Observing Global Ocean Biology. Is new technology the solution?

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*On behalf of the SCOR Panel on New Technologies for Observing Marine Life

Outline

- The Motivation for Biological Observation Systems
- The Challenge
- Whistlestop tour of Existing/Developing Systems and Sensors
  - Biogeochemistry
  - Microbe – Zooplankton
  - Benthic Systems
  - High Trophic Levels
- Feasibility of a truly Integrated GOOS 2010-20?

Inputs/Acknowledgements

- SCOR Panel meeting, Mestre 16-18 Sept 09 : reviewed Current Status of Biological Obs:
  - The Bio in Biogeochemistry
  - Microbes to Plankton
  - Benthic Ecosystems
  - Higher Trophic Level Pelagic - migratory species.

  (Block, Costa, Snelgrove, Daly, Dickson, Palumbi, Urban, O'Dor, Rogers, Fennel, Chavez, Gilbert, Rintoul, Biuw, Cury)

- Ocean Obs '09 white papers
- Ocean Sensors '08 papers.

The Resilience of Ocean Ecosystems is being severely tested today, <u>before</u> the most serious impacts of Climate Change begin to be felt .

- >50% of fish stocks overfished , IUU fishing still rampant
- Trophic cascades are leading to the "rise of slime"
- Growing numbers of endangered marine animals (fishes, sharks, birds, marine mammals, turtles)
- Coral Reefs - indeed many coastal ecosystems - are under serious threat from various sources.
- Growth in Dead zones from hypoxia/anoxia.
- Exponential Growth in HABs

Assessment of Assessments

"The IPCC of Ocean Status"

- Models - for process understanding, ocean health/risk assessment, and "prediction" - are ahead of the supply of data.

- To achieve the goals of the AoA – sustainability and building resilience on a global scale - we need vastly improved observation systems/networks/information bases.

The Universal Challenge
Global Ocean Observation.
(Physics –Species – Ecosystems)

Global Focus – Selected Variables - Expendable – Cheap

V

Locally Focussed – Comprehensive - Redployable

and often ……not so Cheap!

Biogeochemistry

Sensors : T, Conductivity, O_2, Chl fluorescence (proxy for chl; backscatter (proxy for POM), E_d, L_u, PAR, NO_3^-, pCO_2

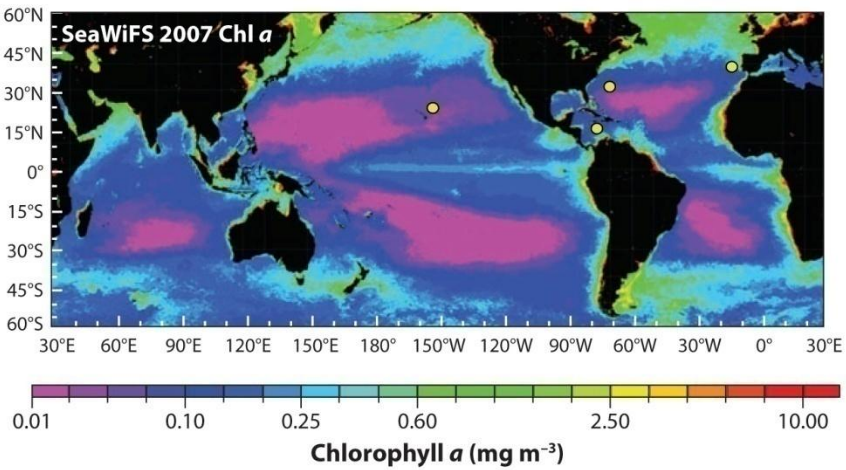
On the horizon: pH, pN_2

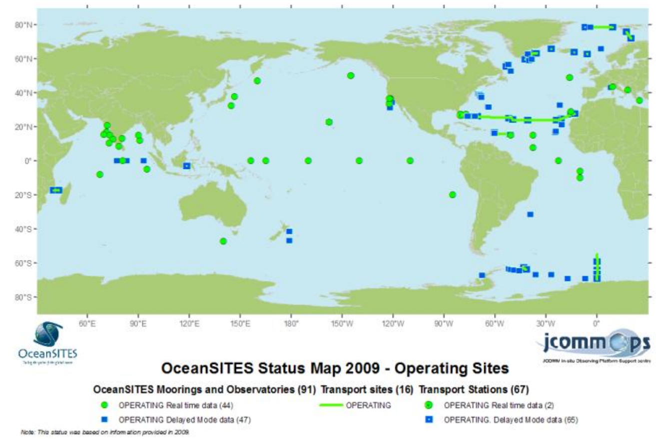
Platforms:

