A Synthesis Plan for the Future Ocean Observing System

Some thoughts to stimulate discussion…….

R. Weller

June 5, 2007

A Synthesis (and Evolution) Plan for the Future Ocean Observing System

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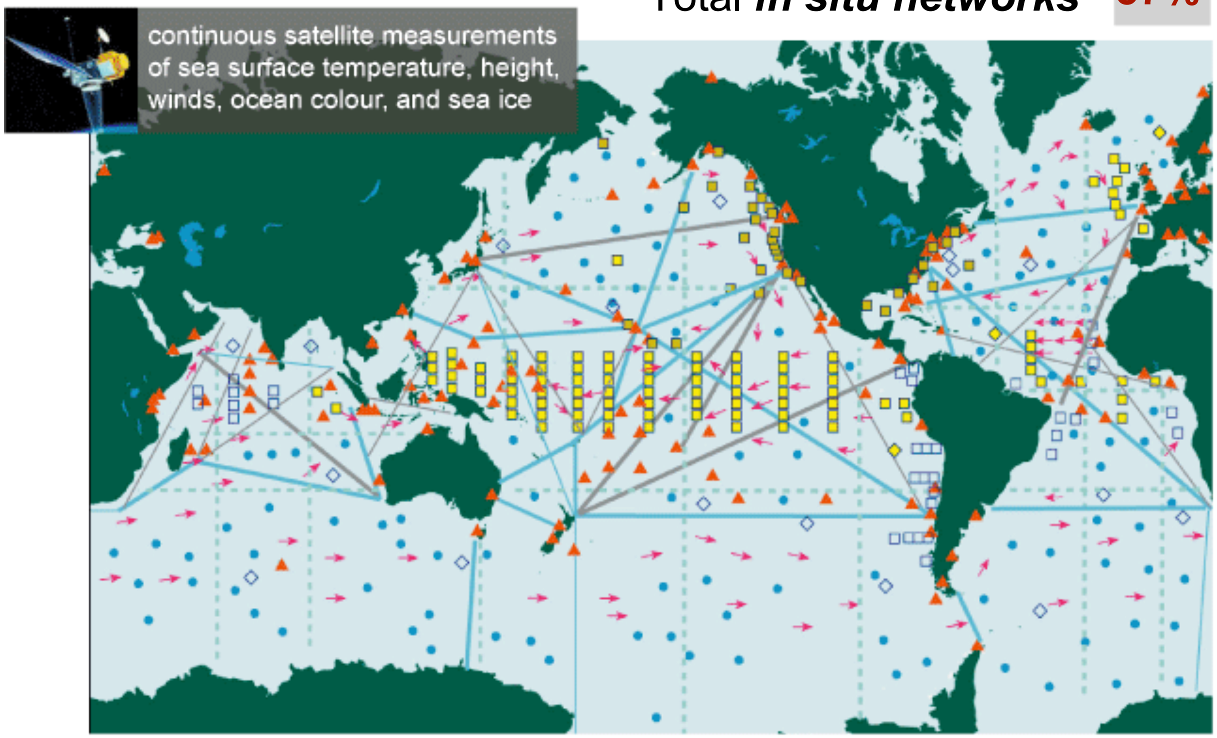
Initial Global Ocean Observing System for Climate

Status against the GCOS Implementation Plan and JCOMM targets

Total ***in situ* networks** 57% January 2007



57% **Surface measurements** from volunteer ships (VOSclim)

200 ships in pilot project

100% Global **drifting surface buoy** array

5° resolution array: 1250 floats

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170 real-time reporting gauges

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51 lines occupied

91% Argo **profiling float** network

3° resolution array: 3000 floats

43% Repeat **hydrography** and **carbon inventory**

Full ocean survey in 10 years

Reference time series 21%

58 sites

48% Global **reference mooring** network

29 moorings planned

66% Global tropical **moored buoy** network

119 moorings planned

- A total of 5635 platforms are maintained globally.
- Of these, 2541 are sponsored by NOAA.

GCOS GOOS jcomm OCEANOGRAPHY & MARINE METEOROLOGY

Annual State of the Climate report (SOTC)

3. GLOBAL OCEANS–J. M. LEVY, ED.

a. Overview–J. M. Levy

As the global ocean observing system matures, climatologies of essential climate variables are growing more robust, as are observations of anomalous departures that shed light on the evolving behavior of the coupled ocean-atmosphere system. Year 2006 exhibited numerous anomalies of interest:

- Global sea surface temperature anomalies were primarily positive, notably so in boreal summer in the N. Atlantic and in the latter part of the year in the central and eastern equatorial Pacific associated with the 2006 El Niño.
- Mean of latent plus sensible heat flux was similar to that in 2005; total flux in both years were at the high end of a long-term upward trend that started in 1977-1978. Significant heat flux anomalies were observed in the regions of the 2006 El Niño and Indian Ocean dipole mode event.
- Global sea surface salinity anomalies accentuated climatological patterns: fresh water regions were fresher, salty regions were saltier. The subpolar N. Atlantic and Nordic seas were anomalously salty in 2006.
- Dramatic westward surface current anomalies associated with the development of El Niño were observed late in the year in the tropical Pacific Ocean, while seasonal reversal of currents were particularly pronounced on the equator in the Atlantic Ocean. Exchange of water between the South and North Atlantic Oceans was weaker than normal.
- The meridional overturning circulation (MOC)

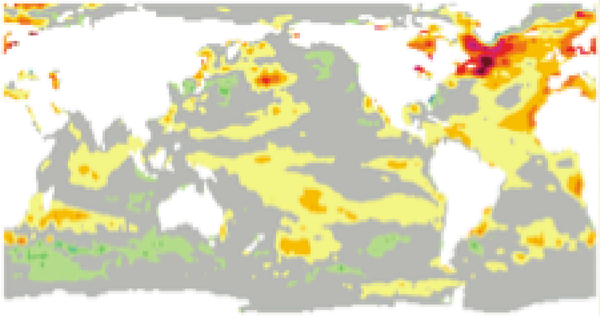


Fig. 3.1. Mean and standard deviation of monthly SST anomalies for 2006 on a 1° spatial grid. The anomalies are computed relative to a 1971-2000 base period. The contour interval is 0.3°C; the 0 contour is not shown. AVHRR satellite data are used.

pogenic CO2 uptake continues to exceed Pacific Ocean uptake.

- Global annual average ocean color anomalies were not markedly different from those observed in the satellite record over the past decade. However, anomalies in the Niño 3.4 region were indicative of a 2006 El Niño that was stronger (considerably weaker) than that of 2002-2003 (1997-1998).

b. Temperature

1) Sea surface temperature–R. W. Reynolds

The SSTs for 2006 are shown as monthly fields interpolated from the weekly 1° optimum interpolation (OI) analyses of Reynolds et al. (2002). All results presented here are shown as anomalies defined as differences from a 1971-2002 climatological base period described by Xue et al. (2003).

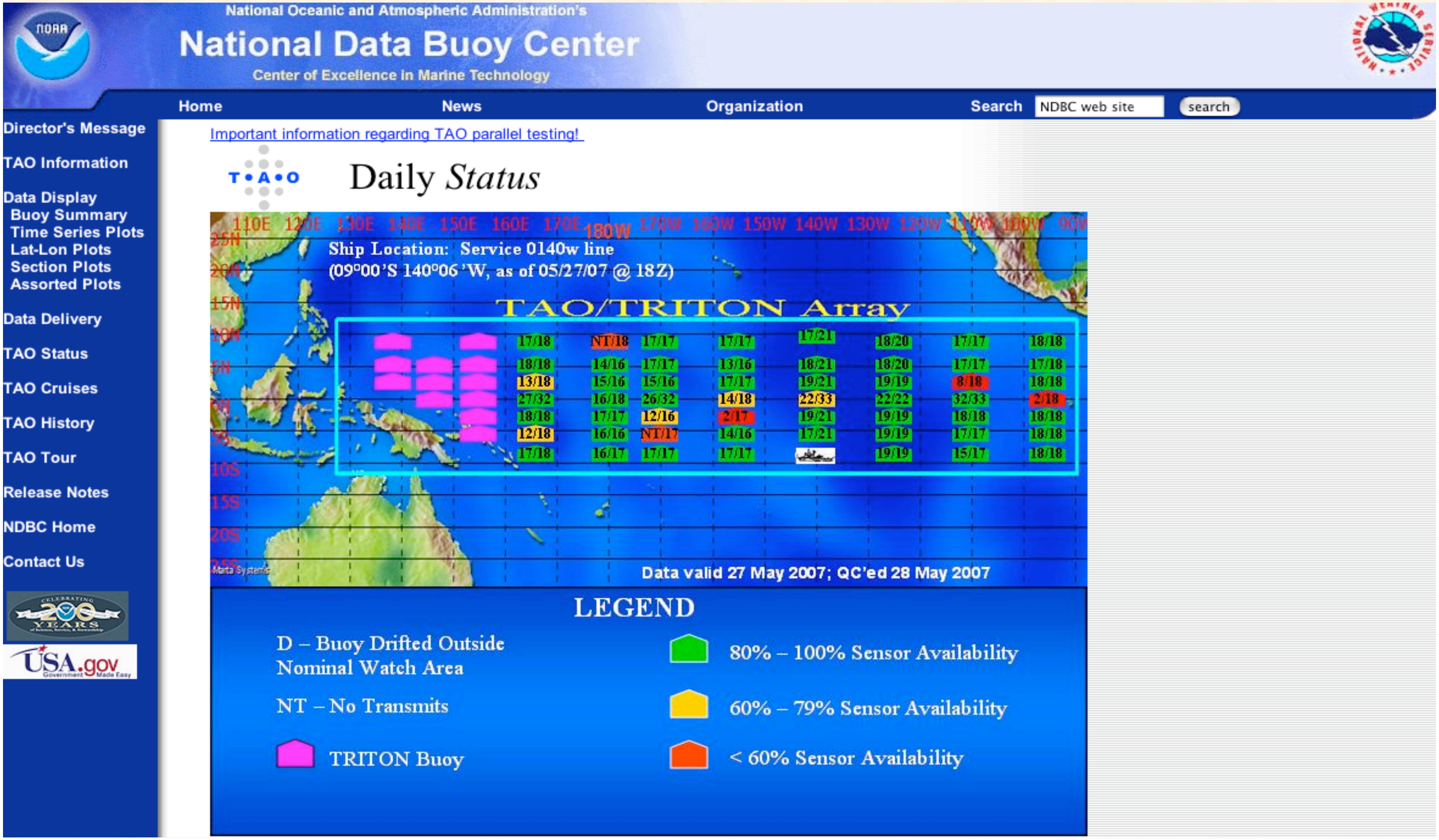
The yearly average and standard deviation of the

