Atmospheric
Measurement
Techniques

Open Access

EGU

Discussions

Interactive comment on "Ice particle sampling from aircraft – influence of the probing position on the ice water content" *by* Armin Afchine et al.

Anonymous Referee #3

Received and published: 6 December 2017

Evaluation of the paper titled: "Ice particle sampling from aircraft – influence of the probing position on the ice water content" by Afchine et al.

Overview: This work examines the important problem of the effects of a probe's location on an aircraft, on the accuracy of its measurements. This topic has a long history of research, and has been explored since the mid-70s by different groups (e.g. Norment and Zalosh, 1974). The most well-known studies in this area were published in a series of papers by Warren King in the mid-80s. Based on the theoretical analysis of particle trajectories followed by in-situ verification (King, 1984; King et al. 1984), it was concluded that the particle number and mass concentrations can be biased by an order of hundreds of percent depending on the mounting location of the probe on the fuselage of the airplane. One of the important outcomes of the King's studies is the identifi-

cation of the regions with enhanced and reduced concentrations of cloud particles at the top of the fuselage. The most favorable places for bulk microphysical instrumentation installation on the fuselage would be the side and bottom positions. This rule has been followed by many research groups when instrumenting research aircrafts for cloud microphysical measurements. The present study reiterates King's conclusion, that the cloud microphysical measurements (specifically IWC) at the side and bottom fuselage locations are more accurate compared to the top location. So, in this regard, this study confirms the existing knowledge about the preferential fuselage locations of the bulk microphysical instruments. In the present work, the conclusion about the accuracy of IWC measurements was obtained based on the comparisons of the TWC probes mounted on the different fuselage locations: top, side and bottom. Even though I agree with the conclusions of this paper, the methodology of the approach employed in this study leaves many questions unanswered. Additionally, critical components of the study of the probing positions are missing: for example, there is no assessment of the dimension of the shadow zone and its distance from the fuselage, the effect of the air density of the particle trajectories and size of the shadow zone is not accounted for, the ice concentration enhancement around the fuselage due to ice bouncing is not accounted for, the particle trajectory analysis has been omitted.

In my opinion, this study should be eventually published. However, in its present form the paper is not suitable for publication in AMT. At this stage I would suggest withdrawing the manuscript and adding the missing necessary components. Because of the great importance of the considered question, and the large anticipated impact of this work on the cloud instrumentation community, I would encourage the authors to address the questions listed below and resubmit the manuscript.

Major comments:

1. This paper validates the conclusion of the King et al (1984) study on a different instrumental basis. Further progress can be achieved by utilizing flow simulations and particle trajectory analysis. At present, CFD analysis is routinely used by different re-

search groups (especially in the aviation community) to analyze the particle trajectories for different aspects of aviation safety and to study the accuracy of measurements of cloud microphysical instrumentation (e.g. Weigel et al., AMT, 2017). It would be highly beneficial for this paper to include these types of simulations. This will help in addressing many aspects of the positioning of the cloud microphysical instrumentation, and provide estimates of the accuracy of measurements. The CFD and particle trajectory analysis may take some time. However, the obtained results will be rewarding for the community.

2. The dimensions of the shadow and enhancement zones at the mounting location of the TWC probes of the HALO aircraft should be provided here. At that stage it is not clear whether the TWC inlets were located inside the shadow zone, enhancement zone or in the relatively undisturbed free flow. Without such information, the discussion is incomplete.

3. King (1984, part 1) considered the formation of the shadow zone on the top of the fuselage for liquid droplets. Liquid droplets after the impact with the fuselage stick to its surface and shed downstream (see Fig.6 in King, 1984, part 1). However, ice particles after impact with the fuselage rebound back into the airflow. Ice particles, after the first rebound, may experience multiple bouncing. This phenomenon was observed in wind tunnels and is well reproduced in CFD simulations (e.g. Korolev et al JTECH, 2013). One of the consequences of this effect is an enhanced concentration of ice particles around the fuselage including side and bottom locations. This is results in a principal difference compared to the King's (part 1 and 2) work, which was focused on the trajectories of liquid droplets. In this regard, it is important to consider the enhancement of ice concentration not only at the top of the fuselage, but all the way around it. This effect may equally affect IWC measurements at the side and bottom locations. This question should be properly addressed.

