US CLIVAR
Climate Variability & Predictability

2014 US CLIVAR SUMMIT REPORT

July 8-11, 2014
Denver, Colorado

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COVER IMAGE

Sunset over the Rocky Mountain National Park from Fall River Road, Colorado, by John B. Kalla, license CC BY-NC-DC 2.0.

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1 Introduction

The 2014 US CLIVAR Summit was held in Denver, CO on July 8-11 and brought together over 60 participants from the science community and federal agencies. Each year, the Summit provides the opportunity to review progress, identify opportunities, and develop strategies to advance US CLIVAR goals.

A focus for the 2014 Summit was to identify and discuss benchmarks and metrics for evaluating improvements in monitoring and analysis, model development, and prediction. Plenary sessions and joint breakout sessions between the Panels were held to accomplish this focus. In addition, two specials sessions were featured to highlight important and timely topics for the community. The first, ENSO Monitoring, Analysis, and Prediction Challenges, provided an engaging discussion on the factors that lead to ENSO events, uncertainties in prediction, and what the models are forecasting for the possible 2014 event. The other special session, Progress and Prospects for Connecting Predictions, Applications, and Decision-Making, brought together members of the climate service community to exchange knowledge on the prospects and limits of climate information and the concerns and needs for end-user organizations.

This year's Summit built upon the release of the new Science Plan by concentrating on the implementation and alignment of activities according to the goals, research challenges, and crosscutting strategies for the US CLIVAR program. The following summary features highlights from the presentations, discussions, and resulting action items the community plans to use as direction for the future.

Presentations from the Summit are available **online**.

2 Day 1: July 8, 2014

2.1 Welcome, Objectives, and Overview of US CLIVAR

The Summit was kicked off by Bob Weller, chair of the US CLIVAR Scientific Steering Committee, with introductions and an overview of the meeting objectives and how they related to the Science Plan. Following contextual presentations on US and International programs and plans, the Summit would focus on panel business, with a review of progress, identification of gaps and opportunities, and cross-panel dialogue on interfacial topics, including tools and metrics for intercomparisons of reanalyses and observation requirements and metrics for quantifying predictability and prediction. Two science sessions would engage discussion of timely research on ENSO monitoring, analysis, and prediction, and connecting climate science and services by exploring application needs.

Weller highlighted the importance of synthesis of data to address a more global, three-dimensional context of the ocean, ranging from the slowing down of the surface warming, thought by some to reflect stronger Pacific trade winds and more heat entering the deep ocean by Ekman pumping, to growing evidence for warming at depth, to identifying what changes are going on at mid-depths and how and when these changes feedback on or impact the equatorial oceans. With much more data now with a decade of Argo, more recent repeat hydrography, and sustained time series, the community is poised to move forward toward more data integrative investigations of the three-dimensional ocean circulation.

Building upon the stage setting for the meeting, Mike Patterson, US CLIVAR Project Office, provided an overview of US CLIVAR including its history and goals for the future. An announcement about the establishment of a US GEWEX program was provided to the community, with the note that the official announcement would occur at the GEWEX Open Science Conference that was taking place in conjunction with the Pan-CLIVAR Meeting at The Hague the following week. Direction was also provided to the participants that up to two new working groups could be established in 2015, and the Summit was a good place to begin nurturing those ideas and to look at previous working groups for measures of success.

2.2 Special Session on ENSO Monitoring, Analysis, and Prediction Challenges

The looming ENSO had been drawing much attention, but also raised the question of next steps needed to reduce the uncertainties in predictive capabilities, extending lead time for the forecast. The then recent reduced data returns from the equatorial Pacific observing system, i.e., TAO array, led to questions of the value of observational data for monitoring and prediction. These questions motivated the ENSO science session.

Yan Xue, NOAA National Centers for Environmental Prediction, explained the current operational approaches to ENSO monitoring and prediction, using observation-based indices, multiple ocean reanalyses, and multi-model ensemble forecasts. NOAA's classification system for El Niño requires that the sea surface temperature anomalies must exceed 0.5°C for a period of five consecutive, overlapping three-month seasons. The NOAA outlook as of June 2014, based on subjective synthesis of ensemble model forecasts and recent evolution of atmospheric and oceanic conditions, was for a 70-80% chance of an El Niño event developing with high confidence. Uncertainties in ocean reanalyses appear to be partially attributed to the decline in the TAO array. However, whether these reanalyses uncertainties have contributed to differences in the forecasts by different coupled models is not clear.

Arun Kumar, NOAA Climate Prediction Center, addressed the uncertainties of ENSO prediction and how it is effectively measured. The spread among a set of model forecasts is used as a measure of uncertainty. Such spread in ENSO forecasts is due to sensitivity to the specification of initial conditions, which incorporate individual model biases, imbalances and initial shocks during initialization, and representation of observational errors. Predicting the right amplitude of an event, which is important for impacts, is found to be equally difficult for large and small events alike. RMSE measures indicate that forecast uncertainty in models is approaching a realistic magnitude. An important related challenge is the effective communication of uncertainty to be useful for incorporating into decision-making. For the 2014 event, Kumar concludes that fewer TAO observations may be affecting the spread (uncertainty) of the forecasts, but that this is likely not dominant factor, as we have seen similarly large spread among forecasts for other events with a fully operational TAO array.

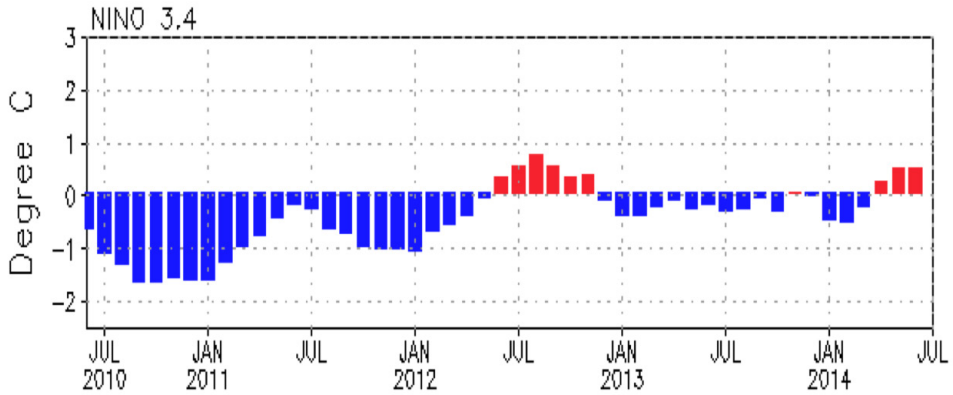

Figure 1. Monthly Tropical Pacific sea surface temperature anomalies (°C) between July 2010 and July 2014.

3 Day 2: July 9, 2014

3.1 Implementing the US CLIVAR Science Plan

The motivation for developing the Science Plan came from the need to update our direction based on the latest science and in light of advances in observing, modeling, and assessments that have emerged since US CLIVAR started over 15 years ago. Now that we have released the plan, it is now time to focus on implementation.

Weller continued by reviewing the mission of US CLIVAR, overarching goals for the program, and the research challenges that are meant to expand the program beyond its traditional foci. Implementation to achieve the goals and address the challenges would be through Panel-organized cross-cutting strategies.

Discussion arose about how the US can coordinate with the international community on particular topics, specifically decadal variability and predictability. A key way to advance the US research challenge on decadal predictability is by enabling US scientists to participate in the international CLIVAR and WCRP conferences and meetings focused on this topic. US scientists who participated in and the approaches developed by the US CLIVAR Decadal Predictability Working Group are being entrained into the international planning effort. There are also research topics for which the US may be ahead of the international community (e.g., climate and carbon cycle interactions); therefore coordination should be in both directions. and be considered an important step prior to applying for funding.

3.2 International CLIVAR

Detlef Stammer, co-chair of International CLIVAR Scientific Steering Group, briefed participants on evolving plans for International CLIVAR, starting with its recast name: Climate and Ocean – Variability, Predictability, and Change. The program's role in the World Climate Research Program is to coordinate research to observe, simulate, and predict changes in Earth's climate system with a focus on ocean-atmosphere interactions. By coordinating with the other WCRP projects, CliC (cryosphere-climate interactions), GEWEX (land-atmosphere interactions), and SPARC (troposphere-stratosphere interactions), CLIVAR leads the WCRP Grand Challenges on regional climate information, sea level rise and regional impacts, and climate extremes. CLIVAR is in the process of formulating its new Science

Plan and Implementation Strategy, and will continue to focus on a global and balanced approach with a new set of research foci, many of which align with US CLIVAR challenges. The CLIVAR office has been restructured with nodes in China and India with sponsorship by China, India, and the US. A CLIVAR Science Conference to review the advances in research and showcase the new Science Plan and research foci is being planned for 2016 in Qingdao, China.

Stammer acknowledged the importance of the very good working relationship between the US program and the WCRP/CLIVAR, noting the considerable US member participation in international panels and research foci/grand challenge teams, the international participation in US working groups, and through long-standing financial sponsorship of the international CLIVAR office. Areas for improvement include closer coordination on science goals, implementation, developing and using the same language, and collaborating on joint activities (e.g., coordinated Climate Process Teams (CPTs), workshops, and the CLIVAR open science conference).

3.3 Agency Updates

NSF

Eric DeWeaver informed participants that as of March,NSF has a newly appointed director, Dr. France Córdova. NSF released a new strategic plan in March 2014, and emphasized that the focus of the "F" in NSF is on frontier, which makes it different than an agency.

The climate science focus of NSF goes well beyond CLIVAR to advance discovery, knowledge, and understanding in all areas. NSF science is a very community-driven; it does not attempt to set priorities for the research communities. Some of the recently supported CLIVAR activities include CPTs, the Dynamics of the MJO (DYNAMO), Atlantic Meridional Overturning Circulation (AMOC), and Climate Model Evaluation Project (CMEP). US CLIVAR can provide value to NSF in a variety of ways, including feedback on long-range scientific priorities, by represent the broader climate research community, promoting activities underway, supporting information and interaction to lead to strong research proposals, and serving as a venue for community input to large field campaigns.

NOAA

Sandy Lucas noted that the NOAA Climate Program Office Strategic Plan was released on June 27 and guides the office for the next 5 years. The CPO strategic goals framework includes partnerships, integrated climate research, people and culture, and business processes. The societal challenges identified for integrated climate research include weather and climate extremes, climate impacts on water resources, coasts and climate resilience, and sustainability of marine ecosystems.

Lucas identified ways US CLIVAR can engage with the agency through organizing the research community to establish needs and requirements, coordinating interagency response to community activities, and linking US and international research initiatives.

Office of Naval Research

On behalf of ONR, Weller presented the current and relevant activities that are of interest to the community, such as studies for the marginal ice zone to CMIP5 analysis support. Relevant

priority interests for ONR include integrated global prediction, the Arctic, and Earth system prediction capability. ONR has very small annual budgets and the main intersection is through the Departmental Research Initiatives, which are five-year well-funded focused, topical research efforts. The Navy also provides great support for the UNOLS program. A variety of ways the US CLIVAR community can get involved with ONR is through interaction with ONR-sponsored scientists, identifying new areas of research, and fostering information exchange.

Department of Energy

Renu Joseph, representing the Regional and Global Climate Modeling program of the Biological and Environmental Research Division, shared various links between DOE and US CLIVAR. Activities supported over the past three to four years include model development, diagnostics, and analyses; support of CMIP5; and infrastructure and research support of projects like VOCALS and DYNAMO. DOE has been instrumental in supporting Earth System Grid Federation, the data informatics program for Earth system and CMIP5 data. In the Regional and Global Climate Modeling portfolio there are science focus areas at the labs relating to US CLIVAR research challenges, such as long- and short-range climate variability and predictabilty and campaigns in the high latitudes. Renu suggested ways to engage with DOE, including participating in workshops to help identify metrics and development of next generation of visualization tools.

Dorothy Koch updated on DOE Earth System Modeling and Accelerated Climate Model for Energy (ACME) programs in the division. ACME – an offshoot of the CESM – will focus on high-resolution modeling and support DOE's mission and science goals. The ACME project is a large proposal and has recently launched its Project Strategy and Initial Implementation Plan.

