CLIVAR: CLIMATE & OCEAN
variability, predictability and change

WCRP Core Project on the
Ocean-Atmosphere System

JSC 38

Detlef Stammer & Annalisa Bracco (SSG co-chairs)

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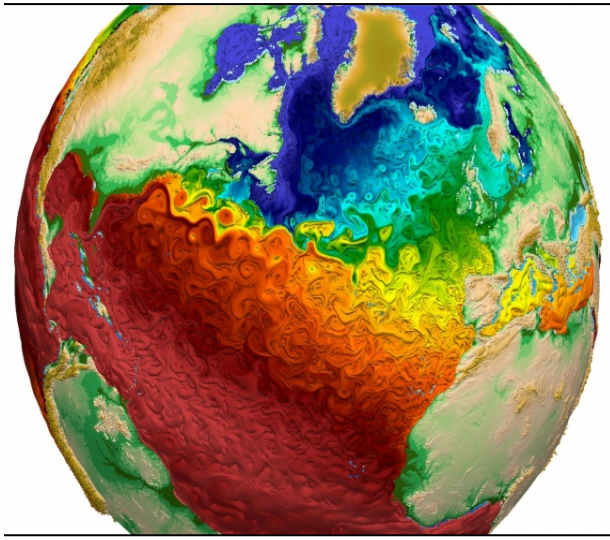
CLIVAR: CLIMATE & OCEAN
variability, predictability and change

- Describe and understand the dynamics of the coupled ocean-atmosphere system,
- Identify processes responsible for climate variability, change and predictability,
- Develop - also through the collection and analysis of observations - and apply models of the coupled climate system.



Credit: Los Alamos National Laboratory

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- **CLIVAR was established 20 years ago** as one of the core-projects of the World Climate Research Programme, building on WOCE and TOGA,
- The CLIVAR legacy includes the
  - **implementation and development of major multinational observing networks** in all the ocean basins;
  - development of **ocean and climate re-analyses**, bridging observations and modeling through data assimilation
  - development of **ocean-climate models, initialized decadal climate predictions building on o&c reanalyses.**

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CLIVAR 20 Years of Progress

SPECIAL ISSUE

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General reflection

- Great enthusiasm and community engagement for CLIVAR and WCRP research

- Large number of unsolved problems that are scientifically challenging and have global societal impacts

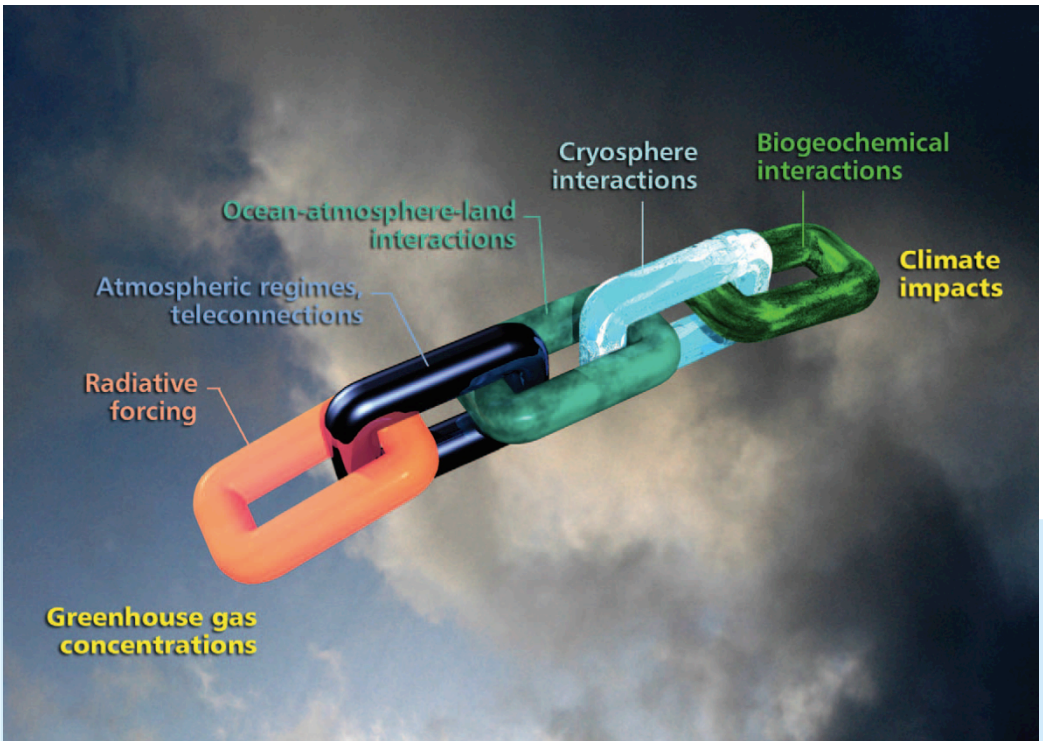
Where are we going: CLIVAR Future

Overarching goal: ***Building a society resilient to environmental changes***

- What is needed (I):
  - Expanding on a climate risk concept (uncertainty)
  - Providing **regional climate information and seamless predictions across timescales**

