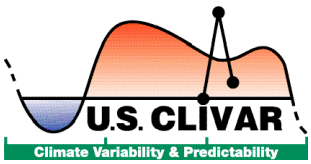

U.S. CLIVAR: Climate Variability and Predictability

U.S. CLIVAR 2010 Summit Report

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U.S. CLIVAR 2010 Summit Report

1 Action Items

Action item 1: **PSMIP to communicate feedback to each of the U.S. CLIVAR process studies by end of summer [process study liaisons].**

Action Item 2: **PSMI to encourage PIs to update their website, and develop and make higher-level datasets available.**

Action Item 3: **PSMI will establish a precedent for archiving microstructure data in a universal format that can be subsequently adopted at NODC.**

Action Item 4: **PSMI will1) Compile a list of all existing climate-related turbulence data sets we would like to see archived, drawing on efforts of Lou St Laurent and Kurt Polzin. 2) Write a memo to NSF/NOAA funding managers. This requires up-to-date knowledge on their policies. 3) Monitor DIMES archiving. Representation from the DIMES microstructure community on the panel would encourage this.**

Action Item 5: **PSMI will contact potential new panel members to encourage them to apply to PSMIP. [Teixeira, Zuidema]**

Action Item 6: **POS will recommend U.S. CLIVAR suggest to the agencies and the Decadal Variability Working Group that more balanced set of research activities are needed to address decadal variability and predictability across different parts of the world's ocean basins.**

Action Item 7: **POS will recommend to the Decadal Variability and Predictability Working Group and the NASA SST Science Team further action that could enhance the awareness of this issue [Tony Lee].**

Action Item 8: **POS will provide further comments about the US AMOC Program, especially in terms of its near-term foci. [All]**

Action Item 9: **POS will respond to the U.S. CLIVAR solicitation for working group proposals by addressing the flavors of ENSO events. [Antonietta Capotondi, Don Chambers, Ben Giese, Tony Lee and Yan Xue]**

Action Item 10: **PPAI will propose a working group on the "Hurricanes and the Role of SST."**

Action Item 11: **PPAI will propose a working group on the "High latitude temperature amplification and sea ice variability" with a focus on synthesizing our current understanding of sea ice decline in the Arctic and its feedbacks in the lower-latitude climate variability (implications for seasonal and initialized decadal predictions).**

Action Item 12: **PPAI will propose a workshop on "Climate Extremes" to highlight various aspects related to climate extremes including: Assess the ability of climate models in simulating hydroclimate (and other) extremes; defining best practices for statistical methods for modeling and analyzing extremes from observations and GCMs; quantifying relative advantages of statistical and dynamical downscaling schemes as they relate to climate extremes.**

2 Welcome and Introductions

David Legler welcomed everyone to the 2010 U.S. CLIVAR Summit. Legler noted the many new Panel members this year, and he encouraged them to become involved in U.S. CLIVAR. Legler thanked Cathy Stephens and Jill Reisdorf for the logistical preparations. Legler then turned the program over to Mike Spall, a U.S. CLIVAR executive committee member, who chaired the session on polar programs and activities. Spall noted to all that U.S. CLIVAR would be introducing new foci this year: one on polar climate, and one on extremes. He was hopeful that the following presentations could help U.S. CLIVAR fill the gaps in these programs and determine which activities within U.S. CLIVAR could be leveraged to support these new themes. Spall recognized that the U.S. CLIVAR Panels and Working Groups are the primary means of accomplishing U.S. CLIVAR goals. He encouraged the Panels this week to identify programmatic issues that would lead to actionable items in polar climate and extremes.

3 Polar Science Theme

3.1 *Arctic Environmental Change*

Peter Schlosser from Columbia University, and co-chair of the SEARCH (Study of Environmental Arctic Change) SSC described Arctic environmental change. He noted that ten years ago, climate change in the Arctic was still unclear. The breadth of Arctic climate phenomena was unknown. However, in recent years, scientists have seen how environmental changes are affecting the Arctic. Schlosser emphasized that now is a good time to revisit these environmental changes in high latitudes and an excellent time for U.S. CLIVAR to become involved in polar climate science. Schlosser highlighted recent changes in Arctic including the polar amplification of global climate change (see the IPCC 2007 report). He noted that even the early coupled models in the 1980s hinted at amplified signals in high latitudes, especially in the Northern Hemisphere. Thus, Schlosser claims, these latest reports of Arctic warming should come as no surprise. Changes seen include: reduced sea ice cover, warmer Atlantic waters, increased air temperature over most of the Arctic, warming of the permafrost, and the melting of the Greenland Ice Sheet.

The physical changes also have large impacts on the Arctic ecosystems and society. Schlosser has examined annual and seasonal changes in the surface air temperature, annually and in the winter season. A two-degree increase in temperatures is noted, with most of the warming actually occurring in winter. The 1930s-40s had a similar warming signal, but in the 2000s, the warming

is observed globally, not just at high latitudes. Schlosser then showed temperatures averaged over land and ocean from Goddard Institute for Space Sciences (GISS) data. The question is whether or not this is a trend or natural variability. Schlosser noted that scientists still are not sure.

Spall wondered if there is a larger scale feature that is forcing Atlantic and Arctic warming? He noted that in the 1930s it appears that the warming comes more from Pacific region and not from Atlantic side.

Schlosser then discussed current sea ice trends. He noted that the Canadian Arctic was very open in 2007, but that sea ice began to grow back by 2009. However, the thicker (multi-year) ice has disappeared since 1982. Even though ice was regenerated in 2008, it was a one year ice cap and thus not as thick as previous ice caps and consequently more vulnerable to warming. Peter stated that 80% of sea ice cover is only one year old; and that the 20% of sea ice that is greater than 2 years has essentially been removed. Sea ice model runs from Holland et al (2006), indicate that by 2050, sea ice in summer will be non-existent. Scientific challenges include interpreting data from observation systems; identifying potential for abrupt changes; and modeling a non-linear system.

The SEARCH Program began publishing Sea Ice Outlooks to estimate the sea ice extent at the end of the melting season (May-Sept). Most of the estimates are very close to actual ice melt. However, though 2010 began with close to average ice extent, the months of April and May were anomalously warm. Currently, the ice extent is approaching the minimal ice levels of 2007.

Schlosser then noted that the Greenland Ice Sheet is a reservoir of fresh water in the Northern Hemisphere and can make a large difference in ocean surface salinities. Schlosser stated that though accelerated melting of the ice sheet surface is observed, the melting might not be completely understood. The flow of glaciers is also faster in recent years. Between the years 1993-2008 a peak in ice quake frequency was observed at the surface, which can make ice slide faster. Schlosser added that it appears as if unanticipated processes are accelerating the melting and outflow process.

Schlosser noted that these physical changes in the Arctic have large impacts on ecosystems and society. The effects include extended shipping lanes opened and eroding coastlines. With the permafrost melting, villages had to be moved from the coast due to deteriorating infrastructure (bridges/roads/buildings). Thus, climate change cannot be viewed in isolation. The same human induced pressures that are forcing the climate system have significant effects on other environmental systems such as water resources and food supply.

Schlosser examined more carefully the role of freshwater feedbacks to the global climate. Key questions include whether or not changes in the freshwater fluxes from the Arctic to the North Atlantic can shut down the conveyor belt, and what the consequences of a conveyor shutdown in a greenhouse world would be. A temperature maximum in the Atlantic Ocean is observed at 300 m depth, with large freshwater observed at surface. This fresh inflow of water stems from the Bering Strait, river runoff, and net sea ice melt. The first signs of freshening occurred in 1993, with an 80% reduction of seawater in the Greenland Sea. A decrease in salinity and broad-scale freshening in the Atlantic occurred during this time, and thus additional freshwater fluxes were observed. But, Peter noted, the real question is how much additional freshwater can we expect due to Precipitation minus Evaporation (P-E) in model projections and due to river runoff. Peter stated that current programs such as the CLIVAR Atlantic Meridional Overturning Circulation

(AMOC) program is looking at the thermohaline circulation stability. The AMOC science team has noted that a reduction of deep-water formation in the North Atlantic leads to cooling, mostly over the North Atlantic. The total freshwater input into the North Atlantic in a greenhouse world could be significantly above 100 m/Sv. But the biggest uncertainty is how will sustained freshwater from the Arctic translate into the Atlantic and be distributed? This could lead to the slowing of MOC and thus a reduction in Atlantic warming.

Schlosser discussed in depth SEARCH's overall objective, which is to understand the nature, extent and future development of the system-scale change presently seen in the Arctic. SEARCH is focused on the state of the Arctic system; to what extent can ongoing changes in the Arctic be attributed to anthropogenic forcing; how the terrestrial and marine ecosystems are affected by environmental change; and what are the most consequential links between the Arctic and the Earth systems. The link of the Arctic region to climate change has moved to the forefront with the International Study for Arctic Change (ISAC). Stakeholder needs have become more important and adaptation and mitigation have become key. Many projects are helping to advance Arctic climate change research. The SEARCH Strategy included a long-term observation period as well as modeling and process studies. The National Science Foundation (NSF) supported the International Polar Year (IPY) project. Available observations are listed through Arctic Observing Network (AON). International partners such as ArcticNet, DAMOCLESE should be embraced in these efforts.

In conclusion, Schlosser reinforced that the Arctic is changing at a rapid pace. The understanding of these changes will require more observations as well as modeling and synthesis activities. The observation must be obtained through a long-term, integrated observing system. The IPY has provided a reason for establishing an Arctic observing system, but additional international efforts and collaborations are needed to maintain the observing system.

Following the presentation, Schlosser reminded everyone of the IPCC projections and noted that the Greenland Ice Sheet is the key. Jim Hurrell, NCAR, stated that the modeling aspects of this region should be strengthened, both process modeling and coupling (downscaling and regional). Rick Rosen, NOAA, noted there would also be benefit in including the impact of changing weather and climate extremes over America. He felt trying to understand winter weather changes given that the Arctic as a source of influence is important. Simon deSzoeke thought it seemed ironic that given the changes felt in Arctic, that very little effort is spent on human/environmental consequences and asked if there were other groups that might be interested in leveraging this information. Schlosser answered that although SEARCH has this as a stated goal, the program is hampered due to the small community engaged in the work. The program is growing and wants to add economists and social scientists, but there is a lot of hesitation by traditional funding agencies to do so. Schlosser also stated that there is no resistance in the community anymore to engage the social scientists and economists.

