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# Blocking Systems Persist over North Hemisphere and Its Role in Extreme Hot Waves over Russia During Summer 2010

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## 1. Introduction

The 2010 Northern Hemisphere summer included severe heat waves that impacted the European continent as a whole, along with parts of, Russia during June, July and August 2010. The 2010 summer heat wave over several parts of Russia was extraordinary, with the region experiencing the warmest July since at least 1880. During summer 2010 all of Europe lies under controlling of blocking systems that persist long time. The formation, persistence, and the role played by blocking systems in abnormal weather and climate in the northern hemisphere challenged in several scientific literatures (e.g; Rex,1951; Namias, 1964, 1978; Dickson & Namias,1976; Dole, 1983); Hafez, 1997; Lejenas, 1989; Cohen, et al., 2001; and recently Hafez, 2008b and 2011). For heat waves, (Stott et al., 2004), for the 2003 western European heat wave, they found that, human influences are estimated to have at least doubled the risk for such an extreme event. Other boundary forcing also contributed to the 2003 European heat wave, including anomalous sea surface temperatures (SSTs) (Feudale & Shukla, 2010). (Dole et al., 2011) studied the 2010 northern hemisphere summer to explore whether early warning could have been provided through knowledge of natural and human-caused climate forcings. They used Model simulations and observational data to determine the impact of observed sea surface temperatures (SSTs), sea ice conditions and greenhouse gas concentrations. They found that, analysis of forced model simulations indicates that neither human influences nor other slowly evolving ocean boundary conditions contributed substantially to the magnitude of this heat wave. Analysis of observations indicate that this heat wave was mainly due to internal atmospheric dynamical processes that produced and maintained a strong and long-lived blocking event, and that similar atmospheric patterns have occurred with prior heat waves in this region. They concluded that the intense 2010 Russian heat wave was mainly due to natural internal atmospheric variability. However, A heat wave is a prolonged period of excessively hot weather, which may be accompanied by high humidity. There is no universal definition of a heat wave, the term is relative to the usual weather in the area. Temperatures that people from a hotter climate consider normal can be termed a heat wave in a cooler area if they are outside the normal climate pattern for that area. The term is applied both to routine weather variations and to extraordinary spells of heat which may occur only once a century. Severe

heat waves have caused catastrophic crop failures, thousands of deaths from hyperthermia, and widespread power outages due to increased use of air conditioning (Meehl et al., 2004). The goal of the present work is to uncover the primary causes of long persistence of blocking systems over the north atmosphere and its teleconnection with the Russian hot wave in summer 2010.

## 2. Data and methodology

The monthly and seasonal time series NCEP/NCAR reanalysis data composites for temperature, geopotential height at level 500 hpa over the northern hemisphere for the period (1980-2010) has been used through the present study (Kalnay et al., 1996). The daily NCEP/NCAR reanalysis data composites are used to study the persistence of blocking systems over the northern hemisphere through 91 days (1 Jun. - 30 Aug.) 2010 year. In addition to that, time series of surface temperature, geopotential height over Russia, NAO and SOI data through the summer seasons from 1980 to 2010 had been plotted and discussed. Anomalies and correlation coefficient methods have been used to analyzed the datasets. Correlation coefficient analysis of these time series was done.

## 3. Results

### 3.1 Study of the synoptic situation and blocking high over Russia on summer of 2010

Russia is occupied a very vast area 17,075,200 sq km in Northern Asia (that part west of the Urals is included with Europe), bordering the Arctic Ocean, between Europe and the North Pacific Ocean. Climate of Russia ranges from steppes in the south through humid continental in much of European Russia; subarctic in Siberia to tundra climate in the polar north; winters vary from cool along Black Sea coast to frigid in Siberia; summers vary from warm in the steppes to cool along Arctic coast. Figure 1 is the geographical map for location of Russia. Since Russia has a vast area it includes several distinct climatic zones. Whereas, the western parts of it have its common weather features rather than the eastern part. Also the climate of the north Russia is completely different of it at the southern boundaries. For example, in its capital, Moscow, the climate is exposed to cold winters, warm and mild summers, and very brief spring and autumn seasons. Typical high temperatures in the warm months of July and August are around 22°C; in the winter, temperatures normally drop to approximately -12°C. Monthly rainfall totals vary minimally throughout the year, although the precipitation levels tend to be higher during the summer than during the winter. Due to the significant variation in temperature between the winter and summer months as well as the limited fluctuation in precipitation levels during the summer, Moscow is considered to be within a continental climate zone. In summer of 2010 weather regime Moscow and several parts of Russia becomes a unique severe hot weather see Figure 2. The anomalies in surface air temperature recorded its maximum value (+6° C) in that summer season through the mean average of the period (1980-2010) as it is clear in Figure 3. (Razuvaev et al., 2010) said that, the center of European Russia was well covered by meteorological observations for the past 130 years. These data, historical weather records (yearbooks or "letopisi", which were carried on in the major Russian monasteries), and finally, dendroclimatological information, all show that this summer temperature anomaly was well above all known extremes in the past 1000 years. A 60-days-long hot anticyclonic weather system with daily temperature anomalies as high as +10° C. The extreme heat, lack



Fig. 1. The geographical map for location of Russia. [Source: climatezone.com]

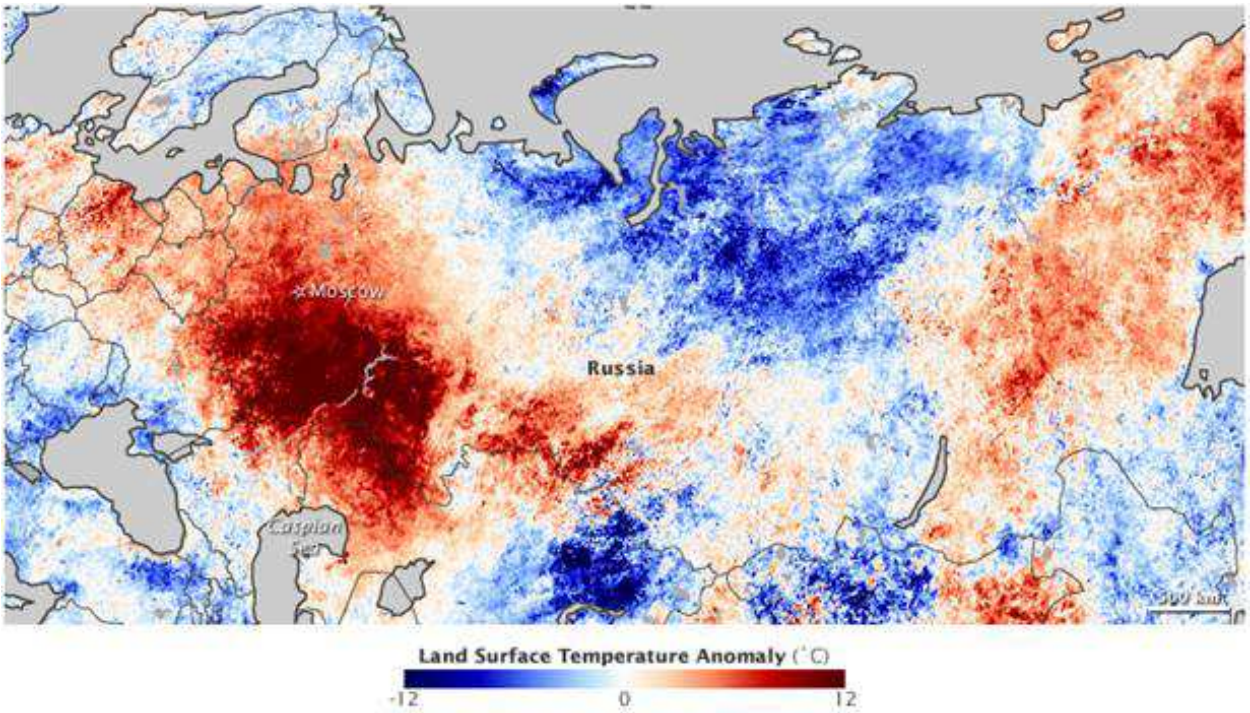


Fig. 2. Shows temperature anomalies for July 20-27 relative to the average for the same dates 2000-2008. [Source: <http://earthobservatory.nasa.gov/IOTD/view.php?id=45069>]

of precipitation, and forest fires have caused hundreds of deaths and multimillion dollars in property losses. Indirect losses of lives due to this weather anomaly, with the ensuing fires and related air pollution. In the present study the synoptic situation over Russia through 2010 summer season has been studied using of temperature and geopotential height at 500 hpa level data. Figures 3 and 4 illustrated that there positive surface air and upper level temperature at 500 hpa anomalies ( +6°C and + 3°C ) over Russia during months of 2010