Where we are going: CLIVAR Future

- What is needed (II):
  - Understanding mechanisms and consequences of climate variability and change, globally and **regionally**



Palmer et al., BAMS 2008

Where we are going: CLIVAR Future

- What is needed (III):
  - Establishing a multi-scale approach in space and time to climate science, and to mitigation/ adaptation
  - Increase awareness (what is settled, what is not yet understood, and why we still **NEED** fundamental climate science after COP21)

Point of pride: Early Career Scientists Symposium

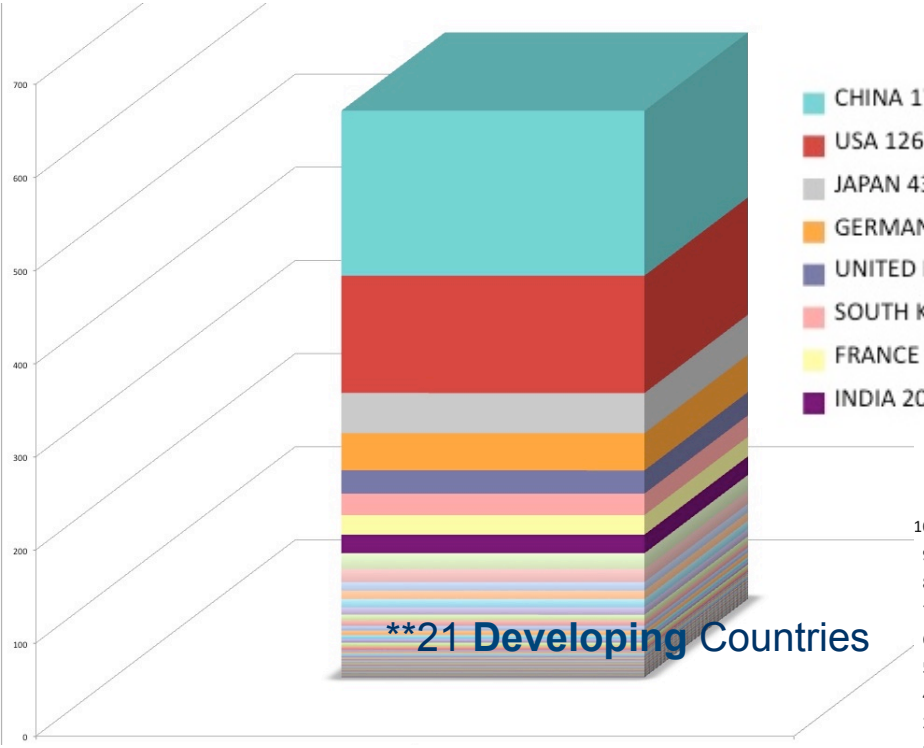
- Hosted by FIO: 18, 23-24 Sept
- Unique opportunity for young scientists to interact and exchange ideas with their peers and senior scientists.
- Designed by and for the CLIVAR ECS community, jointly with YESS

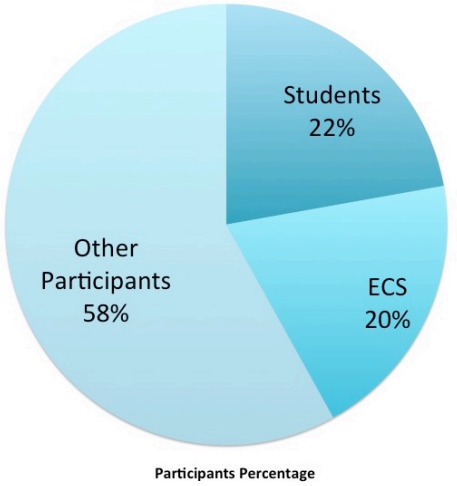
Opportunities at the OSC

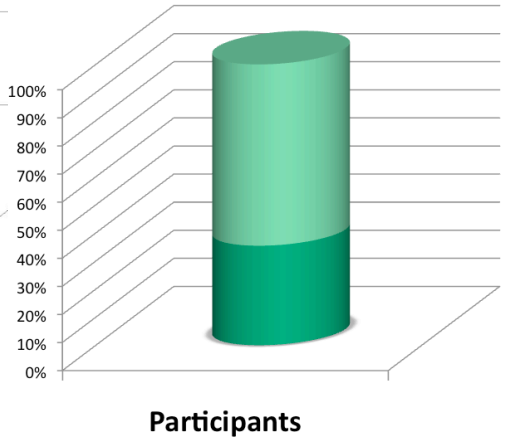
- Career development workshops
- Mentoring

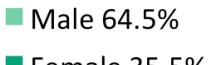
Charting the course for climate & ocean research

