

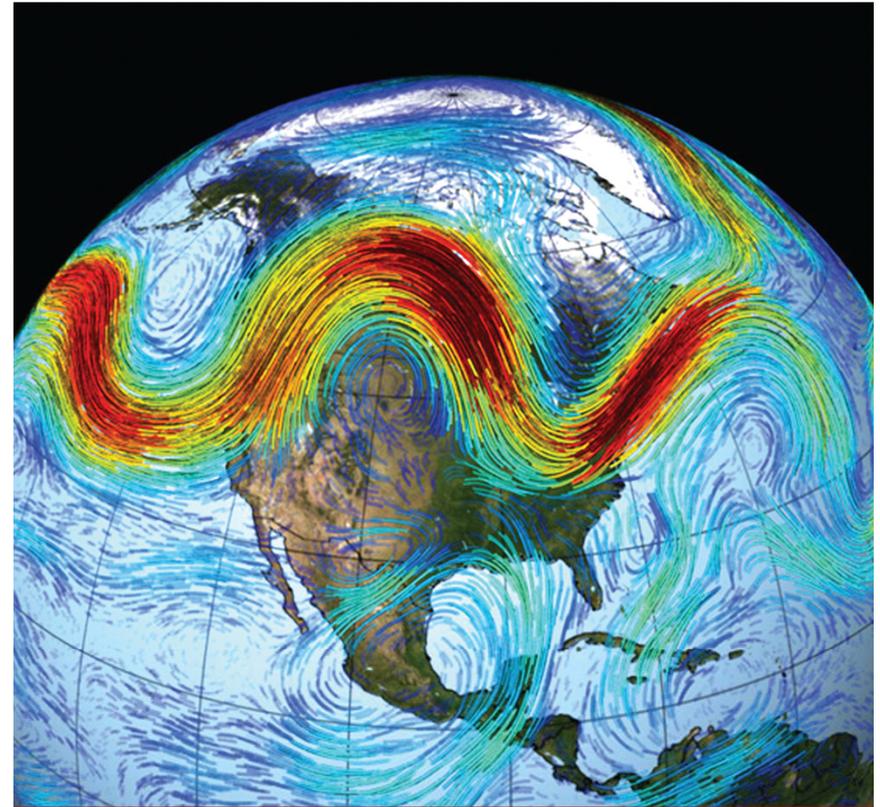
Linkages Between Arctic Warming and Mid-Latitude Weather Patterns: A Workshop Summary

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Linkages Between Arctic Warming
and Mid-Latitude Weather Patterns

Summary of a Workshop

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Who are the National Academies?

National Academy of Sciences (NAS) is a nonprofit organization established in 1863. We were chartered by Congress under the Lincoln Administration to provide independent advice to the Nation on science, engineering, and medicine. We are not a government agency.



National Academy of Engineering (NAE) (est. 1964) and **Institute of Medicine (IOM)** (est. 1970) are connected institutions, expanding our breadth and depth of expertise. (National Research Council is our “operating arm”)

Intellectual leadership comes from volunteer experts, chosen for expertise, balance, and objectivity.

Committee reports are most well known (200+ reports each year) but also research grants, fellowships, workshops, & other uses of independent experts.

BASC and PRB

BASC: ... advance understanding of the earth's atmosphere and climate, and serve as a source for objective, independent advice to the federal government and others.

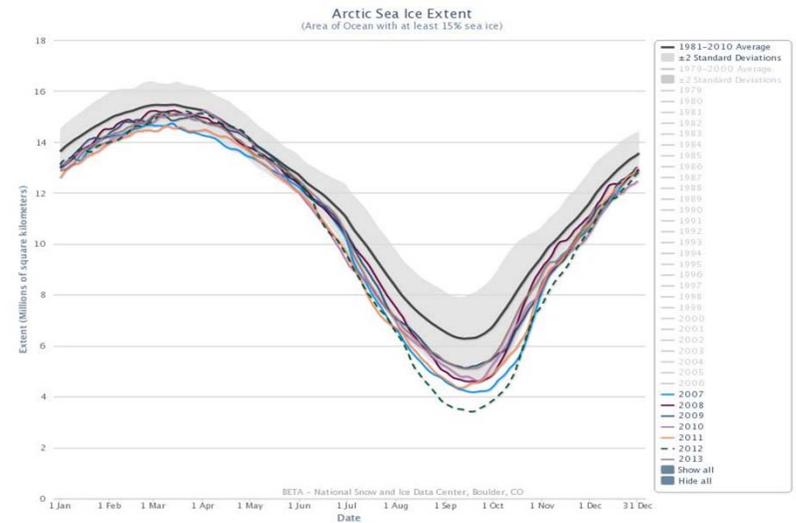
PRB:... enhance understanding of the Arctic, Antarctic, and cold regions and serve as a source for objective, independent advice to the federal government and others.



