Towards combining microwave and infrared radiances for ice hydrometeors

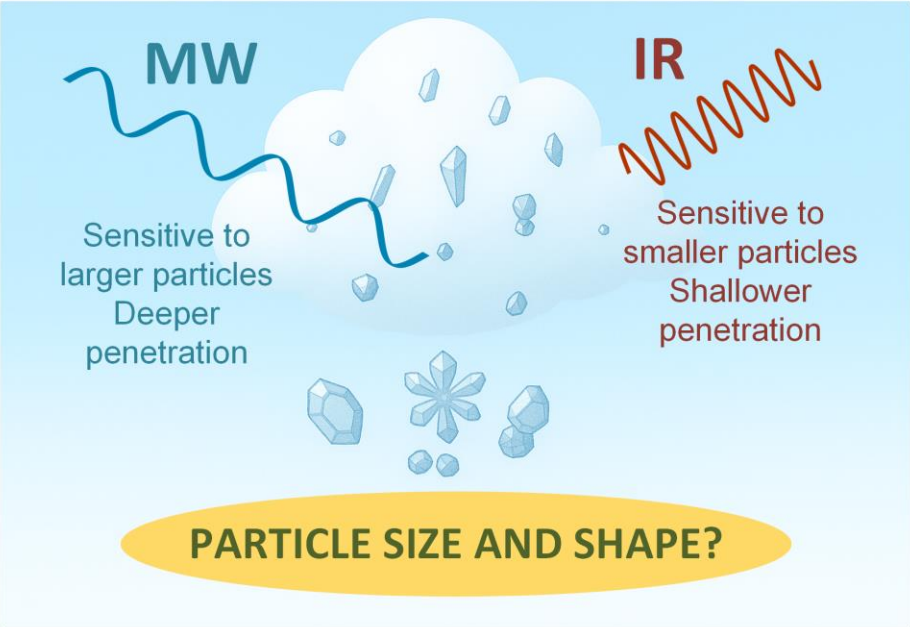
Anqi Li

2026-03-02, Darmstadt

Fellowship Day

MW vs IR on ice cloud

Complimentary information



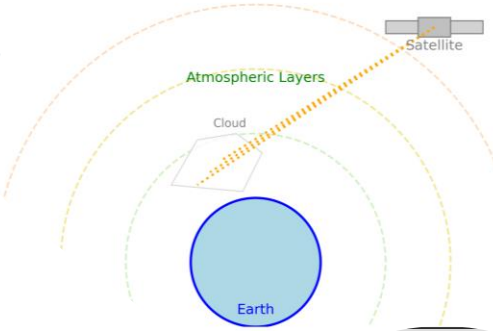
MW: miss the cloud top and thin cloud

IR: opaque to the backside

Sensitive to different size range

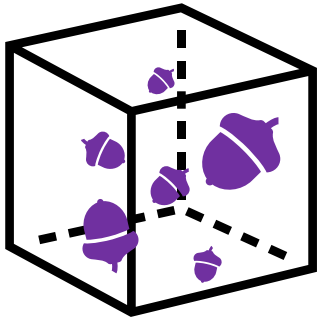
- Joint retrieval and assimilation are currently immature
  - All-sky assimilation
    - Add IR radiances
  - L2 retrieval
    - MW + geostationary IR

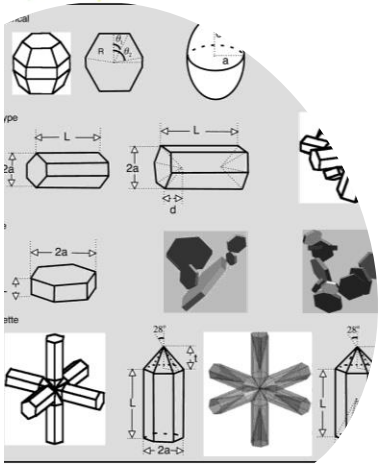
Micro- vs bulk properties



Remote sensing, large scale model

- Look at the column / volume property (='bulk')
- Cannot trace individual particles
- We must put assumption in micro-scale!
  - What shape (i.e. habit)?
  - What size mix (i.e. particle size distribution)?
  - What phase, liquid, solid, gas or mix?

