Use of low level 'detailed' satellite cloud motion wind around tropical cyclones in the JMA numerical weather prediction system

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ABSTRACT

Meteorological Satellite Center / JMA (MSC) produces low level 'detailed' satellite cloud motion wind around tropical cyclone (T-CMW) besides routinely produced conventional cloud motion wind (R-CMW). T-CMW has much higher horizontal resolution than that of R-CMW.

We have investigated the availability and quality of T-CMW data and also its impact to the JMA numerical prediction system. First, wind velocity and its asymmetric component of T-CMW data are statistically examined to apply for creating tropical cyclone (TC) bogus data. In JMA, the symmetric TC bogus data are operationally used to represent TC field in the analyzed field. Since the wind velocity in the right hand side in the direction of TC movement is larger than that in the left hand side, asymmetric bogus data are created by adding this asymmetric wind to the operational symmetric bogus wind. But by the numerical experiment using this asymmetric bogus, forecasted TC tracks are very similar to the tracks with operational symmetric bogus. Secondly, in the case that T-CMW data are directly used in the objective analysis, the analyzed field is often unnaturally distorted, because in almost cases T-CMW data distributes one side of TC. As a result, from the practical point of view, in the objective analysis the horizontal resolution of T-CMW is decreased to that of conventional cloud motion wind observations to avoid the distortion of analyzed fields.

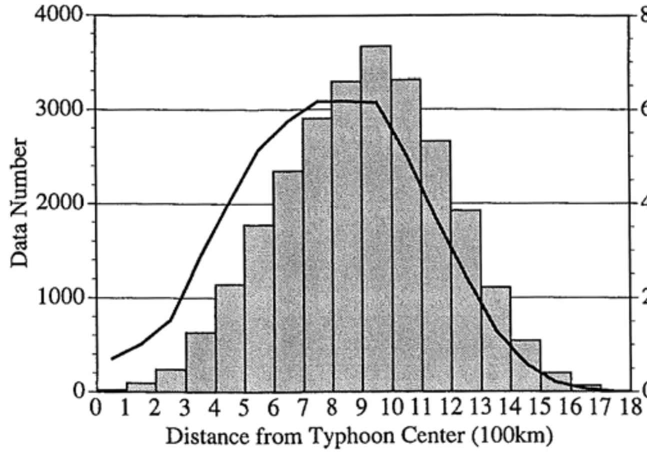


Figure 1 Number and density distribution of all T-CMW data produced in 1990.

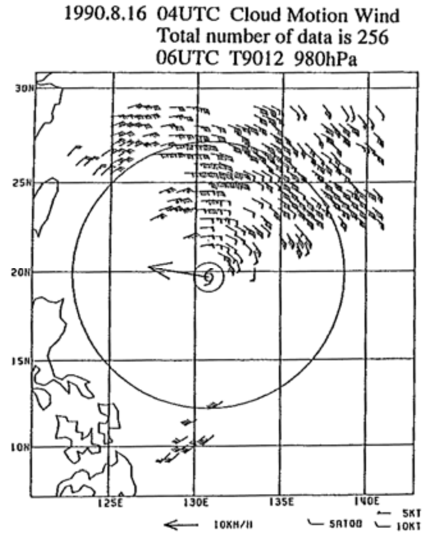


Figure 2 An example of T-CMW data. Inner circle is 25 m/s wind radius, outer circle is 15 m/s wind radius.

1. Outline of T-CMW data

If TCs exist in the coverage area of Geostationary Meteorological Satellite (GMS), MSC produces T-CMW data once a day at 04 UTC. T-CMW data are produced automatically within 10 degrees latitude and longitude from TC center, and with 0.5 latitude longitude degrees resolution from 15 minutes interval images of GMS, while R-CMWs are produced with 1 degree resolution from 30 minutes interval images. Figure 1 shows the number and density distribution of all T-CMW data produced in 1990 with respect to distance from TC center. Number and density of data have the maximum around 900 km from TC center. Figure 2 shows an example of T-CMW data. In almost cases, T-CMW data distribute in one side of TC like this example. This is because T-CMW data can be produced only within low level cloud area. T-CMW data cannot be produced in no cloud areas and also areas of high level cloud such as TC center where convection is very active.

