Observing the Ocean: Why and How?

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pogo Partnership for Observation of the Global Oceans

Partnership for Observation of the Global Oceans (POGO)

A consortium of major oceanographic institutes around the world, represented by their Directors

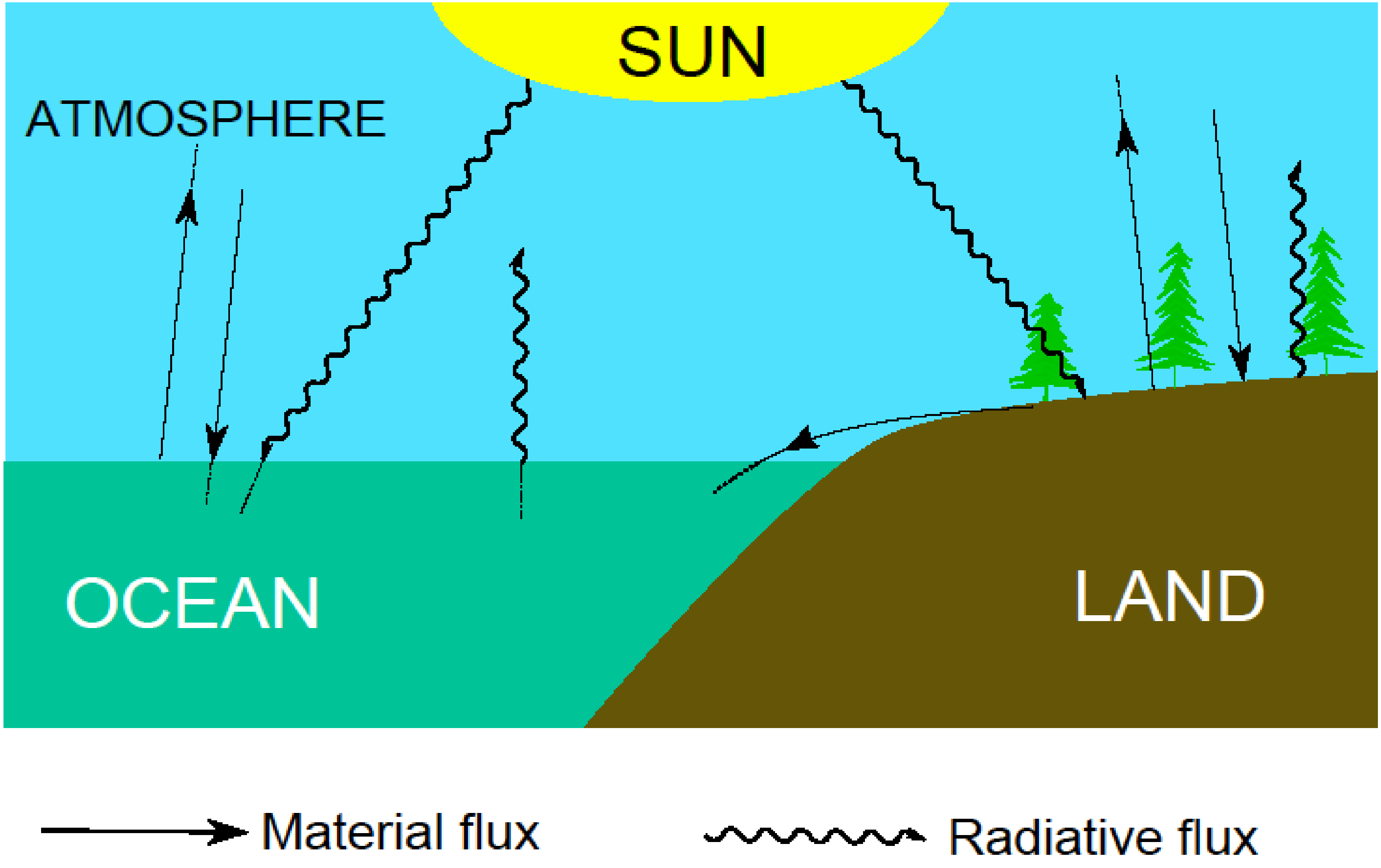
Goal: Promote sustained ocean observations

Observations reflect multidisciplinary nature of oceanography:

physics, chemistry, biology, geology; and

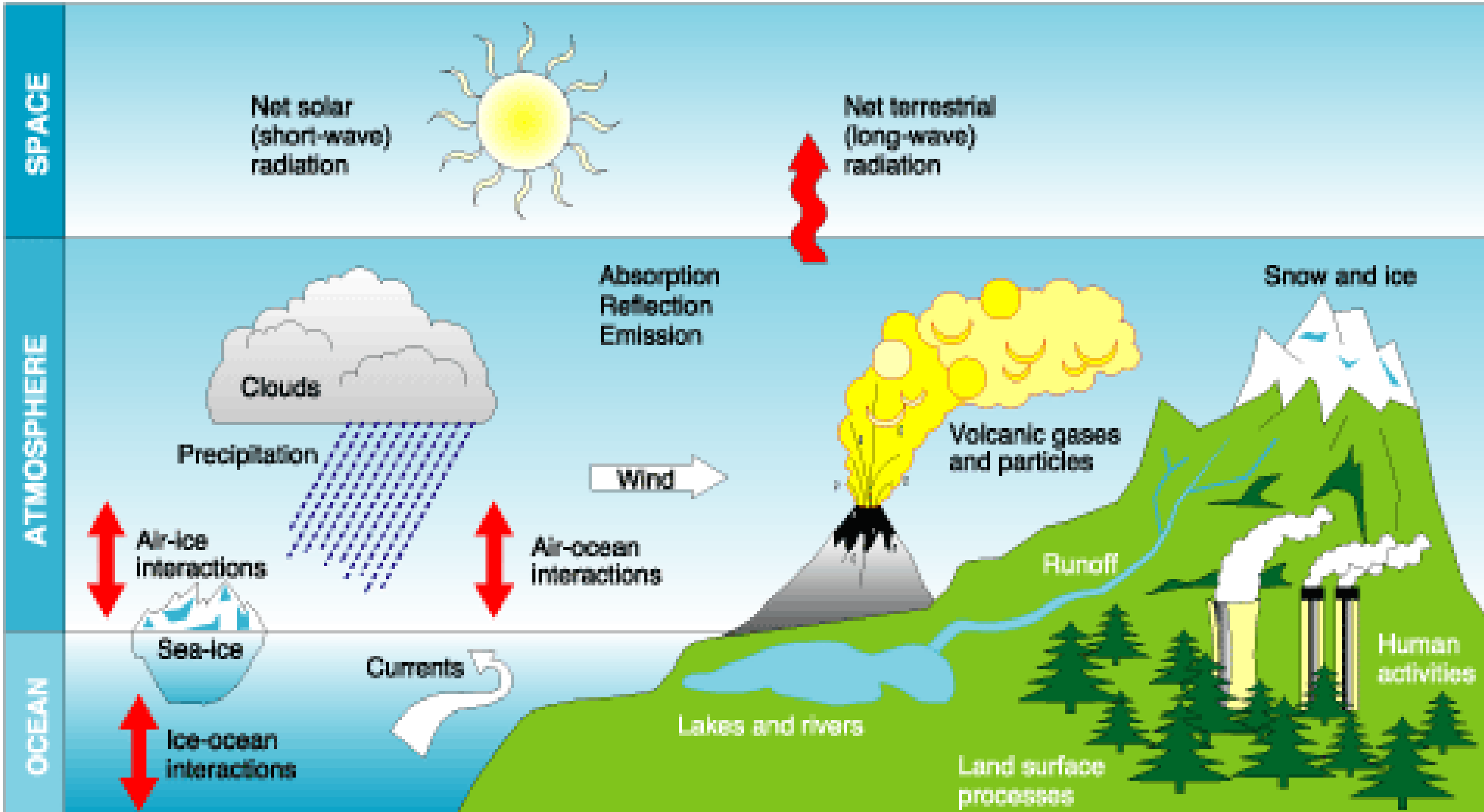
related fields (ecology, fisheries, climate)

Ocean, land, atmosphere and sun are dynamically linked in the Earth System



Fluxes are non-linear and feedbacks exist

Oceans are part of a system



Slingo 2006

Why should Society be interested the the Ocean?

We depend on it for transportation; fisheries; mineral extraction; tourism; and living space on the coasts. Also,

It controls our weather

It has a key role in the Earth's carbon cycle

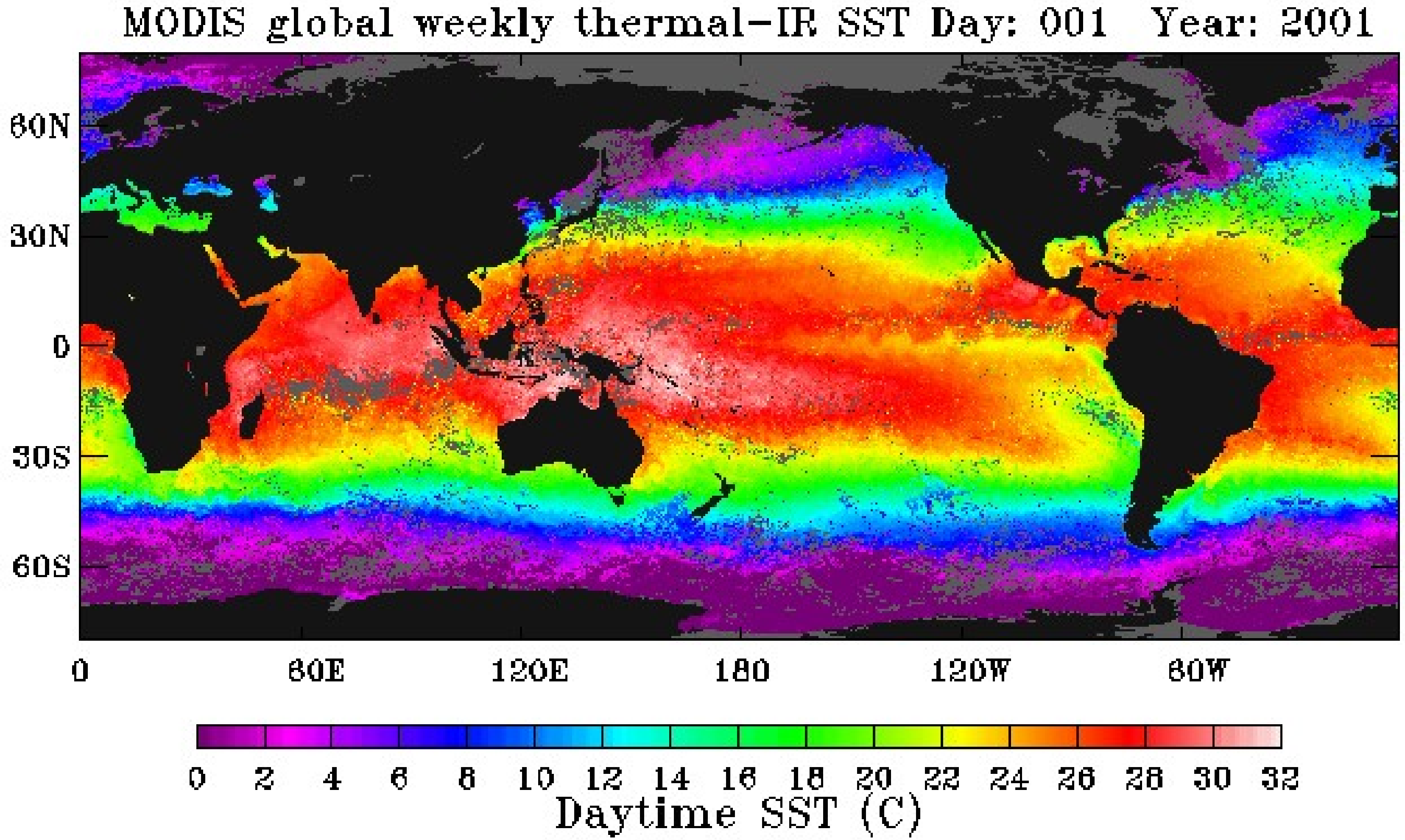
The Earth is a Blue Planet. We hold the ocean in trust and should conserve it, including its biodiversity

