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Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "An evaluation of O_3 dry deposition simulations in East Asia" *by* R. J. Park et al.

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(1) This manuscript has some serious problems that lead to very misleading conclusions. The manuscript reports that the dry deposition model in WRF-Chem based on Wesely (1989) produces more accurate ozone dry deposition velocities than the M3Dry model that is used in the CMAQ model. This conclusion is based solely on Figure 2 that shows hourly measured ozone dry deposition velocities from two field studies in Colorado and model results from Wesely and M3Dry. There is extremely little explanation of this comparison. Are these results averaged over many days or weeks? For what time periods?

→ We obtain the hourly results by averaging the data for the observation period. The

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simulated and observed hourly mean concentrations at the BEACHON site are for Aug. 07-31, 2010, and the values at the Niwot Ridge Ameriflux site are for May 21-31, 2005, and the values at a site in northern Thailand are for Jan-Apr, 2002.

(2) Are the time periods the same for both sites? How were the model results produced?

→ The periods differ at different sites as shown above. We conducted a separate WRF-Chem dry deposition calculation at each site.

(3) The only modeling discussed is for WRF-Chem applications in Asia. Are the results shown in Fig 2 from WRF-Chem in Colorado? Are they box-model results using measured inputs, if so, from which site? These sites are about 100 km apart and are presented as if they are directly comparable.

→ We used the simulations for each observation site. We show a comparison at each site in the different panel in the revised manuscript.

(4) All these questions need to be answered if this Figure is to be taken as evidence of model performance.

→ Yes we modified our manuscript to answer to all the questions that you raised as follows:

We evaluate the dry deposition velocities calculated using the two schemes by comparing such values with the observations and primarily focusing on the diurnal variability. The observations were acquired from the BEACHON_ROCS and Niwot Ridge AmeriFlux sites in Colorado, USA and from the Mae Moh site in northern Thailand. For this comparison, we additionally conducted WRF-Chem dry deposition calculations with the two schemes at each observation site to obtain the simulated ozone dry deposition velocities for the corresponding observation periods. The model classifies surface types of the corresponding model grids to observation sites as shrub land (BEACHON), evergreen needle leaf (Niwot Ridge), and cropland/pasture (Mae Moh).

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Figure 2 compares the hourly measured and simulated ozone dry deposition velocities averaged for the observation periods at the BEACHON and the Niwot Ridge sites in the United States and at the Mae Moh site in northern Thailand. The measured values at the BEACHON_ROCS site are high in the early morning and decrease toward the afternoon, which reflects the friction velocity diurnal variation that depends on solar radiation. The measured values from the AmeriFlux site also show similar diurnal variation with a broad maximum during the daytime; the greatest value is found in the afternoon. Compared to the values at the two US sites, the observations in tropical northern Thailand show relatively sharp daytime variation such that the peak appears in the early morning and a rapid decrease occurs afterward. The different observation periods and vegetation types may contribute to the dissimilar diurnal variation of the observations among the sites.

(5) Another major problem is the lack of explanation about how the M3Dry is implemented in WRF-Chem. The article cited for M3Dry (Pleim et al 2001) presents the dry deposition model as part of a coupled land surface model (LSM) for meteorology and chemistry. This article, and a more recent article by Pleim and Ran (2011), both explain that a key advantage of M3Dry over stand-alone dry deposition models such as the Wesely model is that the stomatal conductance and several other parameters are used directly from the LSM in the meteorology model. In this way, the stomatal pathway for dry deposition is proportional (scaled by the ratio of the chemical diffusivity to the diffusivity of water) to the stomatal conductance used to compute transpiration for surface moisture flux in the meteorology model. In the most recent model versions, dry deposition velocities are computed in CMAQ (M3Dry was removed from MCIP in 2011) using stomatal conductance that is output from the meteorology model. Thus the stomatal pathway for dry deposition in M3Dry is as good or bad as the stomatal pathway for evapotranspiration. If the stomatal conductance is not realistic, the meteorology simulation will not be accurate.

→ Yes we added a following paragraph in Section 2.3 to explain how we implemented

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M3DRY in the WRF-Chem simulations as follows:

The M3DRY that we implemented in WRF-Chem was a standalone package that used a fixed value for a certain parameter such as water stress depending on the surface type for the stomata resistance calculation. However, the latest development of the M3DRY uses the calculated stomata resistance from the Pleim-Xiu land surface model in order to maintain the consistency with meteorological simulations toward an online approach (Xiu and Pleim, 2001). Therefore, we also examine the effect of this change (standalone versus online) on the simulated dry deposition velocities with the M3DRY below. All the simulated results with the M3DRY below are from the model with the standalone package except for Fig. 2, which compares the values from the two applications of the M3DRY (standalone versus online).

