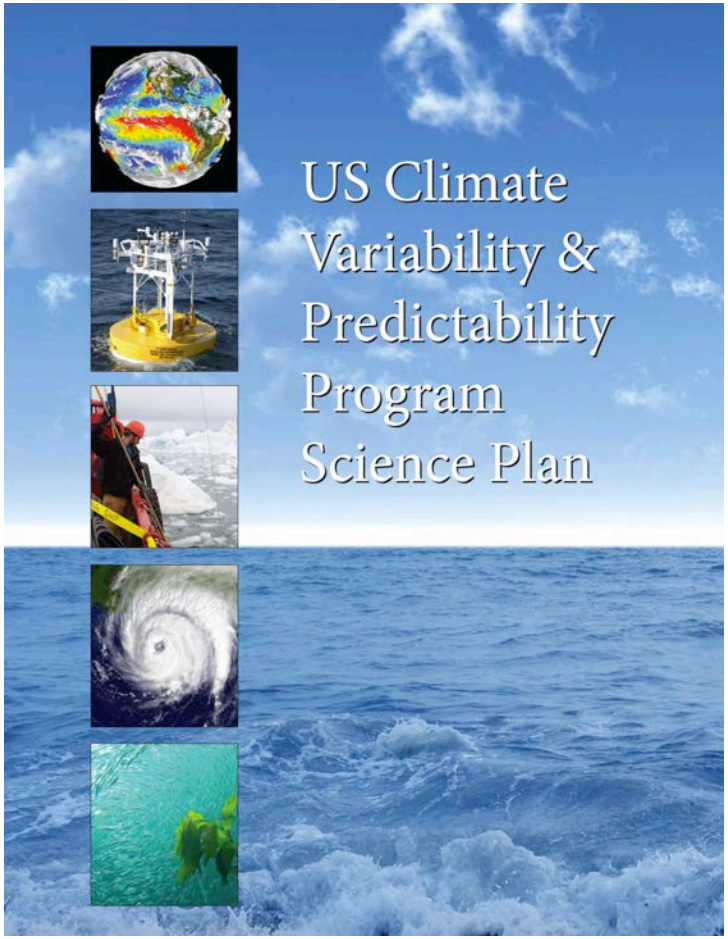
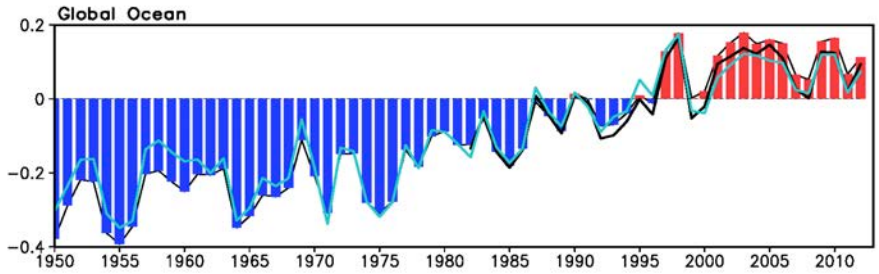


Implementing the US CLIVAR Science Plan

Bob Weller

Science Plan Context and Drivers

Evolution of climate sciences and the advent of services over the past 15 years motivates the need for a revised, updated Science Plan.



Source: BAMS, State of the Climate in 2011

- Expansion of a sustained ocean observing system
- Significant increases in understanding of the climate system and its predictability
- 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

Plan Development

2012	SSC Meeting outline of plan
	Summit review of draft mission statement, goals, and subgoals
	Initial chapter drafting
2013	SSC Meeting to review initial draft
	Internal Panel and external community reviews
	Final editing and layout
2014	Publication and roll-out
	Summit to consider implementation

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

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.

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.

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, subseasonal-to-interannual predictability, understanding climate response to changing boundary conditions.

