The effect of secondary ice process parameterizations on a simulated cold frontal rain band

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MOTIVATION

Observed atmospheric ice number concentrations can be orders of magnitude higher than the ice nucleating particle number concentrations. This multiplication can be explained by *secondary ice processes*.

→ Limited effort has gone into modelling these processes.
→ Even less effort has been devoted to comparison of observations and simulations.

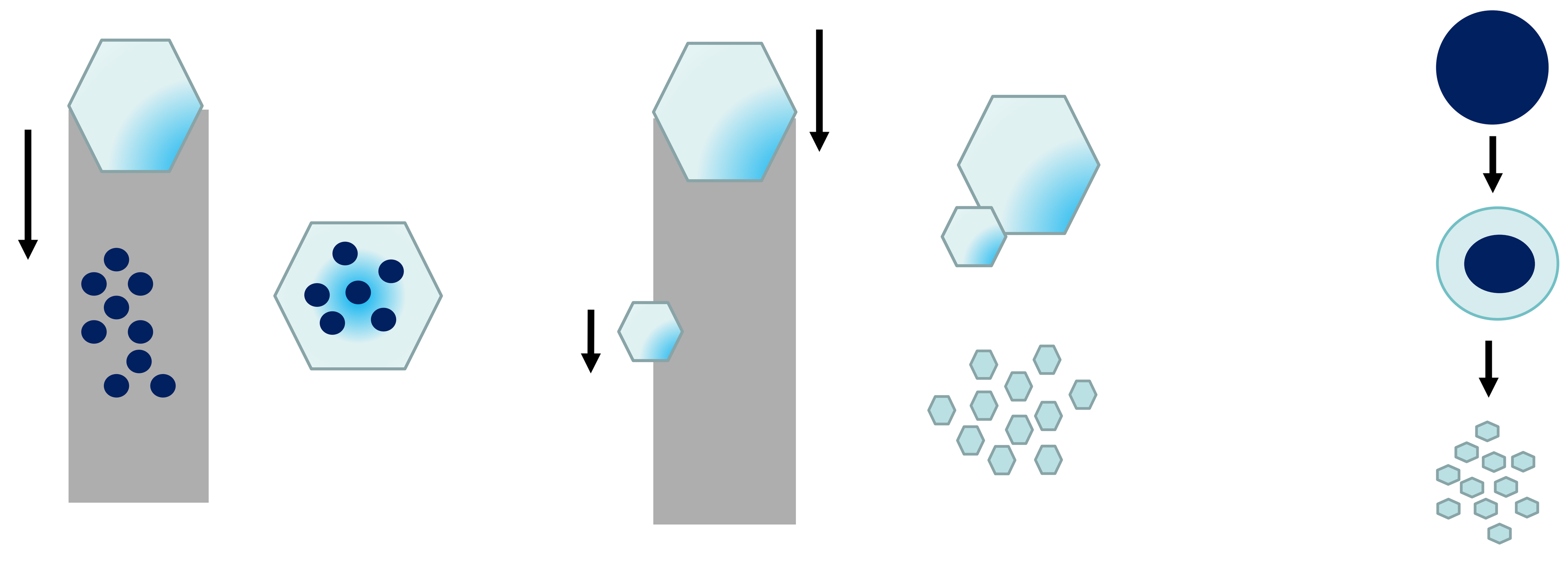


FIGURE 1 Secondary ice processes considered

CASE STUDY: RAIN BAND DURING APPRAISE CAMPAIGN

We modeled a narrow cold frontal rain band, observed during the APPRAISE campaign. Embedded convection provides favorable conditions for secondary ice processes: large hydrometeors can form at higher altitudes.

