THE ROLE OF SEA SURFACE TEMPERATURE IN THE SIMULATION OF DEEP CONVECTIVE STORMS IN THE MEDITERRANEAN BASIN

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1. Introduction

The Mediterranean basin is a strongly cyclogenetic area. Most of the cyclonic events arise from the interplay between the thermal structure of the Mediterranean sea and the orographic structure surrounding it. In many cases, the dynamics of deeply convective cyclones are strongly determined by latent and sensible heat fluxes that, over the sea, are driven by the Sea Surface Temperature (SST). Nevertheless also in these cases other mechanisms, like baroclinic instability and lee cyclogenesis, especially in the early stages, play an important role. In this work, we present numerical simulations of a flash flood event in southern Italy to assess the sensitivity of the forecast of these extreme events to the spatial and temporal evolution of MSG-based high resolution SST patterns. The meteorological model we used is the Weather Research and Forecasting (WRF-ARW) prediction system, with two nested grids (the coarse grid with 10 km horizontal resolution, the fine 3.3 km). Numerical simulations were run with SST fields obtained using both climatological SSTs and MSG-based SSTs at 0.04° horizontal resolution. These latter were computed through two different approaches: one using constant MSG-based SST data for the whole simulation, the other updating the MSG-based SST data every 6 hours. The differences in terms of the most relevant variables (e.g., surface pressure, heat fluxes, CAPE, etc.) are evaluated in order to assess the relevance of an accurate specification of SST fields, their temporal evolution and spatial variability.

2. Model Set-Up and configuration

The model used in this study is the Weather Research and Forecasting (WRF-ARW) Model, version 3.1 (Skamarock et al., 2008). It is a state-of-the-art numerical weather prediction system suitable for operational forecasting and atmospheric research. The model solves the fully compressible, non-hydrostatic Eulerian equations. The main parameterizations for the model microphysics, convection, turbulence, land and PBL processes, radiation and domain set-up are listed in Table 1.

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<th>Coarse Grid</th>
<th>Fine Grid</th>
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<td>Vertical Levels</td>
<td>35 terrain-following hydrostatic pressure coordinate</td>
<td>35 terrain-following hydrostatic pressure coordinate</td>
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<td>Grid Points</td>
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<td>268 x 175</td>
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<td>Radiation (SW/LW)</td>
<td>Dudhia/rrtm</td>
<td>Dudhia/rrtm</td>
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Table 1. Main parameterizations and domain set-up used for WRF-ARW simulations.

In the present study a two grids one-way nested approach was used, as shown in Figure 1.

![Fig. 1. WRF-ARW model domains.](image)

The outermost domain has 399 x 300 horizontal grid points with a grid spacing of 10 km, while the inner domain presents 268 x 275 grid points with a 3.3 km horizontal grid resolution, both having 35 vertical levels. The initial and boundary conditions were provided by the ECMWF 0.25° x 0.25° analysis, every 6 hours. To study and analyse the sensitivity to SST, the model was run with either climatological SST or MSG-based SST data, according to the different approaches described in section 3.2.

3 The case study of 23 September 2009

3.1 Synoptic overview

On 23\textsuperscript{th} September 2009 a large mid level cut-off low centred over Algeria extends to Tyrrhenian sea and a thermal ridge located over eastern Mediterranean acts as a block to the movement of the cut-off to the east (Fig. 2a). At upper levels the southern part of the cut-off is well coupled with the cyclonic side of a branch of the sub-tropical jet-stream, with values of deep layer shear of 15 ms\textsuperscript{-1} to peaks of 20-25 ms\textsuperscript{-1} located over the Tunisian coasts. $\theta_{e850}$ presents values higher than 65°C over a tongue extending to the Ionian sea and Sicily island (Fig. 2b), peaking at impressive 70°C over the Tunisian Gulf, well coupled with the zone of cut-off upper level divergence.
During the night and on the next day (24th September), the structure moves very slowly to the east, maintaining the same characteristics of upper and low level coupling. At 0600 UTC of 24th September, the cut-off is centred over Tunisia, the tongue of maxima $\theta_{850}$ is located over the Ionian sea pointing towards Calabria, with deep level shear maxima located south of Sicily reaching a value of 20 ms$^{-1}$ (Figs. 3a-b).

MSG color-enhanced IR@10.8 $\mu$m and WV@6.2 $\mu$m images for 24th September at 06UTC show a well-defined low pressure located around the Sicilian Channel presenting brightness temperature values down to -60°C, the system embedded with high values of moisture and a broad band of clouds aback (Figs. 4a-b).
Moreover, two deep convective systems associated with lines of convergence are clearly visible in the south of Sicily, having very cold overshooting tops (brightness temperature values of $\sim -70^\circ\text{C}$) and being very rich in moisture content. All the convective systems produced intense precipitation phenomena.