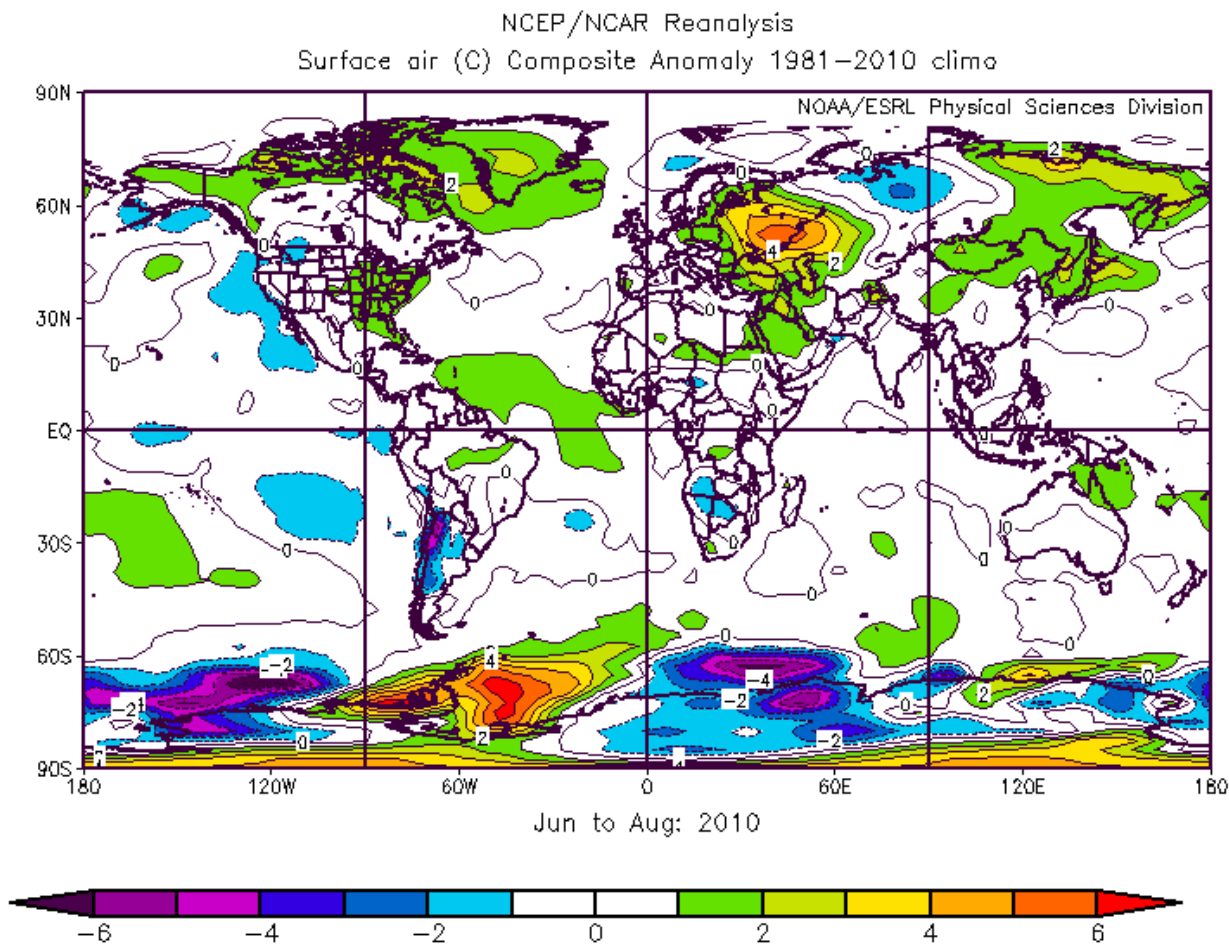


Fig. 3. The global distribution of surface air temperature (C) anomaly for summer 2010

summer season respectively. During this time land surface temperature anomalies over the western part of Russia recorded its extremely maximum value in July +12°C, see Figure 2. The synoptic and numeric criteria of the formation of blocking systems over northern hemisphere according to ( Rex, 1950a, 1950b, 1951; Dole, 1978,1982, and Hafez, 1997 ) had been used to identify and to follow the daily persistence of the blocking systems. These criteria have basic conditions like as; the westerly air current aloft must splitting to two distinct branches, this splitting must be northern latitude of 30 N, the anomalies in geopotential height values at 500 hpa must be more than + 100 m for blocking high pressure system and these conditions must persist more than 10 days. Applying this criteria in the present study revealed that western Russia lies under the influence of blocking system about 75 days during the period of study 92 days which are the days of summer 2010. A 60 days of it through July and August months. Whereas the blocking system developed over western Russia in the next have of June 2010.This blocking episode over the northern hemisphere and mainly over Russia persisted to long time reached to the time of this season. Figure 5 shows the anomalies in geopotential height during summer 2010. It is clear that there are a notably positive anomalies over western Russia. Figures 6, 7 and 8 illustrated a 10-day anomalies of geopotential height at 500 hpa level distribution over Russia during June, July and August months of summer 2010 respectively. In fact the blocking time duration start from one week to a complete season. The historical record of blocking episodes indicated that the episodes that persist for a season are too rarely. The long

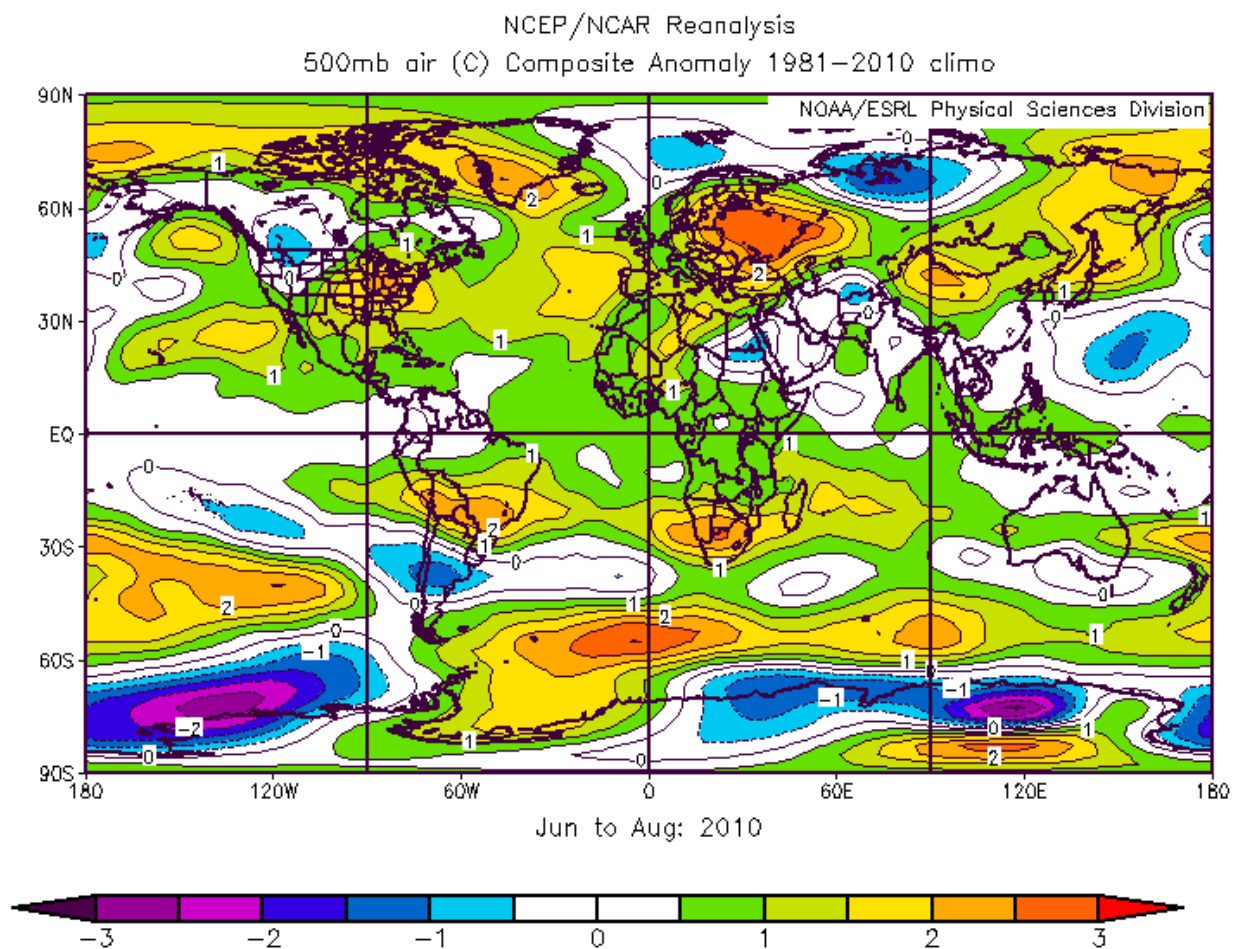


Fig. 4. The global distribution of 500 mb level air temperature (C) anomaly for summer 2010

