Glider data processing and data comparison in optical parameter estimation for rapid environmental characterization.

Pennucci Giuliana and Chuck Trees

18-22 October 2010, MREA10 Conference: Quantifying, Predicting and Exploiting (QPE) uncertainties in marine environment, Villa Marigola, Lerici, Italy.

Outline:

- ✓ Long term and short term goals;
- ✓ Background and Introduction (Slocum glider, why glider?, the NURC glider fleet);
- ✓ The cruise (Rep10);
- ✓ Optical platforms focus: Gliders, and HyperPRO and rosette (CTD, beam and Chl);
- ✓ Work organization;
- ✓ On-site sensor calibration (CTD and downwelling Irradiance);
- ✓ Results: three dimensional glider products and valued added products from model implementation - SRS;
- ✓ Conclusion and Work in progress.

Long term goal:

- ✓ Environmental characterization (assessment of uncertainties) and predictions in costal and unknown (restricted) areas.

- ✓ Integrating *in situ*, autonomous and remote sensing optical platforms to perform rapid environmental characterization (development of a wide area littoral network).

➡ { Ligurian Sea Cal Val 2008
Battlespace Preparation 2009
REP10 }

Short term goal:

- ✓ Increase glider information integrating calibration results;

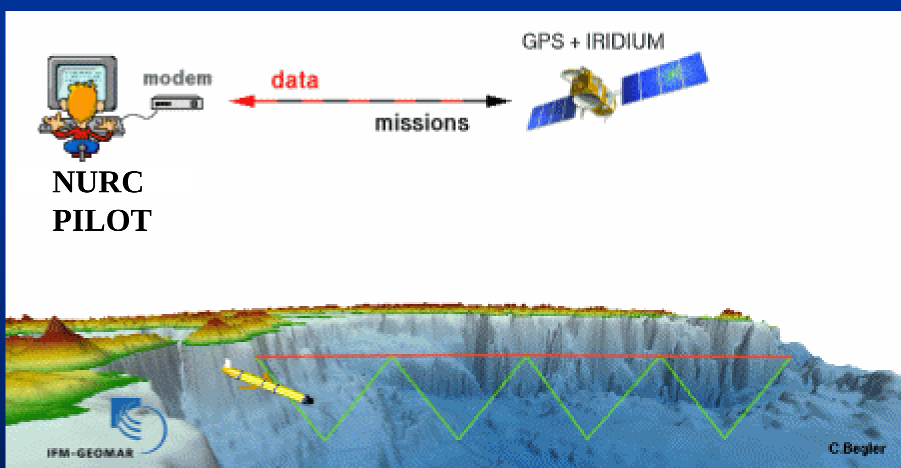
- ✓ Increase the satellite information integrating *in situ* observations.

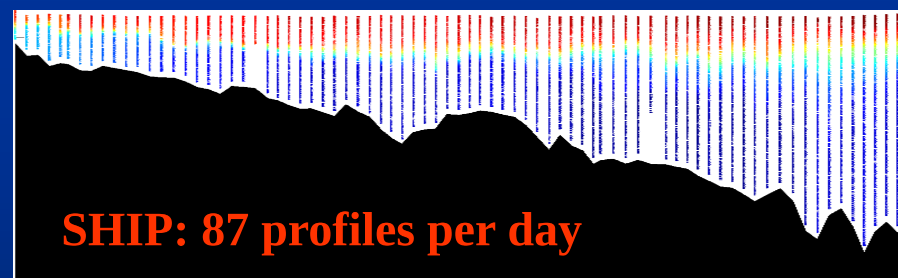
Background

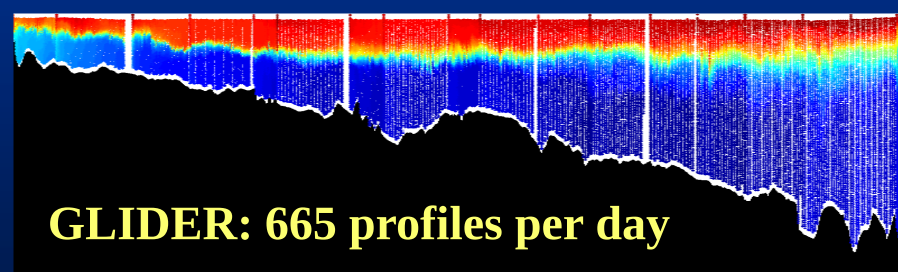
In situ, long range and satellite remote sensing systems are being used to quantify currents, sea surface height, temperature and optical properties of the water enabling modeling and prediction of ocean state variables in coastal areas. The advent of Autonomous Underwater Vehicles Gliders (AUVGs) opens the possibility to set up: **fast-deployable, easily re-locatable** observing instruments to assist traditional platforms such as to explore littoral denied areas.

MAIN GLIDER SCIENTIFIC ADVANTAGES:

- Operability in denied area or in problem areas (cloud cover);
- Better spatial and temporal resolution (increasing density observation);

