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Hydrology and Earth System Sciences Discussions

Interactive comment on "A coupled atmosphere and multi-layer land surface model forimproving heavy rainfall simulation" *by* M. Haggag et al.

M. Haggag et al.

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We would like firstly to thank the anonymous referee no.2 for his work on the manuscript to provide a valuable and exciting discussion of our paper. His meaningful comments will be useful to improve the manuscript allowing us to further clarify the aims of our paper. The reviewer's comments are acknowledged, and will be integrated in the revised version of the paper. In the following we will try to be engaged with the reviewer's comments to answer and explain the different question that were raised.

Anonymous Referee no.2 Specific comments

1. Title: The title suggests that the paper deals with the presentation of a new model, while in fact most of the manuscript is filled with the application and the model is described only briefly. I would therefore suggest to use a different title that covers that

content of the manuscript better.

This manuscript is dealing with the land surface impact on atmospheric variability which is a current topical area of research. Even though the MM5 model has been coupled to various other land surface models (e.g. Chen and Dudhia 2001a, b; Dudhia, 1996, Xiu and Pleim, 2001), this is the first time to be coupled to SOLVEG model which is considered to be one of state-of-the-art in this field. The coupled MM5-SOLVEG is seen to be an original contribution to the atmosphere land surface interactions field of research. The coupling method and coupling routines are all original contributions that are described in the manuscript. MM5 model was not described in details because of the extensive prior validation and citation of the MM5 (mentioned in page 1072 line 14). SOLVEG also was not described in details because of the limitation of the manuscript size; citation was seen to be satisfactory such that interested readers can refer to the various mentioned references (Nagai, 2002, 2003, 2005; Yamazawa and Nagai, 1997; Yates et al., 2003) in pages 1072-1073. The only part that is rather discussed in details is the coupling method and the fluxes interactions between MM5 and SOLVEG in page 1073 and illustration figure (Figure 1) in page 1091. Based on that, the author thought the current title would be suitable for the manuscript, but after the various comments of the reviewers regarding the title, an alternative title will be proposed to reflect that two existing models are coupled and applied to a case study in the paper.

2. Page 1075: Model setup. How was soil moisture initialized in the model? This is relevant since it is the soil moisture that impacts the spatial and temporal variations in latent and sensible heat fluxes in the model. Please describe this in sufficient detail, along with possible impacts of the choice of initialization for the results. Fig 4 suggests that no "spin-up" was performed, and that the soil moisture was initialized as a function of soil texture (spatial pattern of soil moisture is similar to texture). However this correspondence rapidly disappears, suggesting that the tight relation between soil moisture and texture is not realistic, since other factors (i.e. rainfall) also impact soil moisture variability.

Soil moisture initialization is one of the crucial-complex issues in coupling a land surface model in mesoscale model. Inadequate initial soil moisture fields can introduce major biases in the partitioning of surface energy and have an abiding effect on the model performance, (Chen and Dudhia, 2001a). An appropriate initialization of soil moisture in coupled regional/mesoscale models is restricted by the fact that there are no routine soil moisture observations. Recent observations based on aircraft and satellite data can help regarding to this issue (Taylor and Ellis, 2006, Taylor et al., 2007), however it s still important to use a reliable observations to examine the quality and accuracy of such remote sensing procedures. Because of the scarcity of routine soil moisture observations, the initialization of the LSM mostly depend on soil moisture fields obtained from analysis/forecasts from other models. In this manuscript, hindcasting simulations of the atmosphere land surface processes over Japan are used to study the performance of the new coupled model (MM5-SOLVEG), and the evolution of the model derived rainfall distribution to the spatial variation in land surface characteristics. The lower boundary condition represented in the land surface's heat/moisture fluxes are coming from three different land surface parameterizations. In the following, the soil moisture initialization procedures for each of the LSMs implemented in this manuscript will be described:

a) First, the simple LSM (Blackadar, 1976) with five soil layers used in the control run (MM5-CTRL). This LSM, conceptually a ground heat budget model, is not compatible with the complexity of other physics processes in the MM5 model. An important weak point of this model among others is the soil moisture field that is defined as a function of land use and has only two seasonal values (summer and winter). In a short term simulation, the soil moisture is kept constant during model computation and cannot reflect the impact of recent precipitation.

b) Second, NOAH LSM (MM5-NOAH): NOAH LSM is capable of predicting soil moisture and temperature in four layers (10, 30, 60 and 100 cm thick). The LSM makes use of vegetation and soil type in handling evapotranspiration, and has effects such

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as soil conductivity and gravitational flux of moisture. In the current MM5-NOAH, the initial soil moisture/temperature can be obtained from several global forecast/analysis systems, because a similar LSM is used in these systems and the soil moisture fields are compatible to the MM5-NOAH with regard to its dynamic range (e.g. JRA-25 from Japan Meteorological Agency, Onogi et al., 2007; ERA-15 and ERA-40 from ECMWF, Uppala et al., 2005; NCEP-NCAR and NCEP's Final Analyses from National Center for Atmospheric Research, Kalnay et al., 1996). In the current MM5-NOAH, the initial soil moisture is obtained from NCEP Final Analysis (FNL) in the simulation period from 20-25 July in 2006. The reanalysis volumetric soil moisture and soil temperature fields are available for four soil layers, 0-10, 10-40, 40-100, and 100-200 cm , and are used directly without any interpolation to the four soil layers in the MM5-NOAH.

