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Evaluation of EarthCARE Cloud Profiling Radar Observations with a 3.5-km-Resolution NICAM Simulation

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Introduction

Accurate representation of cloud and precipitation processes remains a major challenge in weather and climate models.

- EarthCARE satellite launched to advance cloud and aerosol observation
- Cloud Profiling Radar (CPR) provides an unprecedented view of the vertical structure of clouds.
- High-resolution models are used to validate satellite retrievals.

Research Gap:
Limited validation of EarthCARE CPR with global cloud-resolving simulations

Objectives

This study evaluates EarthCARE Cloud Profiling Radar (CPR) products through systematic intercomparison with multiple observational and modelling datasets at unprecedented resolution.

Evaluate CPR Products
Reflectivity, liquid water content, precipitation

Compare with NICAM
Compare CPR products against high-resolution NICAM simulations at 3.5 km horizontal resolution

Expected Impact
Enhance understanding of model capabilities for climate and weather prediction

Cross-validation
GSMaP and GPM-DPR datasets

Key Innovation

3.5 km Global Resolution

Toward a comprehensive validation of EarthCARE CPR using cloud-resolving global simulations

~40M grid points worldwide

Scientific Impact

- Validate EarthCARE mission products for climate research
- Support data assimilation system development
- Improve weather and climate prediction models
- Benchmark for future satellite missions

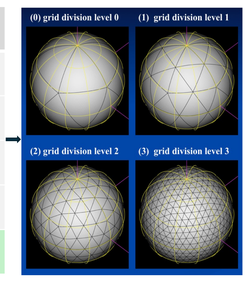
Methodology Framework

Grid Division level

• Cloud-system resolving approach • Icosahedral grid system • Targeting massively parallel supercomputer

$N_r = 10 \times 4^{rl}$ $N_g = 10 \times 4^{gl} + 2$

rlevel	Number of regions	glevel	grid points	Average grid interval (m)
0	10	0	12	7142126
1	40	1	42	3571063
2	160	2	162	1785432
…	…	…	…	…
5	**10240**	**11**	**41943042**	**3487**



ERA5 Reanalysis

Initial Conditions: 0.25º x 0.25º resolution

NICAM Simulation

Resolution 3.5 km resolution	**Duration** 48 hours
Spin-up 24 hours	**Analysis** Second 24 hours

Microphysics:
Single moment six class bulk scheme (Tomita 2008)

Joint Simulator for satellite sensors

Forward operators: Model output ➔ Synthetic observations

CPR Reflectivity	**ATLID** Cloud-top	**Profile** Vertical structure

Multi – datasets Comparison

EarthCARE CPR Real observations	**NICAM synthetic** Simulated	**GPM/GSMaP** Reference data

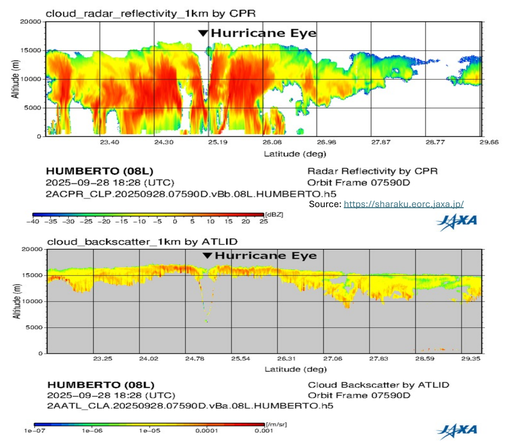


Fig: (a) Cloud radar reflectivity at 1 km from CPR and (b) cloud backscatter at 1 km from ATLID.
Source: https://sharaku.eorc.jaxa.jp/