Research Challenge: Decadal Variability and Predictability

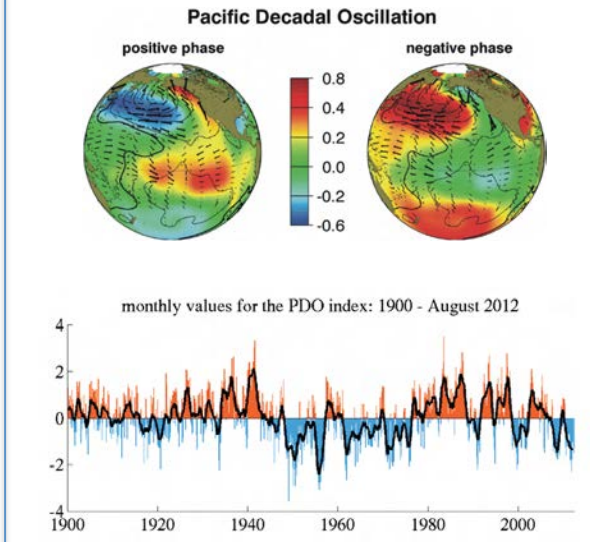
Described in terms of large-scale modes, the dominant patterns of variability that oscillate at decadal timescales

Societally important impacts (e.g., on terrestrial precipitation)

Obfuscates climate trend

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

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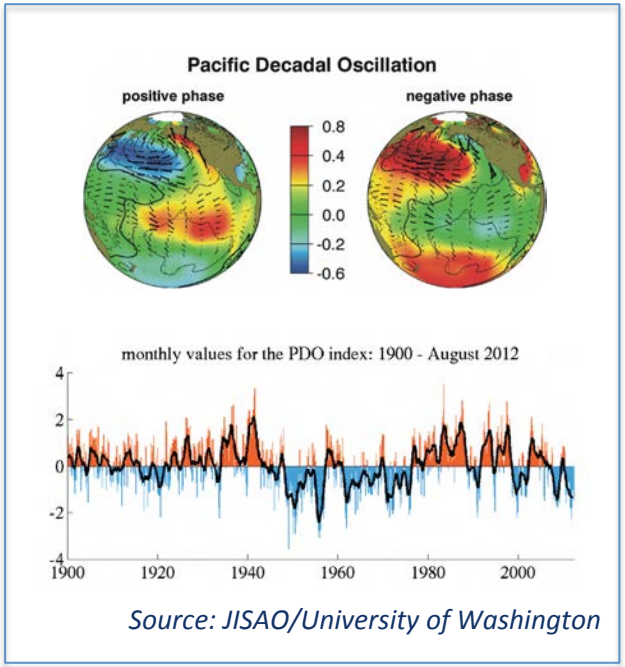


Source: JISAO/University of Washington

<u>Future research</u>

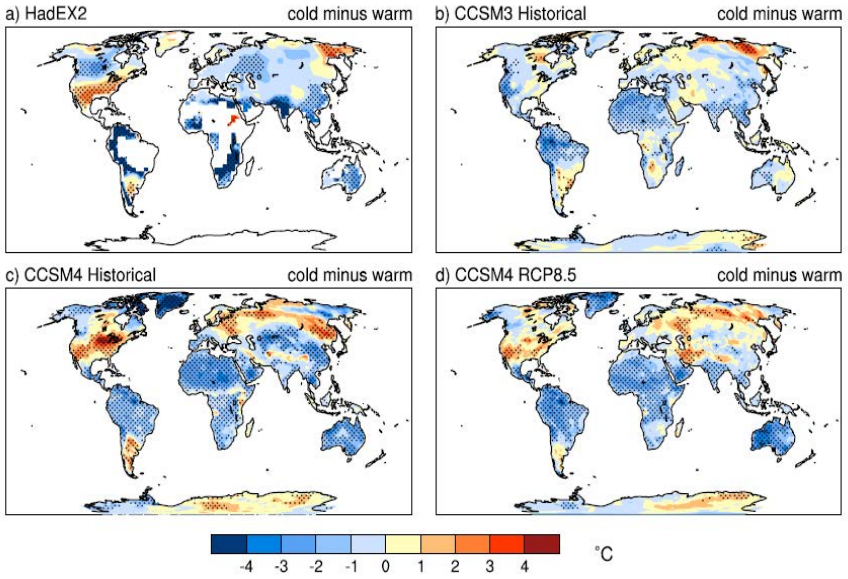
- Identify optimum method for initialization, given imperfect and incomplete observations and assimilation systems
- Determine the added skill in predictions with initialization
- Assess the impact of small ensemble size on the spectrum of decadal means
- Establish what predictions should be attempted,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

