NACP Uncertainty Analysis 11 Aug 2009

Alan Barr, Dave Hollinger and Andrew Richardson

1. Summary

We evaluated the uncertainties in eddy-covariance NEE, RE and GPP associated with (a) random noise and (b) uncertainties in the u_* (friction velocity) threshold u_*^{Th} for all site-years in the NACP site-level synthesis. The sign convention adopted here is: positive for net ecosystem exchange NEE when the ecosystem is a C source, negative for NEE when the ecosystem is a C sink, and positive for both total ecosystem respiration RE and gross primary production GPP:

$$\mathrm{NEE} = -(\mathrm{GPP} - \mathrm{RE}) \tag{1}$$

Data summaries by site are given in Appendix A. The following data products have been submitted to the NACP site-level synthesis archive:

Table 1: Reprocessed NACP data products, submitted Aug 2009.

	Product	**Description**
1	Filled NEE, RE and GPP time series	Modified Fluxnet-Canada gap-filling (Appendix B), with separate products for (a) median annual u_*^{Th} and (b) seasonally-varying u_*^{Th}
2	Random uncertainty	95% confidence intervals in NEE, RE and GPP, at daily, weekly, monthly and annual time scales, and for the mean monthly and annual diel (diurnal) cycles
3	Uncertainty associated with the annual u_*^{Th}	95% confidence intervals in NEE, RE and GPP, at daily, weekly, monthly and annual time scales, and for the mean monthly and annual diel (diurnal) cycles

Site-level data summaries are being sent to each flux-tower PI for their feedback. The gap-filing algorithm produced robust results for most but not all site years (Section 2 and Table A1). As required, a reanalysis and second data submission will be completed this fall, based in PI feedback.

We recommend: (a) that the gap-filled NEE, RE and GPP time series, estimated using the modified Fluxnet-Canada method, be compared with values from other accepted gap-filling methods but using the u_*^{Th} detection method from this study; and (b) that the uncertainty analyses be repeated using another gap-filling method, to confirm that the uncertainty estimates are not sensitive to the gap-filling method.

2. Filling Gaps in NEE and Partitioning NEE into RE and GPP

The uncertainty analyses required the repeated use of a gap-filling / partitioning method. We chose the Fluxnet-Canada method (Barr et al. 2004), with slight modifications (Appendix B), because we were familiar with its use and because it produced robust results at most sites in this study. Annual sums of gap-filled NEE, RE and GPP are given in Tables A3 and A4, Appendix A. At a few sites, the modified Fluxnet-Canada method performed poorly, including sites where temperature was not the primary control on the seasonal cycle of RE (e.g. USSO2, USTon, and USVar, see Table A1), or where part of the year included no night (e.g. UAAtq and USBrw). We are exploring simple methodological improvements to correct these shortcomings.

3. Evaluating the u_*^{Th}

The analyses required automated evaluation of the low-u_* threshold (u_*^{Th}) filter that is used to identify and reject bad NEE measurements during low-turbulence periods at night (Appendix C). The u_*^{Th} detection algorithm was patterned after Papale et al. (2006) as implemented in the La Thuile FLUXNET synthesis but with modifications as described in Appendix C. Results for the u_*^{Th} are given in Table A2, Appendix A.

Following Papale et al. (2005), we evaluated the u_*^{Th} for each site-year of data, stratified into four quarters per year and up to seven temperature classes per quarter. For each of the four by seven strata, the u_*^{Th} was determined from a plot of binned mean nighttime NEE (or F_c, the CO_2 eddy flux without storage, when the storage flux was not available) versus u_*. We modified the u_*^{Th} algorithm with respect to the details used to stratify and bin the data, the method used to assign the u_*^{Th} within each stratum, and the computation of the annual u_*^{Th} from the stratified values (Appendix C). The new u_*^{Th} algorithm included robust detection of cases where no distinct u_*^{Th} was found. The failure rate was high at some sites (Tables A1 and A2).

At some sites with sparse NEE data, where an annual analysis was not possible, a single (multi-year) analysis was done on all years combined. The multi-year analysis often produced smaller uncertainties than the annual analysis, depending on the combined sample size.

Uncertainty in the u_*^{Th} was estimated by bootstrapping, conducted annually with 1,000 draws per site-year, then pooling of all years and calculation of the lower and upper 95% confidence intervals from the median and the 2.5 and 97.5 percentiles of the pooled u_*^{Th} values. Individual annual bootstrap estimates were rejected when any quarter has less than two strata with significant u_*^{Th}, as determined by an F test (Appendix C). The uncertainty analysis was limited to sites where the data were dense enough to support an annual analysis. The site-specific u_*^{Th} was set to the median of the pooled bootstrap annual estimates.

4. Evaluating Uncertainty in NEE, RE and GPP Associated with the u_*^{Th}

The uncertainties in NEE, RE and GPP associated with uncertainties in the u_*^{Th} were evaluated by running the modified Fluxnet-Canada gap-filling routine (Appendix B) at 1,000 u_*^{Th} values, drawn randomly from the pooled annual bootstrapping estimates. This produced 1,000 realizations of the gap-filled NEE, RE and GPP time series. The uncertainties in NEE, RE and GPP, estimated as the upper and lower 95% confidence intervals, were estimated from median and the 2.5 and 97.5 percentiles of the gap-filled data, aggregated over several time scales.

5. Random Uncertainty

Random uncertainty in NEE, RE and GPP, reported as symmetric 95% confidence intervals, were estimated following Richardson et al. (2007). The NEE random uncertainty characteristic curve, which characterizes random uncertainty in NEE as a function of NEE, was estimated for each site-year based on the differences between the measured data and the output of the gap-filling model (Appendix B). The estimation procedure begins with synthetic NEE data generated by the gap-filling model, introduces gaps (the same gaps as in the measured data after u_*^{Th} filtering), adds synthetic noise (defined by the NEE random uncertainty characteristic curve using a Monte-Carlo approach), then fills gaps in the noisy, gappy synthetic data. The process was repeated 1,000 times for each site-year, and the random uncertainty was estimated from median and the 2.5 and 97.5 percentiles of the gap-filled data, aggregated over several time scales.

