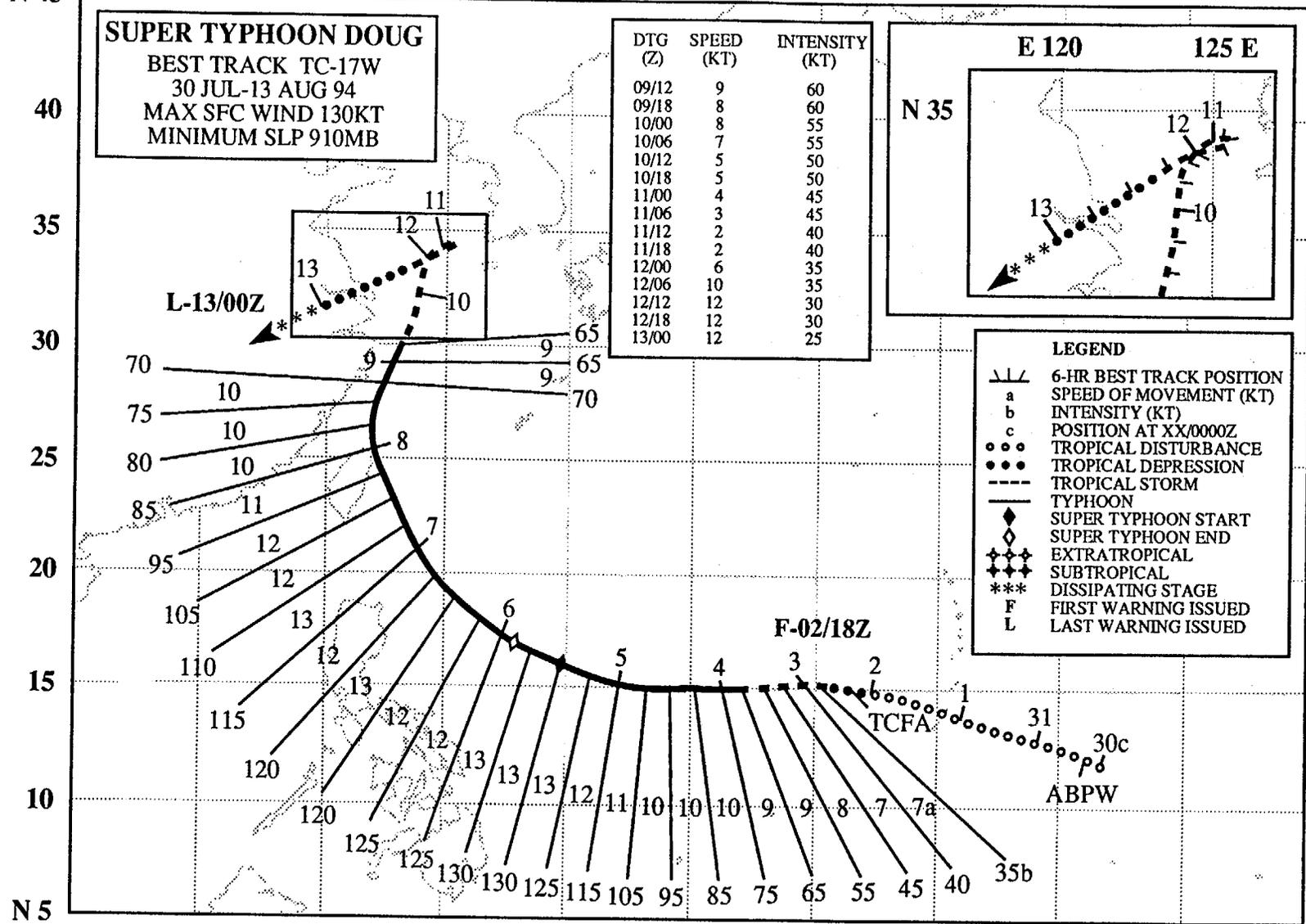
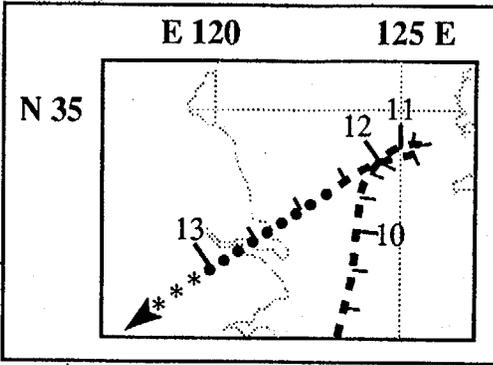


