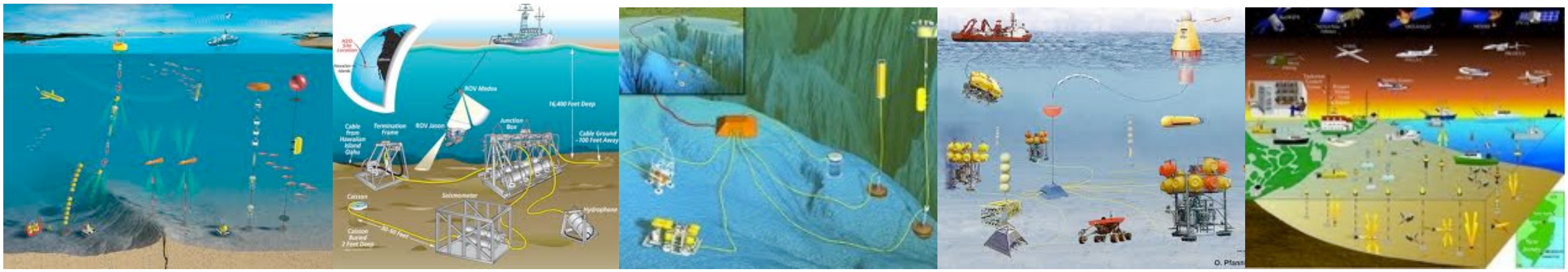
Towards Optics-Based Measurements in Ocean Observatories

Agenda:

- Evolution of Ocean Observatories; **Steven Ackleson**, Consortium for Ocean Leadership
- Data Assimilation and Modeling; **Bob Arnone**, University of Southern Mississippi
- Modern Observatory Operations; **Collin Roesler**, Bowdoin College
- Systematic Approach to Maintaining High Quality Bio-optical Data Streams in a Coastal Observing System; **Lesley Clementson**, CSIRO
- ARGO System of Profiling Drifters; **Emmanuel Boss**, University of Maine
- Data Quality Control; **Jeremy Werdell**, National Aeronautics and Space Administration

Funding graciously supplied by the Marine Alliance for Science & Technology for Scotland

O•cean Ob•serv•a•to•ry (**oh**-sh*uh*'n *uh*'b-**zur**-v*uh*-tawr-ee)



- **Complex, interdisciplinary set of observations**
- **Continuous presence of robotic, autonomous systems**
- **Broad range of temporal and spatial scales**
- **Free and timely (often real-time) access to data**

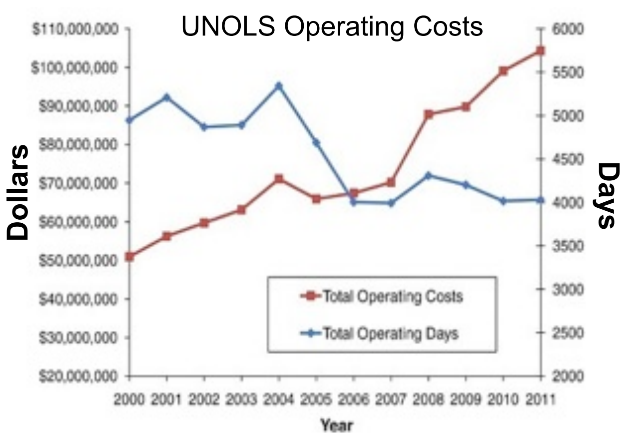
Ocean Observing Time Series Activities

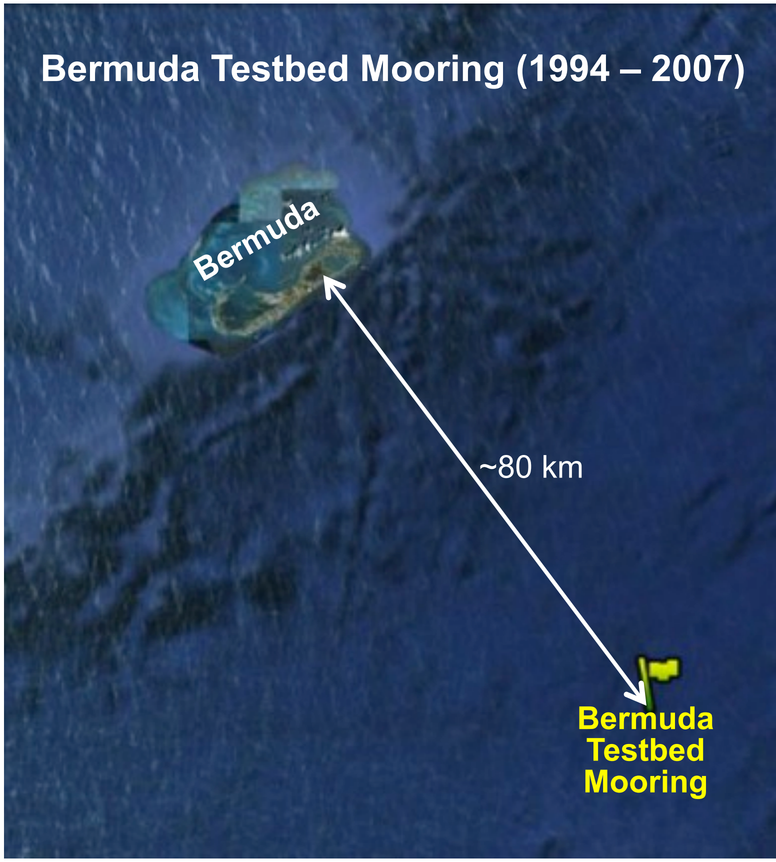
- 1884 Western Channel Biological Observations– English Channel — 1980 Western Channel Observatory
- 1931 Continuous Plankton Recorder Surveys – North Sea and North Atlantic
- 1948 Ocean Weather Station Mike – N. Atlantic
- 1949 CalCOFI Surveys – Southern California Coast
- 1949 Ocean Weather Station Papa / Line P – N. Pacific
- Hydrostation S – Bermuda, Western Atlantic 1954
- Helgoland Road Time-Series Station – North Sea 1962
- Ocean Observing Satellites – Global Ocean 1967
- Tropical Atmosphere Ocean Array (TAO/TRION) – Tropical Pacific 1985
- Bermuda Atlantic Time Series (BATS) – N. Atlantic Gyre 1988
- Hawaiian Ocean Time Series (HOTS) – Central N. Pacific 1988
- Dynamics of Atmospheric Fluxes in the Mediterranean Sea (DYFAMED) – Ligurian Sea 1988
- Ocean Acquisition System for Interdisciplinary Science (OASIS) – Monterrey Bay 1989
- Porcupine Abyssal Plain(PAP Site) – N. Atlantic 1989
- Cariaco Time Series Project – Caribbean Sea 1995
- Indian Ocean Observing System (NIOT/OOS)– Indian Ocean 1996
- Pilot Research Moored Array in the Tropical Atlantic (PIRATA) – Tropical Atlantic 1997
- Indian Ocean Monsoon Analysis & Prediction Array (RAMA) – Tropical Indian Ocean 2000
- Global Profiling Float Array (Argo) - Global 2000
- Irish Sea Coastal Observatory – Irish Sea 2001
- Northwest Tropical Atlantic Station (NTAS) – Tropical Atlantic 2001
- Line W/Station W – N. Atlantic 2001
- Central Irminger Sea – N. Atlantic 2002
- E2-M3A – Adriatic Sea, Mediterranean 2002
- Cyprus Coastal Ocean Observing System (CYCOFOS) – Eastern Mediterranean 2002
- Gulf of Oman Cabled Observatory– Gulf of Oman 2005
- Tropical Eastern North Atlantic Time Series Observatory (TENATSO)– Tropical E. Atlantic 2006
- Integrated Ocean Observing System (IOOS) – US Coastal 2007
- Integrated Marine Observing System (IMOS) - Australia 2007
- Poseidon E1-M3A – Aegean Sea/ Mediterranean Sea 2007
- Monterrey Accelerated Research System (MARS) – Monterrey Bay, CA 2008
- Neptune Canada – Juan De Fuca Ridge 2009
- Dense Ocean-floor Observatory Network for Earthquakes and Tsunamis (DONET) – NW Pacific Floor 2010
- Tasman Bay (TASCAM) – New Zealand 2011
- China – East China Sea 2011
- Arctic Cabled Observatory– Cambridge Bay, Canada 2012
- Ocean Observatories Initiative (OOI) – US Coastal & Global Arrays 2015

