2. RECONNAISSANCE AND FIXES

2.1 GENERAL

The Joint Typhoon Warning Center depends on reconnaissance to provide necessary, accurate, and timely meteorological information in support of advisories, alerts and warnings. JTWC relies primarily on two reconnaissance platforms: satellite and radar. In data rich areas, synoptic data are also used to supplement the above. As in past years, the optimum use of all available reconnaissance resources to support JTWC's products remains a primary concern. The weighing of the specific capabilities and limitations of each reconnaissance platform, and the tropical cyclone's threat to life and property both afloat and ashore, continue to be an important part of careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE — Fixes from Air Force/Navy ground sites and Navy ships provide day and night coverage in JTWC's area of responsibility. Interpretation of this satellite imagery yields tropical cyclone positions and estimates of current and forecast intensities through the Dvorak technique. A new capability provided by the Special Sensor Microwave/Imager (SSM/I) data is used to determine the extent of the 30-kt winds around the tropical cyclone and to aid in tropical cyclone positioning.

2.2.2 RADAR — Land-based radar remotely senses and maps precipitation within tropical cyclones in the proximity (usually within 175 nm (325 km) of radar sites in the Republic of the Philippines, Taiwan, Hong Kong, Japan, South Korea, Kwajalein and Guam. The next radar upgrade will be the arrival of the next generation Doppler radars in the early 1990's.

2.2.3 SYNOPTIC — JTWC also determines tropical cyclone positions based on the analysis of the surface/gradient-level synoptic data. These positions are an important supplement to fixes provided by remote sensing platforms and become invaluable in situations where neither satellite nor radar fixes are available.

2.3 SATELLITE RECONNAISSANCE SUMMARY

The Air Force provides satellite reconnaissance support to JTWC through the DMSP Tropical Cyclone Reporting Network (DMSP Network), which consists of tactical sites and a centralized facility. Tactical DMSP sites monitoring DMSP, NOAA and geostationary satellite data are located at Nimitz Hill, Guam; Clark AB, Republic of the Philippines; Kadena AB, Okinawa, Japan; Osan AB, Republic of Korea; and Hickam AFB, Hawaii. These sites provide a combined coverage that includes most of JTWC's area of responsibility in the western North Pacific, from near the date line westward to the Malay Peninsula. For the remainder of its AOR, JTWC relies on the AFGWC to provide coverage using stored satellite data. The Naval Oceanography Command Detachment, Diego Garcia, furnishes interpretation of NOAA polar orbiting coverage in the central Indian Ocean and USN ships equipped for direct satellite readout contribute supplementary support. Additionally, civilian contractors with the U.S. Army at Kwajalein Atoll provide satellite and radar information on tropical cyclones that develop in the Marshall Islands to supplement Det 1, 1WW's satellite coverage. An additional source of satellite data is DMSP satellite mosaics available from the Fleet Numerical Oceanography Center via the NEDN and NESN lines. This valuable data is used to metwatch the areas not in the DMSP tactical site satellite coverage and provides forecasters the capability to monitor tropical cyclones that AFGWC satellite analysts are fixing.

In addition to polar orbiter imagery, Det 1, 1 WW uses geostationary imagery to support the reconnaissance mission. Low resolution imagery is received through animation loopers at the DMSP tactical sites. The animation of these images is invaluable in depicting systems in their formative stages and determining coarse motion vectors. Animation is also valuable in assessing environmental changes affecting tropical cyclone behavior. In addition to this capability, Det 1, 1WW is able to receive high resolution digital geostationary data through the Naval Satellite Dissemination System-Geostationary (NSDS-G) which is the primary source of geostationary data used for positioning and intensity analyses.

AFGWC is the centralized member of the DMSP network. In support of JTWC, AFGWC processes stored imagery from DMSP and NOAA spacecraft. Stored imagery is recorded onboard the spacecraft as they pass over the earth and is later down-linked to AFGWC via a network of command readout sites and communication satellites. This enables AFGWC to obtain the coverage necessary to fix all tropical cyclones within JTWC's AOR. AFGWC has the primary responsibility to provide tropical cyclone reconnaissance over the entire Indian Ocean, southwest Pacific, and the area near the dateline in the western North Pacific Ocean. Additionally, AFGWC can be tasked to provide tropical cyclone support in the western North Pacific as backup to coverage routinely available in that region.

