Answer to referee #1 for AMT-2018-179 (Bessardon et al. 2018)

Title: Evaluation of Windsond S1H2 performance in Kumasi during the 2016 DACCIWA field campaign

Authors: Geoffrey E.Q. Bessardon, Kwabena Fosu-Amankwah, Anders Petersson, Barbara J. Brooks

We thank the anonymous referee for the helpful comments. We are responding to all the comments of the reviewers in this document and we have prepared a revised manuscripts where major changes are marked and removed parts in red. In the following, comments of the reviewers are given in bold and italic with our responses are given in normal font.

Overall comments:

This paper describes progress towards developing a less expensive but reliable upper-air radiosonde. To evaluate their newly developed S1H2 sonde they compare its data to observations from high-quality Vaisala RS41-SG sondes. The observations were taken from 33 launches during the DACCIWA field campaign in Western Africa. Basically the authors conclude that the S1H2 sonde is a work in progress with the main issues being the poor performance of the GPS sensor leading to questionable winds and the slow response time of the temperature and humidity sensors. It's ironic that an instrument called a "windsond" would do such a poor job measuring winds. They conclude by offering some recommendations for future improvements. From the limited comparisons shown between RS41 and S1H2 observations, it is hard to properly judge the performance of the windsond. For example, only one intercomparison flight is made for data extending above the boundary layer. Figures 5-7 show data from this one flight. To get meaningful statistics to evaluate the windsond, data from 20 or more flights should be presented as in Jensen et al. (2016) and similar intercomparison studies. For soundings within the boundary layer, analyses are shown from (I believe) eleven flights (Figs. 8-9) and in a format that is difficult to interpret. I would recommend that analyses be presented in a more conventional format as biases and rms differences between the RS41 and windsond (see Fig. 8 of Jensen et al. 2016). While the paper has some major concerns in the way the analyses are presented, it is still of value in that it is introducing a new instrument with a promising upside that is in the early stages of development. Under major comments below I suggest several areas where paper could be improved.

Answer:

We agree that only one sounding over the boundary layer is not statistically sufficient to assess the S1H2 performances. A key point about the S1H2 is that its re-usable this particular sonde is of interest as as it illustrates the reusable capacity. Launches in which an S1H2 and RS92 are tapped together by default result in the loss of the sonde and so analysis of its re-use performance cannot be undertaken. Eleven RS41-SG have been launched simultaneously with two S1H2 during the re-use evaluation, so twenty-two S1H2 flights have been compared to eleven RS41-SG in the boundary layer. This method allowed us more data comparison and also less travel time to search the sondes as the two S1H2 launched simultaneously where landing in the same area.

Major comments:

While the windsond system is being marketed as a less expensive replacement to more conventional sondes, no where is the cost of the sonde system (laptop, antenna, etc.) and sondes mentioned in the paper. Please discuss this information.

Answer: We do not want to state the price of the sonde in the paper as the price is subject to evolution. This sondes requires a smaller ballon and and consequently less helium so saving are made on this side. The sonde is also re-usable so re-using the sonde up to 8 times can constitute a significant saving.

Line 24: The vertical resolution is also a function of the sampling rate.

Answer: True it has been added

Line 28-33: So the US sites are spending ~$237K per site per year. I would assume that the US sites are some of the more costly ones to maintain around the globe so I would guess your $440M is gross overestimate. You might want to state a range like from $237M to $440M. The statement referencing Martinez (2016) is confusing. It reads as if you saying that Greenland has 40 operational sites? I'm assuming you mean the Arctic has 40 sites. You may want to reword this statement. Also, is Martinez (2016) a valid reference?

Answer: A sentence to clarify that this estimate is only valid for the US has been added, the reference to Martinez has been removed as it was confusing and does not add essential information in this paper. Some corrections in the last few sentences of the introduction have been made to clarify that Windsond is a less expensive (in terms of initial set up and consumable costs) alternative for boundary layer radiosounding

With an operational ceiling of 6 km, it does not seem that the windsond system can be used to replace the sondes currently being used at operational sites which record data to 25 km and higher. With this mind what are the practical research applications of the windsond S1H2 as an upper-air system? Because of its limited range it seems best suited for use in boundary layer studies. However boundary layers are often characterizes with sharp gradients in potential temperature and moisture which the S1H2 has difficulty resolving because of its slow response time. Please discuss. Are there plans to use improved T and RH sensors with a better response time?

