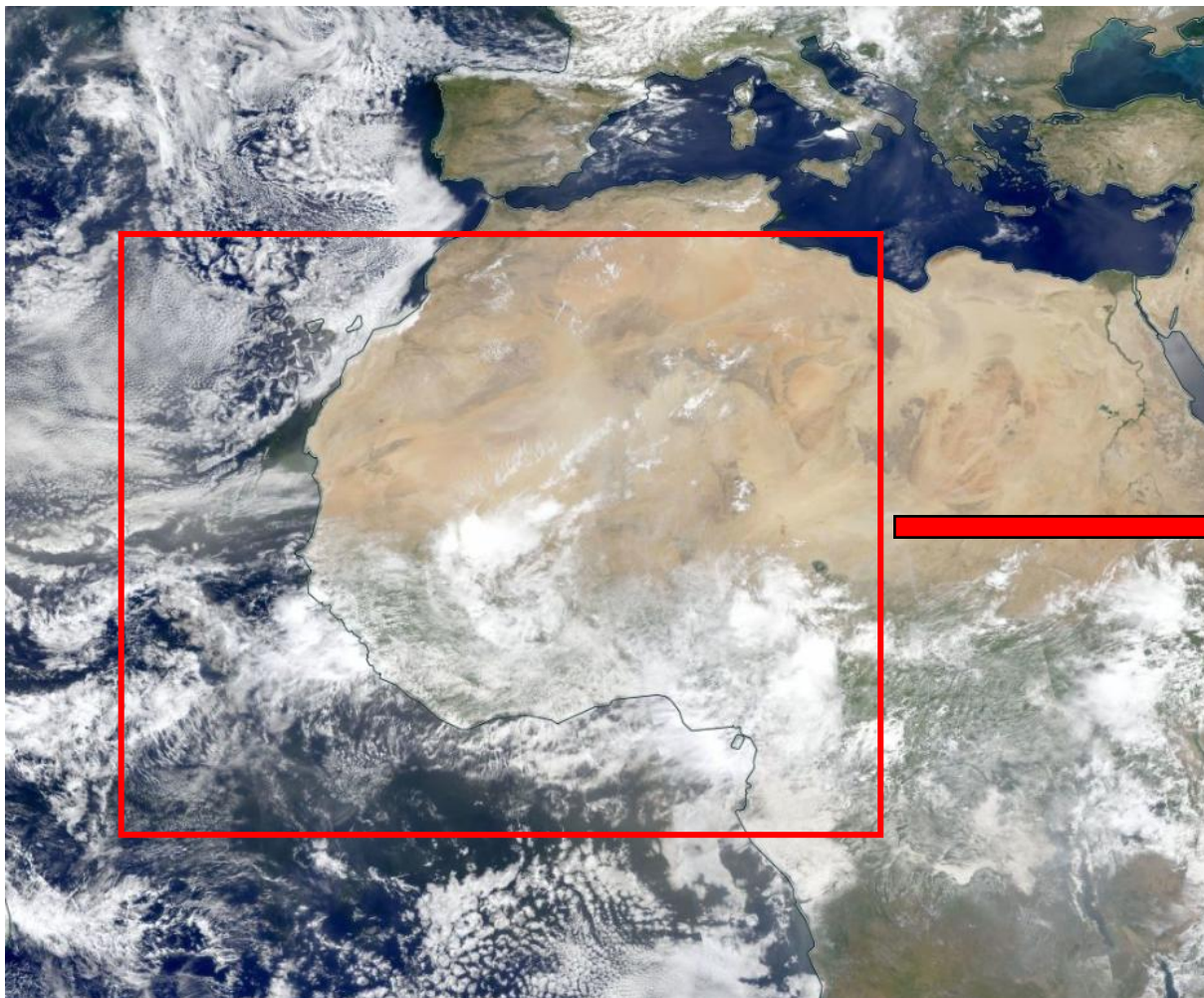


# Impact of cloud overlap on cloud formation and lifetime through radiative coupling

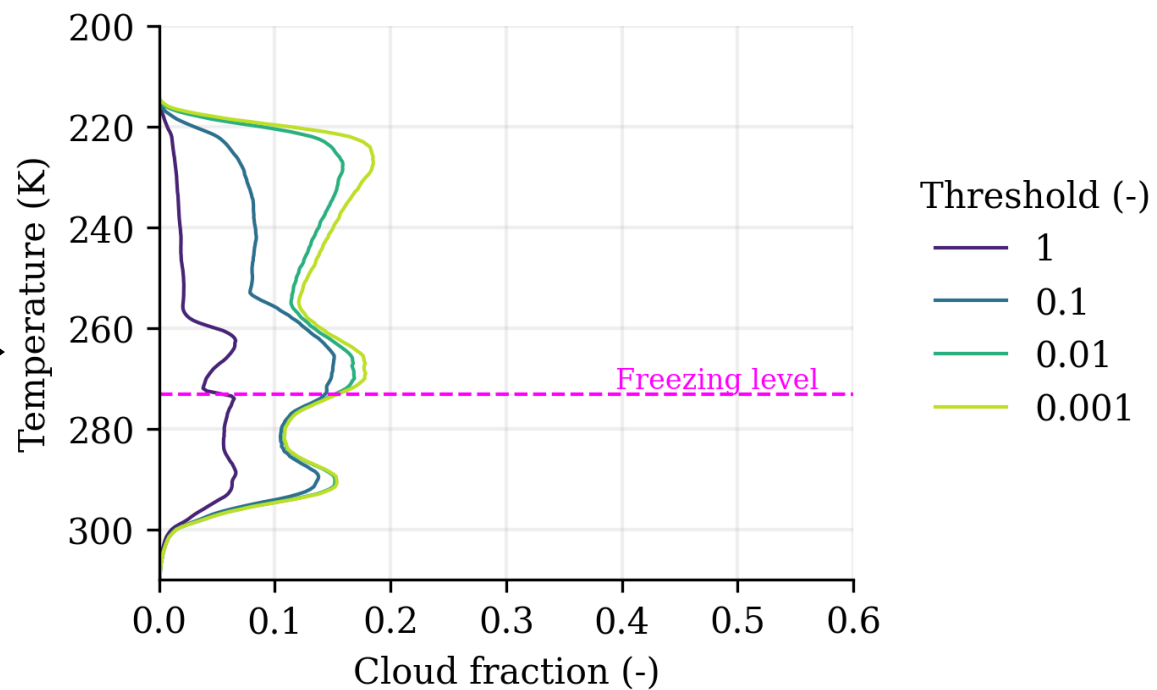
**Wouter Mol**, Blaž Gasparini, and Aiko Voigt  
University of Vienna | Department of Meteorology

EGU 2026 | AS1.10

# Regional hotspots of tri-modal cloud climatology



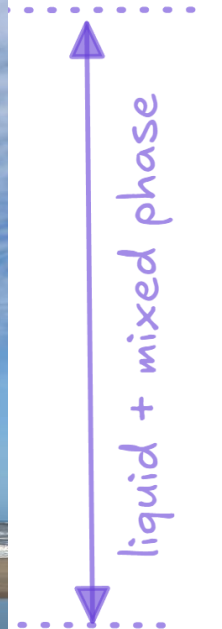
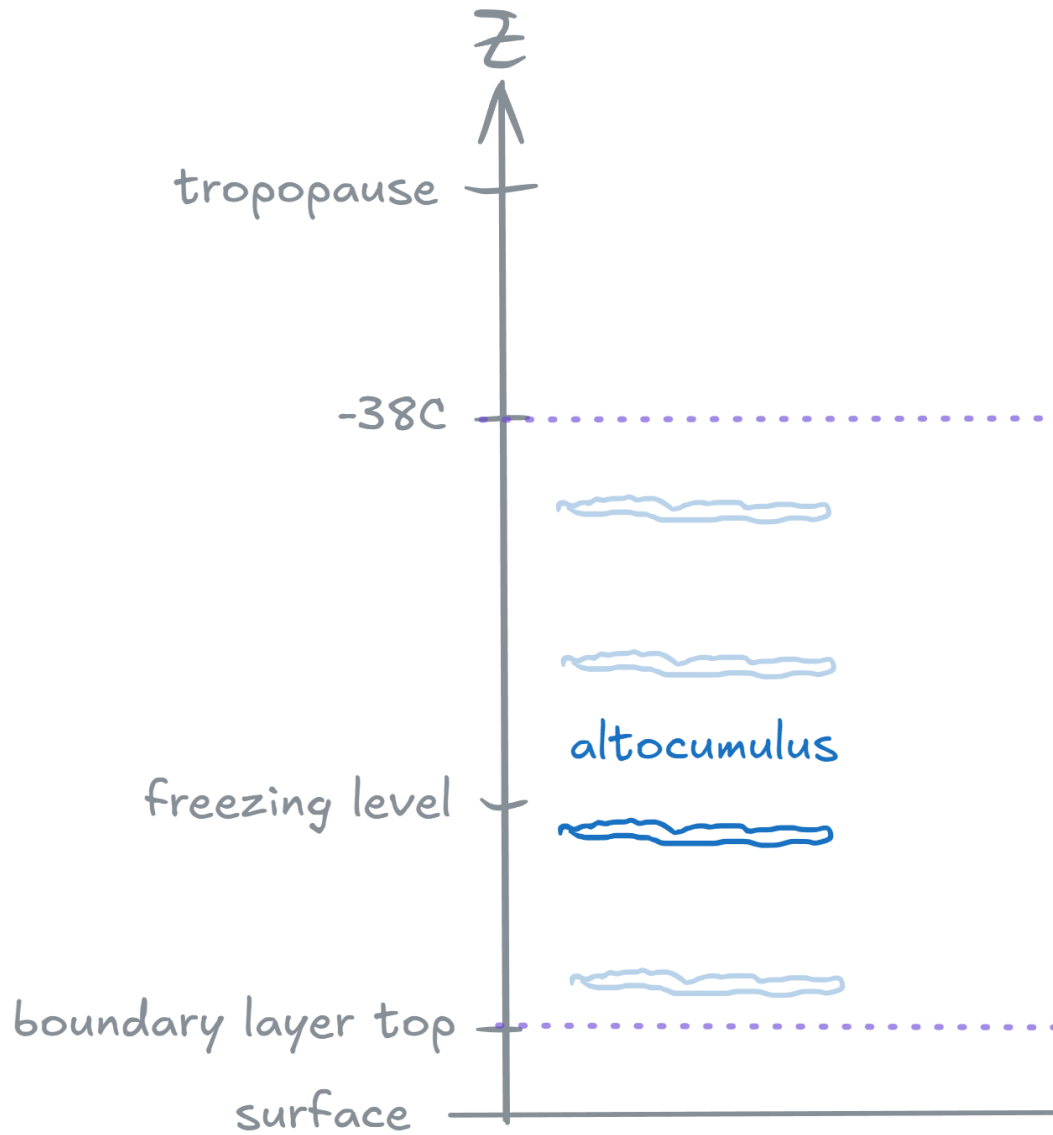
NASA WorldView



