

Coastal Ocean Circulation Experiment off Senegal (COCES - II)

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http://nettuno.ogs.trieste.it/sire/drifter/coces/COCES_main.html

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).

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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

SVP drifters were deployed off Senegal since October 2011 with the help of local oceanographers. In total, 35 drifters were released between October 2011 and September 2012 (see Table 1 for details on the deployment episodes), including 18 units kindly provided by the Global Drifter Programme (GDP) and 17 drifters acquired as part of ONR projects (COCES and COCES-II). The SVP drifters were manufactured in the USA and Canada by Clearwater Instrumentation (CLEAR), Pacific Gyre (PG), Data Buoy Instrumentation (DBI) and Metocean (MET). In total, more than 2500 drifter-days worth of data were collected between October 2011 and September 2012.

Table 1. Chronology of drifter deployments off Senegal in the tropical Atlantic Ocean between October 2011 and September 2012.

Date	Drifters deployed	Ship
October 2011	3 CLEAR ONR	Rented boat / Fishermen
November 2011	3 CLEAR ONR	Rented boat / Fishermen
December 2011	2 CLEAR ONR + 1 MET GDP	Rented boat / Fishermen
January 2012	2 CLEAR ONR	Rented boat / Fishermen
March 2012	3 MET GDP + 6 PG GDP	R/V Le Suroit
April 2012	3 PG GDP	Rented boat / Fishermen
May 2012	3 PG GDP	Rented boat / Fishermen
June 2012	2 PG GDP + 1 DBI ONR	Rented boat / Fishermen
July-August 2012	3 DBI ONR	Rented boat / Fishermen
September 2012	3 DBI ONR	Rented boat / Fishermen
Total	35 SVP (18 GDP + 17 ONR)	

Most drifters were deployed off Cap Vert (Dakar), using rented boats or with the help of local fishermen. Nine drifters were deployed during the UPSEN oceanographic campaign from the French R/V Le Suroit in March 2012 (see more details below). The principal investigator (PI) went to Dakar in March 2012 to help the local oceanographers with the recovery of some units (Figure 1) and their re-deployments off Cap Vert.

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 (see Figure 2). The URL address of the COCES main page is: 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/>).



Figure 1. Picture of Senegalese collaborator (Saliou Faye; right) and Senegalese people with one Metocean SVP drifter recovered in a fisherman village in March 2012.

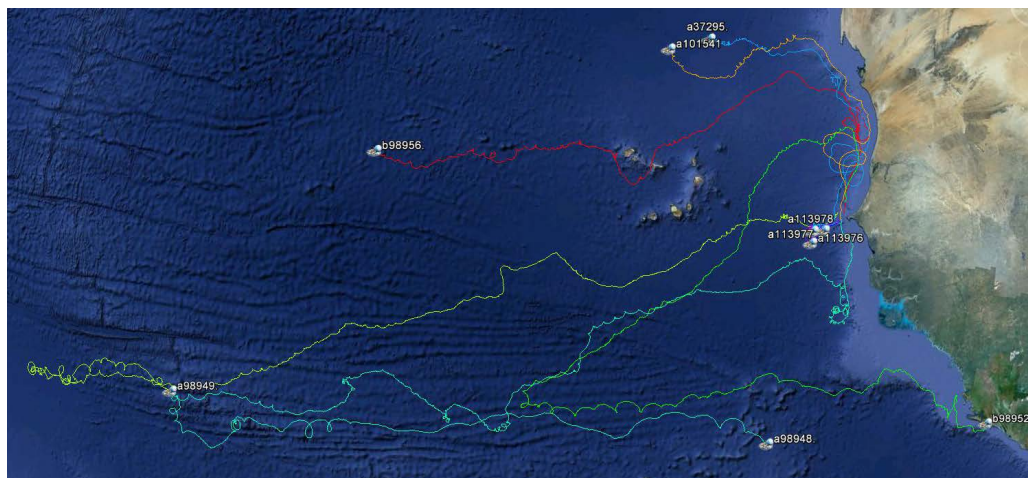


Figure 2. Raw trajectories of the SVP drifters alive in the tropical Atlantic Ocean in September 2012. Drifter identification numbers are posted at the end of the tracks.

