Sensor and Instrumentation
Description and Location

Updated : May 2, 2000

Wind Sensors :

Sonic Anemometer :

Maker : Campbell Scientific
Model : CSAT-3
Data Rate : 10 Hz
Location : Height = 21.5 m
Date First Running : November 4, 1998
Description : 3-D sonic anemometer which gives wind speed along u, v, and w axes. Also provides a fast temperature measurement. It is placed on a boom ~ 2 m from the tower.
Measurements : Sensible Heat, Latent Heat, Momentum, CO_2 flux, Wind Speed, Wind Direction, u* and other turbulence parameters.

Secondary Sonic Anemometer :

Maker: Applied Technologies
Model : ATI-K probe
Data Rate : 10-20 Hz (varied)
Location : varied from 13.5 to 21.5 m
Date First Running : periodically after May 1, 1999
Description : 3-D sonic anemometer which gives wind speed along u, v, and w axes. Also provides a fast temperature measurement. It is placed on a boom ~ 1.5 m from the tower.
Measurements : Sensible Heat,, Momentum, Wind Speed, Wind Direction, u* and other turbulence parameters.

Wind Speed and Direction :

Maker : RM Young
Model: 09101 propvane
Data Rate : 1 Hz
Location : 25.5 m
Date First Running : August 5, 1999
Description : Propvane which gives direction by change in orientation and wind speed by propellor speed. It is placed on a boom ~ 2 m from the tower.
Measurements : Wind speed and direction.

Temperature :

Air Temperature :

Maker : Vaisala
Model : HMP35-D
Data Rate : 1 Hz
Location : 2, 8, and 21.5 m

Date First Running : November 30, 1998

Description : Platinum Resistance Thermometer measured by a 4-wire half bridge on a Campbell 23x data logger. The measurement is made relative to a known resistor with a low temperature coefficient (< 10 ppm $^{o}C^{-1}$). The reference resistor was calibrated by placing the HMP35-D within a closed-end copper tube and immersing it in ice water (at 0 ^{o}C, the resistance of the PRT is 100.0 ohms) and measuring the resistance ratio. All three HMP35-D sensors are located in RM Young aspirated radiation shields to minimize errors due to radiative heating. These also extend the sensor ~ 0.5 m from the tower. From November, 1998 to June 23, 1999, the highest sensor height was 18 m (subsequently moved to 21.5 m)

Measurements : Air Temperature, Sensible Heat Storage Flux

H_2O Vapor :

Relative Humidity :

Maker : Vaisala
Model : HMP35-D
Data Rate : 1 Hz
Location : 2, 8, and 21.5 m
Date First Running : November 4, 1998

Description : Thin film capacitance measurement. Calibrated in temperature and humidity controlled chamber at the National Center for Atmospheric Research, Atmospheric Technology Division. From November, 1998 to June 23, 1999, the highest sensor height was 18 m (subsequently moved to 21.5 m)

Measurements : Relative Humidity, Latent Heat Storage Flux

H_2O Vapor Eddy Covariance Flux :

Maker : Li-Cor
Model : 6262 Gas Analyzer
Data Rate : 10 Hz
Location : Inlet at 21.5 m, Analyzer located at 7 m

Description : H_2O vapor mixing ratio measured by infrared absorption at 2.59 microns For a further description of the inlet line, plumbing, and calibration, please see the section describing the CO_2 Eddy Covariance Flux.

Measurements : H_2O mixing ratio, Latent Heat flux

Pressure :

Barometric Pressure :

Maker : Vaisala
Model : Pt101-B
Data Rate : 1 Hz
Location : 18 m
Date First Running : November 4, 1998
Description : Capacitive Manometer
Measurements : Barometric Pressure

Carbon Dioxide :

