Mixed phase clouds in the spectral coupled cloud microphysics model COSMO-SPECS

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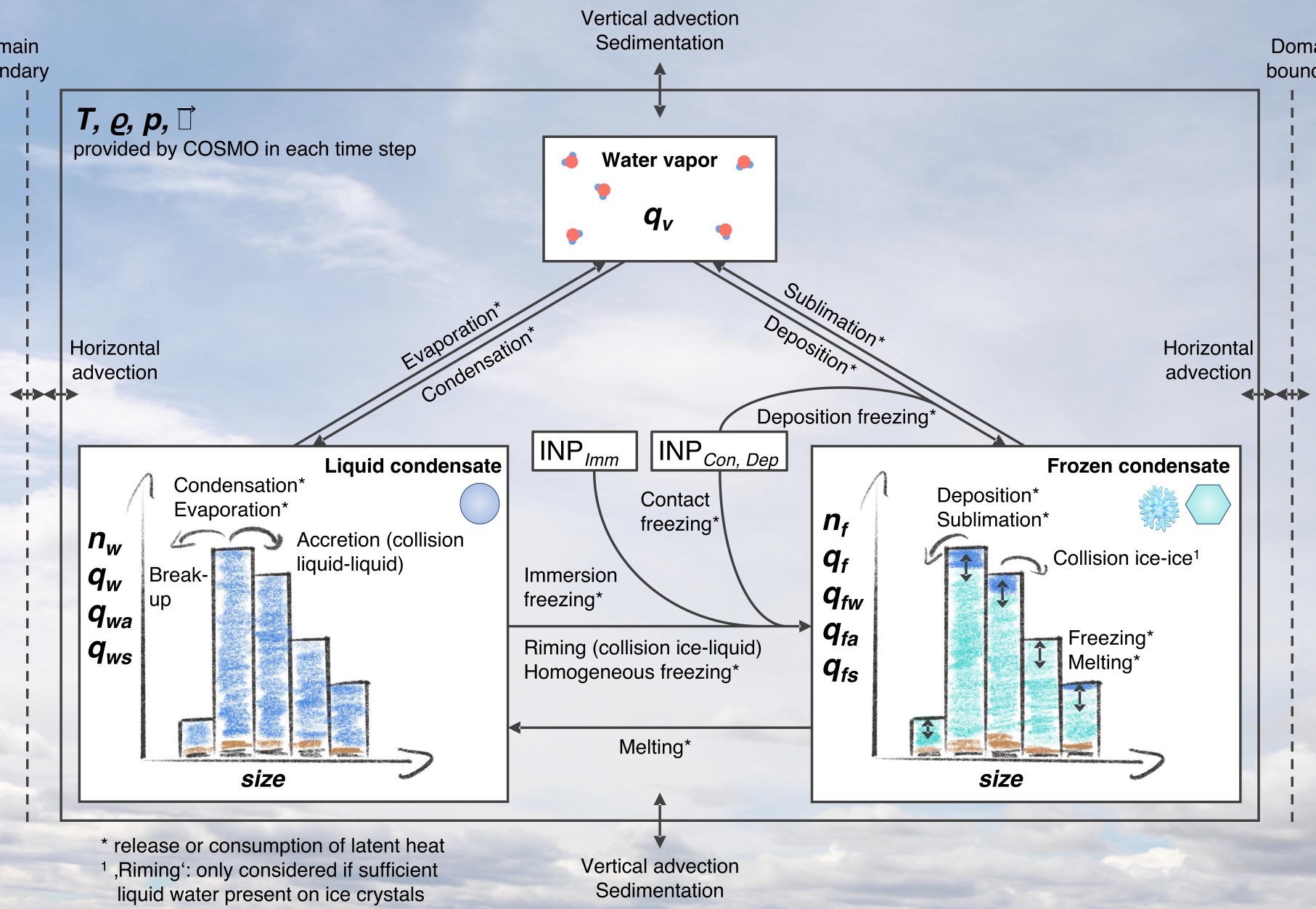
The model system COSMO-SPECS



* release or consumption of latent heat

[1] ‚Riming': only considered if sufficient liquid water present on ice crystals

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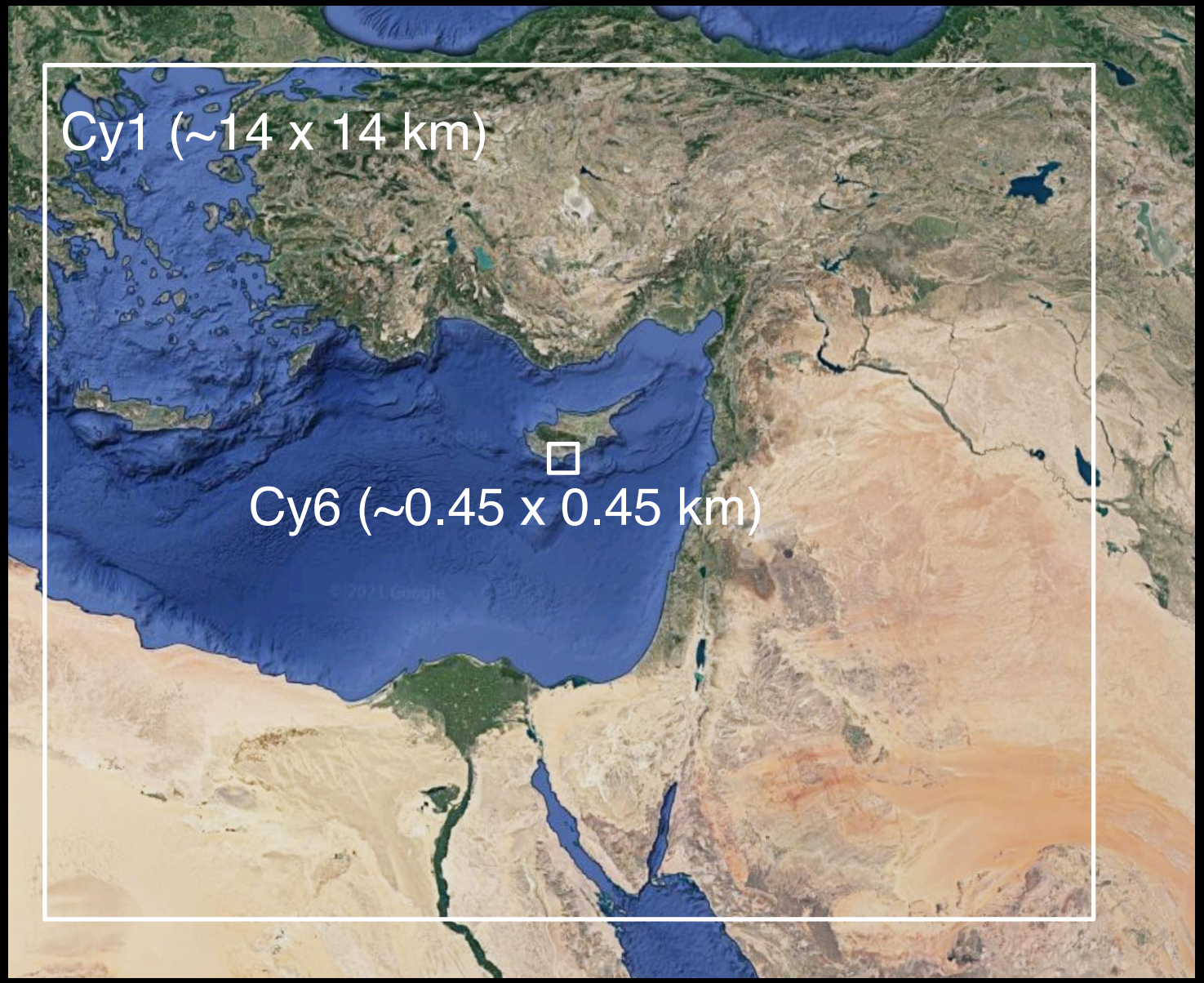
Case study CyCare 2017/01/24



- 6 nesting steps
- Outer nest driven by ICON-Global
- Domains Cy1-Cy5 with two-mom microphysics
- Cy6 with SPECS
- Boundary conditions for hydrometeor distributions -> Seifert and Beheng (2006), Met Atmos Phys
- **~1000 CCN cm^{-3}**
- **~1 INP L^{-1} (-20°C)**

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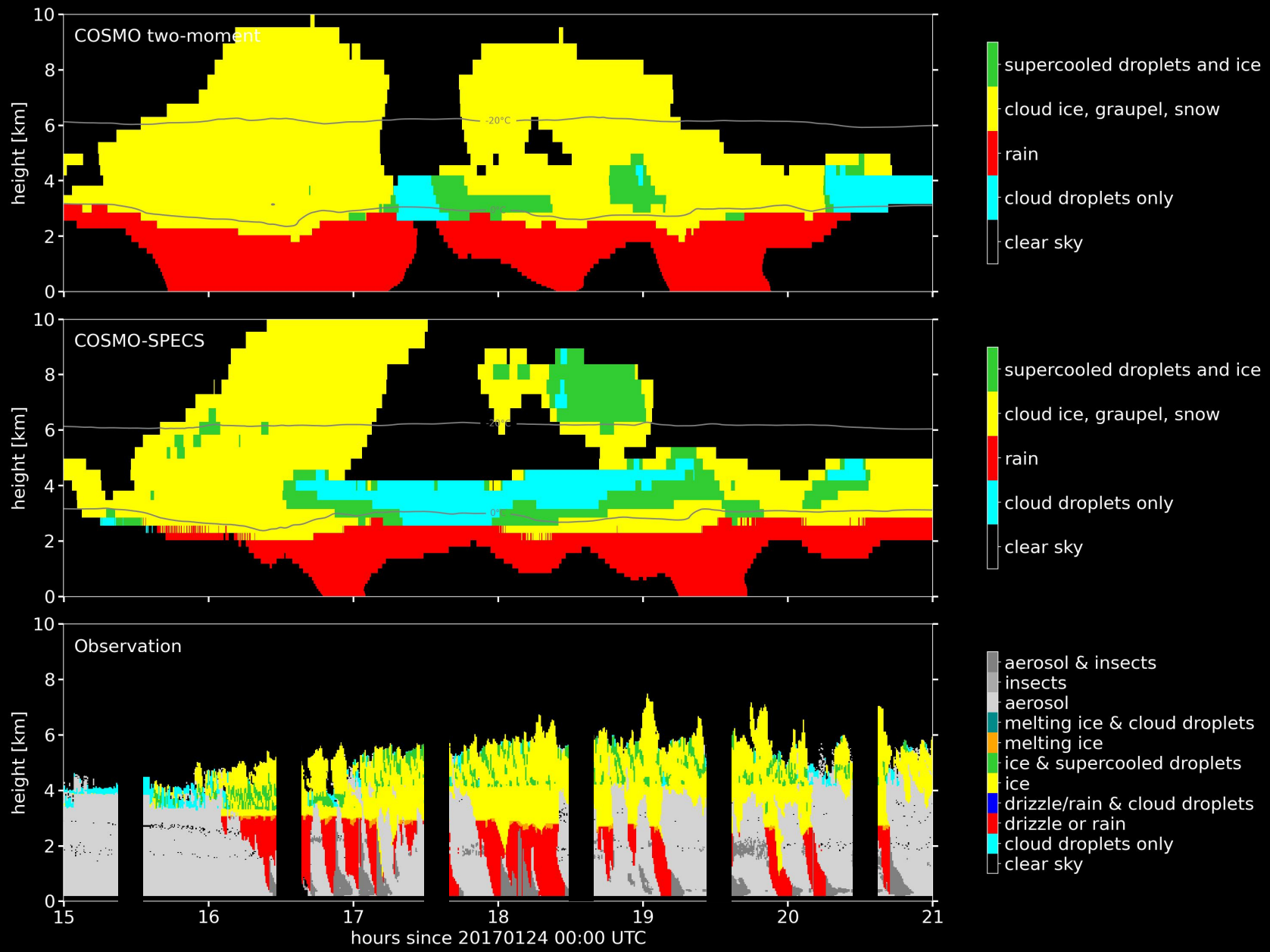
Classification - CyCare 2017/01/24

bulk
(2-mom)

spectral
(SPECS)

obs
(CLOUDNET)



