Day 5: The Way Forward

Towards an integrated observing system:
In-situ observations

Uwe Send

OceanObs'09
Ocean information for society:
sustaining the benefits,
realizing the potential
21-25 September 2009, Venice, Italy

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“integrated….” and global

Webster’s Dictionary:

in·te·grate

1) combine or be combined to form a whole

2) coordination of mental processes into a normal effective personality

Global

Need a permanent presence in all ocean regimes/provinces and provide access to them via platforms/vehicles

(information for understanding and prediction, detect changes, conduct experiments, build a record that allows us to go back 50 years from now,…)

Approach for this presentation

1. Integration – required steps

- enhance and complete the pieces to be combined (sensors, platforms, complete existing networks, add missing pieces)
- combine many observations at same place
- combine the programs (need better coordination)
- combine the data from different platforms
- combine in-situ, satellite, remote sensing
- combine in-situ and ecosystem observations
- data access

2. Find recurring statements…. pieces of a consensus ?

3. Look for synergies

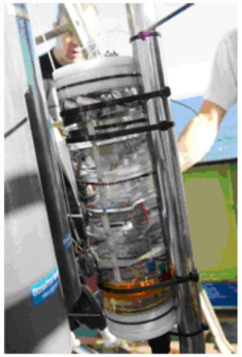
4. Possible way forward

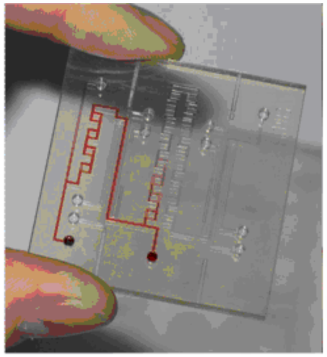
- global in-situ network design
- getting credit for data
- training the next generation

Enhance elements of the observing system

A) Need more and better sensors

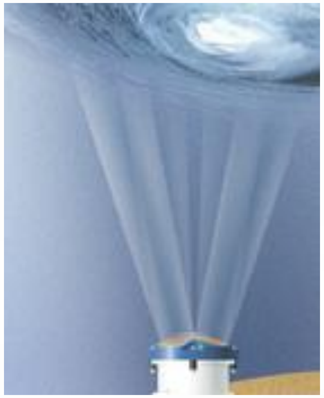
Nutrient sensors (Adornato et al CWP)



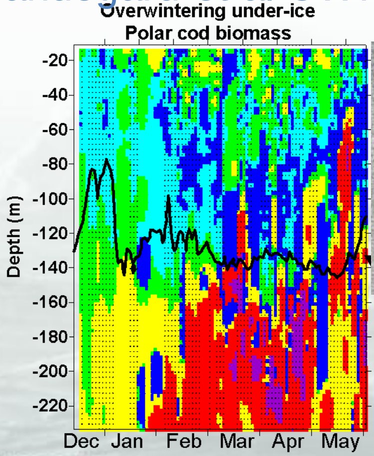


In-situ pCO_2 sensors (Byrne et al CWP)

Wave sensors (Swail et al CWP)



Acoustic fish/zooplankton sonars (Handegard et al CWP)



(Sieracki et al CWP)

Optical plankton imaging sensors

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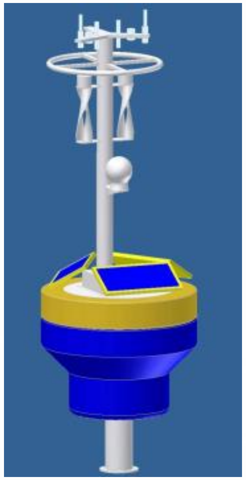
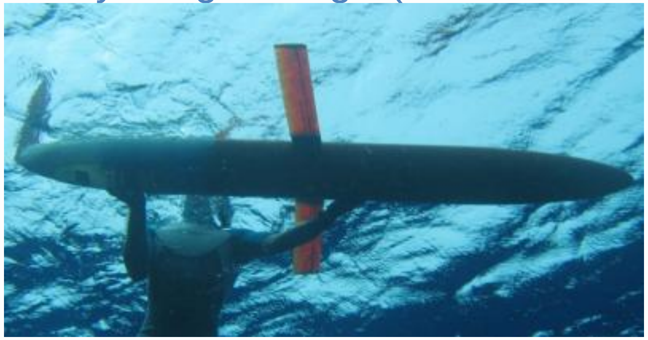
Enhance elements of the observing system