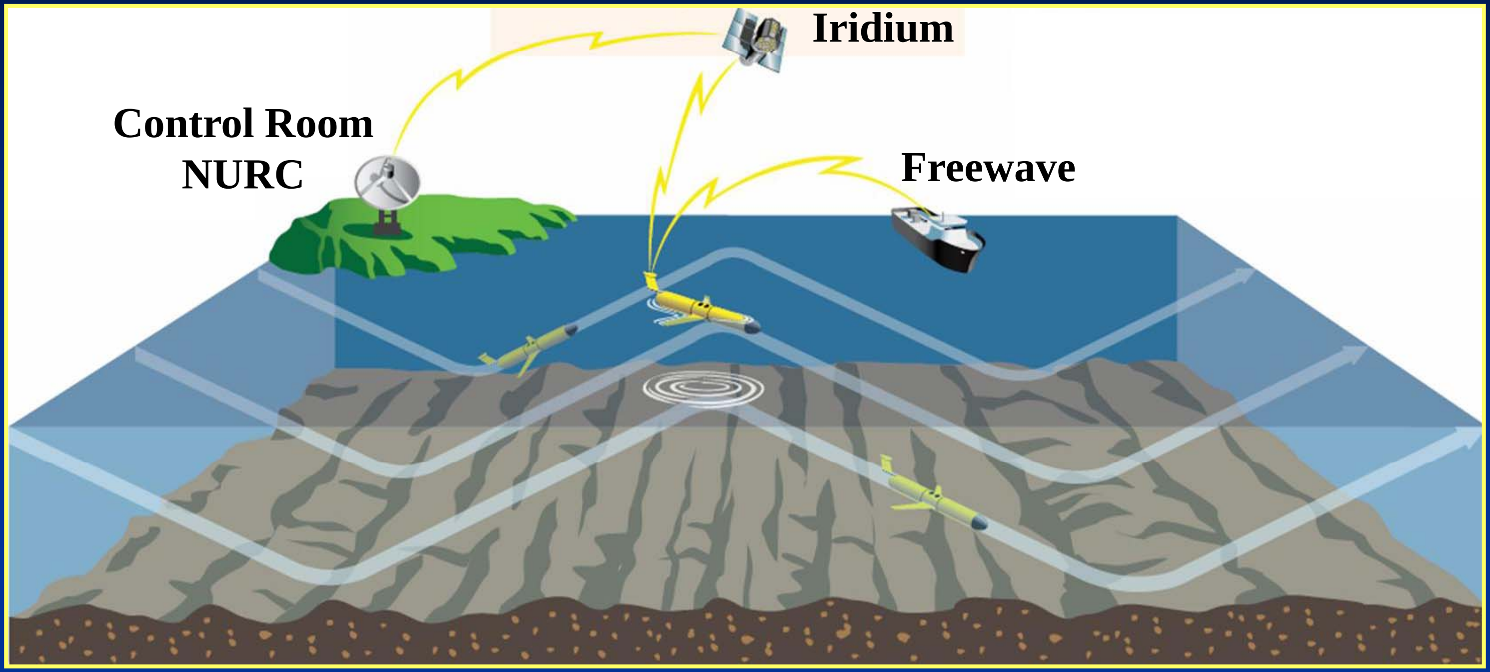




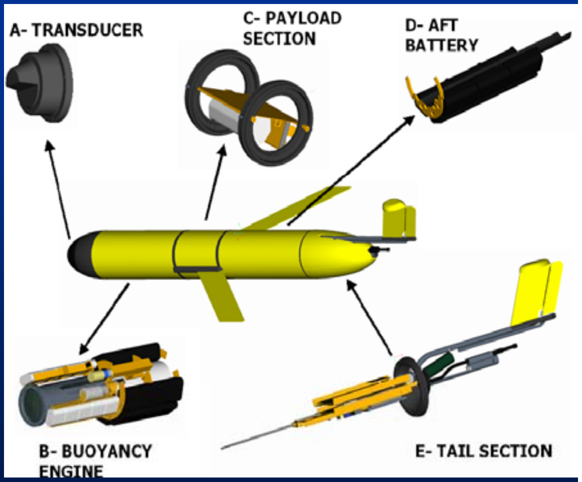


- Low cost; low energy; high autonomy

The *Slocum* Glider



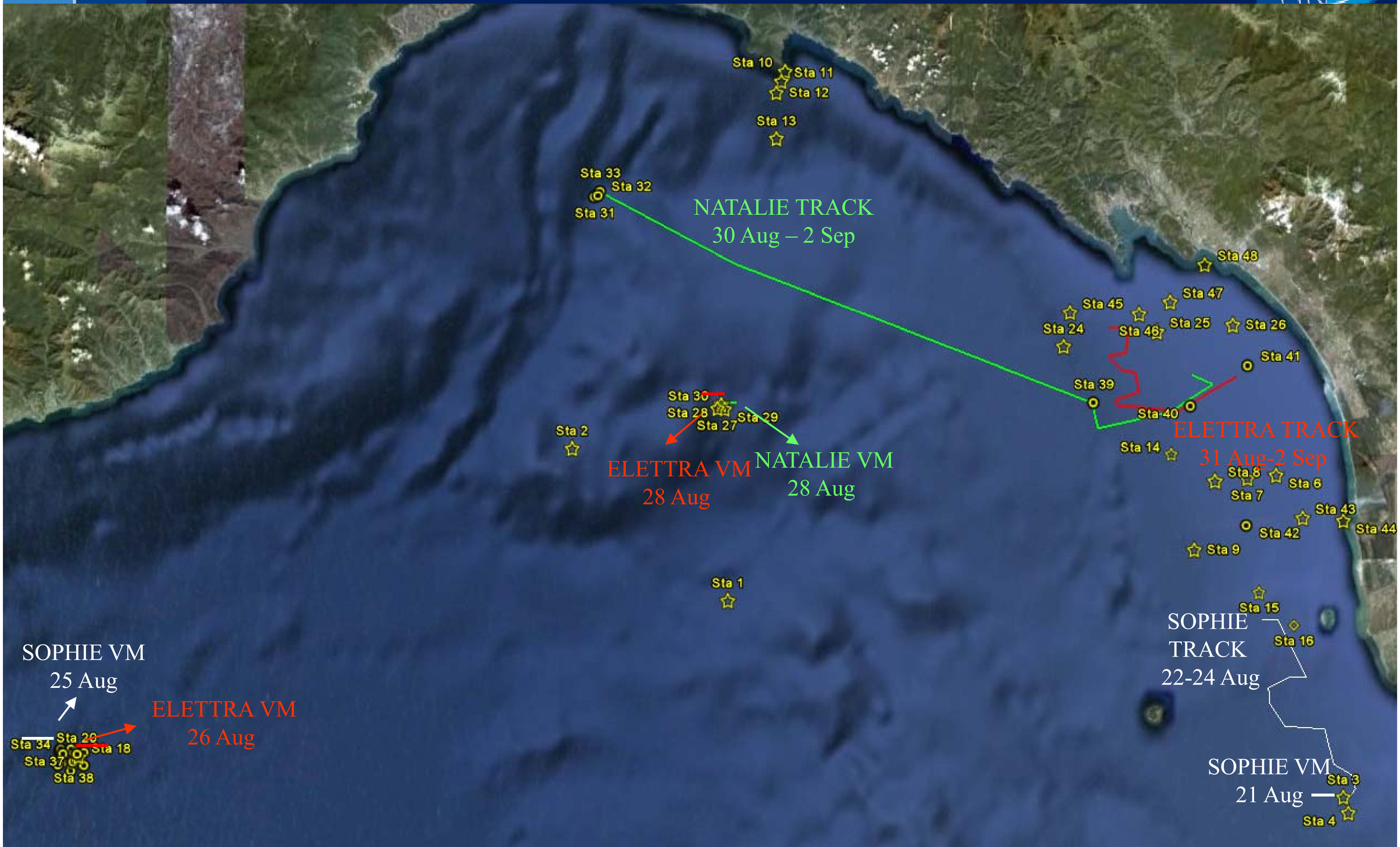
SIZE: weight 52 kg, length 1.8 m.
SPEED: horizontal 0.35 m/s, vertical 0.2 m/s.
RANGE: 5-40 days, 600-1500 km.
DEPTH: shallow: 0-200 m, deep: 0-1000 m.
ENERGY: C-cell alkaline batteries.
NAVIGATION SENSORS: GPS (at surface), dead-reckoning (underwater), compass, pressure, transducer and altimeter.
COMMUNICATION: Satellite (IRIDIUM), RF (freewave, ARGOS transmitter, direct serial connection).



