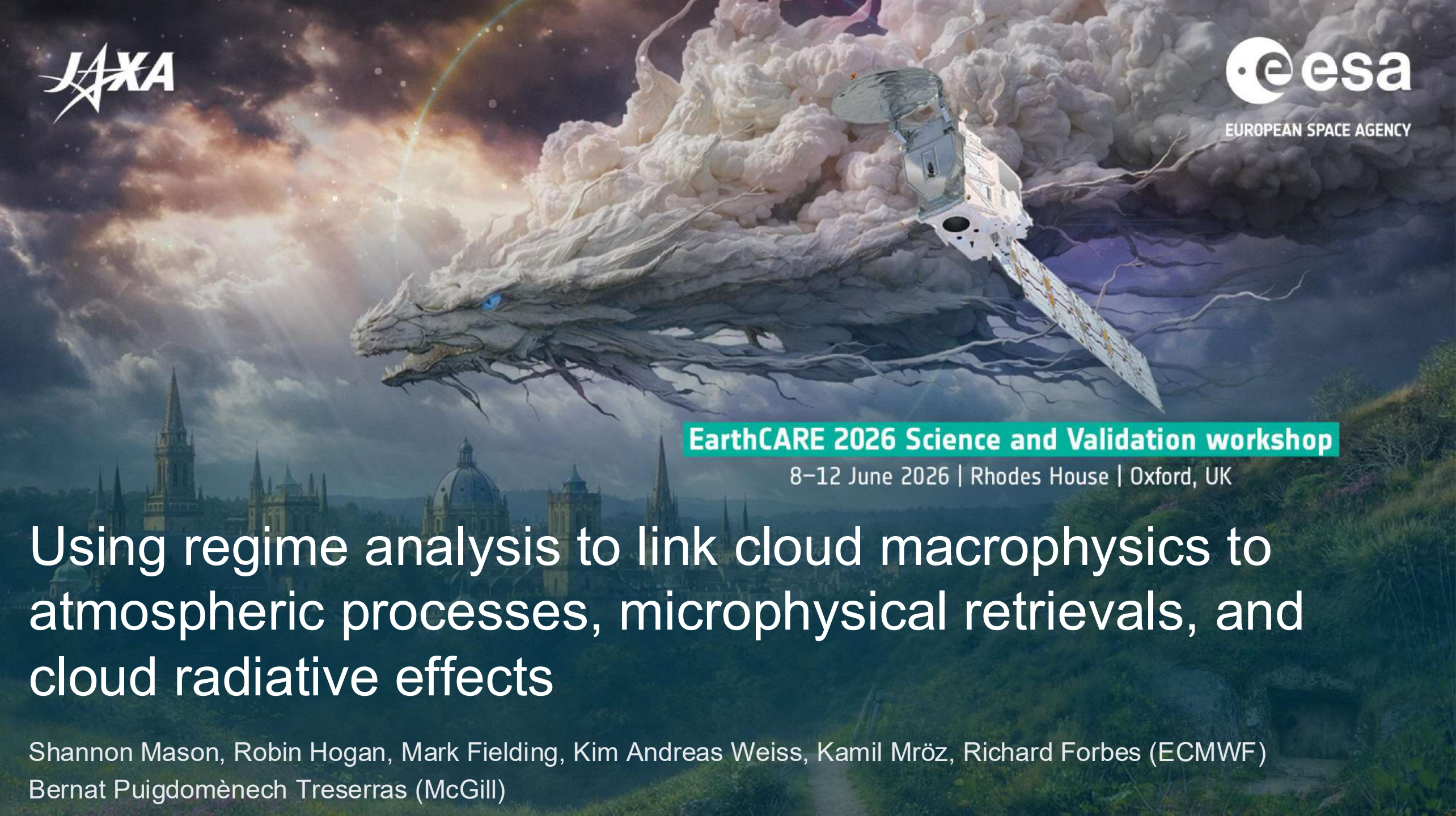


Using regime analysis to link cloud macrophysics to atmospheric processes, microphysical retrievals, and cloud radiative effects

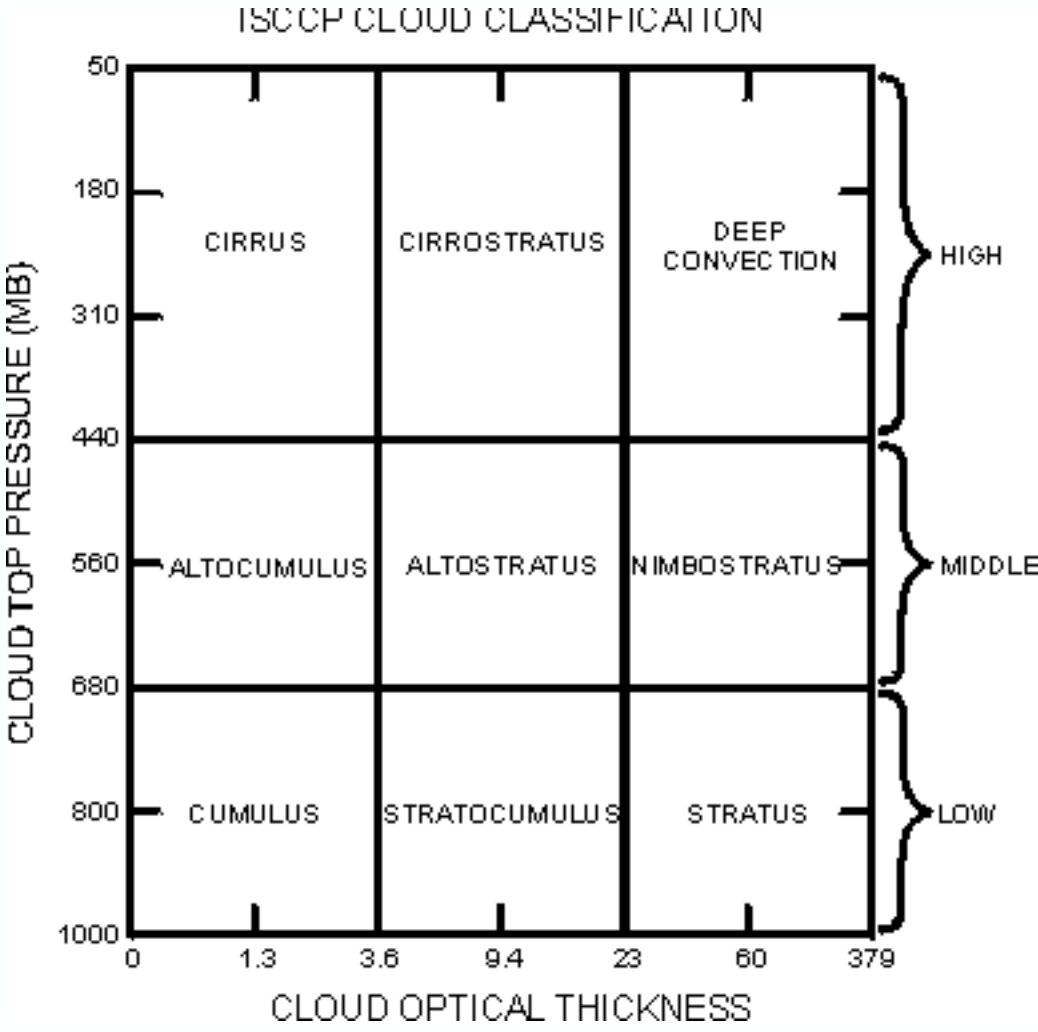
Shannon Mason, Robin Hogan, Mark Fielding, Kim Andreas Weiss, Kamil Mröz, Richard Forbes (ECMWF)
Bernat Puigdomènech Treserras (McGill)