c) Third, SOLVEG LSM fully coupled tom MM5 model (MM5-CPL). The soil sub-model in SOLVEG had seven layers with boundary depths of 2, 5, 10, 20, 50, 100, and 200 cm, respectively. As explained in the manuscript in Page1073 L21-25 and explained in Figure 1, MM5 sends the initialization states to SOLVEG including initial soil moisture (SM), and bottom soil temperature (TB). As for the case of NOAH LSM, the initial soil moisture and the bottom temperature are obtained from NCEP Final Analysis (FNL). In the soil sub-model of SOLVEG, the bottom layer's (100-200 cm) temperature is kept constant throughout the computation, and the initial soil temperature profile at each grid location is made by interpolation between the surface soil temperature (NCEP-FNL air temperature near the soil surface) and the bottom soil temperature. SOLVEG's initial soil moisture at each grid location had a homogeneous distribution of NCEP-FNL first 10-cm depth soil layer's moisture. Regarding the reviewer's inquiry about impacts of the choice of initialization for the results, in this paper the authors did not engage with sensitivity analysis to check the influence of uncertainty in the initial soil moisture and its impacts on the spatial and temporal variations in latent and sensible heat fluxes. The existing literature of NOAH and SOLVEG LSMs had already dealt with the sensitivity analysis of soil moisture initialization on models performance. Nagai (2002) performed a sensitivity analysis to evaluate the performance of SOLVEG LSM setting

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on the surface fluxes. He found that the influence of the uncertainty in the initial soil moisture mainly affected the sensible and latent heat fluxes, but without significance as a whole. Chen and Dudhia (2001 a) demonstrated the sensitivity of the coupled MM5 to NOAH LSM to the initial soil moisture fields. They also showed that partitioning of surface radiation forcing into latent and sensible heat fluxes are significantly influenced by the initial soil moisture fields, especially in arid and semi-arid climatic regions. As for the last part of the reviewer's comment, it is shown in detail in the above discussion that no spin-up performed for to reach initial soil fields for the different models setting. In fact, within this paper, the authors did not think about spin-up as a mean to obtain reliable soil moisture initialization fields because of the scarcity of meteorological observations on regional scale needed to drive a LSM in offline mode to simulate long-term evolution of soil moisture. However for future studies, the spin-up procedure can be performed by using the output of global forecast/analysis systems data to run any LSM in an offline mode to looping repeatedly through a single year until a desired level of equilibrium in soil moisture is achieved.

3. Page 1077, Line 14. Does this feedback really exist? Higher ground temperatures do heat up the surface layer air (only if this is higher than the surface temp!), but this also leads to a heat transport from the soil to the atmosphere (and thus cooling of the surface). This suggests a link with radiation differences between the model runs, which result in surface temperature differences. The reviewer commented our statement in the manuscript P1077L14 that states "SOLVEG has tendency to produce higher ground temperature than the slab land surface model or the NOAH LSM. The higher ground temperature heats up the surface layer air, and the higher air temperature causes further rise in ground temperature". However, there are no technical errors in the statement based on reviewer response; the authors agree with the reviewer that this point was not investigated in enough detail through the manuscript. In P1077L3-14, SOLVEG tendency to produce higher ground temperature was explained by SOLVEG's advanced radiation and stomatal resistance schemes. The treatment of the radiation processes and canopy resistance differ profoundly among the different

models used in this study. The radiation scheme of SOLVEG calculates the radiation transmission in the canopy by separately treating the four solar radiation components (visible and near-infrared bands in direct and diffuse components). By this scheme, the observed albedo can be better simulated which is necessary for the energy balance at the ground surface, (Nagai, 2003). This scheme enables the utilization of stomatal resistance schemes based on the leaf photosynthesis. The stomatal resistance scheme is not only used to determine the stomatal resistance but also to calculate CO2 exchange between vegetation and the atmosphere. In NOAH LSM, a simpler radiation schemes is implemented in which the solar and longwave radiation fluxes are dealt with as isotropic downward and upward fluxes without spectral dependency of radiation assumed. The Jarvis type scheme is implemented in NOAH LSM to calculate the stomatal resistance from the solar radiation flux following Deardorff (1978). No doubt that the radiation transmission in canopy is more realistically parameterized in SOLVEG rather than NOAH. The study by DePury and Farquhar (1997) showed the importance of the separate treatment of direct and diffuse components of visible solar radiation flux for the photosynthesis and energy balance calculation. The effectiveness of photosynthesis based schemes compared to a Jarvis-type scheme is discussed by Niyogi and Raman (1997). The changes of the radiation and stomatal resistance schemes affect the latent and sensible heat fluxes that are reflected in different ground temperature pattern among the different models.

