Towards using EarthCARE and GPM to improve radiance models, retrievals and microphysical understanding

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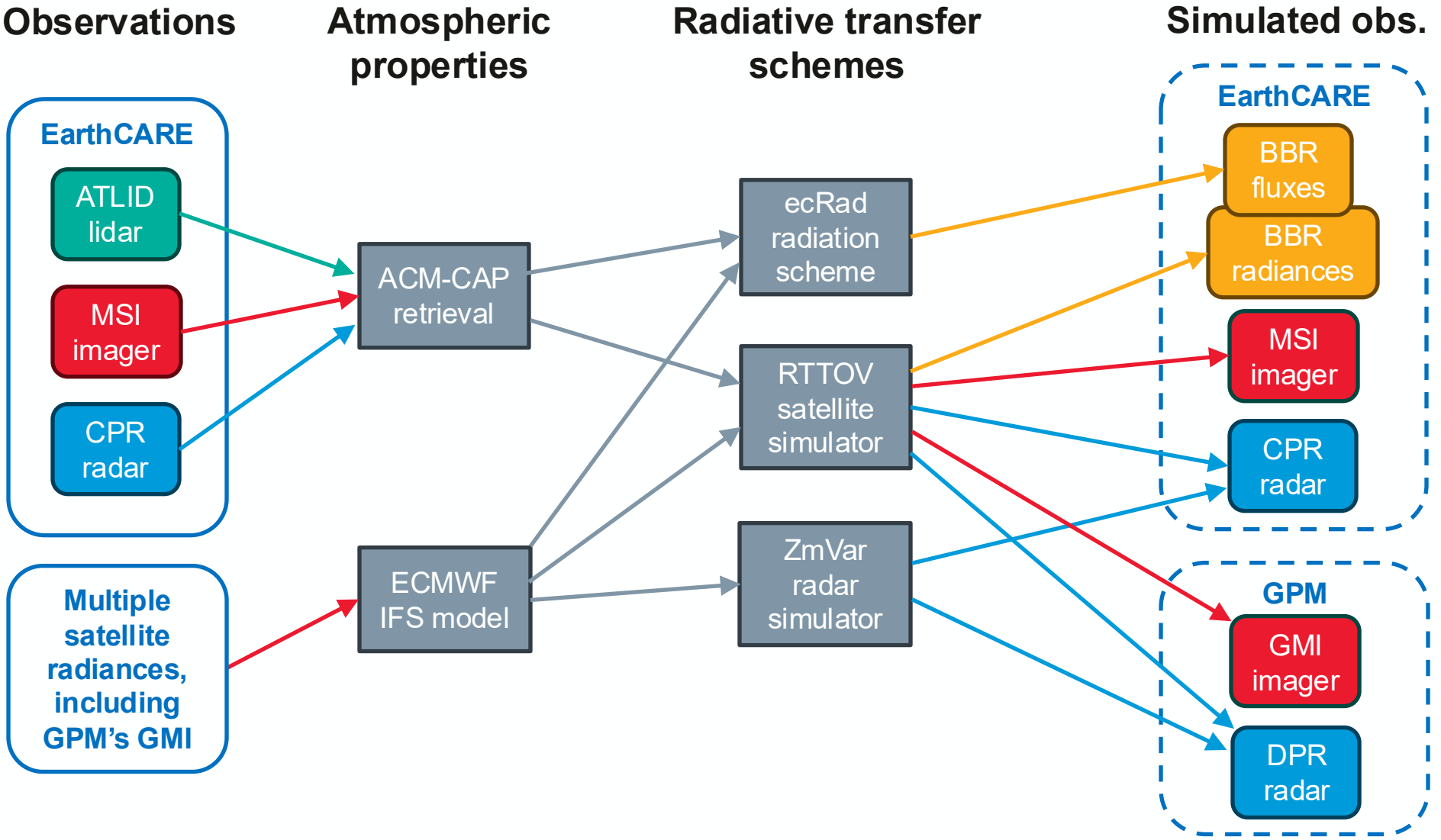
Thanks to Shunsuke Aoki (JAXA) & Leonhard Scheck (LMU)

Overview

- **What can we learn from coincident observations by EarthCARE and GPM?**
  - Wavelengths span 5 orders of magnitude: passive from 0.6 μm to 3 cm, active from 0.3 μm to 2.2 cm
- In this talk we forward-model GPM observations, using as input both EarthCARE synergy retrievals (ACM-CAP) and ECMWF weather forecasts (IFS)
  - Crucial test of **RTTOV radiance model** used in assimilation, recently updated to calculate radar profiles
  - Are our **ice microphysical and scattering assumptions** capable of spanning this wavelength range?
  - How good are **EarthCARE's rain retrievals**? Can we increase the upper limit on retrieved rain rate?
  - How can we use this information to **improve processes in weather and climate models**?
- This is work in progress!