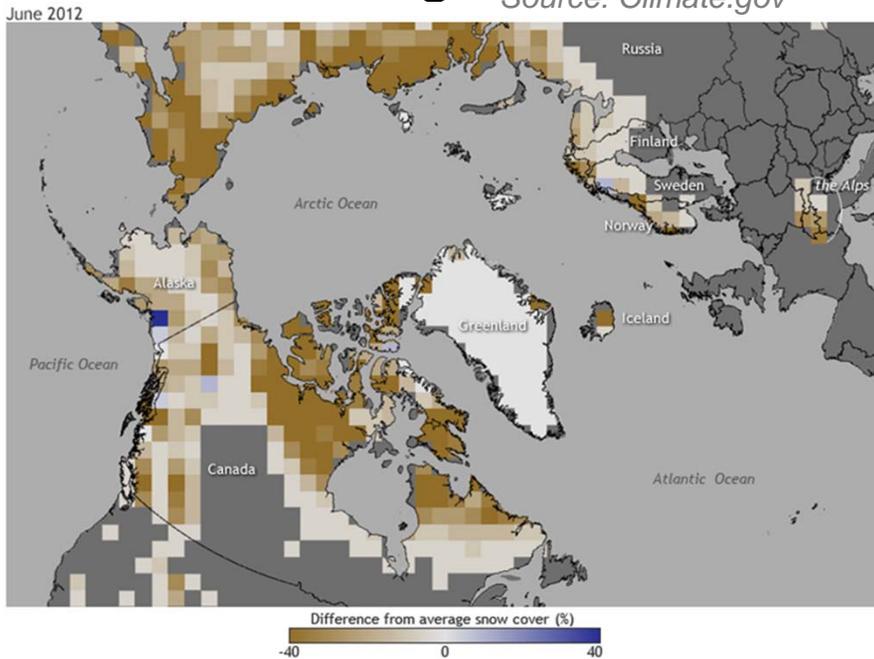
Significant Changes in the Arctic

- Surface temperatures rising 2x faster than global mean.
- The extent and thickness of sea ice is rapidly declining.
- Snow cover in the Arctic is declining

Source: NSIDC



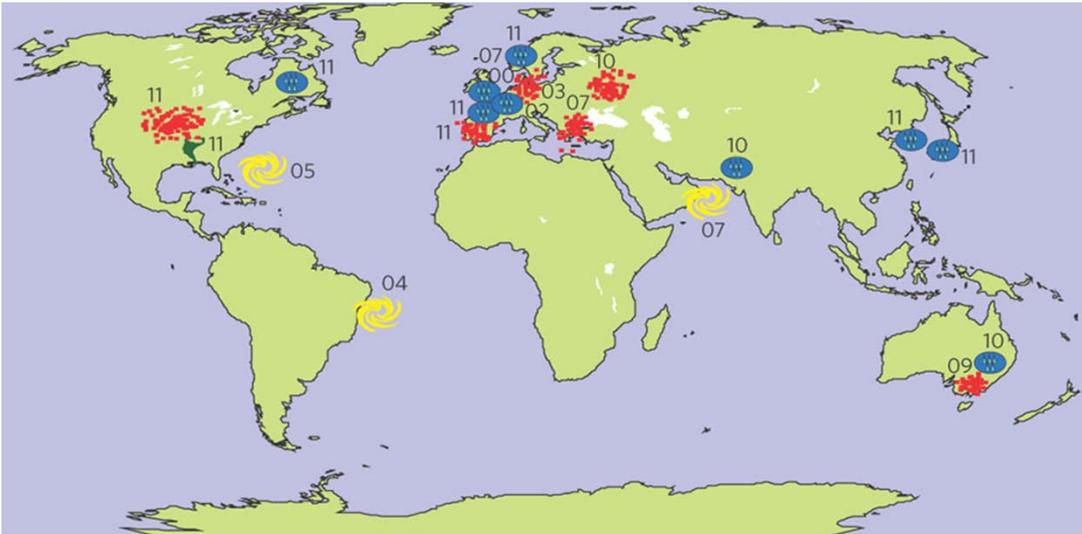
Source: Climate.gov



Source: NASA/Goddard Space Flight Center
Scientific Visualization Studio.