CloudSat-CALIPSO JJA 2010 cloud fraction based on optical depth

See also:  
Zhang et al. 2010  
Riihimaki et al. 2012  
Bourgeois et al. 2018

# Mid level clouds in the (tropical) atmosphere

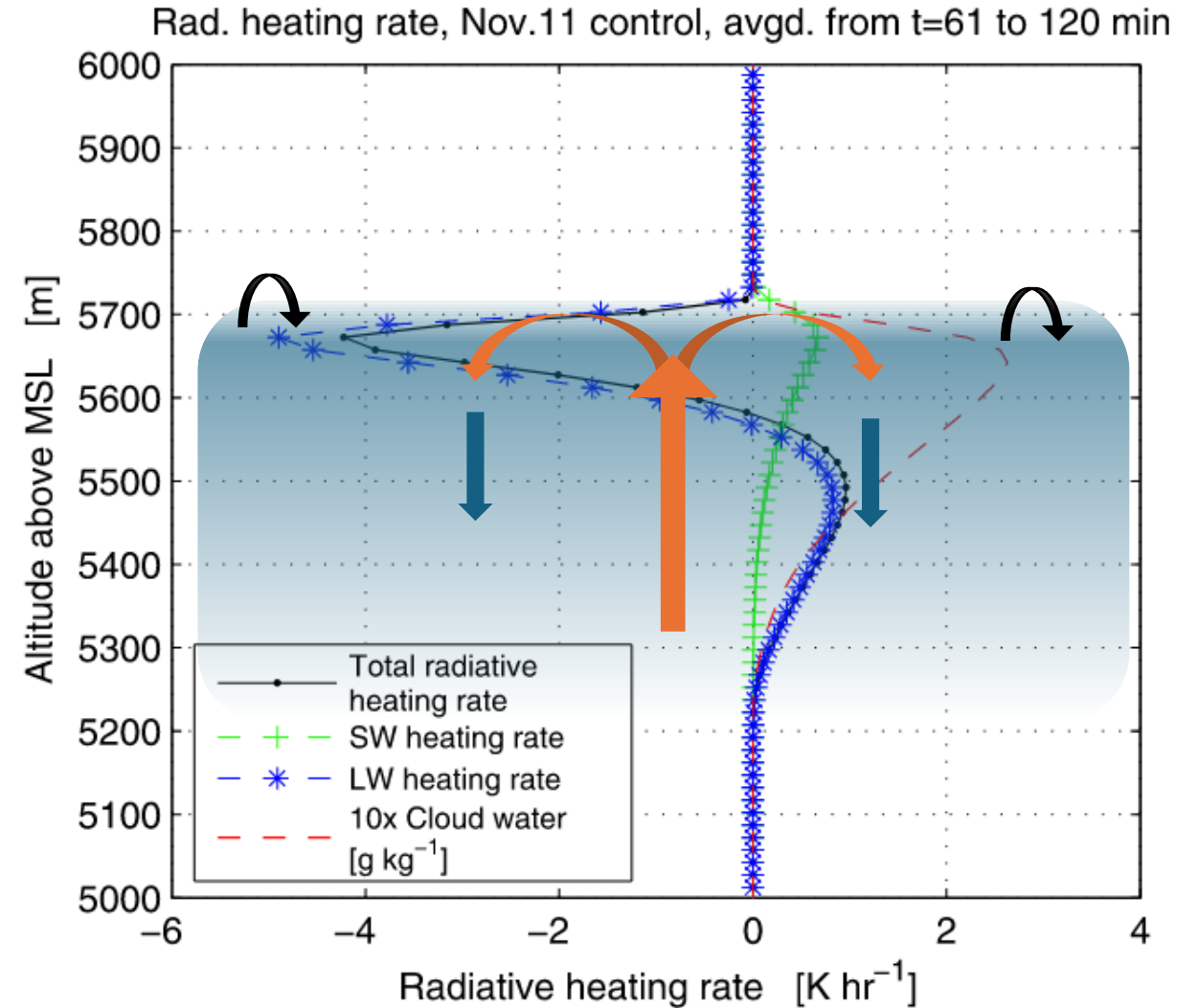


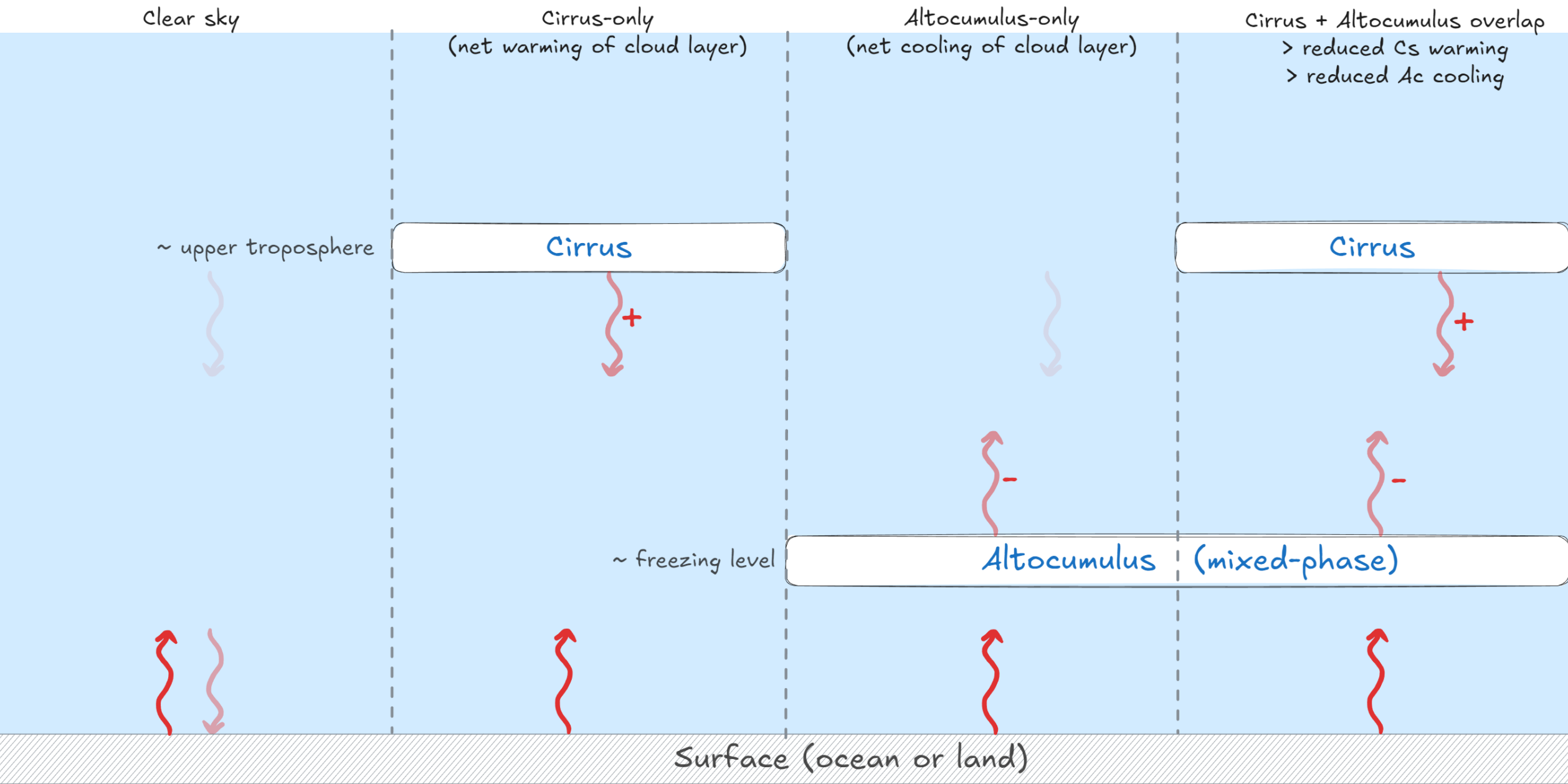
# Altostratus persists due to strong top cooling in liquid layer

## What makes Ac dissipate:

1. Precipitation  
(removal of moisture)
2. Entrainment with dry air above  
(removal of moisture)
3. Large scale subsidence  
(adiabatic heating)
4. **Radiative heating**  
(diabatic heating)

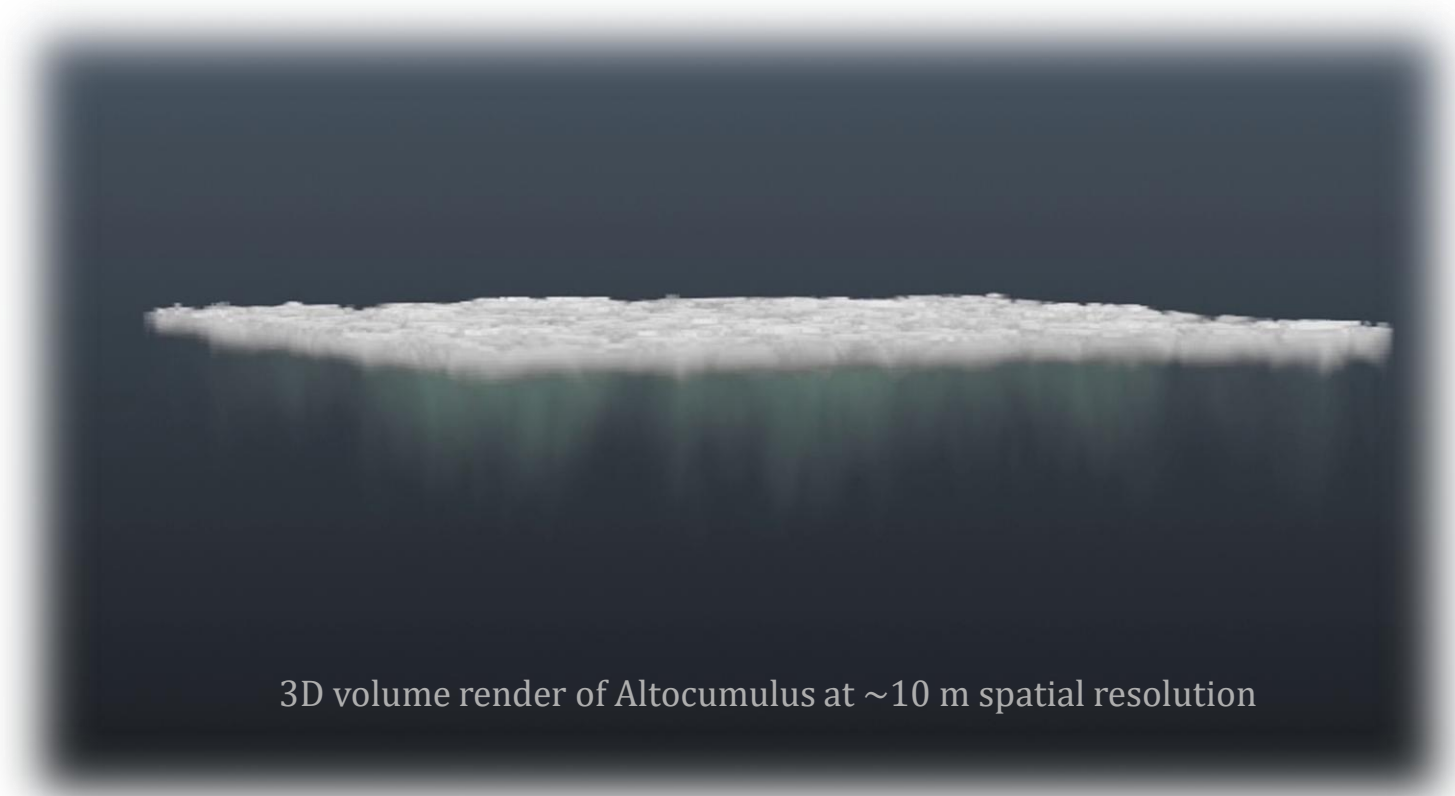
(Larson et al., 2006, JGR Atmospheres)



