
Surface Radiation Measurements Provide Complementary Constraints for EarthCARE Cloud Retrievals

Lei Liu^{1,3}, Yi Huang¹, Zhipeng Qu², Benjamin Riot-Bretêcher¹, Jason Cole²,
Howard Barker², Meriem Kacimi², Zen Mariani²

¹McGill University, Montreal, QC, Canada

²Environment and Climate Change Canada, Toronto, ON, Canada

³Present address: University of Hamburg, Hamburg, Germany

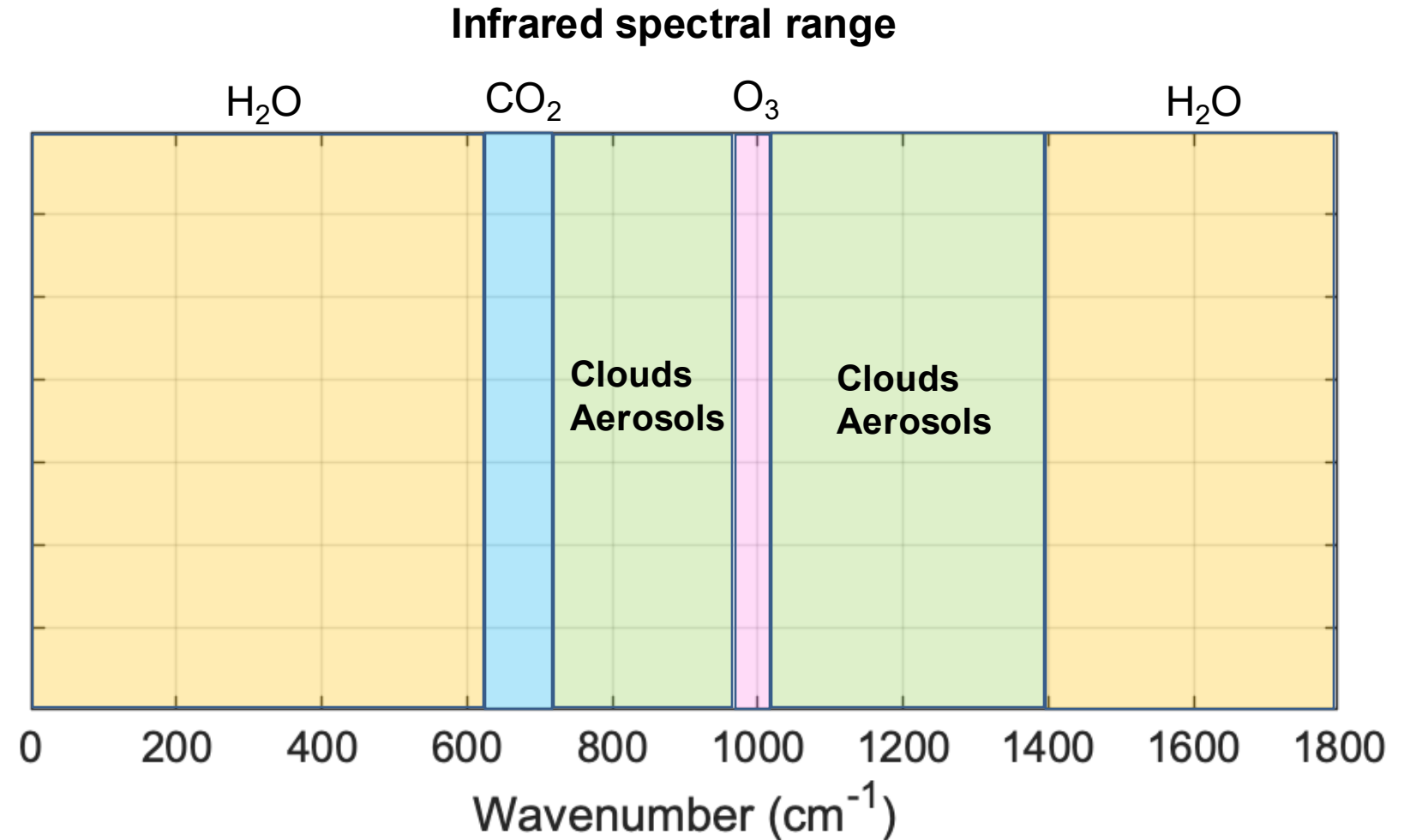
June 10, 2026

Surface DLR as An Independent Constraint for Clouds

EarthCARE



**AERI: Atmospheric Emitted
Radiance Interferometer**



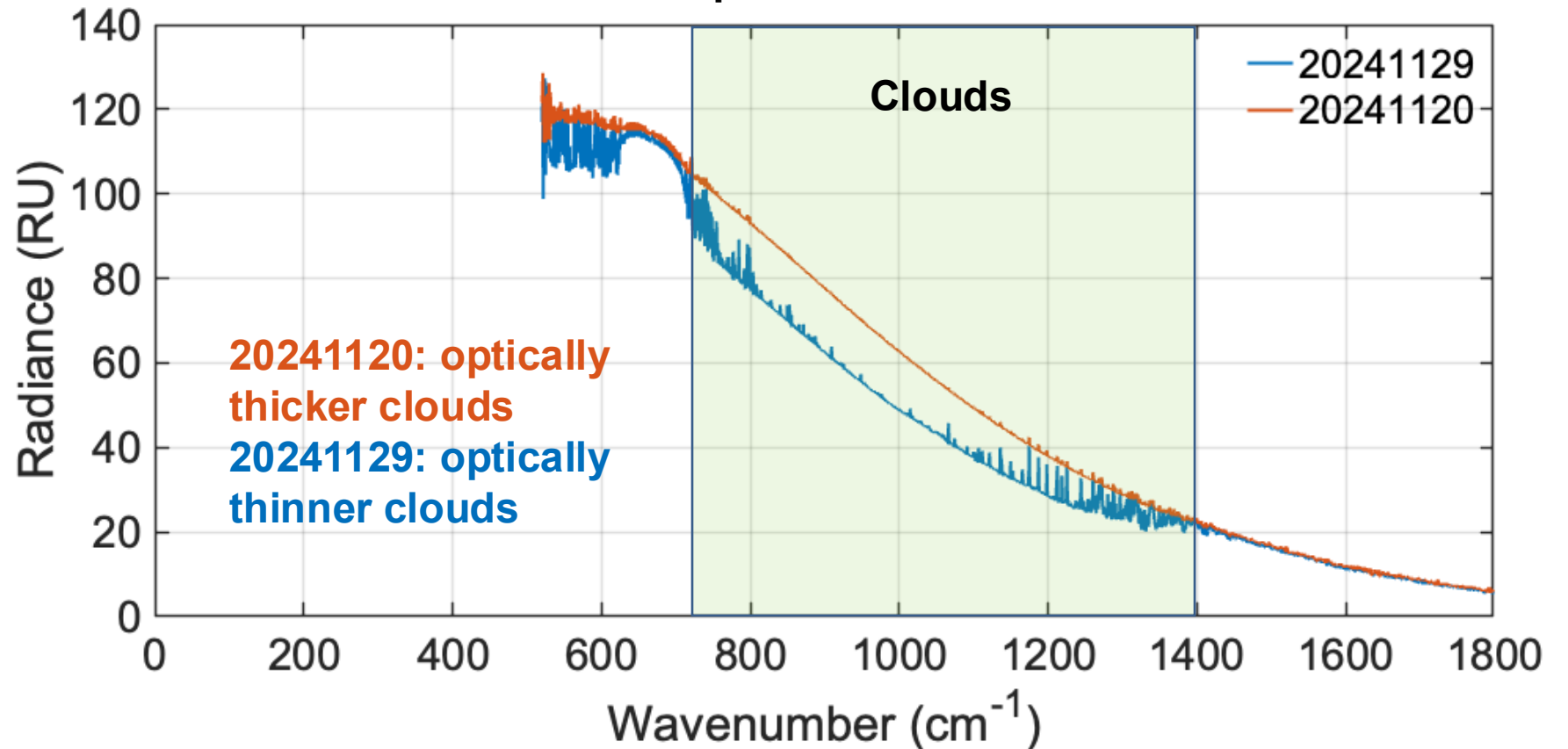
Surface DLR as An Independent Constraint for Clouds

