NOAA Research Addressing Potentially Abrupt Climate Change

Jim Todd

Program Manager, NOAA Climate Program

Aspen Global Change Institute

Abrupt Climate Change: Mechanisms, Early Warning Signs, Impacts and Economic Analyses

Aspen, CO July 14, 2005


John, Sue and Michelle
Thank you!


Coke

Overview

1. NOAA Climate Office (aka NOAA/OGP)
2. Global ocean observations
3. CORC-Arches and "The Changeling's"
4. Contributions from NOAA Research Labs
5. International collaboration
6. Future possibilities

NOAA 101

noaa research

NOAA Fisheries
National Marine Fisheries Service

NATIONAL WEATHER SERVICE

NOAA'S NATIONAL OCEAN SERVICE

NOAA Mission

To describe and predict changes in the Earth's environment, and conserve and wisely manage the Nation's coastal and marine resources to ensure sustainable economic opportunities

U.S. Global Change Research Program Act of 1990

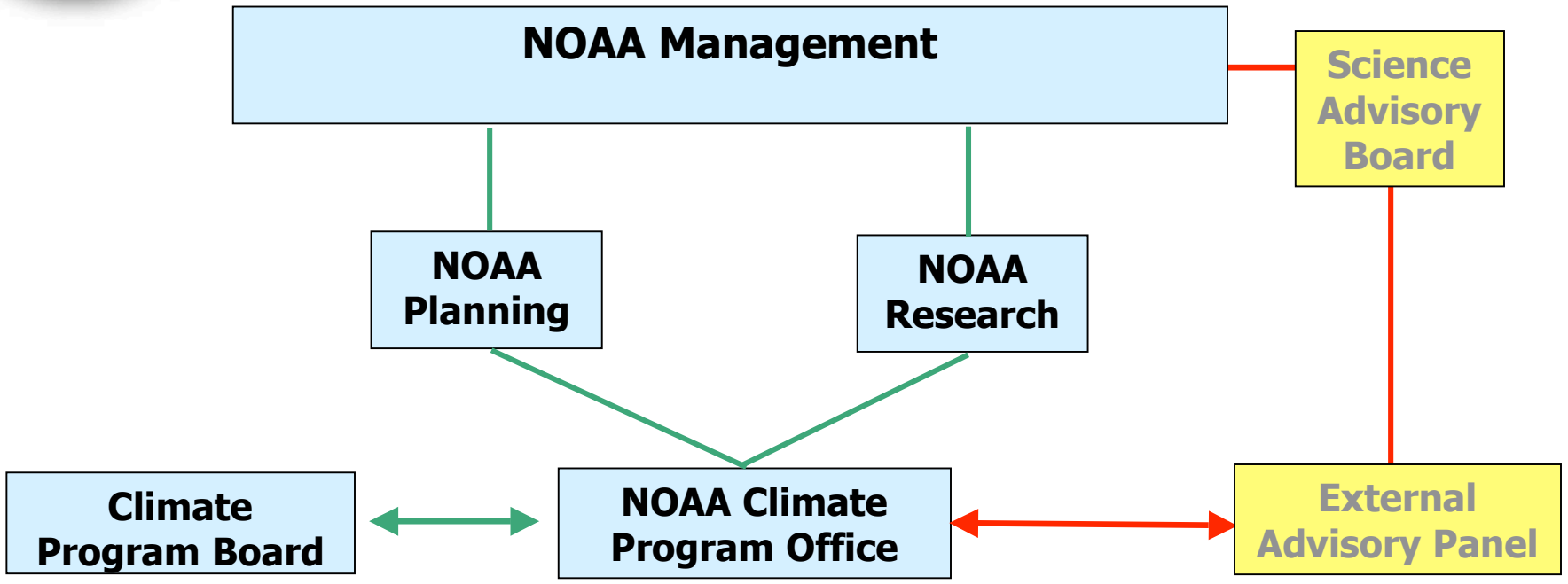
Public Law 101-606 (signed by President on 11/16/90)

"An Act To require the establishment of a United States Global Change Research Program aimed at understanding and responding to global change, including the cumulative effects of human activities and natural processes on the environment, to promote discussions toward international protocols in global change research, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,…….

This Act may be cited as the "Global Change Research Act of 1990……"

NOAA Climate Program
Overarching Organization (NEW)



Develops program

All NOAA represented

NEW
Administers goal and programs

Includes
Climate Office
Office of Global Programs
Climate Observations and Services Program
Office of Climate Observations and ARGO
Arctic Research Office

Provides scientific and programmatic advice

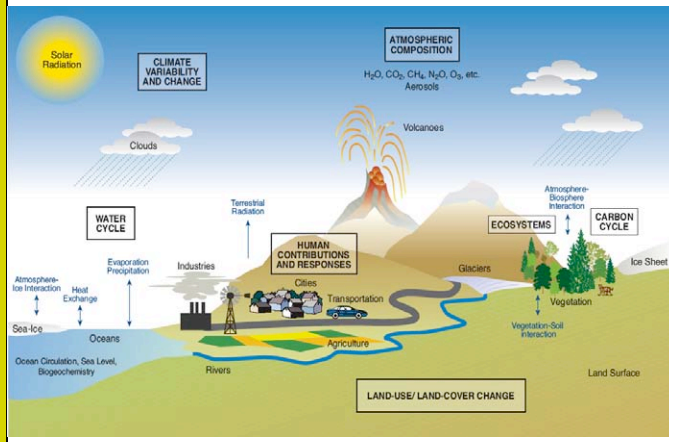
Relationship to 2005 NOAA Strategic Plan

*Understand **Climate** Variability and Change to Enhance Society's Ability to Plan and Respond*

OUTCOMES

1. **A predictive understanding of the global climate system on time scales of weeks to decades with quantified uncertainties sufficient for making informed and reasoned decisions**

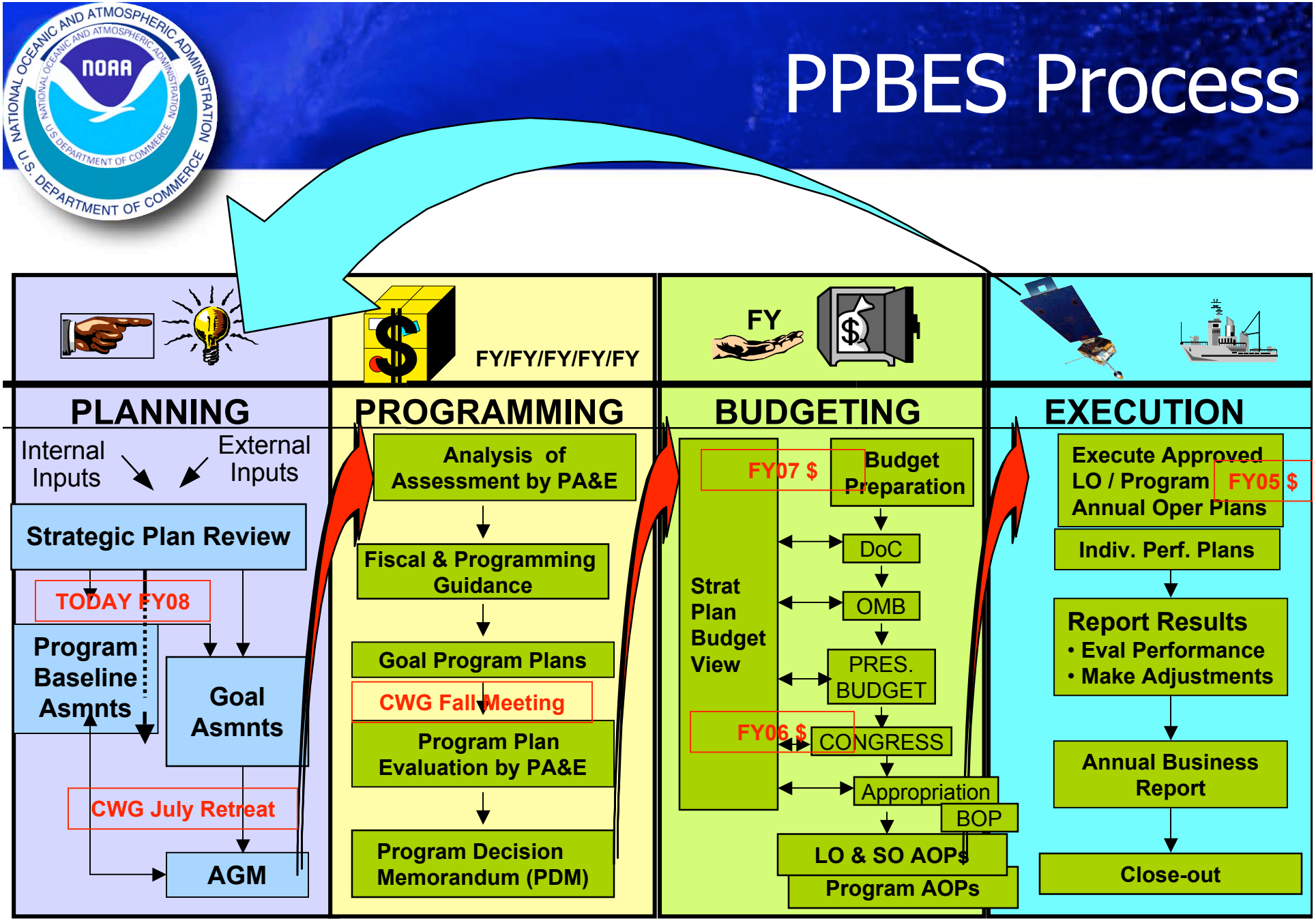
2. **Climate-sensitive sectors and the climate-literate public effectively incorporating NOAA's climate products into their plans and decisions**



Programs

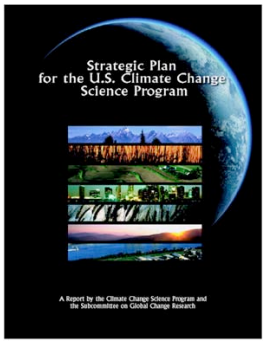
- **Observations & Analysis**
- **Climate Forcing**
- **Predictions & Projections**
- **Climate & Ecosystems**
- **Regional Decision Support**

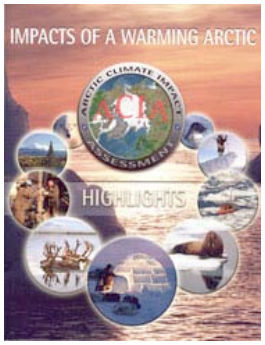
PPBES Process

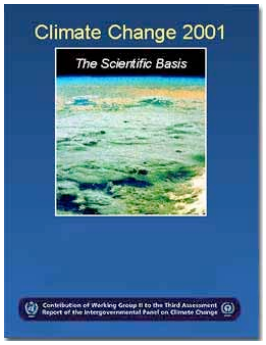


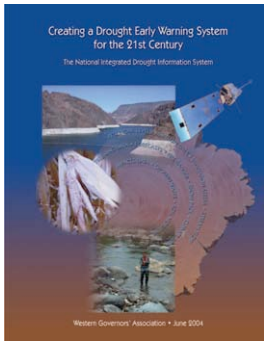
FY08-12 Planning
Compelling National Issues

- US Climate Change Science Program
- Arctic Climate Impact Assessment
- UN Framework Convention on Climate Change
- National Integrated Drought Information System
- Ocean Action Report









NOAA Climate Office

1. Climate Dynamics Division

1. **Atmospheric Composition and Climate (ACC)**
2. **Climate Change Data and Detection (C^2D^2)**
3. **Climate Dynamics and Experimental Prediction (CDEP)**
4. **Office of Climate Observation (OCO)**
5. **Climate Variability and Predictability (CLIVAR)**
6. **Climate Prediction Program of the Americas (CPPA)**
7. **Global Carbon Cycle (GCC)**

2. Climate and Societal Interactions Division (CSI)

Global Ocean Observations

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Building a Sustained Ocean Observing System for Climate

