“Remote” biogeochemical oceanography : potential synergies between bio-optical floats and ocean color satellites

Hervé Claustre and Fabrizio D’Ortenzio
Laboratoire d’Océanographie
06230 Villefranche-sur-mer
France

June, 2008

Introduction and scientific context

(1) Oceanic physical forcing impacts ecosystem structure, the level of living resources and hence elemental cycling.

(2) Climate change will affect the intensity of physical forcing and hence biological response.

(3) Forcing (and associated biological responses) occurs over a continuum of spatial (sub-meso-/ meso-/ basin/ global) and temporal scales (diurnal, seasonal, decadal).

(4) Biological and biogeochemical oceanic properties are chronically under-sampled, especially when using ship-based plate-forms

(5) This represents a major limitation to our understanding of the functioning of the oceans and ultimately for modeling / predicting their future evolution.

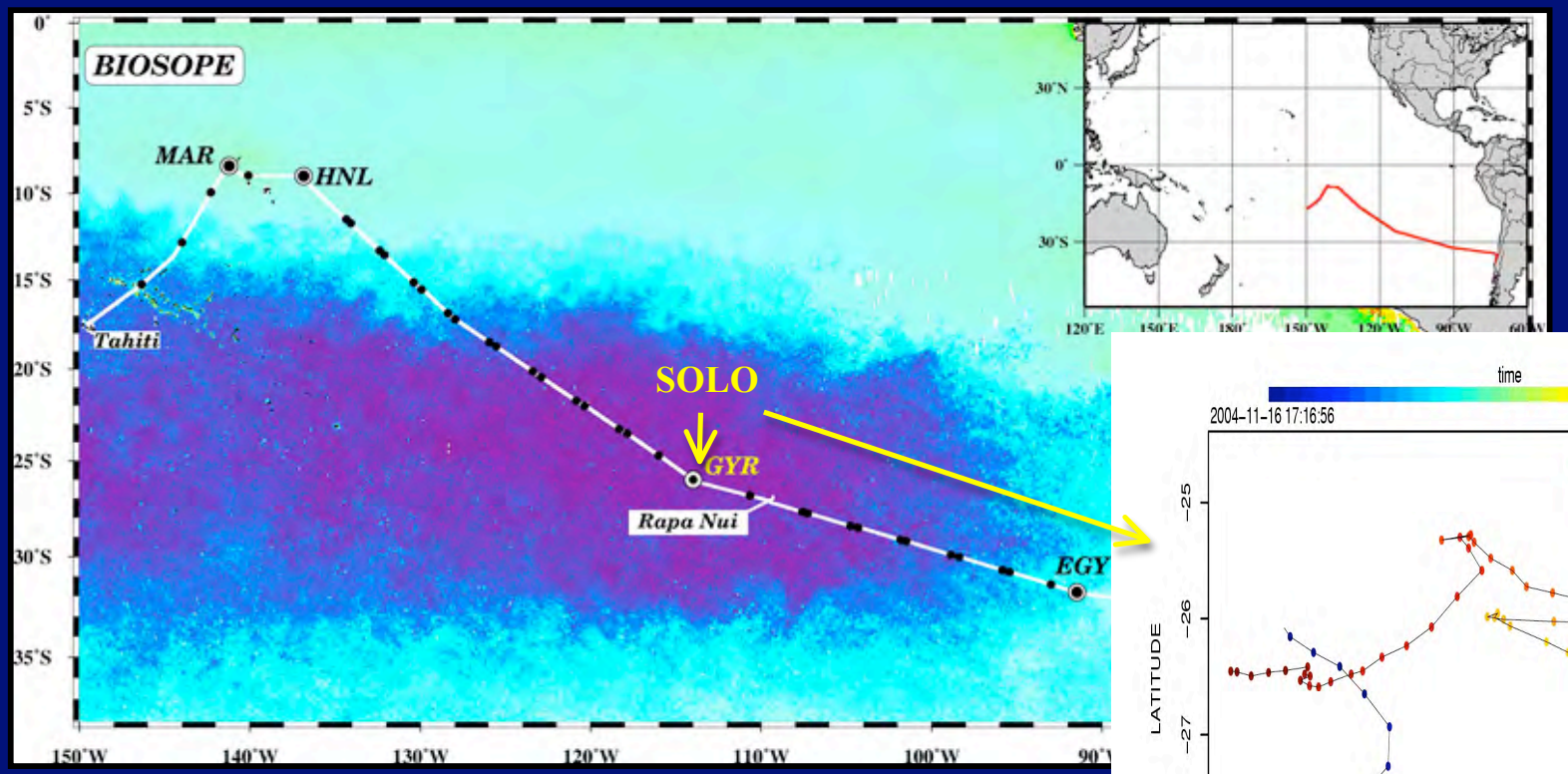
Introduction and scientific context

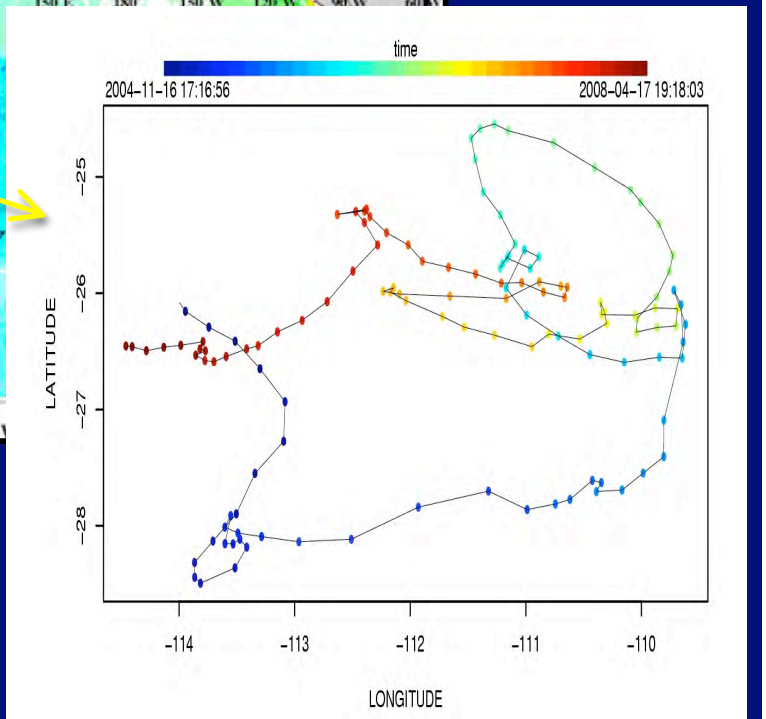
Some hopes for biologists : besides classical ship-based platforms, oceanographic observations have begun to (greatly) benefit from other types of (remote) platforms that have the potential to (partially) overcome the problem of undersampling :