CLIVAR Open Science Conference Qingdao, 2016









608 Participants from 47 Countries

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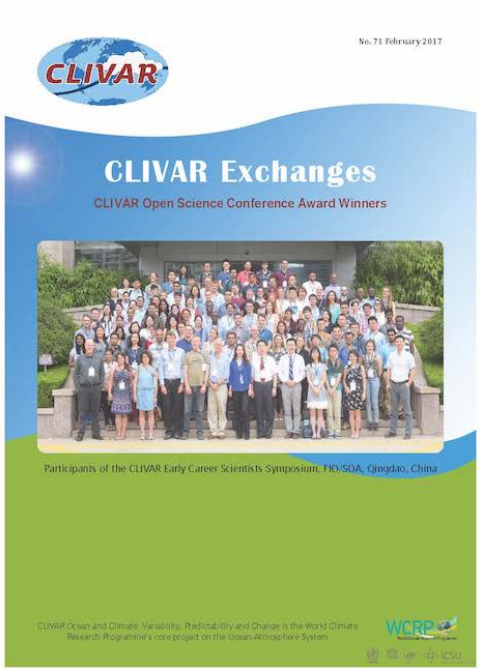
OSC Output

- EOS summary (in press)



- Nature Climate Change article (in preparation)
- ECS point of view paper in late stage of preparation for new NPJ Climate and Atmospheric Science
- CLIVAR Exchanges with contributions from ECS poster winners (available from CLIVAR website)

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New CLIVAR Science

Long term objectives:

- Identify ocean and coupled **climate processes** that are critical for global and regional climate variability and change
- Identify temporal and spatial scales of **climate predictability**
- Quantify constrains on **climate sensitivity**, air-sea exchange and Earth's energy budget / ocean heat content
- Quantify **regional impacts** of climate change in **sea level, cryosphere and water cycle**
- Quantify past/present/future **ocean role in CO_2 and heat uptake** and links between **climate and ocean ecosystems**

New CLIVAR Science Plan will be released in 2017

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CLIVAR Science Goals

Determining mechanisms of climate variability, climate change and climate sensitivity

- The ocean's role in climate variability and change
- Ocean constraints on climate sensitivity, air-sea exchange and Earth's energy budget
- Regional impacts of the changing climate: sea level, cryosphere and water cycle
- Ocean heat and carbon uptake and storage

Quantifying fundamental processes that need to be properly represented in climate models

- Climate Dynamics, feedbacks and regional modes of coupled variability
- Ocean energetics and mixing
- Boundary currents, coastal processes and upwelling systems

CLIVAR Science Goals 2

How predictable is the climate on different time and space scales?

- Intra-seasonal to Inter-annual variability, predictability and prediction
- Decadal variability, predictability and prediction
- Multi-decadal variability and detection/attribution of long-term changes
- Weather, climate and ocean extremes

Integrating climate research across disciplinary borders

- Interdisciplinary studies of coastal oceans
- Climate science and policy

CLIVAR Enabling Capabilities

International cooperation is critical to grow the infrastructure that underpins all CLIVAR science:

- Climate and Ocean Process and Sustained Observations
- Global, Regionally Enhanced and Process Models
- Ocean Data, Synthesis and Assessment
- Capacity Development and Knowledge Exchange

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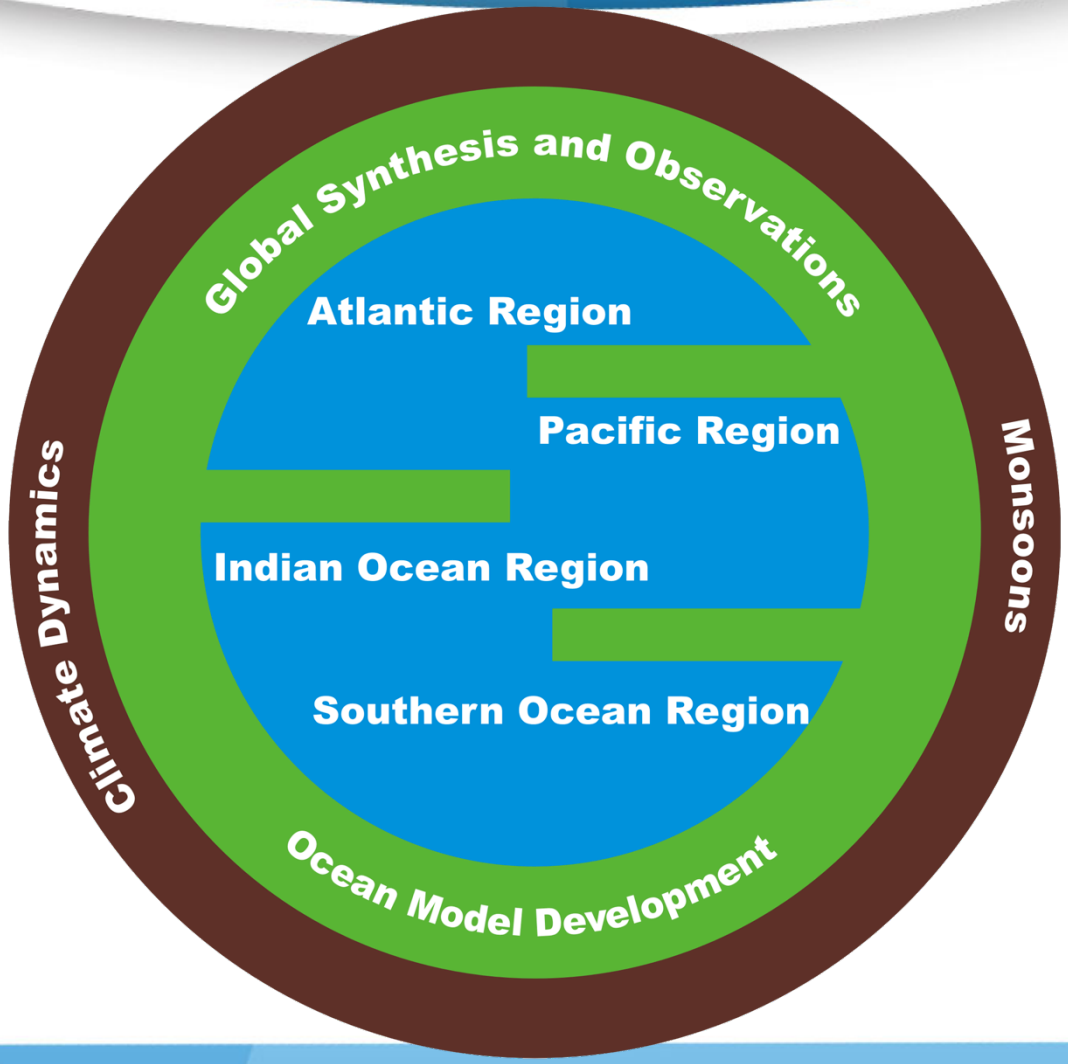
How CLIVAR works