3.4 Coordinated Ocean-Ice Reference Experiments Phase II (CORE-II)

Gokhan Danabasoglu, NCAR, provided updates on CORE-II, an experimental protocol for ocean-ice coupled simulations forced with interannual-varying atmospheric datasets. Of importance to CLIVAR, these hindcast simulations provide a framework for evaluation, understanding, and improvement of ocean models; the investigation of mechanisms for seasonal, inter-annual, and decadal variability; and the evaluation of robustness of mechanisms across models, and the initialization of decadal predictions. Currently there are over 20 participating modeling groups involved with the project, each following consistent simulation protocols, with freedom in choice of parameterizations, treatment of surface freshwater/salt fluxes, and sea-ice models. Data sets are publically available through the CLIVAR CORE webpage. Analyses of the CORE-II data covering all the ocean basins will be published in a special issue of Ocean Modelling. Some of the highlights from the CORE-II analyses show differences in solutions of mean and variability, primarly due to differences in ocean model parameterizations, parameter value choices, and the variety of sea-ice models employed. It was noted that certain models are better for certain basins and applications. Furthermore the CORE-II project is looking at pursuing experiments with high-resolution ocean models and discussing a request to include CORE-II in the CMIP framework.

3.5 Process-Oriented Diagnostics to Inform Model Development

Jim Kinter, George Mason University, provided an overview of the NOAA CMIP5 Task Force efforts to develop process-oriented model diagnostics to inform model development and applications. The approach is to move beyond simple diagnosis of model biases for simulating a particular phenomena, and to gain a physical understanding of why, thereby providing insights into model behavior. Guided by a successful pilot project demonstrating the use of metrics to provide insight into modeling of the MJO, the Task Force is developing diagnostics for blocking, tropical cyclones, Great Plains precipitation, Next steps for the Task Force include expanding beyond atmospheric processes and land-atmosphere interactions to include ocean and sea ice diagnostics, fostering collaborations with additional modeling centers, and exploring use of process-oriented metrics for informing applications and assessments (e.g., National Climate Assessment).

3.6 Science Team and Working Group Reports

US Atlantic Meridional Overturning Circulation Science Team

Danabasoglu updated participants on the structure and progress of the US AMOC Science Team, There are currently 65 funded projects and over 125 scientists supported by NASA, NSF, NOAA, and DOE comprising the Science Team. An external review of the program, completed in 2013, gave a very positive assessment of the US AMOC program objectives, structure, and progress, characterizing the effort as "successful, impressive, and stimulating." The review presented several recommendations now being implemented for improving the program's effectiveness, including formalizing leadership rotations, improving communication through teleconferences and updating the web presence, and setting longer-term goals, that could exceed the lifetime of the Science Team. The 2013international science meeting, convened jointly with UK RAPID, identified a set of collaborative research needs such as faster real-time availability of RAPID data, adoption of new technologies, development of long-term proxies, development and use of coupled data assimilation to combine oceanic and atmospheric observational data, and the testing of variability mechanisms across models. AMOC's influence on things such as the "hiatus", Greenland's ice sheet, and the climate were also discussed. Near-term research priorities, presented in the 2013 Annual Report have been recently expanded, based on the 2013 meeting and subsequent Task Team discussions, and will be presented in more detail in the September 2014 meeting in Seattle, Washington.

Figure 2. Components of the AMOC observing system. Image provided by Jack Cook, WHOI.

Eastern Tropical Oceans Synthesis Working Group

Tom Farrar, Woods Hole Oceanographic Institution, provided the history and an update on the working group. Formed in 2012, the working group is based upon the outputs of a workshop that looked at the eastern tropical Atlantic sea surface temperature biases. The objectives for the working group are being achieved with increased collaboration between observationalists and modelers, and atmospheric scientists and oceanographers (large international collaboration as well); coordinated model assessment, by examining CMIP5 flux biases in both the eastern Pacific and eastern Atlantic; identifying recent model improvements and common and persistent model errors, such as sea surface temperatures along the equator, location of the Angola-Benguela front, and the seasonal cycle of stratocumulus; and providing recommendations of cases for simulation evaluation, using eddy-permitting ocean models. The working group is drafting a white paper/journal article and will wrap up in the next year.

Hurricanes Working Group

Suzana Camargo, Columbia University, provided an overview of the working group objectives and tasks, and noted that the group membership expanded due to large interest in participation, particularly by the international community. Nine (of some 20 planned) papers in a Special Collection of J. Climate and a workshop report have been published. A BAMS paper describing the coordinated model experiments and findings of the working group has been submitted. Currently, Lamont-Doherty Earth Observatory is hosting the database furnishing monthly model outputs. This will soon be made publically accessible for use by other scientists and the general public. However, higher resolution daily and six-hourly data will require a different host (possibly Australia). Highlights of results include the finding that forecasting TC activity in the North Atlantic is difficult for any model. Hurricane intensity improves with higher resolution, and there is not a linear correlation to changes in frequency when adding sea surface temperature and CO_2 data with most of the models. With the completion of the working group this year, there has been discussion of follow-on activities at the international level, with interest to look at ocean impacts from tropical cyclones and/or experiments using coupled models.

Extremes Working Group

Matt Barlow, University of Massachusetts-Lowell, outlined the problem focus of the working group—short-term extreme events (one to five days) that have large societal impact, but are difficult to analyze. The focus is specifically on the North American region and on phenomena such as heat waves, cold snaps, and heavy rains, not related to tropical storms. The group aims to assess and synthesize the existing knowledge of Large Scale Meteorological Patterns (LSMPs) and their relationship to temperature and precipitation extremes, identify key question and gaps, establish a methodology and research protocols, and provide a preliminary assessment of the ability of models to reproduce the correct relationship between LSMPs and extremes for North America. A workshop held in August 2013 at Berkeley National Lab, which assembled researchers from different topical areas including statistics, observations, synoptic dynamics, and modeling, addressed the above objectives and concluded that LSMPs are very useful for analyzing dynamics and to provide a basis for downscaling. The workshop report provides specific, detailed recommendations regarding obervations, analyses, and modeling. Suggested next steps include funding additional work on synoptic dynamics of extremes, encourage modeling groups to assess simulation of extremes in

terms of the synoptic dynamics, continue to improve observations over land and ocean regions, and hold regular workshops with the community.

Greenland Ice Sheet/Ocean Interactions Working Group

Fiamma Straneo, Woods Hole Oceanographic Institution, reported that the goals of the working group had largely been accomplished, with the fostering of a collaborative community of oceanographers, galicologists, atmospheric and climate scientists to advance the understanding of the processes involved in the interaction between glaciers and the ocean in Greenland, which can lead to better representation in models. One of the priorities for the working group, when generating its reports, has been to release it for public feedback and then incorporate input into a final document (e.g., a BAMS publication). The workshop report is meant to bring about as much of a consensus as possible for the community and identified priorities such as targeted process studies to fill specific gaps, develop an in depth study at one or two sites to study the interaction of the different components, develop a Greenland Ice Ocean Observing Systems, compile data and share with the community, and improve bottom topography all around Greenland. As the working group is winding down, the future of GRISO includes creating an international working group. The focus will be slightly different and be reoriented to follow some of the priorities identified in the report.

Southern Ocean Working Group

Joellen Russell, University of Arizona, and Igor Kamenkovich, University of Miami, jointly presented on the outcomes and deliverables set for the working group such as observational data and model metrics for consistent model evaluation, planned publications, and an upcoming joint workshop with the Ocean Carbon Uptake Working Group at Fall 2014 AGU to share metrics, evaluate model biases, and provide guidance for estimating/reducing uncertainty in climate projections. The model spread of heat uptake is very large for the Southern Ocean. It is not stratifying, as originally suggested, but mixing that is changing significantly with increased warming. There are valuable new tools available for studying the region, including an expanding Southern Ocean Observing System, a new Southern Ocean State Estimation using the MITgcm, new Earth system models that include carbon cycle, and mesoscale-resolving climate models. The working group has compiled a series of metrics in 13 areas of interest that can be applied to climate model simulations. Russell presented several example analyses using the various metrics. Recommendations were made to include more in situ biogeochemical observations of the Southern Ocean, implement more CPTs, develop more observationally-based climate model metrics, and initiate a Southern Ocean model intercomparison project.

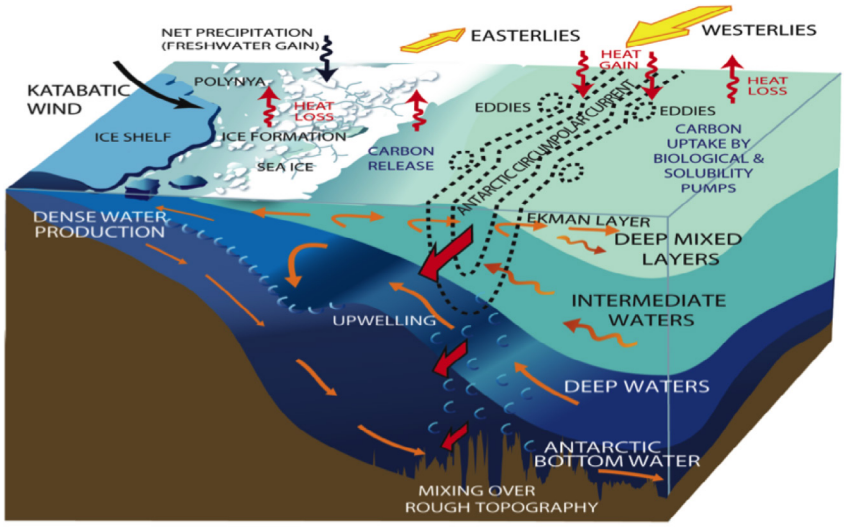

Figure 3. Diagram of the Antarctic circumpolar current system. Image provided by Lynne Talley, Scripps Institution of Oceanography.

Ocean Carbon Uptake Working Group

Take Ito, Georgia Tech University, presented the objectives of the working group, which are to foster and promote collaboration between modelers and theoreticians and to advance the understanding of the processes responsible for the oceanic carbon uptake and their representation in climate models. An improvement with the CMIP5 model, in regards to the carbon-climate feedback cycle, is the uptake of ocean carbon and the response to CO_2. However, there are major differences among the models between the physical and biogeochemistry processes. The weakening of the Southern Ocean convection is a robust feature of the CMIP5 model, and diminishing polar overturning may be trapping the carbon, while less carbon may be entering. Finally, the working group organized the 2013 NCAR Advanced Study Program summer colloquium on Carbon-Climate Connections in Earth System Models, which helped identify common research questions common to both the marine and terrestrial carbon cycle and linking physical and biogeochemistry interactions.

ENSO Diversity Working Group

Antonietta Capontondi, University of Colorado, reported on the importance of understanding ENSO diversity including it's origins, complexity, and response to global warming. The conceptual framework for identifying and understanding differences among El Niño events is a primary focus of the Working Group—particularly centered on the question of bimodality or continuum. Using the Center of Heat Index (CHI) methodology, which characterizes longitudinal distribution of ENSO events without using specific indices, reveals a broad, smooth event distribution by longitude; not supporting the idea of two preferred longitudinal peaks. Dynamical processes appear to differ for different events. Recharge and discharge processes become progressively weaker, while surface heat flux damping and zonal advection are increasing important for events peaking further west. The working group concludes that "ENSO can be described as a coupled atmosphere-ocean phenomenon that exhibits substantial variations with regionally different feedbacks, leading to a diverse continuum of realized ENSO events. Open questions include the origin of the different event types and their predictability precursors, predictions of different ENSO types, and teleconnections and their impacts. The Working Group plans to publish an article and special collection, develop ENSO diversity metrics and a recommendation to the modeling community, and provide input to International CLIVAR.

