Arctic Warming and Midlatitude Extreme Weather

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An important and intriguing scientific question:

- Does the Arctic warming contribute to the midlatitude extreme weather?

We will mainly review two papers

- Francis and Vavrus (2012): Evidence linking Arctic amplification to extreme weather in mid-latitudes
- Barnes and Screen (2015): The impact of Arctic warming on the midlatitude jet-stream: Can it? Has it? Will it?

Arctic Amplification (AA): Anthropogenic warming vs. internal variability

- The Arctic warms at a larger rate than the rest of the northern hemisphere or the globe as a whole in recent decades. Strong AA, however, has occurred in the past.
  - The degree of AA, assessed as the ratio in the annual mean trend for the region 70–90°N to the trend for the globe as a whole, was 2.9 for the 1970–2008 period, compared with 6.9 for 1910–1940.
- Based on the available evidence, Arctic temperature changes during both warm and cold periods consistently exceed Northern Hemisphere averages by a factor of 3–4 (some positive feedback mechanisms also work in reverse).
- The role of internal variability in AA is a topic of debate. Some researchers suggested that greenhouse warming need not be invoked — natural multi-decadal (low frequency) climate variability can provide a sufficient explanation (Hurrell 1995, 1996).

Extreme Weather in a Warmer Climate

- Climate models project that the frequency and intensity of some types of extreme weather will increase due to anthropogenic warming [Meehl et al., 2007].
- How does global warming modulate extreme weather?
  - Thermodynamic: Tropospheric warming will cause an increase in atmospheric water vapor content that is expected to fuel stronger storms and flooding.
  - Dynamic: change of the large-scale circulation patterns and regional climate imply changes in weather statistics
- The link between AA and midlatitude extreme weather is a topic of hot debate .

Basic Dynamic Argument

Arctic warming

↓

reduces in the mean meridional temperature gradient

↓

changes in the storm track and stationary waves

↓

changes in extreme weather

A reasonable argument, but has it happened in the atmosphere?

Evidence linking Arctic amplification to extreme weather in mid-latitudes

Jennifer A. Francis and Stephen J. Vavrus (2012)

Hypothesis, Data and Methods

- Hypothesis: AA contributes to an increased tendency for a slower progression of Rossby waves that favors the types of extreme weather caused by persistent weather conditions, such as droughts, flooding, heat waves, and cold spells in the northern hemisphere mid-latitudes.
- Data: National Center for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis (NRA) data set
  - To reduce the possibility of spurious variability owing to differing data sources assimilated by the reanalysis, only fields from the post-satellite era (i.e., after 1979) are used.

Francis and Vavrus (2012)

