Workflow Development for Snowfall Retrieval Quality Assessment

Lisa Milani

University of Maryland

Giulia Panegrossi, Marco Petracca

Andrea Camplani, Paolo Sanó, Daniele Casella, Leo Pio D'Adderio

ISAC – CNR Rome

Background

- IPWG 2024 (Tokyo, Japan): **Snowfall Focus Group** reached a consensus on the need to establish a standardized validation framework that would enable equitable and consistent evaluation of existing global satellite-derived snowfall products.
- H SAF developed global precipitation products including snowfall modules for PMW radiometers including EPS-SG
- In H SAF all operational products undergo an independent validation carried out by a validation team
- H SAF Associated Scientist Activity **H_AS25_02** to develop a workflow for snowfall retrieval quality assessment

Objectives

The goal of this AS activity is to create a workflow for the quality assessment of snowfall retrieval from the H SAF global instantaneous precipitation rate L2 and L3 products based on conical and cross scanning PMW radiometers.

- The study considers the use of W-band spaceborne radar snowfall products (from **CloudSat and EarthCARE**) for global validation (with focus on the higher latitudes).
- Use of **ground-based radar networks** for regional quality assessment and analysis of case studies.
- Use of **Reanalyses** made available through the ECMWF Climate Data Store (e.g., ERA5 or possibly the Copernicus European Regional Reanalysis (CERRA)) will be considered for further verification of snowfall long term trends at the higher latitudes and over Europe
- Snowfall detection is a requirement so focus on validation of detection

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Methodology – Task 1

Assessment of current reference snowfall products, validation methods and data availability

- Literature review and inventory of existing methods for satellite surface snowfall rate (SSR) product validation;
- Survey on the availability of reprocessed H SAF L2 and L3 snowfall datasets;
- Survey of spaceborne cloud and precipitation radar products and ground-based network products to be used as reference;
- Survey of available reanalyses datasets for snowfall climatology analysis at higher latitudes;

Methodology – Task 2

Workflow development for the quality assessment of surface snowfall rate retrieval considering:

- Preparation of reference datasets (both from spaceborne radar and ground-based networks) to exclude any anomalies or outliers;
- Level 2 products - space-borne reference:
  - Spatial-temporal matching between the product to be compared and the references, considering different resolutions;
  - Pixel-based statistical analysis with different regions of interest, and intensity thresholds;
- Level 3 products - space-borne reference:
  - Temporal matching between the product to be compared and the references considering instantaneous and temporally averaged data;
  - Spatial data downscaling to a suitably defined common grid;

Methodology – Task 2 (continued)

- Level 2 and 3 - ground-based reference:
  - Spatial-temporal matching between the satellite products and the ground-based radars;
  - Case study analysis criteria;

- Snowfall long term comparison methodology at higher latitudes using H SAF L3 product P-IN-PMW and ECMWF reanalyses.

- Selection of the reference metric to uniquely define the quality of the satellite product estimate.

Methodology – Task 3

Application to H SAF precipitation products and case study analysis

- Application of the methodologies to a sample dataset made available for each H SAF product considered.

Task 1

Assessment of current reference snowfall products, validation methods and data availability

H SAF Global Products (Rainfall and Snowfall)

- Level 2
  - P-IN-GMI → P-IN-MWS (H70)
  - P-IN-ATMS → P-IN-MWI (H71)

Development of auxiliary products in preparation for day 1 new sensors products

- Level 3
  - P-IN-PMW (H78)

H-SAF Level 2 P-IN-GMI Snowfall Retrieval

- Derived from the SLALOM algorithm (Rysman et al 2018, 2019)
- Based on ML random forest and multi-linear regression models
- Trained with CloudSat and CALIPSO
- Use GMI TBs and environment data
- 4 modules:
  - Snowfall detection / Precipitation Phase
  - Supercooled liquid water detection
  - SWP estimation
  - Snowfall Retrieval

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H-SAF Level 2 P-IN-ATMS Snowfall Retrieval

- Derived from the SLALOM-CT algorithm (Sanó et al 2022)
- Based on ANN
- Trained with CloudSat and CALIPSO
- Use ATMS TBs, environment auxiliary data and dynamic surface classification at the time of the overpass (PESCA)
- 4 modules:
  - Snowfall detection / Precipitation Phase
  - Supercooled liquid water detection
  - SWP estimation
  - Snowfall Retrieval

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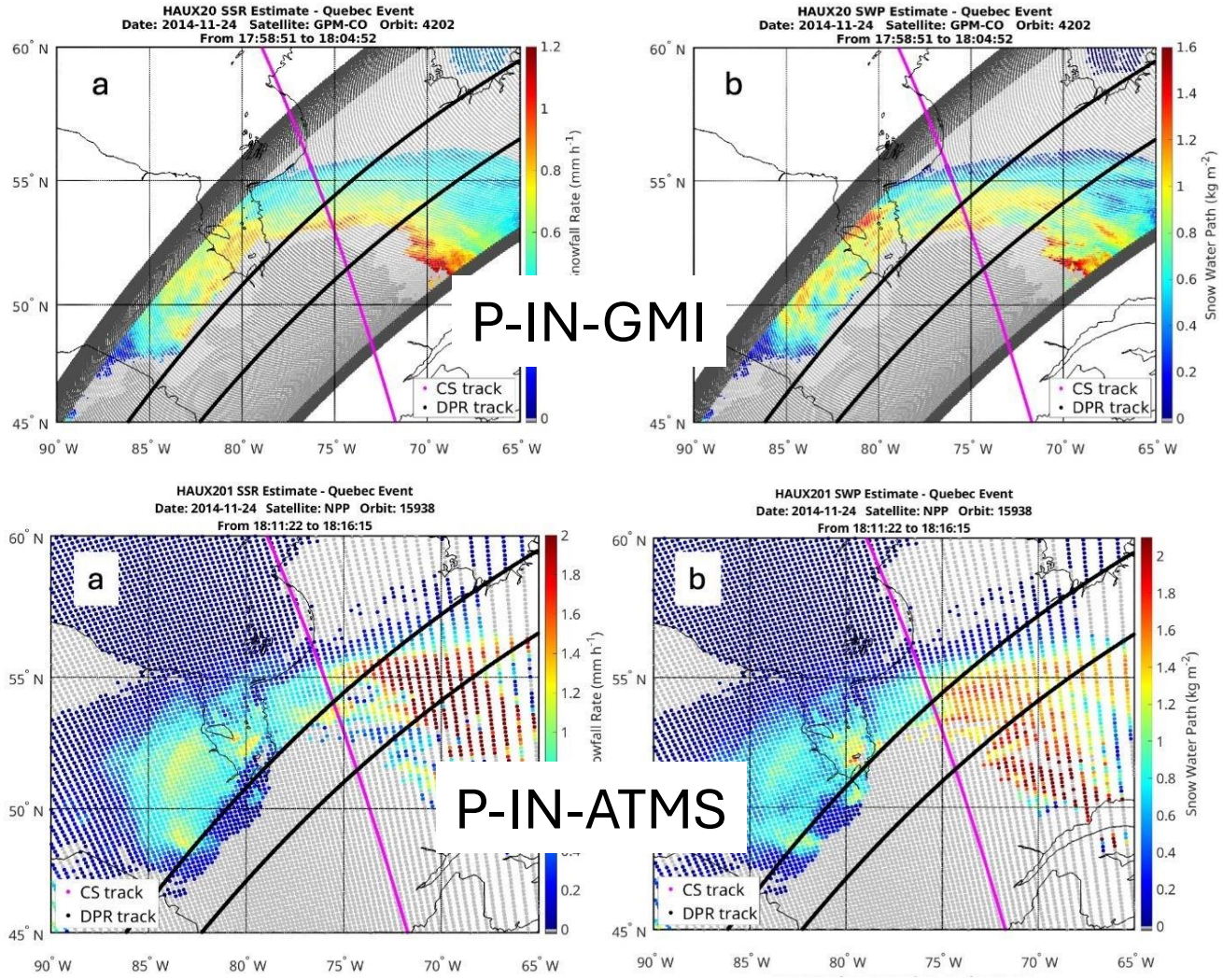
Comparison

