Atmospheric Research 153 (2015) 451–464

Contents lists available at ScienceDirect

Atmospheric Research

journal homepage: www.elsevier.com/locate/atmos

The influence of Sardinia on Corsican rainfall in the western Mediterranean Sea: A numerical sensitivity study

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ARTICLE INFO

Article history:
Received 4 April 2014
Received in revised form 2 October 2014
Accepted 6 October 2014
Available online xxxx

Keywords:
HyMeX
COSMO model
Convection initiation
Island interaction
Heavy precipitation events

ABSTRACT

The interaction of orographic effects and moisture availability is of high importance to the precipitation amount and distribution in the western Mediterranean and neighboring land surfaces. In particular, the forecast of heavy precipitation events is still a challenge for operational weather forecast models. In this study, the thermal and dynamical interactions between the two neighboring islands of Corsica and Sardinia in the western Mediterranean Sea are investigated using the COnsortium for Small-scale MOdeling (COSMO) model. Six cases with different synoptic conditions are analyzed and the dependance of the Corsican rainfall on the presence and terrain characteristics of Sardinia is investigated. Besides a reference run with standard model orography, sensitivity runs with removed and flat island of Sardinia are performed. The numerical results show that the daily precipitation amount over Corsica can increase by up to 220% of the amount from the reference run. Whereas most of the sensitivity runs show a decrease of the precipitation amount under strong synoptic forcing, there is no systematic relationship on days with weak synoptic forcing. The differences in the precipitation amount are induced by (i) missing deviation or missing blocking of the southerly flow by Sardinia and (ii) by the influence of cold pools generated by deep convection over Sardinia. These differences can be attributed to changes of low-level convergence and moisture/heat content and their effect on thermodynamic parameters, like convective available potential energy or convective inhibition. Furthermore, the position and translation speed of frontal systems over Corsica on days with strong synoptic forcing also depend on the Sardinian orography. These results demonstrate the high sensitivity of numerical weather prediction to the interaction of neighboring mountainous islands.

1. Introduction

During the late summer and autumn, most of the Mediterranean countries are regularly affected by heavy precipitation events and devastating flash floods (Llasat et al., 2010; Tarolli et al., 2012). Precipitation amounts of more than 100 mm in less than 6 h are not uncommon in these regions (Bresson et al., 2012). According to Ducrocq et al. (2008), these events are often caused by mid-latitude cyclones with embedded deep convection or mesoscale convective systems. Despite multiple risks from hail, lightning, strong winds, and heavy precipitation, these convective systems are still an important forecasting problem in the western Mediterranean region (Fig. 1).

The highest island in this area is Corsica which features about twenty mountains being higher than 2000 m (Lambert et al., 2011). Its main mountain ridge runs from northwest to southeast with a maximum elevation of 2710 m amsl. In the framework of the Hydrological cycle in the Mediterranean Experiment (HyMeX), a multiparametric observation platform was installed in Corsica in 2012. HyMeX aims at a better understanding and quantification of the hydrological cycle and related processes in the Mediterranean with emphasis on high-impact weather events (Drobinski et al., 2014; Ducrocq et al.,

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http://dx.doi.org/10.1016/j.atmosres.2014.10.004
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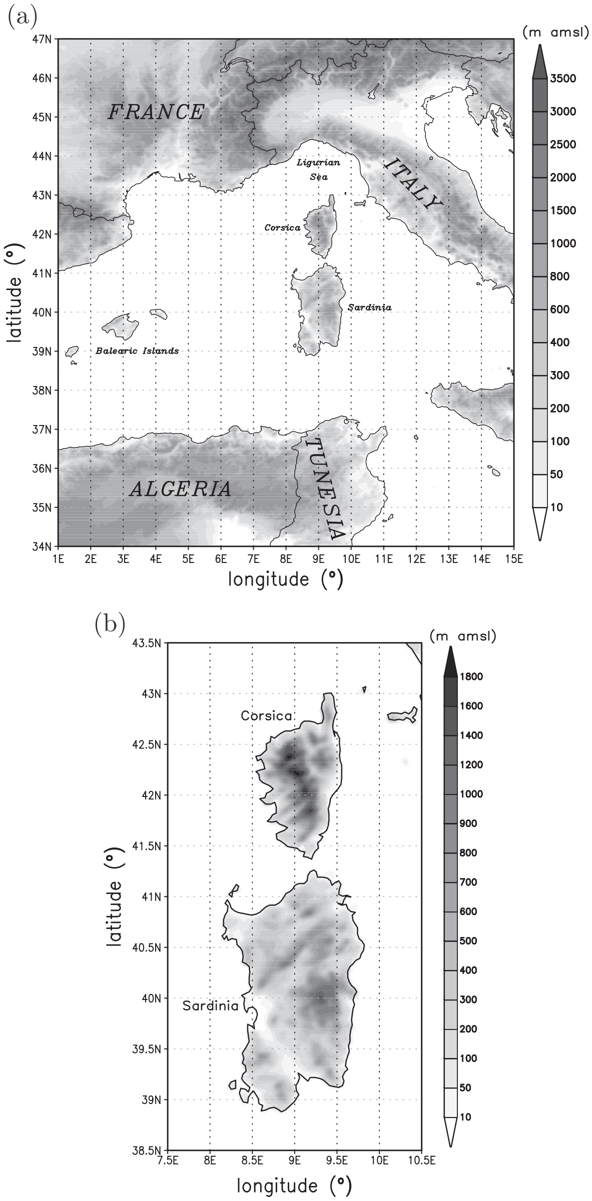

