Validation for EarthCARE Cloud Profiling Radar (CPR) using Ground Based Observations

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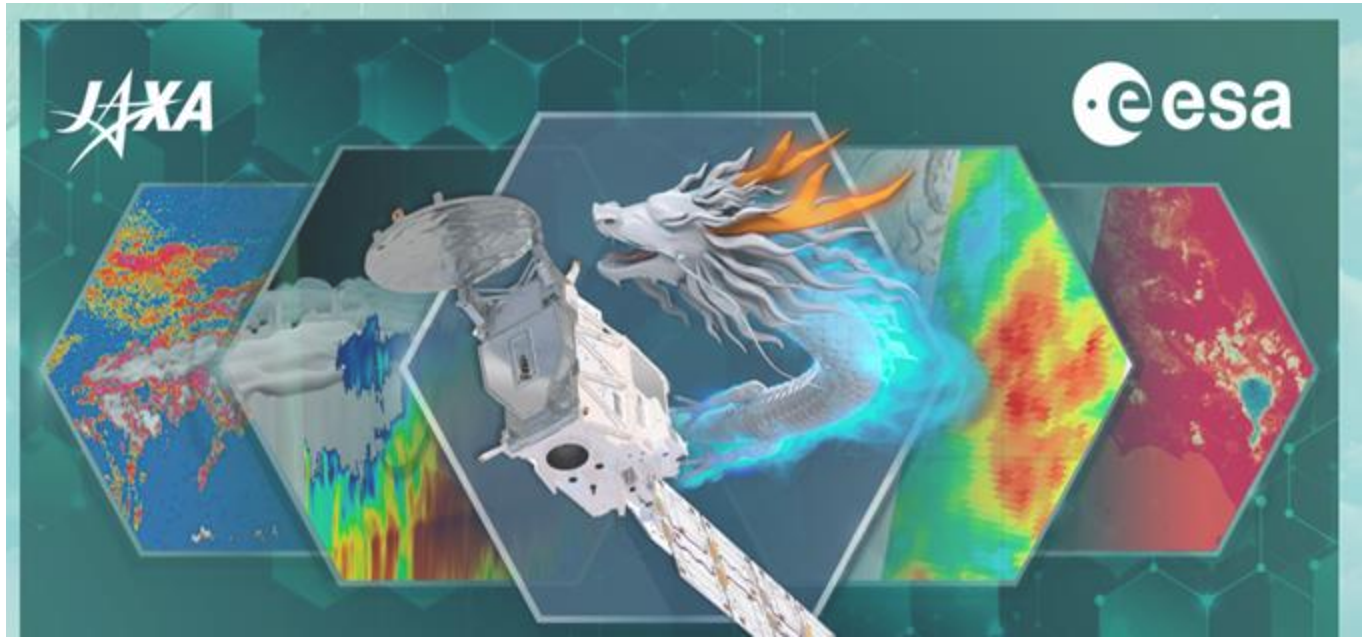
- 2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
- 17-20 March 2025, Rome, Italy

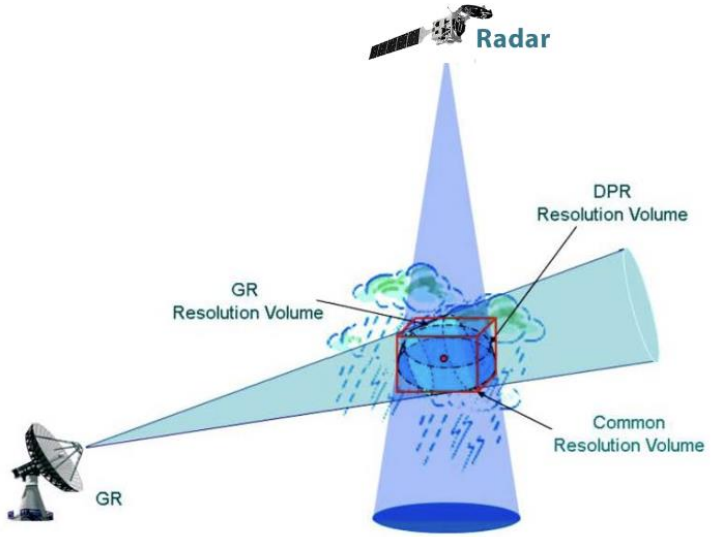


Outline

- The study is focused on the initial validation activities for CPR level 2 products with FMI radar network and NEXRAD radar network. Cases are chosen from 2025-January to February.
- Two validation cases are chosen with FMI network and KFTG/KCYS NEXRAD radars for detailed illustration in this presentation.
- Reflectivity (**CPR_FMR**) and Hydro Class(**CPR_TC**) in CPR level 2 data (**baseline AB**) released to Cal/Val team (https://ec-pdgs-dissemination2.eo.esa.int/oads/access/collection/EarthCAREL2InstChecked) are the main products we validate in this presentation
- Initial comparisons illustrate promising results.

Background

Ground validation for satellite mission



EarthCare CPR radar

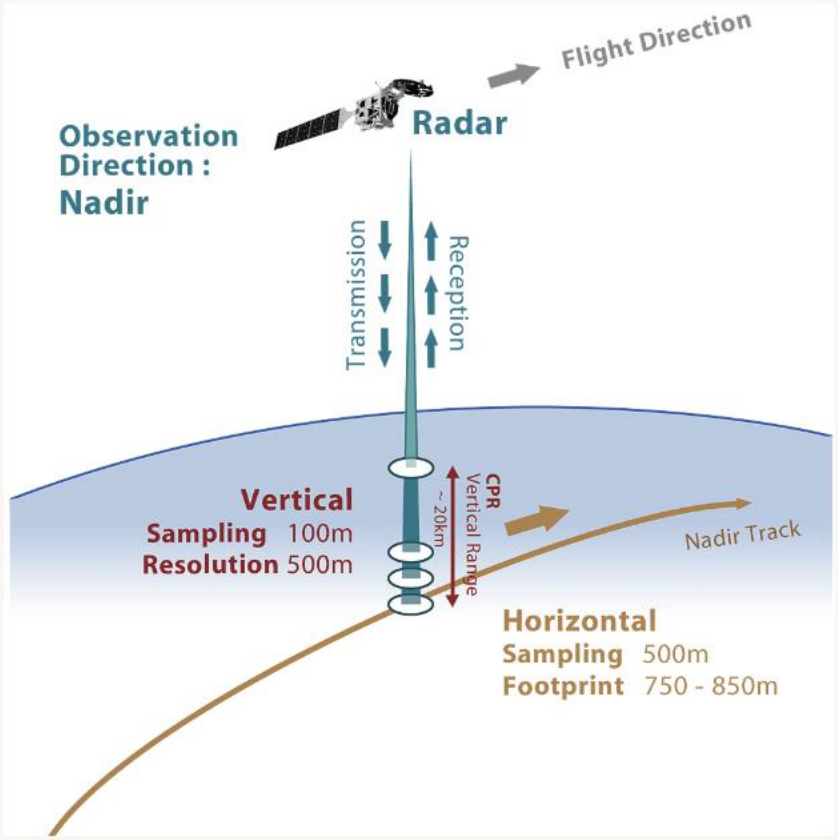


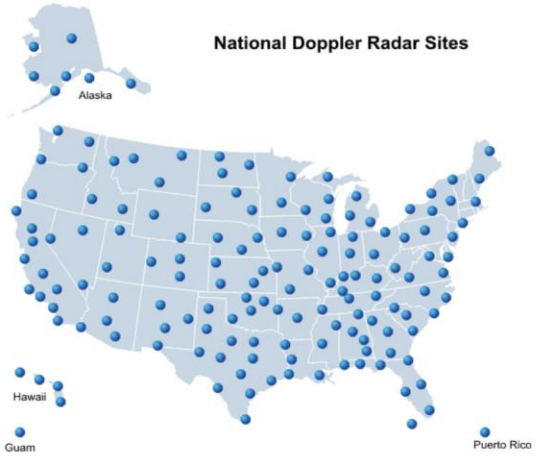
Image and table:
https://www.eorc.jaxa.jp/EARTHCARE/about/inst_cpr_e.html

Main Observation Parameters for CPR

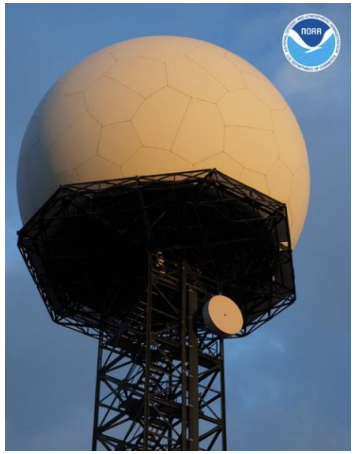
Sensor type	94 GHz (W-band) Doppler radar
Developer	Japan Aerospace Exploration Agency (JAXA) National Institute of Information and Communications Technology (NICT)
Center frequency	94.05 GHz
Pulse width	3.3 μs
Antenna beam width	< 0.095 deg.
PRF	6100 to 7500 Hz (variable)
Sensitivity	< -35 dBZ at atmospheric top (10 km integration)
Doppler accuracy	< 1.3 m/s (10 km integration)
Measurement range	-1 to 12/16/20 km (depending on latitude zone)
Measurement range	-1 to 12/16/20 km (depending on latitude zone)
Footprint (IFOV)(*2)	< 750 m (depending on satellite altitude)
Horizontal sampling	500 m
Vertical resolution	500 m
Vertical sampling	100 m (oversampling)

Validation with Nexrad radar

- KFTG (Denver area) and KCYS (Cheyenne area)

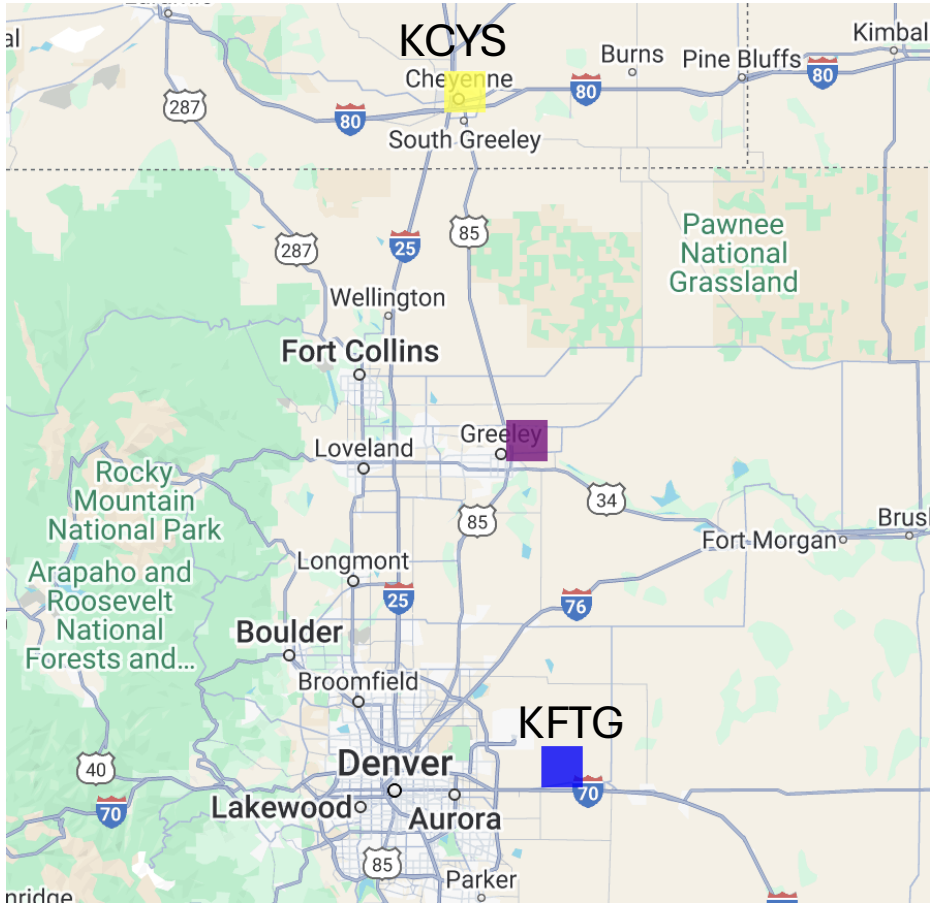


NEXRAD radar network.