4. Page 1081, Line 14. Can slightly higher soil temperature really impact the upper model layers? The heat capacity of the soil is limited, so any heat transport to the atmosphere will in turn lead to a decrease in surface temperature. Differences in soil temperature can only be sustained by differences in air temperature or radiation, non of which is investigated in the paper. This comment and the previous one are almost dealing with the same problem of the mechanism of the higher ground temperature computed by the SOLVEG in the MM5-CPL compared with the ground temperature in MM5-NOAH and MM5-CTRL. The authors agree with the reviewer this point needs more analysis and clarification to be placed in the manuscript. As for the time this was

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not done in a complete manners, the authors will engage with this point in the revised version of the manuscript.

5. Page 1083, Line 22. It is not shown that the MOST profound differences are in the rainfall, but only that the differences in rainfall are profound. The authors agree with the reviewer's statement that only the differences in rainfall are profound. The analysis of the simulation results depended principally on the difference of rainfall results among different model configurations (MM5 with the slab LSM, MM5 with the NOAH LSM, and MM5 with SOLVEG LSM). This is because authors believe that rainfall depends strongly on the atmospheric motion, moisture content, and physical processes, and the quality of a model's rainfall simulation can be used as an indicator of the overall model health (P1076L6-10). Moreover, the availability of dense network of rainfall observations on the study area supported the analysis to be focused on rainfall results.

6. Page 1068, line 2: "represent better" Correction: "better represent"

7. Page 1068, line 5: Earth Correction:

8. Page 1068, line 18/19: "This paper clearly shows" Correction: "This paper shows"

9. Page 1069, Line 20: It is not the parameters that are exchanged, but rather the fluxes. Correction: Page 1069, Line 20 should be "in two-way coupling, models exchange the relevant moisture and heat fluxes".

10. Page 1070, Line 4: TOPMODEL is a concept or framework rather than a complete hydrological model. The correct reference is to Beven and Kirkby, 1979. Correction: We fully agree with the reviewer that the TOPMODEL (Beven and Kirkby 1979) is a framework and approach for the formulation of the subsurface hydrologic behavior and the spatial variability in soil moisture. In the introduction section Page 1070, Line 3, the correction will be "Seuffert et al. (2002) coupled the LM model (Doms and Schattler, 1999) and the land surface hydrologic model known as the the "TOPMODEL"-Based Land Surface;Atmosphere Transfer Scheme (TOPLATS; Famiglietti et al. 1992; Peters-

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Lidard et al. 1997) in a two way-coupling to study the Influence of hydrologic modeling on the predicted local weather".

11. Page 1073, Line 21: again states, or fluxes, rather than parameters. Correction: The authors are apologizing for such kind of repeated inappropriate choice of terms within the manuscript; probably some of the English is a little awkward, because of the nativeness of the main author. Page 1073, Line 21-22 should be "At the first time step, MM5 sends the initialization states to SOLVEG". The manuscript will be proof-read again by the authors and probably by native English speakers before the submission of the final revised manuscript.

12. Page 1077, Line 7: "SOLEVEG" Correction: "SOLVEG"

13. Page 1078, Line 19: "On the contrary to" Correction: "In contrast to... "

14. Page 1082, Line 23: "state of the art" Correction: "state-of-the-art"

15. Figures: The color bars are very small, sometimes i had to look twice to see that in fact they were not missing! These authors agree with the reviewer that some figures are not clear enough, especially the colors bars in Figure 3 and Figure 5. Such figures will be edited for more visibility and clearness in the revised version of the manuscript.

At the end of our response to the reviewer's comments, we will try to answer an important question that has been raised by the reviewer that is what the readers can learn from this study besides that different model setups give different results. The models combination introduced in this study are representing the atmosphere land surface interaction part of a comprehensive Atmosphere-Ocean-Land-Surface-Hydrology coupled model known as ASIA ENVIRONMENTAL SIMULATOR (AES). Haggag and Yamashita (2008) defined AES as a coupled system of computer simulation for meteorology, physical oceanography, land surface, vegetation, hydrology, coastal dynamics, and urban environment (. Our main objective of AES is to make it as an effective environmental assessment tool for the integrated sustainable development plans in Asia

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and Africa. All the models included in AES to represent the different components of the earth environment have been used and validated extensively in the literature, but in isolation from other environmental processes. Our proposed scheme is to model the earth environment in unison to better represent the different feedbacks among the earth environment components and their ultimate influence on the properties of the whole system. In this paper, we want the reader to realize that we are neither developing a new atmospheric circulation model nor a new land surface model from scratch. But we can make use of the available state-of-the-art tools in different fields to build an integrated earth environment modeling system by introducing the feedbacks among the different environment components. The coupling scheme between MM5 and SOLVEG is just an example of what can be done to include many other processes in this proposed modeling system.

Finally, we thank the reviewer for contributing to the discussion of our paper. The reviewer's comments greatly added to the clarity of this manuscript. However, we apologize for any lack of clearness in the first version of the manuscript. After this deep revision, we hope that the reviewers will find the revised manuscript of interest and value for the readers' community.

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