3.2 *Climate Variability Research in the Southern Ocean*

Alex Orsi, Texas A&M University, presented the current state of climate variability research in the Southern Ocean. He began by discussing why the Southern Ocean interactions are important globally. Southern Ocean-Cryosphere-Atmosphere interactions play a part in the stability of the Southern Ocean overturning circulation; they play a large role in the global heat and freshwater balance; contribute to the stability of the Antarctic ice sheet and thus sea-level rise; and are

important to Southern Ocean carbon uptake and Antarctic ecosystems. Orsi noted that progress has been made in observational and modeling programs. Sustained, long-term measurements from CLIVAR repeat hydrography sections and moored time series, in addition to the recent process study, e.g. DIMES, have enhanced sparse Southern Ocean observations. Orsi showed that trends in sea surface height frontal positions and their dynamics have changed in past two decades. Recent studies have shown the Antarctic Circumpolar Current (ACC) may lie in an eddy-saturation regime. Water mass changes in the upper-ocean are also projected as the temperature warms and thus enhanced eddy activity would be seen with stronger westerlies. These changes are not uniform within the region, but the structure is well defined vertically and horizontally down to 2000m. Furthermore, global models have predicted CO_2 fluxes to be weakening as the Southern Annular Mode (SAM) changes. Scientists consider ocean acidification to be near a tipping point. Other climate changes in the Southern Ocean region include increased loss of Antarctic ice mass as a result of warmer air and ocean temperatures, mainly on western coast of Antarctica. Orsi noted that a recent process experiment indicated a reduction in the Pine Island glacier over the past 30 years. The vast melting has a huge freshwater influence in the Southern Ocean towards the Ross Sea, as the Ross Sea is one of the key overturning sites. A steady decrease in salinity can be seen over the past 50 year freshening period. Temperatures are being maintained near freezing point and could impact the overturning circulation. As a result of the climatic impacts observed in the Southern Ocean, CLIVAR has requested the development of imperatives and frontiers of climate science in the Southern Ocean.

CLIVAR imperatives are near-term requirements that must be undertaken. The CLIVAR Southern Ocean panel established the following imperatives:

- ARGO must be maintained through the full water column depth hydrographic (water sampling), and sampling or observational techniques should be extended to the under-ice-covered ocean, up to the ice shelf grounding line.
- As the Southern Ocean appears to be eddy saturated it is crucial the IPCC models should become eddy resolving.
- The gaps in estimates of air-sea fluxes of heat and moisture, CO2, wind stress, and boundary layer parameterization near the continent must be addressed.
- A broader evaluation of the impact of acidification and the ecosystem response should be conducted.
- More accurate diagnoses of freshwater and moisture transfers among the coupled Southern Ocean-Cryosphere-Atmosphere system, and associated feedbacks should be completed.

Frontiers and objectives for the future include examining the future of Antarctic ice, carbon uptake and acidification as well as the Antarctic continental margin. There are still basic science questions which need resolving. A U.S. CLIVAR Working Group on high latitude surface fluxes was developed, and the DIMES Process Study in collaboration with United Kingdom was initiated to refine the present paradigm of mixing and upwelling in the ACC (improving of climate model parameterizations of ocean physics and constrain models of the meridional overturning circulation).

Southern Ocean research was recently enhanced through the International Polar Year (IPY) observations. Orsi is hopeful these observations could lead to a sustained Southern Ocean Observing System. However, remote sensing observations as well as in-situ observations are greatly needed. IPY offered an opportunity to establish observation sites for longer time series

measurements. In addition, another sampling tool under the ice comes from marine mammals with attached CTD samplers. Biogeochemical sensors on the seals would be beneficial as well.

Climate variability challenges still exist though. The Southern Ocean's role in the Earth's climate is predominant, but dynamical understanding of the key modes and feedbacks are still not well understood. The Southern Ocean Observing System (SOOS) is a first for climate observations spanning multiple disciplines. However, the region is vast, remote and difficult to access. Thus, multiple nations and agencies need to be involved in supporting the observing system.

During discussion, Joellen Russell asked that given all the models agree that increased winds lead to increased transport, and given that there is a large gap in the prediction of the heat sink, why are flux buoys not listed in the imperatives or bottom pressure system arrays which could yield better information. Orsi replied that the imperatives listed generalized improvements of fluxes and agreed at least a decade of measurements are needed. Lisa Beal noted that the Drake Passage has about 15 years of measurements, which are typically the benchmark for observations. In terms of transport, a huge effort is underway because of IPY, and hopefully these measurements will be maintained. Another question raised for consideration, was how much is known about the flux changes out of individual basins. For instance, changes in the Ross sea shelf waters so far show no evidence of slowing down overturning rates. In the Weddell Sea a longer record exists, and is now showing evidence of change, but not much has been published with regards to the fluxes.

3.3 *Discussion of Polar Climate as a U.S. CLIVAR theme*

Mike Spall led the polar discussion and invited the two speakers to address gaps in the current science and identify how CLIVAR could help fill these gaps. He also invited the group to comment on and discuss CLIVAR's potential role in polar science. Scholsser identified several key issues including the seamless link between high/low latitudes, and the gaps of scientific knowledge in the Nordic Seas. He also noted that CLIVAR could think about the modeling issues of sea ice retreat, and about relevant coupled processes and impacts of this retreat on other parts of the climate system. Furthermore, downscaling capabilities are needed in high northern latitudes particularly for stakeholders. And finally, the interaction between secular trends and shorter scale variability could use more synergy. Orsi feels that the basic gaps in the Southern Ocean are in understanding and observing, but the most pressing need is radar and lidar altimetry to measure sea ice. Long-term measurements of outflows, source sites, process-oriented issues including eddies and adiabatic processes would be useful as well. Additional needs include climate model parameterizations, looking at the long-term effects and responses of the Southern Ocean. Orsi also noted that the Southern Ocean research community is at an earlier stage than the Arctic community.

The question arose regarding which particular atmospheric observations are necessary. Schlosser replied that Arctic atmospheric observations over the central ocean would be useful. Possibly more meteorological equipment could be placed on drifting buoys, but there are some issues of technical development. Orsi commented that there are only a handful of meteorological stations in the Antarctic.

Jim Hurrell asked about the involvement of Schlosser and Orsi's groups in regional downscaling efforts. Schlosser noted that SEARCH has some contacts in regional downscaling, but not

enough. There has been some discussion on the possibility of an Arctic region downscaling modeling project, but it has not gone forward, possibly due to the lack of community agreement.

Tony Lee, JPL, asked about the gaps in low/high latitudes related to El Nino. He noted that when scientists discuss trends, to what extent is a trend in the SAM related to the trend in ENSO? Schlosser stated that as longer time series become available, the issues of different climate modes and their interactions could be addressed. He noted that a decade ago, all changes were considered related to the AMO or PDO, but now there is a more realistic picture. There are secular trends in the region, but climate modes have influence as well.

Hoerling noted that if scientists think broadly about polar problems, there is an opportunity within the structure of WCRP and CLIVAR to apply polar science research to societal impacts. In the case to policy makers, the poles are now seeing the most climate change and wonders if these Arctic changes remain solely in the Arctic, or do they affect other regions. He also wondered if the sea ice is forcing a winter Arctic Oscillation (AO)? CLIVAR could look at these impacts. Hoerling agreed the time series is much shorter in the Antarctic and the picture more complicated. Hoerling also suggested CLIVAR try and understand the different responses of the two poles to climate change. Orsi agreed that the Southern Ocean interactions are complex, and noted that there is nothing preventing the spread of anomalies northward. Antarctica has 20,000 km of coastline and no two regional seas are similar in circulation or dynamics. Regarding the Southern Ocean ozone problem there is still minimal prediction of the evolution of the ozone hole. It is unknown as to whether it is shielding the climate changes and what will happen when the shield goes away. Schlosser noted that the North Pole has higher amplification and is relatively close to major landmasses compared to South Pole. The North Pole has some interesting questions relating to socioeconomic conditions within the Arctic domain. CLIVAR could examine mechanisms that feed from the Arctic to America and other regions. Great benefit could occur from the global CLIVAR community and Arctic community coming together to look at problem. There is currently enough information to formulate hypotheses in Arctic.

Eric DeWeaver, NSF, was interested in polar feedbacks. How do scientists use ice albedo feedback in Arctic? And how would an observation network be devised? Schlosser stated the group is working on optimizing an observation network, but there is no blueprint to follow. The goal is to have community input: terrestrial input, oceanography input, and to capture the primary patterns/signals in the Arctic Oscillation. He suggested that perhaps climate feedbacks would hopefully be addressed by SOOS.

Key issues also exist surrounding climate modeling over the poles. Schlosser stated the interaction between ocean and atmosphere is accomplished through the ice cover and related processes, but is unsure how to understand downscaling features from global models. On the ocean side, the goal is to figure out what is driving flow underneath ice sheets. Is it more topographic guiding rather than wind? Is ocean mixing playing a role? Climate modeling is still in the infancy stages for the poles. DeWeaver questioned whether or not modelers could provide useful insight to observationalists in their research. Schlosser thought that the modeling of sea ice could point to nonlinear interactions that lead to decrease in sea ice. If a trigger could be identified, then observations could be adjusted to capture preconditioning conditions. The State of the Arctic Conference attempted to bring modelers and observationalists together. There is now at least a dialogue between the two groups. Orsi noted progress from modeling community in ECCO with its high-resolution model.

Finally, Hoerling raised the question regarding the feedback between the reduction of sea ice and the warming of land. He questioned whether or not the Arctic tundra warming was related to sea ice reduction. Large-scale dynamic programs still seem uncertain. Schlosser agreed and noted that an open Arctic Ocean led to the absorption of more energy. He also noted that scientists are looking at the impacts of an open Arctic Ocean on land and ice sheets. Gabe Vecchi reminded everyone that modeling involvement is necessary and that modelers are using observational data more and more. Mike Spall thanked everyone for an interesting discussion.

4 Extremes Theme

4.1 *Extremes and Their Causes*

Xuebin Zhang, Environment Canada, presented an overview of extreme events in climate change. He defined an extreme weather events based on the IPCC4 glossary, and noted that extreme events are easily recognized, but difficult to define. Extreme events can create significant loss, have a low probability of occurrence, and have extreme/anomalous values. End users are interested in extreme events as relating to their rate of occurrence, magnitude, duration, spatial scale and their predictability. The IPCC 4th assessment provides a table of extreme phenomena, their trends, and how likely these phenomena would occur.

Zhang then discussed changes in temperature extremes and what is currently known. Observations from 1950 – 2000 show a strong decrease in cold nights (during Northern Hemisphere winter) and an increase in warm (Northern Hemisphere summer) days. He noted that data are very sparse in northern South America and Africa. Model projections for the years 2081-2100 show significant increase in maximum daily temperatures, especially over land only regions of Europe and North America. Currently there is a concentrated effort to understand causes (e.g. Greenhouse Gas (GHG) forcing, anthropogenic forcing, and the natural variability cycle) of the projected increase in temperatures (Christidis, et al, 2005) through model comparisons. There appears to be a clear increase of anthropogenic forcing in summertime night temperatures. Models seem to produce more warming in daytime temperatures, but less warming in nighttime temperatures. Research has shown an increase in hot extremes and a decrease in cold extremes. In addition, anthropogenic influence on extreme temperatures is detected on both global and regional scales. Hot extremes are projected to increase while cold extremes are projected to decrease. However, there still exists a large gap in data coverage.

Extreme precipitation changes are less understood than temperature changes. Observed changes show an increase in precipitation over most of North America. Again, data is scarce over Africa and South America. Model runs indicate a dramatic decrease in precipitation over all regions. In examining model trends, GHG influence contributed to the observed intensification of heavy precipitation events over large Northern Hemisphere land areas during the latter half of 20th century. However, models seem to under-simulate the observed increase in heavy precipitation. ENSO events provide a substantial probability of heavy precipitation to North America. Current understanding of precipitation extremes include a likely increase of extreme precipitation to occur and anthropogenic influence on extreme daily precipitation might be detectable, but the simulated response is likely smaller than the observed changes. In addition, large-scale features such as ENSO and monsoons are important to extremes, but their future projections are uncertain. And, larger gaps exist in precipitation data compared to temperature data.

