Review report

The “Golden Points” and nonequilibrium correction of high-accuracy frost point hygrometers

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This paper proposes a very active use of the mirror reflectance data (Um) of the balloon-borne Cryogenic Frostpoint Hygrometer (CFH) measurements to obtain much more information than previously done, resulting in less uncertainty and higher temporal/vertical resolution of the measured water vapor concentrations. The central ideas include the so-called Golden Points where the time derivative of Um becomes zero, and moreover, the correction for the data points between these Golden Points, the latter of which is termed as nonequilibrium correction. The theoretical background and actual implementation procedures of this nonequilibrium correction are fully explained and discussed in Section 4; and, the theory with several key assumptions look very reasonable to me. Then, the correction is applied to a large number of (~70) CFH sounding data taken from various locations from the tropics, through Northern Hemisphere (NH) midlatitudes, to NH winter polar region, showing that the proposed method actually results in less uncertainty and higher temporal/vertical resolution of the CFH measurements. I believe that this paper manuscript would mark a very important step historically for balloon-borne chilled-mirror hygrometry.

While the manuscript is very well written after Section 3, I was a little bit ‘uneasy’ while reading through Sections 1 and 2. This is mainly because there is no explanation on the Golden Points nor on the nonequilibrium correction until Section 3. Instead, there are rather lengthy (in-depth) reviews on atmospheric water vapor, observational challenges, etc. (I also notice that there is duplicated information in several places.) I am afraid that this style may even discourage some readers to read it through. I personally think that the authors can go more quickly to the definition of the Golden Points and to the explanation of the nonequilibrium correction in the manuscript. At least, at the end of Section 1, the authors should explain the definition of the Golden Points and the overview of the nonequilibrium correction and describe what will be discussed in each of the following sections. This will make the introductory part even longer, thus the authors may consider shortening the review part and removing duplicated information. (Please let me note that the review part itself is very interesting, but probably is less relevant to the main points of this manuscript.)

Please see below for specific comments and suggestions.

- Section 1: Please see the above comments for this section. (I do agree that this is a very

good set of reviews on the matter, but perhaps less for this particular manuscript.)

- Section 2: I think that the authors can shorten this part as well, describing only the key technical aspects of CFH, RS41, and FLASH-B which are directly relevant to the discussion in and after Section 3. (The main topic of this paper manuscript is the application of Golden Points concept and nonequilibrium correction.)

- Paragraph at lines 171-177: SKYDEW may also be mentioned already here.

- Line 213: Could you add a few more words to explain what does "auto-correlated error component" mean?

- Line 353: "resp." should be "or" (there are few other places where "resp." appears)

- Line 387: Sugidachi et al., 2025 is also a good example.

- Line 434: "less than 0.2 K error" – please add an explanation why (although this may have already been explained implicitly somewhere). Also, add "vapour" to water mixing ratio.

- Paragraph starting from line 438: The technical information on FLASH-B may be moved to Section 2, so that we can concentrate on the Golden Points concept itself here.

- Paragraph starting from line 466: The technical information on RS41 may be moved to Section 2, so that we can concentrate on the Golden Points concept itself here. Also, for RS41 data provided from the ground-receiving system, a time-lag correction may have already been applied within the manufacturer software. Does the sentence mean that the authors make an additional time-lag correction? In other words, do you mean that the manufacturer's time-lag correction is insufficient? Please clarify this in the text.

- Line 520: Please add one sentence to justify this simplification.

- Lines 563-573: This part is related to the Golden Points. I think that this may be moved to Section 3.1, so that we can concentrate on the nonequilibrium equation here.

- Line 587: The term "standard diffusion coefficient" should appear here, not at line 590.

