Examination of Tropical Cyclogenesis using the High Temporal and Spatial Resolution JRA-25 Dataset

Masato Sugi
Forecast Research Department, Meteorological Research Institute, Japan
Correspondence: msugi@mri-jma.go.jp

INTRODUCTION

Imperfect models alone cannot draw a reliable picture of the real world, while temporally and spatially insufficient observation data alone cannot draw a very detailed picture of the real world. Reanalysis may be regarded as an optimum combination of an imperfect model and insufficient observation data, which can produce the most reliable and detailed dataset to describe the real world.

Regarding the future tropical cyclone (TC) activity, a recent very high resolution GCM experiment indicates a reduction in the TC frequency as a whole, with an increase in the frequency of very intense TCs (Oouchi et al. 2006). On the other hand, in the recent IPCC report, it is summarized as "Based on a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs. There is less confidence in projections of a global decrease in numbers of tropical cyclones." (IPCC, 2007). There is no doubt that for a more reliable projection of the future tropical cyclone activity, it is necessary to better understand the physical processes associated with the genesis and development of tropical cyclones, and to assess the capability of GCMs to simulate these processes.

In the present study, in order to understand the physical processes of tropical cyclogenesis, we examine the formation stage of typhoons using the high temporal and spatial resolution JRA-25 dataset. Because of the high quality of the tropical precipitation in the JRA-25 dataset (Onogi et al. 2006), we can expect tropical disturbances and their environmental circulations are analyzed reasonably well in JRA-25.

DATA

The main data used in the present study is the 6 hourly, 1.25 degree latitude-longitude grid, standard pressure level JRA-25 data. For the JRA-25 precipitation data, 1.125 degree latitude-longitude grid, 6 hour forecast data is used. The CDA file is used to check if the TCR data (tropical cyclone wind profile retrieval data) is used or not in each time. To examine the convective activity around the tropical cyclones, 1 hourly, 0.05 degree latitude-longitude grid GMS satellite black body temperature (TBB) data is used. In addition, data from a very high resolution (horizontal grid size 20km) GCM experiment is used for the purpose of comparison. The period of analysis is the three months from August to October in 2004. During this period 14 typhoons are formed, 8 in August, 3 in September and 3 in October. Formation stages of 12 typhoons out of the 14 typhoons are examined, and three of them, T0416 (CHABA), T0418 (SONGDA) and T0422 (MA-ON), are analyzed in some detail.

DEFINITON OF TC GENESIS

In the present study, we define TC genesis time as the time when TCR data is first used for the TC in JRA-25. TCR data is included in JRA-25 when maximum wind ≥ 30 kts in the Neumann's best track data (Hatsushika et al. 2006). On the other hand, the JMA TC genesis time is defined as the time when maximum wind ≥ 34 kts, when tropical depression (TD) becomes named typhoon (TS). Because of the difference in the threshold value for TC genesis, the TCR genesis time is usually 6 to 18 hours earlier than the JMA genesis time. In addition, we should note that the maximum winds estimated from satellite images are considerably different in different best track dataset. The maximum wind in JTWC best track data is usually stronger than that in JMA best track data, particularly in the mature stage of TCs. For example, the maximum wind speed of T0416 (CHABA) at mature stage is 110kts in JMA best track data, while it is 155kts in JTWC best track data.

INTENSIFICATION OF VORTEX

We made maps of vorticity at 925hPa every 6 hours from August to October in 2004 over the tropical western North Pacific (Figures not shown). In these maps we can see many weak vortices, some of which develop into typhoons. The central question regarding TC genesis is why some of these vortices develop into TCs but many others do not. We first examine the development processes of the vortices that eventually developed into typhoons. Intensification of vortices during the TC genesis period, from 2 days before the genesis time to 2 days after the genesis time, is shown in Figure 1 for the 12 typhoons formed in August to October in 2004. There was a concern that the inclusion of TCR data might cause a discontinuous intensification of vortex, but the Figure 1 shows that there is no such gaps in the intensity before and after the genesis time. In some case there is a rapid intensification around the genesis time. For example, a rapid intensification can be seen around genesis time of T0419 or T0422, but the intensification continues sometime after the genesis time, and it may be real intensification rather than the artificial one caused by the inclusion of TCR data at genesis time. All the intensification curves of vortices of the 12 TCs are plotted together in Figure 2, with their average. The average curve shows slow intensification before the genesis time and more rapid intensification after the genesis time. This suggests that a self intensification process starts to take place around the genesis time.

