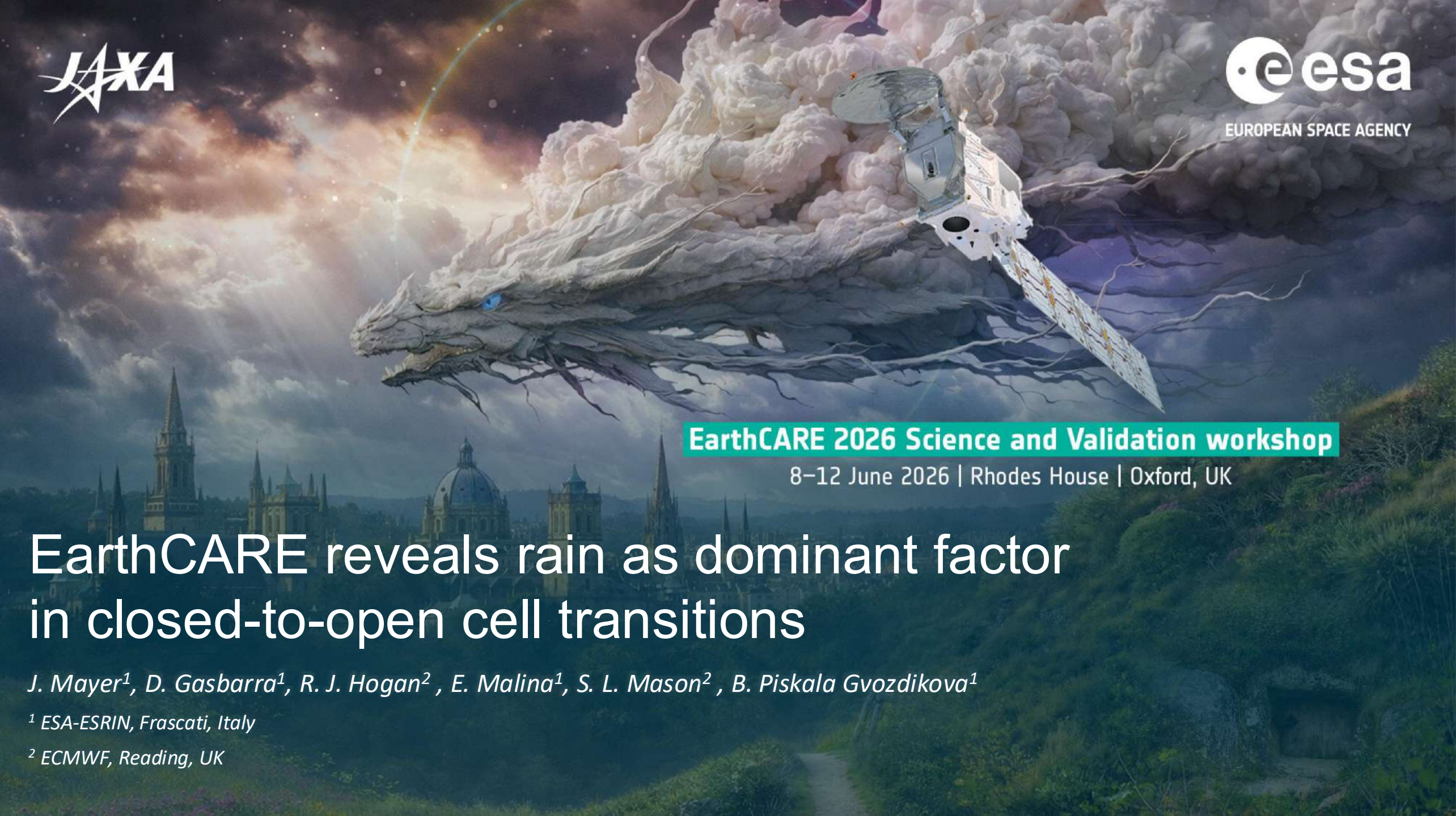


EarthCARE reveals rain as dominant factor in closed-to-open cell transitions

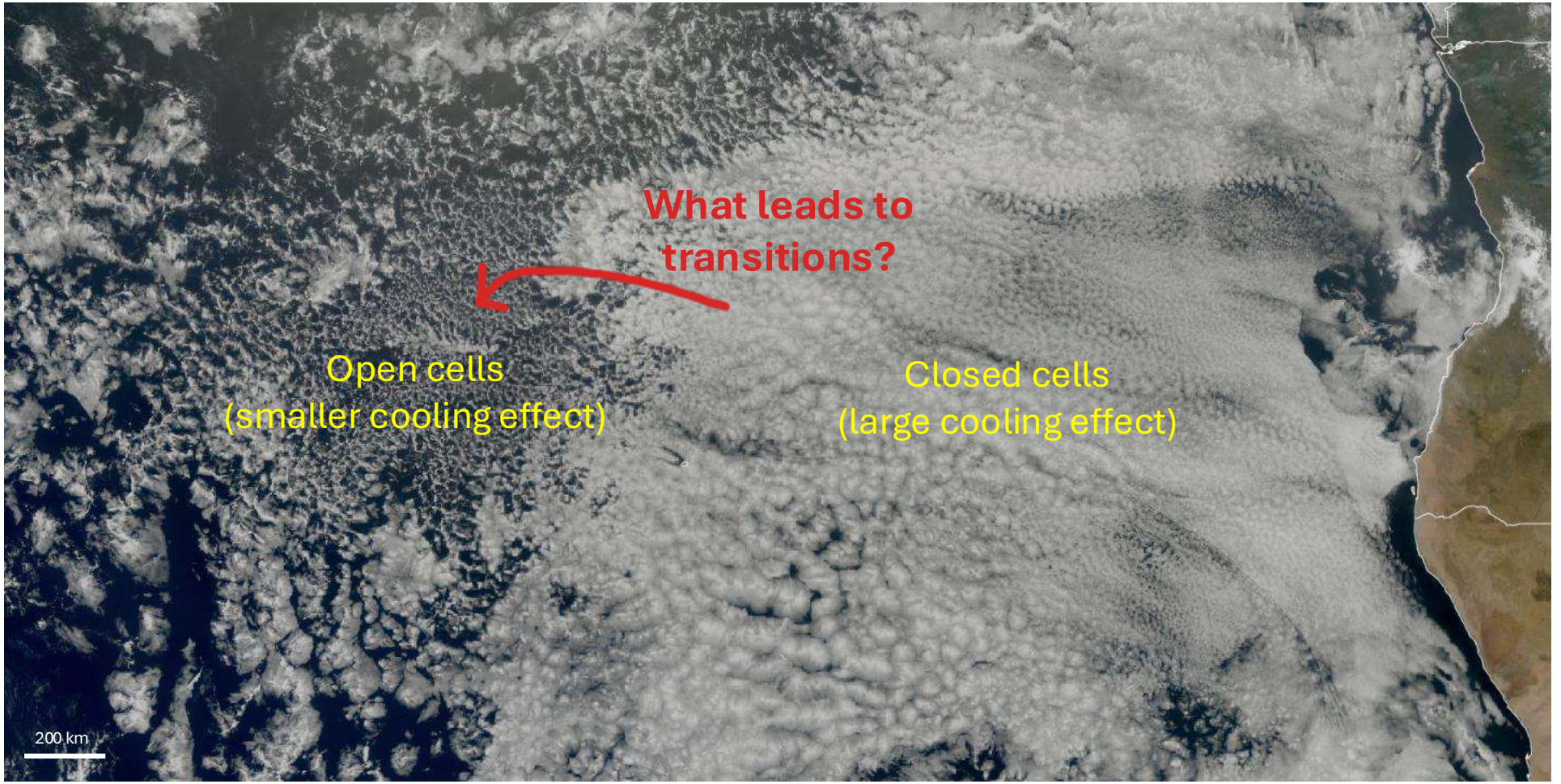
J. Mayer[1], D. Gasbarra[1], R. J. Hogan[2] , E. Malina[1], S. L. Mason[2] , B. Piskala Gvozdikova[1]

[1] *ESA-ESRIN, Frascati, Italy*

[2] *ECMWF, Reading, UK*

MTG, FCI (True Colour RGB), 27.09.25, 13 UTC

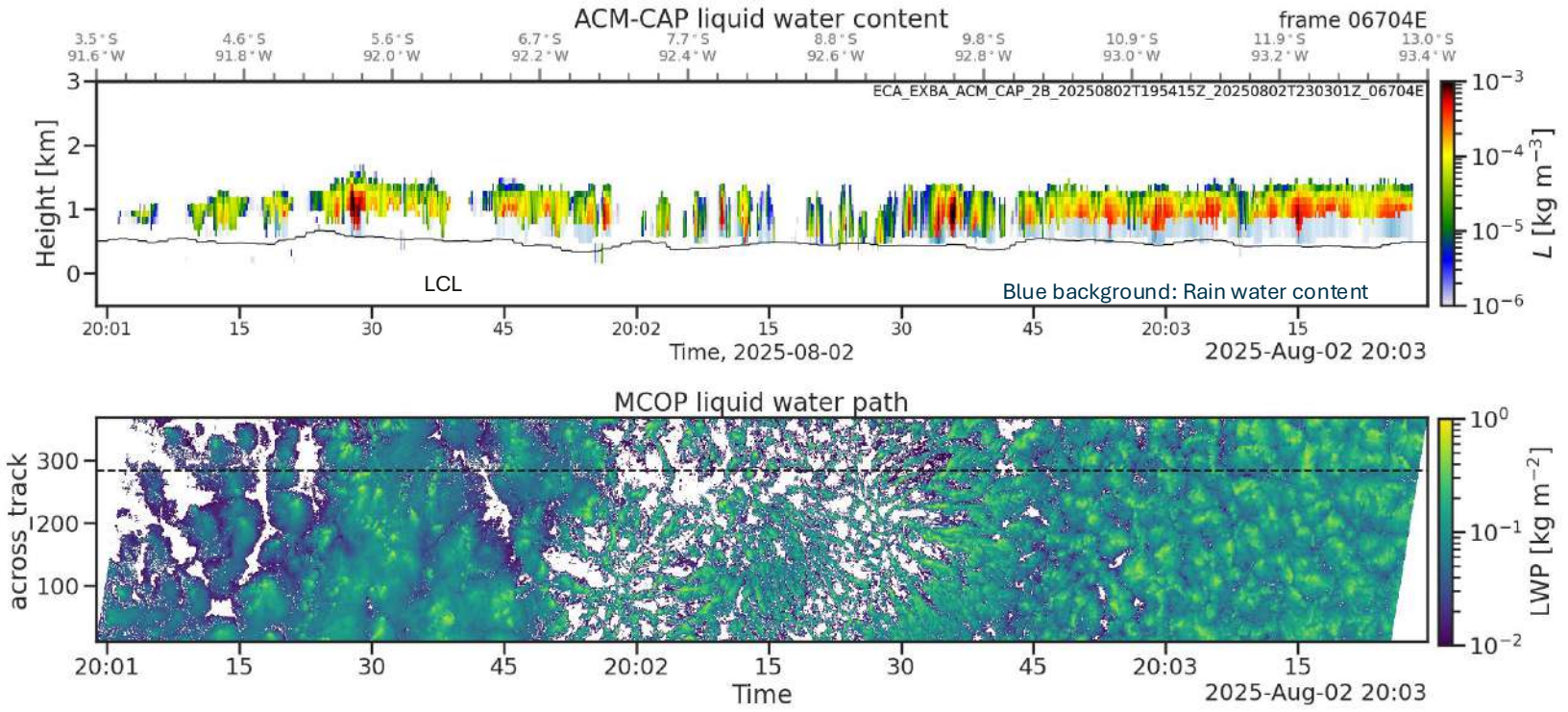
Cloud structure changes can have a large impact on albedo



MTG, FCI (True Colour RGB), 27.09.25, 13 UTC

McCoy et al. (2017, 2023)

EarthCARE enables detailed observations of low clouds



- Higher **horizontal and vertical resolution** compared to previous satellite missions
- **Reduced surface clutter** contamination (suppressed above 500m) (Xu et al. 2025)
- **CPR is more sensitive** than CloudSat's, enabling detection of double the amount of stratocumulus clouds, weak drizzle, and small raindrops (Xu et al. 2025)
- Combining CPR reflectivity and **Doppler velocity** yields better constraints on raindrop sizes and improves retrievals of rain rate and liquid water content (Mason et al. 2024)

