Preparation for global data assimilation of EarthCARE/CPR at JMA

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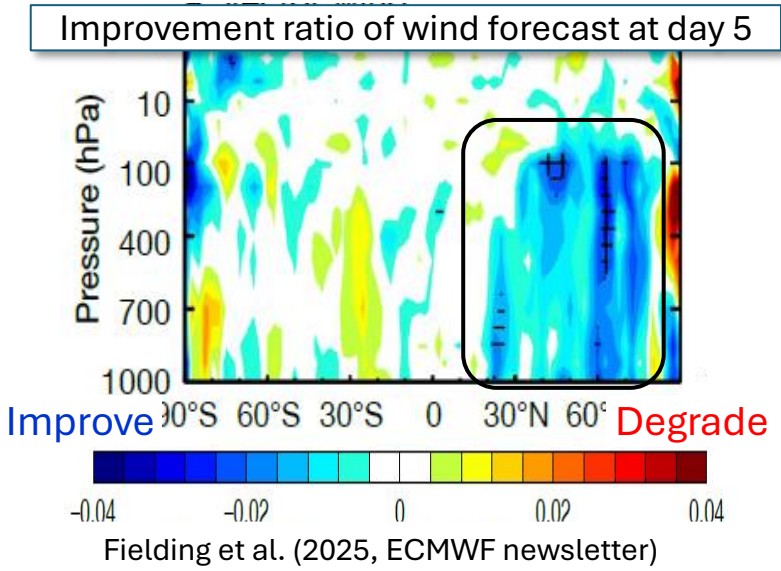
Background and Objectives

- Cloud Profiling Radar (CPR)
  - CloudSat/CPR (28 Apr 2006)
  - Enhance our understanding of cloud process and improve NWP/climate models
- Assimilation of CPR
  - Limited studies
    - ← Small coverage, Challenges in model simulation and data assimilation processings
  - Promising results at ECMWF (Fielding & Janisková 2020; Janisková & Fielding 2020)
  - Unique info that passive obs does not have: Vertically resolved cloud/precipitation
- Objectives of this study
  - Investigate feasibility of assimilation of EarthCARE/CPR Z in JMA's global system
  - Expect synergy with all-sky IR radiance assimilation
- → Examined Z simulation and developed assimilation procedures



Fielding et al. (2025, ECMWF newsletter)

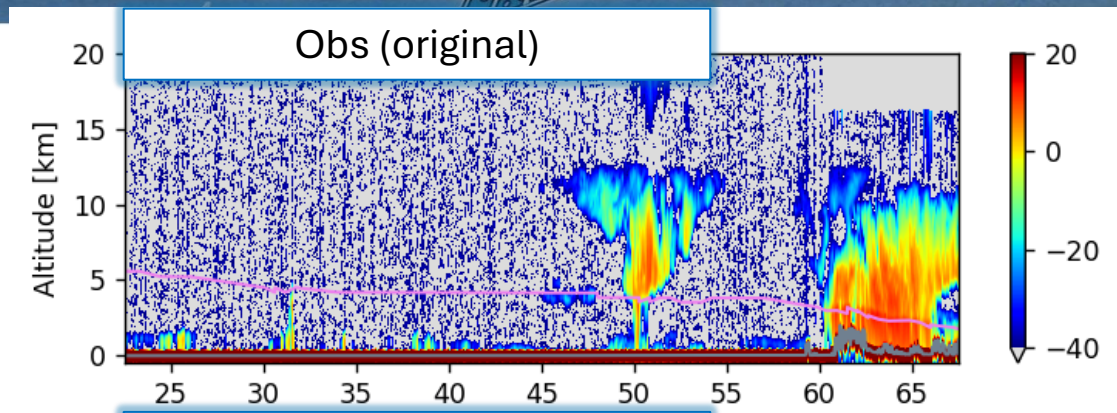
Model, Simulator and Observation

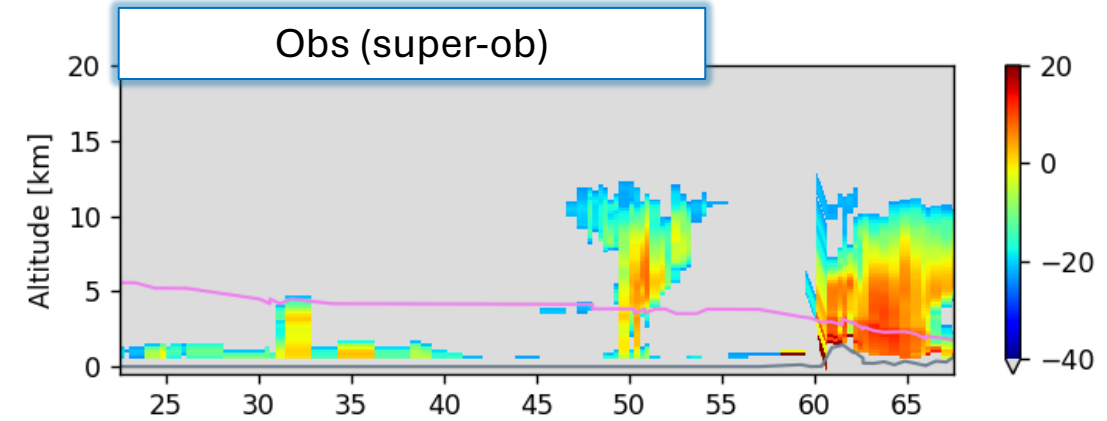
- Model: Global Spectral Model (GSM): JMA's operational model (as of 2020)
  - Horizontal spacing of 20km, 100 layers up to 0.01 hPa
  - Convection scheme： Prognostic Arakawa-Schubert → Convective clouds
  - Large-scale cloud: Smith scheme (Smith 1990, QJRMS) → Stratus clouds
  - Hydrometeor: cloud water+ice, rain flux, snow flux
- Simulator: RTTOV ver13.0
  - Optical parameters of cloud water, cloud ice, rain and snow (Geer 2021, AMT)
  - Calculate attenuated reflectivity factor (Z), and its Jacobian
  - The same fraction for all hydrometeors
- Observations: EarthCARE/CPR L2A CPR_ECO
  - version vBa, 10km integration data
  - Create super-ob (~55 km based on 4DVar inner-loop scale) by averaging reliable data
    - Select reliable data over -30 dBZ, integrated_radar_reflectivity_flag_10km=0, and SNR>-10 [dB]
    - Remove mirror-echo-flagged bins and multiple-scattering-flagged columns
- Examination period: 3-24 Aug 2024

