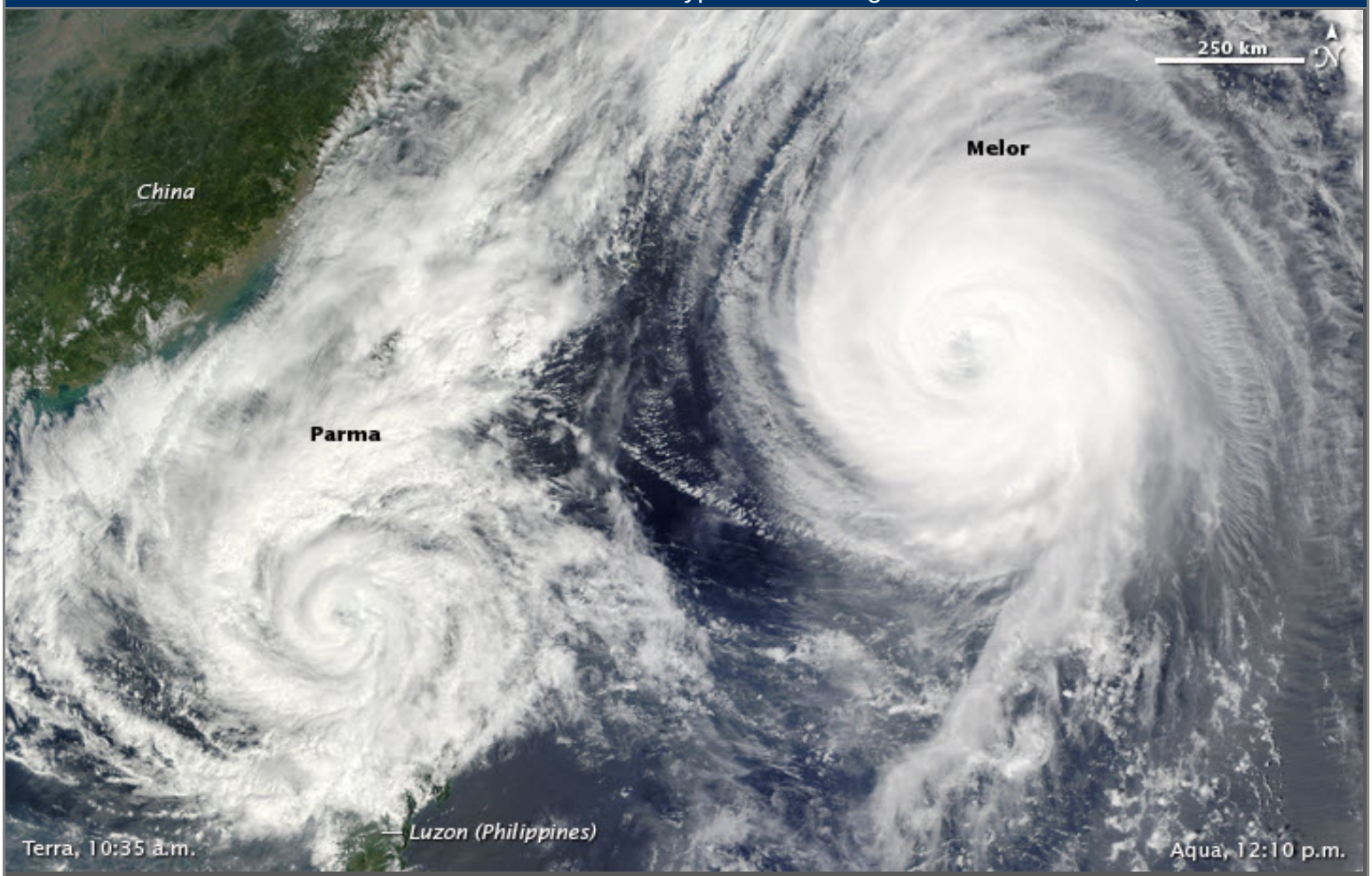
Annual Tropical Cyclone Report
2009

U.S. Naval Maritime Forecast Center/ Joint Typhoon Warning Center Pearl Harbor, Hawaii



MODIS visible image of Super Typhoons Parma (19W) and Melor (20W) as they wreak havoc on the Western Pacific, taken on 03 October 2009. Image courtesy of NASA Earth Observatory.

GRANT A. COOPER

Captain, United States Navy

Commanding Officer

ROBERT J. FALVEY

Director, Joint Typhoon Warning Center

Executive Summary

The Annual Tropical Cyclone Report (ATCR) is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a combined United States Air Force/Navy organization under the operational command of the Commanding Officer, Naval Maritime Forecast Center/Joint Typhoon Warning Center (NMFC/JTWC), Pearl Harbor, Hawaii. JTWC was established on 1 May 1959 when Commander-in-Chief, US Pacific Command (USCINCPAC) directed Commander-in-Chief, Pacific Fleet to provide a single tropical cyclone warning center for the western North Pacific region. Subsequent USCINCPAC directive further tasked Commander, Pacific Air Force to provide for tropical cyclone (TC) reconnaissance support to the JTWC. Currently, JTWC operations are guided by USPACOM Instruction 0539.1.

The JTWC celebrated its 50th Anniversary in late April 2009 at a ceremony at the Ford Island Conference Center. The guest speaker was RDML Tom Copeman, Pacific Fleet Deputy Chief of Staff for Operations, Training and Readiness. In addition, the event included speeches from CAPT Dean Sadanaga, Director of Weather Services, Naval Oceanography Operations Command, Col Scott Van Blarcum, Chief of Weather Resources and Programs, Headquarters Air Force, CAPT Grant Cooper, Commanding Officer NMFC/JTWC, and Lt Col Kurt Brueske, Commander, 17th Operational Weather Squadron. All speakers strongly reiterated the need for JTWC to support US Department of Defense operations. The ceremony concluded with former Commanding Officer CAPT (retired) Ty Aldinger and former Director Lt Col (retired) Chip Guard cutting ceremonial cakes for the 100 or so attendees.

This edition of the ATCR documents the TC season and details operationally or meteorologically significant TCs that highlight significant challenges and/or shortfalls in the TC warning system and that serve as a focal point for research and development efforts.

Below normal activity in the western North Pacific Ocean continued in 2009, with 28 TCs observed compared to the long term average of 31. The North Indian, South Indian and South Pacific Oceans experienced normal activity with 5, 18, and 9 TCs respectively compared to the long term averages of 5, 18, and 10.

Two cyclones that posed significant challenges to JTWC were Super Typhoon (STY) 22W (Lupit) and STY 19W (Parma). STY 22W formed southeast of Guam and initially moved to the west-northwest then west into the Philippine Sea where it moved very erratically. During passage through the Philippine Sea this cyclone made turns to the northeast, then northwest, then southwest and then sharply northeast again, resulting in large 4 and 5 day forecast errors. STY 19W was another notable cyclone that crossed northern Luzon Island three times prior to transiting the South China Sea and making landfall on Hainan Island and then northern Vietnam.

Official and media reports indicated that Typhoon 09W (Morakot) was the most destructive cyclone in the western North Pacific in 2009, with significant damage reported on Taiwan and Fujian, Zhejiang and Jiangsu provinces, China as well as approximately 650+ fatalities reported mainly due to landslides from extremely heavy rainfall. STY 20W (Melor) was the only system to make landfall near DoD installations in 2009. This cyclone formed to the east of Guam, crossed the northern Marianas Islands and attained super typhoon intensity to the southeast of Okinawa Island. STY 20W subsequently went ashore about 150 miles southwest of several DoD installations in the Kanto Plain as a minimal typhoon.

The primary operational changes that occurred in 2009 were the long-line transmission of microwave position estimates in the satellite position and intensity bulletins and the extension of southern hemisphere warnings from 48 hours to 120 hours.

Weather satellite data remained the mainstay of the TC reconnaissance mission at the JTWC. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce over 10,000 position and intensity estimates (fixes), primarily using the USAF Mark IVB and the USN FMQ-17 satellite direct readout systems to produce these fixes. The JTWC also used geo-located microwave satellite imagery overlays available via the Automated Tropical Cyclone Forecast (ATCF) system from Fleet Numerical Meteorology and Oceanography Center and the Naval Research Lab Monterey to make TC fixes. On 23 November 2009 at around 0700Z, the antenna motor on NASA's QuikSCAT failed, ending a long era in ocean surface vector wind data. This loss is expected to have negative impacts on the JTWC reconnaissance and forecast mission.

JTWC continued to collaborate with TC forecast support and research organizations such as the Fleet Numerical Meteorology and Oceanography Center (FNMOC), Naval Research Laboratory, Monterey (NRLMRY), Naval Post Graduate School, the Office of Naval Research, and Air Force Weather Agency (AFWA) for continued development of numerical TC models and forecast aids. Of note, in 2009, improvements to the Navy's version of the Geophysical Fluid Dynamics Lab mesoscale typhoon model (GFDN) were completed and the GFDN became a coupled air/ocean TC forecast model in the western North Pacific. Work continues to add 3-dimensional ocean coupling in other basins within the JTWC area of responsibility. Furthermore, the AFWA has migrated from the MM5 to WRF and is scheduled to provide TC track and intensity information from WRF in 2010. JTWC has also requested the implementation of the Hurricane Weather and Research Forecast model (H-WRF) for use in the western North Pacific in support of National Weather Service local forecast operations in Micronesia.

Late in 2009, operational support of the ATCF system was funded and scheduled to be moved to FNMOC, but instead was transferred to the N6 Department at NMFC/JTWC, with technical reach-back assistance from NRLMRY.

Behind all these efforts are incredible people - the dedicated team of men and women, military and civilian at NMFC/JTWC. Special thanks to the entire N6 Department for their outstanding IT support, Mr. Craig Motell for his computer automation efforts, and the administrative and budget staff who worked tirelessly to ensure JTWC had the necessary resources to get the mission done.

Special thanks also to: FNMOC for their operational data and modeling support; the NRLMRY for its dedicated research; the National Oceanic and Atmospheric Administration National Environmental Satellite, Data, and Information Service for satellite support; for their high quality support; all the men and women of the ships and facilities ashore throughout the JTWC area of responsibility; Dr. John Knaff, Mr. Jeff Hawkins, Dr. Mark DeMaria, and Mr. Chris Velden for their continuing efforts to exploit remote sensing technologies in new and innovative ways; Mr. Charles R. "Buck" Sampson, Ms. Ann Schrader, Mr. Mike Frost, and Mr. Chris Sisko for their support and continued development of the ATCF system.

JTWC Personnel
2009

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LCDR Jeremy Callahan, *Operations Officer*
Mr. Stephen Barlow, *Operations Officer*
LCDR Michael Vancas, *Operations Officer*
Mr. Ed Fukada, *Technical Advisor*

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TSgt Rich Kienzle, *Analyst*
SSgt Rex Ames, *Analyst*
SrA Rachelle Smith, *Analyst*
SrA Brandon Ross, *Analyst*
SrA Michele Gates, *Analyst*

Techniques Development

Mr. Matt Kucas, *Techniques Development Chief*
Maj Joel Fenlason, *Techniques Development Chief*
Mr. Jim Darlow

* ATCR editor

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Chapter 1 Western North Pacific Ocean Tropical Cyclones

Section 1 Informational Tables

Table 1-1 is a summary of tropical cyclone (TC) activity in the western North Pacific Ocean during the 2009 season. JTWC issued warnings on 30 cyclones. Table 1-2 shows the monthly distribution of TC activity summarized for 1959 - 2009 and Table 1-3 shows the monthly average occurrence of TC's separated into: (1) typhoons and (2) tropical storms and typhoons. Table 1-4 summarizes Tropical Cyclone Formation Alerts issued. The annual number of TC's of tropical storm strength or higher appears in Figure 1-1, while the number of TC's of super typhoon intensity appears in Figure 1-2. Figure 1-3 illustrates a monthly average number of cyclones based on intensity categories. Graphics showing 2009 tropical cyclone best tracks appear following Figure 1-3.

Table 1-1

WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 2009

(01 JAN 2009 - 31 DEC 2009)

TC	NAME*	PERIOD**	WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
TY 01W	Kujira	2 - 7 MAY	20	115	936
TY 02W	Chan-Hom	3 - 11 MAY	29	90	955
TY 03W	Linfa	17 - 22 JUN	21	75	966
TS 04W	Nangka	22 - 26 JUN	18	45	988
TS 05W	Soudelor	9 - 12 JUL	11	35	996
TD 06W		13 - 14 JUL	5	30	1000
TY 07W	Molave	15 - 19 JUL	16	105	944
TS 08W	Goni	2 - 8 AUG	15	45	988
TY 09W	Morakot	3 - 9 AUG	25	80	963
TS 10W	Etau	8 - 12 AUG	18	40	992
TY 11W	Vamco	17 - 25 AUG	34	120	933
TY 12W	Krovanh	28 - 31 AUG	16	65	974
TS 13W	Dujuan	3 - 8 SEP	25	55	981
TD 14W	Mujigae	9 - 12 SEP	12	30	1000
STY 15W	Choi-Wan	12 - 20 SEP	33	140	918
TY 16W	Koppu	13 - 15 SEP	9	75	966
TY 17W	Ketsana	25 - 29 SEP	19	90	955
TD 18W		27 - 30 SEP	13	30	1000
STY 19W	Parma	27 SEP - 14 OCT	68	135	921
STY 20W	Melor	29 SEP - 9 OCT	38	150	910
TS 21W	Nepartak	8 - 13 OCT	20	55	981
STY 22W	Lupit	14 - 26 OCT	49	140	918
TY 23W	Mirinae	26 OCT - 2 NOV	31	90	955
TD 24W		2 - 3 NOV	2	25	1003
TS 25W		7 - 9 NOV	10	45	988
STY 26W	Nida	22 NOV - 03 DEC	45	150	910

TD 27W		23 - 24 NOV	5	30	1000
TD 28W		5 - 5 DEC	1	30	1000
TS 01C	Maka	14 - 18 AUG	15	45	988
TD 02C		30 AUG	2	30	1000
* As Designated by RSMC Tokyo or CPHC					
** Dates are based on the issuance of JTWC warnings on system.					
***MSLP converted from estimated maximum surface winds using Knaff-Zehr wind-pressure relationship.					

Table 1-2
DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES
FOR 1959 - 2009

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	0 0 0	0 1 0	0 1 0	1 0 0	0 0 0	0 0 1	1 1 1	5 1 2	4 2 3	2 1 0	2 0 0	2 0 0	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	0 0 1	0 0 0	0 0 1	1 0 0	0 1 0	2 1 0	2 1 0	8 1 0	0 4 1	4 0 0	1 0 0	1 0 0	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	0 1 0	0 1 0	1 0 0	0 1 0	2 1 1	1 1 4	3 2 0	3 1 3	5 1 0	3 2 2	1 0 1	1 0 0	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	0 0 0	0 1 0	0 0 0	1 0 0	2 0 1	0 0 0	5 1 2	7 0 1	3 1 3	3 1 1	3 0 1	0 2 0	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	0 0 0	0 0 0	0 0 1	1 0 0	0 0 0	3 1 0	3 1 1	3 0 1	2 2 0	5 1 0	0 0 0	2 1 0	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	0 0 0	0 0 0	0 0 0	0 0 0	2 0 1	2 0 0	6 1 1	3 5 0	5 2 1	3 3 1	4 2 0	1 0 1	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	1 1 0	0 2 0	0 1 0	1 0 0	1 0 1	3 1 0	4 1 1	3 2 2	5 3 1	2 0 1	1 1 0	0 1 0	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	0 0 0	0 0 0	0 0 0	1 0 0	2 0 0	1 0 0	3 1 0	5 3 1	5 3 2	1 1 2	1 2 2	1 0 1	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	0 1 0	0 0 0	1 1 0	1 0 0	0 1 0	1 0 0	3 3 2	3 4 3	5 3 0	2 1 1	4 0 0	0 1 0	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	0 0 0	0 0 1	0 0 0	1 0 0	0 0 0	2 0 2	1 2 0	3 4 1	4 0 0	5 1 0	4 0 0	0 0 0	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	1 0 0	0 0 0	0 1 0	1 0 0	0 0 0	0 0 0	2 1 0	2 1 0	2 0 4	4 1 0	1 1 0	0 1 0	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	1 1 0	0 2 1	4 2 1	2 2 0	3 2 1	1 3 0	0 0 0	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	0 1 0	0 0 0	0 1 0	2 0 0	2 3 0	2 0 0	6 2 0	3 1 1	5 1 1	3 1 0	1 1 0	0 0 0	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	1 0 0	0 0 0	0 0 1	0 0 0	0 0 0	2 2 0	4 1 0	3 2 0	4 1 1	4 1 0	2 0 0	2 1 0	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	4 3 0	2 3 1	2 0 1	4 0 0	0 3 0	0 0 0	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	0 1 0	0 0 0	0 1 0	0 1 0	1 0 0	1 2 1	2 3 0	2 3 2	3 2 0	4 0 0	2 2 0	0 2 0	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	1 0 0	0 0 0	0 0 0	0 0 1	0 0 0	0 0 0	0 1 0	4 1 1	4 1 0	3 2 1	2 1 0	0 2 0	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	1 0 0	0 1 0	0 0 0	1 1 0	2 0 0	2 0 0	2 2 0	1 3 0	4 1 0	0 0 0	1 1 0	0 2 0	14 11 0

1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	541	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
1987	1	0	0	1	0	2	4	4	7	2	3	1	25
	100	000	000	010	000	110	400	310	511	200	120	100	18 6 1
1988	1	0	0	0	1	3	2	5	8	4	2	1	27
	100	000	000	000	100	111	110	230	260	400	200	010	14 12 1
1989	1	0	0	1	2	2	6	8	4	6	3	2	35
	010	000	000	100	200	110	231	332	220	600	300	101	21 10 4
1990	1	0	0	1	2	4	4	5	5	5	4	1	32
	100	000	000	010	110	211	220	500	410	230	310	100	21 10 1
1991	0	0	2	1	1	1	4	8	6	3	6	0	32
	000	000	110	010	100	100	400	332	420	300	330	000	20 10 2
1992	1	1	0	0	0	3	4	8	5	6	5	0	33
	100	010	000	000	000	210	220	440	410	510	311	000	21 11 1
1993	0	0	2	2	1	2	5	8	5	6	4	3	38
	000	000	011	002	010	101	320	611	410	321	112	300	21 9 8
1994	1	0	1	0	2	2	9	9	8	7	0	2	41
	001	000	100	000	101	020	342	630	440	511	000	110	21 15 5
1995	1	0	0	0	1	2	3	7	7	8	2	3	34
	001	000	000	000	010	020	210	421	412	512	020	012	15 11 8
1996	1	1	0	2	2	0	7	10	7	5	6	3	43
	001	001	000	011	110	000	610	433	610	212	132	111	21 12 10
1997	1	0	0	2	3	3	4	8	4	6	1	1	33
	010	000	000	110	120	300	310	611	310	411	100	100	23 8 2
1998	0	0	0	0	0	0	3	3	8	6	3	4	27
	000	000	000	000	000	000	012	210	413	213	030	112	9 8 10
1999	1	1	0	3	0	1	5	9	6	2	3	3	34
	010	010	000	210	000	100	113	423	240	110	111	003	12 12 10
2000	0	0	0	0	4	0	8	9	6	3	3	1	34
	000	000	000	000	112	000	233	432	411	210	111	100	15 10 9
2001	0	1	0	1	1	2	6	7	5	3	3	4	33
	000	001	000	001	010	200	7411	331	500	300	120	220	20 9 4
2002	1	1	1	1	2	3	6	8	3	5	1	1	33

	0 1 0	1 0 0	0 0 1	0 0 1	1 0 1	3 0 0	3 2 1	4 3 1	1 2 0	3 0 2	1 0 0	1 0 0	18 8 7
2003	1	0	0	1	3	2	2	5	3	6	3	1	27
	0 1 0	0 0 0	0 0 0	1 0 0	1 1 1	1 1 0	2 0 0	4 1 0	3 0 0	2 1 3	3 0 0	0 1 0	17 6 4
2004	0	1	1	1	3	5	2	9	3	3	2	2	32
	0 0 0	0 1 0	0 1 0	1 0 0	2 1 0	5 0 0	1 1 0	6 2 1	1 1 1	3 0 0	2 0 0	0 2 0	21 9 2
2005	1	0	1	1	0	1	4	6	5	3	2	1	25
	1 0 0	0 0 0	1 0 0	1 0 0	0 0 0	1 0 0	1 3 0	6 0 0	4 1 0	2 0 1	1 1 0	0 1 0	18 6 1
2006	0	0	1	0	1	1	3	8	5	4	2	2	27
	0 0 0	0 0 0	0 1 0	0 0 0	1 0 0	0 1 0	2 1 0	3 4 1	3 0 2	2 1 1	2 0 0	1 0 1	14 8 5
2007	0	0	1	0	1	0	3	5	5	5	6	0	26
	0 0 0	0 0 0	1 0 0	0 0 0	1 0 0	0 0 0	2 1 0	3 2 1	2 2 1	3 2 0	3 1 2	0 0 0	15 8 4
2008	1	0	0	1	4	1	2	5	6	3	3	1	27
	0 1 0	0 0 0	0 0 0	1 0 0	3 1 0	1 0 0	2 0 0	1 4 0	3 3 0	0 3 0	0 3 0	1 0 0	12 15 0
2009	0	0	0	0	2	2	3	5	7	4	4	1	28
	0 0 0	0 0 0	0 0 0	0 0 0	2 0 0	1 1 0	1 1 1	3 2 0	4 1 2	3 1 0	1 1 2	0 0 1	15 7 6

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, it was attributed to the second month.

