FLUXNET-CANADA
MEASUREMENT PROTOCOLS

WORKING DRAFT
VERSION 1.3

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Working Draft - NFI Ground Sampling Guidelines

Fluxnet-Canada:
Mandatory Continuous Measurements of Meteorology and Flux

	Mature forest and peatland sites	**Disturbed sites**
Eddy-covariance (EC) fluxes, above canopy	- Carbon dioxide flux - Latent heat flux - Sensible heat flux - Momentum flux	- Same as for mature forests and peatlands
Fluxes or storages below EC level	- CO_2 air column storage - Sensible and latent heat air column storage - Aboveground biomass heat storage - Soil heat flux at the soil surface	- Same as for mature forests and peatlands, where a canopy exists
Radiation	- Net above canopy (using a network standard 4-way net radiometer[1]) - Down- and up-welling photosynthetically active radiation (PAR), above canopy - Diffuse PAR - Fraction of PAR absorbed by the vegetation (fPAR) using at least one ground-level PAR sensors where a significant canopy exists	- Net above canopy Down- and up-welling PAR, above canopy - fPAR using at least 1 ground-level PAR sensor
Meteorology, above canopy	- Air temperature and relative humidity (aspirated and shielded) - Wind speed and direction	- Air temperature and - relative humidity (shielded) - Wind speed and direction
Meteorology within canopy	- Air temperature and relative humidity (shielded)	- Air temperature and relative humidity (shielded), where a canopy exists
Meteorology, other	- Barometric pressure - Precipitation (all-weather accumulating gauge) - Rainfall - Snow depth	- Barometric pressure, not needed if <5 km of mature stand - Rainfall - Snow depth
Soil	- Soil temperature profile (2, 5, 10, 20, 50, 100 cm, 2 replicate profiles) - Soil moisture profile (by depth to at least 50 cm, or, where the roots go deeper, to the rooting depth, 3-6 depths, 2 replicate profiles) - Water table depth (peatlands)	- Same as mature forests and peatlands.

1. This instrument provides downwelling and upwelling shortwave radiation, and downwelling and upwelling longwave radiation as outputs.

Fluxnet-Canada:
Mandatory Measurements of Site Characteristics

	Variable	Frequency
Carbon stocks[1]	- Aboveground biomass by species, including overstory biomass (basal area, sapwood area, stem density) and understory biomass (shrubs, herbs, moss). - Root biomass - Surface detrital C including standing dead trees, coarse and fine woody debris, and forest floor organic layers - Mineral soil C	- At start and end of the experiment. - Once, at the start
Vegetation	- Site history - Species composition - Canopy height - Clumping index - Specific leaf area - Foliar element size - Spatial variability in fPAR - Leaf area index - Rooting depth - Date of budbreak	- Once - At least at the start and end of the experiment, but annually for disturbed sites - For mature sites at start and end of experiment, but perhaps more frequently for regrowth and deciduous. - Annually (coniferous) or seasonally (deciduous) - Once - Annually
Soil	- Profiles (sampled by depth to at least 50 cm, but where the roots go deeper, to the rooting depth) of: - soil texture - bulk density - soil coarse fragment fraction - water retention characteristics (field capacity, wilting point) - pH - Cation exchange capacity - N total, extractable P and K - % base saturation - C content - ^{13}C and ^{18}O - Mineralizable N	- Once - Once per year - Annually

1 Following National Forest Inventory Ground Plot protocols, but with modifications to augment estimation of root biomass and dead organic material and to sample within the flux footprint

Fluxnet-Canada:
Mandatory Measurements of Ecological Variables

	Variable	**Frequency**
Component Carbon Fluxes	- Soil carbon dioxide efflux (automated and portable chambers) - Aboveground growth increment (dendrometers or increment cores) - Fine root phenology/turnover[2] - Litterfall - Overstory mortality - Litter decomposition (bags) - ^{13}C, ^{18}O and ^{2}H in air	- Continuously (automated chambers) or occasionally (portable chambers) - Seasonally[1] with dendrometers or at end of experiment with increment cores - Seasonally - Seasonally for sites with canopy - Annually or from re-measurement of C stocks - Annually - 7 times per year
Vegetation	Foliar nutrients (total N, P, K) ^{13}C & ^{18}O in leaves and wood	- Annually in mid-summer - Annually in mid-summer[3]
Ecophysiology	- Maximum stomatal conductance - *In situ* photosynthetic light response curves (i.e., quantum efficiency and V_{max}). - *In situ* A/C_i curves - Pre-dawn and/or mid-day water potential	- Once[4] - Once[4] - Once[4] - During significant drought periods