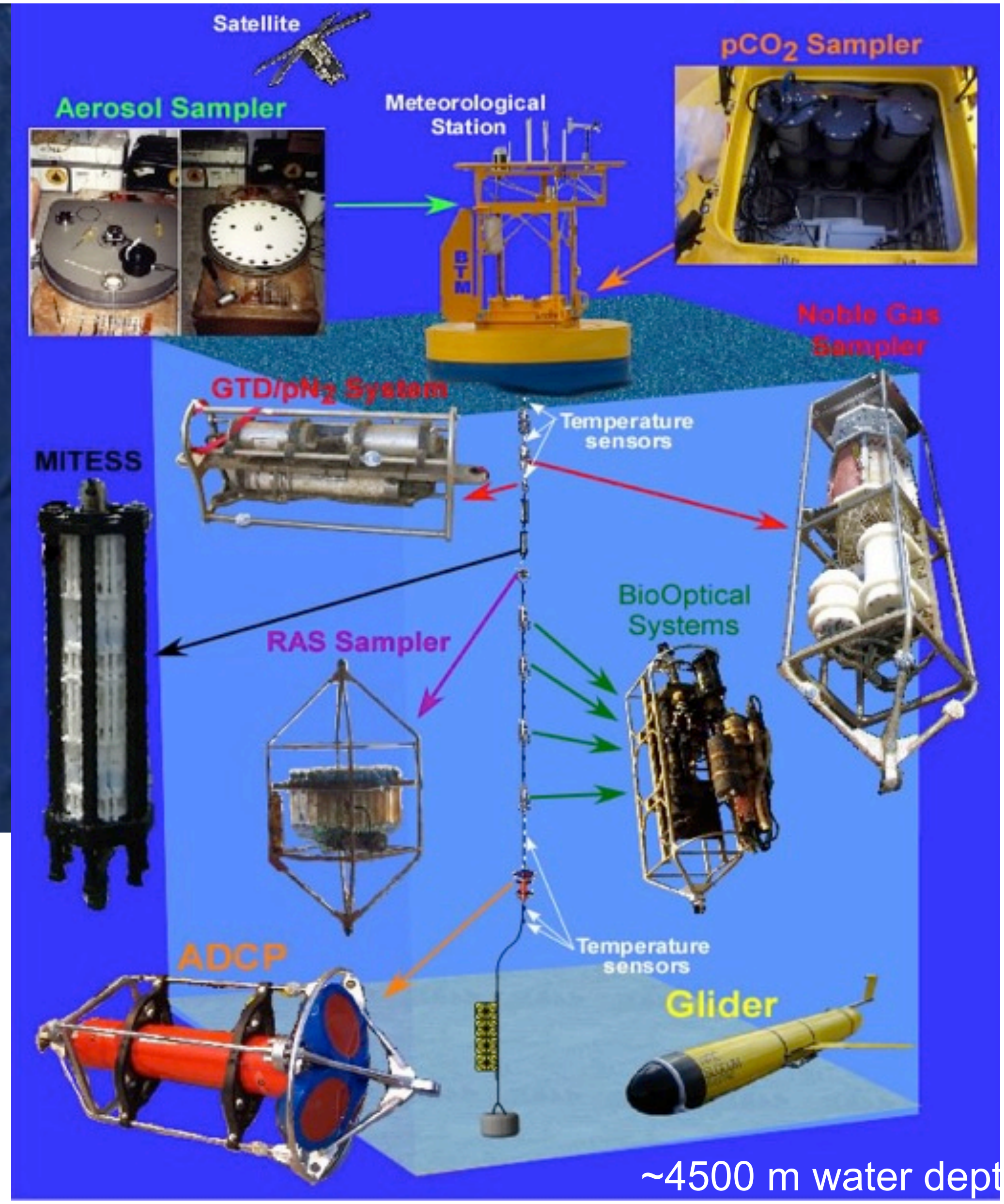
1930 1940 1950 1960 1970 1980 1990 2000 2010

Motivations:

- Long-term monitoring
- Interdisciplinary problems
- Short latencies
- Diverse user groups
- Extreme conditions
- Cost





