A New Ice Fall Speed Considering Riming and its Test in GFDL AM3

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In mixed-phase clouds, riming changes ice particle properties, such as density, shapes, and fall speed. Using the liquid water content (LWC), ice water content (IWC), and radial velocity prepared by Mace et al. (2006) based on long term ARM in situ and remote sensing data, a new ice fall speed formula has been derived and tested in GFDL AM3.

$$Ri = \frac{LWC}{LWC + IWC}, V_i = 3.29 IWC^{0.16}, V_g = 19.3 IWC^{0.37}$$

$$V_{Ri} = V_i \times IWC \times (1 - Ri) + V_g \times IWC \times Ri$$

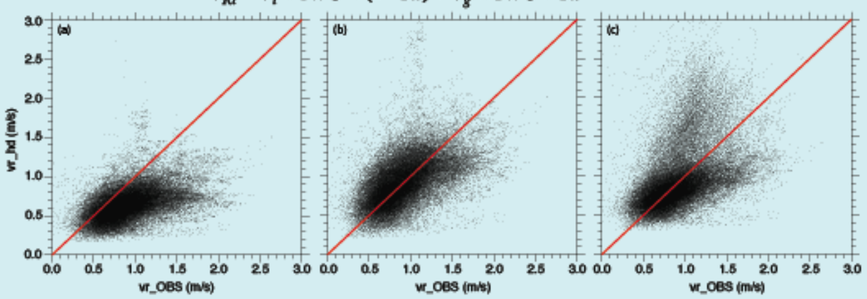

Figure 1. (a) Comparison of derived ice fall speed using Heymsfield and Donner (1990) formula with observed radial velocity; (b) Same as (a), but for the new fall speed considering the riming effect; (c) Same as (a), but for a more general parameterization as indicated in Fig. 2 and Fig. 3.

Implementation

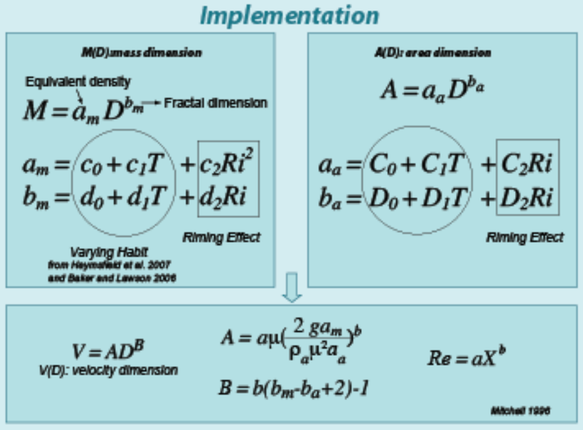

Figure 2. Implementation of the generalized formulae used in the new scheme.

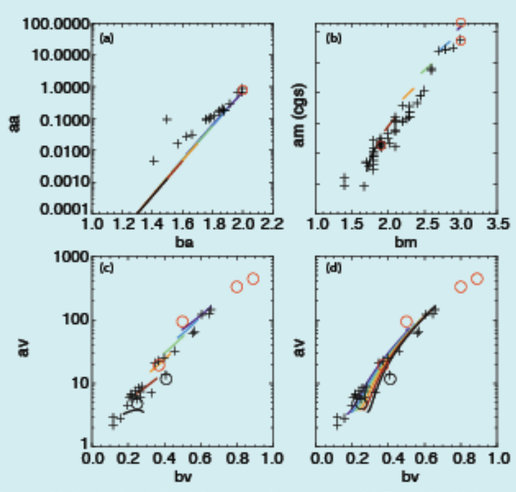

Figure 3. (a) Coefficients of A-D relationship of the new scheme vary with T and Ri. Ri changes from0 (black) to 1 (violet). (b) Same as (a), but for the M-D. (c) Same as (a), but for V-D. (d) Same as (c), but T change from 0 oC (black) to -50 oC (violet). Black crosses are the empirical coefficients from Mitchell et al. (1990), Mitchell (1996), Locatelli and Hobbs (1974), and Barthazy and Schefold (2006). Red circles represent spherical particles in (a); spherical particles with constant density in (b). Graupel fall speed coefficients used in WRF BMP schemes in (c). Black circles in (c) are snow fall speed coefficients used in WRF BMPs.

