Advancing Internal Cloud Structure Studies through CFODD and the EarthCARE

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How about Warm clouds ?

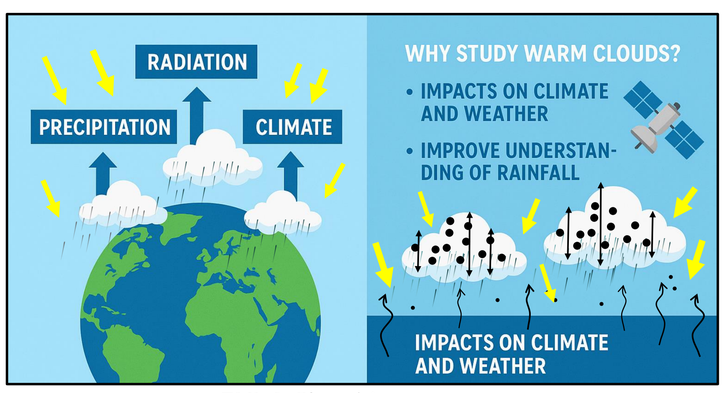


FIG.1 Cloud importance

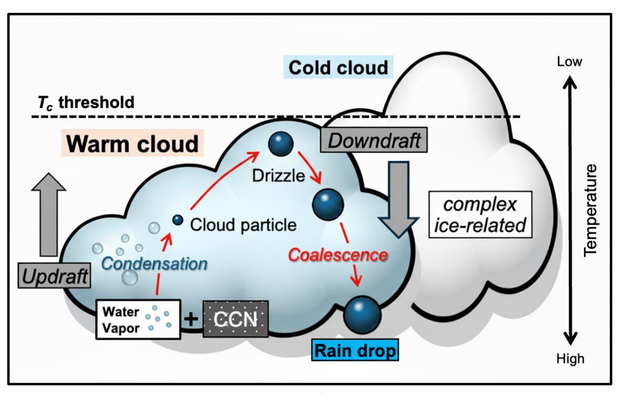


FIG.2 Warm cloud process

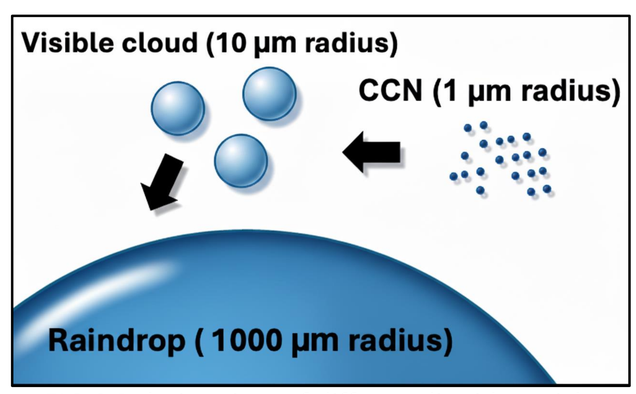


FIG.3 Relative sizes of different liquid particles

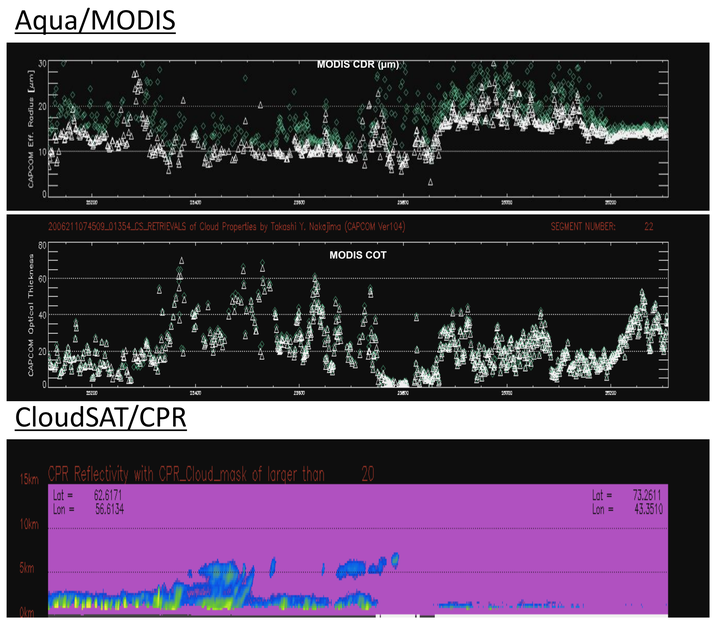
Contoured Frequency by Optical depth Diagrams (CFODD) (Nakajima *et al*., 2010b, Suzuki *et al*., 2010b)

- **CFODD method** is designed to investigate the internal structure of warm clouds.

