Earth Sciences Division

21 October 2016

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Dear Dennis,

Thank you very much for hosting the AmeriFlux Tech Team site visit at Twitchell Island, East End Wetland (US-Tw4) from May 29 – June 9 2015 (DOY 148-160). This report summarizes the findings and key recommendations from the comparison between the AmeriFlux portable eddy covariance system #2 (PECS2) and the *in situ* system for eddy covariance, radiation, and meteorological observations.

The AmeriFlux PECS2 sensors were deployed to minimize separation (both horizontal and vertical) from the *in situ* sensors (Appendix 1), to avoid interfering with existing infrastructure, and to prevent shadowing or wake effects. The AmeriFlux PECS2 was deployed with two CO_2/H_2O infrared gas analyzers (a closed-path (LI-7200), and an open path analyzer (LI-7500A)), as well as an open-path CH_4 gas analyzer (LI-7700). All gas analyzers were calibrated prior to and after deployment, with this comparison focusing on the AmeriFlux open-path IRGAs as they are most similar to the *in situ* eddy covariance system. Data processing of the AmeriFlux PECS2 was handled by EddyPro® (Version 5.2.1), an open-source eddy covariance software package. We are in the process of updating the details of the AmeriFlux data processing and data screening on the AmeriFlux website (ameriflux.lbl.gov). Please contact the AmeriFlux Tech team if you have specific questions.

Four figures were generated for each variable compared. The top figure is a time series of both systems over the evaluation period. The middle figure is a time series of the differences between the systems. The lower left figure is a scatter plot of both systems with the ideal 1-to-1 regression line and the best fit linear regression together with equation and fit parameters. Lastly, the lower right figure is a histogram of the differences between the systems with summary statistics. The enclosed figures only include periods where both datasets are available and quality controlled. Missing data periods occurred when data was screened from one or both systems either through data quality checks, outlier removal, environmental interference (precipitation), or no data (power outage) (Figure 1).

This report is limited in scope because the *in situ* data acquisition of the gas analyzers was disrupted at setup, and no IRGA data was available. As a result this report focuses on sonic anemometer, radiation, and meteorological comparisons.

Key Recommendations:

Overall, the comparison between the AmeriFlux PECS2 and the *in situ* system was good. A few key findings highlighted below:

- On average, sensible heat fluxes agreed closely but we observed that differences increased with wind speed above 5 m s^{-1}. Evidence of sonic transducer deflection at high wind speed has been reported for CSAT anemometers but we have not previously noted this for the Gill anemometers.

In closing, thank you for your cooperation before, during, and after the site visit and we encourage you to continue your active participation in the AmeriFlux network. We are actively soliciting comments or feedback regarding the site visit process and report to maximize the utility of our visits. For all reports, we request a summary from the site to describe how the enclosed recommendations will be addressed. I am available to provide further analysis or discussion of the results, if required. Please review the general site information table in Appendix 1 of this document and let us know if you notice erroneous information. Thank you for working collaboratively with the AmeriFlux Tech team.

All the best,

AmeriFlux Tech Team
Stephen Chan, Sigrid Dengel, Sébastien Biraud

Lawrence Berkeley National Laboratory

Detailed Report

Data availability:

The PECS2 was deployed from May 29 - June 9 2015 (Figure 1). The *in situ* data acquisition of the gas analyzer signal was disrupted (possibly during the PECS2 setup) and unfortunately no data from the *in situ* gas analyzers was available for the comparison. As a result this report focuses on sonic anemometer, radiation, and meteorological comparisons.

Turbulent fluxes:

No comparison of carbon dioxide, water vapor, or methane fluxes was possible due to the malfunction of the *in situ* IRGA. Sensible heat fluxes were small (<100 W m^{-2}) but generally tracked well (Figure 2, slope: 0.99, offset: +15.70 W m^{-2}, R^2 = 0.85). The *in situ* sensible heat fluxes were consistently higher than the PECS2 and the histogram of differences showed a skewed distribution (Figure 2). A strong relationship was observed between wind speed and the difference in sensible heat fluxes (Figure 3). Evidence of transducer deflection at high wind speed has been reported for CSAT anemometers (Burns et al., 2012) but not for Gill anemometers to our knowledge. Particularly confounding is that two Gill anemometers were compared here. We are doing some further analysis across other site visits to probe this idea. Analysis of the rotated three-dimensional wind variances found only small differences (see below section). Additionally, friction velocity comparisons were very similar indicating that both sonic anemometers were observing similar turbulent structures (Figure 4, slope: 1.06, offset: +0.01 m s^{-1}, R^2 = 0.98).

Estimates of random flux uncertainties for the PECS2 turbulent fluxes accompany each figure. Uncertainty estimates were calculated following Finkelstein and Sims (2001) due to the ease of implementation and lack of parameters (see Billesbach, 2011 for a comparison of other methods).

IRGA scalars and statistics:

No evaluation of CO_2 and H_2O concentrations was possible. The CH_4 mole densities from the *in situ* open path CH_4 gas analyzer agreed very well with the PECS2 analyzer (Figure 5, slope: 0.96, offset: 0.00 mmol m^{-3}, R^2 = 0.95). The variance also compared very favorably (Figure 6, slope: 1.00, offset: +0.00 (mmol $m^{-3})^2$, R^2 = 0.99).

Sonic wind components and temperature:

Comparisons of mean wind direction (Figure 7, slope: 1.01, offset: -4.28^{o}, R^2 = 1.00) and horizontal wind speed (Figure 8, slope: 0.99, offset: +0.00 m s^{-1}, R^2 = 1.00) were excellent between the sonic anemometers.

The variances in the rotated sonic anemometer wind components were quite good. The difference was smallest in the stream-wise (u-component) (Figure 9, slope: 1.02, offset: -0.01 m s^{-1}, R^2 = 0.99). The differences in the variances of the perpendicular wind (v-component) (Figure 10, slope: 1.08, offset: -0.01 m s^{-1}, R^2 = 0.99) and in the variance of the vertical wind (w-component) (Figure 11, slope: 0.93, offset: -0.01 m s^{-1}, R^2 = 0.99) were similar but in opposite directions. Such differences could arise from the coordination rotation conducted.

Meteorological and radiation measurements:

Ambient air temperature measurements reported by the PECS2 and *in situ* Vaisala HMP sensors tracked closely (Figure 12, slope: 1.02, offset: -0.99^{o}C, R^2 = 0.99) but a mean offset of approximately 0.6^{o}C was observed. In respect to relative humidity, the two humidity probes agreed fairly well (Figure 13, slope: 0.97, offset: -3.62%, R^2 = 0.99) but an offset of 5% was consistently noted.

The incoming shortwave radiation agreed very well (Figure 14, slope: 1.02, offset: -2.65 W m^{-2}, R^2 = 1.00). Due to space constraints on the scaffold infrastructure, we were unable to mount the PECS2 radiometer boom over similar vegetation cover. The PECS2 boom was deployed to the south while the in situ radiometers were west of the scaffold. The agreement between the outgoing shortwave radiometers was still fairly good given the deployment challenges, with the *in situ* radiometer recording slightly higher values midday values (Figure 15, slope: 1.00, offset: +5.46 W m^{-2}, R^2 = 0.99).

For both longwave components, the *in situ* CNR1 had a small positive offset relative to the PECS2 instrument. Incoming longwave radiation had a 25 W m^{-2} offset (Figure 16, slope: 1.02, offset: +18.99 W m^{-2}, R^2 = 0.93) while the outgoing component had a median offset of 11 W m^{-2} (Figure 17, slope: 0.99, offset: 12.97 W m^{-2}, R^2 = 1.00).One cause for such an offset could be the radiometer body temperature. Since only a single calibration coefficient is used on a CNR1, we do not suspect calibration error given the shortwave comparison.

The net radiation comparison was very good (Figure 18, slope: 1.04, offset: 6.30 W m^{-2}, R^2 = 1.00).

Incoming PAR from the *in situ* Kipp and Zonen PQS1 showed 6% higher values than those from the PECS2 sensor (Figure 19, slope: 1.06, offset: -4.62 µmol m^{-2} s^{-1}, R^2 = 1.00) with daytime readings exceeding those of the PECS2 sensor by up to 100 µmol m^{-2} s^{-1}. Outgoing PAR values recorded by the PECS2 system were likely impacted by the different orientation and position of the sensor. On average, the outgoing PAR (Figure 20, slope: 1.01, offset: +0.87 µmol m^{-2} s^{-1}, R^2 = 0.95) show reasonable agreement but the in situ sensor picks up an afternoon peak that the PECS2 misses (reflection from open water?).

References:

Billesbach, D. P. (2011), Estimating uncertainties in individual eddy covariance flux measurements: A comparison of methods and a proposed new method, Agric. For. Meteorol. 151, 394–405, doi:10.1016/j.agrformet.2010.12.001.

Burns, S. P., Horst, T. W., Jacobsen, L., Blanken, P. D., and Monson, R. K. (2012) Using sonic anemometer temperature to measure sensible heat flux in strong winds, Atmos. Meas. Tech., 5, 2095-2111, doi:10.5194/amt-5-2095-2012.

Finkelstein, P. L., and P. F. Sims (2001), Sampling error in eddy correlation flux measurements, J. Geophys. Res., 106(D4), 3503–3509, doi:10.1029/2000JD900731.

Table of Figures:

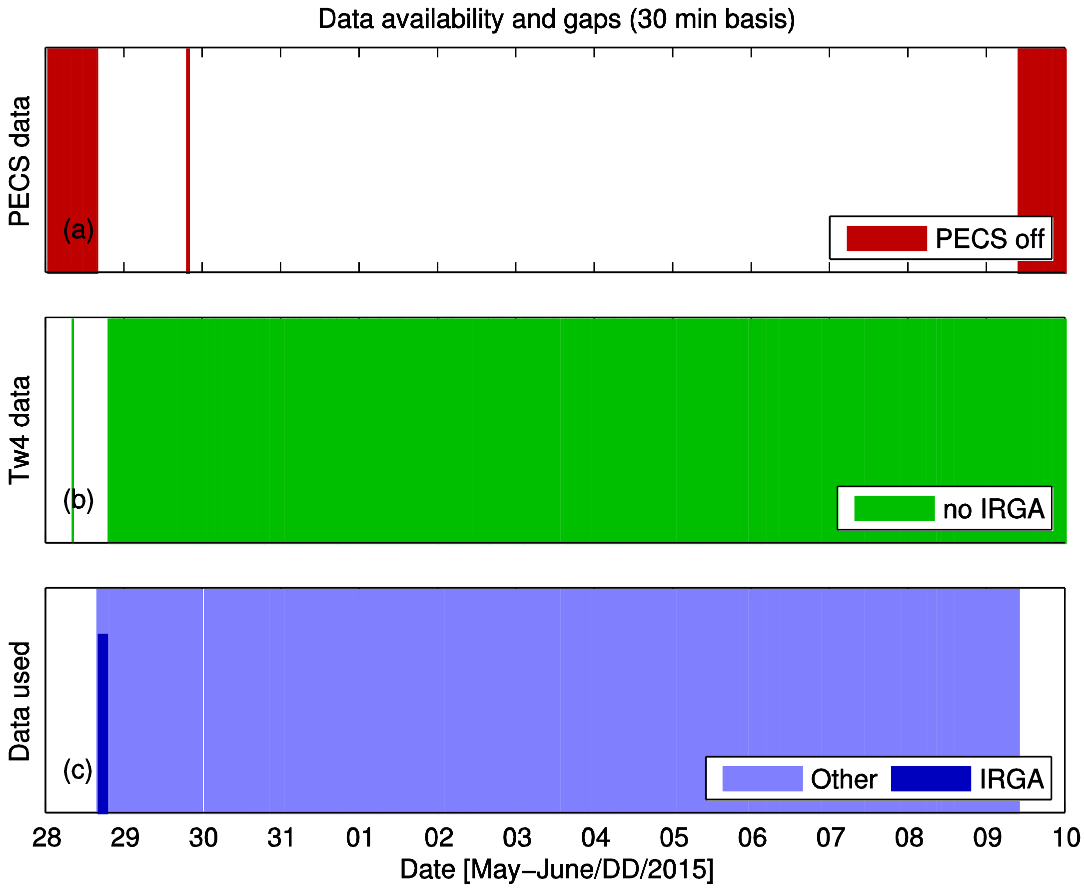


Figure 1 – Data availability for the PECS2 (panel a) and *in situ* system (panel b). Summary of the data used for the inter-comparison (panel c).