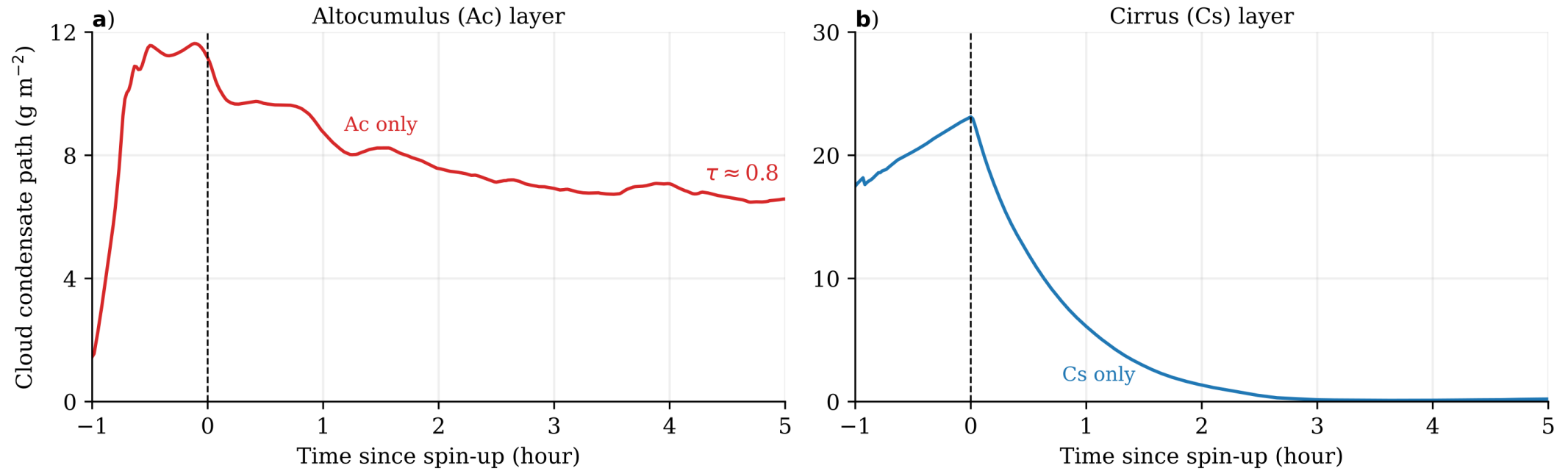


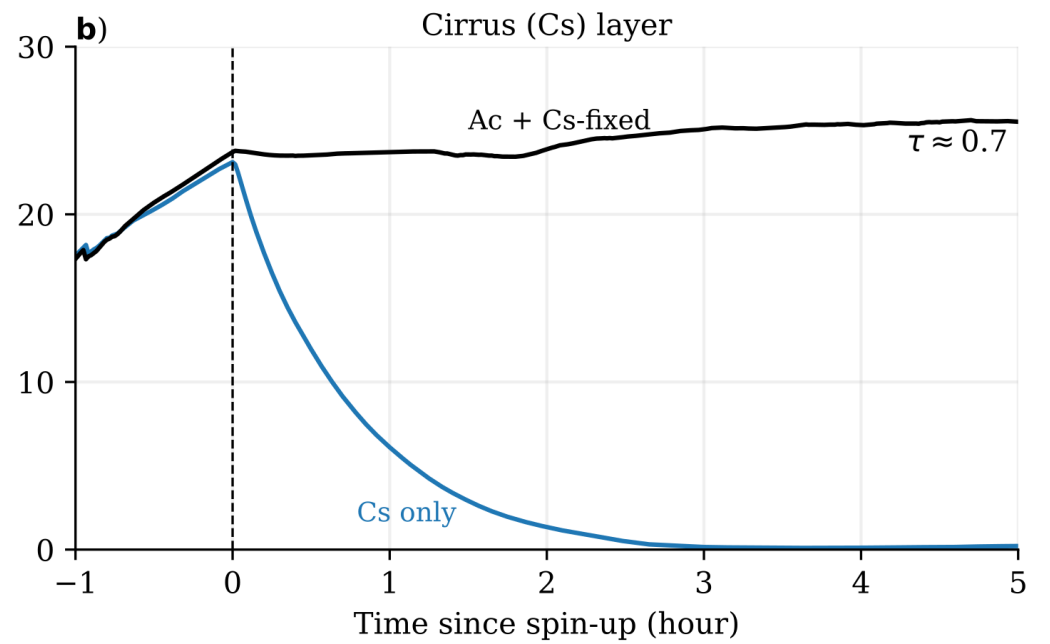
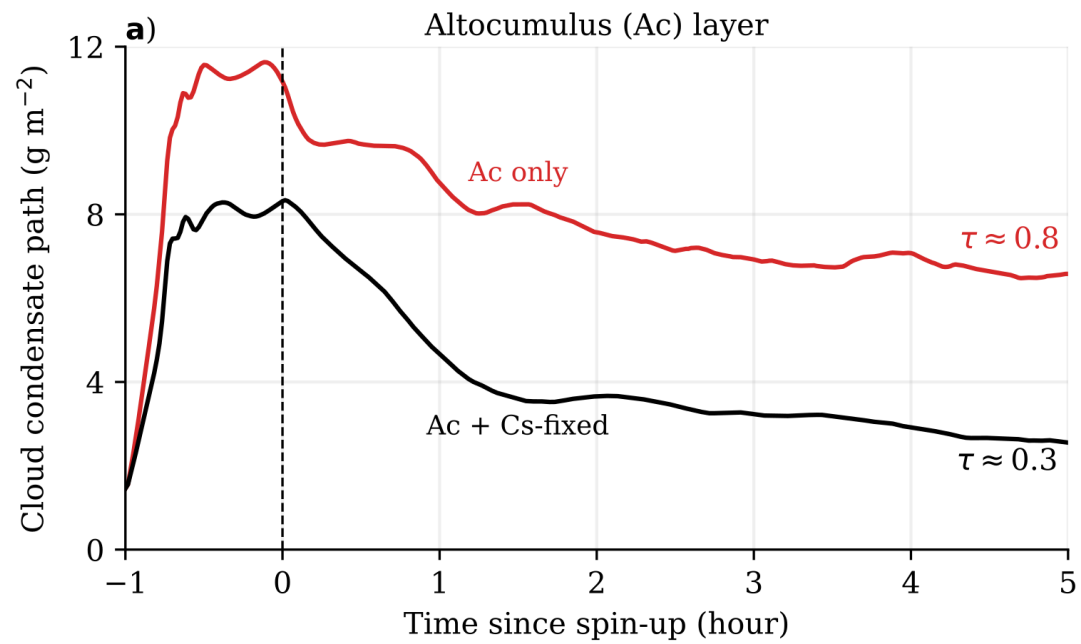
# Experiment setup

