# Report on the Winter Polar Vortex Workshop to IASC Atmosphere Working Group

**Seattle, WA, USA, 11-13 September 2019**

We have 16 people participated the workshop with 12 on-site and 4 remotely. A list of participants is attached as Annex 1. Names with a "*" are earlier-career scientists. It was a productive workshop, see Annex 2 for the workshop agenda. At the end of the workshop, writing assignment was given to all the participants as listed in Annex 3.

Below are the summary from the workshop, and inputs from John Walsh and Timo Vihma.

**Summary from the workshop**

Large and rapid changes in the Arctic represent a new driver of weather patterns in mid-latitudes, potentially affecting millions of people. Recent studies of this north/south linkage, however, are inconsistent. Studies based on observed data report robust conclusions in some areas, seasons, and background conditions, while model-simulated connections and averaging over large areas, long time periods, and many ensemble members are generally less clear.

We suggest that one source of uncertainty arises from the inherent chaotic nature of the atmosphere. Thermodynamic forcing, by a rapidly warming Arctic and loss of sea ice, contributes to latitudinal weather linkages in the past decade. But internal atmospheric dynamics, i.e., large-scale wind patterns (jet stream location, strength, and orientation), may obscure the connections, making understanding of direct cause-and-effect challenging. Three areas in the Arctic Ocean during early winter exhibit linkages through the increasingly delayed freeze-up of sea ice, which allows heat to escape into the atmosphere and helps anchor the geographic locations of large-scale wind patterns: Baffin Bay (BB), Chukchi/Beaufort (CB) Seas, and Barents/Kara (BK) Seas.

*Multiple factors* contribute to these relationships, including BK sea-ice loss with atmospheric responses in the North Atlantic and east Asia and blocking near the Ural mountains, and CB with North Pacific Ocean temperature patterns. In late winter, the occasional disruption (movement, strength, and splitting) of the stratospheric polar vortex (SPV, i.e., the upper-atmospheric wind pattern) can influence weather patterns in Eurasia (e.g., the so-called 'Beast from the East' in winter 2018) and North America (e.g., wavy polar jet stream and associated persistent weather extremes during the winters of 2017/2018 and 2018/2019). The SPV plays a central role in vertically coupling the troposphere and stratosphere. Thus, evidence for Arctic/mid-latitude weather linkages has emerged from analyses of observed extreme events, while natural atmospheric and oceanic variability reduces seasonal correlations and provides weak signals in model studies.

With regard to research issues on the Arctic and East Asia weather linkage, the most important and controversial issue was the robustness of the relation between Arctic Warming and the East Asia cold anomaly. One study focused on the quantification of the relation suggested that at least 44% of recent winter Eurasian cooling is attributable to the sea ice loss over the Barents-Kara seas. Unfortunately, current state-of-the-art climate models underestimate the Eurasian cooling in response to the Arctic sea ice loss compared to the reanalysis suggested. Another study reported multi-decadal fluctuations of the relation between Arctic warming and the East Asia cold anomaly with a weaker relation from 1901 to 1929 and from 1955 to 1979, whereas a stronger relation occurred from 1930 to 1954 and from 1989 to 2013. Besides the cold air outbreak, Arctic cold air mass variability is proposed to be linked to extreme heat waves in summer over East Asia, which is a new perspective. The mechanism of the linkage in summer remains unclear as an incipient stage now and warrants further examination in the future. Knowledge on Arctic warming and sea ice loss and its influence on East Asia extreme weather via the troposphere or stratosphere needs to be

utilized in improving skills for sub-seasonal to seasonal weather prediction in order to mitigate socio-economic impact.