The NURC *Slocum* gliders fleet

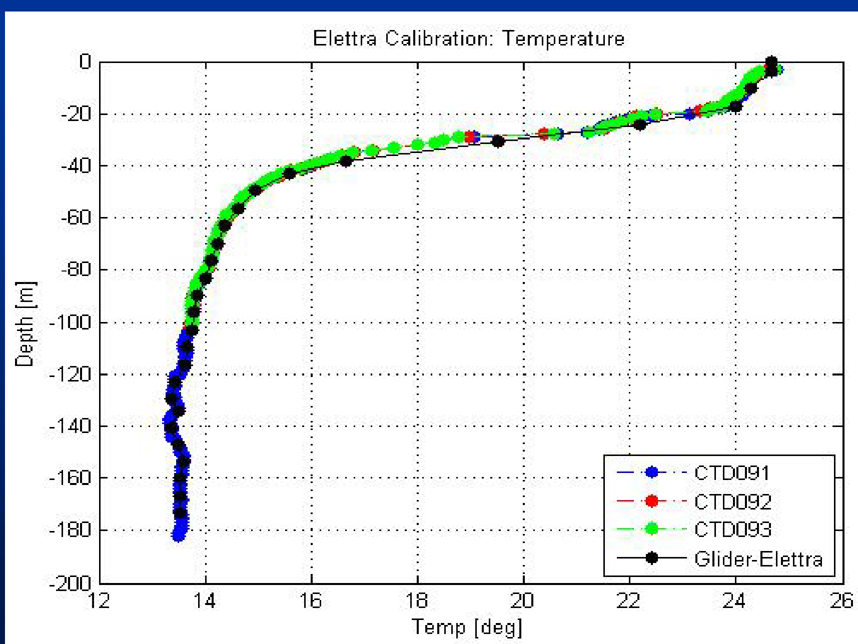
1. ELETTRA: max depth = 200 m, CTD, Chl, CDOM, Ed (4 λ), b_b (532 nm).
2. SOPHIE: max depth = 200 m, CTD, Chl, CDOM, Ed (4 λ), b_b (532 nm).
3. ZOE: max depth = 200 m, CTD, Chl, CDOM, Ed (4 λ), b_b (532 nm).
4. LAURA: max depth = 200 m, CTD, bb (3 λ), BAM (532 nm).
5. NATALIE: max depth = 200 m, CTD, Chl, b_b (532 nm), BAM (532 nm).
6. GRETA: max depth = 200 m, CTD.

