Application of Gliders for Near-Real Time METOC Data Collection Capability for Battlespace Characterization

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LONG-TERM GOALS

The goal of the program is to substantially improve the uncertainty associated with vicarious calibration and characterization (VC^2) of ocean color satellite sensors by combining hyperspectral apparent optical properties (AOP) and hyperspectral inherent optical properties (IOP) measurements in oligotrophic and coastal areas, with state of the art radiative transfer modeling. A modified Satlantic HyperPRO II hyperspectral radiometer is being used as a portable calibration quality instrument of radiometric uncertainty comparable to that demonstrated for Marine Optical BuoY (MOBY) instruments off Hawaii. By combining these numerous observational platforms, especially gliders that have been outfitted with physical and optical sensors, an efficient and integrated method for real time METOC data collection with Tactical Decision Aid evaluations can be developed.

OBJECTIVES

We proposed to design and test an efficient, integrated method for the collection of physical and bio-optical (METOC) data in littoral zones to support military operations. This included an array of sensors that would be operated cooperatively to provide improved and specific data collection capability for local air and sea conditions. The observational platforms included gliders, moorings, drifters, ships, aircraft and satellites. We had three successful Calibration/Validation Cruises in the Ligurian Sea (Cal/Val'08, 15-28 Oct 08; BP'09, 13-27 Mar 09; REP'10, 19 Sep – 4 Oct 10) on the *NR/V Alliance* that collected a comprehensive suite of bio-optical and physical data that is being used to improve our understanding of the physical and optical dynamics of a Mediterranean littoral zone, as well as provide initial parameterization and testing of METOC forecasting models. This data will be used to refine our existing geospatial information services and distributed processing system in order to integrate data acquisition facilities, low level processing resources, modeling capabilities, automated decision making and geospatial information managing and dissemination into a common framework. This work has been in close collaboration with Dr. Schofield's efforts on real-time visualization and command/control capabilities for their fleet of coastal Slocum gliders. This will be a combined research effort by both US and European investigators. Specific objectives are:

1. To collect *in situ* physical and optical data from a variety of observational platforms that can be used for validating hyperspectral and multi-spectral radiometric data and derived products in the littoral zone and the adjacent oligotrophic oceanic areas. This would include two cruises: one in the spring,

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during bloom and elevated river drainage conditions and the other in the fall under more oligotrophic and drier conditions.

2. To improve the capabilities of our AUV's and glider(s) by installing bio-optical sensors in these vehicles. This would enable collection of regional sub-surface bio-optical and physical data in the littoral zone at more frequent temporal periods (once a month) to describe seasonal and storm induced variability.

3. To provide *in situ* measurements, modeling results and remote sensing observations in real time to cruise participants with the existing broadband communications link between NURC and the *NR/V Alliance*, as well as access by Web-based users on an open source, open architecture geospatial web server (GEOS-II). This will allow for adaptive sampling by the cruise participants during the field trials.

4. To determine uncertainty budgets for *in situ* measurements, modeling results and remotely sensed observations that can be used to evaluate derived products for the littoral zone and provide reliability indices for tactical decisions aids developed using these products and models.

APPROACH

NURC has purchased seven Slocum gliders [six-Coastal gliders (4-200 m) and one 1-km glider (1000 m)] and one Bluefin Spray glider. Five of the Slocum Coastal gliders are equipped with bio-optical sensors (Table 1). In Apr and Jun 2009, Dr. Dr. Katarzyna Niewiadomska, a Slocum glider expert, came to the Centre to train personnel to be glider pilots for the up and coming REP’10 cruise.

Overlapping this period was six weeks of engineering field testing of the gliders by deploying them off Palmaria and having them perform a series of transects.

Table 1. Glider sensor specifics.

Name	***Depth***	***CTD***	***Chl Fl***	***CDOM Fl***	***$E_d(\lambda_1:\lambda_4)$***	***$b_b(532)$***	***$b_b(\lambda_1:\lambda_3)$***	***BAM(532)***
SOPHIA	200	Y	Y	Y	Y	Y	-	-
ELETTRA	200	Y	Y	Y	Y	Y	-	-
ZOE	200	Y	Y	Y	Y	Y	-	-
NATALIE	200	Y	Y	Y	-	Y	-	Y
LAURA	200	Y	-	-	-	-	Y	Y
GRETA	200	Y	-	-	-	-	-	-
NOA	1000	Y	-	-	-	-	-	-
Spray	1000	Y	-	-	-	-	-	-

CTD – Slocum gliders have SBE41
EcoTriplet (BBFL2) = Chl Fl + CDOM Fl + $b_b(532)$.
Chl Fl – Chlorophyll Fluorescence Ex/Em = 470 nm/695 nm
CDOM Fl – Colored Dissolved Organic Material Fluorescence Ex/Em = 370 nm/490 nm
$b_b(532)$ – Backscattering at a single wavelength (532 nm)

$E_d(\lambda_1:\lambda_4)$ – Downwelling irradiance (Model 504) in 4 channels (411.7, 443.6, 490.9 and 554.7 nm)
$b_b(\lambda_1:\lambda_3)$ - Backscattering at 3 wavelengths (EcoTriplet, BB3; 470, 532 and 650 nm)
BAM – Beam Attenuation Meter (Diver Visibility) at 532 $\pm$ 5 nm.

