能源及環境學院
SCHOOL OF ENERGY AND ENVIRONMENT

香港城市大學
City University of Hong Kong

Interannual Teleconnection between Ural-Siberian Blocking and the East Asian Winter Monsoon

Hoffman H. N. Cheung[1,2], Wen Zhou[1,2]

(hoffmancheung@gmail.com)

GCACIC
Guy Carpenter Asia-Pacific Climate Impact Centre
City University of Hong Kong

[1]City University of Hong Kong Shenzhen Institute

[2]Guy Carpenter Asia-Pacific Climate Impact Centre,

School of Energy and Environment, City University of Hong Kong

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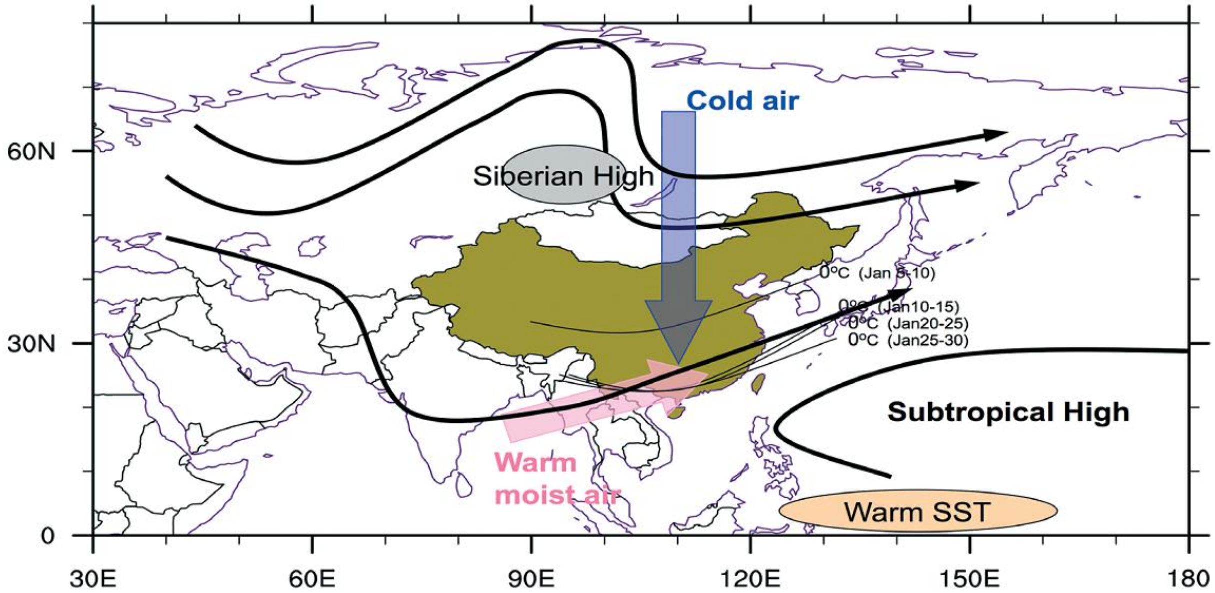
Motivation

Jan 2008



Blocking freq in Jan

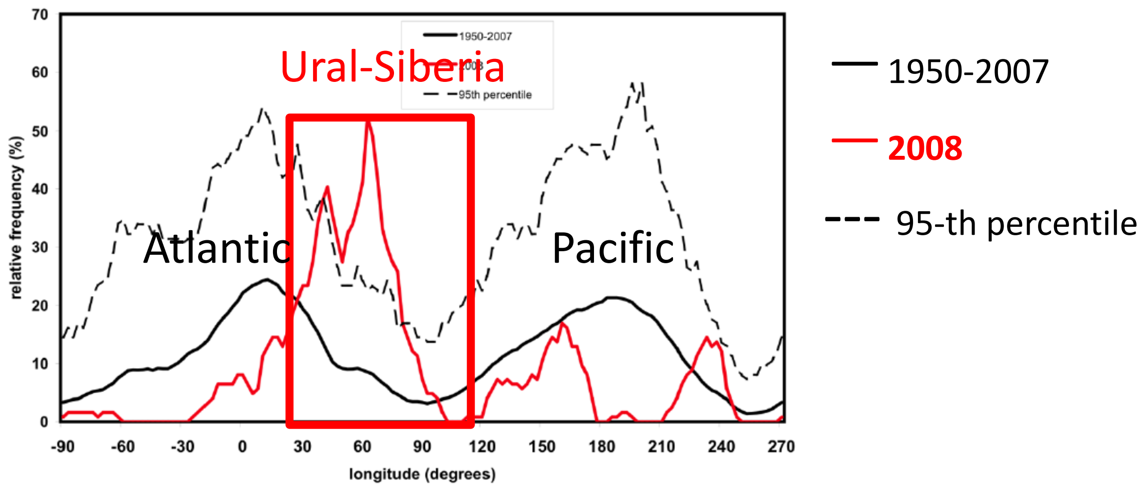


Fig 1. (Top) A schematic diagram showing the atmospheric circulation in Jan 2008, (Bottom) Longitudinal distribution of blocking frequency in Jan 2008 (solid red) in comparison to the 95th percentile (dashed black) and the climatological mean of Jan for the period 1950-2007 (solid black) [Zhou et al. 2009 *MWR*].

Questions

- What are the major blocking patterns in Ural-Siberia?
- What are the linkages between these blocking patterns and the East Asian winter monsoon (EAWM)?
- How can these blocking patterns be explained by large-scale atmospheric teleconnection patterns?

