

Implementation of Modeling the Land-Surface/Atmosphere Interactions to Mesoscale Model COAMPS

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LONG-TERM GOALS

The long-term goal of this project is to improve the treatment of convection and the prediction of convective precipitation in the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS®¹), by including selected land-surface and urban canopy schemes in COAMPS, along with tools that will allow the user to choose the optimum ones for selected nested-grid configurations.

OBJECTIVES

The objectives of this project are to: (a) integrate land-surface models and urban canopy schemes into COAMPS, (b) evaluate the limitations of the proposed schemes in describing surface-atmosphere interactions during drought conditions, (c) investigate the impact of land-atmosphere interactions on Quantitative Precipitation Forecast (QPF) skill, and (d) validate the COAMPS model performance when using the land-surface and urban canopy schemes.

¹ COAMPS® is a registered trademark of the Naval Research Laboratory.

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APPROACH

Our approach is to use COAMPS to study the impact of land-vegetation processes on the prediction of mesoscale convection over central Europe during summer months. This will be accomplished by implementing new and more detailed surface databases into COAMPS, developing a new data assimilation system for surface parameters, and performing numerical tests with COAMPS to determine the importance of selected parameters within the land-surface model (LSM). The results of this study will be applicable to similar continental areas.

WORK COMPLETED

During FY11, we accomplished the following tasks: (a) performed a number of numerical experiments with the NOAH land-surface model coupled to a high-resolution NWP system, (b) investigated the impact of an improved land-surface model coupled on COAMPS convective boundary layer variables, and (c) performed a number of experiments focused on comparisons of parameterized convection with explicit moist physics on grids using horizontal resolutions as low as 1 km.

RESULTS

The initiation of convection over land involves many complex dynamical and physical processes that occur over a variety of time and space scales. Many of these processes occur in the near-surface layer, and can be attributed to land-air interactions. To study these processes, ICM is testing the coupling of relatively newly-developed **land-surface models** to established mesoscale numerical prediction systems that are already being exploited for operational forecasts at the University of Warsaw. Results of precipitation forecasts obtained using different land-surface schemes are compared to radar observations. Two classes of radar observations are used in our study. The first class consists of 15-minute reflectivity data on the 500 m CAPPI level collected from all radars operated in the area of the Baltic Sea catchment. The second class of radar data is PPI (Plan Position Indicator) data from a single radar site.