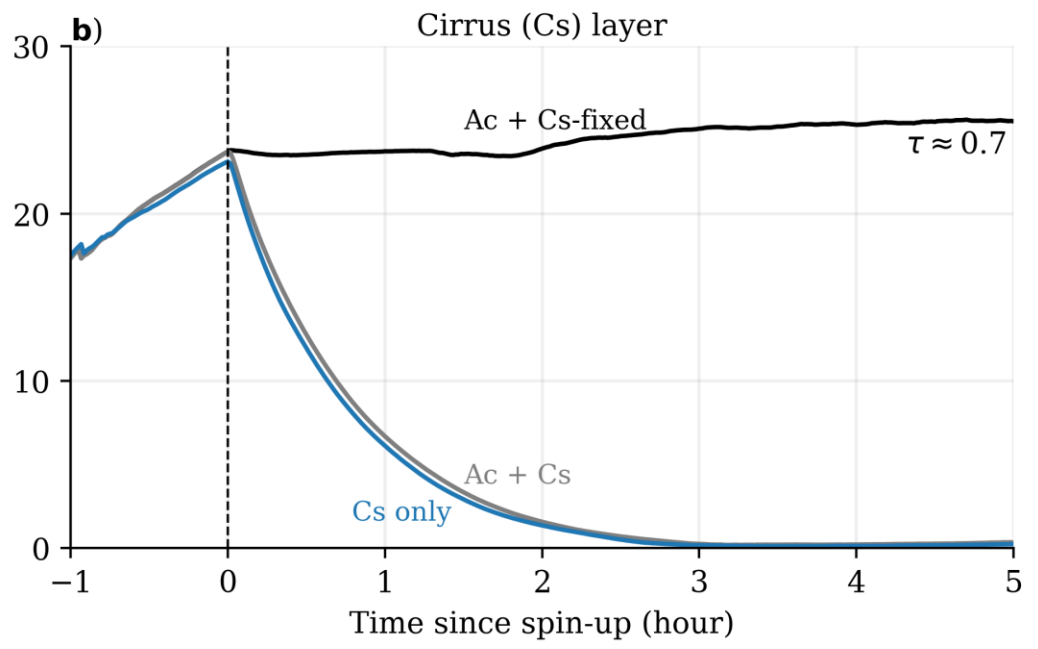
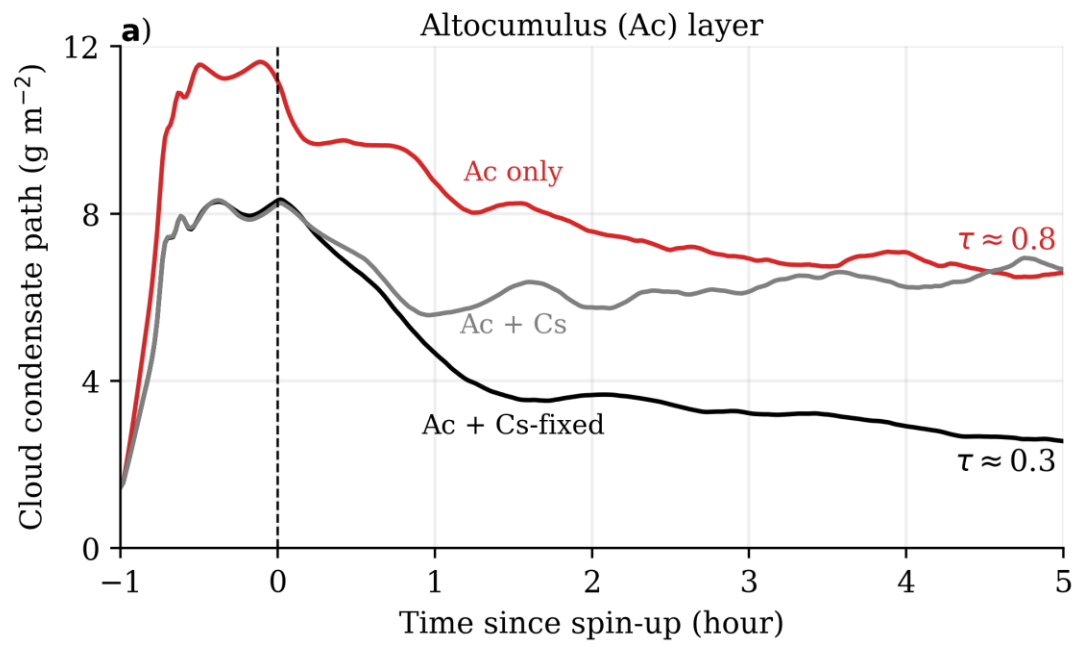
- Large-eddy simulation in GPU mode (<https://microhh.org/>)
- 50 x 50 x 40 m resolution (minimum required)
- 6.4 x 6.4 x 15.2 km domain
  
- ERA5 Sahel mean profile with
  - Saturation in Ac/Cs layer @  $t = 0$  s
  - 1 hour of specific humidity tendency in Ac/Cs layer
  - Layers based on CloudSat climatology
- Interactive radiation (RRTMGp)
  - Fixed solar noon or midnight only
- NSW6 microphysics
  - $q_l/q_i$  diagnostic, single-moment
  
- No wind shear or subsidence
- Doubly periodic lateral boundaries
- Fixed surface temperature



# Results (night only)







# What it means, and next steps

## Our interpretation of results:

Alto cumululi are likely misrepresented in climate models, but closely linked to convective activity.

- If (anvil) cirrus changes with warming, alto cumulus can compensate
- Tropospheric cloud-radiative heating affected, impacts circulation and convective mass detrainment

See also:

Sokol and Hartmann, 2022

Seeley et al., 2019

## What is next:

- Include circulation feedback in our experiments
- Spin-up through convective cycle
- Better represent cirrus microphysics(?)

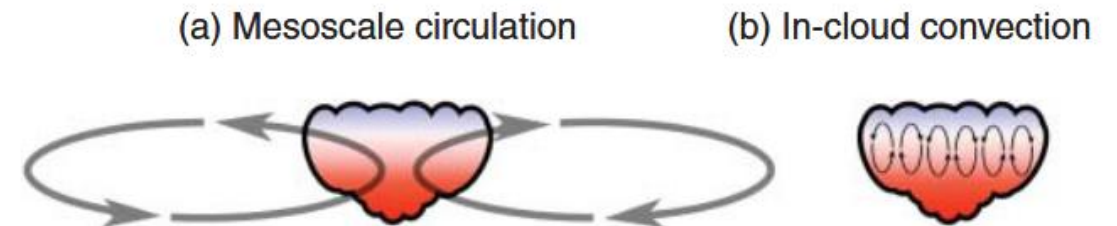
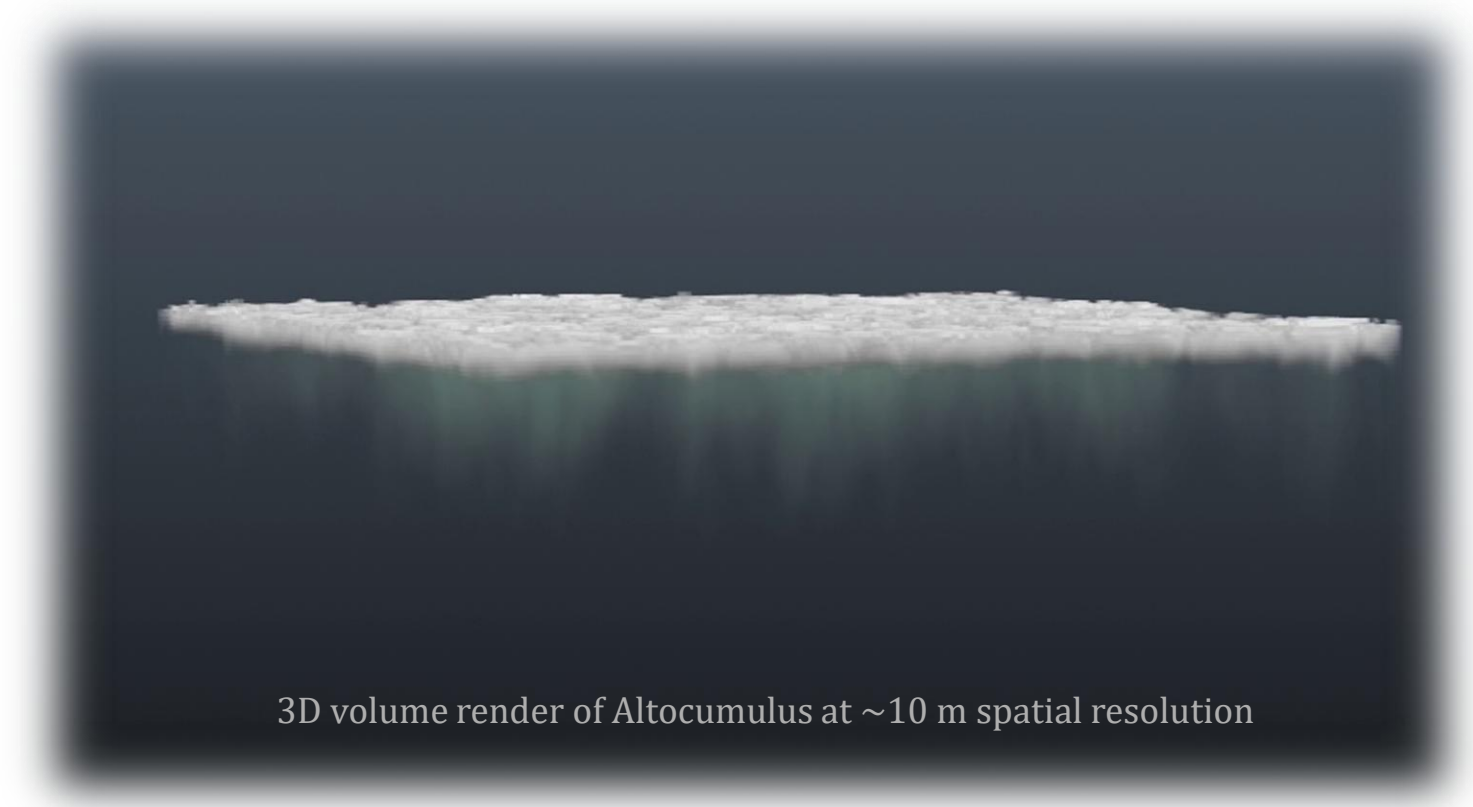