- **Remote sensing**
- **Autonomous and Lagrangian Platforms (e.g. floats)**

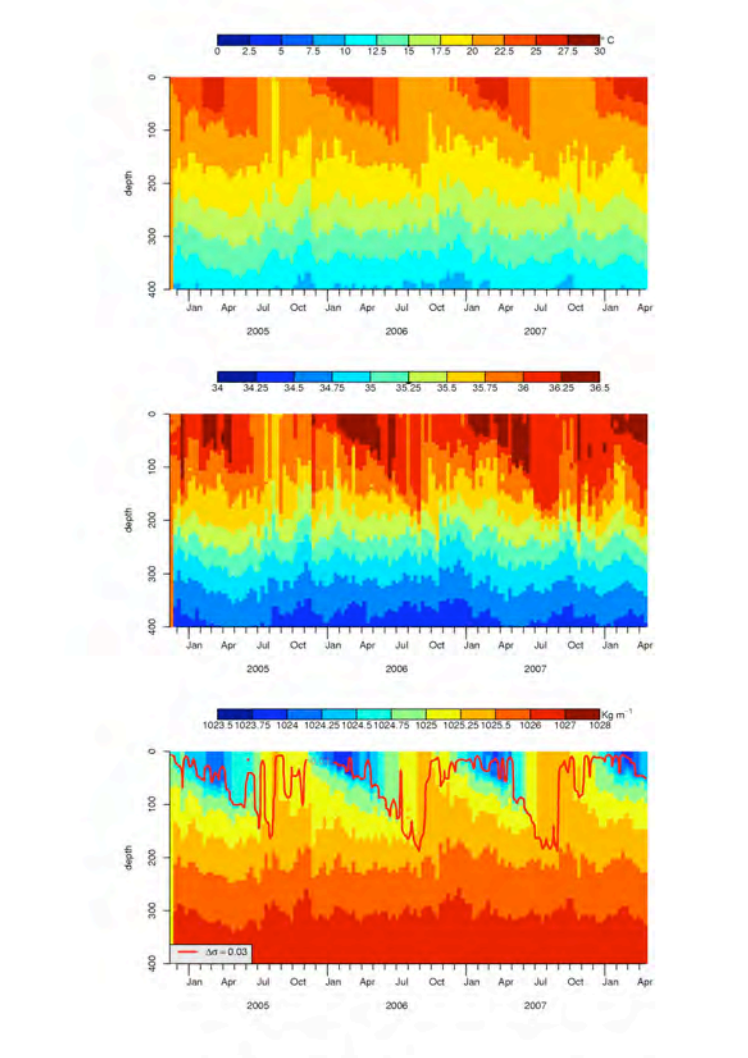
New “end-users” : the biologists

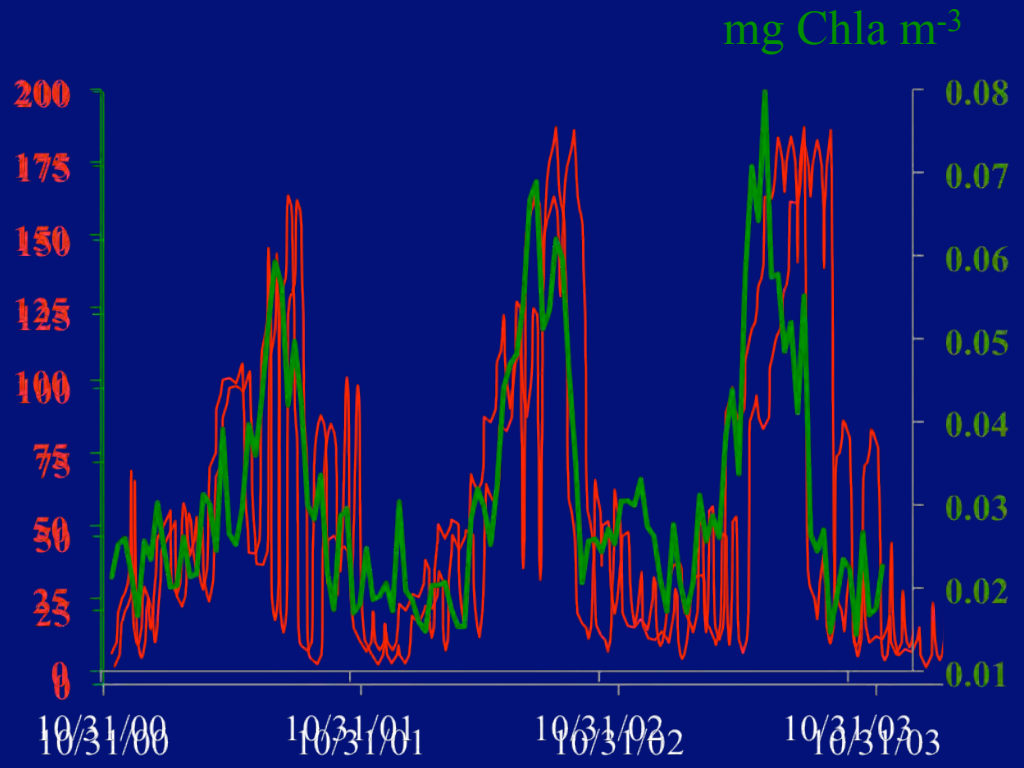
First (simple) case : combining ARGO (TS) and SeaWiFS (Chla)





First (simple) case : combining ARGO (TS) and SeaWiFS (Chla)





