New Technologies for Large-Scale Evapotranspiration Measurements

With the growing scarcity of clean water around the world and concern over climate change, researchers and policy makers are seeking better methods to measure water use from evaporation and transpiration. Large-scale evapotranspiration measurements are now possible and practical thanks to eddy covariance systems with automated data processing in real time, remote communications, and web-based data management.

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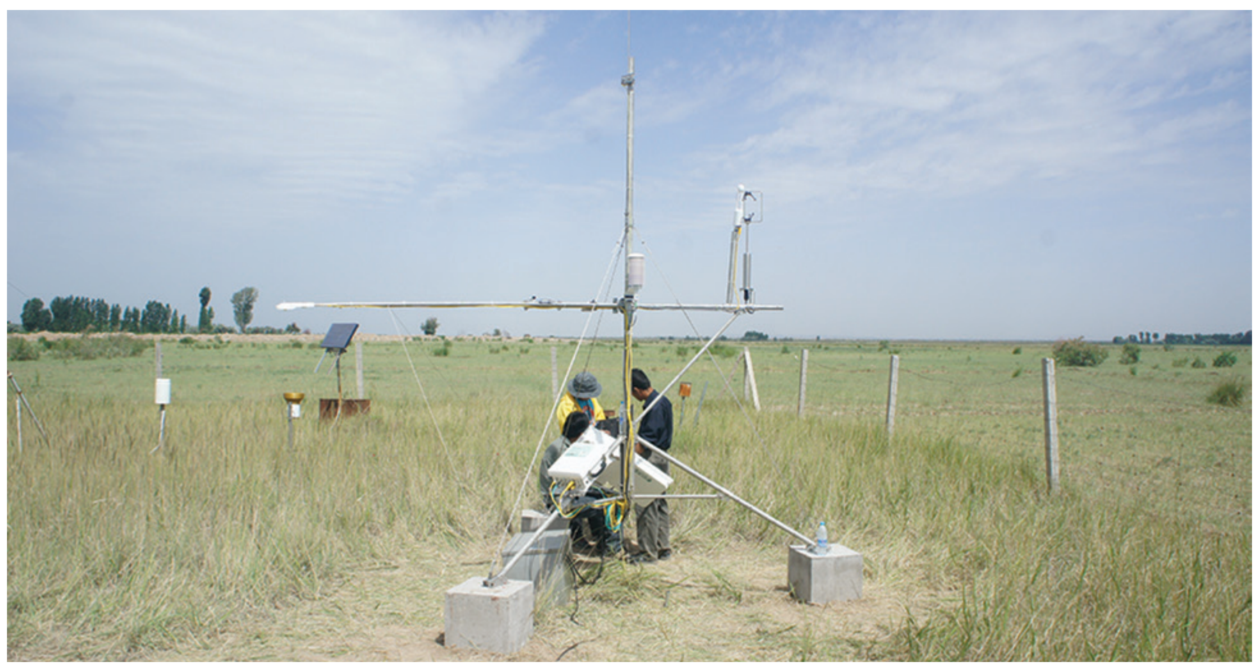

Eddy covariance system for measuring evapotranspiration in Linze, Gansu, China. Photo courtesy of Beijing Ecotek Technology Company Ltd.

Thanks to new data processing and management technologies, the eddy covariance method is now a practical tool for monitoring evapotranspiration. H_2O fluxes from numerous interconnected sites can be automatically calculated in real time and made available for remote viewing and download via the internet. The Chinese Ecosystem Research Network (CERN) has deployed this new system, developed by LI-COR Biosciences, at sites across China.

Why Measure Evapotranspiration?

Water is essential for the functioning of ecosystems and for life itself. The earth's water is always in motion. The largest flow of material in the biosphere is the movement of water through the hydrologic cycle (Chahine, 1992). The transfer of water from soil and water surfaces through evaporation and the loss of water from plants through stomata as transpiration represent the largest movement of water to the atmosphere. Collectively these two processes are referred to as evapotranspiration.

On a global scale, about 65% of land precipitation is returned to the atmosphere through evapotranspiration (Trenberth, 2007). Evapotranspiration measurements on individual fields or plots have long played a role in irrigation management, water conservation, plant science research, and plant breeding. Measurements over a larger scale could help address some of the big issues impacting the world. Measuring evapotranspiration is important for regional water management, agriculture, endangered species protection, and the genesis of drought, flood, wildfire, and other natural disasters. In addition, when thought of in terms of energy as latent heat flux, evapotranspiration consumes about 50% of the solar radiation absorbed by the earth's surface (Trenberth, 2009). This influences both climate and hydrology at local, regional, and global scales.

Why Use Eddy Covariance?

