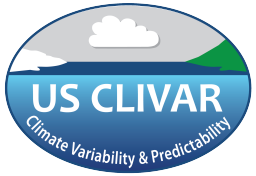
US & International CLIVAR Town Hall

AGU Fall Meeting
December 5, 2012
San Francisco, California

Mike Patterson, US Project Office Director
Bob Weller, US CLIVAR SSC Chair
Martin Visbeck, International CLIVAR SSG Co-chair

Outline

US CLIVAR



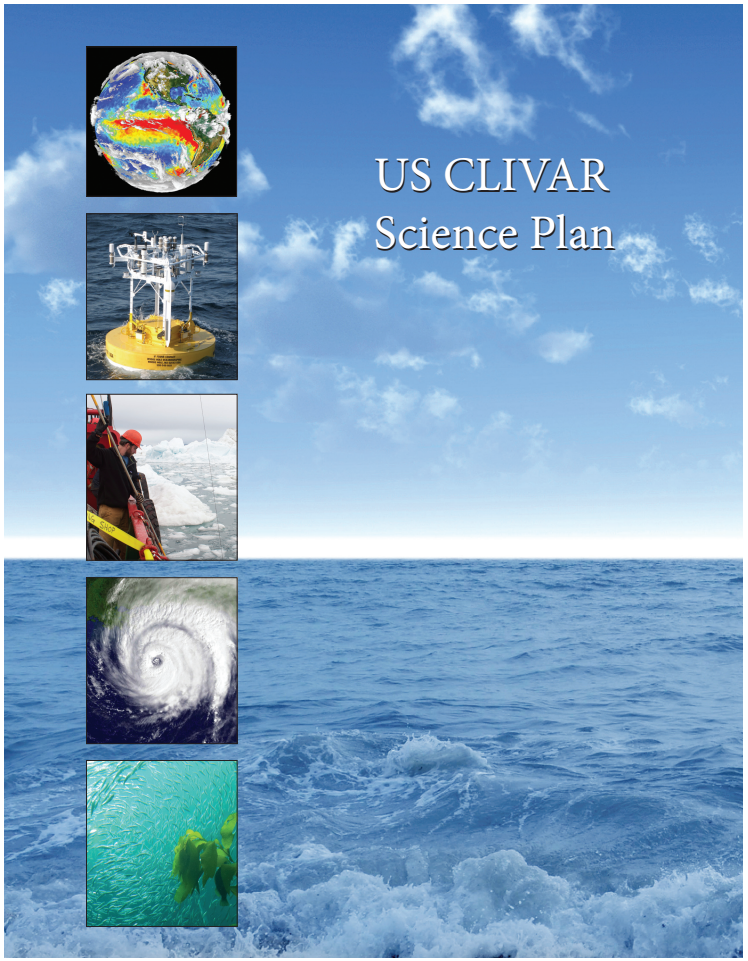
- Introduction of US CLIVAR Science Plan
- Drivers and Science Questions
- Goals, Research Challenges, and Cross-cutting Strategies
- Implementation, Management, and Inter-Program Cooperation

International CLIVAR

- Introduction of International CLIVAR Science Planning
- WCRP Context and CLIVAR Organization
- Imperatives, Capabilities, and Research Foci
- New Organizational Structure

Purpose of a New US Science Plan

- to update goals and priorities of U.S. CLIVAR based on achievements to date
- to articulate expansion of core research to target specific research challenges
- to emphasize strengthened ties to the broader Earth Sciences community and relevance to societal impacts
- to bolster funding commitments by U.S. agencies to achieve their mission objectives
- to articulate the envisioned contributions of the U.S. program to International CLIVAR



The US Planning Effort

In **January 2012** the US CLIVAR SSC initiated a **two-year effort** to draft, edit and publish a new Science Plan to guide climate research for the 15-year period post-2013.

To inform the planning effort, the SSC invited presentations on:

- funding agency interests and needs,
- changing international and national program directions and priorities,
- progress achieved over the past 15 years toward stated goals/objectives, &
- priority research topics and science questions framing the future program

In light of this information, the SSC and Panels, assisted by the Project Office

- determined the scope and presentation format of the Plan
- identified chapter lead authors and writing teams
- generated a draft plan, reflecting community engagement
- conducted a public review of the draft
- incorporated changes recommended from review
- finalized and published plan

US Plan Writing Team

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US CLIVAR
Climate Variability & Predictability

US CLIVAR Science Plan

Bob Weller

US CLIVAR Mission

To foster **understanding and prediction of climate variability and change** on intraseasonal-to-centennial timescales,

through observations and modeling

with emphasis on the **role of the ocean and its interaction** with other elements of the Earth system,

and to serve the climate community and society

through the **coordination and facilitation** of research on outstanding climate questions.

Science Plan Chapters

Chapter 1. Introduction

Chapter 2. History and Achievements

Chapter 3. Fundamental Science Questions

Chapter 4. Goals

Chapter 5. Research Challenges

Chapter 6. Cross-Cutting Strategies

Chapter 7. Management and Implementation Activities

Chapter 8. Program Cooperation and Coordination

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Context and Drivers

Since its inception 15 years ago, US CLIVAR-led research has played a substantial role in advancing our understanding of, and skill in predicting, climate variability and change. Advances include:

- Significant increases in understanding of the climate system and its predictability
- Expansion of a sustained ocean observing system
- Development and coordination of inter-comparisons of ocean and coupled simulations that have let to improved predictive capability
- Development of climate models with improved representation of physical processes
- Integrated Earth-system science and modeling that broadens the interdisciplinary perspective of climate science
- Regular assessments of the changing climate system, its impacts on human and natural systems, and mitigation and adaptation options
- Increased attention to the uncertainties and confidence limits of both observed and predicted climate information

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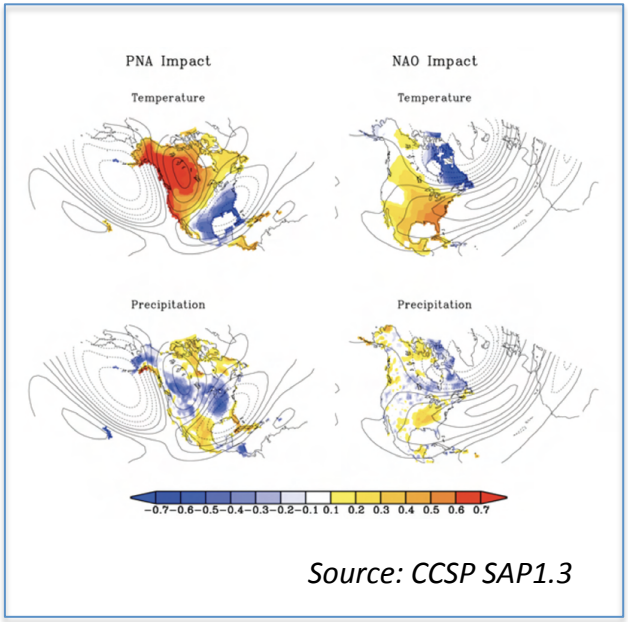
Fundamental Science Questions

These advances have been motivated by fundamental science questions, which guide and drive US CLIVAR activities.

- What **processes** are critical for determining climate variability and change related to the ocean?
- What are the **connections and feedbacks** between oceanic climate variability and other components of the Earth's climate system?
- How **predictable** is the climate on different time and space scales?
- What determines **regional expressions** of climate variability and change?



Source: CCSP SAP1.3

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US CLIVAR Goals

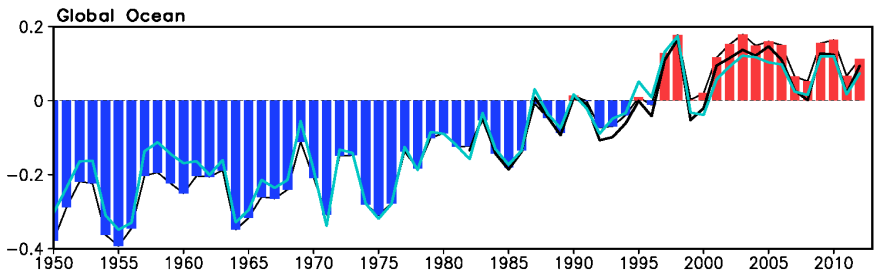
1) Understand the **role of the oceans** in climate variability on different time scales.

2) Understand the **processes** that contribute to climate change and variability in the past, present, and future.

3) Better **quantify uncertainties** in the observations, simulations, predictions and projections of climate variability and change.

4) Improve the **development and evaluation of climate simulations and predictions.**

5) Collaborate with research and operational communities that develop and use climate information.



Time evolution of annual mean of global sea surface temperature anomaly from ERSST (bar) and HadISST (blue line) for 1950-2011 and OISST (black line) for 1982-2011. Source: BAMS, State of the Climate in 2011

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Research Challenges

Broad areas of climate science that are societally important, reflect the interests of the scientific community and funding agencies, concern most of the CLIVAR Panels, and typically **extend US CLIVAR beyond its traditional research agenda**

1) Decadal variability and predictability
2) Climate and extreme events
3) Polar climate
4) Climate and carbon/biogeochemistry

US CLIVAR will continue to support activities to advance its mission, address its fundamental science questions, and support its goals – including, for example, intraseasonal-to-interannual predictability, understanding climate response to changing boundary conditions.