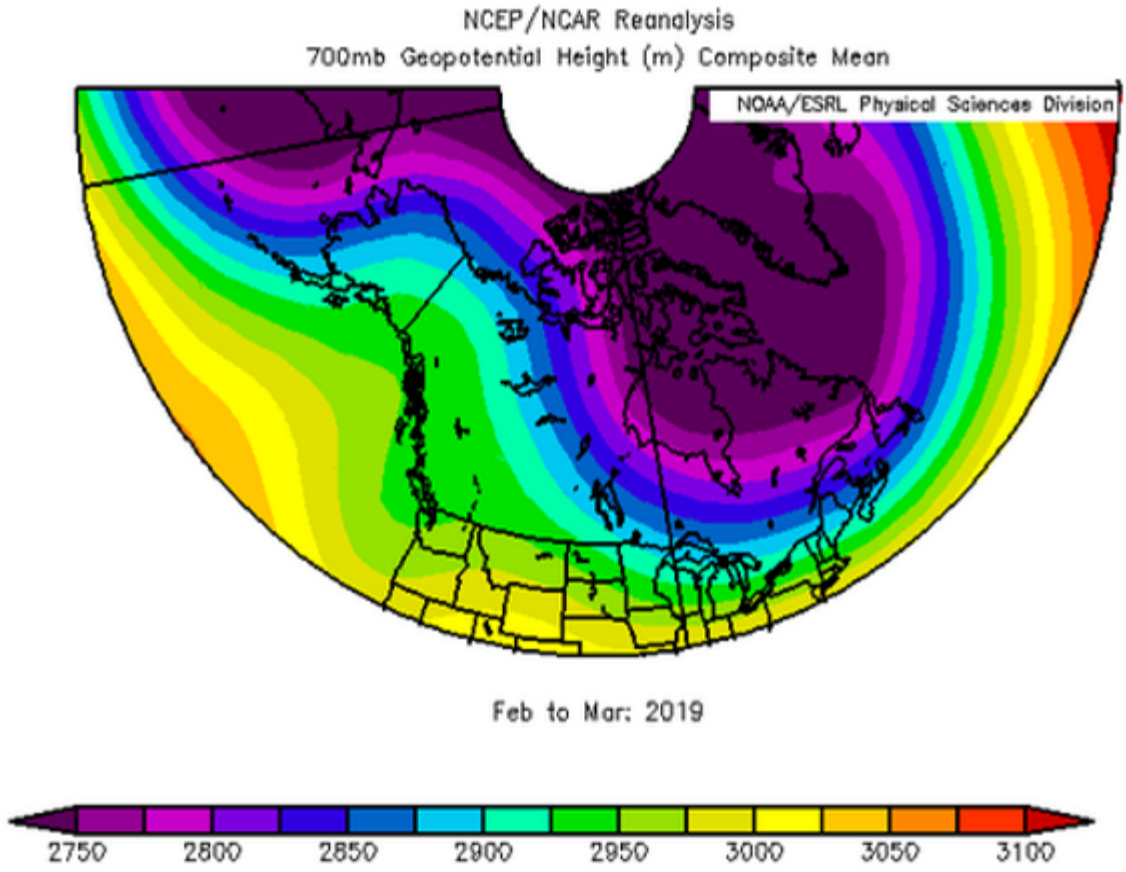


Figure 1 Movement of the Polar Vortex and jet stream over Greenland that resulted in cold eastern US weather, and warm Alaska and loss of Bering Sea sea ice in winter 2019.

## Impressions from the workshop from John Walsh, UAF

It was apparent from several presentations that considerable progress has been made in establishing troposphere-stratosphere coupling mechanisms, which seem to be on a more solid footing than only a few years ago. Presentations by Marlene Kretchmer, Jinro Ukita, and Judah Cohen demonstrated these dynamical coupling mechanisms consistent with observed relationships between Arctic and mid-latitude variations. With regard to methods and metrics, two impressions emerged from the workshop. First, as shown by multiple presentations, clustering techniques (including Self-Organizing Maps) have come into widespread use in quantifying Arctic/mid-latitude linkages. Second, the workshop showed that objective metrics of meanders (sinuosity) of the jet stream have now come into more widespread use in studies of Arctic/mid-latitude linkages, as nicely summarized by Jennifer Francis.

The workshop also highlighted several issues that appear to need further attention. One such issue is the apparent inability of models to capture large-scale atmospheric responses to snow and ice anomalies. An apparent inconsistency between observational results and model simulations is that observational studies have indicated an increase of sinuosity, while climate model projections (in externally forced simulations) show trends towards decreased sinuosity. Finally, an explanation is needed for the apparent change in lead/lag relationship between Greenland blocking and Alaska blocking between 2007 and the most recent decade, as highlighted in Tom Ballinger's presentation.

Several recommendations emerged from the workshop. The first is an expression of support for Jennifer Francis' proposal to confine the use of 'polar vortex' to the stratosphere, and to use 'jet stream' when referring to tropospheric circulation. The media's more general use of 'polar vortex' confounds the science and confuses the public. Second, Timo Vihma's suggestion to build a review paper around an assessment of levels of confidence in mechanistic linkages has considerable merit in view of the growing literature on Arctic/mid-latitude linkages. Finally, the topic of extreme events seems to need a more systematic framework for analysis. A cataloguing (suggested by Tom Ballinger) could be one step in this direction. There also is a need for increased attention to extreme events in the Arctic (vs. the present emphasis on mid-latitude extreme events that may have a linkage to the Arctic).

