Discrepancies in measured sensible heat flux from two different sonic anemometers

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Introduction

Sonic thermometry and anemometry are fundamental to all eddy-covariance flux measurements. They are inherent to many studies of surface energy balance and ecosystem carbon and water relations. While previous studies and AmeriFlux intercomparisons have shown inconsistencies in fluxes measured with different sonic anemometers, it can be difficult to determine which instrument is in error. Here a novel approach was used to isolate the source of error between two sonic anemometers.

Methods

In this study, measurements of sensible heat flux (H) and CO_2 flux (F_c) were made with two different models of sonic anemometer, the CSAT3 (Campbell Scientific, Inc.) and the SATI/3Sx (Applied Technologies, Inc.), at the GLEES AmeriFlux site (southeastern Wyoming, USA). These instruments were tested as part of a second eddy covariance system mounted 2.0 m below the control, which was the GLEES continuous system ($z_{control}$ = 22.7 m). At different times, each sonic was mounted vertically and horizontally to detect attenuation in the vertical axis. A third sonic, SATI/3Vx (Applied Technologies, Inc.) was also tested only in the vertical orientation.

All eddy-covariance data were despiked, QAQC and calibration corrected, planar-fit rotated, time lagged, and u_* filtered ($u_{*threshold}$ = 0.3 ms^{-1}). Spectral corrections and WPL corrections were also done but not presented here because they obscured the measured response of the instruments. CO_2 fluxes were measured with a LI-7500 (Li-Cor, Inc.) for each eddy covariance system. Calibrations were held constant during the test duration.

The CSAT3 in vertical (above) and horizontal (below) orientation.

The SATI/3Sx in vertical (above) and horizontal (below) orientation.

Results

Standard deviations in sonic coordinates were used for comparison between 1-D sonic measurements. Measurements of vertical wind, σw, were consistent among all sonic anemometers, except the vertically mounted CSAT3 which was attenuated. Likewise, with horizontal wind, σu and σv, all instruments were similar, except the horizontally mounted CSAT3 which was attenuated in the v-axis. There was no difference in sonic virtual temperature, σT_s.

Covariances in planar fit coordinates were used for comparison of H and F_c fluxes. There were no detectable orientation effects on the covariances. Instead, it appeared that H and F_c were always higher when measured with the ATI sonics than with the CSAT3.

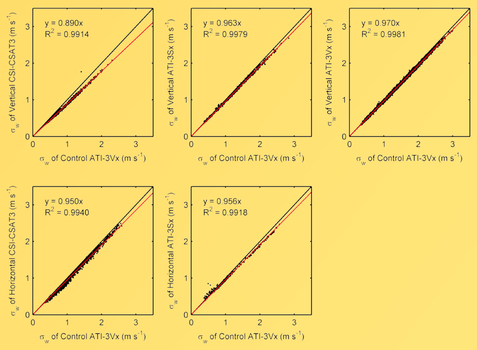

Figure 1. Comparison of the w-axis wind velocity in sonic coordinates. Attenuation of vertical wind velocity occurred in of the vertical CSAT3.

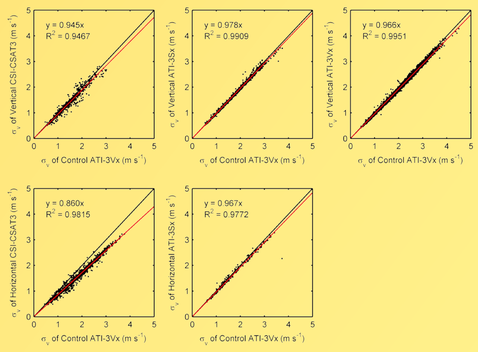

Figure 2. Comparison of the v-axis wind velocity in sonic coordinates. For the horizontal CSAT3, the vertical attenuation (Figure 1) was translated into the v-axis.