Remote sensing of Ocean Colour

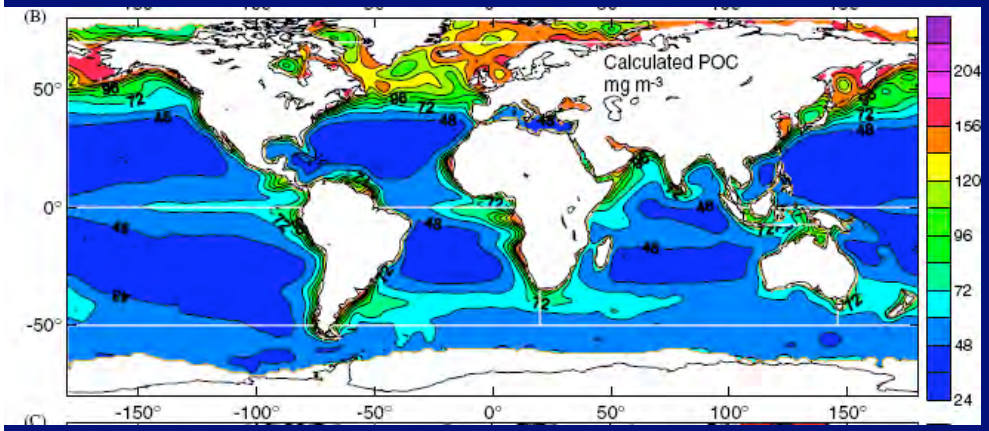
• Remote sensing offers quasi-synoptical coverage of the ocean surface.

• For biology / biogeochemistry, « Chla » is the « primary » variable.

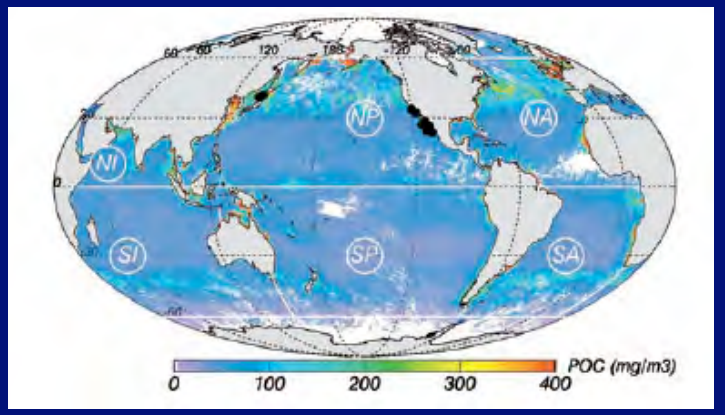
• Algorithmic development has allowed a suite of optically significant substances and associated derived biogeochemical variables to be extracted from space-based observations. (examples)

Remote sensing of ocean color : various « bio-products »

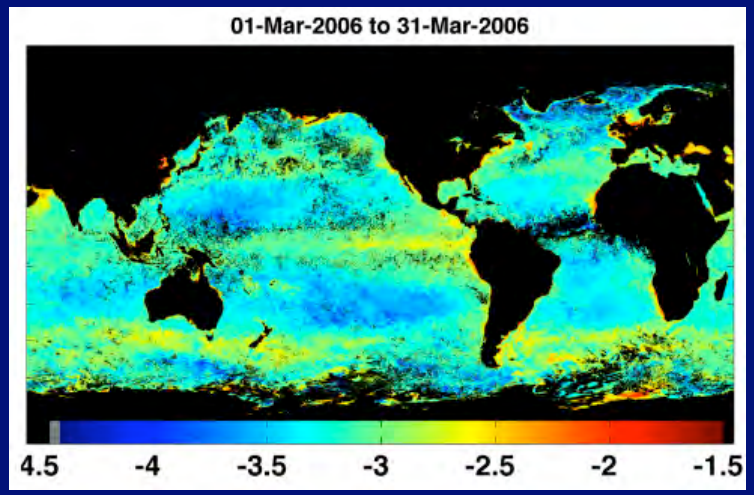
(1) Proxies of particle load or Particulate Organic Content (POC)



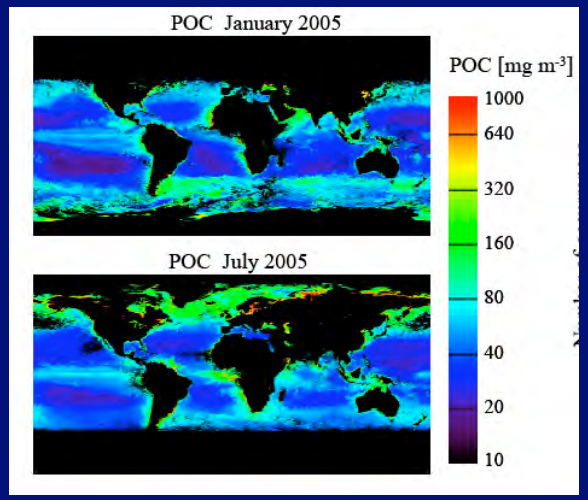
POC : Gardner et al., DSR II 2006



POC : Loisel et al., GRL 2002



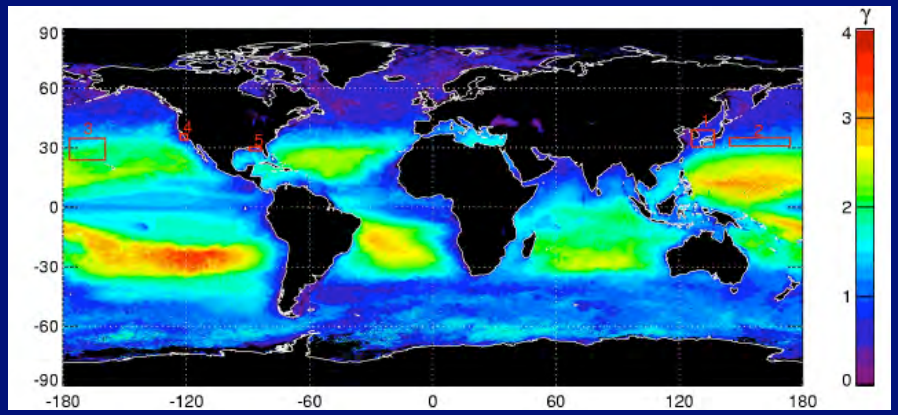
b_{bp} : Brown et al., in press



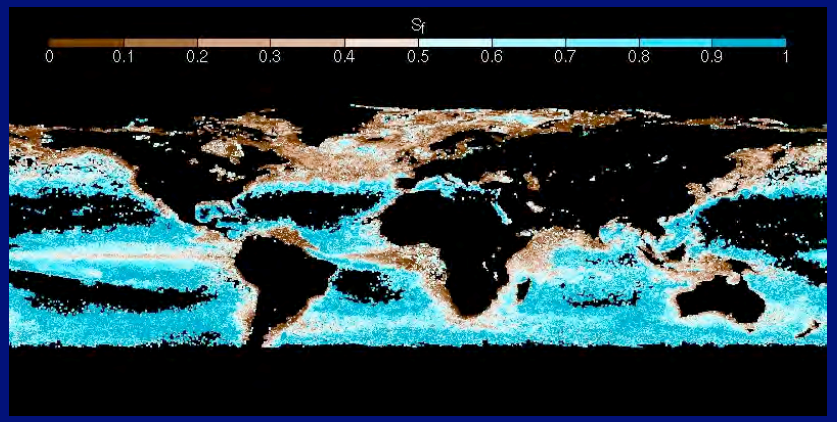
POC : Stramski et al., 2008, Biogeosciences

