

SUPER TYPHOON KEITH (29W)

I. HIGHLIGHTS

The tenth of eleven tropical cyclones (TCs) to attain super typhoon intensity in the western North Pacific during 1997, Keith formed at low latitudes in the Marshall Islands. It was one of ten TCs which formed east of 160E and south of 20N — within the "El Niño" box in Figure 3-3a. Keith was a recurving TC which passed between the Islands of Rota and Tinian (only 50 nm (93 km) apart) on the west-bound leg of its recurving track. NEXRAD imagery from Guam indicated the eye wall cloud of Keith never touched land as it threaded the narrow channel between these two islands. As such, the Mariana Islands were spared the full force of Keith (see the Impacts Section). Keith's compact wind and cloud structure were revealed by Guam's NEXRAD (see the Discussion Section). Equatorial westerly winds bounded by twin near-equatorial troughs preceded the formation of Keith and a Southern Hemisphere twin, TC 03P 98.

II. TRACK AND INTENSITY

During most of October, low-latitude, low-level, westerly winds blew along the equator from approximately 150E and eastward across the international dateline to near 170W. Twin near-equatorial troughs (one in the Northern Hemisphere, another in the Southern Hemisphere) bounded these westerly winds and most of the region's deep convection. During the first week of October, deep convection increased between the twin troughs in association with an equatorial westerly wind burst; and then, during the second week of October, it decreased as three TCs emerged from the twin near-equatorial trough synoptic flow pattern: Ivan (27W) and Joan (28W) in the Northern Hemisphere, and a twin, Lusi (02P98), in the Southern Hemisphere.

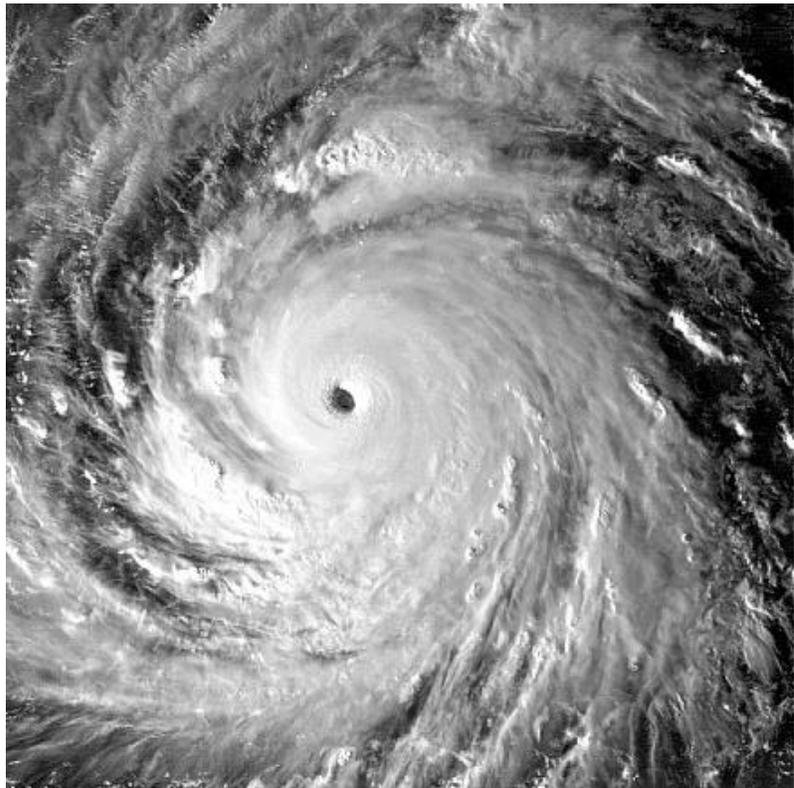


Figure 3-29-1 A low evening sun angle brings out the relief in Keith's clouds. From the satellite perspective, it is hard to imagine that the eye wall cloud, and the extreme winds remained over water between the relatively closely spaced islands of the Marianas (020632Z November visible GMS imagery).