Research Challenge: **Decadal Variability and Predictability**

Definition

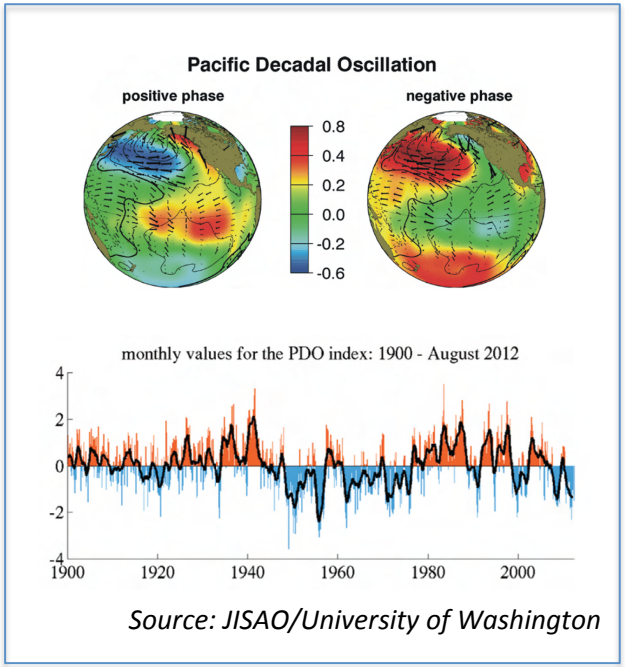
- Described in terms of large-scale modes, the dominant patterns of variability that oscillate at decadal timescales
- Examples include
  - Pacific Decadal Oscillation, ENSO Decadal Variability, Interdecadal Pacific Oscillation, North Pacific Gyre Oscillation
  - Atlantic Multidecadal Oscillation, North Atlantic Oscillation, Tropical Atlantic Meridional Mode,
  - Arctic Oscillation/Northern Annular Mode, Antarctic Oscillation/Southern Annual Mode

Significance

- Societally important impacts (e.g., on terrestrial precipitation)
- Obfuscates climate trend

Dynamics

- Likely origins in coupled ocean-atmosphere interactions
- Other factors: deep soil moisture, vegetation, snow cover, anthropogenic aerosols, stratospheric water vapor



Source: JISAO/University of Washington

Future research

- Identify optimum method for initialization, given imperfect and incomplete observations and assimilation systems
- Determine the added skill in predictions with initialization when compared to uninitialized predictions
- Assess the impact of small ensemble size on the spectrum of decadal means
- Establish what predictions should be attempted, and how they could be verified

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Research Challenge: **Climate and Extreme Events**

Definition

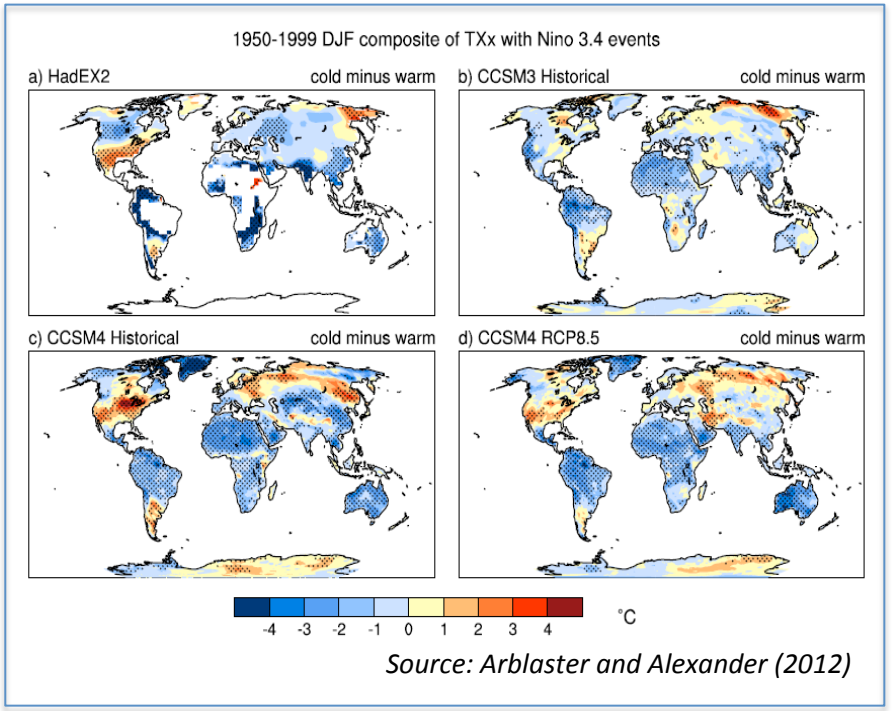
- Events that occur relatively rarely or exceed a threshold
- Examples include
  - Tropical cyclones and hurricanes, intense wind events
  - Heavy wave and storm surge events
  - Heavy precipitation and related floods
  - Drought
  - Cold snaps and heat waves

Significance

- Societally important impacts (e.g., on human life and property, agriculture, and water resources)
- Complex mix of processes and timescales, bridging gap between climate and weather scales

Dynamics

- Climate mode modulation of extremes
- SST and upper ocean heat content influences on atmospheric heating and circulation, including cyclogenesis and blocking
- Other factors: soil moisture and terrestrial evaporation, water availability, vegetation, snow cover & sea ice



Source: Arblaster and Alexander (2012)

Future research

- Identify the important dynamical processes that underlie short-term precipitation and temperature extremes
- Investigate how these short-term processes interact with the larger-scale, slower and potentially-predictable climate fluctuations linked to the ocean
- Determine the timescales, metrics, statistics, and analysis tools that are most relevant for extremes
- Investigate what properties of extremes, if any, are changing under global warming

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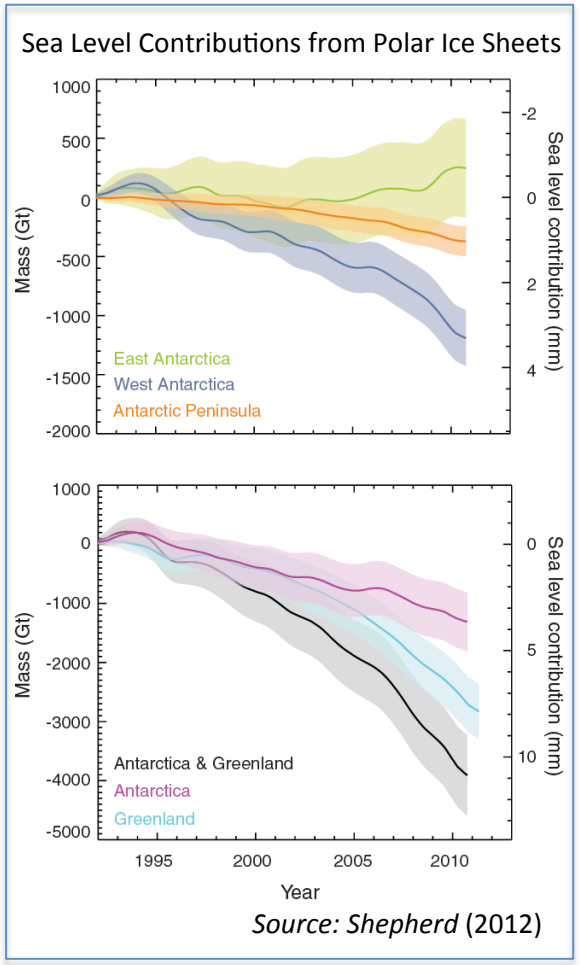
Research Challenge: **Polar Climate**

Definition
- Changes in climate of Arctic and Antarctic/Southern Ocean regions
- Global influence of polar changes

Significance
- Societally important impacts (e.g., on fisheries, ecosystem, and wildlife management, subsistence hunting, transportation, petroleum extraction)
- Response of meridional overturning circulation, ice shelf melt/sea level rise, and carbon balance
- Potential impact of warming and sea ice changes on mid-latitude extremes

Dynamics
- Changes in SH atmospheric circulation and SO eddies on SO/ACC stratificaiton and meridional transport of heat, salt and carbon
- Changes in NH subpolar gyre and inter-basin exchanges of heat and salinity
- Feedbacks of Antarctic and Greenland ice shelf response to warming ocean – strengthening ocean stratification, reducing vertical mixing, inhibiting convection

Future research
- Expand observational basis for monitoring variability/change and understanding mechanisms
- Synchronize data quality control and processing
- Identify processes that models need to capture to improve simulation and predictability



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Research Challenge: **Climate and Marine Carbon/ Biogeochemistry**

