Implementation of the Secondary Ice Production mechanisms in the Single Column Atmosphere Model Version 6 (SCAM6) : Results from MC3E

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Objective

- Model development of CESM global model with SCAM (Single Column Model Version6) MC3E campaign
- Improving the deep convective scheme, with realistic treatment of Ice processes
- One of the steps was to add Secondary Ice Production mechanism

Implementation

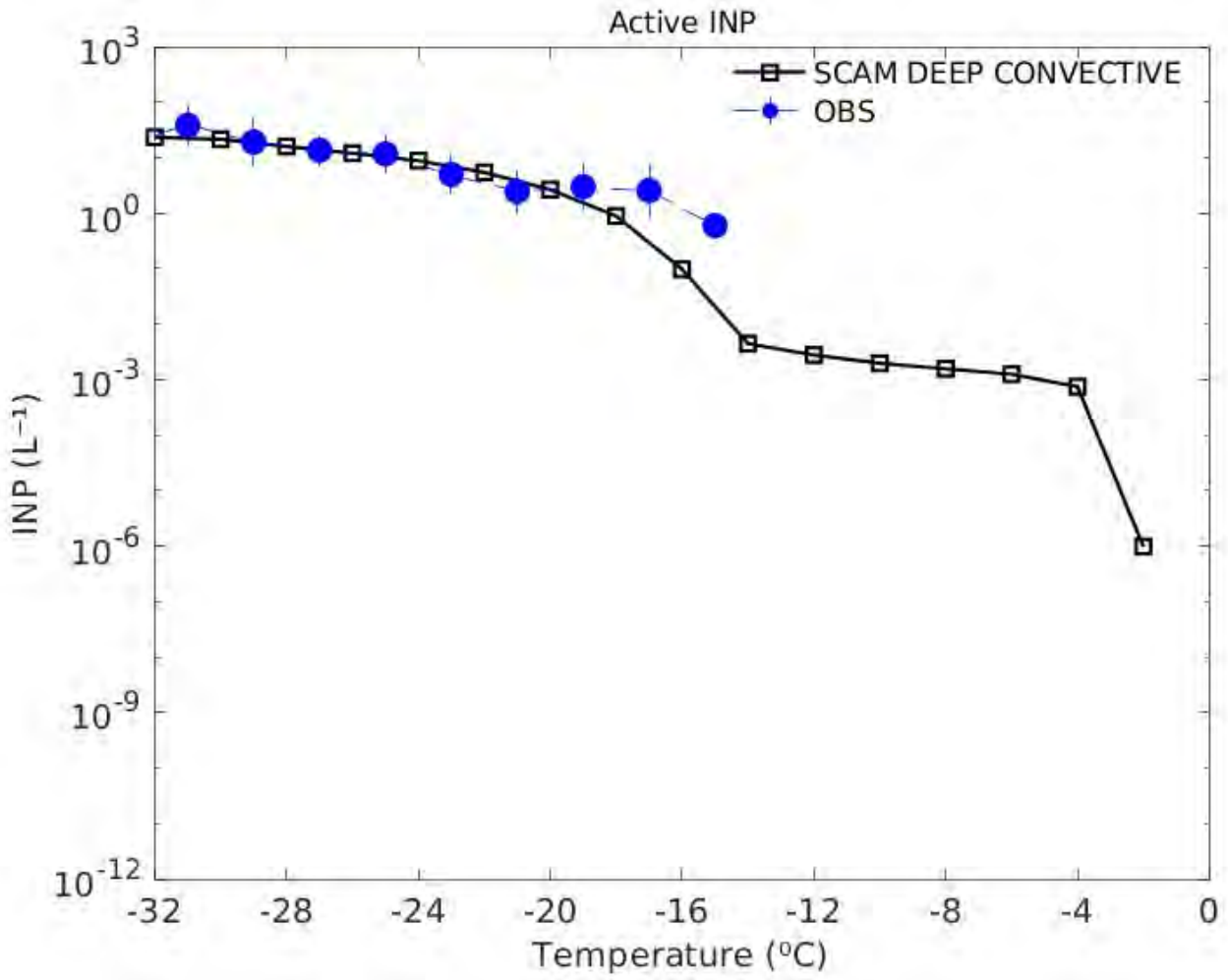
- The observation data collected during the Midlatitude Continental Convective Cloud Experiment (MC3E).

