EarthCARE's Retrievals of Liquid Water Properties: Challenges and the Potential to Advance NWP Model Performance

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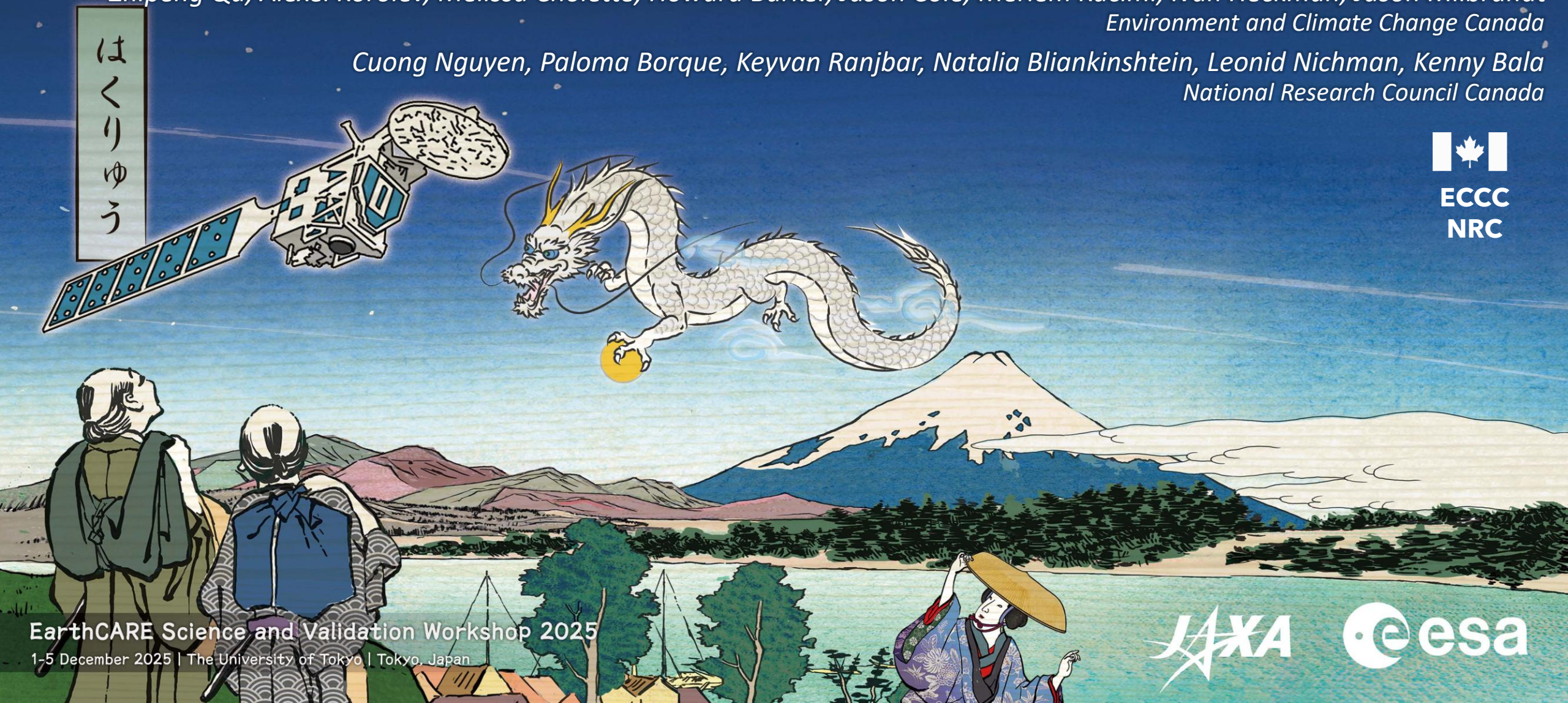
ECCC
NRC



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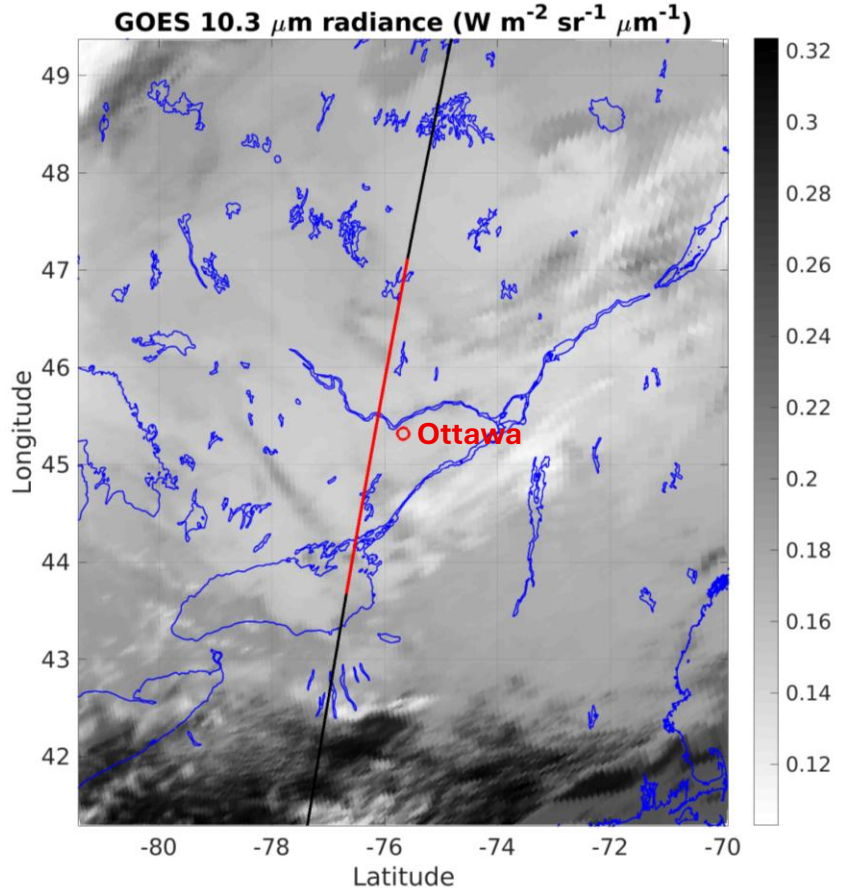
1. Objectives