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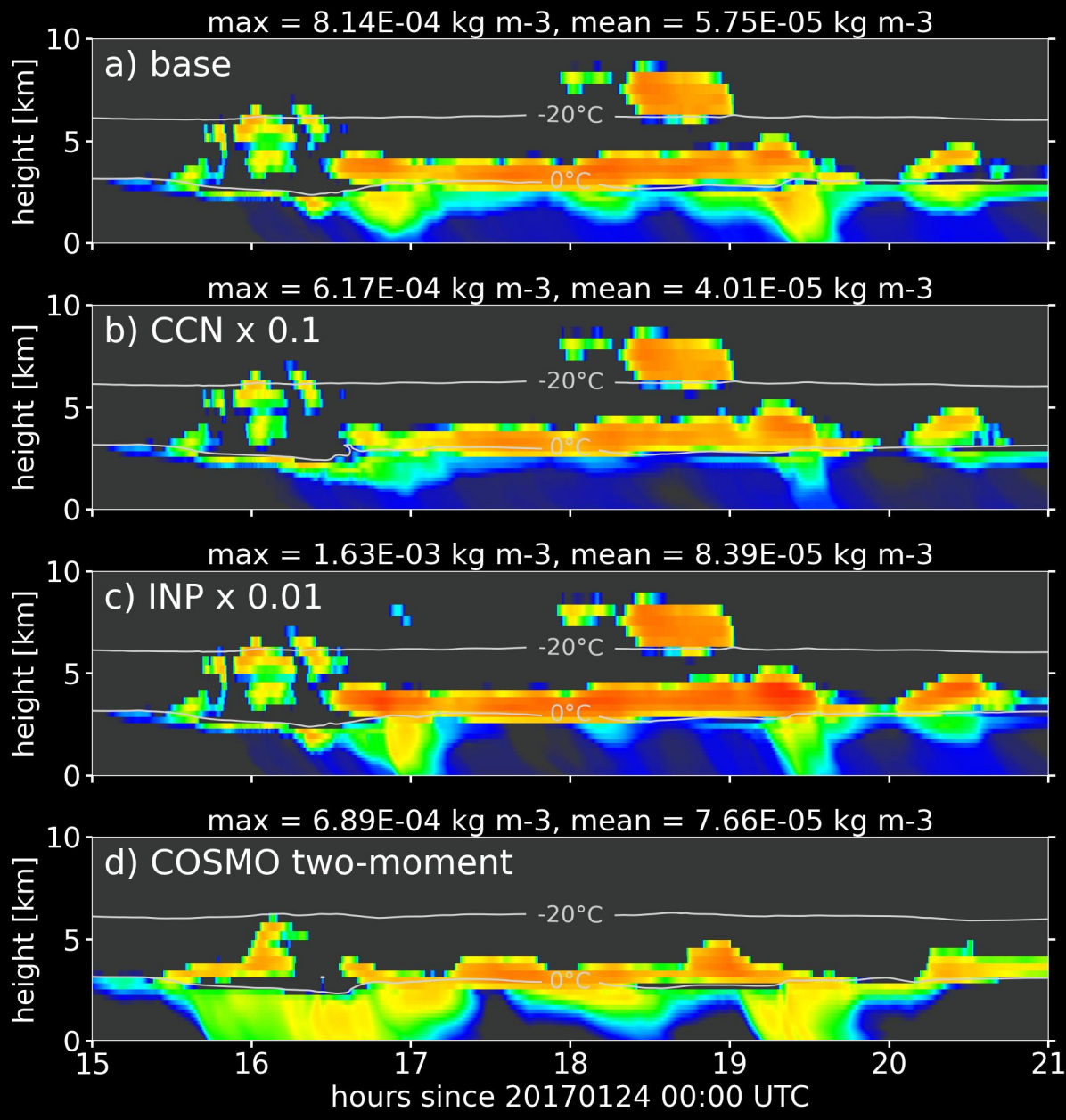
Sensitivity - CyCare 2017/01/24



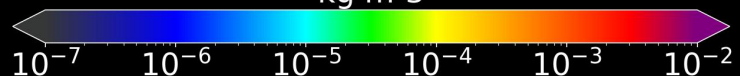
$P_{Obs} \sim 0.1$ mm

P = 0.16 mm

P = 0.02 mm

P = 0.22 mm

P = 2.2 mm



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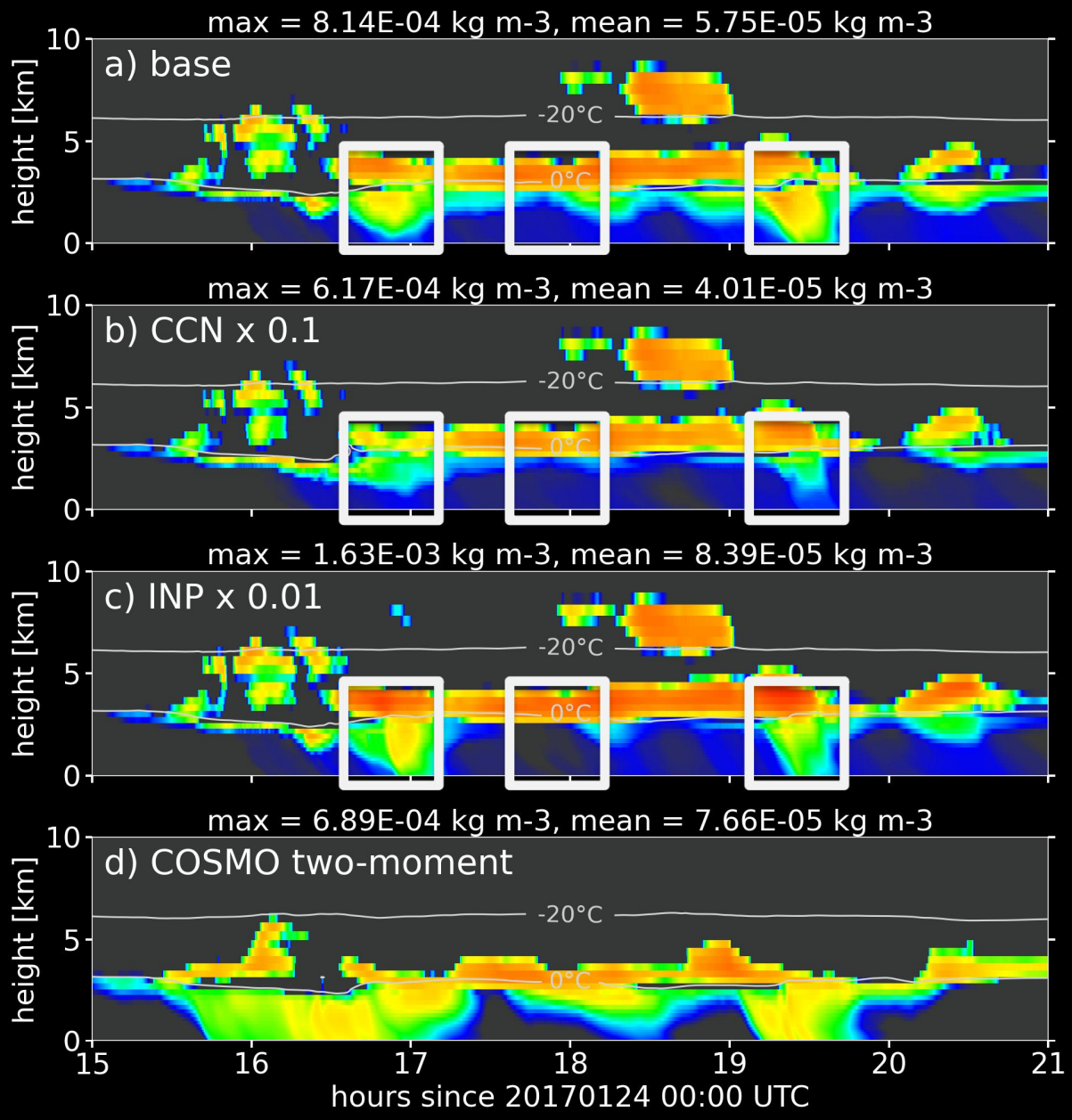
Sensitivity - CyCare 2017/01/24



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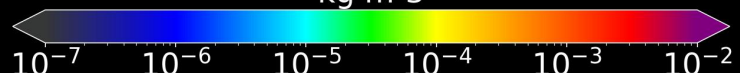