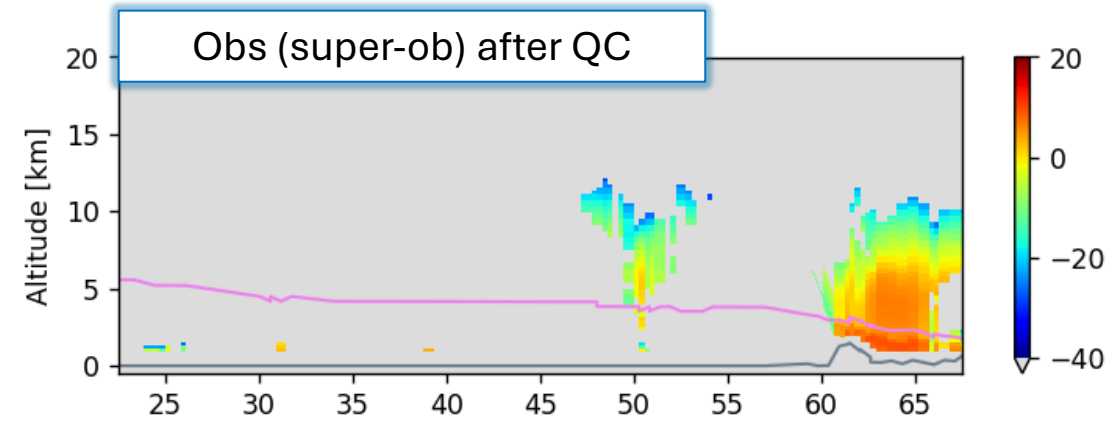
Quality Control (QC)

- Reliability
  - Both observed and simulated Z ≥ -30 dBZ
  - Higher than 1km in altitude to avoid ground clutter
- Homogeneity
  - Standard Deviation < 20 dBZ, cloud fraction > 50 % and effective data number (Npix) > 5
    - These statistics are calculated from effective data composing a super-ob
- Consistency btw obs and sim
  - |Obs-Sim| < 24 dBZ
- These thresholds, especially in homogeneity check, are still under evaluation

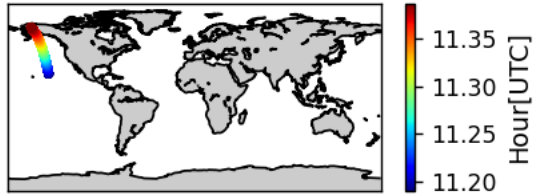
Example of obs and simulation for CPR Z [dBz]

