Cloud and Precipitation ESA product overview

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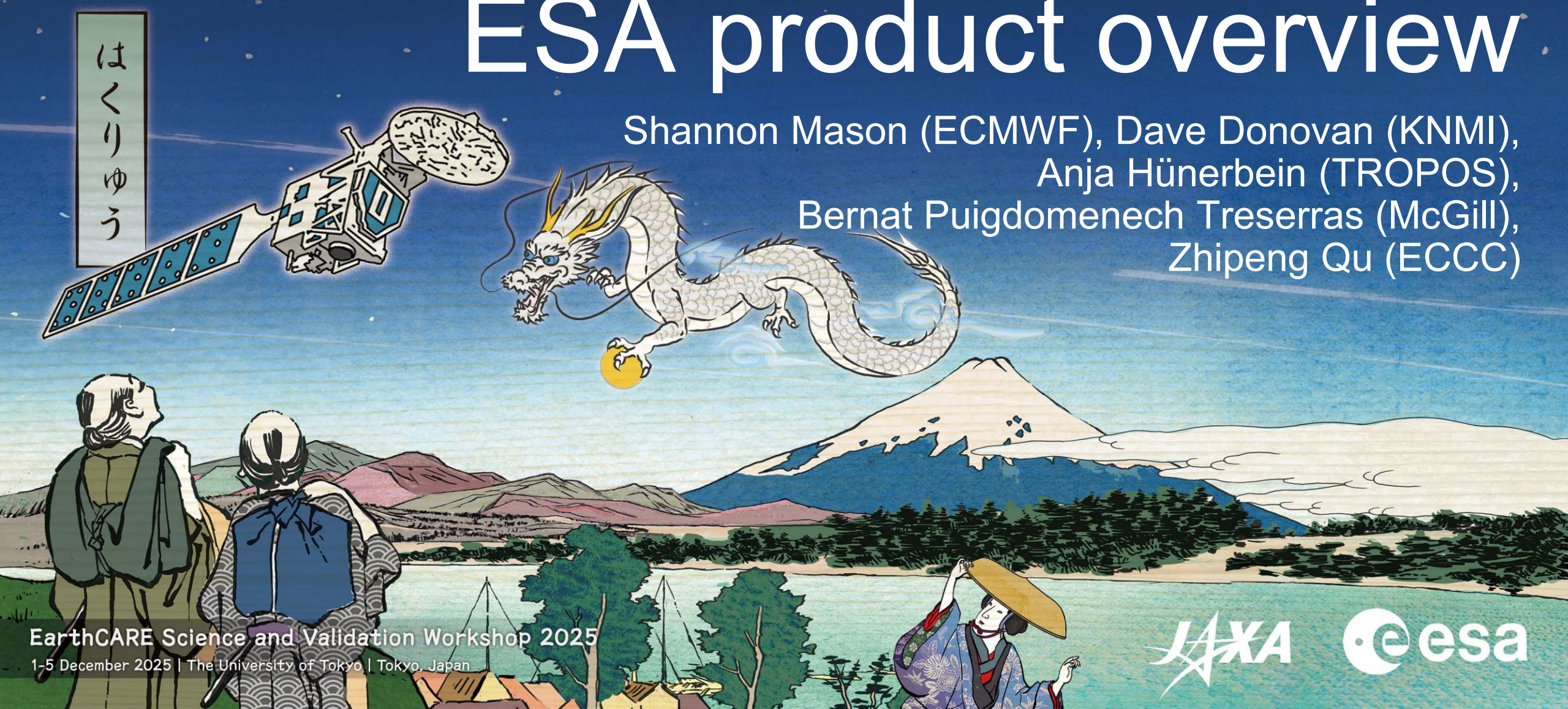
Zhipeng Qu (ECCC)



EarthCARE Science and Validation Workshop 2025
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

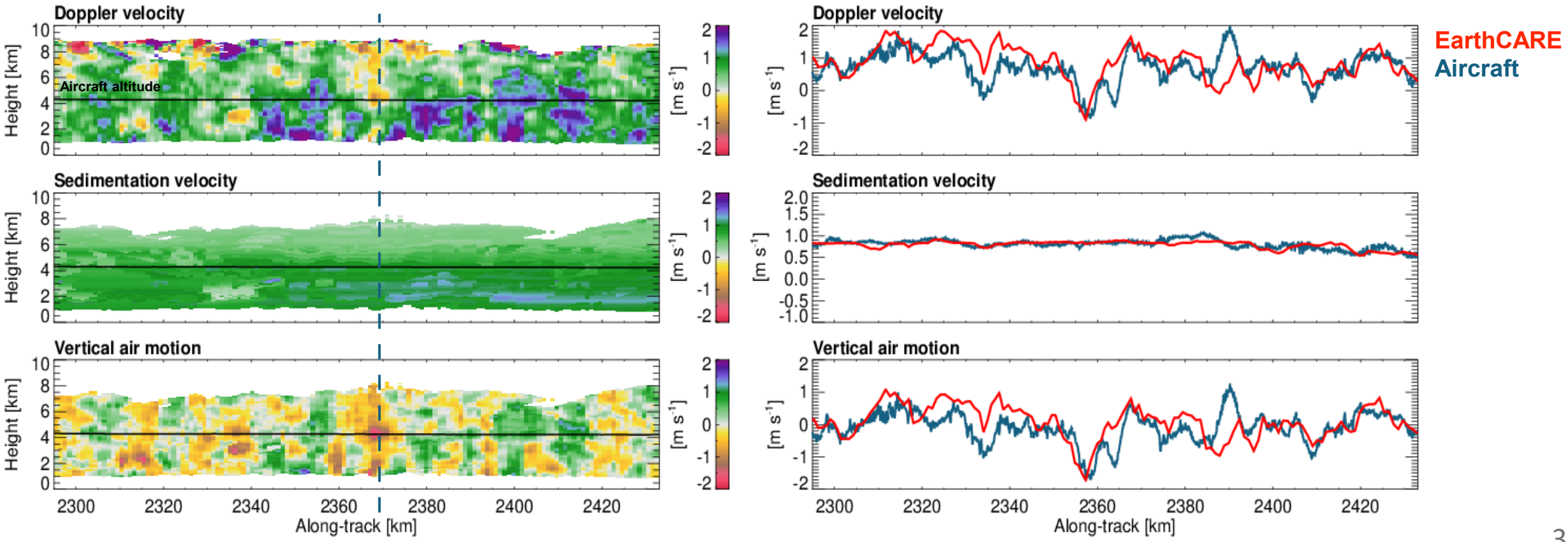
Overview

- Reprocessing complete (baseline BA)
- November 2025: entire L2 chain updated (baseline BC)
- Processor evolution is ongoing…
- Updates on L2a cloud and precipitation products:
  - C-FMR, C-CD & C-CLD
  - M-CM & M-COP
  - A-EBD & A-TC
- Release of L2b 3-instrument synergy products (baselines BA & BC):
  - ACM-CAP
  - ACM-COM

