Effects of soil moisture treatment in MM5 on the land-sea breeze simulation during TexAQS2000 period in the Houston-Galveston area

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1. Introduction

Houston's ground level ozone concentration failed to meet air quality standards for several years (ENVIRON, 2001). In summer, high pressure system persists over the Gulf of Mexico leading to stagnant conditions in southeast Texas. Under this weak synoptic scale forcing, land sea breeze circulation becomes apparent and dominates the weather pattern in the Houston-Galveston area. Texas air quality study 2000 (TexAQS2000) was designed to improve the understanding of chemical, meteorological and atmospheric transport processes that determine ozone and fine particle distributions in Houston-Galveston area. Preliminary results of TexAQS2000 have shown that the movement of ozone and its precursors is highly associated with land-sea breeze circulation in this area.

It has been well known that local circulation like land-sea breeze can be highly affected by land-surface processes. Land surface models have been used to deal with land-surface processes realistically. Soil moisture is one of essential parameters in land-surface processes. In MM5, when simple slab soil model is used, soil moisture is assigned to a constant value for each land use category. Or soil moisture can be calculated prognostically using sophisticated LSMs such as the modified OSULSM. But, how to treat the soil moisture is still an important scientific issue (e.g., Chen and Dudhia, 2000).

2. Model and numerical design

MM5 Version3 Release 5 (MM5v3.5) is used. The simulation period is from Aug.22 to Sep. 02, 2000. MM5 physics options include: 1) Grell cumulus scheme on the 108, 36 and 12 km domains, 2) MRF PBL scheme, 3) Dudhia simple ice microphysical scheme and cloud-radiation scheme. The first guess and boundary conditions are from the NCEP Eta model on the Eta212 (AWIP 40 km). Upper air analysis nudging is used without the surface analyses nudging.

Three contrasting MM5 numerical simulations based on different land surface processes are conducted to investigate the impact of soil moisture treatment on land-sea breeze simulation in the Houston and Galveston area during TexAQS2000 period: (1) slab soil model with temporal varying soil moisture parameter. Here soil moisture was modified in urban area to make it wetter; but rural area was modified to make it drier (Refer to table 1) (Nielsen-Gammon, J. W., 2002). This modification was made to be close to the real situation. (2) slab soil model with constant soil moisture parameter, and (3) modified OSULSM. Hereafter S1, S2 and S3 are used to stand for three different cases respectively. These cases were selected to support air quality simulation in Houston and Galveston area.

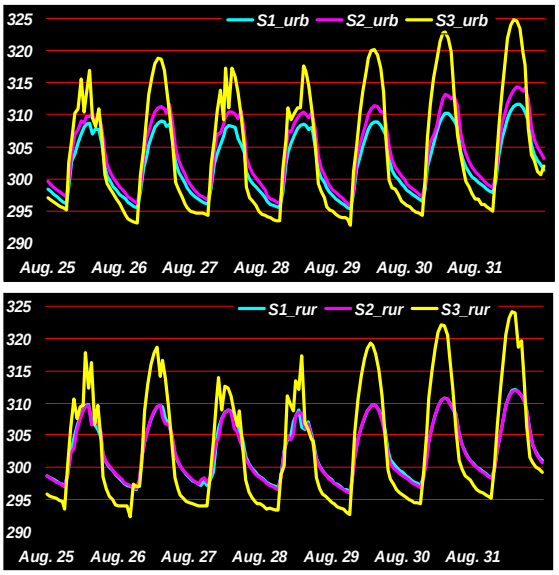

Figure 1. Time series of ground temperature in urban and rural point.

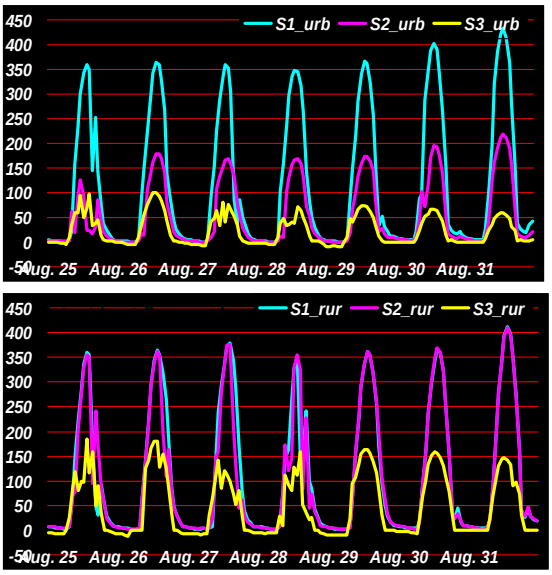

Figure 2. Time series of latent heat flux in urban and rural point.