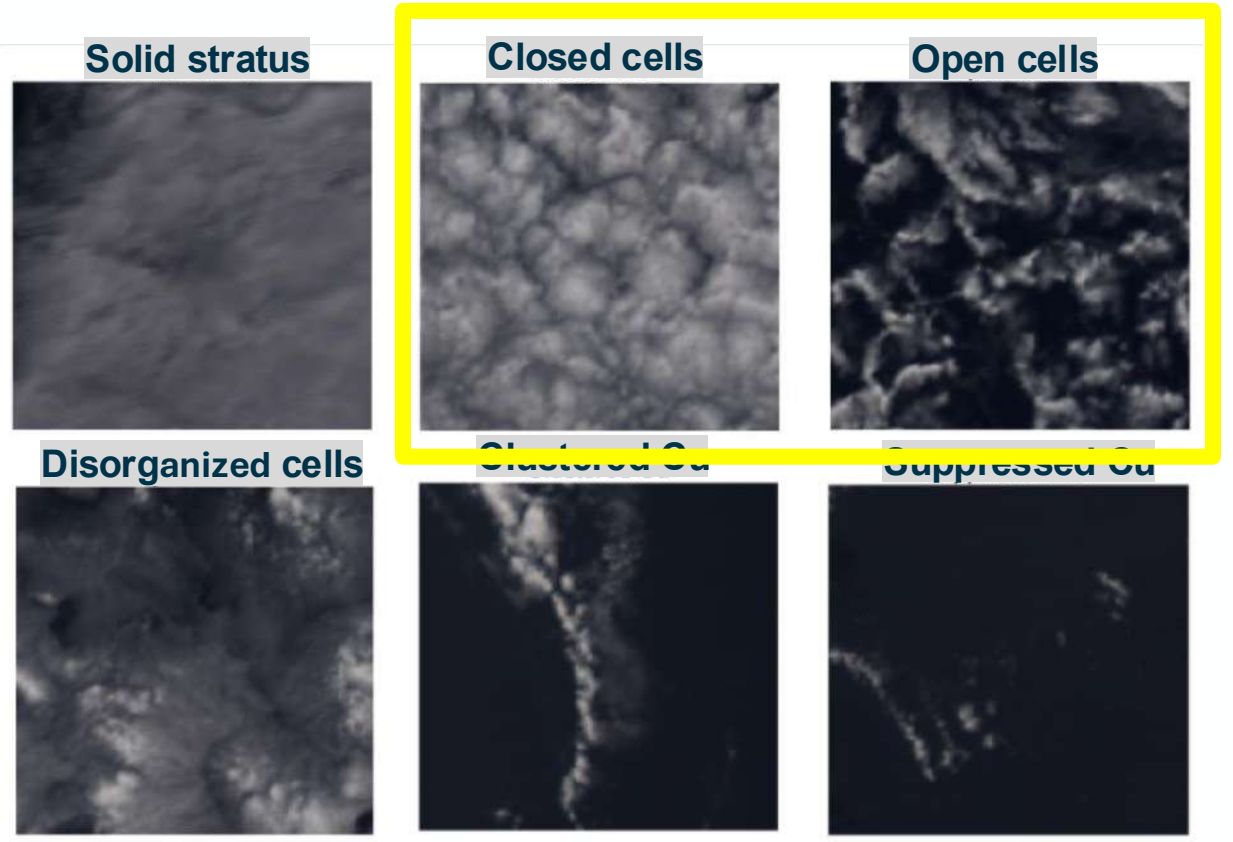
Mesoscale structures are classified using a CNN

- Convolutional Neural Network (ResNet50) of Wu et al. (2025)

- Inputs:
  - scenes of 128 x 128 km from imager (1km resolution)
  - three IR window channels and cloud optical depth → daytime only!

- Outputs: 6 cloud structure classes

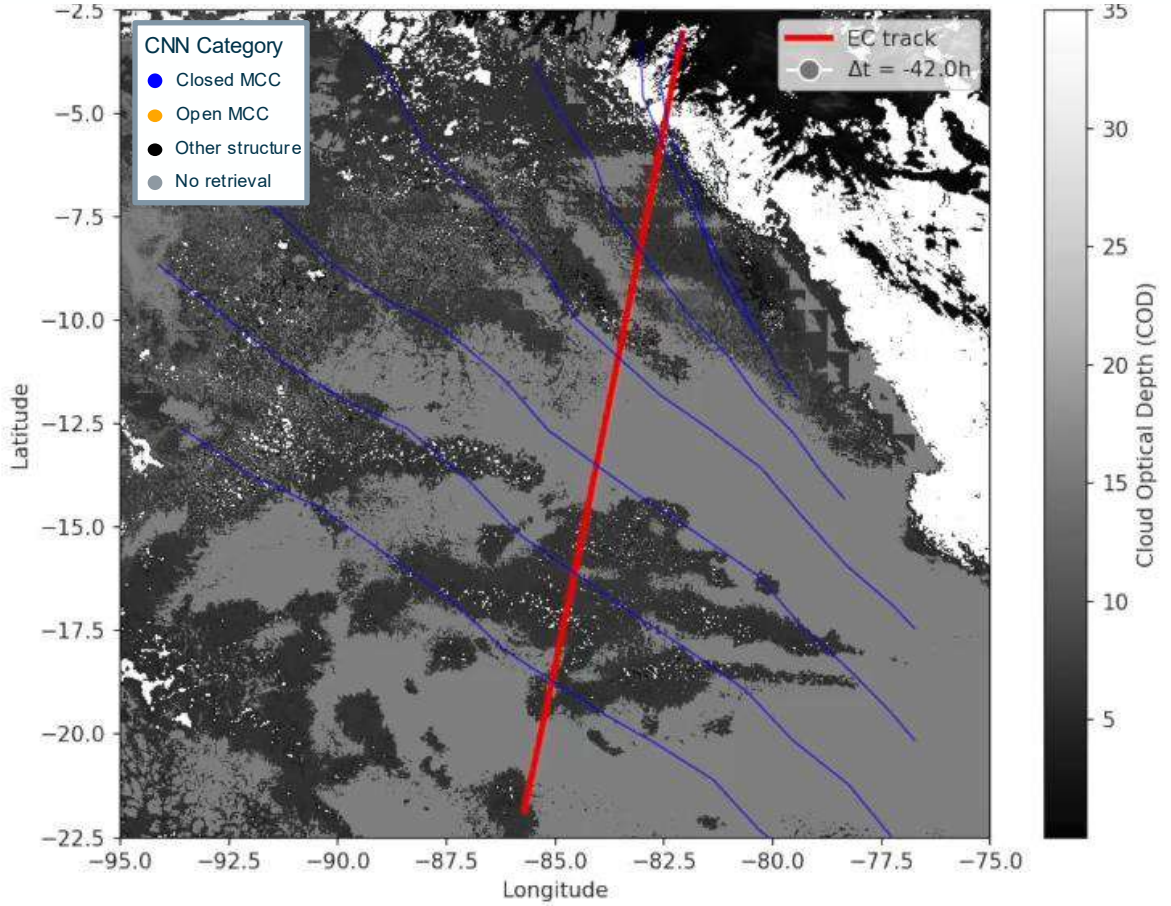
- Original CNN was created for MODIS
  → fine-tune for EarthCARE/MSI and GOES/ABI



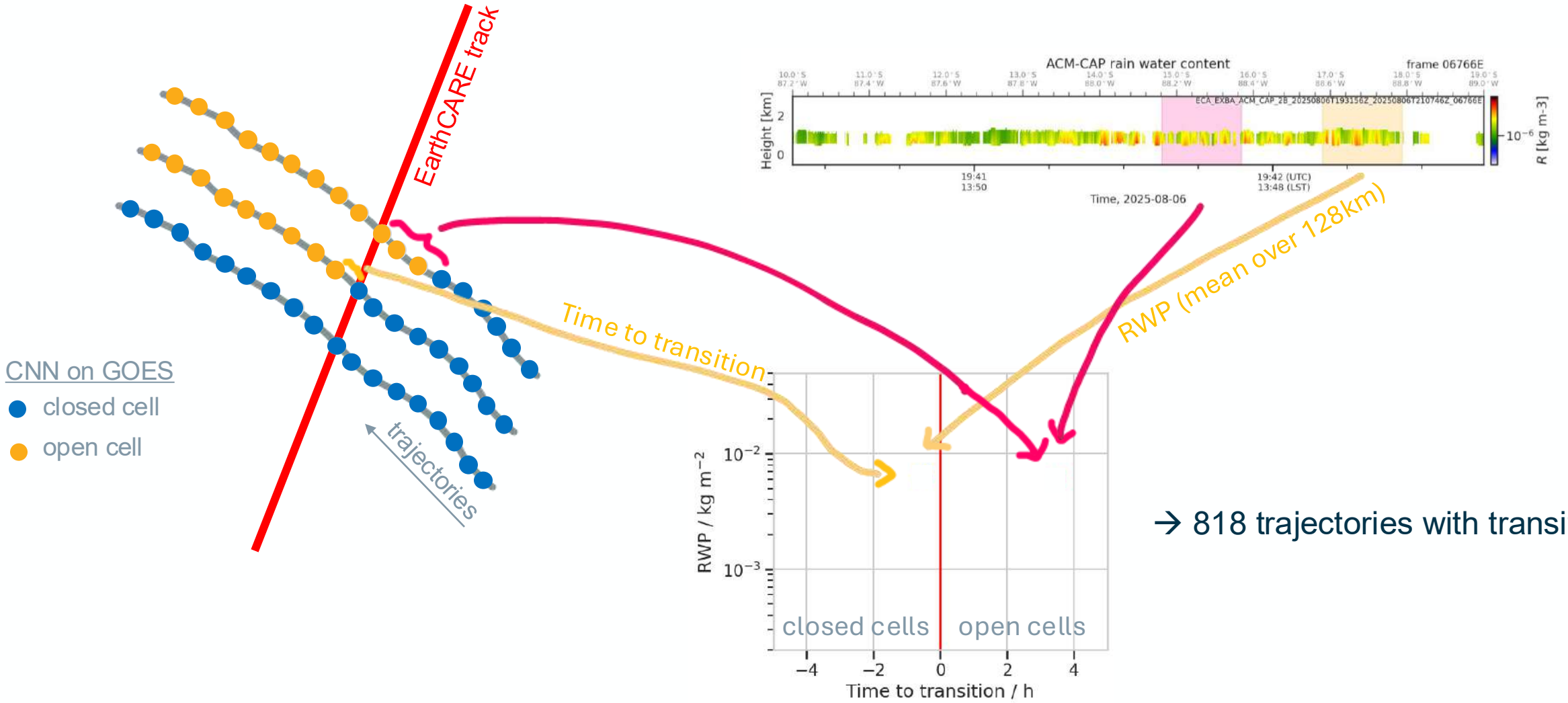
Adapted from Wu et al. (2025)

What happens before, during and after a transition from closed MCC to open MCC?

- Compute trajectories using wind data from ERA5 for South East Pacific region
- Apply CNN on GOES data (daytime only!)
- Data from Aug. 2024 to Nov. 2025