### 3.2 SST data

A fine scale ($\sim 9$ km) climatology of sea surface temperatures has been derived from the Pathfinder archive (AVHRR data from 1985 to 1997, Faugere et al. 2001). This climatology has been made on 5-day basis and it includes minimum and mean values re-mapped over the MSG disk at full IR resolution. Figure 5a shows the climatological SST pentadal map centred on 23rd September 2009, used as input for model run in the first numerical simulation and kept constant during the whole simulation (hereafter PF-CLIMA).

To test the model sensitivity to a different spatial distribution of SST, a non-linear split-window algorithm (EUMETSAT O&SI SAF project, Brisson et al., 1998) was used to compute basic, instantaneous 15-min MSG-based SST maps at a spatial resolution of $0.04^\circ \times 0.04^\circ$.

In the second numerical simulation, SST data were computed as a weighted average between SST of the selected day (using basic SST 15-min. data) and the average SST of the previous 6-days (see Fig. 5b). These temperature values were kept constant during the whole simulation (hereafter MSG-CONST). In the third experiment, the model sensitivity to variable SST data was investigated, using SST computed as weighted average between MSG-based SST of the day and the average SST of the previous 6-days, partitioning SST data in 6-hourly time slices (see Fig. 5c). These maps were updated each 6-hours during the simulation (hereafter MSG-VAR).
The main relevant feature is the difference in the level of detail among the three different SST fields. The climatological SST data present as a very smoothly-varying field with ~3°C temperature decrease from west African coast to east Greek coast, with generally warmer temperatures respect to both MSG-CONST and MSG-VAR simulations. In contrast, MSG-based SST data present very distinctive gradient of 2-3°C along shorter distances, and globally have colder temperatures with respect to PF-CLIMA ones.

5. NUMERICAL SIMULATIONS

Several model runs have been performed, modifying the extent of the domains, the initial/boundary conditions and initialization time. In the present study, we present among all the performed simulations that with the initialization time nearest to the genesis of the observed convective systems, as it has revealed the more reliable in reproducing the dynamics of the studied events. Using different SSTs (PF-CLIMA, MSG-CONST, MSG-VAR), the numerical simulations have been conducted for 23-25 September 2009, setting the model initialization time on 12UTC of 23rd September 2009. The aim of this study is to test and investigate the model sensitivity to SST and how a different spatial and temporal distribution of SSTs can impact on surface circulation and then potentially modify the trigger, location and intensity of the deep convective systems. Some model outputs are shown (Sea level pressure, surface wind at 10m and 3-hours cumulated precipitation) relative to 06UTC of 24th September 2009, for each of the three model runs (see Figs. 6-8).

All the three simulations reproduce well the main atmospheric features as already observed by satellite images (see Figs. 4a-b). The low pressure minima located into the Sicilian channel and the convergence line south of Sicily are well represented, despite of small differences visible in their locations and intensity. The differences in SST fields as reported in Figs., 5a-c, seem to translate directly into variations of surface circulations, with the deepening of pressure minima, strengthening of wind convergence line and consequently intensity of precipitation, as SST values increase.

Fig. 6. WRF-ARW simulated a) Sea level Pressure (hPa), b) Surface wind at 10m (km/h), c) 3-hours cumulated precipitation (mm) for 24th September 2009, 06UTC. Model was run with PF-CLIMA SST data.

Fig. 7. Same as in Fig. 6, but for MSG-CONST SST data.
In particular, analysing PF-CLIMA and MSG-CONST output fields (see Figs. 6 and 7), both the low pressure located in the Sicilian channel and surface convergence line south of Sicily appear more defined with more deep pressure minima for PF-CLIMA simulation respect to MSG-CONST one. This translates into strong winds and precipitation intensities in PF-CLIMA run, with location of convective events shifted eastward respect to MSG-CONST simulation.

The differences in model output fields between MSG-CONST and MSG-VAR simulations are less evident, although small differences in pressure patterns and no negligible modulations in precipitation location and intensity exist (see Figs. 7 and 8). The result is that wind fields are less intense, with the convergence line shifted more toward east respect to that in MSG-CONST simulation.

6. Result and future work

This analysis has shown that model has a no negligible sensitivity to SST fields, almost in reproducing deep convective events which need a lot of energy to start forming. In this framework, SST data seem to be capable of modifying small scale details of surface pressure fields and related low level circulations, thus influencing significantly the trigger, location and intensity of the associated precipitation phenomena.

The initialization time has confirmed its importance for the predictability of the systems; for this reason in future works we will investigate the possibility of extending the predictability horizon of small scale convective phenomena by improving SST data, for example, with integration of ground stations data and hydrodynamic model data.

Further, the study will be improved by comparisons with satellite data (e.g., wind data from scatterometers) and ground measurements, together with a fine tuning of model parameters in order to evaluate the influence of other model variables and parameterizations.

7. ACKNOWLEDGEMENTS

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8 REFERENCES
