Prospectus for a US CLIVAR Working Group: Arctic Change and Possible Influence on Mid-latitude Climate and Weather

1. Motivation

The dramatic retreat of perennial Arctic sea ice has been a wake-up call to the climate community that climate change may not necessarily be slow and steady nor its impacts only of consequence in the far off future. The newly revealed open waters of the Arctic Ocean and the collapse of warm-season snow cover are known to have profound impacts on the energy balance of the Arctic. And just as heating anomalies in the tropics can influence weather around the globe, large heating anomalies in the Arctic basin may have ripple effects at lower latitudes, especially across the industrialized countries and population centers of the Northern Hemisphere (NH).

The Arctic has warmed more than twice as fast as the global average, a phenomenon known as Arctic amplification. Rapid warming and sea ice loss has had significant impacts on the energy balance locally. September sea ice extent has declined at a rate of 12.9% per decade since 1979 (Meier et al. 2012). This decrease in ice extent has been accompanied by an approximately 1.8m (40%) decrease in mean ice thickness (Kwok and Rothrock 2009) and a 75-80% loss in volume (Overland et al. 2014). Snow cover in spring and summer has decreased at an even greater rate (Derksen and Brown 2012). The combined rapid loss of sea ice and snow cover in the spring and summer has played a role in amplifying Arctic warming.

These profound changes to the Arctic system have coincided with a period of ostensibly more frequent events of extreme weather across the NH mid-latitudes, including extreme heat and rainfall events and recent severe winters (Coumou and Rahmstorf 2012; Cohen et al. 2014). Though winter temperatures have generally warmed since 1960 over mid-to-high latitudes (Screen 2014), the number of days continuously below freezing has increased and the minimum temperatures have decreased since 1990 and the frequency of unusually cold winter months (colder than 2 standard deviations below the 1951–1980 mean) has reversed its longer-term downward trend from the end of the 1990s (Zhang et al. 2012; Cohen et al. 2014). This trend reversal in cold extremes has coincided with an acceleration in the rate of warming at high-latitudes relative to the rest of the NH starting approximately in 1990.

The media and public have been quick to make the connection between global, and in particular Arctic, warming and extreme weather (Hamilton and Lemcke-Stampone 2013). Coupled models project boreal winter amplification under greenhouse gas forcing, where the NH landmasses would warm faster in winter relative to the other seasons (Holland and Bitz 2003; Alexeev et al. 2005; Zhang 2010). Warming in the Arctic has continued unabated since at least 1960. Longer-term observed temperature trends in mid-latitudes are consistent with these projections, while shorter-term trends are not. This highlights that results are sensitive to the spatial extent of the analysis, the exact definition used, and especially the duration of an extreme, as extremes of differing durations may be driven by different physical processes.

The possible link between Arctic change and mid-latitude weather has spurred a rush of new observational and modeling studies. These studies have argued that heavy precipitation events, heat waves and even cold waves are due to Arctic warming. While cold extremes may be mostly due to natural variability, a growing number of recent studies argue that recent extreme winter weather is related to Arctic amplification. In part due to the high impact of extreme weather on our society, some of these studies linking Arctic Amplification to the increased frequency of extreme weather have garnered public and media attention. This in turn has resulted in a number of workshops trying to frame the problem and laying the groundwork to improve our understanding of Arctic-mid-latitude linkages and accurate attribution of extreme weather events. These workshops include a National Academy of Sciences (NAS) workshop in Washington DC in September 2013, a NOAA Arctic workshop in Boulder in May 2014, and international workshops in Reykjavik, Iceland, in November 2013 and Barcelona, Spain, in December 2014.