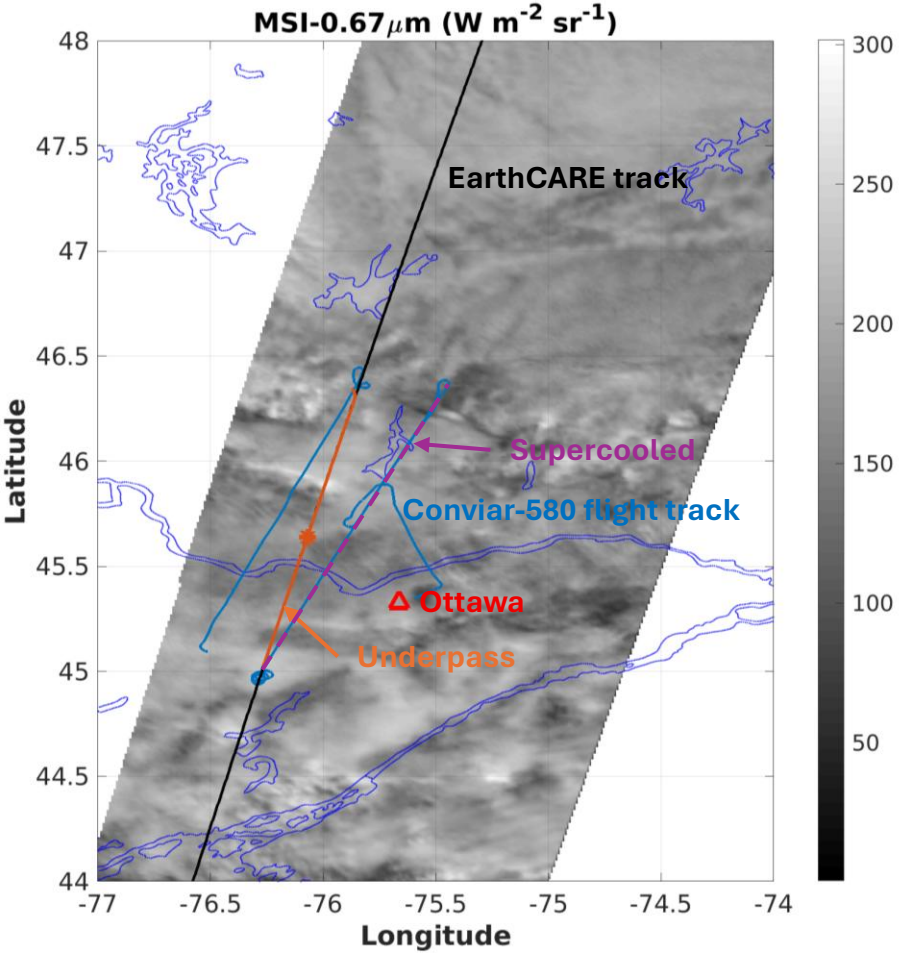
- Supercool liquid layers (SCL) were encountered during ECALOT Campaign.
- Geometrically thin at cloud top or deeper within the cloud.
- **Q1: How well did EarthCARE's L2 algorithms retrieve the SCL? Can EarthCARE data be used as a reference for model verification?**
- Campaign flight planning:
  - ECCC's Global Environmental Multi-scale (GEM) model at 2.5 km horizontal grid-spacing (HRDPS) ***didn't predict*** the top SCL for Flight 7.
  - A SCL ***was observed*** during by the Convair-580's zenith-pointing lidar.
- **Q2: Causes of GEM missing SCL?**
- **Q3: Radiative impact of SCL at cloud top?**

EarthCARE 04681D (~19:30 UTC)
During ECALOT Flight 7 (2025-03-25)