3.7 Special Session on Progress and Prospects for Connecting Predictions, Applications, and Decision Making in the US

Gregg Garfin, University of Arizona, provided an overview of this special session and its purpose to connect the climate services and science communities and improve the coordination between them through direct connections, exchange of knowledge, and learn about the concerns and questions as they relate to US CLIVAR. Garfin equated this session to the analogy of a baby being born – once the baby is born you don't just leave the hospital and say "we are done;" you need to continue to nurture and mature the research and objectives.

Garfin identified various crosscutting strategies to collaborate with the research communities that develop and use climate information:

- Sustained and new observations:
    - Provide multi-disciplinary datasets
- Process studies:
    - Provide process understanding and opportunity for collaboration across disciplines
- Model development:
    - Strengthen communication between observational and model communities
- Quantifying improvement in predications and projections:
    - Improve communication across disciplinary boundaries
- Communication of climate information:
    - Provide information on dominant climate phenomena and predictability.

Water Resource Communities

Jim Prairie, Bureau of Reclamation, shared that the Bureau climate change focus addresses the long-term climate change impacts, short-term variability from floods to droughts and data collection, tools, and training resources. He mentioned an interagency report that recently came out and focuses on where there are gaps and needs in monitoring, forecasting, and information use for the ability to adapt to climate change for the water management community. For example, the Bureau and NASA have partnered for an airborne snow observatory project to monitor the amount of snow pack in some of Colorado's basins. Findings from a NOAA and Bureau of Reclamation workshop on drought identified user needs to include seasonal and subseasonal prediction, particularly during spring runoff.

Natural Resource Communities

Shawn Carter, US Geological Survey, provided an overview of the Climate Science Centers (CSCs), which are a consortium of federal and academic partners that focus on applications of climate science. CSCs have a variety of foci including species distribution, threshold responses, and ecological surprises like big events that will upset these natural resources. They also provide guidance on vulnerability assessments and try to highlight existing tools that are relevant to the region. Some of the needs for the CSCs are making key linkages to the decision community and identifying decision-support tools, develop tangible products that have a practical use for managers, and identify the climate variables that managers needs and will have on the ground application. The idea of actionable science was stressed. Where there are conversations between researchers and managers, there is a need for an iterative, co-development process.

Agriculture and Forestry Communities

Linda Joyce, USDA Forest Service, started by identifying weather and climate needs for the community, which includes historical climate data, extreme events and weather alerts, short-term forecasts from day to month to year, and climate change projections on a fine scale. In regards to extreme events, past experience sets the state for how management responds and the conversation will vary depending on how the event was attributed (i.e., human caused or natural variability). In the agricultural community, short-term forecasts are typically not well received, yet such information has importance for applications such as creating a flexible grazing strategy for farmers. One important aspect the community needs to focus on is framing the risk with downscaling climate projections.

Marine Ecosystem Communities

Mike Alexander, NOAA Earth Systems Research Laboratory, discussed fisheries operations and that the interaction with climate occurs over various timescales and space. Some areas for research within the community include moving from an index based approach in research toward a comprehensive understanding of the system, move from fisheries stock assessments to ecosystem based management, and identify the role of climate change versus other factors like degradation of habitat for endangered species. Some of the impacts of climate change may not seem important on their own, but when looking across the entire spectrum (including social/economic impacts) they can be greatly important. Some of the opportunities and challenges for the community are enhancing communication, downscaling, explaining and quantifying uncertainty in climate forecasts and projections, and developing tools for ease and accessibility.

Water Management Communities

Robin Webb, NOAA Earth System Research Laboratory, presented a case study of the Russian River Basin and the environmental management challenges the region faces. The native salmonoid populations are impacted by the water supply from Lake Mendocino, which is used to manage flood control and stream flows for the watershed. One of the major challenges the managers are facing is the need for better predictability of major precipitation events to help manage the water storage. Webb then identified some of the needs from the research community including the need to know large-scale dynamics of extreme events to better predict the timing of the next extreme precipitation event, a need to better predict changes in extremes on the timescale of three to six month, and the need for reliable and skillful forecasts, decadal outlooks of nutrient content of upwelled waters, and multi-decadal outlooks of sea level rise.

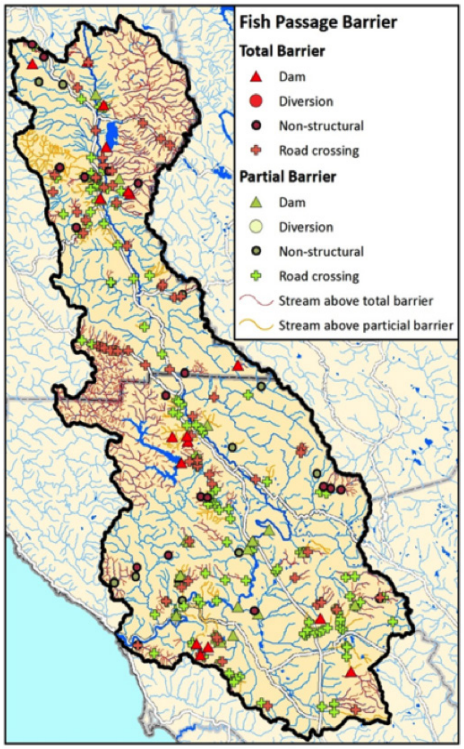

Figure 4. Image of the Russian River Watershed and the complex flood control and water management system for Lake Mendocino and the area.

The special session concluded with a panel discussion. Addressing the question of how they decided what information to pass on to end user communities, panelist responses ranged from the need for a process with stakeholders to show that a new product will work, and focusing on only the information a community needs for decision making, to the concept of thinking of information and products as being in a beta-mode where the science and information will continue to evolve over time. The concept of working in beta-mode, including experimental operations for the agencies, was well received. Challenges include moving information through the agencies, lack of resources, potential scale of a project, too much information and/or not the right information, and long-term planning. The panel identified areas of future research and opportunities for the community such as generating a risk framework for future climate scenarios and identifying and agreeing on the metrics for the models.

4 Day 3: July 10, 2014

4.1 POS Breakout Report

List of panelists attending the Summit

Matt Barlow, Subrahmanyam Bulusu, Antonietta Capotondi, Emanuele Di Lorenzo, David Halpern, Dimitris Menemenlis, Art Miller, Renellys Perez, Yan Xue, Xiao-Hai Yan, and Xiangdong Zhang

Summary of action items from 2013 Summit and update on progress for each

1. Review the POS Panel Terms of Reference.
   Status: Done. The revised terms of reference are listed on the website. The first four terms are specific to the POS Panel. The remaining five terms are shared among all panels.

2. Review POS membership.
   Status: Done. Three new members were selected to join the POS Panel and include Carol Ann Clayson, Emanuele Di Lorenzo, and Renellys Perez.

3. Review of November National Center for Weather and Climate Prediction (NCWCP) GODAE Symposium at next year's summit.
   Status: Done.

4. Revisit extremes issues following the upcoming working group workshop.
   Status: Done.

5. Review Obs4MIPS following their workshop.
   Status: Done.

6. Discussions on possible new working groups.
   Status: Done. Three new working group ideas were proposed during the 2014 Summit.

7. Collaboration with PSMI on reanalyses innovation, increments and residuals.
   Status: A joint session with PSMI Panel was organized at the 2014 Summit to explore this topic.

8. The panel emphasized that continuation of TAO/TRITON array is essential for advancing understanding of ENSO diversity, initialization of prediction models, and evaluation of climate models before they are used for ENSO projections and predictions.
   Status: NOAA and international partners organized a workshop in January 2014, aiming to restore and redesign the Tropical Pacific Ocean observing system for 2020.

Summary of each panel session

Review of November NCWCP GODAE Symposium and real-time multiple ocean reanalyses intercomparison to quantify uncertainties in ocean reanalyses (Yan Xue)

An ensemble of six operational ocean reanalyses has been collected to assess signal (ensemble mean) and noise (ensemble spread) in upper ocean temperature analysis in near real-time. Uncertainties in ocean reanalyses seem partially attributed to the declining TAO array. The spread of ensemble ocean reanalyses decreased abruptly in early 1990s when the TAO array was fully implemented. The spread started to increase since 2010 and reached a peak value in 2013 when the TAO array return rate dropped to 40%. Although there are uncertainties in ocean reanalyses, the ensemble mean of multiple ocean reanalyses likely provides the best estimation of the state of the ocean and can be used to derive climate indicators. The ensemble spread provides uncertainties in estimation. The ensemble mean of temperature analyses has been used in monitoring and prediction for current ENSO conditions.

El Nino, La Nina, and Walker Circulation (David Halpern)

In the Pacific Ocean, surface winds flow from east to west, with a small area east of the Galapagos Archipelago where the wind direction is westerly. In the Indian Ocean, the surface wind flows from west to east, and in the Atlantic Ocean the surface wind is easterly. In the upper troposphere, the zonal wind direction is opposite that at the surface. This global wind pattern, known as the Walker Circulation, is coupled to the zonal sea surface temperature distribution and therefore responds to El Niño and La Niña conditions. The oceanic longitudes of the transitions from eastward-to-westward wind directions at 10- and 700-m heights, and of maximum easterly and westerly 10- and 700-m wind speeds during El Niño, La Niño, and normal conditions were described with satellite vector wind observations during 2000-2011.

Review Obs4MIPS and Ana4MIPS (Felix Landerer)

Primary objectives of Obs4MIPs & Ana4MIPs are to provide data products directly comparable to a model output field defined as part of CMIP5/CMIP6. Obs4MIPs & Ana4MIPs leverages existing CMIP infrastructure, but additional work is still needed to better accommodate data sets. Ana4MIPs is growing, with the goal to include more ocean reanalysis data sets. The goal discussed was less about model evaluation, but to provide observation-based quantities for climate model evaluation that are not available in any other form. Obs4MIPs data: www.earthsystemcog.org/projects/obs4mips Ana4MIPs data: www.earthsystemcog.org/projects/ana4mips

ENSO diversity and impacts (Antonietta Capotondi)

A major factor determining the importance of ENSO diversity is the dependency of ENSO-related impacts upon details of the sea surface temperature anomalies spatial pattern. ENSO impacts climate

both locally and remotely, through atmospheric/oceanic teleconnections. Different event types are also associated with different biological influences, as exemplified by the 1997-1998 and 2009-2010 events. Both event types – in particular eastern Pacific events – influence the strength of the Aleutian Low, which provides the atmospheric forcing for the Pacific Decadal Oscillation. Central Pacific events are also related to the strengthening of the southern lobe of the North Pacific Oscillation, which in turn, forces the North Pacific Gyre Oscillation, a mode of sea surface temperature and sea surface height variability that has a large influence on ecosystem dynamics. Eastern and central Pacific events are associated with different temperature and precipitation anomalies over the US.

Pacific Ocean decadal variability and ecosystem response (Art Miller)

An understanding of the physical processes involved in Pacific Ocean decadal climate variability is needed to properly account for the observed relations between oceanic ecosystem changes and climate indices. Explanations of the basic physical processes associated with the Pacific Decadal Oscillation and the North Pacific Gyre Oscillation were presented both in the context of diagnostics relations and predictable components. Comments on the prospects for exploiting the predictable components of these climate variations for ecosystem forecasts on various timescales (seasonal, interannual, decadal and centennial) was given.

Deeper ocean remote sensing and deeper ocean response to climate change and hiatus (Xiao-Hai Yan)

Global warming hiatus refers to the slow-down or even slightly decreasing trend of the mean global surface temperature since 2000. Subsurface/deeper ocean warming has been identified as one possible cause. Due to lacking of observing data for deeper ocean, deeper ocean remote sensing may play a more important role in climate hiatus research. Satellite remote sensors cannot see far beneath the surface layers of the ocean. However, many of subsurface phenomena have surface manifestations, which can be interpreted with the help of models (including empirical, dynamical and numerical methods), and available deeper ocean observations to derive key parameters of deeper ocean processes. Funding for such efforts should be encouraged and increased.