Fig 11.7 from Sullivan and Gasparini, 2024

## In summary

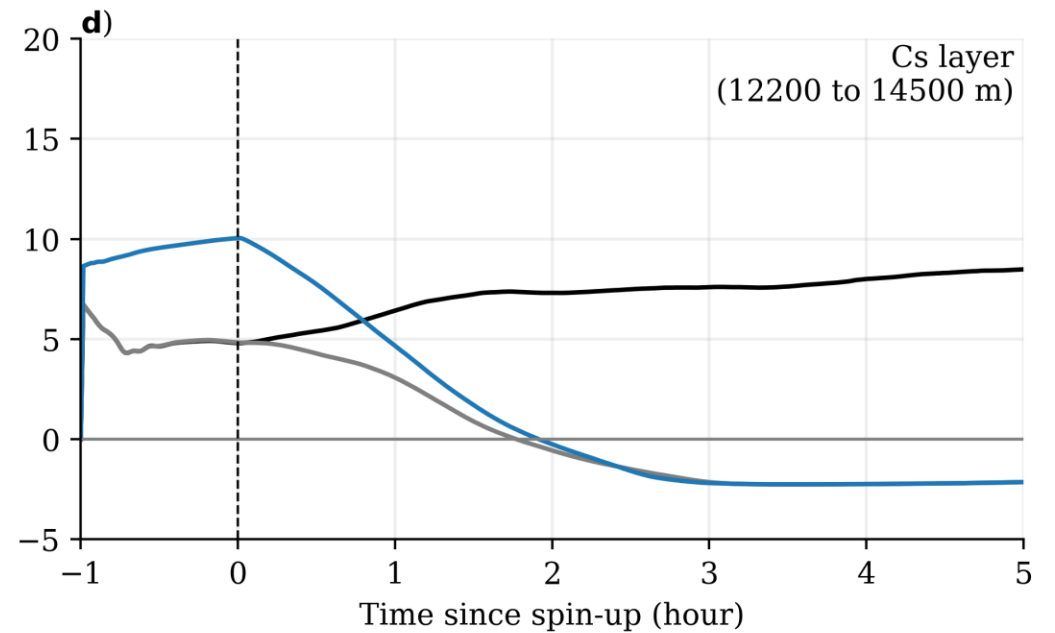
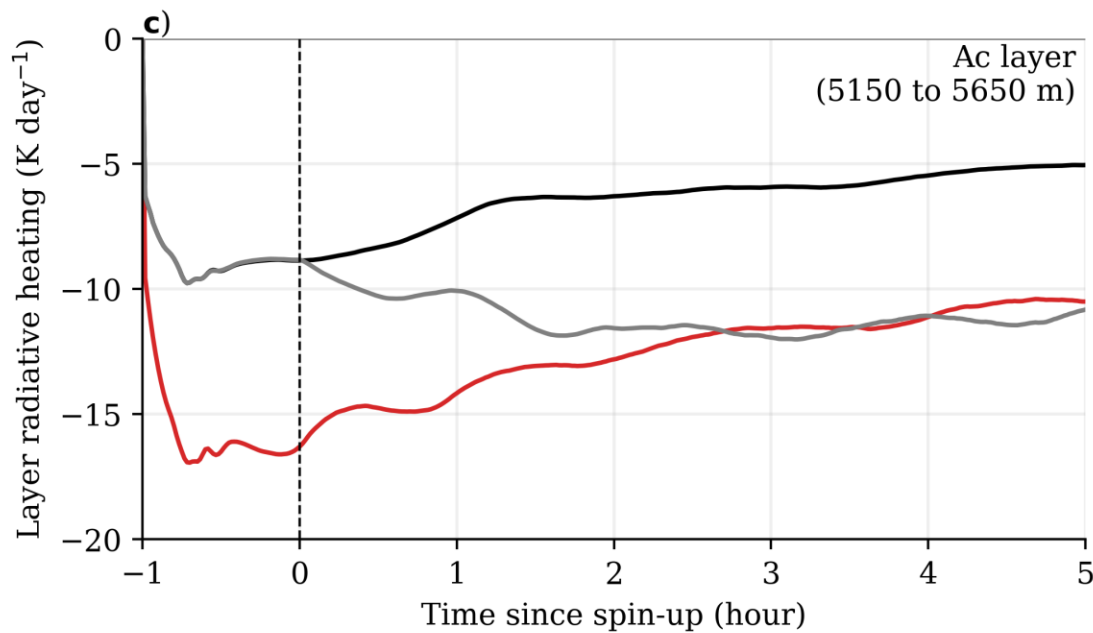
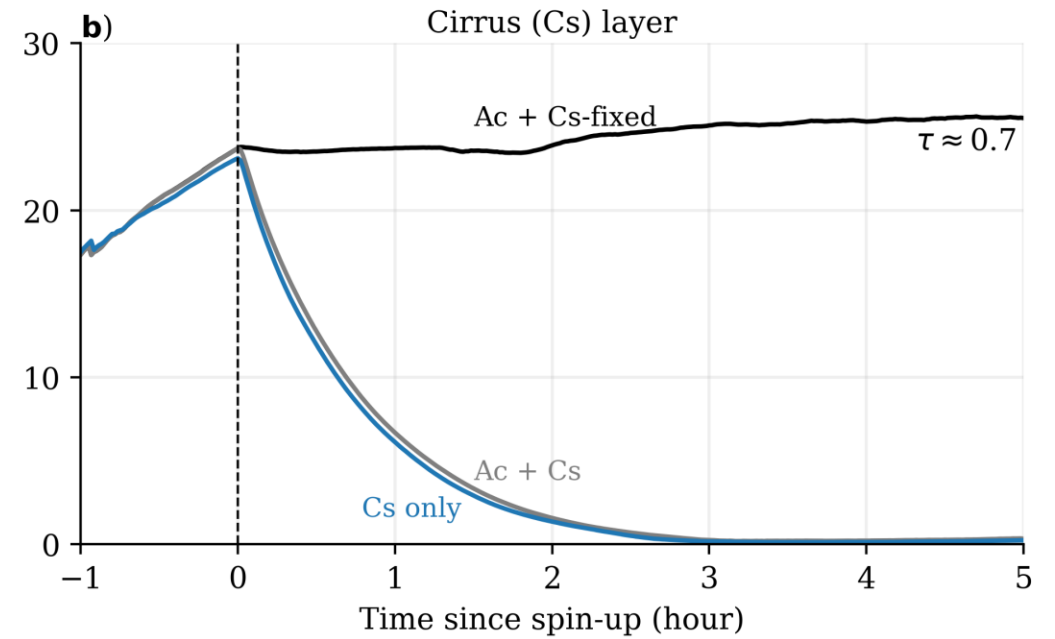
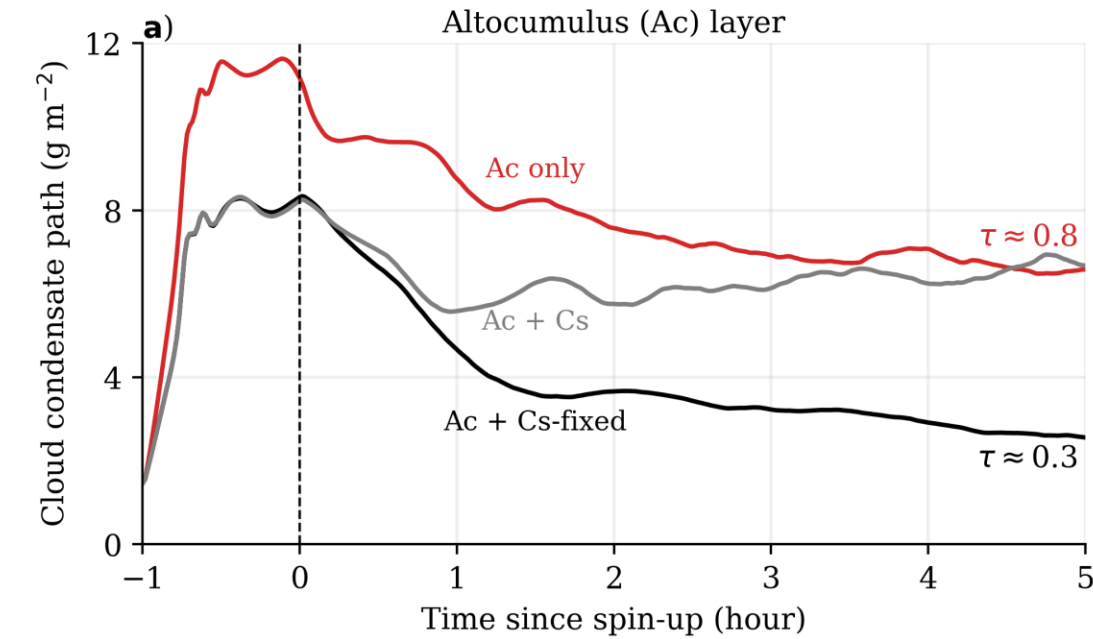
- Mid level clouds, whether stratiform or convective, are common globally – in particular near convection
- Stratiform mid level clouds are shallow, fragile, and difficult to simulate
- Mid level clouds intensify in the absence of cirrus, but cirrus is unaffected\*