When Ivan (27W) and Joan (28W) began to recurve, deep convection once again increased in the aforementioned region, and two more TCs emerged from the twin near-equatorial trough flow pattern: Keith developed in the Marshall Islands, and a Southern Hemisphere twin, TC 03P98, moved south between Fiji and the Islands of Vanuatu. An area of deep convection located in the Marshall Islands was, for several days (beginning at 181730Z October), mentioned on the Significant Tropical Weather Advisory (ABPW). Deep convection (in varying amounts) persisted in the Marshalls, and in postanalysis, the area of deep convection that could be unambiguously linked to the low-level circulation center which became Keith was mentioned on the 230600Z ABPW. This area of deep convection moved slowly westward and remained poorly organized for three days. On 26 October, the organization of the deep convection improved. Water-vapor derived winds showed anticyclonic outflow had become more symmetrical over the system, and synoptic data from Kwajalein and Majuro indicated falling sea-level pressure within a persistent low-level circulation. These factors prompted JTWC to issue a Tropical Cyclone Formation Alert (TCFA) at 260500Z October. During the valid period of this TCFA, the system failed to develop into a significant TC. Since conditions still appeared to be favorable for the formation of a significant TC, a second TCFA was issued at 270500Z. During the night of 27 October, the deep convection became better organized, and based on satellite intensity estimates of 25 kt (13 m/sec), the disturbance was upgraded to Tropical Depression (TD) 29W on the warning valid at 271800Z. On the morning of 28 October, satellite intensity estimates increased to 35 kt (18 m/sec) and TD 29W was upgraded to Tropical Storm Keith at 280000Z. At this time, Keith was anticipated to develop at a normal rate of one T-number per day, and move toward the west-northwest.

For two days, beginning on 280000Z, Keith intensified slowly, increasing by only one T-number (i.e., from 35 kt (18 m/sec) at 280000Z to 55 kt (28 m/sec) at 300000Z). Then, like Ivan (27W) and Joan (28W) before it, Keith underwent a period of rapid intensification which was unforeseen. By 310000Z, Keith had intensified to 105 kt (54 m/sec). The equivalent pressure drop of 43 mb in 24 hours (for an average of 1.79 mb/hr) qualifies as a case of rapid deepening (Holliday and Thompson 1979). Keith continued to intensify rapidly until 011200Z November when it reached its peak of 155 kt (80 m/sec).

When it reached its peak intensity, Keith was moving west-northwest and was just over a day away from passing through the Mariana Island chain. During the 6 hour period 020600Z-021200Z November, Keith passed between the Islands of Rota and Tinian. Though weakened slightly from its peak, it was still a powerful 140 kt (72 m/sec) super typhoon (Figure 3-29-1) as it made its closest approach to these islands. Fortunately, as Guam's NEXRAD showed, the eye wall cloud of Keith remained over water, and no island experienced the full force of Keith, although some damage was reported (see the Discussion and the Impact Sections).

Keith remained at or above super typhoon intensity for three-and-one-half days (311800Z October to 030600Z November), dropped to 125 kt (64 m/sec) for two warning times at 031200Z and 031800Z, and became a super typhoon briefly again for two warning times at 040000Z and 040600Z. Then, late on 04 November, Keith slowed, weakened, and began to recurve. For two days (05-06 November), Keith moved slowly northeastward and continued to weaken. On 07

November, Keith turned more eastward, weakened further, and began its acceleration in the westerly flow to the north of the subtropical ridge. The final warning was issued, valid at 0812200Z, as Keith raced east-northeastward with a translation speed of 45 kt (23 m/sec) and became extratropical.

III. DISCUSSION

a. Keith's structure as revealed by Guam's NEXRAD

As Keith moved between the islands of Rota and Tinian on 02 November, it passed well within the range of Guam's NEXRAD. The most striking aspect of the NEXRAD data was the compact structure of the TC core. A 5-nm-wide (9-km-wide) eye wall cloud surrounded a 20-nm-wide (37-km-wide) eye at beam altitude of approximately 7,000 ft (2134 m) (Figure 3-29-2a). The base velocity product (Figure 3-29-2b) showed that winds in excess of 100 kt were occurring in the eye wall cloud. Peak NEXRAD-observed winds of 135-140 kt (69-72 m/sec) were found in the eye wall cloud; and, as a velocity cross section (Figure 3-29-2c) revealed, these highest wind speeds were found at the lowest altitudes of the cross section.

