Earth Sciences Division

February 4, 2014

Ankur Desai and Jonathan Thom,
Atmospheric & Oceanic Sciences Dept.
University of Wisconsin - Madison
Madison, WI 53706

Dear Ankur and Jonathan,

Thank you very much for hosting the AmeriFlux QA/QC site visit at Willow Creek, WI (US-WCr) from June 16-24 (DOY 167-175). We ended up with a productive comparison despite the challenges of the site generator replacement and thunderstorms. This report summarizes the findings and key recommendations from the comparison between the OSU AmeriFlux portable eddy covariance system (PECS) and the *in situ* system for eddy covariance, radiation, and meteorological observations at Willow Creek.

The AmeriFlux PECS 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 PECS included two infrared gas analyzers (a closed-path analyzer and an open-path analyzer). This comparison focuses on the PECS closed-path (CP) IRGA (LI-7200) and the *in situ* closed-path IRGA (LI-6262). Data processing of the AmeriFlux PECS data was conducted with the OSU AmeriFlux QA/QC Matlab based processing. 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 QA/QC 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 systems. The lower left figure is a scatter plot of both systems with a 1-to-1 line and a best fit linear regression 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 QC'ed. Hence missing data periods (Figure) occurred when data was screened from one or both systems either through data quality checks, rain, or no data (power outage).

Key Recommendations:

Overall, the comparison between the AmeriFlux PECS and the *in situ* system was good with an excellent CO_2 flux comparison. However, several measurements/sensors need more attention. A few key areas of improvement are highlighted below.

- LE (Figure , Figure , Figure , Figure), w'H_20 (Figure 15), and water vapor (Figure , Figure , Figure , Figure) mole density showed discrepancies with the PECS measurements particularly for the final day of the site visit (24 June). Please check inlet tubing for condensation; consider heating tubing or at least the IRGA itself.
- Regular calibration and maintenance of IRGAs is recommended even if the instrument is benchmarked against other sensors (i.e., HMP and profile system).
- Net radiation components were badly off during the site visit, but the radiometer was factory calibrated a few months after the site visit.
- Please check the calibration of your pressure sensor as there was a large offset from the PECS.

In closing, thank you for your cooperation before, during, and after the site visit. We are actively soliciting comments and/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 PIs to describe how the enclosed recommendations will be addressed. We are available to provide further analysis or discussion of the results, if needed. Thank you for working collaboratively with the AmeriFlux QA/QC Tech team.

Please review the general site information table in Appendix 1 of this document and let us know if you notice erroneous information.

All the best,

Chad Hanson[1], Stephen Chan[2], Sébastien Biraud[2], and David Billesbach[3]
Ameriflux QA/QC Technical team
[1]Oregon State University
[2]Lawrence Berkeley National Laboratory
[3]University of Nebraska, Lincoln

Detailed Report

Turbulent fluxes:

The dominant wind direction was from the south west and instruments were deployed facing into the wind. Latent heat (slope: 0.85, offset: 9.40 W m^{-2}, Figure) fluxes were on average underestimated by the *in situ* system relative to the PECS based on a linear regression. Upon closer analysis, a distinct change occurred on 24 June (Figure). When data after 24 June was removed, the comparison improved (slope: 1.05, offset: 7.53 W m^{-2}, Figure). The latent heat comparison between the two PECS gas analyzers was excellent (slope: 0.97, offset -9.16, Figure 6) throughout the campaign suggesting that something changed on the *in situ* IRGA on 24 June. I suspect the differences may be due to condensation in the inlet tube given the high humidity and thunderstorms during the comparison. It is worth noting that we screened a significant amount of data from our closed-path IRGA due to similar issues (Figure). I also recall that there was an issue with the tower top HMP used to calibrate the water channel of the *in situ* LI-6262 and that the lower (80 ft) HMP data was substituted for the period of the campaign. It may be worth investigating whether this played a role in the observed difference on the final day. The covariance of the vertical wind and H_2O showed a similar underestimation with the AmeriFlux PECS (slope: 0.73, offset: 0.17 mmol m^{-2} s^{-1}, Figure), which improved when data after 24 June was removed. In contrast to the H_2O components, the calculated CO_2 fluxes from the *in situ* system were excellent relative to the AmeriFlux PECS (slope: 1.01, offset: -0.51 µmol m^{-2} s^{-1}, Figure), as was the covariance of vertical wind and CO_2 (slope: 0.98, offset: 0.00 mmol m^{-2} s^{-1}, Figure). The *in situ* friction velocity (slope: 0.97, offset: 0.04 m s^{-1}, Figure) and sensible heat flux (slope: 1.00, offset: -0.33 W m^{-2}, Figure) both agreed very well with the AmeriFlux PECS.

To place these results in the context of the broader AmeriFlux network, we selected a few metrics (PAR, sensible heat, latent heat, CO_2 fluxes) to benchmark (Figure) against the accumulated record of AmeriFlux QA/QC site visits since 2002 (Schmidt et al., 2012). To accomplish this, we changed the reference value from a site maximum (equation 1, Schmidt et al., 2012) to a fixed value (Figure).

IRGA scalars and statistics:

Mean CO_2 mole density showed ~1 mmol m^3 overestimation by the *in situ* CP during the comparison (slope: 0.90, offset: 2.47 mmol m^{-3}, Figure). The H_2O mole density was underestimated by the *in situ* CP and there was noise in the regression plot (slope: 0.86, offset: 83.07 mmol m^{-3}, R^2: 0.93, Figure). As discussed above, the water vapor values from the *in situ* IRGA changed behavior relative to the PECS IRGA after 24 June (Figure) however the regression did not improve significantly when those data were removed (slope: 0.83, offset: 89.56 mmol m^{-3}, Figure). It is possible that saturation may have led to liquid water formation in the inlet tubing. Both IRGAs onboard the PECS agreed closely throughout the comparison (Figure 14). No statistics from the IRGA measurements (e.g., variances) were provided.

Sonic wind components and temperature:

Individual wind components from the sonic anemometer were not provided; only comparisons to mean wind speed and direction were conducted. The comparison of mean horizontal wind speed was quite good (slope: 0.95, offset: 0.12, Figure). The comparison of wind direction (derived from the sonic anemometers) was excellent (slope: 0.99 offset, -8.19, Figure).

Mean sonic temperature showed a good agreement (slope: 1.00, offset: 0.83° C) relative to the AmeriFlux sensor (Figure). The half-hourly covariances of the vertical wind and sonic temperature (slope: 0.93, offset: 0.00, Figure) agreed quite well as did the sensible heat flux (Figure).

Meteorological and radiation measurements:

Some meteorological variables compared very well while others needed some attention. Air temperature (slope: 1.02, offset: -0.24°C, Figure) differed by less than two percent. Barometric pressure data showed a large offset of over 6 kPa which I am unable to explain (Figure). No data was provided for the outgoing longwave or net radiation. Incoming shortwave radiation was severely underestimated by the *in situ* sensor while the outgoing shortwave component showed a very poor relationship with the PECS (Figure and Figure). The incoming longwave radiation also showed no real relationship with the PECS CNR1 (Figure). As we discussed during the visit, a replacement net radiometer as planned for the site is clearly needed (we are aware the net radiometer was recalibrated after the site visit). The *in situ* incoming photosynthetically active radiation (PAR) sensor was in excellent agreement (slope: 1.02, offset: 6.84 μmol m^{-2} s^{-1}, Figure). I would like to remind you that the AmeriFlux QA/QC Tech laboratory provides calibration of PAR sensors at no cost. No diffuse radiation sensor was available during the campaign.

References:

Schmidt, A., C. Hanson, W. S. Chan, and B. E. Law, Empirical assessment of uncertainties of meteorological parameters and turbulent fluxes in the AmeriFlux network, J. Geophys. Res., 117, G04014, doi:10.1029/2012JG002100, 2012.

Table of Figures

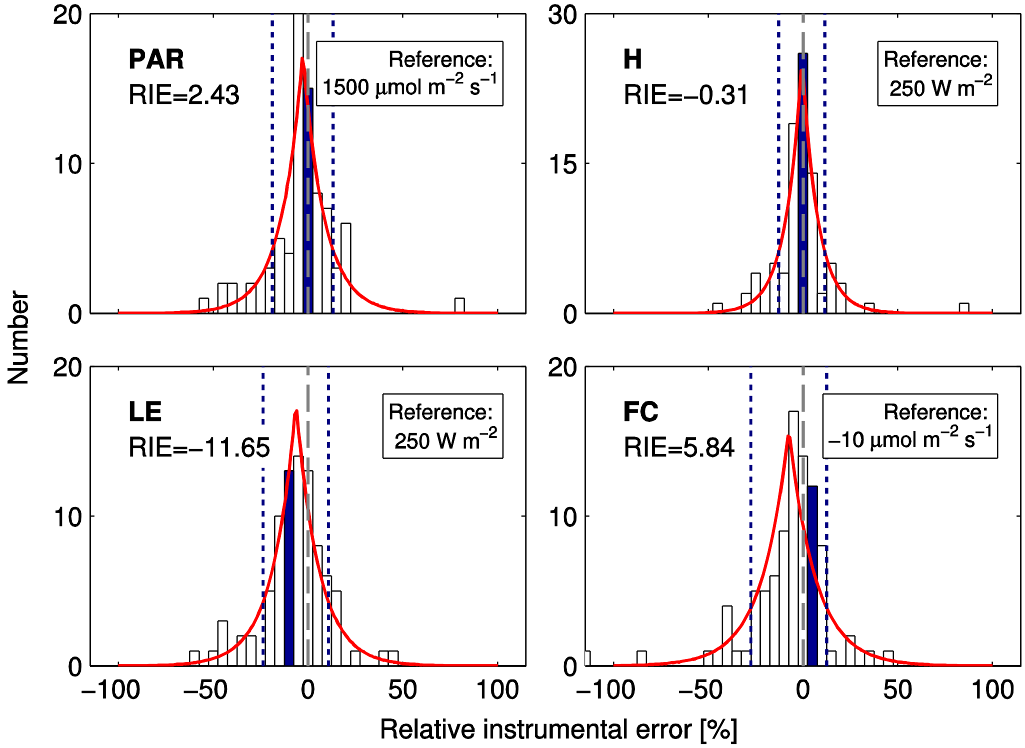

Figure – Histogram of relative instrumental error (RIE) for 4 selected variables based on the accumulated record of AmeriFlux site visits. Blue colored bar denotes the RIE from this site visit (bar width = 5%). Laplace distribution illustrated in solid red line. Dashed, vertical blue lines denote mean ± $\sqrt{2}\beta$, where β is a scale parameter describing the Laplace distribution. The term $\sqrt{2}\beta$ is equivalent to the standard deviation in a normal distribution.

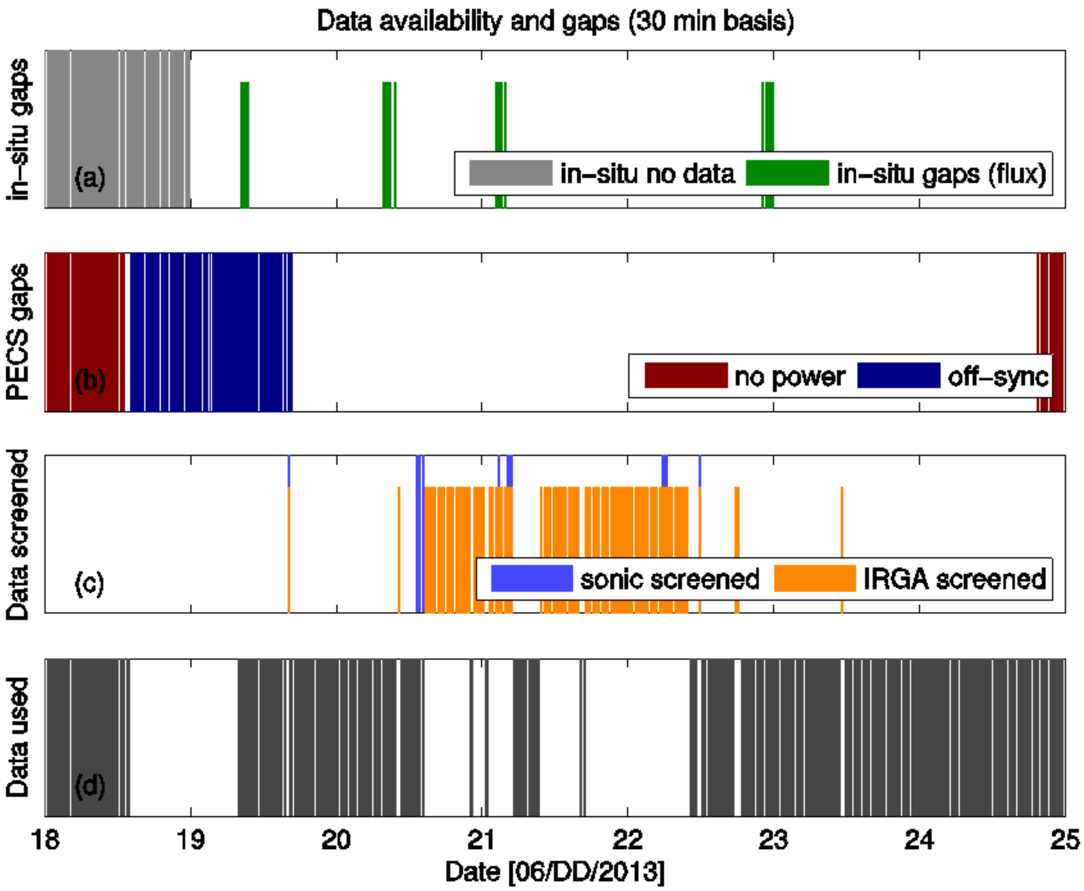

Figure – Data gaps from *in situ* system (top) and PECS (second from top). For the PECS, red areas were due to power outages at the site and green areas were screened. Periods when data was available from both systems is shown in the lower panel.

