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Commentary on "Measurements of ice supersaturations exceeding 100% at the cold tropical tropopause" by E. Jensen et al.

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Abstract

The paper by Jensen et al. (2005) provides an excellent use of a microphysical model to examine the logical consequences of high saturation ratios indicated by measurements during a high altitude flight of the NASA WB-57F. I would like to comment on a turn made by the aircraft that makes this particular event harder to interpret.

1. Comment

By coincidence, the WB-57F made a course correction during its descent through the tropopause on 29 January. The highest saturation ratios were measured during the turn (Fig. 1). The high saturation ratios referred to in the Jensen et al. (2005) paper are at about 2° roll and -1.5° pitch. Throughout much of this descent, aircraft roll is correlated with wind direction. It is hard to tell if the aircraft is rolling in response to wind shear or if the aircraft motions are affecting the differential pressure measurements that form the basis for the derived wind direction.

Accurate relative humidity measurements depend on accurate temperature measurements. Aircraft temperature measurements must be corrected for the adiabatic heating as the air comes to a stop in the temperature probe. Adiabatic heating is 18.6 K at Mach 0.7 and 190 K (Liepmann and Roshko, 1957). The correction is nonlinear, so to make temperature measurements with an accuracy of 0.5 K on a jet aircraft the aircraft Mach number must be known to about 1%. That accuracy is probably more difficult to achieve during a turn than during level flight. In order to check this possibility, I have examined the relative humidity measured as a function of aircraft orientation during the flight described (29 January 2004) as well as the rest of the mission.

Figure 2 shows the measured relative humidity as a function of aircraft roll angle. The measured relative humidity was systematically higher when the aircraft was banked to the right than when it was flying level or banked to the left. Although not shown here, it is clear that it was the temperature rather than the water vapor that had a dependence

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on roll. For an unknown reason, the WB57F flew with a typical roll angle of about +1° on 29 January and much of 2 February whereas for the rest of the mission it typically flew quite level. Most of the ice saturations larger than 2 were measured during those two flights.

The strong dependence on roll angle in Fig. 2 is somewhat of a mystery. If the fuselage is approximated by a cylinder pointed straight forward, by symmetry roll angle cannot directly affect a forward facing probe or inlet. Moreover, the effects seen here are at quite modest roll angles. More likely, the roll angle is a surrogate for other aircraft motions during turns. Aircraft usually have both roll and yaw during a turn. Yaw is more likely to affect the temperature probes but there is no direct measure of yaw from the aircraft navigation system.

In summary, high saturation ratios with respect to ice were systematically observed during the mission when the aircraft was banked slightly to the right. Either by coincidence the aircraft was often banking to the right when it flew through high saturation ratios or there was a systematic bias in the temperature measurement during right hand turns. If so, it would significantly change the interpretation of the event described in the paper under discussion. The aircraft turn in no way invalidates the excellent microphysics modeling in Jensen et al. (2005). A definitive resolution of whether the high ice saturations measured in this event are correct or are due to a turn-induced measurement error is probably not possible without testing the response of the temperature probes to deliberate aircraft maneuvers. These were not performed during the short mission in spring 2004.

Finally, it is not known how specific these issues are to the WB-57F and even this particular mission. The correlation of roll with temperature or relative humidity shown in Fig. 2 was not present in WB-57F data from the CRYSTAL-FACE mission in 2002. Some of the aircraft pressure probes were changed between 2002 and 2004 (K. Rosenlof, personal communication, 2004). In any case, temperature and humidity measurements during spiral ascents and descents as well as other turns should be carefully scrutinized.