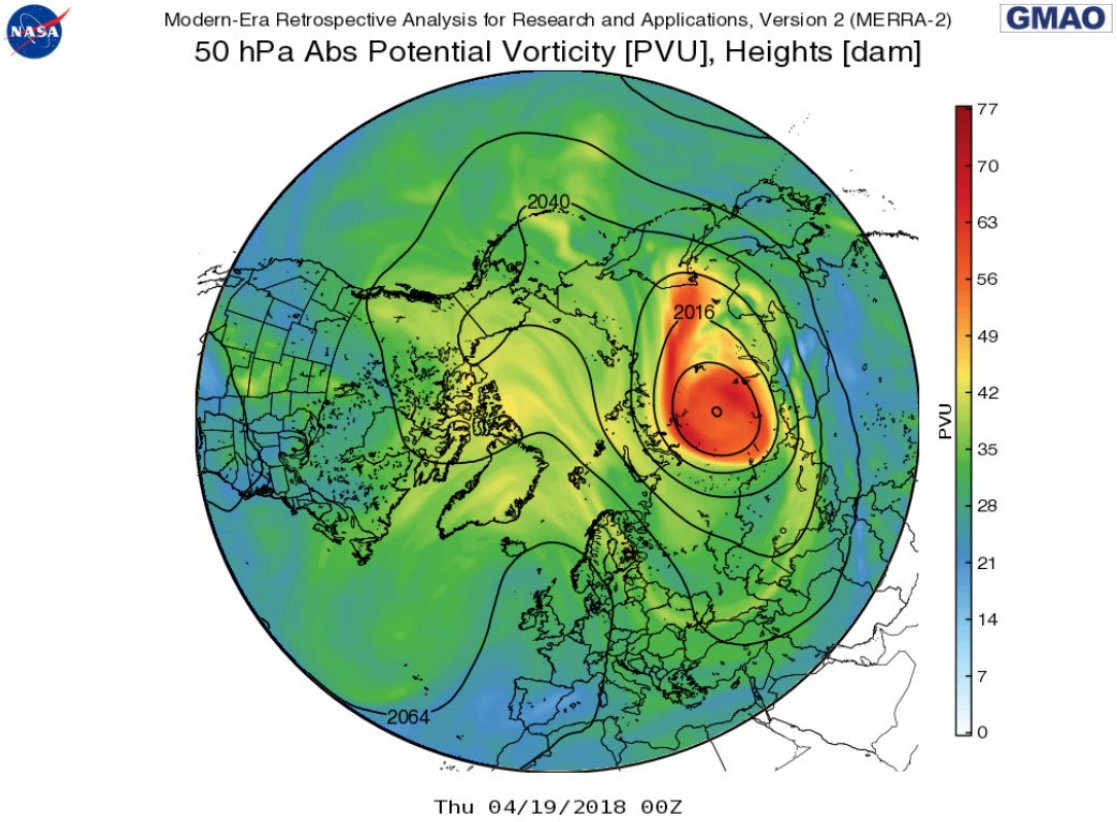
- Section 4.2 (corrections to RS41 data) and Section 4.3 (corrections to FLASH-B data) may be moved to Section 2 or to Appendix/Supplement, because this manuscript mainly discusses the CFH data corrections (and the readers would be primarily interested in those, and probably not the details of the RS41 and FLASH-B corrections although they are important). Having rather long subsections here may disturb the logical flow.

- Lines 942-944: This last sentence, starting from "However" is not clear to me in terms of the logical relationship with the previous sentences. What is the point?

- Lines 1004-1005. I am confused here. Is 10% RH "high"? Probably, additional explanation is needed why this number can be regarded as high.

- Lines 1046-1047: "Thus, it is unclear whether PID control is the most appropriate approach to frost control of chilled mirror hygrometers.": Do you mean that there could be other, more sophisticated and/or appropriate control methods for upper-air chilled mirror hygrometry? Please add a few more words to explain this.

- Section 5.5.1, in particular, the part "High humidity and low number density of aerosol particles point to the polar vortex as a possible region of origin.": Just out of curiosity, I looked at a reanalysis data set MERRA-2 (https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/docs/) whether this could be a case. NASA/GMAO has a website, https://fluid.nccs.nasa.gov/reanalysis/, where we can quickly see weather charts, for example, of potential vorticity at 50 hPa over the Arctic region:
  https://fluid.nccs.nasa.gov/reanalysis/classic_merra2/?stream=MERRA2&field=epv&level=50&fcst=20180419&region=nps&tau=00&track=none



The above figure shows that airmass with relatively high PV values (maybe in the form of differential advection) was actually coming to the western Europe region. The maximum PV stream (colored in yellow) over Europe is located somewhat to the east, but this may be related to difference in time (00 UTC for this figure), actual balloon trajectory, the choice of 50 hPa, etc. More investigation would be needed by downloading and analyzing full model-level reanalysis data (e.g., MERRA-2, ERA5, etc.) to investigate whether the hypothesis is true, although I am not suggesting to do so for this paper manuscript.

- Line 1185: “0.4 s” – perhaps add “for this particular case”