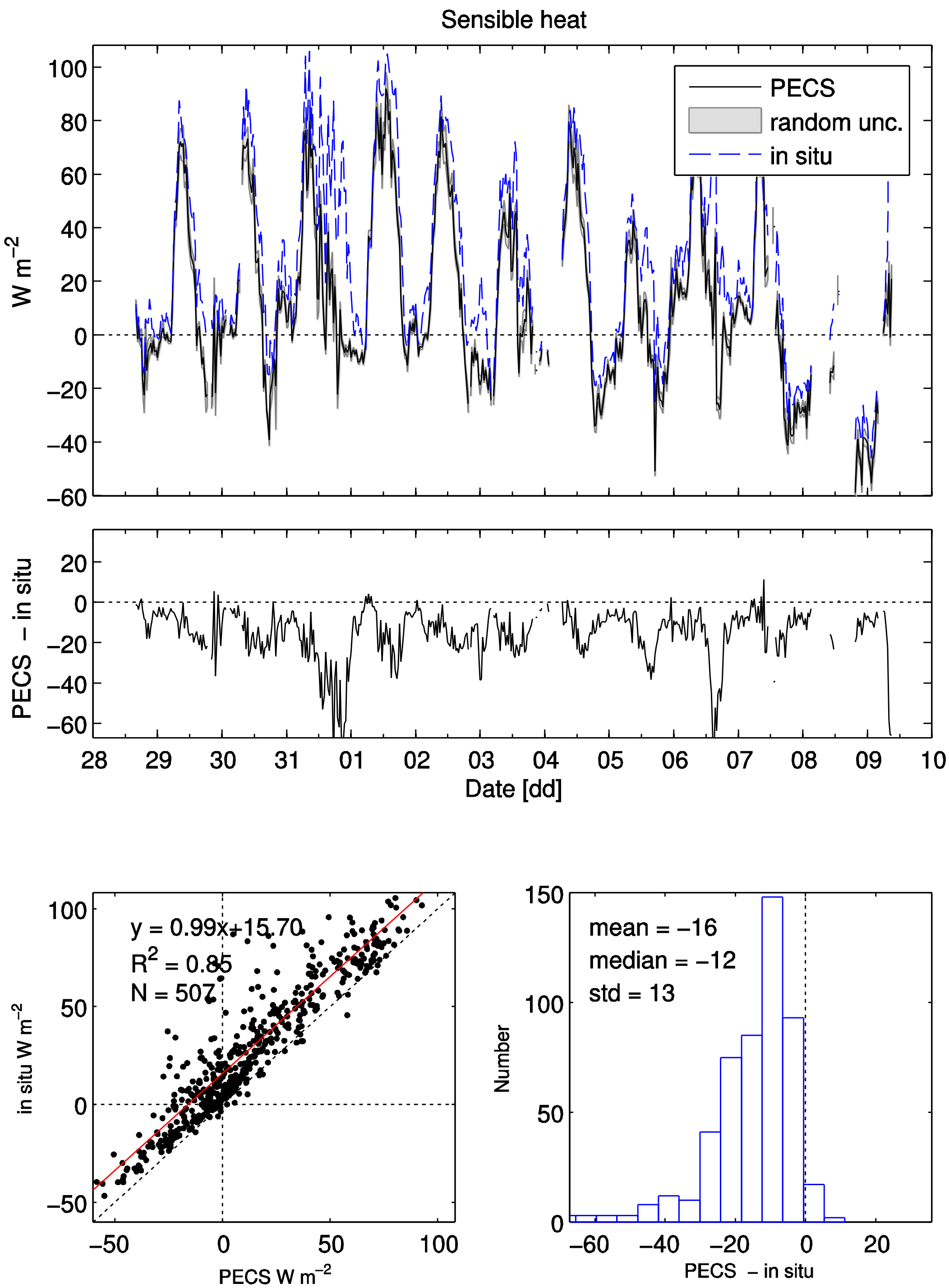


Figure 2 – Sensible heat flux with an estimate of the random uncertainty (Finkelstein and Sims, 2001).

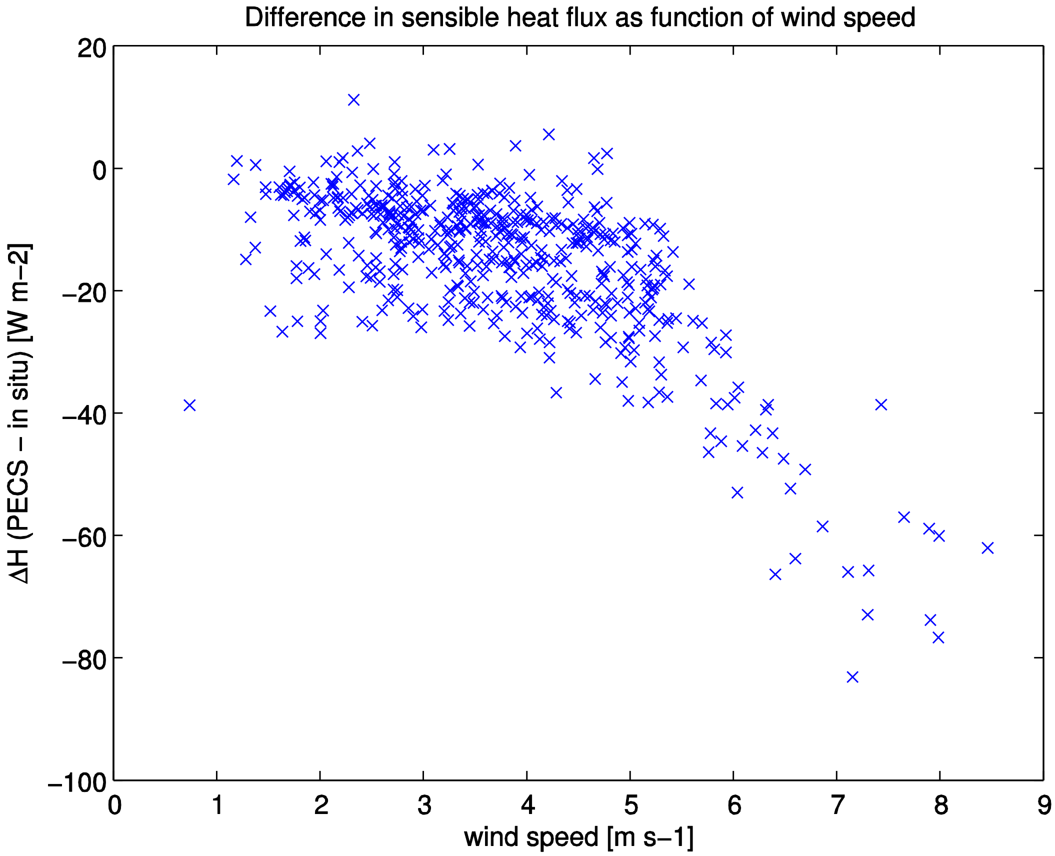


Figure 3 – Difference in sensible heat as a function of wind speed.

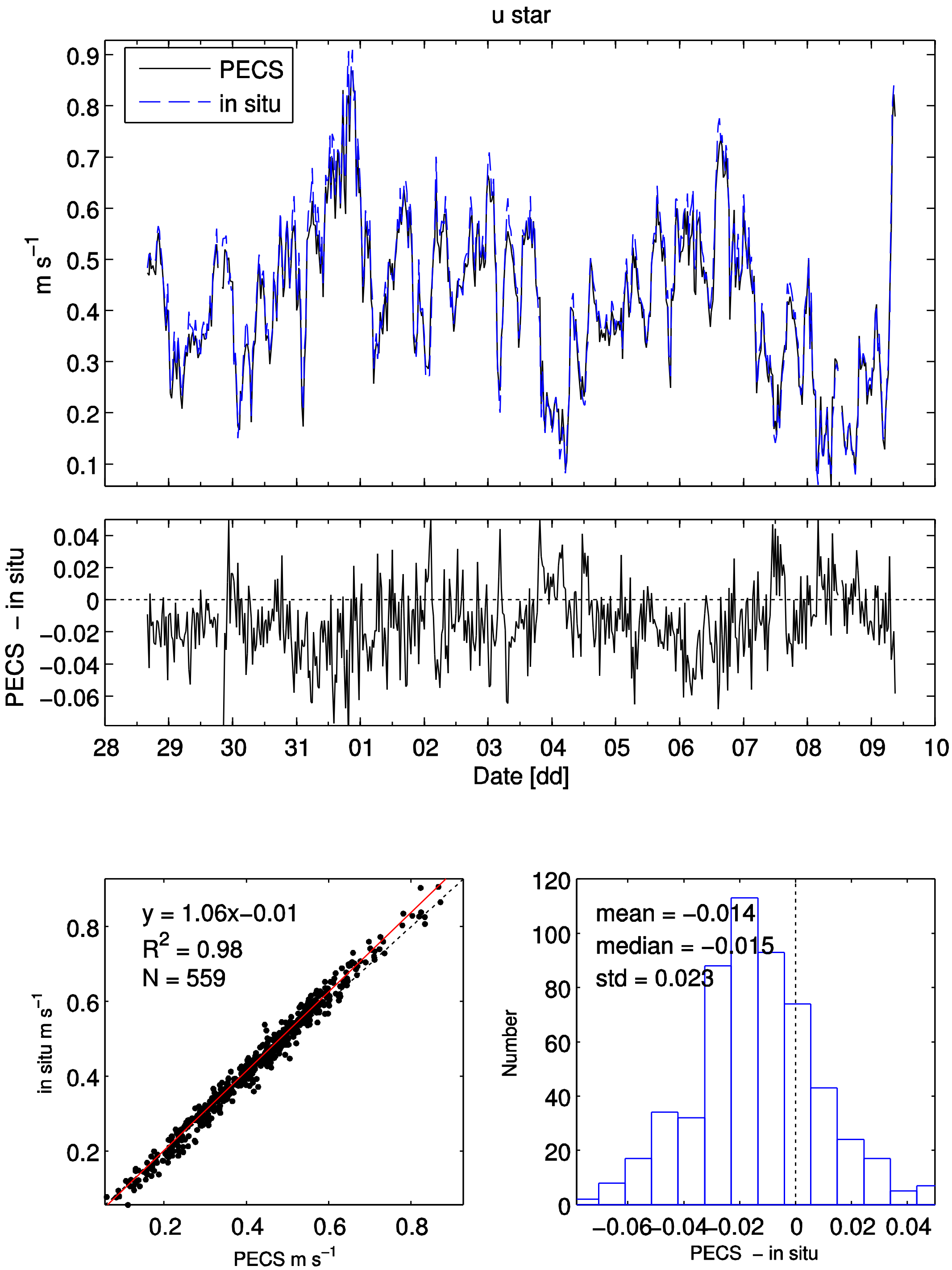
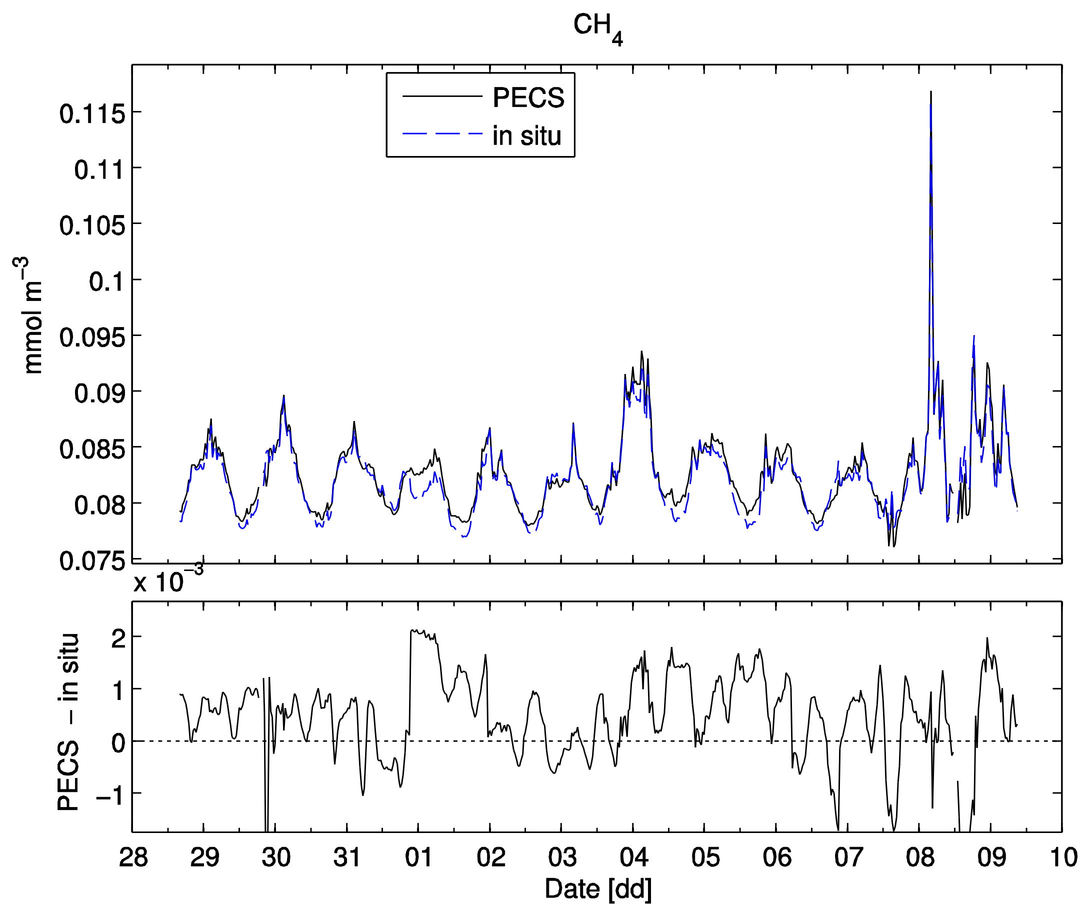