Research Challenge: Climate and Extreme Events

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

SST and upper ocean heat content influences on atmospheric heating and circulation

Other factors: soil moisture and terrestrial evaporation, water availability, vegetation, snow cover & sea ice



Source: Arblaster and Alexander (2012)

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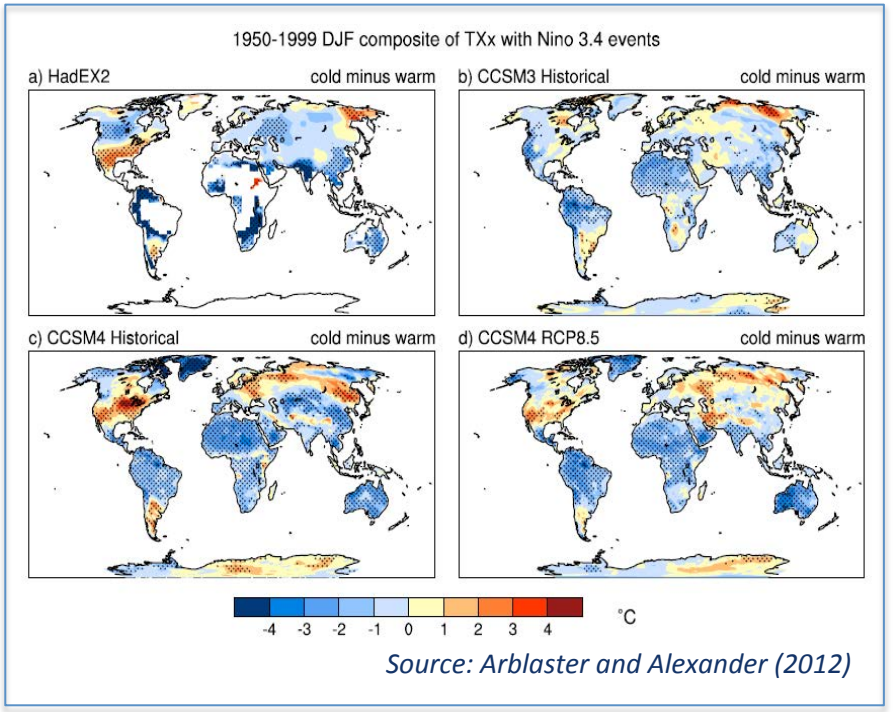


Source: Arblaster and Alexander (2012)

Future research

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

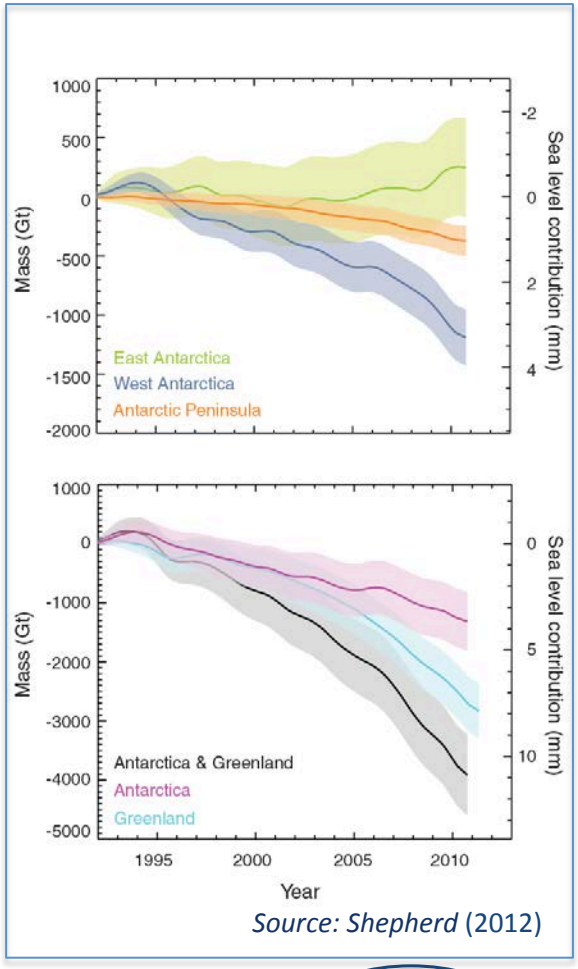
Research Challenge: Polar Climate

Changes in SH atmospheric circulation and SO eddies on SO/ACC stratification 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