The challenges in understanding extreme events include a serious lack of observed data while other variables important to extremes such as soil moisture are even more limited. There is also currently a mismatch in spatial scales between observations and model simulations that hampers proper comparison. Models may lack the proper processes to simulate the environment that generates extremes. The current knowledge and information on past changes and potential extreme changes falls short of user needs and expectations.

Following the presentation, several comments and questions were raised. Meteo France operations are currently looking at patterns associated with precipitation anomalies. When these anomalies are observed, downscaling models are run in that region. Zhang agreed that there would be more success in identifying extremes in this manner. DeWeaver asked if models with more extreme hot days in Europe and say Africa were examined, would there be a correlation between the two? Or do certain models influence one region more than others? Zhang was unsure and stated that it would be nice to get away from geography and head more towards climate processes in the models. Balaji added that a complimentary aspect to downscaling should be pursued, for example statistical methods, especially where models are good at reproducing events such as ENSO. Better yet would be a downscaling tool that feeds directly into statistics. Zhang cautioned that there is still a lot of uncertainty in downscaling processes. Simon de Szoeke reminded everyone that statistical models are necessary for weather downscaling. But, Vecchi countered, downscaling for climate change does not make as much sense as for weather. DeWeaver then questioned why temperature extremes are increasing and asked about the physics involved. Hoerling reminded the panel members that the Summit is an opportunity for the panel to consider processes that underlie extreme changes. Some possible questions for the panels to explore are:

- Why are all frequencies of precipitation not increasing?
- Why have summertime temperatures over the middle United States not increased?

4.2 Climate Extremes: The Drought Hazard

Brad Lyon, IRI, presented a talk on drought as a climate extreme. He discussed the recent advances on drought through the U.S. CLIVAR Drought Working Group and through the Drought in Coupled Models Program (DRICOMP). The new Drought Interest Group (DIG) in CLIVAR, formed upon the completion of the U.S. CLIVAR Drought Working Group (DWG), is currently working on a white paper discussion Drought Predictability and Prediction. Lyon noted that drought is difficult to define. Many definitions exist, but drought is mostly defined by an insufficient supply of water to meet the demand, and is ultimately tied to extended periods of deficient precipitation relative to the expected value at a certain location. Lyon also stated that there are multiple causes of drought and noted that improvements of drought prediction depend on improved predictions of precipitation.

Drought can be broken into three categories: meteorological, agricultural, and hydrological. Currently, the human demand for water is great and has led to an increase in groundwater extraction and thus land subsidence. But with the prospect of climate change, the question remains as to how precipitation will change in the future. Numerous indices exist to monitor drought, but there are still many challenges. These challenges include imperfect data, the lack of real time updates for monitoring, the lack of historical records for satellite-derived products, and large uncertainties in derived quantities such as soil moisture.

In looking at land surface modeling and recent soil moisture estimates, the various models disagree except to show drought in Louisiana and northern Wisconsin. Soil moisture from satellite data is even more complex. The Soil Moisture Observations from Satellites (SMOS) project is under development in Europe, but the ground truth remains unclear. In addition, the role of sea surface temperature (SST) in prolonged drought (Schubert et al., 2004) is being examined with respect to the Great Plains drought. Studies indicate the Northern Plains are not as well connected to Pacific SSTs as the southern plains are. Seager et al., 2005, also examined drought in the Great Plains. Wet ENSO conditions seem to indicate wetter than normal conditions in the plains. A prolonged drought (1998 – 2002) showed that much of the subtropics drought conditions were associated with very warm western Pacific SSTs. There appears to be a relationship between drought in the Great Plains and the eastern equatorial Pacific, but other influences also exist. Depending on spatial distribution of SST, the impacts on precipitation are different for these regions.

Finally, the role of the land surface has been examined through GLACE, a CLIVAR/GEWEX experiment. Findings conclude that the stronger the initial perturbation, the stronger the result. Involving land surface is thus critical for drought prediction in the warm season. Land surface representation can vary greatly in GCMs. For meteorological drought, the land surface is very important.

Following the presentation, Paquita Zuidema, RSMAS, how the DIG differ from the DWG. Lyon noted that following the completion of the DWG, International CLIVAR asked DWG members to establish an informal international group in collaboration with GEWEX to figure out where to take drought. Thus, the U.S. group merged into an international effort. Several asked how drought would fit into the theme of extremes. Lyon said that the answer would depend on what aspect of drought was examined: the enhanced hydrologic cycle, long term climate change, etc… There is an entire spectrum of activities from which to choose. Gregg Garfin noted that drought should not be defined too narrowly, and should have more to do with timing, length, and development. Hoerling reminded everyone that drought is derived from temperature, as well as precipitation, and also implies a certain intensity or rareness. Drought also implies an extremeness of a phenomenon (e.g. lack of monsoons).

DeWeaver then asked how could end users make use of drought information. Lyon stated that AMIP model runs know nothing about initial conditions, but the methodology, that is any index based on meteorological inputs, can trigger actions. Lyon suggested that experiments could tailor to a specific threshold value based on shareholder needs. Garfin stated that users do not use forecasts literally, but they filter all the information and cull any decision they make from the information. Hoerling noted that U.S. CLIVAR has already invested significantly in drought, i.e. DRICOMP, DWG, which was intended to paint a larger picture of drought, and progress has been made in some sense regarding ocean conditions and how they relate to North American drought. But, there is much more that needs to be done. Perhaps there should be a monitored state of the system, which includes hydrology, soil moisture data, and SST information. Hoerling encouraged the panels to consider whether or not drought has a place in U.S. CLIVAR and its theme of extremes.

4.3 *Hurricanes and Climate: Current Challenges*

Gabe Vecchi, GFDL, discussed hurricanes and climate and their current challenges. He mainly focused on the outstanding issues and challenges in the Atlantic Ocean. Vecchi stated that the

current goals for the scientific community are: to document changes in hurricane statistics as far back as possible and quantify their uncertainty; to represent the interactions between hurricanes and climate in dynamical models; to predict and project changes and variations in hurricane statistics, to extend the window of predictability; to expand the predictable characteristics; and the be able to attribute changes in hurricane statistics to particular physical factors.

Current dynamical models can reproduce seasonal basin-wide hurricane frequency with good quality, and can recover recent trends in frequency and interannual variability. However, model response exhibits sensitivity to the forcing used. Vecchi thus questioned how one could access the skill of the model. Tropical mean temperature change in the upper troposphere and tropopause layer is the key difference to explore model sensitivity. This opens the door for direct radiative forcing to affect tropical cyclones. There currently is not a coordinated effort to downscale climate models in a similar way. And there is no consistency in 21st century projections. Most of the uncertainty in hurricane activity projections comes from not knowing what large-scale dynamics will do in 21st century. It is much easier to run a statistical downscaling model, but great uncertainty in how to access the applicability of this method. Vecchi suggested that perhaps U.S. CLIVAR could consider this approach in all realms of science and not just for hurricanes.

Vecchi identified three key issues between ocean climate and hurricanes. First, the biases in the tropical Atlantic mean state and seasonal variability can influence the character of interannual changes, which limit predictability. The definition of the AMO is also an issue. Vecchi also identified forecasting as an issue. Hurricane forecasts are regularly produced, and potentially skill is possible from mid spring to early summer. Several different schemes for forecasting exist. Dynamical models with a short lead show as much or better skill than statistical models. Vecchi pointed out that, in order for these forecasts to be useful for stakeholders, they need to be issued in December. He also indicated that multistep downscaling could be useful to get the extreme hurricanes. Moreover, none of the modeling centers predict land falling hurricanes. Vecchi reminded the panel members that a theory exists regarding control of a hurricane's potential intensity. However, no theory exists for hurricane genesis. He noted that seeking a genesis theory should be a priority. One way of achieving this could be to coordinate forcing experiments with AGCMs. When the ocean warms, potential intensity increases. However, when the entire globe warms, not all things are equal because the troposphere is also affected. Even with uniform warming over the entire globe, the storm count does not increase. However, Atlantic forcing does appear to increase storm count. The Eastern Pacific exhibits a similar effect, but not the Western Pacific due to the monsoon influence. He also pointed out that hurricane data bases are not built as climate data records, and thus these data bases need a lot of work.

Nick Bond noted that the genesis of cyclones sometimes end with bang rather than whimper and wondered if any work existed on what climate change would likely to do to extratropical storms. Vecchi does not know of any work in this area. Grotjahn noticed that an emphasis is placed on SST in Vecchi's presentation, but wondered if wind shear could also be a factor in hurricane genesis. Vecchi answered that the approximate cause of limiting genesis is shear and vorticity, but a lot of that information is contained within the SST. SST in the Atlantic minus the tropical mean temperature is a very good index for Atlantic storms. When Atlantic SST is warmer than the mean, the troposphere is moistened, and intensity increases. Stratospheric chemical changes could also affect hurricane genesis.

4.4 Discussion of Extremes as a U.S. CLIVAR theme

Marty Hoerling invited the three extreme speakers to the front to lead the discussion on extremes as a U.S. CLIVAR theme. He challenged everyone to think about other extremes the panels should discuss. Grotjahn noted that little was said about hottest days/coldest days/wettest days and reminded everyone that even short time scales matter. For example, California has a 3-5 month drought each year. And, a three-day event can cause grapefruit loss in Texas. He also stated that longer time means, popular with climate modelers, are misleading. Some understanding of the meteorology behind the extremes is necessary. The study of extremes appears much farther along in Europe, something perhaps U.S. CLIVAR could learn more about.

Lyon is interested in knowing which statistics within climate are related to weather. Vecchi replied that the mean is the first mode and the one most often examined, but he admits the other modes are interesting as well. For instance, wind shear is too high prior to June and dry air from Africa can limit hurricane development until mid-June even though the Atlantic is warm enough. There is also some interannual correlation between wind shear, vorticity, and thermodynamics.

Spall questioned how to focus the theme of extremes within U.S. CLIVAR. He suggested that the panels in their discussions could provide guidance for such focus. Vecchi felt the focus, which appeared to be emerging, concerned data issues, and a way to enhance existing data. Another focus could be dynamical and statistical tools (eg. downscaling methods). He suggested that the group, rather than focusing on phenomena, focus on tools and problems. Zhang felt building up understanding of the processes of extremes would be another way to approach the problem of extremes. Also key would be to translate the tools and information to stakeholders.

