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Mediterranean tropical-like cyclones: Impacts and composite daily means and anomalies of synoptic patterns

P.T. Nastos[a,*], K. Karavana Papadimou[a], I.T. Matsangouras[a,b]

[a] Laboratory of Climatology and Atmospheric Environment, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, University Campus, GR-15784 Athens, Greece

[b] Hellenic National Meteorological Service, Ellinikon, GR-16777 Athens, Greece

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ABSTRACT

In the Mediterranean region, a rapidly rotating storm system characterized by gale winds, severe precipitation, and low pressure center, accompanied with a spiral pattern of thunderstorms, is occasionally observed. These tropical-like cyclones (TLC), known as Medicanes or Mediterranean 'hurricanes', have similar characteristics with hurricanes and a significant amount of research has been done in recent years to investigate their atmospheric characteristics and impacts. The Laboratory of Climatology and Atmospheric Environment (LACAE), National and Kapodistrian University of Athens, has established a systematic effort since 2009, to document the impact of severe atmospheric phenomena (e.g. medicanes, cyclones, tornadoes, waterspouts), especially over the eastern Mediterranean region.

The objective of this study is to discuss on one hand, the intra annual and inter annual distribution of medicanes along with the composite daily means and anomalies of synoptic conditions and instability indices at the middle and lower troposphere, sea level pressure (SLP) and sea surface temperature (SST) as well, during medicane days, based on the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis data sets. On the other hand, the geographical distribution of medicane impacts over Mediterranean region with respect to period from 1969 to 2014, is illustrated by utilizing the Geographic Information Systems (GIS).

The findings shed light on the high activity of medicanes during autumn and winter with maxima in September, decreasing thereafter with a long tail extending in spring and minimizing in summer. The average number of the selected medicanes is 1.4 ± 1.3 events per year while their inter-annual variability is remarkable, although there is not any statistically significant trend (95% confidence level) within the examined period. We found from the analysis of the composite daily anomalies of the synoptic conditions that medicanes initiate and further develop in Mediterranean regions where cold air intrusions appear in the upper atmosphere associated with warm sea waters. Last but not least, the impacts of medicanes over coastal areas, including infrastructure damage and casualties due to associated strong winds, heavy rainfall, and in rare cases, tornadoes, are well presented, indicating the high concern of such extreme atmospheric phenomena should be given by stake holders towards resilience of the society.

1. Introduction

Mediterranean Sea, appears to be a vulnerable area for cyclogenesis (Petterssen, 1956). The specific orographic structures surrounding the Mediterranean, such as Alps, Pyrenees and Atlas mountains may trigger air flow to vortex development. Besides the synoptic formation of cyclones in the Mediterranean, occasionally there are cases when meso-scale extreme low pressure systems appear, having the characteristics of tropical cyclones, as they captured by satellites. Mediterranean Tropical Like Cyclones (TLC) known as Medicanes are accompanied by strong winds, heavy precipitation and thunderstorms, causing occasional severe damages in private property, agriculture and communication networks, or resulting in flooding of populated areas, posing a risk to human life. Medicanes are rare phenomena that in many cases induce serious impacts, such as infrastructure, telecommunication and transportation damage, farmland damage, and are accompanied by strong winds and surges, floods or even tornadoes, causing also fatalities in some cases. These meso-scale cyclones, with diameter, usually less than

* Corresponding author at: Laboratory of Climatology and Atmospheric Environment, Department of Geography and Climatology, Faculty of Geology and Geoenvironment, National and Kapodistrian University of Athens, University Campus, GR 157 84 Athens, Greece.
E-mail address: nastos@geol.uoa.gr (P.T. Nastos).

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300 km, have a rounded structure and a warm core, as well as intense low sea level pressure (Businger and Reed, 1989). Their intensity appears much weaker than tropical hurricanes; however, some of them have reached tropical hurricane strengths (Akhtar et al., 2014). Tous et al. (2013) analyzing twelve medicane cases, showed that the Genesis Potential Index, developed to describe the formation of tropical hurricanes, exhibits statistically significant high values at the time of medicane formation.

Emanuel (2005) indicated that their genesis is triggered when an upper-level cutoff low is advected over an area, resulting in air mass lifting and cooling causing convective instability. The cold and humid air under the upper low combined to the warmer sea, favor the development of cyclones with tropical-like characteristics. Overall, there is high scientific concern regarding medicane case studies, focusing on different aspects of their structure and evolution (Pytharoulis et al., 1999, 2000; Homar et al., 2003; Moscatello et al., 2008a, 2008b; Miglietta et al., 2011). Conte et al. (2011) analyzed a medicane that affected southeastern Italy in September 2006 by means of instability parameters, which have been used to identify different parameters of severe weather over northern Italy (Costa et al., 2001). Recently, Miglietta et al. (2015) performed numerical experiments using the WRF model to investigate the model physics in simulating the structure and intensity of a Mediterranean hurricane; however, there is not a general perspective on their properties, lifetime and evolution (Miglietta et al., 2013). Generally, the detection of these phenomena is considered to be difficult and includes high resolution meteorological analysis data and dense maritime observations. Besides, there is a number of criteria to identify medicanes, taking into account the diameter, the symmetry and the eye of the cyclone, as well as the duration of these phenomena. The use of satellite data can be complementary to this method as well (Tous and Romero, 2013). Some of the cases classified as medicanes in the literature from direct observations do not meet strictly the selection criteria.