- Both H SAF snowfall products detect and quantify snowfall in northern Quebec
- Some mismatch in the SSR and SWP
  (higher SSR and SWP for P-IN-ATMS compared to P-IN-GMI)

Snowfall Rate

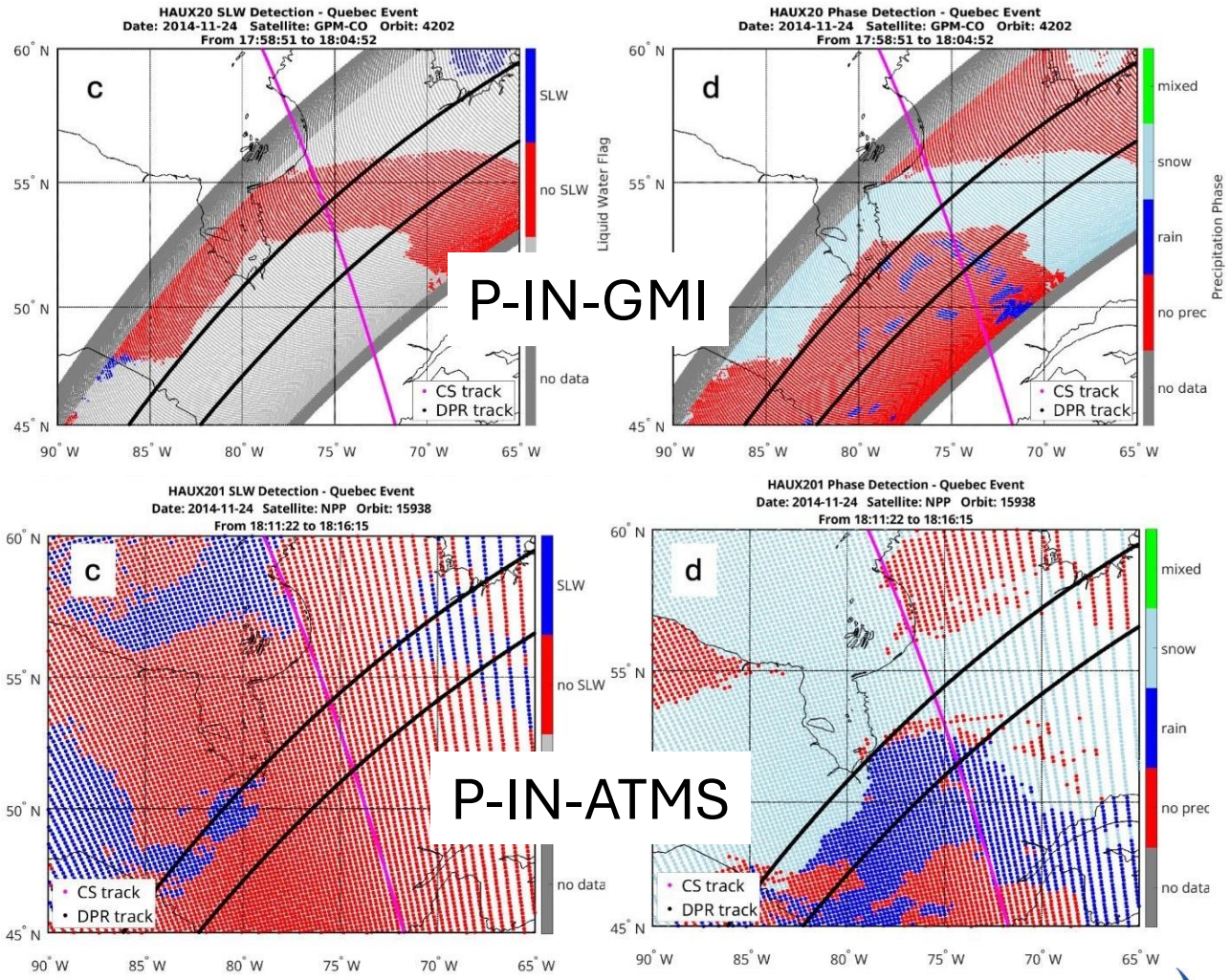
Snow Water Path



Comparison

- Some mismatch in the liquid precipitation detection (blue, right panel)
- Good agreement on supercooled liquid water detection and snowfall detection (blue, left panel and light blue, right panel)

SLW Detection Precipitation Phase

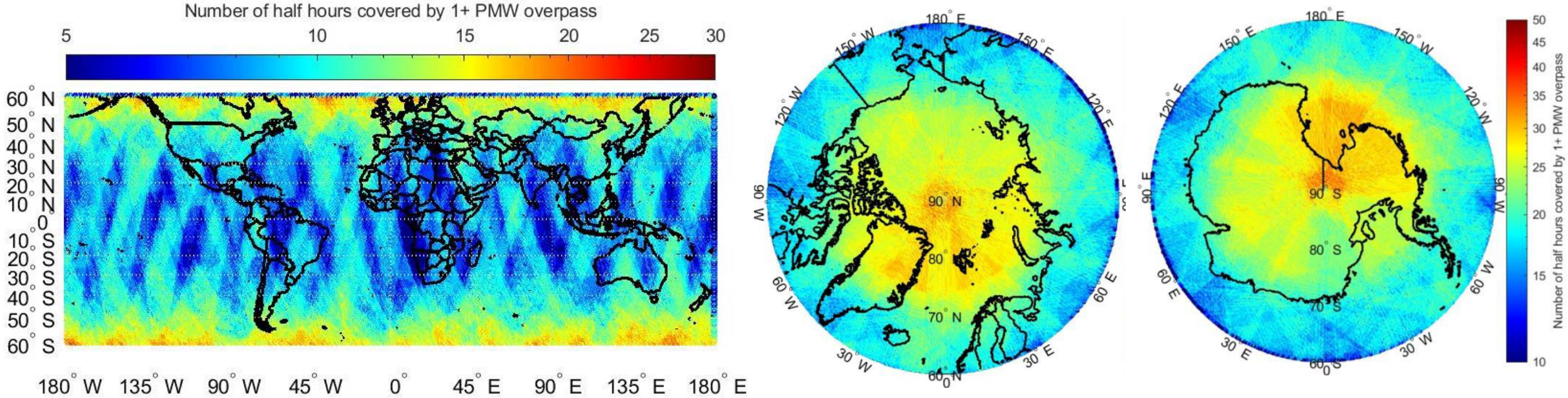


H SAF Level 3 P-IN-PMW (H 78)

- L3 Gridded PMW instantaneous precipitation rate (rainfall and snowfall) based on intercalibrated PMW Level 2 products
- Input: Global L2 instantaneous precipitation rate estimates (e.g., EPS-SG MWI and MWS, ATMS, AMSR2 (->AMSR3), GMI)
- *Remapping* : from Level 2 to Level 3
- *Adjustment* : intercalibration
- *Merging* : mean instantaneous precipitation rate based on Level 2 available products
- Global coverage (with gaps for uncovered areas)
- Every 30 min