Arctic climate change and extreme midlatitude events: Observational analysis and modeling investigation (Xiangdong Zhang)

Rapid climate change has occurred in the Arctic, which is evidant by a decade-long accelerating decline of sea ice. At the same time, drastic changes have also occurred in broader areas in the Northern Hemisphere, including a spatial shift of the maximum surface air temperature warming trends from the Eurasian continent to the central Arctic Ocean, an enhancement of poleward oceanic and atmospheric heat transport from either the North Atlantic or North Pacific oceans into Arctic, and a widespread of extreme cold weather and snow storms from the US east coast to Europe and Asia. The presentation synthesized recent progresses towards improving understanding of the rapid changes in Arctic and the its interactions with global climate.

Automatic differentiation tools (Patrick Heimbach)

Adjoint models are powerful tools in climate research. They are used to minimize model-date misfit. This method is good for comprehensive sensitivity studies, non-normal transient amplification and predictability, formal uncertainty characterization, and quantification. Obtaining adjoints of

full-fledged global climate models is a challenging task. In addition, the structure of the adjoint model depends on the control problem formulated (structure of objective function/target quantity of interest and control/uncertainty space). Algorithmic/automatic differentiation (AD) has proven successful in generating efficient adjoint models for use in climate research. As a result, there is increased interest in the community to use AD tools. However, the AD tools are highly specialized, not easy to use, and sustained funding support is highly fragile. There is a need to broaden accessibility to non-commercial tools that individual investigators can afford.

Fuzzy differentiation tools (Barnabas Bede)

Numerical differentiation techniques based on the concept of fuzzy transform (F-transform) were recently proposed. F-transform is an integral transform based on a fuzzy partition of a certain universe of discourse, and it was generalized into the direction of F-transforms of higher degree. It is shown that higher degree F-transforms provide numerical approximation of higher order derivatives of a function, opening up new research directions in numerical differentiation. Another research direction discussed was that of fuzzy uncertainty quantification and assessment of the propagation of uncertainty in processes governed by differential equations. In this direction generalized fuzzy differentiability concepts and fuzzy differential equations are investigated. This opened up the discussion about a fuzzy automatic differentiation tool that would allow quantification of uncertainty in the automatic differentiation process.

Climate variability in undersampled regions: South Atlantic MOC and tropical Atlantic (Renellys Perez)

Improved understanding of the coupled ocean-climate system will depend on better knowledge of ocean dynamics and ocean-atmosphere exchanges. This talk highlighted observational results and needs for two historically under sampled regions: the tropical and southern Atlantic Ocean. The first part of the presentation will cover what has been learned so far from the international South Atlantic Meridional Overturning Circulation (SAMOC) initiative, which seeks to both encourage and coordinate AMOC-related science in the South Atlantic region. The second part of the presentation included a brief description of ongoing multi-national efforts to improve our knowledge and understanding of coupled ocean-atmosphere variability in the tropical Atlantic. Since the late 1990s, several major field programs have been initiated to monitor the circulation, hydrography, and air-sea fluxes in the equatorial Atlantic with moored arrays, cross-equatorial cruises, and satellite-tracked drifting buoys and Argo floats deployed during those cruises.

Need for sustained and improved ocean observations and synthesis for water cycle studies (Subrahmanyam Bulusu)

Changes in the water cycle have impact on salinity and seawater density, and thus modulate oceanic mixing and the uptake of heat and CO_2. Trends in ocean salinity are very similar to the mean salinity distribution, supporting an intensification of the water cycle well above that predicted by models. These salinity changes are due largely to trends in evaporation and precipitation over the ocean; rivers and glacial melt play only a minor role. New observing capabilities for salinity must be realized and utilized to monitor this key element of the climate system (e.g., AQUARIUS, ARGO, sea surface salinity from drifters, thermosalinographs on volunteer observing ships). Ocean advection and mixing processes must be understood to calibrate the sea surface salinity – evaporation-precipitation

relationship. In the future, the surface water ocean topography (SWOT) mission will improve our understanding of freshwater storage in rivers and lakes.

Extremes Working Group perspective on need for sustained and improved observations (Matt Barlow)

The Extremes Working Group identified some key recommendations to i) evaluate a models' representations of extremes in terms of how well the model reproduces the synoptic-dynamics of the extremes, ii) expand or supplement CMIP database to include more daily and higher frequency fields, in a more easily accessible fashion, and iii) foster more collaboration between different programs working on various aspects of extremes. Next steps were also identified to include i) funding additional work on the synoptic-dynamics of extremes both fundamental understanding but also to develop more informative indices and tests of simulation skill, ii) encouragement of modeling groups to assess model simulation of extremes in terms of the synoptic-dynamics, and iii) hosting workshops on short-term extremes that mix researches and stakeholders in the five topical areas.

Furthermore, a list of specific recommendations on data and observations were presented and based upon the workshop.

- Develop indices specific to exploring the causes of extreme temperature and precipitation that exploit the high quality North American observations. These metrics would be supplemental to the Expert Team on Climate Change Detection and Indices (ETCCDI) indices designed for climate change detection purposes and sparse data. These indices should include measures of the large-scale meteorological patterns (LSMPs) associated with various regional extreme events.
- Better quantify and present the uncertainties in observed datasets as part of the downloadable datasets.
- Increase investments in "Big Data" technologies focused on climate and weather applications. These investments should include both software and hardware technologies.
- Promote efforts to maintain current observing networks, especially those with long observing records.
- Enlist scientists to engage and provide strong encouragement to volunteers who are maintaining cooperative observing networks.
- Foster a community consensus approach to comparing model data at different model grid sizes with observational station data and/or observed gridded datasets. Should one interpolate all gridded data to a common grid (for example to the observed gridded dataset) to make easier metric comparisons? Should there be a common interpolator?
- Build library of extreme climate events for each index that includes the date and location of every event, so that it would be possible to go back to create and analyze the LSMPs of the events.

Joint Session with PPAI on Observation and Synthesis Requirements for Predictability and Prediction Studies

Lisan Yu, Woods Hole Oceanographic Institution, provided a summary of the 2012 US CLIVAR/Global Synthesis and Observations Panel/WHOI workshop that focused on reviewing the current state of surface fluxes obtained from synthesis and observations products, gaps and limitations in products, and recommendations for future activities. Results from the workshop show that there are large

discrepancies in air-sea flux estimates between ocean and atmospheric reanalyses, which can affect ENSO prediction. Overall the workshop provided numerous recommendations and identified areas of collaborative research.

Janet Sprintall, Scripps Institution of Oceanography, presented on the International Quality Controlled Ocean Database (IQuOD), which is an initiative to develop high quality global subsurface ocean temperature observations and standard practices. The project aims to make the data free and easily accessible in addition to developing a template for future efforts, such as a salinity observations database.

Emanuele Di Lorenzo, Georgia Institute of Technology recorded a video presentation that discussed decadal prediction of hypoxia along the US west coast and focused specifically on large-scale ocean dynamics. Results indicate that decadal variability in ocean gyre circulation and subsurface parameters can be exploited for decadal prediction of ecosystem changes, which can lead to improved predictability in factors of interest to marine ecosystem management stakeholders.

Scott Weaver, NOAA's Climate Prediction Center, wrapped up the joint session by presenting on the development of severe weather outlooks by focusing on tornado prediction and possible linkages between sea surface temperature and regional variability.

Discussion during the joint session suggested that using ENSO events to address errors in wind and flux products could help to validate the synthesis and observation products that were discussed during the 2012 workshop. In order to make progress on surface ocean-atmosphere fluxes, the system – including observations – must be seen as a coupled, integrated system, rather than separate atmosphere and ocean reanalyses. A working group could help to develop a strategy for evaluating surface fluxes, coordinate funded activities across agencies, and coordinate with new US climate reanalysis activities, such as the NOAA MAPP Climate Reanalysis Task Force. There is a further need to examine the interface, mixed layer (e.g. Ekman layer) – which could be the focus of a workshop or working group. Emerging opportunities include raising awareness of IQuOD and other efforts to achieve consistency among estimates of ocean heat content. This is an opportunity that would benefit from the involvement and endorsement of International CLIVAR.

Joint Session with PSMI on Diagnostic Tools and Metrics for Intercomparison of Reanalyses and Utilization of Innovation, Increments, and Residuals

Patrick Heimbach, Massachusetts Institute of Technology, presented on examples of innovations, increments and residuals. He noted that there is an emphasis on closed budgets in model/reanalysis products with no artificial long-term trends in climate related variables. Also, there are differences in assimilation foci for numerical weather prediction, where the emphasis is on best initial conditions, while the climate studies require a product that is best for budget analysis and consistent physics throughout the climate record. Hence, incremental assimilation methods are not good for climate study products and current reanalysis products have this drawback.

Dimitris Menemenlis, NASA Jet Propulsion Laboratory, presented example utilizations of simulation and assimilation residuals for the Arctic halocline, Antarctic slope front, and Atlantic waters entering the Arctic Ocean. A key point was to study residuals/increments from data assimilation to understand

sources for model biases. One example presented was work by An Nguyen on implementing a new parameterization for Arctic halocline with sub-grid scale brine rejection and its success in simulating observed profiles from the Arctic. A recommendation was that future CPTs could be more directly motivated by innovations, increments, and residuals of current ocean data-assimilating models.

Gad Levy, Northwest Research Associates, discussed how to use low dimensional information (information contained within a bulk simulation in a climate model even when not directly observed or represented by model variables) and the challenges in using analyzed fields that are not model realizable states. One challenge is the lack of assimilation methods that represent sub-grid scale processes. He noted that methods to quantify and measure uncertainty, agreement, incremental improvement, etc. – along with theory – exist in other fields and can be adapted for climate models.

Barnabas Bede, Digipen Institute of Technology, provided information about metrics based on fuzzy similarities between lower dimensional features for intercomparison of reanalyses. Fuzzy metrics avoid the drawback of root-mean-square error, which penalize models for getting features in the wrong place twice (one where the model has the feature and the other for not having the feature in the right place). An example was presented using six different fuzzy metrics on leads in Arctic ice modeling. It was noted that fuzzy metrics are also useful for uncertainty quantification.

Discussion with the participants offered a couple of questions such as i) how are sub-grid scale processes assimilated into models that do not resolve these processes and ii) what are the nonlinear inverse methods for identifying nonlinear processes that impact the model biases. Examples were discussed, including eddy representation in climate models, and a key point was made that it is important to get the statistics of low dimensional features right rather than exact reproduction.

Discussions on new working groups

Impacts of Arctic Ocean on Midlatitude Extremes
Arctic and its relative role in causing midlatitude extreme events has been a really hot topic since the last year. Xiaodong Zhang proposed a working group to synthesize the state-of-the-knowledge and identify scientific gaps and questions. This working group will help tighten connections and interactions between the Arctic community and traditional CLIVAR community.

Hiatus and Deep Ocean Warming

Xiao-Hai Yan and Patrick Heimbach proposed a working group to better understand the global warming hiatus and its link to the ocean. Recent studies have shown a widespread warming in the world's deep ocean that reflects the response of the deeper ocean to the global climate change. It may have significantly contributed to the global sea level rise over the past decades, and, in turn, to modulate the Earth's climate. However, dynamic processes that control such low-frequency changes remain elusive, which is partly due to a lack of focused studies. Changes in the formation rates and/or the characteristics of intermediate and deep water masses and associated overturning circulation patterns have been suggested, but need to be further investigated. Satellite remote sensors cannot see far beneath the surface layers of the ocean, yet many important ocean processes and features are located well below the sea surface and at considerable depths. Deeper ocean remote sensing is becoming even more important given that the deeper ocean may be responding to climate variability and change more effectively than ever thought.

Global Water Cycle Studies

Subrahmanyam Bulusu proposed a working group to investigate the global water cycle and its connection to key climate indices.

Air-Sea Fluxes and Impacts on Upper Ocean Energetics

Lisan Yu, Dimitris Menemenlis, and Yan Xue proposed a working group to investigate uncertainties in air-sea fluxes, their impacts on upper ocean energetics, and their connections with data constraints by satellite and in situ observing systems. A possible focus will be on tropical warm pools, where all the components can be put together (i.e., fluxes, air-sea coupling, mixed layer processes, ocean heat content, and importance of warm pool to regional and global climate and variability).

