2nd ESA-JAXA EarthCARE In Orbit Validation Workshop
Radiation and synergy session

McGill

Validation of EarthCARE cloud retrievals using surface spectral infrared radiances from ECALOT campaign

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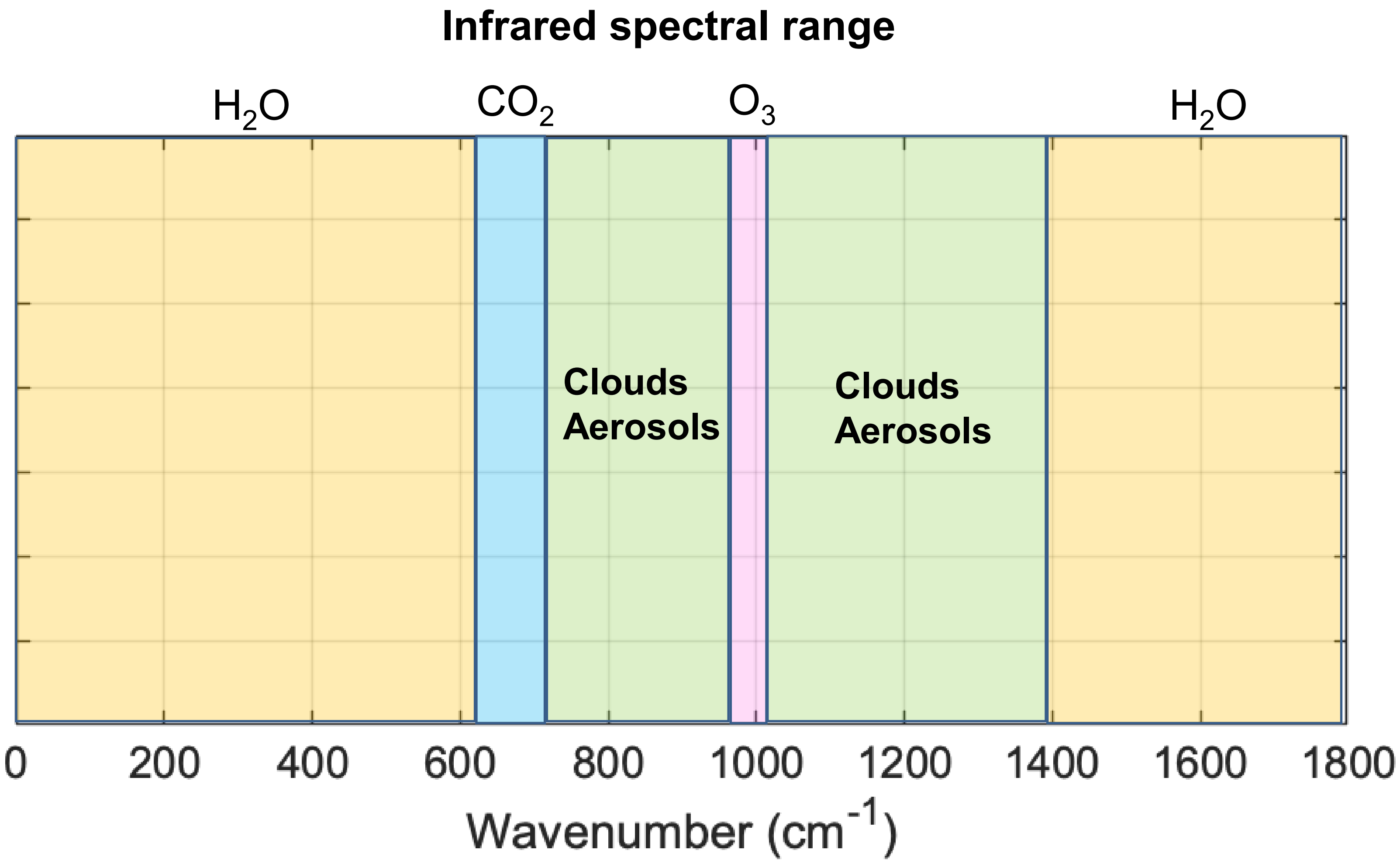
March 19, 2025

EarthCARE Overpasses Over AERI in Ottawa

EarthCARE

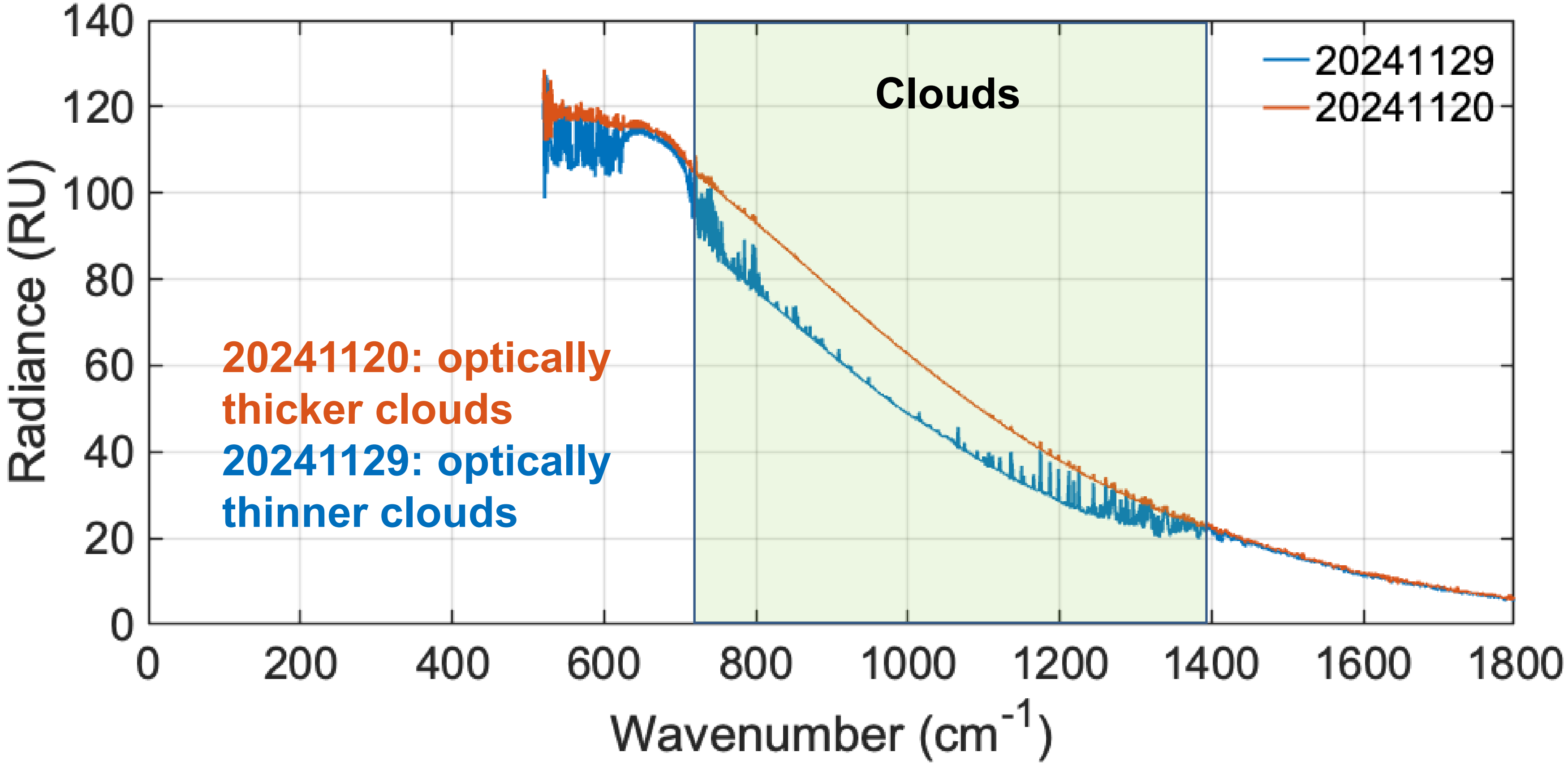


AERI: Atmospheric Emitted Radiance Interferometer

EarthCARE Overpasses Over AERI in Ottawa

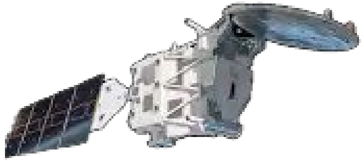
EarthCARE

AERI-observed downwelling longwave radiance (DLR) spectra
Two overpass cases in Ottawa



AERI: Atmospheric Emitted Radiance Interferometer

EarthCARE AERI Validation Overview



EarthCARE Scene Construction Algorithm (Qu et al., 2023, AMT)

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EarthCARE retrieved cloud products (LWC, IWC, liquid cloud R_e, ice cloud R_e)