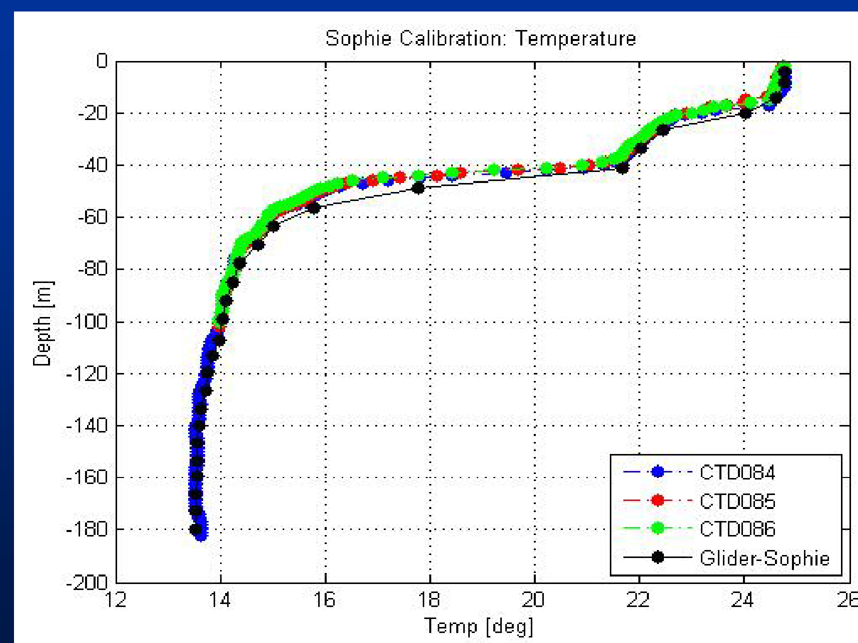
Mission zone – the experiments



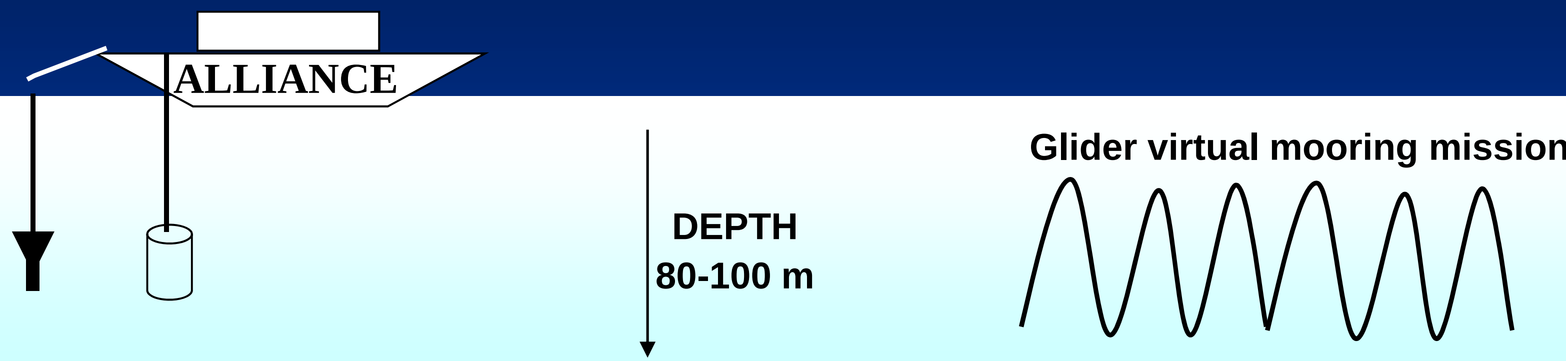
CTD Glider Sensor Calibration

A CTD calibration was done.
Gliders were attached to the rosette and deployed vertically at a typical glider speed (0.5 m/s).





Optical sensors package: the sampling criteria



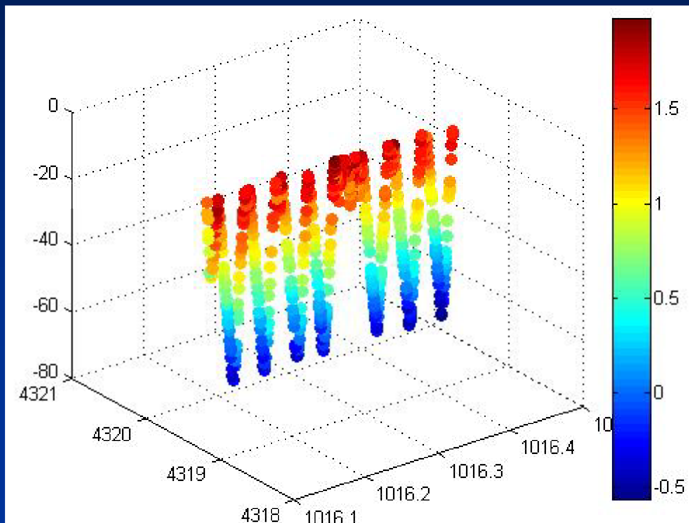
CTD (beam, chl)

HyperPRO

Glider Deployment

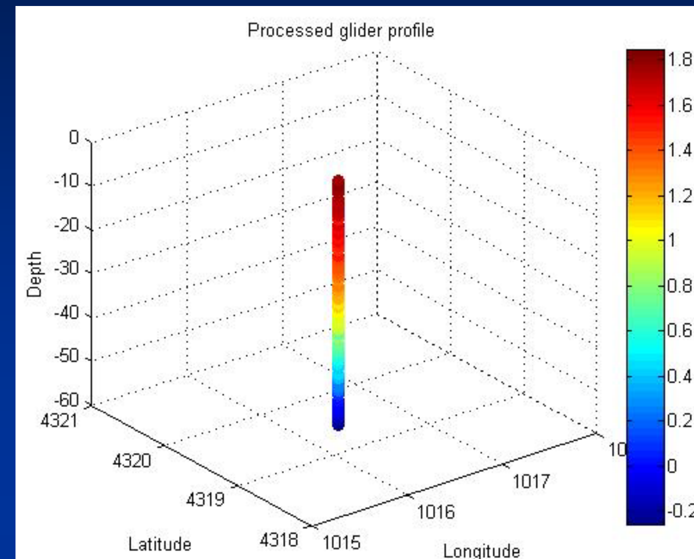
Processing for data comparison

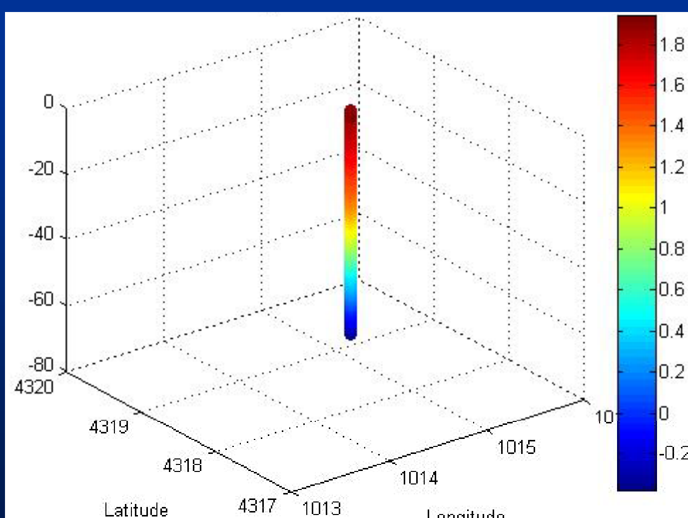
(an example: irradiance at 412 nm)



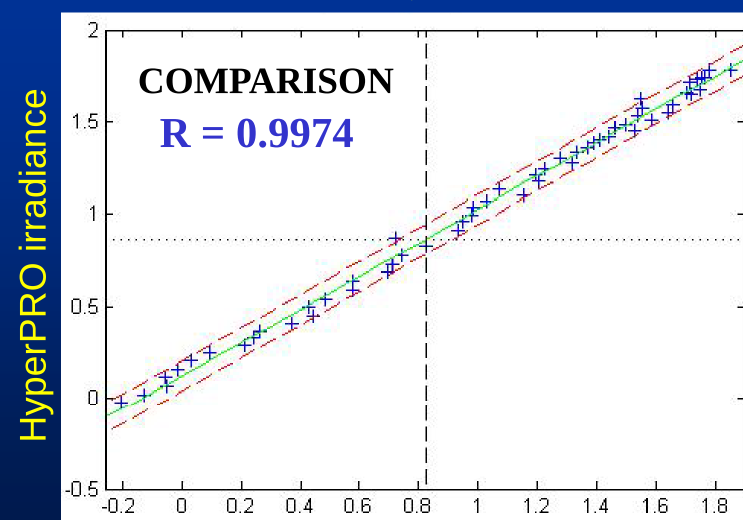
GLIDER TRACK (virtual mooring)

