

TYPHOON MARK (14W)

I. HIGHLIGHTS

Forming at a relatively high latitude, Mark was a very small sized tropical cyclone that moved north-eastward for most of its track. While moving in excess of 20 kt (37 km/hr) toward the polar front, and while passing over increasingly cooler sea surface temperatures, Mark acquired a well-defined eye and reached a peak estimated intensity of 95 kt (49m/sec) as it tracked northeastward from 35°N to 37°N. The relatively high peak intensity attained by Mark was somewhat of a surprise, given the synoptic situation.

II. TRACK AND INTENSITY

The tropical disturbance that became Mark was first detected on the northeastern side of a westward moving TUTT cell. Visible satellite imagery obtained shortly after sunrise on 30 August showed cyclonically curved low-level cloud lines wrapping beneath an area of deep convection. This disturbance was located north-northwest of Minami Tori Shima in a data-poor region in the subtropics of the western North Pacific. Based upon the aforementioned indications on satellite imagery of the development of a low-level circulation center associated with this tropical disturbance, a Tropical Cyclone Formation Alert was issued at 292200Z August. Shortly thereafter, at 300000Z August, the first warning was issued. The prognostic reasoning message accompanying this first warning stated:

“Tropical Depression 14W has formed north of Minami Tori Shima . . . the initial disturbance was spawned from a tropical upper tropospheric trough (TUTT) cell . . . [deep] convection [has] developed rapidly over an 18 hour period.”

Additional comments included:

“Due to the relatively high latitude at which 14W formed, and its proximity to the baroclinic zone to the northeast, 14W is not expected to intensify much past minimal tropical storm [intensity] before it undergoes extratropical transition.”

Tropical depression 14W was upgraded to Tropical Storm Mark at 300600Z August based upon indications from satellite imagery of further intensification. Mark was already moving to the northeast at a relatively high latitude (approximately 30°N), and significant further intensification was not anticipated. On the evening of 31 August, a small ragged eye appeared within the small CDO, and Mark was upgraded to a Typhoon at 310600Z August. Mark was now north of 30°N and moving northeastward at 10 kt. A frontal system was approaching from the west, and JTWC forecasters expected Mark to accelerate, interact with the approaching front, and undergo extratropical transition within 36 to 48 hours.

During the subsequent 24 hours, Mark continued to move northeastward while remaining ahead of the approaching front. In a surprising structural evolution, during the morning of 01 September, the very small sized Typhoon Mark developed a small well-defined eye (Figure 3-14-1a,b). During the evening and night of 01 September, the cloud-top temperatures of the wall cloud surrounding Mark's well-defined eye cooled, and the estimated intensity peaked at 95 kt (49 m/sec) at 010600Z September. While Mark retained its peak intensity during the period 010600Z to 011800Z September, its speed of translation increased from 20 kt to 31 kt (37 to 57 km/hr). This rapid speed of translation delayed Mark's entrainment into the frontal system approaching from the west. On 02 September, the typhoon began to experience vertical wind shear from the west, and Mark was downgraded to a tropical storm late in the day. At 021200Z September, the JTWC issued the final warning on Tropical Storm Mark based upon its acquisition of extratropical characteristics.

