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Atmospheric Measurement Techniques Discussions

Interactive comment on "Performance of WVSS-II hygrometers on the FAAM Research Aircraft" *by* A. K. Vance et al.

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We would like to thank the referee for taking the time to consider this paper and provide the comments to which we reply, below:

======== "Discussion" =1======

Referee_1: I think the Aquavit2 discussions in sections 2.4, 3, and 4 may be a better fit logically in the discussion section.

Response: We feel that, because of its relevance to the uncertain lower limit of the WVSS-II, the reference to AquaVIT-2 in section 2.4 is more useful there than in the discussion section but the other references could, reasonably, be moved.

=2======

Referee_1: So what now? Does this just give us a better idea of the biases? What is the actionable message of the manuscript? What future experiments are needed to further constrain and characterize these effects, particularly with respect to the conditions and extents to which liquid water affects the wvssR. These should be addressed in the discussion Section 5.2 concerning droplet size and wvssR bias is confusing to me.

Response: The intention behind the paper is to publicise the instrument as a possible research tool, to provide the reader with a better idea of the biases, as the reviewer notes, and to do so provide a refereed publication for the benefit of other workers. It is not intended to provide exhaustive analysis of the source of biases as this is a substantial piece of work requiring specific extra measurements and worthy of a paper in its own right; these measurements are currently under way with the intention of publishing a more detailed investigation next year.

Original text (p. 8656 ll 18-22): "Although the wvssF appears to be immune to liquid cloud, the wvssR is not and may, under certain conditions, report a value closer to the total water content than the vapour content. It has not been possible, from these data, to define these specific conditions. Neither WVSS-II appears to be susceptible to the presence of varying sizes and concentrations of ice particles."

Proposed replacement: "Although the wvssF appears to be immune to liquid cloud, the wvssR is not and may, under certain conditions, report a value closer to the total water content than the vapour content. It has not been possible, from these data, to define these specific conditions and in order to make use of wvssR data in liquid cloud further investigation would be required. Alternatively, the provision of an inlet capable of measuring dry conditions, as can the Rosemount inlet, but showing the flush inlet's immunity to liquid, could usefully be investigated. Similarly, the wvssF appears to be insensitive to ice cloud whereas data suggest that the wvssR may be sensitive to it,

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although the situation is less clear for ice than liquid water, and further work would be required to properly characterise its performance under these conditions. Further work is required to characterise biases and offsets between the WVSS-II and the chilled mirror hygrometers, and between the two WVSS-II.

======== "Section 5.2" =3======

Referee_1: Why is it not possible to extract a more general trend using the large amount of data available?

Response: It is possible, although labour intensive, to extract more data but we do not expect a robust relationship to be found as there are large uncertainties are expected. There is some concern that the Rosemount inlet may shatter larger drops, resulting in smaller droplets, more likely to enter the instrument. The relationship between droplet size in undisturbed air and that which exists within the Rosemount head is not known. In addition to this, flow modelling suggests that the size spectrum at the location of the CDP may be significantly different from that at the location of the Rosemount inlet.

Original text (p. 8654 l. 15): "...shows an example of susceptibility to liquid droplets of around 20 [mu]m radius. It is therefore not possible..."

Proposed replacement: "...shows an example of susceptibility to liquid droplets of around 20 [mu]m radius. Flow modelling suggests, however, that the droplet size spectrum at the location of the Rosemount inlet may differ significantly from that at the location of the CDP, and there is also concern that any large droplets reaching the Rosemount inlet may be shattered, with some of the resulting fragments being ingested. It is therefore not possible..."

=4======

Referee_1: Why would an example of 20 um susceptibility invalidate the claim that susceptibility generally increases as particle size decreases?

