2. RECONNAISSANCE AND FIXES

2.1 GENERAL

JTWC depends primarily on two reconnaissance platforms, satellite and radar, to provide necessary, accurate and timely meteorological information in support of advisories, alerts and warnings. When available, synoptic and aircraft reconnaissance data are also used to supplement the above. As in past years, the optimal use of all available reconnaissance resources to support JTWC's products remains a primary concern. Weighing 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 important factors in careful product preparation.

2.2 RECONNAISSANCE AVAILABILITY

2.2.1 SATELLITE — Interpretation of satellite imagery by analysts at Air Force/Navy ground sites and on Navy ships yields tropical cyclone positions, estimates of the current intensity, and forecast intensity. Additional positioning and surface wind estimation information is available for analysis where the DMSP SSM/I data can be received and displayed.

2.2.2 RADAR — Interpretation of land-based radar, which remotely senses and maps precipitation within tropical cyclones, provides positions in the proximity (usually within 175 nm (325 km) of radar sites in the Kwajalein, Guam, Japan, South Korea, China, Taiwan, Philippine Islands, Hong Kong, Thailand, India and Australia. Where Doppler radars are located, such as the new NEXRAD installation on Guam, measurements of radial velocity are also available, and observations of the tropical cyclone's horizontal velocity field and wind structure integrated in the vertical are possible within the radar volume.

2.2.3 AIRCRAFT — Six tropical cyclone fixes were received from the weather reconnaissance aircraft associated with the TCM-93 mini-field experiment conducted near Guam during July and August. In the Southern Hemisphere, one aircraft fix on Tropical Cyclone 16P (Oliver) was logged in February 1993.

2.2.4 SYNOPTIC — JTWC also determines tropical cyclone positions based on the analysis of surface/gradient-level synoptic data. These positions are an important supplement to fixes provided by analysts using data from remote sensing platforms, and become most valuable in situations where neither satellite, radar nor aircraft fixes are available or representative.

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 several tactical sites and a centralized facility. The personnel of Det 1, 633d OSS (hereafter referred to as Det 1), collocated with JTWC at Nimitz Hill, Guam, coordinate required tropical cyclone reconnaissance support with the following units:

Unit	Call sign
15 ABW/WE, Hickam AFB, Hawaii	PHIK
18 OSS/WE, Kadena AB, Japan	RODN
603 ACCS/DOW, Osan AB, Republic of Korea	RKWU
Air Force Global Weather Central, Offutt AFB, Nebraska	KGWC

The DMSP Network sites provide a combined coverage from polar orbiting satellites that includes most of the western North Pacific, from near the international date line westward into the South China Sea. The Naval Pacific Meteorology and Oceanography Detachment at

Diego Garcia furnishes fixes through interpretation of low resolution NOAA polar orbiting satellite imagery that covers the central Indian Ocean, and Navy ships equipped for direct satellite readout contribute supplementary support. Also, civilian contractors with the U.S. Army at Kwajalein Atoll supplement Det 1's satellite coverage with fixes on tropical cyclones in the Marshall Islands and east of the date line.

Additionally, mosaics developed from DMSP satellite imagery are available from the FLENUMETOCCEN via the NEDN and NESN lines. These mosaics are used to metwatch the areas not included in the coverage of DMSP Network tactical sites. They provide JTWC forecasters with the time-delayed capability to "see" what AFGWC's satellite image analysts have been fixing.

Det 1 also uses high resolution geostationary imagery to support the reconnaissance mission. Animation of images is invaluable for determining the location and motion of cloud system centers, particularly in the formative stages. Animation is also valuable in assessing changes in the environment that affect tropical cyclone behavior. Det 1 is able to process high resolution digital geostationary data through its MIDDAS, and the Navy's GSRS. The MIDDAS consists of a network of three microcomputers, advanced graphics software, and large screen work stations that process and display geostationary imagery, NOAA High Resolution Picture Transmission (HRPT) and TIROS Operational Vertical Sounder (TOVS) data, and DMSP imagery. On 1 April 1992 the MIDDAS was formally accepted as a part of Det 1 operations. Further software upgrades of MIDDAS have extended the GMS grid 10 degrees closer to the limb of the earth's disk, and have allowed the normal projection of the GMS image to be warped into a mercator projection. These two upgrades provided a more user-friendly presentation of tropical weather systems over the Bay of Bengal and the Indian Ocean to the south. The most recent software upgrade added the capability to process and analyze DMSP SSM/I data on the MIDDAS.