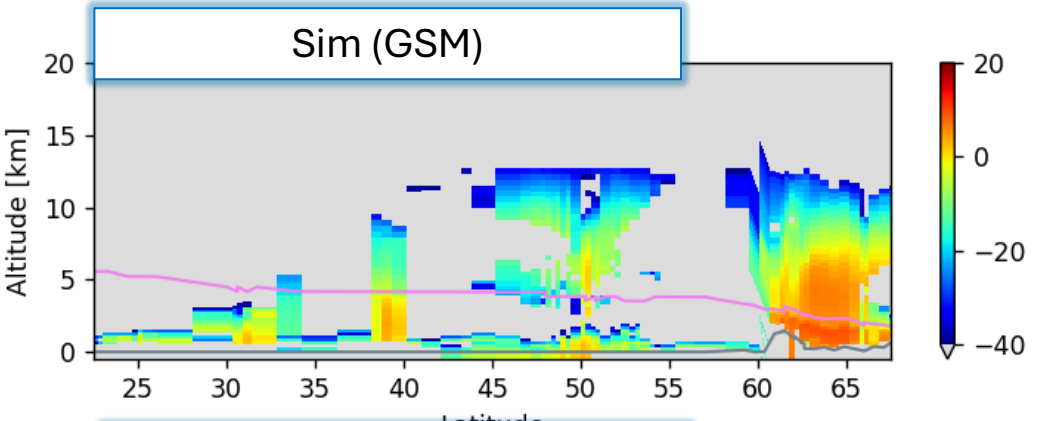


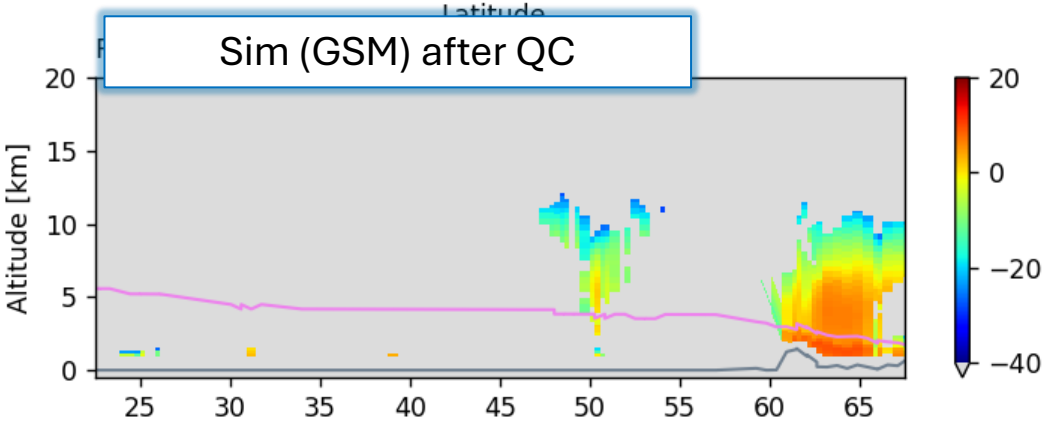




- 12UTC, 3 Aug, 2024

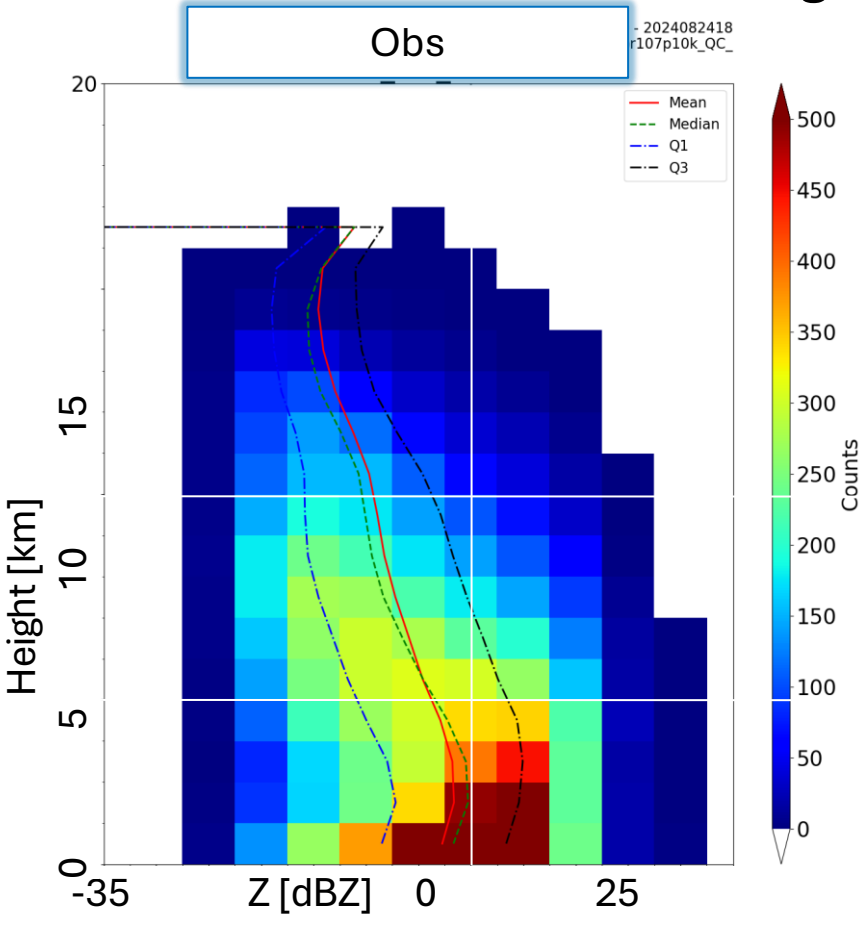


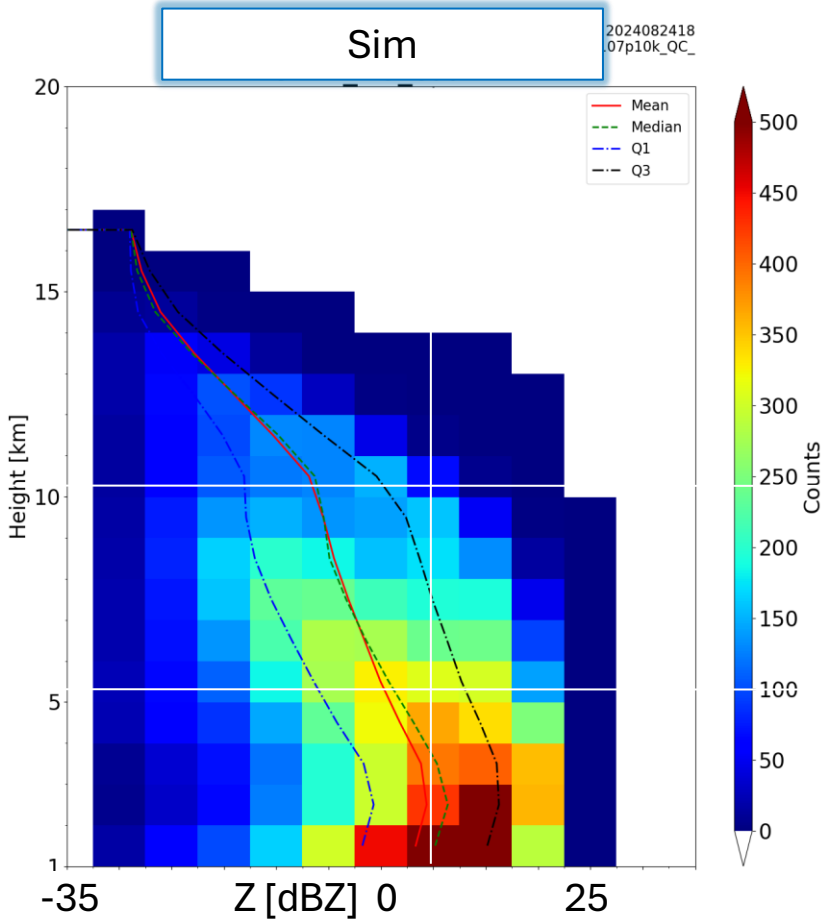