GLIDER DATA PROCESSING





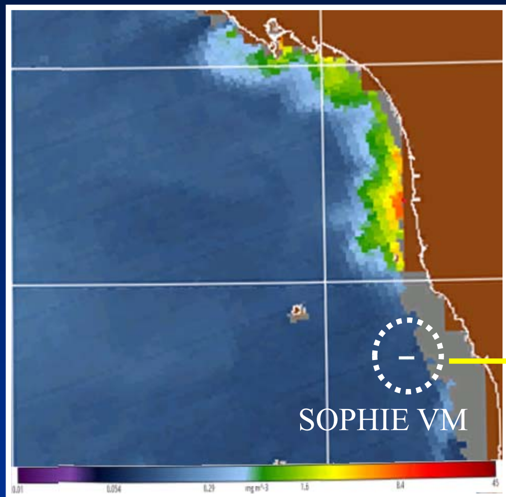
HYPERPRO (profile)



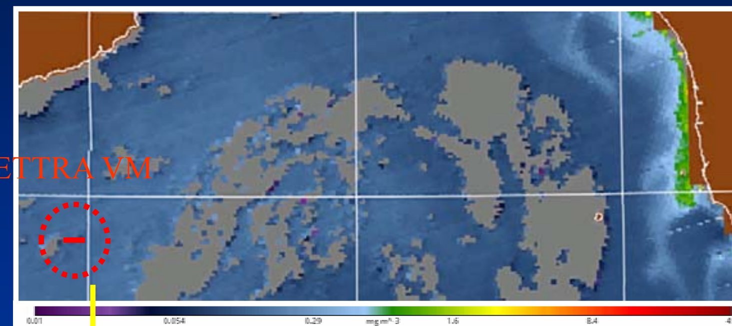
Glider irradiance

NATO UNCLASSIFIED

Results

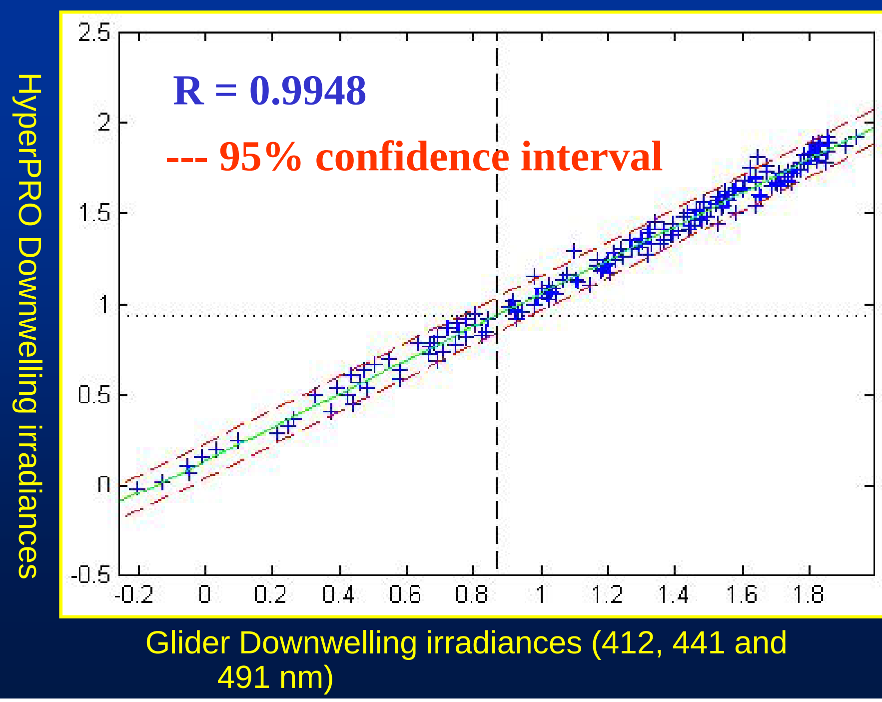


Chl (OC3) from MODIS
(21 August h 8:21)

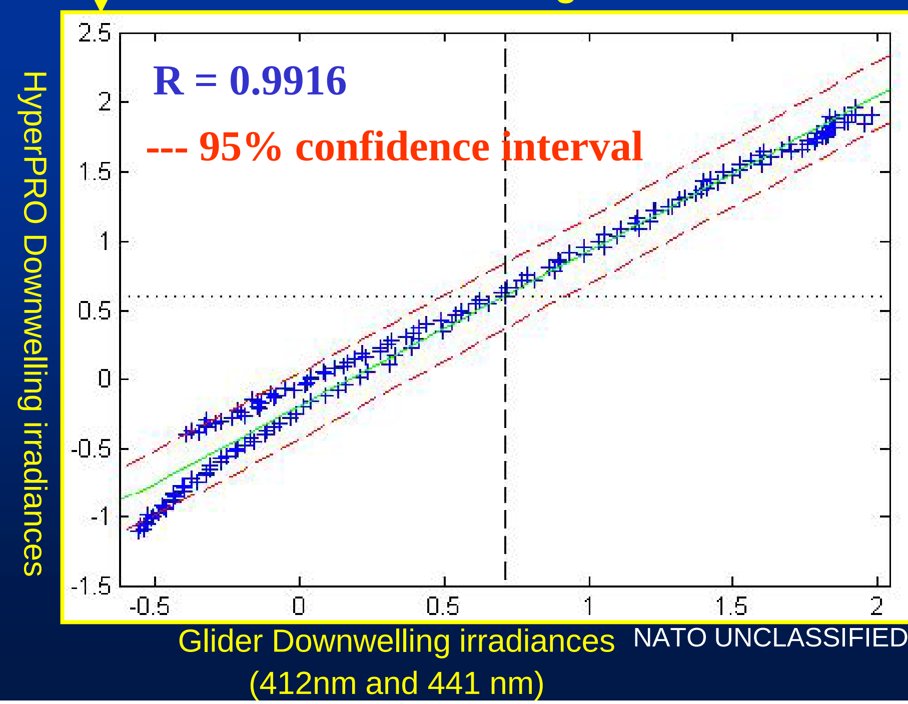


Chl from MODIS
(26 August h 8:26)