Drifter tracks were overlaid on satellite images of sea surface temperature and chlorophyll concentration to describe qualitatively the spatial structure and temporal evolution of the dynamics (see examples in Figures 4 and 5).

An oceanographic campaign aboard the French R/V *Le Suroit* was organized by French and Senegalese collaborators on 6-18 March 2012. The main objective of the cruise was to estimate the vertical and horizontal fluxes of mass and nutrients during the Senegalese upwelling. Details about this cruise are illustrated in Figure 3. The main area of study was Senegalese coastal waters south of Cape Vert (Dakar). Amongst other activities, CTD casts were performed, ship-based ADCP data were collected, Argo floats and SVP drifters were deployed.

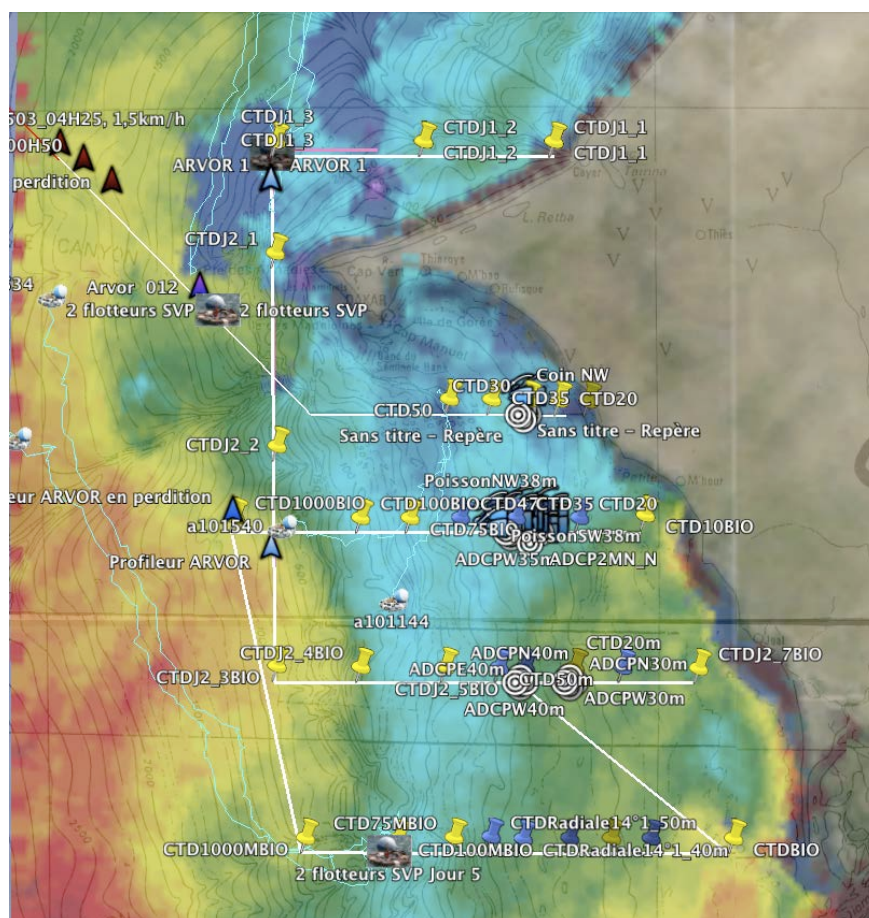


Figure 3. Ship track of R/V le Suroit and locations of CTD casts and deployments of SVP drifters and Argo floats during the UPSEN campaign off Senegal (6-18 March 2012), overlaid on typical SST/bathymetry image.

RESULTS

Two important results have been obtained so far. First, mesoscale and submesoscale eddies were observed in the area between Senegal and Cape Verde Islands in November 2011. The spatial structure and temporal evolution of these structures were studied with the drifter data in concert with satellite images of SST and $\langle \text{Chl} \rangle$ (see Figure 4). The PI co-authored a paper, along with French, German, Italian and Senegalese collaborators, about the sub-mesoscale features observed (Alpers et al., 2012). Second, the majority of the drifters released during the UPSEN cruise in March 2012, moved swiftly

northward and reached the coastal waters of Mauritania in correspondence with an event of relaxation of upwelling-favorable winds (Figure 5). Hence they revealed the presence of a northward surface coastal countercurrent. Later in March and in April 2012, the drifters veered and started to move offshore and towards the south while the typical upwelling situation was restored with the predominance of coastal cold and rich waters moving generally offshore in filaments and eddies.