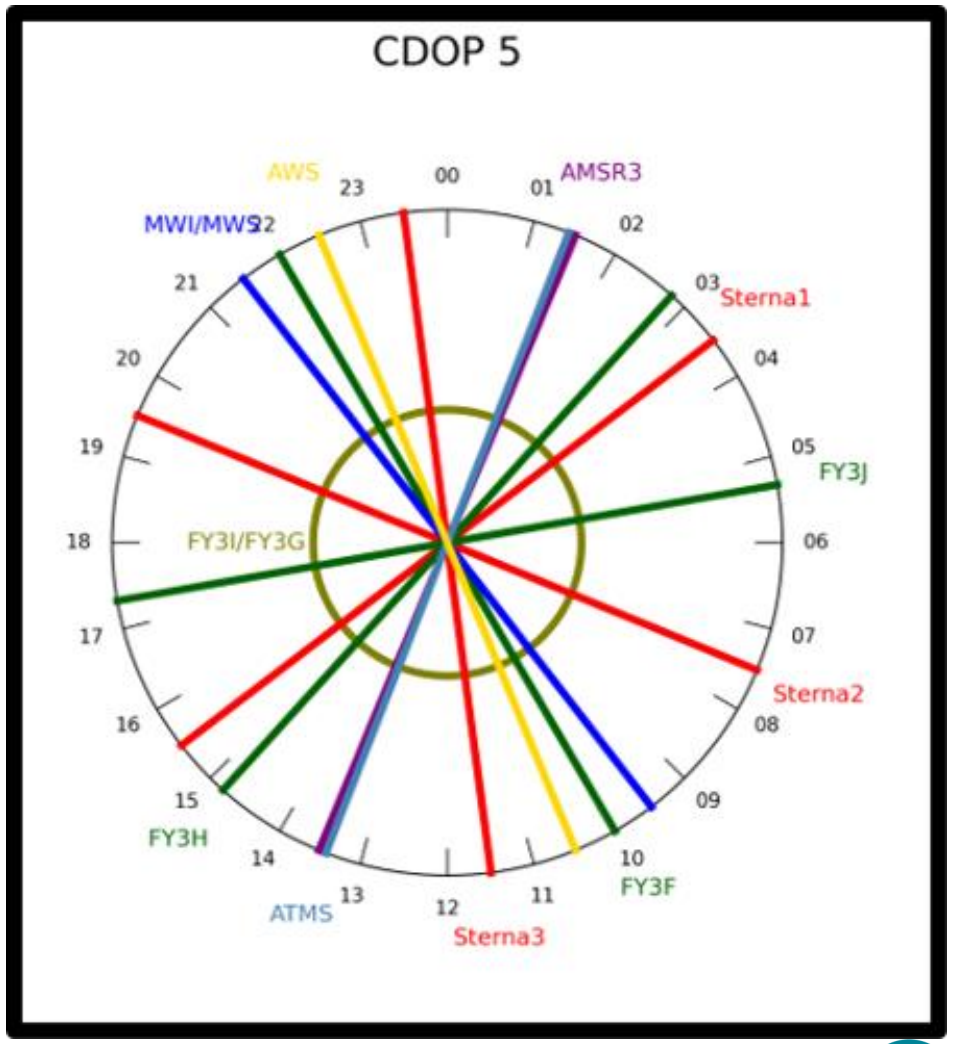
H SAF Level 3 P-IN-PMW (H 78)

Number of 0.5-h intervals covered by 1+ PMW overpass (based on ATMS, GMI e AMSR2)



Future additions of MetOp-SG (MWS e MWI) e FY-3, AWS, e EPS-Sterna

H SAF Level 3 P-IN-PMW (H 78)



Spatial distribution of the orbits within the 24h

(Future additions of MetOp-SG (MWS e MWI) e FY-3, AWS, e EPS-Sterna)

Task 2

Preparation of reference datasets (both from spaceborne radar and ground-based networks) to exclude any anomalies or outliers

Satellite Reference: EarthCARE ACM-CAP

- Use of EarthCARE ACM-CAP product
- Provides a unified, best-estimate retrieval of clouds, aerosols, and precipitation. It uses the CAPTIVATE variational technique to seamlessly integrate active and passive data from three onboard instruments: ATLID (lidar), CPR (radar), and MSI (imager).
- The ‘ice_mass_flux’ (kg/m^2s) variable is used to calculate the vertical profile snowfall rate (SR, mm/h)
- Surface variables are not included in any of the EarthCARE products at this moment

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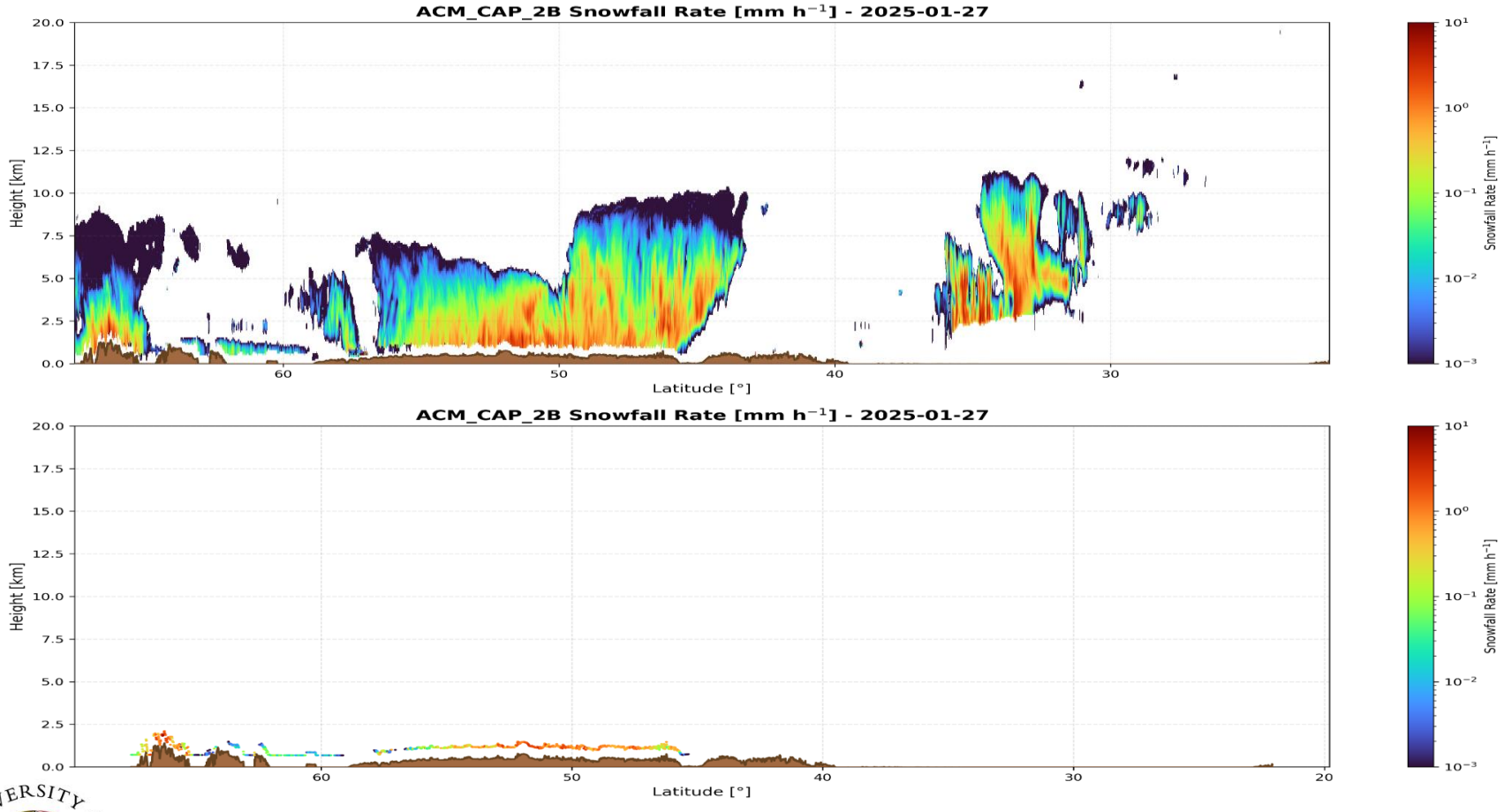
ACM-CAP Snowfall Retrievals

