TYPHOON YULE (15W) AND TROPICAL DEPRESSION 16W

I. HIGHLIGHTS

Yule and Tropical Depression (TD) 16W were two of ten tropical cyclones (TCs) during 1997 which formed east of 160E and south of 20N — within the "El Niño box" in Figure 3-5b. These two TCs existed simultaneously, and underwent a binary interaction resulting in their merger. After merger, the single resultant TC (retaining the name Yule) moved on a north-oriented track and passed close to Wake Island. When it reached the mid-latitudes, the system became a vigorous hybrid system possessing typhoon-force winds.

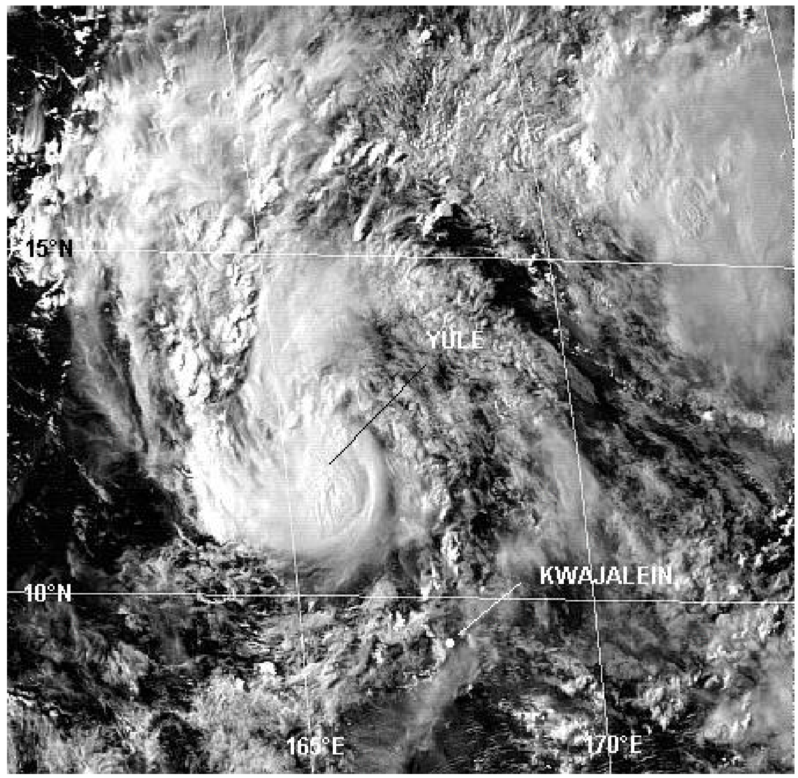


Figure 3-15/16-1 Yule becomes a tropical storm when located about 180 nm (330 km) northwest of Kwajalein (170533Z August visible GMS imagery). Properties of the centroid-relative motion help to reveal the nature of the interaction (which is not always apparent in the actual earth-relative tracks).

II. TRACK AND INTENSITY

During the middle of August, as the large-sized Winnie (14W) approached Okinawa and the east coast of China, low-level westerly winds persisted at low latitude from the Philippines eastward across Micronesia as far as the international date line (IDL). A monsoon cloud band (with some well-defined tropical upper tropospheric trough (TUTT) cells to its north) stretched from Winnie to the eastern end of the monsoon trough. Yule and TD 16W originated from tropical disturbances located at low latitude: Yule from a tropical disturbance west of the IDL in the Marshall Islands, and TD 16W from a tropical disturbance east of the IDL at low latitudes to the southwest of Hawaii.

a. Yule (15W)

Yule (the westernmost of the Yule-TD 16W pair) originated from a very poorly organized tropical disturbance in the monsoon trough which stretched at low latitude across the eastern Caroline and Marshall Island groups. It was first mentioned on the 090600Z August Significant Tropical Weather Advisory (ABPW) when satellite imagery indicated that a possible low-level circulation center was associated with an area of deep convection at very low latitude (3N) and just to the west of the IDL. For nearly a week, this tropical disturbance remained poorly organized and difficult to follow. Then, on 15 August, satellite imagery indicated deep convection had increased and the organization of this deep convection (and other cloud lines) had improved. The first Tropical Cyclone Formation Alert (TCFA) — of two — was issued at 150730Z August. Because of unusual north-northeastward motion of the low-level circulation center, a second TCFA was issued at 160030Z to reposition the alert box. The influence of monsoonal westerlies to its south, and the onset of a binary interaction with the pre-TD 16W tropical disturbance may have been responsible for this north-northeastward motion.