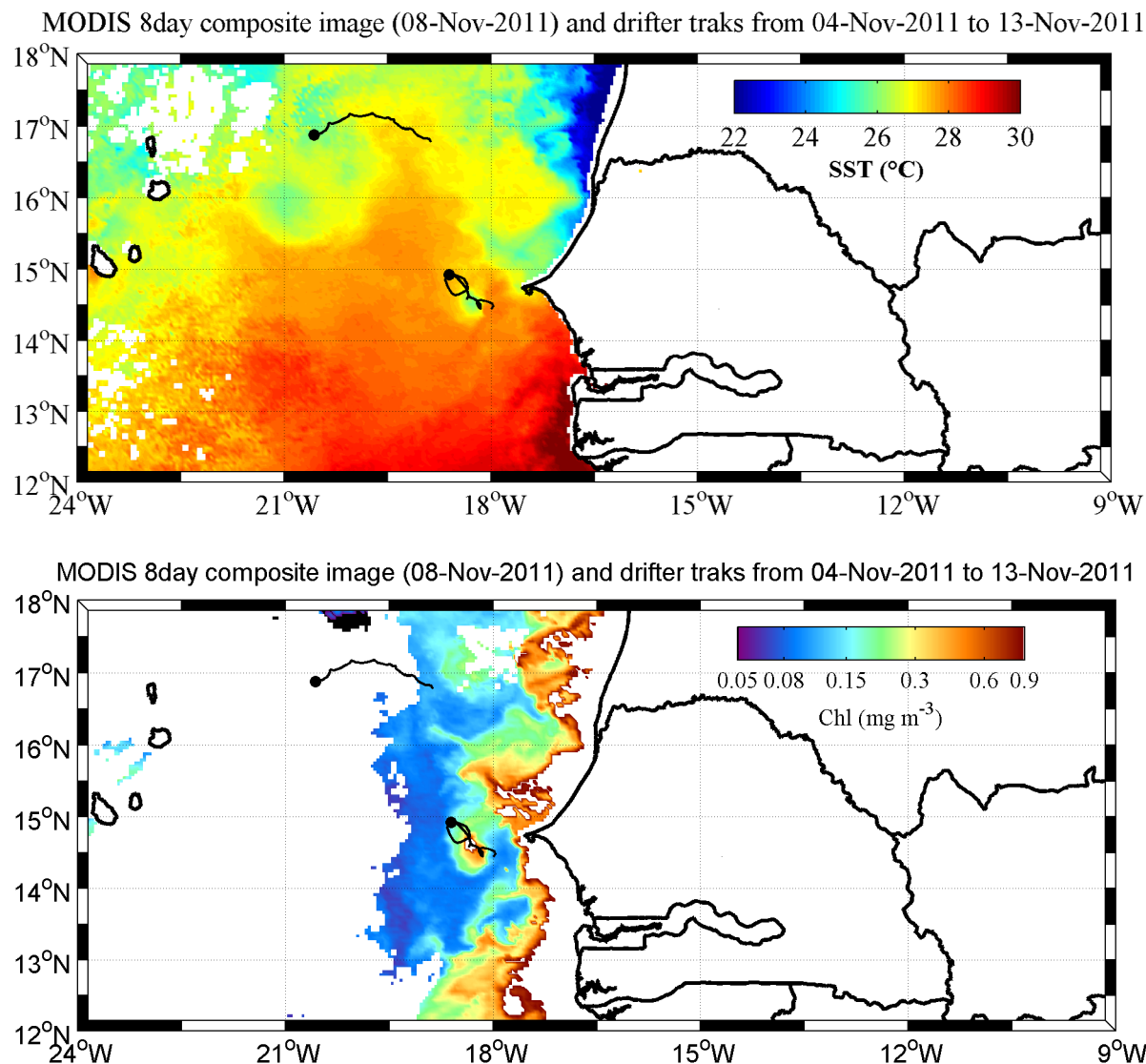
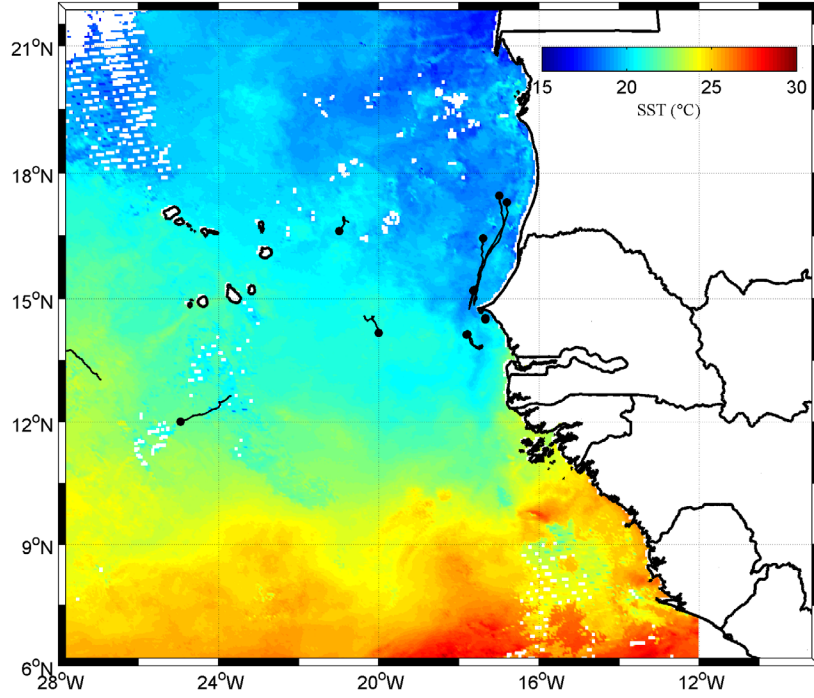