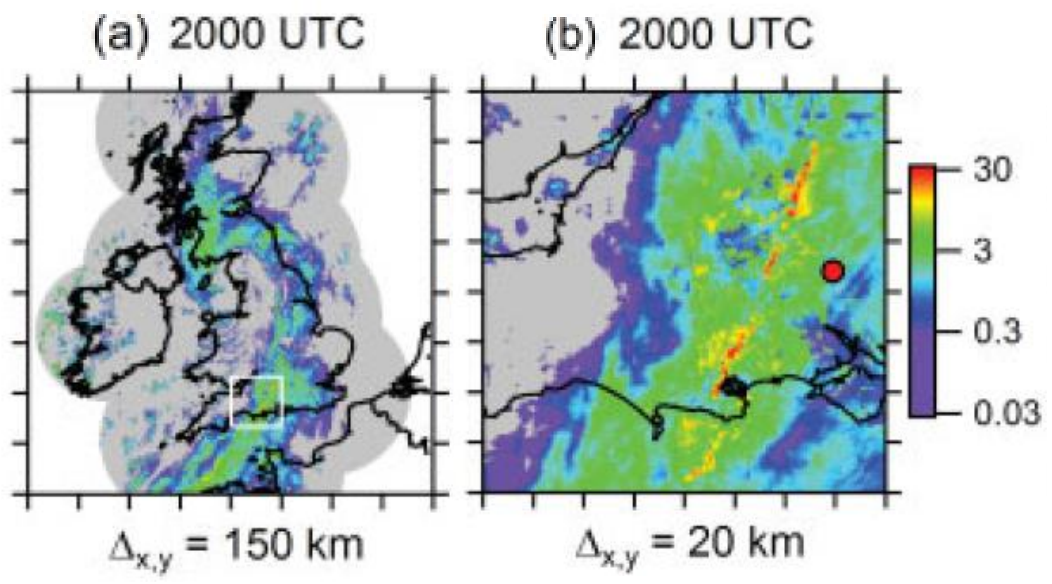


FIGURE 2 Rain band intensity measured by the UK operational radar network on 3 March 2009 in **(a)** small and **(b)** large domains. Images from Crosier et al.

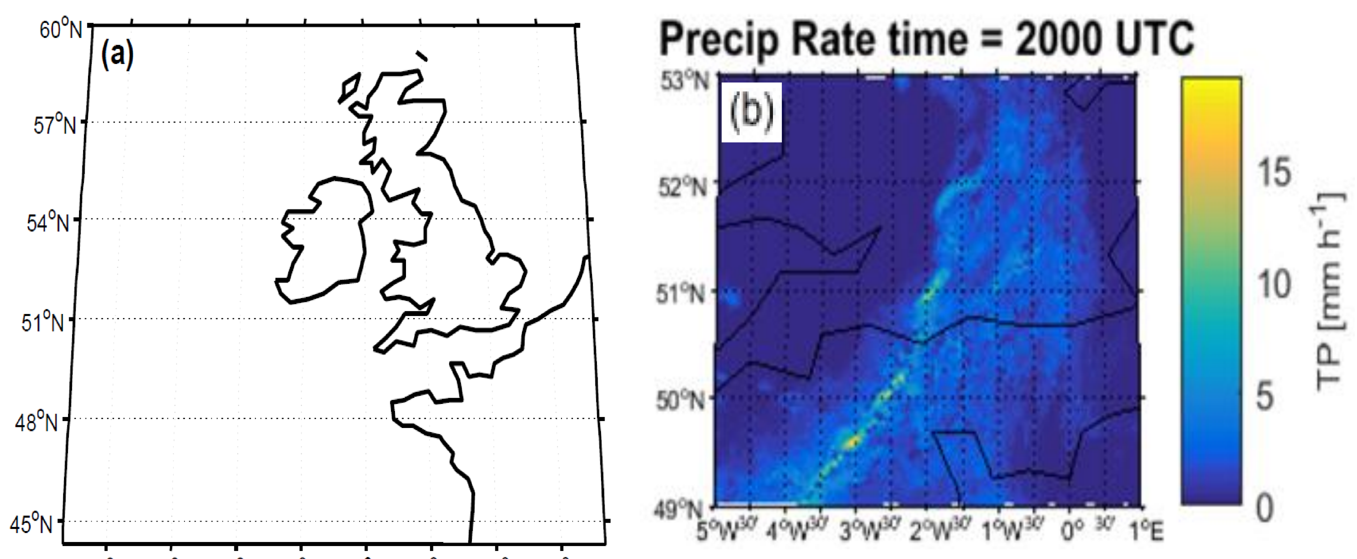


FIGURE 3 **(a)** Simulation domain and **(b)** simulated rain band in the small domain from a control run. The model underestimates precipitation intensity by a factor of 2.

