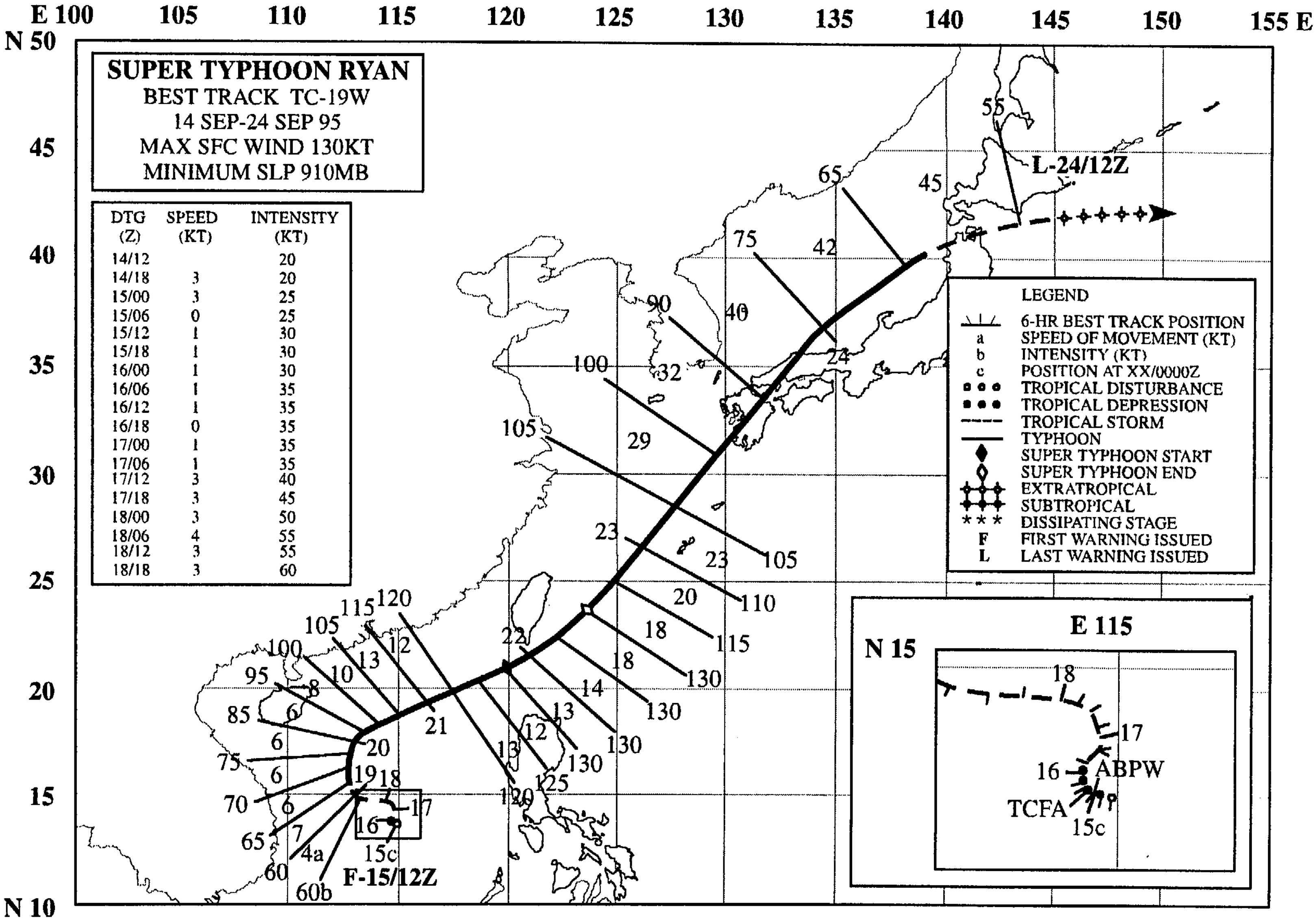


DTG (Z)	SPEED (KT)	INTENSITY (KT)
14/12		20
14/18	3	20
15/00	3	25
15/06	0	25
15/12	1	30
15/18	1	30
16/00	1	30
16/06	1	35
16/12	1	35
16/18	0	35
17/00	1	35
17/06	1	35
17/12	3	40
17/18	3	45
18/00	3	50
18/06	4	55
18/12	3	55
18/18	3	60

SUPER TYPHOON RYAN (19W)

I. HIGHLIGHTS

Ryan was the first tropical cyclone on JTWC's records to both form and attain super typhoon intensity within the South China Sea. Located along the axis of a reverse-oriented monsoon trough, Ryan underwent unusual motion: an "S"-shaped track. Two other tropical cyclones — Oscar (17W) and Polly (18W) — also developed in this reverse-oriented monsoon trough and, along with Ryan, formed a SW-NE chain of tropical cyclones. Estimates of Ryan's intensity based upon Digital Dvorak (DD) numbers exhibited some unusually large and rapid fluctuations. Ryan passed through the southern islands of the Ryukyu chain, and made landfall in southwestern Japan.