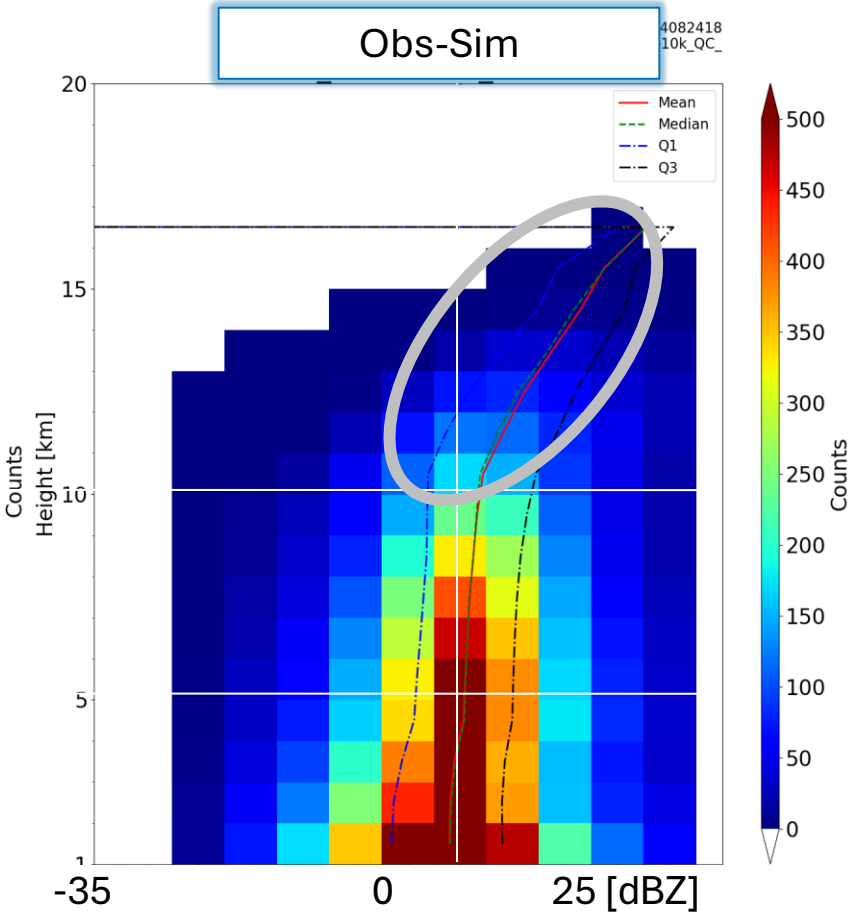


2D-histogram in Z and Height

- 3-24 Aug. 2024
- Simulation underestimate Z above 10 km
  - GSM underestimates high clouds

