

Wintertime Atmospheric Blocking Events over Western Siberia in the Period 2004–2016 and Their Influence on the Surface Temperature Anomalies [†]

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Abstract: We study wintertime blocking events in 2004–2016 over Western Siberia (WS) and their influence on the surface temperature. The period 2004–2016 is very interesting for study because there has been an increase in the blocking frequency over WS beginning with 2004. We used data ECMWF ERA-Interim and blocking criterion proposed by Tibaldi and Molteni. We investigated blockings events with duration of 5 days or more for winter interval (1 November–31 March). We have chosen 15 blockings events. For each event we calculate surface temperature anomaly in the grid points for two sectors 60–90 E; 50–60 N (southern part of WS) and 60–90 E; 60–70 N (northern part of WS). To estimate advective transfer for studied events we analyzed the potential temperature on the dynamical tropopause. We showed that wintertime blocking events over WS lead to the surface temperature increase in the northern part of West Siberia and to the surface temperature decrease in the southern part of WS. This feature apparently due to warm air masses advection from south-west on the western periphery of the blocking ridge and arctic air masses intrusion to the southern part of the WS on the eastern periphery of this ridge.

Keywords: atmospheric blocking; wintertime circulation; surface temperature anomaly; cold winter

1. Introduction

Atmospheric blocking is one of the most important large-scale phenomena of mid- and high latitude circulation in the middle troposphere [1–9]. Atmospheric blocking has quasi-stationary regime and characterized by the barotropic anticyclone with a large amplitude and interruption of westerlies [3,4]. The mid-latitude westerly jet and the eastward progression of synoptic systems are often interrupted in long periods of atmospheric blocking. Thus, atmospheric blocking can significantly impact weather processes. The lifetime of blocking varies from a few days to a few weeks, and, therefore, they may be responsible for various extreme weather events. Temperature, precipitation and air composition are changed during the period of atmospheric blocking. Early we have investigated long-term variability of the atmospheric blockings over Western Siberia for 1948–2015, using three re-analysis archives [1]. We have revealed that there is a decrease of blocking event frequency in this region for the eight months of year. More detailed investigation and comparison our results with those for Ural-Siberia obtained by other authors [5,6] show a good similarity of long-

term trends in these two areas for different seasons. However in both cases insignificance of the calculated trends in comparison with the large amplitude of interannual variations attracts our attention. All 1948–2015 period can be divided into several quasi-decadal intervals with different character of interannual fluctuations and trends. We think that search for the mechanisms responsible for this quasi-decadal climatic regimes and fast switching between them is more perspective than search for trends calculated for period 1948–2015 on the whole. In this paper we study wintertime blocking events in 2004–2016 over Western Siberia and their influence on the surface temperature. The period 2004–2016 is very interesting for study because there has been an increase in the blocking frequency in January–February over Western Siberia beginning with 2004. In other works a close relationship between the formation of extremely cold winters in the first decade of the 2000s and the formation of atmospheric blocking [7] was found. In our early studies it was shown that the Western Siberian blocking events determine the temperature anomalies over a large area [1]. The study of the individual events can help us understand how this happens.

2. Experiments

- We used ECMWF ERA Interim data (geopotential, surface temperature, potential temperature on the dynamical tropopause (PV- θ), sea level pressure) [8].
- To determine blocking events we applied criterion proposed by Tibaldi and Molteni [9]. We investigated blocking events with duration of 5 days or more in wintertime (1 November–31 March).

$$GHGS = \frac{Z(\varphi_0) - Z(\varphi_s)}{\varphi_0 - \varphi_s}$$

$$GHGN = \frac{Z(\varphi_n) - Z(\varphi_0)}{\varphi_n - \varphi_0}$$

where Z —geopotential height 500 gPa, $\varphi_n = 80^\circ \text{ N} \pm \Delta$, $\varphi_0 = 60^\circ \text{ N} \pm \Delta$, $\varphi_s = 40^\circ \text{ N} \pm \Delta$, $\Delta = 4^\circ$.

