Vertical wind in sonic anemometers: observations from AmeriFlux QA/QC site visits

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ABSTRACT

Underestimation of the vertical wind component in sonic anemometers has been attributed to angle of attack errors arising from non-orthogonal transducer geometry and transducer shadowing. Some corrections have been developed for specific instruments but many questions remain concerning their universal applicability. Using data collected from five AmeriFlux QA/QC site visits where two Gill anemometers - having similar (non-orthogonal) geometry - were compared, we found disparate results. Two sites exhibited 20-30% underestimations in the variance of the vertical wind (var(w)) while the other three sites agreed within 5%. The difference in var(w) was found to correspond to a 15% underestimation of sensible heat fluxes. We examine a number of factors which could explain the observed results including: firmware differences, instrument-to-instrument variability, differences in attack angle, and data acquisition methods. Of the 5 sites, only 1 was applying an angle of attack correction to their datasets.

INTRODUCTION

Recent studies (Frank et al., 2013; Kochendorfer et al., 2012; Nakai and Shimoyama, 2012) have identified problems in 3-D sonic anemometry related to the wind angle of attack and sonic geometry (orthogonal vs non-orthogonal transducers). Nakai et al.(2012 ; 2006) described (co)sine errors affecting the horizontal and vertical wind components based on detailed wind tunnel and field experiments using Gill anemometers. Angle of attack (AoA) errors were responsible for underestimations of the vertical wind component which could yield errors (~15%) in turbulent fluxes (Nakai and Shimoyama, 2012). AoA errors could have considerable implications for the flux community (e.g., terrestrial carbon budget and energy balance closure (Kochendorfer et al., 2012)).

To maintain high data quality and ensure data intercomparability, the AmeriFlux QA/QC technical team based at the Lawrence Berkeley National Lab conducts short (10-14 day) site visits using a portable eddy covariance system (PECS). Site visit findings are discussed collaboratively with site staff but remain confidential. Nonetheless, the accumulated record of site visits is a rich dataset that has been used to draw inferences about network-wide statistics (e.g., eddy covariance uncertainties (Schmidt et al., 2013)).

Figure 1 – Photos from AmeriFlux QA/QC site visits.

INITIAL RESULT

Differences between var(w) and fluxes from Site4 (Table 1) could be accounted for after application of AoA correction (Figure 2). However, since two Gill anemometers were compared, AoA corrections should be applied equally as they have nearly identical geometry. Why should the correction be non-uniformly applied?

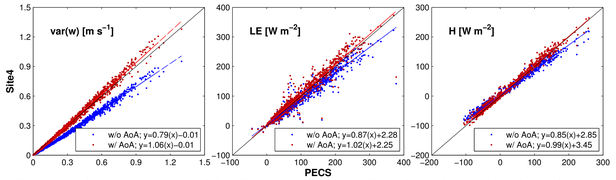


Figure 2 – Comparison of var(w), LE, and H, between PECS (x-axis) and Site4 (y-axis).

SITE DESCRIPTIONS

Data from five AmeriFlux sites was used. Data was collected during QA/QC site visits in 2013-14. Specific sites are not identified.

	N (ave period)	Gill model at site	Separation from PECS anemometer		Sensor height [m]	Data acquisition
			vertical	horizontal		
1	325	WMP	-15 cm	8 m	3	Digital
2	424	WMP	-13 cm	2.2 m	4.9	Digital
3	167	R3	-20 cm	0.5 m	6.6	Digital
4	1111	WM	0 cm	1.2 m	4.9	Analog
5	461	WMP	-30 cm	0.6 m	31.6	Analog

Table 1 – Data from 5 site visits were compared. WMP = WindMaster Pro; WM = WindMaster. Positive vertical separation denotes PECS above site anemometer.

METHODS

AmeriFlux QA/QC site visit description:

- An independent system to collect eddy covariance, meteorological, and radiation measurements was deployed side-by-side at AmeriFlux sites for 10+ days.
- Portable eddy covariance system (PECS) (Figure 3) used Gill R3-50 paired with 2 infrared gas analyzers.
- Data from fast response sensors logged via RS-232 using custom acquisition software (HuskerFlux) on PC.
- PECS clock was aligned to site clocks.

Figure 3 – AmeriFlux portable eddy covariance system (PECS).