KFTG

KCYS



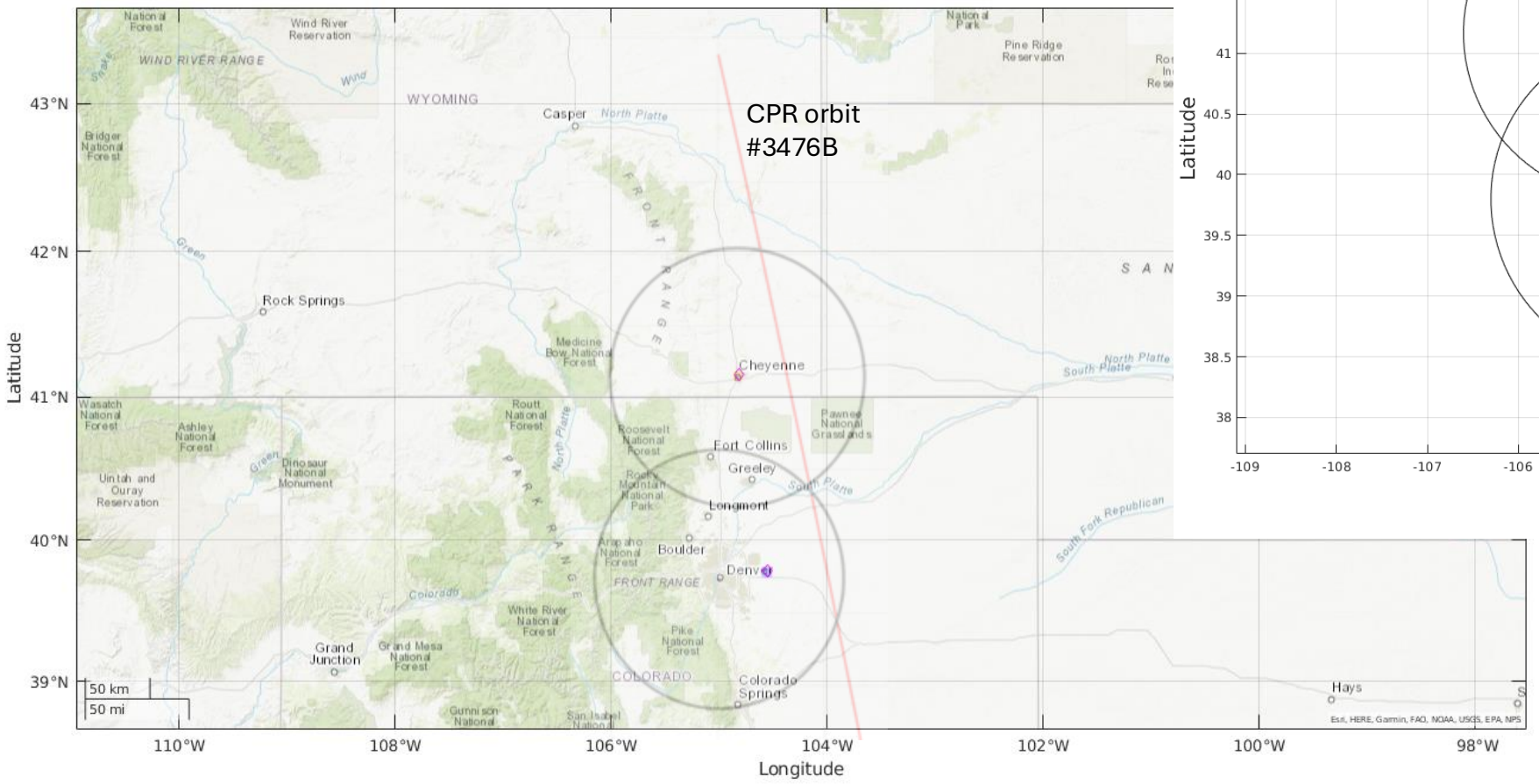
Possible validation cases with Nexrad radar network of KFTG and KCYS between 2024-December to 2025 February

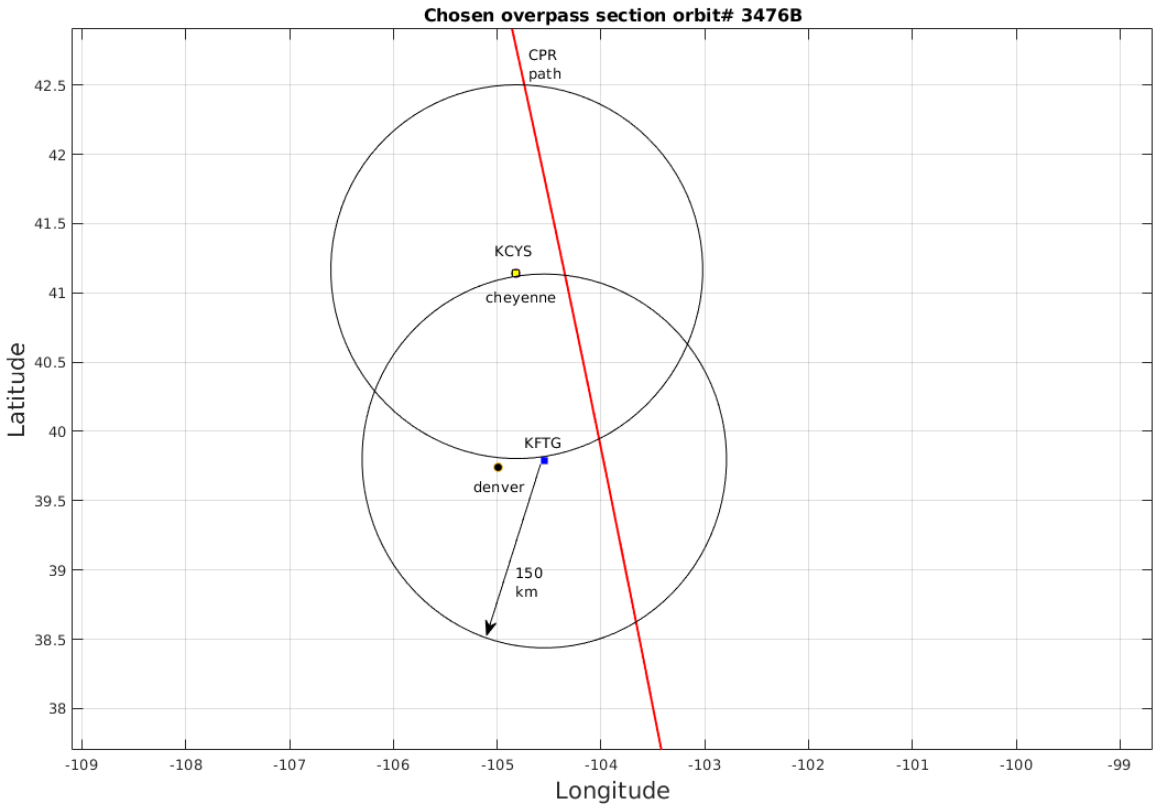
CPR Orbit#	date	UTC	ground radar
1) 3476B	2025-01-07	08:27:04 ~ 08:38:51	Both KFTG and KCYS
2) 4114B	2025-02-17	08:30:20~08:42:06	More KCYS, maybe KFTG
3) 4122D	2025-02-17	21:13:27~21:25:13	Maybe both (not much KCYS)

NEXRAD or Nexrad (Next-Generation Radar) is a network of 159 high-resolution S-band Doppler weather radar operated by the National Weather Service, and agency of the National Oceanic and Atmospheric Administration (NOAA) within the United States.

Sample validation case

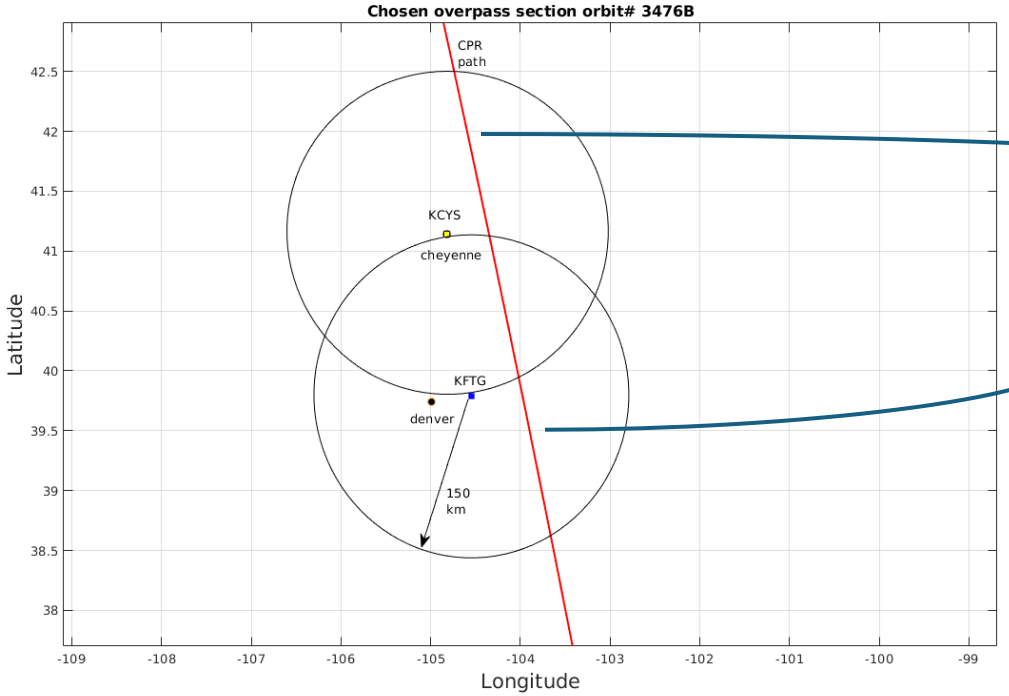
- CPR orbit: 3476B (baseline AB)
- NEXRAD radar: **KFTG** and **KCYS**
- Time: 2025-01-07T08:27:04.000Z ~ 2025-01-07T08:38:51.000Z