TABLE 1-2 Legend		
Total month/year		
GTE 64 knots (Typhoon)	34 to 63 knots (Tropical Storm)	LTE 33 knots (Tropical Depression)

TABLE 1-3 WESTERN NORTH PACIFIC TROPICAL CYCLONES													
TYPHOONS (1945 - 1958)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.1	0.3	0.4	0.7	1.1	2	2.9	3.2	2.4	2	0.9	24.4
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228
TYPHOONS (1959 - 2009)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.2	0.1	0.2	0.4	0.8	1.1	2.5	3.5	3.3	3.0	1.6	0.7	17.4
CASES	11	3	10	20	40	56	127	173	166	151	79	35	871
TROPICAL STORMS AND TYPHOONS (1945 - 1958)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.1	0.5	0.5	0.8	1.6	2.9	4	4.2	3.3	2.7	1.2	22.2
CASES	6	2	7	8	11	22	44	60	64	49	41	18	332
TROPICAL STORMS AND TYPHOONS (1959 - 2009)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.5	0.2	0.4	0.6	1.6	1.6	3.8	5.2	4.8	3.8	2.5	1.1	26.0
CASES	23	9	20	31	78	78	189	262	238	192	125	57	1302

TABLE 1-4
TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976 - 2009

YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	PROBABILITY OF TCFA WITHOUT WARNING*	PROBABILITY OF TCFA BEFORE WARNING
1976	34	25	25	36%	100%
1977	26	20	21	29%	95%
1978	32	27	32	16%	84%
1979	27	23	28	14%	82%
1980	37	28	28	32%	100%
1981	29	28	29	3%	97%
1982	36	26	28	36%	93%
1983	31	25	25	24%	100%
1984	37	30	30	23%	100%
1985	39	26	27	48%	96%
1986	38	27	27	41%	100%
1987	31	24	25	28%	96%
1988	33	26	27	26%	96%
1989	51	32	35	54%	91%
1990	33	30	31	10%	97%
1991	37	29	31	26%	94%
1992	36	32	32	13%	100%
1993	50	35	38	39%	92%
1994	50	40	40	25%	100%
1995	54	33	35	60%	94%
1996	41	39	43	5%	91%
1997	36	30	33	18%	91%
1998	38	18	27	74%	67%
1999	39	29	33	30%	88%
2000	40	31	34	26%	91%
2001	34	28	33	18%	82%
2002	39	31	33	24%	94%
2003	31	27	27	15%	100%
2004	35	32	32	9%	100%
2005	26	25	25	4%	100%
2006	23	22	26	4%	85%
2007	27	26	27	4%	96%
2008	23	23	28	0%	82%
2009	26	22	28	18%	79%
MEAN	35.3	27.9	30.1	24.5%	92.7%
CASES	1199	949	1023		

* Percentage of initial TCFAs not followed by warnings.

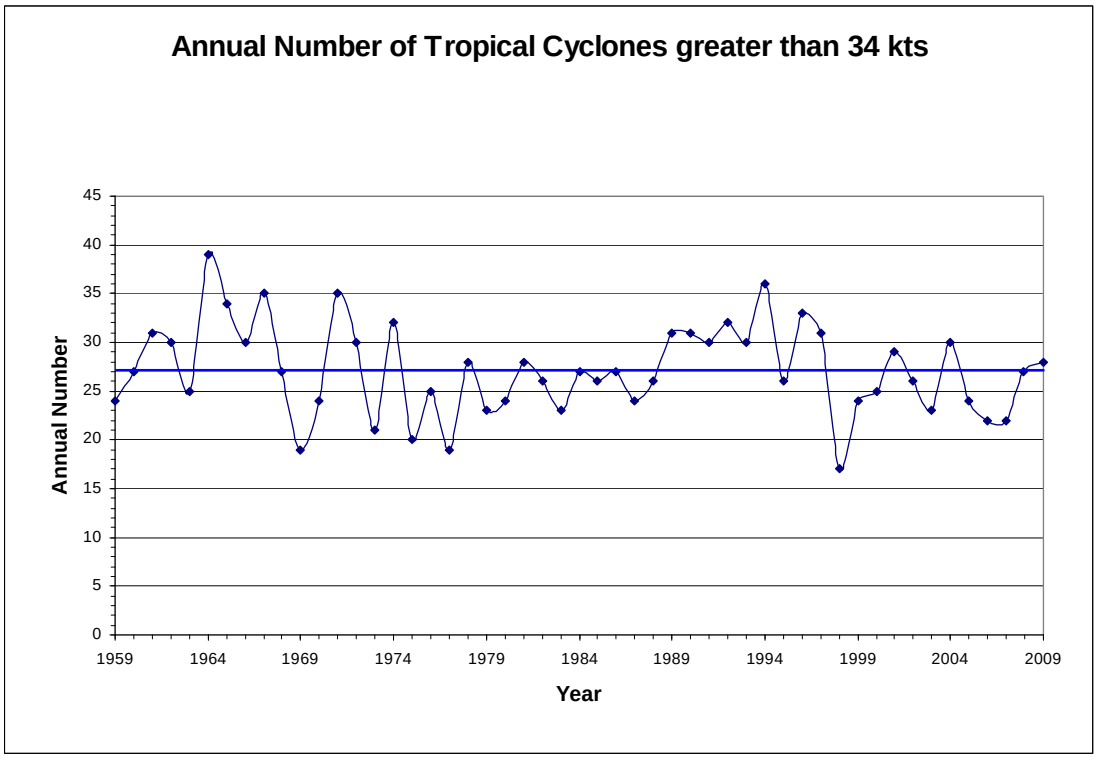


Figure 1-1. Annual number of Tropical Cyclones greater than 34 knots intensity.

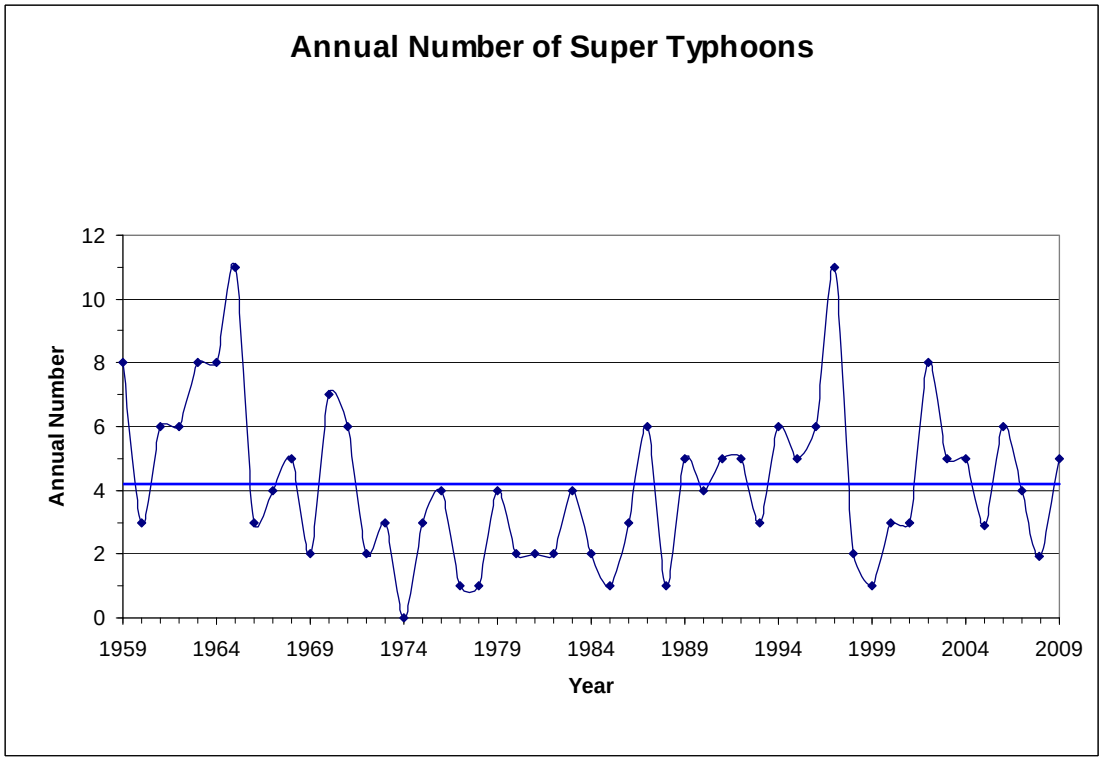


Figure 1-2. Annual number of Tropical Cyclones greater than 127 knots intensity.

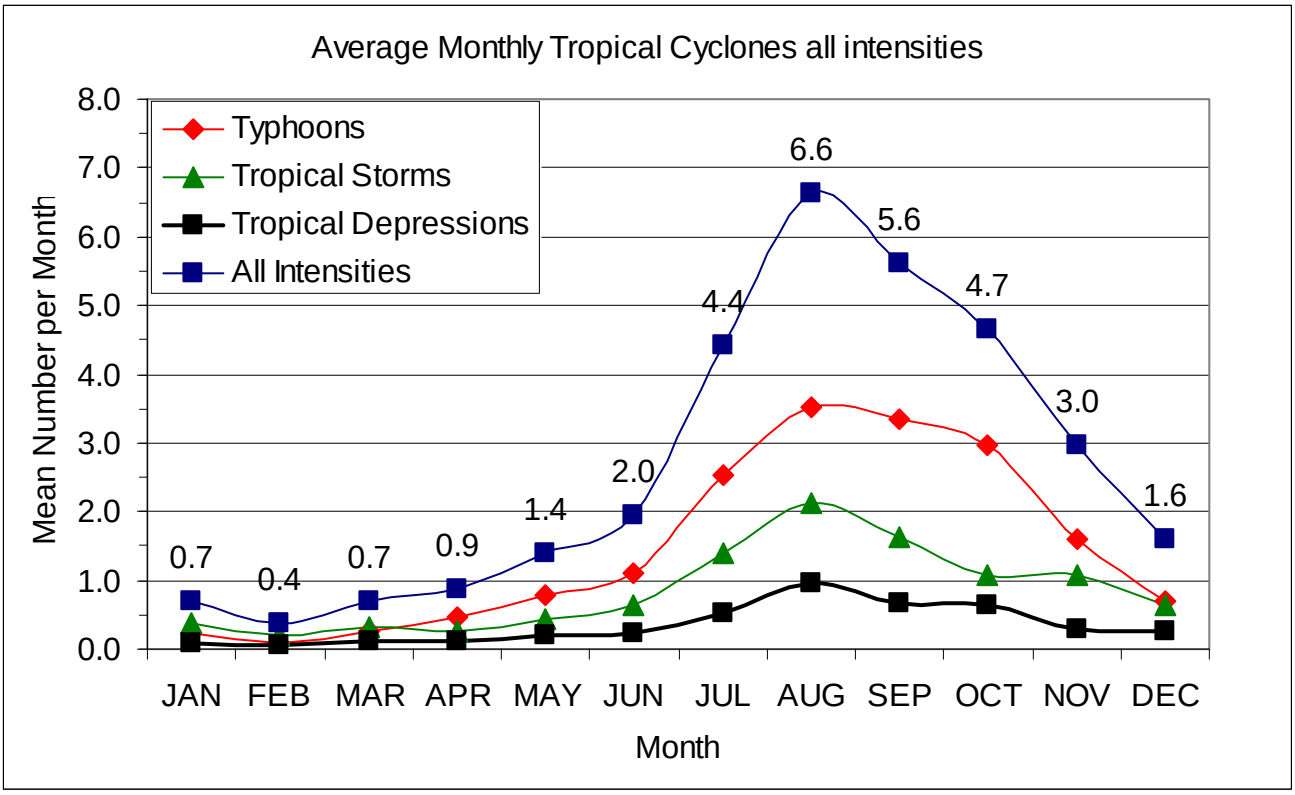


Figure 1-3. Average number of Tropical Cyclones of all intensities by month.

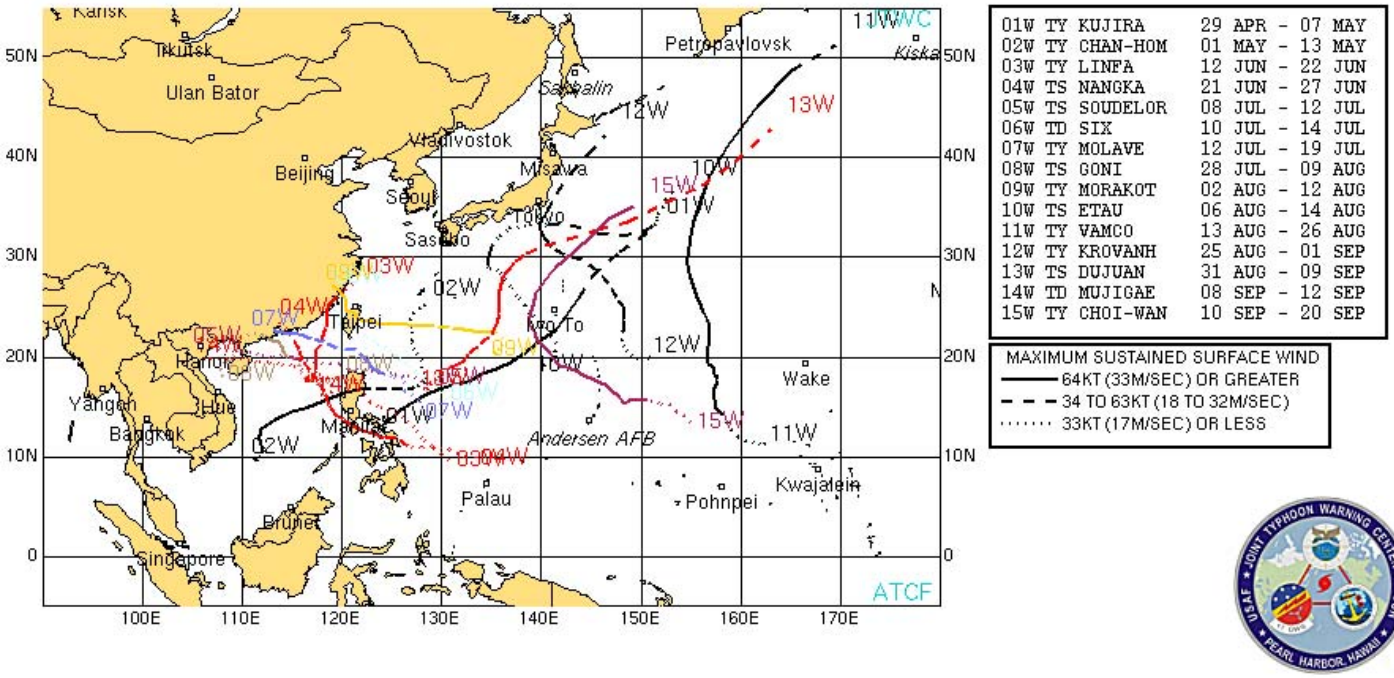


Figure 1-4. Western North Pacific Tropical Cyclones 01W – 15W.

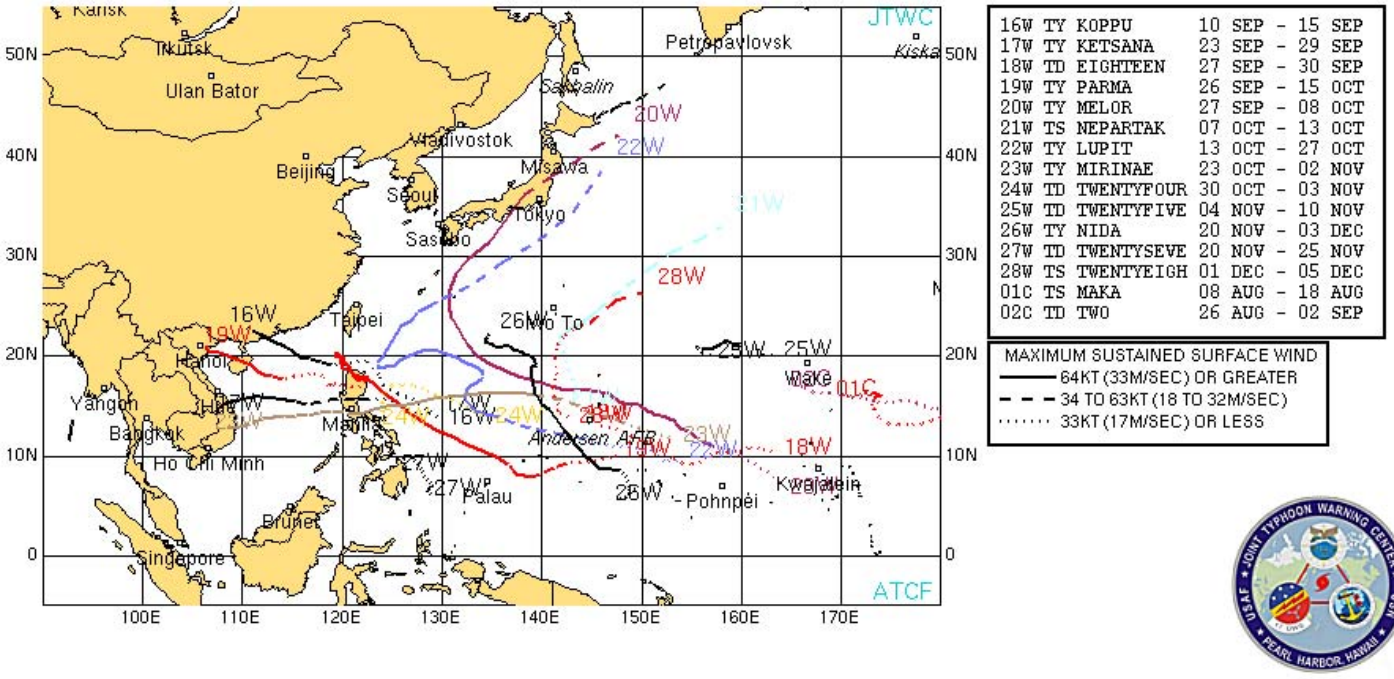


Figure 1-5. Western North Pacific Tropical Cyclones 16W – 02C. [1]

[1] TS 01C and TD 02C were Central Pacific Hurricane Center (CPHC) cyclones that crossed into the JTWC AOR. Only the JTWC portion of the best track is depicted.

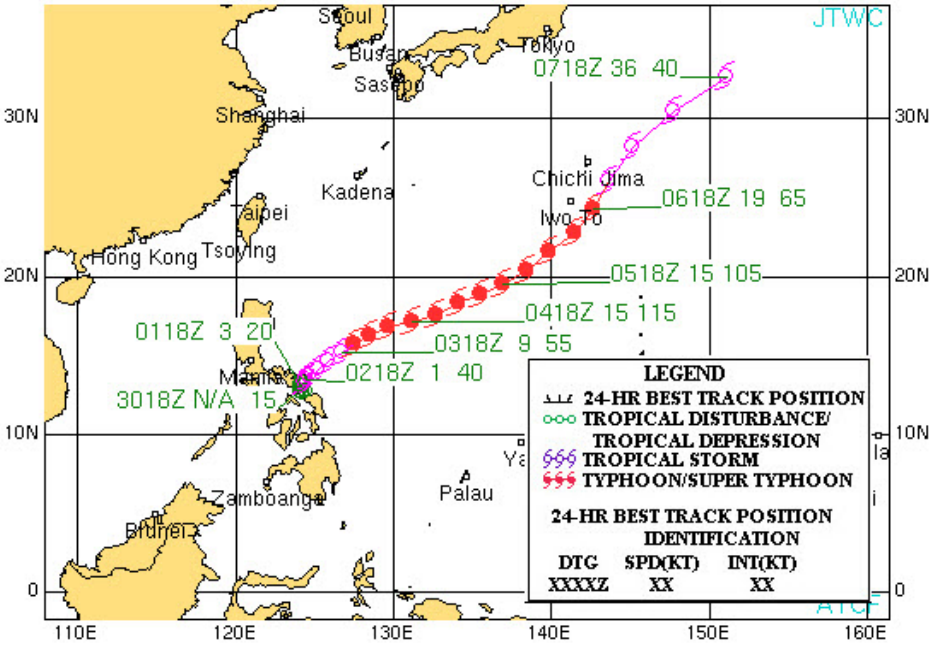
Section 2 Cyclone Summaries

This section presents a synopsis of each cyclone that occurred during 2009 in the western North Pacific Ocean. Each cyclone is presented, with the number and basin identifier used by JTWC, along with the RSMC Tokyo assigned name. Dates are also listed when JTWC first designated the various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development occurring/TC expected (Good classification). Furthermore, first Tropical Cyclone Formation Alert (TCFA), and the initial and final warnings dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

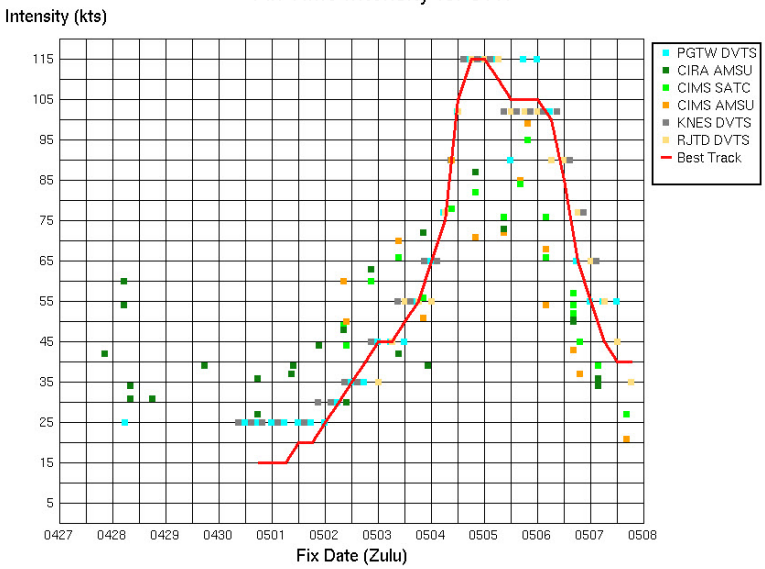
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track positions are marked by date at 0000 UTC, as well as the beginning and end points. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity and fix intensity versus time is presented. The fix plots on this graph are color coded by fixing agency.