Methods

- *Data: NCEP-NCAR; Study period: NDJFM 1950-2009*
- *Blocking event detection algorithm*
- *East Asian winter monsoon indices*

Blocking event detection algorithm

- Barriopedro et al 2006 *JC* [modified version of Tibaldi and Molteni 1990 *Tellus*]

Extension: Western and eastern end longitudes

Center: Grid point with highest longitudinal-averaged and latitudinal-averaged geopotential height

Intensity:

$$\mathrm{BI} = 100.0 \times \left[\frac{Z(\lambda,\phi)}{\mathrm{RC}} - 1.0\right]$$

$$\mathrm{RC} = \frac{Z(\lambda_u,\phi) + Z(\lambda_d,\phi)}{2}$$

The highest value within a blocked region. λ_u and λ_d represents the upstream and downstream longitude, i.e. western end and eastern end of the blocked region

Persistent criteria:

a) Blocking region on day(i+1) **overlaps** with that on day(i); and

b) Distance between the center of the blocking region on day(i+1) and that on day (i) is **closer than 20 degrees**

Zonal index equations

↓

Blocking longitude

↓ (5 consecutive blocking longitudes)

Blocking region

↓ (persists for **4 days**)

Blocking event

Zonal index equations:

$$\mathrm{GHGN}(\lambda) = \frac{Z(\lambda,\phi_N) - Z(\lambda,\phi_0)}{\phi_N - \phi_0} < -10m/\deg \mathrm{lat}$$

$$\mathrm{GHGS}(\lambda) = \frac{Z(\lambda,\phi_0) - Z(\lambda,\phi_S)}{\phi_0 - \phi_S} > 0$$

Characteristic time of blocked region [Pelly and Hoskins 2003 *JAS*]

East Asian winter monsoon indices

1. Siberian high intensity (SHI), area-averaged sea level pressure over 40-65N, 80-120E (Panagiotopoulos et al. 2005 *JC*)
2. Two temperature modes proposed by B. Wang et al. (2010, *JC*), first two leading EOF modes of 2-m air temperature over 0-60N, 100-140E

- TM1 – NTM
- TM2 – STM

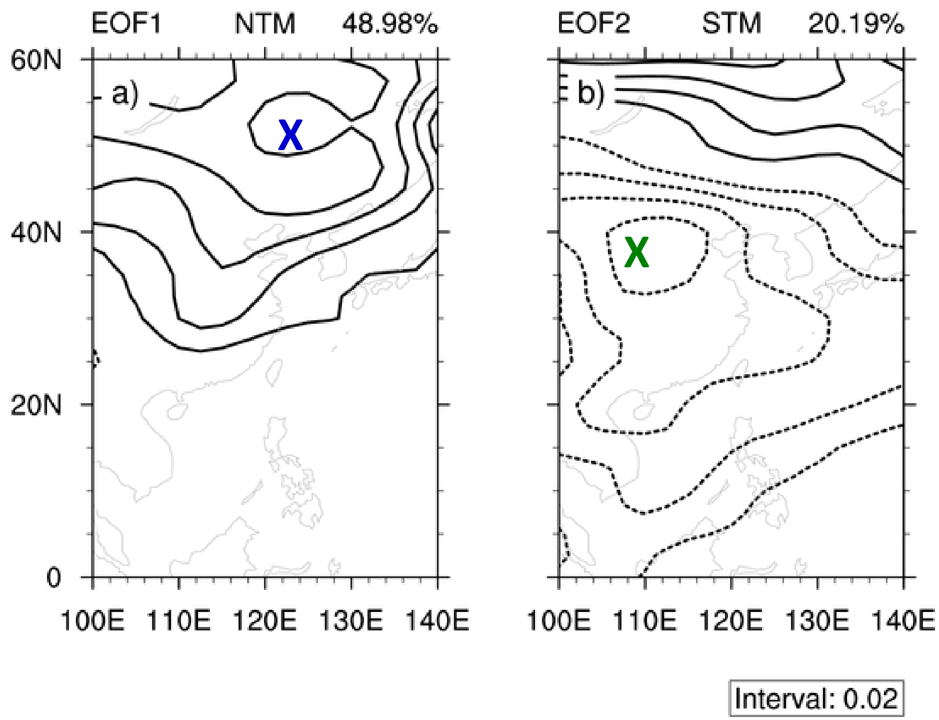
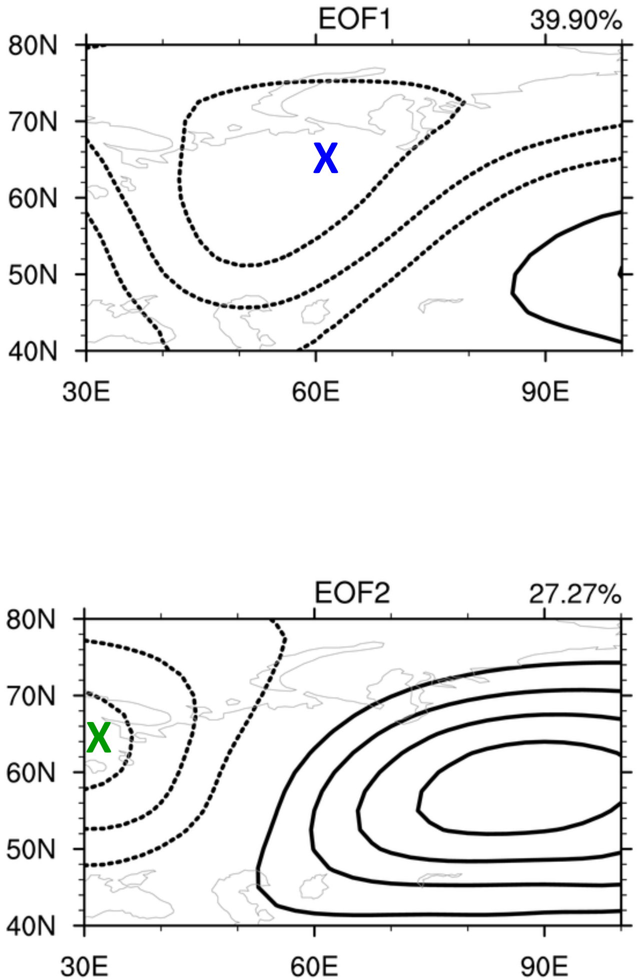