Figure 4 – Friction velocity.



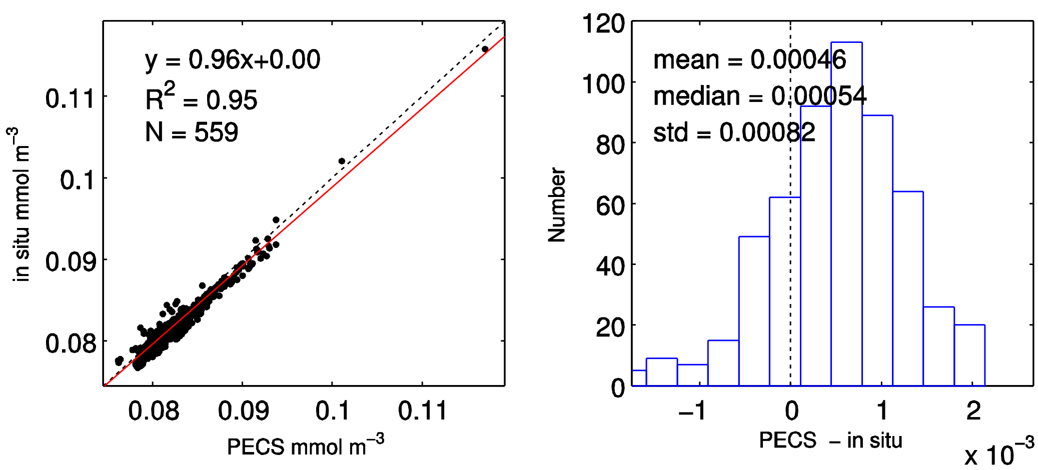


Figure 5 – CH_4 mole density.

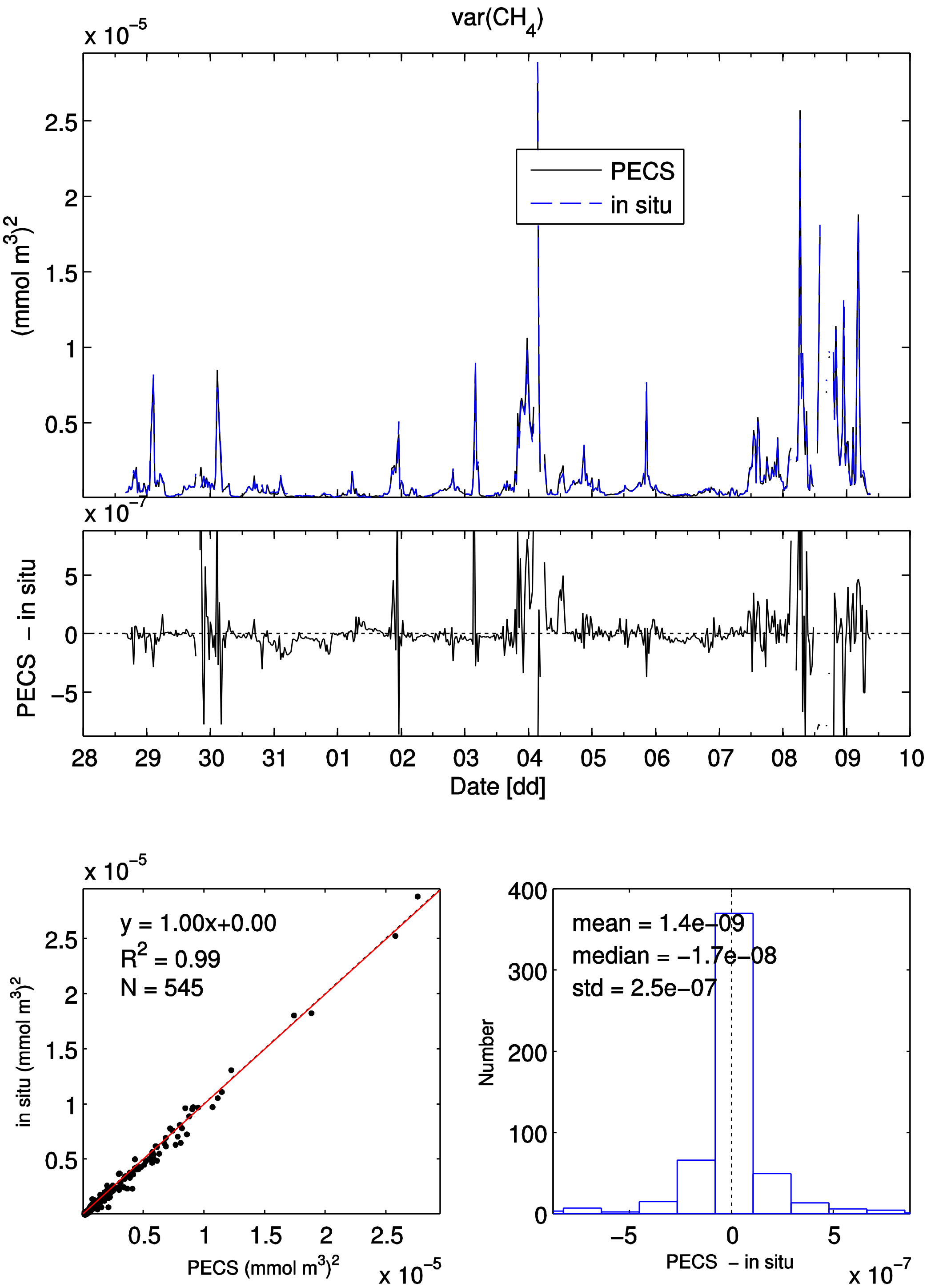


Figure 6 - Variance of CH_4 mole density

Site Name: Twitchell East End Wetland (US–Tw4)
Visit Dates: May 29 - June 9 2015

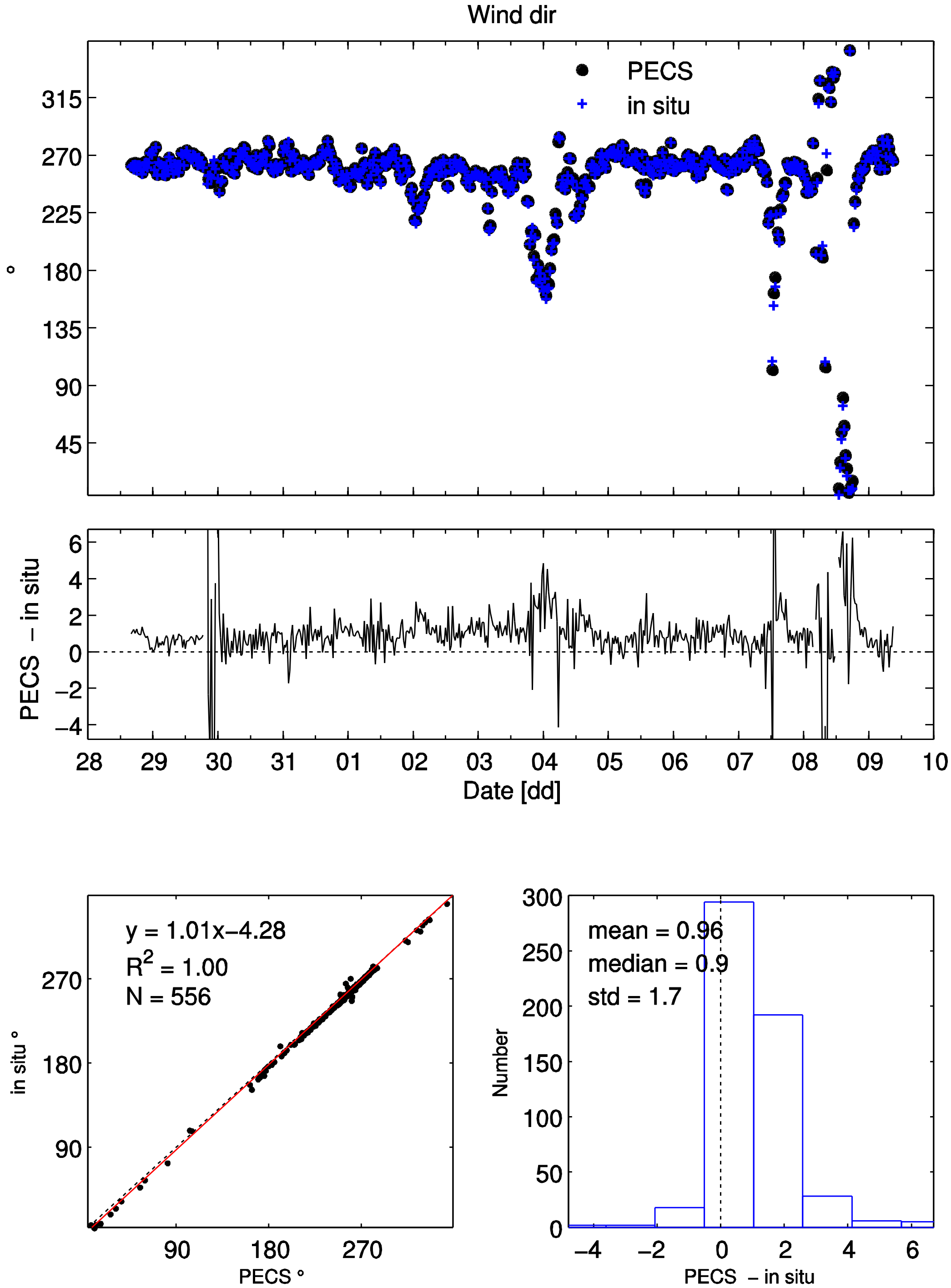


Figure 7 – Wind direction.