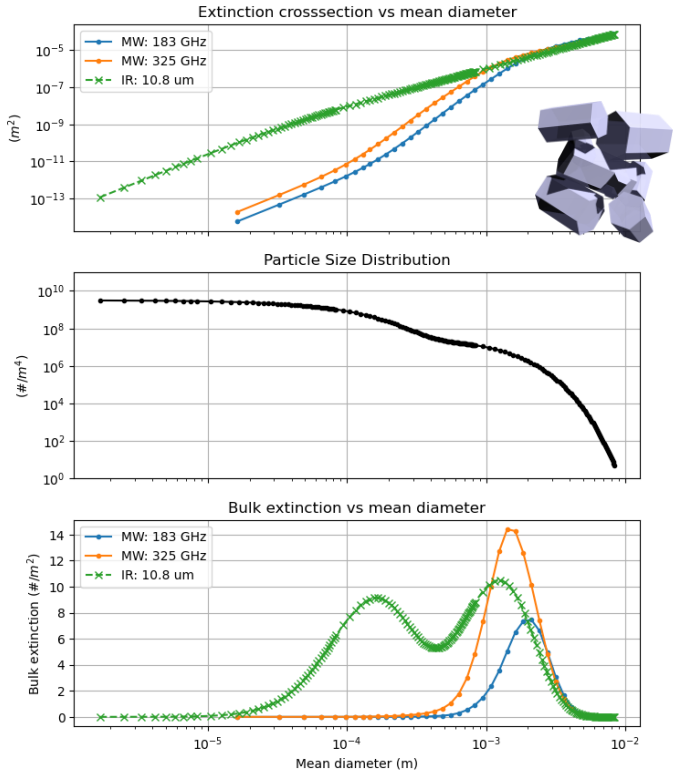




Yang, P., L. Bi, B. A. Baum, K. Liou, G. W. Kattawar, M. I. Mishchenko, and B. Cole, 2013: Spectrally Consistent Scattering, Absorption, and Polarization Properties of Atmospheric Ice Crystals at Wavelengths from 0.2 to 100 μm. J. Atmos. Sci., 70, 330–347, https://doi.org/10.1175/JAS-D-12-039.1.

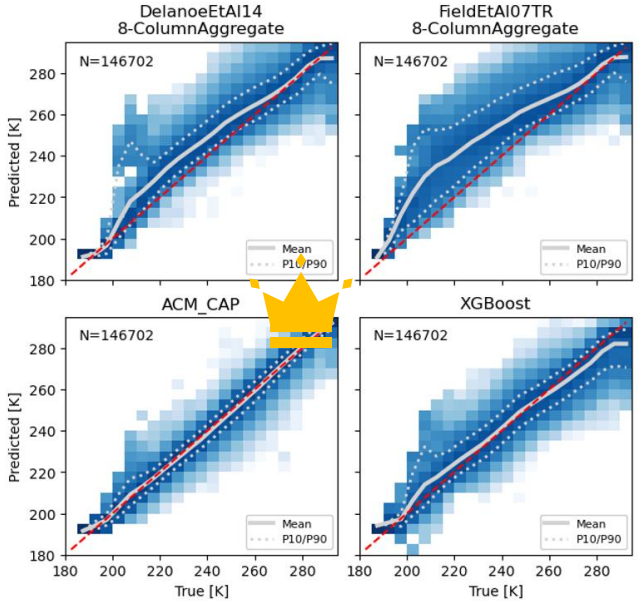
The challenge?