Bond questioned if dynamical downscaling processes were needed for extreme events. He argued for more careful statistical processes. Vecchi agreed that only concentrating on dynamical downscaling was not the answer, but scientists need to be open to the fact that processes that control the future may need some dynamical understanding. Statistics limit and narrow the focus. Statistical techniques must be confronted with dynamical techniques and, when the two merge, truth exists. Kumar suggested some coordinated experiments, which could include more information on extremes. Vecchi agreed that a series of coordinated model studies should be opened up to a larger community. Zuidema was surprised that NOAA and Hadley Centre data sets give vast differences and questioned why. Vecchi replied that the sensitivity of TS to patterns of SST is about 1/10 degree per season. Christiana Stan also noted that the Hadley Centre data is monthly, but NOAA data is weekly. Vecchi noted that he uses the monthly data product from both centers, and they have different global mean trends as well. Lisa Beal inquired about the mixed layer depth. Vecchi indicated that mixed layer depth is key for both intensity and decay. The level of the mixed layer depth is important, as are the coupling aspects of the system.

5 U.S. CLIVAR Report

Lisa Goddard introduced Marty Hoerling, outgoing U.S. CLIVAR chair, to report on U.S. CLIVAR and its panel activities of the previous year. Hoerling noted that the new structure has really flourished and is making great strides in climate science research. He presented an overview on current U.S. CLIVAR activities including themes, working groups, and new Climate Process Teams (CPTs). He also commented that the U.S. Global Climate Research Program (USGCRP) will be writing a new strategic plan and provides U.S. CLIVAR an excellent opportunity to become engaged in the process.

Hoerling highlighted the Panel's current activities. The Process Study Model Improvement Panel (PSMI) panel is coordinating the efforts of the four new CPTs, helping to develop a small grants program for new IPCC model results, and is currently reviewing potential process studies such as DYNAMO and SPURS. The Predictability, Predictions and Applications Interface Panel (PPAI) is working closely with the Decadal Predictability Working Group (DPWG), and continues to expand their Post-Doc program that is increasing the pool of scientists qualified to transfer climate knowledge to decision-frameworks and into tools. Finally, the Phenomena, Observations and Synthesis (POS) Panel is working with the High Latitude Surface Flux Working Group, and is engaged in planning the upcoming Reanalysis/Integrated Earth System Analysis Workshop in November 2010.

Hoerling listed recent publications from the Panels, Working Groups and U.S. CLIVAR. He highlighted the upcoming publication from the DPWG, and provided a brief overview of the paper. Hoerling further noted that there is currently only one active WG in U.S. CLIVAR and encouraged the Panels to recommend new working groups. He also commented on ideas that have advanced from the Panels for a predictive understanding. For example, POS has been discussing in the role of sea ice in high latitude temperature amplification. PSMIP is engaged in narrowing uncertainty in SST trends in the tropical eastern Pacific through a number of field campaigns and model research. Meanwhile, PPAI is examining seasonal prediction and predictability of hurricanes and their relationship to SSTs. Emerging issues in the area of predictive understanding of climate include causes and understanding of recent climate extremes, the role of sea ice in climate variability, and assessing the predictability of decadal variations from the new CMIP5 experiments.

Hoerling then gave an overview of the upcoming IESA Workshop and discussed the objectives of the workshop. These objectives include assessing the strengths and limitations of the new recent U.S. reanalyses and suggesting where improvements of reanalysis products can be made; developing definitions and identify goals of U.S. efforts leading to the forthcoming generation of integrated Earth system analyses (IESA); developing diagnostics to quantitatively assess needed improvements in IESA products; and demonstrating applications of reanalyses in climate and weather that would further highlight needed improvements in reanalysis products.

Hoerling praised the success of the Atlantic Meridional Overturning Circulation Project (AMOC). The program, working with interagency and international partners, will establish an objectively based design for a sustained AMOC observing system required for an early warning system, and assess AMOC predictability, and describe AMOC's role in global climate. Immediate plans include raising the visibility of AMOC within agencies and the community, articulating recent successes, identifying program priorities and needs for the next several years, and increasing coordination with the international community to address these needs.

U.S. CLIVAR themes were listed along with example science questions and challenges. For decadal variability, U.S. CLIVAR is looking at what processes give rise to decadal variations in societally relevant environmental attributes (e.g., precipitation, storms, surface temperature, sea level, ecosystem services), what is the predictability of decadal climate variations, what processes contribute to this predictability, and what are the skill contributions (if any) from internal conditions versus externally forced conditions. For extremes, the agencies indicated that U.S. CLIVAR should identify a small set of questions that are critically important in society. Challenges remain in building the capacity to address attribution. Agencies are interested in polar

climate as it relates to the role of ocean circulation and what is happening to the ice mass, especially Greenland. Other challenges include the effect of the openness of the Arctic Sea due to sea ice loss.

In Washington, DC, Climate Services is the new priority for the agencies in the U.S. Global Climate Research Program (USGCRP). Hoerling encouraged U.S. CLIVAR to consider what their research role will be in climate services. He noted that during the Summit, the Panels should explore the new themes of extremes and polar science, as well as the relevant challenges, gaps and opportunities in these areas. He encouraged the Panels to make recommendations for new working groups and encouraged members to get involved in writing a prospectus for new working groups. He also noted the need for Panels to identify research gaps, initiate community activities, and coordinate climate research.

6 Working Group Reports

6.1 *High Latitude Surface Fluxes Working Group*

Gary Wick presented overview of the High Latitude Surface Flux Working Group. He reminded everyone of the group's two specific objectives: to document the present state of high-latitude fluxes, considering momentum, heat, freshwater, and CO_2, focusing primarily on ocean-atmosphere and ocean-ice-atmosphere fluxes; and to organize a community workshop which would coordinate efforts to improve flux estimates at high latitudes. Since the working group's inception, several articles have been published in U.S. CLIVAR *Variations*, *FluxNews* and OceanObs'09. A Bulletin of the American Meteorological Society (BAMS) article summarizing the current state of fluxes is in preparation. The group has not really looked at solid land to atmosphere fluxes. One of the real challenges for the document is the requirements and accuracies needed for each flux. There is not a good estimate for mesoscale or shorter scale fluxes.

In March 2010, a workshop was held in Boulder, Colorado in conjunction with the SeaFlux Community. All presentations from the workshop are posted on-line: http://www.joss.ucar.edu/events/2010/seaflux/agenda.html. As a result of the workshop, a special collection of the Journal *of Climate* special will be published. From the workshop, consensus strategies for improving fluxes were established. The strategies include:

- ***More routine observations***: Moorings, or routine shipboard observations of momentum and turbulent heat fluxes.
- ***More process studies***: Arctic and Antarctic observations desirable.
- ***New satellites***: Prospect of obtaining momentum, latent heat, sensible heat, radiative fluxes through a well-defined set of sensors, possibly in multi-satellite formation ("Flux Train").
- ***Improved access to observations and reanalyses***: Good meta-data, quality control and uncertainty information.

The need for observations was noted, but the group agreed that it is also crucial to analyze the historical data carefully. The group also encouraged putting flux sensors on ships that are already going to sea for regular maintenance of buoys, etc. The Working Group also wants to facilitate the intercomparison of existing products. SEAFLUX (http://seaflux.gfdi.fsu.edu) is currently focused on comparing gridded products, with contributions from satellites, observations and reanalyses. The assessment of these products remains crucial. U.S. CLIVAR could assist in this

assessment. The upcoming U.S. CLIVAR Reanalysis conference would provide an excellent forum to discuss this assessment. Bringing in a broader community of users to test these products and data would be idea. Wick noted that the Working Group is coming to a close of its two-year lifetime, but that projects are ongoing.

Questions about the reduction of error bars were raised. Wick stated that extreme conditions do hinder measurements, and the intercomparisons, though a challenging issue, would aid in determining "truth". Another question concerned the energy balance of the ocean, and whether or not there is enough information to determine long-wave, and short-wave radiative fluxes. He noted that there is definitely enough work to continue this Working Group in some capacity. DeWeaver wondered if there was any useful guidance from looking at GCMs? The answer was, yes, but there is no singular source to determine the accuracies of the flux requirements. Tower sites do no close the full energy budget and it is hard to evaluate models.

6.2 *Decadal Predictability Working Group*

Arun Kumar updated the group on the Decadal Predictability Working Group (DPWG). He provided the background and motivation for creating the Working Group. The group agrees that considerable natural low-frequency variability exists which can temporarily mask or enhance the externally forced variability and cannot be captured in coupled model runs. However, some of the externally forced variability might be captured if the near-term trajectory of some of slower components of evolving natural variability (i.e. SST) could be predicted. This became the motivation behind the Working Group. Kumar listed the emerging challenges and reviewed the scientific questions the Working Group is pursuing. Scientific questions that drive the group include:

- *What is the decomposition of low-frequency variability into the externally forced and natural components?*
- W*hat are the prospects of decadal predictability as an initial value problem?*
- *How much skill of initialized decadal predictions may improve on other baseline methods*?

This does not mean that all variability is predictable and so the group is examining what are the prospects of Decadal Variability as an initial value problem. In other words, how much of the natural component can you predict?

The Working Group has two main objectives. The first objective is to define a framework to distinguish natural variability from anthropogenically forced variability on the decadal time scale for the purpose of assessing predictability of decadal-scale climate variations. The second objective is important to the next generation IPCC runs; develop a set of metrics that can be used to assess and validate initialized decadal climate predictions and simulations.

Kumar then outlined the group's progress thus far. The group has monthly teleconferences and has met on three separate occasions. The group has submitted a paper to BAMS that is currently under review regarding their first objective of distinguishing natural and anthropogenic decadal variability. Discussions are underway regarding metrics and best practices. The group hopes to focus the metrics, perhaps as a way of assessing prediction skill. In addition, the group has suggested the agencies consider another round of small grants proposals similar to CMEP and

DRICOMP called DECPREP, which could examine the CMIP5 simulations in the spring 2011. They also anticipate coordinating participation in the WCRP Open Science Conference.

Eric DeWeaver was curious as to whether the natural and anthropogenic forcing were in some way looking at aerosol forcing. He noted that for ensemble means to do this, some sort of external forcing must exist and was curious if the WG wanted to look at aerosols. Kumar said the WG was not particularly interested in this, but did reply that the new CMIP5 simulations were run with no aerosol forcing and could be examined. DeSoeke asked if individual runs showed low-frequency variability and if the ensemble could as well. Kumar thought this type of intercomparison was beyond the current scope of the WG. Tony Lee suggested that perhaps the group could coordinate ocean data assimilation synthesis with other groups.

Spall asked if there were any statistical peaks in the variability. For example the Pacific Decadal Oscillation (PDO) exhibits frequency peaks, as does the Atlantic Multidecadal Oscillation (AMO) on a much longer time scale. Spall was curious if there were any analyses of what the natural variability mechanisms are, and to what extent they are understood. Is there a global temperature signal, and could this type of analysis be done with the current archive of models? Kumar stated that objective 1 assumes natural and anthropogenic forcing can be separated, though the question is still open. The methods identified in the BAMS paper are linear in a sense. Spall wondered also if regional climate models and analyzed global temperatures, or non-linear system analysis could be examined by the WG. Kumar stated they could certainly entertain the ideas, but nothing has been done about it at the moment.