In support of JTWC, AFGWC analyzes stored imagery from both the DMSP and NOAA spacecraft. These imagery are recorded and stored onboard the spacecraft for later relay to a command readout site which in turn passes the data via a communication satellite to AFGWC. This enables AFGWC to obtain the global coverage needed to monitor all tropical cyclones worldwide several times a day.

The hub of the DMSP Network is Det 1, which 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 SSM/I-derived surface winds. When a particular satellite pass is selected to support 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. It also supplies independent assessments of the same data to provide TDOs a measure of confidence in the location and intensity information.

The DMSP Network provides JTWC with several products and services. The main service is to monitor the AOR for indications of tropical cyclone development. If development is suspected, JTWC is notified. Once JTWC issues either a TCFA or a warning, the DMSP Network provides tropical cyclone positions and current intensity estimates, with a forecast intensity estimate implied from the code (Dvorak 1975, 1984) shown in Figure 2-1. Each satellite-derived tropical cyclone position is assigned a Position Code Number (PCN), which is a measure of positioning confidence. The PCN is determined by a combination of 1) the availability of visible landmarks in the image that can be used as references for precise gridding, and 2) the degree of organization of

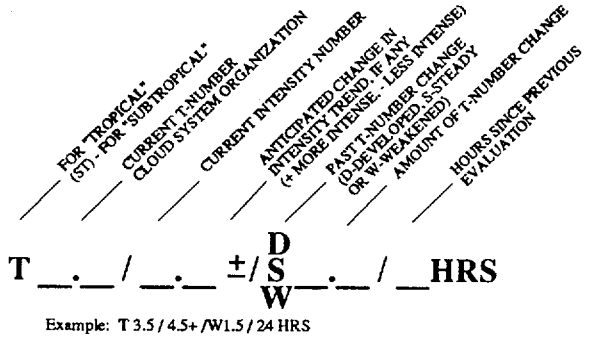

Figure 2-1 Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24-hours earlier. The plus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

the tropical cyclone's cloud system (Table 2-1). Once the tropical cyclone's intensity reaches 50 kt (26 m/sec), the DMSP Network analyzes the distribution of SSM/I-derived 35-kt (18-m/sec) winds in the rain-free areas near the tropical cyclone.

Det 1 provides at least one estimate of the tropical cyclone's current intensity every 6 hours once JTWC is in alert or warning status. Current intensity estimates are made using the

Table 2-1 POSITION CODE NUMBER (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

Dvorak technique for both visible and enhanced infrared imagery. For the intensity analysis of mature tropical cyclones, the enhanced infrared technique is preferred due to its objectivity; however, daily use of the visible technique adds a measure of consistency and helps resolve ambiguities in the enhanced infrared techniques. The standard relationship between tropical cyclone "T-number", maximum sustained surface wind speed, and minimum sea-level pressure (Atkinson and Holliday, 1977) for the Pacific is shown in Table 2-2. For subtropical cyclones, intensity estimates are made using the Hebert and Poteat (1975) technique.

Table 2-2 MAXIMUM SUSTAINED WIND SPEED (KT) AS A FUNCTION OF DVORAK CURRENT AND FORECAST INTENSITY NUMBER AND MINIMUM SEA-LEVEL PRESSURE (MSLP)

T-NUMBER	WIND SPEED-KT	WIND SPEED-(M/SEC)	MSLP (MB) (PACIFIC)
0.0	<25	<(13)	- - - -
0.5	25	(13)	- - - -
1.0	25	(13)	- - - -
1.5	25	(13)	- - - -
2.0	30	(15)	1000
2.5	35	(18)	997
3.0	45	(23)	991
3.5	55	(28)	984
4.0	65	(33)	976
4.5	77	(40)	966
5.0	90	(46)	954
5.5	102	(53)	941
6.0	115	(59)	927
6.5	127	(65)	914
7.0	140	(72)	898
7.5	155	(80)	879
8.0	170	(87)	858