RAINDROP SHATTERING AND BREAKUP PARAMETERIZATIONS

$$\left.\frac{\partial N_{ice}}{\partial t}\right|_{rf} = \left[1 + pN_{frag}^{(rf)}\right]\frac{\partial N_{freez}}{\partial t} \qquad \left.\frac{\partial N_{ice}}{\partial t}\right|_{coll,gh} = -N_{frag}^{(coll,jk)}\left.\frac{\partial N_g}{\partial t}\right|_{coll,gh}$$

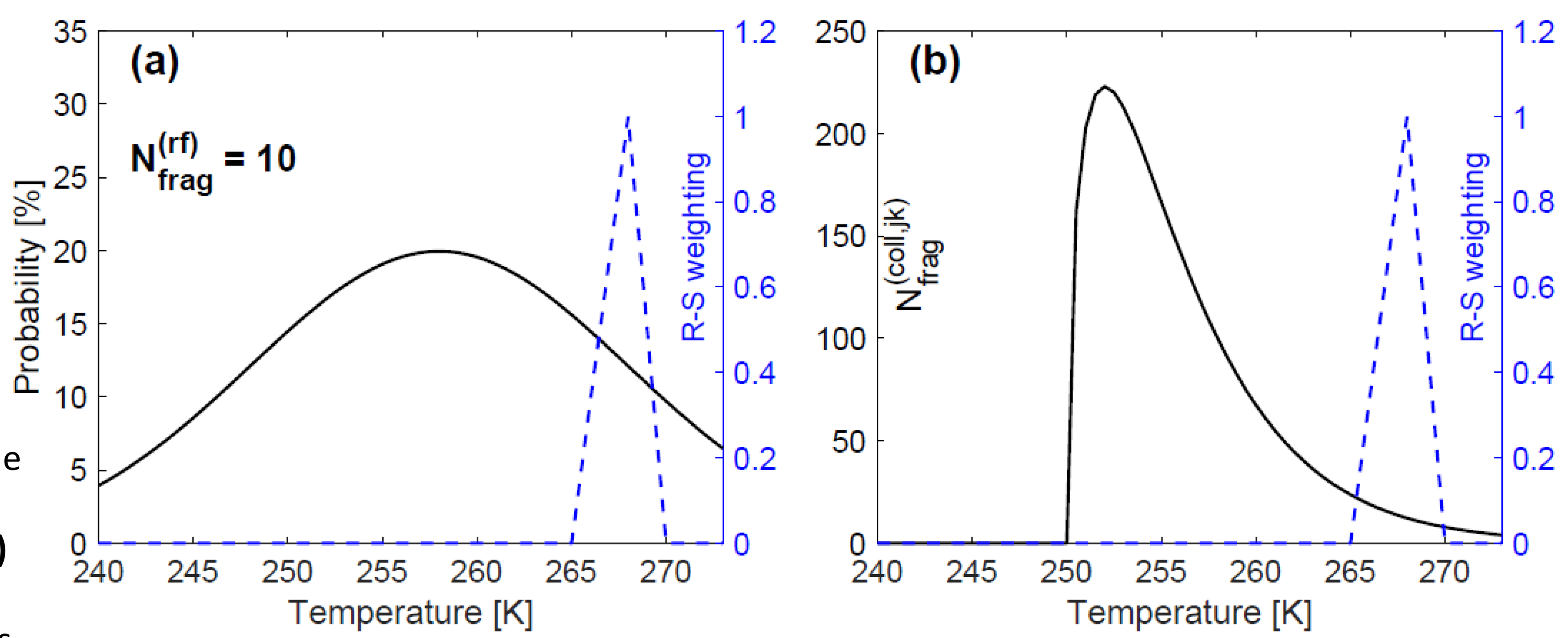
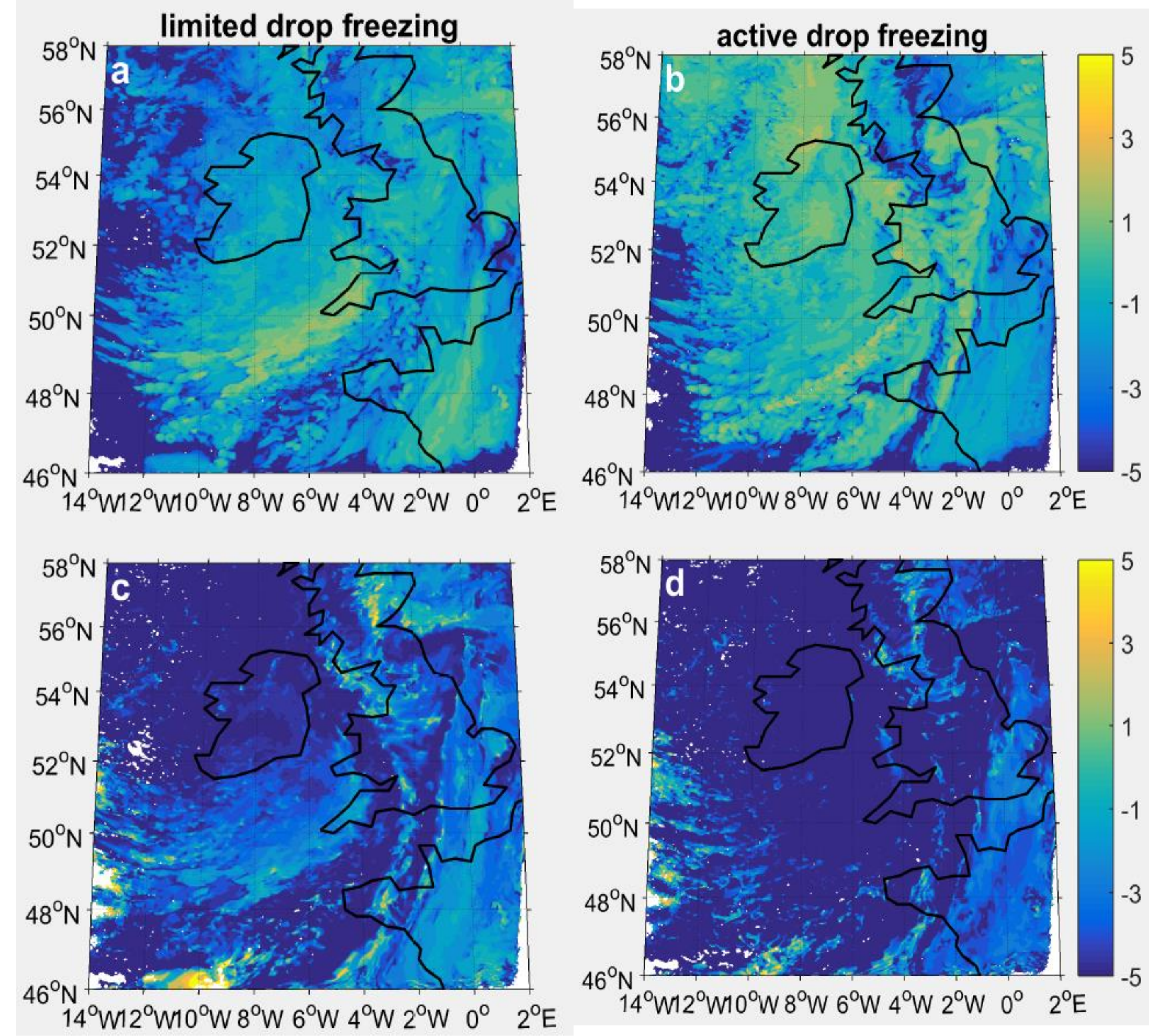


