

Responses to reviewers' comments

We appreciate very much the constructive and helpful comments from the reviewer. The detailed responses are listed one by one as following:

Reviewer #1:

Major comments

1. *Examination of the fluctuations in wind velocities and sonic temperature and flux quantities that were influenced by the geometric deformation of sonic anemometer*

Response: The fluctuations for each wind speed components and sonic temperature are reflected by variance. The variance values of three component wind velocities and sonic temperature in period of two days were analyzed for or the homogeneity between unrecovered and recovered data. The four F-values for three wind speed components and sonic temperature showed the inhomogeneity in variance between unrecovered and recovered data ($P < 0.001$), which indicates that the geometrical deformation of sonic anemometer did significantly influence the fluctuations in each of its measured variables.
(see added Section 8.5).

Figure 8 was added to show the difference in sensible heat flux, latent heat flux, and CO₂ flux between unrecovered and recovered data. The differences in the three fluxes are all statistically significant (e.g. all P-value < 0.005 , see Figure 8 and Section 8.5).

The results from the analyses and Figure 8 were added to Conclusion remarks.

2. *English writing*

Response: Professional English technical writer, Ms. Linda Worlton-Jones, with Campbell Scientific was administratively assigned to polish the English writing.

General comments

1. *Suggestion to shorten the title*

Response: The title was shortened as suggested to:

"Recovery of the 3-dimensional wind and sonic temperature data from a physically deformed sonic anemometer"

2. *Effect of the deformation on the fluctuations and fluxes*

Response: See response to major comment 1.

3. *Actual MATLAB program*

Response: The program in Appendix C is the actual one, but it excludes the code lines for dialogue interface. The other referee, Dr. Thomas Foken, suggested that this section should be published in a separate publication. He also advised us to seek an opinion from the Editor. The Editor (Dr. Laura Bianco) agreed with Dr. Foken's suggestion. We will work on this program in a publication shape. At this

stage, we would keep Appendix C as is. It is noted in Appendix C that the operational code now can be requested from corresponding authors.

4. *Terminology: Flying and transmitted.*

Response: “Transmitted” is right in terminology although we often use “flying” for our training seminars and in-house communications. The term of “Flying” was replaced with “transmitted”.

5. *Crosswind effect*

Response: The crosswind effect on measurements of speed of sound is corrected inside the operating system of sonic anemometer. The speed of sound from each of three sonic paths is separately corrected and the three corrected speeds are used to estimate the sonic temperature. The reference of Schotanus et al. (1983) was added as citation. This reference shows how crosswind influences the measurements of speed of sound [see Figure 1 and equations (1) and (2) in Schotanus et al. (1983)].

Schotanus, P., F. T. M. Nieuwstadt, and H. A. R. de Bruin. 1983. Temperature measurement with a sonic anemometer and its application to heat and moisture fluxes, *Boundary-Layer Meteorology* 26: 81-93.

6. *Drawings/schematics and English*

Response: Thank you so much for your positive comments on the drawings/schematics in the manuscript and specific comments for the revisions of English.

* p.1, l.25, "had been" should be "was"...

Response: Revised as suggested.

* p.1, l.25, remove, "To recover data from this deformed sonic"

Response: Removed as suggested.

* p.1, l.30, replace "to the studies on" with "for"...

Response: Replaced as suggested.

* p.2, l.5, what does "structuring" mean?

Response: Means “forming” three paths in a designed geometry in structure. For simplicity, “structuring” was replaced with “forming” and the whole sentence was revised.

* p.2, l.6, what does it mean by "optimized" angles. Optimized for what?

Response: For wind measurements. The sentence was revised as:

“The three paths are situated as optimized angles for wind measurements in the 3D anemometer coordinate system,”.

*p.2,l.11,this reference to "entropy" seems out of place? Don't see entropy mentioned anywhere else in the manuscript...

Response: The term of “entropy” was replaced with “heat property”.

* p.2, l.12, "geometry embedded" should be "geometrical information embedded".

Response: Revised as suggested.

* p.2, l.15, remove "any more."

Response: Removed as suggested.

* p.2, l.16, replace "cannot output" with "no longer outputs"

Response: Replaced as suggested.

* p.2, l.23, remove "at the time"

Response: Removed as suggested.

* p.2, l.23, remove "to which the anemometer can be shipped back with care."

Response: We would like to keep this writing. If the anemometer was shipped back as usual without care, it might be deformed again in transportation. If deformed again, its geometry re-measurements after back to manufacturer would not be representative to sonic geometry during field measurements, which would bring uncertainties to the data recovery.

* p.2, l.28, replace "site" with "situation"

Response: "In such a site" was revised as "From such a site".

* p.2, l.36, remove "then"

Response: Removed as suggested.

* p.2, l.38-39, awkward sentence, fix the end of it.

Response: Fixed as "More importantly, the 2015 data was also needed by related projects for collaborations."