Remote sensing of ocean color : various « bio-products »

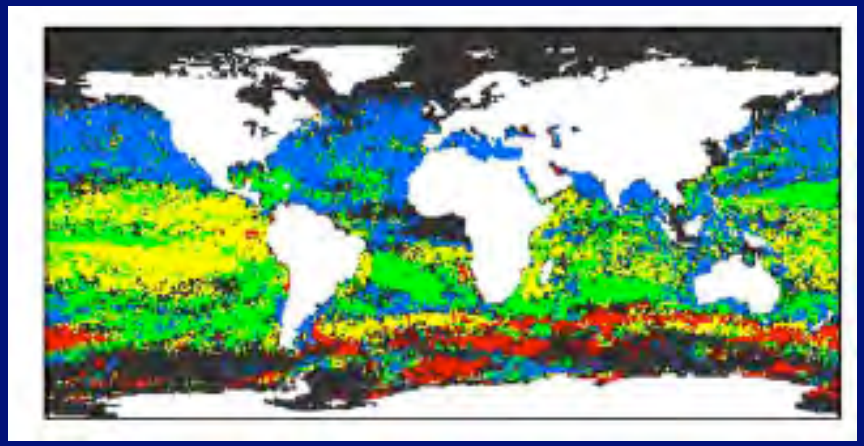
(2) Proxies of the qualitative nature of the particles (size, composition…)



γ (particle size) : Loisel et al., JGR 2006

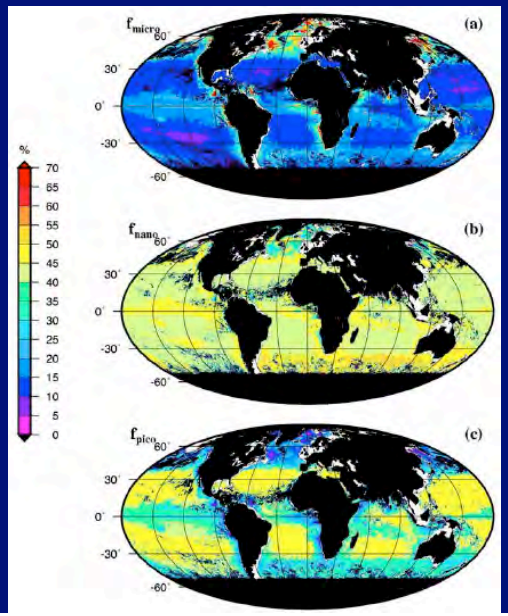


Sf (phyto size) : Bricaud et al., in prep



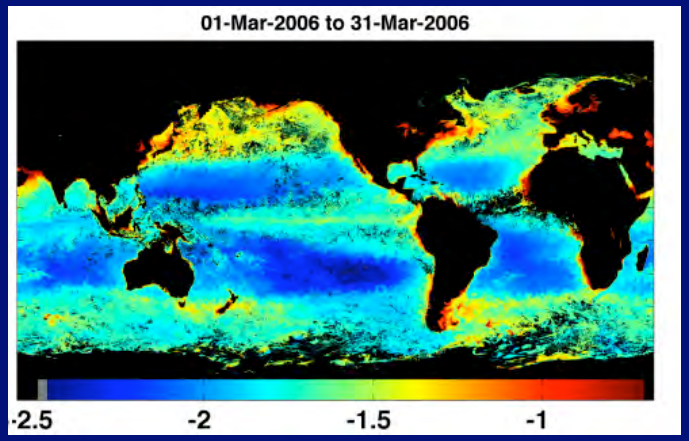
phyto community: Alvain et al., DSR 2005

phyto size classes : Uitz et al., JGR 2006

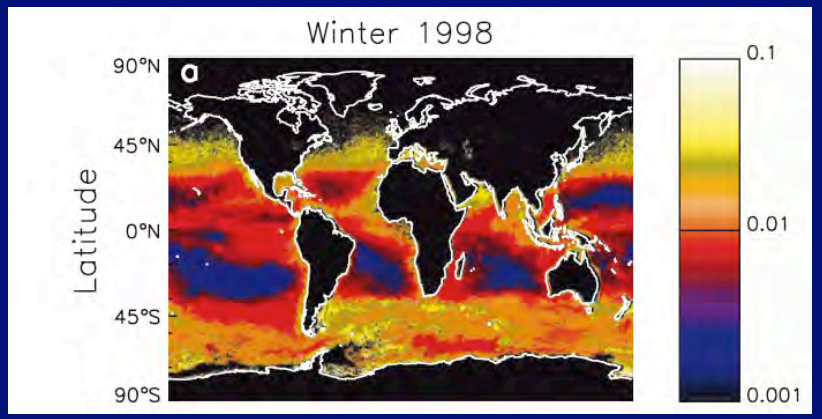


Remote sensing of ocean color : various « bio-products »

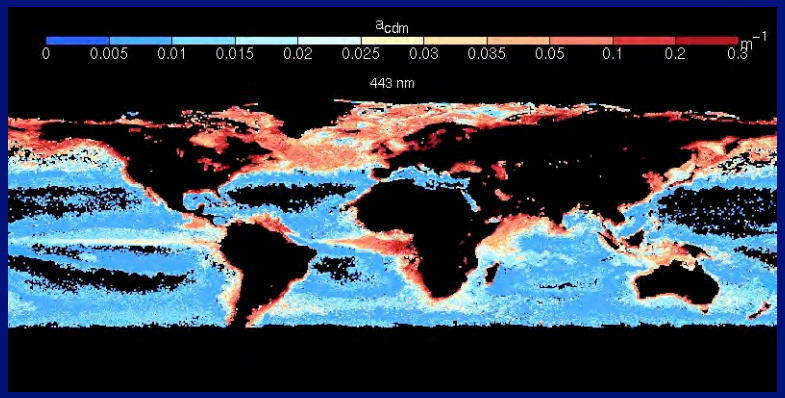
(3) Proxies of dissolved / detrital material



a_{cdm} : Brown et al., in press



CDM : Siegel et al., JGR 2002



a_{cdm} (443) : Bricaud et al., in prep

Remote sensing of Ocean Colour

• Remote sensing offers quasi-synoptical coverage of the ocean surface.

