Sensitivity of ice formation processes in the ice modes scheme

Improvement and calibration of clouds in models

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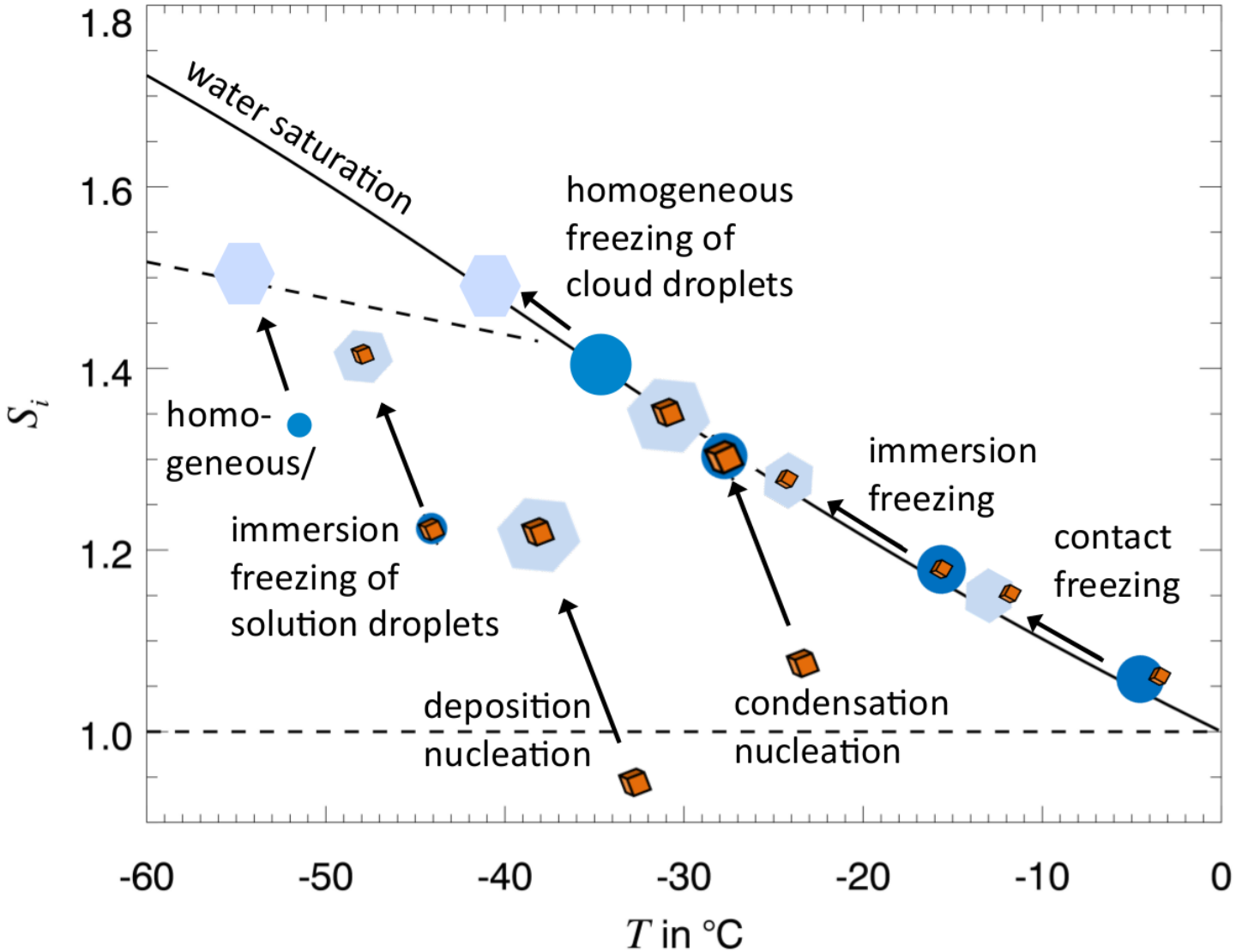
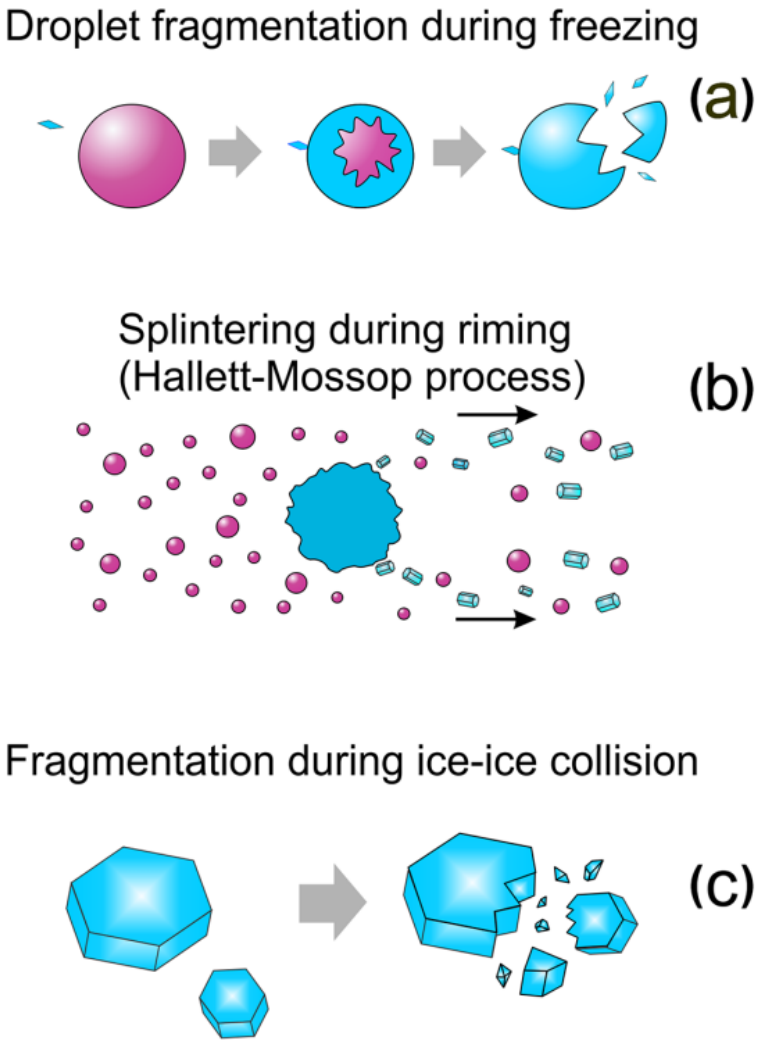
Ice particle formation



