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Estimation of spatially distributed turbulent heat fluxes using thermal information captured from an UAS

Claire Brenner, Christina Elisabeth Thiem, Matthias Bernhardt, and Karsten Schulz

University of Natural Resources and Life Sciences, Vienna, Institute of Water Management, Hydrology and Hydraulic Engineering, Department of Water - Atmosphere - Environment, Austria (claire.brenner@boku.ac.at)

Evapotranspiration is a key component of the Earth's water and energy cycle. However, measuring evapotranspiration is difficult and distributed information with high spatial resolution is rare. Land surface temperature (LST) is often used as source of data for the estimation of evapotranspiration. Actual LST is mainly controlled by the amount of incoming radiation, surface albedo, water availability, ventilation of the surface and in case of vegetation stands also by the intensity of the transpiration process. Thus it contains valuable information on the actual state of the soil-vegetation-atmosphere system.

Typically LST information is available from satellite imagery or from radiometers installed at experimental sites. Thus, measured LST is either representative for areas of hundreds of square meters (satellites), or for certain points (radiometers). Thermal imaging from unmanned aerial systems (UAS) can be used for addressing this scale gap and is a trade-off between flexibility and ease of use on the one hand and spatial coverage on the other hand.

In this study we have measured surface temperatures at a grassland site in Luxemburg in July 2015 by means of a thermal infrared camera mounted on an octocopter drone. At the same time scintillometer measurements were made at the same field. The experimental set-up was completed by meteorological and radiation measurements.

UAS flights were conducted on a sequence of days over a time period of 2 weeks and with up to ten flights a day in order to monitor diurnal variation of LST. The observed spatially distributed surface temperatures were then used to estimate sensible and latent heat fluxes using three algorithms. All of them make use of observed vertical temperature gradients between surface and atmosphere but do show a different complexity. Two of them are single-source models while one is a dual-source representation of the soil-vegetation system.

Although the experimental site was fully covered by grass, LST showed significant in-field variability with temperature variations of up to 15°C within a 30 x 60 m plot. This variability might be attributed to differences in vegetation vitality and soil moisture conditions and results in a spatially heterogeneous pattern of sensible and latent heat fluxes. The performance of the three models in accurately depicting evapotranspiration was tested by means of scintillometer measurements. For an adequate comparison, flux estimates based on LST information were spatially weighted on the basis of the current footprint of the scintillometer measurement (which represents a spatial integral over the footprint area). Subsequently, the weighted LST flux estimates were compared to the fluxes derived from scintillometry for evaluating the performance of the different approaches.