VERTICAL STRUCTURE OF MEDITERRANEAN ANTICYCLOGENESIS

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ABSTRACT

A comprehensive climatology of Mediterranean migratory anticyclonic tracks along with their statistical properties was generated with the aid of the University of Melbourne finding and tracking algorithm (MS algorithm), based on the ERA-Interim 1.5°x1.5° mean sea level pressures for 1979-2012.

For the study of the vertical thermal extent of synoptic systems, an algorithm was developed by the University of Melbourne as an extension module of the MS algorithm. The module uses temperature datasets on several isobaric levels and calculates the average temperature difference between the system core and an environmental ring set at a distance corresponding to the system size. With the aid of the extension module, the Mediterranean anticyclones have been characterized as cold or warm-core, based on the temperature differences for the lower isobaric levels.

With the aim of getting a perspective on the vertical structure of Mediterranean anticyclogenesis, the mean and anomaly fields of geopotential heights, temperature and relative vorticity are studied throughout the troposphere. The thermal type of the systems, their position and the season at the time of generation are taken under consideration with the scope to elucidate their particular role in the formation process. It is found that cold-core anticyclogenesis exhibits a baroclinic character and its thermal signal mostly weakens with height, suggesting the low-level cooling as one of the main forcings of genesis, while warm-core anticyclogenesis exhibits an enhancement of the thermal signal with height.

Keywords: anticyclogenesis, Mediterranean, cold-core and warm-core anticyclones

1. Introduction

Anticyclones are governed by different atmospheric dynamics according to their scale, e.g. the extratropical anticyclones belong to synoptic-scale features induced by baroclinic instability, while mesoscale anticyclones can be triggered by uplift of air masses over a mountain barrier (Bluestein, 1992; Ioannidou and Yau, 2008).

Since the thermal characteristics of anticyclones are characterized by large variations, anticyclones can be also classified according to their thermal structure. Cold-core anticyclones are linked to low-level cooling, developing over continental interiors, while warm-core anticyclones result from convergence in the upper troposphere and subsidence beneath (Musk, 1988).

A comprehensive climatology of anticyclones affecting the Mediterranean was assembled employing, for the first time, an objective identification and tracking scheme (Hatzaki *et al*., 2014). In the present study, aiming to get a perspective on the vertical structure of Mediterranean anticyclogenesis, the mean and anomaly fields of geopotential heights, temperature and relative vorticity are studied throughout the troposphere.

2. Data and methods

2.1. Examined area and dataset selection

The study focuses on the greater Mediterranean area, bounded between 10°W and 40°E, and 25°N and 50°N. The reanalysis datasets of geopotential height, temperature and relative vorticity from the ERA-Interim Project have been used (Dee *et al*., 2011). The data cover the period from 1979 to 2012 and the isobaric levels of 1000hPa, 850hPa and 500hPa on a 1.5°x1.5° resolution were selected.

2.2. Methods

The climatology of the Mediterranean anticyclonic tracks (Hatzaki *et al*., 2014) was generated with the MS tracking algorithm developed according to the Lagrangian perspective, to identify and track low and high pressure centres on a sphere (Murray and Simmonds, 1991).

For the examination of the vertical thermal extent of synoptic systems, an algorithm was developed by the University of Melbourne as an extension module of the MS algorithm (Garde *et al*., 2010). The basic idea of the extension module is that the average temperature difference between the system core and an environmental ring set at a distance corresponding to the system size (as provided by the MS algorithm) is calculated throughout the troposphere during the lifecycle of a system as a metric of the core temperature anomaly. Thus, the Mediterranean anticyclonic systems can be characterized as cold or warm-core, based on the temperature difference (ΔT) between the core and the environmental ring for the lower isobaric levels (1000-925 hPa).

The Mediterranean area is divided in 10 boxes, for each generated anticyclone to be assigned to a box according to its position at the time of anticyclogenesis. This division is made in order to detect the different processes that govern anticyclogenesis throughout the examined area. Then, following the classification of the systems according to their thermal structure at the time of their genesis, the frequency of the cold and warm-core anticyclones in each box is determined and the seasonal composite maps of geopotential heights, temperature and relative vorticity are created. Therefore, 40 composite maps are produced for each examined parameter, which are compared to the respective climatology map, creating, thus, the corresponding composite anomaly maps.

3. Surface thermal structure of the generating anticyclones

Focusing on the spatial distribution of the frequency of anticyclogenesis, it is found that the frequency of anticyclogenesis is similar throughout the year, though exhibits a minimum in autumn (see also Hatzaki *et al*., 2014).

