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Climate variability of winter anticyclones in the Mediterranean-Black Sea region

Elena Voskresenskaya [a, *], Michael Bardin [b], Olga Kovalenko [a]

[a] *Federal State Budgetary Scientific Institution, «Institute of Natural and Technical Systems», Lenina St., 28, Sevastopol 299011, Russian Federation*
[b] *Institute of Global Climate and Ecology of Russian Committee on Hydrometeorology and Russian Academy of Sciences, Glebovskaya St., 20B, Moscow 107258, Russian Federation*

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A B S T R A C T

The climatology of winter anticyclone frequency in the Mediterranean-Black Sea region is studied on the basis of NCEP/NCAR reanalyses for 1951–2012. Time series of average anticyclone frequency are calculated for different parts of the region. It is found that the anticyclone frequency is increased significantly over the Black sea and Western Mediterranean regions while decreased over the Eastern Mediterranean. Regional manifestation of global climate processes in variability of the anticyclone frequency is investigated.

1. Introduction

Synoptic vortices (cyclones and anticyclones) in the Mediterranean-Black Sea region are an important part of the large-scale circulation. The frequency and intensity of these vortices has a strong effect on spatial structure of temperature and precipitation fields, including weather extremes, thus affecting many aspects of human life (economy, infrastructure, health etc.).

Several recent investigations are focused on climatology of cyclones and their variability in the Mediterranean-Black Sea region (for instance, Trigo and Davies, 1999; Bardin and Polonsky, 2005; Voskresenskaya and Maslova, 2011). However, anticyclone variability in this region is not yet clearly understood. It has been examined only by some authors. Polonsky et al. (2007) showed that the anticyclone frequency in the Black Sea region increased from the late 1960s to the end of 1980s in all seasons, especially in winter. Xiangdong et al. (2012) noted that anticyclones in Eurasia, including the Mediterranean region, have intensified since the mid 1990s after a long period of weakening of anticyclone activity.

These changes of anticyclonic activity are associated with global climate processes in the atmosphere-ocean system (e.g. NAO and AMO) as was investigated in a few papers (e.g. Bardin and Polonsky, 2005; Polonsky et al., 2007). It was confirmed that the anticyclone frequency in the North Atlantic, including the Mediterranean-Black Sea region, increases in the positive NAO phase (Bardin and Polonsky, 2005). Polonsky et al. (2007) did not find significant differences of anticyclone intensity (area, height) in the Black Sea region during different NAO phases. At the same time, several studies have found a consistent and statistically significant ENSO signal on the European climate (Fraedrich and Muller, 1992; Moron and Plaut, 2003; Lopez-Parages et al., 2015). It was shown, that during cold phase of ENSO is observed excess of anticyclonic days in winter over western and central Europe. ENSO events are closely linked to the PDO phases (Wolter and Timlin, 1998). Authors found that warm ENSO phase occurs more frequently and intensively during the positive PDO phase and cold ENSO phase-during the negative PDO phase. Their impact on the climate characteristics was investigated for different regions of the North Hemisphere (Gershunov and Barnett, 1998; Kim et al., 2013; Wang et al., 2014). However results obtained by different authors do not clearly describe the anticyclonic activity and its variability in the Mediterranean – Black sea region. This paper is focused on statistics of winter anticyclone frequency in the Mediterranean-Black Sea region and its variability on interannual to interdecadal scales, associated with the global climate processes in the atmosphere-ocean system.

* Corresponding author.
E-mail addresses: elena_voskr@mail.ru (E. Voskresenskaya), mick-bardin@yandex.ru (M. Bardin), kovalenko_olga89@mail.ru (O. Kovalenko).

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2. Data and methods

The set of anticyclone characteristics (coordinates of the center and some indices of intensity, e.g. area and height) within the 20 – 80 N latitudinal belt for 1951–2012 is calculated using data of geopotential height on 1000 hPa from NCEP/NCAR Reanalysis 1 (Kalnay et al., 1996). Temporal resolution of that reanalysis is four times a day (00, 06, 12, 18 GMT), spatial resolution – 2.5° × 2.5°. In this paper we considered only winter season (DJF). The studied areas shown in Fig. 1 include the Black sea region (37–50° N, 27–45° E), Western Mediterranean (35–47° N, 6–18° E) and Eastern Mediterranean (29–41° N, 14–38° E). As a measure of the North Atlantic Oscillation for the period 1951–2012 the NAO index based on the Rotated Principal Component Analysis from Barnston and Livezey (1987) was used, also see (http://www.cpc.ncep.noaa.gov/).

Using the technique developed by Bardin (1995), anticyclones and their frequencies were detected. Synoptic eddy is determined as a domain of elevated pressure bounded by closed isobars and centered at node of the regular grid. If the center of the eddy does not coincide with a node of the grid, this center is specified as the geometric center of the figure located inside the isobar nearest to the node and such that the pressure on this line differs from the pressure at the node by 1 hPa. We analyze anticyclone frequency in a region in particular season. The frequency is defined as the ratio of the number of centers of synoptic formations detected in the region during the season for all observation times to the total number of observation times (we assume a reanalysis field an "observation"). This can be expressed for the seasonal frequency of the year y as

$$f_{Ry} = \sum_{t \in Sy} \sum_{1 \le i \le Ct} \delta_{iR}/Nty$$

where t is observation time, Sy season of the year y, Ct total number of vortices within 20–80 N belt, $\delta_{iR} = 1$ if i-th vortex center belongs to the region, or 0 otherwise (so the sum $\sum_{1 \le i \le Nt} \delta_{iR}$ is the number of centers within the region at time t); Nty is total number of observations within the season of the year y.

