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, continues to be an important factor 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 are 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 — No weather reconnaissance aircraft fixes were received at JTWC in 1994.

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 the Satellite Operations (hereafter referred to as Sat Ops) at 36 OSS/OSJ, 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 Sat Ops 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 DDN. 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.

Sat Ops 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. Sat Ops is able to process high resolution digital geostationary data through its MIDDAS, and the Navy's Geostationary Satellite Receiving System (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.

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 Sat Ops, 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 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.

Sat Ops 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 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;

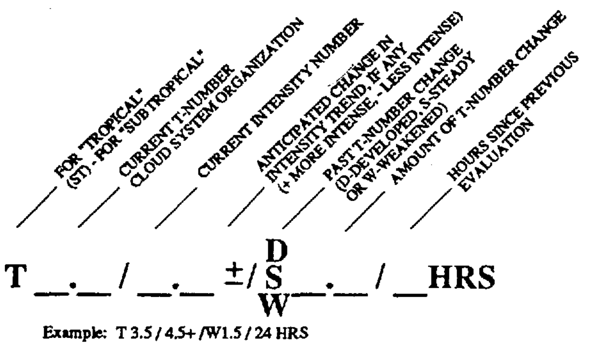

Figure 2-1 Dvorak code for communicating estimates of current and forecast intensity derived from satellite data. In the example, the current "T-number" is 3.5, but the current intensity is 4.5. The cloud system has weakened by 1.5 "T-numbers" since the evaluation conducted 24-hours earlier. The plus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

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 2-1 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

2.3.1 SATELLITE PLATFORM SUMMARY

Figure 2-2 shows the operational status of polar orbiting spacecraft. Data were received from four DMSP spacecraft during 1994. Of these, F8 was limited to only one channel of SSM/I data until it was placed in a standby status in April 94. F10 was operational until September when the Operàtional Line Scan (OLS) instrument failed, however F10 SSM/I data transmissions continued. F11 performed well throughout 1994 and F12, which didn't include a SSM/I instrument, became operational in August. Of the five TIROS-N spacecraft, NOAA9 remained in standby. NOAA10 and NOAA12 were operational throughout the year. NOAA 11 died January 1995. NOAA14, which was launched in December, later became operational in early 1995.

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

T-NUMBER	ESTIMATED WIND SPEED-KT	(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

2.3.2 STATISTICAL SUMMARY

During 1994, fix and intensity information from the DMSP Network was the primary input to JTWC's warnings and post analyses. JTWC received at least 8387 satellite fixes — 4442 covered tropical cyclones in the western North Pacific, 193 in the North Indian Ocean, and 1849 in the Southern Hemisphere. The geosta-

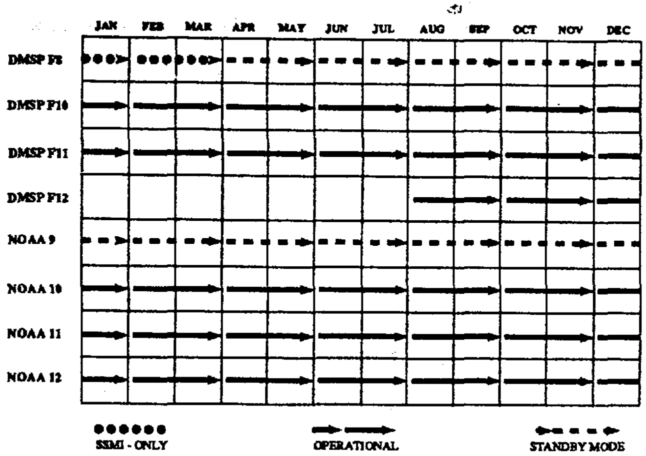

Figure 2-2 Polar orbiting spacecraft status for 1994

tionary platform was the source of 73 percent of the fixes and 27 percent were from polar orbiters. A comparison of all satellite fixes with only their corresponding best track positions is shown in Table 2-3.