CLIVAR Panels



CLIVAR Panels

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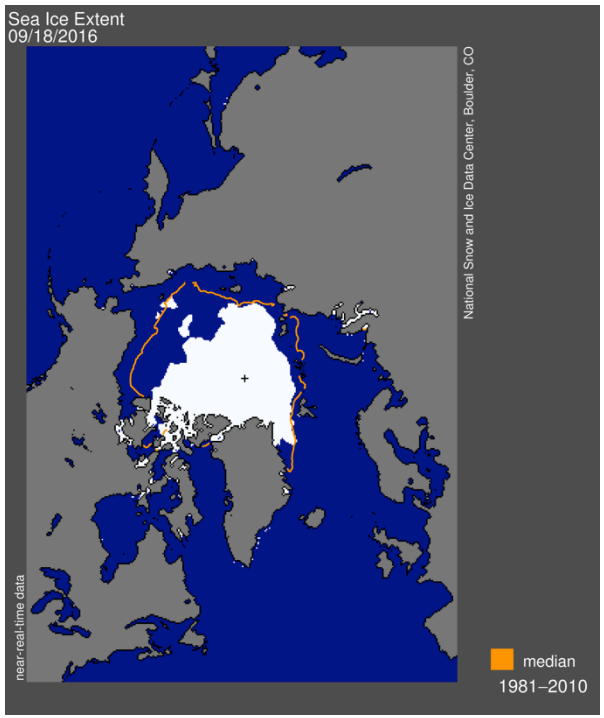
New CLIVAR/CliC panel:
Northern Ocean Region Panel

Approved by CLIVAR and CliC Steering Committees (2/16/17)



An International Panel to Coordinate and Facilitate Activities on the Role of the Northern Oceans in the context of the Global Climate System from a Coupled Ocean-Air-Ice Perspective…

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CLIMATE PROCESSES
Climate Dynamics Panel

Key Themes

- Storm tracks, jet streams and weather systems
- Tropical-extratropical interactions
- Coupled atmosphere-ocean feedbacks

