

Interannual variability of anticyclone activity and temperature extremes in the Black sea region

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Abstract. Manifestations of North Atlantic oscillation (NAO) during its negative and positive phases and during different El Niño (EN) types in the anticyclone parameters and air temperature extreme thresholds in the Black sea region are studied. It is estimated quantitative characteristics of anticyclone frequency anomalies and temperature extremes associated with the NAO phases and the EN types.

1. Introduction

The cyclone and anticyclone activity have a significant impact on the structure of hydrometeorological fields. The most illustrative parameters are average and extreme air temperature. The abnormally hot weather conditions in summer 2010 and 2017 in Europe are perfect examples. They were caused by the prolonged existence of anticyclone [1–3]. The recent decade's studies of climate changes of cyclone parameters in different regions have been given sufficient attention to, in contrast with anticyclones. The anticyclone variability in the Black sea region can be estimated by the papers where the only large-scale region is analyzed. In particular, the anticyclone activity weakening in Eurasia from 1990's to the 2000's and a significant intensification of anticyclone activity afterwards is found in [4]. The authors suggest that the character of anticyclone changes is accompanied by a decrease of mid-latitude surface air temperature over Eurasia and an increase in the frequency of extremely cold weather events. In [5] it is shown that the anticyclone frequency in the Black Sea region was increased in late 1960's - late 1980's during all seasons, especially in winter. At the same time, the anticyclone depth in that region increased in spring, but decreased in summer. However, the authors of this work do not consider the relationship with temperature, and especially with its extreme values. Such study is presented by [6], where the relationship between semi-permanent anticyclones and temperature anomalies in the Atlantic-European region, including the Black sea region, for the period 1952–2000 is analyzed. It is noted that the anticyclone frequency and average temperature during the last decades of the 20th century increased, but changes of extreme high temperature frequency were not detected. In accordance with the findings of [6] it is necessary to cogitate about the changes in anticyclone activity and extreme temperature in local regions, and also together with changes associated with circulation regimes.

It is now known that the interannual climate processes in the ocean-atmosphere system, such as the North Atlantic Oscillation (NAO) and El Niño (EN), are responsible for the changes of global circulation of atmosphere in the Northern Hemisphere, and, as a consequence, the changes of different hydro-meteorological characteristics [e.g., 7]. The study of their role in the generation of anomalies in the Atlantic-European hydrometeorological fields is one of the main tasks of the largest international scientific communities programs (e.g., EGU, EMS and others). The NAO manifestations in the sea level pressure (SLP) field are well described on the example of anticyclone blockings. The positive



NAO phase during winter is accompanied by low blocking activity in Europe [8, 9]. Changes of winter anticyclone characteristics during positive and negative NAO phases were examined by [10] for the Atlantic-European region. In [5] the relationship of anticyclones and NAO during all seasons only for the Black Sea is studied. These authors demonstrate that the NAO intensification in 1960-1990 is accompanied by more frequent winter anticyclones over the Southern Europe, including the Black Sea region.

Recent studies of EN events show the individual differences of various events in intensity, duration, and time of the beginning of ocean anomaly. There are successful attempts to classify them [e.g., 11–15]. So, the regional hydrometeorological manifestations of different EN types have to be different as well [11, 14]. This conclusion agrees with that reported by [12] for the Black Sea region. These authors have shown that the air temperature anomalies during two different EN types are different in sign. At the same time, the relationship between interannual climate processes and anticyclone activity, and also extreme temperature in the Black sea region is shown fragmentarily.

The aim of this study is to analyze the changes of anticyclone activity and extreme temperature over the Black Sea region, associated with the NAO phases and different EN types in 1950-2012.

2. Data and methods

The 1000-hPa geopotential height fields within 20-80 °N latitudinal belts for 1951–2012 were extracted from NCEP/NCAR [16]. Its temporal resolution is four time intervals (00, 06, 12, 18 UTC) and spatial resolution—2.5° latitude × 2.5° longitude. There are some publications, in which this data array was compared with observation data and other reanalyses [e.g., 17, 18]. The Black sea region is limited by 37–50 °N, 27–45 °E.