6.3 *Atlantic Meridional Overturning Circulation (AMOC)*

Chris Meinen, NOAA AOML, presented an overview of the AMOC group. He reviewed the outcomes from the workshop in June 2010. He noted that all presentations from the workshop are available on the AMOC website: www.atlanticmoc.org. Meinen noted a few key points from the presentations of four task teams. Each task team was asked to report on lessons learned in the past five years. The Observations Task Team reported on the progress in characterizing the AMOC structure and variability from observations. Recent understanding of the AMOC includes:

- Increasing evidence that overflows are stable;
- Labrador Sea Water (LSW) production can be temporally monitored by transient tracers;
- LSW makes up *nearly half* of the deep limb of the AMOC;
- Large short-term (intraseasonal to annual) MOC variability in subtropics. Ekman forcing dominates at intraseasonal; geostropic variability dominates on longer time scales; (annual+)
- MOC strength is fairly uniform throughout the basin.

The Climate Impacts Task Team noted that the ARGO network is crucial to achieving the most faithful representation of AMOC in model analysis. The inclusion of changing radiative forcing tends to increase skill on longer time scale. Model bias was noted as a formidable challenge in the models still. Finally, GFDL decadal prediction efforts using observed data are ongoing using an ensemble coupled assimilation system.

The Variability Mechanisms Task Team presented several currently proposed mechanisms that lead to AMOC variability. The group noted that AMOC variability and predictability are more complicated than originally thought, and that proposed mechanisms are not robust across

different models. Unresolved processes such as mesoscale eddies, overflows and ocean mixing do appear to influence the AMOC. The group agreed that key observational priorities listed in the AMOC annual report of 2009 would be extremely helpful in discriminating against some of the proposed mechanisms.

The role of AMOC variability in climate will likely be most notable through its impact on SST. AMOC variability leads to low-frequency changes in SST with a spatially coherent pattern that is well simulated in forced and unforced coupled models. However, there are several factors that make it difficult to use SST for monitoring AMOC changes. All groups agreed that there are still many opportunities and challenges remaining for better understanding, monitoring and predicting the system.

The next steps forward for the AMOC group includes the Task Teams developing proposals to accomplish the near-term goals established in the priorities. A new executive committee will be established to oversee the growing AMOC PIs and team members. The next meeting will be held jointly with the UK RAPID international conference in Bristol from 12-15 July 2011.

Spall stated that there appears to be significant effort in describing AMOC. He noted that most modeling efforts are on large-scale climate models, and there are not many process studies, which seems a bit discouraging. He also noted that mechanisms are not the same from one model to next, a serious physics issue, and encouraged the group to look at more potential process studies. Beal commented that the British are interested in the South Atlantic aspects of AMOC, noting that 35S is important in the African region, but there are large signals to disentangle. She suggested perhaps a more northerly line there would be useful to estimate the leakage and AMOC signals.

7 International CLIVAR Report

7.1 WCRP Open Science Conference

Legler discussed the upcoming WCRP Open Science Conference at the Denver Sheraton in October 2011. All WCRP projects will be represented at the conference. The conference will provide an opportunity for exchange and collaboration across diverse research communities. Goals of the conference include: appraising the current state of climate science, identifying the most urgent scientific issues and challenges, and determining how WCRP can facilitate future research and partnerships. Legler listed the conference organizers and scientific theme, as well as proposed poster and parallel session themes, noting that the scientific program is still under development. He asked that U.S. CLIVAR support the conference through participation and advertising.

Garfin asked about the process for organizing symposia or special sessions. Legler agreed to pass on the information once he knew. Grotjahn asked how extremes fit into International CLIVAR. He noted that CLIVAR was clearly involved in extremes. Legler added that in practical terms, all the WCRP projects were working on extremes to some extent, but various groups took the lead on different aspects of extremes. His advice to U.S. CLIVAR was to flesh out ideas and submit them as a Working Group, and to not worry about which WCRP project should lead.

Schlosser was curious as to whether or not the end goal of WCRP was to dissolve some of the WCRP programs. Do these projects have a sunset date? Legler stated that effectively the sunset date is 2013, but there is no reason to eliminate ongoing activities. Rather, these activities will be

transitioned into a new project. Legler also noted that U.S. CLIVAR is a good example of this metamorphosis.

8 New Climate Process Teams

8.1 *Internal-Wave Driven Mixing in Global Ocean Models*

Jennifer Mackinnon, lead PI, listed the CPT members and noted they are in the process of hiring four post-docs. She noted that most vertical mixing in the ocean interior is due to breaking internal gravity waves. This mixing is patchy in space and time and that the patchiness is crucial for fluxes and ocean circulation. Therefore, the goal of the CPT is to develop a dynamic parameterization of diapycnal mixing that can evolve in a changing climate. She noted that although the internal waves cannot be explicitly resolved in climate models, parameterizations could be developed within the models. The three steps to this parameterization were discussed. In order to understand the internal tide energy, scientists need to know about wave generation (eg. where are waves breaking locally) and wave propagation. This is important because the turbulent mixing determines the large-scale vertical transport of heat, CO_2, and nutrient and drives overturning circulation. Freshwater could shut off the conveyor, but if wind speeds up, the conveyor could also accelerate due to many processes. The CPT will be looking at many aspects of these waves in order to parameterize them.

Russell was curious as to why there were no tracer studies, as plumes would be expected. Mackinnon has not looked at tracer measurements. She noted that some of WOCE sections of the deep ocean had tracers, but the main focus area of the CPT had very little tracer measurements. Questions also arose in regards to overturning circulation studies and different pathways. Mackinnon stated that the overturning circulation is different in multiple studies. One of the major questions for this CPT is to figure out which patterns of conditions matter more.

8.2 *Ocean mixing processes associated with high spatial heterogeneity in sea ice and the implications for climate models*

Meibing Jin, University of Alaska Fairbanks, discussed the second ocean CPT. Motivation of the CPT includes reducing the uncertainty of ice-ocean components in climate models. Jin noted that spatial variations of sea ice thickness are high, and sea ice models use a multi-category thickness distribution in one grid cell to represent the sub-grid thickness variation. This multi-category ice thickness communicates with a single-column ocean grid, which leads to a reduced accuracy of heat and salt fluxes. The study will focus on analyzing and improving the ocean model presentation of processes associated with high spatial heterogeneity in sea ice by implementing a multi-column ocean grid (MCOG) in climate models (NCAR, GFDL, LANL). The ultimate goal is to reduce uncertainties in both short-term and long-term climate model runs, and also to improve the simulations of biogeochemical tracers involving ice-ocean fluxes. Although this CPT is for improving physical models only, strong interest from biogeochemical community exists.

8.3 *Cloud Parameterization and Aerosol Indirect Effects*

Leo Donner, NOAA GFDL, presented the work plan for the new atmospheric CPT on cloud parameterization. The motivation for the CPT is based on the fact that moisture-based PDFs are not linked to the dynamics of cloud formation and dissipation. But instead key microphysical processes are linked to vertical motions. And the key to droplet activation is supersaturation. The problem is how to link cloud macrophysical and microphysical processes. The current scale of a GCM is too large for microphysics that occur in nature. This CPT, therefore, will focus on stratiform clouds, as the current GFDL AR4 model currently produces no clouds. A new parameterization will be implemented in GFDL's GCM (atmospheric model) and NCAR's GCM. The models will be tested against LES, aircraft observations, and satellite observations. The goal is to improve low clouds in the GCMs, with a particular focus on the effects of aerosols on clouds.

Paquita Zuidema asked if the CPT would be evaluating vertical velocity? Yes, and the group will try to interact with ARM at the Department of Energy also. This is a rather expensive strategy but necessary to achieve the right answer. Questions were also asked about the effect of clouds on rainfall parameterizations. Donner felt the biggest problem in the models is the precipitation is too light (through cumulus parameterization). Only the non-precipitating cases were shown in the presentation. When precipitating clouds are introduced, modelers will have to impose some criteria in the vertical structure. An important question is how well will the model will do on precipitating clouds. The CPT will tackle this immediately. Donner would like to see effects of entrainment on droplet size as well. Another question focused on the direct impact of radiative heating/cooling and whether or not it would change with the new parameterization. Donner answered that the optical depths of clouds will change, but this procedure will bring in radiative heating/cooling, and it will be part of evaluation process. Donner hopes to see more realistic microphysics in the models as a result of this CPT.

8.4 Stratocumulus to Cumulus Transition

Joao Teixeira, NASA JPL, informed U.S. CLIVAR on another atmospheric CPT based on stratocumulus to cumulus transitions. The goal is to improve the representation of the cloudy boundary layer in global weather/climate models with a focus on the subtropical stratocumulus-to-cumulus (Sc-Cu) transition. Currently, operational GFS/CFS struggles with too little subtropical Sc in their models. However, NCEP is currently developing/testing new parameterizations for Sc and Cu processes separately. NCEP has shown that CFS Sc-Cu transition could be improved by reducing penetrative Cu entrainment in Sc regions. But, the moist physical parameterization suite has been inadequately tested in controlled single-column settings. Cloud feedback contributes very high levels of uncertainty in models according to the IPCC. Most models are unable to reproduce Sc and transition to Cu clouds. Thus, the CPT's goal is extremely ambitious. Some of the main tasks for this CPT include the development/testing of PDF cloud schemes in NCAR, NCEP models; development/testing of EDMF approach in NCAR, NCEP models; and detailed coupled/uncoupled diagnostics (e.g. ENSO) in these models.

9 Process Study Model Improvement Panel Discussion

The panel agenda consisted of an overview of the ongoing process studies, a presentation by Dr. William Large of NCAR CGD on parameterization development/process study and model improvement interface (joint with the POS Panel), and a presentation by Dr. Steve Riser on a future process study named SPURS, for which PSMIP/POS provided feedback. Friday morning consisted of a discussion of new themes and working groups, and a review of PSMIP goals/action items from the previous year.

9.1 *Ongoing Process Studies*

In advance of the summit, process study liaisons solicited information from process study PIs, which was shared with the full panel at the summit. The panel discussed the process study progress with regard to the best practices, summarized below for each process study (KESS, Climode, DIMES, VOCALS and DYNAMO). At the request of the IAG, we also performed a review of a proposed process study named SPURS, represented by Dr. Steve Riser from the U of Washington.

Action item: **PSMIP to communicate feedback to each of the U.S. CLIVAR process studies by the end of summer [process study liaisons].**

9.1.1 KESS

The field phase of the Kuroshio Extension System Study ended in 2006. The panel was encouraged by the website (uskess.org) serving as a centralized information and data portal, but noticed a lack of gridded datasets and the diagnostics used in publications on the website. The Panel recommends that synthesis datasets be created to use as benchmarks for assessing models, and to make more 'level 3' products available through uskess.org

9.1.2 CLIMODE

The CLIvar MOde water Dynamic Experiment studies the dynamics of eighteen-degree water, the subtropical mode water of the North Atlantic, created just south of the Gulf Stream during winter. The observational component is nearing conclusion. A mix of in situ and satellite-based observations, and high-resolution modeling, will lead to improved air-sea flux parameterizations. In this CLIMODE was working with CPT Emilie. CLIMODE PIs are ramping up their analysis (special issue in J. Climate, and review articles that compare/contrast N Pacific and Atlantic). A website is being maintained (http://www.climode.org/) as well as one at NCAR/EOL, but these appear to be out of date. While PIs don't deny data access, data access is not available on the website. No level-3 datasets or diagnostics are available.