6. Ongoing Analyses

6.1. Seasonality of u_*^{Th}

We assessed seasonality in the u_*^{Th} in two ways:

6.1.1. Four-season
by comparing estimates from the four quarterly strata in 2, and

6.1.2. Seasonal
by estimating seasonal variation in u_*^{Th} using a moving window, applied once (without bootstrapping) to the entire multi-year time series. The window size was flexible, with two constraints: it could not exceed 122 days, and it must contain between 4 and 8 temperature strata with 250 (or 150) points per stratum (i.e. 50 u_* bins with 5 (30-min data) or 3 (60-min data) points per bin). The window was moved to provide 50% overlap between adjacent windows. The mean Julian day t was computed for each stratum and the entire (t, u_*^{Th}) data set was fit to an annual sine curve:

$$u_*^{Th} = a_0 + a_1 \sin(\omega(t - a_2)) \qquad (2)$$

where ω is $2\pi/365.25$. Equation 2 was then used to estimate a seasonally-varying u_*^{Th}, identical for all years.

Table A2 (Appendix A) gives a summary of the u_*^{Th} by site.

6.2. Impacts of NEE outlier rejection

We tested the sensitivities of (a) annual NEE, RE and GEP, and (b) random uncertainty in NEE, RE and GEP, to four levels of NEE outlier rejection for all site-years (Table 2).

Table 2: Values of limits n_s and n_c (5.2.1 and 5.2.2) used to exclude NEE outliers.

	Level	n_s	n_c
0	Off	n/a	n/a
1	Mild	7	2*7
2	Moderate	5	2*5
3	High	3	2*3

Outliers in NEE were found in three passes:

6.2.1. NEE, spike detection

following Papale et al. (2009) but extended to include periods with missing adjacent values. Spikes were detected as:

$$abs(d_i) > n_s s_d \quad \text{where} \quad d_i = x_i - (x_{i-1} + x_{i+1})/2,$$

and

$$abs(\hat{d}_i) > n_s s_d \quad \text{where} \quad \hat{d}_i = x_i - (\hat{x}_{i-1} + \hat{x}_{i+1})/2,$$

where the subscript *i* denotes the period, n_s defines the limits (Table 2), s_d is the annual standard deviation of *d*, *x* is NEE, and $\hat{x}$ is the NEE estimate from the gap-filling model.

6.2.2. NEE bias, asymmetric confidence intervals

applied to the bias *b* between measured NEE and the NEE estimate from the gap-filling model. Outliers were detected as:

$$(q_b^1 - b_i) > n_c(q_b^2 - q_b^1)$$

and

$$(b_i - q_b^3) > n_c(q_b^3 - q_b^2)$$

where *b* is the NEE bias $(x - \hat{x})$ (measured - modeled), n_c defines limits (Table 2), and q_b^1, q_b^2 and q_b^3 are the lower, middle and upper *b* quartiles. For each point, the quartiles were estimated using a window of 28 days centered on the point.

6.2.3. NEE bias, spike detection

repeats 5.2.1 but based on NEE bias rather than NEE.

References

Barr AG, Black TA, Hogg EH et al. 2004. Inter-annual variability in the leaf area index of a boreal aspen-hazelnut forest in relation to net ecosystem production. *Agricultural Forest Meteorology,* 126: 237-255.

Papale D, Reichstein M, Aubinet M, Canfora E, Bernhofer C, Longdoz B, Kutsch W, Rambal S, Valentini R, Vesala T, Yakir D. 2006. Towards a standardized processing of Net Ecosystem Exchange measured with eddy covariance technique: algorithms and uncertainty estimation. *Biogeosciences*, 3: 571-583

Richardson AD and Hollinger DY. 2007. A method to estimate the additional uncertainty in gap-filled NEE resulting from long gaps in the CO2 flux record. *Agricultural and Forest Meteorology*, 147, 199-208.

Appendix A: Analysis Summaries

Table A1: Analysis notes. Except where stated otherwise, the analysis produced stable results.

Site	Analysis Notes and Issues
CACa1	• The CACa1, CACa2 and CACa3 sites are the only Canadian sites where the PI-preferred gap-filling departs from the standard Fluxnet-Canada gap-filling method. The modified method is identical to the Fluxnet-Canada method except for the RE = $f(T_s)$ relationship; the CACa* sites model RE as $\log(\mathrm{RE}) = a_0 + a_1 T_s$. At these sites and especially at CACa1, this modification reduces RE more than GPP, thus making NEE considerably more negative.
CACa2	• See note for CACa1.
CACa3	• See note for CACa1.
CAGro	• The NEE, RE and GPP data in the NACP database do not sum to zero for 2005.
CALet	• The large random uncertainties 2007 probably result from a weakness of the gap-filling method for site-years where soil temperature explains only a limited fraction of the variance in RE.
CAMer	• The NEE versus u_* relationship used to identify the u_*^{Th} was atypical in that NEE was enhanced not suppressed at low u_*. Because the response was subtle, the u_*^{Th} analysis often failed to find a distinct change point.
CANS1	• Because NEE was often missing, missing NEE values were replaced with F_c (i.e., the eddy flux without storage) in all analyses.
CAOas	
CAObs	
CAOjp	
CAQfo	• The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.
CASJ1	• The u_*^{Th} analysis often failed to find a distinct change point.
CASJ2	• The u_*^{Th} analysis often failed to find a distinct change point.
CASJ3	
CATP4	• The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.
CAWP1	
USARM	• The large random uncertainties in 2006 and esp. 2007 probably reflect a weakness of the gap-filling method or a problem in the input data. • The u_*^{Th} analysis often failed to find a distinct change point.
USAtq	• The processing algorithms failed at this site and will require modification.
USBrw	• The processing algorithms failed at this site and will require modification.
USDk2	• The processing algorithms failed at this site and will require modification.
USDk3	• Many outputs seem questionable, with unusual interannual variability and very high uncertainty estimates. The cause may be a weakness in the processing methods.