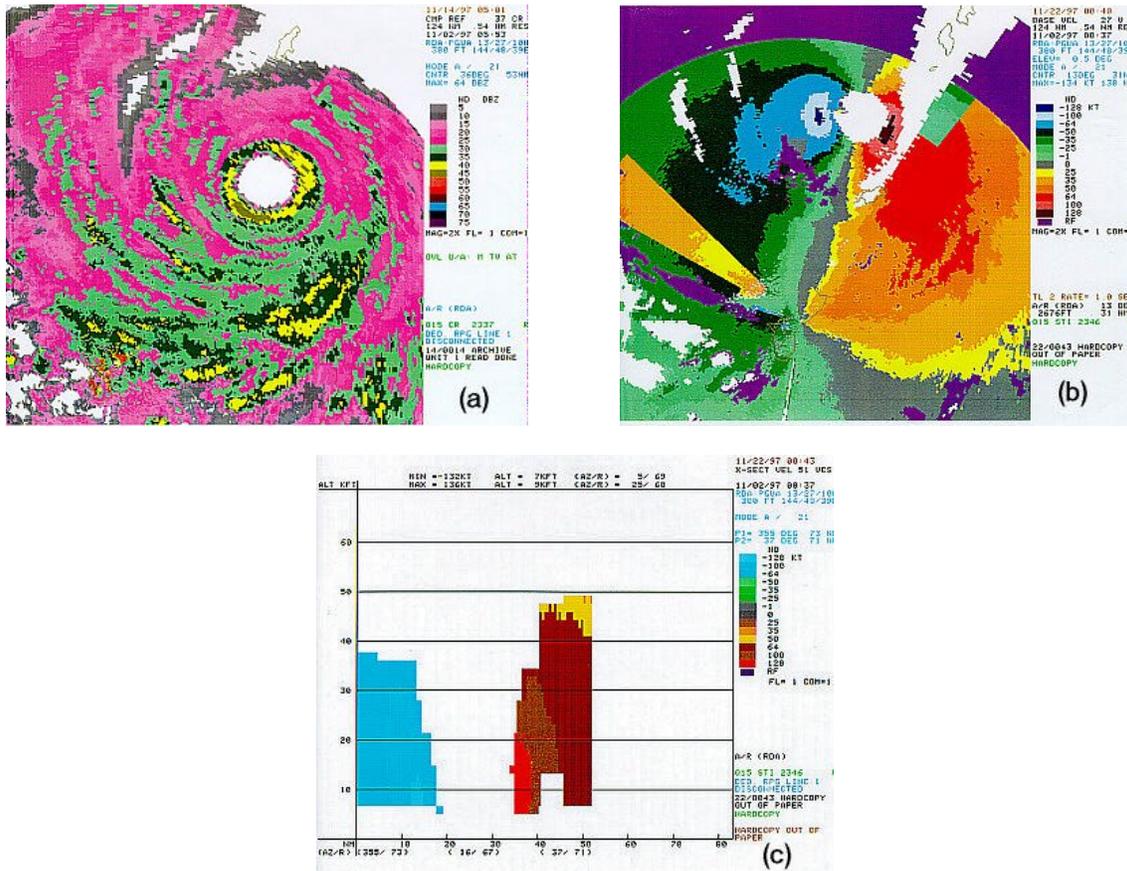


Figure 3-29-2 (a) Keith's eye and eye wall cloud pass between the islands of Rota and Tinian (020553Z November NEXRAD Composite Reflectivity product). (b) A dramatic couplet of high inbound wind and high outbound winds within Keith's eye wall cloud is revealed by the NEXRAD (020837Z November NEXRAD Base Velocity product). Note the narrow width of the region of inbound and outbound winds of 128 kt (66 m/sec) or

greater. (c) Typical of the structure of warm-core vortices, the peak azimuthal flow is at the lowest levels of the vortex and decreases with height (020837Z November NEXRAD velocity cross section in an east-west slice through Keith's eye).