Hoose and Möhler (2012)

Secondary ice



Korolev and Leisner (2020)

Microphysics: Seifert and Beheng (2006)

- Modified version of ICON standard two-moment scheme
- Multiple ice classes: ’ice modes’
- Ice modes have their own size distributions
- Governed by same parametrizations except for particle formation process

Distinction between 5 ice modes:

- Ice from hom. freezing solution droplets: n_{hom}, q_{hom}
- Ice from deposition nucleation: n_{dep}, q_{dep}
- Ice from immersion freezing: n_{het}, q_{het}
- Ice from hom. freezing cloud droplets: n_{frz}, q_{frz}
- Secondary ice production: n_{sec}, q_{sec}

10 particle classes:

- Ice from hom. freezing solution droplets: n_{hom}, q_{hom}
- Ice from deposition nucleation: n_{dep}, q_{dep}
- Ice from immersion freezing cloud droplets: n_{het}, q_{het}
- Ice from hom. freezing cloud droplets: n_{frz}, q_{frz}
- Secondary ice production: n_{sec}, q_{sec}
- Cloud droplets: n_c, q_c
- Rain: n_r, q_r
- Snow: n_s, q_s
- Graupel: n_g, q_g
- Hail: n_h, q_h

Rime splintering

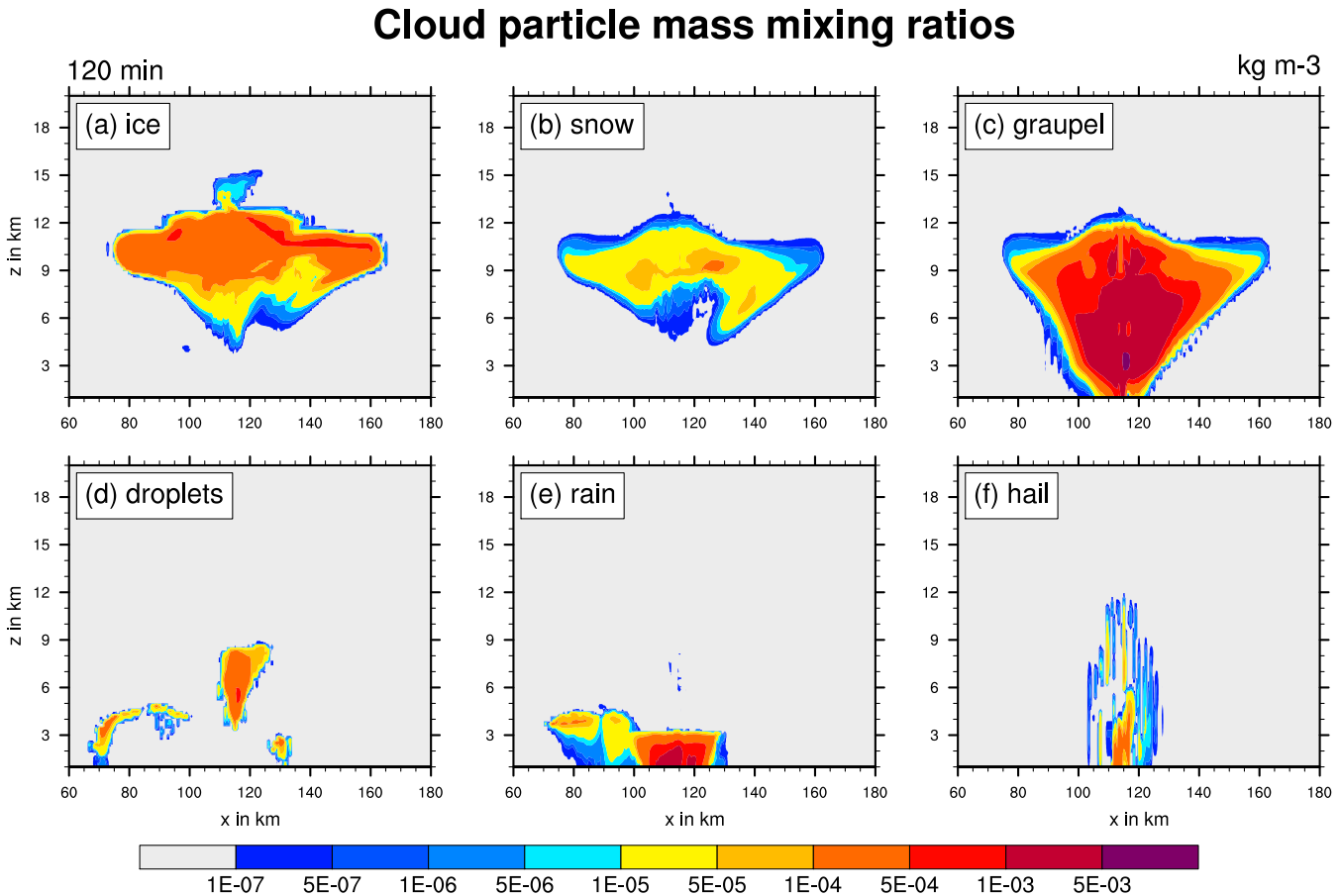
- RS: temperature, riming rate (Hallett and Mossop, 1974)

