MESOSCALE SIMULATION OF HOT WEATHER EVENTS DURING AUGUST 2012 IN GREECE

Diamando Vlachogiannis[1], Athanasios Sfetsos[1], Stylianos N. Karozis[1], George Emmanouil[1], Nikolaos Gounaris[1] and Constantina Mita[2]

[1]Environmental Research Laboratory, Institute of Nuclear & Radiological Sciences & Technology, Energy & Safety, National Centre for Scientific Research "Demokritos", Agia-Paraskevi, Attikis
[2] Hellenic National Meteorological Service, Athens, Greece

Abstract: Last summer was exceptionally hot in Greece with the highest temperatures occurring during the periods of August 2012, 6-9 and 23-27 and with the Etesian winds being very weak compared to the average statistics, according to the climatology report of the Hellenic National Meteorological Service (HNMS). In this study, the Weather Research and Forecasting (WRF) model has been parameterised at the Environmental research Laboratory (EREL) to simulate the meteorology during the particular periods and compare the model output with observations available from HNMS. The initial and boundary conditions for the WRF model simulations were determined by 6-hourly operational analyses obtained from the National Centres for Environmental Prediction (NCEP) Global Forecasting System (GFS). The simulations were performed in two nested domains, the outer of 15x15 km^2 covering the whole Europe and the inner of 3x3 km^2 including the whole country. The analysis of the results focused on the influence of the complex terrain in reproducing the observed wind pattern and the maximum values of the temperature fields.

Key words:** Hot weather, mesoscale simulation, WRF, Greece**.

INTRODUCTION

As the climate in Greece is predominantly Mediterranean, the summer period is hot and usually dry with temperatures reaching 30 to 35°C but sometimes exceeding the value of 40°C. Variations in the meteorological conditions occur between the summer months because of a cooling northerly wind, known as Etesian, formed more frequently during July and August due to the development of a depression over the Southwest Asia and the extension of the subtropical high pressure system over the eastern Mediterranean (Koletsis, I., et al, 2009). The complexity of the topography of the region causes also variations of particular interest in the climate locally. In this study, the performance of a particular set-up of the Advanced Research Weather (ARW) - Weather Research and Forecasting (WRF) model (Wang, W. et al., 2012) is examined with regard to the temperature and wind fields over Greece in comparison to the observational data from local monitoring stations. More specifically, focus has been placed on the simulation of the meteorological conditions over the whole country during two hot periods of August 2012, 6-9 (period A) and 23-27 (period B).

METHODOLOGY

The ARW-WRF model (version 3.4) has been set-up and parameterized to simulate the three-dimensional meteorological fields. The model is Euler non-hydrostatic, fully compressible, with terrain following coordinates. Simulations were performed for periods A and B in two nested domains following a one-way nesting procedure. The outer domain, d01, included 432 x 432 cells of horizontal resolution 15 x 15 km^2 and the inner domain, d02, comprised 286 x 286 cells of 3 x 3 km^2 horizontal resolution (Fig. 1). In the vertical, 27 unevenly spaced levels were used with the maximum resolution dz of 1500 m at the top of the model (at ~100 mb).

There are several physical parameterization schemes available in the WRF model for the representation of radiative and convective processes, boundary layer, surface temperature and soil moisture and microphysics. More specifically, the following schemes have been selected for this case study: for the microphysics, the WRF single-moment 5-class scheme that allows for mixed-phase processes (Hong, S. Y., et al., 2004); for the longwave and shortwave radiation, the Rapid Radiative Transfer Model (Mlawer, E. J., et al. 1997) and the Dudhia scheme (Dudhia, J., 1989), respectively; for the land surface model, the Noah Land Surface Model (Mitchell, K., 2005); for the planetary boundary layer, the Yonsei University scheme (Hong, S. Y., et al. 2006 and Hong, S. Y. and S. W. Kim, 2008); for the cumulus parameterization, the Kain-Fritsch scheme (Kain, J.S., 2004). The initial and boundary conditions for the WRF model simulations were determined by 6-hourly operational analyses obtained from the National Centres for Environmental Prediction (NCEP) Global Forecasting System (GFS) valid at 00, 06, 12, and 18 UTC for the two referenced periods A and B. After initialization of the model run, these data were only applied at the boundaries.