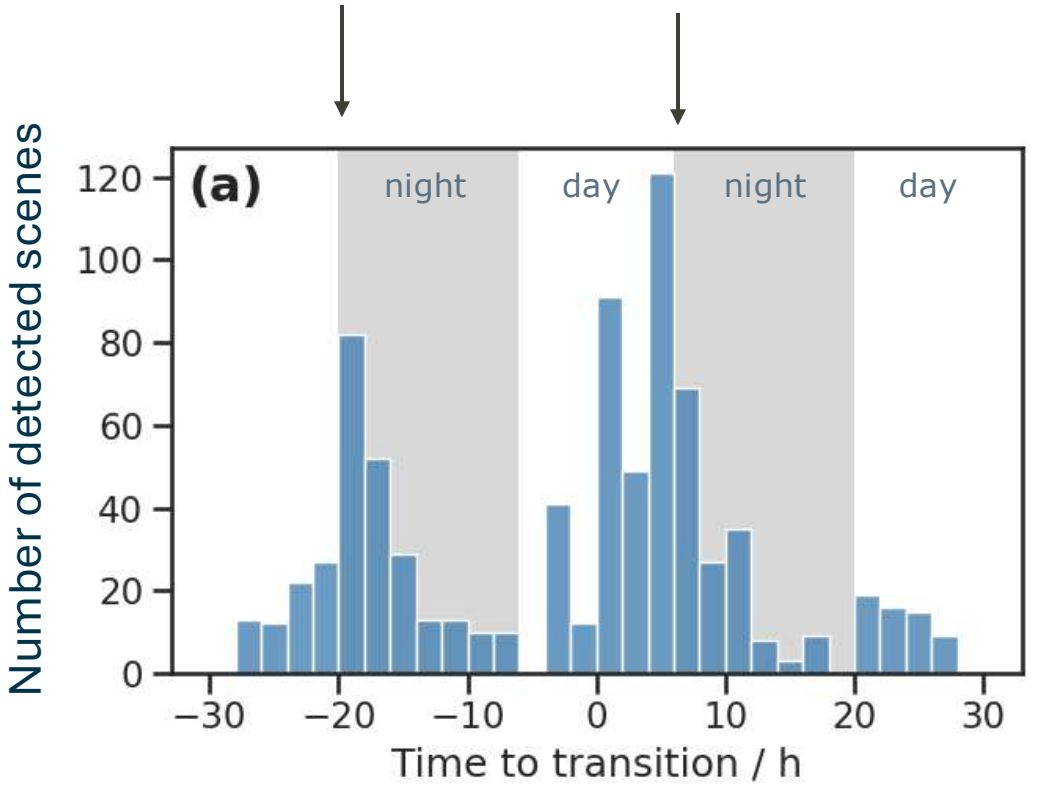


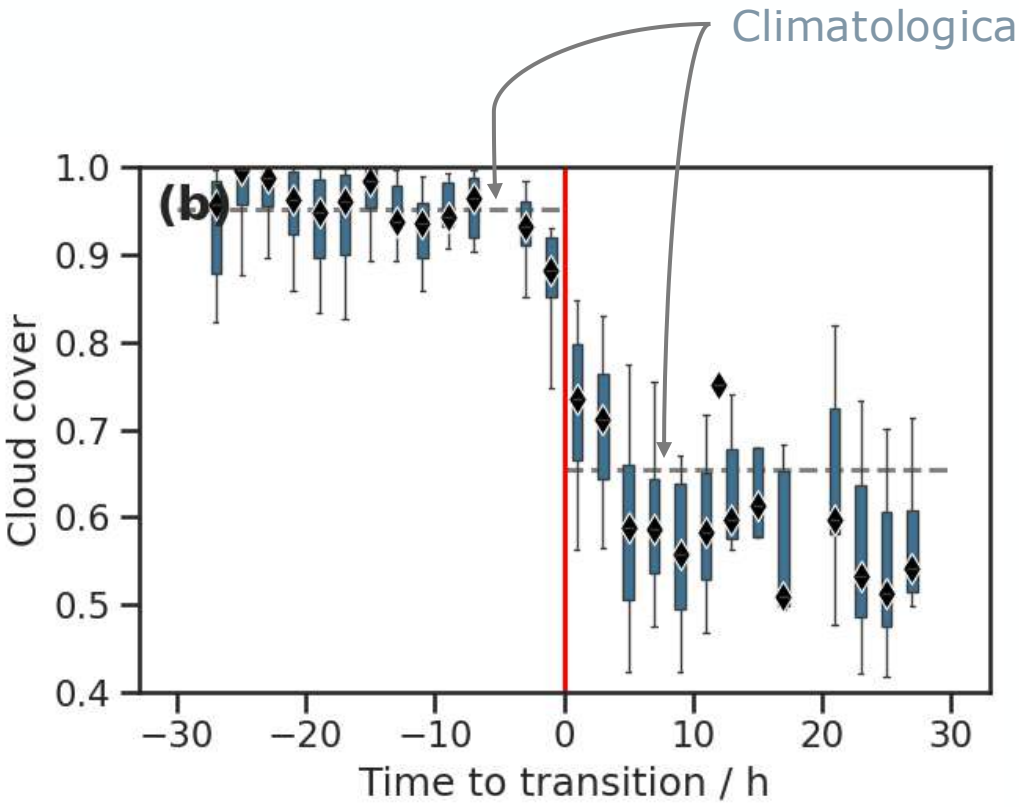
Combine EarthCARE cloud measurements with time information from GOES



→ 818 trajectories with transitions

Combine EarthCARE cloud measurements with time information from GOES

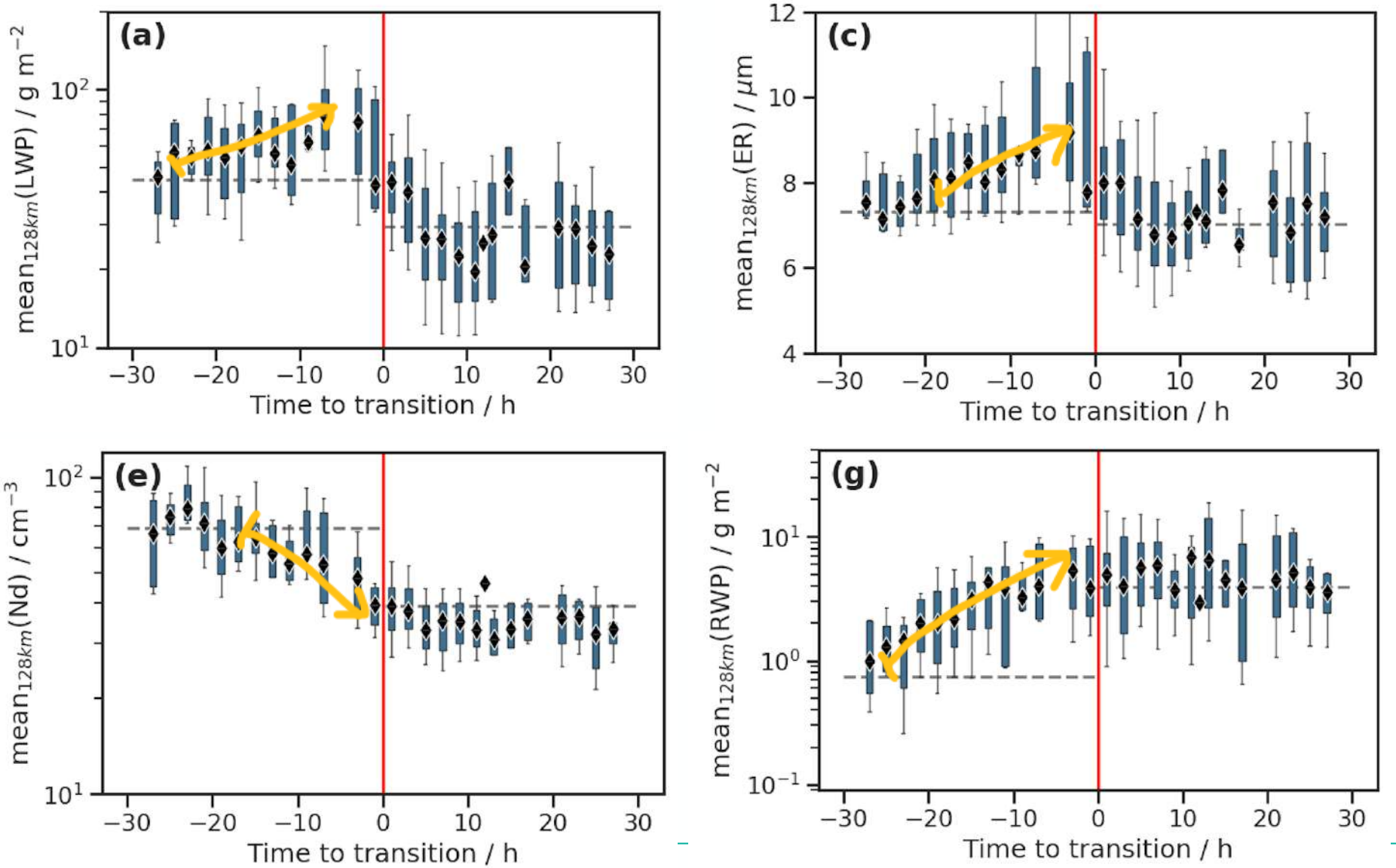




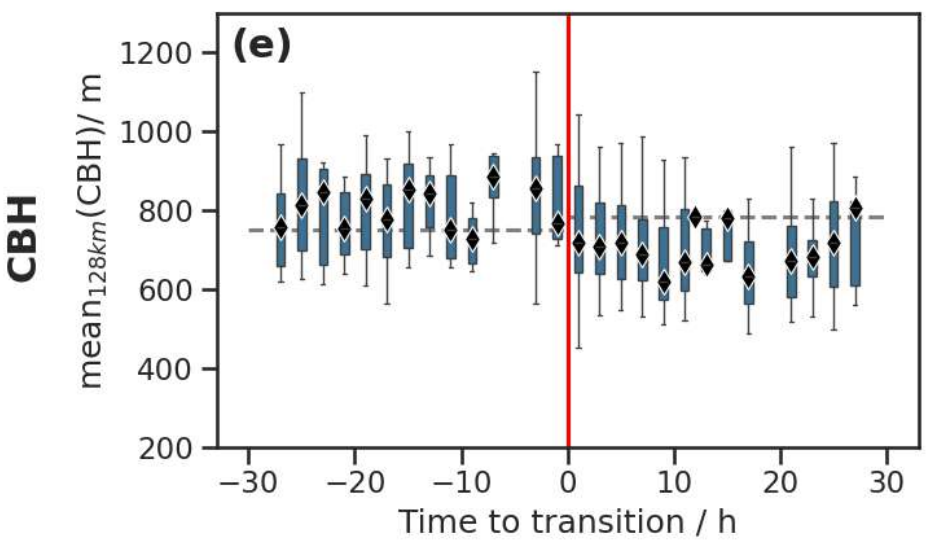
→ Transitions can happen at any time of day
→ Most transitions happen around dawn

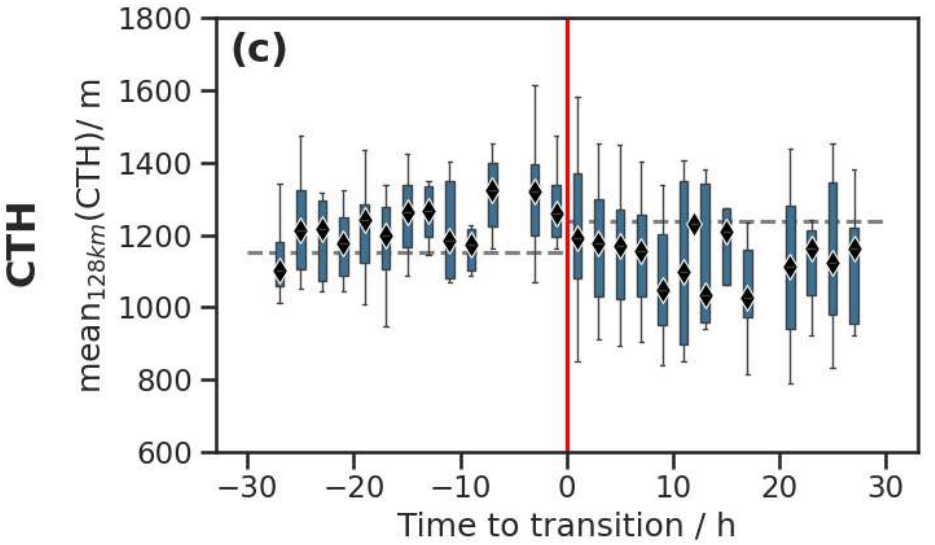
→ Change in cloud cover as expected

Microphysics starts to change well before the transition



Cloud vertical structure remains largely unchanged

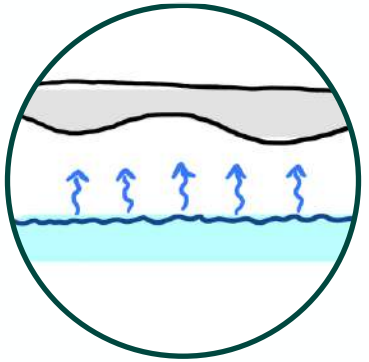




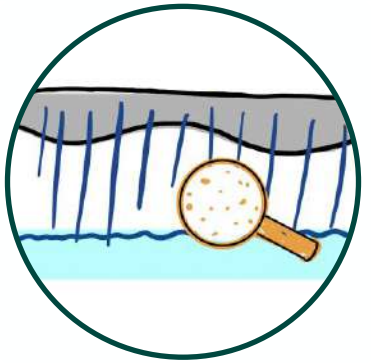
→ Changes in microphysics and unchanging vertical structure suggest a precipitation-linked pathway for closed-to-open cell transitions

Hypothesized timeline for closed-to-open transition

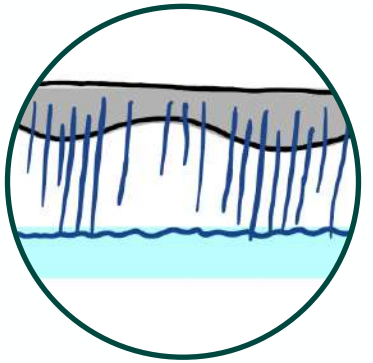
1. Locally increased moisture (e.g. due to increased wind; Eastman et al. 2022)