Site Name: Twitchell East End Wetland (US–Tw4)
Visit Dates: May 29 - June 9 2015

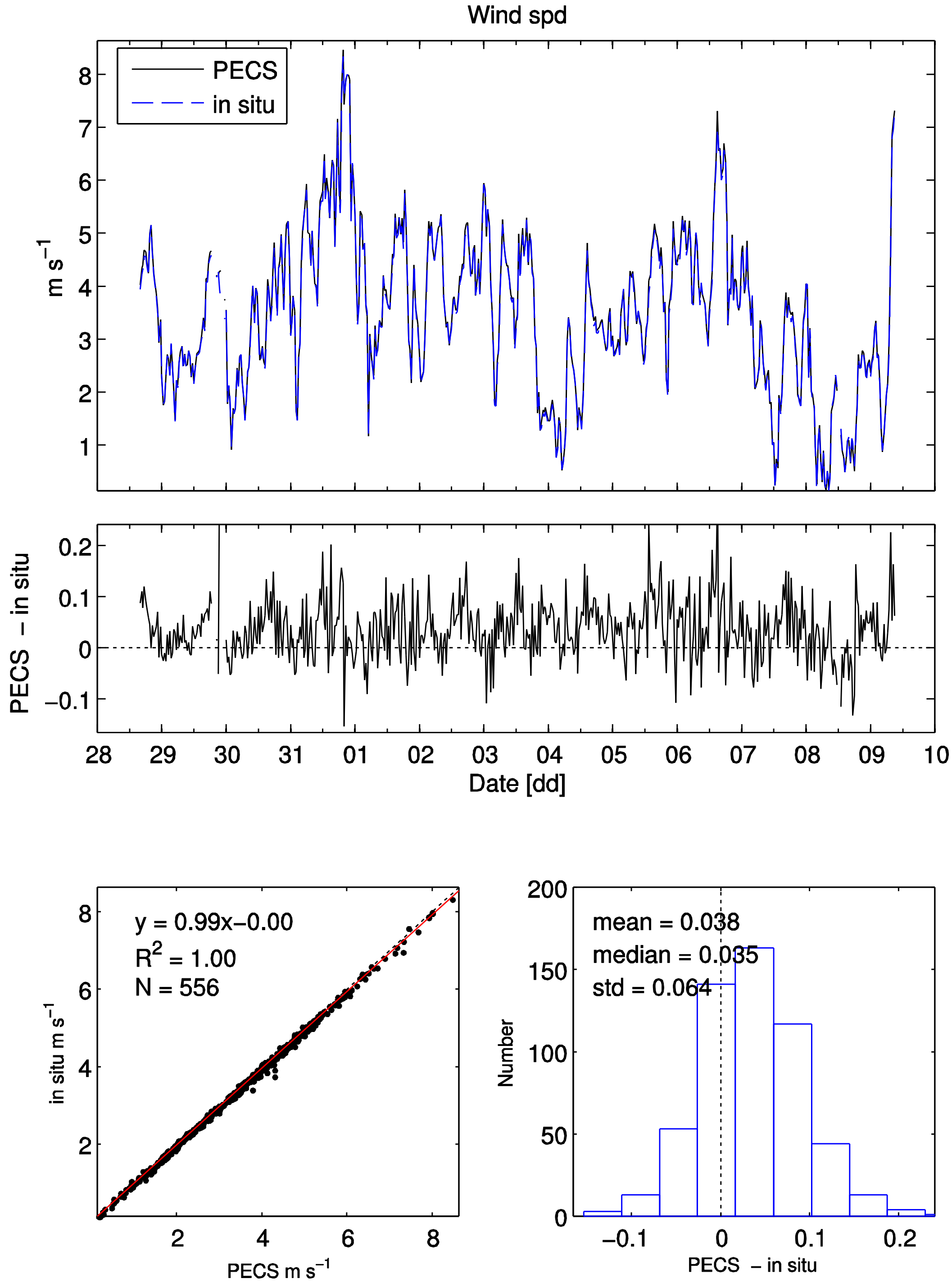


Figure 8 – Wind speed.

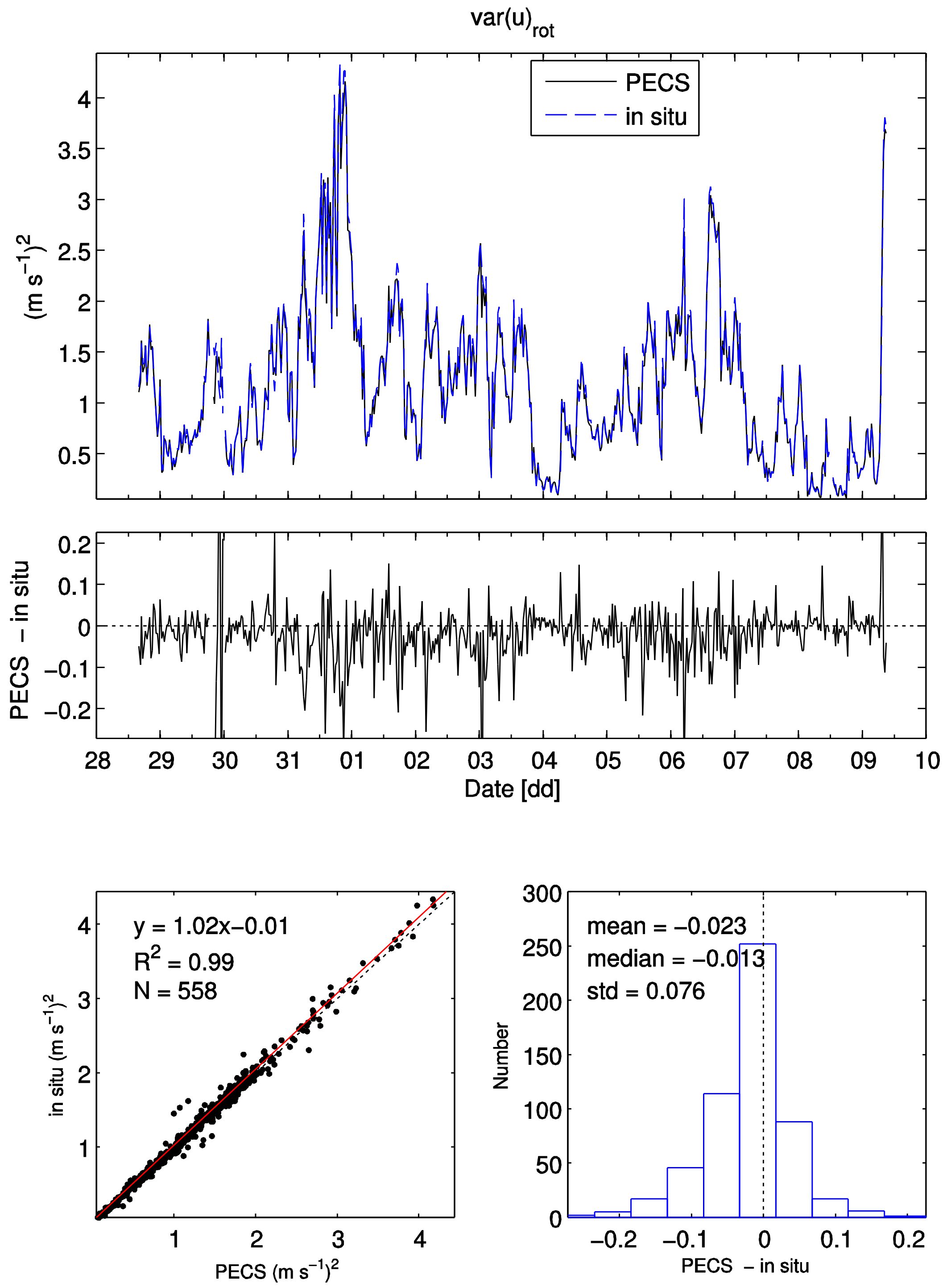


Figure 9 – Rotated u-wind component variance.

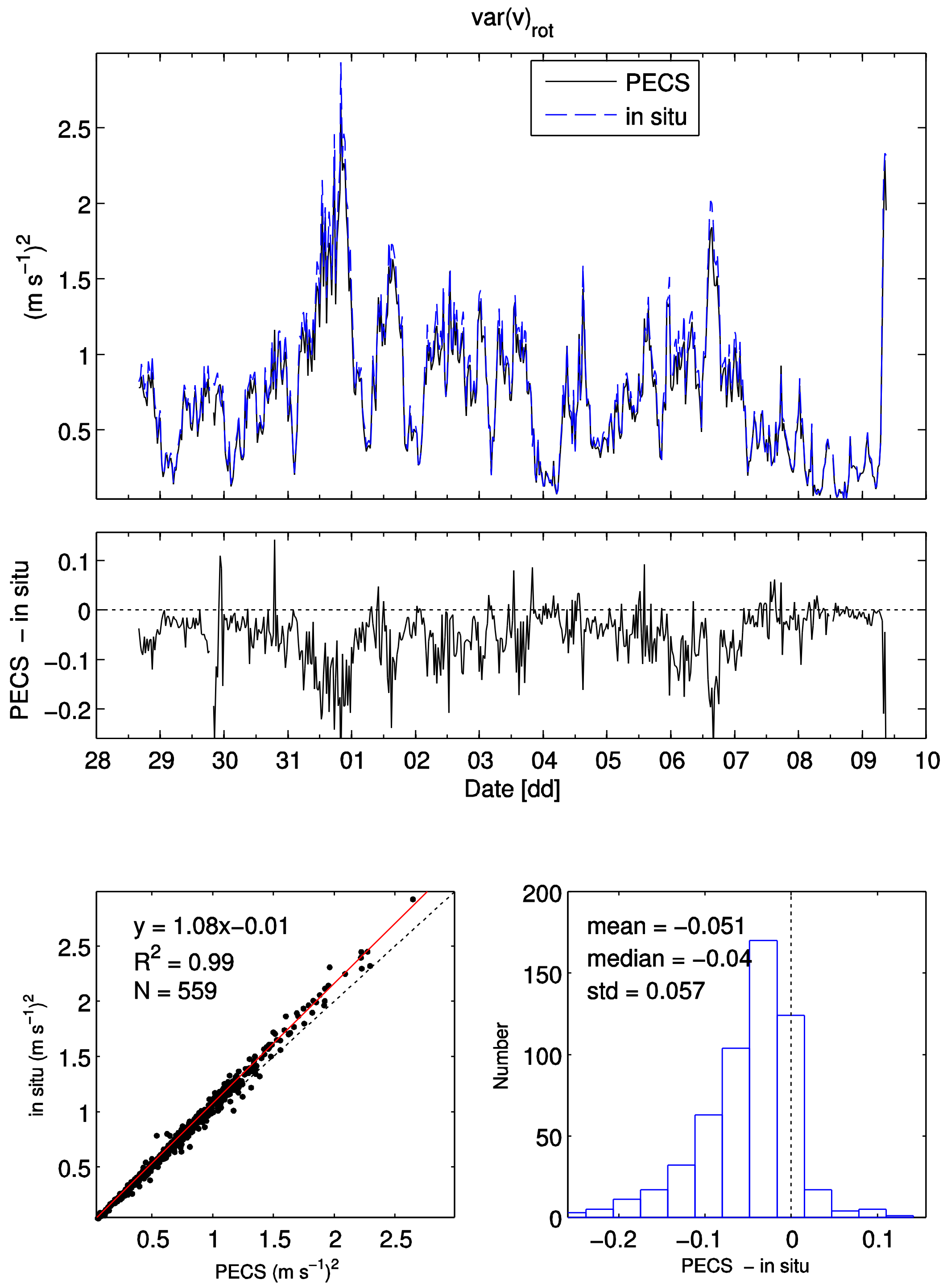
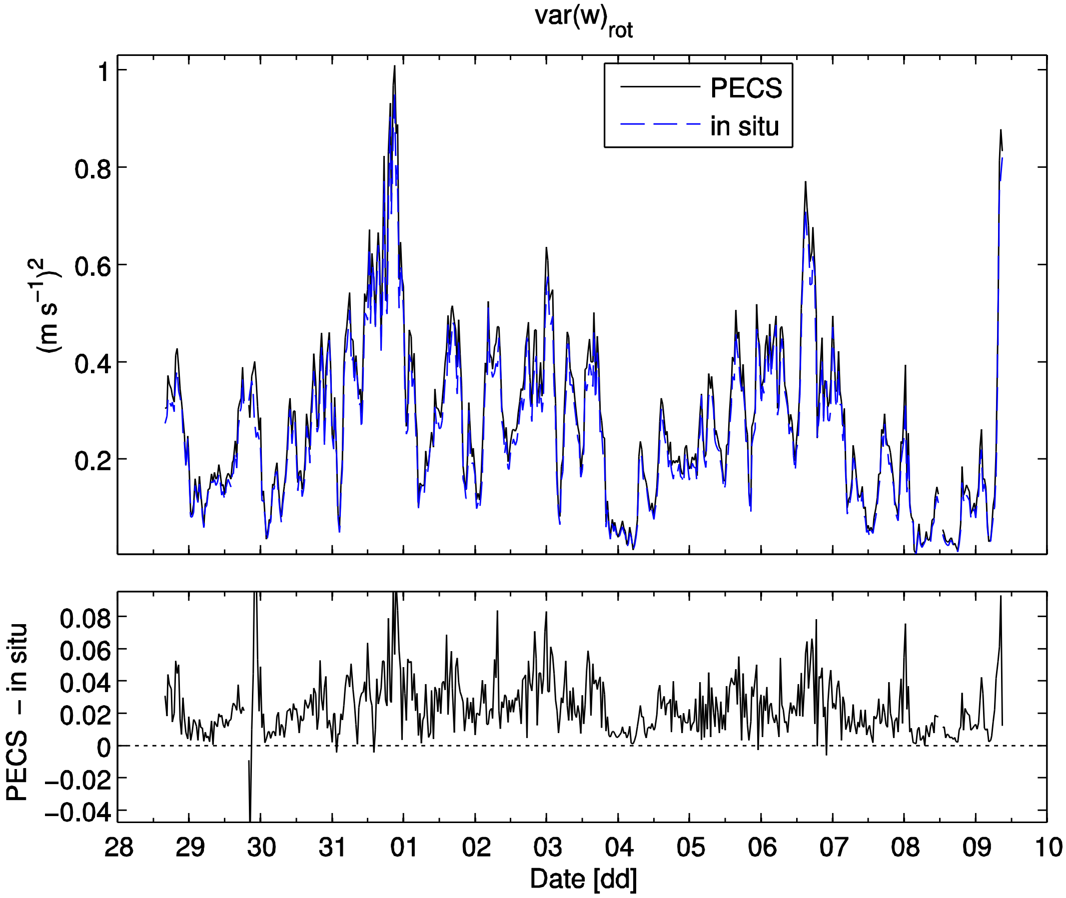