1. Seasonally refers to an attempt to capture at least some seasonal differences. Thus, there could be two, three or four sampling dates (e.g., early, middle and end of the growing season plus winter) depending on the variable and the equipment capabilities of the station.
2. Full network coverage will depend on the availability mini-rhizotrons.
3. See Cross-Transect Stable Isotopes plan.
4. Once is only the bare minimum requirement for all flux sites. Variation in leaf gas exchange parameters is an important. Fluxnet-CA research question and we foresee more frequent measurements at most sites.

FLUXNET-CANADA
PROTOCOL FOR EDDY COVARIANCE (EC) FLUX MEASUREMENTS

The EC/Met Expert SubGroup
of the Measurement Standardization Working Group

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BRIEF DESCRIPTION OF METHOD

The EC method is based on the concept that the vertical flux (F_x) of an entity, x, is equal to the covariance of the vertical velocity (w) and the concentration of x. This can be expressed as $F_x = \overline{w'x'}$, where the prime means difference from the mean and the overbar means time average – usually over a period of a half an hour. If F_x is positive, the flux is upward.

The net ecosystem exchange of CO_2 (NEE) is calculated by adding the rate of change of CO_2 storage in the air column below the EC sensor level ($\Delta S_c/\Delta t$) to the EC flux of CO_2, F_c. NEE is positive for CO_2 loss to the atmosphere and negative for CO_2 uptake (sequestration) by the ecosystem. To a good approximation, net ecosystem productivity (NEP) is equal to –NEE. Baldocchi et al. (1988) provide an overview of the method. Aubinet et al. (2000) describe the eddy covariance methodology used in the European flux network (EUROFLUX). Here we will focus on the measurement of the fluxes of CO_2 and water vapour.

REQUIRED EQUIPMENT

Equipment required are a three-dimensional sonic anemometer-thermometer (SAT), a fast response infrared gas analyzer (IRGA) and a data acquisition system capable of measuring and recording high frequency signals.

In Fluxnet-Canada, two SATs are recommended: the model R3 or R3-50 (Gill Instruments Ltd.) and the model CSAT3 (Campbell Scientific Inc. (CSI)). Both instruments have a 10-cm path length between sonic transducers and are capable of operating at temperatures as low as -40°C. The CSAT3, however, does not make measurements during rain or immediately after rain. The UBC group has compared the two SATs on a number of occasions and found they agree very well in good weather. Where dew, rain or hoar frost are common, it is recommended that the R3 or R3-50 be used to minimize data loss during wet periods in the growing season and snow and frost periods in the winter.

Two types of gas analyzers can be used to make high frequency CO_2 and water vapour concentration measurements: (i) closed-path and (ii) open-path. The first has a temperature-controlled cell (optical bench) through which sampled air must be drawn, while the second has an array open to the atmosphere consisting of a light source and a detector. Models LI-6262 and LI-7000 (LI-COR Inc.) are examples of the first and model LI-7500 (LI-COR Inc.) is an example of the second. The LI-7000 is a much-improved version of the LI-6262. The LI-7000 has a much higher frequency response than the LI-6262, has high frequency digital (serial) output as well as analogue output, and operates in differential mode. Both instruments should be enclosed in a temperature-controlled environment. The LI-7500 has the advantage of an excellent high frequency response but does not operate during or for several hours after rain. Snow, hoarfrost and dew also cause the instrument to fail. Furthermore, it’s environmental specifications (-25 to +50°C) are more limiting than those of the above sonic anemometers.

Closed-path IRGA arrangement

In Fluxnet-Canada, only closed-path IRGAs should be used for year round flux monitoring at main (mature stand) sites. The LI-7000 is recommended. It should be housed in an enclosure in which the air temperature is maintained within ±2°C. This temperature should be at least 5°C above ambient air temperature to allow heat loss to the environment for temperature regulation. The LI-6262 can be used for EC measurements above tall forest stands where low frequency response (< 1 Hz) is adequate. It is not recommended for use in recent clearcuts, which are aerodynamically smooth. The sampling tube should be no longer than 4.5 m. This allows the box containing the IRGA to be placed 2.5-3 m below the SAT and the entrance to the sampling tube, which ensures that the IRGA box causes minimal aerodynamic disturbance of the air flow through the SAT array. An internal pressure transducer should be installed in the IRGA.