FIGURE 4 Temperature-dependent parameters for the **(a)** droplet shattering and **(b)** breakup parameterizations.

SIMULATED SECONDARY ICE PRODUCTION

FIGURE 5 Secondarily-produced ice number (panels **a** and **b**) and the ratio of $N_{i,sec}$ to nucleated ice number from 2000 UTC to 2030 UTC during rain band passage over ground site for two drop shattering parameterizations.



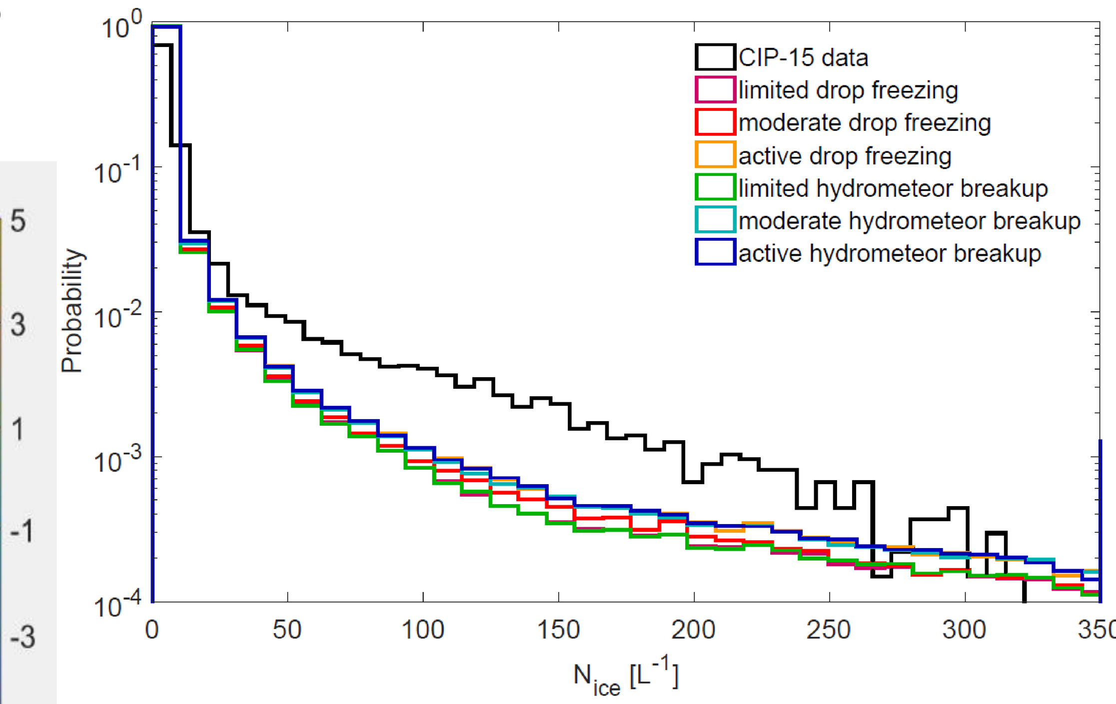
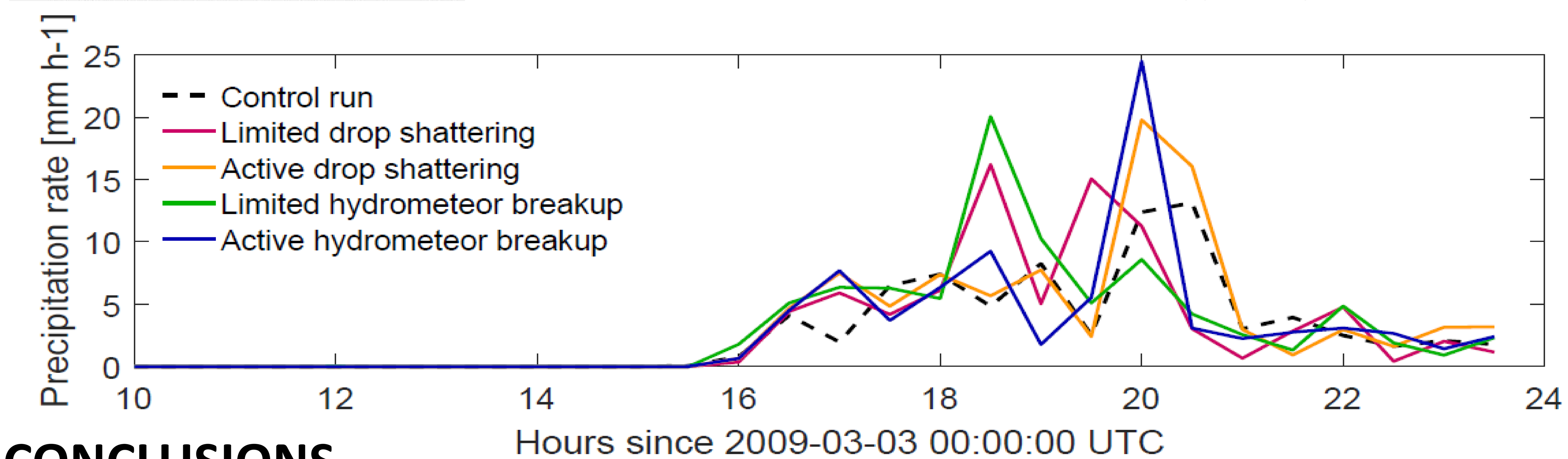


FIGURE 6 Comparison of simulated N_i with various secondary process parameterizations and observed N_i from the Cloud Imaging Probe-15 during Flight B434 of the APPRAISE campaign. Values are filtered for an altitude of about 7.5 km or 258 ± 7 K.

FIGURE 7 Simulated precipitation rate time series at the ground site for a control run and with various secondary process parameterizations.