E 110 115 120 125 130 135 140 145 150 155 160 E



SUPER TYPHOON DOUG
 BEST TRACK TC-17W
 30 JUL-13 AUG 94
 MAX SFC WIND 130KT
 MINIMUM SLP 910MB

DTG (Z)	SPEED (KT)	INTENSITY (KT)
09/12	9	60
09/18	8	60
10/00	8	55
10/06	7	55
10/12	5	50
10/18	5	50
11/00	4	45
11/06	3	45
11/12	2	40
11/18	2	40
12/00	6	35
12/06	10	35
12/12	12	30
12/18	12	30
13/00	12	25



LEGEND

- Δ/Δ 6-HR BEST TRACK POSITION
- a SPEED OF MOVEMENT (KT)
- b INTENSITY (KT)
- c POSITION AT XX/0000Z
- TROPICAL DISTURBANCE
- TROPICAL DEPRESSION
- - - TROPICAL STORM
- TYPHOON
- ◆ SUPER TYPHOON START
- ◇ SUPER TYPHOON END
- ◆◆◆ EXTRATROPICAL
- ◆◆◆ SUBTROPICAL
- *** DISSIPATING STAGE
- F FIRST WARNING ISSUED
- L LAST WARNING ISSUED

94

N 5

SUPER TYPHOON DOUG (17W)

I. HIGHLIGHTS

Doug was the second of six tropical cyclones to attain super typhoon intensity in the western North Pacific basin during 1994. Doug exhibited some unusual structural characteristics: it had an abnormally large eye for a system of its intensity, which grew larger as the system intensified. Doug also went through an unusually long period of rapid intensification. Doug caused extensive damage and loss of life in Taiwan. After affecting Taiwan, Doug moved northward to Korea, creating the conditions which led to a Korean Air Lines A-300 crash landing at Cheju International Airport.

II. TRACK AND INTENSITY

The tropical disturbance that eventually became Super Typhoon Doug was first mentioned on the 300600Z July Significant Tropical Weather Advisory as an area of enhanced convection on the eastern end of a relatively weak monsoon trough that extended eastward across the southern Mariana Islands. After several episodes of normal diurnal fluctuations in deep convection (i.e., night maximum, day minimum), the disturbance began to maintain daytime convection. A Tropical Cyclone Formation Alert was issued at 020700Z August. The amount and organization of the convection increased during that night, and the first warning on Tropical Depression 17W was issued at 021800Z. At this time, the system was moving slowly westward at a speed of 7-8 kt (13-14 km/hr).

Doug began to increase its rate of intensification during the evening of 03 August, and reached typhoon intensity at 031800Z. For the following 48 hours, the system intensified at a steady rate of 10 kt (5 m/sec) / 6 hr or 40 kt (21 m/sec) per day. After reaching a peak intensity of 140 kt (72 m/sec) at 051800Z, Doug began to slowly weaken (Figure 3-17-1). Doug maintained an eye diameter of over 50 nm (95 km) from 051200Z to 060000Z. The Taiwanese radar at Hualien (46699) confirmed Doug's very large eye (Figure 3-17-2) when its intensity was estimated to be 125 kt (64 m/sec). A few hours later, Doug passed between the Taiwanese station of Suao (WMO 46706) and the Japanese station of Yonaguni-Shima (WMO 47912) (the southern-most of the Ryukyu islands). Table 3-17-1 shows the maximum wind speeds observed at these stations (based on the peak observed gust) as Doug passed between them over a 4-hour period. When the translation speed of 11 kt (20 km/hr) is factored into the winds at these stations to account for the asymmetry, the winds at the stations agree very well with each other and with the estimated sustained wind of 110 kt (57 m/sec) for Doug.