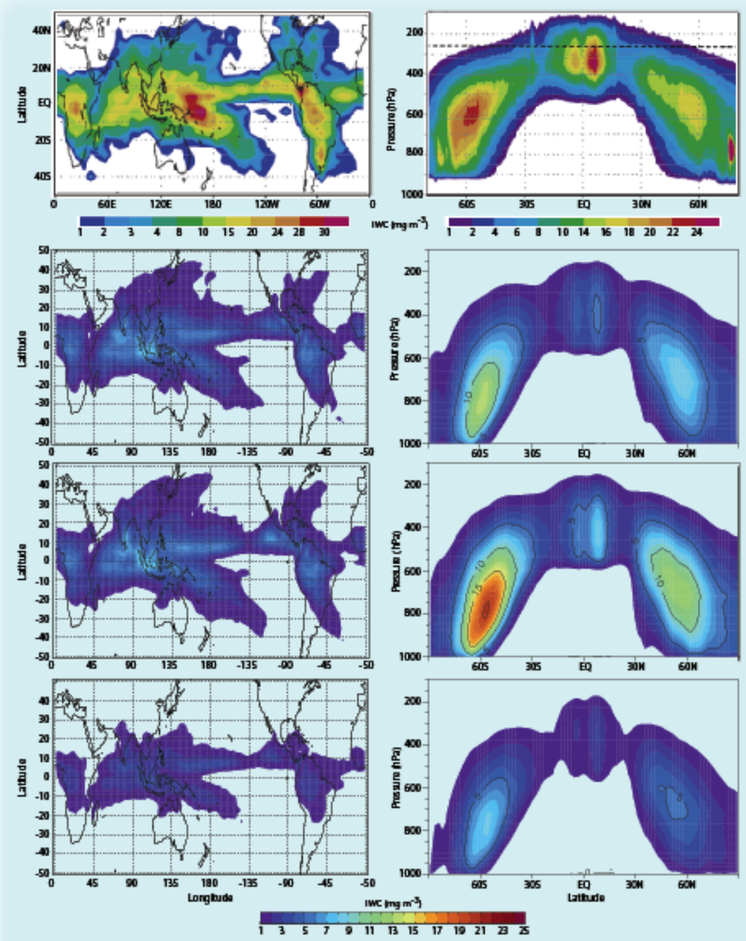

Figure 4. 1st row: Annual mean (2006/08-2007/07) all sky IWC observed by CloudSat at 225 hPa and the zonal mean (Waliser et al. 2009). 2nd row: GFDL AM3 annual mean LS IWC at 225 hPa and the zonal mean for the Ri run. 3rd row: Same as 2nd row, but for the run using vfactor=1.0. 4th row: Same as 3rd row, but for the run using vfactor=2.5.

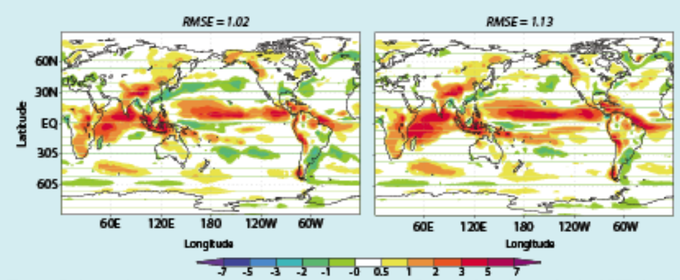

Figure 5. Annual mean precipitation difference between 5-year AM3 climatological SST simulation and 20 year GPCP precipitation for Ri run (left) and control run (vfactor=2.5, right).

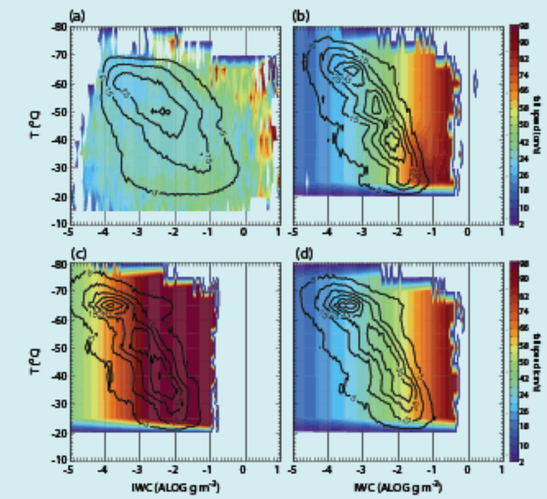

Figure 6. Relative ice cloud occurrence (line contoured) binned by T (every 5 oC) and IWC (every 0.05 log g m-3) and mean fall speed (color shaded) for the cirrus at SGP processed by Deng and Mace (2008). (b) Same as (a), but for the AM3 Ri run. (c) AM3 vfactor=2.5 run. (d) AM3 vfactor=1.0 run.

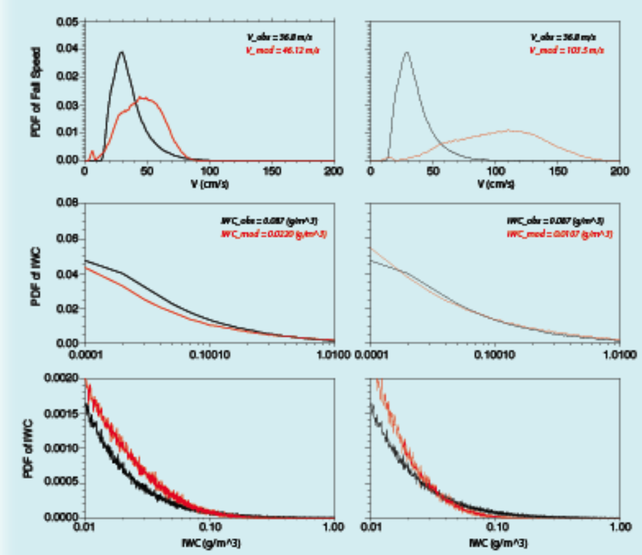

Figure 7. PDF distribution of observed and model ice fall speed (upper panel) and IWC (middle and lower panel) at SGP for vfactor=1.0 run (left) and vfactor=2.5 run (right).

Acknowledgements. The research is supported by U.S. DOE ARM fellowship at GFDL

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