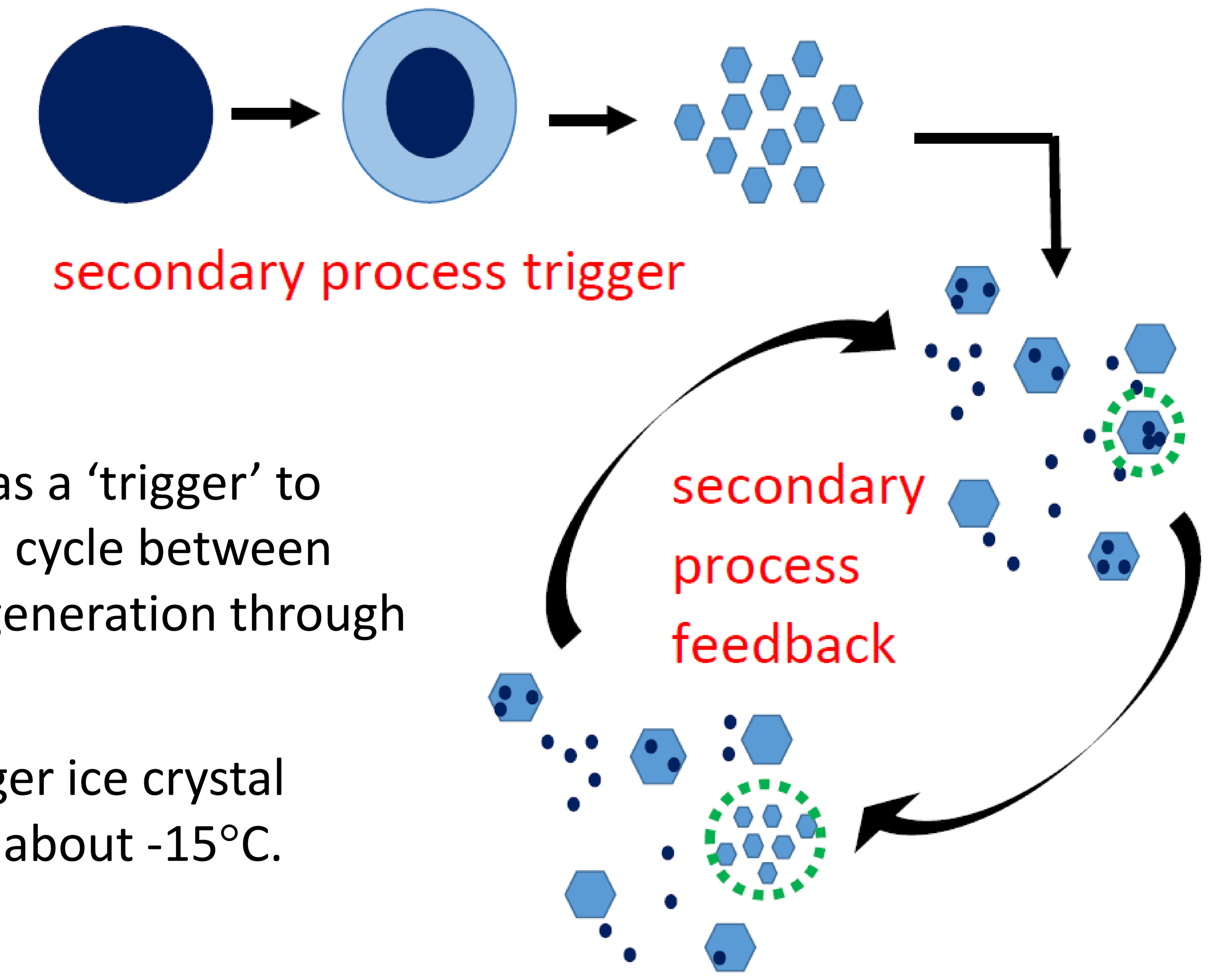


CONCLUSIONS

1. The rate of secondarily produced ice crystals can be up to $O(10^5)$ as the nucleation rate at certain altitudes.
2. The temperature range over which rime-splintering is more influential than the raindrop shattering PDF or breakup fragment number.

   → The modeled secondary processes may act as a 'trigger' to generate small ice crystals, which then begin to cycle between depositional growth and additional ice crystal generation through rime-splintering.

3. Simulations still underestimate the frequency of larger ice crystal numbers O (100 L^{-1}) at an altitude corresponding to about -15°C.



[1] Crosier et al. *QJRMS* **140**: 1257-1268 (2014).