Definition

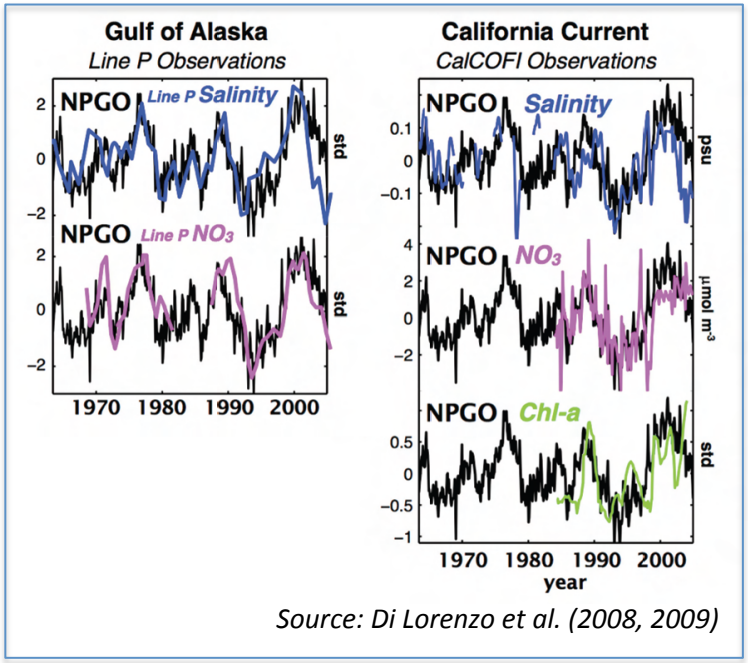
- Understanding of the coupled physical/biogeochemical processes that maintain the marine ecosystem and oceanic sources and sinks of carbon and accurately predict how they will evolve in response to climate variability and change

Significance

- Societally important impacts (e.g., on fisheries, marine ecosystem management)
- Role of ocean in uptake of atmospheric carbon
- Implications of feedbacks enhancing global warming

Dynamics

- Marine ecosystem sensitivity
  - to surface mixed layer thickness, upper ocean stratification, processes that lift subsurface nutrients
- Carbon cycle sensitivity
  - to ocean overturning and stratification, wind forced mixing and upwelling



Source: Di Lorenzo et al. (2008, 2009)

Future research

- Develop and deploy multi-purpose ocean-observing systems
- Continue innovation of oceanographic instrumentation – e.g., volunteer observing ships, autonomous technology
- Undertake integrated ecosystem process studies to gain mechanistic understanding of the biological responses to climate variations and change
- Develop, evaluate, and compare coupled physical/biogeochemical models and support improvement of model interoperability

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Cross-Cut Strategies

Cross-Cutting Strategies⇨ **Goals ⇩**	*Sustained and new observations*	*Process studies*	*Model development strategies*	*Quantifying improvement in predictions and projections*	*Communication of climate information*
Understand the role of the oceans in climate variability on different timescales	Document variations	Data to evaluate and improve models	Improve modeling of climate across processes and timescales	Understand limits of climate predictability	Prioritize observing network and predictability studies and improve predictions of ocean and climate variability
Understand the processes that contribute to climate change and variability in the past, present, and future	Document climate-critical processes	Investigate processes to help explain variations	Property conserving climate reanalyses	Quantifying importance of model uncertainty in projections	Set priorities for observations and predictability studies; communicate about confidence and predictability
Better quantify uncertainties in the observations, simulations, predictions, and projections of climate	Initialize and evaluate model simulations	Model assessment	Improve models	Quantify model, intrinsic and scenario errors	Address needs for predictability and sensitivity studies
Improve the development and evaluation of climate simulations and predictions	Initialize and evaluate climate models	Provide data to develop and test model process representation	Reduce biases in climate models	Quantify importance of model physics errors	Determine key targets for model development across communities
Collaborate with research and operational communities that develop and use climate information	Provide multi-disciplinary datasets	Provide process understanding and opportunity for collaboration across disciplines	Communication between observational and model communities	Improved communication across disciplinary boundaries	Provide information on dominant climate phenomena and predictability

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Sustained & New Observations

US CLIVAR advocates and leverages long-term climate monitoring strategies to better document, understand, model and predict climate variability.

- *Call for continued support to **sustain ongoing collection of key or essential climate variables** at key locations, consistent with Global Climate Observing System (GCOS) goals and the OceanObs'09 call to action*

- *Encourage **extension of recently acquired capabilities** to measure processes of climate variability*

- *Work with other scientific communities to build the next generation of climate observations **spanning traditional disciplinary boundaries***

- *Identify and call attention to climatically important but **currently undersampled regions***

- *Contribute to the development of **new and sustained deep-ocean observations** by highlighting where deep-ocean data gaps exist – in conjunction with the US Global Ocean and Carbon and Repeat Hydrography Program*

- *Advocate a specific focus on polar ocean observational data gaps and how they can be mitigated with the development, deployment, and coordination of additional **high latitude ocean observing systems***

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Process Studies

US CLIVAR promotes process studies to gain a quantitative understanding of the mechanisms controlling climate variability and change, and to provide observational data to evaluate and improve models

- *Ensure that data and process-level understanding gained from process studies is optimally used to **benefit climate model evaluation and development and to inform the design of sustained climate observing systems***

- *Foster **coordination and collaboration across disciplines** for process study design, e.g., through communication with climate-relevant chemical and biological communities*

- *Ensure that the **climate model development community** is closely **involved in the early stages of process study design** to ensure that the data to be collected will maximally benefit model improvement and parameterization development*

- *Ensure that the community takes full advantage of **new facilities** (e.g., NSF OOI and DoE mobile ARM) by integrating them into the design of climate phenomena studies*

- *Develop strategies for using ensembles of eddy-resolving ocean simulations and cloud-resolving regional simulations to **optimize the use of observational platforms** to collect data in process studies and to maximize the use of coordination with the global land-based and satellite observing system*

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Model Development Strategies

US CLIVAR seeks to improve climate models, their representation of processes, data assimilation approaches, and evaluation.

- *Foster **better communication and practices** between model development and observational communities*
- *Encourage using **novel model strategies** such as coupled modeling and modeling with hierarchies of models of differing complexity*
- *Oversee progress and facilitate interagency collaboration for support of **Climate Process Teams** designed to speed development of climate models by bringing together model development specialists with observationalists and process modelers to focus on the most critical model deficiencies*
- *Play an increasing role in strengthening **connections between the climate and weather** model communities, emphasizing the sharing of conventions for data storage, assimilation systems, and model development and evaluation protocols*
- *Aid in the cross-communication of the **design of idealized simulations** so that observations and the scientists who collect them have an opportunity to contribute to the discussion about whether idealized models are being used in the correct regime*
- *Promote use of **empirical and statistical modeling** for prediction, evaluation of physical models, identifying and understanding key processes, and help quantify uncertainty and predictability*

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Quantifying Improvement in Predictions & Projections

US CLIVAR develops and employs techniques to critically assess improvements in predictions and projects in order to build the confidence of users and to identify the most likely targets for future improvements.

- *Understand **intraseasonal-to-interannual forecast quality** and the **limits of prediction skill***
- *Promote activities to identify and exploit **decadal** predictability, establishing a **prediction skill baseline***
- *Promote **hindcast simulation experiments** and their analysis to assess how climate model predictions and projections are improving*
- *Employ a combination of **deterministic and probabilistic metrics** to assess hindcast simulations*
- *Assess whether a **model's ensemble spread** is an appropriate representation of forecast uncertainty*
- *Establish **statistical modeling benchmarks,** facilitating community involvement to determine optimal statistical models, common data formats, and appropriate model experiment design*
- *Employ rigorous **testing of models against observational data**, quantifying model biases and errors, assimilation system problems, and observational deficiencies responsible for the drifts and implement better parameterizations to suppress modeled climate drifts*

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Communication of Climate Information

US CLIVAR will apply fundamental lessons from research on climate to facilitate knowledge transfer between the various scientific communities that generate and use information on climate variability and change.

- *Foster connections with **other scientific communities**, bridging disciplinary boundaries*
- *Improve **practices of model documentation and comparable quantitative evaluation** to promote understanding, engagement, and exploitation of models*
- *Actively seek out and support **forums for dialogue**, such as needs-assessment workshops, forecast use and evaluation, and developing communities of practice*
- *Partner with **science communities and boundary organizations** that study and convey climate information to end users*
- *Provide **information on uncertainties** necessary for climate service agencies to communicate with end users to address their risk tolerances and competition with other factors shaping their decision context*
- *Improve the communication and flow of information essential to build capacity to improve end users' comprehension of **distinctions between climate variability, anthropogenic forcing, and evolution of the current state of climate***

