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Atmospheric Measurement Techniques Discussions

Interactive comment on "Understanding cryogenic frost point hygrometer measurements after contamination by mixed-phase clouds" *by* Teresa Jorge et al.

Anonymous Referee #2

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This manuscript, with 34 figures and 3 appendices, is quite lengthy and, at times, highly technical, making it a very large meal to digest. In general, the paper is well-conceived and it should be of interest to AMT readers.

General Comments: I am not convinced that the appendices A and B add anything extraordinarily different from the main body of the paper. They do serve to greatly increase the paper's length by 4 text pages plus 17 figures (on top of the main body's 16 figures). I have never reviewed a standard (non-review) journal article with more than 20 figures, but here I will let the authors and editor decide about the necessary length for this paper.

I find that section 2.4, although interesting, is not really needed in this manuscript because the conclusions of this paper are not at all dependent on the modeling of mixed-phase clouds. Frost point hygrometer profiles showing the observed degree of contamination are undoubtedly afflicted by ice attached to the inside of the intake tube. This section could easily be removed to reduce the manuscript's length.

In all honesty, I was hoping that the very technical fluid dynamics modeling presented in great detail in this paper was going to result in a way to remove the effects of contamination from the measured profiles. I am guessing that the assumptions involved with such a procedure would cause the resulting corrected profiles to have very large uncertainties.

There are many grammar, clarity and language issues that I will try to help fix with the suggested changes below.

Specific Comments: Page 1 Line 1 (P1 L1): why do measurements only in the "(sub)tropical" UTLS provide "important information on air chemistry and climate"? Don't similar measurements in the mid-latitudes (where this contamination can also occur) also provide important information?

P1 L3: are the measurements rendered "difficult" or "unusable" by the contamination?

P1 L8: isn't the 60° maximum impingement angle somewhat determined by the length of the tether used to suspend the instrument below the balloon?

P1 L11: add "and unrealistically" before "high"

P1 L14: add "during ascent" after "only". This does not happen during descent.

P2 L2: The flight train outgassing contamination will affect all balloon-borne hygrometers, not just cryogenic FPs. Does hydrometeor contamination really affect hygrometers with a short or heated air intake?

P2 L5: "severe" implies worse than elsewhere, but the absolute contamination may be

worse at or below the tropopause than above it. I think you instead mean to say the "relative impact of contamination on the measurements is severe in the stratosphere".

P2 L7: Does increasing the tether length or preferential use of descent data help reduce the hydrometeor contamination, or just the flight train contamination? This statement sounds like both contamination types are influenced.

P2 L11: replace "ropes" with "thin hydrophobic tethers"

P2 L13: add "by radiosondes" after "temperature measurements"

P2 L15: I'm surprised the pioneering FP work by Brewer et al. (1948) is not mentioned here, although they used aircraft for their novel measurements, not balloons. I believe these were the first upper atmospheric water vapor measurements using FP hygrometry.

Brewer, A. W., Cwilong, B., and Dobson, G. M. B.: Measurement of Absolute Humidity in Extremely Dry Air, Proc. Phys. Soc., 60, 52–70, 1948.

P2 L22: Change to "Nearly all balloon-borne frost point hygrometer (FPH) soundings performed by NOAA's Global Monitoring Laboratory (Hall et al., 2016) use this valve."

P2 L24: change "of the instrument" to "by the instrument"

P2 L26: change to "using larger diameter stainless steel intake tubes that allow higher flow rates." Also, insert "the instrument" between "enabled" and "to"

P2 L29: "until today" makes it sound like their use has been discontinued. Please change to "These tubes are currently 2.5 cm"

P2 L30-32: change to "shielding the air flowing into the instrument from the contamination" and "containment" to "insulating container", add "mirror" before "surface" and change "extruding" to "extending"

P3 L12: do you mean "preferential" or "susceptible"?

P3 L18: it is also a common feature of soundings in mid-latitude convective regions like the Asian and North American monsoons

P4 L9: RH corrections for RS41 measurements are provided by the Vaisala MW41 software, not the sonde itself

P4 L11: "automated ground check" of what? A single point check? 0% RH or 100% RH?