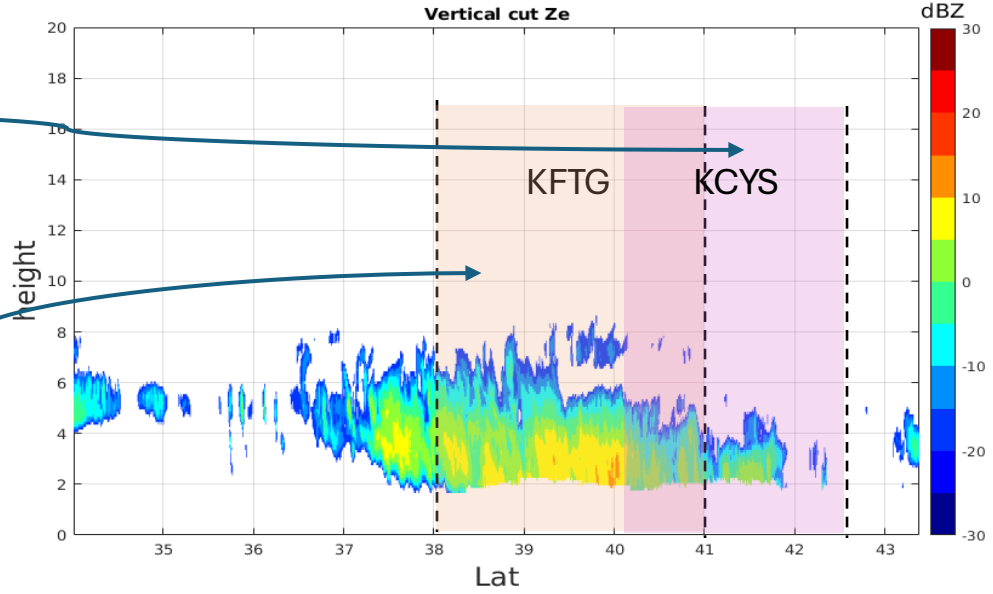


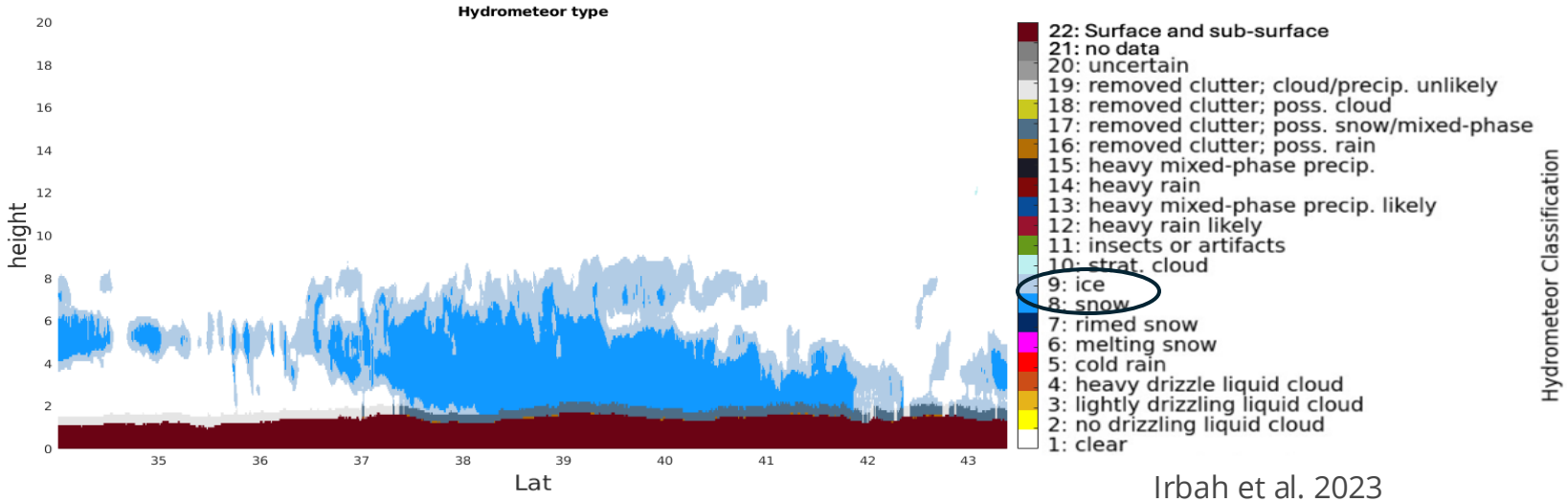


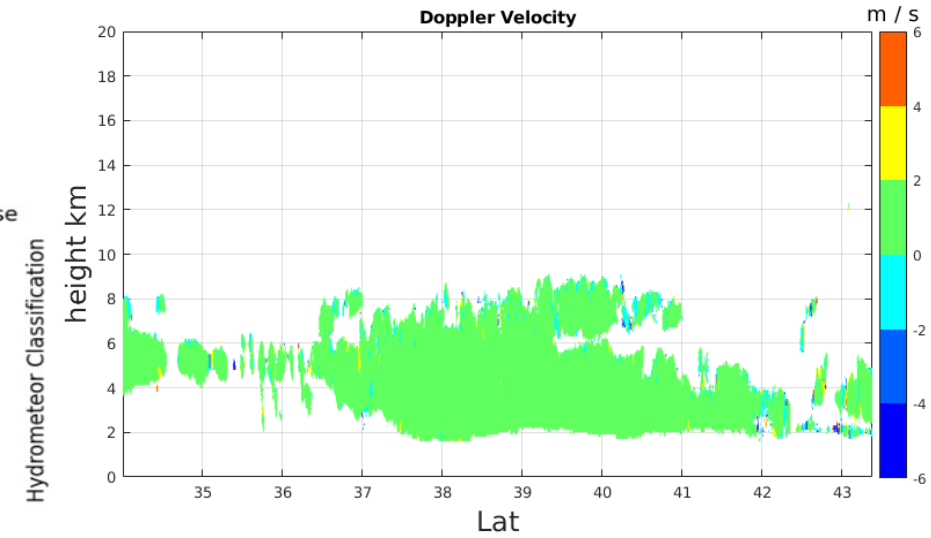
CPR data:

- CPR orbit: 3476B (baseline AB)
- NEXRAD radar: **KFTG** and **KCYS**
- Time: 2025-01-07T08:27:04.000Z ~ 2025-01-07T08:38:51.000Z









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KFTG

radar images:

- KFTG data UTC: 20250107_083222, within time frame of CPR orbit.

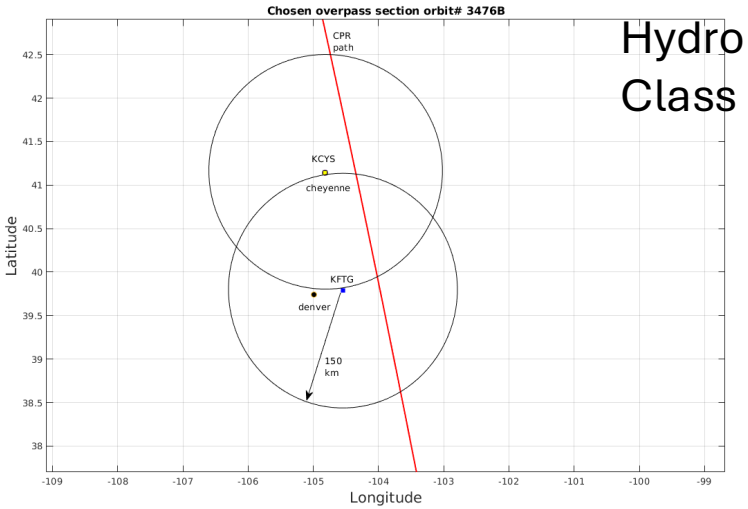
- Altitude of KFTG: 1.68 km
- Covered height from 2.1km ~ 8.2 km.

- Peak of Ze is around 15~20 DBZ at latitude of 40 deg..

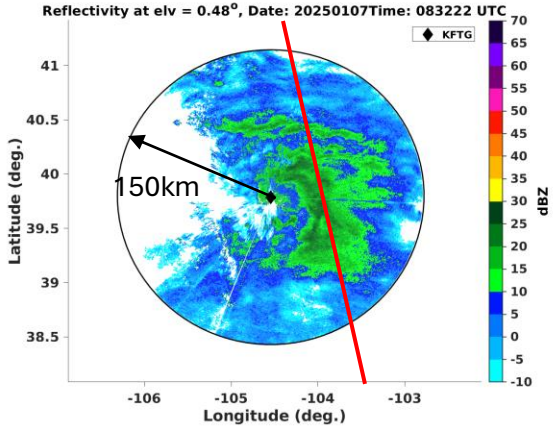
- Hydrotype is also classified as “DS (dry snow)” and “CR(crystal)” (algorithm by Bechini and Chandrasekar, 2015)