- Sensors measure radiances, not cloud!
- “No two snowflakes are alike”
  - Shapes and sizes vary in location, time, process
  - Airplane flight campaign
- Consistent microphysics assumption across regimes
  - Microphysical models used are usually adjusted for a specific size region
  - MW – larger sizes
    - Emphasis on the 'tail' of the distribution
  - IR – smaller sizes
    - Emphasis on the 'head' of the distribution

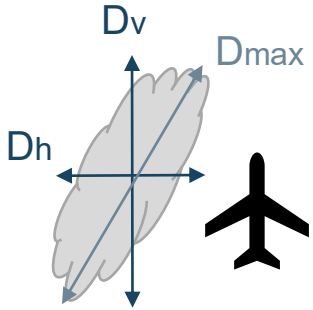


Motivation of EarthCARE L2B

- EarthCARE
  - Launched May 2024
  - The ‘new CloudSat’
- Synergy product level 2B “CAPTIVATE”
  - Combines Lidar + **Radar** + **IR** measurements
  - **Cloud (ice/snow + liquid + rain)** retrieval
    - Particle size distribution (PSD) in the state vector
    - Their forward modelled IR temperature matches very well with the observed brightness temperature
  - ➢ So, we decided to use their retrieval product

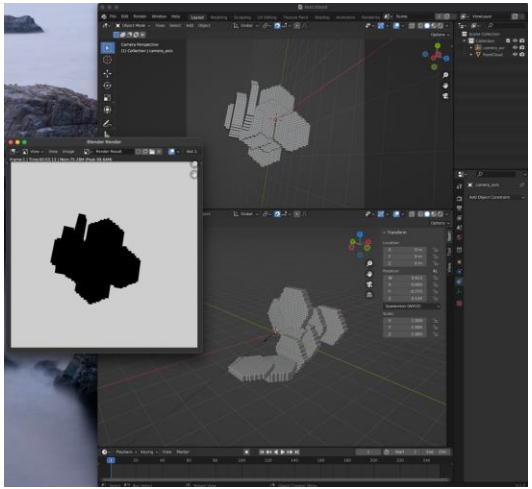


How to measure the size?



- It can be...
  - Mass
  - Volume-equivalent (D_{vol})
  - Melted-equivalent
  - Projected area
  - Maximum length (D_{max})
  - Length parallel/perpendicular to flight (D_h/D_v)
- CAPTIVATE L2B
  - uses the ‘mean size’ calculated by an area-size relationship
  - to mimic flight measurement (Dh+Dv)/2

- We use
  - 2/3 D_{max} + 1/3 D_{vol}



By Peter McEvoy

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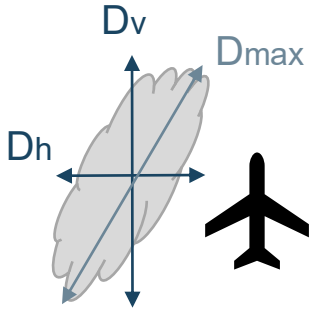

