Sensitivity study of the effects of land surface characteristics on meteorological simulations during the TexAQS2000 period in the Houston-Galveston area

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1. Introduction

In 2000, an important field campaign known as TexAQS2000 was conducted to understand the Houston-Galveston air quality problems. Through this campaign, it was revealed that the movement of ozone and its precursors is highly correlated with the land-sea breeze circulation. To capture the mesoscale circulations in the numerical meteorological simulations, the lower boundary conditions described by the land surface model or simple soil module must provide accurate and adequate information on the surface flux exchange. The goal of this study is to understand how the land surface characteristics affect the meteorological simulation for the Houston-Galveston area (HGA) during the TexAQS period. In this study several sensitivity tests were performed on land surface algorithms to determine their impact on meteorological simulations. These cases were selected to support air quality simulation in the Houston-Galveston area.

2. Model and numerical experiment design

MM5 Version3 Release 6 (MM5v3.6) was used. The simulation period was from August 22 to September 02, 2000. MM5 physics options used include: 1) the Grell cumulus scheme on the 108, 36 and 12 km domains, 2) the MRF PBL scheme, 3) the Dudhia simple ice microphysical scheme and 4) the cloud-radiation scheme. The first guess and boundary conditions were taken from the NCEP Eta model on the Eta212 (AWIP 40 km domain). Upper air analysis nudging was used. Since Version 3.6, the Oregon State University / NCEP Eta Land-Surface Model (OSU LSM) in MM5 (Chen and Dudhia 1999) has been replaced by an updated version of the model, known as the NOAH LSM.

MM5 numerical simulations based on different land surface algorithms were conducted to investigate the impact of land surface treatment on meteorological simulations in the Houston and Galveston area during the TexAQS2000 period. First, we used MM5 simulations coupled with the slab soil model and with temporal varying soil moisture parameters (case S1). Here soil moisture was modified in the urban area to make it wetter; however the rural area was modified to make it drier (Nielsen-Gammon, J. W., 2002). This modification was made to be close to the real situation. Dr. Nielsen-Gammon, TAMU, provided the S1 simulations. Second, we simulated MM5 using NOAH LSM with identical inputs and model configurations as in S1 except for the land-surface module (case S2).

The default MM5/NOAH simulations (S2) showed a very large diurnal range in the temperature predictions in Houston urban areas.

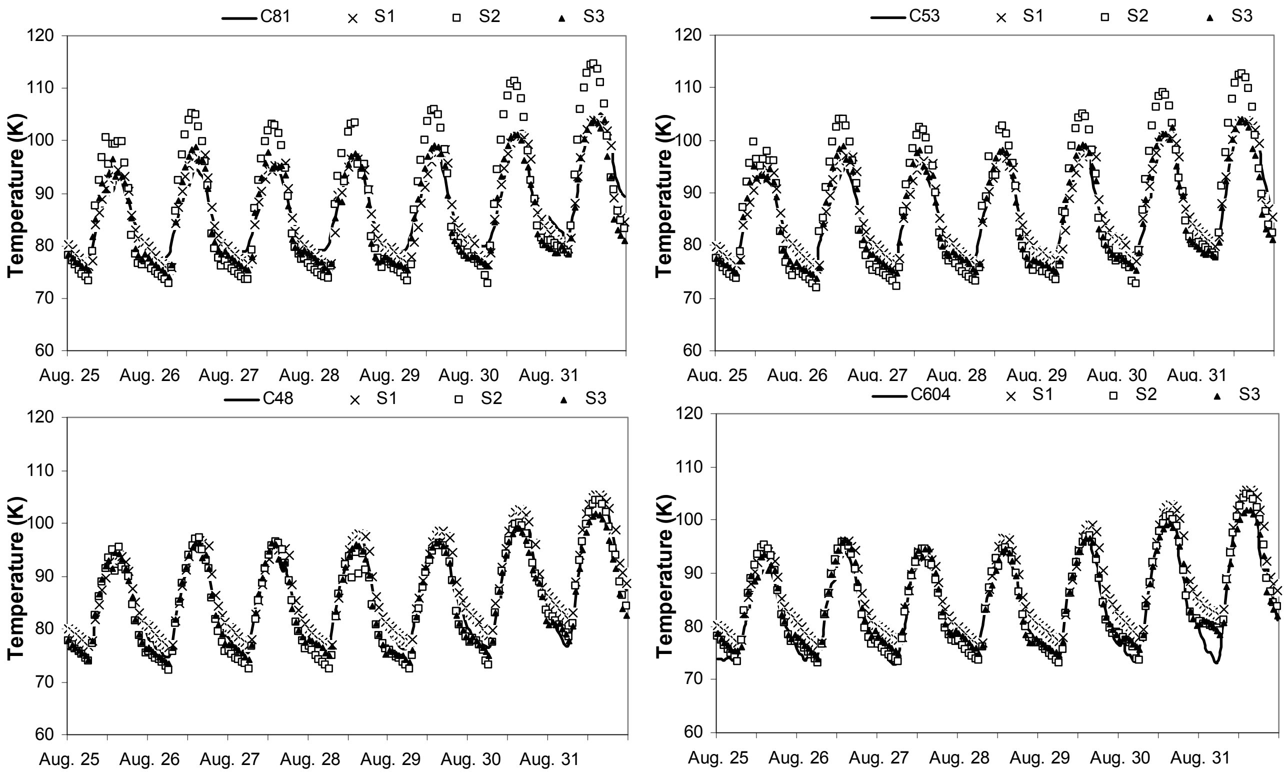

Fig. 1. 2-m temperature on C81, C53 (urban site) and C48, C604 (rural site).