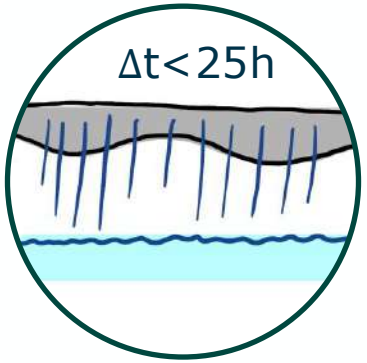


3. Aerosol scavenging, as rain starts to reach the surface

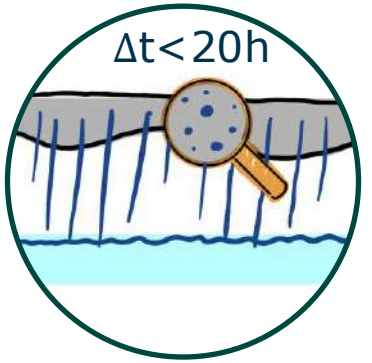


5. Feedback: rain increase → more aerosol scavenging → larger ER → more rain …



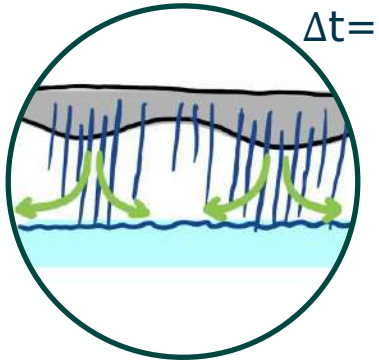


2. increased LWP and RWP



4. Lower Nd and larger ER

Δt=0h



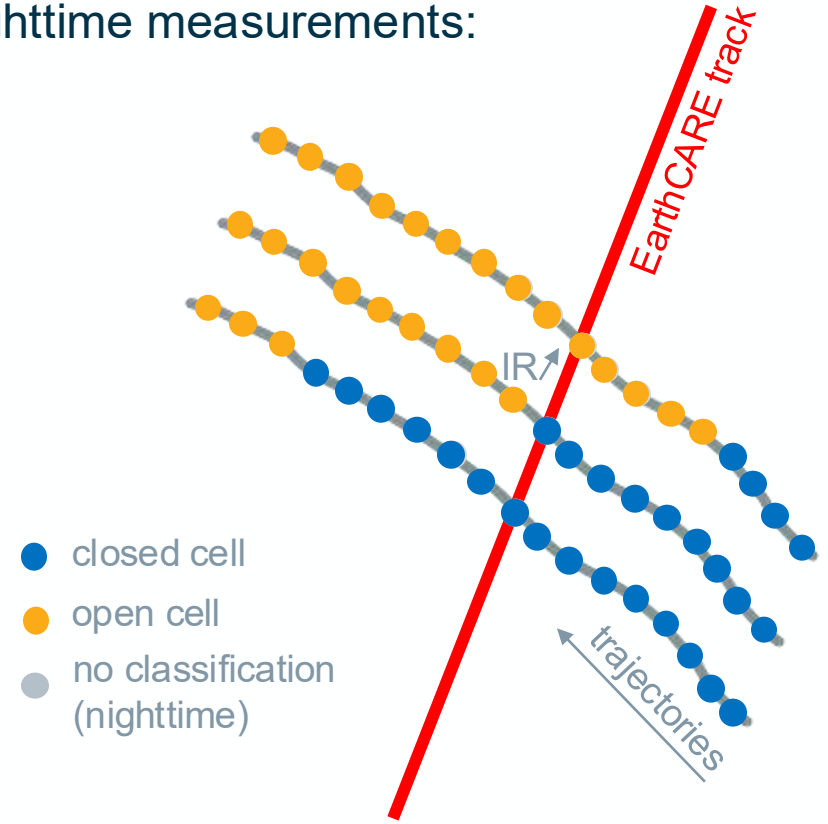
6. Evaporation below cloud leads to cold pools that change cloud structure

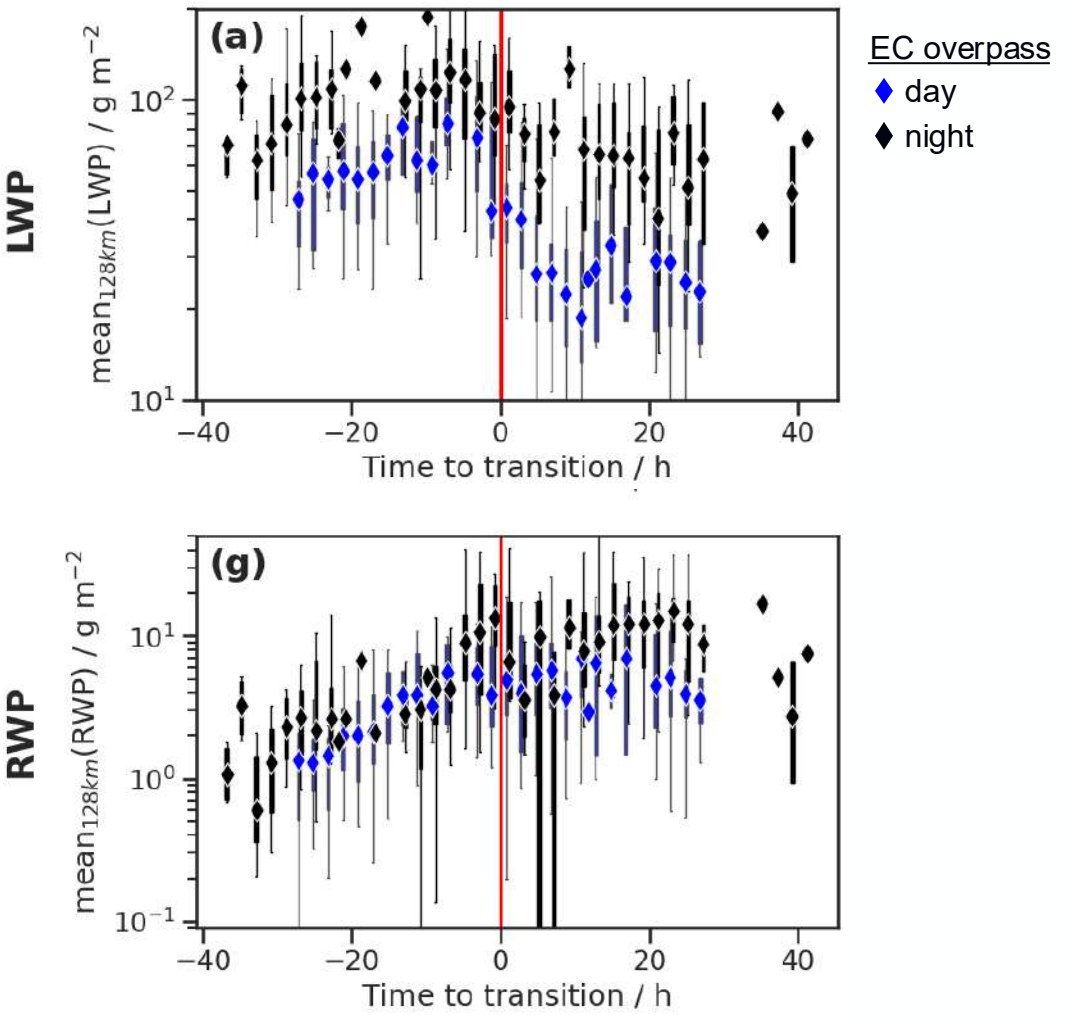
Conclusions

- EarthCARE can provide measurements of stratocumulus cloud and rain properties in unprecedented detail from space
- Closed and open cells differ markedly in their microphysical properties, most notably lower droplet number concentrations and stronger rain in open cells
- Combining EarthCARE cloud and rain observations with the fine time resolution of GOES, allows to follow changes in cloud properties around transitions in detail
- The timeline of cloud property changes leading to a transition is consistent with a precipitation-linked pathway with aerosol-scavenging-feedback

What's next?

Include nighttime measurements:



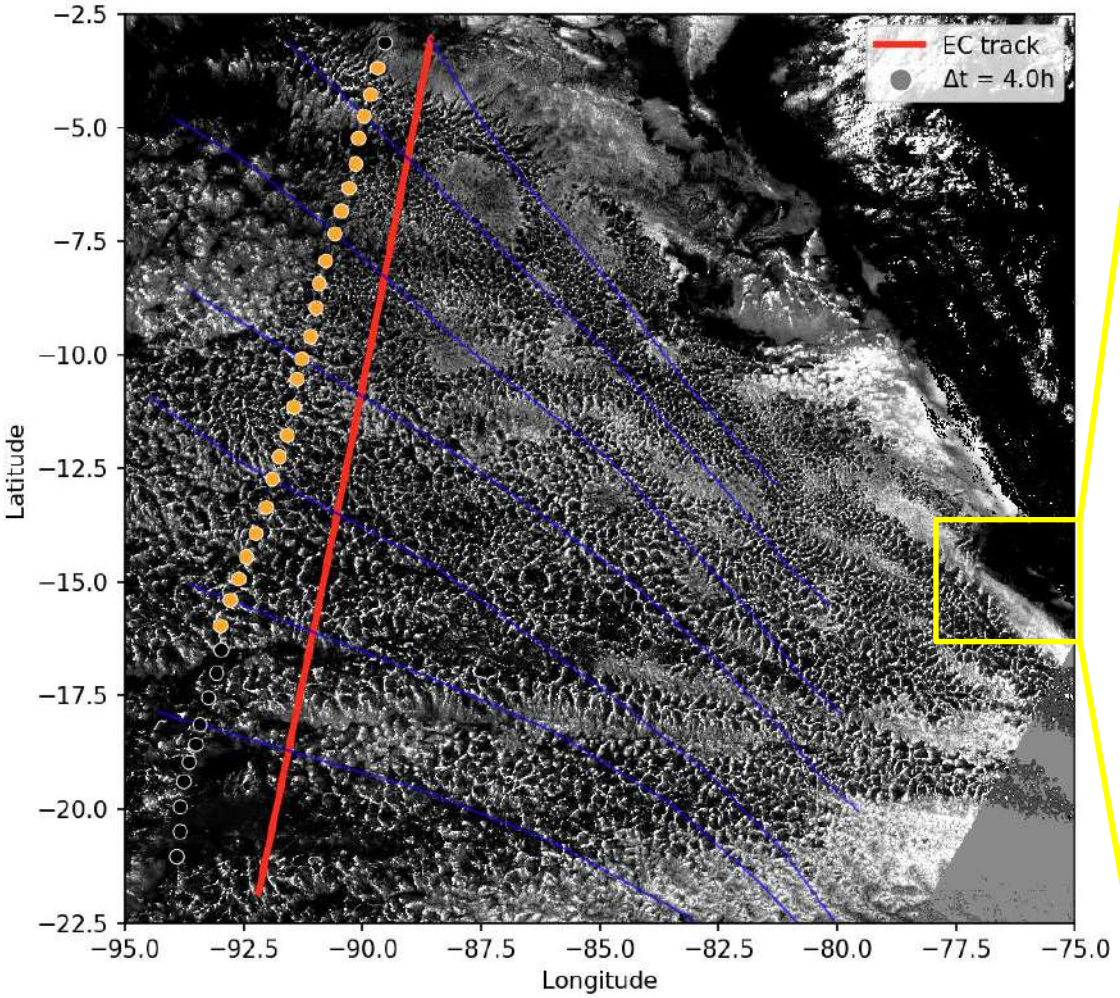


Thank you!