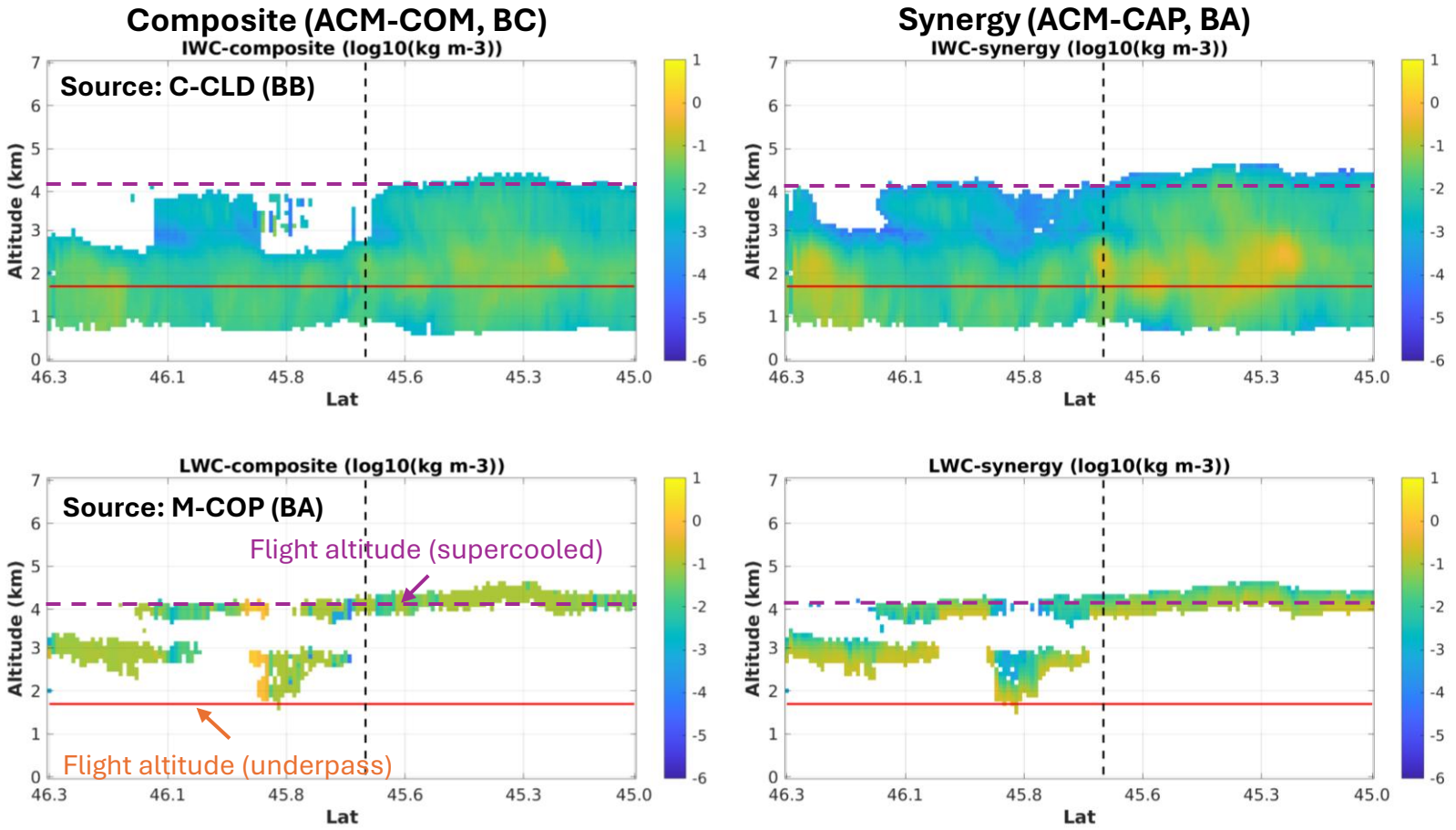


2. ECALOT Flight 7 –EarthCARE Retrievals vs. *In Situ Obs.*

- ECALOT Flight 7: Ns clouds, March 25, 2025 (04681D)