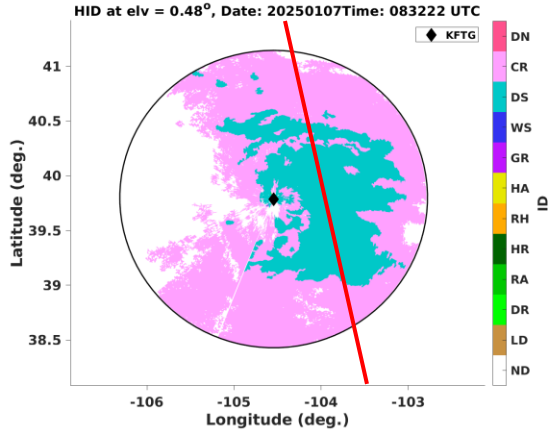
Ze

Hydro Class

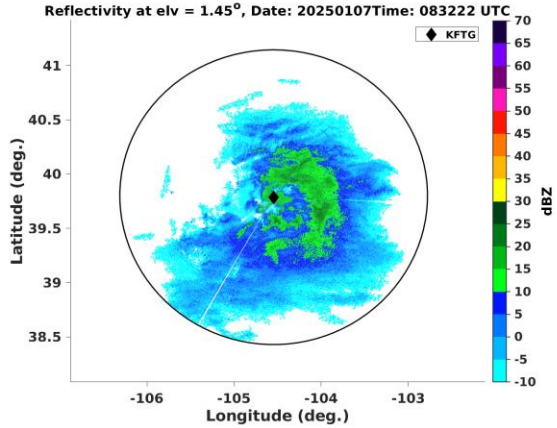


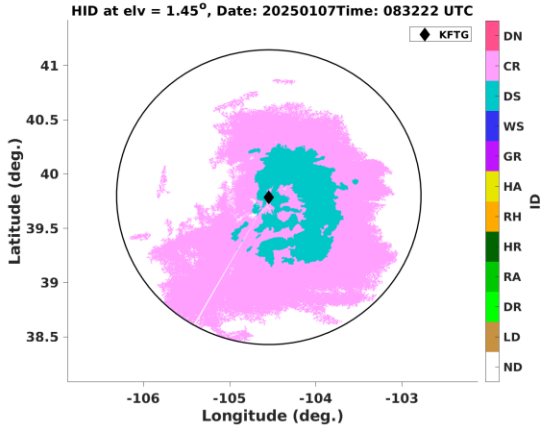
elevation: 0.48°



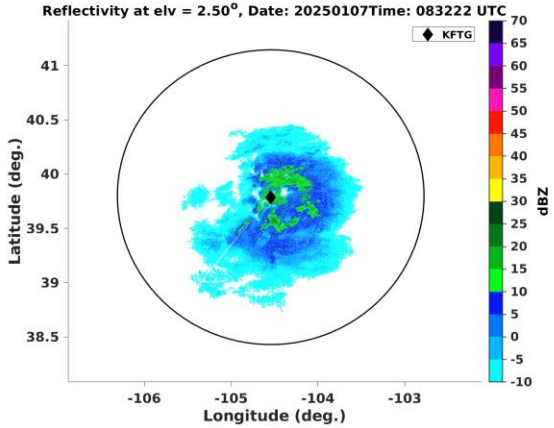


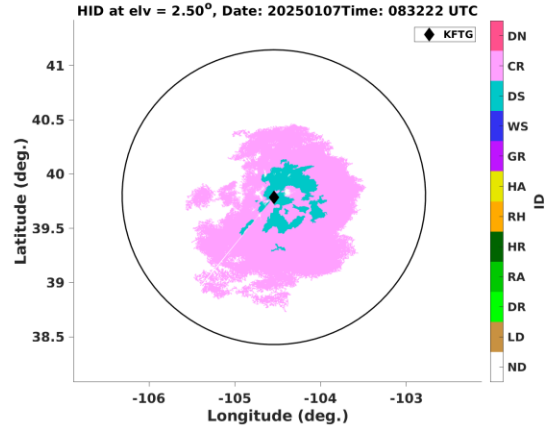
elevation:1.45 °





elevation: 2.5 °

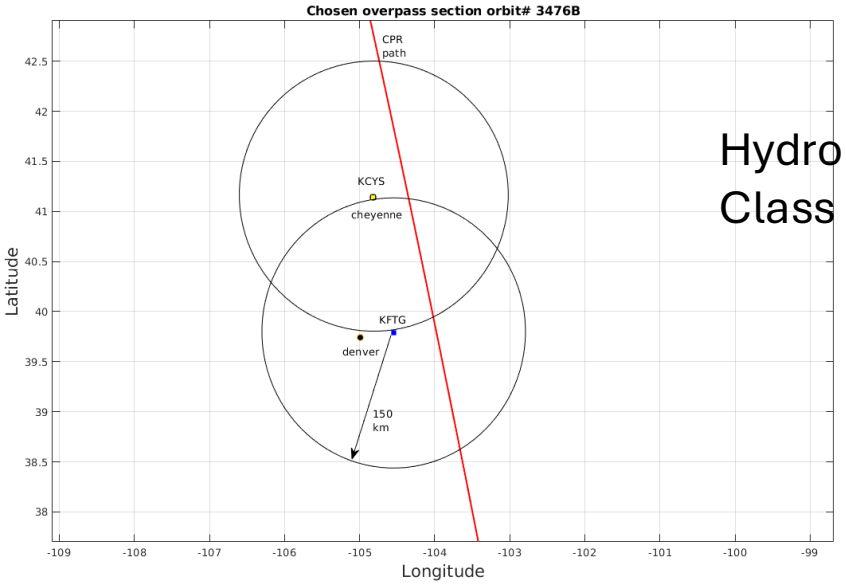




KCYS

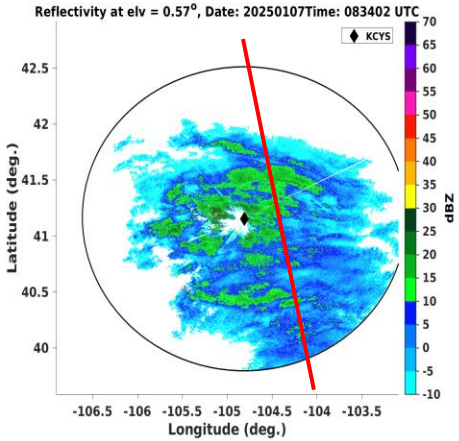
radar images:

- KCYS data UTC: 20250107_083402, within time frame of CPR orbit.
- Altitude of KFTG: 1.87 km
- Covered height from 2.3km ~ 8.4 km.
- Peak of Ze is around 15 DBZ at lat of 41.5 deg, but CPR peak Ze is about 10 dBZ.
- Hydrotype is also classified as “DS (dry snow)” and “CR(crystal)” (algorithm by Bechini and Chandrasekar, 2015)

