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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Formation of large (≃100 μm) ice crystals near the tropical tropopause" *by* E. J. Jensen et al.

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This manuscript calculates the conditions necessary to form some large ice crystals observed during WB57 flights in 2006. Ice crystal images showed a few plate-like crystals up to about 100 micrometers diameter at unexpectedly high altitudes. Growing such large crystals before they fall to lower altitudes places constraints on the water vapor saturation ratio.

The largest uncertainty is the aspect ratio of the plates. This is difficult to ascertain exactly from the images, and the possible range of 6 to 14 has rather different implications for the atmosphere. According to these calculations, extraordinarily high water vapor saturation ratios must be present if the aspect ratio is 6, high but more understandable saturation ratios if the aspect ratio is 14.

The one technical comment I have regards the statement that the crystals would not be preferentially oriented (page 6302). For ice crystals in this size range, orientation is an issue of the competition between Brownian motion that randomizes the orientation and drag forces that favor a horizontal orientation. The issue is important because a preferred horizontal orientation would reduce the fall velocities by perhaps 10 or 15%. That would reduce the required saturation ratios by a similar factor. There is a big difference in the implications of, for example, a saturation ratio of 2.1 versus 1.8. Therefore, the question of orientation is quite important.

The restoring torque from the drag forces that favor a horizontal orientation goes to zero as the Reynolds number goes to zero. Therefore, some minimal Reynolds number is required for a preferred orientation. The manuscript references Fuchs' 1964 book on aerosol mechanics. In it, there are actually several different thresholds given. On page 35, it mentions a threshold of about 0.05 to 0.1. A 100 micrometer falling plate at tropical tropopause conditions has a Reynolds number of about 0.18, so by this criterion it might be oriented. Looking further into the literature, Breon and Dubrulle (J. Atmos. Sci., 2004) show in their Figure 10 that plates as small as about 15 um diameter may fall with a stochastic departure from horizontal of no more than 10 degrees. That figure actually has two alternate calculations. One curve, based on a generalized Langevin equation and the results of Katz (1998), suggests crystals larger than about 15 um can be horizontally oriented. Another curve, based on a Reynolds number threshold of 0.39, suggests crystals must be larger than 100 um to be oriented. The original reference for the threshold (Willmarth, 1964) states that oriented falls were not observed below Re = 0.39 but this was due as much to experimental limitations in the data (from the 1920s) as a definitive threshold. Katz (1998) observed oriented falls at Reynolds numbers between 0.1 and 0.25 and provides the theory to extrapolate to lower Reynolds numbers. It seems to be the more reliable source. I therefore suggest the authors recalculate the reverse fall and growth trajectories with a drag coefficient appropriate to horizontally oriented plates.

ACPD

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Interactive Comment

A paragraph on whether or not these ice crystals should be observable with remote sensors would be helpful. I suspect the number densities are rather small for lidar observations and 100 micrometer particles are too small to efficiently scatter microwaves. The authors could provide quantitative statements.

A minor comment is that the third sentence of the abstract (“Uncertainties...”) could be eliminated to make the abstract shorter, as a more quantitative statement to the same effect is made later in the abstract.

Interactive comment on Atmos. Chem. Phys. Discuss., 7, 6293, 2007.