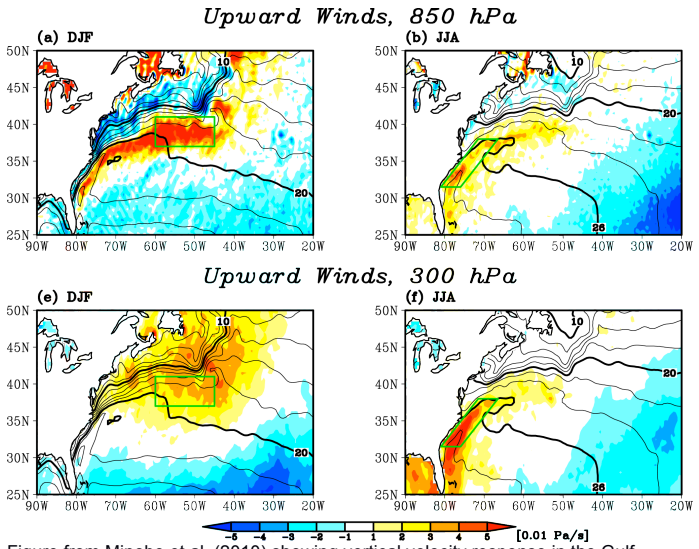
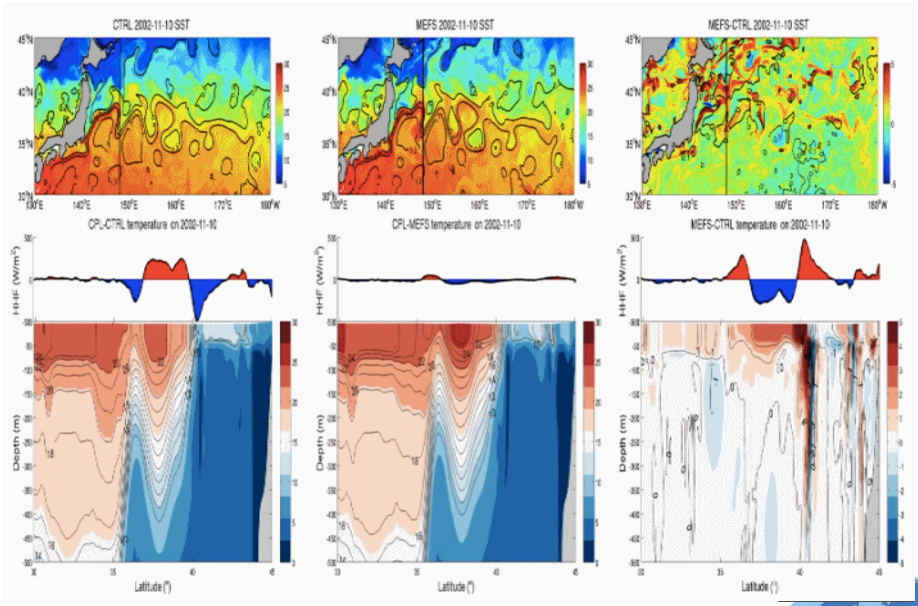


Figure from Minobe et al. (2010) showing vertical velocity response in the Gulf Stream region.



Mesoscale eddy role in air-sea interactions
Ma et al., Scientific Reports, 2015

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CLIVAR/GEWEX Monsoons Panel
Key issues identified by each WG

Asia-Australia

- Designing process-based metrics for the A-A monsoon and making these available to the wider community (Toolkit)
- Renewed effort to bring SE Asia & Sri Lanka *winter* monsoon to fore
- Assessing predictive skill in current forecast models (**S2S**)
- Direct engagement with local stakeholders (start: user-needs survey)

Africa

- Develop process based and user metrics for CMIP5/6
- Variability, predictability, forecast skill at intraseasonal (**exploit S2S**)
- D&A work; climate services

Americas

- **Exploiting S2S** for the South American monsoon (MJO impacts; onset/ demise/active/break prediction)
- Development for process diagnostic of SAMS intraseasonal variability; challenging models
- Provide demonstration forecast products

Research Foci

Research Foci (RF): launched in 2015; focused limited-lifetime initiatives (5 years or less); topics of high priority in the climate research community that would benefit from enhanced international coordination.

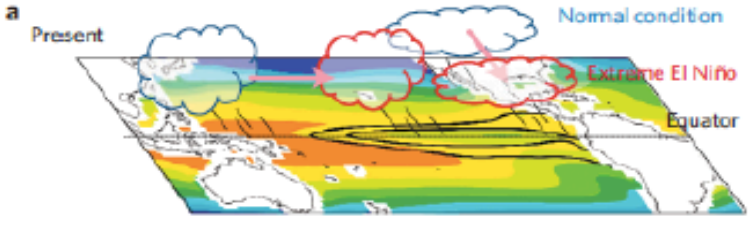
- **Decadal Climate Variability & Predictability**
- **Planetary Heat Balance & Ocean Heat Storage (with GEWEX participation)**
- **ENSO in a Changing Climate**
- **Eastern Boundary Upwelling Systems**
- Regional Sea Level Change & Coastal Impacts (is a GC)

CLIMATE PROCESSES
RF ENSO in a changing climate

nature climate change
LETTERS
PUBLISHED ONLINE: 19 JANUARY 2014 | DOI: 10.1038/NCLIMATE2100

Increasing frequency of extreme El Niño events due to greenhouse warming

Wenju Cai[1,2]*, Simon Borlace[1], Matthieu Lengaigne[3], Peter van Rensch[1], Mat Collins[4], Gabriel Vecchi[5], Axel Timmermann[6], Agus Santoso[7], Michael J. McPhaden[8], Lixin Wu[2], Matthew H. England[7], Guojian Wang[1,2], Eric Guilyardi[3,9] and Fei-Fei Jin[10]