Altimeter and Scatterometer

3°x3° Argo Float Array

Volunteer Observing Ships

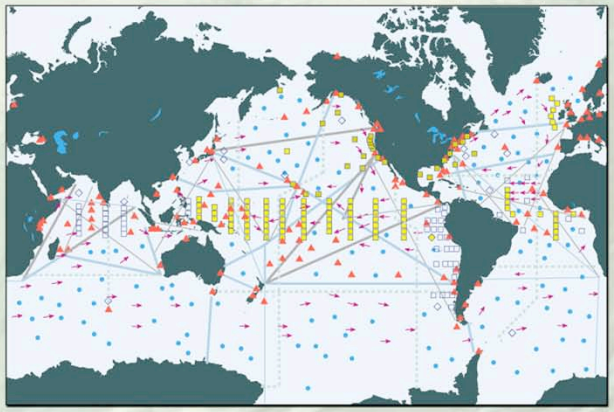
Ocean Reference Stations

Research Ships

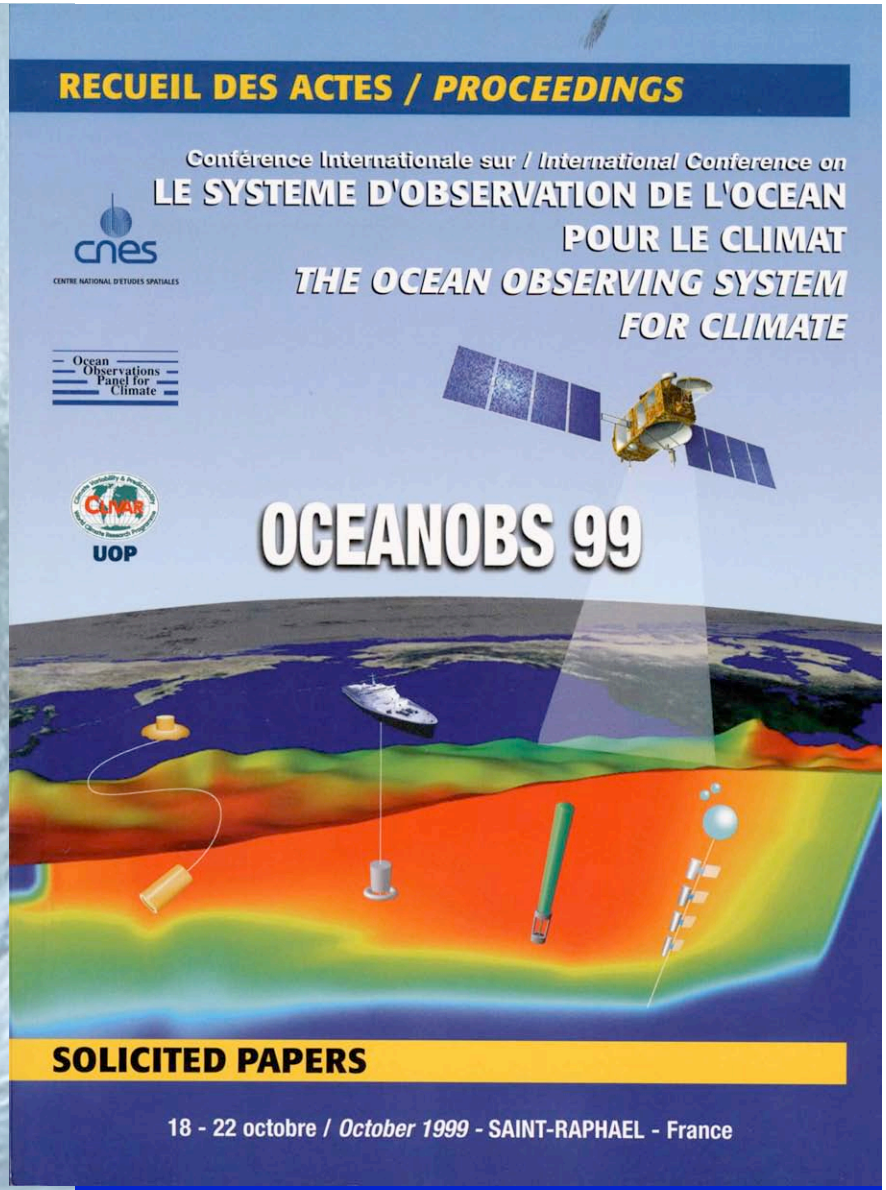
5° x 5° Drifting Buoy Array

Moored Arrays

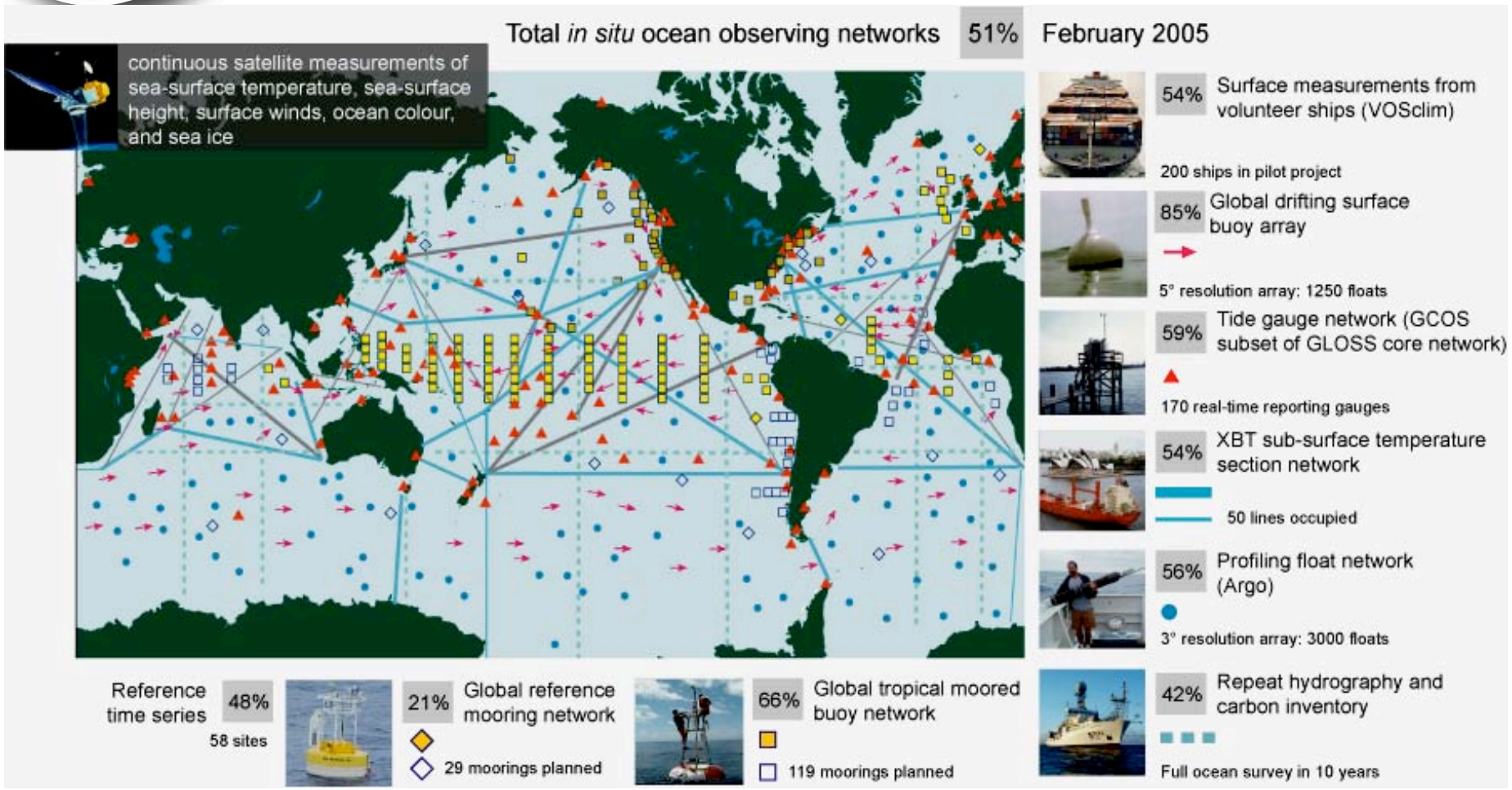
Tide Gauge Stations



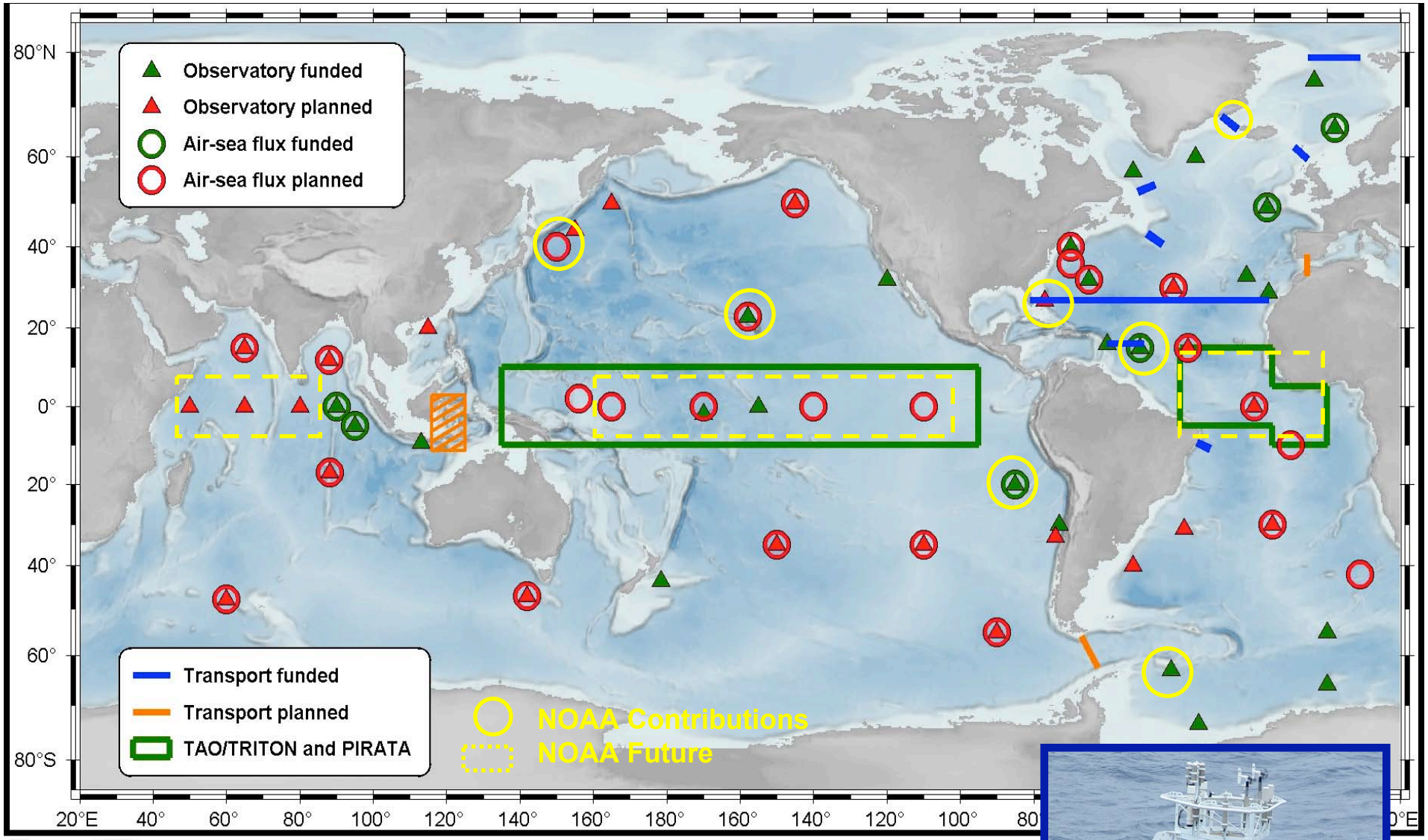
Phased Implementation Plan, including international contributions



Global Ocean Climate Observing System



Global System Status against GCOS Implementation Plan Goals



Deploy and maintain 89 Ocean Reference Stations.

NOAA Administrator Priorities

Executive Council

54th session of the World Meteorological Organization

Geneva, Switzerland

June 11, 2002

"The greatest challenge is to develop one integrated observation plan for the atmosphere, ocean and land that everyone can support"

"Full and open sharing of data between nations is an essential part of this effort -- including making the data available within sufficient time to be of operational use"

Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (Ret.)

Under Secretary of Commerce for Oceans and Atmosphere

Administrator of the National Oceanic and Atmospheric Administration

Atlantic Ocean Observations support from OCO (FY2005)

Denmark strait overflow	$ 45K
ARGO array	$10M
Global surface drifter array	$3.4M
PIRATA (includes 4 more moorings)	$750K
Climate reference station	$550K
WBC monitoring (cable)	$160K
WBC monitoring (Abaco)	$170K
Atlantic high-resolution XBT	$1M
TOTAL	$16.1M

"Most human beings have an almost infinite capacity for taking things for granted."