• For biology / biogeochemistry, « Chla » is the « primary » variable.

• Algorithmic development has allowed a suite of optically significant substances and associated derived biogeochemical variables to be extracted from space-based observations. (examples)

Remotely sensed ocean color is becoming a very important tool for global monitoring of key oceanic biogeochemical variables and their possible evolution as a consequence of global change

Remote sensing of Ocean Colour : powerful, but some limitations

1. restricted to the upper ocean layer
   => no access to 4/5 of the so-called euphotic layer

2. cloudy areas are unobservable by remote sensing
   => North Atlantic during the spring bloom

3. Calibration / validation : seatruthing
   => Essentially dependant on moorings or cruises (some spatio-temporal limitations)

To reach its full potential, remote sensing must be complemented with other techniques

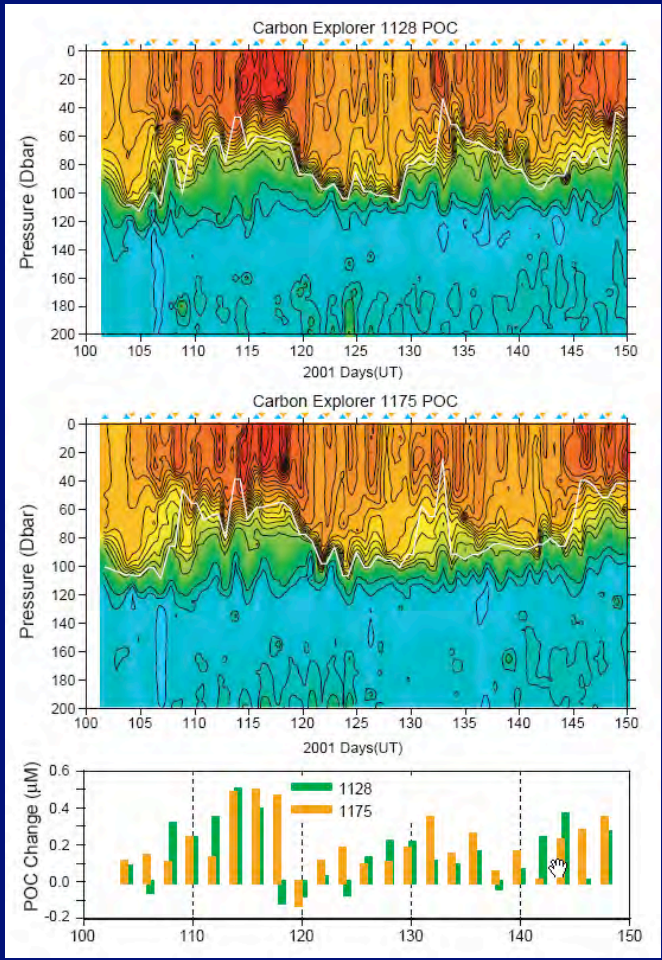
Towards implementation of bio-optical measurements on ARGO floats

Recent development of low-consumption and miniature neutrally buoyant sensors (oxygen, radiometers, backscattering meters, fluorometers, transmissiometers…) provides good candidates for mounting on floats.

…and biogeochemists have begun to implement these sensors on ARGO floats for dedicated local or regional studies. (examples)

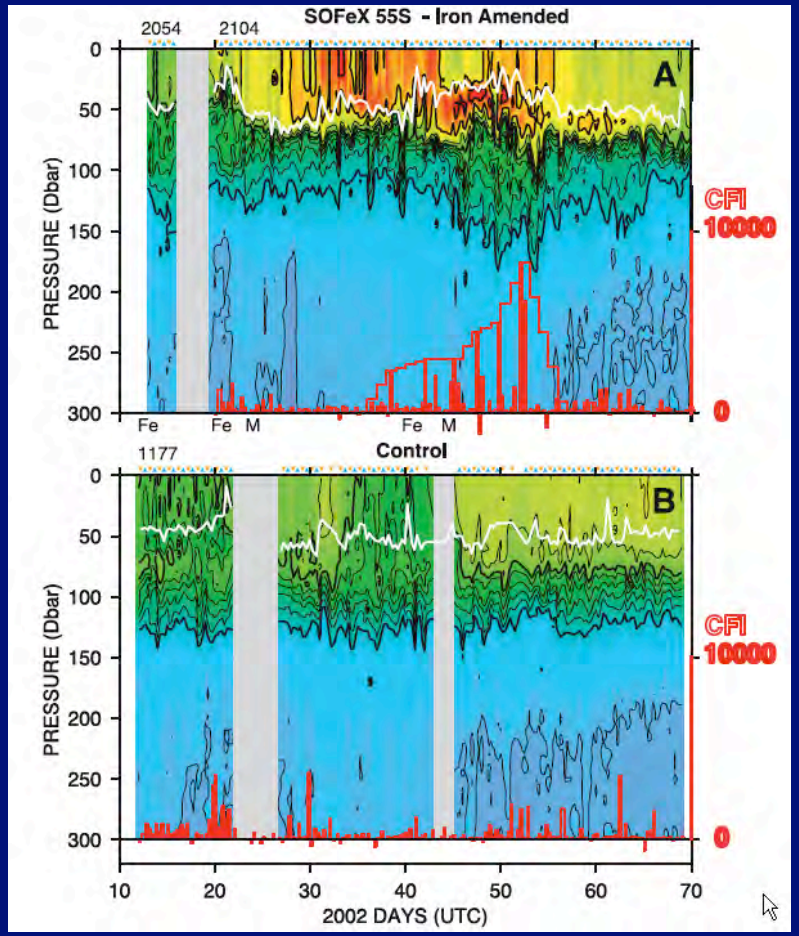
Towards implementation of bio-optical measurements on ARGO floats