Therefore, it is in our own interest to observe the Oceans

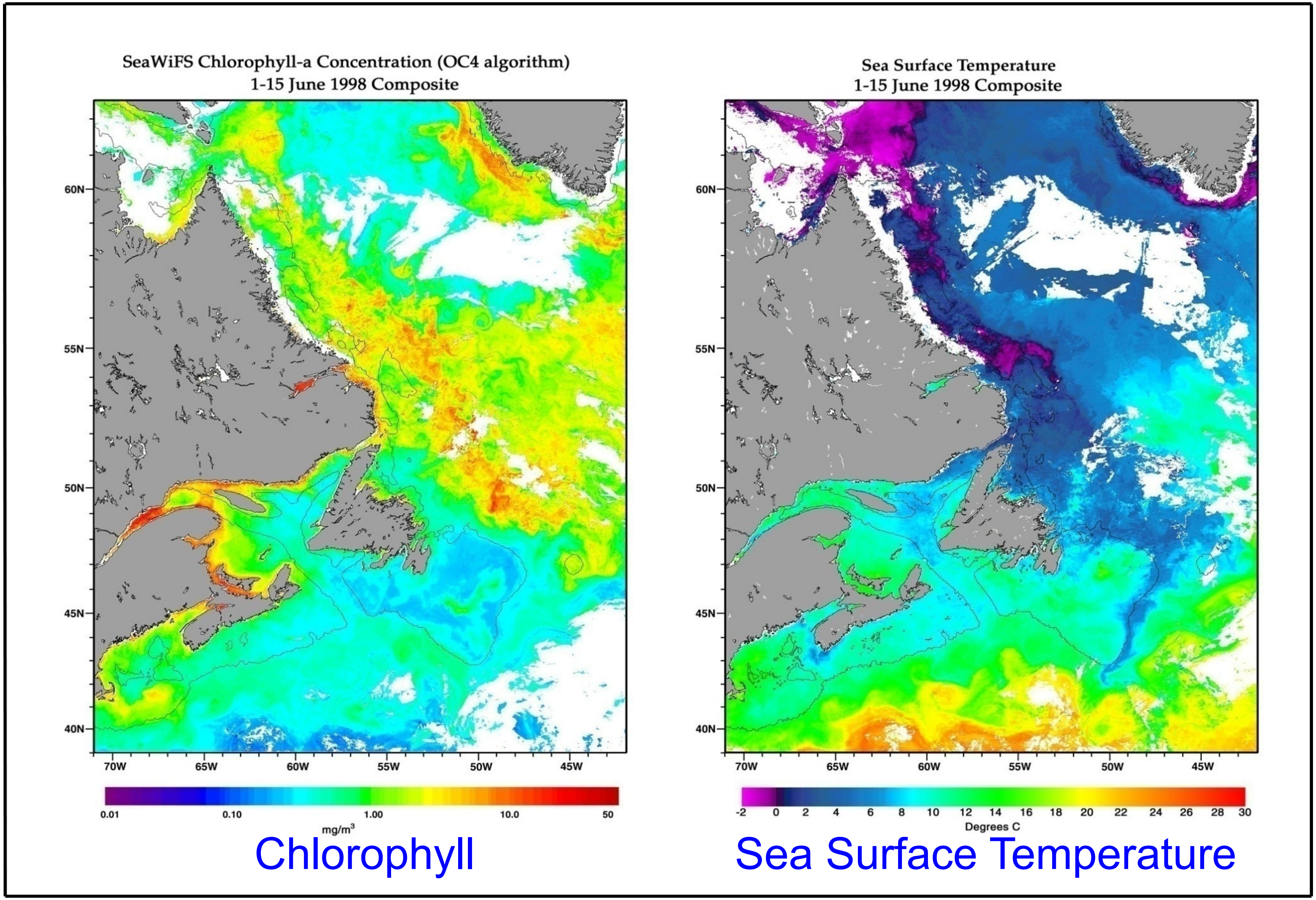
- To know the state of the ocean;
- To understand why it is the way it is; and
- To predict how its state might change:

We need global coverage and we need continuing coverage

Ocean is not the same everywhere



Physical and Biological Structures of the Ocean are Coupled



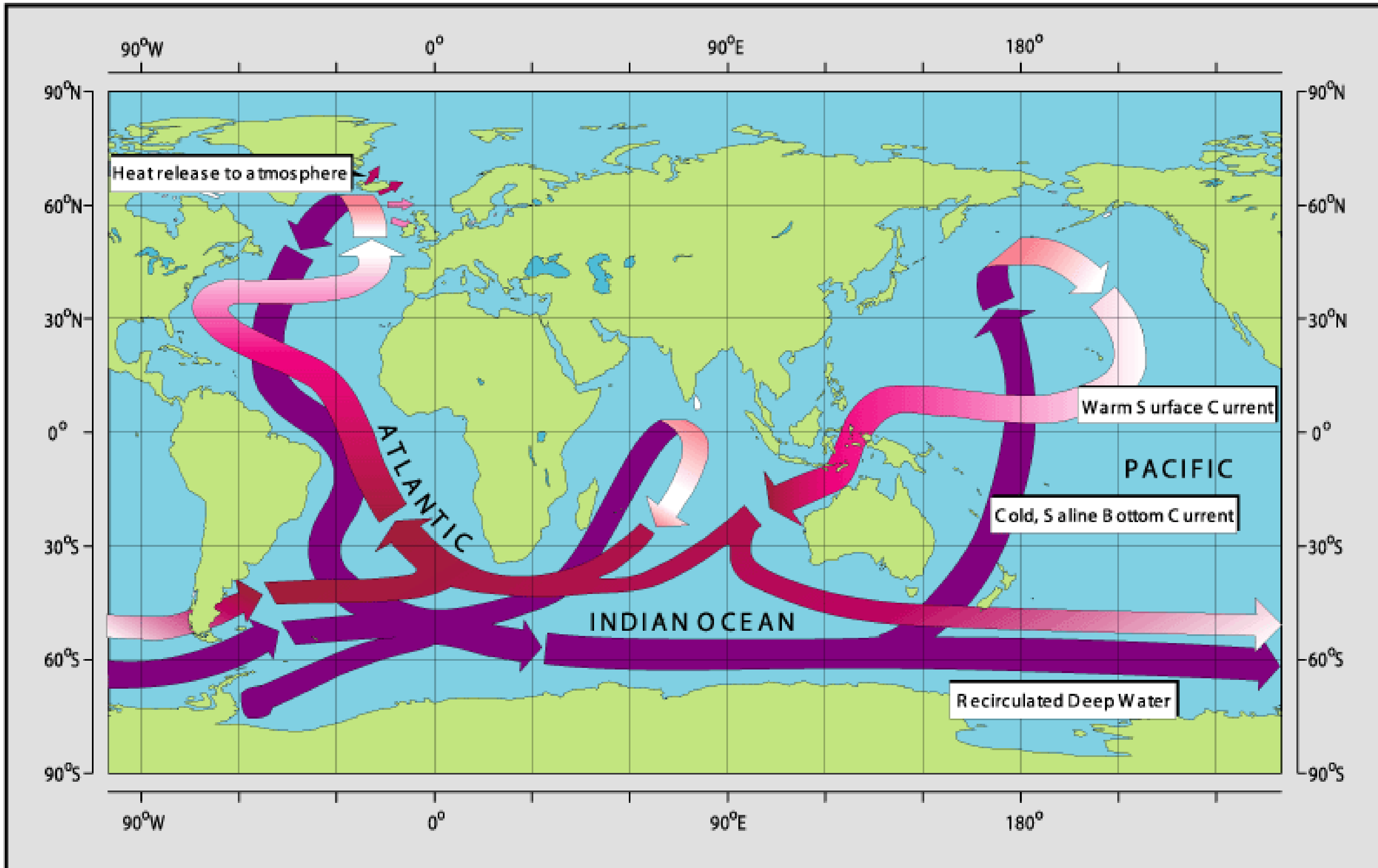
Ocean is Dynamic (Measuring only once is not enough)

The ocean varies with

passage of storms,
with season,
between years and on
decadal time scales (for example, el Niño) and
on longer time scales (climate change)

We need to be able to distinguish the climate change signal from the rest

The Gulf Stream and Thermohaline Circulation



Slingo 2006

Ocean is not easy to observe

Large spatial extent;
Three dimensional;
Hostile environment;
Expensive

Variable on many time scales, we require sustained observations everywhere in the ocean (even in the more difficult places)

What platforms are available for observing the Ocean?

Research vessels
Commercial ships
Spacecraft
Moorings
Gliders
Drifters
Animals

No single platform can be considered as the ideal tool for observing the ocean

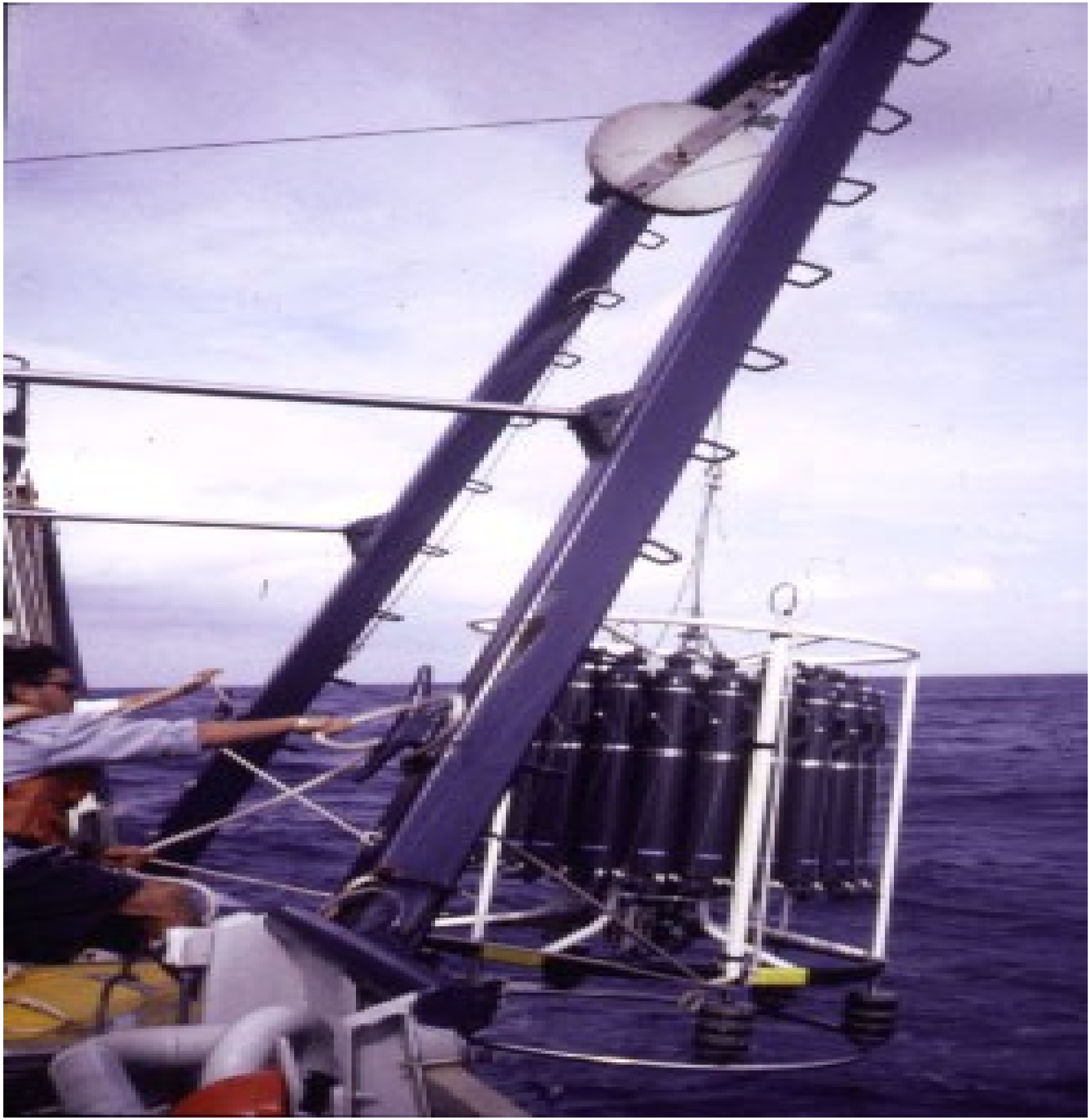
We have to combine data from different methods to achieve a complementary and integrated picture