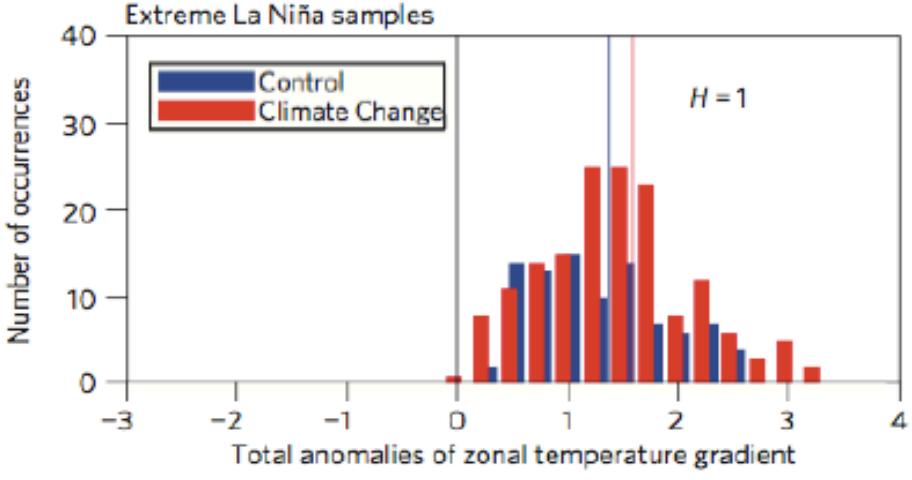
Need for:

- TPOS-type observations
- Continued/enhanced record
- Enhanced obs of Equatorial currents
- Equatorial atmospheric data

LETTERS
PUBLISHED ONLINE: 26 JANUARY 2015 | DOI: 10.1038/NCLIMATE2492
nature climate change

Increased frequency of extreme La Niña events under greenhouse warming

Wenju Cai[1,2]*, Guojian Wang[1,2], Agus Santoso[3], Michael J. McPhaden[4], Lixin Wu[2], Fei-Fei Jin[5], Axel Timmermann[6], Mat Collins[7], Gabriel Vecchi[8], Matthieu Lengaigne[9], Matthew H. England[3], Dietmar Dommenget[10], Ken Takahashi[11] and Eric Guilyardi[9,12]



CLIMATE PROCESSES
Ocean Model Development Panel

- Coordinate Ocean-Ice Reference experiments
  - Evaluation, understanding, and improvement of ocean models
  - Investigation of mechanisms for seasonal, interannual, and decadal variability
  - Evaluation of robustness of physical mechanisms across models
  - Complements data assimilation / state estimation
    - bridges observations and modelling
    - ocean initial conditions for climate (decadal) prediction simulations.

CLIMATE PREDICTABILITY

- Intra-seasonal to Interannual Variability, Predictability and Prediction
- Decadal Variability, Predictability and Prediction (multi-decadal variability and detection/attribution of changes)
- Extreme Weather and Climate and Ocean Extremes

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Decadal Climate Variability and Predictability DCVP RF

- Two focus areas:
  - **Atlantic Decadal Climate Variability and Predictability**: variations of ocean circulation systems (AMOC, gyres), related SST (AMV/AMO extratropical and tropical) and atmospheric (NAO/AO, blocking) variability; their interactions with land areas and other ocean basins.
  - **Pacific Decadal Climate Variability and Predictability**: decadal tropical SST variability (IPO); links to North Pacific ocean circulation and SST

- CLIVAR and WCRP are already engaged in observational, analysis and modeling research on these subjects.
- DCVP RF will draw on these activities but focusing on **process understanding**

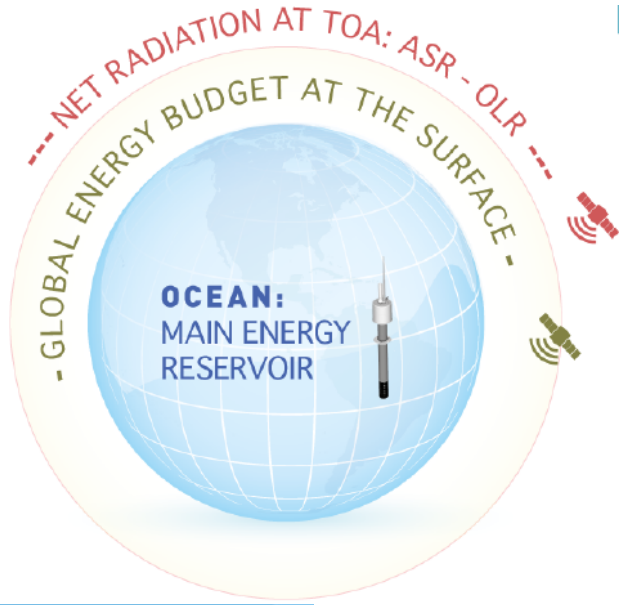
CLIMATE SENSITIVITY
RF CONCEPT-HEAT
Consistency between planetary energy balance and ocean heat storage

K. von Schuckmann, K. Trenberth; joint with GEWEX

Bringing together different climate research communities concerned with the energy flows in the Earth's System to advance on the **understanding of the uncertainties through budget constraints**:

- Atmospheric radiation
- **Ocean Heat Content**
- Earth's surface fluxes (when, where, how much)
- Climate variability and change
- Data assimilation & operational services
- **Climate projection**
- **Sea level**

93% of energy imbalance ends up in the ocean -> OHC is a fundamental metric of climate change. OHC in turn determines the steric component of sea level rise, yet another fundamental metric.



