Guidelines for an integrated ocean observation system for ecosystems and biogeochemical cycles

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Presentation outline

- ❑ The context and the challenges
- ❑ The « bio » variables to be measured.
- ❑ The various component / platforms of a sustained *in situ* observations system.
    - Gliders
    - Floats
    - Animals
    - Eulerian Time Series
    - Ship-based repeated hydrography
- ❑ The OCR satellite observation component.
- ❑ The issue of data flow, data management and data policy.
- ❑ Towards integration
- ❑ Recommendations

The context and the challenges

- ❑ Ocean biology and biogeochemistry under increasing stress.

- ❑ Ocean biology and biogeochemistry heavily depend on physical forcing.

- ❑ Physical forcing and associated "bio" response : a continuum of spatial (sub-meso / meso / basin / global) and temporal (diurnal / seasonal / decadal) scales.

- ❑ The last century : a century of undersampling, especially for "bio": a large part of the variability in oceanic biological processes missed by traditional sampling.

- ❑ Rapid technological advances in ocean observations: physical oceanographers have been the first taking benefit from it (i.e. Argo floats).

- ❑ With a certain time lag, biological and biogeochemical oceanographers are undertaking a similar technological rupture; development of "bio" sensors that fit with the requirement of the new platforms (low consumption, miniaturization, endurance).

- ❑ Biological oceanography is emerging from its data-limited foundations.

- ❑ Based on these new technologies, pilot projects have been launched.

- ❑ If, from these emerging (individual, national) initiatives, we begin to coordinate in terms of networks, arrays, data sharing and management, a revolution can be expected in observation for biological and biogeochemical oceanography.

The context and the challenges

❑ Two main expected outcomes from such an *in situ* observation system:

- Scientific outcomes are : enhanced exploration, improved understanding of change and variability in ocean biology and biogeochemistry (over a large range of spatial and temporal scales), reduction of uncertainties in biogeochemical fluxes.
- Operational outcomes are: ocean biogeochemistry and ecosystem predictability; provide (real time) open data to scientists, users and decision-makers.

❑ Both scientific and operational objectives for biology require the “in situ” part to be designed and implemented in tight synergy with two other essential bricks of an ocean observation system:

- Biogeochemical / Ecosystem modeling: from NPZ models to Plankton functional Types (PFT) models.
- Satellite observation of Ocean Colour Radtiometry (OCR). Global, synoptical, time-series.

The core ecosystem and biogeochemical variables: which ones?

"*For biogeochemical time-series, the list of potential measurements is nearly endless and justifying inclusion / exclusion is difficult. Decisions as to what to measure, as well as how to measure, are never trivial.* ***The list of "essential" measurements for time-series can grow to the point that sustainability of the entire enterprise is put at risk***".

from Send CWP

- ❑ Observation valid for any kind of observation platform.

- ❑ Mandatory : selection (labeling) of core variables of the future system.
  - Scientific relevance (also with respect to modelers needs and OCR remote sensing products)
  - Routinely and autonomously measurable by a variety of platforms (sensors) .
  - Data quality: agreement between established (discrete) protocols

- ❑ At the moment, potential core variables over the vertical dimension are: O_2, NO_3, Chla, POC. Their progressive implementation in the integrated system can be envisaged.

- ❑ Variables of the CO_2 system operational for surface (ship-based underway, VOS, drifting buoys,) or fixed depth (moorings). Not vertically resolved.

- ❑ Progressive implementation / labeling of additional variables with the maturation of sensor technology.

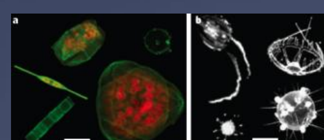
CWPs: Send, Gruber, Claustre, Byrne, Schuster

The core ecosystem and biogeochemical variables: which ones next?

- Variables of the CO_2 system
  - pCO_2 sensor  on floats (Arne *Kortzinger's talk)* 
  - pH : Ion sensitive-field effect transistor (ISFET) (*Martz and Johnson)*
  - required : DIC and TA sensors
  - Particulate Inorganic Carbon (PIC). Birefringence method (*Bishop*)

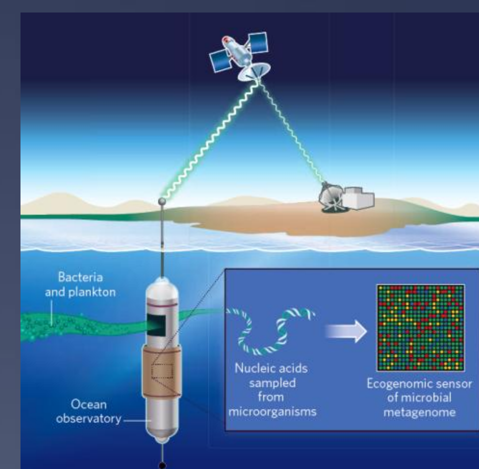
- Mid-trophic Automatic Acoustic Sampler (MAAS)
  - missing link between plankton and fisheries