CPR microphysical retrievals

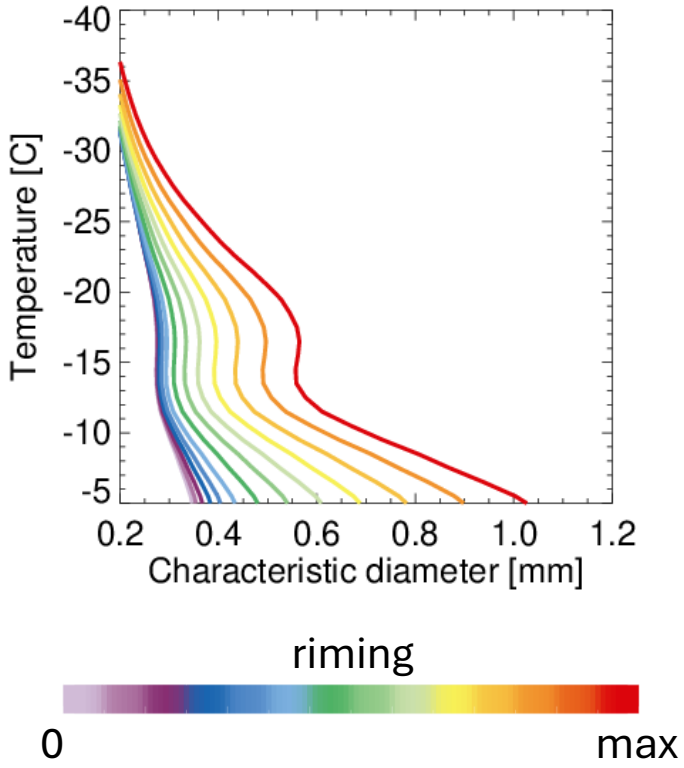
CPR microphysical retrievals rely on three independent measurements: **radar reflectivity, Doppler velocity** and **PIA**. To fully exploit the Doppler signal, we must separate the vertical air motion from the particle fall speed. The **sedimentation-velocity estimate** enables this separation and, for that reason, **becomes fundamental to the quality of the CPR microphysical retrievals**