EarthCARE



AERI: Atmospheric Emitted Radiance Interferometer

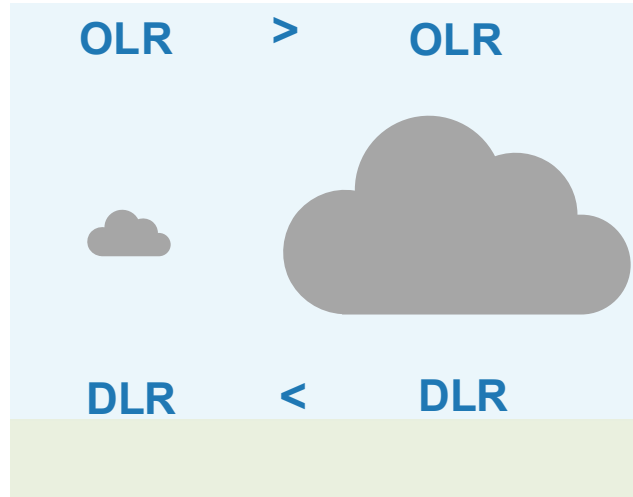
**AERI-observed downwelling longwave radiance (DLR) spectra
Two overpass cases in Ottawa**



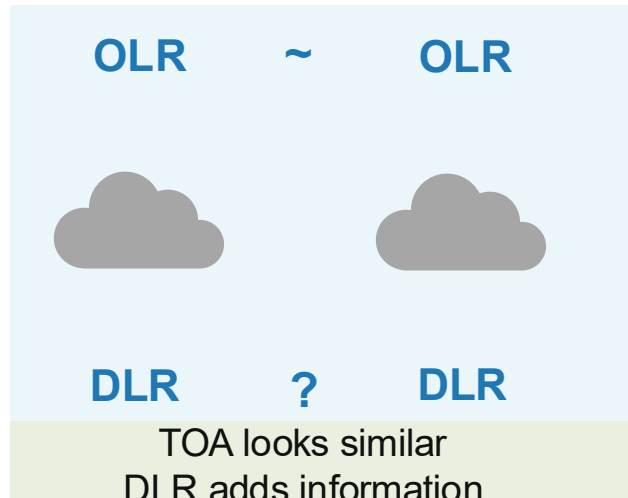
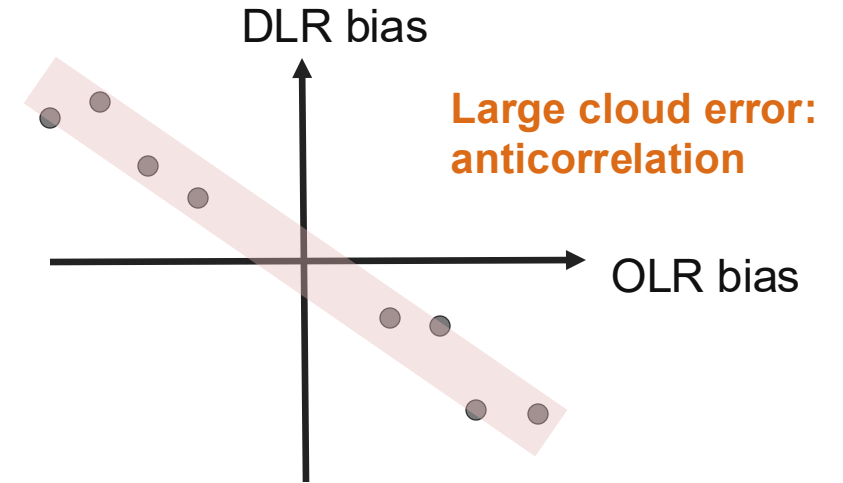
DLR: Radiance Units (RU)
1 RU = 1 mW/(m² sr cm⁻¹)