Extreme Weather Events



Source: Coumou and Rahmstorf, 2012

- Series of record-breaking extreme weather events taking place around the world in the past 10 years.
- Some have been high-profile and high-impact
 - Hurricane Sandy
 - Russian Heat-wave
- In 2011, there were 14 events in the US = \$1billion each



Source: Alex Wong/Getty Images

Are changes in the Arctic impacting atmospheric conditions outside the region?

Examples of Proposed Arctic Linkages

Greater Arctic warming → weakened temperature gradient → weakened, wavier jet stream → more persistent weather patterns in the mid-latitude (Francis and Vavrus, 2012)

Arctic sea ice loss → increase in fall high latitude snow cover → more expansive and strengthened Siberian high pressure in fall and winter → increased in upward propagation of planetary waves → more sudden stratospheric warmings → weakened polar vortex and weakened wavier jet stream (Cohen et al., 2012; Ghatak et al., 2012)

Arctic sea ice loss → changes in regional heat/energy fluxes → unstable polar vortex → cold polar air moves to the mid-latitudes (Overland and Wang, 2010)

Arctic sea ice loss → wavier jet stream and winter atmospheric circulation patterns similar to a negative phase of the winter Arctic Oscillation → frequent episodes of atmospheric 'blocking' patterns (Liu et al., 2012).

Arctic sea ice loss → southward shift of the jet stream position over Europe in summer → increased frequency of cloudy, cool and wet summers over north-west Europe (Screen, 2013)

Arctic sea ice loss → winter atmospheric circulation response resembling the negative phase of the Arctic Oscillation → rainfall extremes in the Mediterranean in winter (Grassi et al., 2013)

Arctic sea ice loss → negative phase of the tripole wind pattern → enhanced winter precipitation and declining winter temperature in East Asia (Wu et al., 2013)

This Activity

- **Small NRC committee** was appointed to plan the workshop
- **Workshop** held on September 12-13, 2013
 - Bring together a diverse array of experts
 - Review our current understanding
 - Discuss research needed to better understand proposed linkages.
 - Take a **global perspective** and consider the influence of the Arctic in the context of forcing from other components of the climate system
- **Workshop Summary**
 - Authored by an NRC Rapporteur
 - Provides an account of the workshop discussions
 - No findings, conclusions, or recommendations
 - Peer-reviewed

Committee, Speakers, and Reviewers

Planning Committee

David A. Robinson, Chair

- Rutgers, The State University of New Jersey

Uma Bhatt

- University of Alaska, Fairbanks

Cecilia Bitz

- University of Washington

Lance F. Bosart

- State University of New York, Albany

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- Ohio State University

Clara Deser

- NCAR

Walter Meier

- NASA

Workshop Speakers

James Screen, University of Exeter

Elizabeth Barnes, Colorado State University

Paul Kushner, University of Toronto

Jennifer Francis, Rutgers University

Steve Feldstein, Pennsylvania State University

James Overland, NOAA

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Dargan Frierson, University of Washington