Fig 2. The (a) first and (b) second eigenvectors (EOF1, EOF2) of NDJFM-mean 2-m air temperature in the EAWM, with the explained variance shown at the top right. They are referred to as temperature mode 1 (TM1) and temperature mode 2 (TM2).

Relationship between Ural-Siberian blocking and the East Asian Winter Monsoon

- *Two major blocking patterns over Ural-Siberia*
- *The impacts of the major blocking patterns*
- *Relationship between blocking and the EAWM*

Major Ural-Siberian blocking patterns



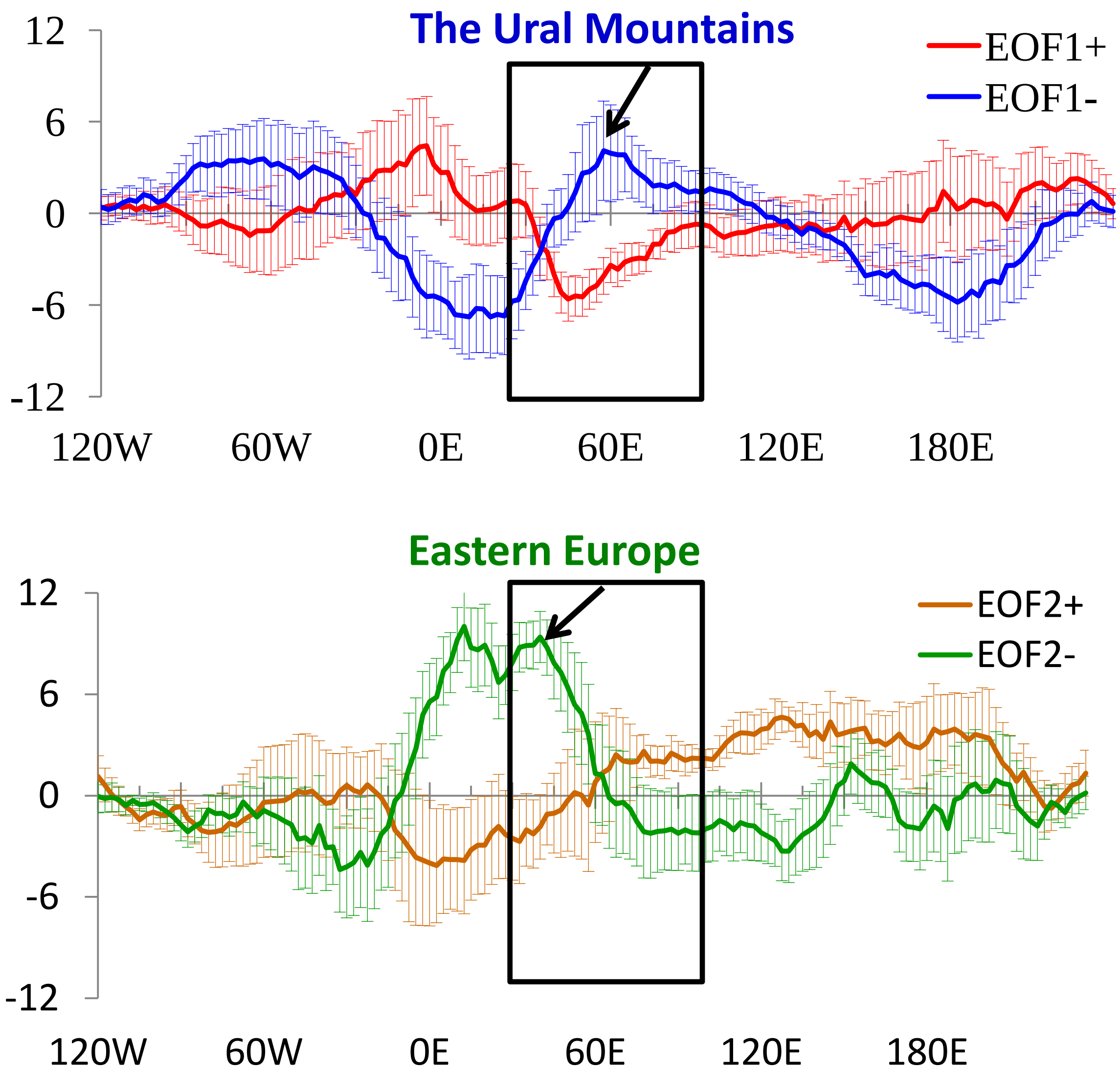


Fig 3. The first two leading eigenvectors of 500-hPa heights : EOF1 (top), EOF2 (bottom)