- Plankton functional types
  - imaging systems
  - particle counting
  - Hyperspectral / multispectral radiometry, spectrofluorometry



- Nutrients: MicroSystem Technology 

miniaturized ecogenomic sensors

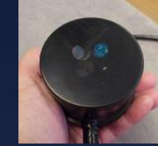


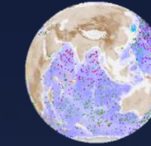
Bowler et al., 2009

CWPs: Byrne, Feely, Sieracki, Schuster, Handegard, Adornato



A “bio” float array





- ❑ Likely the most cost-effective platform to acquire biological data at a global scale.
- ❑ Floats with O_2, NO_3, Chla, POC : growing number of individual projects being funded.
- ❑ Co
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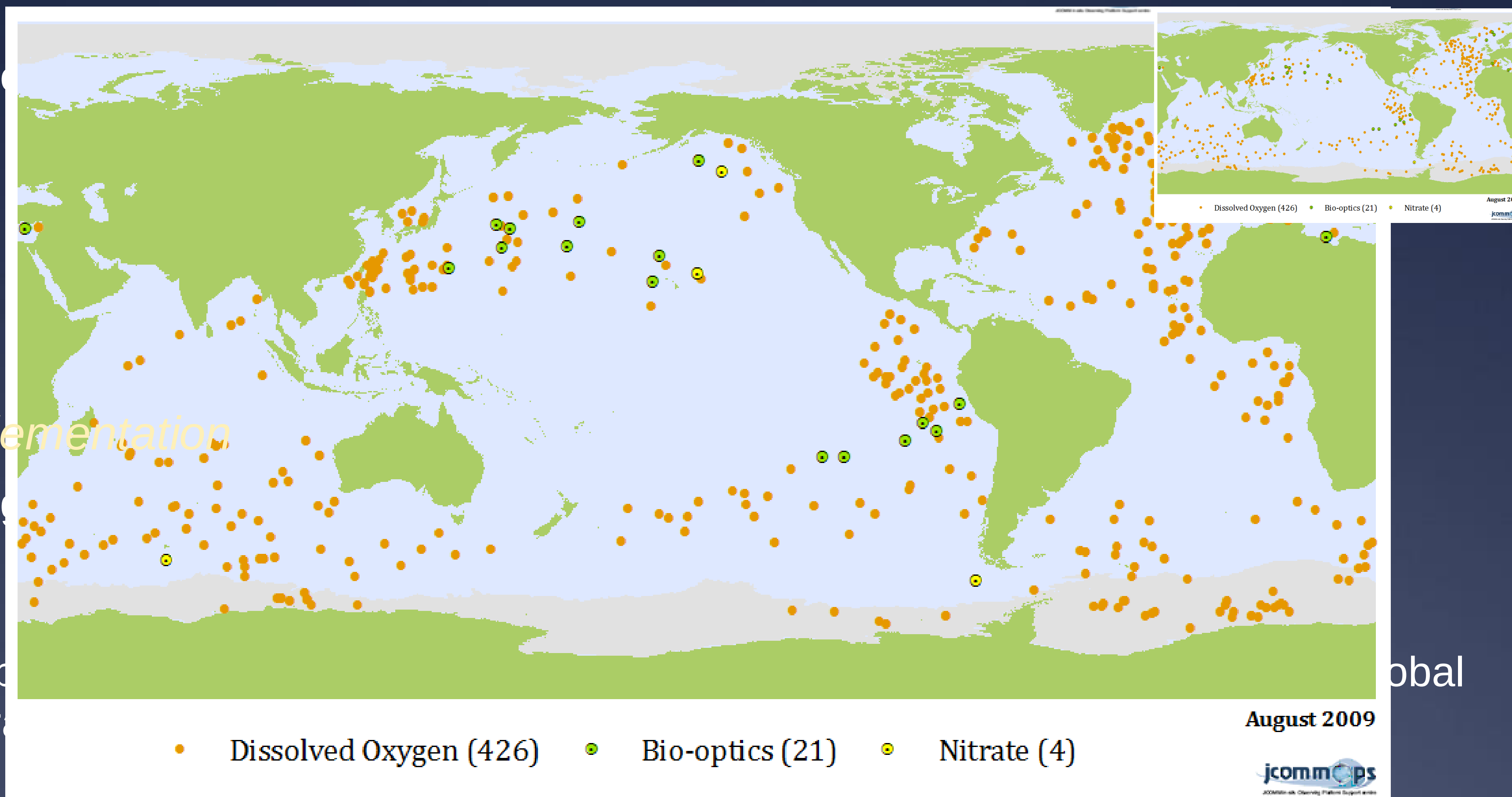