Site Name: Willow Creek (US – WCr)
Visit Dates: 16-24 June 2013

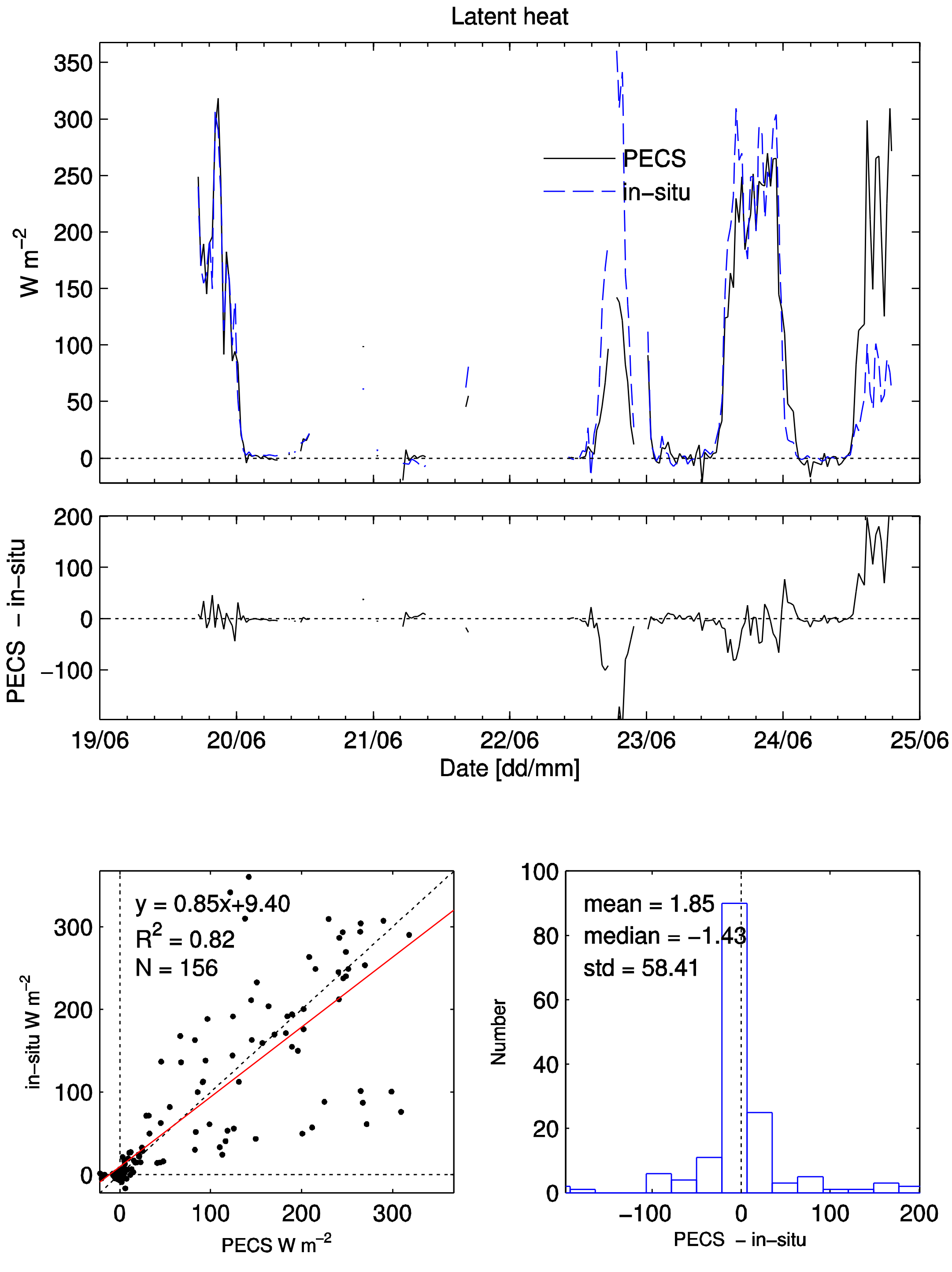

Figure – Closed path latent heat fluxes.

Site Name: Willow Creek (US – WCr)
Visit Dates: 16-24 June 2013

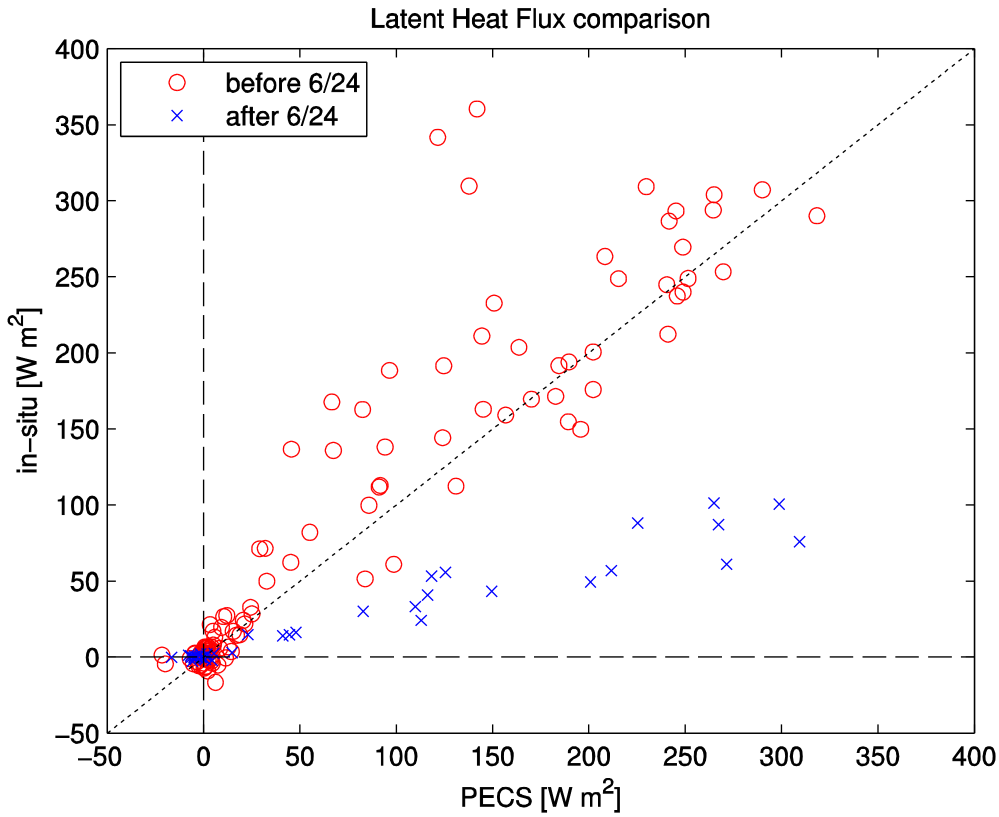

Figure – Scatter plot of latent heat fluxes separated by date.

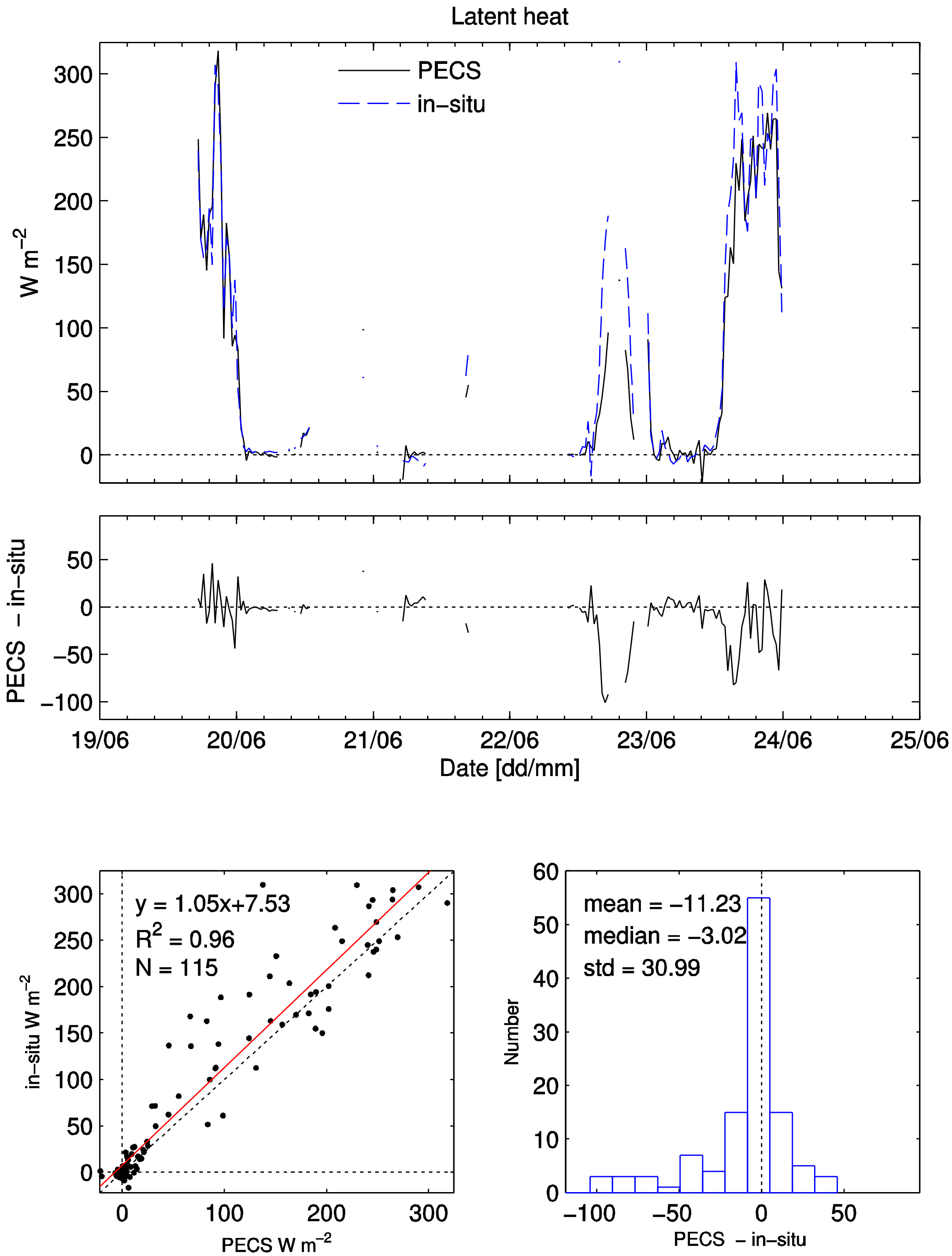

Figure – Closed path latent heat fluxes with points after 24 June removed.

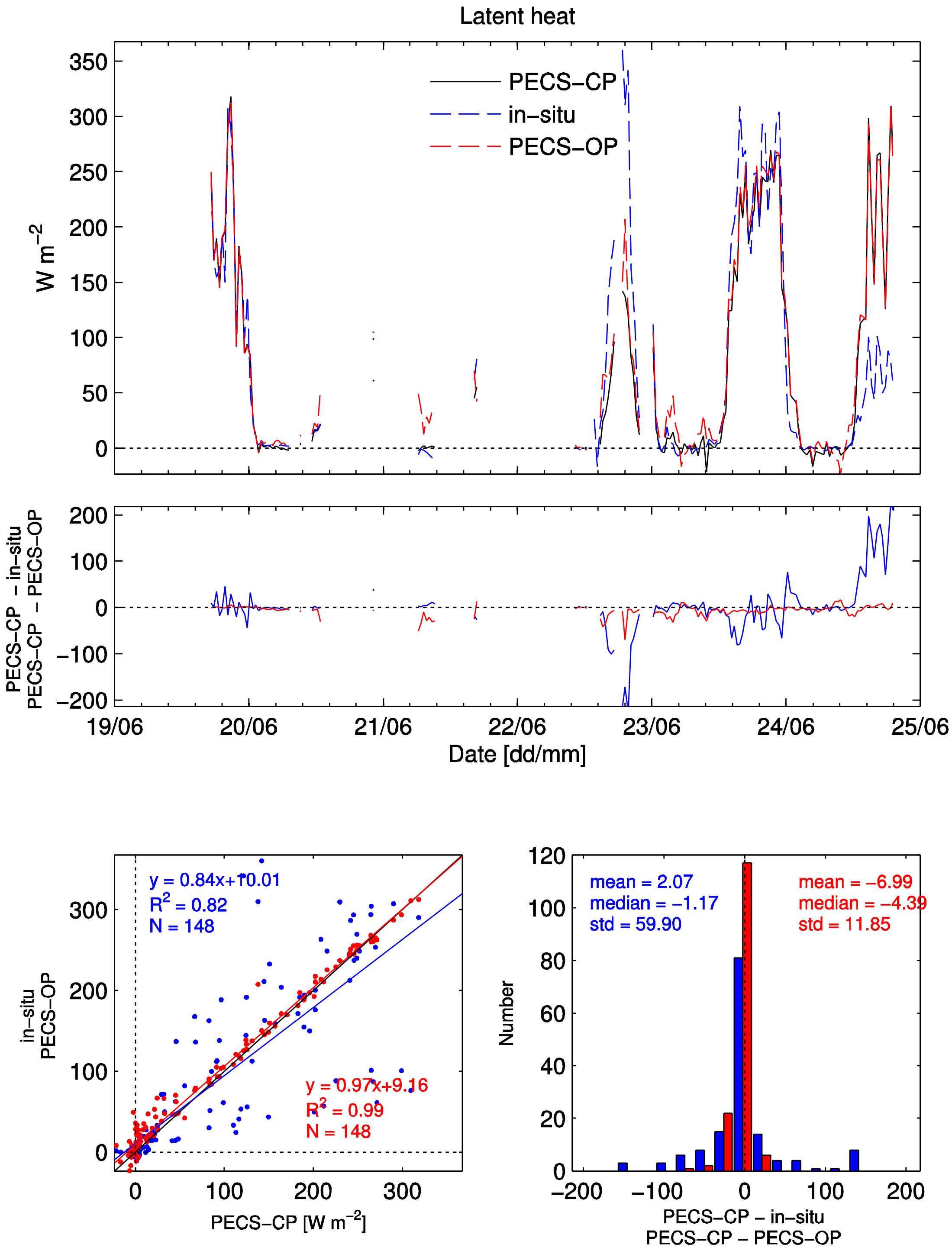

Figure – PECS open-path, closed-path and *in situ* latent heat fluxes.