Aldous Huxley, English author
(1894-1963)

"Thought for Today"
The Aspen Times
Wednesday, July 13, 2005

CORC-Arches

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Consortium on the Ocean's Role in Climate: AbRupt Climate CHangE Studies (ARCHES)

- A partnership between NOAA/OGP and LDEO that includes a number of researchers from other academic institutions
- Dedicated to the study of mechanisms that can lead to an abrupt and significant shift in the state of the climate system
- PI's: Peter Schlosser, Wally Broecker

Consortium on the Ocean's Role in Climate: AbRupt Climate CHangE Studies (ARCHES)

Questions

What triggers the transitions between the observed states?

What amplifies a small trigger into a robust global climate change

Components

Modern Observations

Paleo observations

Modeling

Infrastructure (invited visitors, mini-conferences, annual meetings

Consortium on the Ocean's Role in Climate: AbRupt Climate CHangE Studies (ARCHES)

Modern Observations

Gordon/Visbeck: Southern Ocean Modern Observations (Western Weddell Sea time series)

Schlosser: Tracers (tritium, helium, oxygen isotopes) in the S. Ocean (Weddell Sea) /N. Atlantic

Smethie: Tracers (CFCs) in the Southern Ocean (Wedell Sea) /N. Atlantic (Denmark Strait, Iceland)

Dickson: ASOF freshwater flux and densewater flux arrays (SE Greenland shelf and slope)

Modeling

Martinson/Yuan/Pitman: Southern Ocean modeling and analysis

Seager/Cane/Kushnir/Ting/Naik/Clement/Pitman: Mechanisms of Abrupt Climate Change

Paleo Reconstructions

Broecker: Understanding abrupt change and the Glacial to interglacial CO_2 record

Lynch-Stieglitz: Patterns and timing of deglacial climate change in the Equatorial Pacific

Anderson/Burckle: Paleo sea-ice distributions

Hemming/Goldstein: Changes in winds, the conveyor and local currents during periods of ACC

Bond: Causes of persistent century-scale change in the North Atlantic Holocene climate

Denton: Mountain snowlines in the Southern Hemisphere

Hayes: Accelerator mass spectrometric analyses of radiocarbon (organic C and carbonate)

"The Changeling's"

A study group on Abrupt Climate Change commissioned in 1997 by Dr. J. Michael Hall (Director, retired) of NOAA Office of Global programs.

Established along the same lines as the TOGA Theoretical Panel

"The Changeling's"

George Denton (University of Maine)
Richard Alley - (Penn State University)
Jeff Severinghaus - (Scripps Institution of Oceanography)
Wallace Broecker - (Lamont Doherty Earth Observatory)
Ray Pierrehumbert - (University of Chicago)
John Shepherd - (National Oceanography Center - Southampton)
Mark Cane - (Lamont Doherty Earth Observatory)
Stefan Rahmstorf - (Potsdam; PIK)
Peter Schlosser - (Lamont Doherty Earth Observatory)
David Battisti - (University of Washington)
John Chiang - (University of California - Berkeley)
Jess Adkins - (Caltech)

Now supported by private funding

NOAA/OGP: Abrupt CC-related funding

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C^2D^2 Funded Proposals in FY05 (Paleoclimate component)

Extreme Cooling of the US-Canadian Eastern Seaboard During the Holocene - Julian Sachs (MIT)

North Pacific Dec-Cen Variability from Deep Sea Corals: A New Archive for Climate Change Detection - Rob Dunbar (Stanford)

Volcanic Forcing of Climate over the Past 2000 Years: An Improved Ice-Core-Based Index for Climate Models - Alan Robock (Rutgers)

Ocean Heat Content - Sid Levitus (NOAA)

Assessment of Arctic Snow Cover Change and its Impact on Large River Runoff - Daquing Yang (U. Alaska - Fairbanks)

C^2D^2 Funded Proposals in FY05 (Paleoclimate component)

Extreme Cooling of the US-Canadian Eastern Seaboard During the Holocene - Julian Sachs (MIT)

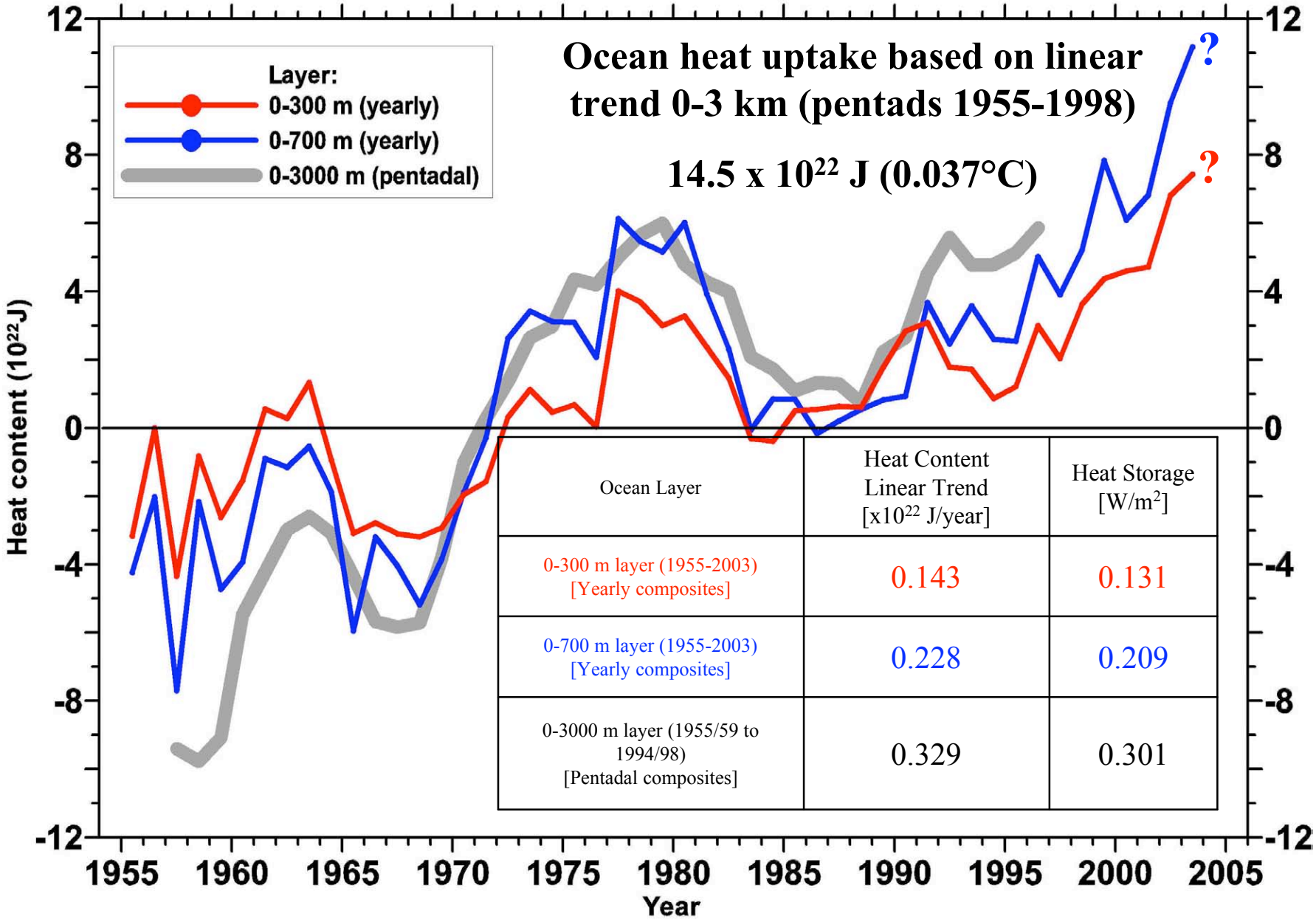
"Currently investigating hydrographic changes in the slopewaters along the eastern seaboard of the US and Canada during the Holocene. These waters comprise a dynamic and coupled system because the fluxes and positions of currents and water masses vary in concert with atmospheric changes on annual-to-decadal timescales. Sea surface temperatures will be determined by the alkenone paleotemperature technique in well-dated, rapidly-accumulating sediments from the continental shelf and slope, and seaward to the abyss, between Labrador and Virginia."

C^2D^2 Funded Proposals in FY05 (Paleoclimate component)

Assessment of Arctic Snow Cover Change and its Impact on Large River Runoff - Daquing Yang (U. Alaska - Fairbanks)

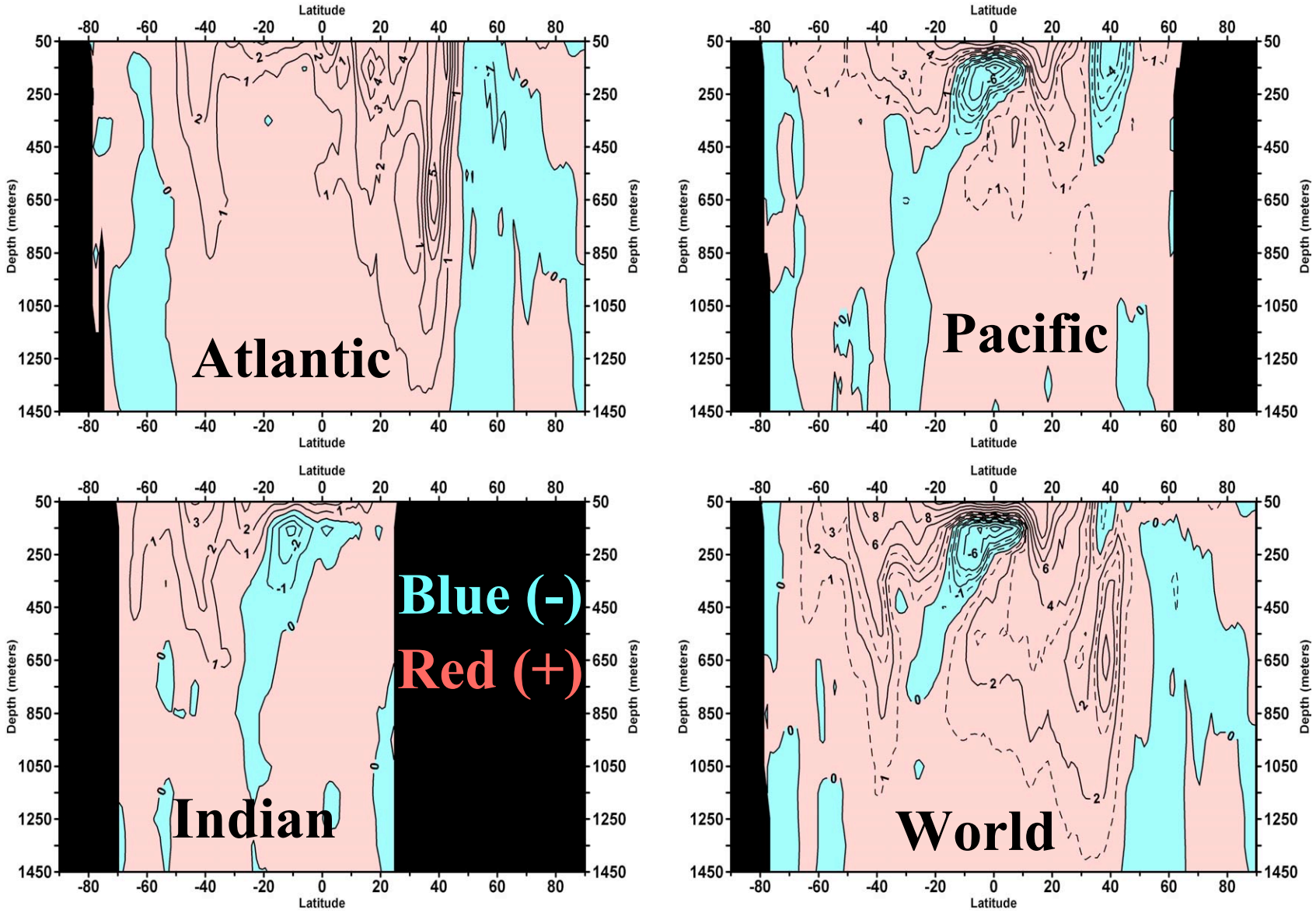
"Funding is requested for a comprehensive assessment of changes in snowcover conditions and their impact on runoff from the large Arctic river systems. The proposed work, ……will compile and analyze both remotely sensed and in-situ snowcover, climatic and hydrological datasets in order to define the variations and changes in streamflow and its relationships to snowcover conditions and other atmospheric and climate variables."