↓

GFDL cloud library

↓

Spectrally resolved cloud optical depth

MWR
ECMWF forecast

→ Temperature and water vapor profiles

↓

CO_2, CO, CH_4, O_3, N_2O, CFC11, CFC12, and CCl_4 → LBLRTM v12.16

↓

Spectrally resolved gas optical depth

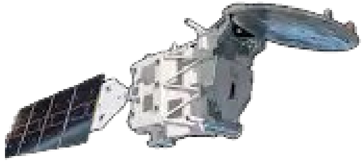
Spectrally resolved cloud optical depth → DISORT v4.0.99 ← Spectrally resolved gas optical depth

↓

Simulated all-sky DLR

Observed all-sky DLR ↔ Simulated all-sky DLR

EarthCARE AERI Validation Overview



- Liquid cloud
  - Gamma distribution parameter
- Ice cloud
  - Gamma distribution parameter
  - **Ice habits**
  - Roughness

EarthCARE Scene Construction Algorithm (Qu et al., 2023, AMT)

EarthCARE retrieved cloud products (LWC, IWC, liquid cloud R_e, ice cloud R_e)

GFDL cloud library

Spectrally resolved cloud optical depth

MWR
ECMWF forecast

Temperature and water vapor profiles

CO_2, CO, CH_4, O_3, N_2O, CFC11, CFC12, and CCl_4

LBLRTM v12.16

Spectrally resolved gas optical depth

DISORT v4.0.99

Observed all-sky DLR

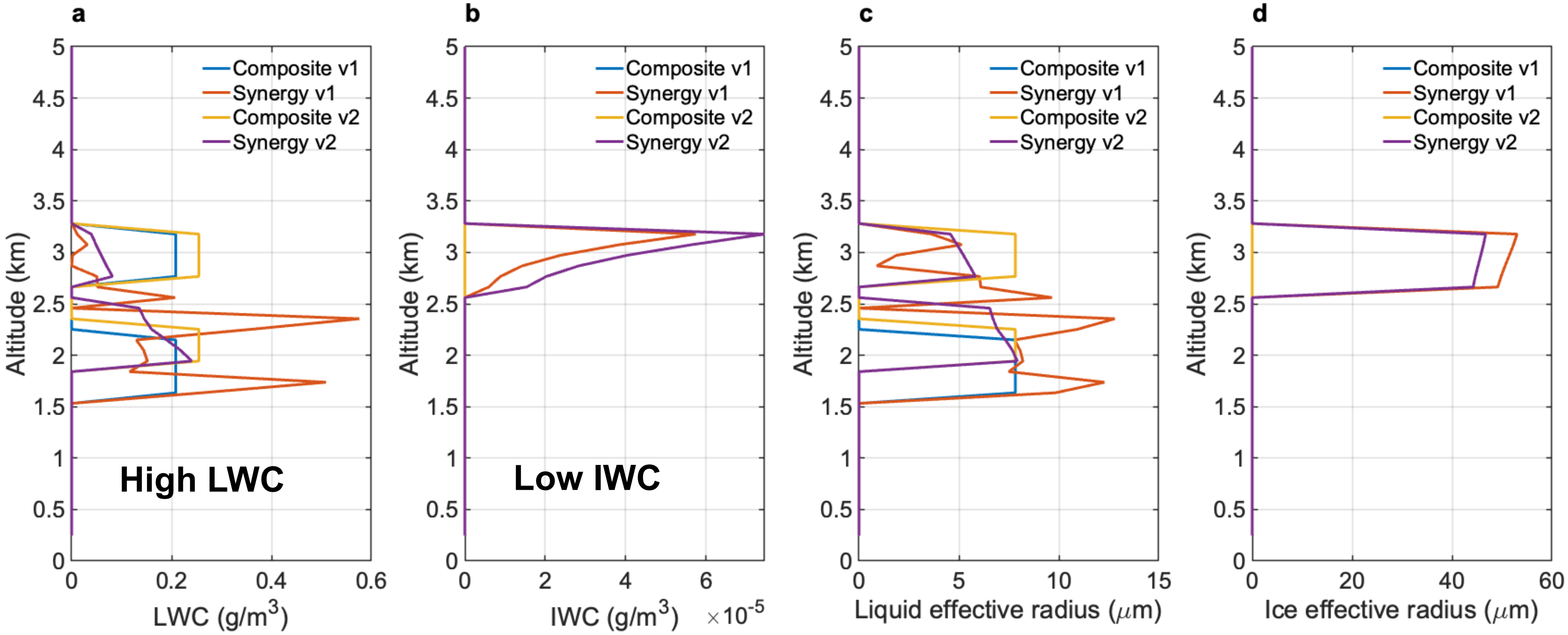
Simulated all-sky DLR

EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC

Key Radiative Transfer Inputs

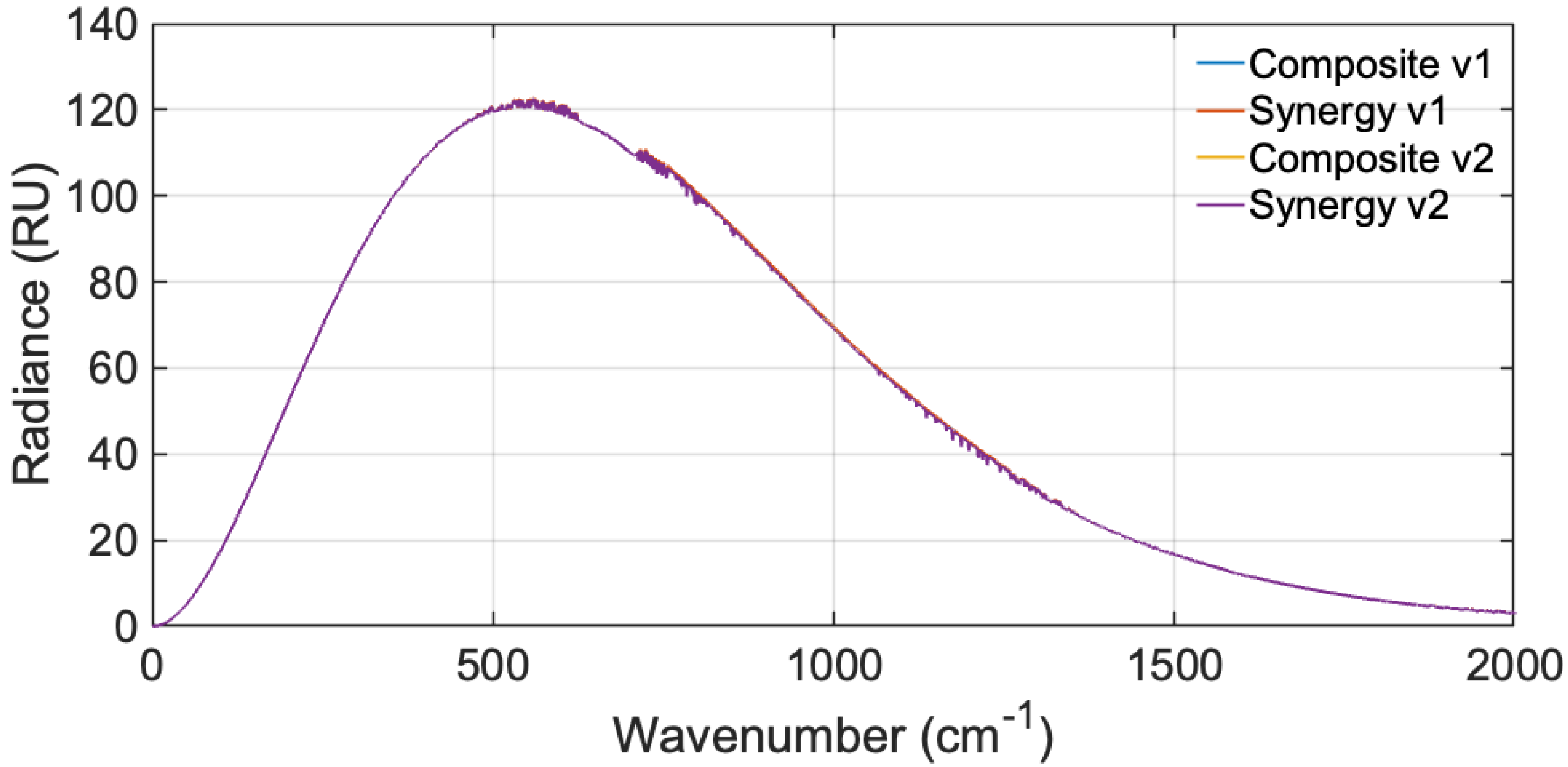
- Cloud microphysical properties: EarthCARE retrieval products (composite vs. synergy: two versions)
- Composite: Liquid cloud only
- Synergy: Liquid and ice clouds

