Eddy Covariance Systems for Water Management Research and Agroecosystem Monitoring

Sui, R.; Reddy, K.; Anapalli, S.; Murrell, C.

Three eddy covariance (EC) systems were set up in the Mississippi Delta for agroecosystem monitoring and assessment, and evapotranspiration (ET) measurement. One EC system is located in Stoneville, MS and two others in Arcola, MS. The EC system consisted of a CH_4 analyzer for measuring methane gas flux, CO_2/H_2O analyzer for measuring carbon dioxide and water vapor fluxes, three-dimensional sonic anemometer for determining wind speed in three dimensions, and biomet (biological & meteorological) sensors to collect ancillary data for filling measurement gaps and interpreting flux results. Installation and preliminary field tests of the EC systems have been completed. The systems are being used to collect data for research on water management technologies and climate change impact on agroecosystems in the Mississippi Delta.

Background

There is around 1300 mm of annual precipitation in Mississippi. However, uncertainty in amount and timing of precipitation during the crop growing season becomes a serious risk to Mississippi producers. To reduce the risk and optimize crop yield, the producers have become reliant on supplemental irrigation. In recent years, irrigated acreage is rapidly increasing in Mississippi. Almost all irrigation water in this region is pumped from the Mississippi River Valley Alluvial Aquifer, and excessive withdrawals of underground water have resulted the level of the aquifer declining. Novel irrigation techniques and tools are needed for improving water use efficiency to maintain Mississippi water resource sustainability. Eddy covariance (EC) method is capable of measuring exchanges of carbon dioxide, water vapor, methane, and energy between the surface of the earth and the atmosphere. Eddy covariance systems have been widely used for monitoring agroecosystems and measuring crop evapotranspiration (ET) for irrigation scheduling. Objectives of this project were to use EC systems to monitor the agroecosystem and measure evapotranspiration for research on water management technologies and agroecosystem assessment.

System Description

A basic EC system consists of a variety of gas analyzers, including a LI-7700 CH_4 Analyzer (LI-COR, Linclon, NE), LI-7540 CO_2/H_2O Analyzer (LI-COR), and three-dimensional (3D) sonic anemometer (CSAT3, Campbell Scientific, Logan, UT, USA; WindMaster, Gill Instruments, Lymington, UK). In addition to these basic instruments, biomet (biological & meteorological) sensors may be used in an EC system to collect ancillary data for filling measurement gaps and interpreting flux results. The LI-7700 CH_4 Analyzer has a calibration range from 0 to 25 ppm at -25 °C, and 0 to 40 ppm at 25 °C. The linearity is within 1% of the reading across the full calibration range. Measurement resolution is 5 ppb RMS noise at 10 Hz, 2000 ppb CH_4. LI-7540 CO_2/H_2O Analyzer is capable of making simultaneous CO_2 and H_2O flux measurements in the free atmosphere. The CO_2/H_2O Analyzer has a calibration range of 0 to 3000 ppm for CO_2 and 0 to 60 mmol/mol for H_2O. Measurement accuracy is within 1% of the reading for both CO_2 and H_2O. The sonic anemometer is a three-dimensional sonic sensing device that measures three orthogonal wind components and the speed of sound. In eddy covariance systems, it measures the turbulent fluctuations of horizontal and vertical wind, which are then used to calculate momentum flux and friction velocity. The CSAT3 3D sonic anemometer has a programmable measurement rate from 1 to 60 Hz in instantaneous measurements. The offset error of orthogonal wind components u_x, u_y, and u_z is < ±8 cm s^{-1}, < ±8 cm s^{-1}, and < ±4 cm s^{-1}, respectively. The WindMaster 3D sonic anemometer (model 1590-PK-020) has a sampling rate up to 32 Hz.

Its measurement range is 0 to 45 m/s with an accuracy of < 1.5% RMS.

System Installation

Three EC systems have been installed in the Mississippi Delta, one in Stoneville, MS (hereinafter referred to as System 1) and two others in Arcola, MS (hereinafter referred to as Systems 2 and 3) as shown in Fig. 1. System 1 is located in a Research Farm of the USDA-ARS Crop Production Systems Research Unit (33.44331749N, 90.88650123W) and is shown in Fig. 2. This system is surrounded by a variety of crop fields and catfish ponds, which represent a typical agroecosystem in Mississippi. System 1 consists of a LI-7700 open-path CH_4 analyzer for measuring methane gas flux, LI-7540 open-path CO_2/H_2O analyzer for measuring carbon dioxide and water vapor fluxes, CSAT3 3D sonic anemometer for measuring wind speed, and biomet sensors to collect ancillary data. The biomet sensors include a net radiometer, soil heat flux plates, soil temperature sensors, and precipitation gauge. System 1 was designed for long-term Mississippi Delta agroecosystem monitoring and assessment. System 2 was installed in the center of a 210-ac field (33.27581111N, 90.90645W) under corn or soybean cultivation. System 2 includes the same open-path CO_2/H_2O analyzer, CSAT3 3D sonic anemometer, and the biomet sensors as in System 1. There is no CH_4 analyzer in System 2 since it was designed for determining ET for water management research. System 3 has the CH_4 analyzer, CO_2/H_2O analyzer, and WindMaster 3D sonic anemometer. There are no biomet sensors involved in System 3 yet because the location of this system was geographical close to the location of System 2 (Fig. 1) and meteorological conditions for these two systems should be similar. System 3 was installed in the center of a 235-ac field (33.27649444N, 90.90653056W), planted to soybean or rice. System 3 is used to determine the crop ET and methane gas flux emitted from the field, especially as rice is grown in the field.

Installation of these three EC systems in the Mississippi Delta has been completed. The systems are being used to collect data and preliminary results indicate that the systems are performing well. A couple of issues with solar power panel and biomet sensors have occurred and were resolved during system installation and testing. Using these EC systems, we expect to obtain accurate ET and other agroecosystem data for our research on development of water management technologies and climate change impact on agroecosystems in Mississippi Delta region.

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Figure 1. Locations of three eddy covariance systems setup in Mississippi Delta.

Figure 2. Eddy covariance system in Stoneville, MS for long-term agroecosystem monitoring and assessment.