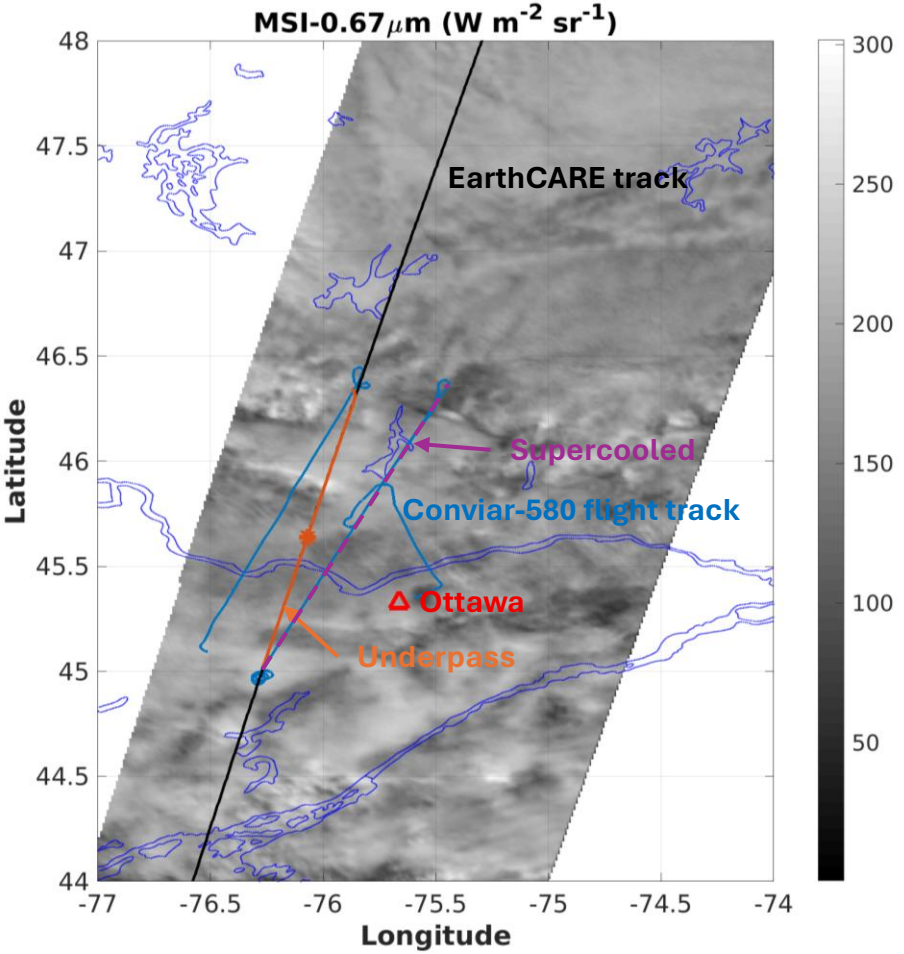


(2025-03-25, 19:20-20:00 UTC)



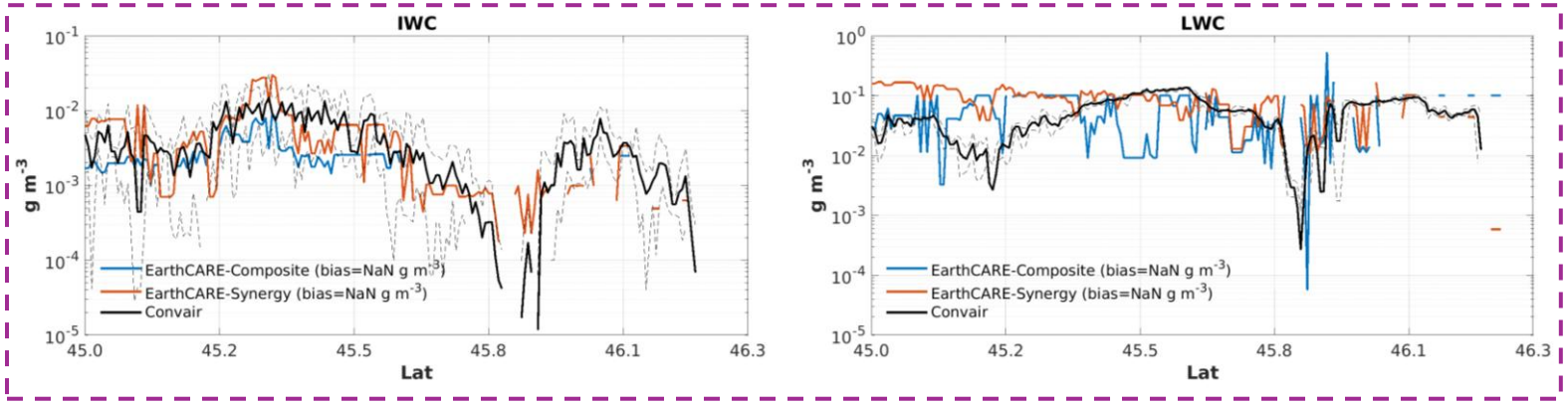
2. ECALOT Flight 7 –EarthCARE Retrievals vs. *In Situ Obs.*

- Top layer mixed-phase clouds → good retrievals from EarthCARE → **good for model validation**
- Challenging to retrieve SCL deep in clouds due to full attenuation of ATLID's signal