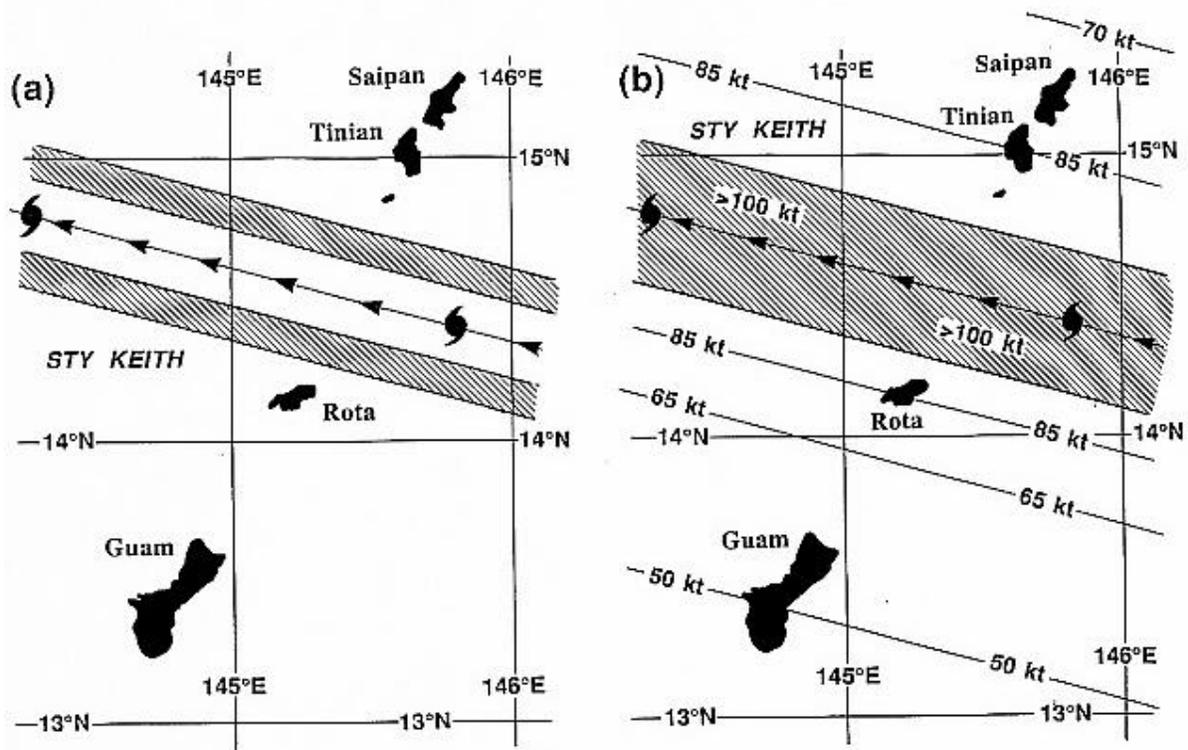


Figure 3-29-3 (a) The path of Keith's eye through the Marianas as depicted by Guam's NEXRAD. The typhoon symbols indicate the position of Keith at 020600Z and 021200Z November. The path of the 5-nm-wide (9-km-wide) eye wall cloud is indicated by the hatched swaths. (b) The wind distribution of Keith as it passed through the Marianas based upon the NEXRAD Base Velocity product, and from synoptic data from Guam and Saipan. Winds of 100 kt (51 m/sec) or greater occurred in Keith's eye wall cloud. An asymmetry in the wind field has been introduced by considering Keith's 15-kt (28-km/hr) speed of translation.

The NEXRAD data showed that the eye-wall cloud of Keith did not touch any land as it passed between islands only 50 nm (93 km) apart (Figure 3-29-3a). Also, the base velocity measurements (coupled with synoptic reports from the islands) indicated that sustained winds in excess of 100 kt (51 m/sec) most likely did not occur on any of the islands (Figure 3-29-3b), but passed between them in the same 30-nm-wide (56-km-wide) swath as traversed by the eye wall cloud. The super typhoon pictured in Figure 3-29-1 passed through the Marianas and left the islands relatively untouched. On a clear day, free of salt haze, each of the Mariana Islands can be viewed from the shores of its immediate neighbors. It is hard to imagine, viewing the neighbor islands from the shore, that the eye, eye wall cloud, and the destructive winds of a super typhoon can all fit over the waters of the channel and largely spare the islands. In Paka's (05C) summary, this is borne out even more dramatically. As Paka passed over the northern half of the island of Guam, wind gusts of approximately 150 kt (77 m/sec) and major damage to vegetation and structures were experienced on the parts of the island where the eye wall cloud passed, while

only 10 nm (20 km) to the south, outside of the eye wall cloud, gusts reached only to minimal typhoon intensity and little damage to structures or vegetation was noted.

b. Keith's Digital Dvorak (DD) time series

Keith was one of several typhoons during 1997 for which a time series of its hourly DD-numbers (Figure 3-29-4) was calculated. Keith's DD-numbers are unusually well-behaved. During the two-day period 010000Z-030000Z November, the DD-numbers fluctuated only a few tenths above and below T 7.0. The eye was obscured by cirrus on 03 November (possibly as a manifestation of an eyewall replacement cycle), but then reappeared and became well-defined on 04 November as Keith neared its point of recurvature. Keith's DD time series shows little or no diurnal variation, which for some typhoons is quite prominent. Why some typhoons show a strong diurnal signal in the DD-numbers and why others do not is an unsolved mystery.

c. Asymmetries in pressure fluctuations on microbarographic recordings

In the microbarograph trace of the pressure recorded at JTWC as Keith passed to the north of the station (Figure 3-29-5), an asymmetry is observed in the small fluctuations of pressure which are superimposed on the general longer period trends: the fall of pressure as the typhoon approaches is smoother than the rise of pressure after the TC is moving away from the station. This feature is presented here, because it also occurs in pressure traces from two different locations recorded as Super Typhoon Paka (05C) passed over Guam. While only a curiosity with perhaps a simple explanation, its repeated occurrence in two different typhoons, and at two separate locations during the same typhoon, raises the level of interest.