II. TRACK AND INTENSITY

On 13 September, the axis of the monsoon trough extended eastward from Southeast Asia across the South China Sea to Luzon, and from there, east-northeastward to Oscar (17W) in the northern Mariana Islands. Westward from Oscar (17W), and along the trough axis, lay the tropical disturbance that became Polly (18W) (then east of Luzon), and (in the South China Sea) the tropical disturbance that became Ryan. The pre-Ryan tropical disturbance was first mentioned on the 130600Z September Significant Tropical Weather Advisory based upon 24 hours of persistent deep convection associated with a weak low-level circulation center. Over the next two days, the sea-level pressure (SLP) slowly fell in the pre-Ryan tropical disturbance. At 151000Z September a Tropical Cyclone Formation Alert was issued based primarily on synoptic reports that indicated that the central SLP had fallen to 1002 mb within a well-defined low-level cyclonic circulation. The JTWC issued the first warning on Tropical Depression 19W valid at 151200Z.

Improvements in the organization of its deep convection resulted in an upgrade of Tropical Depression 19W to Tropical Storm Ryan at 160000Z. During the period 16 through 19 September, Ryan moved very slowly northward and then very slowly westward. After making a turn toward the north early on 19 September, Ryan was upgraded to a typhoon at 190600Z. On the morning of 20 September, the typhoon turned to the east-northeast, accelerated, and continued to intensify (Figure 3-19-1). Ryan attained its peak intensity of 130 kt (67 m/sec) at 211800Z as it swept around the southern tip of Taiwan, whereafter, it accelerated further, made a slight left turn, passed near (or over) Ishigaki Shima (WMO 47918) (see impact section), and then moved northeastward toward Japan.

Ryan made landfall on the Japanese island of Kyushu late on 23 September. Its landfall intensity was just under 100 kt (51 m/sec). After crossing Kyushu, Ryan tracked across the westernmost portion of the Japanese main island of Honshu and entered the Sea of Japan. Encountering strong deep layer westerly wind flow, Ryan weakened as it turned toward the east on the last leg of its "S" track, and passed over the northern tip of Honshu between 0600Z and 1200Z on 24 September. Under the influence of shear in the westerly wind flow at the higher latitudes, Ryan continued to weaken and began to transition to an extratropical cyclone. The final warning was issued valid at 240600Z.

III. DISCUSSION

a. *First super typhoon to form in the South China Sea*

Since the JTWC was established in 1959, there have been no super typhoons (130 kt (67 m/sec), or greater) in the South China Sea (although there have been super typhoons in the Philippine Sea that have moved into the South China Sea at lesser intensities). During the period 1945 to 1959, before the