Implementation

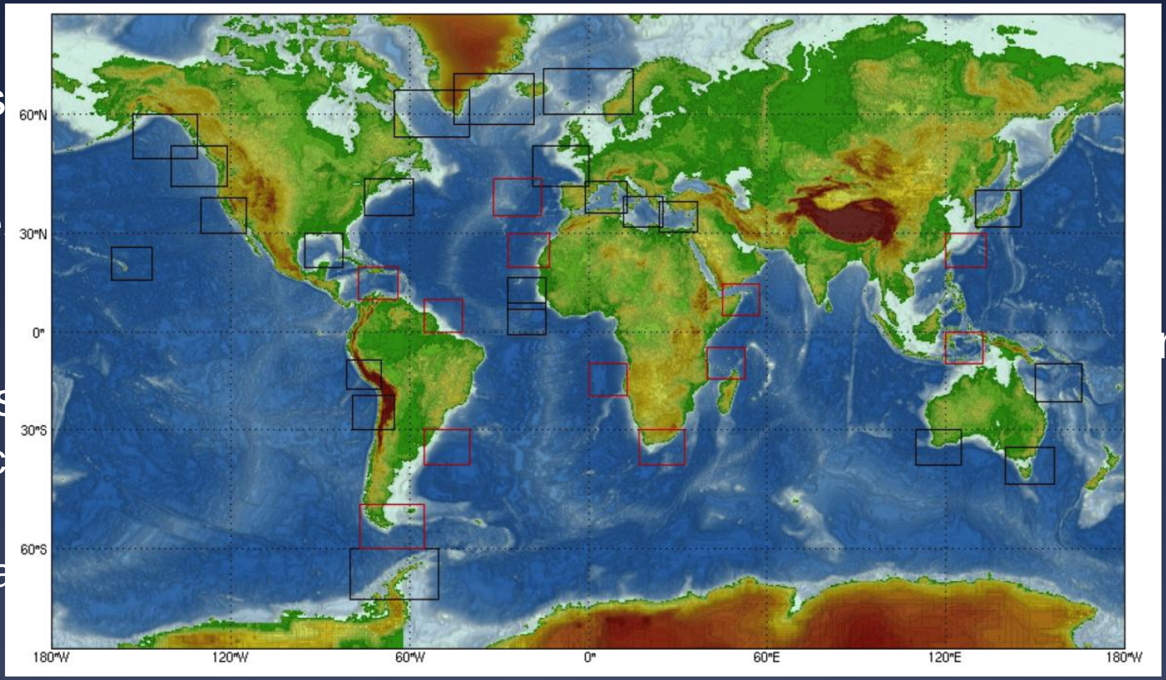
- ❑ Re
  - ■
  - ■
- ❑ In p … obal covera

CWPs: Gruber, Claustre, Freeland, Roemmich



“Bio” Glider network


- ❑ Same “bio” sens
- ❑ Ideal for sub-me
- ❑ Complementary … ritical areas for biology and ecos
  - open ocean / c
  - Regional seas.
  - Eastern bounda



Implementation

❑ Glider ports / centers emerge in various places

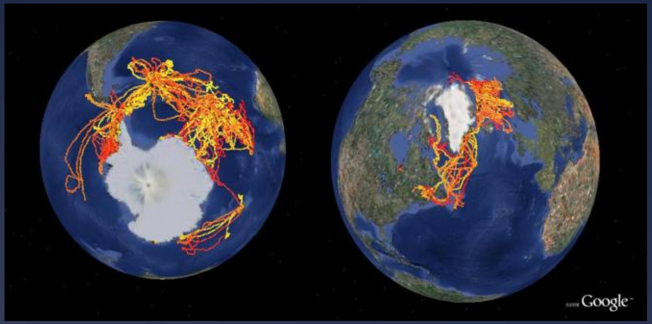
❑ Rely on presently forming cluster of (individual / national / international) initiatives (e.g. EGO) to build the network for the next decade.

❑ Future : Transoceanic “ship repeated transect-like” lines from glider port to glider port.

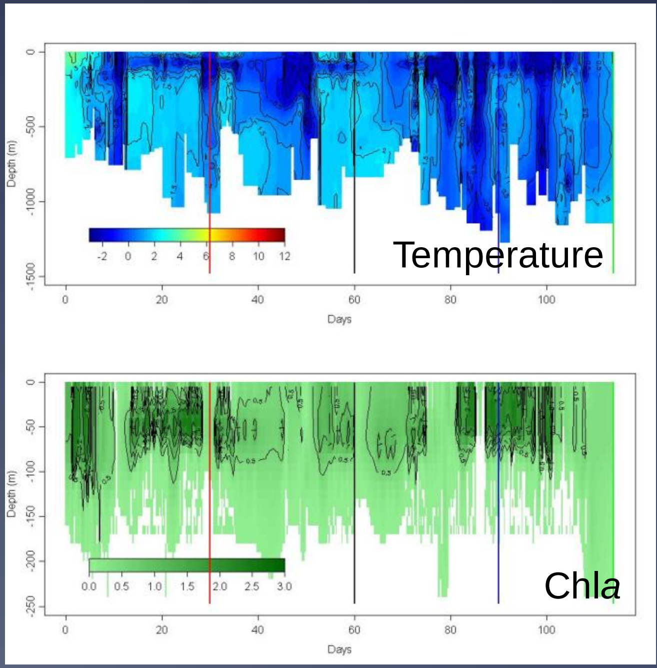
CWPs: Testor, Roemmich


“Bio” Animals in Polar Latitudes


- ❑ Animal-borne systems nicely complement gliders and floats at polar latitudes.