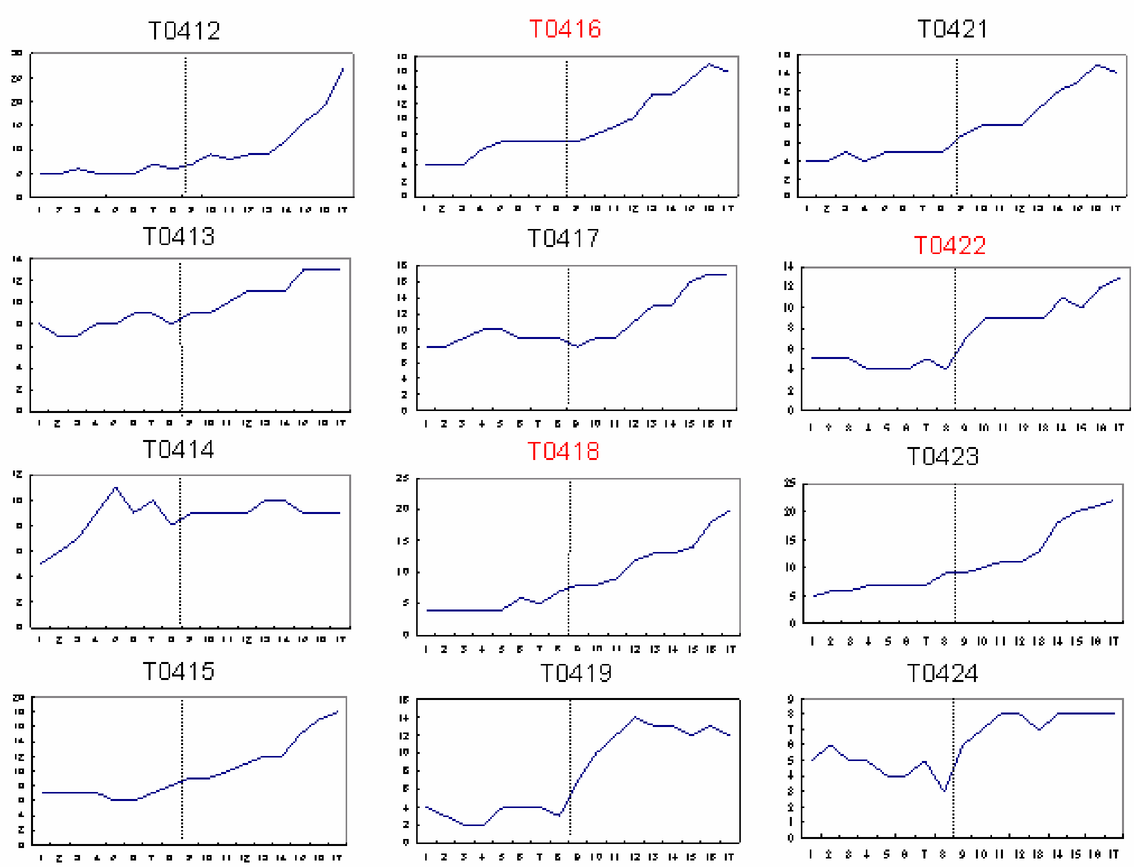

Figure 1 Variation of the intensity of vortex at 925hPa during the 4 day period centered at the genesis time for 12 typhoons formed in August to October of 2004.