Action Item: **PSMIP will encourage PIs to update their website, and develop and make higher-level datasets available.**

9.1.3 DIMES

The Diapycnal and Isopycnal Mixing Experiment is a joint US-UK field experiment, investigating mixing in both quiescent and turbulent regimes of the Antarctic Circumpolar Current. This experiment is still in an early phase: a total of eight field campaigns will be carried out by early 2012, of which the first was completed in February 2009. The Panel notes that there is overlap between DIMES and the CPT on improving internal ocean mixing within global ocean models being led by Dr. McKinnon.

Action Item: **PSMIP will establish a precedent for archiving microstructure data in a universal format that can be subsequently adopted at NODC.**

9.1.4 NAME

The North American Monsoon Experiment field phase ended in 2005; a data archive is maintained at EOL, and synthesis datasets have been created. Current activities include a NAME Forecast Forum and 'legacy coordination'; the latter includes continued development of a regional observing system design. In the past year two new journal special issues were developed. While NAME is basically 'sunsetting', the process study remains valuable for its connections to IASCLIP. PSMIP will fold NAME into IASCLIP for its future discussions.

9.1.5 VOCALS

The VAMOS Ocean-Coupled-Land-Atmosphere Study completed its Regional Experiment during Oct-Nov 2008. A pre-experiment modeling assessment of 2006 conditions along 20S is done, and a modeling assessment of 2008 conditions is underway. Data are being archived at EOL with EOL contacting PIs during the summer of 2010 for their data contributions. Several dedicated VOCALS sessions have occurred at the national and international conferences, and a special EGU issue joint between Atmospheric Chemistry and Physics and Ocean Sciences has been set up.

9.1.6 DYNAMO

At the time of the summit, preparation for DYNAMO was underway. A workshop was held in Seattle, WA, coinciding with the U.S. CLIVAR Summit. NSF has approved the Scientific Program Overview document and the Experimental Design Overview document, with individual proposals due August 2010. A preliminary site survey of Gan Island has been done. DYNAMO was conceived as a U.S. contribution to an already confirmed international (primarily Japanese) experiment CINDY2011; the 1st international CINDY2011 workshop will be held in Nov. 2010. DYNAMO has connections to U.S. CLIVAR through the original MJO working group, now the MJO Task Force. NCAR EOL is expected to provide the data archiving for the experiment.

9.1.7 IASCLIP

IASCLIP currently consists of a Forecast Forum set and several NOAA-funded projects, including a visit and survey of regional capabilities. A workshop was held on re-establishing the Caribbean Regional Climate Outlook Forum in Barbados, during June of 2010. Although IASCLIP was not so involved with this, this Forum, should it continue, overlaps with IASCLIP interests. IASCLIP does not have a process study associated with it, the NOAA Climate Program Office reorganization, which has moved away from a regional focus to a more methods-based division of labor, is also perceived by some within the IASCLIP scientific community as a discouragement for pursuing a field campaign.

9.1.8 Review of Salinity Processes in Upper ocean Regional Studies (SPURS)

NASA is expected to fund $6M towards a process study coinciding with the Aquarius surface salinity satellite mission. Dr. Steve Riser accepted an invitation to provide a presentation on SPURS, delivered jointly to the PSMIP and POS panels, after which interested panel members discussed their impressions of the Study. This review was written up and distributed to U.S. CLIVAR, SPURS scientists, and the IAG. Highlights are noted below. SPURS is focusing on a homogeneous, high salinity area of the Atlantic, with a stated goal of closing the upper-ocean salinity budget over one full annual cycle on several different spatial scales. At the time of the summit the error/uncertainty analysis was still thin. One suggestion made was to review the Subduction Experiment held in the same region in the early 1990's. The reviewers also noted that the process study provided an opportunity to gather data for other, simultaneous studies, such as a

heat or turbulent flux budget closure, which could be explored more. Ties to U.S. CLIVAR goals and climate research in general, for example to the AMOC, or to hurricane research, would also be worthy of further exploration. PSMIP would expect that all data collected as part of SPURS be placed somewhere that will encourage future parameterization development for climate models. The reviewers also noted that the letters of intent or proposal abstracts of interested researchers had not been distributed to potential investigators, discouraging cooperation towards better process study design.

9.2 PSMIP's relationship with process studies

PSMIP discussed its "non-endorsement" charge for process studies. PSMIP can provide a forum and feedback for process studies interested in engaging with U.S. CLIVAR. The panel cannot officially endorse, however, as this implies a funding preference be granted to 'endorsed' process studies, when in fact the process studies are still subject to normal programmatic review procedures. This charge contrasts with International CLIVAR, whose panels do endorse process studies furthering its goals. A short statement to this effect is now included on the PSMIP panel terms of references webpage: "Through its review process, U.S. CLIVAR encouragement of nascent process studies does not imply a formal endorsement."

9.3 Working Group Ideas

Several ideas were discussed such as carbon and heat uptake in the Southern Ocean, and gaps in our Arctic understanding. The latter included discussion of the Arctic's salinity budget, which include large freshwater flux inputs. How anomalous air-sea fluxes map onto the budget, how to connect Arctic salinity to the AMOC, or the mid-latitudes, received discussion. Another working group suggestion was for one on "Arctic weather": how Arctic climate changes are influencing changes in weather both in the Arctic and mid-latitude.

The panel also felt, however, that our current membership was not optimal for leading such working groups. We thus suggest a more competitive process for the working group proposals, with solicitations for new working groups be widely distributed, and allowing anyone to propose one so long as it included some U.S. CLIVAR participation.

9.4 Best practices for parameterization development

Following a presentation by Leo Donner last year, and ensuing discussion, an opinion piece on best practices in parameterization development has been proposed. Due to other commitments, this has not been completed, but it is still considered an important task. This action item was revisited this year. The panel felt that, unlike the relatively uncontroversial 'best practices for process studies' piece, approaches to successful parameterization development are more intellectually nuanced and varied. Different practitioners can espouse different approaches with equal integrity. A relevant U.S. CLIVAR publication is desirable but more valuable if it provides a broader view of what can be considered a 'best practice'. The Climate Process Teams provide such individual views. Since CPT representation is already on the PSMIP (Joao Teixeira and Rob Wood), with oceanic CPT representation sought for the coming year, the U.S. CLIVAR Summit

of 2011 could provide a venue for such a discussion, with a small written piece as an outcome. The panel suggests this be pursued.

9.5 *Ocean turbulence data stewardship*

The panel has addressed the issue of appropriate stewardship of ocean turbulence data for several years. This has tended to be left to the discretion of individual investigators, and as a result is haphazard, incomplete, and not centralized (see also the OceanObs'09 Community White Paper write-up by Margarita Gregg). Pat Caldwell maintains a web bulletin board on Lowered Acoustic Doppler Current Profiler (LACDP) data at http://ilikai.soest.hawaii.edu/ladcp/ with a metadata template for submitting data that was agreed on in 2001, but there are yet no archived data. A similar website for shipboard ADCP data, also maintained by Patrick Caldwell (http://ilikai.soest.hawaii.edu/sadcp/) is in better shape though incomplete, and has a dated data format (no netcdf). Proactive ACDP data archiving, both shipboard and lowered, needs to be brought to a higher priority (thus better funded). Pat Caldwell is willing to archive LADCP data but needs more resources, and a LADCP processing expert needs to join any effort Pat Caldwell undertakes to archive LADCP data. One suggestion made previously by the panel was for analysis proposals to require that the PI datasets be submitted to NODC before funding be considered. This is partially in place at NSF, where new proposals must now address data archiving and budget for it.

On a brighter note, the funding of an oceanic CPT that will make use of DIMES microstructure data provides optimism those previous suggestions to use the DIMES process study, as a prototype for microstructure data archival will be followed. DIMES microstructure data will be archived at Scripps.

Action item: **PSMIP will 1) Compile a list of all existing climate-related turbulence data sets we would like to see archived, drawing on efforts of Lou St Laurent and Kurt Polzin. 2) Write a memo to NSF/NOAA funding managers. This requires up-to-date knowledge on their policies. 3) Monitor DIMES archiving. Representation from the DIMES microstructure community on the panel would encourage this.**

A lead on these action items has not yet been identified. The most effective way forward on this item may be to include a representative from the DIMES microstructure community or a representative from the ocean internal-wave driven mixing CPT.

9.6 *2011 Summit Preparation*

Several ideas were put forth for how to use our time at the U.S. CLIVAR Summit in 2011. These included a discussion on 'best practices for parameterization development' involving CPT representatives that could form the basis for an opinion piece, and a talk on the use of satellite data, specifically CLARREO, for model evaluation.

9.6.1 Panel Membership

Several members of PSMIP will be rotating off the panel: Bryan, Donohue, Schneider, Wang and Zuidema. The panels will need to find new panel members, which can include applicants from last year. Representation from the oceanic CPTs is desirable, in particular an ocean turbulence

observationalist. Representation of expertise relevant to possible new working groups is also desirable.

Action item: **PSMIP will contact potential new panel members to encourage them to apply to PSMIP. [Teixeira, Zuidema]**

10 Phenomena, Observation and Synthesis (POS) Panel Discussion

10.1 *Decadal (and longer) variability and predictability: knowledge and funding gaps*

This is an area in which several POS members remain actively involved (for example, through the participation of activities related to the Decadal Predictability Working Group and the AMOC Program). POS discussed knowledge and funding gaps in decadal (and longer) variability (and changes), including a discussion of whether agency funding has been sufficiently focused and coordinated. Dan Vimont, who could not attend the summit, provided two-page updates of related activities (including publications) and his comments on these subjects. There is a general feeling that there is encouraging momentum for research related to Atlantic Multi-decadal Variability (AMV) and predictability, often in the context of the Atlantic Meridional Overturning Circulation (AMOC) program. However, there has been a general lack of focus by the decadal variability and predictability community and by coordinated agency effort on other parts of the world ocean such as the Indo-Pacific sector and the Southern Ocean (admittedly, the latter has been hampered by the lack of historical data). In particular, there remains a large knowledge gap in the understanding of the mechanisms of decadal variability for these regions (including synthesis of already proposed mechanisms, say, for PDO) and the relationship between observed decadal variability in different regions. For example, the physics of the multi-decadal warming trend and internal variability in the tropical Indian Ocean and the impacts on the Pacific sector are not well understood. More efforts on observations, data syntheses, mechanism studies and model improvements with a focus on the Indo-Pacific sector should lead to better understanding of decadal variability and predictability.

Action Item: **POS will recommend U.S. CLIVAR suggest to the agencies and the Decadal Variability Working Group that more balanced set of research activities are needed to address decadal variability and predictability across different parts of the world's ocean basins.**

10.2 *Uncertainty of SST products on decadal and longer time scales*

This discussion was related to two oral presentations (by Gabe Vecchi and Bill Large, respectively) about SST uncertainty and impact on climate models. In addition to the concern of SST trend uncertainty on multi-decadal time scales, we also discussed the difficulty in understanding multi-decadal change in the characteristics of shorter time-scale climate variability (such as the amplitude of El Nino) due to the uncertainty of SST product.

