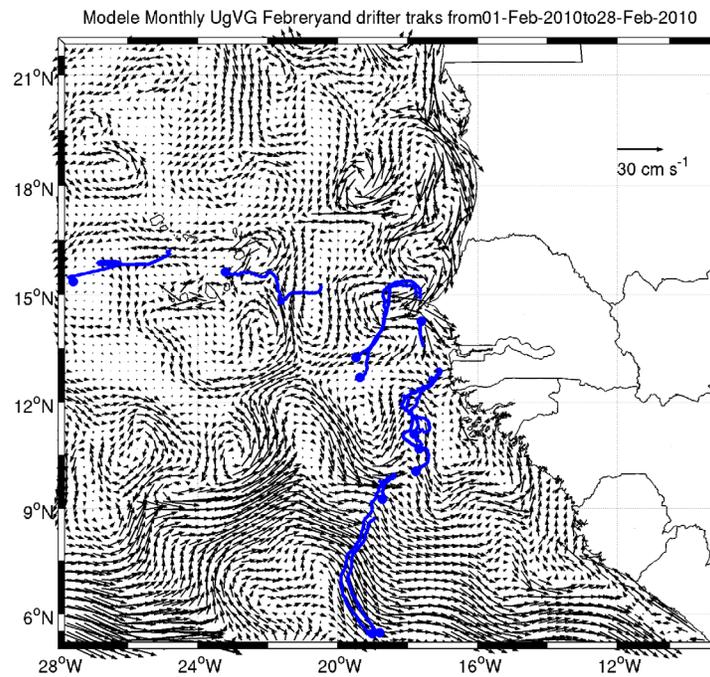


**Figure 4. Selected MODIS 8-day composite images of sea surface temperature off west Africa for the period January-May 2010. Ten-day long drifter track segments are overlaid in black, with solid circles at the end of the segments.**

COCES drifter trajectories from October 2012 to September 2013



*Figure 5. Kriged and low-pass filtered trajectories of the SVP drifters in the eastern tropical Atlantic Ocean for the period October 2012 – September 2013. Open circle and star symbols correspond to the first and last positions of each drifter, respectively.*



*Figure 6. Low-pass filtered and kriged trajectories of the SVP drifters in the eastern tropical Atlantic Ocean for the period 1-28 February 2010, superimposed on the map of the mean surface geostrophic currents for February 2010 as produced by the NEMO model. Dots correspond to the last position of each drifter.*

## **IMPACT/APPLICATION**

The scientific impact of this project is to increase our understanding of the coastal dynamics off NW Africa and its interaction with the tropical Atlantic Ocean. Future application could be the validation of diagnostic numerical models and the assimilation of the drifter data into prognostic numerical models of coastal ocean circulation.

## **RELATED PROJECTS**

In addition to national programs conducted by collaborators in Senegal, the COCES-II project has benefited from a synergy with the GDP (P.I.'s: Dr. Luca Centurioni, SIO, La Jolla, and Dr. R. Lumpkin, NOAA/AOML, Miami), that has provided additional SVP drifters at no charge.

COCES-II is connected to the African, German and French members of the consortium for an ecosystem Approach to the management of fisheries and the marine environment in West African waters (AWA). In particular, strong collaboration with French oceanographers [Dr. Alban Lazar (CNRS/IRD, Paris), Dr. Dominique Dragone (IRD, Brest) and Jean-Marc Molines (LGGE, Grenoble)] has been strengthened.

Finally, COCES-II is related to the Argo international programme, as floats have been deployed during COCES-related oceanographic cruises and the joint use of Argo and ship-based CTD profiles, in concert with drifter and satellite data, is planned to study the circulation dynamics off northwest Africa.

## **REFERENCES**

Wade, M. and B. C. M'baye, 2013. Rapport de mission: Campagne COCES2 sur N/O Hermès, 23 au 25 avril 2013. 6 pp.