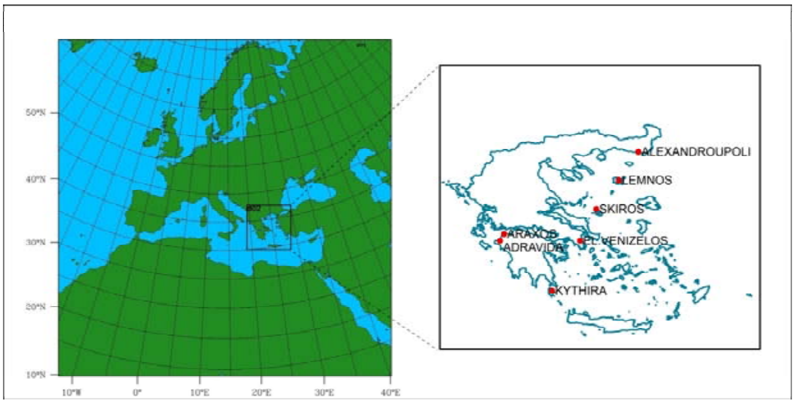

Figure 1. Depiction of the two WRF modeling domains (d01 and d02) and position of observational stations.

RESULTS

The results from the WRF meteorological model runs are presented in this section. The computed near surface temperature T at 2 meters above ground level (T at 2 m a.g.l.) and the wind speed (**v** at 10 m a.g.l.) were compared with meteorological station data. Hourly observational data were available from a number of stations operated by the Hellenic National Meteorological Service (HNMS). The location of the stations is described in terms of latitude and longitude in Table 1.

Table 1. Geographical position of the observational stations.

Station Name	Latitude (deg.)	Longitude (deg.)	Station type
El. Venizelos	23.947315	37.926517	Mainland
Alexandroupoli	25.883333	40.850000	Mainland
Lemnos	25.233333	39.916667	Island
Skiros	24.483333	38.966667	Island
El. Venizelos	23.947315	37.926517	Mainland
Kythira	23.016667	36.283333	Island
Andravida	21.288333	37.923888	Mainland
Araxos	21.423333	38.149722	Mainland

The maximum and the average near surface temperature (T at 2 m) calculated by the model over the two periods A and B are shown in Figures 2 and 3, respectively. Overall, the period A was characterized by higher temperatures than the period B occurring mainly over a greater area of northern and western parts of the country. The maximum temperatures of up to 40°C were found over several regions of low elevation of the mainland. The urbanized region of Attica (Athens) experienced the highest temperatures in both periods examined in August 2012. The maximum (up to 41.8°C) and the average values (24.0 to 30.7°C) agree well with those of the climatology report of HNMS (HNMS, 2012) for both periods. The comparisons of the hourly average temperature values with the observed ones are shown for periods A and B in Figures 4 and 5, respectively, for four selected stations (due to space limitations). Inspection of the plots reveals that there is no consistent bias of the model with respect to the period studied or the type of the station although in most cases the model seems to underestimate the temperatures at the stations during the day and overestimate them at night hours.

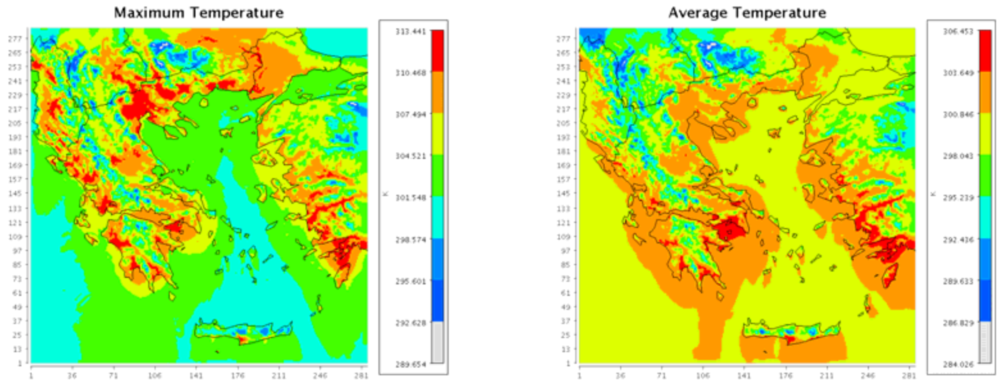

Figure 2. WRF calculated Maximum and Average temperature fields (in K) over period A.