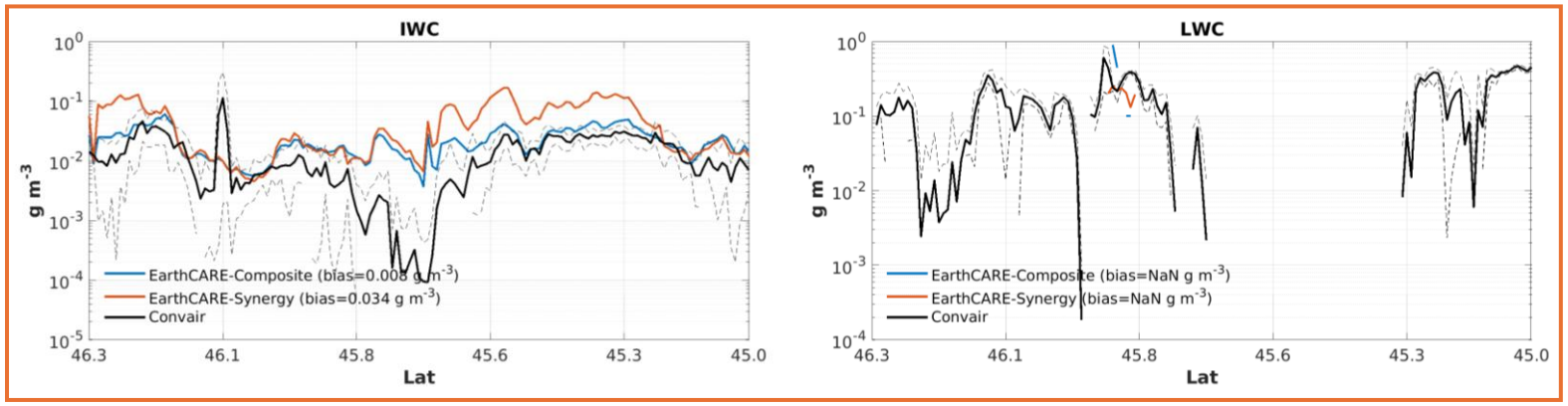


(2025-03-25, 19:20-20:00 UTC)

Top mixed-phase layer ~ 4.1 km , in situ: OAP, scene constructed cross-section (H117)



Underpass ~ 1.8 km, in situ: Nevzorov



3. GEM Simulations – Model Setting

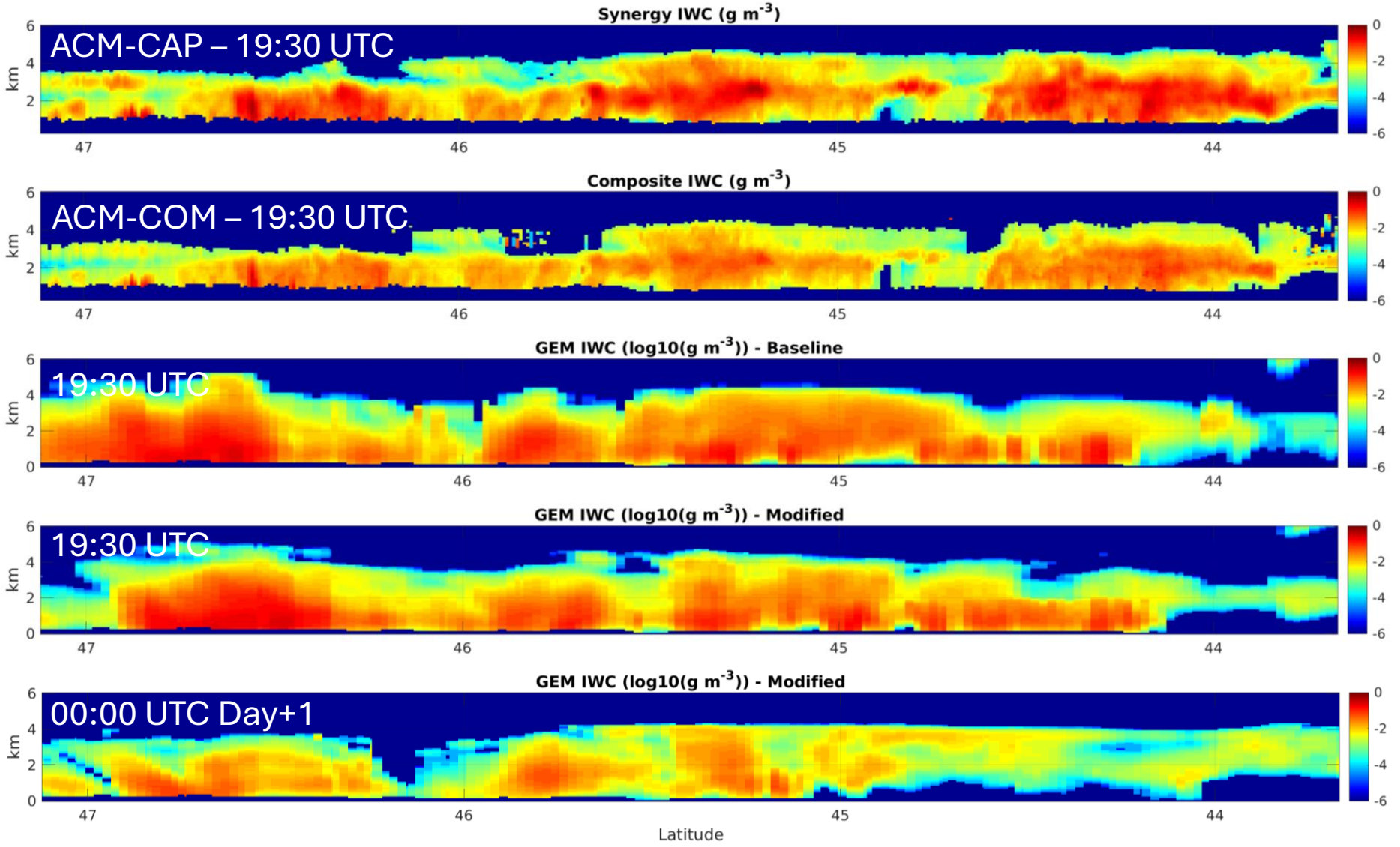
- **GEM-Baseline:**
  - 2.5 horizontal resolution, **84** vertical hybrid layers (~370 m near cloud top at 4.5 km)
  - Predicted Particle Properties (P3) bulk microphysics (Morrison and Milbrandt, 2015)
    - Triple-moment ice (Milbrandt et al. 2021)
    - Liquid fraction of ice (Cholette et al., 2019, 2024)
    - Free-evolving ice (single category)

