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Supporting Information for

**Deducing** **Aerodynamic Roughness Length from Abundant Anemometer Tower Data to Inform Wind Resource Modeling**

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1.1 Data

A more detailed supplementary explanation of data used in this study is listed according to their purposes as follows.

First, two remote sensing datasets were used to analyze the distribution of over different surface conditions. They are the 500-m MODIS Global Land Cover Type product (MCD12Q1 (IGBP), Friedl et al., 2010) and the 8-day 500-m Leaf Area Index (LAI, Yuan et al., 2011; Lin et al., 2023) in 2019. The 8-day LAI was averaged to yearly LAI. The land cover type and LAI value at each anemometer tower were determined by the mode and the average of remote sensing data at the nearest nine grids, respectively.

Second, three gridded datasets of were evaluated. They were from ERA5 (Hersbach et al., 2020 & 2023a), NCEP Climate Forecast System Version 2 (CFSv2, Saha et al., 2012 & 2014) and Peng et al. (2022). The aerodynamic roughness length from ERA5 () was derived based on vegetation types and snow cover with the temporal and spatial resolution of month and . CFSv2 offered monthly mean () at 00:00, 06:00, 12:00, and 18:00 UTC with the spatial resolution of . We found that has similar characteristics to (Figure S1), which suggests that is most likely also determined by land cover types, although no indication was found in the official documentations. Peng et al. (2022) provided 1-km monthly (), which was produced based on truth data of and MODIS remote sensing data with the aid of machine learning techniques. These “true” values were derived from observations provided by FLUXNET network (https://FLUXNET.org/data/download-data/), AmeriFlux network (https://AmeriFlux.lbl.gov/data/download-data/), and other sites. Note that only provided over vegetated areas. In the evaluation, we ignored their temporal variations by averaging to yearly . The values at anemometer towers from the three products were determined by in the nearest grid.

**1.2** **Derivation of** **aerodynamic roughness length**

We derived values from neutral wind profiles, because anemometer towers cannot provide observations of the temperature profile or sensible heat flux, which are required for the atmospheric stability correction. The core theory is the neutral logarithmic wind profile equation (LWPE):

(S1)

where is the wind speed () at , the measuring height above ground (), is the friction velocity (), is the von Karman constant and equals to 0.4, and is the zero-plane displacement height ().

To test the reliability of the derived values, we used them and the wind speeds at any height from anemometer towers to extrapolate the wind profiles, and compared the extrapolations with measurements of anemometer towers. The extrapolation accuracy was measured in terms of the correlation coefficient (), the mean bias percentage () and the relative root mean-squared error (). In the “all samples” case, the stability correction function must be taken into account in LWPE (Equations S2-5). We calculated stability correction functions based on the hourly surface sensible heat flux and surface pressure from ERA5 (Hersbach et al., 2023b).

(S2)

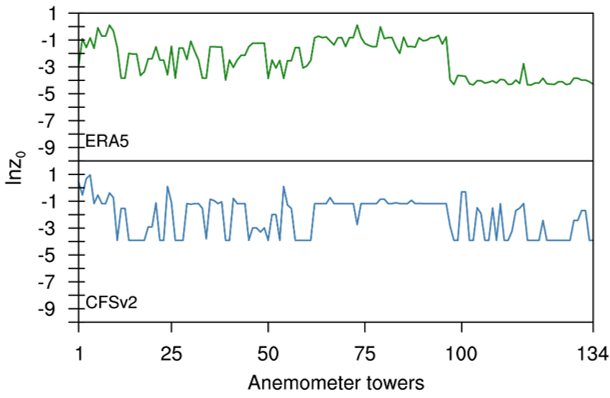
where *L* is the Monin–Obukhov length (), and represent the stability correction function. Specifically, following Dyer & Hicks (1970):