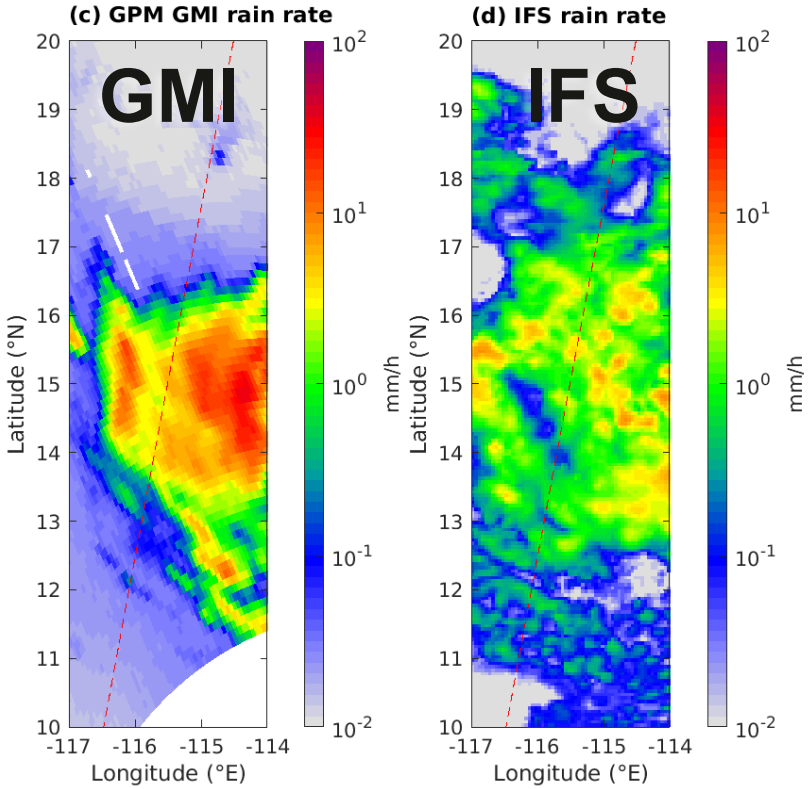
Data flow in this talk…

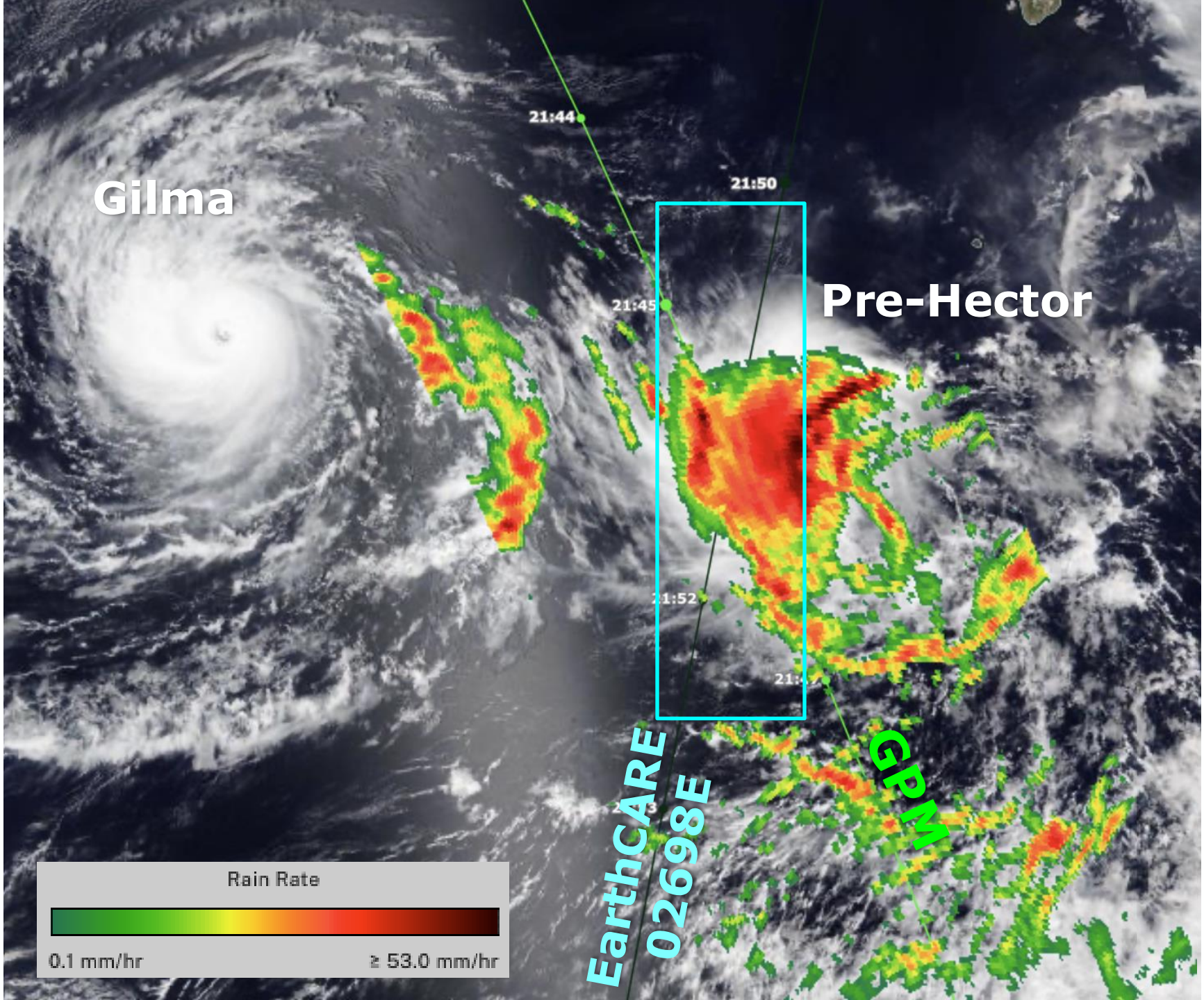


- Test BE baseline of ACM-CAP, radiative closure using BBR
- Test weather forecasts using same models
- RTTOV used for assimilating radiances, recently able to simulate radar profiles as well
- ZmVar used for assimilating CPR and soon ATLID at ECMWF

Pre-Tropical Storm Hector (NE Pacific) 22 August 2024

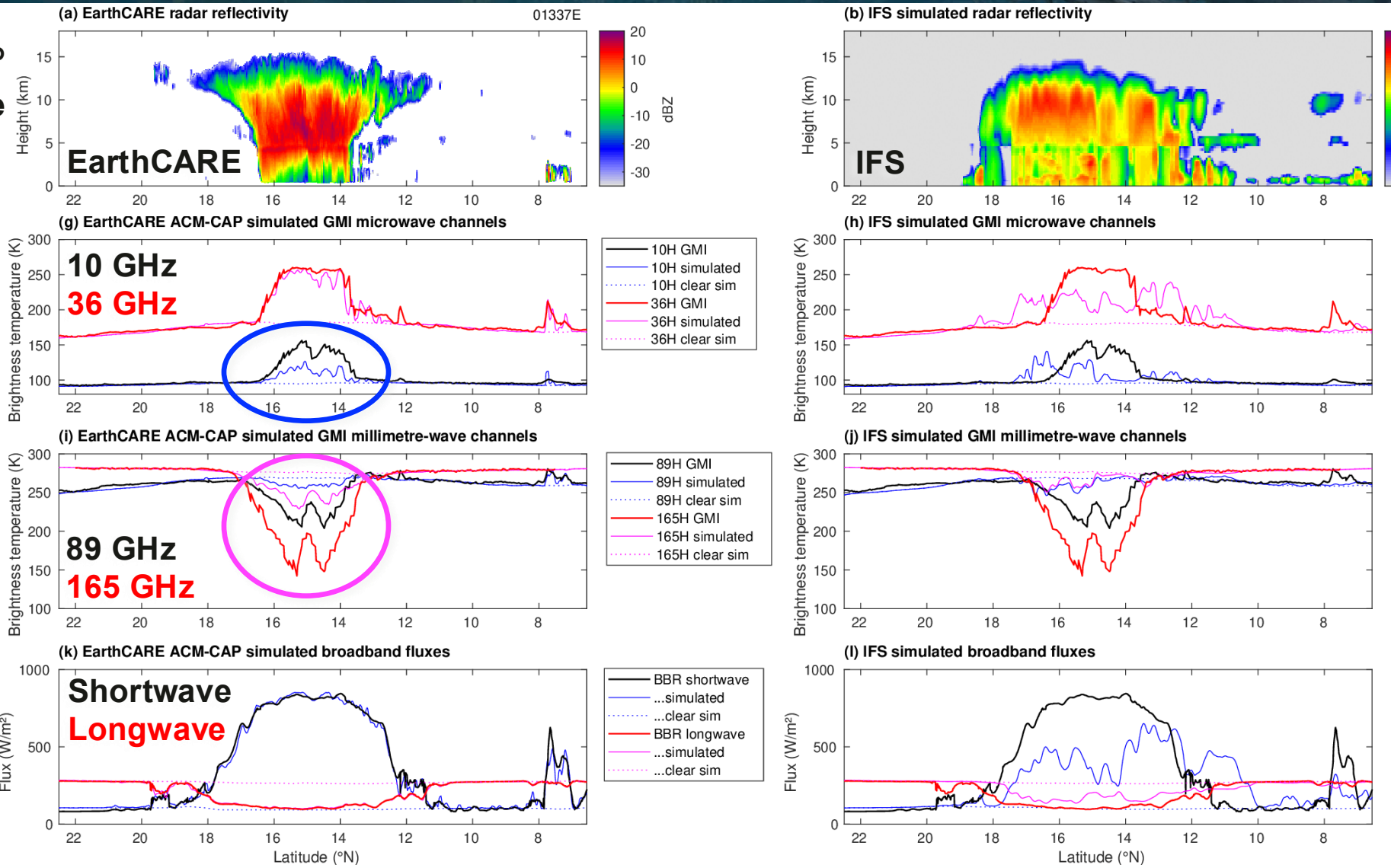
- VIIRS NOAA-20: 21:10
- GPM rain rate: 21:46
- EarthCARE overpass: 21:51