Typhoon 01W (Kujira)

ISSUED POOR:	0600Z 30 Apr 2009
ISSUED FAIR:	2330Z 30 Apr 2009
FIRST TCFA:	0130Z 02 May 2009
FIRST WARNING:	0600Z 02 May 2009
LAST WARNING:	0000Z 07 May 2009
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	20

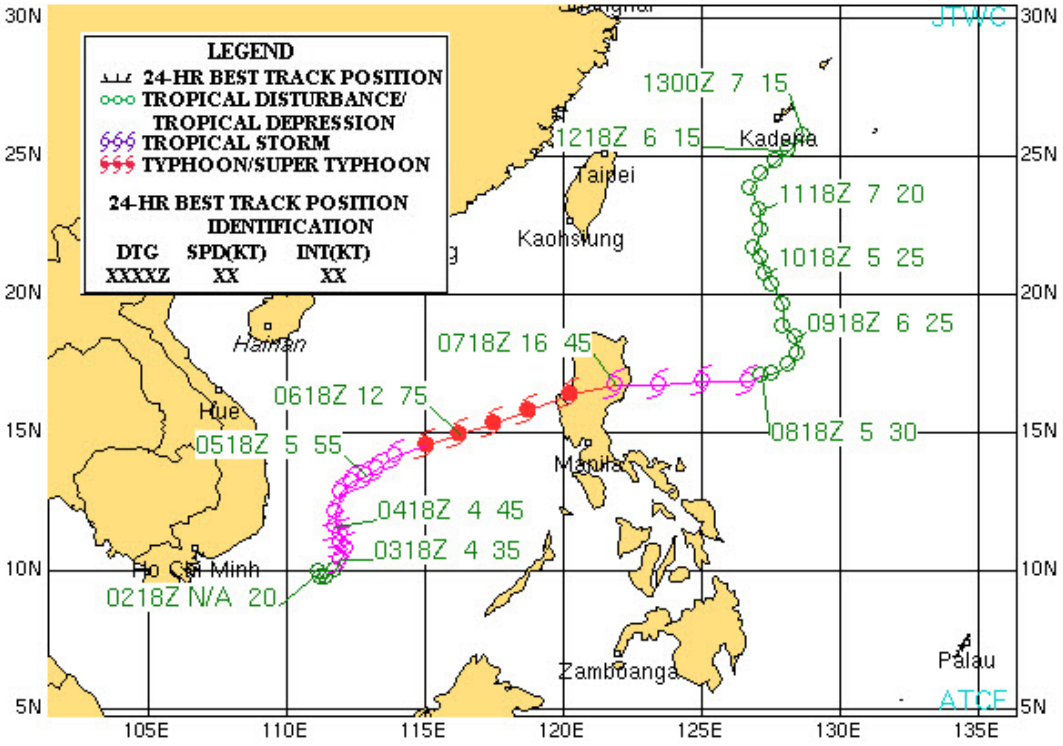


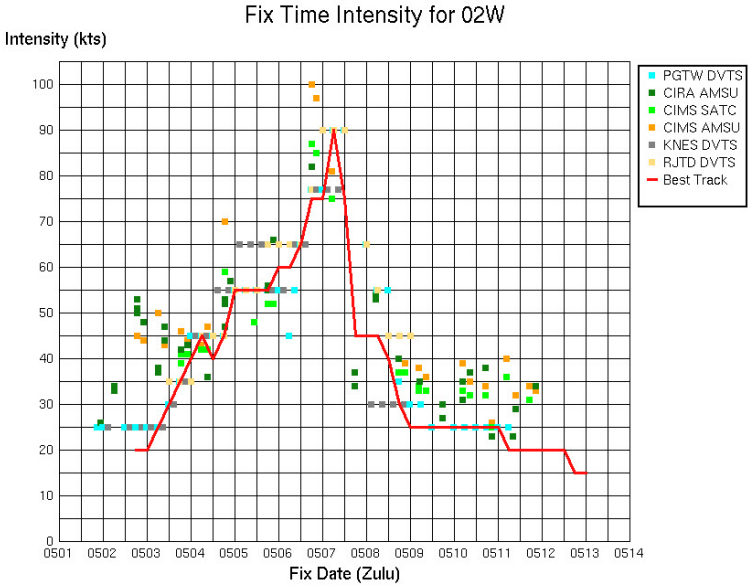
Fix Time Intensity for 01W



Typhoon 02W (Chan-Hom)

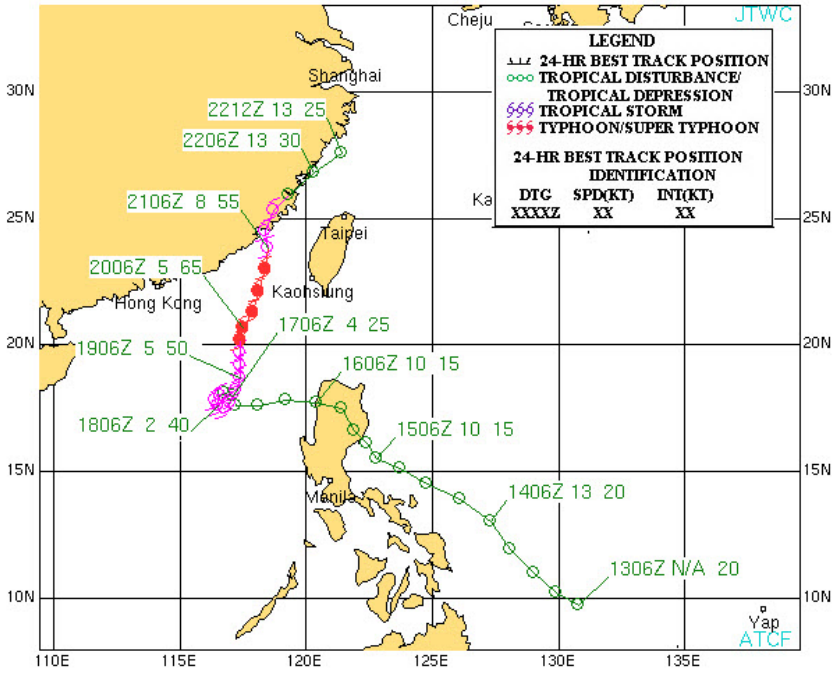
ISSUED POOR: N/A
ISSUED FAIR: 0600Z 02 May 2009
FIRST TCFA: 2200Z 02 May 2009
FIRST WARNING: 1200Z 03 May 2009
LAST WARNING: 0600Z 11 May 2009
MAX INTENSITY: 90 Kts
NUMBER OF WARNINGS: 29

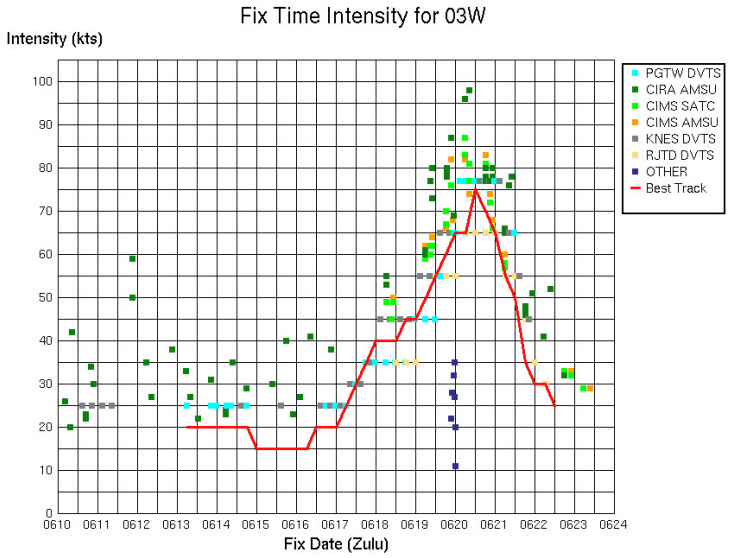




Typhoon 03W (Linfa)

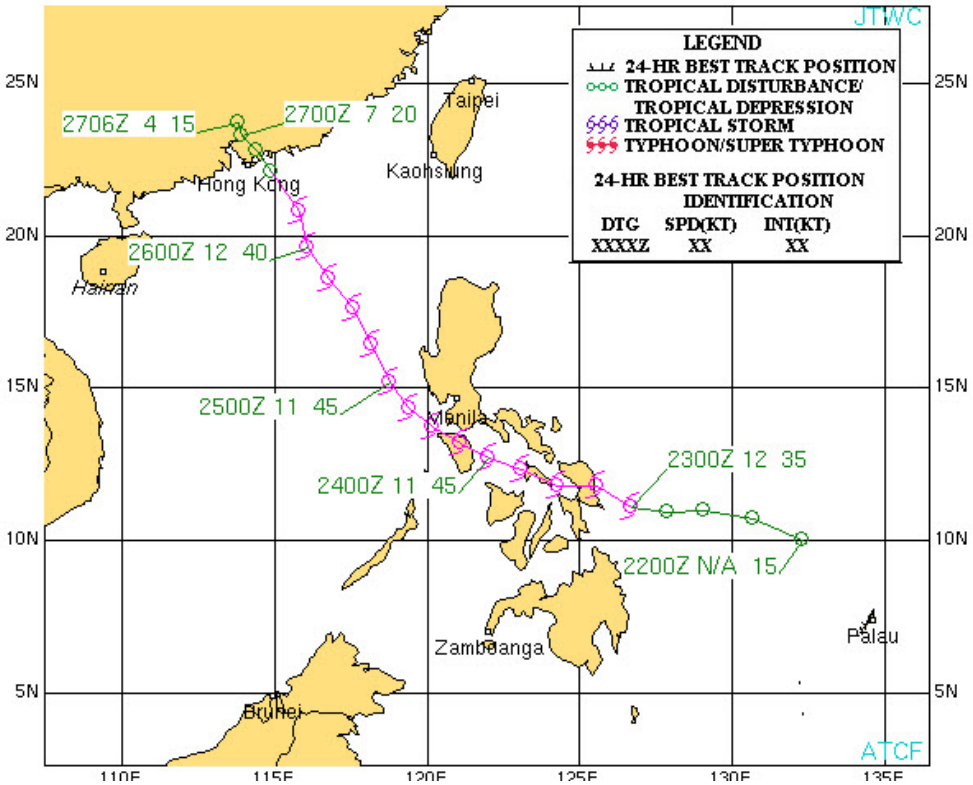
ISSUED POOR: 2330Z 14 Jun 2009
ISSUED FAIR: 2200Z 16 Jun 2009
FIRST TCFA: 0300Z 17 Jun 2009
FIRST WARNING: 0600Z 17 Jun 2009
LAST WARNING: 1200Z 22 Jun 2009
MAX INTENSITY: 75 Kts
NUMBER OF WARNINGS: 21

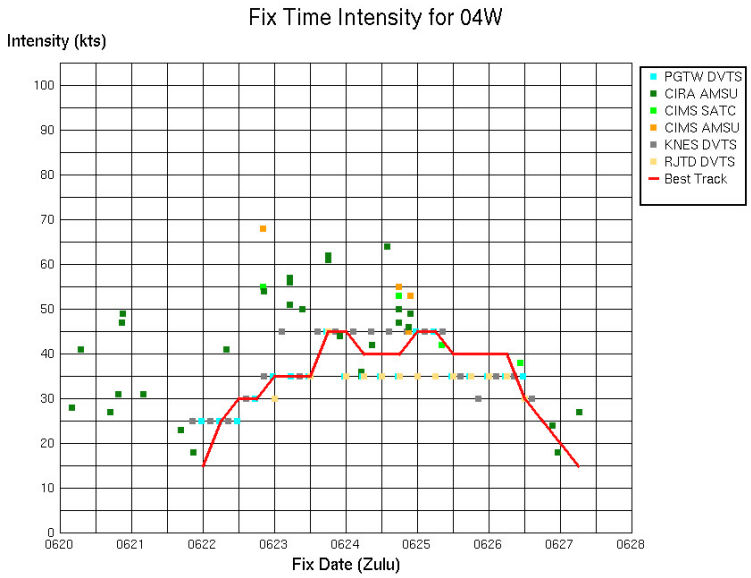




Tropical Storm 04W (Nangka)

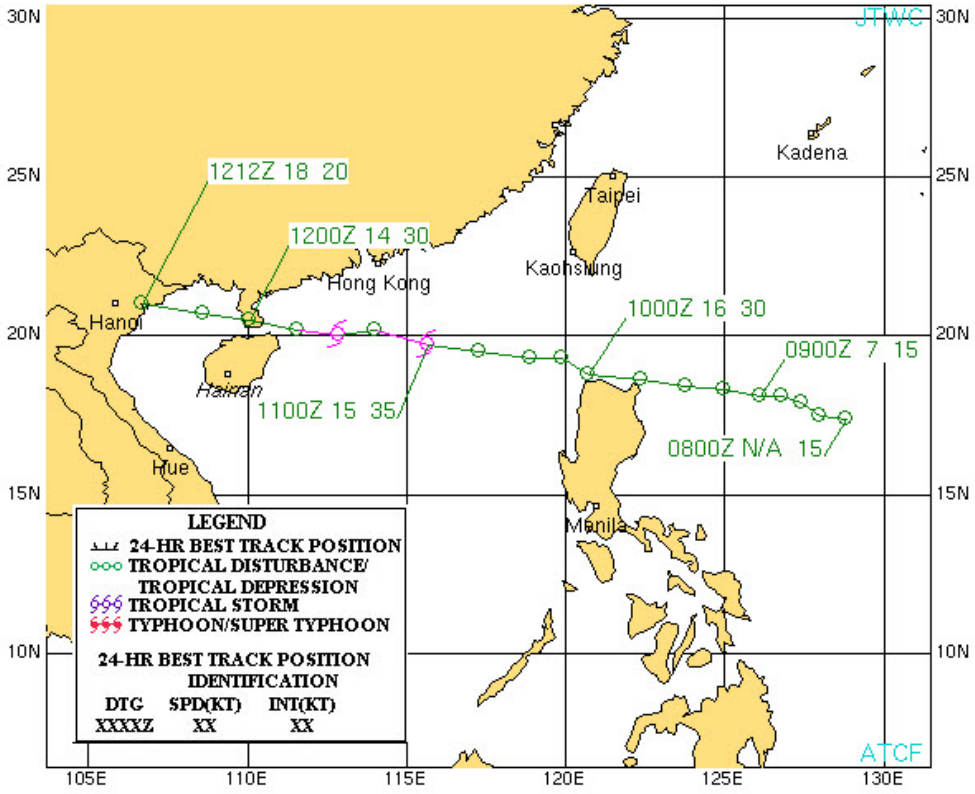
ISSUED POOR: 0600Z 21 Jun 2009
ISSUED FAIR: 0600Z 22 Jun 2009
FIRST TCFA: 1000Z 22 Jun 2009
FIRST WARNING: 1200Z 22 Jun 2009
LAST WARNING: 1800Z 26 Jun 2009
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 18

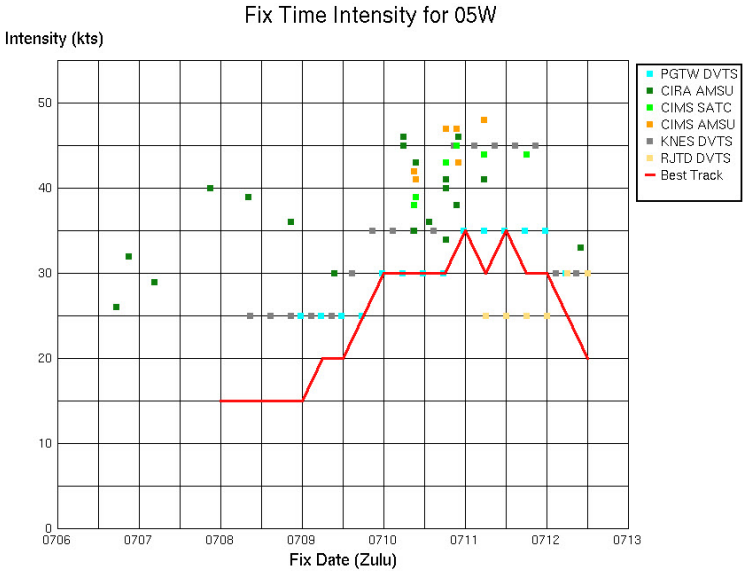




Tropical Storm 05W (Soudelor)

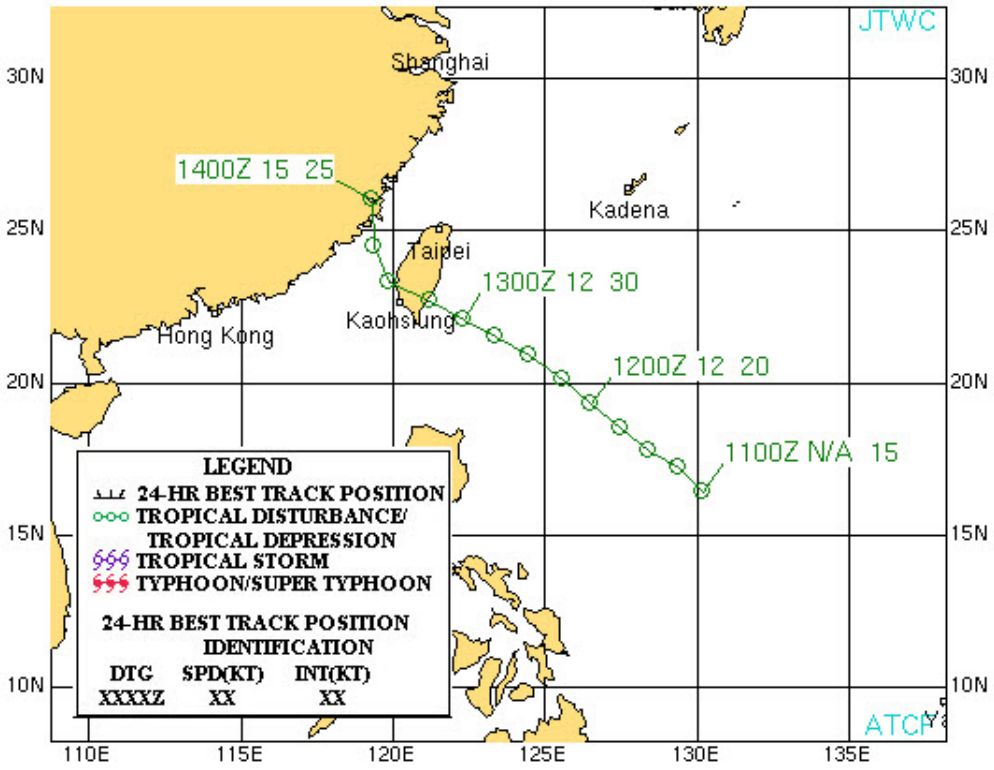
ISSUED POOR:	1900Z 07 Jul 2009
ISSUED FAIR:	0000Z 08 Jul 2009
FIRST TCFA:	0930Z 09 Jul 2009
FIRST WARNING:	1800Z 09 Jul 2009
LAST WARNING:	0600Z 12 Jul 2009
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	11

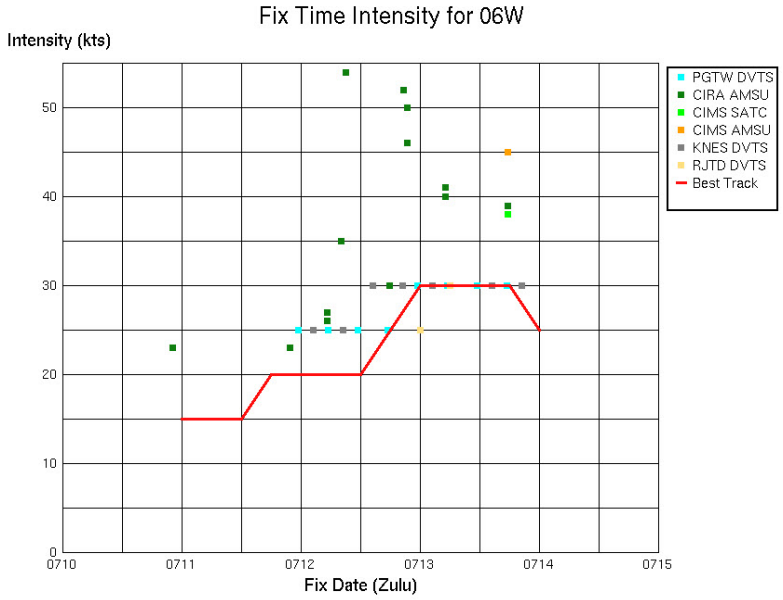




Tropical Depression 06W

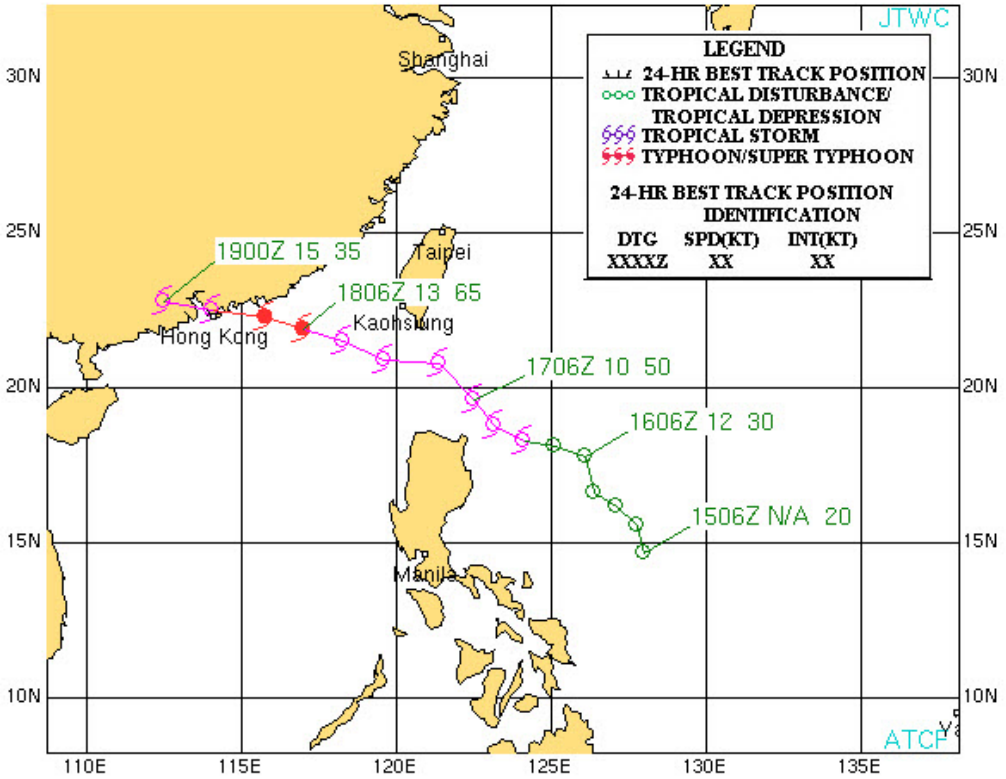
ISSUED POOR: 2200Z 10 Jul 2009
ISSUED FAIR: 2300Z 11 Jul 2009
FIRST TCFA: 0430Z 12 Jul 2009
FIRST WARNING: 0000Z 13 Jul 2009
LAST WARNING: 0000Z 14 Jul 2009
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 5