Answer: Windsond main objective is to enable boundary layer studies, so the Windsond has no upper-atmosphere application. The current response time limitation is the weakness of the system for boundary layer applications. In small scale, Sparv Embedded uses temperature and relative humidity sensors with a better response time, but currently, the cost is high in the context of radiosondes. Lowering the per-unit cost would take a sizeable investment in the production process to automate assembly and calibration. A key point is that the windsond system can be used in countries with limited resources to deploy a radiosounding network utilising the more accurate but more expensive sondes as well as field campaigns were multiple shallow sounding are required. An example of this application is the VORTEX-SE project,

where Penn State University released 24 sondes at the same time to study winds around storm supercells and might release as many as 100 at a time in the next season. This is a unique feature of Windsond for dense measurements (http://windsond.com/swarmsonde-is-in-the-news/)

Line 56: Why is the operational ceiling at 8 km? Is this the burst altitude of the party balloon used with the sonde or are there some other considerations?

Answer: Supporting soundings higher than 8-10 km requires technology that more closely resembles traditional radiosondes, diminishing the advantages of Windsond. The sondes would be heavier and require a more expensive sensor suit to overcome the hasher measurement conditions in the upper atmosphere. Moreover, while not all users find it worthwhile to recover the sondes, at high altitude the sondes would drift too far for any recovery to be feasible. Windsond does not try to replace traditional sondes, but rather enable new low-altitude soundings.

Figure 4: It's difficult to see the ruler in this picture to get an idea of the length of the sonde.

Answer: The picture brightness has been fixed to see the ruler

Line 104: Also mention that the RS41-SG pressure calculation uses the hypsometric equation.

Answer: This has been added line 104

Line 123-124: Please clarify what it means "that the MW41 only produces the highest degree of signal processing". In other places you mentioned RS41 data before and after processing.

Answer: The predecessor of the MW41, the MW31 had a research mode and an operational mode. The research mode processes the data as little as possible only correcting solar radiation and pendulum effects, while the operational mode produces the highest degree of signal processing filtering raw data and interpolating discontinuous data. The MW41 has only the operational mode available, to obtain the equivalent of the MW31 research mode data (data before processing in the text) the flight have to be simulated from the flight archive with the minimum amount of data processing enabled

Line 126: Please clarify what corrections have been introduced. Have these corrections been implemented in the results from this study?

Answer: The sentence has been changed to: "During this experiment, the uncorrected data have been used, but the ground pressure altitude and temperature have been adjusted to the value measured by the ground-based instrumentation available on the Kumasi supersite."

Line 153: What is experiment 6?

Answer: The experiment 6 is the reproducibility experiment presented in section 6 this information has been added to the text

Line 167-168: This discrepancy between sensors at 2000 m is difficult to see in the manner that the data is displayed. Could the data be presented as a function of height or pressure to better show this?

Answer: We have chosen to directly compare each variable as the altitude error on the Windsond S1H2 would have superposed on each sensor error and not each sensor performance. Moreover, the Vaisala system does not have a pressure sensor and the pressure is calculated by the MW41 as detailed in section 3.3 while the Windsond has a pressure sensor so the profiles as a function of pressure would display data as a function of a calculated variable in one hand to a measured variable on the other hand. We could also display both sonde data as a function of the Vaisala altitude, but this will involve modifying the shape of the S1H2 profile to fit in the Vaisala altitude profile and consequently not display the actual profile obtained with the S1H2 system. We consequently think that displaying the data of the Vaiala sonde as the function of the Windsond data is the best way to assess the performance of each sensor without interference from other sensor errors.

Line 176: Please verify that Vaisala does not use GPS differential correction to compute winds as I thought they did. In fact this statement seems to contradict what is said earlier in lines 111-113. Did you mean the S1H2 does not do differential correction to compute winds.

Answer: Section 3.4 lines 110-118 have been rephrased for clarity as it was confusing the way it was presented.
The Vaisala sonde uses differential correction for latitude longitude and altitude positioning. However, the Vaisala system computes the wind speed independently from the position using the GPS signal without Differential correction.
The Windsond system does not have a differential correction on its GPS to compute latitude and longitude and uses pressure to compute altitude.