2.3.3 APPLICATION OF NEW TECHNOLOGY

Sat Ops continued to make use of the real-time direct transmissions of SSM/I data received, processed and displayed by the Air Force's Mark IVB tactical terminals for surface wind speed estimation. These data were routinely used to identify areas of 35-kt winds, particularly surrounding tropical cyclones. Time-late SSM/I data, stored on board the DMSP spacecraft for later reception, processing and forwarding from FNMOC to be displayed on the MISTIC II, provided coverage over the JTWC's entire AOR. These time-late SSM/I data were used by analysts at AFGWC to develop 35-kt wind envelope bulletins for tropical cyclone warning support.

2.3.4 FUTURE OF SATELLITE RECONNAISSANCE

Sat Ops remains committed to, and strives to, improve the support to the PACOM tropical cyclone warning system. Expected in mid 1995 is the next software upgrade for the DMSP Mark IVB that will allow for the processing of water vapor channel from the geostationary meteorological satellite (GMS). Also, in 1995, the MIDDAS will be upgraded to allow for the processing and display of GMS water vapor and spit-window infrared. Near-term plans include the upgrade of the MIDDAS processing computers for quicker image processing. In addition, access to the Internet allows for receipt of mosaics of the European Space Agency (ESA) Remote Sensing satellite (ERS-1) scatterometer data which provides wind vectors to better define the tropical cyclone's surface wind envelope and surrounding environment.

2.4 RADAR RECONNAISSANCE SUMMARY

Of the 41 significant tropical cyclones in the western North Pacific during 1994, 19 passed within range of land-based radar with sufficient precipitation and organization to be fixed. A total of 661 land-based radar fixes were logged at JTWC. As defined by the World Meteorological Organization (WMO), the accuracy of these fixes falls within three categories: 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 661 radar fixes encoded in this manner, 133 were good, 311 fair, and 217 poor. The radar network provided timely and accurate fixes which allowed JTWC to better track and forecast tropical cyclone movement. In addition to fixes, the Andersen AFB (Guam) NEXRAD Doppler radar supplied meteorologists with a new look into the vertical and horizontal structure of precipitation and winds in tropical cyclones passing near the island.

In the Southern Hemisphere, four radar reports were logged for tropical cyclones. No radar fixes were received for the North Indian Ocean.

2.5 TROPICAL CYCLONE FIX DATA

Table 2-4a delineates the number of fixes per platform for each individual tropical cyclone 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 DMSP NETWORK DERIVED TROPICAL CYCLONE POSITIONS FROM JTWC BEST TRACK POSITIONS (NUMBER OF CASES IN PARENTHESES)

NORTHWEST PACIFIC OCEAN

PCN	1984-1993 AVERAGE		1994 AVERAGE	
1&2	14.0	(6091)	13.9	(1105)
3&4	22.8	(6213)	26.8	(784)
5&6	37.9	(14557)	50.8	(2278)
Totals	29.0	(26861)	36.5	(4167)

NORTH INDIAN OCEAN

PCN	1984-1993 AVERAGE		1994 AVERAGE	
1&2	13.5	(151)	11.4	(14)
3&4	34.7	(116)	33.3	(19)
5&6	38.9	(1323)	38.7	(132)
Totals	36.2	(1590)	35.8	(165)

WESTERN SOUTH PACIFIC AND SOUTH INDIAN OCEAN

PCN	1984-1993 AVERAGE		1994 AVERAGE	
1&2	16.3	(2478)	15.7	(302)
3&4	27.2	(2160)	28.0	(216)
5&6	36.7	(9755)	46.3	(1174)
Totals	31.7	(14393)	38.5	(1692)