The hub of the DMSP network is Det 1, 1WW, colocated with JTWC at Nimitz Hill, Guam. Based on available satellite coverage, Det 1, 1WW is responsible for coordinating satellite reconnaissance requirements with JTWC and tasking the individual network sites for the necessary tropical cyclone fixes, current intensity estimates and forecast intensities. When a particular satellite pass is selected to support the development of JTWC's next tropical cyclone warning, two sites are tasked to fix the tropical cyclone from the same pass. This "dual-site" concept provides the necessary redundancy that virtually guarantees JTWC a satellite fix to support each warning.

The network provides JTWC with several products and services. The main service is one of monitoring the AOR for indications of tropical cyclone development. If development is detected, JTWC is notified. Once JTWC issues either a Tropical Cyclone Formation Alert or warning, the network provides three products: tropical cyclone positions, current intensity estimates and forecast intensities. Each satellite tropical cyclone position is assigned a Position Code Number (PCN), which is a measure of positioning confidence. The PCN is determined by the combination of availability of visible landmarks in the image that can be used as references for precise gridding and the degree of organization of the tropical cyclone's cloud system (Table 2-1).

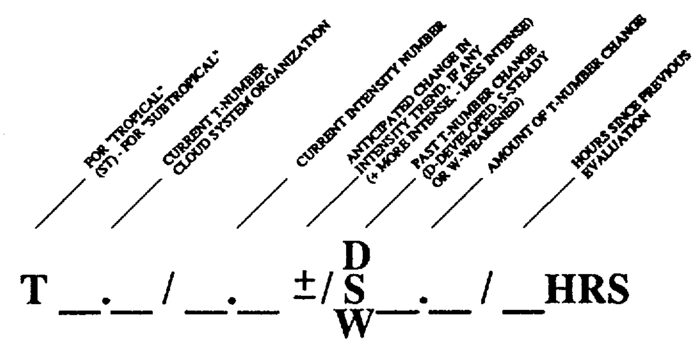
Det 1, 1 WW provides two estimates of the tropical cyclone's current intensity per day once JTWC is in alert status and four estimates when in warning status. Current intensity estimates and 24-hour intensity forecasts are made using the Dvorak technique (NOAA Technical Report NESDIS 11) for both visual and enhanced infrared imagery (Figure 2-1). The enhanced infrared technique is preferred due to its increased objectivity and accuracy, however, the visual technique is used to supplement this information during the daylight hours. For subtropical cyclones, intensity estimates are made using the Hebert and Poteat technique (NOAA Technical Memorandum NWS SR-83, 1975).

TABLE 2-1 **POSITION CODE NUMBERS (PCN)**

PCN	METHOD FOR CENTER DETERMINATION/GRIDDING
1	EYE/GEOGRAPHY
2	EYE/EPHEMERIS
3	WELL DEFINED CIRCULATION CENTER/GEOGRAPHY
4	WELL DEFINED CIRCULATION CENTER/EPHEMERIS
5	POORLY DEFINED CIRCULATION CENTER/GEOGRAPHY
6	POORLY DEFINED CIRCULATION CENTER/EPHEMERIS

2.3.1 SATELLLITE PLATFORM SUMMARY Figure 2-2 shows the status of operational polar orbiting spacecraft. Two DMSP spacecraft were operational during 1989. Spacecraft 19543 (F8), which carries the Special Sensor Microwave/Imager (SSM/I), was operational throughout the year. Spacecraft 20542 (F9) was operational throughout the year, despite some thermal channel degradation problems which were corrected in early 1989. The NOAA 10 and NOAA 11 spacecraft performed well throughout the year.

2.3.2 STATISTICAL SUMMARY — During 1989, the DMSP network was the primary input to JTWC for operational warnings and post analysis best tracks in the entire 53 million square mile area of responsibility for the warning center. Almost all the warnings were based on satellite reconnaissance. JTWC received a total of 3133 satellite fixes from the DMSP network on 35 tropical cyclones in the western North Pacific Ocean. Of this, 49 percent were from polar orbiters, while 51 percent were from geostationary. With the increased emphasis this year on the early detection of tropical depressions, the DMSP network began fixing storms earlier in their lifecycle and continued fixing them until they weakened below 25 kt or became extratropical. This emphasis contributed significantly to the 50 percent increase in the total number of fixes this year as compared to 1988. In addition, 124 fixes were made on tropical cyclones in the North Indian Ocean and 1625 on cyclones in the Southern Hemisphere. A comparison of those fixes with their corresponding best track positions is shown in Tables 2-2A and 2-2B. For the western North Pacific, the total mean error was comparable to the multi-year average and has essentially remained constant. In addition to the mean errors verses JTWC best track, Figure 2-3 depicts the 90th percentile values, i.e. 90 percent of the fixes fall within these limits, stratified by current intensity. This figure shows that errors decrease as a system becomes more intense. The greatest errors are found in the formative stages, with maximum sustained winds less than 25 kt. In general,



Example: T 3.5 / 4.5+ /W1.5 / 24 HRS

Figure 2-1. Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the previous evaluation conducted 24-hours earlier. The plus (+) symbol indicates an expected reversal of the weakening trend or very little further weakening of the tropical cyclone during the next 24-hour period.

