# *Importance of Long Time Series, Worldwide*

**Harrison, Dickey, Johnson, Karl, Knap, Malone, McPhaden, Send, Weller, Visbeck**

# *There is Wide Interest in Marine Environmental Change*

- **How fast will sea level rise?**
- **How fast will atmospheric $CO_2$ increase?**
- **Is El Nino changing?**
- **Is Atlantic Overturning Circulation weakening?**
- **Is arctic summer ice going to disappear?**
- **How much will environmental change affect fisheries?**
- **What other marine ecosystem changes should we expect?**

**Our waters seem familiar, yet little is well-enough known for clear decision-making.**

***"Not known, because not looked-for***

***But heard, half-heard, in the stillness***

***Between two waves of the sea"***

***T.S. Eliot***

# *Sustaining Marine Observations*

- We cannot answer these and other key questions under present national ocean observing paradigms.
- The consequences of oceanic sampling constraints, including need for multi-decadal, well sampled, high accuracy records, are profound.
- Estimates from inadequately sampled systems can seriously mislead
- Need integrated observations and analyses

***Increasingly, we are able to ‘half-hear’ important oceanic signals***

***Too often we are not looking hard enough to know, much less to be able to predict, the things we seek to know***

***Often the pressure to ‘do something new’ leads resources to be redirected away from long term observations.***

***Yet long term perspectives are critically important.***

***Time Series are a critical part of the observing system.***

***They are a key tool to communicate about changes***

***But every index oversimplifies, context is needed***

***When they tell a simple story everyone understands***

***Trends are simple to grasp***

***Interannual variability has become more familiar, but…***

***Decadal variability poses new communication (and action) challenges***

***Have to do better at explaining sampling and aliasing***

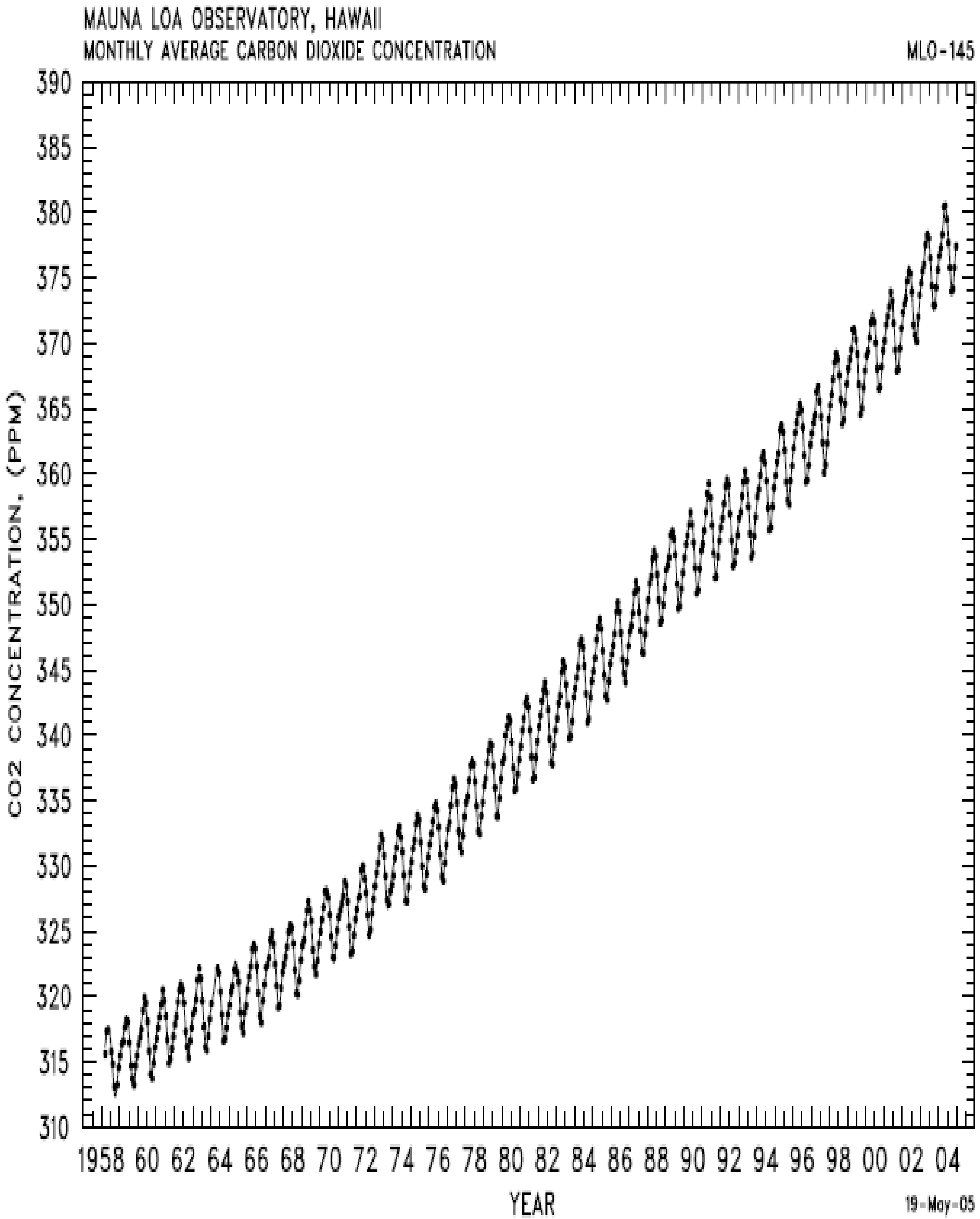
# *Some Examples*

- **Recent Atmospheric CO2**
- **Vostok ice core records**
- **Sea Level Rise**
- **ENSO**

