16C.1 HAVE THERE BEEN ANY TYPHOONS STRONGER THAN SUPER TYPHOON TIP ?

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1. INTRODUCTION

With many believing that climate change is on-going (i.e., global warming), scientists involved in tropical cyclone (TC) programs might well wonder if the frequency of extremely intense TCs will increase. Before researchers go ahead and try to extrapolate the future activity of extreme TCs in a warmer climate, there is a preliminary issue: what is the intensity of the strongest TC which has already formed? Super Typhoon (STY) Tip is still considered the strongest tropical cyclone to have formed in the Western North Pacific since the beginning of the reconnaissance aircraft era (ATCR). The minimum sea level pressure was measured at 870 hPa on 12 October 1979 at 0353 UTC (Dunnavan and Diercks, 1980), but the surface maximum sustained wind (MSW) of 85 m/sec over one minute was estimated from the pressure-wind relationship developed by Atkinson and Holliday (1977).

Since the end of routine aerial reconnaissance in the Western North Pacific (WPAC) in August, 1987, the primary question is: have there been tropical cyclones which have reached an intensity greater than 85 m/sec, based on satellite imagery? Or, are we obliged to regard this intensity as a superior limit for a tropical cyclone in the absence of aircraft measurements (Lander and Guard, 2001)? A second question is: if it is possible to have a TC with a surface MSW greater than 85 m/sec, what magnitude of Dvorak T-numbers, both manual and objective (ODT), should a TC display in order to be regarded as a stronger typhoon than Tip? In an attempt to answer the first question in the affirmative, we obtained satellite images of STY Tip as well as pictures of the strongest WPAC typhoons which have occurred since August, 1987.

2. METHOD

The first step was to analyze the main features of STY Tip. The study indicates that Tip displayed a maximum ODT number of 8.2 well before the lowest pressure was recorded, a feature previously hightlighted by Lander in the 1996 ATCR. In fact, on 11 October at 1529 UTC, a reconnaissance plane found a SLP of 900 hPa, although the ODT was already at 8.2 based on the 1603 UTC GMS picture. Interestingly, manual Dvorak T-numbers reached 8.0 during a 4.5-hour period which ended one hour before the measurement of 870 hPa. These T8.0 numbers have been obtained by taking into account a band feature of +0.5T on the EIR pictures. At this time, the ODT was decreasing progressively at 7.8. This is the basis for agreeing with the 85 m/sec previously estimated and believing that the 870 hPa was probably the minimum SLP. So, in the case of Tip, the satellite data (DT-numbers) led the current intensity. In order to determine if this was a common feature in the WPAC, we made a study of about a dozen super typhoons with an intensity of at least 72 m/sec from 1981 to 1987 when there was aerial reconnaissance data. The results show that the satellite data represented by DT-numbers peaked 6 to 12 hours before the lowest pressure was reached when the cyclones were undergoing a rapid deepening. This was observed for the average-sized and large TCs. For the smaller TCs, the satellite data led the intensity by 3 to 6 hours. In most of the cases, the minimum SLP was recorded near the end of the best satellite presentation of the typhoon, or in a few cases, even a few hours after the beginning of a weakening trend as seen on the images. Moreover, it is interesting to notice that the manual Dvorak T-numbers worked well to estimate the current intensity for cases which caught the satellite data at the end of the rapid deepening period.

From all of these features, we decided that a typhoon should display the following characteristics to be considered as more intense than STY Tip: manual Dvorak T-numbers of 8.0 (with no spiral band added) for 6 to 12 hours, and ODT numbers greater than 8.2 for a period of at least 6 hours. For this study, we used the original satellite images (hourly and tri-hourly) from GMS with a 5-km resolution. And we utilized the same data for a given hour when we compared the Basic Dvorak enhancement pictures between NOAA and GMS satellites.

3. THE STRONGEST SUPER TYPHOONS

In a preliminary study we found three possible candidate typhoons stronger than Tip among the strongest TCs in the WPAC since August 1987. After having gathered hourly GMS data, we did not consider STY Yuri (in November, 1991) at more than 82 m/sec. But, we kept two extremely solid candidates, STY Angela in November, 1995, and STY Gay in November, 1992. Angela and Gay had ODT numbers higher than Tip, between 8.3 and 8.7, and for a longer time period. These typhoons attained manual Dvorak T-numbers of 8.0 which persisted for at least nine hours without a spiral band. A remarkable and common feature of these two cyclones was that the ODT and manual Dvorak T-