Two experiments for utilizing T-CMW data were performed. One is utilizing the statistics of T-CMW on creating TC bogus data, the other is using T-CMW data directly into the objective analysis. For statistical study, 5 years data from 1988 to 1992 are used.

2. Utilization for creating TC bogus

(1) Outline of JMA TC bogussing method

In the JMA objective analysis, TC bogus data are used to describe reasonable typhoon structure in the analyzed field, especially in data sparse area where typhoon structure cannot be represented without bogus data. JMA's TC bogus has only axi-symmetric component. The outline of TC bogussing method is as follows; TC position and center surface pressure and 15 m/s wind radius (R_{15}) are manually analyzed by forecasters in the forecast division. R_{15} is a key factor of TC bogussing. In the first place, TC domain (R_{BAR}) is defined by the empirical formula based on R_{15}. The radius of R_{BAR} is about 1.5 times as large as R_{15} and in almost cases it is smaller than 700 km. The profiles of TC surface pressure, geopotential height and wind are calculated in this domain. The surface pressure profile is defined by using Fujita's formula (1952). We assume gradient wind field, and calculate the surface pressure profile to satisfy the gradient wind balance at R_{15}. Upper geopotential height profile is defined by the empirical formula based on the analysis of Frank (1977) and wind fields of upper layers are derived from gradient wind balance with this geopotential profile. Bogus profiles are inserted under 400 hPa layers. These geopotential and wind bogus profiles are superposed onto the original first guess fields. The operational objective analysis is performed by using this bogussing first guess field.

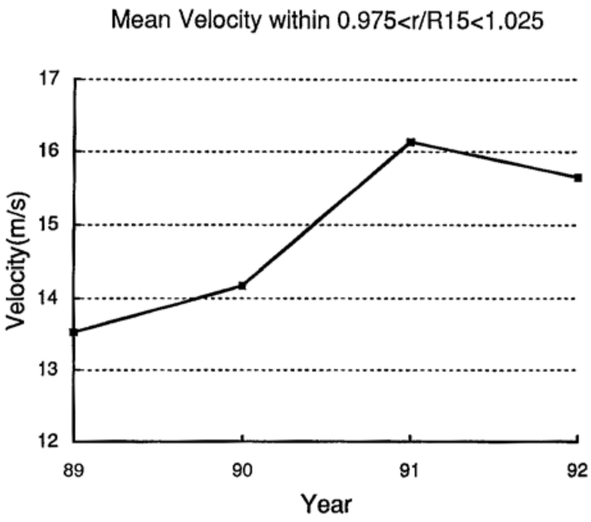


Figure 3 The mean wind velocity of T-CMW data in R_{15} vicinity for every year.

(2) Checking R_{15} radius size by T-CMW

The comparison of T-CMWs with ship observed wind indicated that the mean wind velocity of T-CMWs is about 1.1 times as large as that of ship wind. This is the same as the study by Oshima et al (1991). So we can say R_{15} is reasonably estimated, if T-CMW wind velocities in R_{15} vicinity is about 16.5 m/s. Figure 3 shows the mean wind velocity of T-CMWs in R_{15} vicinity for every year. R_{15} vicinity is defined by the region of $0.975 \leq r/R_{15} \leq 1.025$, where r indicates the distance from TC center to each T-CMW data. Before 1990, the mean wind velocities are smaller than 15 m/s, so that R_{15} radius was over-estimated. After 1991 they have increased to about 16 m/s. We can say that the R_{15} radius estimation is reasonable now.

(3) Asymmetric wind component relative to TC moving direction

Figure 4 shows that mean wind velocity in right hand side relative to TC moving direction is larger than that in left hand side. So the comparison of T-CMW's wind velocity is performed between right hand side quadrant and left hand side quadrant which are hatched parts in Figure 5. As it is impossible to derive such difference from each case, averaged difference between these areas (ΔV_{RL}) are calculated from five years data. ΔV_{RL} are calculated for each classification of r/R_{15} and TC moving speed. Due to the shortage of sample data, dependency of ΔV_{RL} on more detail category such as TC latitude and TC moving direction was not investigated.