Action Item: **POS will recommend to the Decadal Variability and Predictability Working Group and the NASA SST Science Team further action that could enhance the awareness of this issue [Tony Lee].**

10.3 *Multi-decadal SST Changes*

Sasha Gershunov mentioned a large multi-decadal trend of increasing SST off Baja California (over a region of 10x10 degrees), a phenomenon that deserves further investigation, including its uncertainty and physical nature because of its potential implication for regional climate and ecosystems.

10.4 *AMOC:*

Chris Meinen presented a summary of the US AMOC Science meeting (that took place a month earlier in Miami, FL) and recommended near-term foci for different aspects of the AMOC program. The truncation of the POS breakout discussion due to the extension of the plenary program limited the amount of discussion time for AMOC. However, the POS panel concurs with the plan of the US AMOC program in terms of its near-term foci. Additional comments, if any, will be provided directly to POS co-chairs after the summit.

Ocean synthesis products have the potential to be used in monitoring and understanding AMOC variations in near real time. As one of the near-term foci, the US AMOC could encourage analysis and validation of AMOCs simulated by ocean synthesis products and support developments for improved AMOC simulations.

Action Item: **POS will provide further comments about the US AMOC Program, especially in terms of its near-term foci. [All]**

10.5 *Feedback to SPURS (joint session with PSMIP):*

After the overview of SPURS by Steve Riser in a joint PSMID-POS session, Tony Lee suggested that CLIVAR (though PSMIP and POS) could coordinate with the community to have modeling groups (especially those running eddy-permitting models) to archive upper-ocean salinity budget terms (various tendency terms) for the SPURS region and to coordinate an intercomparison among products with incoming observations, and, in particular, to evaluate the terms that are difficult or costly to observe (e.g., eddy effects, vertical processes).

10.6 *(1) Integrated Earth System Analysis*

Our breakout session included a preview of an upcoming workshop for the Integrated Earth System Analysis (IESA), as presented by Ben Giese. This workshop will feature assessment of the strengths and weaknesses of atmospheric and oceanic reanalyses. Important goals include the identification of future efforts, and mapping out how to best develop and integrate coupled reanalysis. Specific topics to be addressed include observational and modeling needs, and limitations due to scientific gaps. An important emphasis will be on how to include proper error/uncertainty estimates in future reanalyses.

10.7 *Central-Pacific (Modoki) El Nino*

Tony Lee led a discussion of how the climate community is becoming increasingly aware, and interested in, the differences between El Ninos with their most prominent anomalies in the central tropical versus eastern tropical Pacific. Recent papers on the subject include Kao and Yu (2009), Kug et al. (2009) and Yeh et al. (2009). This subject is not just of academic interest in that the different types of events have different expressions on the global atmospheric circulation and ultimately the seasonal weather anomalies accompanying El Niño. Two very interesting and related questions are emerging and that is whether the "flavor" of El Niño is predictable, and how much the recent preference for central Pacific El Niño's may be forced (perhaps due to climate change) versus a result of natural variability. The panel agreed this would be an appropriate topic for a new CLIVAR working group. Panel members indicating interest in participating in such a group include Antonietta Capotondi, Don Chambers, Ben Giese, Tony Lee and Yan Xue.

Action Item: **POS will respond to the U.S. CLIVAR solicitation for working group proposals by addressing the flavors of ENSO events. [Antonietta Capotondi, Don Chambers, Ben Giese, Tony Lee and Yan Xue]**

10.8 *High-latitude Working Group*

Sirpa Hakkinen provided a short report on the High Latitude Surface Flux Working Group. She pointed out that while there is a general appreciation of the recent loss of multi-year ice in the central Arctic, much less attention has been focused on the changes in the Arctic oceanography. Paleoclimate studies have indicated deep mixing during previous periods of lower sea ice concentration, but that is contrary to some projections from IPCC-class climate models. Specifically, the GFDL model suggests increasing freshening/salinity stratification in its simulations for the 21st century. There are important implications for getting this right from the perspectives of global water cycling, carbon cycling, and impacts on the AMOC. The relative lack of activity devoted to the oceanography of the Arctic might warrant a working group; here the POS panel may be best suited as playing a contributing rather than a leading role.

10.9 *Membership*

We had a brief discussion of membership. Three names emerged in this discussion: Rick Lumpkin (NOAA/AOML; air-sea interactions), Mike Winton (NOAA/GFDL; high-latitude climate/sea ice) and Noah Knowles (USGS; hydrology and climate change). It was agreed that the panel should try to retain a broad range of interests and expertise and be mindful of the overall directions of CLIVAR.

10.10 *Other Potential Working Groups*

There were a few topics introduced that could potentially be developed to the point of proposing a working group. Examples here include how upwelling is linked to climate variability and the implications for marine ecosystems (Nick Bond) and how to better monitor and diagnose ENSO events through improved ocean synthesis products (Yan Xue). The present thinking is that these two topics will not be proposed in the upcoming call for working groups, but may be developed

in the next year. There was also brief discussion of the need for instrumentation to improve monitoring of clouds, and that it would be worthwhile to follow-up on the IESA workshop with intercomparisons between reanalyses.

11 Prediction, Predictability and Applications Interface Panel Discussion

11.1 *Decadal Prediction*

The PPAI discussions focused first on U.S. CLIVAR themes beginning with Decadal Prediction. Arun Kumar and Cristina Stan presented a summary of the Decadal Prediction Working Group (DPWG) activities and a summary of decadal prediction runs under the CMIP5 (as part of the IPCC AR5 initiative). The discussion also focused on the PPAI recommendation for possibility for a Climate Modeling Evaluation Project (CMEP). The PPAI Panel was enthusiastic about the making a strong recommendation for initiating such a project to the U.S. funding agencies. A discussion on the analysis of decadal runs for attribution and prediction of quantities relevant to users (change in the PDF of sequence of events; extreme events; hurricanes) also followed. Difficulties in quantifying skill of decadal prediction given a small sample size were also noted.

11.2 *Carbon Cycle and Ecosystems*

Annalisa Bracco, in collaboration with Ning Zeng (absent) then summarized the possibility of 'Carbon Cycle and Eco-system" as a future theme for the U.S. CLIVAR. This possibility may be followed further during the U.S. CLIVAR summit in 2011. Some preliminary thoughts on proposing a working group, and connecting it with the carbon cycle in the southern oceans were also made.

11.3 *Polar Climate*

Ron Lindsey led a discussion on the U.S. CLIVAR Polar theme and provided an overview of sea ice prediction, and recent trends in Arctic sea ice. An extensive discussion followed. Strong agreement emerged on the push for making a proposal for sea ice working group related to the prediction and understanding of sea ice variability and trends over the Arctic, and quantifying the influence of sea ice decline on the high latitude climate variability.

11.4 *Extremes*

Balaji Rajgopalan and Gabe Vecchi led the discussion on U.S. CLIVAR theme on the extremes. Gabe summarized the current understanding of hurricane variability and trends. A strong connection between the interannual variability in hurricanes and SST was noted. The presentation also noted the current gaps in understanding of predictability of hurricanes, and it was strongly felt that a U.S. CLIVAR working group would be the right avenue to advance the current state of understanding.

Balaji's presentation focused more on the questions related to definition of extremes (e.g., How to quantify extreme events when extremes, by definition, are rare? In attempting to make predictions of extremes what would be the best practices for combining dynamical and statistical methods

etc.). PPAI also felt that although "extremes" is one of the U.S. CLIVAR themes, the scope and focus for this particular theme is not well defined, and a holding a US sponsored workshop on climate extremes would be a worth effort. Parts of discussion also dealt with should CLIVAR develop a white paper on identifying basic science behind changes in extremes? Such a working paper could be used by funding agencies for a call for proposals. Is there a possible funding gap between need for prediction (NOAA) and science issues (NSF) on extremes.

11.5 *Applications Interface*

Focusing on the "application" component of the PPAI panel, Gregg Garfin and Balaji Rajgopalan made a presentation on the application aspects of seasonal and decadal forecasts. The focus of presentations, and follow up discussion, was on prediction of what quantities may be of importance from the perspective of application (i.e., different from the prediction of seasonal or decadal averages). For example, prediction for changes in the probability of sequence of events may be far more relevant from the application perspective. Similarly, describing a plausible range of future scenarios may be much more important in developing adaptation strategies than actually predicting the probability for the likely outcome. Regarding the ongoing efforts on dynamical downscaling, assessing the reliability of dynamical downscaling procedures was judged to be of importance. This presentation concluded the breakout session on Thursday.

11.6 *Potential Working Groups*

The Friday session of the breakout primarily focused possible working groups, and workshops, that could be proposed as part of the U.S. CLIVAR.

Action Item **Propose a working group on the "Hurricanes and the Role of SST."**

The focus of this working group should be on quantifying the uncertainties in the role of SSTs on hurricane variability (of relevance for attribution and for quantifying uncertainties in future changes); Influence of differences in SST analysis on the attribution of hurricane variability; quantifying dependence of interannual variability on SST analysis and models. The proposed working structure of the group would be set of coordinated model experiments along the lines of the Drought Working Group. This working group would be of relevance for the U.S. CLIVAR theme on extremes.

Action Item **Propose a working group on the "High latitude temperature amplification and sea ice variability" with a focus on synthesizing our current understanding of sea ice decline in the Arctic and its feedbacks in the lower-latitude climate variability (implications for seasonal and initialized decadal predictions).**

This working group will connect with the U.S. CLIVAR theme on polar variability.

Action Item	**Propose a workshop on "Climate Extremes" to highlight various aspects related to climate extremes including: Assess the ability of climate models in simulating hydroclimate (and other) extremes; defining best practices for statistical methods for modeling and analyzing extremes from observations and GCMs; quantifying relative advantages of statistical and dynamical downscaling schemes as they relate to climate extremes.**

It was also felt that such a workshop would help better define the focus of the U.S. CLIVAR theme on extremes.

Overall, the PPAI breakout session had a vigorous and lively discussion and resulted in some concrete ideas about proposing working groups and a workshop during the coming year. The PPAI Co-Chairs, Annalisa Bracco and Arun Kumar, presented a summary report of the breakout session in the subsequent plenary session.

12 Closing

Each Panel provided a brief summary from their Panel discussions, listing ideas for potential Working Groups. PSMIP would also like to make the Working Group proposal process more competitive, to be reviewed by current Panel members in keeping aligned with U.S. CLIVAR objectives.

Legler thanked the Panels for considering the polar and extreme themes in great detail. One way to move forward on the new themes is through the Working Groups. Legler noted that there would be a call for new Working Groups prospectuses due on October 1 with a January 1 start date. He encouraged the Panels to consider writing prospectuses on these themes. The next Summit will take place in Woods Hole, MA the week of July 18, 2011. Legler again thanked everyone for traveling to Denver and adjourned the Summit.