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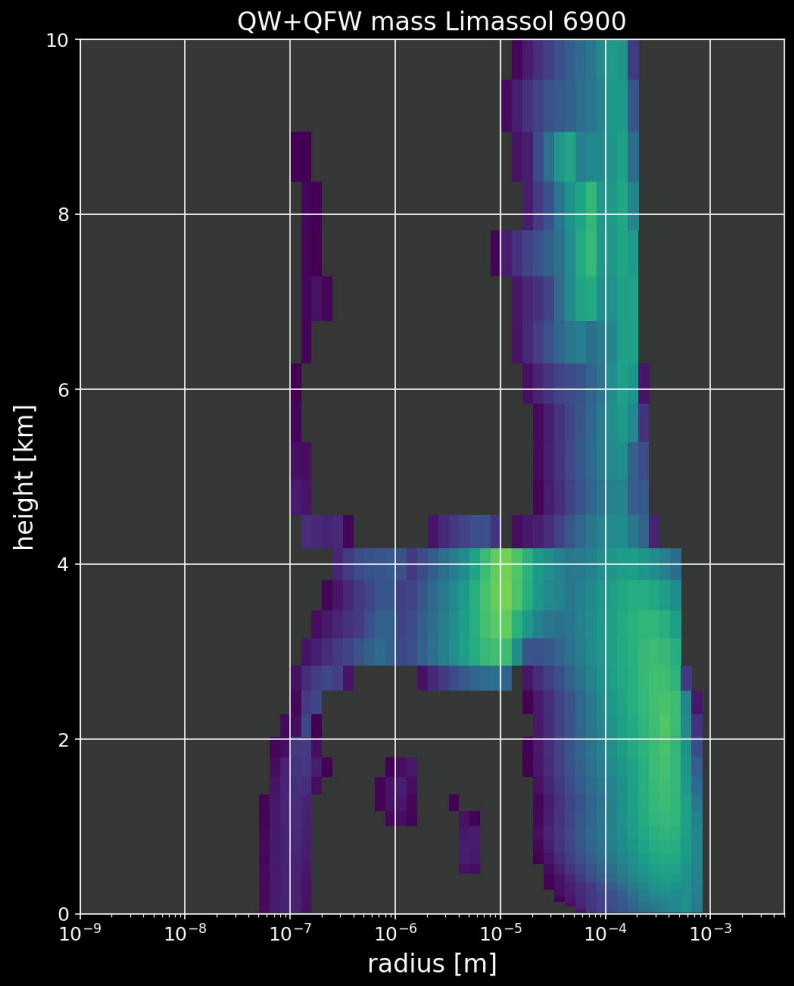
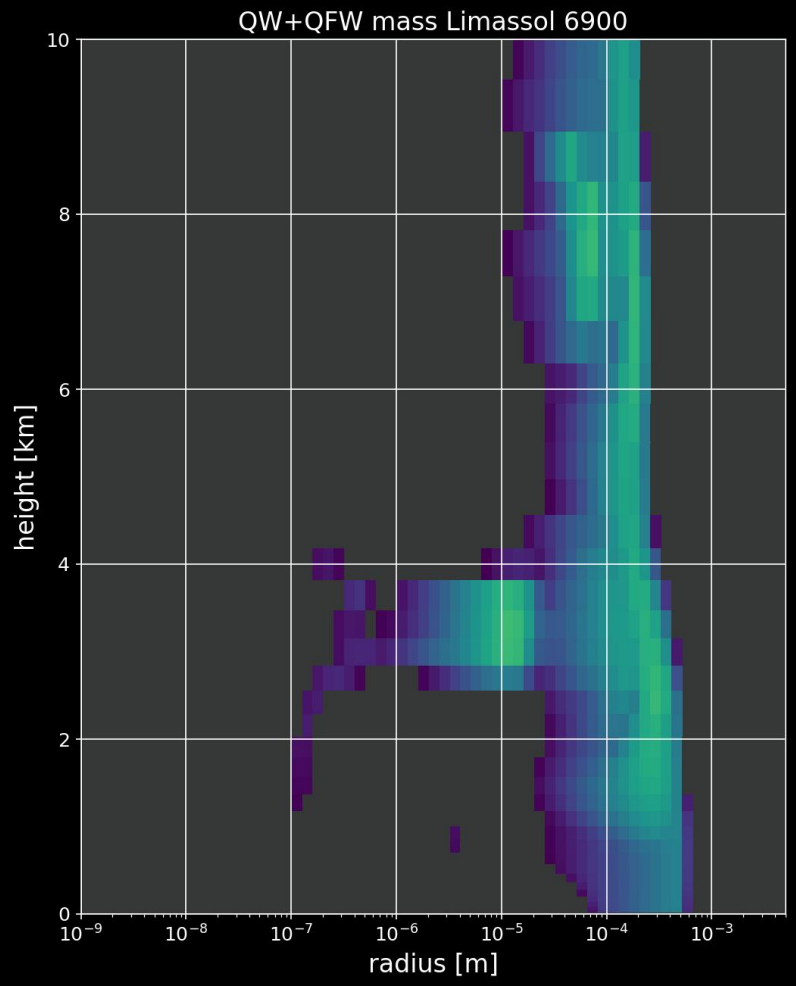
Hydrometeor mass spectra: liquid + frozen

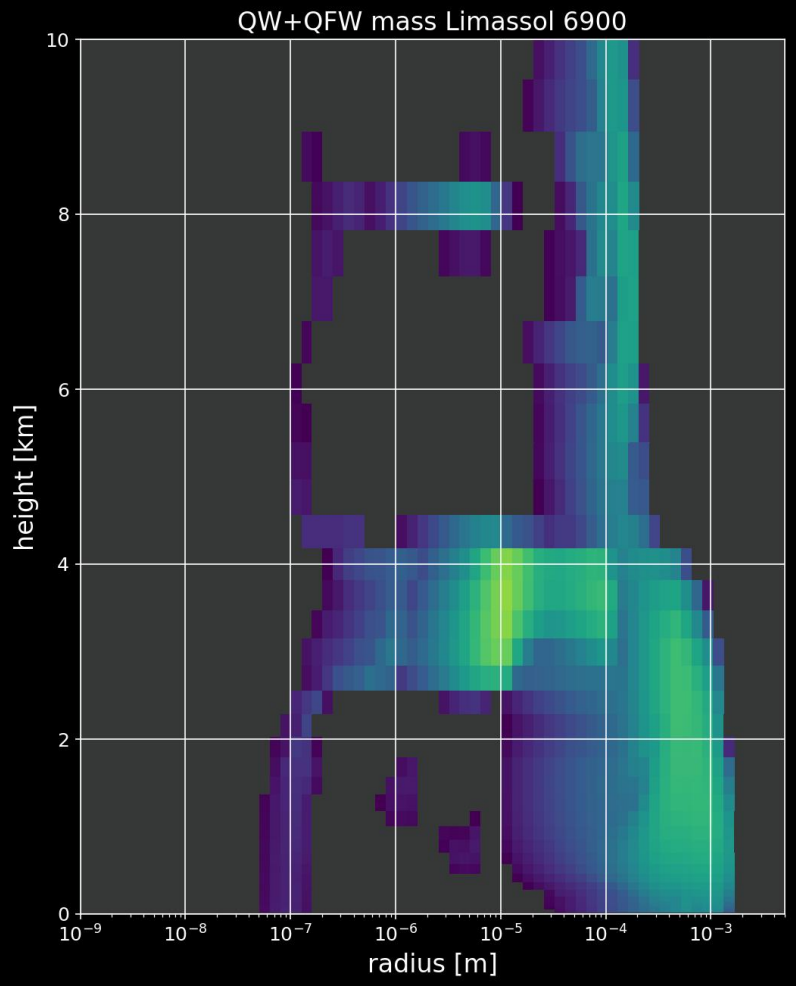
base

CCN x 0.1: less condensate, smaller rain droplets

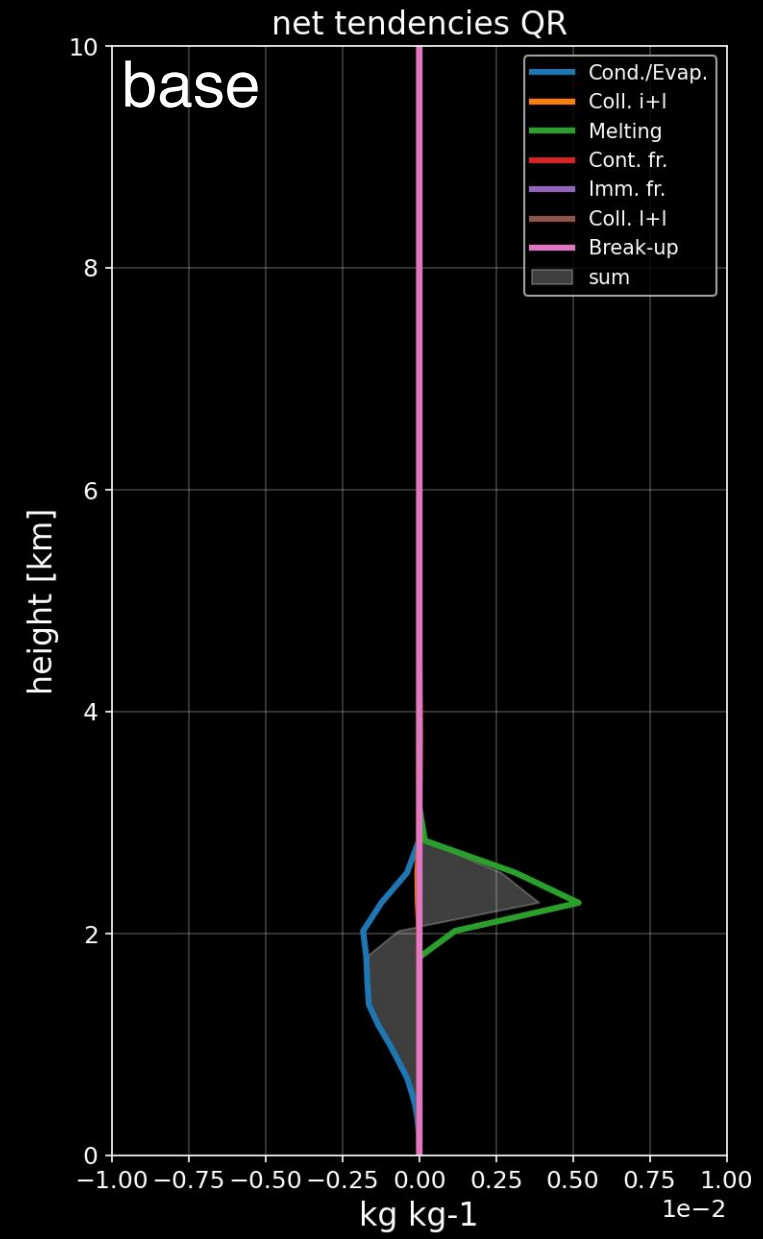
INP x 0.01: less ice, larger rain droplets

