Quantifying Water Vapor and Carbon Dioxide Cycles

Challenge

In nature, the exchange of water vapor (H_2O) between vegetated surfaces and the atmosphere — part of the global water cycle — is closely linked to the exchange of carbon dioxide (CO_2), another greenhouse gas affecting global climate. Too little is known about the influences of natural processes, global change, and regional human activities on water supply and quality. A new DOE pilot study aims to fill this knowledge gap (Figure 1).

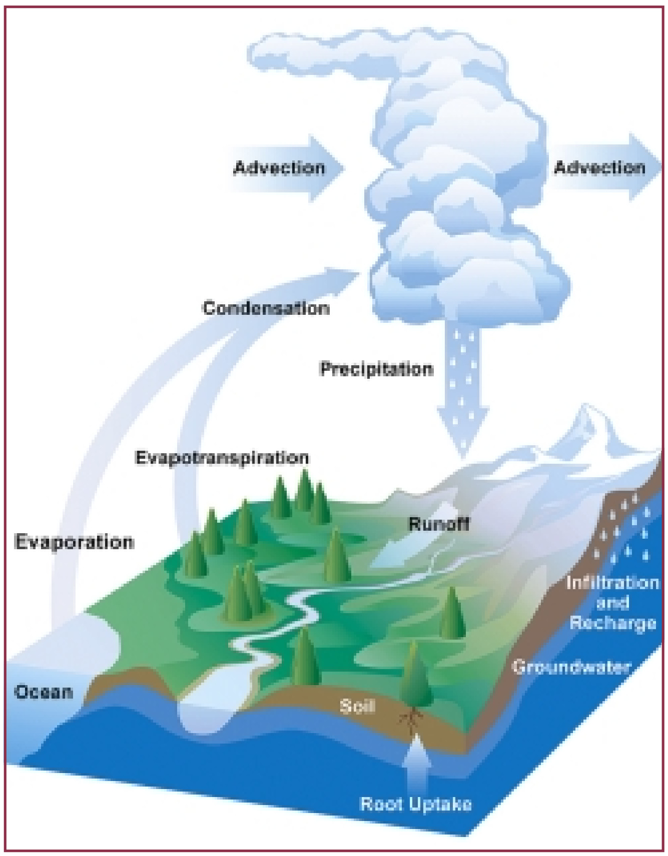

Figure 1. The water cycle.

Argonne's Solution

Argonne scientists are measuring and modeling the air-surface exchange of H_2O and CO_2 in studies for DOE's Water Cycle Pilot Study and carbon cycle program,

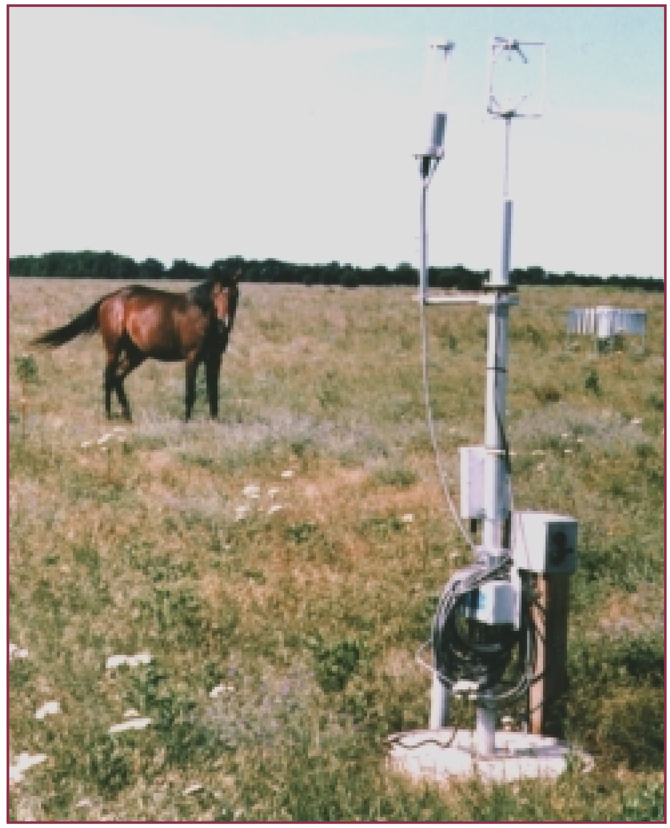

Figure 2. AmeriFlux site near Smileyburg, Kansas.

which contributes to the AmeriFlux network. Our study site in the Walnut River Watershed (WRW), just east of Wichita, Kansas, was developed during the 1990s with Argonne seed funding. This 5000-km^2 site provides instrumentation needed for the three-year Water Cycle Pilot Study. The long-term AmeriFlux effort measures the net ecosystem exchange of CO_2 above a grassland site in the WRW (Figure 2).