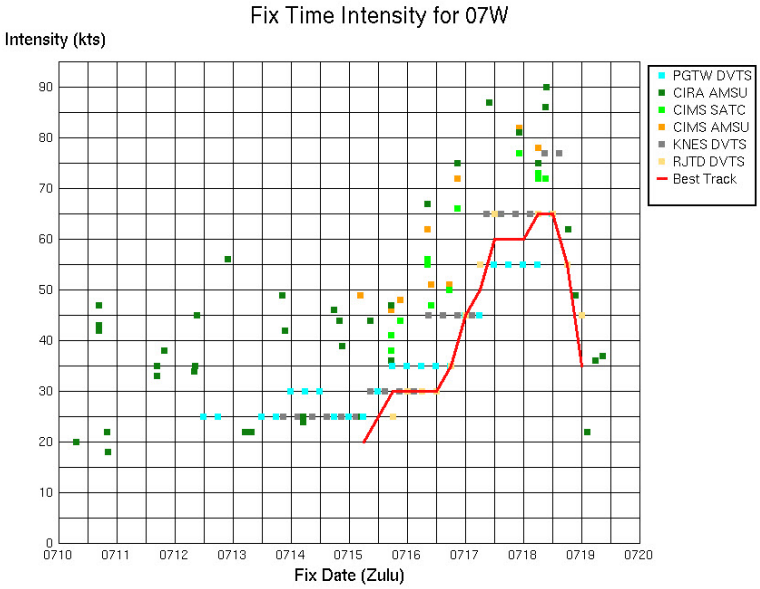




Typhoon 07W (Molave)

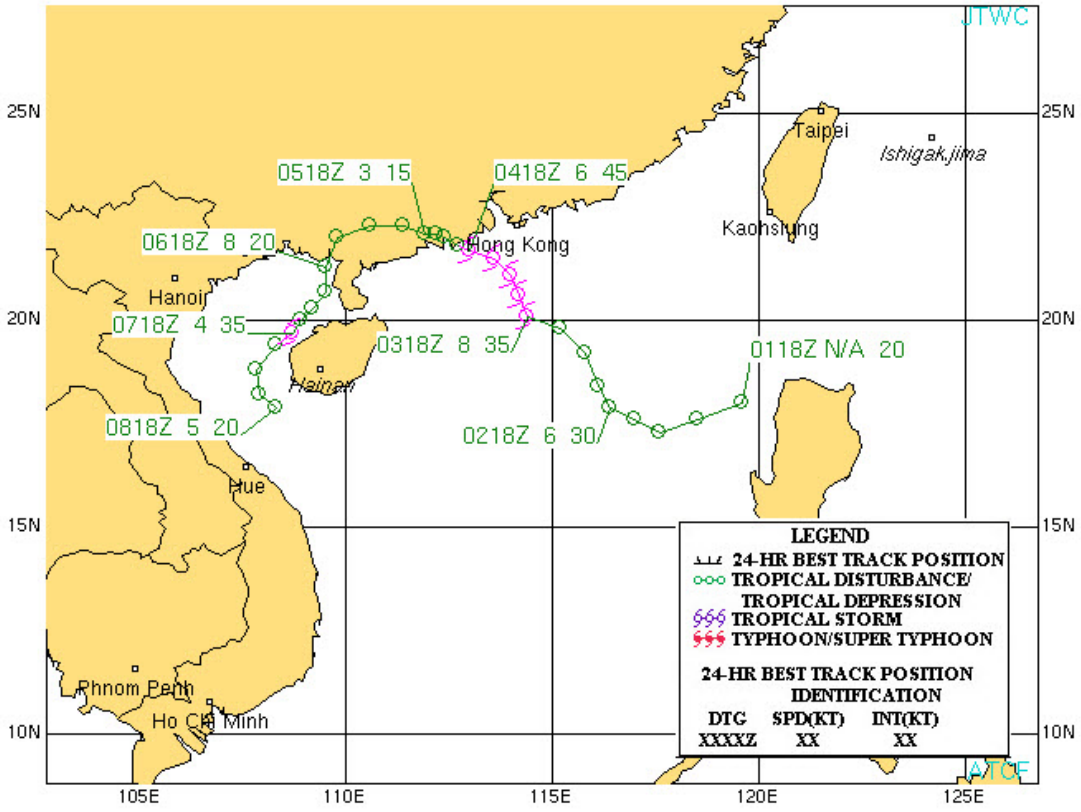
ISSUED POOR: 2300Z 10 Jul 2009
ISSUED FAIR: 0600Z 11 Jul 2009
FIRST TCFA: 2330Z 13 Jul 2009
FIRST WARNING: 0600Z 15 Jul 2009
LAST WARNING: 0000Z 19 Jul 2009:
MAX INTENSITY: 65 Kts
NUMBER OF WARNINGS: 16

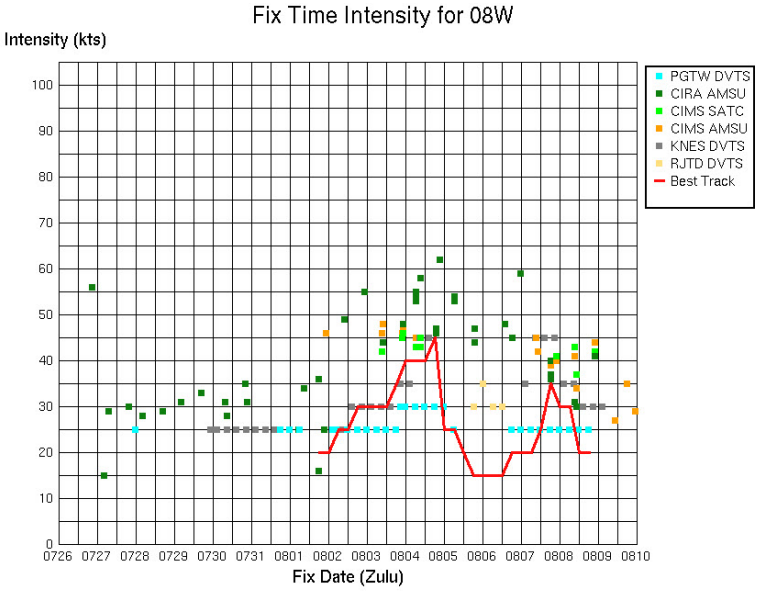




Tropical Storm 08W (Goni)

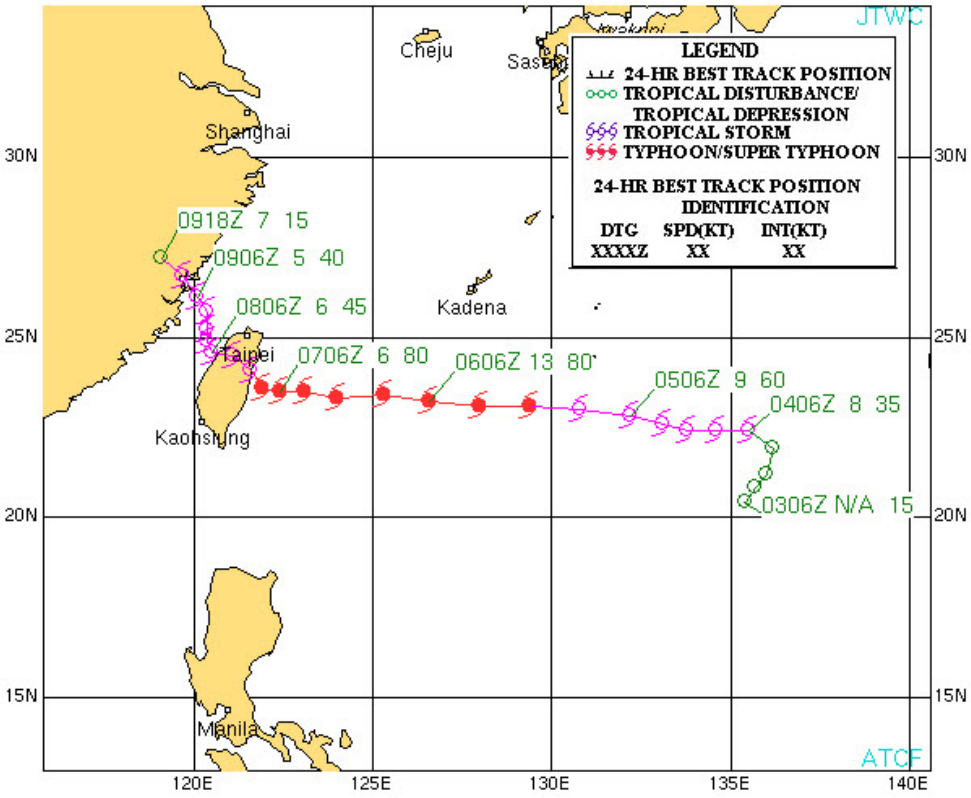
ISSUED POOR: 0300Z 28 Jul 2009
ISSUED FAIR: 0600Z 31 Jul 2009
FIRST TCFA: 0300Z 01 Aug 2009
FIRST WARNING: 1800Z 02 Aug 2009
LAST WARNING: 1800Z 08 Aug 2009
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 15

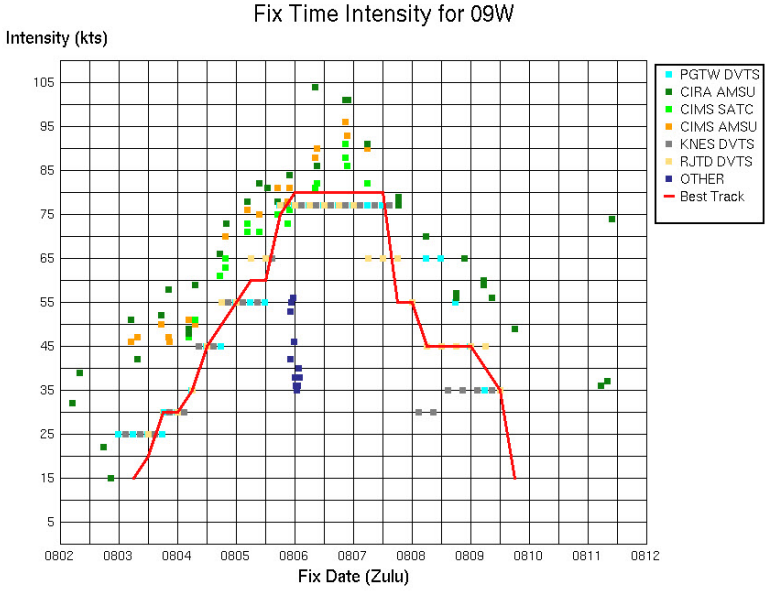




Typhoon 09W (Morakot)

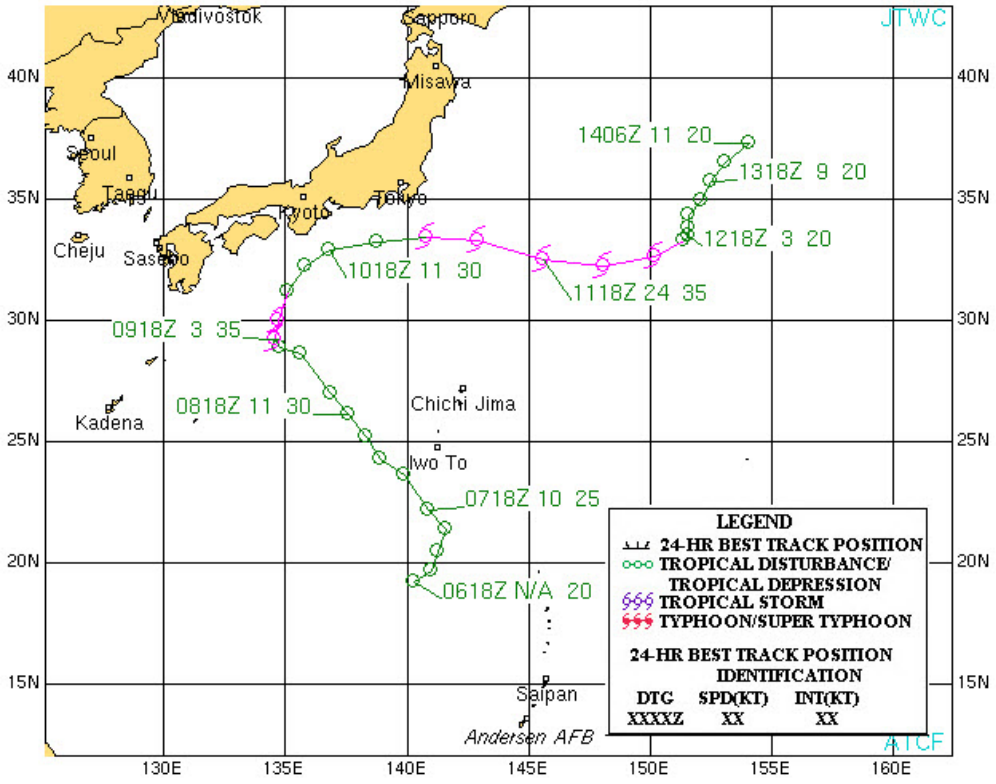
ISSUED POOR: N/A
ISSUED FAIR: 0000Z 03 Aug 2009
FIRST TCFA: N/A
FIRST WARNING: 1800Z 03 Aug 2009
LAST WARNING: 1800Z 09 Aug 2009
MAX INTENSITY: 80 Kts
NUMBER OF WARNINGS: 25

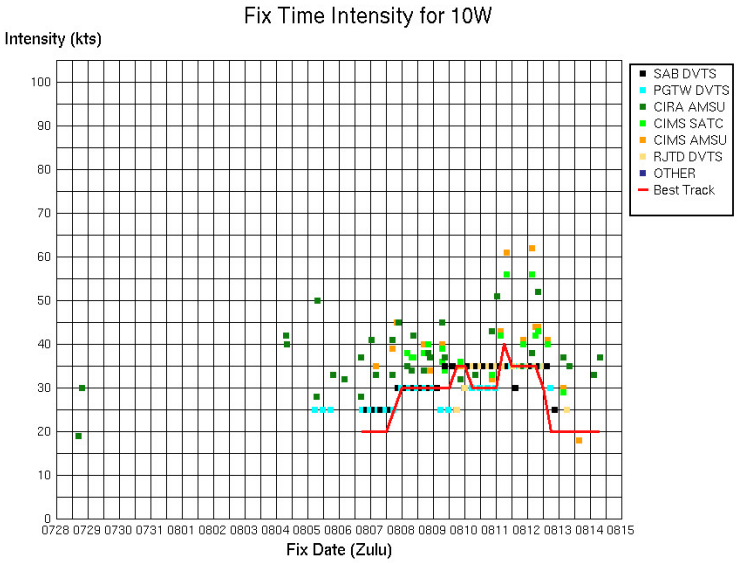




Tropical Storm 10W (Etau)

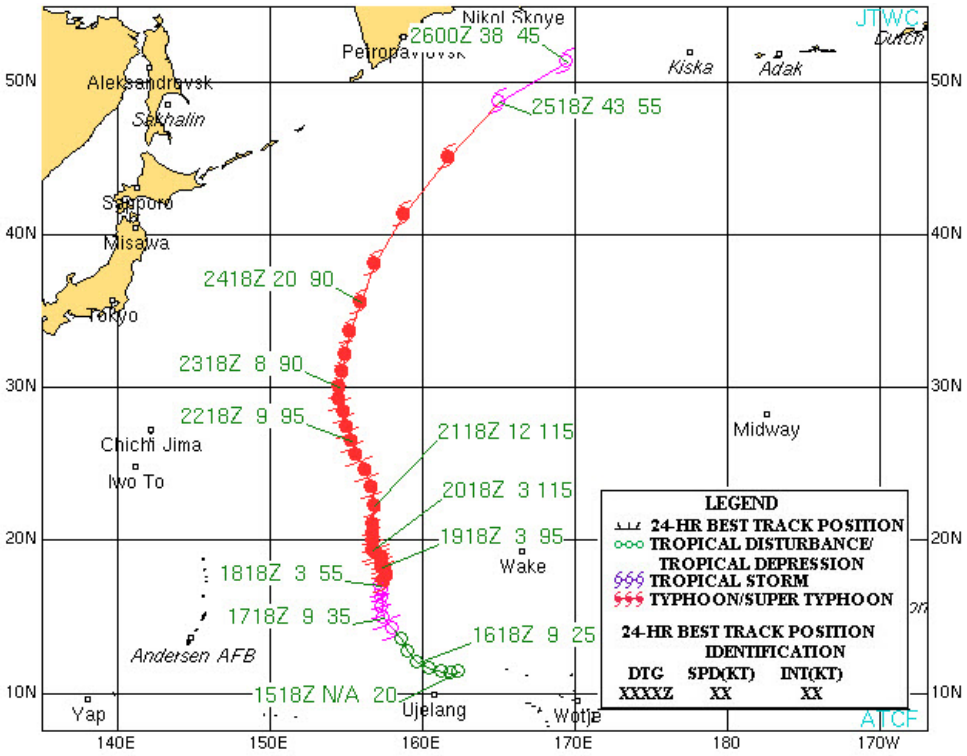
ISSUED POOR: 0600Z 05 Aug 2009
ISSUED FAIR: 2100Z 06 Aug 2009
FIRST TCFA: 0000Z 07 Aug 2009
FIRST WARNING: 0000Z 08 Aug 2009
LAST WARNING: 0000Z 12 Aug 2009
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 18

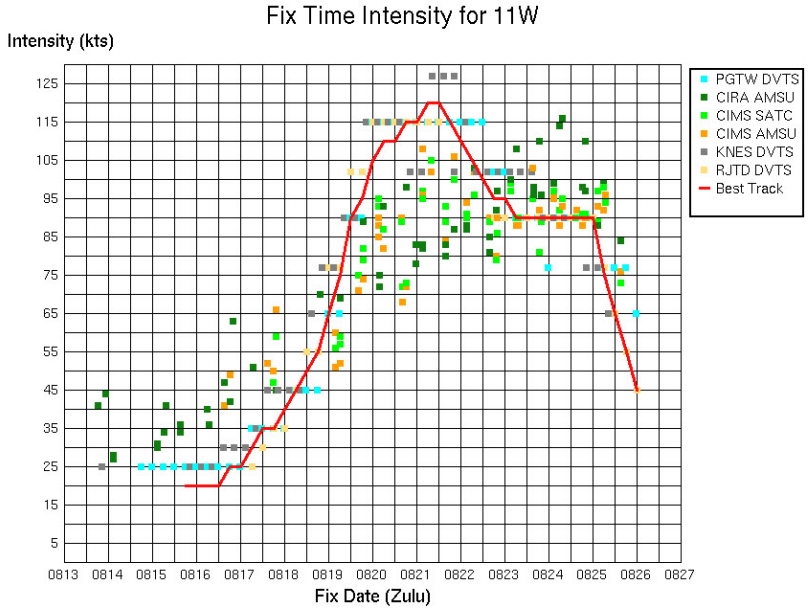




Typhoon 11W (Vamco)

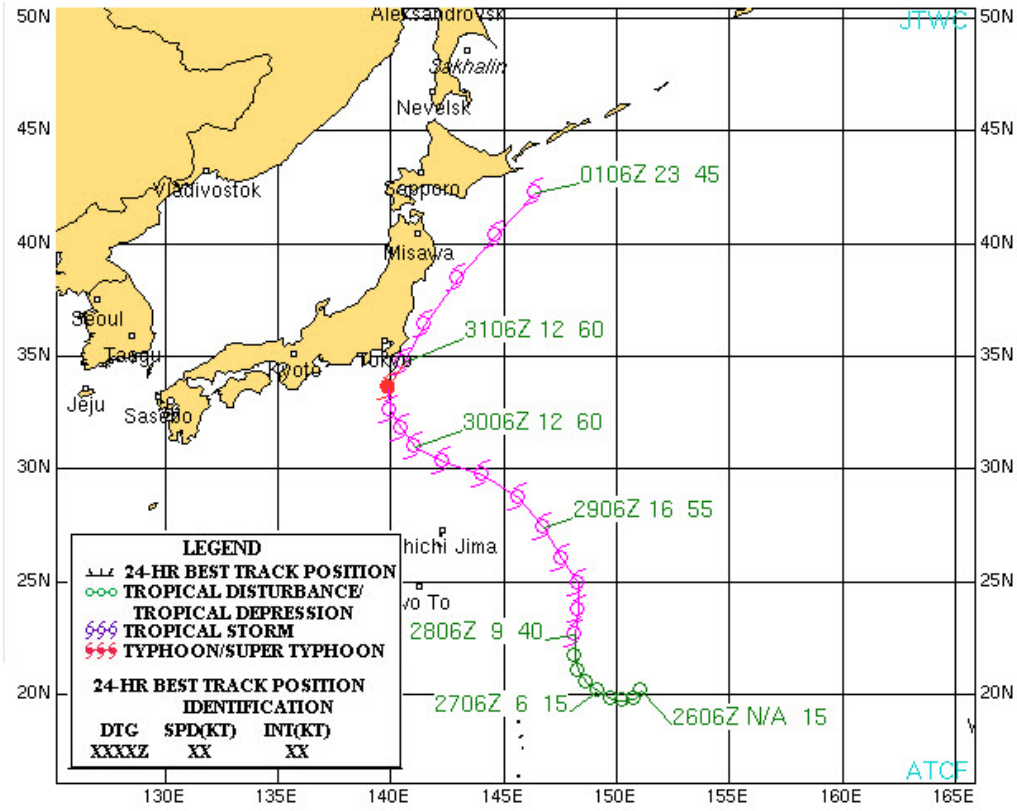
ISSUED POOR:	N/A
ISSUED FAIR:	2130Z 13 Aug 2009
FIRST TCFA:	0600Z 16 Aug 2009
FIRST WARNING:	0000Z 17 Aug 2009
LAST WARNING:	0000Z 25 Aug 2009
MAX INTENSITY:	120 Kts
NUMBER OF WARNINGS:	34