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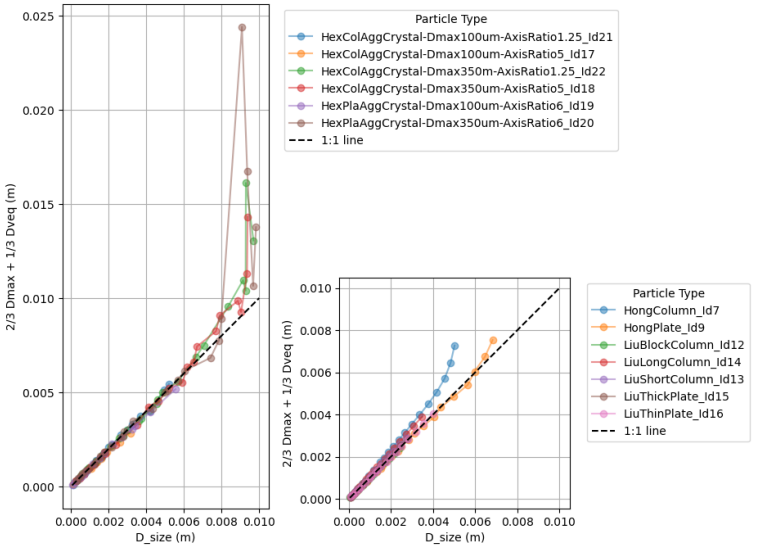
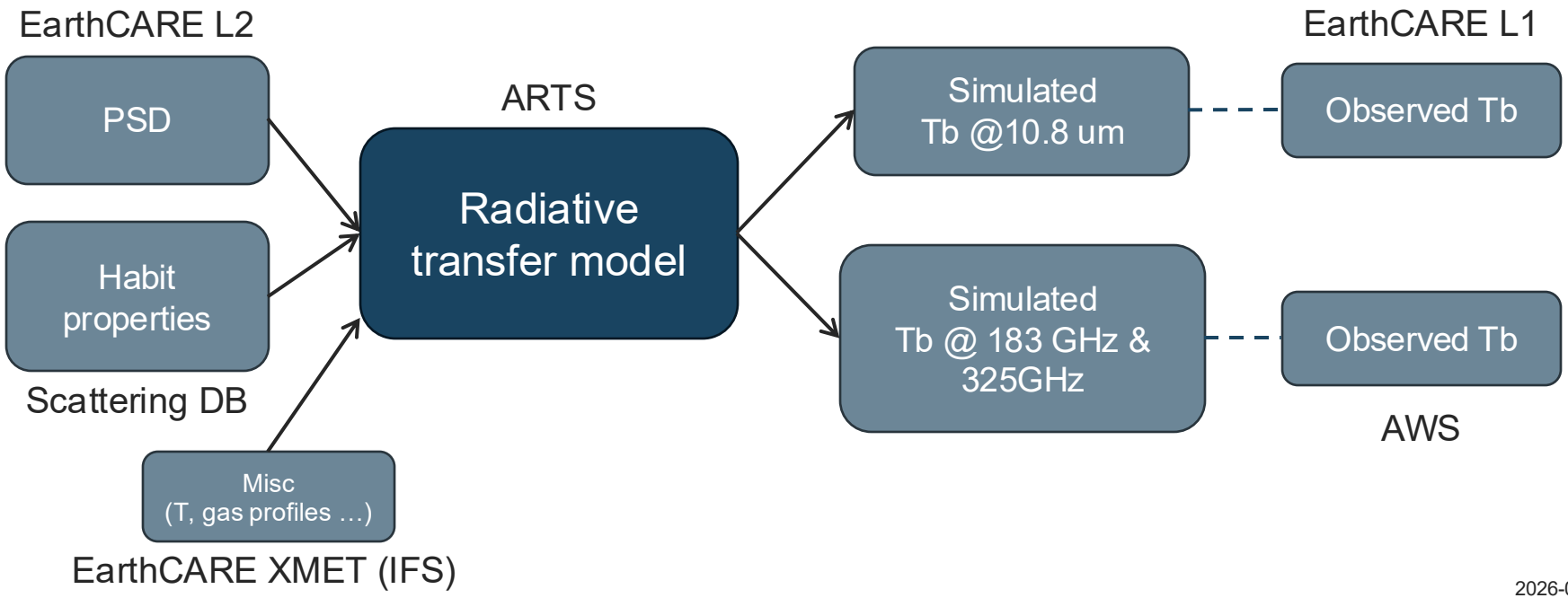


The workflow



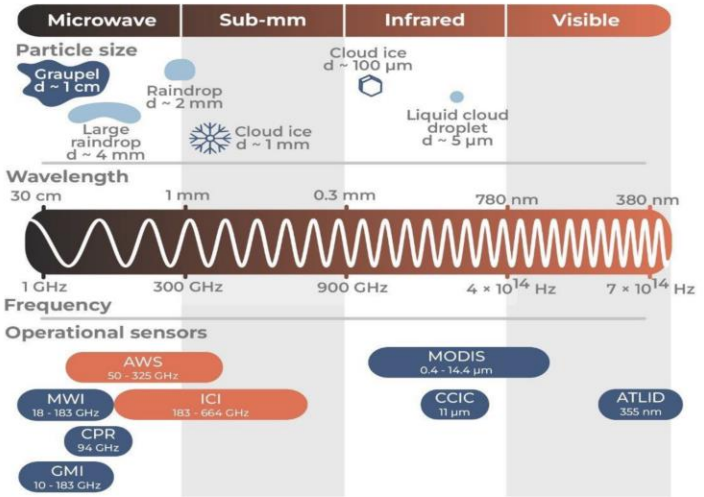
New sub-mm satellite missions

Arctic Weather Satellite (AWS)