Surface DLR as An Independent Constraint for Clouds

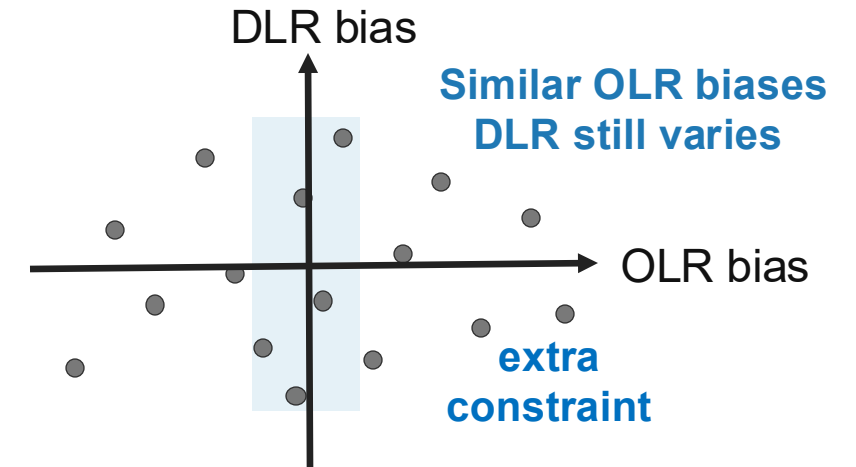
EarthCARE



if cloud is very wrong



if cloud is not very wrong

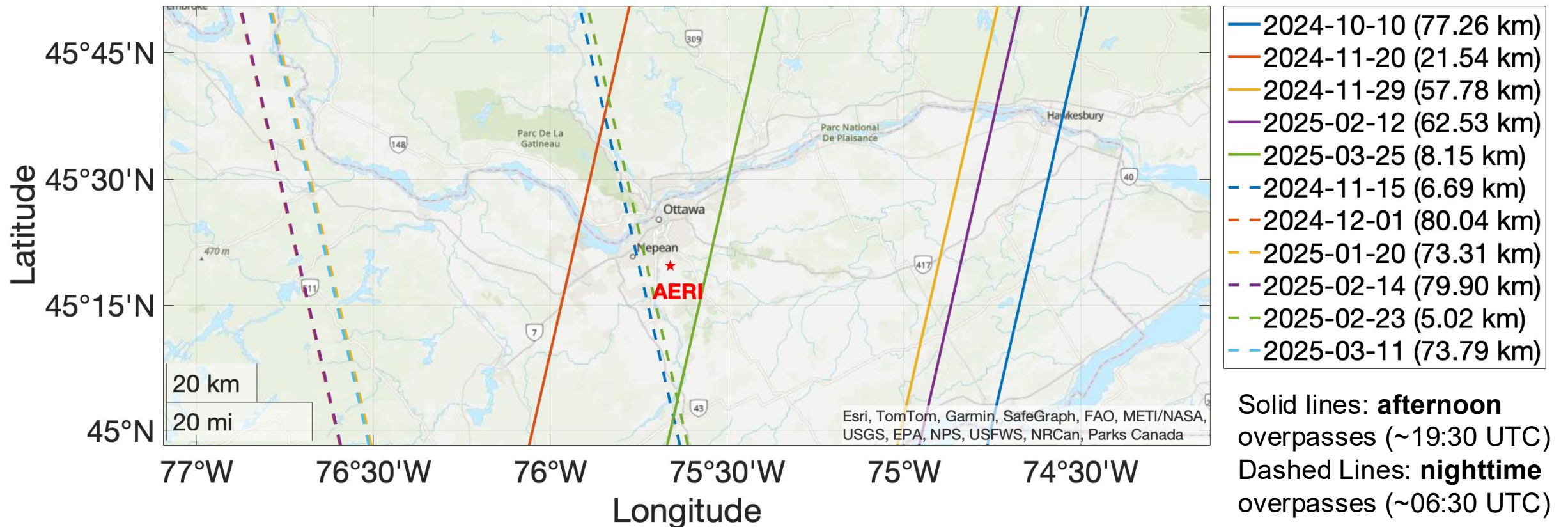


AERI: Atmospheric Emitted
Radiance Interferometer



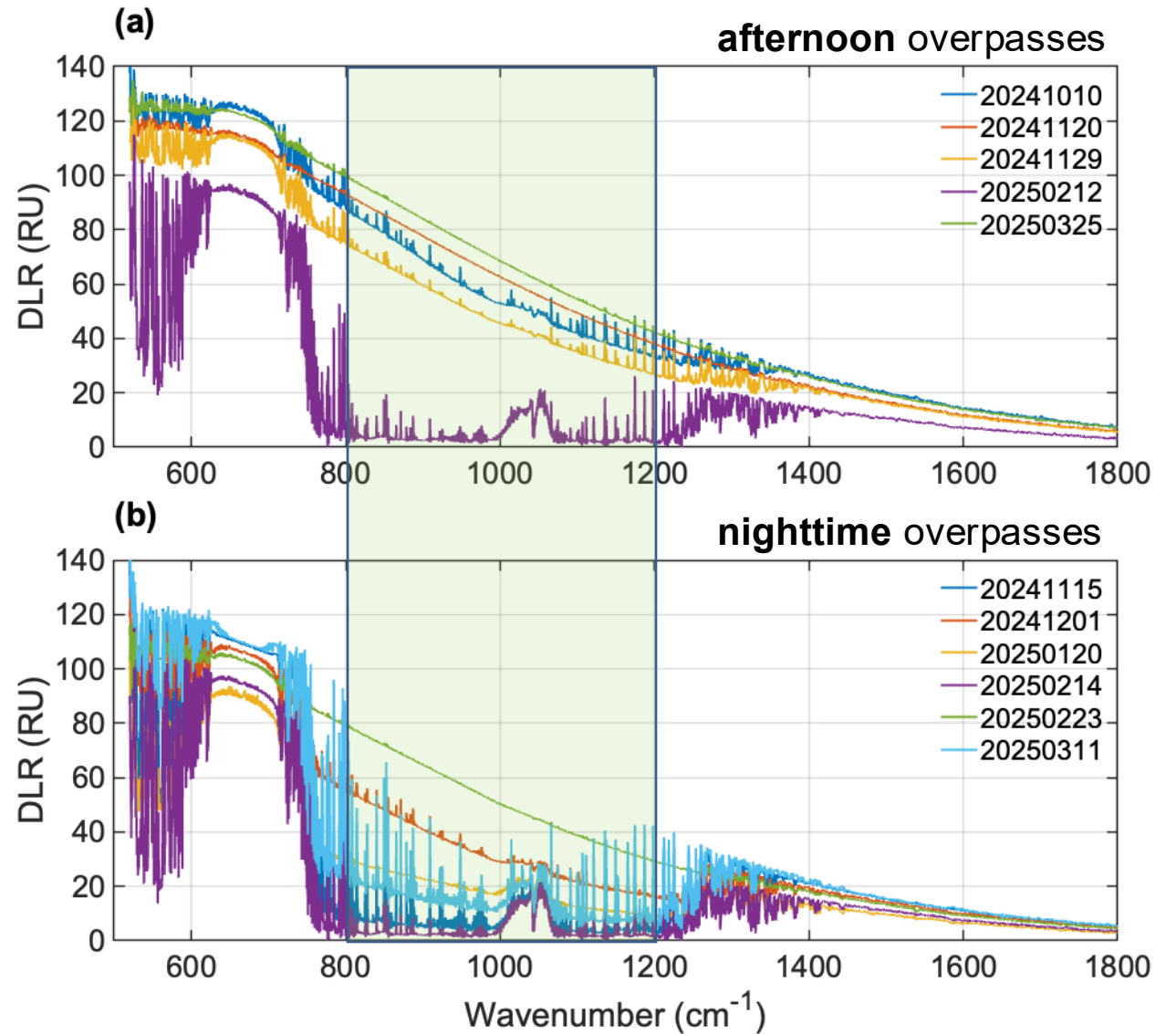
EarthCARE Ottawa Overpass

- Study period: October 2024 - March 2025
- 11 overpasses selected, with the EarthCARE ground track passing within 100 km of the AERI site in Ottawa



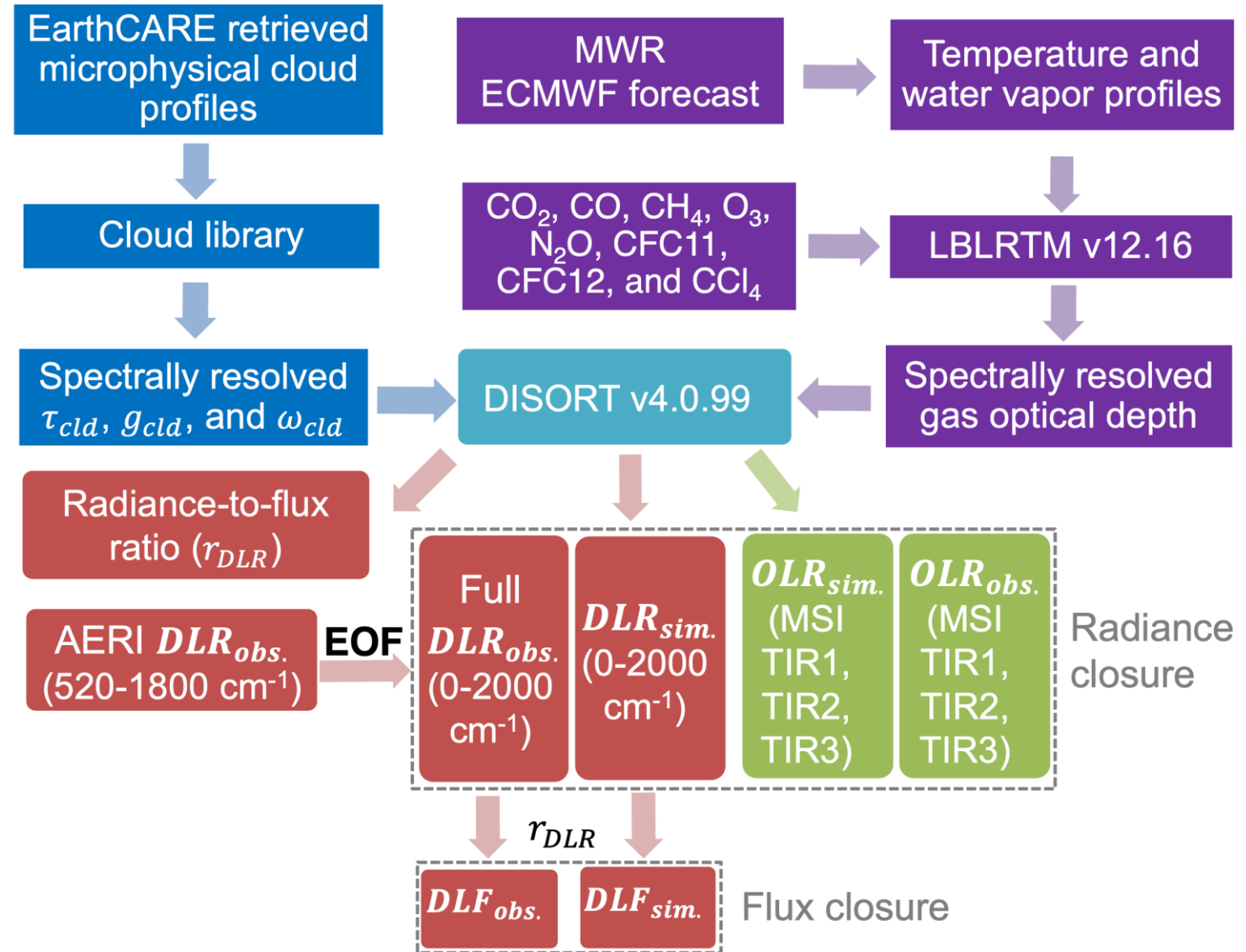
EarthCARE Ottawa Overpass

- AERI observations:
 - Substantial variability in the window band indicates a wide range of sky conditions, from clear skies to cloudy scenes characterized by diverse cloud optical depths and cloud-emitting temperatures.



