A Warming Arctic and Potential Shifts in Mid-latitude Weather: Faster than Expected

James Overland
NOAA
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Seattle
50% Decline in Arctic Ocean Multiyear Sea Ice Coverage

75% Loss in Sea Ice Volume since 1980

One Way Trip!

Area (10^3 km^2)

Year

(Kwok, 2010)
Figure 1. Latitudinal distribution of potential insolation for the Northern Hemisphere. Units are in W/m².
Arctic Air Mass – cold, dry
Maritime Air Mass- warm, moist
“Arctic Amplification”: Global Warming + Multiple Feedbacks

- **Teleconnection and circulation pattern change**
- **Atmosphere warming**
- **Ocean absorbs more heat**
- **Heat releases to atmosphere in the fall.**
- **Arctic amplification**
- **Reduction of Arctic sea ice**
- **Sept Sea Ice Extent**
- **Surface albedo decrease**

**Global Warming**

- **Heat releases to atmosphere in the fall.**
- **Teleconnection and circulation pattern change**

**JAS SSTA**

**OND Temp Anomaly**

**2008**

**Greenland**

**Russia**

**Alaska**

**Sea Ice**

**Surface albedo decrease**
Variation in general circulation

Warming Pattern is Different from Natural Variability (Arctic Oscillation) Pattern

Adapted from Wood & Overland (2006), F.M. Exner (1913) Über monatliche Witterungsanomalien auf der Nördliche Erthalfe im Winter; NAO & AO/NAM courtesy of J.M. Wallace
Wide Range of September Sea Ice Extent Hindcasts and Predictions

89 ensemble members from 36 CMIP5 (IPCC) models under strongest (RCP8.5) emissions scenario

Muyin Wang
Pacific Arctic Ocean Heat Storage

Real World  
Sept 12-13, 2011

Arctic Dipole Winds
Albedo Feedbacks
Melt stratification
Ocean Currents
Mackenzie Plume
East Winds
+6-8°C ocean anomalies, the largest in the world.

Alaska

MODIS Sea surface temperature (colors) and true-color composite image (land, sea ice, and clouds)
June Snow Cover 2012 relative to 1971-2000
MELTING AWAY GREENLAND FROM ABOVE

Land mass  | Surface ‘melt’ (detected by 2 or 3 Satellites) | Surface ‘melt’ (detected by at least one Satellite)
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**SUNDAY 8 JULY 2012**

**THURSDAY 12 JULY 2012**

SOURCE NASA
Declared reserves

2795 GT CO₂

2 °C of warming

565 GT CO₂

Man-made CO₂ in atmosphere now

Global CO₂ in 1750

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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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www.carbonvisuals.com
Sources of uncertainty in Arctic temperature projections

One-Way Trip!

Human forcing is already in the climate system. Arctic amplifies the changes.

Summer Arctic-wide sea ice loss is likely to occur within a decade or two.

Cutting Greenhouse gases can reduce Arctic temperature increases in 2090 by half.
A Smörgåsbord of Wacky Weather...

What do these events have in common?
“Stuck” weather patterns
Will Arctic changes lead to mid-latitude weather extremes in the coming decades?

Attribution is Controversial

Length of time series (<10 Years) is too short to robustly differentiate Arctic forcing from random events

Complex interaction of Arctic forcing with chaotic mid-latitude flow; will not happen the same way in every year

Worth further investigation for potential of improving seasonal forecasts, especially with continued Arctic external forcing
Normal “POLAR VORTEX” of west to east flowing winds traps cold air in the Arctic:

Positive Arctic Oscillation

850 GEO HGT DEC Climatology
Attack of the Polar Vortex – Early January 2014
Chain of Events Linking Arctic Amplification with Increased Extreme Weather in Mid-Latitudes

- Arctic Amplification
- Poleward temperature gradient weakening
- 500 mb zonal winds decreasing where gradient weakens
- Amplitude of Rossby waves increasing, blocking more likely
- Large-scale waves progress more slowly eastward
- Upper-level flow becoming more meridional
- More persistent weather patterns, extremes more likely
Composite 1000-500 hPa geopotential thickness anomaly field (proportional to air temperature) for December-January 2009-10, 2010-11, 2012-13 and 2013-14.
Davani 2012
Pattern of preferred latitudes is robust over time, but with changing proportions for each peak.

0-60°W, 16-76°N, 900-700hPa, zonal winds, from 20CR

R Hall
All regimes are not necessarily represented in an individual season.

2009-10 an extreme example with a large number of days representing the southern regime. Cold winter in W Europe and E USA. A negative NAO prevalent

2013-14 an extreme example with a large number of days representing the northern regime. Mild, very wet and Stormy in UK (but not the US!) A positive NAO prevalent
Warm Arctic-Cold Continents

Loss of sea ice and snow pushes toward a wavy jet stream and greater chance for north-south wind flow over N. America. Negative AO

BUT Complexity: chaotic jet stream; it will not happen the same way in every year and location

NAO is a resulting Indicator; Greenland Blocking is primary dynamic indicator, resulting in more southern shift to North Atlantic wind jet