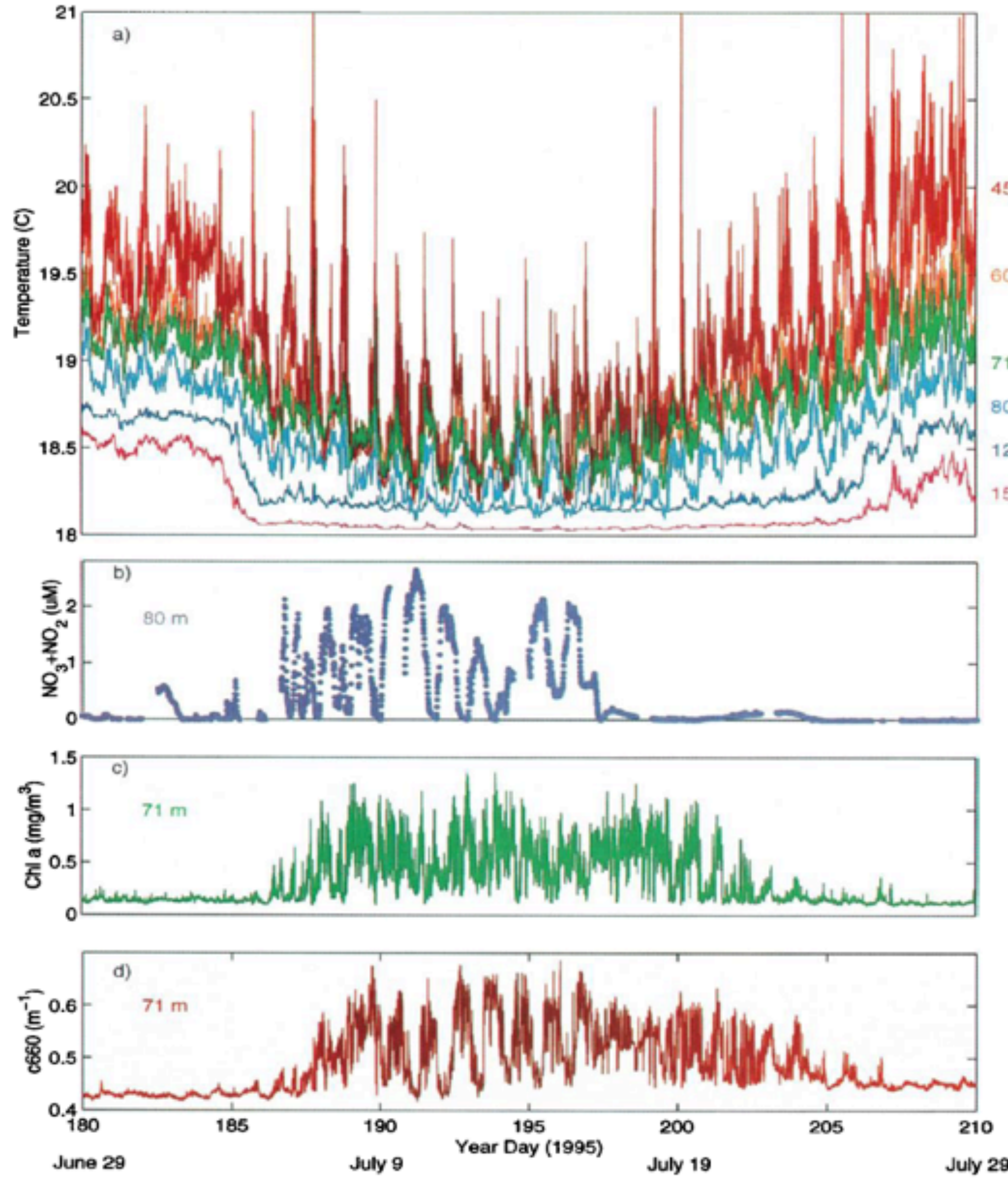


Tommy Dickey, UCSB

- Deep-water platform for community-wide development and testing of interdisciplinary sensors and systems for observatories
- Time series in support of Bermuda Atlantic Time Series (BATS)

Bermuda Test Bed Mooring Example: The Passage of a Mesoscale Eddy

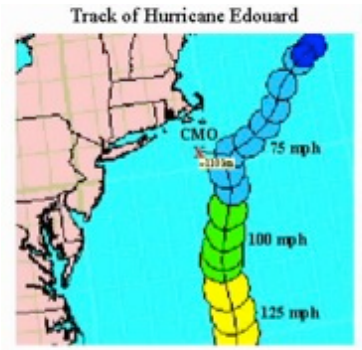
- 30-days centered on 14 July 1995
- Isotherm doming
- Cold surface
- Warm anomaly between 50 and 1000 m water depth
- Peak nitrate near 3.0 mmol at 80 m
- Peak Chl-*a* of 1.4 mg m^{-3} at 71 m (at the time, highest recorded since BATS began in 1988)
- Increase in beam c from 0.42 m^{-1} to 0.7 m^{-1}
- 25 to 30 m shoaling of 1% light level
- Doppler shift from inertial period (22.8 hr) to 25.2 hr
- Inertial pumping of cold, nutrient rich waters to euphotic zone
- Silicic acid depleted (unprecedented observation)
- Estimated new production of 630 mg C m^{-2} d^{-1}

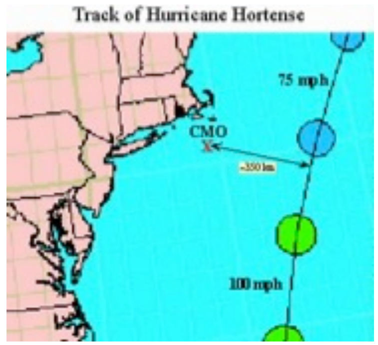


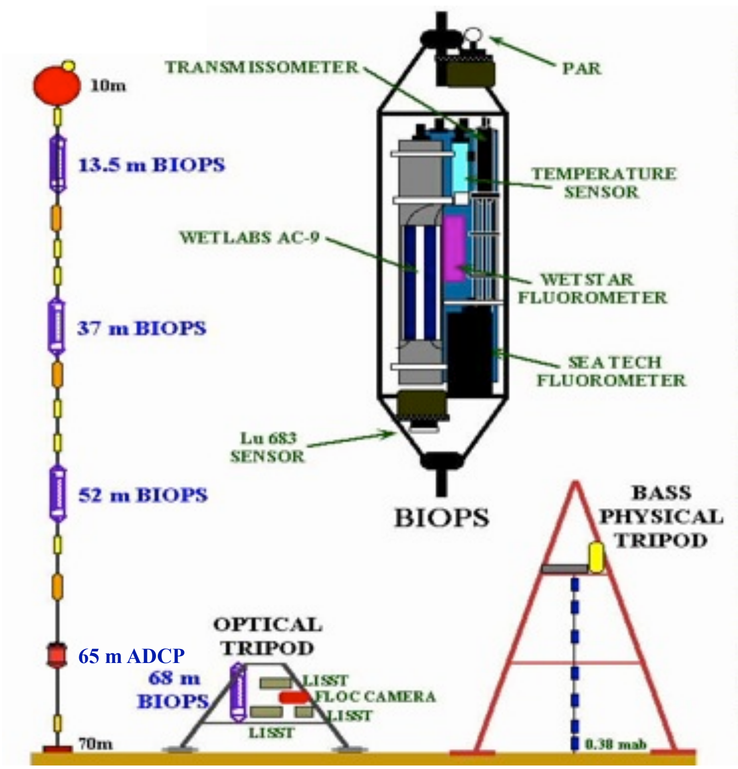
Reference:

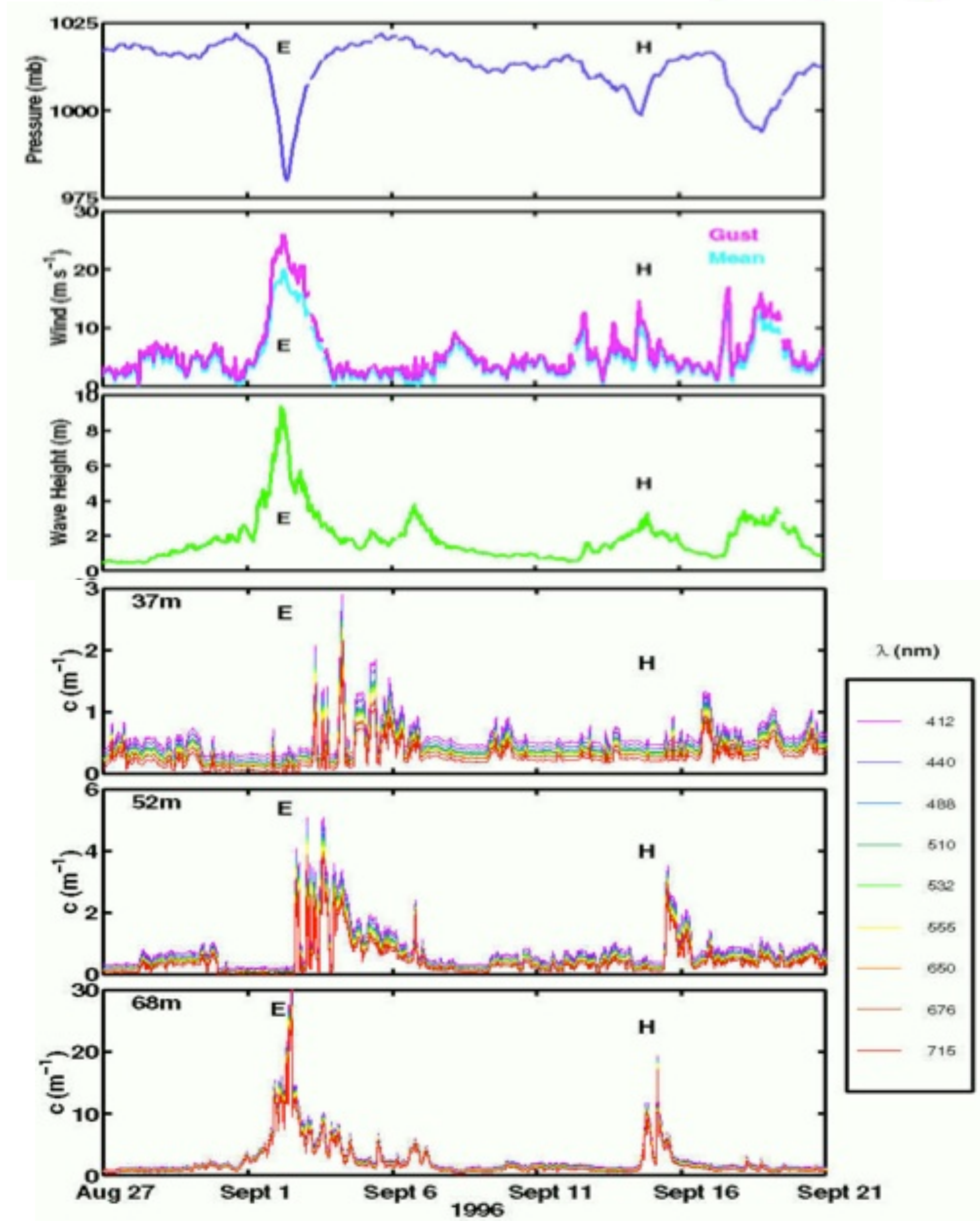
McNeil, J.D., H.W. Jannasch, T. Dickey, D. McGillicuddy, M. Brzezinski, and C. M. Sakamoto (1999) New chemical, bio-optical, and physical observations of upper ocean response to the passage of a mesoscale eddy off Bermuda, J. Geophys. Res., 104, 15,537-15,548.