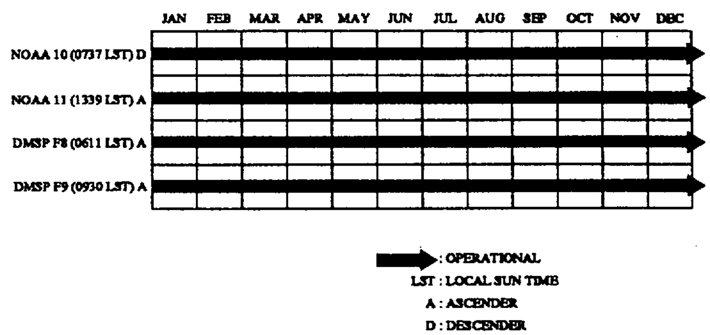


Figure 2-2. Polar orbitters for 1989.

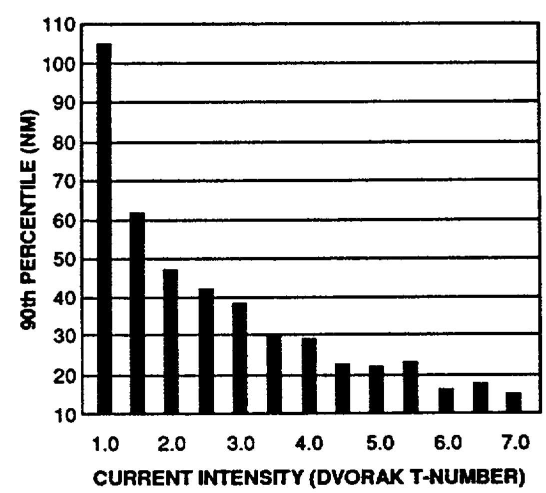


Figure 2-3. A stratification of western North Pacific satellite fix errors (90th percentile) and current intensities (Dvorak T-numbers). For example: for a tropical cyclone with a current intensity of T1.0, 90% of the fixes fell within 105 nm (195 km) of the final best track position.

TABLE 2-2A **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN NORTH PACIFIC AND NORTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

	WESTERN NORTH PACIFIC OCEAN		NORTH INDIAN OCEAN	
PCN	1979-1988 AVERAGE	1989 AVERAGE	1980-1988 AVERAGE	1989 AVERAGE
1	14.0 (1698)	11.4 (150)	16.5 (44)	10.7 (20)
2	14.9 (3070)	11.8 (583)	15.2 (13)	12.0 (20)
3	21.0 (2275)	19.2 (140)	24.7 (42)	17.4 (5)
4	21.7 (2441)	19.6 (550)	41.3 (26)	18.4 (13)
5	36.8 (3932)	26.4 (209)	38.2 (343)	28.9 (32)
6	36.1 (6120)	31.7 (1467)	40.3 (481)	31.1 (15)
1&2	14.6 (4768)	11.7 (733)	16.2 (57)	11.3 (40)
3&4	21.3 (4716)	19.6 (690)	31.1 (68)	18.1 (18)
5&6	36.4 (10052)	31.1 (1676)	39.4 (824)	29.6 (47)
1,3&5	27.4 (7905)	19.9 (499)	34.7 (429)	21.5 (57)
2,4&6	27.4 (11631)	24.7 (2600)	39.7 (520)	19.7 (48)
TOTALS:	27.4 (19536)	23.9 (3099)	37.4 (949)	20.7 (105)

TABLE 2-2B **MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS IN THE WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEANS (NUMBER OF CASES IN PARENTHESES)**

PCN	1985 - 1988 AVERAGE	1989 AVERAGE
1	16.3 (103)	15.3 (108)
2	16.5 (564)	15.3 (240)
3	34.8 (125)	20.3 (45)
4	27.0 (538)	23.7 (93)
5	40.6 (548)	30.9 (210)
6	37.1 (3651)	33.7 (735)
1 & 2	16.5 (667)	15.3 (348)
3 & 4	28.5 (663)	22.6 (138)
5 & 6	37.6 (4199)	33.1 (945)
1, 3 & 5	36.4 (776)	24.9 (363)
2, 4 & 6	33.5 (4753)	28.7 (1068)
TOTALS:	33.9 (5529)	27.7 (1431)