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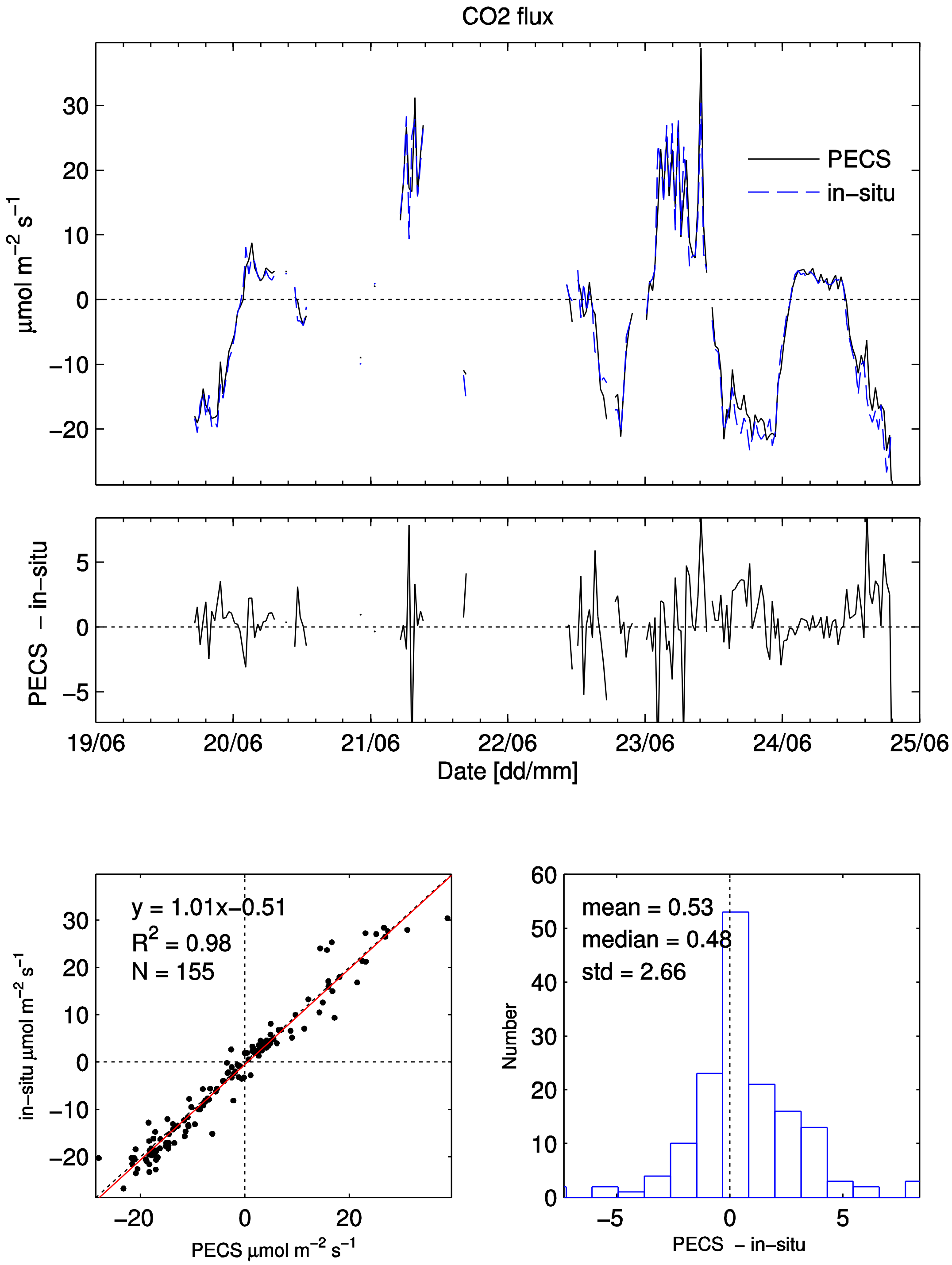

Figure – Carbon dioxide flux.

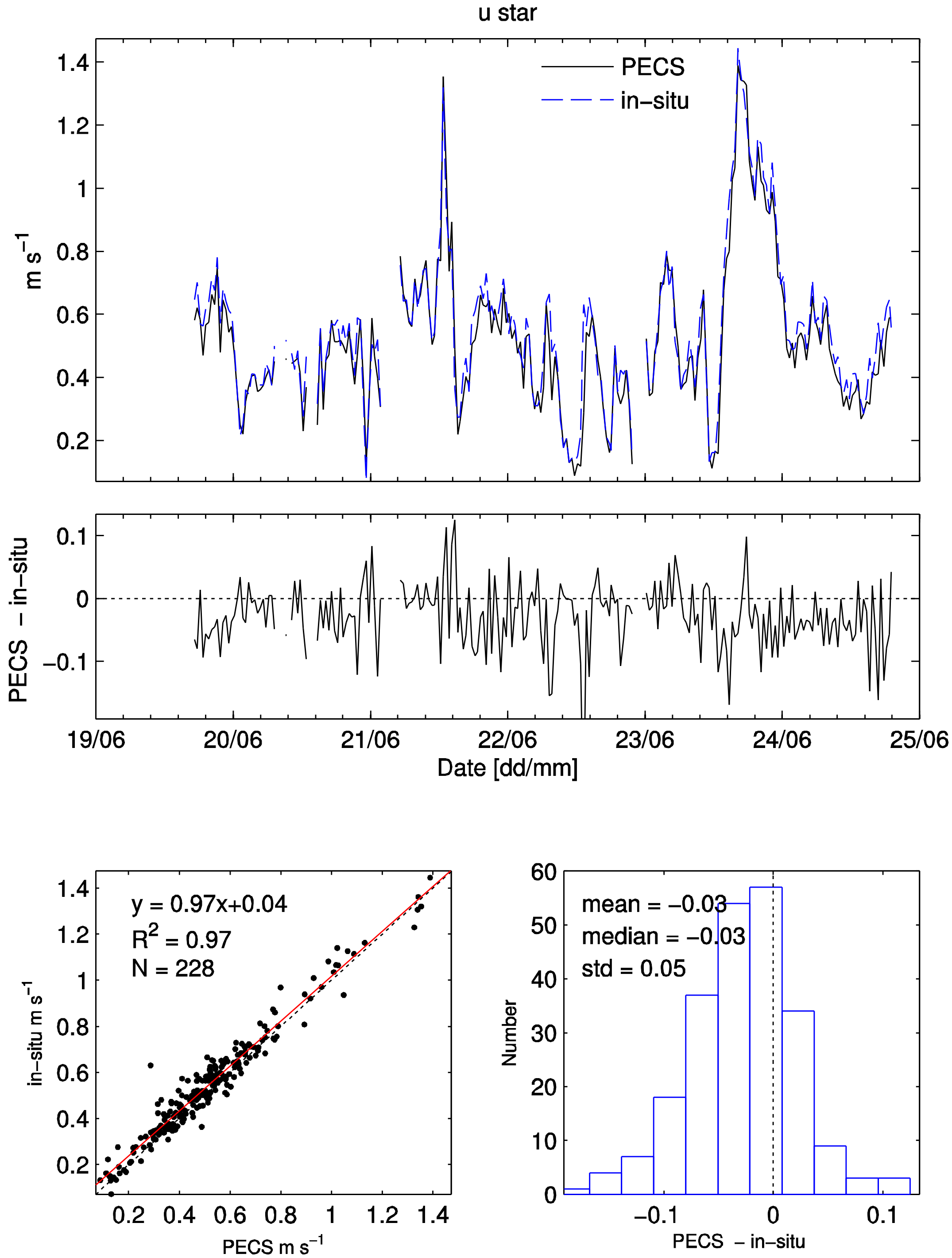

Figure – Friction velocity.

Site Name: Willow Creek (US – WCr)
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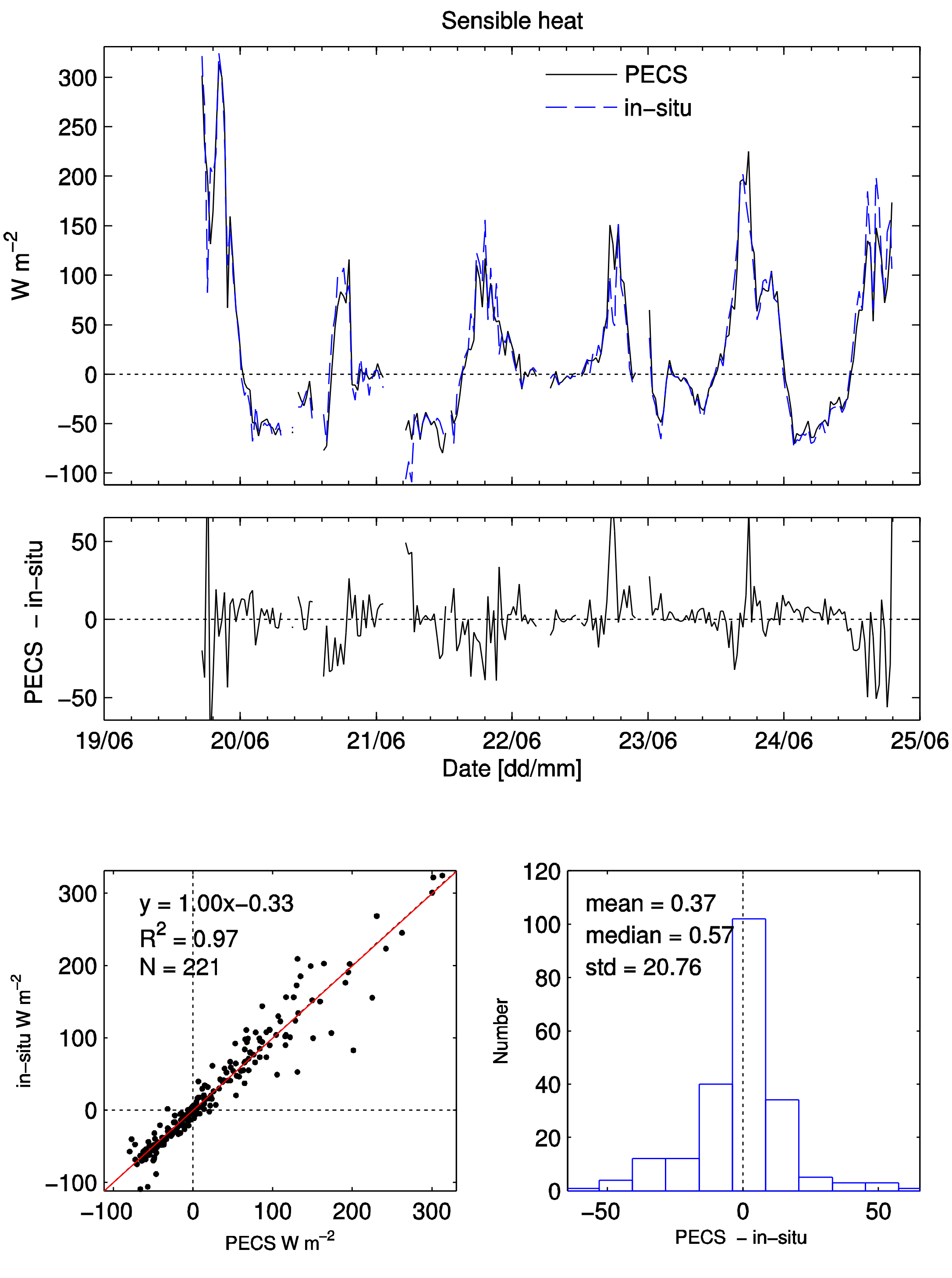

Figure – Sensible heat flux.