13 U.S. CLIVAR Summit Agenda

U.S. CLIVAR Summit Agenda: 7-9 July 2010
Warwick Hotel, 1776 Grant Street, Denver, CO 80203

Wednesday 7 July

Time	Agenda	Room
0800 – 0830	Refreshments	Millennium Gallery
0830– 0845	Welcome and introductions	Millennium
0845 – 1130	**Polar Science** (break 10:15-10:45). Speakers: Peter Schlosser (LDEO) and Alex Orsi (TAMU)	Millennium
1130 - 1300	Lunch (on your own)	
1300 – 1630	**Extremes** (break 3-3:30) Speakers: Xuebin Zhang (Env Canada), Gabe Vecchi (GFDL), Brad Lyon (IRI)	Millennium
1630 - 1715	Panel Member Orientation (for everyone!)	Millennium
1730 - 1815	U.S. CLIVAR SSC (only) Meets with program managers	Millennium
1830 - 2000	Reception	Randolph's Patio – the hotel restaurant

Thursday 8 July

0800– 0830	Refreshments	Millennium Gallery
0830 - 0845	U.S. CLIVAR Report - Marty Hoerling	Millennium
0845 - 1015	Working Group Reports High-latitude Fluxes (Gary Wick)– 15 min Decadal Predictability (Arun Kumar)– 15 min AMOC (Chris Meinen) – 30 min	Millennium
1015 - 1045	**Morning Break**	Millennium Gallery
1045 - 1115	International CLIVAR - Jim Hurrell	Millennium
1115 – 1215	New CPTs (4 reports) – Jennifer MacKinnon, Meibing Jin, Leo Donner, and Joao Teixeira [15 min each + 15 min disc]	Millennium
1215 - 1330	**Lunch** (on your own)	
1330 - 1730	Panel Breakouts (break from 1545-1600)	Executive Lounge (POS); Cambridge (PPAI); Millennium (PSMI)

Friday 9 July

0800 - 0830	Refreshments	Millennium Gallery
0830 – 1030	Panel Breakouts	Millennium
1030 - 1050	**Morning break**	Millennium Gallery
1050 – 1145	Panel Reporting to Plenary	Millennium
1145-1230	Wrapup	Millennium

14 U.S. CLIVAR Summit Participant List

Michael A. Alexander
NOAA Earth System Research Laboratory
Mail code: R/CDC1
325 Broadway
Boulder, CO 80305-3328
E-mail: michael.alexander@noaa.gov

Lisa Beal
RSMAS/MPO
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149
E-mail: lbeal@rsmas.miami.edu

Nicholas A. Bond
JISAO
NOAA, Pacific Marine Environmental Laboratory
7600 Sand Point Way, NE
Seattle, WA 98115-6349
E-mail: nicholas.bond@noaa.gov

Michael G. Bosilovich
Global Modeling and Assimilation Office
NASA Goddard Space Flight Center
8800 Greenbelt Rd., Building 33, Code 610.1
Greenbelt, MD 20771
E-mail: michael.g.bosilovich@nasa.gov

Annalisa Bracco
Assistant Professor
School of Earth and Atmospheric Sciences
Georgia Institute of Technology
311 Ferst Dr.
Atlanta, GA 30332
E-mail: abracco@gatech.edu

Frank Bryan
Climate and Global Dynamics Division
National Center for Atmospheric Research
P.O. Box 3000 - ML
Boulder, CO 80307-3000
E-mail: bryan@ucar.edu

Antonietta Capotondi
NOAA CIRES CDC
325 Broadway
Boulder, CO 80305
E-mail: antonietta.capotondi@noaa.gov

Don Chambers
University of South Florida
140th 7th Avenue S
St. Petersburg, FL 33701
E-mail: dchambers@marine.usf.edu

Eric DeWeaver
National Science Foundation
4201 Wilson Blvd
Arlington, VA 22230
E-mail: edeweave@nsf.gov

Leo J. Donner
NOAA Geophysical Fluids Dynamics Laboratory
201 Forrestal Rd.
Princeton, NJ 08540-6649
E-mail: leo.j.donner@noaa.gov

Kathleen Donohue
Graduate School of Oceanography
University of Rhode Island
215 South Ferry Road
Narrangansett, RI 02882-119
E-mail: kdonohue@gso.uri.edu

Joshua Fu
University of Hawaii, IPRC
1680 East West Rd.
Honolulu, HI 96822
E-mail: xfu@soest.hawaii.edu

Gregg Garfin
University of Arizona
845 N. Park Ave, Suite 532
Tucson, AZ 85721
E-mail: gmgarfin@email.arizona.edu

Sasha Gershunov
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla, CA 92093
E-mail: sasha@ucsd.edu

Benjamin S. Giese
Associate Professor
Department of Oceanography
Texas A&M University
O&M Building
College Station, TX 77843-3146
E-mail: b-giese@tamu.edu

Richard Grotjahn
University of California, Davis
36189 Road 30
Davis, CA 95616
E-mail: grotjahn@ucdavis.edu

Lisa Goddard
International Research Institute for Climate and Society
Lamont-Doherty Earth Observatory
228 Monell Bldg.
61 Route 9W
Palisades, NY 10964-8000
E-mail: goddard@iri.columbia.edu

Sirpa Hakkinen
NASA Goddard Space Flight Center
Code 971
Greenbelt, MD 20777
E-mail: hakkinen@gsfc.nasa.gov

Scott Harper
Office of Naval Research
Code 322, Physical Oceanography
Arlington, VA
E-mail: harpers@onr.navy.mil

Martin P. Hoerling
Meteorologist
NOAA/CIRES Climate Diagnostics Center
325 Broadway (R/E/CD)
Boulder, CO 80305-3328
E-mail: martin.hoerling@noaa.gov

Meibing Jin
International Arctic Research Center
930 Kooyukuk Drive
Fairbanks, AK 99775
E-mail: mjin@iarc.uaf.edu

Sean Kennan
Physical Oceanography Program
Division of Ocean Sciences
National Science Foundation
4201 Wilson Blvd., Rm. 726 N
Arlington, VA 22230

Arun Kumar
Chief, Development Branch
Climate Prediction Center
NOAA, NWS, NCEP
5200 Auth Road, Rm 807
Camp Springs, MD 20746
E-mail: arun.kumar@noaa.gov

David Lawrence
NCAR
PO Box 3000
Boulder, CO 80307
E-mail: dlawrence@ucar.edu

Tony Lee
NASA Jet Propulsion Lab
4800 Oak Grove Dr.
Pasadena, CA 91109
E-mail: tlee@pacific.jpl.nasa.gov

David M. Legler
Director, U.S. CLIVAR Project Office
1717 Pennsylvania Ave., NW, Ste. 250
Washington, DC 20006
E-mail: legler@usclivar.org

Ron Lindsay
University of Washington
1013 NE 40th Street
Seattle, WA 98105
E-mail: Lindsay@apl.washington.edu

Eric Lindstrom
Program Manager - Physical Oceanography
NASA Headquarters
300 E. Street SW, Code YS
Washington, DC 20546
E-mail: eric.j.lindstrom@nasa.gov

Brad Lyon
International Research Institute for Climate and Society
110 Monell Building
Palisades, NY 10964
E-mail: blyon@iri.columbia.edu

Jennifer Mackinnon
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla, CA 92093
E-mail: jmackinn@ucsd.edu

Christopher Meinen
Cooperative Institute for Marine and Atmospheric Studies
University of Miami
NOAA/AOML/PHOD
4301 Rickenbacker Causeway
Miami, FL 33149
E-mail: Christopher.meinen@noaa.gov

Joel Norris
Scripps Institution of Oceanography
9500 Gilman Drive
La Jolla, CA 92093
E-mail: jnorris@ucsd.edu

Alex Orsi
Texas A&M
Department of Physical Oceanography
College Station, TX 77843
E-mail: aorsi@tamu.edu

Balaji Rajagopalan
Assistant Professor and Fellow, Cooperative Institute for Research in Environmental Science (CIRES)
University of Colorado at Boulder
Campus Box 428, ECOT-541
Boulder, CO 80309-0428
E-mail: balajir@spot.colorado.edu

Jill M. Reisdorf
Meeting Planner
Joint Office for Science Support
University Corporation for Atmospheric Research
P.O. Box 3000 - FL4, Rm. 2344
Boulder, CO 80307-3000
E-mail: reisdorf@ucar.edu

Steve Riser
University of Washington
Box 355351
Seattle, WA 98195
E-mail: riser@u.washington.edu

Joellen Russell
University of Arizona
1040 E Fourth Street
Tucson, AZ 85721
E-mail: jrussell@geo.arizona.edu

Peter Schlosser
Columbia University
Lamont-Doherty Earth Observatory
Palisades, NY 10964
E-mail: schlosser@ldeo.columbia.edu

Michael Spall
Physical Oceanography Dept.
Woods Hole Oceanographic Institute
MS #21
Woods Hole, MA 02543
E-mail: mspall@whoi.edu

Christiana Stan
Center for Ocean-Land Atmosphere Studies
4041 Powder Mill Rd., Suite 302
Calverton, MD 20705-3106
E-mail: stan@cola.iges.org

Diane Stanitski
NOAA Climate Program Office
1100 Wayne Avenue, Suite 1210
Silver Spring, MD 20910
E-mail: diane.stanitski@noaa.gov

Catherine O. Stephens
Program Specialist III
U.S. CLIVAR Project Office
1717 Pennsylvania Ave., NW, Ste. 250
Washington, DC 20006
E-mail: cstephens@usgcrp.gov

Liqiang Sun
International Research Institute for Climate and Society
110 Monell Building
Palisades, NY 10964
E-mail: sun@iri.columbia.edu

Joao Teixeira
NASA JPL
4800 Oak Grove Dr.
MS 169-237
Pasadena, CA 91109
E-mail: teixeira@jpl.nasa.gov

James F. Todd
Program Manager, Climate Variability and Predictability (CVP) Program
NOAA Climate Program Office
1315 East-West Hwy., SSMC3, Rm. 12114 South
Silver Spring, MD 20910
E-mail: james.todd@noaa.gov

Gabriel Vecchi
NOAA/GFDL
Princeton Forrestal Campus Route 1
Princeton, NJ 08542
E-mail: Gabriel.a.vecchi@noaa.gov

Wanqiu Wang
CPC/NCEP/NOAA
5200 Auth Road
Camp Springs, MD 20746
Wanqiu.wang@noaa.gov

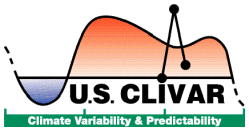
Robert Wood
University of Washington
Box 351640
Seattle, WA 98195
E-mail: robwood@atmos.washington.edu

Yan Xue
NOAA Climate Prediction Center
5200 Auth Road Room 605-A
Camp Springs, MD 20746
E-mail: yan.xue@noaa.gov

Xubin Zeng
Department of Atmospheric Sciences
University of Arizona
PAS Bldg., #81 P.O. Box 210081
Tucson, AZ 85721
E-mail: xubin@atmo.arizona.edu

Xuebin Zhang
Environment Canada
4905 Dufferin Street
Downsview M3H 5T4
Canada
Email: xuebin.zhang@ec.gc.ca

Paquita Zuidema
Rosenstiel School of Marine and Atmospheric Science
Department of Meteorology and Physical Oceanography
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149
E-mail: pzuidema@rsmas.miami.edu



U.S. CLIVAR Office
1717 Pennsylvania Ave NW
Suite 250
Washington DC 20006
(202) 419-3471
(202) 223-3064 - Fax
http://www.usclivar.org
info@usclivar.org

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