Review of

'The "Golden Points" and nonequilibrium correction of high-accuracy frost point hygrometers' by Poltera et al.

Author response to reviewer comments

We would like to thank the two anonymous reviewers and Takuji Sugidachi for their constructive and critical evaluations. Some of their comments were challenging and required considerable effort, but they also helped to improve the quality and readability of our manuscript. The reviewers' comments are listed below in black font, and our responses are in italicized blue font. We would like to thank our reviewers once again, as well as the editor for allowing us additional time for revision.

CC1 - Community Comment 1

'Comment on egusphere-2025-2003', Takuji Sugidachi, 06 Jul 2025

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This article demonstrates that the use of "Golden Points" and the nonequilibrium correction for chilled-mirror hygrometers results in more reasonable frost point profiles with higher vertical resolution. I believe these approaches are based on the measurement principles of chilled-mirror hygrometers, and therefore provide a more appropriate method for mitigating the oscillations caused by PID control in the mirror temperature profile.

I have a specific comment regarding the section on the SKYDEW hygrometer. Section 5.6 describes the application of the Golden Point method to SKYDEW. To compensate the timing error associated with the Golden Point, the mirror temperature data are shifted by 0.4 s relative to the scattered light signal. This 0.4 s shift appears to be appropriate for the profile shown in Figure 10, as well as for many other cases where shifts in the range of 0 ~ 0.6 s are observed. I am aware that the timing of the condition Um/dt=0 often lags behind the expected frost point. Do you have a theoretical explanation for why this shift is necessary? Or do you consider this timing error to be random?

Additionally, you mention that a small |dUm/dt| indicates a good measurement (e.g., lines 404 and 1372). However, for chilled-mirror hygrometers, the profiles with small |dUm/dt| typically indicates low sensitivity to changes in the condensate. In my view, an ideal measurement is when the profiles of mirror reflectance (or scattering) signal and mirror temperature exhibit large |dUm/dt| and small |dTm/dt|, which makes more reliable and less uncertain determination of the point where dUm/dt=0.

Dear Takuji Sugidachi,

Thank you for your comment on our manuscript.

(i) Timing error on the SKYDEW hygrometer

We believe that the instrument developers best understand the source of the timing error, as it originates from sub-second internal processing and telemetry aspects.

Usually, the mirror temperature Tm and the reflectance Um are not sampled in parallel in a chilled-mirror hygrometer, but at different times (within 1 second). The microcontroller sometimes even performs multiple other actions between the sampling of Tm and Um. In order to reduce the timing error, these sub-second differences in sampling (and possibly averaging) time between Tm and Um should be taken into account and - if possible - be reduced as far as is feasible.

We do not consider the timing error to be random, but rather of systematic nature, i.e., constant over a given flight section. At least, this is how we have successfully treated the case study in Section 5.6 (Figure 10). However, here again, instrument developers are best suited to answer this question. The residual timing error, i.e., the error after correction of sub-second timing issues, might be considered of random nature.

(ii) Metric for good chilled mirror measurement

There are arguably different metrics for a high-quality frost point measurement.

One metric is the frequency of Golden Points (dUm/dt=0) occurrences. Large |dUm/dt| coupled with frequently occurring dUm/dt=0 and well-synchronized and accurate Tm data is a good quality measurement. The main advantages are the high frequency of Golden Points and the self-correction ability (which is made possible through the high frequency of Golden Points and large |dUm/dt| in-between Golden Points, see the case study in Section 5.7). A disadvantage is the post-processing requirement, as non-equilibrium errors between the Golden Points and sub-second timing issues degrade the quality and vertical resolution of the measurement in case they are not corrected (or smoothed out).

Another metric is the nonequilibrium error |Tm-Tf|. Small |dUm/dt|, together with a high sensitivity to changes in the condensate (A) and well-synchronized and accurate Tm data is also a good quality measurement (Eq. 8a). As you point out, the disadvantage is that small |dUm/dt| alone do not guarantee that the nonequilibrium error is small, as small |dUm/dt| might be caused by a low sensitivity to changes in the condensate, which is difficult to determine at first glance in the absence of additional sensors such as RS41 or FLASH on the same payload.

In our view, the frost point measurements achieve highest quality when all conditions are fulfilled: i) frequent dUm/dt=0 occurrences, coupled with ii) small |dUm/dt| and iii) a high sensitivity to condensate.

You describe the situation with large |dUm/dt| and small |dTm/dt|. This would indeed be an ideal measurement scenario for Golden Point (dUm/dt=0) sampling, especially if the Golden Points occur frequently. Large |dUm/dt| requires large non-equilibrium error |Tm - Tf| (see Eq. 8a). This means that for small |dTm/dt| and large |dUm/dt| to occur, |dTf/dt| has to be large. There are however many situations where |dTf/dt| is not large (i.e., where the atmospheric frost point is varying only slowly), such as during pre-launch, within clouds, within the well-mixed boundary layer, or in the stratosphere.

In addition, for the large |dUm/dt| and small |dTm/dt| measurement strategy to work consistently, the morphological sensitivity (A') and/or ventilation (v) would have to increase with altitude, which is challenging to implement (see Eq. 8a).

For these reasons, while we acknowledge that large |dUm/dt| and small |dTm/dt| would be an ideal measurement scenario, we don't think there is an instrument design that can consistently achieve this.