Fig. 1. The western Mediterranean Sea with the surrounding continental land masses (a) and COnsortium for Small-scale MOdeling (COSMO) model topography of Corsica and Sardinia (b).

2014). As Corsica is regularly affected by intense meteorological events like heavy precipitation, lightning, or wind storms (Giorgetti et al., 1994), it is important to understand the phenomena responsible for triggering convection.

Deep convection often initiates due to mesoscale surface heterogeneities associated with variations in land use, soil moisture (e.g. Findell and Eltahir, 2003; Barthlott and Kalthoff, 2011), land–sea contrast, and orography. Mediterranean islands are hot spots for thunderstorm development due to the sharp surface heterogeneity and the low-level moisture supply by adjacent warm water bodies (e.g. Wilson et al., 2001; Qian, 2008; Robinson et al., 2008). Particularly effective at initiating convection are mountainous islands, where the sea breeze and valley winds fall roughly into phase and the two breezes may combine to strengthen the diurnal wind cycle and form an extended sea breeze (Kottmeier et al., 2000). For the island of Corsica, Metzger et al. (2014) investigated the initiation of convection as a function of the incoming flow characteristics (instability, mid-level moisture, wind direction, and wind speed) with convection-resolving idealized numerical simulations. They found that in the case of a weak incoming flow, the location of convective triggering is determined by thermally induced circulations whereas dynamic effects prevail when the incoming flow is stronger. Furthermore, small changes in the direction of the incoming flow in the range of $\pm 30°$ can discriminate between triggering and no triggering of convection. Recently, Barthlott and Kirshbaum (2013) investigated the influence of terrain forcing on the convection over Corsica and Sardinia by numerical sensitivity runs with removed and modified orography. They found that the presence of a land surface is sufficient to initiate convection, but the amount and timing of convective precipitation depend on terrain height. In addition, the proximity of Corsica to a second island of Sardinia has important effects on the low-level wind field as well as the temperature and moisture structure. Sardinia is not as high in elevation as Corsica, but roughly three times as big in horizontal extent (Fig. 1b). As the interaction between both islands may also strengthen the impact of Corsica to continental weather (Lambert et al., 2011), it is important to understand these interactions and the processes involved. By atmospheric measurements alone, those island interaction effects are difficult to assess, or not assessable at all. Therefore, we perform numerical simulations for a number of convective cases. Besides a reference run with standard model orography, we conduct sensitivity tests where we either remove the Sardinian island or where we restrict its maximum elevation to 10 m. This approach allows for identifying and separating individual processes leading to deep convection and for comparing the flow responses of two neighboring islands with different physical characteristics. In particular, we seek to determine the thermal and dynamical impact of Sardinia on Corsican rainfall. Up to now, there exist only few studies about the influence of neighboring islands on convection initiation and most of them were made for the Maritime Continent in South-East Asia (e.g. Qian, 2008; Wu and Hsu, 2009; Wapler and Lane, 2012). In those studies, however, the island sizes were much larger than found in the Mediterranean Sea and the focus was less on local convection initiation but rather on the interactions between large-scale synoptic phenomena. The investigation of island interactions on smaller scales with respect to convective precipitation in the western Mediterranean area and the relevance of those islands for the HyMeX project in general are the main motivation for this study.

2. Method

2.1. Analyzed cases

In order to select suitable cases for our investigation, we use two criteria: (i) the existence of convective clouds on visible and infrared satellite pictures and (ii) a southerly mid-level flow. In total, six days between 2009 and 2011 are chosen for the present study (Table 1): 26 August 2009, 27 August 2009, 15 June 2010, 04 June 2011, 25 October 2011, and 05 November