After passing very near the extreme northeastern tip of Taiwan (the western half of Doug's eye wall moved over land there), Doug turned to the north and then to the north-northeast. Doug weakened to tropical storm intensity after 090600Z when approximately 100 nm (185 km) southeast of Shanghai. At 091800Z, Doug produced sustained winds of 60 kt (31 m/sec) with a gust to 72 kt (37 m/sec) at Mosulpo, Cheju-Do (WMO 47187) when the storm was 180 nm (335 km) south-southwest of the island (Figure 3-17-3). The weakening system meandered toward the small islands at the southwestern tip of the Korean peninsula, and its convective organization and circulation weakened drastically. The remaining low-level circulation was redirected by low- to mid-level northeasterly flow on the southern periphery of a blocking high-pressure system over northern China. Doug, now downgraded to Tropical Depression 17W, then moved to the southwest across the Yellow Sea, and into mainland China. The final warning was issued at 120000Z as it dissipated northwest of Shanghai.

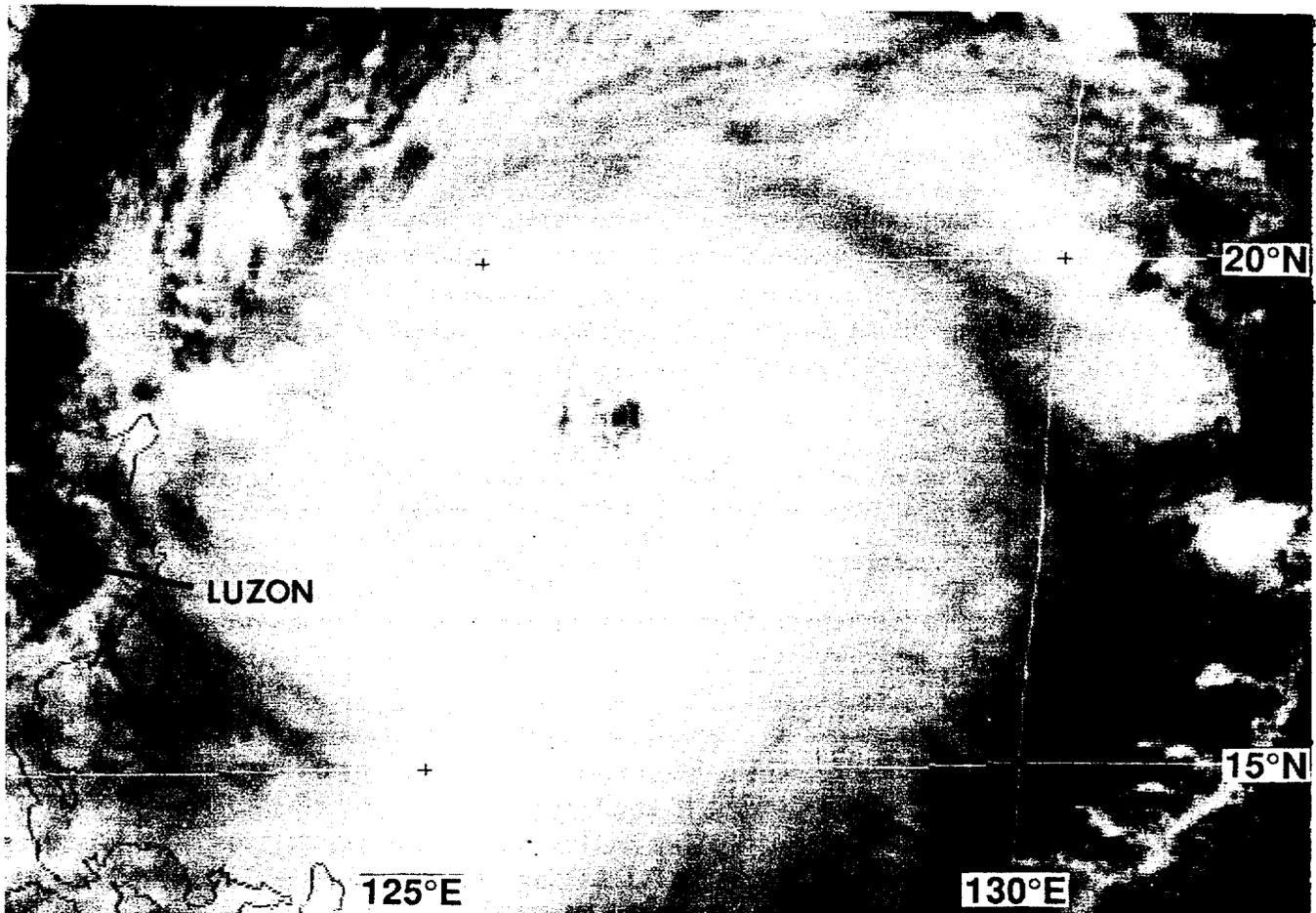


Figure 3-17-1 Super Typhoon Doug is located 240 nm (445 km) east of the northeast tip of Luzon just after reaching its 140 kt (72 m/sec) peak intensity (060530Z August visible GMS imagery).