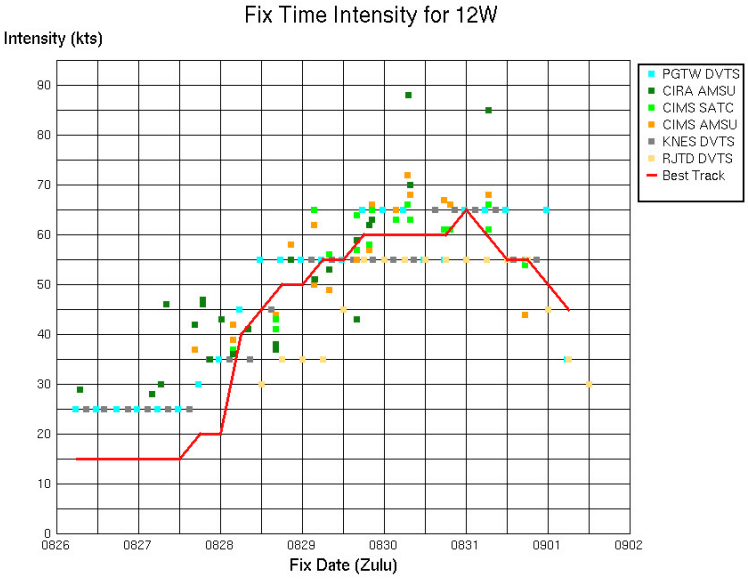




Typhoon 12W (Krovanh)

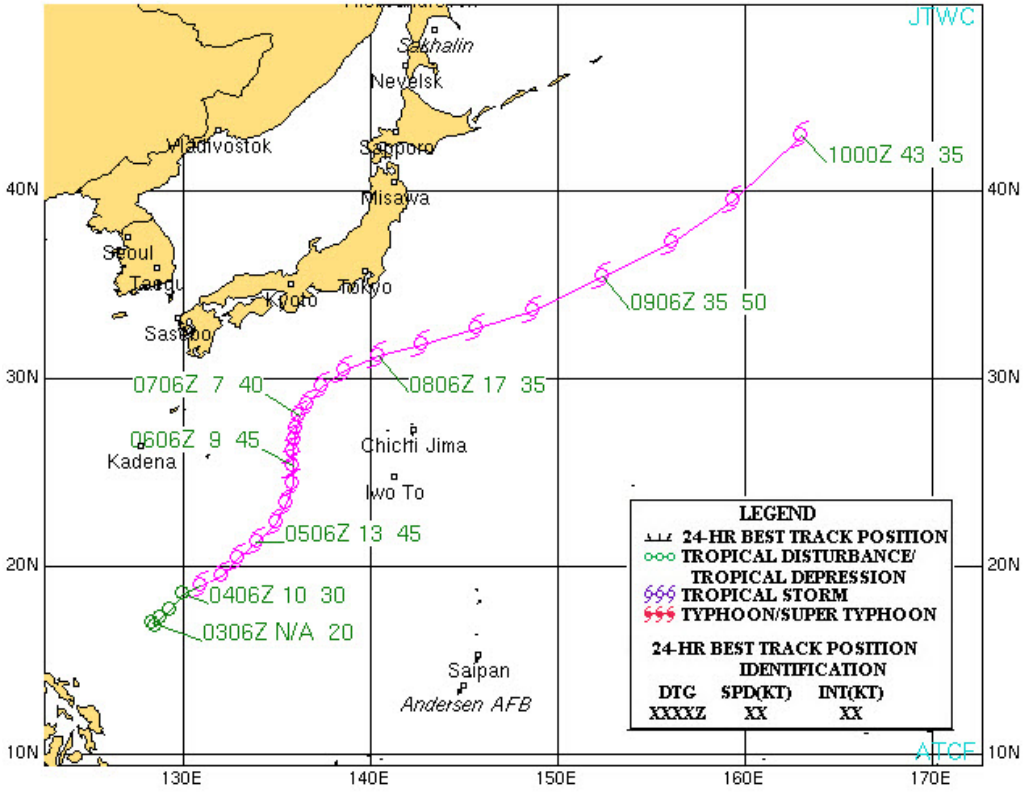
ISSUED POOR:	1200Z 26 Aug 2009
ISSUED FAIR:	1700Z 27 Aug 2009
FIRST TCFA:	2000Z 27 Aug 2009
FIRST WARNING:	0000Z 28 Aug 2009
LAST WARNING:	1800Z 31 Aug 2009
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	16

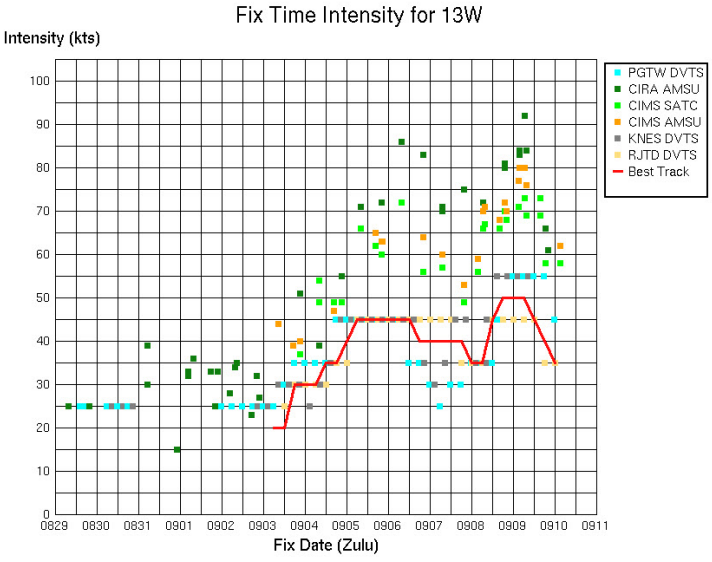




Tropical Storm 13W (Dujuan)

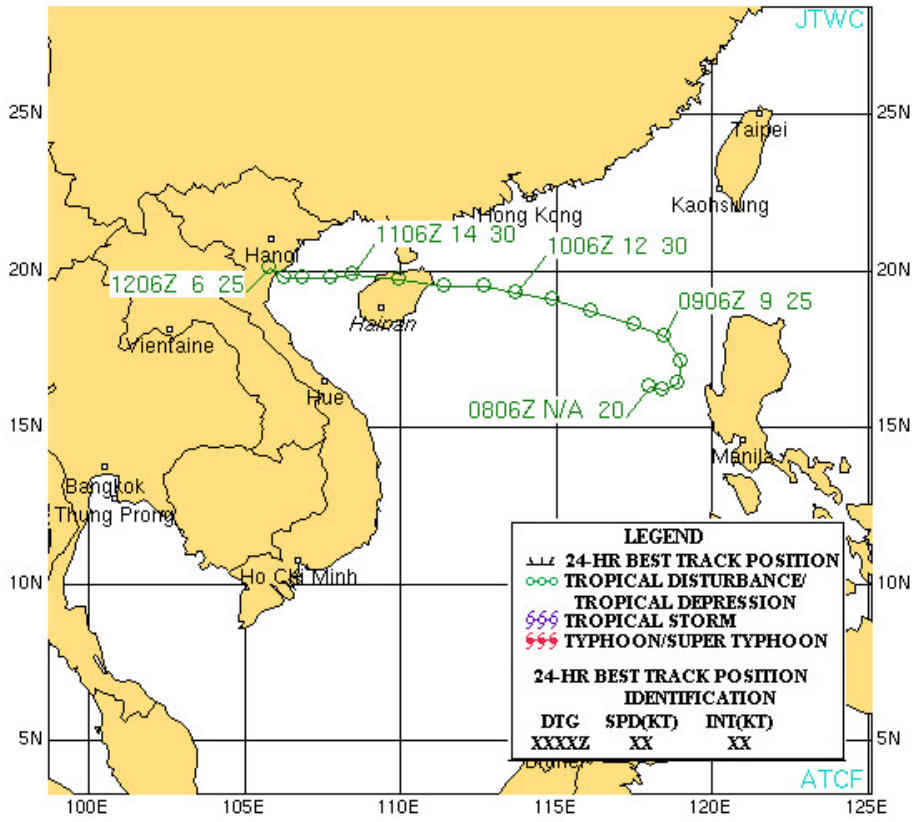
ISSUED POOR: N/A
ISSUED FAIR: 1800Z 29 Aug 2009
FIRST TCFA: 1500Z 02 Sep 2009
FIRST WARNING: 1200Z 03 Sep 2009
LAST WARNING: 1200Z 08 Sep 2009
MAX INTENSITY: 50 Kts
NUMBER OF WARNINGS: 25

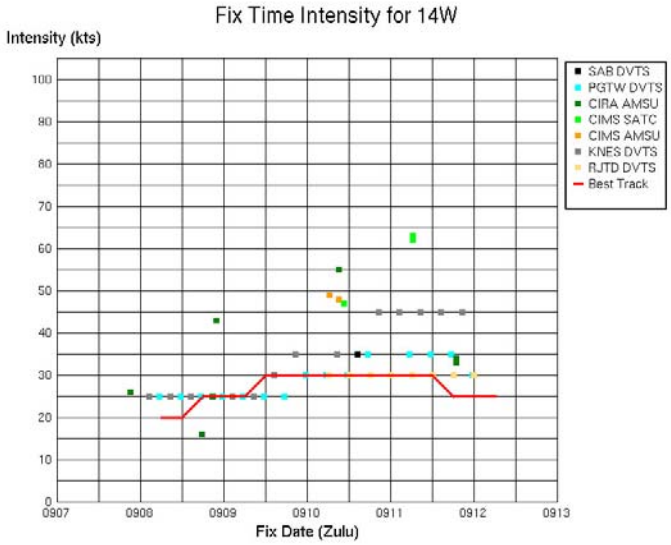




Tropical Depression 14W (Mujigae)

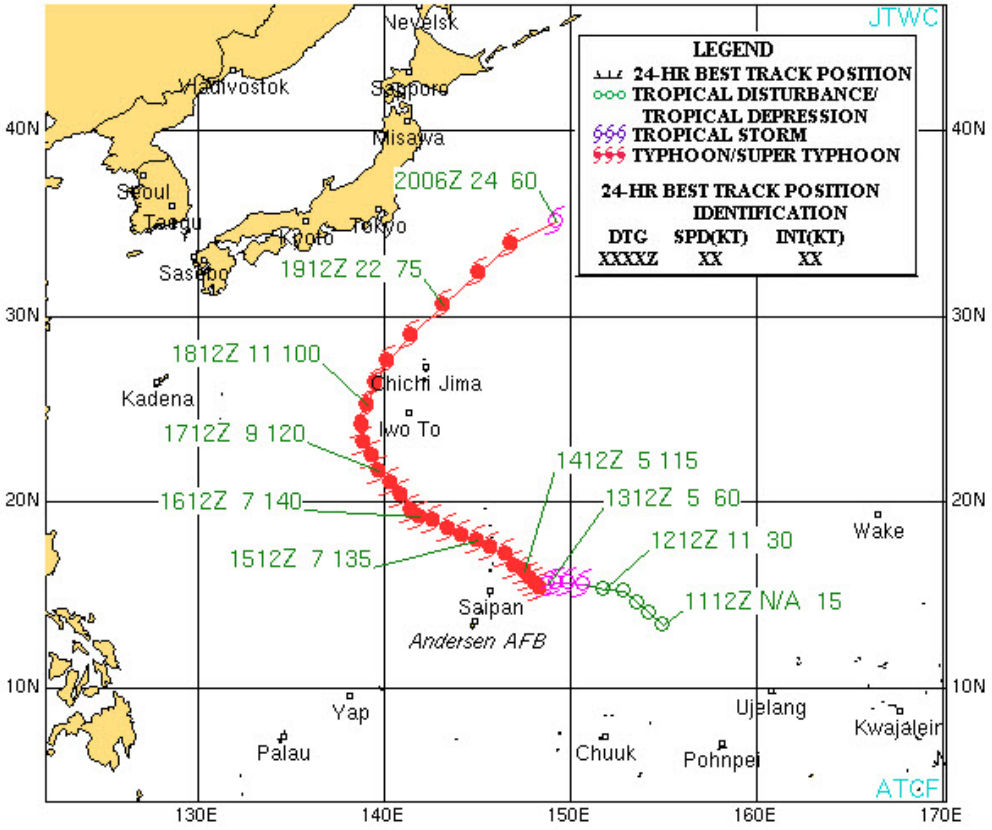
ISSUED POOR:	0600Z 08 Sep 2009
ISSUED FAIR:	2100Z 08 Sep 2009
FIRST TCFA:	N/A
FIRST WARNING:	0600Z 09 Sep 2009
LAST WARNING:	0000Z 12 Sep 2009
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	12

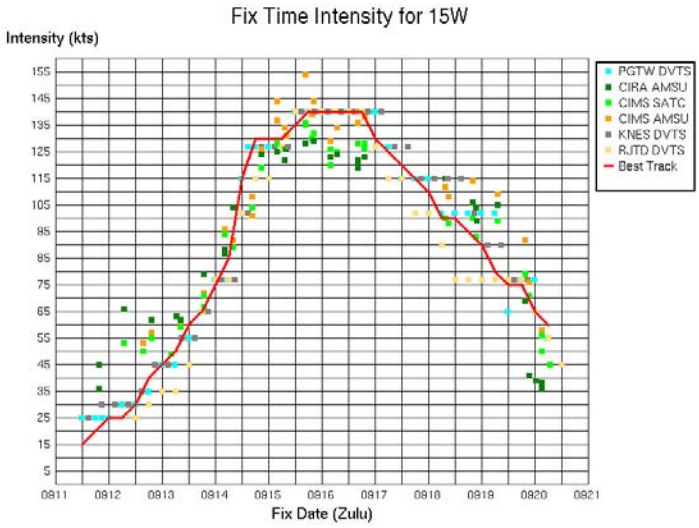




Super Typhoon 15W (Choi-Wan)

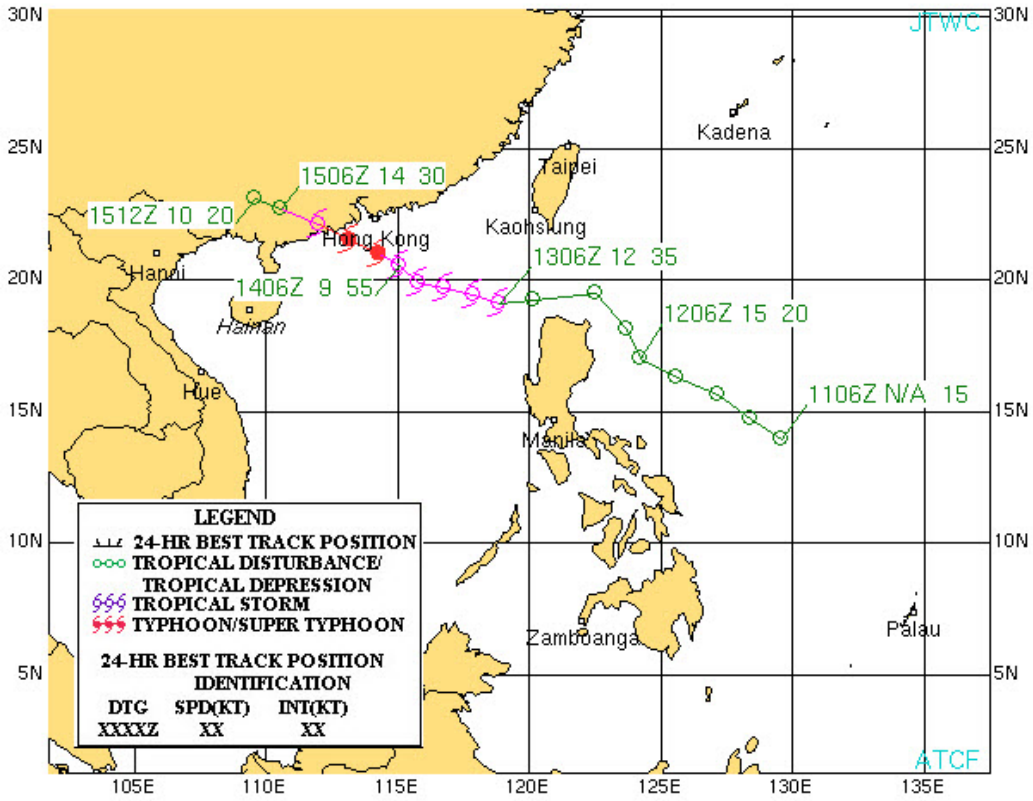
ISSUED POOR:	N/A
ISSUED FAIR:	1430Z 11 Sep 2009
FIRST TCFA:	2200Z 11 Sep 2009
FIRST WARNING:	0000Z 12 Sep 2009
LAST WARNING:	0000Z 20 Sep 2009:
MAX INTENSITY:	140 Kts
NUMBER OF WARNINGS:	33

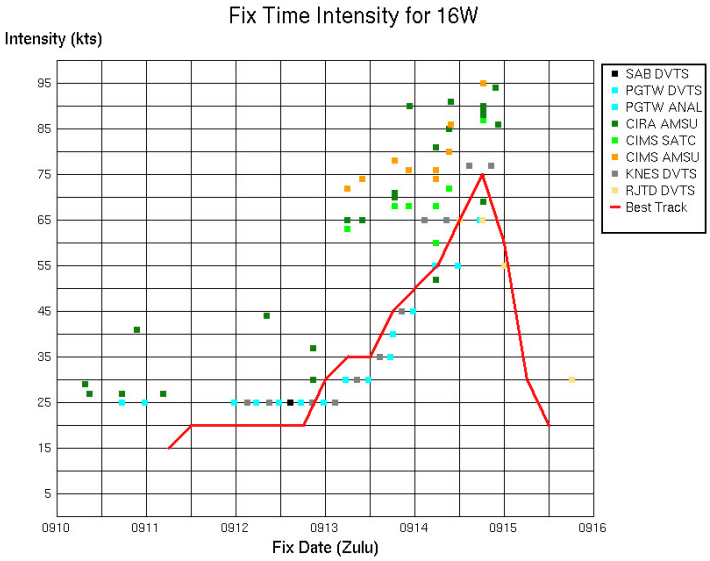




Typhoon 16W (Koppu)

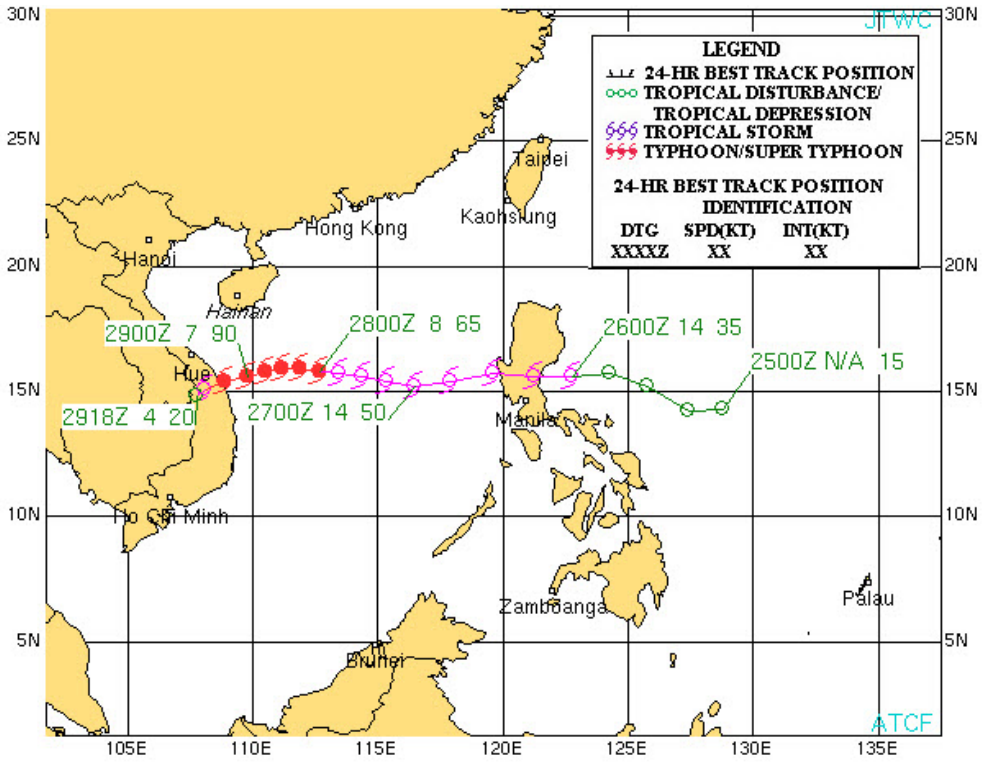
ISSUED POOR: 1930Z 09 Sep 2009
ISSUED FAIR: 0600Z 11 Sep 2009
FIRST TCFA: 0200Z 12 Sep 2009
FIRST WARNING: 0000Z 13 Sep 2009
LAST WARNING: 0000Z 15 Sep 2009
MAX INTENSITY: 75 Kts
NUMBER OF WARNINGS: 9

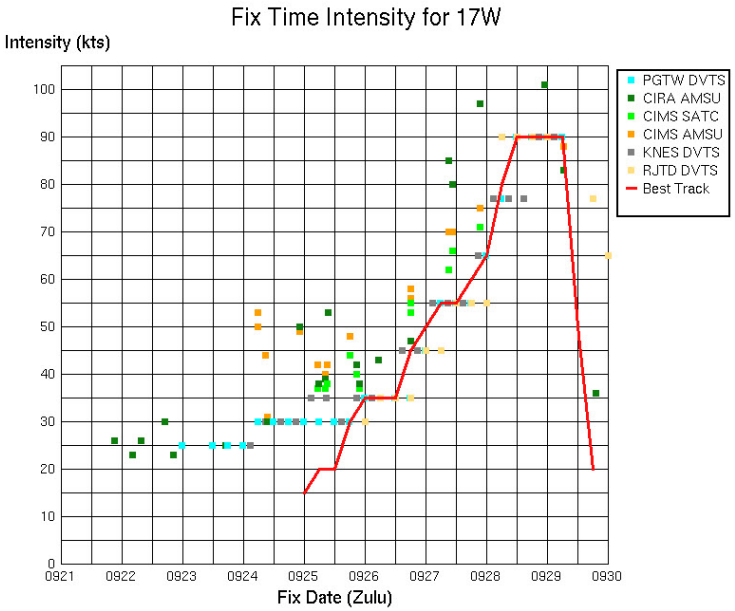




Typhoon 17W (Ketsana)