Forcing functions for the Observing System

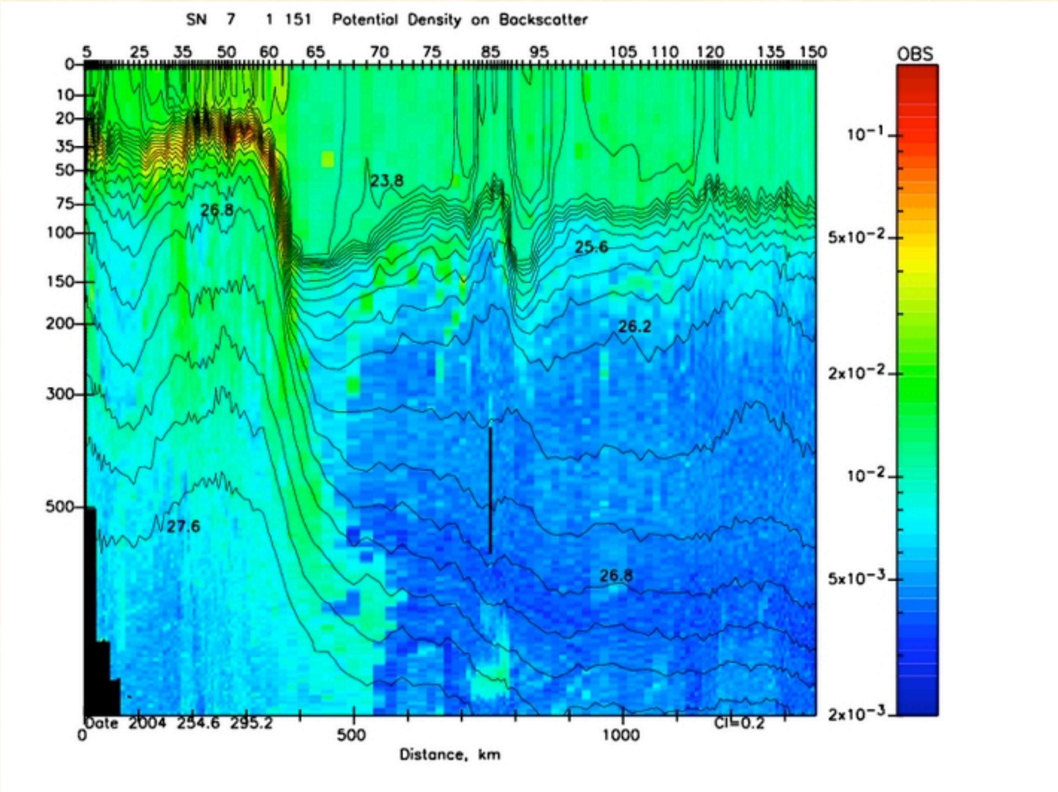
- Transition from research to operations
- Technological advances
- Multi-purpose globalization of ocean observations
- Effectiveness
- Value

Observing system will evolve as it performs

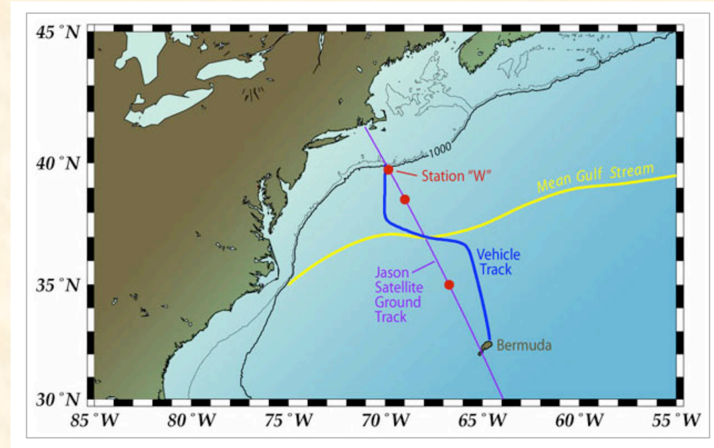
Elements are being transitioned. TAO in process, Argo floats discussed for after 2010.



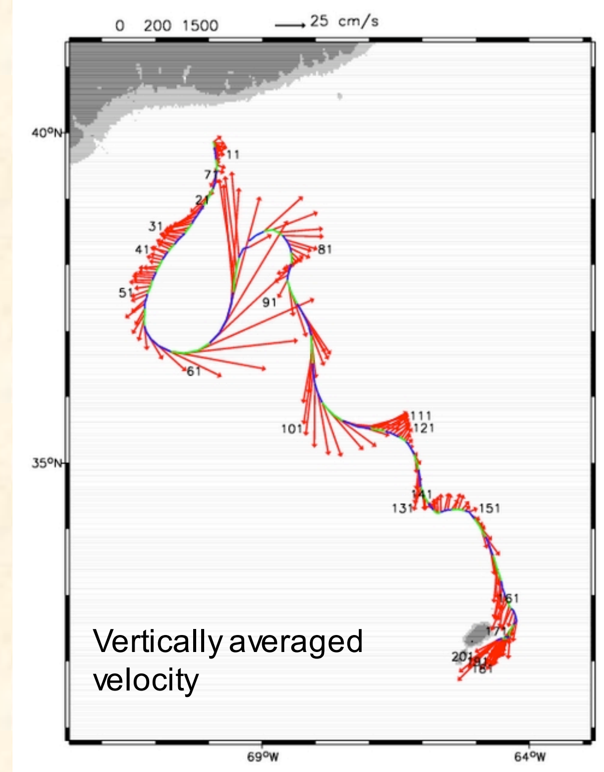
Potenital density (contours) on optical backscatter (color)

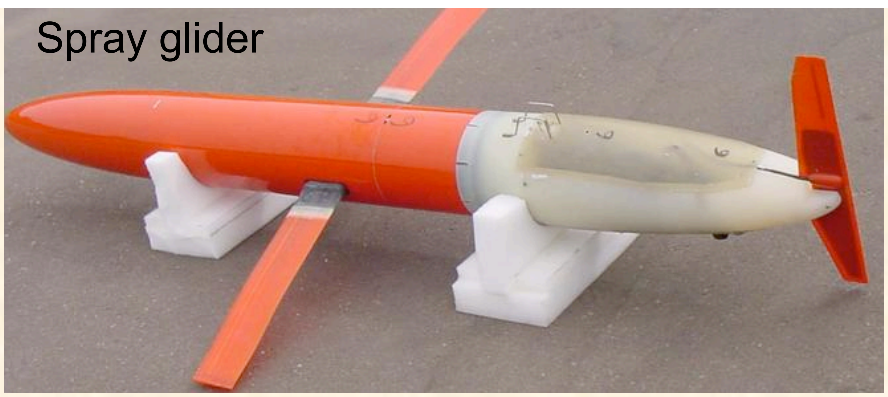


Cross Gulf Stream transect



Gulf Stream 2004





Evolution of observing technologies

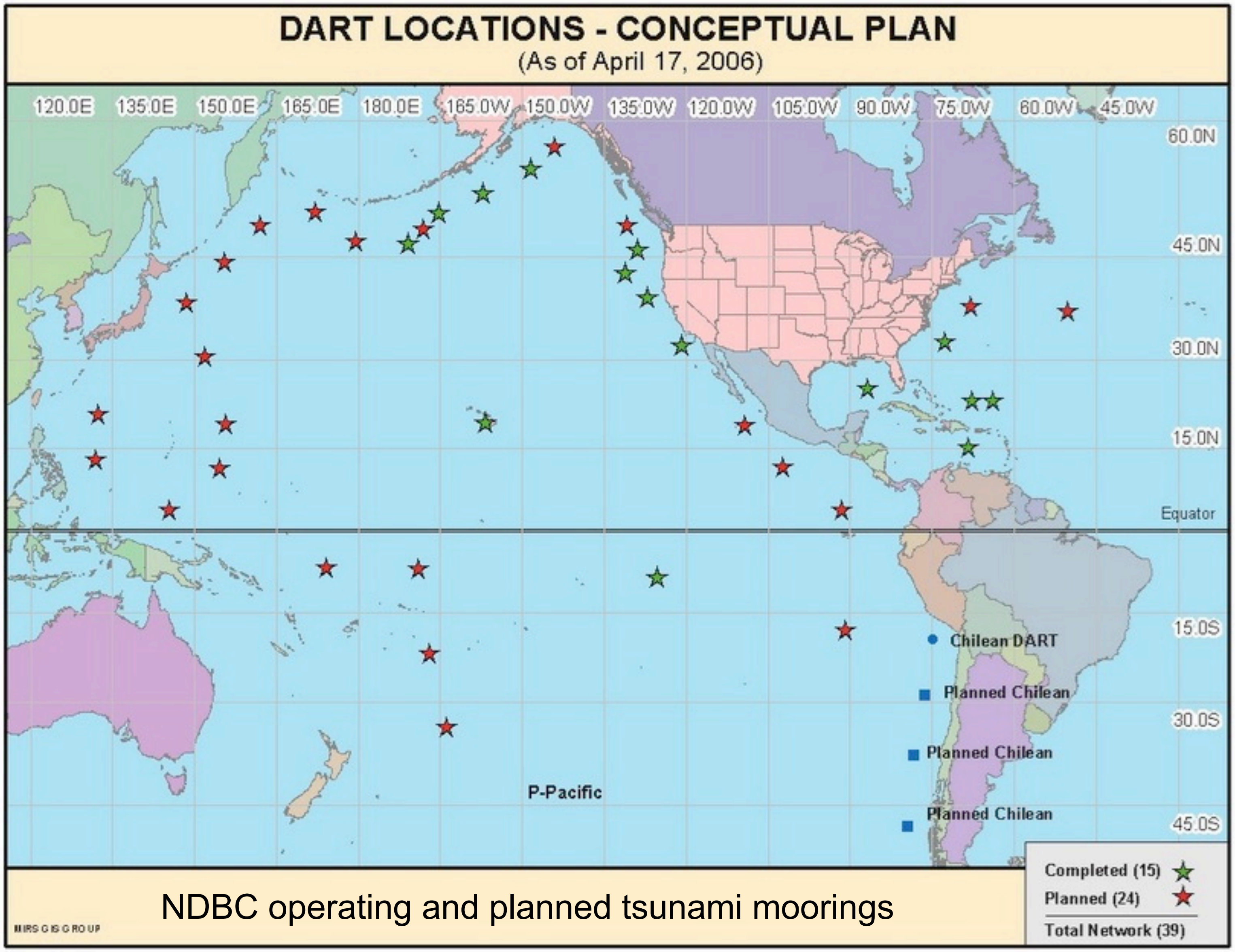
(from Breck Owens, WHOI)

Technological advances enabling progress towards *global, real-time*

- More data in real time (e.g., more subsurface data from moorings, NDBC data insertion on GTS)
- Communication between subsurface moorings and mobile, subsurface platforms and surface platforms
- Multidisciplinary sensors
- Platforms capable of operating in challenging regimes (e.g. KEO surface mooring; under ice)

More platforms…..