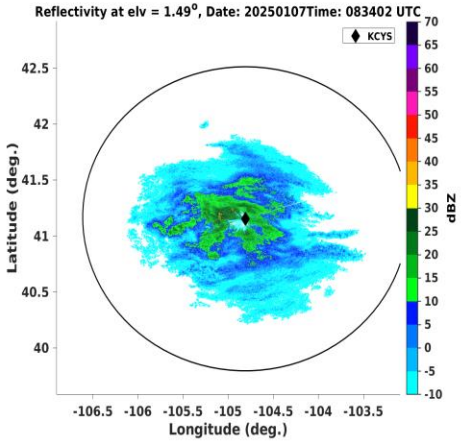


Ze

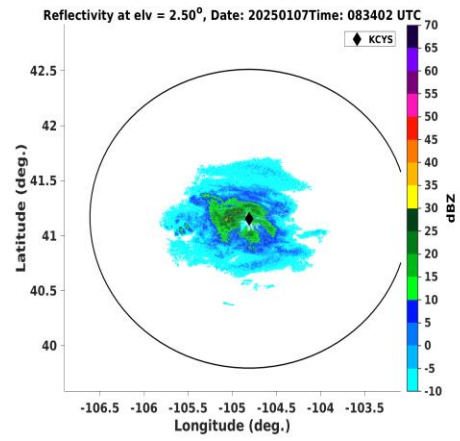
elevation: 0.57°



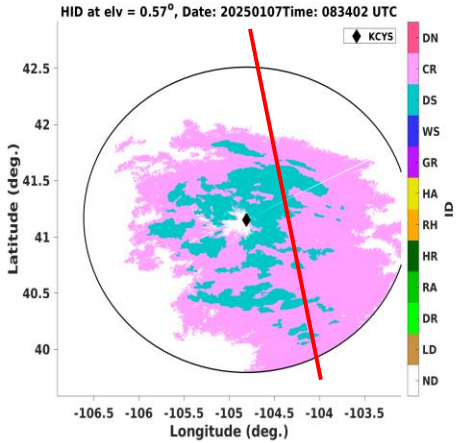
elevation:1.45 °

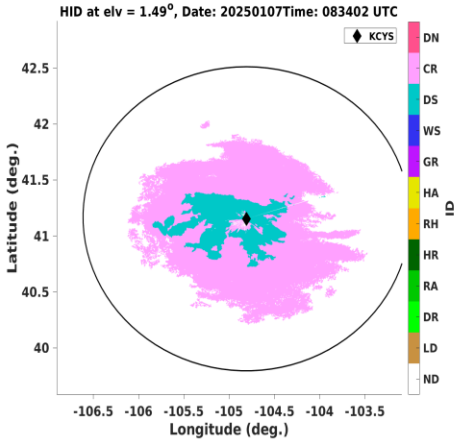


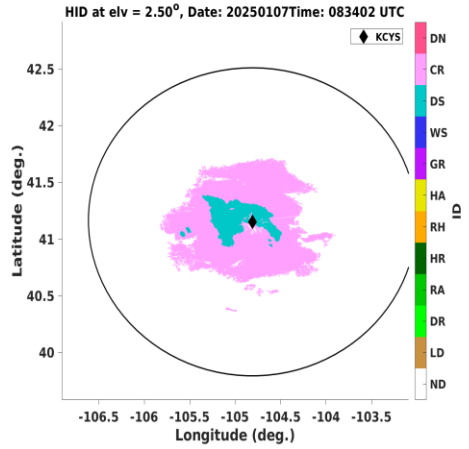
elevation: 2.5 °



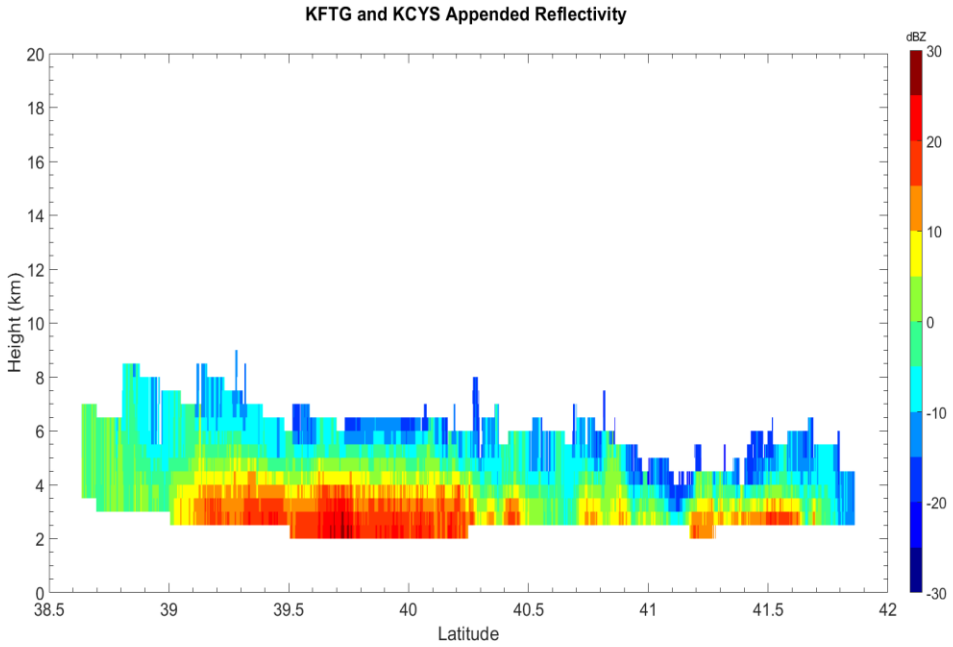
Hydro Class

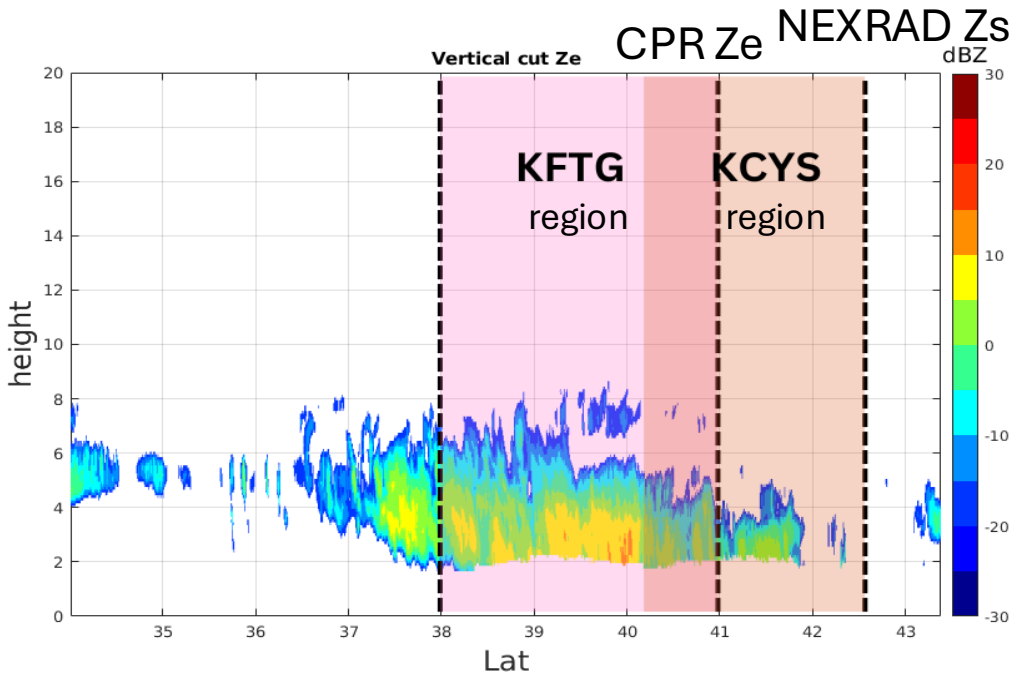




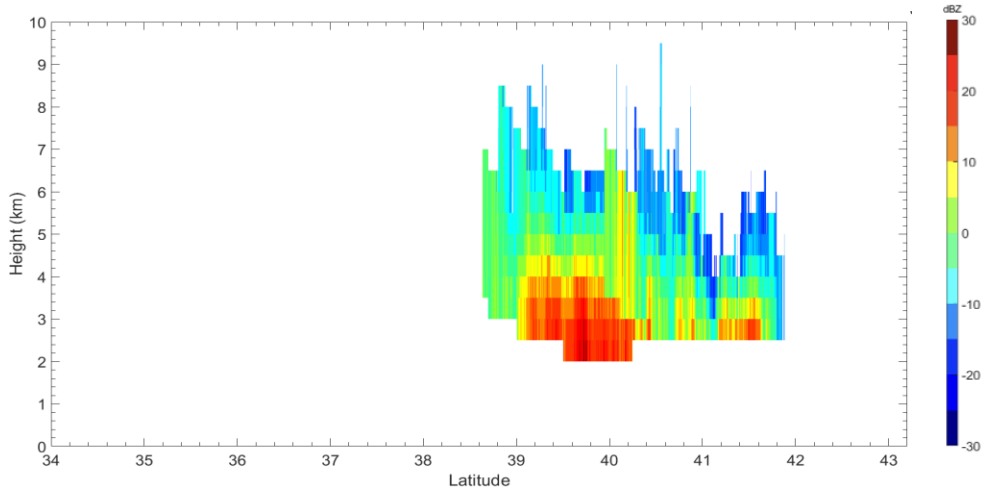


KFTG & KCYS NEXRAD vs EarthCare CPR





Merged NEXRAD vertical reflectivity along the **CPR track**

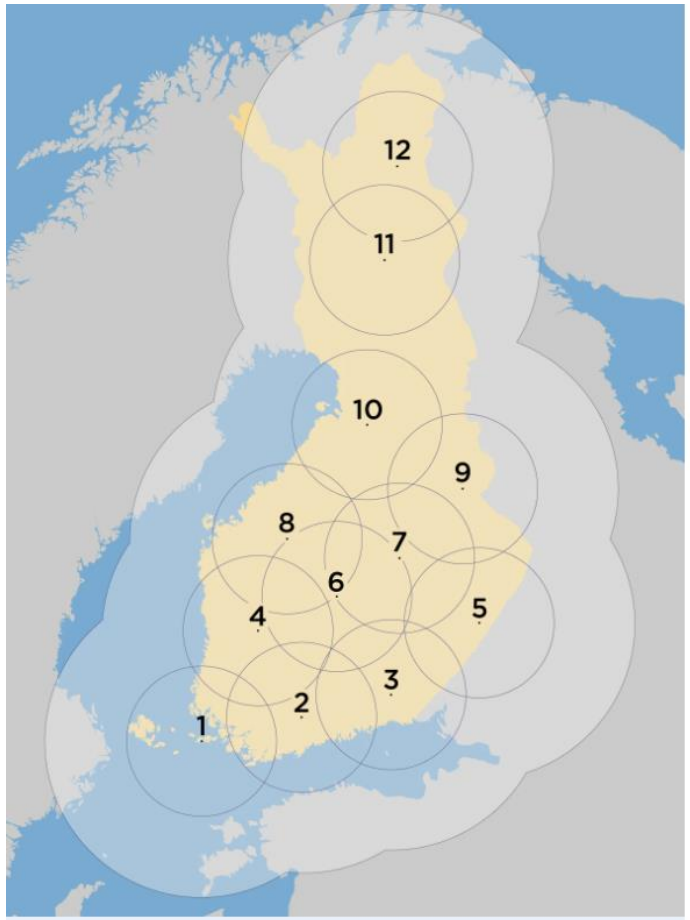


Validation with FMI radar

The FMI Radar Network

- 12 dual-polarization C-Band Doppler radars
- Fully automated network
- Design, planning, maintenance and operation by FMI
- Data availability annually > 98%

1. Korppoo / Parainen Rumar
2. Vihti Ylimmäinen
3. Anjalankoski / Kouvola Kaipiainen
4. Kankaanpää / Kankaanpää Ylisenharju
5. Kesälahti / Kitee Kesälahti
6. Petäjävesi / Petäjävesi Kintaus
7. Kuopio / Kuopio Rytky
8. Vimpeli / Vimpeli Lakeaharju
9. Nurmes / Nurmes Mujejärvi Riihivaara
10. Utajärvi / Utajärvi Korkiakangas
11. Luosto / Sodankylä Luosto
12. Inari / Saariselkä Kaunispää (in use in 2025)



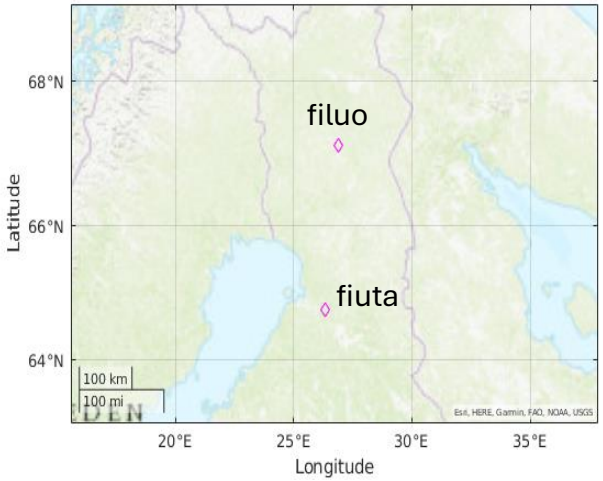
Coverage of FMI's radar network.

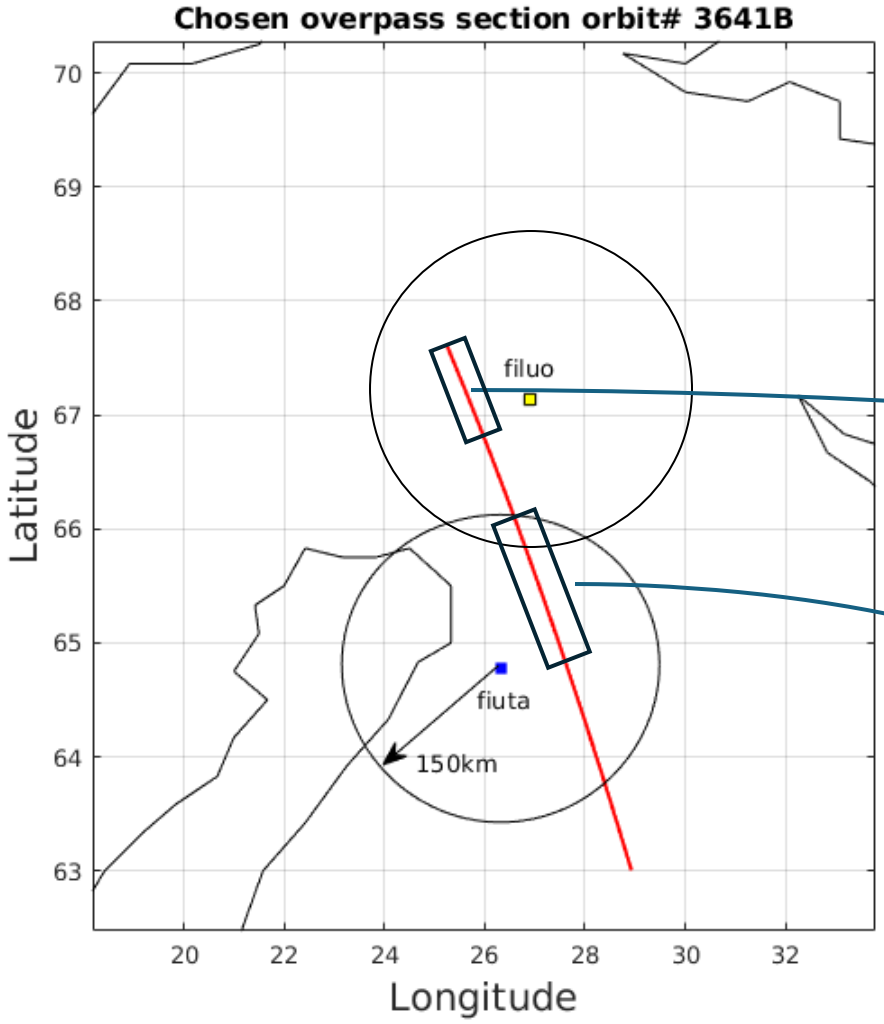
Possible validation cases with FMI radar network between 2024-December to 2025 February

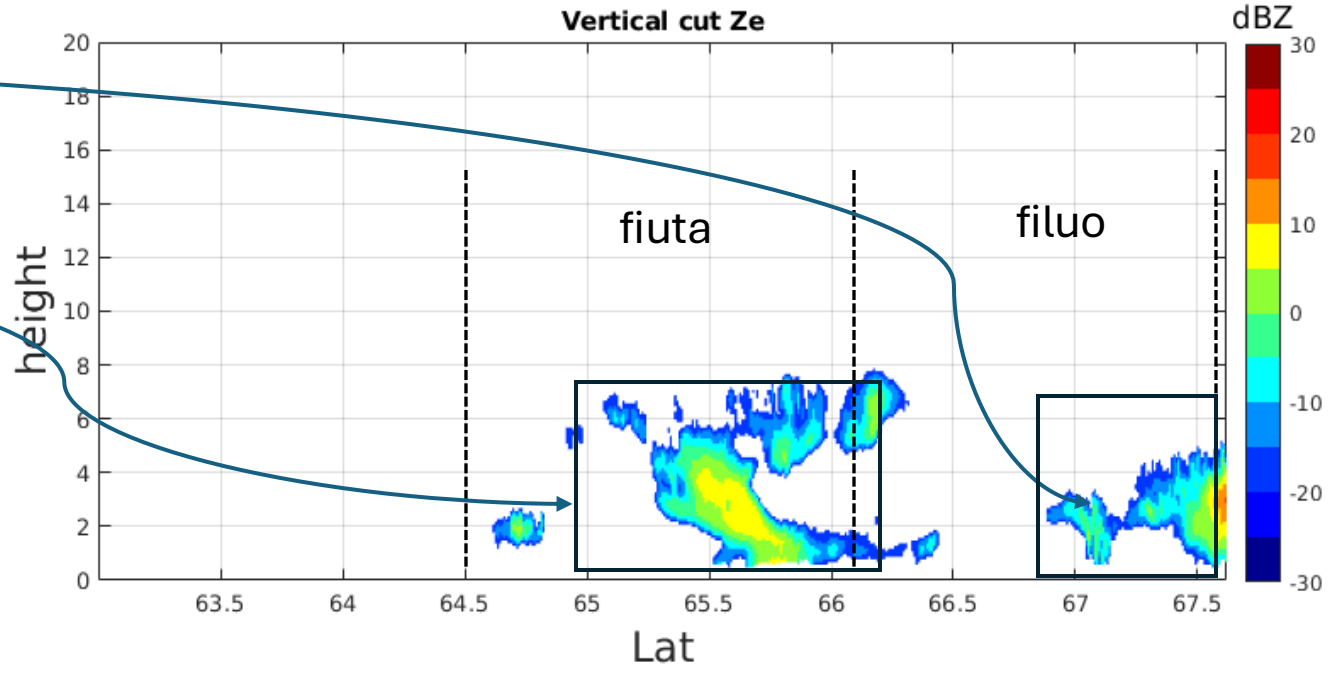
CPR Orbit #	Date	UTC	FMI radar# in the network
1) 3361B	2024-12-30	23:04:58~23:16:45	#11
2) 3501C	2025-01-08	23:12:33~23:23:37	#11
3) 3532C	2025-01-10	23:01:33~23:12:37	#12
4) 3619D	2025-01-16	13:23:54~13:35:47	#8,4,10,11
5) **3641B**	2025-01-17	22:57:04~23:08:50	#10, 11
6) 3728C	2025-01-23	13:20:01~13:31:05	# 11 or 12
7) 3750B	2025-01-24	23:04:19~23:16:05	#11
8) 3781B	2025-01-26	22:53:10~23:04:56	#5,7
9) **4008C**	2025-02-10	13:12:29~13:23:33	#12