Summary and recommendations

- In the US, there is a need to fund climate-quality ocean reanalyses and make them accessible to the research community and general public. There is also a need for long-term reanalyses to continue.
- Given the many open questions on ENSO diversity (origin of the different event types, teleconnections and impacts, challenges in ENSO prediction, influence of climate change on ENSO), research on ENSO diversity should continue and, in turn, it should help ENSO prediction efforts.
- Long-term ocean reanalyses and climate hindcasts are needed to better understand and forecast North Pacific decadal variability and ecosystem impacts.
- A Climate Process Team (CPT) on representation of tidal mixing in ocean models is recommended.
- The community should advocate for operational/near-real-time oceanography, field programs, and climate data provider websites to remain open during government shutdown.
- There should be a process-oriented evaluation of coupled model simulations in tropical Pacific, to answer questions such as what processes are missing in coupled models and what observations are needed to constrain models.
- The POS Panel encourages regional evaluations of model representation for short-term extreme dynamics.
- The POS Panel supports Ana4MIPs to include ocean reanalyses in addition to atmospheric reanalyses for CMIP model validations and climate research.
- Members of the POS Panel will assess the decline of the US research vessel fleet, which limits the research community's ability to sustain and improve ocean observations.
- Additional studies should be encouraged that focus on subsurface climate variability for ecosystem applications.
- The findings from innovations, increments, and residuals in ocean syntheses should be saved and used to examine and motivate climate process studies.

List of action items

1. Letter in support of International Quality Controlled Ocean Database (IQuOD) for improving climate records and ocean synthesis products.

2. Letter supporting development of open-source automatic differentiation tools. OpenAD tool should be supported at agency level for climate applications.

3. Issue a statement about role of US research vessels in sustaining ocean observations.

4. Develop a mechanism to evaluate sustainability of ocean observing systems.

5. Look for new US CLIVAR panelists representing Repeat Hydrography (physics, carbon, etc.); ideas include Richard Feely and Lynne Talley.

6. Look for new US CLIVAR panelists representing Arctic Climate community; ideas include Jennifer Kay, Julienne Stroeve, Marika Holland, and Mark Serreze.

4.2 PSMI Breakout Report

List of panelists attending the Summit

J. Thomas Farrar, Maria Flatau, Alessandra Giannini, Igor Kamenkovich, Gad Levy, Joellen Russell, Aneesh Subramanian, and Caroline Ummenhofer

Summary of action items from 2013 Summit and progress for each

1. The PSMIP Terms of Reference should be reviewed for consistency with the new Science Plan
   Status: Completed. Existing PSMI Panel Terms of Reference align with the new Science Plan.

2. A recommendation that future process study reviews might request a "Nature Figure" rather than a long list of slides. It is hoped that this figure might actually be used in a future publication, but in the meantime it would serve as a focal point for PSMI discussions.
   Status: The Panel discussed and more-or-less agreed that it is a good idea to ask for a single figure summarizing the essential ideas/results of a process study, but that this might not be appropriate or feasible for all process studies, therefore the request would be phrased gently.

3. Best practices for metrics that demonstrate model impact. Gad Levy (and others) have suggested that the next needed best practices document should cover metrics and demonstration of impact of particular processes. Many panel members were eager to volunteer to help carry forward this project in future years.
   Status: This was discussed in the October 2013 teleconference, but no specific actions were taken then. During the 2014 SSC meeting, the topic was put forward as a possible basis for joint sessions at the 2014 Summit. The rationale was that this would help germinate the idea and develop a pathway toward a future, more formal effort to address this topic (e.g., a US CLIVAR working group). There were two relevant joint sessions at the Summit related to model-improvement metrics, one PSMI-POS joint session on "Diagnostic Tools and Metrics for Intercomparison of Reanalyses and Utilization of *Innovation, Increments, and Residuals" (page XX of report) and one PSMI-PPAI joint session on "Modeling Metrics for Quantifying Predictions and Predictability" (page XX of report).*

Summary of PSMI Panel sessions

Session 1: Process-study reviews

PSMI reviewed 11 process studies (five oral presentations and six written reports) at the 2014 Summit. This was a substantial reduction from the number reviewed in 2013 (17 total, 12 oral, five written).

ASIRI Air-Sea Interaction Regional Initiative in the Northern Indian Ocean (Amala Mahadevan)

This is the study of the Indian monsoons and their freshwater input. It is important because of population density and the size of developing economies of the region. Major challenges for prediction are dry biases in models and large uncertainty in surface heat flux estimates. The task is to improve monsoonal prediction on sub-seasonal time scales through a better understanding of the upper ocean structure, processes, and air-sea exchanges. The project is carried out through partnership with the Indian Ministry of Earth Science. The targeted quantities and processes are: boundary-layer physics (bulk formulae), air-sea fluxes, small-scale ("subgrid") processes (no parameterization is planned), upper-ocean structure, and mixing rates. Broader outcomes include training of new generation of oceanographers, new instrumentation, and a sustainable observing system. A major challenge is the lack of access to the exclusive economic zones (EEZs), which makes coastal measurements nearly impossible. Cooperation with local authorities and scientists is critical, and the possibility of Indian scientists collecting coastal data themselves is promising, although many obstacles exist.

SPURS 1 and SPURS 2 (Tom Farrar)

SPURS 1: This is a study of processes that influence upper-ocean salinity and of the relationship between sea surface salinity and the water cycle. The goal is to understand processes on regional to small scales, and studies of subgrid processes makes this project relevant to model improvement. The main part of the field campaign took place from September 2012 to September 2013. Multiple observational platforms were used, including floats, gliders, drifters, moorings, ships, AUVs, satellite, and CTDs. The main strategy was to "nest" observational domains, resulting in sequence of box regions, which allows to "zoom in" on small-scale processes. Data management was a separately funded effort, and it was very successful in facilitating data sharing as the project progressed.
SPURS 2: This is a study of the upper-ocean salinity near the eastern Pacific ITCZ, which is a high-precipitation region where a lot of freshwater is being input into the ocean. It is a one-year campaign with the following goals, (i) determine what governs the structure and variability of the upper-ocean salinity, (ii) determine where the freshwater goes and how it gets redistributed from small to regional scales, and (iii) determine what local and non-local effects the freshwater flux has on the ocean and what the feedbacks are on the atmosphere. Some panel members expressed concerns regarding whether one year is enough in this region with high interannual variability. Perhaps, model simulations (OSSEs) can be used to estimate what we can and cannot learn from a one-year effort and to determine the extent to which this array will be representative of the relevant processes. Another suggestion was to consider consequences of further decline of the TAO array, since the preliminary experimental design is integrated into the TAO/TRITON mooring array.

DYNAMO & Year of Maritime Continent (Chidong Zhang)

DYNAMO: This is a study of the dynamics of the Madden-Jullian Oscillation (MJO). The project

employed ships and land-based radars, RAMA, and DYNAMO moorings. Three MJO events were captured, which made the program very successful. Some of the unexpected outcomes included aerosol regime transition, interaction between ITCZ and MJO, and ocean memory of atmospheric forcing. Products include data archived after less than 1 year at 3 data centers. Plans for data use include legacy products that are easy-to-use for modelling and further analysis. Integration with models include a model-evaluation project with a large number of global models with detailed output, and building a hierarchy of regional models toward cloud-permitting models. Education and training was substantial with 100 students and postdocs from 37 universities of 14 countries, training of Maldivian Met Service, and continued engagement.

There were complications with the project including visas and risk management due to piracy. Another challenge during the funding process was the unclear connection between US CLIVAR recommendations to incorporate modeling efforts and recommendations from reviewers who were skeptical about proposing a CPT before the actual campaign. Program managers stressed the importance of reviewers' comments, and explained that the way to address this is to involve modelers from the start of the project, but that CPTs are intended to be separate from data-collection efforts (and would normally take place years after data are collected). Cooperation of funding agencies is crucial, and it works best when a project addresses different agency priorities. This project is essentially a study of an important phenomenon that meets this criterion. The need of sufficient lead-time for interagency coordination was discussed; getting broad interagency participation in a major campaign requires three to five years for money to be lined up, and international cooperation requires extra time and effort.

Year of the Maritime Continent (YMC): The importance of the maritime continent is in active ITCZ convection, sources of aerosols, being in the center of the warm pool, and being an MJO barrier. The relevance to modeling is outlined by large biases in climate models such as wrong diurnal peak time in parameterized convection, and biases in MJO prediction barrier and mean precipitation. The main hypotheses are the importance of the (i) upscale effects of the diurnal cycle on MJO, monsoon and mean precipitation, (ii) interaction between sources, transport, and removal of aerosols, and (iii) effects of air-sea interactions and upper-ocean processes on diurnal, MJO, monsoon timescales. Among the studied fields are the atmospheric convection, aerosols, upper-ocean mixing (tidal, turbulent, inertial, SST feedback) upwelling, and through-flows.

Marginal Ice Zone and Arctic Sea State (Craig Lee)

There is a new emerging regime in the Arctic with more open water in summer and tighter coupling with the atmosphere. Models cannot reproduce observations and despite substantial improvement, essential physics seems to be missing. The objectives include characterization of the physics of ice breakup and melt, changes in physics associated with less ice, exploration of feedbacks, wave forecasting, theory of waves and wave-ice interactions, and collection of a benchmark dataset. Access in the Arctic is poor for ships, but good for aircraft. Persistence is required to resolve important timescales and transient events. Products include ice mass data, wave measurements, profiles from acoustic navigation floats and ice-tethered profilers, and models (ice, climate, forecast).

Project data are open between researchers, with some protection for students and postdocs, but the access for the broader public is restricted for the duration of the project. Data submission is required

to the Arctic Observing Network. While this approach is widespread and understandable, the panel discussed the idea that the scientific community may be more supportive of an observational campaign if data were publicly available sooner. In terms of funding, lead times are different for different agencies, and funding is hard to synchronize. Such synchronization and support by multiple agencies is desired, since these surface ice/wave data can be used by other agency projects and additional data (such as profiles below ice) could be collected.

Session 2: Review of process study written reports

Six reports were reviewed (DIMES, IASCLiP, SAMOC, OSNAP, SOCRATES, and a potential program in the Southeast Atlantic) – some of them such as DIMES were in the final phase providing interesting scientific results and a developed database, while others such as SOCRATES were in the planning stage. PSMI had hoped to have an oral presentation on DIMES this year (because the program is nearing completion), but the Summit conflicted with a DIMES meeting, so a DIMES presentation should be requested for next year.

The six reports were summarized and presented individually, and there was a block of discussion afterward. Two issues were emphasized during the discussion – the first was the accessibility of the data shortly after the experiment. The early release of data promotes collaboration and leads to better scientific results, but there is a concern that experimentalists will not have enough credit for the work. There is also concern that there needs to be a mechanism to protect or withhold data being used by graduate students. The need for expert quality control of the data by the groups collecting it is one factor that delays release of the data. Ways of getting the data released as soon as possible were discussed—one model is SPURS, which had a funded data management team to coordinate and urge release of the data in stages (e.g., initial/raw, preliminary, and quality-controlled).

Another issue discussed was the format of the reports. Reports should be somewhat standardized by using a template, so the information can be easily extracted. Panel members, who take notes, should also use templates in the review process.

Session 3: CPT reviews and discussion of current and future CPTs

The panel heard presentations by Gokhan Danabasoglu (NCAR) on ocean-related Climate Process Teams (CPTs), Vincent Larson (University of Wisconsin) about the CPT on cloud macrophysics and aerosol indirect effects, and Joao Teixeira (NASA Jet Propulsion Laboratory) on the stratocumulus to cumulus transition CPT.

Danabasoglu's presentation on ocean-related CPTs offered a synthesis view of previous ocean-related CPTs and lessons learned that takes into account input from others at NCAR:

- Ocean CPTs have been successful, resulting in better physics and improved simulations, even though parameterizations have not necessarily yet been routinely implemented, as this takes time.
- Successful CPTs should last between three to five years with parameterizations completed by year three, so implementation can take up to two years, along with required coordination/ collaboration between modeling centers.
- Successful CPTs should have existing observational data and existing process modeling frameworks.