A technique by [10] is applied to separate the anticyclone eddies and their frequencies are calculated. The selected anticyclone parameter is reduced to the area of 1 km², dividing frequency by the area of a region. The Black sea anticyclone case snapshot, received by the technique and NCEP/NCAR data, is shown in figure 1a (24 March 1976, 0 UTC).

Daily data of air temperature observations from the European Climate Assessment & Dataset project [19] at 13 stations in the Black sea region for 1951–2012 were used. These Black sea stations are Anapa (44.9 °N, 37.33 °E), Armavir (44.98 °N, 41.12 °E), Feodosiya (45.03 °N, 35.38 °E), Gelendzhik (44.56 °N, 38.08 °E), Henichesk (46.17 °N, 34.82 °E), Izmail (45.37 °N, 28.85 °E), Kerch (45.4 °N, 36.42 °E), Krasnodar (45.03 °N, 38.98 °E), Odessa (46.43 °N, 30.77 °E), Rostov-on-Don (47.25 °N, 39.75 °E), Simferopol (44.96 °N, 34.12 °E), Sochi (43.6 °N, 39.72 °E), Tuapse (44.1 °N, 39.07 °E). The time series of air temperature on selected stations do not contain more than 25% of the date void for 1950–2012. The map where stations are marked is shown in figure 1b.

Using the temperature data set, the values of the 5th (P5) percentile of the intraseasonal daily temperature anomalies (i.e. threshold value of the extreme low temperature), calculated from the smoothed annual cycle, were obtained [21].

The NAO phases and different EN types manifestation on analyzed climate characteristics was studied using composite analysis. The monthly NAO index for 1951–2012 was used from website [20]. To select the NAO phases, about 15% of the total sample size (~30 months) were selected from either end of the ranked sample, i.e., for each phase, positive or negative, with maximum absolute values of the NAO index. This technique is described in detail in [10]. The EN classification by [12] is attracted to estimate the EN influence on anticyclone parameter and extreme temperature. Composite significance was estimated by the Student's t-test (significance level $p < 0.1$).

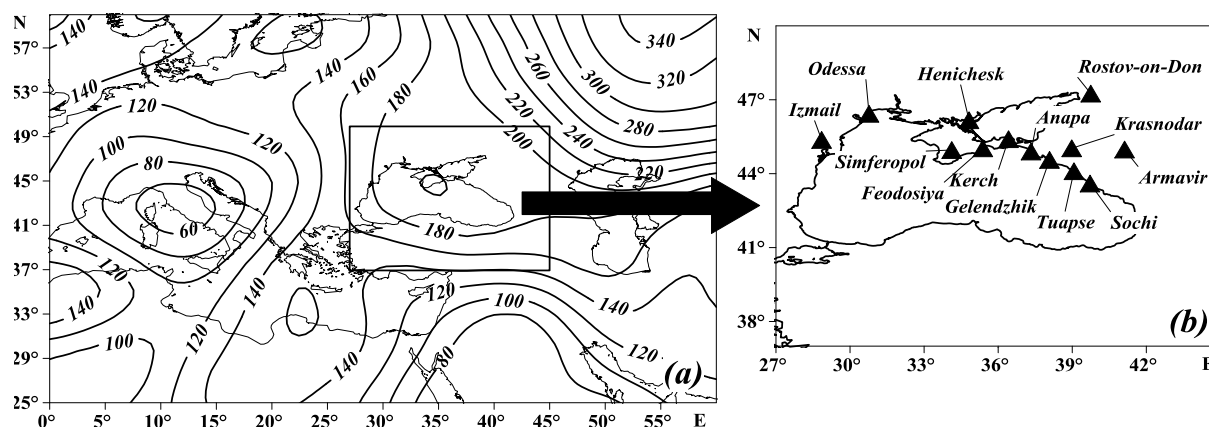


Figure 1. Geopotential height at 1000 hPa for 24 March 1976, 0 UTC (a) and location of stations (b) in the Black sea region.