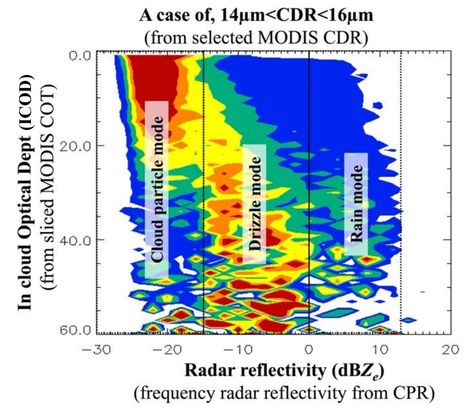
CFODD Design

- Nakajima *et al*. (2010a): Finding the MODIS 2.1 μm band as can separating drizzle from cloud particles under vertical inhomogeneity conditions.
- Nakajima *et al*. (2010b): Designed the CFODD method with In-Cloud Optical Depth (ICOD) at cloud top to track warm cloud growth via radar reflectivity strength.
- Suzuki *et al.* (2010b): Applied the CFODD to investigate warm cloud microphysics and used the resulting systematic slopes to explain key Land/Ocean differences in warm cloud evolution.

Aqua/MODIS



CloudSAT/CPR



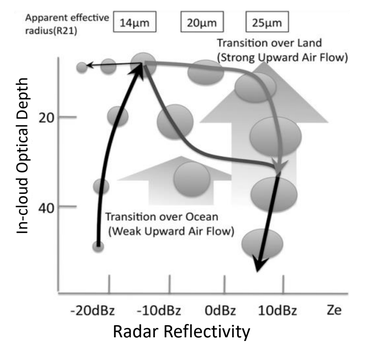


FIG. 4 Transition diagram of the CFODD (Nakajima *et al*., 2010b)

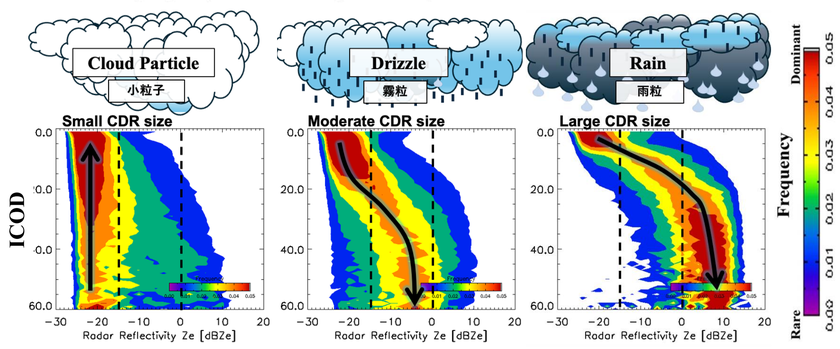


FIG. 5 Warm cloud mode for CFODD visualization

Concept of EarthCARE Compatible Products

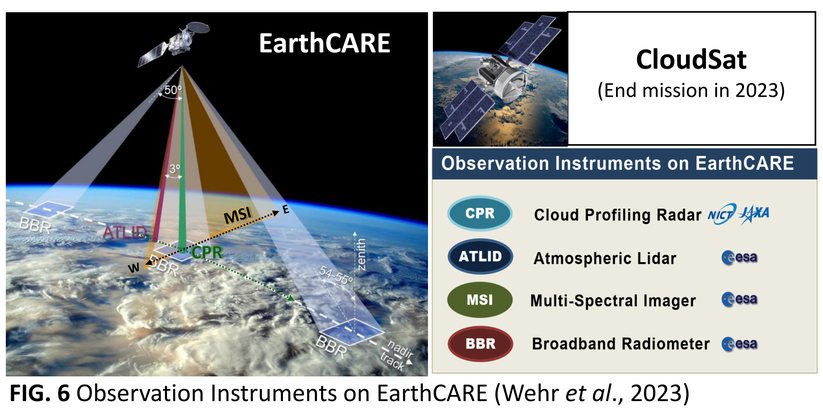


FIG. 6 Observation Instruments on EarthCARE (Wehr *et al*., 2023)

Table 1. Technical Characteristics of the EarthCARE (EC) and CloudSat (CS) Cloud Profiling Radars (adapting Burns et al., 2016)

Parameter	EC/CPR	CS/CPR
Doppler capability	Yes	No
Frequency (GHz)	94	94
Altitude (km)	393 (mean)	705–732
Antenna diameter (m)	2.5	1.85
Pulse length (μs)	3.3	3.3
Range resolution (m)	500	485
Vertical sampling rate (m)	100	240
Along-track sampling rate (m)	500-1000	1100
Antenna beam width (deg)	0.095	0.12
PRF (kHz)	6.1-7.5	3.7-4.3
Sensitivity (dBZ)	-36	-30