Field Plan --- There was one cruise (REP10) during this reporting period that investigated the bio-optical properties of the Ligurian Sea. The focuses of the cruise (19 Aug – 4 Sep 10) was on the exploitation of remotely sensed satellite data for:

(1) extraction of near surface geophysical parameters,
(2) utilization of a fleet of gliders (AUVs) to map out the physical and bio-optical properties in the water column prior to and during the cruise,
(3) deployment of drifters and HF radar to determine turbulent transport and dispersion,
(4) deployment of moorings to initialize and set boundary conditions for atmospheric and oceanic models and finally
(5) assimilation and fusion of all data into bio-optical and physical METOC models, providing an integrated approach for near real-time METOC data collection and modeling.

A satellite ocean color image for the area showed the pronounced oligotrophic conditions that were present during the REP10 cruise (Fig 1).

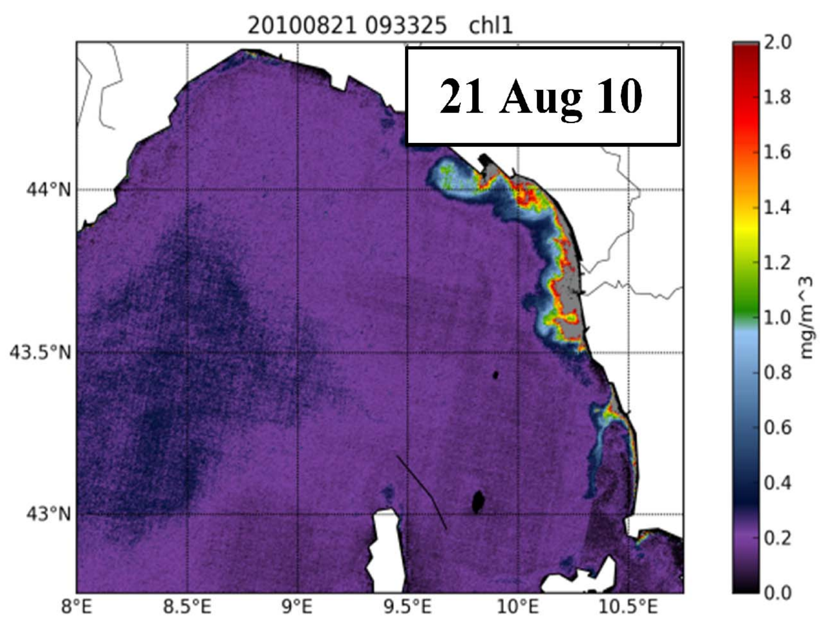

Figure 1. MERIS chlorophyll image of the Lagurian Sea for 21 Aug 2010.

Historically, the optical properties in the Ligurian Sea are lowest in August with a maximum in Mar-Apr. Figure 2 shows the average chlorophyll values by month covering a 10 year period.

