Teleconnections between the Arctic and the Asian/Pacific regions and related air-sea-ice interactions

Hisashi Nakamura
RCAST (Research Center for Advanced Science and Technology)
The University of Tokyo

Teleconnection: remote influence mainly by atmospheric wave propagation
Rapid decrease in Arctic sea ice cover

- under pronounced warming in the Arctic: “Arctic amplification”
  == “ice-albedo feedback” (more isolation absorbed into the Arctic Sea)
- increasing moisture transport into the Arctic
- enhanced inflow of warm Atlantic water into the Arctic Sea

September, 2012 vs Climatology

September ice volume

Data Source: APL/UW

Trend = $-3.26 \times 10^3 \text{ km}^3/\text{decade}$

Overland (2014 Earth’s Future)
Enhanced heat release from the ice-free Barents/Kara Seas allows more cyclones to travel away from the coasts, exerting feedback forcing to reinforce the poleward deflected westerlies. When the Barents/Kara seas are ice covered, cyclones travel preferentially over ice-free area close to the coasts of Norway and Barents Sea.
Remote response to ice decline in the Barents-Kara Sea

Mori et al. (2014 Ngeo)

**Observation (light–heavy ice)** (Dec-Jan-Feb)

SLP (contour), SAT anomalies (color)

“Warm Arctic/Cold Eurasia”

warming in the Arctic
cooling in midlatitude Asia
with stronger Siberian High

500hPa height anomaly

anticyclonic anomaly over western Siberia
with poleward deflected westerlies

*teleconnection from the Arctic to E. Asia*

cyclonic anomaly over midlatitude Asia

⇒ anomalous NEs surface cooling in midlatitudes

• any teleconnection from the Atlantic?
Atmospheric response to ice decline in the Barents-Kara Sea

Mori et al. (2014 NGEO)

SLP (contour), SAT anomalies (color)

Dec-Jan-Feb

500hPa height anomaly

Verification by global atmospheric model (AGCM)

250hPa height anomaly

AGCM 100-member ensemble experiment
Evolution into extremely cold January over the midlatitude Far East occurs with modulated seasonal development of the atmospheric planetary waves, whose surface manifestations are semi-permanent cyclones and anticyclones (e.g., Aleutian/Icelandic Lows; Siberian High).
• Transformed Eulerian mean (TEM) residual circulation, which approximate “effective (or Lagrangian)” mean-meridional circulation as induced by generation or decay of large-scale waves or diabatic heating, is downward climatologically over the Arctic.

• The response to ice cover decrease in the Barents/Kara seas modulates tropospheric planetary waves, so as to enhance downward residual motion over the subpolar region in exerting positive feedback on the warming.

Response of residual circulation to ice decrease
Recent global warming hiatus and its seasonality

Kosaka, Xie (2013 Nature)

- Global-mean SAT over the last 40yrs shows a clear rising trend, but since the “super El Niño” in 1997/98 the warming slows down (global warming hiatus).

- The hiatus over the extratropics is more obvious in boreal winter than in summer.

- The hiatus is concomitant with persistent cooling in the tropical Pacific, manifested as a prolonged La Niña-like condition.

Dec-Jan-Feb SAT trend (° C) observed from 2002 to 2012

Jun-Jul-Aug

cooling warming
Recent global warming *hiatus* and the role of Arctic warming

Kosaka, Xie (2013 Nature)

**2002~12 SAT trend (°C) in DJF**

- Weakening of the Aleutian Low and associated cooling over Canada and Alaska are likely due to the tropical Pacific cooling via teleconnection.

- Intensification of the Siberian High and associated Eurasian cooling are likely due to the sea-ice loss rather than the tropical Pacific cooling.

**2002~12 SLP trend (hPa) in DJF**
Cold-air outbreak associated with the WP-type blocking: 12~18 January, 2011 (JMA)

Western Pacific (WP) pattern is characterized by dipolar pressure anomalies (Wallace, Gutzler 1981 MWR).

WP-type blocking enhances the winter monsoon (Takaya, Nakamura 2005, JAS).

Record-setting snow accumulation

31 Jan, 2011 @Takada, Japan (38° N)
Among the 32 monthly positive WP events,

• 19 events were concomitant with La Niña, but 13 were not.

→ WP pattern can be triggered not only as ENSO teleconnection but also by other processes, including variability of the midlatitude ocean and internal dynamics of the atmosphere.
Planetary-wave modulation by Western Pacific pattern and possible influence from the ocean


Possible impact of SST along the Tsushima warm current on WP blocking (Yamamoto, Hirose)

Intensification of the cold polar vortex in the Arctic stratosphere

Influence of WP blocking on the stratosphere is the opposite to blocks in other geographical regions

Development of WP-blocking high

Modulations of planetary waves

Possible impact of the Oyashio front variability on WP blocking (Frankignoul et al. 2012)

“Hotspot project” (LPI: H. Nakamura) as Grant-in-Aid in innovative areas (2205) by MEXT
Increase in potential PSC area due to WP blocking

Nishii, Nakamura, Orsolini (2010 GRL); cf. Dörnbrack et al. (2012 ACP)

Composited 50hPa temperature 20 days after the peak time of WP blocking

all 18 events

- Area for potential formation of polar stratospheric clouds (PSC) where temperature is below \(-78^\circ\) tends to increase over the Arctic, following the formation of WP blocking in late fall or early-midwinter.

\( \Rightarrow \text{potential for ozone depletion over the Arctic} \)
The project aims to deepen our understanding mechanisms for seasonal to decadal-scale climate variability at regional scale toward improving prediction skill of them, in focusing on atmospheric and oceanic teleconnections between distant regions that potentially affect regional weather extremes.
“InterDec” tasks

1) Arctic warming impact on Northern Hemisphere continental climate variability and extreme events

2) Tropical-Arctic linkages involving sub-seasonal processes

3) Influence of stratosphere on the Arctic–Midlatitude–Tropics linkages

4) Impact of enhanced resolution on the realism of lower latitudes-Arctic linkages

5) Quantify the role of tropical and extratropical oceanic forcing for Arctic and midlatitude variability

6) Quantify the role of Subpolar North Atlantic Gyre (SPG) and MOC in linking polar and lower latitudes

7) Inter-basin linkages

8) Implications of polar-lower latitude linkages for seasonal-to-decadal climate predictions

9) Translation and dissemination of achieved predictive capacities information to relevant stakeholders, end-users and decision makers

NORPAN project

[T. Spengler- A. Abe]
“InterDec” project
The potential of seasonal-to-decadal-scale inter-regional linkages to advance climate predictions

Large-scale waves forced by SST, sea ice, snow variations, and MJO/PNA

High-low-latitude exchange of heat, salt, water/vapor, O_3, and aerosols

Stormtrack and air-sea interaction

Solar

Stratospheric Polar Vortex

AO

Arctic influence

NAO

Mid-latitude extreme weather

East Asian Monsoon

Indian Monsoon

AMOC

IOD

MJO

QBO

ENSO

PNA

PDV

ADV

PJ

Sahel Monsoon

Solar

Belmont Forum

Arctic Challenge for Sustainability