Combining MODIS LAI with ICESat-Based Canopy Heights Improves Spaceborne Estimates of Vegetation Roughness Length for Momentum

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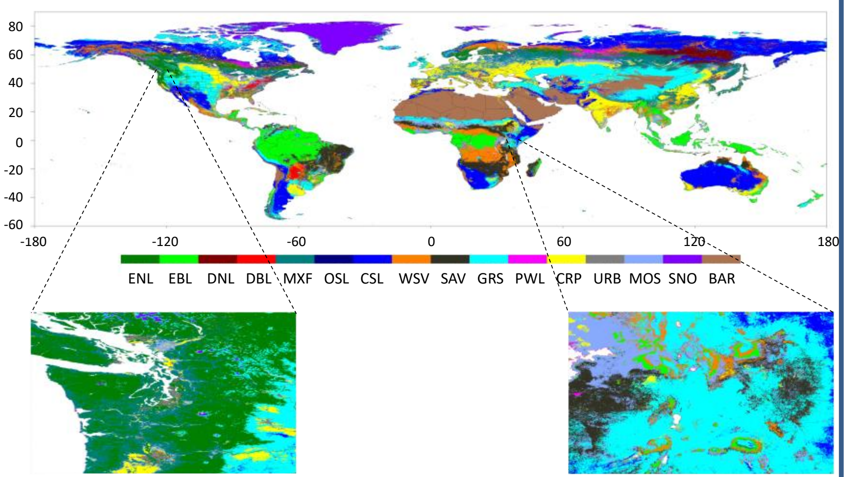
KEY FINDINGS

Most land-surface models require parameterization of vertical wind profiles within the atmospheric boundary layer. For vegetated surfaces, it is common to assume a logarithmic profile in the surface layer, which includes estimates of vegetation roughness length for momentum (z_0) and zero-plane displacement height (d_0). This study finds that remotely-sensed forest canopy heights improve estimates of aerodynamic roughness length for momentum using a previously-developed representation of the roughness sublayer (Raupach 1992; Jasinski et al. 2005). Resulting roughness products consist of two datasets: 1) 14 years of 8-day snapshots of the global land surface at a nominal spatial resolution of 500-meters for users who wish to retain full temporal resolution and interannual variability; and 2) multiyear averages of the 8-day snapshots, here referred to as "climatologies" of roughness, which retain underlying seasonality. Both products are suitable for use in data assimilation and reanalyses such as the National Climate Assessment Land Data Assimilation System (NCA-LDAS), for which these products were initially developed.

Figure 1: Land Cover Types for Domain and Regions of Interest



Approach

This research employs satellite data to estimate z_0 and d_0 at 500-m resolution for vegetated land surfaces. Here, it is assumed that winds in the surface layer follow the logarithmic vertical wind profile as:

$$\frac{U_h}{u_*} = \frac{1}{\kappa} \ln\left(\frac{h - d_0}{z_0}\right) + \varphi_h \qquad (1)$$

where U_h is the mean horizontal wind speed at height h, u_* is friction velocity, κ is von Karman's constant and φ_h is a stability correction. Inputs consist of V6 MODIS Leaf-Area Index (LAI) Combined Terra/Aqua MCD15A2H product (Yan et al. 2016), and forest canopy heights derived from ICESat data (Simard et al. 2011). LAI quantifies plant density – both live canopy and dead leaf/woody elements, collectively represented by the canopy area index (CAI). A time series of CAI drives the roughness model, computing z_0 and d_0 at each pixel per the approach of Jasinski et al. (2005); this is the full-resolution product. The climatological product is simply the mean annual cycle at each domain location; that is the focus of these results.

Regions of Interest

The full domain consists of the global terrestrial land area from the North Pole to 60°S. For this study, two regional subsets from the USA and East Africa were selected to illustrate finer detail as shown in Figure 1.

Climatological Results

Figure 2 displays roughness length and displacement height for the Pacific Northwest region in January and July. The dominant vegetation type here is evergreen needle-leaf forest (see land cover detail of Figure 1); however muted seasonality is apparent, with z_0 higher during the winter, and d_0 higher in the summer. Coniferous forest may exhibit spuriously low LAI values In wintertime, under conditions of low solar zenith angle or whenever snow-covered observations are included in LAI model retrievals. Summertime LAIs are less prone to these conditions, and yield lower roughness lengths due to skimming effects at higher tree densities during the growing season. Estimates of d_0 are consistently positively correlated with vegetation density. Figure 3 depicts roughness length for the Serengeti during the wet and dry seasons, and illustrates how environments with less biomass produce rougher (non-skimming) canopies during the growing season.

Figure 2: Climatologies of z_0 and d_0, Pacific Northwest

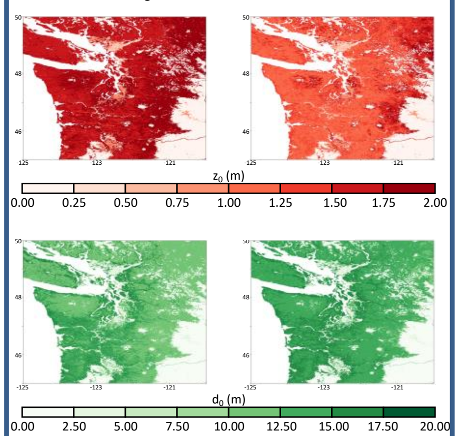


Figure 3: Climatology of z_0, Serengeti Plain

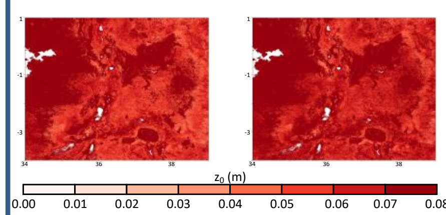


Figure 4: Evaluation of z_0

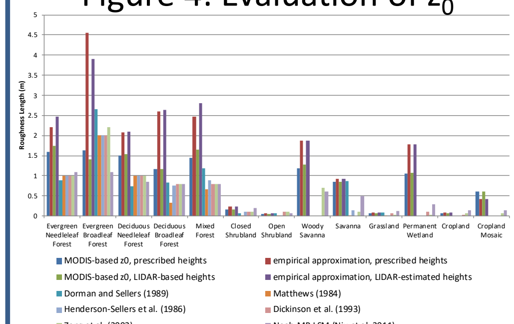


Figure 4 compares z_0 derived from various published sources to the results of this research. Compared to prescribed values based on broad land types, the fusion approach presented here produces more representative estimates of roughness parameters. In addition, limited direct evaluation indicates that use of LIDAR-based canopy heights reduces errors in z_0 by ~13% for both needleleaf and broadleaf forest types.

References

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