- CPTs represent great value for the resources invested.
- CPTs should involve multiple large modeling centers (e.g., NCAR, GFDL)
- Prior to a new CPT, funding agencies should check with modeling centers to avoid duplicative efforts and/or determine how the new CPT will tie in with existing developments.

The ensuing discussion led the panel to consider the idea of having a workshop to brainstorm new CPT topics. The workshop should include input from the larger community to make sure that not only modelers were being queried on topics, but also observationalists and theoreticians. One benefit of the workshop would be to initiate dialogue between observational and modeling communities that could fertilize discussion early on and serve as cross-pollination in the planning for future CPTs. The panel concluded that it would start scoping for new CPTs through a short survey of the community — framing it around earth system modeling — followed by a workshop to develop ideas further.

Some other points made during the discussion include:

- Guidance to community in how to 'pitch' a successful CPT would be useful.
- CPTs are a great way to help the careers of early-career faculty, postdocs, and students and such involvement should form a strong part of future CPTs.
- CPTs are a great opportunity for a concerted, coordinated effort to solve an otherwise intractable problem across modeling centers.
- Outcomes of CPTs can vary and it is fine if it improves parameterizations, but does not improve climate representation, because this result shows that a particular process is not overly important.
- Proposals for CPTs should not be too broad in scope, so that results from different projects are integrated, rather than in parallel.

Session 4: Joint session with PPAI on Metrics for Quantifying Predictions and Predictability Limits

Andy Wood, NCAR, presented a metrics framework to evaluate new approaches for drought monitoring and prediction that has been developed by NOAA's Drought Task Force as part of the Modeling, Analysis, Predictions, and Projections program. The Task Force has identified future activities including identifying major US droughts to use as case studies for progress on assessment, engaging the research community at the national and international level, and encouraging drought researchers to use a similar protocol for monitoring and prediction.

Kathy Pigeon, University of Colorado/NOAA, presented next on metrics for quantifying predictability limits and four different approaches. A key point from the talk is that different metrics produce different estimates of skill, hence different estimates of room for prediction improvement. This left an open question about how process based analysis could help improve predictability.

Barnabas Bede, Digipen Institute of Technology, presented on fuzzy logic and methods that acknowledge uncertainty and allow for rule (or linguistic logic)-based determination of metrics, which in turn benefits by co-development of metrics by practitioners and scientists and allows for adaptive learning. Fuzzy metrics can naturally handle uncertainty and be used with decision-making, such as a fuzzy measure between 0 and 1 to rank climate models for aggregation based on their skill score. And it is potentially simpler to explain than Bayesian methods of weighting models based

on their performance. Yet, it was unclear on how the fuzzy score would be determined for climate models based on arbitrary skill scores.

Joe Barsugli, University of Colorado, wrapped up the session by providing a perspective of a practitioner's dilemma for using climate information. An example given was a publication on the performance evaluation of ENSO simulations in the recent CMIP5 models. The paper discussed the good and bad models, but didn't specify how to use their analysis for applications related to ENSO. It was noted that metrics can be used to bridge science and application by addressing the practitioner's needs and thus the best available science may be defined by its credibility, suitability to the problem at hand, and a common language for testing.

Discussion among the group pointed out that scientists and users should better collaborate to determine each other's needs and determine what can be provided, which is not always clearly understood. Therefore, co-development of metrics, such as process-based metrics, should be done by first determining a suite of user needs and determining the processes that are associated with these needs. Metrics, evaluations, and data must also be made available to the broader research community and accompanied by adequate metadata. And use of simpler metrics will make them more accessible to users and possibly more popular. Furthermore, adding graphics and visualization techniques will enhance comprehension.

Session 5: Joint Session with POS on Diagnostic Tools and Metrics for Intercomparison of Reanalyses and Utilization of Innovation, Increments, and Residuals

See page 18 for a summary of the joint session.

Summary and recommendations

Recommendations for 2015 Summit and coming year:

- Joint session with POS on observing system/process study overlap – long time scale processes, process studies organized around elements of the global observing system, and transitioning from process studies to long-term observing.
- Joint session or plenary on wrap-up reports on large field programs (e.g., DYNAMO).
- Request written process study reports earlier and distribute them to PSMI panelists earlier.
- PSMI is perennially pressed for time at the Summit. For the 2015 Summit: (i) panel co-chairs should resist the temptation to participate in two joint sessions and instead focus on allowing ample time for reviewing programs, discussion of lessons learned, and ways to facilitate model improvement, (b) a template or 'worksheet' should be created for scribes to allow them to efficiently and consistently record information.
- Given the activity and discussions related to metrics for evaluating things like model predictions and model improvement, the time seems ripe for a working group on best practices for establishing metrics. This idea should be explored further.

List of action items

1. Update US CLIVAR CPT webpage.
2. Conduct a survey to solicit input from modeling centers, and possibly the broader community, on needs for future CPTs (perhaps focusing on biases, not readiness); complete by summer 2014 and

use this as basis for CPT workshop planning; request information from current/previous CPTs on early interactions with modeling centers (Amala, Caroline, and Aneesh).

3. Apply for funding and organize a workshop, perhaps at one of the national modeling centers, to "incubate" CPT project ideas by facilitating interactions between modelers, theorists, and observationalists and exchange of ideas well before CPT proposals are due.

4.3 PPAI Breakout Report

List of panelists attending the Summit

Bruce Anderson, Judah Cohen, Enrique Curchitser, Gregg Garfin, Hyemi Kim, Xin-Zhong Liang, Kathy Pegion, Andrea Ray, and Scott Weaver

Summary of action items from 2013 Summit and update on progress for each

1. Review and revise PPAI terms of reference for consistency with the new Science Plan.
   Status: Completed.

2. Lay groundwork for a US CLIVAR workshop on "Connecting Predictions and Applications."
   Status: Hosted a plenary session at 2014 Summit and continued development of workshop idea.

3. Promote to funding agencies the concept of CMEP-like activity for assessment of seasonal predictability using NMME datasets.
   Status: Part of current FY15 budget for NOAA.

4. Promote to funding agencies a Science Team on "Natural and Societal Impact of Decadal Climate Variability: Predictability and Predictions."
   Status: Hosted an AGU session and workshop planning in ongoing.

5. Scope the concept for the Application Process Teams before the 2014 Summit
   Status: Carried this action item into 2014.

6. Develop additional thematic papers on current challneges for inclusion in US CLIVAR Variations.
   Status: Published a summer edition of Variations on Arctic climate variability and linkages with midlatitudes, with Judah Cohen serving as guest editor.

Summary of PPAI Panel Sessions

Session 1: Benchmarking Predictions and Predictability Limits

Arun Kumar (NOAA Climate Prediction Center) presented during this session on predictability and best practices for quantifying improvements and Kathy Pegion (University of Colorado/NOAA) presented on estimating predictability for benchmarking predictions and predictability limits. A key point during the presentations was that noise-limited predictability is irreducible, can be better quantified, and can be dealt with through forecasts of opportunity. Furthermore, science-limited predictability results from a lack of good simulation of well-known processes, thus process-based studies and approaches are key. For communicating improvements and limitations, the community

needs to embed forecasts and projections in vulnerability assessments (bottom-up approach) and impact assessments (top-down), and convey that uncertainty is not the same as a lack of information.

Discussion among the participants determined that many members of the applied research community need information and briefings on the latest research about predictability limits and potential improvements. The US CLIVAR community could develop a summary of various methods for estimating predictability to share with this community. It was also recognized that research scientists would be interested in a quick guide to linear-inverse methods, which can be used to help determine predictability. The PPAI Panel can connect with predictability initiatives, such as the NOAA MAPP Climate Prediction Task Force, NMME, Intraseasonal Variability Hindcast Experiment, and others, to expand upon these ideas and collaborations.

Session 2: Joint Session with PSMI Metrics for Quantifying Predictions and Predictability limits

See page 25 for a summary of the joint session

Session 3: Joint Session with POS on Observation and Synthesis Requirements for Predictability and Prediction Studies

See page 17 for a summary of the joint session.

Summary and conclusions

Overall, the breakout sessions, including the PPAI-led plenary session, provided fertile material for a robust set of subsequent discussions among the panelists (spread over the course of four hours), leading to a lengthy set of action items (see below). Recommendations from the invited plenary speakers included interest in information on the limits of predictability, co-development of predictability metrics, prediction and attribution of extreme events, explaining and quantifying uncertainty and confidence in forecasts and projections, reliable and skillful forecasts of climate parameters at a variety of time scales (special emphasis on subseasonal extremes, and interannual-to-decadal precipitation totals) including subseasonal to seasonal coastal upwelling outlooks, alignment of climate and hydrology (including snowpack) forecasts, and understanding of non-ENSO teleconnections germane to regions with weak ENSO response signals. It was fairly well agreed that the plenary session was informative and well structured and should serve as a framework for future such sessions.

As for the breakout sessions, it was felt that the inclusion of too many talks limited the discussion time, particularly for the joint sessions, which represent the only opportunity for joint action items to be developed between panels.

List of action items

1. Propose a working group on "The Influence of the Arctic on Midlatitude Weather and Climate" (Judah Cohen; Xiangdong Zhang, POS)
    a. Aligns with US CLIVAR Research Challenges: Polar climate changes, Climate and extremes, Decadal variability and predictability
2. Propose a working group on "Climate and Marine Ecosystems: Ocean and Climate Influences on Coastal Shelf Ecosystems" (Enrique Curchitser)

    a. Aligns with US CLIVAR Research Challenges: Climate and marine carbon/biogeochemistry, polar climate changes, decadal variability and predictability
3. Propose a working group on "Subseasonal Predictions: Evaluation, Uncertainty, and Predictability Metrics" (Hyemi Kim)
    a. Aligns with US CLIVAR Research Challenges: Climate and extremes
4. Propose a workshop on "Predictability Metrics and their Application" (Kathy Pegion)
    a. Aligns with US CLIVAR Research Challenges: Decadal variability and predictability
    b. BAMS article, outreach to decision-making communities
    c. COMET course and/or short course
5. Propose a workshop on "Systems Sensitive to Decadal Variations" (Bruce Anderson)
    a. Aligns with US CLIVAR Research Challenges: Decadal variability and predictability
6. Investigate development of the Applications Process Team (APT) concept, using drought simulation (e.g., GCMs), prediction, and management/decision making as a tangible point of departure for proof of the APT concept (Andrea Ray)
    a. Aligns with US CLIVAR Research Challenges: Climate and extremes, Decadal variability and predictability
    b. Leverage NIDIS reauthorization, and needs, articulated in the reauthorization act, "to enhance the predictive capability of drought early warnings that include—"(i) the length and severity of droughts; "(ii) the contribution of weather events to reducing the severity or ending drought conditions;
    c. For decision maker interaction, springboard off of PPAI plenary session, and integrate with at least one agency intermediary, and with POS, PPAI members of the US CLIVAR Extremes Working Group
7. Cultivate participation of additional agencies (e.g., DOI, USDA) in US CLIVAR
    a. Propose ex-officio membership, or membership in the Interagency Group (IAG)
    b. This would bring in a stakeholder/decision maker/end user perspective
8. Develop a PPAI plenary session paper for US CLIVAR Variations, summarizing plenary session, decision maker concerns regarding uncertainty and predictability, and other issues in bridging the science-applications-use gap (Gregg Garfin)

5 Day 4: July 11, 2014

The last day of the Summit began with Panel breakouts in the morning, followed by Panel summary reports in plenary. The action items identified by each Panel are provided below.