Figure 4. Ten-day long drifter track segments overlaid on MODIS 8-day composite images of sea surface temperature (top) and chlorophyll concentration (bottom) centered on 8 November 2011. Black solid circles represent the end of the track segments. A sub-mesoscale cyclonic eddy (with cold and high <Chl>) is evident near 15°N and 18°W.

MODIS 8day composite image (12-Mar-2012) and drifter traks from 08-Mar-2012 to 17-Mar-2012



MODIS 8day composite image (05-Apr-2012) and drifter traks from 01-Apr-2012 to 10-Apr-2012

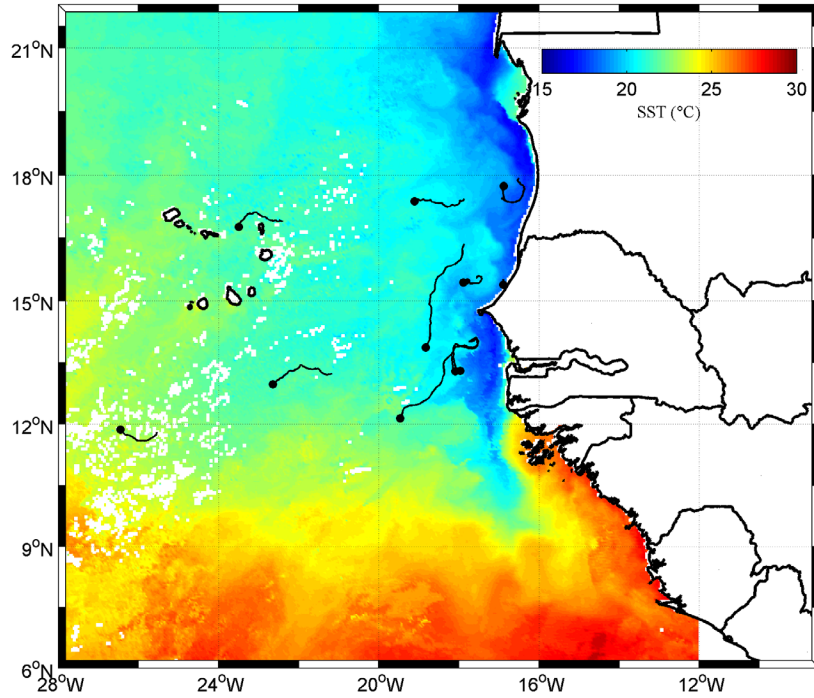


Figure 5. Ten-day long drifter track segments overlaid on MODIS 8-day composite images of sea surface temperature centered on 12 March 2012 (top) and 5 April 2012 (bottom). Black solid circles represent the end of the track segments.

