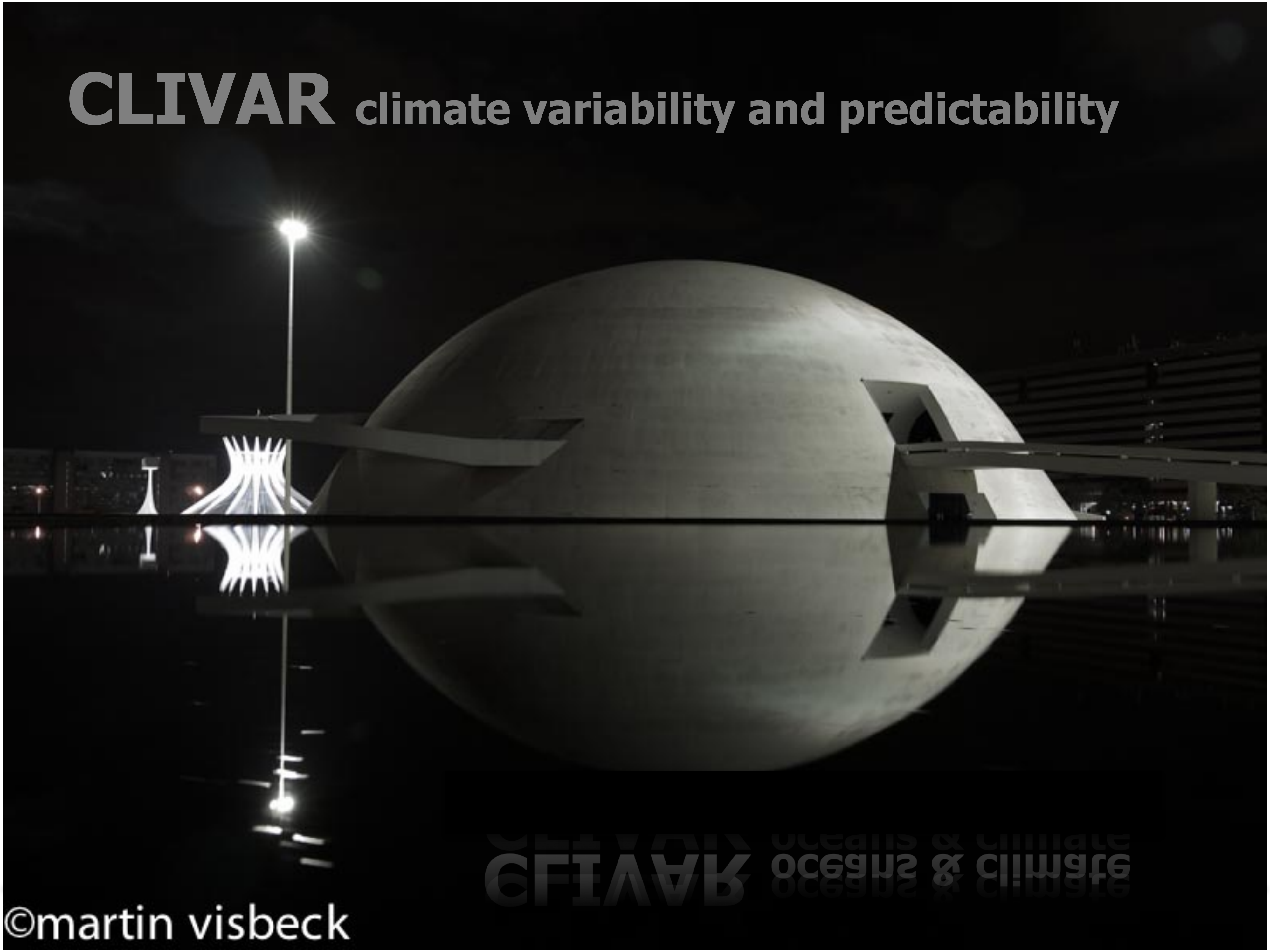

CLIVAR climate variability and predictability
CLIVAR oceans & climate
©martin visbeck

Evolution of CLIVAR

The World Climate Research Programme's project on ocean-atmosphere interactions

Scientific Steering Group Members

Professor Martin Visbeck
(Co-chair 2014)
IGEOMAR, Kiel, Germany

Dr. Lisa Goddard
(co-chair 2015)
Earth Institute at Columbia, USA

Dr. Annalisa Bracco
(2015)
School of Earth & Atmospheric Sciences, Atlanta, USA

Dr. Ken Drinkwater (2014)
Institute of Marine Research, Bergen, Norway

Dr. Sergey Gulev (2014)
Russian Academy of Sciences, Moscow, Russian Federation

Dr. Ed Hawkins (2015)
Department of Meteorology, University of Reading, UK

Dr. Valerie Masson-Delmotte (2013)
Atomic Energy Commission & Energy Alternatives, France

Dr. Steve Rintoul (2013)
CSIRO, Australia

Dr. Pedro MS Monteiro
(2015)
CSIR, South Africa

Dr. Sigfried Schubert
(2014)
NASA Goddard Space Flight Centre

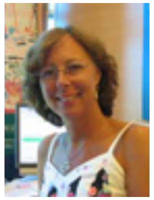
Dr. Lixin Wu (2015)
Ocean University of China, China

International CLIVAR Project Office (ICPO)

Roger Barry
Director

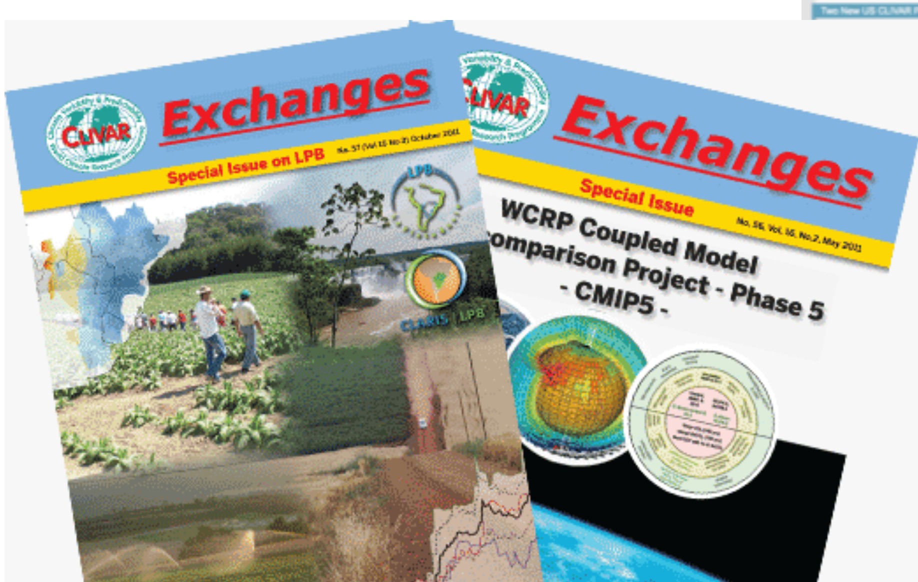
Jennifer Riley
Staff Scientist

Nico Caltabiano
Staff Scientist



Valery Detemmerman
WCRP JPS

Carlos Ereño
Staff Scientist



Anna Pirani
Staff Scientist

Xiaohui Tang
Staff Scientist

www.clivar.org

Panel and Workshop Meeting held 2012

Meeting Title	Panel	Location	Date
15th VAMOS Panel Meeting	VAMOS	Brazil	June -12
CLIVAR VAMOS Workshop on Modeling and Predicting Climate in Americas	VAMOS	Brazil	June -12
IMBER ClimECO3 Summer School	IMBER	Turkey	July -12
12th Annual Meeting of the Asian-Australian Monsoon Panel	AAMP	China	September-12
12th Session of the Implementation Panel	AIP	Germany	September-12
WCRP/CLIVAR Workshop on Decadal and Multi-decadal Variability in the Pacific and Indian Ocean	PP -IOP	China	September -12
9th Session of the CLIVAR/IOC- GOOS Indian Ocean Panel	IOP	South Africa	October -12
Ocean Synthesis and Air- Sea flux evaluation Workshop	GSOP	USA	November -12

Panel and Workshop Meeting held 2012 and planed for 2013

Meeting Title	Panel	Location	Date
GSOP 6 Workshop for Assembly of Observational Data for Climate and Decadal Prediction and Predictability	GSOP	USA	November -12
Third Workshop on the Evaluation of ENSO Processes in Climate Models	**PP**	**Australia**	**January -13**
11th Session of WGOMD	WGOMD	Australia	January -13
8th Session of the CLIVAR/CLiC/SCAR	SOP	Australia	February -13
WGOMD/SOP Workshop on sea level rise, ocean/ice shelf interactions and ice sheets	WGOMD/ SOP	Australia	February -13
CLIVAR SSG-20	SSG	Germany	May-13
CLIVAR/GSOP Workshop on Global Ocean Sub-Surface Climate Data	GSOP	Australia	June -13
WCRP/CLIVAR Second International Symposium on Boundary Current dynamics	CLIVAR/ IOC-GOOS	China	July -13

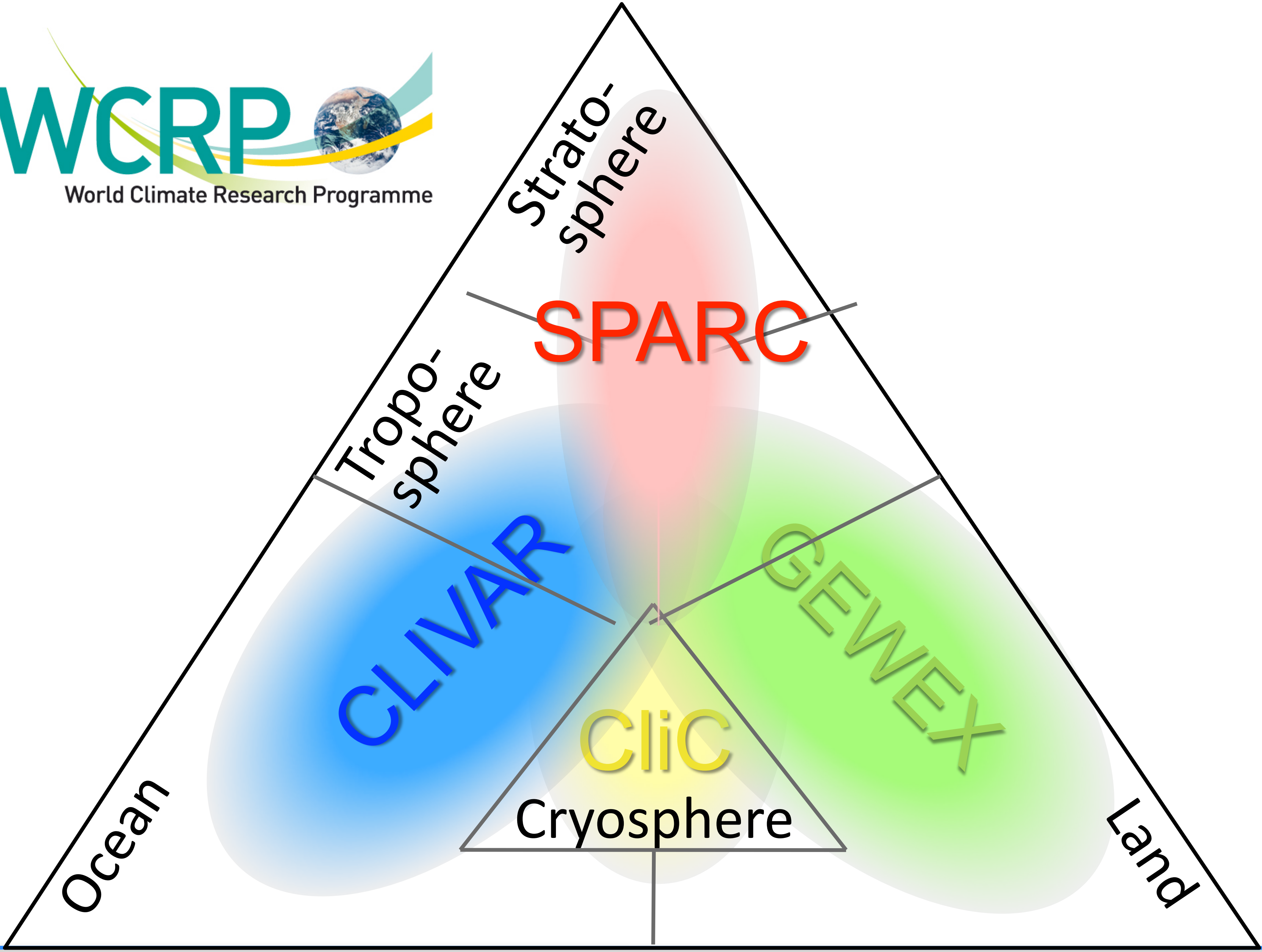
Future Arrangements of (ICPO) to start early 2014

CLIVAR OCEANS & CLIMATE

variability, predictability and change

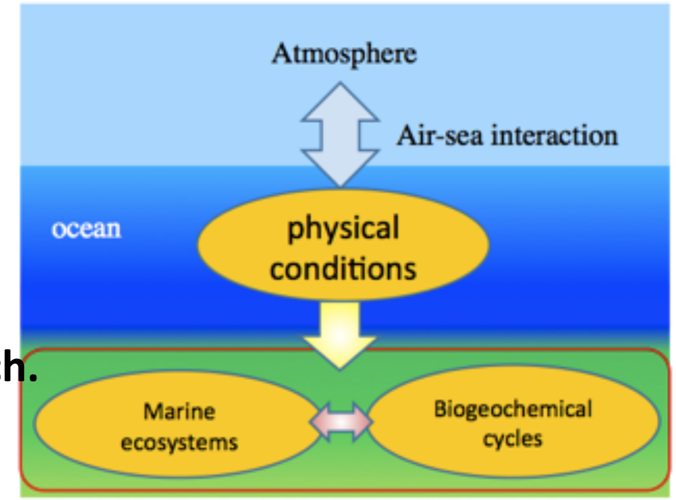
The World Climate Research Programme's project on ocean-atmosphere interactions

To improve understanding and prediction
of ocean-atmosphere interactions
and their influence on climate variability and change,
to the benefit of society and the environment.


Strato-
sphere
SPARC
Tropo-
sphere
CLIVAR
GEWEX
CliC
Cryosphere
Ocean
Land

Evolution of CLIVAR – Main Directions

- **CLIVAR remains the ocean-atmosphere program of the World Climate Research Program**
- **CLIVAR is in the process of formulating a new set of research opportunities that will contribute to the Grand Challenges of WCRP and the wider context of the oceans role in climate variability and change.**
- **CLIVAR will retain its global and balanced approach based on observations, models and theory and their joint exploitation for climate assessment and climate prediction.**
- **CLIVAR supports the development of sustained climate and ocean observations as well as targeted improvements to the climate and ocean components of earth system models.**
- **CLIVAR will intensify its partnerships with the marine biogeochemistry and eco-system community as well as with a selected spectrum of its information user community.**

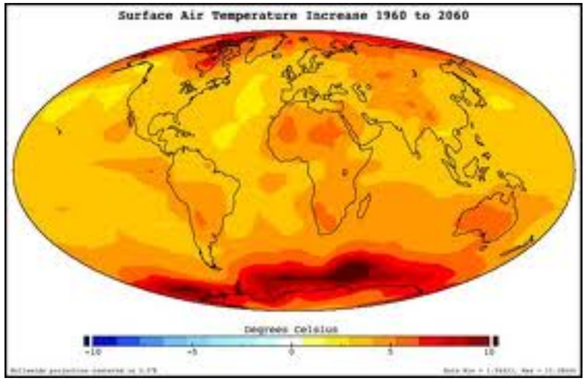


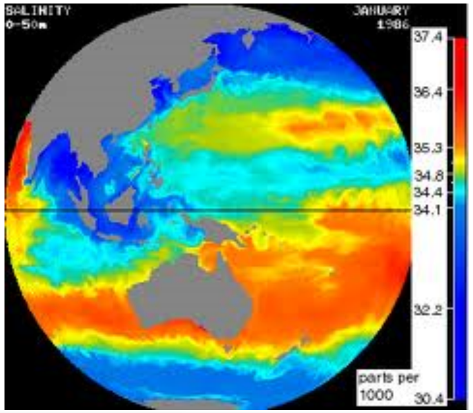
- **CLIVAR support education, capacity building and outreach.**
- **Next Steps**
  - AGU (December 2013) & AMS (February 2014) townhall discussion
  - OCEAN SCIENCE MEETING (March 2014) rollout of NEW CLIVAR strategy and plans
  - PAN-CLIVAR meeting in 16-18 July 2014

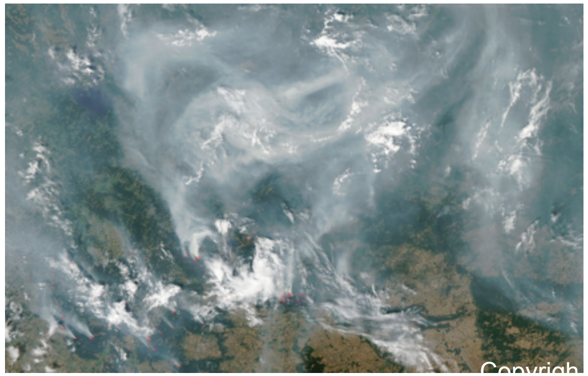
CLIVAR (Climate Variability and Predictability)

Mission

To observe, simulate and predict changes in Earth's climate system with a **focus on ocean-atmosphere interactions**, enabling better understanding of climate variability, predictability and change, to the benefit of society and the environment in which we live.







CLIVAR Objectives

- Understand the causes of climate variability on intra-seasonal to centennial time-scales through observations, analysis and modeling.

- Improve predictions of climate variability and change associated with both internal and external processes.

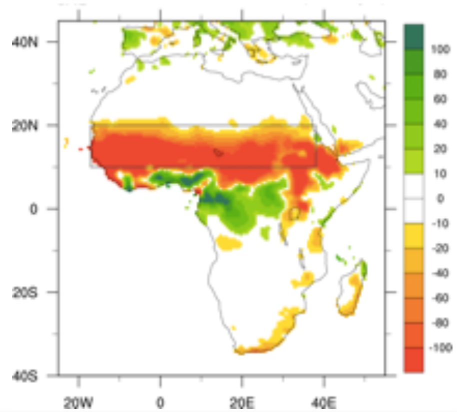
- Extend observational climate record through assembly of quality-controlled data sets.