TABLE 2-3

MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

TROPICAL CYCLONE INTENSITY NUMBER	WIND SPEED	MSLP (NW PACIFIC)
0.0	<25	- - - -
0.5	25	- - - -
1.0	25	- - - -
1.5	25	- - - -
2.0	30	1000
2.5	35	997
3.0	45	991
3.5	55	984
4.0	65	976
4.5	77	966
5.0	90	954
5.5	102	941
6.0	115	927
6.5	127	914
7.0	140	898
7.5	155	879
8.0	170	858

errors become smaller with increasing intensity. The network also provided an additional 345 fixes on tropical disturbances which did not develop into significant tropical cyclones. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed (Dvorak, 1984) and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-3.

2.3.3 NEW TECHNIQUES — In the past, one of the biggest challenges in providing satellite reconnaissance to JTWC has been in detecting and tracking low-level circulation centers and low level clouds lines at night. When available, the satellite analyst used the low light visual capability of the DMSP spacecraft. However, during 1989, DMSP network satellite forecasters developed an infrared enhancement for the NOAA spacecraft 3.7 micrometer channel which significantly improves the capability to identify and track exposed or partially exposed low-level circulations and low level cloud lines through the nighttime hours when mid or high cloud do not obscure the low clouds. This enhancement also accentuates the land-sea contrast, highlighting geography which can be used for more precise gridding. This enhancement is now routinely applied to images of tropical cyclones where shearing is either suspected or in progress.

As was mentioned earlier, the SSM/I, mounted on the F8 DMSP spacecraft, was operational most of 1989. Through the majority of the 1989 season, SSM/I technique development support was provided exclusively by analysts in the AFGWC Tropical Section. This support included bulletins describing the extent of 30-kt winds surrounding the tropical cyclone for all systems with maximum sustained winds of 50 kt or greater. Winds can only be obtained in rain-free areas and areas free of deep moisture. If the cloud system center was rain free, analysts provided center/eye positions based on the 85 gigahertz (GHz) microwave channel display. These positions provided a comparison with those made using visual and infrared spectral windows. Multispectral imaging, particularly with the 85 GHz channel which is able to "see through" the cirrus canopy, offers a rich area for development. In October 1989, Det 1, 1 WW obtained a prototype capability to ingest,

TABLE 2-4A

1989 NORTHERN HEMISPHERE FIX PLATFORM SUMMARY

WESTERN NORTH PACIFIC	SATELLITE	RADAR	SYNOPTIC	TOTAL
TS WINONA (01W)	78	11	1	90
STY ANDY (02W)	129	50	0	180*
TY BRENDA (03W)	96	24	0	120
TY CECIL (04W)	53	6	0	59
TY DOT (05W)	116	17	0	133
TS ELLIS (06W)	39	2	1	42
TS FAYE (07W)	102	9	1	111
STY GORDON (08W)	160	24	0	184
TS HOPE (09W)	109	69	0	178
TS IRVING (10W)	48	16	0	64
TY JUDY (11W)	132	93	0	225
TD 12W (12W)	23	6	0	29
TS KEN-LOLA (13W-14W)	94	112	4	210
TY MAC (15W)	123	61	1	185
TY OWEN (16W)	104	1	7	112
TY NANCY (17W)	65	0	0	65
TS PEGGY (18W)	37	0	0	37
TD 19W (19W)	43	9	2	54
TS ROGER (20W)	61	98	2	161
TD 21W (21W)	37	0	1	38
TY SARAH (22W)	140	73	0	213
TS TIP (23W)	60	0	0	60
TS VERA (24W)	70	62	0	132
TY WAYNE (25W)	54	160	0	214
STY ANGELA (26W)	182	31	0	213
TY BRIAN (27W)	57	6	0	63
TY COLLEEN (28W)	108	0	0	108
TY DAN (29W)	81	21	1	103
STY ELSIE (30W)	153	15	0	168
TY FORREST (31W)	141	7	0	148
TY GAY (32W)	38	14	0	52
TY HUNT (33W)	127	18	3	148
TY IRMA (34W)	146	0	0	146
TD 35W (35W)	30	0	3	33
TY JACK (36W)	97	63	0	160
TOTALS NWP:	3133	1068	27	4238*
PERCENTAGE OF TOTAL:	73.9%	25.4%	0.7%	100%

NORTH INDIAN OCEAN	SATELLITE	RADAR	SYNOPTIC	TOTAL
TC 01B (01B)	27	0	0	27
TC 02A (02A)	24	0	0	24
TC 32W (32W)	73	0	0	73
TOTALS NIO:	124	0	0	124
PERCENTAGE OF TOTAL:	100%	0%	0%	100%