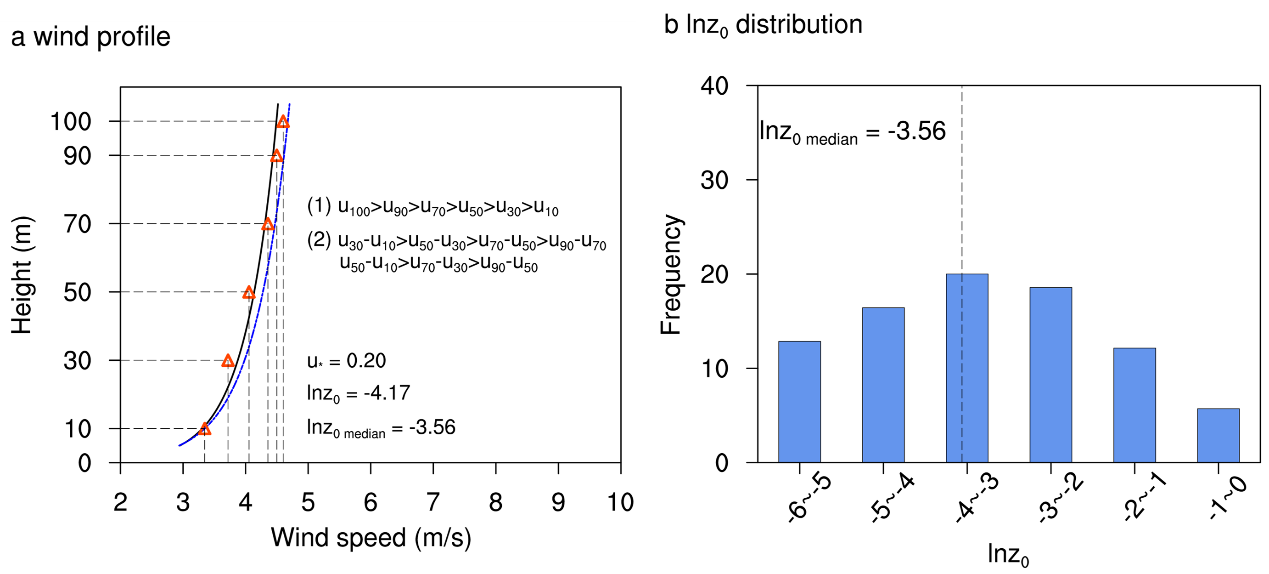
(S3)

(S4)

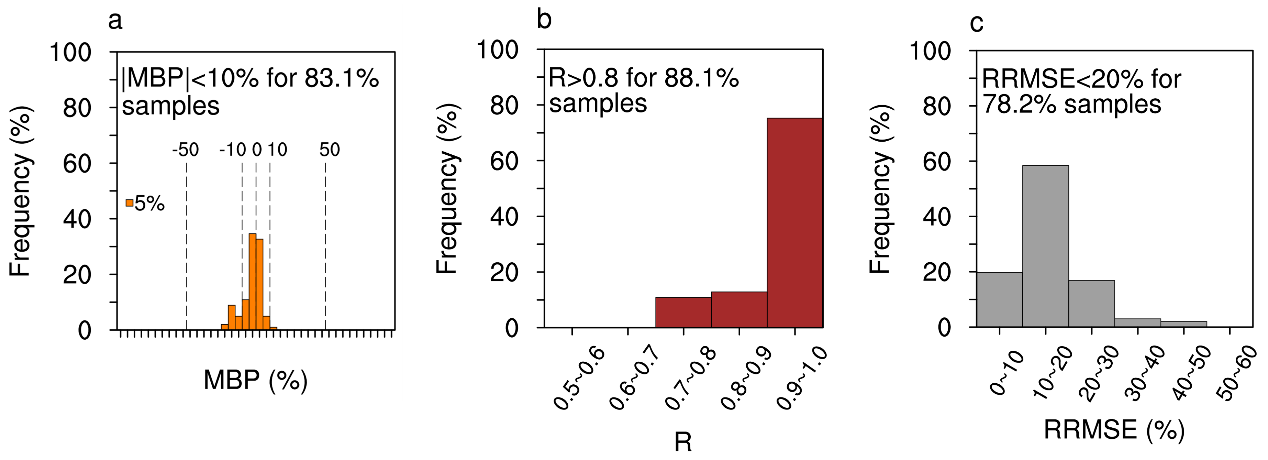
(S5)

among them, is density (), is temperature (), is surface pressure (), is heat capacity , is the gravitational constant (), is the sensible heat flux (), and ranges from to (Sozzi, 1998).