- Composite v1: Composite (with C-CLD AA, M-COP AB)
- Composite v2: Composite (with C-CLD AC, M-COP AB)
- Synergy v1: Synergy (ACM-CAP AA)
- Synergy v2: Synergy (ACM-CAP v11.40)



EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC
Radiative Transfer Analysis

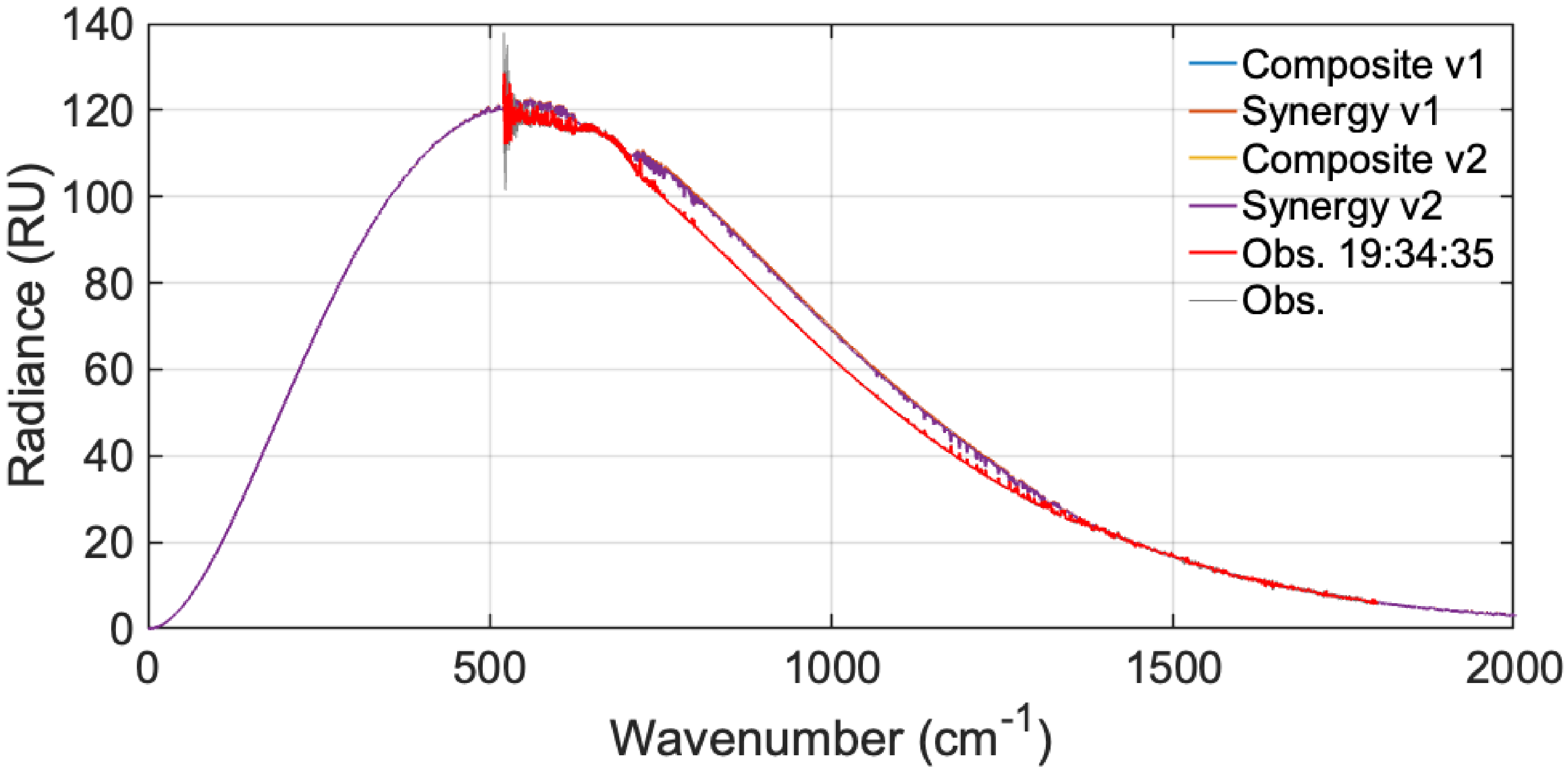
- Simulated DLR spectra:
  - Planck-like shape
  - Low variability across various cloud retrieval products



EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC

Radiative Transfer Analysis

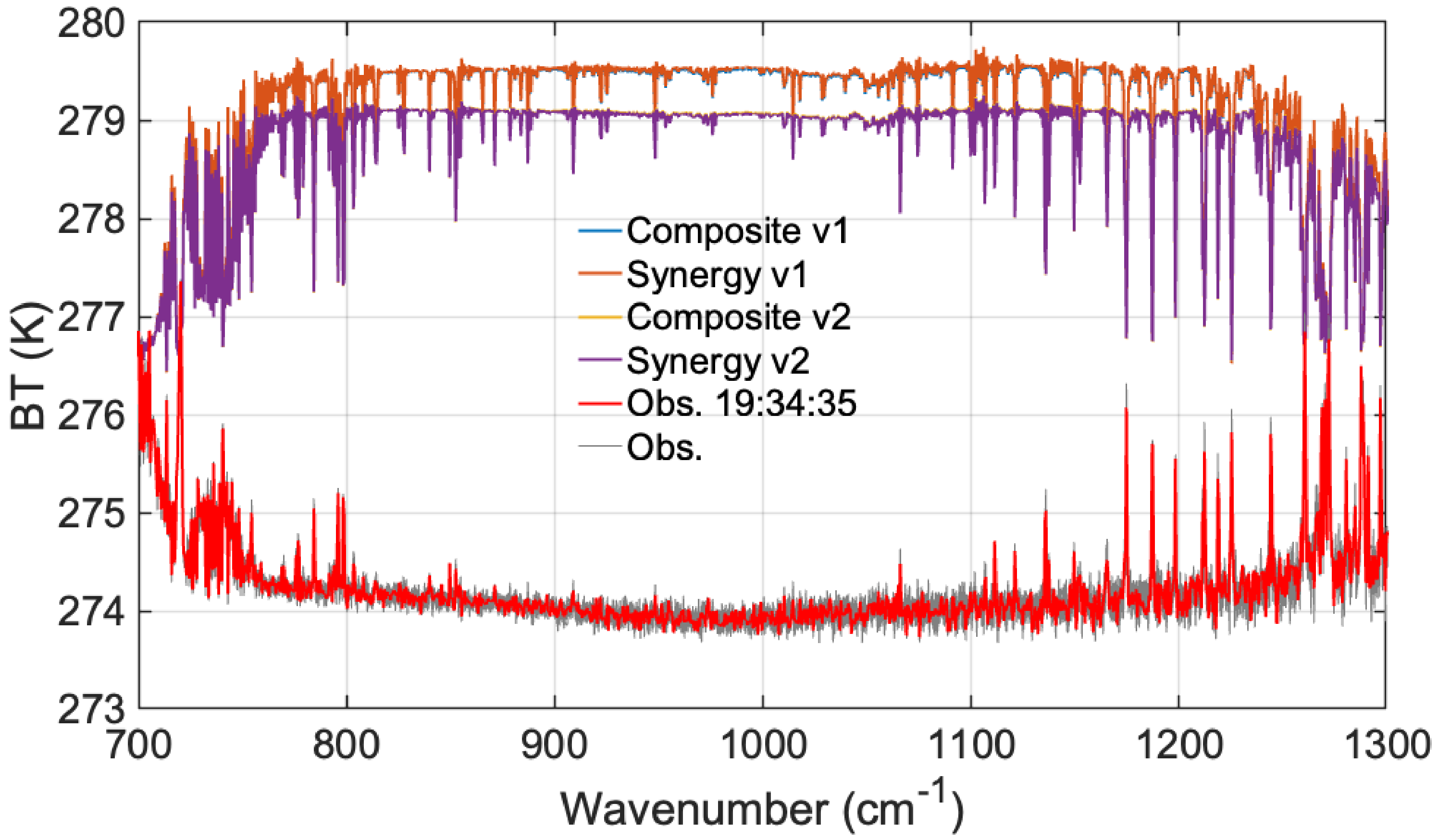
- Simulated DLR spectra:
  - Planck-like shape
  - Low variability across various cloud retrieval products
- Observed DLR spectra:
  - Planck-like shape
  - Low variability across 6-minute observational window



EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC

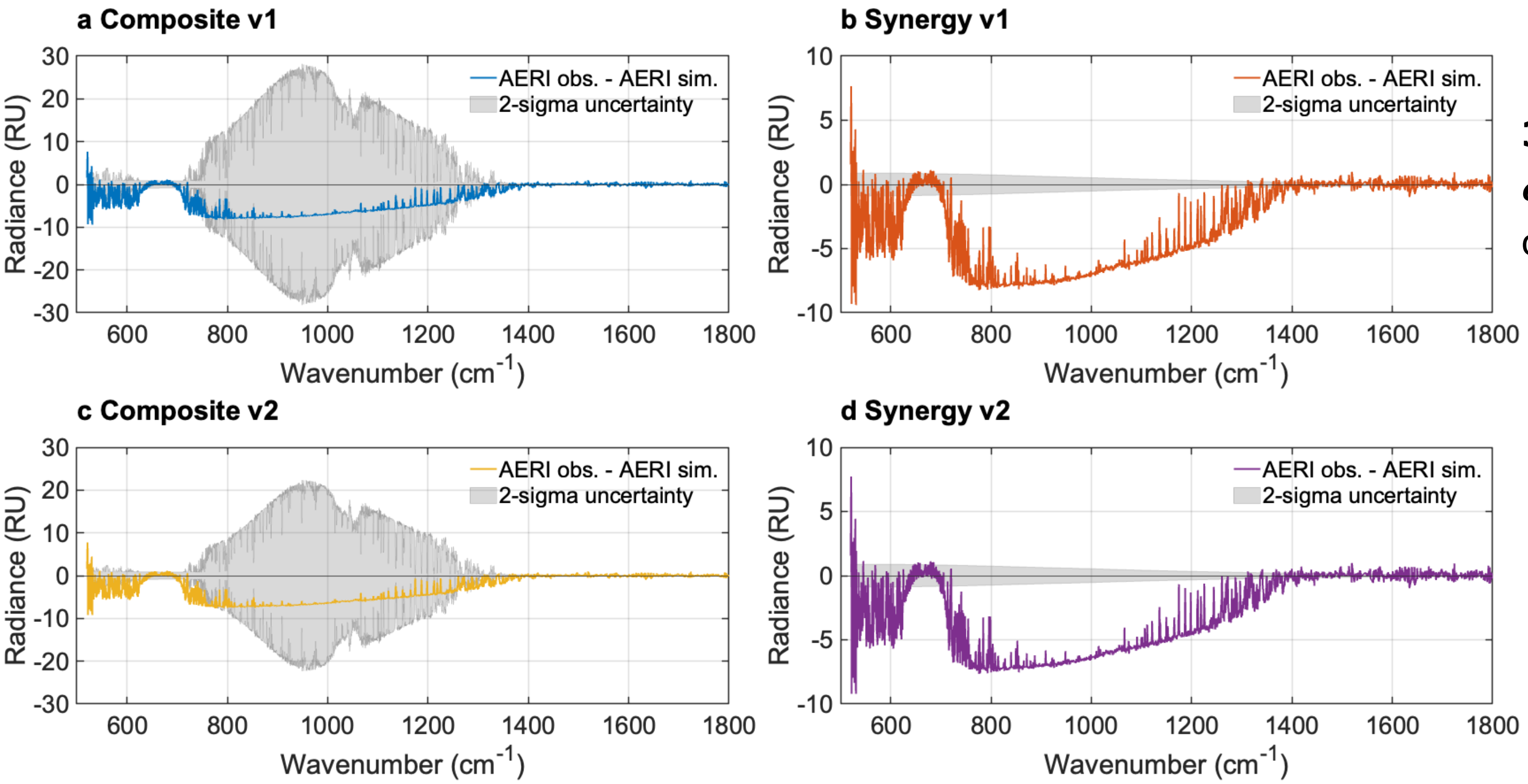
Radiative Transfer Analysis

- In the window band, brightness temperature (BT) difference between observations and simulations: **5~6 K**



EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC

Radiative Transfer Analysis



$$R_{bias}^{v} = R_{obs}^{v} - R_{sim}^{v}$$

$$\sigma_{R_{bias}^{v}} = \sqrt{\sigma_{R_{obs}^{v}}^{2} + \sigma_{R_{sim}^{v}}^{2}}$$

$3\sigma_{R_{obs}^{v}}$: 1% ambient radiance

$\sigma_{R_{sim}^{v}}$: spatial variability of the cloud microphysical products

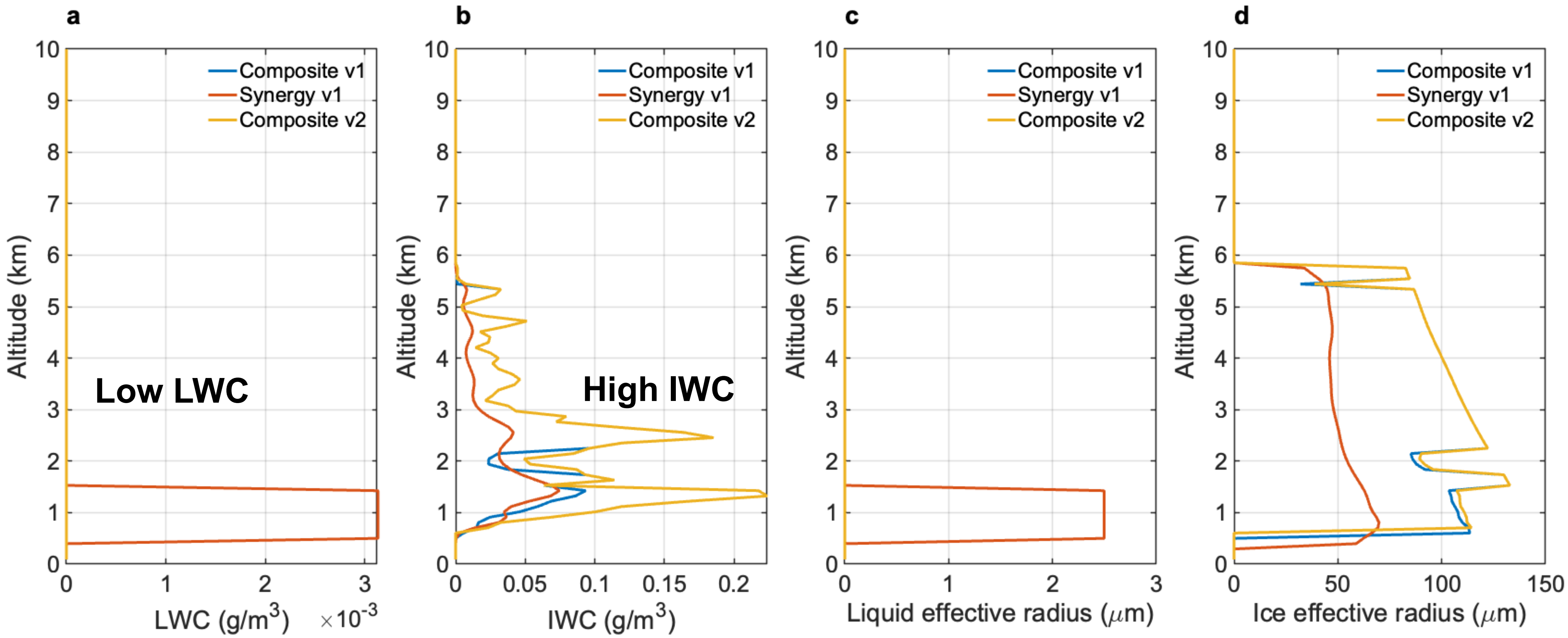
- Similar DLR biases across various cloud retrieval products, with biases remaining within 10 RU
- Composite retrieval products exhibit higher cloud spatial variability compared to synergy retrieval products

EarthCARE Overpass: Ottawa 20241129 19:30:09 UTC

Key Radiative Transfer Inputs

- Cloud microphysical properties: EarthCARE retrieval products (composite vs. synergy: two versions)