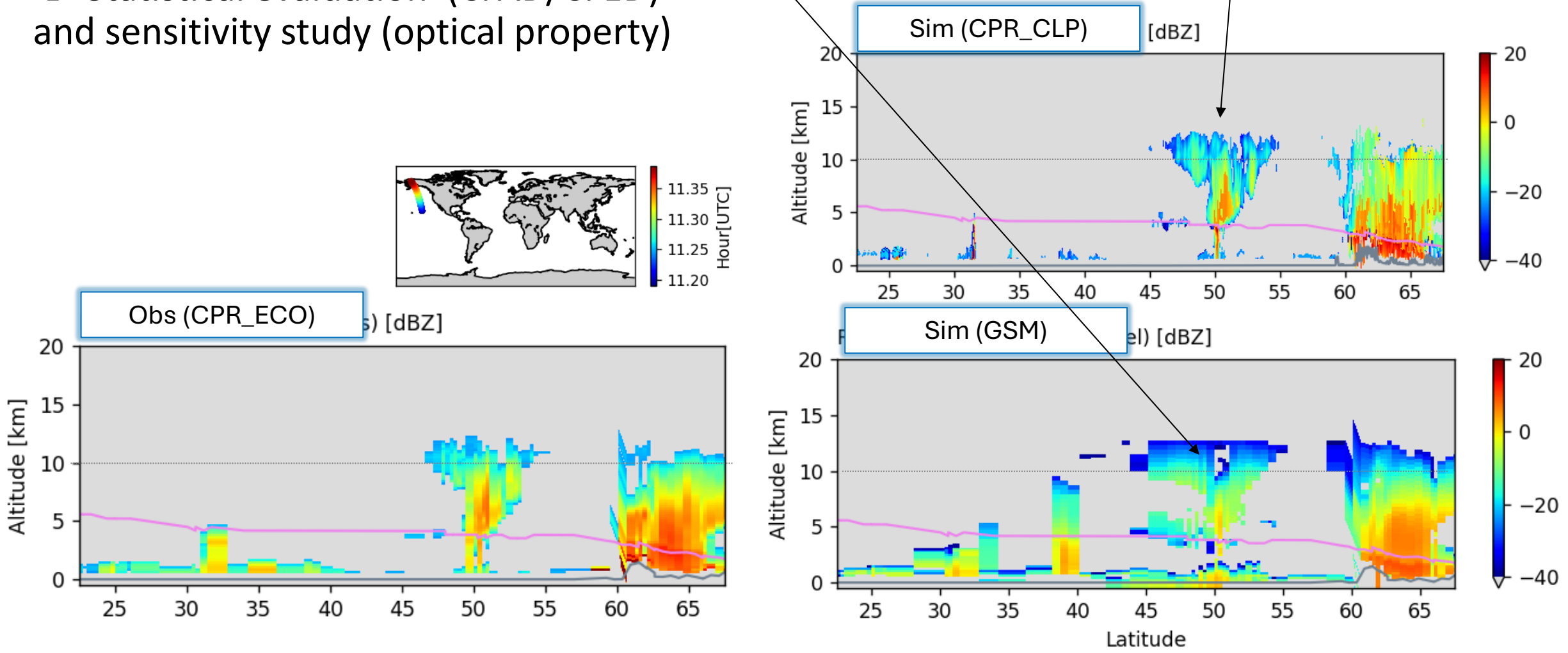






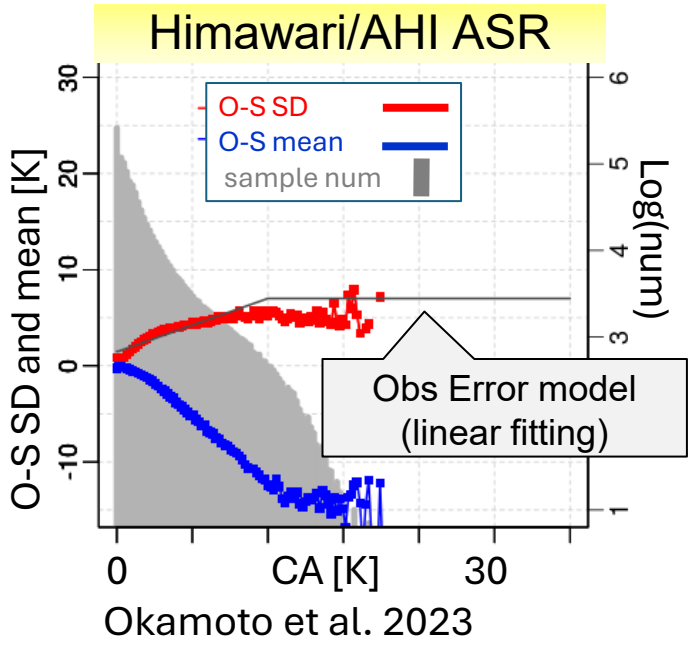
Investigate bias sources

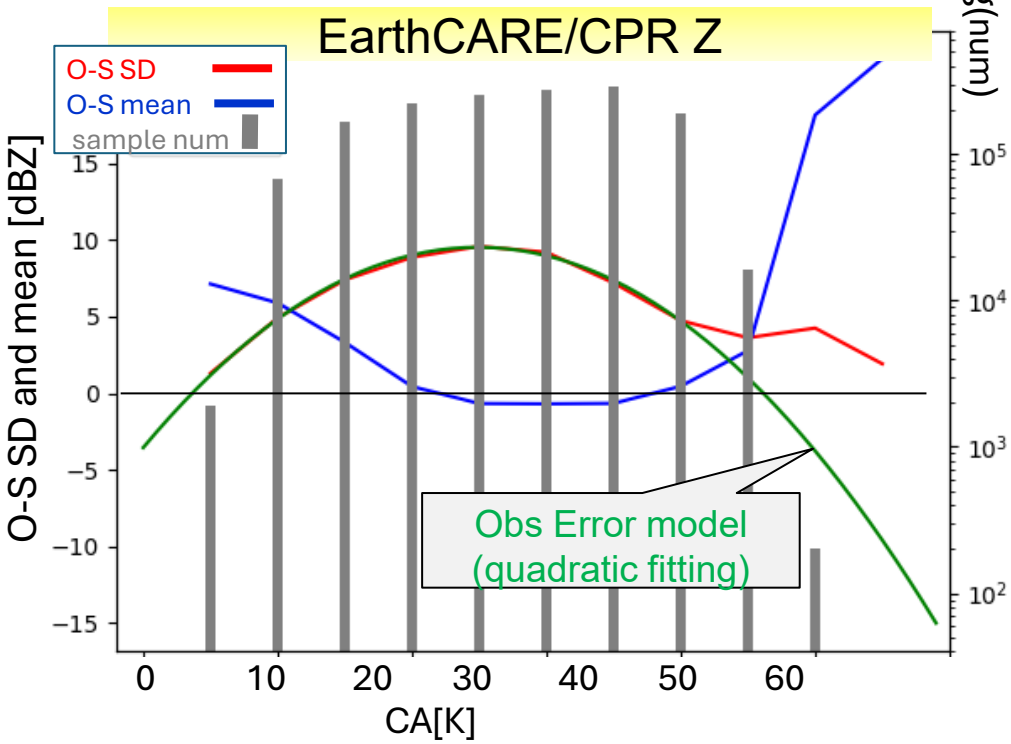
- Use more reliable cloud input (CPR_CLP) to compare GSM input
- This case suggests underestimation of not only GSM but also RTTOV above 10 km
- ➔ Statistical evaluation (CFAD/CFED) and sensitivity study (optical property)