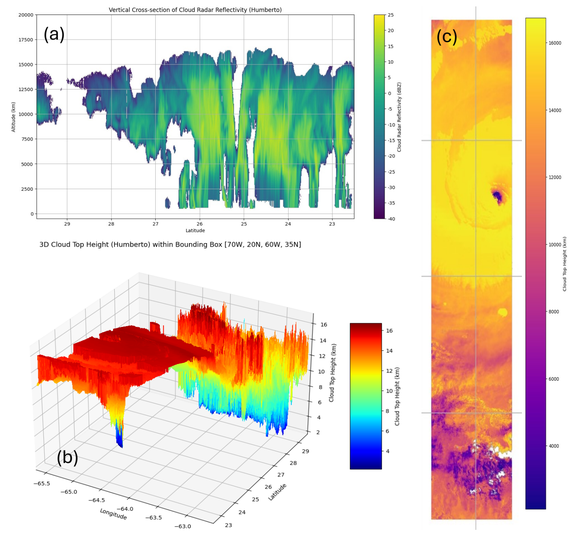


Fig: (a) Vertical cross section of CPR reflectivity, (b) 3D cloud-top height, and (c) top view of Hurricane Humberto from EarthCARE CPR data.

Data Sources overview

Dataset	Resolution	Key Variables	Role
EarthCARE CPR	500m Vertical bins	Reflectivity, LWC	Primary validation
NICAM	3.5 km horizontal	All hydrometeors	Model simulation
GPM-DPR	5 km horizontal	Precipitation	Cross-validation
GSMaP	0.1 (~10 km)	Surface rainfall	Reference

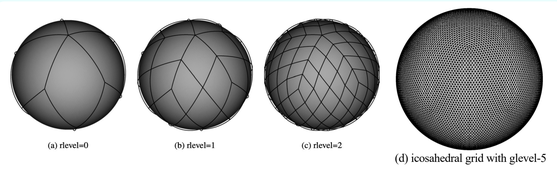
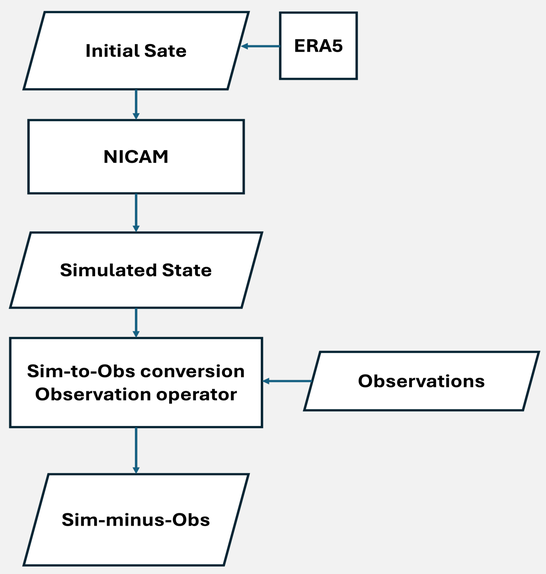


Fig: The different regions level and; (d) icosahedral grid with glevel-5 (Tomita et al., 2008)



Flowchart of NICAM system

Expected Results

Spatial correspondence
Strong agreement in cloud distribution patterns between NICAM and EarthCARE

Vertical structure
Improved representation of cloud layers and radar reflectivity profiles

Temporal Evolution
Realistic capture of precipitation system life cycles

Cross-validation
Consistency with GPM-DPR and GSMaP datasets

Previous Studies Results:
High-resolution NICAM simulations achieve strong correlation (r > 0.8) with satellite precipitation observations (Kotsuki et al. 2014)

Conclusions & Next Steps

✓ A comprehensive and scalable framework has been established for the validation of EarthCARE Cloud Profiling Radar (CPR) observations.
✓ The NICAM model demonstrates strong capability in reproducing key vertical cloud and precipitation structures in global cloud-resolving simulations.
✓ The use of a multi-dataset evaluation strategy improves the robustness and reliability of the assessment.

Future Work

→ Extend the validation to multiple seasons, climate regimes, and geographic regions to assess consistency and limitations.
→ Incorporate the validated EarthCARE CPR insights into ensemble-based operational data assimilation systems to improve extreme-event predictability.

References:

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