- Hybrid bin-bulk scheme for the representation of the cloud hydrometeors (cloud droplet, cloud ice, rain, snow and graupel)

- The SIP mechanisms added following Phillips 2007 ;2008 ;2017a ;2017b

Ice Initiation Process

- Heterogeneous ice nucleation (from aerosol species (active Ice Nuclei's present in the atmosphere)
- Homogeneous freezing (Spontaneous freezing of the cloud droplets)



Secondary Ice Production

- Hallett-Mossop (Hallett and Mossop 1974)

  Small ice splinters break away during riming of supercooled cloud droplets larger than 24 μm, for temperatures between -3^{o}C and -8^{o}C.

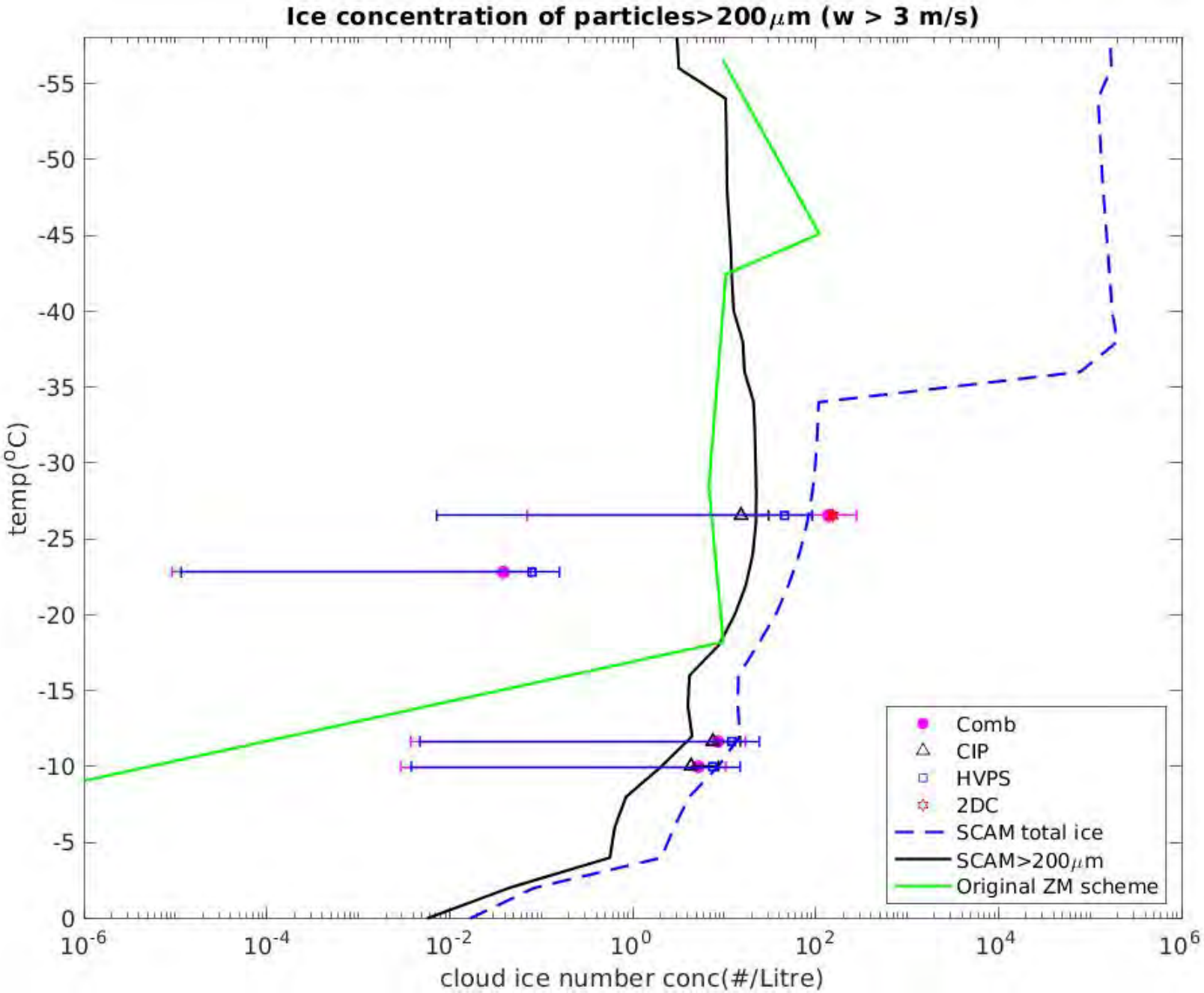
- Ice-ice collisional breakup

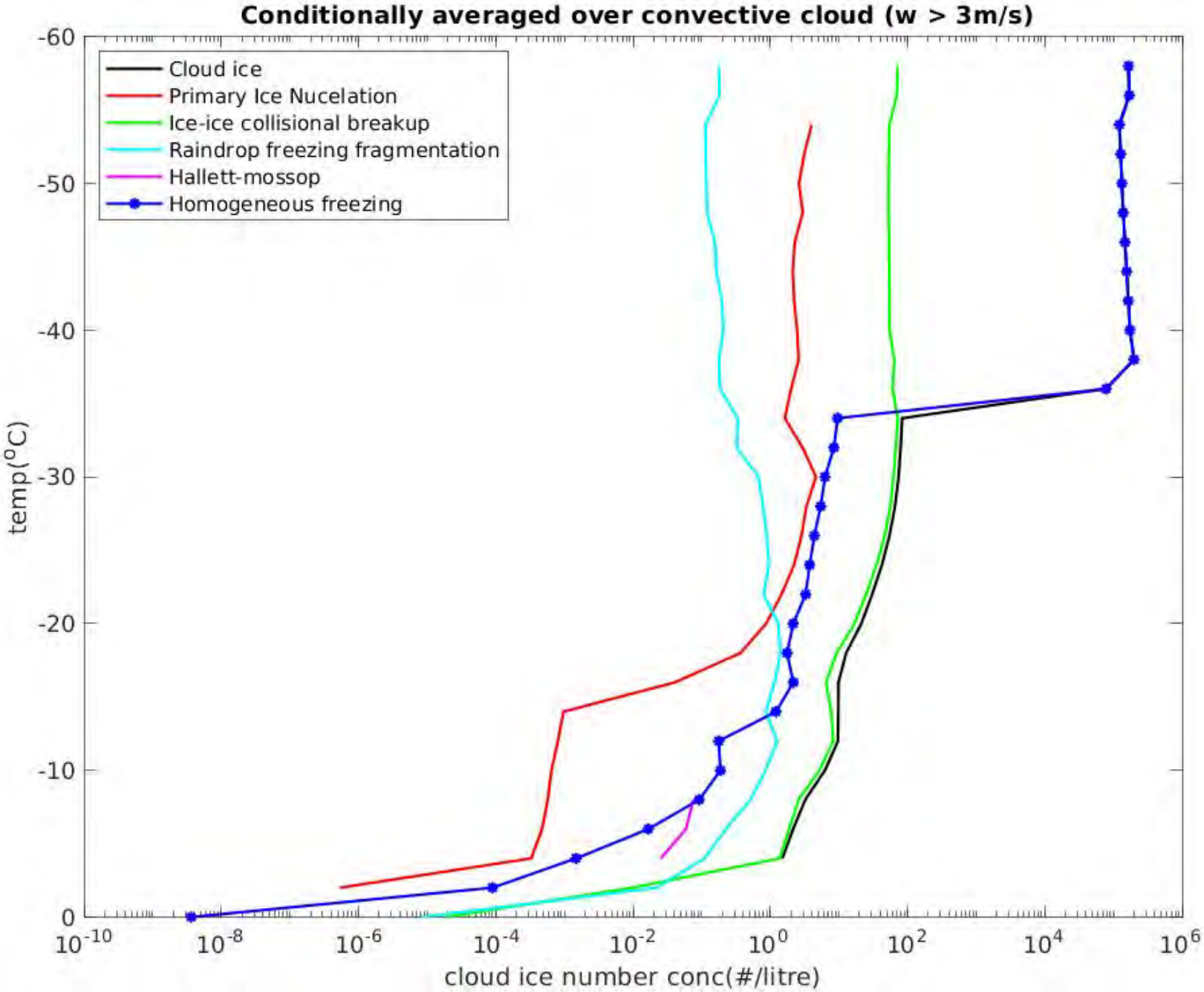
  collisions involve ice crystal, snow, and graupel (Phillips et al.,2017)