2.3.1 SATELLITE PLATFORM SUMMARY

Figure 2-2 shows the status of operational polar orbiting spacecraft. Three DMSP spacecraft were available to the tactical sites in 1993. Of these, F8 provided only vertically polarized 85 GHz channel SSM/I data after the loss of its Operational Line Scan (OLS) imaging system, F10's OLS functioned normally, but the eccentricity of its orbit presented gridding challenges, and F11 performed flawlessly. Of the four NOAA spacecraft, NOAA 9 remained in standby mode, while NOAA 10, 11 and 12 were operational. The NOAA 13 satellite which was launched 9 August failed shortly after launch.

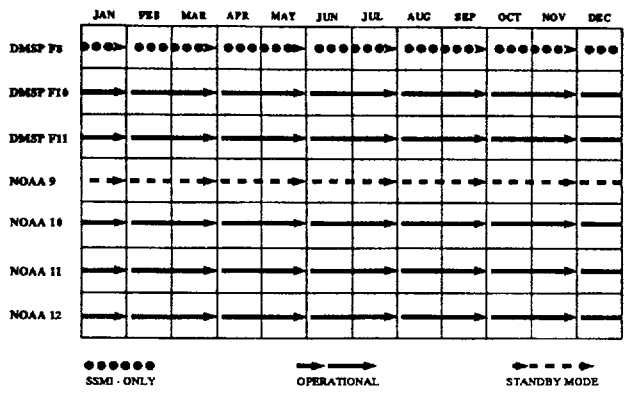

Figure 2-2 Polar orbiting spacecraft status for 1993

2.3.2 STATISTICAL SUMMARY

During 1993, fix and intensity information from the DMSP Network was the primary input to JTWC's warnings and post analyses. JTWC received at least 4520 satellite fixes — 3199 covered tropical cyclones in the western North Pacific, 96 in the North Indian Ocean, and 1225 in the Southern Hemisphere. The geostationary platform was the source of 73 percent of the fixes and 27 percent were from polar orbiters. A comparison of satellite fixes from all data sources with their corresponding best track positions is shown in Table 2-3.

2.3.3 APPLICATION OF NEW TECHNOLOGY

In April 1993, all tactical sites in the DMSP Network received the Mission Sensor Tactical Imaging Computer (MISTIC) II system upgrade, which allowed processing of the full resolution 12-bit SSM/I data and coregistration of the SSM/I and OLS. The Tropical Section at AFGWC, using its Satellite Data Handling System with 12-bit SSM/I capability, continued to provide the bulk of the SSM/I support to JTWC throughout the year.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

Det 1 remains committed to maintaining, and at the same time improving the DMSP Network's support to the PACOM tropical cyclone warning system. Work continues to progress on the installation of new MARK IV-B tactical terminals in the western Pacific.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 38 significant tropical cyclones in the western North Pacific during 1993, 18 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 784 land-based radar fixes were logged at JTWC. The World Meteorological Organization (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 784 radar fixes encoded in this manner, 197 were good, 307 were fair, and 280 were poor. Excellent support from the radar network through timely and accurate radar fix positioning allowed JTWC to track and forecast tropical cyclone movement during even the most erratic track changes. In the Southern Hemisphere, 19 radar reports were logged for tropical cyclones. No fixes were received for the North Indian Ocean.

The weather radar for Guam, which was destroyed in August 1992 by Typhoon Omar was restored, and improved, in February 1993, with the installation of the Andersen AFB NEXRAD Doppler radar.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-4a delineates the number of fixes per platform for each individual tropical cyc-

lone for the western North Pacific. Totals and percentages are also indicated. Similar information is provided for the North Indian Ocean in Table 2-4b, and for the South Pacific and South Indian Oceans in Table 2-4c.

