A Comparative Study of Two Land Surface Schemes in WRF-ARW Model

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In the present study the sensitivity of short range weather forecast on land surface schemes was investigated. To this end the WRF-ARW numerical weather prediction model was used, focusing on the area of Macedonia -Thermaikos Gulf, using two different land surface schemes (NOAH, NOAH-MP) for a period of one month (January 2012) and a spatial resolution of 1.667 Km, with the use of telescoping nesting. The model results of the two experiments were evaluated against the measured values of mean sea-level pressure, 10m wind, 2m air temperature and 2m relative humidity. Statistical evaluation indicate a notable improvement in 2m temperature predictions when the latent heat was negligible. When heat flux was considerable enough (daytime hours) the NOAH-MP overestimated latent heat leading to unrealistic relative humidity forecasts and a temperature cold bias. Considering the consistency problems between NOAH-MP canopy radiation and turbulence with WRF physics and that it needs about 15% more computational time than the NOAH unified model, the use of NOAH-MP is not currently suggested for operational forecasting.

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1 Introduction

Land surface processes play a key role in the spatiotemporal evolution of the atmospheric variables in the near surface environment (Pielke 2001). The exact quantification of these processes through the land surface parameterization schemes, not only supply the lowest boundary conditions to the numerical weather prediction models, but are largely responsible for the quality of model produced near surface meteorological parameters, such as dew point, screen temperature and low level wind (Viterbo and Beljaars 1995).

In the framework of WaveForUs project, the Laboratory of Meteorology and Climatology of the Aristotle University of Thessaloniki provides to the partners and the public, operational numerical weather predictions for Europe, Greece and mainly Thermaikos Gulf, which is the target area. The latter area is characterized by different land uses (heavily irrigated areas, industrial and urban areas) with different heat characteristics, which result to different surface energy fluxes and consequently making the near surface weather sensitive to the land surface processes. Moreover, warm biases in the predicted nighttime temperatures in winter months, provide a strong motivation to investigate the sensitivity of short range weather forecasts to the land surface parameterization schemes.

2 Data and Methodology

The nonhydrostatic Weather Research and Forecasting model with the Advanced Research dynamic solver (WRF-ARW Version 3.5.1; Skamarock et al. 2008, Wang et al. 2010) was utilized in the numerical experiments. The model integration area consists of three 2-way telescoping nests, which cover Europe and northern Africa (D01; Fig. 1), the central and a large part of eastern Mediterranean sea, including Greece and the Aegean sea (D02; Fig. 1) and the wider region of Macedonia - Thermaikos Gulf (D03; Fig. 1) at horizontal grid-spacings of 15km, 5km and 1.667km respectively. Fine-resolution USGS data (30’’ x 30’’) were used in the definition of topography and land use. Daily NCEP SSTs, with a grid-spacing of 1/12°x1/12° lat.-long was utilized. GFS analyses and 3-hourly forecasts (0.5°x0.5° lat.-long.) of the 12 UTC cycle were employed as initial and boundary conditions of the coarse domain and the production of 72hrs forecasts. The two inner domains were initialized 6 hours after the coarse domain (D01) in order to reduce the model spin-up. In the vertical, 39 sigma levels (up to 50 hPa) with increased resolution in the boundary layer were used by all nests. The Ferrier scheme, Betts-Miller-Janjic scheme, RRTMG, Monin-Obukhov (Eta) and Mellor-Yamada-Yanjic represented microphysical processes, sub-grid scale convection, longwave and shortwave radiation, surface layer and boundary layer, respectively.

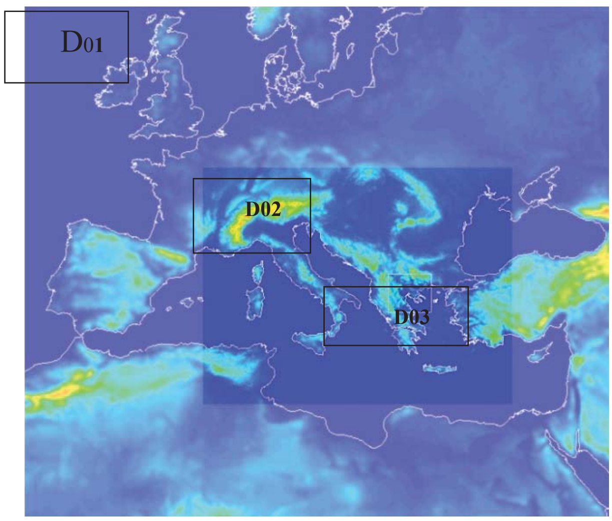

Fig. 1. The topography of models integration domains.