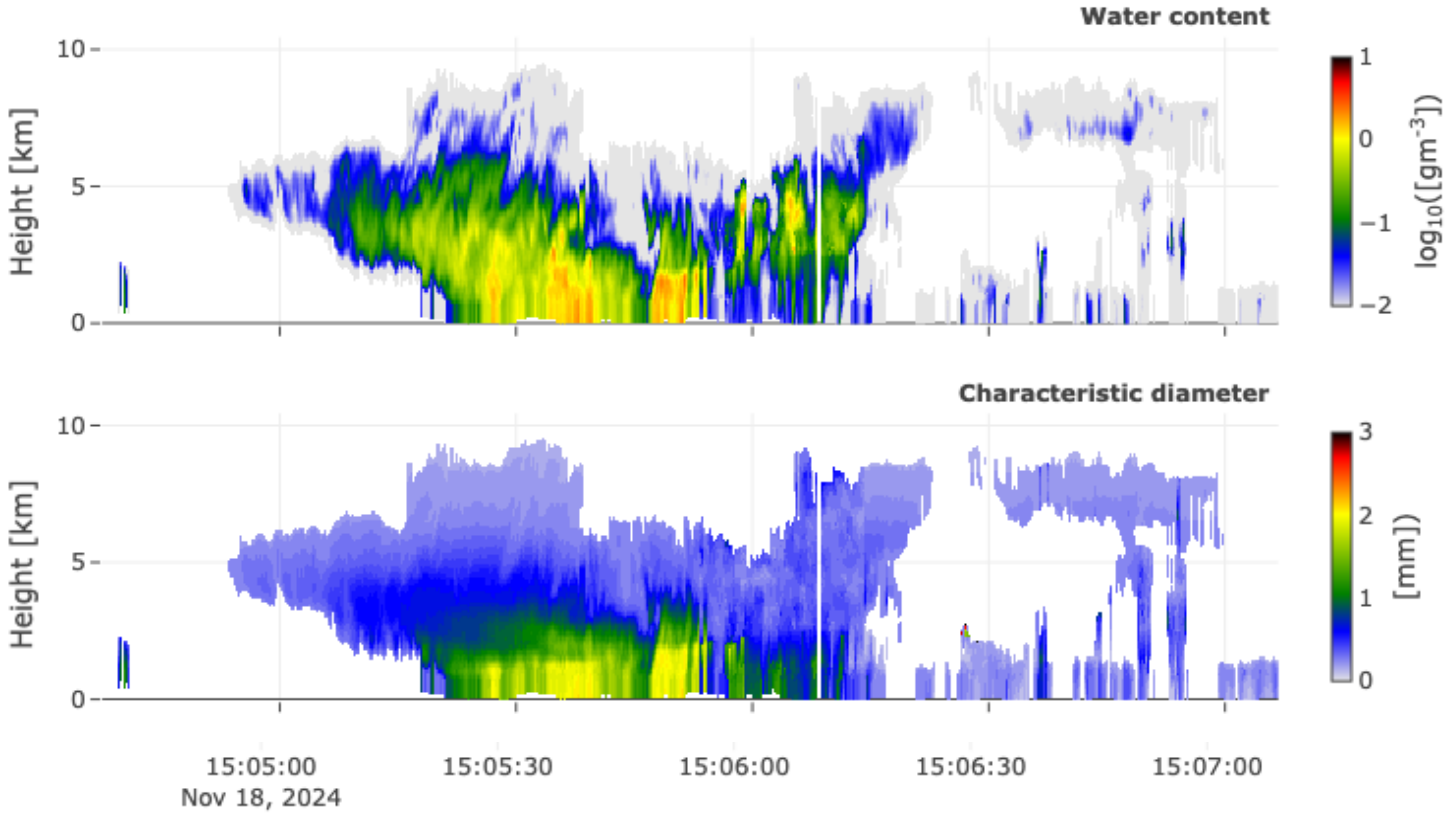
ECALOT flight 6



CPR microphysical retrievals

Z–V–T-based ice/snow characteristic melted diameter reduced solution space





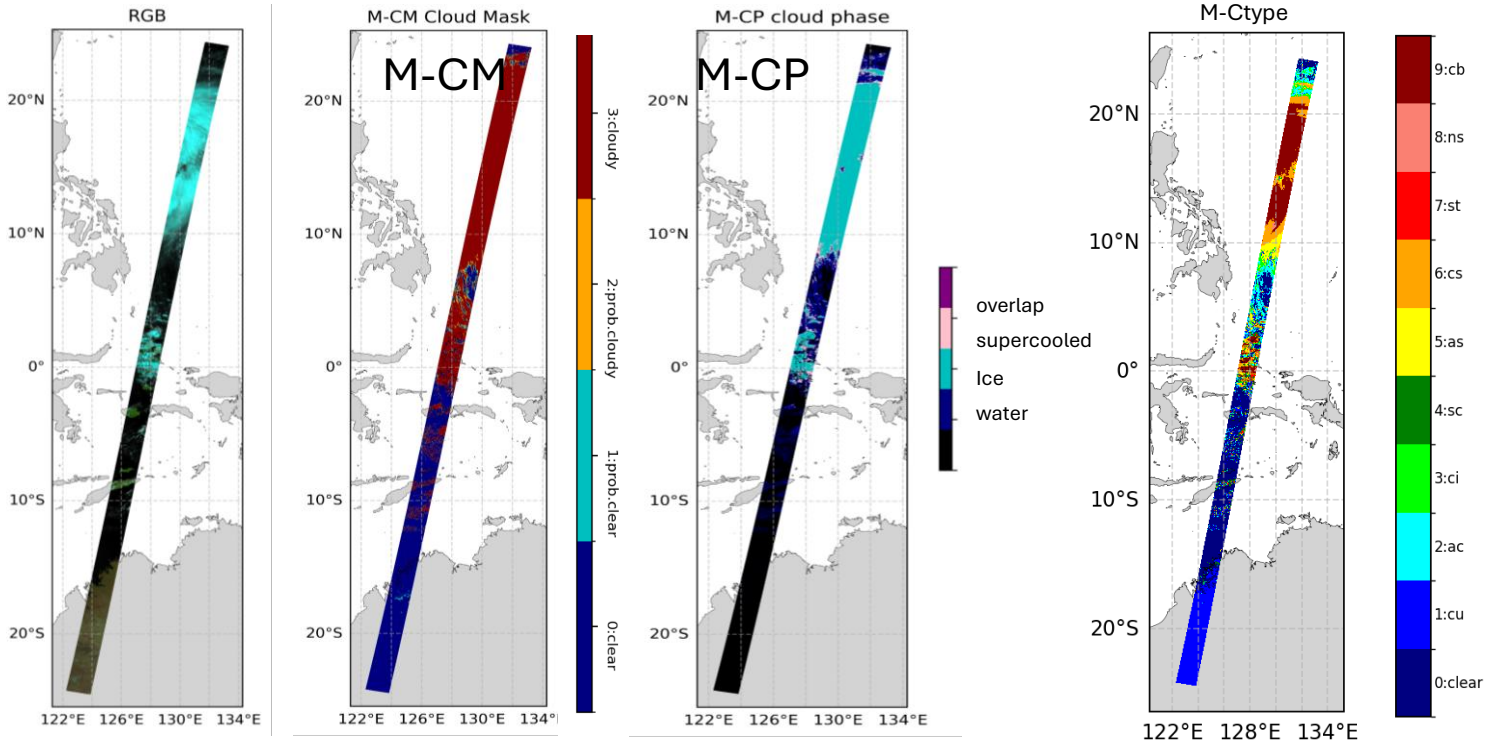
The microphysical retrievals are constrained by the **Z–V–T sedimentation-velocity climatology**, providing physically consistent estimates. **Mass–density** relationships are constrained by mass-flux continuity assumptions

Modifications in the **Doppler velocity** ***forward model, a-priori*** and **mass-density** assumptions, significantly improving the C-CLD retrievals

MSI level 2 products cloud mask products (M-CM)

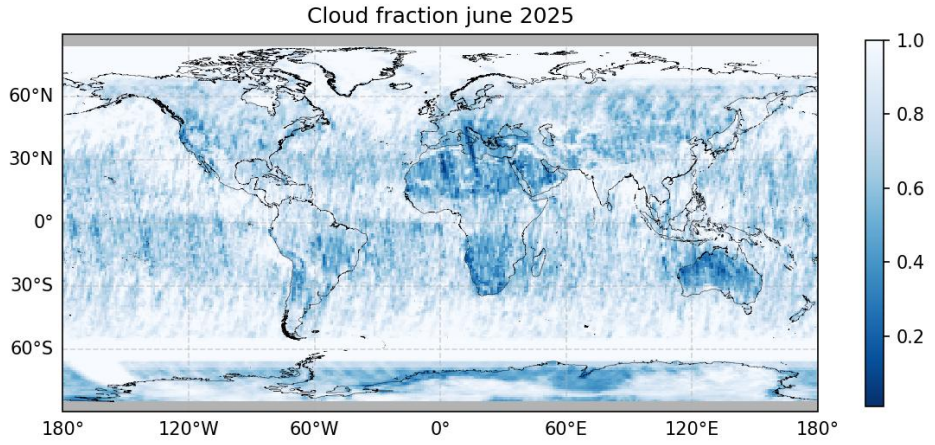
Responsible developer: Anja Hünerbein

BC 07457E frame - Storm Boris



Recent improvements (baseline BA)

- MSI's Level 1 radiometric calibration (ad-hoc vicarious calibration)
- First global daily and monthly composites for BA



Recent improvements (baseline BC, since 18 Nov. 2005)

