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GLOBCURRENT: A PRE-OPERATIONAL MONITORING SYSTEM FOR SURFACE CURRENT AND UPPER OCEAN DYNAMICS BASED ON SENSOR SYNERGY

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Abstract

The GlobCurrent project (http://www.globcurrent.org) aims to advance the quantitative estimation of ocean surface currents from combined use of satellite and in situ sensor synergy. It is demonstrated that sharp gradients in the sea surface temperature, the sun-glitter, the surface current and the ocean chlorophyll-a distribution are often spatially correlated with the sea surface roughness anomalies across a wide range (1-100 km) of spatial scales. Such expressions of 2-dimensional surface structures represent evidence of the dynamics in the upper (~100-200 m) ocean. In this presentation we will demonstrate that systematic utilization of sensor synergy integrated into an advanced visualization platform strengthen the ability to study sub-mesoscale to mesoscale processes associated with upper ocean dynamics. As such, it is also highly valuable for regular intercomparison and validation of ocean models.

Keywords: GlobCurrent project, sensor synergy, surface current, dynamics

1. Introduction

Thanks to satellite and in situ observations combined with high resolution numerical ocean models new knowledge and view of the global ocean surface dynamics filled with a large number of various mesoscale (~30-100 km) and sub-mesoscale (<~3-10km) meandering surface current features and eddies has emerged during the

last decade. However we are still faced with challenges when it comes to process understanding and accurate quantification of the surface current associated with these features. Nor is it always possible to provide forecasts of the exact locations and evolution of the frontal features and eddies with sufficient accuracy. This deficiency results primarily from inability to adequately characterize the upper ocean dynamics atfine spatial resolution. This is partly resulting from a lack of regular high-quality in situ observations with sufficient temporal and spatial resolution. However, more consistent quantitative use of satellite observations is also required to advance the understanding and reduce the knowledge gaps. The GlobCurrent project (http://www.globcurrent.org) is anchored on this fundamental view (Johannessen *et al.*, 2016). The overall objective of the project is: to advance the quantitative estimation of ocean surface currents from satellite sensor synergy and demonstrate impact in user-led scientific, operational and commercial applications that, in turn, will increase the uptake of satellite measurements.

To accomplish this multi-variable observations from past and presently operating remote sensing satellites have been consistently and systematically explored in a synergetic approach. As such, satellite-based high-resolution sea surface temperature, ocean color, sun glint, surface roughness and range Doppler observations ensure highly complementary information of the two-dimensional surface current structures and dynamics (Shutler *et al.*, 2016). Hence, it makes sense to regularly collocate and combine these observations with coarser resolution sea surface height measurements from altimetry as illustrated in Fig. 1 linking platforms, sensors, variables and derived surface current types. From the radar altimeter, infrared radiometer and imaging spectrometer (including sun glint) as now provided from Sentinel-3 one can obtain 6 geophysical variables, notably: small scale roughness anomalies, ocean color, sea surface height (SSH), significant wave height, near surface wind speed and sea surface temperature (SST). These variables and their spatial and temporal structure and changes contain direct or indirect manifestations of the surface current conditions, notably: surface current boundaries; surface tracer velocity; surface Ekman current; inertial motion; surface current vorticity; surface geostrophic current and Stokes drift.

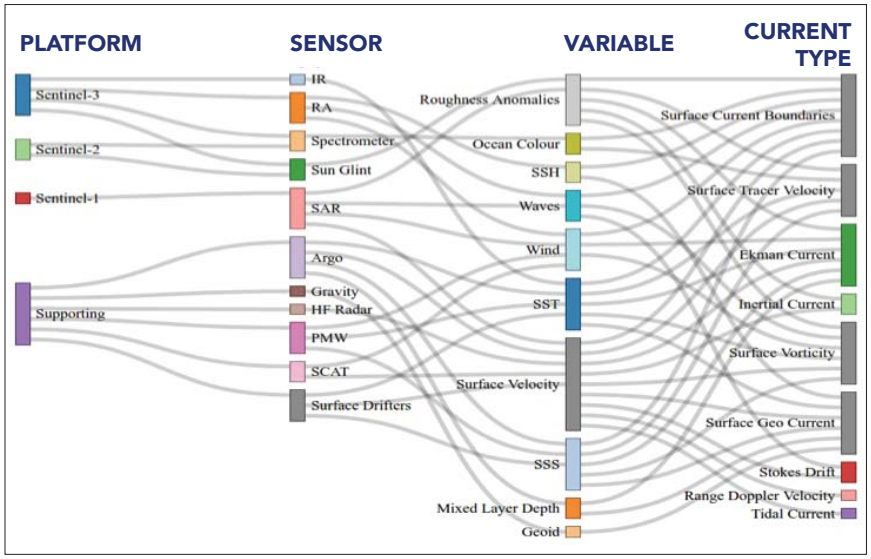

Fig. 1. Provision of data and information products from the Sentinels in support to the global, regional and local surface current estimations. Additional provision of complementary data and information from other missions and in situ data further demonstrates the importance and strength of the systematic use of sensor synergy. temperature (blue dots), salinity (green dots) and sound level (orange dots).