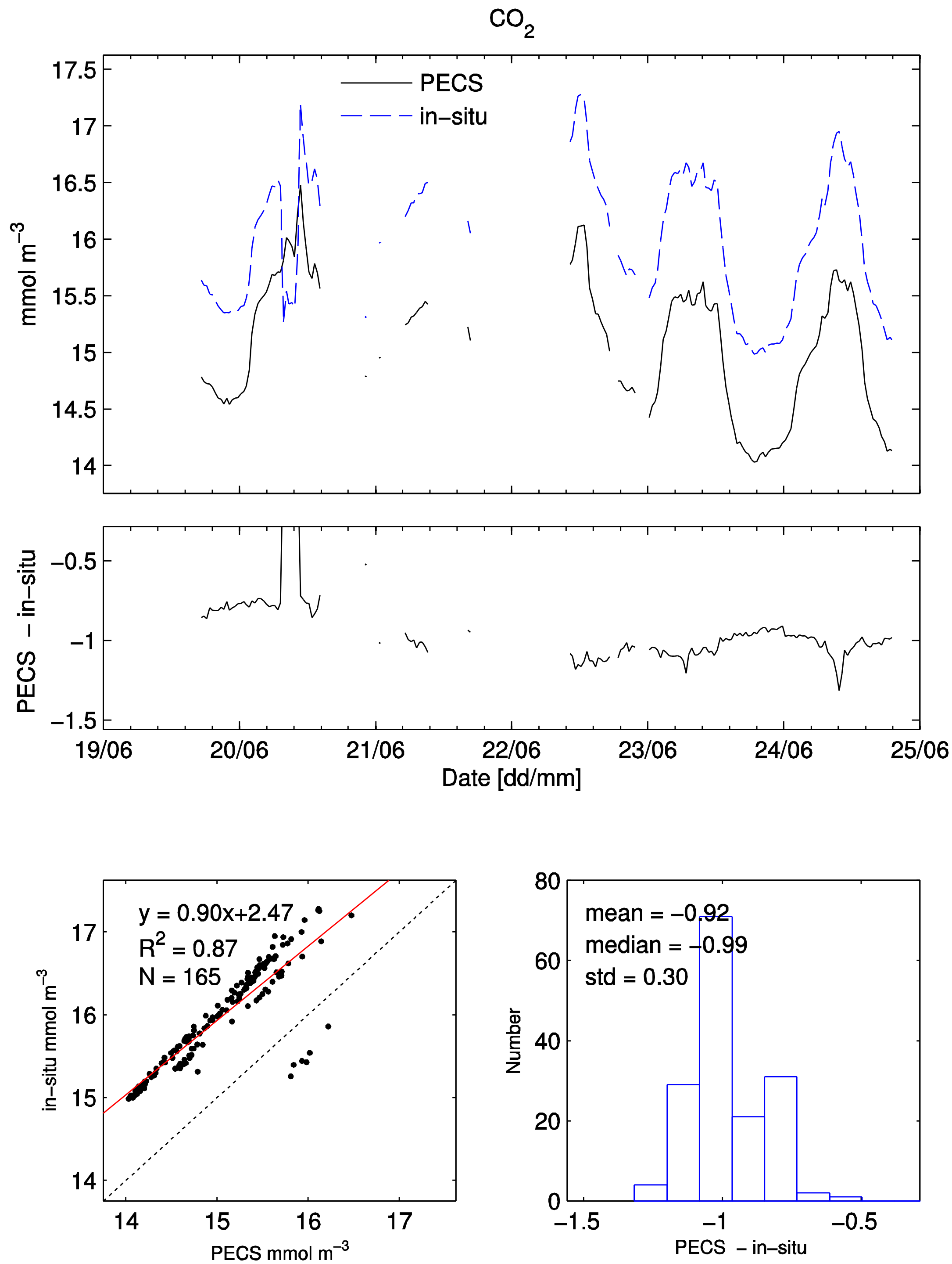

Figure – Carbon dioxide molar densities.

Site Name: Willow Creek (US – WCr)
Visit Dates: 16-24 June 2013

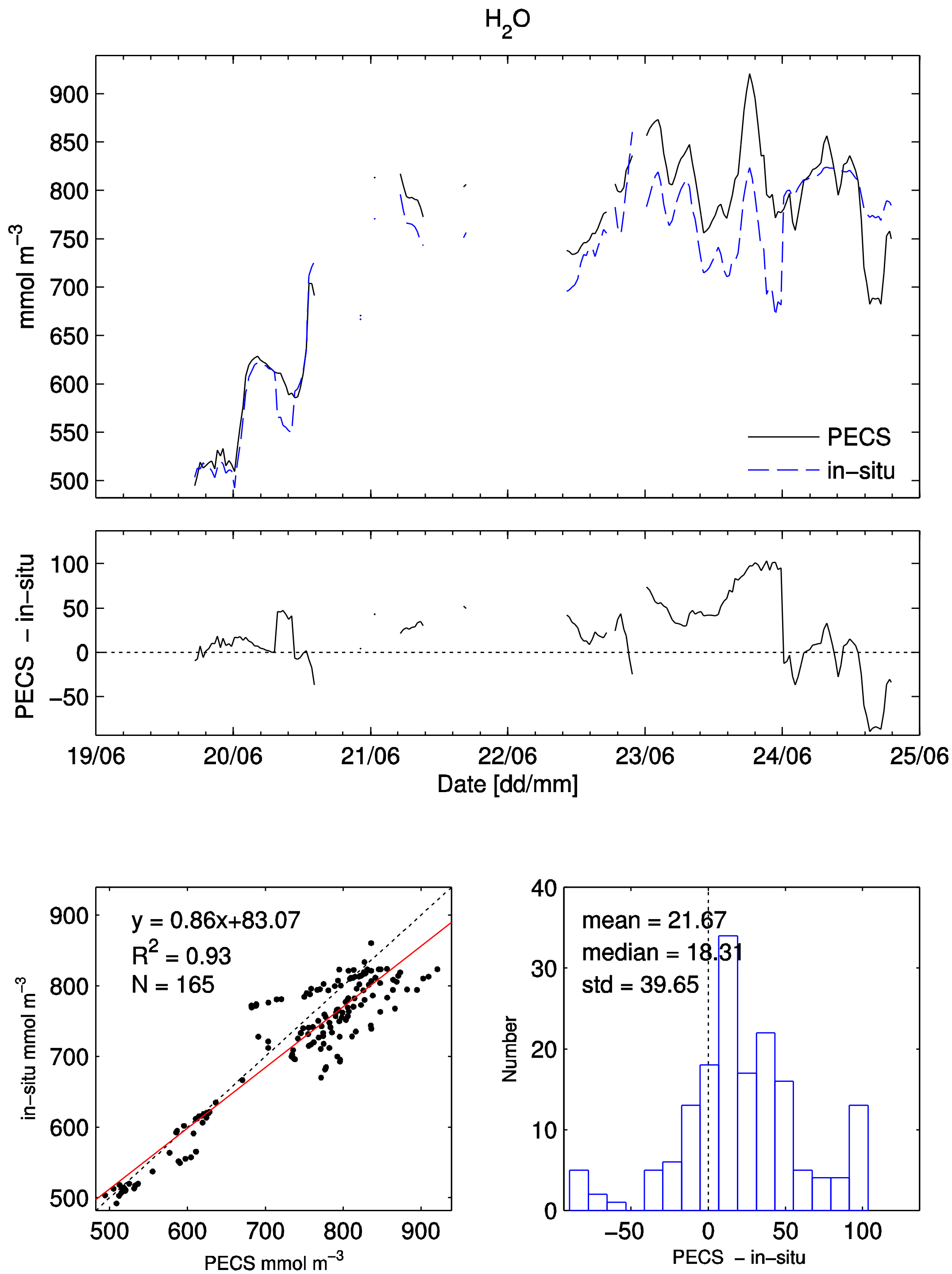

Figure – Water vapor molar densities.

Site Name: Willow Creek (US – WCr)
Visit Dates: 16-24 June 2013

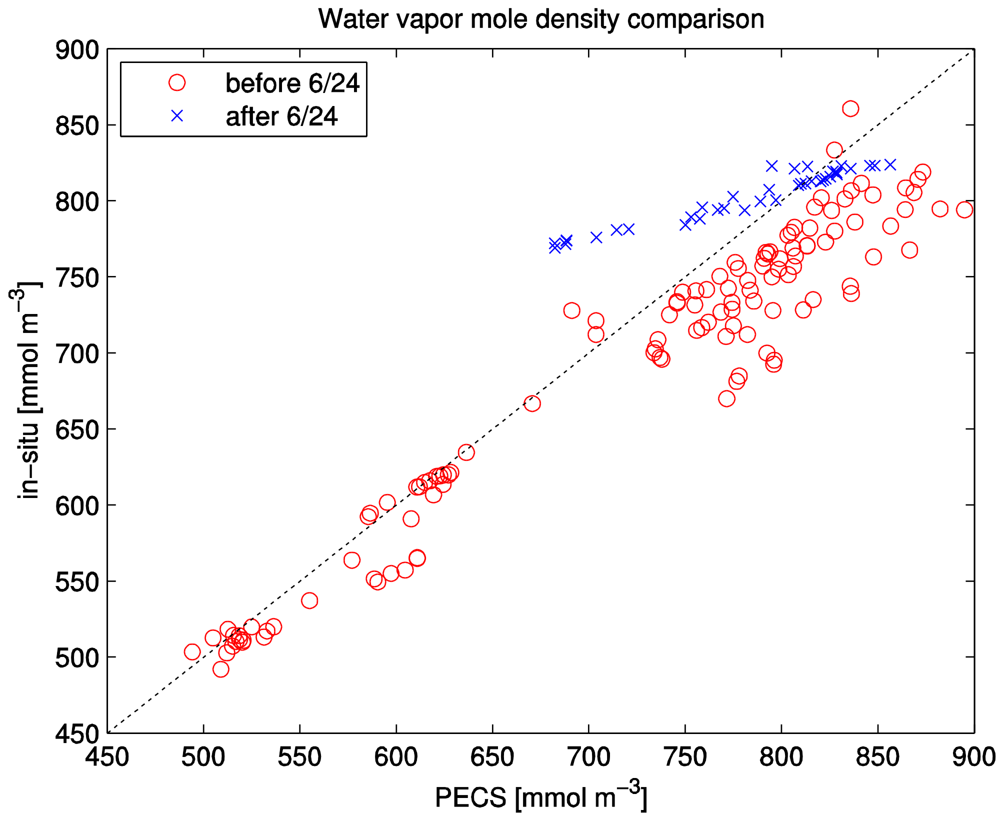

Figure – Scatter plot of water vapor molar densities separated by date.

Site Name: Willow Creek (US – WCr)
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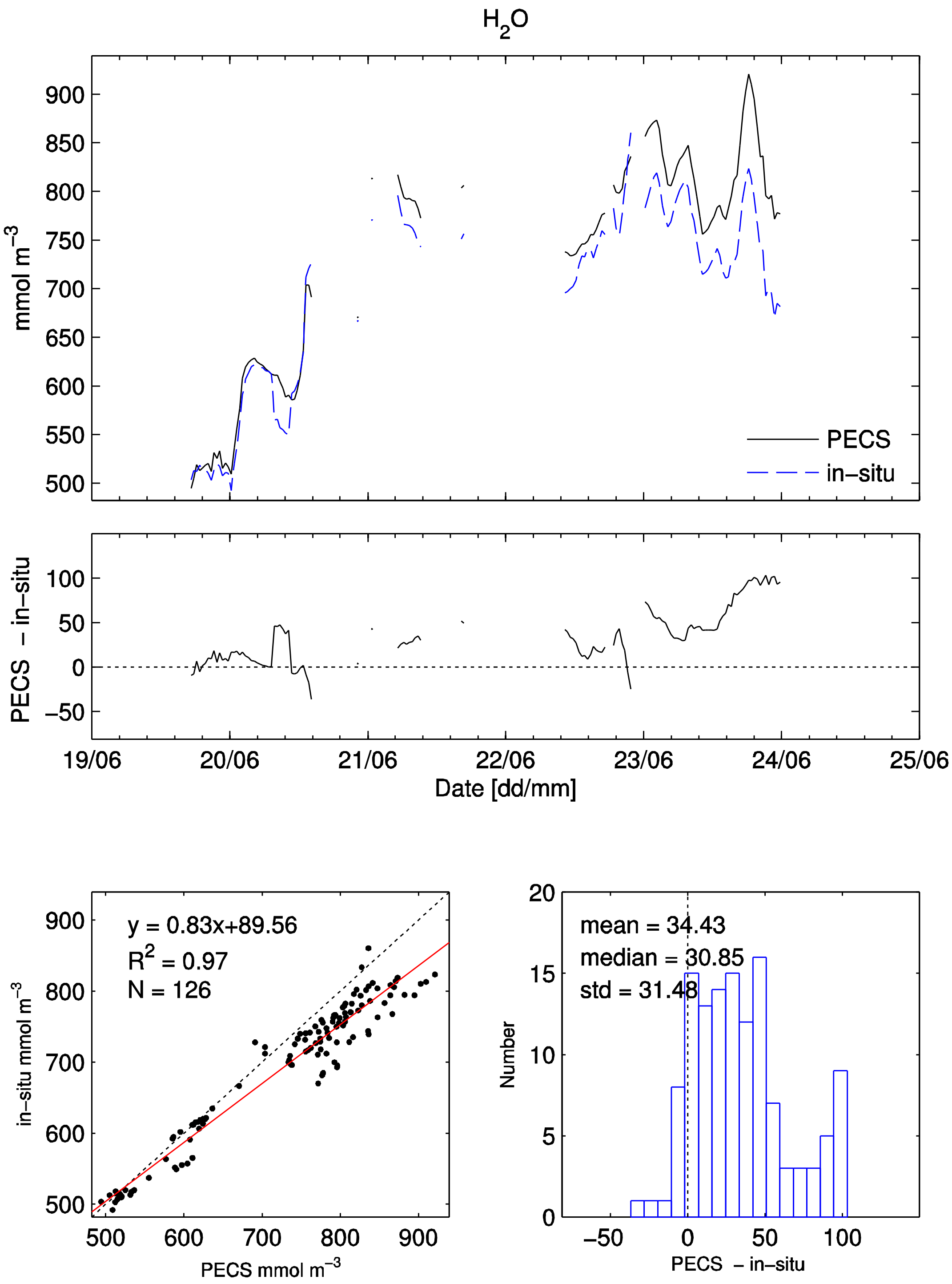

Figure – Water vapor molar densities with points after 24 June removed.