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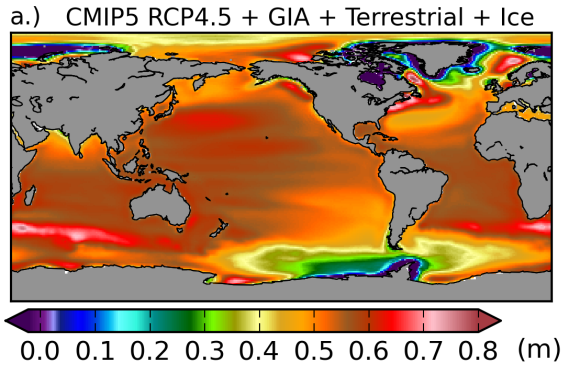
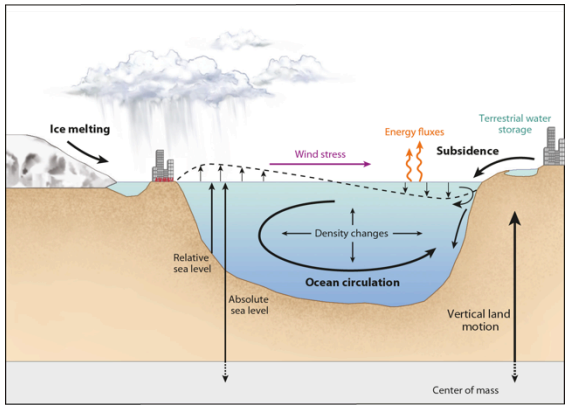
REGIONAL IMPACTS
GC Regional Sea Level Change and Coastal Impacts

Five parallel, but interconnected, working groups:

1. **An integrated approach to paleo time scale sea level estimates**
2. **Quantifying the contribution of land ice to near-future sea level rise**
3. **Causes for contemporary regional sea level variability and change**
4. **Predictability of regional sea level**
5. **Sea level science for coastal zone management**





International Conference on Sea Level Change: New York University, July. 10 – 15, 2017

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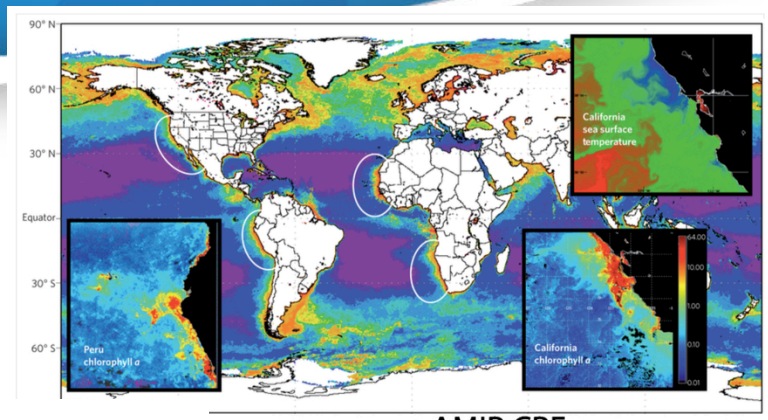
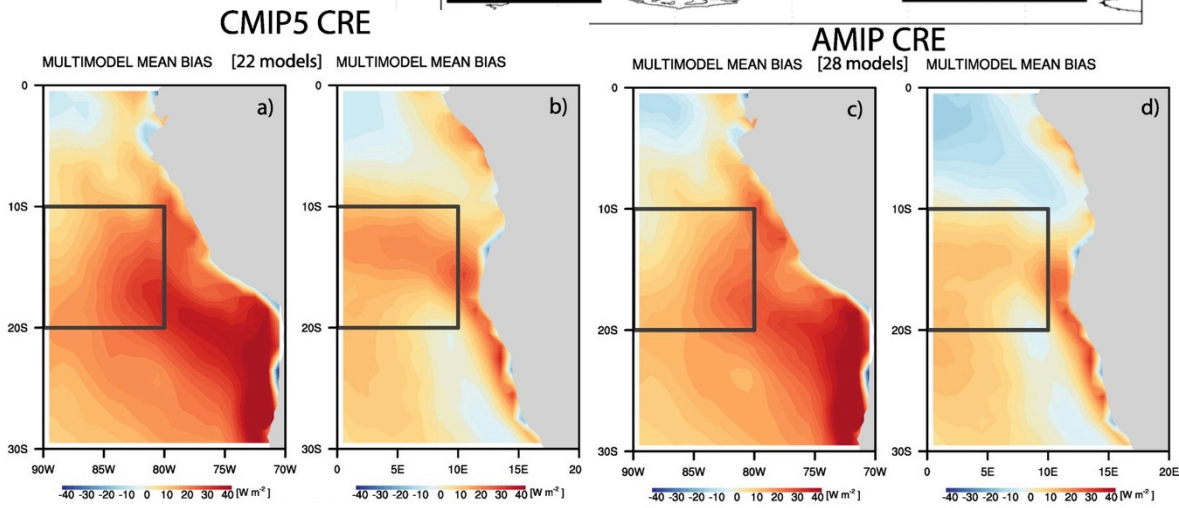
REGIONAL IMPACTS / CO_2 and HEAT UPTAKE RF on Eastern Boundary Upwelling Systems