Forward-modelled radiances

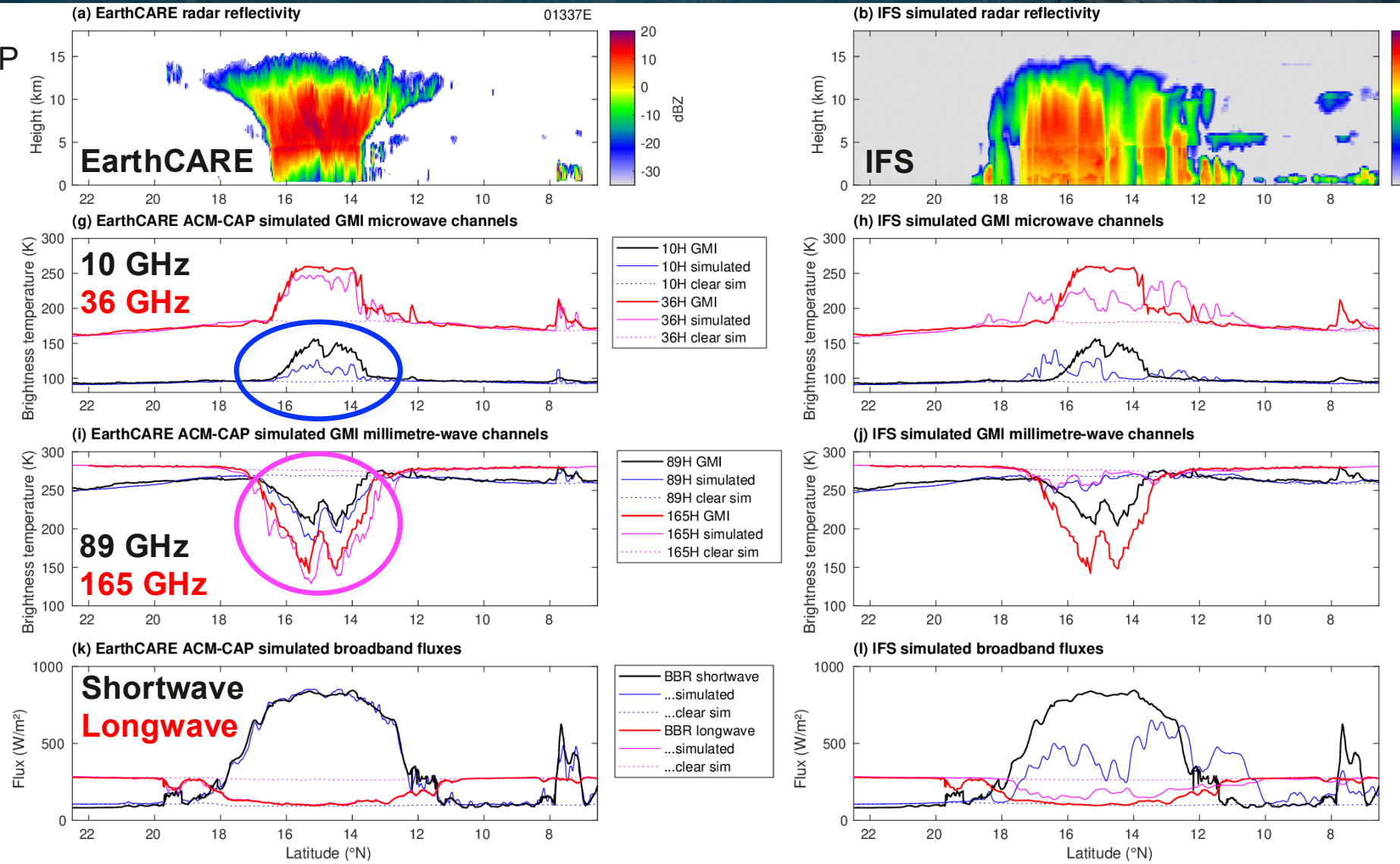
- Treat ACM-CAP ice as **cloud ice** in RTTOV
- Rain-sensitive radiances are **too low**
- Ice-sensitive radiances are **too high**
- Broadband fluxes **well captured**



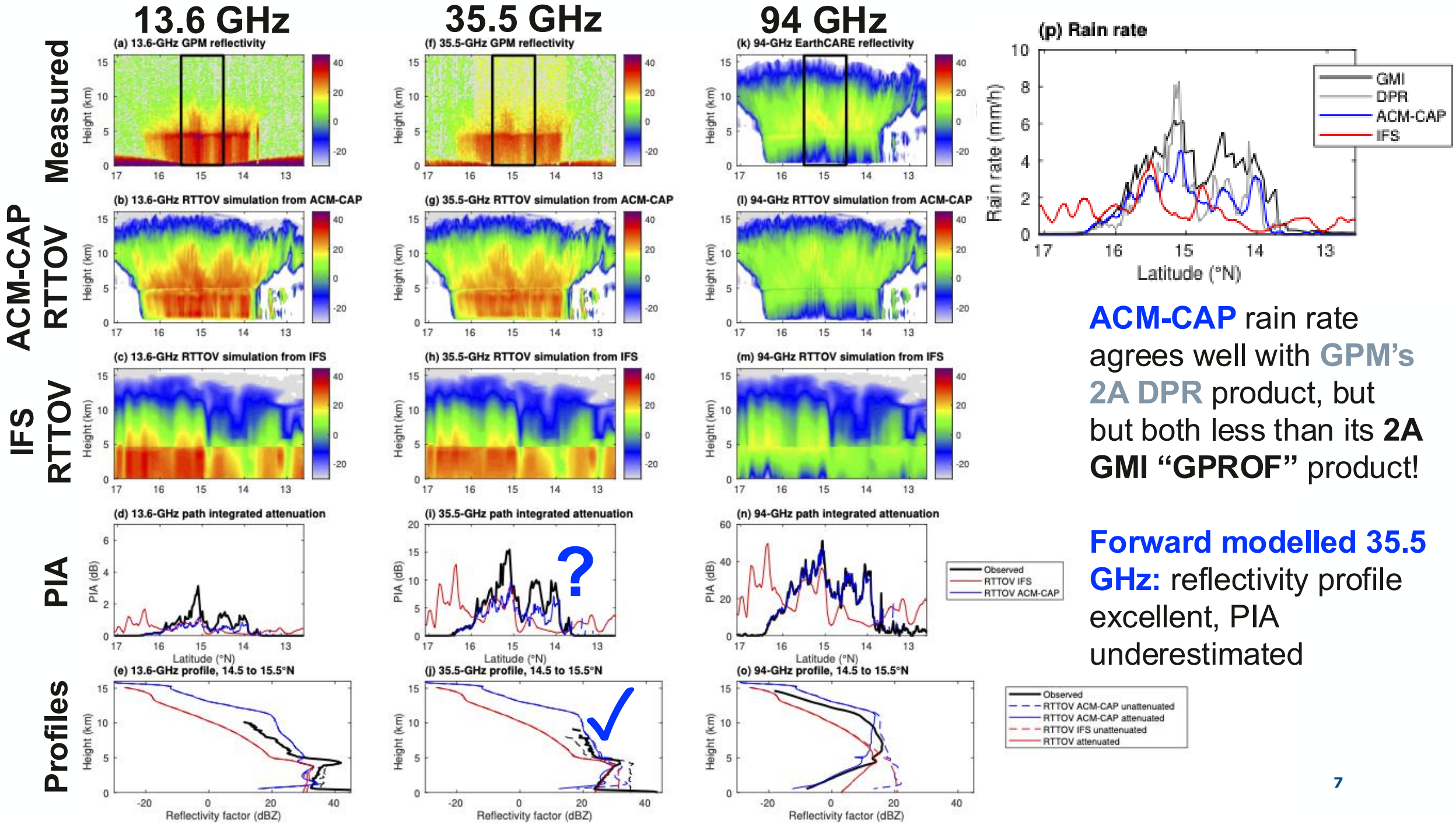
- **Poor** ZmVar simulation using IFS microphysical assumptions
- Storm system too broad and weak