The sampling tube should be Dekoron, Teflon or stainless steel. These materials have acceptably low water vapour and CO_2 adsorption if kept clean and above dew-point temperature (see below). Dekoron is robust and convenient to work with in the field, and is recommended for EC measurement in Fluxnet-Canada. A convenient size of the sample tubing is 3.9 mm internal diameter (ID) (this is the ID of ¼" outer-diameter Dekoron tubing). It is imperative to maintain the air flow in the sampling tube turbulent to insure maximum frequency response of the gas analysis system. Generally, a Reynold's number (Re) exceeding 2300 (6.5 L min^{-1} for the above ID) results in turbulent flow in a tube. In practice, however, frequency response continues to improve with increasing flow rate. In Fluxnet-Canada, a flow rate of 8.5 to 9.0 L min^{-1} (Re = 3000 to 3,500) is recommended. It should be noted that the flow rate through the LI-6262 should not exceed 10 L min^{-1}. Also it is important to avoid using high flow rates because they can disturb the airflow around the sonic transducer array. It is important that the walls of the sampling tube stay above the dew point temperature of the air. This is usually the case during the daytime with the tubing being warmed by solar radiation. At night, however, net loss of longwave radiation by the tubing can result in cooling of the walls below dewpoint temperature. It is, therefore, recommended to warm the tubing electrically. The tubing should be enclosed in thermal insulation (e.g., ¾" OD x ½" thick hot water pipe insulation) and 2-4 W/m of heat applied beneath the insulation (e.g., using nichrome heater wire wound around the tubing). The insulated tube should be wrapped with aluminum foil tape to keep out moisture and reduce radiative cooling at night.

The entrance to the sampling tube should be positioned about 35 cm from the centre of the sonic transducer array and level with the lower transducers. The position should be downwind of the array for the main wind directions at the site so that there is minimum disturbance of the airflow through the array by the sampling tube. Disturbance should also be minimized by having the sampling tube extend vertically from beneath the sonic array and by using a small conical "roof" (4 cm diameter x 4 cm high) to prevent precipitation from entering the sampling tube. Mosquito screen (or a 10 µm Nupro filter) should be used to prevent insects and large air borne particles from entering the sampling tube.

The sampling tube must be replaced or cleaned every 6-8 months or more often. The filter (1 µm Gelman Co., placed at the sample input to the IRGA) must be replaced every 2 months or more frequently during the pollen or forest fire season.

The flow rate of the nitrogen gas that passes through the reference cell of the IRGA should be maintained at 80 to 300 mL min^{-1}, but should be kept consistent. It should be scrubbed using soda lime and manganese perchlorate to remove trace quantities of CO_2 and water vapour.

Open-path IRGA arrangement

The open-path IRGA (LI-7500) can be used at satellite sites especially where monitoring may not be year round. It is useful for clearcuts where high frequency response is desirable. It is valuable in tests assessing the high frequency losses in closed-path IRGA systems.

It should be mounted following the recommendations for positioning the entrance of the sampling tube in the closed–path IRGA arrangement (see above). Orienting the main axis of the instrument 15°-30° with respect to the horizontal helps drain water from rain or dew off the light-source (lower) window. It is not recommended to use the LI-7500 as a long-term flux-monitoring instrument, particularly at sites with significant rainfall events.

Fine wire thermocouples

It is recommended to use 25 µm chromel-constantan (Type E) thermocouples to check on sonic temperature measurement. These should be mounted 35 cm from the centre of the SAT array in a down wind direction. It is convenient to use at least two because they frequently break in strong wind and rain or wet snow. The thermocouples are used to check the air temperature obtained from the speed of sound measurement by the SAT. More important, however, is the comparison of the sensible heat flux values obtained from the covariance of w and sonic temperature with the covariance of w and thermocouple temperature. Good agreement between these two covariances indicates that the SAT is making a good sensible heat flux measurement thus indirectly indicating that the CO_2 and water vapour fluxes are reliable.

DATA ACQUISITION EQUIPMENT AND PROCESSING

Quality of power to data acquisition equipment

An uninterruptible power supply (UPS) must be used at all sites using line power or electric generators. A UPS provides a clean AC signal for the data acquisition system that is free of spikes that frequently occur in line power during bad weather. The batteries in the UPS enable it to continue to supply power for up to 45 minutes (depending on demand) when there is a power failure, which enables the system to be shut down safely.