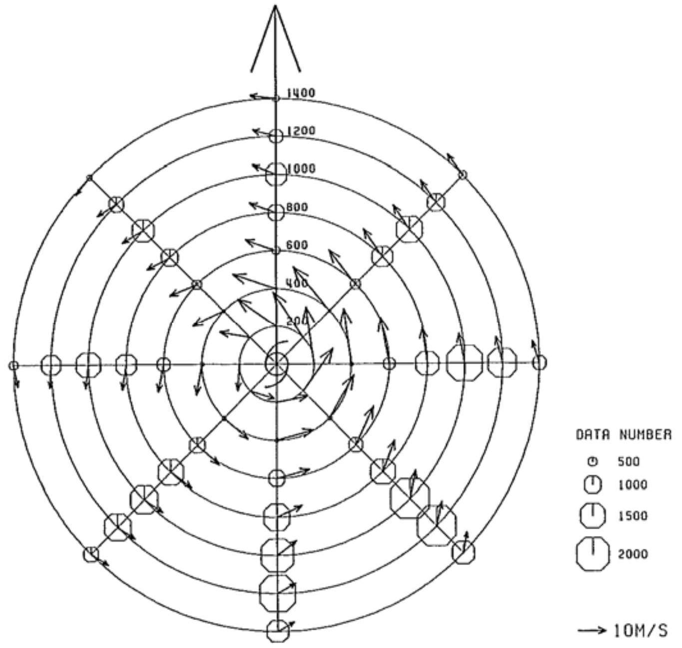


Figure 4 Distribution of mean wind velocities classified by distance from TC center and direction relative to TC moving direction.

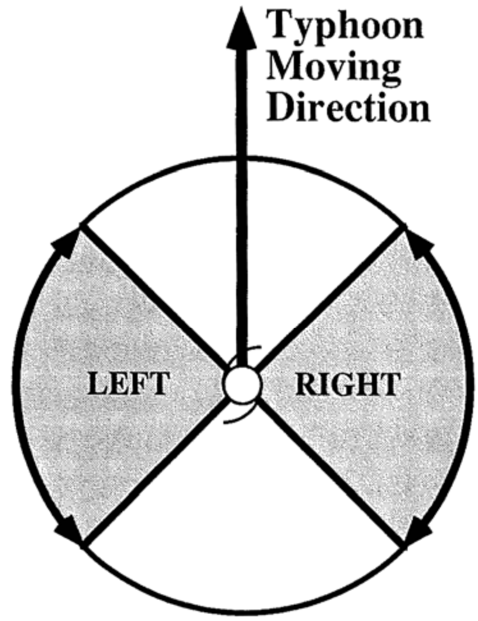


Figure 5 Schematic chart of Left and Right hand side quadrant relative to TC moving direction.