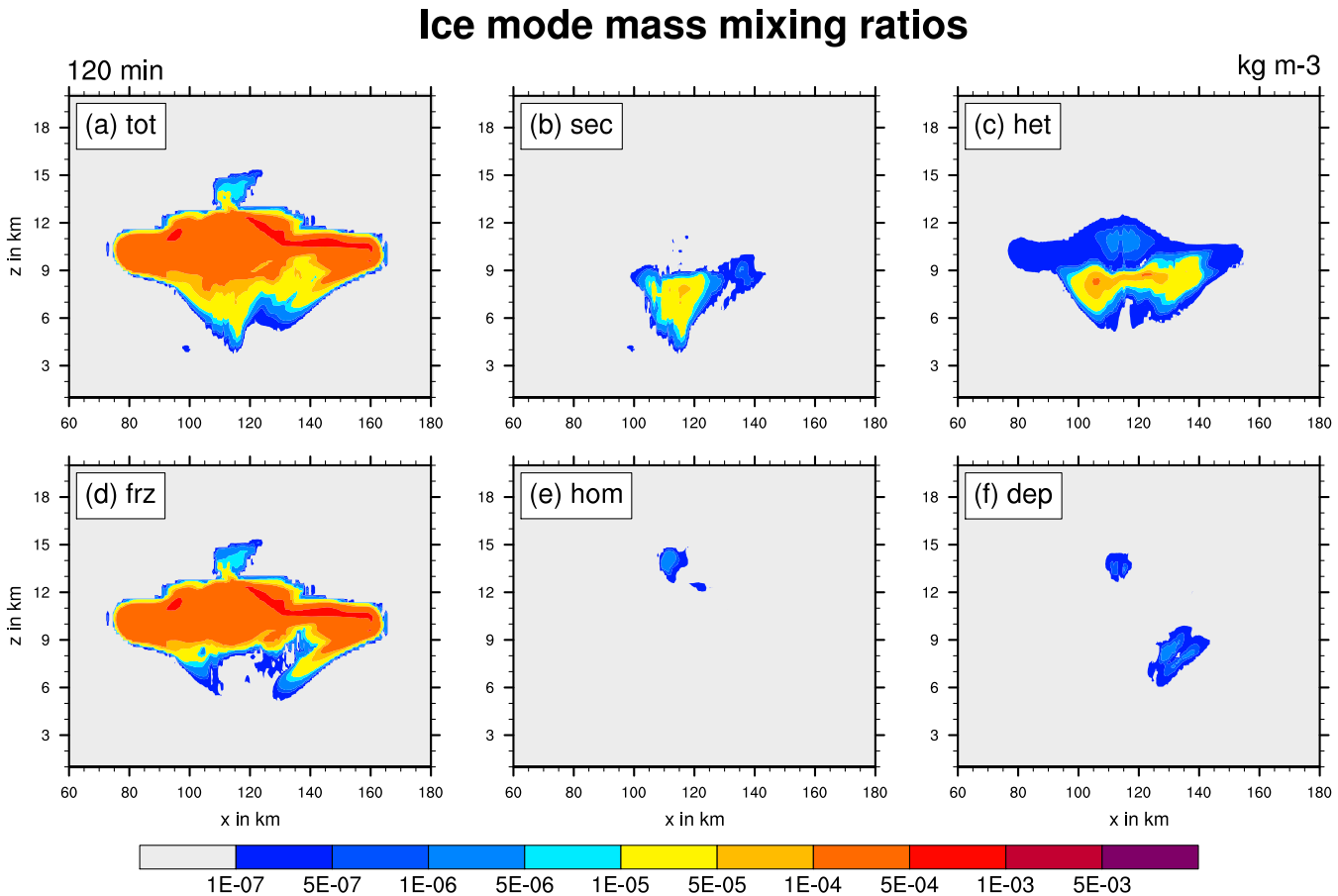
Collisional breakup

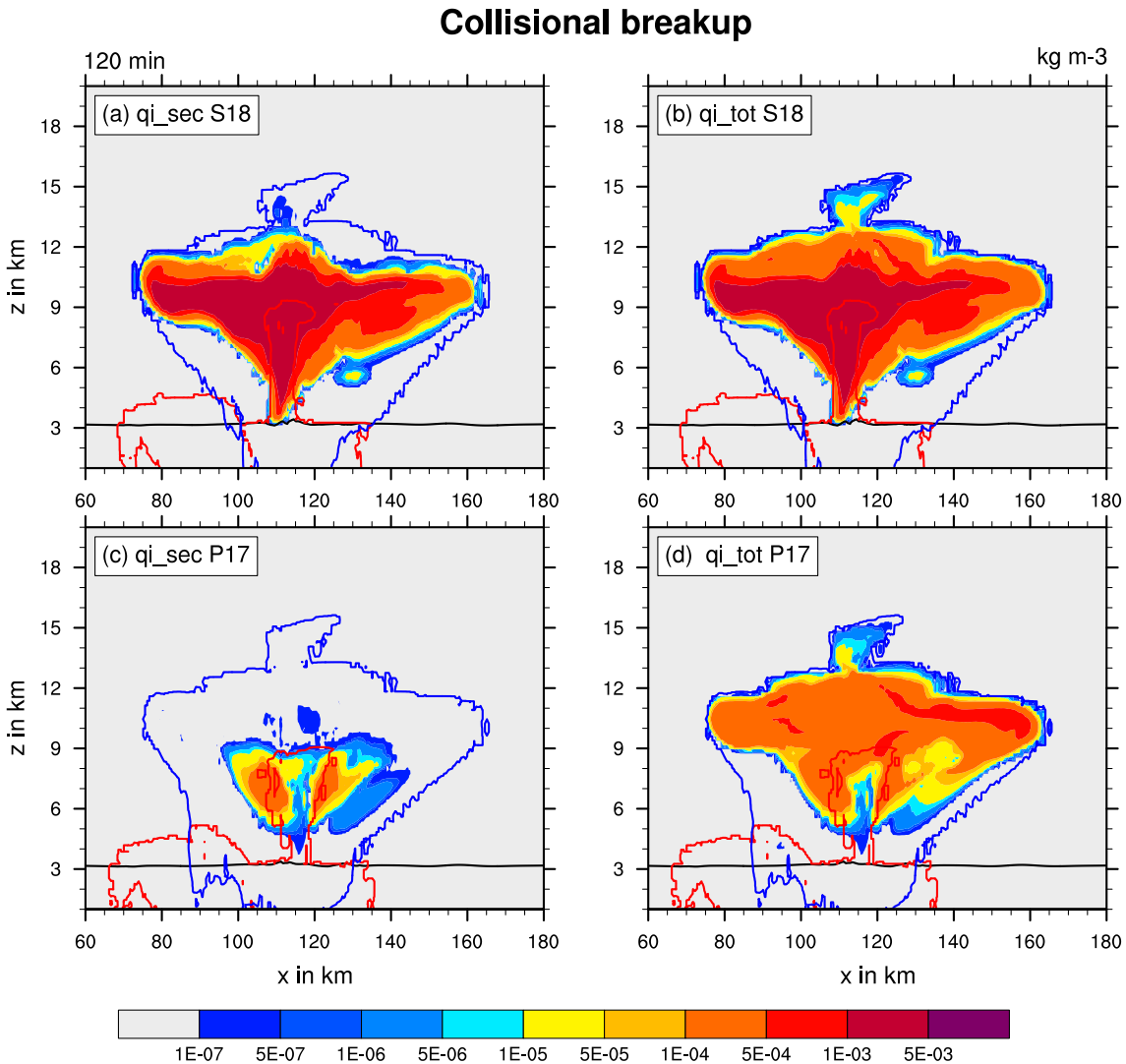
- S18: temperature, bulk collision rates (Sullivan et al., 2018b)
- P17: temperature, mass resolved size and collision rates (Phillips et al., 2017)