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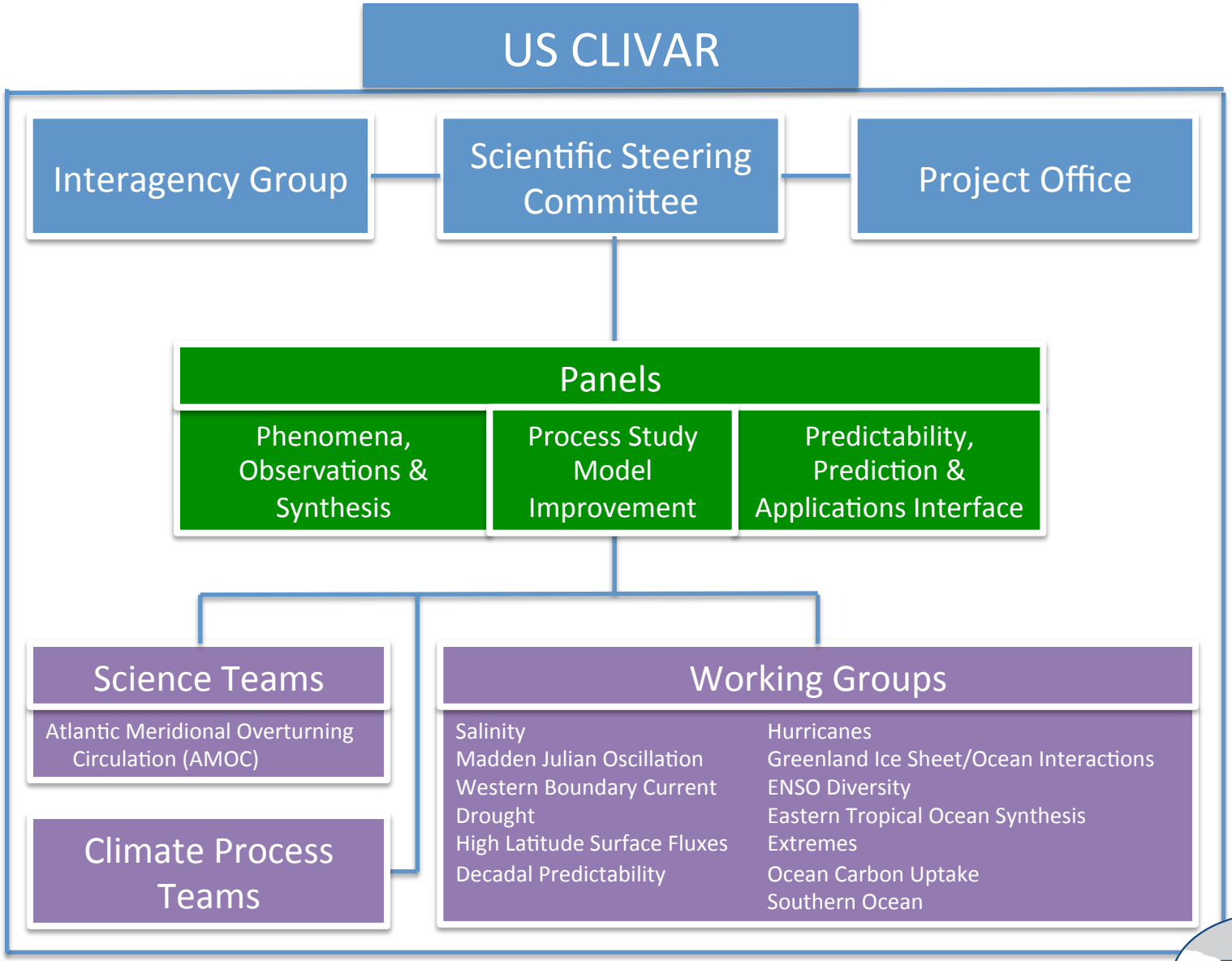
Management

US CLIVAR will continue its current organizational structure designed to facilitate close cooperation between the climate-science community and the funding agencies that support climate research.

Three-part management structure:

- **Scientific Steering Committee and Panels** of representatives drawn from range of subdiscplines to guide science planning and implementation to ensure progress toward program goals, identify gaps, and promote balance across the program
- **Interagency Group** of Program Managers from sponsoring agencies to coordinate resources and implementation of research projects and activities responsive to U.S. CLIVAR goals
- **Project Office** with a Director and staff to manage the day-to-day planning and implementation of activities of the program, communicate research advances and needs, and support international engagement and collaboration


US CLIVAR
Interagency Group
Scientific Steering Committee
Project Office
Panels
Phenomena, Observations & Synthesis
Process Study Model Improvement
Predictability, Prediction & Applications Interface
Science Teams
Atlantic Meridional Overturning Circulation (AMOC)
Climate Process Teams
Working Groups
Salinity
Madden Julian Oscillation
Western Boundary Current
Drought
High Latitude Surface Fluxes
Decadal Predictability
Hurricanes
Greenland Ice Sheet/Ocean Interactions
ENSO Diversity
Eastern Tropical Ocean Synthesis
Extremes
Ocean Carbon Uptake
Southern Ocean

Panels

Phenomena Observations & Synthesis (POS) Panel
Mission is to improve understanding of climate variations in the past, present and future, and to develop syntheses of critical climate parameters while sustaining and improving the global climate observing system.

Process Study & Model Improvement (PSMI) Panel
Mission is to reduce uncertainties in the general circulation models used for climate variability prediction and climate change projections through an improved understanding and representation of the physical processes governing climate and its variation.

Predictability, Predictions & Applications Interface (PPAI) Panel
Mission is to foster improved practices in the provision, validation and uses of climate information and forecasts through coordinated participation within the US and international climate science and applications communities.

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Panel Responsibilities

	POS Panel	PSMI Panel		PPAI Panel	
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Panels align with cross-cutting strategies to address program goals

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Implementation Approaches

US CLIVAR will achieve its goals through PI participation in:

- **Science Teams**
  - Interagency established PI group; coordinate projects; annual meeting & report; 5-10 year duration
- **Working Groups**
  - Grassroots small group on specific topic; produce products for community; 2-3 year duration
- **Climate Process Teams (CPTs)**
  - Agency funded projects assembling observationalists and model developers to advance specific process representation/parameterization in GCMs; 3-5 year duration
- **Science Meetings/Workshops**
  - Community organized on relevant topics
- **Agency-supported Research Calls**
  - Implementing coordinated observation and data projects; field campaign and process research; modeling, prediction and applications projects
- **Opportunities for Students, Postdocs, and Early-career Scientists**
  - Participation emphasized in above activities; assistance for attending meetings

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Program Cooperation & Coordination

Engagement of of US and International programs and infrastructure

- **USGCRP**
  - Land surface hydrology and terrestrial ecosystem impacts research
  - Carbon cycle, ocean biogeochemistry and marine ecosystem research
  - Atmospheric aerosol-cloud interactions
  - Polar and cryospheric research
- **WCRP**
  - International CLIVAR
  - Global Energy and Water Exchanges (GEWEX)
  - Climate and Cryosphere (CLIC)
  - Stratospheric Processes and their Role in Climate (SPARC)
- **Enabling Infrastructure**
  - Sustained observing systems
  - Data centers
  - Ship and aircraft
  - Modeling centers and high-performance computing
  - Operational and real-time information centers
  - International and US national climate change assessments

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Core Climate Science Contribution to USGCRP

US Global Change Research Program

Advance Science Goal

Integrated Observations

Integrated Modeling

Earth System Understanding
Climate Dynamics
Biogeochemisty/Carbon Cycle
Ecosystems & Biodiversity
Freshwater Resources
Human Systems & Social Drivers
Choices and Responses

Adapt & Mitigation Science

Info Management

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U.S. Contribution to International CLIVAR

International CLIVAR

Focused & Integrated Research 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

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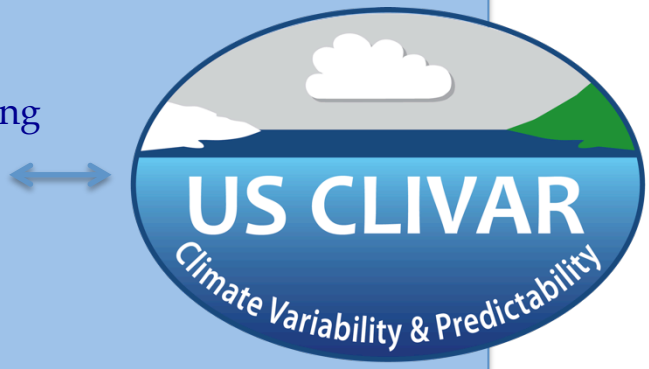