- **GEM-Modified:**
  - Vertical resolution ↑ to 90 m → less ideal mix of ice & liquid due to stratification
  - Suppression for the first 300 m below cloud top:
    - Condensation freezing/deposition ice nucleation (to reach S_{liquid}) – Cloud top T=-25°C
    - Vapor deposition (WBF process↓)
    - Collection of liquid by ice (sink of liquid↓)

3. GEM Simulations – Ice Water Content (IWC)

EarthCARE & GEM:

- Consistent IWC values among the L2 synergy product, the composite product, and all GEM simulations.



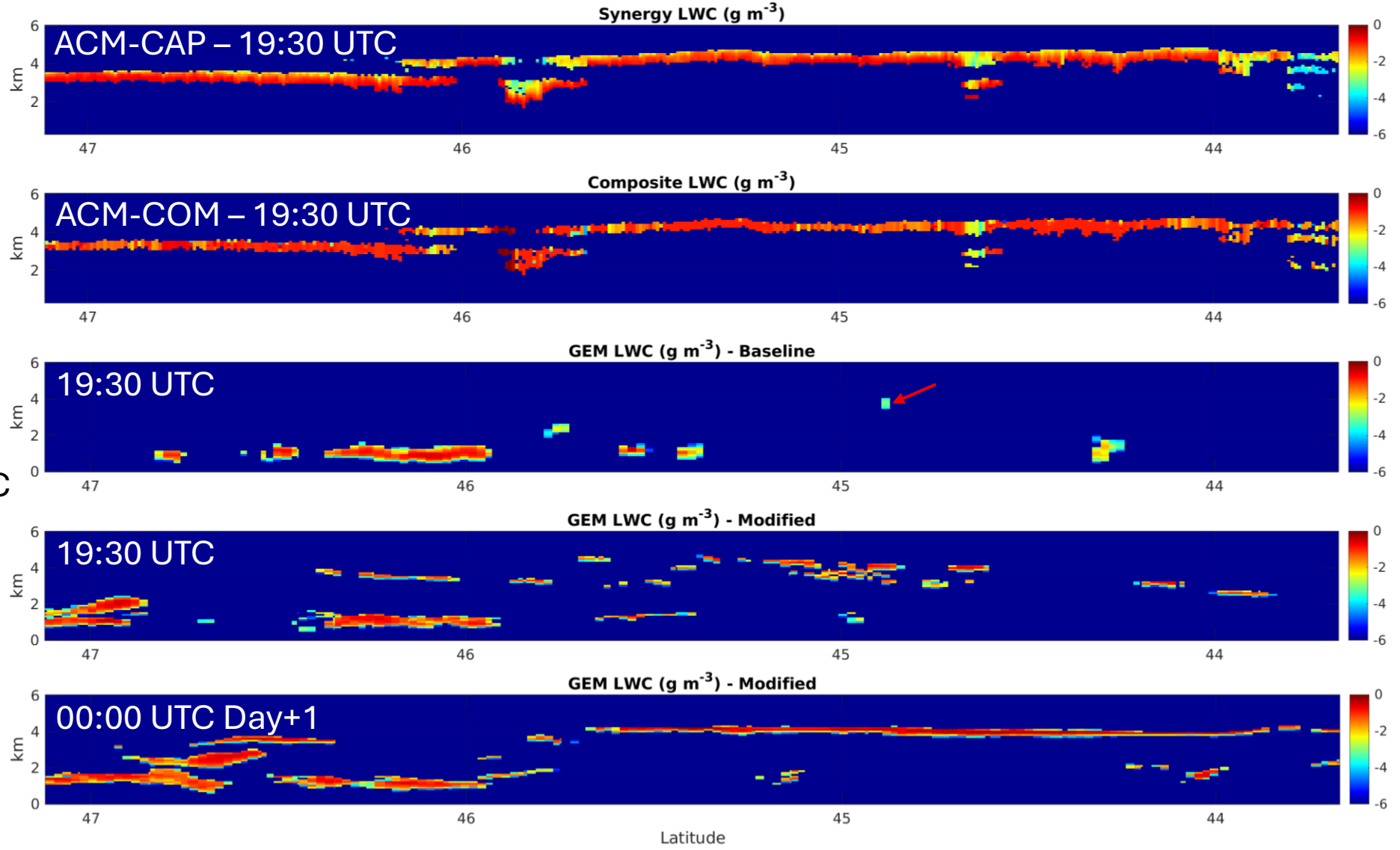
3. GEM Simulations – Liquid Water Content (LWC)