- ❑ Implementing bio-sensors on animals even more complicated than on floats and gliders
  - Argos telemetry, data reduction, sze and energy



- ❑ Promising Chl*a* measurements (*Guinet*).
  - O_2 on the way.

Implementation

- ❑ ~100 animals for both polar regions.
- ❑ 20% equipped with fluorometers to start.

CWPs: Boehme



Ship-based Repeat Hydrography and “Bio” measurements



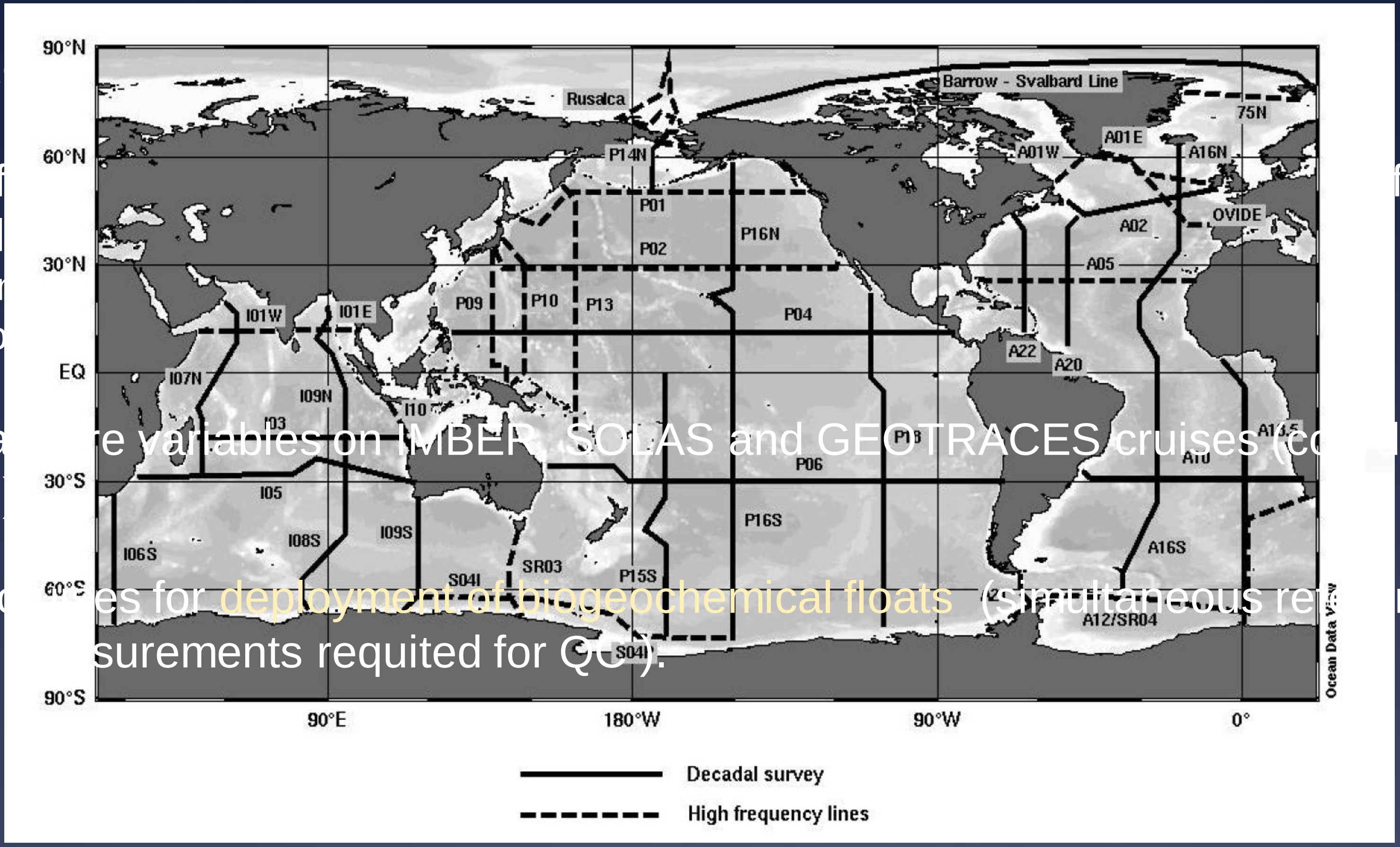
❑ Alrea

❑ Near f ... f them not amenabl

- Sor
- Bio

❑ Simila ... re variables on IMBER, SOLAS and GEOTRACES cruises (co ... dination required)

❑ Ideal c ... es for deployment of biogeochemical floats (simultaneous ref ... nce discrete ... surements requited for QC).