B) Need improved platforms

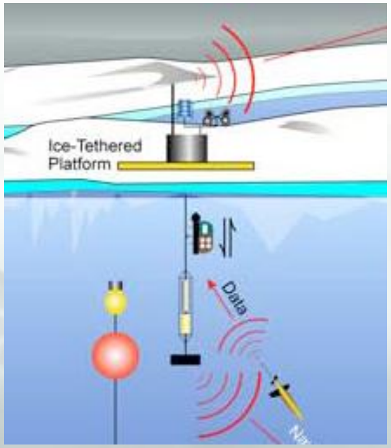
Profiling and high-latitude moorings (Brasseur et al CWP)



Gliders with acoustic navigation and acoustic telemetry, longer range (Testor et al CWP)



Under-ice platforms (Lee et al CWP)



Biologging (Boehme et al CWP)

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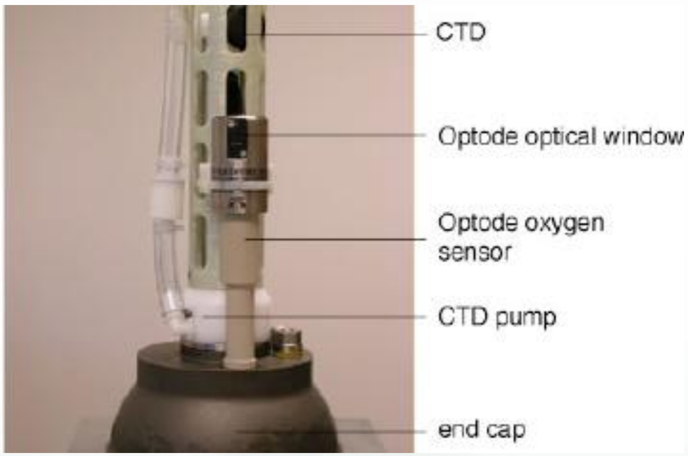
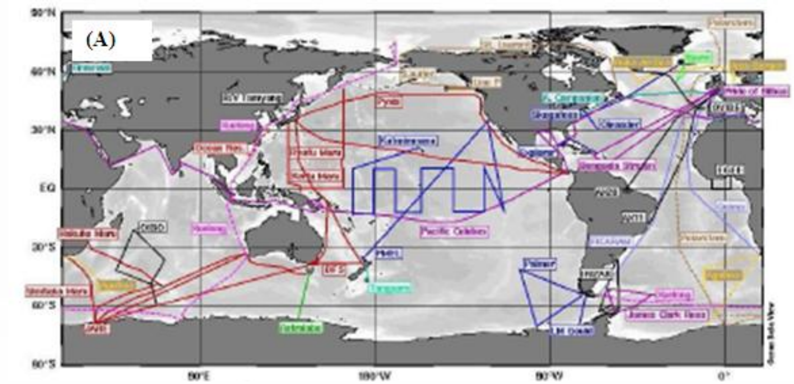
B) Make existing networks more versatile

ARGO + O_2 (Gruber et al CWP)

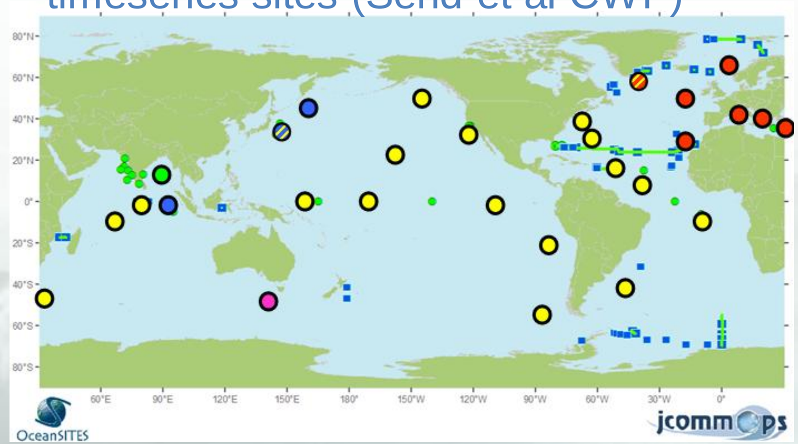


plus other sensors ??