* p.3, l.17, It seems odd to mention the funding in the manuscript?

Response: Removed the wording related to the funding.

* p.3, l.21, replace "4-way net radiometer" with "4-component radiometer" (also, not necessary to describe the components, the radiation is not really important to the study, so be as brief as possible in this description.)

Response: Revised as suggested and removed the words how net radiation is measured.

* p.4, l.7, "unexpectedly various individually"?

Response: Revised the sentence as

..... that the sonic temperature values from the three sonic paths unexpectedly deviated around -12, 5, and -7 °C

* p.4, l.35, replace "production of recalibration" with "the calibration".

Response: The path lengths are measured in two cases: production calibration and return calibration processes. The phrase of "production calibration and return recalibration" may be wordy. The phrase of "during production or recalibration" is to express our description.

* p.4, sec 2 (and photo in Fig 2). I don't quite understand there was a CSAT3B there, but you are not comparing the "deformed" sonic results to it (especially for the fluxes)? The best comparison would be to have the "deformed" sonic mounted side-by-side with a "normal" sonic, and then the post-processing correction of the

deformed sonic could be evaluated quite well. Was this never done and/or impossible to do (even after it was recalibrated)?

Response: The photo was taken after the deformed IRGASON was replaced with the manufacture-provided swap unit. Before the deformed IRGASON was thoroughly inspected and checked by the manufacturer, we were not 100% sure what caused the incorrect measurements of sonic temperature. What we were worried about was that IRGASON could not be used in such cold conditions. To ensure the sonic temperature data, a CSAT3B was installed as an alternative although the swap unit was installed. The deformed IRGASON and CSAT3B were not deployed side-by-side. For this case, the best comparison as you suggested is impossible.

* p.5, eq 3 and 4: probably don't need eq3?

Response: In Figure 1, we must use a specific sonic path to illustrate the measurements of wind speed and speed of sound. For a better spatial illustration, the third sonic path was used. As a result, equations (1) and (2) are particularly referred to the sonic path and equation (3) is used to make transition from the third sonic path to the i th sonic path where $i = 1, 2, \text{ or } 3$. We feel that the use of equation (3) could make an entrance-level reader easier.

* p.5, l.25, replace "based" with "depending"

Response: Replaced as suggested.

* p.8, eq. 21, this is only true for dry air, correct?

Response: We cannot correctly answer this question simply using either "correct" or "incorrect". This question would be better answered using the following explanations.

In acoustics, the speed of sound (c) in a homogeneous gaseous medium as in the atmospheric surface-layer flows is well defined as (Barrett, E.W., V.E. Suomi. 1949. Preliminary report on temperature measurement by sonic means. Journal of Meteorology 6: 273-276)

$$c^2 = \gamma \frac{P}{\rho} \quad (\text{R1})$$

Where γ is the ratio of moist air specific heat at constant pressure to moist air specific heat at constant volume, and ρ is moist air density. Substituting the ideal gas equation,

$$P = R_a \rho T \quad (\text{R2})$$

where R_a is the gas constant of moist air. Using two equations above, T can be related to c as:

$$T = \frac{c^2}{\gamma R_a} \quad (\text{R3})$$

This equation enlightens the use of measured c for T calculation; however, both γ and R_a depend on air humidity undermined by any sonic anemometer; equation

(R3) is, therefore, not applicable for T calculations inside a sonic anemometer. Alternatively, γ is replaced with its counterpart for dry air [γ_d (1.4003), the ratio of dry air specific heat at constant pressure ($1,004 \text{ J K}^{-1} \text{ kg}^{-1}$) to dry air specific heat at constant volume ($717 \text{ J K}^{-1} \text{ kg}^{-1}$)] and R_a is replaced with its counterpart for dry air (R_d , gas constant for dry air, being $287.04 \text{ J K}^{-1} \text{ kg}^{-1}$). After both replacements in equation (R3) and although, in magnitude, γ_d is close to γ (and R_d is close to R_a), the variable in its left hand side is not a measure of T anymore. Instead, it is defined as sonic temperature denoted by T_s :

$$T_s = \frac{c^2}{\gamma_d R_d} \quad (\text{R4})$$

This equation is the equation (21) in manuscript. It is the definition of sonic temperature.

* p.11, l.3, isn't the point of the paper verifying that the recovery works?

Response: The recovery of wind data does not need verification because the equations (10) to (16) for recovering the wind data do not include any assumption and approximation.

* p.11, l.22, what does "bare satisfactory" mean?

Response: The phrase of "bare satisfactory" means marginally satisfactory. The word of bare was replaced with "less". The related context ahead of this sentence was revised accordingly.

* p.16, l.2, "Li-Cor" should be "LI-COR".

Response: Revised as suggested.

* p.16, l.9, "popularly used around the world", should be "used around the world". Considering several of the authors work for Campbell Sci. such subjective word choices should not be used.

Response: Revised as suggested.