EarthCARE:

- Both synergy & composite products retrieved SCL

GEM:

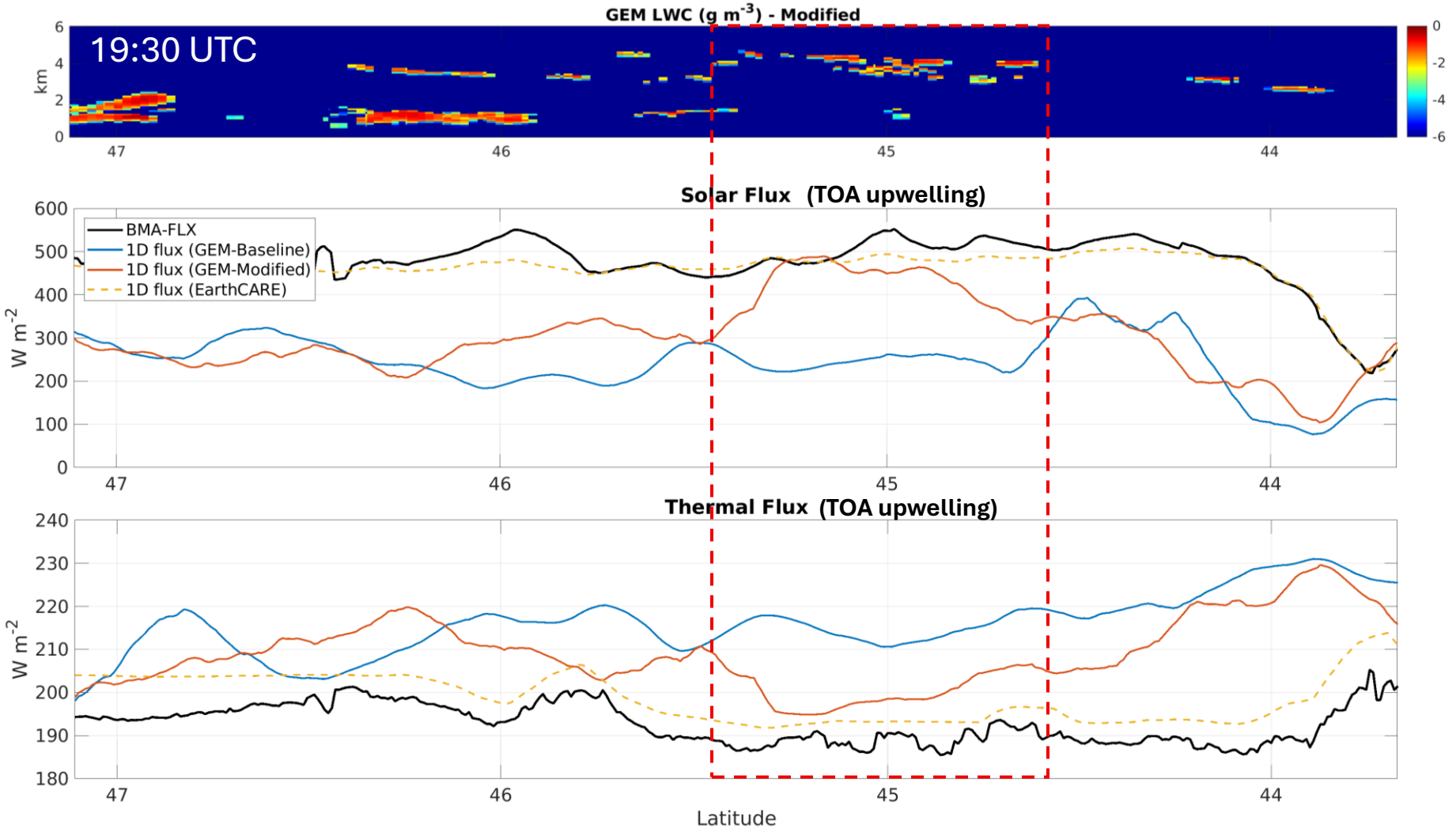
- Baseline: ~no cloud top SCL
- Modified:
  - ✓ SCL formed at 19:30 UTC
  - ✓ Fully formed at 00 UTC



4. Radiative Closure Assessment

Radiative closure:

- ACM-RT (EarthCARE, 19:30 PM):
  - ✓ ≈ BMA-FLX
- GEM-Baseline (19:30 PM):
  - SW fluxes↓
  - LW fluxes ↑
- GEM-Modified (19:30 PM):
  - ✓ Improved SW fluxes
  - ✓ Improved LW fluxes
  - ✓ 44.5-45.5° N
  - ✓ SW: up to 200 W m^{-2} more
  - ✓ LW: up to 15 W m^{-2} less