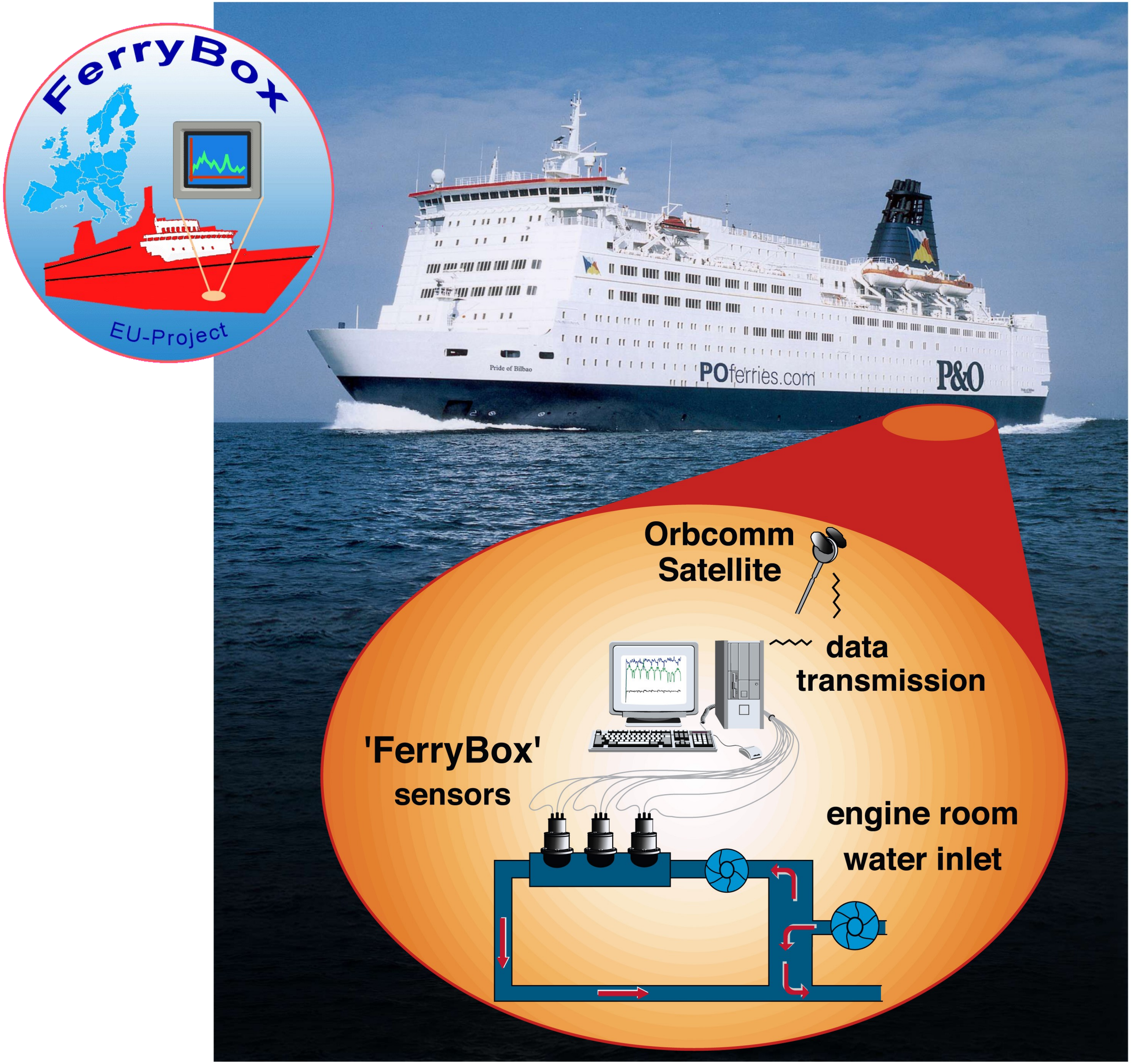
Research Vessels

Vehicles

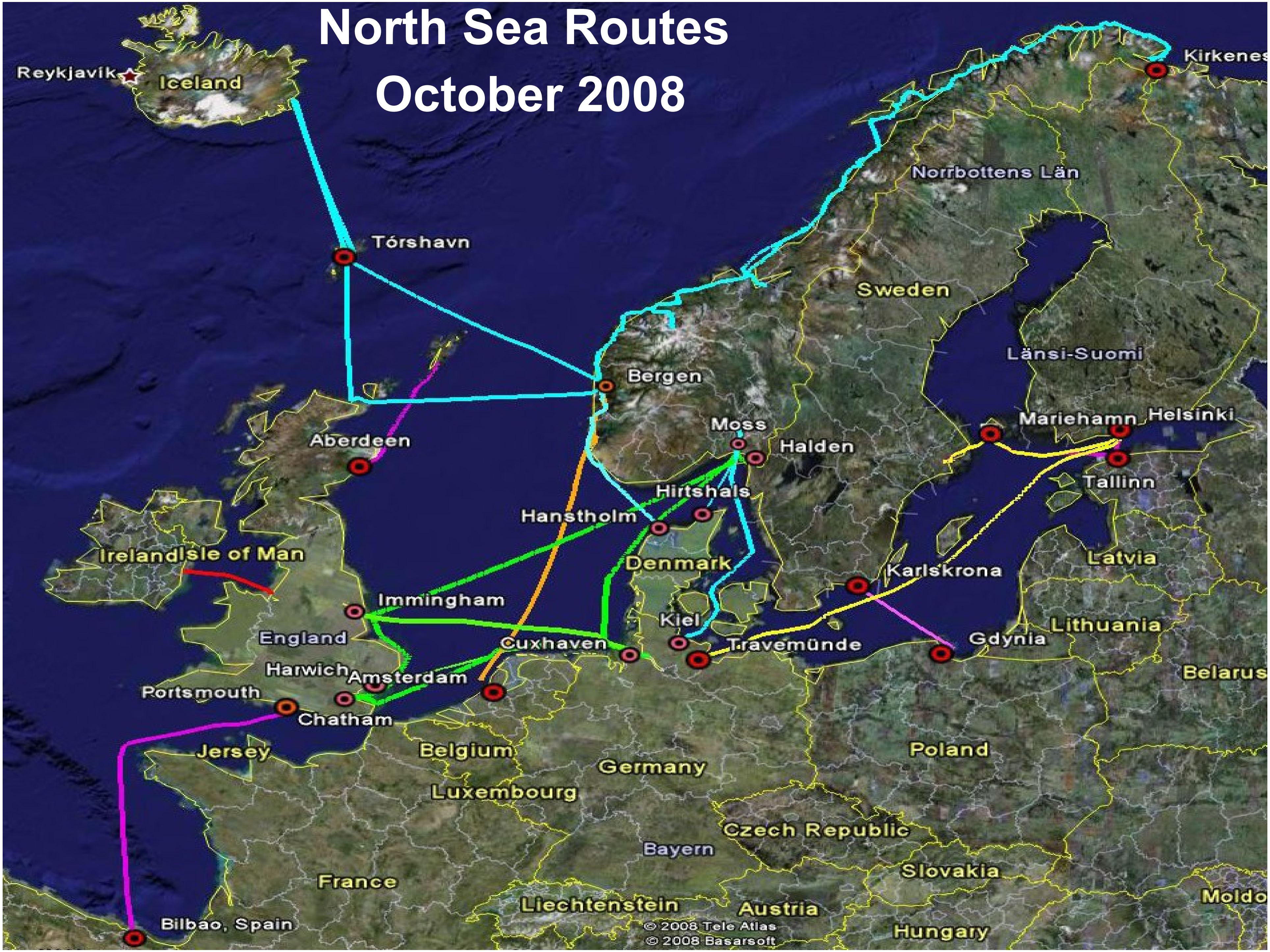
Research Vessels and Vehicles

Sampling with Bottles: Rosette




FerryBox
EU-Project
Pride of Bilbao
POferries.com
P&O
Orbcomm
Satellite
data
transmission
'FerryBox'
sensors
engine room
water inlet

North Sea Routes
October 2008



Training Ship's Personnel

Ocean and the Earth's Carbon Cycle

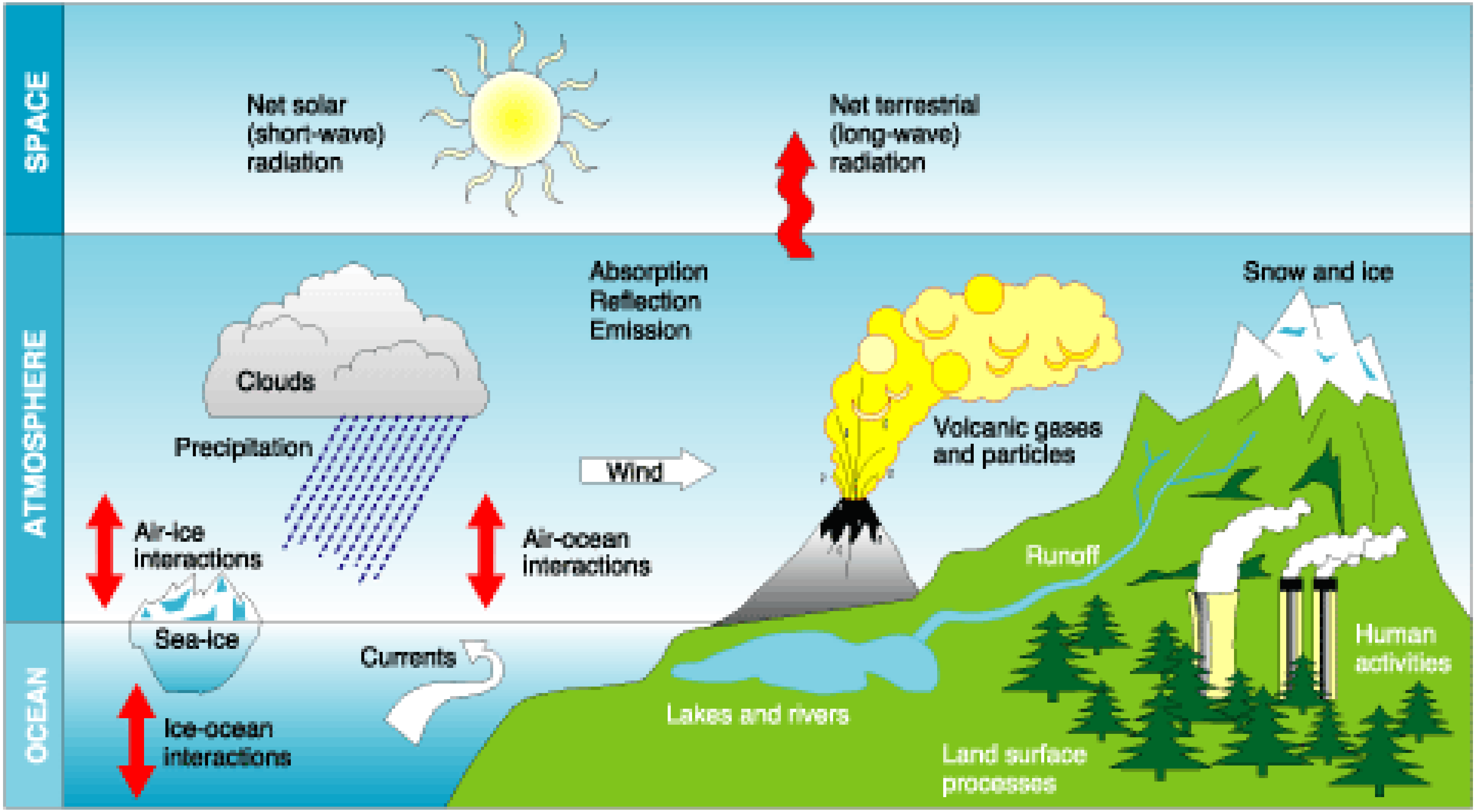
Ocean has a microscopic flora of green plants (phytoplankton)

Ubiquitous,
Abundant,
Pigmented (chlorophyll),
Photosynthesis (consume carbon dioxide),
Metabolically active,
Collective carbon flux 50 Giga tonnes per annum,
Slight negative buoyancy

Sinking phytoplankton carry carbon to deep ocean (biological pump)