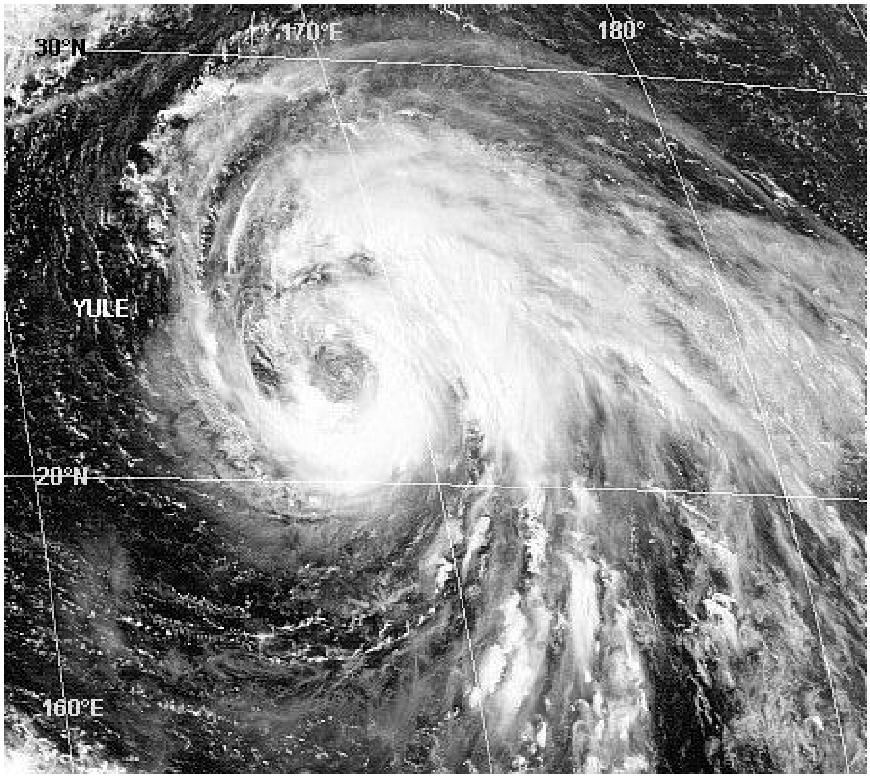


Figure 3-15/16-2 Possessing a large ragged eye, Yule briefly attains typhoon intensity (210333Z August visible GMS imagery).

When satellite intensity estimates reached 30 kt (15 m/sec), the first warning, valid at 161800Z, was issued on TD 15W. The warning indicated TD 15W would move northwest and intensify. Although the TD did intensify, it continued tracking to the north-northeast. On the second warning, valid at 170000Z, the warning acknowledged the north-northeast motion and forecast it to become northwest during the forecast period. Based on satellite intensity estimates of 35 kt (18 m/sec), TD 15W was upgraded to Tropical Storm Yule at 170600Z (Figure 3-15/16-1). Once again, the system, though moving north-northeast, was expected to turn to the northwest after 24 hours. By 180000Z, it was recognized that Yule was interacting with the newly formed TD 16W. The official forecast given on the warning valid at 180000Z was for Yule to move northeast for 24 hours and then turn toward the west and follow TD 16W. The alternate scenario of merger with TD 16W was mentioned on the Prognostic Reasoning message accompanying this warning.