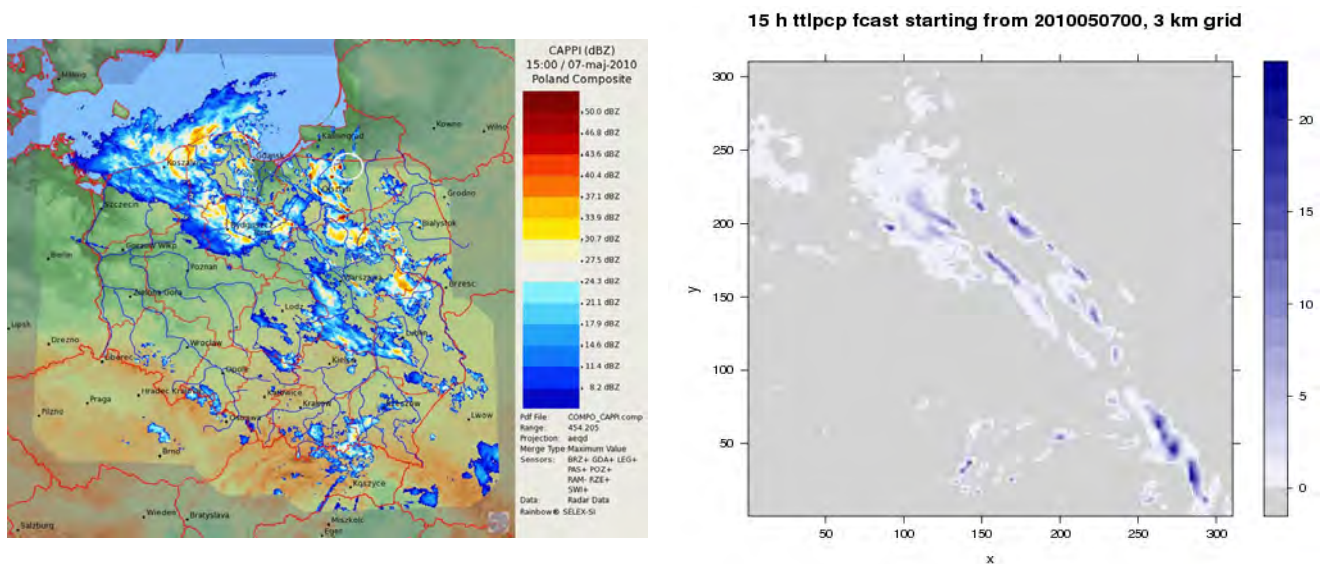


Figure 1. Observed radar reflectivity (left panel) and simulated 1-h precipitation accumulation, 07 May 2010, 15Z.

The usefulness of the NOAA land surface model coupled to COAMPS has been tested on a case of convection development during 7 May 2010. The initiation of convection in northern Poland started at 1430 UTC. A number of convective cells developed approximately one-half hour later. The COAMPS 1-h accumulated precipitation forecast at 15 UTC (right panel of Fig. 1), when compared with the observed precipitation estimated from radar reflectivity (left panel), shows some similarities, but also some differences. While the forecast zone appears to be too narrow, the bands of precipitation are forecast to be in the correct location, and the areal coverage of precipitation / no precipitation appears to be qualitatively correct.

The effect of surface heterogeneity on the fair-weather convective boundary layer structure has been the subject of numerous modeling studies. Two snapshots of boundary layer height are presented in Fig. 2. The left panel shows a large zone exhibiting PBL heights of 25-50 m, with a number of locations below 25 m, which were also areas with precipitating convection. The right panel shows two convergent zones of well-mixed boundary layers with heights about 1200 m. We are currently investigating the role that the boundary layer depth, and the processes that operate within it, have on the initiation of convection.

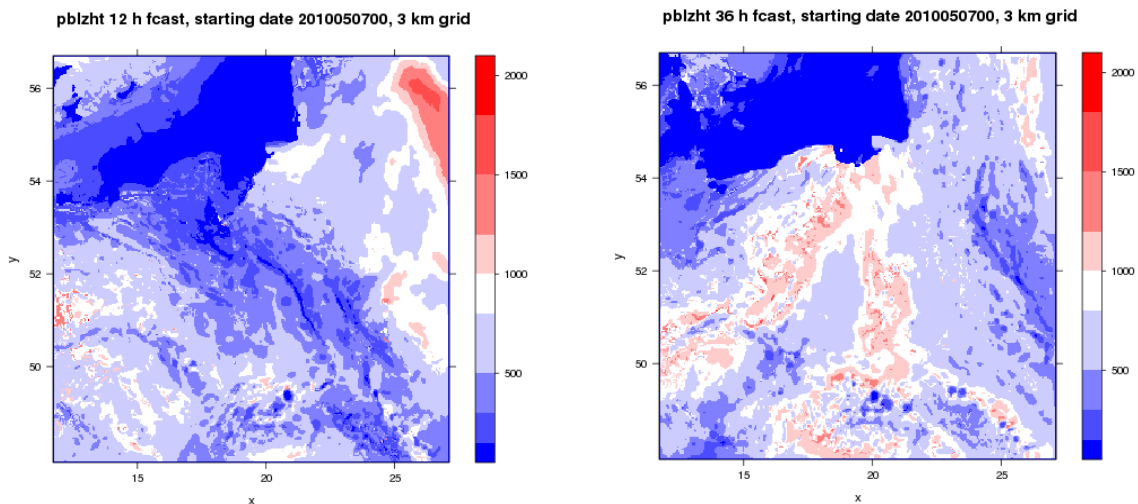


Figure 2. Boundary layer height during a rain episode (left panel) and during a dry episode (right panel).

Previous studies have shown that surface heterogeneities can modify the surface fluxes, and generate mesoscale circulations, that can lead to increased convection (Pielke 2001, Taylor and Ellis, 2006). The influence of soil moisture on precipitation patterns seems to vary and may be dependent on multiple factors including the study region, the atmospheric model used, and the existing synoptic-scale pattern. The usefulness of the NOAA land surface model coupled to COAMPS has been tested on cases of convective development during the four day period of 7-10 May 2010. While strong convective development connected to intense precipitation episodes was evident on 7 and 10 May, both 8 and 9 May were dominated by fair weather conditions. The patterns of forecast sensible heat fluxes shown in Figure 3 are related to the patterns of the forecast reflectivity fields. In places where precipitation occurs, the sensible heat fluxes are lower than the same fluxes in the precipitation-free areas.