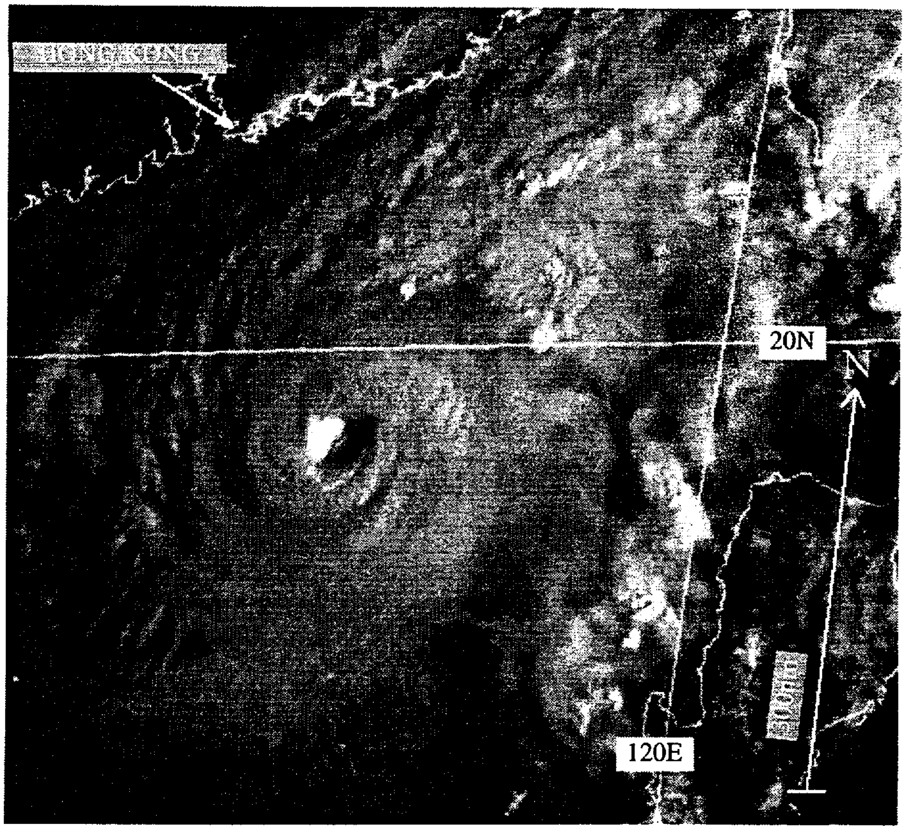


Figure 3-19-1 Ryan at 115 kt (59 m/sec) continues to intensify and will reach super typhoon intensity in 18 hours. The low sun angle in this image accentuates the cloud top topography (202332Z September visual GMS imagery).

JTWC was established, tropical cyclones in the western North Pacific were nonetheless reconnoitered by Air Force and Navy aircraft. During these years, two typhoons — Gloria (1952) and Betty (1953) — were reported to have attained super typhoon intensity after crossing the Philippines and while over the South China Sea. In the case of these two typhoons, it is difficult to assess the reliability of the reconnaissance reports of super typhoon intensity.

In the case of Gloria (1952) a Navy reconnaissance flight departed from Sangley Point at 222055Z December 1952, and made two eye fixes, one at 222309Z and the other at 230400Z. During the first pass through the eye, the crew estimated the maximum surface wind to be 110 kt (57 m/sec) in the northwest quadrant of the system accompanied by an estimated minimum sea-level pressure (SLP) in the eye of 982 mb. On the second pass through the eye, the maximum estimated surface wind was 130 kt (67 m/sec) in the southeastern quadrant accompanied by an estimated minimum SLP in the eye of 983 mb. The Atkinson/Holliday wind-pressure relationship (currently used as a baseline by the JTWC) requires a minimum SLP of 910 mb for a wind intensity of 130 kt (67 m/sec); conversely, a minimum SLP of 982 mb corresponds to a maximum wind speed of 55 kt (28 m/sec). In the case of Betty (1953), a Navy reconnaissance flight estimated the surface winds to be 130 kt (67 m/sec) in the left forward quadrant of the system. The lowest "observed" SLP (most probably obtained from a dropsonde) was 988.6 mb; however, owing to severe turbulence, the aircraft was unable to penetrate the eye.

Historical reconnaissance reports during the early years of record frequently have large mismatches between the minimum SLP and the associated maximum wind speed. Such large mismatches (as was the case with Gloria) render the data suspect. This is typical of historical reports during the early years of tropical cyclone reconnaissance.

Returning now to the case of Ryan, It must be noted that its super typhoon intensity was diagnosed from satellite using the techniques developed by Dvorak (1975, 1984), and one could raise questions as to the accuracy of its peak intensity estimate. Dvorak's techniques have been in use now for two decades, and for the most part, have been proven to be reasonable from coincident aircraft and land-falling "ground truth" measurements. There are occasional outliers from Dvorak intensity estimates, and examples have been pointed out in past Annual Tropical Cyclone Reports (e.g., see the summaries of Seth and John in the 1994 ATCR). Given that there may be a significant level of uncertainty of tropical cyclone intensity as estimated from satellite imagery, the least that can be said of Ryan is that during the past two decades of intensity estimation by satellite (accompanied by aircraft reconnaissance until 1987), no typhoon has ever been estimated to have attained super typhoon intensity while in the South China Sea.

b. *Ryan's north-oriented motion*

The north-oriented track was first recognized by the Japan Meteorological Agency (JMA) (1976). Lander (1996) further elaborated on the characteristics of north-oriented tracks. One particular type of north-oriented motion described by Lander was the "S" track. "S" motion is north-oriented motion of a TC that features eastward motion at low latitude, a later bend to the north or northwest, and then eventually northeastward motion as the TC enters the mid-latitude westerlies.