III. DISCUSSION

There are two aspects of Doug's structure and evolution that were of special interest. The first was its long period of a high rate of intensification, and the second was the diameter of its eye that enlarged during intensification and shrunk during much of its weakening.

a. Unusual intensification rate of Doug.

Mundell (1990) indicates that most of the western North Pacific typhoons that reach super typhoon intensity undergo an episode of rapid intensification (central pressure falls > 42 mb/day (Holliday and Thompson 1979)), that usually lasts about 24 hours. From 030600Z to 051200Z, Doug increased in intensity at a rate of 10 kt (5 m/sec)/6 hr and peaked at 140 kt (72 m/sec) at 051800Z. The 24-hour falls of central pressure during much of Doug's intensifying phase gradually increased from the low 30s (mb per day) to values in the low 40s (mb per day) (Table 3-17-2). The periods 040600Z-050600Z and 041200Z-051200Z exhibited pressure falls of 42 mb and 43 mb respectively. The evolution of the intensities of Doug and Super Typhoon Yuri (1991), are representative of the minority of western North Pacific typhoons that intensify at rapid or near-rapid rates for unusually long periods (at least 48 hours). Characteristics common to both Doug and Super Typhoon Yuri (1991) include: very large size, an extended period of intensification rates near the lower threshold of the established criteria for rapid

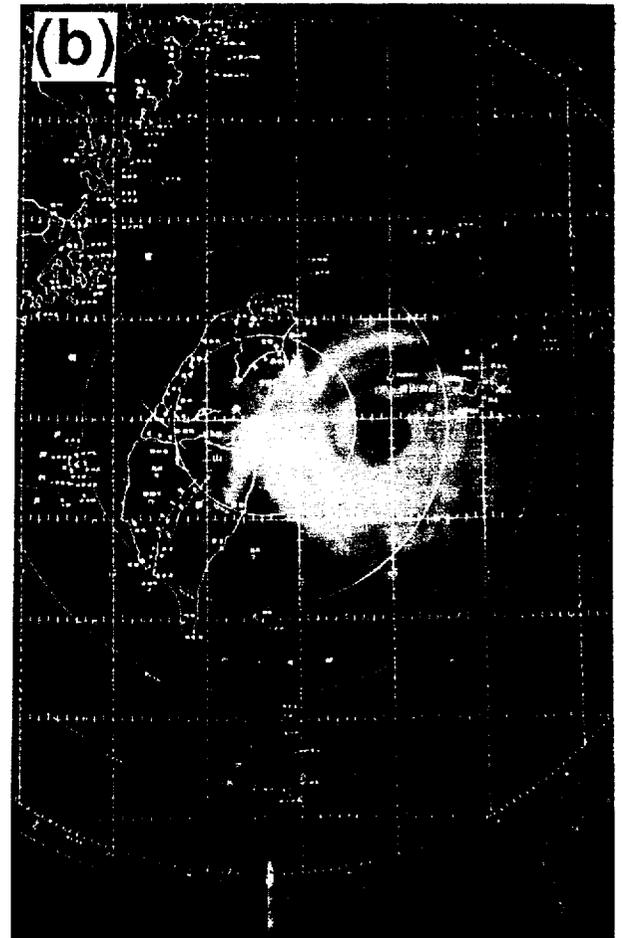


Figure 3-17-2 Two radar images of Typhoon Doug from the Hualien, Taiwan (WMO 46669) radar at: (a) 071000Z August , and (b) 071300Z August. In (a) the center of Doug's large eye was approximately 120 nm (220 km) southeast of the radar. In (b) the eye wall is nearing Yonaguni-Shima which recorded its peak gust of 136 kt (70.2 m/sec) at 131337Z. (Radar photos courtesy of the Central Weather Bureau, Taipei, Taiwan.)