VOS CO2 + other chemicals (discussion fora)



Backbone of identical multidisciplinary timeseries sites (Send et al CWP)



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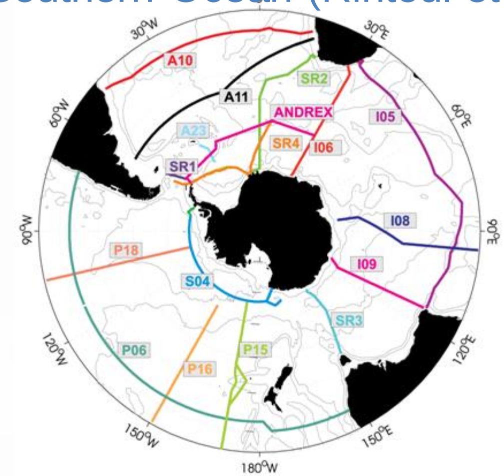
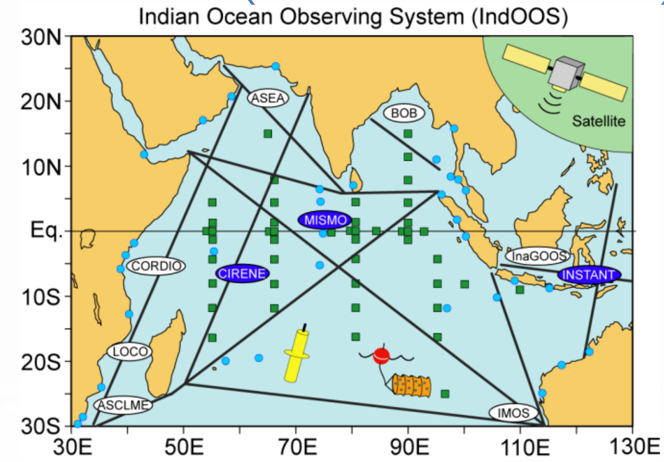
D) Close gaps in the global system

Southern Ocean (Rintoul et al CWP)

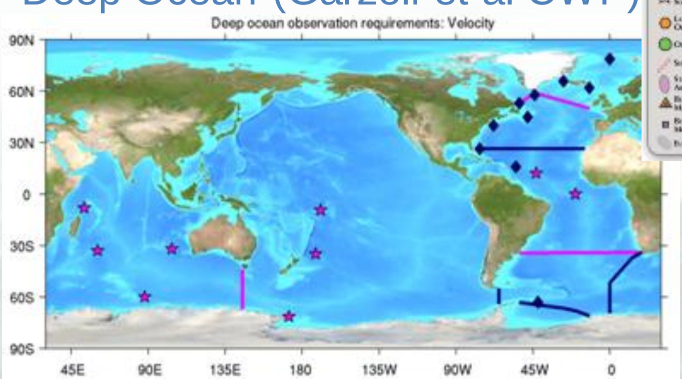


Arctic (Calder et al, Lee et al CWP, Sagen et al ACP)

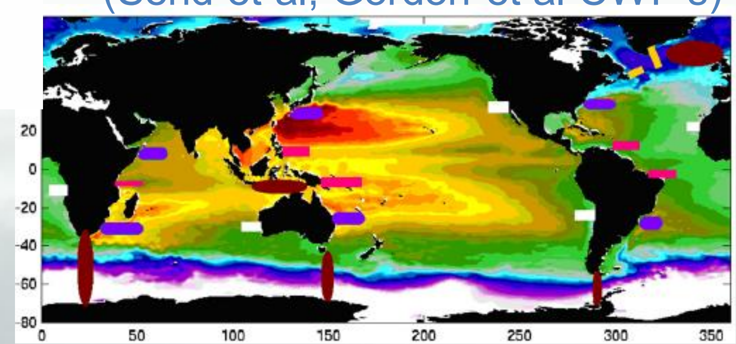
Indian Ocean (Masumoto et al CWP)



Deep Ocean (Garzoli et al CWP)



Boundary Currents and inter-ocean (Send et al, Gordon et al CWP's)