Fig 4. Longitudinal distribution of blocking frequency anomalies (in days)

Blocking-EAWM relationships

Less blocking

More blocking

Less blocking

More blocking

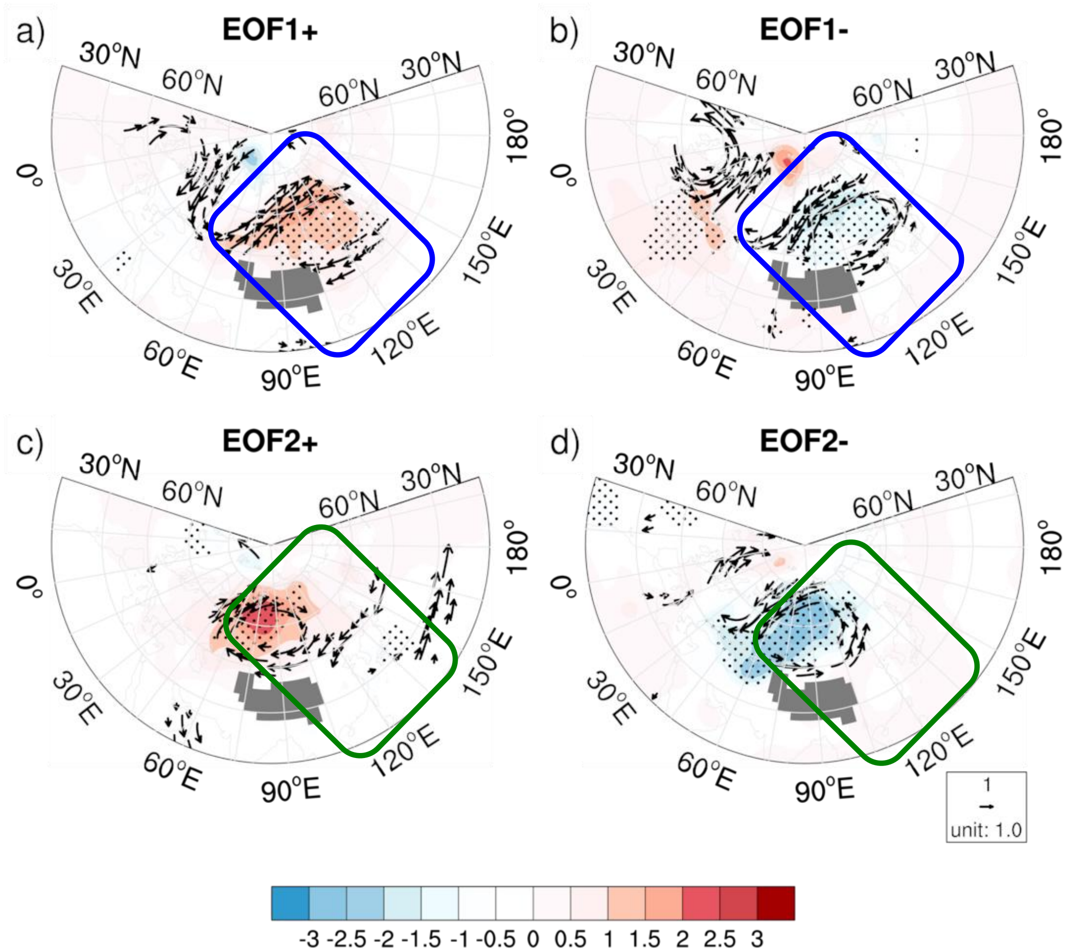


Fig 5. Anomalies of surface air temperature (°C) and wind (ms^{-1}) in NDJFM for the years demonstrating dominance in (a) positive EOF1 mode, (b) negative EOF1 mode, (c) positive EOF2 mode and (d) negative EOF2 mode. The air temperature enclosed by the dotted regions and the surface wind represented by the vectors are significantly different from the 60-year climatology of air temperature and either zonal wind or meridional wind component respectively at the 95% confidence level.

Blocking-EAWM relationships

Table 1. Linear correlations between the two EOF modes and the EAWM indices, where the bold (italic) values exceed the 99% (95%) confidence level.

Correlation		Blocking pattern: The Ural Mountains -PC1	Blocking pattern: Eastern Europe -PC2
EAWM index	SHI	**0.653**	0.214
	TM1	**-0.683**	*-0.296*
	TM2	0.094	**0.449**

EOF1 stands out → distinct blocking frequency near the Ural Mountains → stronger linkage with the Siberian high index (SHI) and the temperature mode TM1.

EOF2 stands out → distinct blocking frequency near Eastern Europe → statistically significant linkage with the temperature mode TM2.

The effects of large-scale atmospheric teleconnection patterns

- *The impacts of the AO*
- *The modulations of the ENSO*
- *The blocking-EAWM relationship under the combined effect of the AO and ENSO*

Relationship between AO/ENSO and blocking/EAWM

Table 2. Linear correlations between the AO/ENSO and the two EOF modes and EAWM indices, where the bold (italic) values exceed the 99% (95%) confidence level.

	Correlation	ENSO	Blocking pattern: Urals -PC1	Blocking pattern: Eastern Europe -PC2	EAWM index: SHI	EAWM index: TM1	EAWM index: TM2
Climate index	AO	-0.110	**-0.438**	-0.288	**-0.336**	**0.598**	-0.183
	ENSO		0.125	0.116	-0.115	0.008	*0.328*

AO is closely related to Ural blocking (-PC1), Siberian high index (SHI) and the temperature mode TM1.