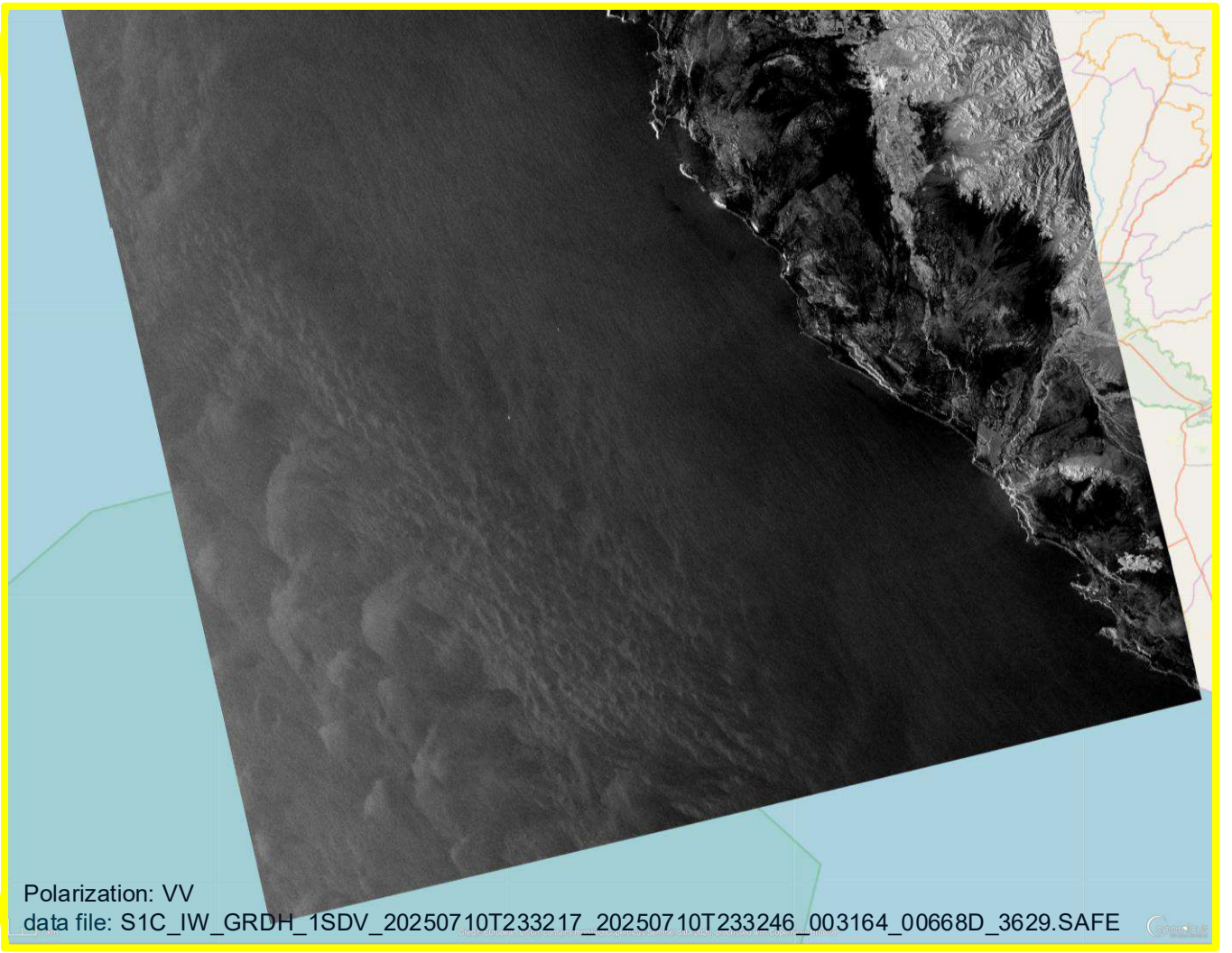
Johanna.Mayer@esa.int

Cold pools below open cells detected in Sentinel-1 SAR data

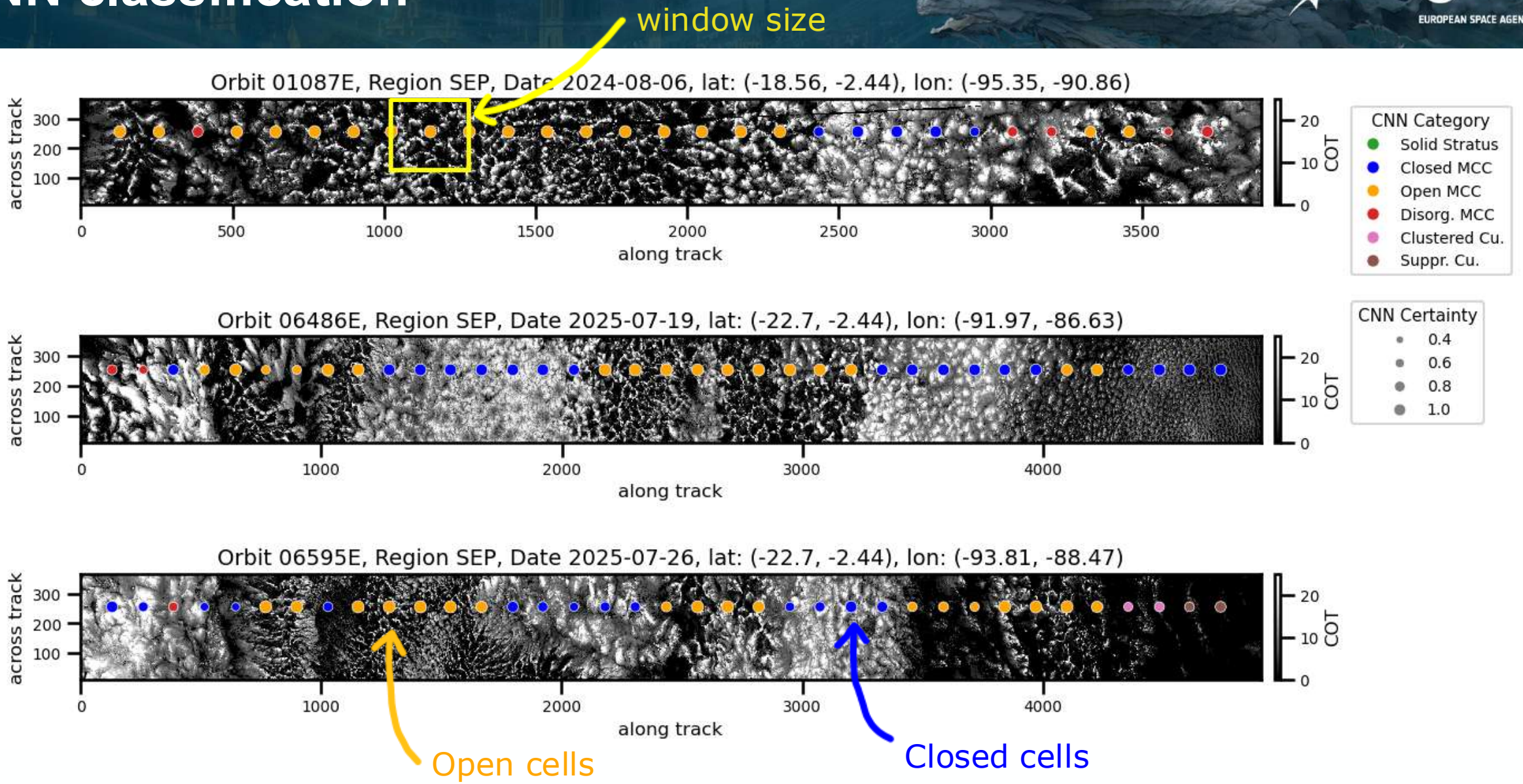
GOES, 2025-07-10 22 UTC



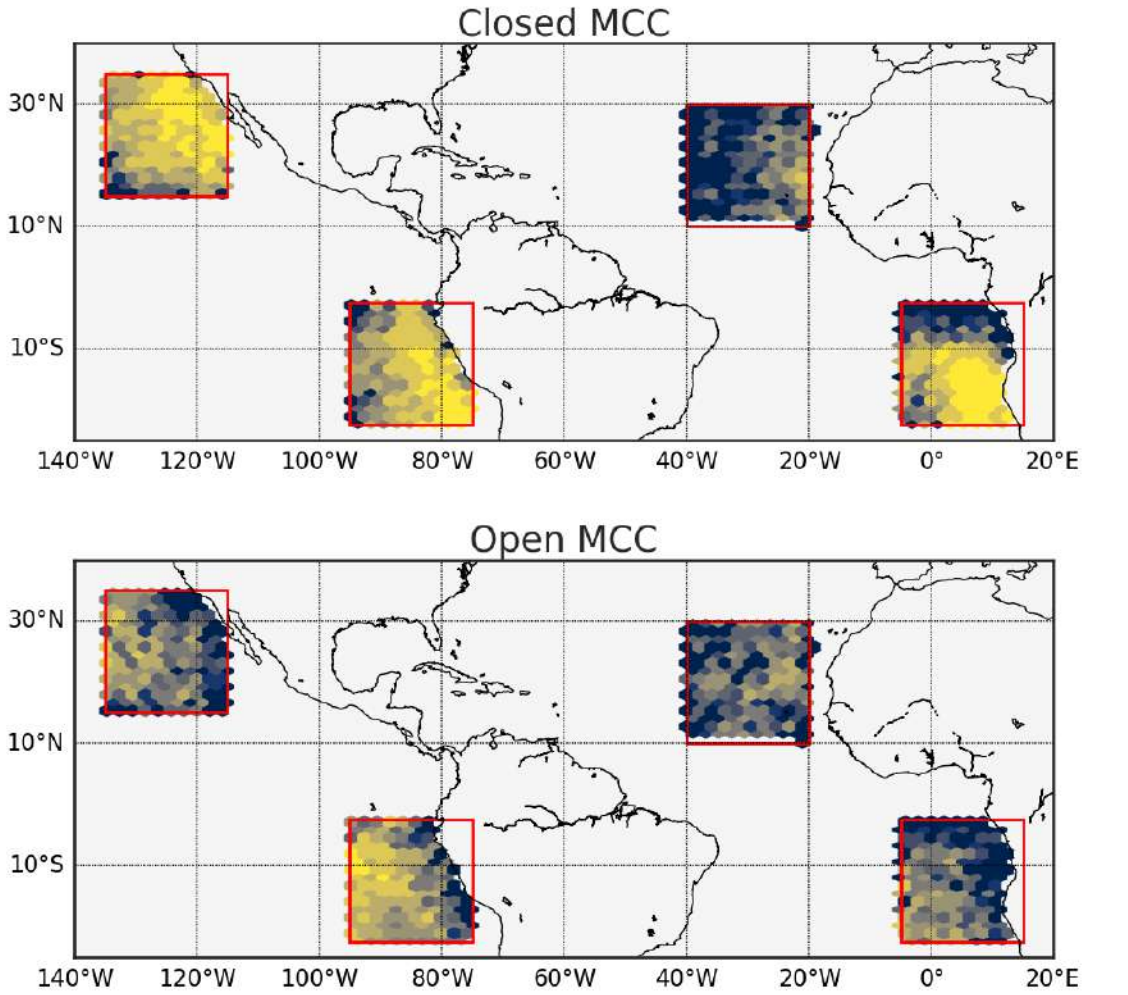
Sentinel-1, 2025-07-10 23:32 UTC



CNN classification



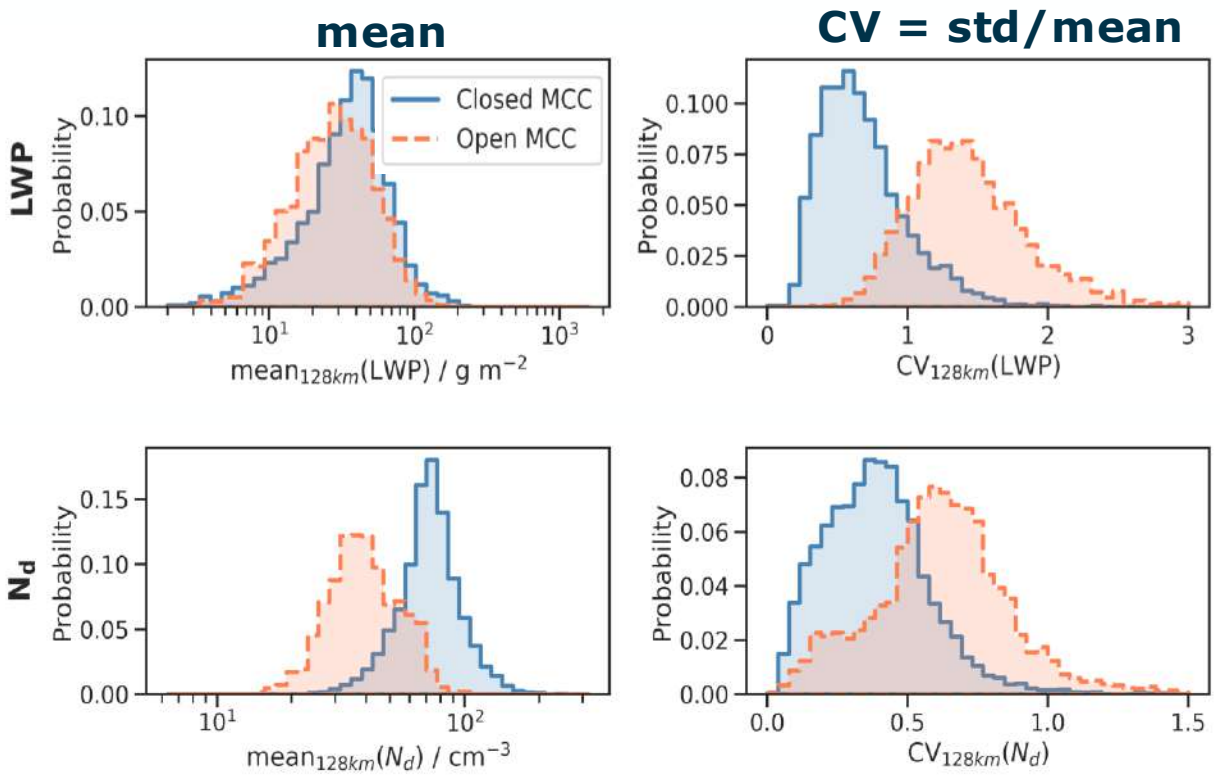
Geographic distribution of closed and open cells

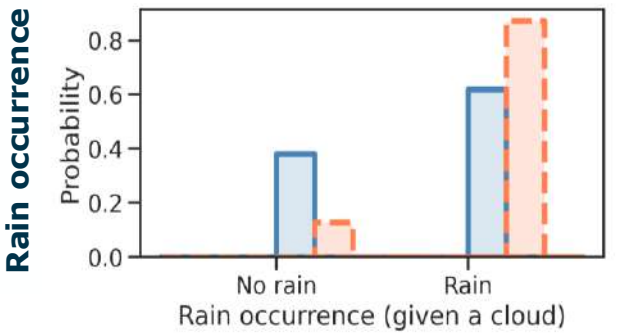


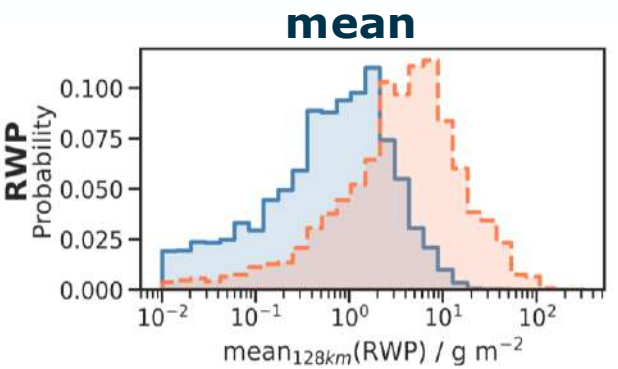
EarthCARE data from Aug 2024 to Nov 2025 (overall ~7500 scenes)