For the land surface physics the NOAH unified model and the NOAH-MP were utilized for the control and the experiment simulations, respectively. The NOAH multi-parameterization model (NOAH-MP) (Niu et al. 2011) is an enhanced version of the NOAH v.3.0 unified model, considering: a) a vegetation canopy layer to compute the canopy and the ground surface temperature separately, b) a modified two stream radiation transfer scheme with canopy gaps to compute fractions of sunlit and shaded leaves and their absorbed solar radiation, c) a Ball Berry type stomatal resistance scheme that relates stomatal resistance to photosynthesis of sunlit and shaded leaves and d) a short term dynamic vegetation model. In the present study, the options suggested by the developers were employed. These options are the dynamic vegetation calculation, Ball-Berry scheme for canopy stomatal resistance, modified two-stream canopy radiation scheme, TOPMODEL with ground water, NOAH soil moisture factor for stomatal resistance, CLASS for snow albedo and the semi implicit time scheme for snow/soil temperature computation.

All the experiments were performed at operational forecast mode, which means that the boundary conditions were based on GFS forecasts and the initial SSTs were valid one day before the initial time of WRF. Three-day forecasts were performed for each day of January 2012.

3 Results

The two experiments were performed for January 2012 which was characterized by strong synoptic activity and low temperatures (associated with cold air intrusions). Due to consistency problems with the NOAH-MP experiment only 13 runs from 31 were completed the 72hr forecast period. The 13 forecasts produced at each experiment were statistically analyzed using 17 stations of the Hellenic National Meteorological Service (Pytharoulis 2009) for the D02 and 7 stations from the World Meteorological Organization (WMO) network for the D03.

(a) (b)

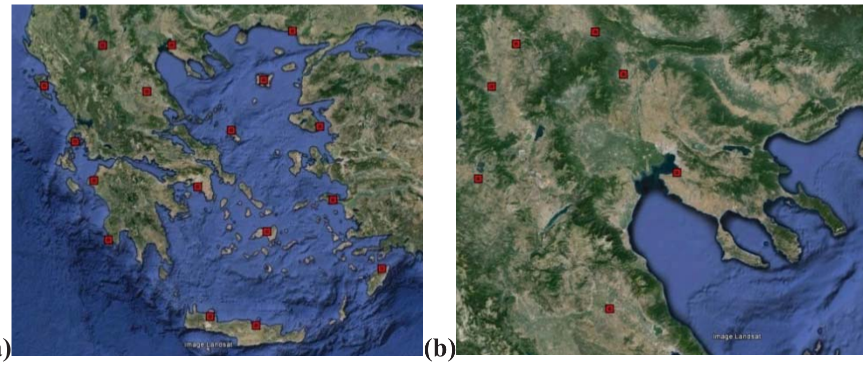

Fig. 2. Location of observation stations in (a) D02 and (b) D03

The mean absolute error (MAE) for the 2m temperature ranges from 1.3 to 3.7K in D02 and from 2.6 to 7K in D03 when NOAH is used. The large value of MAE in D03 was expected due to the fact that 5 out of the 7 stations were located in snow covered areas with low temperatures ranging between 260 and 256K during the study period. Fig. 3 shows the improvement of 2m temperature prediction in D03 when the NOAH-MP was utilized, especially for the nighttime and the early morning temperatures, where the improvement ranges from 20% to 50%. For the domain 2 the NOAH unified model predominated in the daytime with 3% to 15% improvement. In both domains the NOAH-MP experiment was less biased.

The mean absolute error of the relative humidity (Fig. 4) present very high values in both domains when the NOAH-MP is utilized. This discrepancy was also reported from other researchers (Mukul Tewary et al. 2012) and is due to unrealistic computation of surface energy fluxes. The overestimation of latent heat fluxes leading to reduced sensible heat fluxes, explains the cold bias in 2m temperature in the daytime and the overestimation of relative humidity.

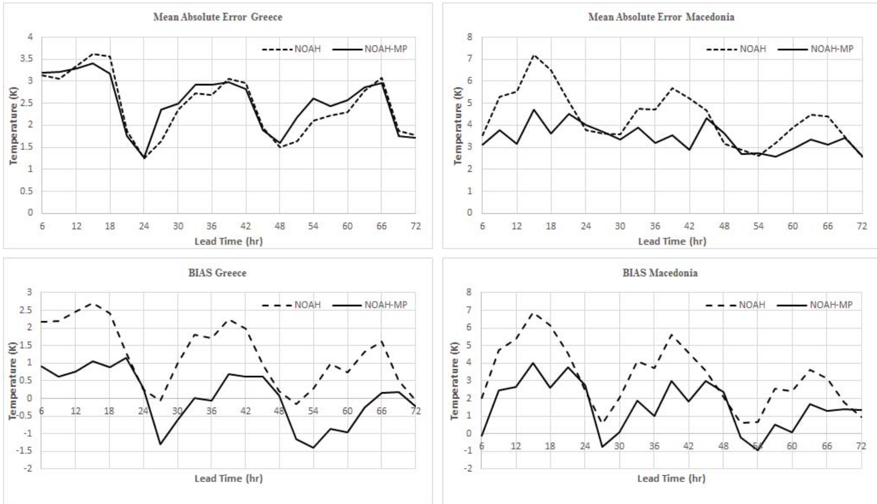

Fig. 3. The Mean Absolute Error and Bias of 2m temperature in D02 and D03.