380

350

320




# *Mauna Loa*

# *CO2*

# *Record*

**1957-2005**

**Trend:**

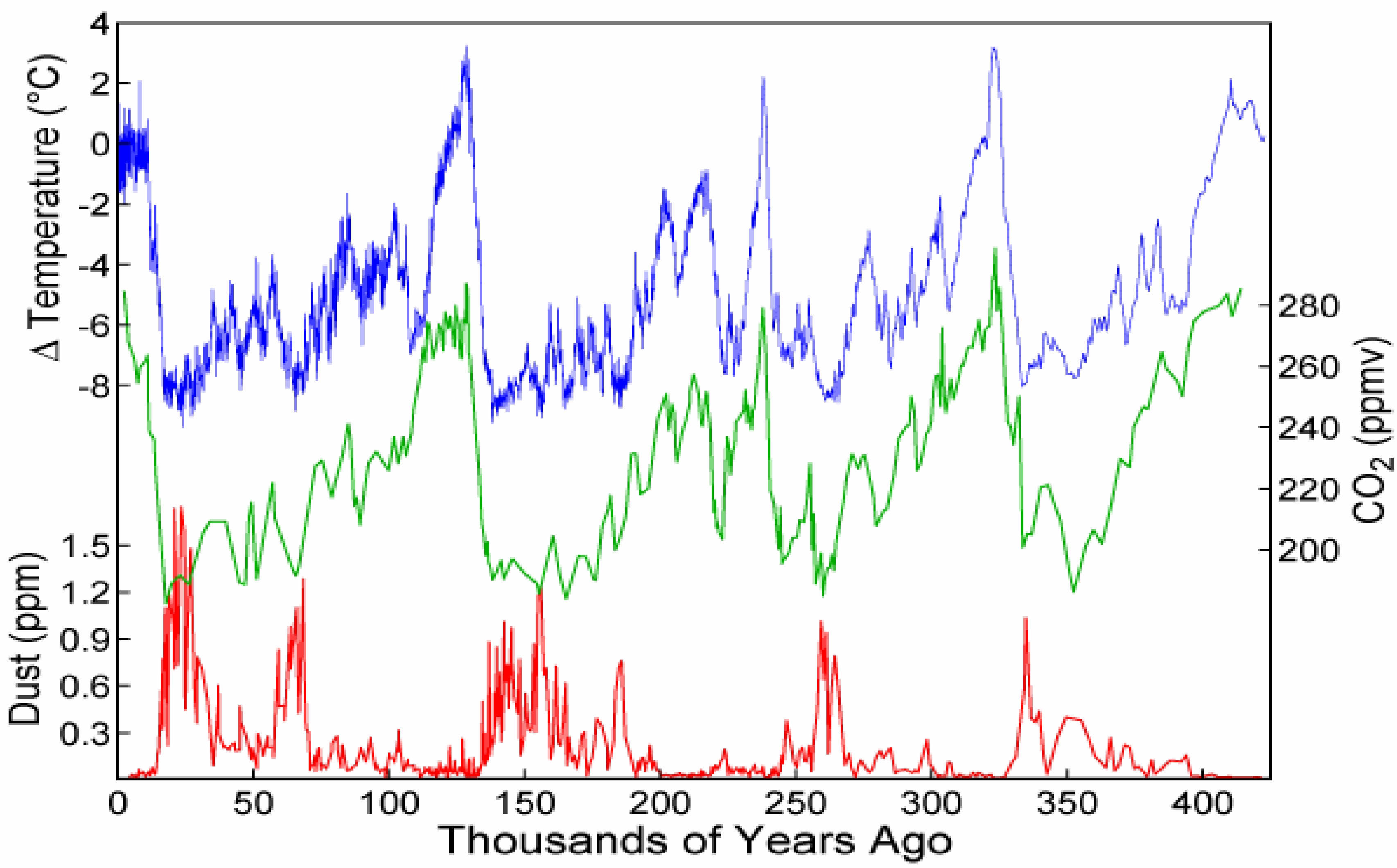
**~1.5 ppm/yr**

**Not uniform**

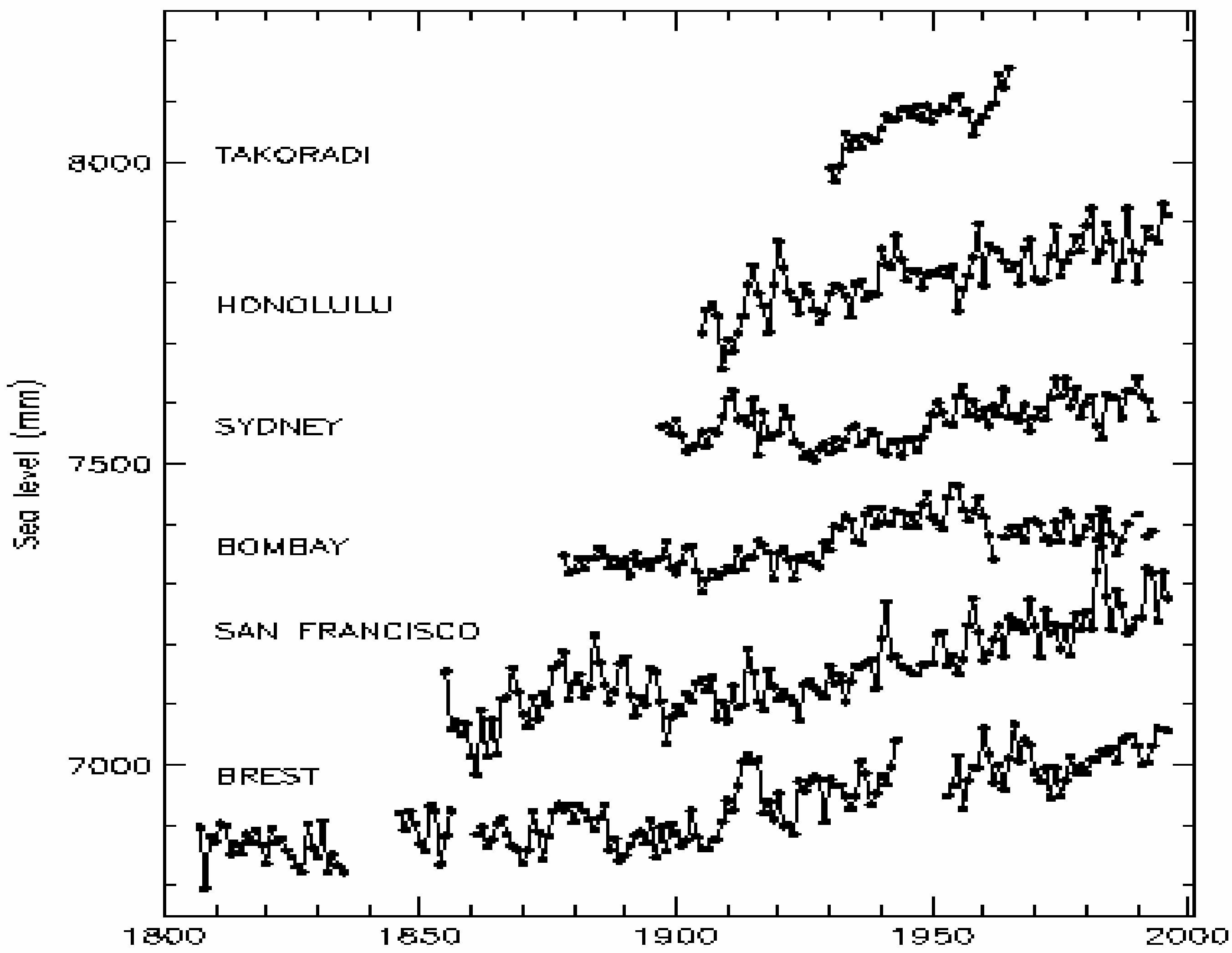
**Oceanic roles?**

# *Vostok Ice Core Time Series -*

## Temperature, CO2, Dust



# *Sea Level from Tide gauges - 1800-2000*

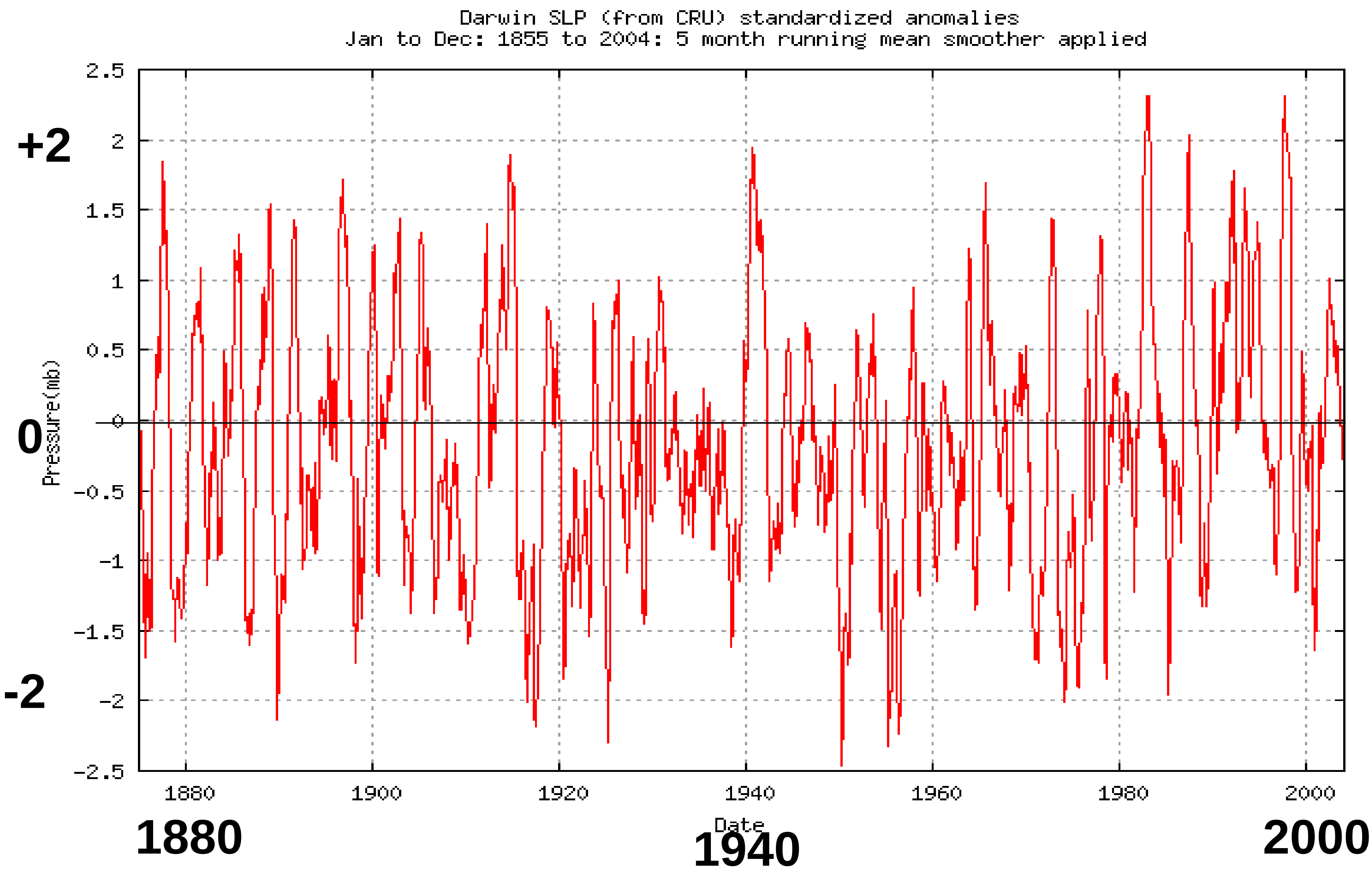



**Ave. Trend: ~1.5 mm/yr (1900-2000)**

**Not the full story though…**

***Sometimes the stories are more complex***

# Darwin Sea Level Pressure, 1875-2005



# *ENSO*

- "El Nino" has different statistics depending upon the index used.
- Important to recognize that different parts of the world respond differently to tropical Pacific interannual variability
- There may be no single index that is globally useful.
- Need to identify what affects region of interest.
- How to help users & policy-makers understand?
- What do we need to make better forecasts?

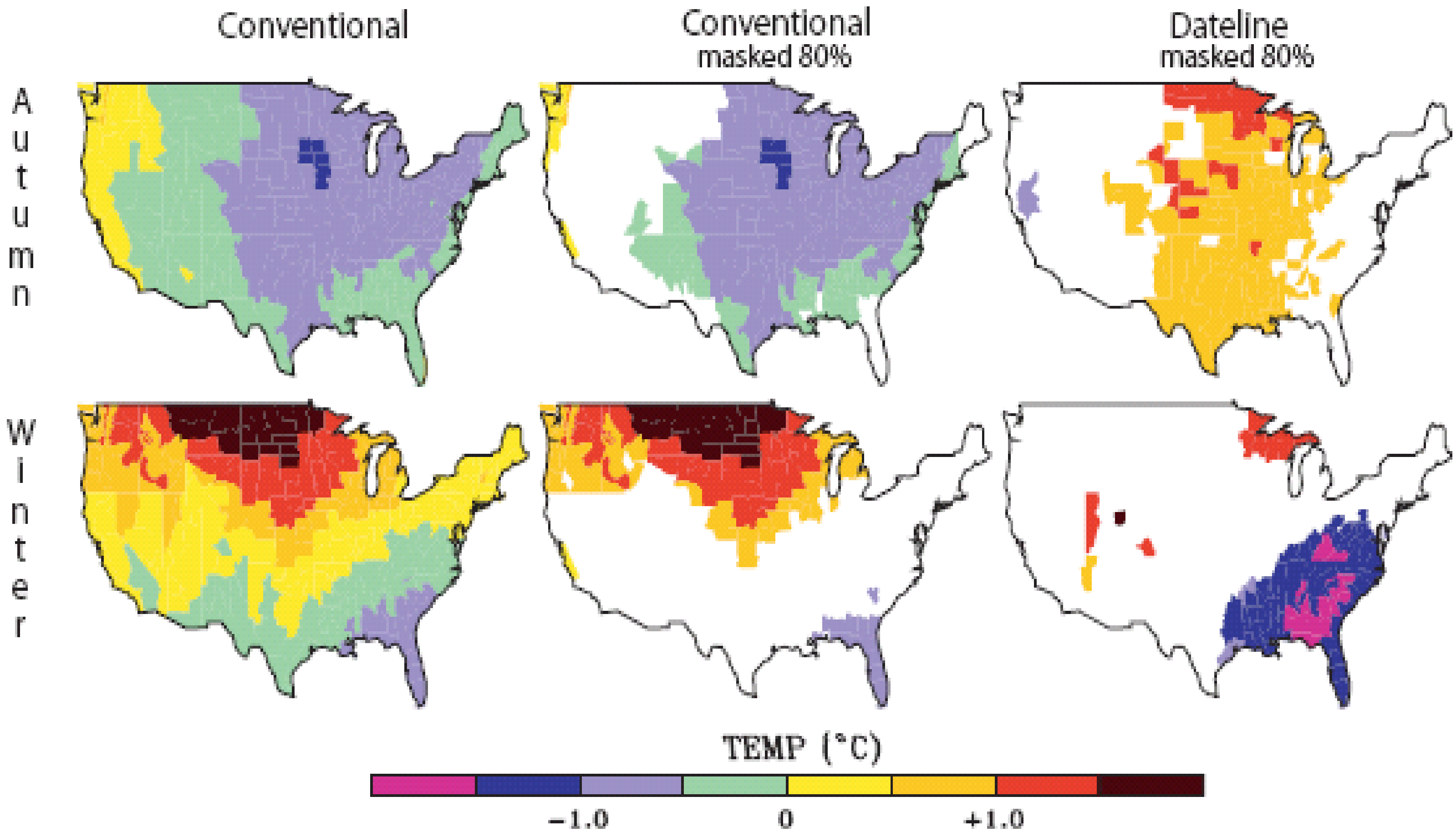
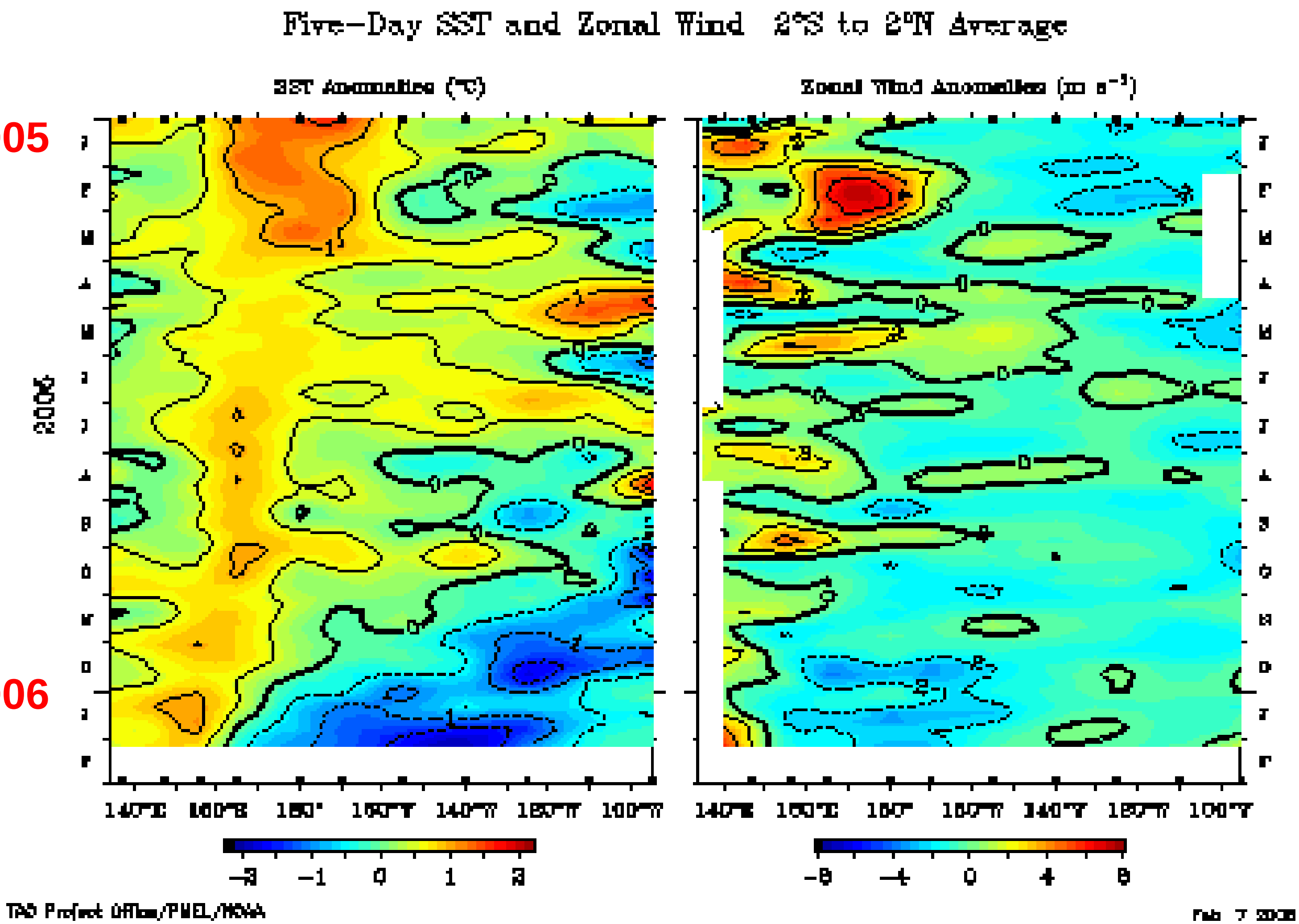



**Figure 1.** El Niño-Seasonal Average U.S. Temperature Anomaly Associations for Autumn(SON) and Winter(DJF). The left two columns are based on the "Conventional" 1950–2003 El Niño seasons; the right column is based on the "Dateline" El Niños. The right two columns are masked for 80% statistical significance. See text for details.

# La Nina returns to Tropical Pacific, Winter 2005-06

Jan 2005

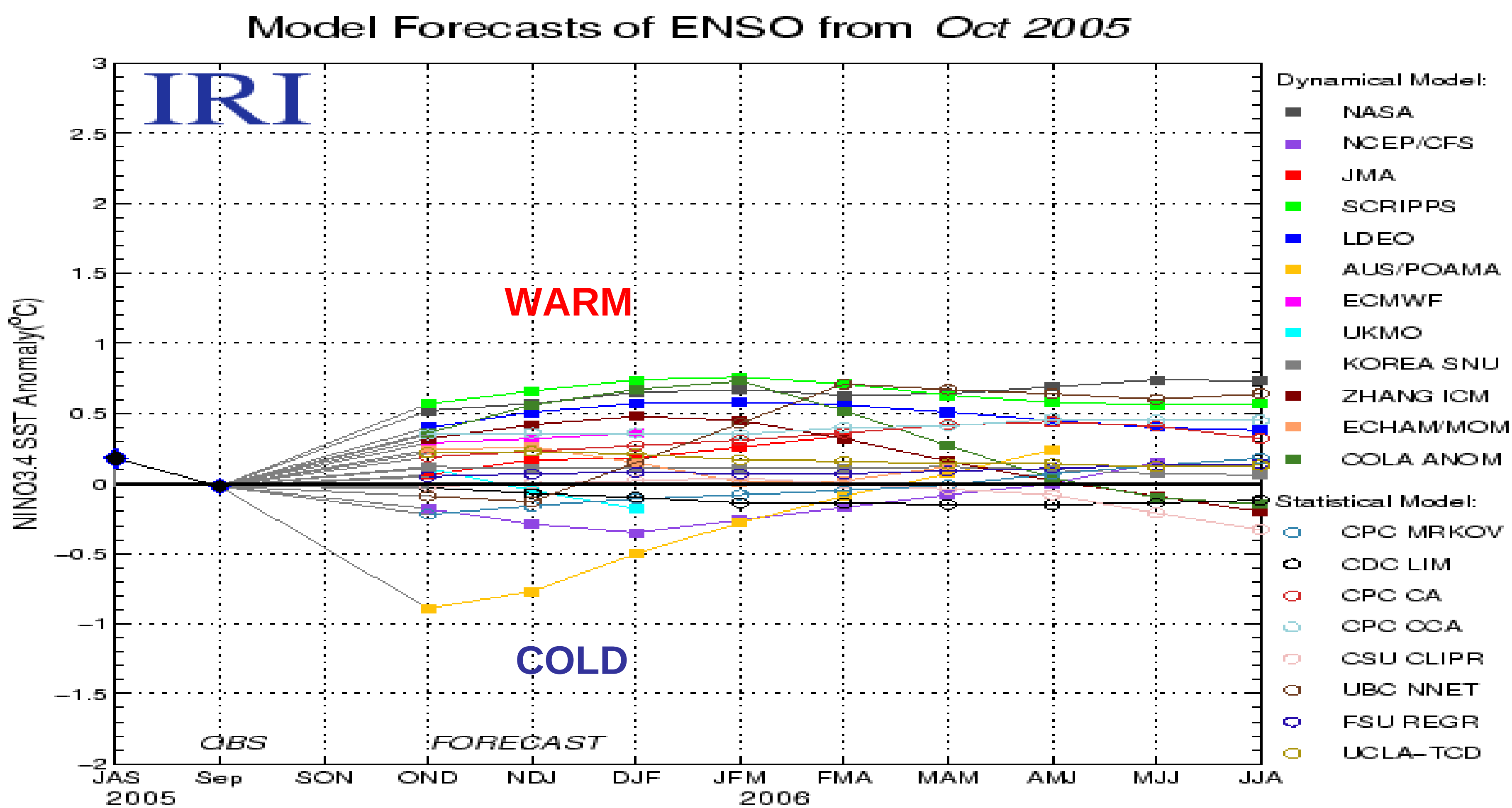



Jan 2006

SST Anomaly

Zonal Wind Anomaly

# October 2005 ENSO Forecasts

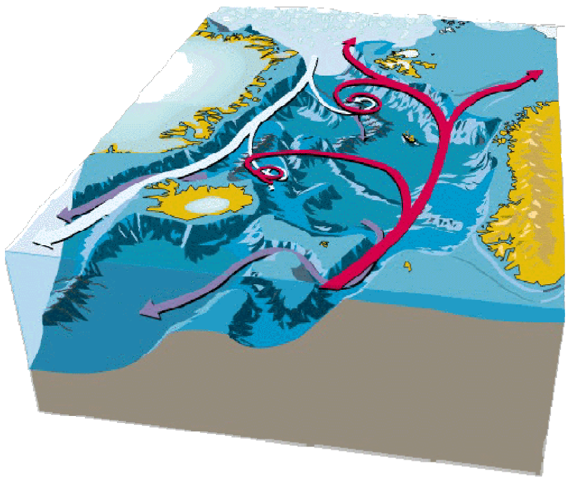


# *Sampling & Aliasing*

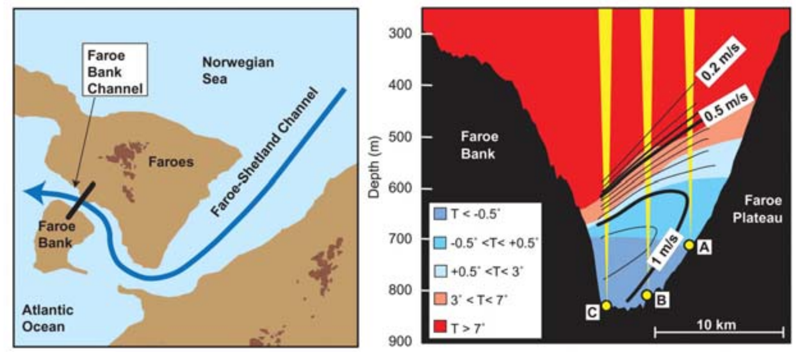
- **Familiar to specialists, but often not to more general audiences.**
- **Uncertainty estimates and statistical inference are seldom familiar**
- **Trends over a few years or even a couple of decades can be quite misleading**
- **Need to explain better**