At 190000Z, Yule and TD 16W merged (for more details on this merger, see the Discussion Section). The merger was asymmetric in that the low-level circulation center of TD 16W was horizontally sheared and swept into the intact circulation of Yule. Based on this analysis, JTWC decided the merged system would retain the name Yule. The system continued to move north-northeast on a long north-oriented track following the merger. The system also intensified, and briefly became a typhoon with a large ragged eye at 210600Z (Figure 3-15/16-2).

On 22 August, Yule approached a cloud band which was located to the east of an upper-level midlatitude trough and to the west of a blocking high. Entering this baroclinic cloud zone on 23 August, Yule was steered back toward the northwest. Acquiring extratropical characteristics, the final warning on Yule was issued valid at 230600Z. Instead of weakening, Yule intensified after it transitioned to an extratropical low. This was anticipated and was mentioned on the final warning. As a vigorous extratropical low (with some tropical characteristics) (see the Discussion Section) the system possessed typhoon-force winds of 65 kt (33 m/sec) during the period 231200Z to 251800Z. At nearly 50°N, the system finally entered weak westerly steering. It turned to the east after 241800Z. The system dropped below typhoon intensity after 251800Z as it drifted slowly eastward and weakened.

b. Tropical Depression 16W

Tropical Depression 16W (the easternmost of the Yule-TD 16W pair) originated from a poorly organized tropical disturbance which was first detected when it was east of the IDL. This tropical disturbance was first mentioned on the 130600Z August Significant Tropical Weather Advisory when synoptic data indicated a low-level cyclonic circulation was associated with a persistent but disorganized area of deep convection, and water vapor imagery indicated good upper-level outflow. The system was still east of the IDL at this time, but was heading westward. Moving slowly westward, the disturbance remained poorly organized for several days. It crossed the IDL and moved into JTWC's AOR on 15 August. On 17 August, the deep convection associated with this disturbance became better organized and a TCFA was issued at 172030Z. Located less than 450 nm (830 km) to the northeast of Tropical Storm Yule, the tropical disturbance which became TD 16W was already locked in a binary interaction with Yule (Figure 3-15/16-3). The first warning on TD 16W was issued valid at 180000Z based upon satellite intensity estimates of 25 kt (13 m/sec). Its binary interaction with Yule was entered as a comment on the warning message. Two scenarios of the outcome of the binary interaction of TD 16W with Yule were mentioned on the prognostic reasoning message for the first warning: the primary scenario was for TD 16W to slow as it moved westward, lose latitude, and increase its separation distance from Yule; an alternate scenario called for TD 16W to merge with Yule. The latter scenario is what occurred. The final warning was issued on TD 16W, valid at 190000Z, when it was apparent that the two systems were merging (Figure 3-15/16-4), and the sheared remains of TD 16W were being swept into the dominant circulation of Yule.

III. DISCUSSION

a. Tropical cyclone merger

In order to study the interaction between two TCs, it is best to produce a diagram illustrating the motion of each TC with respect to their centroid.

In the case of Yule and TD 16W, the centroid-relative motion (Figure 3-15/16-5) indicates little interaction at first, then a period of rapid approach followed by merger at 190000Z. The common features of TC interaction noted by Lander and Holland (1993) of mutual approach followed by a period of cyclonic orbit ending in merger are present, albeit somewhat distorted from their ideal model: the centroid relative motion of Yule and TD 16W is dominated by a rapid, zonally-

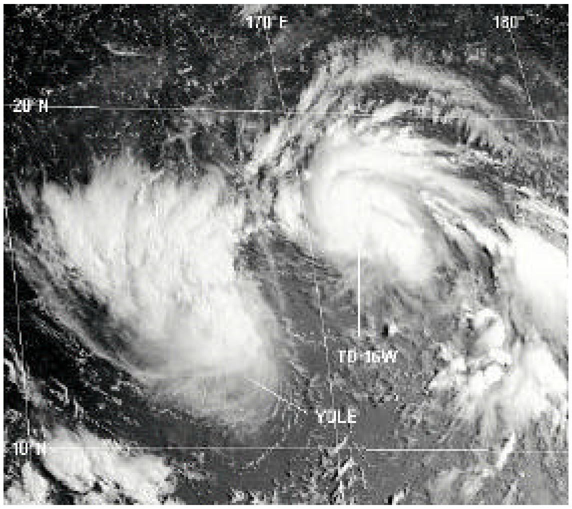


Figure 3-15/16-3 Yule and TD 16W are locked in a binary interaction that will end in merger (172133Z August visible GMS imagery).