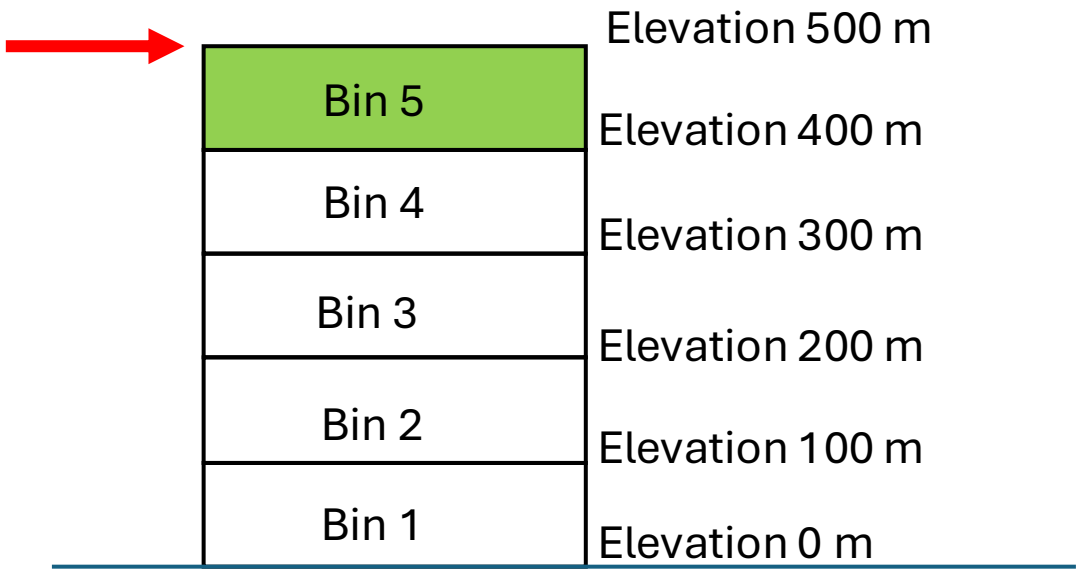


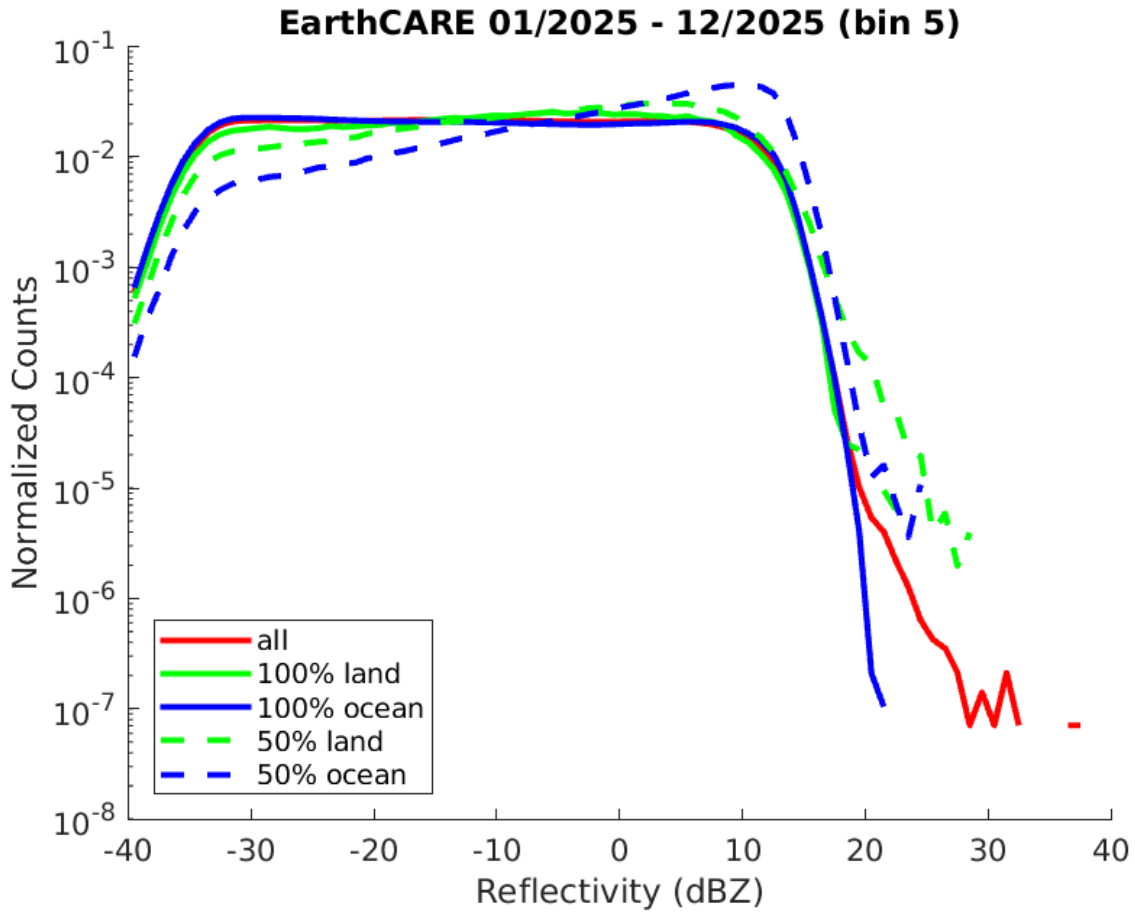
SUGGESTION FROM THE DEVELOPERS:

The Near Surface Bin, defined around 500m independently of the surface type, can be used for calculating the snowfall rate at the surface.

Some adjustments might be needed in order to avoid the potential ground clutter contamination described for CloudSat.