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Isaac Held, NOAA

Peggy LeMone, NCAR

Mark Serreze, NSIDC

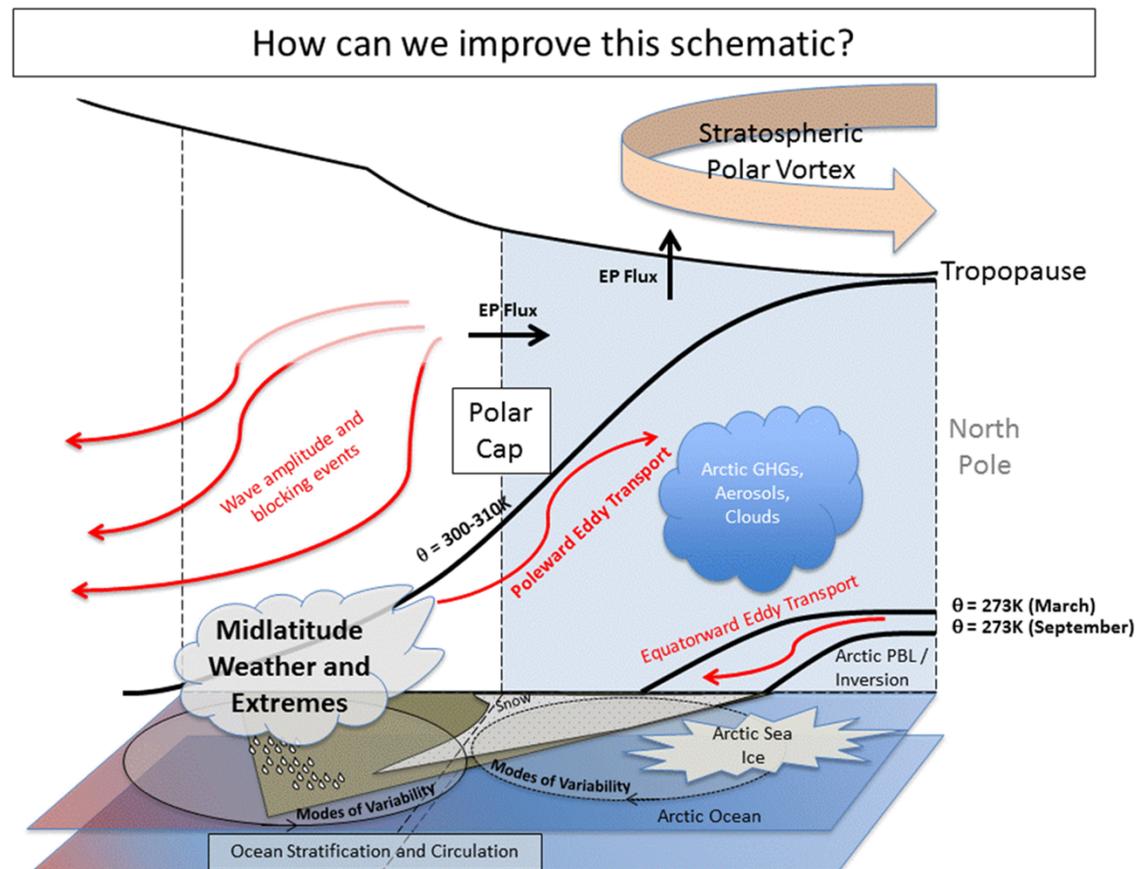
John Walsh, UAF

Workshop and Report Structure

- Plenary Sessions
 - Big Picture
 - Observational Evidence
 - Modeling Work
- Open panel sessions
- Breakout groups on future research needs