International CLIVAR Plans

Martin Visbeck

International Science Organization

ICSU
International Council for Science

IOC

WMO

Global Environmental Change Programs

WCRP
World Climate Research Programme

futureearth
research for global sustainability

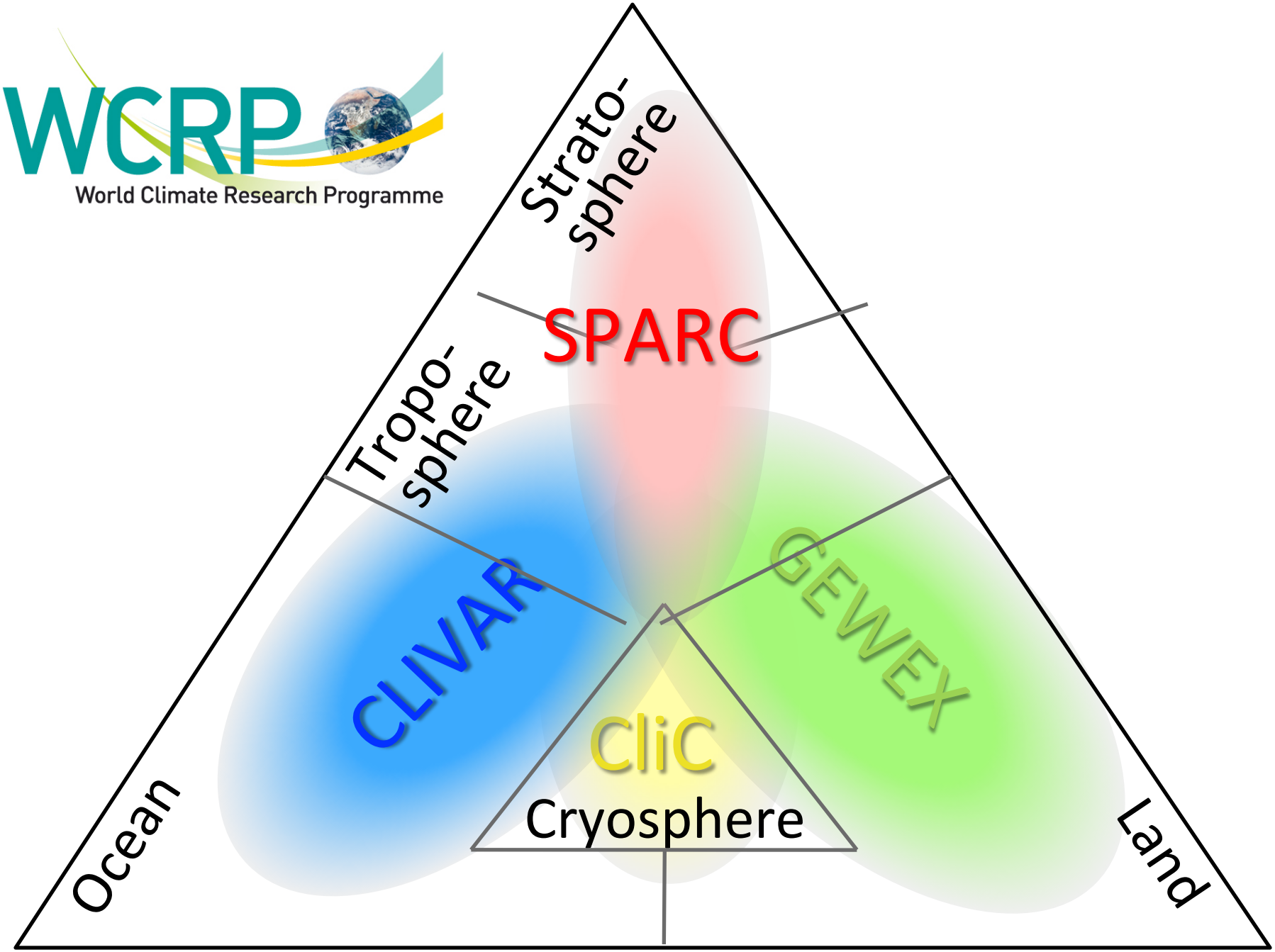
World Climate Research Program's Projects

GEWEX

CLIVAR

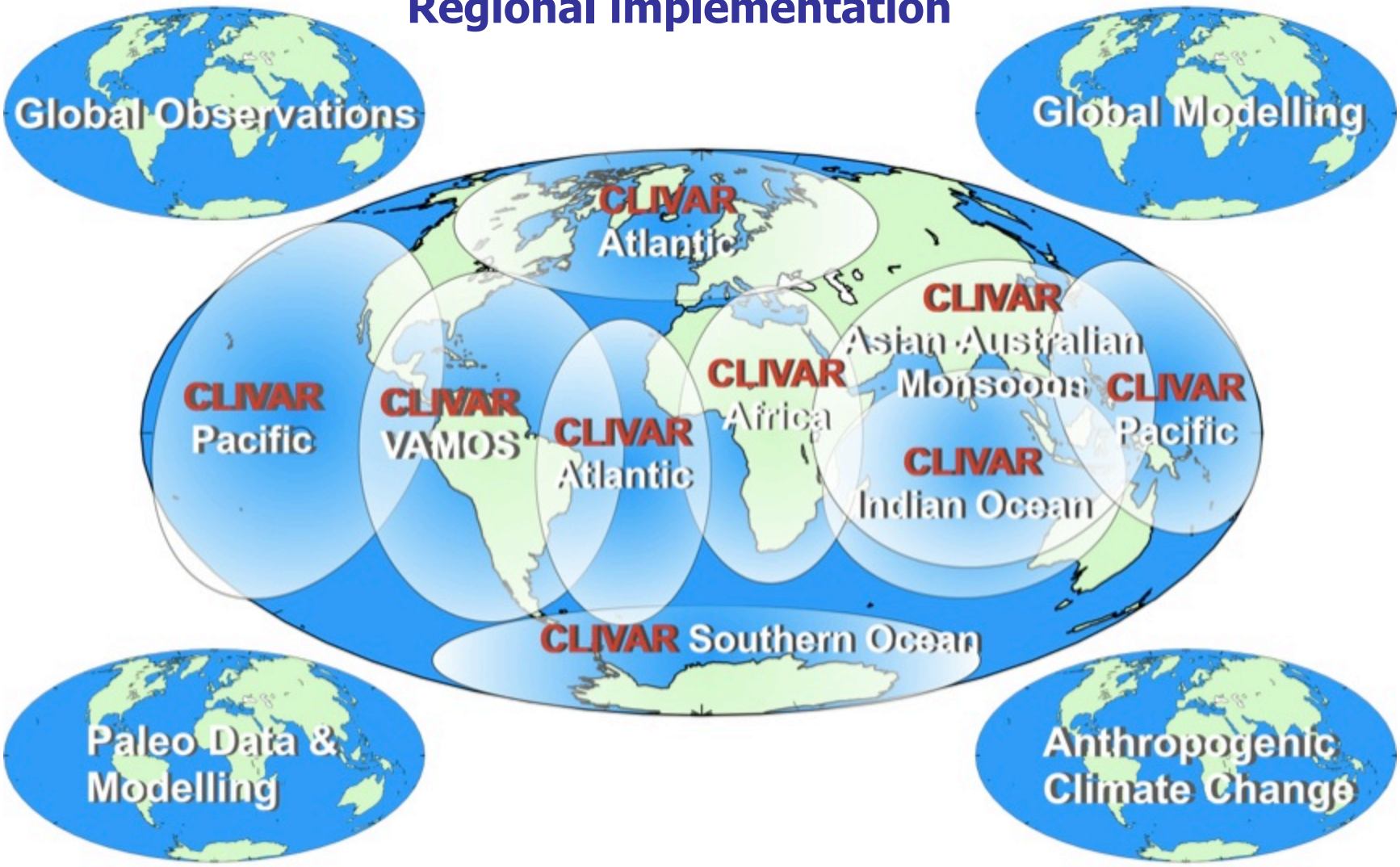
WCRP·SCAR·IASC
CliC

SPARC
WCRP


WCRP
World Climate Research Programme
Strato-sphere
SPARC
Tropo-sphere
CLIVAR
GEWEX
CliC
Cryosphere
Ocean
Land

CLIVAR – A Global View

Regional implementation



Scientific Steering Group Members

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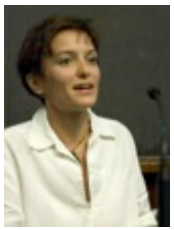

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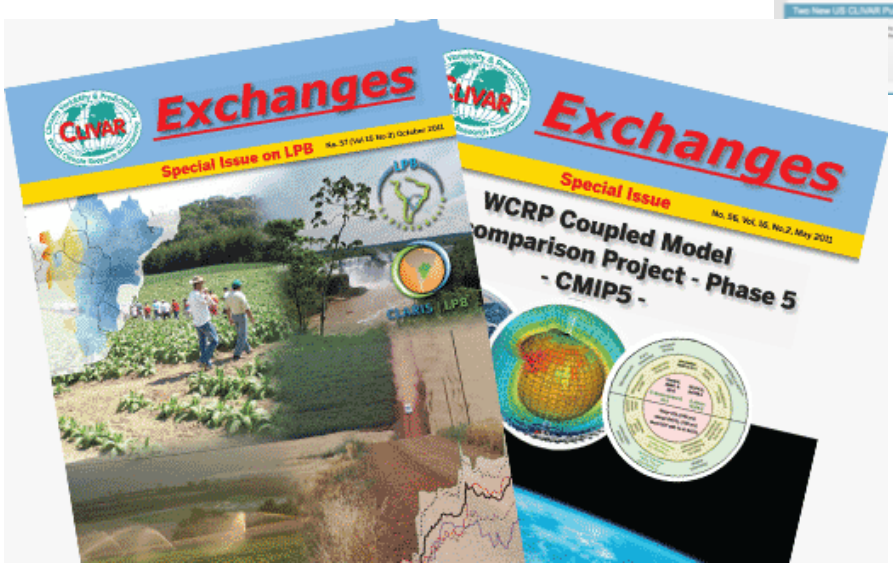

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Staff Scientist

Xiaohui Tang
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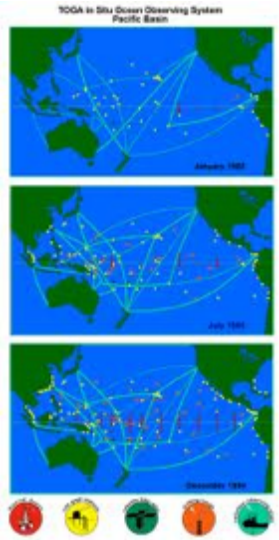
Current CLIVAR Research&Imperatives