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numbers peaked at the same time. The peak MSW of Angela and Gay have been estimated at 80 m/sec and 82 m/sec, respectively (1995 and 1992 ATCRs). In order to show how cold the clouds tops associated with Angela and Gay were, we highlighted a new grey shade inside the Cold Dark Grey ring (CDG = at least -81C) and called it Very Cold Dark Grey (VCDG). This latter grey shade shows cloud tops of at least -84C. In the WPAC, only Angela and Gay displayed a warm eye embedded 55 km in such a cold ring of convection. In contrast, STY Tip never did. Additionally, in 1997 three TCs were estimated to have peaked at 82 m/sec: Ivan and Joan (October), and Paka (December). If the analysis of these latter typhoons justifies 82 m/sec, this would strongly suggest that Angela and Gay were even more intense. So, we believe that these two TCs should have been classified at the top of the Dvorak scale with a MSW of at least of 87 m/sec.

Satellite data revealed that Typhoon Angela underwent an explosive deepening on 31 October around 0900 UTC after a rather slow development. At that time, the intensity could be estimated at 49 m/sec as the center was embedded under the convection with no eye visible on the EIR images. Then, the DT-numbers increased dramatically while an eye formed and warmed in the middle of the convection: 5.5 at 1230 UTC, 7.0 at 1430 UTC, 7.5 at 2030 UTC and 8.0 from 0130 UTC until 1430 UTC on 1 November. STY Tip displayed a comparable evolution on 11 October 1979 when the DT-numbers increased from 5.0 at 0530 UTC, to 5.5 at 0830 UTC, and to 7.0 at 1130 UTC. A reconnaissance flight made at 0951 UTC found a SLP of 949 hPa and a maximum 700 hPa flight wind of 55 m/sec. This matches with an intensity of 49 m/sec. It is obvious that the satellite data led the current intensity. And Tip reached its first peak intensity of 72 m/sec (900 hPa measured by a dropsonde at 2340 UTC) after the DT-numbers had remained at 7.0 for 12 hours. So, in the Angela case, we think that 72 m/sec was reached at 0000 UTC on 1 November, although the Best Track gives a peak MSW of 80 m/sec. As Angela was a rather large typhoon, the current intensity probably did not have time to reach 80 m/sec. Moreover, we cannot, as the best track did, consider that Angela reached its peak at 0000 UTC on 1 November. At this time, an eye of -3.8 C was surrounded by a CDG shade. This gave DT numbers of 7.5. Then, the eye warmed significantly at more than +9 C while the clouds top temperature remained very cold at CDG. This matched with manual Dvorak T-numbers of 8.0 which lasted more than 12 hours. The ODT numbers reached an average of 8.3 over a period of 12 hours beginning at 0030 UTC on 1 November. And they peaked at 8.5 from 0830 UTC to 1230 UTC when the 24-km round eye was warmer at 20.5 C. STY Angela was displaying an incomparable pattern with a round and symmetrical VCDG grey shade (-84 C and cooler) which measured 74 km in diameter with the coldest cloud tops at -91.5 C to -94 C. These data, never displayed by STY Tip (85 m/sec), would indicate that STY Angela peaked at 90 m/sec around 1200 UTC on 1 November 1995.

STY Gay intensified more progressively in November, 1992, than STY Angela did. Gay reached an intensity of 77 m/sec as indicated in the JTWC best track on 20 November at 1200 UTC. Then, the DT numbers increased to 8.0 from 1530 UTC until 21/0030 UTC. The ODT numbers reached an average of 8.3 also over a period of 12 hours beginning at 1230 UTC. Like Angela, Gay had an average ODT of 8.4 over a period of 6 hours with a peak of 8.7 at 1730 UTC and a VCDG ring 83 km wide. But we consider that STY Gay was a little less intense than STY Angela with a peak MSW of 87 m/sec on 21 November 1992 at 0000 UTC. In fact, the bigger eye of Gay was not as warm (+17.6 C) as Angela's eye, and in addition Angela had a more circular pattern and was larger than Gay.

4. CONCLUSION

In summary, based on the satellite data, we strongly believe that STY Angela and STY Gay were more intense than STY Tip and that they reached the top of the Dvorak scale, not only because the ODT numbers reached figures never reached in other tropical cyclones before, including Tip, but also because the manual Dvorak T-numbers were at the maximum possible of 8.0 during a period of at least 9 hours, which almost guarantees that the current intensity had had time to catch up with the satellite data, based upon studies of the strongest typhoons of the WPAC from 1981 to 1987 when reconnaissance aircraft were available.

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