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Final Report: Eddy-Covariance Flux Tower and Tracer Technology Support for the University of Georgia Proposal: From Tower to Pixel: Integration of Patch-Size NEE Using Experimental Modeling Footprint Analysis

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Final Report

Eddy-Covariance Flux Tower and Tracer Technology Support for the University of Georgia Proposal: From Tower to Pixel: Integration of Patch-Size NEE Using Experimental Modeling Footprint Analyses

Project EE-544-EEBA

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Summary:
Brookhaven National Laboratory has been funded since October of 2000 to provide assistance to the University of Georgia in conducting footprint analyses of individual towers based on meteorology and trace gas measurements. Brookhaven researchers conducted air flow measurements using perfluorocarbon tracers and meteorological instrumentation for three experimental campaigns at an AmeriFlux research site maintained by Dr. Monique Leclerc near Gainesville, FL. In addition, BNL provided assistance with remote data collection and distribution from remote field sites operated by Dr. John Hom of the US Forest Service in the Pine Barrens of New Jersey and at FACE research sites in North Carolina and Wisconsin.

Introduction:
The Office of Biological and Environmental Research (BER) in the Department of Energy (DOE) funded Brookhaven National Laboratory (BNL) to provide assistance to the AmeriFlux research programs from FY2001 through FY2006. The specific tasks were to assist a University of Georgia team lead by Dr. Monique Leclerc conducting research examining the effective footprint of individual towers in a forested ecosystem and to extend the acquired knowledge to other research groups and programs. BNL worked with the University of Georgia to conduct three experimental campaigns using perfluorocarbon tracers to quantify air movement through and above a slash pine plantation ecosystem located in Gainesville, FL. BNL also designed and deployed instrumentation and software that allow real time data collection, visualization, and storage of multiple 10 Hz data streams using commercially available wireless networking hardware. The custom software developed for this program can manipulate and provide quality assurance tests to the collected data streams. These designs and computer programs were made available to other research groups through presentations at the annual AmeriFlux science meetings and through collaborations with individual research groups. The wireless networking and data handling technologies developed through this project have been used in US Forest Service projects studying the micrometeorology of the New Jersey Pine Barrens, with sap flow and micro meteorological measurements at FACE research sites in North Carolina and Wisconsin,

Discussion:

Tower footprint analyses at the AmeriFlux research site in Gainesville, FL:

In response to a request from the University of Georgia, DOE funded Brookhaven National Laboratory to assist with studies on the spatial extent of influences on flux measurements taken at individual tower locations. The goal of this research activity was to improve the models used to extrapolate information collected at individual towers to regional scales. BNL was selected to collaborate on this project with the University of Georgia due to BNL's unique capabilities to quantitatively trace air movement through complex terrain using perfluorocarbon tracers and their experience in conducting field experiments at remote sites. It was expected that equipment and procedures developed for this project would be transferred to other AmeriFlux groups as well as to the general scientific community.

BNL supplied and supervised the installation of a walk-up tower equipped with ten three meter instrument support booms at a forested location selected by the University of Georgia team. BNL installed AC power to the tower and a trailer supplied by the University of Georgia. Staff from the Tracer Technology Center at BNL designed three series of tracer releases; each using six unique perfluorocarbon tracers to document air flow through and above the forest canopy. The first experiment, conducted in 2001, examined the near-tower airflow, with releases at three heights, 1.0, 6.4 and 10.1 meters above the forest floor at radii of 10.75, 21.5, and 43 meters from the sampling tower. The second study examined medium to far field transport, with release heights of 1 and 11.5 meters, and radii of 50, 125, and 300 meters from the tower. The third experiment examined transport from the ground surface during mildly unstable atmospheric conditions, with sources placed just above the litter layer at radii of 100, 200, and 400 meters from the tower. These three studies are described in more detail in *Florida Tower Footprint Experiments*, T.B. Watson et al **(**BNL-78032-2007). At the conclusion of research activities at the Gainesville, FL site, BNL dismantled and transported the walk-up tower to the site of a new AmeriFlux site being established at the DOE Savanna River Site in Aiken, SC.

BNL also supplied data collection hardware and software that allowed the simultaneous collection, real-time display and archiving of 10 Hz data streams from seventeen three-dimensional sonic anemometers, two open path CO_2 analyzers and three closed cell CO_2 analyzers. A wireless network using the 802.11b WiFi standard was established for communication between the instruments located on the tower and the data processing computers placed in a control trailer approximately 100 meters from the tower. This allowed high speed data transfers without installing dedicated network cabling. The software used to display, manipulate and store the data streams, and to test the operation of the equipment was designed to work with a broad array of hardware and experimental designs, so it could be easily configured to accept information from the various instruments and data loggers used in this experiment. In addition to allowing the simultaneous display and archiving of multiple 10 Hz data streams, this software can provide separate files of averaged data in formats that can be transmitted over low bandwidth pathways and used in Web based displays and modeling activities.