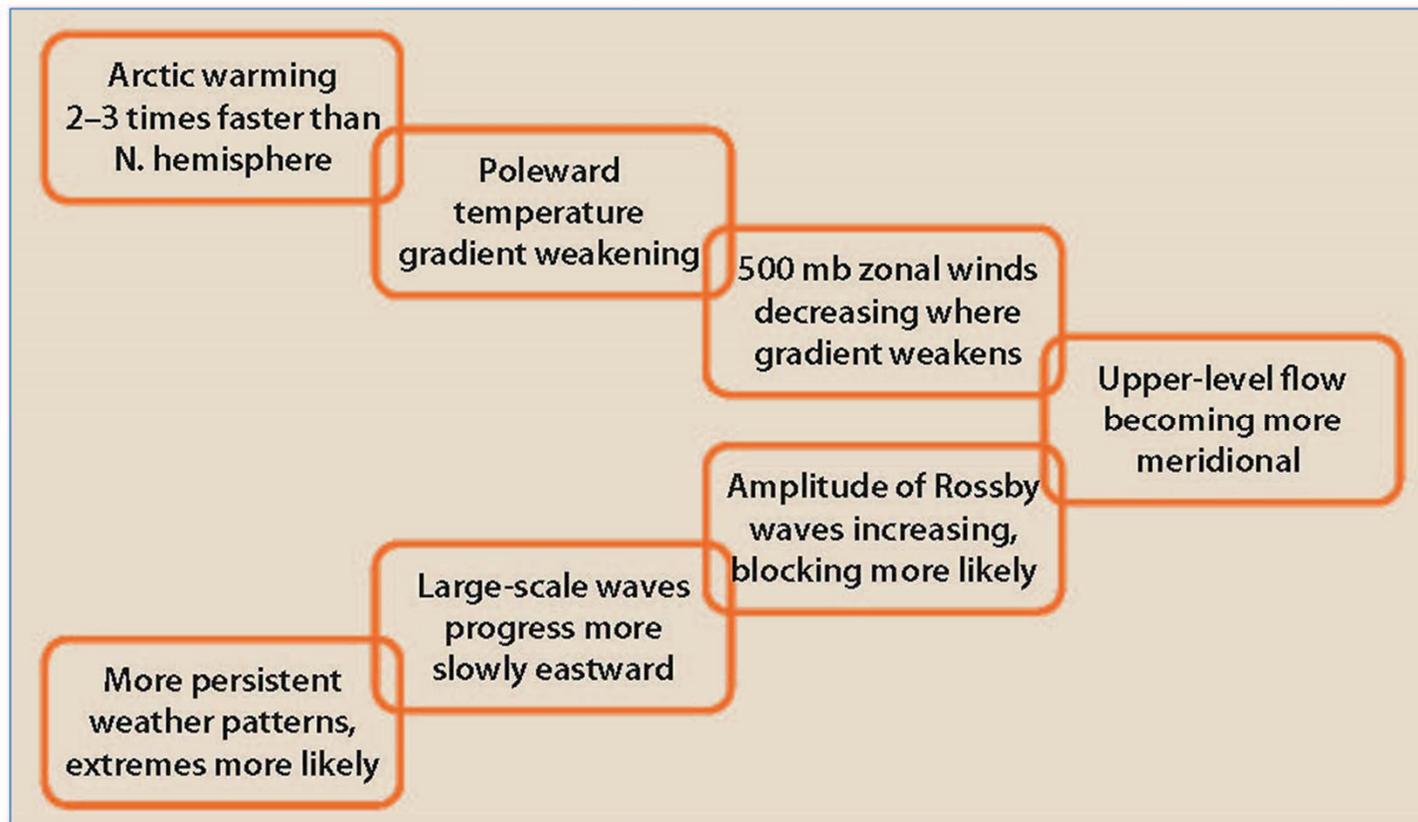
Big Picture: Key Messages

- Complex mechanisms and feedbacks link the tropics, poles, and mid-latitudes
 - Can be bidirectional and are not necessarily direct
- Natural variability of the atmosphere and Arctic sea ice complicates attribution



Big Picture: Key Messages

- Proposed linkages are composed of multistep hypotheses
- Understanding of the various steps is complicated by inconsistent evidence from observations and modeling studies



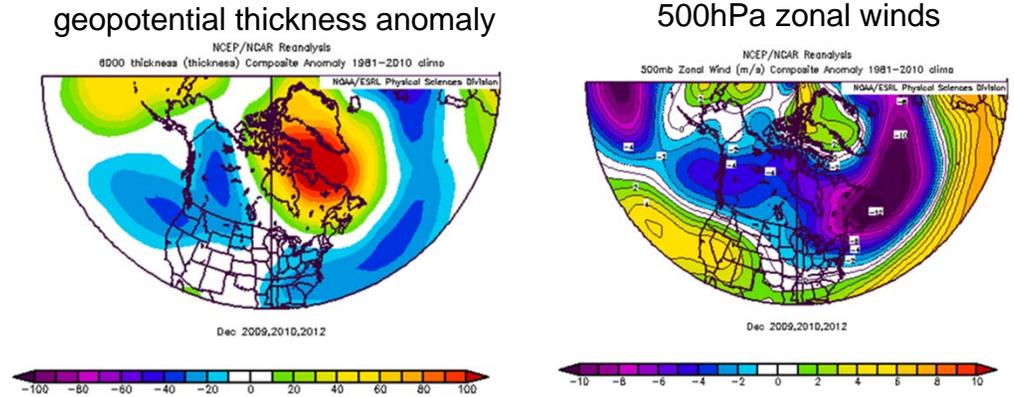
Observational Evidence of Trends

Trends that were discussed at the workshop as possibly linking Arctic amplification and mid-latitude weather:

- Arctic warming faster than the Northern Hemisphere
- Decrease in the temperature gradient between the Arctic and the mid-latitudes
- Slowing of upper-level zonal winds
- Upper-level flow becoming more meridional
- Increase in the amplitude of large-scale waves
- Increase in blocking events
- Large-scale waves progress more slowly eastward
- Increase in extreme events
- Weakening of the polar vortex

