Recent variabilities of East Asian winter monsoon

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Structure of this presentation

- How has the winter been in East Asia recently?
- What atmospheric phenomena bring recent severe winter in East Asia?
- To where and how?
- What is the factor of interannual variability?
  - Tropical forcing?
  - Decadal variability?
  - Arctic sea ice?
  - Stratosphere?
- Summary and conclusion
Global mean temperature

Trend=0.68 (°C/Century)
Base Line: 1981-2010 Average

Anomalies are deviation from baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-term linear trend.

Japan Meteorological Agency
Interannual variability of winter temperature

Hiatus in global warming

4th consecutive severe winter

Area averaged surface temperature by JRA-55
Outline of JRA-55

- The second Japanese global reanalysis conducted by JMA
- The first comprehensive global atmospheric reanalysis that applies 4D-Var to the last half century
- Aiming at providing a comprehensive atmospheric dataset that is suitable for studies of climate change and multi-decadal variability
## Data assimilation system

<table>
<thead>
<tr>
<th></th>
<th>JRA-25/JCDAS</th>
<th>JRA-55</th>
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<tbody>
<tr>
<td><strong>Version</strong></td>
<td>Operational as of Mar 2004</td>
<td>Operational as of Dec 2009</td>
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<tr>
<td><strong>Resolution</strong></td>
<td>T106L40 (~ 120 km) top layer at 0.4 hPa</td>
<td>TL319L60 (~ 60 km) top layer at 0.1 hPa</td>
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<tr>
<td><strong>Assimilation scheme</strong></td>
<td>3D-Var 6-hour time window T106 resolution</td>
<td>4D-Var 6-hour time window T106 inner model</td>
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<td></td>
<td><em>Background error covariances are inflated by 1.8 before 1972</em></td>
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<tr>
<td><strong>Satellite radiance bias correction</strong></td>
<td>Adaptive but not variational (<a href="#">Sakamoto and Christy 2009</a>)</td>
<td>Variational Bias Correction (VarBC) (<a href="#">Dee 2005</a>)</td>
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<tr>
<td><strong>Long-wave radiation scheme</strong></td>
<td><em>Line absorption</em> Statistical band model Water vapor continuum e-type only</td>
<td><em>Line absorption</em> Table lookup + K-distribution Water vapor continuum e-type + P-type</td>
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<tr>
<td><strong>Greenhouse gases</strong></td>
<td>CO₂ only (constant at 375 ppmv)</td>
<td>CO₂, CH₄, N₂O, CFC-11, CFC-12, HCFC-22 (historical concentrations)</td>
</tr>
</tbody>
</table>
Relationship between temperature and SLP or Z500

- **Mongolia area** (45-50N, 100-110E)
- **Arctic Oscillation**
- **EU Pattern**
- **WP Pattern**

- **Japan area** (35-40N, 130-140E)

Correlation coefficient to area averaged temperature in 1958-2012 winter by JRA-55
Arctic Oscillation mode
( EOF 1\textsuperscript{st} mode in N.H. winter )

SLP

500hPa height

Correlation coefficient to EOF-1 in 1958-2012 winter by JRA-55
EU and WP pattern
( EOF 3rd mode in N.H. winter )

The pattern over the Atlantic should be ignored for EAWM.

Correlation coefficient to EOF-3 1958-2012 winter by JRA-55
EAWM is composed of EU and WP

Conveniently we define EAWM-Index as follows,

\[
\text{EAWM-Index} = \text{SLP}(S) - \text{SLP}(A)
\]

where

area S : 50-60N, 90-110E
area A : 35-45N, 140-160E

Climatic normal for winter mean SLP and its standard deviation of interannual variability

Correlation coefficient to EOF-3 for SLP 1958-2012 winter by JRA-55
Correlation coefficient to EAWM-index in 1958-2012 winter by JRA-55
Development of Siberian high with EAWM mode

Height-longitude cross section of correlation coefficient to EAWM for 40-50N averaged height

1. Strong radiative cooling over Siberia
2. Stationary Rossby wave propagation from the Atlantic
3. Development of barotropic anti-cyclonic circulation around 60E
4. Southward advection of lower cold air mass
5. Cold air mass strengthen Siberian high
6. Upward propagation of Rossby wave merge with one propagated from the Atlantic
7. Development of Far East trough and strong cold wave hit Eastern Asia

Takaya and Nakamura (2005)
Where do AO and EAWM bring sever winter

AO mode
>>> mainly affect northern East Asia

EAWM mode
>>> mainly affect Eastern East Asia

Correlation coefficient to each mode in 1958-2012 winter by JRA-55
Recent four winter SLP anomaly pattern