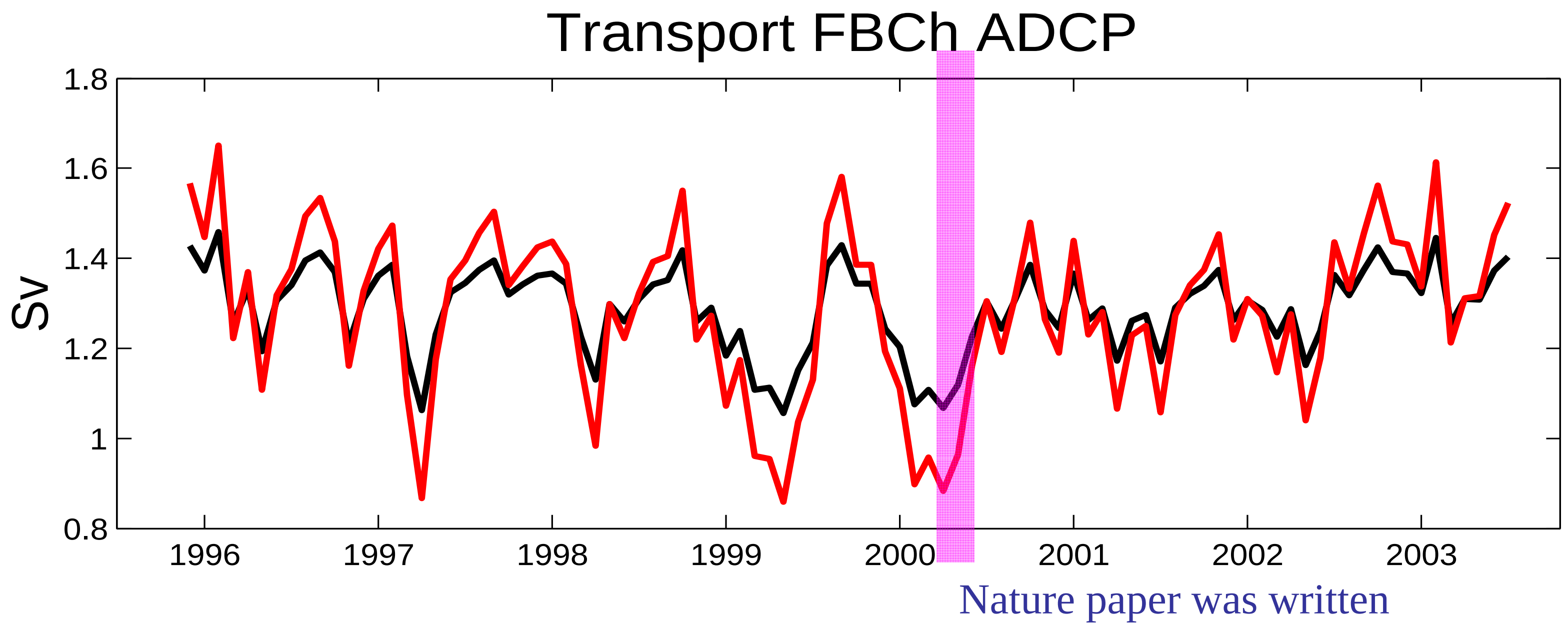
# *Atlantic Meridional Overturning*

- **Bryden et al (Nature 2005) used a few repeat hydro sections**
- **Models say lots of variability that cannot be well sampled by historical data**
- **Current meter transport records need to be long. “Rapid” has been started.**
- **Need integrated long term approach**



# Faroe-Bank Channel overflow




**No trend – but the time series is only one decade**

**Hansen, Turrell and Osterhus (2001), updated by Hansen et al. (2004)**

# *Three Values for Sea Level Rise*

**20th Century Trend from Tide gauges-**

**~1.5mm/yr**

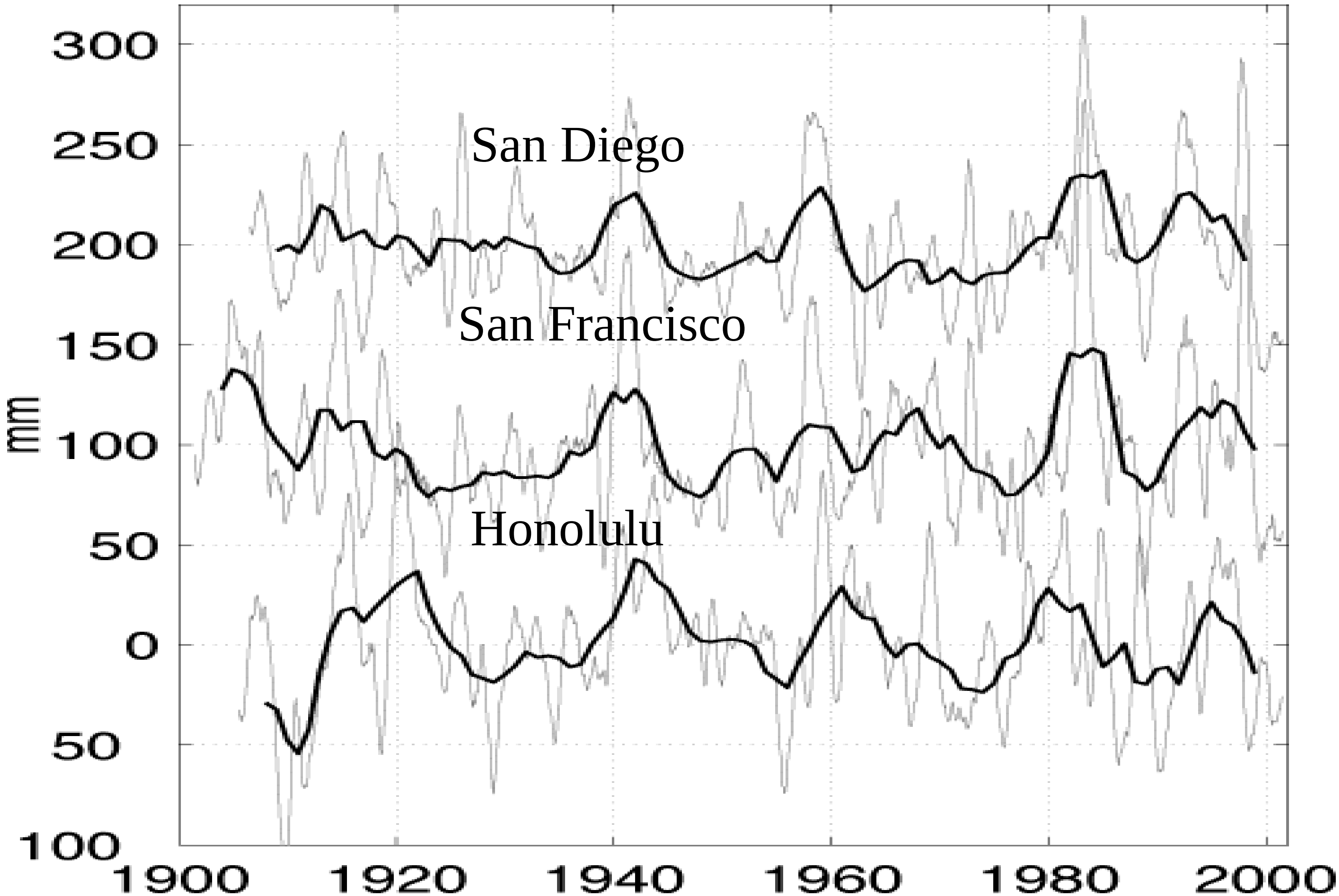
**1950-2000 Change from Oceanic Heat Content (World Ocean Data Base) –**

**~0.7mm/yr**

**1992-2005 Trend from Altimeter, adjusted for Tide gauges-**

**~3.3mm/yr**

# Sea Level Decadal Variability



# *Sorting out the marine part of sea level rise*

- **Continue high precision altimetric satellites**
- **Improve global tide gauge distribution & geocentrically locate them**
- **Continue Argo profiling floats & XBT sections**
- **Devise and implement appropriate deep ocean density sampling plan**

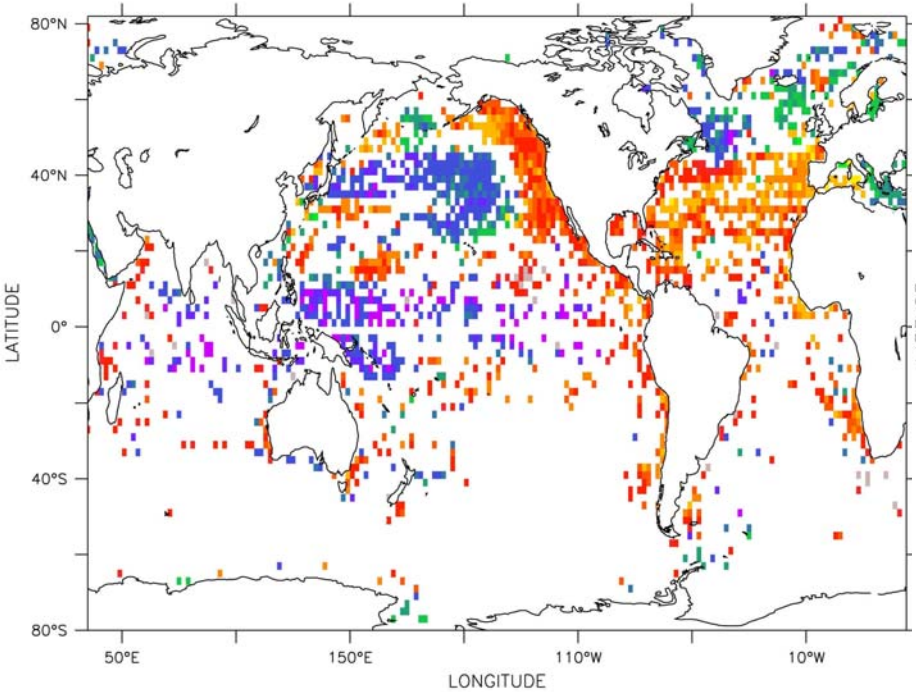
# *Is the global ocean warming?*

- **Historical sampling imposes substantial uncertainty on long term global ocean calculations.**

# *Multi-decadal subsurface Temperature Trends*

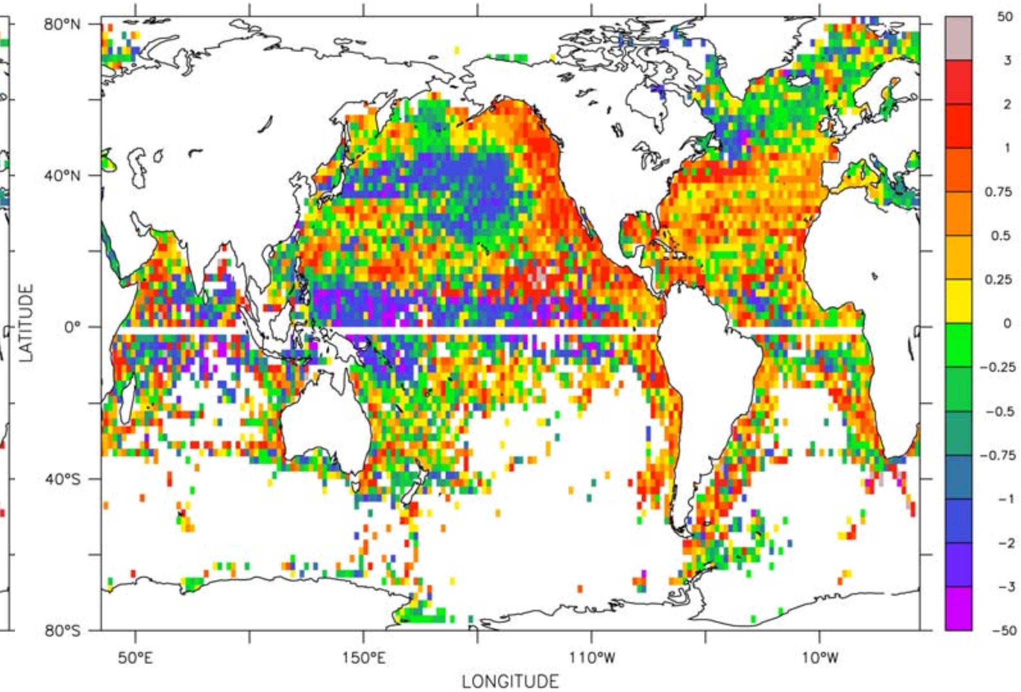
- **Most do not realize how variable (space and time) subsurface oceanic trends are.**
- **The satellite era trends are not representative of previous decades**
- **With so much variability, even 50year trends may not well represent really long term behavior.**

