Reviewer's comments:
Title: Response of the Nevzorov hot wire probe in Arctic clouds dominated by very large droplet sizes
Author(s): A. Schwarzenboeck et al.
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By Walter Strapp, Environment Canada

General Comments:

This article contains valuable new information on the Nevzorov LWC/TWC probe and should be published. I am glad to see someone is still doing this kind of work, as it is essential to do detailed instrument studies to make progress in cloud physics. The article does contain some errors that need to be corrected. I also think it would be a much better article if authors include some additional discussion of the uncertainties that I have noted in the "Specific Comments" below. I have also made some recommendations throughout the text that the authors may choose at their discretion to implement.

Specific Comments:

Page 1294, line 22: Is the LWC-100 the DMT version of the King Probe? If so, please add DMT to the sentence.

Page 1295, line 1: After the end of the sentence (beyond 40 μm), I recommend that you refer to Biter et al. (1987) and Strapp et al (2003). This evaporation and breakup effect is not a theoretical result; it is rather an empirical observation first measured by Biter.

Biter C.J., Dye, J.E. Huffman, D. and King, W.D. 1987 The drop response of the CSIRO liquid water content. J. Atmos. Ocean Techn., 4, 359-367

Page 1295, line 3: The PVM also suffers from rolloff with MVD. You might want to refer to Manfred Wendish's paper.

Wendisch, M., T.J. Garrett, and J.W. Strapp, 2002: Wind Tunnel Tests of the Airborne PVM-100A Response to Large Droplets. *J. Atmos. Oceanic Technol.*, **19**, 1577–1584.

Page 1295, starting at line 6: The sentence is not quite accurate. It is easier for me to rewrite the sentence than try to explain it. I think it will be self-explanatory. The FSSP is not an imaging probe.

"Besides these direct measurements of LWC, estimates of the total condensed water content, including the ice phase (IWC and/or LWC) can be derived by integrating the size spectra from the Forward Scattering Spectrometer Probe FSSP (Baumgardner, 1985), and the spectra derived from imagery from the 2D-C (Knollenberg, 1981) or the Cloud Particle Imager CPI (Lawson, 1998)."

Page 1295, line 14: Recommend change to "The CVI technology has been recently integrated into an oversize PMS canister, including hygrometer, by Droplet Measurement Technologies (DMT)."

Page 1296, line 8: I don't understand the sentence starting with " The quite good correlation ..". This seems to imply that the probe fails in large droplets or the ice phase. In the case of the ice phase, isn't this the principle of operation of the phase discrimination, that the TWC will read higher in ice than in liquid? I would suggest changing the sentence to the following:

"The Nevzorov LWC and TWC sensors correlate very well in small droplet cloud. In mixed phase clouds, the TWC sensor measurement exceeds the LWC measurement due to its much higher efficiency in detecting ice particles, as expected due to the aerodynamic design of the capture volume. In liquid-only large-droplet conditions, the TWC measurement exceeds the LWC measurement, because the TWC sensor has much lower re-entrainment losses, and due to the fact that the existing collection efficiency assumptions for these probes in such conditions have not been well characterized to date."

Page 1296, line 13: This is not correct. The Strapp et al. (2003) study presents results as a function of the median volume diameter. This is the diameter in the LWC versus diameter distribution at which 50% of the water is below, and 50% is above. Usually, the median volume diameter is higher than the mean volume diameter, which you have shown on page 1303. Also, you are missing a 'pi' and a 6 in equation 10, although we didn't use that anyway.

Furthermore, the drop distributions in a wind tunnel are typically not narrow and monodisperse as you state in the text. There are quite wide. The large MVDs are normally produced by long tails in the distributions. Normally, the LWC-versus-diameter forms a 'bell' type distribution. The biggest difference with atmospheric distributions is the lack of a mode in the small-droplet part of the distribution. The droplet concentrations continue to increase with decreasing diameter. This causes problems for the FSSP, especially for the lower MVDs, because the drop concentrations are so high. You will need to rewrite all the sections that discuss the IRT distributions. If you would like to send it to me for inspection, I would be happy to do it.

Page 1296, line 22: Please consider adding the following sentences and references before "Further tests". This covers some earlier work on the high-speed video images of ice particles bouncing from hot-wires, and the resulting underestimates of IWC from hot wires, including the Nevzorov TWC.

"However, a series of tests at the Cox and Co. wind tunnel, using ice shaved from blocks to simulate ice particles, revealed that a fraction of these ice particles bounce out of the sample volumes of various hot wire devices, including the Nevzorov TWC probe, resulting in an underestimate of the IWC measurement (Emery et al. 2004, Strapp et al. 2005). "Further tests …" and then take out the redundant information after that. If you decide to take my suggestion and rewrite the paragraph, I would be happy to inspect the new paragraph after you have completed it.

Emery, E., Miller, D., Plaskon, S., Strapp, J.W., and Lilie, L.E., 2004: Ice Particle Impact on Cloud Water Content Instrumentation, *42nd AIAA Aerospace Sciences Meeting and Exhibit*, Jan. 2004, AIAA-2004-0731.