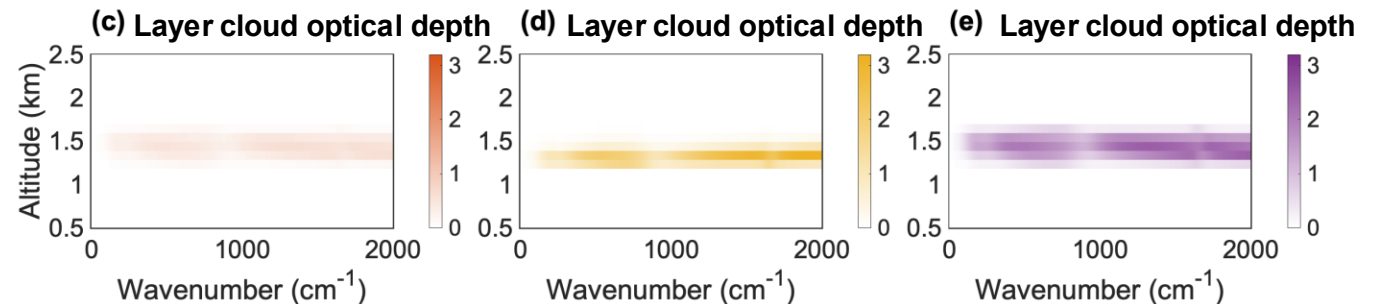
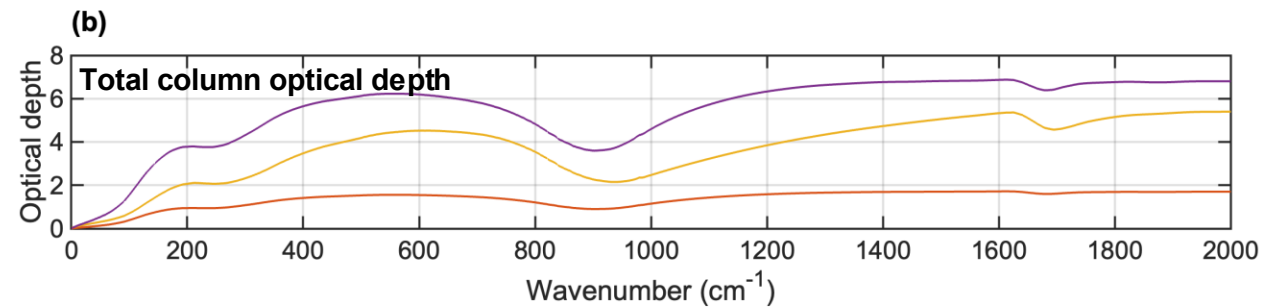
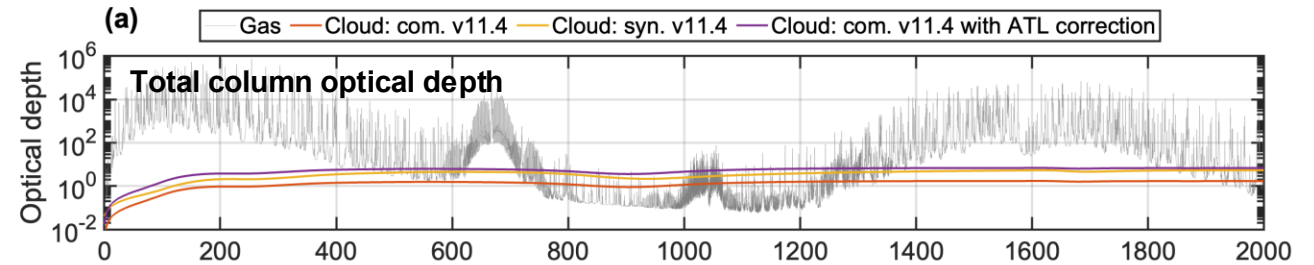
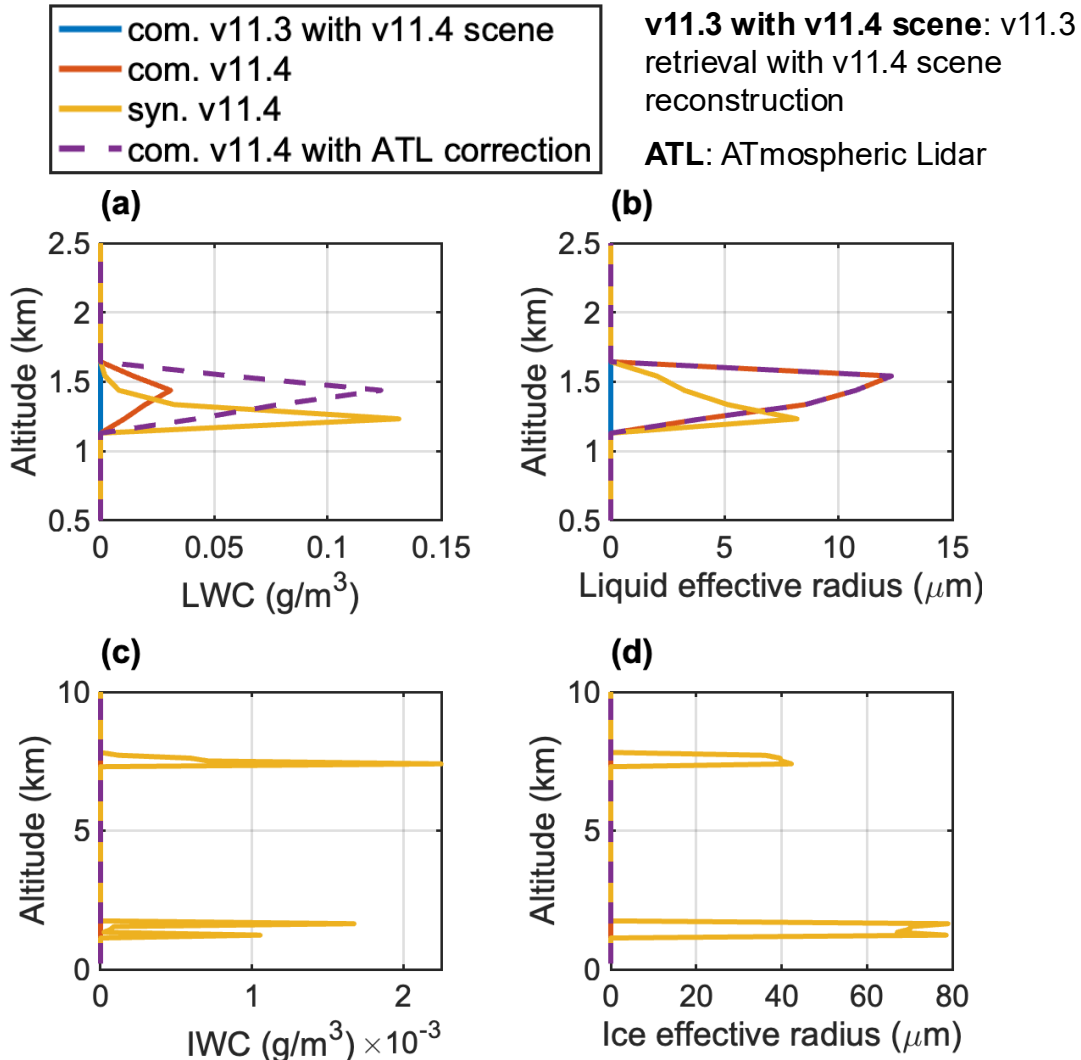
EarthCARE AERI Validation Overview

- v11.3 and v11.4 with EarthCARE scene construction algorithm: *Qu et al. (2023) AMT*
- **Composite** and **Synergy** retrieval products



EarthCARE Ottawa Overpass: October 10, 2024

- Different EarthCARE **retrieval versions** under different cloud conditions



EarthCARE Ottawa Overpass: October 10, 2024

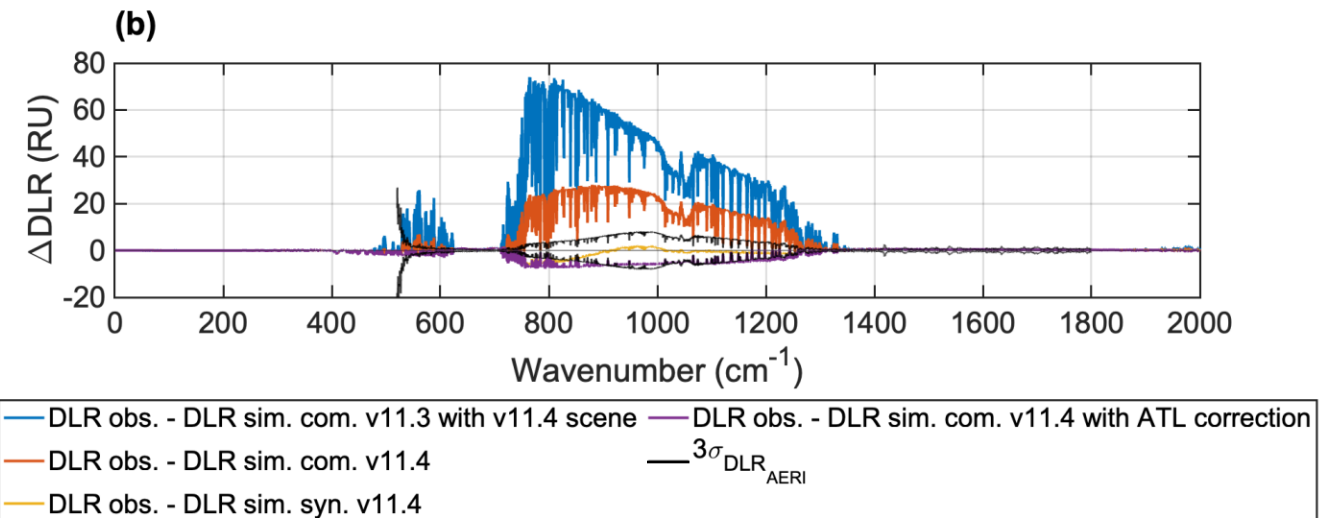
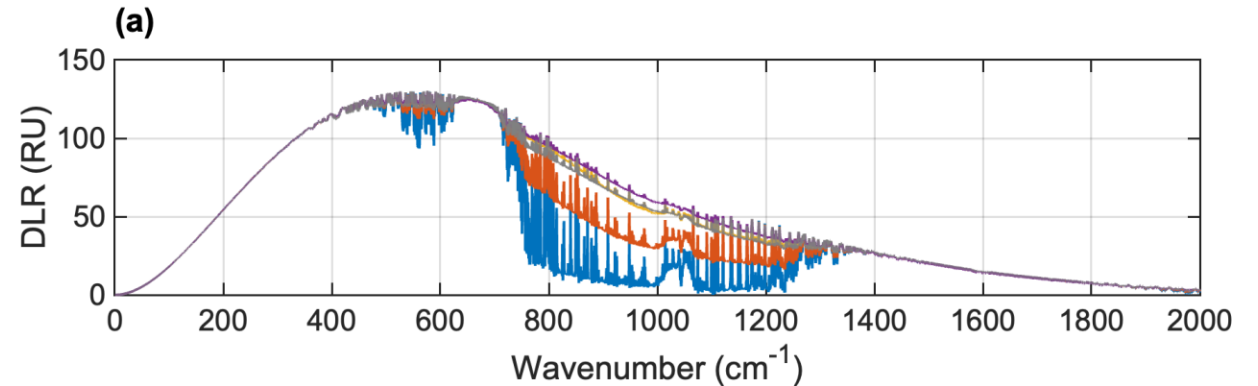
- **DLR observations** act as an independent referee for EarthCARE **retrieval versions**.