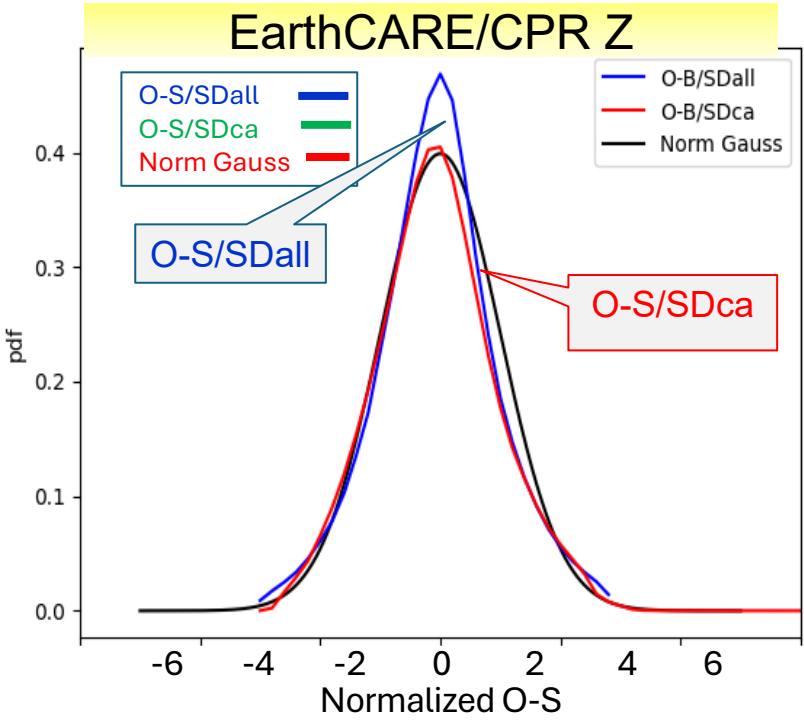


Preparation for data assimilation: Cloud effect parameter

- Cloud effect parameter is a key to all-sky radiance (ASR) assimilation
  - Cloud effect parameter for IR ASR: CA = (|O-Sclr| + |S-Sclr|)/2 (Okamoto et al. 2014)
    - O: observation, S: simulation, S:clear-sky simulation, defined in brightness temperature [K]
  - O-S SD models used as obs error model (Geer and Bauer 2011; Okamoto et al. 2023, 2034)
- Successfully apply ASR's CA to CPR Z
  - CPR's CA = (O+S)/2 + Sclr [dBZ], Sclr=-35dBZ
  - O-S normalized by the obs model shows Gaussian form



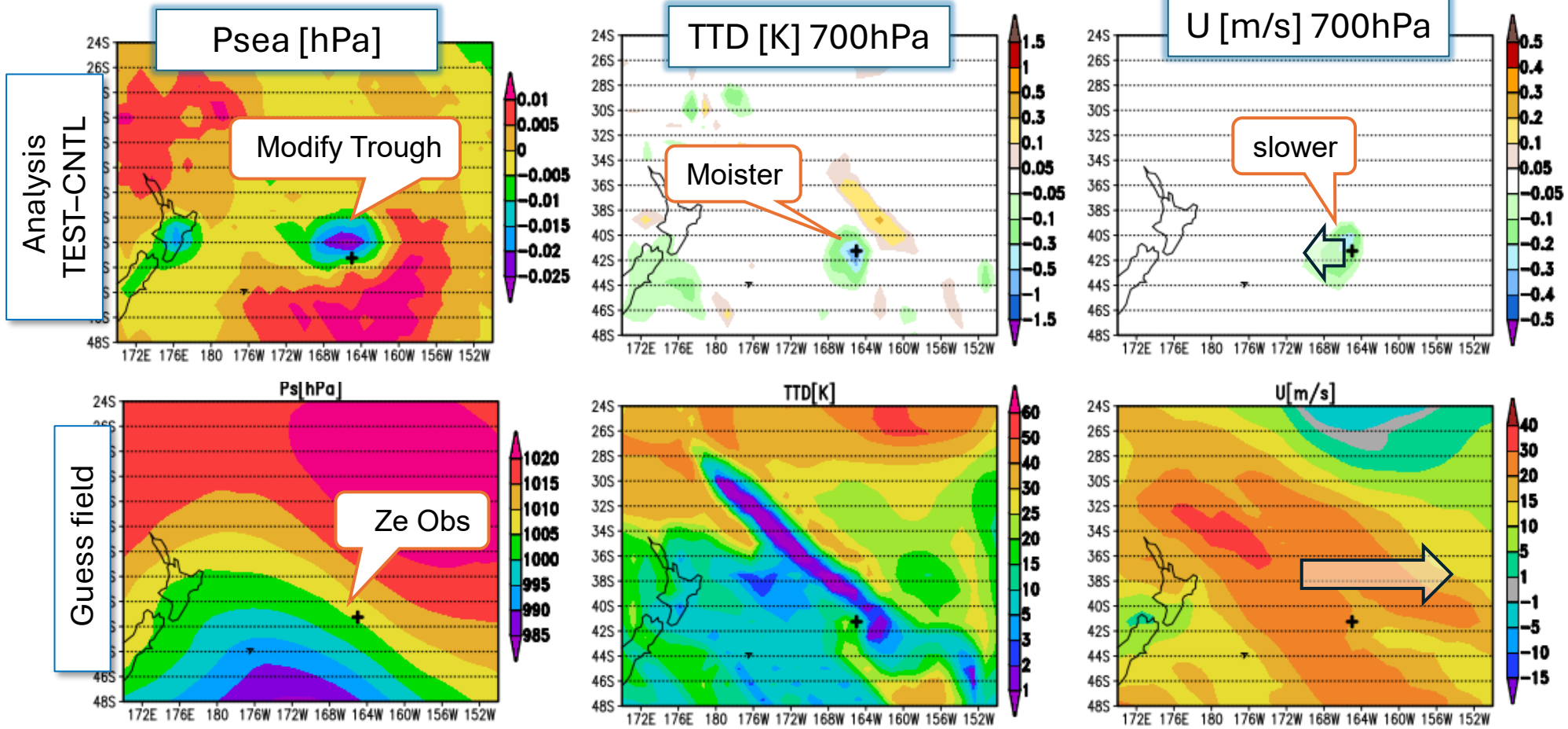




Single obs assimilation impact for CloudSat/CPR

- Upgraded the operational global data assimilation system to include CloudSat/CPR
  - However, the extension to EarthCARE/CPR is still underway
- Assimilation test for CloudSat/CPR: A single profile of Ze with Obs-Sim>0 (insufficient cloud) made a small but reasonable analysis increment