Twenty-five of 37 cases (68%) of observed "S" motion during the years 1978 through 1995 occurred when tropical cyclones undergoing "S" motion were located along the axis of a reverse-oriented monsoon trough. The "S" motion of Ryan — and also that of Polly (18W) — occurred when these tropical cyclones were located along the axis of a reverse-oriented monsoon trough. During 1995, the tracks of Ryan, and Polly (18W) were the only "S" tracks; and they comprised two of only five north-oriented tracks during the year (see Table 3-1).

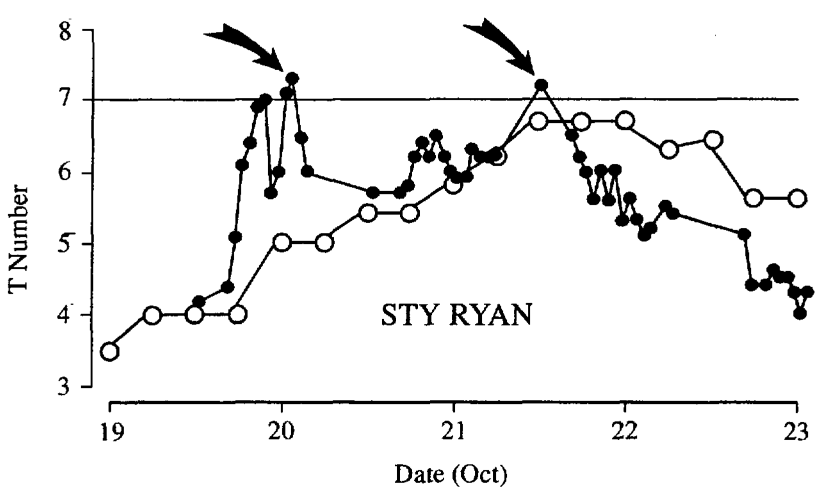


Figure 3-19-2 This comparison of the DD numbers (solid circles) and final best track intensity (open circles) converted to T-numbers for the period 19 to 23 September shows the variation between raw data and the final smoothed product for Ryan. Arrows indicate the two instances where the "digital" values exceeded T7.0.

c. *Rapid fluctuations in Ryan's DD numbers*

During 1995, detailed records of the hourly values of the DD numbers were tabulated for five typhoons: Oscar (17W), Polly (18W), Ryan, Ward (26W), and Angela (29W). (See the more detailed description of the DD numbers in Oscar's (17W) summary.) The time series of the hourly values of the DD numbers for Oscar (17W) was relatively stable, and was in good agreement with the JTWC warning intensity and the final best-track intensity. With Ryan, the time series of the hourly DD numbers underwent some large fluctuations (Figure 3-19-2) that were not in good agreement with the warning intensity or with the final best track intensity. The magnitude of Ryan's DD numbers exceeded T 7.0 — equivalent to an intensity of 140 kt (72 m/sec) maximum sustained wind speed — twice during its life (for maximum wind and minimum sea-level pressure equivalents to Dvorak's T numbers, see Table 2-2). The first DD of T 7.0 occurred at 192230Z, and reached T 7.3 at 200230Z (see Figure 3-19-3a) before falling back into values in the vicinity of T 6.0. The warning intensity at this time was 90 kt (46 m/sec), and the final best track intensity was 85 kt (44 m/sec) — this intensity is approximately T 5.0 on the Dvorak scale.

After the first DD peak of T 7.3 at 200230Z, the hourly time series of the DD fell back to within a few tenths of T 6.0 for a period of about 30 hours, after which the DD rose once again above T 7.0 at 211230Z (see Figure 3-19-3b). The warning intensity (and final best-track intensity) for Ryan reached a peak of 130 kt (67 m/sec) at this time (211200Z). An intensity of 130 kt lies between a T 6.5 and a T 7.0 on the Dvorak scale. The warning intensity and the DD were in close agreement at this time.