Coastal Mixing and Optics (CMO)
07/1996 to 06/1997

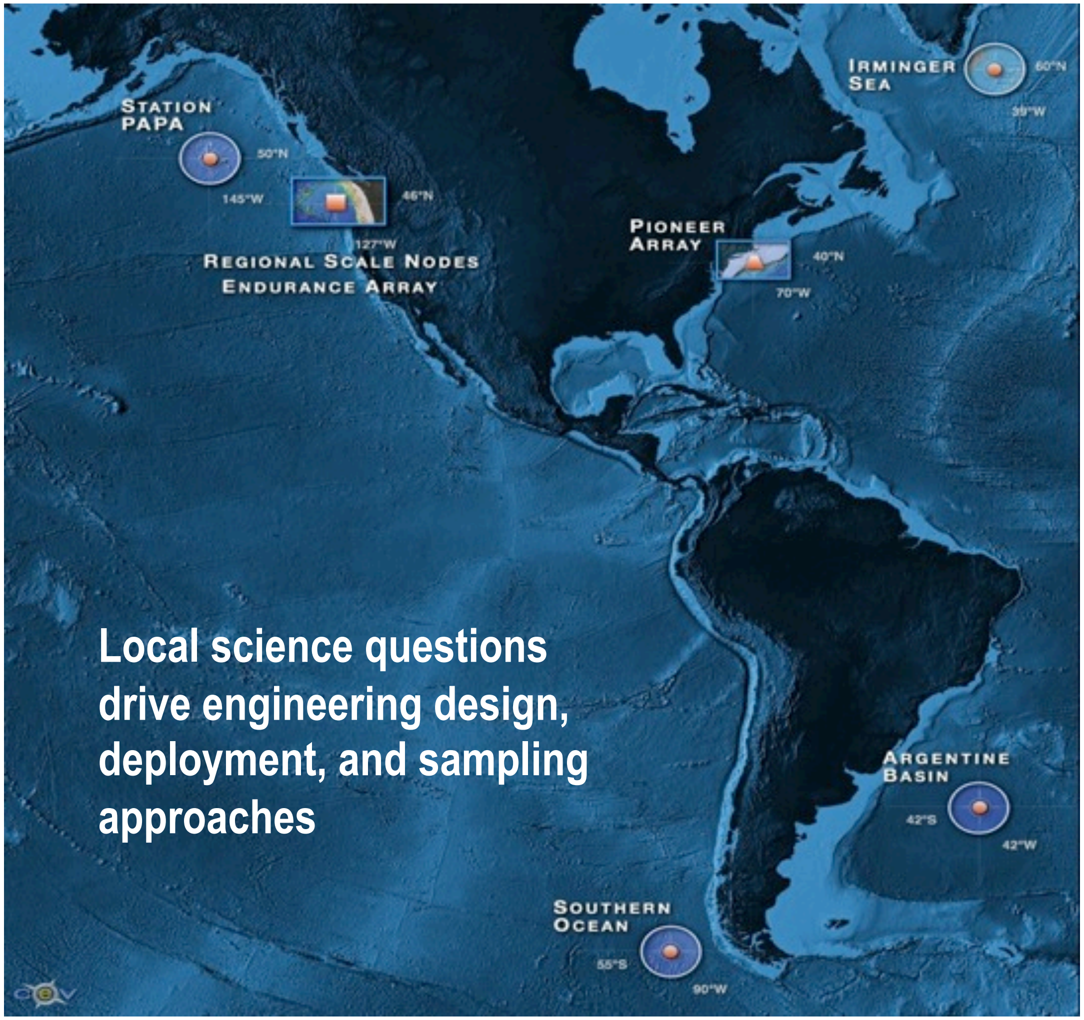








Ocean Observatories Initiative (OOI)



Four high latitude sites

Ocean Station Papa (NW Pacific)
Irminger Sea (North Atlantic)
Argentine Basin
Southern Ocean

Two coastal ocean networks

Endurance Array (Oregon & Washington)
Pioneer Array (North Atlantic Bight)