It was found that the simulated surface conditions in the urban areas were too dry to be realistic. Therefore, we have increased soil moisture in the NOAH LSM as in the TAMU MM5 case. We call this set of MM5 simulations as S3.

3. Results

Four sites in the rural (C48, C604) and urban areas (C81, C53) were selected to investigate the effects of land surface characterization algorithms. Figure 1 shows simulated and observed time series of 2-m air temperatures at these sites. At the urban site, the S2 simulation shows very large diurnal temperature variations. This discrepancy is corrected in the S3 simulation because of the addition of soil moisture to the urban area. The S3 simulation compares well with observations, in particular for the maximum temperature. However, the nighttime low temperature bias still exists.

For the S3 simulations, the PBL heights estimated by MM5 match very well with profiler data. Here, the August 27 and August 30 dates were selected to compare the development of the simulated PBL heights with profiler observations.

In Fig. 2, the solid lines show results from MM5 simulations and the dotted lines are from profiler observation data. The La Marque (LM) site is located close to the coastline and was influenced by the marine air. Therefore it shows lower observed PBL heights than other sites. However both the S1 and S3 simulations fail to capture the low PBL height at the LM site, especially on August 30.

On August 30, the profilers at Houston Southwest (HS) and Wharton (WH) measured mixing depths of about 2000 m and 1300 m, respectively at 16:00 CST.

Other profiler data showed mixing heights over the Ellington (EL) site reaching about 2500 m, which is much higher than the WH site located far north west of the Houston urban area. These observations need to be investigated to determine if they support the hypothesis of the Houston heat island effect suggested by Christoph Senff (2002). Similar features are captured in the S3 simulations. In general, S3 gives better PBL predictions than S1.

Fig. 3 provides vertical profiles of potential temperatures in the boundary layer from the MM5 output. A grid cell close to the EL wind profiler site was selected. Plate (a) is for August 27 and plate (b) is for August 30, CST 1600. On August 27, all the MM5 simulations show similar vertical development of potential temperature. However, on August 30, the capping inversion for the S1 simulation is much weaker than the S2 and S3 simulations. This explains why S1 predicts a much higher PBL height on August 30. A further study is needed to understand the causes of these differences among the simulations.

4. Conclusion and future work

MM5 simulations coupled with the NOAH LSM using the default parametric set up resulted in very dry urban conditions and thus created a much larger diurnal range of the surface temperatures than the observations. The simulation was improved by increasing soil moisture for the urban area in the NOAH LSM. However, the NOAH LSM predicts significantly lower nighttime temperatures than observations, requiring further investigation. For the PBL heights, MM5 simulations coupled with NOAH LSM results show better comparisons with profiler observations than the MM5 with SLAB soil module.

From these preliminary results, it has been demonstrated that meteorological conditions that affect subsequent air quality simulations are heavily dependent on the land surface modules utilized in MM5. With the further improvements to the MM5 simulations, air quality modeling will be performed to evaluate the effects of the meteorological conditions on the Houston-Galveston area high ozone problem.