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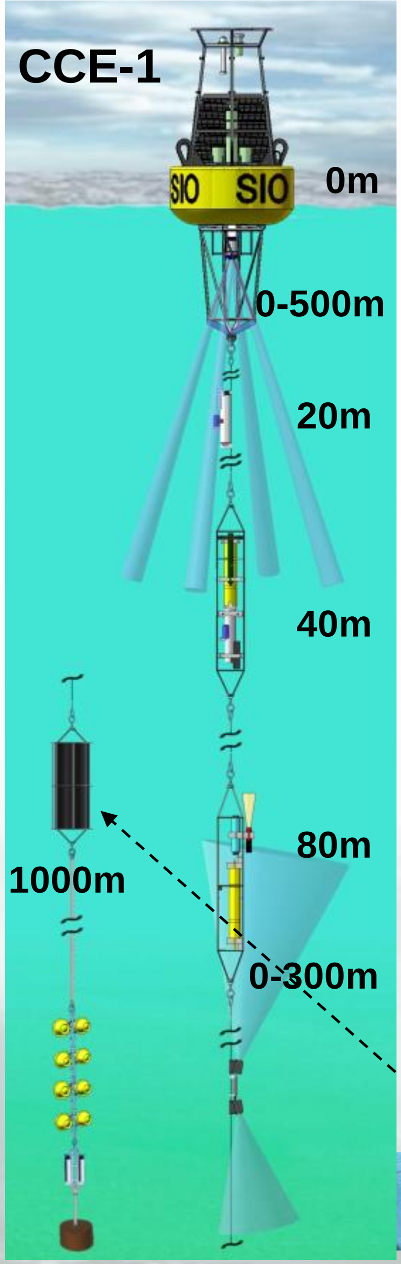
Combine many simultaneous variables

"Often the physical and chemical measurements needed to link ecosystem variability to environmental variability do not exist."
(Rintoul et al. CWP)

Need more collaborative efforts, sharing of platforms, funding, expertise… in order to obtain integrating observations



meteor.,
7-ch radiation
pCO_2, T/S
pH, O_2

ADCP

T/S, Chl-a
turbidity

T/S, Chl-a
NO_3, turbidity
pH, O2

T/S
7-ch radiation

acoust.zooplankt
still camera

passive mammal

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http://mooring.ucsd.edu

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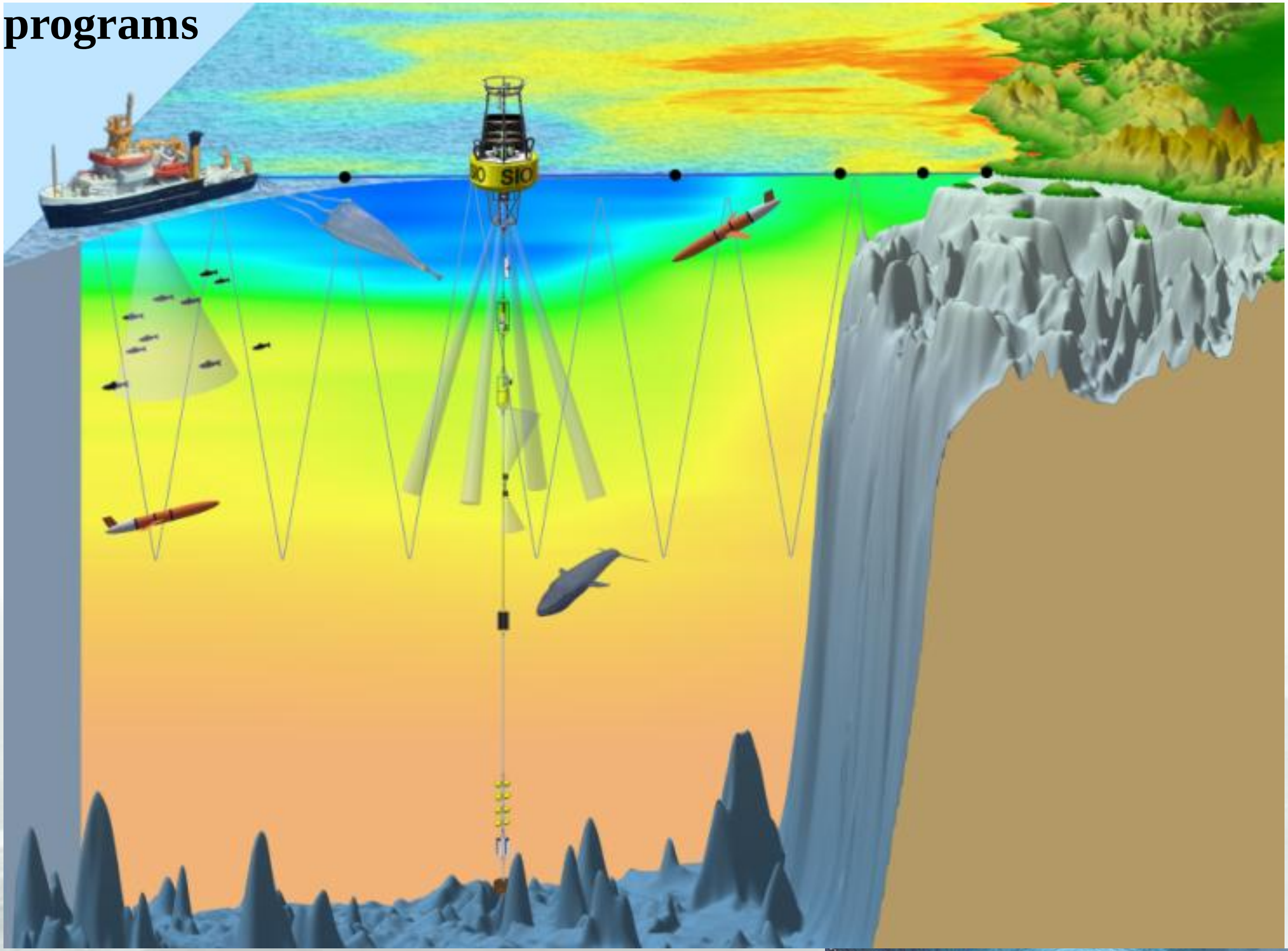
Combine observations into a local context