Table 2 CloudSat product details for CFODD development

Product for CFODD	Product details
ECMWF-AUX	Interpolated atmospheric state variables for generate Warm cloud properties product
MODIS-AUX	MODIS radiance data near each CloudSat CPR footprint for generate Warm cloud properties product
2B-GEOPROF	Radar reflectivity (cloud and precipitation signals)

Table 3 CloudSat to EarthCARE product equivalency for CFODD

CloudSat Product	EarthCARE Product
Warm cloud properties	ECA_J_MSI_CLP
2B-GEOPROF	ECA_J_CPR_ECO

Table 4 EarthCARE product details for CFODD development

Feature	CPR_ECO	MSI_CLP
Sensor	Active	Passive
View	Vertical Profile	Horizontal Profile contains algorithms of CLAUDIA & CAPCOM
Variables	• Radar Reflectivity • Doppler Velocity • Geolocation Information	• Cloud Optical thickness • Cloud Effective radius • Cloud top temperature

Concept further studying

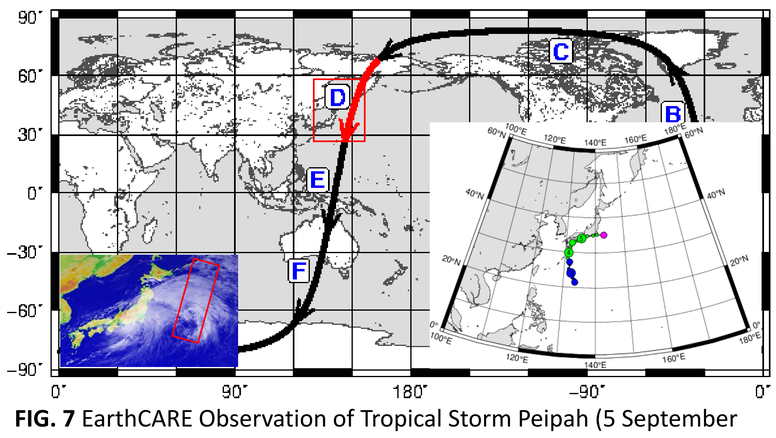


FIG. 7 EarthCARE Observation of Tropical Storm Peipah (5 September 2025) based on data from the JAXA EarthCARE Quicklook products and the NII Digital Typhoon Project's track data.

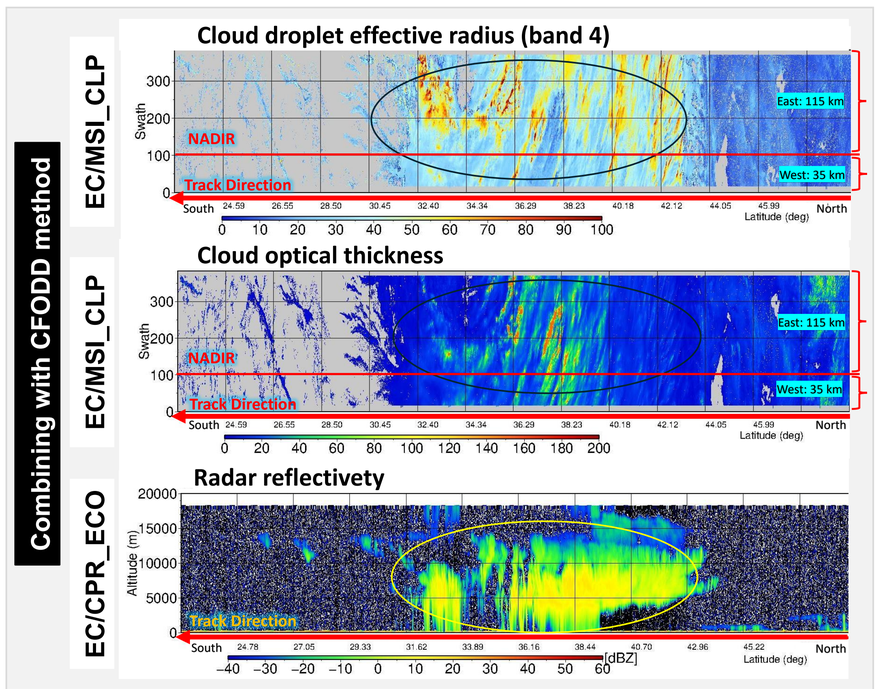


FIG. 8 Cloud and precipitation properties of Tropical Storm Peipah as observed by the EarthCARE satellite on 5 September 2025, sources from the JAXA database

Expected Outcomes and Future Study

- ❑ To support continued observation of warm cloud characteristics
- ❑ Climatology Database: Develop a CFODD-based climatology using EarthCARE data.
- ❑ Regional Analyses: Focus on aerosol impact, regional effect.
- ❑ Enhanced Detection: Improved detection of cloud layers and internal structures.

References

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