Invoking additional data and information products from Sentinel-1 SAR and Sentinel-2 high resolution spectrometer as well as other supporting satellite missions jointly with data from *in situ* observing systems (e.g. surface drifters, Argo profiling floats) increase the number of derived ocean variables as seen in Figure 1. In turn, more complementary information on the surface current conditions can be derived. Systematic use of satellite sensor synergy combined with *in situ* data is therefore strengthening and improving the ability to obtain high quality and consistent information on surface current conditions at scales from severalkm to hundreds of km. It also provides a mean for investigating relationship to the upper ocean (~100 m) dynamics and processes as demonstrated in the GlobCurrent project.

2. Data and methods

The GlobCurrent data (available for downloading at http://www.globcurrent.org) contains offline global and Mediterranean Sea data from 1993 to 2016. The global data has a 1/4° grid resolution and includes: - 3 hourly and daily mean Ekman current at the surface and at 15m; - daily surface geostrophic current; and 3 hourly and daily mean total (geostrophic + Ekman) current at the surface and at 15m (Rio *et al.*, 2014). Comparably, the Mediterranean Sea data has a 1/8° grid resolution with the following components: - 6 hourly and daily mean Ekman current at 15m; - daily surface geostrophic current; and 6 hourly and daily mean total (geostrophic + Ekman) current at 15m. In addition, there is a near real time GlobCurrent data product at a 1/4° resolution from the 15th of March 2016 to present, including: - 6-hourly and daily mean Ekman current at 15m; - daily mean surface geostrophic current; and daily mean total (geostrophic + Ekman) current at 15m. The current fields are furthermore combined and collocated with satellite-based sea surface temperature fields at a daily timescale and 10km spatial resolution. Finally, these collocated fields of SST and currents are also regularly combined and blended with "snapshot satellite images" including ocean colour data, sunglint observations and SAR roughness anomaly as well as surface drifter data (Lumpkin and Johnson, 2013) and Argo profiling floats.

The GlobCurrent products can be visualized using the data portal http://globcurrent.oceandatalab.com. Selecting from a "Products" menu and timeline different viewing options the global and Mediterranean Sea data to be collocated and overlaid. In addition, when selecting drifter trajectories, for instance, one month of trajectory is shown related to the selected month and with a diamond shape indicating the position of the drifter at the selected time. The ability to display these trajectories on top of the near coincident SST and surface current maps as shown in Fig. 2 clearly demonstrates the strength of this visualization platform both for research and dedicated applications including planning and execution of field campaigns.

The use of the visualization platform moreover allow efficient combination and overlays of the surface geostrophic current and SST field with other high-resolution snapshot images such as the Sentinel-1 SAR surface roughness image and the radar altimeter tracks centred to 23 March 2015 as shown in Fig. 3. This allow further investigation of the multiple types of 2-D surface signal expressions and their relationship to mesoscale processes and upper ocean dynamics as demonstrated by Kudryavtsev *et al.*, (2012) and Rascle *et al.*, (2017).

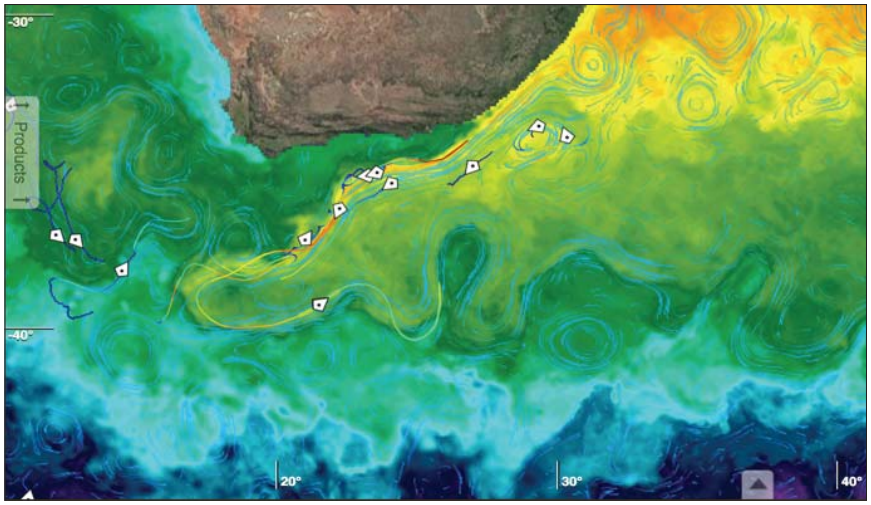

Fig. 2. Zoom in the greater Agulhas Current region with GlobCurrent geostrophic current component as blue streamline overlaid on a ODYSSEA SST map (color) and with the drifter trajectories indicated with colors representing different speed ranges.