ENSO shows a rather weak linear relationship with the blocking patterns and the EAWM indices, only that with the southern temperature mode exceeding the 95% confidence level.

The impacts of AO

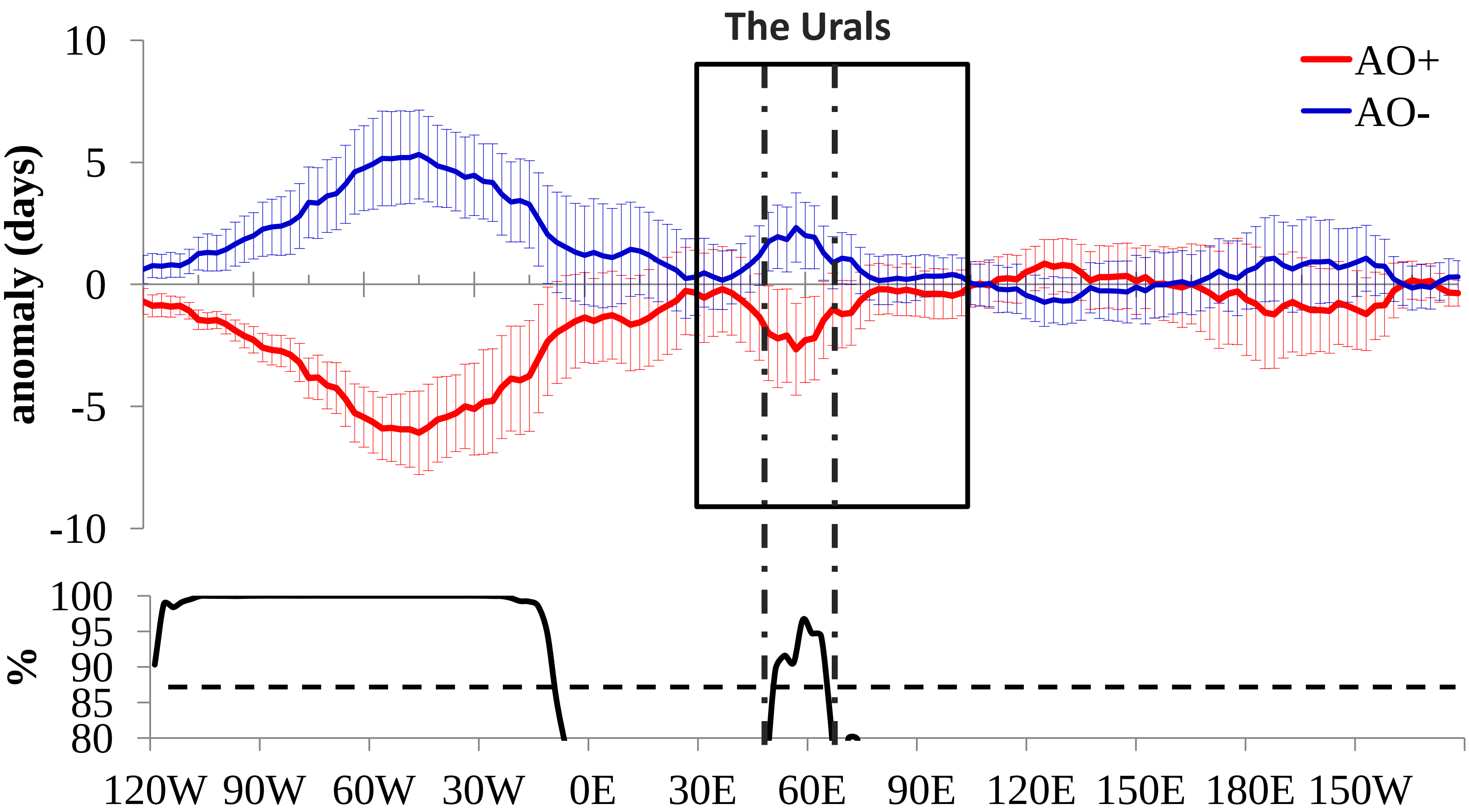


Fig 6. Longitudinal distribution of blocking frequency anomalies in the Northern Hemisphere under different phases of AO (top); the confidence level for the difference between the two phases of AO (down)