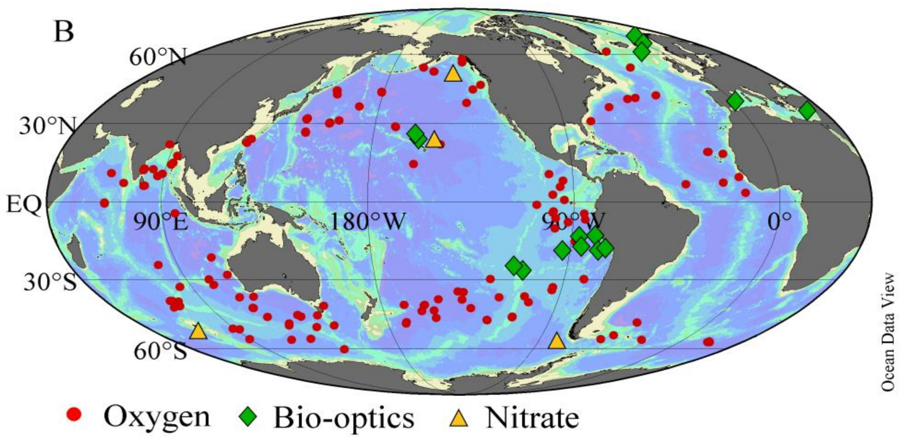
- Satellites
- Gliders (Slocum gliders and Seagliders),
- Floats (Lagrangian and Argo),
- Biologging (e.g. seals, sharks etc)
- Ships of Opportunity
- Array of moorings and sea floor observatories

"Mature", ready for global long term deployment now.

Sustained Global Biogeochemistry







"BIO-ARGO"
Johnson *et al.* (2009)
>200 sensors with oxygen
>12 with fluorometers or backscatter
4 with nitrate (funding available for 36 more)

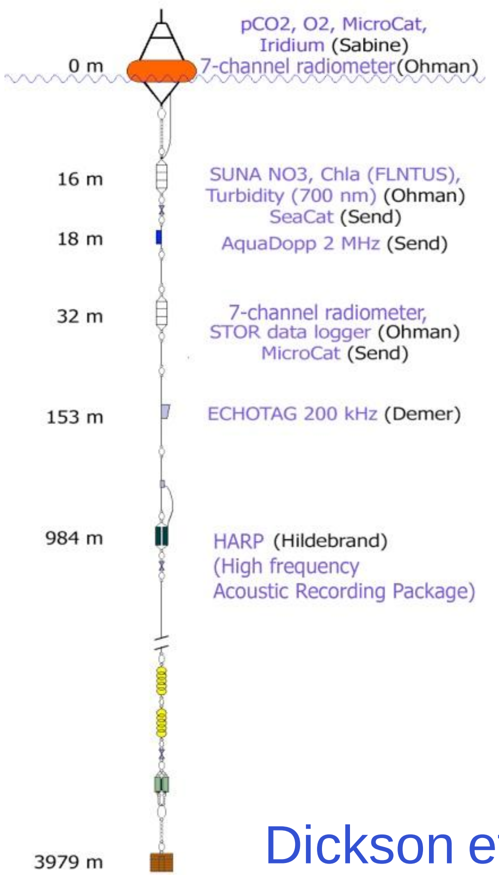
Short Term – Local Focus

E.g. Autonomous Measurements of Carbon Fluxes in the North Atlantic Bloom *Eric D'Asaro et al. :* combining sensor-heavy floats and gliders with ship-based observations, satellites and models.

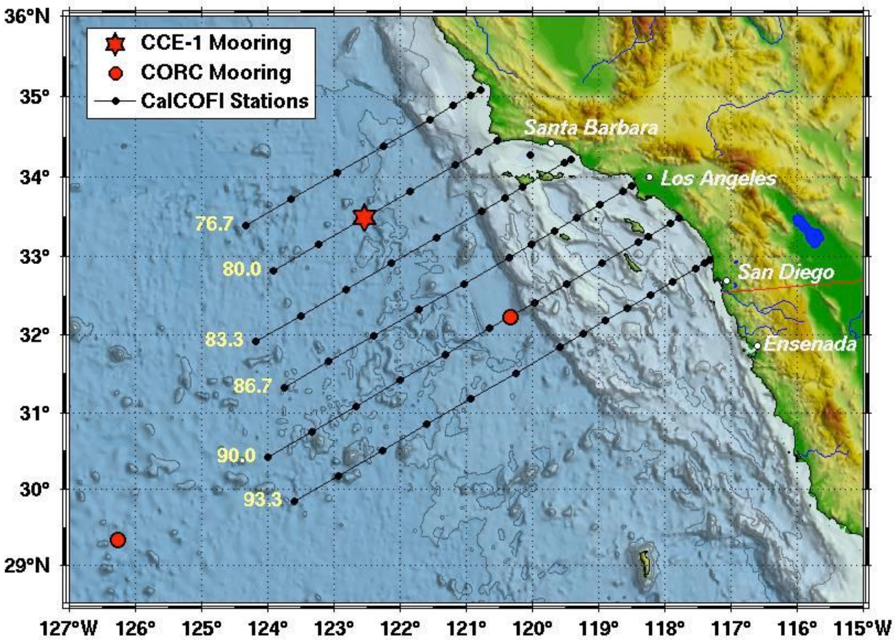
Sea Gliders
(float-following)
- T, C
- O_2 (2 types)
- Chl fluorescence (2)
- Backscatter (3λ)
- CDOM fluorescence