* ONE AIRBORNE RADAR FIX WAS RECEIVED

TABLE 2-4B 1989 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY

TROPICAL CYCLONES		SATELLITE	SYNOPTIC	RADAR	TOTAL
TC 01S	ADELININA	35	0	0	35
TC 02S	BARISAONA	125	0	0	125
TC 03S	ILONA	55	0	5	60
TC 04P	DILILAH	42	0	0	42
TC 05P	GINA	20	0	0	20
TC 06S	- - - -	34	0	0	34
TC 07S	EDME	37	0	0	37
TC 08S	FIRINGA	61	0	0	61
TC 09S	KIRRILY	68	0	0	68
TC 10P	HARRY	156	0	0	156
TC 11S	HANITRA	91	0	0	91
TC 12S	GIZELA	32	0	0	32
TC 13P	IVY	85	0	0	85
TC 14P	- - - -	21	0	0	21
TC 15P	JUDY	29	0	0	29
TC 16S	- - - -	16	0	0	16
TC 17S	MARCIA	23	0	0	23
TC 18S	- - - -	14	0	0	14
TC 19S	JINABO	66	0	0	66
TC 20S	NED	88	0	0	88
TC 21S	KRISSY	80	0	0	80
TC 22P	KERRY	26	0	0	26
TC 23P	AIVU	57	0	0	57
TC 24S	LEZISSY	22	0	0	22
TC 25P	LILI	68	0	0	68
TC 26S	ORSON	91	0	0	91
TC 27P	MEENA	112	0	0	112
TC 28P	ERNIE	71	0	0	71
TOTAL NUMBER OF FIXES:		1625	0	5	1630

process and display the SSM/I data realtime. Current plans are for the prototype system to be upgraded with improved hardware and software. Installation of these new systems is projected for Det 1, 1 WW and for DMSP sites at Clark AB, Kadena AB and Hickam AFB during the summer of 1990.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE — The future of satellite reconnaissance provides many unique challenges. As the SSM/I imagery becomes available throughout the DMSP network, training must be accomplished quickly to maximize the benefit. At this time, the majority of the emphasis has been placed on the 85 GHz and surface wind information. However, a great deal of unrealized information may lie in the other channels. Several Air Force investigators are examining this potential.

Det 1, 1 WW expects to receive an automated satellite imagery processing and display system designed specifically for the tropical cyclone reconnaissance mission during the 1991-1992 timeframe. The system will process and display polar orbiter and geostationary satellite data. It will have a broad spectrum of satellite data manipulation applications which will significantly enhance Det 1, 1WW support to the reconnaissance mission. In the meantime,. Det 1, 1WW is developing its capabilities using a MacIntosh IIx™ computer system which has been programmed to ingest and display polar orbiter and geostationary satellite data.

In addition to SSM/I, the Mark III and Mark IV DMSP ground systems located at the Pacific DMSP sites should be upgraded with the Mark IVB state-of-the-art satellite imagery ingest and display system during the 1992-93 timeframe. The near future of satellite reconnaissance is becoming more and more dependent on this upgrade, as the current systems become more difficult to support.

2.4 RADAR RECONNAISSANCE SUMMARY

Twenty-eight of the thirty-five significant tropical cyclones in the western North Pacific during 1989 passed within range of land-based radar with sufficient cloud pattern organization to be fixed. The land-based radar fixes that were obtained and transmitted to JTWC totaled 1068 for the Northern Hemisphere and 5 for the Southern Hemisphere. One radar fix was obtained by an aircraft of opportunity.

The WMO radar code defines three categories of accuracy: good (within 10 km (5 nm)), fair (within 10-30 km (5-16 nm)), and poor (within 30-50 km (16-27 nm)). Of the 1073 radar fixes encoded in this manner; 314 were good, 341 were fair, and 418 were poor. Compared to JTWC's best track, the mean vector deviation for land-based radar sites was 20 nm (37 km). Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement through even the most difficult erratic tracks.

Five radar reports were received on Southern Hemisphere tropical cyclones; however, as in previous years, no radar reports were received on North Indian Ocean tropical cyclones.

2.5 TROPICAL CYCLONE FIX DATA

A total of 4238 fixes on thirty-five western North Pacific tropical cyclones and 124 fixes on three North Indian Ocean tropical cyclones were received at JTWC. Table 2-4A delineates the number of fixes per platform for each individual tropical cyclone for the western North Pacific and North Indian Oceans. Season totals and percentages are also indicated. Table 2-4B provides similar information for the South Pacific and South Indian Oceans.