An updated drifter dataset downloaded from the Surface Drifter - Data Assembly Center (SD-DAC) at AOML (http://www.aoml.noaa.gov/phod/dac/dacdata.php) has been used for validating the GlobCurrent products (Danielson *et al.*, 2016). These data cover the period January 1993-December 2015, and include separated fields with 15m drogued and undrogued drifters. At the surface, the YOMAHA surface velocities based on Argo floats from 1997 to 2015 are used as reference. In addition high-resolution satellite sensor synergy (e.g., optical glitter, roughness anomalies) is used on a case-by-case basis as illustrated in Fig. 3. It is found that the best results are obtained using the GlobCurrent based total geostrophic + Ekman current at both the surface and at 15m depth (Rio, personal communication). The visualization platform furthermore allows for evaluation of fields and identification of inconsistency in the products. For instance, due to the lack of temporal resolution in altimeter data, the retrieved surface geostrophic velocities are not always consistent with the daily updated SST field. This has prompted the development of methods to constrain and align the altimeter-based surface geostrophic velocity vector along SST fronts where the geostrophic assumption is valid (Rio *et al.*, 2016).

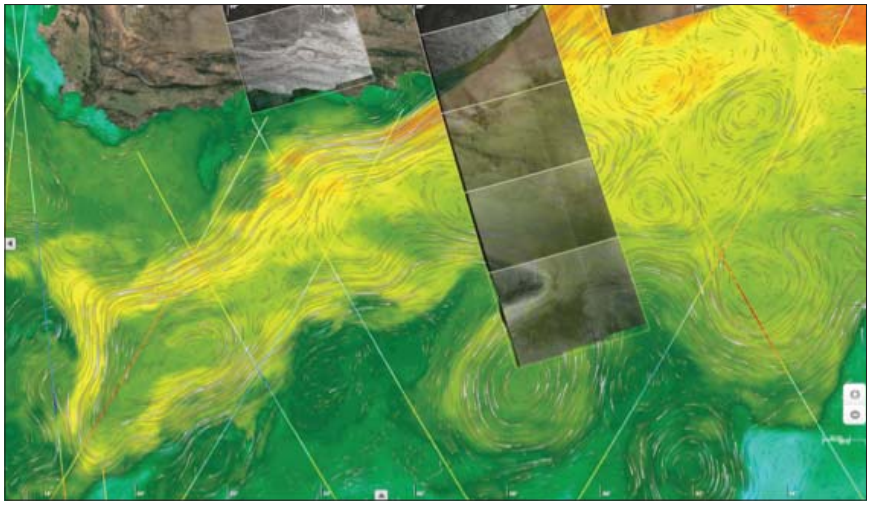

Fig. 3. The combined SST and surface geostrophic current (stippled streamlines) field together with a snapshot surface roughness map from the Sentinel-1 SAR image obtained on 23 March 2015. The altimeter track data are overlaid. The color bar gives the SST in degree Celsius.

3. Summary

Both delayed time and near real time current products have been calculated in the framework of the GlobCurrent project for the global oceans and for the Mediterranean Sea for the period 1993-2017. These products are now considered to be routine (see Table I) and ready for transition into CMEMS-phase II. It is therefore expected that they will be made available both as delayed mode and near-real time products from May 2018.

Table I. Status of the GlobCurrent routine and R&D products.

PRODUCT	AVAILABILITY
Global surface geostrophic velocity	Routine
Global Ekman term	Routine
Total (geostrophic + Ekman) current	Routine
Regional surface geostrophic currents (Mediterranean Sea)	Routine
Regional Ekman currents at 15m (Mediterranean Sea)	Routine
Regional total currents at 15m (Mediterranean Sea)	Routine
Drifter and Argo float match-ups	Routine
Current gradient from swell reflection	R&D
Velocity Projection	R&D
Frontal sharpening	R&D
Eddy tracking	R&D
Range Doppler shift retrievals	R&D
Lagrangian diagnostics	R&D

Moreover, there are a number of highly important complementary research and development activities and tools (as indicated in Table I) such as wave-current interaction and refraction, velocity projections, frontal sharpening, automated range Doppler velocity retrievals, eddy tracking and Lagrangian diagnostics. Sustaining these R&D activities may subsequently evolve towards later important uptake by CMEMS. Altogether the key scientific findings and major achievements form the GlobCurrent project will be published in a special issue on "Advances in the Science of Surface Currents" to appear in Remote Sensing of the Environment (RSE) with expected publication in August 2018.

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