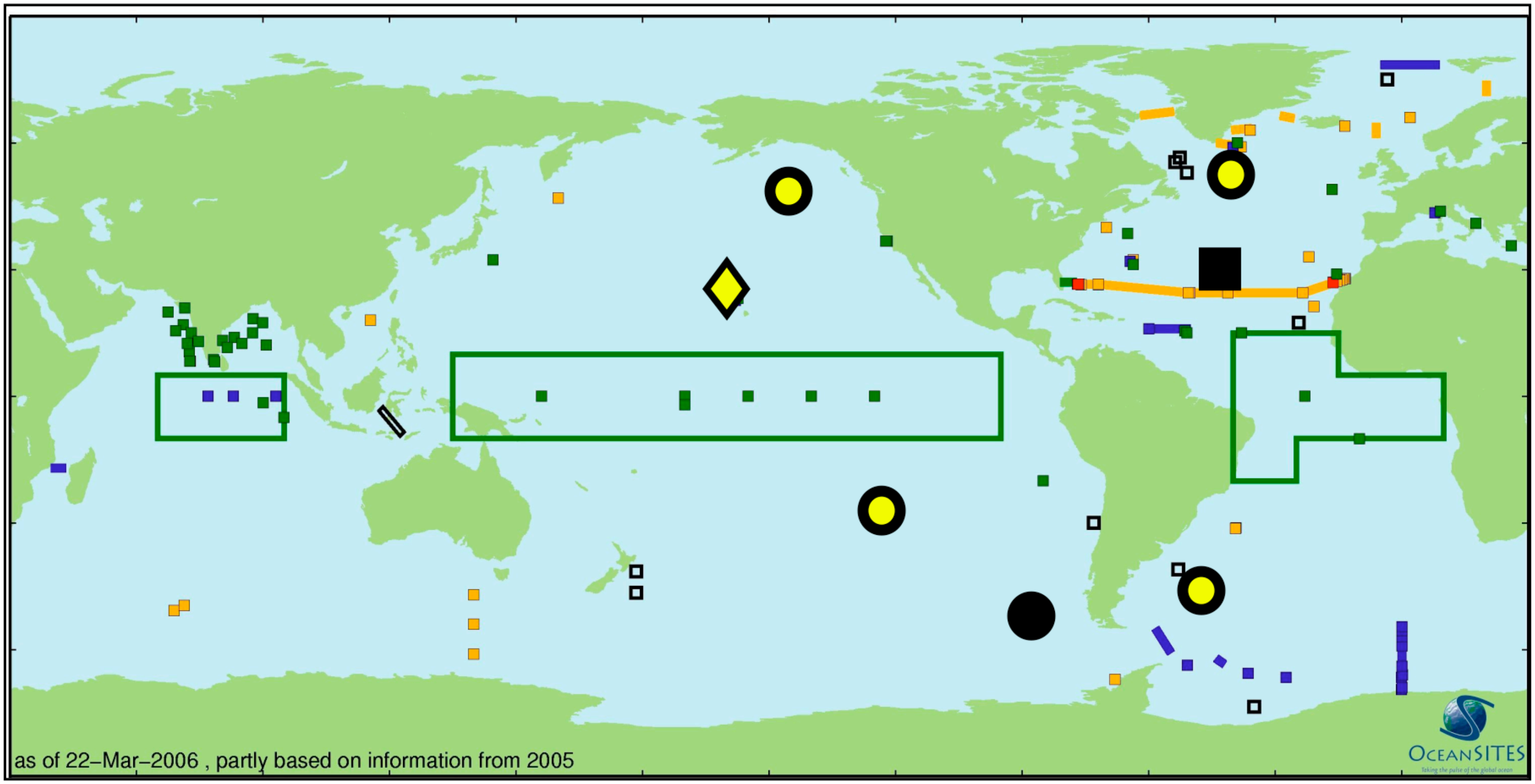
Global observing - different drivers



NDBC operating and planned tsunami moorings

National Science Foundation - ORION

Global Sites identified in Request for Proposals for
5-year build, 5-year operate

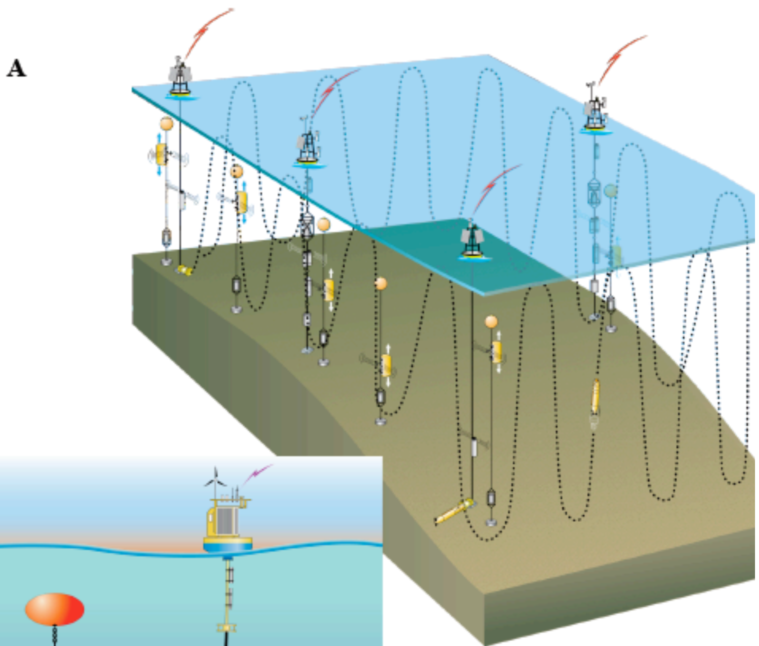


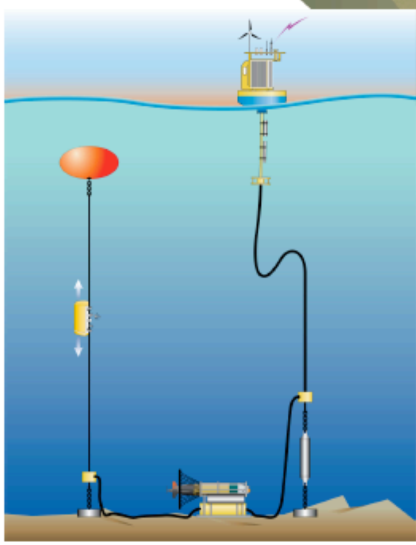
Circles - surface/subsurface mooring pair - real time
Square - stable platform, high bandwidth
Diamond - surface mooring for acoustic tomography

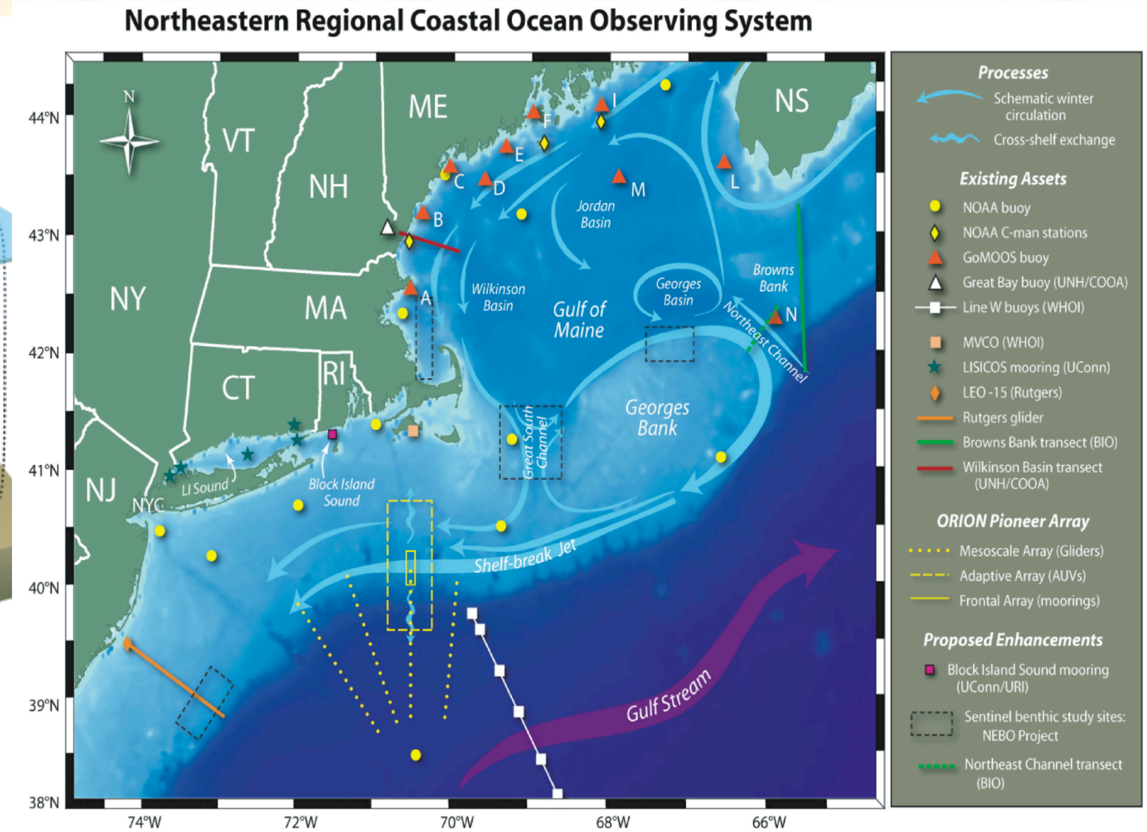
One design to be proposed for Orion stable platform for mid-Atlantic Ridge site

Power, bandwidth

Platform for comprehensive atmospheric observations; soundings, radar, aerosols, …