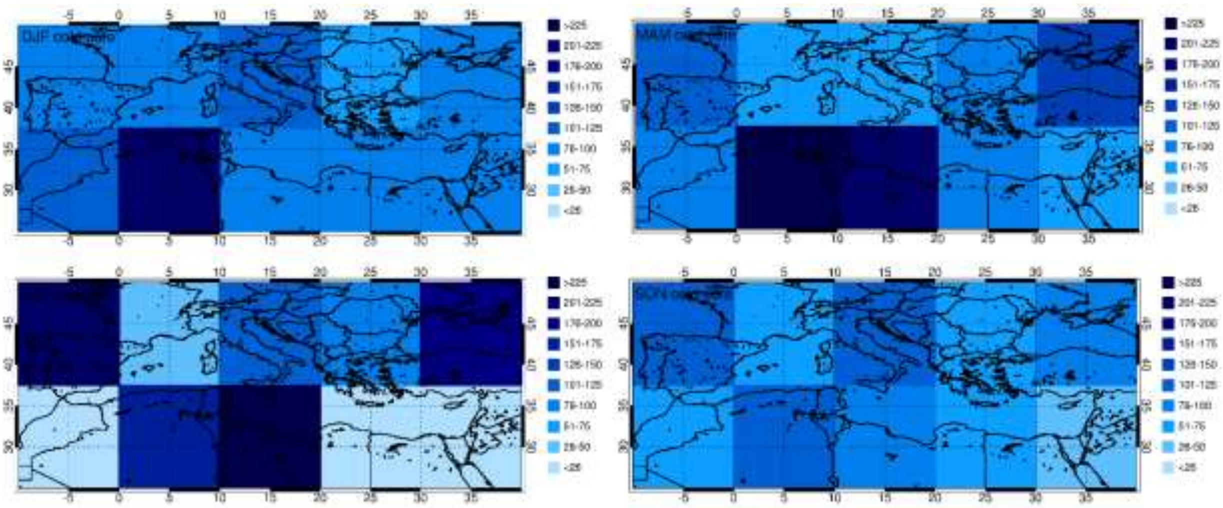

Figure 1: Seasonal variations (DJF, MAM, JJA, SON) of cold-core anticyclogenesis. The values indicate the total number of generating systems in each box.

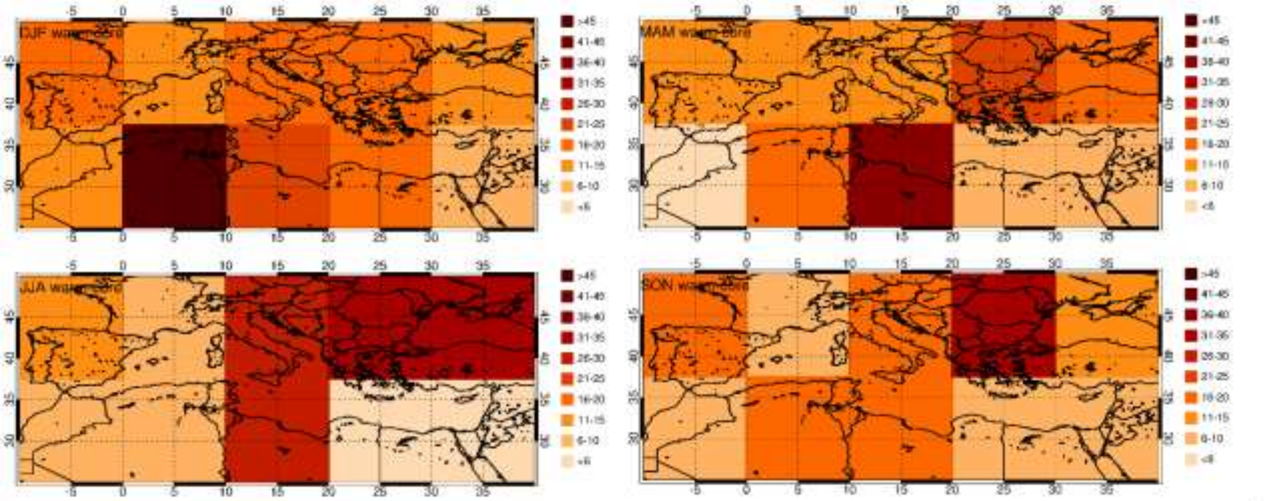

Figure 2: As in Figure 1, but for warm-core anticyclogenesis.

