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Plot-scale retrieval of land surface temperature and emissivity estimation

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The surface energy balance (SEB) is defined as the balance between incoming energy from the sun and outgoing energy from the Earth's surface. All components of the SEB depend on land surface temperature (LST). Therefore, LST is an important state variable that controls the energy and water exchange between the Earth's surface and the atmosphere. LST can be estimated radiometrically, based on the infrared radiance emanating from the surface. At the landscape scale, LST is derived from thermal radiation measured using satellites. At the plot scale, eddy covariance flux towers commonly record downwelling and upwelling longwave radiation, which can be inverted to retrieve LST using the grey body equation :

$$R_{lup} = \varepsilon\sigma T_s^4 + (1 - \varepsilon) R_{ldw} \quad (1)$$

where R_{lup} is the upwelling longwave radiation, R_{ldw} is the downwelling longwave radiation, ε is the surface emissivity, T_s is the surface temperature and σ is the Stefan-Boltzmann constant. The first term is the temperature-dependent part, while the second represents reflected longwave radiation. Since in the past downwelling longwave radiation was not measured routinely using flux towers, it is an established practice to only use upwelling longwave radiation for the retrieval of plot-scale LST, essentially neglecting the reflected part and shortening Eq. 1 to:

$$R_{lup} = \varepsilon\sigma T_s^4 \quad (2)$$

Despite widespread availability of downwelling longwave radiation measurements, it is still common to use the short equation (Eq. 2) for in-situ LST retrieval. This prompts the question if ignoring the downwelling longwave radiation introduces a bias in LST estimations from tower measurements. Another associated question is how to obtain the correct ε needed for in-situ LST retrievals using tower-based measurements.

The current work addresses these two important science questions using observed fluxes at eddy covariance towers for different land cover types. Additionally, uncertainty in retrieved LST and emissivity due to uncertainty in input fluxes was quantified using SOBOL-based uncertainty analysis (SALib). Using landscape-scale emissivity obtained from satellite data (MODIS), we found that the LST obtained using the complete equation (Eq. 1) is 0.5 to 1.5 K lower than the short equation (Eq. 2). Also, plot-scale emissivity was estimated using observed sensible heat flux and surface-air temperature differences. Plot-scale emissivity obtained using the complete equation was generally between 0.8 to 0.98 while the short equation gave values between 0.9 to 0.98, for all land cover types. Despite additional input data for the complete equation, the uncertainty in plot-scale LST was not greater than if the short equation was used. Landscape-scale daytime LST

obtained from satellite data (MODIS TERRA) were strongly correlated with our plot-scale estimates, but on average higher by 0.5 to 9 K, regardless of the equation used. However, for most sites, the correspondence between MODIS TERRA LST and retrieved plot-scale LST estimates increased significantly if plot-scale emissivity was used instead of the landscape-scale emissivity obtained from satellite data.