The analysis/forecast of typhoon parameters by using AMSU data

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abstract

The Advanced Microwave Sounding Unit (AMSU) data is useful for retrieving the parameters of typhoons because the AMSU observations are high resolution and are not subject to the obstruction of cloud. The three-dimensional rotational wind component associated with a typhoon can be obtained by solving the nonlinear balance equation using the retrieved temperature from AMSU, assuming hydrostatic and gradient-wind balance and that the 50 hPa height at the top of a typhoon is uniform (same as the environmental value). The divergent wind component can be evaluated from the omega equation. The diabatic term in the omega equation is estimated from the rainfall rate obtained from AMSU observations. The friction-induced convergence in the boundary layer is represented by a parameterization. With these techniques, in this study we formulate a procedure to analyze the structures of temperature and wind in typhoon based on the AMSU data. In several case studies, the basic structures of a typhoon are captured by the AMSU observations. A simulation made with the MM5 model, 3DVAR data assimilation system and the retrieved wind indicates the potential of using AMSU data in numerical weather forecast.

Key words: microware，typhoon

1. introduction

The AMSU data has been used to analyze tropical-cyclone (TC) parameters due to the high resolution of the data and the ability of the AMSU observation to penetrate cloud. Most tropical cyclones develop over the tropical ocean where traditional observations (soundings) are sparse. Rosenkranz *et.al* (1978) detected the temperature anomalies in the core of typhoon using microwave observation. Kidder *et. al.* (1978, 1980) noted that the temperature anomalies are related to the pressure at the center of a tropical cyclone and the associated outer surface wind. The intensity, or the minimum surface pressure, of a typhoon has been estimated using the brightness temperature and the retrieved temperature at 250 hPa from the Microwave Sounding Unit (MSU) data (e.g., Venlden *et. al.* 1991). The relationship between the gradient of microwave brightness temperature and 500 hPa wind has also been reported by Grody *et. al.* (1982). Kidder *et.al.* (2000) used AMSU data to analyze the structures of a tropical cyclone. The tangential wind was calculated as function of radius and high from the retrieved temperature field. The axisymmetric temperature retrieved from AMSU and the wind derived from a (gradient-wind) balance balance equation have been used to study the relationship between the structures of a tropical cyclone and its environmental vertical wind shear. Knaff et al. (2004) showed that an increased wind shear leads to a shallower balanced vortex. Zhu *.et .al* (2002) built an algorithm to retrieve the three-dimensional temperature and wind structures of a hurricane from the AMSU data and incorporated the retrieved vortex into a numerical weather prediction model. They showed promising results in the forecast that incorporated the

AMSU data. In this paper we will adopt and modify the procedure of Zhu et al. (2002) to analyze the structures of typhoons and perform forecast experiments that incorporate the retrieved typhoon-like vortices into a meso-scale numerical weather prediction model.

2. method and data

The procedure of Zhu *.et .al* (2002) that we will adopt first retrieves the temperature from the AMSU data by a statistic method. Assuming hydrostatic balance, the height of each level can be obtained by a vertical integration. Using the estimated height at each level, the streamfunction at that level can be solved from a balance equation. The rotational component of the wind can then be calculated from the streamfunction. In this work, we use the framework of Zhu et al. (2002) but adopt the assumption of Kidder (200) that the height at the 50 hPa level is uniform (assumed to be the environmental value). With the height field at 50 hPa given, a downward integration with the hydrostatic equation and the retrieved temperature would produce the height fields at all levels. After the height of the 920 hPa level is calculated with an assumed surface temperature, surface pressure can be calculated through the hydrostatic equation. The 50 hPa height for the area containing a typhoon is evaluated from the environmental data (outside the typhoon) in which the surface pressure is provided by a numerical weather forecast system. When the surface pressure and temperature are specified, the hydrostatic equation can be integrated upward to determine the height at the 50 hPa level.

In the algorithm of Zhu *et al.* (2002), the divergent wind is calculated in a similar manner as Tarbell *et al.* (1981), i.e., by solving the omega and continuity equations. In the omega equation, the vertical distribution of latent heat is related to precipitation rate, which can be estimated from the AMSU data as described by Grody *et al.* (2000). The surface stress that is needed as the lower boundary condition is presented by a bulk aerodynamic formula (Smith, 2002).

The AMSU data used in this work was collected period of 2004 for the area in the vicinity of Taiwan. We have selected the observations in which a tropical cyclone is fully covered by one swath. The AMSU channels from 6 to 11 are use to retrieve the temperature profiles. Channels 1 and 2 are used to estimate the parameters of cloud liquid water and the precipitation rate.