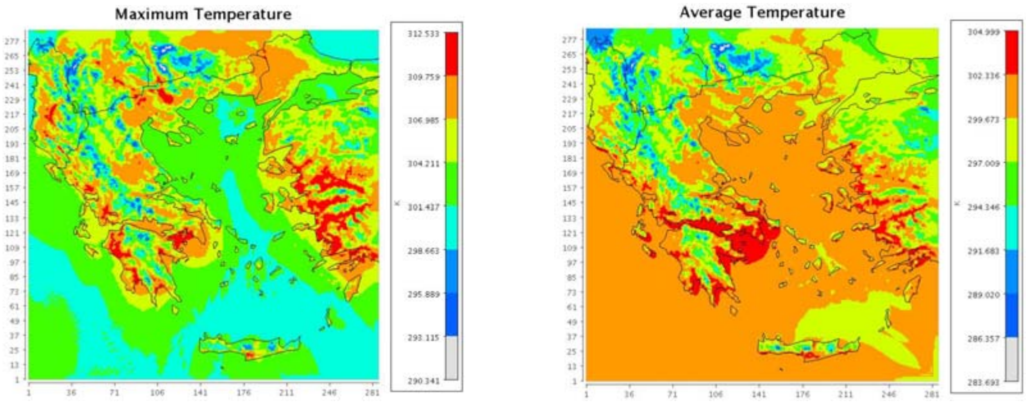

Figure 3. WRF calculated Maximum and Average temperature fields (in K) over period B.

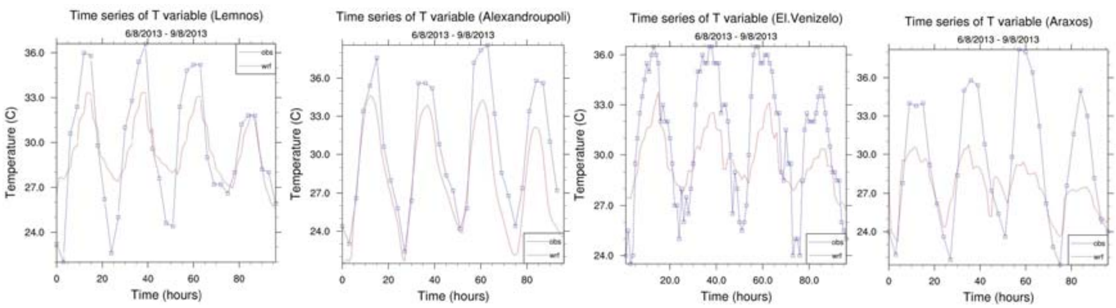

Figure 4. Comparison of WRF calculated temperature with observations at Lemnos, Alexandroupoli, El. Venizelos and Araxos stations during period A.

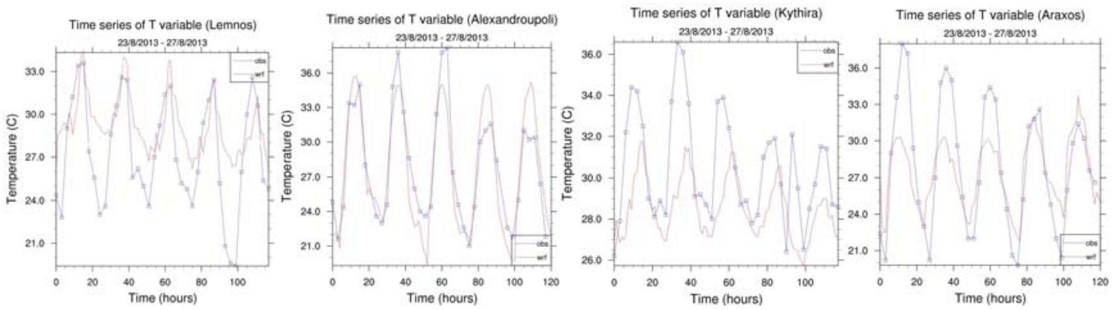

Figure 5. Comparison of WRF calculated temperature with observations at Lemnos, Alexandroupoli, Kythira, and Araxos stations during period B.