5.1 POS Panel Recommendations and Action Items

- In the US, there is a need to fund climate quality ocean reanalyses that are easily available to the research community and general public.
- The POS Panel supports Ana4MIPs to include ocean reanalyses in addition to atmospheric reanalyses for model validations and climate research.
- Letter in support of open-source differentiation tools by DOE (Patrick Heimbach).
- Recommend that we address the decline of the US fleet, which limits ability to sustain and improve ocean observations (Renellys Perez).
- Support operational/near-real-time oceanography and field programs in the event of government shutdowns (Renellys Perez).
- Letter in support of Interntaional Quality Controlled Ocean Database (IQuOD) for improving climate records and ocean synthesis products (Janet Sprintall).
- Encourage studies on subsurface climate variability for ecosystem applications (Emanuele Di Lorenzo and Art Miller).
- Innovations, increments, and residuals in ocean syntheses should be saved and used to examine and motivate climate process studies.
- Develop proposals for:
    - Working group to investigate influences of rapidly changed Arctic on recent Northern Hemisphere midlatitude storm tracks, surface climate, and extreme events (Xiangdong Zhang);
    - Working group to investigate global warming "hiatus" and deep ocean heat content (Xiao-Hai Yan and Patrick Heimbach);
    - Working group to investigate uncertainties in air-sea fluxes and their impacts on ocean property budgets; and
    - Working group or science team to investigate global water cycle studies and connections to key climate indices (Subrahmanyam Bulusu).
- Encourage ENSO diversity working group to address forecasting. Proposed that ENSO prediction and impacts be considered as Grand Challenge (Yan Xue)

- Promote process-oriented evaluation of coupled model simulations in the tropical Pacific, identifying processes that are missing in coupled models and the observations needed to constrain them.
- Encourage regional evaluations of model representation of short-term extreme dynamics (Matt Barlow).

Discussion of action items included a suggestion to develop a white paper or report that discusses the warming "hiatus" in a robust way including identifying all the theories. A working group could be an effective mechanism to synthesize this discussion and would be very timely.

5.2 PSMI Panel Recommendations and Action Items

- Update US CLIVAR CPT web page.
- Survey to solicit input from modeling centers and possibly the broader community on needs for future CPTs (perhaps focusing on biases, not readiness).
    - Complete summer 2014 (Amala Mahavedan, Caroline Ummenhofer, Aneesh Subramanian)
    - Use this as a basis for CPT workshop planning.
- Request information from current/previous CPTs on early interactions with modeling centers.
- Plan join session with POS on observing system/process study overlap—long time scale processes, process studies organized around elements of the global observing system, transitioning from process studies to long-term observing.
- Plan wrap-up reports to plenary on large field programs (e.g., DYNAMO).
- Distribute written process study reports earlier.
- Propose working group on best practices for establishing metrics (check with DOE).

Discussion about the PSMI Panel recommendations and action items included developing synthesis data products, as is being done in DYNAMO. Why this is not typically done is a disconnection following the end of the field campaign ends and the availability of funding for such synthesis and making the data available. A capstone report/article at the end of a process study is recommended to address the original goals and experimental design of the study, what has been learned and how well goals have been achieved, and what remains to be explored.

5.3 PPAI Panel Recommendations and Action Items

- Develop time history of predictability estimates.
- Develop a summary of methods for estimating predictability.
- Develop a quick guide to Linear Inverse Modeling (LIM).
- Coordinate with NOAA MAPP Climate Prediction Task Force, NMME, Intraseasonal Hindcast Variability Experiment and others.
- Co-develop process-based metrics that are highly transparent, with metrics, metadata, and evaluation data made available to the broader research community.
- Convene a scientist-practitioner workshop on metrics and climate change projection data to explore/develop application-relevant and process-based metrics.

- Coupled, integrated analysis of surface fluxes (mixed-layer focus) is needed, and a working group could help with coordination across agency efforts and development of strategies for reconciling data.
- International CLIVAR endorsement of IQuOD would help achieve consistency of OHC estimates.
    - Future effort on salinity data could reap big benefits.
    - There is a connection to gyre/upwelling/ecosystem research.
- Develop proposals for:
    - Working group on Arctic-midlatitude influence on processes and predictability (Judah Cohen)
    - Working group on ocean and climate influences on coastal (shelf) ecosystems
    - Working group on subseasonal predictions: evaluation, uncertainty, and predictability metrics (Hyemi Kim)
    - Workshop on subsystems sensitive to decadal variations (Bruce Anderson)
    - Science team on predictability and predictions to focus on methods, metrics, uncertainties, and applications as integrated study.
- Investigate development of APT using drought simulation (including regional climate projection), prediction, and management (decision making) as a proof of APT concept (Andrea Ray)
- Document predictability metrics across time scales (Kathy Pegion)
    - Produce 1-2 papers, outreach to decision-making communities, and plan COMET course and/or short course
- Cultivate participation in US CLIVAR of additional agencies (e.g., DOI, USDA) as ex-officio or part of the IAG.
- Revise terms of reference.
- Promote assessment of seasonal predictability and predictions using NMME datad sets.
    - PPAI to draft white paper describing motivation and benefits of an interagency program call (Arun Kumar, Bruce Anderson).
- Develop additional thematic papers on current challenges for inclusion in CLIVAR Variations.
    - Communication and utilization of uncertainty in decision-making
    - Predictability of high-latitude climate variability

Discussion about the PPAI Panel recommendations and action items included a note to involve more agencies in the discussions. It was recommended that this can be done on a "as needed" basis and in a strategic manner.

Weller summarized some of the important highlights from the meeting, feedback on the overall format, and upcoming activities. He mentioned that the IQuOD initiative is a great and promising example that can be a good model for ensuring quality control of data. He further emphasized that there are some vulnerabilities and opportunities where the US CLIVAR community can be synthesized from end to end.

Appendix A: Organizers

Scientific Steering Committee

Bob Weller, Chair
Woods Hole Oceanographic Institution

Arun Kumar, Co-Chair
NOAA National Centers for Environmental Prediction

Janet Sprintall, Co-Chair
Scripps Institution of Oceanography

Bruce Anderson
Boston University

J. Tom Farrar
Woods Hole Oceanographic Institution

Gregg Garfin
University of Arizona

Gad Levy
Northwest Research Associates

Dimitris Menemenlis
NASA Jet Propulsion Laboratory

Yan Xue
NOAA National Centers for Environmental Prediction

Project Office

Mike Patterson
Jill Reisdorf
Kristan Uhlenbrock

Appendix B: Participants

Name	Institution
Michael A. Alexander	NOAA Earth System Research Laboratory
Bruce Anderson	Boston University
Anjuli S. Bamzai	National Science Foundation
Dan Barrie	NOAA Climate Program Office
Matt Barlow	University of Massachusetts-Lowell
Joe Barsugli	University of Colorado/NOAA Earth System Research Laboratory
Barnabas Bede	DigiPen Institute of Technology
Subrahmanyam Bulusu	University of South Carolina
Suzana J. Camargo	Lamont-Doherty Earth Observatory
Antonietta Capotondi	University of Colorado/NOAA Earth System Research Laboratory
Shawn L. Carter	US Geological Survey
Judah Cohen	Atmospheric and Environmental Research, Inc.
Enrique N. Curchitser	Rutgers University
Eric DeWeaver	National Science Foundation
Gokhan Danabasoglu	National Center for Atmospheric Research
John T. Farrar	Woods Hole Oceanographic Institution
Maria K. Flatau	Naval Research Laboratory
Gregg Marc Garfin	University of Arizona
Alessandra Giannini	Columbia University
David Halpern	NASA Jet Propulsion Laboratory
Patrick Heimbach	Massachusetts Institute of Technology
Eric Itsweire	National Science Foundation
Hunter Jones	NOAA Climate Program Office
Linda Joyce	Rocky Mountain Research Station
Igor V. Kamenkovich	University of Miami
Hyemi Kim	Stony Brook University
James L. Kinter III	George Mason University
Arun Kumar	NOAA National Centers for Environmental Prediction
Felix W. Landerer	California Institute of Technology/NASA Jet Propulsion Laboratory
Craig M. Lee	University of Washington
Gad Levy	NorthWest Research Associates
Xin-Zhong Liang	University of Maryland
Sandy Lucas	NOAA Climate Program Office
Amala Mahadevan	Woods Hole Oceanographic Institution

Dimitris Menemenlis	California Institute of Technology/NASA Jet Propulsion Laboratory
Arthur J. Miller	University of California, San Diego
Michael Patterson	US CLIVAR Project Office
Kathleen Pegion	University of Colorado/NOAA Earth System Research Laboratory
Renellys Perez	University of Miami/NOAA Atlantic Oceanographic and Meteorological Laboratory
James R Prairie	University of Colorado
Andrea J. Ray	NOAA Earth System Research Laboratory
Jill M. Reisdorf	University Corporation for Atmospheric Research
Joellen Russell	University of Arizona
Karyn Sawyer	University Corporation for Atmospheric Research
Janet Sprintall	Scripps Institution of Oceanography
Detlef Stammer	University of Hamburg
Diane M Stanitski	NOAA Climate Program Office
Aneesh C. Subramanian	Scripps Institution of Oceanography
James Todd	NOAA Climate Program Office
Kristan M. Uhlenbrock	US CLIVAR Project Office
Caroline Ummenhofer	Woods Hole Oceanographic Institution
Scott Weaver	NOAA National Centers for Environmental Prediction
Robert S. Webb	NOAA Earth System Research Laboratory
Robert A. Weller	Woods Hole Oceanographic Institution
Yan Xue	NOAA National Centers for Environmental Prediction
Xiao-Hai Yan	University of Delaware
Lisan Yu	Woods Hole Oceanographic Institution
Chidong Zhang	University of Miami
Xiangdong Zhang	International Arctic Research Center

Remote Participants	
Manu Di Lorenzo	Georgia Tech University
Taka Ito	Georgia Tech University
Renu Joseph	Department of Energy
Felix W. Landerer	California Institute of Technology
Vincent Larson	University of Wisconsin-Madison
Fiamma Straneo	Woods Hole Oceanographic Institution
Joao Teixeira	NASA Jet Propulsion Laboratory
Andy Wood	National Center for Atmospheric Research

Appendix C: Agenda

Tuesday, July 8

1745 – 1800	Check-in	Millennium Gallery
1800 – 1815	Welcome, introductions, meeting objectives, and outcomes (Bob Weller)	Millennium Ballroom
1815 – 1830	US CLIVAR overview (Mike Patterson)	
1830 – 1900	Working dinner	
1900 – 2030	ENSO Monitoring, Analysis, and Prediction Challenges · Challenges in Monitoring and Prediction for Current ENSO Conditions (Yan Xue) · Uncertainities in Prediction – An ENSO Perspective (Arun Kumar)	Millennium Ballroom

Wednesday, July 9

0730 – 0800	Refreshments/Check-in	Millennium Gallery
0800 – 0830	Morning Plenary (Mike Patterson, moderator) Implementing the US CLIVAR Science Plan (Bob Weller)	Millennium Ballroom
0830 – 0900	International CLIVAR Program update (Detlef Stammer)	
0900 – 1000	US agency engagement (Agency Managers)	
1000 – 1020	Break	Millennium Gallery
1020 – 1040	Coordinated Ocean-Ice Reference Experiments (CORE) (Gokhan Danabasoglu)	Millennium Ballroom
1040 – 1105	Process-Oriented Model Diagnostics (Jim Kinter)	
1105 – 1230	Science Team and Working Group reports (20 min each) Introduction (Mike Patterson) US AMOC (Gokhan Danabosglu) Eastern Tropical Ocean Synthesis (Tom Farrar) Hurricanes WG (Suzana Camargo) Extremes WG (Matt Barlow)	
1230 – 1350	Lunch on your own	
1350 – 1510	Working Group reports (20 min each) Greenland Ice Sheet/Ocean Interactions (Fiamma Straneo via webcast) Southern Ocean Heat & Carbon Uptake (Joellen Russell, Igor Kamenkovich) Ocean Carbon Uptake in CMIP5 Models (Taka Ito via webcast) ENSO Diversity (Antonietta Capotondi)	Millennium Ballroom
1510 – 1530	Break	Millennium Gallery