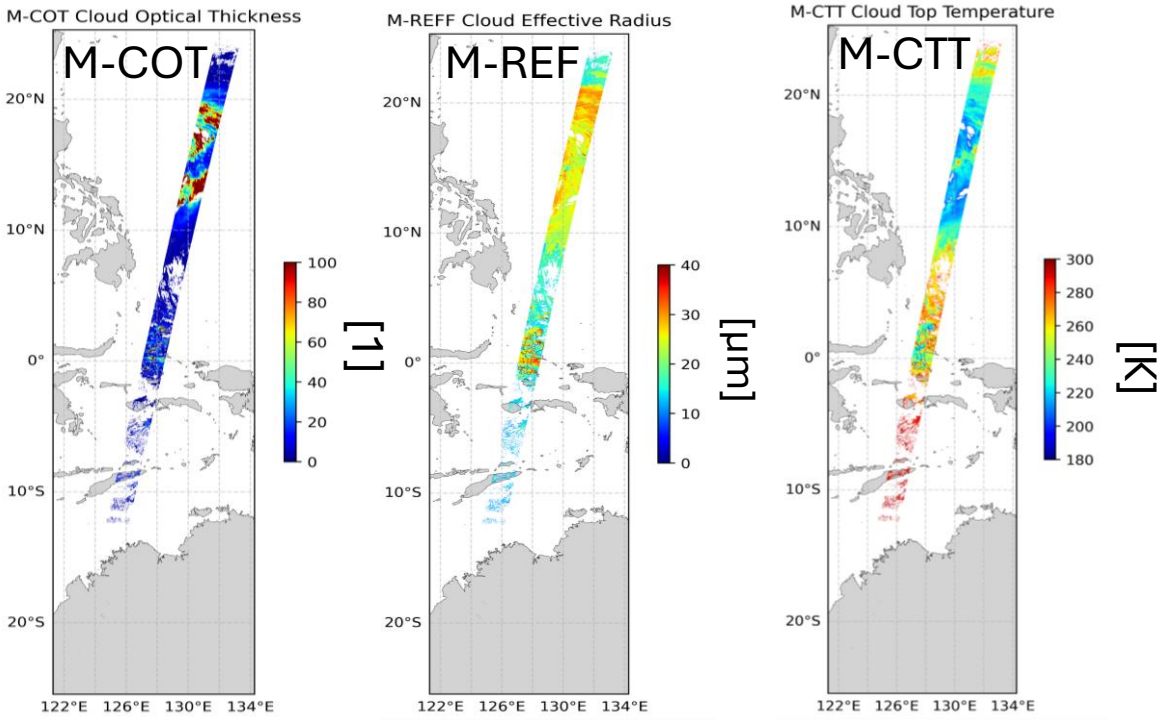
- Improved X-MET interpolation (e.g. sea ice)
- Updated of sunglint handling by combining geometrical sunglint detection and the L1 sunglint_reflectance

POSTER: A. Hünerbein et al. "Current Status and Enhancements of Cloud Retrieval Algorithms from EarthCARE's Multi-Spectral Imager (MSI)" **on THURSDAY Annex 56**

MSI level 2 products cloud optical and physical products (M-COP)

Responsible developer: Anja Hünerbein

BC 07457E frame - Storm Boris



Challenges, open issues, planned developments

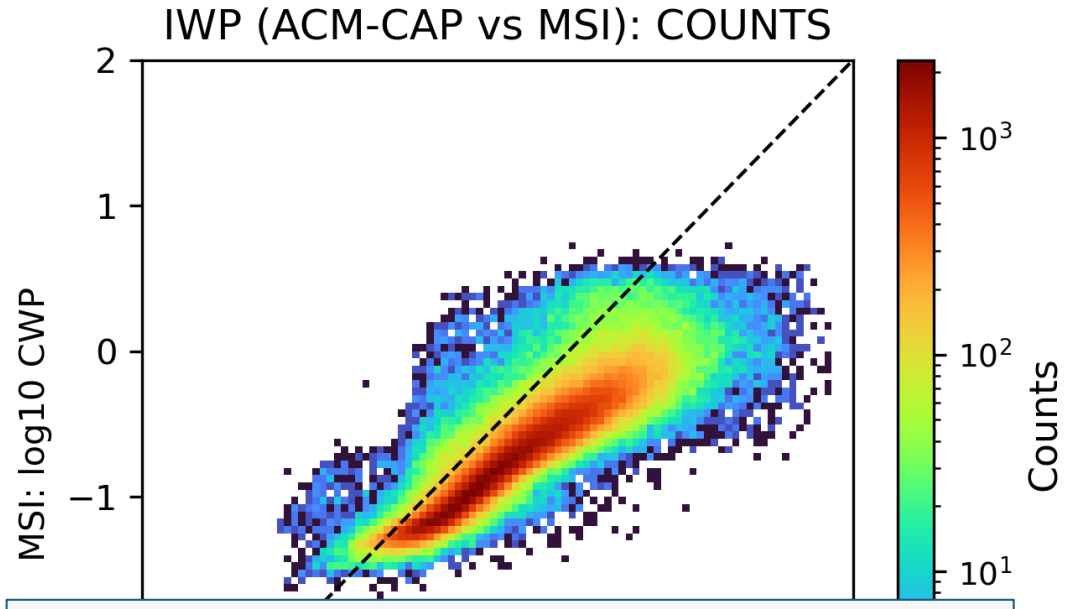
- Improvements of L1 data
- Optimization of the cloud thresholds
- Updates of the cloud type LUT with one year MSI data

Validation needs

- Validation ongoing, more validation from ground, airborne and satellite for SMILE characterization

Recent improvements (baseline BA+)