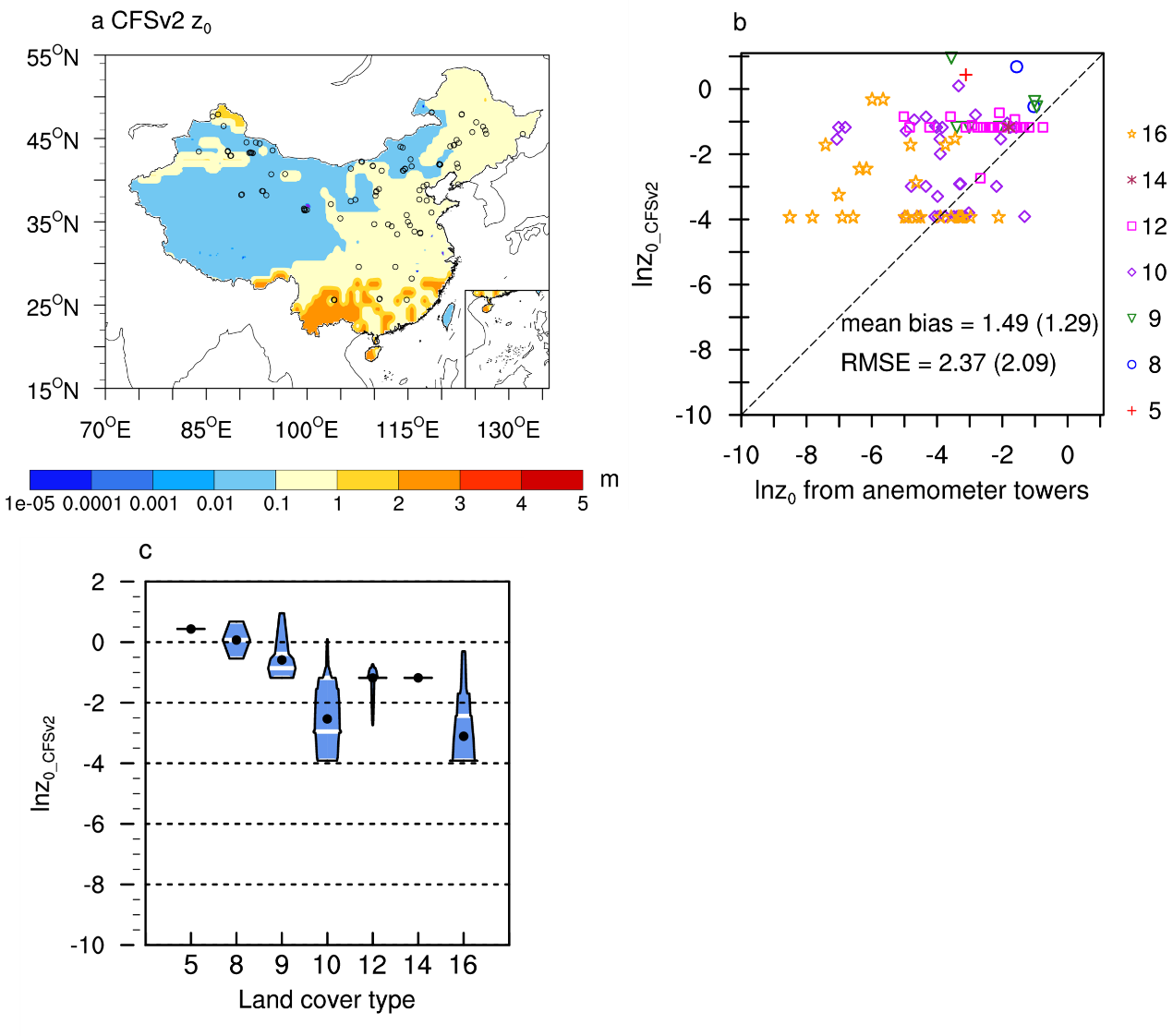


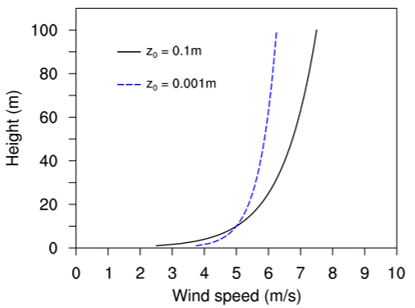
**Figure S1**. The comparison of from ERA5 and CFSv2 at each anemometer tower. The horizontal axis represents the serial number of anemometer towers sorted by land cover types. The above green and the below blue solid lines represent from ERA5 and CFSv2.****

**Figure S2.** A schematic illustration of the derivation, taking a randomly selected anemometer tower as an example. (a) Wind profiles at a timestamp. The red triangles correspond to measured wind speed at each height of the