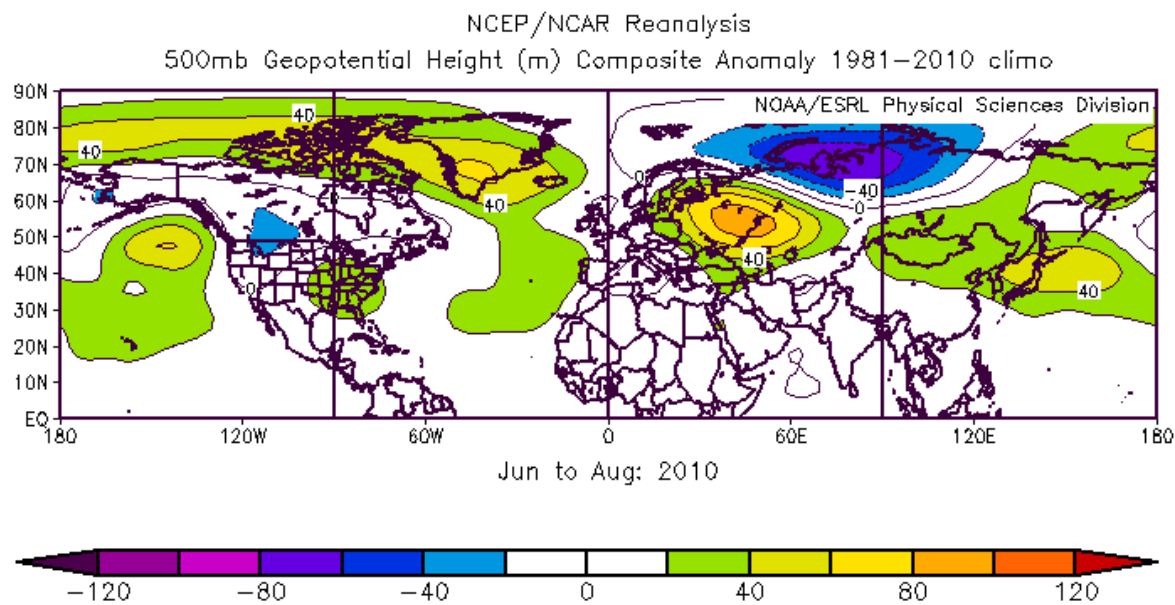


Fig. 5. The northern atmosphere distribution of geopotential height (m) anomaly for summer 2010

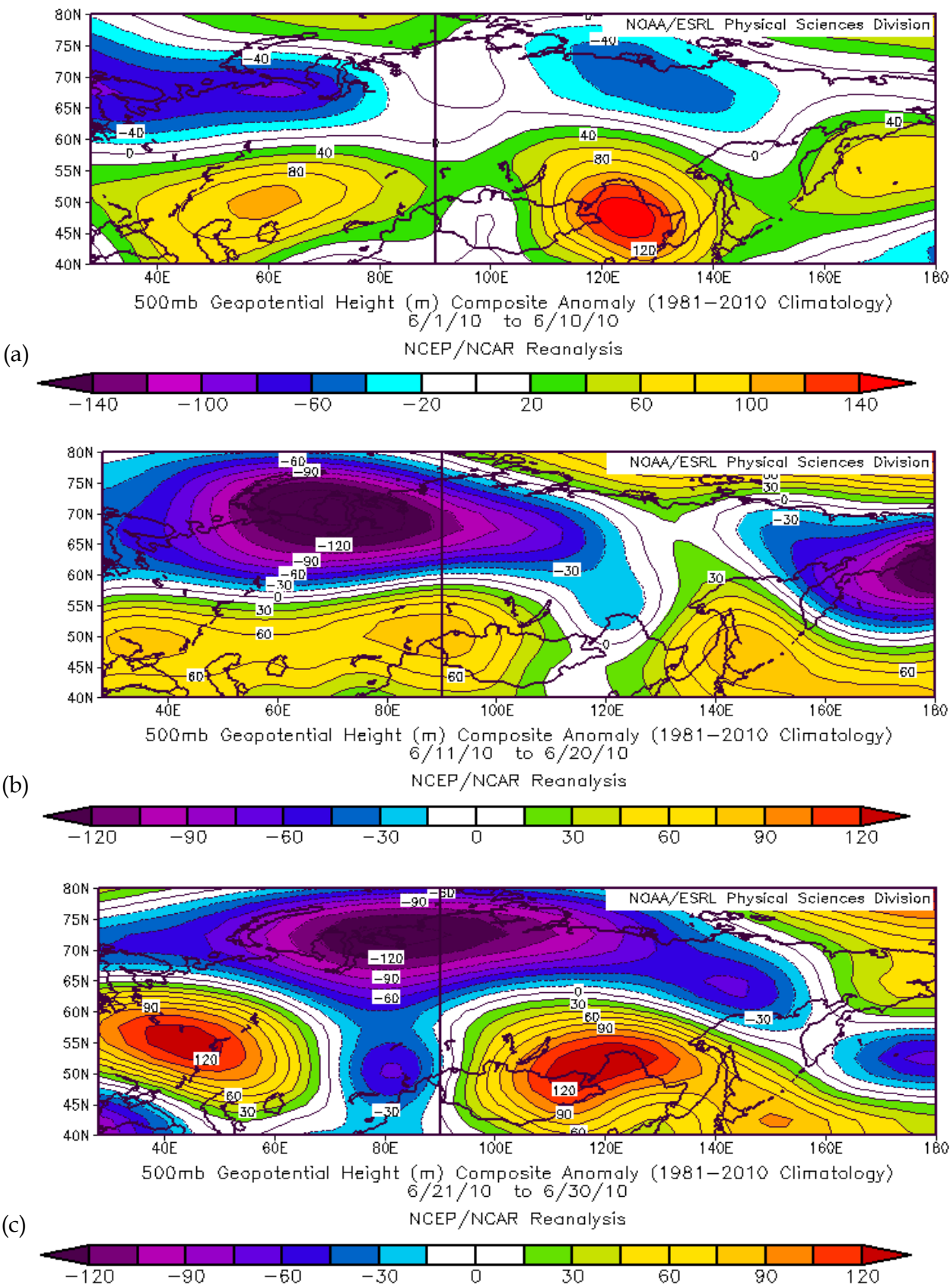


Fig. 6. A 10-day distribution of 500mb geopotential height (m) anomaly over Russia for June month of year 2010

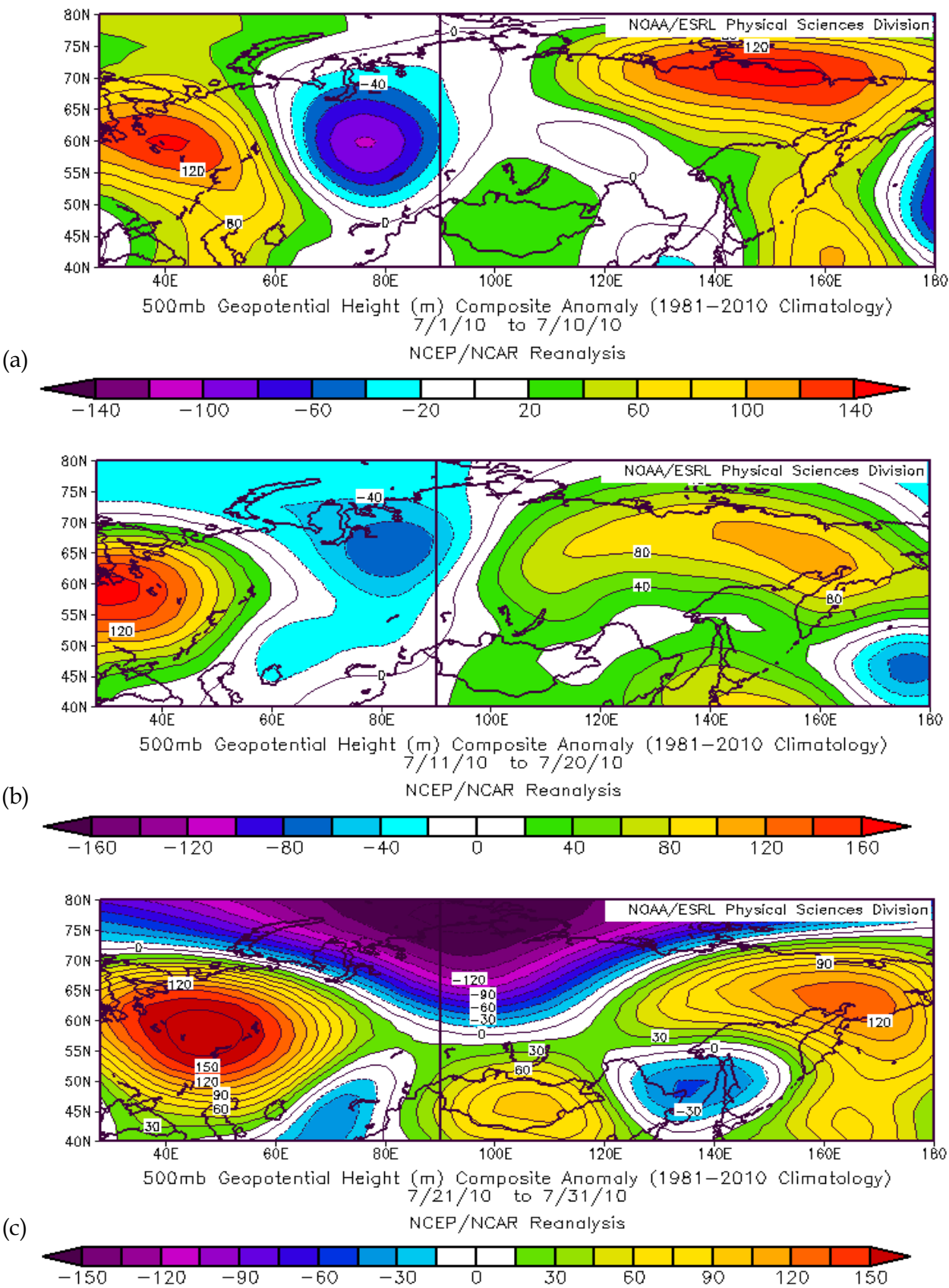


Fig. 7. A 10-day distribution of 500mb geopotential height (m) anomaly over Russia for July month of year 2010