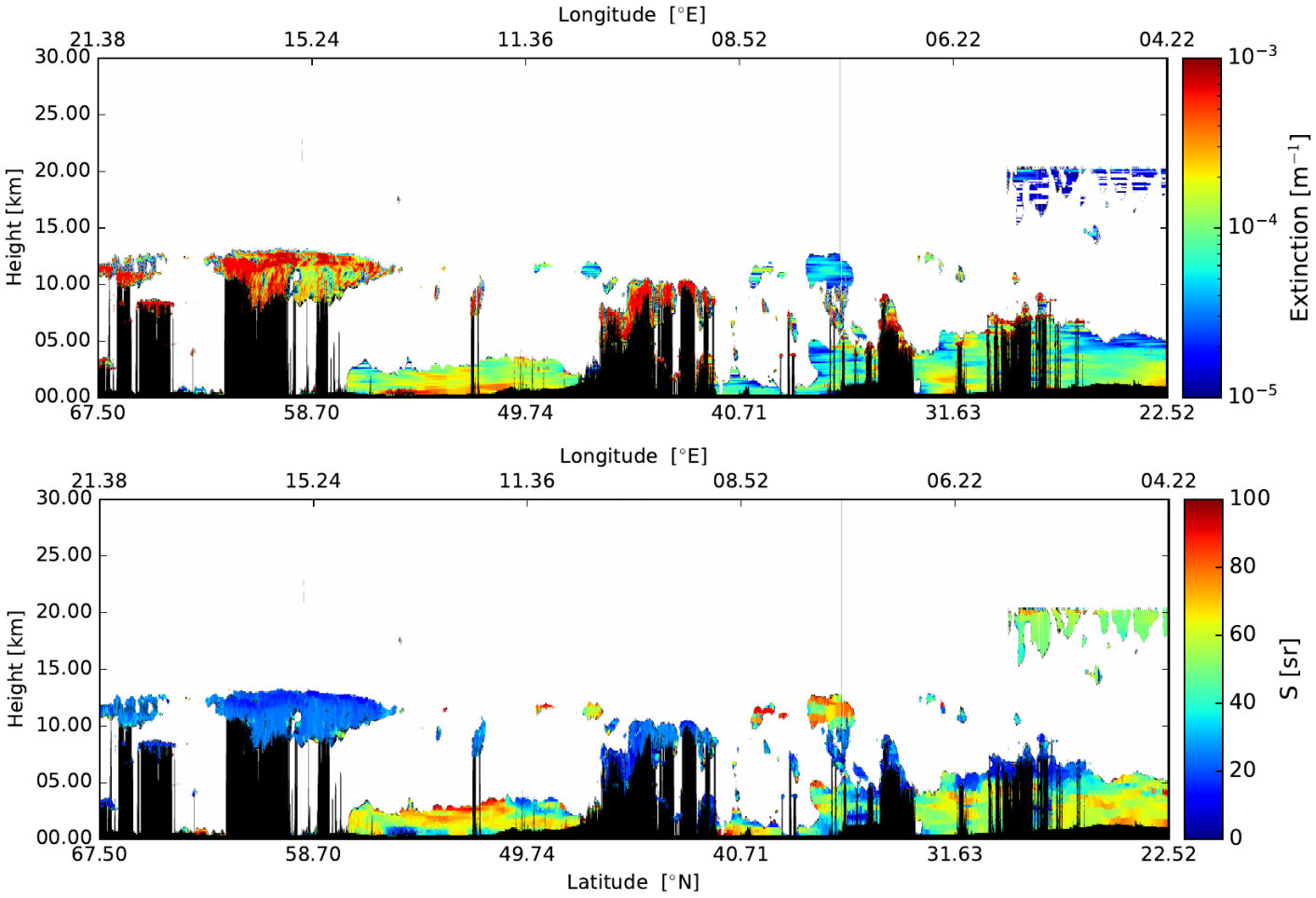
- Comparison with other imager e.g. FCI/MODIS and EarthCARE active measurements



POSTER: G. Walter "Potential of combining MSI (M-COP) with the EarthCARE synergy (ACM-CAP) derived cloud properties" **on THURSDAY Annex 50**

A-EBD (Cloud and Aerosols, Extinction, lidar ratio etc..)

Responsible developers:
D.P. Donovan and G-J van Zadelhoff



Recent improvements (baseline BA+)

- Improved low and medium resolution outputs.
- Internal tropopause height determination improved
- Misc bug fixes.

Challenges, open issues, planned developments

- QA flags should be improved.
- Extinction in top regions of water clouds is likely underestimated
  - 100 meters coarse for high extinction targets.
  - Use depol to correct ?
- Cloud and Aerosol regions can be overfilled (blurring effect).
  - Flagging (or removal) of ``false layers'' using depol. uncertainty and other error estimates.

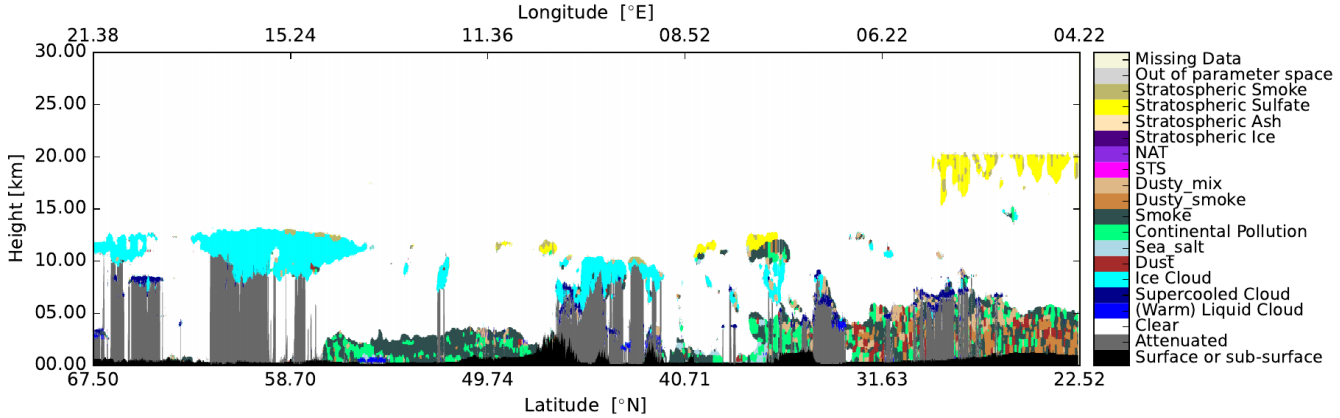
Validation needs

- Co-located Ext, Beta, S, Depol lidar measurements
  - Close co-locations (e.g. aircraft).
  - Longer-term stats with ground-based lidars.
- Conditions that challenge the cloud/aerosol discrimination (e.g. optically thick aerosol plumes and broken thin BL clouds)