Figure 10 – Rotated v-wind component variance.



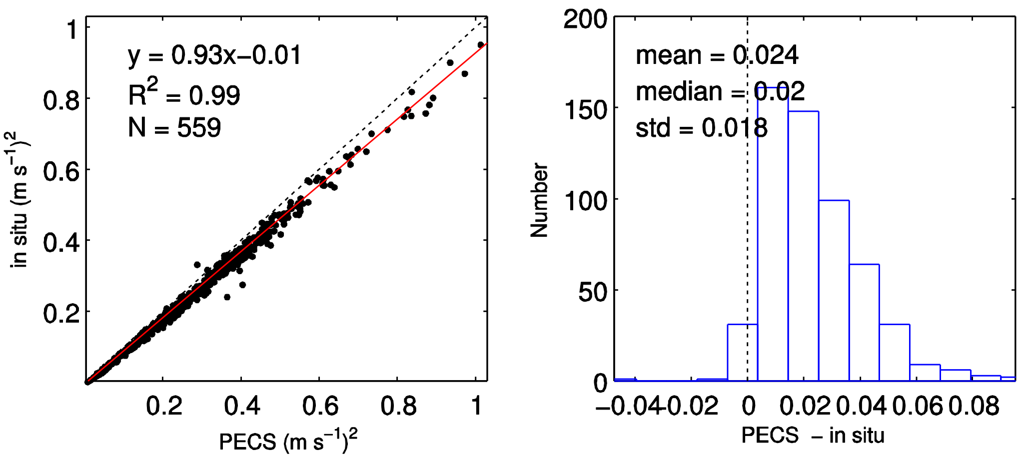
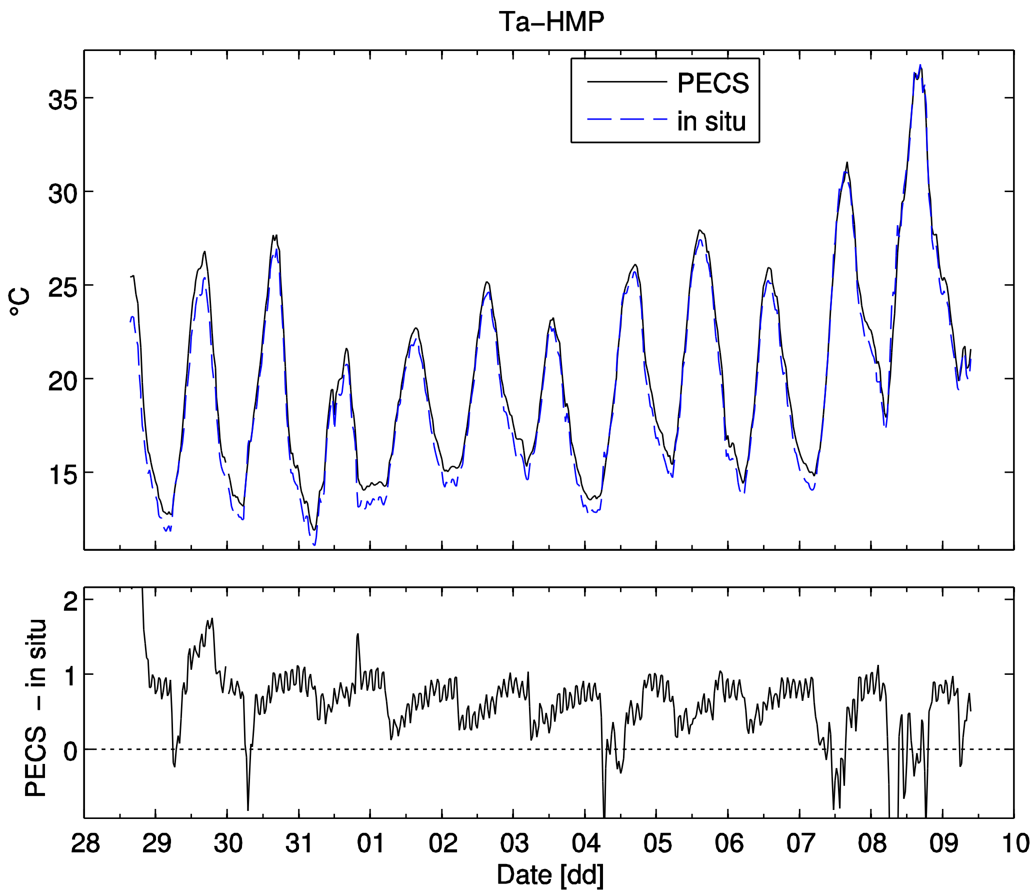
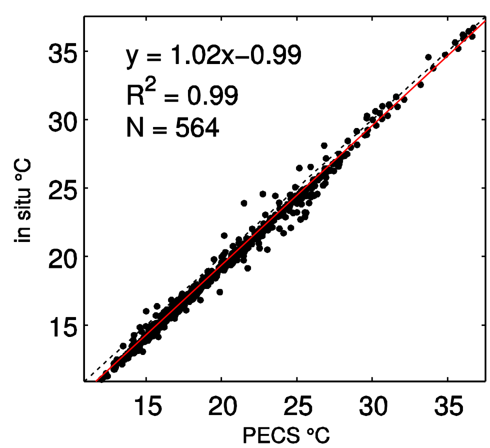


Figure 11 – Rotated w-wind component variance.





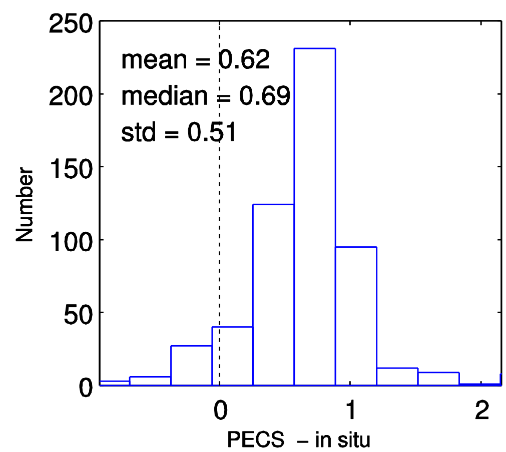
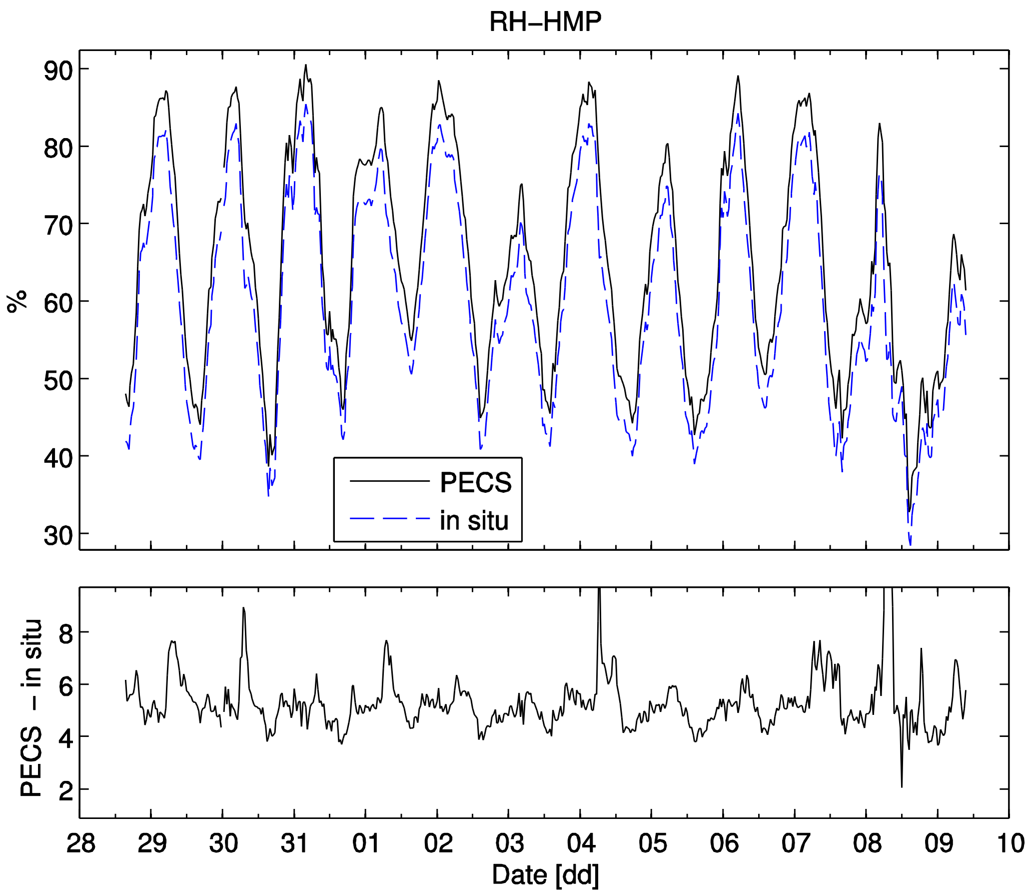


Figure 12 – Air temperature.