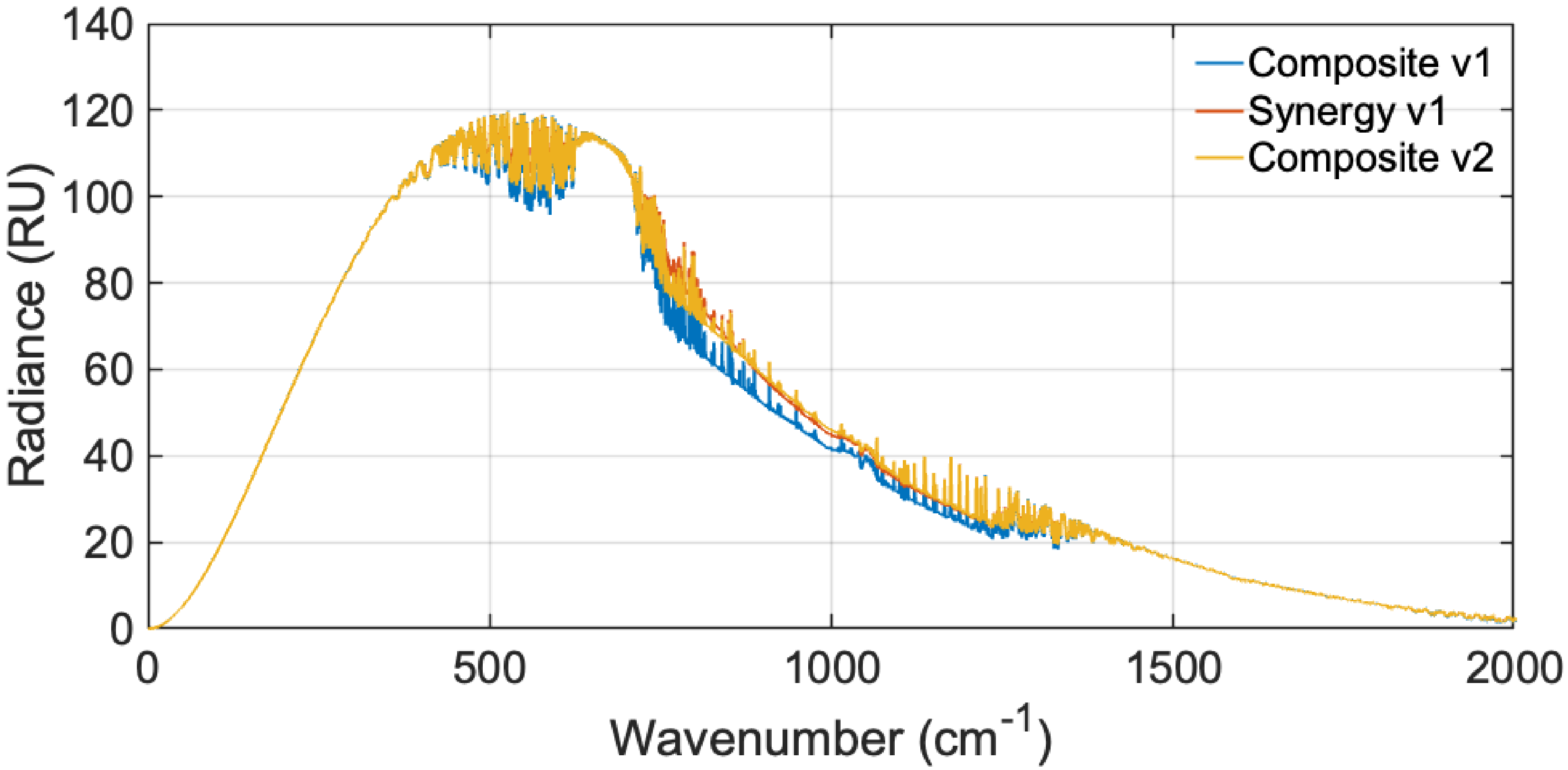
- Composite: Ice cloud only
  - Composite v2: higher IWC
- Synergy: Liquid and ice clouds



EarthCARE Overpass: Ottawa 20241129 19:30:09 UTC

Radiative Transfer Analysis

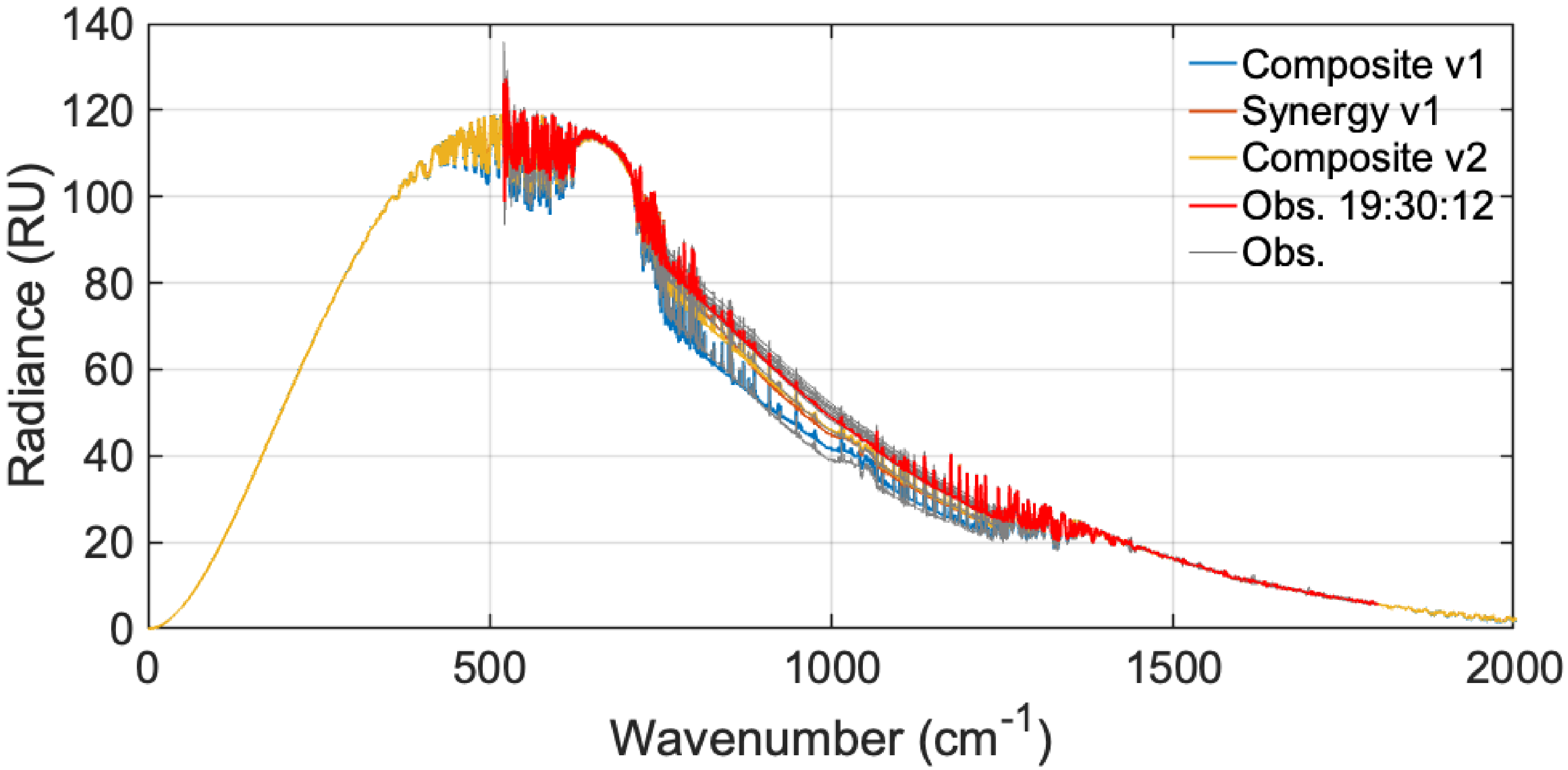
- Simulated DLR spectra:
  - Composite v2 and synergy v1 retrieval cases exhibit larger DLR in the window band



EarthCARE Overpass: Ottawa 20241129 19:30:09 UTC

Radiative Transfer Analysis

- Simulated DLR spectra:
  - Composite v2 and synergy v1 retrieval cases exhibit larger DLR in the window band
- Observed DLR spectra:
  - Relatively larger variability across 6-minute observational window