In order to provide comparability of statistics for different regions, the calculated values were reduced to the area of 1 km^2 dividing f_R by the area of a region; resulting relative density will be denoted by f^*_R. The mean and standard deviation of regional anticyclone frequency f^*_{Ry}, and its linear trend for the whole period 1951–2012 were calculated for every studied region.

Standard statistical methods (cross-correlation and composite analysis) were used to estimate the connections between the anticyclone frequency and global climate processes. Lagged cross-correlation analysis was applied to study some aspects of relationship between NAO and the anticyclone frequency. A positive shift in the lagged cross-correlation function means a leading NAO index relative to the anticyclone frequency. Statistical significance of the correlation coefficient, linear trend and difference of composites at 95% confidence level was estimated using Student's t-test.

3. Climatology of anticyclone frequency

The Mediterranean-Black Sea region is located between the subtropics and mid-latitudes of the Northern Hemisphere, and, therefore, has a specific climate. The climate variability in this region is associated with five large subtropical high pressure systems above the oceans: the Azores High, South Atlantic High, North Pacific High, South Pacific High, and Indian Ocean High. These high pressure systems are characterized by spatial shift from winter to summer and playing a major role in the generation of cyclones and anticyclones and principal directions of their

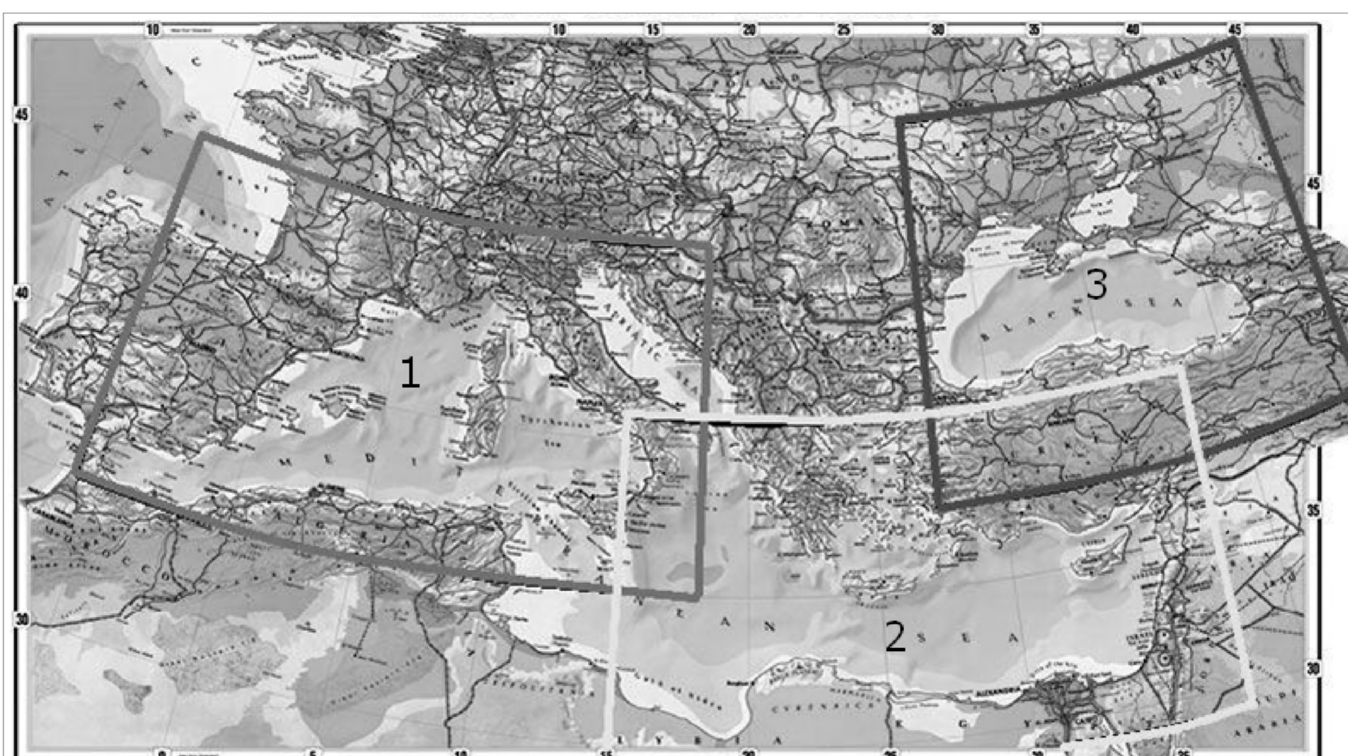

Fig. 1. Scheme of the Mediterranean-Black Sea region: (1) – the Western Mediterranean, (2) – the Eastern Mediterranean, (3) – the Black Sea region.