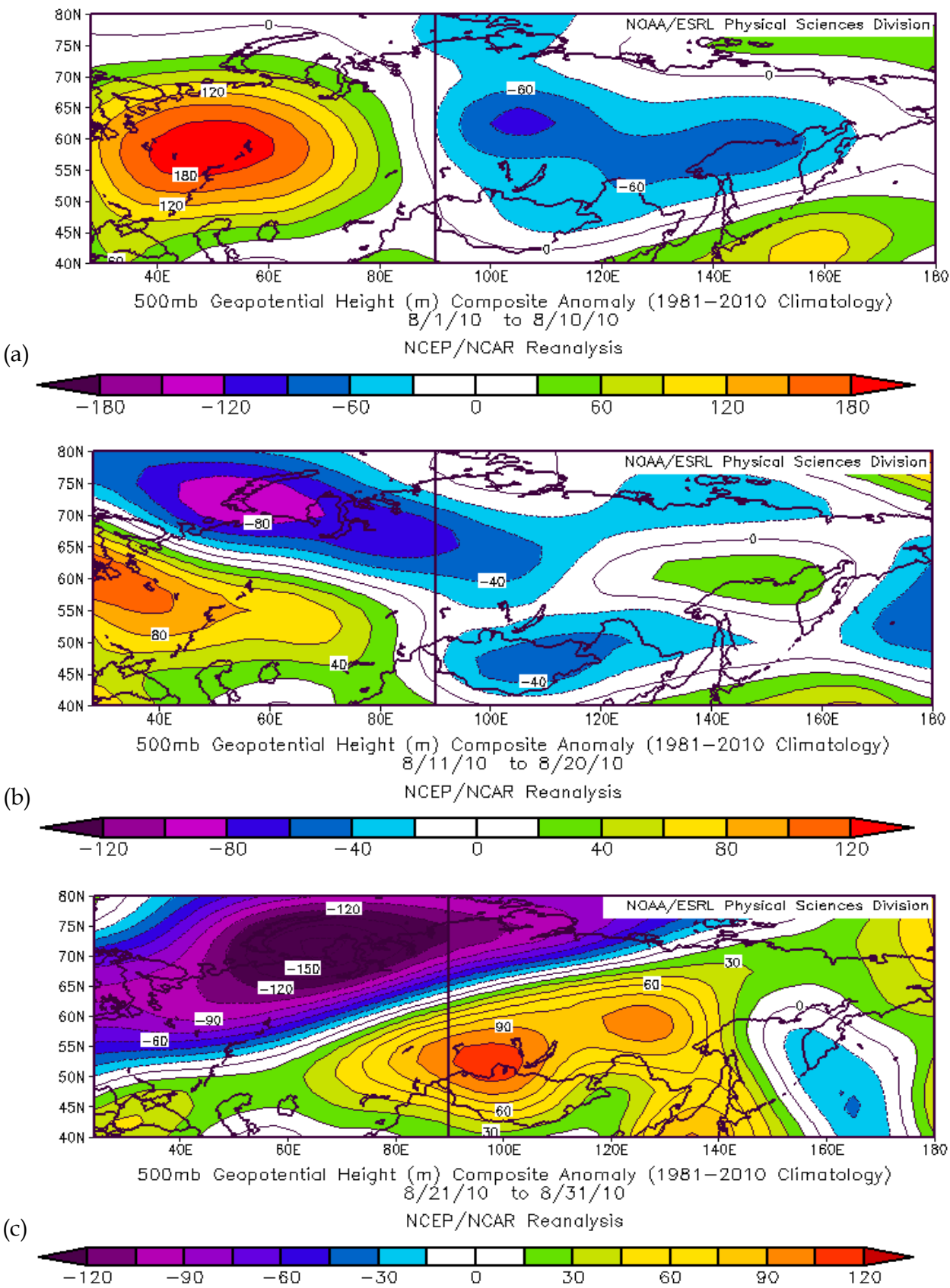


Fig. 8. A 10-day distribution of 500mb geopotential height (m) anomaly over Russia for August month of year 2010

persistence of a block means that there are an extreme disturbances in the large scale atmospheric circulation. The disturbance in the atmospheric circulation is not easy to persist for a long time like a one season in summer 2010. For the purpose of the present study we consider that, a hot wave is a heat wave with extreme anomalies in surface air temperature more than 5 °C through a ten days. A study of a 10-day anomalies in surface air temperature over Russia in the same summer has been done, see Figures 9, 10 and 11. It is noticed that the location of hot waves (hot wave in the present study indicated by positive anomalies in surface air temperature more than 5 °C through a ten days) was matched with the blocking high pressure location in the upper atmosphere.

### **3.3 Study the variation of NAO, SOI and geopotential height over Russia through period of (1980-2010) summer seasons**

#### **3.3.1 The variation of NAO**

The North Atlantic Oscillation (NAO) is one of the major modes of variability of the Northern Hemisphere atmosphere. The NAO index is defined as the pressure gradient between Greenland and the Azores and describes the zonality of the flow in the North Atlantic region. i.e., NAO is the difference of the normalized sea level pressures between Ponta Delgada, Azores and Reykjavik, Iceland. It is particularly important in winter, when it exerts a strong control on the climate of the Northern Hemisphere. It is also the season that exhibits the strongest interdecadal variability. However, NAO is associated with changes in the system of westerly winds across the North Atlantic onto Europe. The state of this North Atlantic Oscillation (NAO) is positive when the Azores high is strong and the Icelandic low is deep and negative when reversed. Both phases are associated with changes in the intensity and location of the North Atlantic westerlies, jet stream and storm tracks, and with resulting changes in temperature and precipitation patterns. The NAO can be seen as a reflection of the fluctuation of the normal winter tropospheric flow in the northern hemisphere (Rogers, 1985; Hurrell, 1995; Ambaum, 2001; Rogers, & McHugh 2002). In the present work, the variability in NAO through the period (1980-2010) has been studied. The results of analysis of NAO dataset through the period (1980-2010) of summer seasons shows that NAO values in summer months (June, July and August) varies from year to year during the period of study. It is noticed that through summer of 2010 the NAO has negative values ( -2.4 and -2.01) for months of June and August respectively. Meanwhile it was a very weak positive value (+0.06) for July as shown in Figure 12. The NAO value for July 2010 is the lowest positive value recorded through the period (1980-2010). So, in general one can say that, summer of 2010 has a characteristics of negative NAO phase weather regime.

In addition to that, study of daily NAO dataset represent the summer season of 2010 revealed that almost of these days had a negative NAO values. The days of positive NAO values occurred mainly in July month, as it is clear in Figure 13. The main features of this analysis is that the daily NAO has a negative phase weather conditions through that summer. On 14 August 2010 the NAO recorded the lowest negative value (-2.01) recorded per a day.

#### **3.3.2 The variation of SOI**

The southern oscillation index (SOI) is defined as the difference between sea level pressure at Tahiti (145° W and 18° S) and Darwin (135° E and 16° S). SOI is coupled with El-Nino