## Impressions from the workshop Timo Vihma, FMI

A lot of new results and interesting points of view on the winter Polar vortex and related interactions and feedbacks were presented in the workshop. Some of my impressions are summarized below.

The Arctic and mid-latitudes are linked via both tropospheric and stratospheric interactions and feedbacks, which were addressed in several talks. The tropospheric ones include positive feedbacks to amplified Arctic warming related to (1) sea-ice decline (warm Arctic causes sea-ice decline, which enhances heat and moisture fluxes from the ocean to atmosphere, further warming the Arctic), and (2) more meandering jet stream (warm Arctic results in a reduced meridional temperature gradient, which favors a weaker and more meandering jet stream, which favors more frequent and stronger cases of warm, moist air advection to the Arctic, which further increases Arctic air temperatures). The second feedback loop is associated with opposite effects in mid-latitudes, favoring cold-air outbreaks from the Arctic and mid-latitude winter cooling, which contributes to the reduced meridional temperature gradient.

The stratosphere-troposphere interactions were well-summarized in the workshop, the highlights including identification of the differences in impacts on Eurasia and North America. The Eurasian case is characterized by upward propagating waves absorbed in the stratosphere, whereas upward propagating waves that are reflected downwards from the stratosphere affect the tropospheric conditions in North America (Kretchmer's presentation). Climate model results for stratosphere-

troposphere interactions were found sensitive to model deficiencies, and improvement of models via interactive ozone chemistry was found beneficial (Jaiser's presentation). Furthermore, the geopotential height difference between 10 and 50 hPa pressure levels was found to be a good metric for the Polar Vortex (Francis' presentation).

There is a strong need to summarize existing information and remaining knowledge gaps related to tropospheric and stratospheric pathways linking the Arctic and mid-latitudes. Ukita presented a draft summary table on tropospheric and stratospheric pathways, which serves as an excellent starting point in work towards a more comprehensive review.

Considering a review on Arctic/mid-latitude linkages in winter, at least the following questions deserve attention:

1. What are the key processes acting in different regions (North America, Europe, Asia), layers (stratosphere, troposphere, air-snow/ice-ocean interphases), and months (November – March)?
2. How well do we understand the physical mechanisms, interactions and impacts of the processes? What are the primary feedbacks? Do we have good examples of events that we understand in the level of physical mechanisms and those that we do not understand? What are the major knowledge gaps?
3. Which of the observed changes in mid-latitude winter weather and climate can be attributed to Arctic forcing?
4. What are the projected impacts of Arctic amplification according to climate models? Are the models reliable enough? Which of the published results have been based on most reliable models?

**Annex 1**

# List of Participants

| Name | Institute | E-mail |
|---|---|---|
| Tom Ballinger* | Texas State University, Department of Geography, 601 University Drive, ELA 139, San Marcos, TX 78666, USA | tballinger@txstate.edu |
| Judah Cohen | Atmospheric and Environmental Research (AER), 231 Hartwell Ave., Lexington, MA 02421, USA | jcohen@aer.com |
| Jennifer Francis | Woods Hole Research Center, 149 Falmouth Rd., Woods Hole, MA, USA | francis@marine.rutgers.edu |
| Edward Hanna | School of Geography and Lincoln Centre for Water & Planetary Health, Lincoln, UK | EHanna@lincoln.ac.uk |
| Ralf Jaiser* | Alfred-Wegener-Institut, Telegrafenberg A45, 14473 Potsdam, Germany | ralf.jaiser@awi.de |
| Baek-Min Kim | Pukyong National University, Busan, Republic of Korea | baekmin@gmail.com |
| Seong-Joong Kim | Korea Polar Research Institute, Incheon #21990, Republic of Korea | seongjkim@kopri.re.kr |
| Marlene Kretschmer (remote)* | Potsdam Institute for Climate Impact Research, Telegraphenberg A 62, 14473 Potsdam, Germany | kretschmer@pik-potsdam.de |
| James Overland | NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115, USA | james.e.overland@noaa.gov |
| Janet Pawlak | Arctic Monitoring and Assessment Programme Secretariat, Postal: The Fram Centre, Box 6606 Langnes, 9296 Tromsø, Norway | jpawlak@dahm.dk |
| Eugene Petrescu (remote) | NOAA Federal | eugene.m.petrescu@noaa.gov |
| Jinro Ukita | Niigata University, Ikarashi-2, Niigata, Japan, 9502181 | jukita@env.sc.niigata-u.ac.jp |
| Timo Vihma (remote) | Finnish Meteorological Institute, Helsinki, Finland | timo.vihma@fmi.fi |
| John Walsh (remote) | University of Alaska Fairbanks, Fairbanks, AK, USA | jewalsh@alaska.edu |
| Muyin Wang | University of Washington | muyin.wang@noaa.gov |
| Xiangdong Zhang | University of Alaska Fairbanks, Fairbanks, AK, USA | xzhang9@alaska.edu |