- Launched in 2024
- 50.3 – 325 GHz
- First operational sub-mm satellite
- Prototype for EPS-Sterna

Ice Cloud Imager (ICI)

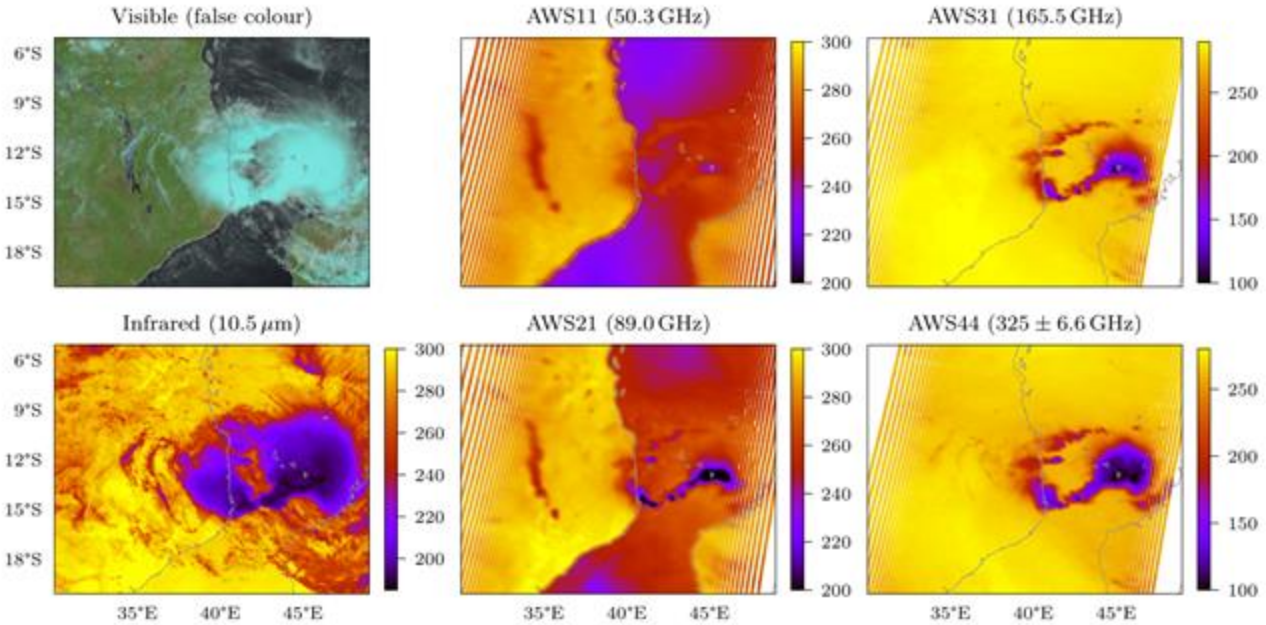
- Launch in 2026 (& 2033 & 2040)
- 183 – 664 GHz
- On Metop-SG B