The variety of impacts that characterize the phenomena reflects the diversity of the systems as far as its path, diameter and life span, while their physical parameters also play a critical role. Impacts caused by medicanes have been reported in literature, but no complete database of events is available. Most of the impacts are found in case studies, generally including numerical analyses (Reed et al., 2001; Arreola et al., 2003; Homar and Stensrud, 2004) and meteorological environments studies (Emanuel, 2005; Tous and Romero, 2011), while others use a combined modeling and satellite approach (Levizzani et al., 2012; Miglietta et al., 2013). The reason a complete database of impacts is difficult to maintain, is that for a number of cases, mostly older events, there are no officially reported impacts attributed to specific events. On the contrary, more resent cases are well studied in literature (Levizzani et al., 2012; Terranova and Gariano, 2014; Sachweh, 2015). Also, some impacts that can be attributed to medicanes are found in flood risk assessment studies (Diakakis et al., 2011; Benouar, 2015).

Medicane's impacts around the Mediterranean vary among different cases. Some cases have caused few impacts with no damages reported, while others can be extremely catastrophic and damaging for economies. For example, the catastrophic medicane in September 2003, caused large socioeconomic impact in Tunisia (Ouali et al., 2008), where many areas were flooded and there was a large number of damages in private and public property. Extreme rainfall was recorded during the two days when the cyclone was located over the Gulf of Tunis and the Gulf of Hammamet (16–18 September), resulting in flash floods in many areas. In addition, there were also casualties estimated in some dozens (Ouali et al., 2008), although the exact number of fatalities is not known.

Tornadoes can also be induced by medicanes; however their record has not been systematic. For example, in September 1996 a tornado outbreak was produced by a cyclone formed offshore the Valencian coast: six tornadoes were developed over the Balearic Islands (Homar et al., 2003) and strong winds caused damages in boats and trees, while total damages were estimated at €6 million (Homar et al., 2001). Tornadoes have been reported for other cases of medicanes as well, but in most cases there is no reference for these in literature.

In most cases, damages and casualties can be attributed to severe weather induced by medicanes, as a combination of strong winds, extreme rainfall, tornadoes and, secondarily, flood. Although not all different impacts refer to all medicane cases, these phenomena can be very damaging for economies and can potentially result in loss of human lives. Furthermore, it is important to address that coastal populated areas are strongly affected by these cyclones having impact on infrastructure and transportation.

The aim of this study is to make an effort to identify the variability and the large scale patterns associated with medicanes, by means of composite daily mean and anomalies (1981–2010 Climatology) of climatic parameters and thermodynamic indices, for the period 1969–2014, based on satellite images, literature research and impact studies. Therefore, the classification of the reported impacts has been accomplished and the geographical distribution of them has been visualized by the application of Geographic Information Systems (GIS). The study is organized as follows: Section 2 presents the data and methodology used, while the impacts classification along with the composite daily means and anomalies of the synoptic pattern, are discussed in Section 3. Finally the summary and conclusions are presented in Section 4.

2. Data and methodology

The Laboratory of Climatology and Atmospheric Environment (LACAE; http://lacae.geol.uoa.gr), National and Kapodistrian University of Athens, has established a systematic effort since 2009, to document the impact of severe atmospheric phenomena (e.g. medicanes, cyclones, tornadoes, waterspouts, lightnings), especially over the eastern Mediterranean region. Taking into account that medicanes are rare atmospheric phenomena differentiating from common cyclones developed within the Mediterranean, we examined all available cases published in the literature as well as administrative records, impact reports and registered medicanes derived by satellite images from METEOSAT infrared channel (http://www.eumetsat.int/website/home/index.html) and Earth Observing System Data and Information System (https://earthdata.nasa.gov/) (see Table 1 in the Appendix). In this point it is worthy to note the difficulties met in order to identify medicanes only from satellite imagery. Tous and Romero (2013) after having examined around four hundred cyclonic events over 20 years as possible medicane cases, they finally classified only six events as medicanes by the application of specific conditions related to the symmetry of the cloud shape and the presence of an eye-like structure. Thus, the criteria we applied to identify these extreme events concern the detailed structure, the size and the lifetime of the systems using Meteosat satellite images. They must have a continuous cloud cover and symmetric shape around a clearly visible cyclone eye. According to the above criteria and the international literature we have focused on 63 medicane cases, during the period 1969–2014.

The synoptic patterns for the selected medicane cases were identified and discussed by means of composite daily means and anomalies (1981–2010 Climatology) of sea surface temperature (K), sea level pressure (hPa), air temperature (K) and geopotential heights at the isobaric levels of 850 hPa, 500 hPa and 300 hPa, wind shear (m/s; 850 hPa–500 hPa), lifted index (K; surface – 500 hPa) and surface precipitation rate (mm/day). The daily composite means and anomalies of synoptic conditions were based on the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis data sets (Kalnay et al., 1996). As medicane date, it was considered the day corresponding to the first incidence of this rare event in the Meteosat images.

The geographical information system (GIS) software ArcGis 10.3 was used to develop a geo-database with the impacts of medicanes by