EarthCARE Overpass: Ottawa 20241129 19:30:09 UTC

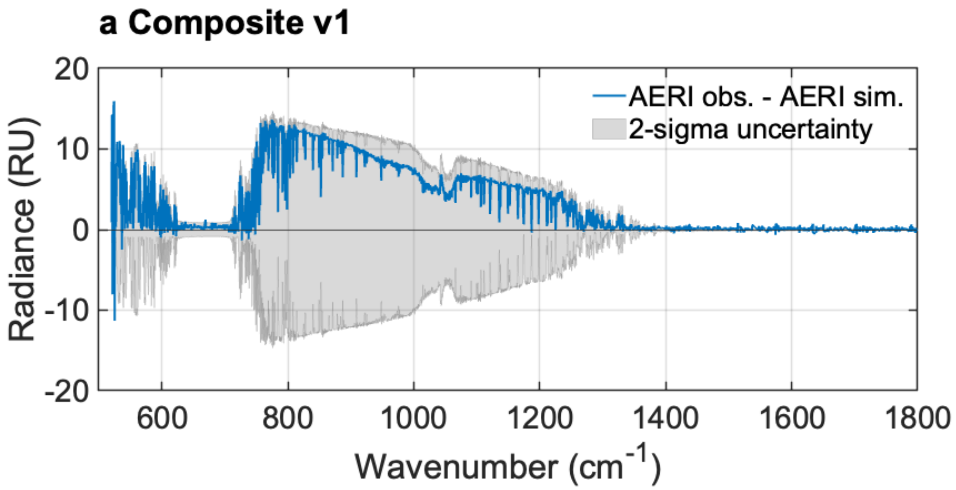
Radiative Transfer Analysis

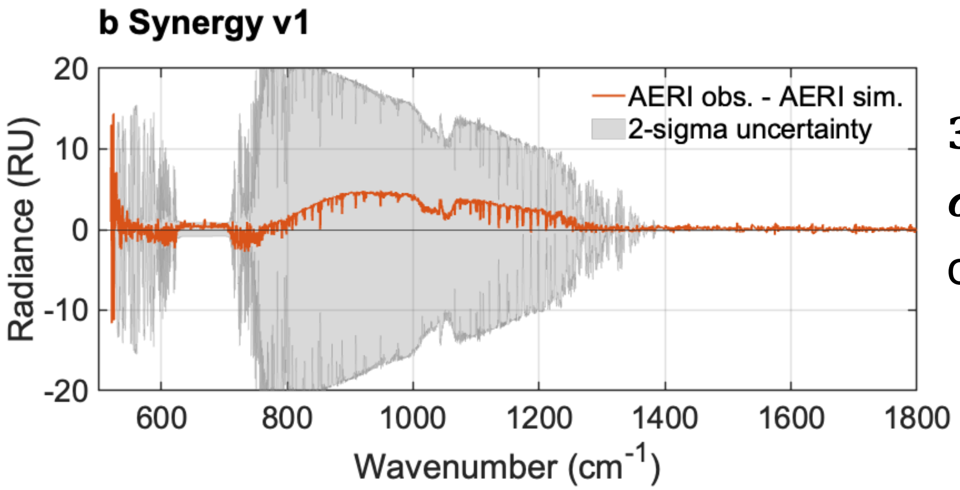
$$R_{bias}^{v} = R_{obs}^{v} - R_{sim}^{v}$$

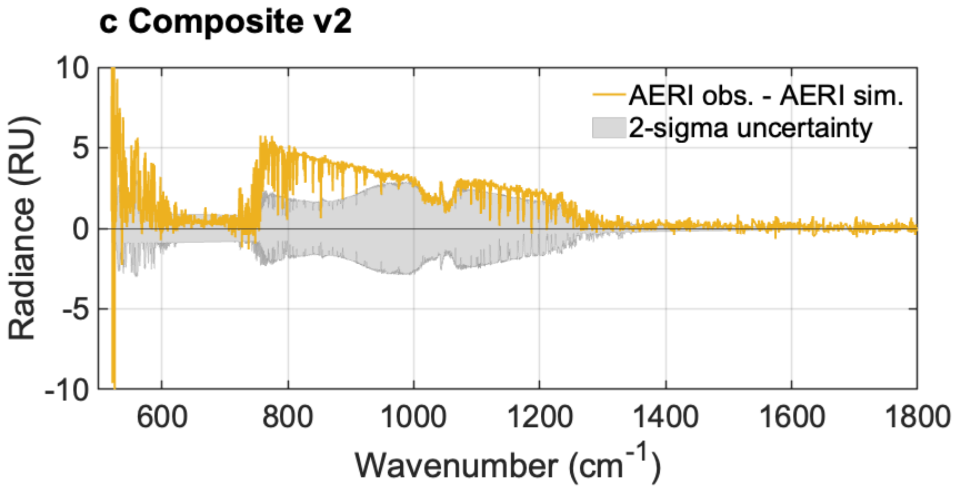
$$\sigma_{R_{bias}^{v}} = \sqrt{\sigma_{R_{obs}^{v}}{}^{2} + \sigma_{R_{sim}^{v}}{}^{2}}$$

$3\sigma_{R_{obs}^{v}}$: 1% ambient radiance

$\sigma_{R_{sim}^{v}}$: spatial variability of the cloud microphysical products







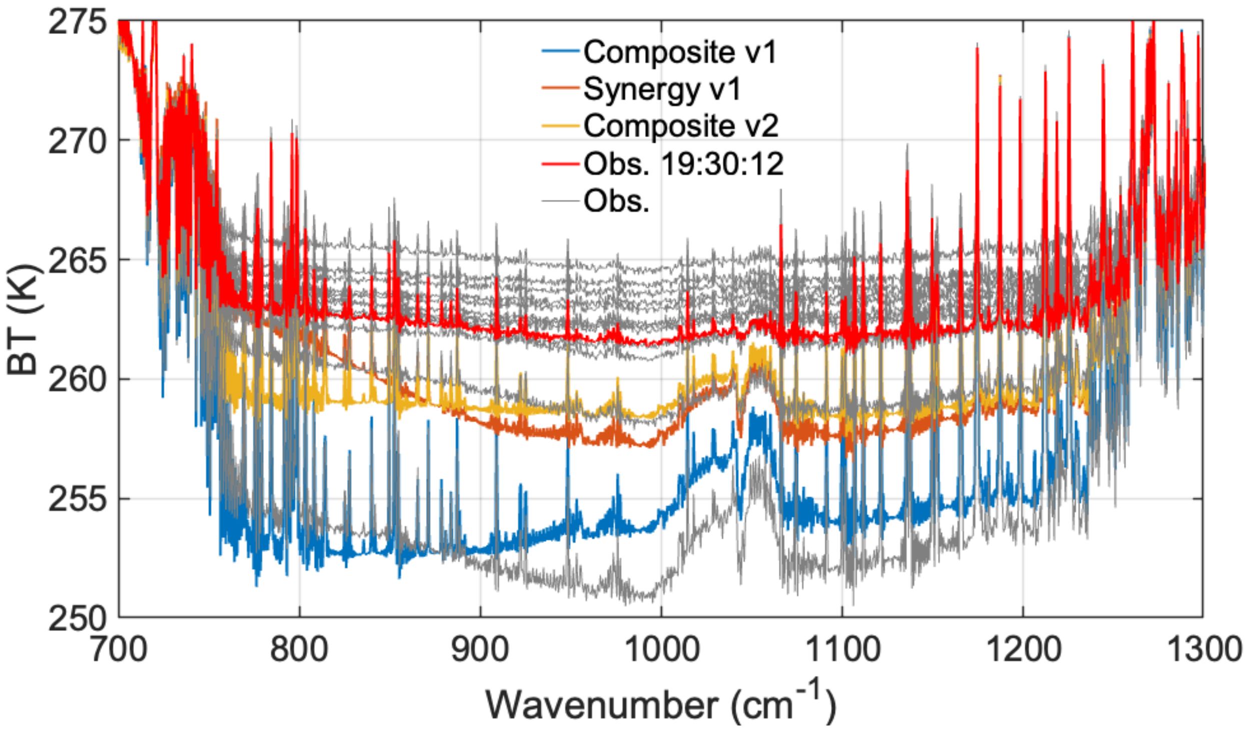
- DLR biases in the window band:
  - Composite v1 > Composite v2 ≃ Synergy v1
- Different cloud retrieval products exhibit varying levels of cloud spatial variability
- Optically thin clouds play a crucial role in evaluating retrieval products