- Raindrop freezing fragmentation

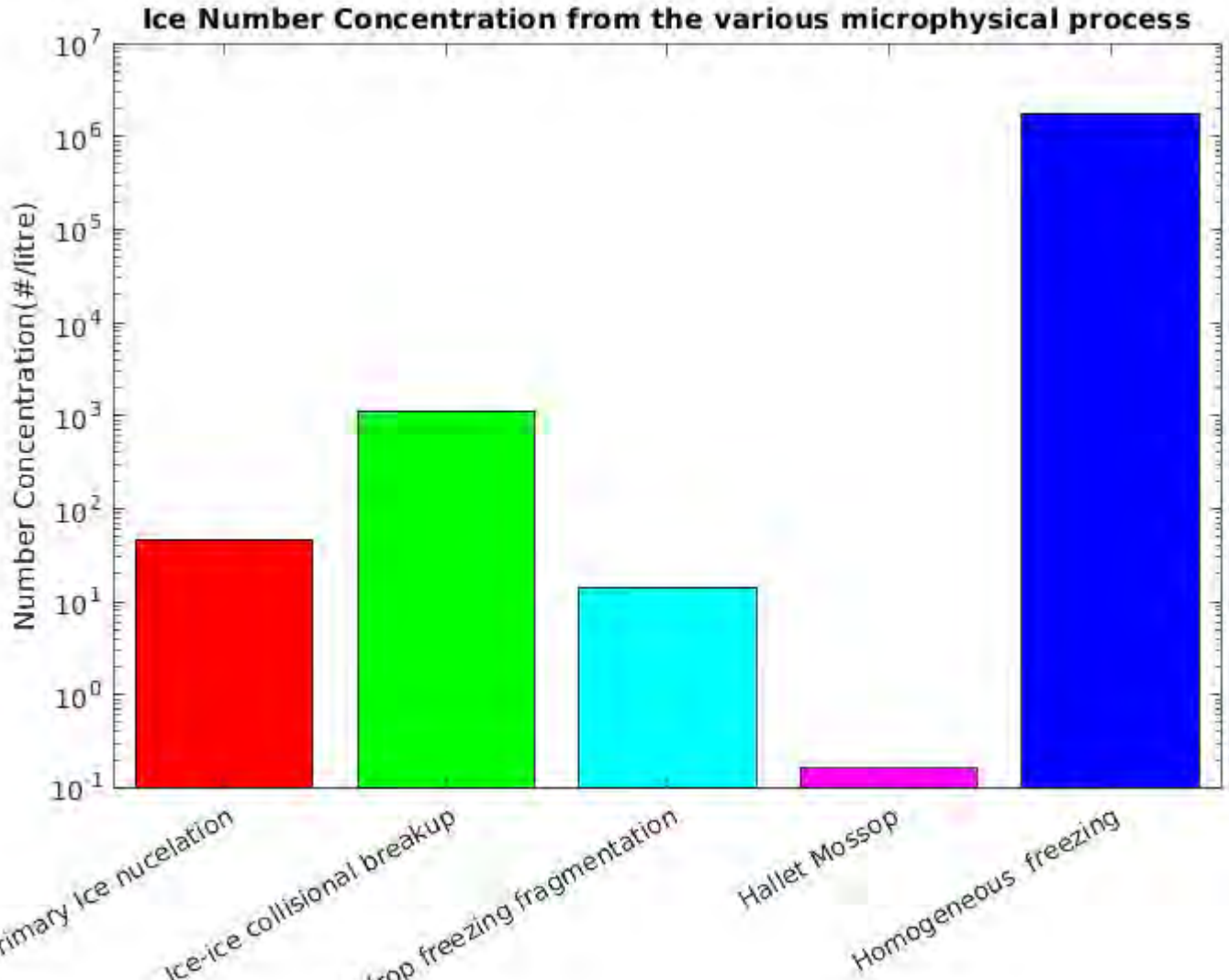
  Mode 1: collision between less massive ice particles and cloud droplets