1530 – 1600	Special Session: Progress and Prospects for Connecting Predictions, Applications, and Decision Making in the United States (Gregg Garfin) · Introduction: goals, participants, format · US CLIVAR overview of science challenges and uncertainties	Millennium Ballroom
1600 – 1700	Special Session: Progress and Prospects for Connecting Predictions, Applications, and Decision Making in the United States Climate Applications Science and Services Session: concerns, needs, key process, modeling, and prediction questions Panelists: · Water Resources - Jim Prairie (US Bureau of Reclamation) · Natural Resources – Shawn Carter (USGS) · Agriculture and Forestry - Linda Joyce (USDA-Forest Service) · Marine and Ocean Environments - Mike Alexander (NOAA Earth System Research Lab, on behalf of NOAA NMFS) · Experimental Applied Climate Science and Services - Robin Webb (NOAA Earth System Research Lab)	
1700 – 1725	Facilitated discussion	
1725 – 1730	Questions to be addressed by Panels	
1830 – 2000	Networking event	

Thursday, July 10

0730 – 0800	Refreshments	Millennium Gallery
0800 – 0830	Charge to the panel breakouts (Bob Weller)	Millennium Ballroom
0830 – 1200	Panel breakouts (break at 1000) Phenomena, Observations & Synthesis Process Study Model Improvement Predictability, Predictions and Applications Interface (See below for detailed agenda of breakout sessions)	
1200 – 1330	Lunch on your own	
1330 – 1730	Breakouts resume (break at 1500)	
1730	Break for day; dinner on your own	

Friday, July 11

0730 – 0800	Refreshments	Millennium Gallery
0800 – 1000	Panel breakouts (continued) Phenomena, Observations & Synthesis Process Study Model Improvement Predictability, Predictions and Applications Interface	
1000 – 1030	Break	Millennium Gallery
1030 – 1130	Plenary (Janet Sprintall, moderator) Panel breakout summaries and action items (Panel Co-chairs, each 15 min presentation plus 5 min Q&A)	Millennium Ballroom
1130 – 1200	Conclusions and Next Steps (Bob Weller)	
1200	Summit adjourns	

POS Panel Breakout - Thursday, July 10

0830 – 0845	Welcome, session objectives and outcomes (Dimitris Menemenlis)	Cambridge
0845 – 1000	Session 1: Evaluation of Ocean Phenomena, Observations, and Synthesis	
0845 – 0905	Review of November NCWCP GODAE Symposium and Real-time multiple ocean reanalyses intercomparison to quantify uncertainties in ocean reanalyses (Yan Xue)	
0905 – 0925	El Nino, La Nina, and Walker Circulation (David Halpern)	
0925 – 0945	Review Obs4MIPS and Ana4MIPS (Felix Landerer via webcast)	
0945 – 1000	Discussion on key challenges and opportunities (Yan Xue)	
1000 – 1030	Break	
1030 – 1200	Session 2: Utilization of Ocean Observations and Synthesis	Cambridge
1030 – 1050	ENSO diversity and impacts (Antonietta Capotondi)	
1050 – 1110	Pacific Ocean decadal variability and ecosystem response (Art Miller)	
1110 – 1130	Deeper ocean remote sensing and deeper ocean response to climate change and hiatus (Xiao-Hai Yan)	
1130 – 1150	Arctic climate change and extreme midlatitude events: Observational analysis and modeling investigation (Xiangdong Zhang)	
1150 – 1200	Discussion on key challenges and opportunities (Antonietta Capotondi)	
1200 – 1330	Lunch on your own	
1330 – 1500	Session 3: Joint Session with PPAI on Observation and Synthesis Requirements for Predictability and Prediction Studies	Millennium Ballroom
1330 – 1350	Recommendations of the 2012 CLIVAR/GSOP/WHOI air-sea flux workshop, follow-on activities, and specific recommendations for reducing air-sea flux estimation errors (Lisan Yu)	
1350 – 1410	International Quality Controlled Ocean Database (IQuOD) (Janet Sprintall)	
1410 – 1430	Predictability resulting from subsurface climate variability in the Pacific (Emanuele Di Lorenzo via recording)	
1430 – 1450	Advancing the Nation's capability to anticipate tornado and severe weather risk (Scott Weaver)	
1450 – 1500	Discussion on key challenges & opportunities (Lisan Yu)	
1500 – 1530	Break	

1530 – 1640	Session 4: Joint Session with PSMI on Diagnostic Tools and Metrics for Intercomparison of Reanalyses and Utilization of innovation, Increments, and Residuals	Capitol
1530 – 1540	Innovation, increments, and residuals: Definitions and examples (Patrick Heimbach)	
1540 – 1550	Example utilization of residuals: Arctic Halocline and Antarctic Slope Front (Dimitris Menemenlis)	
1550 – 1600	Challenges in evaluating lower-dimensional features (Gad Levy)	
1600 – 1615	Metrics based on fuzzy similarities between lower dimensional features for intercomparison of reanalyses (Barnabas Bede)	
1615 – 1640	Discussion on key challenges and opportunities (Detlef Stammer)	
1645 – 1730	Session 5: Automatic Differentiation Tools	Cambridge
1645 – 1700	Automatic differentiation tools (Patrick Heimbach)	
1700 – 1710	Fuzzy differentiation tools (Barnabas Bede)	
1710 – 1730	Discussion on key challenges and opportunities (Detlef Stammer)	
1730	Break for day, dinner on your own	

POS Breakout Continued - Friday, July 11

0730 – 0800	Light breakfast	Millennium Gallery
0800 – 1000	Session 6: Need for Sustained and Improved Ocean Observations and Synthesis	Cambridge
0800 – 0820	Climate variability in under sampled regions: South Atlantic MOC and tropical Atlantic (Renellys Perez)	
0820 – 0840	Need for sustained and improved ocean observations and synthesis for water cycle studies (Subrahmanyam Bulusu)	
0840 – 0900	Extremes Working Group perspective on need for sustained and improved observations (Matt Barlow)	
0900 – 0930	Discussion on key challenges and opportunities (Renellys Perez)	
0930 – 1000	Wrap up discussion: Summary, recommendations, workshops, and working groups (Yan Xue and Dimitris Menemenlis)	

PSMI Panel Breakout - Thursday, July 10

0830 – 0845	Welcome, session objectives, and outcomes	Executive
0845 – 1000	Session 1: Process Study Reviews	
0845 – 0900	ASIRI (Amala Mahadevan)	
0900 – 0915	SPURS 1 and SPURS 2 (Tom Farrar)	
0915 – 0930	DYNAMO (Chidong Zhang)	
0930 – 0945	Year of Maritime Continent (Chidong Zhang)	
0945 – 1000	Marginal Ice Zone and Arctic Sea State (Craig Lee)	
1000 – 1030	Break	
1030 – 1200	Session 2: Joint Session with PPAI on Modeling Metrics for Quantifying Predictions and Predictability Limits	Millennium Ballroom
1030 - 1045	The Drought Task Force Drought Assessment Protocol and use to evaluate model improvements (Andy Wood)	
1045 – 1100	Methods for identifying science-limited (and noise-limited) metrics/ measurements of the ocean state (Kathy Pegion)	
1100 – 1115	Predictions using fuzzy metrics-based aggregation of climate models (Barnabas Bede)	
1115– 1130	Metrics from the Perspective of the Practitioner's Dilemma (Joe Barsugli)	
1130 – 1200	Discussion on key challenges and opportunities (Bruce Anderson and Gad Levy)	
1200 – 1315	Lunch on your own	
1315 – 1345	Session 1 (cont.): Review of process study written reports · DIMES (by Jim Ledwell) · IASLCIP (by Vasu Misra) · OSNAP and N. Atlantic/Arctic (by Fiamma Straneo) · SAMOC (by Renellys Perez) · SOCRATES (by Rob Wood) · Eastern Tropical Atlantic (by Paquita Zuidema)	
1345 – 1415	Discussion of process studies	
1415 – 1515	Session 3: CPT reviews	Executive
1415 – 1430	Internal wave driven mixing in global ocean models (Gokhan Danabasoglu)	
1430 – 1445	Ocean mixing processes associated with high spatial heterogeneity in sea ice and the implications for climate models (Gokahn Danabasoglu)	
1445 – 1500	Cloud parameterization and aerosol indirect effects (Vince Larson, webcast)	
1500 – 1515	Stratocumulus to cumulus transition (Joao Teixeira, webcast)	
1515 – 1530	Break	

1530 – 1630	Session 4: Joint Session with POS – Diagnostic Tools and Metrics for Intercomparison of Reanalyses and Utilization of Innovation, Increments, and Residuals	Capitol
1530 – 1540	Innovation, increments, and residuals: Definitions and examples (Patrick Heimbach)	
1540 – 1550	Example utilization of residuals: Arctic Halocline and Antarctic Slope Front (Dimitris Menemenlis)	
1550 – 1600	Challenges in evaluating lower-dimensional features (Gad Levy)	
1600 – 1615	Metrics based on fuzzy similarities between lower dimensional features for intercomparison of reanalyses (Barnabas Bede)	
1615 – 1640	Discussion on key challenges and opportunities (Detlef Stammer)	
1640 – 1730	Session 3 Cont.: Discussion of CPTs (current and future)	Executive
1730	Break for day	

PSMI Breakout Continued - Friday, July 11

0730 – 0800	Light breakfast	Millennium Gallery
0800 – 0900	Session 5: PSMI Discussion: Synthesize reports, big picture view, future foci	Executive
0900 – 1000	PSMIP wrap-up discussion	

PPAI Panel Breakout - Thursday, July 10

0830 – 0900	Welcome, session objectives and outcomes	Millennium Ballroom
0900 – 1000	Session 1: Benchmarking predictions and predictability limits	
	Identify and prioritize strategies that: · Identify "science-limited" targets that offer the most promise for improved predictability of the ocean and climate · Determine best practices for quantifying improvements in predictions and projections · Provide/solicit guidance on methods of communicating these improvements (and limitations) to broader research, operational and user communities Speakers: Arun Kumar, Mike Alexander, Kathy Pegion	
1000 – 1030	Break	
1030 – 1200	Session 2: Joint session with PSMI on Modeling Metrics for Quantifying Predictions and Predictability Limits	Millennium Ballroom
1030 - 1045	The Drought Task Force Drought Assessment Protocoal and its use to evaluate model improvements (Andy Wood)	
1045 – 1100	Methods for identifying science-limited (and noise-limited) metrics/ measurements of the ocean state (Kathy Pegion)	
1100 – 1115	Predictions using fuzzy metrics-based aggregation of climate models (Barnabas Bede)	
1115– 1130	Metrics from the Perspective of the Practitioner's Dilemma (Joe Barsugli)	
1130 – 1200	Discussion on key challenges and opportunities (Bruce Anderson and Gad Levy)	
1200 – 1330	Lunch on your own	
1330 – 1500	Session 3: Joint Session with POS on Observation and Synthesis Requirements for Predictability and Prediction Studies	Millennium Ballroom
1330 – 1350	Recommendations of 2012 CLIVAR/GSOP/WHOI air-sea flux workshop, follow-on activities, & specific recommendations for reducing air-sea flux estimation errors (Lisan Yu)	
1350 – 1410	International Quality Controlled Ocean Database (IQuOD) (Janet Sprintall)	
1410 – 1430	Predictability resulting from subsurface climate variability in the Pacific (Emanuele Di Lorenzo via recording)	
1430 – 1450	North American hydroclimate variability in observationally constrained and climate model datasets (Scott Weaver)	
1450 – 1500	Discussion on key challenges and opportunities (Lisan Yu)	
1500 – 1530	Break	
1450 – 1500	Session 4: Implementing strategies for connecting predictions, applications, and decision making	Millennium Ballroom
	Identify and prioritize scientific, programmatic, and administrative strategies and action items needed to make progress in connecting predictions, applications, and decision making efforts	
1730	Break for day	

PPAI Breakout Continued - Friday, July 11

0730 – 0800	Light breakfast	Millennium Gallery
0800 – 1000	Session 5: Continuation of implementation strategies for connecting predictions, applications, and decision making and a wrap-up discussion	Millennium Ballroom

For more information visit:

https://usclivar.org/meetings/2014-us-clivar-summit

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