P4 L13: "cold", "cryogenic" and "refrigerant" all imply the same thing. How about "against continuous cooling of the mirror by a cryogenic liquid."

P4 L13: change "air mass" to "air flowing past the mirror"

P4 L18: I presume these biases are for the Vaisala-corrected RS41 RH measurements. This should be stated here.

P4 L20: "could"? or "did"?

P4 L21: how is the 10 ppmv limit "empirical"? Isn't this instead a "realistic threshold"?

P4 L22,23: change "was" to "were" (data a is plural noun). Here and throughout the paper.

P4 L27: "the operation" is vague. Instead, describe the poor sensitivity at low RH values in a cold environment.

P4 L28: "clearing and freezing cycles" will not be understood by many readers. Please briefly describe why this is done.

P4 L30: and not just "ice", but "hexagonal ice" (rather than cubic ice)

P5 L5: How do the potential biases in RS41 temperature and pressure measurements increase the uncertainties of these comparisons?

P5 L13: change "would allow for very little vertical resolution" to "yields measurements at much lower vertical resolution than during ascent"

P5 L21: why do you presume that the mean (gray) profile is completely “uncontaminated”? There must be some proof. Very low flight-to-flight variability in these “uncontaminated” profiles? Comparisons to satellite profiles in the region? I think the term “uncontaminated” is not warranted here unless you provide some sort of evidence.

P5 L29: Please briefly state why the COBALD must only be flown at night

P6 L11: Here and throughout the paper. Please restrict the labeling of Figure markers, lines and curves in the body text, e.g., “air temperature from RS41 (green)”, to Figure captions, otherwise you are simply repeating in the body text what is stated in the captions. When viewing the figures it is much easier for readers to consult the captions for this information than the body text.

P6 L13: Does the “freezing cycle at Tfrost= -15°C” include a “burn-off” of the existing condensate on the mirror followed by a re-growth of ice, or just a forced freezing of any liquid present on the mirror? If the former, why is the existing condensate first evaporated/sublimated?

P6 L18: How were “reasonable values” determined? Climatologies? Satellite profiles? Could high mixing ratios (>10 ppmv) actually be present in the LS due to overshooting convection? Jim Anderson and his group claim they measured >12 ppmv in the LS over the North American monsoon.

P6 L21: Some readers may not know what “glaciation” means in this context. Please briefly explain.

P6 L32: only “icing”? How about liquid water depositing on the warmer-than-ambient skin of the balloon? The balloon fill gas typically cools down at a slower rate than the ambient air temperature and keeps the balloon skin at super-ambient temperatures.

P7 L2: Some readers may not know what the Wegener-Bergeron-Findeisen process is. Please briefly explain.

P7 L13: I find this section, “Modelling of mixed-phase clouds”, to be interesting, but

not really an essential part of this paper about the contamination of FP measurements. See my general comment above.

P8 L18: again, “mirror extrusion” doesn’t make sense. The mirror is not extruded in manufacture nor an extrusion of any type. It is the mirror itself that extends into the flow of air.

P8 L20: “finite” is not needed here since angles cannot be “infinite”. “Non-zero” is better terminology.

P8 L22: “rotational motion” may need explanation here, since it is more of a 3-dimensional motion than a 2-D “pendulum” motion. The payload does not rotate around itself (tumble), but around the vertical axis like a helicopter rotor. A quick explanation will clear up any possible misconceptions.

P9 L14: change “rubber” to “latex”, since the balloon skin is synthetic, not natural

P9 L26” change “to stem form” to “stems from”

P9 L28: change “decomposed” to “separated”

P10 L4: I’m ok with the term “impingement angle”, but not the use of “impingement” as a verb in this situation. I think “impact”, which is both a noun and verb, is a better choice. “Droplets impacting the walls” or “Droplets that impacted the walls” is much clearer. Please change throughout the paper.

P10 L20: I do not understand what you mean by “also for the circulation around the equilibrium point”. Are you addressing payload rotation (helicoptering) around the equilibrium point? Please clarify.

P10 L28: change “after the ice sublimated” to “until the ice sublimates”

P11 L14: “extends for 34 cm” from what? Presumably the insulating container?

P11 L15: more “extruding” and “extrusion” problems here. Change “extruding” to “that

extends", while the word "extrusion" can be omitted.