3. results

a. Analysis of the structures of typhoons

The first case to be analyzed is typhoon MEARI (2004) at 0457 UTC on 29 September when it was on track to Japan. Figures 1 and 2 show the retrieved temperature anomaly and wind at 850 and 250 hPa using the method described in Sec 2. Notably, the circulation center of the typhoon at 850 hPa does not coincide with that at 250 hPa (the center tilts slightly northeastward with height), likely because cold air coming from the north eroded the lower-level thermal structures of the typhoon. At the upper level (250 hPa) where the influence of the low-level inflow of cold air is not strong, the circulation center coincides with the center of the temperature anomaly. The circulation at 850 hPa shown in Fig. 1 is representative of those at other levels from 950-500 hPa (not shown). In general, the circulation of the typhoon is not axisymmetric. The southern branch of the vortex is stronger than the northern one. The influence of the low-level northerly inflow of cold air is that it destroys the axisymmetric thermal structure of the typhoon at the lower levels. It might have also slowed down he moving speed of the typhoon, given that the direction of the cold air stream is opposite to that of the track of the typhoon.

The next case is typhoon MINDULLE (2004) at 0541 UTC on 29 June that is developing over the tropical ocean in the vicinity of the Philippines and slowly moving westward. Figure 3 shows that the retrieved temperature anomaly and wind at 850 hPa for this typhoon are more axisymmetric than the first case shown in Fig. 1. Figure 4 shows a vertical cross section of the tangential wind field associated with this typhoon. The center of this typhoon is well-defined for all levels and it does not significantly tilt with height. The intensity (measured by the magnitude of the maximum tangential velocity) of the typhoon also does not change significantly through the troposphere. These structures, derived from the AMSU data, indicate that the tropical cyclone has developed into the mature stage at this time. Comparing the vertical cross section in Fig. 4 to analysis field shown in Fig. 5, we can find that the overall structures are similar between the two but some differences remain. The radius of the typhoon, measured by the distance between its center and the location of the maximum wind, is smaller in the circulation derived from AMSU in Fig. 4. In the analysis field the tangential velocity decreases more rapidly with height, such that at the upper troposphere the AMSU-derived wind is stronger than that in the analysis.

Figure 6 shows the structures at 500 hPa of the same typhoon but for a later time at 1812 UTC on 29 June. A closed circulation is still well-defined for the typhoon, but its shape becomes more elliptical than circular (this is true for most of the lower troposphere up to 400 hPa, not shown). How the structures of the typhoon evolve during the 12-hour period from Fig. 3 to Fig. 6 remains to be investigated.

b. A case study of forecast

The fifth-generation Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model (MM5) with 3DVAR data assimilation has been used to test the results of typhoon forecast when typhoon temperature and circulation three dimensional fields were estimated from AMSU data. Other initial fields are generated from regional model of Center Weather Bureau in Taiwan. The model horizontal resolution is 45Km and 15Km in two nests grid and vertical resolution is 24 levels. We simulate typhoon MINDULLE with initial condition at 0600 UTC on 29 June and at 1800 UTC on 30 June when the AMSU data cover typhoon at 0541 UTC on 29 June and 1801 UTC on 30 June. Fig.7 shows the best track analysis and the simulation tracks of both cases. Observing the case of initial at 0600 UTC on 29 June we can find that the slowly westward moving and changing direction to north could be simulated. After about 0000 UTC on 1 July the simulation tack deviation becomes significant. From the simulation results of initial condition at 1800 UTC on 30 June the landing situation could be captured. After landing the typhoon will interact with terrain and the structure become complicate. Comparing the best tack with simulation we can find that some feature can be simulated but some effort still needed. However the simulation study shows the encouraging potential of using AMSU data to analysis typhoon parameters.

4. Concluding remarks

In this work the AMSU data is used to retrieve the structures of several typhoons. A preliminary comparison of the AMSU-derived structures of a typhoon with those in the analysis field reveals encouraging similarities. Our results demonstrate the potential of using the AMSU data to depict the three-dimensional temperature and velocity structures of typhoons. The outlook is promising since the AMSU observations provide an excellent coverage over the tropical ocean where conventional observations are sparse. The AMSU data may also be used to derive the values of a set of dynamical and thermodynamical parameters for a typhoon, defined in the sense of Hart (2003) for depicting the different stages of a tropical cyclone.