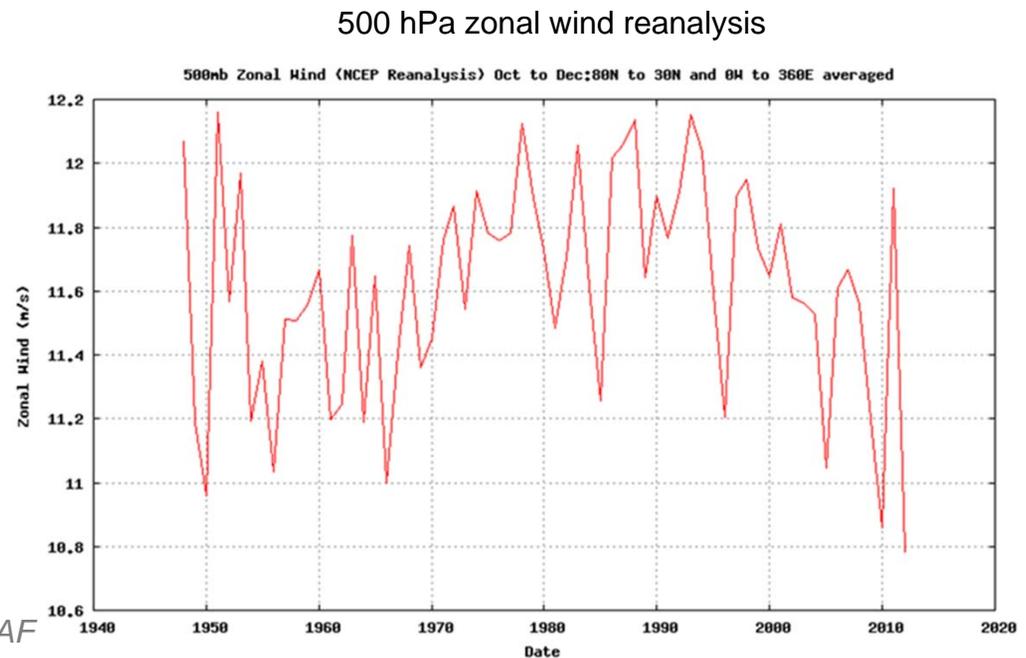
Example: Slowing of Upper-Level Winds

- Upper-level zonal winds decreasing in areas where the temperature gradient has also weakened



Source: James Overland, NOAA

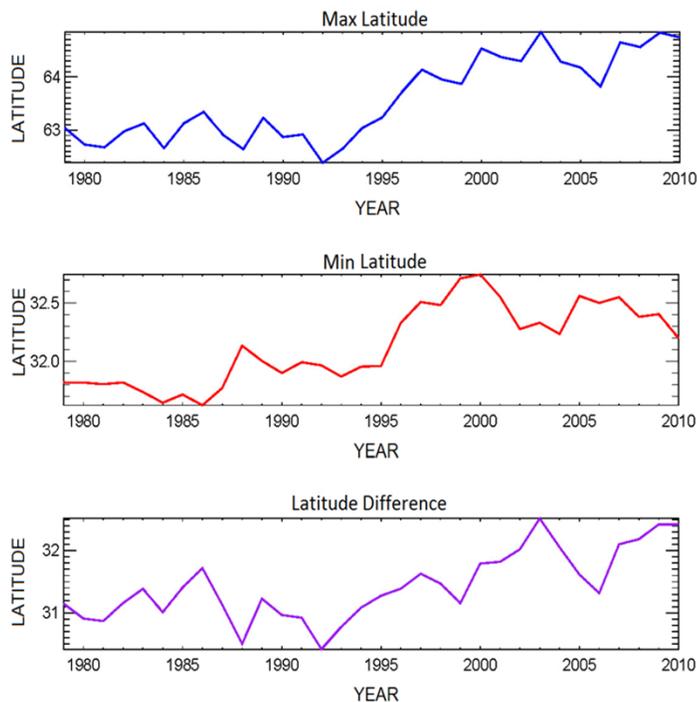
- If observations are extended back to 1948, zonal wind speed increases from the 1950s to the late 1970s and there is no known corresponding trend of increasing sea ice cover