# Annex 2

Winter Polar Vortex Workshop

NOAA/Pacific Environmental Laboratory

7600 Sand Point Way NE, Seattle, WA 98115

11-13 September 2019

**Final Agenda**

Each talk has 20-minute presentation + 10-minute discussion

**Wednesday, 11th September**

| | | |
|---|---|---|
| 08:00 | Van leaves Silver Cloud, Check-in at PMEL<br>*Chair: Wang* | |
| 08:30 | Overland, James | Introduction, background, and goal |
| 09:00 | Ukita, Jinro | Partition of early and late Winter Weather/ Explain E-P Fluxes |
| 09:30 | Jaiser, Ralf | Troposphere versus stratosphere pathways |
| 10:00 | Coffee Break | |
| 10:30 | Kretschmer, Marlene (remote) | Cluster analysis of late winter vortex; Europe connection |
| 11:00 | Zhang, Xiangdong | Explain PV and Isentropic Analysis, Review of AAISE workshop |
| 11:30 | Cohen, Judah | Late winter vortex variability; Snow and delayed freeze-up connections |
| 12:00 | Lunch | |
| | *Chair: Wang* | |
| 13:00 | Kim, Baek-Min & Kim, Seong-Joong | Vortex connection/impacts on Eurasia AMAP Asia Workshop |
| 13:45 | Ballinger, Thomas | Upstream connections (N American Ridge, E Siberia), precursors? |
| 14:15 | Hanna, Edward | Greenland, Downstream connections (N Atlantic and Europe) vortex movement/precursors |
| 14:45 | Coffee Break | |
| 15:15 | Francis, Jennifer | Multiple indices of wavy jet stream/vortex; any late winter Arctic forcing? |
| 15:45 | Group Discussion | |

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|---|---|---|
| 16:30 | Overland/Wang/Pawlak | Summary of the day |
| 17:00 | Van leaves PMEL return to hotel | |
| 18:30 | Dinner | Tian Fu (Si-chuan cuisine) |

**Thursday, 12th September**

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|---|---|---|
| 8:00 | Pick up at hotel, leave for Kingston and Olympic Peninsula | |
| 9:00-18:00 | Informal Discussion | Outline for paper on late winter vortex and key scientific points. |

**Friday, 13th September**

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|---|---|---|
| 08:00 | Van leaves Silver Cloud, Check-in at PMEL | |
| | *Chair: Overland* | |
| 08:30 | Walsh, John | Impressions from day one |
| 08:45 | Vihma, Timo (remote) | Impressions from day one |
| 09:00 | Petrescu, Eugene | NWS Perspective |
| 09:15 | Group Discussion | Way forward: how do we proceed |
| 10:00 | Coffee Break | Join PMEL Coffee hour |
| 10:30 | Group Discussion | Outline a Synthesis Paper: list of sections, writing assignments, place to submit |
| 12:00 | Adjourn | |

**Annex 3**

# Writing Assignment: Arctic/Mid-latitude State of the Science

1. Introduction
   J. Overland

2. Motivation of the paper
   - 2.1 Need for case studies
     X. Zhang, J. Cohen, B.-M. Kim
   - 2.2 Synthesis Figure
     R. Jasier, T. Vihma
   - 2.3 Integration of metrics: how to describe and explain the processes
     SOM, EOF, Wave
     J. Francis, T. Ballinger
     Tug-of-war: denier vs supporter

3. Seasonality
   J. Ukita, T. Vihma, J. Francis

4. Barents/Kara Revisit – multiple processes
   B.-M. Kim, J. Cohen,

5. East Connection
   S.-J. Kim, J. Ukita

6. Late winter vortex/Jet
   - 6.1 Europe:
     E. Hanna, M. Kretschmer, T. Vihma
   - 6.2 NA Ridge Trough
     J. Francis, T. Ballinger, M. Wang, G. Petrescu
   - 6.3 Central Asia
     S.-J. Kim, B.-M. Kim, X. Zhang