Response: If, generally, susceptibility decreased with increasing particle size, one

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would not expect to see the large increase in humidity illustrated in the first cloud penetration shown in figure 12 of Vance et al., 2011, particularly when cloud with a much smaller modal radius produces no change. As the data are inconclusive, however, we propose to simplify section 5.2, as follows:

Original text (p. 8654, ll. 6-19): "It should be noted, however, that the mean volume radius at which the departure from the total water values occur varies. In all penetrations but the second one, there appear to be a gradual transition between approximately 5 and 10 [mu]m but in the second cloud penetration there is a relatively rapid transition from about 7.5 to 10 [mu]m, where the wvssR might be expected to report total water content. When the mean volume radius is larger than this, the wvssR reports between the total water and vapour only values, as seen elsewhere, but when the mean volume radius drops below 5 [mu]m there appears to be an enhancement, with the wvssR reporting higher values than the estimated total water content. Although this would suggest that the susceptibility of this inlet to liquid increases as droplet size reduces, Vance et al. (2011) shows an example of susceptibility to liquid droplets of around 20 [mu]m radius. It is therefore not possible to draw conclusions about the importance of droplet size, from these data but, but it is clear that the wvssR is likely to ingest and evaporate liquid cloud droplets whereas the wvssF is not. This is, perhaps, not surprising as it has been noted that Rosemount

Proposed replacement: "It should be noted, however, that the mean volume radius at which the departure from the total water values occur varies. Vance et al. (2011) shows examples of susceptibility to liquid droplets of around 20 [mu]m radius but no susceptibility to cloud with a modal radius of $\sim$8 [mu]m. It is therefore not possible to draw conclusions about the importance of droplet size, from these data but, but it is clear that the wvssR is unreliable in liquid cloud as it can ingest and evaporate some liquid cloud droplets whereas the wvssF does not. This is, perhaps, not surprising as it has been noted that Rosemount

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Referee_1: What is the hypothesized significance of the wvssR reporting higher values than total water? The effect appears very minimal in the figure. An inset showing this region in greater detail would perhaps clarify the existence of the enhancement.

Response: We do not regard this as of especial significance, in itself, but rather see it as further illustrating that the wvssR is susceptible to liquid cloud and that it is "not possible to draw conclusions about the importance of droplet size".

======== "Minor Comments" =6======

Referee_1: General: The manuscript contains a significant number of single sentence paragraphs. These points should be either fleshed out or combined with other paragraphs.

Response: Paragraph breaks to be removed at: p 8646 l 5 p 8650 l 21 p 8653 l 11 p 8656 ll 17 & 20

=7======

Referee_1: Sect. 2: It would be more useful if the accuracies/precisions were all described using the same units (e.g. dew/frost point, g/kg)

Response: On the face of it, this would be helpful but, in practice, it becomes involved and, potentially, misleading. The problem is that some measures of humidity depend not only on the number of water molecules present, but also on the temperature and pressure. This means that there is not a simple, direct equivalence, and so, in converting a manufacturer's figure to a different measure, it is necessary to provide information on the relevant temperatures and pressures. To illustrate the non-equivalence and, thereby how a simple statement of accuracy may not be readily converted between measures, we attach a randomly selected humidity profile, plotted as relative humidity, mass mixing ratio, dew point and absolute humidity, scaled so as to overlie. The issue becomes more involved if the instrument measures one quantity but reports a different one, as is the case with the WVSS2, which measures absolute humidity but reports

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VMR; in such cases the manufacturer's figures may not be an accurate description of the instrument's capabilities. Because of this, we feel that it is less problematic to present these figures as originally reported.

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Referee_1: Page 8648, line 2: isokenetic -> isokinetic

Response: Yup.

=9======

Referee_1: Page 8648, line 18: The authors should reference the reasoning behind their belief the wvssR inlet is outside the aircraft boundary layer. I was unable to find reasoning in Vance et al. that addresses this.

Response: We fully appreciate the reviewer's interest in this, and would very much like to be able to cite a source, but are in the awkward position that the data used come from a confidential report provided by the aircraft manufacturer. We would welcome suggestions.

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Referee_1: Figure 1: it maybe be beneficial to add something indicating the direction of the front of the FAAM aircraft

Response: We believe that this should be apparent as the text describes them being both fitted on the starboard side, and angled down.

=11=====

Referee_1: Figure 7 I do not really see the Buck and GE as necessary for this figure due to the already stated fact that their behaviour was highly oscillatory. It might be worth taking a look at zooming in on some of the fall streaks rather than the larger picture to see if it clarifies this point further. I also do not really see the point the

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authors are making with the lower panel. It would be very difficult to make out the effects of the ice enhancements with this type of figure, and I think this point is clear enough with the upper panel anyway.