Time series of ocean heat content (10^{22} J). Levitus *et al.*, 2005



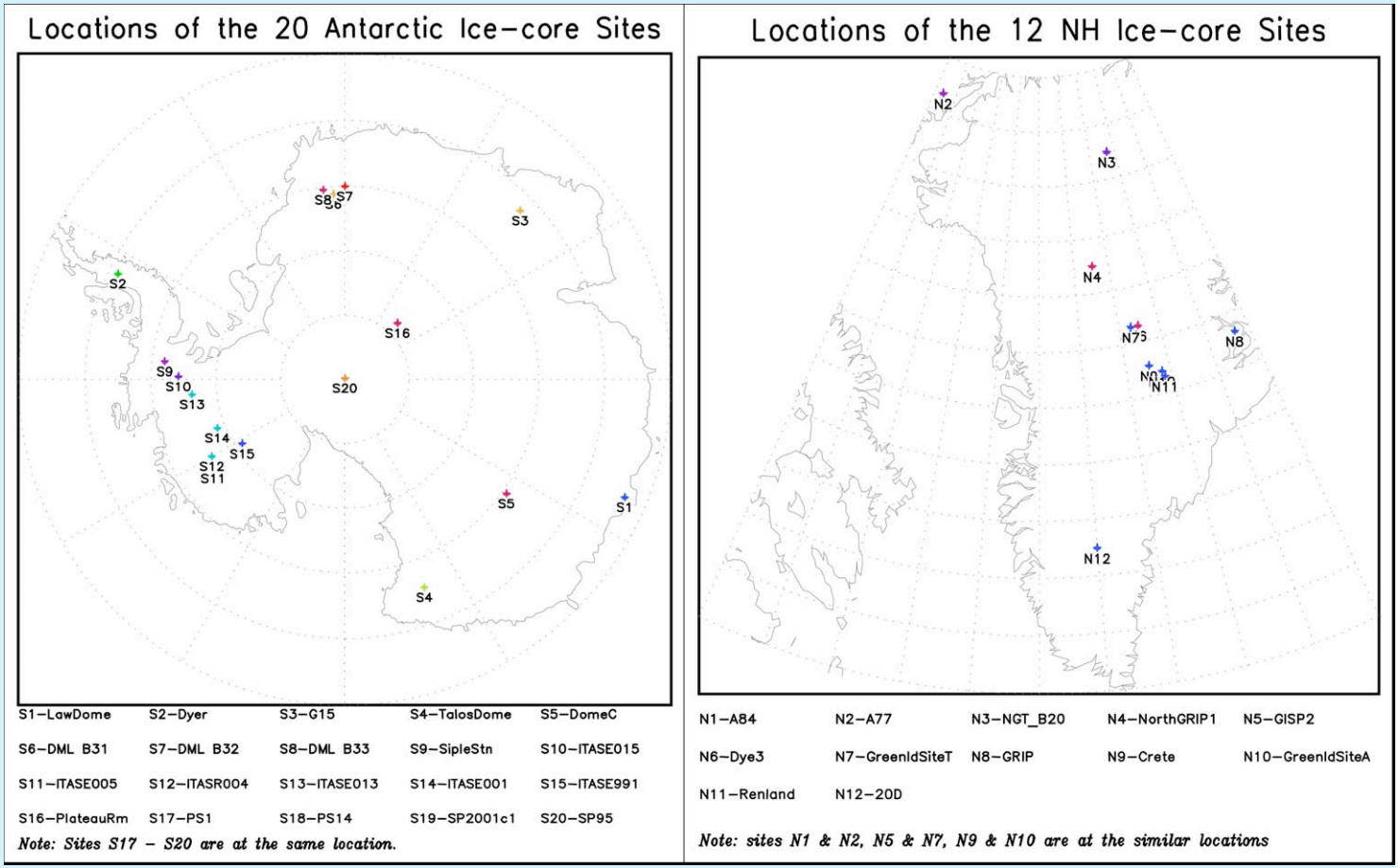
Ocean Layer	Heat Content Linear Trend [x10^{22} J/year]	Heat Storage [W/m^2]
0-300 m layer (1955-2003) [Yearly composites]	0.143	0.131
0-700 m layer (1955-2003) [Yearly composites]	0.228	0.209
0-3000 m layer (1955/59 to 1994/98) [Pentadal composites]	0.329	0.301

Linear Trend of the zonally integrated heat content (x 10^{18} J/year) for 100 m thick layers (1955/59 to 1994/98). Levitus *et al.*, 2005]



NOAA OGP, NA03-OAR-4310155, "Volcanic Forcing of Climate over the Past 2000 Years: An Improved Ice-Core-Based Index for Climate Models," August 1, 2003 – July 31, 2006, Alan Robock, P.I., Chaochao Gao, Ph.D. student

We have assembled the most comprehensive data set of ice core records of past volcanism. These are the ones we used to study the 1452 Kuwae eruption in Vanuatu (16.83ºS, 168.54ºE)

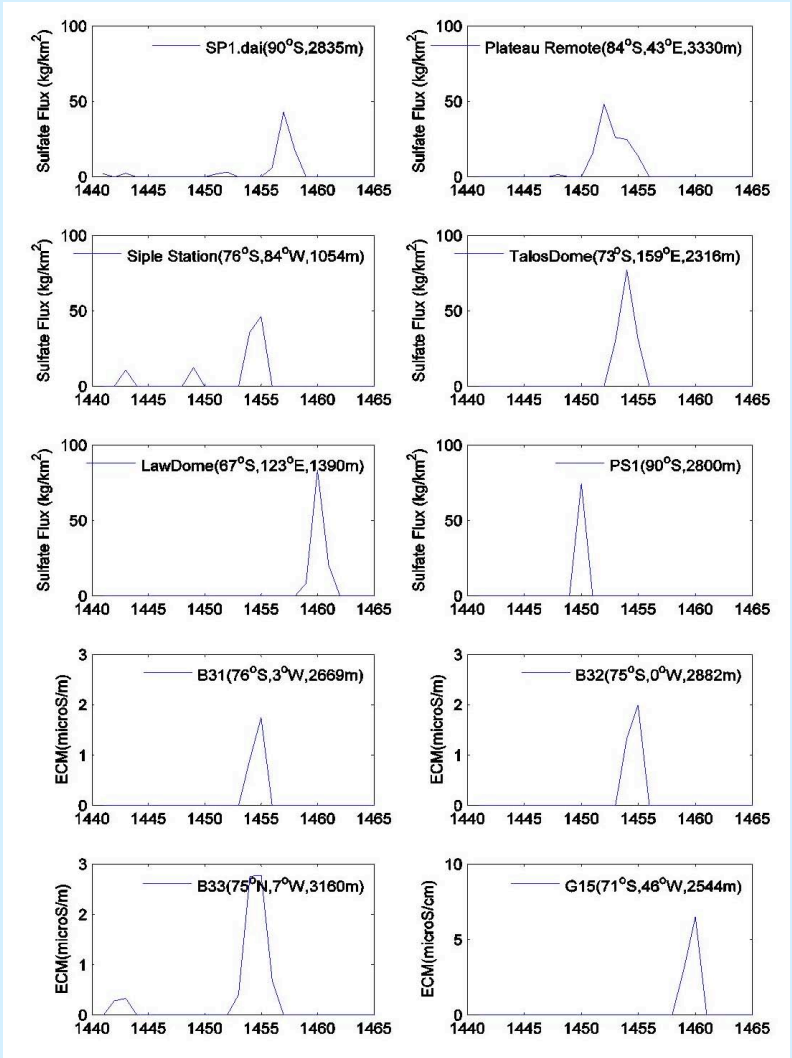


Alan Robock
Department of Environmental Sciences

THE STATE UNIVERSITY OF NEW JERSEY RUTGERS

NOAA OGP, NA03-OAR-4310155, "Volcanic Forcing of Climate over the Past 2000 Years: An Improved Ice-Core-Based Index for Climate Models," August 1, 2003 – July 31, 2006, Alan Robock, P.I., Chaochao Gao, Ph.D. student

These are the Southern Hemisphere Kuwae deposition peaks. After signal detection and time adjustment, we have determined that **the 1452 Kuwae eruption produced the largest climate forcing of any eruption for the past 700 years.** It was even greater than the 1815 Tambora eruption, which produced the "Year Without a Summer." The average total sulfate deposition from the Kuwae eruption was 103 kg SO_4/km^2 in Antarctica and 44 kg SO_4/km^2 in Greenland as compared to 65 kg SO_4/km^2 in Antarctica and 53 kg SO_4/km^2 in Greenland for Tambora.



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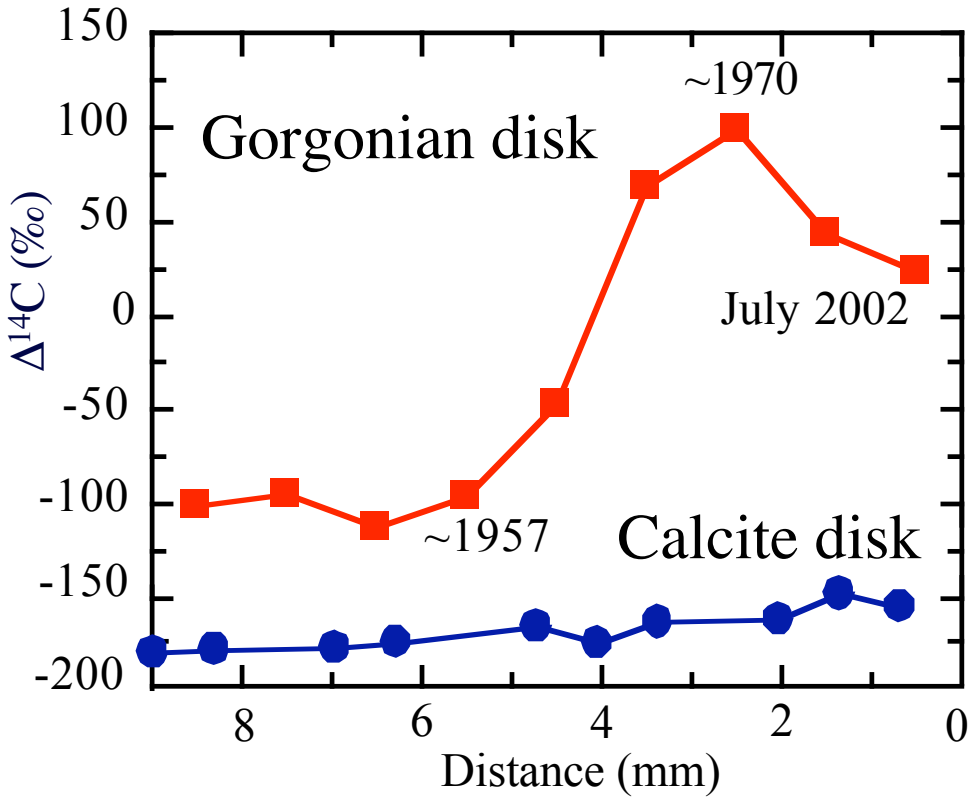


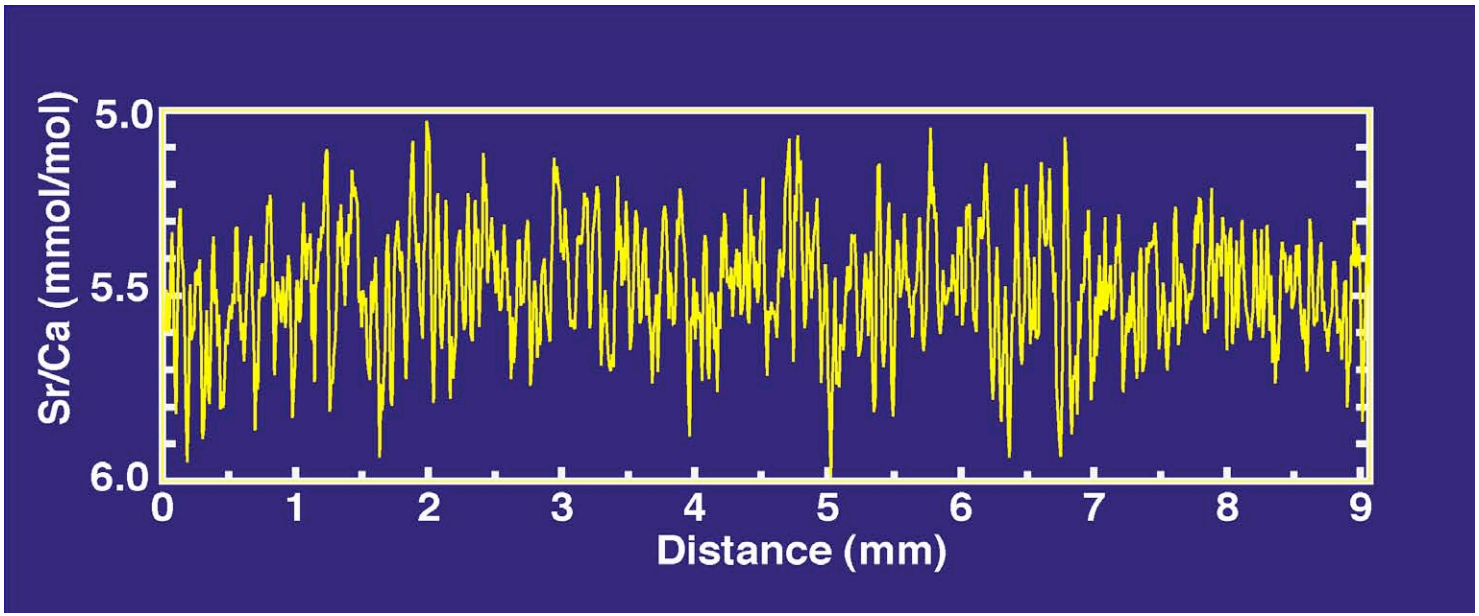
Warwick Seamount

Bamboo Corals
Family *Isididae spp*.
~750 m Water Depth
Radiocarbon based age and growth studies to develop age models

- Corresponding linear "growth rate" is ~120μm/year. Sample is ~75 years old.