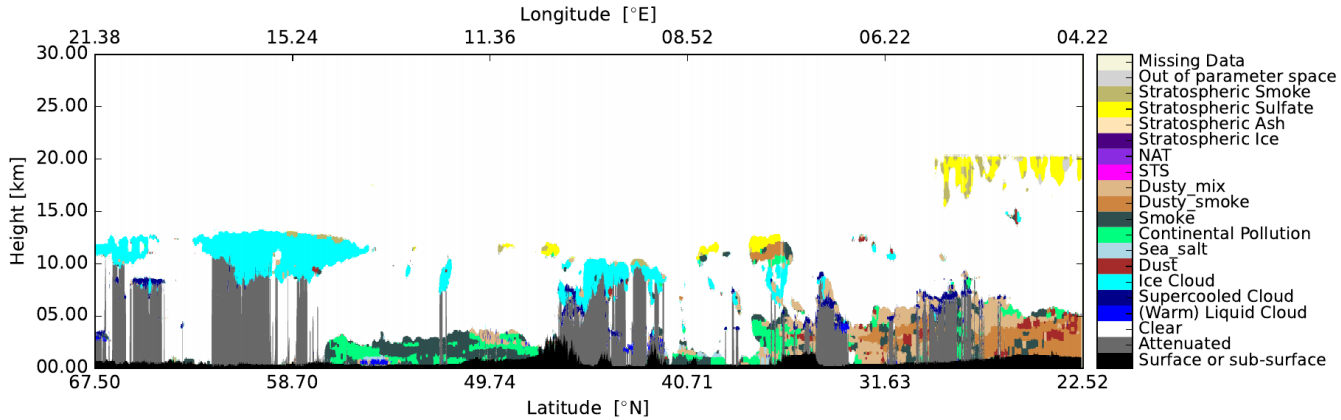
A-TC (Clouds and Aerosols Classification)

Responsible developers:
D.P. Donovan and G-J van Zadelhoff

Medium Resolution Target Classification



Low Resolution Target Classification



Recent improvements (baseline BA+)

- Improvements in A-EBD feed through to A-TC (and visa-versa!)
- T,P,RH added to output
- Better cloud/aerosol discrimination; still could be improved.

Challenges, open issues, planned developments

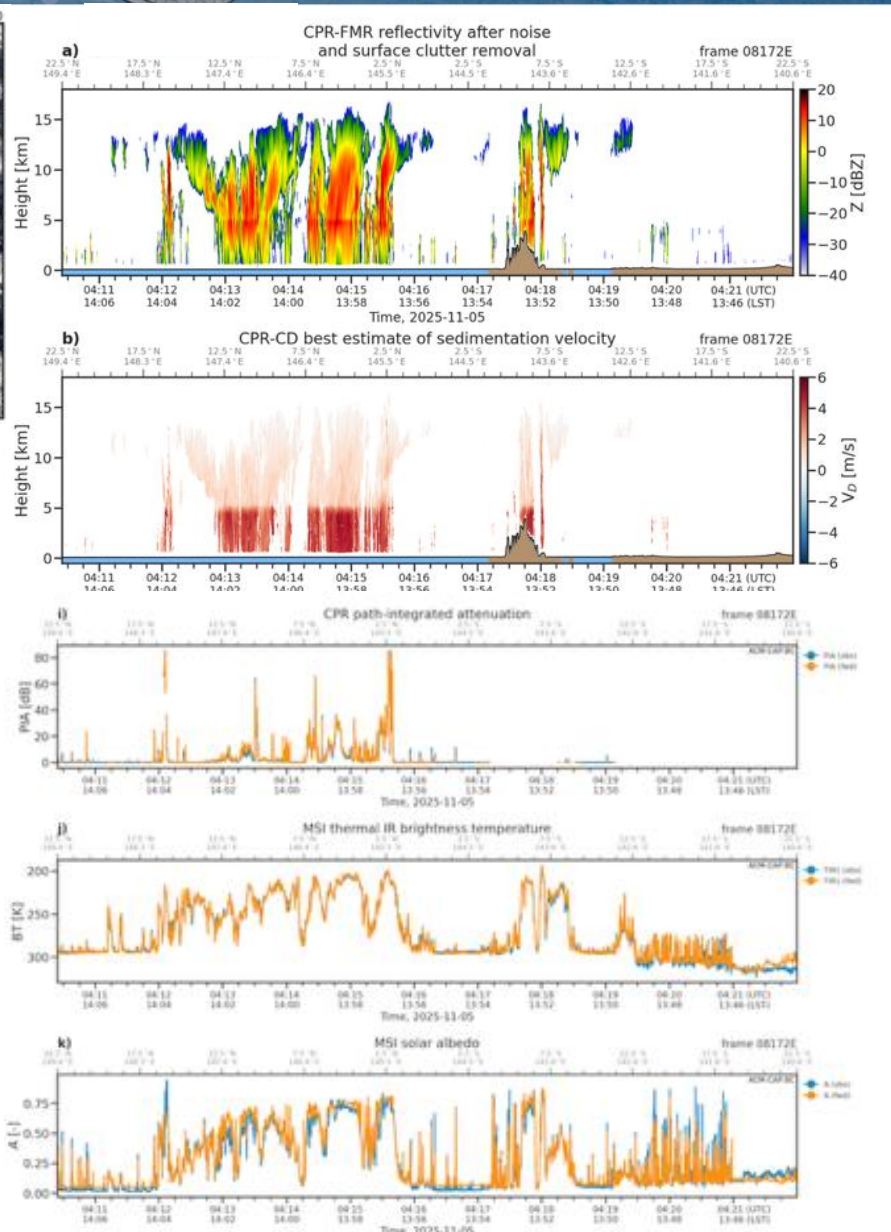
- QA flags should be improved
  - Should better respect the classification uncertainty.
- Cloud/aerosol discrimination still needs to be improved
  - Intense smoke remains a challenge
- Smoke remains a challenge as it exhibits significant evolution in terms of S and depol.
- Stratospheric classification still has not had a whole lot of attention paid towards.

Validation needs

- Cases, cases, cases !
  - Co-located high quality lidar-based S,depol and class data based up by e.g. trajectory analysis or in-situ to verify actual microphysics.
  - Conditions that challenge the cloud/aerosol discrimination (e.g. optically thick aerosol plumes and broken thin BL clouds)