- Identifying key **physical processes, similarities and differences** between EBUS
- Improving **model representation** of EBUS
- **Examining biogeochemical interactions** and role in carbon and nutrient cycling
- **Understanding future variability**





Zuidema et al. BAMS, 2016a,b

In collaboration with IMBER and SOLAS

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Contribution to IndOOS review

- IORP/SIBER/IRF/IOGOOS
- **30 January to 1 February, 2017, Perth, Australia**
- **24 presentations, 40 participants**

Indian Ocean Observing System (IndOOS) mission statement

The goal of IndOOS is to provide sustained high-quality oceanographic and marine meteorological measurements to support knowledge based decision-making through improved scientific understanding, weather and climate forecasts, and environmental assessments for the benefit of society.

+ Terms of Reference for IndOOS review

+ Outline of IndOOS Review paper with several CLIVAR members contributing

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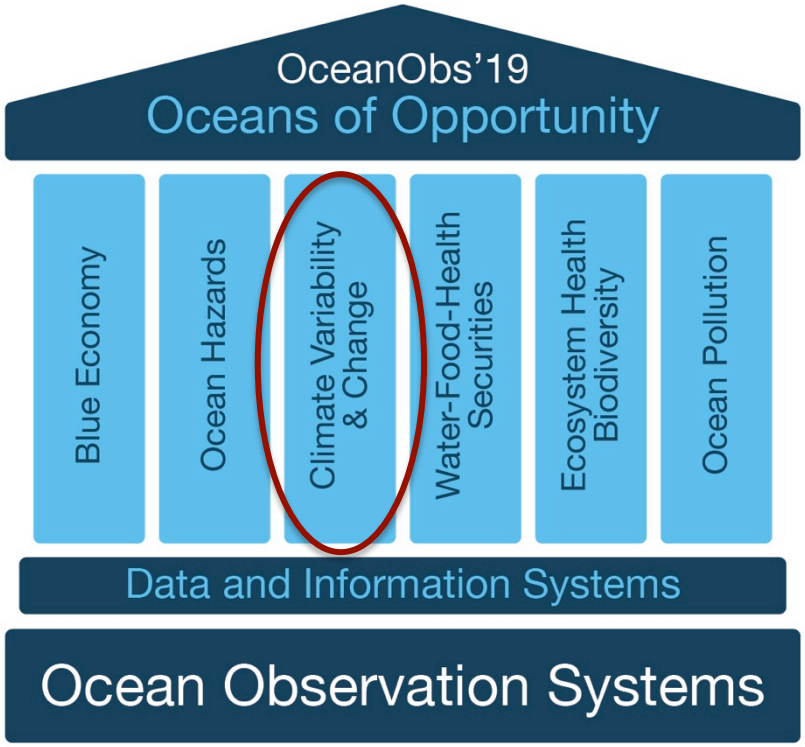
OceanObs'19

Exploratory activities for potential CLIVAR involvement in the organization of OceanObs'19, especially in the area of Climate Variability & Change



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Dissemination

- ✓ Town halls: AGU Fall Meeting, Ocean sciences
- ✓ Session at major conferences
- ✓ Themed workshops
- ✓ Training Schools (ICTP and FIO/China every other year on the horizon)
- ✓ Exchanges

Recent CLIVAR capacity development activities

2016:

- CLIVAR-ICTP Advanced School on Earth System Modelling, IITM, Pune, India, July 2016
- ECSS, Qingdao, China, September 2016
- ICGPO intern from China, Dec-2016/July-2017

Welcome and Big Thank You

- New ICPO director: We are very happy to welcome Dr. Jose Luis Santos Davila!!
- We wish to thank Dr. Nico Caltabiano for all his work and help during during the transition as interim ICPO director!!
- The ICPO funding appears secured for the next 3-4 years through FIO.

Challenges Ahead

- **Sustained funding and enthusiasm/ engagement for CLIVAR/WCRP activities.**

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Thank you

Observational Challenges

- Deep observations (e.g., deep-Argo) and biogeochemical observations (BIO-Argo)
- Continuous observations
- Full depth, basin-wide, AMOC and associated transports, including the Arctic Ocean
- Carefully-derived error estimates for observational data
- Expanded and improved paleo-climate data

Modeling Challenges

- Improved representations of unresolved physics, e.g, mesoscale and submesoscale eddies
- Southern Ocean biases e.g., heat and carbon uptake
  Western boundary current separation problem
- Warm biases off the west coast of continents (upwelling)
  Ocean physics and BGC interactions