Thickness Gradient and Zonal Wind

Seasonal 1000–500 hPa thickness differences between 80–60N and 50–30N

Seasonal zonal mean winds at 500 hPa between 60–40N

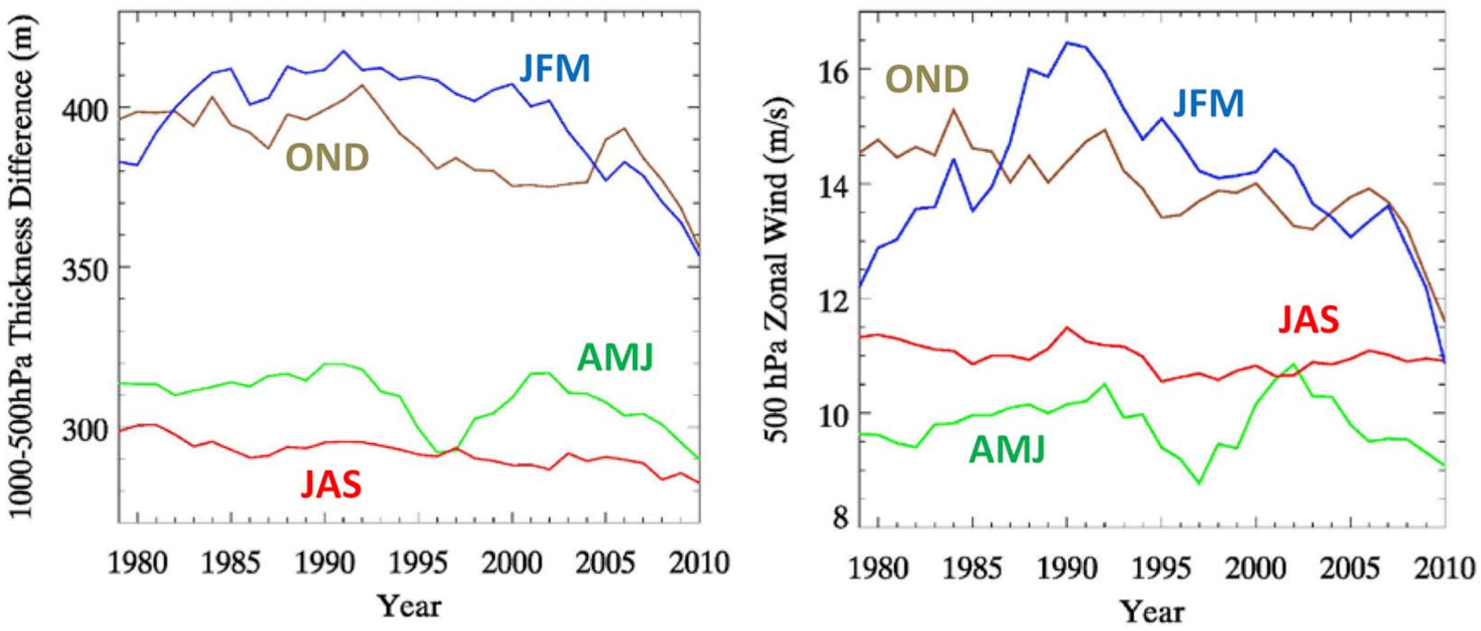

Figure 3. (left) Time series of seasonal 1000–500 hPa thickness differences between 80–60°N and 50–30°N over the study region (140°W to 0°). (right) Seasonal zonal mean winds at 500 hPa between 60–40°N over the study region. Seasons are labeled. Data obtained from the NCEP/NCAR reanalysis, http://www.esrl.noaa.gov/psd.

- Larger warming in the Arctic → reduced thickness gradient → weakens upper-level zonal winds
- There is a decreasing trend in the thickness difference and zonal wind in the recent decade
- There is also large low-frequency variability in thickness and zonal wind time series

Fig. 3 Francis and Vavrus (2012)

Estimating the Wave Amplitude

Time series of the maximum latitude of daily H500 contours (solid; please neglect the dotted line)

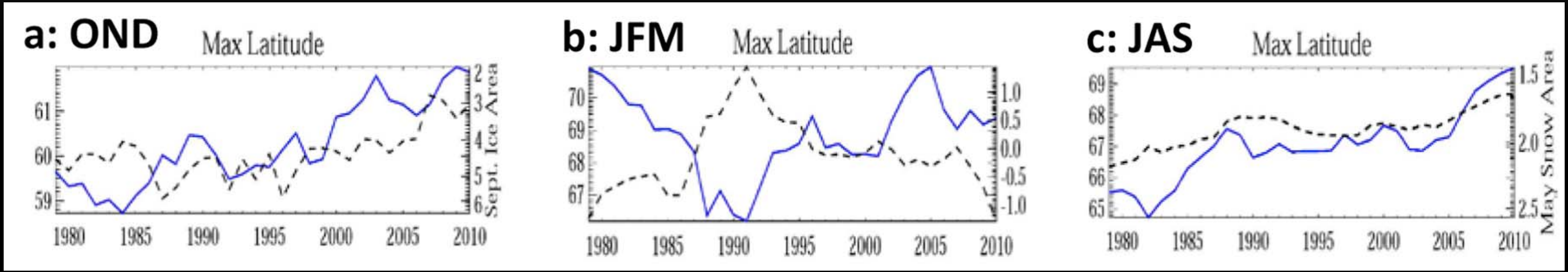

Fig. 4 from Francis and Vavrus (2012)

