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Multiple SIP mechanisms: organisation by cloud-type and by cloud age

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Background

- History of SIP thinking in community

1970s – 1990s: Lab studies

- **HM (1974) process** of rime-splintering
- lab expts **for raindrop-freezing fragmentation (RF), sublimational breakup (SB) and breakup in ice-ice collisions (BR)**
- Harris-Hobbs and Cooper (1987) finds correlations in aircraft data for HM process

2000s: modern aircraft studies

- Rangno (2008) and Lawson et al. (2015) observe raindrop-freezing fragmentation (RF)

2010s: modeling of SIP

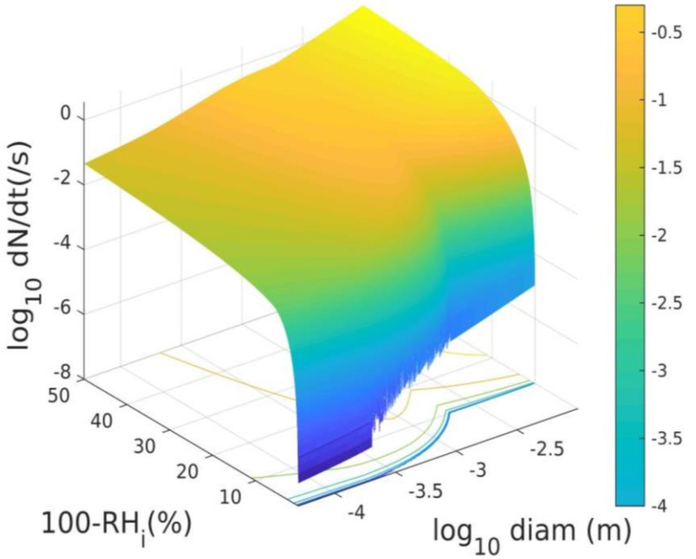
- Korolev et al. (2011) anti-shatter tips on probes
- New aircraft campaigns about ice initiation
- Workshop at Manchester on SIP
- Formulations of BR, RF and cloud simulations

2020s: ?

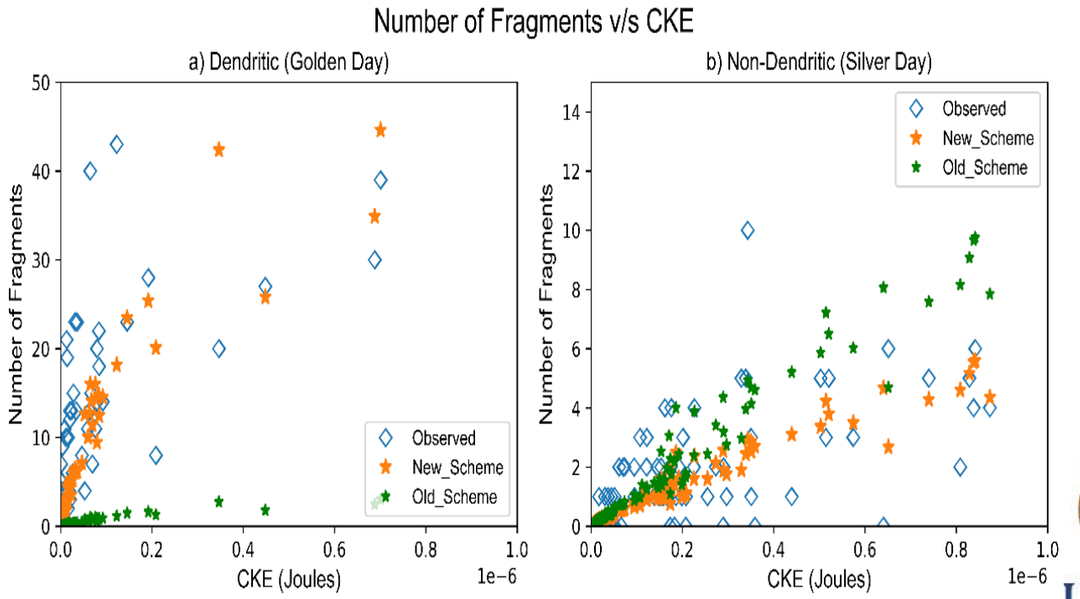
- Cloud modeling of observed cases
- Deshmukh et al. (2022) treat sublimational breakup (SB)
- Lab expts (Hartmann, Mainz group, Lund, Manchester …)