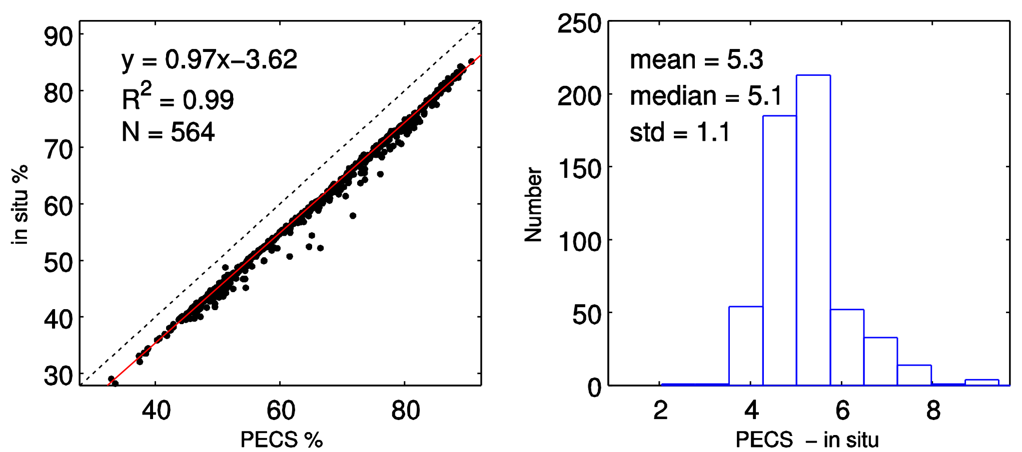


Figure 13 – Relative humidity.

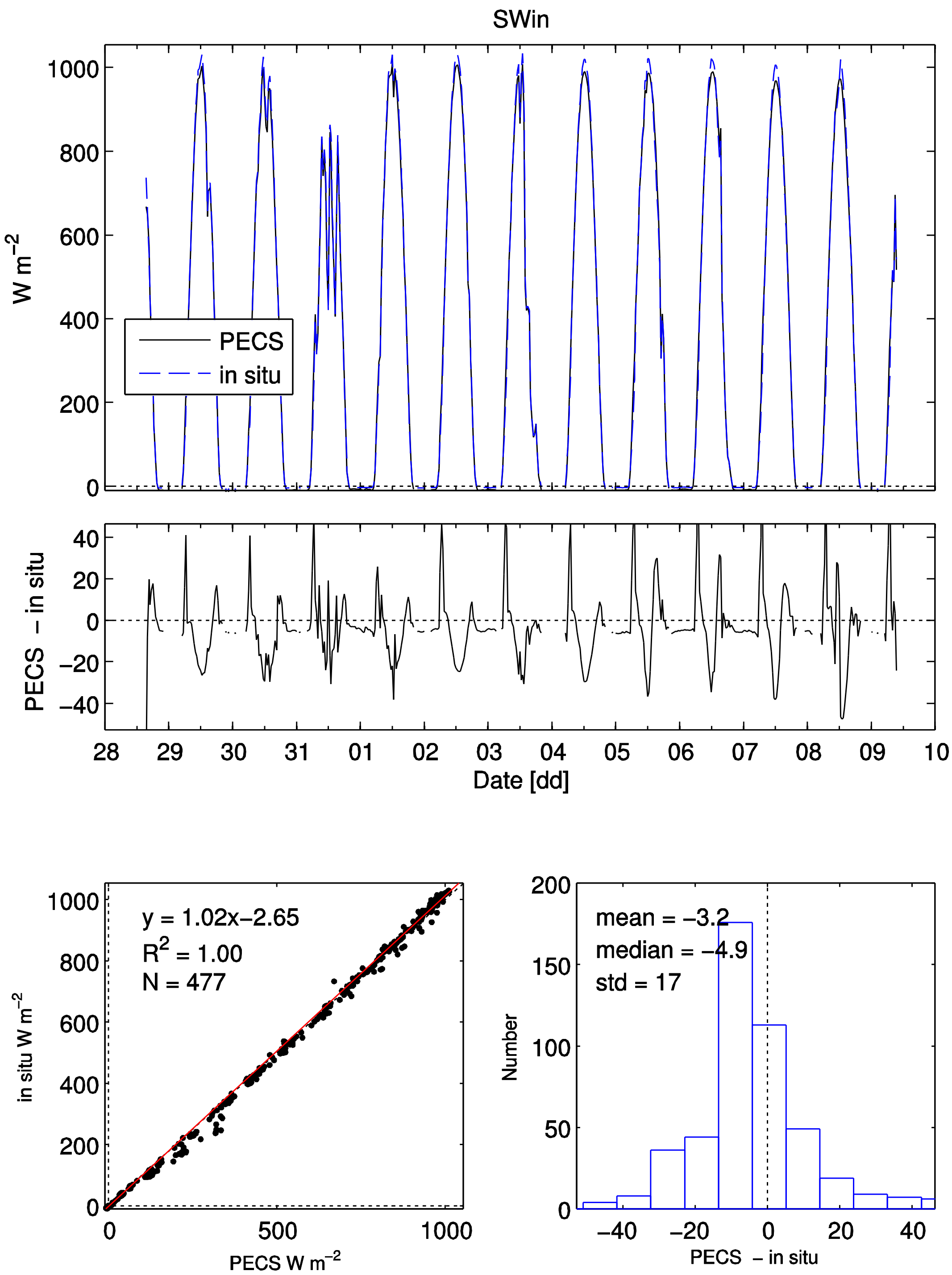


Figure 14 – Incoming shortwave radiation.

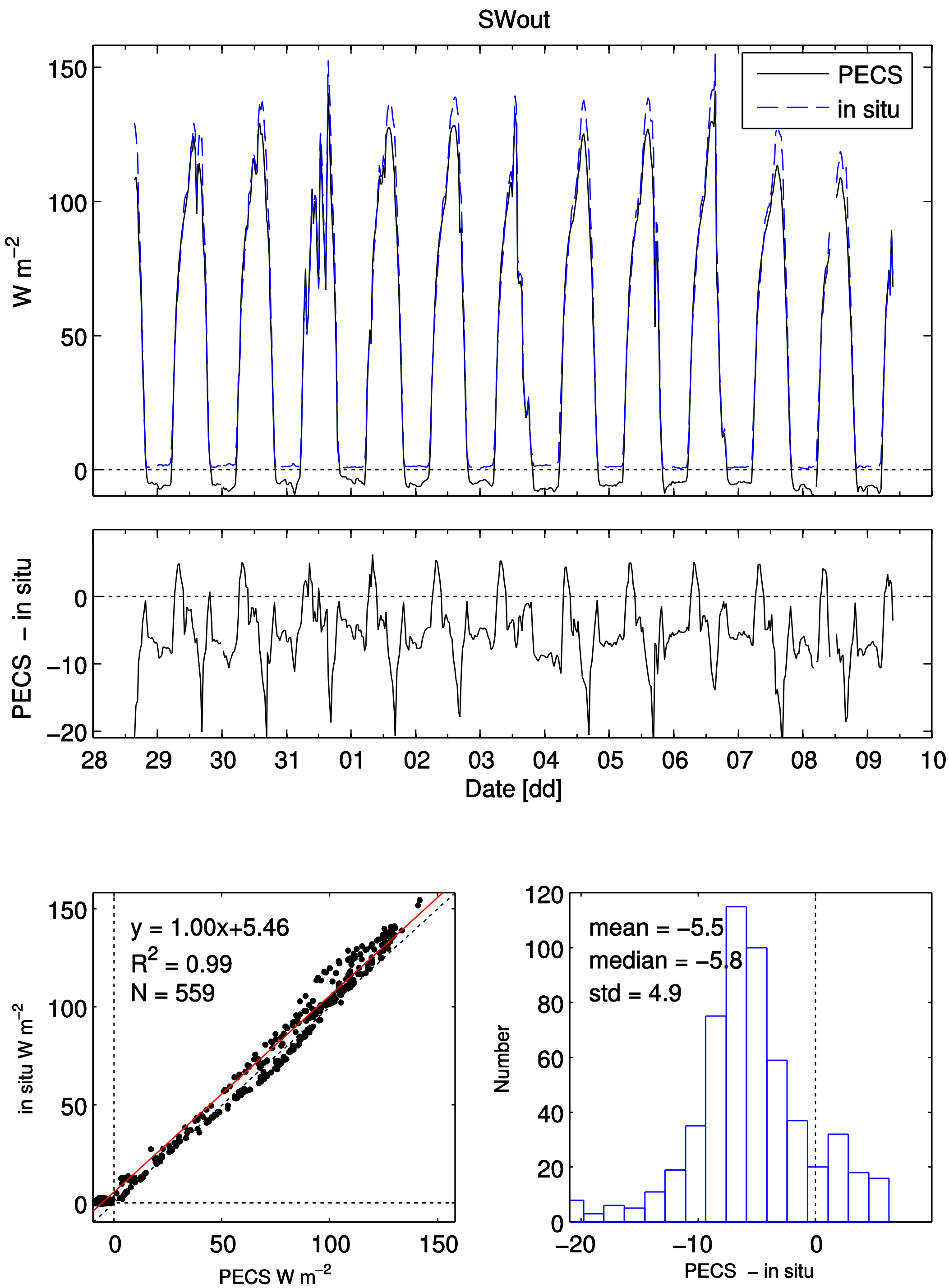


Figure 15 – Outgoing shortwave radiation.

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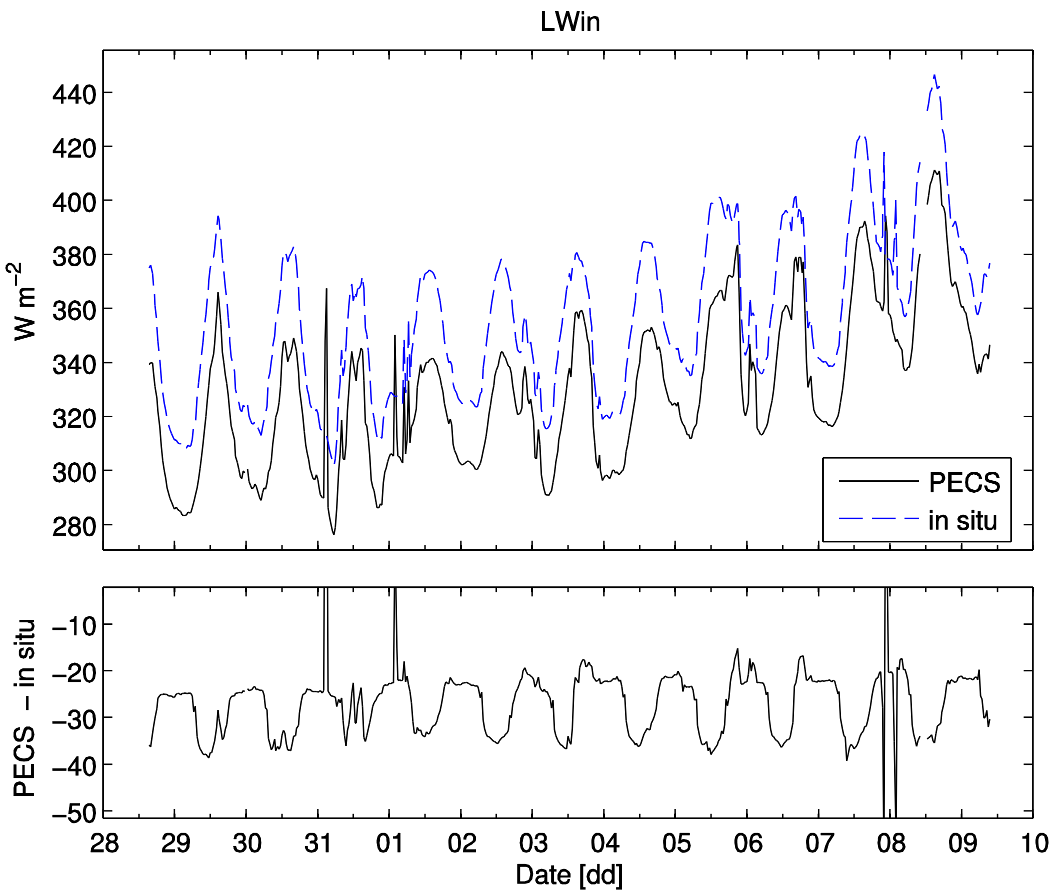