# 2x2 51-yr Temp trends at 100m




2x2 100m 90% CL anomalies

**90% significant trends**

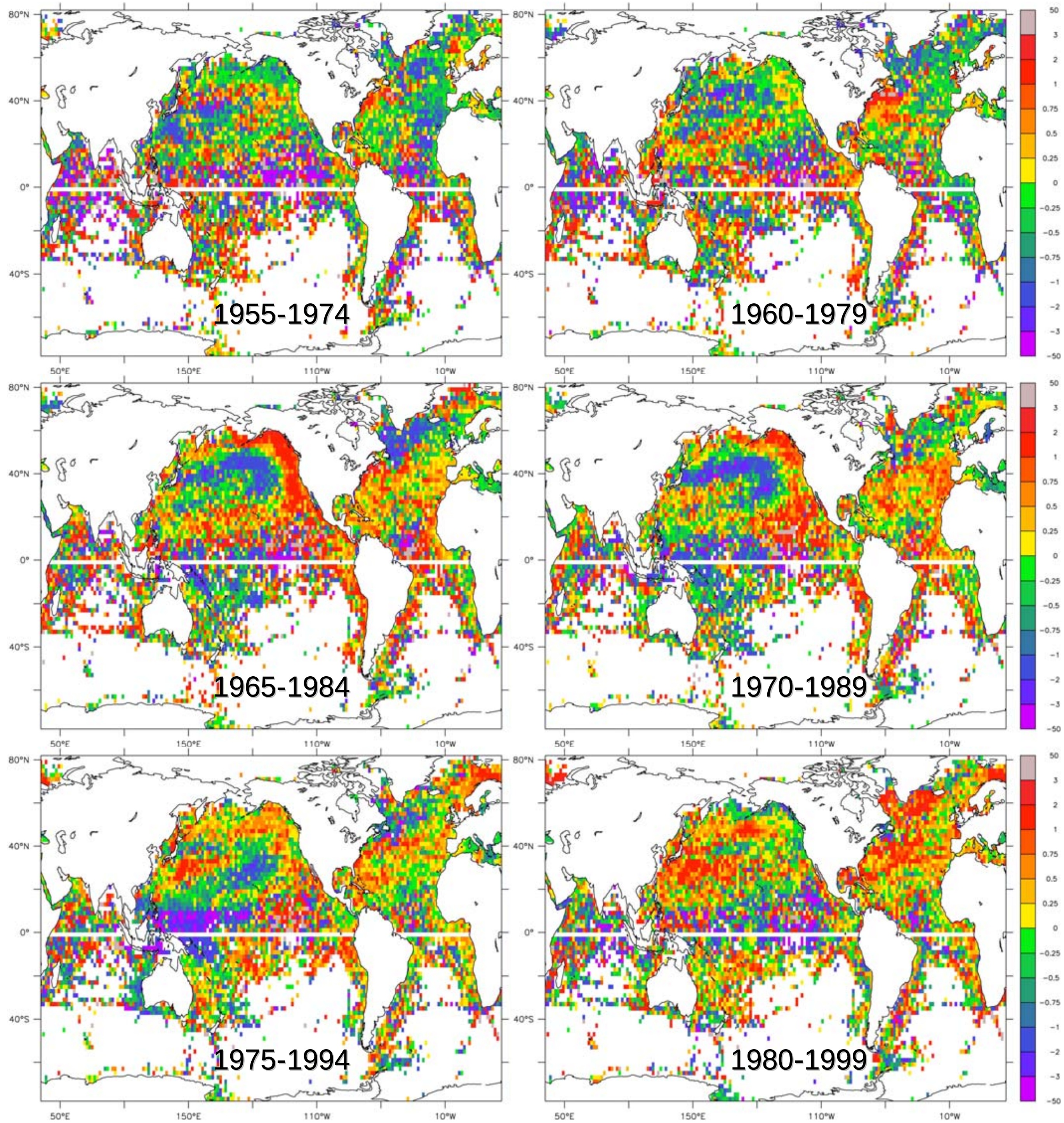



2x2 100m criterion−selected anomalies

**Trends over all boxes meeting sampling criteria**

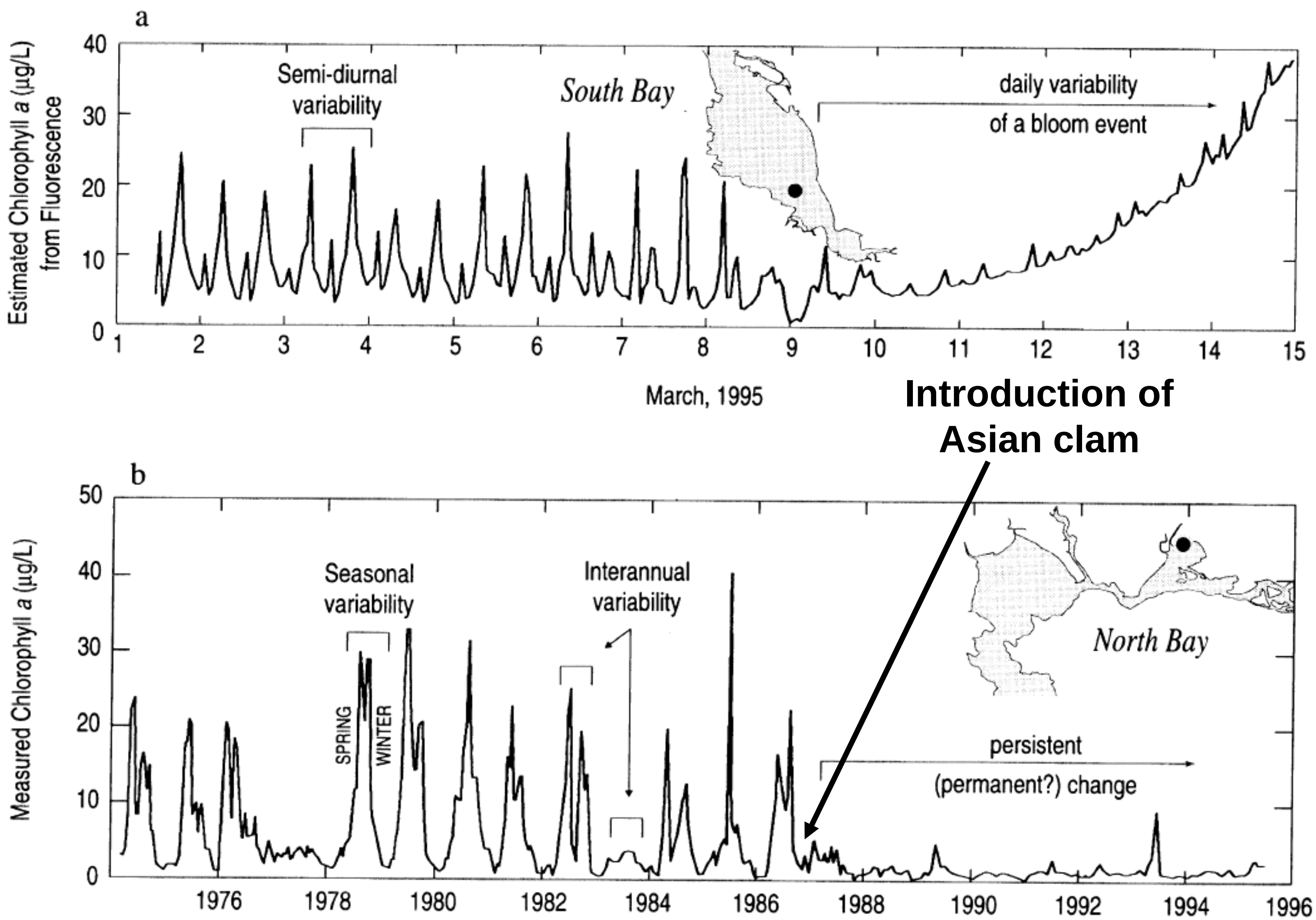
# 20 year T trends at 100m

95% of all boxes change sign at least once over this 45-year period

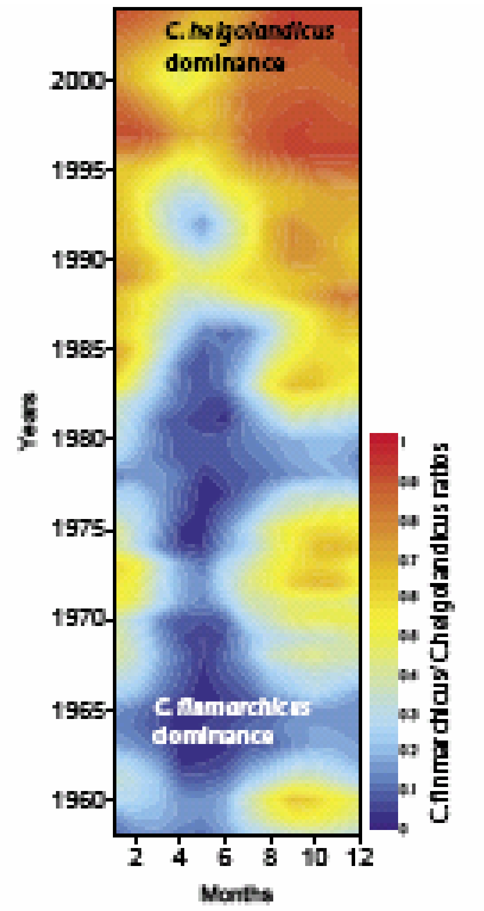


# *A Few More Time Series*

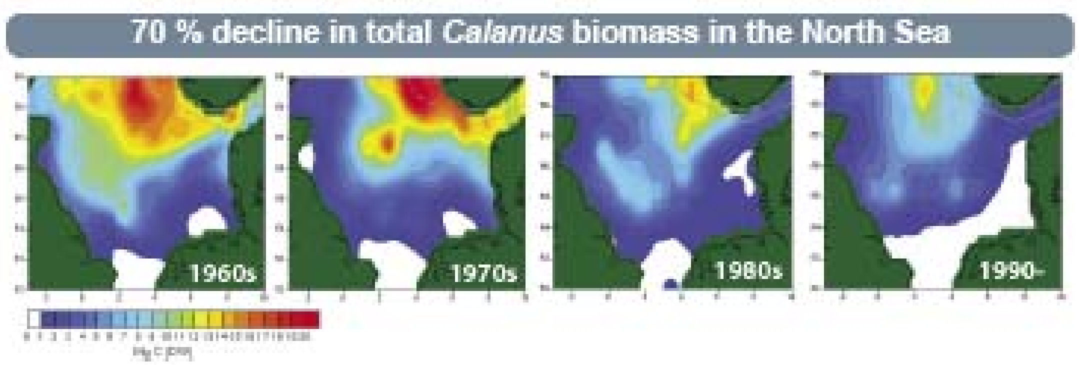
Records from San Francisco Bay, CA illustrate the patterns and magnitudes of semi-diurnal, daily, seasonal, and interannual chlorophyll variability and a regime change of persistent low chlorophyll that started in 1987 (Cloern, J. 1996. Reviews of Geophysics 34/2:127-168)



Ratio between a warm (*Calanus helgolandicus*) and cold (*C. finmarchicus*) species of copepods in the North Sea from 1968 – 2004 (red – dominance of *C. helgolandicus*, blue – dominance of *C. finmarchicus*).



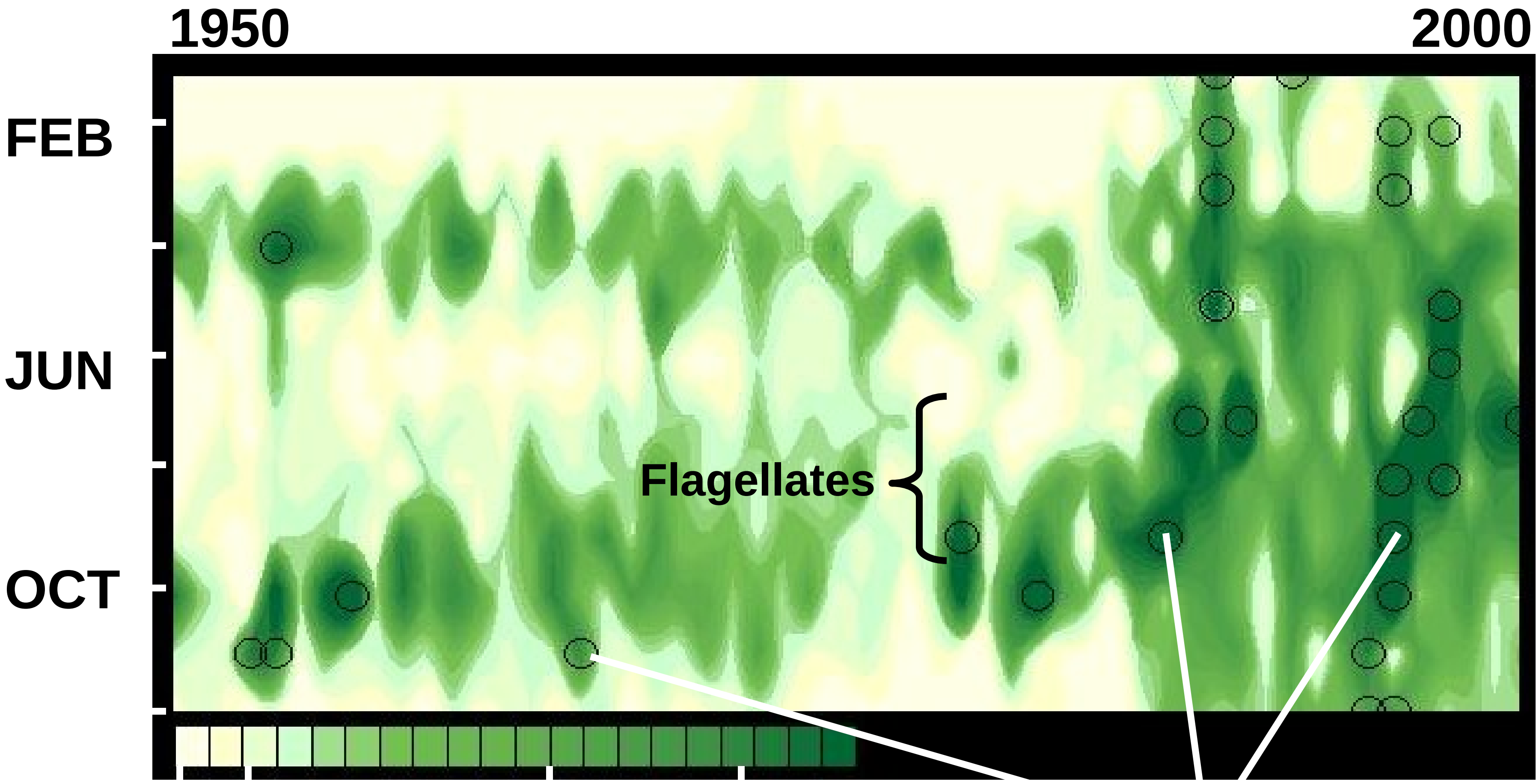

## Continuous Plankton Recorder




Warmer water species are currently increasing in the North Sea due to regional climate warming and the NAO. This is considered detrimental because the warmer species are not replacing the colder species in similar abundance so the biomass of higher trophic levels is also decreasing.