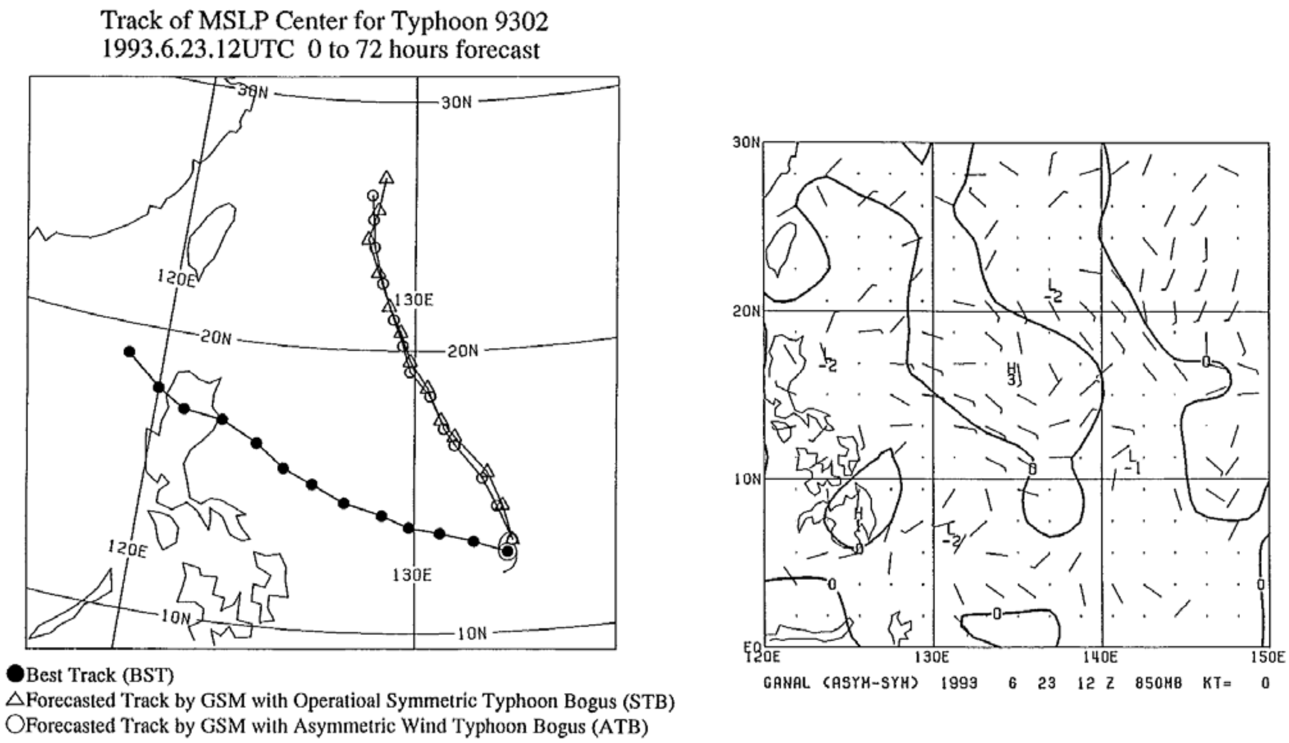


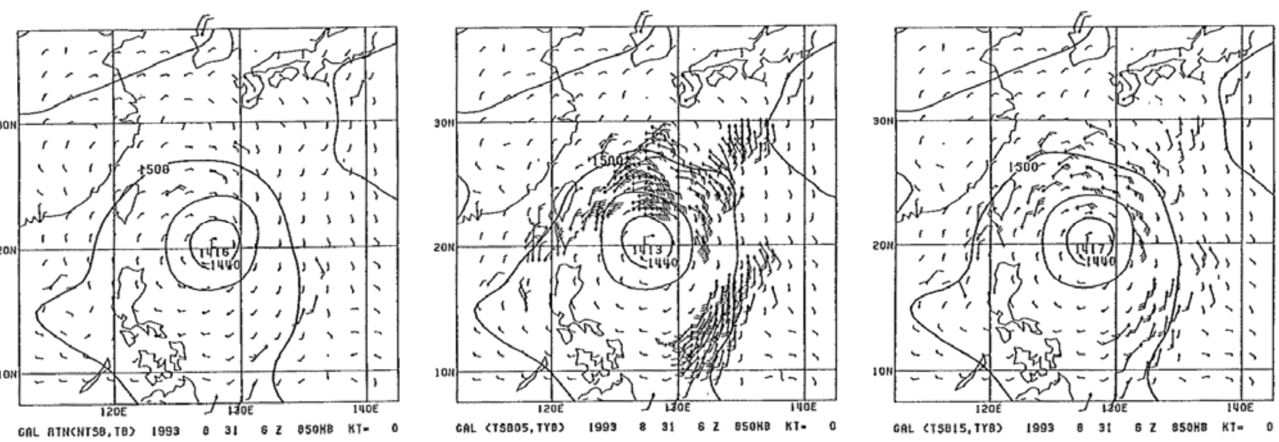
Figure 6 (a) An example of typhoon track forecast by GSM with operational symmetric TC bogus (STB) and asymmetric wind TC bogus (ATB).