Signal measurement frequency

It is recommended that EC signals are measured at a frequency of 20 Hz; however, a minimum of 10 Hz is acceptable for tall stands. At aerodynamically smooth sites (e.g., clearcuts), it is desirable to measure at 20 Hz; to ensure that there is no loss of high frequency contributions. This also increases the statistical precision of approaching the true covariance for some quantities, reduces aliasing, offers additional high-frequency information for spectra, and provides more flexibility in correlating lags.

High frequency data storage

Main sites:

At these (mature forest) sites in Fluxnet-Canada, all high frequency EC data must be stored throughout the year. These data must include the following raw measurements from the EC system, which can be either in mV or engineering units:

Primary signals: Variables used in the flux calculations; three components of wind speed (*u*, *v*, *w*), sonic temperature or speed of sound, fine wire thermocouple temperatures (at least two), CO_2 and water vapour.

Auxiliary signals: Variables used to convert the primary signals to useful units (IRGA optical bench temperature and pressure) and high frequency quantum flux density (i.e. PAR) to assess stationarity of radiation.

At the main sites, the data acquisition system must be either a PC or a CSI CR5000. For example, with 8 EC signals, this requires a daily storage of 27 MB by the PC (2-byte integers) or twice this by the CR5000 with 4-byte integers. With the PC, a minimum of 3 months of data can be stored on a 5GB hard disc, while about 3 weeks of data can be stored on a 1 GB Compact Flash card used by the CR5000. If there is limited storage space (e.g., during the winter), data can be stored at a minimum of 5 Hz provided it is properly down sampled to avoid aliasing. The advantage of the CR5000 is that it has a low power requirement (<1W) compared to the PC (8-12 W). One of the advantages of the pc is that it can accept digital data directly from measuring instruments (see below) and can operate many other measurement or control systems at the site (e.g., a CO_2 profile system, an understory EC system, and a soil chamber system).

Satellite sites:

At these sites where high frequency data are not stored routinely, the CSI 23X data logger is acceptable. It can measure at 7-10 Hz for EC flux measurements. It is recommended to use the logger's burst software with a laptop computer (or invoke a program that retains high frequency data on a storage module) to record high frequency data for periods of several hours in different meteorological conditions to examine the EC power spectra and cospectra at the site. The accuracy of the 23X-based EC system should be evaluated by operating it next to the EC system at the Flux Station's main site for a period of a several days (see below).

Digital versus analogue signals

Digital input doesn't require an analogue to digital converter so these signals can go directly into the PC. Digital signals are easier to protect and isolate, there is no noise pickup, and there is more information (diagnostics) transmitted. Signal wires can be much longer than analogue signal wires. Digital input takes advantage of linearization already done by the measuring instrument. Care must be taken, however, when synchronizing data from multiple measuring instruments. With analogue signals, 16 bit resolution is necessary, anti-aliasing filters should be used, and signal wires must be less than 100 m. Noise pick up and ground loops are common problems. It is easier to synchronize the analogue signals from multiple instruments than the digital signals. It is recommended to use digital input when possible, e.g. with a PC-based system when using the LI-7000, LI-7500, R3 and CSAT3. The LI-6262 can not output digital data faster than 5 Hz so it's preferable to use its analogue output. With the CR5000, it is necessary to use analogue signals from these instruments.

Data processing programs

For all flux stations, there will be only one set of EC data processing (i.e., data acquisition and flux calculation) programs used for each of the three data acquisition systems, i.e., those based on the PC, the CR5000 and the 23X. Each set of programs will be developed jointly by the researchers involved. In some cases, an existing set of programs will be used initially. For example, the UBC programs will be used for the PC-based system. This will standardize flux calculations across the network and permit valid inter-site CO_2, water vapour and sensible heat flux comparisons. Differences between site EC systems will then be attributable to only sensor calibration or response differences, which will be identified by the cross-site EC inter-comparison procedure.

All high frequency EC data processing must be done using the MATLAB programming language. This includes the on-site flux calculations with the PC-based system, as well as the post-processing of the high frequency data recorded by the CR5000 and PC-based systems. The on-site MATLAB program used in the PC-based system will be identical to that used in post-processing all recorded high frequency data.