References

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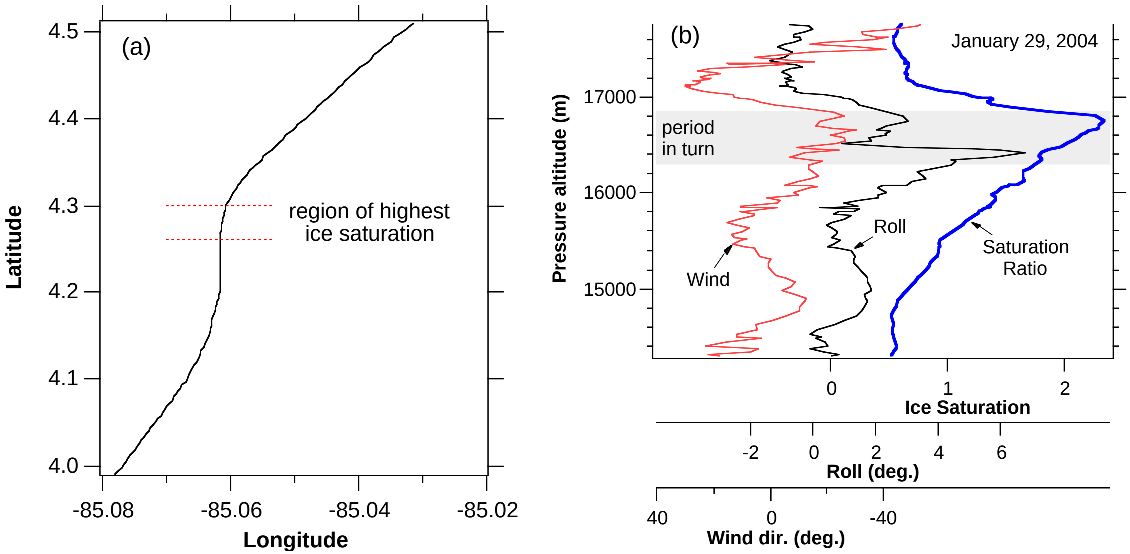

Fig. 1. WB-57F flight track **(a)** and vertical profile **(b)** during the event described by Jensen et al. (2005).

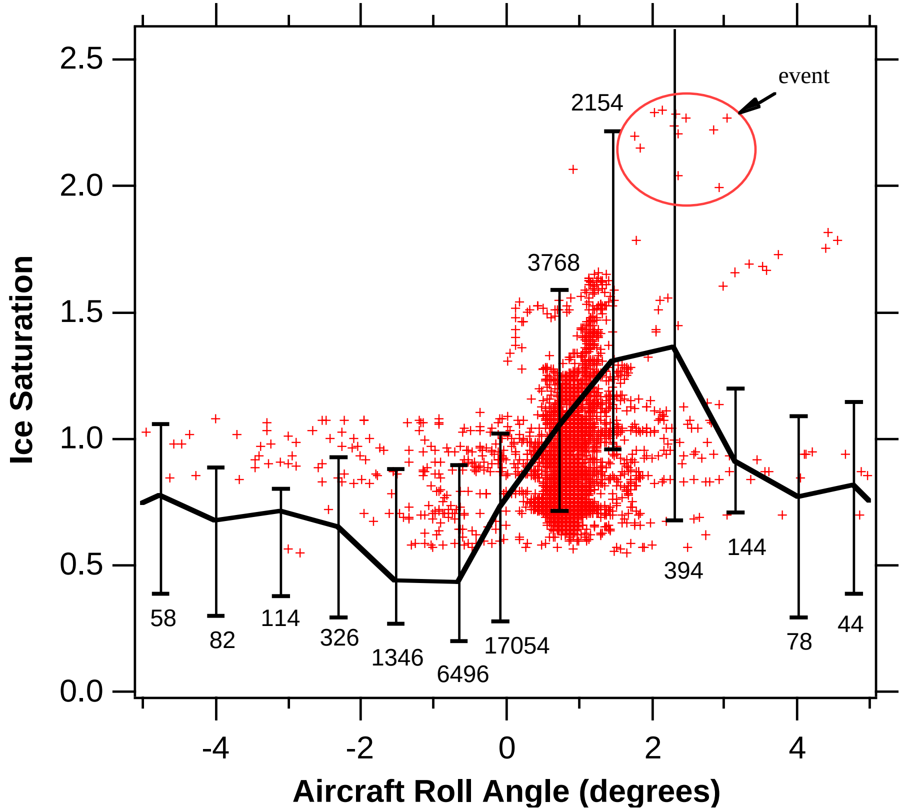

Fig. 2. Measured relative humidity as a function of roll angle. The red points are 2 second averages from the flight of 29 July and the black curve shows medians and quartiles for rest of the mission not including 29 July. The numbers for the mission curve give the number of 2 second data points in each bin. To restrict the data to near the tropopause, only data from 15 to 18 km and with ozone less than 500 ppbv are included. This graph uses JPL water vapor measurements but the Harvard measurements give very similar results.

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Commentary on ice supersaturations

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