…improved ice assumptions

- Treat ACM-CAP ice as **snow** in RTTOV
- Rain-sensitive radiances are **too low**
- Ice-sensitive radiances are **much better**
- Broadband fluxes **well captured**



- **Better** ZmVar simulation using ACM-CAP microphysical assumptions!
- Storm system too broad and weak

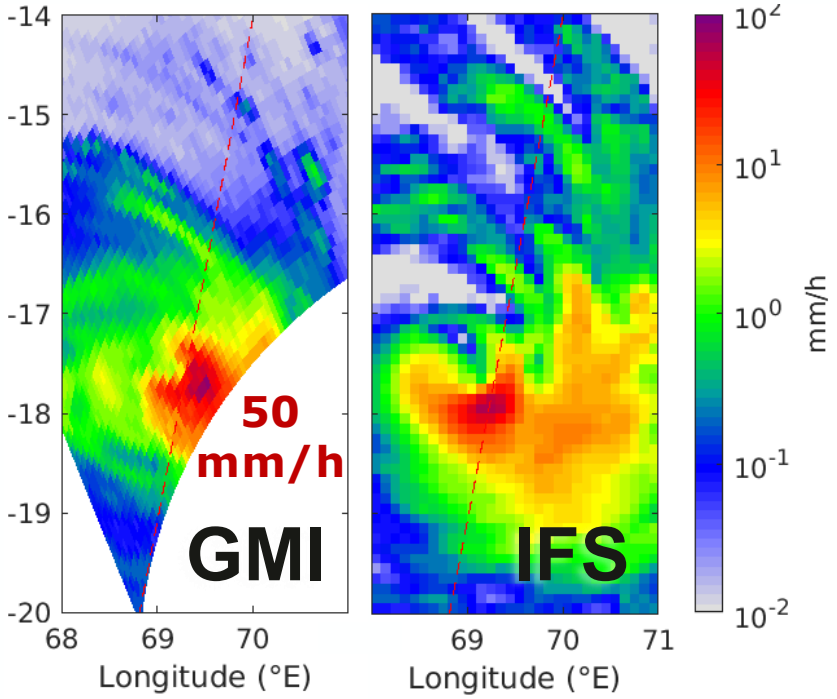


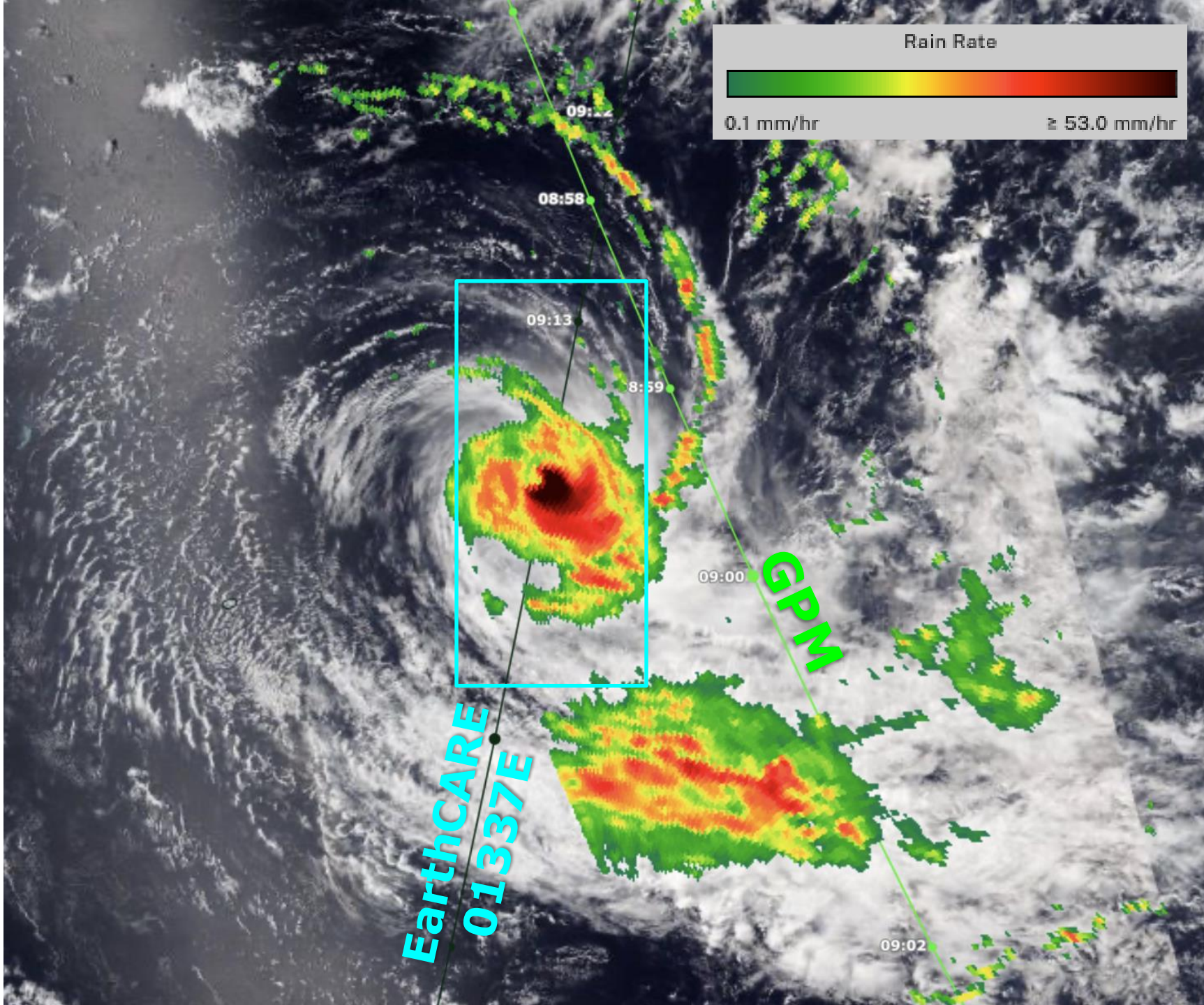
ACM-CAP rain rate agrees well with **GPM's 2A DPR** product, but but both less than its **2A GMI "GPROF"** product!

Forward modelled 35.5 GHz: reflectivity profile excellent, PIA underestimated

Tropical Cyclone Bheki (Indian Ocean) 18 Nov 2024 (Cat 4)