Motivation

Passive ”cloud regimes” or “weather states” originally derived using ISCCP (then MODIS) measurements: thermal channels for cloud-top pressure (CTP), and visible channels for cloud optical thickness (τ)

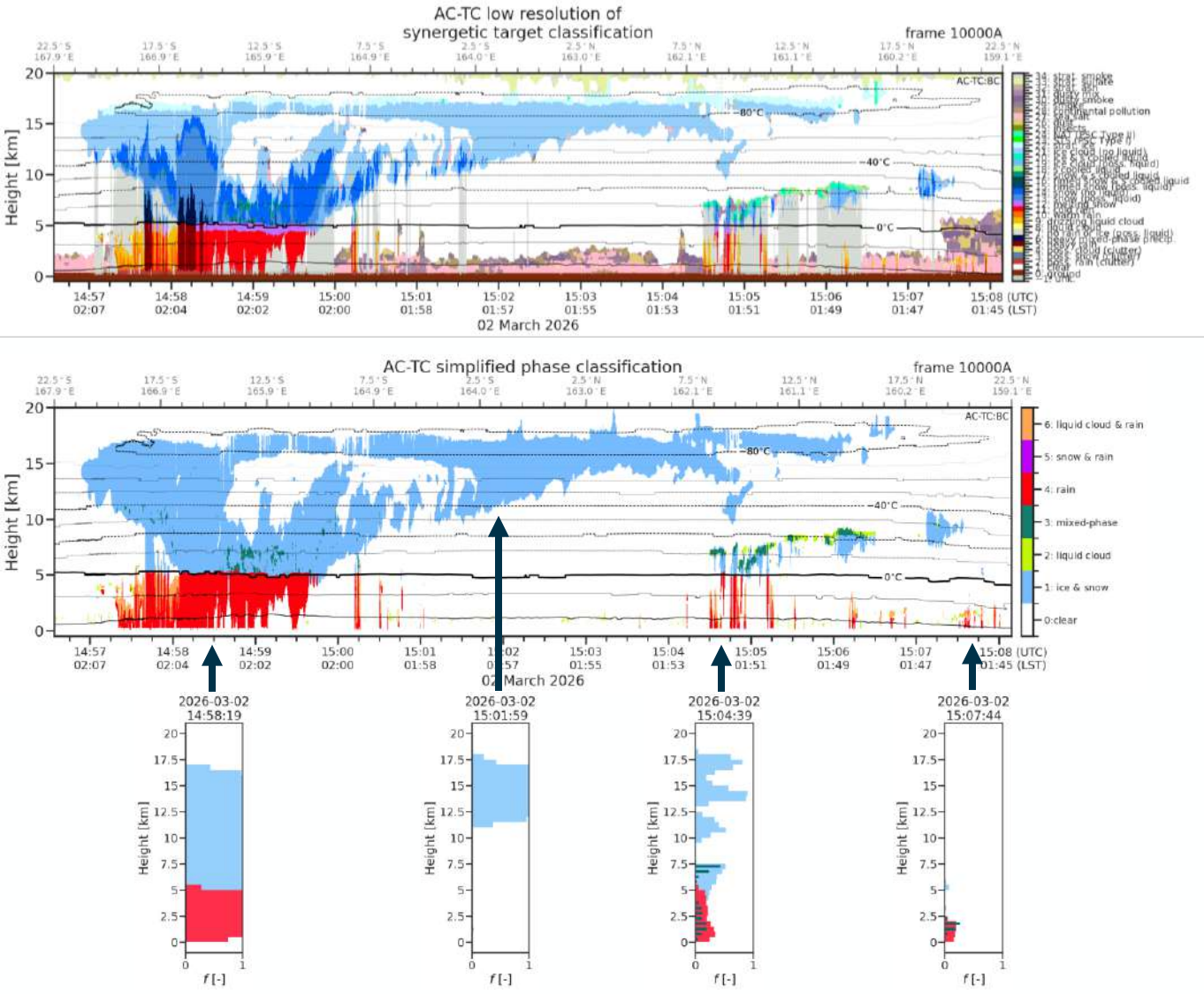
- Uncertainties around thermodynamic phase and in complex/layered scenes
- *Cloud macrophysics indicate atmospheric conditions and cloud and precipitation processes*

With radar-lidar synergy, we have a near-complete profile of cloud & precipitation including thermodynamic phase information (AC-TC product)