intensification (> 42 mb per day), peak intensity in the 140-150 kt (75-77 m/sec) range, and relatively large eye diameters that bordered on the 45 nm (85 km) large-eye threshold set by Dvorak (1984) for purposes of capping intensity at 115 kt (59 m/sec).

b. Unusual eye behavior

Doug's eye diameter showed an unusual evolution. It increased in size from 11 to 47 nm (20 to 87 km) during Doug's intensification phase; expanded further to 57 nm (106 km) just after peaking; but then decreased in size as it weakened. Except for the six hours of expansion after reaching peak intensity, the trends were opposite to those normally observed, and lend further support to the premise that Doug did not undergo the typical process of rapid intensification, since the process normally involves shrinking of the eye.

The diameter of Doug's eye was abnormally large for a very intense typhoon, similar to the case of Super Typhoon Yuri (1991). The potential problem that occurs is with the rule in the technique that restricts the intensity of tropical cyclones for eye diameters of 45 nm (85 km) or greater: for large ragged eyes the intensity is capped at 90 kt (46 m/sec); for large well-defined eyes the intensity is capped at 115 kt (59 m/sec). It is likely that both Doug and Yuri had large eyes with accompanying

intensities in excess of the Dvorak caps. During Doug's intensification phase, the large eye was embedded in the deep (eye wall area) convection by average distances over 120 nm (220 km). These are extraordinarily large embedded distances. Also, the percentage of cloud within three degrees latitude (180 nm) of the center that was colder than -70°C remained relatively high, even during the weakening phase. Super typhoons like Doug and Yuri may represent a special case of very large tropical cyclones with large eyes and very wide eye walls that can exceed the intensity bounds which Dvorak placed on tropical cyclones with large eyes.

IV. IMPACT

Doug spent much of its life over open ocean. However, during its passage near Taiwan, it produced torrential rains and strong winds, blowing vehicles off of highways. At least 19 people lost their lives, 45 were injured, and damage in Taiwan was estimated to be in excess of US \$110 million. Destruction must also have been heavy in the southwestern Ryukyu islands, although no reports were received. The anemometer at Yonaguni-Shima (WMO 47912) failed when wind gusts reached 136 kt (70.2 m/sec). Doug also caused considerable flooding in China, but reports of damage were not received. As the system approached Korea, it created poor weather and gusty winds on Cheju-Do. A Korean Air Lines A-300 jet trying to land at Cheju International Airport (WMO 47182), buffeted by 40 kt (20 m/sec) winds, skidded on the wet runway into a barrier. Fortunately, all 160 passengers and crew got off the aircraft before it was engulfed in flames.

Table 3-17-1 Observed maximum winds at Suao, Taiwan (WMO 46706) and Yonaguni-Shima, Japan (WMO 47912), as Typhoon Doug passed between the two stations. Peak gusts are observed, but sustained winds are one-minute average based on 0.88 of peak gust (Atkinson 1974). "Distance" refers to the distance from the station to the typhoon center at the time of peak wind. "COR Vmax" shows what the expected peak gust would be when corrected for the 11 kt (20 km/hr) translation speed of Doug. "BT" is the best-track intensity at the time of the peak wind at each site.

Location	Date / Time (Z)	Peak Wind (kt)	Distance (nm)	COR Vmax (kt)	BT (kt)
Suao	071657	95G115	25	126	110
Yonaguni	071337	110G136	30	125	115