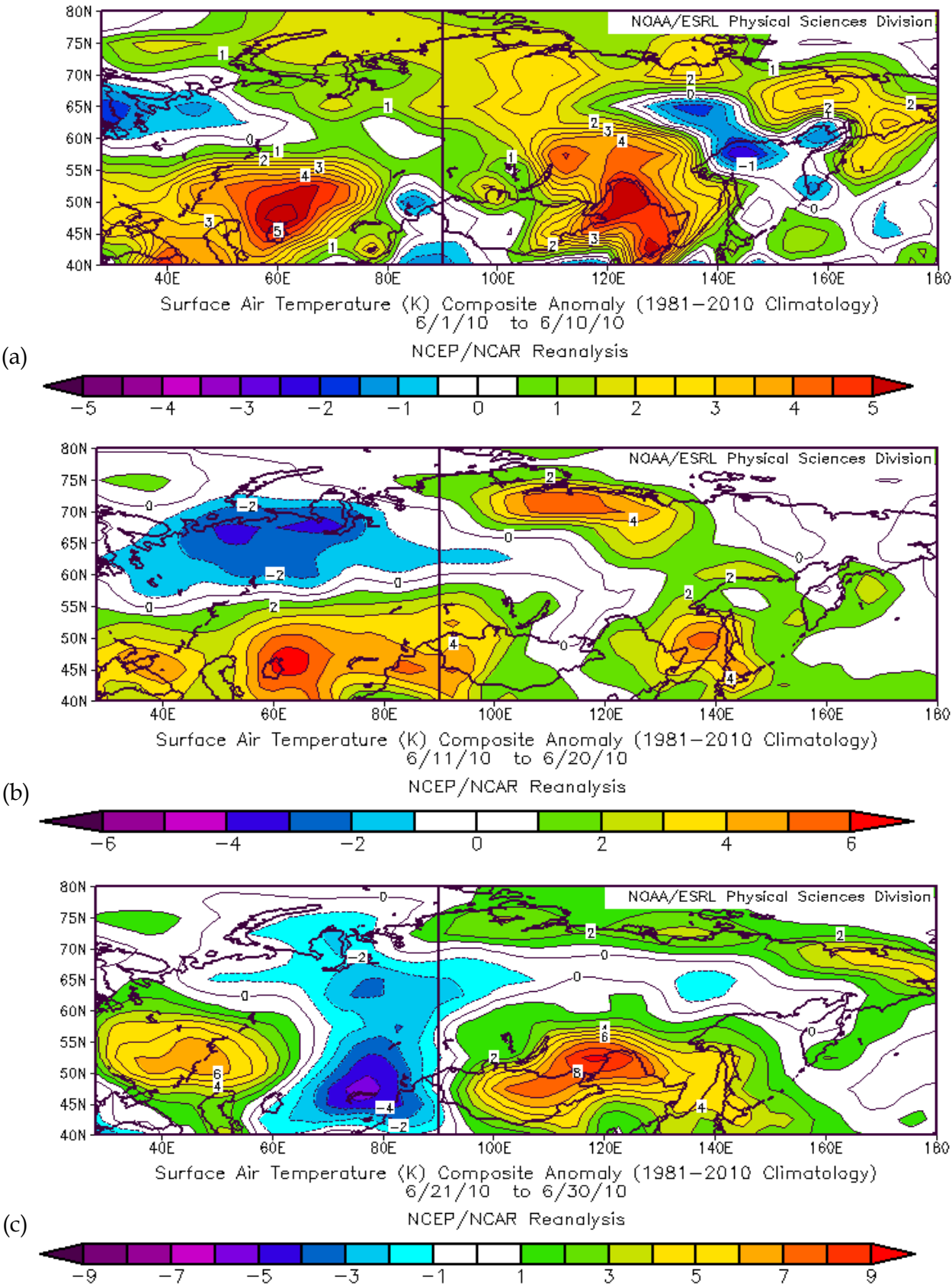


Fig. 9. A 10-day distribution of surface air temperature (°C) anomaly over Russia for June month of year 2010

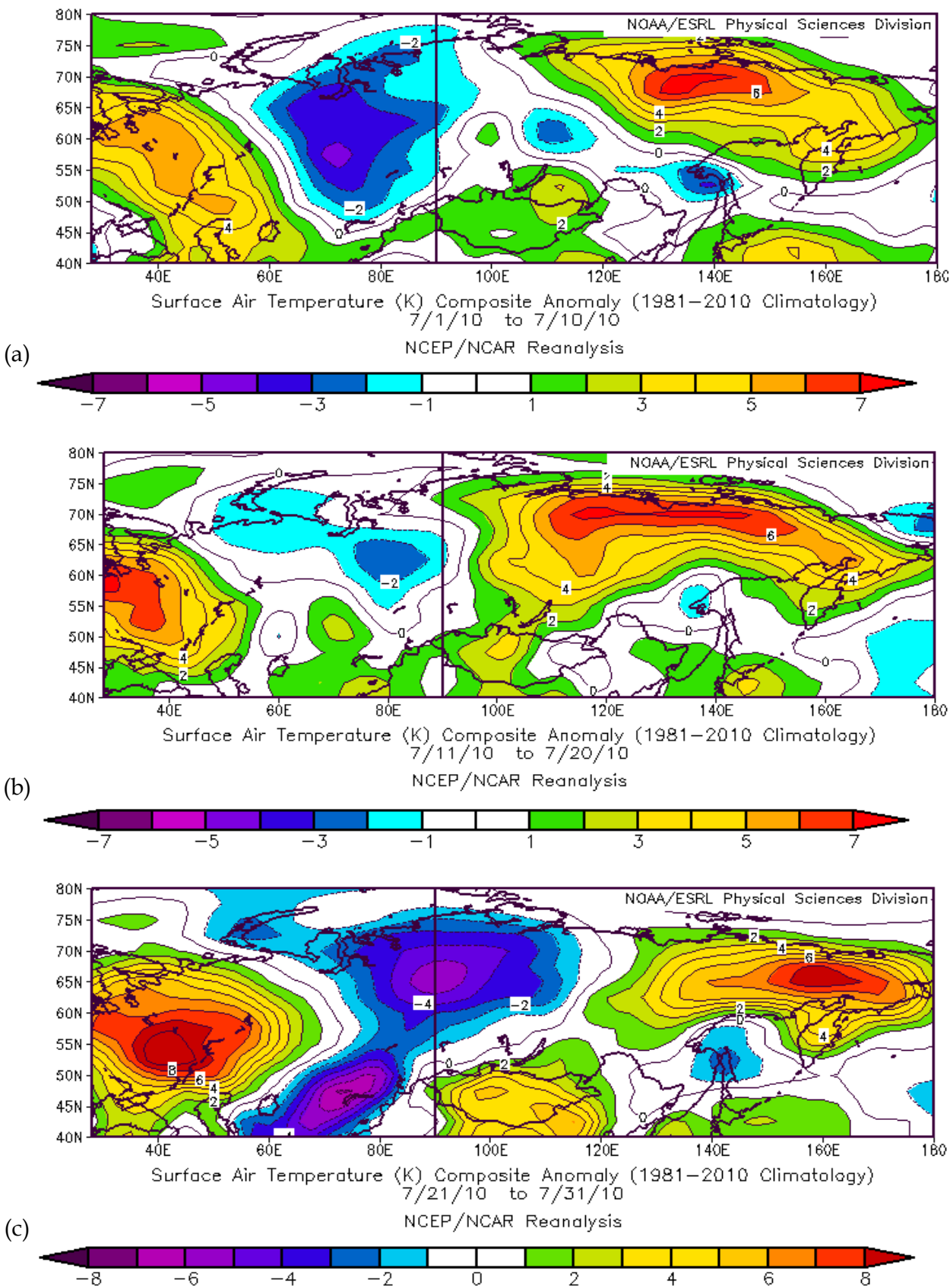


Fig. 10. A 10-day distribution of surface air temperature (°C) anomaly over Russia for July month of year 2010



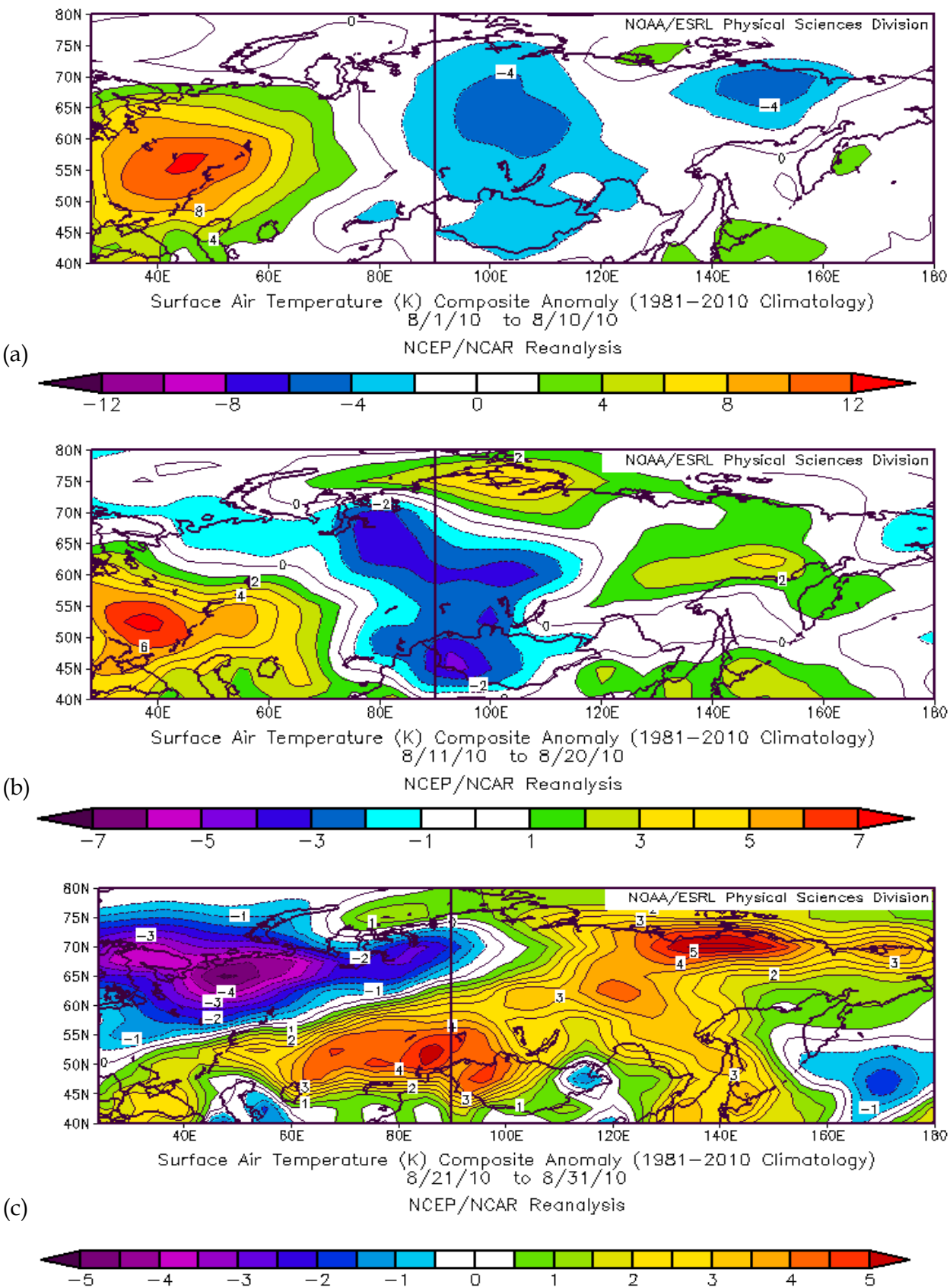


Fig. 11. A 10-day distribution of surface air temperature (°C) anomaly over Russia for August month of year 2010