A series of experiments were performed using the research version of COAMPS both with, and without, the NOAH land surface model. The first set of experiments we did is a simulation of a heavy rain event in Poland in May 2010. COAMPS was initialized at 0000 UTC 7 May 2010 with fields from the Global Forecast System (GFS) from the National Centers for Environmental Prediction (NCEP). These fields served as the initial conditions for two 24-hour forecasts: the first using the COAMPS/NOAH system, the other (control run) using COAMPS without the NOAH LSM.

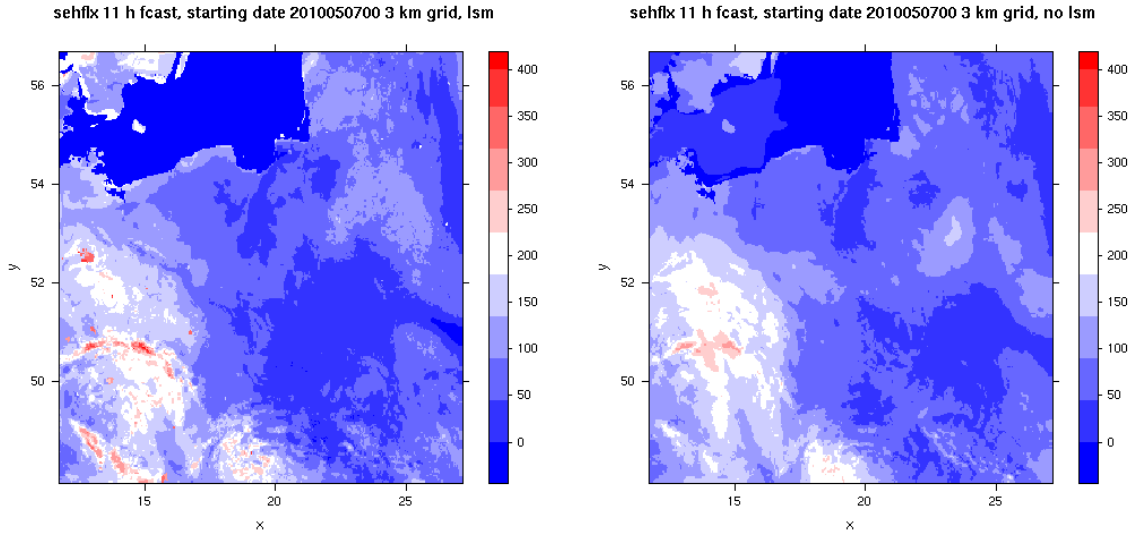


Figure 3. 7 May 2010, 11 UTC: Sensible heat fluxes from LSM (left panel) and no LSM (right panel) runs.