Name	Category	108 and 36 km	12 km	4km		
				08/22 to 08/26	08/26 to 08/28	08/28 to 09/02
Urban	1	10	10	30	20	20
Dryland	2	30	20	30	20	10
Cropland	5	25	15	25	15	10
Grassland	7	15	10	10	10	10
Deciduous forest	11	30	30	30	25	15
Evergreen forest	14	30	20	30	20	10

Table 1. Temporal modified soil moisture value (%) in S1 simulation.

3. Results

Two sites in urban and rural area are selected to see the impact of the soil moisture and the effect of land surface processes.

Figure 1 shows the time series of ground temperature at urban and rural two sites. In the urban point, S1 simulation has a lower prediction of temperature than S2 due to the increased soil moisture but in rural point S1 has almost the same prediction of ground temperature as S2. S3 simulation has a much drier condition than S1 and S2 therefore it shows higher diurnal range.

Figure 2 shows the time series of latent heat flux. In urban point, S1 simulation has much higher latent heat flux prediction than S2 and S3 due to the increased soil moisture. In the rural point, S1 has almost the same simulation result as S2. S3 shows much drier condition than S1 and S2.

Figure 3 is from the spatial distribution of latent heat flux to see the effect of soil moisture in HG area. Plates (a), (b) and (c) stands for the simulations S1, S2 and S3 respectively. Here the effect of added soil moisture in urban area is clearly displayed and distinguished in figure 3(a) and (b). S1 simulation shows higher latent heat flux than S2 in urban area. In rural area, although soil moisture is reduced, S1 and S2 show similar simulation result. In figure 3(c), S3 simulation has more spatial variation of the latent heat flux than S1 and S2, and shows a much drier condition.

Figure 4 shows the wind distribution simulated with different land surface processes. Plates (a), (b) and (c) stands for the simulations S1, S2 and S3 respectively.

All the three simulations show the similar wind distribution and strong sea breeze phenomena. Simulation with OSULSM (figure 3(c)) has a much drier condition than S1 and S2. This drier condition will increase the diurnal range of ground temperature therefore cause the stronger sea breeze penetration than S1 and S2 simulations.

4. Conclusion and future Work

Comparing with S1 and S2 simulation, S1 apparently shows the effects of the added soil moisture in urban area however in rural area the simulation result is quiet the same between S1 and S2. In wind field, all the three simulations show the similar wind distribution and very strong sea breeze phenomena. S3 is simulated with OSULSM and it shows much drier condition than S1 and S2. This drier condition will furthermore intensifies the comparison between land and sea and cause stronger sea breeze penetration.

From the preliminary result, the effect of land surface processes on meteorological condition can be understood. In the following step, three simulations will be used for air quality study. Air quality modeling will be performed with a set of mesoscale meteorological simulations based on the previous simulation to evaluate the effects of the meteorological conditions on Houston high ozone problem.