- We chose 15 blockings events: December 2004, January–February 2005, December 2005, November 2006, January 2008 (two events), December 2008, December–January 2010–2011, January 2011, February 2011, December 2011, January–February 2012, December 2012, February–March 2015, December 2015–January 2016. So, we studied 12 winters. Only 2 winters has no blocking events (2009/2010 and 2013/2014). 4 winters are distinguished by high blocking frequency 2004/2005 (2 events), 2007/2008 (2), 2010/2011 (3), 2011/2012 (2). 6 winters have one event each.
- For each event we calculate surface temperature anomaly in the grid points for two sectors 60–90 E; 50–60 N (southern part of West Siberia) and 60–90 E; 60–70 N (northern part of West Siberia). Anomalies were calculated as deviation of daily surface temperature values from 1979–2015 mean. We chose sectors based on the result of the work [1], in which the correlation pattern between West Siberian blocking events and surface temperature was demonstrated (Figure 1). This pattern shows that Western Siberia is divided into two parts: the northern, over which there is positive blocking's influence on the surface temperature and the southern, over which there is negative blocking's influence on the surface temperature.
- To estimate advective transfer we analyzed the potential temperature on the dynamical tropopause (PV- θ) [3] for each of studied 15 events.

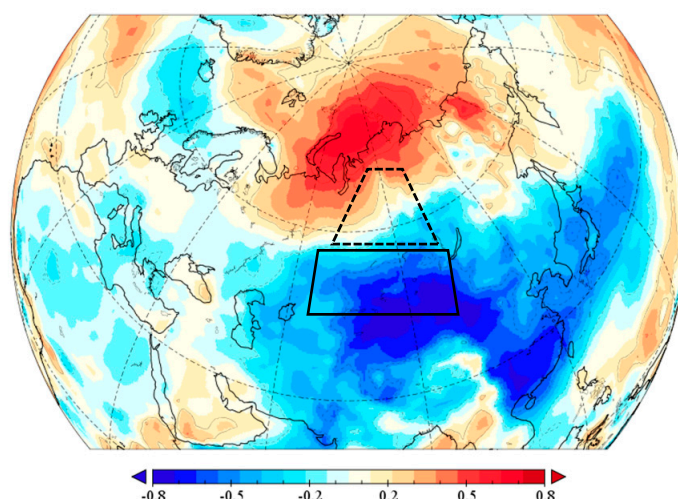
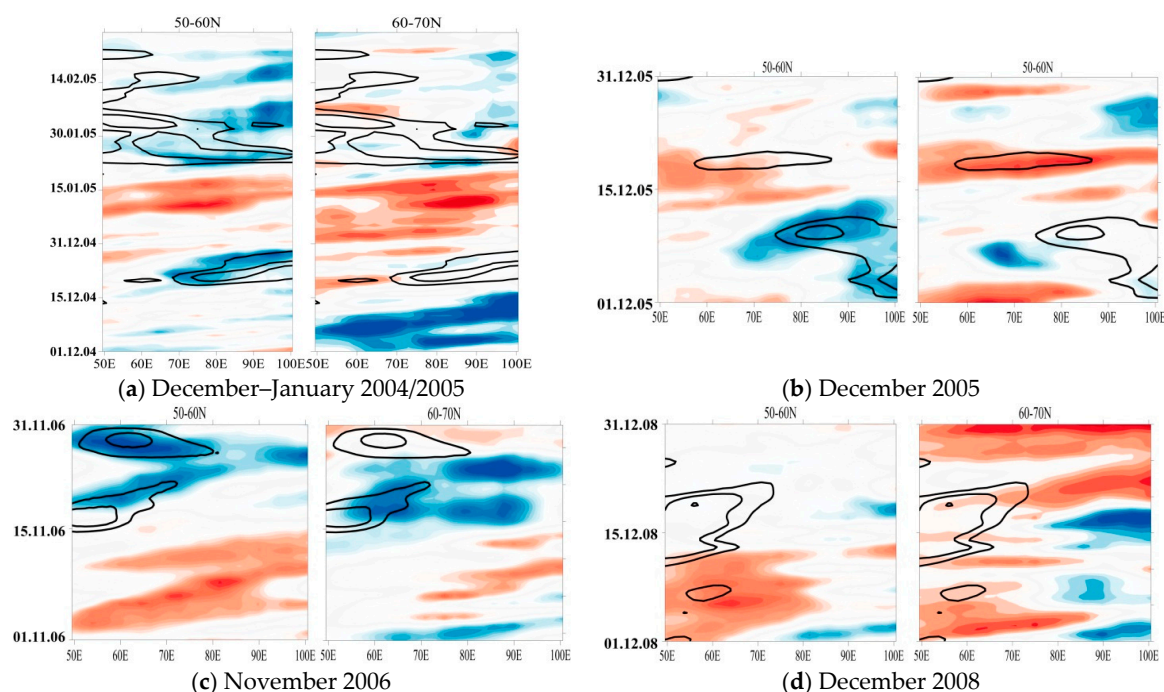


Figure 1. The distribution of the correlation coefficient between the blocking frequency (60–90 E) and the surface temperature from work [1]. Based on ERA-Interim $1.5^\circ \times 1.5^\circ$ [8]. Solid curve—south part of Western Siberia, dashed curve—north part Western Siberia.

