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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Effect of explicit urban land surface representation on the simulation of the 26 July 2005 heavy rain event over Mumbai, India" *by* M. Lei et al.

M. Lei et al.

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Response to Reviewer's Comments on "Effect of explicit urban land surface representation on the simulation of the 26 July 2005 heavy rain event over Mumbai, India"

1. Regarding the use of the TEB model: There are other key input variables needed for TEB, for example, the thermal conductivity and heat capacity of the city roof, walls, and road, the thickness of the roof and walls, and the albedo of these surfaces. Table 1 should be expanded to include these. How were values for these chosen? How were the values of traffic and industrial heat fluxes determined? Were these applied at each time step of the model or was a diurnal cycle imposed (e.g., traffic fluxes generally have a diurnal cycle). How important were these anthropogenic fluxes to the simulation of

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the UHI?

Table 2 (which contains this information) is expanded. Values are based on our knowledge of the Mumbai area and from prior studies such as Masson (2000), Johnson et al. (1991), Oke (1988), and Rozoff et al. (2003). A constant value was used for traffic and industrial heat flux, and applied for each time step only over the urban cells. Each of the model input parameters and values can affect the UHI. The sensitivity of the anthropogenic fluxes is not the focus of this paper.

2. Section 4.1, line 4: It's clear that RAMS TEB simulates an urban heat island, but I am not sure one can say that it is "well-simulated" since there are no comparisons to observations of temperature made here.

The text has been modified in the manuscript.

3. Section 4.1, line 18: I don't quite understand the statement that "TEB did not change the latent heat flux significantly due primarily to the very low evaporation over the urban region". I would think that the control run (black line in Fig. 11) would have higher evaporation than TEB since presumably LEAF-2 is using some vegetation type to represent the urban area.

Though it is not an explicit representation of urban area, LEAF-2 has a simplified treatment for urban landscape. Therefore, the change is relatively small.

Technical Corrections

1. Abstract, line 5: suggest: "We conducted experiments using the Regional..., coupled with and without an explicit urban...". 2. Abstract, line 21: change "TEB/urban" to "TEB". 3. Section 2, line 16: the last sentence is repetitive. 4. Section 2, line 17: suggest: "The urban model was coupled to RAMS over the inner-most region...". 5. Section 2, line 23: suggest: "...quickly produced spatial heterogeneity in the region." 6. Section 2, line 18: Is there a reference for the USGS global data set? What is the spatial resolution of this dataset? 7. Section 3.2, line 2: suggest: "...the majority of the

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950mm total occurred...". 8. Section 4.3, line 20: suggest: "Fig. 15 shows the cloud water mixing ratio at 12Z, 26 July." 9. Figure 10 caption: suggest: "July sensible heat fluxes in both simulations and their differences..." 10. Section 4.2, line 27: The text refers to Figs. 13a-d, but the figure only has labels for 13a and 13b. 11. Section 4.3, line 25: The text refers to Fig. 15c, which doesn't exist.

All editorial suggestions have been adopted in the revision. The USGS global data is at 30s resolution. The Pielke et al. (1997) citation was in reference to the USGS dataset.

Primary Comments

1. The authors should be careful when describing the urban rainfall effect. In recalling Rozoff et al. results, they focused on more than the UHI. They were also concerned about the effect of the urban landscape on convergence, etc (e.g. through roughness; mechanical turbulence). The point I am making is that the urban effect is probably a more accurate reflection than UHI effect. Your results even confirm this later in section4.2 of the paper. You should probably adjust this in the conclusions section as well.

Agree. Text was changed to reflect this.

2. In figure 6 and related discussion in the text, the authors should be a bit more specific about what TRMM product this is? Is it the TRMM MPA product (real-time or not) (e.g. Huffman et al. 2007), a gridded version of TMI only, etc. I suspect it is one of the TRMM MPA products which is a combination of TRMM, IR, and other passive microwave data. If so, this product should be properly identified in the text and other places.

The TRMM product we used here is a gridded version of TRMM Microwave Imager (TMI).

3. In section 4.1, the discussion about the advection of the UHI downwind is consistent with previous studies in the literature. The authors should refer to some of the previous

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literature supporting this type of observation.

Bornstein (2000) reference is added.

4. While reviewing figure 8, it became apparent to me that a useful figure or addition to this paper would be to show the urban land cover of Mumbai. This could be done as a separate figure or with urban land cover extent included under the images in figure 8. This would qualitatively show the UHI-spatial variability relative to the land cover.

The majority of the innermost domain is urban area. Therefore we are not adding this figure. While we cannot add it here due to copyright issues, readers can review the urban extent using Google Earth imagery.

5. In section 4.1, I would recommend adding another historical reference in addition to the Niyogi et al. 2006 establishing that the UHI is maximized overnight (maybe something from Oke or Bornstein).

Oke's book (1988) is cited here.

6. In section 4.2, you should refer to previous literature noting the enhancement of convergence due to mechanical turbulence induced by urban roughness.

Thietin et al. (2000) is cited.

7. Could the authors clarify whether 0.8 roughness is being used at every urban grid-point or is this being subjectively adjust based on the assumptions on morphology. Also, I actually think that 0.8 is probably too low in model simulations for large urban CBDs although I know that it is commonly employed. The authors should offer some future direction about the need for improved global urban morphological datasets.

0.8 m roughness is the average value, and we generally set effective roughness as 1/10 of the building height. We have stated the need for detailed urban morphology datasets.