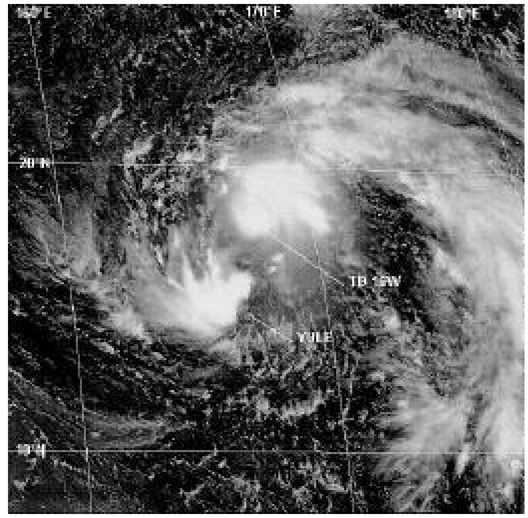


Figure 3-15/16-4 The merger of Yule and TD 16W is nearly complete (190133Z August visible GMS imagery).

oriented approach, with a curved cyclonic orbit noted only within 24 hours of merger. The location of these two TCs in a large-scale sheared flow (i.e., the monsoon trough with westerlies to its south and easterlies to its north) might lead one to expect such a departure from the idealized binary interaction of Lander and Holland. Such an effect is described by Dong and Neuman (1983).

In summary, Yule and TD 16W underwent a binary interaction ending in merger. Although satellite imagery was somewhat ambiguous, scatterometer data (Figure 3-15/16-6) clearly indicated that Yule was the dominant system during the merger and that TD 16W became horizontally sheared apart as the merger occurred.

b. The fate of a TC as it enters the midlatitudes

Establishing the defining characteristics of a TC is not a trivial exercise. For purposes of public warning, the nature of a TC has been simplified to a stratification based upon its intensity. Dvorak (1975, 1984) developed techniques for estimating the intensity of TCs from satellite imagery. The basic TC pattern types identified by Dvorak are: (1) the "shear" pattern; (2) the "curved band" pattern; the "central dense overcast" (CDO) pattern; and the "eye" pattern. These are the set of basic, or conventional, TC pattern types. At the highest taxonomic level, there are two categories of atmospheric storms of synoptic scale that possess a region of low pressure accompanied by a cyclonic wind circulation: the extratropical (ET) cyclone and the TC. Besides the basic differences of latitude of formation, the ET cyclone and the conventional TC differ in their primary source of energy and in their thermal structure. The ET cyclone derives the larger portion of its energy from potential energy present along the polar front of midlatitudes. The TC derives the bulk of its energy from the latent heat released by deep convection. The thermal structure of the ET cyclone is commonly said to be cold core, while that of the TC is said to be warm core. The term "cold core low", however, is actually an oxymoron, since lowered sea-level

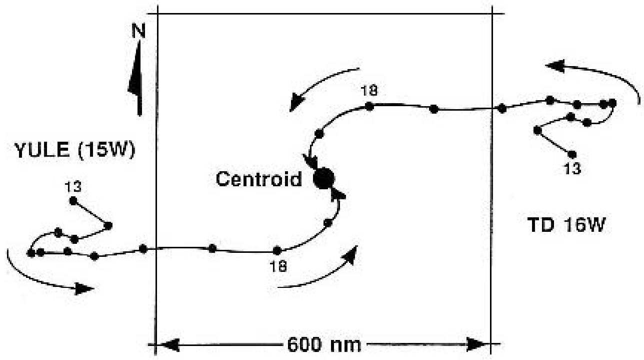


Figure 3-15/16-5 The centroid-relative motion of Yule and TD 16W. Black dots indicate positions at 12-hour intervals beginning on 130000Z August and ending at the merger location (large black dot) at 190000Z August. The square provides a length scale (as indicated) and the orientation of the cardinal directions.