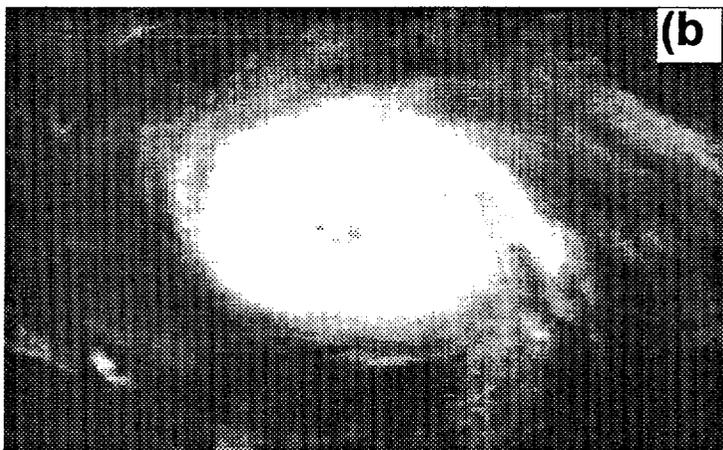
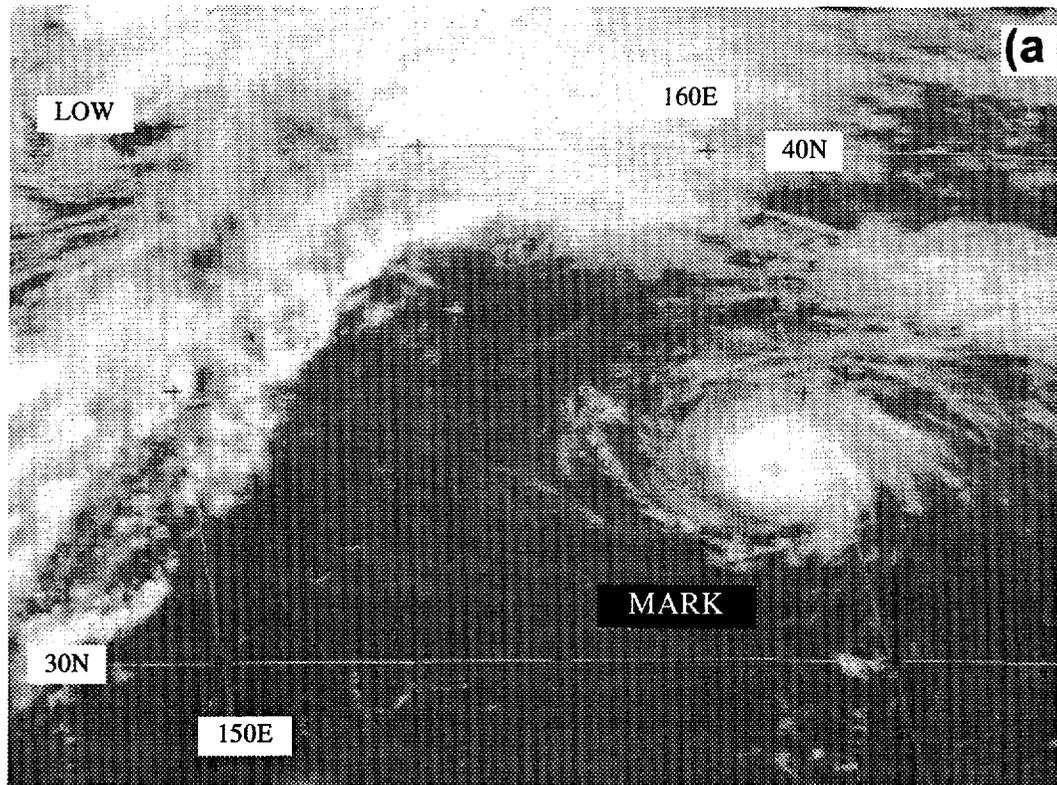


Figure 3-14-1 (a) Typhoon Mark intensifies as it moves rapidly northeastward in the warm sector of an approaching mid-latitude low-pressure system. (b) An expanded image of Typhoon Mark at the same picture time as in (a). (Both images are 010031Z September visible GMS imagery).

III. DISCUSSION

a. *Formation and development at high latitude*

Relatively few tropical cyclones (TCs) form in the western North Pacific poleward of 25°N — during the 21-year period 1970 to 1990 only twenty-four of 585 tropical cyclones (4%) that formed in the western North Pacific first attained 25 kt (12 m/sec) intensity at, or north, of 25°N. Mark first attained 25 kt intensity at 27°N. It became a tropical storm at 29°N, a typhoon at 31°N, and reached its peak intensity of 95 kt (49 m/sec) at 35°N. The sea surface temperature at the point where Mark's intensity peaked was approximately 24°C (Figure 3-14-2).