4. CFD simulations showed that particle trajectories are sensitive to air density air. Therefore, the dimensions of the shadow and enhancement ice particle zones depend

on the air density air along with other parameters such as TAS, AoA, etc. This is a very important issue and it should be properly addressed in this study. Could you also comment on the effect of air on the dependences of IWC ratio vs Rice shown in Fig.10?

5. Page 10. The equation mean mass radius Rice = IWC/Nice should be written as Rice = (3IWC/4πice Nice)^1/3. I believe this a typo. Unfortunately, no information about ice was provided in the text. Since the size-to-mass parameterization M=aRice^b was applied for the IWC calculation, then ice is a function of Rice, i.e. ice = 3aRice^(b-3)/4π. Therefore, the mean mass radius should be calculated as Rice = (IWC/aNice)^1/b. Could you please clarify how Rice was calculated?

6. It is important to indicate the distance of the TWC probes inlets from the fuselage and from the nose of the airplane. This is necessary to understanding the effect of the probe's location on the accuracy of its measurements. Along this way, it would be beneficial to include a summary table with the positioning of the TWC probes, type of the airplane, name of the project, TWC probe, particle probe used as a reference, etc.

7. The diagrams in Figs 7, 8, 9 in their present form visualize the scattering of the IWC points. However, it is difficult to judge about the biases and the degree of scattering of the data points. It is suggested to add a linear regression line, indicate a relevant linear equation, standard deviation, and correlation coefficient in each diagram. This information will help to quantify of the degree of agreement between the IWC measurements. Please also provide the averaging time used for the data these diagrams.

8. The IWC calculated from the cloud particle probes (CAS-DPOL, CIP-G,2DS) was used as a reference for the TWC probes (FISH, HAI, Waran) measurements. The processing of the scattering and imaging probes are sensitive to the algorithms and assumptions employed in the processing software. Thus, CAS-DPOL is usually calibrated in assumption that the cloud particles are spherical water droplets. Were any corrections for ice applied for the CAS-DPOL data? What algorithms and corrections were used during the processing of the 2D probe's data? What are the typical, min, and

max number of particles in the CAS, CIP and 2DS data? Please provide an assessment of the statistical significance of PSDs used for the IWC calculations. Statistically insignificant PSDs may result in large random errors in IWC calculations. These questions should be elaborated upon and explained in the text. The assessment of the errors in the IWC calculations for the particle probe data should be provided as well.

9. The diagrams in Fig.10 are supportive of the statement about oversampling of small particles and undersampling of large particles at the roof location. Similar diagrams should be provided for the side and bottom locations of the TWC inlets on Geophysica and WB57. Otherwise, one could argue that the 'duck' type behavior of the IWC ration vs Rice is a result of the errors in calculations of IWC from the particle probes.

10. Page 4, Line 15: "However, isokinetic sampling (= the flow inside the inlet is the same as in the free flow), which in principle enables the undisturbed measurement of H2Otot, is not possible for fast flying aircraft, since the air flow speed is always much higher than the velocity inside of the inlet." The airborne version of the isokinetic probe for measurements of cloud condensed water was designed by NRC: (Davison, C., J. MacLeod, J. Strapp, and D. Buttsworth, 2008: Isokinetic total water content probe in a naturally aspirating configuration: Initial aerodynamic design and testing. Proc. 46th AIAA Aerospace Sciences Meeting and Exhibit, Reno, NV, American Institute of Aeronautics and Astronautics, AIAA 2008-435. [Available online at http://arc.aiaa.org/doi/abs/10.2514/6.2008-435.]) This probe was successfully operated during several field campaigns on different aircrafts. Some results were published in JTECH.