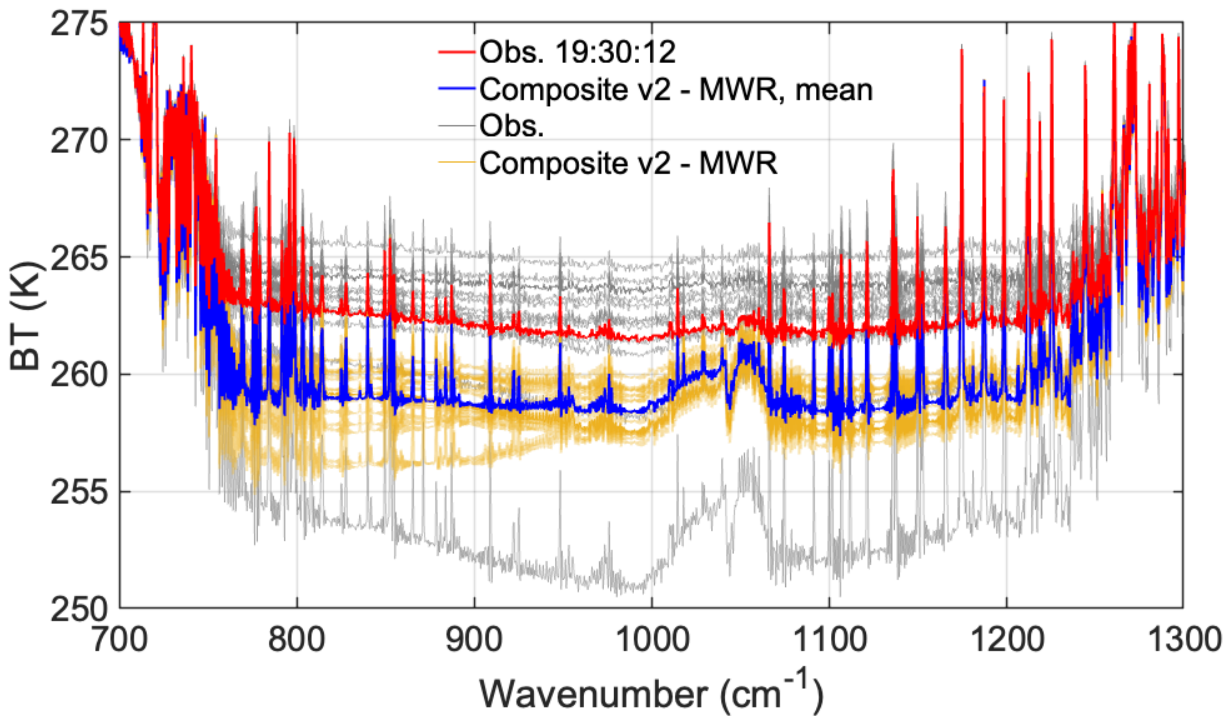
EarthCARE Overpass: Ottawa 20241129 19:30:09 UTC

Radiative Transfer Analysis

- In the window band:
  - Different spectral signatures among various retrieval products

- In the window band, BT difference between
  - Obs. 19:30:12 and Composite v2 – MWR, mean: **~ 3 K**
  - Obs. 19:30:12 and closest Composite v2 – MWR: **~ 1.5 K**

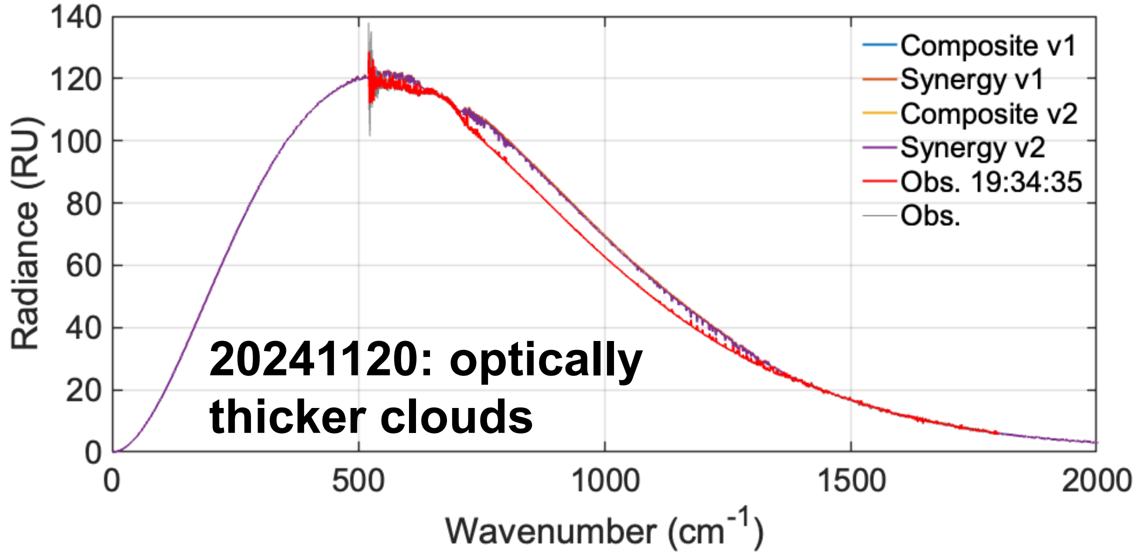


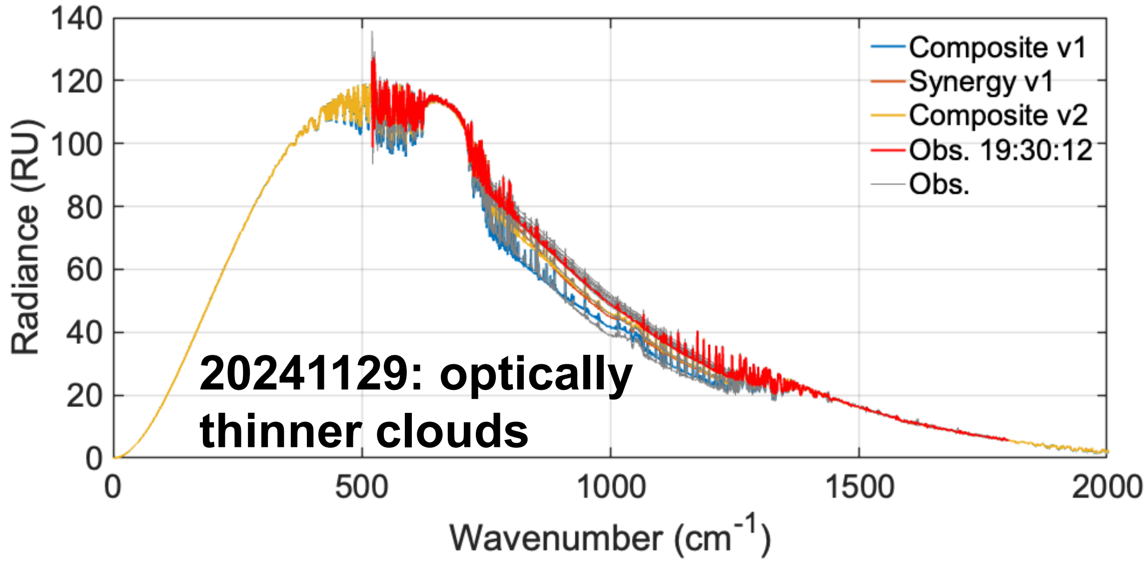


EarthCARE AERI Validation Conclusion

Collocated spectrally resolved infrared measurements provide a unique approach for validating and refining EarthCARE cloud retrieval products:

- Multiple versions of the retrieval products were compared.
- Radiative closure is relatively good for both optically thin and thick cloud conditions with DLR biases remain within 10 RU in the window band.
- Certain spectral shape biases persist, necessitating further analysis to identify their root causes and explore potential solutions for improving the retrieval products.





Thank you!

Lei Liu

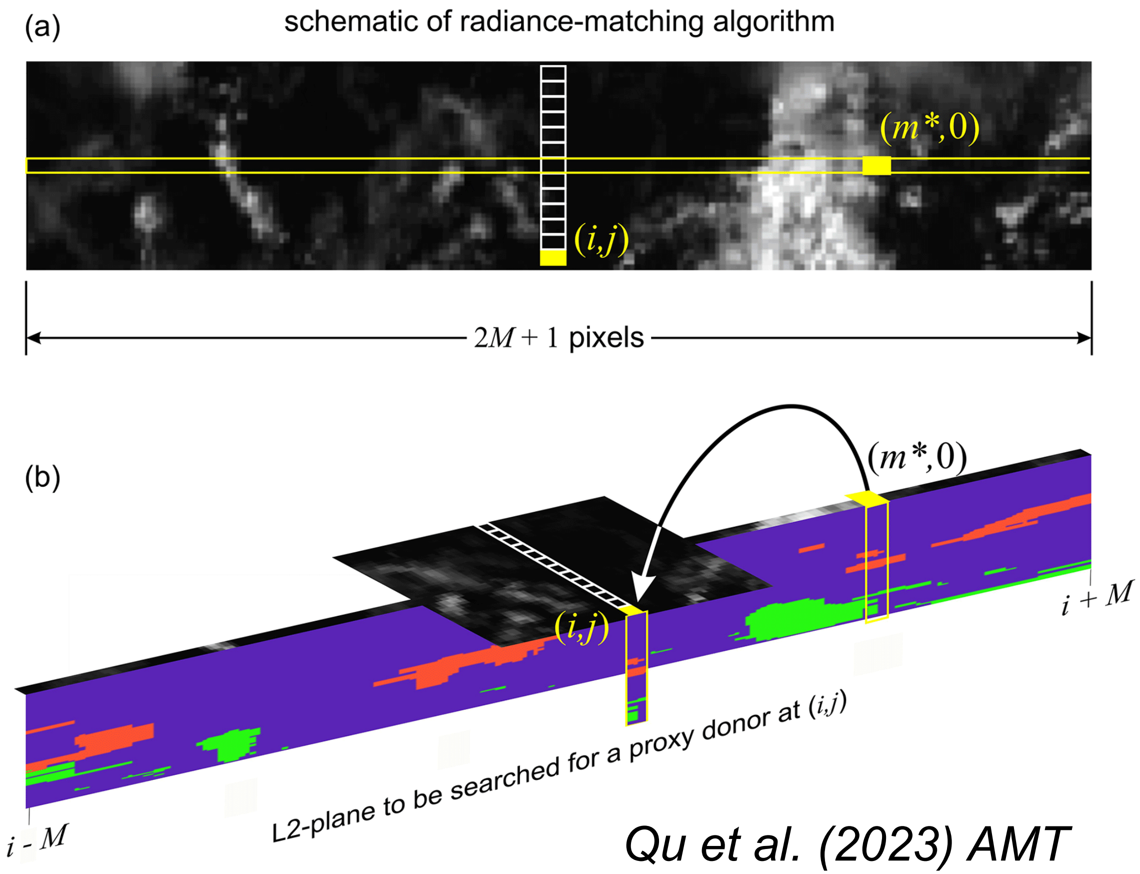
EarthCARE AERI Validation Overview

- gamma distribution: $f(x) = \frac{\beta^{\alpha}}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x}$