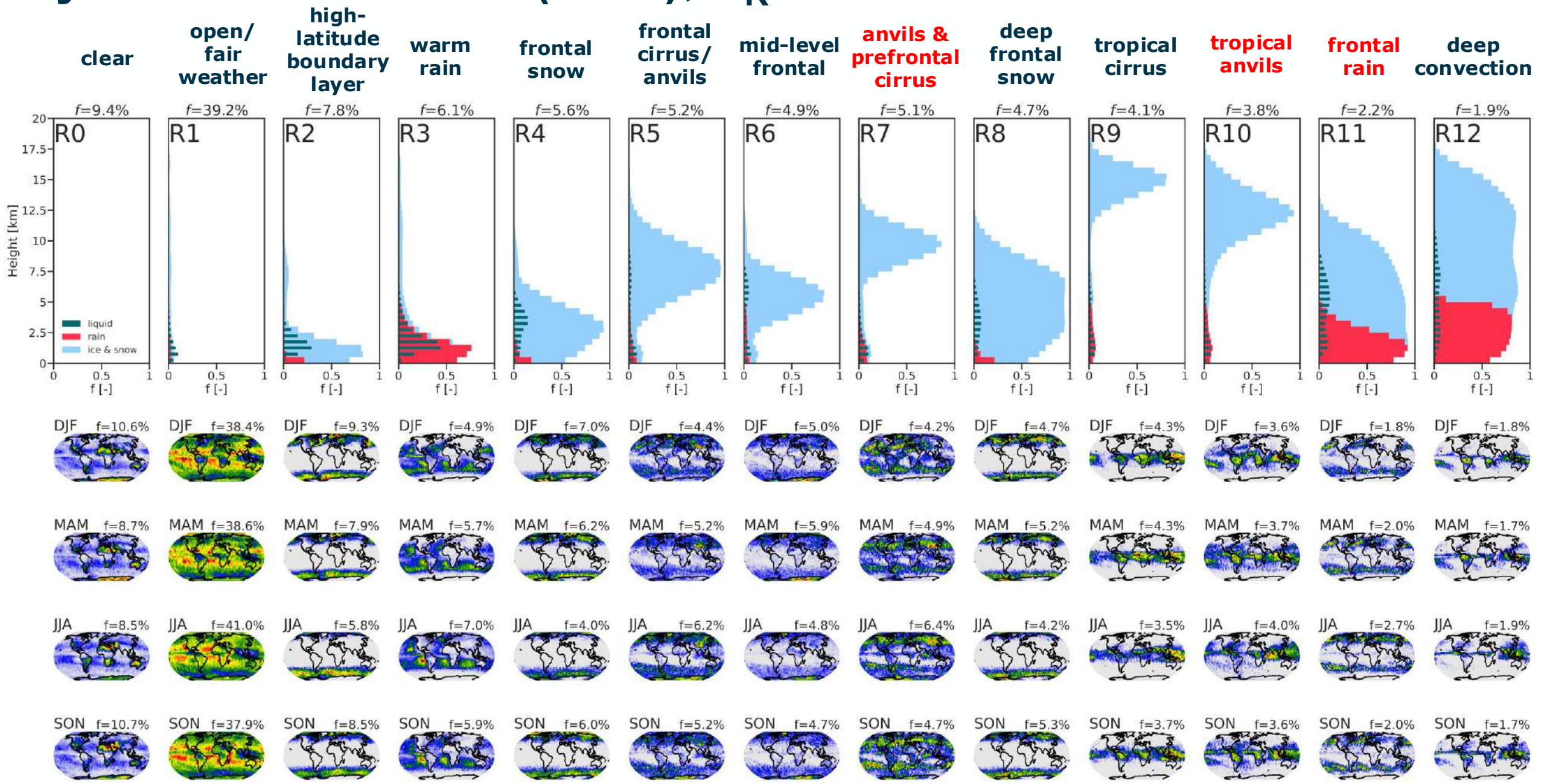


Macrophysical clustering

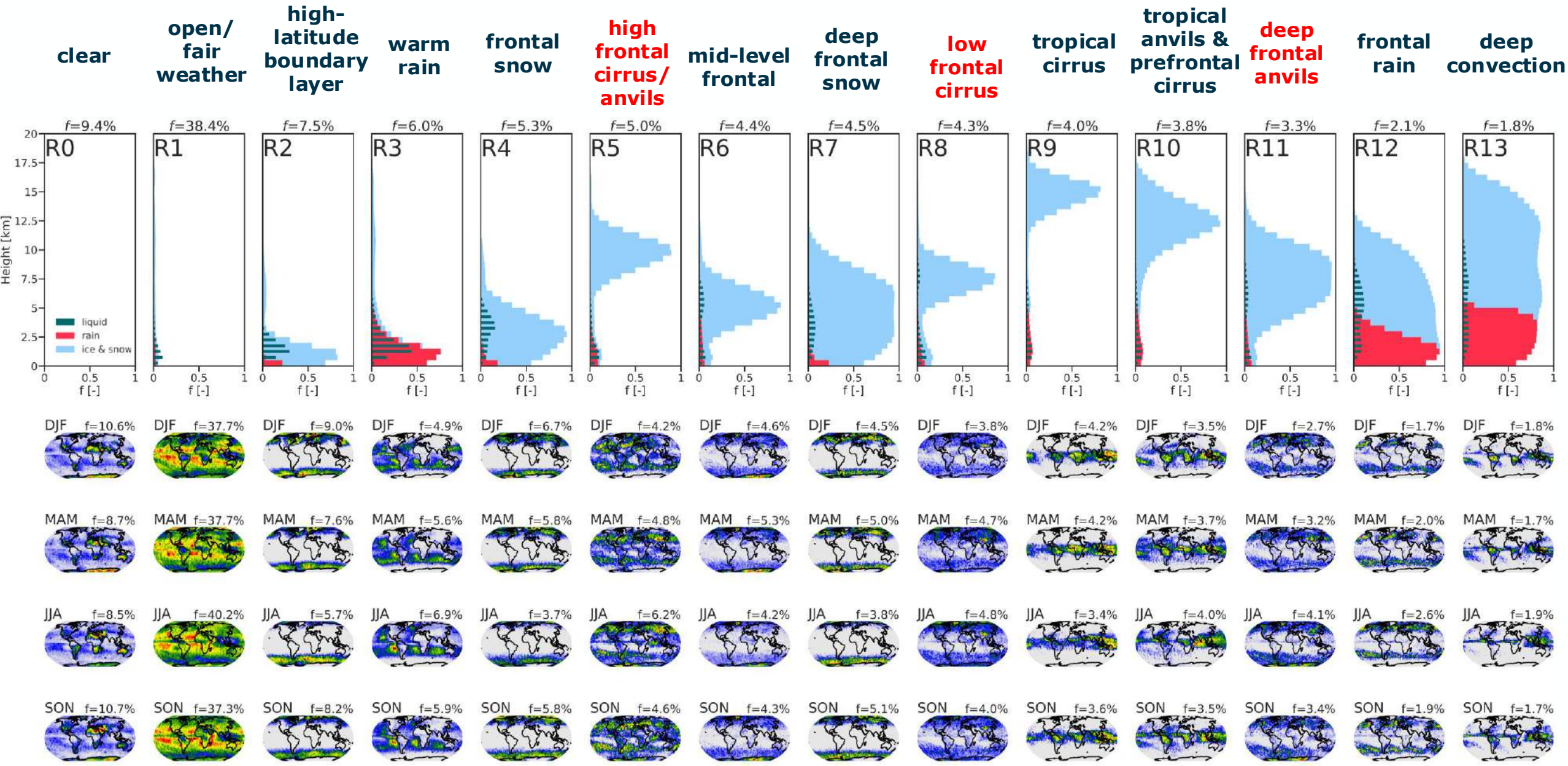
- Based on ATLID-CPR target classification (AC-TC) product
- Clustering over a simplified classification of cloud and precipitation fraction and thermodynamic phase: **ice & snow**, **rain**, **liquid**
- ~20km along-track chunks;
  500m vertical bins from 0—20 km
- K-means clustering on profiles of cloud/precipitation fraction:
  - Cluster centroids characterise recurring vertical structures
  - ***Need to select number of clusters—subjective***