New formulations of SIP from observations and pooling published lab results

- **SB from Deshmukh et al. (2022):**
  - theoretical formula fitted to published data from Hallett
  - Quasi-equilibrium concentration during descent
    - balance between continual emission and destruction during descent



- **BR by Phillips et al. (2017), improved by Gautam (2022):**
  - Modern probe in N Sweden
  - Qualitative confirmation of formulation dependencies
  - More fragmentation than in 2017 formulation



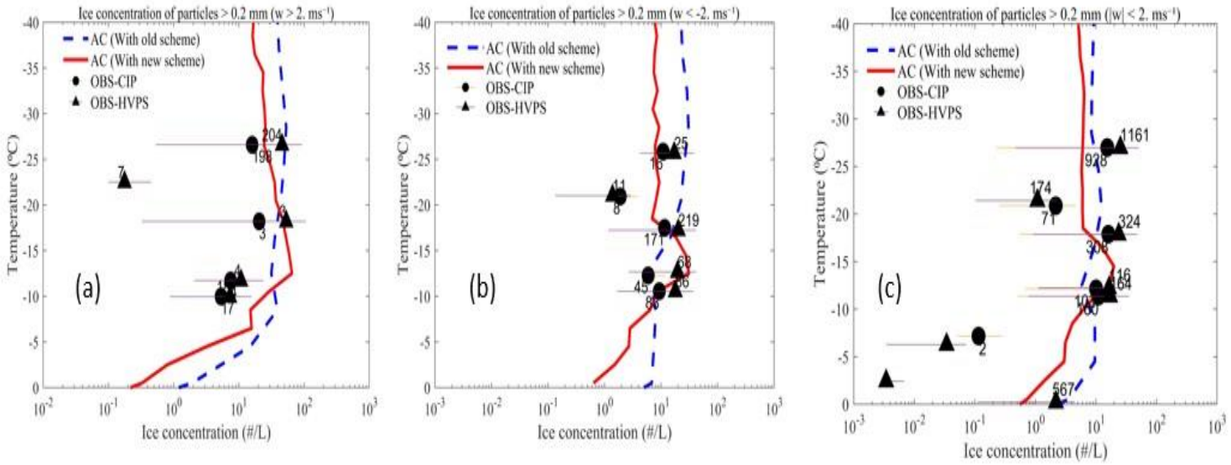
- **RF:**
  - Mode 1: quasi-spherical freezing (Phillips et al. 2018)
  - Mode 2: freezing on impact with more massive ice (James et al. 2021)

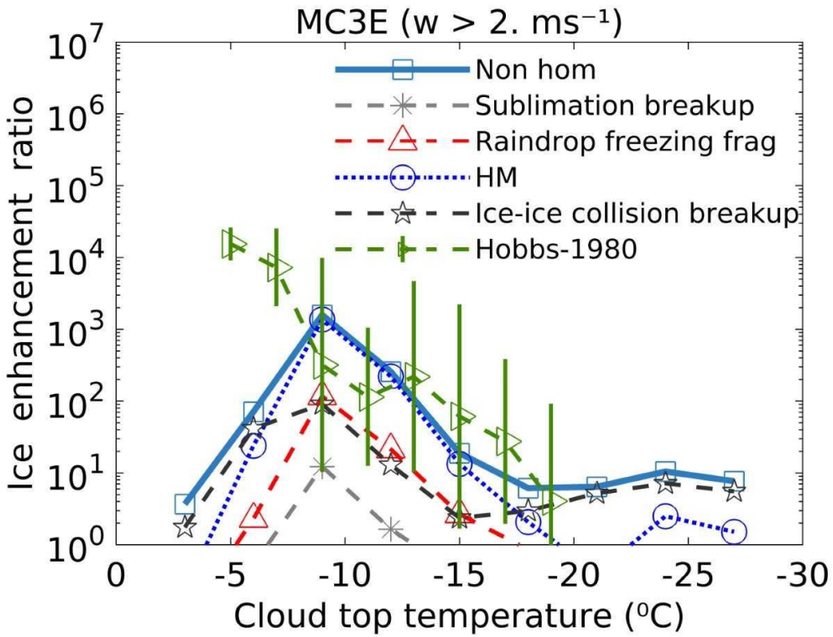
Validation of cloud simulations with 4 SIP mechanisms