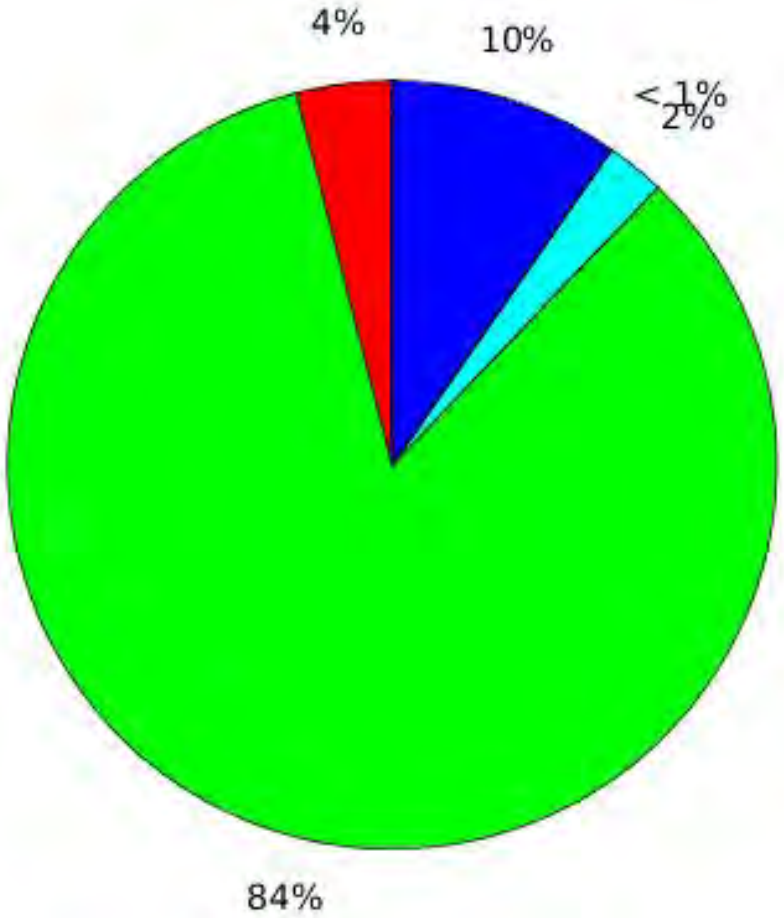
  Mode 2: Collision of more massive ice particles with raindrops


Ice concentration of particles>200μm (w > 3 m/s)
temp(^{o}C)
cloud ice number conc(#/Litre)
-55
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}
10^{4}
10^{6}
Comb
CIP
HVPS
2DC
SCAM total ice
SCAM>200μm
Original ZM scheme


Conditionally averaged over convective cloud (w > 3m/s)
Cloud ice
Primary Ice Nucelation
Ice-ice collisional breakup
Raindrop freezing fragmentation
Hallett-mossop
Homogeneous freezing
temp(°C)
-60
-50
-40
-30
-20
-10
0
10^-10
10^-8
10^-6
10^-4
10^-2
10^0
10^2
10^4
10^6
cloud ice number conc(#/litre)

Budget Analysis





References

Hallett, J., and S. C., Mossop, 1974: Production of secondary ice particles during the riming process. *Nature*, **249**, 26–28.

Phillips, V. T. J., J. I., Yano, M., Formenton, E., Ilotoviz, V. P., Kanawade, I., Kudzotsa, J., Sun, A., Bansemer, A. G., Detwiler, A., Khain, S. A., Tessendorf, 2017: Ice multiplication by breakup in ice-ice collisions. Part II: Numerical simulations, *J. Atmos. Sci.*, **74(9)**, 2789–2811.

Phillips, V. T. J., S. Patade, J., Gutierrez, A., Bansemer, 2018: Secondary ice production by fragmentation of freezing drops: Formulation and theory, *J. Atmos. Sci.*, **75(9)**, 3031–3070.