Flux calculations

Flux calculations must be done on a half-hour basis, which is the interval currently recommended by Ameriflux.
The following processing steps must be applied to calculate fluxes:

1. **Unit conversion**: Change units from the raw data to m/s for wind speeds, °C for temperatures, and mixing ratios (mol mol^{-1} dry air) for CO_2 and H_2O. Unit conversion of the high frequency data avoids the need to apply the WPL terms to calculated fluxes.
2. **Spike removal**: Find single data points whose deviation from a running mean is above a threshold value and replace with a running mean value. This eliminates faulty data due to electronic noise as well as raindrops blocking the sonic path and indicates flawed data when too many spikes occur.
3. **Lag removal**: Shift data from closed path sensors forward with respect to sonic output to account for travel time of the air in the sample tube. The lag used here should be predetermined by the investigator using covariance maximization when the sample tube is clean and the fluxes are high.
4. **Calculation of Statistics**: Means, standard deviations, minima and maxima (hereafter referred to as statistics), and the covariances between variables must be calculated. No filter is to be applied before these calculations. This is equivalent to a block averaging, which is the procedure currently recommended by Fluxnet. Fluxes are calculated from these covariances.
5. **Coordinate rotation**: Express statistics, covariances, and fluxes with respect to a reference frame where $\overline{v} = 0$, $\overline{w} = 0$, and $\overline{w'v'} = 0$. This is equivalent to calculating the fluxes normal to the half-hourly streamline above the forest at the tower.
6. **Calculation of Diagnostics**: These are the statistics of the raw data and of the auxiliary channels, the number of spikes removed from each variable, the lag and covariances after covariance maximization, and the rotation angles.

Quality control

To allow checking of the EC system status, a quality control data set must be assembled from the on-site calculations. This data set includes the final statistics and fluxes, mean wind speed components and their standard deviations before rotation, the number of spikes for all channels, the lags calculated for CO_2 and H_2O, and statistics of the auxiliary channels.

It is essential to obtain this minimum data set from the main sites daily. Each of the main sites must have a phone (land line or cellular) or satellite internet connection. These data sets must be examined immediately after they are received to see if all instruments are working properly. If an instrument appears to be broken action should be taken as soon as possible to replace or repair it. This is essential to ensure that flux and climate data gaps are kept to a minimum.

Standard gap filling procedure

Gaps as short as 5 days are difficult to fill reliably using mean diurnal variation or other methods (Falge et al. 2001). Such gaps can be serious losses during short-duration phenological stages, e.g., senescence or leaf emergence. Frequent lengthy gaps will jeopardize our estimates of annual carbon sequestration. A standard gap filling procedure for all Fluxnet-Canada sites should be established to ensure comparison of fluxes between sites. (Further work required on this section)

Supplemental Measurements

Barometric pressure measured by a sensor mounted in the instrument hut.
CO_2 concentration profile in order to calculate air column CO_2 storage change to calculate *NEE* from F_c.
Operational diagnostics and control: Zero and calibration gas tank pressures, enclosure/hut temperatures, sample tube temperatures.
A CR10 data logger must be dedicated to storing half-hourly average values of these variables. It should also be used to monitor the PC and reboot it when it fails to respond to a query from the logger.

Calibration Procedures

IRGA calibration

Table 1 summarizes the options available for the calibration of the closed and open path IRGAs. Calibration can be manual (M) or automatic (A).

Table 1. Calibration options for open and closed path IRGAs

		Open		**Closed**	
		CO_2	**H_2O**	**CO_2**	**H_2O**
Zero	**On tower**	M	M	A/M	A/M
	Off tower	M	M	M	M
Span	**On tower**	M	-	A/M	-
	Off tower	M	M	M	M

On tower calibrations of closed path IRGAs

For CO_2, it is necessary to calibrate by injecting zero and calibration (360 to 380 ppmv CO_2 in dry air, secondary standards) at the sampling tube entrance at a rate exceeding the sampling flow rate by 20-30% or about 2-3 L min^{-1}. This ensures that no ambient air is drawn in during this procedure. For automatic calibration, it is recommended to run the calibration gases for 30-60 s each, depending on the flow rate of the system. Slower flow rates need longer calibration runs. For example, at 10 L min^{-1} of sample flow, the calibration flow should be 12-13 L min^{-1} and last for about 40 s, while at 8 L min^{-1} of sample flow, the calibration flow should be only 9.5–10.5 L min^{-1}, but it should last for more than 60 s. The calibration values should be obtained by averaging the last 3-5 seconds of the zero and calibration measurements. These are guidelines. The exact flow rate can be obtained by using the lowest flow rate that gives the same zero and span values as at higher rates. This latter procedure results in the same sample cell pressure as during a regular measurement run and helps conserve calibration gas. Automatic calibration once a day (Table 2) allows the researcher to notice any changes in instrument performance that might indicate the onset of a serious problem. If calibrations are done manually, they should be done at least once per month. Calibration records should be saved in all cases.