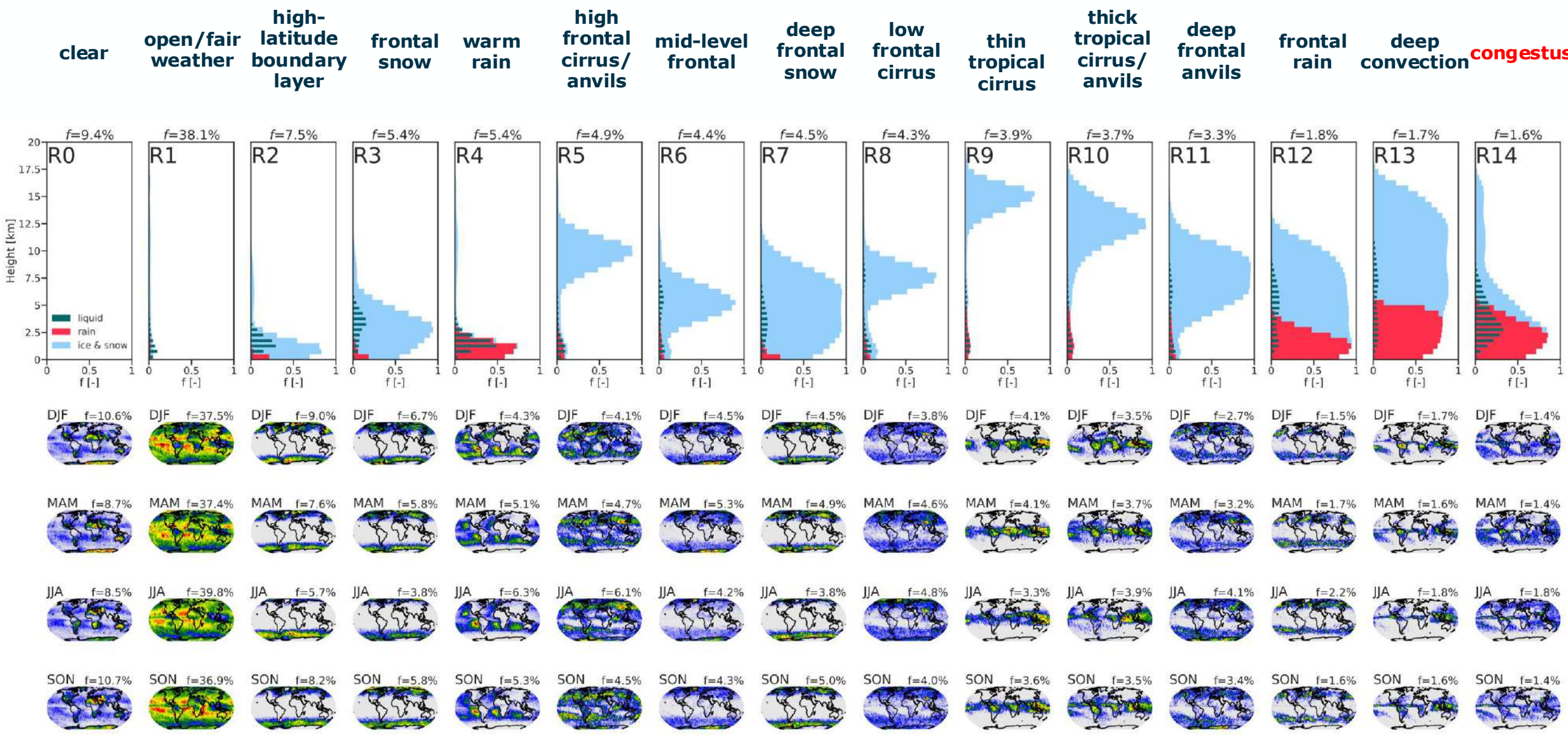
1 year of AC-TC data (2025); n_R=12

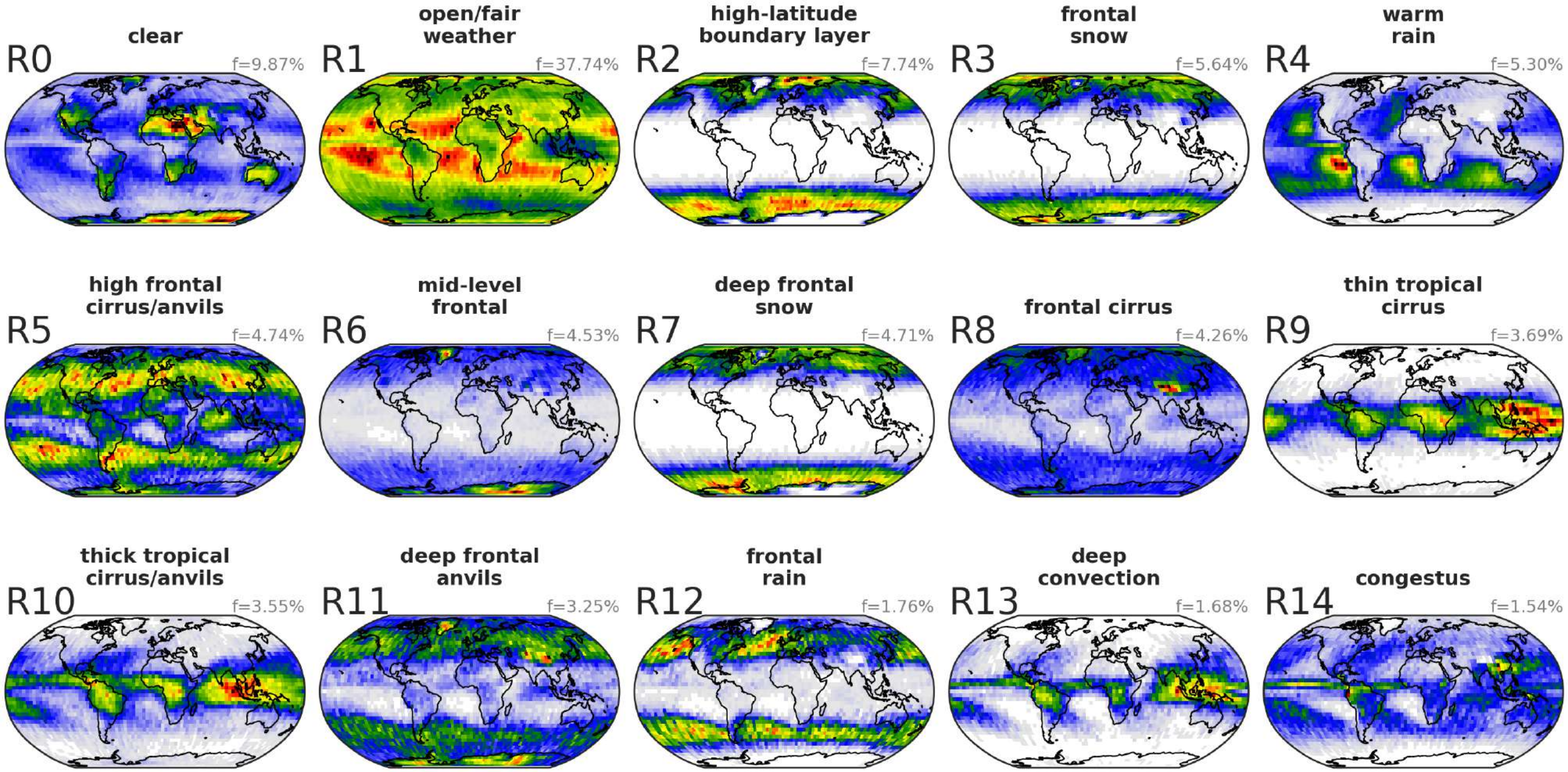


1 year of AC-TC data (2025); n_R=13

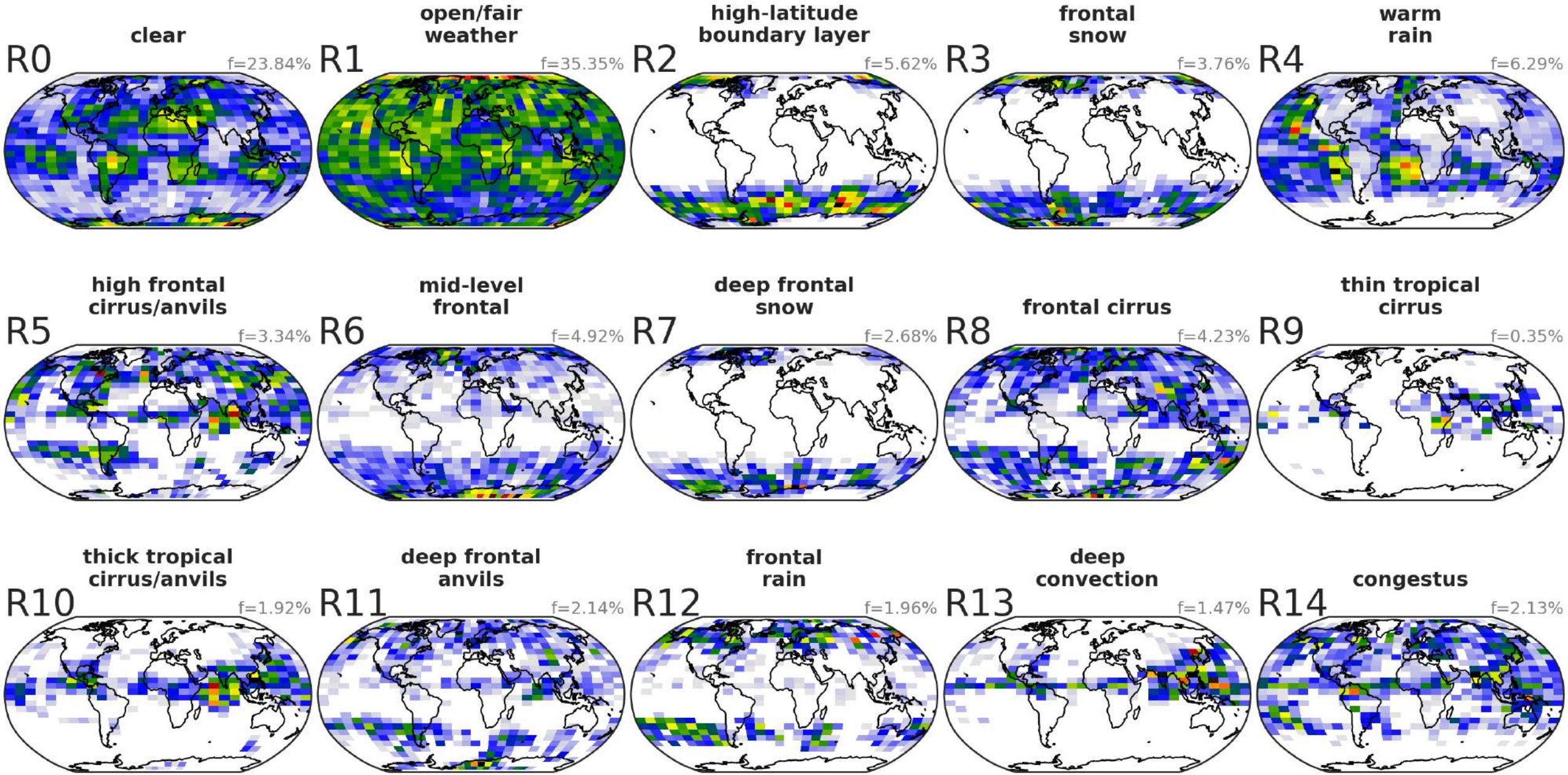


1 year of AC-TC data (2025); n_R=14





AC-TC
