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Assessment of the role of sea surface fluxes on eastern Mediterranean explosive cyclogenesis with the aid of the limited-area model COSMO.GR

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ABSTRACT

Explosive cyclogenesis, being characterised by complex non adiabatic dynamics at low levels, is difficult to be predicted by operational models, especially in closed maritime regions such as the Mediterranean Sea. The objective of this study is to examine the sensitivity of the limited-area atmospheric model COSMO.GR, which runs operationally at the Hellenic National Meteorological Service (HNMS) as a forecast tool, in effectively simulating the deepening rate and to further explore the role of sea surface heat fluxes for two cases of explosive cyclogenesis in the eastern Mediterranean. Model runs were performed for six different values of the sea roughness model parameter, being proven, among others, to significantly affect the evolution of sea surface heat fluxes. The simulation justified the crucial role of sea surface heat fluxes in explosive cyclogenesis in the eastern Mediterranean by influencing the cyclone deepening rates and the respective minimum values of mean seal level pressure. The smaller values of the sea roughness parameter as compared to the default model value (equal to 20), leads to significant enhancement of the simulated sea surface heat fluxes and in turn produces higher deepening rates during the explosive deepening period. For both cases, the evaluation of the simulated mean sea level pressure values against observations demonstrated that values 10 and 1 better simulated the evolution of the mean sea level pressure along the cyclonic tracks. The results of this study act as a motivation to test the role of specific parameters in operational models associated with diabatic processes towards the improvement of local forecasts, mainly during severe phenomena.

1. Introduction

Explosive cyclogenesis is a phenomenon that takes place over the cold period of the year, it is characterised by exceptionally and unusually large deepening rates, causing heavy rain with the potential of widespread flooding, as well as significant wave heights and gale force winds with serious economic impacts (Nissen et al., 2010). The study of various explosive cyclogenesis cases in the oceans demonstrated that both low-level baroclinic and diabatic processes have a decisive role on explosive deepening, under a variety of upper-level dynamic mechanisms (e.g. Sanders and Gyakum, 1980; Bosart, 1981; Anthes et al., 1983; Keyser and Johnson, 1984; Wash et al., 1992; Fink et al., 2012). It is known that numerical weather prediction models are not always capable of simulating effectively the real surface deepening rates due to the effect of the diabatic processes (Reed and Albright, 1986; Anthes et al., 1983; Kuo and Reed, 1988a, 1988b; Müllen and Baumhefner, 1988; Reed and Albright, 1986; Reed et al., 1988; Giordani and Caniaux, 2001; Katsafados et al., 2011). Latent heat release plays an important role on the deepening rate of explosive cyclones (Gyakum, 1983a, 1983b; Smith, 1984; Plant et al., 2003; Ahmadi-Givi et al., 2004; Gray and Dacre, 2006; Dacre and Gray, 2013), while, in general, the role of sea surface heat fluxes is not considered so crucial and they can either accelerate the deepening rate at some stages of development (Reed and Albright, 1986; Davis and Emanuel, 1988; Gyakum and Danielson, 2000) or they can slightly decrease it (Kuo and Reed, 1988a, 1988b; Lagouvardos et al., 2007; Fink et al., 2012).

In the Mediterranean, explosive cyclogenesis has been extensively studied on a climatological basis with the aid of reanalysis data

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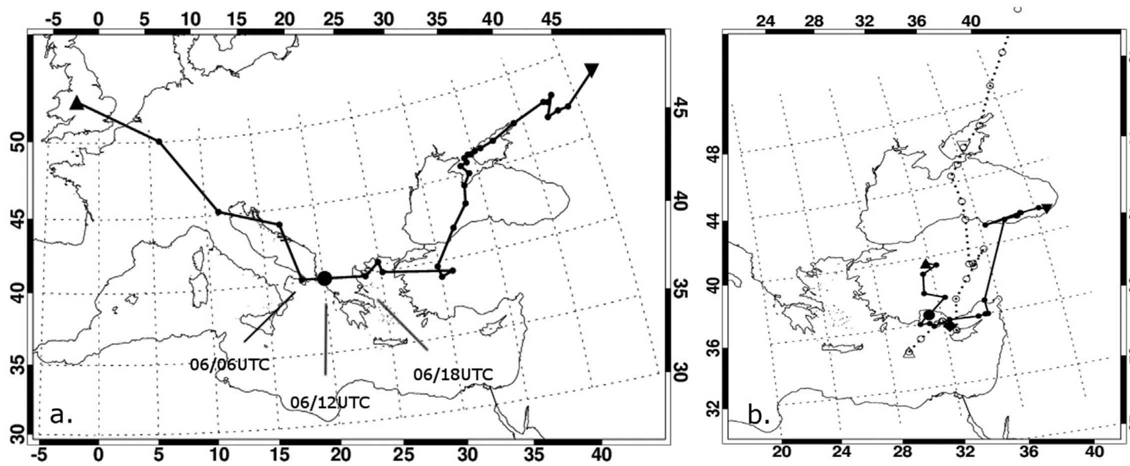

Fig. 1. a) The track of the 5–6 January 2012 explosive cyclone, and b) the tracks of the 10–11 December 2010 main and secondary explosive cyclones. Upward (downward) triangles denote cyclogenesis (cyclolysis); thick circles indicate the position of explosive cyclogenesis.