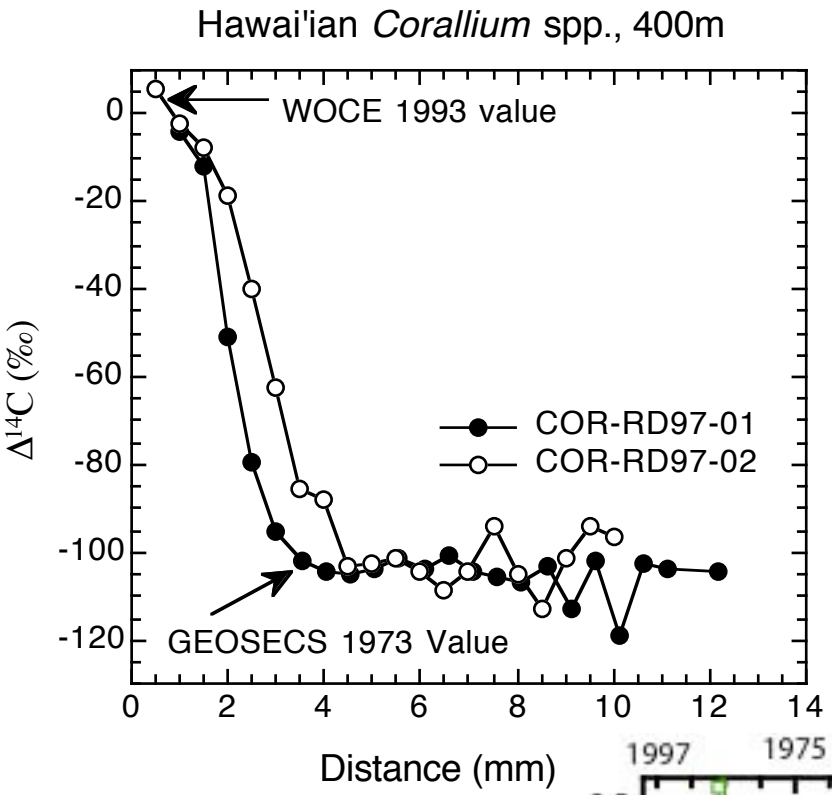
Minor and trace element studies by laser ablation ICP-MS

- 84 Sr/Ca cycles --> annual



Rob Dunbar
(Stanford)

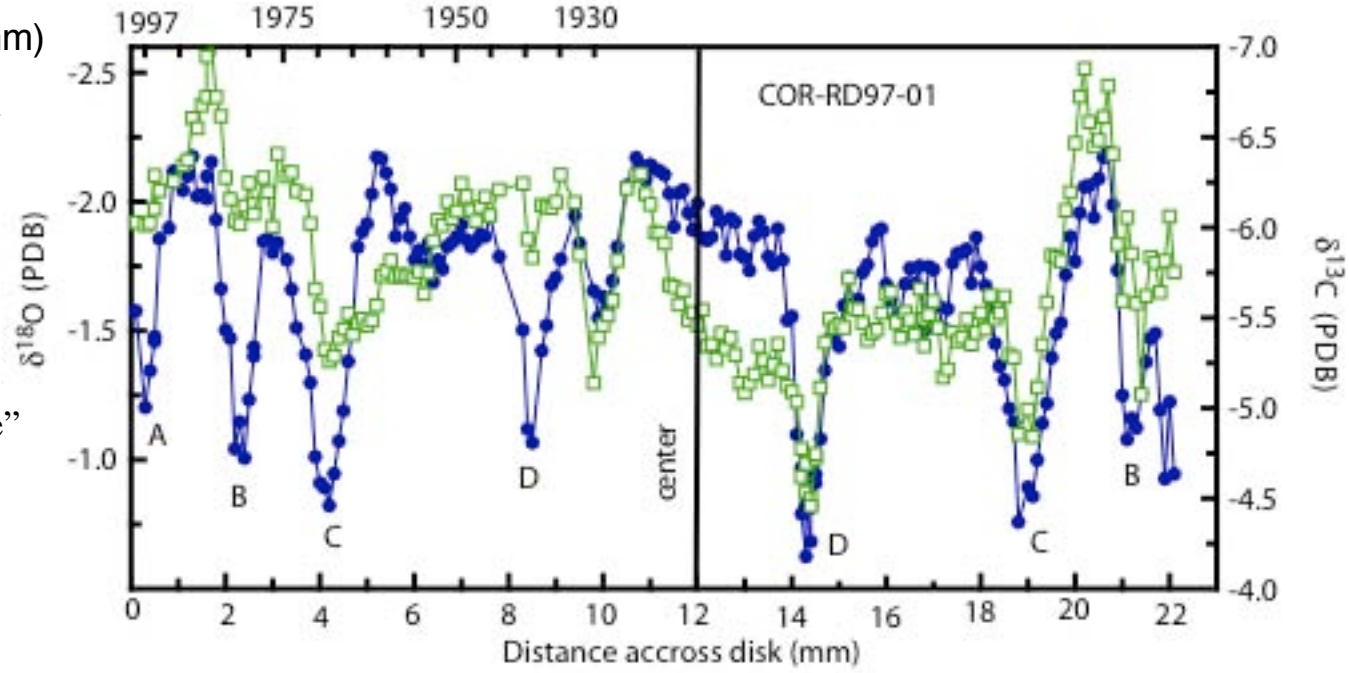
Rob Dunbar (Stanford)



Stable isotope measurements in the *Corallium* samples do not exhibit strong kinetic effects typical of most deep sea corals.

$d^{18}O$ implies decadal modulation of temperature at 400 m and/or changes in the depth of the permanent thermocline.

- ^{14}C-based age model using milled discrete samples (0.5mm).
- GEOSECS data is used to set our initial time-marker and assigned a $D^{14}C$ value of ~-100‰ to be no later than 1973.
- Corresponding linear "growth rate"
  - COR-RD97-01 ~150μm/year, ~75 years old
  - COR-RD97-02 ~180μm/year, ~55 years old



Other NOAA/OGP

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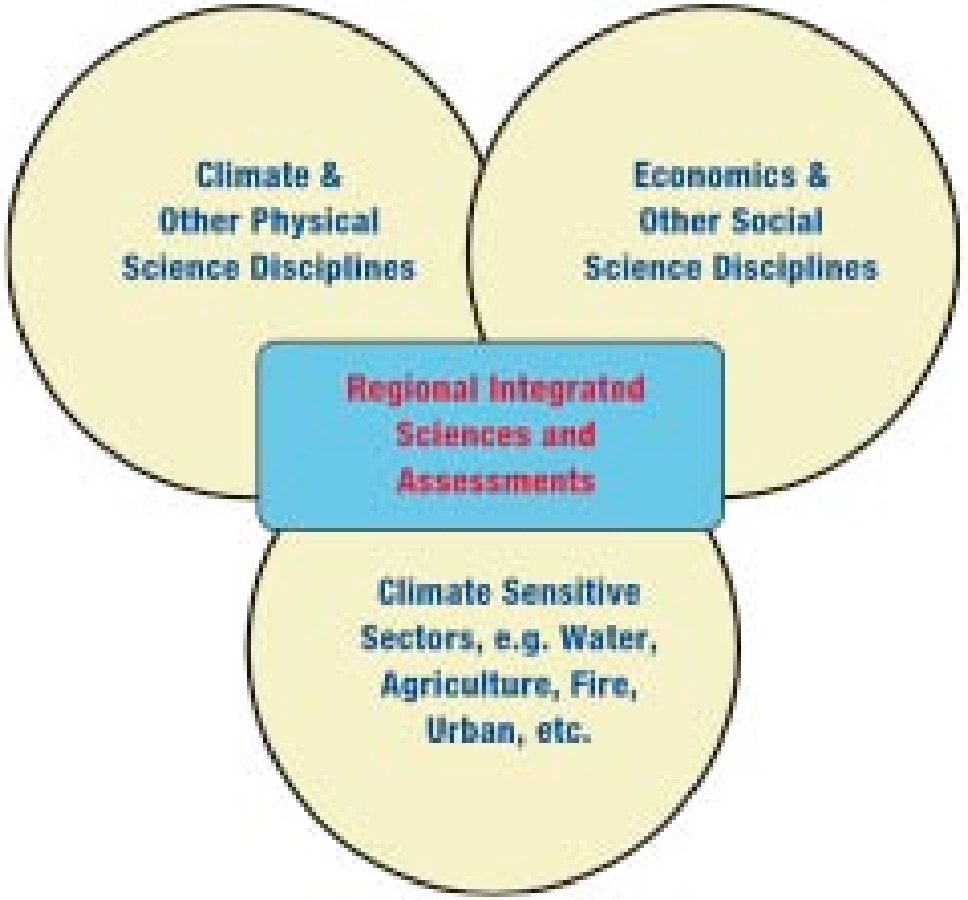
Climate and Societal Interactions

RISA

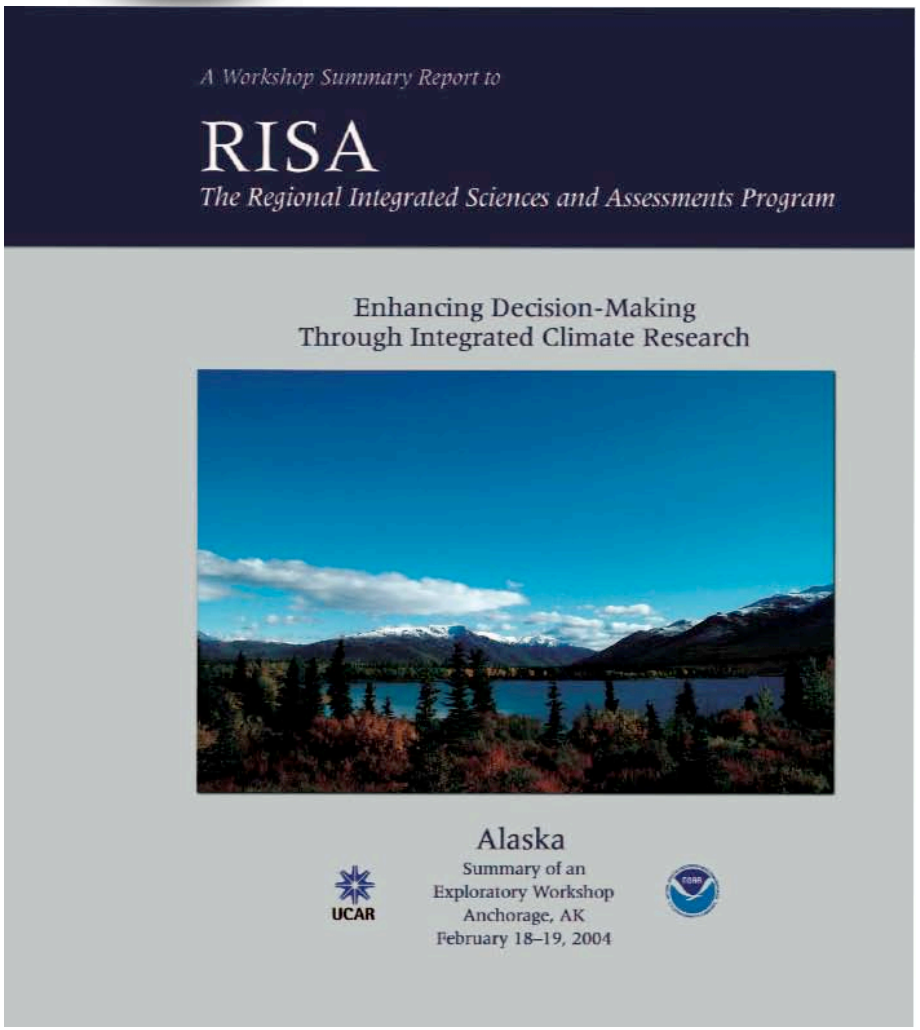
Regional Integrated Sciences and Assessments