- Improve the atmosphere and ocean components of Earth-System Models.

current CLIVAR Research

- Anthropogenic Climate Change
  - Natural variability versus forced change
  - Climate sensitivity and feedbacks
  - Regional phenomena (e.g., ENSO, AMOC, …)
  - Extremes
  - CMIP#
  - Climate Engineering (Geo-engineering)

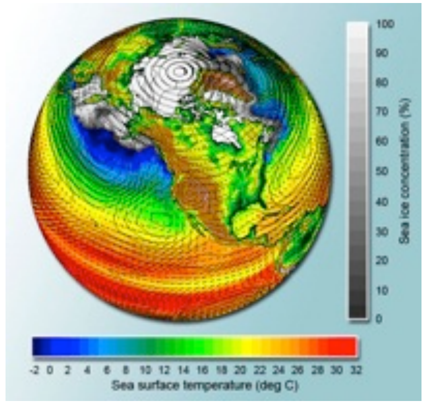
- Intra-to-Seasonal Variability, Predictability and Prediction
  - Monsoons (and ENSO, TAV, …)
  - ISV/MJO
  - Quantifying prediction uncertainty
  - Building pan-WCRP and WWRP links
  - CHFP



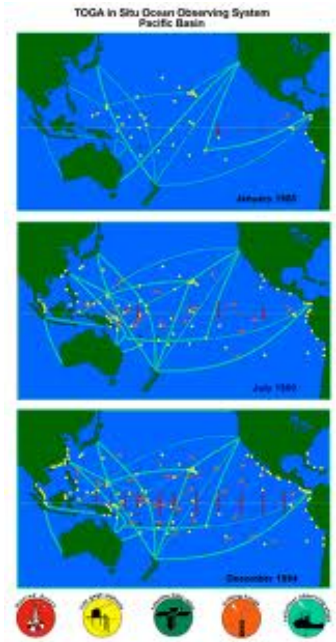
- Decadal Variability, Predictability and Prediction
  - Determine predictability
  - Mechanisms of variability (AMO, PDV, …)
  - Role of oceans
  - Adequacy of observing system
  - Coupled Initialization
  - Quantifying prediction uncertainty
  - Building pan-WCRP links

current CLIVAR Imperatives

- Improved Atmosphere and Ocean Components of ESMs
  - Analysis and Evaluation
  - “Climate Process Teams” (process studies)
  - Building links pan-WCRP and IGBP
  - Model-Data comparisons



- Data Synthesis and Analysis
  - Ocean
  - Coupled Data Assimilation Systems
  - Links – carbon, biogeochemistry, marine-ecosystems

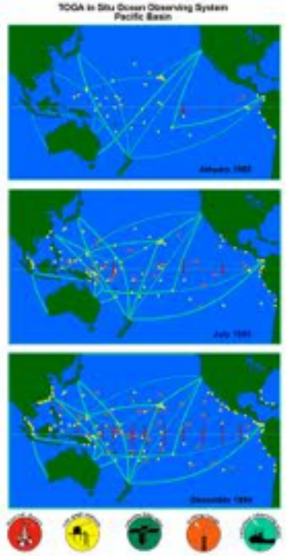


- Ocean Observing System
  - Development, implementation and system design
  - Advocacy for sustained observations
  - IGBP links for Carbon, Biogeochemistry, Ecosystems

- Capacity Building
  - Summer schools and topical workshops
  - Expert training
  - Call for panel membership

Current CLIVAR Research&Imperatives

- Anthropogenic Climate Change
- Intra-to-Seasonal Variability, Predictability and Prediction
- Decadal Variability, Predictability and Prediction
- Improved Atmosphere and Ocean Components of ESMs
- Data Synthesis and Analysis
- Ocean Observing System
- Capacity Building



All Must Remain WCRP Priorities

CLIVAR – A Global View

Regional implementation

current **CLIVAR** Organization

Scientific Steering Group | ICPO

Crosscutting (global) Panels

Observations & Data

- Global Synthesis & Observations Panel
- PAGES / CLIVAR Working Group (WCRP)
- CCI / CLIVAR Expert Team on Climate Change Detection and Indices (joint with GEWEX)

Modeling

- Worl ng Gr … Seasonal to Interannual Prediction (WCRP) ✔
- / C … Working Group on Coupled Modeling (WCRP) ✔
- Working Group on Ocean Model Development

Regional Panels

- CLIVAR / IOC Indian Ocean Implementation Panel
- Atlantic Implementation Panel
- Asian-Australian Monsoon Panel (joint with GEWEX)
- Variability of the American Monsoon Systems (VAMOS)
- Pacific Implementation Panel
- Southern Ocean Implementation Panel
- Variability of the African Climate System Panel

Highlights against CLIVAR Objectives

- Understand the causes of climate variability on intra-seasonal to centennial time-scales through observations, analysis and modeling.

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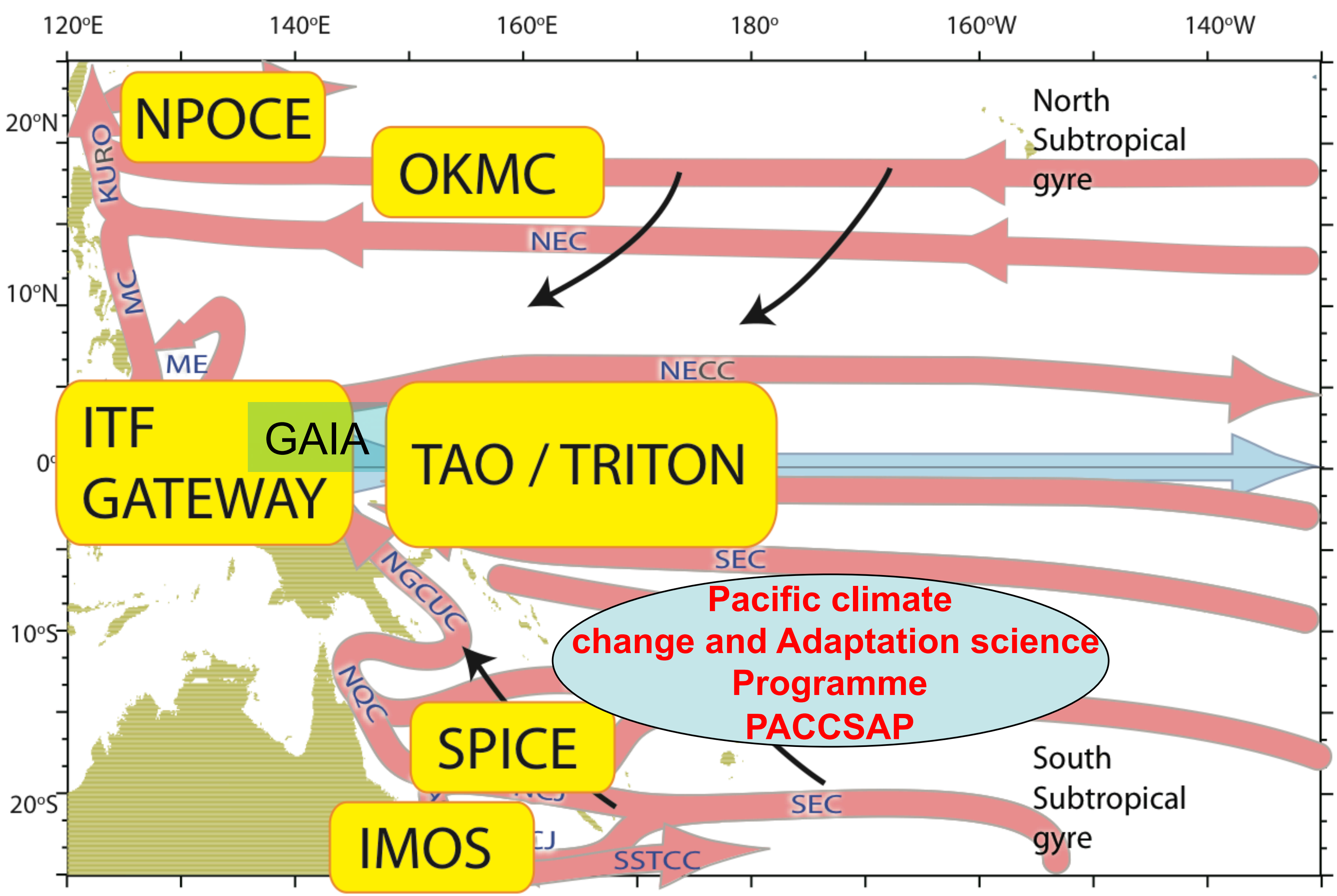
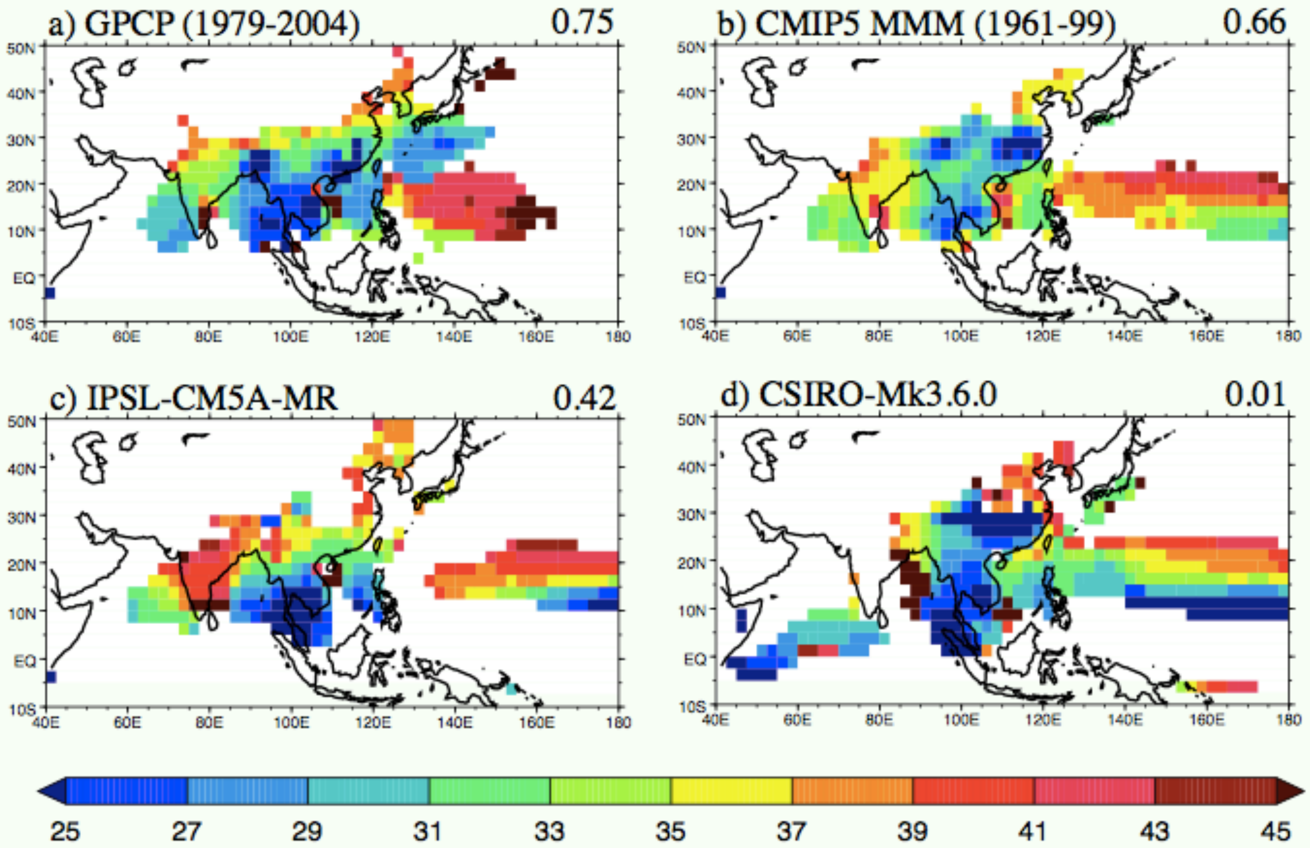
Process Experiments in the Pacific

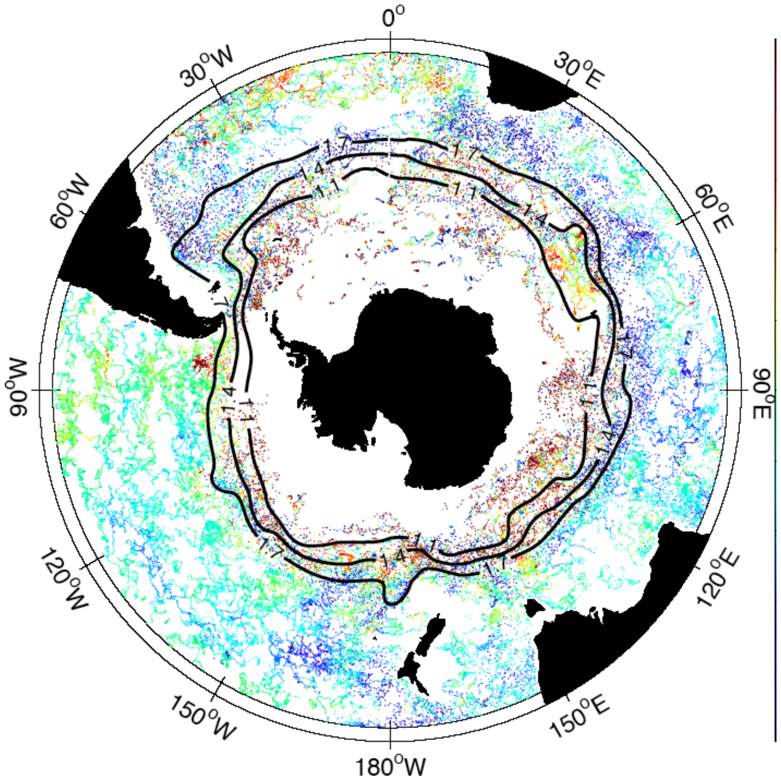


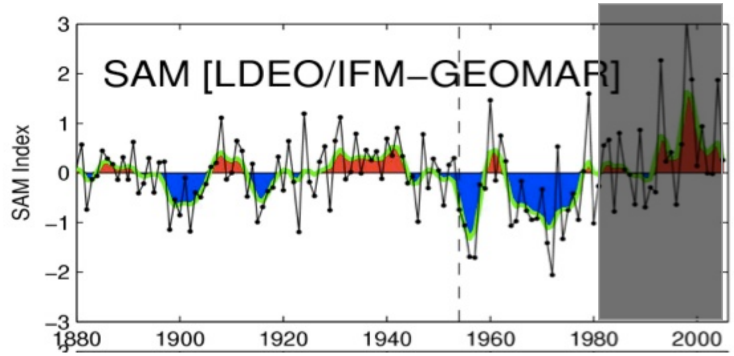
Climatological monsoon onset (pentad 31 ~June 1)

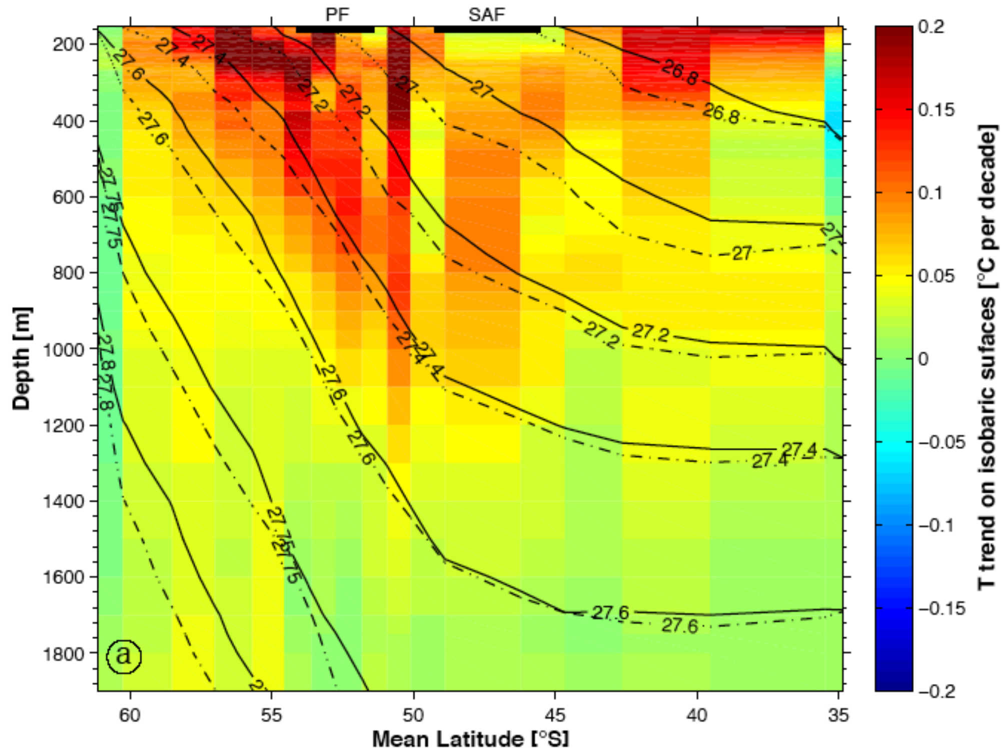
- Observed and simulated results include data from the CMIP5 MMM, and two CMIP5 models
  - Individual models outperform the multi-model mean (not shown)
  - Bias in the time of onset: too late over India (CMIP5 MMM and IPSL-CM5A-MR)
  - Spatial extent of monsoon not defined over: China (IPSL-CM5A-MR) and India (CSIRO-Mk3.6.0)



Warming across the ACC

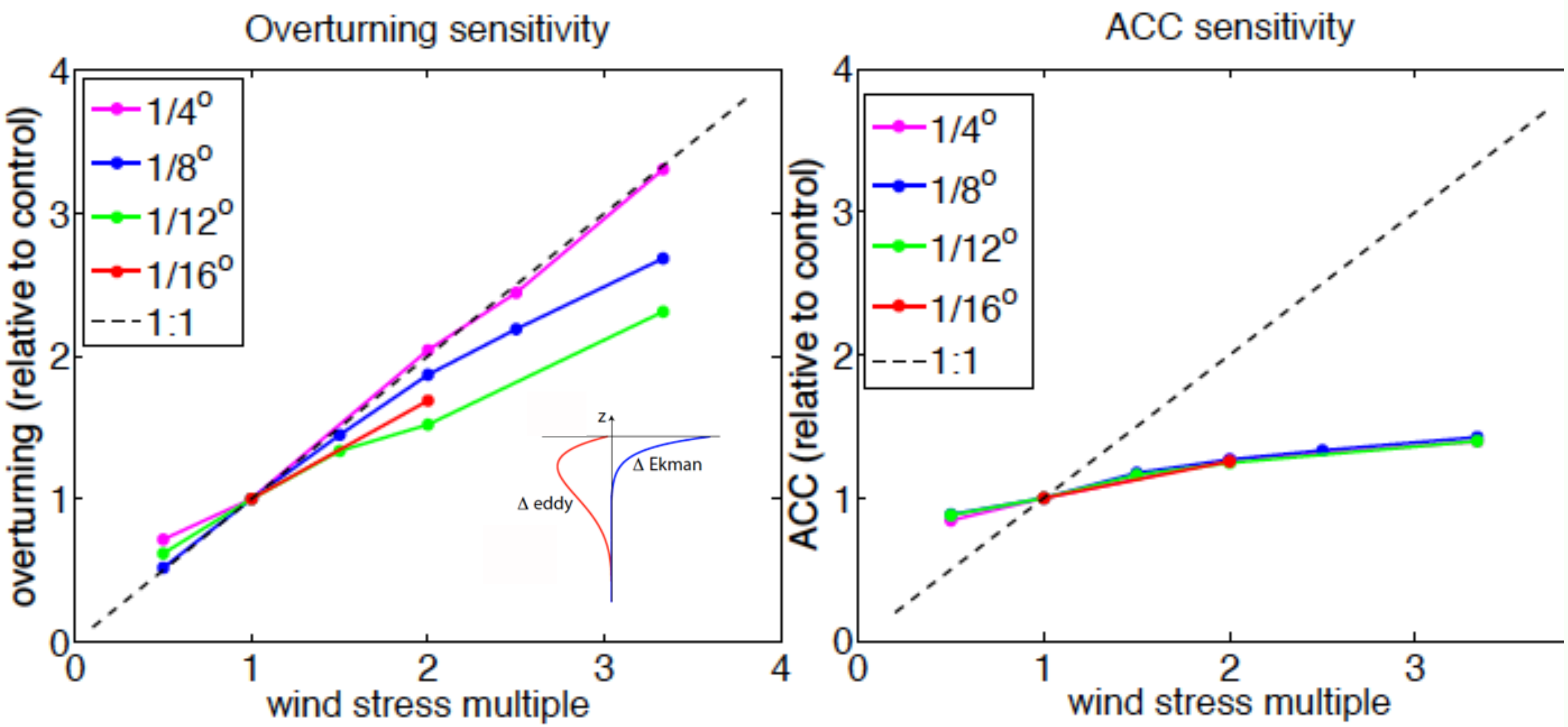






No change in isopycnal slope despite increase in winds (SAM)

Overturning and ACC response



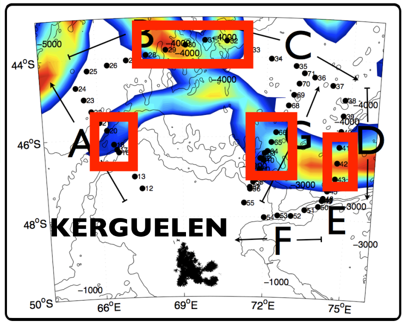
- Eddy compensation is not perfect.
- ACC response shows no resolution dependence.
- Eddy saturation (ACC) does not imply eddy compensation (overturning).
- Overturning changes larger than ACC changes.