For water vapour, only zeroing is possible when doing tower calibrations. This is done when the CO_2 zero and span are done (both gases are dry). See procedure above. To do daily checks on the span or sensitivity of the IRGA water vapour detector, the IRGA water vapour measurement should be compared (using a 1:1 plot) with a Vaisala HMP humidity sensor (calibrated every 6-12 months, see the meteorological measurements protocol) mounted at the same level as the EC sensors. A week of half-hourly mean values should be adequate for the analysis.

Table 2. IRGA calibration frequency

		Open		**Closed**	
		CO_2	**H_2O**	**CO_2**	**H_2O**
Zero	**On tower**	Monthly	Monthly	Daily	Daily
	Off tower	6-12 months	6-12 months	Annually	Annually
Span	**On tower**	Monthly	-	Daily	-
	Off tower	6-12 months	6-12 months	Annually	Annually

Off tower calibration of closed path IRGAs

This should be done every 6-12 months assuming that tower calibrations are done at least at the intervals suggested above. These are done following procedures described in the instrument manuals. Flow rates must be kept low (0.5-1.0 L min^{-1}) as specified in the manual. During the dew-point calibration, the length of the tubing between the dew point generator and the IRGA must be kept short (< 20 cm) so the calibration of the closed-path IRGAs must be done without the sampling tube. This means that in this calibration the effect of the sample tube is not accounted for.

On tower calibrations of open path IRGAs

These must be done manually using the LI-COR calibration chamber. Since this requires a long Dekaron tube from the hut, it is only possible to use gas cylinders and not the dew point generator. As indicated in Table 1, the H_2O span can not be done this way.

Off tower calibrations of open path IRGAs

This must be done manually once a month if the on tower calibrations described above have not been done. If they have been done then every 2-4 months should be adequate if no problems (i.e., unexpected zero drifts, CO_2 span changes or presence of extra noise) have been observed during the on tower calibration procedure. It requires the use of the chamber provided by LI-COR.

IRGA CO_2 detector calibration (zero and span) and water vapour detector zero

For all sites and all IRGAs (i.e., LI-6262, LI-7500, LI-7000), whether it is automatic or manual calibration, the procedure is:

1) Keep the data acquisition system running in the normal operating mode.
2) Run the zero gas and record the voltages from CO_2 and H_2O concentration, pressure and temperature channels.
3) Run the calibration gas and record the voltages from CO_2 and H_2O concentration, and pressure and temperature channels.
4) Do not adjust any potentiometers on the IRGAs or change any values in the data acquisition software.
5) If using the LI-6262, use the above voltages to calculate the gains and offsets, and record these values.

If you are manually calibrating the LI-7500 or LI-7000, the procedure continues as follows:

1) Run the zero gas again and then use the software to “zero” the instrument.
2) Run the calibration gas again and use the software to “span” the instrument.
3) Run the zero and calibration gases through the now calibrated instrument, and record the measured values. If the values disagree with the true values, repeat the calibration.

IRGA water vapour detector span

The IRGAs should also be manually calibrated using a dew point generator (LI-610): monthly for the LI-7500 and once a year for the LI-6262 and LI-7000. As indicated above, the length of the tubing between the LI-610 and the IRGA must be kept short (< 20 cm) so the calibration of the closed-path IRGAs must be done without the sampling tube. These manual calibrations can be done in the instrument hut on site or in the laboratory.

Sonic anemometer-thermometer calibration

Each flux station should attempt to carry out short-term (3-10 day) comparisons of their operating field sonic anemometers with their spare unit. The spare unit should be mounted at the same level as the field unit.

An important goal of the cross-site EC calibration program is to assess the performance of the sonic anemometer operating at the main site of each flux station.

An important daily check is the comparison of half-hour values of "cup wind speed" calculated from horizontal wind vector components (*u* and *v*) measured by the sonic anemometer ($\sqrt{u^2 + v^2}$) with wind speed measured by the R.M. Young propeller-vane anemometer. The agreement should be within 5%.

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FLUXNET-CANADA
MEASUREMENT PROTOCOLS FOR METEOROLOGICAL VARIABLES

The EC/Met Expert SubGroup
of the Measurement Standardization Working Group

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