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Quantifying Soil Evaporation and Plant Transpiration from Plant Communities with Isotopes and Micrometeorology

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Recorded Presentation

Isotope fractionation is now much used 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, the study described here used 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 ^{18}O and ^{2}H 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.

Isotope fractionation

By assuming that ƒ¢T is at isotopic "steady state" (transpired vapour = stem water), there is no condensation, and source contributions do not change over the collection period, the fractional contribution from transpiration, F_T is given by:

F_T (%)= (dET-dE)/(dT-dE) x100

where dE is the $d^{18}O$ of the water vapour evaporated from the soil surface, dET is the $d^{18}O$ of the water vapour evaporated from the crop surface and dT is the $d^{18}O$ of the water vapour transpired by the foliage of the crop. In our study, similar calculations were made for $d^{2}H$.

Lagrangian dispersion

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. As described by Raupach (1989), it uses a Lagrangian (fluid-following) framework to track an ensemble of "marked fluid particles" as they disperse. It recognizes 2 modes of dispersion: near the source, coherence of eddies causes particles to travel in straight lines; far from it, trajectories resemble random walks. This description is called linearised near-field theory. The analysis of Raupach (1989) calculates the contributions of each mode to the concentration at any point in the canopy.

Inverse Lagrangian dispersion analysis does the reverse of the forward analysis; it predicts source profiles from mean concentration profiles. The dispersion equation employed in both analyses 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 u*, the standard deviation of the vertical velocity sw and the Lagrangian time scale T_L (a measure of eddy coherence). The analysis calculates the contributions of the various canopy layers to the net flux.

For stable solutions, the number of concentration measurements (n) should be > number of prescribed source layers (m). This allows for error minimization. Typically, for m=4, n=8; the bottom layer includes contributions from the ground. (The wheat in our study was only 23 cm high. Because the crop was so small, there were only 4 measurement heights in the canopy, and 2 above it, and m was set at 3). sw(z) can be measured, but TL must be inferred from theory or canopy turbulence models such as 2nd order closure. The analysis is