Table 2-4a 1994 NORTHWEST PACIFIC OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE			SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01W	TD		50	0	0	0	50
02W	TY	Owen	112	0	1	0	113
03W	TY	Page	122	0	2	0	124
04W	TD		64	0	0	0	64
05W	TS	Russ	71	42	0	0	113
06W*	TS	Sharon	64	0	3	0	67
07W	TD		35	12	0	0	47
08W	TY	Tim	99	24	0	0	123
09W	TS	Vanessa	22	0	0	0	22
10W	STY	Walt	204	144	1	0	349
11W	TS	Yunya	52	0	0	0	52
12W	TY	Zeke	78	0	0	0	78
13W	TD		14	0	1	0	15
14W	TS	Brendan	90	2	1	0	93
15W	TS	Amy	29	0	0	0	29
16W	TS	Caitlin	54	3	0	0	57
17W	STY	Doug	197	38	0	0	235
18W	TY	Ellie	186	43	0	0	229
08E	TS	Li	65	0	0	0	65
20W	TY	Gladys	163	55	0	0	218
21W	TS	Harry	73	17	0	0	90
22W	TY	Ivy	102	0	0	0	102
23W	TS	Joel	63	0	0	0	63
24W	TY	Kinna	148	21	0	0	169
25W	TY	Luke	83	2	0	0	85
26W	STY	Melissa	116	0	0	0	116
10E	TY	John	136	0	0	0	136
27W	TS	Nat	88	12	0	0	100
28W	STY	Orchid	228	106	0	0	334
29W	TY	Pat	68	0	0	0	68
30W	TS	Ruth	58	0	0	0	58
31W	TD		63	0	0	0	63
32W	TY	Seth	198	17	1	0	216
33W	TY	Verne	208	19	0	0	227
34W	TY	Teresa	126	0	0	0	126
35W	TY	Wilda	161	19	0	0	180
36W	TS	Yuri	37	0	0	0	37
37W	STY	Zelda	216	31	0	0	247
38W*	TY	Axel	147	0	5	0	152
39W	TS	Bobbie	96	0	0	0	96
		Totals	4373	661	17	0	5051
Percentage of Total			87%	13%	<1%	0%	100%

* Regenerated

Table 2-4b 1994 NORTH INDIAN OCEAN FIX PLATFORM SUMMARY

TROPICAL CYCLONE	SATELLITE	RADAR	SYNOPTIC	TOTAL
01B	54	0	0	54
02B	67	0	0	67
03A	17	0	0	17
04B	24	0	0	24
05A	32	0	0	32
Totals	194	0	0	194
Percentage of Total	100%	0%	0%	100%

Table 2-4c 1994 SOUTH PACIFIC AND SOUTH INDIAN OCEANS FIX PLATFORM SUMMARY

TROPICAL CYCLONE		SATELLITE	RADAR	SYNOPTIC	AIRCRAFT	TOTAL
01S	Alexina	68	0	0	0	68
02S	Bettina	59	0	0	0	59
03S	Cecilia	75	0	0	0	75
04S	Naomi	32	0	0	0	32
05P	Rewa	249	3	0	0	252
06S	Oscar	62	0	0	0	62
07P		6	0	0	0	6
08S	Daisy	31	0	0	0	31
09S	Pearl	98	0	0	0	98
10S	Edema	35	0	0	0	35
11P	Sarah	90	0	0	0	90
12S	Quenton	64	0	0	0	64
13S	Geralda	59	0	0	0	59
14P	Sadie	18	0	0	0	18
15S	Hollanda	10	0	0	0	10
16S	Ivy	95	0	0	0	95
17S		74	1	0	0	75
18P	Theodore	55	0	0	0	55
19S	Kelvina	15	0	0	0	15
20S	Litanne	87	0	0	0	87
21S	Mariola	107	0	0	0	107
22S	Sharon	62	0	0	0	62
23S*	Nadia	53	0	0	0	53
24P	Tomas	55	0	0	0	55
25P	Usha	59	0	3	0	84
26S	Odille	143	0	0	0	143
27S	Tim	39	0	0	0	39
28S	Vivienne	75	0	0	0	75
29P		21	0	0	0	21
30S	Willy	44	0	0	0	44
	Totals	1940	4	3	0	1947
	Percentage of Total	99.6 %	<1 %	<1 %	0 %	100 %

* Regenerated