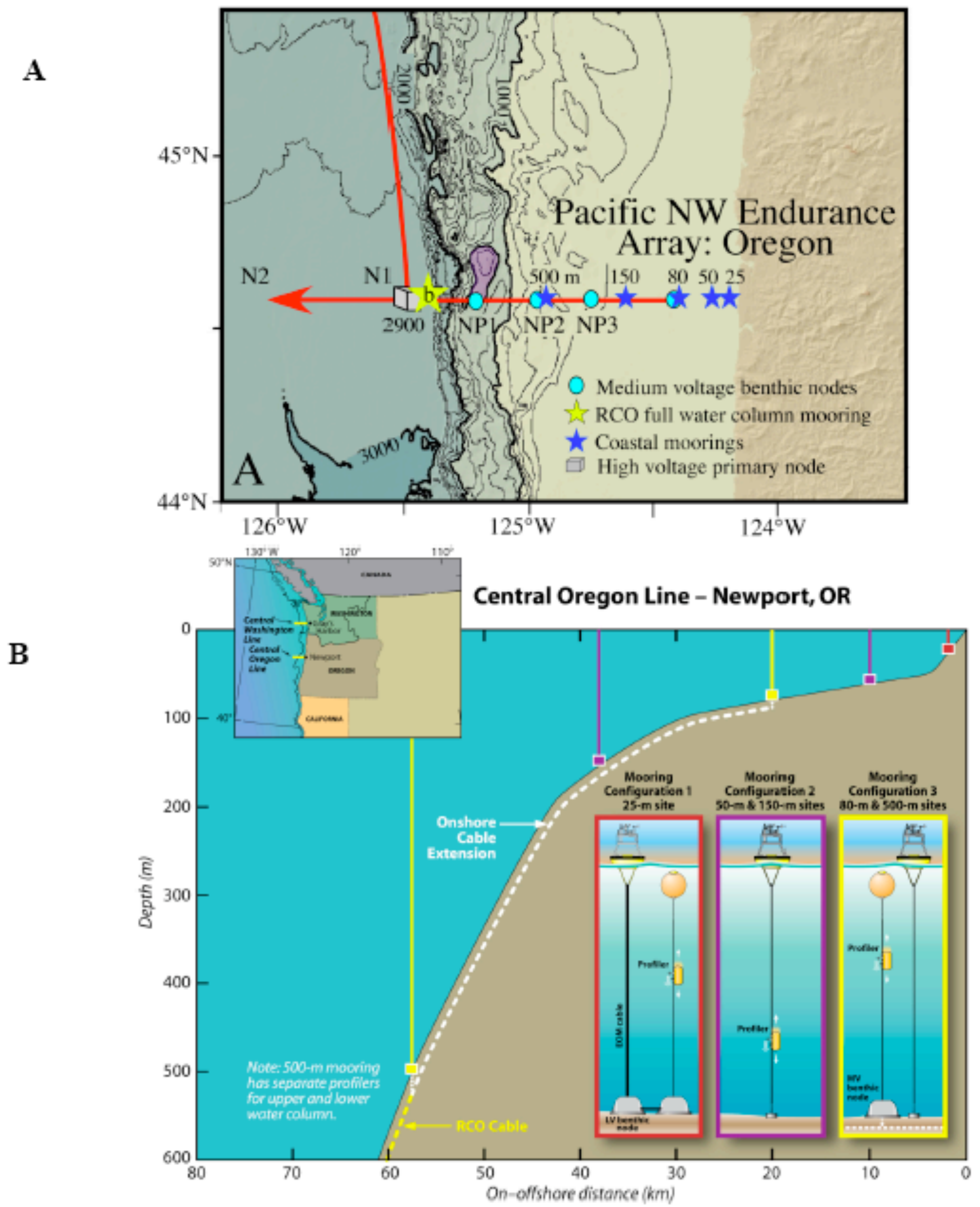






More comprehensive coastal observations

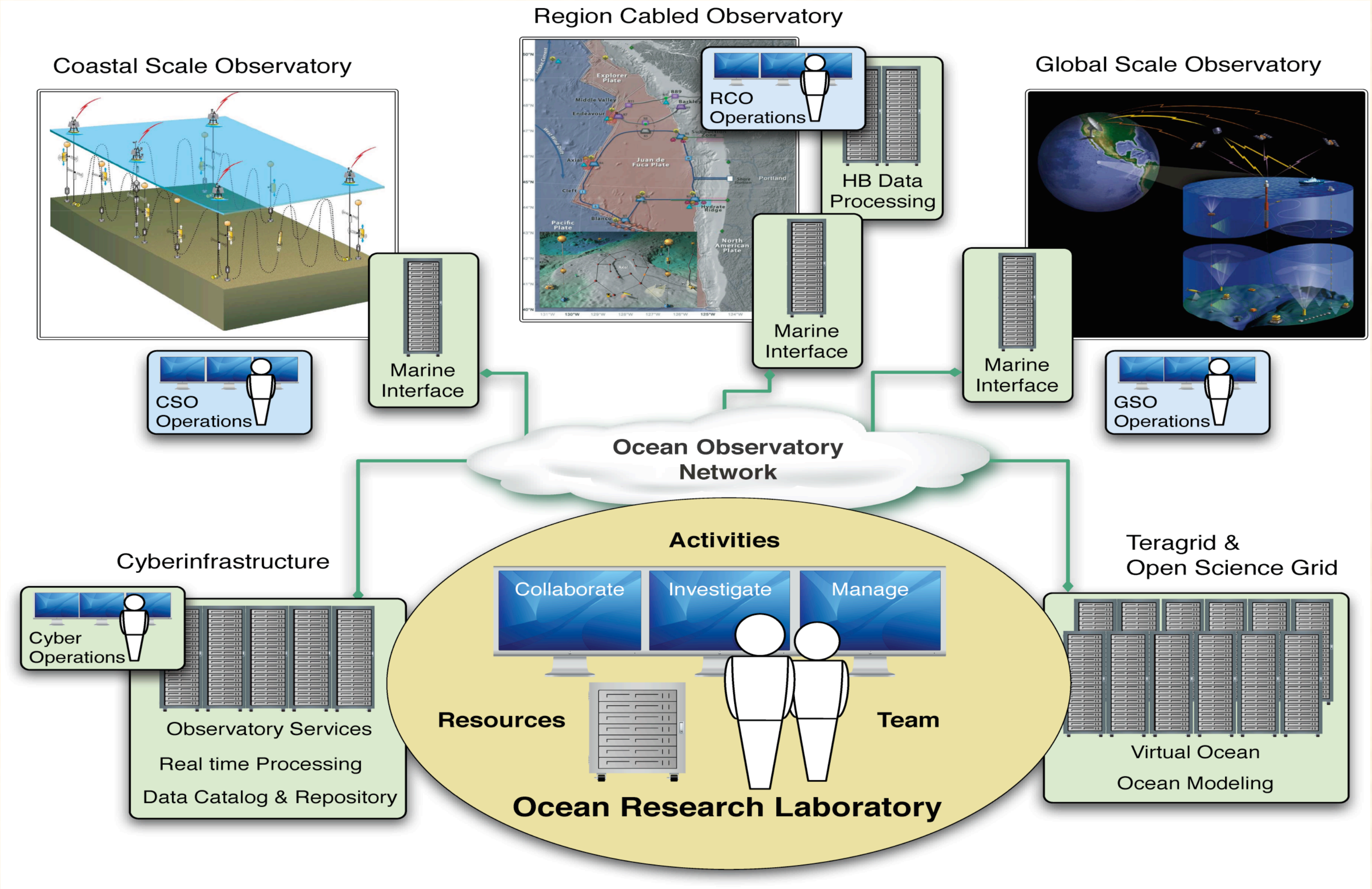
ORION Pioneer array (left), embedded in NE regional coastal observing system



ORION - Endurance arrays off Oregon and Washington

Wired into the regional cabled (RCO) observatory off Washington

Increased real time delivery from ocean observations
Increased availability and integration?



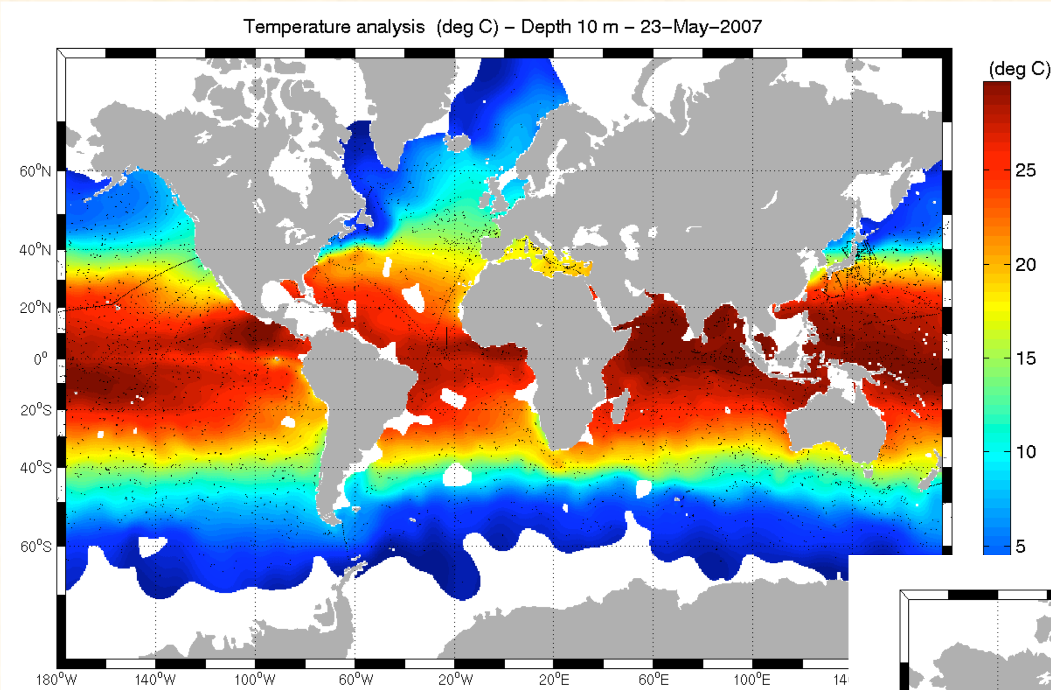
Above: ORION Cyberinfrastructure schematic   Other drivers: NDBC collection, QC, and insertion on GTS of data from diverse IOOS platforms

The present OOS and Syntheses

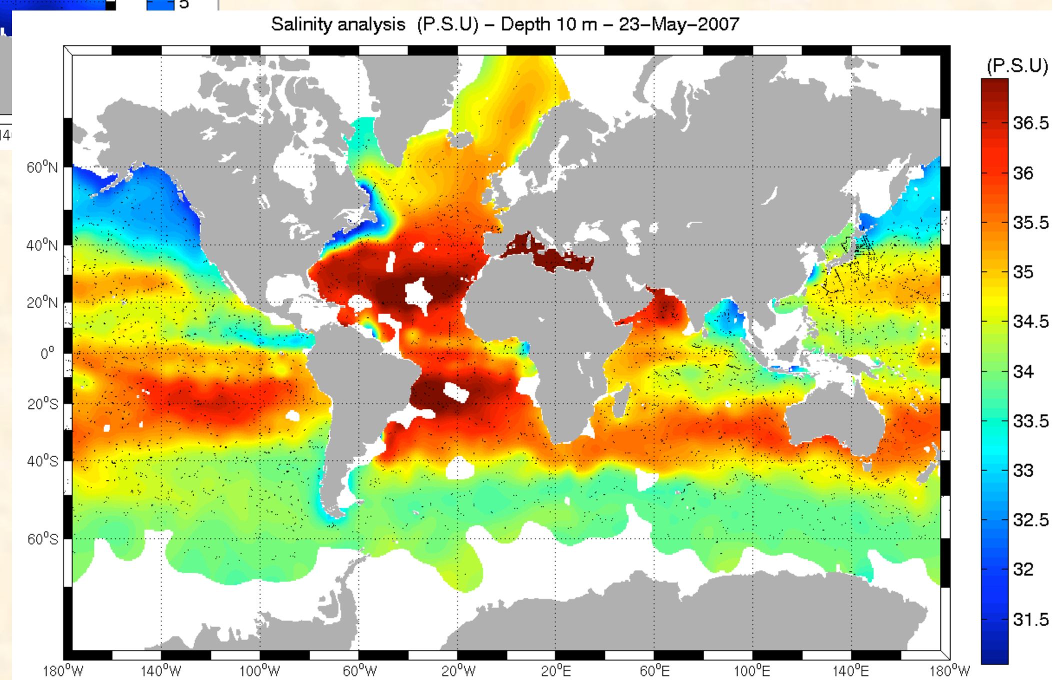
- GODAE
- Reanalysis efforts
- CLIVAR GSOP - recent workshop

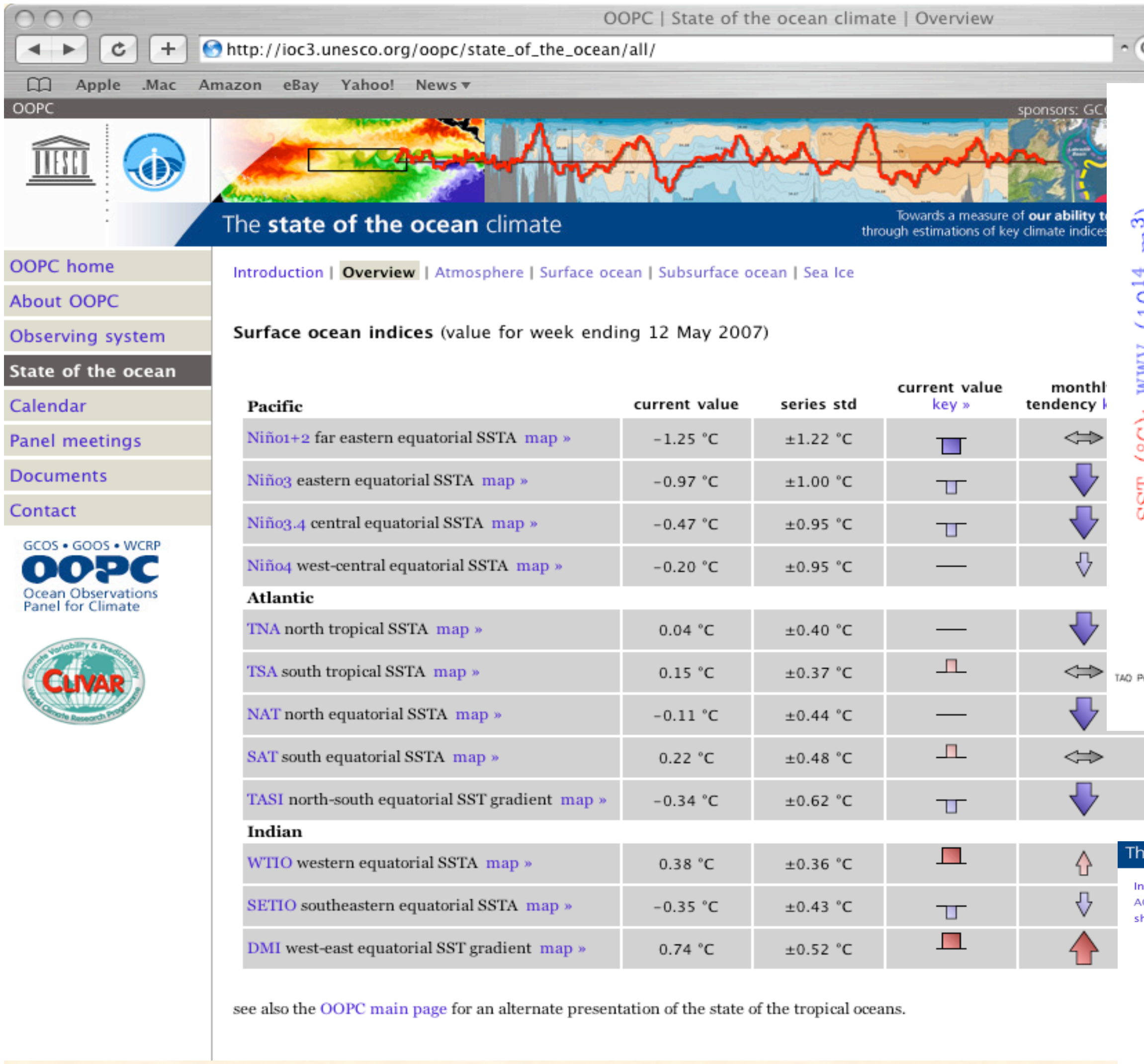
- *Are these guiding the evolution of the system or assessing its effectiveness?*
- *Are we responding to the forcing functions?*