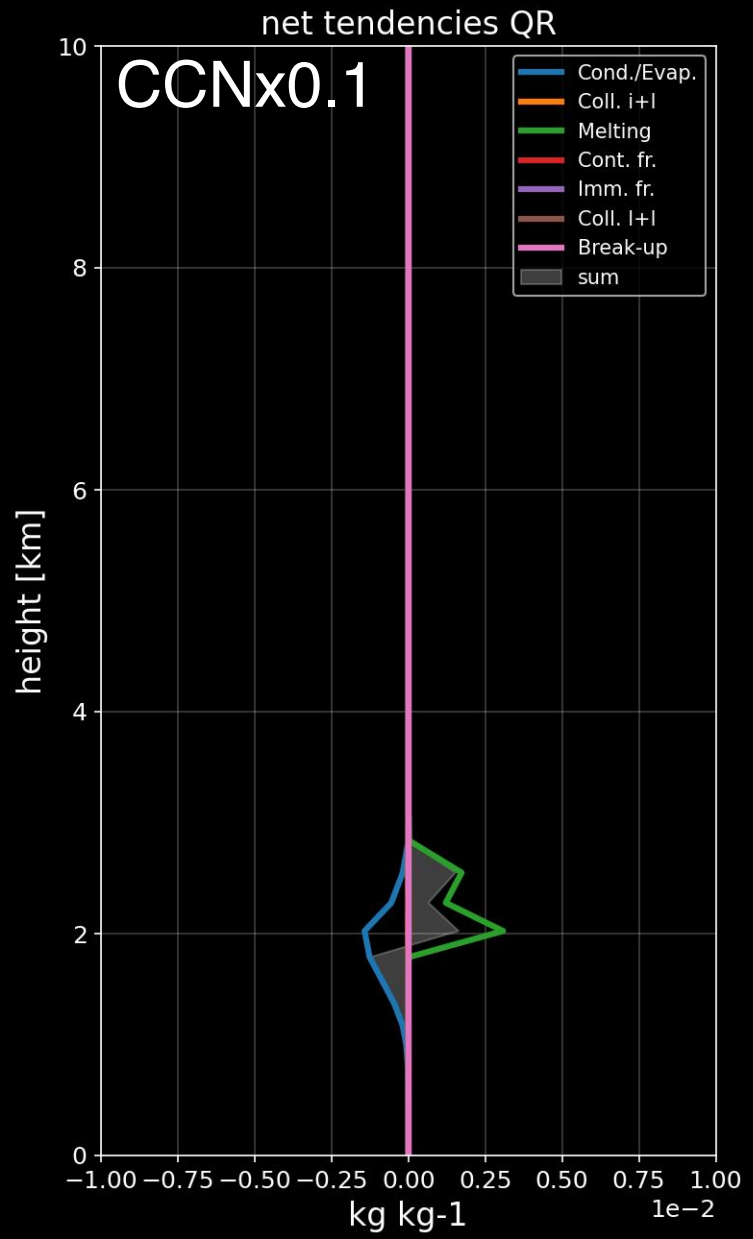


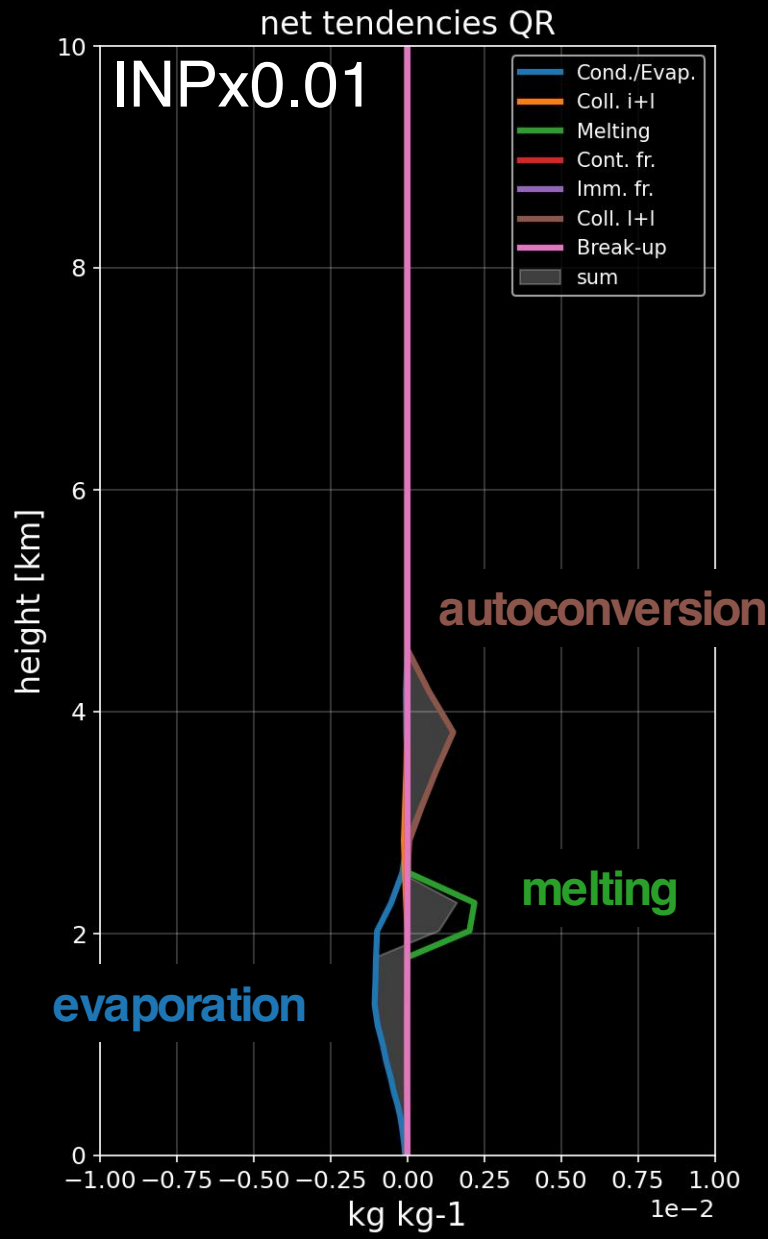




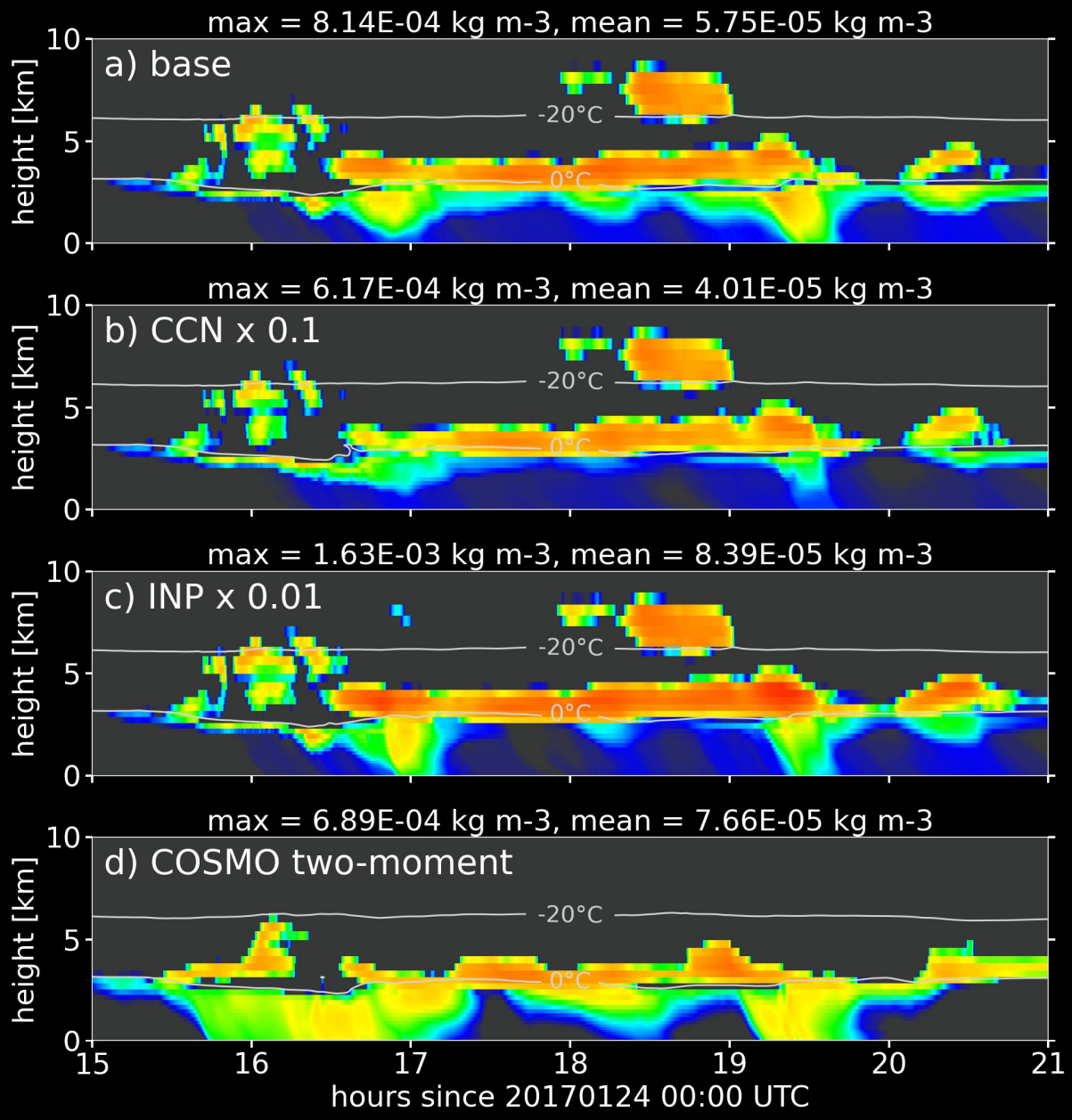
30min rain mass tendencies (> 100 μm)







Sensitivity - CyCare 2017/01/24



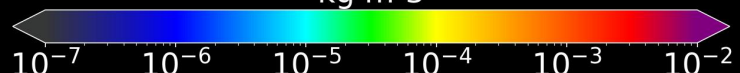
$P_{Obs} \sim 0.1$ mm

P = 0.16 mm

P = 0.02 mm, riming ↓

P = 0.22 mm, riming ↓, autoconversion ↑

P = 2.2 mm



TROPOS

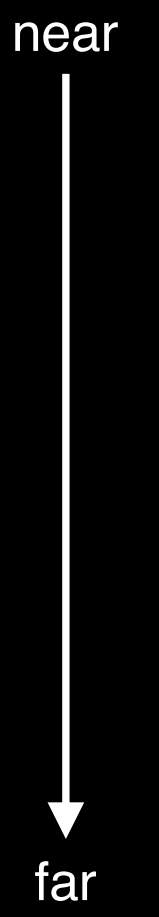
Summary

- Tasks achieved
  - COSMO-SPECS running for realistic 3D scenarios
  - Updated treatment of INP for immersion, contact, deposition freezing
  - Implemented latest SPECS process model updates (Diehl and Grützun, 2018)
  - Full output of all microphysical tendencies
  - Application and analysis of CyCare cases
  - Sensitivity studies on the effect of different processes and setup
    - e.g. INP concentration, aerosol concentration
    - Interesting response for INP variation
    - Competition in precipitation formation between riming and autoconversion

