Geophysical Research Abstracts
Vol. 18, EGU2016-10500-1, 2016
EGU General Assembly 2016

Quantifying the Components of Evapotranspiration from Plant Communities, Soil Evaporation and Plant Transpiration, with Isotopes and Micrometeorology

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Isotope fractionation has been used in recent years to separate the components of evapotranspiration (ET):soil evaporation (E) and plant transpiration T. The technique estimates the ratio of T to ET, but without further information on the magnitude of ET, can not estimate the magnitudes of the components. To accomplish this, we conducted a study using the micrometeorological technique of eddy covariance to determine ET for a developing crop of winter wheat in conjunction with measurement of enrichment of the isotopes 18O and H2 in the vertical profiles of water vapour within and above the crop canopy. As well, the study employed a second micrometeorological technique based on a Lagrangian description of dispersion in the canopy (Raupach, 1989) to infer the source strengths for water vapour at the soil surface and in the various foliage layers in the canopy.

Lagrangian dispersion analysis provides a means of linking canopy sources and sinks with mean concentration profiles using statistics of the turbulence in and above the canopy. Forward Lagrangian dispersion analysis predicts mean concentration profiles generated by given canopy source distributions. It uses a Lagrangian (fluid-following) framework to track an ensemble of “marked fluid particles” as they disperse. Inverse Lagrangian dispersion analysis does the reverse of the forward analysis: it predicts source profiles from mean concentration profiles. The dispersion equation uses information on the turbulence and gas concentrations in the canopy to relate the concentrations at any level to the source strengths at all levels. The necessary turbulence statistics are the friction velocity (a measure of vertical turbulent exchange in the air flow over the plant canopy), the standard deviation of the vertical wind velocity, and the Lagrangian time scale (a measure of eddy coherence). The analysis calculates the contributions of the various canopy layers to the net flux.

In this study, agreement between the micrometeorological and isotopic analyses was excellent: the inverse Lagrangian analysis estimating E to be 4% of ET and isotopic analysis 6%. While encouraging, it must be acknowledged that these results were obtained on a drying soil (moisture content, 9-12%) and a small crop (only 0.23 m high and an LAI, leaf area index, near 1). It is planned to make further measurements using this approach on soils with a range of soil moisture contents and taller crops with higher LAIs.