Specifically, the vast majority of anticyclogenesis affecting the Mediterranean is cold-core (~85%), as the generated anticyclones are mostly shallow systems, easily created by radiative cooling at the surface or by increased stability due to low-level cold air advection. During winter, spring and autumn, cold-core anticyclogenesis is maximized mainly over the Northern African continental areas (Figure 1), possibly due to the strengthening of the Atlas Mountains cyclogenetic activity, mainly during spring, which favours the generation of cold anticyclones after the passage of the frontal depressions of orographic origin in the area or due to radiative cooling over the extensive desert areas (Ioannidou and Yau, 2008).

The warm-core anticyclogenesis exhibits its maximum over North Africa during the cold season that can be possibly attributed to the increased frequency of the extended upper level blocking anticyclones in the Atlantic and the European area (HMSO, 1962), regulating the frequency of the surface warm anticyclones and the cyclogenetic activity as well (Kouroutzoglou *et al*., 2015). During summer, warm-core anticyclogenesis is maximized over the Balkans and the Black Sea, while the increased frequency over North Africa reflect the eastward extensions of the Azores anticyclone accompanied by upper level warm ridges, a behaviour connected to heat waves in the Mediterranean (Figure 2).

4. Vertical structure of the generating anticyclones

The examination of the vertical structure of cold-core generating system reveals a baroclinic character for both winter and summer, followed by an enhancement of relative vorticity anomalies with height. The thermal vertical structure shows an alternation of the thermal signal with height. This pattern is, for example, connected to the subtropical anticyclones of Northern Africa during winter (Figure 3), whose the primary forcing appears to be low level cooling as they are accompanied by the presence of cold anomalies at low levels (Ioannidou and Yau, 2008).

On the other hand, the majority of the warm surface anticyclones exhibit a less prominent baroclinic character, while connected to a warm ridge and enhanced negative vorticity anomalies in the middle troposphere, as a result of the existence and northward extension of the sub-tropical jet stream along with the existence of upper-level blocking anticyclones (Figure 4).

5. Conclusions

In this study, some aspects of the Mediterranean anticyclogenesis are presented. Specifically, the Mediterranean is subject to anticyclogenesis, mainly cold-core, throughout the year, though a spatial transition of its maxima is evident among seasons. Cold-core anticyclogenesis exhibits a baroclinic character, while its thermal signal mostly weakens with height, suggesting the low-level cooling as one of the main forcings of genesis. The warm-core anticyclogenesis is much less frequent and followed, thus, by unclear vertical characteristics, though an enhancement of the thermal signal is noted for both cold and warm season. They exhibit their maximum frequency during summer, with a prominent peak over Balkans that is connected with the Etesian winds that affect the Aegean Sea.

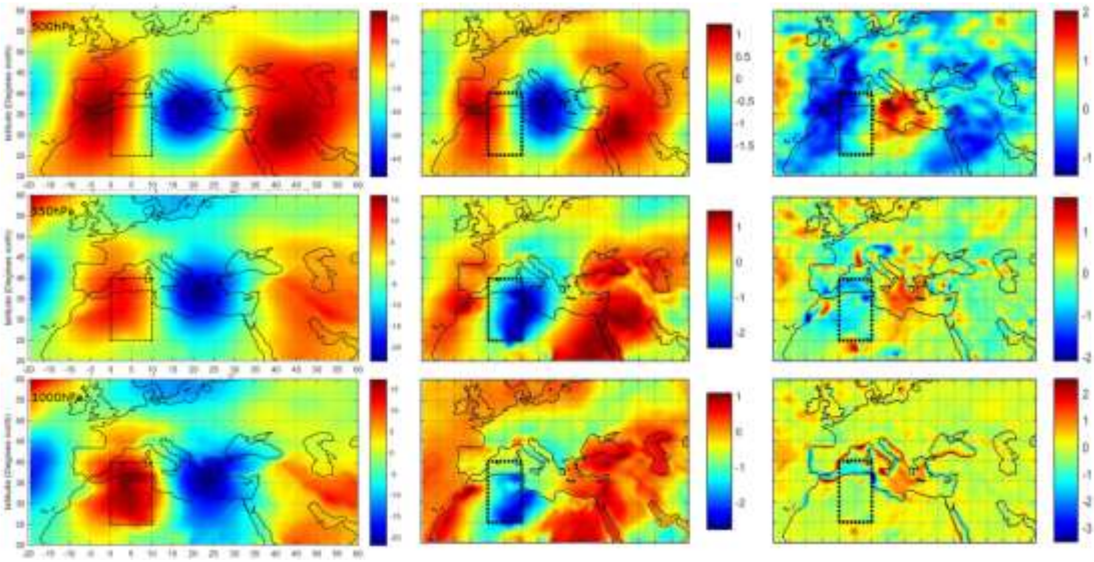

Figure 3: Spatial distributions of geopotential height (in m; left column), temperature (in K; middle column) and relative vorticity (in 10^{-1} PVU; right column) anomalies at 500, 850 and 1000hPa for cold-core anticyclogenesis during winter. The box encompasses the generated systems under consideration.