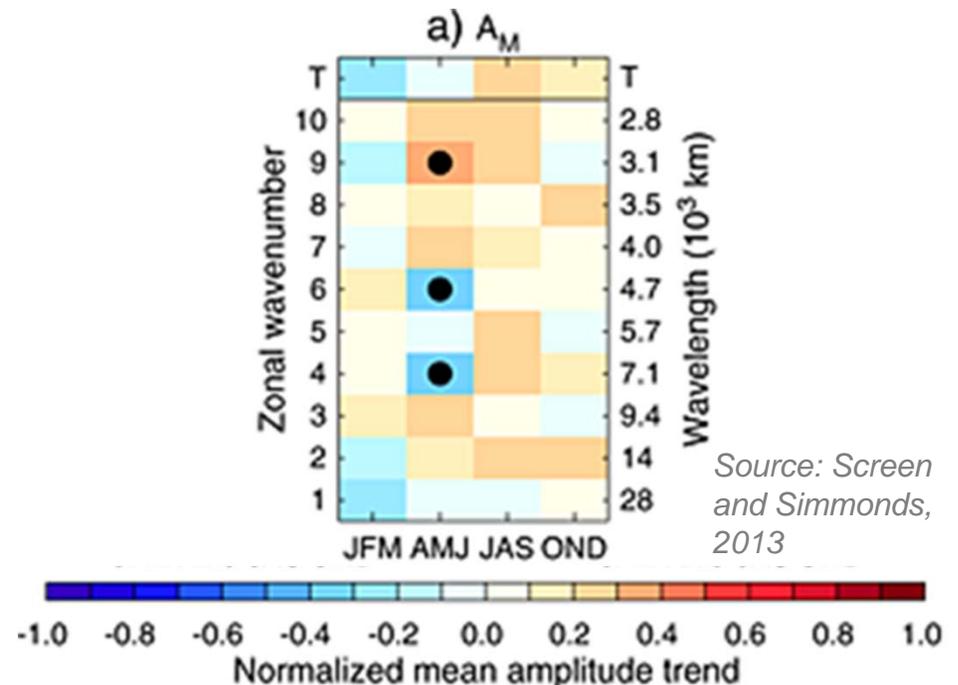
Source: John Walsh, UAF

Example: Increase in the Amplitude of Rossby Waves

- Wave amplitude is increasing meridionally in **summer, fall, and winter** in the Northern Hemisphere
- When wave amplitude measured differently: Significant increases in meridional wave amplitude over Europe during **spring**, but not in any other months or seasons.



Source:
Jennifer
Francis



Observational Evidence: Main Messages

- Some significant trends have been observed, however:
 - Other trends are not significant or are opposite of what we would expect
 - There may be several mechanisms behind a single trend
 - The method of measurement or how a particular variable is defined can affect the outcome of some of the observations
 - The short time series of the recent significant sea ice loss (less than 10 years) is a limiting factor

Observational Evidence: A Way Forward

- Participants suggested:
 - Trends could be clarified through quantifying uncertainty in data products.
 - Extend the observational record: 1) atmospheric reanalyses and 2) efforts to extend Arctic sea ice records back in time
 - Under-utilized observations could also be harnessed from often overlooked sources, such as the National Ice Center (NIC) operational products.
 - A better understanding of the range of blocking systems and how they are impacted by various components of the climate system is needed.
 - Deploying process-based studies on the “weak links” of the specific hypotheses.

Modeling Studies

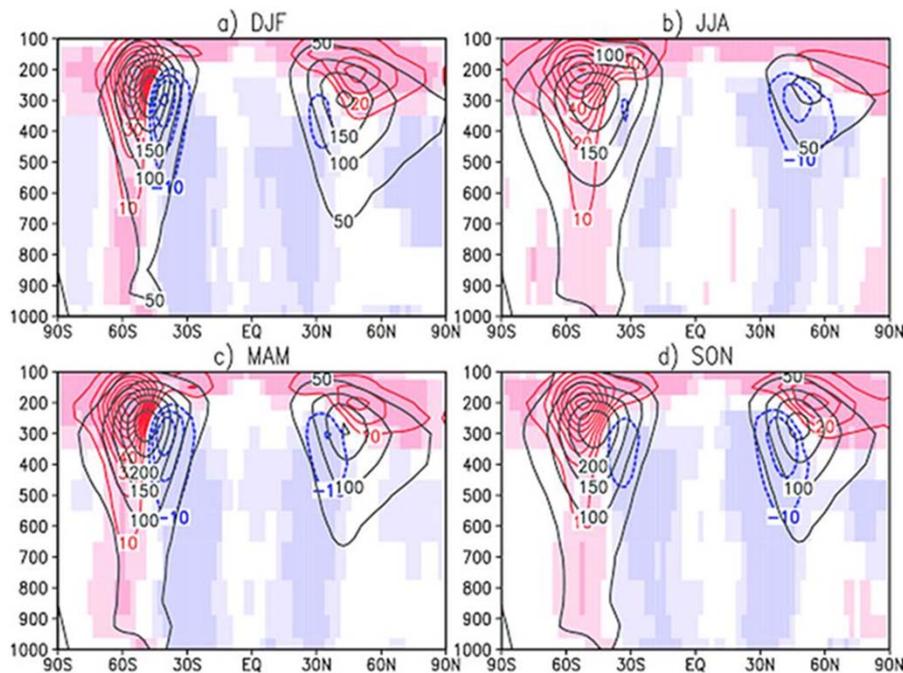
- Model studies
 - offer clues to mechanisms
 - assess a large number of possible pathways to influence weather
 - identify contributions of external factors that influence the atmosphere