	• Years 1998-2002 have too few good RE values to characterize the annual RE cycle. • The u_*^{Th} analysis often failed to find a distinct change point. • The NEE versus u_* relationship used to identify the u_*^{Th} was atypical in that NEE was enhanced not suppressed at low u_*.
USHa1	• The u_*^{Th} analysis often failed to find a distinct change point. • The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.
USHo1	
USIB1	
USIB2	
USLos	• Missing NEE values were replaced with F_c (i.e., the eddy flux without storage) in all analyses.
USMMS	
USMe2	• The u_*^{Th} analysis often failed to find a distinct change point.
USMe3	
USMe4	• Unidentified processing problems.
USMe5	• The u_*^{Th} analysis often failed to find a distinct change point.
USMoz	• The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.
USNR1	• The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.
USNe1	• The u_*^{Th} analysis often failed to find a distinct change point.
USNe2	• The u_*^{Th} analysis often failed to find a distinct change point. • We have not allowed for interannual differences in the u_*^{Th} associated with crop rotation.
USNe3	• The u_*^{Th} analysis often failed to find a distinct change point. • We have not allowed for interannual differences in the u_*^{Th} associated with crop rotation.
USPFa	
USSO2	• The gap-filling and partitioning analysis produced questionable outputs in most years, esp. 2002.
USShd	
USSyv	• The u_*^{Th} analysis often failed to find a distinct change point.
USTon	• The u_*^{Th} analysis often failed to find a distinct change point.
USUMB	• The u_*^{Th} analysis often failed to find a distinct change point.
USVar	• Many outputs seem questionable, with unusual interannual variability and high uncertainty estimates. The cause may be a weakness in the gap-filling method at sites where soil temperature explains only a limited fraction of the variance in RE. • The u_*^{Th} analysis often failed to find a distinct change point.
USWCr	• The standard processing seems to have failed for 2001. • The u_*^{Th} had strong seasonality (Table A2) which may weaken the results obtained using a fixed u_*^{Th} at this site.

Table A2 Analysis of the u_* threshold u_*^{Th} (m s^{-1}) used to exclude eddy-covariance NEE measurements during low wind speed periods at night, including annual mean, quarterly medians, and moving window analysis fit to Equation 2.

					Annual (Bootstrap)				Quarterly Medians				Moving Window (Equation 2)					
Site	**Analysis Period [1]**	**Flux**	**% Sig[2]**	**% Ex[3]**	**n[4]**	**Prc 2.5**	**Mdn**	**Prc 97.5**	**DJF**	**MAM**	**JJA**	**SON**	**n**	**Mdn**	a_0	a_1	a_2	r^2
CACa1	Ann	NEE	63	74	5640	0.28	0.34	0.44	0.34	0.35	0.39	0.29	669	0.34	0.35	0.05	70	0.08
CACa2	Ann	NEE	45	77	2623	0.09	0.12	0.14	0.10	0.13	0.12	0.11	303	0.12	0.12	0.01	64	0.08
CACa3	Ann	NEE	52	73	2099	0.15	0.17	0.22	0.15	0.18	0.18	0.18	279	0.19	0.19	0.01	245	0.00
CAGro	Ann	F_c	55	66	1006	0.33	0.44	0.55	0.55	0.44	0.43	0.33	201	0.39	0.40	0.06	11	0.05
CALet	Ann	NEE	62	54	4758	0.15	0.20	0.32	0.23	0.20	0.18	0.19	748	0.21	0.21	0.01	303	0.00
CAMer	Ann	NEE	51	44	3015	0.07	0.12	0.19	0.17	0.11	0.06	0.10	327	0.14	0.14	0.04	293	0.09
CANS1	Ann	F_c	60	61	3067	0.25	0.33	0.42	0.48	0.29	0.28	0.23	545	0.29	0.31	0.08	328	0.14
CAOas	Ann	NEE	61	44	7162	0.24	0.31	0.45	0.29	0.35	0.25	0.30	759	0.34	0.34	0.05	298	0.04
CAObs	Ann	NEE	83	55	5870	0.22	0.28	0.34	0.27	0.25	0.28	0.28	584	0.28	0.28	0.03	229	0.02
CAOjp	Ann	NEE	56	50	3881	0.18	0.25	0.39	0.34	0.24	0.21	0.21	437	0.27	0.27	0.06	294	0.07
CAQfo	Ann	F_c	52	60	1705	0.28	0.39	0.49	0.51	0.42	0.26	0.36	219	0.37	0.40	0.17	290	0.27
CASJ1	MYr	NEE	33	69	65	0.34	0.44	0.52	0.57	0.50	0.19	0.52	43	0.37				
CASJ2	Ann	NEE	27	53	268	0.10	0.14	0.17	0.29	0.08	0.11	0.08	111	0.14				
CASJ3	Ann	F_c	61	66	1234	0.25	0.31	0.37	0.43	0.27	0.29	0.25	150	0.31	0.32	0.07	321	0.11
CATP4	Ann	F_c	53	57	2914	0.36	0.45	0.61	0.83	0.42	0.31	0.29	372	0.46	0.50	0.23	308	0.34
CAWP1	Ann	NEE	54	50	2478	0.07	0.12	0.21	0.14	0.11	0.14	0.09	323	0.13	0.13	0.03	261	0.04
USARM	Ann	NEE	23	64	247	0.24	0.29	0.36	0.45	0.19	0.17	0.31	69	0.29				
USAtq	MYr	NEE											31	0.31				
USBrw	MYr	NEE																
USDk2	MYr	NEE											39	0.37				
USDk3	MYr	NEE	19	63	170	0.23	0.31	0.39	0.35	0.37	0.23	0.28	84	0.28				
USHa1	Ann	NEE	36	66	543	0.35	0.49	0.67	0.75	0.60	0.19	0.45	225	0.46	0.49	0.33	302	0.61
USHo1	Ann	NEE	49	53	3098	0.20	0.27	0.36	0.30	0.27	0.21	0.26	434	0.27	0.28	0.05	306	0.06