P13 L21: replace the comma with "while"

P14 L11: remove the "-" from in-homogeneously

P14 L26: it isn't clear what the phrase "air mass experienced by the mirror in real flight conditions" means here. Are you asserting that the entire flow of air through the instrument influences the frost point temperature, and not just the air flowing right next to the mirror? If so, I agree.

P16 L28: change to "during the traverse through the mixed-phase cloud"

P16 L31: change "water" to "ice" since liquids don't sublimate. Same for "condensate" in line 33

P17 L4: only solids sublimate, so the phrase "more water vapor sublimated" makes no sense. Similar problem P18 L24

P17 L30: "more hit" is awkward. How about "hit most frequently"? And "during the mixed-phase cloud" is also awkward, so please change to "within the mixed-phase cloud"

P17 L33: remove "with some water vapor"

P18 L2: Why is the range "4-8 ppmv" expected? 8 ppmv seems excessive for the altitude limits of balloons. However, in the LS, 8 ppmv might be possible from overshooting convection, but that would be very infrequently sampled.

P18 L14: change to "day-to-day"

P18 L15: change "have in average a dry bias" to "have, on average, a dry bias" and change to "flight-by-flight" (add hyphens)

P18 L17-19: "it was not clear whether RS41 had a dry bias or if CFH measured a too high humidity" sounds like a sold argument for NOT using the RS41 RH measurements

to check if the CFH measurements were contaminated. Then you emphatically state that this is what you did. This is somewhat confusing and needs to be re-written with greater clarity.

P19 L10: "CFH under-estimated the water vapour measurement in relation to the RS41" is awkward. The instrument doesn't "estimate" anything, it measures the frost point temperature. Please fix this sentence.

P19 L14-15: Combine these two sentences by including "1.45 mg" in the first sentence.

P19 L25: By "instrument payload" you are referring to the insulating container surrounding the CFH, correct? Something like a radiosonde on the other side of the container could not possibly contaminate the air flow into the CFH, correct?

P19 L30: add "(2084 masl)" after Nainital. This explains the surface pressure of 800 hPa.

P20 L10: in this instance, is "circular movement" what was earlier referred to "rotational motion"? If so, I prefer "circular movement" throughout the manuscript because it's meaning is perfectly clear, unlike "rotational motion".

P20 L13: "in this region at this pressure level" seems redundant

P20 L22: I don't think "exclude" is justified here, but identifying the balloon as "a minor contributor to contamination" is.

P20 L33: omit "mixing ratio" since it is clear what 12 ppmv is.

P21 L27: "As conclusion" is awkward. "In conclusion" is better.

P21 L21: change to: "We investigated the potential contamination of water vapor measurements . . ."

P22 L2: I'm pretty sure you didn't encounter mixed-phase clouds, but the balloon and payload certainly did.

P22 L3: Pardon my ignorance, but doesn't "mixed-phase" imply the presence of both liquid water and ice? Otherwise, what two phases are mixed in the cloud? So why is it even necessary to say that "liquid water was likely present in all of them"?

P22 L10: omit "already"

P22 L16: do you really mean "protecting" here? Or is "preserving" a better way to describe this?

P22 L22: "fast ascent balloon velocities" is awkward. I would remove "balloon".

P22 L25: replace "a slow balloon ascent through the entire flight between 3 and 4 m/s" with "the ascent rate was slow (3-4 m/s) for the entire flight"

P22 L29: the contamination does not "affect the operation of the CFH", it affects what is being measured.

P22 L31: replace "found in these cases" with "below 20 hPa during these three flights."

P22 L32: replace "the enhanced and contaminated water vapor values" with "the contamination"

P23 L1: what is a "two balloon tandem"? "flying two balloons separated" is clearer.

P23 L4: you showed (above) that the contamination from the balloon skin was nearly negligible, but now are concerned that a payload spending more time in the balloon wake would be more prone to contamination. Is more of something negligible necessarily a problem?

P23 L10: "atmospheric air" is redundant. Omit "atmospheric"

P23 L19: Just for your information, the older Vaisala RS92 did this with its dual RH sensors, deicing one while the other made measurements, then switching.

P23 L23: change to "We made many assumptions"

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