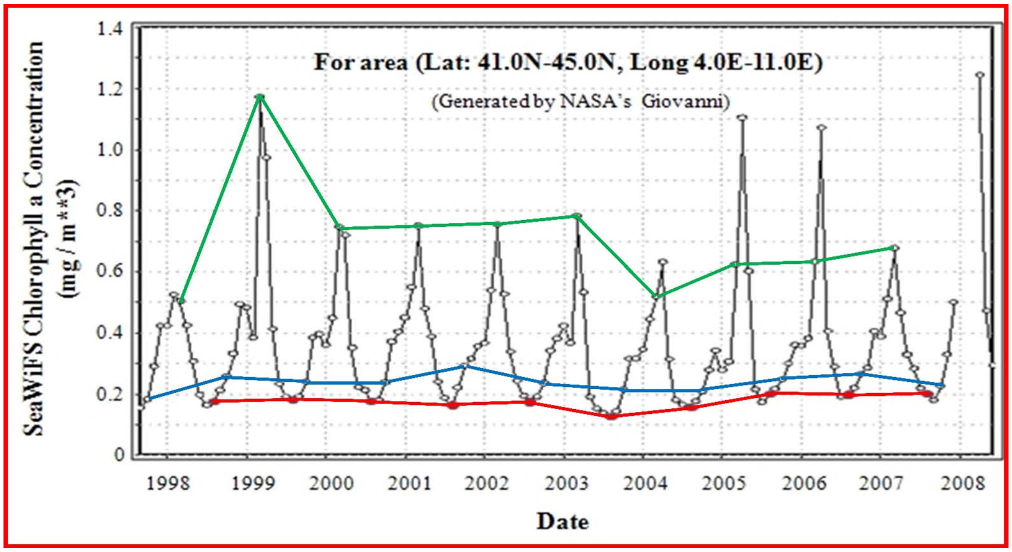

Figure 2. Ave chlorophyll concentrations for Ligurian Sea (SeaWiFS, 1980-2008)
(red – REP10; green – BP09; blue- LSCV08

REP10 cruise was a major success with numerous optical and CTD stations being occupied as well as towing the ScanFish II across coastal frontal boundaries and off shore areas. Figure 3 is a summary of the locations for most of these stations and transects.

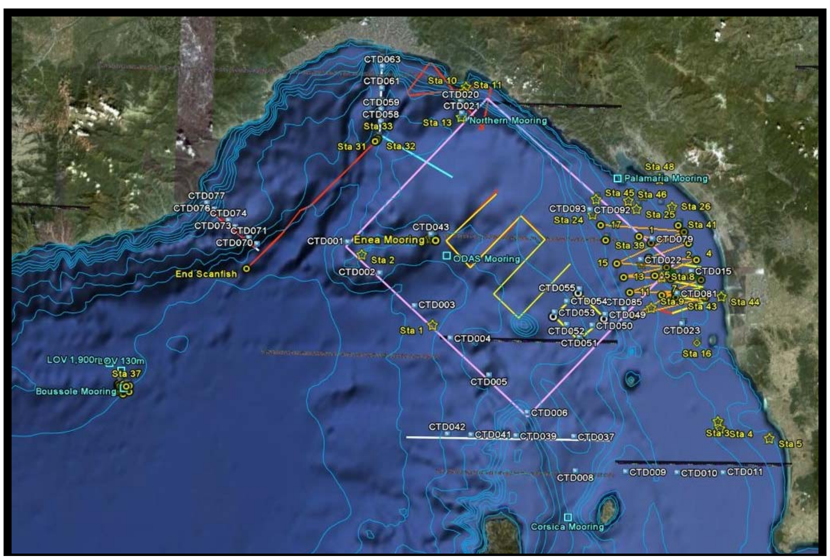

Figure 3. Optical, CTD and ScanFish transects for the REP10 cruise (19 Sep – 4 Oct 10).

WORK COMPLETED

During REP10 seven gliders were flown simultaneous with two being deployed directly from the NR/V Alliance to support optical and CTD stations and 5 being flown under an adaptive sampling experiment. Efforts were made to compare glider temperature and conductivity data with that acquired by the shipboard CTD. Figure 4 shows a picture of a Slocum glider being strapped to the CTD for a profiling comparison. Results for the temperature sensors is shown Figure 5.

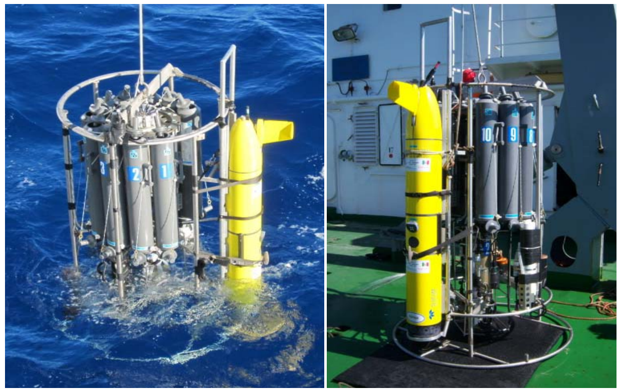

Figure 4. Slocum glider attached to CTD during REP'10 cruise for intercalibration of the glider CTD (SBE 41) with the rosette CTD [SBE 911(+)].