ACM-CAP Surface Snowfall Retrievals





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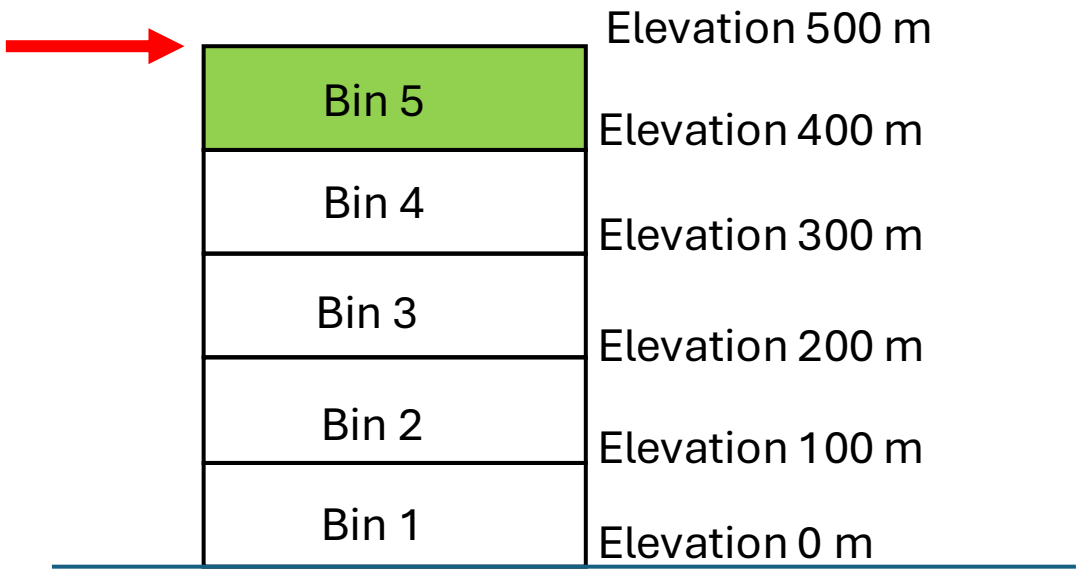
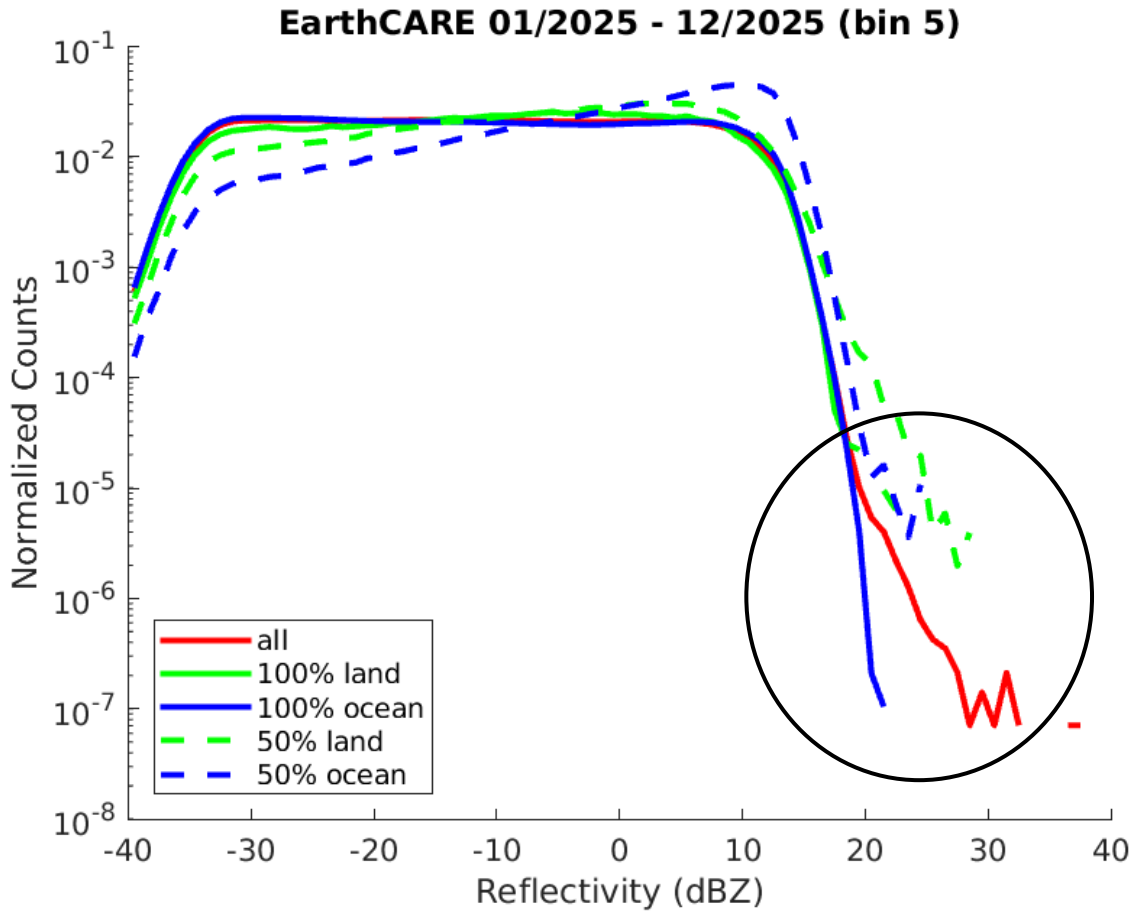
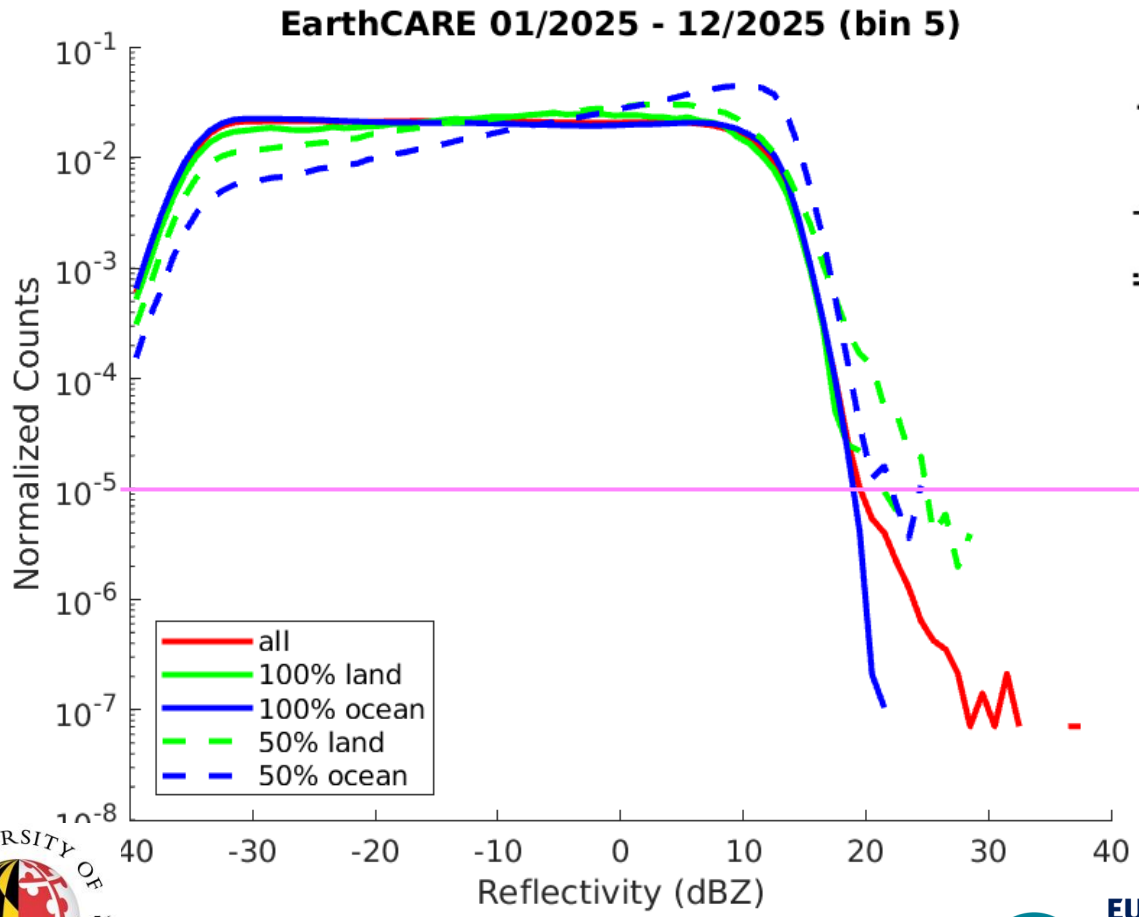
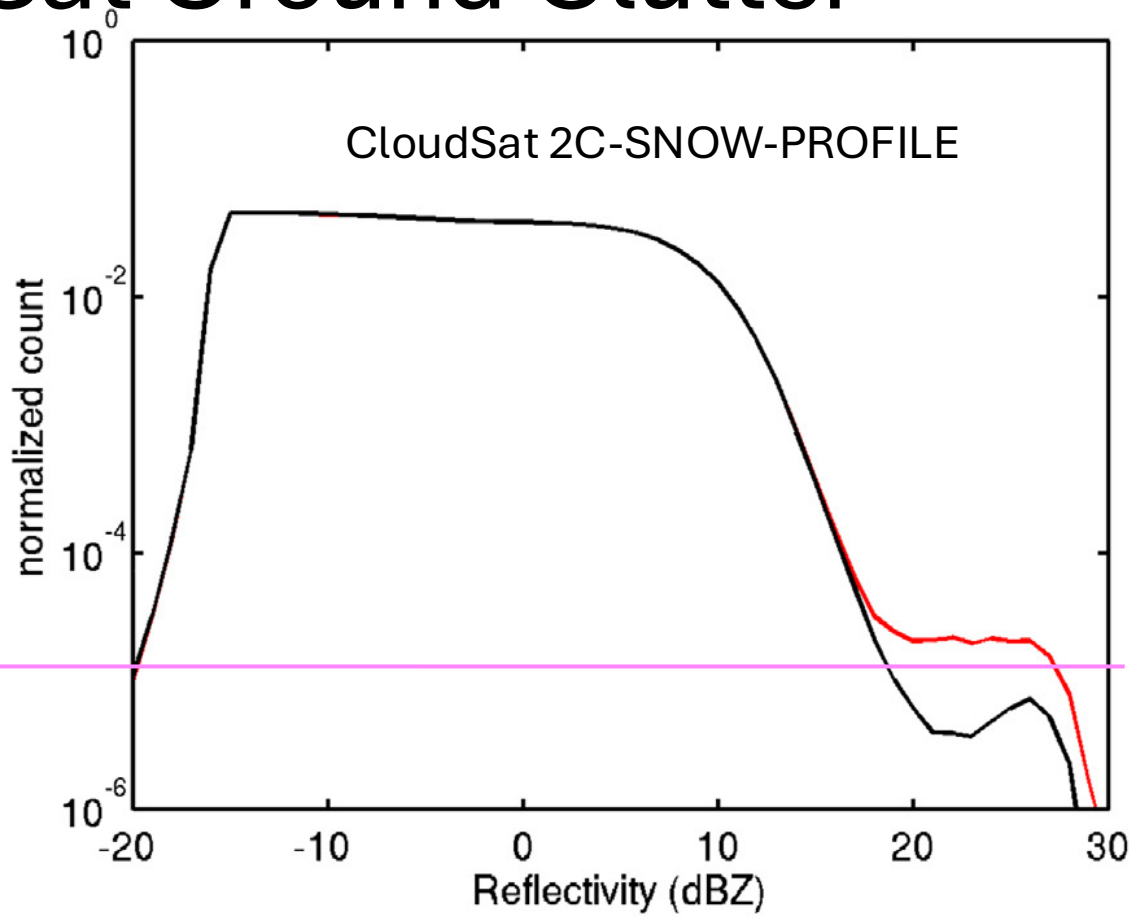