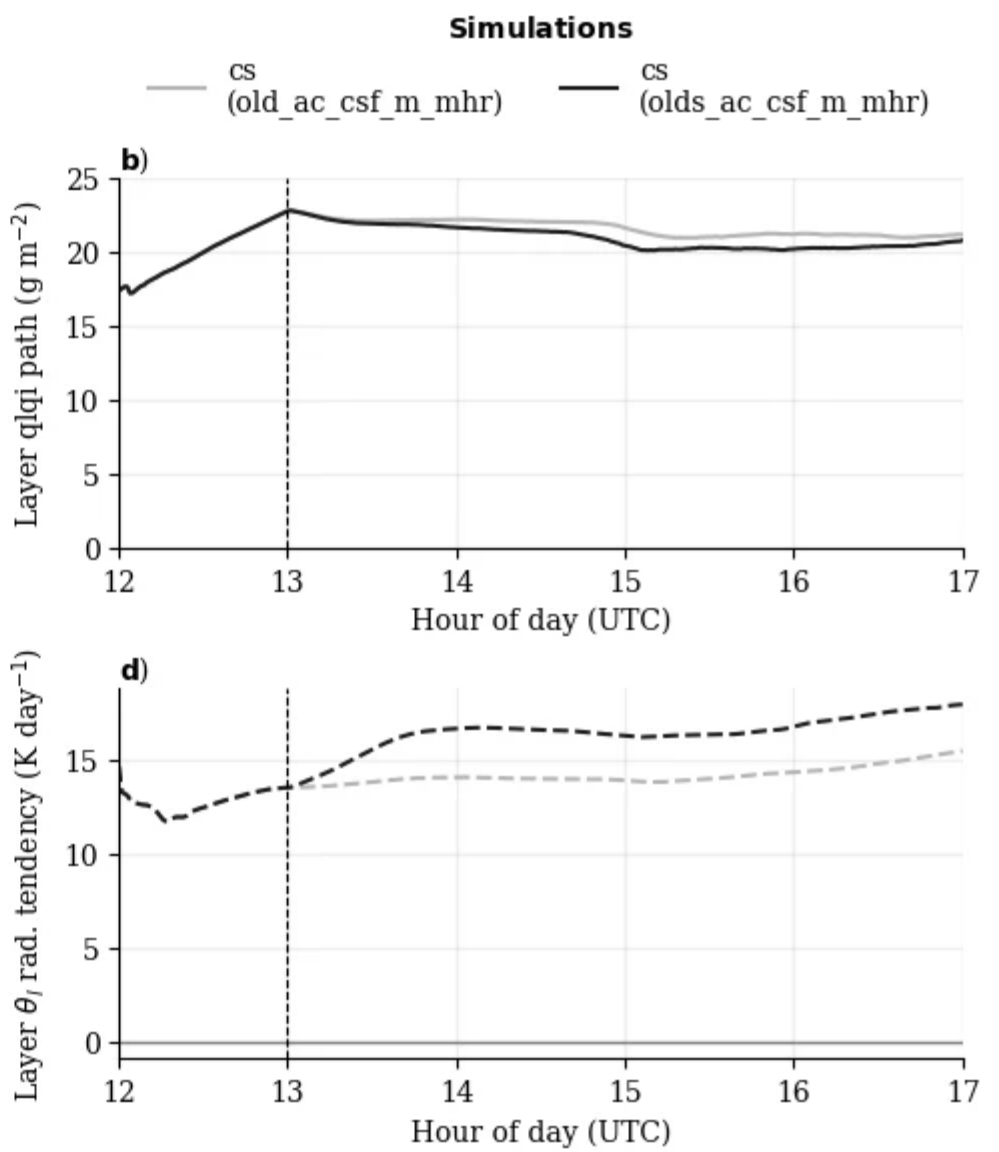
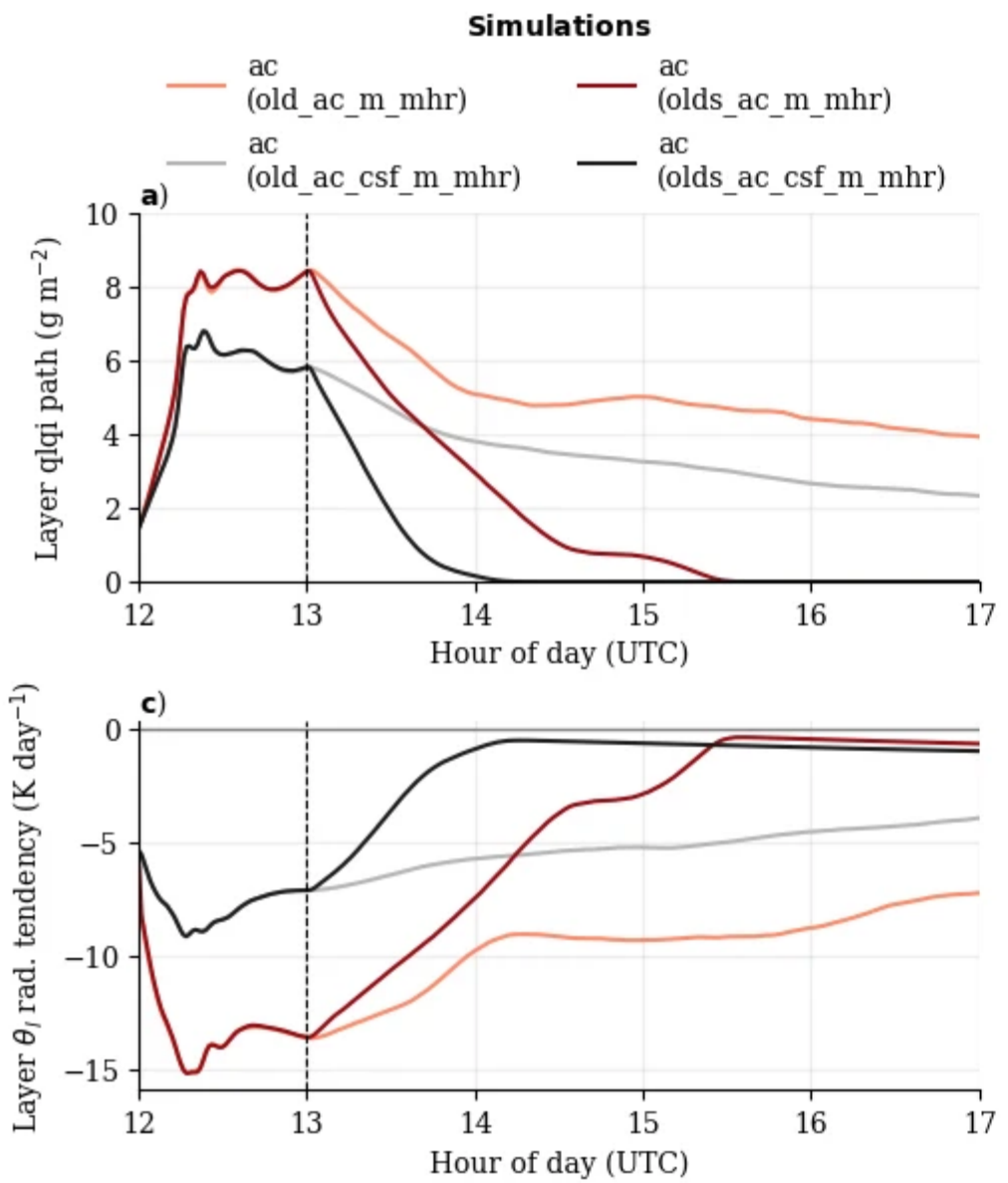
\*) in simulations that do not allow for circulation changes



