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Validating Monin Obukhov theory and comparing published with a new stability correction over snow

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Modeling turbulent fluxes over a homogenous snow cover is already a challenging task because atmospheric stability has often a strong but difficult to quantify influence. Monin Obukhov theory and stability corrections are often applied over complex terrain and non-equilibrium boundary layers with the result of unknown errors. Four different data sets collected with 3-D ultrasonics over snow-covered terrain of varying complexity in the Swiss Alps, were analyzed in order to 1) test the Monin-Obukhov theory, 2) evaluate the performance of different published parameterization schemes of the stability correction and 3) develop a new simple approach for a stability correction over snow.

We first conducted a comprehensive analysis of the existence of a constant flux layer by analyzing the vertical evolution of turbulent sensible heat fluxes at the four different test sites. Three already published stability corrections were evaluated and compared with the assumption of a neutrally forced boundary layer. Non-parameterized stability correction values were directly calculated from measured friction velocities. Those values allowed a comparison between the Eddy Covariance method and the Monin Obukhov bulk formulation and a quantification of the uncertainty of modeling turbulent fluxes using the Monin Obukhov approach. Furthermore, the independent uncertainty that is introduced to energy balance modeling by applying a parameterization of the non-parameterized stability correction values was analyzed. This parameterization was conducted (a) assuming a linear dependence on the stability parameter and (b) assuming a two-parameter dependence on buoyancy and shear terms in a first order statistical model.

Our results show that the constant flux layer occurs totally in 10 % of the time, particularly in the morning. Modeling sensible heat fluxes with the physics-based model SNOWPACK, which uses a typical Monin Obukhov flux parameterization with a choice of stability correction, results in a small mean error for cases with a measured constant flux layer and a up to 10 W/m^2 larger mean error if a constant flux layer was not measured. The mean error of the sensible heat flux is lowest using the stability correction of Holtslag and de Bruin (1988) and highest assuming a neutral boundary layer. The stability correction of Stearns and Weidner (1993) (modified by Michlmayr et al. 2008) performs worse than a simple Log-Linear approach. Our analysis further showed that the uncertainty coming from an assumption of the validity of the Monin Obukhov approach (i.e. the constant flux layer) is below 10 W/m^2. Additional uncertainty of around 5 W/m^2 is added applying the stability correction parameterizations. In addition, the mean error of the two-parameter statistical model developed in our study is much lower than the mean error using the stability correction of Stearns and Weidner (1993) (modified by Michlmayr et al. 2008) and slightly lower than the stability correction of Holtslag and de Bruin (1988).