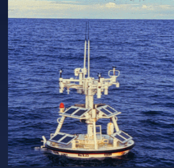


Implementation

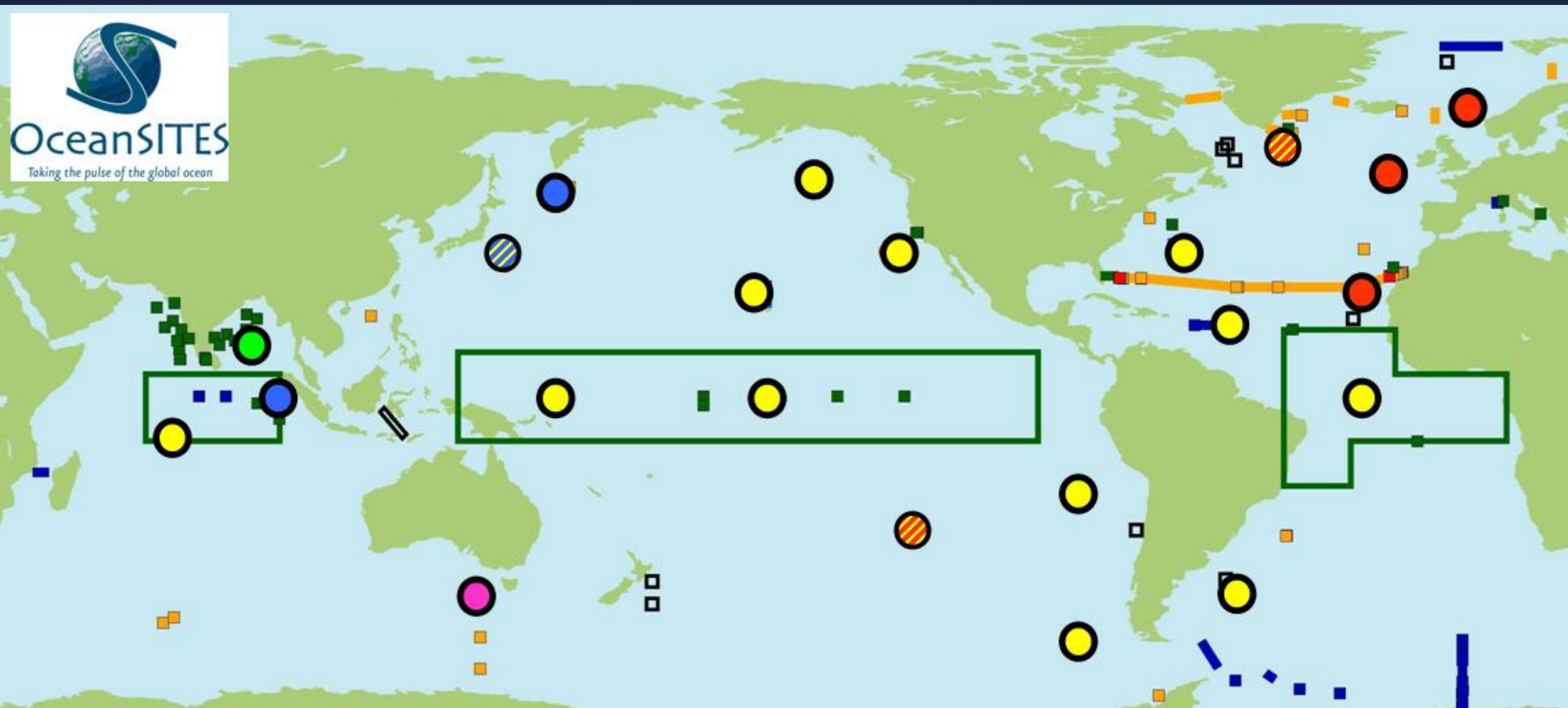
❑ Decadal survey requiring full basin synopticity (over <3 years)