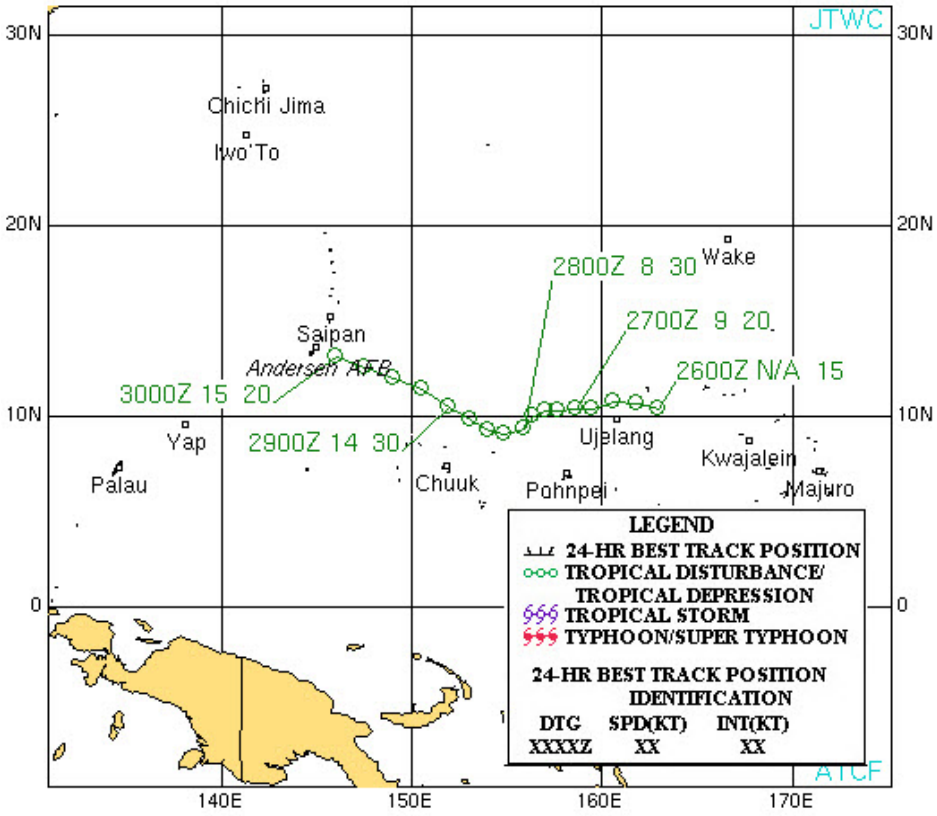
ISSUED POOR: 0600Z 23 Sep 2009
ISSUED FAIR: 1400Z 23 Sep 2009
FIRST TCFA: 0430Z 24 Sep 2009
FIRST WARNING: 0000Z 25 Sep 2009
LAST WARNING: 1200Z 29 Sep 2009
MAX INTENSITY: 90 Kts
NUMBER OF WARNINGS: 19

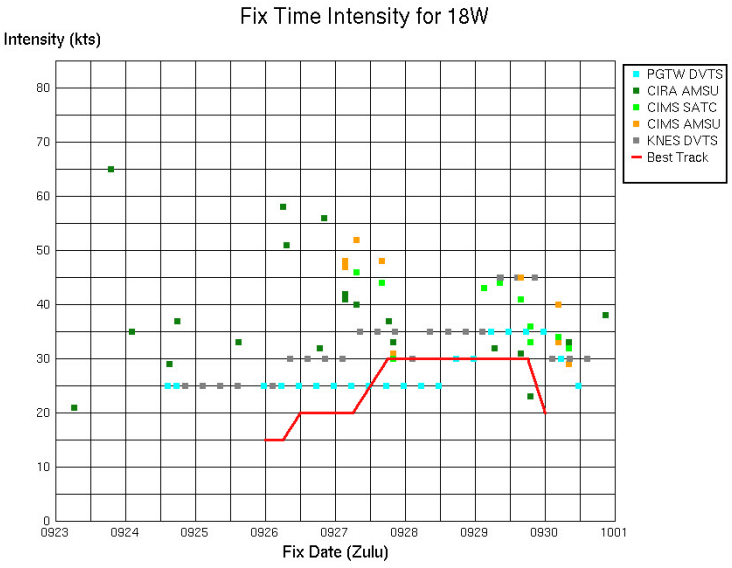




Tropical Depression 18W

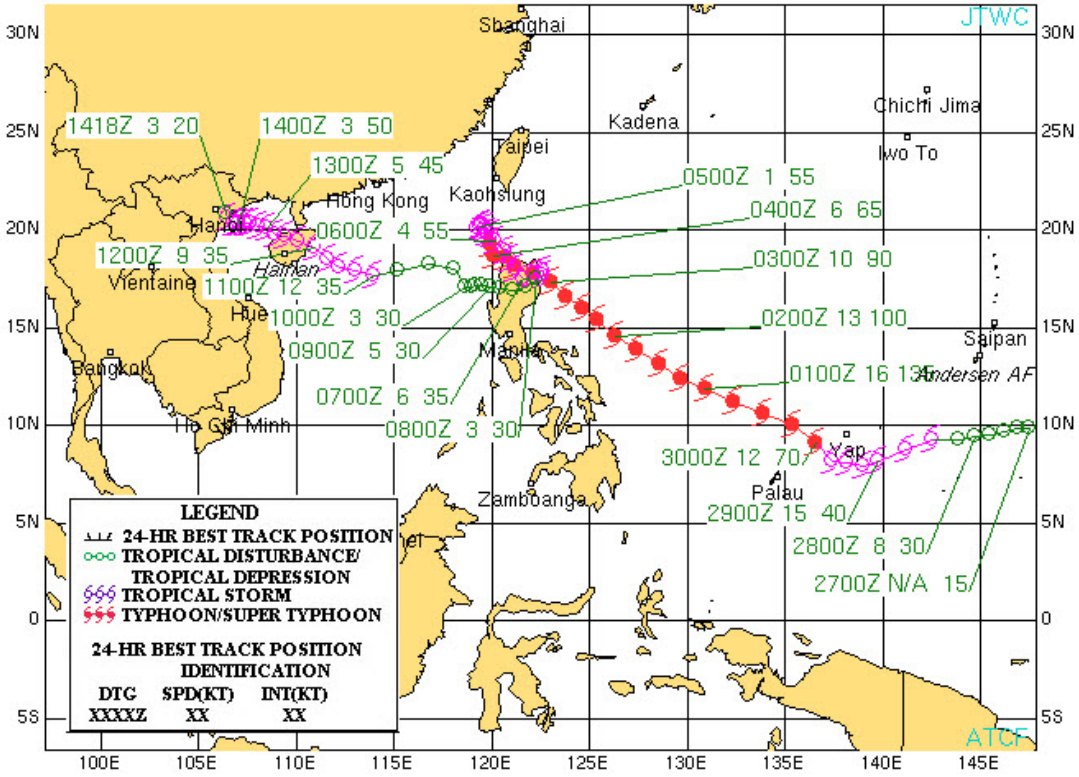
ISSUED POOR: 0600Z 25 Sep 2009
ISSUED FAIR: NA
FIRST TCFA: 1530Z 26 Sep 2009
FIRST WARNING: 0600Z 27 Sep 2009
LAST WARNING: 0600Z 30 Sep 2009
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 13



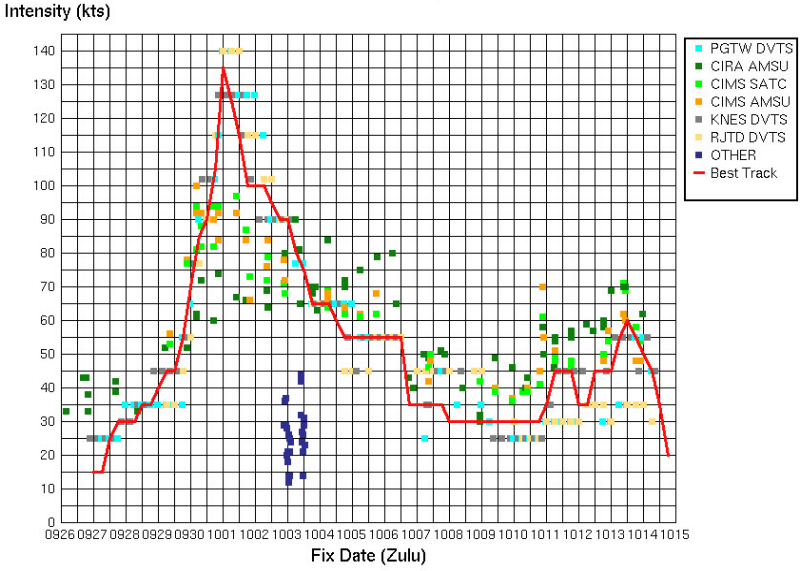


Super Typhoon 19W (Parma)

ISSUED POOR:	0600Z 27 Sep 2009
ISSUED FAIR:	1100Z 27 Sep 2009
FIRST TCFA:	N/A
FIRST WARNING:	1800Z 27 Sep 2009
LAST WARNING:	1500Z 14 Oct 2009
MAX INTENSITY:	135 Kts
NUMBER OF WARNINGS:	68

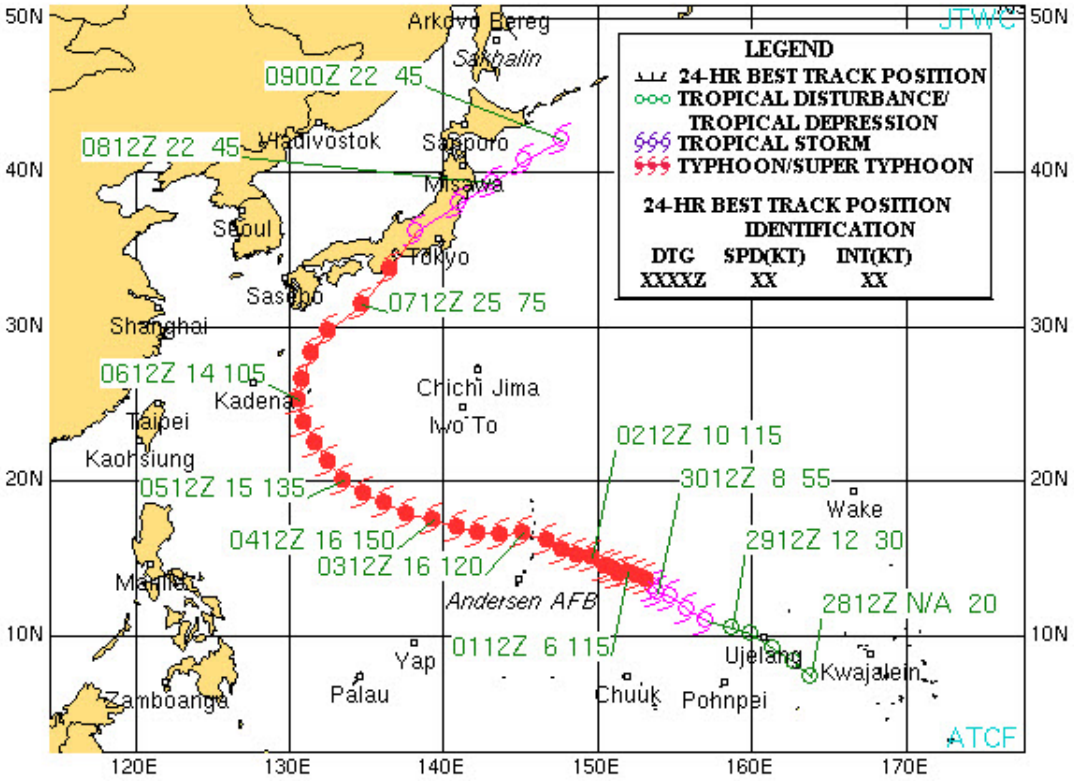


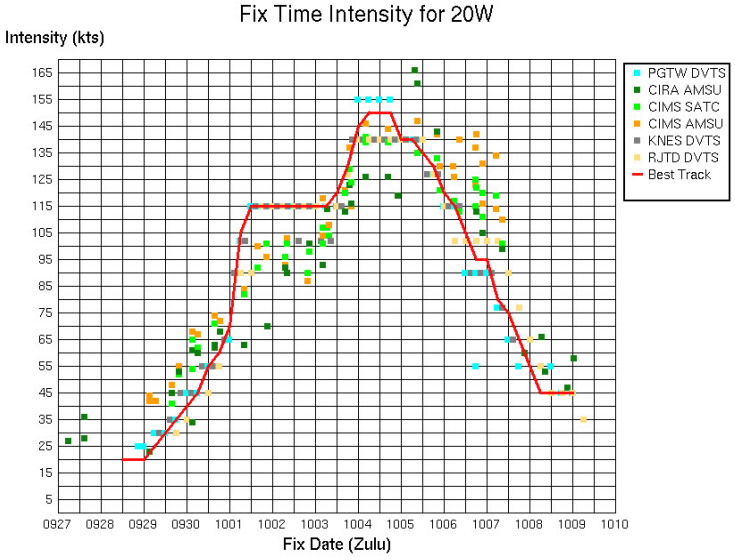
Fix Time Intensity for 19W



Super Typhoon 20W (Melor)

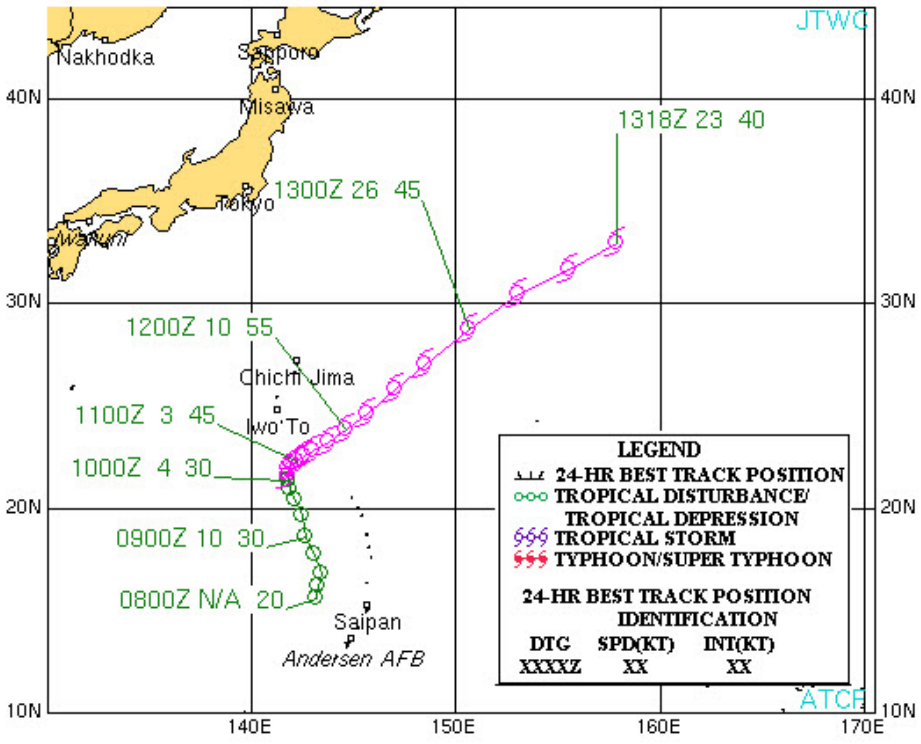
ISSUED POOR:	2300Z 27 Sep 2009
ISSUED FAIR:	1730Z 28 Sep 2009
FIRST TCFA:	2330Z 28 Sep 2009
FIRST WARNING:	0600Z 29 Sep 2009
LAST WARNING:	1200Z 09 Oct 2009
MAX INTENSITY:	150 Kts
NUMBER OF WARNINGS:	38

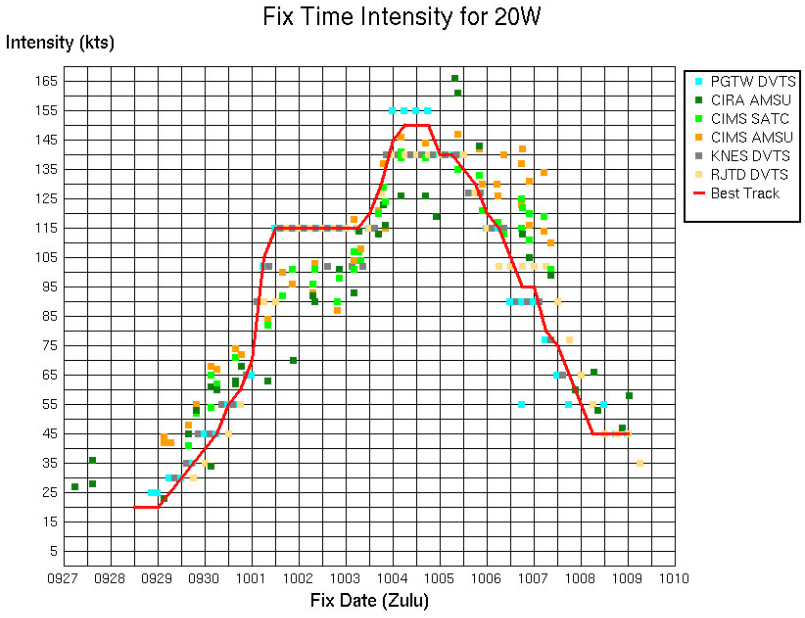




Tropical Storm 21W (Nepartak)

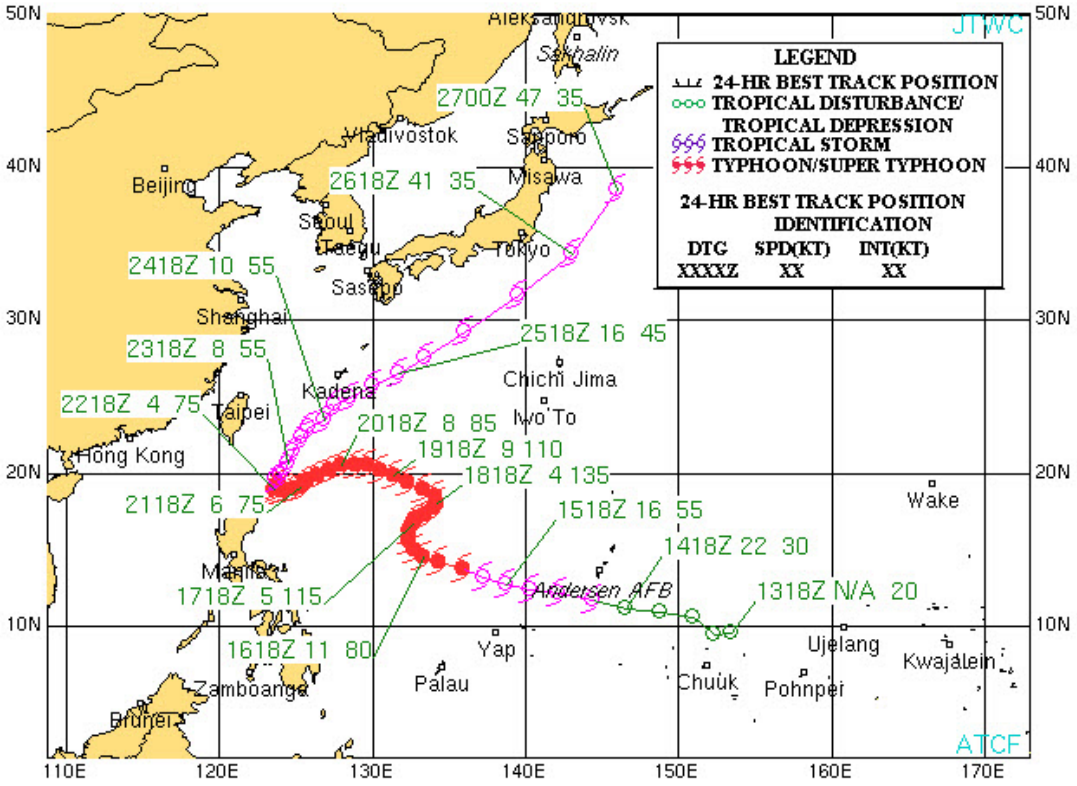
ISSUED POOR: 0600Z 07 Oct 2009
ISSUED FAIR: 2330Z 07 Oct 2009
FIRST TCFA: 0230Z 08 Oct 2009
FIRST WARNING: 1200Z 08 Oct 2009
LAST WARNING: 0600Z 13 Oct 2009
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 20

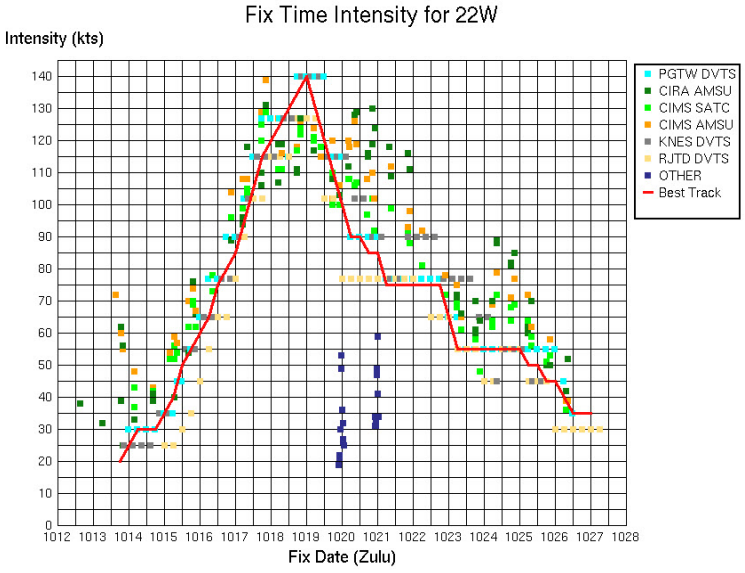




Super Typhoon 22W (Lupit)