Lagrangian Bio-Heavy Floats
(water-following)
- T, C (2 each)
- O_2 (2 types)
- Transmission (c)
- Chl fluorescence
- Backscatter (2λ)
- Ed (λ) and Lu (λ)
- PAR
- ISUS NO_3^-

A Simple and Relatively Cheap Approach



CCE-1 Mooring



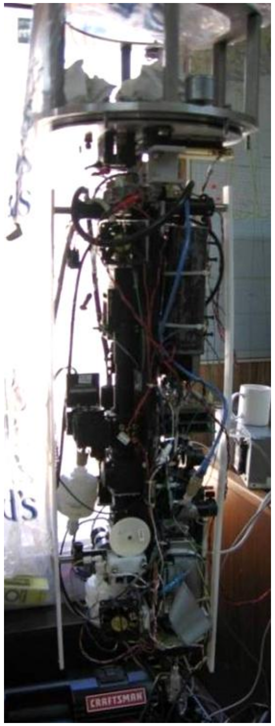
Dickson et al.

Microbes to Plankton

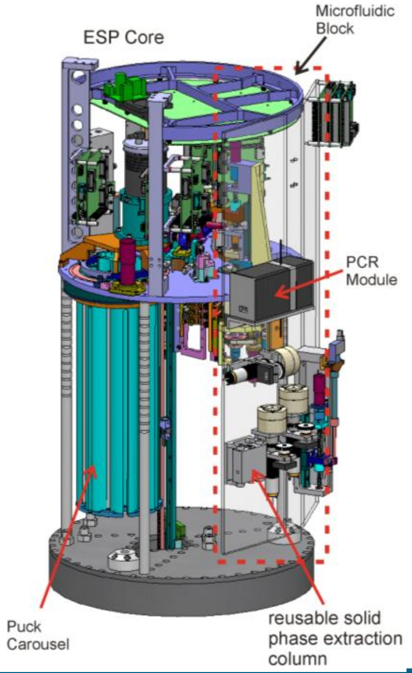
- Satellites – global coverage for Chl BUT not species/community information.
- Regional / Global time series - CPR, CalCOFI, reference sites. **Simple technology**, **Huge value**.
- Paradigm shift recently from the "classic" food web concept to ones incorporating the vitally important microbial loops presents added observation challenges
- Holy grail – fast, automated, cheap species ID.

Exciting In- Situ Technology

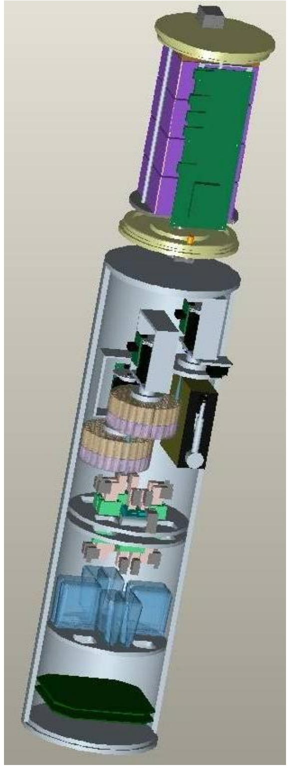
Imaging Flow Cytobot (IFCB) Campbell et al.



Autonomous Microbial Genosensor (AMG) Paul & Fries



Environmental Sample Processor (**ESP**) Scholin et al.



Current Functions of ESP

Real-time application of DNA and protein arrays

- collect sample/ homogenize/ filter the lysate
- develop the array/ image with CCD camera/ broadcast results

Real-time application of qPCR

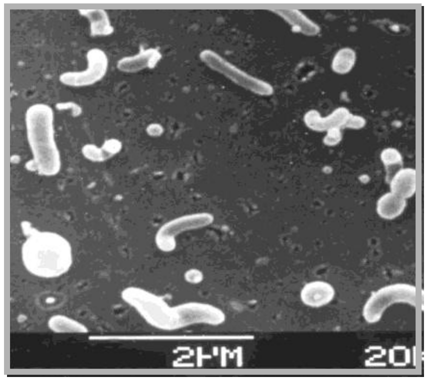
- collect sample/ homogenize/ filter the lysate
- SPE for DNA
- run series of qPCR reactions