Site Name: Willow Creek (US – WCr)
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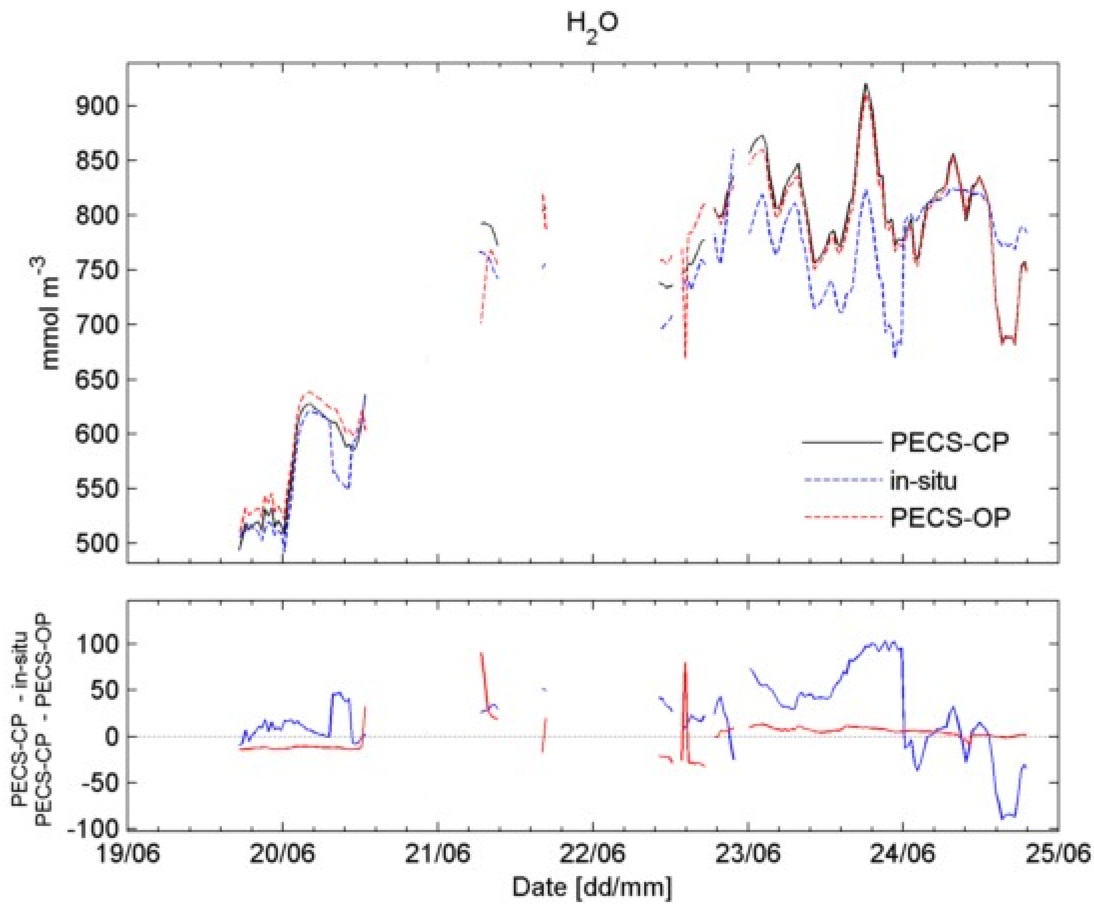

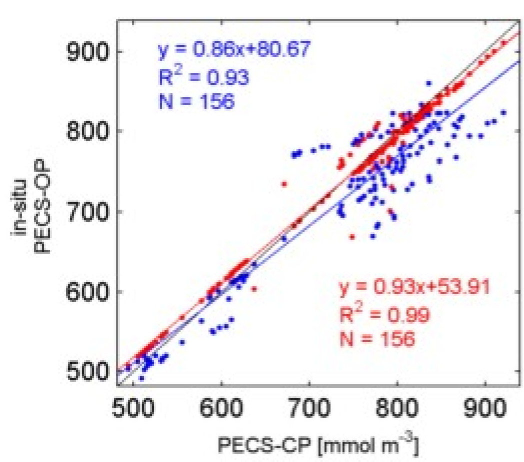

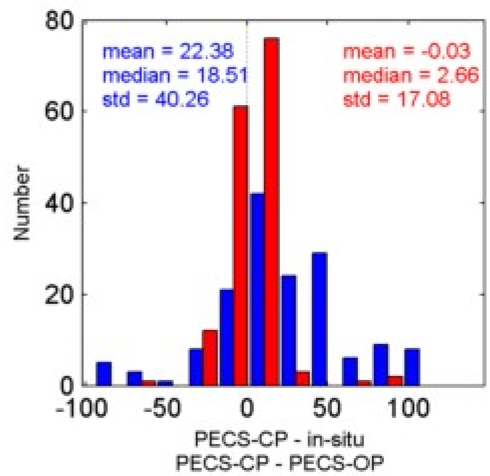

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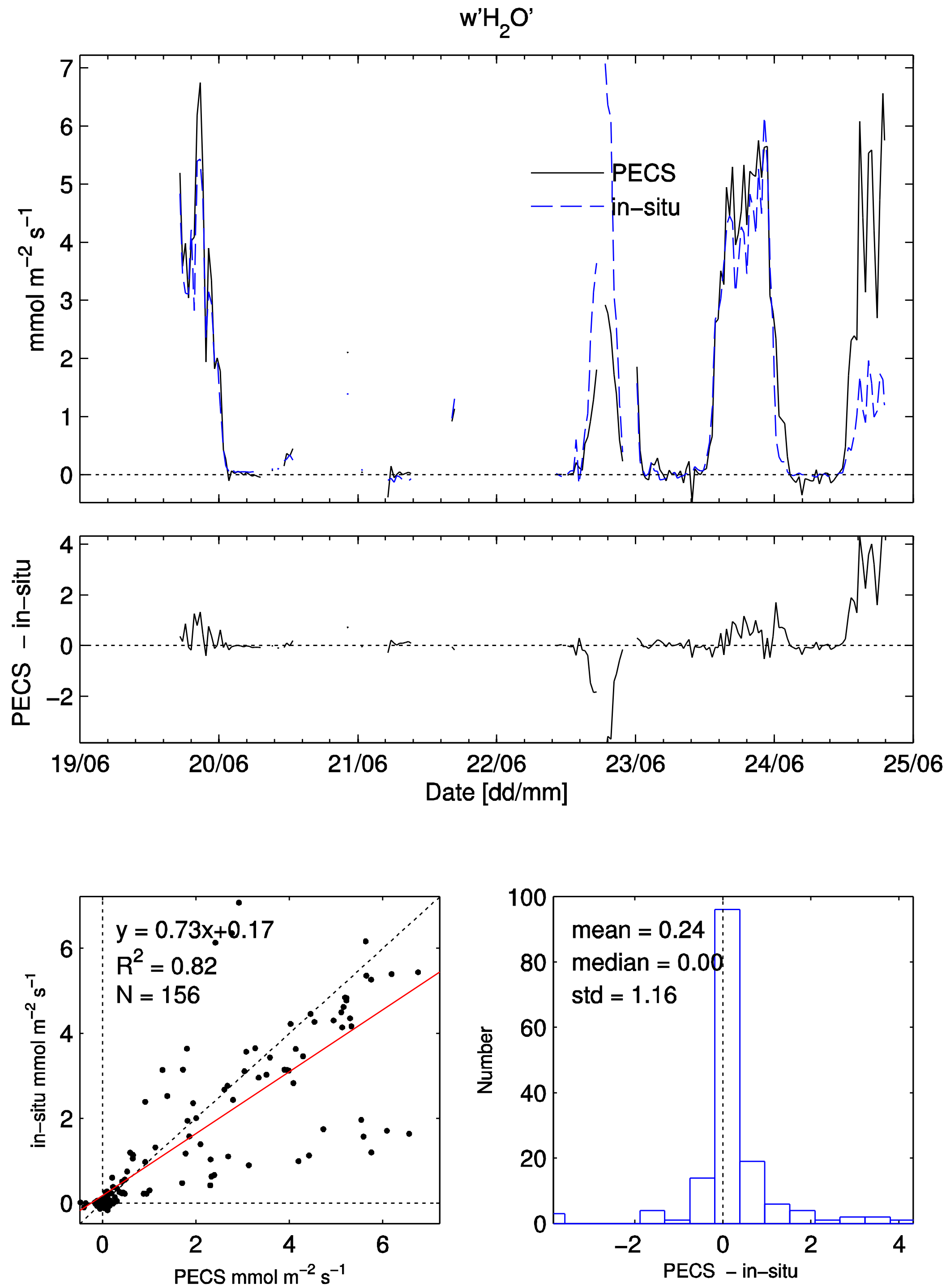
Figure – PECS open-path, closed-path, and *in situ* water vapor molar densities.



Site Name: Willow Creek (US – WCr)
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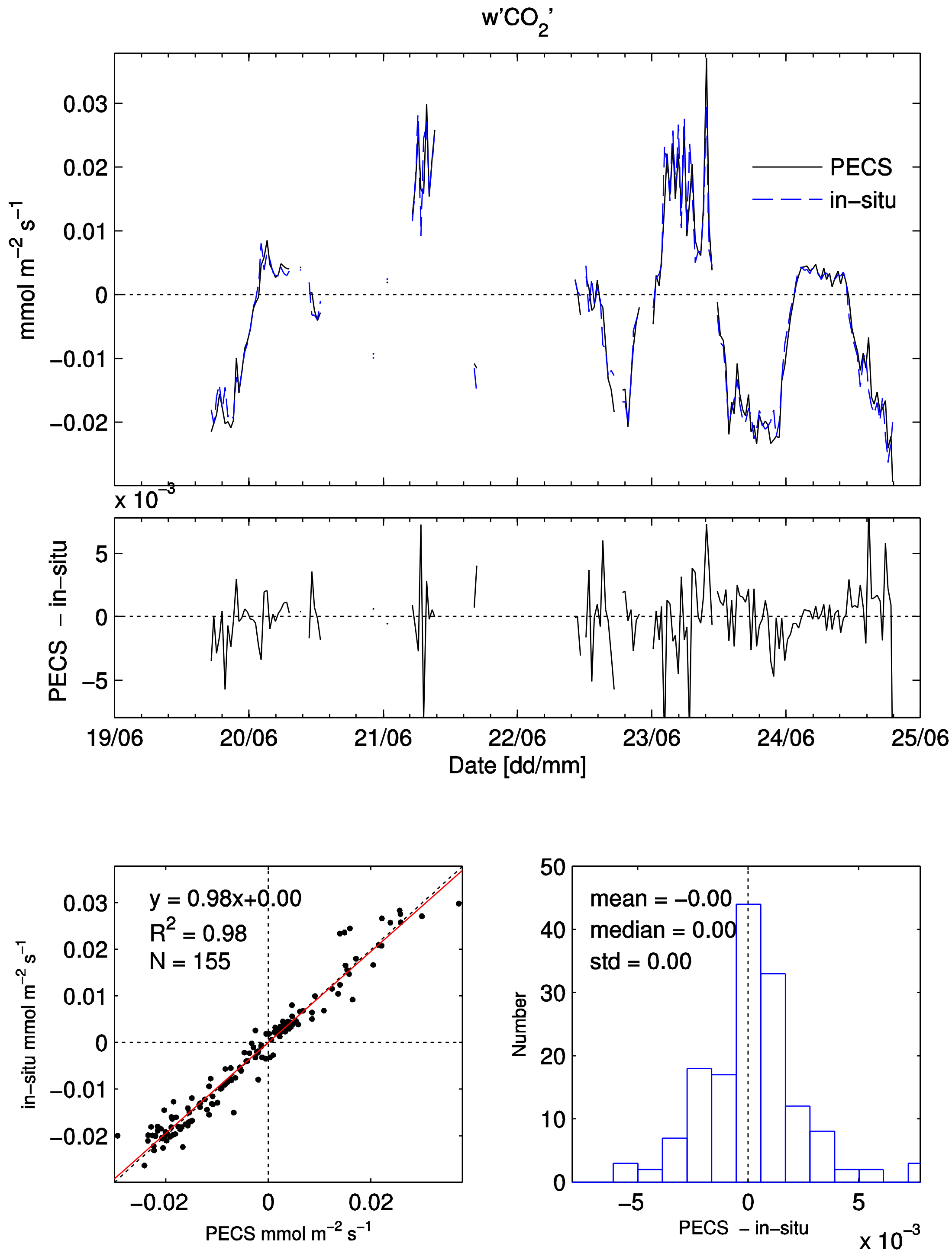
Figure - Covariance of vertical wind and water vapor.