Eddy covariance is the most direct and widely used method for measuring evapotranspiration (Baldocchi et al., 2001, Jung, 2010). The eddy covariance technique has four prominent advantages compared to other methods for measuring evapotranspiration:

- In situ, providing direct measurements of evapotranspiration and sensible heat flux
- Minimal disturbance to the region of interest
- Measurements are spatially averaged over a large area
- Systems are automated for continuous long term measurements

Eddy covariance measures the exchange of gases (including H_2O) between terrestrial ecosystems and the atmosphere. As wind moves across the surface of Earth, it does so in the form of rotating vortices called eddies. As a result, the air is almost always moving either up or down, much like a wave in the ocean or swirling smoke. When an eddy is moving upward or downward, it will move air with a specific gas content, temperature, and energy. The eddy covariance method of gas flux measurement uses simultaneous high-speed vertical wind speed from sonic anemometers and gas concentration from gas analyzers, using turbulent transport theory in the surface layer of the atmosphere. Common measurements include carbon dioxide (CO_2), water vapor, and energy flux.

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Instruments

The basic instruments required for measuring evapotranspiration with the eddy covariance method include a water vapor analyzer and a sonic anemometer, both of which must be capable of making high frequency measurements. The H_2O analyzer measures water vapor density, while the anemometer measures 3-dimensional wind speeds and directions. Measurements are typically made at 10 Hz (10 times per second) or faster in order to catch fast-moving eddies.

LI-COR's LI-7500A Open Path CO_2/H_2O Analyzer is an excellent choice for measuring evapotranspiration because air moves freely through its open measuring volume. It requires only 12W to operate, making solar power (also available from LI-COR) a feasible option for remote locations. Several models of Gill sonic anemometers are available directly from LI-COR. Compatible anemometers are also available from other manufacturers, including Campbell Scientific®, RM Young Company, Metek and Kaijo-Denki.

In addition, biological and meteorological (biomet) sensors such as a net radiometer, soil heat flux plates, and precipitation gauge can be used for flux measurement validation through energy balance closure, gap-filling, and interpreting the flux results.

New Technologies for Large Scale Systems

The eddy covariance method provides the average flux over its footprint in the upwind direction, a distance of approximately 100 times the instrument height above the ecosystem. This can be over a field, forest, ocean, or any other type of terrain. Regional-scale evapotranspiration can be estimated by linking data from multiple sites.

LI-COR's new SMARTFlux™ System, remote communication options, and data management solutions provide a seamless, immediate, integrated flow of computed H_2O fluxes, ambient H_2O, and other data from multiple research sites to a central location. LI-COR's eddy covariance solutions allow an entire network of sites to act together rather than as individual data islands. This integration includes automatic synchronization of instrument clocks across the network (using a global positioning system), automated data processing, and centralized management of computed results. With a computer or mobile device connected to the internet, an operator can monitor real-time fluxes from numerous sites and better understand the status of instrument operation at different stations.

Real-Time Results

The SMARTFlux System (Synchronization, Management And Real Time flux system) is a powerful tool that provides fully processed flux results in real time at the research site. The SMARTFlux System is fully integrated into LI-COR's greenhouse gas and energy flux systems. At the heart of the SMARTFlux System is EddyPro®, the flux processing software used by more than 3000 scientists and adopted by the major worldwide flux networks, including AmeriFlux and ICOS. The SMARTFlux System features a built-in GPS receiver and a compact processor that runs EddyPro flux processing software. With the SMARTFlux System you can remotely view final fluxes in real time, including sensible heat flux (H), latent heat flux (LE), evapotranspiration (ET), carbon dioxide flux (Fc), methane flux (CH_4; LI-7700 required), and ambient concentrations of CO_2, H_2O, and CH_4. A wind rose plot shows the predominant wind direction, while biomet sensors deliver soil and air temperature and other bio-meteorological data. The SMARTFlux System also provides a variety of outputs including random error estimates for fluxes, footprint estimates, and daily summary files that are well suited for system diagnostics.

New Technologies Implemented in China

Researchers at the Chinese Ecosystem Research Network (CERN) wanted to measure evapotranspiration across a large geographical area. They chose the latest eddy covariance system from LI-COR. At 27 sites across China, CERN installed eddy covariance systems featuring the LI-7500A Open Path CO_2/H_2O Analyzer and the SMARTFlux System. Remote access and online data management permit real-time access to final fluxes from all these sites. The evapotranspiration network established by CERN is giving researchers better insight into a regional-scale hydrologic cycle than ever before possible. An expansion of such networks around the world could play an important role in addressing global-scale issues such as drought, water management, and climate change.

Contact LI-COR to learn more about eddy covariance, the SMARTFlux System, evapotranspiration, and other environmental monitoring applications.

One of the eddy covariance systems installed by the Chinese Ecosystem Research Network to measure evapotranspiration. Photo courtesy of Beijing Ecotek Technology Company Ltd.

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