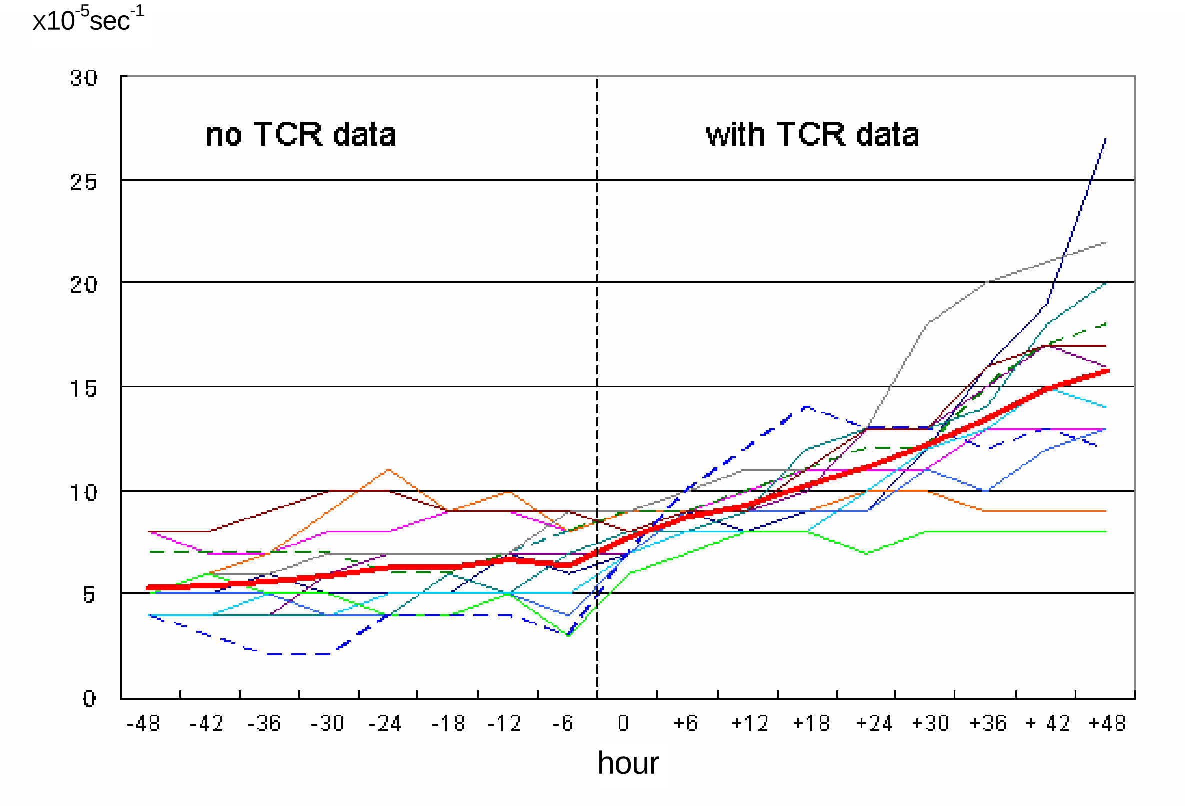

Figure 2 The same as Figure 1 but all curves for 12 typhoons are plotted together, with their average (thick red curve). 0 hour is the genesis time.

CASE STUDIES

We examine genesis processes of three typhoons in some detail. Figure 3 shows the evolution of vorticity, sea level pressure, convective clouds (GMS TBB), precipitation and vorticity generation term $-(\zeta+f)D$ for the TC0416 (CHABA) during the 4 days period centered at the genesis time (18UTC of 18 August 2004). The vertical cross sections of vorticity show the upward development of the vortex from bottom to top, suggesting that the vorticity is generated in the boundary layer and advected upward to free atmosphere by convections. Before the genesis time when the TCR data is first included, a development of vortex together with the surface low pressure area can be seen, indicating that the tropical cyclogenesis process is well captured by the JRA-25 data. Concentrated active convective clouds can be seen near the vortex center after the genesis time, while some scattered active convective clouds can be seen before the genesis time. The role of these scattered convective clouds during the genesis stage seems to be producing a large scale convergence in the boundary layer, leading to an intensification of the vortex through the vorticity generation term. Although the 6-hour forecast precipitations in the JRA-25 are not well concentrated near the vortex center, we can see vorticity generation in the boundary layer near the vortex center. This indicates that the large scale convergence associated with the ensemble of scattered convections around the vortex play an important role in the development of vortex.

The evolutions of the other two typhoons (T0418 and T0422) are almost similar to T0416 (Figures not shown), although there are some minor differences. For both typhoons, we can see upward development of vortex similar to T0416 during the TC genesis period. A development of surface low pressure area and an intensification of vorticity