July 2024 to May 2026

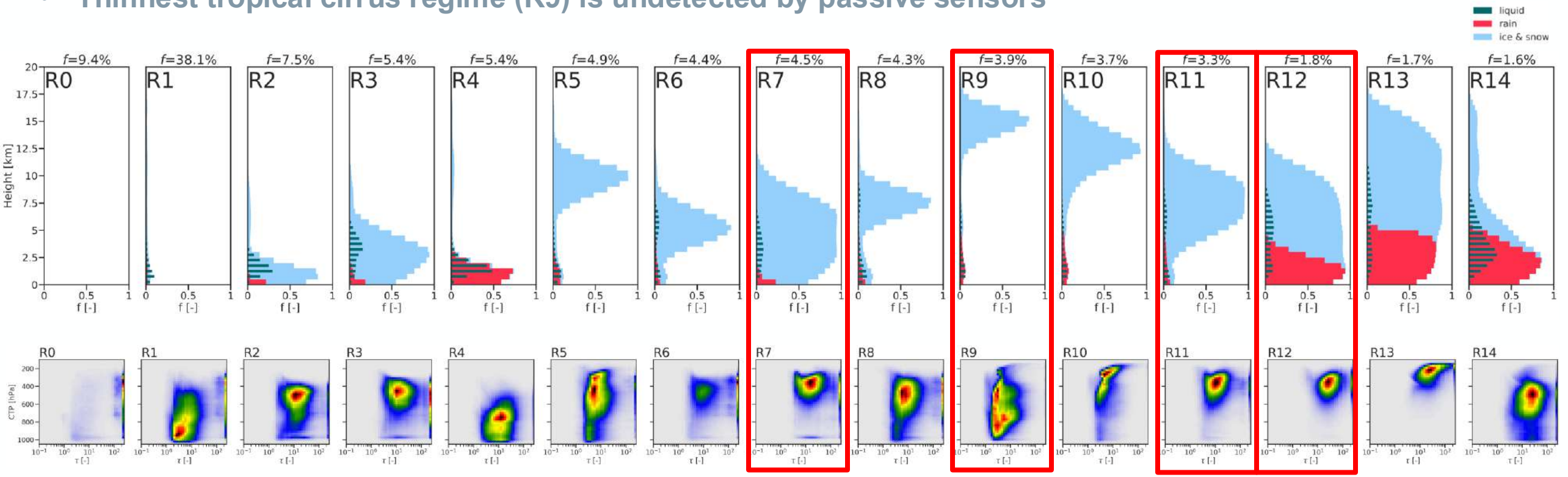


ACM-CAP:BA
July 2024

Passive cloud-top pressure/optical thickness

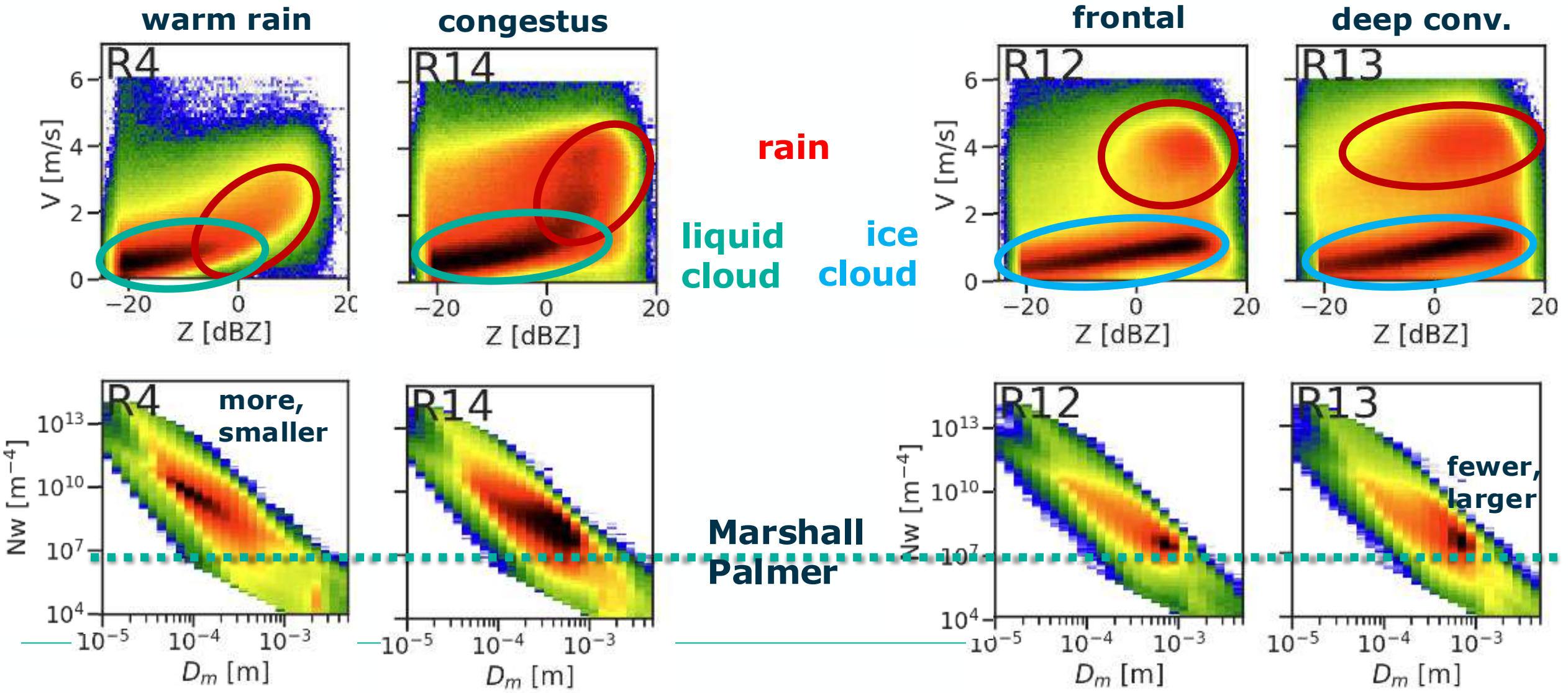
CTH-τ joint histogram used for ISCCP & MODIS cloud regime analyses