3. Results

Figure 2 shows the time-longitude cross sections of surface temperature anomalies associated with blocking events. We see that the periods of blocking often correspond to negative anomalies in the southern part of Western Siberia (December–January 2004/2005 (Figure 2a), December 2005 (Figure 2b), November 2006 (Figure 2c), December–January 2010/2011 (Figure 2f)) and positive in the north part (December 2005 (Figure 2b), November 2008 (Figure 2d), January 2008 (Figure 2e), December–January 2015/2016 (Figure 2h)).



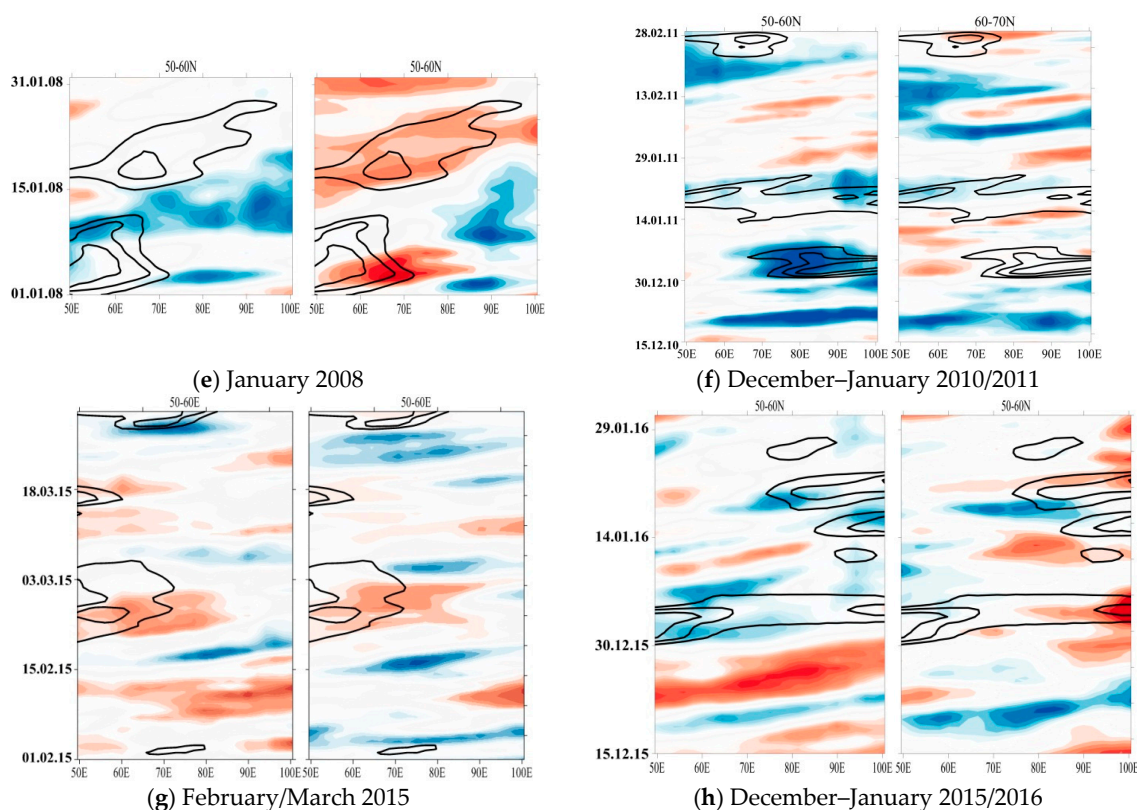


Figure 2. Time-longitude cross-section of anomaly of surface temperature and GHGS > 0 for two latitude bounds for several of chosen atmospheric blocking events. Blue - negative deviations, red - positive

Figure 3 shows development of several wintertime blocking events. General features of Western Siberian blocking events consequences are shown on the Figure 1. And there are also some individual characteristics in the development of blocking processes that cause differences in the distributions of surface temperature anomalies associated with these processes. We demonstrate the dynamics of PV- θ during the periods: 16–24 January 2005, 29 December 2010–2 January 2011 and 29 December 2015–2 January 2016 to outline these similarities and differences.