TROPOS

Outlook

- Work in progress
  - GMD paper on the model and example application
- Further plans
  - More case studies incl. DACAPO-PESO
  - Enable forward operator(s)
  - Process updates: ice multiplication, INP recycling, ice crystal shape
  - Inform SPECS by MUSCAT aerosol properties
  - Coupling to ICON + extended parallelisation



TROPOS

Treatment of INP

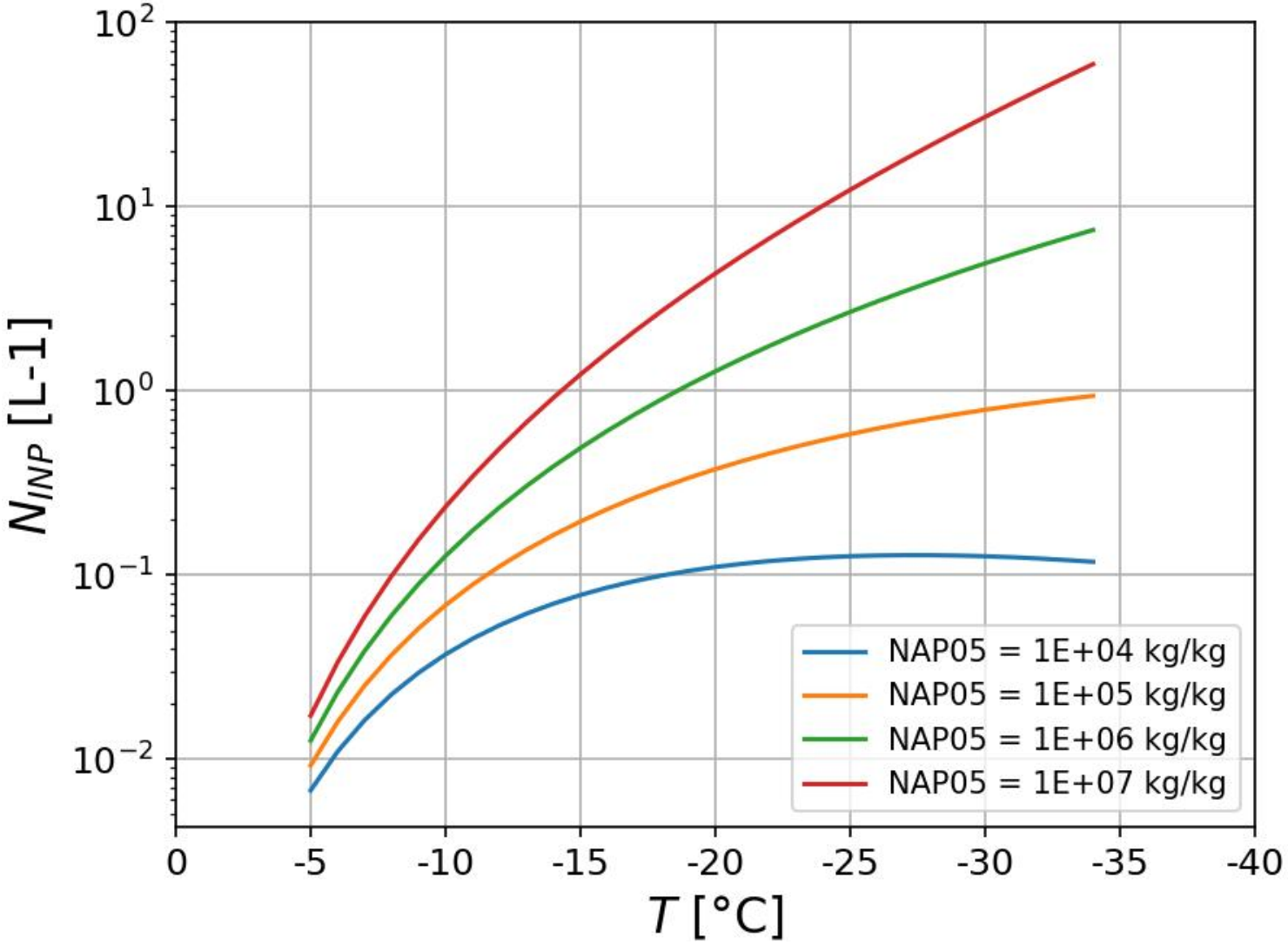
Approach #1: INP budget

- Initialize budget of INP at simulation start and boundaries
  - e.g. using INP parameterization (fixed, or depending on aerosol)
- Consume INP
- No release of INP

Approach #2: Diagnose INP based on immersed aerosol

- INP directly depend on current aerosol distribution
- INP are consumed and released

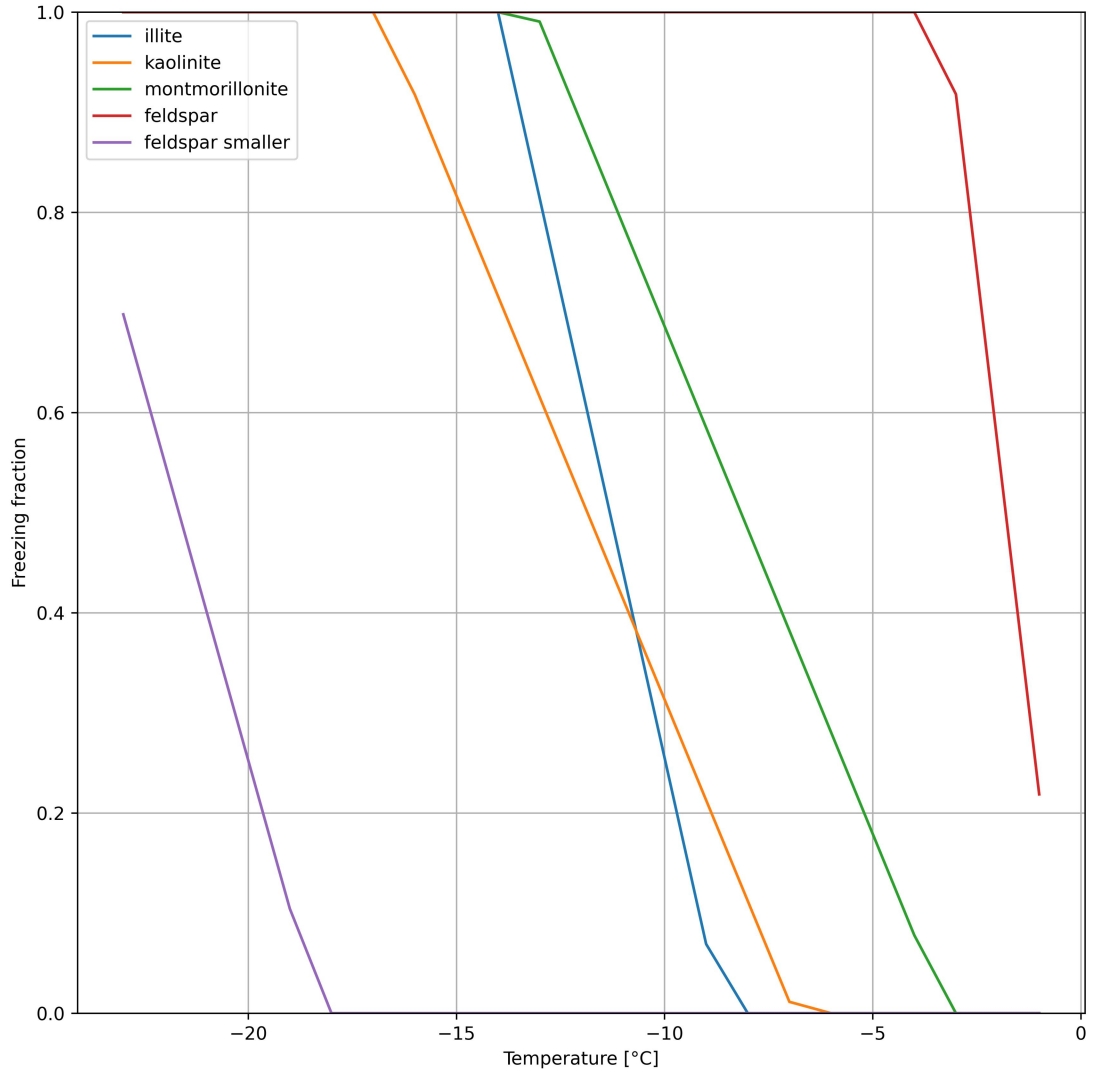
Treatment of INP – immersion freezing



- Calculate or set $N_{AP} > 0.5\ \mu m$
  - Budget: Init, Boundaries
  - Diagnosis: every time step
- Calculate $N_{INP}(T)$
- Freeze N_{INP} droplets
- Budget: decrease N_{INP}