- Derived from near-nadir of MSI cloud optical properties (MSI-COP) product
- **R7 (snowing), R11 (non-precipitating) & R12 (rain) all look the same**
- **Thinnest tropical cirrus regime (R9) is undetected by passive sensors**



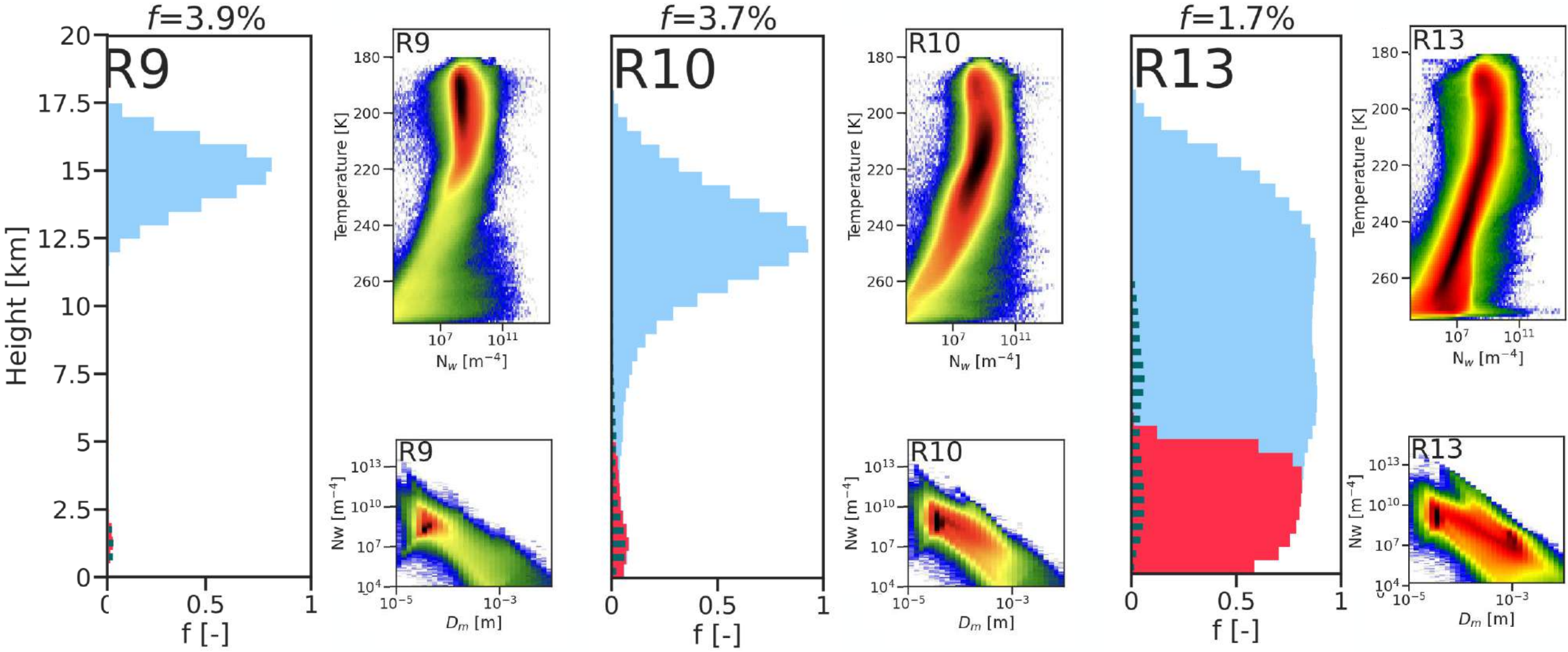
Microphysical properties: rain

Observed and retrieved (ACM-CAP) properties of rain regimes justify a distinct representation of warm vs cold rain



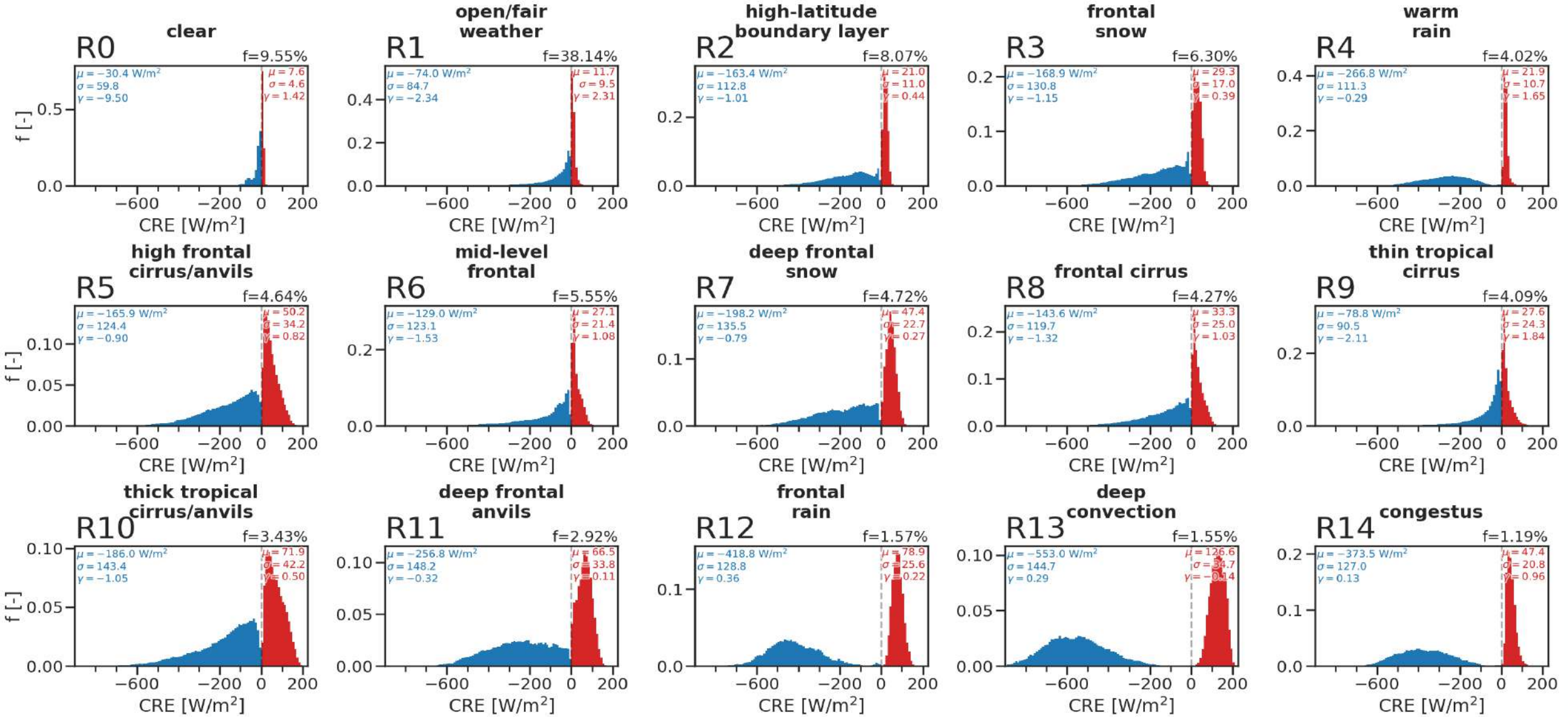
Microphysical properties (tropical ice cloud)