Droplet fragmentation

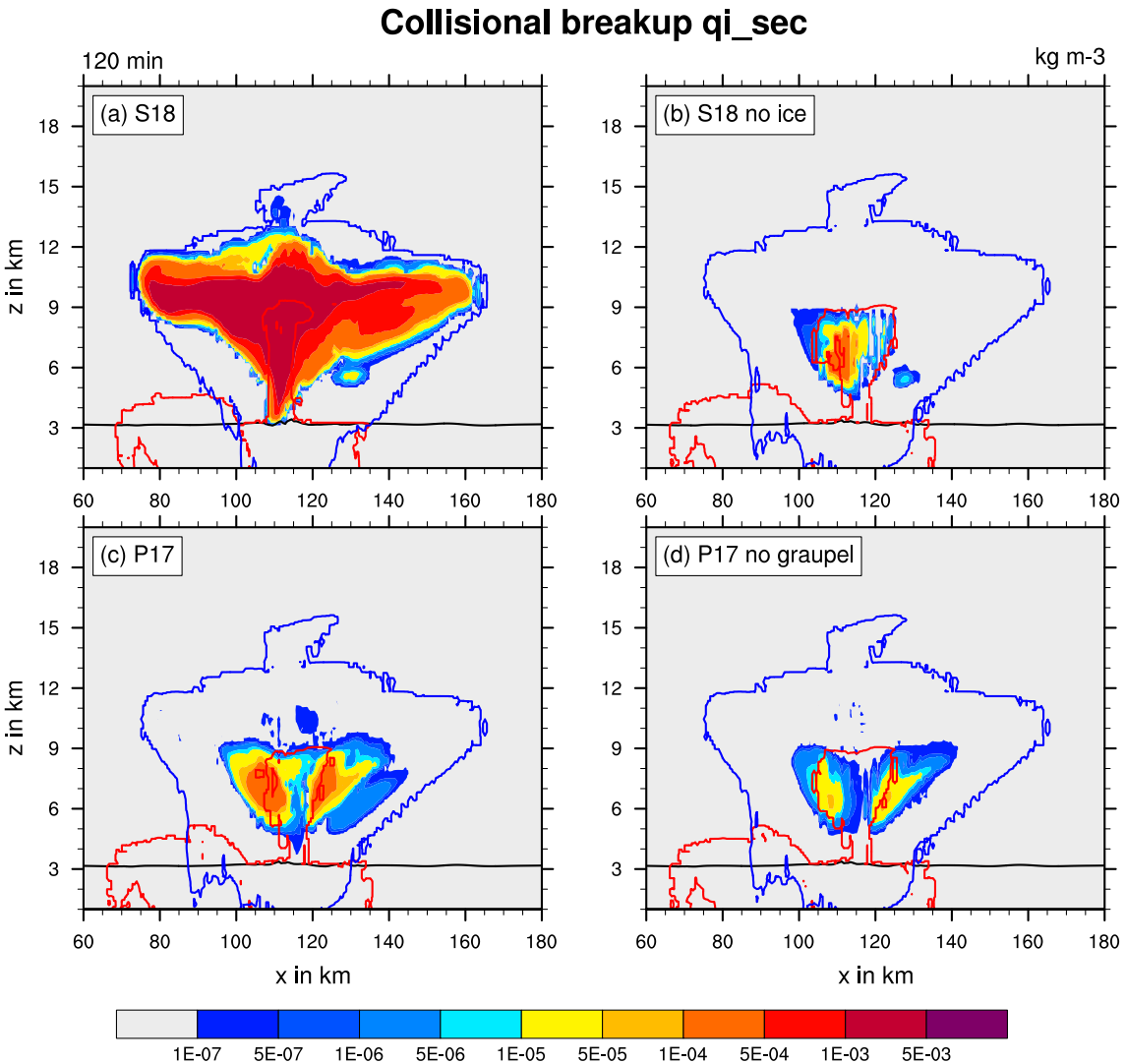
- S18 constant: temperature, freezing rates (Sullivan et al., 2018b)
- S18 polynomial: temperature, freezing rates, size (Sullivan et al., 2018a)
- S18 sigmoidal: temperature, freezing rates, size (Sullivan et al., 2018a)
- P18: temperature, freezing rates, size (Phillips et al., 2018)


Cloud particle mass mixing ratios
120 min
kg m-3
(a) ice
(b) snow
(c) graupel
(d) droplets
(e) rain
(f) hail
z in km
x in km
1E-07
5E-07
1E-06
5E-06
1E-05
5E-05
1E-04
5E-04
1E-03
5E-03

