The Implication of Ural Blocking on the East Asian Winter Climate in CMIP5 Models

**Hoffman H. N. Cheung, Wen Zhou**

(hncheung-c@my.cityu.edu.hk)

City University of Hong Kong Shenzhen Institute
Guy Carpenter Asia-Pacific Climate Impact Centre, School of Energy and Environment, City University of Hong Kong

Conference on East Asia and Western Pacific Meteorology and Climate
2-4 Nov 2013, Hong Kong SAR
Fig 1. (Top) A schematic diagram showing the blocking pattern in Jan 2008, (Bottom) Longitudinal distribution of blocking frequency [From Zhou et al. 2009 MWR].
Blocking

Increased ability in simulating blocking in models and higher agreement on projections indicate that there is medium confidence that the frequency of Northern and Southern Hemisphere blocking will not increase, while trends in blocking intensity and persistence remain uncertain. The implications for blocking-related regional changes in North America, Europe and Mediterranean and Central and North Asia are therefore also uncertain. [Box 14.2, 14.8.3, 14.8.6, 14.8.8]

Questions

When compared to observational reanalysis,

1. How well do CMIP5 models reproduce the wintertime Ural blocking (UB) and its associated circulation pattern?
2. To what extent are CMIP5 models able to capture the relationship between UB and the EAWM?
3. What are the implications of UB on the East Asian winter climate?
25 winters (DJF), 1980/81-2004/05

25 CMIP5 models vs. NCEP-NCAR reanalysis (OBS)

Multiple model ensemble (MME): Unweighted average of 25 CMIP5 models

Table 1. List of 25 CMIP5 models.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Institution, Country</th>
<th>Model</th>
<th>Horizontal resolution (lat x lon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC1</td>
<td>CSIRO, Australia</td>
<td>ACCESS1-0</td>
<td>144x192</td>
</tr>
<tr>
<td>AC2</td>
<td></td>
<td>ACCESS1-3</td>
<td>144x192</td>
</tr>
<tr>
<td>BC1</td>
<td>BCC, China</td>
<td>BCC-CSM1-1</td>
<td>64x128</td>
</tr>
<tr>
<td>BC2</td>
<td></td>
<td>BCC-CSM1-1(m)</td>
<td>160x320</td>
</tr>
<tr>
<td>CAN</td>
<td>CCCma, Canada</td>
<td>CanESM2</td>
<td>64x128</td>
</tr>
<tr>
<td>CM1</td>
<td></td>
<td>CMCC-CESM</td>
<td>48x96</td>
</tr>
<tr>
<td>CM2</td>
<td>CMCC, Italy</td>
<td>CMCC-CM</td>
<td>240x480</td>
</tr>
<tr>
<td>CM3</td>
<td></td>
<td>CMCC-CMS</td>
<td>96x192</td>
</tr>
<tr>
<td>CNR</td>
<td>CNRM, France</td>
<td>CNRM-CM5</td>
<td>128x256</td>
</tr>
<tr>
<td>FGO</td>
<td>IAP-LASG, China</td>
<td>FGOALS-g2</td>
<td>60x128</td>
</tr>
<tr>
<td>GF1</td>
<td></td>
<td>GFDL-CM3</td>
<td>90x144</td>
</tr>
<tr>
<td>GF2</td>
<td>GFDL, USA</td>
<td>GFDL-ESM2G</td>
<td>90x144</td>
</tr>
<tr>
<td>GF3</td>
<td></td>
<td>GFDL-ESM2M</td>
<td>90x144</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Institution, Country</th>
<th>Model</th>
<th>Horizontal resolution (lat x lon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAD</td>
<td>MOHC, UK</td>
<td>HadGEM2-CC</td>
<td>144x192</td>
</tr>
<tr>
<td>IP1</td>
<td>IPSL, France</td>
<td>IPSL-CM5A-LR</td>
<td>96x96</td>
</tr>
<tr>
<td>IP2</td>
<td></td>
<td>IPSL-CM5A-MR</td>
<td>143x144</td>
</tr>
<tr>
<td>IP3</td>
<td></td>
<td>IPSL-CM5B-LR</td>
<td>96x96</td>
</tr>
<tr>
<td>MI1</td>
<td></td>
<td>MIROC5</td>
<td>128x256</td>
</tr>
<tr>
<td>MI2</td>
<td>CCSR, Japan</td>
<td>MIROC-ESM</td>
<td>64x128</td>
</tr>
<tr>
<td>MI3</td>
<td></td>
<td>MIROC-ESM-CHEM</td>
<td>64x128</td>
</tr>
<tr>
<td>MP1</td>
<td>MPI-M, Germany</td>
<td>MPI-ESM-LR</td>
<td>96x192</td>
</tr>
<tr>
<td>MP2</td>
<td></td>
<td>MPI-ESM-MR</td>
<td>96x192</td>
</tr>
<tr>
<td>MP3</td>
<td></td>
<td>MPI-ESM-P</td>
<td>96x192</td>
</tr>
<tr>
<td>MRI</td>
<td>MRI, Japan</td>
<td>MRI-CGCM3</td>
<td>160x320</td>
</tr>
<tr>
<td>NOR</td>
<td>NCC, Norway</td>
<td>NorESM1-M</td>
<td>96x144</td>
</tr>
</tbody>
</table>
Climatology of atmospheric blocking

Reversal of north-south geopotential height gradients over the mid-latitudes (Tibaldi and Molteni 1990 Tellus)