Site Name: Willow Creek (US – WCr)
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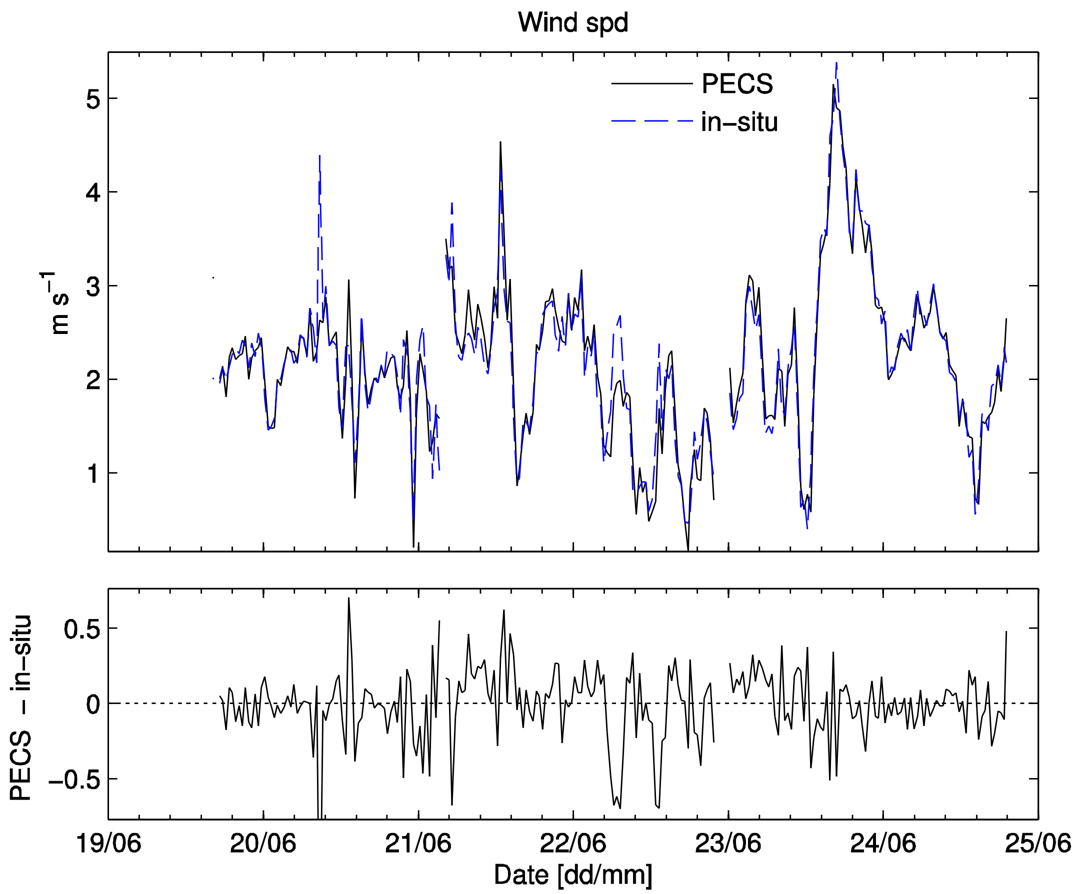
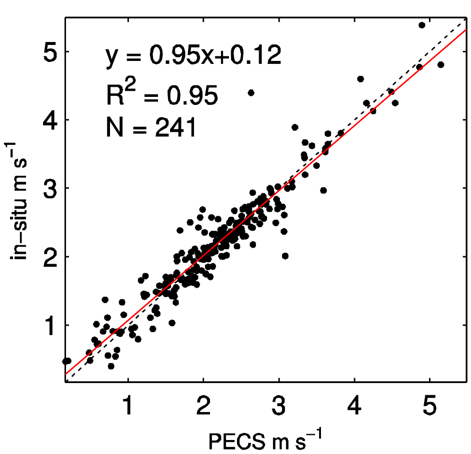
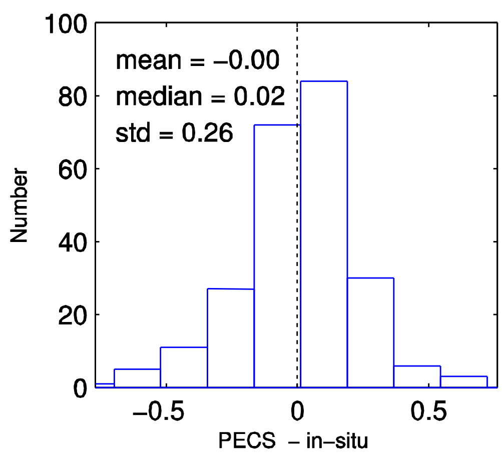
Figure - Covariance of vertical wind and carbon dioxide.

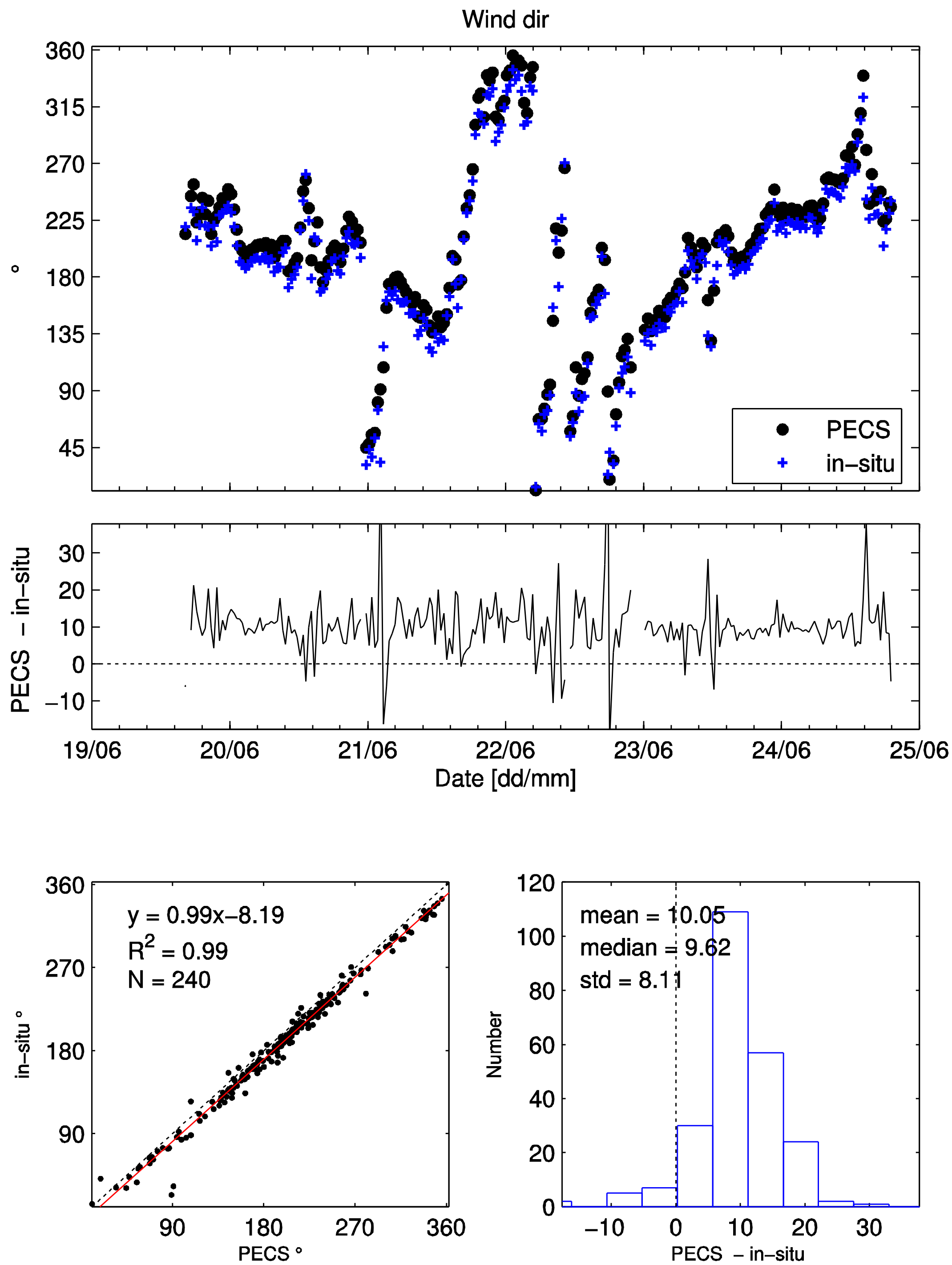






Site Name: Willow Creek (US – WCr)
Visit Dates: 16-24 June 2013

Figure – Mean horizontal wind speed.



Site Name: Willow Creek (US – WCr)
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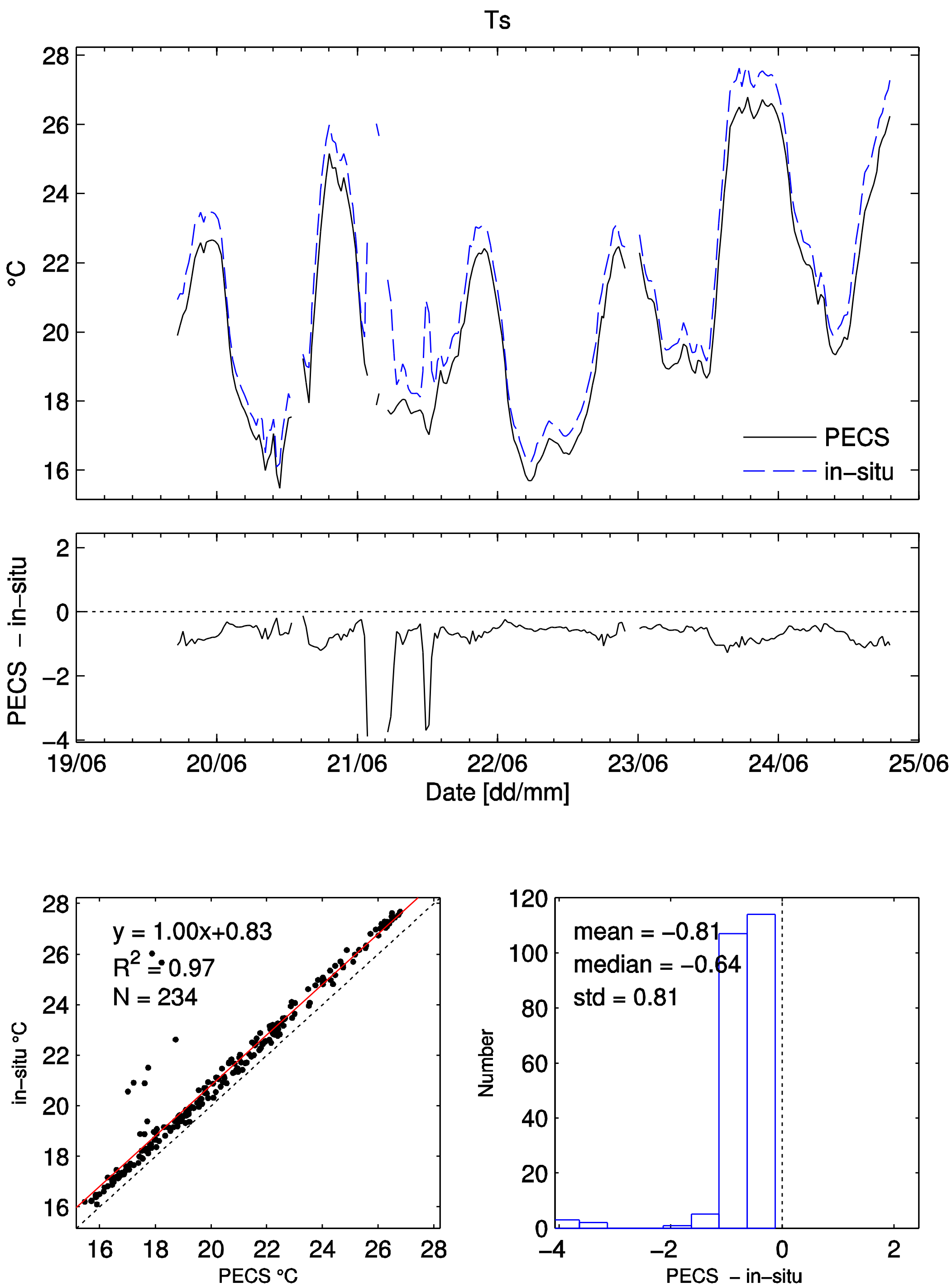
Figure – Wind direction.