11. Traditionally, condensed water content is measured in g/m3 (liquid, ice or total water content) or g/kg (mixing ratio). These units are well adapted by the cloud and climate modeling communities (both g/m3 and g/kg), remote sensing community (g/m3), aviation industry (mainly g/m3). The present paper is utilizing non-conventional units in the cloud physics community (ppmv) in order to describe condensed water content. This unit is usually used to describe concentration of a gas phase, rather than to char-

acterize the weight of a liquid or solid phase per unit volume. This unit is mainly employed by the subcommunity formed around the evaporators used for measurements of the condensed cloud phase (e.g. FISH, HAI, Waran, etc.). I am not sure that employing this unit adds clarity; rather, it creates barriers in the dissemination of the IWC measurements that employ this unit. In my opinion, the cloud and climate modeling communities and the remote sensing community are unlikely to switch to this unit. The aviation industry is quite conservative, and it most likely they will ignore the measurements of condensed water content in this unit. I recommend using the conventional units of g/kg or g/m3. At minimum, I suggest using additional axes with conventional units in Fig. 7, 8 ,9, 10.

Minor comments:

1. Page 2, Line 11: "The IWC of a cirrus is a bulk quantity which is composed of the sum of all ice particles..." The term "of a cirrus" is redundant here. This statement is relevant to any cloud, not just cirrus.

2. Page 2, Line 11: It should be "...the sum of all ice particles masses..."

3. Page 2, Line 15: "In particular, King (1984) shows that above the roof of an aircraft the sampling of particles is disturbed." Strictly speaking, the sampling of particles is disturbed everywhere around the fuselage. However, the scale of this disturbance is different. Please reword this sentence.

4. Page 2, Line 16: "However, to simulate and quantify losses or enrichment of ice particles and the effect on IWC at a specific position of an aircraft is hardly possible, since this depends on the prevailing particle size distribution and also the irregular shape of the ice crystals." This is a too strong of a statement. The irregular ice particle shapes can be replaced with spheres with equivalent aerodynamic size. For example, particle trajectory analysis can be performed using spheres with the mass density calculated from size-to-mass parameterization $M = aD^b$.

5. Page 2, Line 27: "The IWC of cirrus can be recorded from aircraft either by bulk cloud measurements using airborne closed path hygrometers mounted behind an inlet tube or via integration of the ice particle number size distributions (PSDice) measured by cloud spectrometers. In both cases, the ice particles must be properly sampled before the measurement." Hot-wire probes are missed in this statement.

6. Page 2, Line 29: "The bulk IWC is less error prone in comparison to the IWC from PSDice in case of an undisturbed measurement." This is a questionable statement. Both techniques have its own problems and advantages.

7. Page 3, Line 1: replace "Fore" to "For".

8. Page 3, Line 18: "To precisely detect H2Otot" replace by "To precisely measure H2Otot"

9. Page 4, Line 6: "To specify the size ranges of the 'smaller' and 'larger' cloud particles, CFD calculations for the specific conditions of fuselage shape, aircraft speed and inlet distance from the nose of the aircraft need to be performed." This sentence is disconnected from the following text and it appears to be redundant.

10. Page 4, Line 7: "Very roughly, cloud particles with radii <30 μm can be assumed to belong to the smaller, while those >30 μm are associated to the larger part of the cloud particle size spectrum at jet aircraft with high air speeds." What is the basis for this statement? References should be provided here.

11. Page 4, Line 23: "...shattering into small artifacts at the cloud probes head..." should be "...shattering into small fragments at the cloud probes' housing..."

12. Page 4, Line 23: "However, for the calculation of the IWC, the uncertainty from shattering does not play a significant role since the shattered crystals still contribute to the integrated mass of PSDice." This sentence should be reworded.

13. Page 4, Line 9: IWCS should be IWCs

C7

14. Figure 11. The y-labels are not easily legible. Please enlarge the font size.