Comparison to CloudSat Ground Clutter





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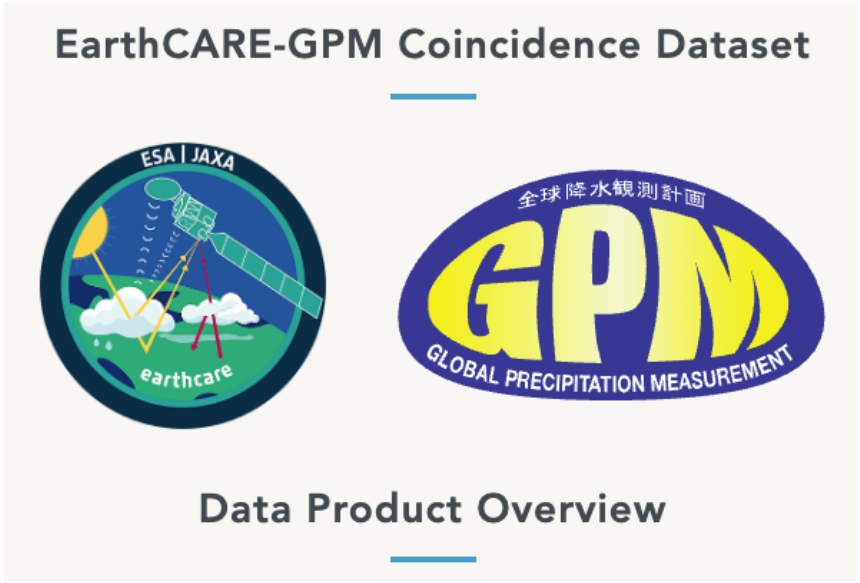
(Milani et al. 2018)

EarthCARE-GPM Match

- Use of the Coincident EarthCARE-GMI Dataset
- DOI: 10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y



Data Product Overview

Data Provision Period	From August 2024
Contents of Provided Data	GPM/DPR, GPM/GMI, EarthCARE/CPR, and ECMWF environmental field data are stored while maintaining the resolution and other properties of each original dataset.
Format of Provided Data	netCDF4 format * Quick-look PNG images are provided for the vertical distribution of radar reflectivity (GPM/DPR and EarthCARE/CPR) and Doppler velocity (EarthCARE/CPR), and the brightness temperature data of GPM/GMI.
Extraction conditions for simultaneous observations	+/-15-min time difference between the cross-over time of the two spacecraft
Algorithm Theoretical Basis Document (ATBD)	EarthCARE-GPM Coincidence Dataset Version 1 (3 October 2025)
DOI	10.57746/EO.01ka7xakvwj6pcthxkvgt0vr0y