Thinnest cirrus has a very narrow range of retrieved ice effective radius (lidar-only retrieval)



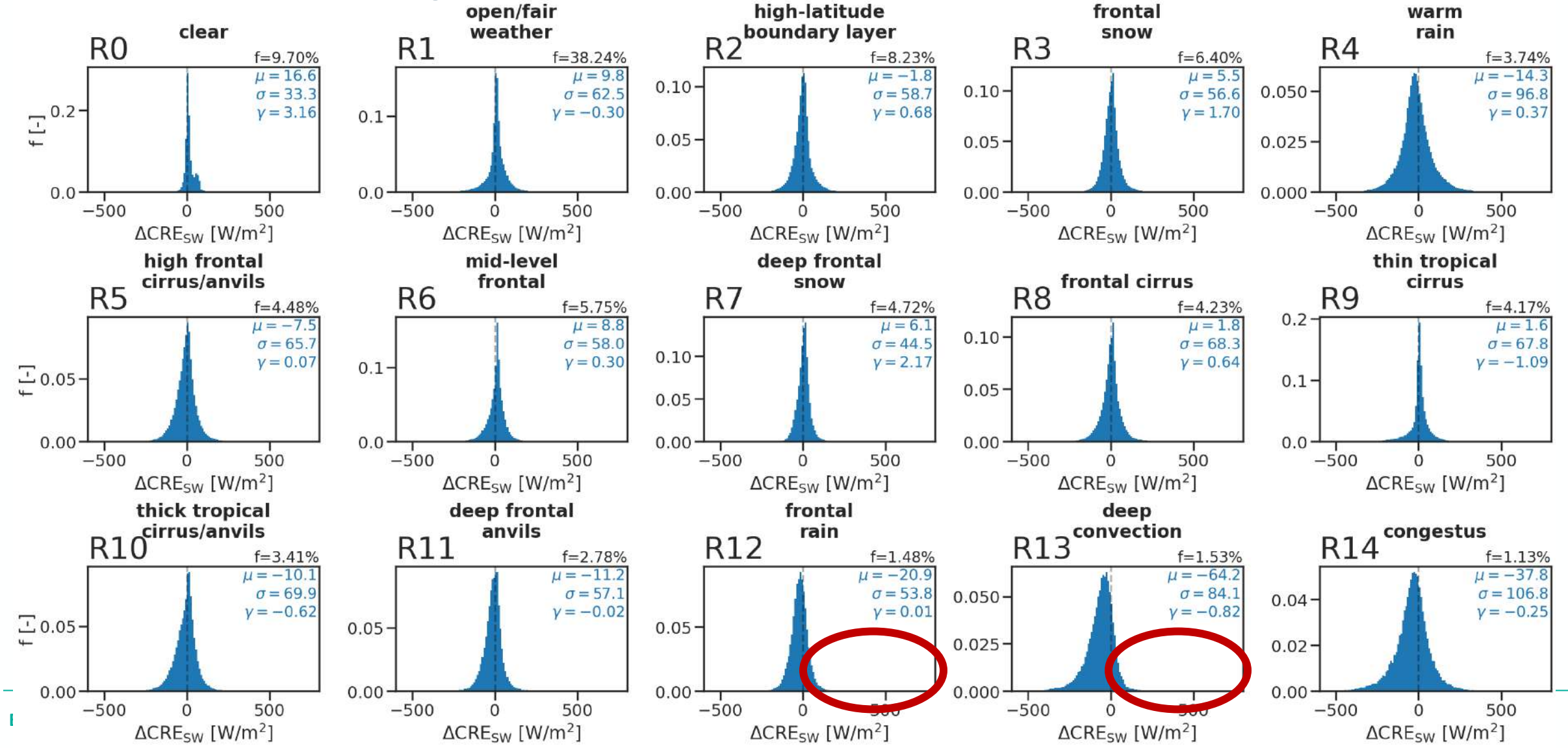
Observed cloud radiative effects (BMA-FLX)

Derived LW and SW cloud radiative effects (CRE) from BMA-FLX



Contributions to radiative closure bias (ACM-RT)

Radiative transfer modelling based on ACM-CAP reveals radiative impact of retrieval errors



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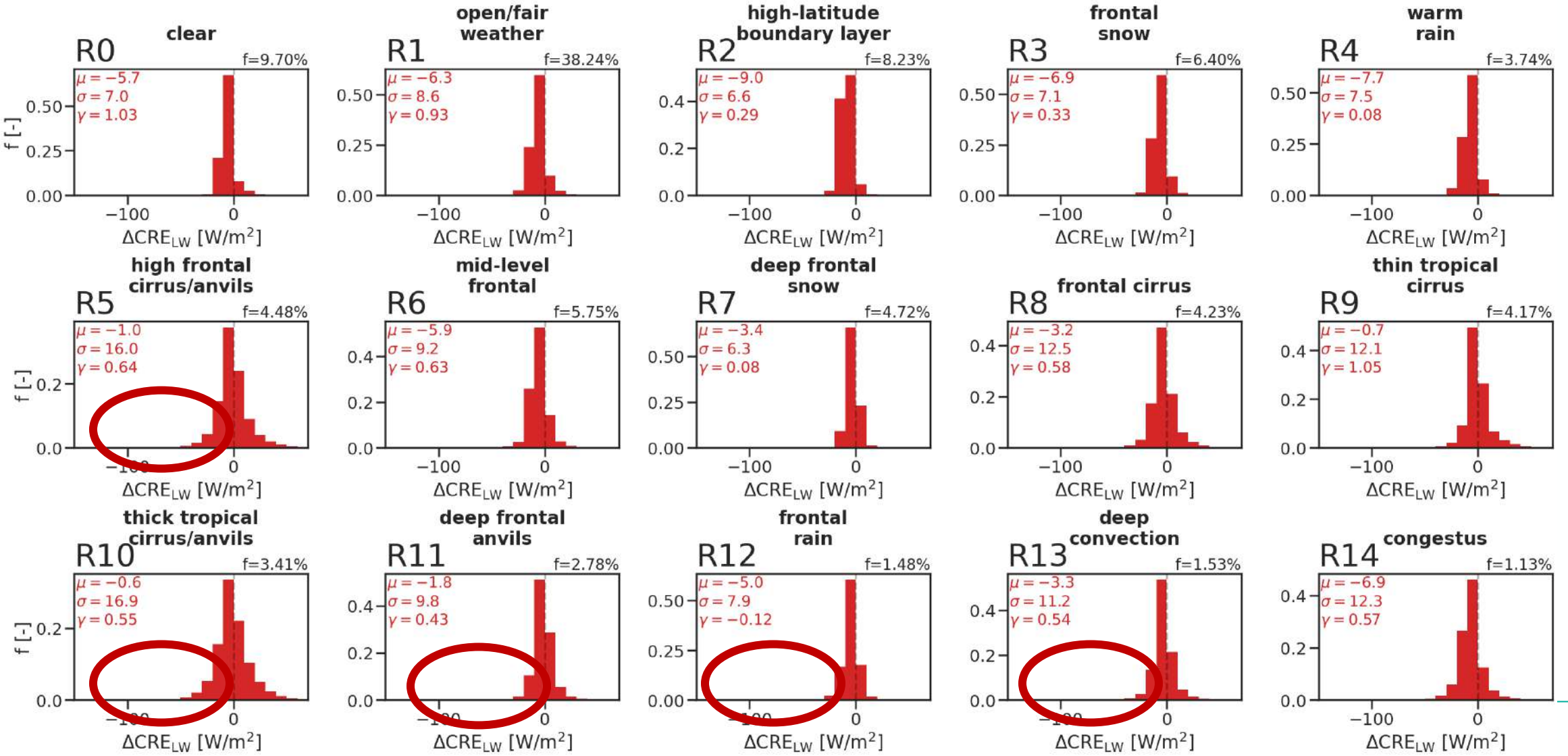