The low-pass filtered and kriged drifter trajectories of the COCES-II drifters between October 2011 and September 2012 are shown in Figure 6.

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 March 2012). 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. Two drifters moved through the Cape Verde Islands. Some drifters left the North Equatorial Current to join the North Equatorial Counter Current and proceed eastward as far as the African coast.

Inertial motions are ubiquitous in the motion of most long-lived drifters, as depicted by the preponderance of small anticyclonic loops along their trajectories.

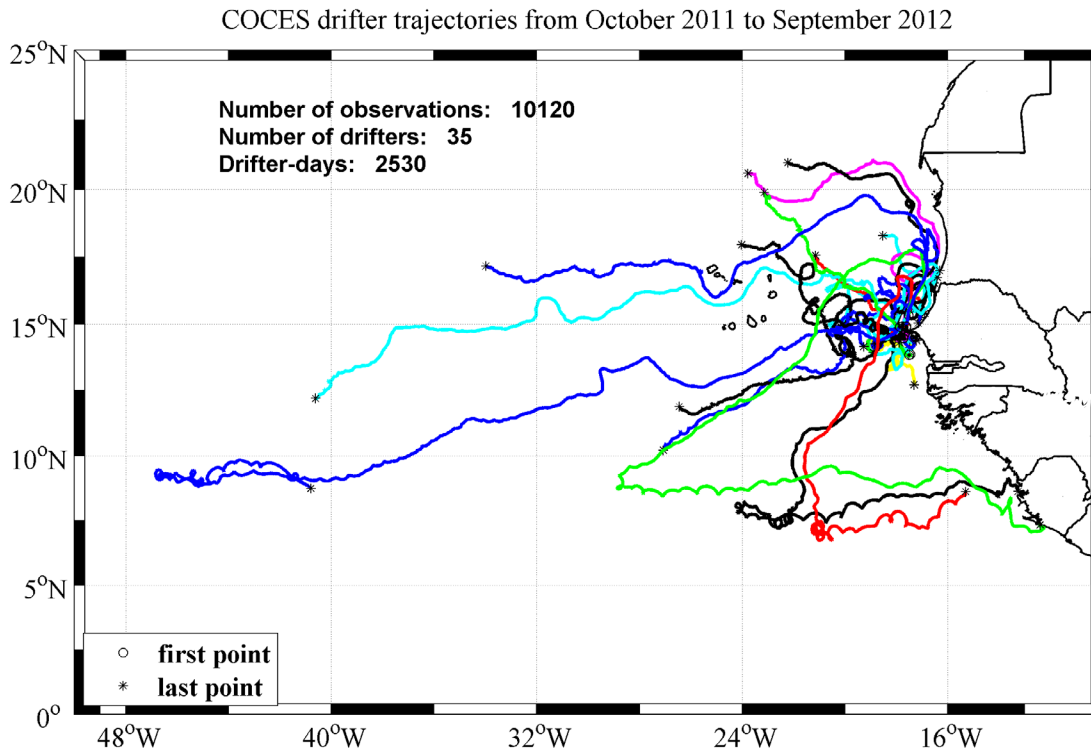


Figure 6. Low-pass filtered and kriged trajectories of the SVP drifters in the eastern tropical Atlantic Ocean for the period October 2011 – September 2012. Open circle and star symbols correspond to the first and last positions of each drifter, respectively.

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 35 SVP drifters at no charge to match the COCES contribution.

<http://www.aoml.noaa.gov/phod/dac/gdp.html>

COCES-II took advantage of the UPSEN oceanographic campaign (sponsored by the French Government) in March 2012 to collect data (ship-based CTD, ADCP, etc.) and deploy drifters and floats in the Senegalese coastal waters during the upwelling period. Collaboration was also established between COCES-II and 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).

<http://awa-project.org>

REFERENCES

Alpers, W., P. Brandt, A. Lazar, D. Dagorne, B. Sowe, S. Faye, M. Hansen, A. Rubino, P.-M. Poulain, and P. Brehmer (2012) A small-scale oceanic eddy off the coast of West Africa studied by multi-sensor satellite and surface drifter data. Submitted to Remote Sensing of Environment.