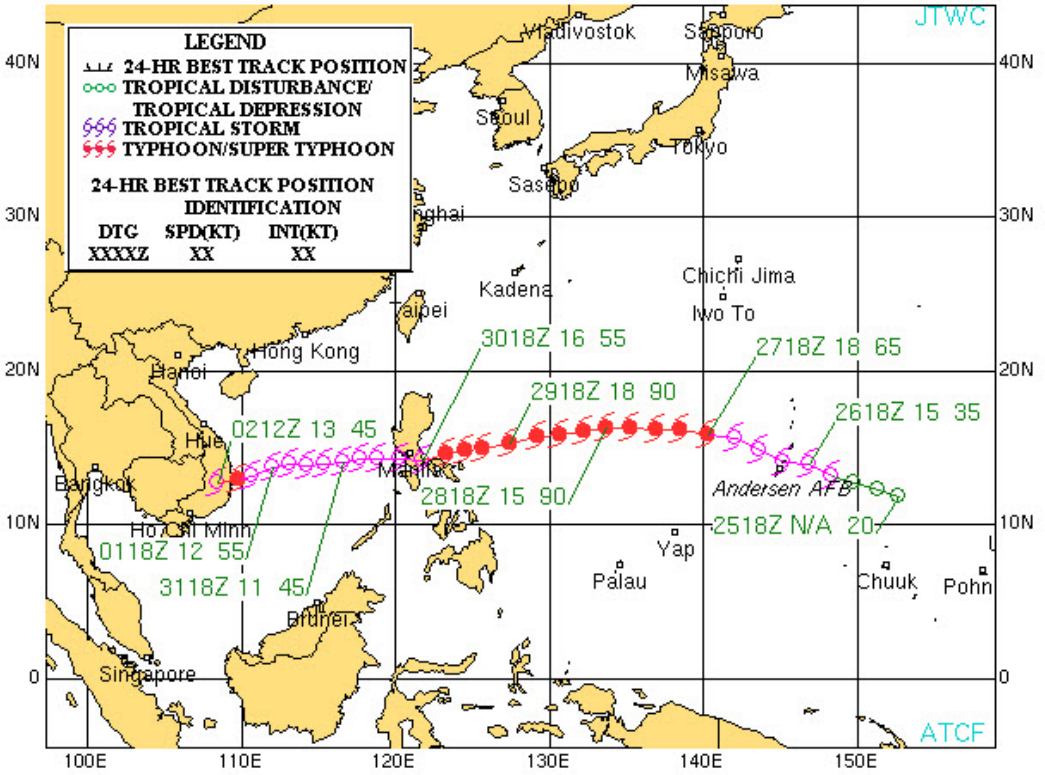
ISSUED POOR:	N/A
ISSUED FAIR:	0600Z 13 Oct 2009
FIRST TCFA:	2330Z 13 Oct 2009
FIRST WARNING:	0000Z 14 Oct 2009
LAST WARNING:	0000Z 26 Oct 2009
MAX INTENSITY:	140 Kts
NUMBER OF WARNINGS:	49

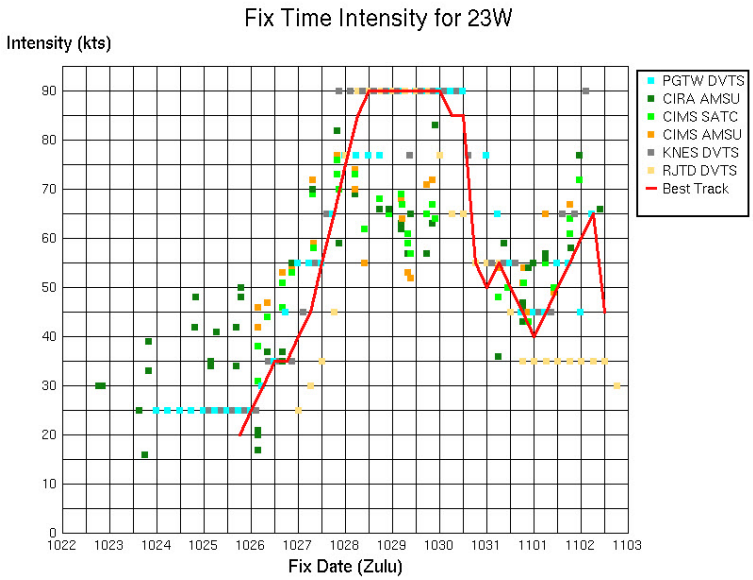




Typhoon 23W (Mirinae)

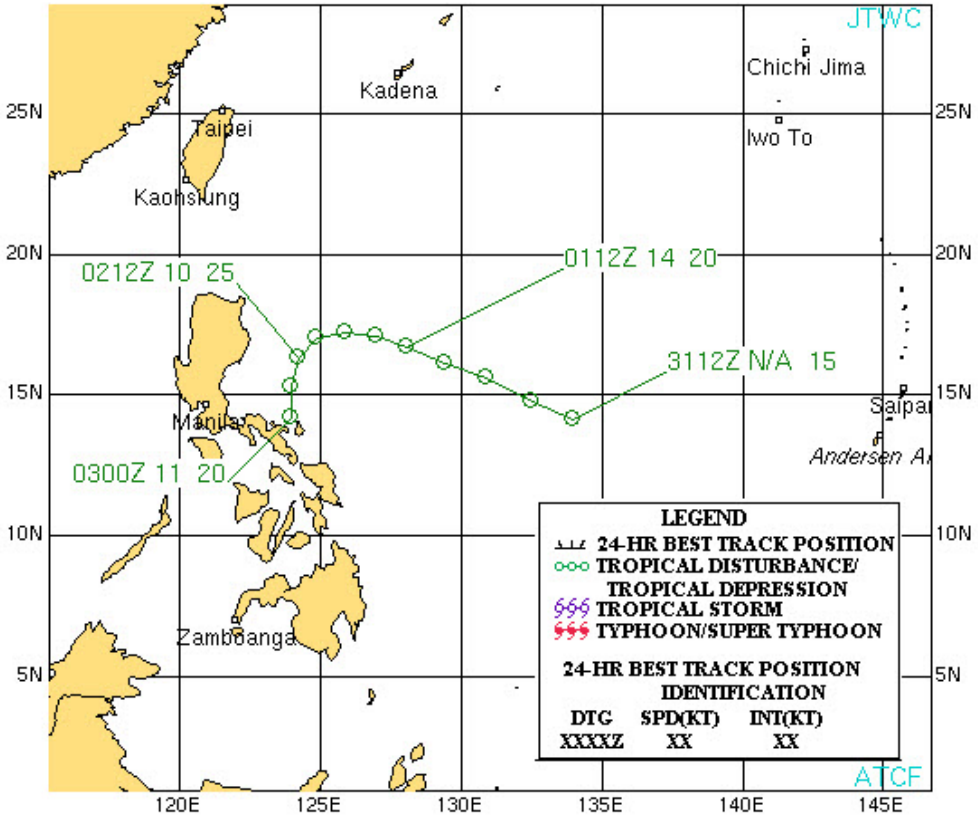
ISSUED POOR: 0600Z 23 Oct 2009
ISSUED FAIR: 0600Z 24 Oct 2009
FIRST TCFA: 2100Z 25 Oct 2009
FIRST WARNING: 0000Z 26 Oct 2009
LAST WARNING: 1200Z 02 Nov 2009
MAX INTENSITY: 90 Kts
NUMBER OF WARNINGS: 31

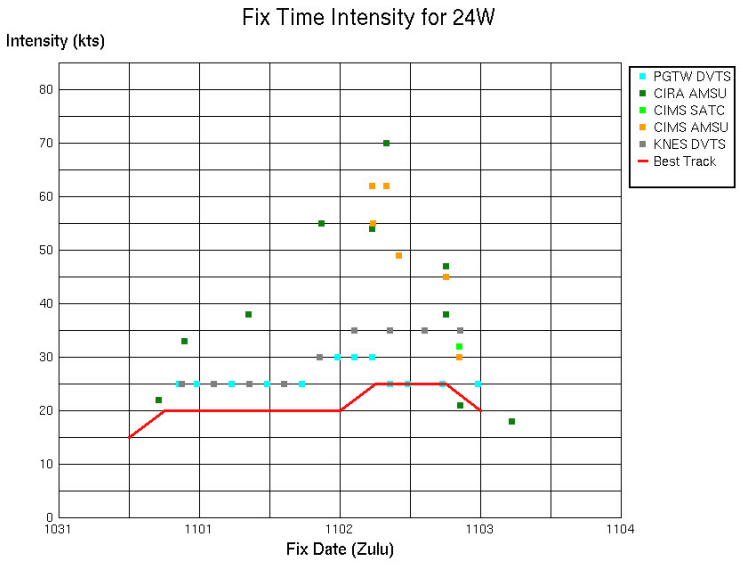




Tropical Depression 24W

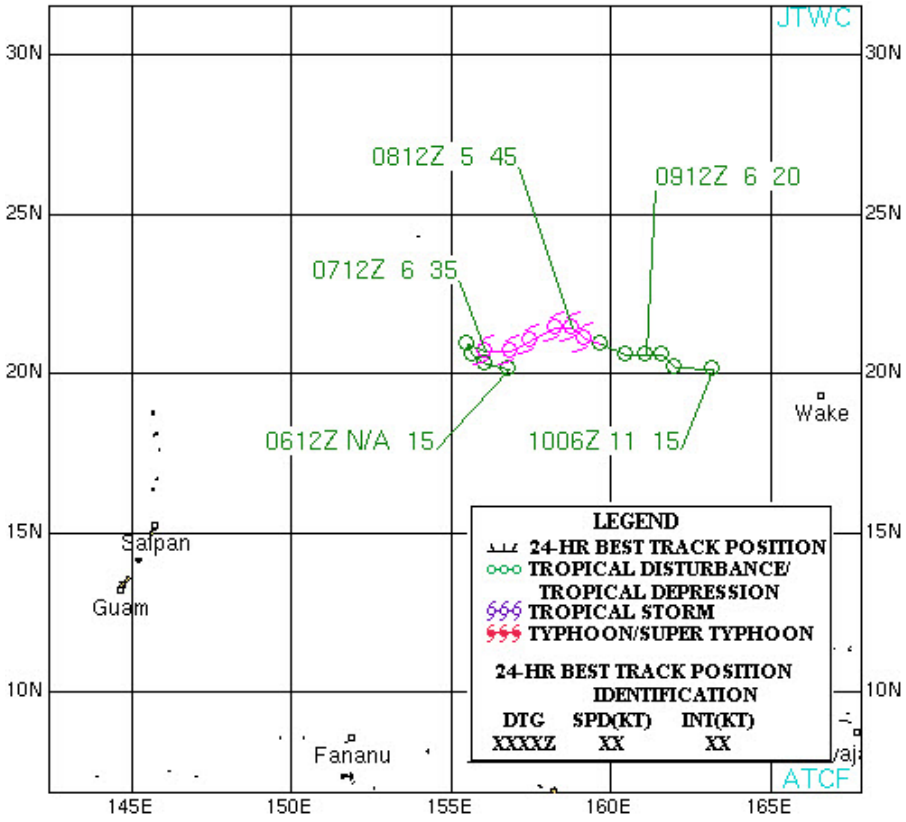
ISSUED POOR: N/A
ISSUED FAIR: 2030Z 31 Oct 2009
FIRST TCFA: 2200Z 01 Nov 2009
FIRST WARNING: 1800Z 02 Nov 2009
LAST WARNING: 0000Z 03 Nov 2009
MAX INTENSITY: 25 Kts
NUMBER OF WARNINGS: 2

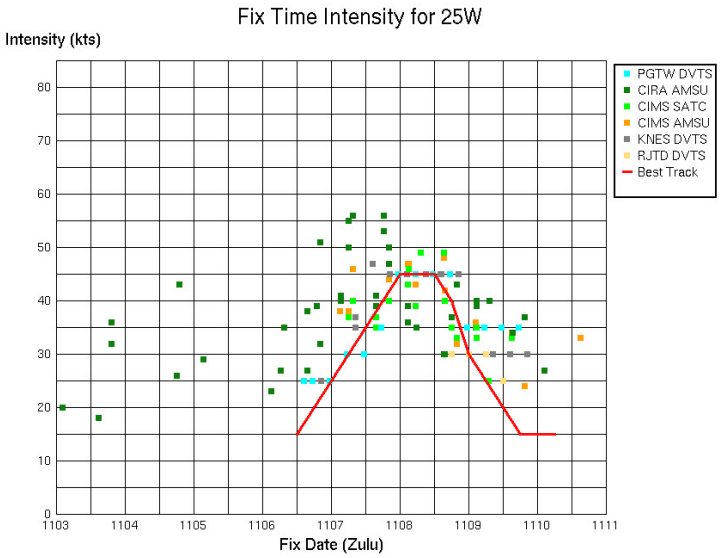




Tropical Storm 25W

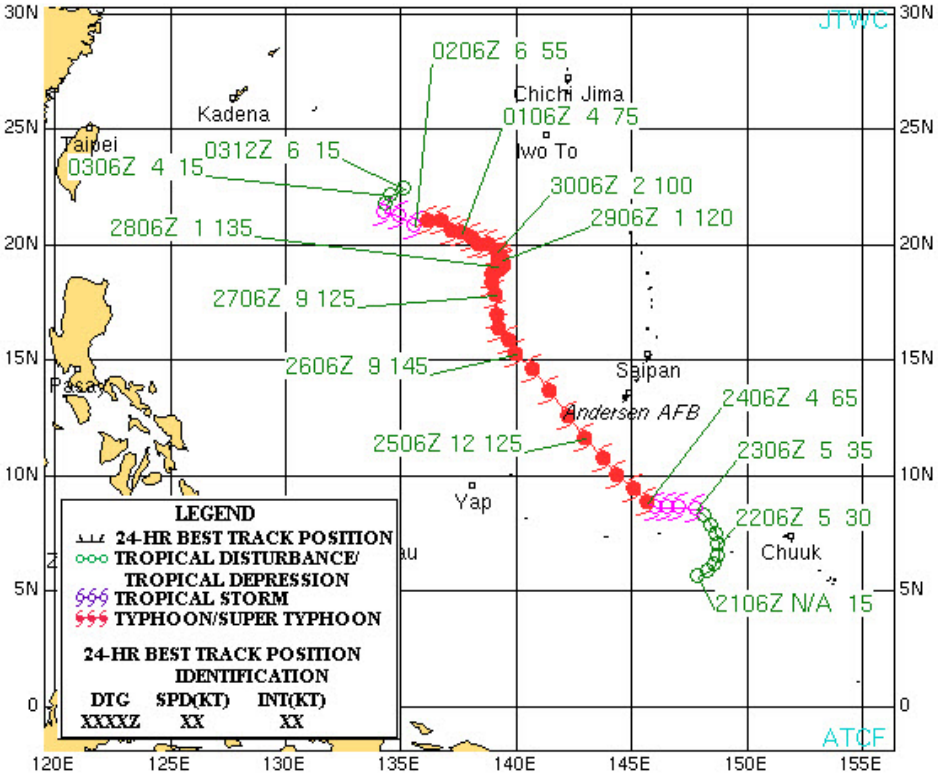
ISSUED POOR: 0600Z 03 Nov 2009
ISSUED FAIR: 1430Z 06 Nov 2009
FIRST TCFA: N/A
FIRST WARNING: 0000Z 07 Nov 2009
LAST WARNING: 0600Z 09 Nov 2009
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 10

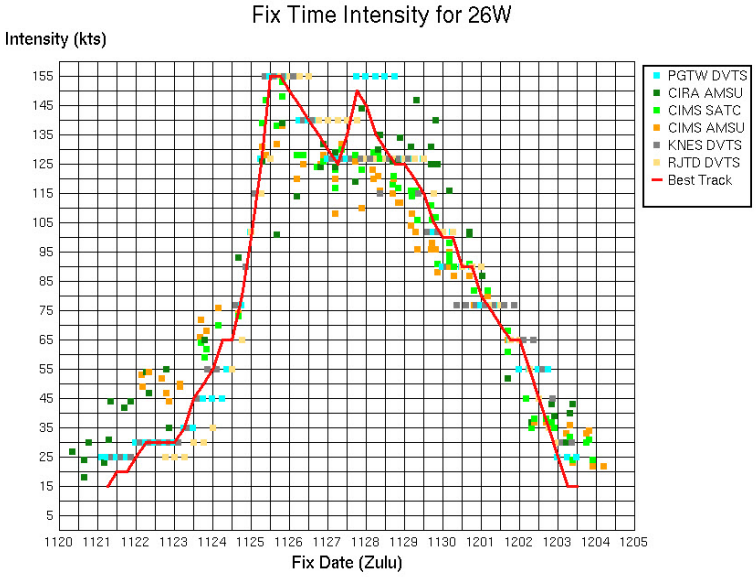




Super Typhoon 26W (Nida)

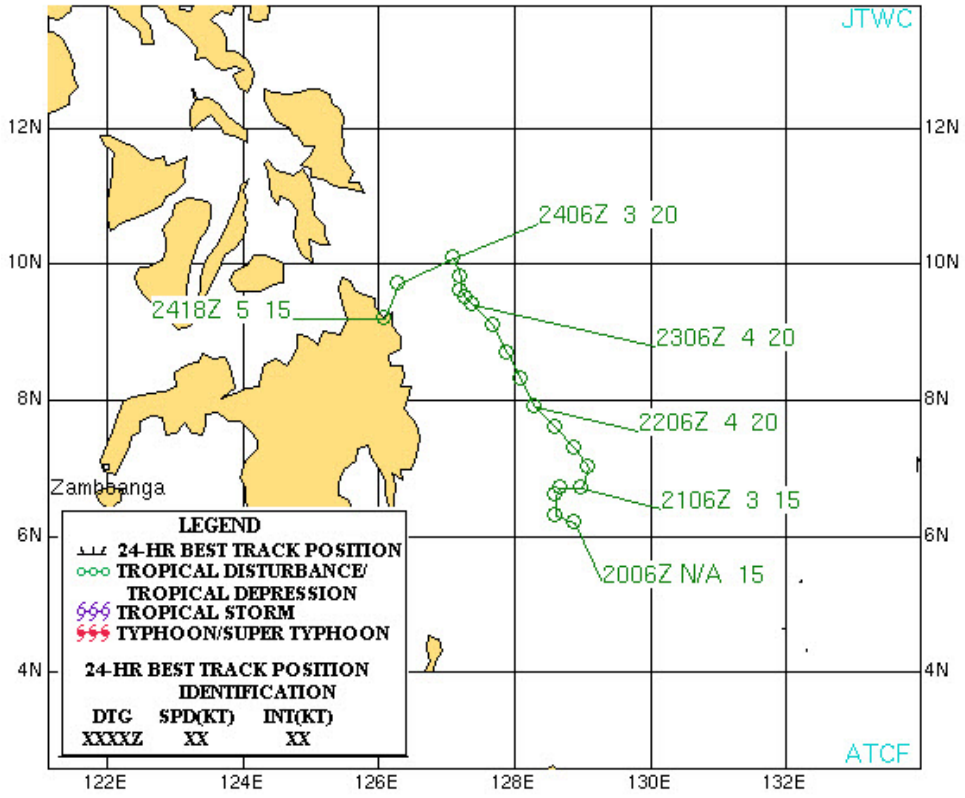
ISSUED POOR:	N/A
ISSUED FAIR:	0600Z 21 Nov 2009
FIRST TCFA:	1100Z 21 Nov 2009
FIRST WARNING:	0000Z 22 Nov 2009
LAST WARNING:	0000Z 03 Dec 2009
MAX INTENSITY:	155 Kts
NUMBER OF WARNINGS:	45

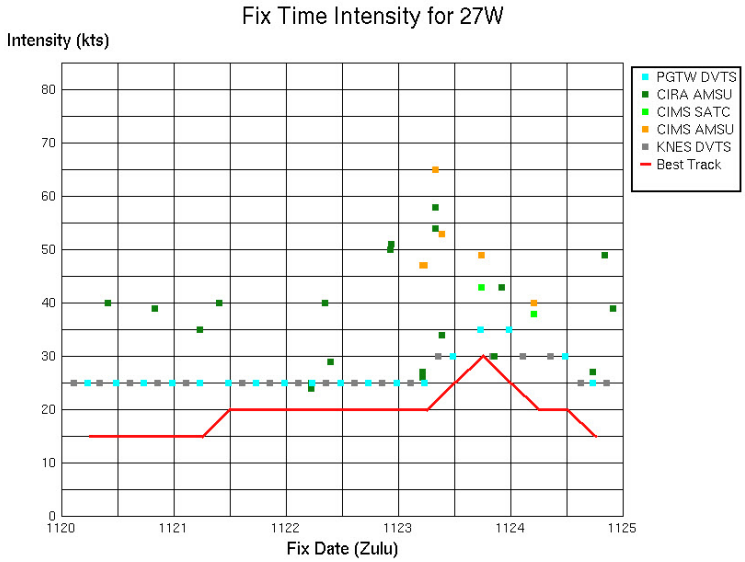




Tropical Depression 27W

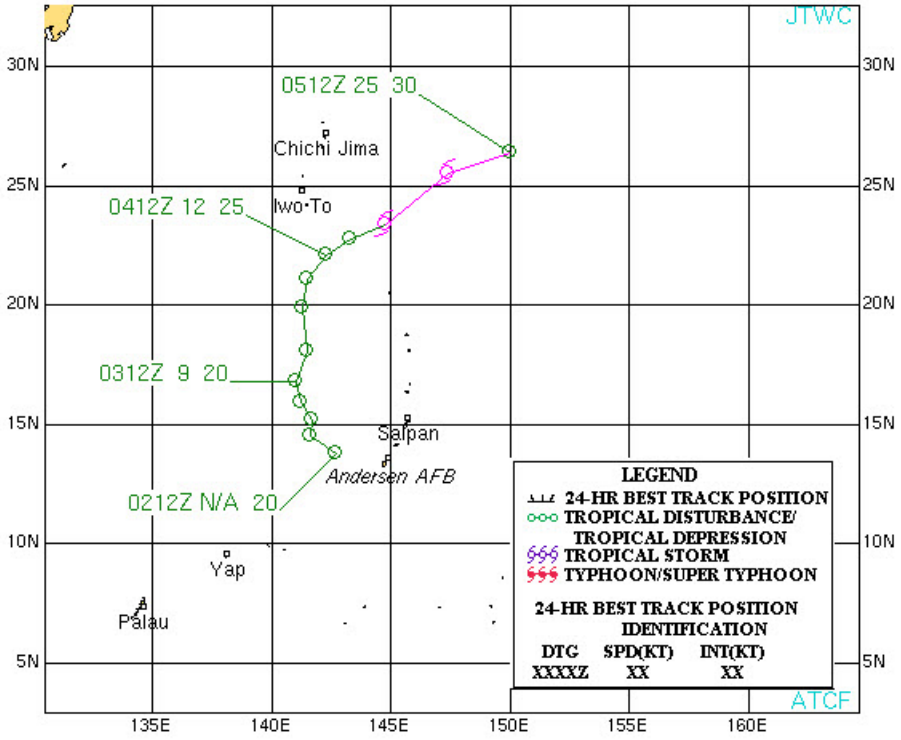
ISSUED POOR: 0600Z 20 Nov 2009
ISSUED FAIR: 0600Z 21 Nov 2009
FIRST TCFA: 1000Z 22 Nov 2009
FIRST WARNING: 1200Z 23 Nov 2009
LAST WARNING: 1200Z 24 Nov 2009
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 5