SOPHIE – 21 August 2010

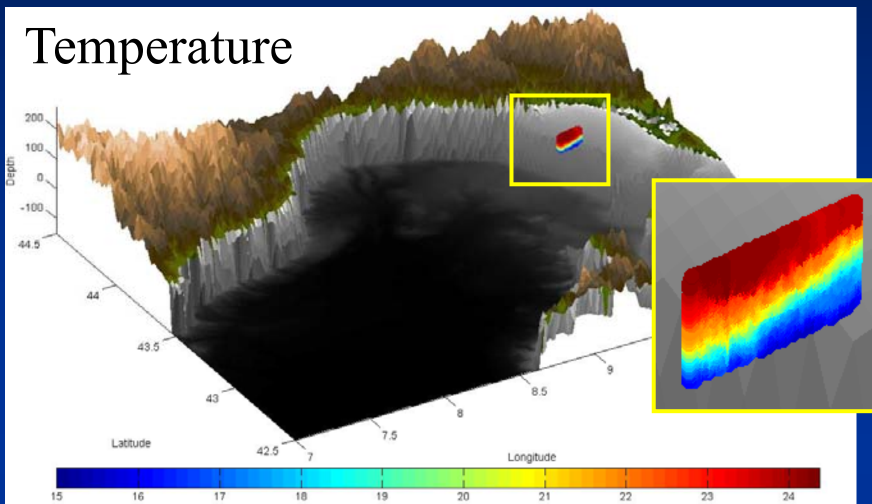


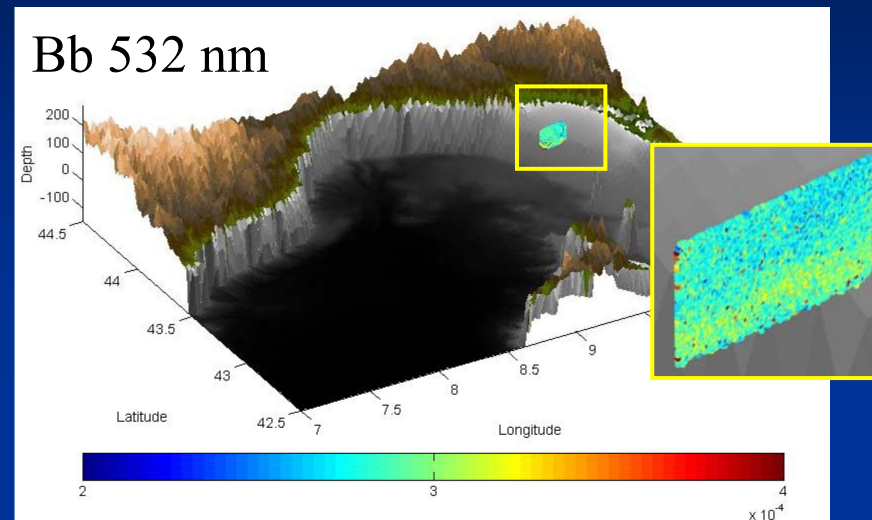
ELETTRA – 26 August 2010

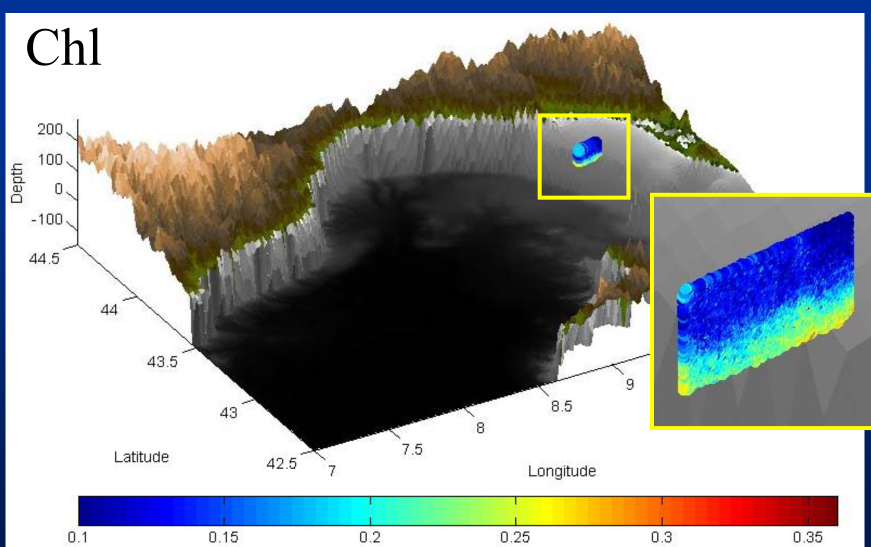


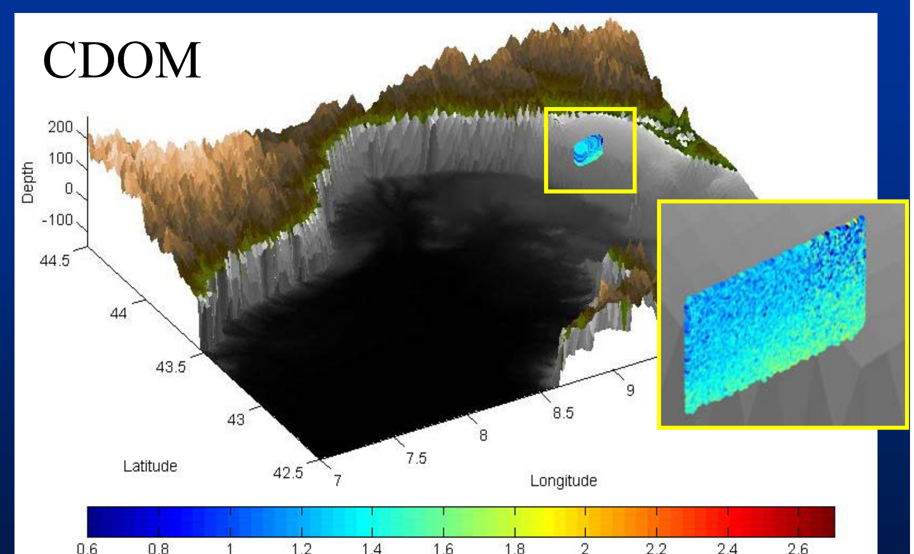
Glider 3D products

Once time optical glider sensors have been validated and tested, it's possible to increase the accuracy of the gliders long track sampling products. Below an example from ELETTRA long track (31 August 2010)









Applying models on glider data:
The SRS concept

Method to determining the optical properties (diffuse attenuation coefficient, K_d) of seawater above Z and the optical character of the atmosphere, using optical measurements at a depth Z (below the surface).