Data processing description:

- High frequency data was obtained from AmeriFlux PECS and *in situ* eddy covariance sensors.
- Identical processing steps (spike removal, 2-D coordinate rotation) were taken using EddyPro software (v 4.2.1).
- No frequency or angle of attack corrections were applied.
- Data averaging interval was 30 minutes, except for one site which reported hourly.

RESULTS

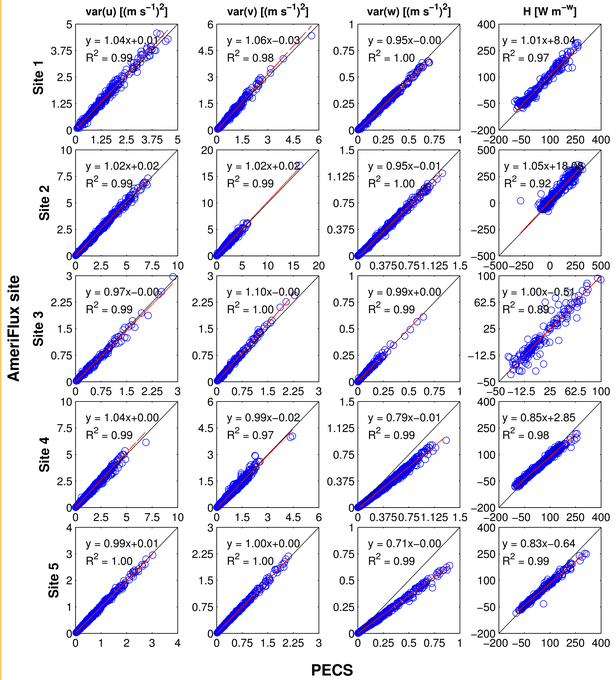
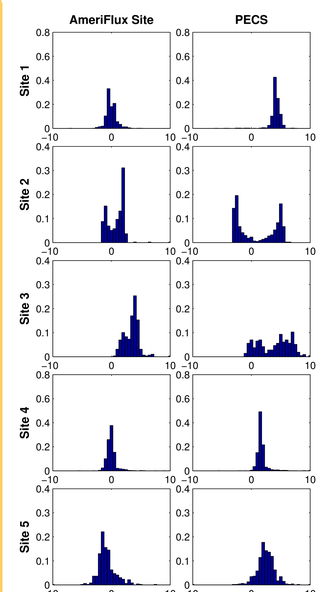


Figure 4 (above) – Scatterplot of variances of rotated wind components and sensible heat fluxes from the PECS Gill sonic anemometer (x-axis) compared to five AmeriFlux sites (y-axis) with Gill anemometers (Table 1). Linear regression (red) and 1:1 line (black) shown for reference.



- All sites reported similar variances in along- and cross-wind components.
- The variance of the vertical wind at sites 4 & 5 was smaller by 21 and 29%, respectively, compared to the PECS anemometer.
- The sensible heat fluxes from sites 4 & 5 were 15% and 17% smaller while the other sites agreed closely with the PECS.

Figure 5 (left) – Histograms of average attack angles over flux averaging periods (done prior to rotation). Bin size is 0.5º.

DISCUSSION

A number of factors could contribute to the underestimation of var(w) between some Gill anemometers and not others.

- Different attack angles. Angle of attack distributions do not explain the underestimation in var(w) (Figure 5).
- AoA correction specific to sonic model. Based on the collection of Gill models tested (Table 1), this is unlikely. Similar geometries.
- Anemometer firmware differences. Not all firmware versions used are known at this time. We are perusing this and will contact the manufacturer to identify changes between firmware.
- Sensor malfunction. The two underreporting anemometers could have been faulty or damaged. However one of those sensors was newly purchased and deployed for less than 6 months.
- Data acquisition method. We are conducting additional tests to confirm this explanation. Initial results based on data collected from a single anemometer logged via an analog signal and RS-232 also found an underestimation in var(w), but smaller in magnitude to results presented here. Data not shown.

CONCLUSIONS

- Side-by-side comparisons between two Gill anemometers found that the variance of the vertical wind component, critical to calculating vertical exchanges using the eddy covariance technique, was underestimated at some sites but not others.
- At two sites var(w) was lower by more than 20%; corresponding to 15% lower turbulent fluxes of sensible heat.
- A number of factors were examined to explain the findings. Data acquisition method was not ruled out but more work is required.
- AoA errors and their corrections can result in significant differences in the magnitude of turbulent fluxes. Quantifying (and adopting) these errors is critical for the flux community.

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