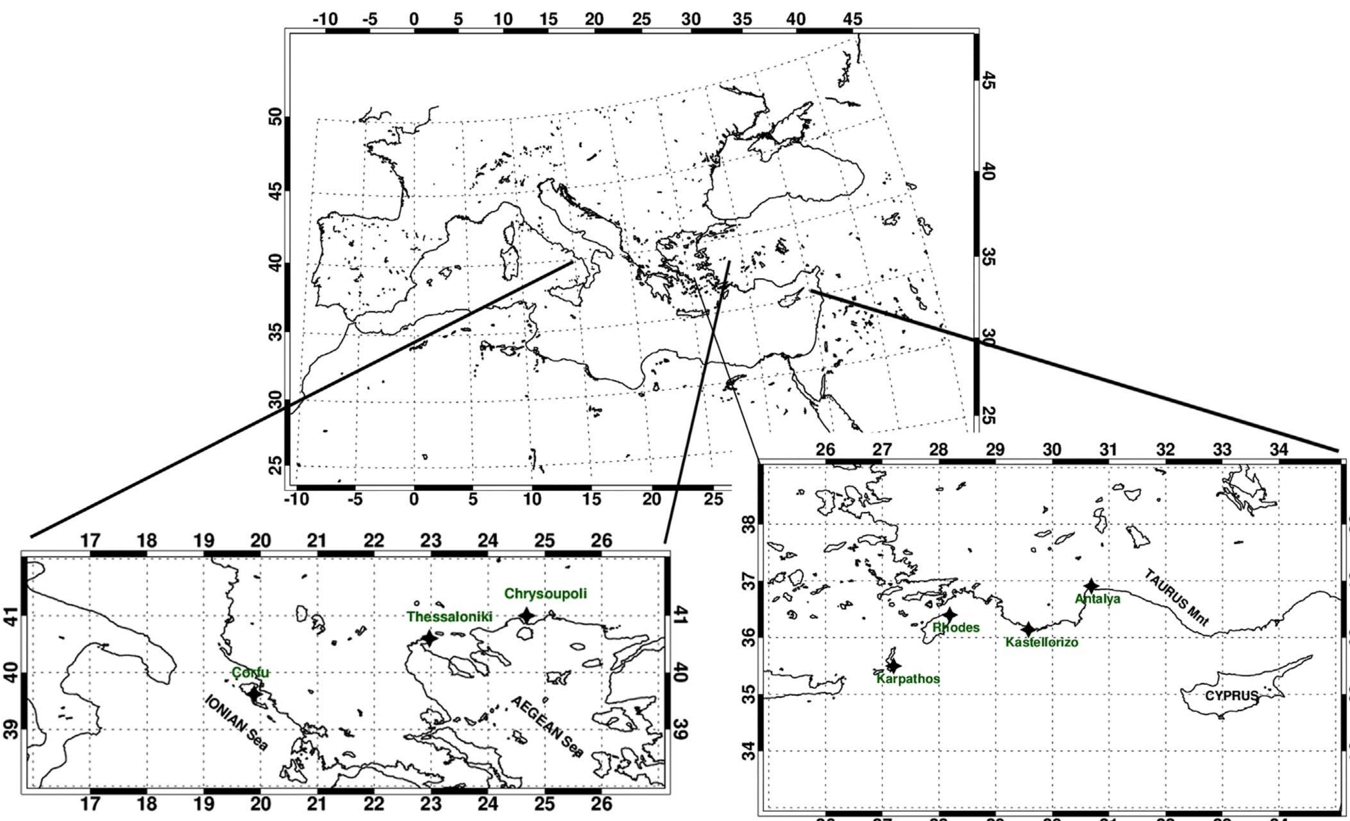

Fig. 2. Wide simulation domain for both explosive cyclogenesis cases (upper map) along with the inner domain corresponding to the explosive zone of the first case (lower left map) and the inner domain corresponding to the explosive zone of the second case of explosive cyclogenesis (lower right map).

(Kouroutzoglou et al., 2011a, 2011b, 2012; Kouroutzoglou, 2014). The baroclinic structure of explosive cyclogenesis combined with the contribution of diabatic heating has been demonstrated for specific cases (Homar et al., 2002; Emanuel, 2005; Fita et al., 2006; Lagouvardos et al., 2007; Kouroutzoglou et al., 2015). In the eastern Mediterranean (hereafter EM), low-level diabatic heating is enhanced compared to the western and central Mediterranean areas through the presence of stronger mean surface turbulent fluxes and the existence of higher sea surface temperature (Shay-El and Alpert, 1991; Lolis et al., 2004; Papadopoulos et al., 2012). Consequently, explosive cyclones in the EM generate in a pre-existed warm and moist low-level environment (Kouroutzoglou et al., 2012).

However, the role of the low-level dynamics in the EM explosive cyclogenesis has not been investigated and, mainly, the role of sea