anemometer tower. The black and blue solid lines represent the fitted wind profiles with = -4.17 or at the corresponding timestamp and as the median (-3.56) of valid samples. (b) The histogram distribution of all of valid samples.

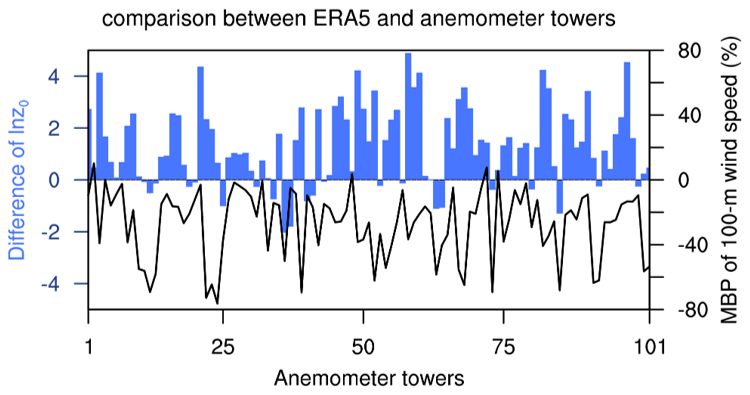


**Figure S3**. (a) Frequency distribution of mean bias percentage () for all samples when wind speeds are extrapolated from 10 m. The width of each bar means the MBP is divided at 5% intervals. (b and c) are the same as (a) but for the correlation coefficient () and relative root mean-squared error ().