Carbon explorer : SOLO float + transmissiometer



55°N;145°W

Bishop et al., *Science*, 2002

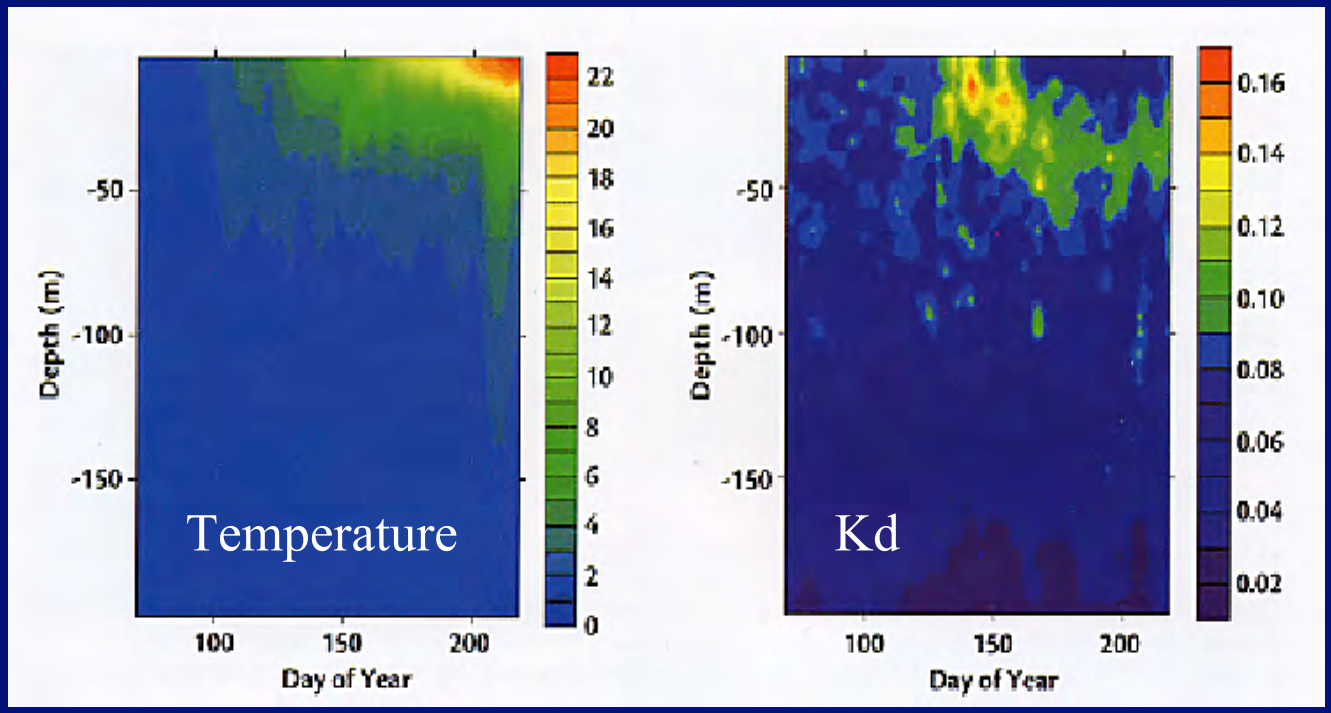


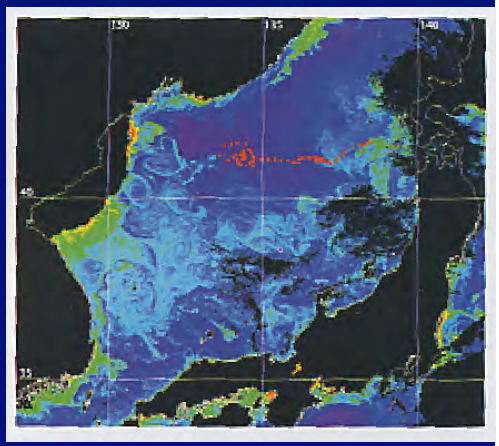
55°S ;170°W

Bishop et al., *Science*, 2004

Towards implementation of bio-optical measurements on ARGO floats

K-SOLO : SOLO float + radiometer

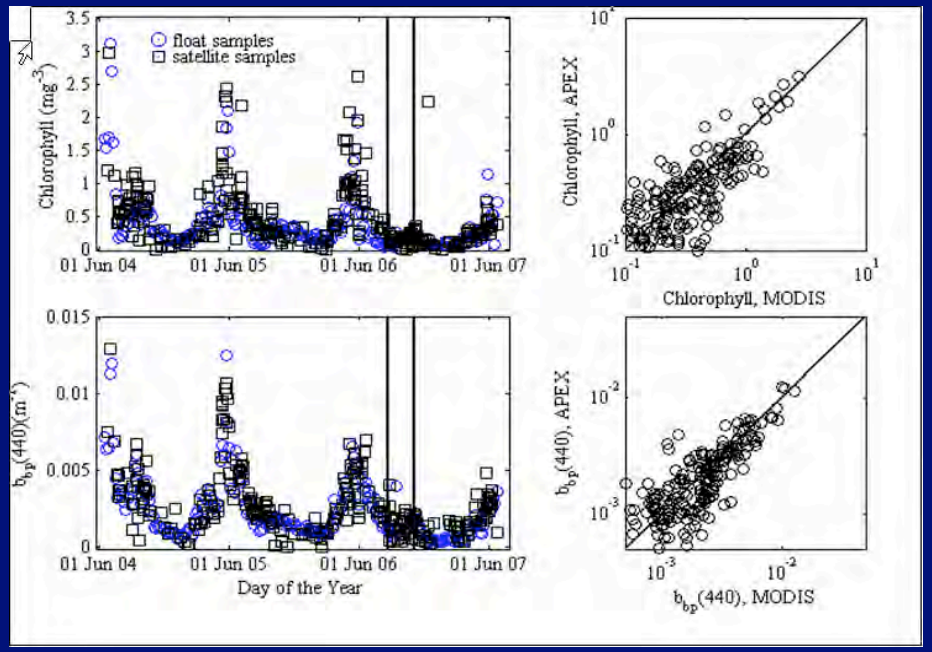


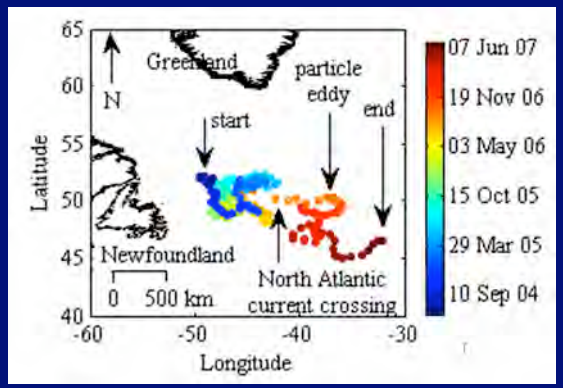


Experiment in the Japan Sea (Mitchell et al, 2003)