Sample validation case

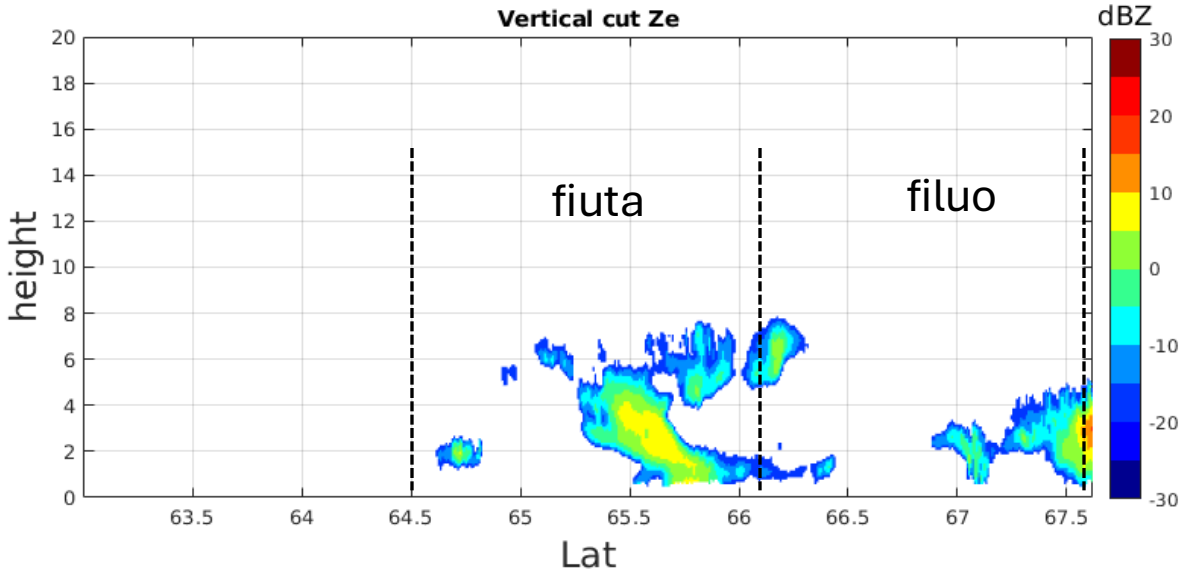
- CPR orbit: 3641B (Baseline AB)
- FMI radar: **fiuta (#10)** and **fiuo (#11)**
- Time: 2025-01-17T22:57:04.000Z ~ 2025-01-17T23:08:50.000Z

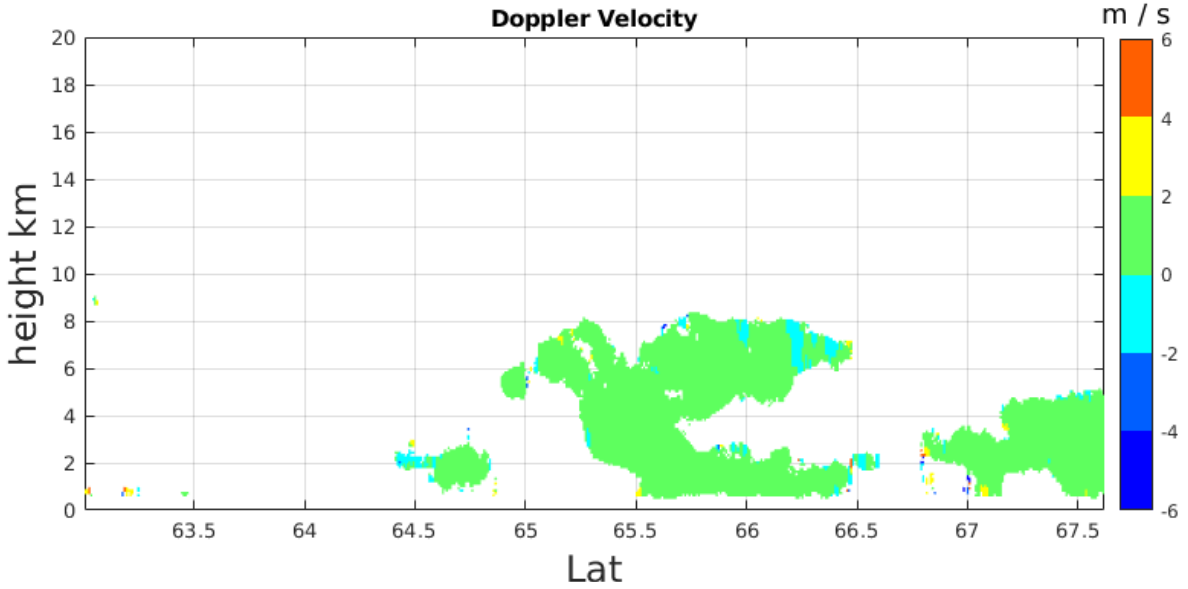


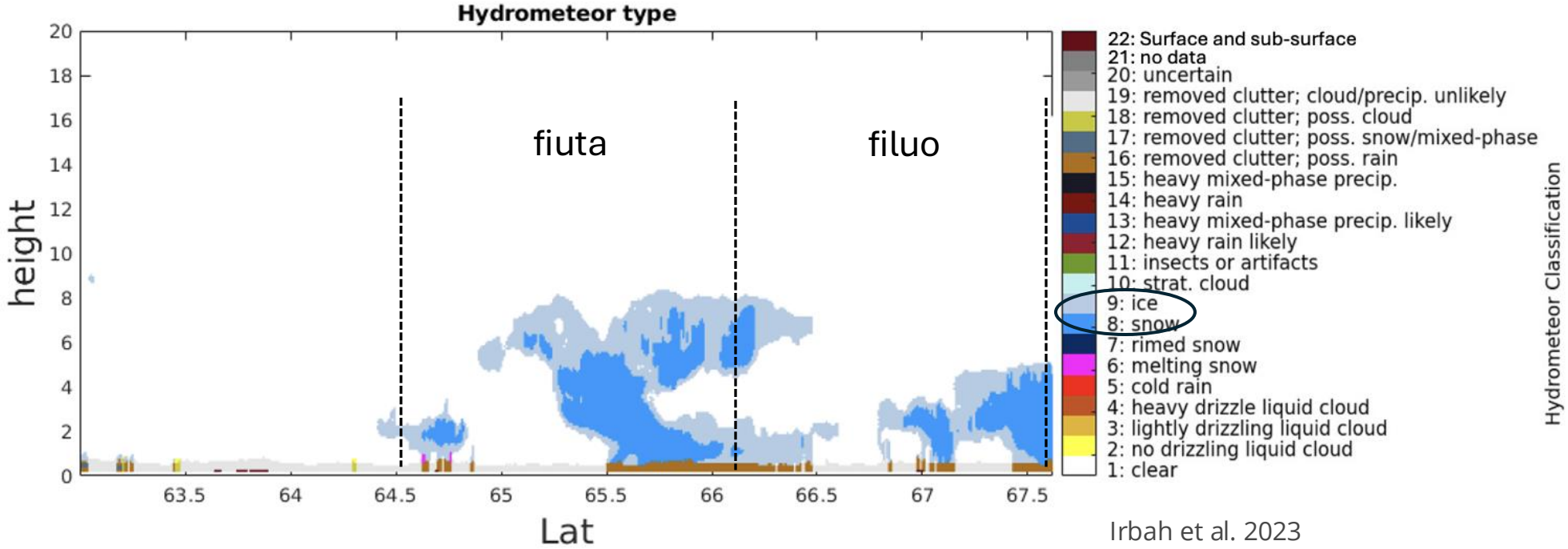




CPR data (latest baseline AB)







<u>Fiuta region:</u>

- Maximum of Ze is around 10 dBZ.
- Hydro Class: Snow & ice

<u>Filuo region:</u>

- Maximum of Ze is around 15 dBZ.
- Hydro Class: Snow & ice

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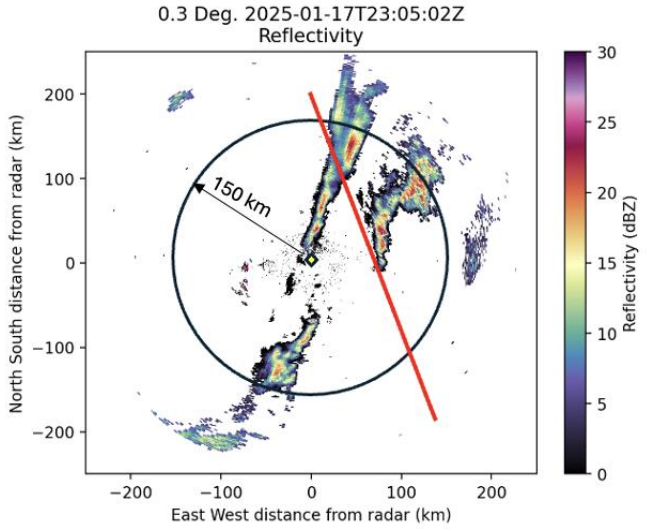
Fiuta

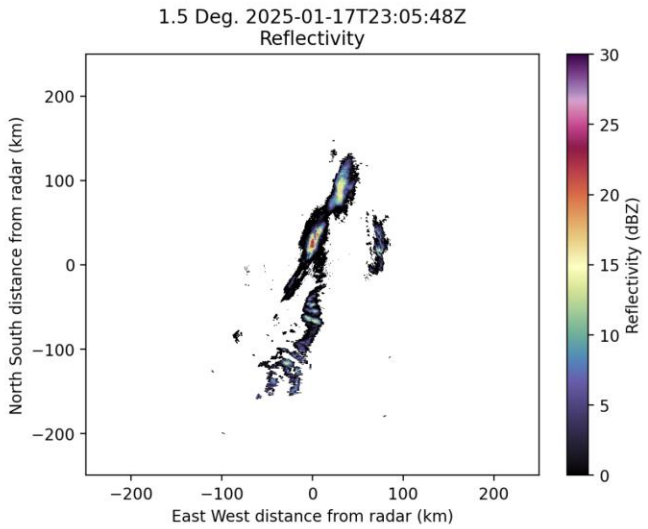
radar images:

- Fiuta data UTC 202501172305, within time frame of CPR orbit.
- Covered height : 0.36 km ~ 7.8 km.
- Maximum of Ze is around 10 dBZ.
- Hydro Class: **Snow**