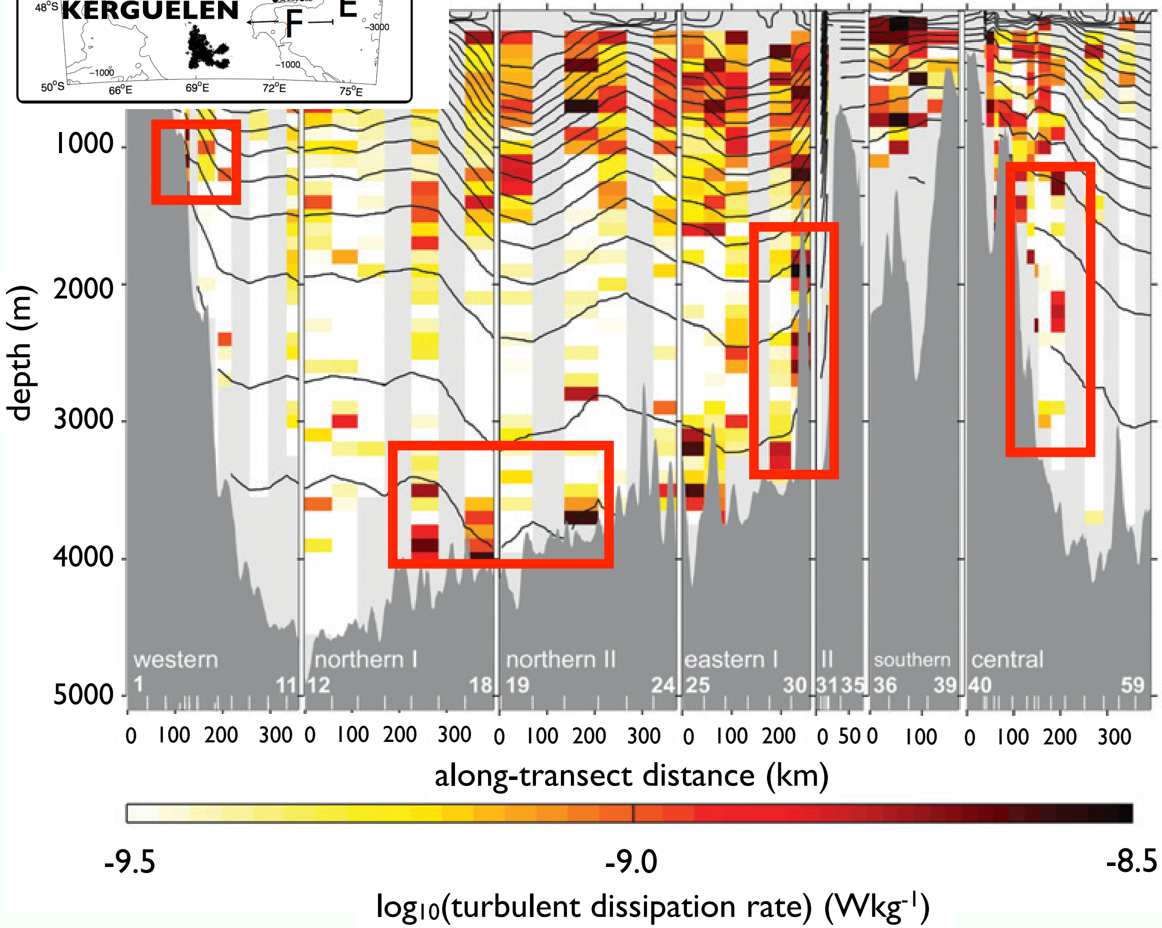
Morrison & Hogg (2013)

The Southern Ocean FINEstructure project (SOFINE) 2008 - 2011

the first full-depth microstructure observations of the turbulent dissipation rate in the ACC

Confirms several of our expectations of the relation between the internal wave field and turbulent mixing and dissipation in the Southern Ocean interior ...





There was interest expressed to propose a new CLIVAR research opportunity on Ocean Mixing

Highlights against CLIVAR Objectives

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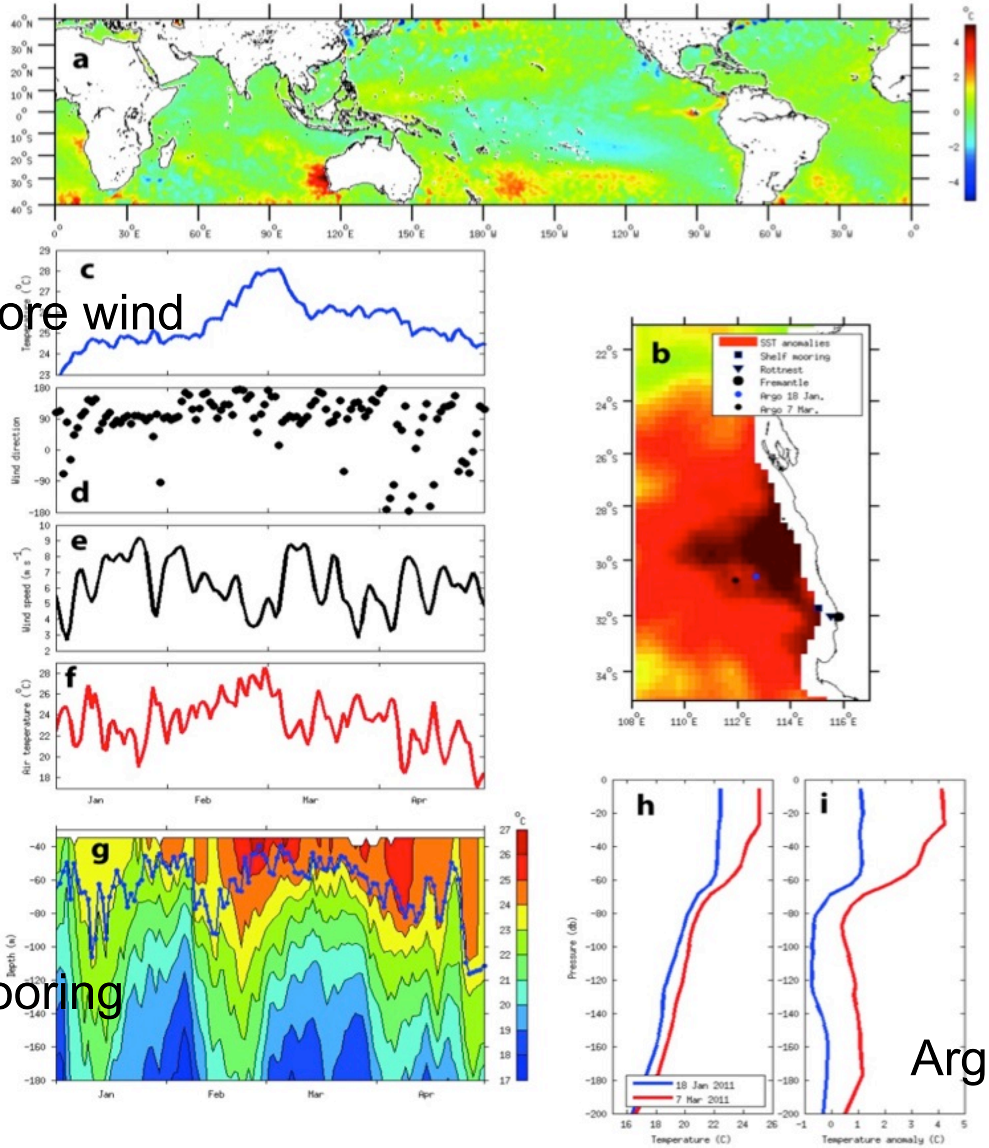
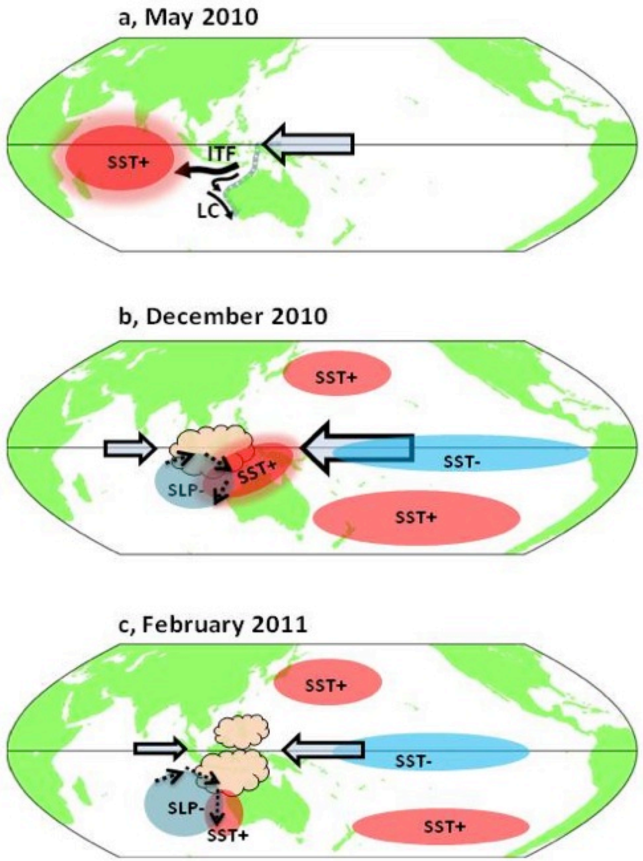
Warming event in the Southeast Indian Ocean

Alongshore wind



Shelf mooring

Argo profiles



Ming Feng, et. al., Nature

LETTER

doi:10.1038/nature11358

More extreme swings of the South Pacific convergence zone due to greenhouse warming

Wenju Cai[1], Matthieu Lengaigne[2], Simon Borlace[1], Matthew Collins[3,4], Tim Cowan[1], Michael J. McPhaden[5], Axel Timmermann[6], Scott Power[7], Josephine Brown[7], Christophe Menkes[8], Arona Ngari[9], Emmanuel M. Vincent[2] & Matthew J. Widlansky[10]

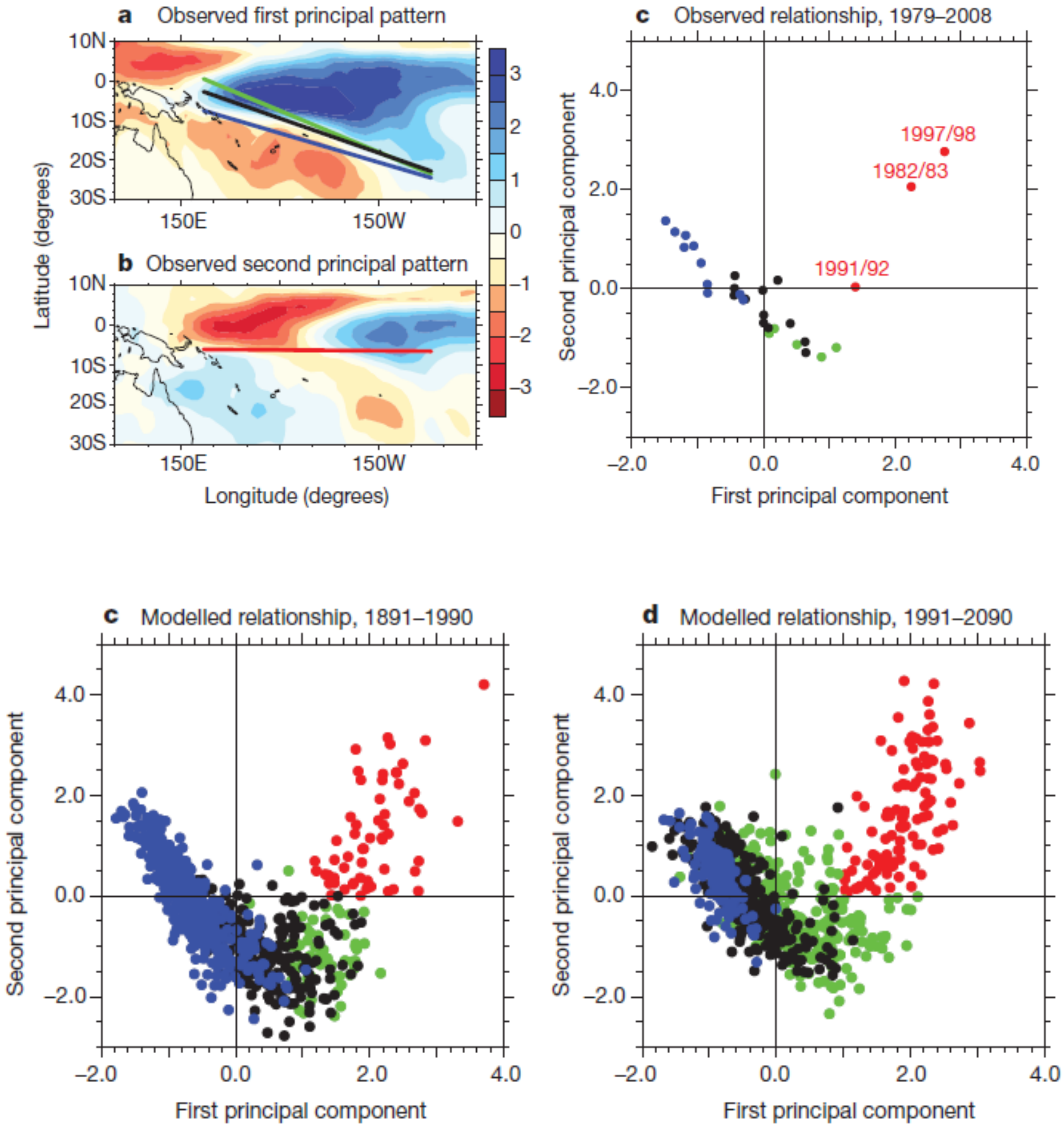
nature climate change

ARTICLES

PUBLISHED ONLINE: 28 OCTOBER 2012 | DOI: 10.1038/NCLIMATE1726

Changes in South Pacific rainfall bands in a warming climate

Matthew J. Widlansky[1*], Axel Timmermann[1,2], Karl Stein[2], Shayne McGregor[3], Niklas Schneider[1,2], Matthew H. England[3], Matthieu Lengaigne[4] and Wenju Cai[5]



a Observed first principal pattern
b Observed second principal pattern
Latitude (degrees)
Longitude (degrees)
10N
0
10S
20S
30S
150E
150W
3
2
1
0
−1
−2
−3
c Observed relationship, 1979–2008
1997/98
1982/83
1991/92
Second principal component
First principal component
4.0
2.0
0.0
−2.0
−2.0
0.0
2.0
4.0
c Modelled relationship, 1891–1990
d Modelled relationship, 1991–2090
Second principal component
First principal component

CLIVAR Pacific Panel:
science outreach to decision makers and adaptation

Impact on fisheries and food security (Pacific Islands)

nature climate change

ARTICLES

PUBLISHED ONLINE: 10 MARCH 2013 | DOI: 10.1038/NCLIMATE1838

Mixed responses of tropical Pacific fisheries and aquaculture to climate change

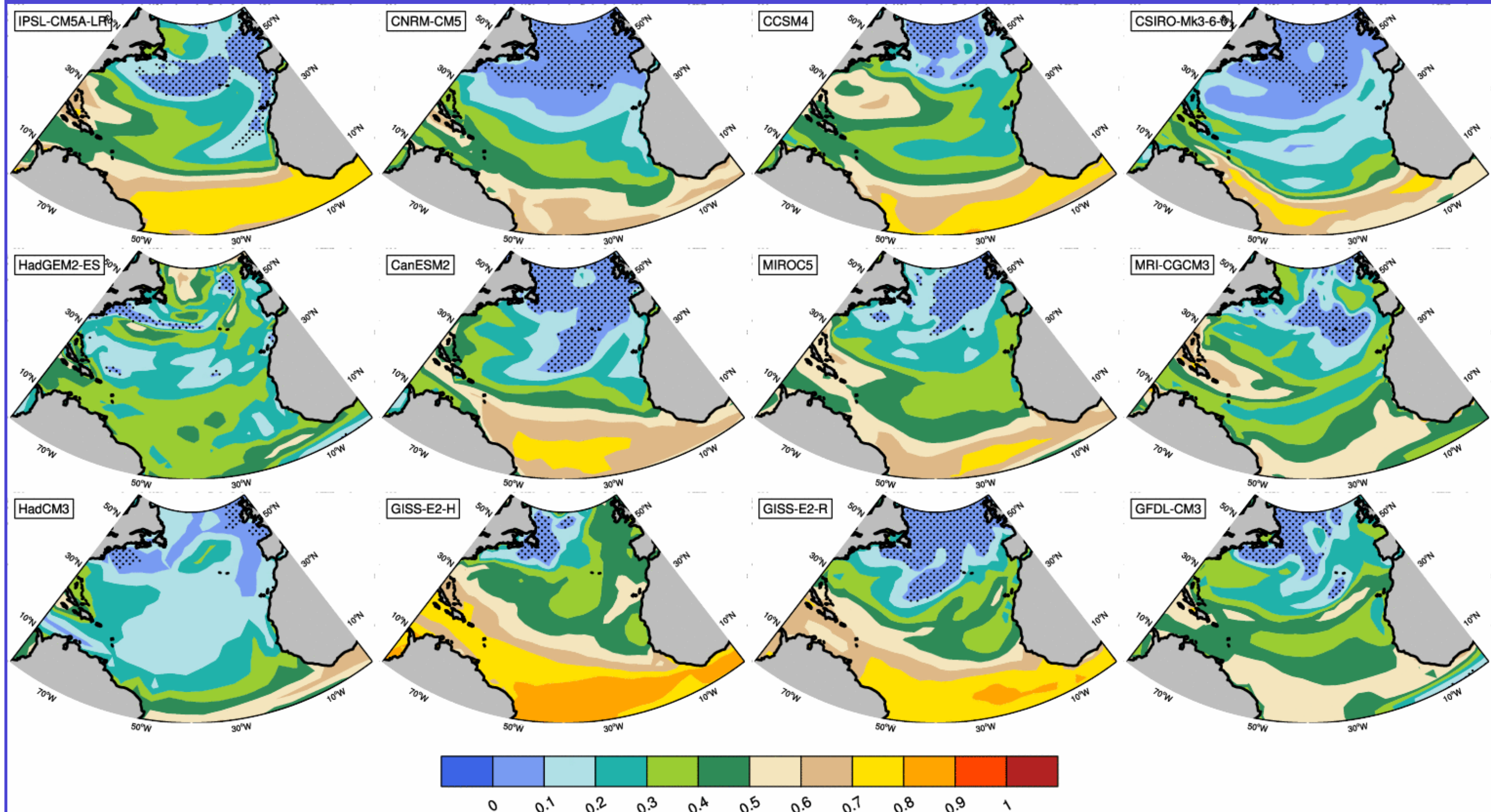
Johann D. Bell[1]*, Alexandre Ganachaud[2,3], Peter C. Gehrke[4], Shane P. Griffiths[5], Alistair J. Hobday[6], Ove Hoegh-Guldberg[7], Johanna E. Johnson[8], Robert Le Borgne[2], Patrick Lehodey[9], Janice M. Lough[10], Richard J. Matear[6], Timothy D. Pickering[11], Morgan S. Pratchett[12], Alex Sen Gupta[13], Inna Senina[9] and Michelle Waycott[14,15]

Cascade down climate information
Work with local organization (S. of the Pacific Communities)
80 authors; 900-p book; country reports;
Adaptation recommendations

CLIVAR AIP: Near-term issues and challenges

Seasonal to decadal prediction

- Some large projects adressing decadal predictions: US AMOC, German MiKlip, EU-COMBINE, EU-NACLIM, EU-SPECS
- AIP involvement in CMIP5 analyses



Ratio of forced to total decadal SST variance (Stippling: forced variance ≈ 0 at the 5% level). Estimated over 1850-1960; Decrease with increasing latitude; Decadal SST variance in mid to high latitude regions due to internal variability.