USIB1	Ann	F_c	67	54	944	0.12	0.17	0.23	0.27	0.21	0.12	0.07	165	0.17	0.18	0.11	318	0.45
USIB2	Ann	F_c	54	51	779	0.11	0.19	0.24	0.43	0.12	0.13	0.08	161	0.17	0.18	0.08	293	0.17
USLos	Ann	F_c	84	46	5999	0.12	0.15	0.21	0.16	0.13	0.14	0.14	610	0.17	0.16	0.03	300	0.04
USMMS	Ann	F_c	43	64	980	0.33	0.45	0.57	0.61	0.42	0.34	0.40	218	0.43	0.43	0.14	311	0.21
USMe2	Ann	NEE	80	54	252	0.51	0.65	0.73	0.76	0.69	0.64	0.53	39	0.62				
USMe3	Ann	F_c	67	72	1143	0.18	0.23	0.30	0.25	0.24	0.23	0.20	112	0.22	0.22	0.03	354	0.10
USMe4		NEE											31	0.16				
USMe5	MYr	F_c	44	52	176	0.13	0.24	0.40	0.38	0.29	0.13	0.15	146	0.17				
USMoz	Ann	F_c	51	67	1585	0.27	0.34	0.44	0.56	0.30	0.26	0.25	232	0.36	0.38	0.16	297	0.32
USNR1	Ann	NEE	46	56	3953	0.28	0.54	0.85	0.81	0.40	0.37	0.43	611	0.59	0.62	0.35	288	0.29
USNe1	MYr	NEE	25	58	120	0.12	0.22	0.29	0.32	0.24	0.15	0.14	126	0.17	0.17	0.03	339	0.03
USNe2	Ann	NEE	40	49	541	0.09	0.14	0.23	0.21	0.10	0.12	0.10	147	0.16	0.16	0.05	339	0.08
USNe3	Ann	NEE	34	45	376	0.09	0.15	0.25	0.14	0.15	0.11	0.13	148	0.16	0.16	0.04	311	0.04
USPFa	MYr	F_c	54	70									60	0.33				
USSO2	Ann	F_c	54	70	2636	0.17	0.23	0.31	0.23	0.29	0.15	0.23	378	0.24	0.24	0.10	293	0.20
USShd	Ann	F_c	57	51	1460	0.16	0.22	0.28	0.24	0.25	0.23	0.14	271	0.25	0.24	0.04	331	0.05
USSyv	MYr	NEE	47	49	122	0.39	0.49	0.60	0.57	0.42	0.58	0.38	59	0.45				
USTon	Ann	NEE	31	75	381	0.18	0.23	0.28	0.24	0.23	0.20	0.23	209	0.24	0.24	0.03	321	0.09
USUMB	Ann	NEE	57	61	686	0.32	0.40	0.53	0.43	0.39	0.38	0.37	149	0.39	0.39	0.01	302	0.00
USVar	Ann	NEE	35	78	284	0.10	0.14	0.16	0.16	0.13	0.12	0.14	178	0.13	0.13	0.01	239	0.01
USWCr	Ann	F_c	57	45	2574	0.33	0.40	0.51	0.59	0.44	0.25	0.28	258	0.45	0.41	0.18	302	0.32

[1] Ann (annual) -- the u_*^{Th} and its uncertainty were analyzed separately for each year; MYr (multi-year) -- the u_*^{Th} and its uncertainty were analyzed for all years combined because the data were too sparse to support an annual analysis.

[2] Percentage of cases (strata) when the change-point detection algorithm found a significant u_*^{Th}.

[3] Percentage of nighttime NEE data excluded by median annual u_*^{Th}.

[4] Number of bootstraps, summed over all years, that successfully produced annual estimates of u_*^{Th}, i.e., that had at least two strata with significant u_*^{Th} values in each of the four quarters.

Table A3 Annual NEE, RE and GPP (g C m^{-2} y^{-1}) and its uncertainty. The annual fluxes are from the NACP database (PI-preferred values for Canadian sites and La Thuile MDS estimates for US sites) and from a reprocessing using the modified Fluxnet-Canada gap-filling method (Appendix B) with fixed annual and seasonally varying u_*^{Th} (Table A2). The uncertainties are symmetric 95% confidence intervals for (a) random uncertainty and (b) the uncertainty associated with uncertainty in the u_*^{Th}.

Notes:

- *Values are missing where the site-year had a data gap of 31 days or longer, or where the algorithm failed to identify the* u_*^{Th}.
- *A few values (included but not flagged) are questionable and may show a failure of the processing methods for these site-years.*
- *The uncertainties associated with uncertainty in the* u_*^{Th} *are based on an annual bootstrapping analysis at most sites. At a few sites where the NEE data were to sparse to support an annual analysis (Table A1), a single (multi-year) analysis was done on all years combined.*

		NACP Database (PI values for CA, LaThuile for US)			**Reprocessed Moving u_*^{Th}**			**Reprocessed Fixed u_*^{Th}**			**Random Uncertainty (95% CI)**			**Uncertainty from u_*^{Th} (95% CI)**		
		NEE	**RE**	**GPP**	**NEE**	**RE**	**GPP**	**NEE**	**RE**	**GPP**	**NEE**	**RE**	**GPP**	**NEE**	**RE**	**GPP**
CACa1	1998	-379	1752	2131	-312	2010	2322	-300	2030	2330	56	150	103	19	46	30
CACa1	1999	-382	1642	2024	-262	1981	2243	-273	1944	2217	59	122	76	28	63	36
CACa1	2000	-400	1693	2093	-282	1999	2281	-287	1990	2276	57	121	70	23	56	33
CACa1	2001	-410	1667	2077	-285	2053	2338	-297	2023	2320	56	128	78	22	61	38
CACa1	2002	-277	1676	1953	-124	2033	2157	-118	2027	2146	55	112	66	42	94	53
CACa1	2003	-353	1725	2078	-253	2009	2261	-257	1986	2243	46	98	61	33	76	43
CACa1	2004	-267	2071	2338	-149	2349	2498	-151	2338	2489	63	138	82	28	71	43
CACa1	2005	-355	1955	2310	-228	2272	2500	-241	2232	2473	57	113	69	17	52	35
CACa1	2006	-386	1726	2112	-273	2028	2301	-275	2017	2291	49	99	62	22	49	28
CACa2	2001	535	698	163	606	919	313	602	907	306	28	54	31	26	63	38
CACa2	2002	570	1099	530	625	1161	536	613	1127	514	26	54	31	19	41	24
CACa2	2003	580	1202	622	624	1269	644	622	1258	635	23	49	30	7	15	10

CACa2	2004	593	1453	859	655	1515	860	647	1494	847	30	65	38	9	25	17
CACa2	2005	422	1533	1111	456	1517	1061	456	1519	1063	30	67	41	13	33	20
CACa2	2006	420	1204	784	492	1372	879	490	1358	868	29	75	50	16	54	38
CACa3	2002	121	1393	1272	161	1513	1352	152	1486	1334	39	92	72	17	45	28
CACa3	2003	99	1306	1207	120	1430	1310	115	1416	1301	35	66	44	20	50	32
CACa3	2004	133	1589	1457	167	1702	1535	167	1702	1534	28	56	38	22	61	39
CACa3	2005	-20	1674	1694	9	1825	1816	7	1815	1807	30	74	54	17	47	30
CACa3	2006	-15	1475	1490	23	1654	1632	15	1633	1619	27	63	47	27	76	49
CAGro	2004	-111	851	962												
CAGro	2005	-71	958	1031	-51	1059	1109	-46	1064	1110	32	59	43	14	39	26
CAGro	2006	-93	1027	1086	-32	1133	1165	-27	1145	1172	28	56	43	16	37	21
CALet	1999															
CALet	2000				12	269	257	12	269	257	7	11	8	3	10	7
CALet	2001				-17	240	258	-18	240	258	8	9	9	6	16	10
CALet	2002				-295	527	822	-295	527	822	13	21	19	6	22	16
CALet	2003				-230	439	669	-230	438	668	14	16	17	6	21	15
CALet	2004				-117	500	618	-117	502	619	13	24	20	4	16	12
CALet	2005				-260	588	849	-261	587	848	14	24	21	10	36	26
CALet	2006				-124	377	501	-124	378	502	11	16	14	7	21	15
CALet	2007				-30	148	178	-30	148	178	18	59	90	17	66	95
CAMer	1999	-65	582	646	-61	555	617	-65	560	626	15	54	51	10	4	13
CAMer	2000	-32	431	463	-38	463	501	-39	468	507	12	28	24	22	28	9
CAMer	2001	-2	541	543	2	540	539	-12	520	532	12	30	27	34	61	27
CAMer	2002	-13	498	511	-21	492	513	-26	479	504	11	21	16	24	41	20
CAMer	2003	-15	480	495	-17	511	528	-23	498	521	13	39	33	27	50	24
CAMer	2004	-115	568	683	-129	587	716	-134	581	715	11	22	18	13	20	7