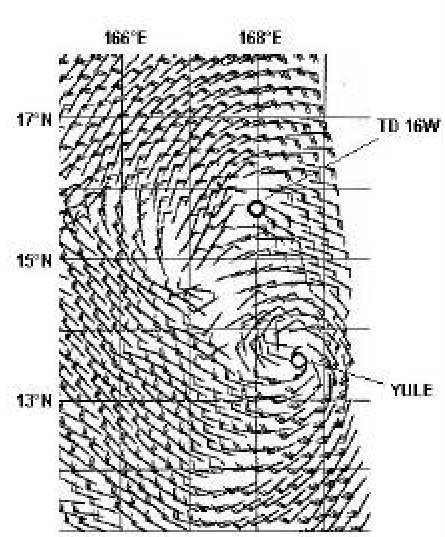


Figure 3-15/16-6 Scatterometer-derived marine surface wind speed and direction in a swath over both Yule and TD 16W (locations indicated). This scatterometer pass over these two TCs occurred approximately 12 hours prior to their merger. One can clearly see that the circulation of TD 16W is being sheared into the circulation of Yule (181131Z August ERS-2 scatterometer-derived marine surface wind vector).

pressure must, by hydrostatic considerations, be the result of an integrated density deficit in the atmospheric column above the area of lowered sea-level pressure. This density deficit is primarily the result of a warm anomaly somewhere in the atmospheric column. Therefore both the ET cyclone and the TC must possess warm cores; the true difference is in the location of the warm anomaly that results in the lowered sea-level pressure. In the mature ET cyclone, although much of the troposphere is generally colder than in the surrounding regions (hence its cold core designation), the tropopause is greatly lowered, and the stratosphere above the system is much warmer than in the surrounding regions. The lowered tropopause accompanied with the stratospheric warmth accounts for the lowered sea-level pressure in the mature ET cyclone. In the TC, the column density deficit due to higher core temperature occurs in the troposphere. In addition to tropospheric warmth above the TC low-pressure center, the TC differs from the typical ET cyclone in horizontal structure as well. The maximum winds in a mature TC are usually found very close to the center. The radius of maximum winds of even very intense TCs may be on the order of 10 km. The winds beyond the radius of maximum wind may fall off quickly. The maximum winds in an ET cyclone are usually displaced farther from the center than they are in the TC, and the highest winds are spread out across a larger area.

So far, it seems as if the differences between the ET cyclone and the conventional TC are so great that their differential diagnosis should be simple. This, however, is not the case. There exists, in nature, types of cyclones that possess characteristics of both ET cyclones and conventional TCs. For example, the subtropical cyclone (Hebert and Poteat 1975), the arctic hurricane (Businger and Baik 1991), the monsoon depression (Ramage 1971, and JTWC 1993), and the monsoon gyre (Lander 1994, Carr and Elsberry 1994). These types of cyclones have caused confusion and forecast problems for decades. Further complicating things is the fact that transitions among the types are possible. For example, at what point does a TC entering the midlatitudes become extratropical?