Closed and open cell properties

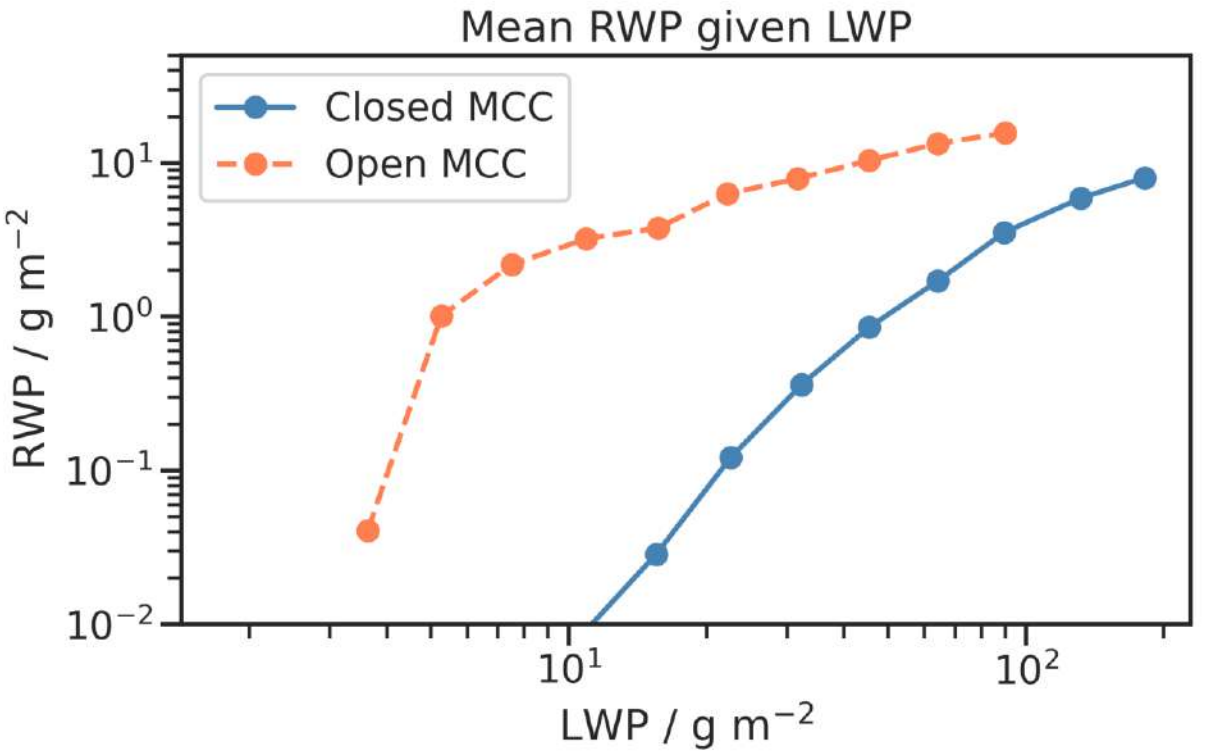
ACM-CAP cloud and rain statistics over data from Aug 2024 to Nov 2025;
mean and CV are taken over 128km (= CNN scale)