The modulations of ENSO

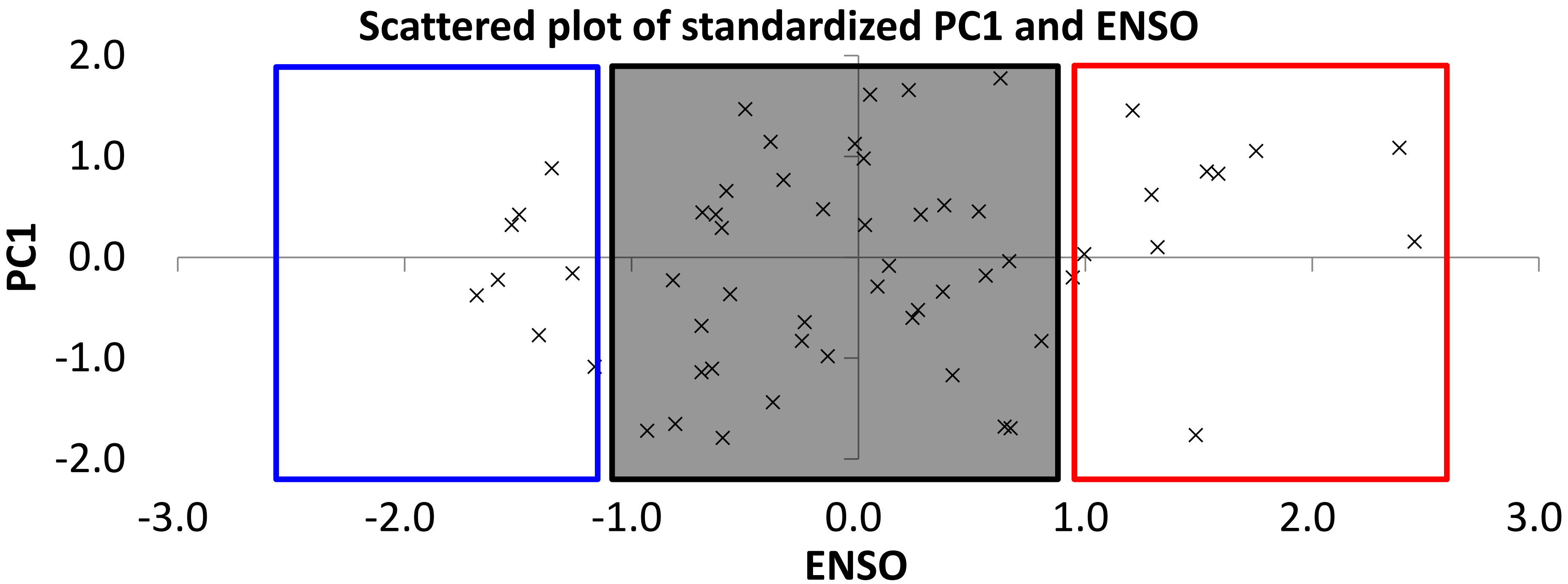
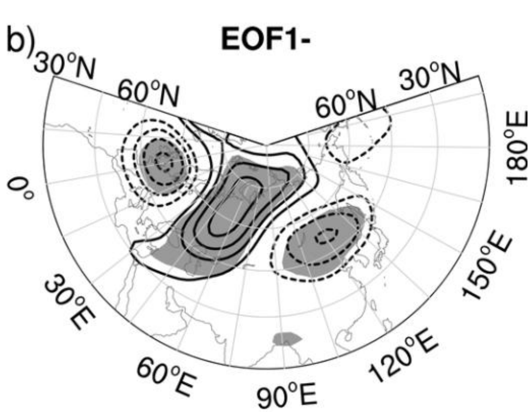
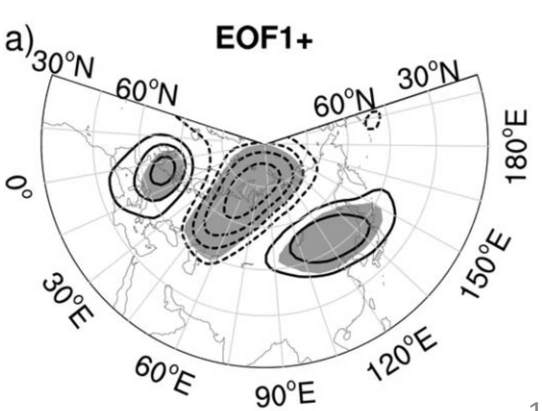


Fig 7. Scattered plot between Niño 3.4 anomaly and standardized values of the PC1