Minor grammar/English/presentation issues

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a. In a few places, "the" is need before some words. Please review to capture these issues. If the author's first language is not English, it may be useful to have a native English speaker review the text.

The manuscript has been reviewed by a technical editor.

b. Many of the figures were somewhat difficult to read (e.g. the value of the numbers). This may somewhat a function of the pdf rendering but please be cognizant of this fact.

Figures have been modified.

c. The authors should be consistent in presentation. For example, in some figures you show the CONTROL and TEB. In some places you say, "Differences" and in other figures you say, "Changes". Just pick one and be consistent.

This has been changed.

General open questions

1. As mentioned on Page 8778 (ln 5) RAMS model skill to simulate convective system, Is RAMS able to simulated convective cell, If yes then please justify the role of UHI on strong convective cells.

The focus of our study is on heavy rain simulation, and within that scope we can verify that UHI had a role in placing the heavy rain over the urban area. The factor separation results presented in the paper provide an explicit value of UHI and the UHI; SST interactions in modulating the heavy rains.

2. Level at which, westerly become easterly called as critical level. My question is how this critical level get affected during starting time of rain to ending time of rain. Is there any significant change on this critical level while heavy rain time?

Adding the urban model enhanced convergence and the upward motion. This modified the critical level. It is about 400 mb. Critical level increased during the rainfall.

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3. Page 8787 (ln: 1-5) - With TEB experiment, rainfall increased by 150-200 mm, can author explain and show how it affected mesoscale circulation of 850 hPa level and 500 hPa (for e.g.: geostrophic flow). I just want to understand the TEB effect of mesoscale circulation at this two levels if it changes rainfall intensity by 200 mm.

Because of convergence over urban region, there is a change in the critical level as well as circulation pattern. The 850 mb flow is decreased and a similar but smaller impact is noted for 500 mb. So the mechanism is the modification in the location and intensity of the convergence zone.

Minor Comments and Discussion

1. Page 8774 (ln:21) - Realistic gradient in what parameters that are important in relation to convergence zone.

For our study the surface temperature, humidity, and flux gradients were important.

2. Page 8775 (ln: 24-25) - Vaidya and Kulakrni (2006) found cloud burst phenomenon was the main reason for the heavy rain or they just assumed that this heavy rain may occur due to cloud burst. Please correct statement.

Vaidya (coauthor on this paper) and Kulkarni suggest (not conclude) that cloud burst phenomenon may cause this heavy rain. Statement not changed.

3. Page 8778 (ln:7-9) - Nested RAMS model domain are chosen by author as 80,20,5 km with time step 27,9,3 sec. My question is time step is 9:3:1 ratio order, which is not consistent with grid ratio. Are this kind of model configuration affect result?

While we report only 4 experiments in detail, over 30 different model experiments and configurations were tested to develop a better understanding of the processes that may be affecting the heavy rain occurrence for this event. Specific to the question posed there was insignificant difference due to time step. The most significant factors (SST, urban energy balance) are hence discussed in the manuscript.

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4. Page 8779 (ln:7) - SST figure shows larger gradient over west coast prior to heavy rain. Is it unusual sst variation during this time and year, what past studies indicate?.

This is a region with relatively low data coverage. We could not identify any studies or data to confirm this. However, we reviewed the TRMM SST from 1997 to 2008 at the end of July. From 2002, the SST near the coast show relatively warmer regions from east to the west. This is a relatively short time period and hence one cannot conclude if this climatologically significant unusual or not.

5. Page 8780 (ln: 15) Please provide reference of offshore trough over Arabian Sea. Just give reference which can establish the mechanism and evolution of this offshore.

Kumar et al. (2008): A. Kumar, J. Dudhia, R. Rotunno, D. Niyogi, U C Mohanty, 2008, in review with Quart. J. Roy. Meteor. Soc. is added.

6. Page 8781 (ln: 1-2) NCEP analysis or NCEP reanalysis. Please correct. Secondly, NCEP analysis is repeated in text. Corrected as reanalysis.

7. Page 8782 (ln: 16) - not feasible to use hotspot word. This has been retained

8. Page 8782 (ln: 16) - Figure 6c should be in mm units. This figure is updated

9. Page 8782 (ln: 24) - Can we called this event as "Storm" during Monsoon period. Yes.

10. Page 8782 (ln: 26)- "0Z" corrected to 00Z. Ok.

11. Page 8783 (ln: 16) - If author provide some bias and rmse statics then it helps to determine urban effect more efficiently.

The observations are limited and have high uncertainty. Therefore the focus has been on comparing regional dynamical features.

12. page 8784 (ln:15) - In fig 8e over seas surface, 1000 hPa air temperature shown high variation. Justify?

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Interactive Comment

The air temperature is responding to SST changes and modified circulations.

13. Page 8785 (ln: 25) - Where is Fig (12c)?. 14. Page 8786 (ln: 4-5) - Where is Fig 13c and 13d?. 15. Page 8786 (ln: 25) - In fig 15, where is fig 15c and Is fig 15b missing?.

All the figures have been updated.

16. Page 8789 (conclusion 4.) Where this moisture came from. Is from RAMS we can understand the moisture source as it run on high resolution we can determine the moisture source.

The origin of moisture transport is studied and reported in Kumar et al. (2008) and not discussed here. The prime source is Arabian Sea. The change in convergence causes change in timing and location of the moisture availability and the heavy rain occurrence.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 8773, 2008.