CAMer	2005	-90	597	687	-100	617	717	-102	614	716	10	20	15	7	14	7
CAMer	2006	-148	624	772	-149	655	804	-147	664	811	11	20	14	7	19	13
CANS1	1994	168	796	614												
CANS1	1995	40	828	783	36	705	668	47	757	709	26	51	43	6	27	23
CANS1	1996	89	800	707	59	697	633	59	708	644				12	25	13
CANS1	1997	39	745	700												
CANS1	1998	-6	764	768												
CANS1	1999	-6	746	744												
CANS1	2000	-10	690	691	-12	607	619	-8	628	636	32	36	51	11	86	11
CANS1	2001	-22	710	729	-13	615	628	-4	653	656	17	36	29	8	24	17
CANS1	2002	-24	585	607	42	537	495	53	572	520	17	37	30	13	34	21
CANS1	2003	-57	637	692	65	618	553	80	656	576	20	48	39	25	74	49
CANS1	2004	-19	614	623	-29	465	494	-32	471	503	13	33	29	3	13	11
CANS1	2005	-5	697	697	-22	547	568	-23	550	573	15	25	20	2	6	4
CANS1	2006	-73	710	781	-73	642	715	-84	645	729	21	58	57	9	16	8
CAOas	1997	-123	1015	1139	-100	1035	1134	-103	1031	1134	22	35	27	22	45	23
CAOas	1998	-263	951	1214	-249	979	1228	-249	978	1228	21	35	29	28	89	61
CAOas	1999	-116	965	1081	-116	983	1099	-113	996	1108	19	32	25	22	65	43
CAOas	2000	-144	945	1088	-138	961	1099	-138	964	1102	18	30	24	11	27	17
CAOas	2001	-325	892	1217	-332	902	1235	-332	903	1235	22	33	28	28	79	51
CAOas	2002	-125	766	891	-124	773	896	-120	783	903	18	23	21	21	54	33
CAOas	2003	-94	823	917	-100	817	916	-100	816	916	15	23	20	13	36	22
CAOas	2004	-16	842	858	-15	862	877	-13	867	880	15	26	22	23	68	45
CAOas	2005	-122	924	1046	-119	968	1087	-120	963	1083	17	26	22	16	48	32
CAOas	2006	-281	1024	1305	-293	1014	1308	-292	1023	1315	19	32	26	32	93	60
CAObs	2000	-56	765	821	-58	776	834	-57	781	838	13	26	20	10	27	17
CAObs	2001	-77	743	820	-76	758	834	-75	763	838	14	34	26	7	20	12

CAObs	2002	-30	684	714	-28	685	713	-29	683	712	14	26	20	7	20	13
CAObs	2003	-76	690	766	-68	715	783	-67	720	786	14	25	19	8	21	14
CAObs	2004	-35	665	700	-31	693	724	-31	695	726	12	24	18	6	18	12
CAObs	2005	-45	767	812	-55	777	833	-54	784	838	14	26	19	8	26	17
CAObs	2006	-67	748	816	-83	734	817	-81	743	825	16	32	24	12	36	24
CAOjp	2000	-65	522	586	-70	548	618	-64	566	629	13	23	17	9	38	29
CAOjp	2001	-37	578	614	-53	558	611	-45	586	631	13	29	20	7	30	23
CAOjp	2002	21	531	510	9	526	517	15	544	530	12	24	17	5	19	14
CAOjp	2003	-24	529	553	-22	556	579	-19	563	582	12	23	17	5	17	13
CAOjp	2004	-4	556	560	-15	575	590	-15	581	597	17	32	25	6	22	16
CAOjp	2005	-36	558	594	-36	606	642	-39	594	634	13	26	20	6	13	7
CAOjp	2006	-33	606	639	-59	582	641	-42	640	681	21	54	41	20	60	36
CAQfo	2004	-8	582	590	-41	559	600	-22	619	641	17	28	19	24	58	35
CAQfo	2005	-4	687	691	-3	697	699	3	722	719	16	27	18	11	27	16
CAQfo	2006	-25	632	657	-19	685	704	-22	680	703	13	23	16	8	18	10
CASJ1	2002													1	5	4
CASJ1	2003							0	263	263	9	18	14	1	2	1
CASJ1	2004	-66	494	560				59	452	392	11	32	23	6	14	9
CASJ1	2005	-79	513	592				25	534	508	25	41	31	4	7	4
CASJ2	2003	152	225	72												
CASJ2	2004	155	245	89	150	223	74	154	243	88	5	14	12	2	5	4
CASJ2	2005	123	222	99	104	215	111	105	222	117	6	17	14	2	5	4
CASJ2	2006	173	453	280	98	277	179	92	267	175	6	19	15	3	8	6
CASJ3	2005	31	542	512	-72	552	624	-74	549	623	13	32	24	2	10	8
CASJ3	2006				-98	528	626	-90	556	646	21	57	45	8	31	23