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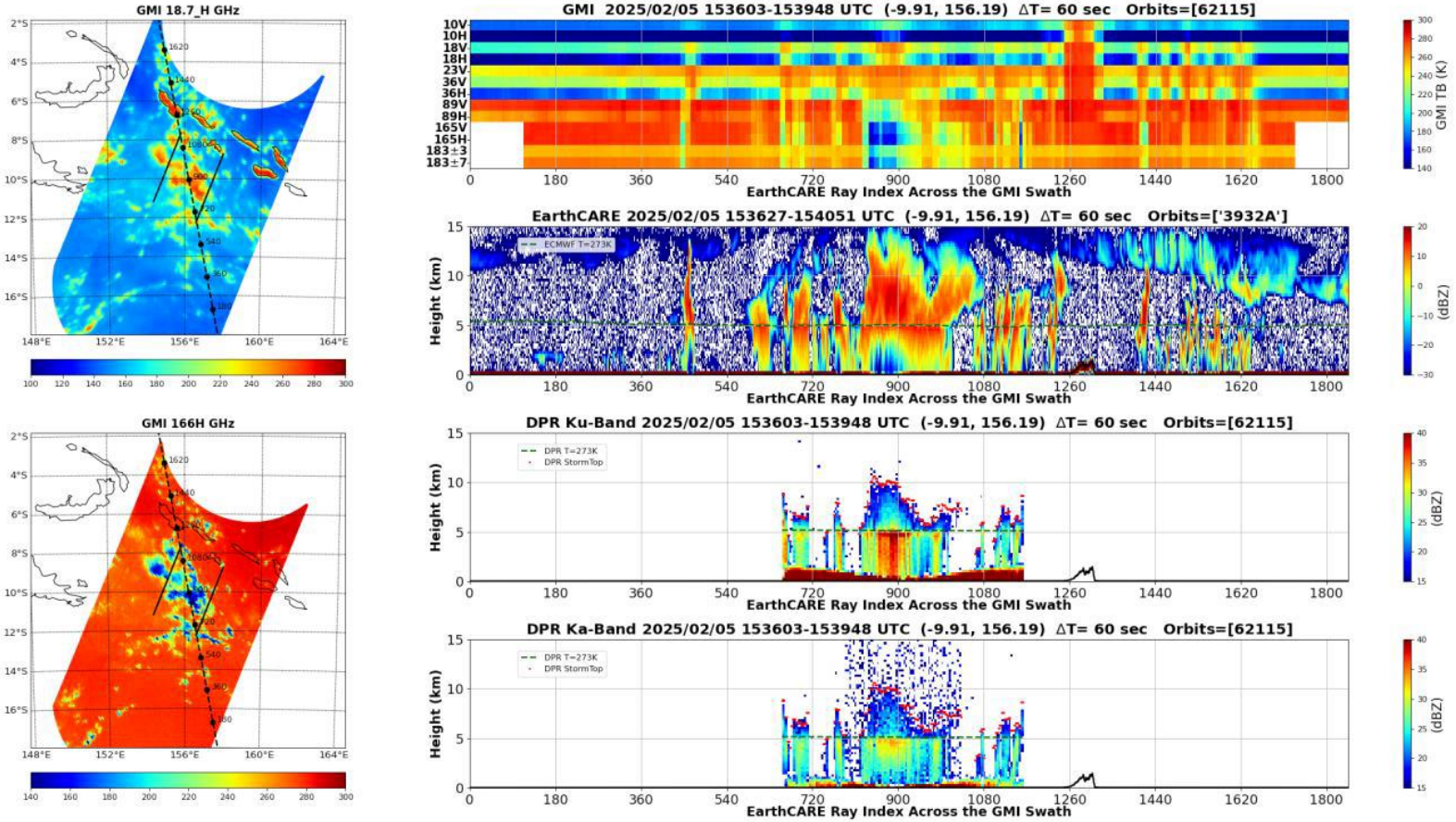
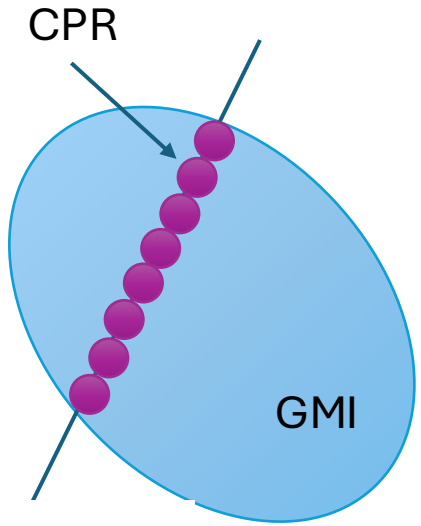
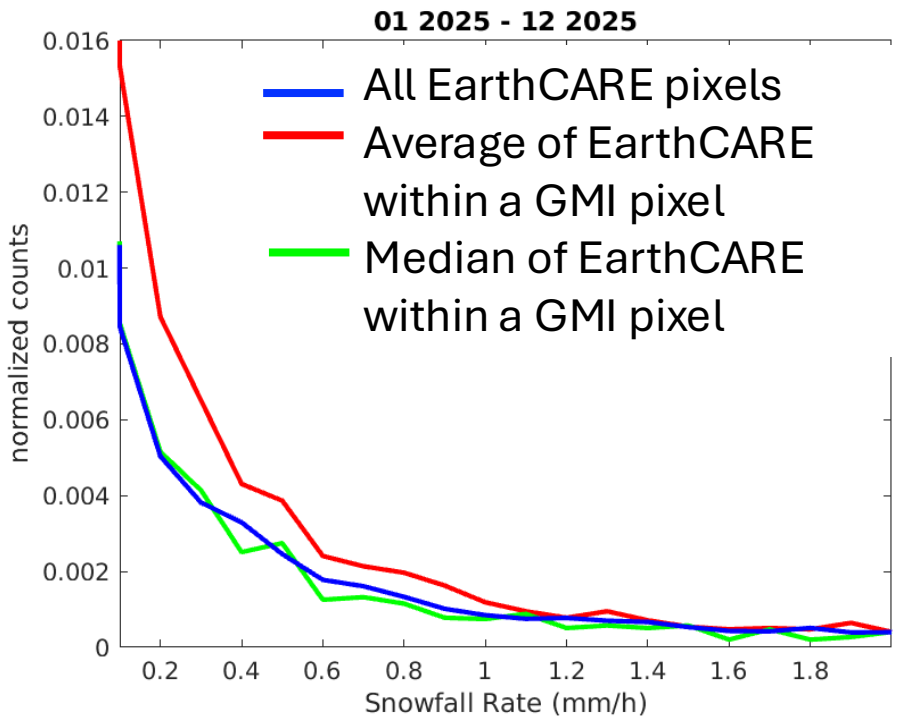
EarthCARE-GPM Match