Enhancements to U.S. Forest Service AmeriFlux towers in the New Jersey Pine Barrens:

Hardware and software enhancements were made to the U.S. Department of Agriculture Forest Service AmeriFlux towers in the New Jersey Pine Barrens region. The changes resulted in

increases in quality assurance and safety, and enabled reporting in near real-time of a new fire hazard indicator called the Drought Stress Index (DSI) (Clark et al., in preparation).

There are currently three AmeriFlux towers in the New Jersey Pine Barrens. Each tower installation contains essentially the same instrumentation. Originally there were two data collection subsystems at each tower that operated completely independently of each other.

The first subsystem consists of a three-dimensional sonic anemometer, a closed-path CO_2/H_20 infrared gas analyzer (IRGA), a laptop computer, and supporting equipment. The linearized DAC outputs of the IRGA are connected to two of the auxiliary ADC inputs of the sonic anemometer. Data (u, v, w, sonic temperature, $[CO_2]$ and $[H_2O]$ as millivolts, and instrument status word) are transferred as ASCII strings from the RS232 serial output of the sonic anemometer to the laptop computer at a rate of 10 Hz. The program Hyperterm, included with Microsoft Windows, was used to read data records and recorded them to disk. The process is very simple and robust, but Hyperterm just copies records into files. There were no quality checks performed on the data as it was collected and records were not time stamped. Scientists periodically climbed the towers to retrieve the computers, transferred the data to a workstation and then replaced the computers.

The second subsystem was centered around a Campbell Scientific CR23X datalogger. The datalogger measures solar energy, PAR, net radiation, air temperature, relative humidity, wind speed, wind direction, rain, three soil heat flux plates, three soil temperatures, three fuel stick temperatures, and three fuel stick moisture levels every ten seconds, and saves 30-minute averages. A digital cellular modem is attached to the RS232 port of the CR23X datalogger. Every half hour a computer at Rutgers University in New Brunswick calls to collect the 30-minute data from the CR23X. The data are processed and made available on a statewide web site for meteorology and fire hazard conditions. However, the Drought Stress Index was not available since it requires measurements from the eddy flux subsystem.

Enhancements included both hardware and software improvements:

1) Dropping a weather proof, surge protected Cat5 Ethernet cable from the eddy flux computer at the top of the tower to a junction box at the base of the tower and installing Symantec PCAnywhere (a remote access program) on the eddy flux computer. These additions allowed operators to access the computer without climbing the tower for diagnostics, maintenance, and eddy flux data downloads. They also allowed the same activities to be performed on the datalogger through the hardware link between the eddy flux computer and the logger.
2) Installation of the ECCheck program written by BNL to replace Hyperterm for eddy flux data collection. ECCheck provides graphics, QC monitoring, output record time stamping, 1-minute averages, 30-minute averages and covariances. The averages and covariances are made available on a TCP/IP socket.
3) Installation of a serial PCMCIA card as the second RS232 port on the eddy flux computer.
4) Installation of a link (cable and SC32B converter) from the second RS232 port to the CS I/O port of the datalogger.
5) Installation of the software program DataXbar, also written by BNL. This is a data transfer program that collects 30-minute averages and covariances from the TCP/IP socket of

ECCheck, makes a connection to the datalogger, and writes the data to datalogger input locations.

6) Code was added to the datalogger program to compute the DSI by combining information from the eddy flux computer and the datalogger and write the results to Final Storage where it is picked up by the Rutgers University computer.

Enhancing measurements at FACE research sites in North Carolina and Wisconsin:
Data collected at multiple locations within the FACTS-1 and Aspen FACE research facilities has historically been collected by manually downloading data from each datalogger. The information collected was checked for accuracy and completeness off-line at a later date. This required considerable manpower to collect the data files and led to delays in recognizing data collection problems. Early attempts to automatically collect the data at a central computer were limited by the need for a separate serial connection between the central computer and each datalogger. BNL used techniques developed for the Florida AmeriFlux site to establish site-wide local area networks at each FACE facility and connect the dataloggers to the central computer over this network. This allowed the centralized data collection system to include many additional dataloggers. Sap flow data from the FACTS-1 facility is now automatically collected by a single computer and placed on a private FTP site for collection over the Internet.

The lack of an always on, high bandwidth Internet connection at Aspen FACE precludes exporting all collected data over the Internet. As a work-around for this limitation, data collected at the Wisconsin site are automatically checked for missing values and out-of-range errors every day. An error report covering the prior day's data collection is automatically sent to the data managers each morning for their information and action.

Conclusion:
This activity provided technical expertise and quantitative data that will assist in the determination of the effective footprint of a single flux tower. Perfluorocarbon tracers were demonstrated to be an effective way to quantify the movement of air through and above a forest canopy under moderately stable to unstable atmospheric conditions, over distances from 10 to 400 meters. The simultaneous collection of tracer concentrations and micrometeorological information from multiple sources will allow more detailed modeling of the influence of the surrounding areas on tower foot-print models used in eddy-flux studies. The success of this method has resulted in the inclusion of perfluorocarbon tracer releases at additional AmeriFlux sites. The research designs, hardware and software developed during this activity have been successfully exported to other flux and atmospheric transport experiments.

Publications and presentations related to this project:

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