Reply to Dr. Ma

We thank the reviewer for the careful reading of the manuscript and helpful comments. We have revised the manuscript following the suggestion, as described below.

Comment: WRF-Chem modeling was, to some extent, performed using an "improved" roughness length (line 162, eq. 3 which should be eq. 6), which presumably took into consideration of surface heterogeneities within a model grid cell. The influences of surface heterogeneities on surface momentum and heat transfer have been extensively studied in the 1990s partly aiming to more precisely simulate surface stress induced sub-grid inhomogeneous terrain in a climate model. Dynamically, the area average of the roughness length in a heterogeneous terrain would produce the correct spatial average value of the surface stress. A heuristic argument was presented to show that this effective value of z0, or "effective roughness length", could be obtained by averaging drag coefficients based on a 'blending' height approach. In other words, the correct formulation of an effective roughness length, defined as the area average of the roughness length in heterogeneous terrain, relies upon the appropriate determination of a height scale (blending height). At this height a meteorological quantity is approximately in equilibrium with local surface conditions and independent of horizontal position. Authors of this paper appeared not aware of the progresses in this aspect. However, they should at least comment on previous studies and compare their model with "effective roughness length" approach, and add some discussions to defend their roughness model, which might be subject to uncertainties.

Response:

We have revised the Eq. 3 to Eq. 6 in Section 2.3.

We have also clarified in Section 2.3: "*In order to more precisely simulate surface stress within the sub-grid scale in heterogeneous terrain, the effective roughness length has been extensively studied, especially in the 1990s. Claussen (1990) has defined the effective roughness length as a value of the area average of the roughness length in heterogeneous terrain. The effective roughness length relies upon the*

blending height (Wieringa, 1986; Mason, 1988; Wood and Mason, 1991; Philip, 1996; Mahrt, 1996), at which the flow is approximately in equilibrium with underlying surface conditions and independent of horizontal position (Ma and Daggupary, 1998). We have modified the Noah SFz0 calculation using the spatial average of the vegetation roughness length."

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