❑ Sub-set of decadal survey line every 2-3 years

CWPs: Hood, Schuster, Feely,



Eulerian Time series and “Bio” measurements

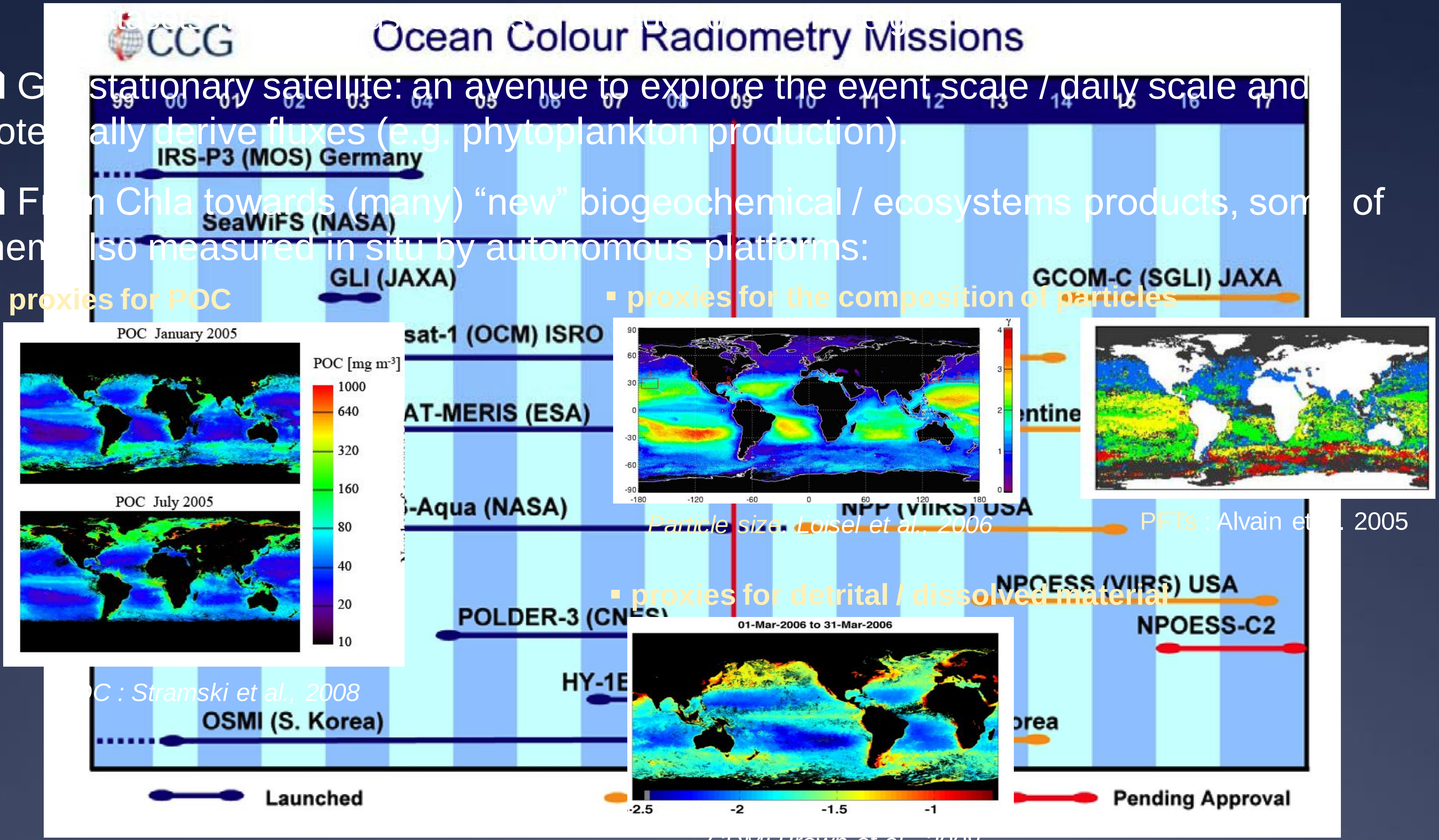


- *Implementation*
  - 10-15 selected sites in representative biogeochemical provinces.
  - Core variables: pCO2, O2, NO3, optical measurement of phytoplankton biomass
  - Other significant variables will join this minimal list within the next few years

CWPs: Send

The OCR satellite component

- ❑ To produce climate – research valuable data sets, it is critical that:
  - **There is no interruption in the OCR missions**



- ❑ G stationary satellite: an avenue to explore the event scale / daily scale and pote ally derive fluxes (e.g. phytoplankton production).

- ❑ Fr n Chla towards (many) "new" biogeochemical / ecosystems products, som of them lso measured in situ by autonomous platforms:

- **proxies for POC**

C : Stramski et al., 2008

- **proxies for the composition of particles**

Particle size: Loisel et al., 2006

PFTs : Alvain et . 2005

- **proxies for detrital / dissolved material**

CDM: Brown et al., 2008

CWPs: Sathyendranath, Yoder, Lequéré

The key to success : “Bio”-data management #1

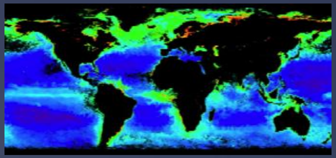
- Tremendous amounts of “bio” data will be acquired in the near future.