- LBLRTM v12.9 + DISORT
- High spectral resolution simulations (0.05 cm^{-1})
- Convolute with AERI scan function
- Cloud library from GFDL (Feng et al. 2024)
  - Sensitivity tests of ice habits: 9 habits selected
- Sensitivity tests of phase function
  - HG: Henyey-Greenstein
  - GS: Garcia-Siewert

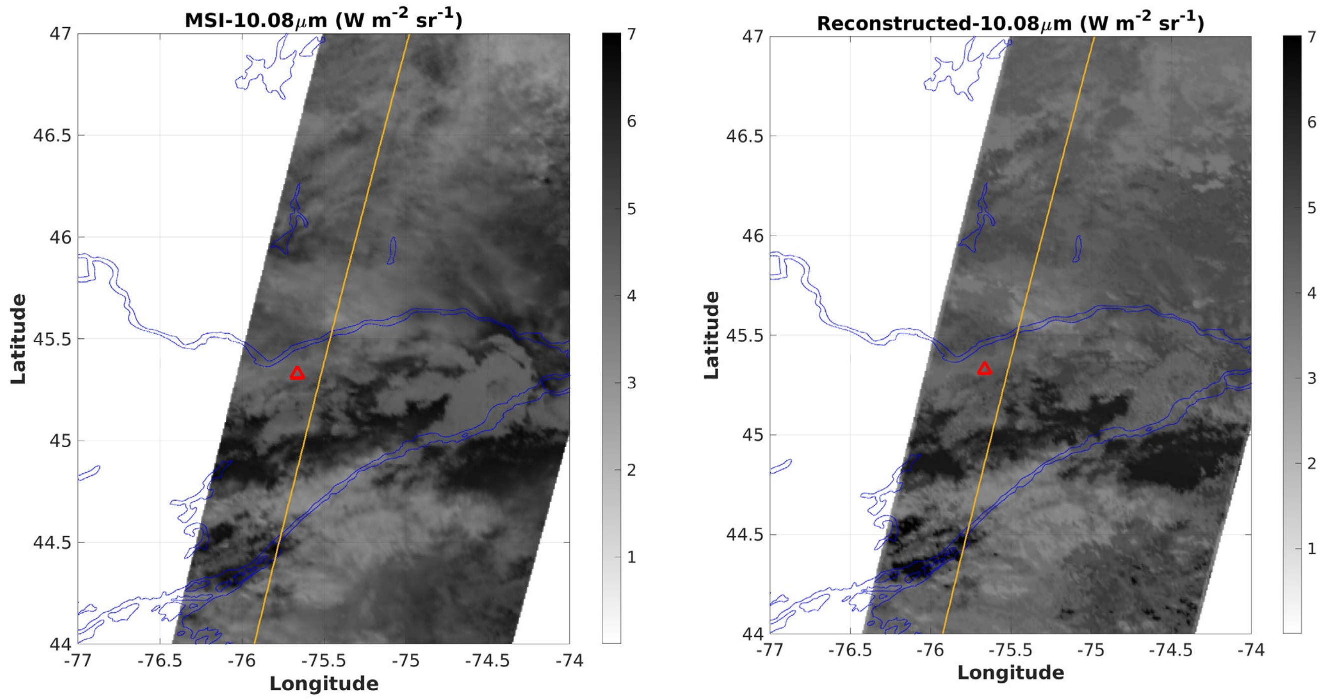
(1). hexagonal column
(2). plate
(3). hollow column
(4). droxtal
(5). hollow bullet rossette
(6). solid bullet rossette
(7). 8-element column aggregate
(8). 5-element plate aggregate
(9). 10-element plate aggregate

EarthCARE's Scene Construction Algorithm



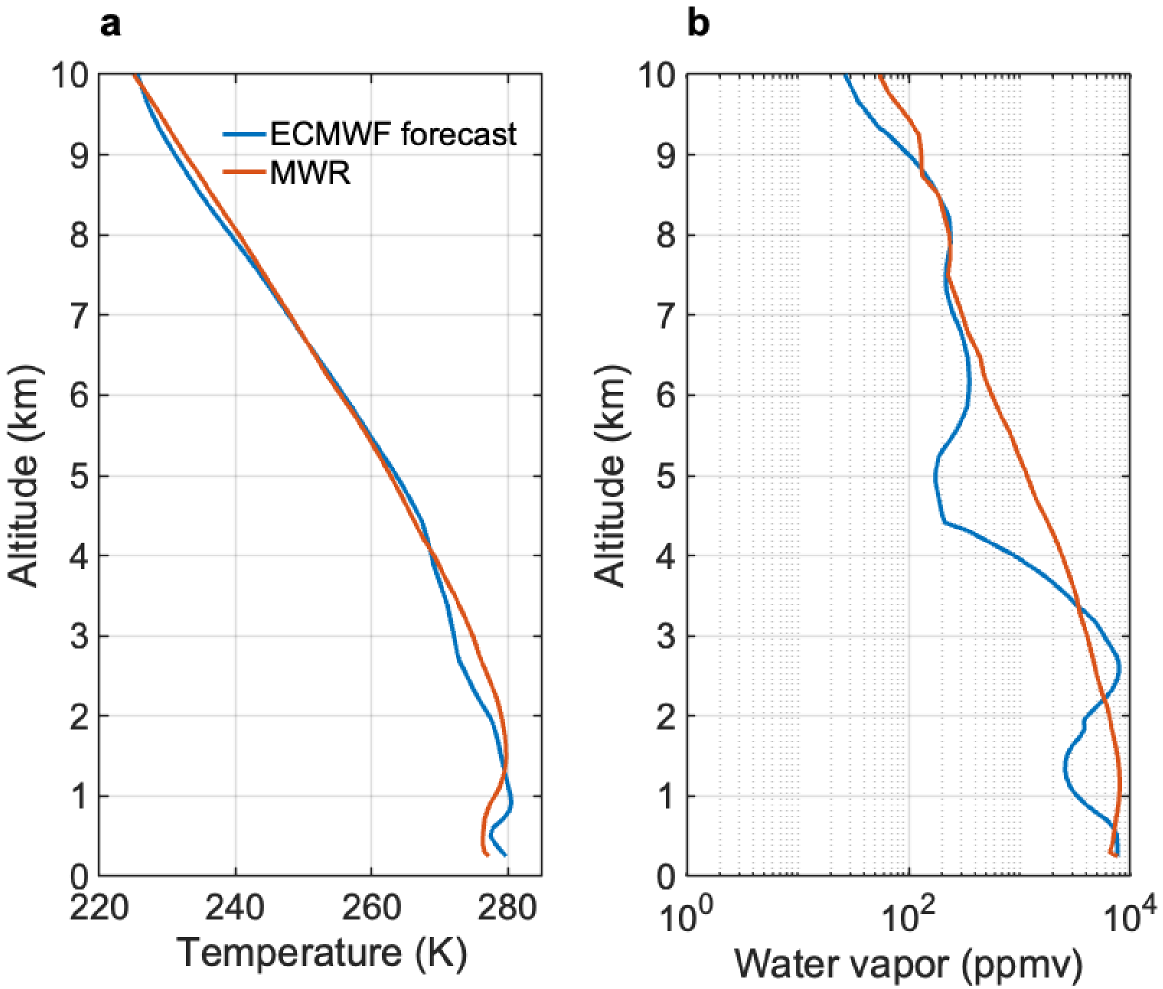
Qu et al. (2023) AMT

20241129



EarthCARE Overpass: Ottawa 20241120 19:34:27 UTC

Key Radiative Transfer Inputs



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Key Radiative Transfer Inputs