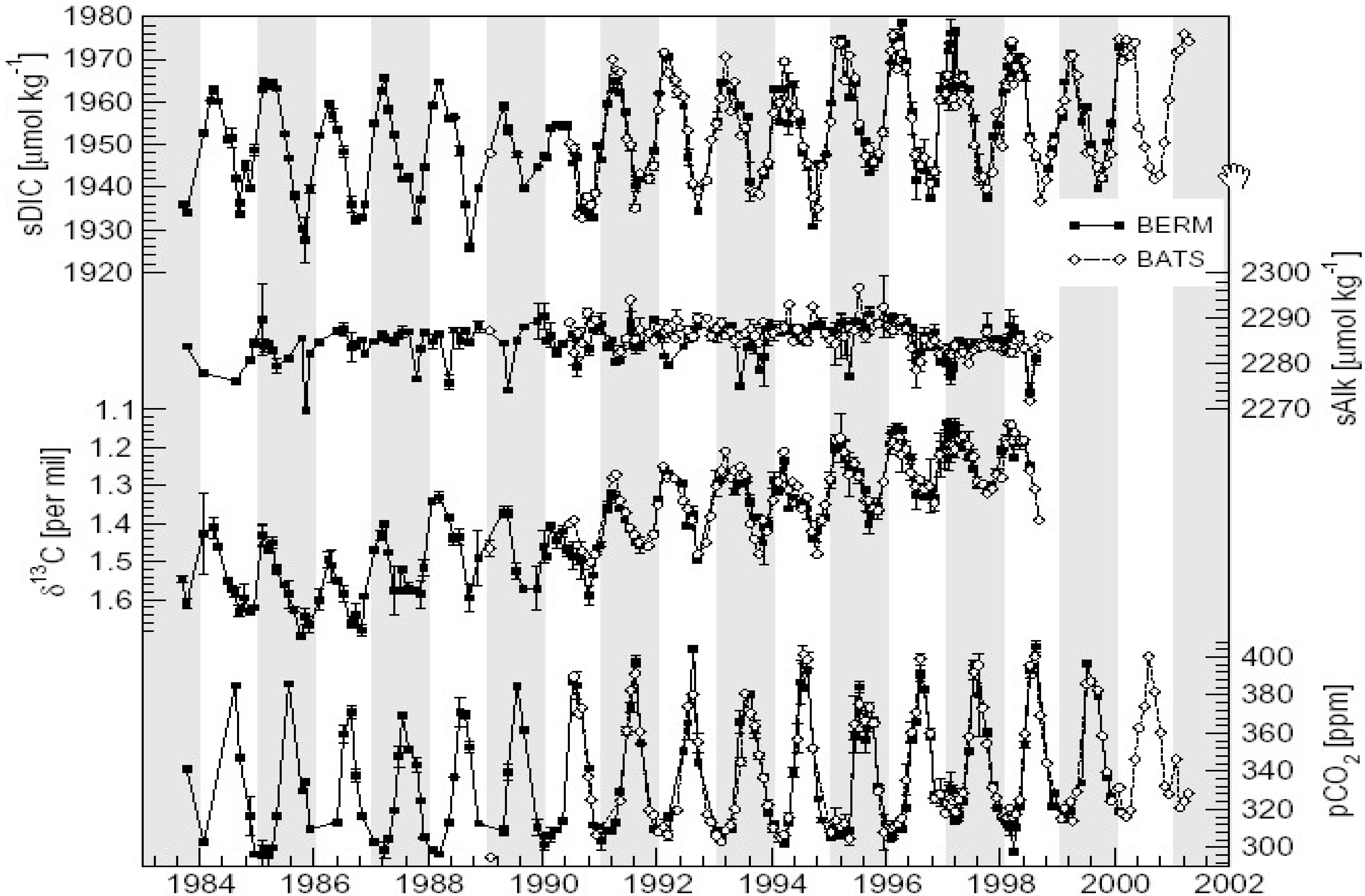
# Eutrophication

## Central North Sea

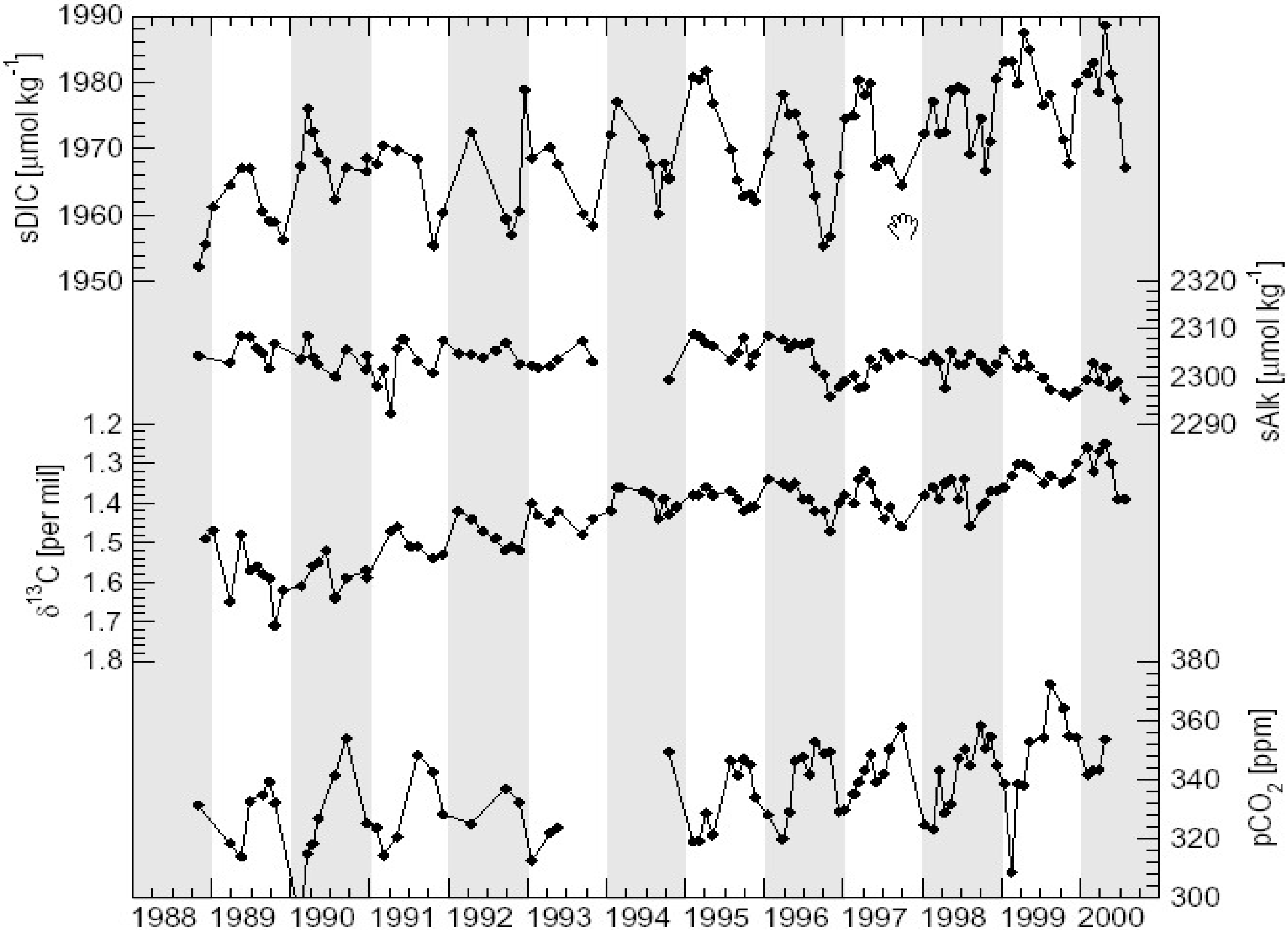



Phytoplankton Chl color index from CPR records

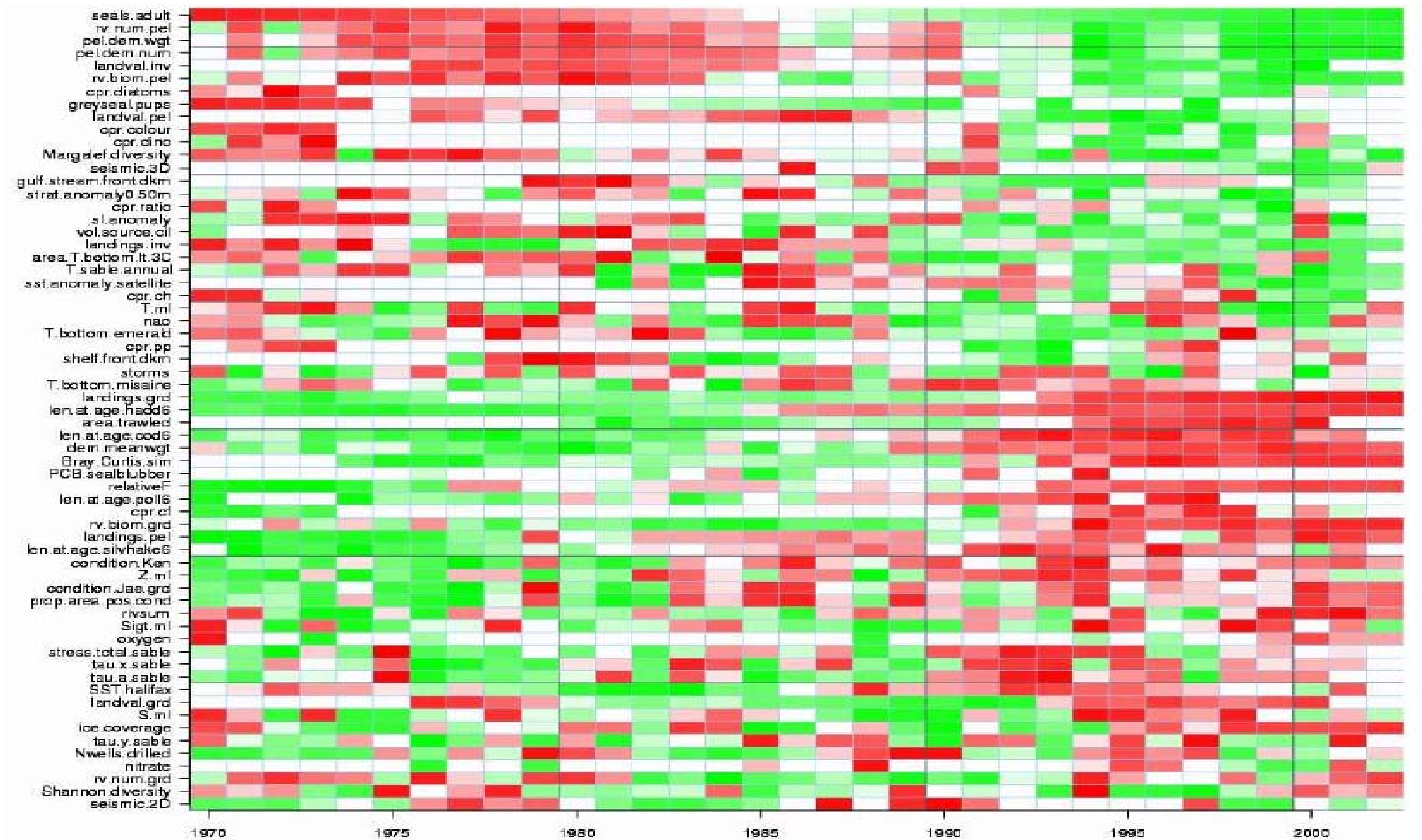
Bermuda : Mixed Layer Carbon Observations



# Hawaii Station HOT: Mixed Layer Carbon Observations



# ICES Multi-variate Ecosystem/Climate Matrix




**1970** **1985** **2000**

***Bottom trawl surveys in Pavlov Bay, Alaska (Bottsford et al. 1997, Science)***

Late 1960's

Late 1970's

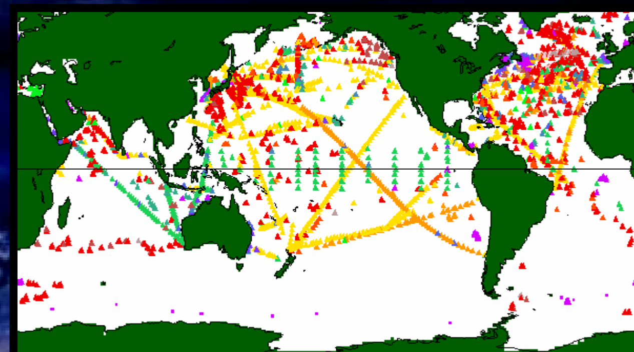
1980's

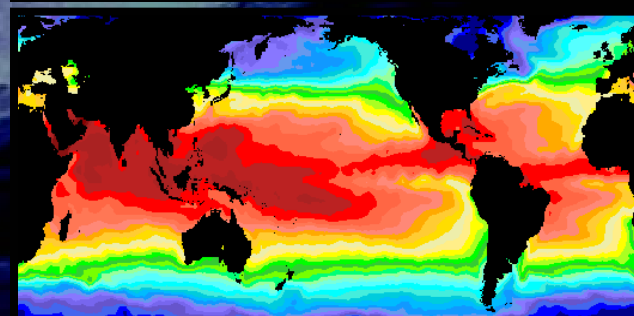
# *Toward knowing the global ocean*

- **To address many of the needs of the ocean community an international plan for a sustained integrated global ocean observing system has been agreed (GOOS, GCOS, WCRP).**
- **Accepted by UNFCCC & GEO**
- **Makes use of existing observing efforts as possible & calls for some additional efforts**
- **See www.wmo.ch/web/gcos/ for an assessment & implementation plan**

# Capabilities Required

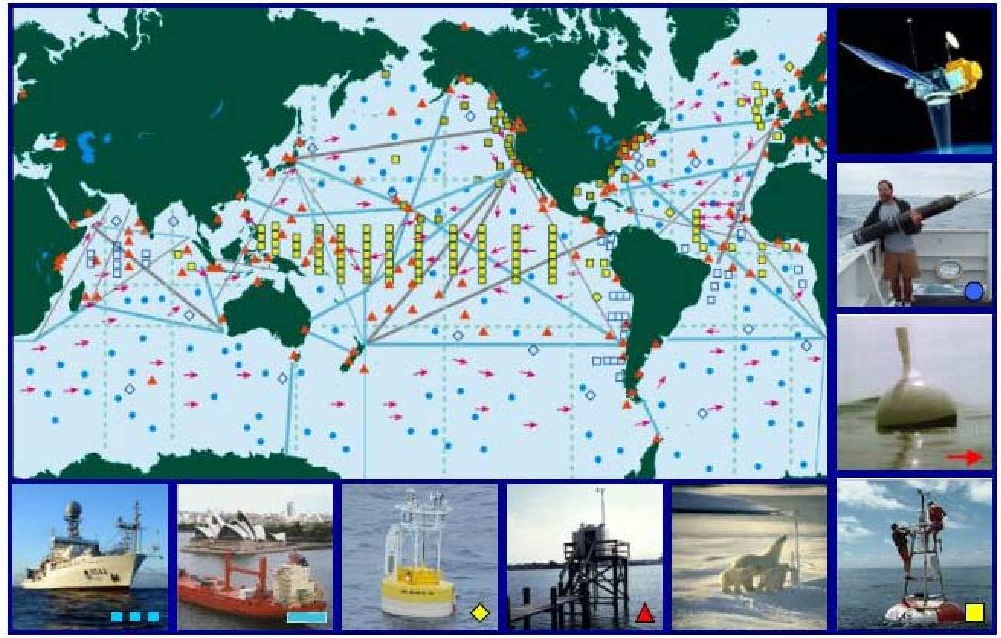
- Global coverage by moored and drifting buoy arrays, profiling floats, tide gauge stations, and ship-based systems.
- Continuous satellite missions for sea surface temperature, sea surface height, surface vector wind, ocean color, and sea ice.
- Data and assimilation subsystems
- System management and product delivery