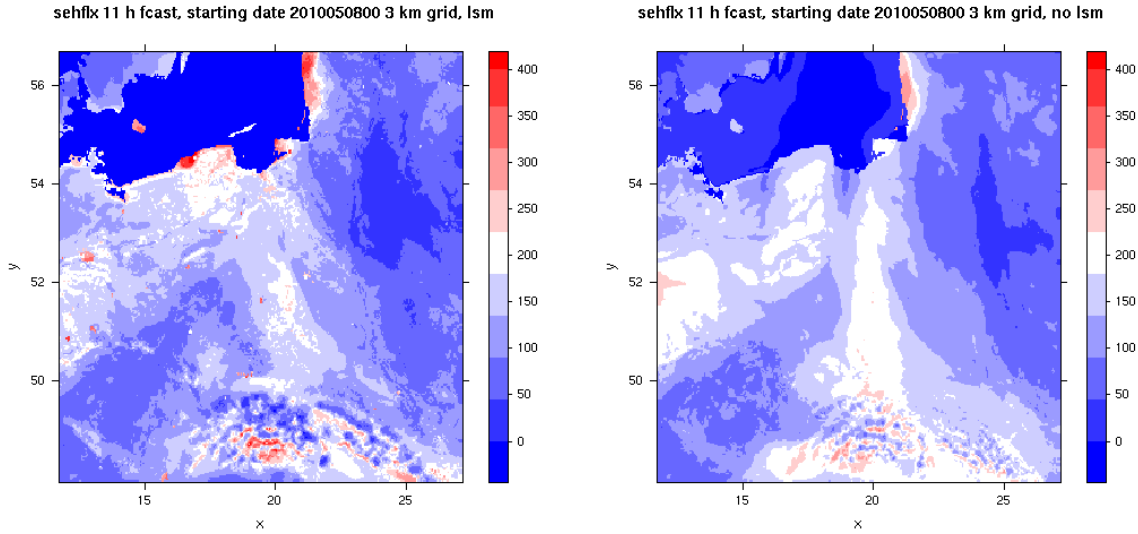


Figure 4. 8 May 2010, 11 UTC: Sensible heat fluxes from LSM (left panel) and no LSM (right panel) runs.

For these runs, the coarse mesh (9 km) grid covered most of the Central European area, the medium mesh (3 km) covered all of Poland, and the fine grid (1 km) covered an area roughly corresponding to the area covered by one radar site inside north-central Poland. The model used 40 vertical levels.

A comparison of the results between the LSM and no LSM runs for the strong convective case (Figure 3) and the fair weather case (Figure 4) leads us to conclude that areas covered by rainfall are characterised by lower values of sensible heat fluxes compared to areas without precipitation. Also, the sensible heat fluxes are found to be reduced more in the LSM case than in the no LSM case. The next phase of our study will be to further validate the fluxes produced in the LSM and no LSM tests, determine how the fluxes relate to convective initiation, and determine the role of the fluxes in the evolution of the convection.

Summary: Proper partitioning of the surface energy fluxes that describe the evolution of the planetary boundary layer in numerical prediction models requires an accurate representation of the initial and the forecast land-surface conditions. Our results indicate that a high-resolution numerical weather prediction model coupled to a land-surface model is able to simulate the evolution of the planetary boundary layer such that the forecast values agree, in a qualitative sense, with observed values; and furthermore, the model is also able to qualitatively simulate the space and time evolution of forced convective events. We will continue to study the cases we have now run, and use additional case studies on other convective events to gain a better appreciation on the role that the surface characteristics and planetary boundary layer have in the initiation and maintenance of convection.

PERSONNEL EXCHANGES AND TRAVEL COMPLEMENTED

Bogumil Jakubiak, University of Warsaw – participated in ESA, iLEAPS EGU joint Conference in Frascati, Italy in a period 3-5 Nov 2010, giving one oral presentation.

Richard Hodur, University of Warsaw, ICM, working for ICM in US – visited ICM, University of Warsaw, during a period 28 Nov- 08 Dec 2010, working on development of the COAMPS system.

Bogumil Jakubiak, University of Warsaw – participated in COST Action ES0905 workshop on “Concepts for Convective parameterization in large-scale models. IV: Convection organization. Cambridge, UK, 23-25 March 2011, giving one oral presentation titled “Some questions about lightning data assimilation into mesoscale models”.

Richard Hodur, University of Warsaw, ICM, working for ICM in US – visited ICM, University of Warsaw, during a period 15 - 26 May 2011, working on development of the COAMPS system.

Bogumil Jakubiak, University of Warsaw – participated in Agriculture Conference in Tlen, Poland, 29 June - 01 July 2011, giving two oral presentations.

Bogumil Jakubiak, University of Warsaw – participated in ITEE Conference in Poznan, Poland, 8 - 8 July 2011, giving one oral presentation.

Karolina Szafranek, University of Warsaw, participated in 11th ESM Annual Meeting and 10th European Conference on Applications of meteorology, Berlin, Germany, 12-16 Sep 2011, taking part in a course and workshop “Tools for forecasting high impact weather”.

IMPACT/APPLICATIONS

This improvement in the treatment of convective processes in COAMPS will be useful for improving precipitation forecasting.

TRANSITIONS

None.

RELATED PROJECTS

COST Action 731 project – Propagation of uncertainty in advanced meteo-hydrological forecast systems. Within this action, we started to develop a radar data assimilation scheme using the ensemble Kalman filter approach.

COST ESSEM Action ES0905 – Basic Concepts for Convection Parameterization in Weather Forecast and Climate Models

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