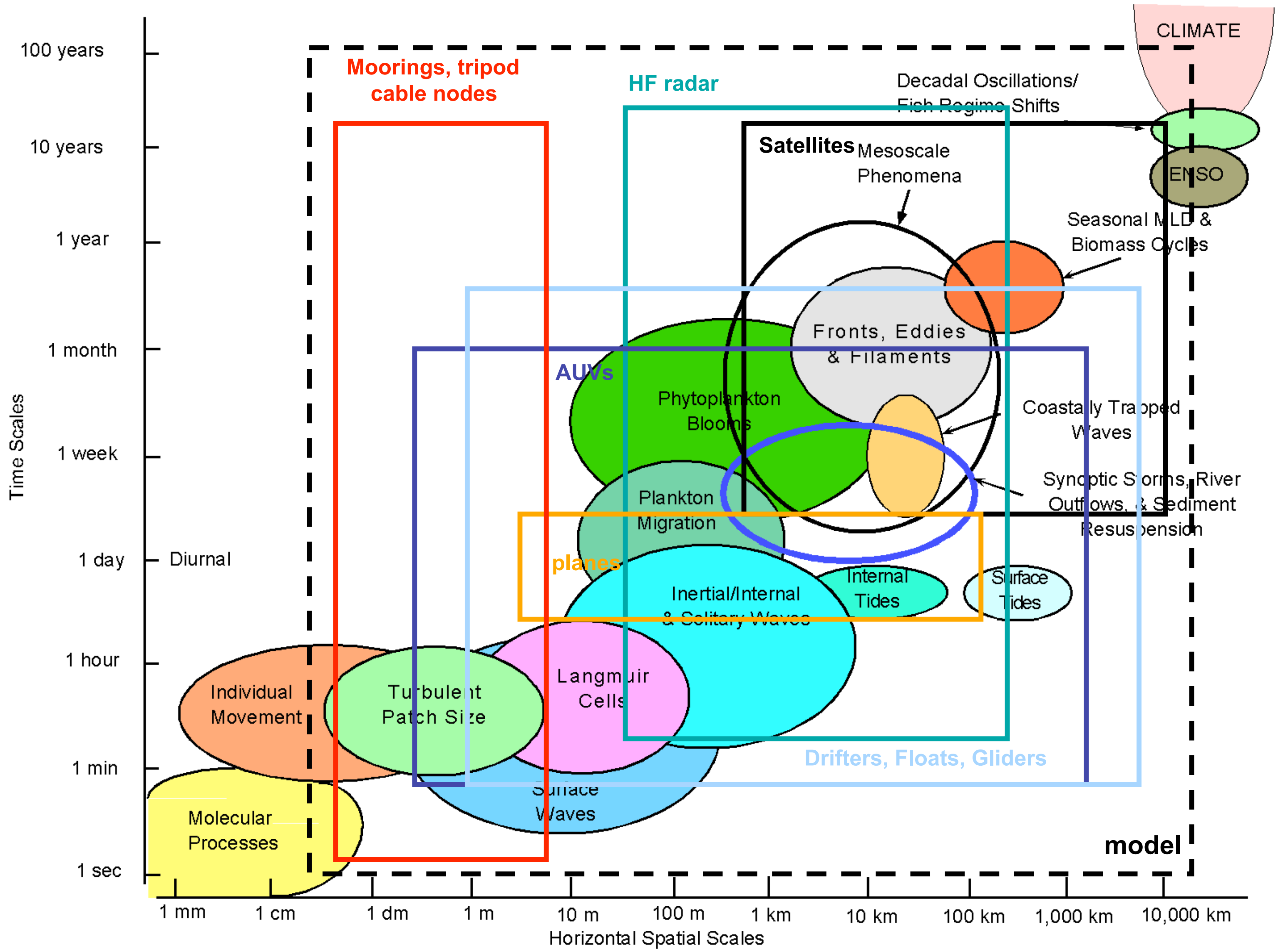
Regional scale array

Axial Seamount (Juan De Fuca Plate)
Fixed Moorings and Mobile Platforms

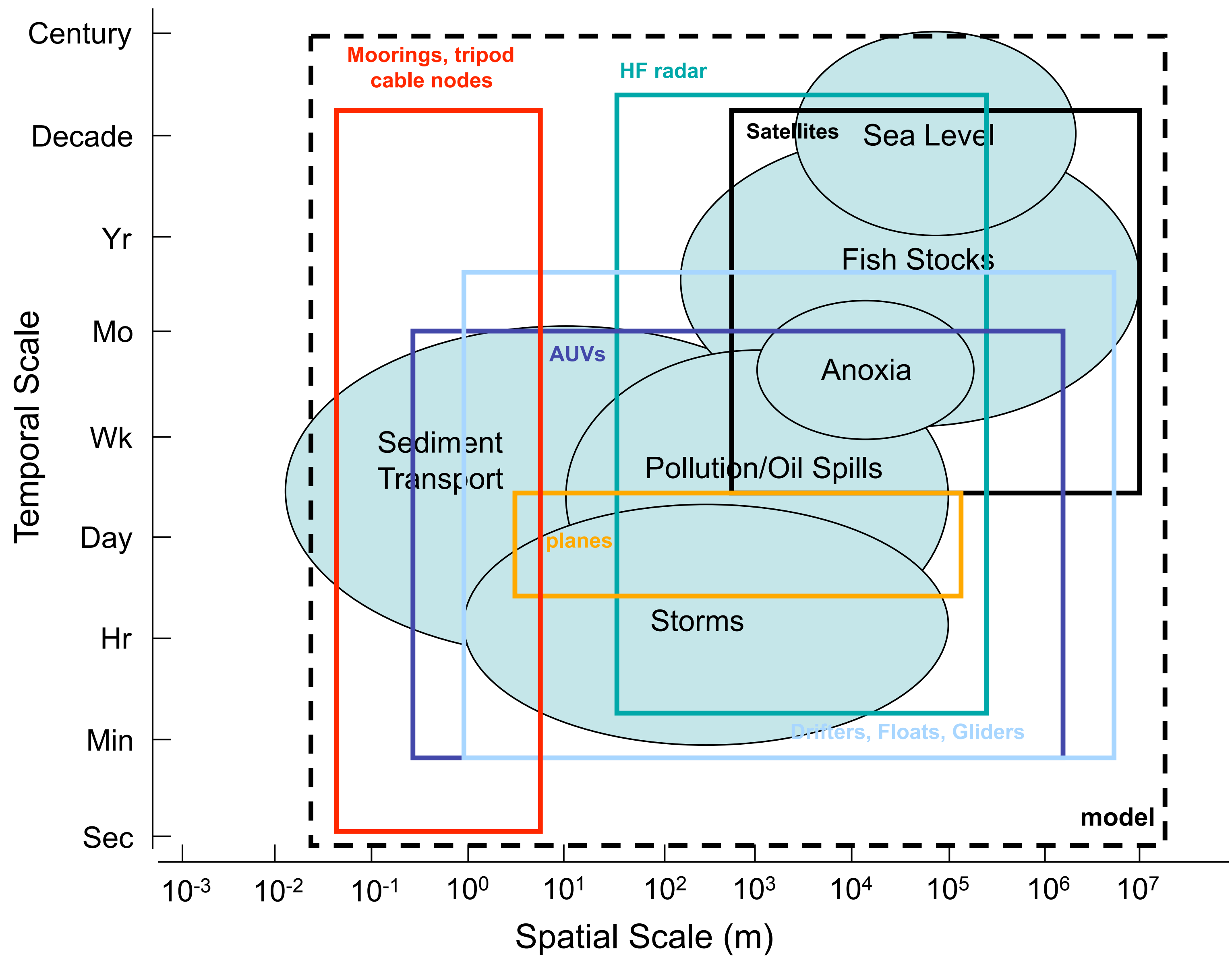
By The Numbers:

$386M Construction Project (MREFC)
6 Regional Arrays
48 Instrument Types
764 Simultaneously Deployed Instruments
78 Data Products
25-30 Year Operational Lifetime