Response: We tend to agree with the reviewer regarding figure 7, upper axes, and GE and Buck are indeed oscillating and have removed these from the plot. We do feel, however, that the lower axes should be retained as contains a much wider range of data (being from the full flight) and it may be useful to see any trend as a function of vapour mixing ratio.

Original text (p8667): "Time series from flight B672 showing part of a Lagrangian, 'race-track' pattern descent through cirrus cloud with embedded fall streaks. Upper panel shows absolute humidity from wvssF (black), wvssR (red), Buck (green), GE (blue) and TWC (purple). Lower panel shows a comparison of wvssR (red) and wvssF (grey) to the Buck during this period in terms of absolute humidity with boxes indicating upper and lower quartiles."

Proposed replacement: "Time series from flight B672 showing part of a Lagrangian, 'race-track' pattern descent through cirrus cloud with embedded fall streaks. Upper panel shows absolute humidity from wvssF (black), wvssR (red) and TWC (purple). Lower panel shows a comparison of wvssR (red) and wvssF (grey) to the Buck during this flight in terms of absolute humidity with boxes indicating upper and lower quartiles."

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Interactive comment on Atmos. Meas. Tech. Discuss., 7, 8643, 2014.

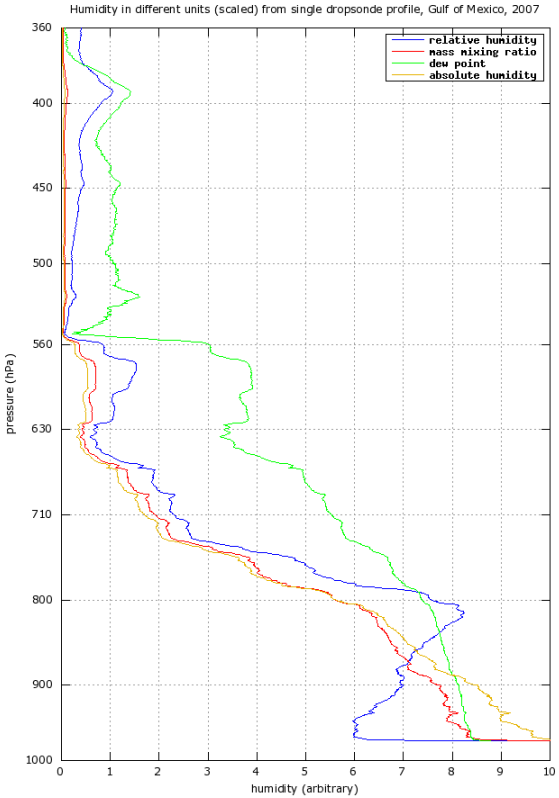

Fig. 1. Illustration of non equivalence of various hygrometric quantities (comment no. 7).

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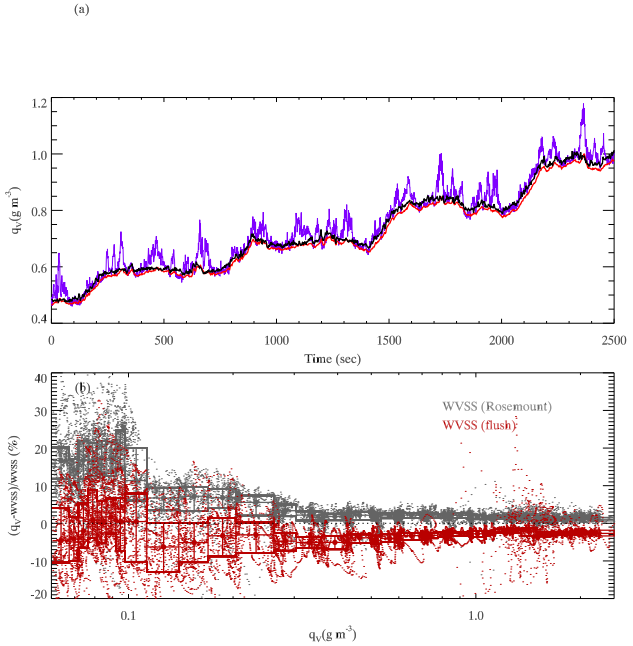

Fig. 2. Replacement for figure 7 (comment 11).

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