Sample archiving

- whole cell microscopy/ FISH
- nucleic acids (DNA, RNA)
- phycotoxins

The First Steps with ESP

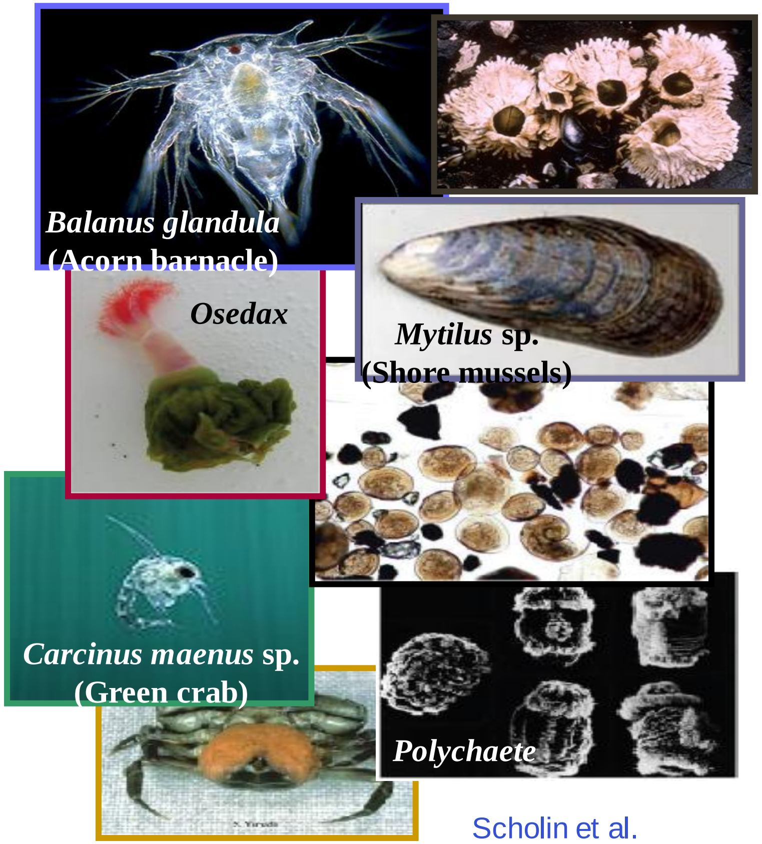
Marine Microbes



Haywood et al. 2007 *Journal of Phycology*
Jones et al. 2008 *Molecular Ecology Notes*
Mikulski et al. 2008 *Harmful Algae*
Preston et al. 2009 *Environmental Microbiology*

Harmful Algae

Invertebrate Larvae



Scholin et al.

Benthic Systems

Ecosystem services/functions :

C sequestration, pollutant breakdown, nutrient regeneration, secondary production, biogenic habitat

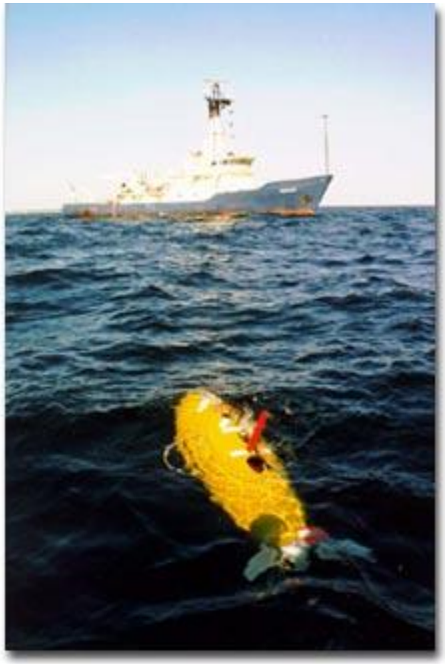
Paul Snelgrove's summation to SCOR Workshop

"Satellites = Not so interesting for benthic studies

Observatories = Interesting for benthic studies

Observatories + Ships = REALLY interesting for benthic studies"

