

# ***Interactive comment on “An evaluation of O<sub>3</sub> dry deposition simulations in East Asia” by R. J. Park et al.***

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## Responses to the Comments by anonymous reviewer #1

(1) In-situ ozone dry deposition velocity measurements in Asia: The authors state that their evaluation is limited due to the lack of observations of ozone deposition velocity in East Asia. I would generally agree with this statement. However, Matsuda et al (2005) (as referenced by the authors) presented measurement of ozone dry deposition in deciduous (teak) forest in northern Thailand. The observed diurnal cycle of dry deposition velocity is shown in Figure 3. I wonder why this data are not included in Figure 2. I would suggest the authors to consider this observation in comparison with their model, and modify the sentences accordingly.

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→ Thanks for the constructive comment. We added a comparison at the Mae Moh site in northern Thailand 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.

(2) Seasonal variations of ozone dry deposition: The authors mainly discuss deposition in spring with an example in May 2004. Why is it? Do the authors have any specific reasons?

→ Yes as we wrote in the manuscript, May is the ozone peak month in East Asia.

(3) As it noted in the manuscript, it seems that stomata plays a dominant role in determining the total deposition velocity, particularly during photosynthetically active period. I presume that the dry deposition would have seasonal variations. Is the impact by dry deposition greater in warm seasons than in cold ones? Is the impact greater in summer than in spring? Well, greater but not much, maybe? I am interested in how dry deposition perturbs the balance of photochemical production and long-range transport from spring to summer seasons, since these two are competing factors in controlling distributions of surface ozone in East Asia. For example, photochemical production is

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stronger in summer than in spring, while transport from Asian continent to downwind happens more efficiently in spring than in summer. I would like to see some analysis for the seasonal variations of ozone dry deposition and its roles in seasonal cycles of ozone in East Asia.

→ Following your suggestion, we examined the monthly change of dry deposition velocity and ozone concentrations from May to June. After June, the Asian summer monsoon significantly affects ozone in East Asia so we did not focus our analysis on summer. The discussion of the monthly change is added in the revised manuscript as follows:

Table 3 summarizes the simulated surface ozone concentration and ozone dry deposition velocity averaged over the domain for May and June 2004, respectively, to examine their seasonal variation from spring to summer. We do not find considerable change in the simulated values between the two months except that the ozone dry deposition velocity with the M3DRY slightly increases in June relative to May because of the increase of the vegetation cover. However, the ozone concentration remains the same in June compared with May because an increased ozone production offsets the increased ozone loss through dry deposition.

(4) L17: observations of “flux” or “dry deposition”?

→ We clarified it as “ozone flux observations”.

(5) Figures 3 and 4: NIER and EANET sites. Are these plots averages at several sites or at specific single sites? Many of the EANET sites are located at island but the characteristics are greatly different between north and south (Tanimoto et al., GRL, 2005). Diurnal cycles are observed in summer at some sites, for example, at Rishiri. Please be more specific to the locations and seasons of the observations. Also, any references or websites for the NIER sites?

→ We clarified our discussion on the surface O<sub>3</sub> sites and how we perform the com-

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parison in the revised manuscript as follows:

Figure 4 shows the hourly mean observed and simulated ozone concentrations averaged at the NIER sites in Korea and EANET sites in Japan for May 2004. The simulated values are sampled from the corresponding model grids to the observation sites for this comparison. The diurnal variation differs between the two networks such that the observed ozone concentrations in Korea show a strong diurnal variation, a peak in the afternoon and a minimum at night, which reflects a direct influence from local pollution.

(6) Page 929, L9-12: How large is the difference between the two schemes?

→ We revised the paragraph as follows:

The model generally captures the observed diurnal variation, but also shows considerable discrepancies from the observations (Fig. 4). For example, at the NIER sites in Korea, the M3DRY overestimates the observations by 4.4-17.1 ppbv. This high bias is reduced when we use the Wesely although the model still cannot capture the lowest ozone concentration in the early morning, caused by the NO titration during the rush hour traffic. We further examine this issue in Section 5. On the other hand, the simulated ozone concentrations are lower than the observations at the EANET sites. This low bias is consistently shown in the model with both the Wesely and the M3DRY. The ozone differences between the two methods are 4.6-5.1 ppbv, smaller than 5.4-7.4 ppbv at the NIER sites. Although the M3DRY shows smaller biases than the Wesely, it is difficult to validate the dry deposition simulation alone because the EANET sites are primarily located at the coast where the ocean heavily influences the observed ozone concentrations. It is known that the model and observation discrepancies at the coastal sites are caused by the model's inability to simulate steep sub-grid land-to-sea gradients at a mixing depth (Gao and Wesely, 1994; Loughner et al., 2011) that is shallower over the ocean compared with the continent. Our model with 45 x 45 km spatial resolution may not adequately represent the shallow mixing depth at the EANET sites.

(7) Figure 8: Why is the difference larger in marginal sea off the coast of Asian conti-

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ment, compared to open oceans? Any comments?

→ We added the explanation as follows:

As shown in Fig. 1, the largest difference of the simulated dry deposition velocity appears on the continents, but the ozone concentrations difference is the greatest over the downwind ocean. We think that this feature is caused by the efficient ozone export from the polluted continent to the downwind oceans where ozone accumulates because of inefficient dry depositional loss (Goldberg et al., 2014). The export of ozone precursors also contributes to high ozone over the oceans, but is relatively minor compared with the direct ozone export. In addition, the ozone differences up to 8.7 ppbv over the ocean may partially be attributed to excessively high surface water resistance (low deposition loss) in the M3DRY relative to the Wesely, which is not clearly shown in Fig. 1. This issue is discussed in Section 5.

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Interactive comment on *Atmos. Chem. Phys. Discuss.*, 14, 919, 2014.

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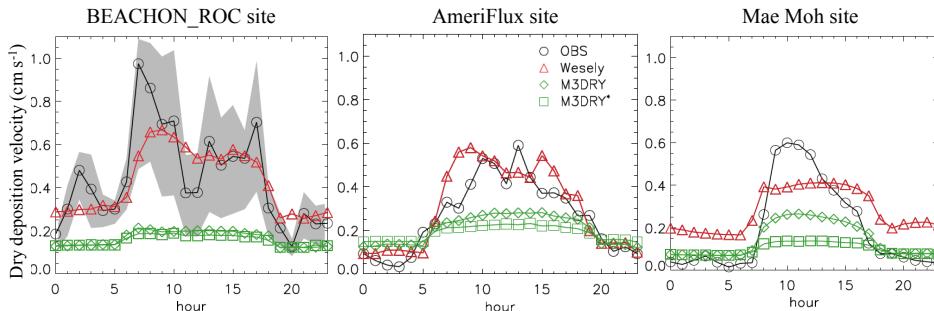
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Figure 2. A comparison of the simulated and observed hourly mean O<sub>3</sub> dry deposition velocities from the BEACHON-ROCS campaign at the Manitou forest observatory for Aug. 07–31, 2010 (left panel), at the Niwot Ridge AmeriFlux site in the Roosevelt 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.

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**Fig. 1.**