Mercator/Coriolis



Global temperature and
salinity at 10m,
May 23, 2007
From Coriolis website

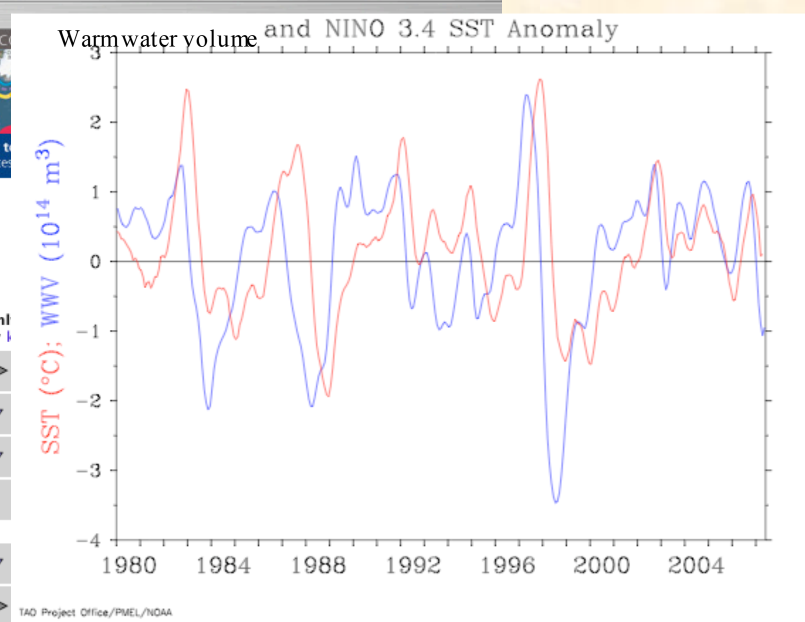


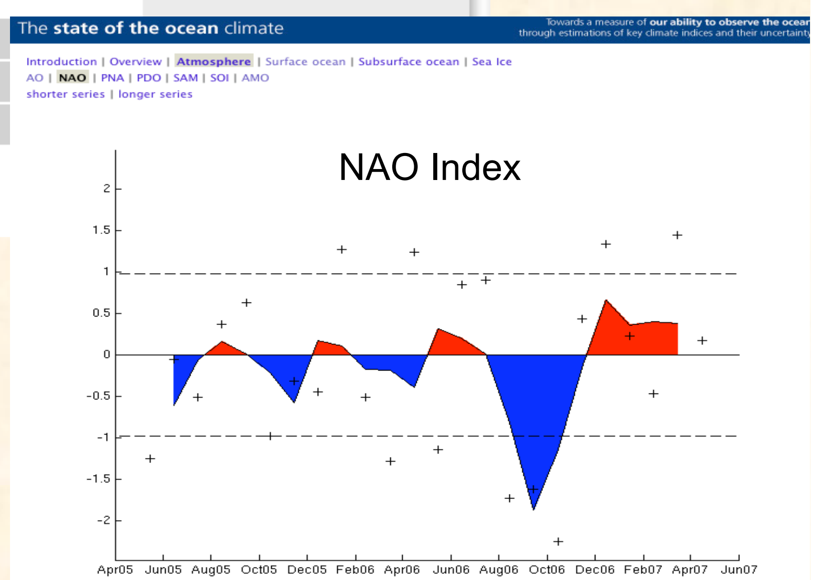


Surface ocean indices (value for week ending 12 May 2007)

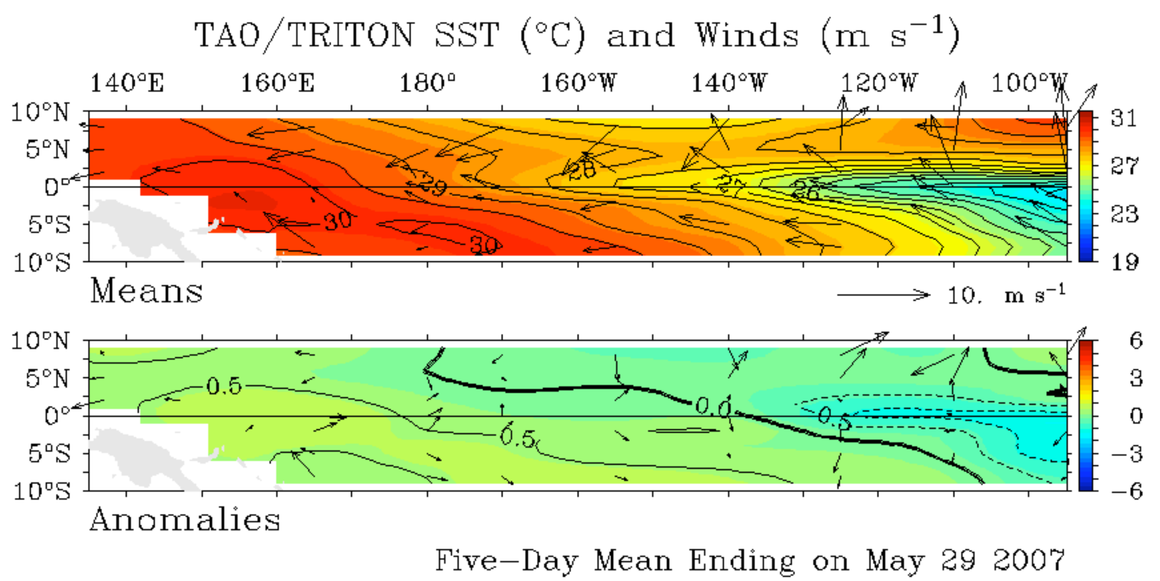
Pacific	current value	series std	current value key »	monthl tendency
Niño1+2 far eastern equatorial SSTA map »	-1.25 °C	±1.22 °C		
Niño3 eastern equatorial SSTA map »	-0.97 °C	±1.00 °C		
Niño3.4 central equatorial SSTA map »	-0.47 °C	±0.95 °C		
Niño4 west-central equatorial SSTA map »	-0.20 °C	±0.95 °C		
Atlantic				
TNA north tropical SSTA map »	0.04 °C	±0.40 °C		
TSA south tropical SSTA map »	0.15 °C	±0.37 °C		
NAT north equatorial SSTA map »	-0.11 °C	±0.44 °C		
SAT south equatorial SSTA map »	0.22 °C	±0.48 °C		
TASI north-south equatorial SST gradient map »	-0.34 °C	±0.62 °C		
Indian				
WTIO western equatorial SSTA map »	0.38 °C	±0.36 °C		
SETIO southeastern equatorial SSTA map »	-0.35 °C	±0.43 °C		
DMI west-east equatorial SST gradient map »	0.74 °C	±0.52 °C		

see also the OOPC main page for an alternate presentation of the state of the tropical oceans.





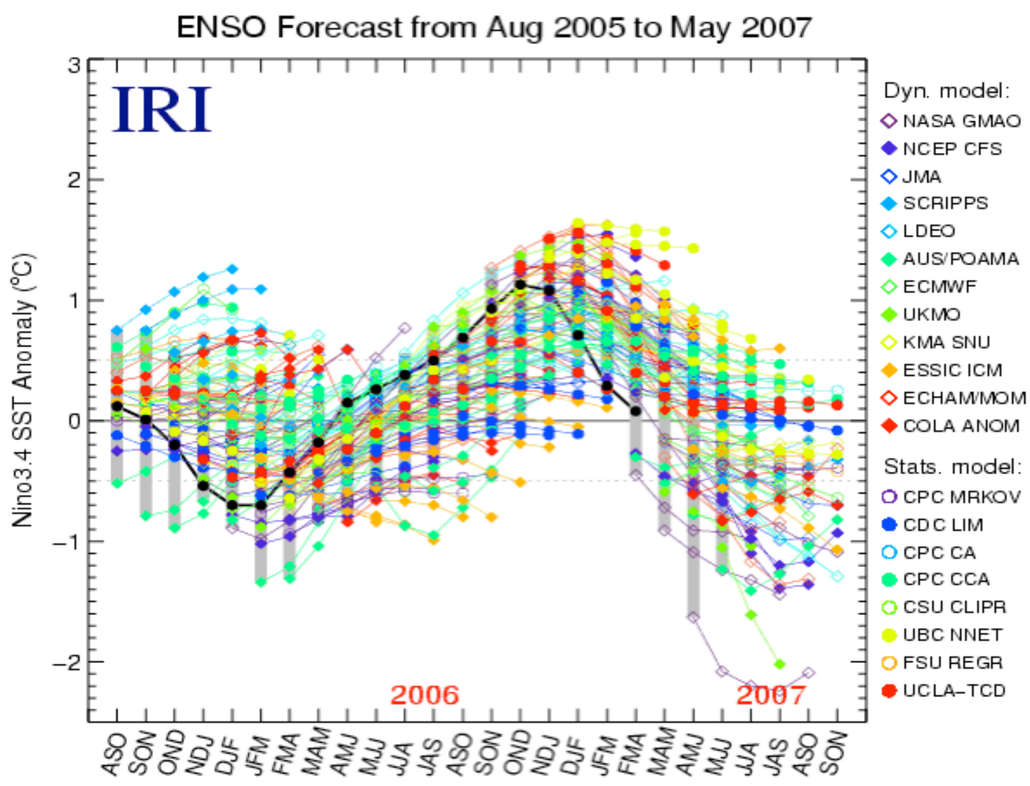
Indices

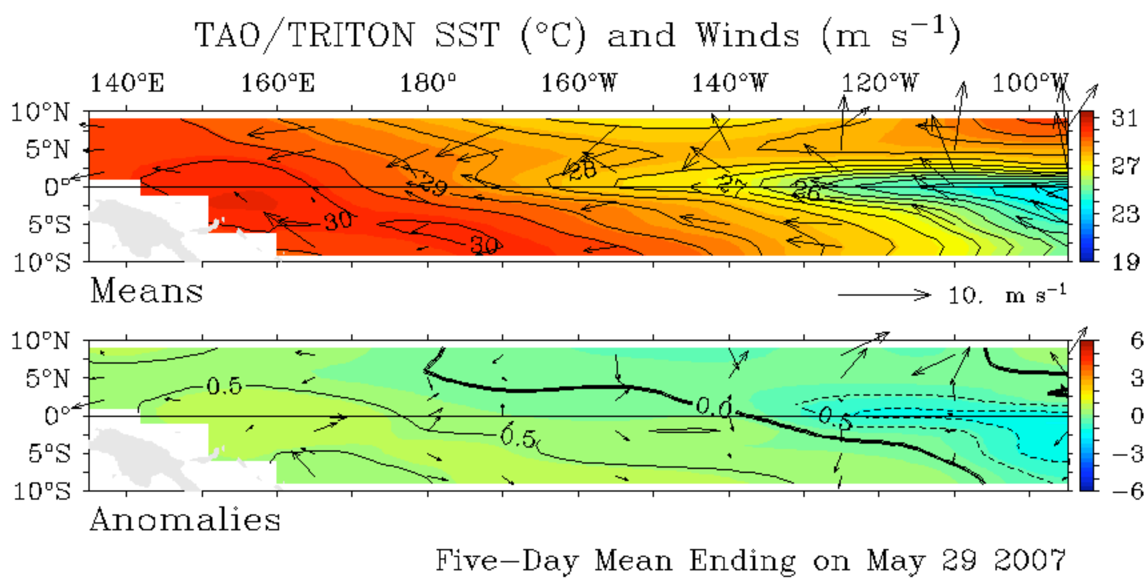


Eastern Tropical Pacific

What is used for monitoring, understanding, prediction?