Maker : Li-Cor
Model : 6251 Gas Analyzer
Data Rate : 1 Hz
Location : inlets at 0.5, 1, 2, 5, 10 and 21.5 m
(Note - these heights have been positioned differently at earlier times - these are the heights since Sept. 20, 1999)
Date First Running : May 1, 1999
Description : The commercially available gas analyzer measures the CO_2 mixing ratio by infrared absorption at 4.26 microns. The analyzer is integrated into an automated sampling manifold which cycles between six inlets which are located at different heights on the tower in order to measure a profile of CO_2 within the space below the sonic anemometer where fluxes are measured. Each inlet line is made of approximately 21.8 m of 3/8" Dekabon tubing with a 1 micron Gelman-type filter at the intake. Lengths of tubing were the same on all inlets to maintain a constant pressure between the lines. Lower inlets (z = 0.5 - 5 m) were placed on a mast ~ 7 m from the base of the tower. Higher inlets were extended from the tower ~ 1 m. The sampling manifold which goes to the gas analyzer is connected to all six inlet lines - the inlet lines are continuously pumped at a rate of ~ 2.3 Lpm. The sampling manifold consists of a series of electrically-actuated solenoid values which are controlled be a Campbell 23x datalogger such that only one inlet is being sampled at al time. The data logger cycles through all six inlets every 10 minutes (100 seconds / level). After the solenoid valves, the gas flows through a magnesium perchlorate dessicant trap to remove water vapor, then through a second 1 micron filter and then the gas analyzer. The sampling flow rate through the Li-6251 is ~ 0.43 Lpm. Data for the first 50 seconds of each level is discarded, so that complete flushing of the desicant trap is achieved. The Li-6251 is operated in absolute mode with UHP Nitrogen flowing through the reference cell at a rate of 50 sccm. Automated calibrations, consisting of 100 seconds of zero gas and 100 seconds of a span gas (of known CO_2 mixing ratio), occur every 4 hours. Needle valves are adjusted such that the pressure within the gas analyzer during spanning is the same as when sampling (typically ~ 65 kPa).
Measurements : CO_2 mixing ratio, CO_2 Storage Flux

CO_2 Eddy Covariance Flux :

Maker : Li-Cor
Model : 6262 Gas Analyzer
Data Rate : 10 Hz
Location : inlets at 21.5 m, Analyzer located at 7 m
Date First Running : November 4, 1998
Description : Ambient air is pumped from a inlet approximately 0.25 m from the path of the sonic anemometer (CSAT-3, Campbell Scientific). The inlet is

equipped with a 2 micron stainless steel filter. The gas flows through ~ 18 m of 1/4" Dekabon tubing at a flow rate of 8.5 sLpm to insure turbulent flow within the tube. It then passes through 1 m of copper tubing which acts as a heat exchanger to remove temperature fluctuations (Leuning, R. and Judd, Murray J., (1996) *Global Change Biology,* **2**, 241-253), a second filter and a flow meter (MKS 259C) before entering the gas analyzer. The Li-6262 is operated in absolute mode with UHP Nitrogen flowing through the reference cell at a rate of 50 sccm. Automated calibrations, consisting of 20 seconds of zero gas and 20 seconds of a span gas (gas of known CO_2 mixing ratio), occur every 4 hours and are controlled by a Campbell 21x datalogger. Needle valves are adjusted such that the pressure within the gas analyzer during spanning is the same as when sampling (typically ~ 49kPa). Pressure is typically measured with the pressure transducer supplied with the 6262; however, secondary comparison with an MKS Baratron (Model 122-A) indicated no significant errors in the pressure measurement by the 6262. Typically, CO_2 mixing ratio measurements of from the Eddy Covariance Li-6262 and the 21.5 m inlet from the profile system (Li-6251) are within 2-3 ppm.

Measurements : CO_2 mixing ratio, CO_2 Eddyflux

Radiation :

Net Radiation:

Maker: REBS
Model: Q*7.1
Data Rate : 1 Hz
Location : 25.5 m before Sept., 1999
varied after that date
Date First Running : November 4, 1998
Description : A high output 60 junction thermopile which outputs a mV signal proportional to net radiation between 0.25 to 100 μm. The radiometer is ventilated with a REBS RV2 Ventilator to minimize wind speed effects. The Q*7.1 is extended on a boom ~ 2 m from the tower and leveled using the incorporated bubble level.
Measurements : Net Radiation

Net and Total Radiation :

Maker : Kipp and Zonen
Model : CNR-1 four component radiometer
Data rate : 1 Hz
Location : 25.5 m
Date First Running : July 12, 1999
Description : A four component radiometer which contains both upward and downward facing pyranometers and pyrgeometers. The pyranometers measure the incoming and outgoing short wave solar radiation (0.3 to 3 μm) and the pyrgeometers measure incoming and outgoing long wave radiation (5 to

50 μm). Long-wave measurements are corrected for the instrument temperature which is measured by a platinum resistance thermometer contained in the radiometer housing. Pyranometers consist of a thermopile with a black absorbent coating below a glass dome which transmit the short wave radiation, but not the long wave radiation. Pyrgeometers are also blackened thermopiles with a silicon window which passes the long wave radiation while obstructing the short wave radiation. The CNR-1 is extended on a boom ~ 2 m from the tower and leveled using the incorporated bubble level. In a side-by-side comparison of the two net radiometers it was found that the REBS Q*7.1 typically gave values that were 3-4 % higher than those measured with the CNR-1. This difference is especially noticable at night, suggesting that the differences in sensitivity to long-wave radiation is primarily responsible for the small discrepancy.