Largest mutual benefit if observations are placed into context of other information or programs



Combine efforts across programs

At present, each component (ARGO, SOT, OceanSITES, waves) and each community (CLIVAR, carbon, IMBER, SOLAS) is busy/struggling to make its own part work…

ARGO, SOT, OceanSITES need to work more with biogeochemical and ecosystem community:

- plan/design the network together
- share the funding/proposal writing
- share the implementation
- merge disciplinary expertises
- joint data system
- interact on analyses

Combine the data from different components

Synthesis of the data from very diverse systems plus remote sensing is a big challenge.

Usually via state estimation – some issues:

- **How best to use point timeseries in an eddy resolving model ?**
  - straight insertion like ARGO data mismatches space/time scales, force only larger scales with low-frequency part ?
  - assimilate the temporal statistics ?
  - withhold and use for validation
- **Some data/processes require very high accuracy but data error in usual cost functions is too large to constrain process (e.g. MOC transports)**
- **Need to find new ways to make use of derived/indirect data which may be hard to invert by themselves (total biomass or displacement volume, fluorescence, backscatter cross-section, etc)**

Combine data from in-situ, satellite, models

Example: remote sensing depends on in-situ data for

- knowing the internal structure/distribution
- ground-truthing
- critical parameter which cannot be observed from space.

→ Need to interact both ways and extract <u>products</u> needed

- by satellite community from in-situ observing system to help use, interpret, and understand satellite data
  (vert. structure of Chl, surface/subsurface currents, nutrients)
- by in-situ community from the "truckloads of" satellite data
  (spatial statistics, maps, temporal variability of large scales)
- by modelling community from in-situ observing system
  (fluxes, timeseries for validation, statistics, integral constraints)
- by in-situ community from model systems

Combine in-situ climate data & ecosystem data

Types of data sets between the communities are orthogonal:

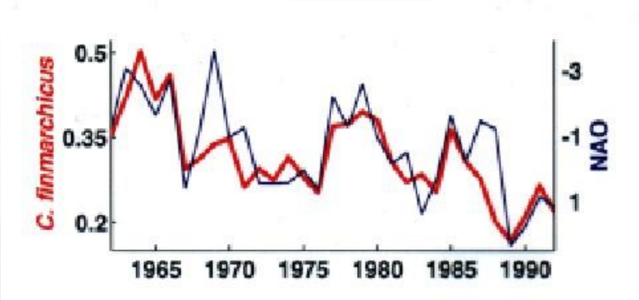
- **A: Databases of single parameters in 1-D, 2-D, or 3-D fields**
  (timeseries, sections, maps)
- **B: Databases with millions of samples, identifying organisms and their concentrations**