CATP4	2003	-219	1096	1330	-220	1165	1385	-223	1172	1394	20	30	24	10	21	12
CATP4	2004	-155	1180	1357	-167	1220	1387	-170	1223	1393	22	35	26	9	25	15
CATP4	2005	-36	1176	1237	-38	1209	1247	-34	1221	1256	30	55	38	10	26	16
CATP4	2006	-148	1292	1468	-113	1387	1499	-145	1338	1482	28	47	34	10	18	9
CATP4	2007	-120	1203	1354	-92	1317	1409	-94	1334	1429	34	66	44	23	53	30
CAWP1	2004	147	568	715	-168	541	710	-158	581	740	14	39	32	8	40	32
CAWP1	2005	270	530	800	-279	566	845	-278	578	855	13	28	22	4	27	23
CAWP1	2006				-187	690	877	-183	703	886	15	69	66	7	24	19
CAWP1	2007				-170	797	967	-164	832	996	18	78	73	8	71	64
USARM	2003	-236	375	611	-145	486	630	-129	525	654	26	43	26	24	53	30
USARM	2004	-269	357	626	-203	489	692	-198	510	707	31	54	36	24	68	44
USARM	2005	-278	228	506	-233	347	580	-225	368	593	31	64	49	11	79	68
USARM	2006				81	510	429	79	506	427	60	92	66	4	9	5
USARM	2007				-176	758	935	-169	778	944	216	319	108	14	24	11
USAtq	2003	12	10	-2												
USAtq	2004	-25	31	55												
USAtq	2005	10	64	55												
USAtq	2006	-87	94	181												
USDk3	1998															
USDk3	1999							-114	1301	1415	214	412	207	76	158	82
USDk3	2000							-483	1044	1527	132	265	132	65	147	82
USDk3	2001															
USDk3	2002							248	2594	2346	242	468	245	72	269	39
USDk3	2003							-273	1499	1771	66	115	71	23	52	29
USDk3	2004							-592	1537	2129	64	115	68	27	56	30

USDk3	2005							-886	1644	2530	62	99	61	32	81	49
USHa1	1992	-138	970	1108	-172	963	1135	-190	954	1145	54	99	70	49	94	44
USHa1	1993	418	2003	1586	-127	1175	1301	-164	1139	1302	63	119	85	50	90	43
USHa1	1994	-166	1008	1174	-121	1098	1220	-117	1142	1259	41	71	50	49	95	46
USHa1	1995	-252	999	1251	-225	1021	1247	-238	1018	1256	39	67	48	31	125	255
USHa1	1996	-101	1192	1294	-158	1175	1334	-148	1250	1399	45	89	58	48	168	255
USHa1	1997	-65	1295	1361	-96	1295	1391	-89	1360	1449	53	115	85	58	131	79
USHa1	1998	-108	1137	1245	-85	1085	1170	-89	1129	1218	45	80	56	34	174	269
USHa1	1999	-193	1166	1359	-191	1178	1369	-175	1245	1420	45	87	60	32	65	48
USHa1	2000	-269	1188	1457	-216	1234	1450	-262	1143	1405	42	64	45	44	84	41
USHa1	2001	-386	1172	1558	-355	1233	1587	-382	1157	1538	46	82	60	59	79	262
USHa1	2002				-177	1371	1548	-225	1309	1534	58	111	81	60	115	64
USHa1	2003	-123	1288	1412	-151	1327	1478	-116	1427	1543	59	124	83	76	353	587
USHa1	2004	-418	1271	1689	-405	1267	1673	-432	1227	1659	48	72	57	18	32	15
USHa1	2005	-312	977	1289												
USHa1	2006	-471	1082	1553	-405	1214	1619	-416	1186	1601	43	70	51	15	33	23
USHo1	1996	-218	1143	1361	-171	1254	1424	-172	1252	1424	36	66	44	16	39	23
USHo1	1997	-242	1075	1317	-184	1213	1397	-180	1228	1408	31	57	42	16	41	26
USHo1	1998	-214	1303	1518	-172	1380	1552	-176	1367	1543	32	55	39	11	27	17
USHo1	1999	-220	1337	1557	-238	1340	1578	-243	1307	1550	40	68	49	7	32	27
USHo1	2000	-316	1272	1587	-305	1326	1631	-296	1342	1638	32	55	41	9	29	21
USHo1	2001	-263	1360	1623	-234	1417	1652	-234	1431	1665	30	50	34	13	37	25
USHo1	2002	-194	1238	1432	-162	1322	1484	-158	1338	1496	29	45	34	6	13	8
USHo1	2003	-305	1065	1370	-258	1196	1453	-254	1202	1456	28	46	31	10	19	10
USHo1	2004	-326	1113	1439	-293	1193	1486	-294	1188	1482	27	43	32	8	19	12
USIB1	2006				-269	1187	1456	-269	1214	1483	30	55	41	9	18	10

USIB2	2006				-100	1187	1287	-86	1233	1319	41	64	50	9	31	22
USLos	2001				-75	758	834	-77	759	836	22	33	32	16	36	21
USLos	2002				-83	679	762	-84	679	762	15	38	32	8	21	13
USLos	2003				-53	731	784	-47	747	794	17	64	58	9	24	15
USLos	2004				-53	650	702	-51	665	716	21	47	39	3	18	18
USLos	2005				-115	863	978	-115	882	997	15	79	75	3	21	20
USLos	2006				-94	903	997	-94	896	989	17	69	67	4	10	9
USMMS	1999	-359	810	1169	-347	900	1247	-348	899	1248	31	33	34	4	12	8
USMMS	2000	-288	923	1211	-298	1021	1319	-301	1010	1311	34	37	36	7	11	8
USMMS	2001	-330	1059	1389	-312	1100	1412	-314	1098	1412	37	49	41	5	19	15
USMMS	2002	-402	1052	1455	-372	970	1342	-364	983	1347	40	53	43	12	22	12
USMMS	2003	-336	891	1227	-293	971	1264				56	71	60	38	95	174
USMMS	2004	-460	922	1382	-415	926	1341	-406	953	1358	65	76	66	15	44	30
USMMS	2005	-420	892	1312	-367	924	1291	-356	953	1309	53	75	61	13	29	17
USMMS	2006	-618	628	1246	-500	571	1071	-334	895	1228	152	274	143	155	299	179
USMe2	2002	-339	1081	1419												
USMe2	2004	-570	991	1561												
USMe2	2005	-480	997	1477				-475	987	1461	34	67	49	16	49	33
USMe2	2006	-468	754	1223												
USMe2	2007	-578	800	1378				-597	858	1455	82	122	71	46	85	39
USMe3	2004	-188	718	906	-238	617	855	-239	619	857	30	61	43	20	50	31
USMe3	2005	-96	702	797	-155	597	751	-157	599	757				6	113	112
USMe4	1999	-863	383	1246												
USMe5	2000				-276	538	814	-276	537	813	10	11	11	1	5	4