Strapp, J.W., Lilie, L.E., Emery, E.E., and Miller, D.R., 2005: Preliminary Comparison of Ice Water Content as Measured by Hot Wire Instruments of Varying Configuration, *43rd Aerospace Sciences Meeting and Exhibit*, Reno, NV, 11-13 Jan. 2005, AIAA-2005-0860.

Page 1297, line 25: What type of instrument was used to measure aerosol, and what was its minimum size limit? This is relevant to the comment that concentrations were low.

Page 1298, line 7: Regarding “feeder-seeder”, do you mean that ice crystals from a higher cloud were falling into the lower cloud? If yes, please state explicitly that there were higher clouds.

Page 1301, line 20:
Please consider adding the next sentence. I think this adds value by showing that this result is common to other hot-wire cylinders, and therefore it is not specific to the Nevzorov LWC. In my mind, this makes the result more believable.

“Similar results were first shown by Biter et al. for the King probe, another cylindrical hot wire like the Nevzorov LWC, and for various other cylindrical hot wires by Strapp et al. (2003). “

Page 1302, line 15: Is not the 1.595 * V**2(LWC)/V**2 (TWC) the same as LWC(uncorrected)/TWC(uncorrected). I don’t quite understand the reason for carrying the voltages at this stage of the article. It makes it more difficult to conceptualize. However, it is not a big issue.

Page 1303, lines 2-7: same comment as Page 1296, line 13: This is an error.

Page 1303: line 14: Regarding Figure 7, I have two major points (1) and (2), and a minor point (3):

(1) Strapp et al. (2003) discuss with some detail that the measurement of MVD is very difficult when you need to use more than one probe (i.e. when the MVD is large), and this is probably the worst for MVDs in the range of 30-100 μm. In your own paper you state: “below 150 μm the (2D-C) is underestimating the crystal concentration”, and therefore presumably also the droplet concentration. Your paper needs to have some kind of a discussion about the uncertainties in MVD. For example, someone might use your correction equation using their own MVD estimate that might be highly biased to yours, especially if they are using different cloud probes. A discussion is necessary to warn the reader that MVD estimation can be difficult with common probes. This could be causing

some of the difference between Strapp et al. (2003) and your results in Fig. 7. It would be nice if this were stated in your text, so that the differences between Strapp et al and the present article have some possible explanation (i.e. MVD). Also, please note that your results in Fig. 7 show how to correct the Nevzorov LWC so that it is the same as the Nevzorov TWC. This is OK, but it is maybe not so obvious to all readers. The results of Strapp et al. display the response of the instrument to its readings at 20 microns MVD, which is not exactly the same thing as yours.

(2) How do you propose to use your equation (14) in mixed phase situations, as you have in section 5.2? Accurate determination of the liquid MVD from particle probes in mixed-phase conditions is exceedingly difficult. Maybe you can do it with the CPI … I am not sure. It depends on whether you believe the CPI distributions, and the separation of the ice particles from the water droplets. Please explain this in the text somewhere.

(3) What is the potential effect of small gain differences between the LWC and TWC probe in Figure 7? We cannot measure the calibration constants perfectly, so there will be some linear effect. I suspect it is small, but it is worth a few lines in the text somewhere.

Page 1304, line 5: same comment as Page 1296, line 13:

Page 1304, line 15 and beyond:

Strapp et al. 2003 showed collection efficiencies from the LEWICE CFD model as follows:

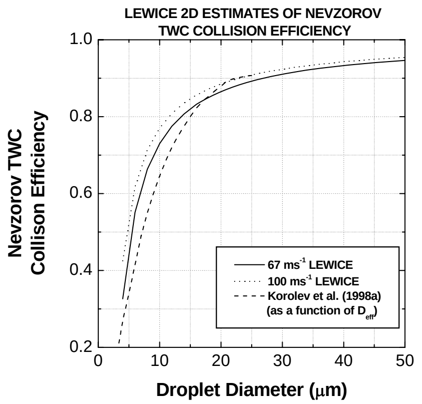

Figure 14: Collision efficiency estimates for a two-dimensional representation of the Nevzorov TWC sensor, using the LEWICE model. The experimental results of Korolev et al. (1998a), as a function of effective diameter, are also shown.

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Do the above efficiencies affect your results at all?

Page 1305, line 1: same comment as Page 1296, line 13:

Page 1306, section 5.2:

First, see comment Page 1303: line 14, item (2)

Second, it is almost certain that the standard Nevzorov TWC is about a factor of 3 low in situations where large ice crystals are not present. This has been the case in wind tunnels and in natural cloud studies, when compared to both the CVI and the deep cone. To quote Alexei Korolev's ICCP 2008 paper,

> "For ice particle spectra with D_{max}<4mm, the IWC measured by the standard Nevzorov shallow cone is approximately 3±0.2 times lower than that measured by the Nevzorov deep cone and CSI. Assuming that the close agreement between the CSI and the deep cone indicates that both are measuring approximately correctly, this allows for corrections of IWC data sets collected with the Nevzorov shallow cone TWC sensor during previous flight campaigns, in cases where large particles are not present. The correction must take into account any liquid fraction in the cloud, which will be measured at a much higher efficiency."

Did you have particles larger than 4 mm in your arctic cases? I am not sure why you don’t just use a factor of 3 correction and apply it to Fig. 9. This figure is for illustration of a real application, and you might as well use the best estimates of the efficiencies.

Walter Strapp