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The effect of surface heterogeneity on the temperature-humidity

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For flows in the lower part of the atmospheric boundary layer the cornerstone of (the analysis of) experiments and modelling is Monin-Obukhov Similarity Theory (MOST). For scalar standard deviations, the similarity relationship is $\sigma_x/x_*= f_x\,(z/L)$. Whether (and when) the similarity relationships should be identical for all scalars (in particular temperature and humidity) is a subject of ongoing debate. In this debate two violations of MOST conditions are often cited (usually as if they are mutually exclusive): surface heterogeneity and influence of processes in the entrainment zone on surface layer turbulence (for an overview, see e.g. Moene *et al*., 2006).

In this study we will concentrate on the effect of surface heterogeneity on scalar variances. By quantifying the effect of that *single* MOST violation, we hope to be able to separate the effect of the *two* MOST violations mentioned before.

We have developed a conceptual model of a heterogeneous surface consisting of two types of patches with contrasting Bowen ratios (β1 and β2). In this model the relative magnitude of the patch Bowen ratio (β1/β2), the mean Bowen ratio $\overline{\beta}$, and the relative size of the patches can be varied. Observations of θ and *q* fluctuations at a certain level above the surface are simulated by releasing air parcels below and above the observation level. The upward moving parcels have properties tied to the underlying patch, whereas downward moving parcels have uniform properties.

The most important predictions of the model are:

1. decorrelation between θ and *q* increases with increasing contrast between the

patches;

2. scaled humidity variance is larger than scaled temperature variance for mean dry conditions (high $\overline{\beta}$) implying a lower transport efficiency for humidity. The reverse holds for mean wet conditions (low $\overline{\beta}$) (lower transport efficiency for heat and relatively high scaled variance).This is consistent with the model and literature review of Lamaud and Irvine (2006);

For the purpose of model validation, data from a heterogeneous savannah site in Ghana are used. Although the spread in the data is considerable, the transition from wet to dry conditions as present in the data is predicted qualitatively well by the model. In the data, the effect of entrainment is probably present as well, making an exact match between data and model unlikely (and undesirable).

The presented model gives a quantitative sketch of one of the important mechanisms that cause dissimilarity of temperature and humidity in the surface layer. It opens the route to the understanding of the (dis-)similarity of other scalar pairs as well, which is, among other things, of importance for the use of variance methods for flux calculations.

Lamaud, E. and M. Irvine, 2006: Temperature-humidity dissimilarity and heat-to-water vapour transport efficiency above and within a pine forest canopy: the role of the Bowen ratio. *Boundary-Layer Meteorol.* **120**, pp. 87 - 109.

Moene, A.F., D. Schüttemeyer, and O.K. Hartogensis, 2006: Scalar similarity functions: the influence of surface heterogeneity and entrainment. *17th Symposium on Boundary Layers and Turbulence*, 22-25 May 2006, San Diego, California. p. 5.1.