DJF 2010

AO

DJF 2011

AO

EAWM

DJF 2012

EAWM

DJF 2013

AO

EAWM
Interannual variability of AO and EAWM

Correlation coefficient between AO and EAWM is -0.46
Tropical forcing to AO and EAWM (interannual)

AO mode

EAWM mode

Stream function 200hPa

Velocity potential 200hPa

SST

Correlation coefficient to each mode in 1958-2012 winter by JRA-55

95% significant
Interannual variability of AO and EAWM

Correlation coefficient between AO and EAWM is -0.46
Decadal change of tropical forcing

1988 – 2003 winter

- Stream function anomalies 200hPa
- OLR anomalies

Positive AO

2004 – 2013 winter

- Rossby wave propagation
- La Nina-like condition

AO-index and EAWM-index
Intra-inter decadal variability of AO & EAWM

Power spectra by FFT analysis

Correlation coefficient between AO and EAWM is -0.92

AO also has
- decadal variability
- multi-decadal variability

Meanwhile,
- long-term trend maybe apparent due to lack of data
Tropical forcing to AO (decadal)

Correlation coefficient to 9-year running mean AO
Velocity potential 200hPa

The discontinuity in the tropical convection due to the existence or non-existence of satellite data shows a trend of velocity potential in JRA-55. → ignored

EOF3 for V.P.200hPa (trend mode)

Apparent trend of AO and the positive SST trend in the Indian Ocean are well correlated. → ignored

Trend of SST in DJF (1958-2012)
Does AO have any relationship with PDO?

Correlation coefficient between AO and PDO for each year is +0.23, for 9-year running mean is +0.40.

Statistical relationship in two indices shows significant signal, but, Relationship between AO and PDO is not so significant. In other words, there maybe a weak relationship.

Distribution of Correlation coefficient between PDO and SLP does not show the typical AO pattern.

95% significant
Effect of Arctic sea ice to EAWM

Relationship between sea ice concentration in the Barents sea and atmospheric circulations (detrended)

Contour: regression coefficients (1980-2013)

Shade: significant level

Is the dominant Siberian high in less sea ice years a cause or an effect or both (positive feedback)?
Impact experiment of sea ice and SST in the Atlantic area for 2012/2013 winter

11 ensemble run of AGCM (TL159L60 SST anomaly fix) from 1st Nov. 2012

Given anomalies for sea ice concentration(left) & SST (right)

Analysis (Z500 & anomalies)

Impact (anomaly run - normal sea ice & SST run)

In case of winter 2012/13, it is possible that warmer Atlantic and less sea ice are one of the factors behind the dominant AO and EU.
How does Arctic sea ice affect EAWM

One hypothesis
SLP anomalies composite for less sea ice years in the Barents sea (Inoue et. al., 2012)

Typical cyclone track
- in less sea ice years
- in more sea ice years

Statistical relationship
between EAWM and 700hPa eddy activities

Correlation coefficient in 1958-2012 winter by JRA-55

Mechanism is not understood yet

95% significant

inconsistent

Effect of stratosphere to AO

Correlation coefficient between AO-index and 30hPa height (DJF)

Lag correlation coefficient between AO-index (DJF) and 30hPa height (Nov.)

Correlation coefficient in 1958-2012 winter by JRA-55

95% significant

95% significant
Effect of stratosphere to AO

**Typical** vertical structure throughout troposphere and stratosphere in the negative AO (2012/13 winter)

**Typical** downward evolution of deceleration of westerlies in the dominant AO(-) winter (2005/06 winter)

1. Strong upward propagation of Rossby wave
2. Convergence of EP-flux decelerate westerlies
3. Rossby wave is disable to propagate upward and refract to high latitude under the condition of weak westerlies
4. Deceleration of westerlies progress downward
5. The case that refraction of Rossby wave at lower stratosphere contribute to strengthen the EU pattern is also reported
Summary

- There seems to be a decadal variability in East Asian winter monsoon.
  - Recently, the phase of decadal variability shows a strong EAWM.
  - The interannual variability of EAWM is mainly accompanied with the EU teleconnection pattern.
  - The EU pattern is basically considered an internal mode of atmosphere, but it is possible that the tropical convection is concerned with the exciting of Rossy wave source which build the EU pattern.
  - It is possible that the less sea ice in the Barents sea is one of the cause of dominant Siberian high, but the mechanism has not been understood yet.
- Interannual variability of AO is also considered an internal mode of atmosphere.
  - Decadal and multi-decadal variability of AO maybe concerned with those of ocean. The relationship is not so significant.
  - Stratospheric circulation in late Autumn seems to be a precursor of AO in winter.
Conclusion

Recent strong EAWM has been caused by the recent La Nina-like condition under the negative AO phase in multi-decadal time scale.
Thank you