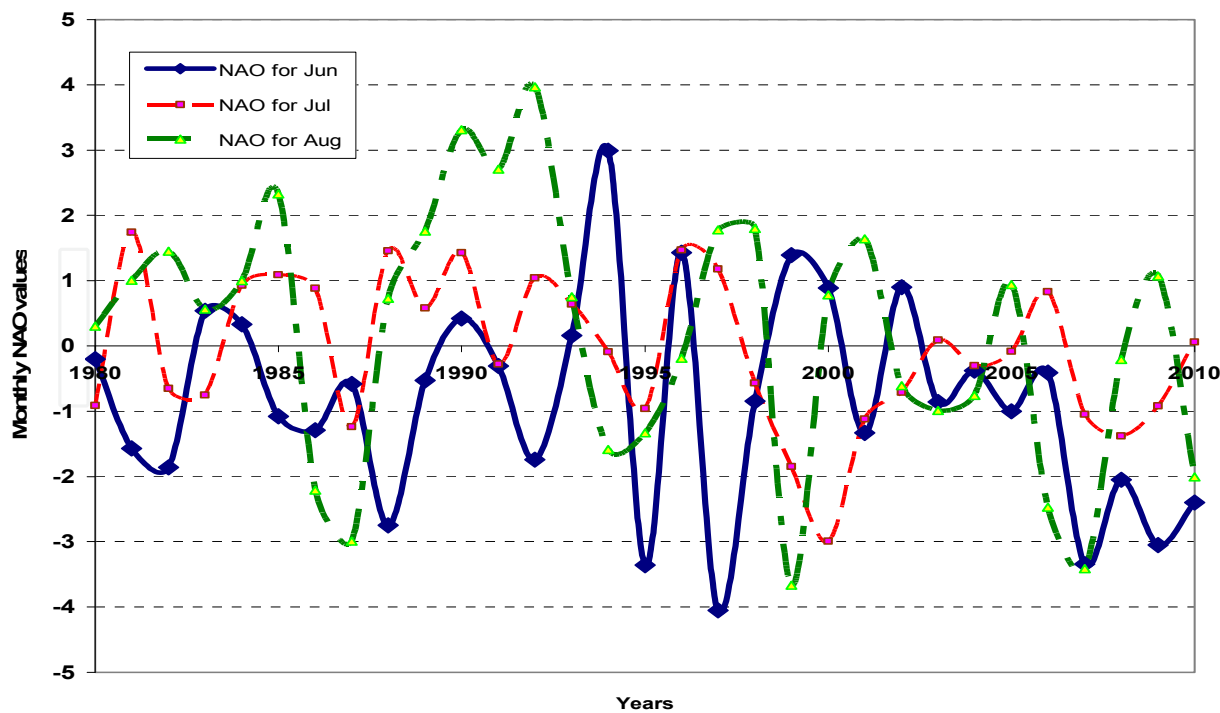


Fig. 12. The timeseries of monthly NAO values for months of June, July and August for the period (1980-2010)

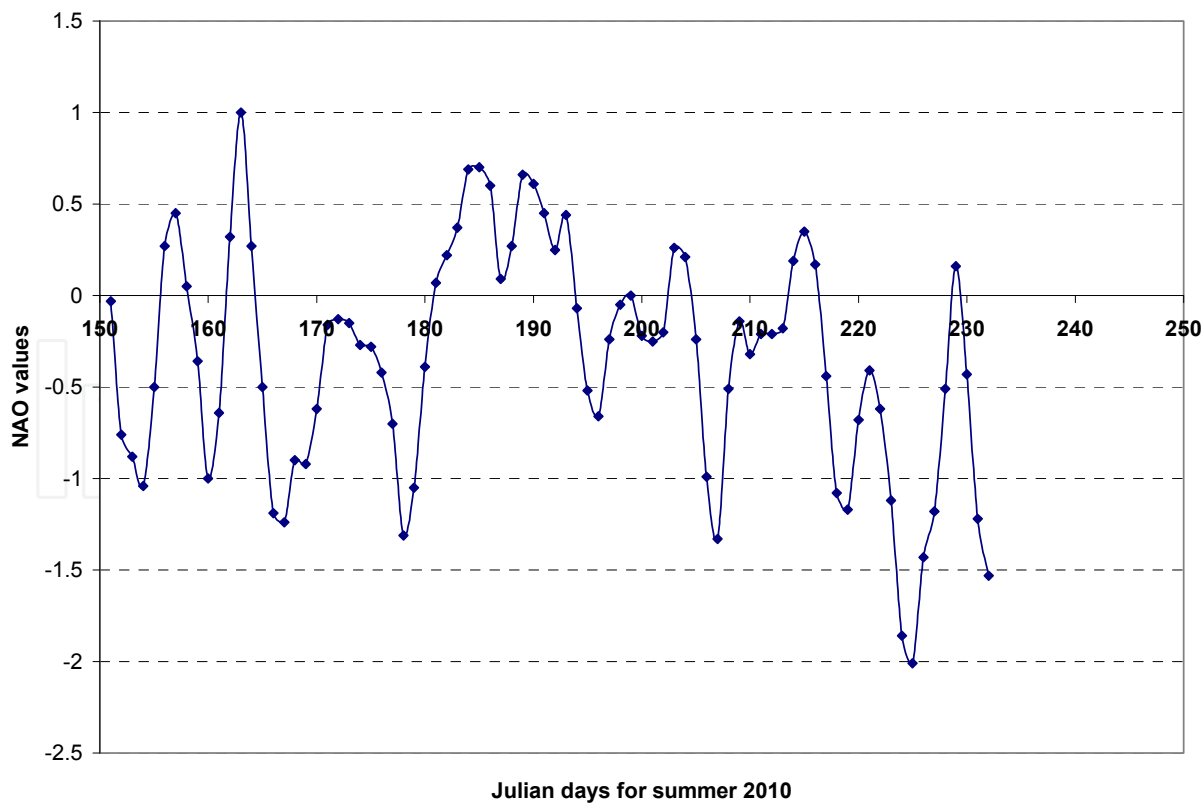


Fig. 13. The timeseries of daily NAO values for months of summer season of year 2010(NAO daily data for last week of August is missed)

which is called ENSO. Whereas, El Nino is the name given to the phenomenon, which occurs when sea-surface temperatures (SSTs) in the equatorial Pacific Ocean off the South American coast becomes warmer than normal. Nino3 is defined as the sea surface temperature at the Pacific Ocean in the region (90 °W - 150 °W, 5° S -5° N), (Trenberth,1976). Many studies have shown that the El Nino-Southern Oscillation (ENSO) has a significant influence on climate in many parts of the globe (Malmgren,1998).

In the present study, the variability in SOI through the summer seasons study period (1981-2010) has been studied. The results of analysis of monthly SOI dataset through this period of shows that sign of SOI values in summer months (June, July and August) varies from year to year. It is varied strongly mainly through the period (1980-2000). Meanwhile the SOI values has a little variation through the period (2001-2009). It is noticed that through summer of 2010 the SOI has extreme climatic positives (+20.5 and +18.8) for July and August months respectively. Also, SOI has a positive value +1.8 in June of this summer season. It is shown in Figure 14 that represents the monthly variation of SOI through the period (1980-2010). So, in general one can say that, summer of 2010 has a characteristics of extreme climatic positive SOI phase weather regime mainly on July and August. Also, study of daily SOI dataset for 92 days represent the summer season of 2010 shows that almost of these days had an extreme maximum positive SOI values. The days of extreme positive SOI values occurred mainly in July and August months, as it is illustrated in Figure 15. The main features of this analysis is that the daily SOI has an extreme positive phase weather conditions through that summer. The recorded SOI value during July 2010 never reached to this value for July month since the recording of SOI data. Whereas, 27 July 2010 observe a