- 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 OCEANS & CLIMATE

variability, predictability and change

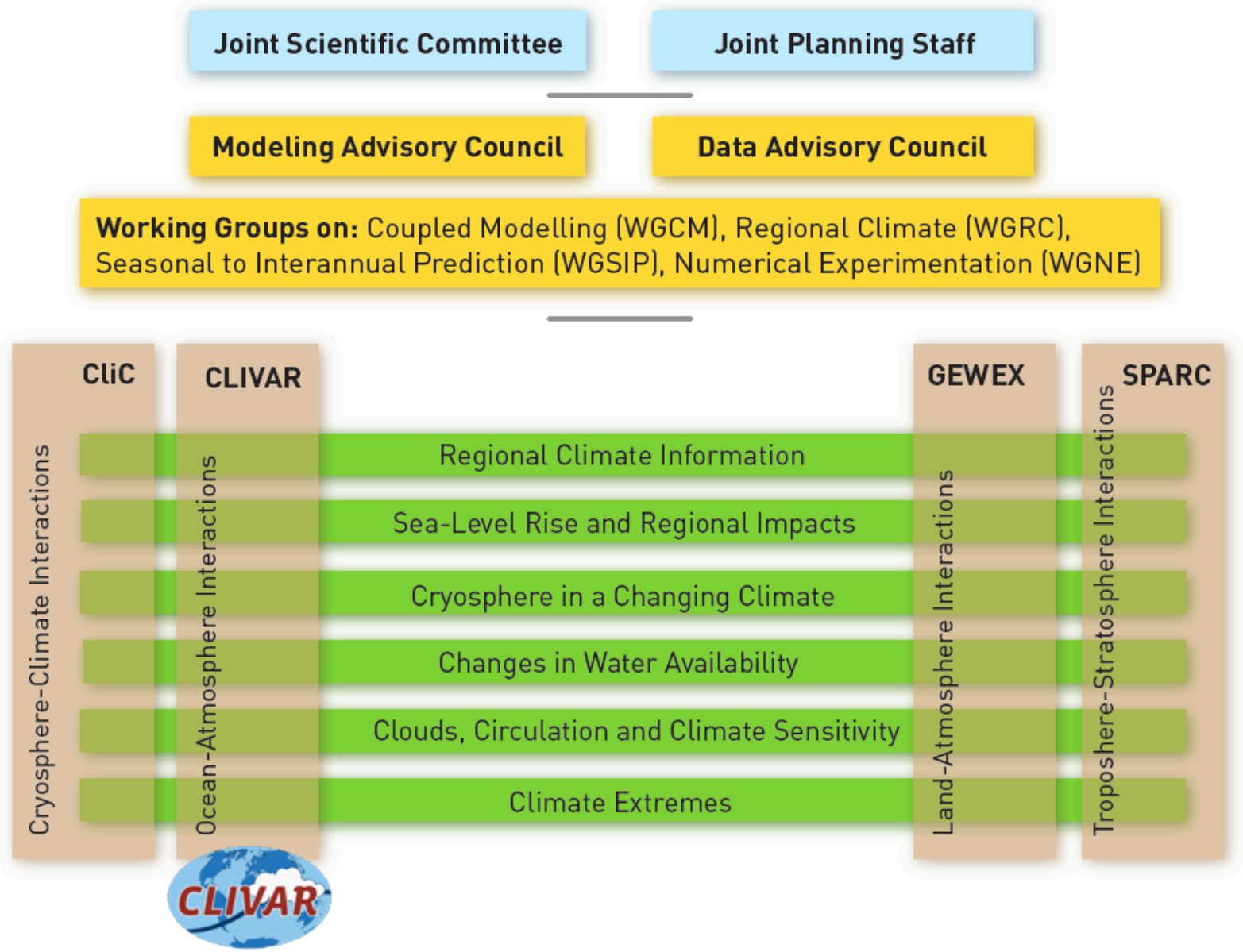
The World Climate Research Programme's project
on ocean-atmosphere interactions

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

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.

WCRP Grand Challenges



CLIVAR Research Foci

- 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
- … (your idea!)

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.

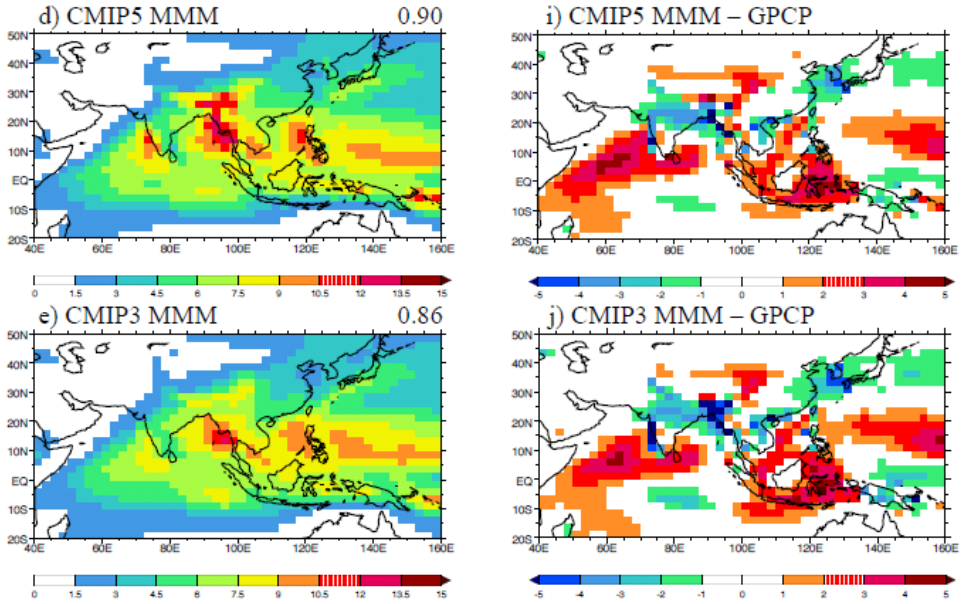
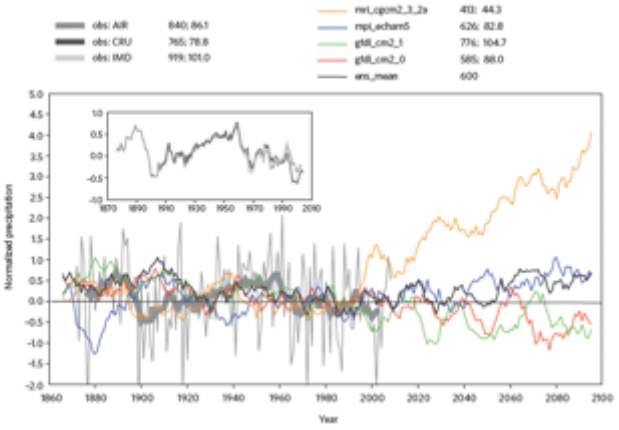


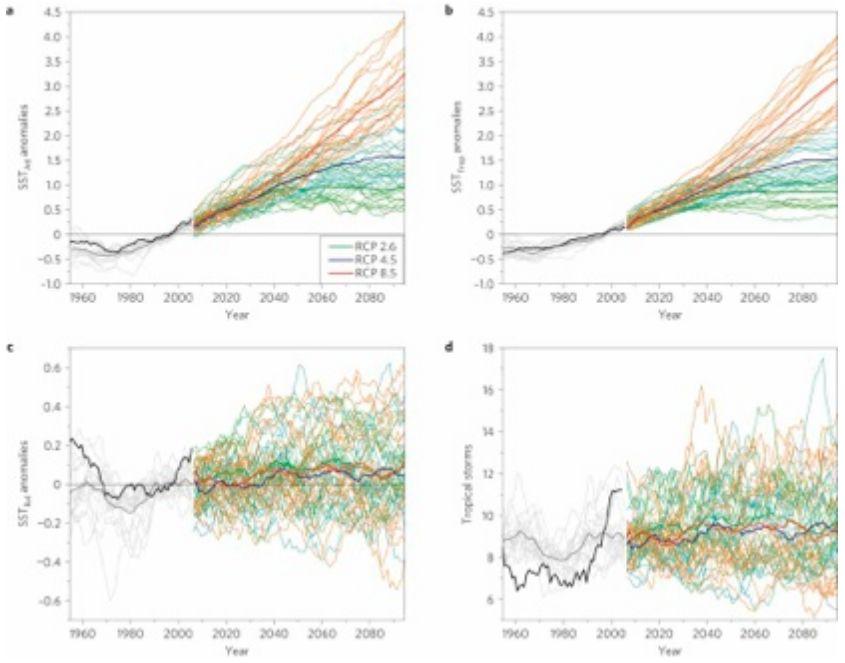
Figure shows large multi-model mean precipitation biases are present for the Asian summer monsoon in CMIP5 (from Sperber *et al*., 2012, *Clim. Dyn.*).