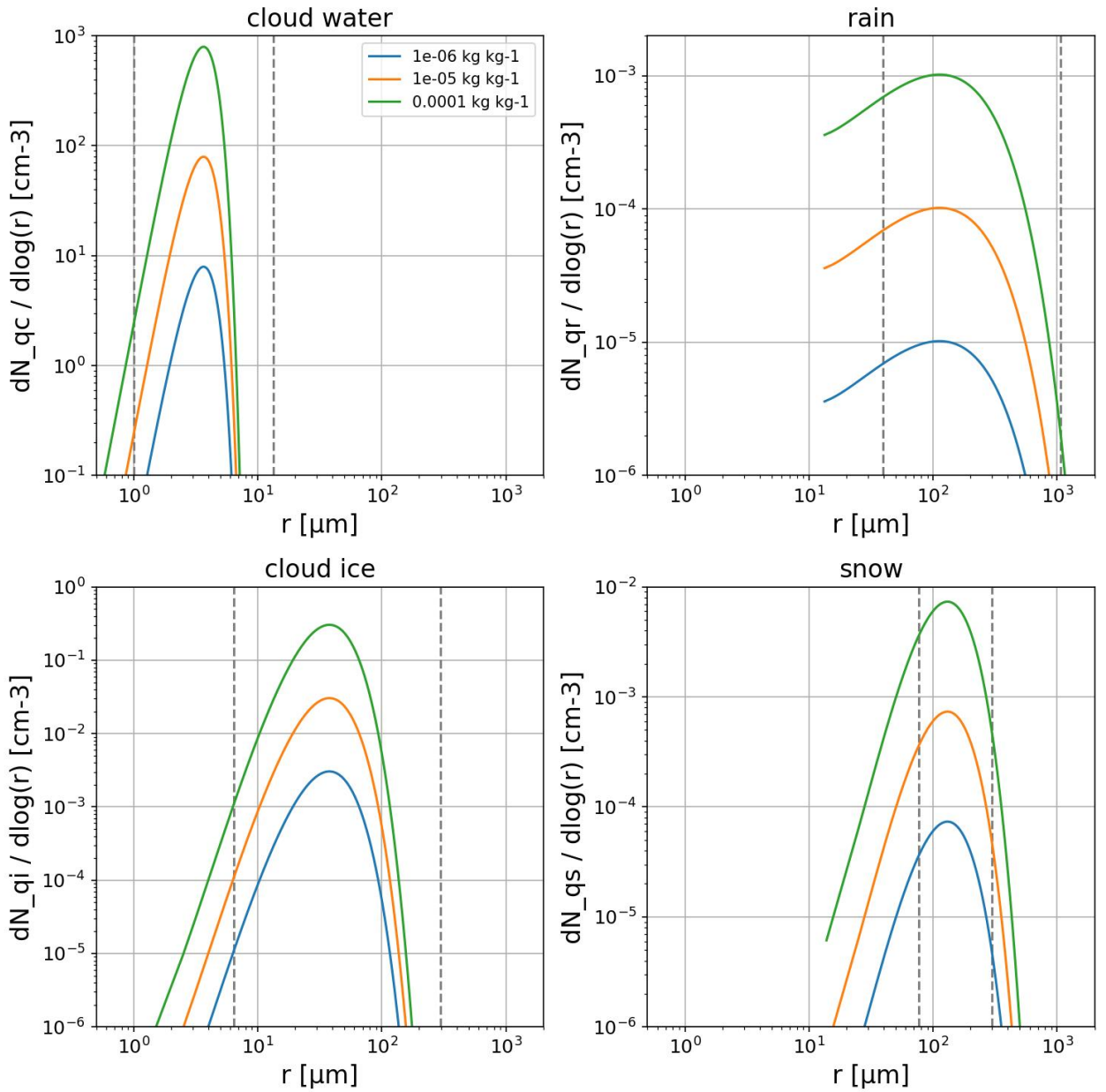
Treatment of INP – contact freezing

- Collision kernel as for hydrometeo
- Separate field for contact IN
  - Interstitial aerosol particles

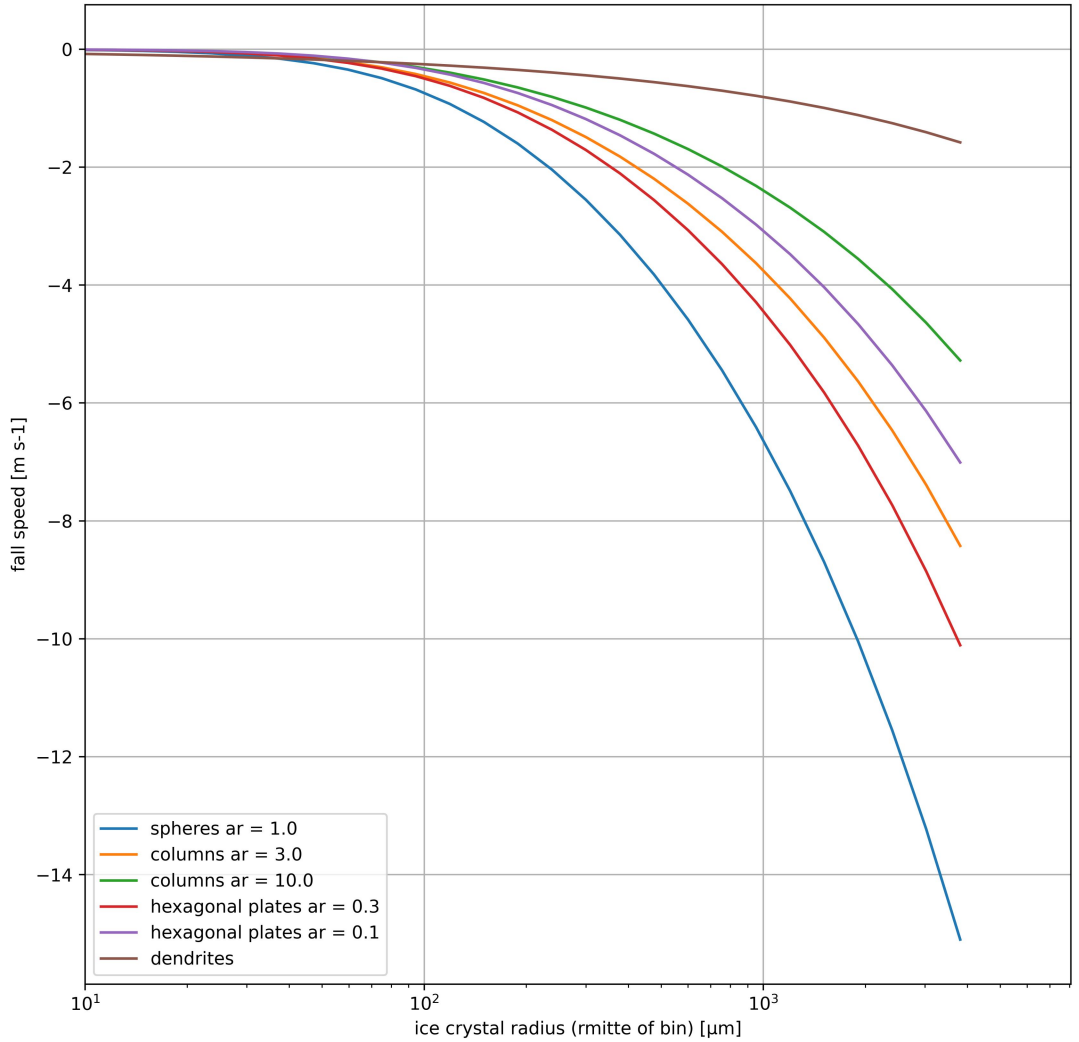


Initialization of the hydrometeors

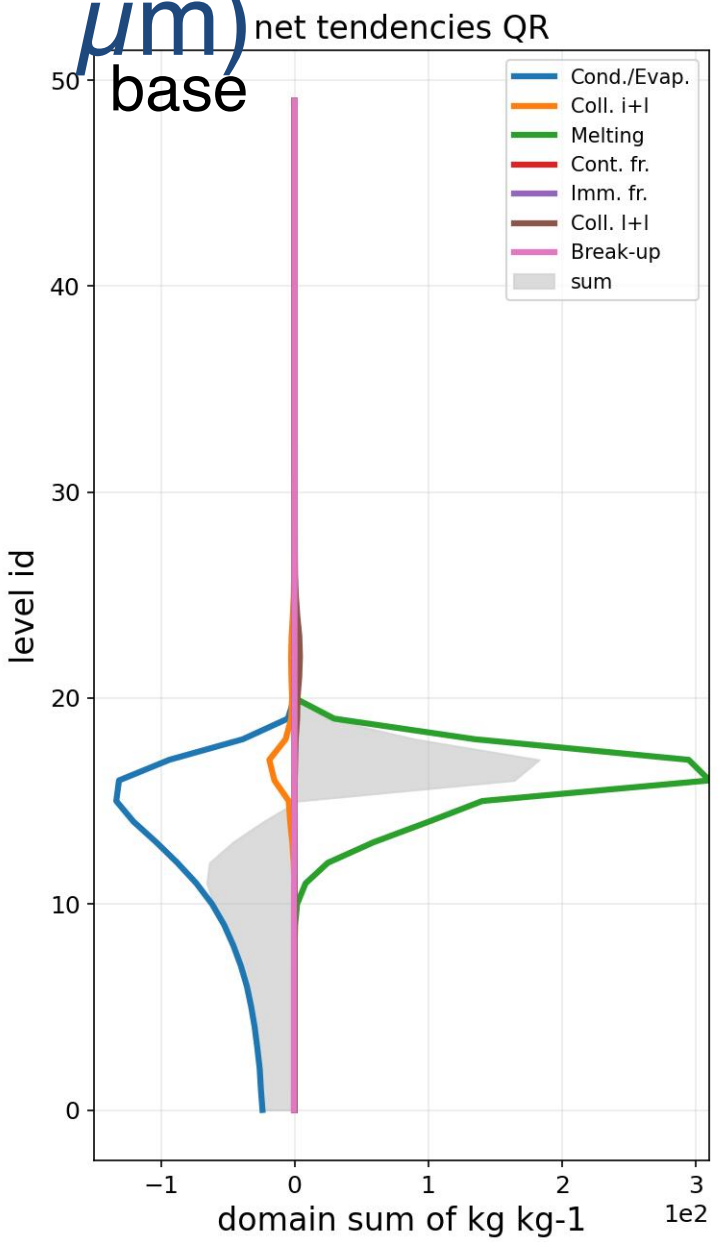
- Gamma functions from COSMO‘s 2
- Boundaries as used in COSMO
- Size distribution is discretized in SI
- Overlap for cloud ice and snow
- Bulk mass is maintained