Towards implementation of bio-optical measurements on ARGO floats

Apex float + optical package

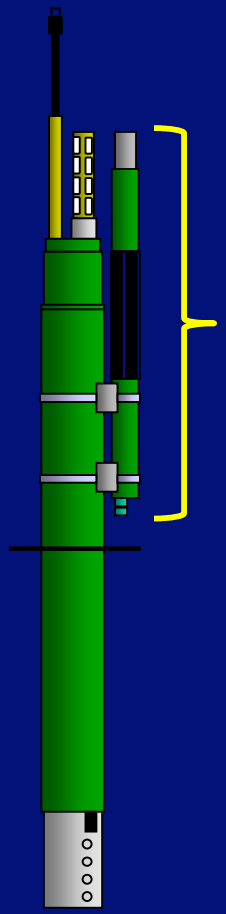


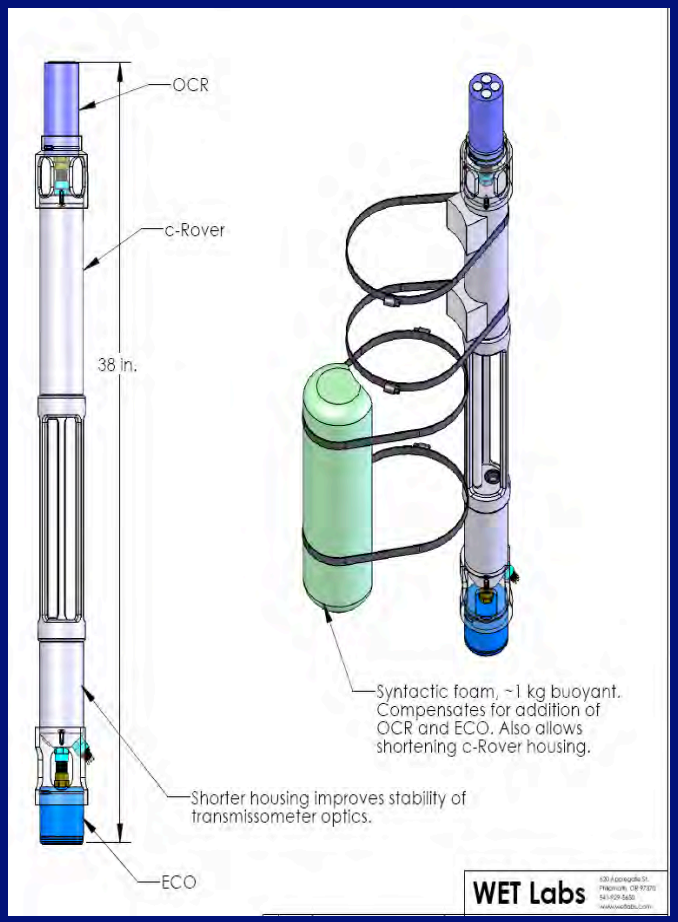


Boss et al., EOS, 2008,,
Boss et al., *L & O*, in press

Towards implementation of bio-optical measurements on ARGO floats

PROVBIO : A & B PROVOR CTS 3 float + optical package + iridium





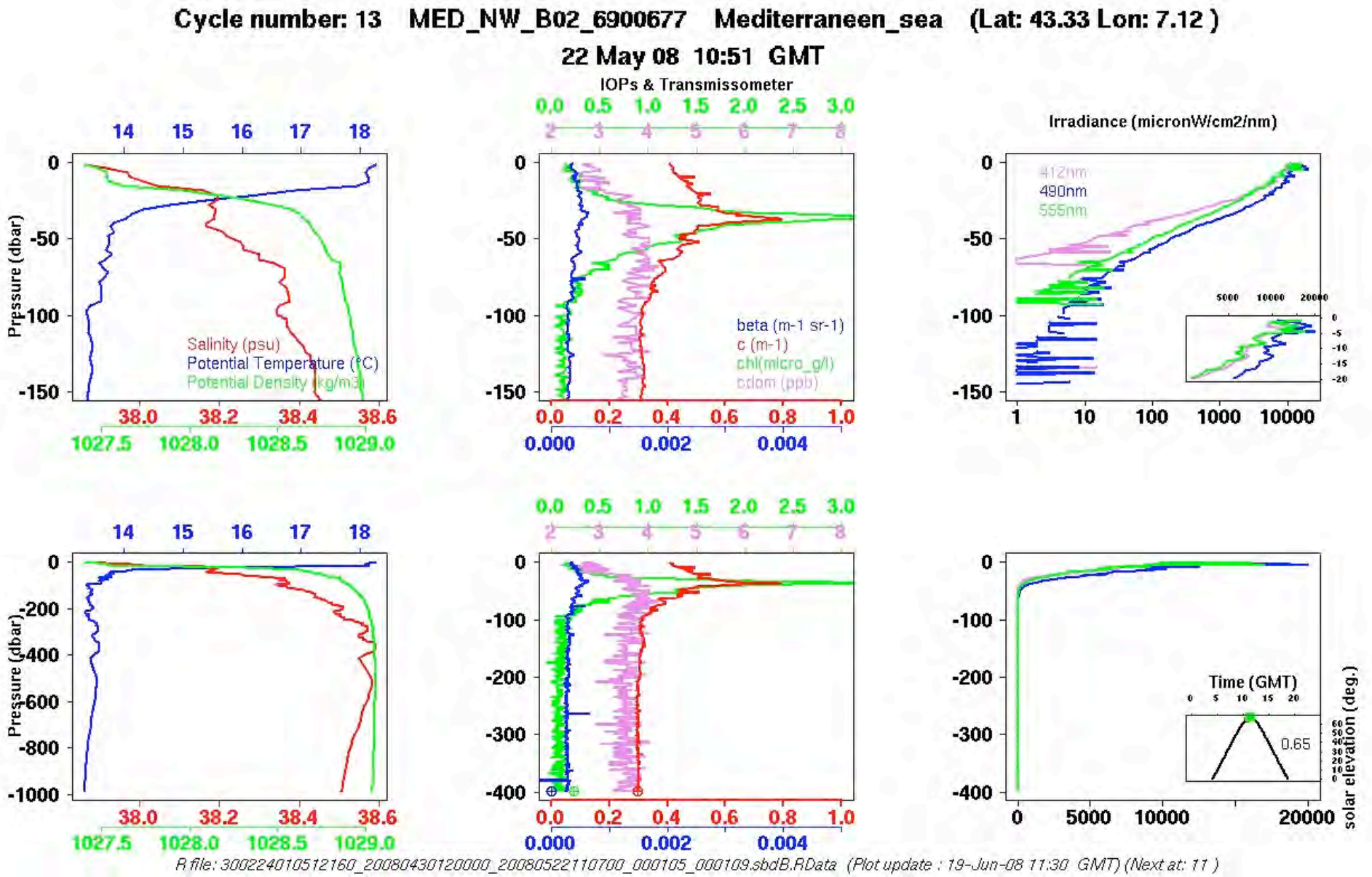
ProvBio A

- Radiometer (412, 490, 555)
- Transmissometer (660)

ProvBio B

- idem ProvBio A
- Chla
- CDOM
- bb (540)

First measurements with PROVBIO B2 in the Mediterranean Sea



Towards implementation of bio-optical measurements on ARGO floats

The advantage of iridium

- cost effective high resolution; presently CTD (3 m resolution; optics).
- Adaptative sampling
  - ✓ to fit with event processes
  - ✓Caracterisation of the seasonal bloom (North Atlantic)
  - ✓ take benefit of satellite ocean color and of forecasts (e.g. storms, mixed layer)
  - ✓ Diel cycle (and measurement of biological fluxes)
- Recovery of floats : switch to “end of life” mode; very interesting for regional Sea (e.g. North Western Med Sea) in the EuroArgo context.

Introduction to BIO-ARGO IOCCG WG scientific context

ARGO floats with optical / biogeochemical sensors have a very large potential to provide high density biogeochemical data.

- ARGO floats provide the vertical dimension of properties that is missed by satellites
- ARGO floats can provide information from anywhere anytime, including under cloudy conditions (North Atlantic during the spring bloom)
- ARGO floats have an extensive global coverage
- ARGO floats could provide large amounts of data for validation purposes of ocean color sensors

Thus ARGO technology together with new sensors represent a very promising avenue for synergetic applications with remote sensing of ocean color. IOCCG asked us to investigate this topic and make recommendations.

Introduction to BIO-ARGO IOCCG WG scientific context

Thus ARGO technology together with new sensors represent a very promising avenue for synergetic applications with remote sensing of ocean color.

IOCCG asked us to investigate this topic and make recommendations.

Introduction to BIO-ARGO WG strategic context

Our working group is involved in the preliminary steps before envisaging an (eventual) BIO-ARGO program. We will need to make two types of recommendations

(1) **Clear scientific and technical recommendations** (TOR), keeping in mind that our first objective is linked to ocean color remote sensing (this is the first mission given to us by our IOCCG sponsor)

See : http://www.ioccg.org/groups/argo.html

(2) **Strategic recommendations which enhance the value of our work in a more multidisciplinary context**