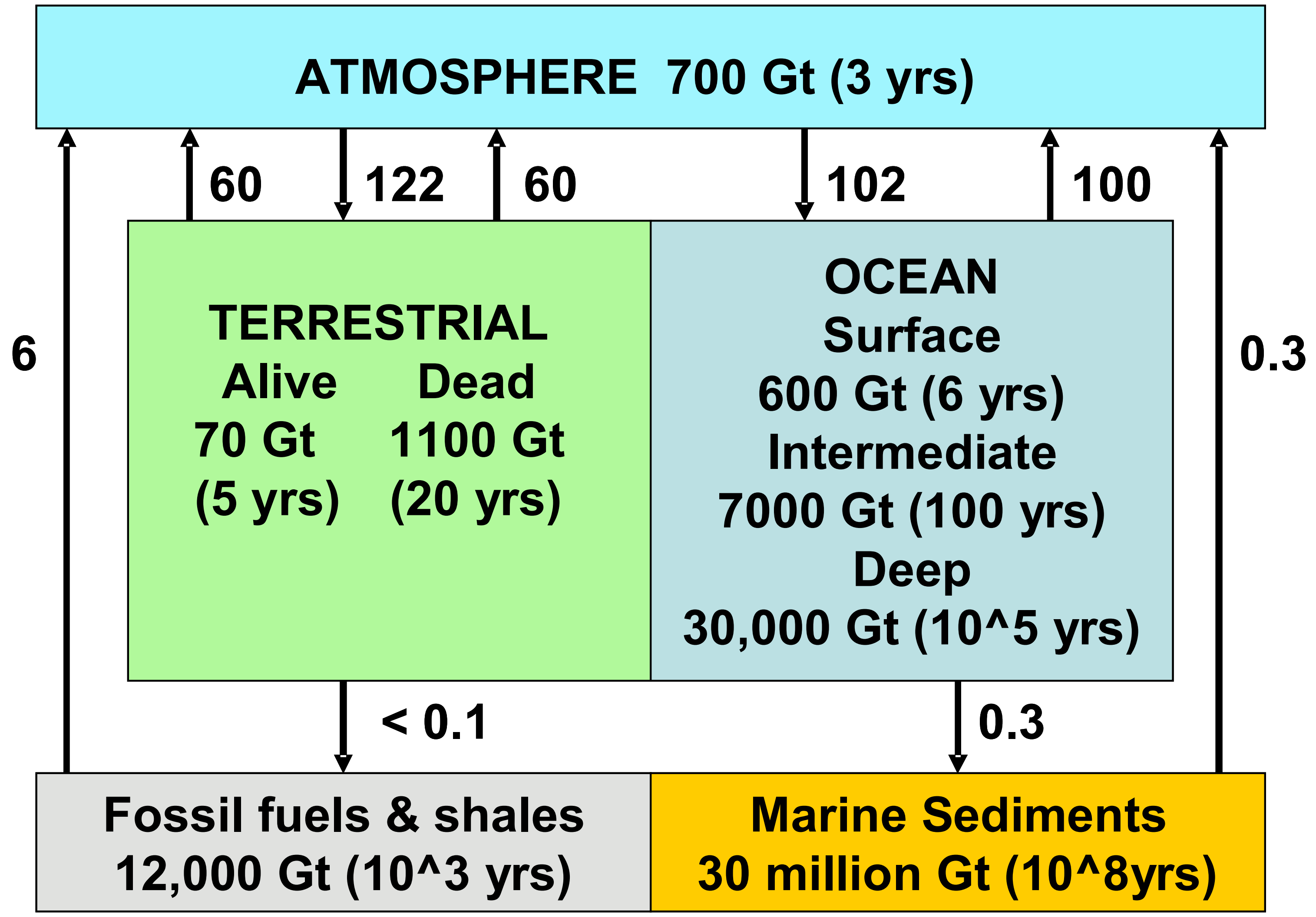
Therefore, we need to study the biosphere as well as the physical system

Oceans are part of a system



Slingo 2006

Global reservoirs of Carbon and exchanges between them



We add 6,000,000,000 tonnes (6 Gt) of Carbon each year

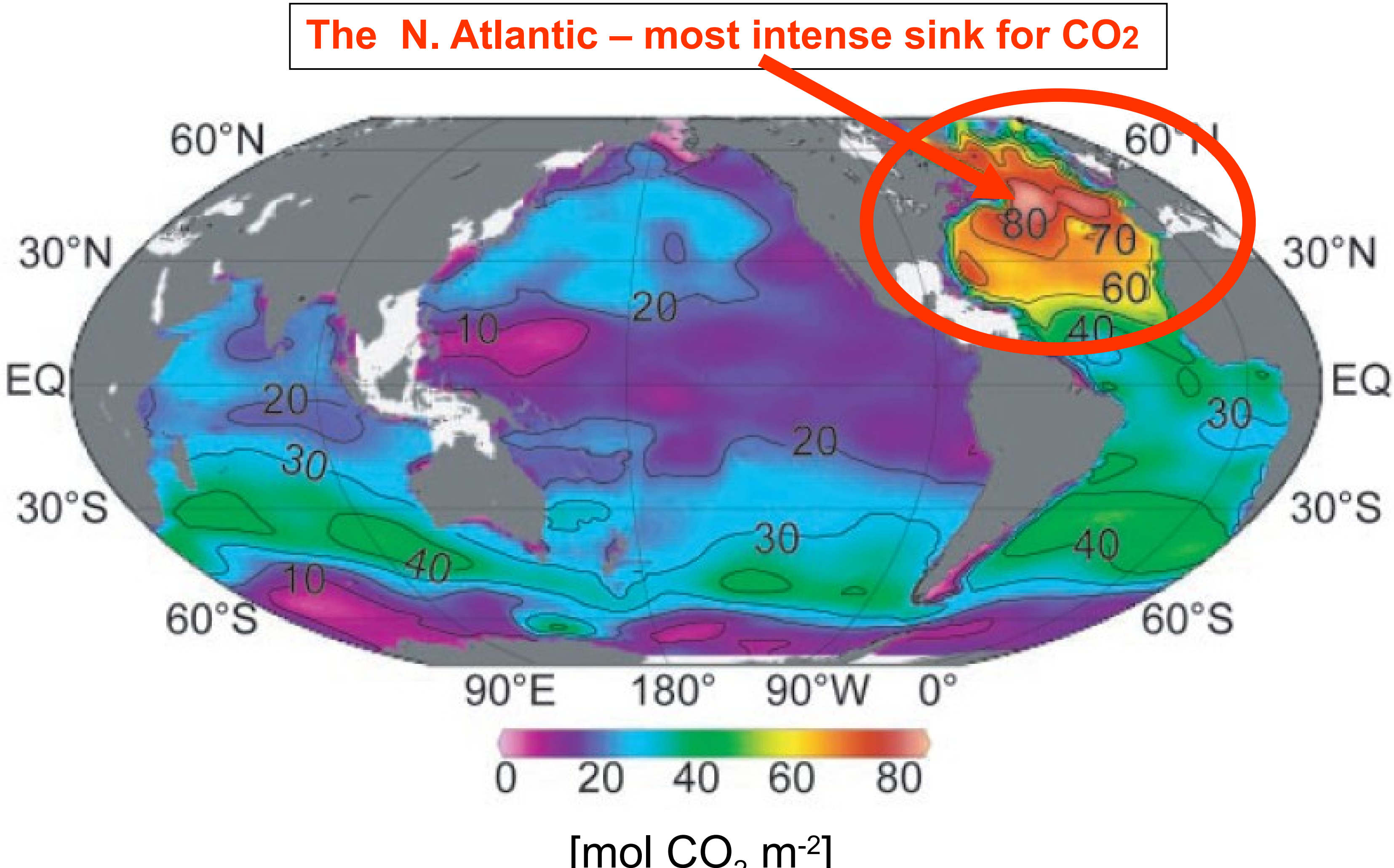
The North Atlantic CO_2 monitoring system

Ute Schuster

UEA
University of East Anglia

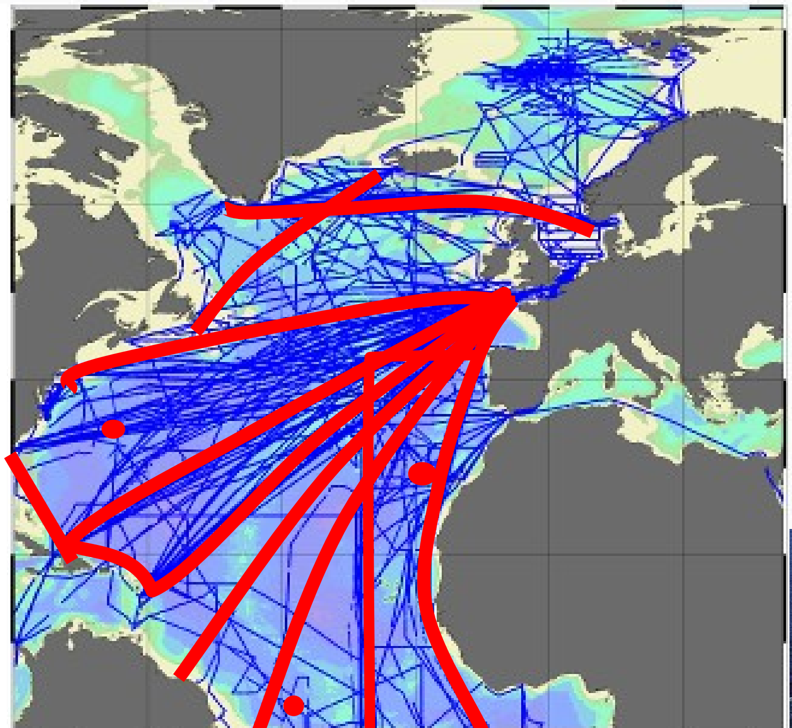
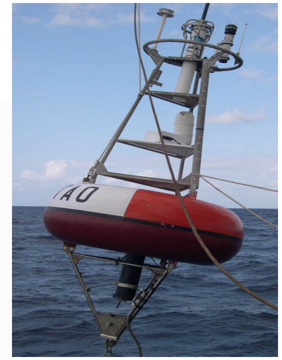
The North Atlantic is an important sink of CO_2

Total ANTHROPOGENIC CO_2 in the oceans in 1994



from Sabine et al (2004) *Science* **305**: 367 - 371

The North Atlantic measuring network







Remote sensing of the ocean

Surface temperature;

Sea-surface height (altimetry);

Winds;

Visible spectral radiometry

A global consensus

Jurisdiction over marine resources should be conducted under ecosystem-based management