Applying zonal index equations,

\[
ZGN(\lambda) = \frac{Z(\lambda, \phi_N) - Z(\lambda, \phi_0)}{\phi_N - \phi_0} \leq -10 \frac{\text{gpm}}{\text{deg lat}}
\]

\[
ZGS(\lambda) = \frac{Z(\lambda, \phi_0) - Z(\lambda, \phi_S)}{\phi_0 - \phi_S} > 0
\]

\[
Z500(\lambda, \phi_0) - Z500(\lambda, \phi_0) > 0
\]

where \( \lambda \in [0, 357.5]^{\circ} \text{E} \)

\( \phi_N = 80^{\circ} \text{N} + \Delta, \)
\( \phi_0 = 60^{\circ} \text{N} + \Delta, \)
\( \phi_S = 40^{\circ} \text{N} + \Delta, \)
\( \Delta = -5^{\circ}, -2.5^{\circ}, 0^{\circ}, 2.5^{\circ} \text{ or } 5^{\circ} \)

Minimum extension: 12.5 degrees
Minimum persistence: 4 days

Fig 2. The 25-year wintertime blocking frequency climatology in the Northern Hemisphere.
Developing stage (day -2 wrt UB onset)

• **Center:**
  The high anomaly over the Urals: slightly shifts eastward;

• **Upstream:**
  The low Z500 anomaly over Europe shifts southeastward;

• **Downstream**
  The low Z500 anomaly near Japan is very pronounced in the MME but not robust across the CMIP5 models.

**Fig 3.** Composite maps of the Z500 anomaly (contour, unit: gpm) and the MSLP anomaly (shading, unit: hPa) on day -2 with respect to the UB onset.
Mature stage (day 0, UB onset)

**Center:**
The high anomaly extends eastward toward western Siberia;

**Upstream:**
Like day -2, the low anomaly over Europe shifts southeastward;
Surface low anomaly weakens;

**Downstream**
The low anomaly over western Siberia becomes robust, corresponding to intensification of the surface Siberian high.

Compared to day -2,

**Fig 4.** Composite maps of the Z500 anomaly (contour, unit: gpm) and the MSLP anomaly (shading, unit: hPa) on the UB onset date.
Mature stage (day 2 wrt UB onset)

Fig 5. Composite maps of the Z500 anomaly (contour, unit: gpm) and the MSLP anomaly (shading, unit: hPa) on day 2 with respect to the UB onset.

• Center: The blocking high persists;
• Upstream: The low anomaly further weakens and no coherent signals can be seen;
• Downstream: The low Z500 anomaly over western Siberia is still robust; The Siberian high extends southeastward toward East Asia;

Compared to day 0,
Siberian high intensity during the evolution of UB

Fig 6. Time series showing the daily Siberian high index (SHI; MSLP anomaly over 40°-65°N, 80°-120°E).
**Fig 7.** Linkage between the long-term mean bias of the UBI and that of the winter-mean circulation in the 25 CMIP5 models.

**Ural blocking index (UBI)**
- Blocking frequency over 45°-90°E

**UBI bias**
- UBI of a CMIP5 model minus UBI of OBS

UBI bias across the models is related to mean circulation bias over the Atlantic region (a +ve NAO-like dipole pattern).

UBI bias seems not significantly impact the East Asian winter-mean circulation.
Relationship between UB and large-scale circulation

**Fig 8.** (top) Regression of Ural blocking index (UBI) against the Z500 and MSLP in the MME; (bottom) coherence of the regression coefficients across the CMIP5 models.
The relationship between long-term mean of Ural blocking frequency and Siberian high intensity is shown in the following diagram.

**Fig 9.** Linear correlation coefficient between the Ural blocking index (UBI) and the Siberian high index (SHI) as a function of the UBI in the 25 CMIP5 models.

The diagram illustrates the correlation between the UBI and SHI, with the correlation coefficient shown for each of the 25 CMIP5 models. The significance level of 10% is indicated by the dashed line. 

For a detailed analysis of the correlation and significance, please refer to the 25 CMIP5 models.
Relationship between long-term variance of Ural blocking frequency and Siberian high intensity

**Fig 10.** Year-to-year variance of Siberian high index (SHI) as a function of the year-to-year variance of Ural blocking index (UBI) in the 25 CMIP5 models during the period 1980/81-2004/05.
Hypotheses

UB events usually persists for less than two weeks

UB rarely exerts a persistent forcing on the East Asian winter monsoon (EAWM)

Performance of UB simulation unlikely affects the mean state of the EAWM

Wintertime UB frequency accounts for significant fraction of long-term variance of the Siberian high (~30%)

Models have different ability of simulating UB frequency

Performance of UB simulation probably affects the long-term variance of the EAWM
• Most of CMIP5 models are able to simulate the large-scale circulation features associated with Ural blocking, though the center of action over the Atlantic has a southeastward shift compared to OBS;

1) Low height anomaly over the North Atlantic Ocean

2) A ridge/blocking high over the European continent or the Urals

3) A trough over the Asian continent

• The bias of Ural blocking in CMIP5 models is attributed to the mean circulation bias over the Euro-Atlantic region, which may affect the storm activities. Among the CMIP5 models, the long-term variance bias of Ural blocking may contribute to the that of Siberian high intensity, so does the EAWM circulation.

• Ural blocking is important for assessing the variability of the EAWM.
Fig 11. Change of blocking frequency in the RCP4.5 and RCP8.5 scenario compared to the historical scenario of CMIP5 GCMs.

No systematic change of blocking frequency in the Ural sector.
Outlook of future climate conditions

Fig 12. Linkage between the long-term mean bias of the UBI and that of the winter-mean circulation in the future climate condition of CMIP5 models.
Thank you! All comments are appreciated!