Terray (2012)

Highlights against CLIVAR Objectives

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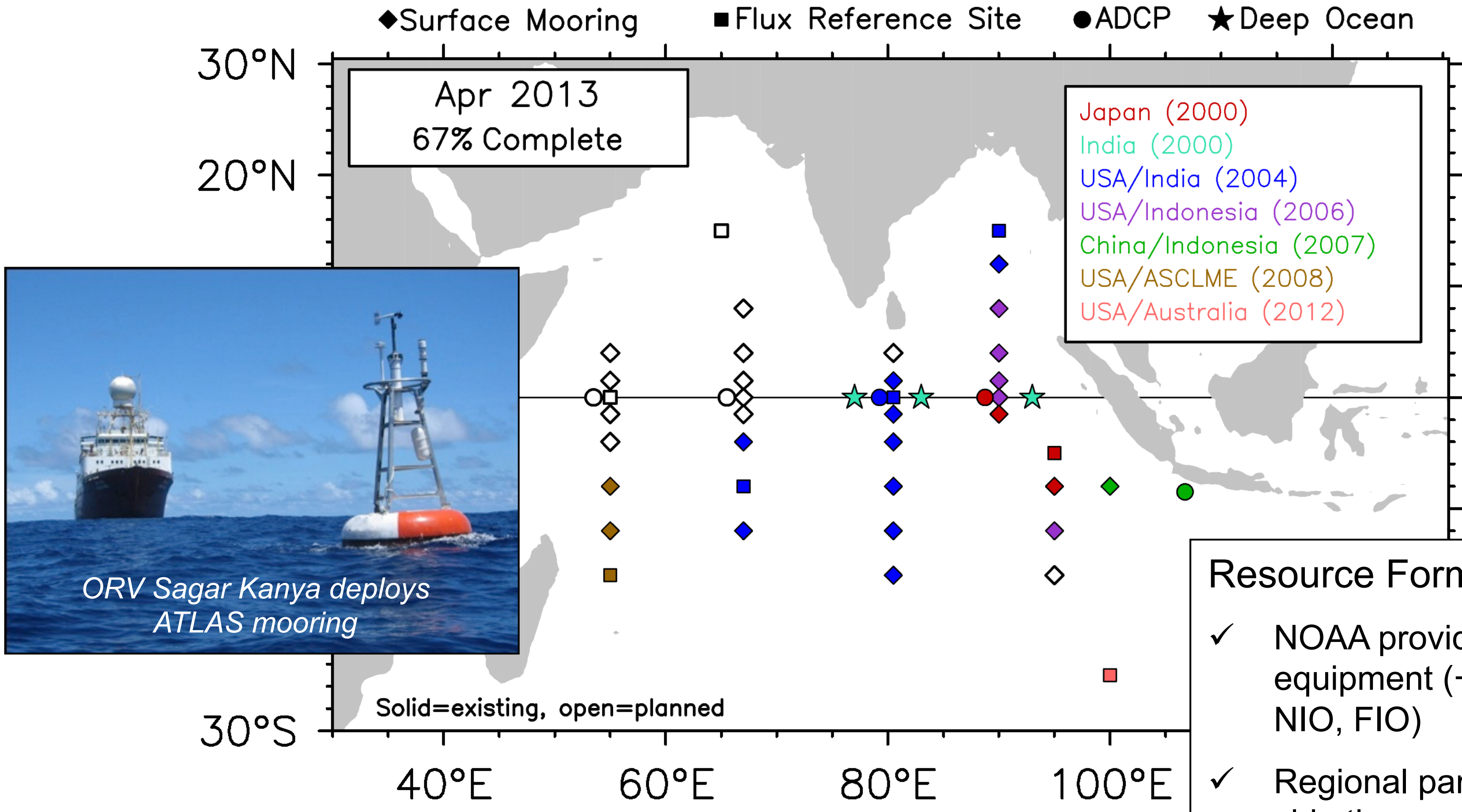
RAMA

Indian Ocean Panel

Research **M**oored **A**rray for **A**frican–Asian–Australian **M**onsoon **A**nalysis and Prediction (**RAMA**)

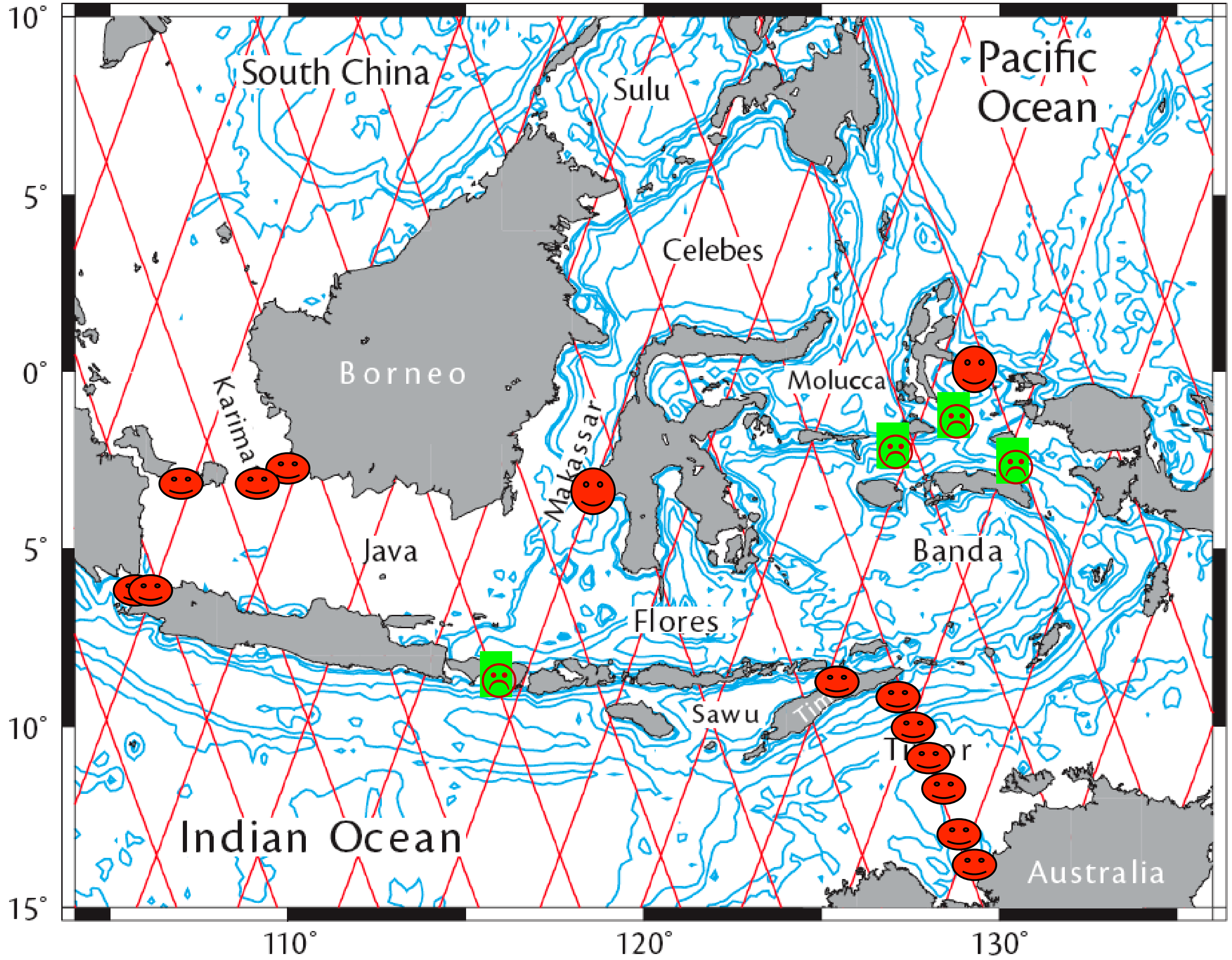


Resource Formula:

- ✓ NOAA provides most equipment (+JAMSTEC, NIO, FIO)
- ✓ Regional partners provide ship time

67% of sites occupied at present (31 of 46)

Putting our Dots on your Maps!



Funded and deployed

Not funded but planned

CLIVAR Indian and Pacific Panels: Including our moorings on your maps is important international recognition for regional funding agencies

CLIVAR/CliC/SCAR Southern Ocean Region

Observing System Issues and Challenges and the development of the SOOS

The Southern Ocean Observing System

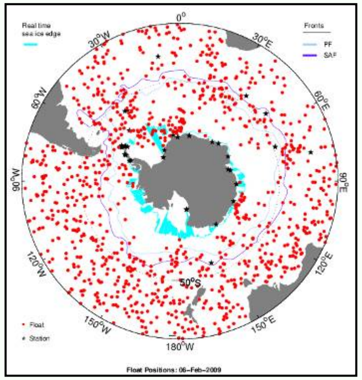
- Design and implementation of an observing system that encompasses *physical, biogeochemical* and *ecological* processes is therefore a formidable challenge
- Requires multiple nation and agency involvement since the region is vast, remote and logistically difficult to access and thus is one of the least sampled regions on Earth

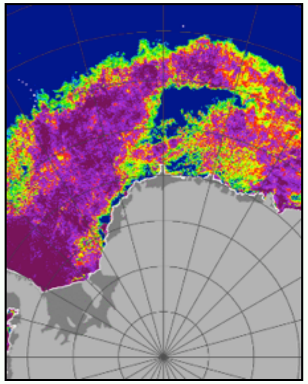
Observing gaps?

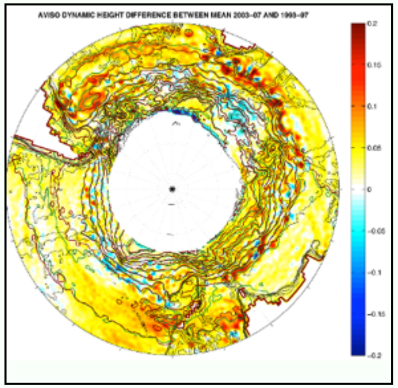
- Ecosystem monitoring on Argo profiling (CSOBOM – application pending) aims to address this gap)
- CO2 gas fluxes
- Need to expand ocean coverage under sea-ice zone (CSOBOM and Argo to implement more profiling floats, but other technologies should be under consideration)
- Need to include atmospheric boundary layer and better observe SO clouds
- Must include ice interaction regions
- Process studies

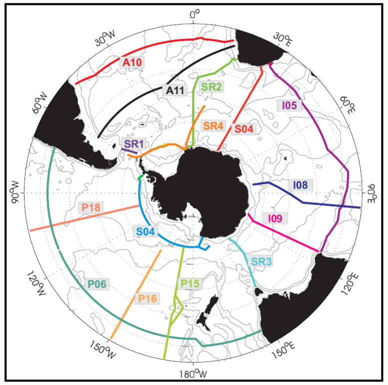
International SOOS office to carry forward this work

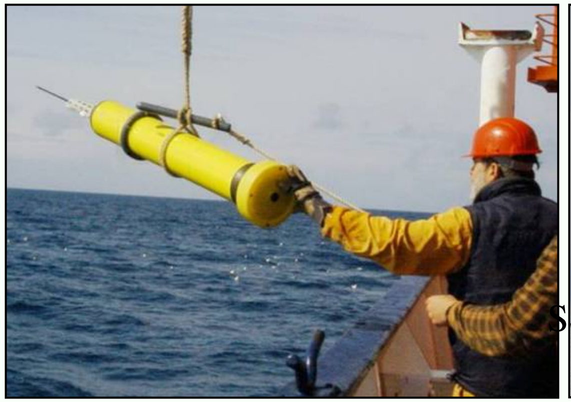
A Southern Ocean Observing System – SOOS



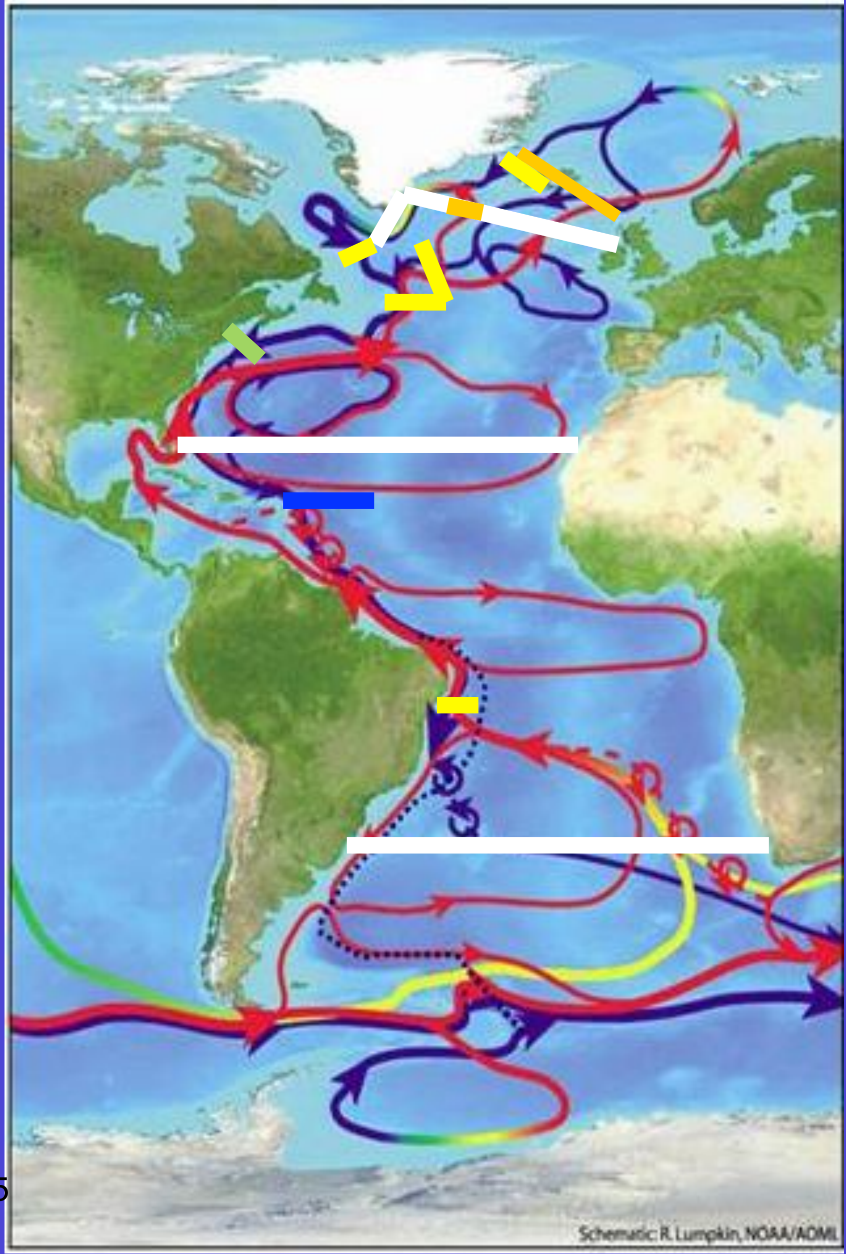








AMOC Observing System



AMOC observing system including trans-basin, overflow & western boundary current observations.

EU-NACLIM exchange across Greenland-Scotland ridge, subpolar North Atlantic

BMBF RACE (different locations, overflow and western boundary)

OSNAP in the subpolar North Atlantic

WHOI Line W at 40°N

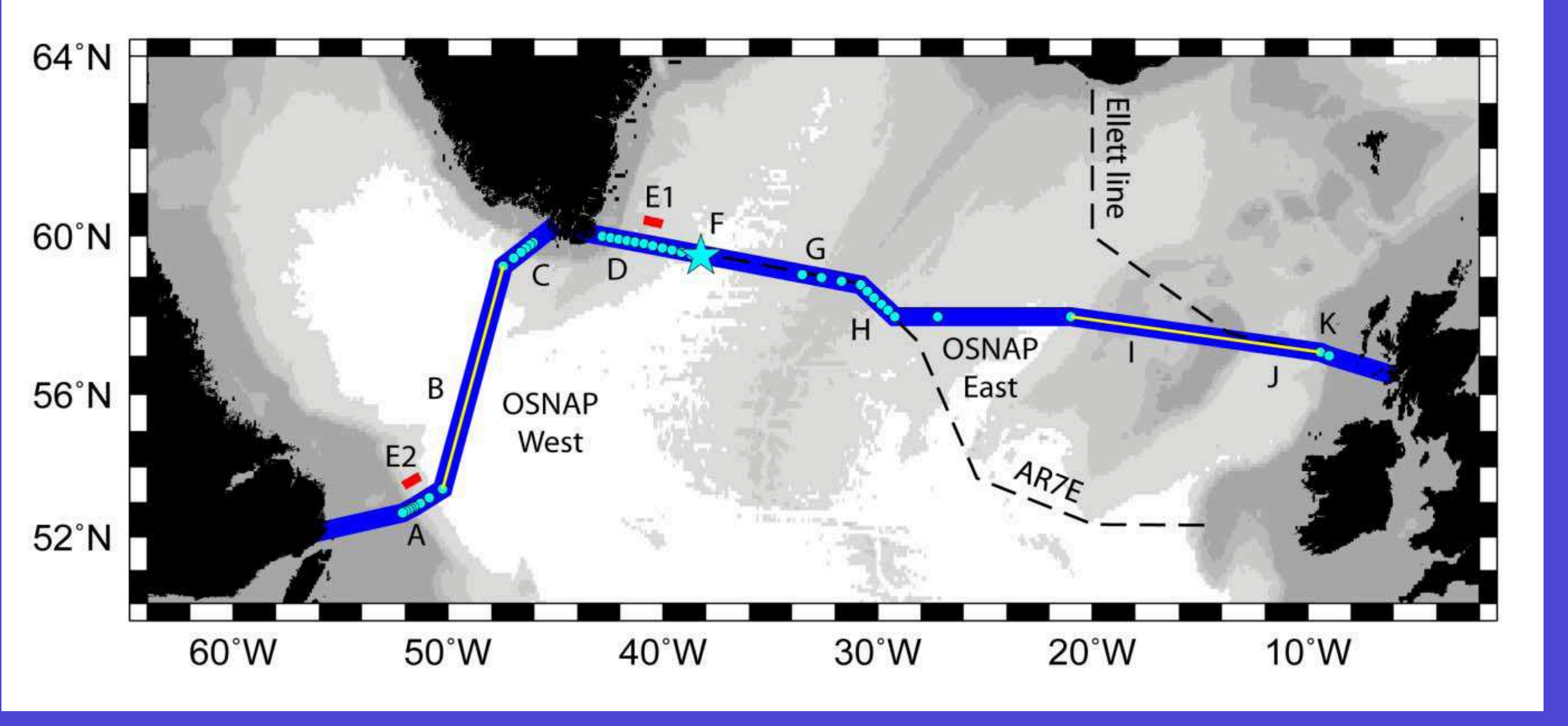
RAPID-WATCH/MOCHA/WBTS at 26°N

US MOVE at 16°N

SAMOC at 34.5°S

OSNAP: Overturning in the Subpolar North

Objective: ***"To quantify the large-scale, low-frequency, full water-column net fluxes of mass, heat and fresh water associated with the meridional overturning circulation in the subpolar North Atlantic."***

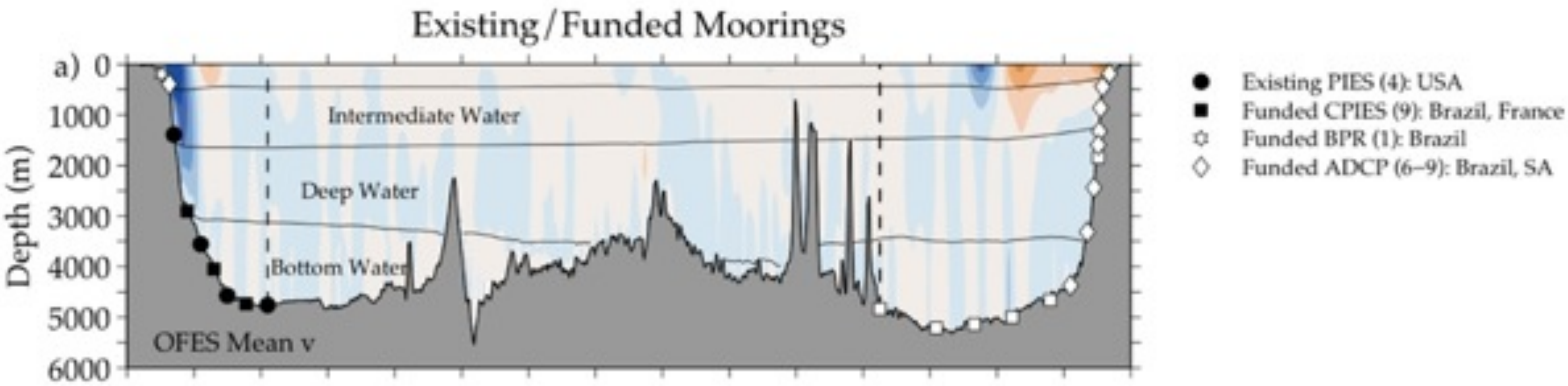


OSNAP elements: (A) German 53°N western boundary array, supplemented by Canadian shelfbreak array; (**B**) US Lab Sea glider survey; (**C**) US West Greenland boundary array; (**D**) US/UK East Greenland boundary array; (**E1** and **E2**) US float launch sites; (F) US OOI Irminger Sea global node; (G) Netherlands western Mid-Atlantic Ridge array; (**H**) US eastern Mid-Atlantic Ridge and Iceland Basin array ; (**I**) UK glider survey (Rockall-Hatton Plateau); (**J**) UK glider survey (Rockall Trough); (**K**) UK Scottish Slope current array.