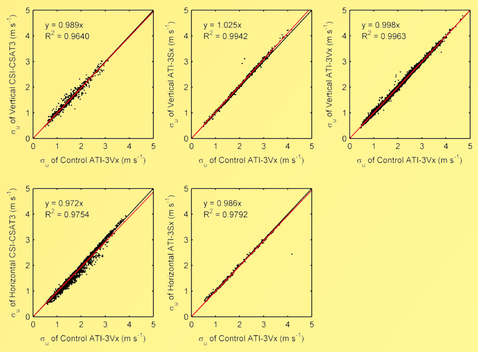

Figure 3. Comparison of the u-axis wind velocity in sonic coordinates. Instrument rotation occurred around this axis thus there was no effect in either the ATI/3Sx or CSAT3.

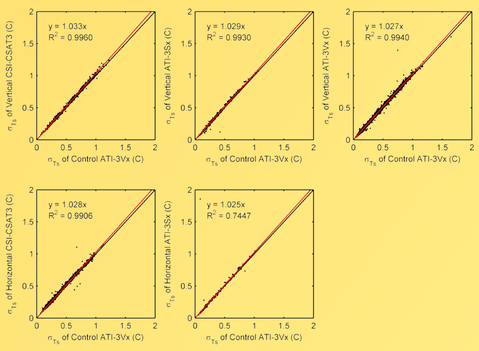

Figure 4. Comparison of sonic virtual temperature. There were no differences between sonic anemometers or orientations.

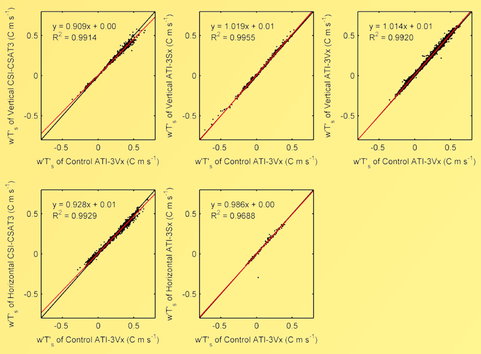

Figure 5. Comparison of sensible heat flux in planar fit coordinates. No orientation effect was detected in the covariance, yet fluxes were higher with the ATIs than the CSAT3. Note w and T_s were not independent measurements.

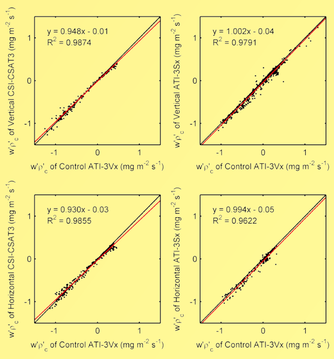

Figure 6. Comparison of CO_2 flux in planar fit coordinates. No orientation effect was detected in the covariance, yet fluxes were higher with the ATIs than the CSAT3.

Discussion

With wind velocity measurements, the SATI/3Sx did not appear to change regardless of the orientation. Yet, the CSAT3 showed an attenuation in the vertical wind velocity, which was translated into the horizontal wind (v-axis) by rotating the sonic onto its side.

There was no detectable difference in H from orientation, but w and T_s are not independent measurements and thus may invalidate the comparison. The result that the ATI H was higher than the CSAT3 H was previously seen during the AmeriFlux intercomparison at GLEES using the AmeriFlux primary standard. Mauder et al. (2007) also found that the ATI H was higher than the CSAT3 H, yet they attributed it to higher variance in the ATI w.

The lack of evidence of an orientation effect on the CO_2 flux is puzzling considering the LI-7500 is an independent measurement. It is possible that frequencies involved in the attenuation of w in the CSAT3 had no bearing on CO_2 fluxes.

Conclusions

The CSAT3 had a detectable attenuation in the vertical wind velocity when mounted vertically that was not found in the SATI/3Sx. Yet, the orientation test did not give a satisfactory explanation for the increased H and F_c measured with ATI sonic based eddy covariance systems.

References - Mauder, M, S.P Oncley, R. Vogt, T. Weidinger, L. Ribeiro, C. Bernhofer, T. Foken, W. Koshsiek, H.A.R. De Bruin, and H. Liu. 2007. The energy balance experiment EBEX-2000. Part II: Intercomparison of eddy-covariance sensors and post-field data processing methods. *Boundary Layer Meteorology. 123*:29-54.

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