

Analysis of typhoon rananim using ATOVS retrieval products

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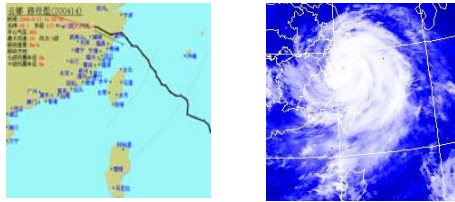
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Background

The number 0414 typhoon rananim has caused serious damage to part of the districts in Zhejiang province of China. In this paper, the thermal structure and intensity of rananim was analyzed by the products of temperature and humidity profiles retrieved from ATOVS.

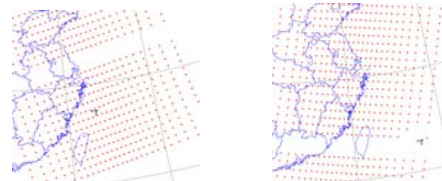


Introduction:

- Certain wavelengths of microwave energy are able to penetrate ice clouds (such as the cirrus above the storm). Therefore, it offers a unique perspective into tropical cyclone structure.
- Kidder et al (1978) first attempted passive microwave in monitoring tropical cyclone intensity estimation using SCAMS aboard Nimbus-5 and Nimbus-6 satellites.
- Velden and Smith (1983) using MSU data to estimate the intensity and central pressure. They derived a set of linear regression coefficients that related observed brightness temperature anomalies with aircraft observed minimum sea level pressure(MSLP).
- Kidder et al (2000) using the retrieved data from AMSU analyzed the upper tropospheric thermal anomalies; they also calculated the gradient winds from the temperature profiles.
- Brueske (2001) developed a method to explicitly account for subsampling and diffraction effects.
- By using the International ATOVS Processing Package (IAPP) by Cooperative Institute of Meteorological Satellite Studies (CIMSS) of the University of Wisconsin (UW), the ATOVS data can be finally translated into the retrieval products including the atmospheric temperature profile, moisture profile etc.
- ATOVS temperature and dew-point soundings were retrieved at 42 vertical levels from 0.1 to 1000hPa.
- The root mean square (rms) differences between ATOVS retrieval temperature profiles and radiosonde observation profiles are less than 2k and 2.5k when under the clear and cloudy weather respectively. As to dew-point profiles, the rms error is about 3.0-6.0k.

Data

Although the cross-track-scanning ATOVS retrieval products swaths are about 2200km wide, the sample was limited to those cases in which the typhoon center fell near the center of ATOVS retrieval swaths such as the chart listed on the left. However, the chart listed on the right is not suit for research due to the coarse horizontal resolution



A portion of the ATOVS retrieval products swath (*T was the central position of typhoon rananim)

Method

First of all, determine the domain of typhoon center cloud field according to the coincident infrared image.

Thermal structure

- Temperature anomalies were calculated by subtracting the average temperature of outer radius from the temperature at each grid in the domain

The minimal sea level pressure

- ATOVS retrieval temperatures at 23 levels from 920 to 50hPa were used to calculate the MSLP
- The virtual temperature effects were considered under the 500hPa pressure level
- A two-pass distance-weighted analysis method (Barnes, 1964) was applied to interpolate the unevenly spaced temperature to a radial grid with the origin at the typhoon center

- The hydrostatic equation was integrated at the outer radius of the domain by using NCEP reanalyzed data as initial parameter up to the 50hPa level, then the equation was downward from 50 to surface in the center grid

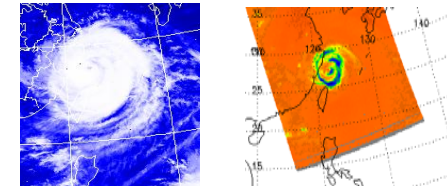
The gradient wind field in any height

- Assuming a linear variation in temperature with height between two pressure levels to calculate the temperature and pressure as a function of height at any height from surface to the tropopause
- Calculate the density at each grid with ideal gas equation
- According to the gradient assumption, the radial pressure gradients was to calculate the tangential wind at any height