Ship + ROV/AUVs : superb spatial resolution



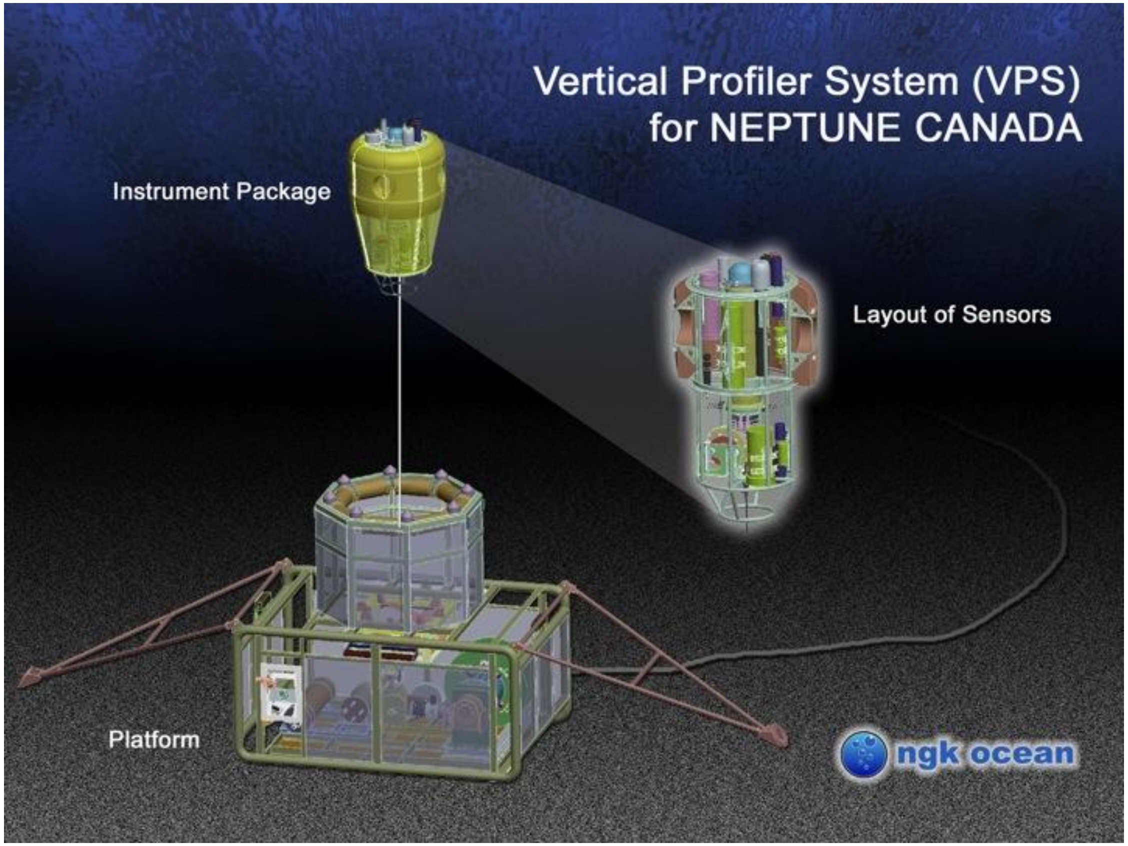
MIT Sea Grant

CSIRO

Jacobs Univ., Bremen,Germany

Snelgrove

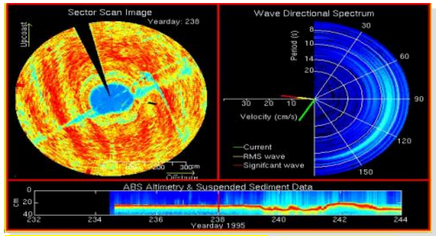
Neptune Observatory Vertical Profiler



- CTD
- Oxygen sensor
- Fluorometer
- Transmissometer
- Nitrate sensor
- CO_2 sensor
- Upwelling/downwelling radiometer
- Broadband hydrophone
- ADCP
- Bottom pressure sensor

Neptune Benthic System

- Acoustic Doppler Profiler
- Rotary SONAR
- Multi-Beam SONAR
- CTD
- Microbial package
- Sediment trap
- Plankton pump
- Fluorometer
- Hydrophone
- Video cameras
- High resolution still camera



Craig Smith – Equatorial Pacific Abyssal Plain

Higher Trophic Levels

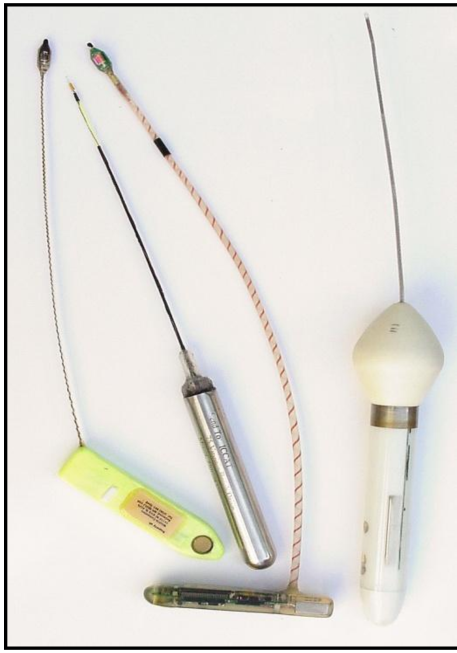
There is a critical need for improved Observing Technology to examine mid-trophic level/meso-pelagic communities.

- These communities are the "missing link" in the Physics – BGC – Fish chain, and critical to our understanding of the relative influences of bottom up : top down controls in oceanic ecosystems.
- CWPs note the promise of acoustic technology – ship based and upwards looking (e.g. MAAS) – development needed, ideally allowing acoustic data collection by SOO/VOS.
- Long-range Ocean Acoustic Waveguide Remote Sensing (OAWRS)