Decisions should not threaten the integrity of the ecosystem

But how would we know? Easier said than done

Ecological indicators

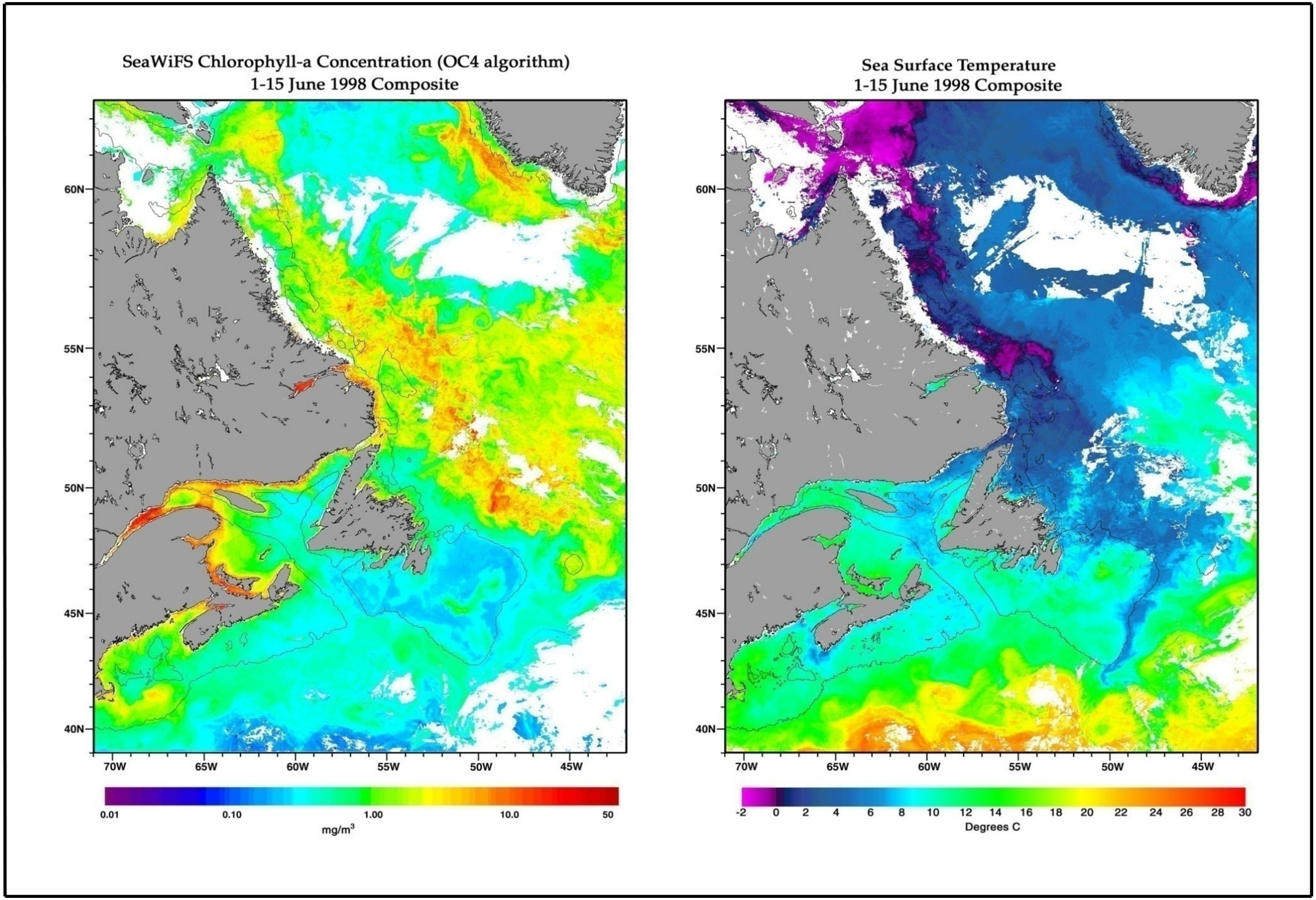
Objective metrics to be estimated serially, in operational mode, to detect change in the ecosystem as a response to perturbation, either natural or man-made

Visible spectral radiometry (Ocean colour)

Remote sensing of ocean colour provides our only window into the ocean ecosystem on synoptic scales

The main product (chlorophyll concentration) is an important property of the marine ecosystem (the autotrophic biomass)

Chlorophyll and Temperature: Fundamental properties of the ecosystem

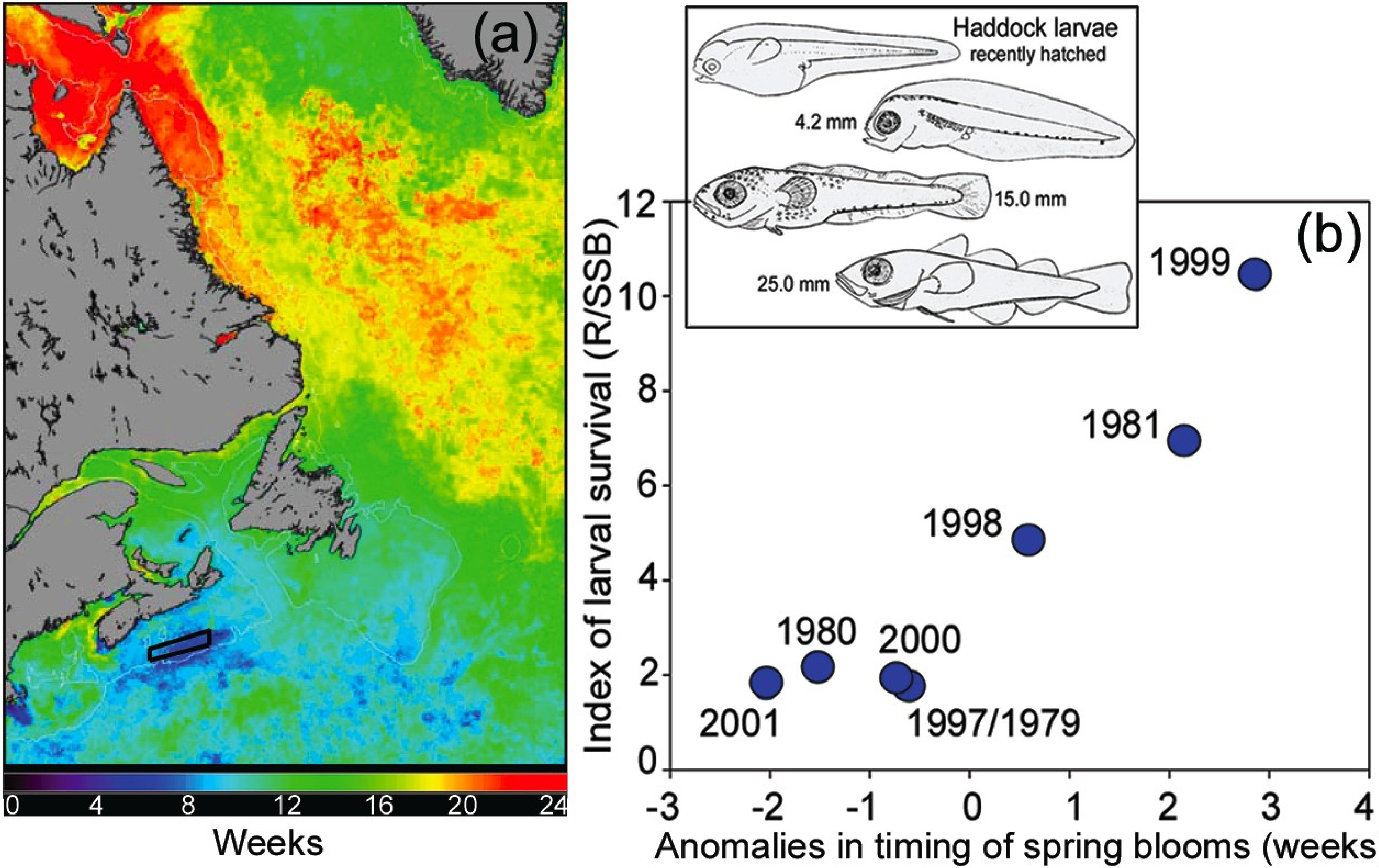


Ideal Characteristics of Pelagic Indicators

- Represent a well-understood and widely-accepted ecosystem property
- Quantifiable unambiguously in standard units
- Measurable rapidly at low incremental cost
- Repeat frequency compatible with intrinsic time scale of properties under study
- Measurable at a variety of scales
- Possibility to create long (multi-decadal) time series

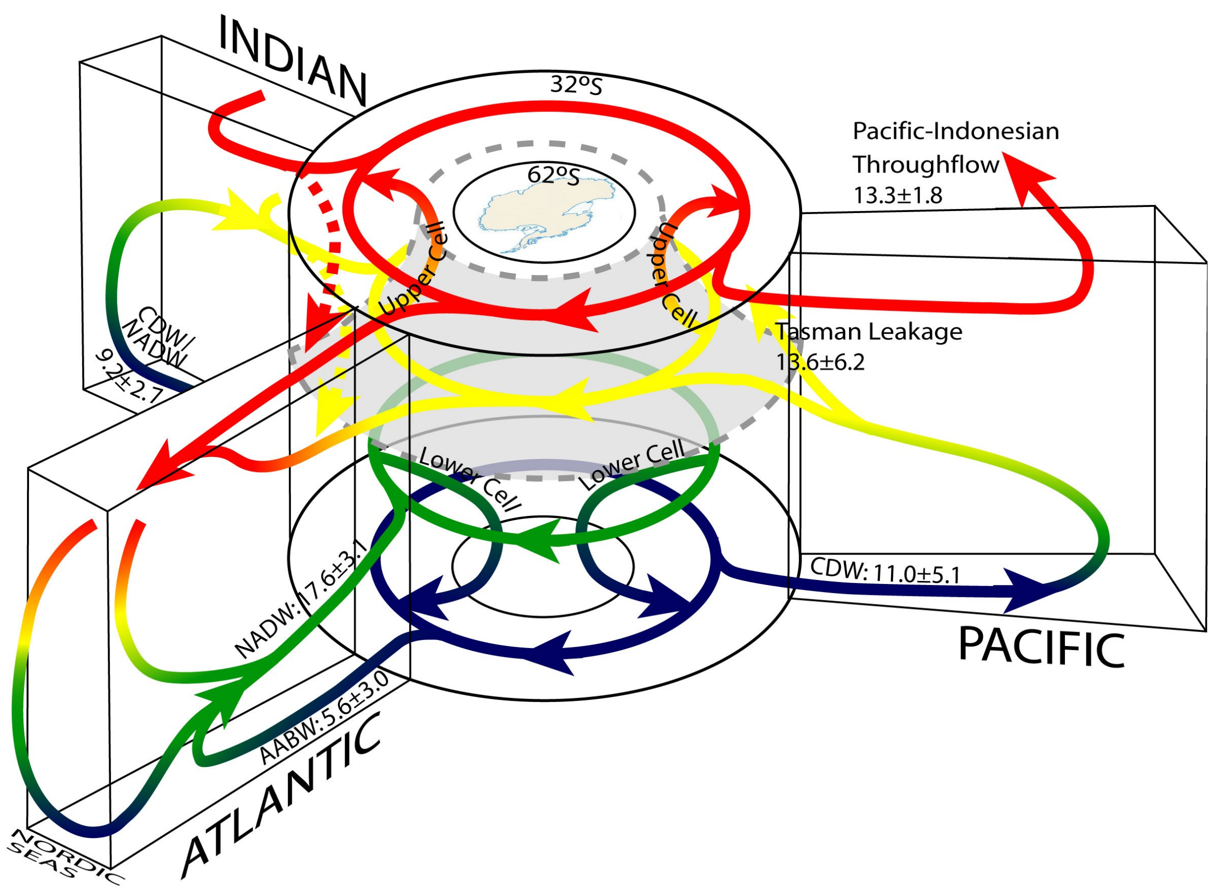
Visible spectral radiometry (remote sensing) meets these requirements

Timing of the Spring Bloom



Many more ecosystem indices possible by remote sensing

Global reach of the Southern Ocean



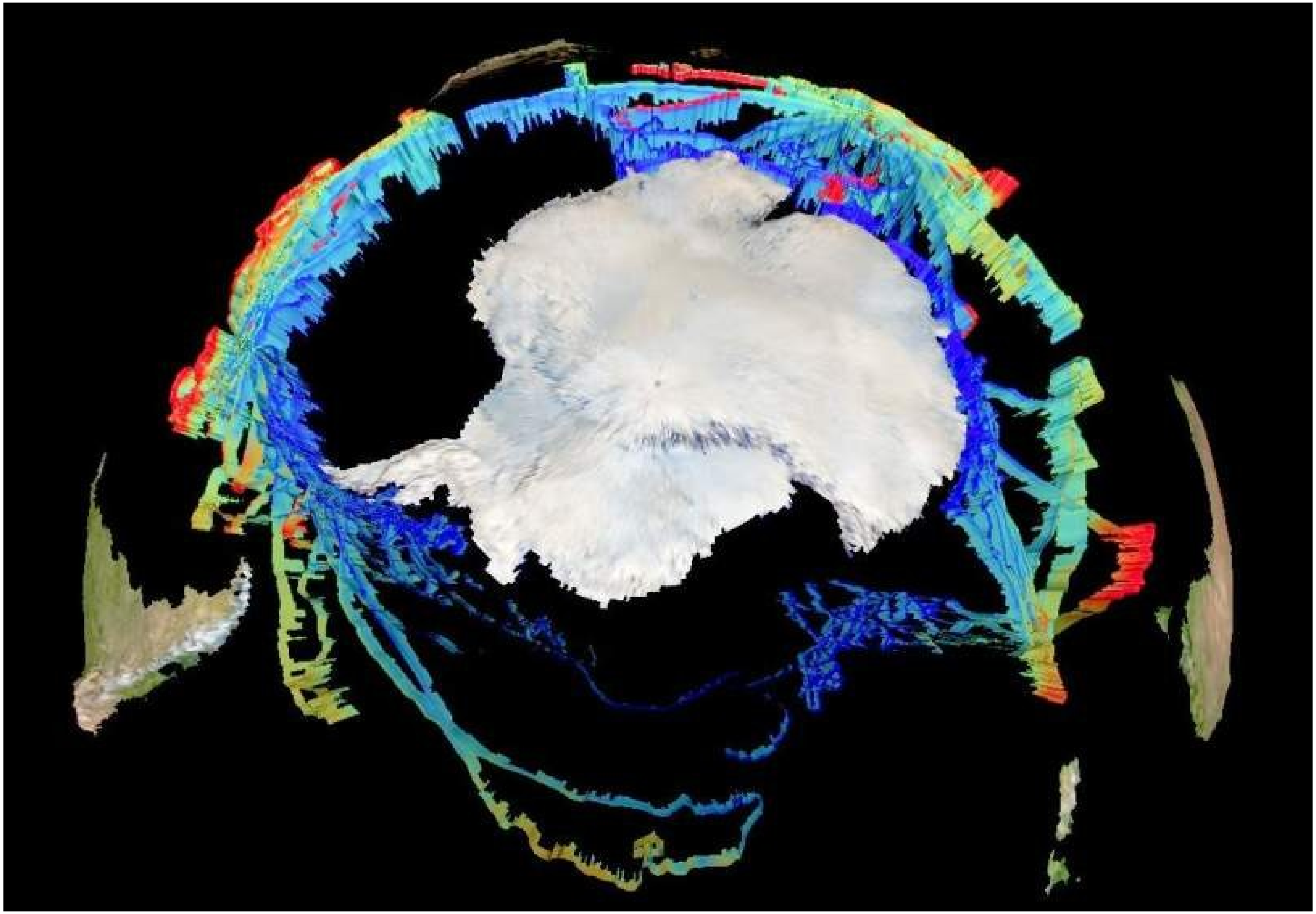
Lumpkin and Speer (2006)