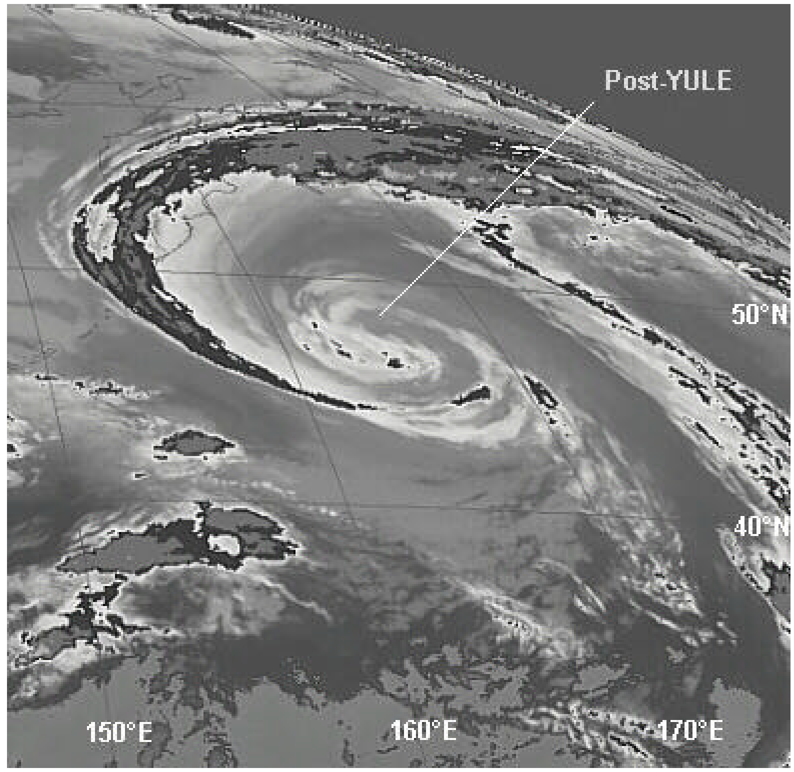
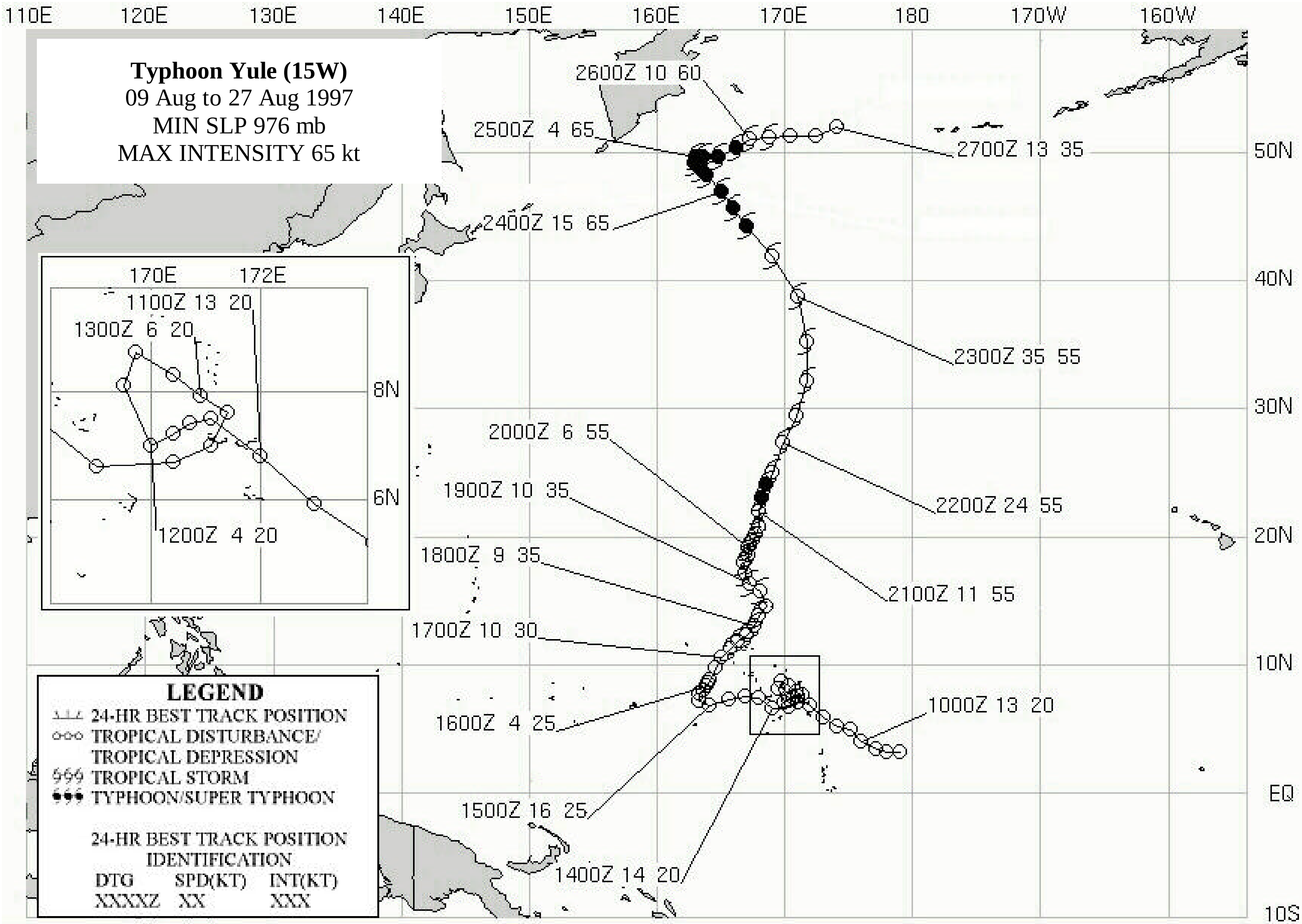