v11.3 with v11.4 scene: v11.3
retrieval with v11.4 scene
reconstruction

ATL: ATmospheric Lidar

October 10, 2024 (W/m ²)	Δ DLRF (obs. - sim.)
com. v11.3 with v11.4 scene	112.16
com. v11.4	39.20
syn. v11.4	-2.28
com. v11.4 with ATL correction	-9.24

- Radiance closure: < **10 RU**
- Flux closure: < **3 W/m²**



EarthCARE Ottawa Overpass: December 1, 2024

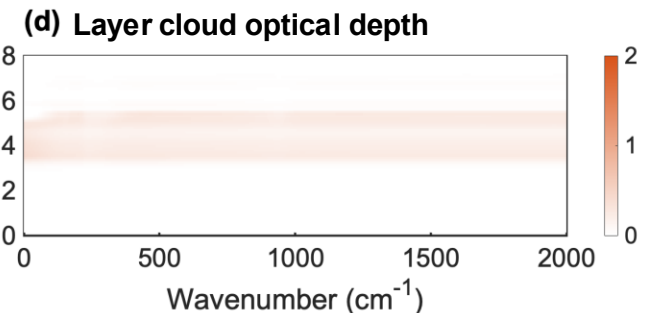
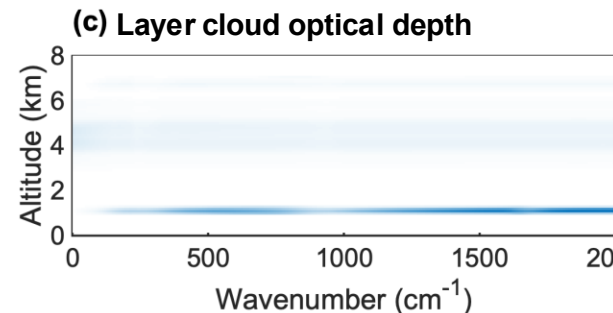
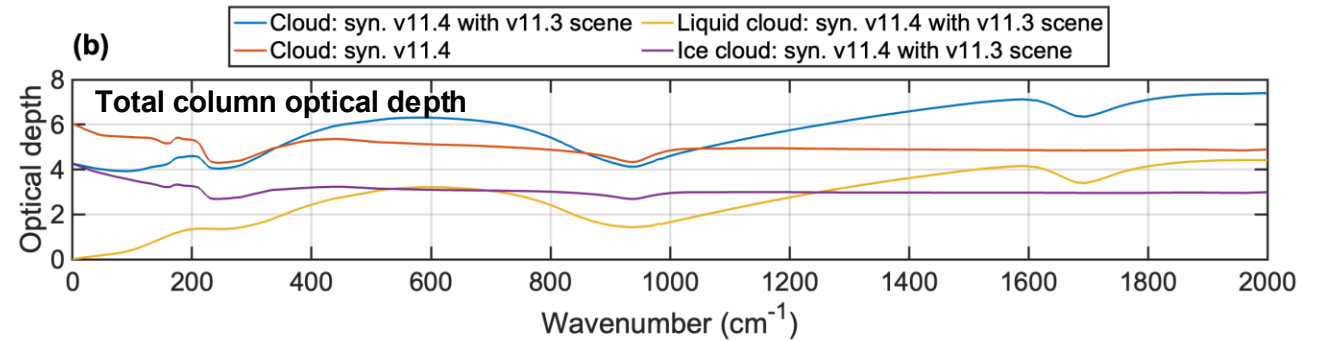
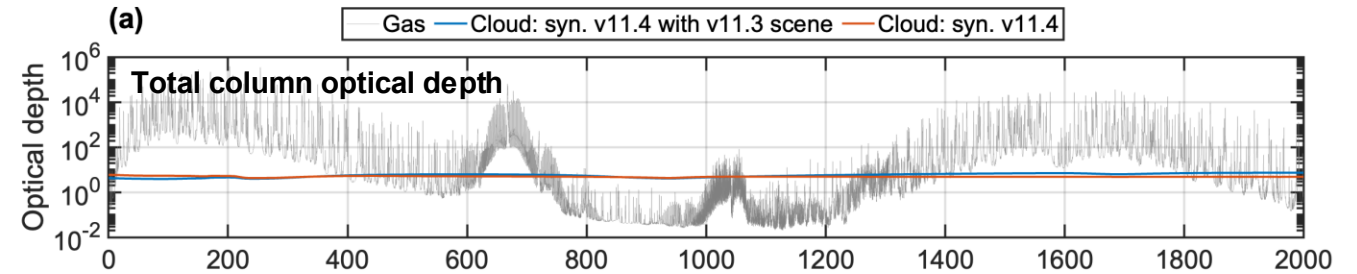
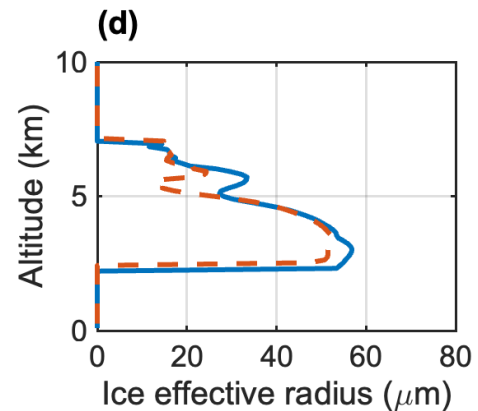
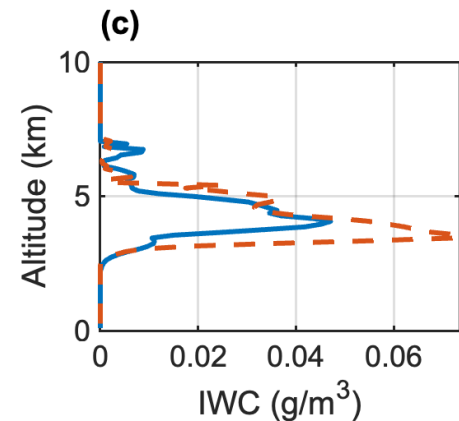
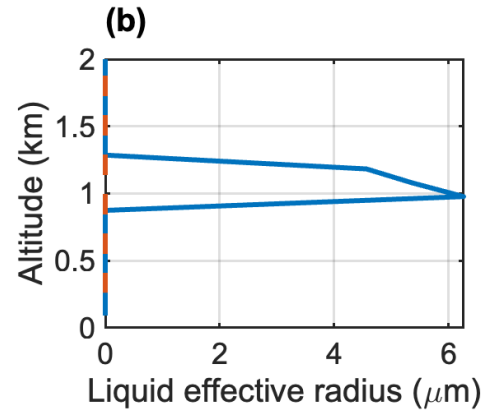
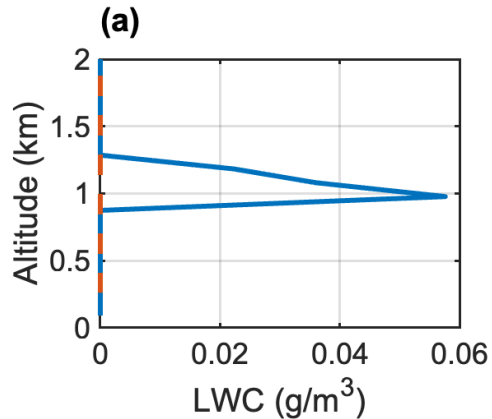
- Different EarthCARE **scene reconstructions** under cloudy conditions