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

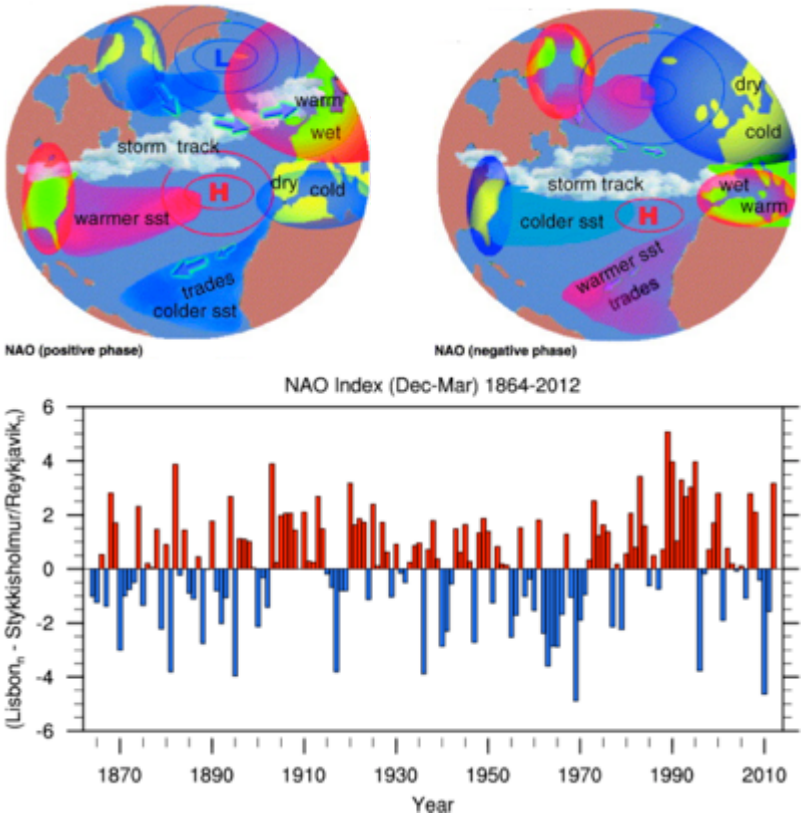
- **Improving understanding** of decadal variability and predictability.
- **Application of past data** sets including instrumental and proxy data.
- **Improving models** to better represent key processes associated with decadal variability.
- **Analysis and development** of current prediction potential 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

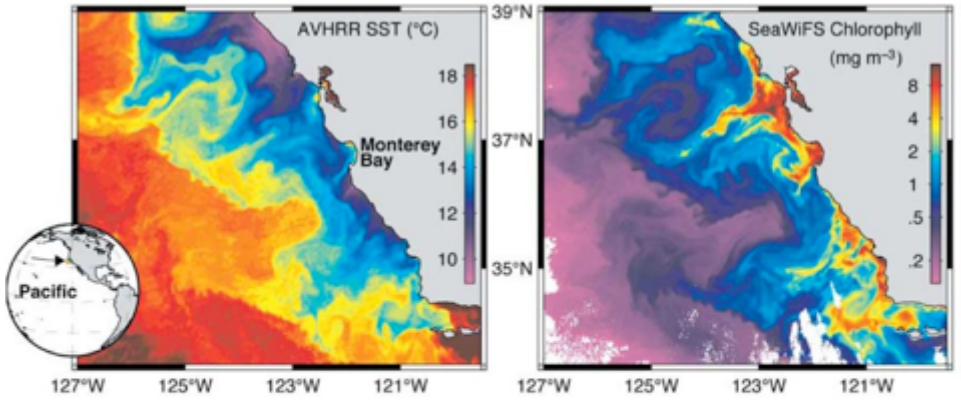
- **Ocean-atmosphere variations** influencing the magnitude and frequency extreme events, both now and in the future.
- **Increasing observational data sets**, providing higher temporal and spatial resolution for ocean-atmosphere processes.
- **Developing ocean-atmosphere models,** which simulate extreme 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

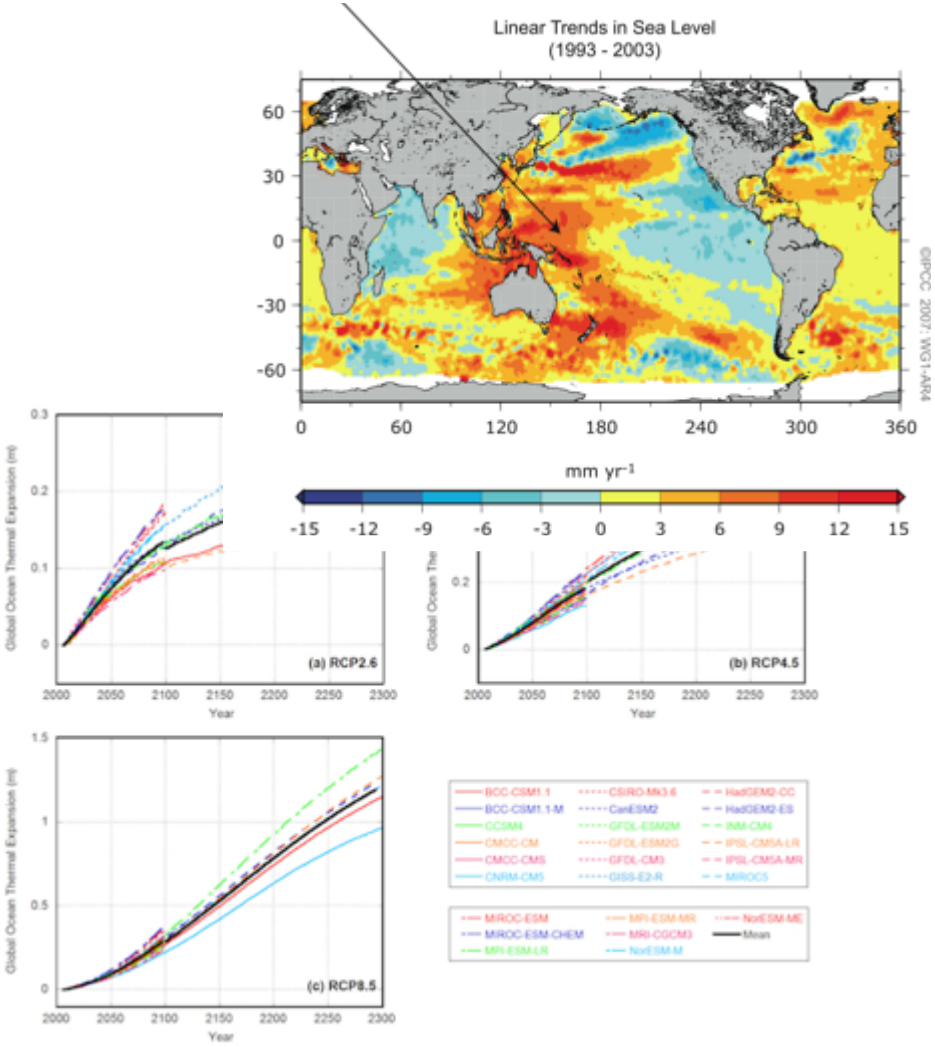
- **Identifying the key physical processes** that are responsible for upwelling.
- **Improving model representation** of upwelling processes.
- **Examining interactions** between the physical, biogeochemical and marine ecological systems.
- **Examining the cause of tropical bias** in climate models.
- **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).

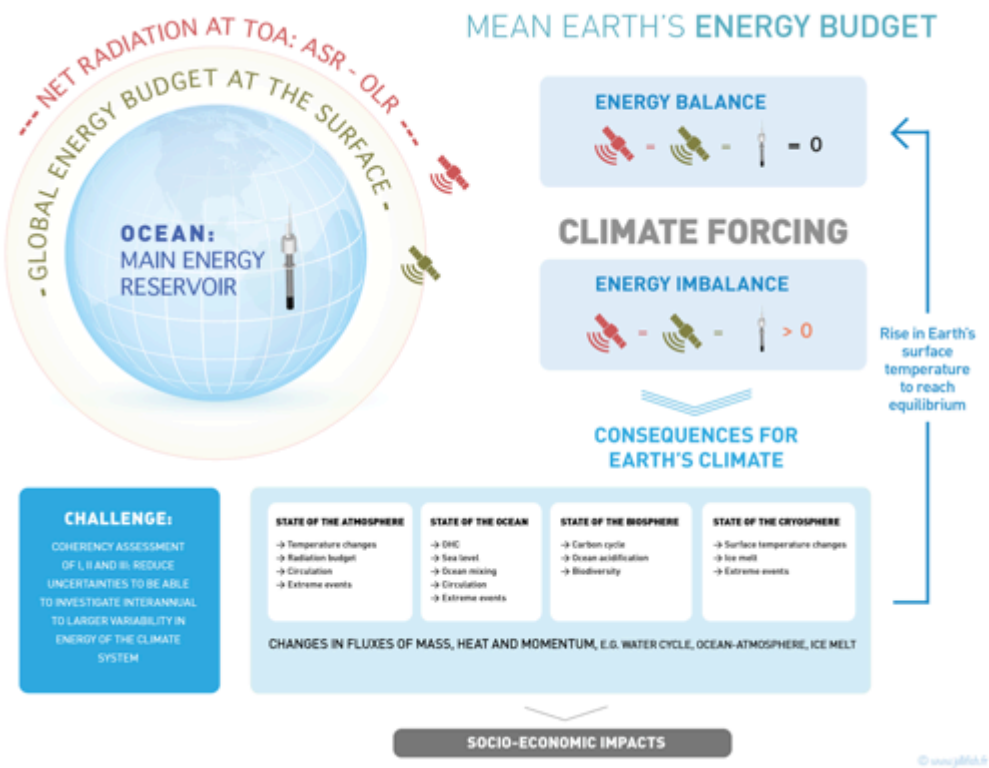


Projections of ocean global thermal expansion under low, medium and high representative concentration pathways, relative to 2006 (Yin 2012).