# Overview

- **Composite system of systems designed to meet Climate requirements, but also supports:**
  - **Weather prediction**
  - **Global and coastal ocean prediction**
  - **Marine hazards warning**
  - **Transportation**
  - **Marine environment and ecosystem monitoring**
  - **Naval applications**

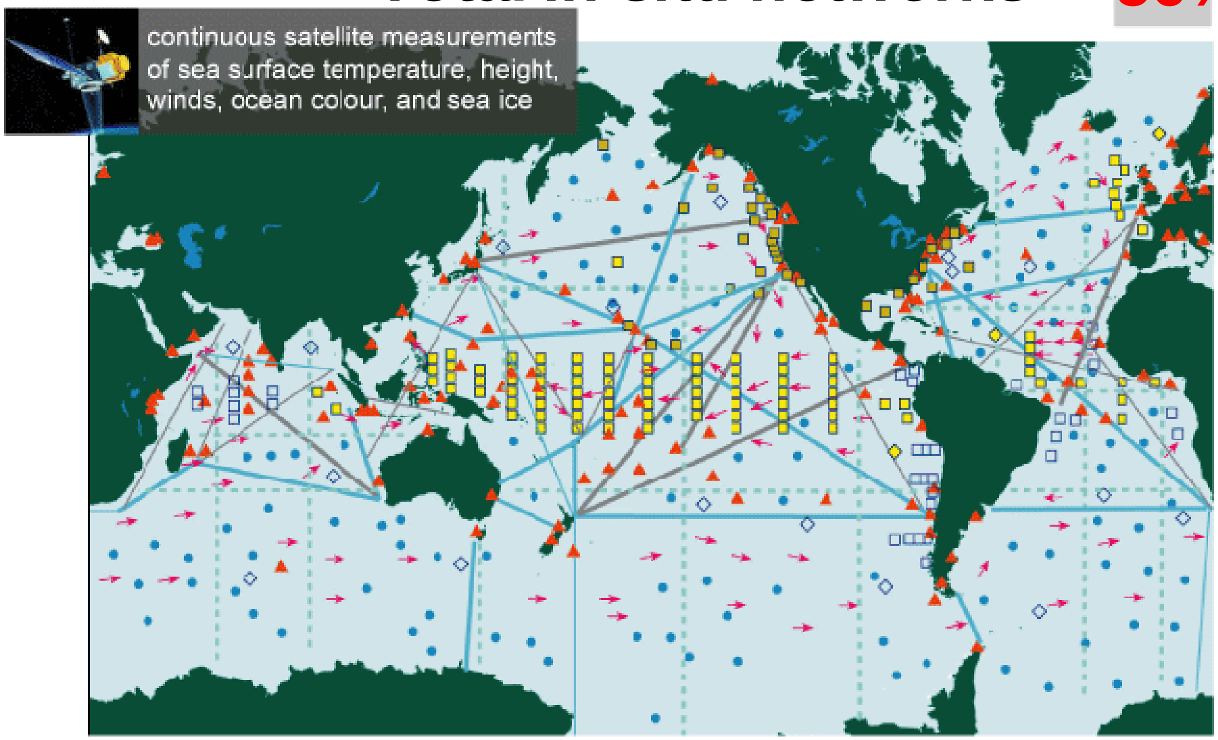


- **Tide gauge stations**
- **Drifting Buoys**
- **Tropical Moored Buoys**
- **Profiling Floats**
- **Ships of Opportunity**
- **Ocean Reference Stations**
- **Ocean Carbon Networks**
- **Arctic Observing System**
- **Dedicated Ship Support**
- **Data & Assimilation Subsystems**
- **Management and Product Delivery**
- **Satellites -- SST, Surface Topography, Wind, Color, Sea Ice**

# Initial Global Ocean Observing System for Climate

Status against the GCOS Implementation Plan and JCOMM targets

## Total *in situ networks* 56% April 2006




75% **Surface measurements from volunteer ships (VOSclim)**

200 ships in pilot project

100% **Global drifting surface buoy array**

5° resolution array: 1250 floats

42% **Tide gauge network (GCOS subset of GLOSS core network)**

170 real-time reporting gauges

81% **XBT sub-surface temperature section network**

51 lines occupied

81% **Argo profiling float network**

3° resolution array: 3000 floats

43% **Repeat hydrography and carbon inventory**

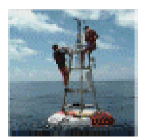
Full ocean survey in 10 years

**Reference time series** 21%

[illegible] sites

48% **Global reference mooring network**

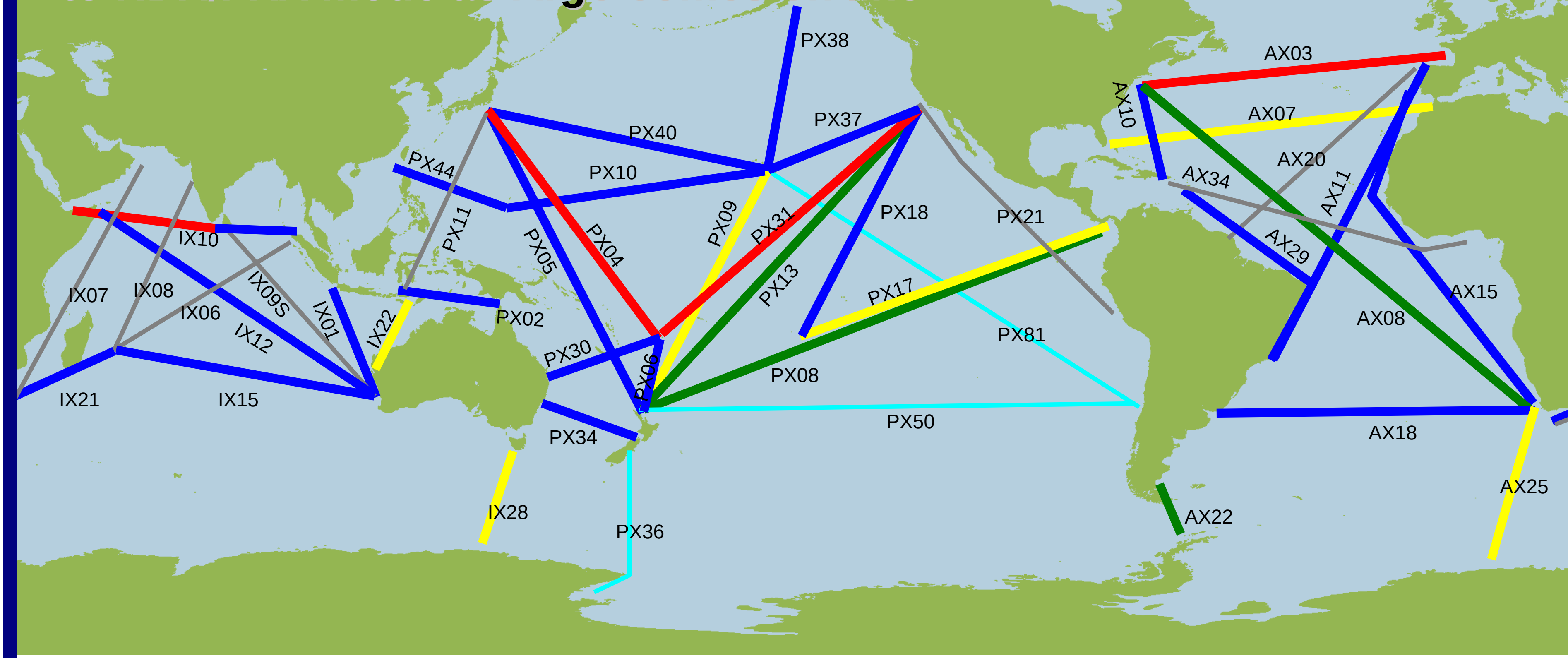
29 moorings planned



66% **Global tropical moored buoy network**

119 moorings planned

# International goal: Evolve from Broadcast XBT to HDX/FRX mode as Argo comes on line.




SOOP : January - December 2004

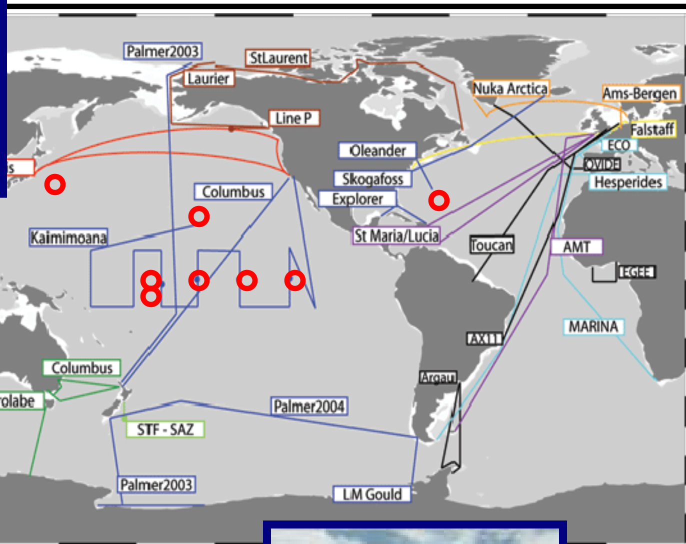
| | |
|---|---|
| Well sampled | blue |
| Over sampled | green |
| Partially sampled | yellow |
| Under sampled | red |
| Not sampled HDX | cyan |
| Not sampled FRX | grey |

*Note : AX08 is Under sampled in FRX Mode*

**39 of 51 lines occupied**

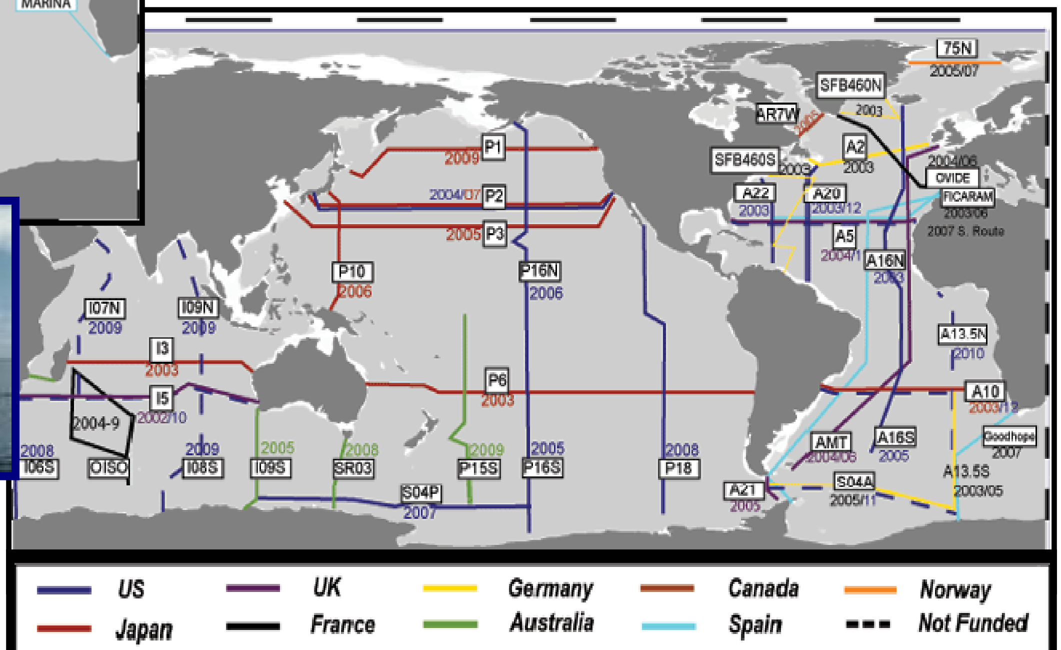
**24000 XBTs required per year (if perfect deployment)**
**<u>19,686</u> Present drops per year, estimate**
**4,314 Additional XBTs needed**

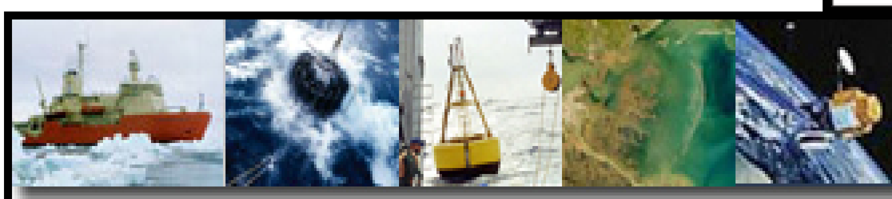
# Measuring Ocean Carbon Sources and Sinks




Global ocean carbon inventory every 10 years and air-sea exchange of CO2 seasonally.