v11.4 with v11.3 scene:

v11.4 retrieval with v11.3 scene reconstruction

v11.4: v11.4 retrieval with v11.4 scene reconstruction

— syn. v11.4 with v11.3 scene
- - syn. v11.4



EarthCARE Ottawa Overpass: December 1, 2024

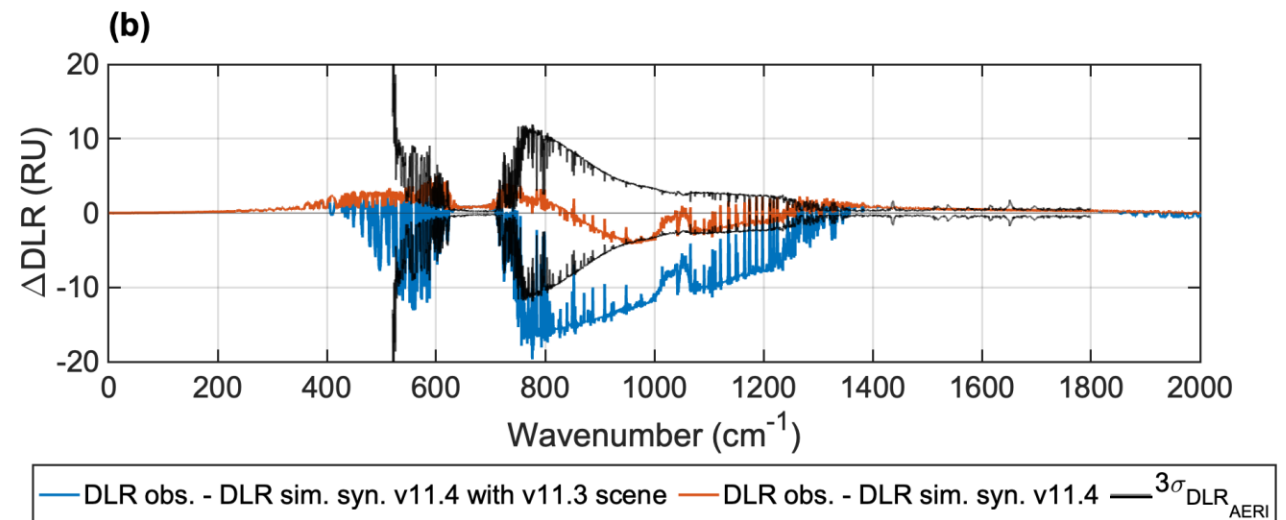
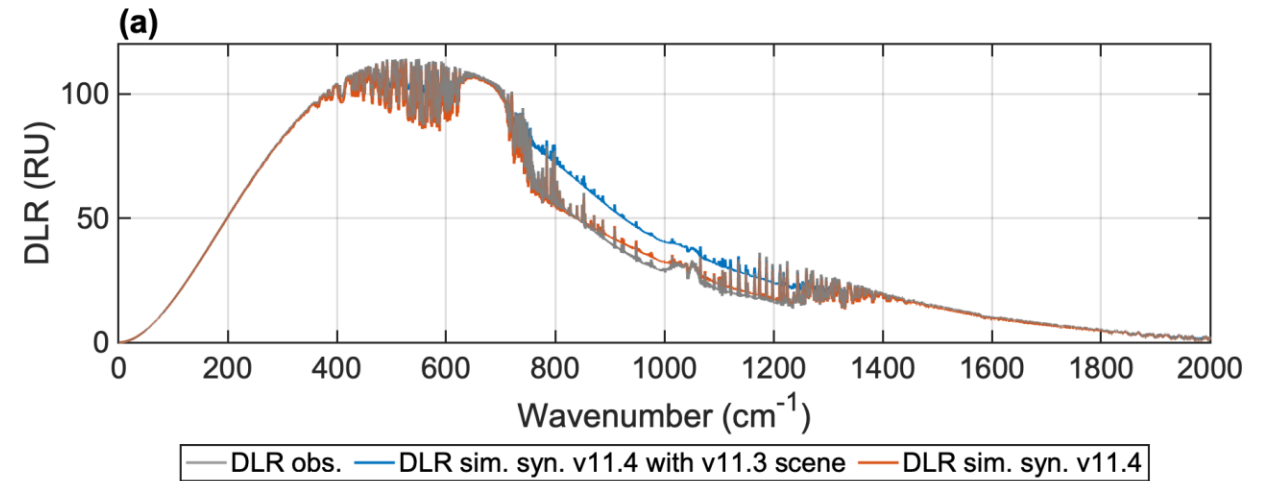
- **DLR observations** act as an independent referee for EarthCARE **scene reconstructions**.

v11.4 with v11.3 scene: v11.4 retrieval with v11.3 scene reconstruction

v11.4: v11.4 retrieval with v11.4 scene reconstruction

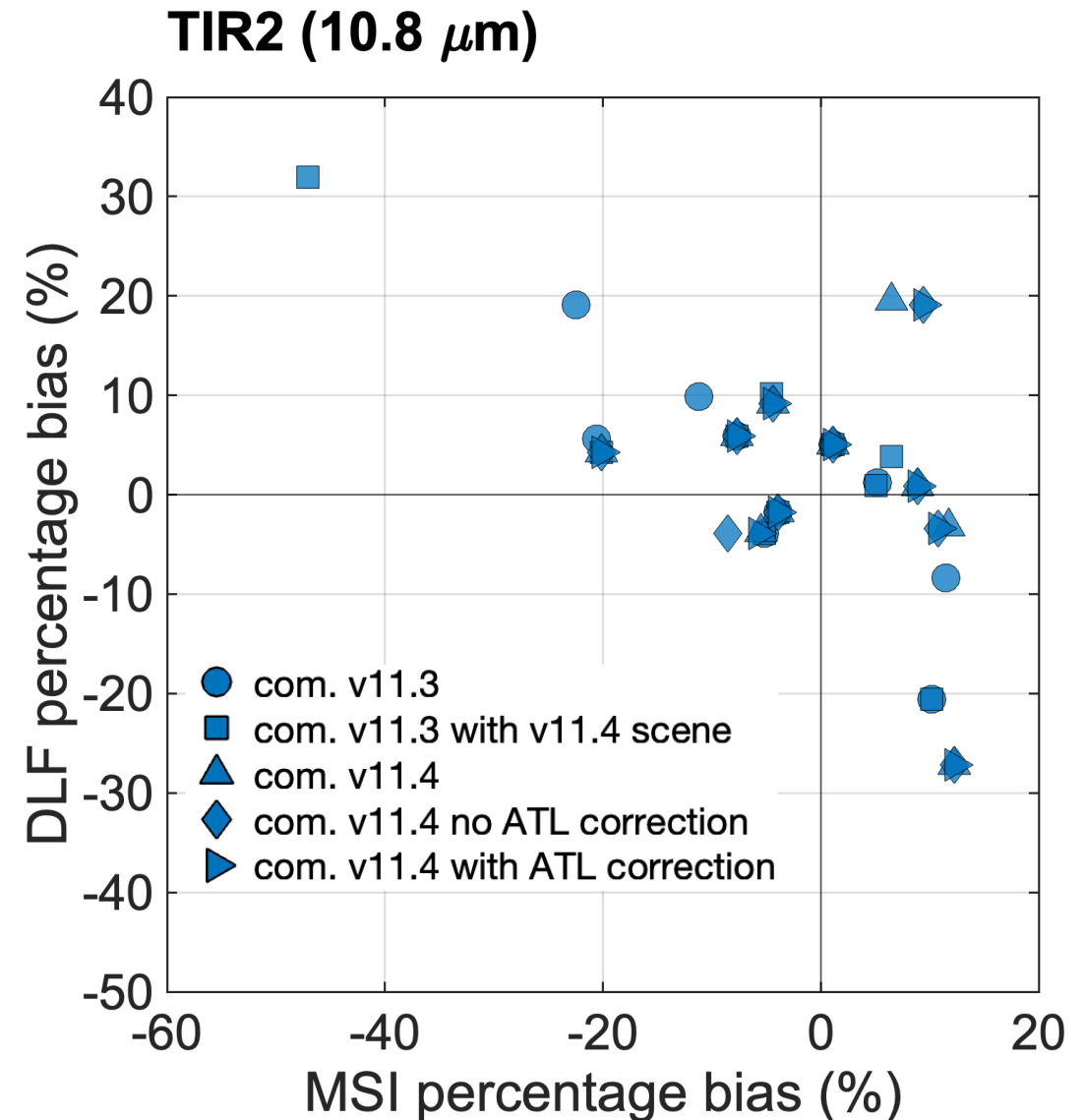
December 1, 2024 (W/m ²)	Δ DLRF (obs. - sim.)
syn. v11.4 with v11.3 scene	-22.24
syn. v11.4	-1.47