South AMOC (SAMOC) at 34.5°S

Current state and evolution of the Atlantic ocean observing system

- Boundary current measurement systems have been started on the western boundary (USA-NOAA, Argentina-SHN, Brazil-USP, Navy) and on the eastern boundary (France-Ifremer, South Africa-UCT) along 34.5°S.
- The funded and proposed field programs have initial durations of 3 to 5 years.

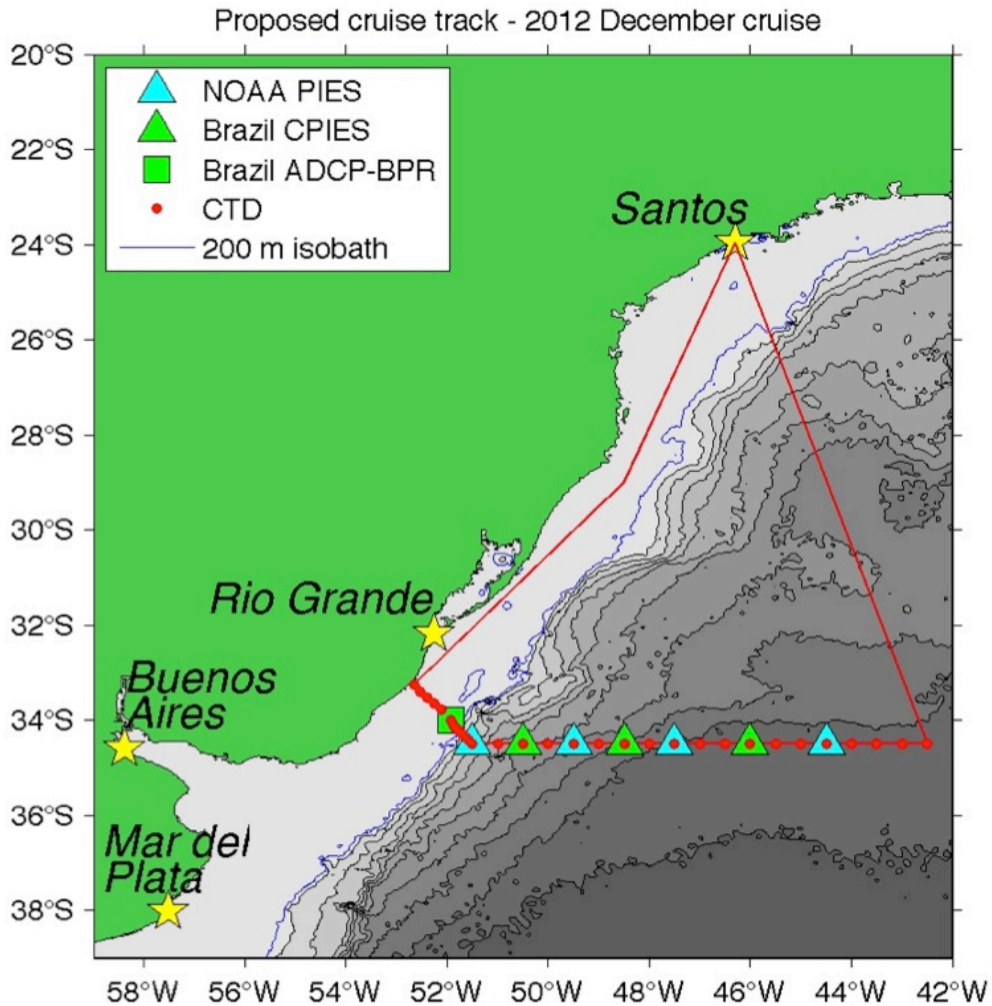


Upcoming augmentations/ expansions of the existing SAM pilot array at 34.5°S

The first turn-around for the NOAA pilot array will be done in December 2012 as part of a joint Brazilian, Argentine, and US cruise.

In addition to the NOAA turn-arounds, this cruise represents a crucial expansion of the MOC observing system in the region, as Brazil will be deploying additional instruments to improve the existing western boundary array and to expand it up onto the continental shelf.

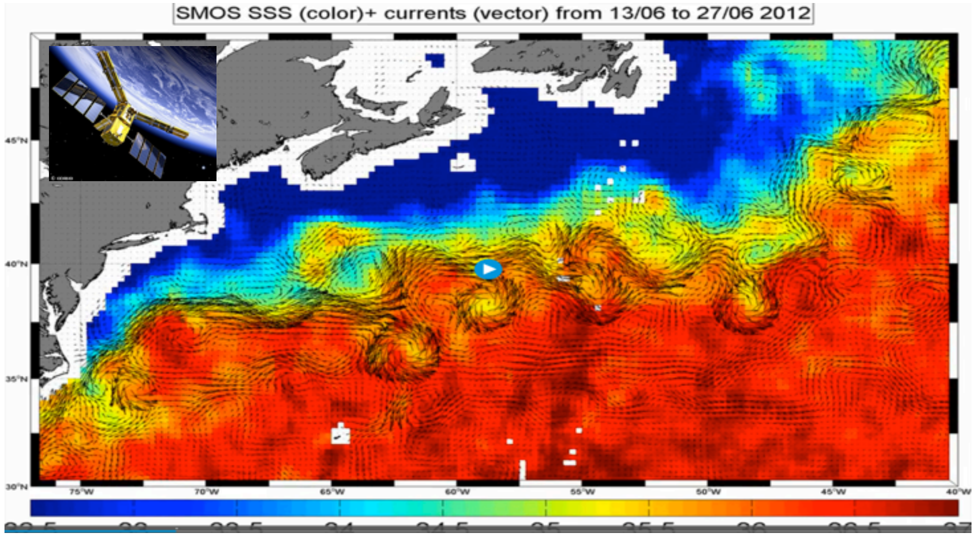
High resolution hydrographic/ biogeochemical data will be collected during the cruise.



Tentative cruise track for the planned December 2012 joint cruise on the Brazilian research vessel Alpha Crusis. Three of the four existing NOAA instruments will be recovered and redeployed, while the new Brazilian moored instruments will be deployed for the first time. A joint Brazilian/Argentine science party will also collect a detailed hydrographic section.

SSS measurements from SMOS & Aquarius provide new view of the dynamic ocean, complement existing obs, bring new understanding

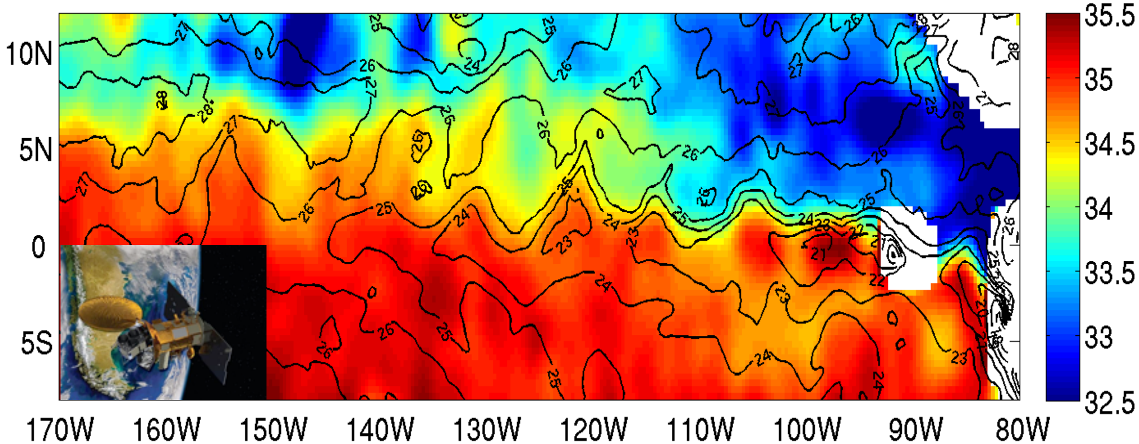
SMOS SSS & alt. surface current, June 13-27, 2012



- SMOS reveals the rich salinity structure of Gulf Stream meanders & rings.
- Give a great opportunity to study cross-frontal exchanges.

N. Reul et al. (2013)

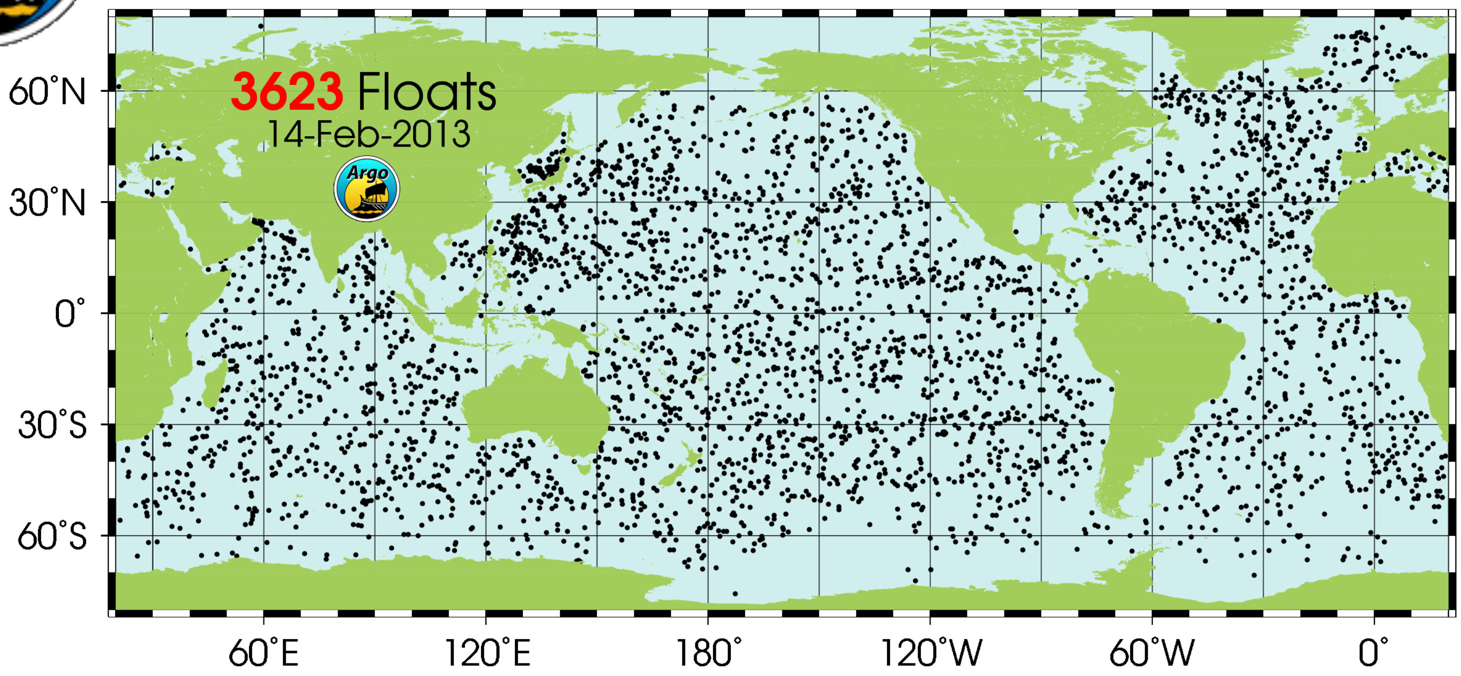
Aquarius SSS & Reynolds SST, Dec. 18 2011



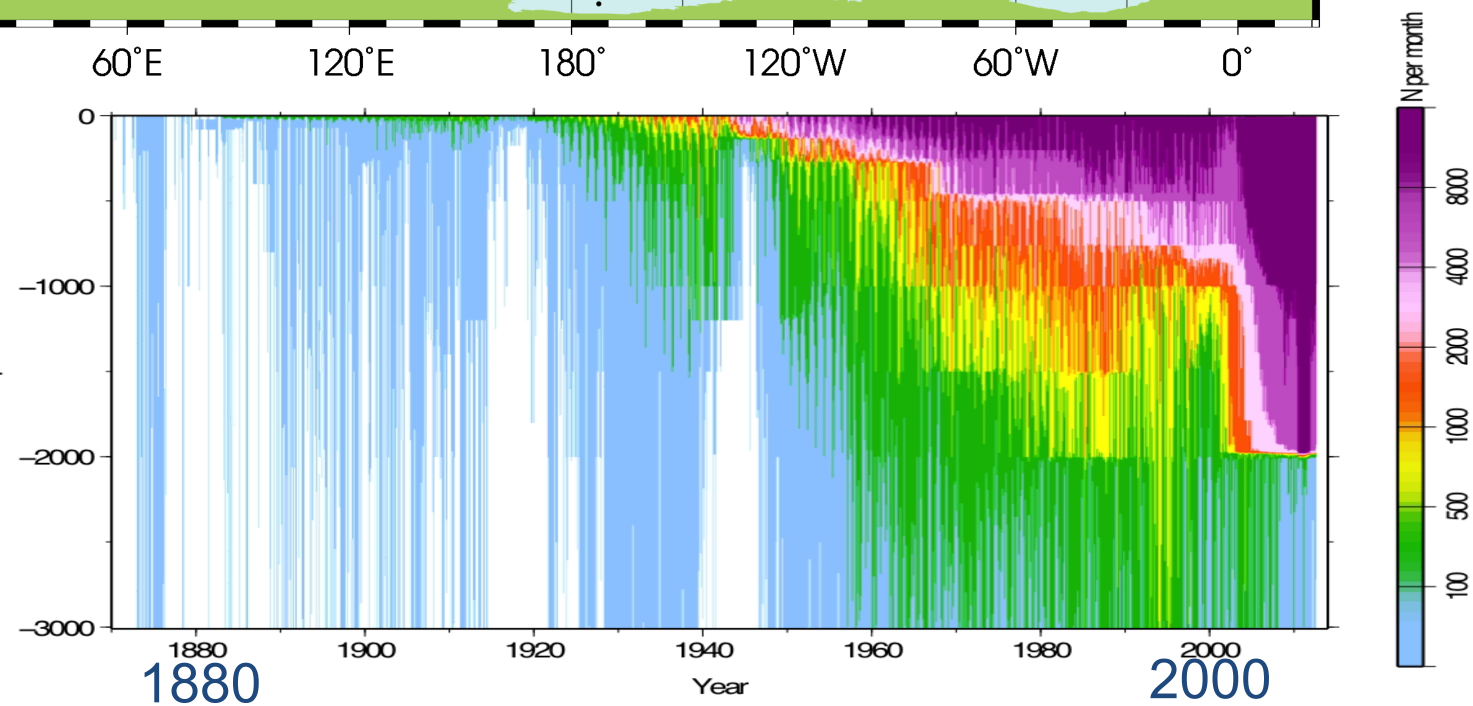
- Aquarius reveals SSS structure of tropical instability waves (TIWs) for the 1st time from space.
- Dominant TIW speed at equator is twice as fast as that off equator (not reported in the past 3.5 decades of literature).
- Implications to eddy-mean flow interaction & eddy mixing.

Lee et al. (2012)

ARGO profiling float network



Temperature observations per month



1880

2000

Global ocean heat content change and significant depth contribution (based on ECMWF ORAS4 ocean reanalysis)

Balmaseda, Trenberth, and Källén (2013)

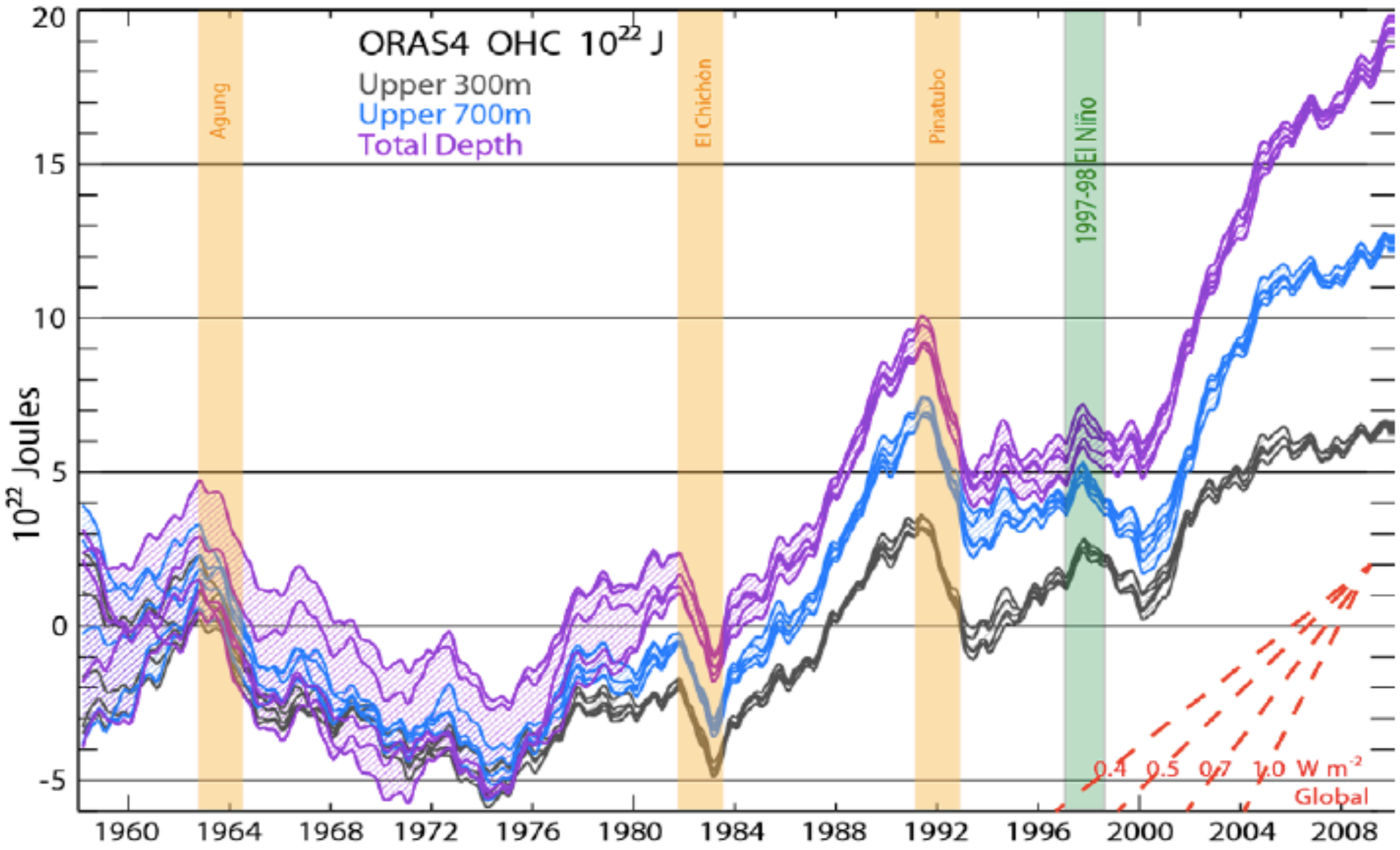


Fig. 1. OHC integrated from 0 to 300m (grey), 700m (blue), and total depth (violet) from ORAS4, as represented by its 5 ensemble members. The time series show monthly anomalies smoothed with a 12 month running mean, with respect to the 1958-1965 base period. Hatching extends over the range of the ensemble members and hence the spread gives a measure of the uncertainty as represented by ORAS4 (which does not cover all sources of uncertainty). The vertical colored bars indicate a two year interval following the volcanic eruptions with a 6 month lead (owing to the 12 month running mean), and the 1997-98 El Niño event again with 6 months on either side. On lower right, the linear slope for a set of global heating rates (W m^{-2}) is given.