Measurements : Net Radiation, Short and Long-wave components of net radiation, Albedo.

Photosynthetically-Active Radiation :

Maker : Li-Cor
Model : Li-190SA quantum sensor
Data rate : 1 Hz
Location : 25.5 m
Date First Running : July 1, 1999
Description : The Li-190SA is a silicon photodiode with an enhanced response in the visible range of the solar spectrum. It is covered with bandpass filter so that its spectral response range is from 400 to 700 nm. Two Li-190SA quantum sensors are mounted together, one facing upwards, the other downwards. They are mounted such that leveling the upward facing quantum sensor automatically levels the other. Both are mounted on a boom to extend the sensors ~ 1.5 m from the tower and leveled.
Measurements : incoming and outgoing PPFD, % absorbed PPFD.

Wetness and Precipitation :

Wetness :

Maker : Campbell Scientific
Model : 237-L
Data Rate : 1 Hz
Location : 13.5 m
Data first Running : July 1, 1999
Description : Essentially a piece of circuit board which conducts a current when water droplets form that are large enough to create electrical contact between its leads. It is made to mimic a leaf of a broadleaf deciduous tree; however, since our forest is primairly coniferous (~ 1 % aspen within the footprint), this sensor does not give an adequate measure of the wetness of the canopy. Primarily it is used as an indicator of rain, snow or dew and can be useful in diagnosing when other sensors may be failing due to

precipitation.
Measurements : Wetness

Precipitation :
Maker : Met One
Model: #385-L
Data Rate : 1 Hz
Location : 10 m
Date First Running : July 12, 1999
Description : A heated tipping bucket rain/snow gage which is read by a pulse counting channel on a Campbell 23x data logger. The heater is controlled by a thermostat which begins heating when ambient temperature goes below 0 ^{o}C.
Measurements : Precipitation

Soil Measurements :
Soil Heat Flux :
Maker : REBS
Model : HFT-1
Data Rate : 0.1 Hz
Location : 8-10 cm belowground
Date First Running : July 1, 1999
Description : The soil heat flux reported is the average of 10 different HFT-1 sensors placed within a 15 m diameter in groups of two (5 groups). Locations of groups were chosen to maximize coverage of soil environments (eg., open, dry clearing, vs. a damp, shadowed base of tree.) These were buried ~ 8-10 cm below the surface of the ground by digging a small trench and then inserting a flat screwdriver into the soil at one end of the trench at a depth of 8-10 cm. The heat flux plate was inserted into the slot made by the screwdriver, making sure that it was in good thermal contact with the soil. The sensor cable was run through the trench (about 30 cm long) at a depth of 10 cm to avoid water channeling towards the sensor. Soil was then replaced carefully over the trench.
Measurements : Soil Heat flux

Soil Temperature :
Maker : REBS
Model : STP-1
Data Rate : 0.1 Hz
Location : 0-10 cm belowground
Date First Running : July 1, 1999
Description : The STP-1 is a platinum resistance thermometer which is read by a 4-wire half-bridge relative to a known resistance. The sensor design is such that it gives an average temperature over the length of the sensor head (~ 10 cm). The sensor was inserted at a slight angle such that it just covered the sensor head. Five STP-1 sensors were co-located with the 5 groups of heat flux

plates.
Measurements : Soil Temperature, Soil Heat Storage

Soil Temperature :
Maker : Campbell Scientific
Model : 107-L
Data Rate : 0.1 Hz
Location : 0-10 cm belowground
Date First running: N/A
Description : T-Thermocouple designed to be used underground (or underwater).
Measurements : Soil Temperature

Bole Measurements :
Bole Temperatures :
Maker : Campbell Scientific
Model : 107-L
Data Rate : 0.1 Hz
Location : 2-8 cm within the boles
Date First running: July 1, 1999
Description : T-Thermocouple designed to be used underground (or underwater). Holes of specific depth were drilled in boles of designated trees. Thermocouples were coated with a thermal contact adhesive and inserted. Typically each tree contained one thermocouple within the sapwood (depth of 2-4 cm) and one within the heartwood (depth of 6-8 cm). Three trees of each species were instrumented in this fashion.
Measurements : Bole Temperatures, Bole Heat Storage