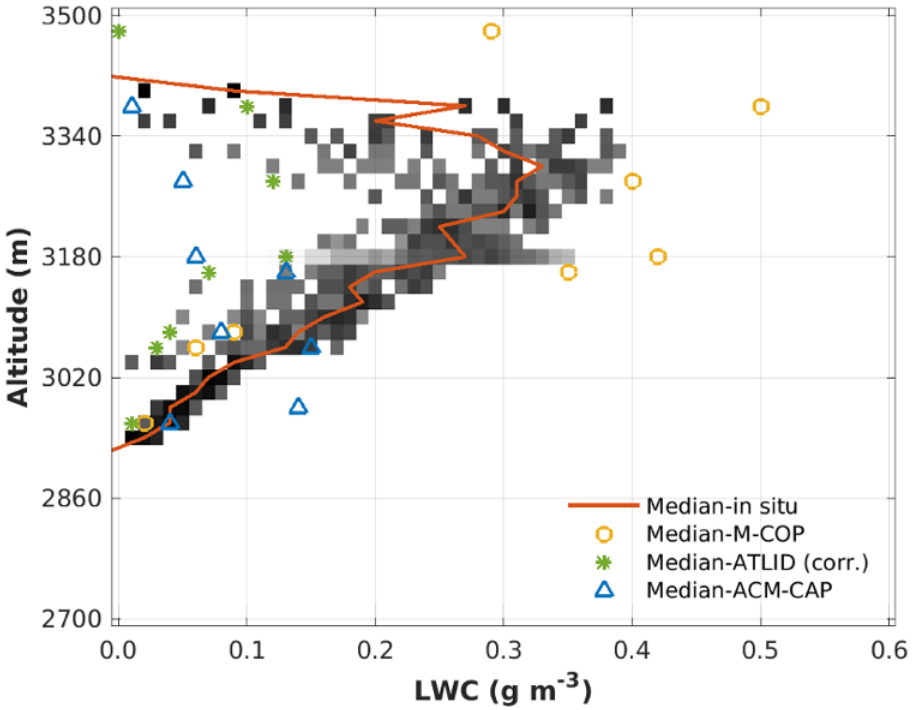
ACM-CAP: current status & recent changes

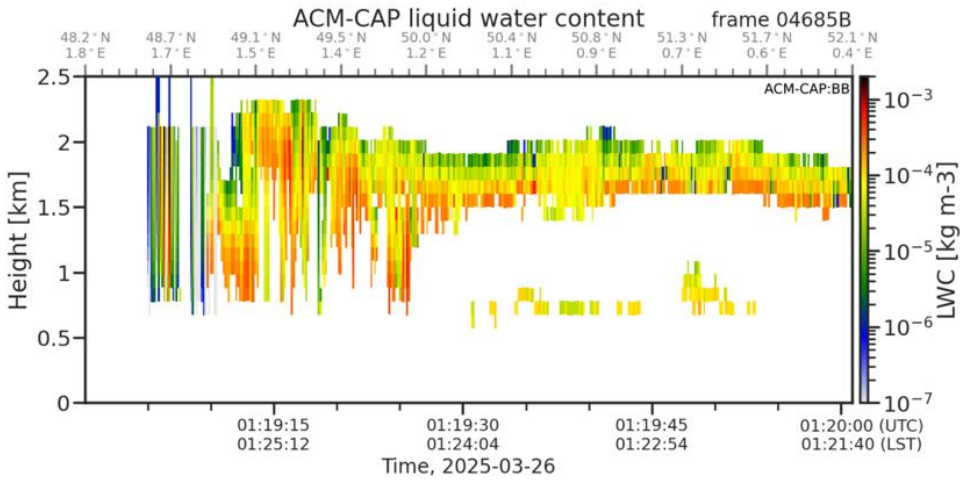
- Unified and synergistic retrieval of cloud, aerosols and precipitation
  Mason et al. (2023), *AMT*
- Significant evolution of ice microphysical assumptions and upstream ATLID & CPR processors using in-flight and campaign data; *Robin Hogan* ***poster Tuesday Lobby 10***
- Baseline BA: full record to November 2025
- Baseline BC:
  - addresses an overestimation of cloud and precipitation in deep convective clouds (especially ice clouds)
  - Upstream improvements in CPR sedimentation velocity; *Bernat* ***talk Tuesday Session 1***



ACM-CAP: caveats & ongoing work

- Liquid clouds:
  - Strong integrated constraints from MSI solar radiance and CPR path-integrated attenuation
  - Profile of liquid water content is under-constrained by the rapid extinction of ATLID: should be closer to an adiabatic profile.
  - Future work to apply stronger vertical constraints on the profile of liquid cloud water.

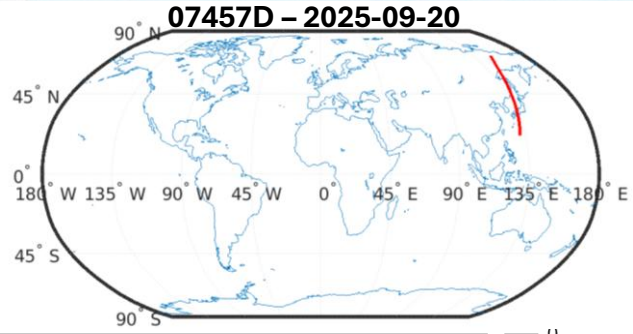




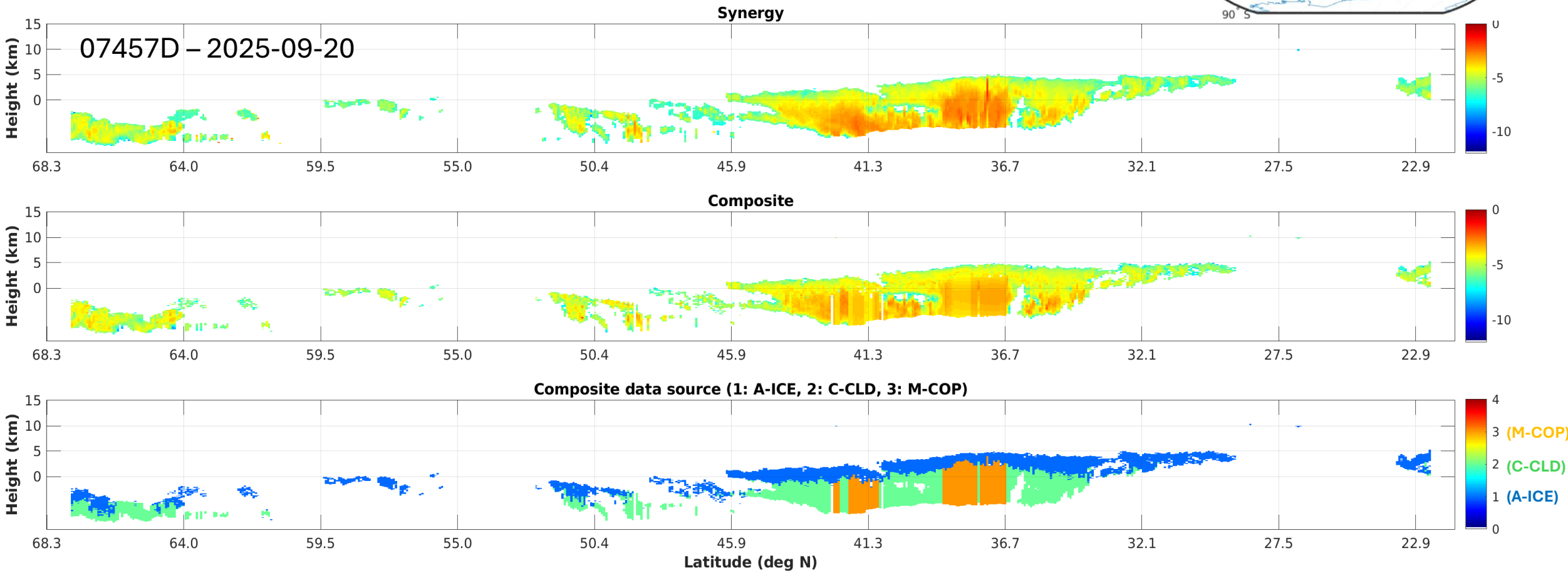
ACM-COM (ice clouds, 07457D)