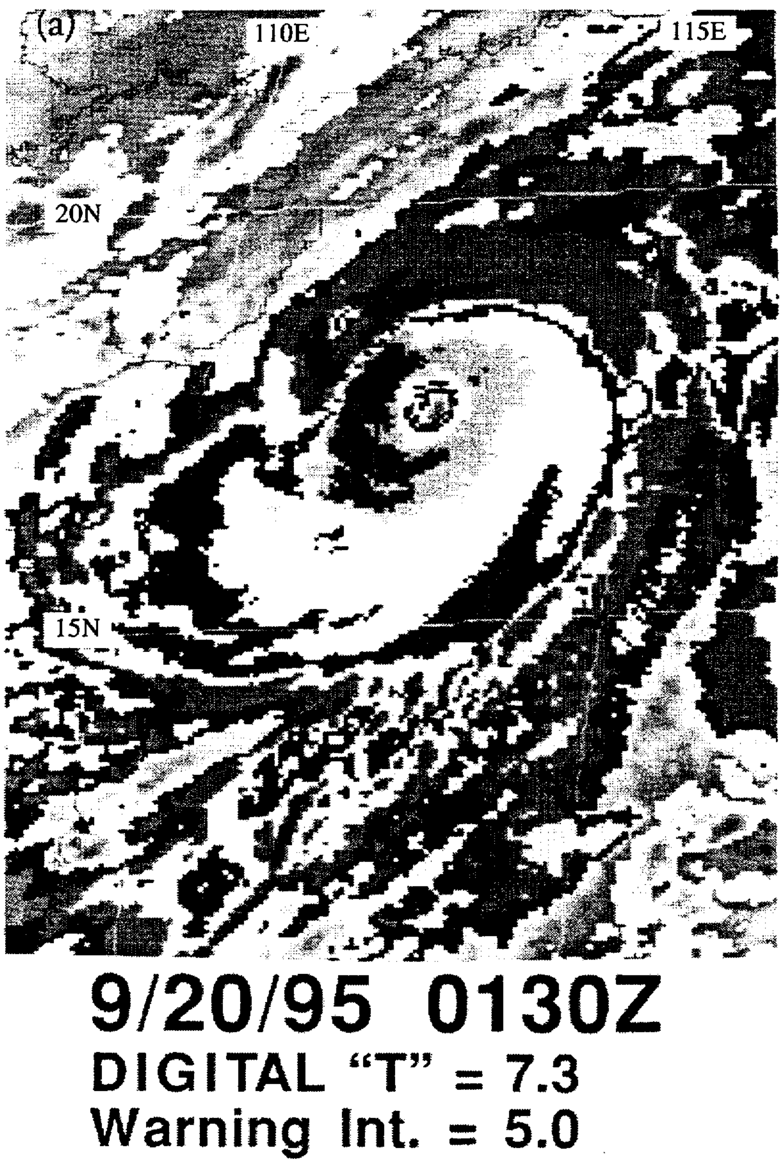
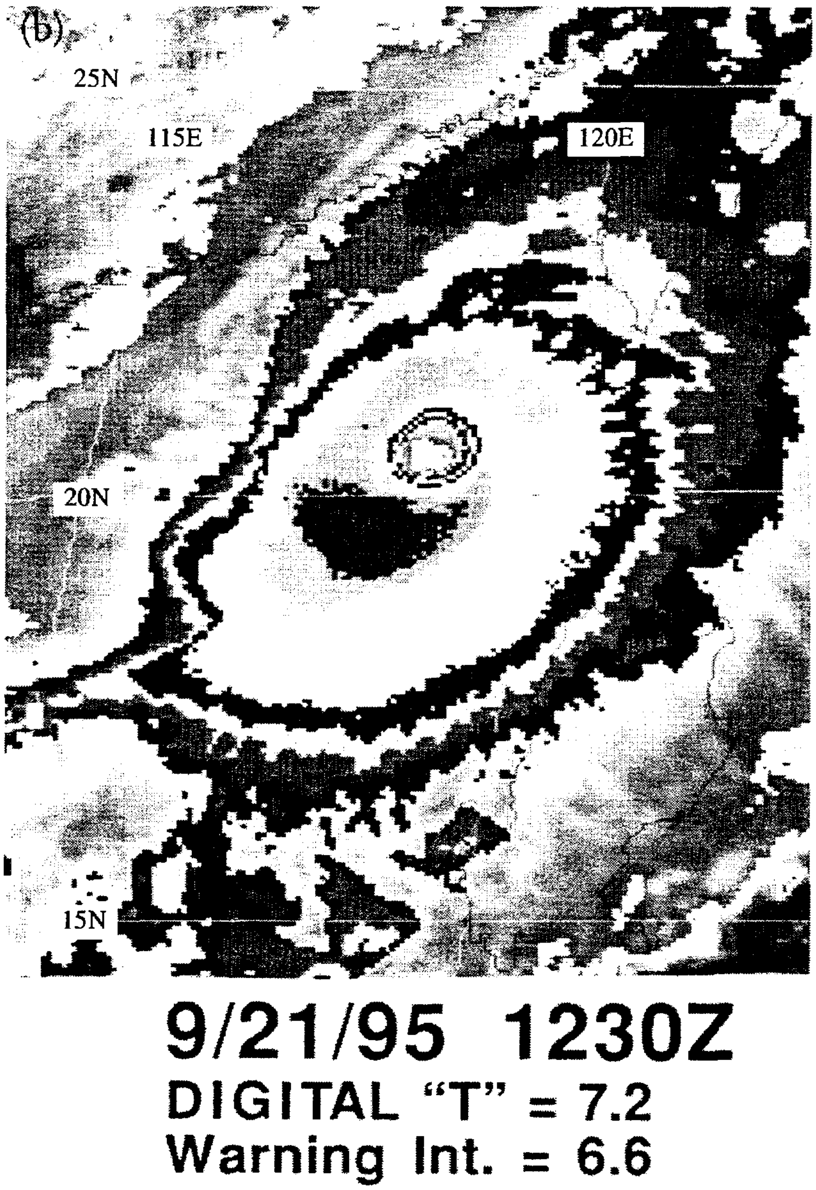