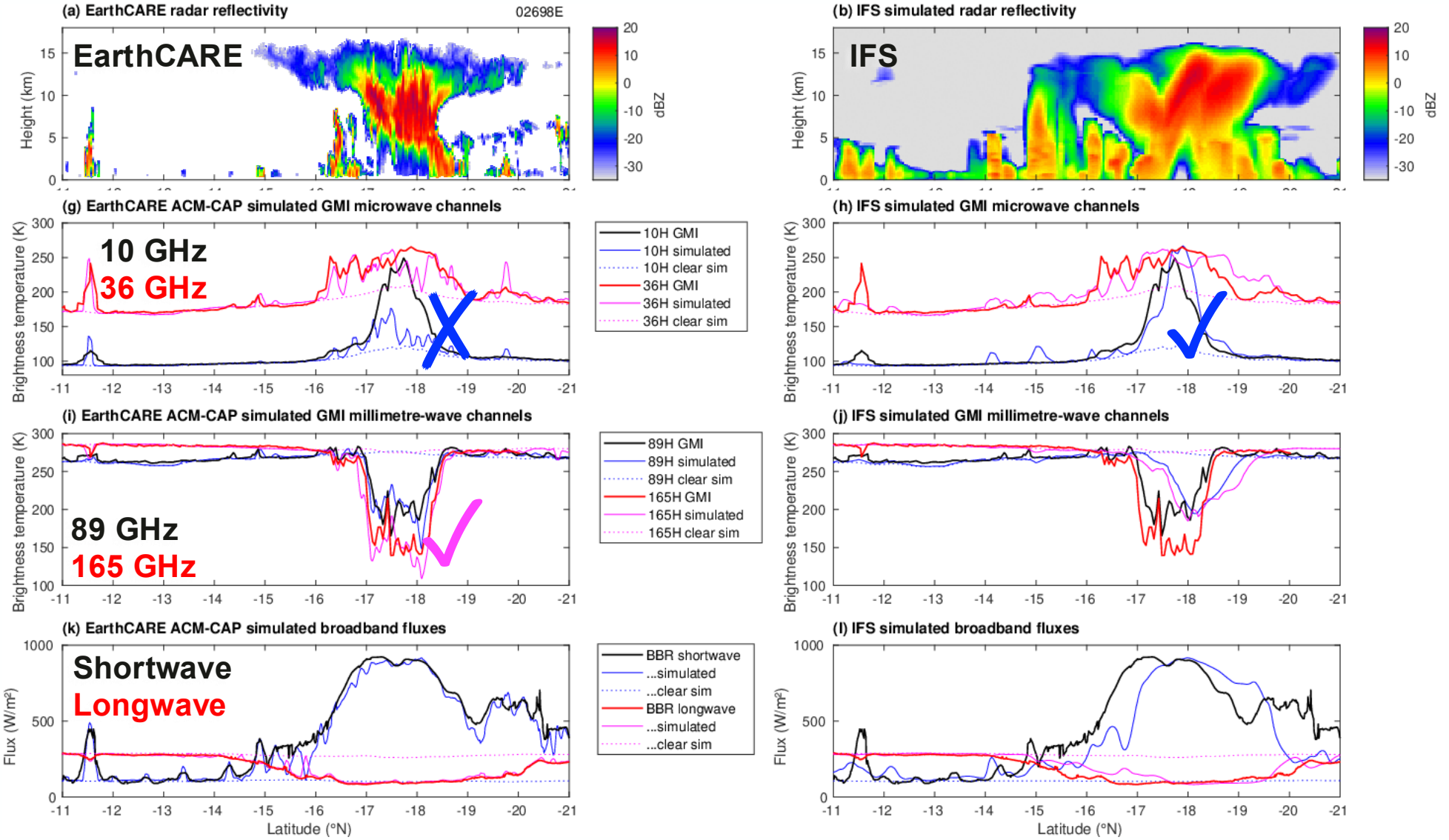
- VIIRS NOAA-21: 09:13
- GPM rain rate (used in IMERG): 09:00
- EarthCARE overpass: 09:14

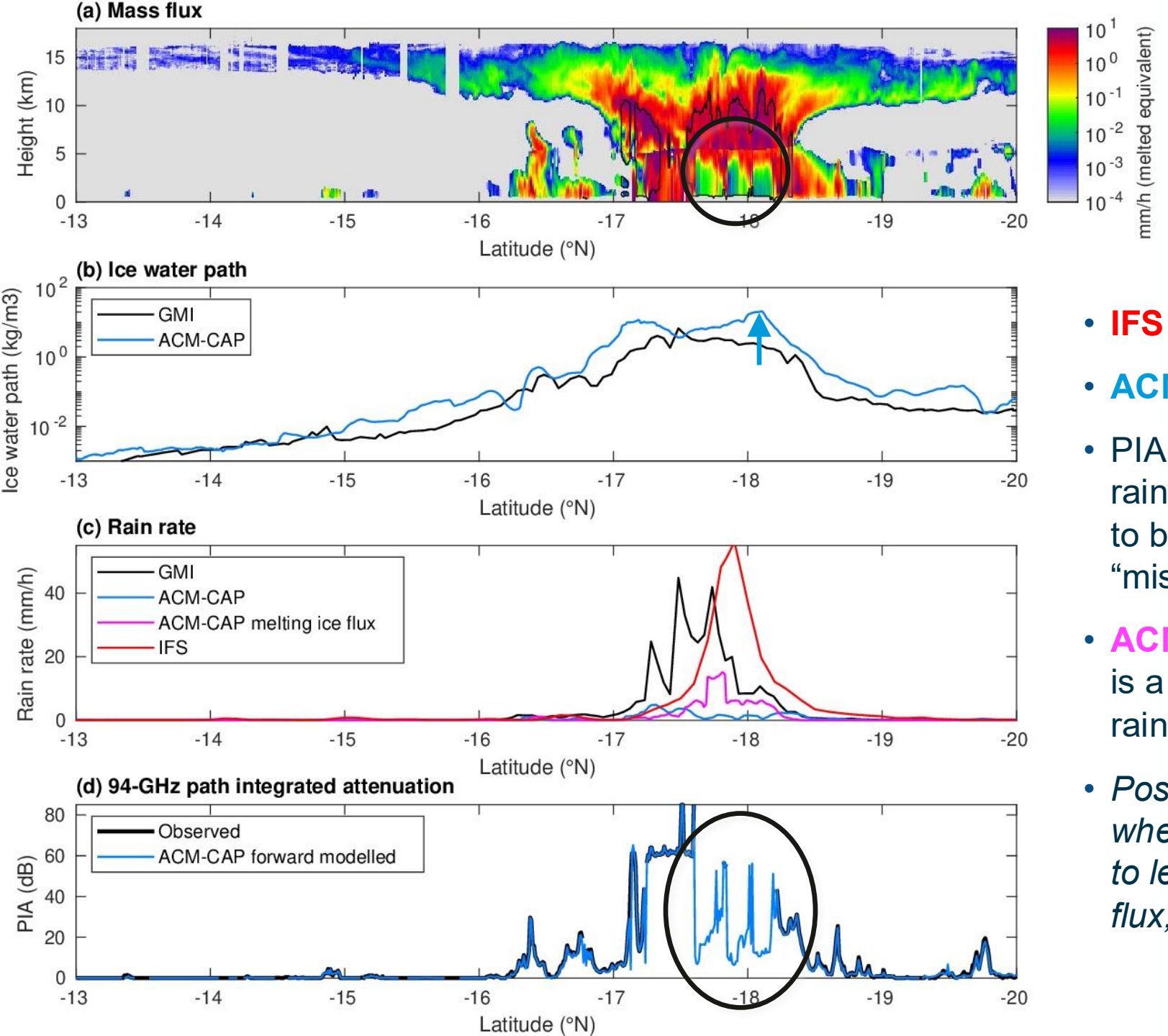




Bheki: forward-modelled radiances

- Rain-sensitive radiances **much too low** with ACM-CAP, **about right** with IFS
- Ice-sensitive radiances are **well captured**
- Broadband fluxes **well captured**