By Eleanor May

Sample AWS L1B

Tropical cyclone Dikeledi

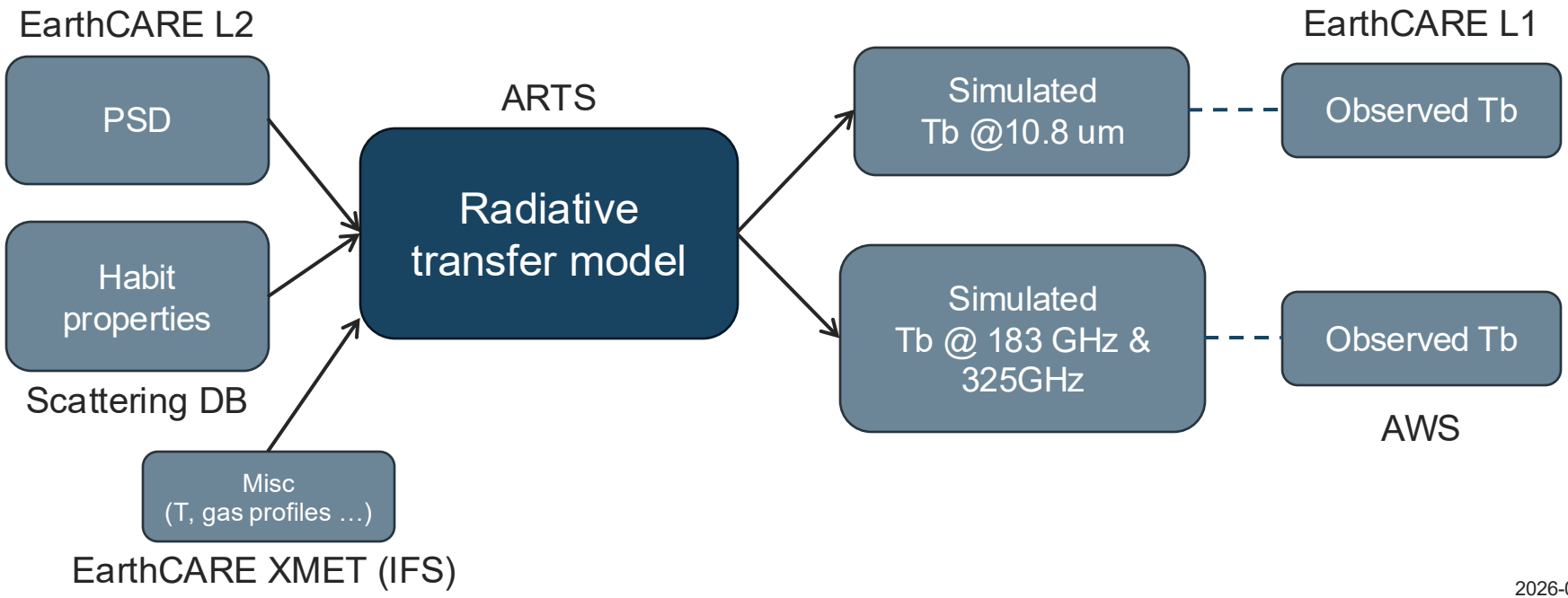


From Meteosat

Four of the AWS channels

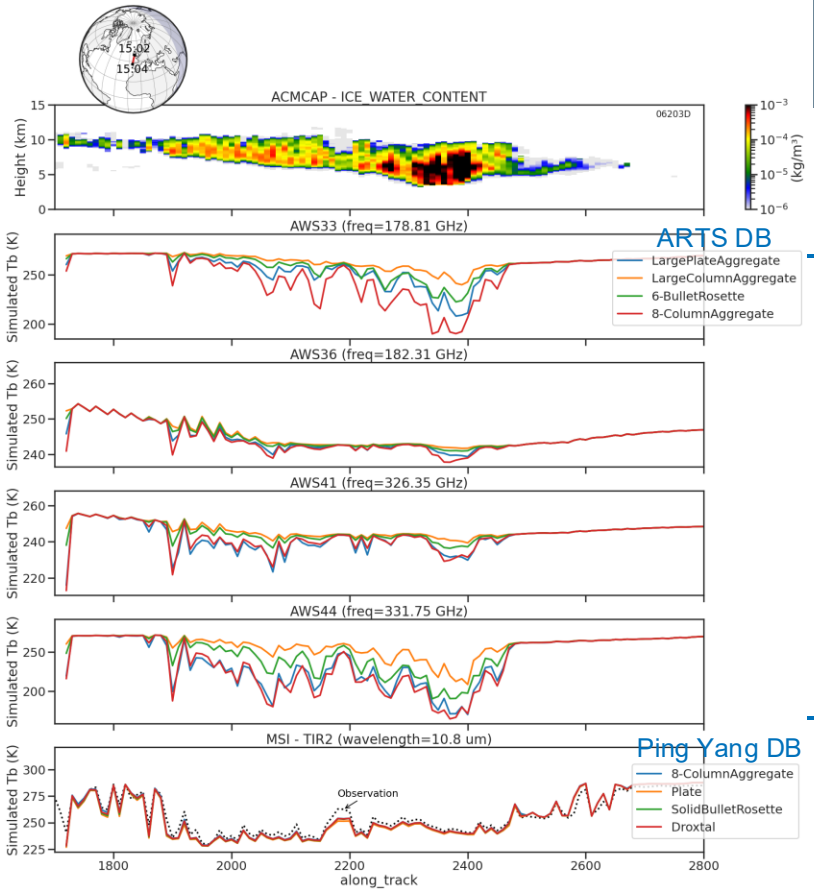
Eriksson et al, “The Arctic Weather Satellite radiometer”, AMT, 2025