Figure 3-15/16-7 After Yule entered a baroclinic cloud band, it transformed into a vigorous extratropical low. In this enhanced infrared image, the transformed Yule is moving northwest toward the Kamchatka peninsula with maximum winds of typhoon intensity (282333Z August enhanced infrared GMS imagery). Enhancement curve is "BD" (Basic Dvorak).

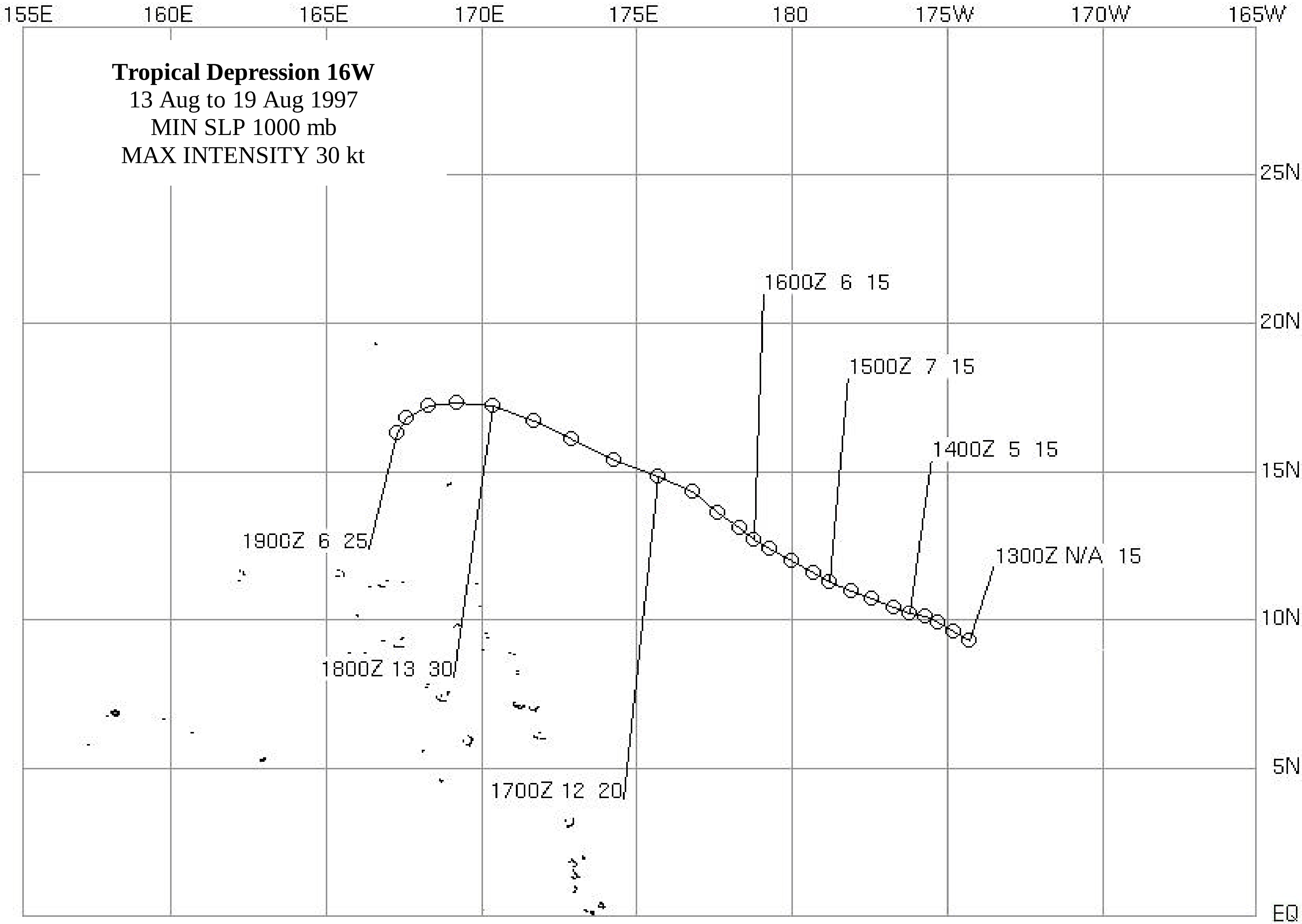
In the case of Yule, it transformed into a vigorous extratropical low (Figure 3-15/16-7) after it moved into the cloud band associated with the baroclinic zone located between a midlatitude upper-level trough and a blocking high. Yule, as a transforming — or transformed — low, intensified. Maximum wind speeds increased to typhoon intensity as the system moved northwest from 45°N to 50°N. Few TCs intensify as they become extratropical, nor is the extratropical low into which they transform generally more intense than the transforming system. Some TCs dissipate when they enter the midlatitudes. According to Harr (personal communication 1997) the fate of a TC which enters the midlatitudes may be governed primarily by what type of mid-latitude flow pattern is in place when the TC arrives there. Certainly the extratropical transition of TCs is a topic requiring much study.