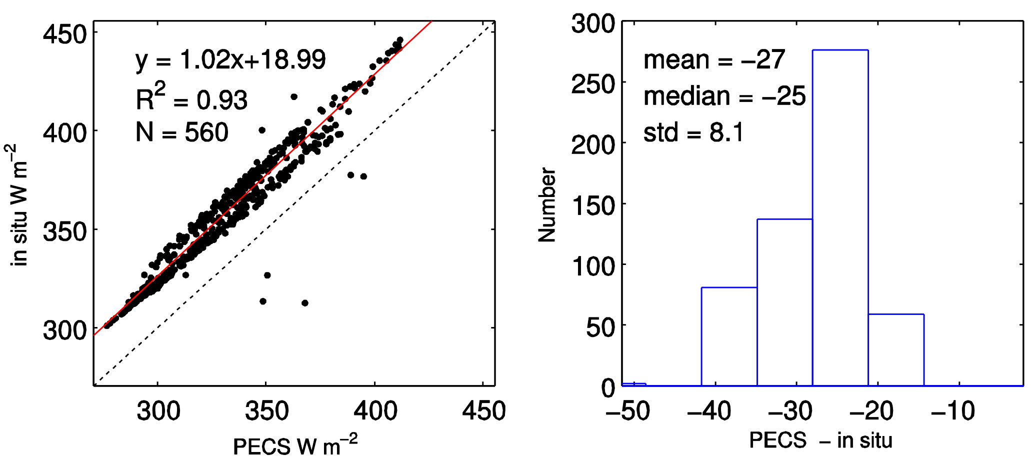

Figure 16 – Incoming longwave radiation.

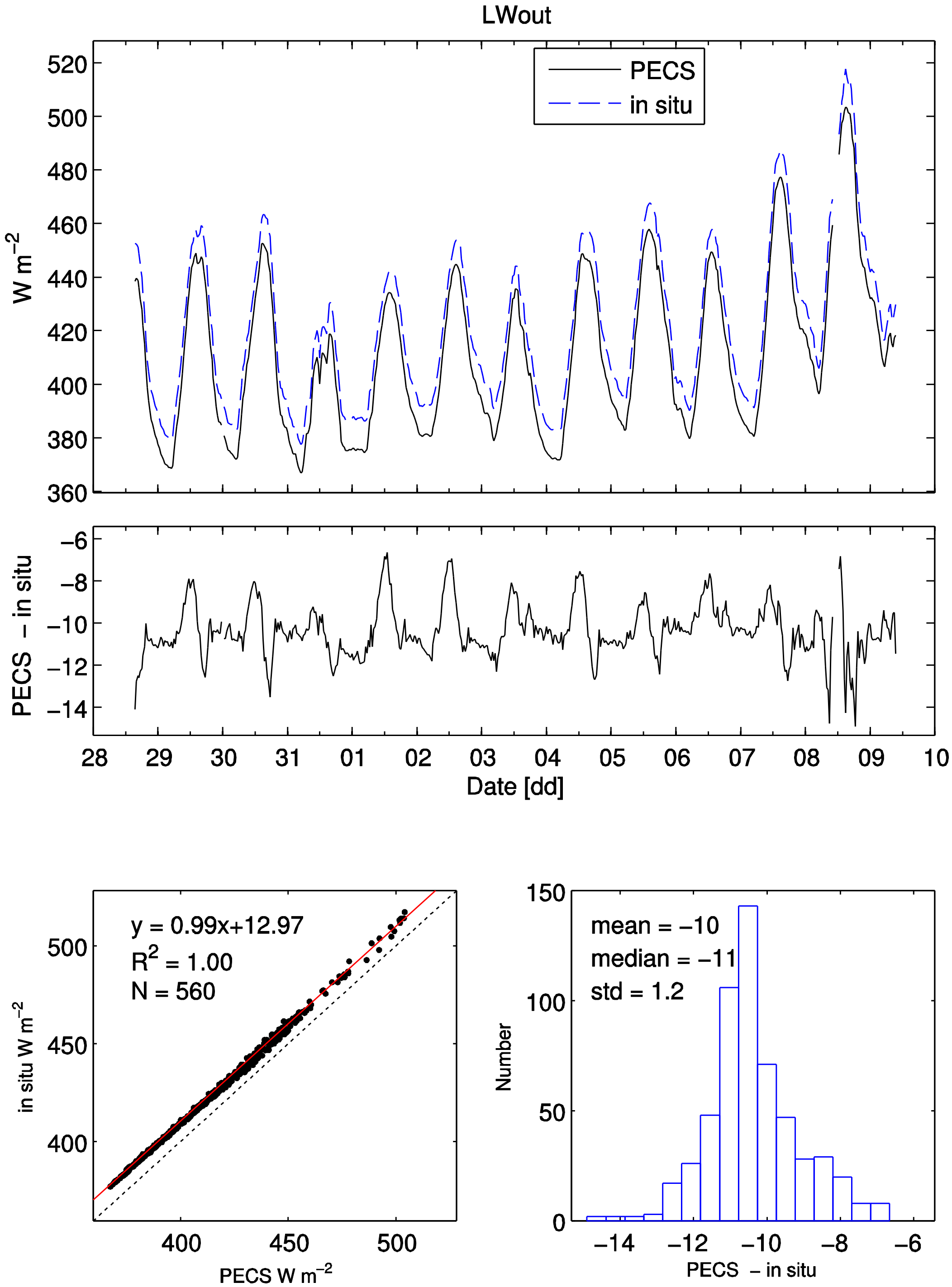

Figure 17 – Outgoing longwave radiation.

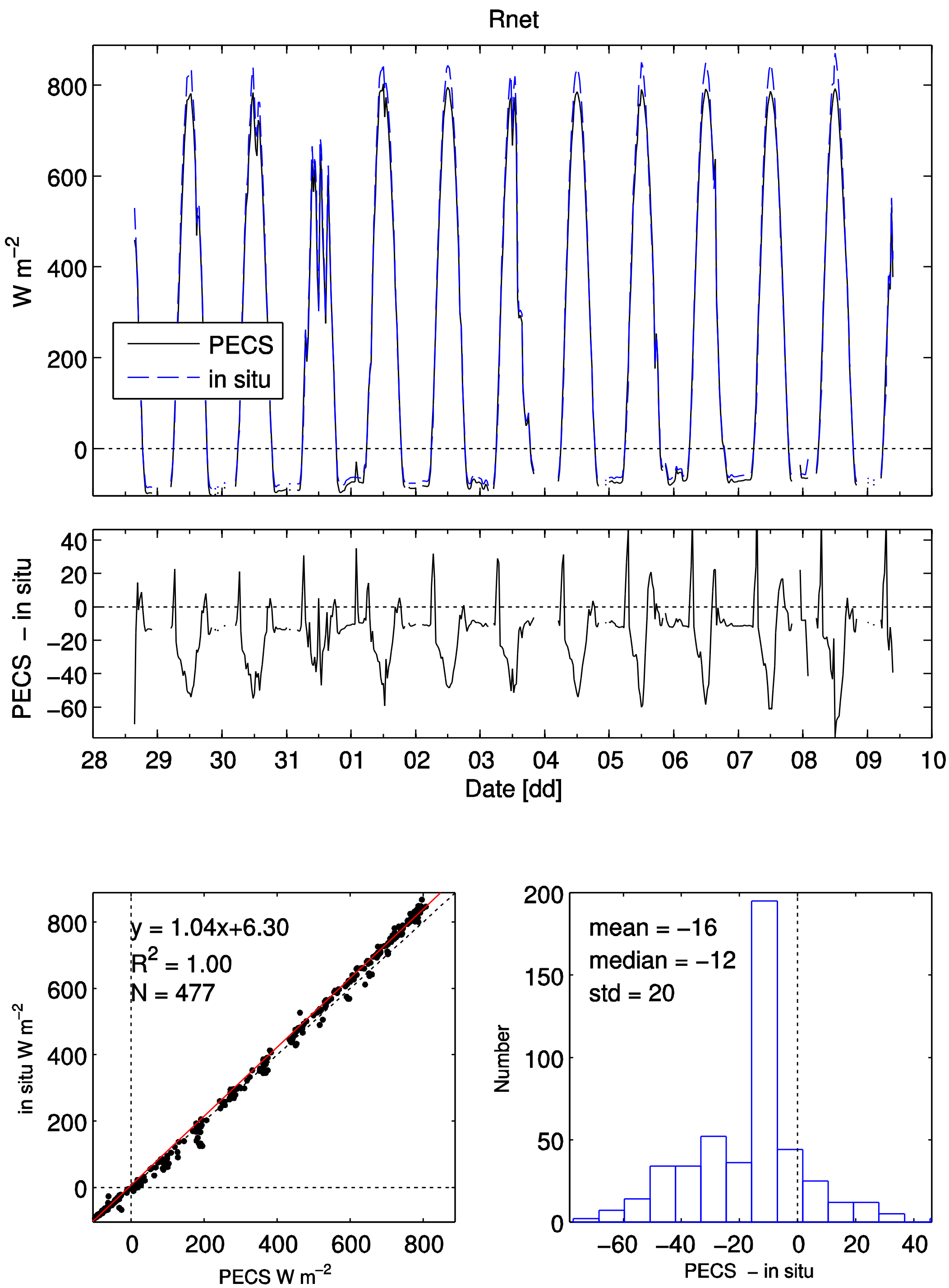

Figure 18 – Net radiation.

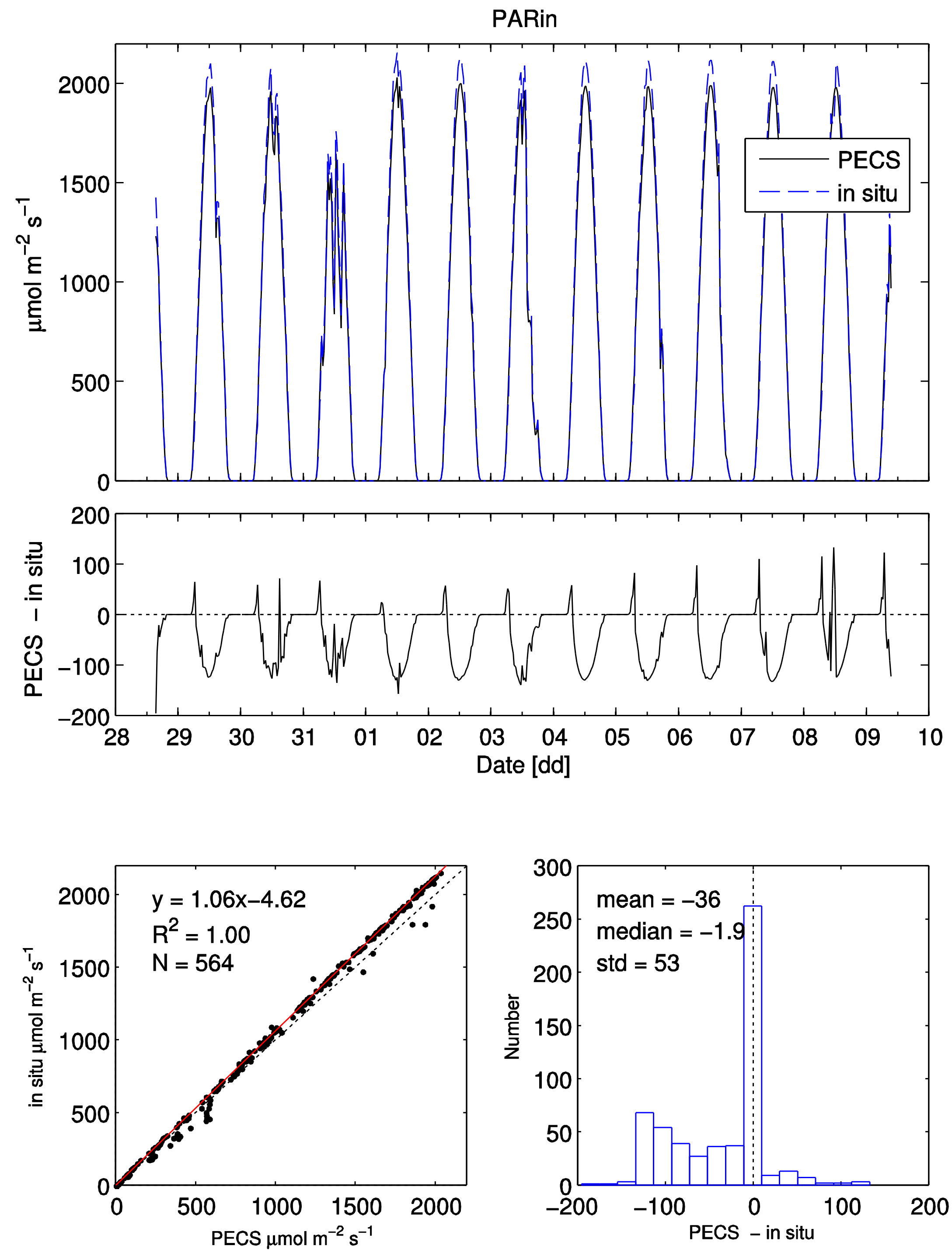

Figure 19 – Incoming photosynthetically active radiation (PAR).