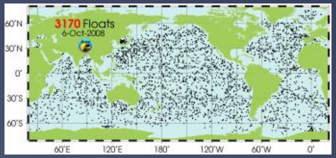
- An integrated observation system will be operationally useful and scientifically relevant if and only if it is supported by an efficient data management system….BUT

- The “problem” of biologists with data management
  - we are not used to the management of huge datasets.
  - we are not used to make data publicly available
  - we are not used with real time

- A “revolution” is thus required in the way we will apprehend data management

- Very efficient data management (and a good example for the “bio” community) : Ocean Color and Argo
  - Real-time delivery with real-time QC (operational data)
  - Delayed mode QC delivery after data reprocessing (scientific, climatic-trend value): real issue of climatologies for biology / biogeochemistry.
  - Generation of derived products





CWPs: Pouliquen, Send, Lequéré and many others

The key to success : "Bio"-data management # 2

❑ The management of "bio" data is likely a more complicated task than for physical variables because of the diversity of ways of measuring the variables

❑ For example, [Chl*a*], the "universal" proxy of phytoplankton can be measured:

- from space: reflectance ratios, fluoresence.
- In situ, non intrusively by sensors: (spectro)fluorescence, absorption (676 nm).
- In situ, from filtered water samples : HPLC, (spectro)fluorometry, spectrophotometry.
- In fine, [Chl*a*] should represent the same "bio" product regardless of the method of acquisition. Consider modelers who visit databases…

❑ It is thus mandatory to develop a unified format and language which is essential for streamline and interfacing datasets.

❑ Upstream of data management, QC and unified format, it will be essential to

- Establish best-practice manual / practical training / capacity building.
- Establish reference material.
- Support regular international intercomparison exercises.
- Develop internationally agreed calibration centers.

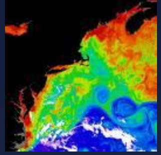
Calibration of numerous optodes for O2-Argo at Bergen

CWPs: Pouliquen, Send, Lequéré, Sathyendranath



Integration





Bio-physical integration

- Integration is not just adding “bio”-sensors to an existing physical observational system.

- “Bio”-processes strongly dependent on physical forcing.

- Physical processes (generally) do not depend on biological and biogeochemical processes.

- A BIO-program (Bio-Argo, Bio-Glider, Bio-Time series…) should not be a side program, independent of the corresponding physical program. Optimally, it should be clearly defined and then implemented in close association with physical oceanographers.

- Gliders: operational maturity same time as biogeochemical / bio-optical sensor maturity. Spatial domain covers sub-meso and mesoscale, critical for biogeochemistry.

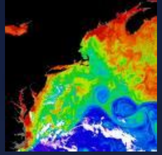
- Time series, Go-ship: core “bio-variables” now implemented in the physical system. New science can be easily developed.

- Floats: synergy / integration, a priori, less obvious.
  - Argo is well organized and mature, while the “BIO”-counterpart is in infancy.
  - New measurements: technically challenging, costly, generate their own issues (Law of the sea)



Integration





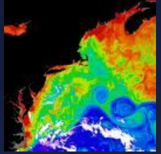
Satellite (OCR) in situ integration

- *In situ* data extend the satellite data into the ocean interior.
- Satellite data fills the gap of loose spatio-temporal resolution of *in situ* data.
- Essential to develop synergetic use of “bio” in situ and OCR satellite data:
  - Produce 3D/4D fields of some “bio”-variables for the global ocean: Chla.
  - “Initial climatologies” => required for developing delayed-mode QC procedures.
  - In situ data for validation of OCR products (e.g. “VAL-floats”).



Integration #2





Integration = “Synergetic Interplay” of the various elements

❑ At the moment, the “bio” community is mostly engaged in making the various platforms of the observation system mature.

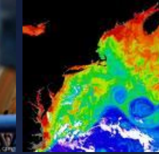
❑ Integration of the various “bio-platforms” into an integrated system requires the sizing of this system (density of bio-gliders, bio-floats, bio-animals…) according to:

- the scientific questions and their relevant spatio-temporal scales.
- the specificity of the various “bio-platforms” in resolving these scales.