3. Results and discussion

3.1. Manifestation of NAO

It is known that the NAO has a strong influence on the structure of hydrometeorological fields over the Atlantic-European region during all seasons [10, 22]. The phases of this mode are characterized by spatial shift of the Iceland Low and Azores High. It is accompanied by increase/decrease in the SLP gradient between these action centers of atmosphere, strengthening/weakening of the zonal flow [10, 22, 23]. As a result, the cyclone and anticyclone tracks are displaced, characteristics of these eddies are changed [18, 24].

Composite analysis shows significant changes of anticyclone and extreme temperature parameters during different NAO phases only in the winter. It is found out that winter positive NAO phase (NAO+), relative to the negative phase (NAO-), is accompanied by about 50% increasing of anticyclone frequency in the Black Sea region. This result coincides with study of [25]. The winter threshold value of the extreme low temperature (P5) in the Black Sea region during NAO+, relative to the opposite phase, increases by ~ 60%. This demonstrates a smaller absolute threshold value during NAO+. For example, the P5 value at the Krasnodar station for NAO+ is -2.9 °C, and it for NAO- is -10.7 °C.

Previous studies [5, 10, 26] shows that the positive NAO phase is associated with the strong anticyclone frequencies increase in the subtropical gyre between 30° and 40° N and displacement of anticyclone tracks to south Europe. As a result, it was to cause the increasing of extreme winter daily temperature at the end of the 20th century. However, here we present quantitative measures of both anticyclone frequencies and thresholds of extreme low temperature for the NAO phases over the Black sea region from the end of the 20th century to the beginning of the 21st century.

3.2. Manifestation of different El Nino types

To analyze the EN manifestations on anticyclone and extreme temperature parameters during different types, the classification, more detailed in [14], is attracted. According to this classification, the EN events are separated into three types: spring (SPR), summer-autumn short-lived (SAS) and summer-autumn long-lived (SAL) types. Their typical characteristics are given in table 1. During the 62-yr analyzed period, the first type was observed 8 times, the second type - 7 times, and the third type - only twice. To obtain statistically significant estimates the lengths of time series (i.e. 7–8 or 2 months·year⁻¹) are not enough, but it is possible to demonstrate the different character of regional manifestations of the EN types. In this investigation the analysis of manifestations of different EN types on studied climate parameters is given for only the SPR EN type and SAS EN type.

The seasonal average changes of anticyclone parameters in the Black Sea region during SPR EN type, relative to SAS EN type, are insignificant. However, the two EN types are accompanied by anticyclone frequency anomalies of the opposite signs during certain months, especially in April and September, and by positive frequency anomalies in cold months, when the EN event is intensive (figure 2). At the same time the SPR EN type is characterized by more intensive extreme cold temperatures than SAS type (figure 3). Such temperature distribution is consistent by [14].

Table 1. Typical properties of different El-Nino types by [14].

Characteristic	Spring type	Summer-autumn short-lived type	Summer-autumn long-lived type
Beginning	April	July	September
Maximum SST anomaly in Nino 3.4 region, °C	+1.85	+1.24	+1.26
Duration, months	12	9	20