The NAS workshop reviewed existing research results and indicated complications and uncertainties in testing the hypothesized Arctic-midlatitude linkage due to inconsistent observations and modeling results, as well as the short time period. The workshop acknowledged that the hypothesized linkage between Arctic warming and midlatitude weather pattern is still in its research infancy. The workshop in Reykjavik recommended more rigorous hemispheric and regional case studies of changes in jet-stream variability and extreme events, examination of multiple individual ensemble members from modeling studies, a better understanding of climate-model biases in response to Arctic sea-ice loss, and a clearer attribution of the recent sea-ice decline as well as of extreme weather events. At the NOAA Arctic workshop in Boulder and in a recent review article (Cohen et al. 2014), it was concluded that we lack an understanding of the coupling between Arctic variability and midlatitude weather and that there are strongly differing opinions on the linkages including the influence of tropics. Furthermore the number one suggested action item at the NOAA workshop related to Arctic-mid-latitude linkages was to draft a synthesis report on the topic outlining what is currently known and unknown on this topic. The most recent workshop in Barcelona recommended a better understanding of the links between the Arctic and lower latitudes and to what extent future investments in forecasting system development in polar regions (e.g., observing system and coupled models) can provide benefit for the prediction of weather and climate in lower latitudes. *Although these workshops identified existing problems and difficulties, and provided broad recommendations, they did not synthesize the diversified research results to identify where community consensus and gaps exist. Through the three-year efforts of this proposed working group, we will use the outcome of these workshops and newly planned activities to guide the synthesis efforts, coordinate on-going research to fill out key gaps, and provide specific recommendations for accelerating scientific progress.*

This topic is highly relevant and timely to US CLIVAR. The subject of Arctic-mid latitude linkages is strongly related to the three of the four US CLIVAR research challenges in the new science plan posed on 1) predictability of high-latitude climate variability, 2) decadal variability and the question of the warming hiatus and 3) climate extremes. The summer publication of the US CLIVAR newsletter Variations was dedicated to the topic; Predictability of Arctic Climate Variability, and the guest editor is one of the proposing co-chairs. There is much interest from the climate community and the public in this topic and momentum has been growing for leadership and to commit resources to increase our knowledge on this important topic.

2. Objectives, Tasks, Timeline

The main objectives of the working group are:

1) Assess and synthesize existing knowledge on the links between Arctic climate change and mid-latitude weather variability including weather extremes;
2) Identify key questions and knowledge gaps, with a particular an attention on physical processes and scale interactions considering the relatively short time period and multiple components included in the hypothesized linkages;
3) Propose or recommend targeted measurements that will allow better understanding of Arctic climate variability and surface-atmosphere coupling;

4) Provide a preliminary assessment of the ability of current models to reproduce the correct relationship between Arctic and mid-latitude weather and climate variability. Small sample size in the observations remain a challenge, therefore modeling studies are needed to test for significance;
5) Coordinate our efforts with those of other national and international programs, such as SEARCH (Study of Environmental Arctic Change), CliC (Climate and Cryosphere), and IASC (International Arctic Science Committee), by including their members among our WG, in teleconferences, and possibly joint meetings; and
6) Inform funding agencies through US CLIVAR Interagency Group and the IARPC (Interagency Arctic Research Policy Committee) of opportunities for advancing scientific understanding of Arctic influences on midlatitude climate.

The proposed specific tasks are:

1) Assess and synthesize existing research and identify key knowledge gaps.
2) Begin to implement recommendations by previous workshops and conduct/include new research activity on the topic. Coordinated and standardized modeling studies of sea ice loss on the climate will be conducted through the WG members among various modeling groups. Extreme weather is driven by synoptic systems though large-scale circulation may play a steering role (e.g., Zhang et al. 2004; Zhang et al. 2012). However, storm track dynamics and scale interactions were missing pieces in the previous workshops, which will be included in this proposed research and synthesis effort.
3) Address the challenge of small sample size from the observations. Available proxy data and modeling data will be used to supplement observational data. Identify and recommend needed measurements to enhance current datasets. Also artificial data can be generated through bootstrapping and Monte Carlo simulations. We will also assess possible process studies of large-scale sea ice-atmosphere coupling.
4) Provide a preliminary assessment of where the current climate models stand in their simulation of Arctic-midlatitude coupling at different temporal and spatial scales.
5) Organize bi-monthly teleconferences on progress, and WG meeting coincident with US CLIVAR summits.
6) Convene a workshop to facilitate community engagement in assessing and synthesizing understanding, gaps, and opportunities.
7) Draft and submit a white paper/review article summarizing workshop and working group findings and recommendations for publication. The article will examine different ways the Arctic and mid-latitudes could be coupled, how the Arctic may influence the frequency of extreme events, how to standardize the identification of extremes, what limitations of data sets and models are, and identify knowledge gaps (dynamical mechanisms, ocean-ice-atmosphere coupling, seasonality, storm track dynamics, scale interactions, etc.).