- Ice concentration validated for several cases in AC simulations
  - Cold-based US convection (STEPS): Phillips et al. (2017);
  - Warm-based US convection (MC3E, 11th and 20th May): Waman et al. (2022, 2023); Patade et al. (2022)
  - Layer-clouds (ACAPEX in USA and APPRAISE in UK): Waman et al. (2023)
  - Very warm-based convection (GOAMAZON): Gupta et al. (2023, Nature Comm)

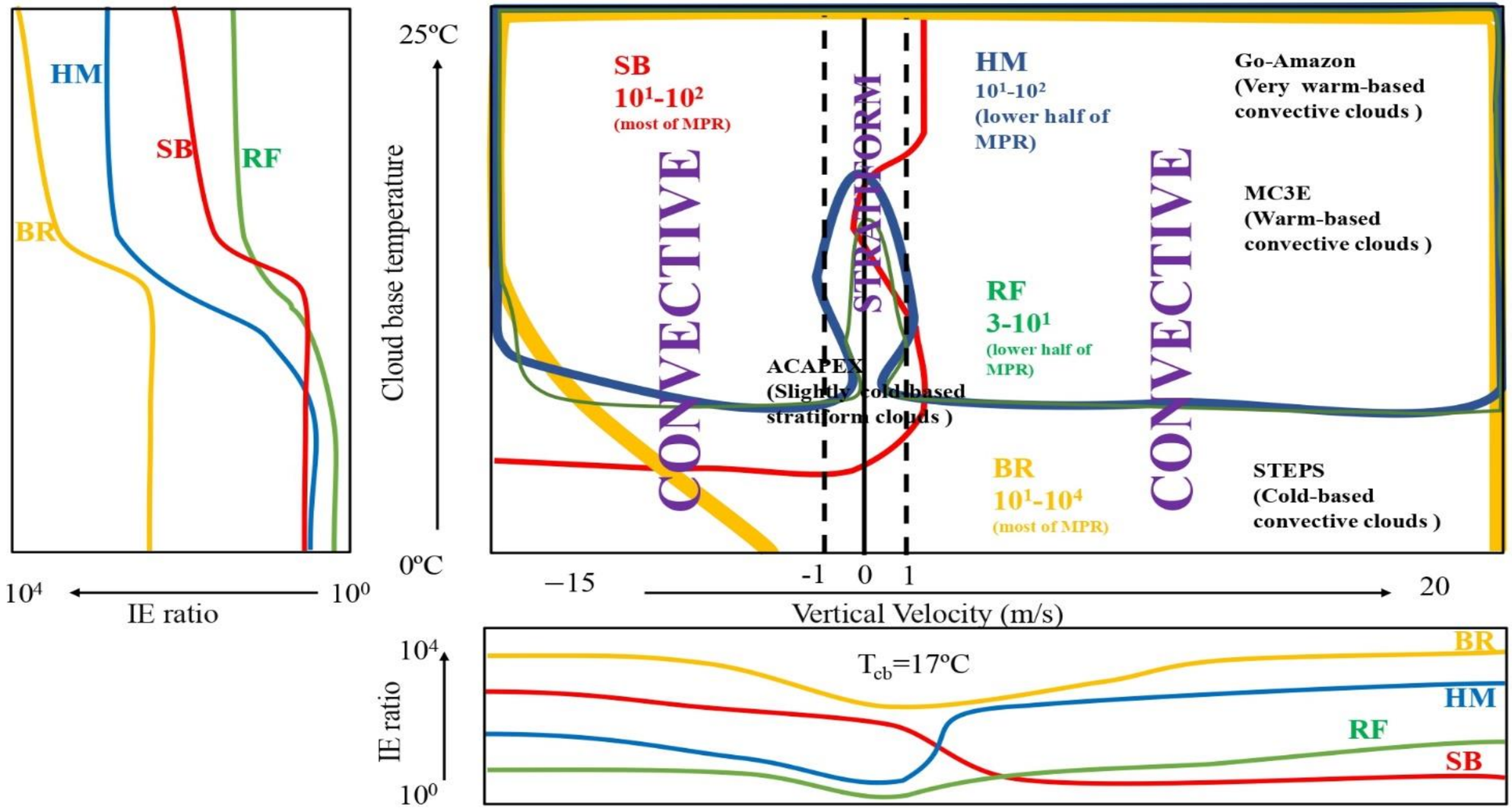
- Breakup in ice-ice collisions prevails overall for mesoscale cloud systems
  - long time-scales