IV. IMPACT

Despite its track between the islands, Keith caused damage on Rota, Tinian, and Saipan in the Marianas. Red Cross officials reported that at least 790 houses were destroyed or damaged on these islands. About 15 power poles were reported downed on Saipan, and 20 on Tinian. Wind gusts of 95 kt (49 m/sec) were reported at Saipan's International Airport. Sea-level pressures fell to 964 mb on Rota and to 977 mb on Saipan. On Guam, little damage occurred, but power was knocked out to the entire island for nearly a day. Wind gusts reached 67 kt (35 m/sec) and nearly 6 inches of rain fell on parts of the island. Very large surf from the east deposited rubble on the coastal road on the southeast side of the island, forcing officials to close the road.

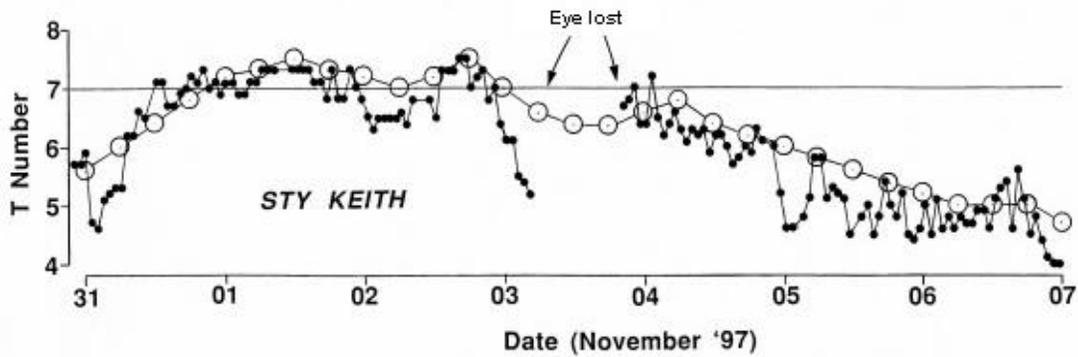


Figure 3-29-4 A time series of Keith's hourly DD numbers (small black dots) compared with the best-track intensity (open circles).

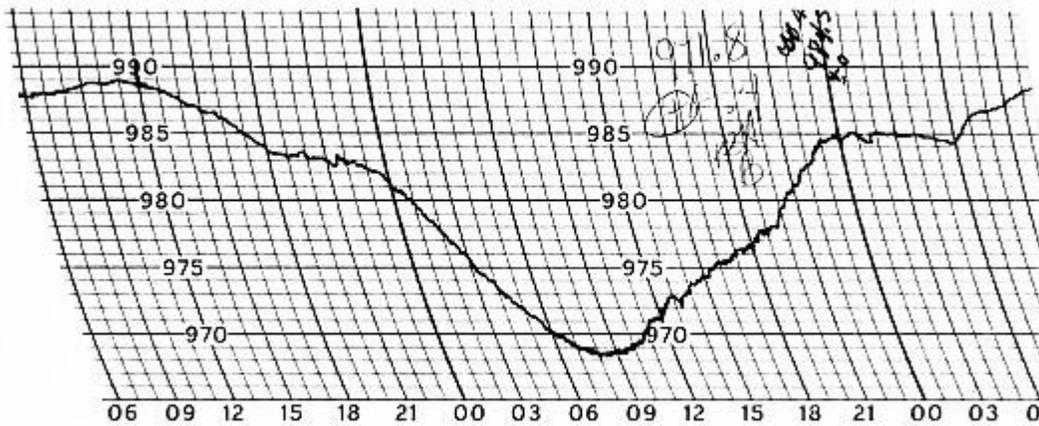


Figure 3-29-5 Microbarograph trace of the station pressure (in millibars) at the JTWC as Keith passed to the north of the island. At the 600-ft (183-m) elevation of the station approximately 18.5 mb must be added to obtain an estimate of the SLP. Note the smooth fall of pressure followed by an increase in small fluctuations as the pressure begins to rise.

120E 125E 130E 135E 140E 145E 150E 155E 160E 165E 170E 175E 180 175W 170W 165W 160W

Super Typhoon Keith (29W)

22 Oct to 10 Nov 1997

MIN SLP 878 mb

MAX INTENSITY 155 kt

LEGEND

— 24-HR BEST TRACK POSITION
○○ TROPICAL DISTURBANCE/
TROPICAL DEPRESSION
555 TROPICAL STORM
●●● TYPHOON/SUPER TYPHOON

24-HR BEST TRACK POSITION
IDENTIFICATION
DTG SPD(KT) INT(KT)
XXXXZ XX XXX