1. Inventory survey
2. Ships of opportunity
3. Moored buoy time series

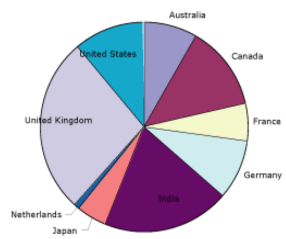


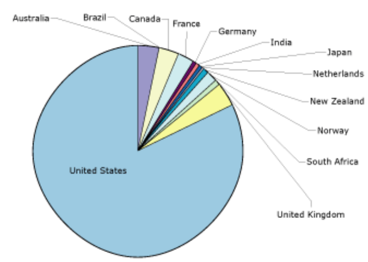
International Ocean Carbon Coordination Project

# Implementation by nations

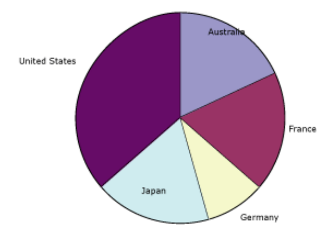
VOSClim surface network



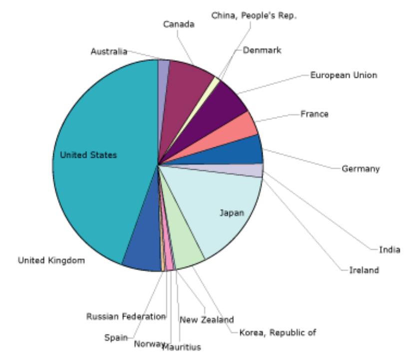

Surface drifters

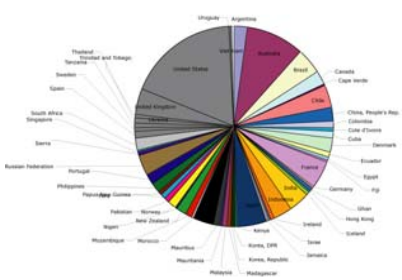



Frequent-mode XBT lines

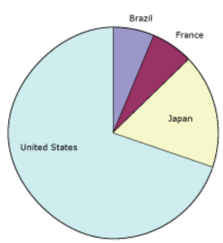



Argo

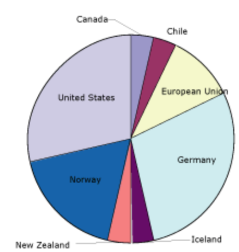


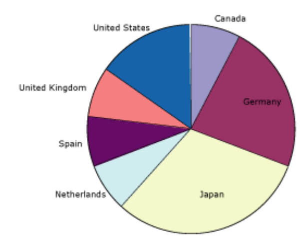
Tide gauges GLOSS




Tropical moored array



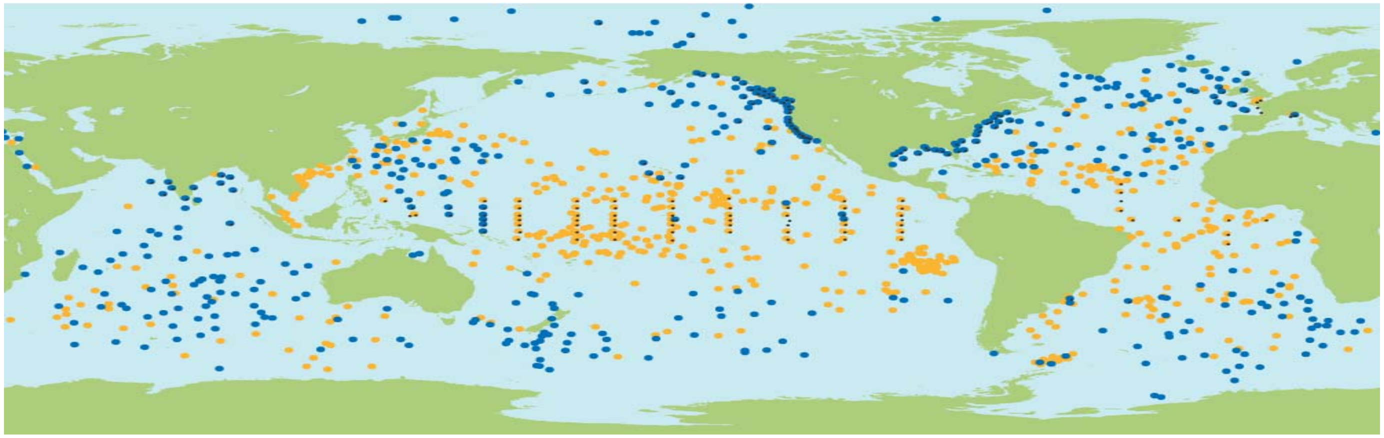

Reference time series




Carbon hydrography

JCOMM OPA

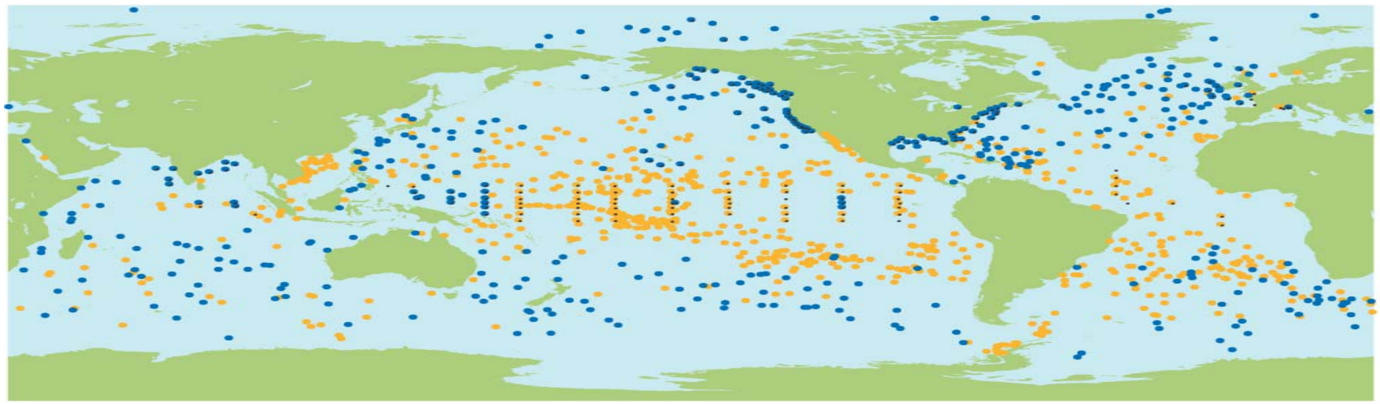
66 nations contribute; majority of system contributed by a smaller group



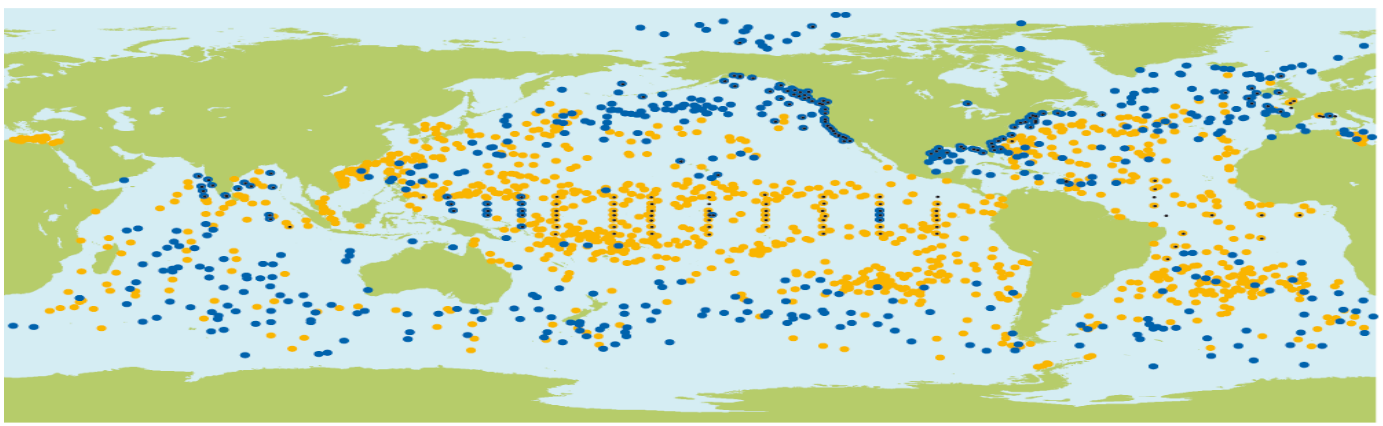
***GTS***

***Surface Data Buoys***

**FEB 2004**



**FEB 2005**



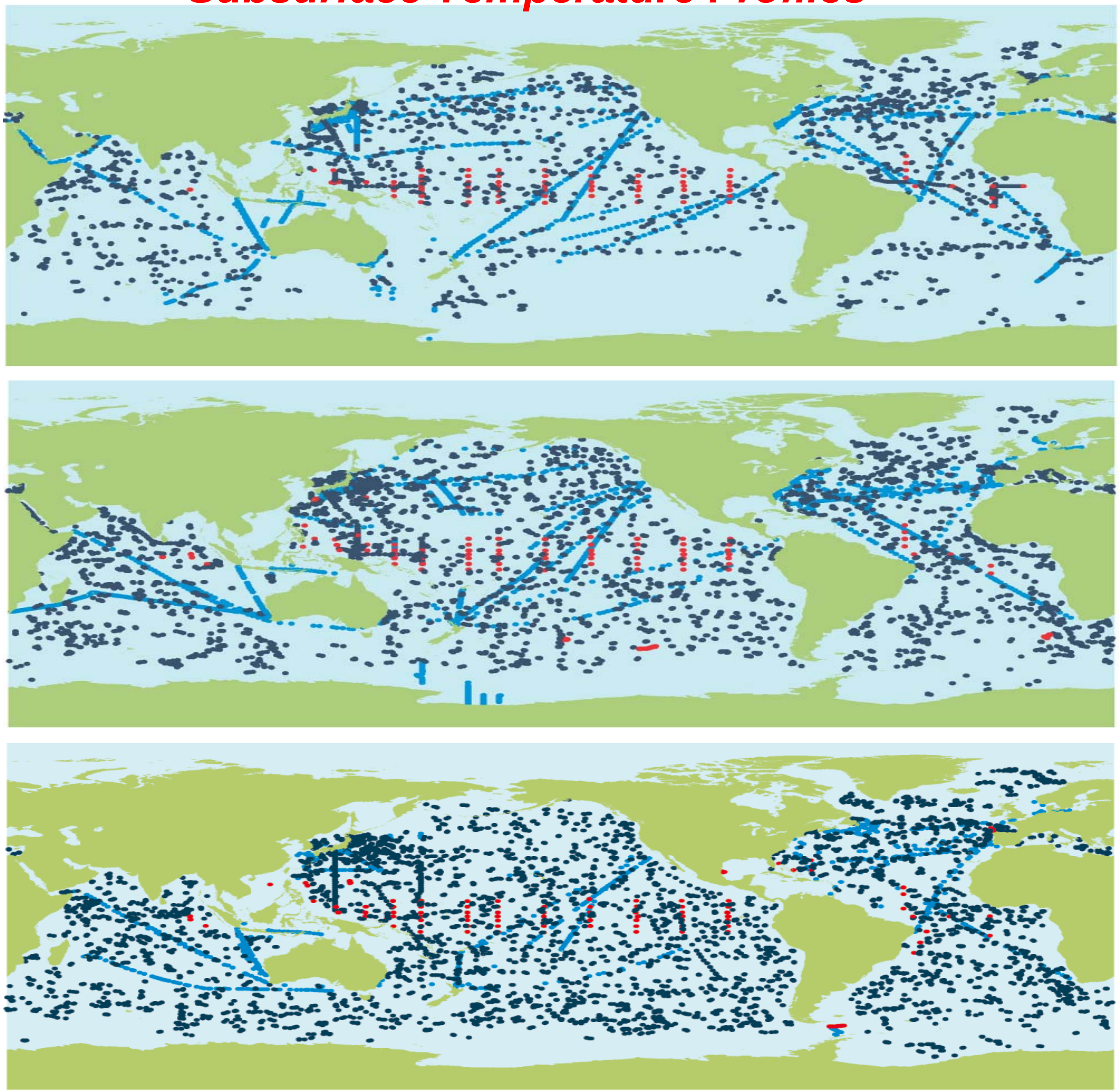
**Feb 2006**

**Gold – SST**

**Blue – SST & SLP**

**Dot - mooring**

## *Subsurface Temperature Profiles*



***GTS Temperature Profiles:***

**FEB 2004**

**FEB 2005**

**Feb 2006**

OceanSITES

Taking the pulse of the global ocean

**http://www.oceansites.org**

R. Weller

OOPC 11

May 16-20, 2006

# OceanSITES Steering Committee

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NIOZ, Netherlands
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IFM Kiel, Germany

# A statement of purpose:
# A global ocean timeseries observatory system is now under development

**A GOOS/CLIVAR/POGO sponsored (via OOPC/COOP) activity**

- **The system is multidisciplinary in nature, providing physical, meteorological, chemical, biological and geophysical timeseries observations**

- **Goal is to make the data are publicly available as soon as received and quality-controlled by the owner/operator**

- **An international Science Team provides guidance, coordination, outreach, and oversight for the implementation, data management and capacity building**

- **A pilot system (2001-2006) has been defined consisting of all operating sites and those planned to be established within 5 years, subject to evaluation in terms of the qualifying criteria by the Science Team.**

## Milestones since 2004

- New website
- Review of all stations
- White papers for Atlantic, Pacific, Indian, Southern oceans
- New maps
    - Present
    - Near term
    - Vision
- Increased emphasis on data sharing
- Data policy, format, data serving
- Data team meeting, Hawaii February 2006
- Steering Committee meeting, Hawaii February 2006
- Brochure

OceanSITES : Taking the Pulse of the Global Ocean

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# OceanSITES

*Taking the pulse of the global ocean*

**A worldwide system of deepwater reference stations providing:**

- Home
- Global Network
- Data
- Global Team
- Meetings
- Documents
- Links
- Contact

OCEANSITES

## Elite technology puts eyes in the deep ocean

OceanSITES is a worldwide system of long-term, deepwater reference stations measuring dozens of variables and monitoring the full depth of the ocean from air-sea interactions down to 5,000 meters.

Since 1999, the international OceanSITES science team has shared both data and costs in order to capitalize on the enormous potential of these moorings. The growing network now consists of about 30 surface and 30 subsurface arrays. Satellite telemetry enables near real-time access to OceanSITES data by scientists and the public.

OceanSITES moorings are an integral part of the Global Ocean Observing System. They complement satellite imagery and ARGO float data by adding the dimensions of time and depth.

For more information or to coordinate your research with the OceanSITES program, please contact the NOAA Cooperative Institute for Climate and Oceans Research at the Woods Hole Oceanographic Institution: cicor@whoi.edu

**Coming Soon:**

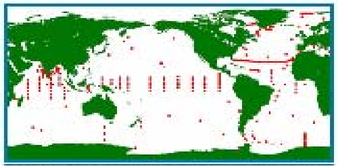
**OceanSITES Brochure**

**April 2006**

In this animation, a seismometer at an OceanSITES reference station monitors an active fault zone.