The workflow



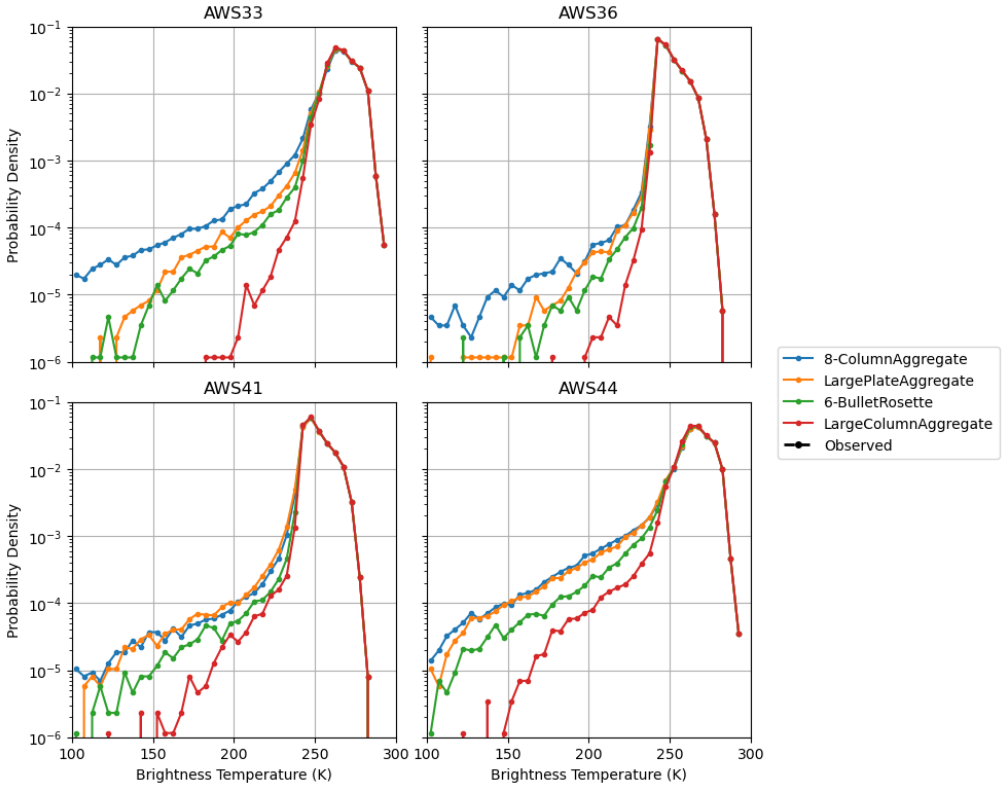
Simulation result

- Simulated over ocean profiles
  - Avoiding complication of land surface emissivity, for now
- The capability of IR detecting thin cloud at the anvil
- IR closely follows the observation
  - Little difference among habits
- Large differences in sub-mm MW among habits
  - Which one is the truth!?