INPUT DATA: time (solar zenith angle), two Downwelling Irradiances at depth Z: $E_d(Z,\lambda_1)$ and $E_d(Z,\lambda_2)$.

STEP 1: calculation of the Extraterrestrial Solar Irradiance, E_0 (Thuillier et al. 2003 Solar Physics).

STEP 2: calculation of optical depths: $\tau_R(\lambda)$, $\tau_0(\lambda)$ and $\tau_a(\lambda)$. Calculation of:

$$A = \log\left(\frac{E_d(\lambda_1)}{E_d(\lambda_2)}\right) - \frac{\tau_B(\lambda_2) - \tau_B(\lambda_1)}{\cos(zenith)}$$

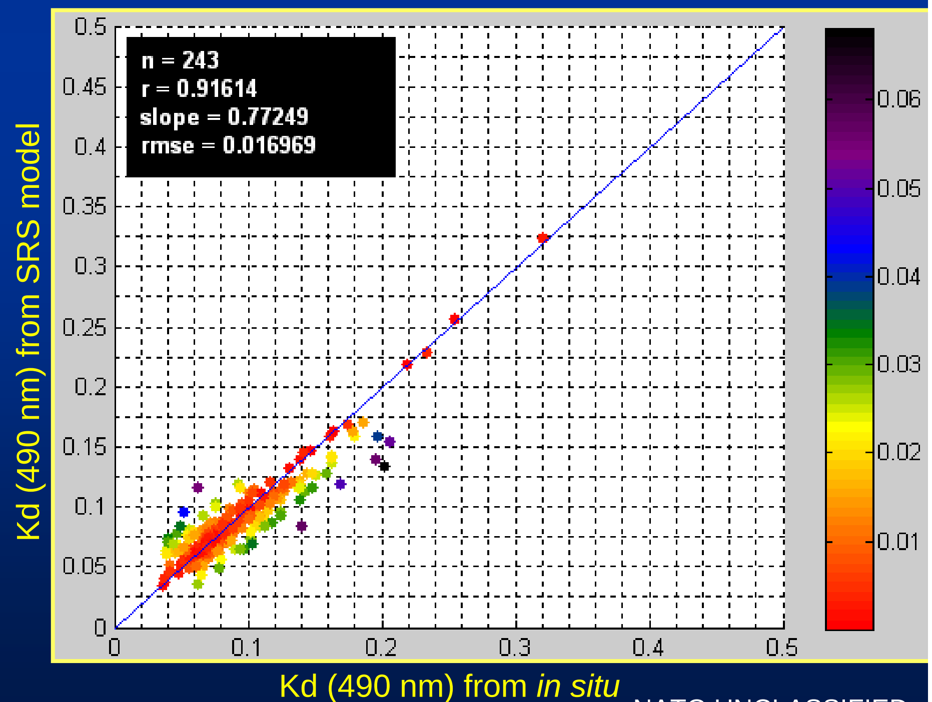
$$B = \frac{1}{Z}\left(A - \log\left(\frac{E_d(\lambda_2)}{E_d(\lambda_1)}\right)\right)$$

STEP 3: calculation of $K_d[490\ nm]$ (Austin and Petzold, '81) and implementation of the spectral model (Austin and Petzold, '92) to retrieve K_d at any wavelength (from 350 to 700 nm).

$$K(\lambda) - K_w(\lambda) = M(\lambda)\cdot\left[K(490nm) - K_w(490nm)\right]$$

$$K(\lambda_1) = \frac{1}{M-1}\left(B + MK_w(\lambda_1) - K_w(\lambda_2)\right)$$

BP09 data

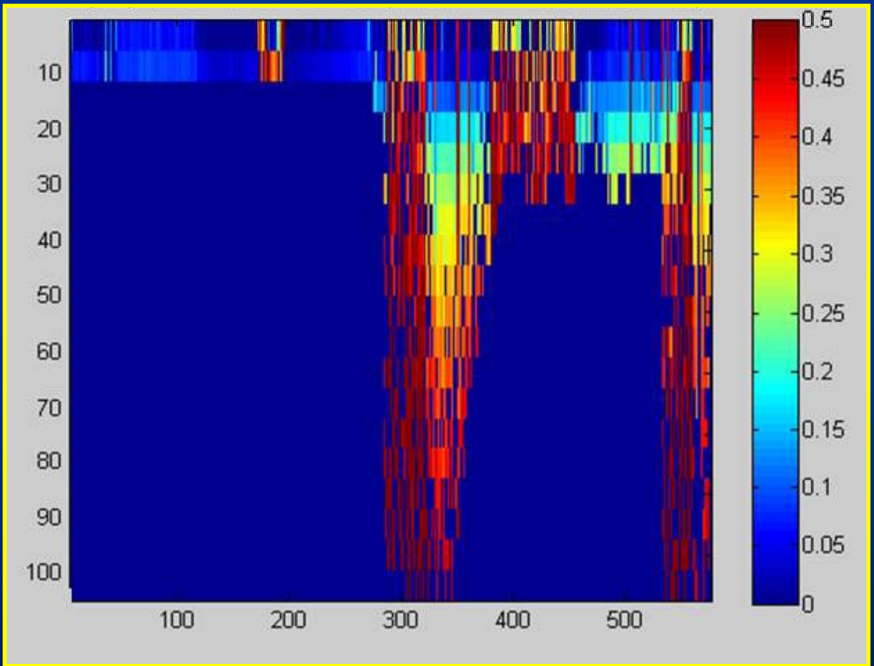


Applying models on glider data:
an example from SRS implementation

The Submerged Remote Sensing (SRS) model was tested with HyperPRO data with satisfactory results. On the basis of this we have implemented it on the glider data (preliminary results, this work still in progress!).