→ Need to manipulate ecological database for quantitative analyses or models

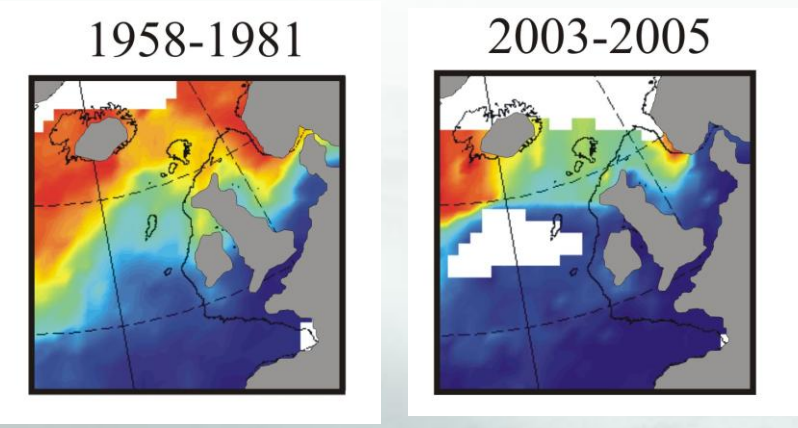
Approach 1: extract parameter/index timeseries and spatial distributions. Can then be merged/compared with climate/biogeochemical data.

CPR examples (Burkill)

Calanus finmarchicus



Arctic species distributions



Combine in-situ climate data & ecosystem data

Approach 2 (conceptual proposal):

In a given sample, the concentration of a species “i” be c_i.

Define a set of bulk properties b_k that can be measured autonomously, like other climate/biogeochemical parameters

- optical absorption (many wavelengths)
- optical backscatter (various wavelengths)
- acoustic backscatter (various frequencies)
- volume displacement
- flourescence (some wavelengths)
- …..

Lab experiments can give relation between concentration of species “i” and property “k” as $b_k = g_{jk}\, c_i$,

Total backscatter, absorption, etc, for the sample then is $\mathbf{b} = \mathbf{G}\,\mathbf{c} + \mathbf{e}$.

→ **Synthetic data, for qualitative comparisons**
→ **study from lab data which species can be constrained by which bulk measurements**
→ **look for useful well-constrained linear combinations (total mass or volume, etc)**
→ **formalism to use bulk data for constraining models which have SOME species**

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Integration needs open and seamless data access

- **Many programs have their own data system established (ARGO, SOT, OceanSITES, CPR, COML), need to provide seamless/cross-linked access**

- **No standards (format, QC, best practices) exist currently for profiles or timeseries of many biogeochemical and ecosystem parameters. OceanSITES is trying to set a new standard for that gap.**

- **Recommend that realtime biogeochemical/ecosystem data (autonomous systems) be shared in realtime, even without good automated quality control procedures in place.**

Recurring statements during days 1-4

- **Need to focus on applications that society cares about**
  - sea level and storms
  - climate change prediction (IPCC models initialization/testing/validation)
  - changes in carbon uptake (incl biological pump), fate of anthrop. carbon
  - acidification (ecosystem damage, coral reefs, plankton carbon sink impact)
  - management of LMR, attribution of climate impact
  - health of ecosystems, HAB’s, hypoxia
  - changes in the Arctic
  - pollution and pollutant transports

These are plenty of societal justifications for sustained global observations, if the three communities join forces…

- **Link with coastal/reef environments and observing systems**

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Recurring statements during days 1-4

- **Need to make data&information available, share them freely**
  - between countries and communities
  - data yield benefits only when they are USED
  - data base of data bases

- **Need co-located observations, observe in a <u>context</u>**
  - observe the linked variables in physics, climate, geochemistry, ecology

- **Need long timeseries**
  - events
  - changes in circulation, fluxes, processes
  - to detect/observe regime shifts
  - <u>changes</u> in biogeochemistry
  - not sexy but critical !

Protect funding for timeseries (difficult in research funding)

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Recurring statements during days 1-4

- **Model errors (hindcasts, forecast ensembles, state estimates)**
  - heat fluxes, MOC, ecosystem, etc
- **More global coverage, more key variables**
  - close the gaps in global sampling
  - undersampled in space and time
  - even basic quantity like heat content has an unexplained imbalance, worse for surface fluxes, CO_2 flux/inventory, etc
  - need new sensors/techniques (and platforms for them)
- **Capacity building**
  - hard to build/maintain a global network without it

Potential synergies

Probably efficient to add to existing programs, infrastructure, logistics, data systems, rather than building separate programs.