- The observation error model is not yet used
- Correct wind, pressure and humidity to slow down the moist belt passing eastward
- → Keep slightly higher humidity around obs location (→ Slightly increase clouds)



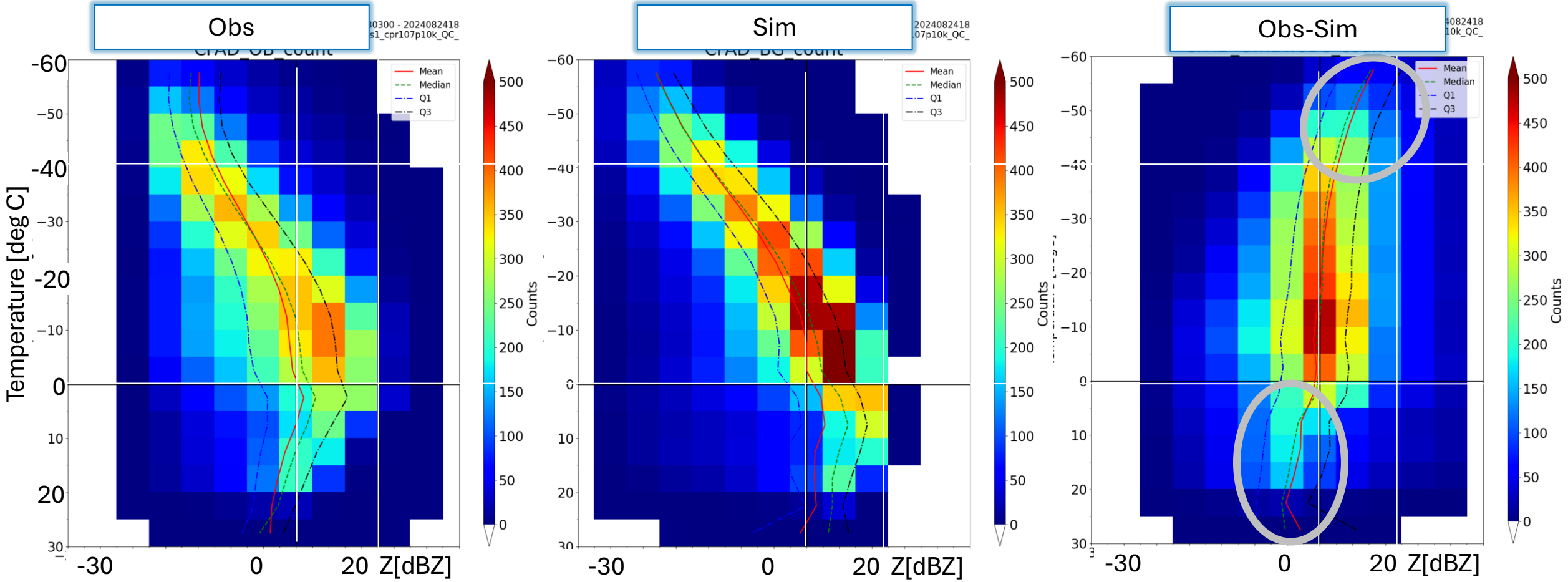
Summary

- Examine reflectivity simulation using the global DA system
  - Generally agreed with observation, but underestimated above 10km (~ -40 deg C)
  - Investigating the sources of the biases using L2a CPR_CLP
- Data assimilation development
  - The cloud effect parameter (CA) seemed work well to make an obs error model
  - Assimilation of single profile Z of CloudSat/CPR produced a small but reasonable analysis increment
- Plans
  - Investigate bias sources and sensitivity to optical parameters in more detail
  - Revise QC, especially for cloud-homogeneity (representativity)
  - Extend DA system to EarthCARE/CPR and implement assimilation experiments