Multi-platform approach for observing scales ranging over 10 orders of magnitude

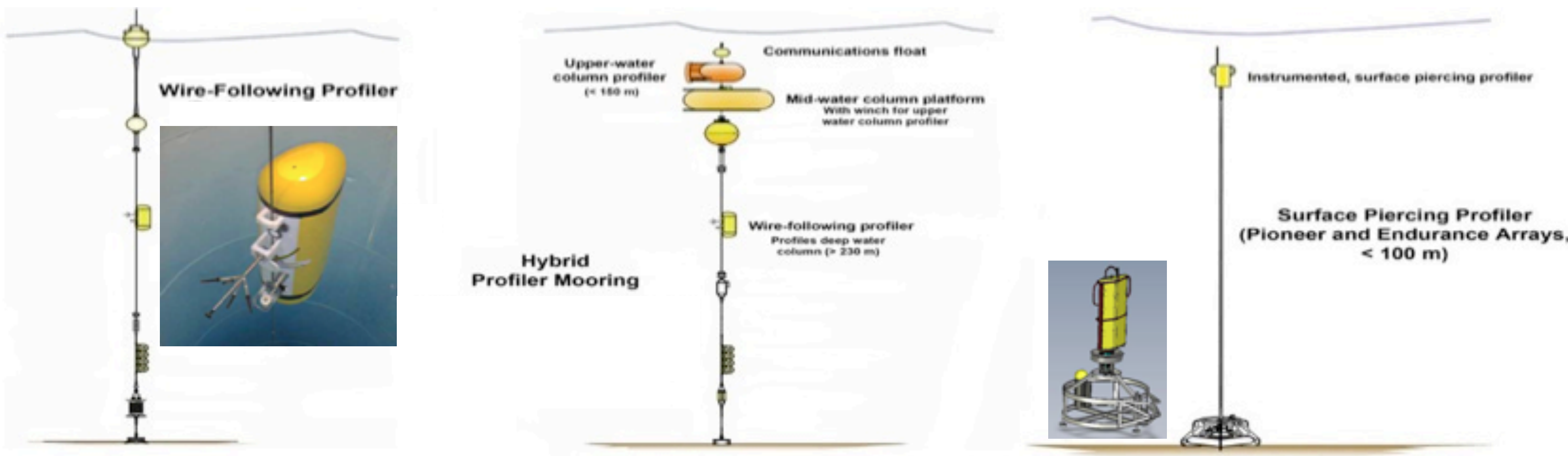


Ocean Observing Scales Relative to Modern Societal Issues

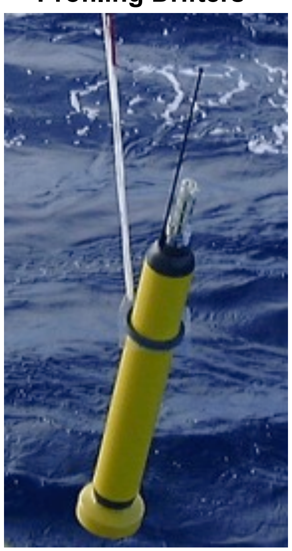


Mobile Platforms

Moored Profilers



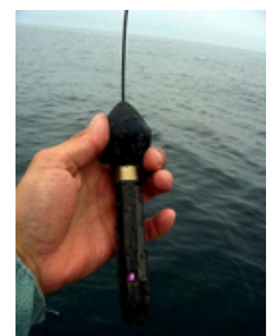
Profiling Drifters



Autonomous Underwater Vehicles

Underwater Gliders

Marine Mammals

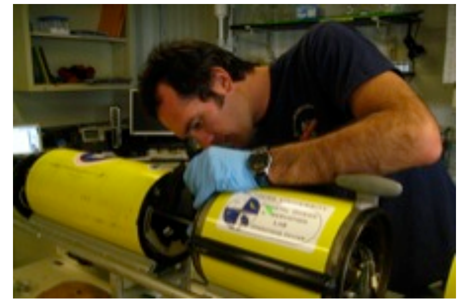


Sensors

The need for routine observations (key variables) continues to drive sensor technology towards cheaper, simpler, and more robust instruments.

SeaTech Transmissometer

Wet Labs Seastar Transmissometer

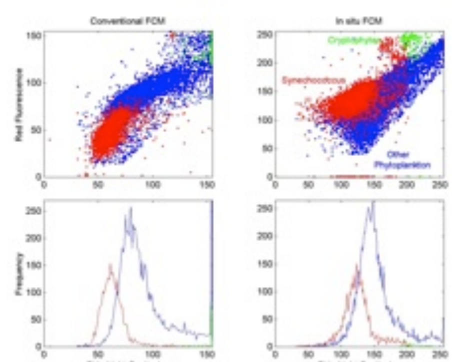


Glider Payload Bay

Continued to invest in new technologies that are capable of revealing poorly understood aspects of the ocean environment that are, consequently, oversimplified within predictive models.

Desktop Flow Cytometer

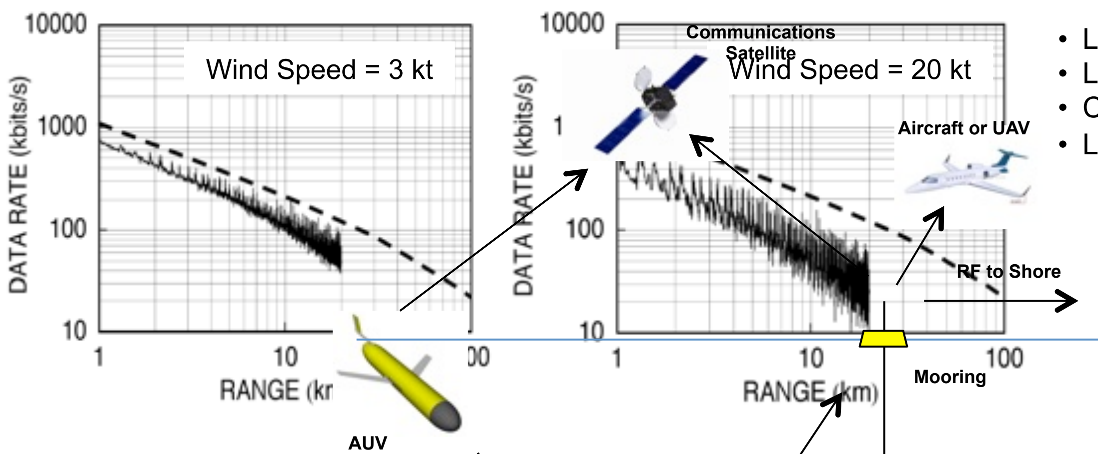
In Situ Flow Cytometer (Sosik & Olson)



Underwater Communications

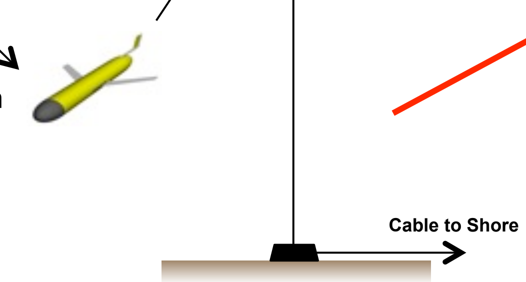
Data transmission, especially underwater, is and will continue to be a bottleneck for ocean observations due to power and environmental constraints

- **Acoustic:** characterized by water attenuation, path effects, and slow sound speed (1500 m/s)



  - Long transmission distance (>100 km)
  - Low transmission rate (< 100 kbits/s)
  - Commercially-available
  - Limited to underwater transmission

- **Optical**: characterized primarily by water absorption
  - Short transmission distance (< 200 m)
  - Potentially > 10 Mbits/s
  - Potential through the surface transmission
  - Not commercially available yet