The synoptic conditions under which TCs form at very high latitude include:

- 1) formation in the mei-yu front,

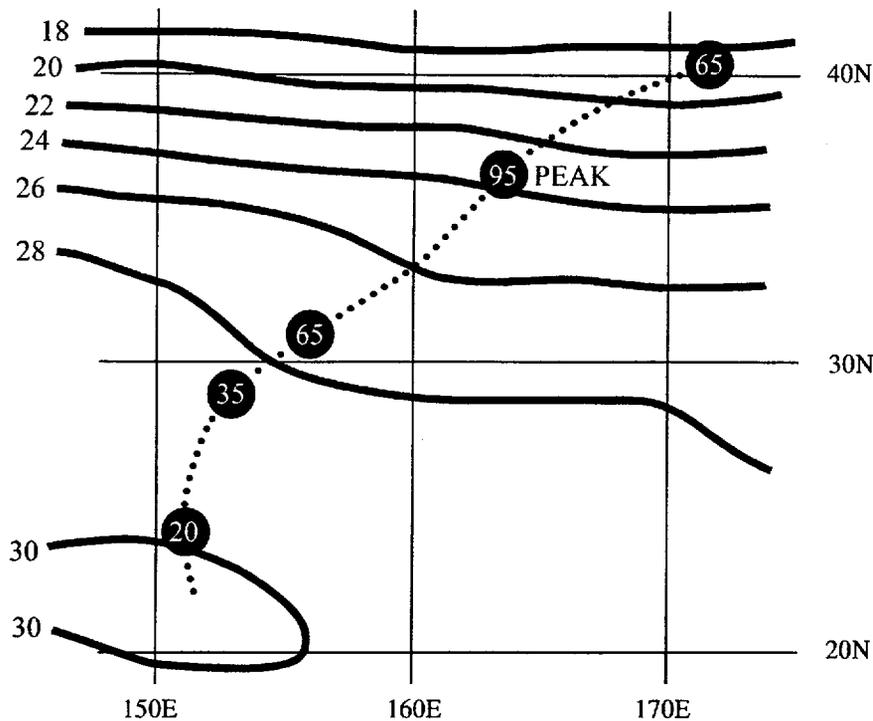


Figure 3-14-2 Selected threshold intensities (in kt) of Mark (white numbers within the black circles) along Mark's track (dotted line) superimposed on the NOGAPS sea surface temperature analysis ($^{\circ}\text{C}$) of 02 September.

- 2) formation at the northeastern reaches of a reverse-oriented monsoon trough,
- 3) formation in association with a TUTT cell, and
- 4) formation at the base of a mid-latitude trough.

Mark formed in association with a TUTT cell. On 28 August, the tropical disturbance that became Mark was located in the northeastern quadrant of a TUTT cell that was centered at about 20°N over the Mariana Islands. The pre-Mark disturbance moved northward, intensified and approached the polar frontal boundary which then stretched east-west along approximately 35°N . Mark reached its peak intensity while traveling northeastward at a relatively high speed of translation, and while in the warm sector of an eastward moving mid-latitude low-pressure system (Figure 3-14-1a).

b. *Small size*

Like most TCs that form at high latitude in association with TUTT cells, Mark was a very small tropical cyclone. The diameter of its cloud shield was about 100 nm (185 km), and it encompassed a very small eye whose diameter fluctuated within a range from 5 (9 km) to 10 nm (18 km) on satellite imagery. As with many very small tropical cyclones, the intensity forecasts were quite poor: on the first eight warnings (issued at six-hour intervals from 300000Z August to 311800Z August), the 24-hour intensity was under-forecast by anywhere from 20 to 40 kt (21 m/sec); and, the 48-hour intensity was under-forecast by as much as 65 kt (33 m/sec).

IV. IMPACT

For its entire track, Mark remained far at sea, and no reports of significant damage were received.