Building Bridges Between Climate Sciences and Society



http://www.risa.ogp.noaa.gov/

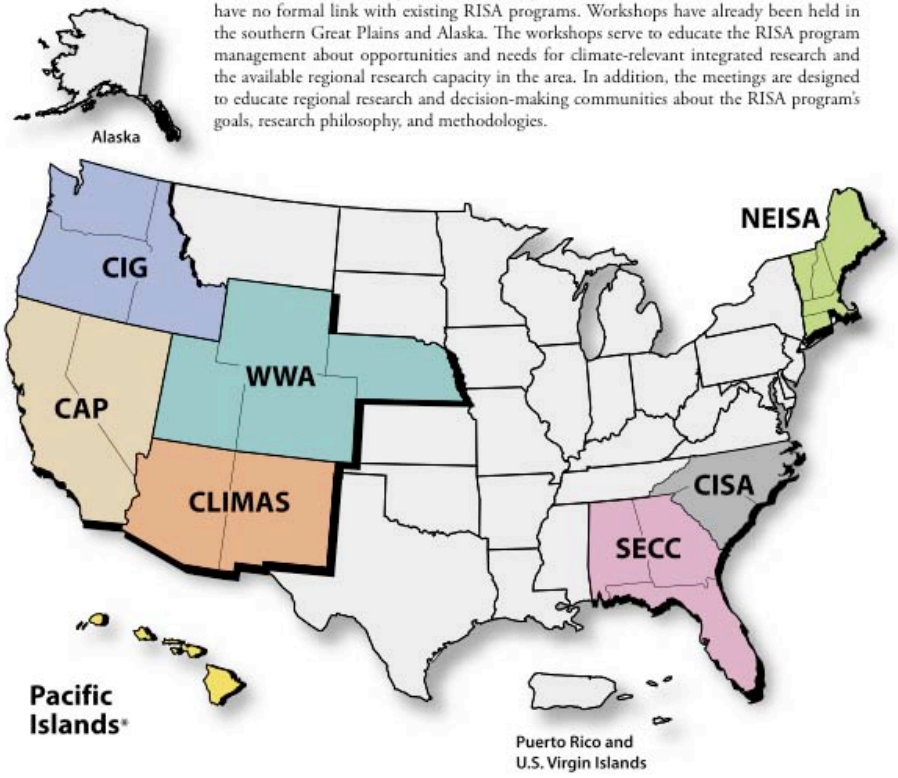
Alaska RISA



THE RISA NETWORK

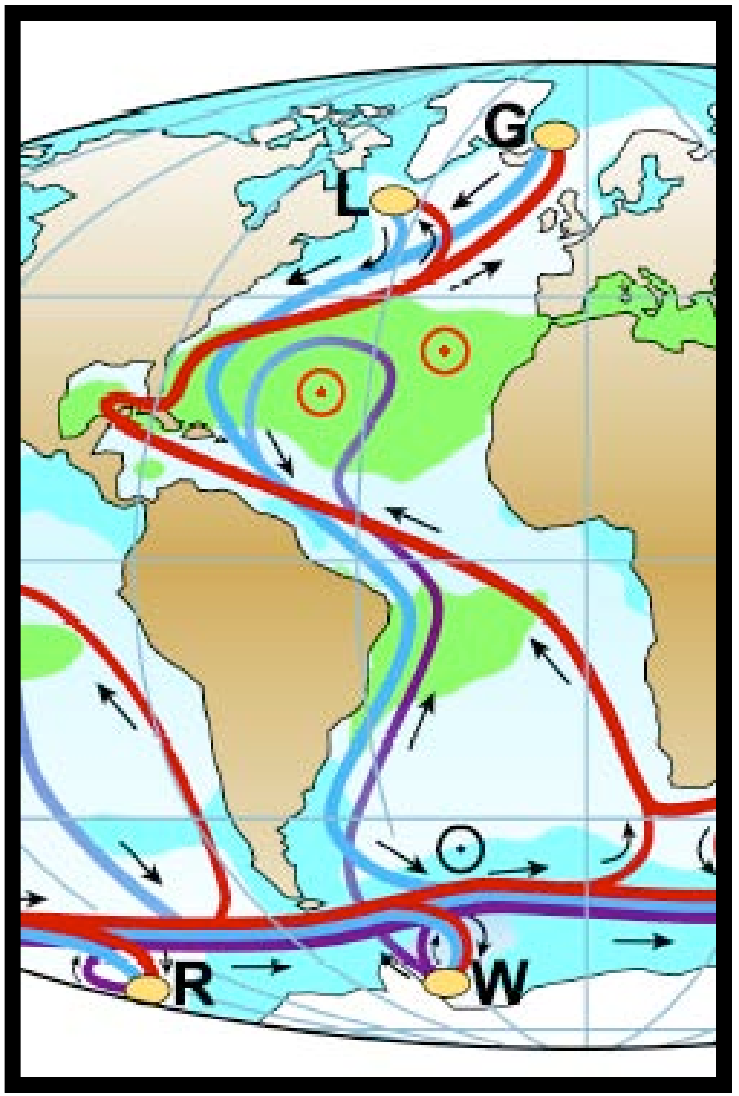
The map below shows eight regions where currently funded RISA programs operate. While each RISA targets a specific U.S. region, the work of each program extends past these boundaries—creating research and products that are useful for stakeholders across the country and beyond.

NOAA is also sponsoring workshops in regions across the United States that currently have no formal link with existing RISA programs. Workshops have already been held in the southern Great Plains and Alaska. The workshops serve to educate the RISA program management about opportunities and needs for climate-relevant integrated research and the available regional research capacity in the area. In addition, the meetings are designed to educate regional research and decision-making communities about the RISA program's goals, research philosophy, and methodologies.



Other NOAA

Contributions from NOAA Research Laboratories



"Water-hosing" experiments at GFDL

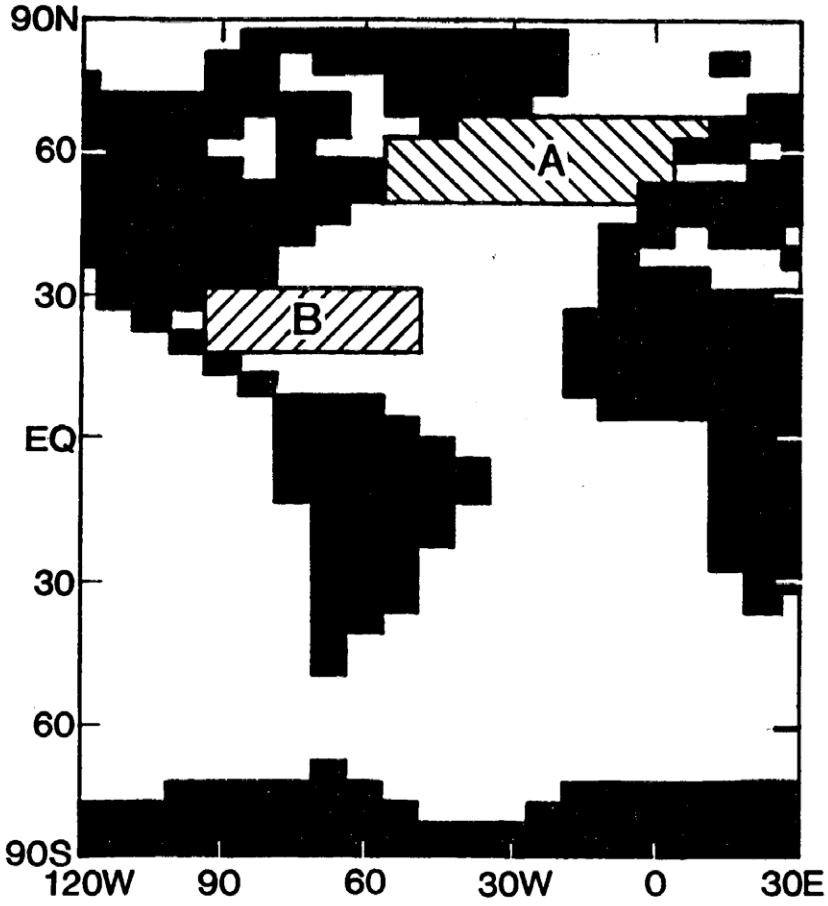
CMIP/PMIP Coordinated "Water-Hosing" Experiment

0.1 Sv freshwater perturbation over 50°~70°N of the North Atlantic (Box A) for 100 years.

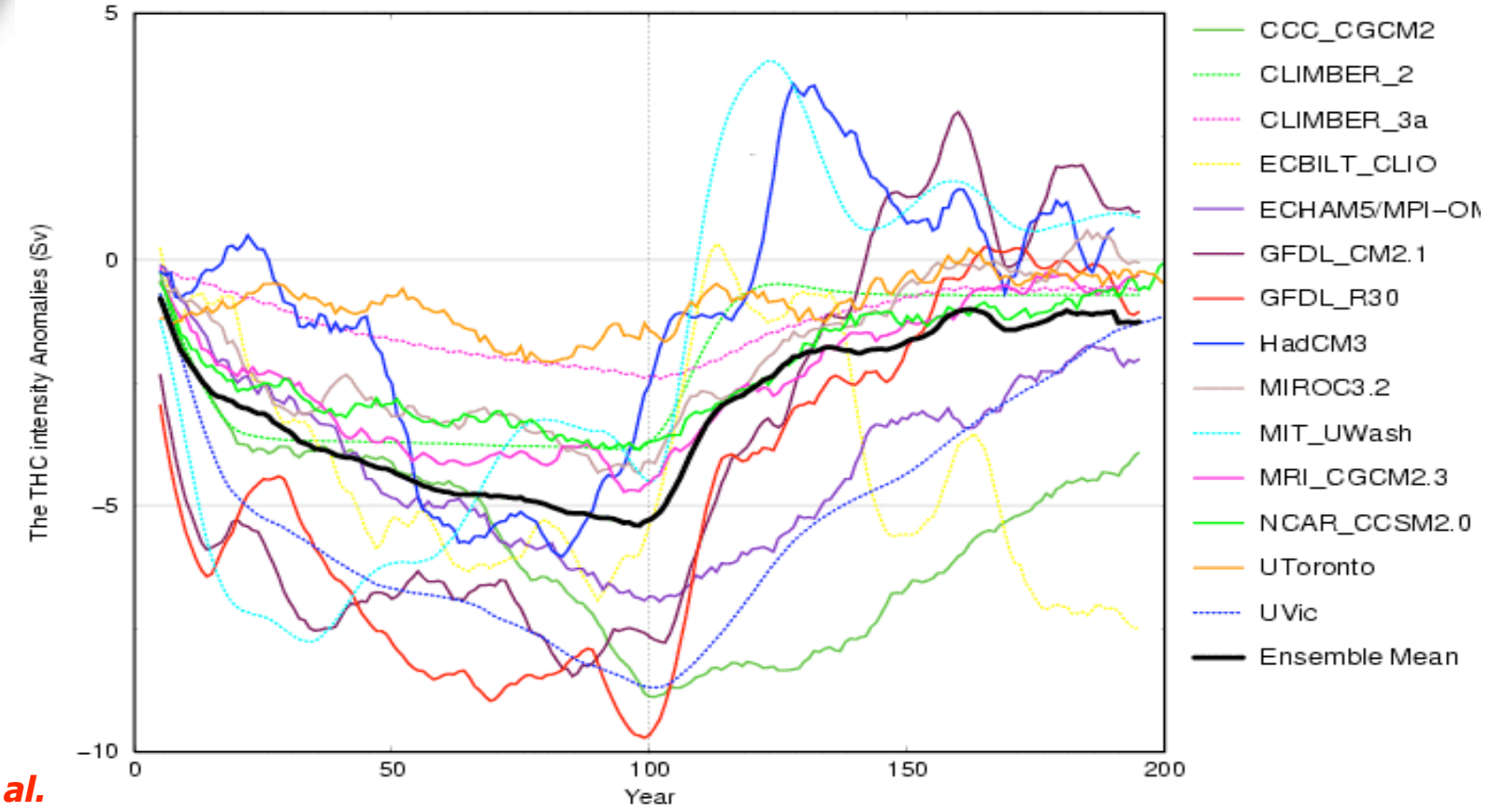
The freshwater perturbation is removed after the 100th year. Allow the ~~THC~~ MOC to recover.

An optional 1 Sv "water-hosing" experiment was also performed by a subset of groups.

Ron Stouffer et al.