- **Mitigating Approaches**

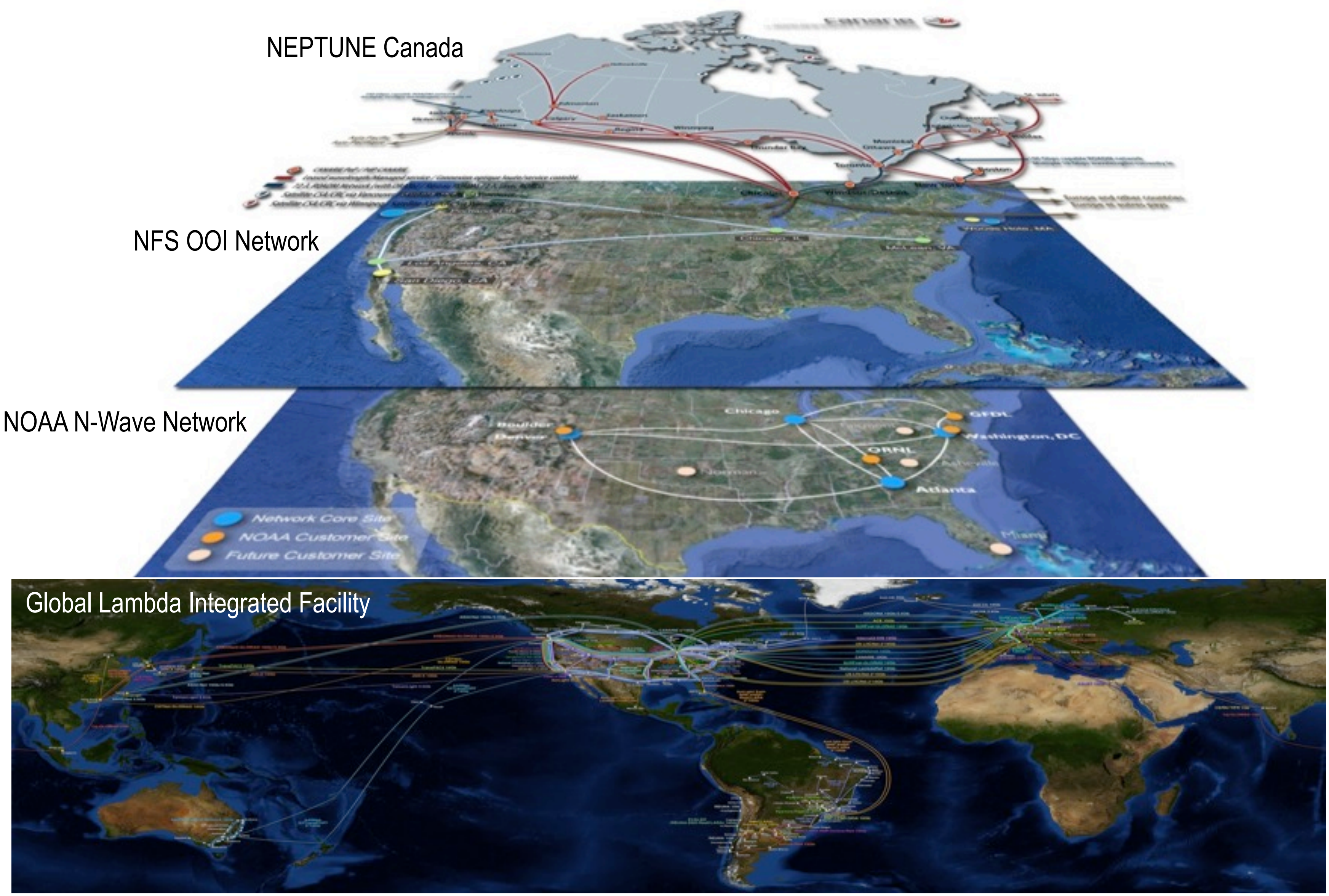
  In situ data analysis

  Intelligent observing systems (don't measure everything everywhere)

  Cabled observatories

Cyberinfrastructure

Data Discovery and Distribution



Emerging International Relationships and Governance

1940

1948: Ocean Weather Ships, *illustrated the power of international scientific collaboration*

1950

1950: World Meteorological Organization, *under UN, provided international framework for coordinating climate research.*

1957: International Geophysical Year, *set the president for free and timely data access*

1960

1960: Intergovernmental Oceanographic Commission, *under UN, provided international framework for coordinating ocean research.*

1960-78: Meteorological and Oceanographic Satellites, *provided global views of the Earth's natural systems for the first time.*

1970

1987: International Geosphere/Biosphere Program, *established to coordinate international efforts to determine the impact of human activities on natural processes.*

1980

1992: Global Ocean Observing System, *support office established under aegis of IOC and other international environmental groups.*

1990

1994: UNCLOS, *established an international legal framework defining ocean-related rights and responsibilities of nations.*

1999: Joint Commission for Oceanography and Marine Meteorology, *established by WMO and IOC to coordinate international activities in oceanographic and atmospheric research.*

2000

1999: OceanSITES, *international team established to coordinate deep-ocean observations within GOOS.*

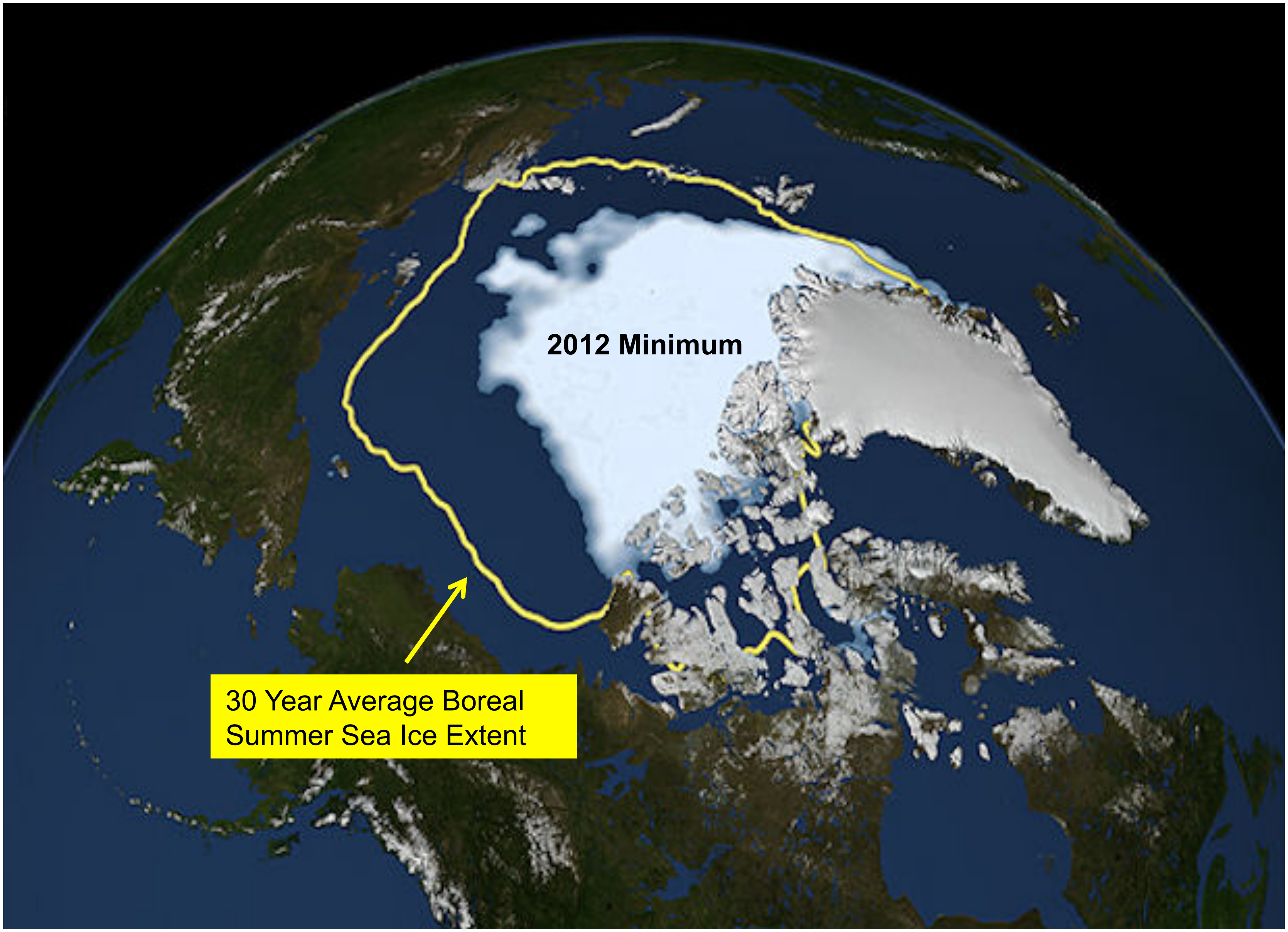
2005: Group on Earth Observations, *established in response to the 2002 World Summit on Sustainable Development, conducting a 10-year effort to develop an integrated Earth observing system of systems (GEOSS).*