Probably easier to sell 3 expanded, highly capable/versatile programs that address MANY societal needs, than many specialized ones.

VOS (global surface distributions)

- merge TSG, CO_2, add trace metals and other chemicals, pollutants
- try to merge with some XBT and CPR lines ?

ARGO (global subsurface distributions)

- biogeochemical and ecosystem sensors (O_2, pH, LOPC, etc)
- broadband acoustic receiving (tomography, animal tracking)
- under the ice

Potential synergies

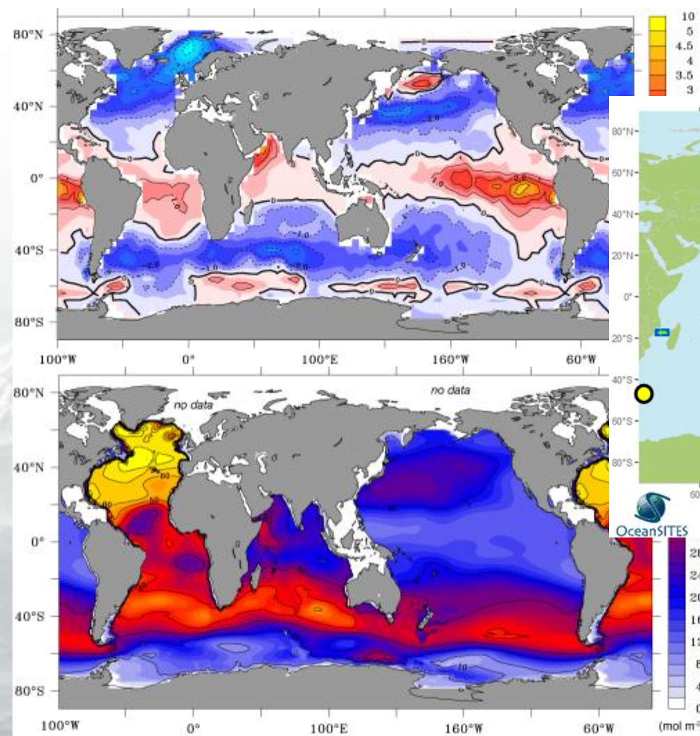
OceanSITES (air-sea to bottom, temporal resolution, many sensors, post-calibration)

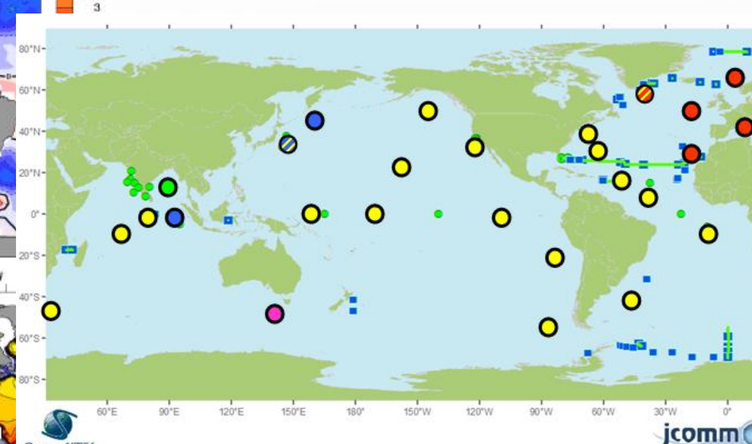
- biogeochemical and ecosystem sensors (O2, pH, LOPC, etc)`
- COML upward fish/zooplankton sonar
- imaging techniques (Sieracki et al CWP)
- deep observatories (MOC passages, deep T/S changes, carbon inventory)
- subsurface reference information

OceanSITES

Taking the pulse of the global ocean

Choose hotspots or locations representative of ocean provinces, to establish long-term multi-community presence.