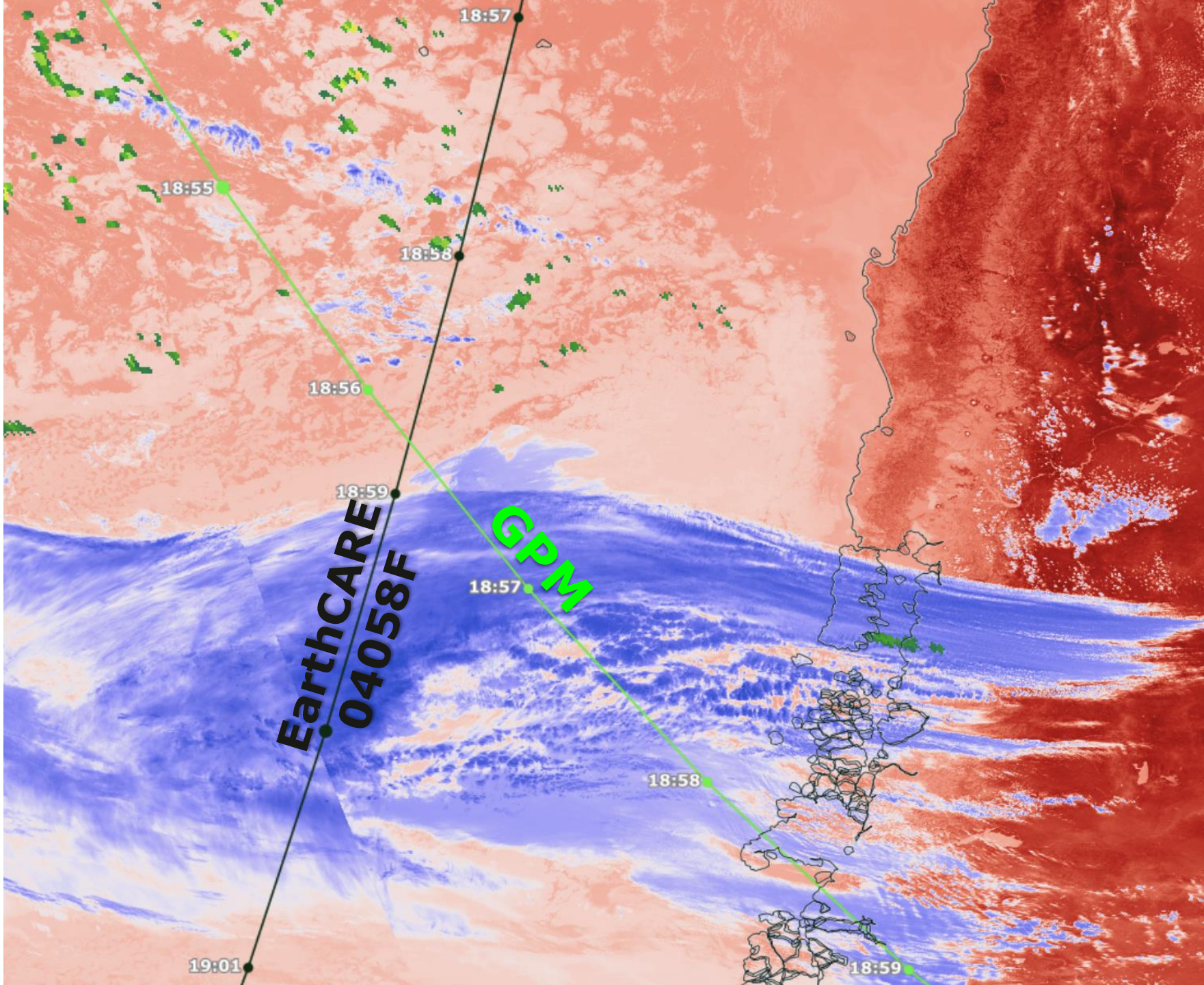


Potential to improve EarthCARE retrievals of heavy rain?

- **IFS** simulates the rain intensity well!
- **ACM-CAP** ice water path too high: 20 kg m^{-3}
- PIA saturates at 65-85 dB, corresponding to a rain rate of around 5 mm/h: **ACM-CAP** needs to be able to distinguish “saturated PIA” from “missing PIA” and use in retrievals
- **ACM-CAP snow flux** just above melting layer is a bit better: can we extend it down into the rain?
- *Possible improvement: assume denser ice when multiple scattering diagnosed, leading to less IWP but potentially higher ice mass flux, and feed this into rain retrieval below?*