View Quicktime »

View Windows Media Player »



Go to maps of the global network

OceanSITES Taking the pulse of the global ocean

- Home
- **Global Network**
  - Atlantic Ocean
  - Indian Ocean
  - Pacific Ocean
  - Southern Ocean
- Data
- Global Team
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- Documents
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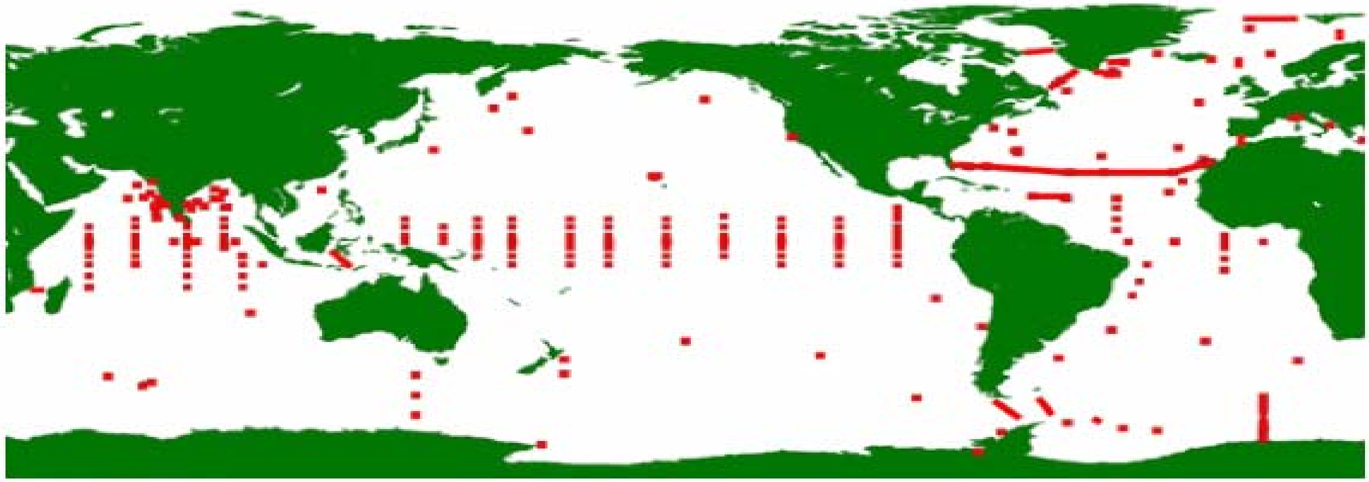
OceanSITES

# OceanSITES Current Global Time-series

More than 60 OceanSITES time-series stations are now operating. The links below take you to global maps showing where these stations are, and to what degree the data are shared. "Maps by discipline" show which OceanSITES stations are recording particular types of data.

See the links at left (grouped by ocean), for a list of individual sites, their locations, and project PIs and websites. Also on those pages: links to detailed descriptions of each station (Word documents), and an Excel spreadsheet summarizing all OceanSITES locations in the global network.



## View Maps of Global Network:

- Current sites
- Current and funded sites
- The OceanSITES vision map

## View Maps by Discipline

## View Maps of Global Network:

- Current sites
- Current and funded sites
- The OceanSITES vision map

## View Maps by Discipline

- Biogeochemical
- Carbon Dioxide
- Geophysical
- Meteorological
- Physical

## Get Information in bulk:

- For summary information on sites in all oceans: Download MS Excel file (136 KB)
- Feb. 2006 White Papers containing detailed descriptions of sites by ocean:
  - Atlantic: Download MS Word file (21.2 MB)
  - Indian: Download MS Word file (1.9 MB)
  - Pacific: Download MS Word file (8.8 MB)
  - Southern: Download MS Word file (2.4 MB)

OceanSITES

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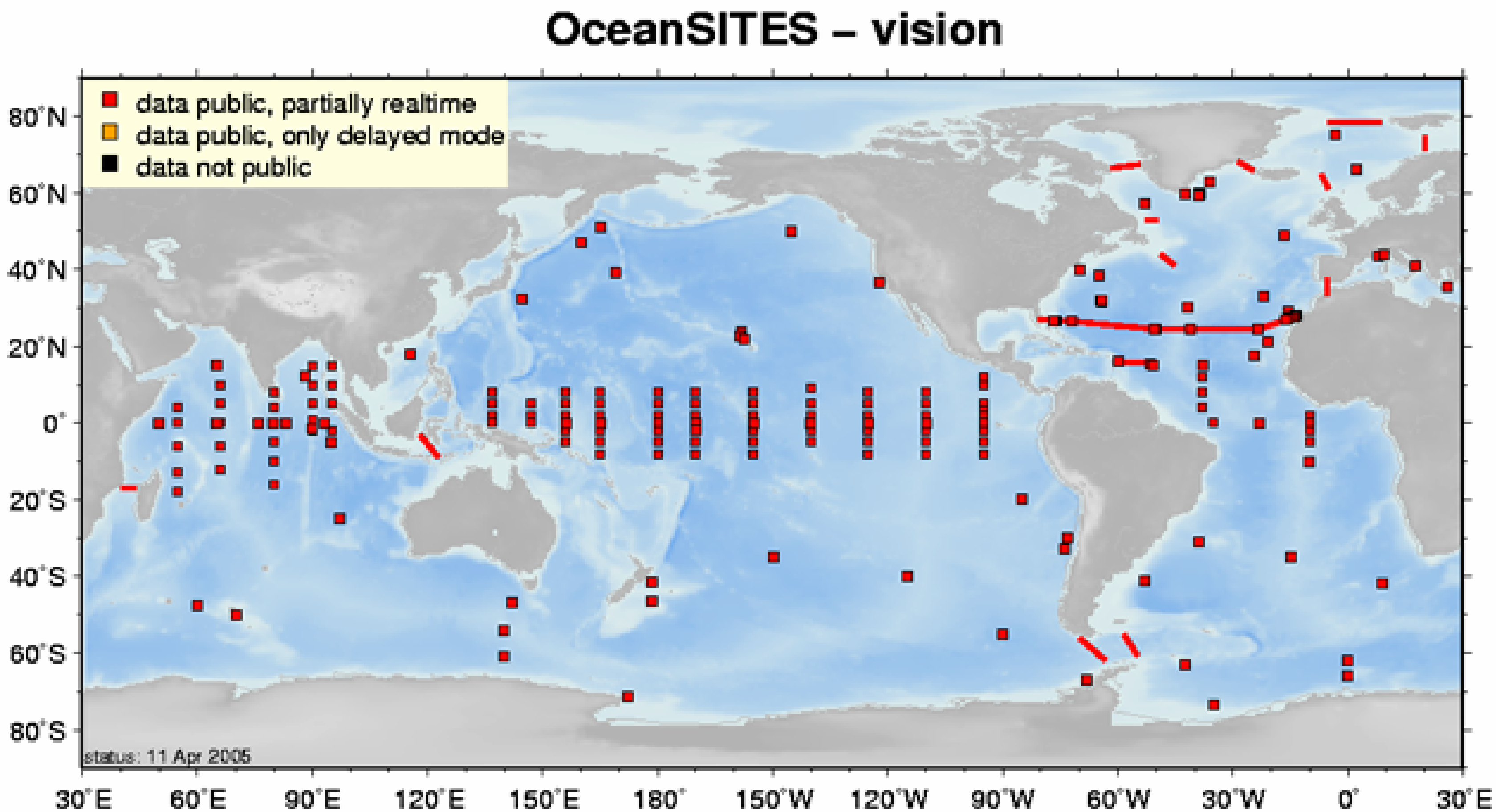
# OceanSITES: Pacific Ocean

Click on site names to go to the individual project websites. Download a detailed description of each site (MS Word file) by clicking the file icons at right. These individual site descriptions are compiled into a single, large file in the February 2006 **Pacific** White Paper.

Discipline Key: (p: phys., m: meteorol., g: geophys., b: biogeochem.)

| Site | Lat | | Lon | | Discipline(s) | | | | | Contact | File |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | p | m | g | b | CO2 | | |
| PAPA, Station P, Line P | 50 | N | 145 | W | x | x | | x | x | Freeland, Howard ; Whitney, Frank | |
| Northwest Pacific (HiLaTS) | 51 | N | 165 | E | x | | | x | | Honjo, Susumu (WHOI); Honda,Makio (JAMSTEC) | |
| | 47 | N | 160 | E | x | | | x | | | |
| | 39 | N | 169 | E | x | | | x | | | |
| California Current MBARI | 36.75 | N | 122 | W | x | x | | x | x | Chavez, Fransisco (MBARI) | |
| | 36.7 | N | 122.38 | W | x | x | | x | x | | |
| Kuroshio Extension Observatory (KEO) | 32.3 | N | 144.5 | E | x | x | | | | Cronin, Meghan; Johnson, Michael; Sabine, Chris (CO2) | |
| HOT – Station ALOHA | 22.75 | N | 158 | W | x | x | | x | | Lukas, Roger (UH/SOEST); Karl, David (UH/SOEST); Santiago-Mandujano, F. | |
| HOT – MOSEAN (H-A mooring ) | 22.75 | N | 158.1 | W | x | x | | x | x | Dickey, Tommy (UCSB); Karl, Dave (UH/Soest); Sabine, Chris (CO2) | |
| WHOTS | 22.75 | N | 157.9 | W | x | x | | | | Weller, Robert (WHOI); Plueddemann, A.(WHOI); Lukas, Roger (UH/SOEST) | |

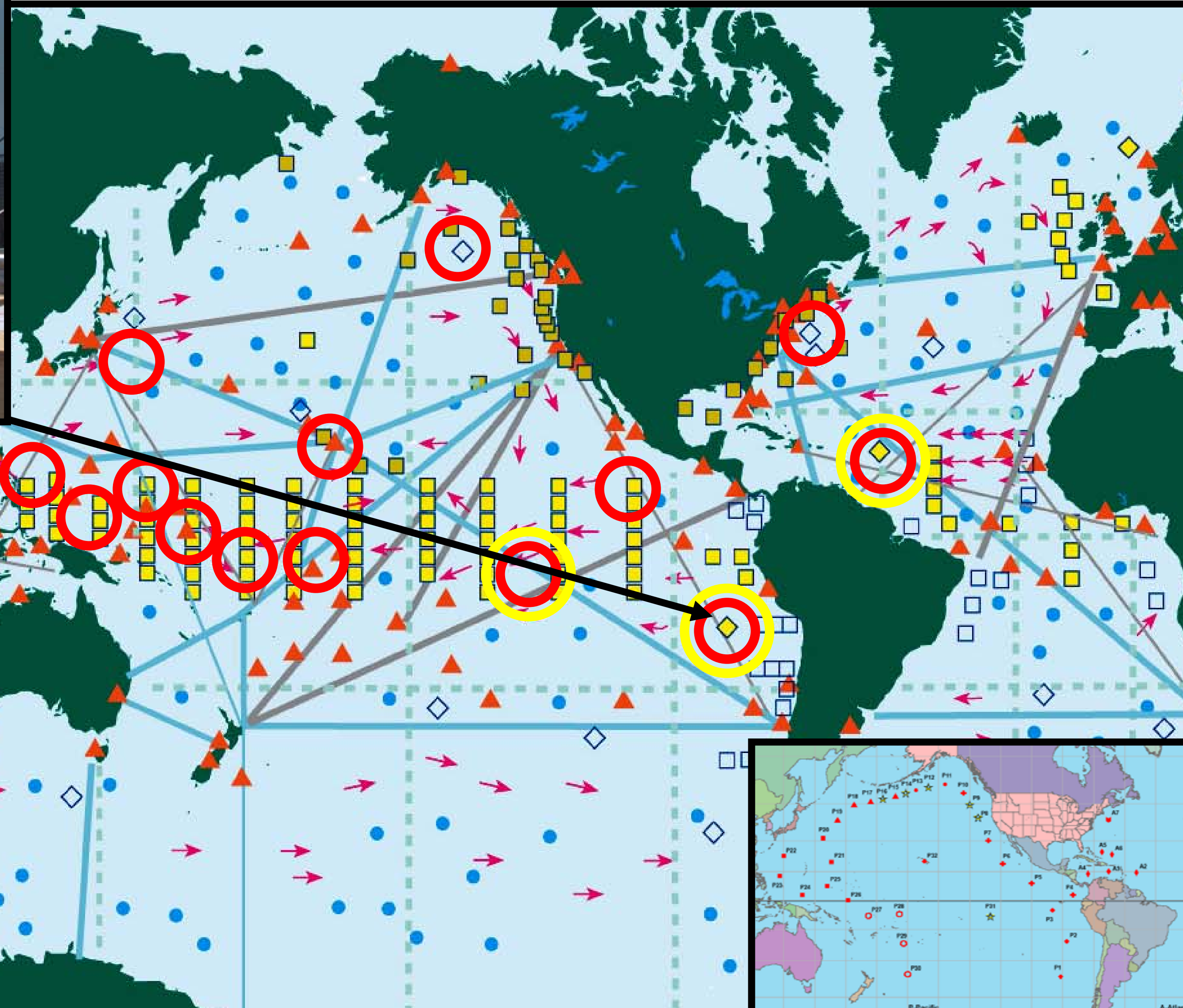
OceanSITES


OceanSITES – vision
data public, partially realtime
data public, only delayed mode
data not public
80°N
60°N
40°N
20°N
0°
20°S
40°S
60°S
80°S
status: 11 Apr 2005
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
30°E

***How can we best work together with natural disaster (tsunami) community?***

# Integrating Climate & Tsunami Buoy Ship Support

Chilean Tsunami Buoy being deployed during a U.S. Climate mission



Sites where Tsunami and Climate plans overlap -- potential for coordination

Sites where Climate missions already deploy tsunami buoys routinely

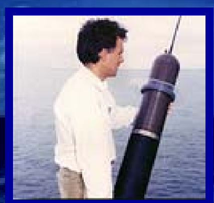
# *Toward the future*

- “Line P” activities are important.
- They will be most useful if sampling considerations are weighed carefully.
- Canadian participation in the full range of global ocean observing activities is also important.
- Ecosystem/climate connections must be better documented and understood
- Analysis/prediction skill must increase

# News from JCOMMOPS strategic planning meeting, 09 May 2006, in Washington

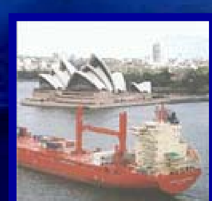
Recommendation: Over the next five years JCOMMOPS should evolve toward Observing Program Support for all international global ocean systems

Present program support
Is for:

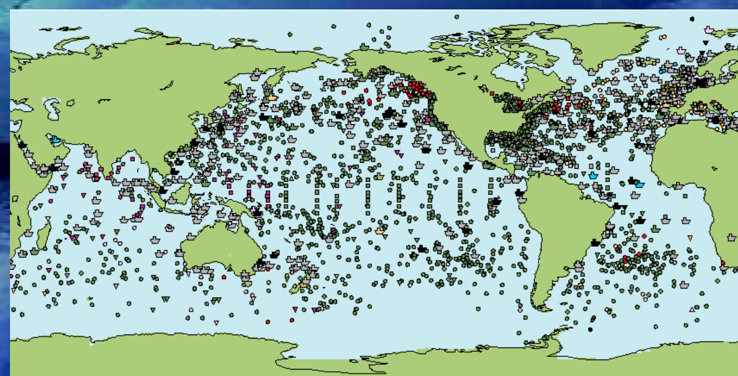


Argo

DBCP



SOT



Future program support
Should include also:

Satellite
product requirements

OceanSITES

GLOSS

IOCCP

Research
Vessels

# *How to sustain observing efforts?*

- **Present funding paradigms do not yet incorporate the critical need for multi-decadal high resolution observing.**
- **We cannot answer society's questions with only process studies and pilot projects**
- **To carry out these observing efforts will require additional funding**
- **Can research frameworks provide the needed support?  If not, then what?**

**T.S.Elliot has more wisdom for us.**
**He suggests that**

***"…We shall not cease from our exploration***
***And the end to all our exploring***
***Will be to arrive where we started***
***And know the place for the first time…"***

**There is much work ahead.**
**Let us gather our nations to act.**
**Let us move forward together.**

# *Thank You*