Critical part of the global thermohaline circulation

Animals as Observers: Bio-logging

Courtesy: Census of Marine Life

Near circumpolar coverage by elephant seals

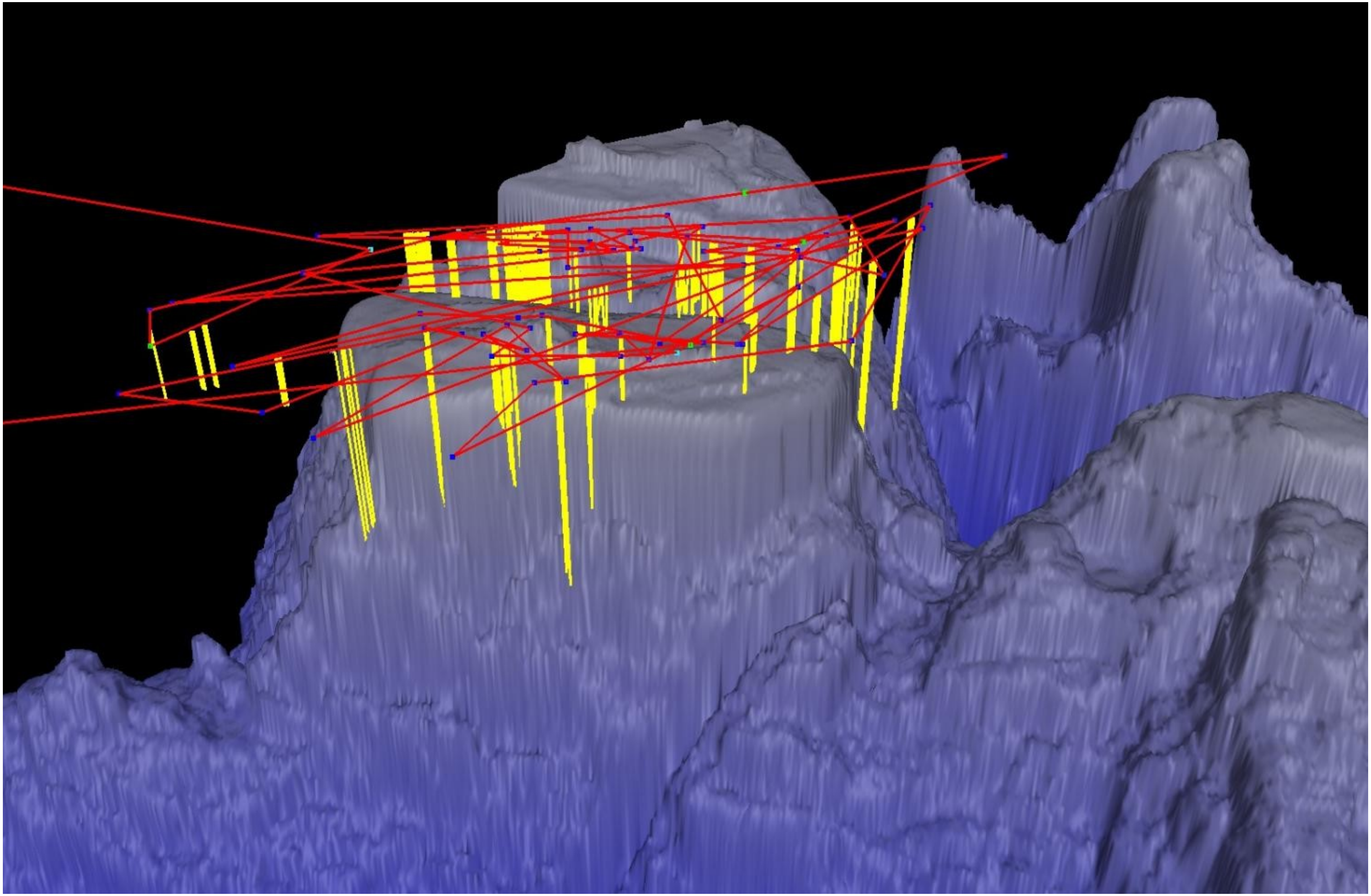


Other species can be targeted to access specific icy regions.
Invaluable data for both ecological and physical sciences.

Courtesy: Census of Marine Life

Tracking in conjunction with bathymetry

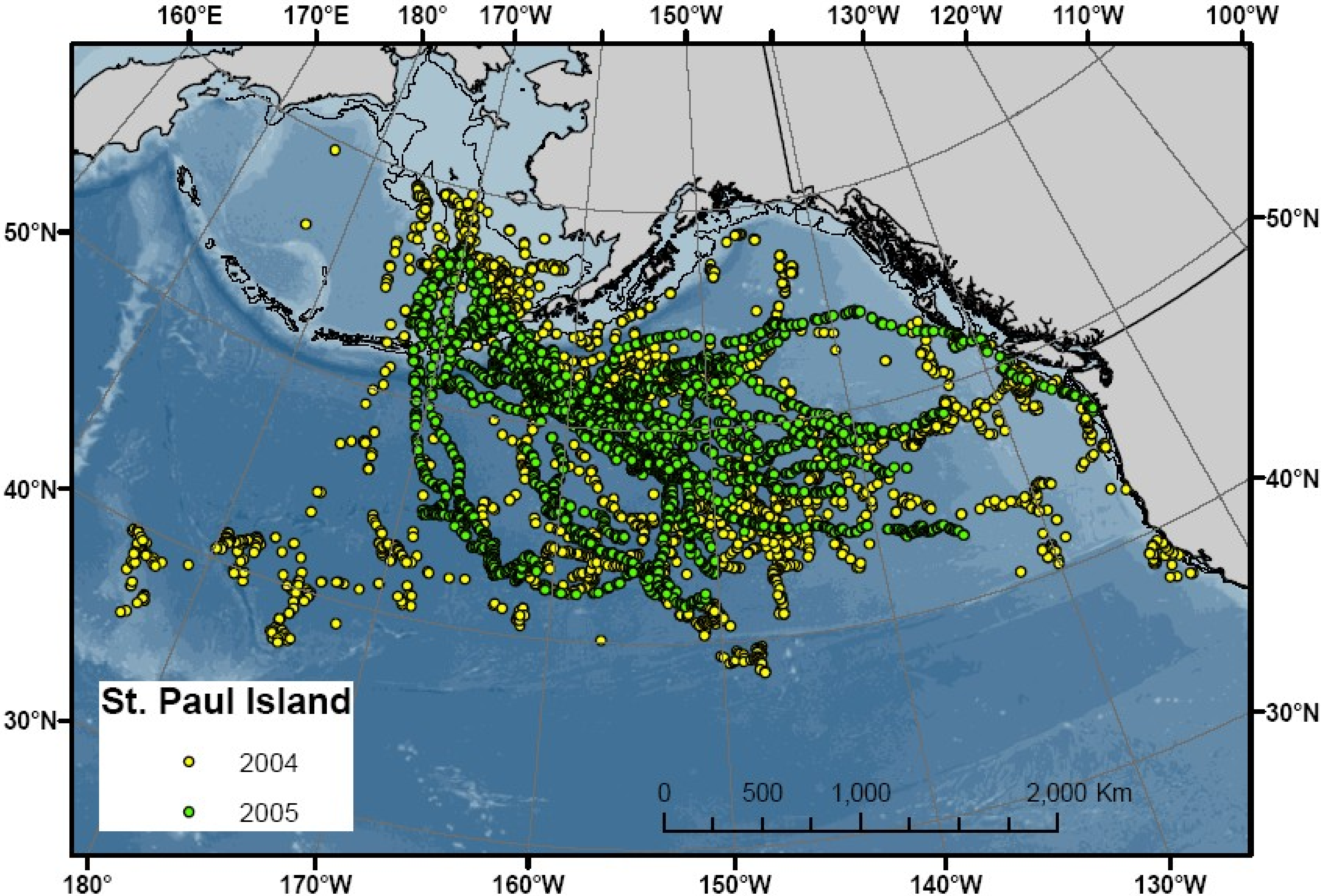
Elephant Seal Foraging on Cortez Bank, Southern California



Courtesy: Census of Marine Life

Continuous tracking through a physical barrier:

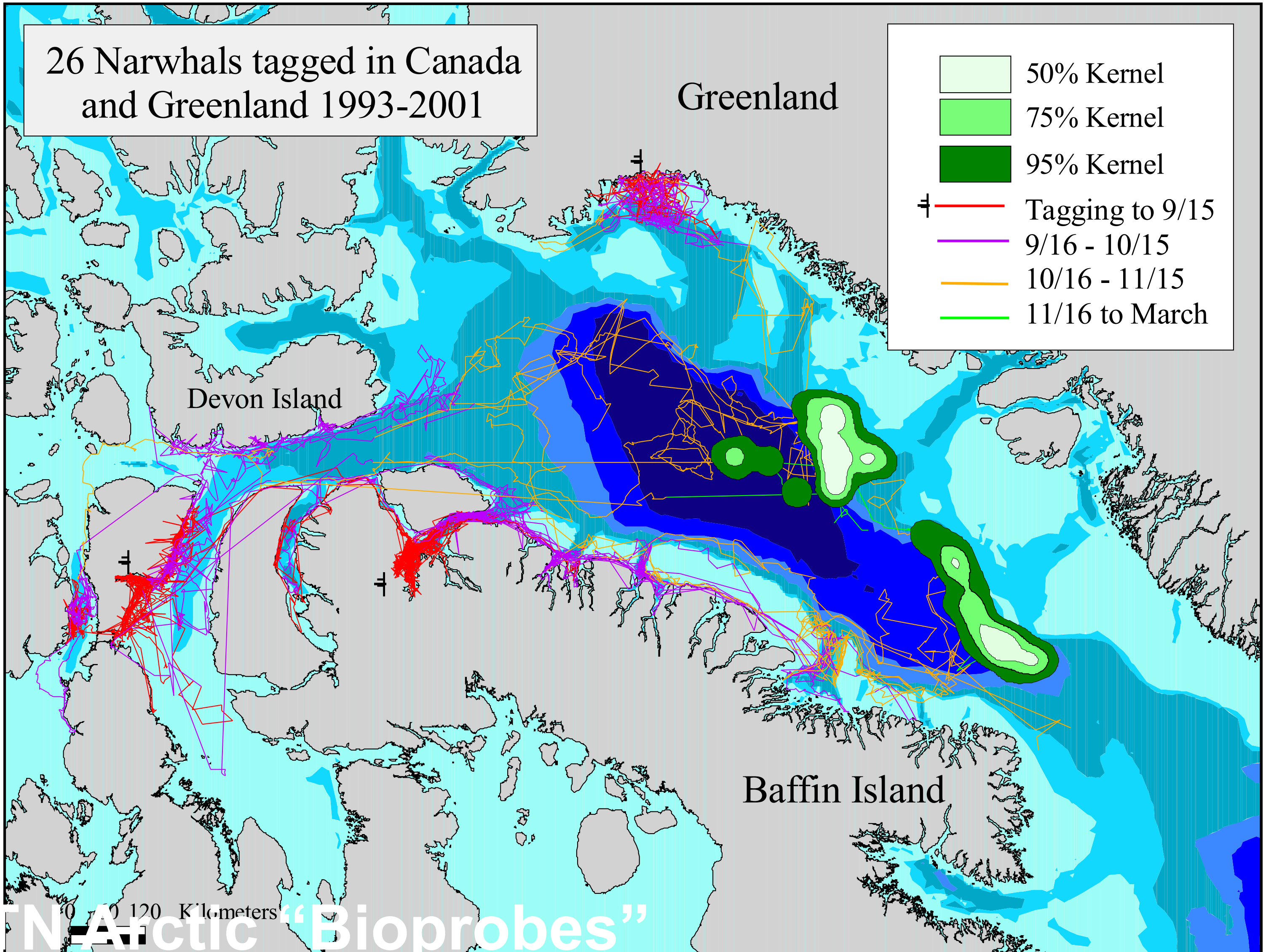
from Pacific through Aleutians into Bering
Northern Fur Seals, Iverson, Unpublished