The THC Response (0.1 Sv)



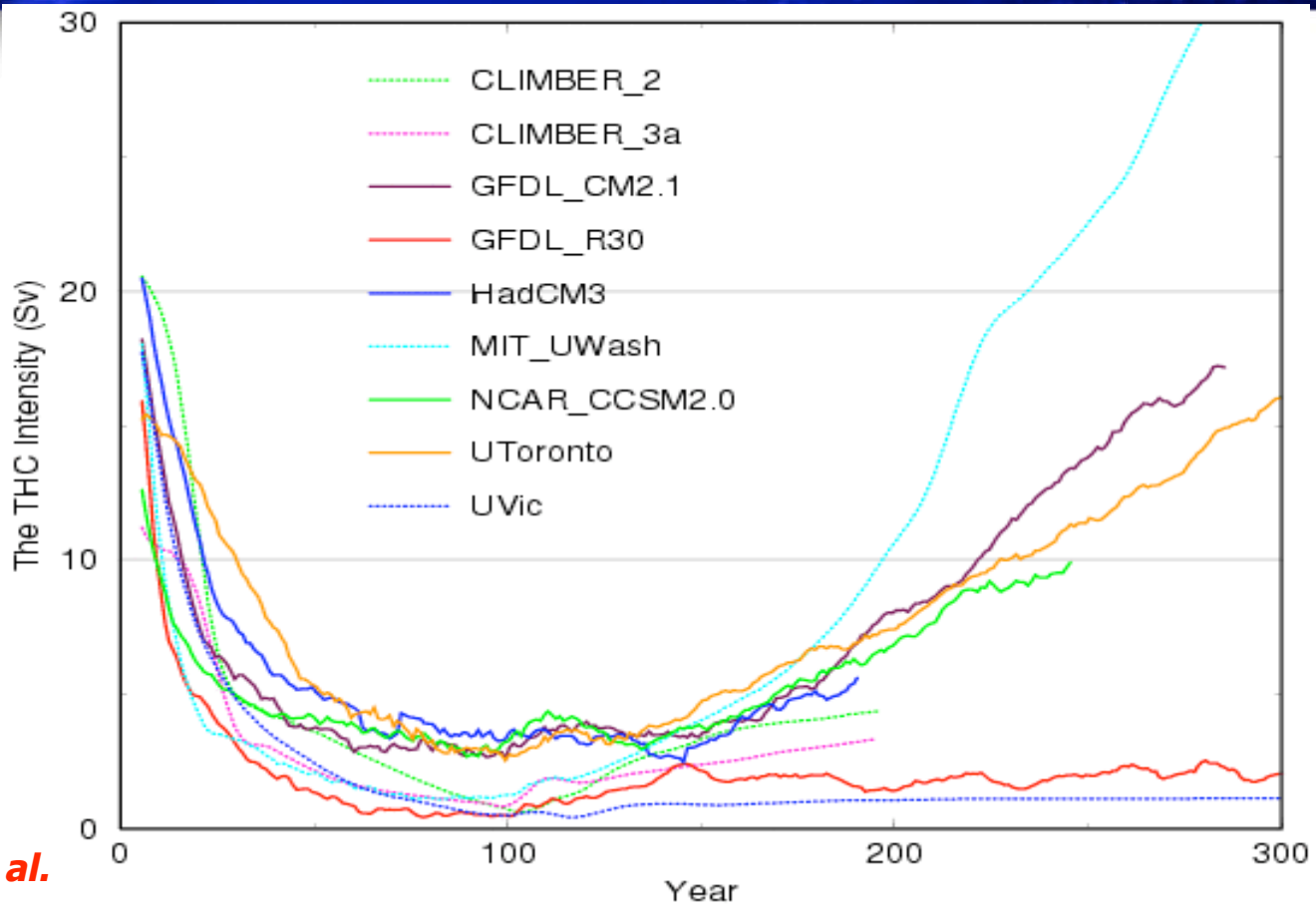
Ron Stouffer et al.

All models show some weakening of the THC during the hosing period and recovery after the end of the hosing.

Response magnitude are very different among models.

1.3~9.7 Sv or 9%~62% weakening; Model ensemble: 5.6 Sv or 30%.

The THC Response (1 Sv)



Ron Stouffer et al.

Reversible Shutdown: GFDL_CM2.1, MIT_UWash, NCAR_CCSM2.0, UToronto

Irreversible Shutdown: GFDL_R30, UVic

"Water-Hosing" Summary

0.1 Sv "water-hosing" experiment

(1) The THC gradually weakens by 30% after 100-year freshwater input in ensemble mean. No model simulates a shutdown of the THC. After the termination of the freshwater perturbation, the THC recovers rapidly.

(2) The climate response is proportional to the response of the THC intensity. The SAT anomaly pattern has a complex pattern with a cooling south of Greenland and a warming over Barents and Nordic Seas. The Atlantic ITCZ tends to shift southward after the slowdown of the THC.

(3) In spite of large simplifications of model formulation, the EMICs can capture the general structures of the THC and climate responses.

1 Sv "water-hosing" experiment

(4) Has implications for past abrupt climate changes. 1 Sv freshwater perturbation is highly unlikely for the future.

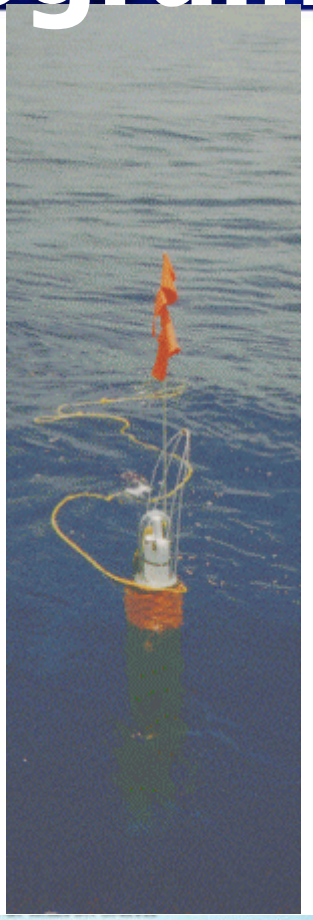
(5) The THC shuts down rapidly during hosing. After its collapse, some models show re-intensification once freshwater is removed, whereas some models do not.

(6) The climate response is large. The entire NH becomes cooler with smaller warming in the SH. The maximum cooling over the northern NA can be up to 14°C. The magnitude is comparable to the past abrupt climate change indicated by paleoclimate records. The entire Atlantic ITCZ moves into SH during NH cold period.

UK RAPID
2nd Annual Meeting
Swansea, Wales UK

28 June - 1 July 2005

Florida Current Monitoring Program



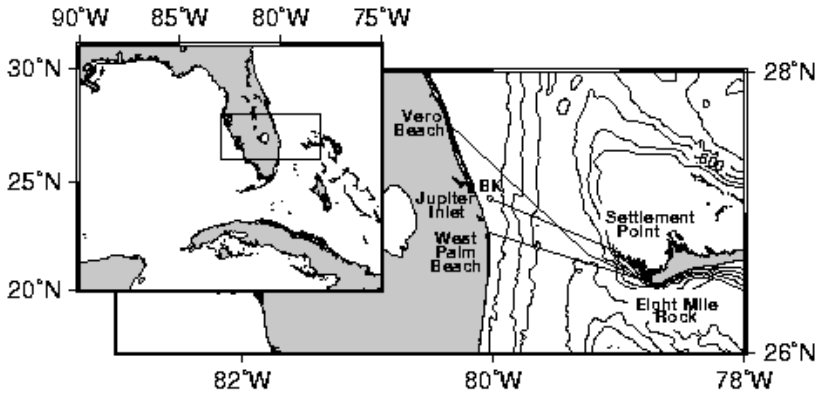
This project is part of the NOAA-funded Western Boundary Time Series project.

Project has been maintained since 1982 in a nearly continuous manner

Project includes dropsonde, XBT, CTD, and LADCP data obtained on as many as 12 cruises per year in addition to continuous monitoring via a submarine cable

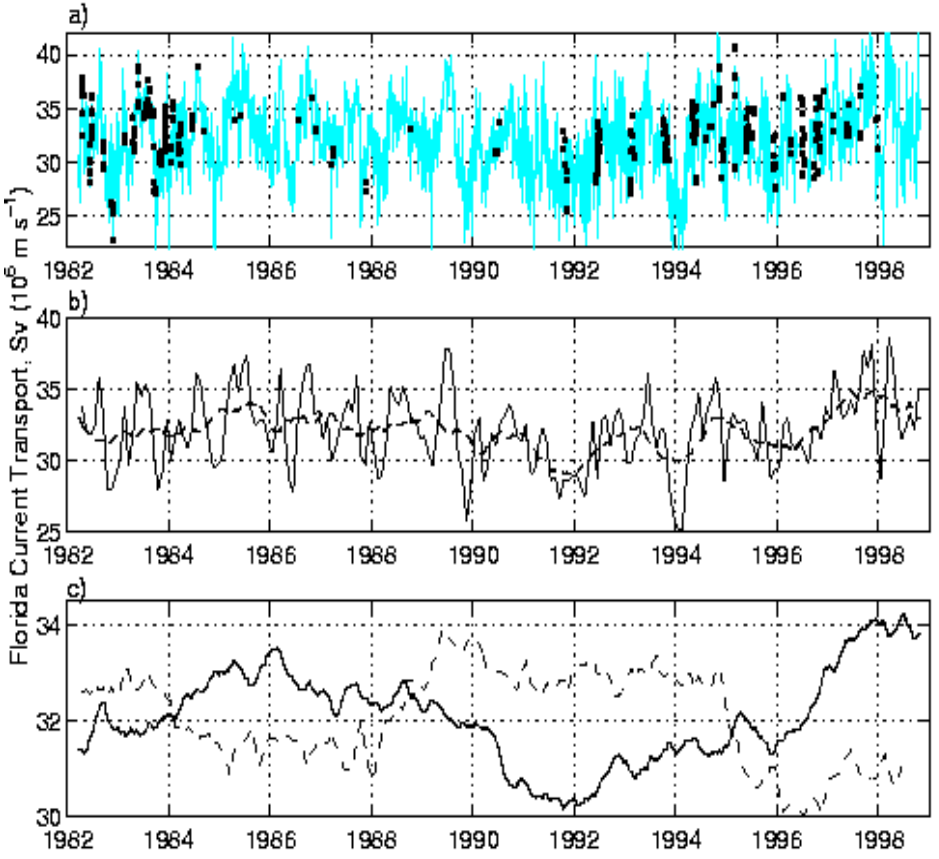
Cable measurements are made at a one minute sampling rate. Geomagnetic and tidal variations are removed and a daily mean value of transport is produced. These data are placed on a web page five days after collection.

Florida Straits Cable Time Series



The time series of Florida Current transport from the ongoing cable observations.

Bottom panel (right) shows the 2-year running mean Florida Current transport relative to the NAO index (dashed).