5. Reference:

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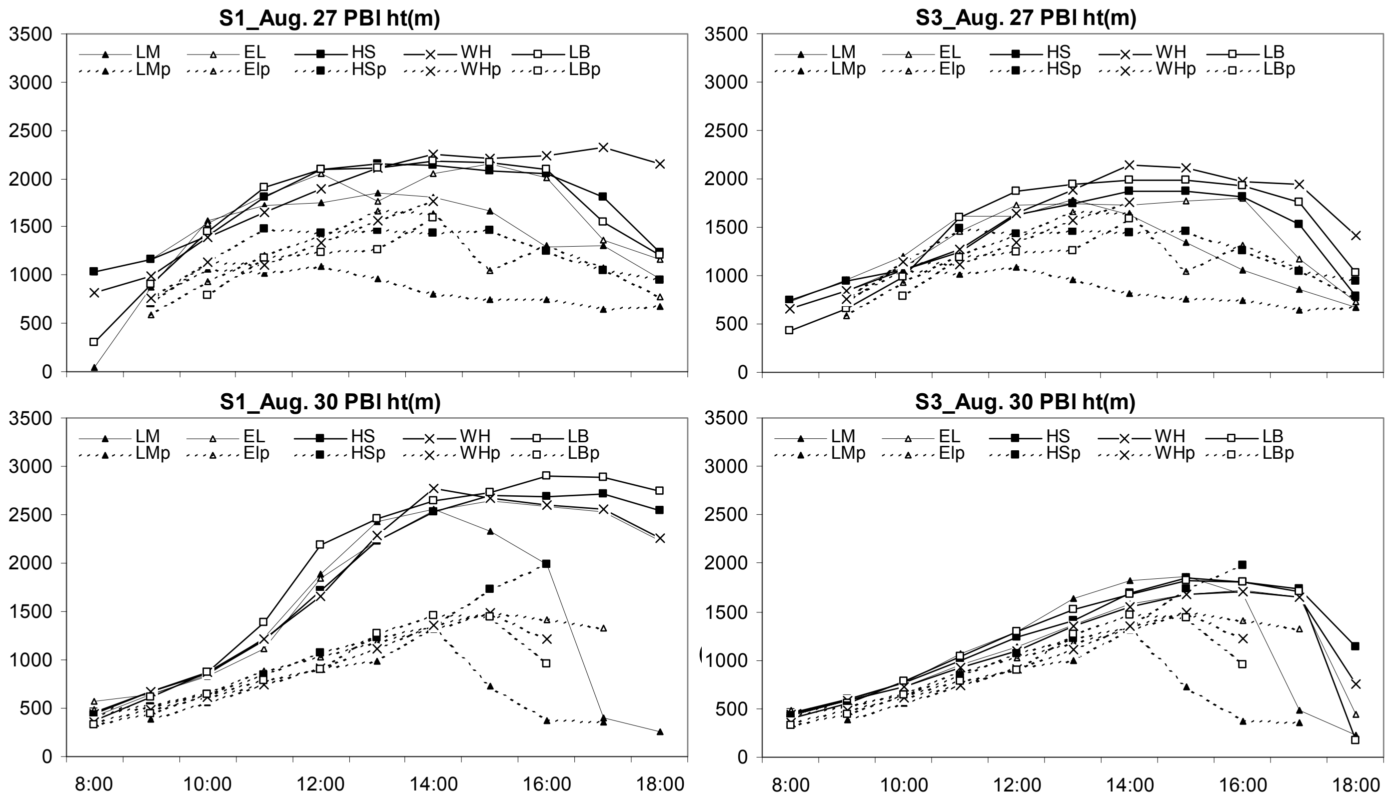
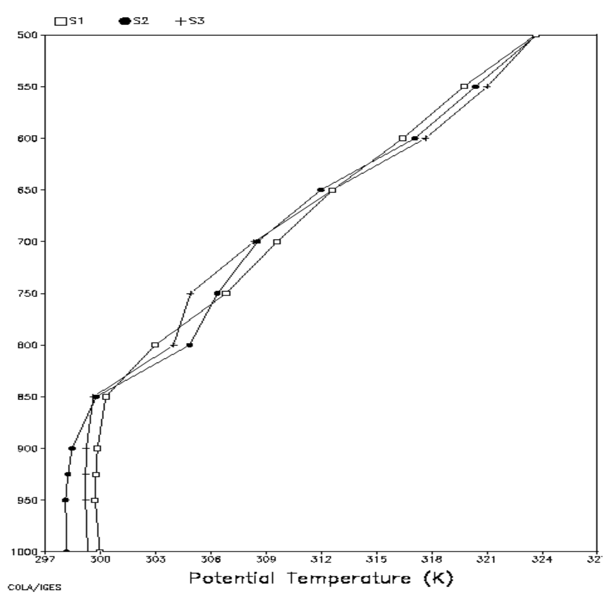


Fig. 2. Comparison of the PBL height development from MM5 simulations and wind profiler data on Aug. 27 and Aug. 30. (Solid line is from MM5 simulation; dotted line is wind profiler data)

(a)



(b)

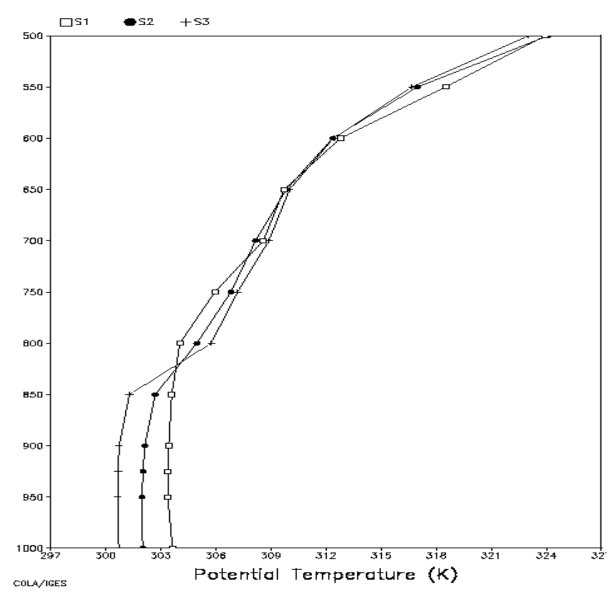


Fig. 3. Comparison of the vertical profile of PBL potential temperature from MM5 simulations on (a) August 27, 1600 and (b) August 30, 1600 CST.