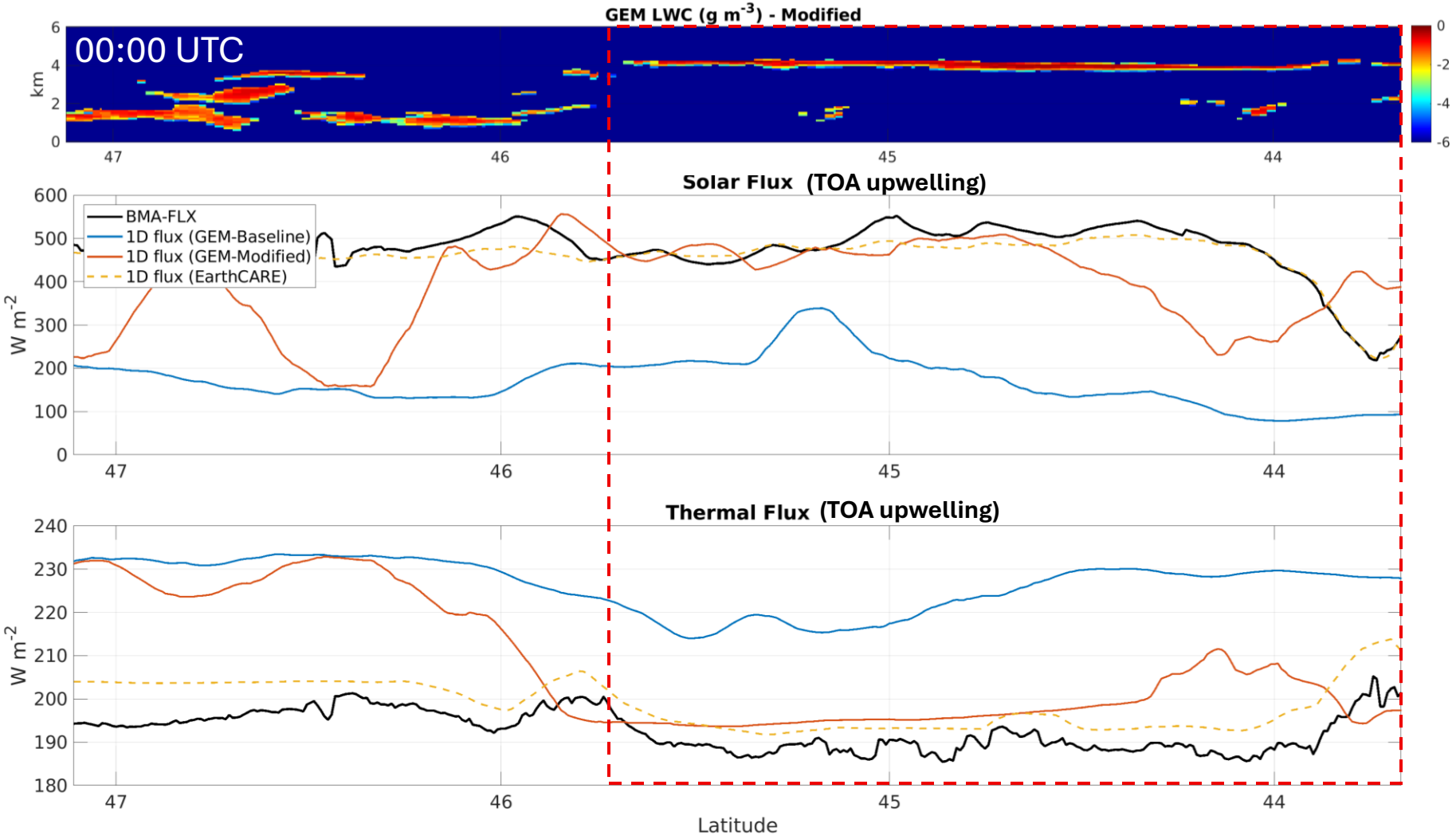
4. Radiative Closure Assessment

Radiative closure (test only):

- GEM-modified: 4.5h later SCL well formed.
- Better results using GEM's clouds at **00:00 PM (D+1)** in the RT closure…
- Large impact on both TOA SW & LW fluxes!
- Important to simulate this geometrically **THIN** SCL

Significant RT impacts:

- Energy budget in NWP/GCM
  - Night: warming
  - Day: cooling
  - Polar day/night?
- Cloud-radiation interaction
- Cloud physics
- Aviation safety



5. Summary

- EarthCARE's retrievals of SCL
  - Good quality for SCL at cloud top → NWP model validation
  - Challenging for SCL deep in cloud (ATLID signal attenuation)
- Baseline GEM: SCL at cloud top not formed or depleted too efficiently
- Modified GEM: SCL better formed
  - Increased vertical resolution → less well mixed ice & liquid due to stratification
  - Suppression of primary ice nucleation → permitting S_{liquid}
  - Suppression of vapor deposition rate → WBF↓
  - Suppression of collection of liquid by ice → reduced sink term for liquid
- Radiative impact (significant):
  - SW: increase of TOA upwelling fluxes by +200 W m^{-2}
  - LW: decrease of TOA upwelling fluxes by +15 W m^{-2}

ECALOT Flight 7 (March 25, 2025)

Thank you for your attention!
Any questions?

Icing on the Convair-580's radome