Cirrus and boundary-layer cloud (SE Pacific) 13 Feburary 2026

- VIIRS NOAA-21: 18:41
- GPM rain rate: 18:56
- EarthCARE overpass: 18:59

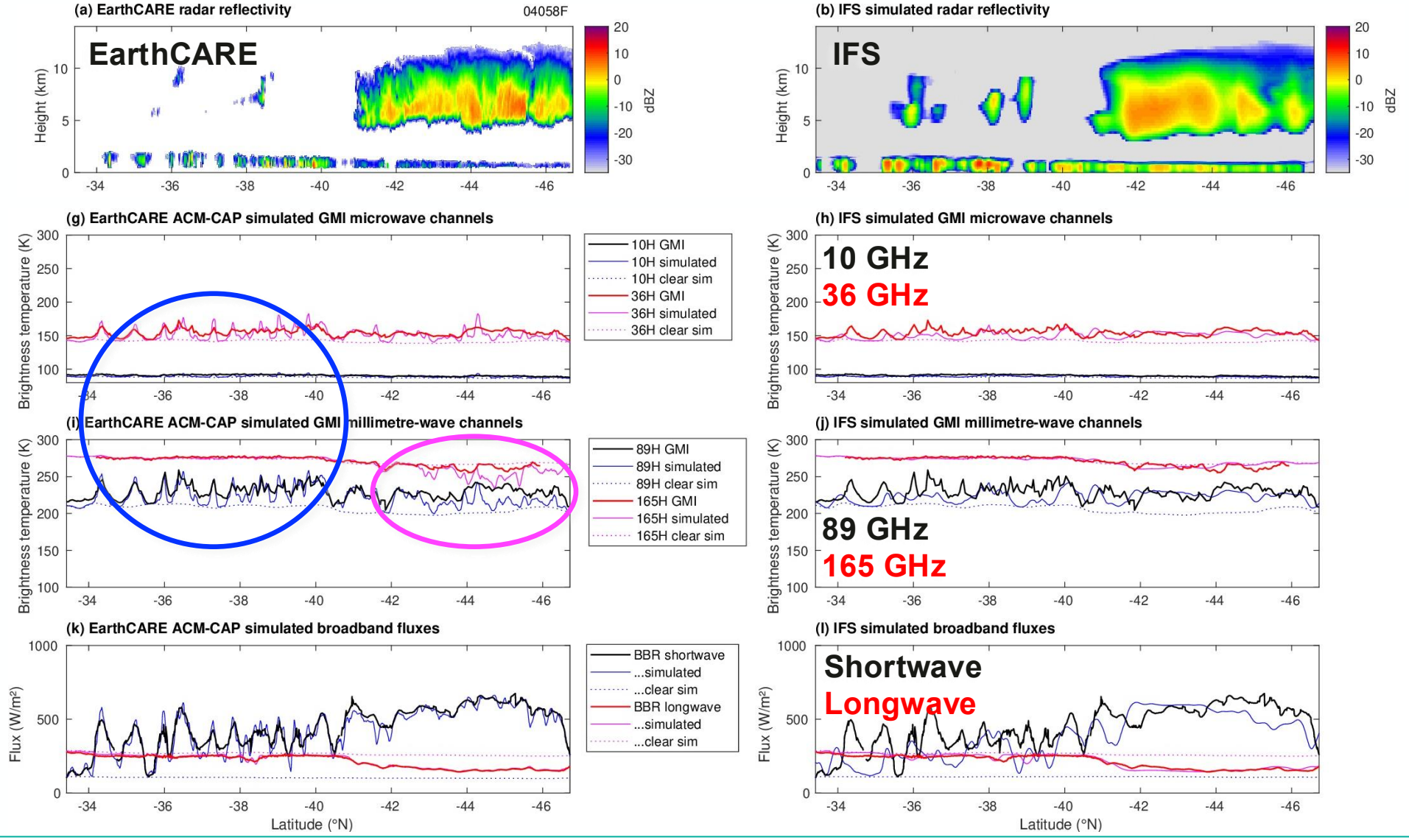


Infrared brightness temperature

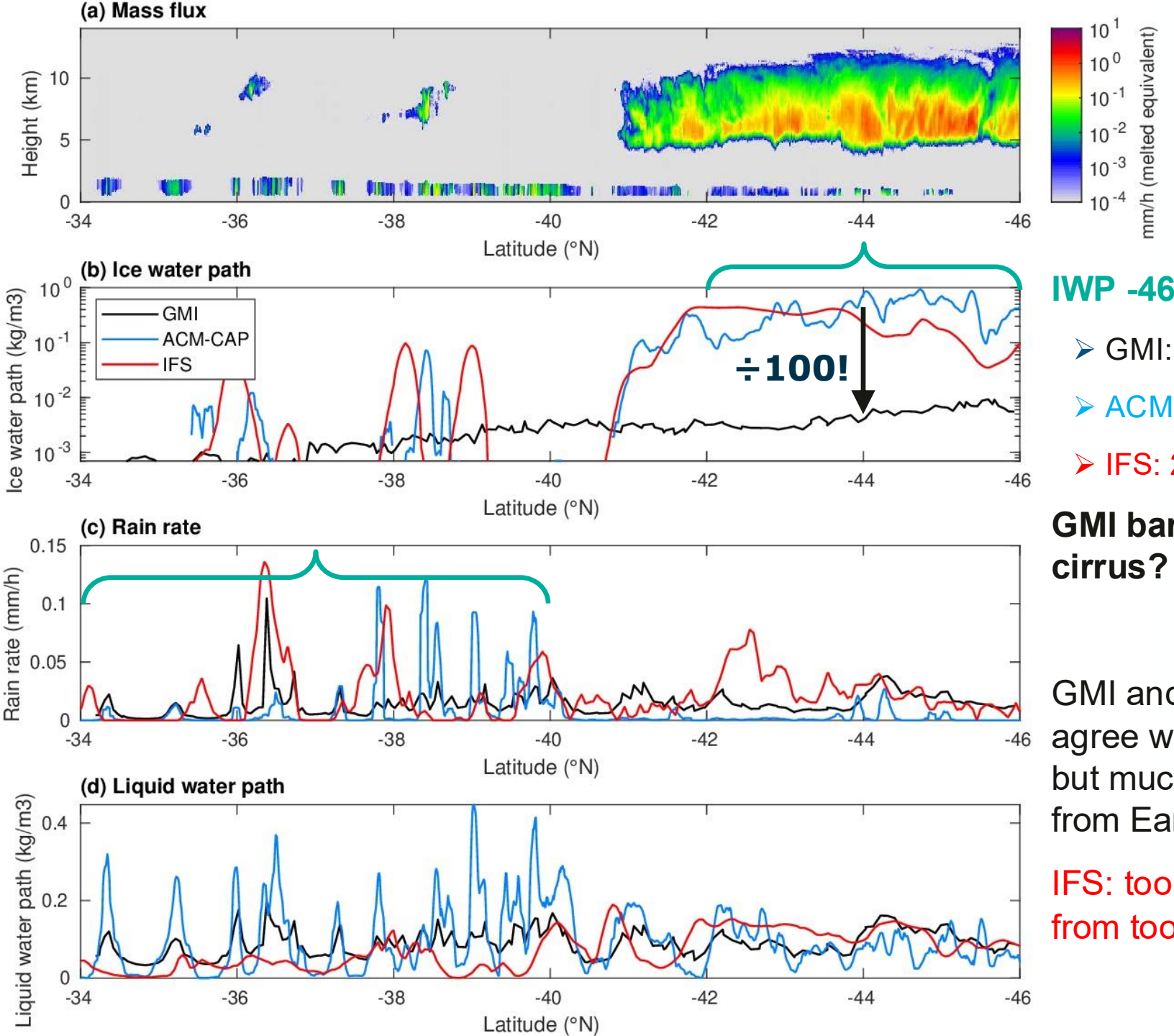
210 K 330 K

Low cloud & cirrus: radiances

- 35/89 GHz radiances in low clouds agree well
- ACM-CAP predicts a larger scattering signal in 89/165 GHz channels than observed by GMI



Comparison of retrievals



Mean ice optical depth: 10

IWP -46°N to -42°N:

- GMI: 4.9 g m^{-3}
- ACM-CAP: 395 g m^{-3}
- IFS: 254 g m^{-3}

GMI barely detects cirrus?

Rain rate -40°N to -34°N:

- GMI: 0.012 mm/h
- ACM-CAP: 0.013 mm/h
- IFS: 0.020 mm/h

Liquid water path

- GMI: 84 g m^{-3}
- ACM-CAP: 105 g m^{-3}
- IFS: 36 g m^{-3}

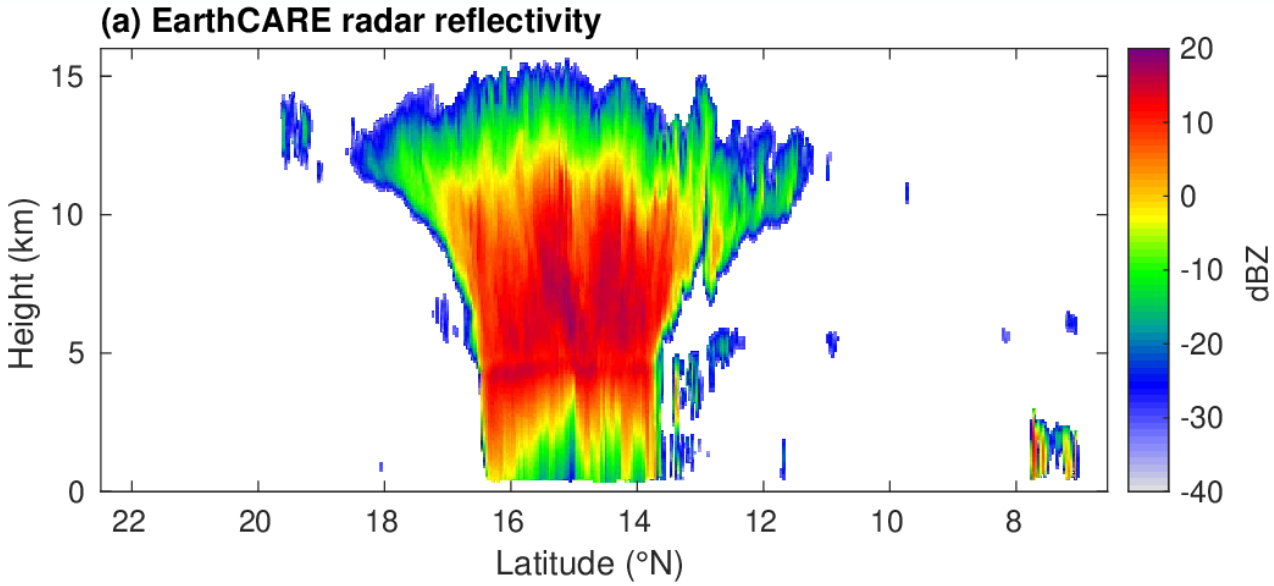
GMI and ACM-CAP agree well in low cloud but much finer scale from EarthCARE