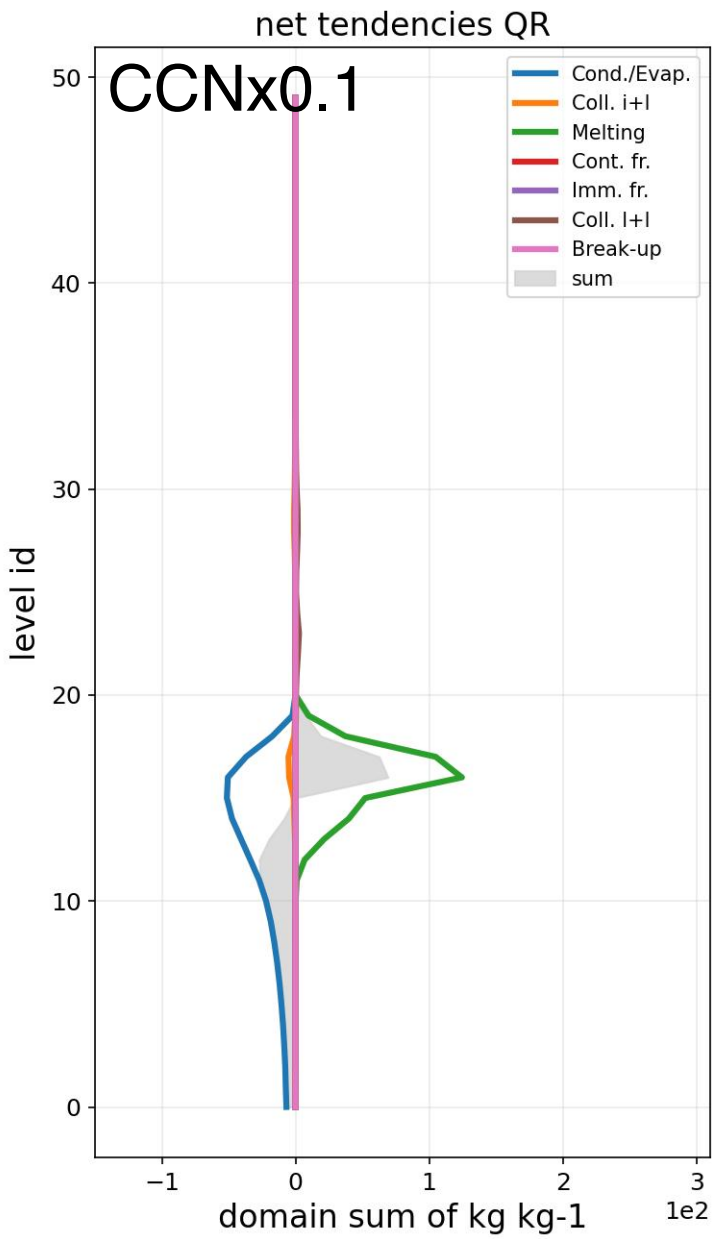


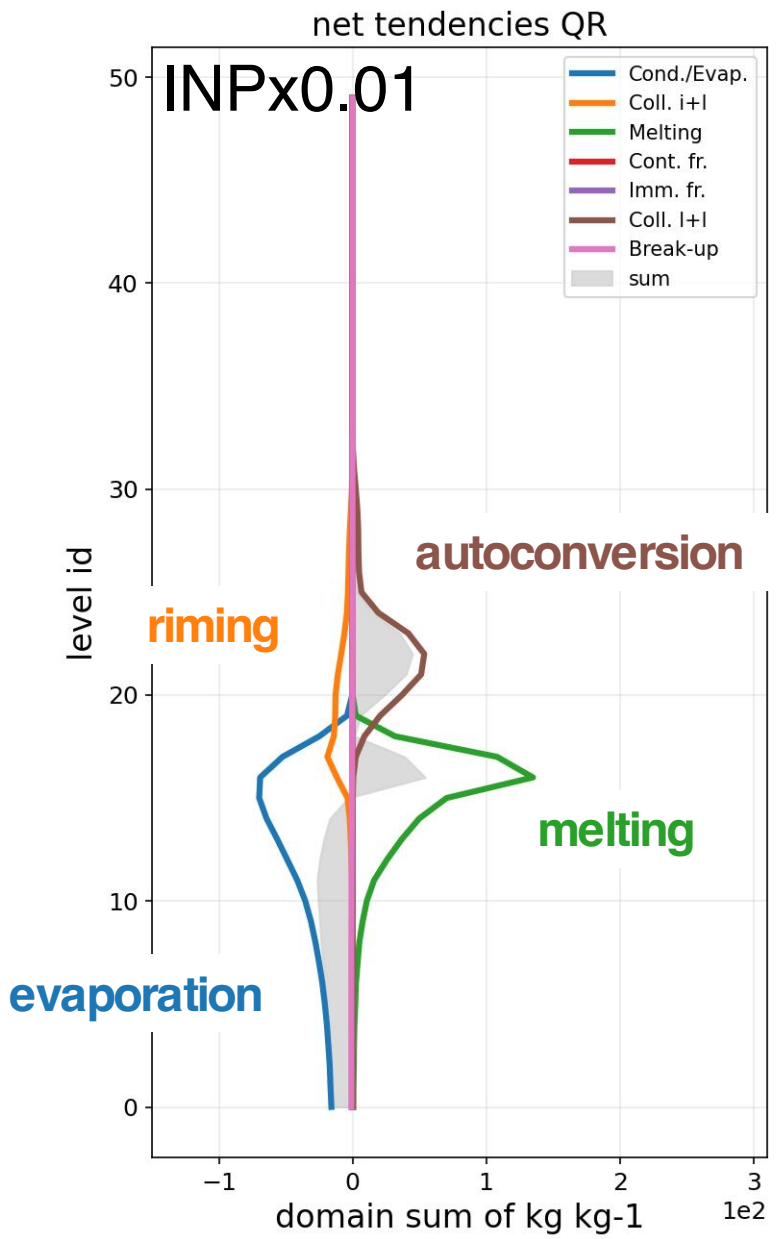
Fall speed


0
−2
−4
−6
−8
−10
−12
−14
fall speed [m s-1]
10^1
10^2
10^3
ice crystal radius (rmitte of bin) [µm]
spheres ar = 1.0
columns ar = 3.0
columns ar = 10.0
hexagonal plates ar = 0.3
hexagonal plates ar = 0.1
dendrites

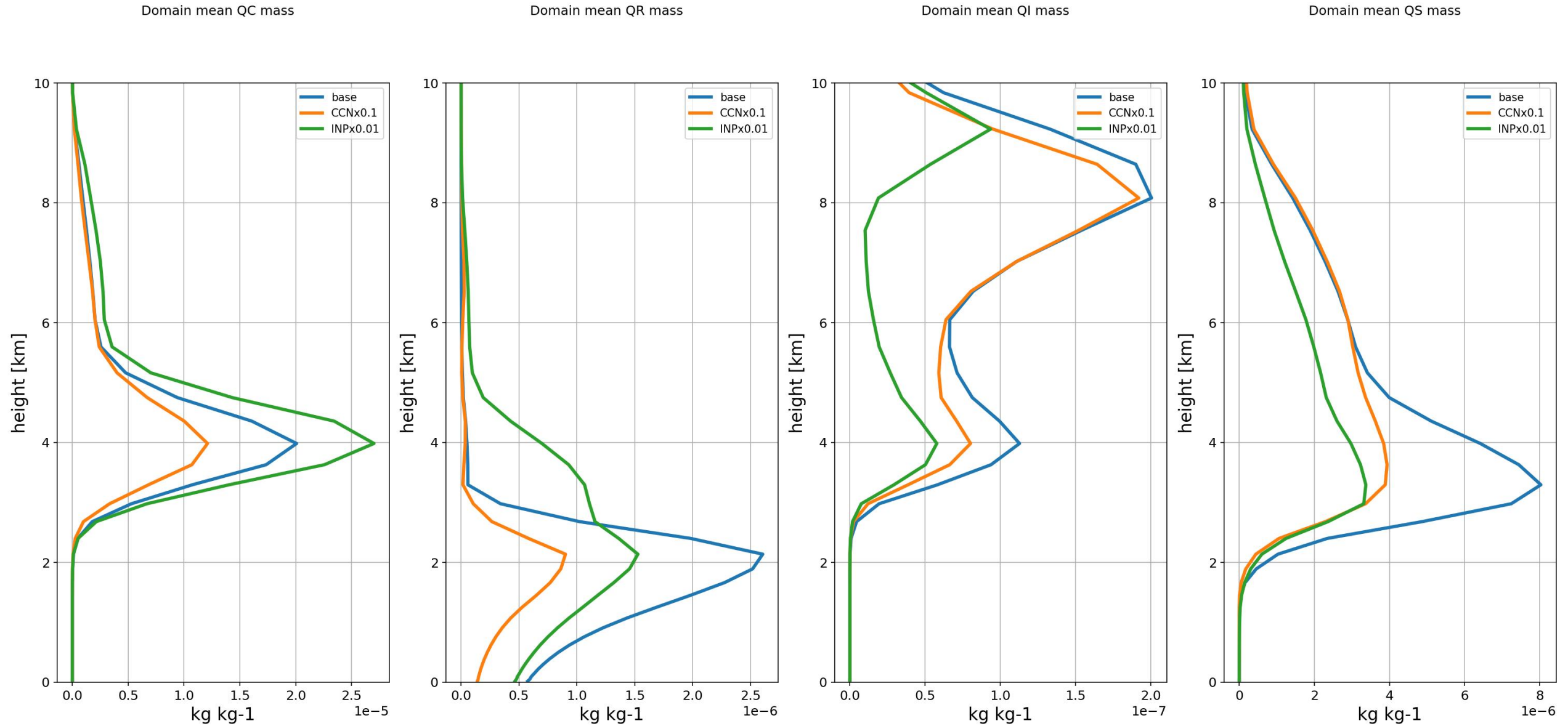
Full domain 6hr rain mass tendencies (> 100 μm)