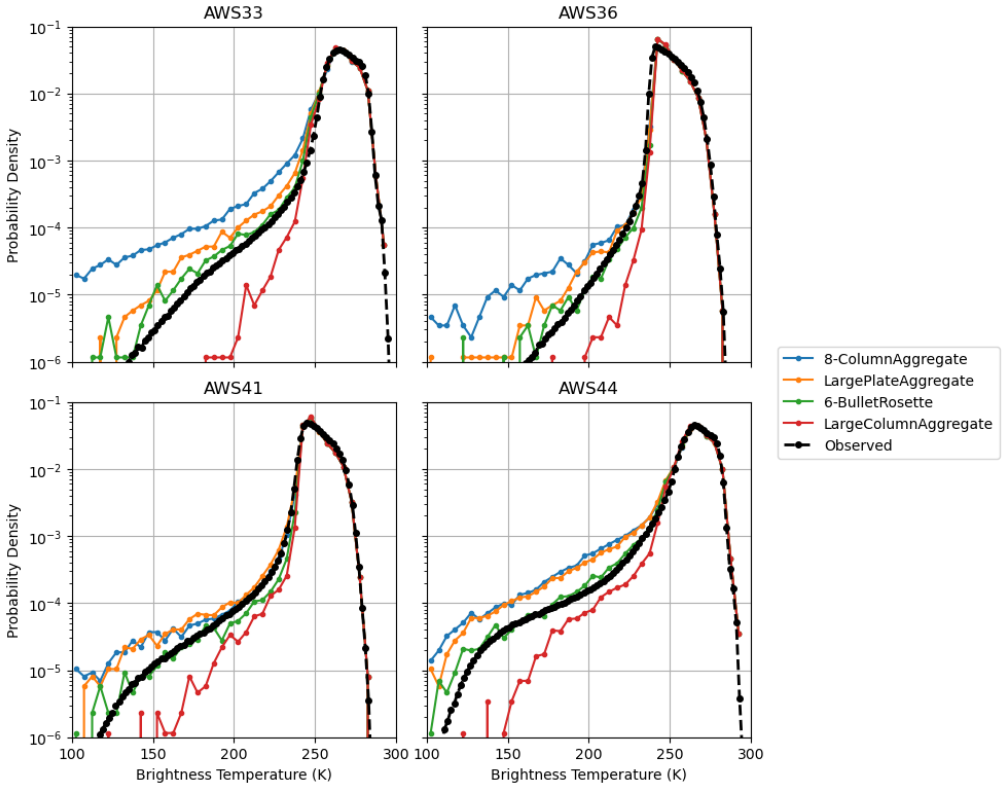
Simulation result

- Histogram distribution
  - Preliminary result
    - 2025-07
    - Based on EarthCARE profiles
    - Over ocean only to simplify surface emissivity assumption



Simulation result

- Histogram distribution
  - Preliminary result
    - 2025-07
    - Based on EarthCARE profiles
    - Over ocean only to simplify surface emissivity assumption
- 6-BulletRosette is the winner!?



Summary

- Synergy between passive MW (sub-mm) and IR
- Goal: parameterize size and shape assumptions consistently for MW and IR sensor
- Tested different microphysics in a radiative transfer model (ARTS)
  - PSD from EarthCARE synergetic retrieval product
  - Habit shapes from scattering database
  - Output IR (10.8um) and sub-mm MW (185GHz and 325GHz) brightness temperature
- Good agreement:
  - Simulated vs observed (collocated and statistically)

Outlook

- Make a lot of simulation to build up a retrieval database
  - X: ice water content / ice water path
  - Y: AWS Tb and 10.8um Tb
- Build a retrieval model
  - Quantile Regression Neural Network (QRNN)
- Pair geostationary IR radiances with AWS
  - Synergetic retrieval
- Input to IR all-sky assimilation?
  - Parameterise PSD
  - Parameterise scattering properties

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