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Atmospheric Measurement Techniques Discussions

Interactive comment on "Advancements, measurement uncertainties, and recent comparisons of the NOAA frostpoint hygrometer" *by* Emrys G. Hall et al.

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The authors would like to thank all of the anonymous referees for their constructive comments helping to improve this manuscript. Below, we provide detailed responses to each of the comments. Manuscript changes are listed below the author's response when warranted.

Anonymous Referee #2

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Review report on "Advancements, measurement uncertainties, and recent comparisons of the NOAA frostpoint hygrometer" by Hall et al.

This paper describes the historical NOAA FPH instruments and the recently developed corrections to the old thermistor data, discusses the measurement uncertainty budget, and shows some recent intercomparison results for the latest version of the NOAA FPH. This is a very good summary paper for the instrumental details of the NOAA FPH whose >30-year record at Boulder, USA is one of the key climate data record for stratospheric water vapor. The paper is very well written. I only have some minor comments.

Pages 4-5, Sections 2.1-2.4. It would be very useful to show a photograph of each version together with the combined radiosonde.

Author's response: We have added figure 2 showing all four versions of the NOAA FPH throughout the ongoing 36 year record along with their accompanying radiosonde in a four paneled photograph (see attachment).

Page 5, lines 2-3; page 6, lines 4-5; page 6, line 18. Pressure sensors are mentioned. I think they are for the mirror temperature controller, not for the calculations of mixing ratio, geopotential height, etc. Please explicitly write this to avoid confusion.

Author's response: Clarification concerning pressure sensors is now made for each of the different versions of the NOAA FPH. This comment along with the previous comment helped the authors find that FPH V1 integrated the electronics and baroswitch from a 1680 MHz VIZ "A" radiosonde into the FPH electronics.

Author's change in manuscript: We have modified the following text in section 2.1 to read: "The components from a 1680 MHz VIZ "A" radiosonde were integrated inside the FPH electronics package excluding the carbon hygristor humidity sensor which was intentionally left off (Fig. 2a). This included the specially designed baroswitch and electronics of the radiosonde with the thermistor protruding on a stick off to the side. The baroswitch controlled hygrometer gain changes during the flight and served as the main pressure source for this version of the FPH. The data was telemetered wirelessly and recorded on a paper strip chart."

Author's change in manuscript: The following sentence was added to section 2.2 regarding the pressure sensor for version V2 and V3 of the FPH: "This sensor was only used for gain changes as the Vaisala RS-80 radiosonde measured pressure for all calculations for FPH V2 and V3 hygrometers."

Author's change in manuscript: The final sentence in section 2.4 was modified to now read: "A digital calibrated pressure sensor was incorporated into the hygrometer adding the flexibility to perform tasks throughout the flight based on pressure and also served as a backup source if the radiosonde had issues."

Page 8, line 3. The actual temperature points should be written here, not at page 9, lines 22-26. This is in part because there are some discussions on the temperature points at page 9, lines 9-11.

Author's response: The temperature points for the 3-point thermistor calibration are listed in section 3. The discussion at page 9, lines 9-11 is in reference to an error in the older 3-point fit at the 0 °C calibration point when using the HP3490A multimeter prior to 1987. We have added text to clarify the self-heating problem in section 3.2. We decided to keep the six calibration temperatures listed in section 3.3 as there was no reference to the actual temperatures prior.

Page 11, lines 21-22. It would be useful to have a summary of the uncertainty information on the VIZ A radiosonde as well.

Author's response: We have added the uncertainty of the VIZ "A" radiosonde along with two new references (Tarasick et al., 2016 and Richner and Phillips, 1981). Now each radiosonde type used throughout the NOAA FPH record has an uncertainty and a reference supporting the uncertainty provided in the manuscript.

Author's change in manuscript: The text was modified to read: "Manufacturer quoted radiosonde pressure sensor uncertainties are used for the iMet-1-RSB (1070–400 hPa: ± 1.8 hPa / 400–4 hPa: ± 0.5 hPa), the Vaisala RS-80 (1080–3 hPa: ± 1.0 hPa), and

the VIZ "A" (1050–5 hPa: ± 2.0 hPa) at the 2-σ accuracy limit (Stauffer et al., 2014; Richner and Phillips, 1981; Tarasick et al., 2016)."

