Supplement of

Improvement of near-surface wind speed modeling through refined aerodynamic roughness length in built-up regions: implementation and validation in the Weather Research and Forecasting (WRF) model version 4.0

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S1. The settings of z_{0_Peng} in the WRF model

Before conducting the simulation of wind speed in the WRF model with the gridded z_{0_Peng}, we had adjusted the roughness length over vegetated fraction (z_{0_veg}) in each grid from z_{0_Peng}. Then, the default z_0 values in WRF over vegetated fraction were replaced with z_{0_veg}.

The mean shear stress ($\tau = \rho u_*{}^2$) in a grid is the sum of the shear stress over the bare and the vegetated areas weighted by vegetation fraction (*FVEG*):

$$u_{*mean}{}^2 = u_{*bare}{}^2 * (1 - FVEG) + u_{*veg}{}^2 * FVEG \tag{1}$$

where u_{*mean} is the mean friction velocity (m/s) derived with z_{0_Peng}; u_{*veg} and u_{*bare} are the friction velocity in the vegetated and the bare fraction, which are derived with z_{0_veg} and the roughness length over the bare fraction (z_{0_bare}).

Under neutral conditions, z_{0_veg} can be expressed as:

$$z_{0_{veg}} = e^{\ln(z_{ref}) - \left\{\left[\left(ln\left(\frac{z_{ref}}{z_{0peng}}\right)\right)^{-2} - (1-FVEG)*\left(ln\left(\frac{z_{ref}}{z_{0bare}}\right)\right)^{-2}\right]*\frac{1}{FVEG}\right\}^{-\frac{1}{2}}} \tag{2}$$

where z_{ref} is the reference height (m), and z_{0_bare} and *FVEG* can be obtained from WRF model.
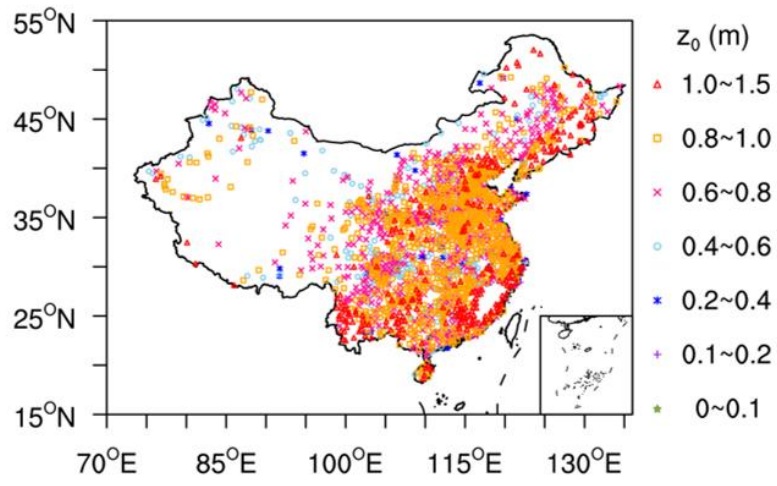
Figure S1. Spatial distributions of annual mean $z_{0\_optimal}$ across 2,162 CMA stations.
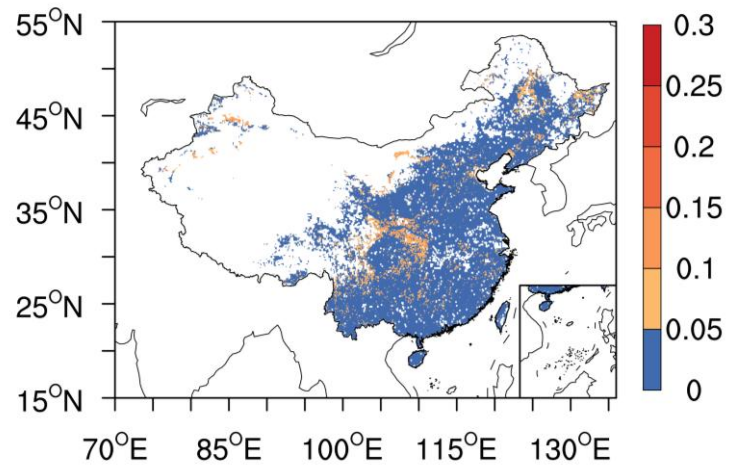
Figure S2. Spatial distributions of the standard deviation of monthly $\ln z_{0\_RFR}$.
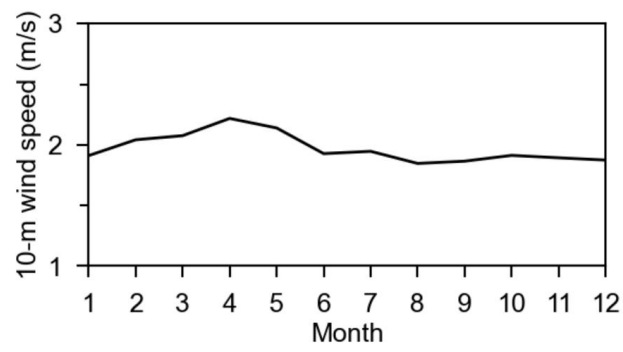
Figure S3. Monthly variations of the 10-m wind speed averaged over the d02 domain during 2015-2019 from ERA5.
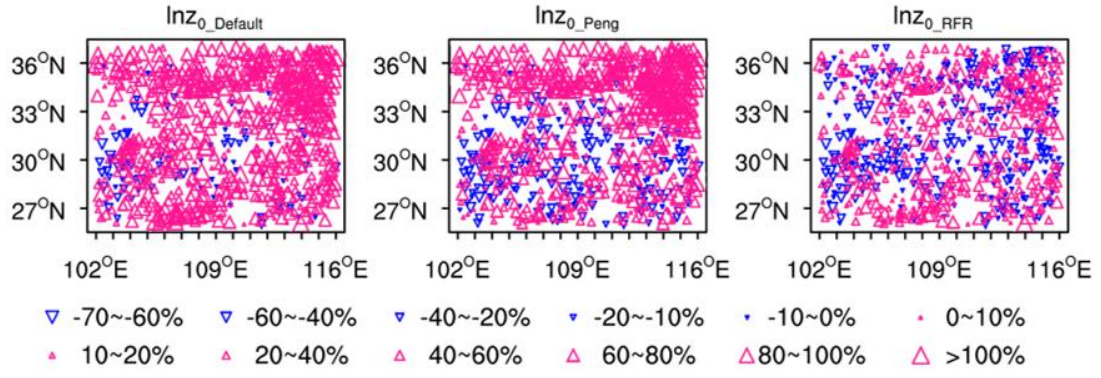
Figure S4. Distributions of mean bias percentage (*MBP*) in 10-m wind speed from simulations using $z_{0\_Default}$, z_{0_Peng} and z_{0_RFR} against observations from CMA stations, calculated as $[u_{simulations} - u_{CMA}]/u_{CMA} \times 100\%$.