The modulations of ENSO

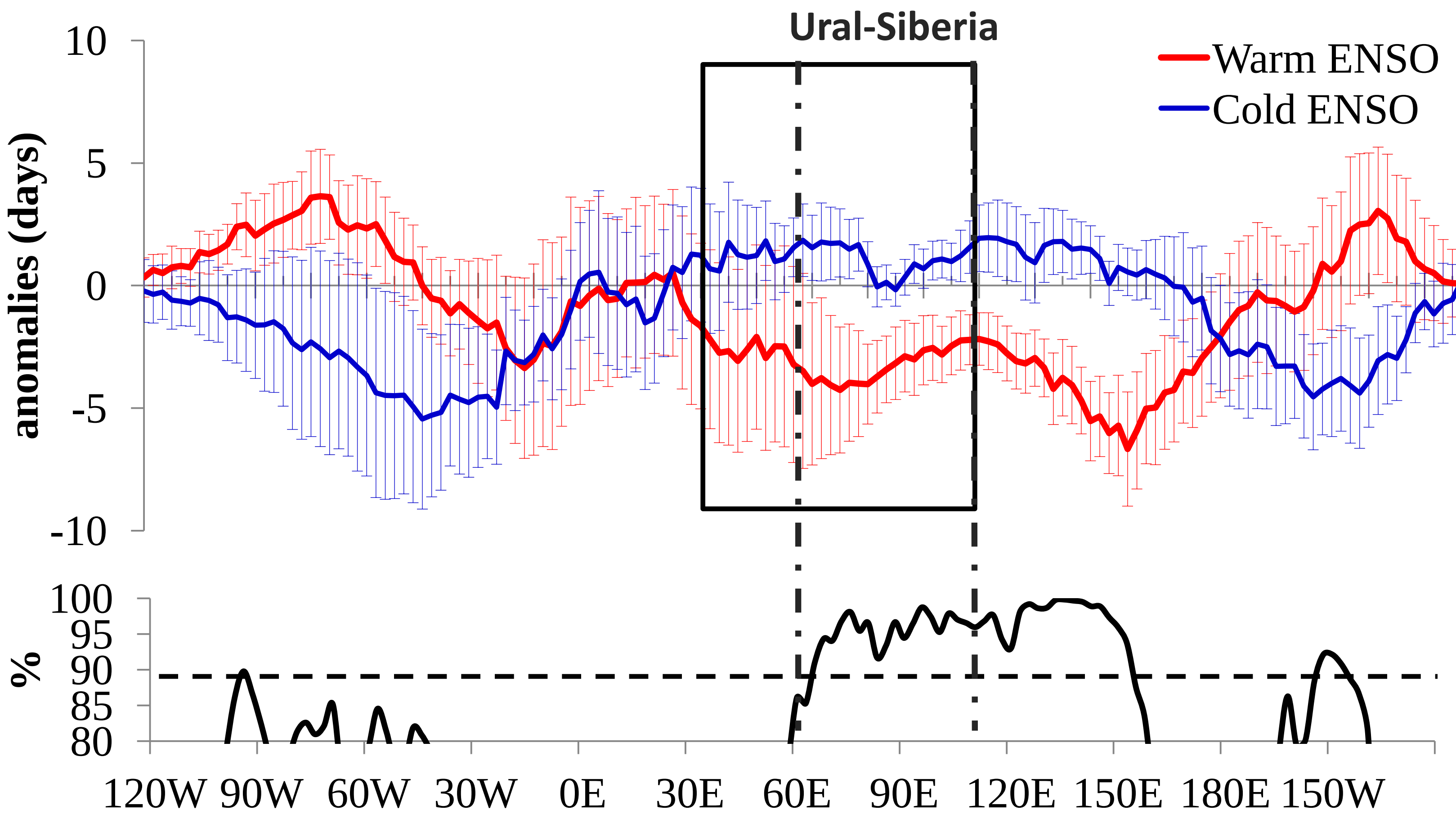


Fig 8. Longitudinal distribution of blocking frequency anomalies in the Northern Hemisphere under different phases of ENSO (top); the confidence level for the difference between the two phases of ENSO (down)

The combined effects of AO and ENSO

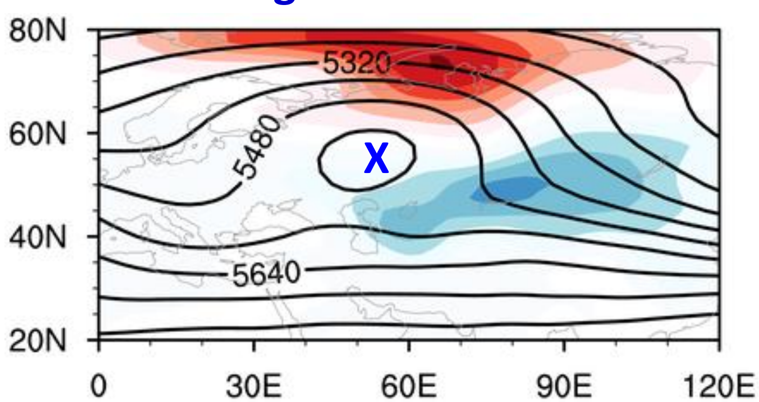
Table 3. Mean and standard error of the standardized values of the first two leading principal components under different combinations of the AO and ENSO.

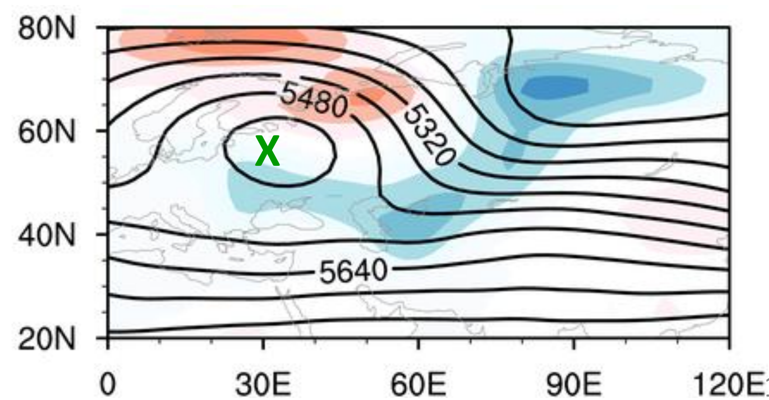
Combined effect		Eigenvalue of two leading eigenvectors	
		EOF1	EOF2
In phase	AO+ ENSO+	**0.34±0.16**	0.11±0.25
	AO- ENSO-	**-0.45±0.23**	0.08±0.23
Out of phase	AO+ ENSO-	0.24±0.28	**0.28±0.27**
	AO- ENSO+	-0.02±0.27	**-0.41±0.23**

AO+ EOF1 and EOF2 tend to be positive → less Ural-Siberian blocking

AO- In phase → EOF1 negative → Blocking over Ural Mountains

Out of phase → EOF2 negative → Blocking over eastern Europe





AO in phase with ENSO

Table 4. Linear correlations between the AO/ENSO and the two leading EOF modes and EAWM indices when the AO and ENSO are in phase, where the bold and italic values exceed the 99%, and 95% confidence levels, respectively. Note that the EOF1 is the dominant blocking pattern.

