

Applications of spaceborne millimeter-wave radar data in analyzing typhoon structures in Western Pacific

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Introduction

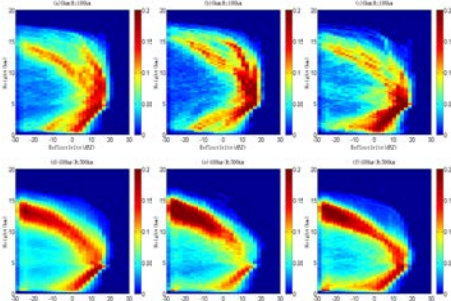
- Tropical cyclone exerts a great influence on oceangoing voyage, offshore aquaculture, marine resources exploitation, aerospace and military activity. At present, most researches just focus on occurrence frequency, evolution feature, intensity estimation and track forecast by using best-track data. The detailed macro- and micro-physical characteristics and thermal structures should be studied urgently.
- Cloud Profiling Radar (CPR) onboard CloudSat operates at W-band (94GHz), which provides vertical structures of clouds from space. It flies with Aqua, CALIPSO and other missions referred to as A-Train, which realizes collaborative observation and provides valuable data for further research on tropical cyclones.
- By using the CloudSat tropical cyclone crossing dataset from 2006 to 2010 within 500km of center, the cloud, precipitation and thermal structure characteristics on typhoons in Western Pacific are analyzed.

Data and Methodology

- The CloudSat tropical cyclone crossing dataset combines CloudSat observations with MODIS, AMSR-E, CALIOP, Navy Operational Global Atmospheric Prediction System (NoGAPS), European Centre for Medium-Range Weather Forecasts (ECMWF) and best-track information. Until 2010, it gets 561 granules, 393028 profiles which overpass 53 typhoons.
- According to maximum sustained wind speed during life cycle, typhoons are divided into five scales based on Saffir-Simpson (SS) category. Each life cycle is classified as developing, mature and decaying stages. The mature stage is defined as the period when instantaneous wind speed exceeds the 80% of maximum sustained wind speed. The periods before and after are called developing and decaying stages, respectively.
- Radar reflectivity, cloud occurrence probability and ice cloud microphysical parameters could be directly obtained from CloudSat products. Both AMSR-E and CloudSat may provide rain rate while the bigger one is selected. Relative humidity and pseudo-equivalent potential temperature are calculated from temperature and specific humidity, which can be provided by ECMWF auxiliary data.

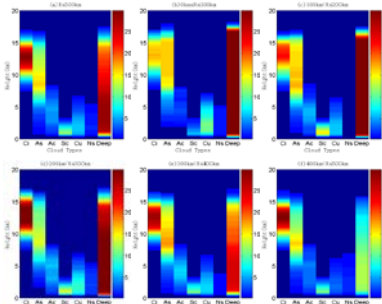
Results

Radar reflectivity



- The radar reflectivity peaks at 5km in height and shows opposite distributions below and above this altitude level. The intensity of convection weakens in outer area and the contents of water droplets and ice particles are much less than those in inner-core area.
- In inner-core area, the maximum radar reflectivity at developing or mature stage occurs at 5-10km height, where large probability also appears, which shows that strong convection exists and a mass of water droplets and ice particles are concentrated in this altitude level.
- In outer area, large probability appears above 10km in height where radar reflectivity is generally less than 0dBZ at all stages.

Cloud occurrence probability

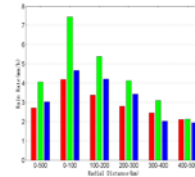


- Deep convective cloud has maximum occurrence probability within 300km and covers

the whole vertical scale of typhoon. Ci mainly occurs at 11-15km in height, with less probability in inner-core area. The probability of As is relative large at 8-15km in height.

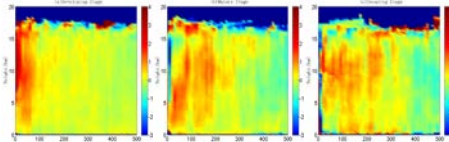
- Occurrence probability and vertical distribution for Ac, Cu and Ns have little variability in different radial rings, while Sc always appears at lower altitude levels and occurs more frequently in rainband area.

Rain rate



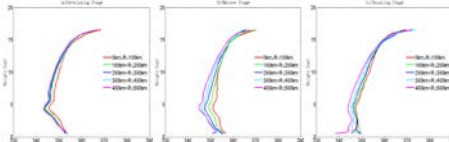
- For the area within 500km of center, the maximum of rain rate occurs at mature stage (4.07mm/h) while the minimum exists at developing stage (2.70mm/h).
- Rain rate at each stage decreases with increasing radial distance and the heaviest rainfall is found in inner-core area.
- Within 300km of center, rain rate at developing stage is lower than that at decaying stage, while it is on the contrary beyond 300km.

Temperature anomaly



- At each stage, there is a warm core with temperature anomaly larger than 0°C. At developing stage, warm core assembles in inner-core area above 3km in height with maximum temperature anomaly up to 7.6°C. At mature stage, warm core extends to the region that is 200km away from center with temperature anomaly less than 3°C. At decaying stage, the horizontal scale of warm core reaches nearly 300km while the vertical scale is significantly narrowed.
- Wider vertical scale and larger temperature anomaly of warm core at developing or mature stage indicate that intensive convection exists in inner-core and rainband areas.

Pseudo-equivalent potential temperature (PEPT)



- At each stage, the inflection point of PEPT appears at 4.5km in height in each radial ring. Above this point, PEPT increases with increasing altitude and lapse rate is positive, indicating that the atmosphere stratification is stable.
- Below 4.5km in height, lapse rate is negative at developing stage, which illustrates that atmospheric stratification is instable. At mature stage, most atmospheric layers are instable, except some neutral and stable layers. At decaying stage, complicated atmospheric stratification occurs, where it is instable in 100-200km radial ring while for other radial rings stable and instable stratification both appear.

Conclusions

- Radar reflectivity peaks at 5km in height and shows opposite changes below and above this altitude level.
- Deep convective cloud has maximum occurrence probability and covers the whole vertical scale of typhoon, which indicates that it plays an important role in the convective motion of typhoon.
- Rain rate decreases with increasing radial distance and the heaviest rainfall is found in inner-core area.
- At each stage, there is a warm core which exists above 5km in height. At developing stage, the warm core assembles in inner-core area, while at mature and decaying stages it extends to the rainband area.
- Convection in typhoon mainly stems from instable stratification that exists below 4.5km in height at developing or mature stage.

Acknowledgments

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