Site Name: Willow Creek (US – WCr)
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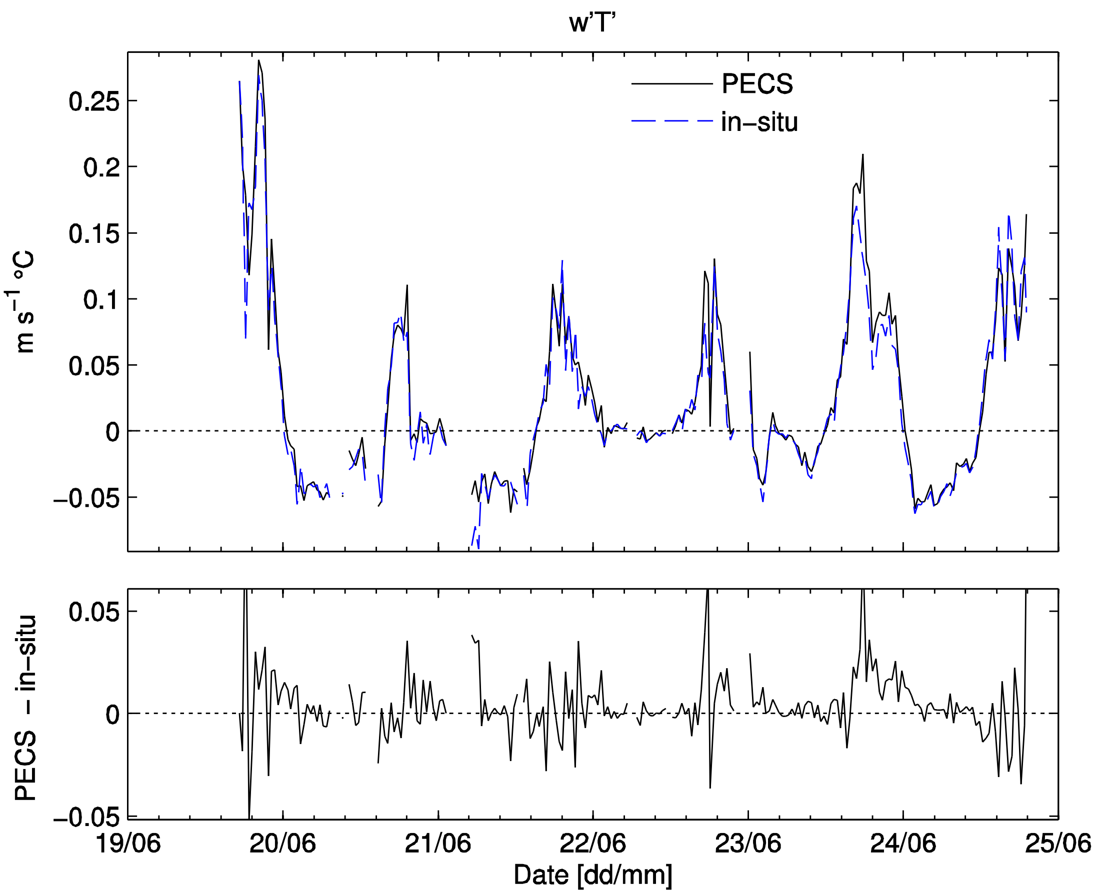
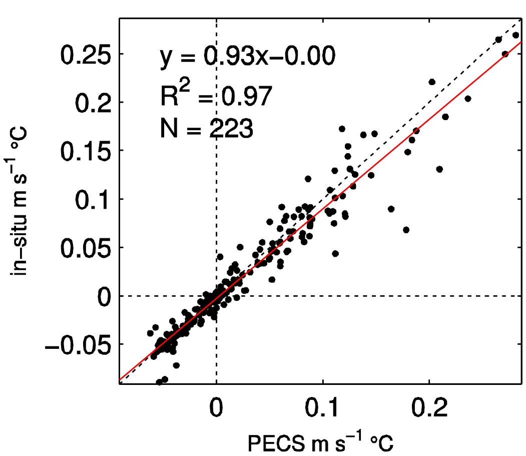
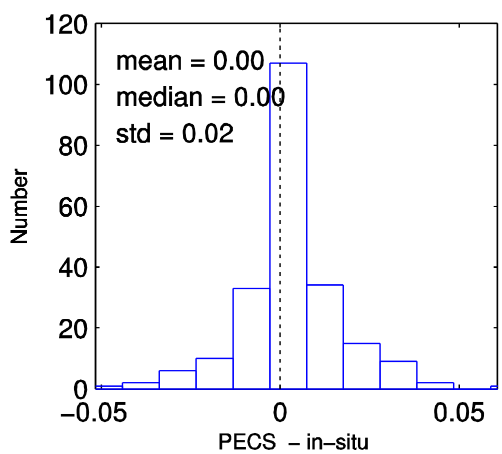
Figure - Mean sonic temperature.







Site Name: Willow Creek (US – WCr)
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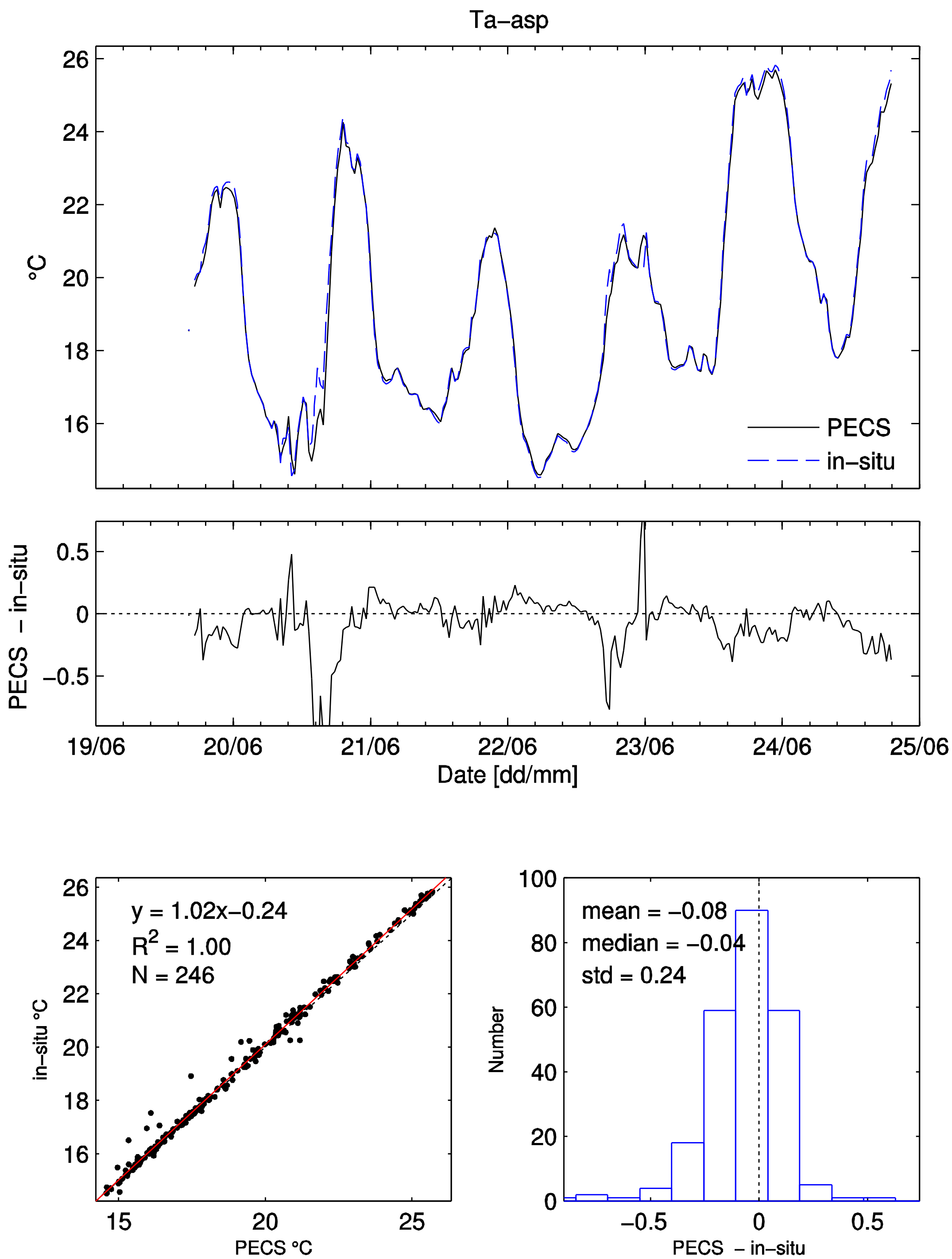
Figure - Covariance of sonic temperature.



Site Name: Willow Creek (US – WCr)
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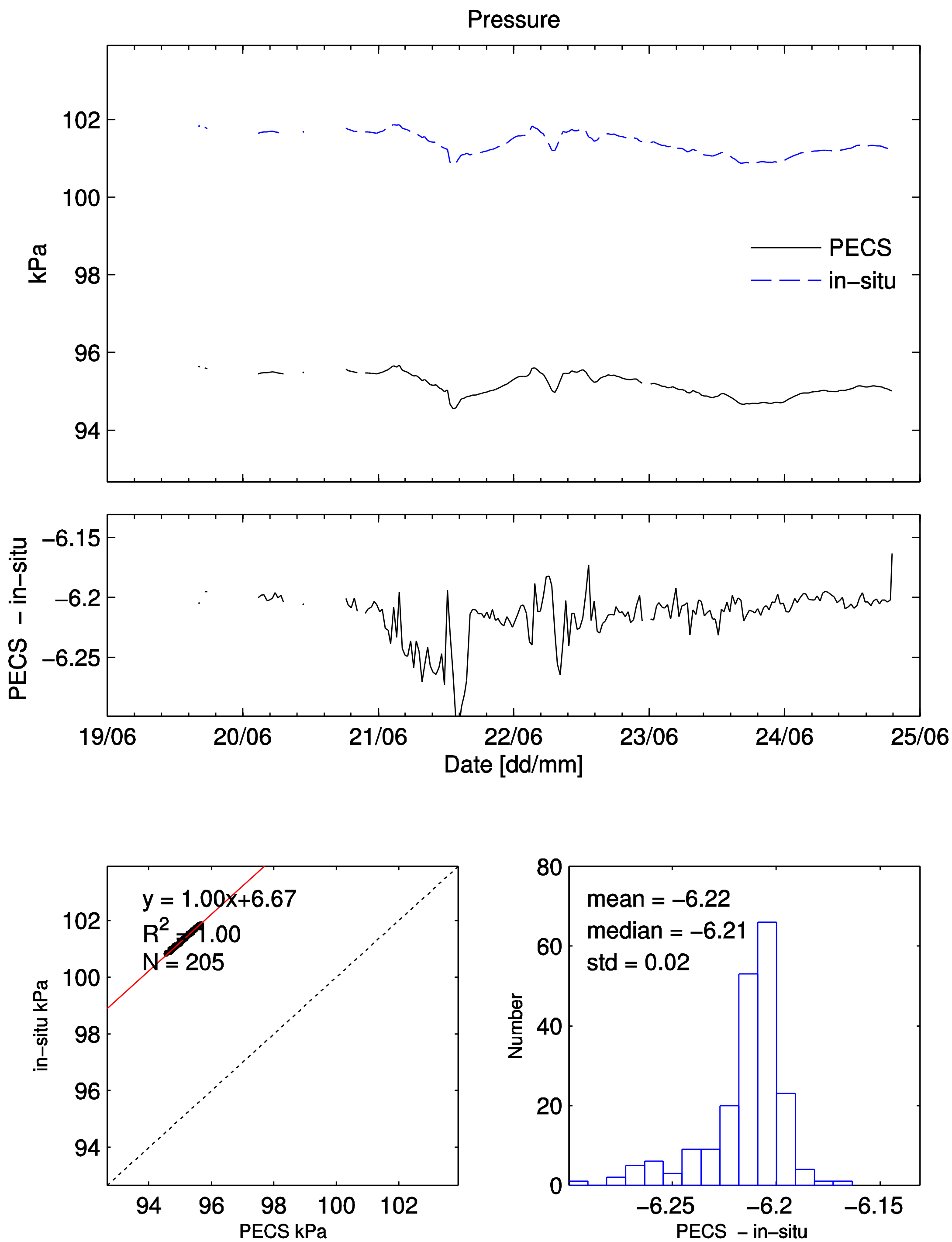
Figure – Air temperature.



Site Name: Willow Creek (US – WCr)
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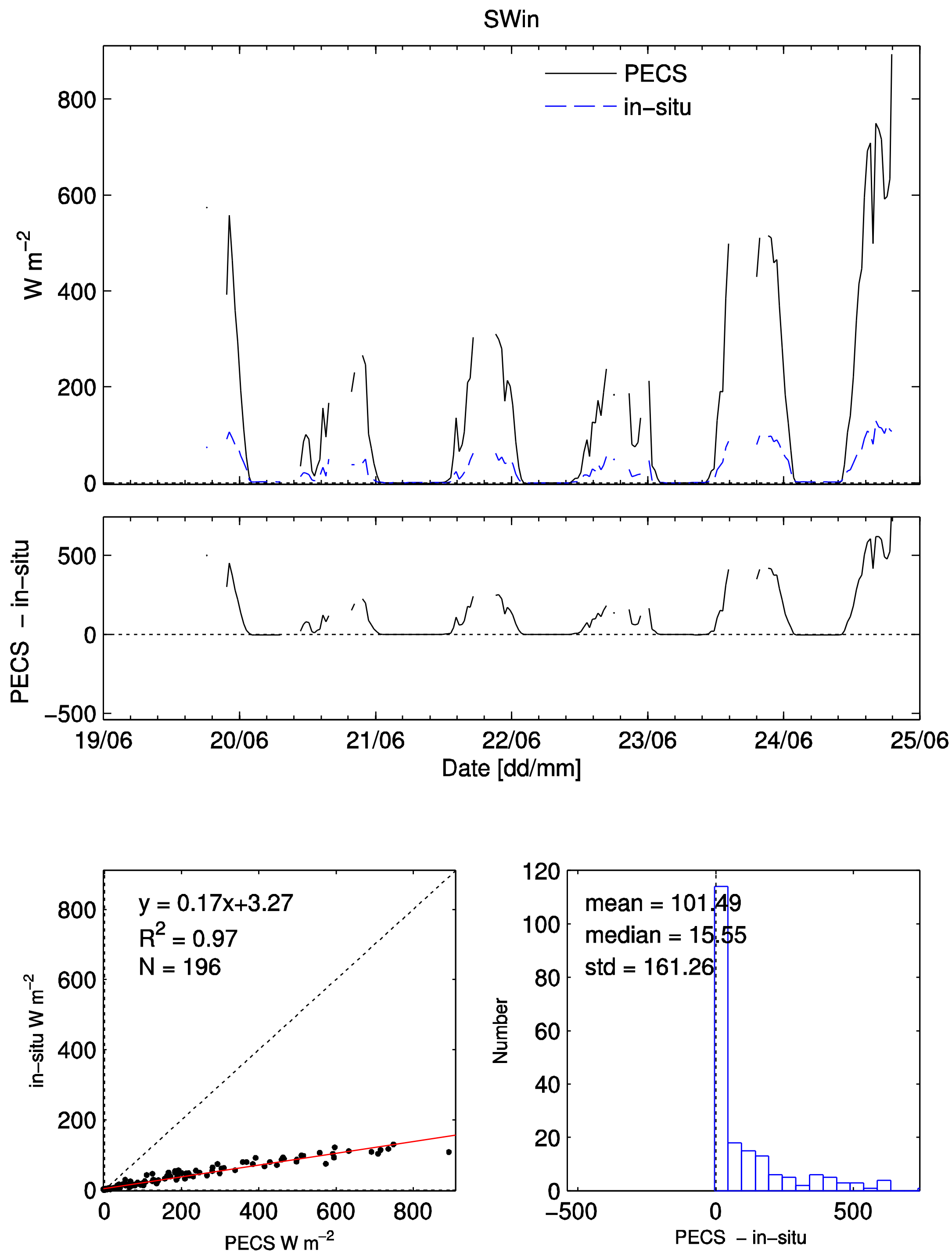
Figure - Barometric pressure.