- Radiance closure: < **5 RU**
- Flux closure: < **2 W/m²**



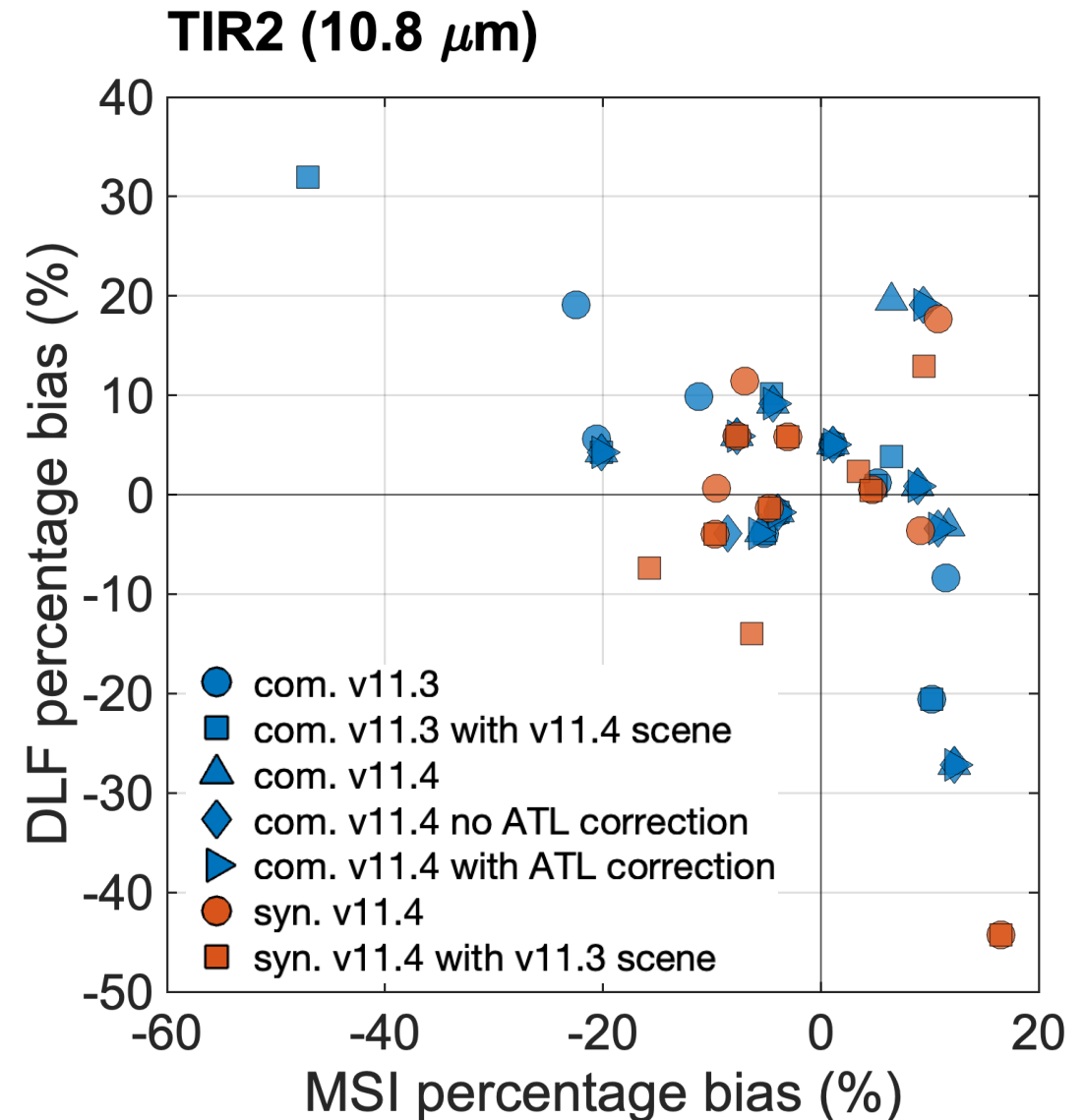
DLR vs. OLR Radiative Closure

- For poorly constrained cloud profiles (**Composite with older v11.3 version**), cloud-profile errors are detectable through validation against either OLR or DLR, whose errors show the expected anti-correlation ($\rho = -0.46$)



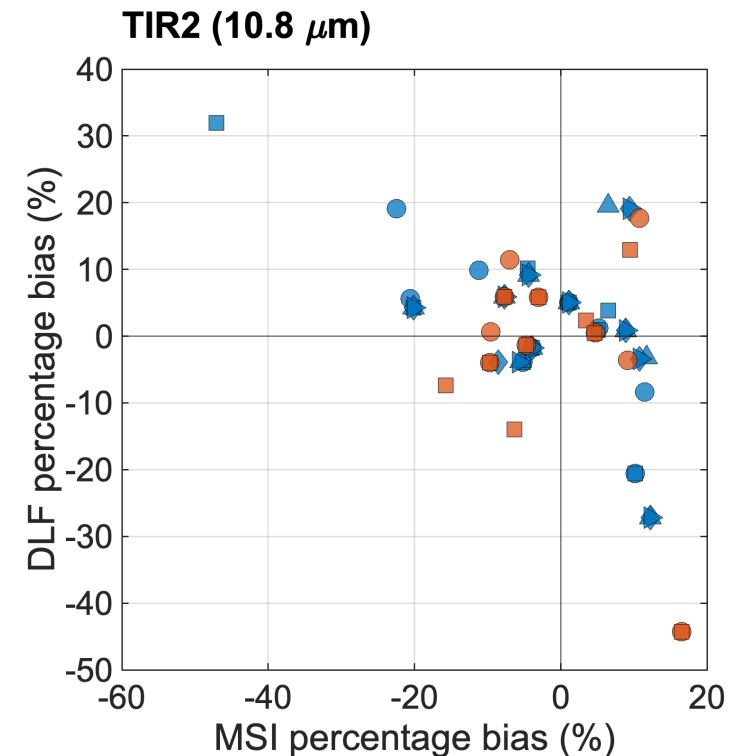
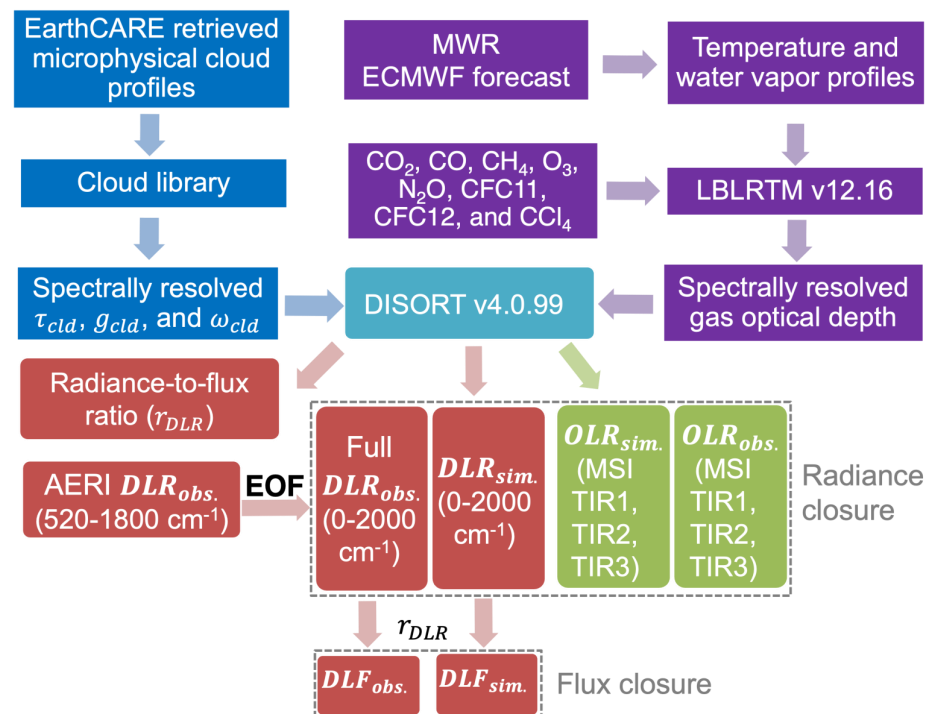
DLR vs. OLR Radiative Closure