Bio-logging Technology

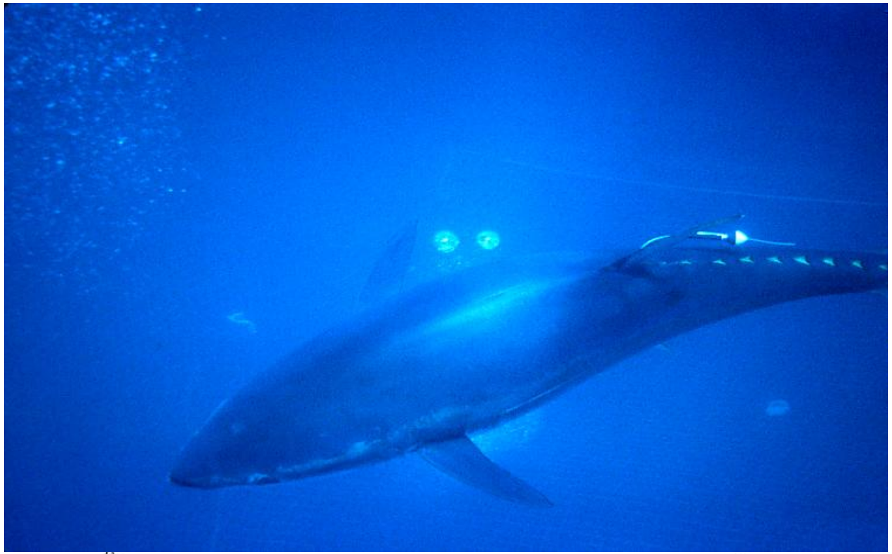
TOPP - CoML

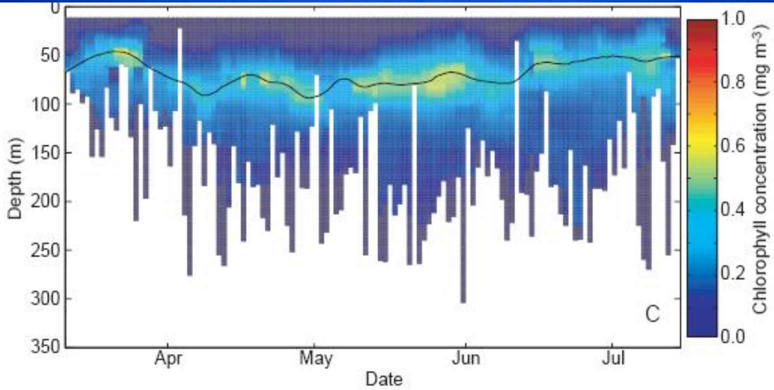
- Archival Tags
- Satellite Tags
- Pop-Up Satellite Tags
- Acoustic Tags
- Natural Tags



Bio-logging Sensors

- Position
- Species Identification
- Temperature (Ta & Tb)
- Light
- Pressure
- Salinity
- Fluorescence
- Chlorophyll Proxy
- Foraging Events
- Heart Rate
- Speed/Acceleration