- Seasonal Max/Min: for each season and at each longitude, find the maximum and minimum latitudes obtained by a specific Z500 isopleth over that season. The meridional extent is then calculated as (max – min) to represent the peaks of ridges
- The authors suggested that the northward progression of ridge peaks supports the hypothesis that AA is contributing to the wave amplification (or a wavier pattern)

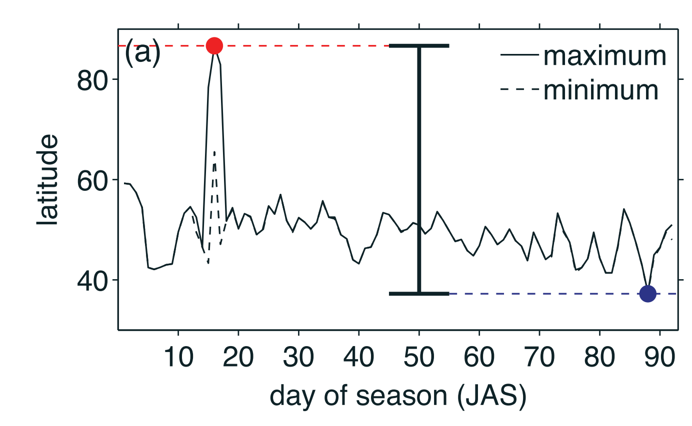

Fig. 1a from Barnes 2013

Conclusions: Francis and Vavrus (2012)

- Daily fields of 500 hPa heights from the NCEP Reanalysis are analyzed over N. America and the N. Atlantic to assess changes in Rossby wave characteristics associated with AA and the relaxation of poleward thickness gradients.
- Two effects are identified that both contribute to a slower eastward progression of Rossby waves in the upper-level flow: 1) weakened zonal winds, and 2) increased wave amplitude.
- Slower progression of upper-level waves would cause associated weather patterns in mid-latitudes to be more persistent, which may lead to an increased probability of extreme weather events that result from prolonged conditions,

A Critique of Francis and Vavrus (2012)

What did Francis and Vavrus (2012) show?

- AA is associated with a reduction in the zonal wind, but the causal relationship is not clear
- AA is associated with waves of larger amplitude – a wavier pattern (?)
- Slower progression of Rossby waves ?
- More persistent weather conditions (such as blocking) ?

Barnes (2013) showed that

- The positive trends in meridional extent of atmospheric waves are likely an artifact of the methodology.
- Rossby wave phase speeds do not show a significant decrease except October-November-December, and even this trend is sensitive to the analysis parameters.
- No significant increase was found in blocking frequency in any season.

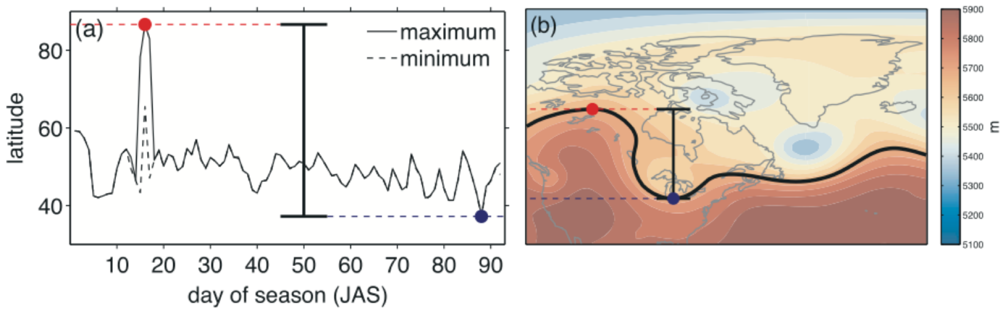

Figure 1. Examples of the (a) SeaMaxMin and (b) DayMaxMin meridional wave extent metrics for July–September 2009 (in Figure 1a) and 29 August 2009 (in Figure 1b) over the AtlanticNA region. In both panels the 5700 m Z500 isopleth is used and the vertical black bars denote the resulting meridional extent.

Barnes 2013

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