Using Narwhals as Ocean-Observing Platforms in the High Arctic

Observing in difficult environments

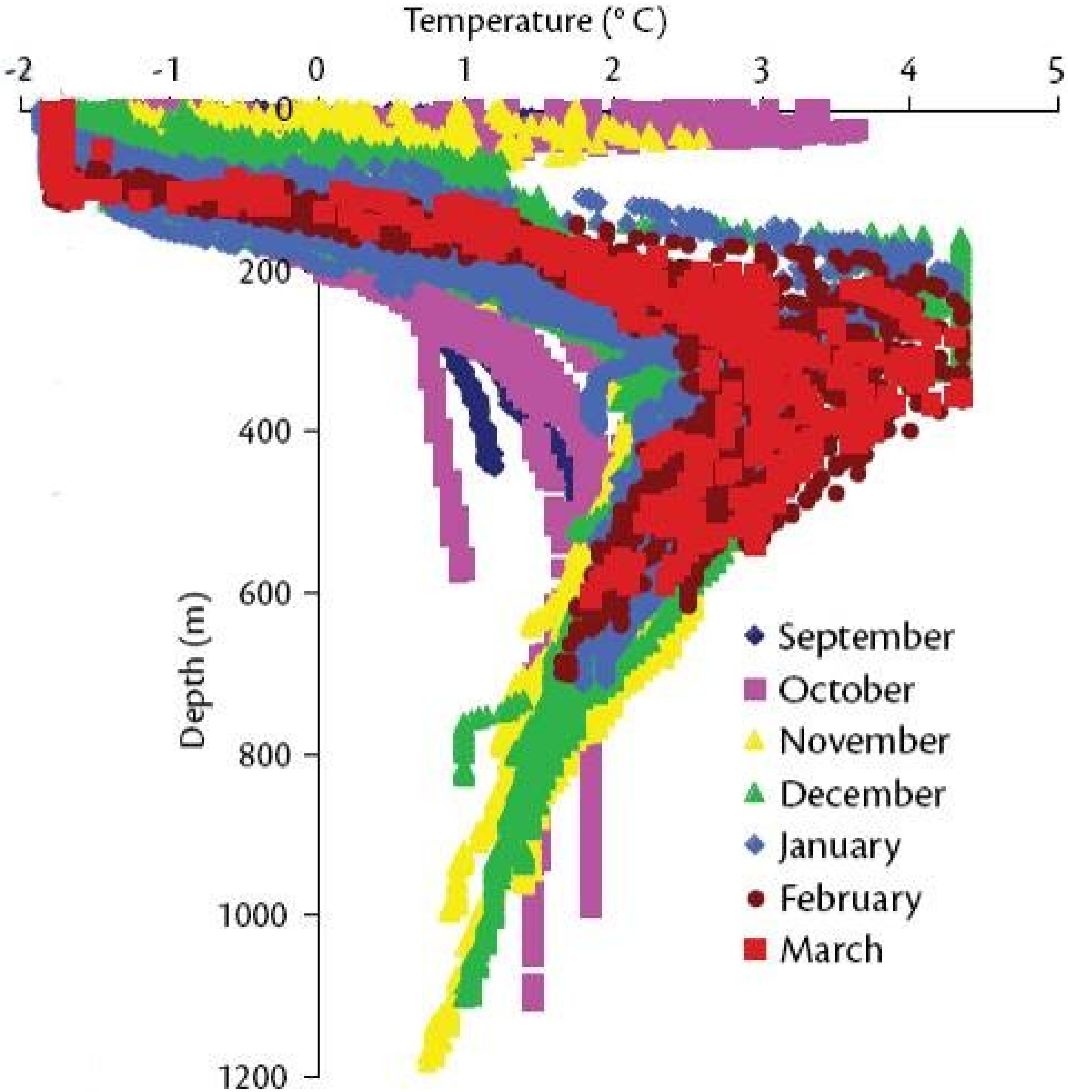
Laidre & Heide-Jorgensen, *Oceanograpy* 2007



N-Arctic “Bioprobes”

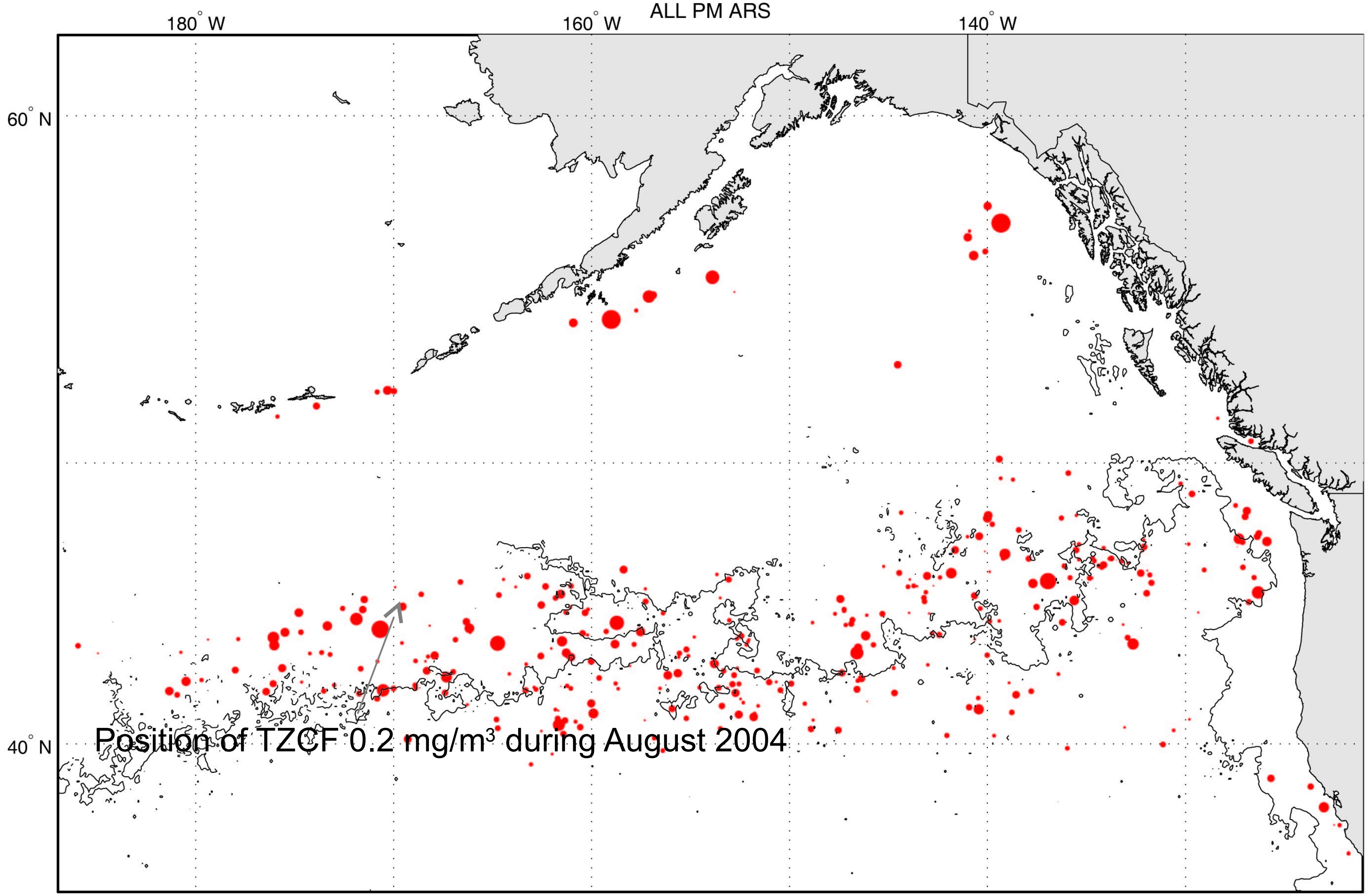
Laidre and Heide-Jørgensen
Greenland Institute of Natural Resources

Narwhals, Baffin Bay
Satellite tags



Integration with physical information:

Female Elephant Seal Area Restricted Searching Relative to Transition Zone Chlorophyll Front



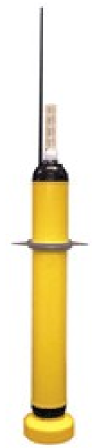
Red dots: where seals spent time searching

Simmons in prep

Merging Datasets

Argo

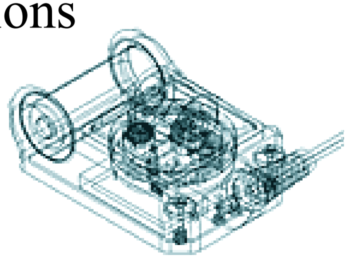
- higher accuracy
- higher vertical resolution
- every 10 days
- freely drifting
- down to 2000 dbar