In this study we assume that the height at 50 hPa is constant and integrate the hydrostatic equation from 50 hPa downward to obtain the height field at each pressure level. This approach is likely simpler than integrating the equation from surface upward, as the lower boundary condition is strongly inhomogeneous and not trivial to determine. Integrating from top to bottom, one needs an accurate estimate of the atmospheric state in the upper troposphere to begin with. In addition to improving the retrieval techniques for the upper levels using the AMSU data, a good estimate of the atmospheric state at the upper troposphere may also be aided by the uses of the Atmospheric Infrared Sounder (AIRS) data, since contamination by cloud is not an issue above the cloud top.

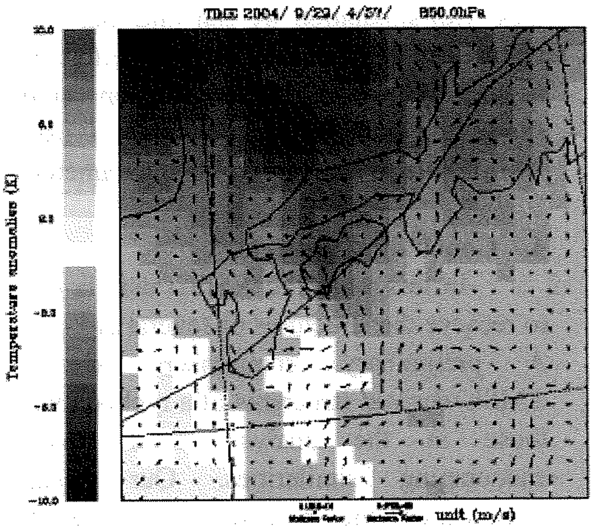

Fig1. The retrieved 850 hPa temperature anomaly (color image) and horizontal wind derived from a balance equation (vectors) for typhoon MAERI (2004) at 0457 UTC, 29 September. The solid line is the track of the typhoon that moves from southwest to northeast. The magnitude of the maximum vector is 0.178E+02 m/s as indicated at bottom.

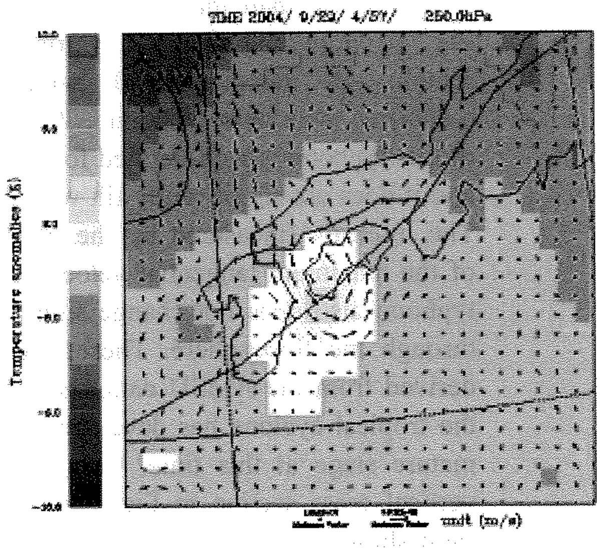

Fig2. Same as Fig. 1. but for the 250 hPa level. The magnitude of the maximum vector is 0.201E+02 m/s.

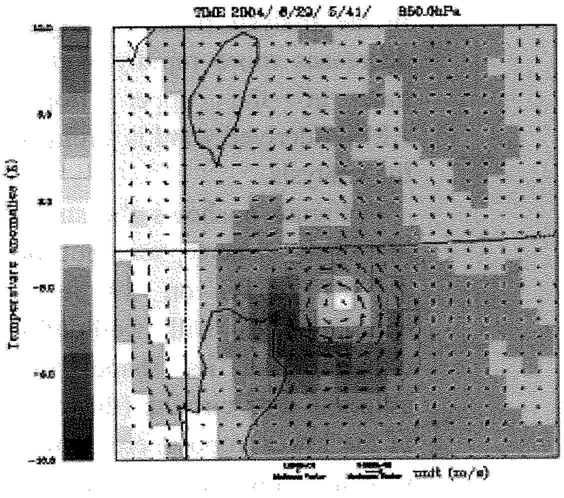

Fig3. Same as Fig. 1 but for typhoon MINDULLE (2004) at 0541 UTC, 29 June. This typhoon is moving from east to west. Shown is its structure at 850 hPa. The magnitude of the maximum vector is 0.380E+02 m/s.