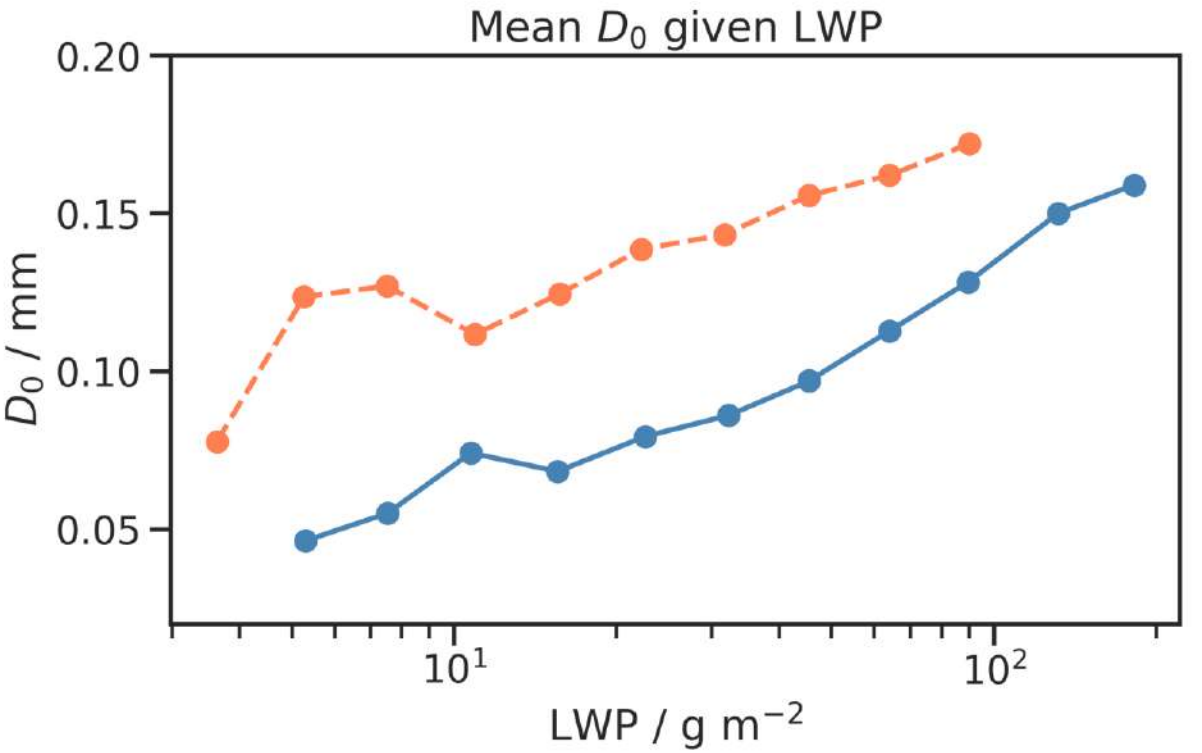


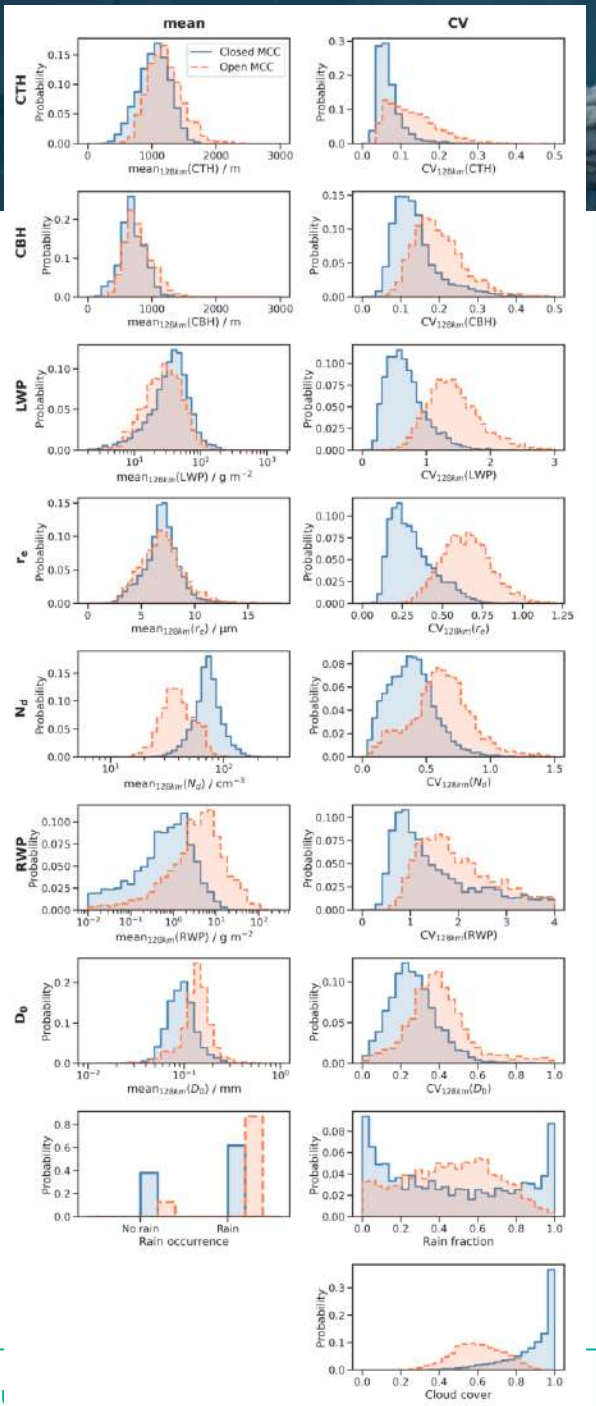




Open cells are more effective at producing rain

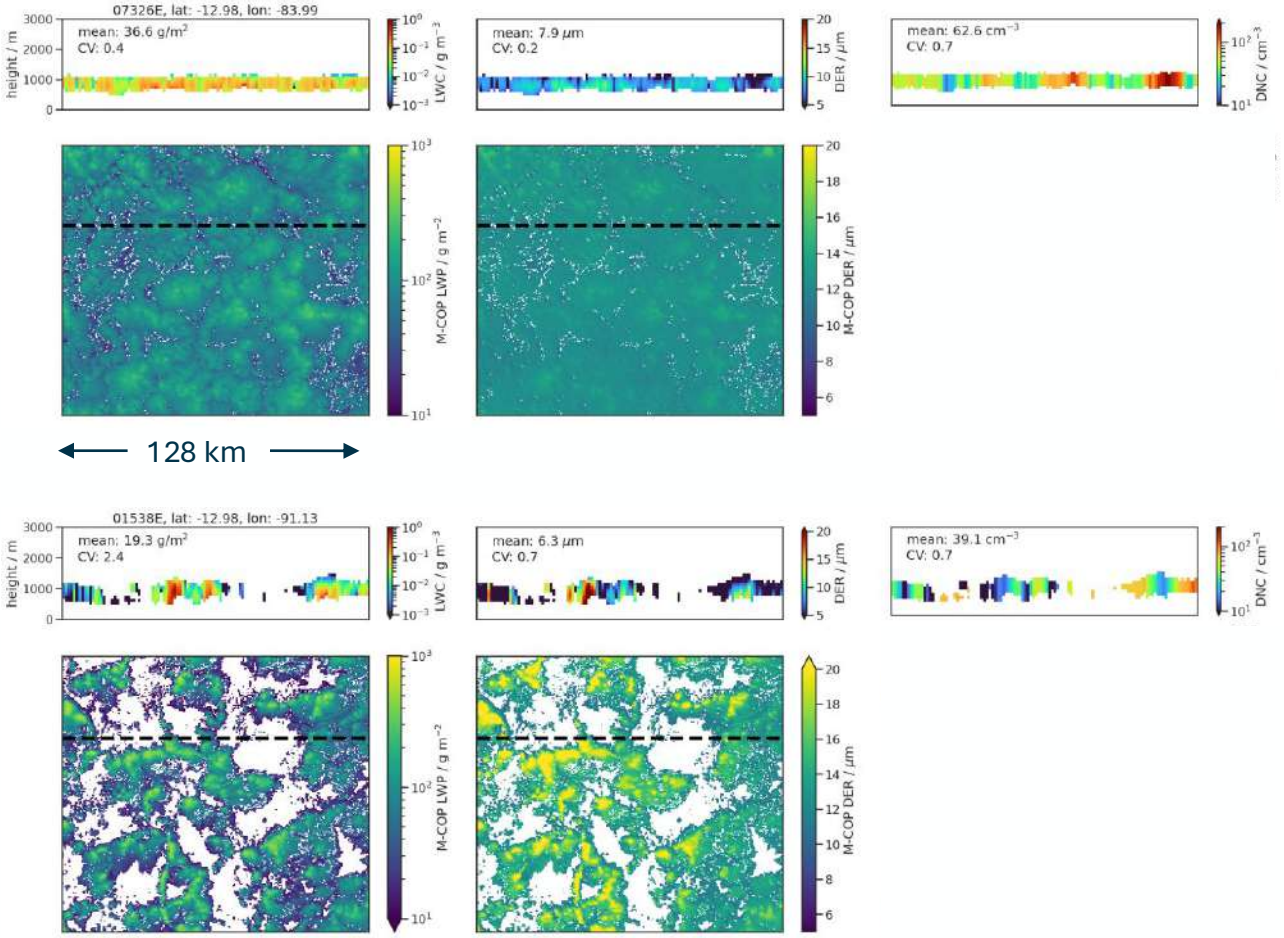




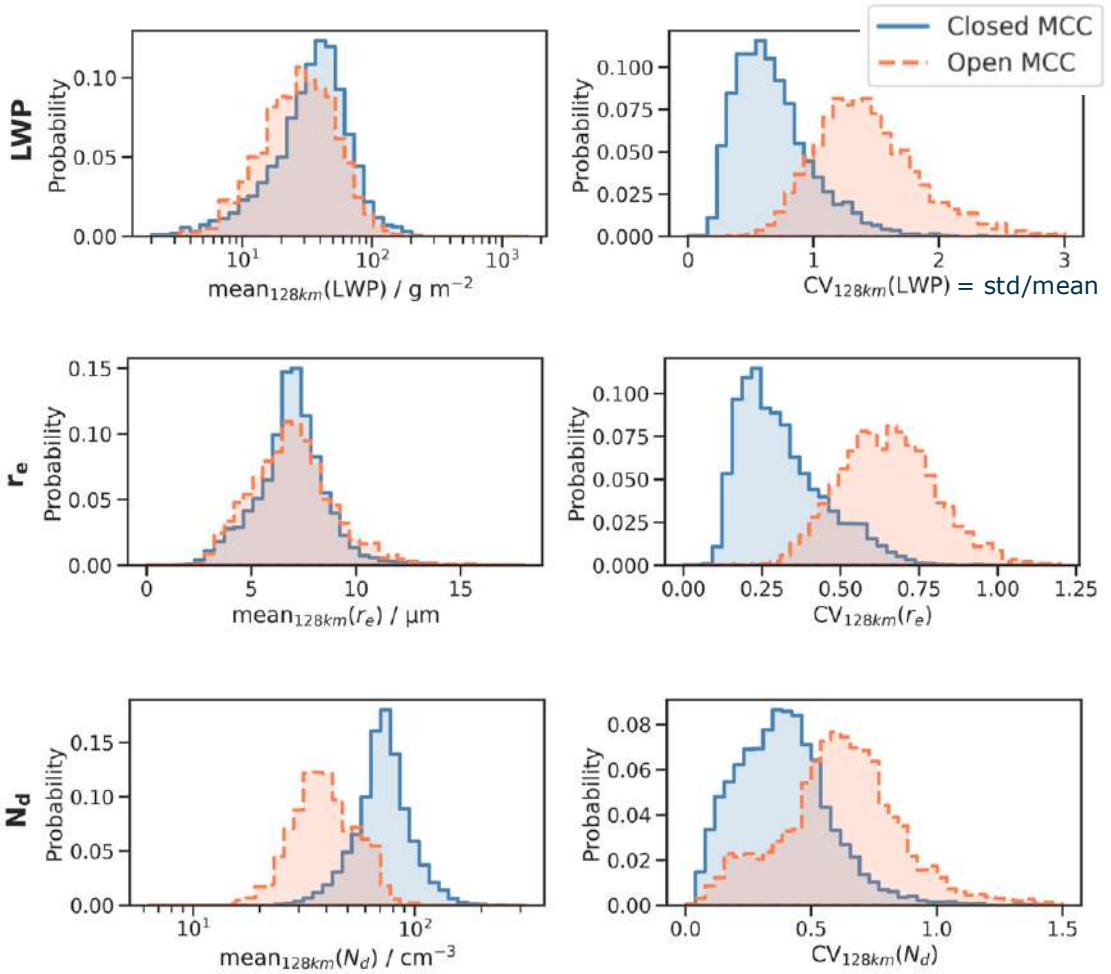

mean
CV
Closed MCC
Open MCC
CTH
CBH
LWP
r_e
N_d
RWP
D_0
Probability
mean_{128km}(CTH) / m
CV_{128km}(CTH)
mean_{128km}(CBH) / m
CV_{128km}(CBH)
mean_{128km}(LWP) / g m^{-2}
CV_{128km}(LWP)
$\text{mean}_{128km}(r_e)$ / µm
$CV_{128km}(r_e)$
$\text{mean}_{128km}(N_d)$ / cm^{-3}
$CV_{128km}(N_d)$
mean_{128km}(RWP) / g m^{-2}
CV_{128km}(RWP)
$\text{mean}_{128km}(D_0)$ / mm
$CV_{128km}(D_0)$
No rain
Rain
Rain occurrence
Rain fraction
Cloud cover

Closed and open cells

Examples for typical cloud scenes

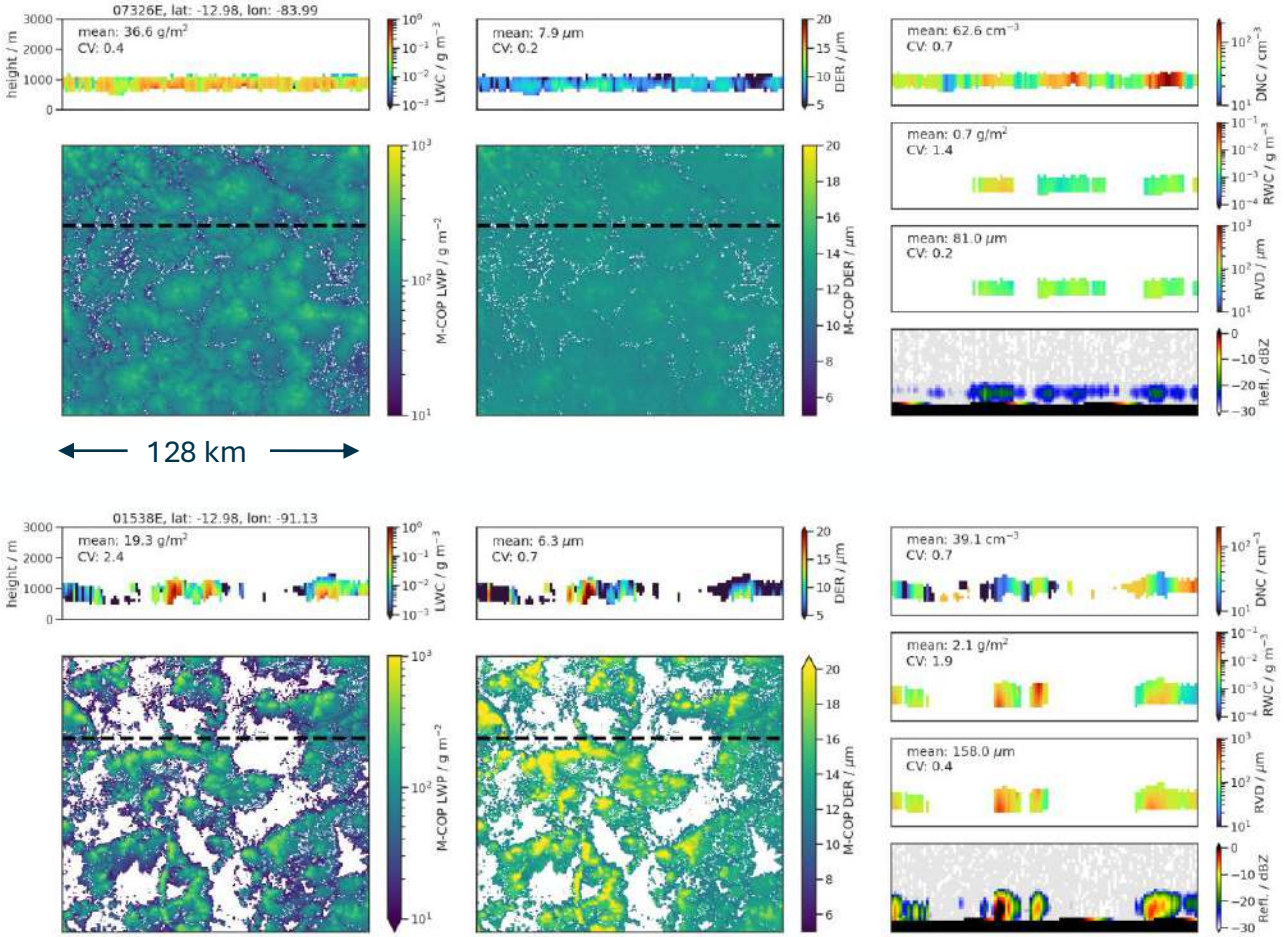


Cloud properties (statistics over data from Aug 2024 to Nov 2025, ~7500 scenes)

