Responses to reviewers' comments

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

Major comments

1. *Applications*

   Response: Thank you for the positive comments on the applications of this study. The equations and algorithms are useful to recover data not only from geometrically deformed sonic anemometers, but also from CSAT3 sonic anemometers using unmatched electronic boxes in the field. The geometry data of each CSAT3 sonic anemometer embedded into its electronic box. If a CSAT3 head is used with an electronic box for other CSAT3, this CSAT3 head would use wrong geometry data to calculate the 3D wind and sonic temperature. Such cases are equivalent to the data acquisition using a sonic anemometer slightly deformed. The measured data could be recovered using the geometry data from the unmatched electronic box for other CSAT3 (equivalent to geometry data before deformation in this study) and from its own electronic box (i.e. geometry data after deformation in this study).

   The geometry data can be requested from manufacturer. Over years, the requests to recover the data from such cases were received, but the equations and algorithms to recover the sonic temperature data with full satisfaction were not available because sonic temperature was corrected for the crosswind effect inside the sonic anemometer OS separately for each of three sonic paths, which complicates the recovery of sonic temperature. This study greatly improved the recovery of sonic temperature data from slightly deformed sonic anemometers and CSAT3 sonic anemometers using unmatched electronic box. The newer models of sonic anemometers such as CSAT3B, CSAT3A, and IRGASON sonic anemometer embed the geometry data inside a component of anemometer head (e.g. an electronic chip attached to sonic anemometer head connector); therefore, considering the length of manuscript, we did not tell such a story.

2. Citations of manufacturer's documents

   Response: The citations of some manufacturer's documents were removed or replaced with journal publications. In particular, earliest Hanafusa et al. (1982) and most recent Foken (2017) were added. For sensor specifications, manufacture documentations have to be referenced.

3. Highlight firmware for sonic anemometer

   Response: The version number of EC100 OS for sonic anemometer was EC100.04.10 (02/25/2014) when this anemometer was used in the Antarctic. This version number was added in the statement related to EC100 in Section 2.

   The equations and algorithms in this study are not relevant to the version number of sonic anemometer OS, but the application of the equations and algorithms needs the embedded geometry data and the embedded transform matrixes inside the sonic anemometer firmware. The geometry data and transform matrixes are unique for each Campbell sonic anemometer and are identified by serial number. These data and matrixes for sonic anemometer SN: 1131 in this study were acquired from Campbell Scientific and were given in Table A1 and matrixes (A3) to (A6) in Appendix A. Following Dr. Foken's advice, the information related these data and matrix was highlighted in related lines as pointed by Dr. Foken and other related statements.

Additionally, Burns et al. (2012, including Larry Jacobsen) found the underestimation in sonic temperature fluctuations when wind speed > 8 m/s if CSAT3 OS 4.0 was used. Larry Jacobsen fixed the problem encountered in this particular version of CSAT3 OS 4.0.

Burns, S.P., Horst, T.W., Jacobsen, L., Blanken, P.D., Monson, R. K. 2012. Using sonic anemometer temperature to measure sensible heat flux in strong winds, Atmos. Meas. Techn., 5, 2095-2111.

4. Transducer-shadow correction

Response: After Horst et al. (2015), Larry Jacobsen implemented transducer-shadow correction into CSAT3A, IRGASON sonic anemometer, and CSAT3B as an option. For CSAT3A and IRGASON, OS EC100.07.01 or later has this option. If this option is used, the data recovery must use the equations and algorithms including shadow correction.

The parameters in the correction equation are not same as those used by Wyngaard and Zhang (1985). Using the sonic transducer diameter of 0.6 cm and ratio of sonic path length to diameter (19.25), the parameters were determined based the Figure 5, equation (1a), and Table 1 in Wyngaard and Zhang (1985) as indicated by equation (7) in our manuscript. The equations related to transducer-shadow correction are the same as those used inside IRGASON, OS EC100.07.01 after Horst et al. (2015); therefore, the citation for equation (7) was revised as "Following Host et al. (2015) based on Wyngaard and Zhang (1985), …………."