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.

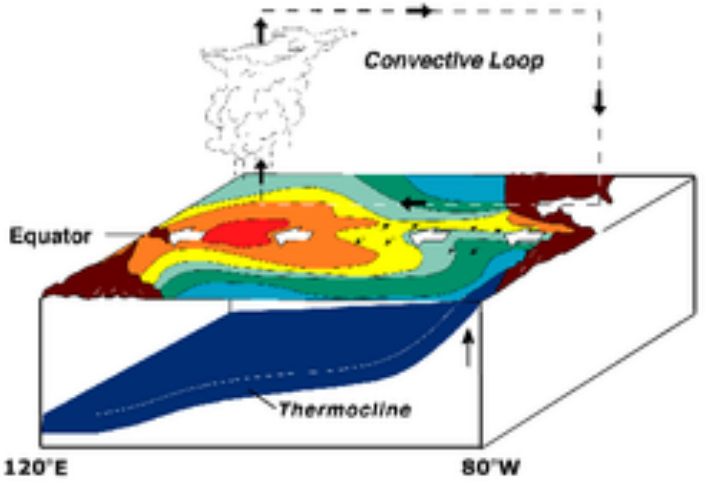
3. To propose ENSO evaluation protocols and develop a strategy for coordinated ENSO analysis of CMIP models, including development and maintenance of an interactive website, in coordination with the WGCM Metrics Panel.

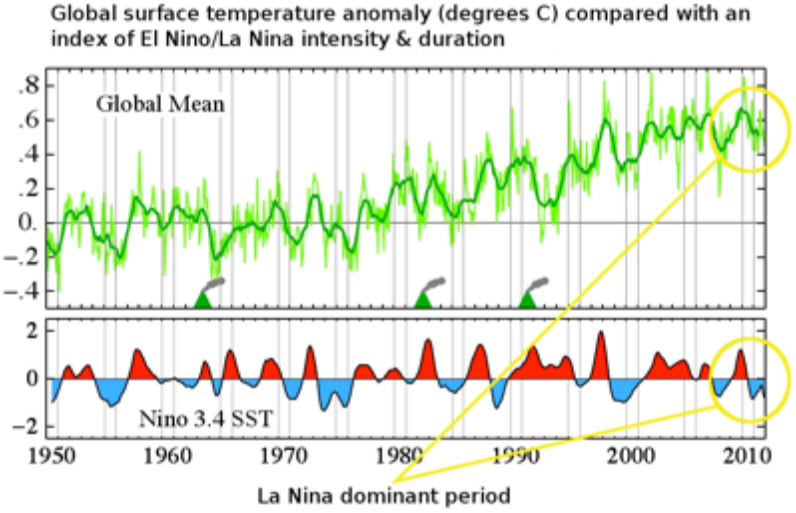
4. To identify new observations needed to better constrain ENSO processes, both for the current climate and for past climates (via paleo proxies).

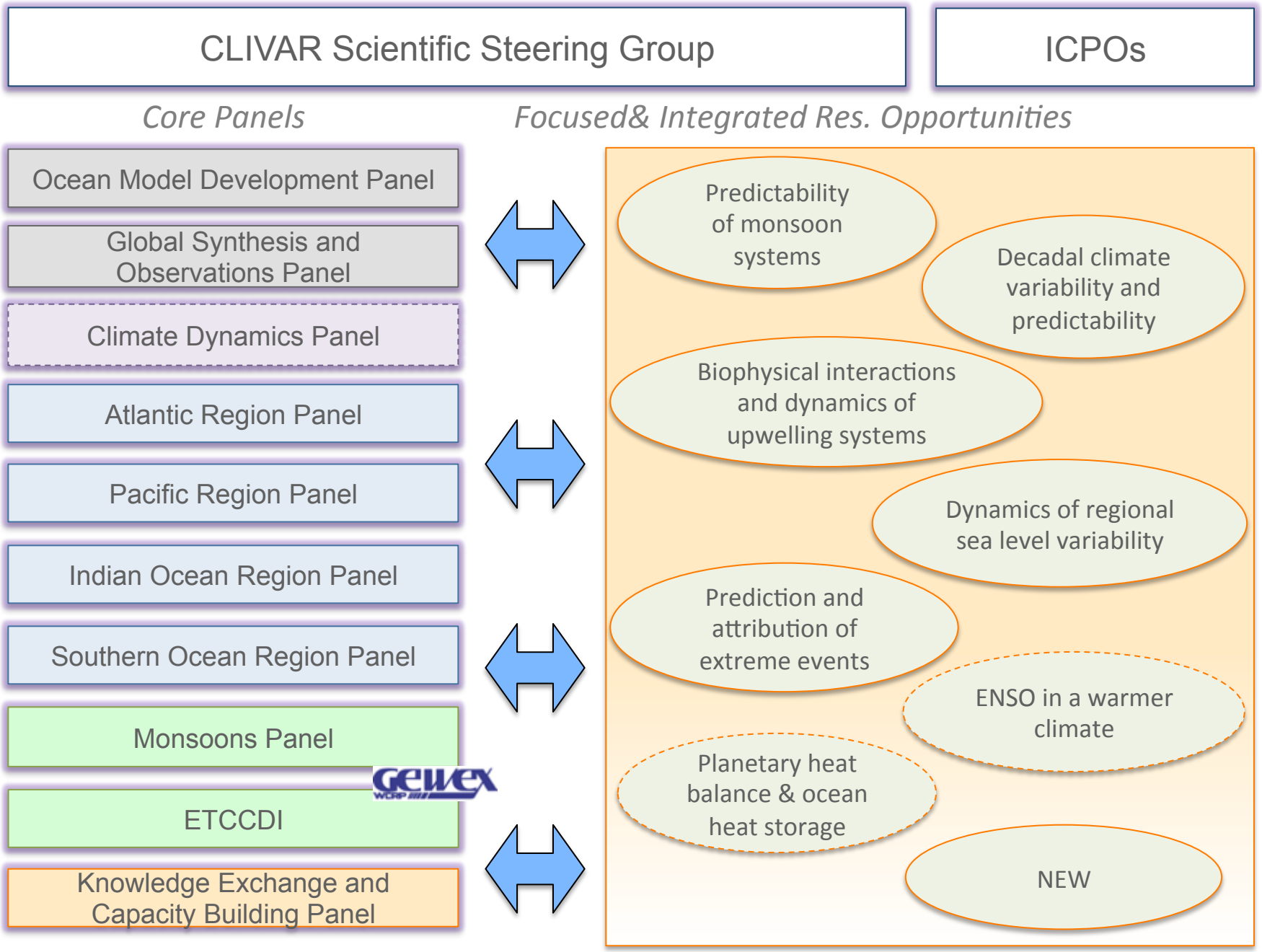
5. To provide a better understanding of how ENSO might change in the future.

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.






CLIVAR Scientific Steering Group
ICPOs
Core Panels
Focused& Integrated Res. Opportunities
Ocean Model Development Panel
Global Synthesis and Observations Panel
Climate Dynamics Panel
Atlantic Region Panel
Pacific Region Panel
Indian Ocean Region Panel
Southern Ocean Region Panel
Monsoons Panel
GEWEX
ETCCDI
Knowledge Exchange and Capacity Building Panel
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
Planetary heat balance & ocean heat storage
NEW

Transition of Int. CLIVAR Project Office from UK to 3 node structure in 2014

ICPO

NOC UK

ICPO Global (China)

ICPO Monsoon (India)

Executive Director

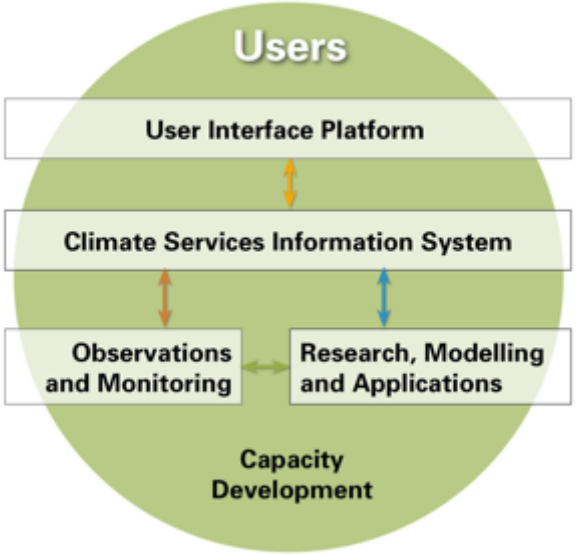
ICPO Modeling (Italy)

WCRP / CLIVAR partners and users

WCRP
World Climate Research Programme

GFCS
GLOBAL FRAMEWORK FOR CLIMATE SERVICES

futureearth
research for global sustainability



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global change SysTem for Analysis, Research & Training

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The Global Ocean Observing System
GOOS

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INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

your engagement and support

CLIVAR OCEANS & CLIMATE

variability, predictability and change

To improve understanding and prediction
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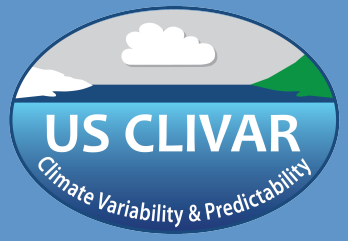
Thank You



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