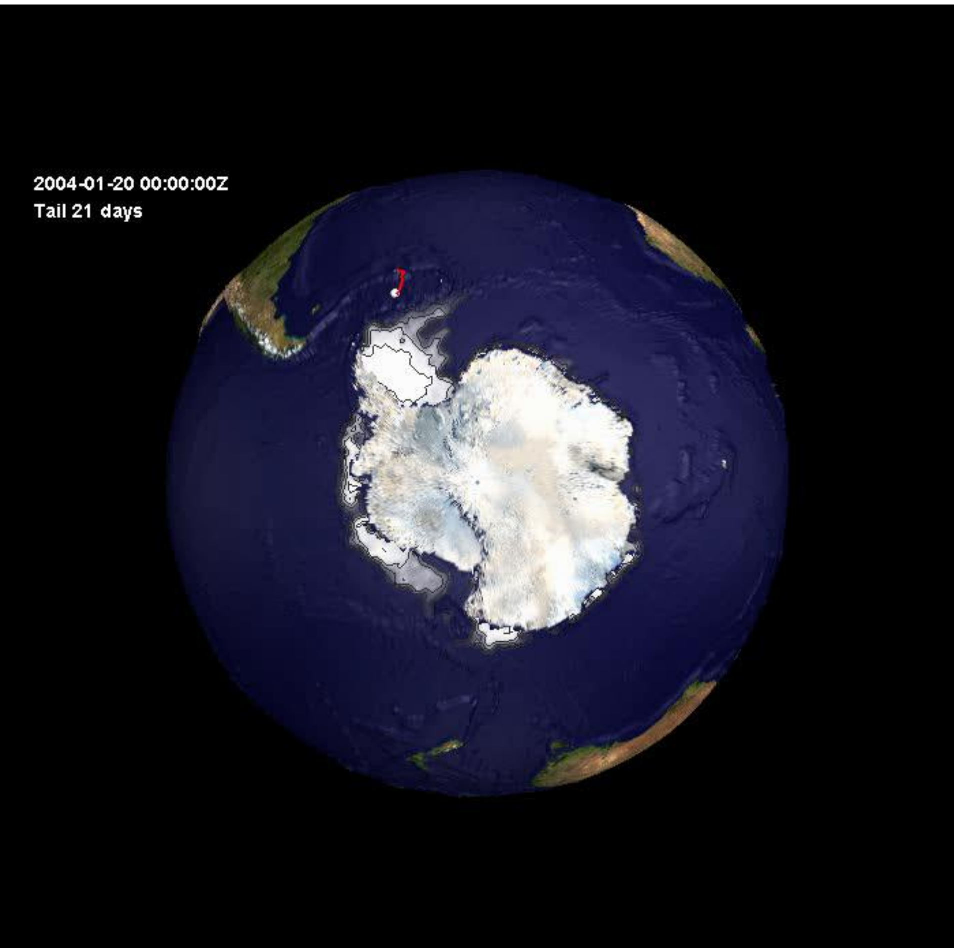


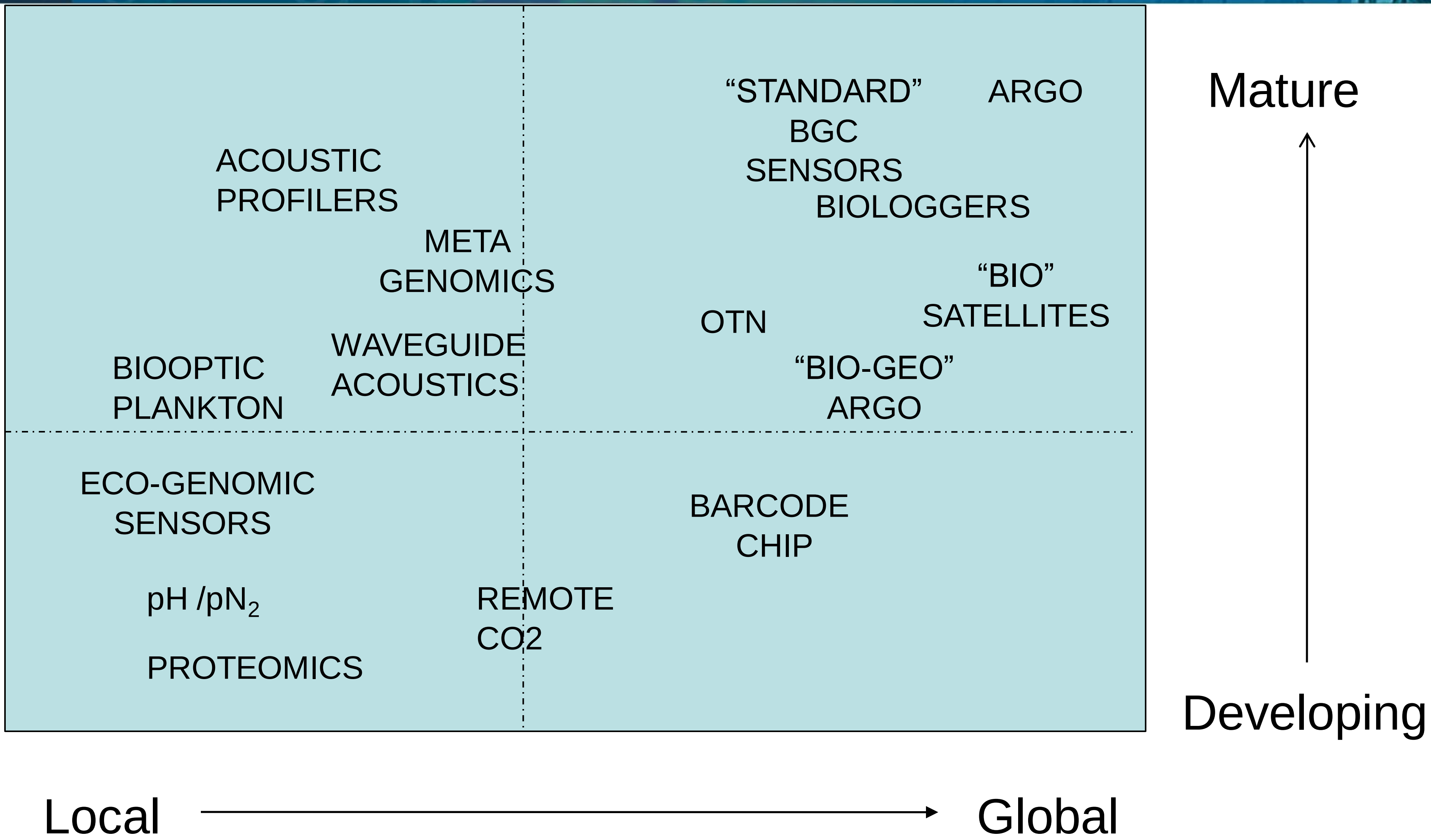


Biologging Scope and Application

- >50 Species,
- 3 trophic levels
- Tropics to poles
- Coasts to Open Ocean
- Oceanography
- In Situ Measurements
- Habitat Utilization
- Behavior: Forage & Breeding
- Physiology
- Population Biology
- Management: Assessment