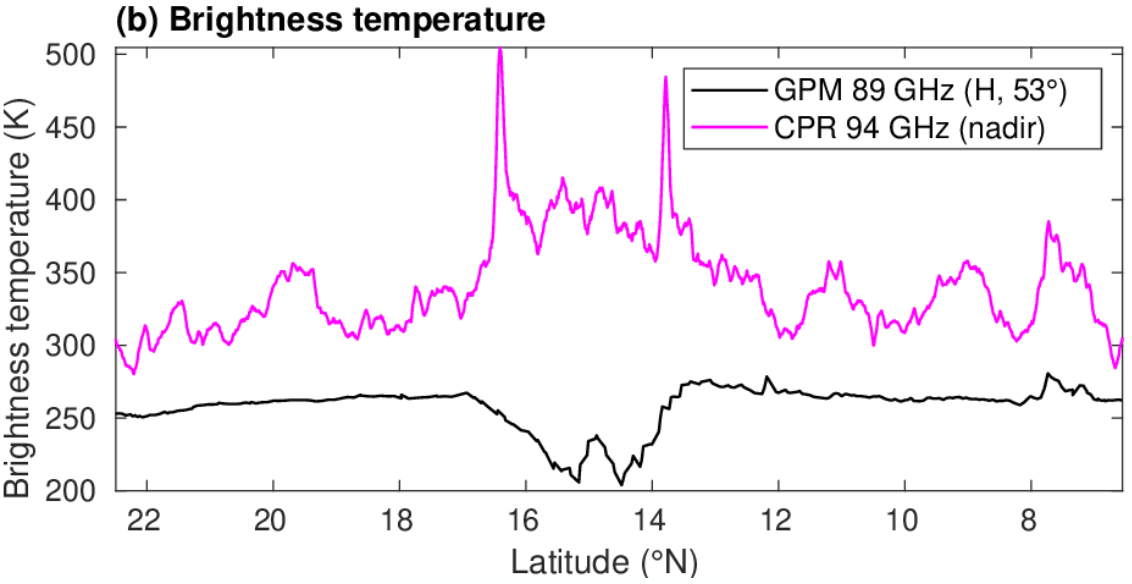
IFS: too much rain from too little cloud

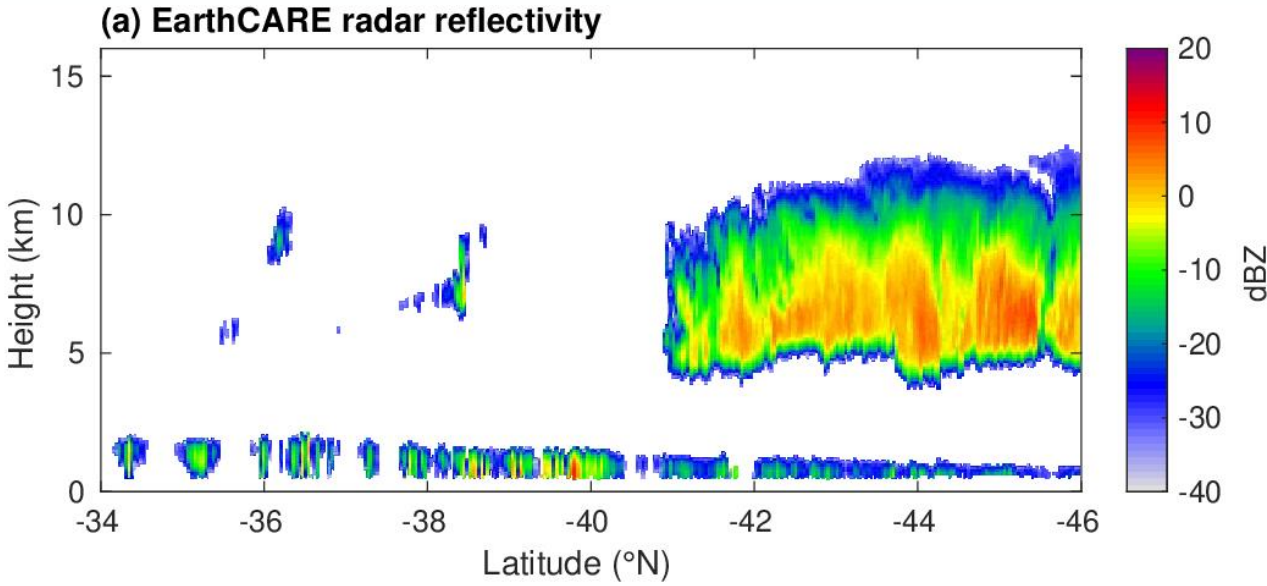
Outlook

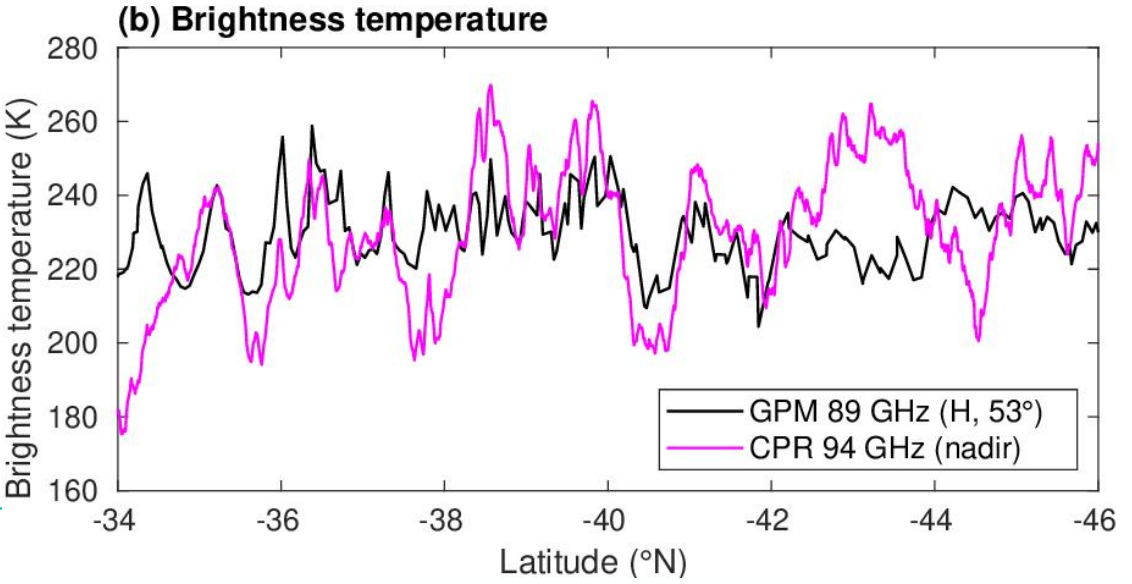
- Huge potential to use EarthCARE/GPM coincidences to improve ice & rain size distribution and scattering assumptions, and to improve retrievals
- Next steps:
  - Ensure microwave forward models in RTTOV use **consistent ice scattering model** with retrieval, and provide **constraints on ice size distributions and density**
  - Understand differences in size distributions between **warm and cold rain**, reconciling raindrop number/size retrievals and making use of Doppler velocity
  - Can we bridge the gap between mid-infrared and microwave to obtain consistent ice optical properties in the **far-infrared in preparation for FORUM**?
  - Also evaluate **CPR-only retrievals**, e.g. C-CLD
- Other ideas:
  - Can we **assimilate EarthCARE's PIA**? Tight constraint on rain rate
  - **EarthCARE II** should carry a suite of microwave radiometers!

CPR brightness temperature









Pre-Hector: Comparing Nw

- Normalized number concentration from GPM 2B synergy retrieval and from EarthCARE's ACM-CAP