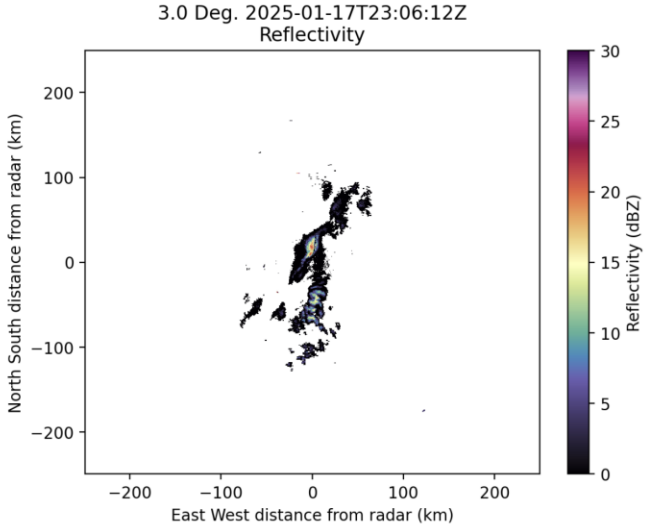
elevation: 0.3°

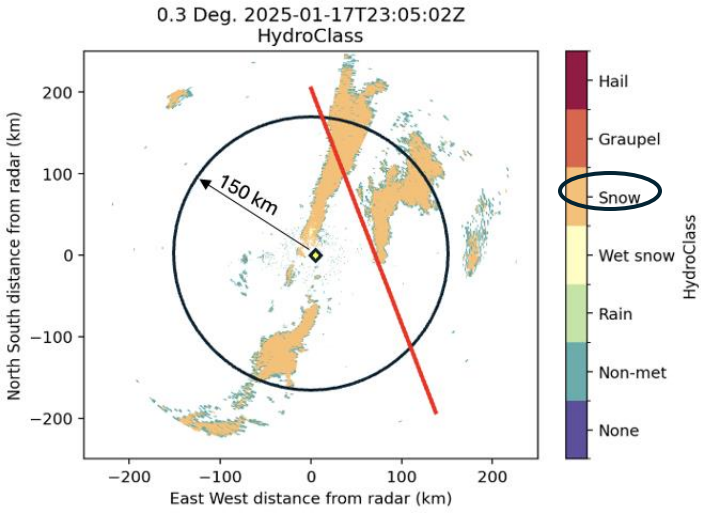


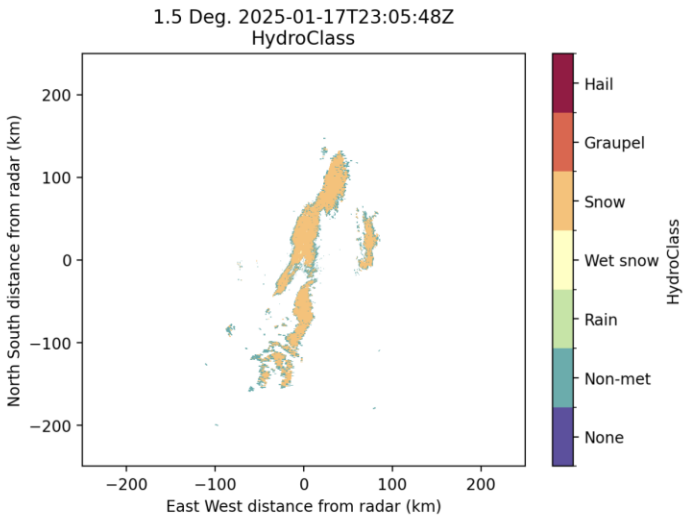
elevation:1.5 °

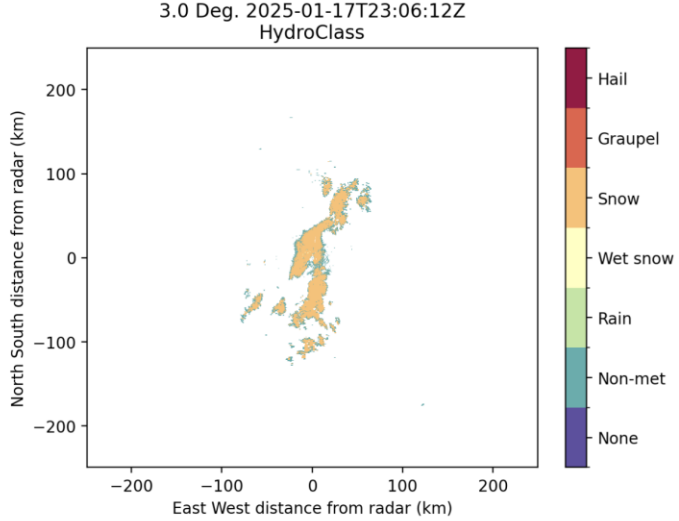


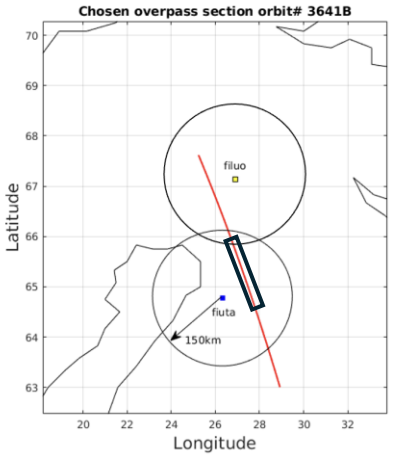
elevation: 3 °







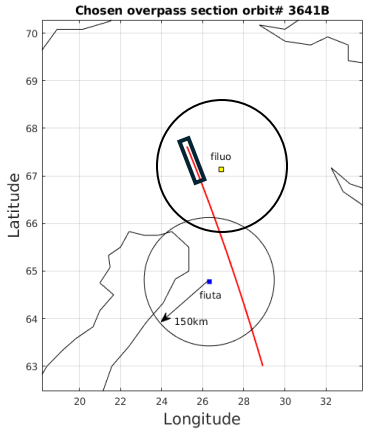




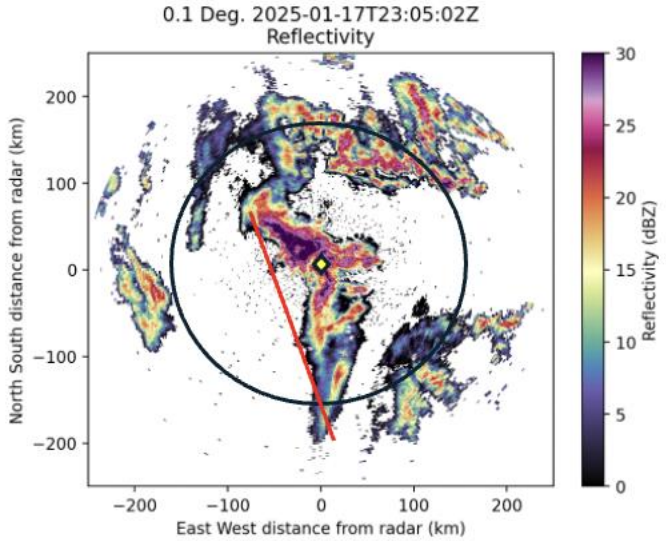
Filuo

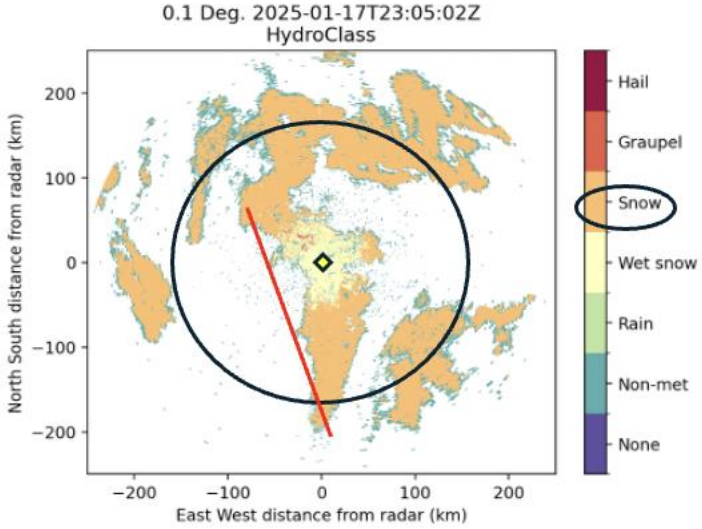
radar images:

- Filuo data UTC 202501172305, within time frame of CPR orbit.
- Covered height : 0.11 km ~ 4.4 km
- Maximum of Ze is around 15 dBZ.
- Hydro Class: **Snow**

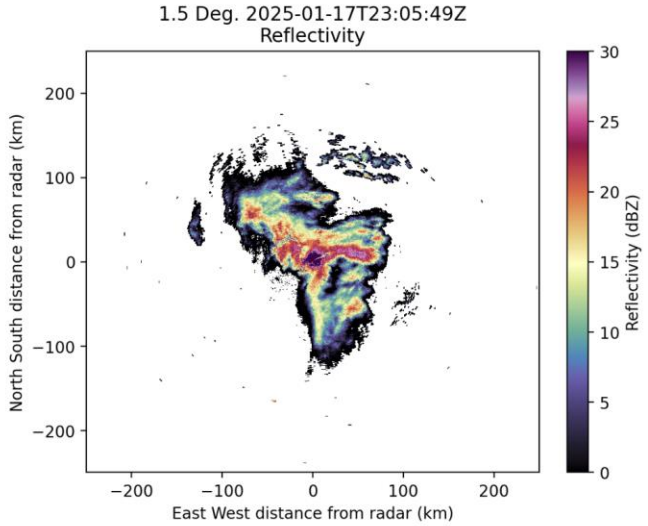


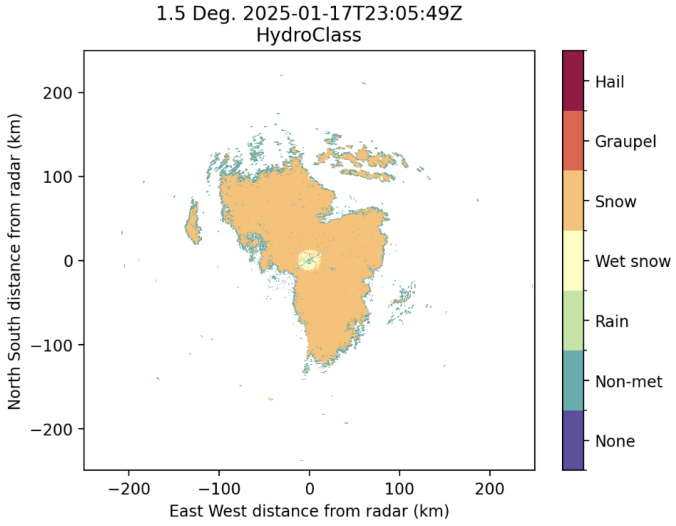
elevation: 0.1°



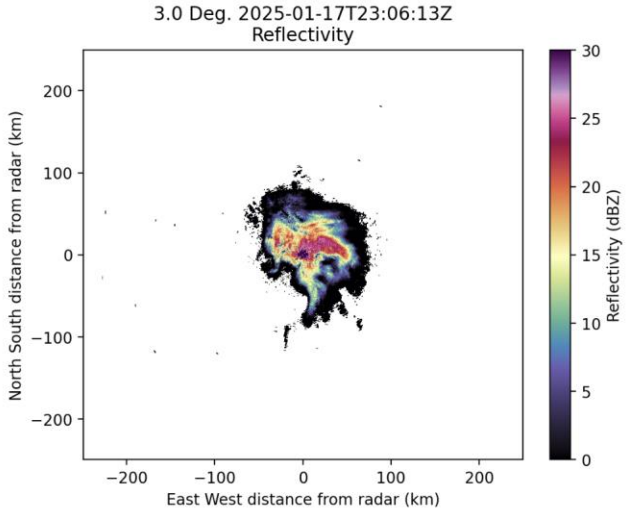


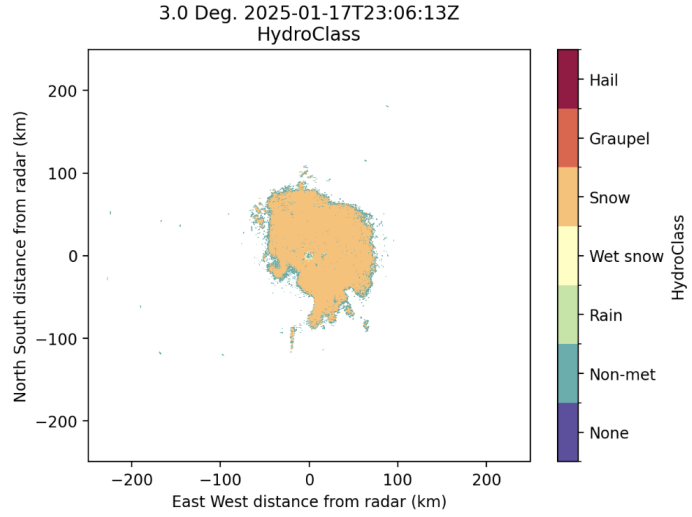
elevation:1.5°





elevation: 3°





Summary

- Initial validations for CPR level 2 products (reflectivity, hydroClass) are illustrated.
- Two cases are chosen from 2025 January to February with FMI radar network in Finland and NEXRAD radar network in USA.
- In general, all three products show promising results in the comparisons.
- More detailed validations will be performed in the near future.

backup

Frequency mapping relation for snow

J. Leinonen, D. Moisseev, V. Chandrasekar and J. Koskinen, "Mapping Radar Reflectivity Values of Snowfall Between Frequency Bands," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 49, no. 8, pp. 3047-3058, Aug. 2011, doi: 10.1109/TGRS.2011.2117432.