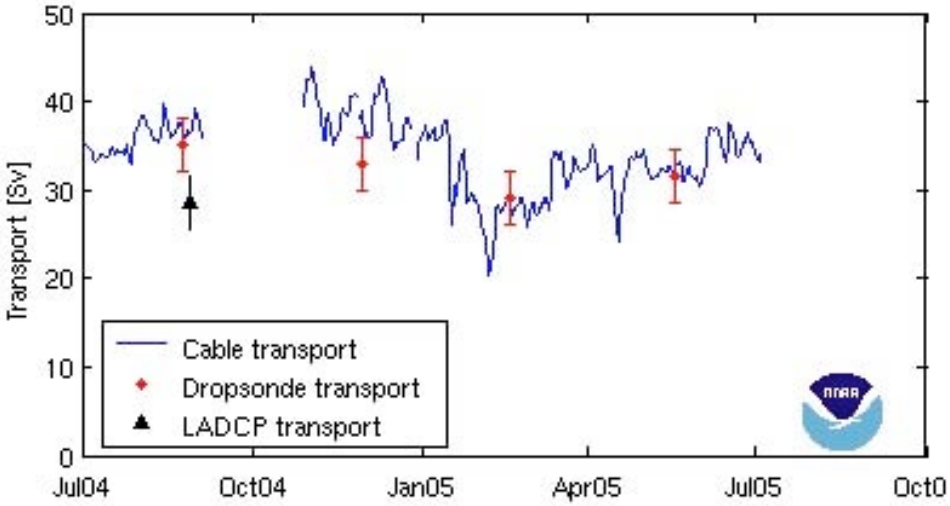
NAO (--) Current (-)

Molly Baringer, Chris Meinen

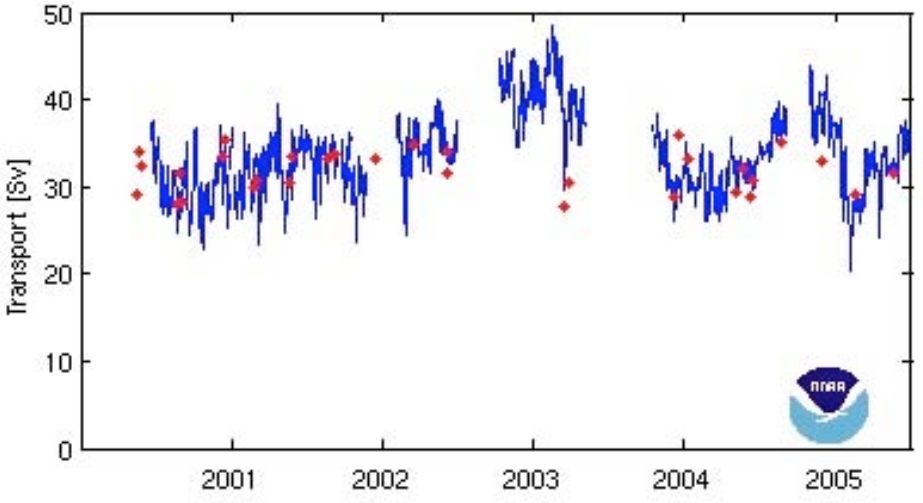
Florida Straits Cable Time Series

Molly Baringer, Chris Meinen

The daily mean transport estimates from the submarine cable voltage and in situ transport estimates from the calibration cruises in the last 365 days (top)



The daily mean transport values are available as ASCII tables for each year. Each file has one year of daily transport estimates, the units are Sverdrups(1 Sv = 10^6 m^3s^{-1}) (bottom)



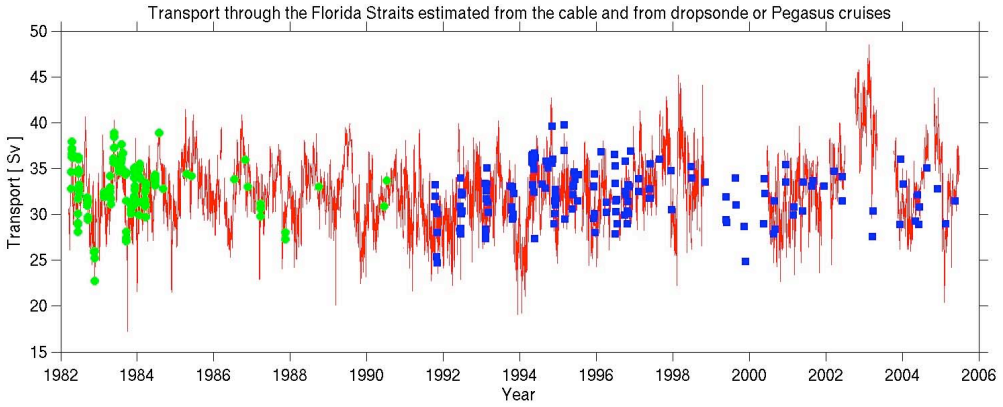
AOML

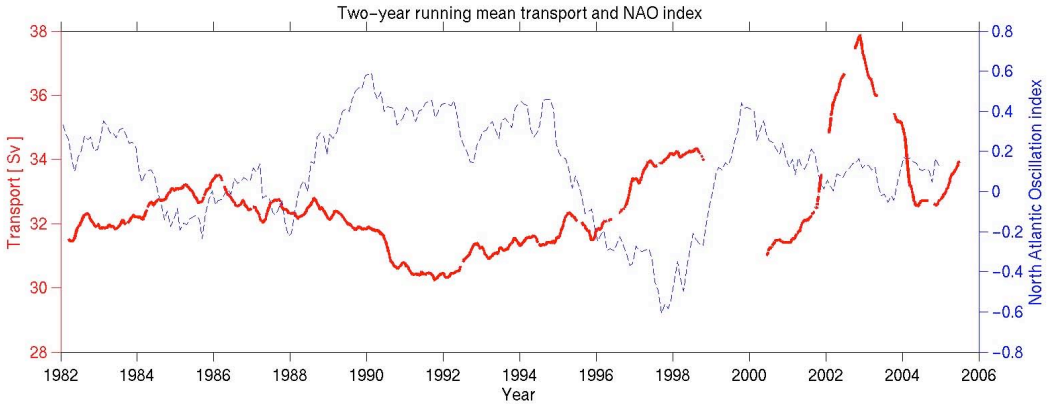
Florida Current Transport

Measurements of the Florida Current have been made for over 20 years using a submarine cable along with calibration sections (upper panel).

These observations have shown that the Florida Current, which carries the upper limb of the Meridional Overturning Circulation (MOC) is negatively correlated with the North Atlantic Oscillation (NAO).

Molly Baringer, Chris Meinen





Annual mean transport = 32 Sv
Variations in annual mean < 1 Sv
Seasonal signal represents less than 10% of the total variance
More than 50% of the variance is at periods of 100 days or less

"Most human beings have an almost infinite capacity for taking things for granted."

Aldous Huxley, English author
(1894-1963)

"Thought for Today"
The Aspen Times
Wednesday, July 13, 2005

NOAA Paleoclimatology

Site Map | What's New!

A Paleo Perspective On ABRUPT CLIMATE CHANGE

Español

Welcome to the Paleoclimatology Branch of the *National Climatic Data Center*. We provide the paleoclimatic data and information needed to understand the climate of the past, in order to assess the current and potential future climate in the context of natural climate variability.

We host the World Data Center for Paleoclimatology, providing many types of climate proxy data from thousands of locations worldwide.

The data come from scientists who make a special effort to contribute their results in order to make them widely available.

- **PALEOCLIMATIC DATA**: Access and Submit Data, Climate Reconstructions, Search by Contributor, Search by Proxy, WDC Mirror Sites.
- **PALEO PERSPECTIVES**: How paleoclimatology relates to societally relevant climate issues including Abrupt Climate Change, Drought, and Global Warming.
- **EDUCATION & OUTREACH**: Introduction to Paleoclimatology, Slidesets, Climate TimeLine, Related Educational Sites.
- **ABOUT US**: Goals, National and International Initiatives, Funding Opportunities, Publications, Staff Directory. The Paleoclimatology Program cooperates closely with the National Geophysical Data Center.
- **OTHER FEATURES**: Site Map, Free Software, Places of Interest, What's New, Paleoclimatology Discussion List, Awards, Privacy.

WDC | GLOBAL CHANGE IGBP | PAGES | CLIVAR | NSF

http://www.ncdc.noaa.gov/paleo/paleo.html

NCDC Paleoclimate Scope---

provide access to data & information about past climate and environmental change derived from paleo proxies

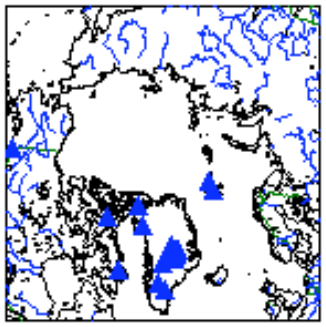
Data archives are diverse:

- ice cores
- boreholes
- corals
- tree rings
- ocean, lake sediments
- speleothems
- historical documents

Includes reconstructions of climate and climate forcings and feedbacks

Data access and display:

- Proxy-specific search engines
- Web mapper geographical-search tool
- Time series display tool
- Mirror sites in Africa, Asia, Europe, and South America



Ice core sites

Data servers

Arctic Research Office

http://www.arctic.noaa.gov/aro/

International Coordination

- **International project offices**
- **Science Steering Committees**
- **Science meetings/workshops (AGCI meeting on Abrupt Climate Change)**

"Big" vs. "Small" Science (Professor G. Philander)

PAGES
PAST GLOBAL CHANGES

Interactions With Other Program Managers

Interactions With Other Program Managers

Future Possibilities

109th CONGRESS

1st Session

S. 245

To provide for the development and coordination of a comprehensive and integrated United States research program that assists the people of the United States and the world to understand, assess, and predict human-induced and natural processes of abrupt climate change.

IN THE SENATE OF THE UNITED STATES

February 1, 2005

Ms. COLLINS (for herself, Ms. CANTWELL, Ms. SNOWE, Mrs. MURRAY, Mr. JEFFORDS, and Mr. DEWINE) introduced the following bill; which was read twice and referred to the Committee on Commerce, Science, and Transportation

A BILL

To provide for the development and coordination of a comprehensive and integrated United States research program that assists the people of the United States and the world to understand, assess, and predict human-induced and natural processes of abrupt climate change.

Be it enacted by the Senate and House of Representatives of the United States of America i n Congress assembled,

Future Possibilities (cont'd)

SECTION 1. SHORT TITLE.

This Act may be cited as the `Abrupt Climate Change Research Act of 2005'.

SEC. 2. ABRUPT CLIMATE CHANGE RESEARCH PROGRAM.

(a) ESTABLISHMENT OF PROGRAM- The Secretary of Commerce shall establish within the Office of Oceanic and Atmospheric Research of the National Oceanic and Atmospheric Administration, and shall carry out, a program of scientific research on abrupt climate change.

(b) PURPOSES OF PROGRAM- The purposes of the program are as follows:

(1) To develop a global array of terrestrial and oceanographic indicators of paleoclimate in order to sufficiently identify and describe past instances of abrupt climate change.
(2) To improve understanding of thresholds and nonlinearities in geophysical systems related to the mechanisms of abrupt climate change.
(3) To incorporate such mechanisms into advanced geophysical models of climate change.
(4) To test the output of such models against an improved global array of records of past abrupt climate changes.

(c) ABRUPT CLIMATE CHANGE DEFINED- In this section, the term `abrupt climate change' means a change in the climate that occurs so rapidly or unexpectedly that human or natural systems have difficulty adapting to the climate as changed.

SEC. 3. AUTHORIZATION OF APPROPRIATIONS.

There is authorized to be appropriated to the Department of Commerce for each of fiscal years 2006 through 2011, to remain available until expended, $10,000,000 to carry out the research program required under section 2.

Program Management 101

The Financial Planner

The Program Promoter

Communicating Your Science

Writing and visiting your Local, State and Congressional Representatives

Testifying before Congressional committees

Talking with the media

"Scientists Are Citizens"

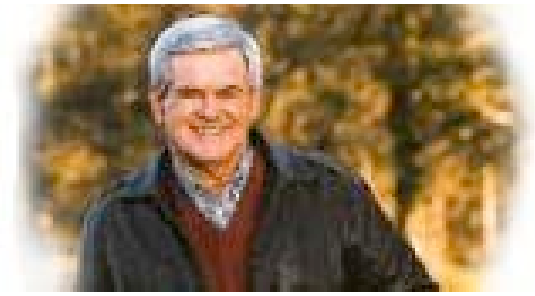
"….Scientists are citizens.

This baloney that because what you're doing is noble and interesting and therefore above demeaning yourself by being part of a democracy is just that, baloney. Scientists have fully as much an obligation to go to their Congressman's Town Hall Meeting or their Senator's Town Hall Meeting, they have fully as much an obligation to write a letter to the editor. They have fully as much an obligation to come to Washington and visit their Congressman as dairy farmers, sugar planters, coal miners, or any other legitimate group who represent their concerns.

…. And I would urge every scientist, if you don't at least once a year talk to your elected official, then shame on you. Don't tell me about the problem of Washington understanding scientific research if every scientist in the country isn't willing to take on the burden of once in a year talking to somebody who is in a position of authority. That's a simple challenge.

And then you've got to actually phrase two or three paragraphs in a common language that are understandable without having a Ph.D. in whatever your subspecialty is.

I don't mean to sound so harsh, but I am just fed up,……..I'm fed up with brilliant people explaining that they're too important to be a part of a democracy."



25th Annual Policy Colloquium
Remarks by Newt Gingrich
American Association for the Advancement of Science
Washington, DC
April 13, 2000

Issues/Challenges/Opportunities

Funding is tight

- **research must be compelling**
- **being asked to do more with less**

NOAA-University partnerships are important

Funding more tied to performance-based metrics and deliverables (NOAA mission is prediction)

Deliverables are "stakeholder-driven"

Emphasis on decision-support (http://www.climatescience.gov/workshop2005/)

Issues/Challenges/Opportunities

Multidisciplinary studies have become more prevalent (e.g., physical climate system and biogeochemical cycles, coupled models) - *Be flexible!*

Politicization of climate science (program results subject to the "Information Quality Act")

Ship-time for sustained observations and process studies

Sustained observations

- **Must generate products; observing system not just for research**
- **Transition of research to operations is a challenge and opportunity since it frees up funding for research - *must be done carefully!* (e.g.,TAO array, NOAA Climate Test Bed)**


Thank You