(6) Prior to 2012, MCIP did include an option for a standalone stomatal conductance calculation for use if this parameter was not available from the meteorology model output. This option was never used at the USEPA (the developers of CMAQ) since stomatal conductance is a standard output from WRF when using the Pleim-Xiu LSM. The stomatal conductance from other LSM options in WRF can also be used. Since this manuscript does not explain how the stomatal conductance was computed for the WRF-Chem modeling presented, I guess that the alternate standalone stomatal calculation was probably used. This is not the preferred way to apply M3Dry and is in fact no longer available in recent CMAQ versions. I strongly suggest that the M3Dry be applied as intended using the stomatal conductance and other parameters such as aerodynamic conductance from the LSM in WRF. This should not be difficult since WRF-Chem is an online met-chem model. The results shown here provide no valid basis for concluding that either M3Dry or Wesely are better for calculating ozone dry deposition velocity. If, as I suspect, the stomatal conductance for the M3Dry model runs did not use the stomatal conductance from the WRF LSM (in this case Noah), the results are not representative of the model's typical performance since it used an option that is not recommended, never used in EPA applications of CMAQ, and is no

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longer supported or available.

→ We appreciated very much for your constructive comments. In our manuscript that you reviewed, we used an option for a standalone stomatal conductance calculation, which is a function of the surface type. The Wesely method also uses its own standalone parameterization of stomatal conductance. The difference between these two standalone parameterizations is the key for the discrepancy of simulated O3 dry deposition velocities and O3 concentrations. But as you pointed out that the preferred way of applying M3DRY is to use stomatal conductance from LSM models. Therefore, following your suggestion we modified the WRF-Chem code and used the calculated stomatal conductance from the Pleim-Xiu LSM model in the M3DRY. We discuss this in the revised manuscript as follows:

Figure 2 also presents the simulated results with the Wesely and the M3DRY. The former appears to calculate values higher than the latter particularly during the day, and shows a larger diurnal variation. The large diurnal variation is a pronounced observed feature at all three sites and is well captured by the Wesely, whereas the M3DRY significantly underestimates the observations especially during the day. The stomata resistance is the most dominant factor for determining the dry deposition velocity during the day and is certainly better resolved in the Wesely than the M3DRY. Moreover, the underestimates of daytime values are consistently shown in the two different M3DRY applications: standalone and online. In fact, the online approach that uses the stomata resistance directly from the land surface model performs slightly worse than the standalone M3DRY for reproducing the daytime values. Understanding this discrepancy is also important but beyond the scope of our present work. We plan to examine this issue in the future study.

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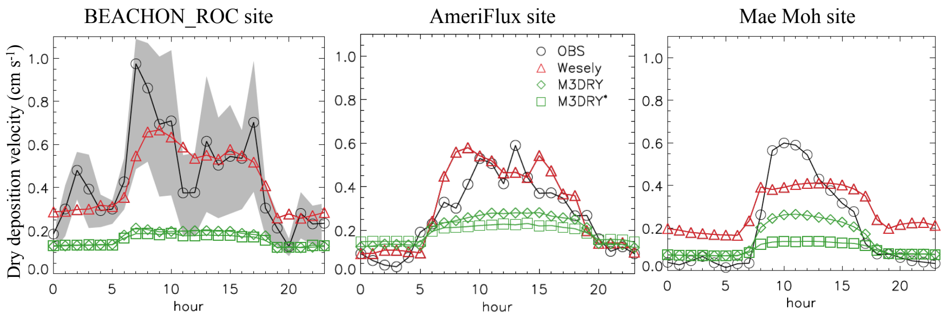

Figure 2. A comparison of the simulated and observed hourly mean O3 dry deposition velocities from the BEACHON−ROCS campaign at the Manitou forest observatory for Aug. 07−31, 2010 (left panel), at the Niwot Ridge AmeriFlux site in the Roosevelt National Forest in the Rocky Mountains of Colorado for May 21−31, 2005 (middle panel) in the United States, and at Mae Moh site in Northern Thailand for Jan−Apr 2002 (right panel). The circles show observed values. The triangles, diamonds, and squares show the simulated values using the Wesely, the M3DRY with standalone stomata resistance, and the M3DRY with stomata resistance of the Pleim−Xiu land surface model, respectively. The shaded area indicates the observed dry deposition velocity range for the various zero−plane displacement heights ( ) in equation 4 from the BEACHON−ROCS campaign.

Fig. 1.

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