What does the observing system need to deliver?

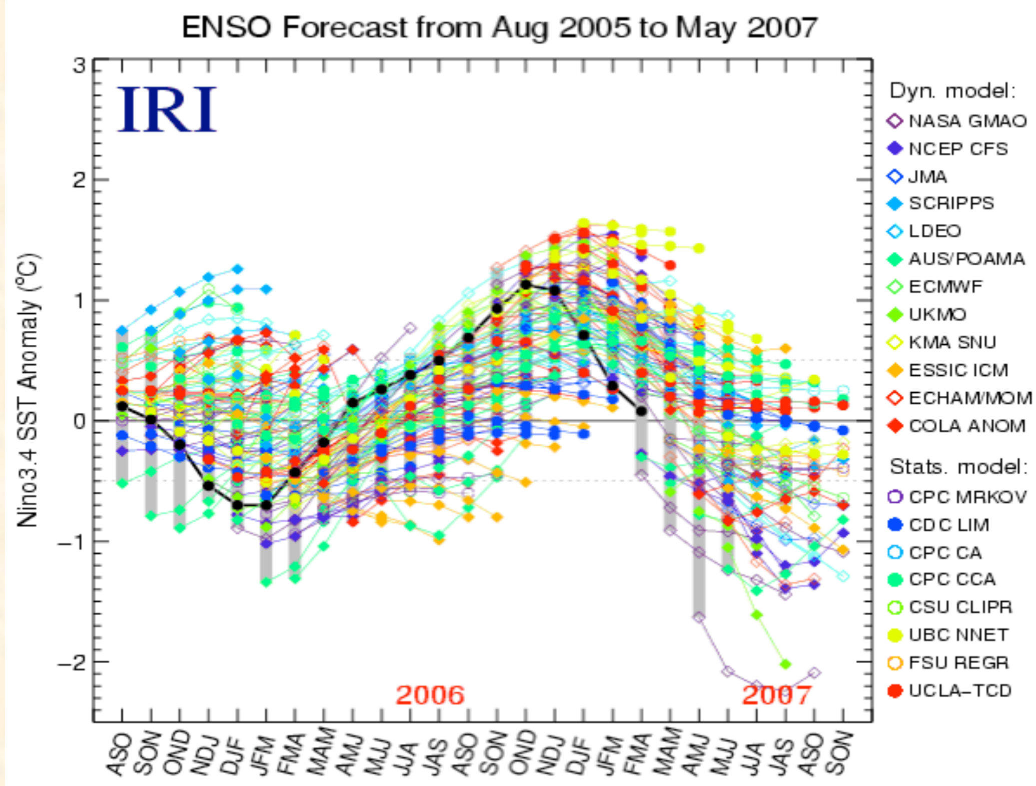




Do we now synthesize three-dimensional temperature, salinity fields using all data?

How robust is this when some data is missing?

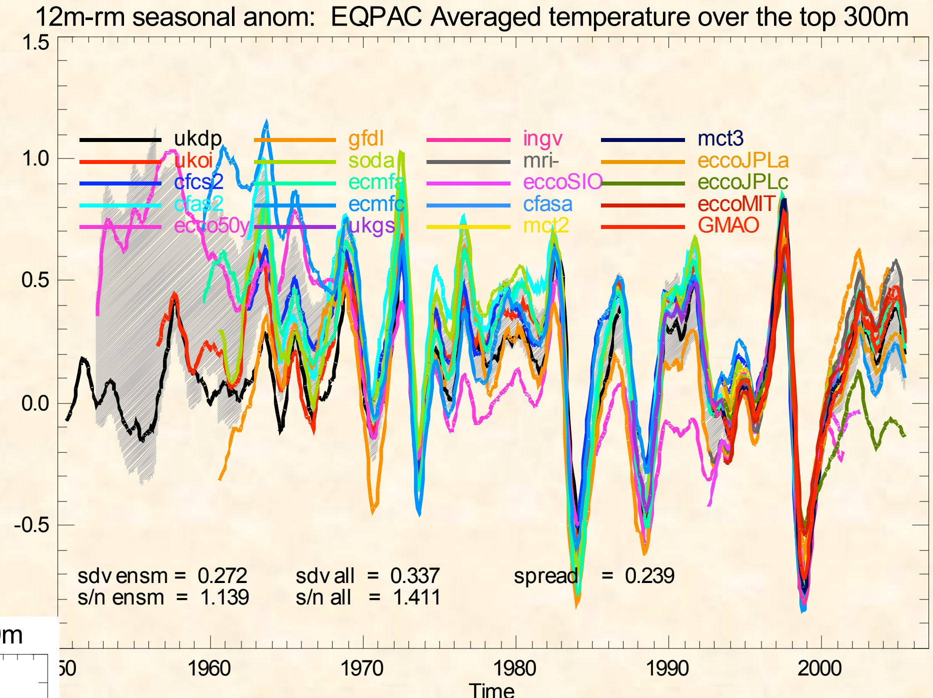
Eastern Tropical Pacific

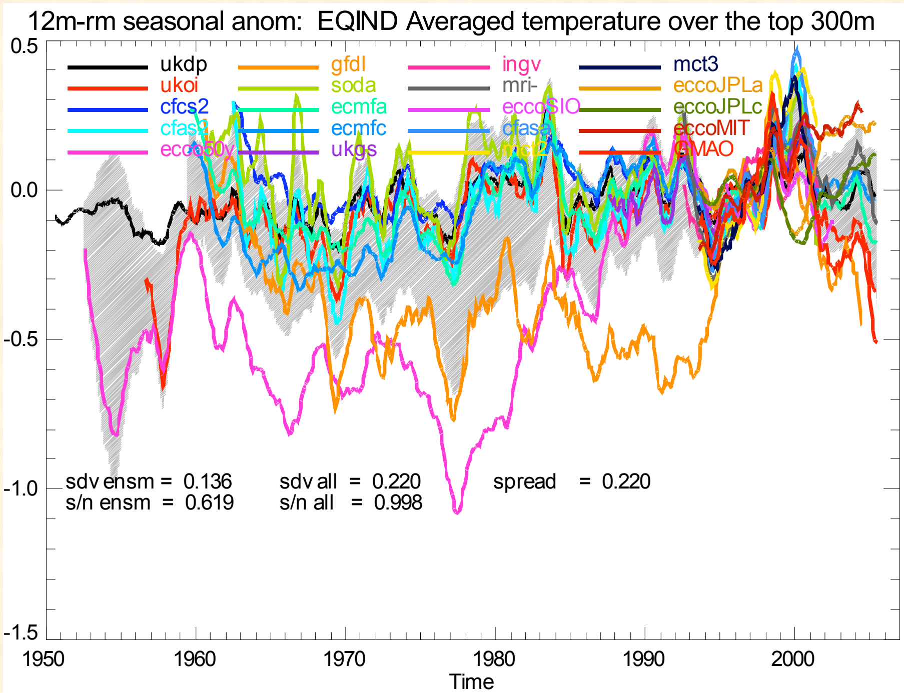


T300: Equatorial regions

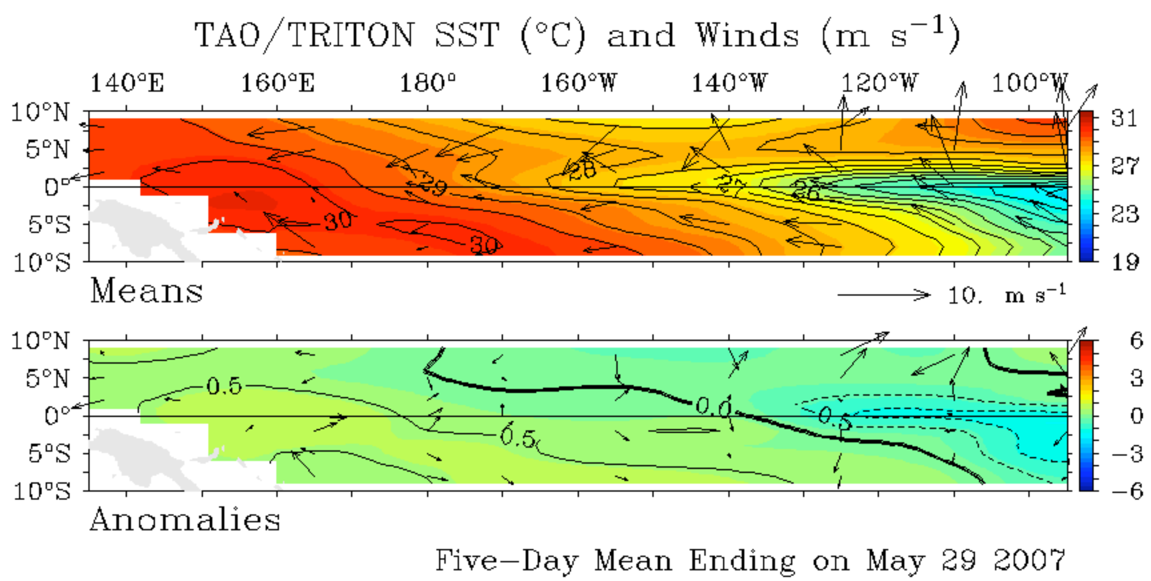
Magdalena A. Balmaseda and Anthony Weaver CLIVAR GSOP Workshop

- **Eq Pac: Uncertainty decreases with time.**
- **Relatively robust interannual variability.**
- **Increased uncertainty after 2000. Why?**