USMe5	2001	-116	620	737	-131	561	692	-131	560	691	10	15	14	4	10	5
USMe5	2002	-200	587	787	-211	578	789	-211	579	790	11	18	16	2	5	3
USMoz	2005	-455	1086	1541	-398	1135	1533	-376	1218	1594	53	110	70	25	69	44
USMoz	2006	-264	1022	1285	-178	1166	1344	-182	1180	1362	37	65	40	18	34	17
USMoz	2007	-432	805	1236	-382	892	1274	-359	947	1306	42	75	50	21	47	26
USNR1	1999	-19	832	851	-84	764	848	-78	796	874	19	35	27	18	38	20
USNR1	2000	-26	742	768	-50	701	752	-36	758	794	16	29	22	19	47	29
USNR1	2001	-51	734	786	-69	712	782	-52	769	821	16	26	20	26	58	33
USNR1	2002	-24	601	625	-60	589	649	-41	659	699	18	37	27	14	42	29
USNR1	2003	-18	660	679	-28	678	707	-13	742	755	24	53	35	22	56	35
USNR1	2004	-42	460	502	-16	782	798	-6	850	855	20	50	42	20	68	49
USNR1	2005	4	714	710	-21	722	744	-7	778	785	18	40	32	19	53	34
USNR1	2006	-28	685	713	-68	689	757	-54	755	809	19	37	28	19	56	39
USNR1	2007	-52	698	749	-69	709	778	-48	796	843	19	56	45	17	53	35
USNe1	2002	-511	1152	1663	-535	1215	1750	-502	1291	1793	37	56	46	26	69	45
USNe1	2003	-421	1052	1473	-445	1200	1645	-434	1224	1659	40	94	77	17	53	39
USNe1	2004	-376	1141	1517	-403	1278	1681	-391	1300	1691				26	91	67
USNe1	2005	-380	1122	1502	-387	1302	1689	-369	1352	1722	33	64	54	11	38	27
USNe2	2003	-671	918	1590	-612	1327	1939	-620	1306	1927				40	108	71
USNe2	2004	95	954	859	88	1076	988	64	1079	1016	34	74	65	10	60	56
USNe2	2005	-577	1016	1593	-584	1289	1873	-590	1330	1920	33	127	121	25	71	53
USNe3	2002	-28	772	800	-45	780	825	-23	836	860	33	52	41	38	97	59
USNe3	2003	-418	866	1284	-417	1055	1472	-411	1095	1505	40	80	69	31	66	43
USNe3	2004	-17	832	849	-35	857	892	-39	885	923	32	62	52	18	82	64
USNe3	2005	-534	926	1460	-558	1044	1603	-559	1048	1607	32	57	53	19	60	43

USPFa	1997							8	1086	1078	34	97	83	3	16	14
USPFa	1998							63	1061	998	53	110	87	8	25	17
USPFa	1999							50	1075	1025	48	107	79	8	18	11
USPFa	2000							30	1004	975	31	55	39	6	15	9
USPFa	2001							74	1024	950	37	61	48	11	29	18
USPFa	2004													4	17	14
USSO2	1999															
USSO2	2000				-62	459	521	-76	439	515	35	45	18	13	19	6
USSO2	2001															
USSO2	2002				86	82	-4	107	81	-27						
USSO2	2004				164	408	243	164	417	253	15	37	23	11	24	17
USSO2	2005				-76	435	511	-65	466	532	19	38	26	28	58	30
USSO2	2006	-75	183	259	-14	311	325	-18	304	322	14	29	20	8	9	9
USShd	1998				-30	1209	1239	-32	1207	1239	20	21	21	4	12	9
USShd	1999				-118	1279	1397	-119	1280	1398	23	26	24	5	17	12
USSyv	2002	-85	995	1079				-62	1117	1179	36	71	48	6	32	29
USSyv	2003															
USSyv	2004															
USSyv	2005	-85	1088	1173												
USSyv	2006	107	1168	1060				159	1296	1136	31	70	45	12	36	25
USTon	2002	-216	612	829	-65	738	803	-82	798	880	40	73	42	25	43	19
USTon	2003	-169	732	902	-26	924	949	-36	904	940	46	84	56	32	60	29
USTon	2004	-189	606	794	-105	725	830	-130	687	818	43	69	41	25	42	18
USTon	2005	-219	823	1042	-109	1064	1173	-142	1021	1163	57	94	55	58	100	47
USTon	2006	-63	776	840	-37	796	833	-30	808	839	35	64	38	13	24	13

USTon	2007	-69	739	808	32	864	832	13	832	819	37	62	34	22	39	17
USUMB	1999	-156	1093	1247	-101	1200	1301	-104	1181	1285	45	84	58	24	48	24
USUMB	2000	-160	1030	1190	-123	1065	1189	-121	1080	1202	33	55	44	20	45	25
USUMB	2001	-92	1084	1176	-39	1119	1158	-32	1134	1167	37	66	49	23	54	30
USUMB	2002	-171	1018	1189	-123	1084	1207	-124	1076	1200	36	69	50	15	37	21
USUMB	2003	-179	965	1144	-125	1038	1162	-117	1051	1169	39	71	48	24	52	29
USUMB	2004	-179	1111	1290	-109	1043	1153	-104	1064	1167	39	64	42	19	41	22
USUMB	2005	-179	1072	1251	-219	966	1184	-219	965	1184	41	76	53	11	23	13
USUMB	2006	-226	1025	1251	-234	908	1142	-235	907	1142	37	65	47	8	17	10
USVar	2001	-58	610	668	-72	572	645	-78	562	640	29	62	56	7	12	5
USVar	2002	-37	605	641	-23	606	629	-2	548	549	28	64	61	18	49	46
USVar	2003	-68	724	792	18	830	812	16	824	808				25	55	26
USVar	2004	-6	512	518	88	483	395	68	491	423	52	73	74	23	64	52
USVar	2005	-148	898	1046	-21	843	864	-18	852	870	86	96	62	408	532	136
USVar	2006	19	665	647	48	685	637	59	708	649	46	60	72	8	15	7
USVar	2007	-8	656	665	-2	681	683	6	697	690	131	329	354	152	362	363
USWCr	1999	-222	628	850										13	41	52
USWCr	2000	-395	747	1142	-325	851	1177	-357	758	1115	25	43	34	3	10	8
USWCr	2001	-32	986	1017	249	879	630	237	849	612	102	171	68	21	41	22
USWCr	2002	-444	687	1131	-165	714	879	-192	653	845	51	78	42	36	71	36
USWCr	2003	-481	853	1334	-335	874	1209	-373	744	1117	38	62	44	19	62	45
USWCr	2004															
USWCr	2005	-470	967	1437	-382	989	1371	-428	864	1292	41	60	42	6	16	10
USWCr	2006	-472	702	1173										20	50	31

Appendix B: Modified Fluxnet-Canada Gap-Filling Method

Six modifications were made to the Fluxnet-Canada standard gap-filling method (Barr et al. 2004).