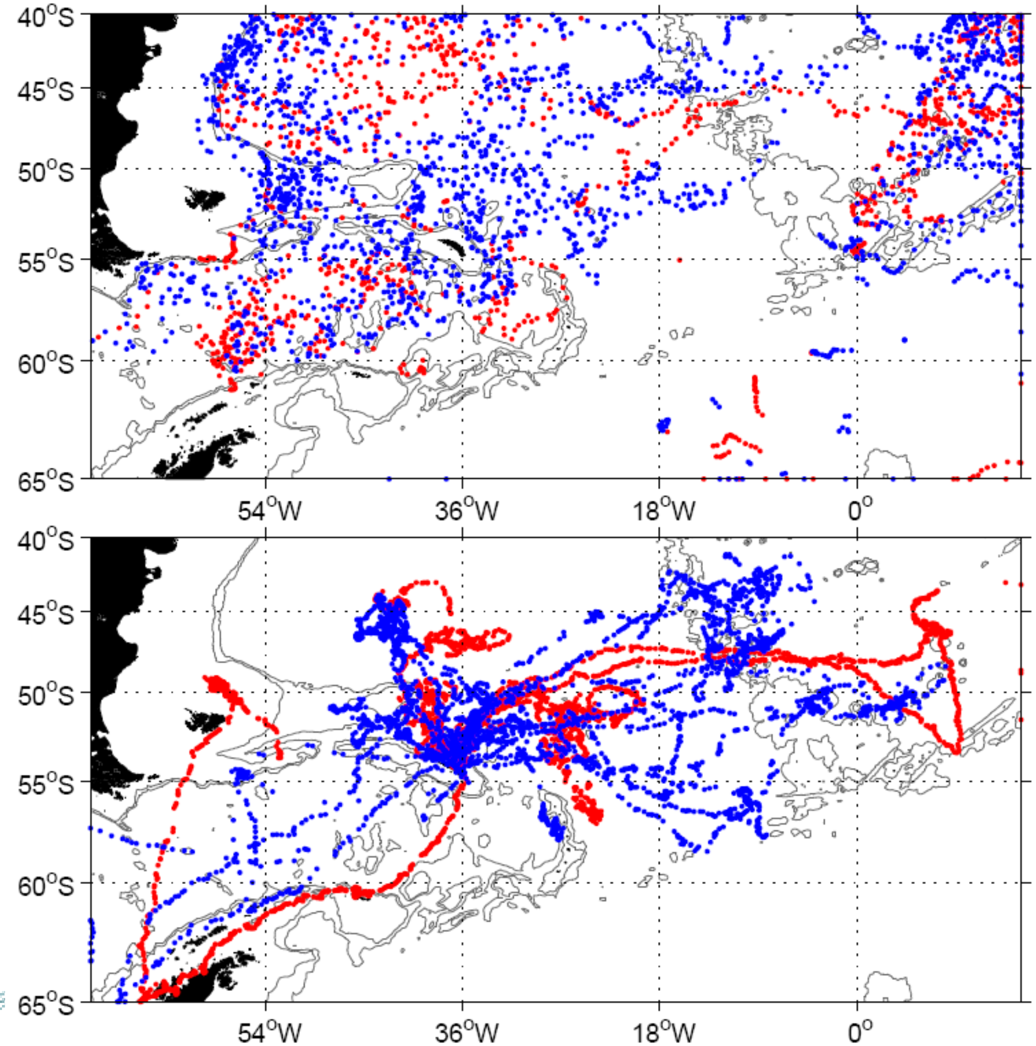


SEaOS

Southern Elephant Seals as Oceanographic Samplers

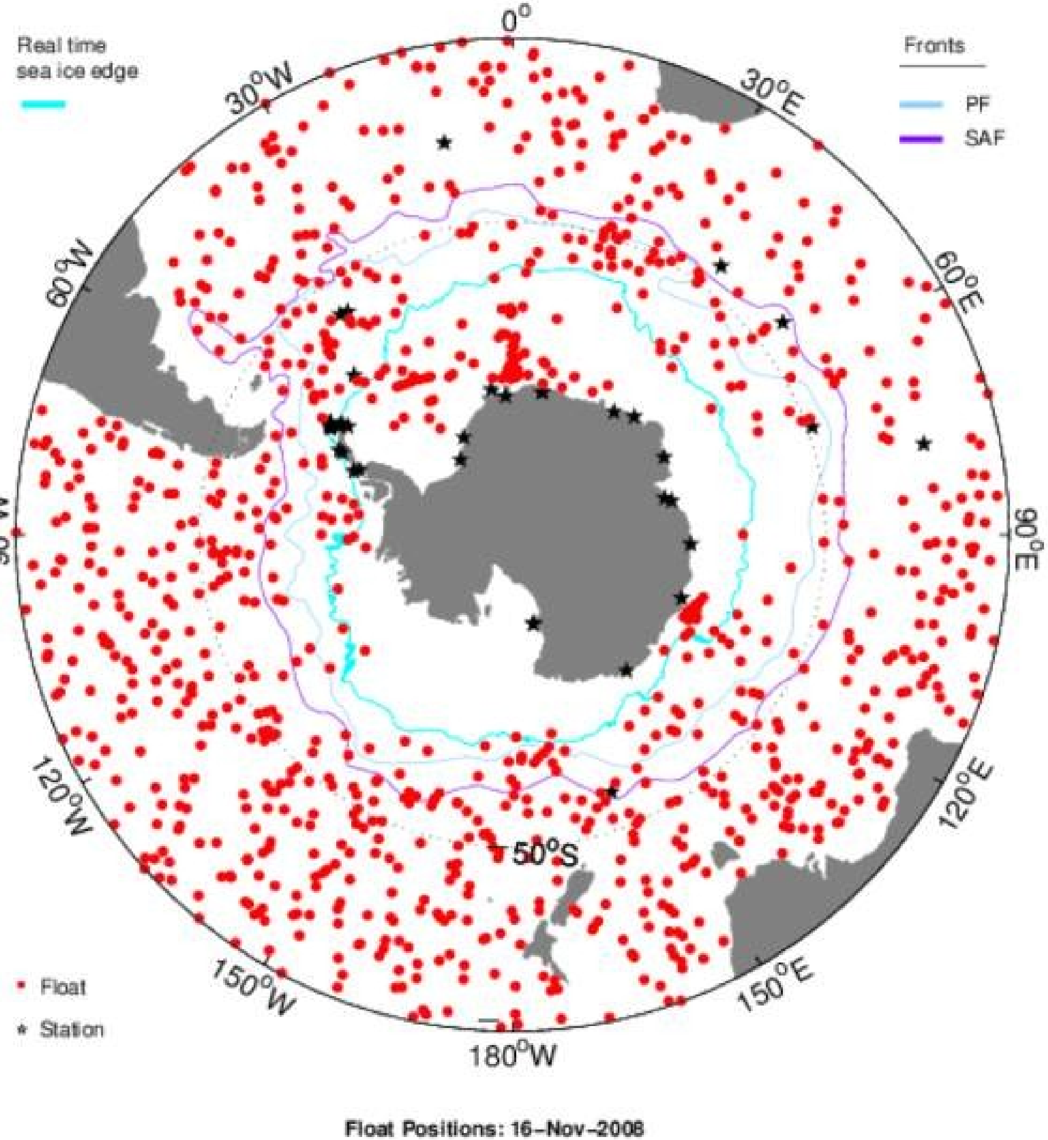
- higher temporal resolution (daily)
- higher spatial resolution (<50km)
- along animal migrations
- down to 2000 dbar





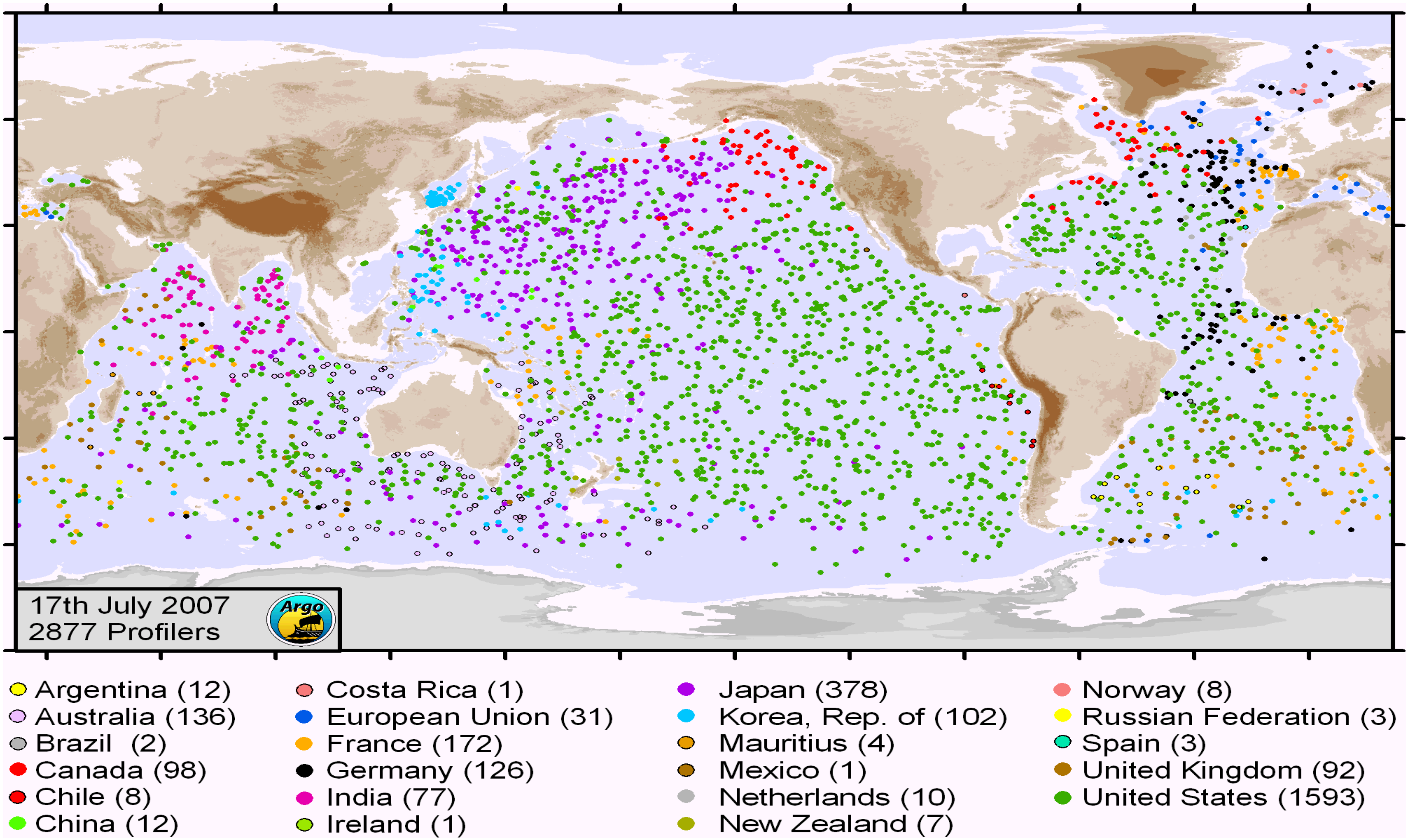
* 2004 * 2005

Argo



http://argo.ocean.fsu.edu/

ARGO: A Critical Observation System



Oceanography now: from research to operations

Operational oceanography is application of mature science in routine manner with rapid dissemination of results

Analogue: Weather forecasting is the operational side of the science of meteorology, a mature initiative (WMO)

Oceanography still has a long way to go along this road (JCOMM)

What international structures exist?

Intergovernmental Oceanographic Commission (UNESCO)

Group on Earth Observation (GEO)

POGO

GEO, the Group on Earth Observations

An Intergovernmental Organization with 78 Members and 57 Participating Organizations

What needs to be done?

Justify investment in the observing system through cost of not doing it

Advocate the observing system (POGO)

Emphasise the benefits to society (they are diffuse)

THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS

Observing the Oceans: Why & How?

Why? Original interest motivated by curiosity (Research Oceanography)

Why? Present interest stresses the societal benefits of sustained, routine observation (Operational Oceanography)

These two elements are intimately linked

How? Through an increasing variety of techniques whose outputs must be merged for visualisation and Interpretation

How? It needs inputs from experts in many fields (science, engineering, law, sociology, mathematics and statistics)

It is endlessly interesting

Meredith, BAS

What is GEO?

Group of Earth Observations

A coordinating body, at Ministerial level, to ensure development of the Global Earth Observation System of Systems (GEOSS)

Organised around nine themes or societal-benefit areas (disasters, health, energy, climate, water, weather, ecosystems, agriculture, biodiversity)

What is being done?

GEO & GEOSS

Aggregation of tasks within nine societal-benefit areas

Underfunded

Operational Context: Stewardship of the Ocean

- Global consensus: Management should have ecosystem basis, integrity of ecosystem should not be compromised.

- Requires a suite of Ecological Indicators as an aid to ecosystem-based management

- They are objective metrics for the pelagic ecosystem that can be applied serially, in operational mode, to detect changes that may occur in response to environmental perturbation

Remote sensing for Operational Metrics

- Meets requirements of speed, resolution, repeat frequency and cost-effectiveness
- Autotrophic biomass is an important ecosystem property
- Primary production fields can also be generated
- SST and chlorophyll obtainable at same resolution
- Can construct time series: seasonal dynamics can be quantified objectively
- Allows interannual comparisons

Some Ecological Indicators from Remote Sensing

Initiation of spring bloom

Timing of spring maximum

Total production in spring bloom

Initial slope, light-saturation curve

Particulate organic carbon

Carbon-to-chlorophyll ratio

Generalised phytoplankton loss rate

Spatial variance in biomass field

Phytoplankton functional types

Amplitude of spring bloom

Duration of spring bloom

Annual phytoplankton production

Assimilation number

Phytoplankton carbon

Phytoplankton growth rate

Integrated phytoplankton loss

Spatial variance in production field

Biogeochemical provinces

Platt and Sathyendranath, 2008

Complementarity of in situ and remotely-sensed data

- Remotely-sensed data can be used to construct time series
- Remotely-sensed time series provide a spatial context for fixed-station time series
- Remotely-sensed time series provide a basis to interpolate data from fixed-station time series
- In situ data invaluable for interpretation and validation of satellite data
- Remotely-sensed data complement and enhance the value of in situ time series data