being aware of the achievements and exchanging with :

- the "friend of oxygen on ARGO" community => develop a broader « biogeochemical » ARGO community
- the ARGO physical community in general

Introduction to BIO-ARGO WG strategic context

Long-term, remote in situ observations of ocean biogeochemical cycles at ocean basin to global scales using profiling floats and gliders

A Scoping Workshop Proposal to the US Ocean Carbon and Biogeochemistry Program

Kenneth Johnson, Steve Emerson, Steve Riser, Mary Jane Perry, Emmanuel Boss, Arne Kortzinger, Niki Gruber, Hervé Claustre, Dennis Hansell

Introduction to BIO-ARGO WG strategic context

We already have some arguments to convince the physical ARGO community:

• There are some scientific outputs from optical sensors that the physical community could be interested in: (e.g. radiometer => heating rate)

• the addition of bio-optical bio-geochemical sensors might enhance the value of ARGO as a whole

- ARGO = Climate vs waters mass property changes program
- BIO-ARGO = Climate vs carbon cycle / ecosystem changes

• The biogeochemical community and ocean color /space agencies, if interested, « can pay » for additional costs (e.g. Coriolis + CNES + CNRS) of even new floats (e.g. ANR)

Introduction to BIO-ARGO WG preliminary recommandations

A : Three types of ARGO like floats have been identified for bio-optical / bio-geochemical activities

1 : VAL-ARGO : VALidation products for remote sensing activity only

2 : Process Study-ARGO : Very complete set of sensors (including nitrate). The available energy of a float could be use in one / few months (for example as part of or in parallel with process study cruises)

 # 3 : BIO-ARGO Float: Set of limited low consumption bio-optical and chemical sensors, that could fit with the ARGO array with a minimal cost and would provide very valuable data in conjunction with remote sensing for global (GCM-coupled) biogeochemistry models

- Fluorescence sensor for Chla
- Turbidity sensor for POC
- O2 sensor
- Radiometer (4 λ)

Introduction to BIO-ARGO WG preliminary recommandations

B : Developping an energy budget simulator and make it available to the community

Given the increasing variety of float / sensors / transmission it is essential to properly evaluate the energy cost a particular ARGO mission.

As part of this working group, a mission simulator has to be developed (in fine, in an user friendly format) to evaluate these costs according to various configurations including :

- types of floats (APEX, APEX UW, NEMO, PROVOR)
- type of sensors
- max depth of the profile and resolution
- cost (and duration) of the transmission (Argos vs iridium)

The issues of the additional costs of data management have to be examined too.

Thanks for your attention