Elephant Seal Ecology in a Changing Environment

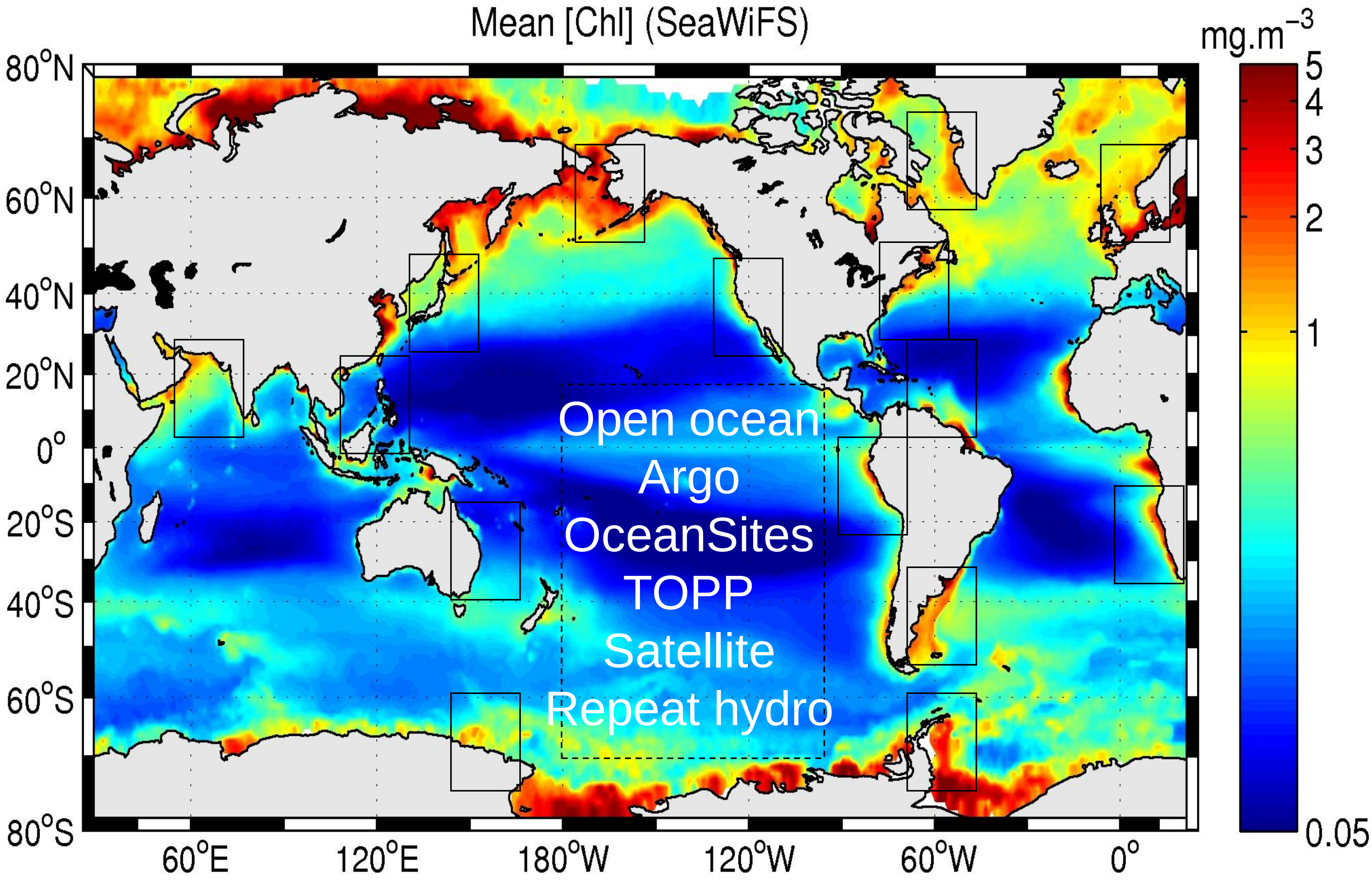



"STANDARD" BGC SENSORS
ARGO
BIOLOGGERS
ACOUSTIC PROFILERS
META GENOMICS
"BIO" SATELLITES
OTN
WAVEGUIDE ACOUSTICS
BIOOPTIC PLANKTON
"BIO-GEO" ARGO
ECO-GENOMIC SENSORS
BARCODE CHIP
pH /pN2
REMOTE CO2
PROTEOMICS
Mature
Developing
Local
Global

Prospects for a Truely Integrated GOOS?

- Platforms
- Mature /Prospective Technology
- Globally and Locally Relevant Questions
- Nested design (local – global) or Centralized?
- Willingness to Compromise?
- Willingness to Share Data, Set Standards?
- Community (ies) Buy-In?
- Funding?

Do our oceans have the resilience to cope if we take another decade to decide and invest?


Mean [Chl] (SeaWiFS)
mg.m^{-3}
5
4
3
2
1
0.05
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
60°E
120°E
180°W
120°W
60°W
0°
Open ocean
Argo
OceanSites
TOPP
Satellite
Repeat hydro