IV IMPACT

Prior to becoming a typhoon, and as it moved to the north-northeast, Yule passed to the east of Wake Island. Peak winds on Wake (WMO 91245) reached 45 kt (23m/sec) sustained with a gust to 58 kt (30 m/sec) from the north at 201000Z August. Damage on Wake was light with one power pole down. A few palm and ironwood trees were also downed. No buildings were damaged. High surf pushed rocks onto the road going around the east end of the main runway, forcing the road's closure.



Typhoon Yule (15W)
09 Aug to 27 Aug 1997
MIN SLP 976 mb
MAX INTENSITY 65 kt
110E
120E
130E
140E
150E
160E
170E
180
170W
160W
50N
40N
30N
20N
10N
EQ
10S
2600Z 10 60
2500Z 4 65
2700Z 13 35
2400Z 15 65
2300Z 35 55
2000Z 6 55
2200Z 24 55
1900Z 10 35
2100Z 11 55
1800Z 9 35
1700Z 10 30
1000Z 13 20
1600Z 4 25
1500Z 16 25
1400Z 14 20
170E
172E
1100Z 13 20
1300Z 6 20
8N
6N
1200Z 4 20
LEGEND
24-HR BEST TRACK POSITION
TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON/SUPER TYPHOON
24-HR BEST TRACK POSITION
IDENTIFICATION
DTG
SPD(KT)
INT(KT)
XXXXZ
XX
XXX



Tropical Depression 16W
13 Aug to 19 Aug 1997
MIN SLP 1000 mb
MAX INTENSITY 30 kt
155E
160E
165E
170E
175E
180
175W
170W
165W
25N
20N
15N
10N
5N
EQ
1600Z 6 15
1500Z 7 15
1400Z 5 15
1300Z N/A 15
1900Z 6 25
1800Z 13 30
1700Z 12 20