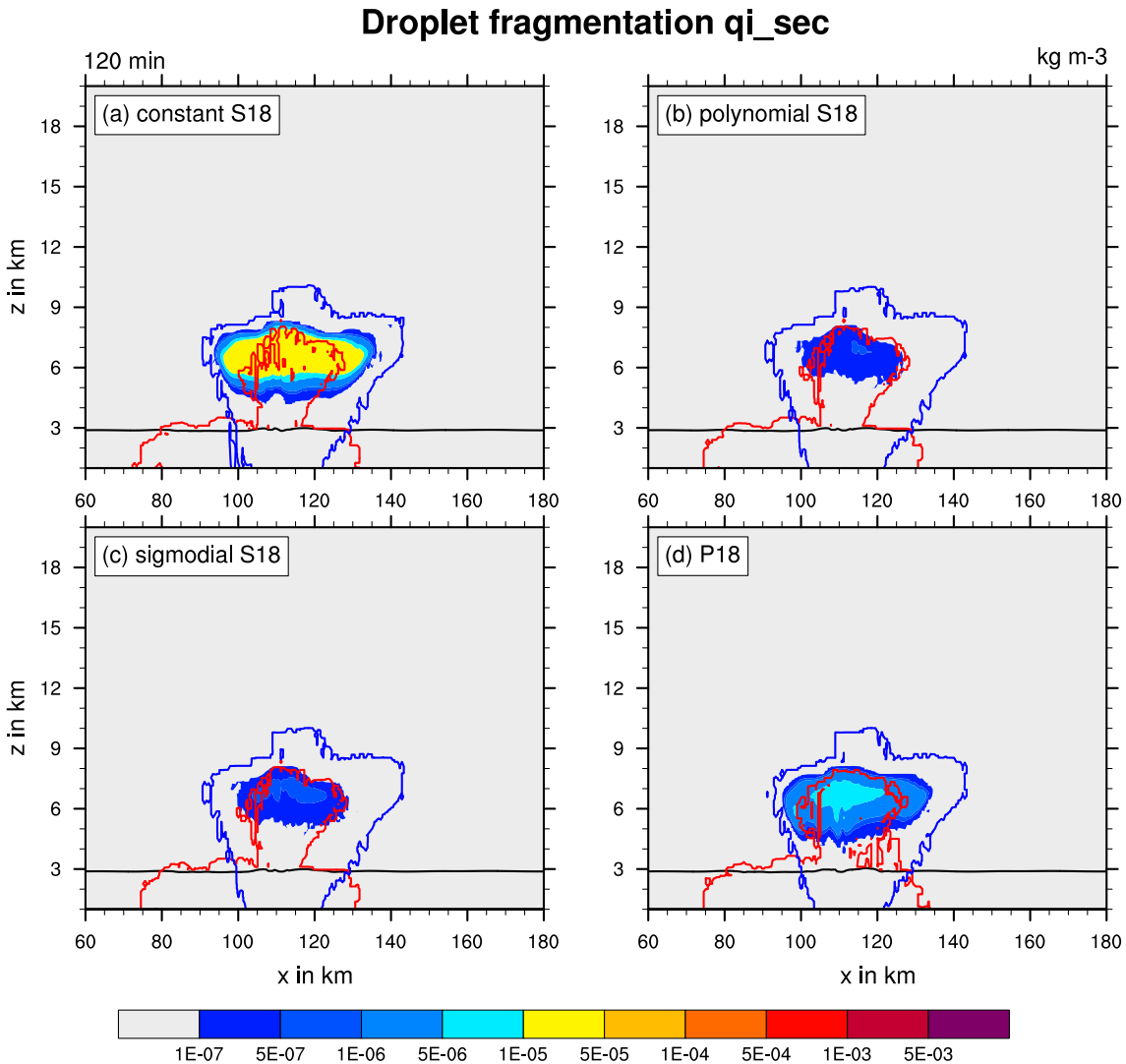

Ice mode mass mixing ratios
120 min
kg m-3
(a) tot
(b) sec
(c) het
(d) frz
(e) hom
(f) dep
z in km
x in km
1E-07
5E-07
1E-06
5E-06
1E-05
5E-05
1E-04
5E-04
1E-03
5E-03


Collisional breakup
120 min
kg m-3
(a) qi_sec S18
(b) qi_tot S18
(c) qi_sec P17
(d) qi_tot P17
z in km
x in km
1E-07
5E-07
1E-06
5E-06
1E-05
5E-05
1E-04
5E-04
1E-03
5E-03

Collisional breakup sensitivity



Droplet fragmentation



Summary

- Rime splintering findings consistent with other studies
- Collisional breakup with P17 scheme shows reasonable results
- Graupel important for collisional breakup
- Strong size and temperature dependencies lead to weak frozen droplet shattering
- Ice modes scheme useful to investigate ice formation pathways and test parametrisations

Outlook

- Secondary ice processes on a synoptic scale
- Secondary ice processes in WCB trajectories
- Statistics with an ensemble of synoptic cases

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