3D volume render of Altocumulus at ~10 m spatial resolution

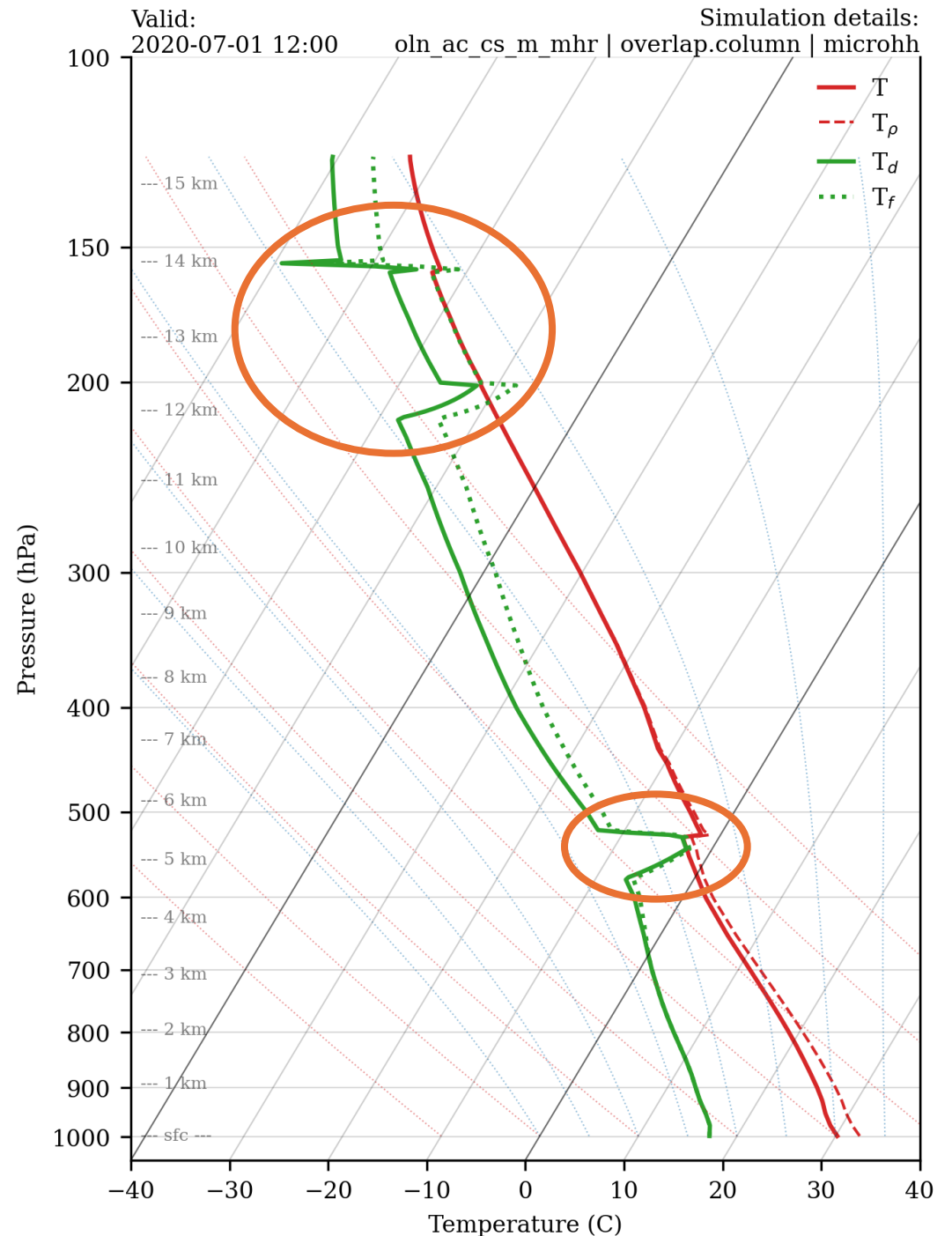
Bonus slides



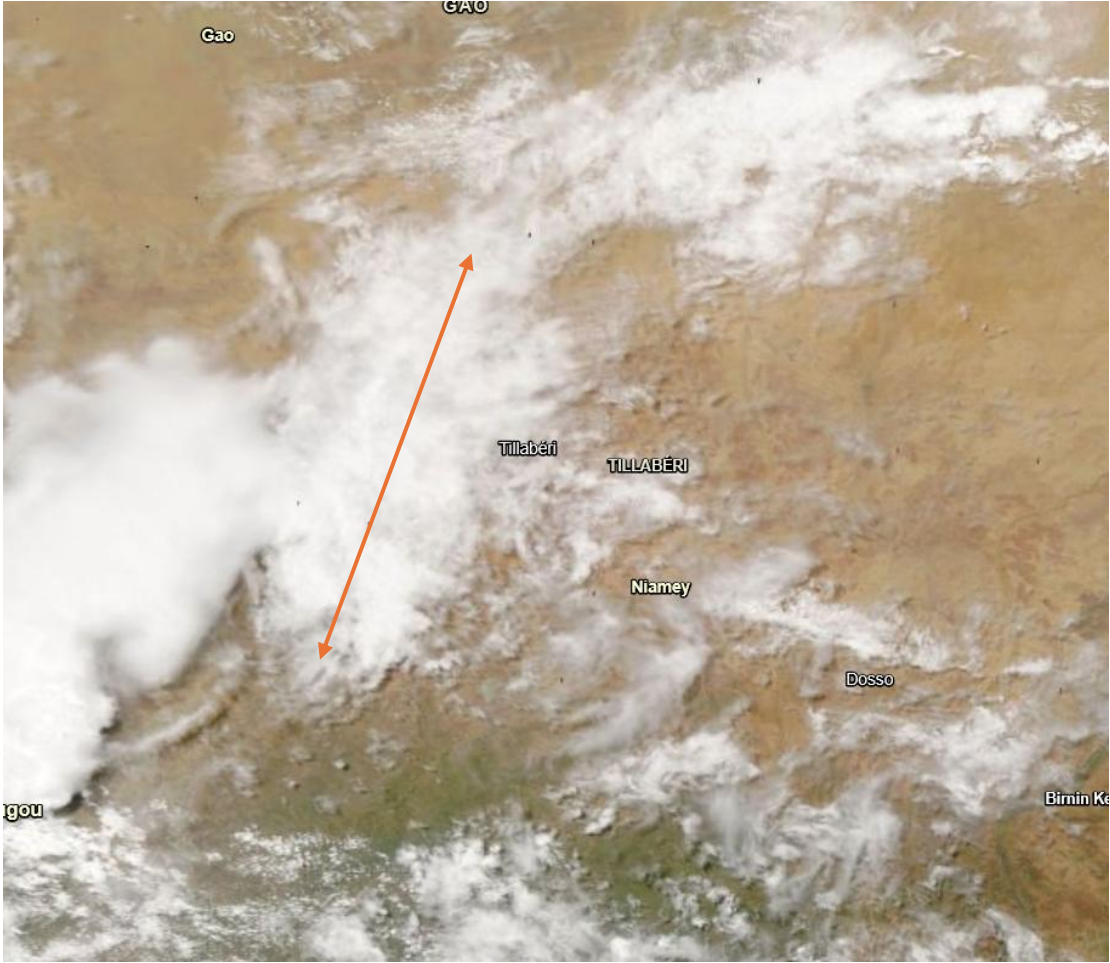
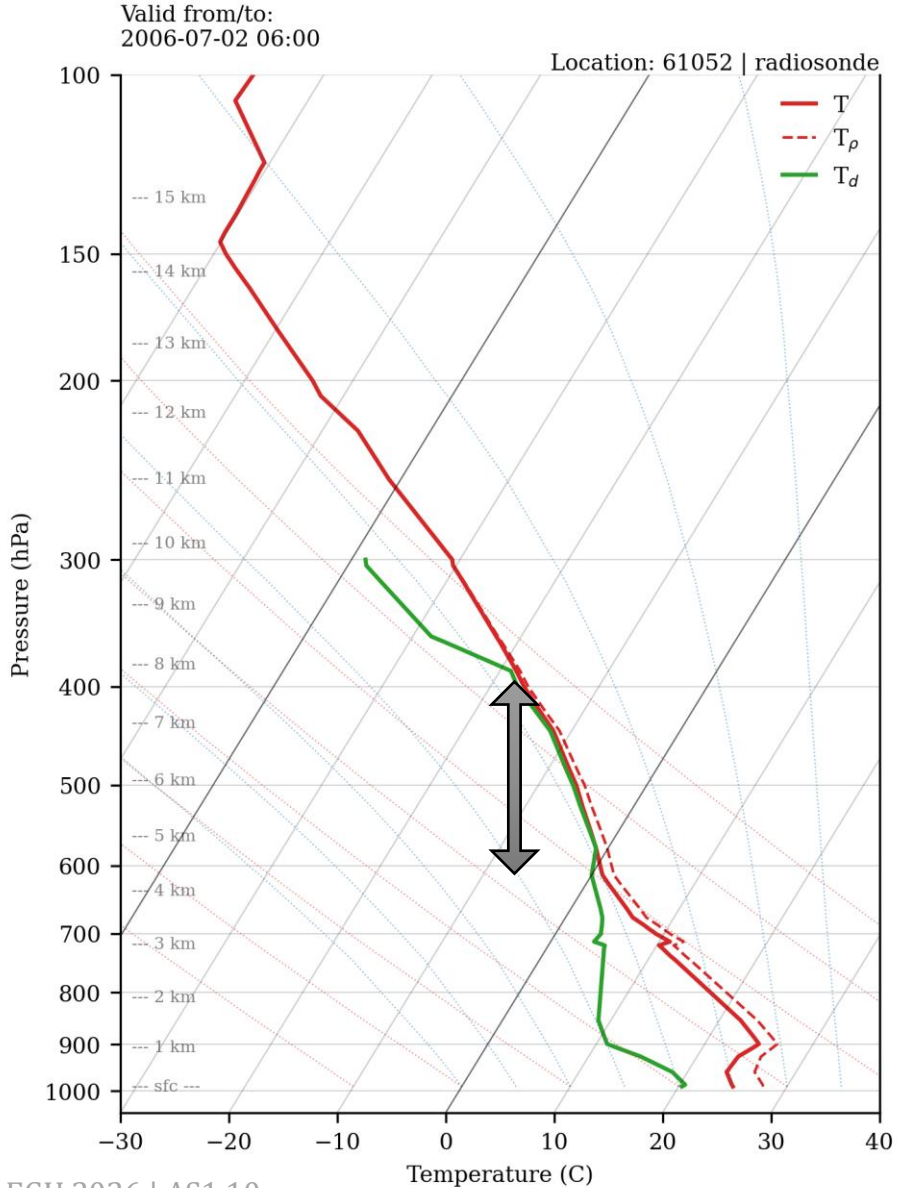


# Experiment setup

- Large-eddy simulation in GPU mode (<https://microhh.org/>)
- 50 x 50 x 40 m resolution (minimum required)
- 6.4 x 6.4 x 15.2 km domain
- ERA5 Sahel mean profile with
  - Saturation in Ac/Cs layer @ t = 0 s
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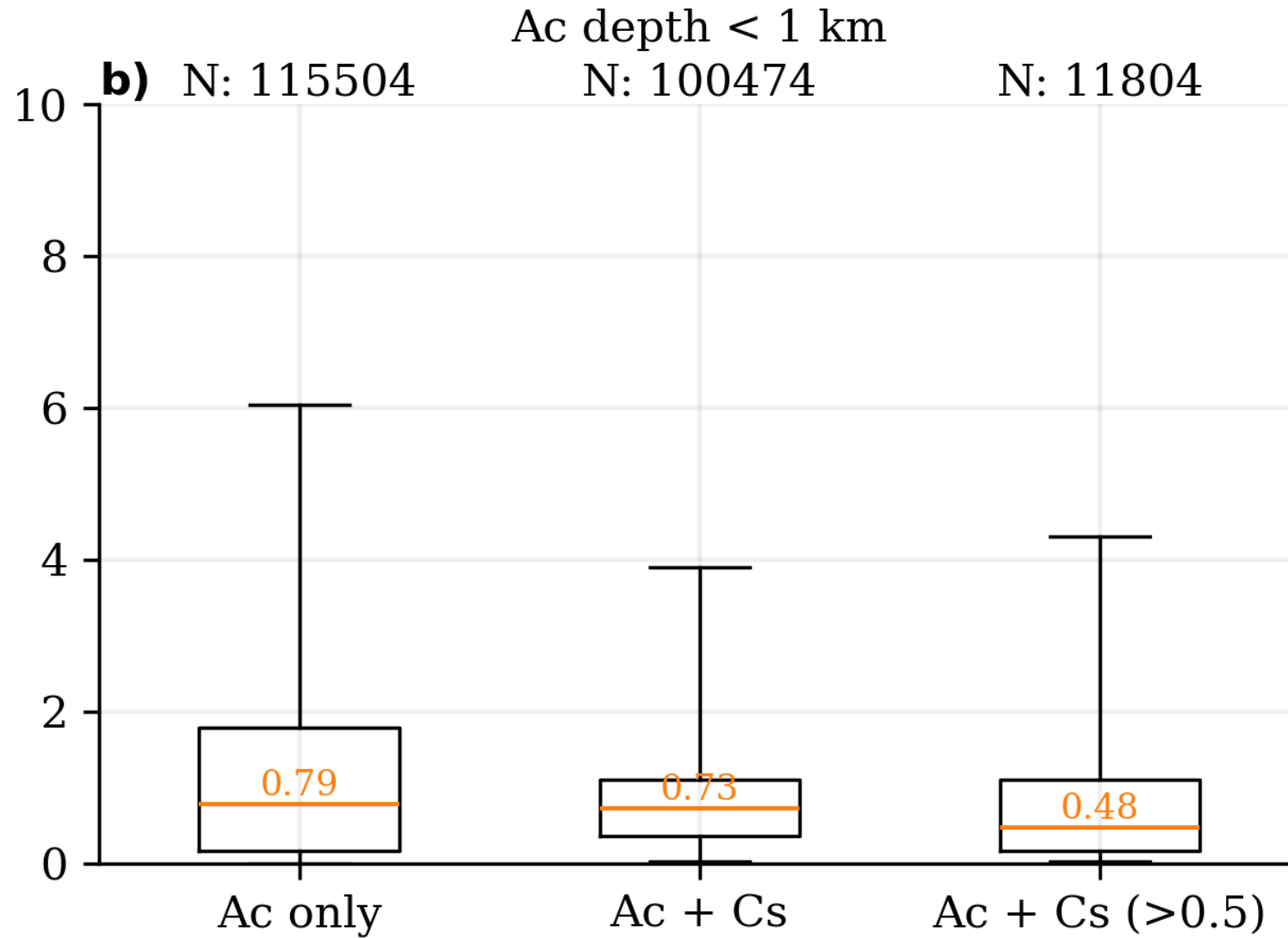


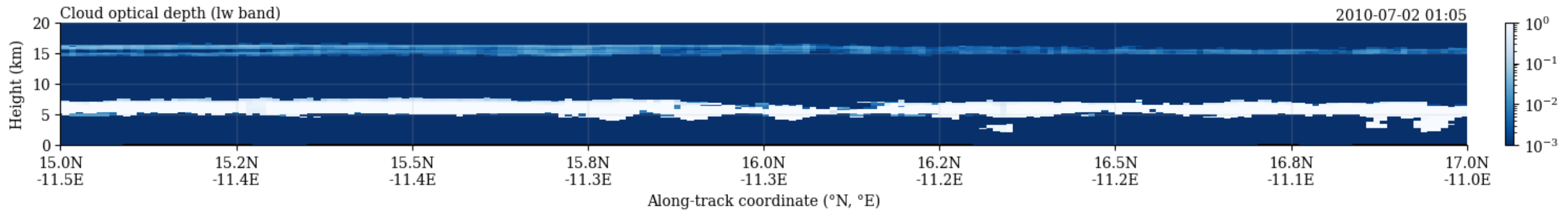
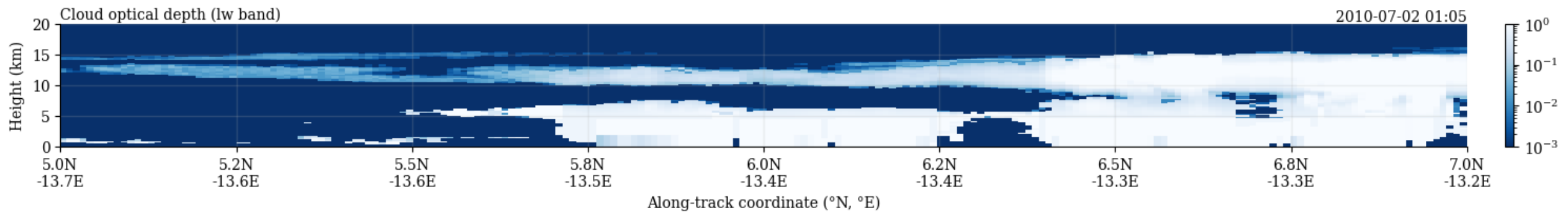
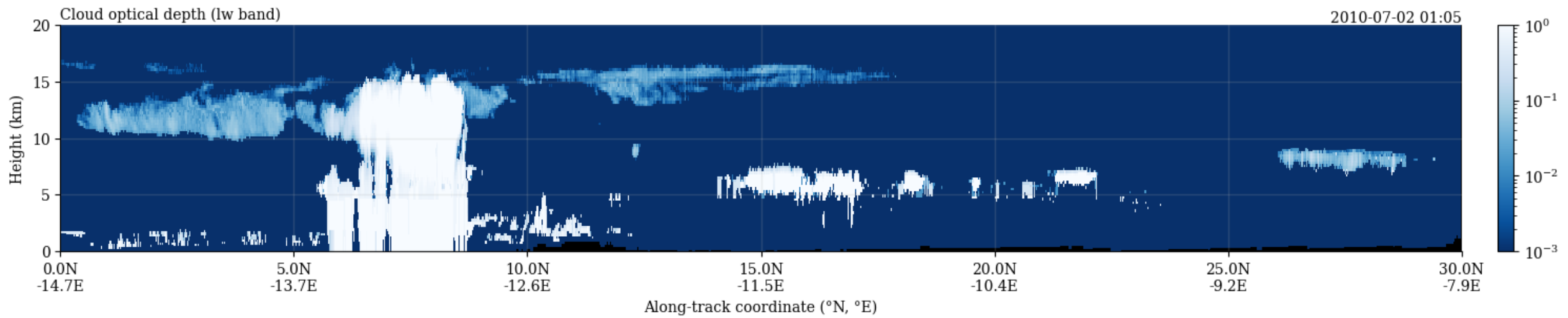
# Elevated convection needs large domain