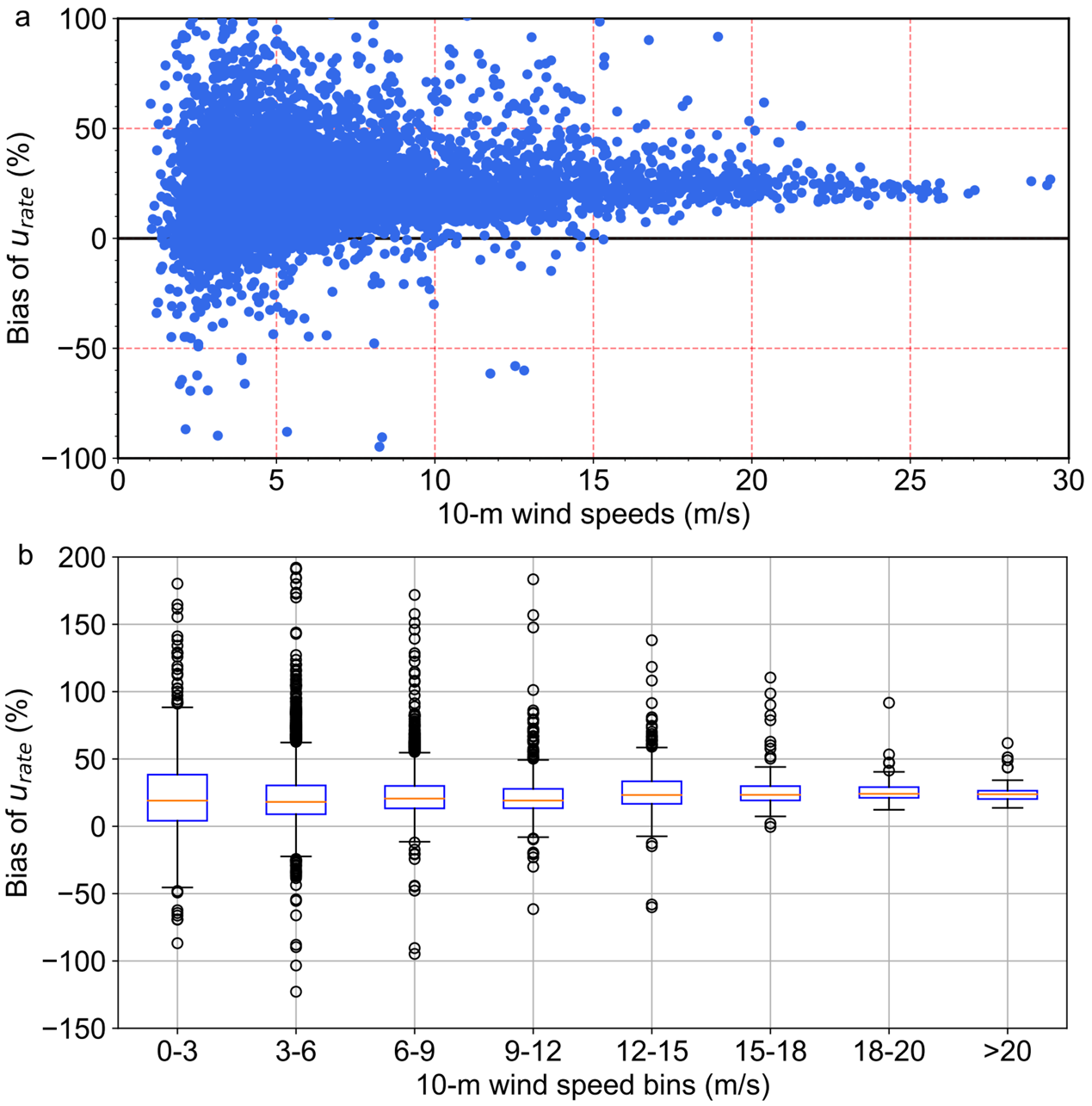
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**Figure S4**. The performance of gridded products from CFSv2 (), (a) Spatial pattern of . The circles represent locations of anemometer towers. (b) The comparison of against derived from anemometer towers. The symbols with different colors and shapes represent land cover types. The legends on the right refer to specific land cover types, including mixed forests (legend “5”), woody savannas (legend “8”), savannas (legend “9”), grasslands (legend “10”), croplands (legend “12”), cropland/natural vegetation mosaics (legend “14”) and barren or sparsely vegetated type (legend “16”). The mean bias and root mean squared error (RMSE) outside and inside parentheses were calculated based on all anemometer towers and towers over vegetated areas, respectively. (c) Violin plot of under different land cover types. The numbers in the horizontal coordinate correspond to land cover types as the same as in (b). For each violin shape, the width means the relative frequency with which each value occurs; black dot represents the average value, and the three white lines from top to bottom mean the upper quartile, the median and the lower quartile. Some white lines overlap.****

**Figure S5**. A schematic illustrating the effect of on wind profile under neutral condition.



**Figure S6**. Based on valid near-neutral samples of wind profiles, the difference of () and mean bias percentage (MBP) of 100-m wind speed between ERA5 and anemometer towers. For anemometer towers without measurements at 100 m, the 100-m wind speed was extrapolated from the 10-m wind speed using .



**Figure S7.** (a) Biases in of ERA5 at 32 anemometer towers () as a function of 10-m wind speeds for valid near-neutral samples of wind profiles. The anemometer towers are those where the difference in between ERA5 and the anemometer towers () is greater than 2. (b) Box plot of bias in of ERA5 across different wind speed bins. Each box shows the median (orange line), interquartile range (white box), whiskers representing the 1.5 interquartile range (IQR, spanning from the 25th to the 75th percentile) and open circles representing outliers.

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