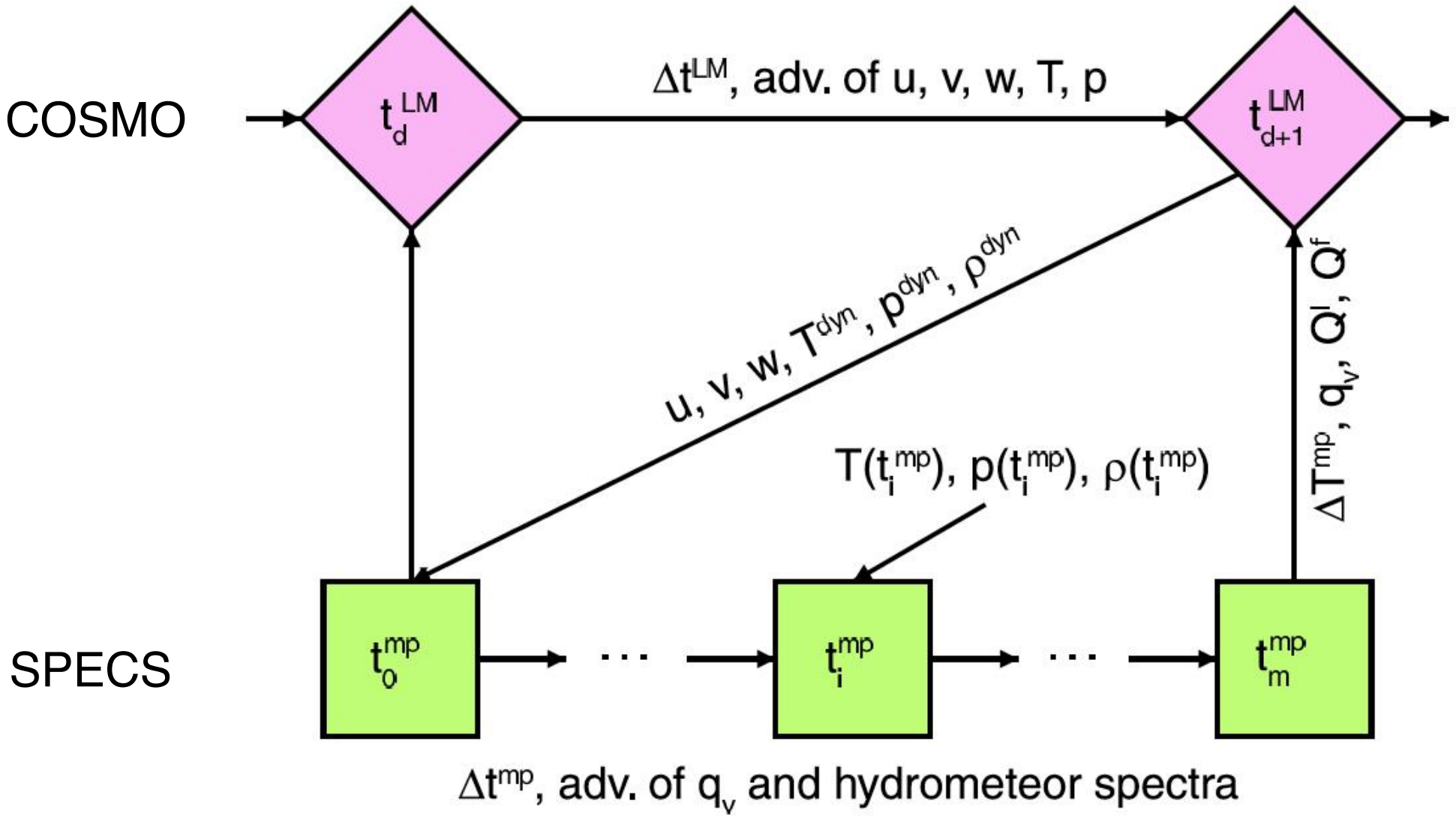




Sensitivity condensate mass



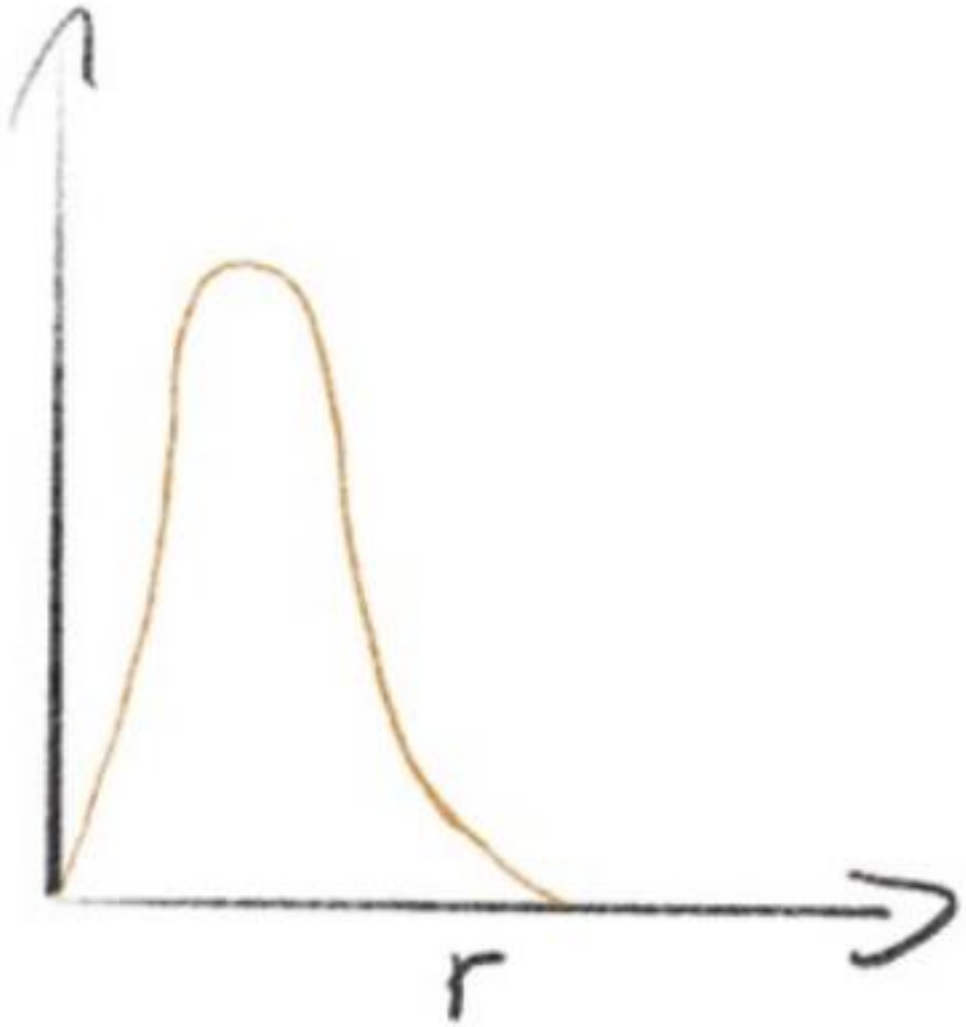
Coupling COSMO <-> SPECS



Grützun, 2009

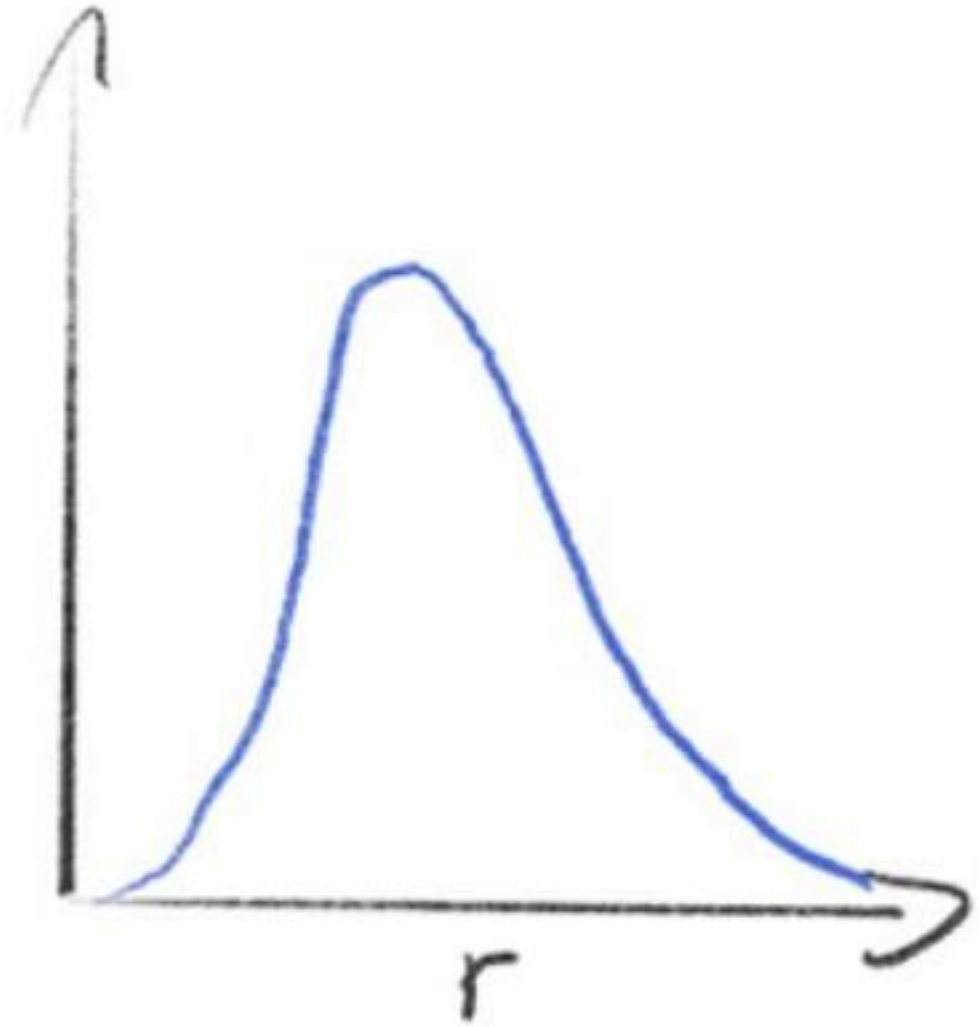
Initialization of the hydrometeors

Initial (assumed) aerosol distribution



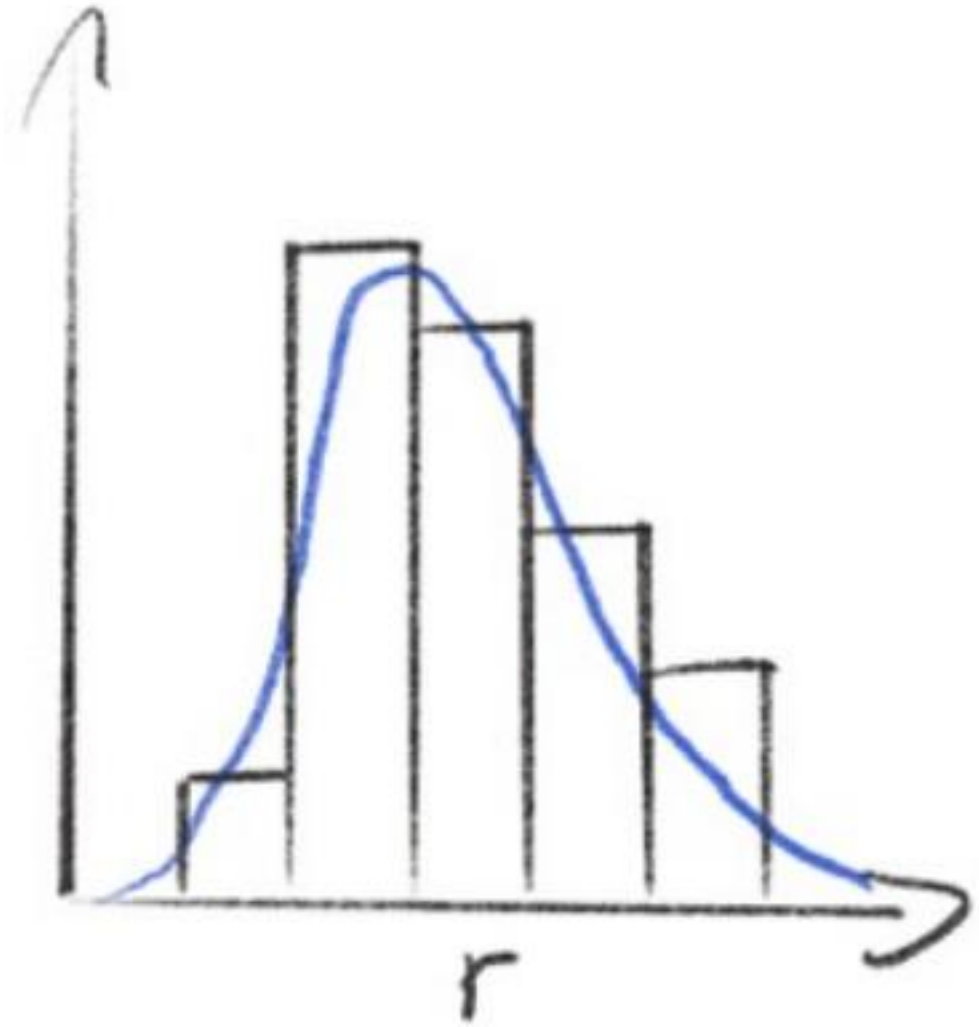
Initialization of the hydrometeors

Add water until equilibrium with water vapor in the surrounding



Initialization of the hydrometeors

Discretize into given SPECS bins (66 at present ~1 nm – 4 mm)



Initialization of the hydrometeors

Add already existing COSMO cloud and ice water