We see that that blockings shown in Figure 3 are accompanied by powerful advection of heat and cold air masses. Advection of heat air from southwest precedes blockage over Western Siberia and accompanied by advection of the cold air from the east of the thermal ridge. These advective processes are closely related. The meridional inversion of the potential temperature is the final stage of the processes development. Each of examples shown in Figure 3 demonstrates that blocking over Western Siberia is accompanied by a polar vortex shift and strong cooling in the southern regions of Western Siberia. The polar cold reservoir «flows down» to the southern regions of Siberia. The accumulation of cold air in the surface layer leads to the formation of an anticyclone there. Figure 4 illustrates this feature. It shows the correlation coefficient distribution between the blocking frequency over Western Siberia and surface level pressure. The area of maximum positive values of correlation coefficients coincides with the climatic position of Asian high. This fact confirms idea about the strong influence of blocking in Siberia on Asian high intensity [6]. Heat and cold transports are variable from year to year. Therefore, the average influence of heat and cold transports on air temperature in Western Siberia is not large and depends on the individual characteristics in each year. Sometimes (Figure 3a), the influence of heat transport is limited to the western boundaries of western Siberia, and sometimes the heat advection is more powerful and reaches the north of Western Siberia. (Figure 3c). Attention is drawn to the fact that the influence of heat transport associated with blocking over Western Siberia has a very strong effect on the Arctic region. We can assume, that with an increase of the blocking event frequency over Western Siberia, the rate of melting of ice in the Arctic is accelerate.