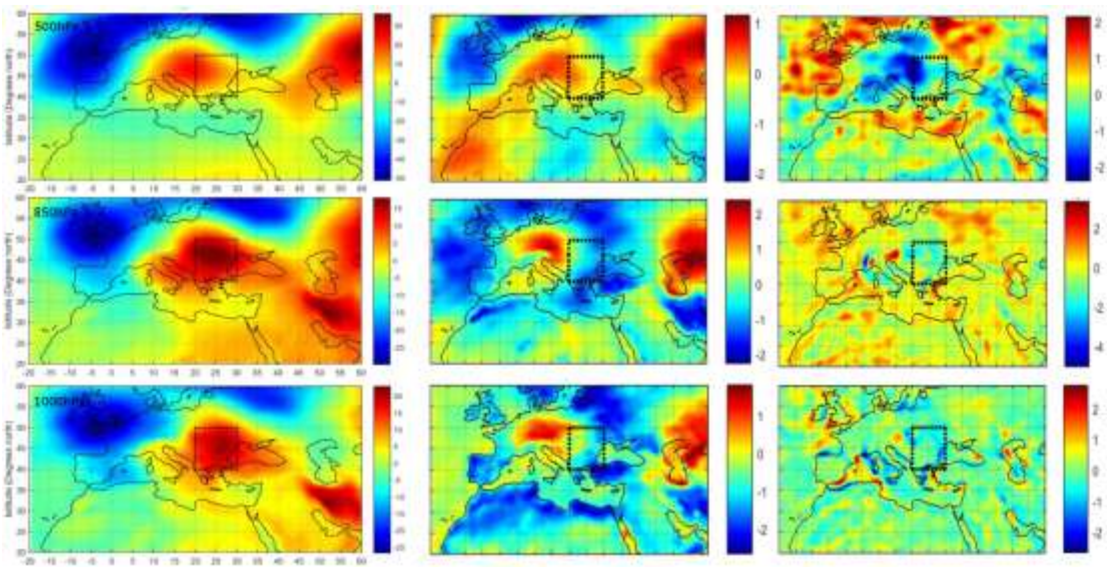

Figure 4: As in Figure 3, but for warm-core anticyclogenesis during summer.

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REFERENCES

1. Bluestein H.B. (1992) Principles of Kinematics and Dynamics. Vol. 1, Synoptic–Dynamic Meteorology in Midlatitudes, Oxford, University Press.
2. Dee D.P. and Coauthors (2011) The ERA-Interim reanalysis: Configuration and performance of the data assimilation system, Quart. J. Roy. Meteor. Soc., **137**, 553–597.
3. Garde L.A., Pezza A.B., Simmonds I. and Davidson N.E. (2010) A methodology of tracking transitioning Cyclones, IOP Conf. Series: Earth and Environmental Science, **11**, 012007.
4. Hatzaki M., Flocas H.A., Simmonds I., Kouroutzoglou J., Keay K. and Rudeva I. (2014) Seasonal aspects of an objective climatology of anticyclones affecting the Mediterranean, J Climate, **27**, 9272–9289.
5. HMSO (1962) Weather in the Mediterranean I: General Meteorology, 2nd ed, London, Her Majesty's Stationery Office.
6. Ioannidou, L. and Yau M.K. (2008) A climatology of the Northern Hemisphere winter anticyclones, J. Geophys. Res., **113**, D08119.
7. Kouroutzoglou J., Flocas H.A., Hatzaki M., Keay K., Simmonds I. and Mavroudis A. (2015) On the dynamics of a case study of explosive cyclogenesis in the Mediterranean, Meteorol. Atmos. Phys., **127**, 49–73.
8. Murray R.J. and Simmonds I. (1991) A numerical scheme for tracking cyclone centres from digital data. Part I: Development and operation of the scheme. Aust. Meteorol. Mag., **39**, 155–166.
9. Musk L.F. (1988) Weather Systems, Cambridge University Press.