Potential impact of warming and sea ice changes on mid-latitude extremes



Source: Shepherd (2012)

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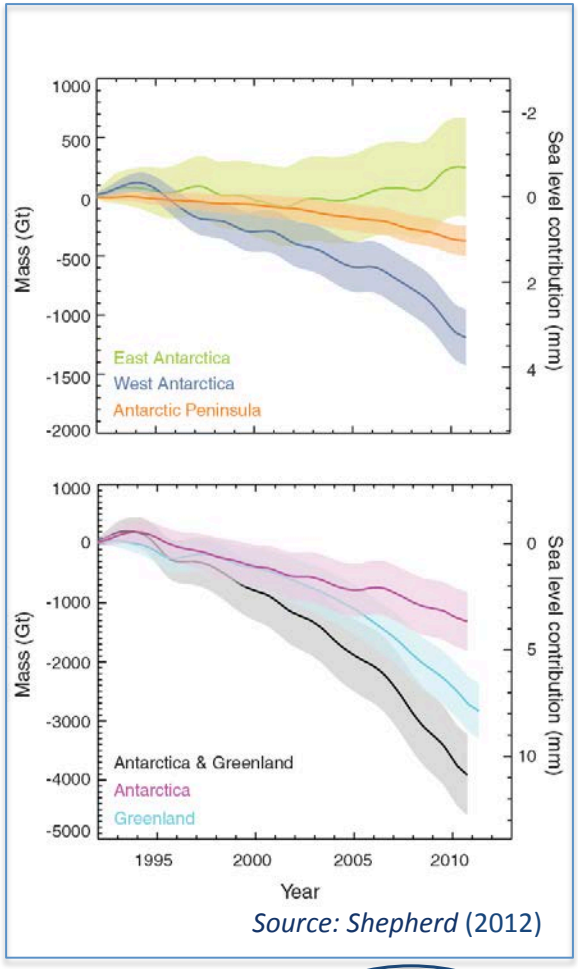


Source: Shepherd (2012)

<u>Future research</u>

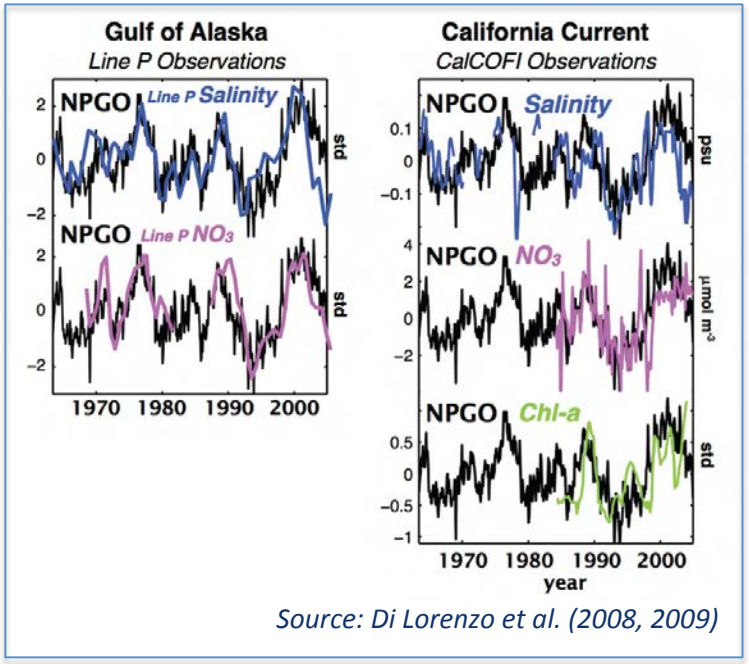
- Expand observational basis for monitoring variability/change and understanding mechanisms
- Synchronize data quality control and processing
- Identify processes that models need to capture to improve simulation and predictability