Kd 490 nm from glider irradiances

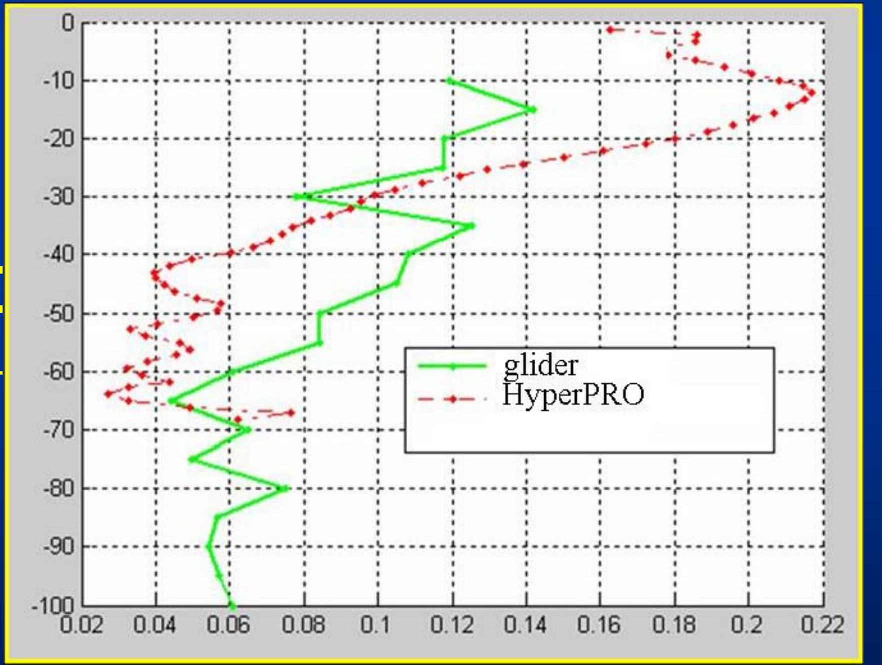
Depth [m]



Time

COMPARISON between Kd profiles retrieved from glider and from *in situ*

Depth [m]



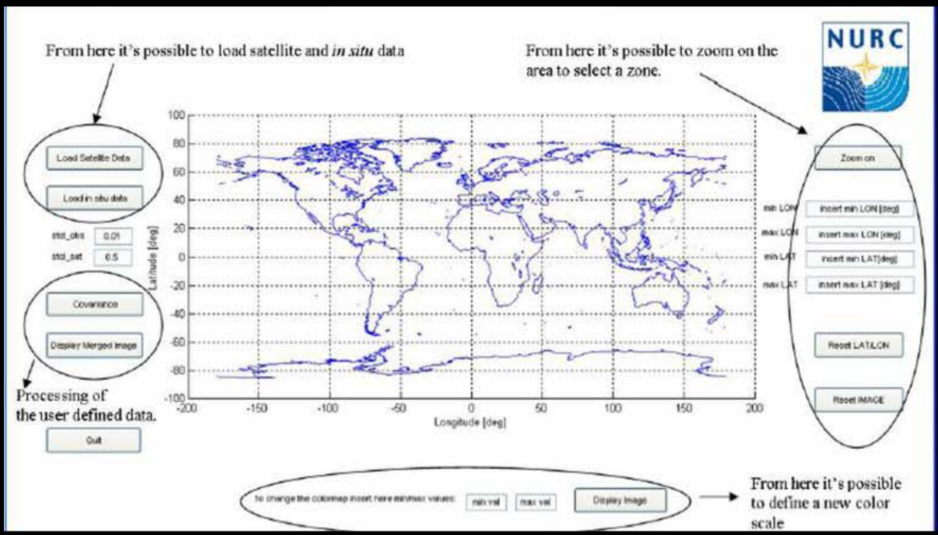
Kd 490 nm

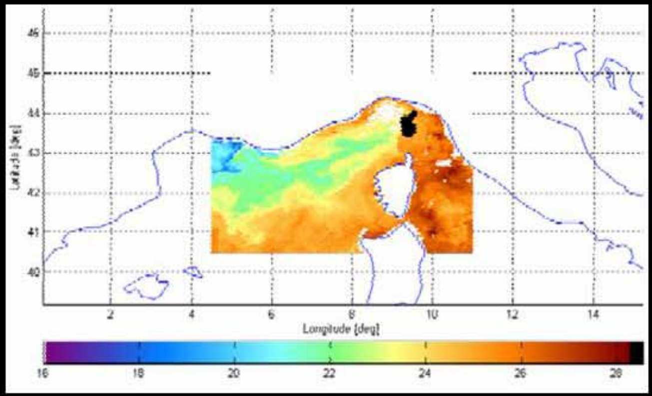
Conclusion and work in progress

This study used *in situ* measurements to glider data validation in optical parameter estimation for environmental characterization. This analysis was tested during NATO cruises that have been held in the Ligurian Sea. The common points of those sea trials were the generation of an extensive and accurate optical data set (in coastal and oceanic waters) and the deployment of Slocum gliders. Results show that there is a good linear relationship between glider and *in situ* optical data, showing a correlation coefficient of 0.9924 (Sophie).

Work in progress

Using the gliders products retrieved here, a procedure to integrate *in situ* measurement to improve the satellite accuracy is under development.





Acknowledgements

All NURC staff involved in the preparation, deployment and collection of glider and *in situ* data are strongly acknowledged; special thanks to R. Stoner (ETD-Engineering coordinator), M. Ampolo Rella (HyperPRO) and D. Galletti (Gliders).

Appreciation is also expressed to J. Kerfoot and K. Niewiadomska (Webb Lab) for the support to gliders operations and to the NURC glider pilots team (G. Baldasserini, M. Coffin, D. Cecchi, C. Lewis, G. Pennucci and P. Zanasca).

? QUESTION ?