Responses to reviewers' comments on the manuscript "Effect of Land Cover on Atmospheric Processes and Air Quality over the Continental United States – A NASA Unified WRF (NU-WRF) Model Study"

We are grateful to the insightful comments from two anonymous reviewers that help make the presentation better. The following lists our responses to the comments. The original reviewer's comments are in bold.

Anonymous Referee #1:

1. This paper uses a new WRF-based modeling system to examine the effects of different land cover data sets on air quality in the U.S. It is an interesting study that is worthwhile of publication. However, there is minor English editing that needs to be done, and either additional references or discussion are needed in the description of the model and of the observation datasets.

Thanks for the positive feedback. We thoroughly edited the manuscript and added the additional references to due diligence.

2. Page 5434 (sentence starting on line 26) to 5435 (end of that sentence): insert "the" before all of the items being described.

Done.

3. Also either add a reference or further discuss the "new Grell cumulus scheme".

The new Grell cumulus scheme is an improved Grell-Devenyi ensemble cumulus scheme (Grell and Devenyi, 2002) that allows subsidence spreading for high resolution simulation (Lin et al., 2010). The references have been added.

4. Page 5441, line 1: replace "of" with "for" Page 5452: lines 10-11: replace "human" with "humans" Page 5455, line 28: insert "the" before "conceptual".

All done.

5. Page 5456: I would have liked to see a recommendation on which dataset is best.

This is a million dollar question. We now added in Table 3 of the manuscript the additional statistics for the E_MODIS and E_UMD. Overall, for the simulation period over the CONUS domain, all three LULC datasets present the similar comparison statistics without a clear winner. However, when only urban and developed land category is considered, the MODIS dataset shows superior to both the UMD and USGS ones with the least bias for both ozone (2.4% NB vs. more than 5% from the E_USGS and E_UMD) and PM2.5

(7.7% NB vs. 26.1% for the E_USGS and 16.9% for the E_UMD). This description is inserted in sect. 2.4 (Model evaluation).

Anonymous Referee #2:

1. This manuscript aims at testing uncertainty of land cover and urbanization impacts on surface meteorological conditions and air quality using the NASA NU-WRF experiments. Using simulations with three different land cover datasets, the authors show that the discrepancies among these three land cover data could cause noticeable differences in soil moisture, surface fluxes, boundary layer height, temperature and winds, and how they in turn influence dust emissions and air quality (O3, NO2, PM2.5). The authors also evaluated the impacts of urbanization on these meteorological and air quality variables. I completely agree with the authors that it is highly important to assess the impacts of inconsistency among different ancillary datasets on uncertainty of the model simulations. This study serves as a good example that demonstrates this point. I recommend for publication with minor revision considering address these points.

Thanks for the recommendation. We echo the reviewer's comment and hope more attention can be directed to this topic.

2. Since the results are based on 5-day simulations, are the differences between the simulations forced by different land cover data significant relative to the internal variability of the model? I would recommend that the authors to indicate the ranges of the random errors within each experiments and compare them to the differences caused by different land cover datasets in all the relevant figures.

We thank the reviewer for bringing this up. Internal variability of a regional model, like NU-WRF, arises from the nonlinear nature of atmospheric processes such that the model is sensitive to perturbations of initial conditions (IC) (e.g., Giorgi and Bi, 2000; Vanvyve et al., 2008). Changes in atmospheric parameters due to physical modifications of a model are only significant when outside of the model internal variability. Although the full-scale investigation of the NU-WRF internal variability is beyond the scope of this paper, we did take procedures to minimize the impacts of IC perturbation on the model results. For example, we conducted the 3.5 year spin-up run of offline LIS to allow the land surface and soil profiles to reach thermodynamic equilibrium to initialize soil temperature and soil moisture for NU-WRF simulation. Following the recommendation by Berge et al. (2001) who pointed out that the local emissions and meteorology would take control and the uncertainties in IC would have a minimal impact on air quality simulation after the 3-day spin-up, we only took the final 5 day results out of an 8-day NU-WRF simulation for analysis (added in sect. 2.2). In addition, based on the study by Vanvyve et al. (2008) who investigated the regional model internal variability by randomly altering the IC, the maximum variability for 5 day average air temperature at 10 m and boundary layer wind speed ranged from 0.03 to 0.18 K, and from 0.06 to 0.31 m/s, respectively, depending on the location in their West Africa domain. Giorgi and Bi (2000) conducted the model internal variability study for the eastern China domain and concluded that the model response to perturbations was insensitive to the origin, location, and the magnitude of perturbation but sensitive to the perturbation timing. The variability for the daily average surface temperature, wind speed, and water vapor content over late May to early June was within 0.1 K, 0.1 m/s, and 0.1 g/kg, respectively. If those numbers are assumed to serve as the model random error bounds, it is obvious that the modeled differences (Fig. 5 and right panel of Fig. 6) due to the usage of different LULC datasets are well beyond the model internal variability. We added the discussion in Summary and Conclusion.

3. Fig. 2: Does this baseline simulation based on E_USGS data represents the best case scenario? It would be helpful to add evaluations of the PDF of the NB and NGE for simulations with MODIS and UMD land cover data.

No, E_USGS doesn't represent the best case scenario. It is illustrated in Fig. 2 simply due to its wide usage in the WRF modeling community. As in response to the comment 5 of the reviewer one, for the simulation period over the CONUS domain, all three LULC datasets present the similar comparison statistics without a clear winner. The PDFs of the NB and NGE for the E_MODIS and E_UMD closely mimic that of the E_USGS. Put them together would make Fig. 2 too crowded. Instead, we inserted the comparison statistics for the E_MODIS and E_UMD in Table 3.

4. The entire urbane impact discussion is based on one line in Table 4. Are the urban impacts on surface conditions significantly different from other land cover? Are the differences showing in this table caused by the local effects or the gradients between the urban and surrounding land cover?

Table 4 compares the difference between E_USGS and E_MODIS for the ***MODIS urban land category***. Over the MODIS designated urban areas (115,600 k m^2), only 36.7% (42,400 km^2) is designated as urban in the USGS dataset and the remaining is various croplands (25.6%), various forest (17.0%), grassland (6.9%), shrubland (4.5%), and so on (as shown in Table 4). Since emissions are the same for the E_MODIS and E_USGS and the land characteristics are the same for the same land categories from the different LULC datasets (see Table 2), the gradients between urban and the surrounding land is the major driving force of the modeled differences for meteorology and air quality over the area where both MODIS and USGS designate as urban. Over the areas where MODIS designates as urban but USGS defines as non-urban, however, both local effects (through different land characteristics, e.g., roughness, albedo, LAI, and RS) and gradients play roles in modeled discrepancies. We added the discussion in sect. 3.7 to reflect this analysis.