Line 176: It seems really puzzling why the Windsond winds are of such poor quality. For example the IMET sonde system does not use a differential wind correction and its winds compare quite favorable to the RS41 sonde. Can you give some explanation for the poor performance of the Windsond winds? Is some of this error due to the pendulum motion of the sonde swinging below the balloon which is filtered out in the RS41 processing but not filtered out by S1H2 system?

Answer: The poor agreement surprised Windsond as informal comparisons with Vaisala and Graw have shown good agreement in wind speed and direction. The pendulum is a possibility as the Windsond has since increased the length of the tether line. During the performance flight, both Windsond and Vaisala were on the same tether line, while on the reproducibility flight the Windsond was on a shorter line compared to the Vaisala and there was no significant increase in the wind speed and direction error between the two experiments. This suggests that the pendulum correction does not have a significant impact on the wind speed and direction.

Wind gusts and local wind variation associated with the general slower response time of the Windsond system are more likely to explain this error.

Line 195: One sounding does not provide statistically significant evidence for this statement. See comments above.

Answer: We agree that one flight is not statistically significant for definitive conclusion. We have added that this has to be confirmed by more flights

Section 5.2.2. So to clarify are you saying that the results shown for the S1H2 have no post processing and no corrections applied? Can you state what processing and corrections the MW41 performs. You mention smoothing in line 194. Is this smoothing of all fields? Is the balloon pendulum motion only taken out in the MW41 processed data?

Answer: The S1H2 has no post-processing applied especially no pendulum and radiation correction while the data processed by the MW41 have been filtered, pendulum and solar radiation effect have been corrected, and data gaps have been interpolated.

Figure 7: It appears that the surface or starting pressure used is different between the systems. Why is this?

Answer: The surface pressure is the same there is one point with the coordinate (0,0). However it is hard to see so the 2 zero lines have been added to figure 7 for clarity.

Line 207: Does the pressure difference between the two systems continue to increase with altitude?

Answer: A typo has been found and has been corrected in the manuscript. The altitude error increases with height while the pressure error remains stable.

Line 229: What is a .kml file? Does this need to be mentioned?

Answer: kml files or Keyhole Markup Language files are files used for expressing geographic annotation and visualization within Internet-based, two-dimensional maps and three-dimensional Earth browsers such as Google earth.
As this information is not essential the information have been deleted and replaced with:
“the system automatically predicts and displays the expected landing point on a map view.”

Line 232: Are these flashes of light coming from the sonde? Please clarify.

Answer: Yes, the flashes of light are coming from inside the sonde we changed the sentence to “the contact between the sonde and the ground station was established, the sonde started immediately to emit loud beeps (about 15 seconds time interval) and flashes of light.”

Line 235: Have you considered if a 4m string is long enough to prevent balloon effects on the sonde observations? I believe the Vaisala system uses a much longer string (20-30m) to prevent any balloon impacts on the sonde data.

Answer: The 4 m string has been chosen following the constructor recommendation, however Windsond has since changed its recommendation for the sondes suggesting that balloon effects have been noticed.
During the performance flight, both sondes where tapped together under the 20 m meter string and the winds errors are a similar magnitude as during the reproducibility experiment so the balloon effect does not seem to have a significant impact on the sonde data.

Line 244: Please clarify what the "data alteration study" is.

Answer: The data alteration study is the study of the alteration of the sounding performance through sonde re-use. The text was changed to "data alteration from sonde re-use study"

Line 285: This is good suggestion and should be a standard practice for all flights (i.e.,proper surface base-lining of sondes)

Table 3: Please mention the RH sensor response time.

Answer: The response time of the RH sensor was added

Listed below are some additional minor suggested changes the authors may want to consider.

Minor comments

All the suggested rewording have been applied to the manuscript
Line 48: suggested rewording, "because the LLC cover …"
Line 50: suggested rewording, "boundary layer sounding during …"
Line 69: "Figure 4 shows the Windsond …"
Line 74 "sensor is used in …"
Line 134 and elsewhere like Table 6: mention if time is GMT or LT.
Line 160: "all the assessed meteorological parameters …"
Line 168: "sudden warming …"
Line 171 and 172: change "reply" to "response"
Line 234: "When re-using the sonde …"
Line 256: "for locating soundings …"
Line 289: Seems like "different altitudes" should be "lower altitudes". This would be a good place to state the specific niche that the Windsond is trying to fill. Certainly in its current configuration it will never be used as an operational sounding.
Line 292: "longer response time …"