Supplemental slides

2D-histogram in Z and Temperature

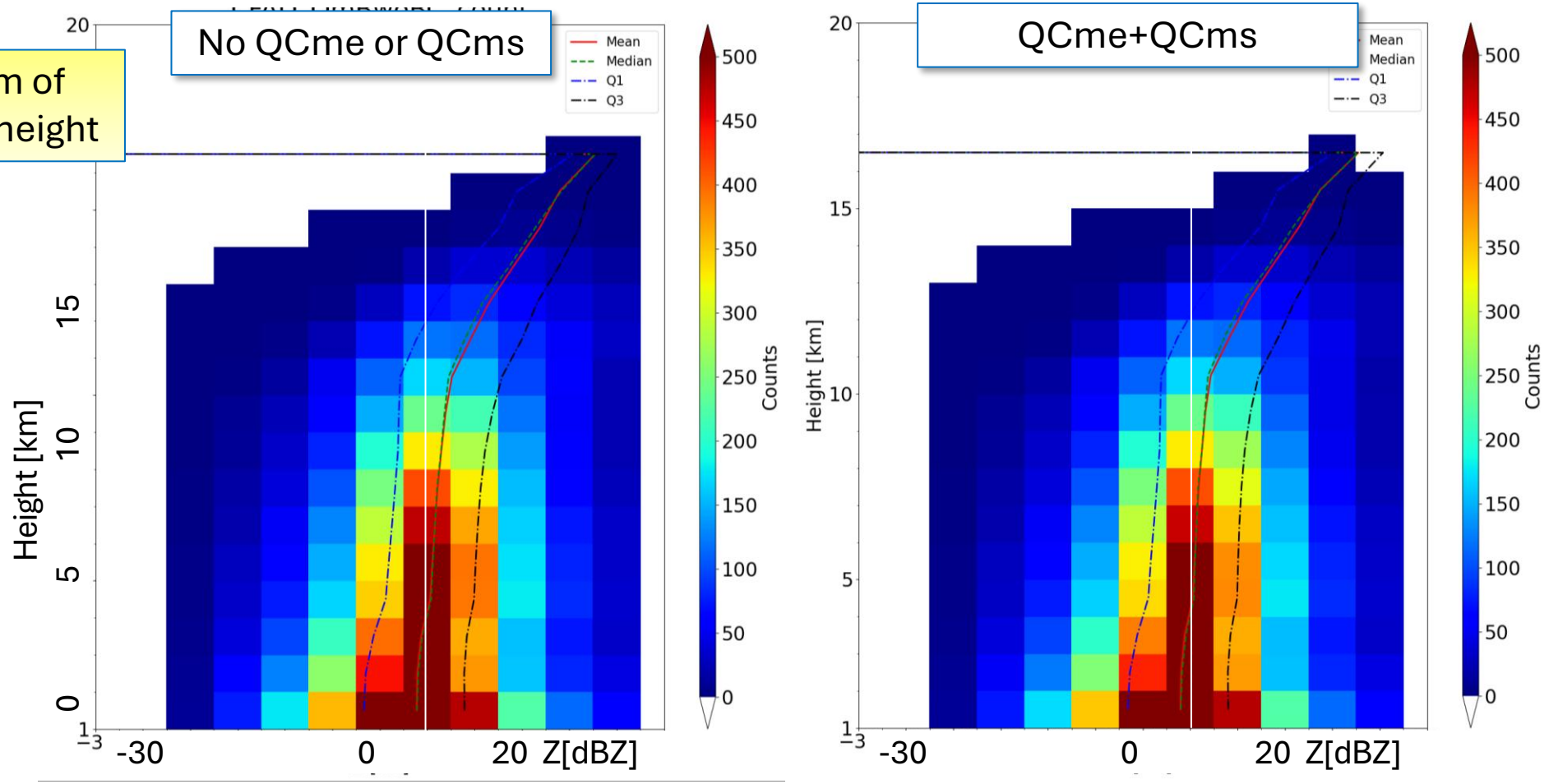
- Simulations underestimate Z below -40 deg C and overestimate above 0 deg C
  - Overestimation may come from the lack of sub-grid variability of rain in simulation?
- Smaller variability in simulation



Preparation for data assimilation:
QC Effect: mirror echo and multi-scattering flags

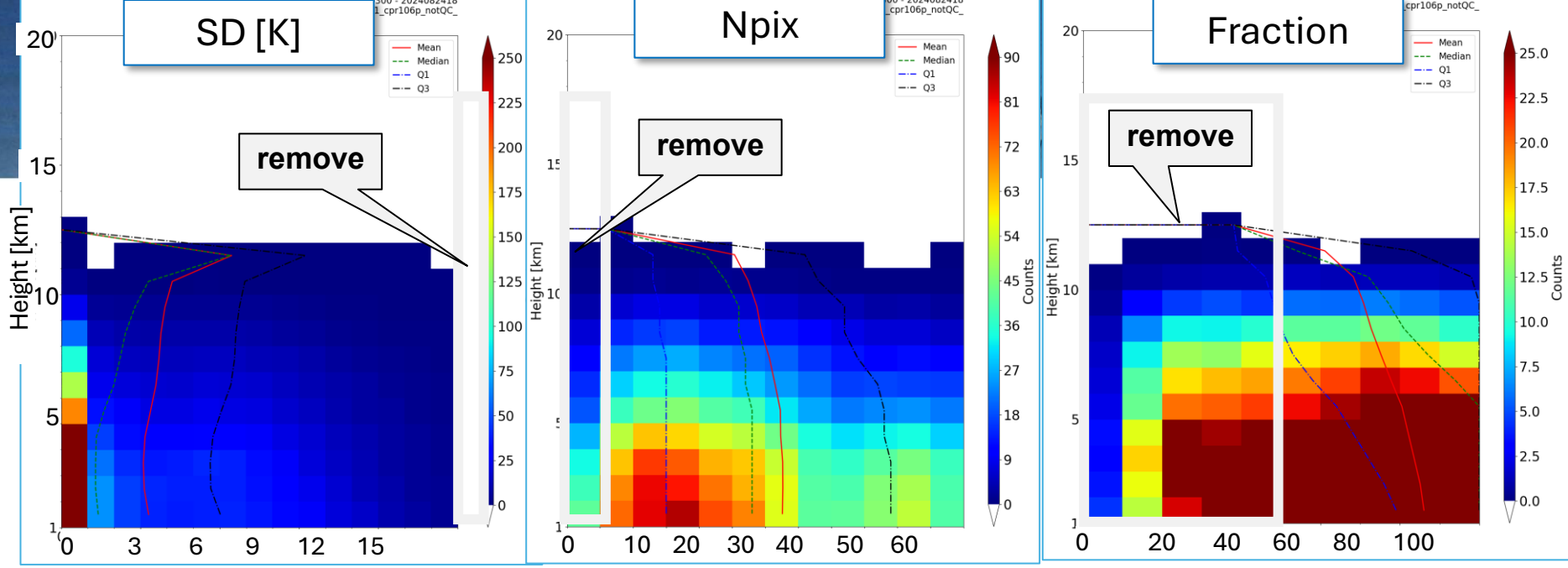
- QCme: Reject bins above the lev where mirror echo is detected ← False signal
- QCms: Reject all bins when any one multiple-scattering bin is detected ← RTTOV not include
- → Both QC has no major statistical effect, though case studies are needed

2D histogram of Obs-Sim and height



QC

- Homogeneity QC
  - SD<20dBZ
  - Npix (Num of data comprising super-ob) > 5
  - fraction > 50%
- Need stricter threshold for SD-QC (and others)?



QC