Table 2-3 MEAN DEVIATION (NM) OF ALL SATELLITE DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS (NUMBER OF CASES IN PARENTHESES)

NORTHWEST PACIFIC OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	13.8	(6108)	13.9	(513)
3&4	21.9	(6398)	30.0	(434)
5&6	37.1	(13668)	39.7	(2252)
Totals	27.9	(26174)	34.2	(3199)

NORTH INDIAN OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	13.3	(167)	18.5	(4)
3&4	30.9	(117)	66.1	(9)
5&6	38.1	(1335)	43.9	(83)
Totals	35.1	(1639)	45.4	(96)

WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEAN

PCN	1982-1992 AVERAGE		1993 AVERAGE	
1&2	15.9	(1971)	13.8	(248)
3&4	26.9	(1668)	19.6	(220)
5&6	36.1	(7947)	33.2	(757)
Totals	31.3	(11586)	26.8	(1225)

Table 2-4a 1993 NORTHWEST PACIFIC OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE			SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01W	TD		23	0	0	0	23
02W	TS	Irma	106	0	0	0	106
03W	TD		28	0	0	0	28
04W	TD		105	0	0	0	105
05W	TS	Jack	79	0	0	0	79
06W	STY	Koryn	155	10	4	0	169
07W	TD		42	0	0	0	42
08W	TY	Lewis	91	6	24	0	121
09W	TS	Marian	62	0	11	0	73
10W	TY	Nathan	96	22	0	0	118
11W	TS	Ofelia	45	57	0	1	103
12W	TY	Percy	51	51	0	0	102
13W	TY	Robyn	139	88	0	5	232
14W	TY	Steve	92	6	0	0	98
15W	TD		33	0	0	0	33
16W	TY	Tasha	89	26	0	0	115
17W	TY	Vernon	90	55	0	0	145
18W	TS	Winona	89	0	1	0	90
19W	STY	Yancy	107	166	0	0	273
01C	TY	Keoni	87	0	0	0	87
20W	TS	Zola	66	74	3	0	143
21W	TY	Abe	98	100	0	0	198
22W	TY	Becky	56	16	0	0	72
23W	TY	Cecil	75	0	0	0	75
24W	TY	Dot	23	0	0	0	23
25W	STY	Ed	117	38	0	0	155
26W	TY	Flo	96	13	3	0	112
27W	TS	Gene	60	0	0	0	60
28W*	TD		57	15	0	0	72
29W	TS	Hattie	84	0	0	0	84
30W	TY	Ira	118	13	0	0	131
31W	TS	Jeane	95	20	0	0	115
32W	TD		53	0	0	0	53
33W	TD		34	0	0	0	34
34W	TY	Kyle	66	0	0	0	66
35W	TY	Lola	105	8	0	0	113
36W	TY	Manny	158	0	0	0	158
37W	TY	Nell	114	0	0	0	114
		Totals	3084	784	46	6	3920
Percentage of Total			79%	20%	1%	<1%	100%

* Regenerated

Table 2-4b 1993 NORTH INDIAN OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE	SATELLITE	RADAR	SYNOPTIC	TOTAL
01A	23	0	0	23
02B	76	0	0	76
Totals	99	0	0	99
Percentage of Total	100%	0%	0%	100%

Table 2-4c 1993 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY

TROPICAL CYCLONE		SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01S	Aviona	48	0	0	0	48
02S	Babie	13	0	0	0	13
03P	Joni	107	0	0	0	107
04S	- - - -	17	0	0	0	17
05S	Ken	66	0	0	0	66
06P	Nina	152	10	0	0	162
07P	Kina	123	0	0	0	123
08P	- - - -	5	0	0	0	5
09P	- - - -	12	0	0	0	12
10S	Colina	40	0	0	0	40
11S	Dessilia	7	0	0	0	7
12S	Edwina	67	0	0	0	67
13S	Lena	69	0	0	0	69
14P	- - - -*	64	0	0	0	64
15P	Lin	38	0	0	0	38
16P	Oliver	120	9	0	1	130
17P	Mick	32	0	1	0	33
18P	Nisha	43	0	0	0	43
19S	Finella	20	0	0	0	20
20P	Oli	33	0	5	0	38
21P	Polly	77	0	0	0	77
22P	Roger	88	0	0	0	88
23P	Prema	79	0	0	0	79
24S	Jourdanne	61	0	0	0	61
25S	Monty	39	0	0	0	39
26S	Konita	48	0	0	0	48
27P	Adel	42	0	0	0	42
	Totals	1510	19	6	1	1536
	Percentage of Total	98 %	1 %	<1 %	<1 %	100 %

* Regenerated