Approach

Argonne uses micrometeorological techniques to measure the air-surface exchange due to turbulence transfer of H_2O and CO_2 in the lowest 50 m of the atmosphere. We emphasize the eddy covariance method, the technique approved by the AmeriFlux network. This method requires measurements of wind components and concentrations of H_2O and CO_2, typically at a rate of about ten samples per second. To determine the net vertical flux above the surface, we average the instantaneous upward and downward fluxes over periods of 30-60 min. Several other types of measurements complete the characterization of the vegetation, soil, and near-surface atmosphere. Measurements at individual locations are extended to the entire WRW with our PASS (parameterized subgrid-scale surface) model, which uses remote sensing data from satellites and conventional surface meteorological data in an efficient computational scheme.

Accomplishments

An initial effort with PASS successfully estimated the water cycle components for 1999 (Figure 3).

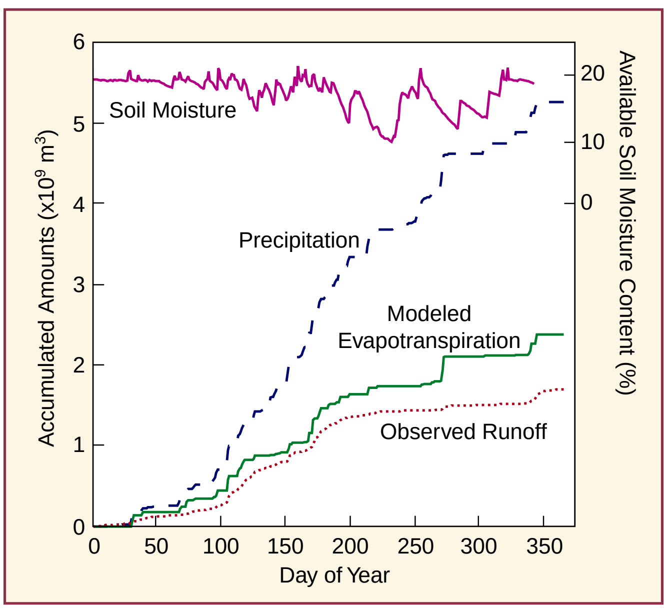

Figure 3. Surface hydrological components at the study site in 1999.

In 2002, a three-month intensive experiment estimated all components of the water cycle more precisely by using additional instrumentation and several high-resolution atmospheric and hydrological models. The purpose was to evaluate the feasibility of determining water cycle components in potential future DOE studies. A careful comparison of eddy covariance measurements and CO_2 concentration standards, aimed at producing reliable seasonal and annual estimates of the net ecosystem exchange of CO_2 (Figure 4), resulted in recommendations for improved analysis of eddy covariance data.

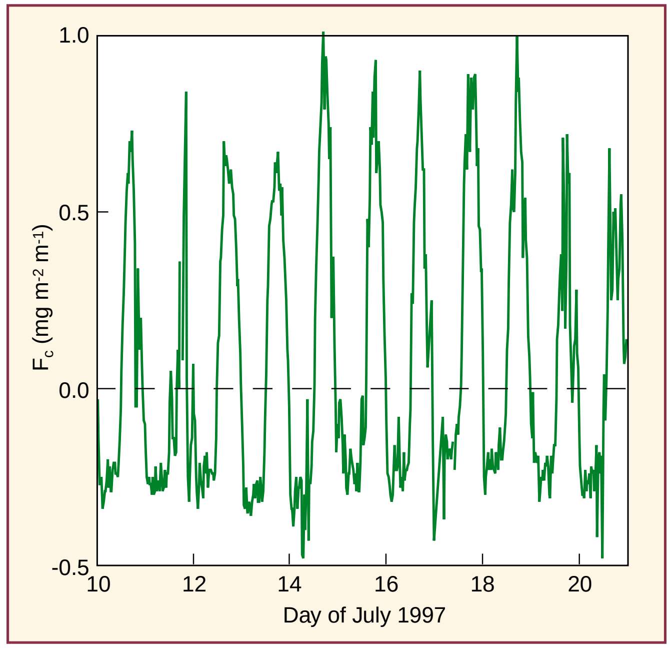

Figure 4. High-resolution diurnal cycles of carbon dioxide concentration.

Sponsors and Collaborators

The DOE Water Cycle Pilot Study is a collaborative effort involving Argonne, Brookhaven, Lawrence Berkeley, Los Alamos, and Oak Ridge national laboratories. The carbon cycle studies at the WRW are interactive with AmeriFlux sites supported by DOE and other agencies; more than 40 AmeriFlux sites are in operation across North, Central, and South America.

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