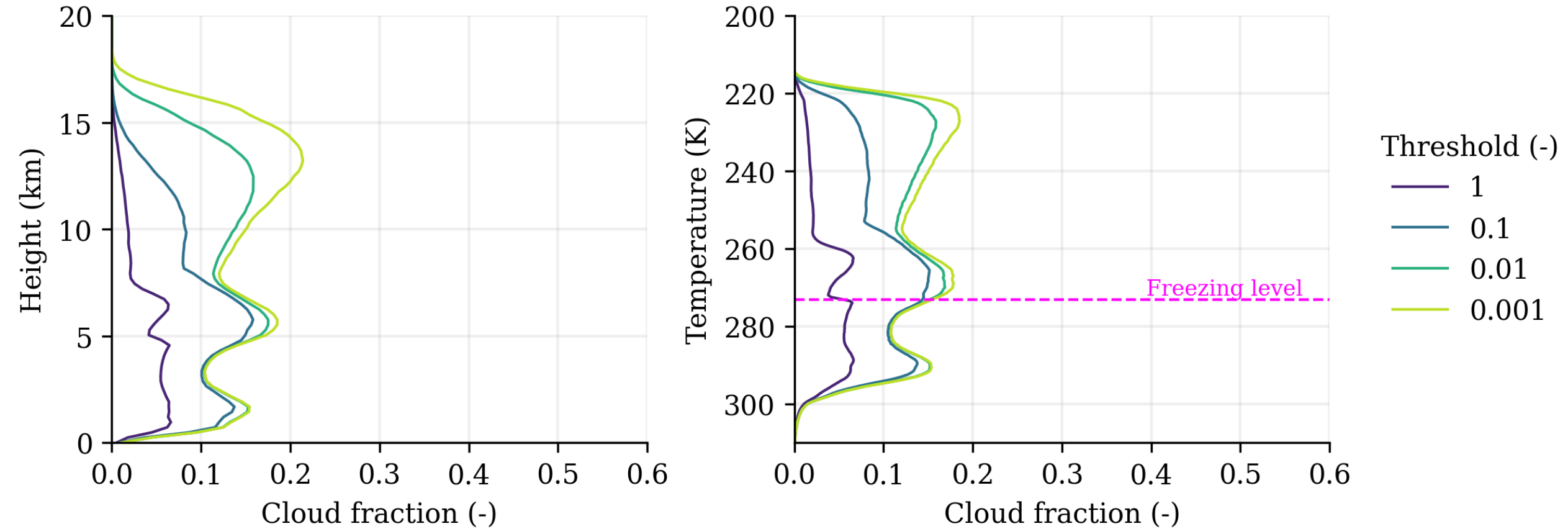
Niamey radiosonde (left), NASA WorldView (right)

# Observations support weaker Ac when Cs is present





## Cloud fraction based on cloud optical depth (JJA 2010)



# Distinguishing **Alto**cumulus and Congestus

- Mid level cloud climatology from single vertically staring lidar (N. Australia)
- Shallow clouds occur throughout
- Second mode scales with cloud thickness = congestus clouds

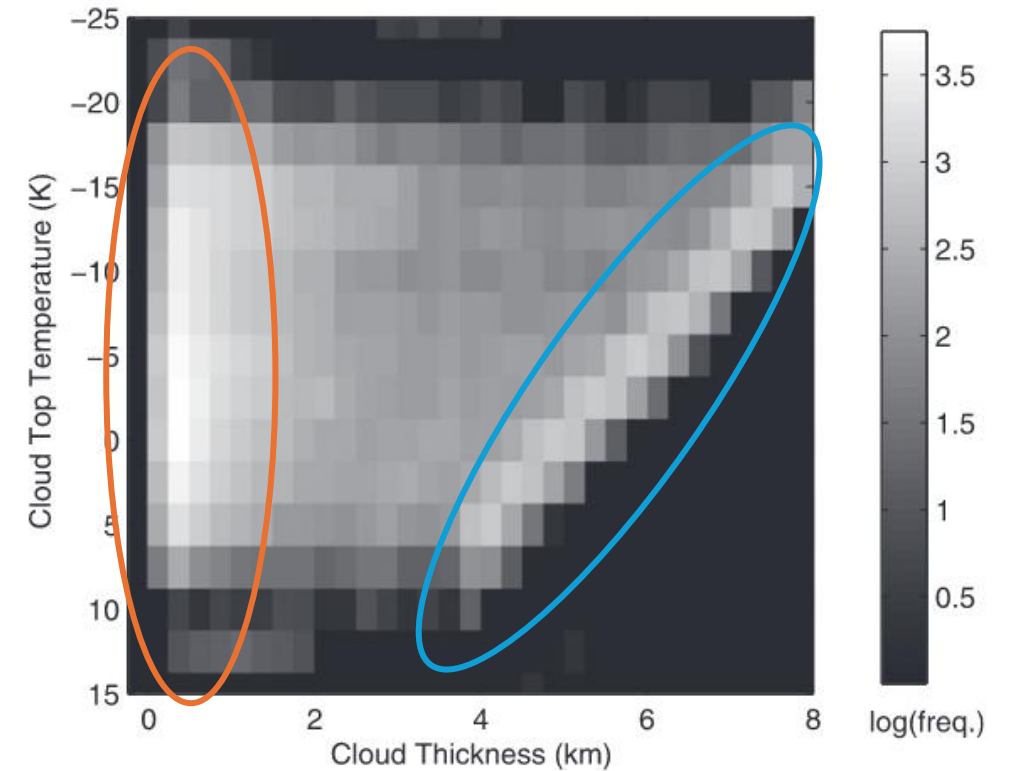
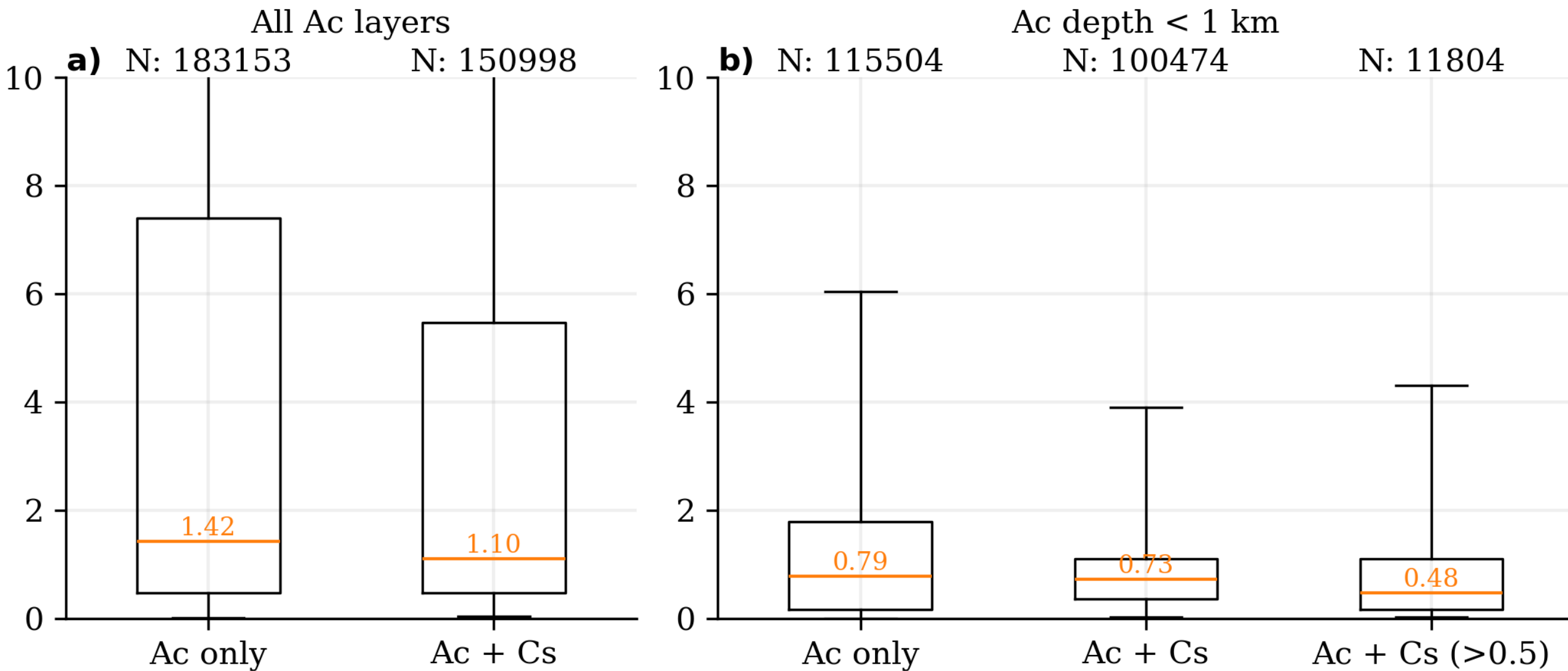


FIG. 6. Cloud-top temperature vs thickness for midlevel clouds.

# Observations support weaker Ac when Cs is present



# CloudSat-CALIPSO cloud overlap statistics

418743 profiles from JJA 2010