ETCCDI
Observations: evaluation of Indices

HadEX2 released

Better coverage than HadEX

Regional ETCCDI workshop data is ingested

A separate dataset based on GHCN data offers near real time update for monitoring

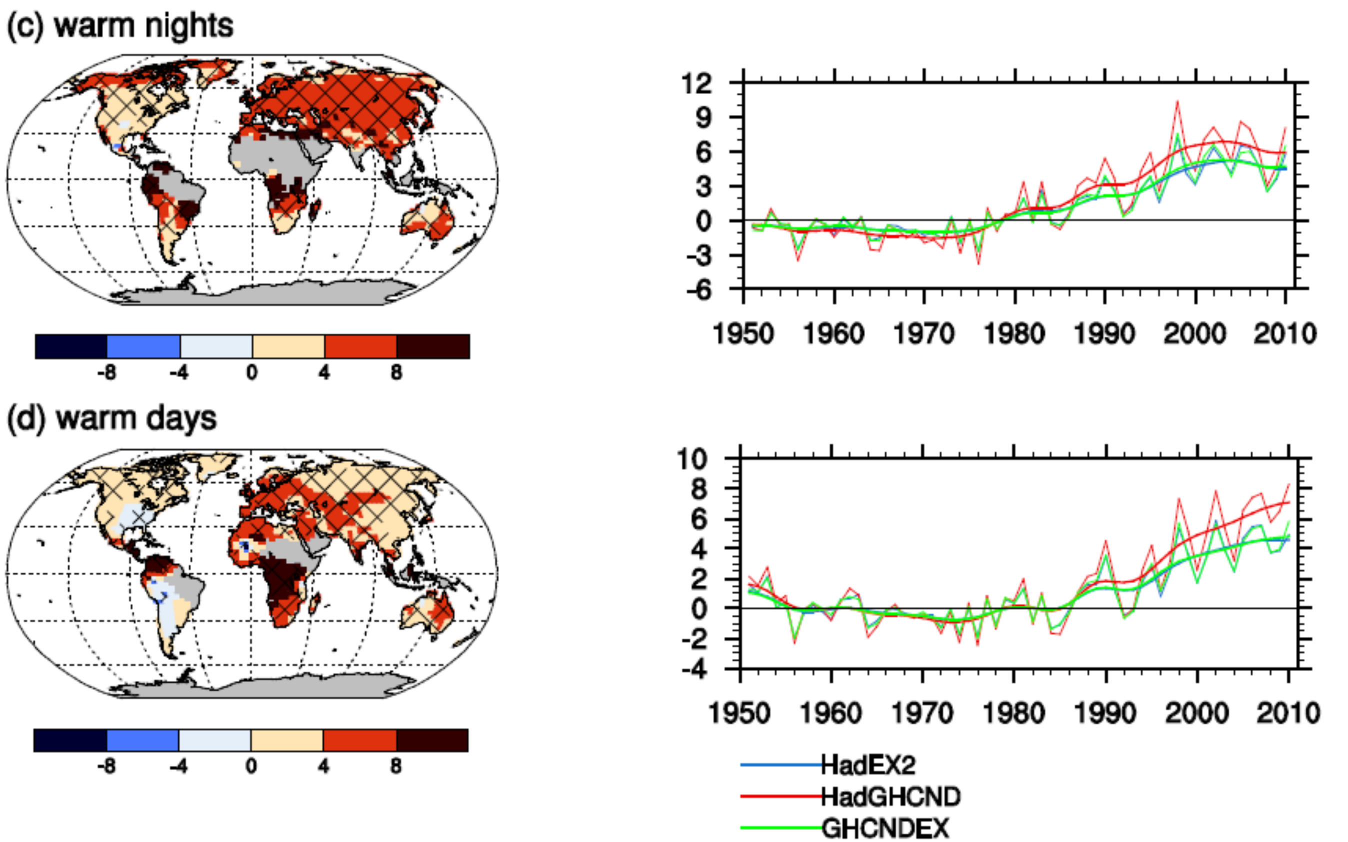


Figure 2.41: Maps show observed trends (days per decade) in the frequency of extreme temperatures, over the period 1951 to 2010, for: (a) cool nights (10th percentile), (b) cool days (10th percentile), (c) warm nights (90th percentile) and (d) warm days (90th percentile). Trends were calculated only for grid boxes that had at least 30 years of data during this

Donat et al. 2013

Capacity building, regional workshops

- Practice and goals:
  - Free software + hands-on training + post workshop follow-ups
  - build capacity to analyze observed changes in extremes
  - improve information services on extremes
  - publish peer-reviewed papers from each workshop
  - contribute to worldwide database of derived indices

ETCCDI Key science questions

- Detection and attribution of anthropogenic influence on weather and climate extremes at regional scale and attribution to causes of extreme climate events.
- Mechanisms by which modes of ocean-atmosphere variability affecting weather and climate extremes.
- If and how these modes of ocean-atmosphere variability may change under global warming and possible impacts on future weather and climate extremes.

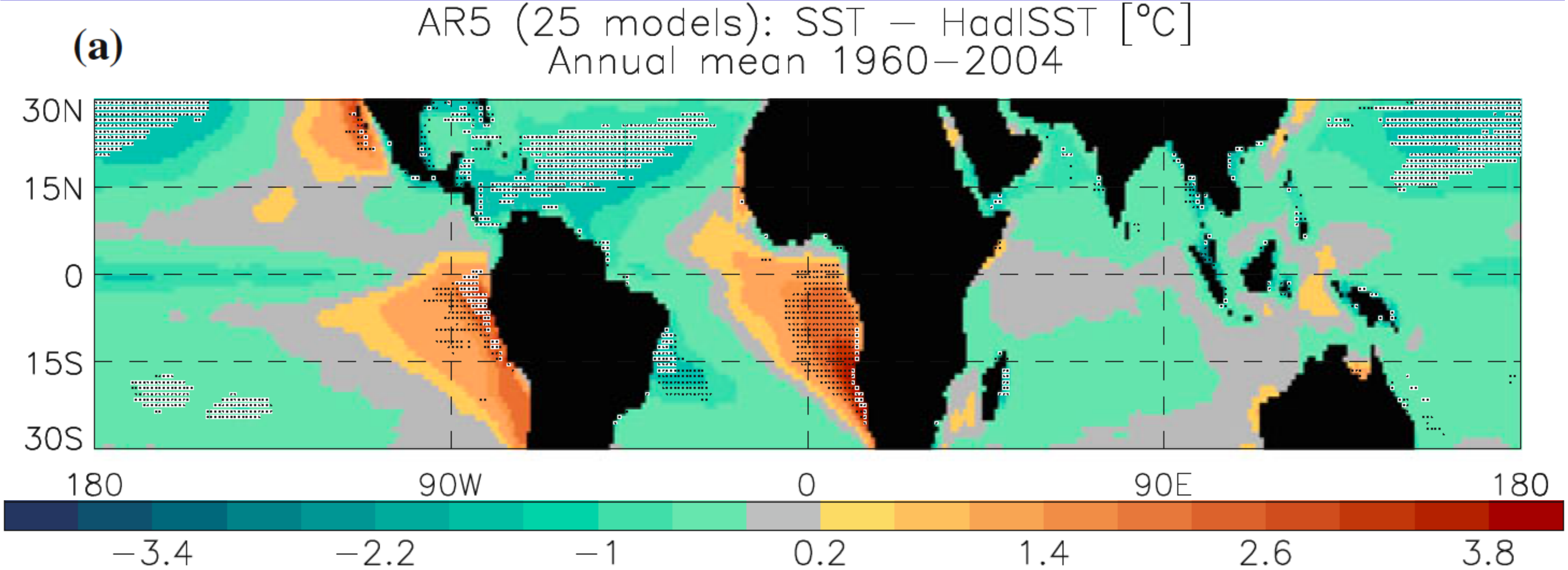
Highlights against CLIVAR Objectives

- Understand the causes of climate variability on intra-seasonal to centennial time-scales through observations, analysis and modeling.
- Improve predictions of climate variability and change associated with both internal and external processes.
- Extend observational climate record through assembly of quality-controlled data sets.
- Improve the atmosphere and ocean components of Earth-System Models.

CLIVAR AIP: Near-term issues and challenges

Eastern Tropical Atlantic SST Bias

Foster research to improve observational network, reduce systematic model errors, and improve tropical Atlantic predictability

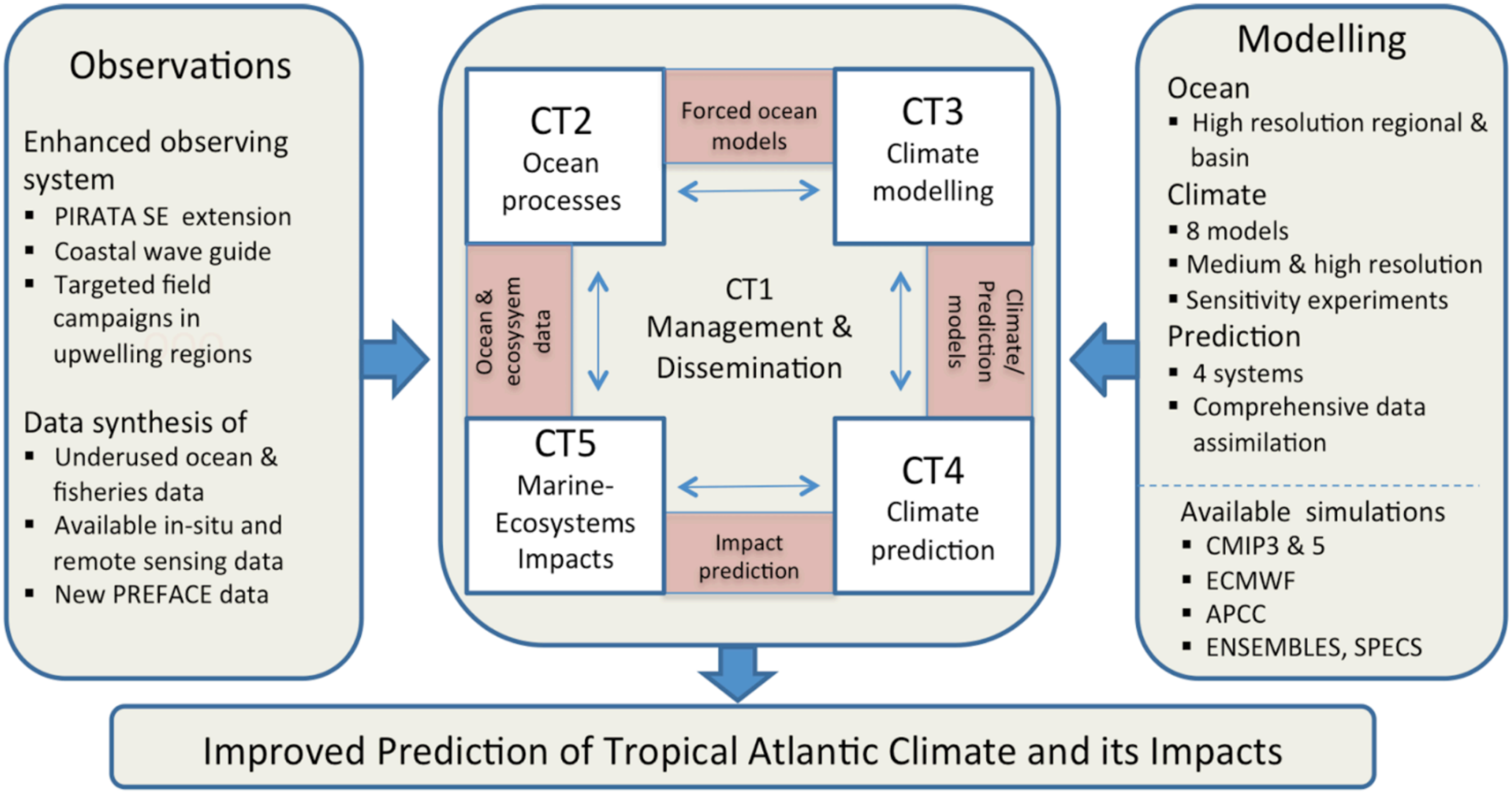


Mean SST error in the historical integrations of a set of 25 coupled GCMs in the CMIP5 ensemble. White hatching denotes areas where the sign of the error agrees in all models; black dots where all but one (CSIRO-Mk3.6.0) agree. *Toniazzo and Woolnough (2013)*

EU-PREFACE (N. Keenlyside, Bergen)

Enhancing PREdiction oF Tropical Atlantic ClimatE and its Impacts

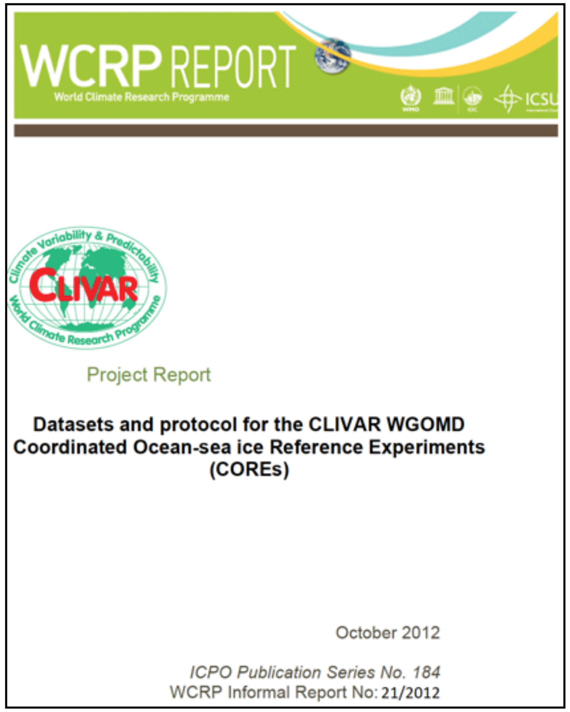
- **27 partner institutts, 17 from Europe, 10 from Africa**



Working Group on Ocean Model Development (WGOMD)

Coupled Ocean-ice Reference Experiments Phase II - *CORE-II*

An experimental protocol for ocean – sea-ice coupled simulations forced with inter-annually varying atmospheric data sets for the 1948-2007 period (Large and Yeager 2009).



WCRP REPORT
World Climate Research Programme

CLIVAR

Project Report

Datasets and protocol for the CLIVAR WGOMD Coordinated Ocean-sea ice Reference Experiments (COREs)

October 2012

ICPO Publication Series No. 184
WCRP Informal Report No: 21/2012

These hindcast simulations provide a framework for

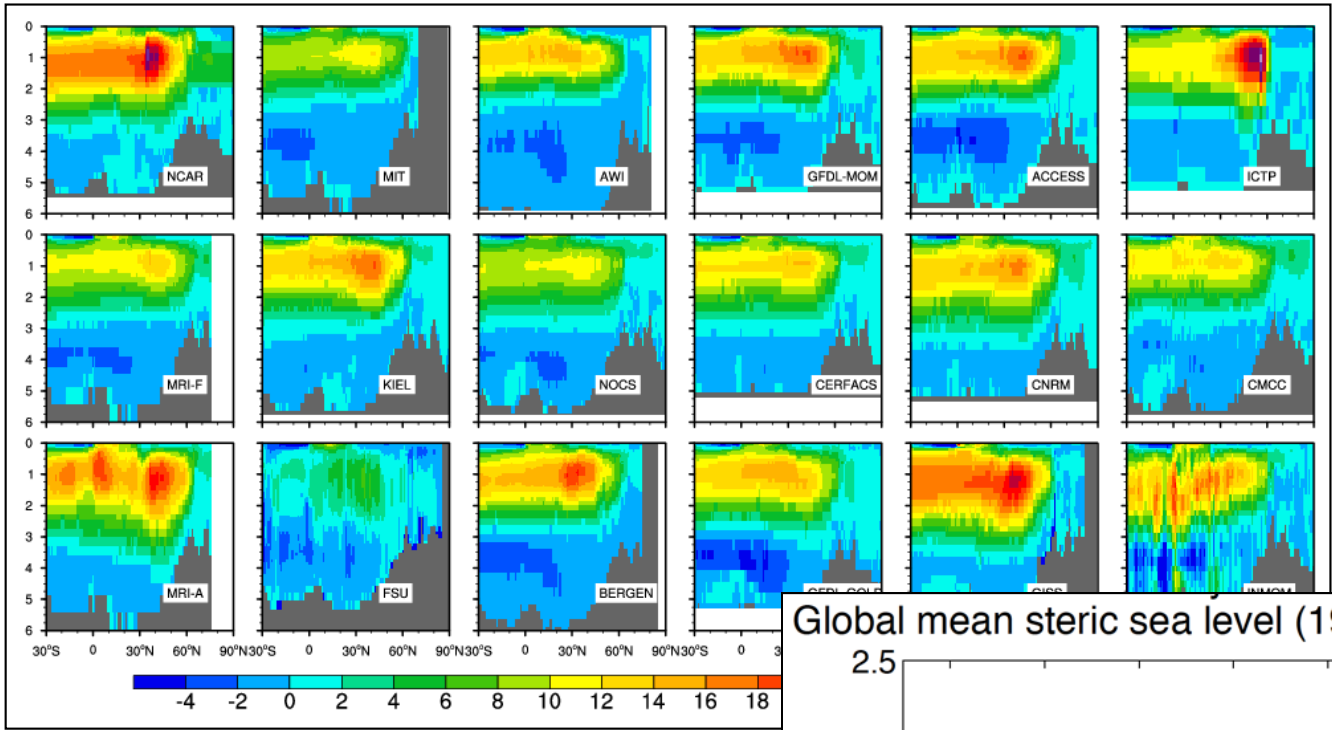
- evaluating, understanding, and improving ocean models
- investigating mechanisms for seasonal, inter-annual, and decadal variability
- evaluating the robustness of mechanisms across models,
- complementing data assimilation in bridging observations and modeling and in providing ocean initial conditions for climate prediction simulations.