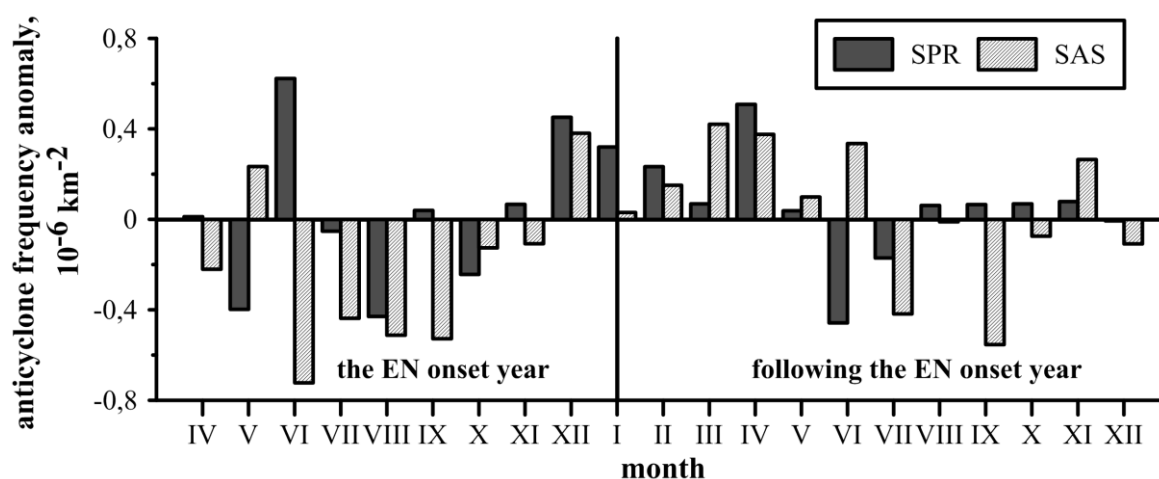


Figure 2. Composites of anticyclone frequency anomalies during SPR and SAS EN types in the Black sea region.

4. Discussion and conclusions

Thus, the changes of anticyclone activity and extreme temperature over the Black Sea region, associated with the NAO phases and the EN types have been studied. It is shown that the most intense NAO manifestations in the anticyclone parameters and extreme temperature anomalies are in winter. The positive NAO phase, relative to the negative one, is accompanied by a statistically significant increasing of anticyclone frequency and decreasing of the threshold of extreme cold temperature in the Black Sea region during winter.

The mechanism of NAO influence on anticyclone activity over Europe has been specified. It is estimated that anticyclone frequency in the Black Sea region in winter positive NAO phase is about 50% higher than in negative one. At the same time it is shown that winter threshold value of the extreme low temperature (P5) in the Black Sea region during NAO positive phase increases by ~ 60% relative to the opposite phase.

The interannual changes of anticyclone frequency and extreme low temperature are examined

in association with the EN taking into account its classification. It is shown that the manifestations of EN types are more intense in the autumn-winter. The SPR EN type and SAS type are characterized by anticyclone frequency anomalies of the opposite signs in the Black Sea region. The absolute threshold extreme of cold temperature values in the region under consideration are higher during SPR EN than in SAS type.

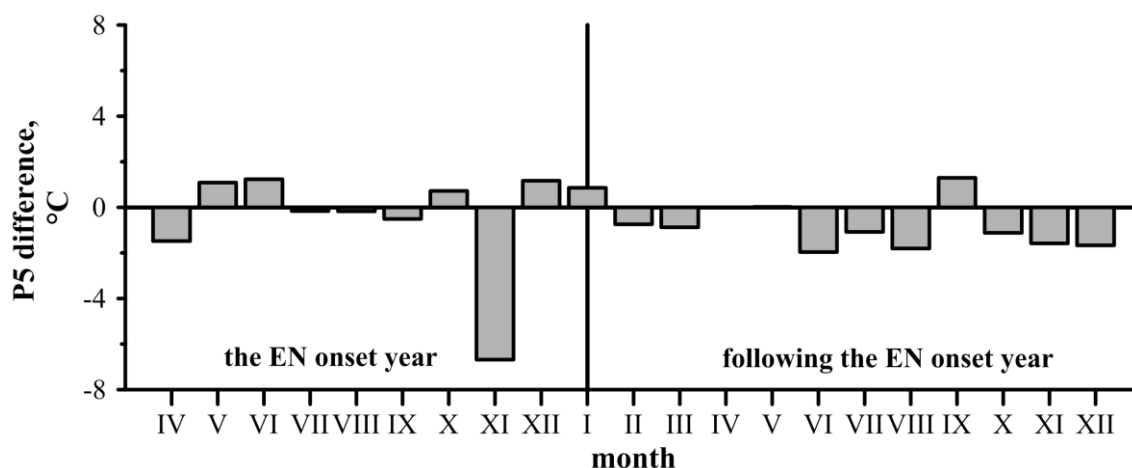


Figure 3. The difference of P5 thresholds during SPR and SAS EN types in Krasnodar station.

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