Timeline:

Year 1: Plan WG activities, finalize bi-monthly teleconference schedules, review research accomplishments, and identify key scientific questions that have not been answered;

Year 2: Prepare and organize the planned workshop, draft the review article/white paper, and coordinate and conduct the preliminary assessment of climate models; and

Year 3: Finalize and submit the review article/white paper for publication, report the WG results to the PPAI and POS panel and the US CLIVAR Summit, and propose physical processes targeting for future field measurements.

3. Publications and Outreach

We anticipate that a refereed journal paper that synthesizes the state of our knowledge on the linkage between Arctic and mid-latitude climate and its potential influence on extreme weather events will result from the proposed WG efforts. Outreach will be accomplished through presentations to US CLIVAR, the program newsletter Variations, the planned workshop, as well as other conferences and meetings (such as AGU or AMS annual meeting).

4. Reporting Plan

By helping to improve our understanding of the influence of Arctic ocean/sea ice variability has on weather (including extremes) and climate across different spatial and time scales, and to operationalize this information into improved predictions and projections, this WG has relevance to all of the stated goals of US CLIVAR (page viii of the Science Plan). The topic is also highly relevant to each of the three US CLIVAR panels:

a) POS - mission is to improve understanding of climate variations in the past, present and future, and to develop syntheses of critical climate parameters while sustaining and improving the global climate observing system.
b) PSMI - mission is to reduce uncertainties in the general circulation models used for climate simulations through an improved understanding and representation of the physical processes governing climate and its variation.
c) PPAI - mission is to foster improved practices in the provision, validation and uses of climate information and forecasts through coordinated participation within the US and international climate science and applications communities.

Several members of the POS and PPAI panels jointly created the idea for this WG and therefore we propose to report our progress to both of these panels and seek their advice and support. We further propose to report on our progress at the annual US CLIVAR summits, SSC, and panel meetings, as appropriate.

5. Leadership and Suggested Membership

Judah Cohen of PPAI and Xiangdong Zhang of POS will be co-chairs. Cohen was guest editor of the most recent US CLIVAR Variations on the topic of Predictability of Arctic Climate Variability and was first author on a review article on Arctic linkages to extreme mid-latitude weather. Xiangdong Zhang has conducted extensive studies about Arctic climate, and Arctic-lower latitude interactions and has organized a workshop sponsored by the WCRP/CliC and NSF Arctic Program in 2010 to synthesize state-of-knowledge about systematic changes in the Arctic.

Other proposed members and their focus: observations (O), modeling (M) or both (B). Core members listed above and alternate/contributing and international (IM) members listed below second double line.

Scientist	Affiliation	Expertise
Jennifer Francis	Rutgers University	Arctic climate - O
James Overland	NOAA/PMEL	Arctic - O
Uma Bhatt (SEARCH)	University of Alaska	Arctic climate - O
Emily Riddle (ECS)	University of Massachusetts	Climate variability - M
Yannick Peings (ECS)	University of California	Ice-snow-atmosphere coupling - M
Julienne Stroeve	NSIDC	Sea ice -O
Ignatius Rigor	University of Washington/APL	Coordinator IAPB program - O
Elizabeth Barnes (ECS)	Colorado State University	Atmospheric dynamics - M
Ron Kwok	NASA/JPL	Remote sensing/Arctic climate - O
Wieslaw Maslowski	Naval Postgraduate School	Arctic Oceanography - M
Mike Wallace	University of Washington	Climate dynamics - B
Cecilia Bitz	University of Washington	Sea ice - M