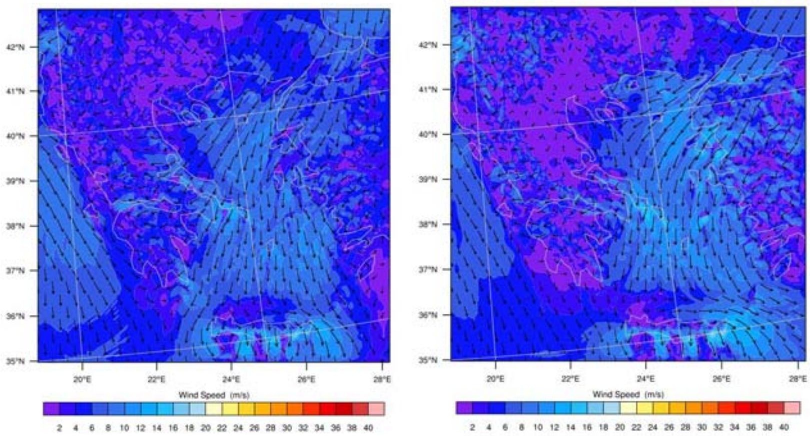

Figure 6. WRF calculated wind velocity fields (10 m a.g.l.) at 0900 UTC (left) and 2100 UTC (right) in August 9, 2012.

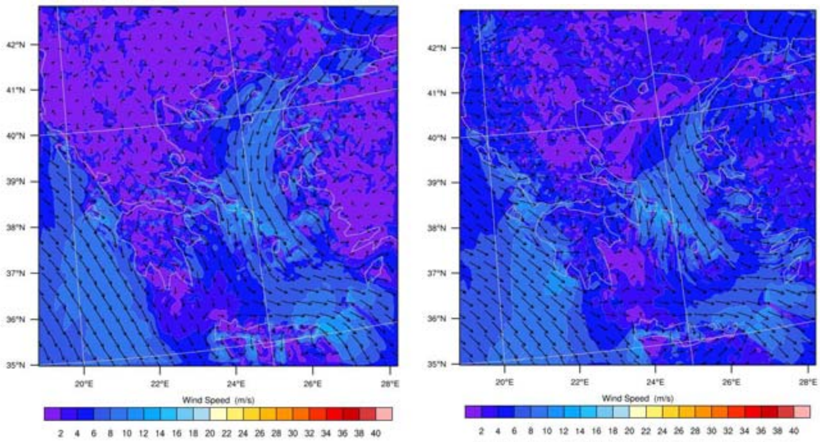

Figure 7. WRF calculated wind velocity fields (10 m a.g.l.) at 0300 UTC (left) and 1200 UTC (right) in August 26, 2012.

The wind velocity fields at 10 meters a.g.l. are shown in Figure 6 at 0900 and 2100 UTC hours for August 9, 2012 (period A). Similarly, but at 0300 UTC and 12 UTC, wind fields are plotted in Figure 7 for August 26, 2012 (period B). The model captures well the northeasterly flow over the Aegean Sea (etesian wind) and the northwesterly wind over the Ionian Sea (in the west). The wind velocity fields have revealed that the etesian winds were weak of comparatively low to medium speeds in the range of 2 – 18 ms^{-1} in agreement with the HNMS report (HNMS, 2012). The winds persisted during the day and night hours and over the whole periods studied in agreement with the HNMS report. The figures show also the funneling effect that is the increase in the wind speed between the straits of the islands. The comparison of the model calculated hourly wind speed with the observations (Figure 8) yielded a fair agreement with RMSE (root mean square error) values of 3.72 and 4.26, respectively.

CONCLUSIONS

This work attempted to test the set up and parameterization of WRF over Greece by studying two rather warm periods in August 2012. Overall, the model produced near surface maximum and average temperature and wind velocity fields were in agreement with the report of HNMS. The model results were compared with observational meteorological data from several monitoring stations. The comparisons revealed a good agreement of the calculated hourly average temperature values and the observed data. Although the model captured well the wind fields and the rather weak northeasterly and westerly flows, the comparison of the hourly wind speed values against the observational data yielded a fair agreement. To improve the calculated wind fields other parameterization schemes will be incorporated. Moreover, the model results will be evaluated for winter cold periods as well.