- But: for a parcel simulation of ascending convective turret, RF and HM process prevail
  - short time-scales



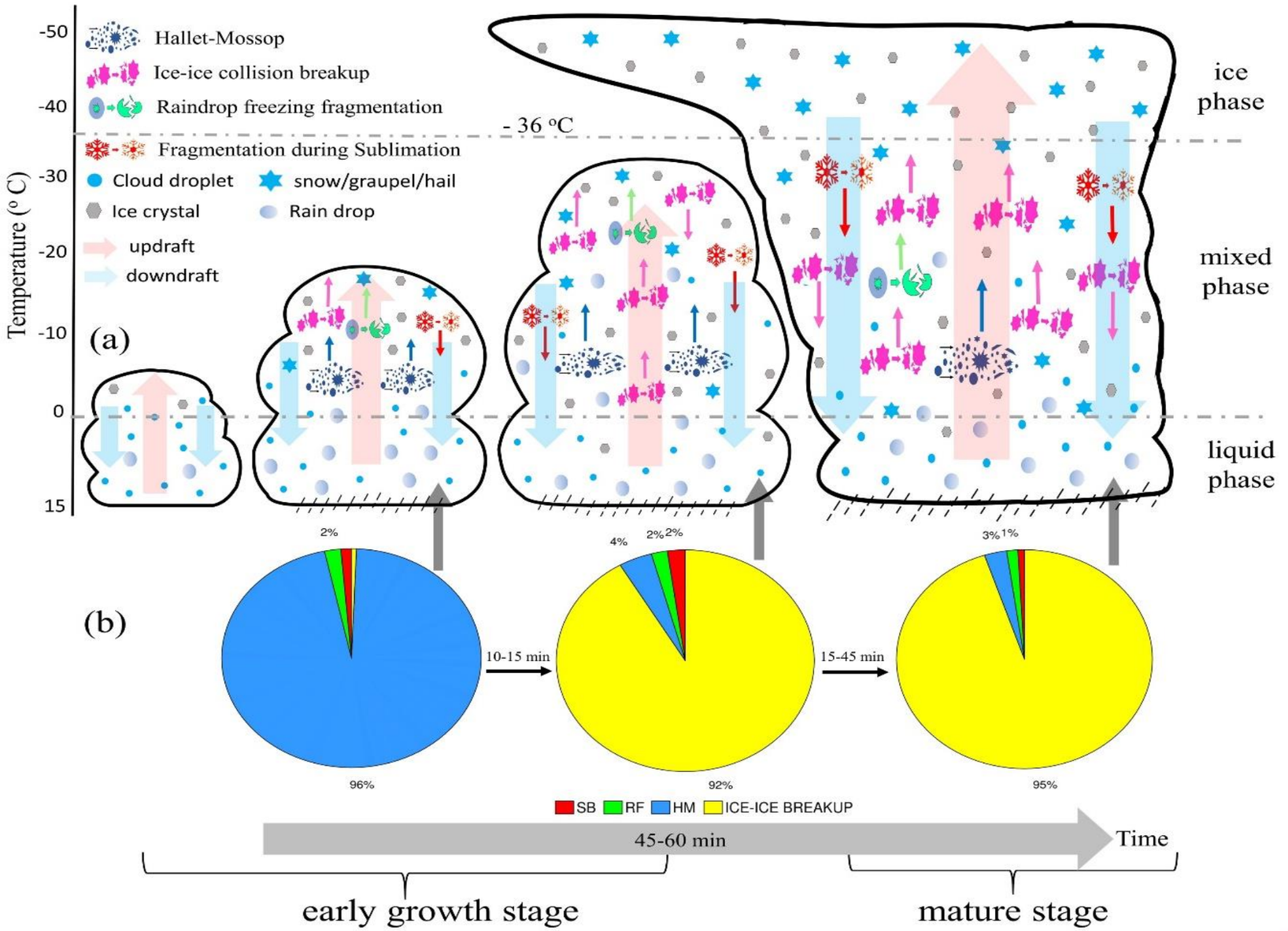


Organisation of SIP among cloud-types



Cloud Age and SIP

- Waman et al. (2023, JAS)
- Poster today



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