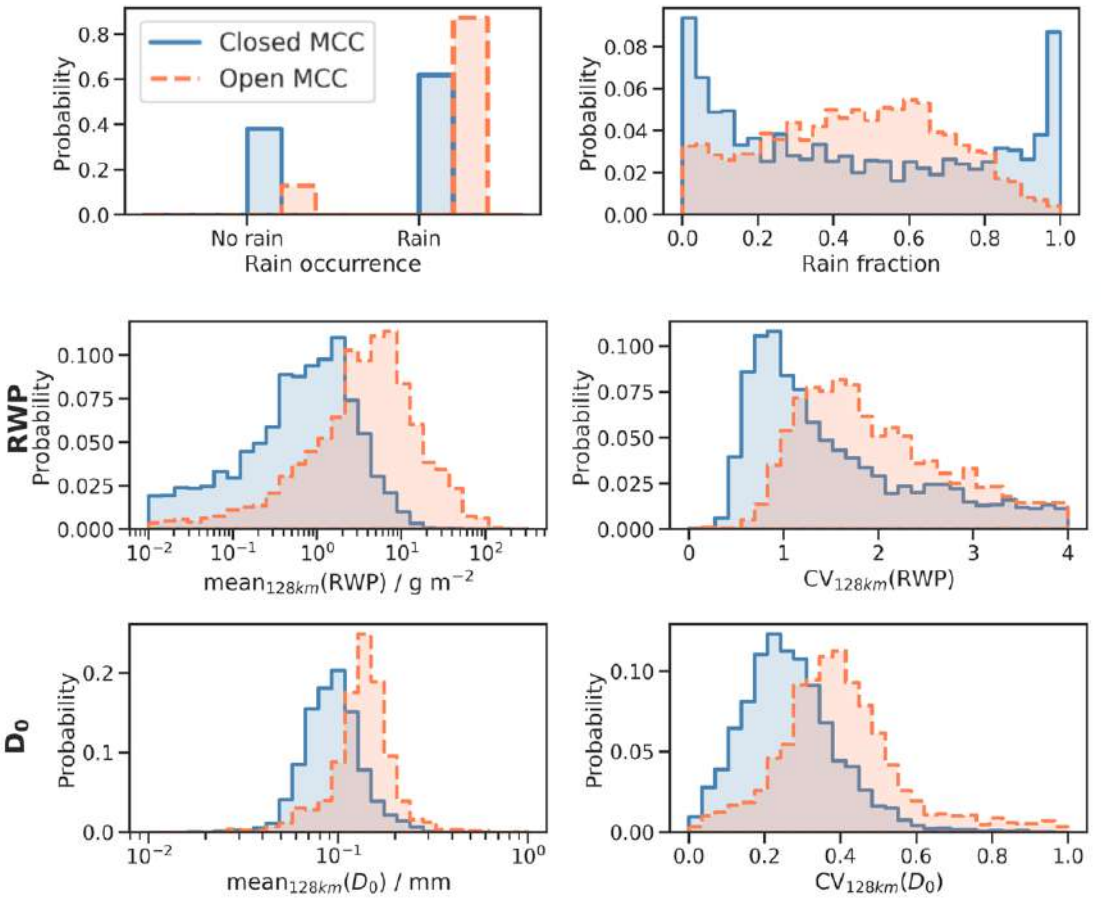


Closed and open cells

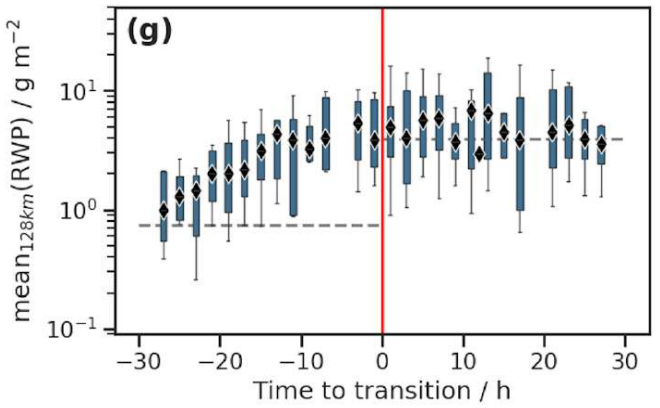
Examples for typical cloud scenes

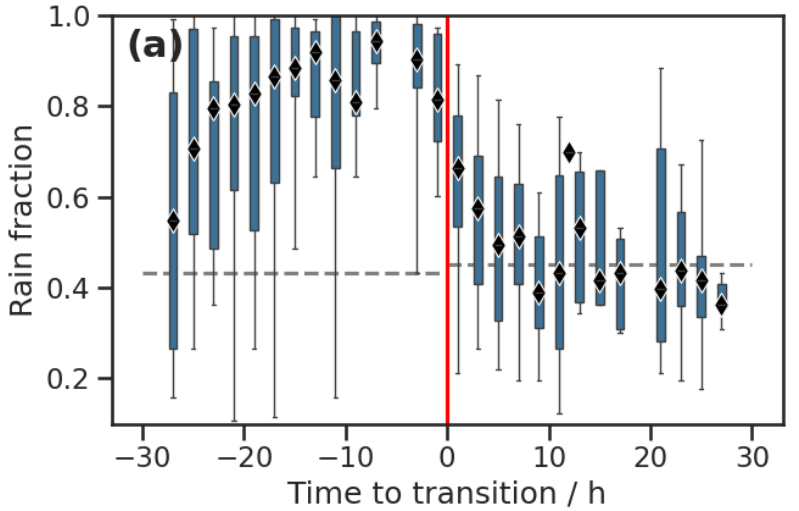


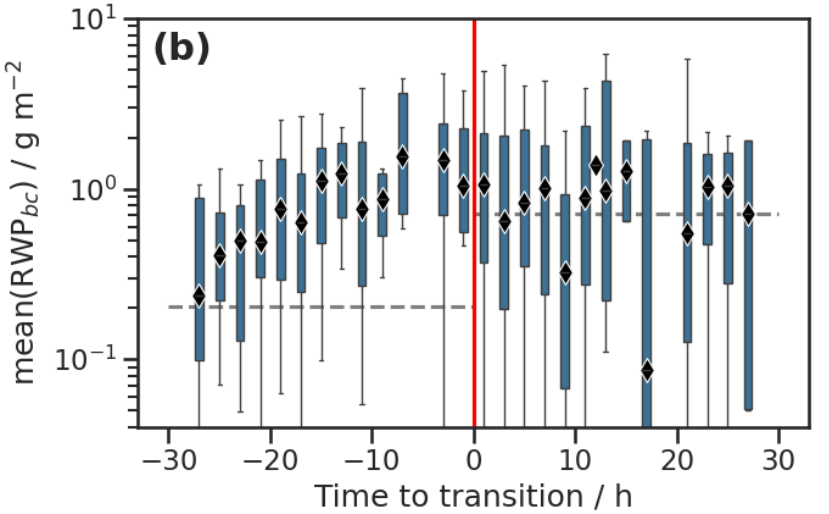
Rain properties (statistics over data from Aug 2024 to Nov 2025, ~7500 scenes)

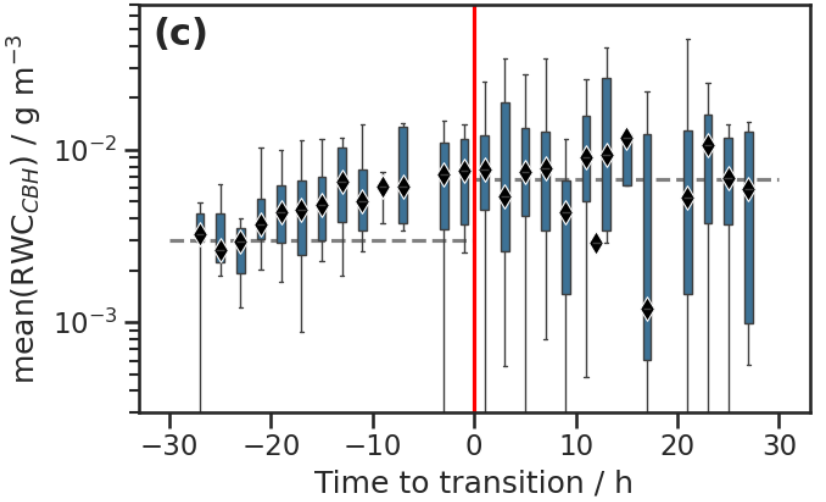


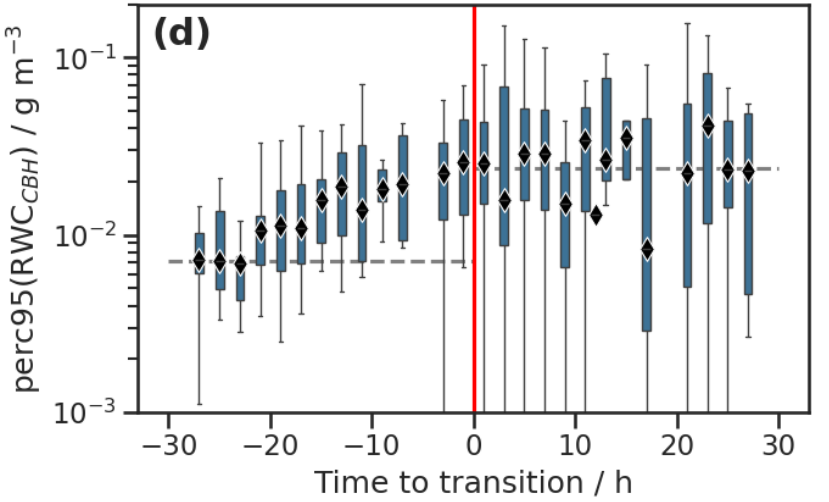
Increase in RWP is due to both higher rain fraction and rain intensity

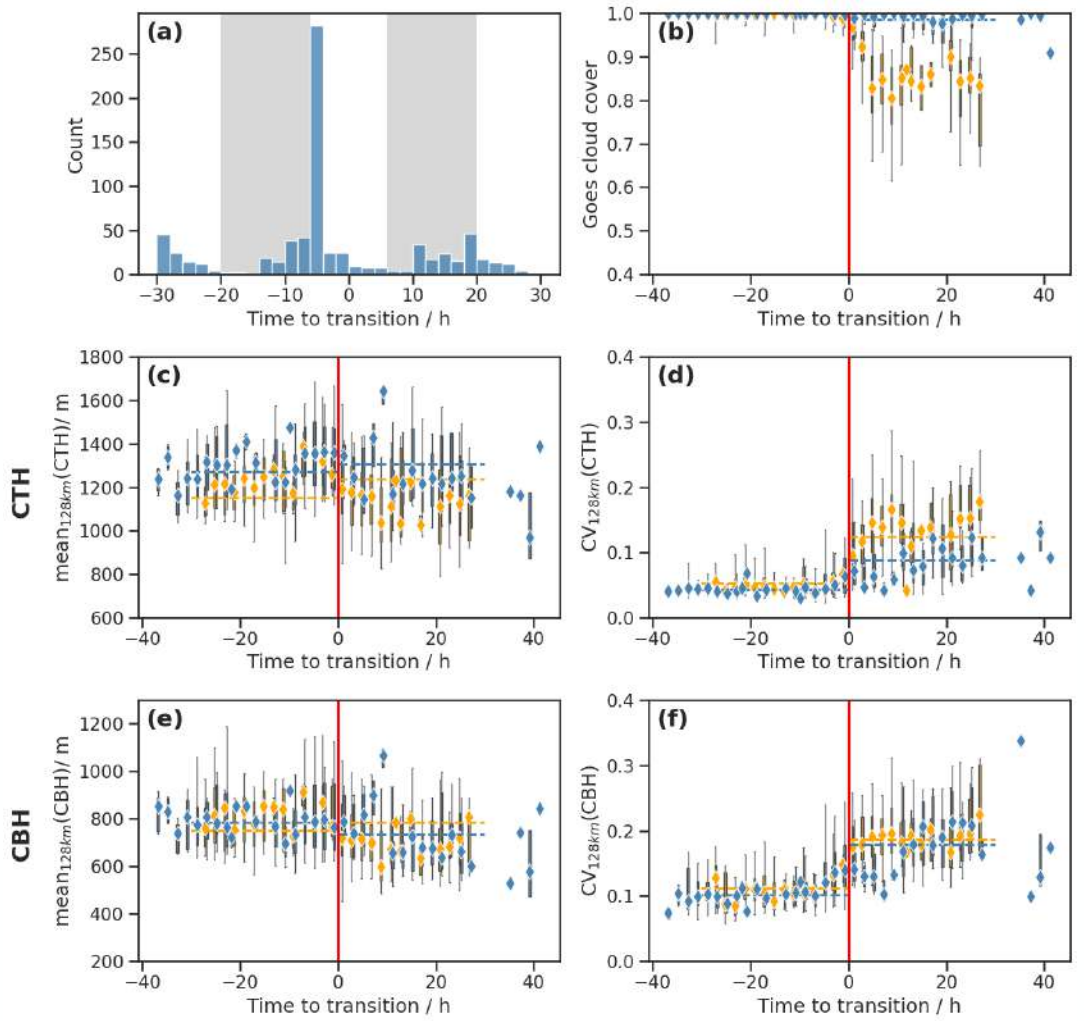


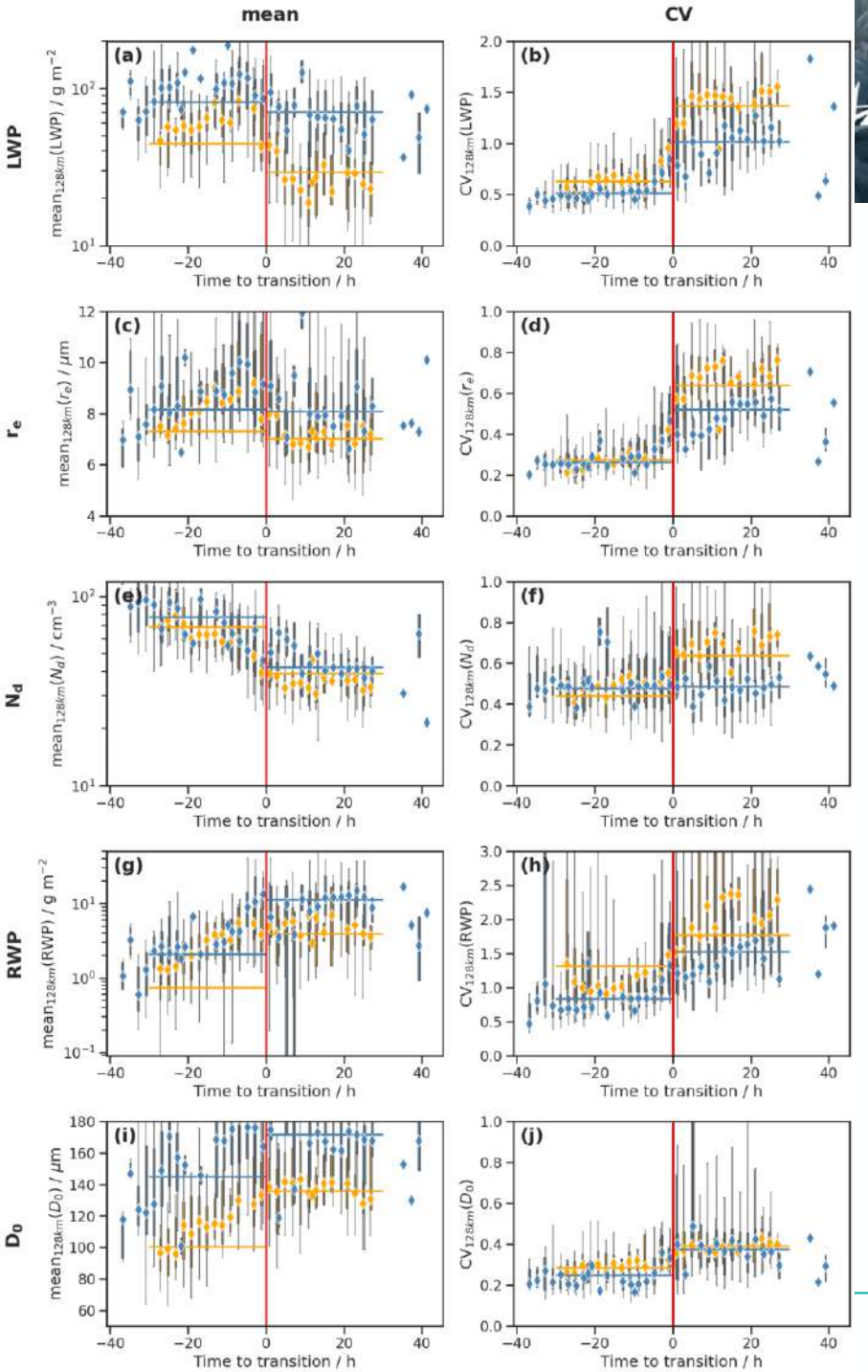









(a)
Count
Time to transition / h
(b)
Goes cloud cover
Time to transition / h
CTH
(c)
mean128km(CTH)/ m
Time to transition / h
(d)
CV128km(CTH)
Time to transition / h
CBH
(e)
mean128km(CBH)/ m
Time to transition / h
(f)
CV128km(CBH)
Time to transition / h


mean
CV
LWP
(a)
mean128km(LWP) / g m−2
Time to transition / h
(b)
CV128km(LWP)
Time to transition / h
re
(c)
mean128km(re) / μm
Time to transition / h
(d)
CV128km(re)
Time to transition / h
Nd
(e)
mean128km(Nd) / cm−3
Time to transition / h
(f)
CV128km(Nd)
Time to transition / h
RWP
(g)
mean128km(RWP) / g m−2
Time to transition / h
(h)
CV128km(RWP)
Time to transition / h
D0
(i)
mean128km(D0) / μm
Time to transition / h
(j)
CV128km(D0)
Time to transition / h