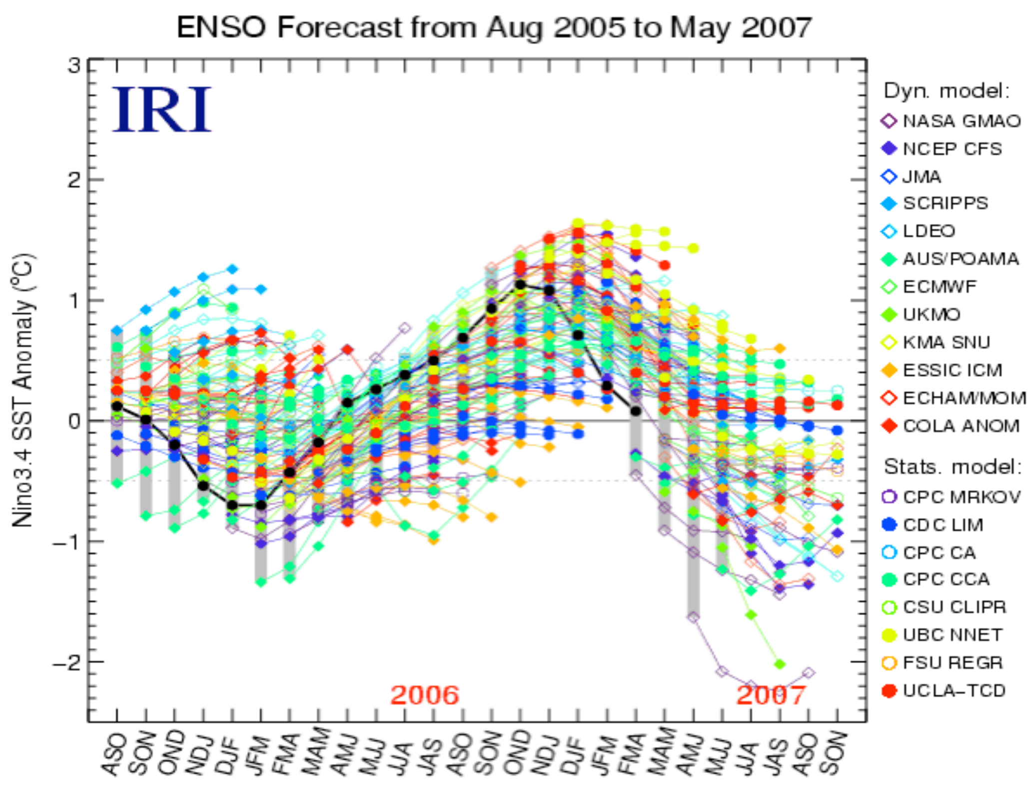
- **Eq Indian: Uncertainty remains large throughout the record.**
- **Signal to noise <1. Outliers**
- **This is also the case for the Eq Atlantic**



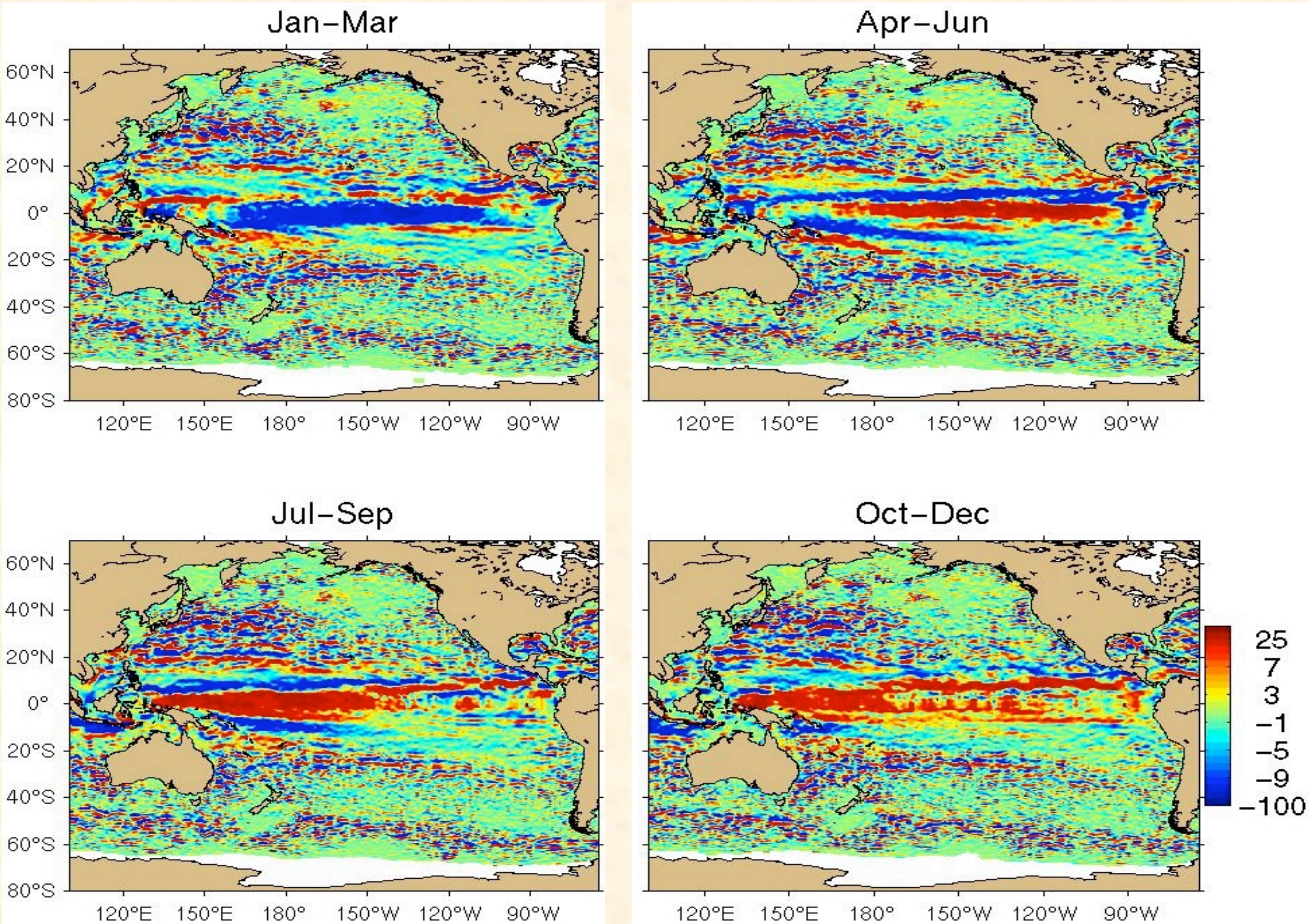
Eastern Tropical Pacific

How does the observing system deliver what is needed if in the next decade as fish stocks are depleted surface moorings will not be practical in the eastern tropical Pacific.

Argo? Gliders from the Galapagos? Surface drifters with acoustic wind? Satellite wind, altimetry?



Move and re-equip the TAO moorings and use the moorings to observe zonal velocities and drive model improvements?



(Lumpkin and Goni, SOTC, BAMS)

Some Summary and Conclusions from

Magdalena A. Balmaseda and Anthony Weaver CLIVAR GSOP Workshop

- There is large uncertainty in climate signals
  - **Signal to noise ratio > 1 in the Eastern Pacific for Temperature**
  - **Signal to noise ratio <1 for salinity in most regions**
  - **Warming trend in the 90's is consistently reproduced**
  - **What is happening now? There is not consistent picture**
- Forcing fluxes and analysis methods are largest source of uncertainty
  - **Data Assimilation does not always collapse the spread: <u>We need to pay more attention to the assimilation methods.</u>**

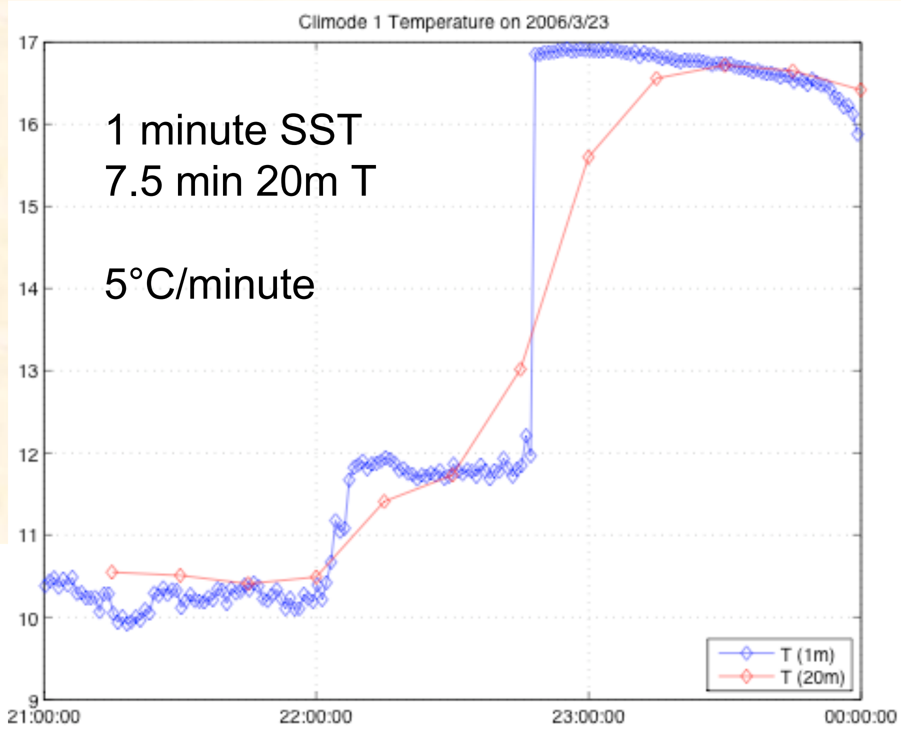
Global averaged heat flux

Lisan Yu, WHOI, CLIVAR GSOP Workshop 2006

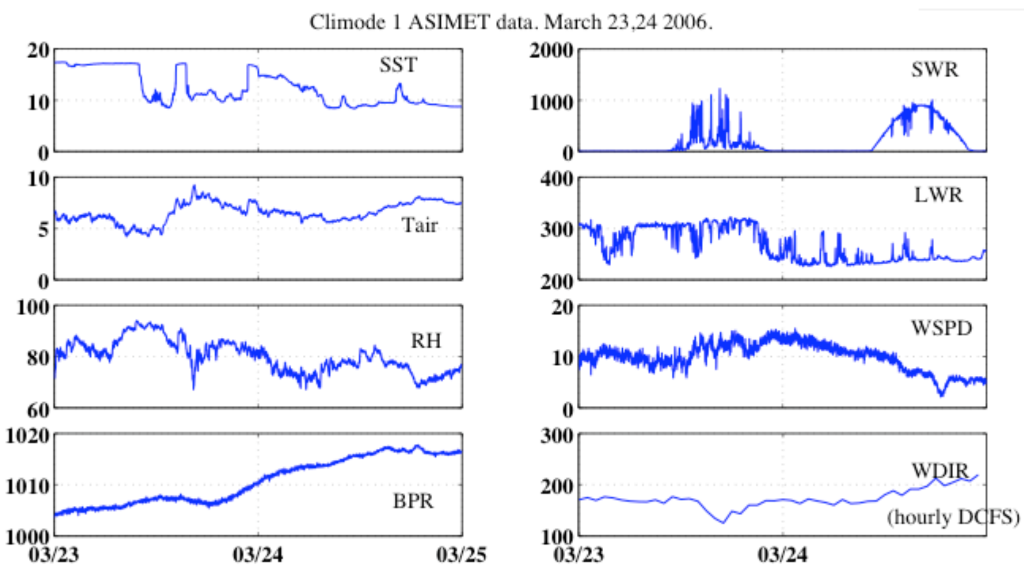
Model Q_{net} (Wm^{-2})		Product Q_{net} (Wm^{-2})	
ECCO-MIT	1.94	NCEP	1.29
ECCO-JPL	0.20	ERA40	5.24
ECCO-SIO	0.89	NOC	20.13
ECCO-50yr	1.50	OAFlux+ISCCP	29.61
MCT2	-1.84		
MCT3	2.56		
GFDL	-12.71		
INGV	2.91		
NASA	6.29		

- Where do model fluxes differ most?
  Ocean fronts: western boundary currents, the equatorial cold tongue, and Antarctic circumpolar currents.
- What are the implications? The surface flux estimation depends on the model's ability to resolve the frontal dynamics.