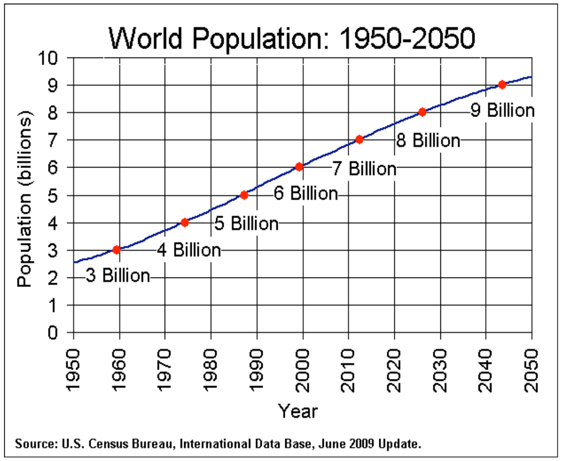
2010

2007-8: International Polar Year, *encouraged continued international cooperation in high-latitude research in the context of climate change.*

2009: OceanObs 09, i*nternational community agreement on GOOS decadal vision; draft Framework for Ocean Observing*

Rapid changes in the natural environment ...

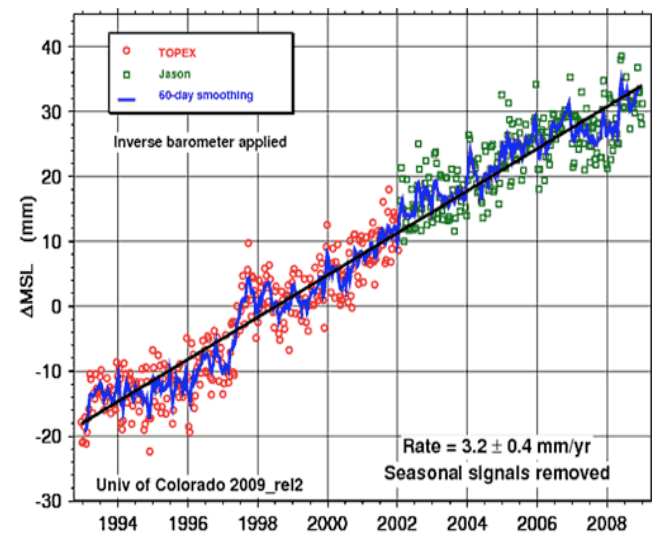




Global population is increasing at a rate of 200 million people per day or 1 billion every 13 years.

- **50% of the global population lives within 200 km of the coast**
- **Ocean as a source of increasingly scarce resources:**

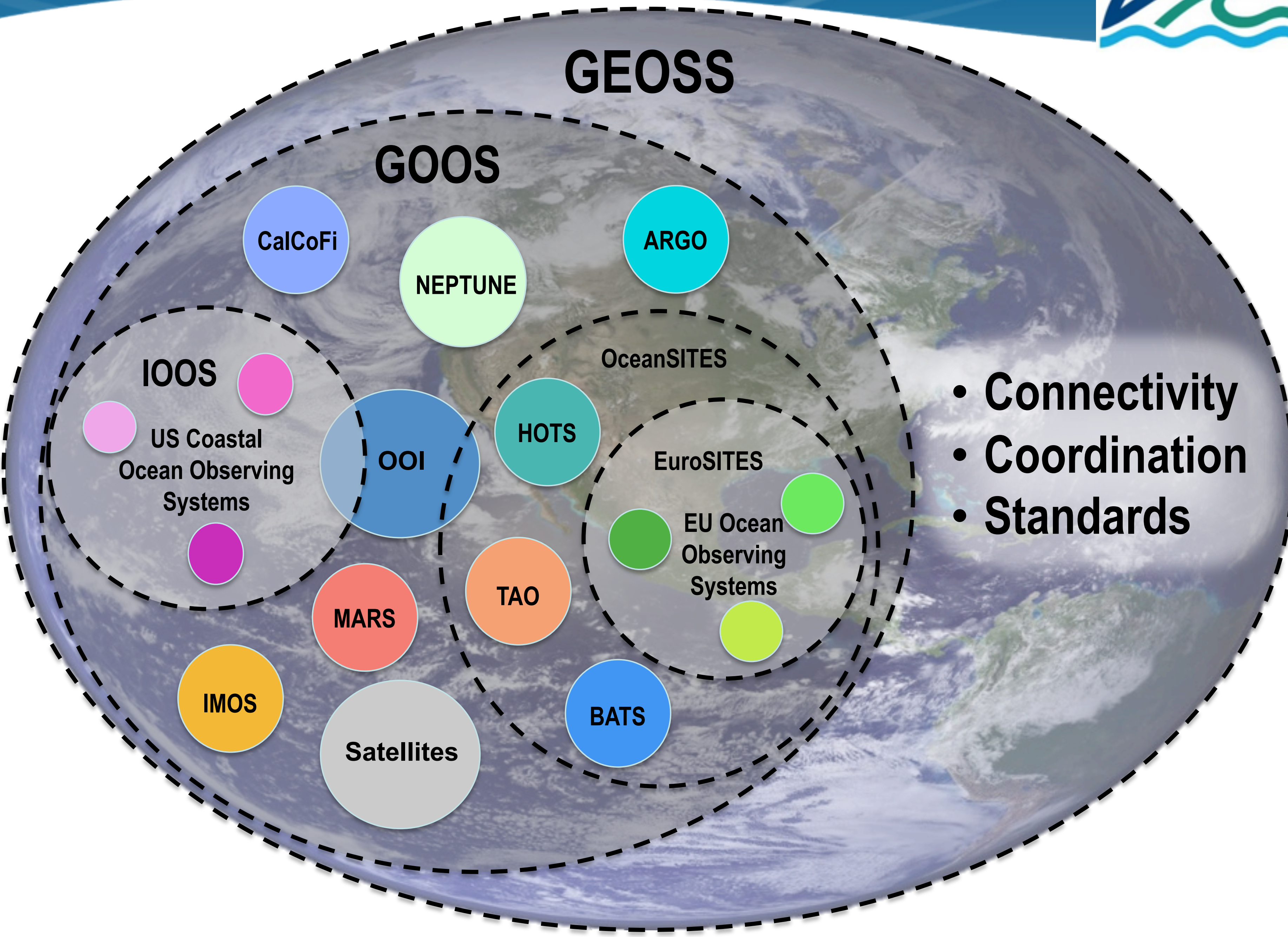
  - Food: Globally, seafood provides more than 1.5 billion people with almost 20 percent of their average per-capita intake of animal protein and 3 billion people with at least 15 percent of animal protein.
  - Energy: hydrocarbon and alternate sources (wind and hydrokinetic)
  - Minerals



- **Marine management strategies require science-based decisions that consider entire ecosystem (land, ocean, and atmosphere).**

Societal adjustment will likely be painful!

Then		Now
	→	**Coastal Marine Spatial Planning**



- Connectivity
- Coordination
- Standards

Future Ocean Observatory Trends

- Networked systems (global ocean, atmosphere, terrestrial)
- International standards
- Increasing complexity
- Increasing system autonomy
- Observations increasingly defined by societal needs and assimilated into Earth systems models