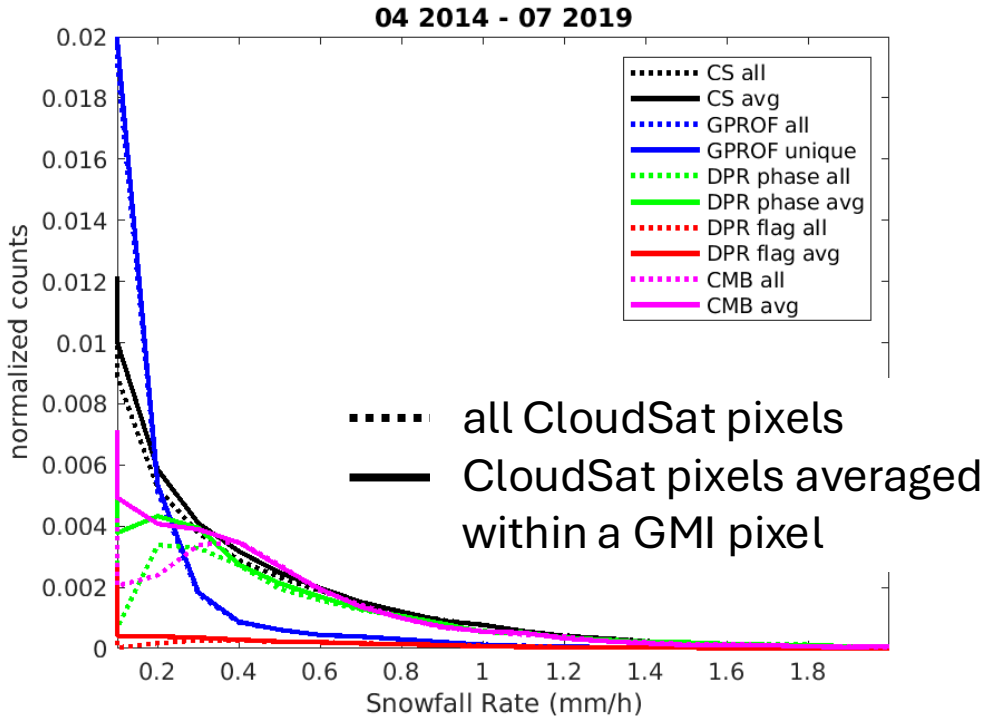


Example of EarthCARE-GPM quick look

EarthCARE – GMI spatial match







Next Steps – Space-borne reference

- Level 2 products - space-borne reference:
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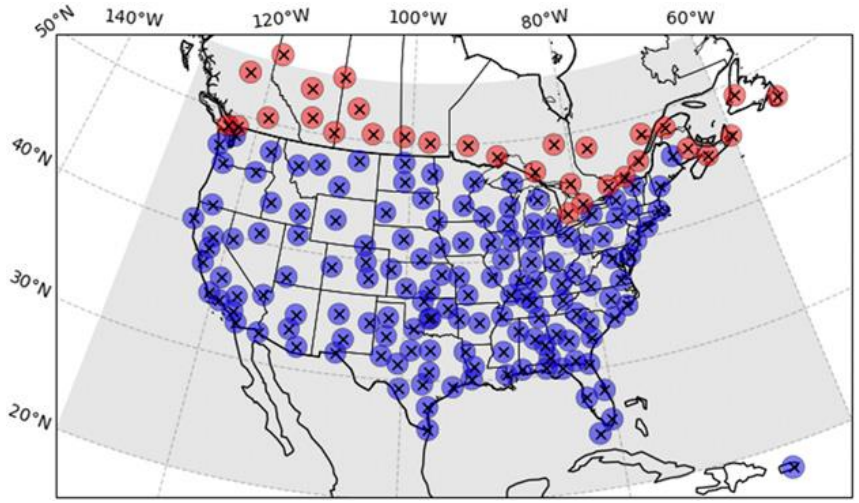
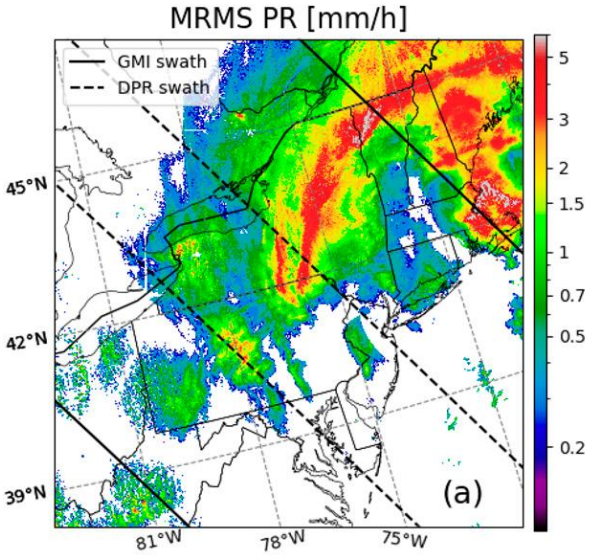
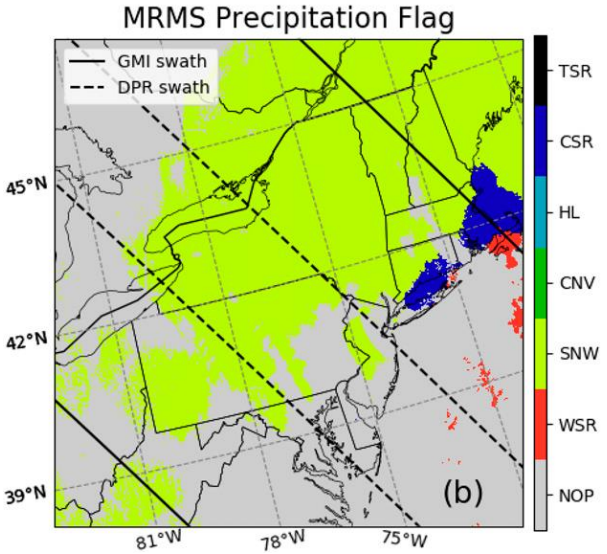




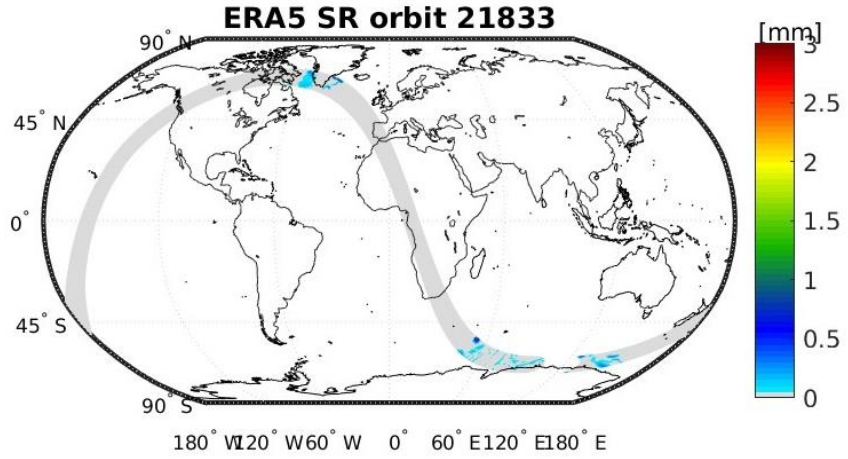


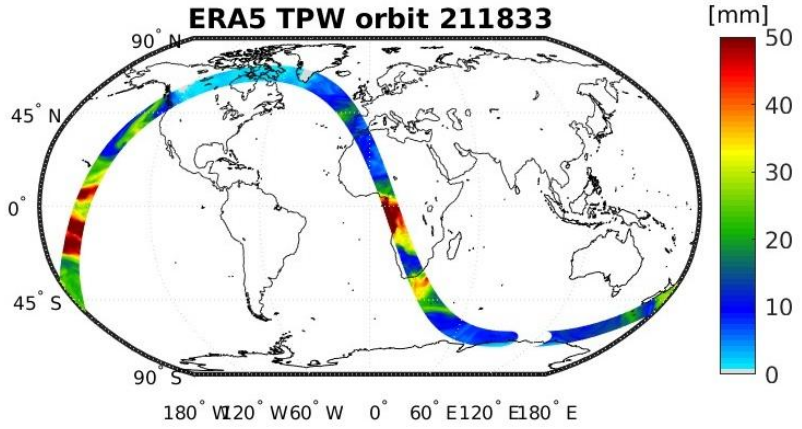
(Mroz et al. 2021)

Next Steps – L3-Reanalyses and metrics

- Snowfall long term comparison methodology at higher latitudes using H SAF L3 product P-IN-PMW and ECMWF reanalyses.

- Selection of the reference metric to uniquely define the quality of the satellite product estimate.





Collaborations and Future

- Any insight on surface snowfall rate estimation of EarthCARE is welcome
- We would be happy to consider the use of JAXA surface snowfall rate estimates if/when available
- Once concluded, the documentation describing the workflow will be made available on the H SAF website and shared within IPWG
- Future applications: AWS and EPS Sterna to be developed during the next H SAF phase

Thanks!
Feel free to contact me to discuss further:

lisa.milani@nasa.gov

Acknowledgement:
H SAF Associated Scientist Activity **H_AS25_02**