Clara Deser	NCAR	Climate modeling - M
Dorothy Hall	NASA/GSFC	Cryosphere/Climate - O
Arun Kumar	NOAA CPC	Climate prediction - M
John Walsh	University of Alaska	Arctic -B
Steven Feldstein	Penn State University	Large Scale dynamics - B
Gudrun Magnusdottir	University of California	Sea ice-atmosphere coupling -M
Stephen Vavrus (SEARCH)	University of Wisconsin	Arctic climate - M
James Screen IM	University of Exeter	Climate variability and change - B
Timo Vihma IM	Finnish Meteorological Inst.	Arctic boundary dynamics - O
Asgeir Sorteberg IM	University of Bergen	Climate/storm dynamics - O

6. Resource Requirements

The WG will meet once per year for 2-3 days, will hold monthly teleconferences and publish a white paper requiring travel funds and teleconference support. Specifically:

- Travel support for two annual WG meetings
- Support for a larger conference near the end of year 2
- One white paper/review article, summarizing key results from WG and workshop/conference

References:

Alexeev, V. A., P. L. Langen, P. L. and J. R. Bates, 2005: Polar amplification of surface warming on an aquaplanet in "ghost forcing" experiments without sea ice feedbacks. *Climate Dyn.,* **24,** 655–666, doi:10.1007/s00382-005-0018-3.

Cohen, J., J. A. Screen, J. C. Furtado, M. Barlow, D. Whittleston, D. Coumou, J. Francis, K. Dethloff, D. Entekhabi, J. Overland, and J. Jones, 2014: Recent Arctic amplification and extreme mid-latitude weather. *Nature Geosci*., **7**, 627-637, doi:10.1038/ngeo2234.

Coumou, D. and S. Rahmstorf, 2012: A decade of weather extremes. *Nature Climate Change,* **2,** 491–496, doi:10.1038/nclimate1452.

Derksen, C. and R. Brown, 2012: Spring snow cover extent reductions in the 2008-2012 period exceeding climate model projections. *Geophys. Res. Lett.* **39,** L19504, doi:10.1029/2012GL053387.

Hamilton, L. C. and M. Lemcke-Stampone, 2013: Arctic warming and your weather: public belief in the connection. *Int. J. Climatol*., **34,** 1723–1728, doi:10.1002/joc.3796.

Holland, M. M. and C. M. Bitz, 2003: Polar amplification of climate change in coupled models. *Climate Dyn.,* **21,** 221–232, doi:10.1007/s00382-003-0332-6.

Kwok, R. and D. A. Rothrock, 2009: Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008. *Geophys. Res. Lett.,* **36,** L15501, doi:10.1029/2009GL039035.

Meier, W. N., J. C. Stroeve, A. Barrett, and F. Fetterer. 2012: A simple approach to providing a more consistent Arctic sea ice extent time series from the 1950s to present, The Cryosphere, **6**, 1359-1368, doi:10.5194/tc-6-1359-2012.

Overland, J. E., M. Wang, J. E. Walsh and J. C. Stroeve, 2014: Future Arctic climate changes: Adaptation and mitigation timescales. *Earth's Future,* **2,** 68–74, doi:10.1002/2013EF000162.

Screen, J. A., 2014: Arctic amplification decreases temperature variance in northern mid- to high-latitudes. *Nature Climate Change,* **4,** 577–582, doi:10.1038/nclimate2268.

Zhang, X., J. E. Walsh, J. Zhang, U. S. Bhatt, and M. Ikeda, 2004: Climatology and interannual variability of Arctic cyclone activity, 1948-2002. *J. Climate*, **17**, 2300-2317, doi:10.1175/1520-0442(2004)017<2300:CAIVOA>2.0.CO;2.

Zhang, X. 2010: Sensitivity of Arctic summer sea ice coverage to global warming forcing: Towards reducing uncertainty in Arctic climate change projections. *Tellus A*, **62**, 220-227, doi: 10.1111/j.1600-0870.2010.00441.x.

Zhang, X., C. Lu, and Z. Guan, 2012: Weakened cyclones, intensified anticyclones, and the recent extreme cold winter weather events in Eurasia. *Environ. Res. Lett.,* **7**, 044044, doi:10.1088/1748-9326/7/4/044044.