Participating Groups: 18 models

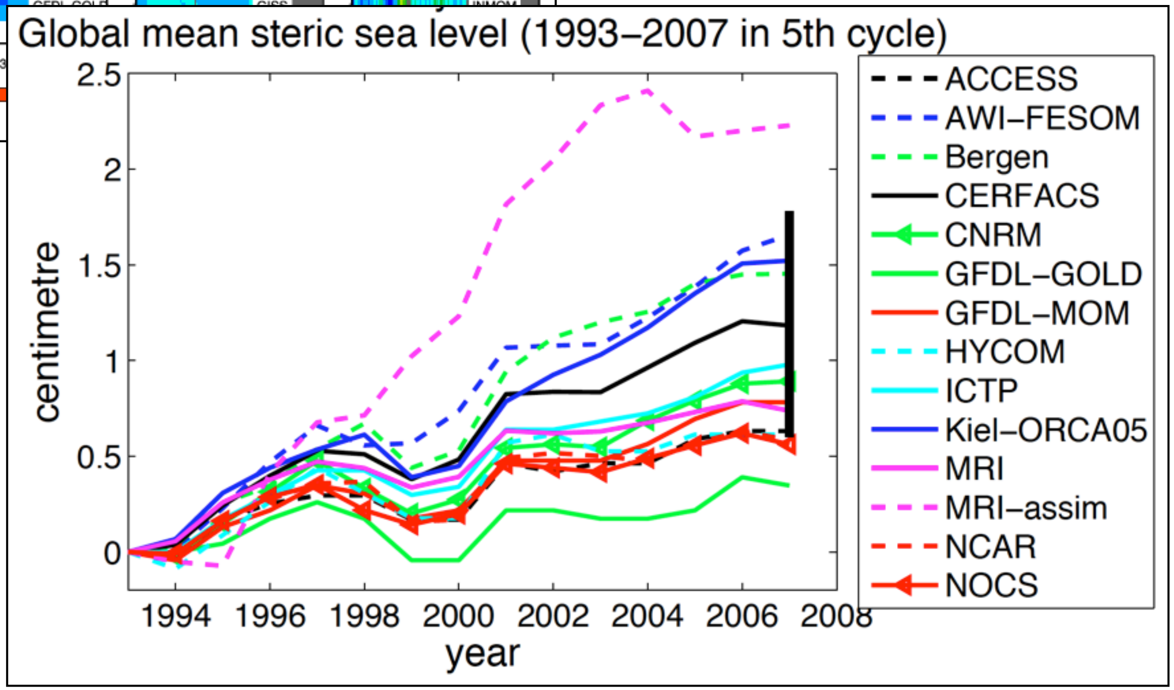
Level, isopycnal, hybrid, mass, and sigma coordinates; unstructured finite element ocean model; mostly nominal 1^{o} resolution

CORE II Results

AMOC Mean (1988-2007) in Depth Space

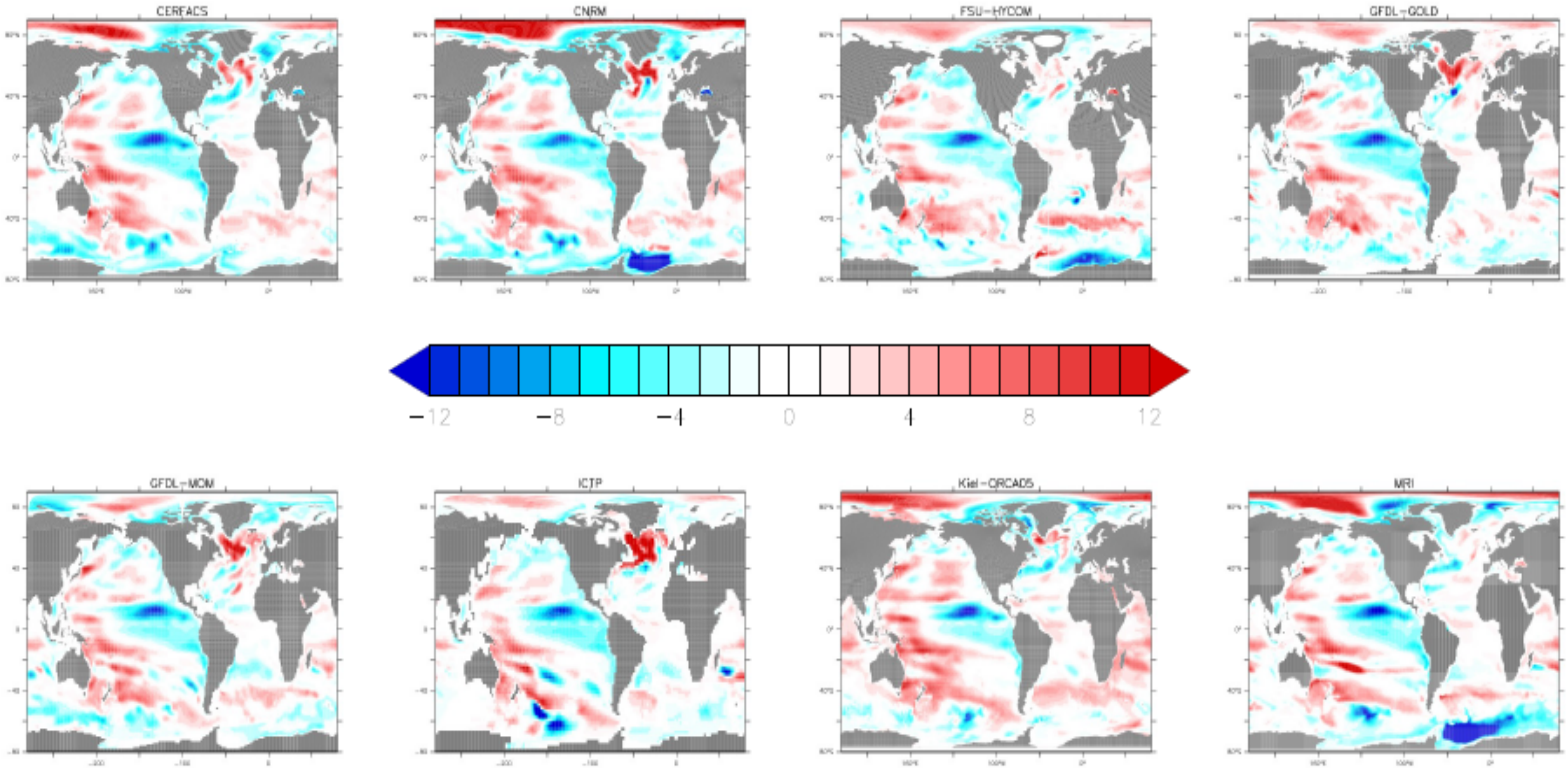


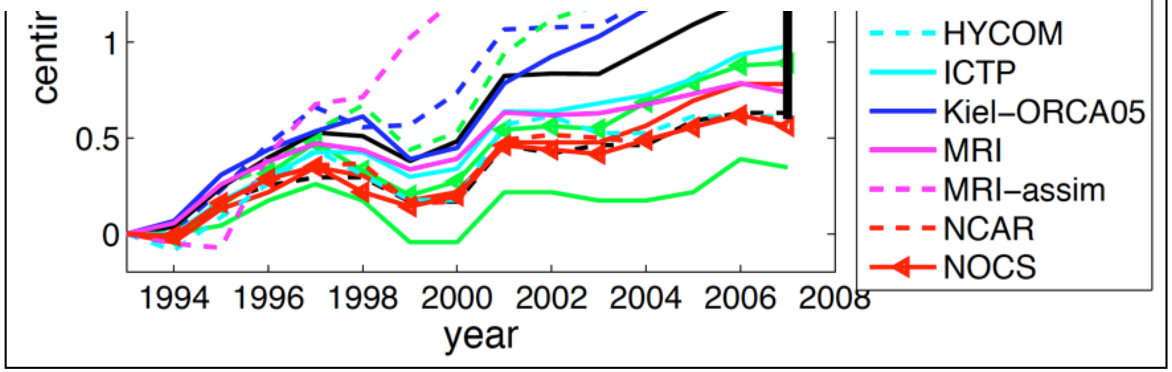
Danabasoglu et al, submitted



Griffies et al, in prep.

CORE II Results





Griffies et al, in prep.

CORE II Results (more topics to come)

North Atlantic simulations with a focus on the Atlantic meridional overturning circulation, Part I: Mean states; Part II: Variability (Danabasoglu, Yeager, Bailey et al.)

- Global and regional sea level (Griffies & Yin, et al.)
- Arctic Ocean and sea-ice (Gerdes, Wang, Drange et al.)
- The Antarctic Circumpolar Current and Southern Ocean overturning circulation with a focus on eddy compensation (Farneti & Downes, et al.)
- Evolution of Southern Ocean water masses and ventilation (Downes & Farneti, et al.)
- South Atlantic simulations (Treguier & Weiner, et al.)
- Ocean circulation in temperature and salinity space (Nurser & Zika, et al.)

WGOMD Key Activities over next 1-10 years

- Model biases and improve model physics, considering biogeochemistry and ecosystems,
- High resolution modeling and regional/coastal modeling (scale aware parameterizations),
- Sea level and interactions with ice sheets,
- Role of ocean in decadal variability (e.g., AMOC),
- Operational oceanography and data assimilation.

Evolution of CLIVAR

The World Climate Research Programme's project on ocean-atmosphere interactions

SSG20 Issues

- Finalize the words that go with the *NEW* CLIVAR
- Develop and agree on an action plan for the next 12-18 month to roll out the *NEW* CLIVAR
- Advance the concept of CLIVAR research opportunities and how to implement them in the context of WCRP-Grand Challenges
- Develop and hopefully agree on a revised CLIVAR governance model to be presented at the JSC end on May
- Broader science community engagement (ECS, national reports, communication)
- Engagement with other groups (WCRP family, Future Earth, IOC regions, GOOS, ...)
- Knowledge exchange with users of climate research (GFCS, IPCC, AoA, prediction centers, data centers, nations)


FROM WEATHER GODS
TO MODERN METEOROLOGY
A PHILATELIC JOURNEY

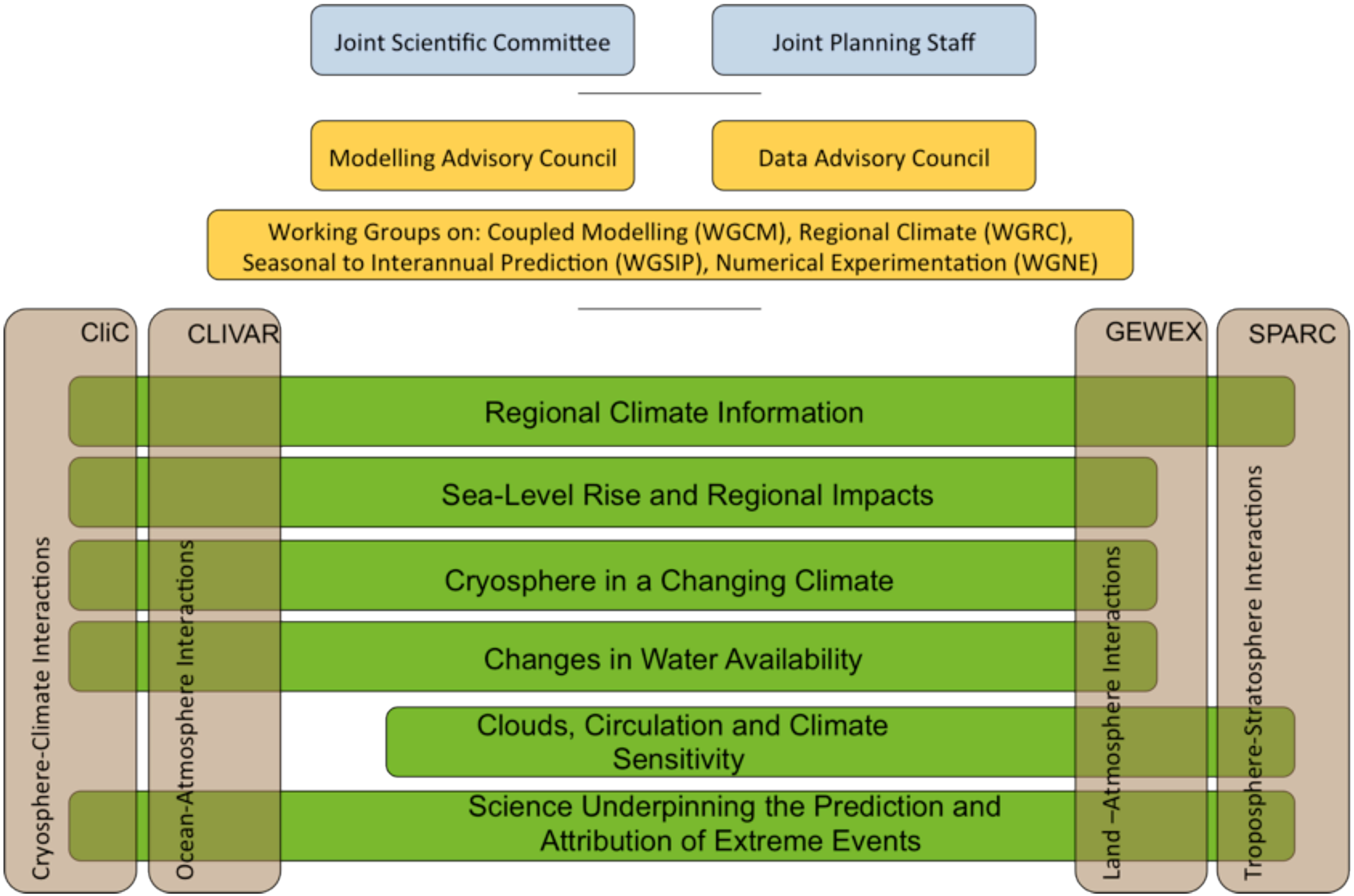
CLIVAR OCEANS & CLIMATE

variability, predictability and change

The World Climate Research Programme's project on ocean-atmosphere interactions

To improve understanding and prediction
of ocean-atmosphere interactions
and their influence on climate variability and change,
to the benefit of society and the environment.

WCRP Grand Challenges



new CLIVAR Capabilities

- Improving the atmosphere and ocean component of Earth System Models.
- Implementing innovative process and sustained ocean observations.
- Facilitate free and open access to climate and ocean data, synthesis and information.
- Support Regional and global networks of climate and ocean scientist.
- Facilitate knowledge exchange and user feedback.
- Support education, capacity building and outreach.

new CLIVAR Research Opportunities

- Intraseasonal, seasonal and interannual variability and predictability of monsoon systems
- Decadal variability and predictability of ocean and climate variability
- Trends, nonlinearities and extreme events
- Marine biophysical interactions and dynamics of upwelling systems
- Dynamics of regional sea level variability
- Consistency between planetary heat balance and ocean heat storage
- ENSO in a warmer world

Intraseasonal, seasonal and interannual variability and predictability of monsoons

Key areas for progress in the next 5-10 years:

- **Improved model constraint** on monsoon variability and change.
- **Better model representation** of the key processes involved in monsoon variability.
- **Improved prediction** of monsoon variability and change using land surface modelling and incorporation of land surface initialisation.
- **Enhanced understanding** of natural climate variability and anthropogenic change on monsoon systems.

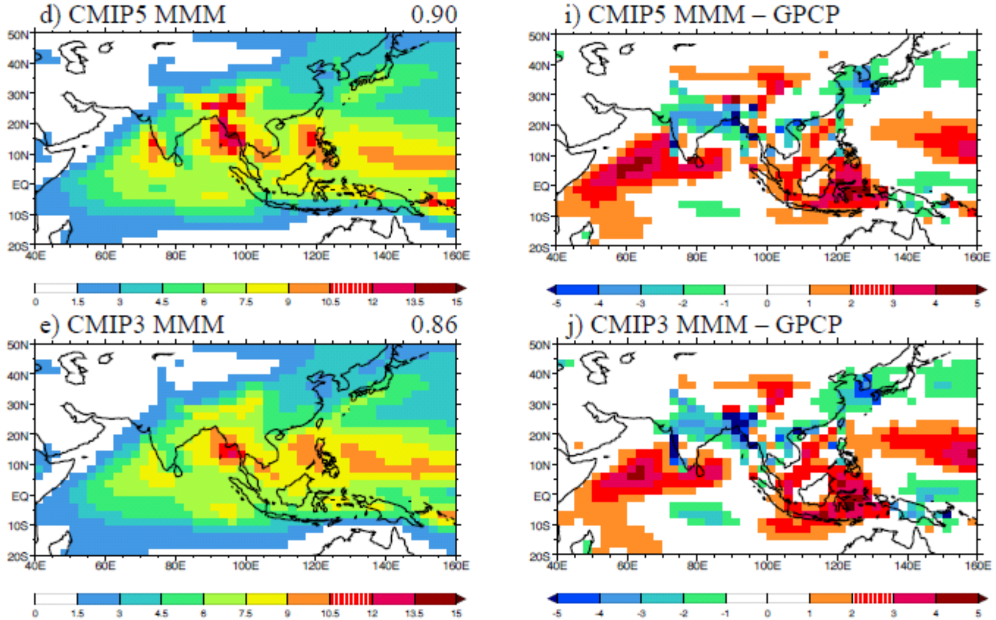
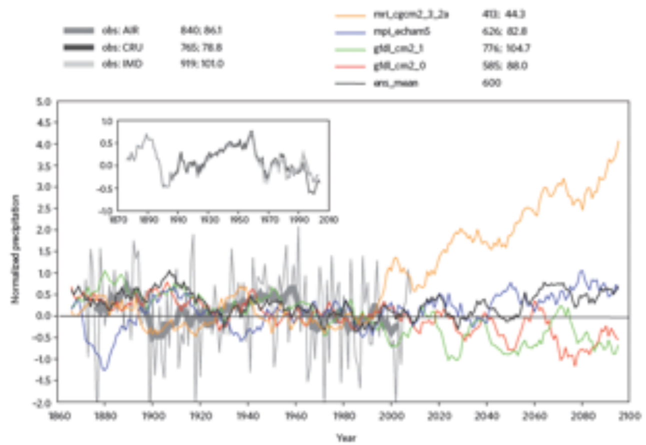


Figure shows large multi-model mean precipitation biases are present for the Asian summer monsoon in CMIP5 (from Sperber *et al*., 2012, *Clim. Dyn.*).

Figure demonstrates (for South Asian monsoon):

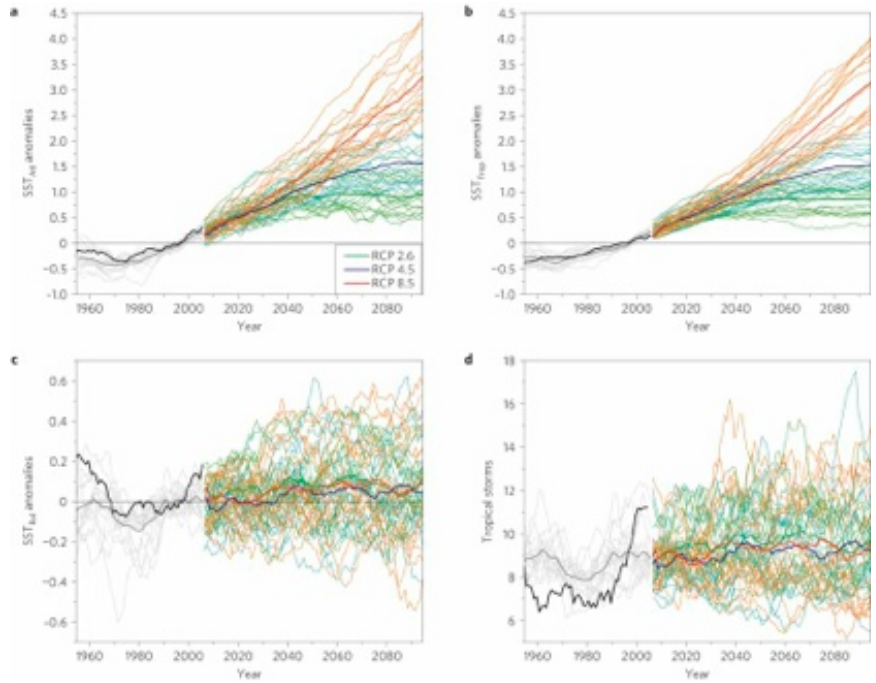
- Discrepancies between observed datasets.
- Apparent recent downward trend in monsoon rainfall
- Large decadal variability
- Uncertainty in future projections in SRES-A1B

(from Turner & Annamalai, 2012, *Nature Climate Change*).