5. Reference:

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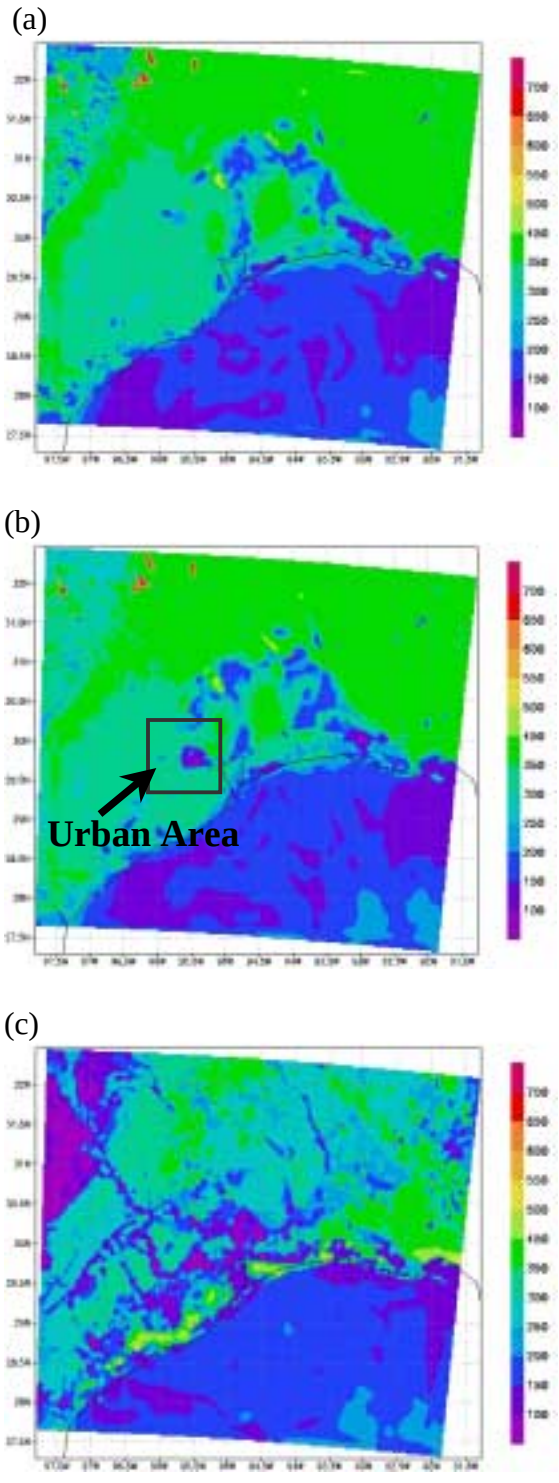

Fig 3. Simulation of latent heat flux in Aug25, CST1200 with (a)S1, (b)S2 and (c) S3 experiments.

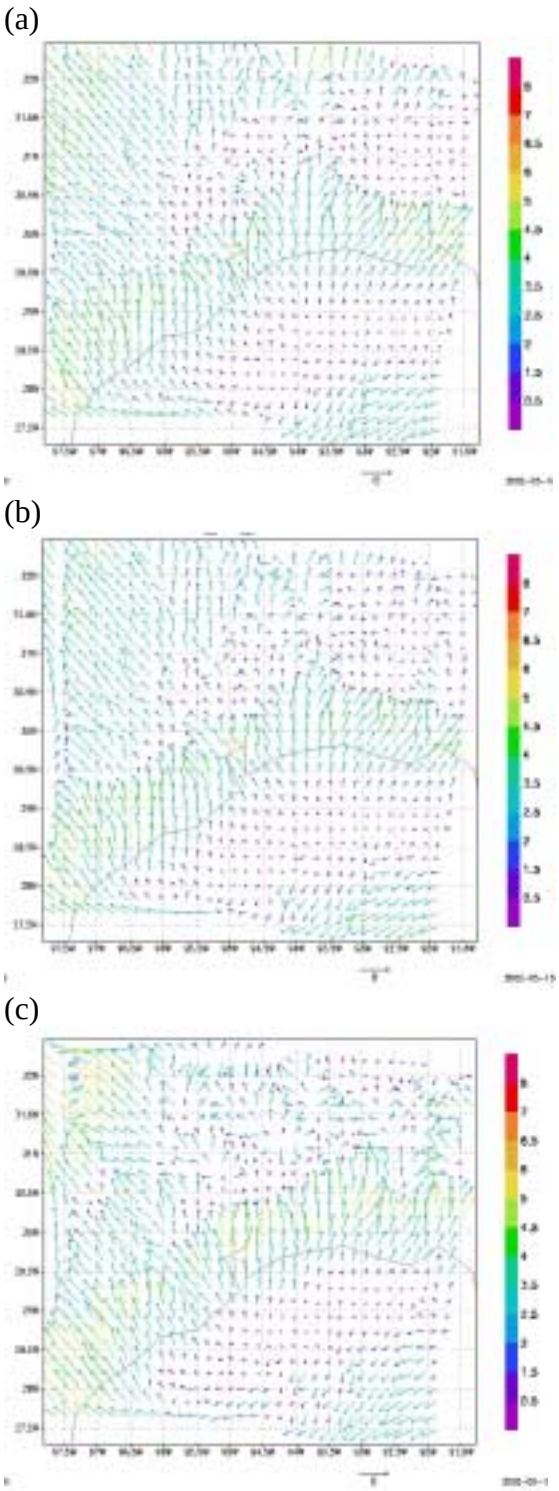

Fig 4. Simulation of wind vector in Aug.25, CST1800 with (a)S1 (b)S2 (c) S3 experiments.