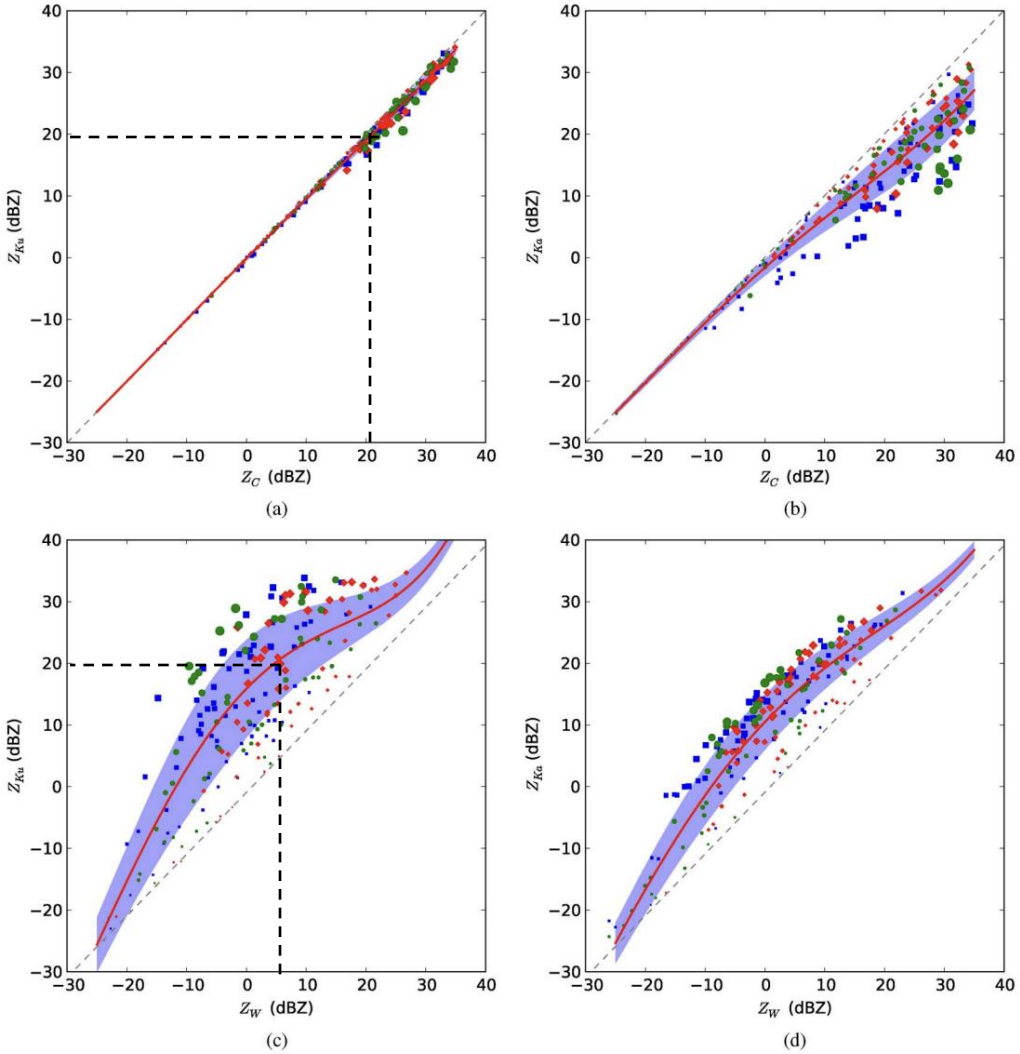


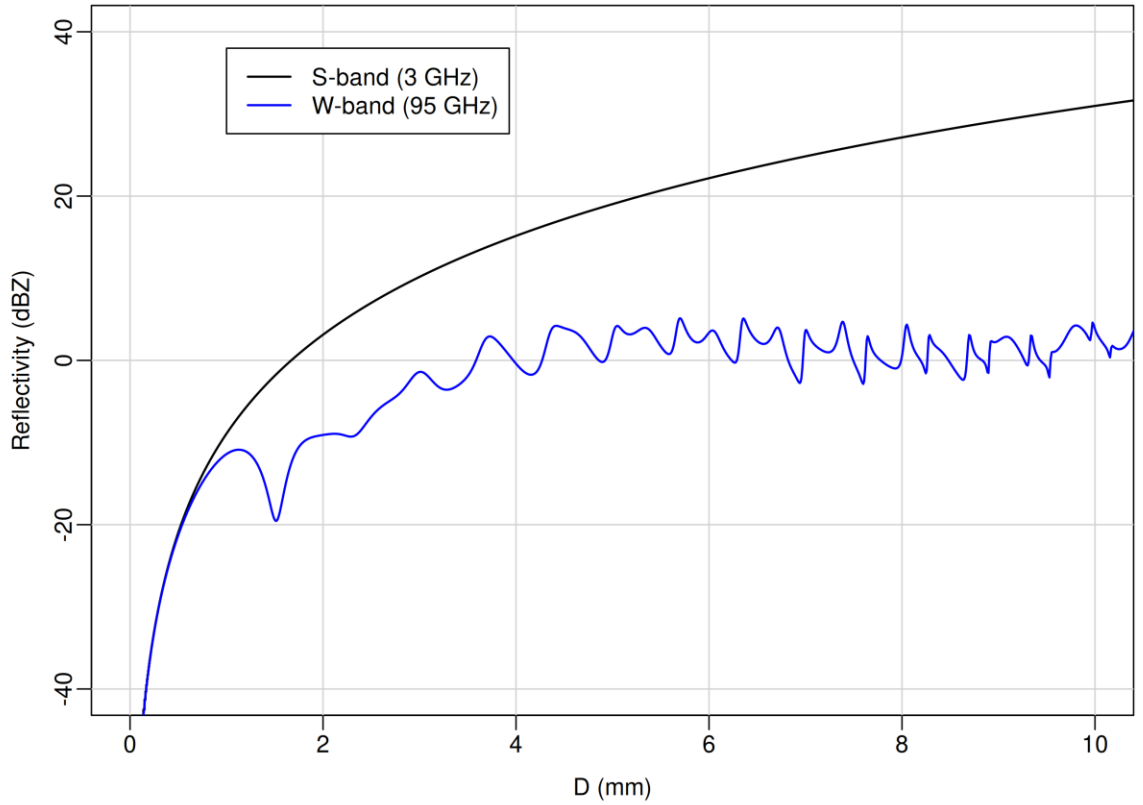
Fig. 1. Cross-frequency relations from C- and W-bands to K_u- and K_a-bands. The shapes of markers show the mass-dimensional relation used: Squares for (10), diamonds for (11), and circles for (12). The shaded area gives the spread of the relation, and the dashed line gives the same relation with the assumption of Rayleigh scattering. (a) $C \rightarrow K_u$. (b) $C \rightarrow K_a$. (c) $W \rightarrow K_u$. (d) $W \rightarrow K_a$.

1000 identical ice particles (solid ice) of diameter D (the number is just to reach a reasonable range of reflectivities).

I calculated the backscattering cross-section with T-matrix for spherical particles and then converted to reflectivity:

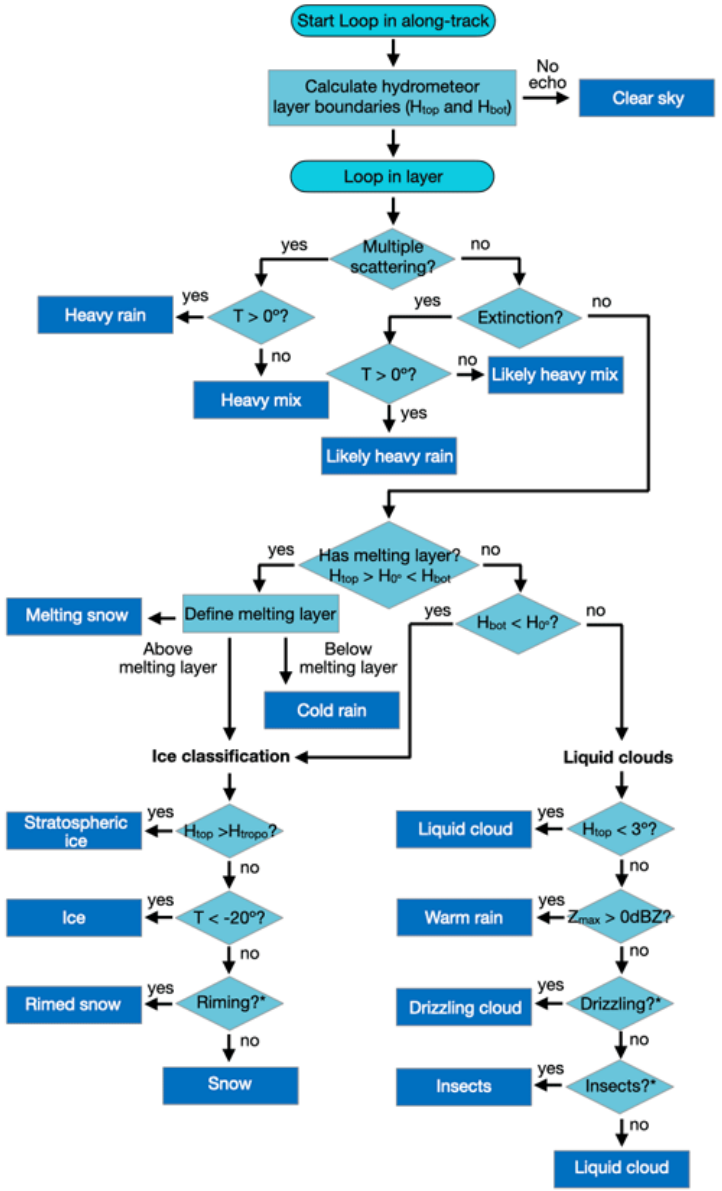
Z = nparticles * cross_section * lambda^4 / (K2 * pi^5)

- with K2 = 0.175 (ice).



Hydrometeor classification algorithm for CPR

- The EarthCARE CPR target classification (C-TC) is based on a decision tree algorithm with fixed rules, and it is designed to work as a stand-alone product. The main steps of the detailed C-TC classification procedure are depicted in Fig. In order to facilitate its use and integration in the synergistic target classification, we have adopted similar target classification definitions and names. Doppler velocity classification provides additional information about the quality or applicability of the mean Doppler velocity measurements for the cloud and precipitation retrieval algorithms.



Irbah, A., Delanoë, J., van Zadelhoff, G.-J., Donovan, D. P., Kollias, P., Puigdomènech Treserras, B., Mason, S., Hogan, R. J., and Tatarevic, A.: The classification of atmospheric hydrometeors and aerosols from the EarthCARE radar and lidar: the A-TC, C-TC and AC-TC products, Atmos. Meas. Tech., 16, 2795–2820, https://doi.org/10.5194/amt-16-2795-2023, 2023.