Fig. 4. The Mean Absolute Error and Bias of 2m relative humidity in D02 and D03.

The mean absolute error of wind speed and MSLP in D02 ranges from 1.8 to 3.5m/s and 0.8 to 3.25hPa, respectively, with the NOAH model to exhibit a better performance than NOAH-MP. The mean absolute error of D03 ranges from 1 to 3m/s for the 10m wind speed and from 1 to 4hPa for the MSLP, with NOAH-MP generally to display better scores than the NOAH model. Generally the forecast error seems to follow the energy partitioning errors. The NOAH-MP experiment had the best performance when the latent heat flux was zero or very small, while the opposite occurred when the latent heat fluxes were very high. In the latter case, the NOAH-MP computed unrealistic energy fluxes leading to large biases in relative humidity.

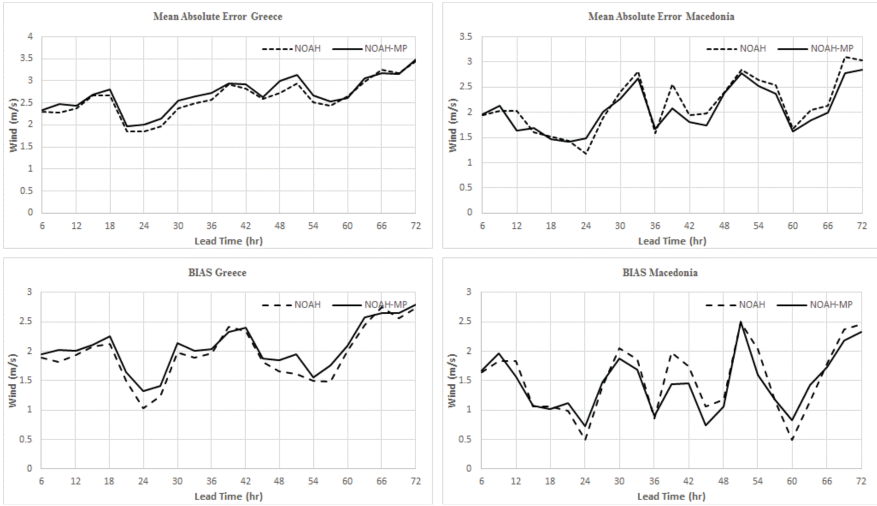

Fig. 5. The Mean Absolute Error and Bias of 10m wind speed in D02 and D03.

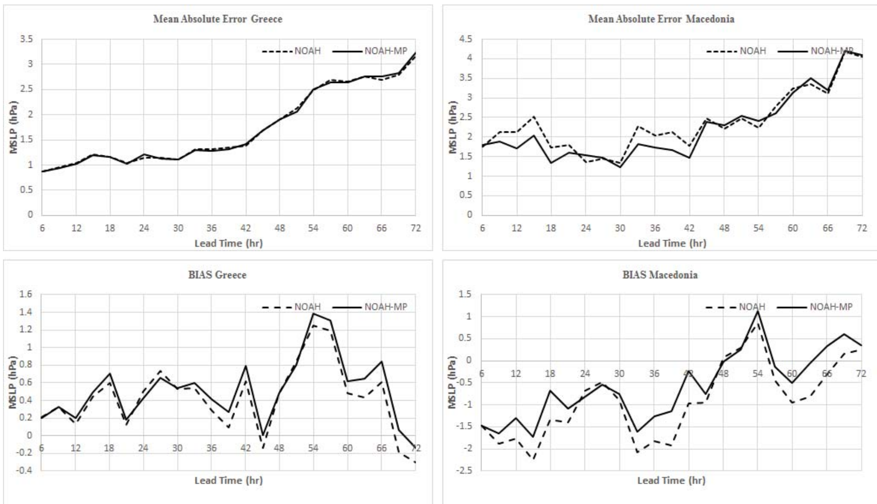

Fig. 6. The Mean Absolute Error and Bias of MSLP in D02 and D03.

4 Conclusions

The study investigated the sensitivity of WRF-ARW short range forecasts on land surface processes. To achieve this research goal, the WRFv3.5.1 numerical weather prediction model was used, focusing on the area of Macedonia -Thermaikos Gulf, (with a grid spacing of 1.667 km) and using two different land surface schemes (NOAH, NOAH-MP) for a period of one month (January 2012). Statistical results indicate a notable improvement in 2m temperature when the latent heat flux was negligible. When heat flux was considerable enough (daytime hours) the NOAH-MP overestimated latent heat leading to unrealistic relative humidity forecasts and a temperature cold bias. Also the execution time of NOAH-MP was 15% more than the one of the unified NOAH model. Although further research is needed to investigate model performance using different combinations of physics options and in different seasons of the year, all the above results suggest that the NOAH-MP model is not yet suitable for operational use.

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