Can a global IOOS and or models used for syntheses address the frontal regions well enough to fix this mismatch in global fluxes?



Covariability of surface fluxes with SST?



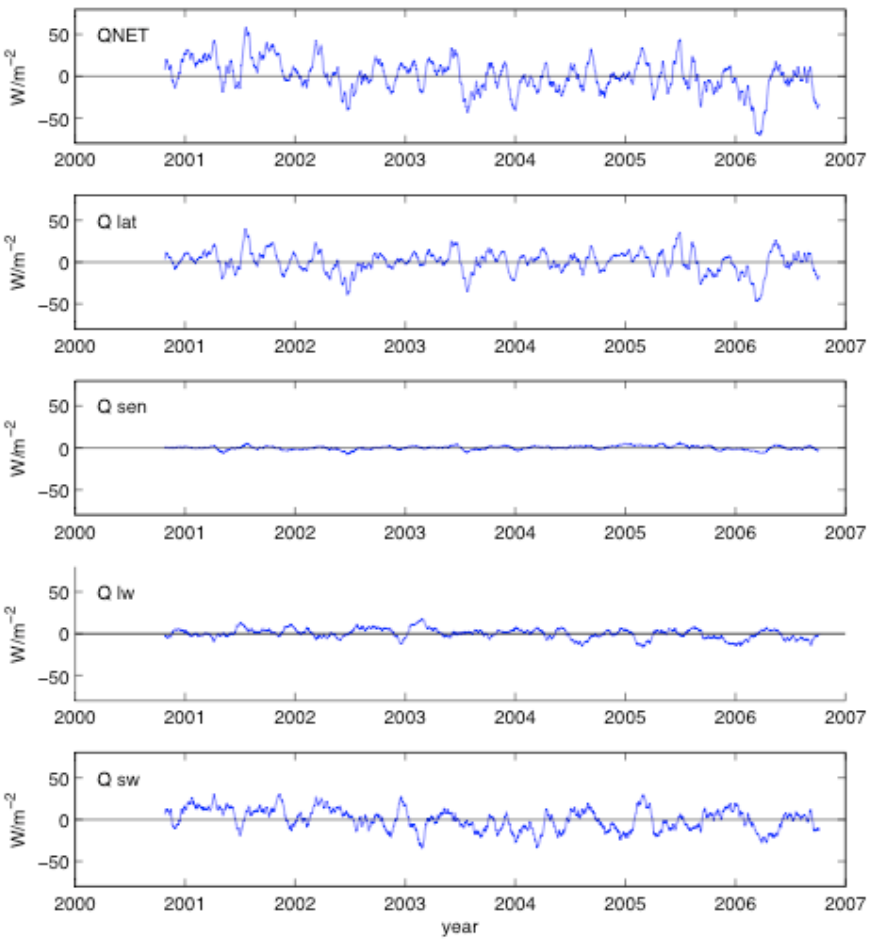
Surface mooring in the Gulf Stream

Regional syntheses - Ocean Reference Stations with nearby VOS tracks

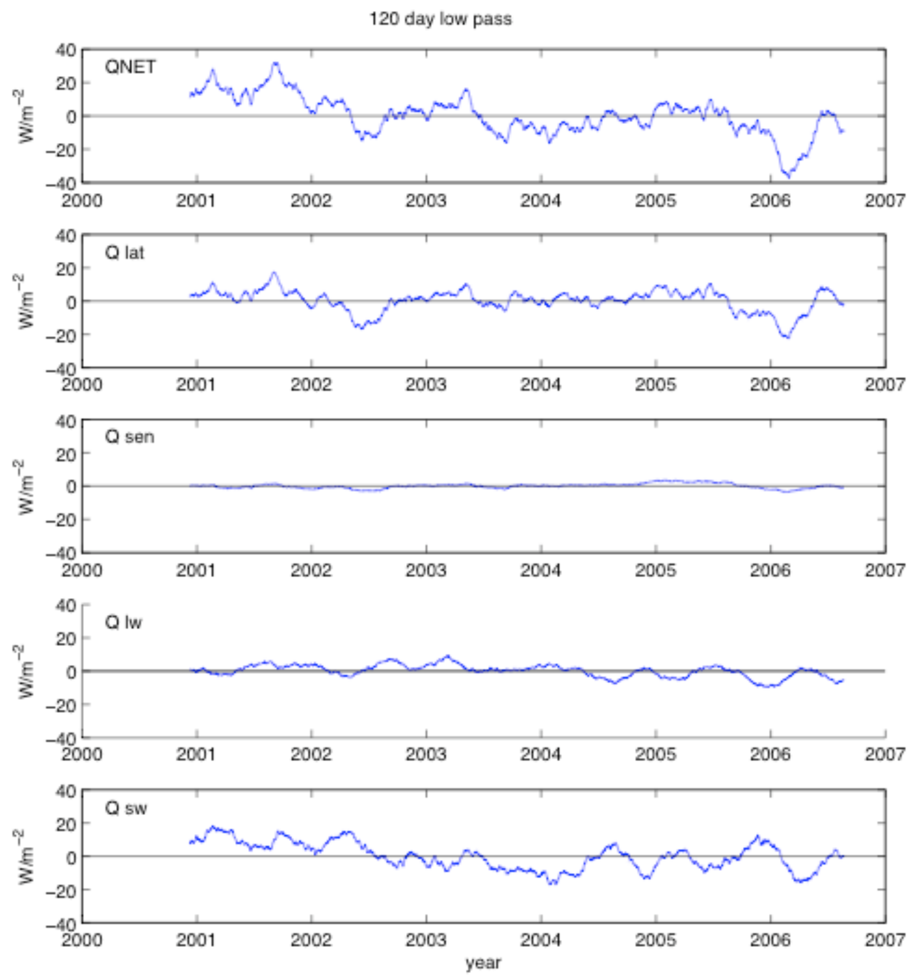
- Surface meteorology and fluxes
  - Known accuracy
  - Validation for flux products
  - Point info, fluxes, ocean structure
- Temperature (z), Salinity (z), U(z)
- Some with 6+ years of data
- Document air-exchange, ocean change/variability, air-sea covariability at the point
- Test local closure

TAO was completed and has been effective; other elements of the OOS have built their histories (ARGO, ORS, drifters, HR XBT lines,…)

Stratus ORS - 6 years of heat flux anomalies



30-day rm low pass



120-day rm low pass

Regional syntheses

- Extend radially the sea surface-meteorology and fluxes
  - Nearby VOS tracks, satellite, NWP, drifters, flux products
- Extend radially the ocean volume
  - ARGO, XBT, satellite, gliders
  - Space/time scales of the ocean/representativeness of the point
  - Increase regional sampling (XBTS, floats, gliders, drifters)
- Identify the space/time scales of the atmosphere, and ocean, the representativeness of the point
  - Decorrelation scales

Regional synthesis: Ocean Reference Stations

- Contrast this point/volume with model and model-based fields
- Capitalize on process studies to elucidate processes (e.g., VOCALS - in the Chilean stratus deck region)
- Perform regional OSSE's; withdraw some elements of the sampling

- Programs like TOGA COARE did balance the surface energy budgets, identify the important processes on both sides of the interface

- Challenge ocean reanalyses, analyses, and models to match the observations and understandings in the regions around the ORS

Regional syntheses

- Guide evolution of the observing system
  - Respond to pressures, evolve - eastern tropical Pacific
    - Make more robust, integrative products
    - Address uncertainties in models
    - Move away from vulnerable or overly redundant observations
  - Complete synthetic analyses at well-observed regions
    - The Ocean Reference Stations now
    - The NSF ORION global sites later
    - Verify air-sea fluxes, examine covariability across air-sea interface
    - Establish ‘representativeness’, space/time scales
    - Leverage process studies
    - Complement with additional elements to make long-term regional observing commitments
    - Determine what can be removed to accomplish Climate Obs Program goals and leave robust capability and products

Regional syntheses

- Integration of the observing system
  - Bring on board other elements (e.g., DART)
- Construct the patchwork quilt of regional syntheses
  - Build toward the regional syntheses converging with global syntheses and analyses
  - This may lead to more effort to address ‘problem’ or challenging regions
  - Build toward understanding the differences between different integrative, global measures: transports, global averaged surface fluxes
- Take on ‘regions’ bordering coastal IOOS domains and work toward integration of the global and coastal observations and analyses

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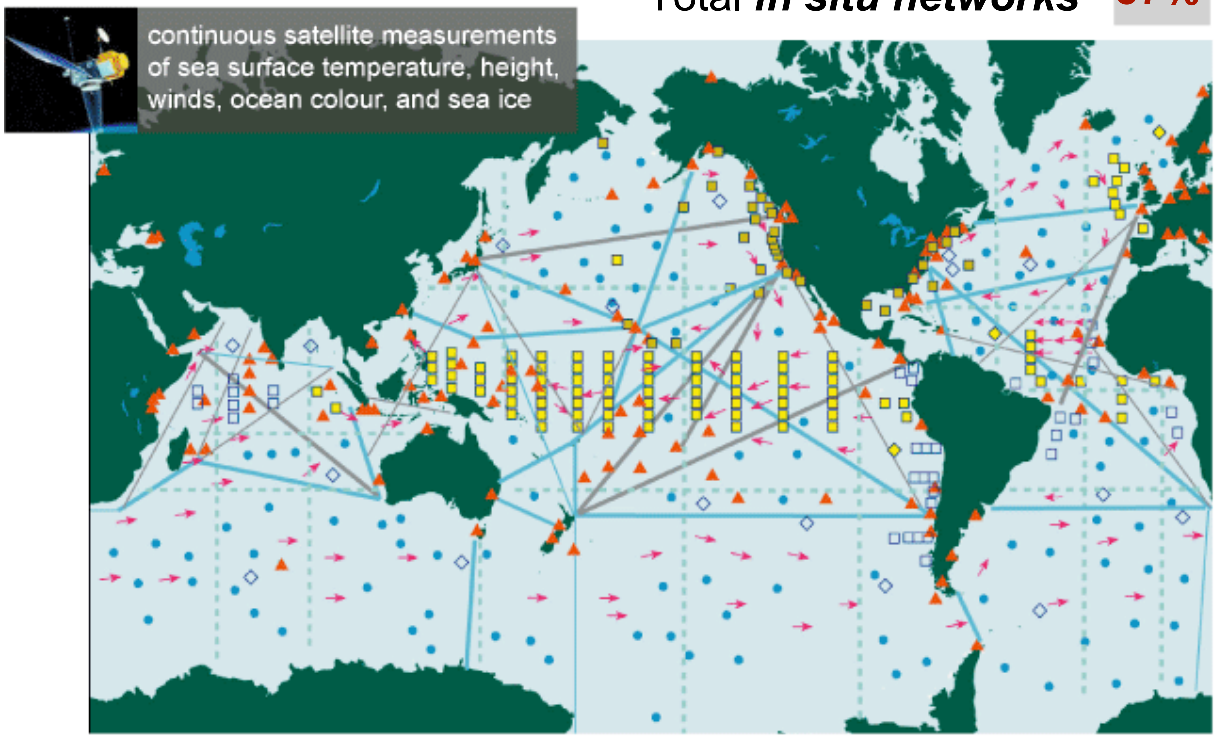

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