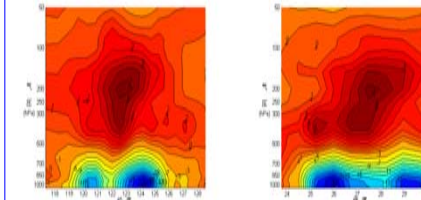
Case study

This set of ATOVS retrieval data we selected began at 0546UTC on 12 Aug,2004. By interpolating the 3-hourly interval position and strength from the typhoon reporting of Center Meteorology Station(CMS), we got the central position of rananim at that time was (27.2°N, 122.6°E), the MSLP was 950hPa and the maximum wind speed(MSW) near eyewall was 45m/s, showing that rananim belongs to mature stage.

Seen from GOES-9 image, rananim shows a well-developed broad central dense overcast (CDO) and a clear eye, several spiral bandings kept transporting water vapor from the warm sea to strengthen its intensity. AMSU-B 150GHz window channel has the ability to sense precipitation-sized particles through the CDO because its sensitivity to precipitation causes greater contrast between the eye and eyewall



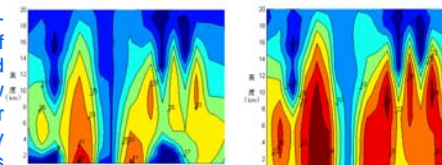
Infrared image of GOES-9 AMSU-B 150GHz image of NOAA-16



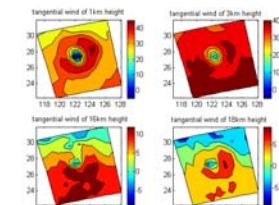
The cross section of temperature anomalies

The maximum temperature anomaly is about 7k at 300hPa, the warm anomaly extending down into the lower troposphere at about 500hPa inside the eye. What's more, under 600hPa pressure level, there appear negative temperature anomalies, which were caused by heavy precipitation contamination. On the other hand, this contamination provides us useful information on the location and intensity of precipitation.

With low-level cyclonic flow and an upper-level anticyclone, the basic structure of typhoon rananim's tangential wind field seems reasonable. However, the flow becomes anticyclonic in the low levels near the eyewall. This phenomenon is probably due to the unrealistic cold anomalies caused by the strong precipitation attenuation near the eyewall under 5km. According to the method introduced by kidder(2000), the temperature anomalies at pressure levels between the surface and 500hPa were set to zero and the gradient winds were recalculated. The tangential wind at large radius appears more reasonable. However, the MSW was down to 39m/s. Thus, other methods should be developed to address the problem.

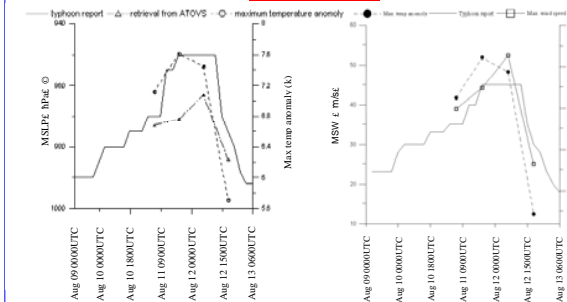


Cross-section of Tangential wind Removed low-level cold anomalies



Tangential wind fields of different height

Result



MSLP and MWS calculated from ATOVS Compared with typhoon report

Because the area range of ATOVS data received by National Satellite Meteorology Center are not wide enough, After mapping the area range of ATOVS retrieval data with rananim tracks from CMS, we got four ideal sets of ATOVS retrieval data.

The MSLP and MSW was calculated respectively and compared with the typhoon warning report of CMS, the mean discrepancy was 11.8hPa and 4.3m/s, showing similar time-variant tendency of rananim as described by CMS.