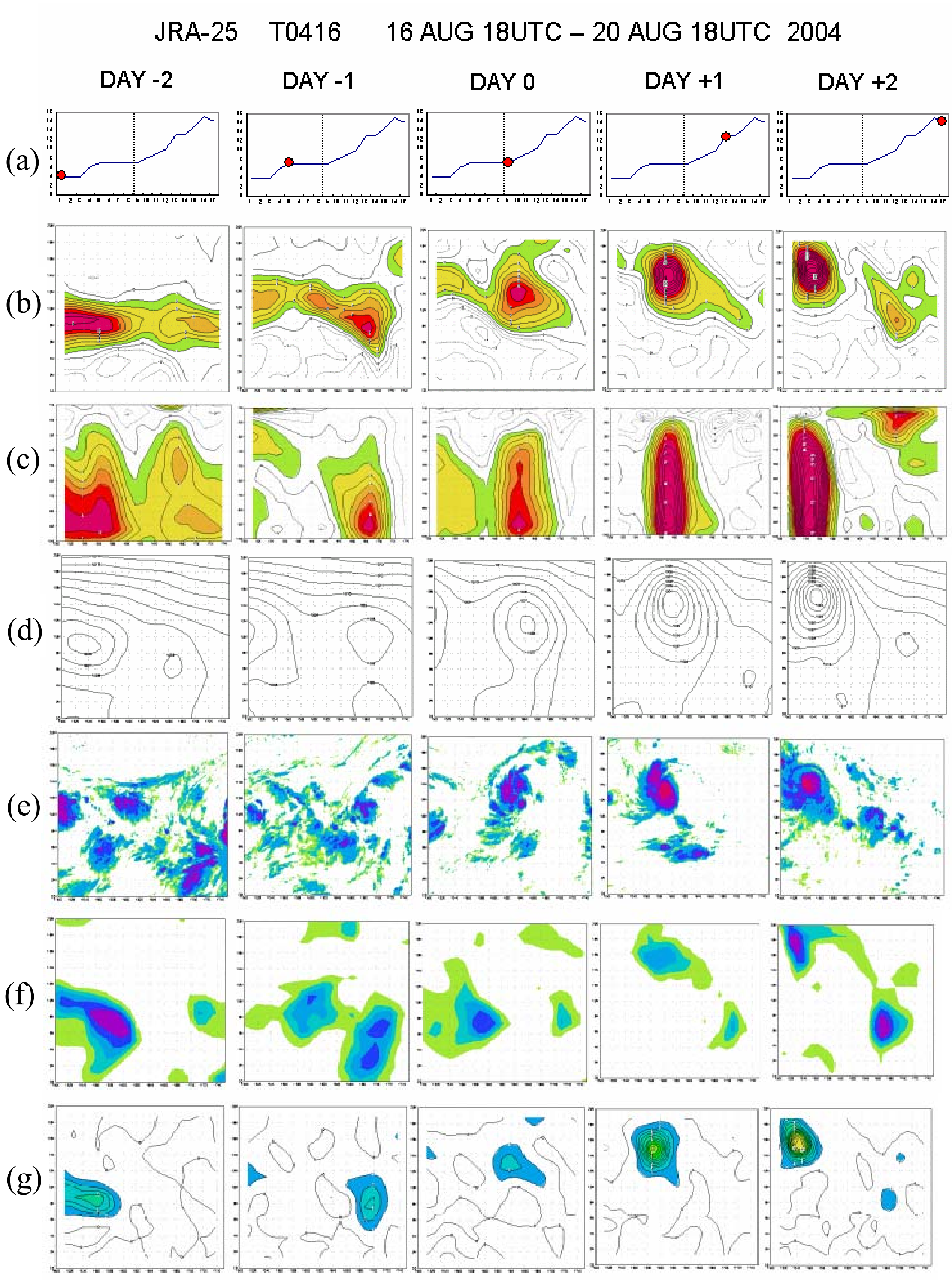

Figure 3 Evolution of T0416 during 4 days centered at the genesis time (18UTC 18 August 2004). (a) Variation of intensity of vortex. (b) Vorticity at 925 hPa. (c) Vertical cross section of vorticity . (d) Sea level pressure. (e) Convective clouds. (f) 6hr forecast precipitation. (g) vorticity generation term ($-(\zeta+f)D$)

generation term around the vortex center can be seen in both cases. We can also see some scattered convective clouds around the vortex center before the genesis time, and concentrated convective clouds near the vortex center as in the T0416 case. Furthermore, a similar evolution of vortex during the TC genesis period is also seen in the very high resolution GCM simulation.2.

CONCLUSIONS

The main conclusions of this study are:

1) High resolution JRA-25 dataset is very useful for TC genesis study. TC genesis process is reasonably well captured by the JRA-25. TCR data makes no significant gaps in the intensity of TC before and after TC genesis.

2) There are many weak vortices ($\leq 5 \times 10^{-5}$ sec^{-1}) in the boundary layer over the tropical western North Pacific. Some of them develop into typhoons but many of them do not develop.

3) It seems that the vorticity generation in the boundary layer through convergence of absolute vorticity ($-(\zeta+f)D$) and its upward advection to free atmosphere by convection are the most important processes for the development of the vortex.. Further quantitative analysis of these processes is an important future work.

4) During the genesis stage of TC, scattered active convective clouds can be seen around the vortex center. The role of these scattered convective clouds during the genesis stage seems to be producing a large scale convergence in the boundary layer, leading to an intensification of the vortex through the vorticity generation term.

5) To assess the capability of GCMs to simulate TC genesis processes, a comparison of GCM simulation with cloud resolving model (CRM) simulation is also an important future work.

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