Model evaluation: missing cirrus

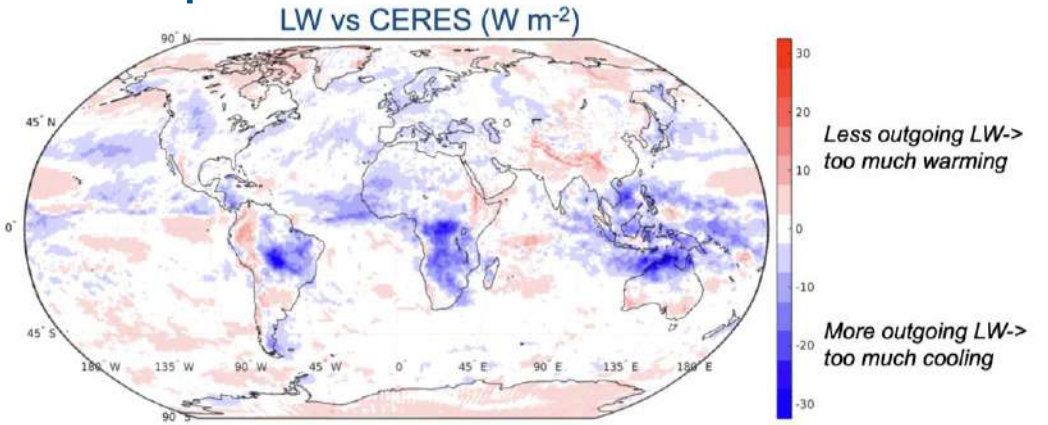
Applied to ECMWF forecast model (IFS):

- Cloud & precipitation fractions and phase information are readily available; can either fit to observed regimes or cluster model data independently.
- Using ZMVar instrument simulators developed for EarthCARE Data Assimilation

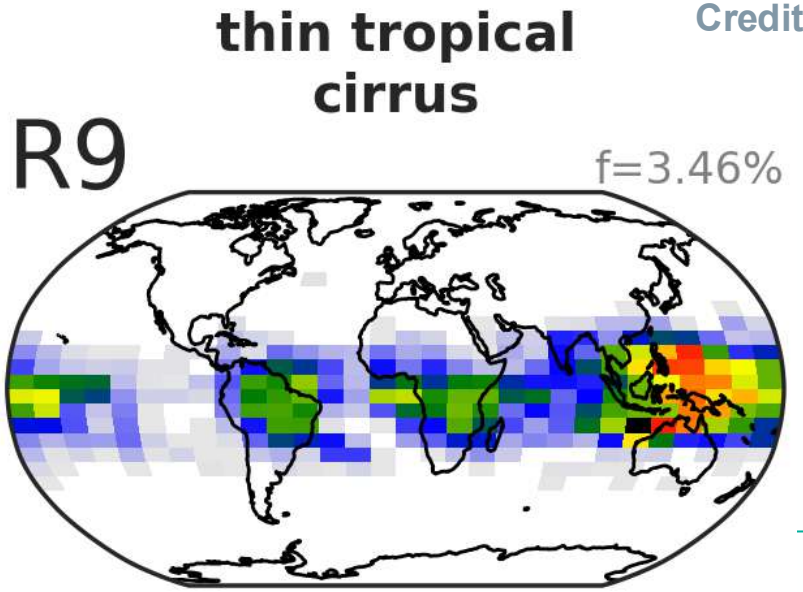
Example model bias investigation:

- LW bias vs CERES dominated by excess radiative cooling over tropical landmasses
- Strongly correlated with observed occurrence of thinnest tropical cirrus regime (R9)
- Improve representation of processes targeting this regime (Rebecca Murray-Watson, Thursday morning)

One-month Tco399 analysis experiment December 2024



Credit: Mark Fielding



Ongoing work

Cloud & precipitation regimes provide a framework for evaluation of retrievals:

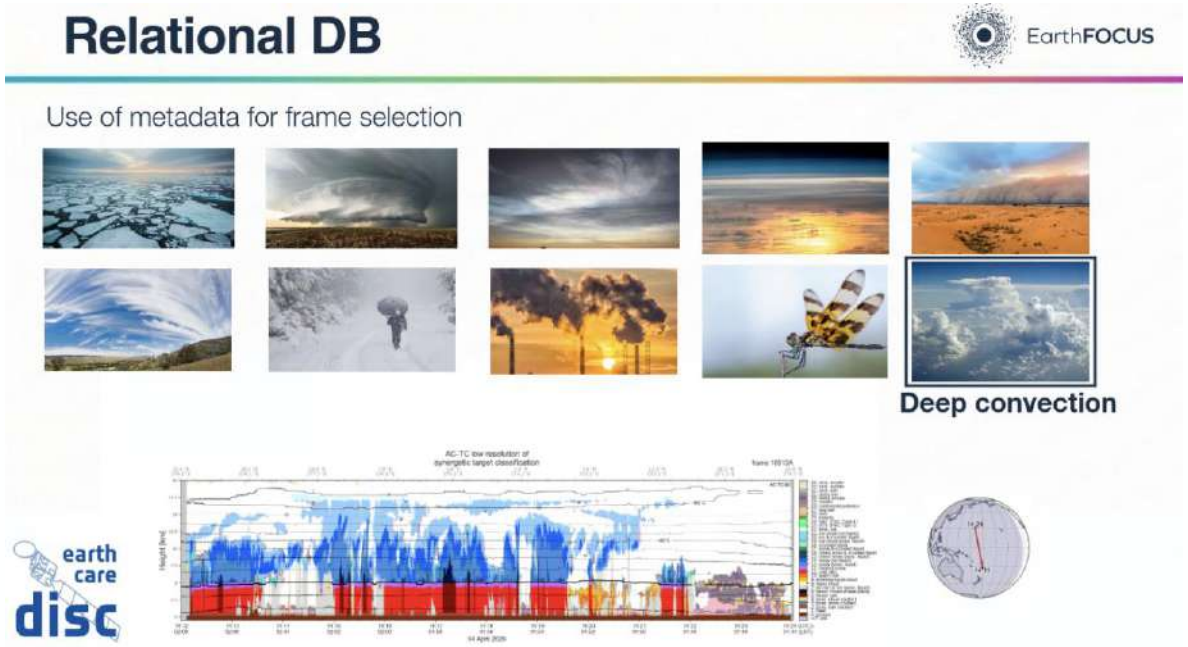
- Identifying biases & tracking changes between baselines
  saturated optical thickness issue in ACM-CAP:BA caused radiative closure issues in both LW & SW; fixed in BC
- **macrophysics → retrieved microphysics → radiative properties → radiative closure biases**

Model evaluation:

- Link outstanding model biases to processes/parameterizations
- Decompose radiative biases into contributions of each regime: frequency of occurrence vs microphysical properties errors

Uses with EarthCARE data:

- To be included in future version of AC-TC: lightweight dataset used to subset over any EarthCARE product
- Forthcoming EarthCARE ATLAS: search by regime, link statistics to case study selection



Credit: Bernat Puigdomènech Treserras