New Eddy Correlation System for ARM SGP Site

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Background

Eddy correlation (ECOR) systems are widely used for in situ measurement of the turbulent fluxes in the atmosphere. The ECOR technique is the most direct method for determining fluxes; vertical fluxes are obtained by correlating the vertical wind component with the horizontal wind component (momentum flux), temperature (sensible heat flux), water vapor density (latent heat flux), and a scalar admixture density (e.g., CO_2 flux). Typically, an ultrasonic anemometer-thermometer ("sonic anemometer") is used for rapid, high-precision, three-dimensional (3D) wind measurements, as well as for temperature fluctuation measurements. A fast-response humidity sensor, such as an infra-red gas analyzer (IRGA) is used for water vapor density measurements, and a variety of other sensors might be incorporated to measure fluxes of various compounds or aerosols.

The first-generation Atmospheric Radiation Measurement (ARM) ECOR system did not perform up to expectations and was removed from service in the summer of 2002. Development and testing of a new ECOR system began in November 2002; field deployment started in August 2003. The design phase was prolonged because we found that all of our sonic anemometers had to be calibrated in a temperature-humidity chamber to improve the accuracy of the sensible heat flux measurements. Currently, nine fully functional ECOR systems are deployed at extended facilities E1 (Larned), E3 (LeRoy), E5 (Halsted), E6 (Towanda), E10 (Tyro), E14 (Central Facility), E16 (Vici), E24 (Cyril), and E21 (Okmulgee). The data are ingested and sent to the ARM Archive regularly and are available to users through the standard archive user interface.

General Description

The new ECOR design is based on a 3D sonic anemometer (Gill Instruments, Ltd., model WindMaster Pro, http://gill.co.uk/data/windmast.pdf), an infrared CO_2/H_2O gas analyzer (LI-COR Inc., model LI-7500, http://licor.com/env/PDF_Files/LI7500.pdf), a LINUX-powered data acquisition computer, and the ECOR software package developed at Argonne National Laboratory. An important new feature is the capability to measure the vertical flux of CO_2, one of the major greenhouse gases. Another significant improvement is a network connection to a site communications computer for automatic data transfer. This connection allows remote access to the ECOR computer for upgrading or troubleshooting, which dramatically decreases downtime, unrecoverable data losses, and maintenance efforts.

The WindMaster Pro and the LI-7500 are fully programmable devices connected to the data acquisition computer via serial links; analog outputs from the LI-7500 are sampled by the WindMaster Pro analog-to-digital conversion system synchronously with wind measurements. The data acquisition computer collects two serial data streams, makes flux computations, prepares the data, and provides File Transfer Protocol (FTP) service for data transfer to the site communications computer.

In a typical arrangement, the ECOR system is placed on the north side of a wheat field (Figure 1a); sonic and IRGA sensor heads are mounted on a small tower at 3 m above ground level, at the end of a horizontal boom pointing south (Figure 1b). The computer and communication devices are installed in an enclosure with basic temperature control (ventilation or heating).

The system has storage capacity on the local hard drive for several months of data; currently the backup data holding time is limited to 60 days, and all older data are automatically deleted. This setup provides a time window long enough to verify that the data were ingested successfully and reached the ARM archive.

Figure 1. (a) The ECOR system at the Central Facility; (b) sonic (right) and IRGA (left) sensor heads installed on the boom.

Data Examples

Figure 2 presents example of data comparison between the ECOR system and the energy balance Bowen ratio (EBBR) system at the central facility. The data were collected in June-July and September-November of 2003. Flux comparisons were restricted to cases with wind direction from 90° to 270° (to avoid ECOR tower impacts), wind speed above 2 m/s, and friction velocity of 0.3 to 1.3 m/s.

The systems were generally in a good agreement on total atmospheric heat flux, $H + LvE$ (Figure 2c); however, the EBBR system split the total flux into sensible H (Figure 2a) and latent LvE (Figure 2b) parts quite differently than the ECOR did, especially in June-July (red x's on Figure 2a-b). This dissimilarity may be explained, in part, by (1) the differences in local conditions, especially surrounding vegetation and (2) the different principles of operation.

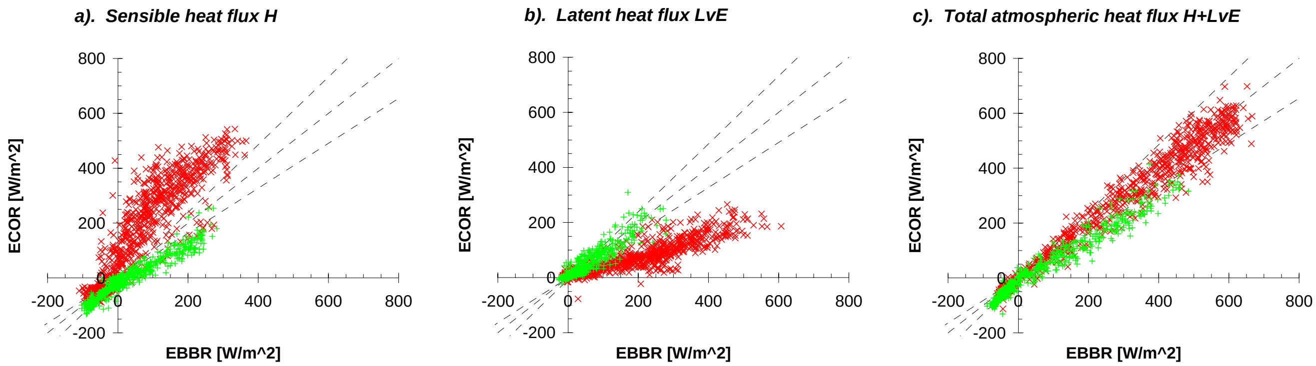

Figure 2. Atmospheric heat flux; ECOR vs. EBBR at the Central Facility. a). Sensible heat flux H; b). Latent heat flux LvE; c). Total atmospheric heat flux (H+LvE). Red (x) is June, July, and September; green (+) is October-November; all the data presented are for wind speed greater than 2 m/s, wind direction from 90° to 270°, and friction velocity from 0.3 m/s to 1.3 m/s. Dashed lines correspond to +/-10% difference.

The ECOR system is located on the border of a wheat field; in 2003, the wheat was harvested in late July. The system faces a gentle hilltop about 100 m to the south. The EBBR is situated on a pasture site, about 200 m southeast of the ECOR, near the crest of a local hill that slopes downward farther to the southeast, with a height difference of about 15 m. Although the wheat was still present, it apparently was not growing actively and was not enhancing evapotranspiration; thus, the major portion of the total heat flux was sensible heat. On the other hand, grass around the EBBR was still active, making the latent heat more important. In October-November, both systems looked over inactive vegetation or bare soil; hence, their estimates of sensible and latent heat flux were more similar.

Conclusion

The new ECOR systems were designed and successfully deployed at nine extended facilities. All sonic anemometers were calibrated in an RH/T chamber. The ECOR data are routinely retrieved, ingested, and sent to the ARM Archive; they are available to the end user through a standard interface. The ability to measure the vertical flux of CO_2 is an important new feature that should attract new data users. The system has proved to be robust and highly reliable; during several months of operation (since August 2003) no sensor has failed. Periods of data corruption or data loss resulted from power failures or adverse weather conditions, when open-path sensors cannot operate.

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