1. NEE outliers were identified and excluded using the methods described in 6.2 above, level 1.
2. Because the soil temperature T_s depths in the NACP database were not always shallow enough to meet our requirements (2 or 5 cm), we used a weighted temperature T as the dependent variable in the RE = $f(T,t)$ relationship, estimated as $(2*T_s + T_a) /3$ where T_a is air temperature. This ensured a significant diurnal cycle.
3. The time-varying parameters $r_w(t)$ and $p_w(t)$ (Equations B2 and B4 below) were estimated, not by forced-origin linear regression, but as the ratio of means (see below). They were also not allowed to be negative.
4. Night was delineated, not from solar position, but from global shortwave radiation of less than 5 W m^{-2}.
5. Gaps of 31 days and longer were not filled.
6. At a few sites where NEE was routinely unavailable, we substituted F_c for missing NEE.

The Fluxnet-Canada gap-filling procedure: (a) derives measured RE and GPP from measured NEE, (b) fills gaps in RE and GPP using simple empirical models that are highly constrained by the measured data, and (c) fills gaps in NEE from the gap-filled RE - GPP. The data are processed one year at a time. Two simple annual empirical relationships are determined from measured data, one between RE and temperature T and the other is between GPP and downwelling PAR radiation $Q_\downarrow$ above the stand. For each relationship, annual parameters are first obtained for the annual analysis, then one additional parameter per relationship is allowed to vary over time with the other parameters held constant. The temporal variation in the time-varying parameter accounts in part for changes in vegetation and environmental variables, such as, e.g., LAI, soil water content, air temperature, air saturation deficit and freeze-thaw events.

The time-varying parameters are determined using a flexible moving window. Within each window, the time-varying parameter is calculated as the ratio of the mean RE (or GPP) obtained from the measurements and the corresponding mean from the annual regression relationships (equations B1 and B3). The implementation of the moving window uses a fixed number (100) of measured (non-missing) data points rather than a fixed period of time. The window is moved in increments of 20 (non-missing) points at a time. For each window, the corresponding time is assigned as the mean time of the 100 data points (i.e. usually near the centre of the window). The values of the time-varying parameters for each individual half-hour period are then estimated by linear interpolation. These adjusted relationships are then used to fill data gaps. The sensitivity of RE to T and GPP to $Q_\downarrow$, respectively, is largely determined by the annual relationships, but is modified to some extent by the time-varying parameters within each window period.

The post-processing steps are as follows. First, nighttime NEE data are excluded at low u_* (below the u_*^{Th}). Small gaps in NEE (four periods or less) are filled by linear interpolation before larger gaps are filled using the procedure outlined below.

Measured RE is estimated as RE = NEE during periods when GPP is known to be zero, i.e., at night and during both night and day in the cold season (periods when both T_a and T_s are less than 0 ˚C). An empirical, logistic relationship is fit to the measured R values from the entire year:

$$\text{RE} = r_1/(1+\exp[r_2(r_3-T)]) \tag{B1}$$

where r_1, r_2 and r_3 are empirical constants. An additional empirical parameter, $r_w(t)$, is introduced into (B1), resulting in

$$\text{RE} = f(T_s,t) = r_w(t)r_1/(1+\exp[r_2(r_3-T)]) \tag{B2}$$

where $r_w(t)$ is allowed to vary in time (t). Its value is estimated within a 100-point moving window as the ratio of mean measured RE to mean modeled RE from (B1). The RE = $f(T,t)$ model (B2) is used to estimate RE during the day and to fill gaps in RE at night.

“Measured” GPP is estimated as –NEE (measured) + RE (modeled daytime) or zero (nighttime and during periods when both T_a and T_s are less than 0˚ C). An empirical model is fit to the daytime, warm-season GPP data for the entire year:

$$\text{GPP} = \alpha Q_\downarrow P_x/(\alpha Q_\downarrow + P_x) \tag{B3}$$

where α is the quantum yield and P_x is the photosynthetic capacity (P at light saturation). Both parameters are treated as constants. An additional empirical parameter, $p_w(t)$, is introduced into (B3), resulting in

$$\text{GPP} = f(Q_\downarrow,t) = p_w(t)\alpha Q_\downarrow P_x/(\alpha Q_\downarrow + P_x) \tag{B4}$$

$p_w(t)$ is allowed to vary in time and is estimated within a 100-point moving window as the ratio of mean measured GPP to mean modeled GPP from (B3). The GPP = $f(Q_\downarrow,t)$ model (B4) is used to fill gaps in GPP.

Gaps in NEE are filled using modeled GPP – modeled RE from (B2) and (B4).

Appendix C: Modifications to the Papale u_*^{Th} Detection Algorithm

We adopted the u_*^{Th} detection approach of Papale et al. (2005) as implemented in the La Thuile FLUXNET synthesis, but with important modifications to the stratification, binning, threshold detection and averaging details, as outlined in Table C.

Table C: Modifications to the Papale et al. (2005) u_*^{Th} detection algorithm.

	Detail	**Papale et al. (2005)**	**NACP**
1	**Stratification and binning**		
	Quarter delineation	JFM, AMJ, JAS, OND	DJF, MAM, JJA, SON
	Temperature used to stratify	Air temperature	Shallow soil temperature
	Number of NEE data per u_* bin	?	• Minimum of 5 (30-min data) • Minimum of 3 (60-min data)
	Number of u_* bins per strata	20	50+
	Number of temperature strata per quarter	3 to 7	3 to 7
2	**Threshold detection**		
	Method	Stabilization of 5-point moving mean	Change-point detection (Lund and Reeves 2002 but modified to two connected line segments)
	Failure detection	Unclear	F test (Wang et al. 2007)
3	**Uncertainty analysis**	Bootstrapping, 100 replications	Bootstrapping, 1000 replications
4	**Averaging**		
	Within year	Median within each quarter, then maximum of four quarterly medians, then annual distribution from bootstraps	Median within each quarter, then mean of four quarterly medians, then annual distribution from bootstraps. Individual bootstraps excluded if any quarter had less than two strata with a significant u_*^{Th}.
	Among years	Different u_*^{Th} for each site-year	Site-specific u_*^{Th}, all years pooled