Site Name: Willow Creek (US – WCr)
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Figure – Incoming shortwave radiation

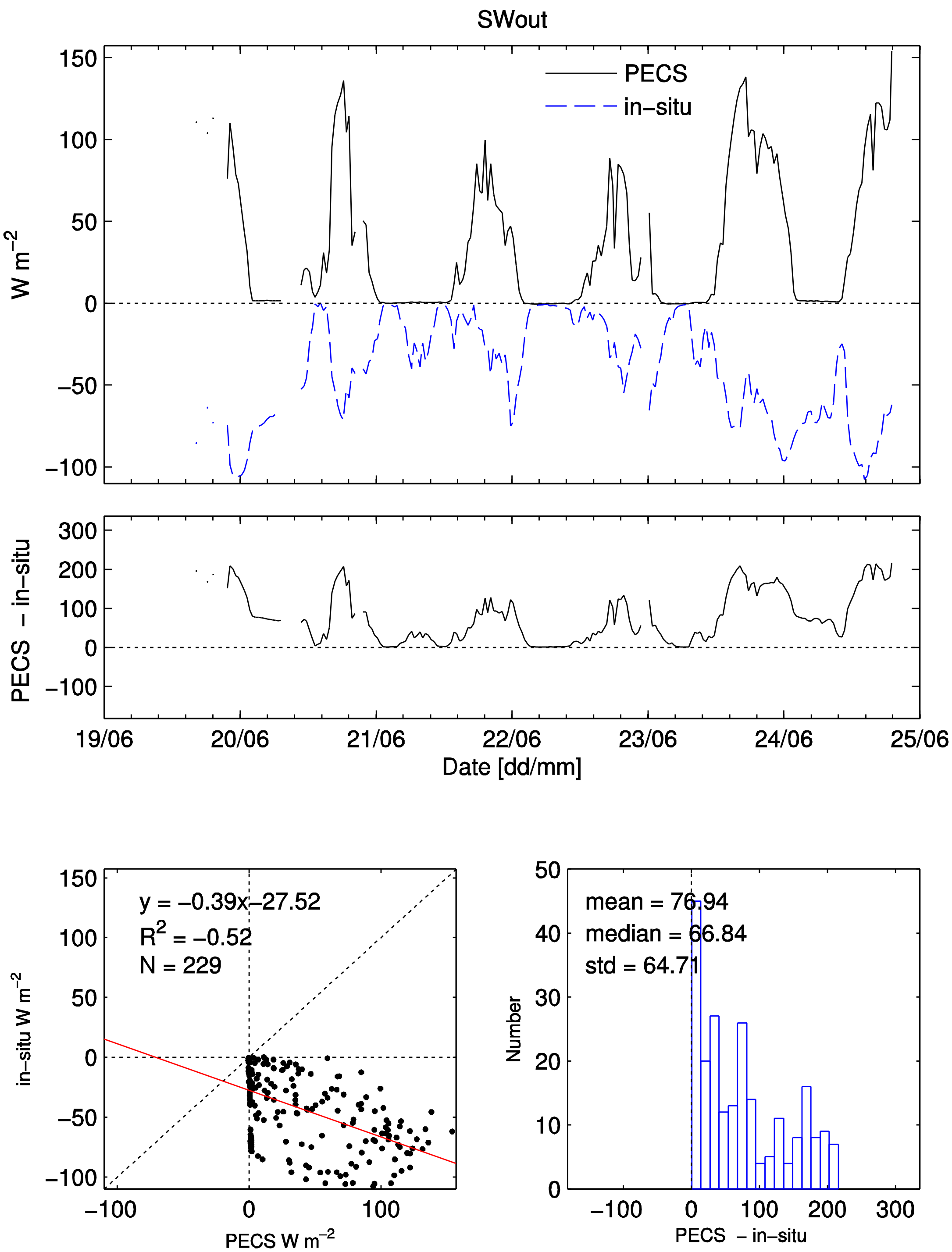

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Figure – Outgoing short-wave radiation.

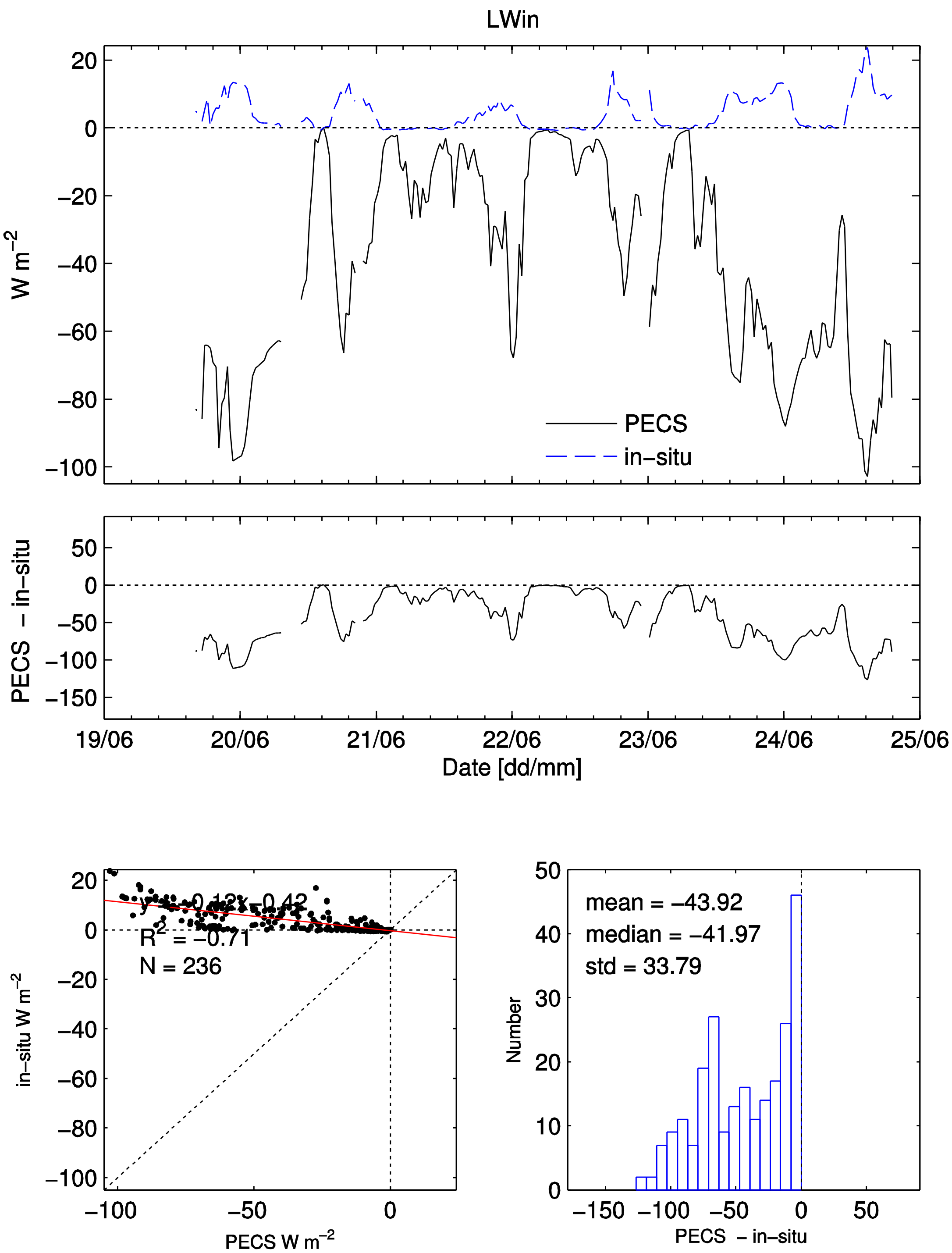

Figure – Incoming long-wave radiation.

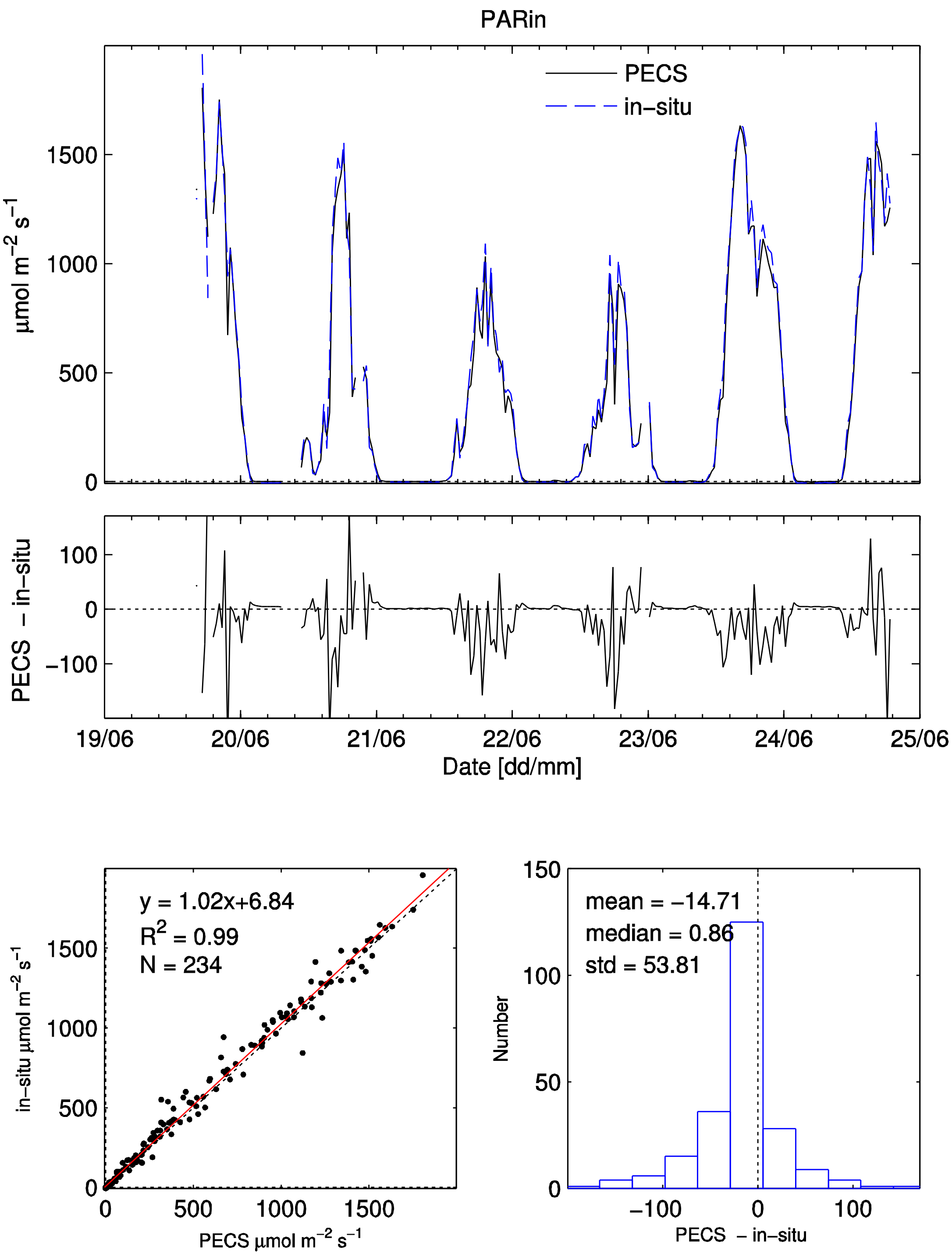

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Figure – Photosynthetically active radiation (PAR).

Appendix 1 – Site Information

Instruments	Brand/model	Levels/depths	Type	Frequency
AG_BIOMASS_TW			Live Aboveground Woody BioMass; www.cheas.psu.edu/data/cheas/biometry	
Anemometer	Campbell: CSAT3	2, 12.2, 24.4, and 29.6 m	3-D, sonic	
Barometer	Vaisala: PTB101B			
Gas Analyzer	LI-COR: LI-6251	0.6, 1.5, 3.0, 7.6, 13.7, 21.3, and 29.6 m	CO2, infrared	
	LI-COR: LI-6262	29.6 m	CO2/H2O, infrared	
Leaf wetness sensing grid	Campbell: CS237			1 min
Quantum sensor	LI-COR: Li-190SA			
	LI-COR: Li-190SB	29.6 m (also 2, 7.6, 12.2, and 18.3 m)		
Radiometer	Kipp & Zonen: CNR 1	29.6 m	net	
Rain/snow gauge	Campbell: CS705		tipping bucket	
RS_MEAN			1999-2002 as per Bolstad et al., 2004, Tree Phys. 24:493-504. Bole respiration 24-hour, year round, leaf nightime only, growing season	
Soil heat flux plates	REBS: HFT3	7.5 cm		10 min
Temperature and relative humidity probe	Campbell: CS500			
Temperature probe	R. M. Young: 43347	0.25, 0.5, 0.75, 1, 2, 7.6, 12.2, 18.3, 24.4, 29.6 m	RTD	
Thermocouple		0, 5, 10, 20, 50, 100 cm		10 min
		maple north and south facing		10 min
Time domain reflectometer	Campbell: CS615	0, 5, 10, 20, 50, 100 cm		10 min

Appendix 2 – Photo of installation during comparison