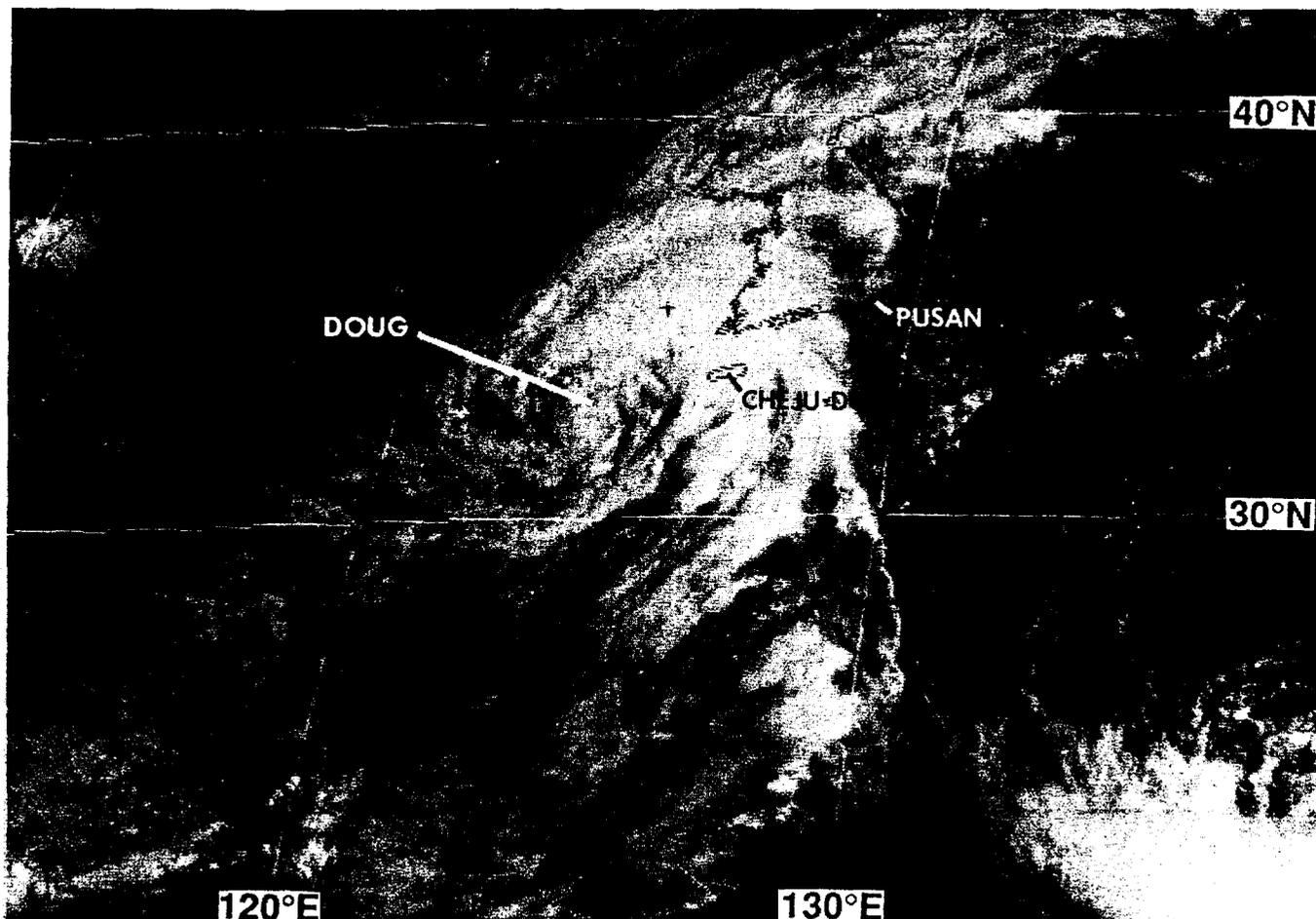


Figure 3-17-3 Tropical Storm Doug at 55 kt (28 m/sec) intensity as it moves toward Korea. Approximately six hours prior to picture time (091800Z), Cheju-Do (WMO 47187) received its peak wind gust of 72 kt (37 m/sec) (092331Z August visible GMS imagery).

Table 3-17-2 Twenty-four hour pressure changes for each six-hour warning period prior to Doug's maximum intensity, beginning at 030600Z and ending at 050600Z.

Date/Time Period	Wind Change (kt)	Pressure change (mb)
030600 - 040600	+40 (45 - 85)	-33 (991 - 958)
031200 - 041200	+40 (55 - 95)	-35 (984 - 949)
031800 - 041800	+40 (65 - 105)	-38 (976 - 938)
040000 - 050000	+40 (75 - 115)	-41 (968 - 927)
040600 - 050600	+40 (85 - 125)	-42 (958 - 916)
041200 - 051200	+40 (95 - 135)	-43 (949 - 906)
041800 - 051800	+35 (105 - 140)	-40 (938 - 898)
050000 - 060000	+25 (115 - 140)	-29 (927 - 898)
050600 - 060600	+15 (125 - 140)	-18 (916 - 898)