Composite ice clouds (three sources, since Baseline BA):

- **A-ICE** + **C-CLD** + **M-COP**
- **C-CLD** no retrieval when multiple-scattering ↑ → use of M-COP
- Vertical variation using climatology (CloudSat)



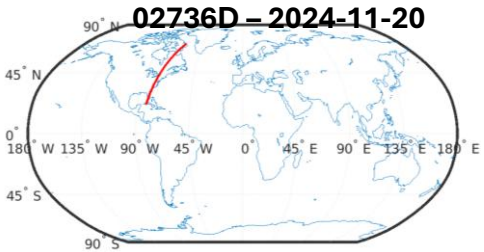
IWC (log10(g m^{-3}))

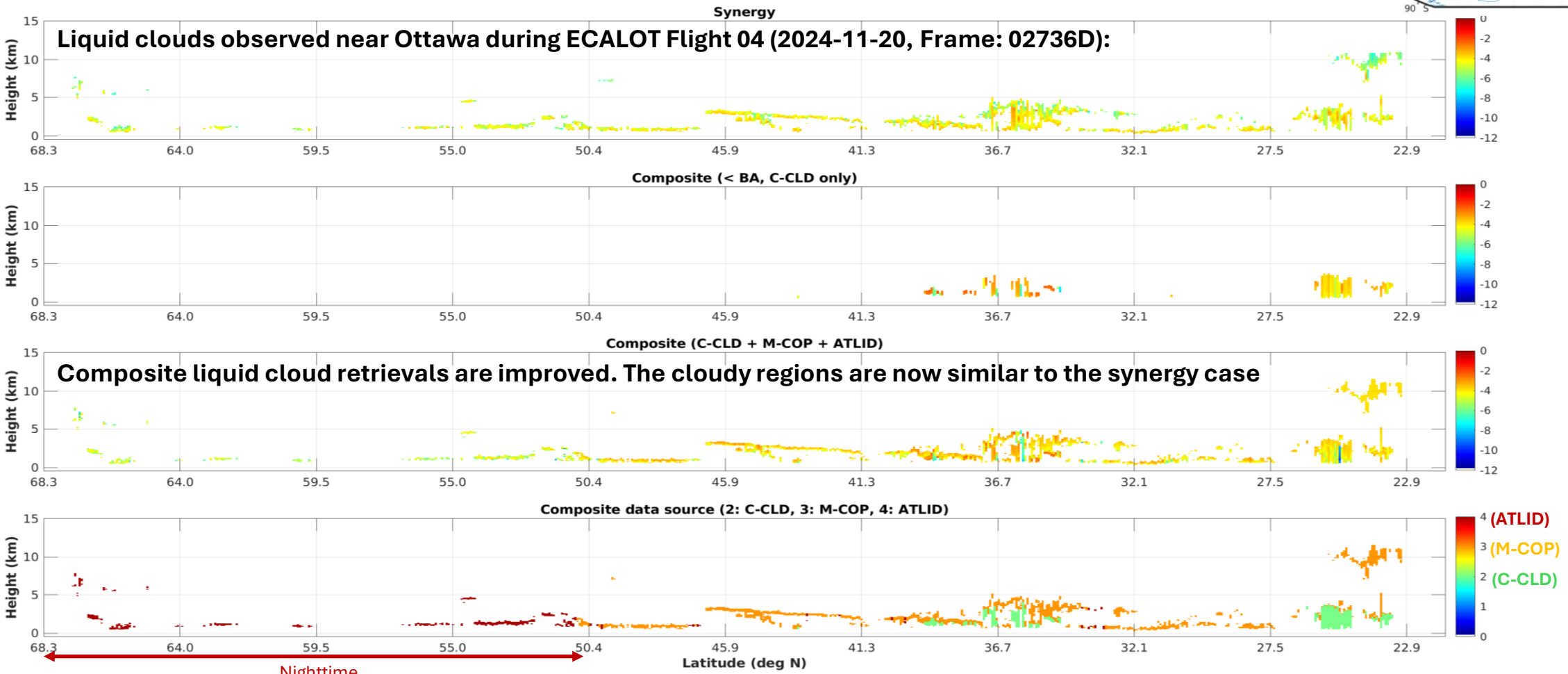


ACM-COM (liquid clouds, 02736D)

Composite liquid clouds (three sources – Baseline BC):

- **C-CLD:** retrieved LWC, might miss thin liquid clouds!
- **ATLID:** extinction-based (A-EBD) → LWC for **nighttime** or when M-COP data is missing
- **M-COP:** LWP → LWC, for **daytime** only





For more information…

- CPR:
  - Warm rain retrievals, Pavlos Kollias: **talk Tuesday session 1**
  - Doppler contributions, Bernat P Treserras: **talk Tuesday session 1**
- MSI:
  - MSI cloud retrievals, Anja Hünerbein: **poster Thursday, Annex 56**
  - Comparison with ACM-CAP, Gregor Walter: **poster Thursday, Annex 50**
- ATLID:
  - ATLID & MSI cloud-top height: Athena Floutsi: **poster Thursday, Annex47**
- ACM-CAP:
  - Ice particle size distributions, Robin Hogan: **poster Tuesday Lobby 10**
- ACM-COM:
  - And 3D scene construction, Zhipeng Qu: **talk this sessions**
  - Liquid cloud retrievals, Zhipeng Qu: **talk Wednesday session 1**