Research Challenge: Climate and Marine Carbon/ Biogeochemistry

Understand 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

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)

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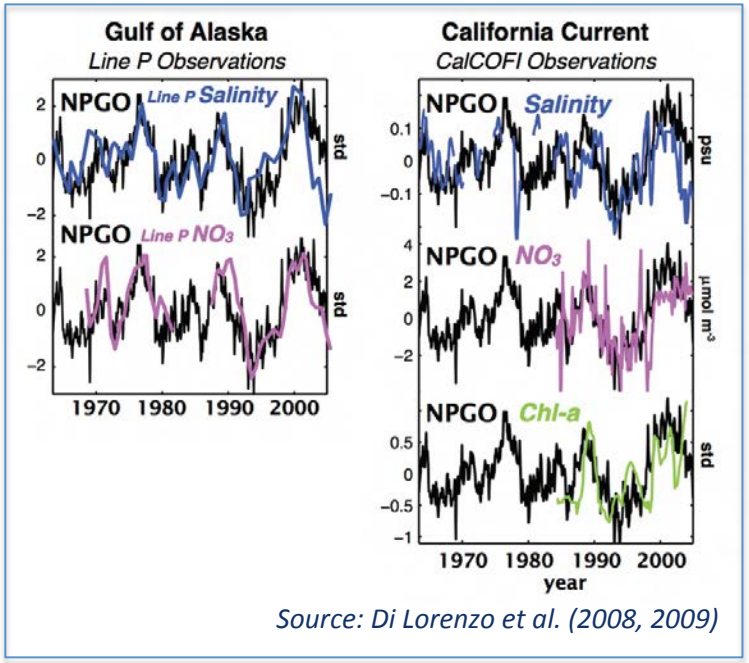

Source: Di Lorenzo et al. (2008, 2009)

Future research

- Develop and deploy multi-purpose ocean-observing systems, exploiting innovation in oceanographic instrumentation – e.g., 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

Cross-cutting 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 observed 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 variability and change 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

Cross-cutting Strategies

	POS Panel	PSMI Panel		PPAI Panel	
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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***

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*

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*

Quantifying Improvements 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*

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***

Implementation Approaches

- **Science Teams**
  - Considered and determined by agencies
- **Working Groups**
  - Are current WGs achieving their objectives?
  - What additional topics for future WGs (two new in 2015)?
- **Climate Process Teams (CPTs)**
  - How well have CPTs achieved objectives?
  - What are lessons learned that have emerged?
  - Are other approaches recommended for future model improvements?
- **Science Meetings/Workshops**
  - Are there priority topics for US workshops beyond those organized by WGs?
- **Agency-supported Research Calls**
- **Opportunities for Students, Postdocs, and Early-career Scientists**
  - How well are students and early-career scientists presently engaged?
  - Are there other approaches to provide opportunities?

Program Cooperation and Coordination

Engagement of US and International programs and infrastructure

- **USGCRP**
  - Land surface hydrology (**with US GEWEX**) and terrestrial ecosystem impacts research
  - Carbon cycle, ocean biogeochemistry and marine ecosystem research **(with OCB**)
  - Atmospheric aerosol-cloud interactions
  - Polar and cryospheric research (**with SEARCH/IARPC and Polar Programs)**
- **WCRP**
  - International CLIVAR
  - Global Energy and Water Exchanges (GEWEX)----------
  - Climate and Cryosphere (CLIC)
  - Stratospheric Processes and their Role in Climate (SPARC)----

  } Engaged through International CLIVAR
- **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

Summary

- Science Plan presents motivation for continued US program on role of the ocean in climate
- It presents new US CLIVAR Goals, reflecting the progress of the program and evolving context
- It outlines societally important Research Challenges that will benefit from coordinated focus for next decade
- Implementation to achieve Goals and address Research Challenges is facilitated through Panel-organized cross-cutting strategies
- Specific implementation activities are identified by the SSC and Panels to foster community-based work
- Coordination with other US and International science programs, infrastructure programs, and service providers is essential for achieving the US CLIVAR mission

Thank You

US CLIVAR
Climate Variability & Predictability