(b) Difference of Global Analysis field between STB and ATB. (Forecast-Analysis cycle started at 1993.6.21.12UTC)

Asymmetric TC bogus data is created by superposing the half value of ΔV_{RL} onto the symmetric bogus under 400 hPa layers and some experiments were performed using this asymmetric bogus. Figure 6(a) shows an example of the experiment by the operational global model. This is one of bad forecast cases. The track was forecasted far northward against best track. Unfortunately, both of the forecasted tracks with symmetric and asymmetric bogus are very similar. Moreover, several other experiments showed the same results. This means that the asymmetric bogus does not affect TC track forecast. This result may be caused by the facts; 1) wind asymmetric components become small as is shown in Figure 6(b), because various data are averaged; 2) the asymmetric components are large only near TC center and do not contribute to the improvement of TC track forecasting, because steering flow around TC is considered to be more effective than neighborhood of TC center.

3. Using T-CMW data in the objective analysis

Figure 7(a) shows an example of the objective analysis using all T-CMW data. Comparing Figure 7(a) with Figure 7(b) which uses no T-CMW data, the part of analyzed field where many T-CMW data are entered is greatly affected by T-CMWs, while the other part with no T-CMWs is not affected. In general T-CMW data do not distribute uniformly in the area of TCs. Therefore the analyzed field cannot help being distorted by T-CMWs, even if resolution of T-CMW data is much higher than that of conventional R-CMW data. Figure 7(c) shows the analyzed field using some of the T-CMW data reduced to the extent that its horizontal resolution is comparable to that of R-CMW data. You can see that the analyzed field is not so distorted as in Figure 7(c).



(a) (b) (c)

Figure 7 An example of analyzed field;

(a) without T-CMW data (b) with all T-CMW data

(c) with some of T-CMW data reduced to the extent that its horizontal resolution is comparable to that of R-CMW data.

4. Conclusions

Since the averaged T-CMW winds are not effective to TC track forecast, it is difficult to use T-CMW data for creating TC bogus wind data. On the other hand, if all T-CMW data are used in the objective analysis, the analyzed field is often unnaturally distorted.

There are some difficulties for using T-CMW data in the JMA numerical prediction system. The main difficulty is that T-CMW data do not distribute uniformly in all directions around TC. Another difficulties are that many parts of T-CMW data distribute in the outside of TC bogus creating area, and that T-CMW data are produced only once a day, while the operational data assimilation is performed four times a day.

Therefore, from the practical point of view, it is the only way that using some T-CMW data in the objective analysis. T-CMW data quantity must be reduced to the extent that its horizontal resolution is comparable to that of R-CMW data by extracting some data or taking average of some near T-CMWs.

Although T-CMW data have some difficulties to use, T-CMW data are very useful for data assimilation, because there are few data around TC area especially in the ocean. Concerning with data quality, MSC reported that T-CMW data quality is almost same as R-CMW data. So we will utilize not only conventional R-CMW data but also T-CMW data in the JMA operational numerical prediction system.

References

Fujita,T. (1952) Pressure Distribution within Typhoon. Geophys. Mag., **23,** 437-451.

Frank,W.M. (1977) The Structure and Energetics of the Tropical Cyclone I. Storm Structure. Mon. Wea. Rev., **105,** 1119-1135.

Onogi,K., M.Ueno (1992) Improvement of Typhoon Bogus Data for JMA Numerical Weather Prediction Models. Journal of Meteorological Research, **44,** No.5, 247-270. (in Japanese)

Onogi,K. (1993) Low-level Detailed Satellite Wind around Typhoon. Numerical Prediction Division Report Bessatsu, **39,** 74-81. (in Japanese)

Oshima,T., H.Uchida, T.Hamada, S.Osano (1991) A Comparison of GMS Cloud Motion Winds with Ship-Observed Winds in Typhoon Vicinity. The Geophysical Magazine, **44,** No.1, 27-36.

Uchida,H. T.Oshima, T.Hamada, S.Osano (1991) Low-Level Cloud Motion Wind Field Estimated from GMS Short Interval Images in Typhoon Vicinity. The Geophysical Magazine, **44,** No.1, 37-45.