Figure 3-19-3 (a) Ryan reaches a DD number of 7.3 (200130Z September enhanced infrared GMS imagery).

That the warning intensity and best track intensity do not reflect the first rise of the DD to T 7.0 has several explanations. For one, the magnitude of the rise of 2.6 T numbers in five hours (from T 4.4 to T 7.0) exceeds the constraints allowed by Dvorak's technique. For another, given the large fluctuations of the intensity at this time (both up and down), the best-track intensity has been greatly smoothed. In the absence of ground-truth measurements, it will never be known if the intensity of Ryan was actually on the order of 140 kt (72 m/sec) at one, both, or neither of the places along its track where the DD exceeded T 7.0. If the DD numbers truly represented Ryan's intensity, there are two topics for further research: (1) how are the extremely rapid fluctuations of intensity, if they are genuine, to be incorporated into the warning? and, (2) how can the best-tracks, having had these rapid fluctuations removed, be used to study the processes governing what may prove to be real intensity fluctuations of the magnitude indicated by the DD numbers?

d. *Record tying wind gust*

At 220300Z September, Ryan passed near the Taiwanese island of Lanyu (WMO 46762) where a peak wind gust of 166 kt (85.3 m/sec) tied the strongest wind gust ever recorded in a typhoon. The other event occurred at Miyako Jima (WMO 47927) in September 1966 near the eye of Typhoon Cora.



(b) Ryan's DD number once again is greater than 7.0 (211230Z September enhanced infrared GMS imagery).

IV. IMPACT

Ryan affected the Philippines, Taiwan, and Japan. In the northern Philippines, at least three fishermen died when high waves generated by Ryan overturned their boats. Nearly 2,500 people were forced to flee when high surf washed into homes along the coast of Ilocos Norte. A Philippine Navy ship, the Badjao, was reported adrift and listing badly in high seas, and members of the crew of 54 were being rescued. Reports concerning the ultimate fate of this ship were not received by the JTWC. In Taiwan, two people were reported to have died in typhoon-related incidents, and wind damage cut electricity to 4,500 households in the central and southern parts of the island. Rail and air traffic was disrupted. Taipei's financial markets, government offices and schools were closed for one day. In southwestern Japan, heavy rain flooded more than 950 homes and high winds cut off electrical power to about 17,400 homes. More than 1,500 buildings were damaged by heavy rain. Three people were hurt by flying glass in Kagoshima, and two people were injured by flying objects on the southern island of Okinawa. Domestic air and rail service was disrupted. The highest wind gust on the main islands of Japan was 90 kt (46 m/sec) recorded at Hiroshima. Earlier, as Ryan passed through the southern Ryukyu islands, a minimum sea-level pressure of 956.5 mb accompanied by a peak gust of 123 kt (63.5 m/sec) was observed on Ishigaki Shima (WMO 47918).