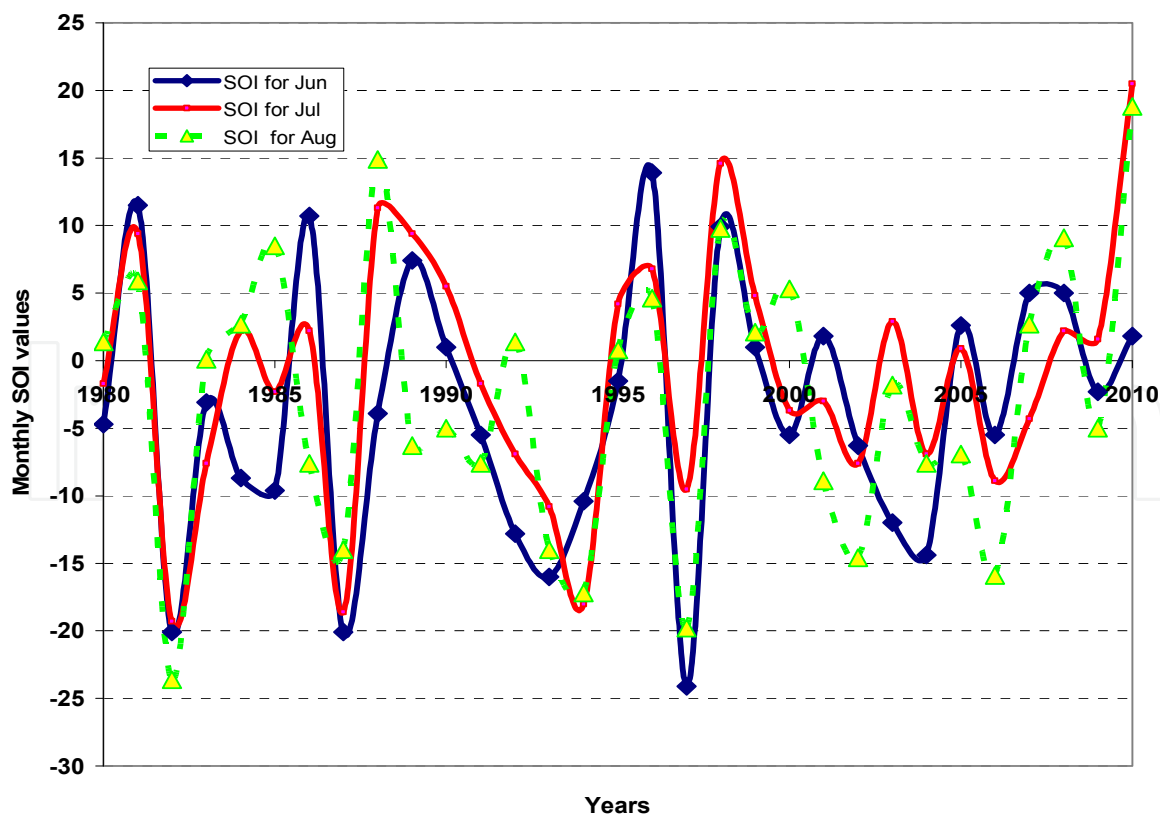


Fig. 14. The timeseries of monthly SOI values for months of June, July and August for the period (1980-2010)

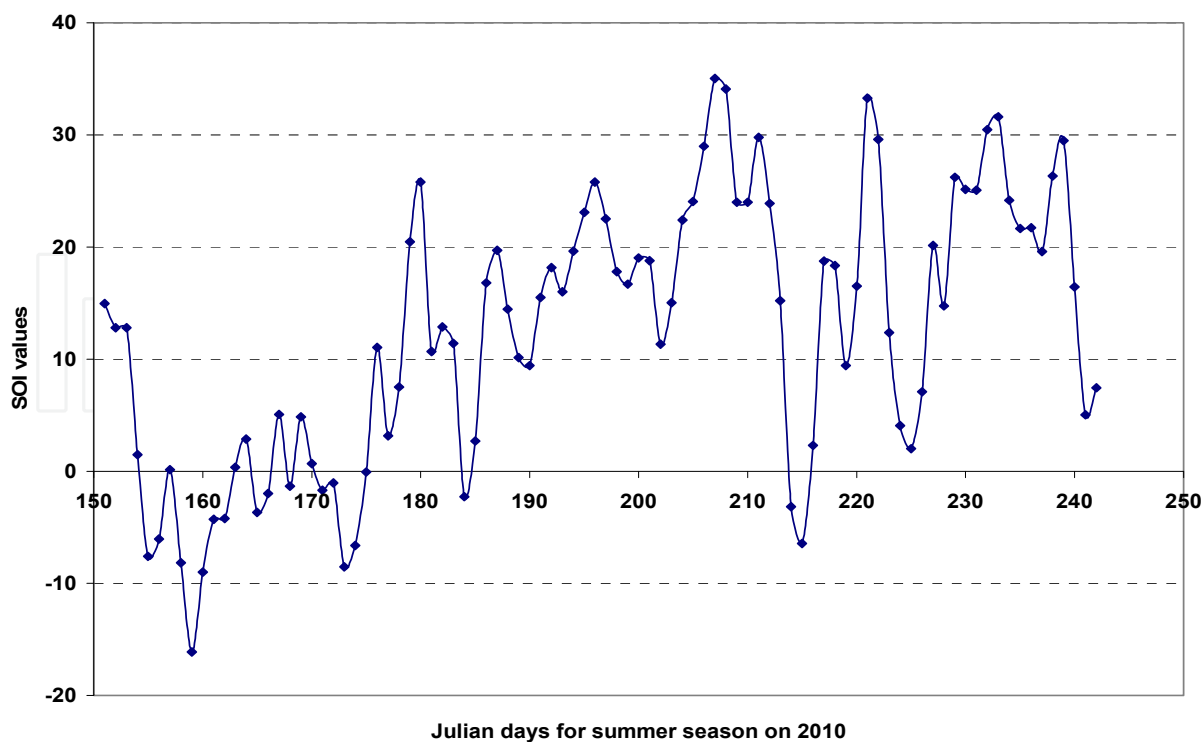


Fig. 15. The timeseries of daily SOI values for months of summer season of year 2010

daily new climatic SOI record value (+35.02). This value never reached through summer seasons of all SOI records.

### 3.3.3 The variation of the geopotential height

The time series of monthly variation of the geopotential height at level of 500 hpa over Russia during summer months of June, July and August through the period (1980-2010) had been plotted, analyzed and discussed. This dataset comes from the monthly mean values over the Russia area [40° N – 80° N] latitudes and [28° E -190° E] longitudes. The results revealed that the monthly geopotential height values varies from year to year for each month. The geopotential values are increase from June to July and decrease toward August. It is noticed that these values varied little variation on July months for the period (1999-2009) as shown in Figure 16. Month of July on 2010 record a first maxima of geopotential height values (5671m). Whereas, The maximum value is (5682 m) reached on 1998 July. The geopotential height values for the summer months of 2010 are greater than that on 2009.

### 3.3.4 The variation of the surface air temperature

The time series of monthly variation of the surface air temperature over Russia during summer months of June, July and August through the period (1980-2010) had been analyzed. This dataset comes from the monthly mean values over the Russia area. The results revealed that the variation in surface air temperature is typical in general with the variation of geopotential height values from year to year for each month. See Figures 16 and 17. Whereas, the surface air temperature values are increase from June to July and decrease toward August. It is noticed that these values varied little variation on July months for the period (1999-2009) as shown in Figure 17. Month of July on 2010 record the maximum value



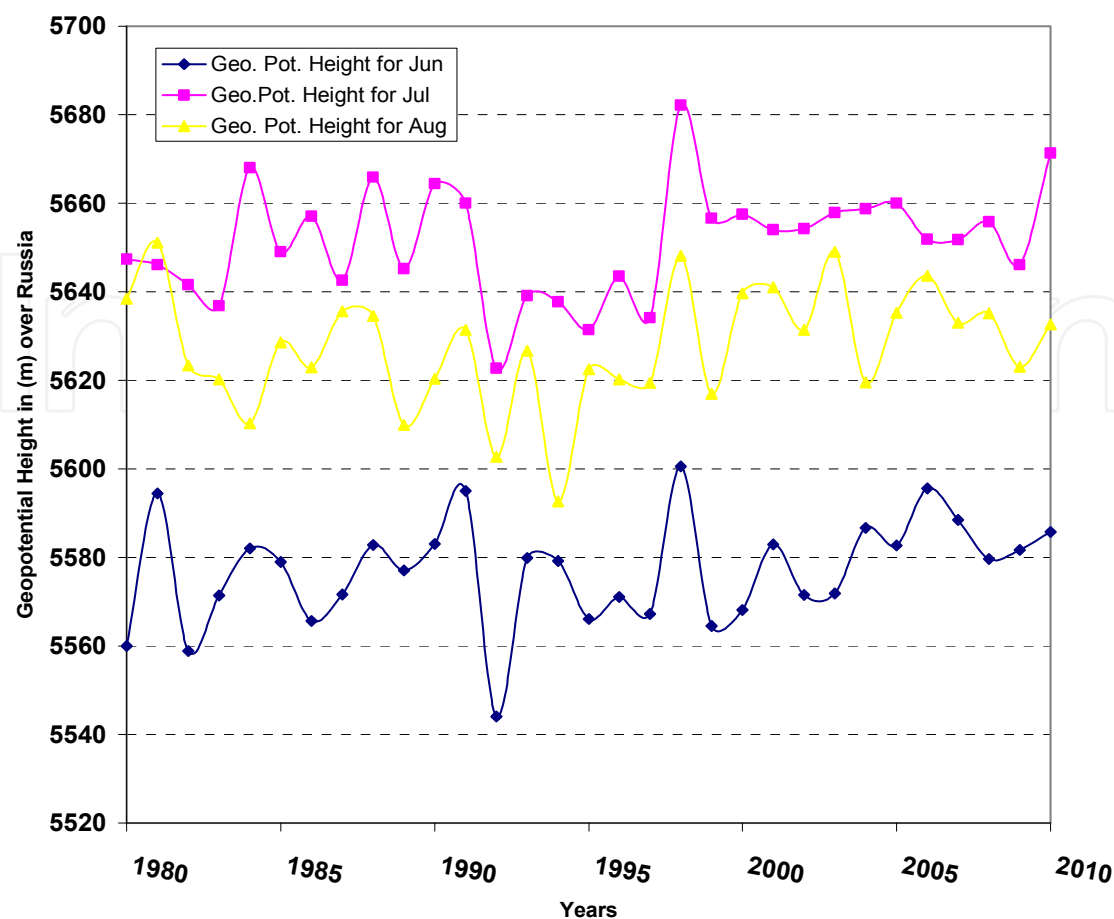


Fig. 16. Timeseries of geopotential height over Russia for summer months June, July and August through the period (1980-2010)

is (14 °C) reached. Also, Month of August 2010 record the maximum value is (14 °C) reached through the period (1980-2010). The temperature values for the summer months of 2010 are greater than that on 2009 as it is shown in Figure 17.