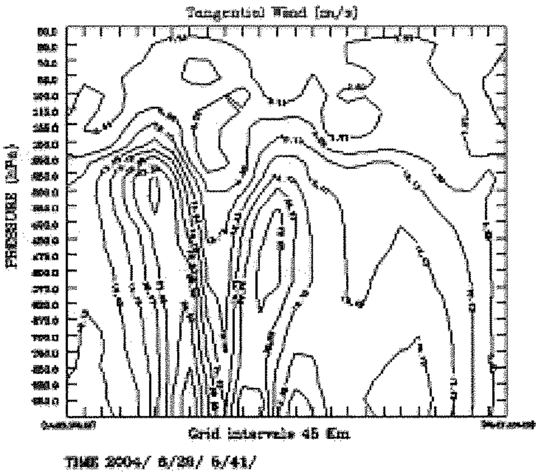

Fig4. A vertical cross section of the tangential wind driven from the AMSU data for the same typhoon and selected time shown in Fig.3.

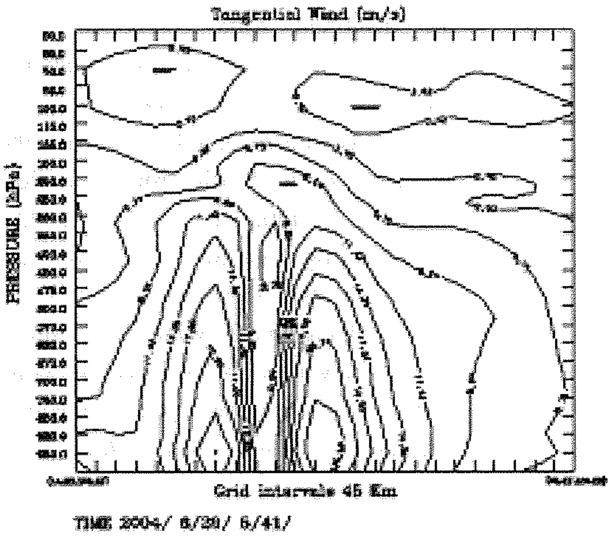

Fig5. Same as Fig. 4. but for analysis from the Region Model of Central Weather Bureau in Taiwan.

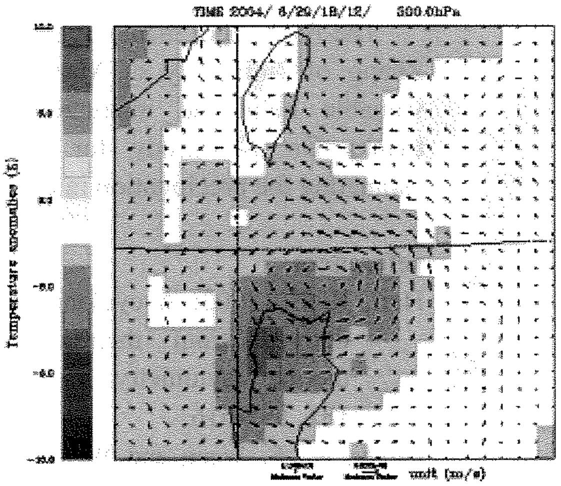

Fig6. Same as Fig 3. but for a later (after about 12 hours) time at 1812 UTC, 29 June. The magnitude of the maximum vector is 0.237E+02.

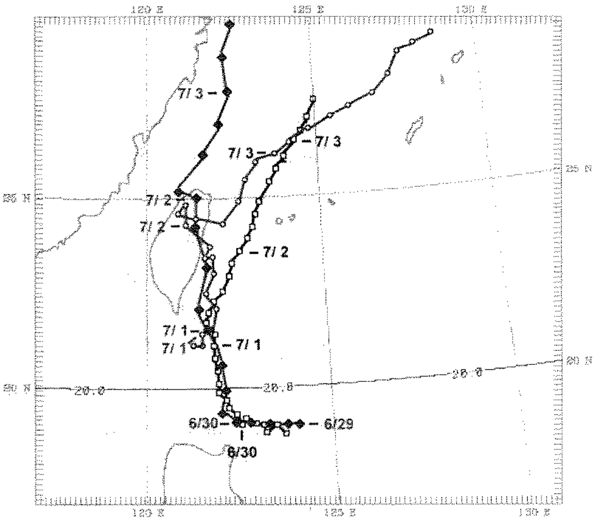

Fig7. The track of typhoon MINDULLE (2004). Red line represent best track. Green line represents the track of initial condition at 1800 UTC on 30 June. Blue line represents the track of initial condition at 0600 UTC on 29 June.

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