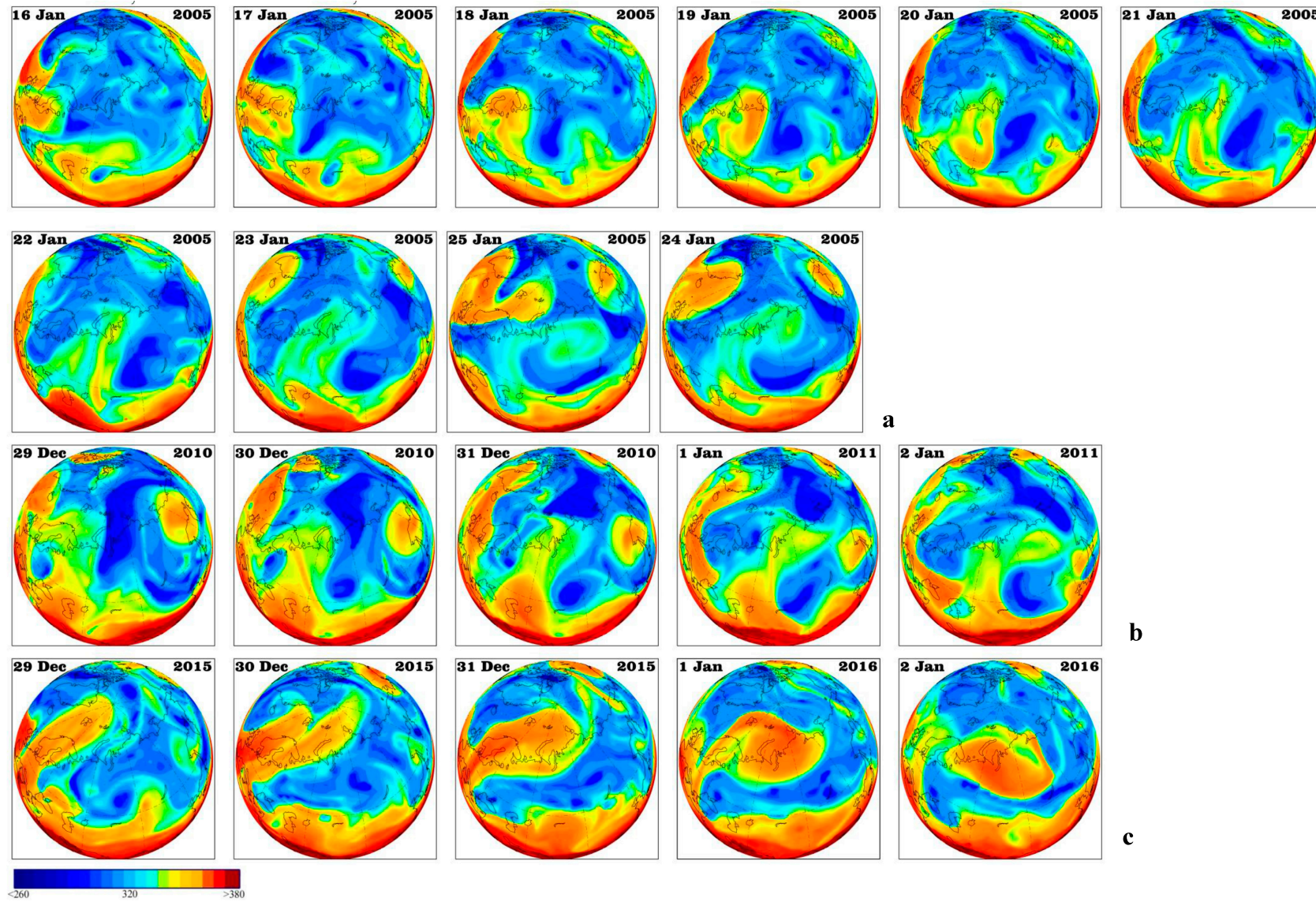


Figure 3. Dynamics of PV- θ for blocking events. (a) 16–21 January 2005; (b) 29 December–2 January 2010/2011; (c) 29 December–2 January 2015/2016.

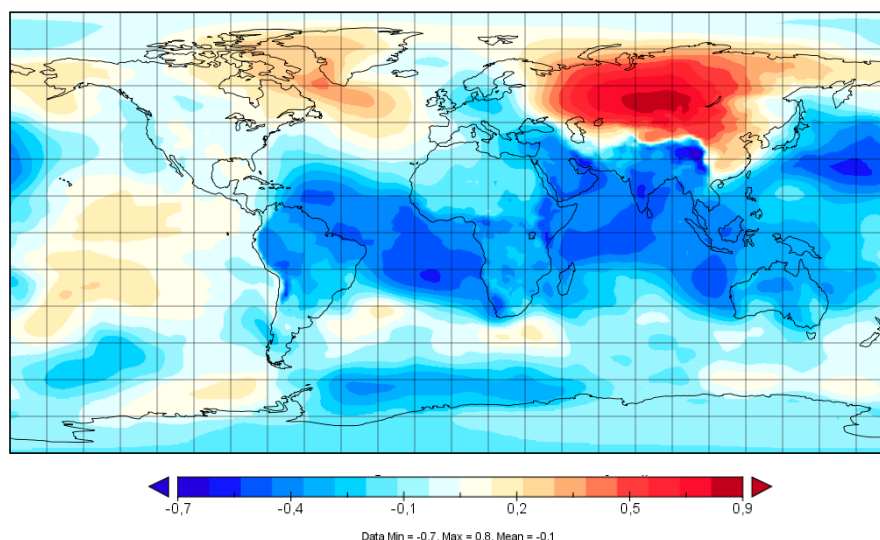


Figure 4. The distribution of the correlations between the blocking frequency (60–90 E) and sea level pressure.

5. Conclusions

We studied wintertime blocking events in 2004–2016 over Western Siberia and their influence on the surface temperature. We investigated blockings events with duration of 5 days or more for winter intervals (1 November–31 March). We chose 15 blockings events: December 2004, January–February 2005, December 2005, November 2006, January 2008 (two events), December 2008, December–January 2010–2011, January 2011, February 2011, December 2011, January–February 2012, December 2012, February–March 2015, December 2015–January 2016. So, we studied 12 winters. Only 2 winters has no blocking events (2009/2010 and 2013/2014). 4 winters are distinguished by high blocking frequency 2004/2005 (2 events), 2007/2008 (2), 2010/2011 (3), 2011/2012 (2). 6 winters have one event each. For each event we calculate surface temperature anomaly in the grid points for two sectors 60–90 E; 50–60 N (southern part of West Siberia) and 60–90 E; 60–70 N (northern part of West Siberia). We showed that wintertime blocking events over the Western Siberia lead to the surface temperature increase in the northern part of West Siberia and to the surface temperature decrease in the southern part of West Siberia. This feature apparently due to warm air masses advection from south-west on the western periphery of the blocking ridge (reinforcing it) and arctic air masses intrusion to the southern part of the Western Siberia on the eastern periphery of this ridge.

Weather blocking effects: meridional reverse of the temperature gradient leads to warming over West Siberian sector of the Arctic and cooling over southern part of Siberia. The tropospheric polar vortex deformation and displacement take place.

Climatic blocking effect: There is a strengthening of ice melting in the adjacent sector of the Arctic.

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Conflicts of Interest: The authors declare no conflict of interest.

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