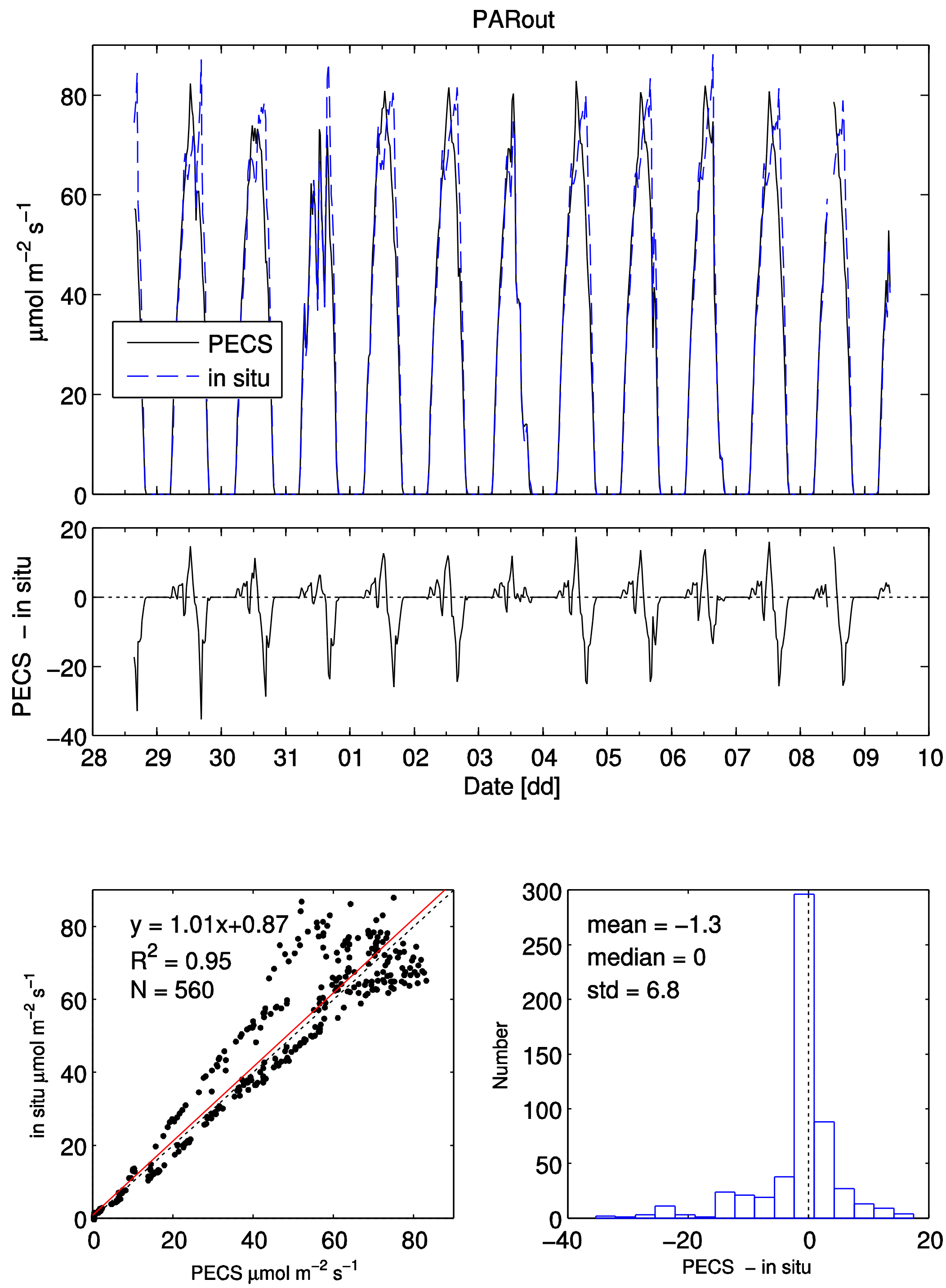

Figure 20 – Reflected photosynthetically active radiation (PAR).

Site Name: Twitchell East End Wetland (US–Tw4)
Visit Dates: May 29 - June 9 2015

	Statistics				PECS				in situ			
	slope	intercept	R2	N	mean1	std1	max1	min1	mean2	std2	max2	min2
Sensible heat	0.99	15.70	0.85	507	11.79	31.49	92.06	-58.88	27.40	33.88	105.98	-46.09
u star	1.06	-0.01	0.98	559	0.42	0.15	0.87	0.06	0.43	0.16	0.91	0.06
var(u)_{rot}	1.02	-0.01	0.99	558	1.16	0.75	4.16	0.06	1.18	0.77	4.35	0.07
var(v)_{rot}	1.08	-0.01	0.99	559	0.73	0.44	2.64	0.04	0.78	0.47	2.93	0.04
var(w)_{rot}	0.93	-0.01	0.99	559	0.28	0.17	1.01	0.01	0.25	0.16	0.95	0.00
Ta-HMP	1.02	-0.99	0.99	564	20.11	5.11	36.64	11.95	19.49	5.23	36.80	11.10
RH-HMP	0.97	-3.62	0.99	564	65.21	13.93	90.53	32.78	59.92	13.61	85.40	28.47
Wind spd	0.99	0.00	1.00	556	3.51	1.49	8.46	0.15	3.47	1.48	8.34	0.14
Wind dir	1.01	-4.28	1.00	556	252.70	37.95	351.99	6.13	251.75	38.48	351.23	4.32
SWin	1.02	-2.65	1.00	477	387.32	374.60	1008.24	-9.97	390.51	380.59	1033.33	-5.16
SWout	1.00	5.46	0.99	559	43.54	49.47	141.27	-9.47	49.05	49.76	155.07	0.07
LWin	1.02	18.99	0.93	560	329.98	28.50	411.22	276.15	356.79	30.26	446.64	301.72
LWout	0.99	12.97	1.00	560	411.11	29.12	503.45	366.96	421.48	28.96	517.72	377.61
Rnet	1.04	6.30	1.00	477	252.17	321.61	803.94	-101.91	268.26	334.46	870.46	-89.31
PARin	1.06	-4.62	1.00	564	628.28	718.69	2029.25	0.00	663.79	765.09	2154.01	0.00
PARout	1.01	0.87	0.95	560	26.82	28.50	82.87	0.00	28.09	29.71	88.25	0.00
CH_4	0.96	0.00	0.95	559	0.08	0.00	0.12	0.08	0.08	0.00	0.12	0.08
var(CH_4)	1.00	0.00	0.99	545	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 1 – Summary of basic statistics from linear regression and for each system of compared variables.

Appendix 1

General Site Information

Site name:	Twitchell East End, US-TW4
Mean canopy height (m); provide source of measurement:	?? (m)
Time zone of site data acquisition?	PST
Was PEC system sync'd to their local time? when?	Yes; May 28, 2015 (at PECS2 startup)
Sampling frequency of fast response system:	20 Hz

Latitude (+N/-S): 38.1030 (38° 06' 10.8")
Longitude (+E/-W): -121.6414 (-121° 38' 29.04")
Elevation: -5 m
Declination: 13.70° E on 2015-05-28

http://nature.berkeley.edu/biometlab/sites.php?site=US-Tw4

Site Instrumentation (make/model) - heights recorded below

Instrument	**Make/model**
Sonic anemometer	Gill WMP
Fast temperature sensor	
IRGA#1 (closed)	LI7500
IRGA#2 (open/closed)	
Other gas analyzer (describe)	
Radiometer#1 (specify net or which component)	CNR1
Radiometer#2 (specify net or which component)	
Radiometer#3 (specify net or which component)	
PAR#1	?
PAR#2	?
Temp. sensor#1 (is aspirated?)	HMP, fan aspirated
Temp. sensor#2 (is aspirated?)	
Humidity sensor (is aspirated?)	HMP, fan aspirated
Barometer	
Wind sensor	N/A
Vertical profile systems (temperature, winds, trace gases)	
Miscellaneous sensors (describe)	
Miscellaneous sensors (describe)	
Miscellaneous sensors (describe)	
Miscellaneous sensors (describe)	
Miscellaneous sensors (describe)	
Miscellaneous sensors (describe)	

Eddy covariance details (sensor heights, orientation, separation)

	PECS	in-situ
Sonic anemometer		
height [m]	5	5.05
orientation of sensor [o]	160	335
distance from tower/tripod [m]	0.25	0.25
orientation of boom (if different) [o]		
Open-path IRGA (measure relative to sonic)		
Vertical separation [cm] (pos if IRGA is above sonic)	-10	-1
E/W separation [cm] (pos if IRGA is east of sonic)	+7	+17
N/S separation [cm] (pos if IRGA is north of sonic)	+16	+22
Closed-path IRGA (measure relative to sonic)		
Vertical separation [cm] (pos if IRGA is above sonic)	-1	N/A
E/W separation [cm] (pos if IRGA is east of sonic)	+24	N/A
N/S separation [cm] (pos if IRGA is north of sonic)	+5	N/A
Inlet tube length [cm]	70	
Inlet tube inner diameter [mm]	5.3	
Inlet tube flow rate [lpm]	15	

Slow response details (sensor heights, orientation, separation)

	PECS	in-situ
Radiometer#1 - height [m]	3.8	4.15
Radiometer#1 - orientation [o]	170	260
Radiometer#2 - height [m]		
Radiometer#2 - orientation [o]		
PAR - height [m]	3.8	4.15
PAR - orientation [o]		
Temp. sensor#1 - height [m] (Asp)	4.13	4.65
Temp. sensor#2 - height [m] (HMP)	4.45	
Humidity sensor - height [m]	4.45	4.65
Barometer - height [m]		
Wind sensor - height [m]		

Separation between systems (relative to in-situ)

System components	Vertical separation (specify units) (pos. if PECS above in-situ)	Horizontal separation (specify units)	Orientation to PECS (o)
Eddy covariance	-0.05	1.25 m	180
Radiometer#1	-0.35 m	3.5	90
Radiometer#2			
PAR			
Temp. sensor#1	-0.2 m	2.2 m	180

(asp)			
Temp. sensor#2 (HMP)			

Appendix 2 – Photograph of site.

Photograph of deployment during the US-Tw4site visit. The PECS2 eddy covariance sensors were located in the center of the scaffold while the in situ eddy covariance sensors were on the left side.