	PC1	PC2	SHI	NTM	STM
AO	**0.524**	0.106	*-0.400*	**0.536**	0.056
ENSO	*0.394*	0.190	*-0.421*	**0.527**	0.261
PC1			**-0.665**	**0.644**	-0.180
PC2			0.199	0.234	*-0.444*

The combined effect of AO and ENSO is comparable to that exerted by the EOF1 mode, i.e. there is a strong relationship between Ural-Siberian blocking and Siberian high index (SHI) and northern temperature mode (NTM)

AO out of phase with ENSO

Table 5. Linear correlations between the AO/ENSO and the two leading EOF modes and EAWM indices when the AO and ENSO are out of phase, where the bold, italic, and underlined values exceed the 99%, 95%, and 90% confidence levels, respectively. Note that the EOF1 is the dominant blocking pattern.

	PC1	PC2	SHI	NTM	STM
AO	*0.380*	*0.449*	-0.287	**0.657**	-0.411
ENSO	-0.065	<u>-0.338</u>	0.192	<u>-0.334</u>	0.377
PC1			-0.642	0.743	-0.049
PC2			0.259	0.301	**-0.437**

The combined effect of AO and ENSO looks like that exerted by the EOF2 mode, i.e. the center of action of blocking pattern is not likely to locate over the Ural Mountains, suggesting a weaker blocking-EAWM relationship.

The correlations between each of the factors and AO are in opposite sign to that with ENSO, suggesting an incoherent forcing exerted by AO and ENSO.

Summary

What are the major blocking patterns in Ural-Siberia?

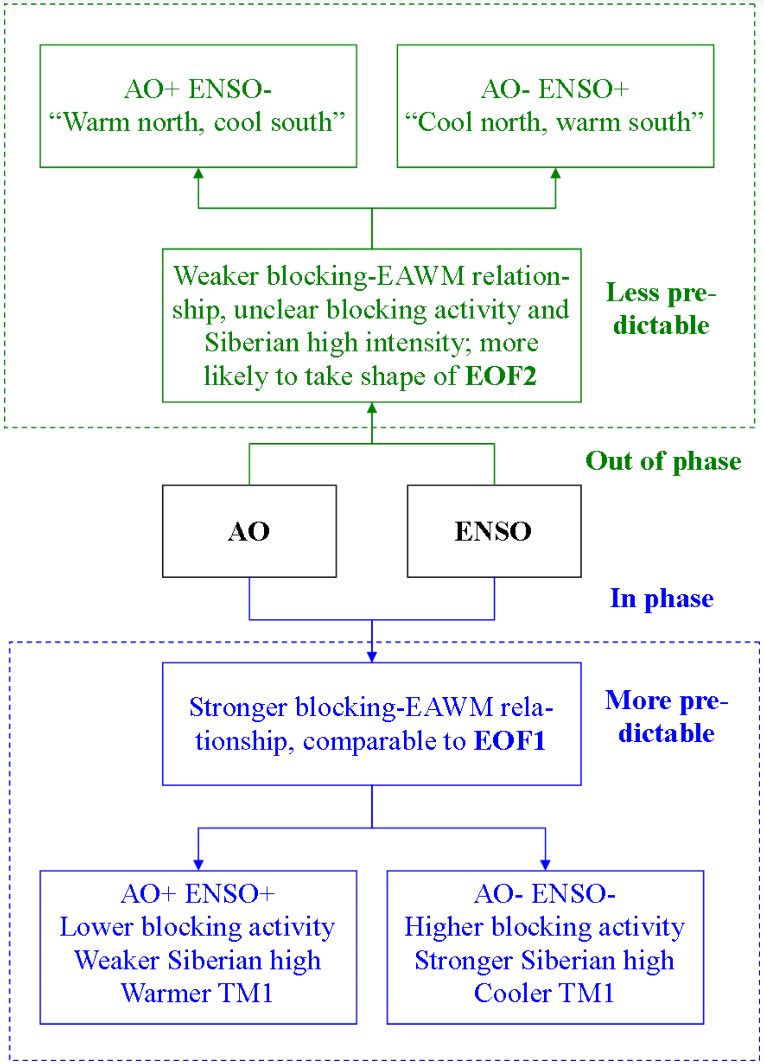
There are 2 major patterns identified by performing EOF analysis to 500-hPa geopotential height. They are centered over the Ural Mountains (EOF1) and Eastern Europe (EOF2), respectively.

What are the linkages between these blocking patterns and the East Asian winter monsoon (EAWM)?

The EOF1 mode – uniform sign of temperature anomaly in the EAWM

The EOF2 mode – probably an opposite sign of temperature anomaly pattern in the EAWM

Summary



How can these blocking patterns be explained by large-scale atmospheric teleconnection patterns?

- The AO plays a major role in extratropical climate variability with more (less) blocking in the negative (positive) phase, but the occurrence of blocking over Ural-Siberia may be influenced by the remote impact of the ENSO
- When the AO and ENSO are in phase (out of phase), they exert coherent (incoherent) forcing on tropical-extratropical interaction in East Asia such that the strength of EAWM is uniform (not uniform) and the blocking pattern is close to EOF1 (EOF2), giving rise to a strong (weak) blocking-EAWM linkage.

Fig 9. Schematic diagram for the predictability of the Ural-Siberian blocking and EAWM by taking the role of the AO and ENSO into consideration.

Thank you!

For detail,

- Cheung H.N., W. Zhou, H.Y. Mok, and M.C. Wu, 2012: Relationship between Ural-Siberian Blocking and the East Asian Winter Monsoon in Relation to the Arctic Oscillation and the El Niño-Southern Oscillation. *J. Climate*. In press.