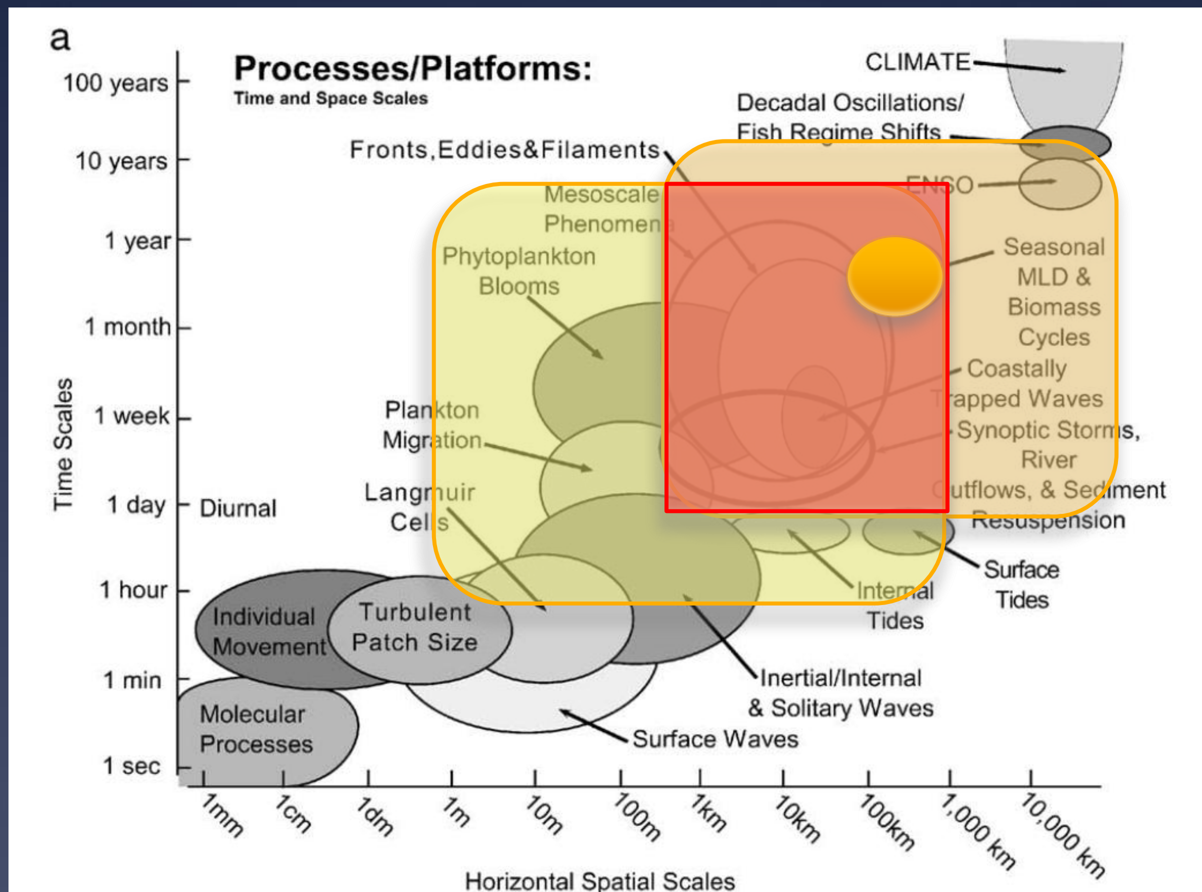


Integration #3





Integration = “synergetic Interplay” of the various elements
an example



satellite

Synergetic domain

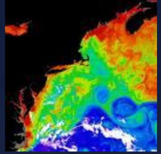
floats and gliders

Dickey, 2003



Integration #4





Integration = “Interplay” of the various elements #2

❑ While the global scale is obviously the target to set up the “final” observation system, the implementation of pilot studies on regional “hot-spot(s)” could be a first and reasonable step towards integration.

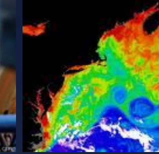
❑ There are indeed regional “hot-spots” ” that are “natural laboratories” for addressing key scientific questions of global relevance, and which would require to be tackled in a highly integrated way, *e.g.*:

- **The eastern boundary currents**: upwelling and OMZ areas ; biogeochemical cycles (C, N,..); fisheries; coastal / open ocean interface.
- **The North Atlantic**: variability in MOC; decrease/variability in the CO2 sink over inter-annual, decadal time scales.



Integration #5





*Regional studies at "**super sites**" : case studies towards global integration*

- To prepare the global integrated system, think first to redesign "JGOFS-like" process studies that were the first integrated approaches of oceanic biogeochemical cycles.

  - **Ship** for detailed biogeochemical investigation essential for:
    - Key variables (*e.g.* microbiology, iron..) or fluxes (*e.g*. nitrogen) not amenable yet to autonomous sensor detection
    - Establish / refine parametrization of **BGC models**

  - **Gliders**: bio-physical observations in a coherent **<u>spatial</u>** and temporal context.
  - **Floats**: bio-physical observations in a coherent **<u>temporal</u> and spatial** context.
  - **Time series**: bio-physical observations in a coherent temporal context.

  - **Satellite**: the first process studies with OCR….

Conclusions / final recommendations

MESSAGE 1: Integration means a real synergy between physical and biological oceanographers.

MESSAGE 2: The implementation and the sustainability of the observation system rely on the critical choice of the “Bio” variables.

MESSAGE 3 : The sustainability of the entire system will depend on the availability of QC data and hence on the rigor in setting the data management system.

MESSAGE 4 : Consider to study “super sites” in key areas of global relevance as a first step towards integration.

Overall this is a collaborative effort with a broad international participation!

Thank you !