3.4 Teleconnection between hot waves over Russia and climatic indices NAO and SOI and blocking systems

Teleconnection patterns reflect large-scale changes in the atmospheric wave and jet stream patterns, and influence temperature, rainfall, storm tracks, and jet stream location and intensity over vast areas (e.g. Hafez, 2008b). Thus, they are often the culprit responsible for abnormal weather patterns occurring simultaneously over seemingly vast distances. Through this section, a correlation coefficient analysis according to (Spiegel, 1961) has been done between the hot waves (represents by anomalies in surface temperature) and blocking highs (represents in anomalies in geopotential height at 500 hpa), and climatic indices NAO and SOI. The datasets for all of these parameters had been taken for the period (1980-2010). The results revealed that, for June month, there exist a very strong, high significant positive correlation coefficient (+0.675) with a significant level of 0.99 % between anomalies in surface air temperature and geopotential height over Russia for month of June through the period of study. In addition to that through , anomalies in surface air temperature has a significant negative correlation coefficient (-0.205) with a significant level of 0.95 % with

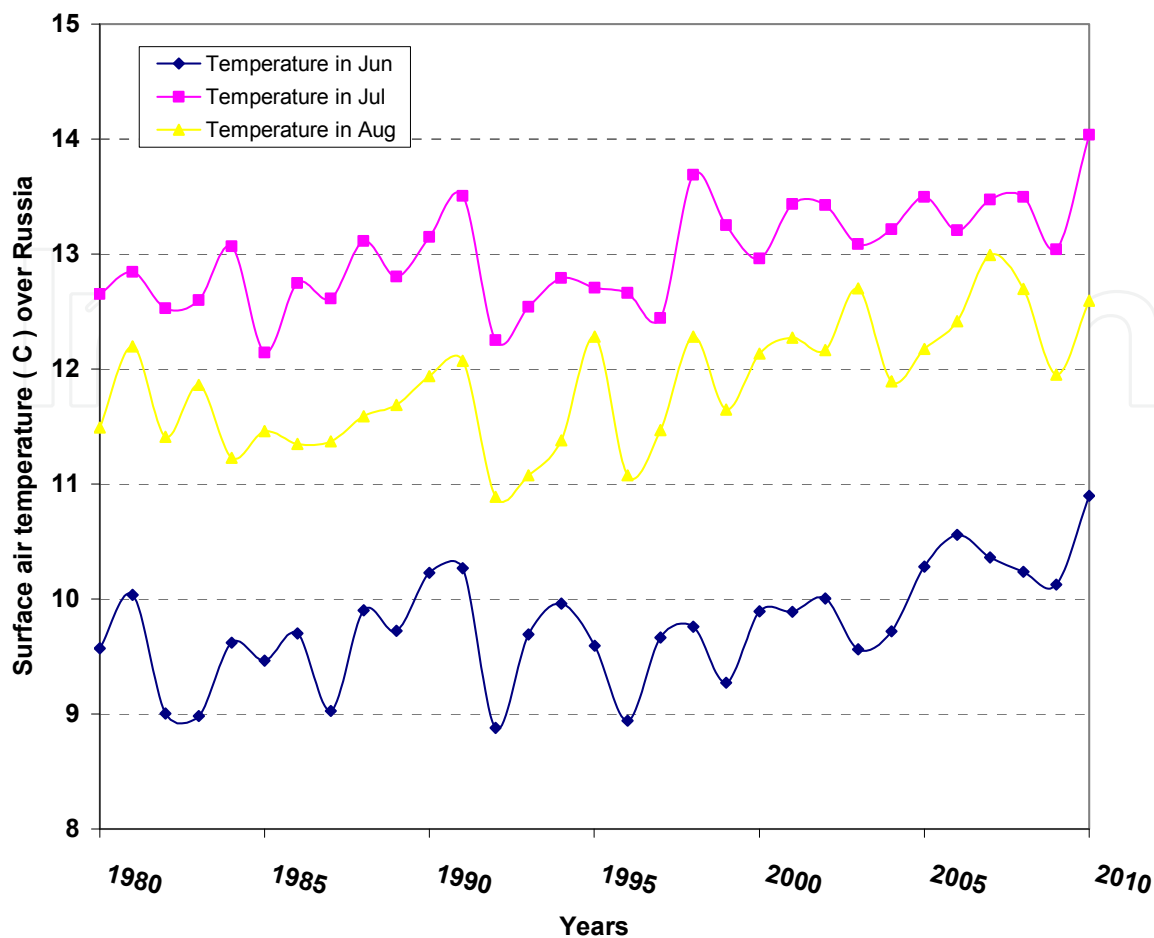


Fig. 17. Timeseries of surface air temperature over Russia for summer months June, July and August through the period (1980-2010)

NAO. Also, the results show that there is a strong significant positive correlation coefficient (0.299) with a significant level of 0.97% between the anomalies of surface air temperature over Russia and SOI as shown in Table(1).

Correlation coefficient	Surface air temperature over Russia	Geopotential height at 500 hpa level over Russia	NAO	SOI
Weather and climatic parameters				
Surface air temperature over Russia	1	+0.675	-0.205	+0.299
Geopotential height at 500 hpa level over Russia	+0.675	1	-0.019	+0.343
NAO	-0.205	-0.019	1	-0.086
SOI	+0.299	+0.343	-0.086	1

Table 1. Correlation coefficient matrix for Weather and climatic parameters over Russia and climatic indices NAO and SOI for June month

The results revealed that, for July month, there exist a very strong, high significant positive correlation coefficient (+0.764) with a significant level more than 0.99 % between anomalies in surface air temperature and geopotential height over Russia through the period of study. In addition to that through , anomalies in surface air temperature has a significant negative correlation coefficient (-0.289) with a significant level of 0.95 % with NAO. Also, the results show that there is a strong significant positive correlation coefficient (+0.477) with a significant level of 0.975% between the anomalies of surface air temperature over Russia and SOI as shown in Table(2).

Correlation coefficient	Surface air temperature over Russia	Geopotential height at 500 hpa level over Russia	NAO	SOI
Weather and climatic parameters				
Surface air temperature over Russia	1	+0.764	-0.289	+0.477
Geopotential height at 500 hpa level over Russia	+0.764	1	-0.06479	+0.573
NAO	-0.289	-0.064	1	+0.217
SOI	+0.477	+0.573	+0.217	1

Table 2. Correlation coefficient matrix for Weather and climatic parameters over Russia and climatic indices NAO and SOI for July month

For August month, there exist a strong, high significant positive correlation coefficient (+0.605) with a significant level more than 0.97 % between anomalies in surface air temperature and geopotential height over Russia through the period of study. In addition to that, anomalies in surface air temperature has a significant negative correlation coefficient (-0.285) with a significant level of 0.95 % with NAO. Also, the results show that there is a strong significant positive correlation coefficient (+0.264) with a significant level of 0.90 % between the anomalies of surface air temperature over Russia and SOI as shown in Table(3).

Correlation coefficient	Surface air temperature over Russia	Geopotential height at 500 hpa level over Russia	NAO	SOI
Weather and climatic parameters				
Surface air temperature over Russia	1	+0.605	-0.285	+0.264
Geopotential height at 500 hpa level over Russia	+0.605	1	-0.101	+0.255
NAO	-0.285	-0.101	1	+0.018
SOI	+0.264	+0.255	+0.0184	1

Table 3. Correlation coefficient matrix for weather and climatic parameters over Russia and climatic indices NAO and SOI for August month

#### 4. Discussion and conclusion

Abnormal hot and dry weather has hit Russian regions in the summer of 2010. Many Russians are suffering from the record-breaking heat and the worst drought in 40 years. Russia was not import grain this year despite drought wiping out a quarter of its crops. The present study the hot wave over Russia on summer 2010 are a result of extreme global atmospheric abnormal interaction between the southern hemisphere (represented by SOI) and the northern hemisphere (represented by NAO) through that season. Abnormal interaction between these two major climatic indices of pressure systems that controlling the atmospheric dynamic in the globe generates a unique blocking high over the northern hemisphere. This blocking high persisted for a long time over Russia about 80 days with anomalies in geopotential height more than +100 m in 500 hpa level. The long persistence of this episode is due to the long abnormal interaction between SOI and NAO through that summer. The blocking high over Russia associated with abnormal warming in the upper atmosphere and causing of very extreme heating in the surface. Hot waves over Russia are a results of the long persistence of the blocking high episode that existed from the abnormal atmospheric interactions in the globe. One can concluded that, extreme flow air currants in both hemispheres (represented in the extreme values of NAO and SOI) disturb the flow to be stationary and blocked the air current flow aloft over the northern hemisphere during summer 2010. The hot waves over Russia is a result from the extreme atmospheric climatic interaction between both hemispheres.

#### 5. Acknowledgment

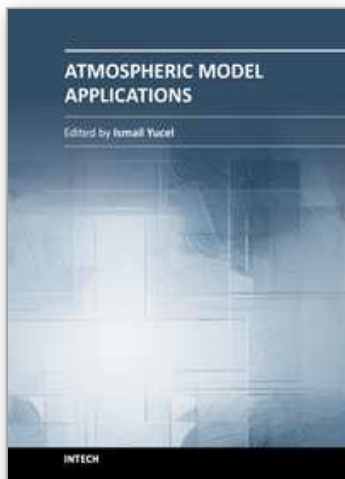
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