- For poorly constrained cloud profiles (**Composite with older v11.3 version**), cloud-profile errors are detectable through validation against either OLR or DLR, whose errors show the expected anti-correlation ($\rho = -0.46$)
- For better constrained cloud profiles (**Synergy**), OLR and DLR errors reveal different cloud-property errors (e.g., cloud top vs. cloud base) and therefore show little correlation ($\rho = -0.04$)



EarthCARE Overpass Radiative Closure in Ottawa

- DLR (Radiance) closure: **< 5 RU**; DLF (Flux) closure: **< 2 W/m²**
- **DLR observations** act as an independent referee for EarthCARE **retrieval versions** and **scene reconstructions** under different cloud conditions.
- **OLR** and **DLR** closure provide complementary constraints on the retrieved cloud profiles.



Thank you!

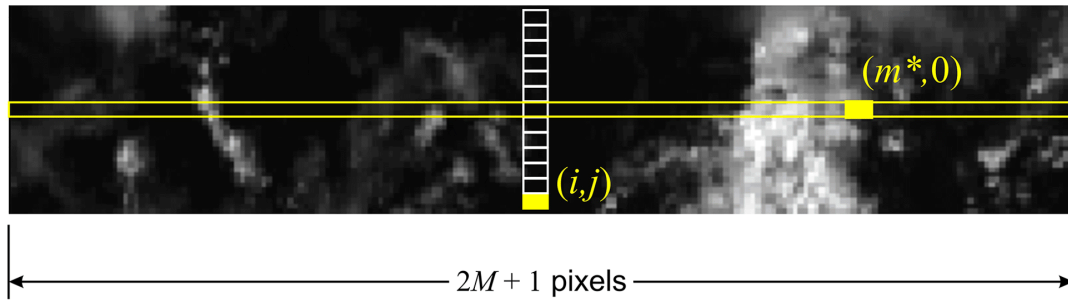
Lei Liu

EarthCARE AERI Validation Overview

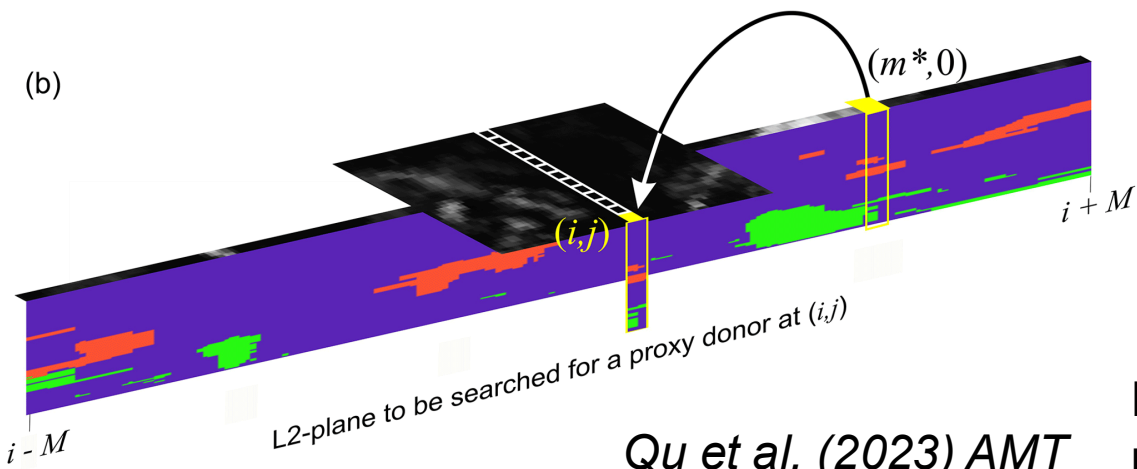
- gamma distribution: $f(x) = \frac{\beta^\alpha}{\Gamma(\alpha)} x^{\alpha-1} e^{-\beta x}$
 - LBLRTM v12.16 + DISORT
 - High spectral resolution simulations (0.05 cm⁻¹)
 - Convolute with AERI scan function
 - Cloud library from GFDL (Feng et al. 2024)
 - Sensitivity tests of ice habits: 9 habits selected
 - Sensitivity tests of phase function
 - HG: Henyey-Greenstein
 - GS: Garcia-Siewert
- (1). hexagonal column
 - (2). plate
 - (3). hollow column
 - (4). droxtal
 - (5). hollow bullet rosette
 - (6). solid bullet rosette
 - (7). 8-element column aggregate
 - (8). 5-element plate aggregate
 - (9). 10-element plate aggregate

EarthCARE's Scene Construction Algorithm

(a) schematic of radiance-matching algorithm

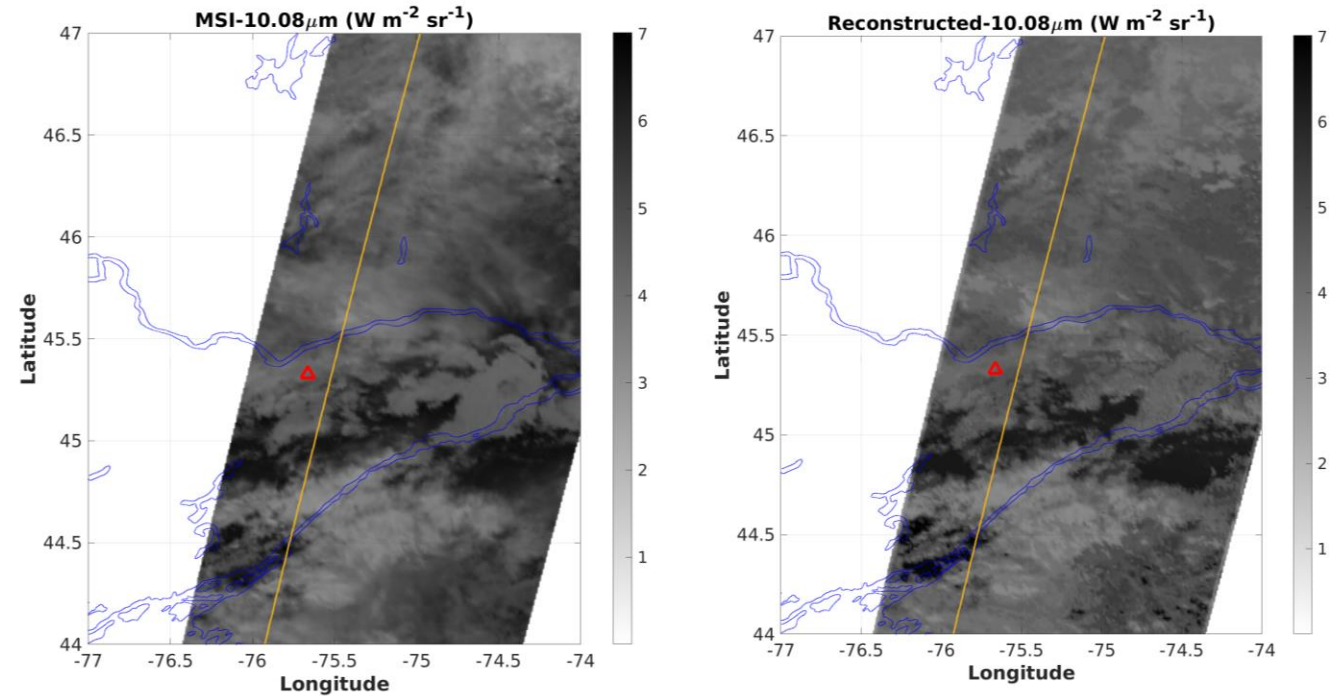


(b)



Qu et al. (2023) AMT

20241129



For the scene construction, we only use the MSI scanned (nearly nadir) images. The matched profile are from the active/passive sensors retrieved profiles (only available for the nadir profiles).

DLR vs. OLR Radiative Closure