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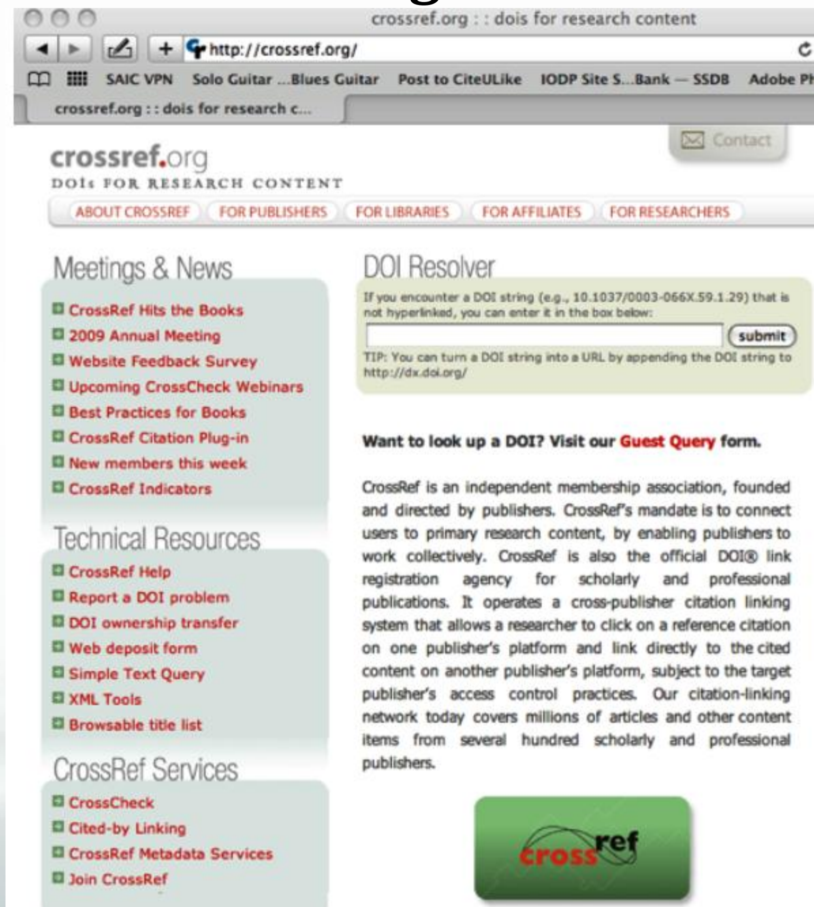
Getting credit for generating community data

Digital Object Identifier (DOI)

Crossref Organization



John Helly (UCSD Supercomputer Center) has worked out a way for Crossref to assign a journal-like number (digits before the /) to data centers or atlases, they can provide citeable DOI numbers to data sets.

Citations then get counted in Web of Science etc

Building the 3rd decade of global ocean observation

Climate community
Research driven

- **WOCE (1990 – 2002)**
  observing the mean state

OceanObs99

- **CLIVAR (2000 – present)**
  variability of ocean climate processes

OceanObs09

Three communities
Application driven

- **Next 10 years**
  Embracing biogeochemistry&ecosystems
  - **maintain existing system**
  - **close gaps**
  - **enhance ARGO, OceanSITES, VOS to serve multiple communities**

> - **Jointly fund and implement → up to 3x the resources.**
> - **In addition, societal needs/application may channel more resources.**
> - **Build a system that is ready for the unknown unknowns.**
>
> **TOGETHER WE CAN DO IT…..**

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Training the next generation….

The system will require large human resources to build and run

- need to train scientific, technical, data management staff
- set up structures within academia to build and operate such systems
- mechanisms for recognition and career advancement

Creates employment and a new "industry"

FACULTY POSITIONS
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The Scripps Institution of Oceanography (SIO) at the University of California in San Diego (http://scripps.ucsd.edu) invites faculty applications (tenure track to tenured) to fill one or more positions in one or more of the fields listed below….

Biology Section: Biochemistry, Genetics or Physiology….
Ocean acidification. Impacts of acidification on ocean life and ecology….
Marine Population Dynamics: for Fisheries and Protected Species….
Earth Section: Sciences of the solid Earth….
Oceans & Atmosphere Section: development of technology for observing the ocean, collection and analysis of data, ocean-state estimation and modeling,…

Integration needs to provide information

Step from data to information:

- Use scientific analyses and forecasting systems to provide services.
- Make information and products freely available
- provide results people can use and want to use

  e.g. - ecosystem indices
  - short-term forecasts (HAB's, etc)
  - long-term forecasts (climate)
  - ice cover