- The following variables were discussed in the context of models that were forced with Arctic sea ice loss or Arctic warming:
 - temperature gradients,
 - upper-level zonal winds,
 - large-scale wave amplitudes,
 - blocking, and
 - weather patterns and storm tracks.

Example: Changing Weather Patterns and Storm Tracks in the Mid-Latitudes

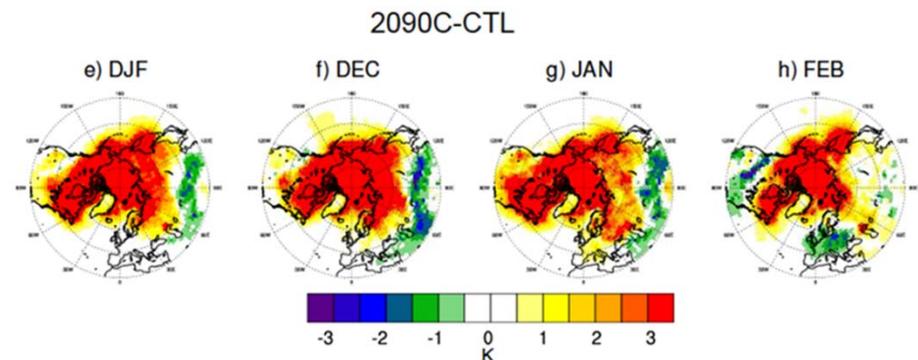
Winter Northern hemisphere upper-level **storm tracks will weaken** on equatorward flank by 2100 under RCP8.5

Source: *Change et al., 2012*



With a strong sea-ice forcing (2090), the intensity of **cold extremes decreases everywhere north of 45N** and are more intense south of 45N.

Source: *Peings and Magnusdottir, 2014*



Modeling Studies: Key Messages

- Models are the best tools available to complement observational studies, and to test robustness of the proposed mechanisms
- However:
 - They offer a large amount of divergence in ways that are not well understood
 - Different boundary and/or initial conditions are often used, making it a challenge to compare results
 - Model limitations and biases need to be considered

Modeling Studies: A Way Forward

- Participants suggested:
 - Organizing careful model intercomparisons and model sensitivity studies with similar boundary and/or initial conditions to allow for a more systematic review and comparison of the results
 - Organizing attribution studies to understand the proportion of Arctic amplification that is due to processes outside of the Arctic
 - Developing higher resolution models to study processes in the Planetary Boundary Layer (below 850 hPa)

Big Picture: A Way Forward

Research on Arctic linkages is still in its infancy, making it difficult to draw conclusions regarding the existence of such linkages or their mechanisms.

To address this, participants suggested:

- A large-scale research program dedicated to understanding the mechanisms of proposed Arctic linkages, particularly because it could lead to improved seasonal forecasts.
- Consideration of other mechanisms of Arctic linkages, such as zonal temperature gradients, static stability, and moisture changes.
- Collaboration between the climate and weather communities to apply the sophisticated methods and diagnostics developed in the meteorological community to better understand linkages.
- Consideration of the possibility of regional impacts of Arctic warming.

Acknowledgments

- Sponsors (NSF, NASA, NOAA)
- Committee
- Reviewers
- Speakers
- Participants
- NRC Staff

Additional Info

- Report can be downloaded for free:
 - http://www.nap.edu/catalog.php?record_id=18727
- Workshop presentations:
 - <http://dels.nas.edu/global/basc/all-presentations>
- Compilation of papers suggested by participants:
 - <http://dels.nas.edu/resources/static-assets/basc/miscellaneous/basc-arctic-linkages-workshop-references.pdf>