Horst, T.W., Semmer, S.R., Maclean, G. 2015. Correction of a non-orthogonal, three-component sonic anemometer for flow Distortion by transducer shadowing, Boundary-Layer Meteorol., 155, 371-395.

Wyngaard, J.C., Zhang, S.F. 1985. Transducer-shadow effects on turbulence spectra measured by sonic anemometers, J. Atm. Oceanic Techn. 2: 548-558,

5. More sensitivity of sonic temperature to a measurement error

Response: We are really appreciated with your deep and substantial insight about the issue of verification on the data recovery. From equations (3), (17), and (21), the error analysis can be derived. Sonic temperature is sensitive at one order higher than wind speed to the errors in measurements of sonic path lengths and ultrasonic signal travel times; therefore, the calculated sonic temperature instead of wind speed was used to verify the data recovery in Section 8. Your suggested argument "…..if the sonic temperature for corrected path lengths is within the accuracy limits of the sensors then this should be realized for the wind components as well.", however, consider the length of our manuscript, we do not prefer to add more equations in our manuscript for error analysis mentioned in this response. Instead, this comment was cited in our discussion section.

6. Different response time of sensors

Response: For the data mean of half hour, the response time is not an issue. For simplicity, the discussion related to the time lag was removed.

7. Discuss with the editor about the software (Appendix C) publication
Response: We have discussed with the Editor (Dr. Laura Bianco), the Editor agreed with your 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.

General comments

Perhaps you could reduce the number of equations by writing the basic equations in a more general form like Eqs. 3, 4, 12, 13 etc.
Response: In Figure 1, we should 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, or 3. We feel that the use of equation (3) can make an entrance-level reader easier. Same to other equations.

p. 3, line 33: information about the used radiation shield of the HMP-sensor is necessary (ventilated?) for Section 8.
Response: It was not fan-ventilated. It was naturally ventilated. Power is a limited factor in the Antarctic area.

p. 11, line 10ff: Could you please give temperature differences in the SI-dimension K. In the present form misunderstanding is possible.
Response: The unit of degree C for temperature differences was revised as K. Throughout the manuscript and figures, K is used for the unit for temperature difference.

p. 12, line 1: The symbol cT2 could be misunderstood because CT2 is the standard symbol for the temperature structure parameter; perhaps you can find a better symbol.
Response: All c_{T1}, c_{T2}, c_{T3}, and c_{Ti} are renamed as c_{01}, c_{02}, c_{03}, and c_{0i} where subscript 0 indicates the speed of sound at the crosswind speed equal to 0. This revision was made through the manuscript and figures.

p.14, line 2-3: I do not understand the sentence "sonic path becomes shorter by some degree". If the geometry of the sonic anemometer changes below–20◦C, why can you not correct this effect with your software.
Response: Thermo-expansion or -contraction happens to the whole body of sonic

anemometer structure. As a result, the sonic path can be longer or shorter, which can influence the measurement. However, this topic goes beyond the scope of this study that recovers the data from geometrically deformed sonic anemometer to those from a normal one.

p. 16, line 4-5: Energy balance closure is not a good indicator for data quality (Foken et al., 2012). However your result is in the typical range reported in the literature.
Response: Yes. Following Foken et al., (2012), the discussion was revised.

p. 22, line 12: Buck (1981) is not an acceptable reference, because the temperature scale has been changed (ITS-90). A relevant reference is WMO (2014 (update 2017)) or the original reference (Sonntag, 1990).
Response: Thank you so much for your update. LI-COR and Campbell Scientific, the two manufacturers to manufacture H_2O-related gas analyzers for flux measurements, have been using Buck (1981) for their calculations and H_2O span. Campbell Scientific will accept your recommendation to switch Buck (1981) to Sonntag (1990) for future use. For this study now, the use of Buck (1981) is consistent with the same use by LI-COR and Campbell Scientific.