Decadal variability and predictability of ocean and climate variability

- **Improving understanding** of decadal variability and predictability.
- **Application of past data** sets including instrumental and proxy data.
- **Improving models** to better represent key processes associated with decadal variability.
- **Analysis and development** of current prediction potential of CMIP5 hindcasts.
- **Developing critical evaluations** of proposed climate/geo engineering methods.



Twenty-first-century projections of SST (top) and North Atlantic Tropical Storm frequency (bottom) using CMIP5 (Villarini and Vecchi 2012)

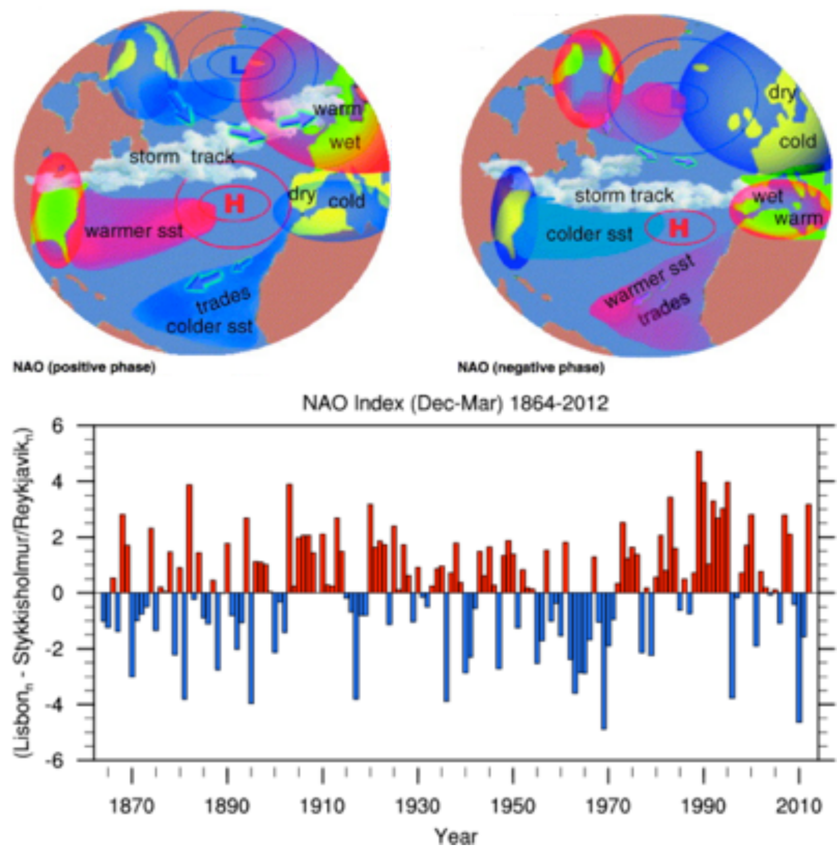
Trends, nonlinearities and extreme events

- **Ocean-atmosphere variations** influencing the magnitude and frequency extreme events, both now and in the future.

- **Increasing observational data sets**, providing higher temporal and spatial resolution for ocean-atmosphere processes.

- **Developing ocean-atmosphere models,** which simulate extreme events, focusing on observational approaches.

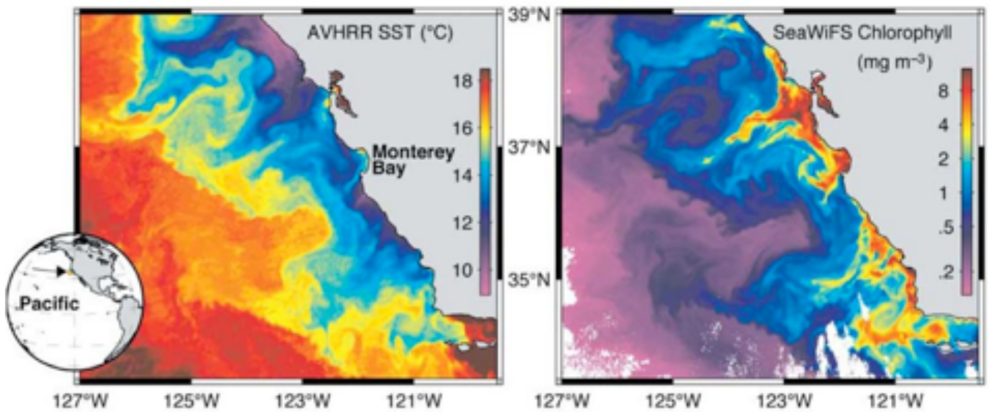
- **Investigating the physical mechanisms** leading to changes in high impact extreme events.



Top: The positive and the negative phases of the North Atlantic Oscillation (Bojariu and Gimeno 2003); Bottom, Hurrell North Atlantic Oscillation (NAO) Index (Hurrell 2012).

Marine biophysical interactions and dynamics of upwelling systems

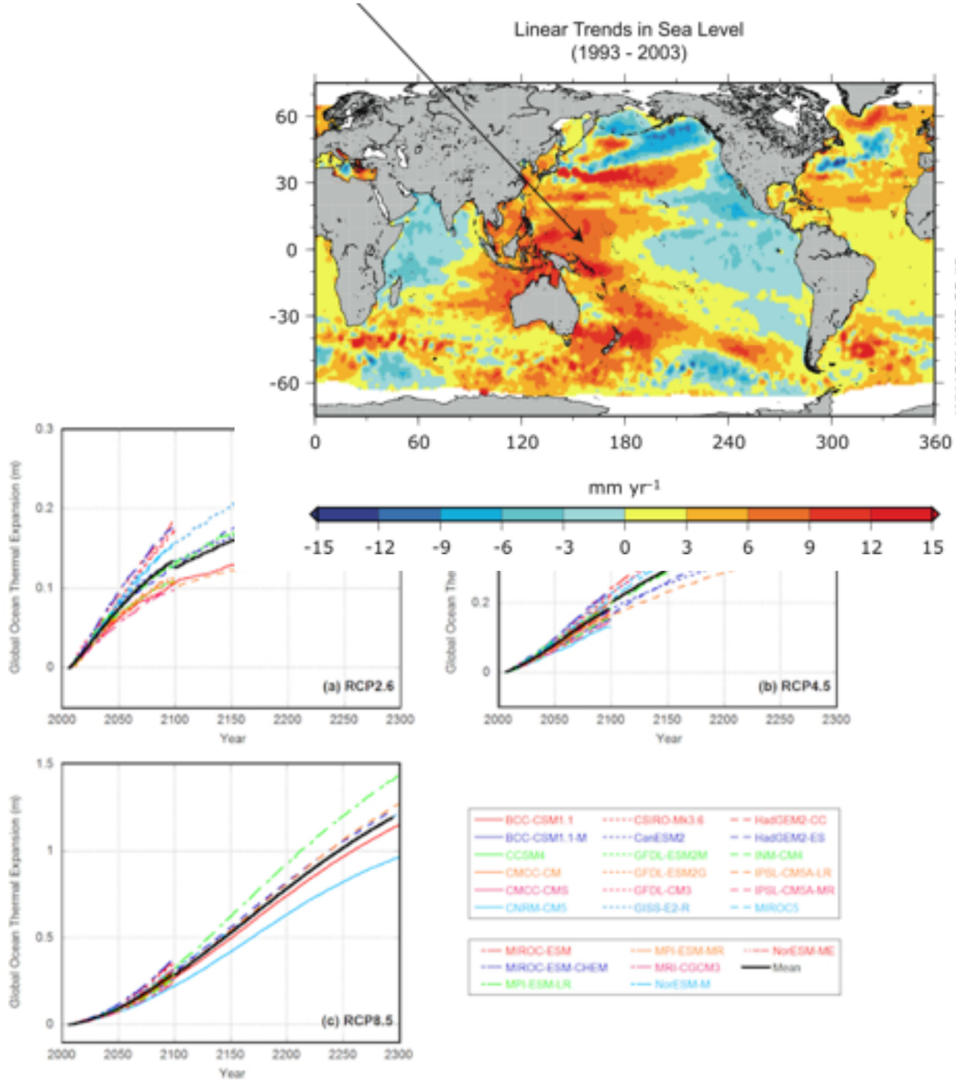
- **Identifying the key physical processes** that are responsible for upwelling.
- **Improving model representation** of upwelling processes.
- **Examining interactions** between the physical, biogeochemical and marine ecological systems.
- **Examining the cause of tropical bias** in climate models.
- **Understanding future variability** of upwelling systems, including changes in the biology and biogeochemistry associated with upwelling.



Satellite remote sensing imagery of the central California Current upwelling system. (a) Sea surface temperature (SST) from the Advanced Very High Resolution Radiometer (AVHRR) on August 14, 2000, and (b) surface chlorophyll from the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) on August 16, 2000. Source: Ryan et al. (2005). Marine Ecology Process Series. 287:23-32.

Dynamics of regional sea level variability

- **Examining wind-driven circulation** changes to sea level variability.
- **Regional distribution of ocean heat content changes** by ocean circulation and regional warming.
- **Understanding ocean-ice sheet** interactions in Southern Ocean and Greenland.
- **Representation of gravitational attraction** in climate models (with geodetic community).

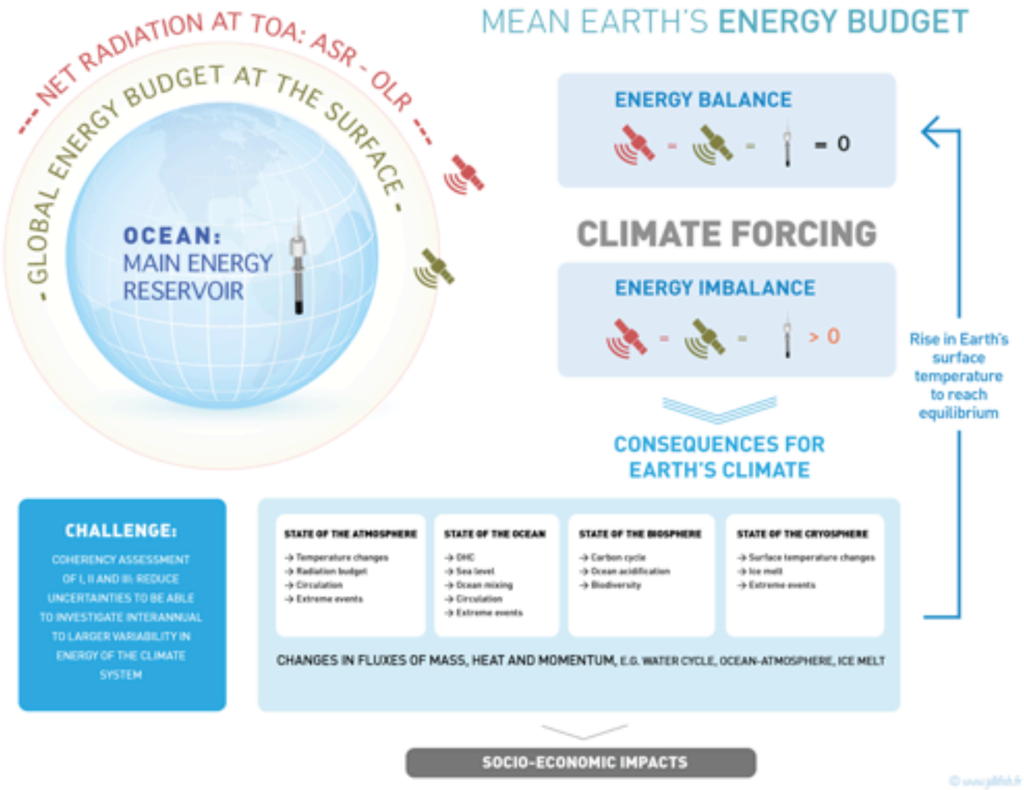


Projections of ocean global thermal expansion under low, medium and high representative concentration pathways, relative to 2006 (Yin 2012).

Consistency between planetary heat balance and ocean heat storage

Analyze the consistency between planetary heat balance and ocean heat storage estimates, data sets and information products based on different parts of the global observing systems and ocean reanalysis.

- **Earth Observation Measurement Constraints on Ocean Heat Budget**
- **In situ observations of ocean heat content changes**
- **Ocean reanalysis for atmosphere-ocean heat exchange and ocean heat content estimate**



ENSO in the climate system and how it may change in a warmer world

1. To better understand the role of different physical processes that influence ENSO characteristics.

2. To provide a synthesis of existing ENSO evaluation methods in GCMs.

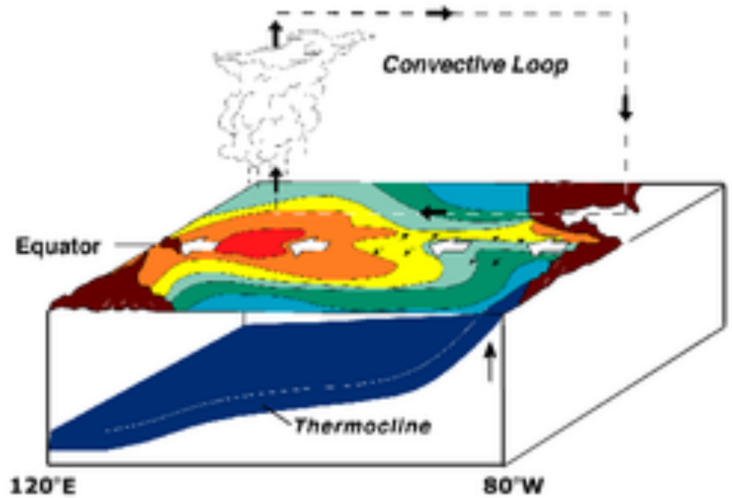
3. To propose ENSO evaluation protocols and develop a strategy for coordinated ENSO analysis of CMIP models, including development and maintenance of an interactive website, in coordination with the WGCM Metrics Panel.

4. To identify new observations needed to better constrain ENSO processes, both for the current climate and for past climates (via paleo proxies).

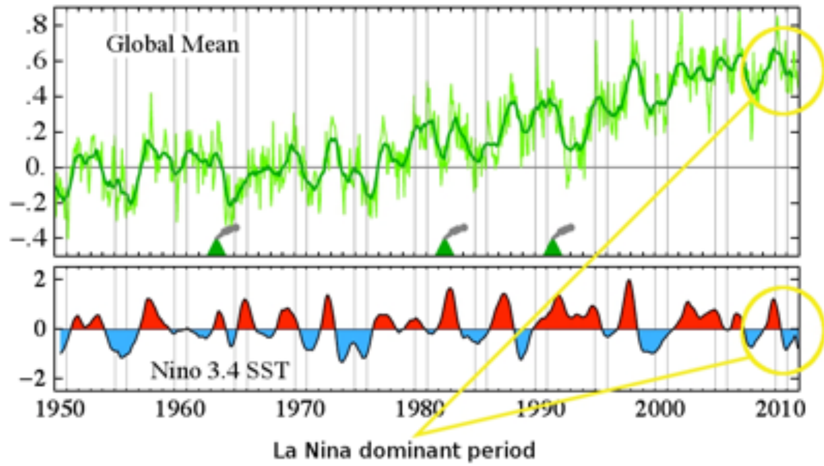
5. To provide a better understanding of how ENSO might change in the future.

6. To promote and coordinate international collaboration between observationists and modelers for studies of ENSO

7. To build research capacity by contributing to the development of the next generation of talent dealing with ENSO science.



Global surface temperature anomaly (degrees C) compared with an index of El Nino/La Nina intensity & duration



CLIVAR Organization

Proposed after SSG-20

Scientific Steering Group | ICPO

Core Panels

- Ocean Model Development Panel
- Global Synthesis and Observations Panel
- Atlantic Region Panel
- Pacific Region Panel
- Indian Ocean Region Panel
- Southern Ocean Region Panel
- Monsoons Panel
- ETCCDI
- Knowledge Exchange and Capacity Building Panel

Focused & Integrated Res. Opportunities

- predictability of monsoon systems
- Decadal climate variability and predictability
- biophysical interactions and dynamics of upwelling systems
- Dynamics of regional sea level variability
- Prediction and attribution of extreme events
- ENSO in a warmer climate
- ocean heat storage
- NEW

SSG20 Follow up

- Pan CLIVAR meeting during July 16-18 2014 in The Hague, Netherlands jointly with GEWEX
  (all panels and WGs members meet at the same time)
- CLIVAR SSG meeting in the fall 2014 (Moscow)?

CLIVAR			Wednesday			Thursday				Friday			
730 -	730 -	730 -											
830 - 1230	830 - 1230	830 - 1230	Registration			5 Paralell Sessions (20-30)				6 Panel Meetings	(20-30)	(20-30)	(20-30)
1230 - 1400	1230 - 1400	1230 - 1400	Lunch			Lunch				Lunch			
1400 - 1530	1400 - 1530	1400 - 1530	Plenary Pan-CLIVAR (80-100)			Plenary Pan-GEWEX/CLIVAR (250)				6 Panel Meetings	(20-30)	(20-30)	(20-30)
1530-1730	1530-1730	1530-1730	5 Parallel Sessions			6 Panel Meetings (20-	(20-30)	(20-30)	(20-30)	Plenary Pan-CLIVAR (80-100)			
			Dinner										

Issues for the JSC

- CLIVAR proposed to have a single Monsoons panel that should serve all of WCPR's monsoon activities. Focused working groups under that are encouraged with the possibility to be regional.
- CLIVAR has no concrete plans to include the Arctic in its scope of activities. We defer to CLiC to take the initiative.
- CLIVAR will rework all the TORs for its panels. Plan to make the WGOMD a panel.
- CLIVAR will not support a separate panel of PAGES-CLIVAR. activities, but encourages all groups to liaise with PAGES where appropriate (like we do with CARBON and IMBER).
- CLIVAR will consult further with GEWEX on the ETCCDI member etc.
- … wrestle with the connection to WGSIP and WGCM …

Evolution of CLIVAR – Main Directions

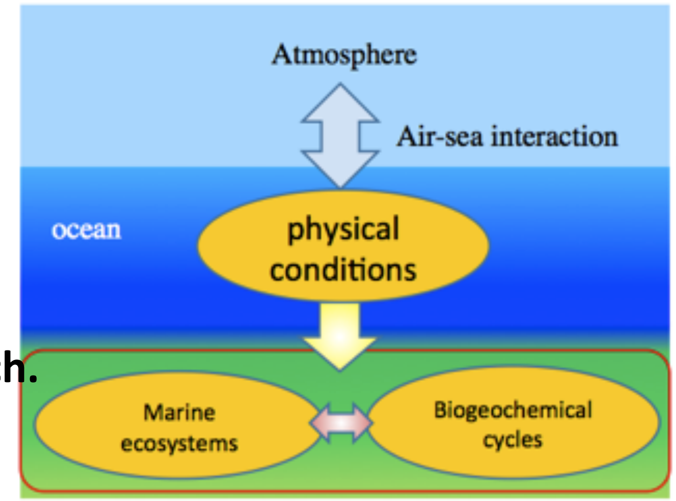
- **CLIVAR remains the ocean-atmosphere program of the World Climate Research Program**

- **CLIVAR is in the process of formulating a new set of research opportunities that will contribute to the Grand Challenges of WCRP and the wider context of the oceans role in climate variability and change.**

- **CLIVAR will retain its global and balanced approach based on observations, models and theory and their joint exploitation for climate assessment and climate prediction.**

- **CLIVAR supports the development of sustained climate and ocean observations as well as targeted improvements to the climate and ocean components of earth system models.**

- **CLIVAR will intensify its partnerships with the marine biogeochemistry and eco-system community as well as with a selected spectrum of its information user community.**



- **CLIVAR support education, capacity building and outreach.**

- **Next Steps**
  - AGU (December 2013) & AMS (February 2014) townhall discussion
  - OCEAN SCIENCE MEETING (March 2014) rollout of NEW CLIVAR strategy and plans
  - PAN-CLIVAR meeting in 16-18 July 2014

Visualization of the Monsoons Panel