Page 12, lines 22-23. The implication of this sentence ("The older analog instruments switched gains around -55C instead of -53C") is unclear. Is there a possibility that the older instruments may have the cubic ice issue? If so, is there any way to detect the issue and to correct the vapor pressure data? Also, it would be interesting to show an example of the FPH data actually affected by the cubic ice.

Author's response: We added text explaining the gain change on the older instruments which creates a sublimation and regrowth of the frost layer similar to the dedicated mirror clear at -53 C. We also added a line explaining that we have not identified cubic ice on any profile collected from a NOAA FPH and do not believe cubic or any other form of metastable ice forms on the FPH mirror during a flight.

Author's change in manuscript: The text was modified to the following: "Prior to 2008 the older instruments switched from low to high gain around -55 °C creating a similar sublimation and regrowth of the frost layer due to frost control oscillations instead of the dedicated mirror clear at -53 °C. It is unlikely that cubic ice or any other metastable form of ice forms on the FPH mirror after the mirror clear or gain change. To date, there have not been any profiles where cubic ice has been identified.

Page 15, Section 7.2. I do not understand why frostpoint temperature is shown in Figure 10 while mixing ratio is shown in Figure 11. In mixing ratio comparisons, the radiosonde pressure sensor uncertainty is included.

Author's response: Figure 10 (now 11) shows frostpoint temperature profiles in panel (b) and frostpoint temperature difference in panel (a) in order to show the reader the full range measured during a typical NOAA FPH profile. Panel (c) shows good agreement with the stratospheric water vapor mixing ratio profile. On the other hand, figure 11 (now 12) was plotted in mixing ratio in order to show the full range measured during a typical flight. By having full profiles showing both frostpoint temperature and water vapor mixing ratio the reader is better able to understand the instrumentation and range of data that is collected from the surface to the lower stratosphere.

Author's change in manuscript: We added the following paragraph at the end of section 7.2: "Figure 11 a and b are plotted in absolute frostpoint temperature and frostpoint temperature differences to show the principal raw measurement of the instrument over an entire profile. However, the CFH FPH dual flight data are plotted in mixing ratio and mixing ratio percent difference to show the full range of water vapor mixing ratio measured during a flight."

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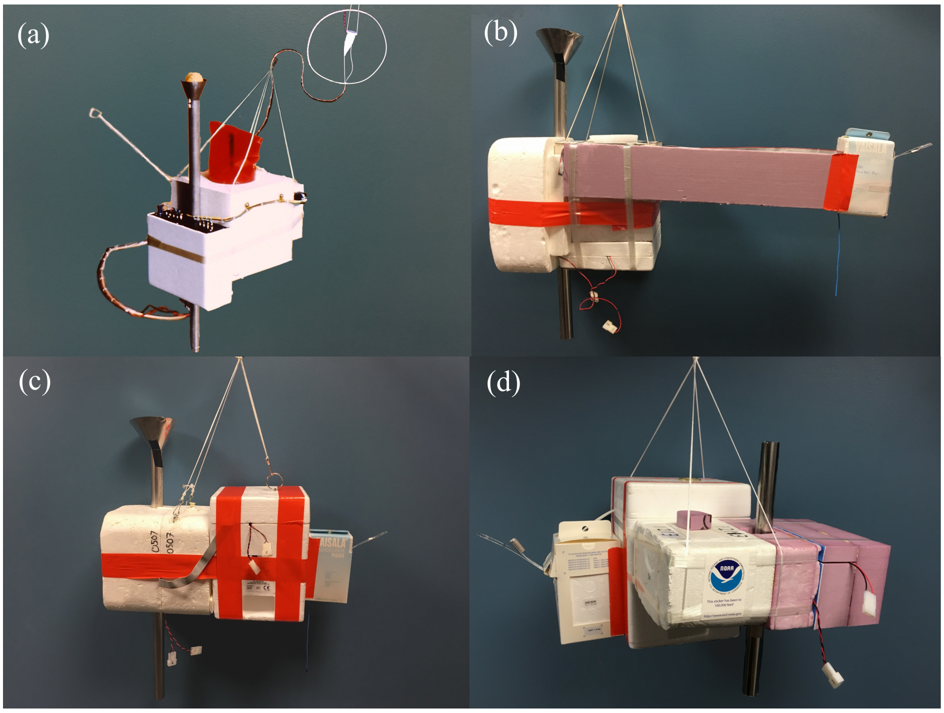

Fig. 1. We have added this as Figure 2 to the paper as suggested by the referee.