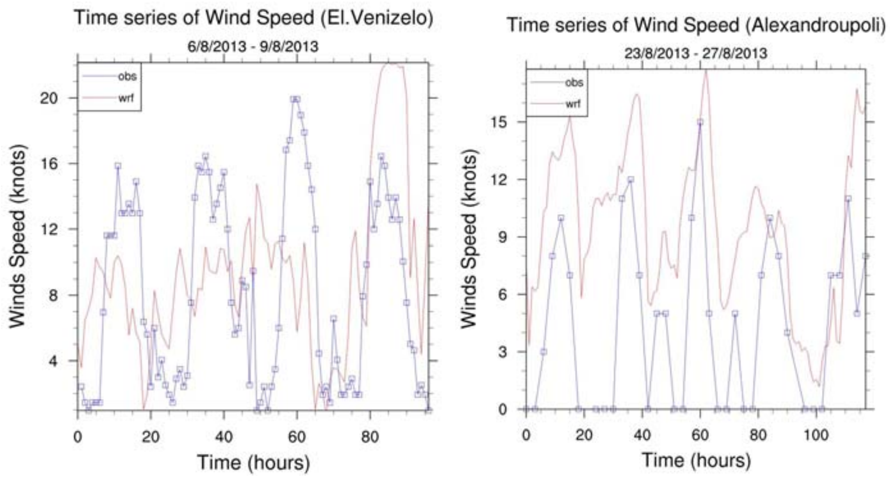

Figure 8. Comparison of WRF calculated wind speed (at 10 m a.g.l.) with observations at El. Venizelos (period A), and Alexandroupoli (period B).

Acknowledgments

This work was partly funded by the National Strategic Reference Framework (NSRF) 2007-2013 grand No 09SYN-31-667. The authors acknowledge the support of the Hellenic National Meteorological Service for provision of observational data.

REFERENCES

Dudhia, J., 1989: Numerical study of convection observed during the Winter Monsoon Experiment using a mesoscale two-dimensional model. *J. Atmos. Sci.*, **46**, 3077–3107.

Hellenic National Meteorology Service Climatology Report: August 2012, (*in greek*), available at http://www.hnms.gr/hnms/greek/climatology/climatology_html.

Hong, S. Y., and S. W. Kim, 2008: Stable boundary layer mixing in a vertical diffusion scheme. Proc. Ninth Annual WRF User's Workshop, Boulder, CO, National Center for Atmospheric Research, 3.3. [Available online at http://www.mmm.ucar.edu/ wrf/users/workshops/WS2008/abstracts/3-03.pdf.]

Hong, S.-Y., Y. Noh, and J.Dudhia, 2006: A new vertical diffusion package with explicit treatment of entrainment processes. Mon. Wea. Rev., **134**, 2318–2341.

Hong, S.-Y., J. Dudhia and S.-H. Chen, 2004: A Revised Approach to Ice Microphysical Processes for the Bulk Parameterization of Clouds and Precipitation. *Mon. Wea. Rev.*, **132**, 103–120.

Kain, J. S. 2004: The Kain-Fritsch convective parameterization: An update, J. Appl. Meteorol., **43**, 170–181.

Koletsis I., K. Lagouvardos, V. Kotroni and A. Bartzokas, 2009: The interaction of northern wind flow with the complex topography of Crete Island – Part 1: Observational study. Nat. Hazards Earth Syst. Sci., **9**, 1845–1855.

Mitchell, K., 2005: The Community Noah Land-Surface Model (LSM), User's Guide Public Release Version 2.7.1, at ftp://ftp.emc.ncep.noaa.gov/mmb/gcp/ldas/noahlsm/ver_2.7.1.

Mlawer, E. J., S. J. Taubman, P. D. Brown, M. J. Iacono, and S. A. Clough, 1997: Radiative transfer for inhomogeneous atmosphere: RRTM, a validated correlated-k model for the longwave. J. Geophys. Res., **102** (D14), 16 663–16 682.

Wang W., C. Bruyère, M. Duda, J. Dudhia, D. Gill, M. Kavulich, K. Keene, H.-C. Lin, J. Michalakes, S. Rizvi, and X. Zhang, 2012: ARW, Version 3 Modelling System User's Guide, July 2012, Mesoscale and Microscale Meteorology Division, National Centre for Atmospheric Research.