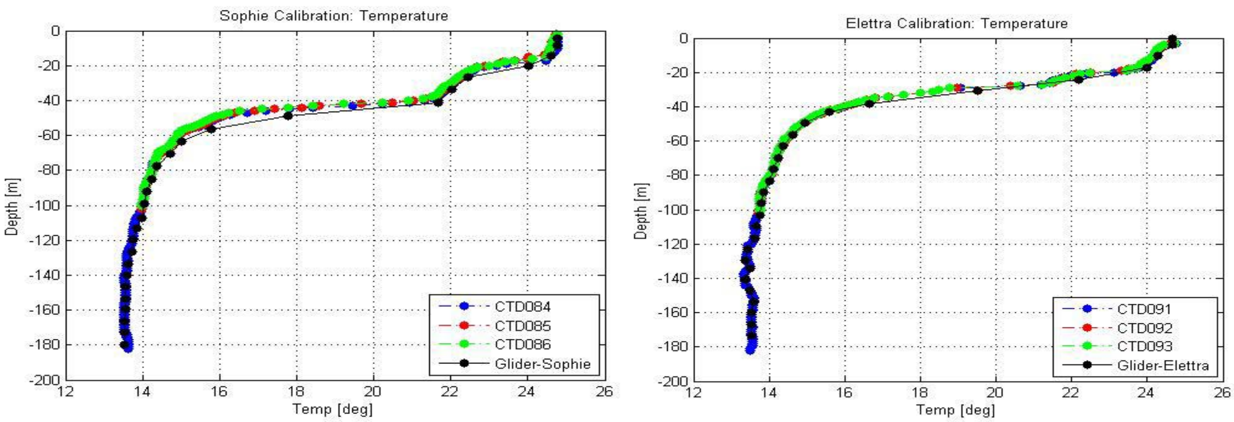

Figure 5. Glider and shipboard CTD comparisons for vertical profiles of temperature.

RESULTS

All cruise data to include glider data is currently being displayed on NURC's GEOS2 database. A preliminary comparison between optical data collected by a Slocum glider and that collected from shipboard profiling system is shown in Figure 6.

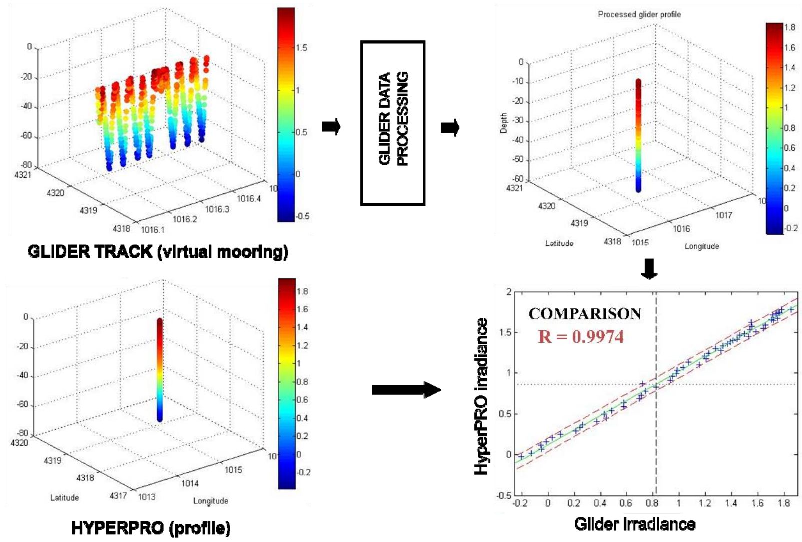

Figure 6. Comparison of downwelling irradiance [E_d(412)] between a Slocum glider profiling in a virtual mooring condition using a 4-channel radiometer and a ship deployed HyperPRO II radiometer (hyperspectral). Data collected at similar location (400m distance apart) and time.

IMPACT/APPLICATIONS

Littoral zones are highly dynamic areas in which conditions are spatially variable and rapidly changing. This is the most difficult area to accurately make optical measurements, let alone extract in-water optical and physical properties from remotely sensed data. Optical properties of the littoral zone are governed by the surrounding drainage basin, bottom characteristics, bottom resuspension based on the energetic nature of the zone, vertical and horizontal flux of nutrients, etc. Therefore, any one littoral zone may have completely different optical properties from another thus potentially requiring regional specific remote sensing algorithm. Higher uncertainties will be found in these complex littoral waters because of the bio-optical composition (suspended material, algae and dissolved material that do not co-vary), vertical and horizontal inhomogeneities, bottom reflectance, instrument shadowing, optical extrapolation to just beneath the surface, increased atmospheric absorbing aerosols and bidirectional reflectance distribution variabilities. Because of this complexity, a specific program is required that collects optical data in littoral regions, compares these results to remote sensed data and develops improved models to spatially and temporally predict optical distributions. The uncertainty of *in situ* measurements and remote sensing data must be known, so that this information can be used in an additive or multiplicative manner to derive the total uncertainties of derived products and thus reliability indices for tactical decision aids (TDA's), which then can be used for end-user evaluation.