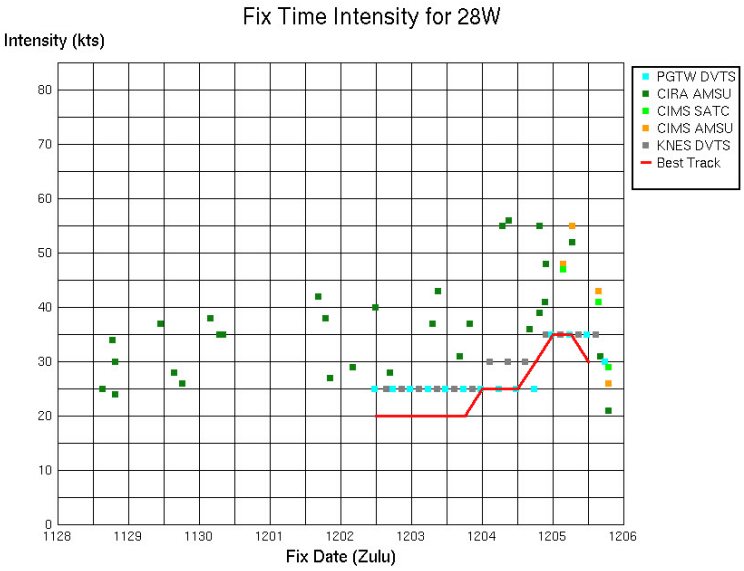




Tropical Storm 28W

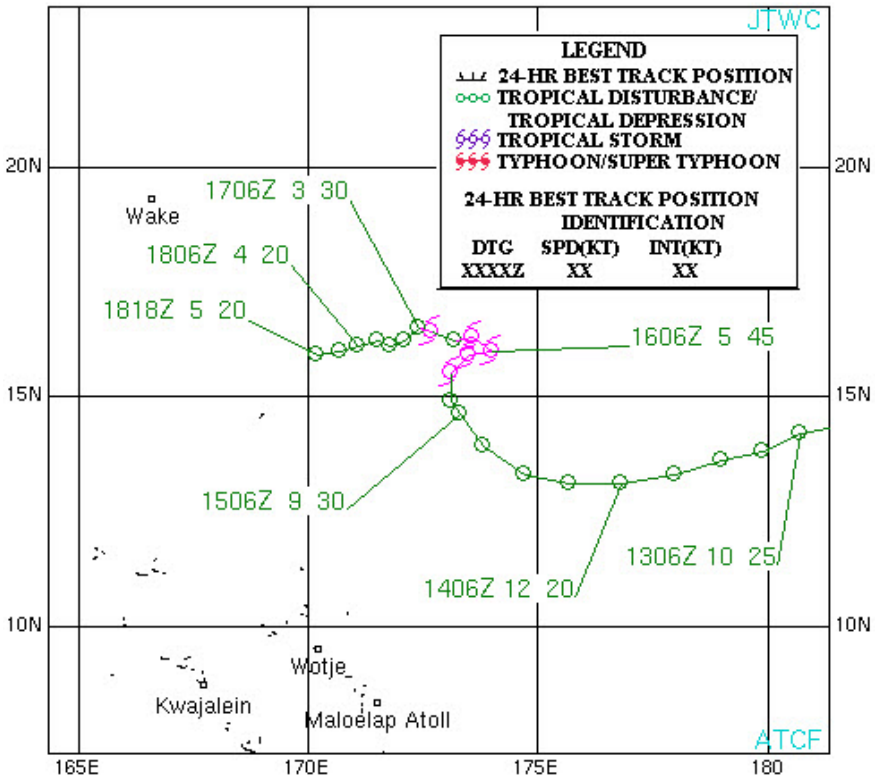
ISSUED POOR: 0600Z 04 Dec 2009
ISSUED FAIR: N/A
FIRST TCFA: N/A
FIRST WARNING: 0000Z 05 Dec 2009
LAST WARNING: 0000Z 05 Dec 2009
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 1

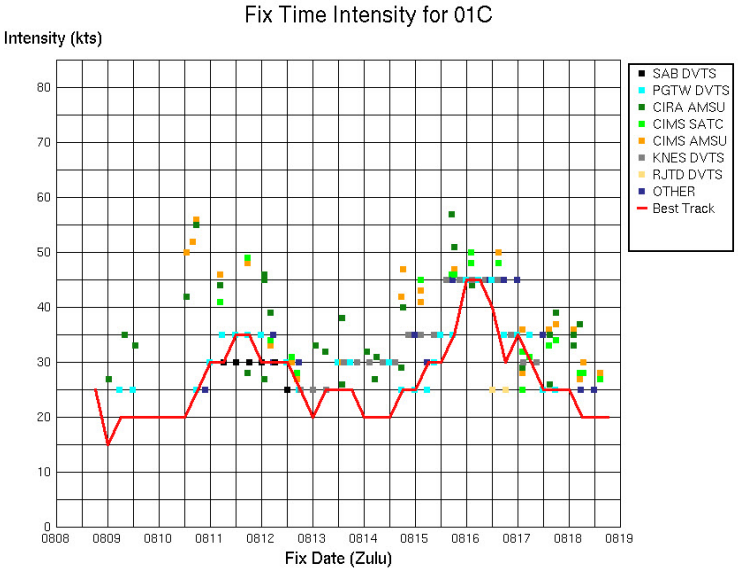




Tropical Storm 01C (Maka)

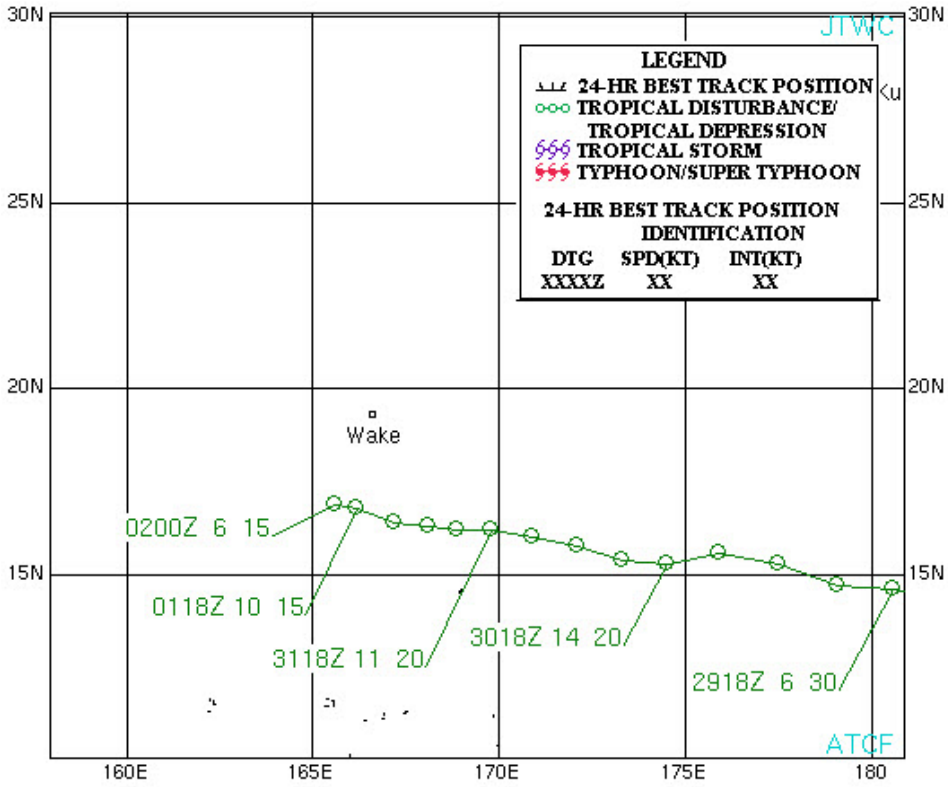
ISSUED POOR: N/A
ISSUED FAIR: N/A
FIRST TCFA: 1200Z 14 Aug 2009
FIRST WARNING: 1800Z 14 Aug 2009
LAST WARNING: 0600Z 18 Aug 2009
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 15

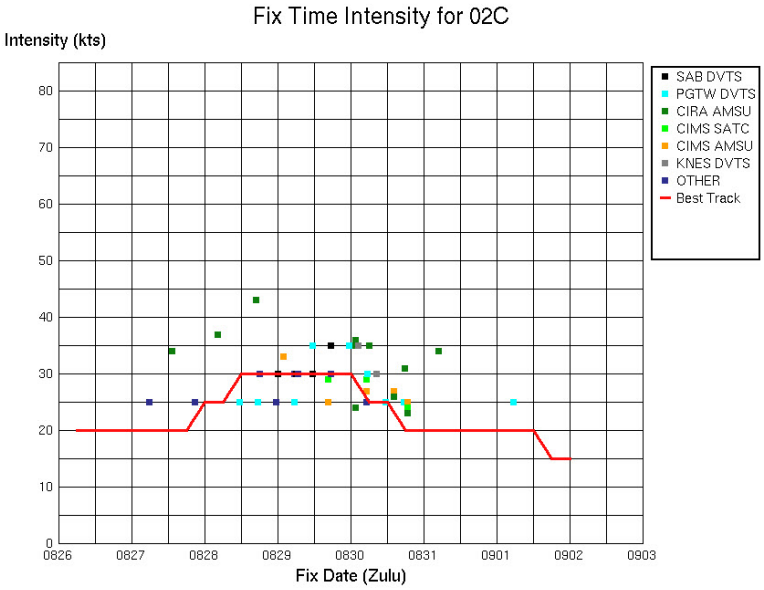




Tropical Depression 02C

ISSUED POOR: N/A
ISSUED FAIR: N/A
FIRST TCFA: 2300Z 28 Aug 2009
FIRST WARNING: 0000Z 30 Aug 2009
LAST WARNING: 0600Z 30 Aug 2009
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 2





Tropical Storm 13W (Dujuan)

Tropical Storm 13W (Dujuan) formed in the Philippine Sea, within the monsoon trough, during the first few days of September. The cyclone initially moved northeastward in response to a near-equatorial ridge to the southeast then northward along the western periphery of the mid-tropospheric subtropical ridge approximately 24 hours after attaining tropical storm intensity .

At approximately 1800Z on 7 September, Dujuan began to move east-northeast and accelerate in response to a trough in the mid-latitude westerlies and transformed to an extra-tropical (XT) cyclone far to the east of Hokkaido.

Tropical Storm Dujuan is another example that illustrates the extra-tropical cyclone transition forecast challenge. In this case, JTWC forecast the extra-tropical transition to occur up to 30 hours too early and did not maintain a consistent timing of transition on 20 forecasts covering 5 days. (See Figure 3-1)

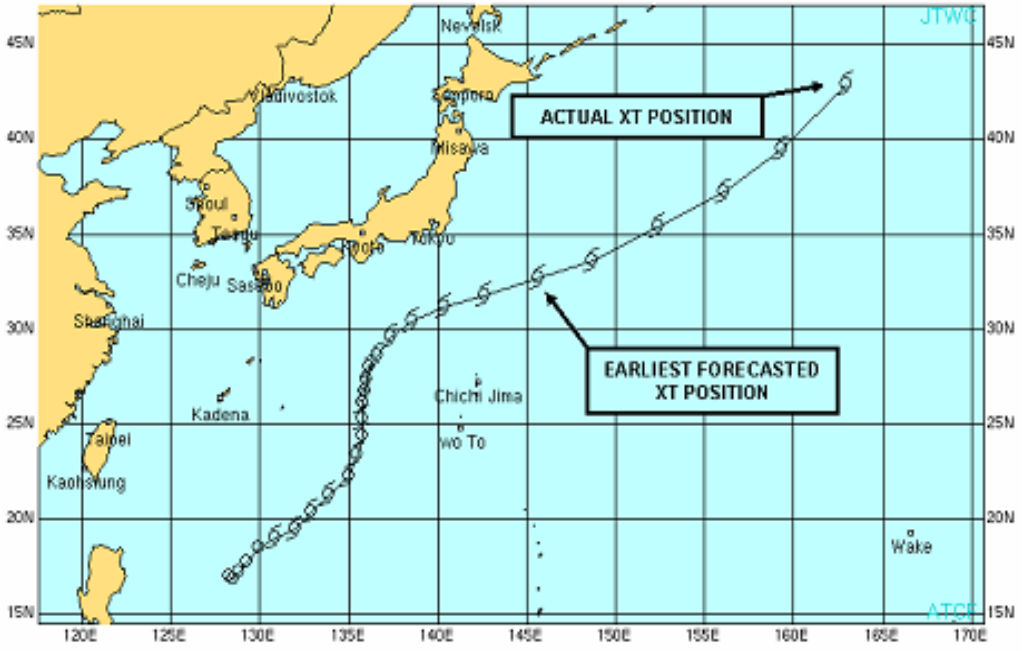


Figure 3-1. Graphic comparing the earliest forecast and actual extra-tropical transition location.

On 5 September at 0000Z, JTWC initially and correctly forecasted the system to complete extra-tropical transition (ET) at 0000Z on 10 September. However forecasters slowly moved the forecasted ET to progressively earlier times (See Table 3-1). By the 6 September 1800Z warning, the forecasted time for Dujuan to become an XT cyclone was at 1800Z on 8 September, near 33N latitude 146E longitude.

Fcst Time \ Verify Time	08/18Z	09/00Z	09/06Z	09/12Z	09/18Z	10/00Z	10/06Z
05/00Z						XT	
05/06Z							XT
05/12Z				XT			
05/18Z					XT		
06/00Z						XT	
06/06Z			XT				
06/12Z				XT			
06/18Z	XT						
07/00Z		XT					
07/06Z	XT						
07/12Z		XT					
07/18Z	XT						
08/00Z		XT					
08/06Z			XT				
08/12Z		XT		XT(AMD)			
08/18Z					XT		
09/00Z						XT	
09/06Z							XT
09/12Z						XT	
09/18Z						XT Verification	

Table 3-1. Timing error on extra-tropical transition illustrated in tabular format.

This forecast was based on analysis of the mid-latitude synoptic pattern and model derived products (i.e., phase-space diagrams (See Figure 3-2) and 1000-500mb thickness charts).

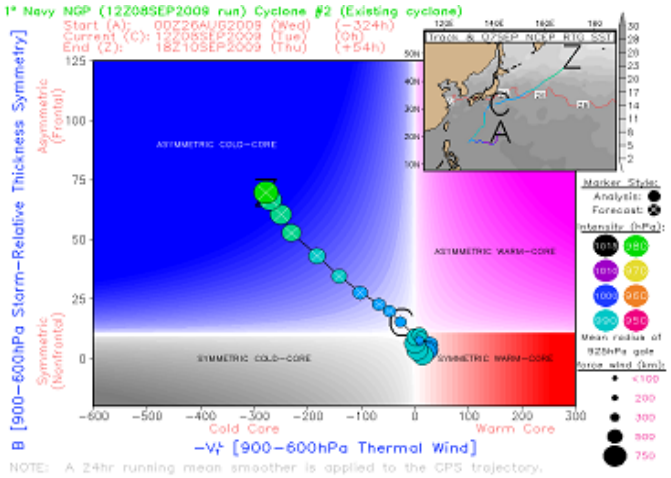


Figure 3-2. Phase-Space diagram from the NOGAPS model showing the model depiction of Dujuan transitioning to an asymmetric cold core cyclone (upper left quadrant). (Courtesy of Florida State University)

Additionally, a 1211Z NOAA 17 AMSU-B image on 6 September indicated impending interaction with the baroclinic zone to the northwest (See Figure 3-3a). Also, starting about this time a significant decrease in convection was noted around the cyclone center, a southwest-to-northeast elongation in the cloud pattern, and water vapor imagery showed a significant weakening of the equatorward outflow and

strengthening of the poleward outflow in the diffluent region ahead of an approaching trough in the mid-latitude westerlies.

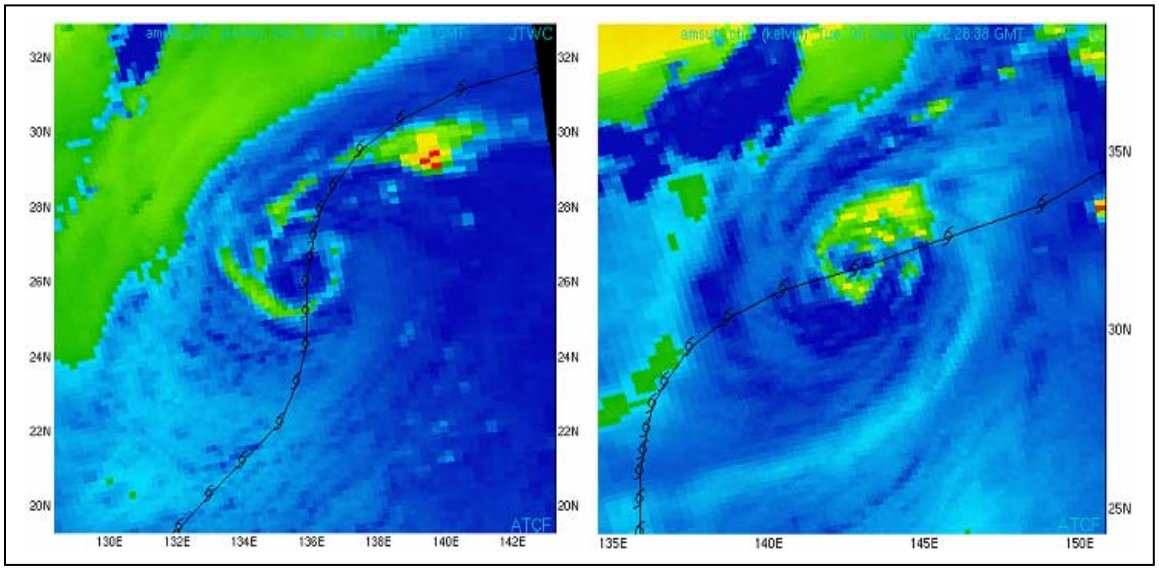


Figure 3-3. 06/1211Z AMSU-B image (a) showing weakening convection and elongation and 08/1228Z AMSU-B image (b) showing stronger central convection and less elongation.

Later data, however, as seen in the 1228Z NOAA 17 AMSU-B image from 8 September (See Figure 3-3b), indicated a decrease in the cloud pattern elongation. Tropical Storm Dujuan did not fully become XT until 0000Z on 10 September near 43 degrees north, as supported by a 092320Z AMSU-B image (See Figure 3-4).

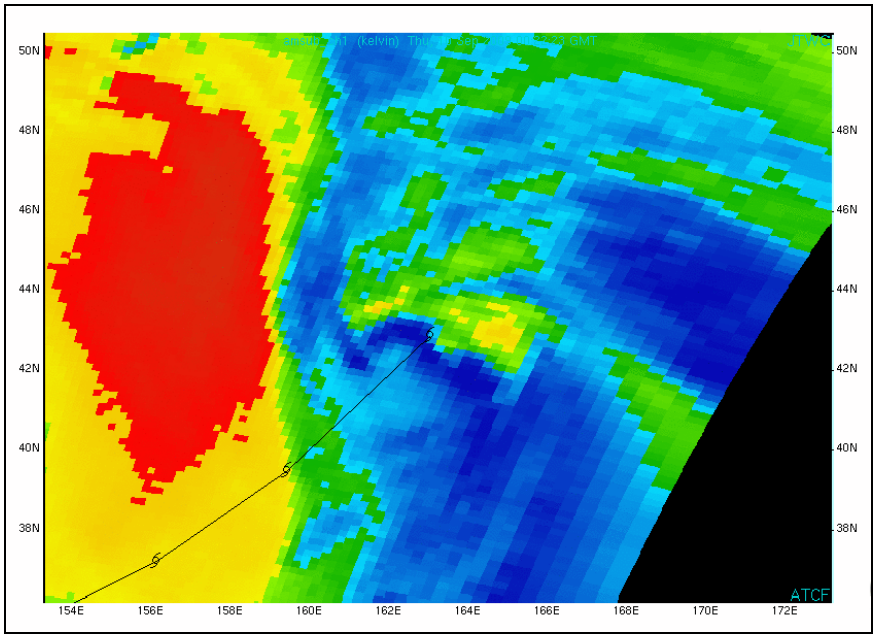


Figure 3-4. 09/2320Z AMSU-B image showing warm frontogenesis and cold, dry air moving around the western periphery of the system as Dujuan completes extratropical transition.

Tropical Storm Dujuan illustrates some of the challenges forecasters face when trying to predict tropical cyclone extra-tropical transition. In this case, Dujuan retained tropical characteristics during the passage of a mid-latitude trough that temporarily affected the cyclone but did not "capture" it and it appears to have shown

some signs of started extra-tropical transition but failed to complete the transition until several days later, remaining a warm core cyclone for an additional 48 hours before eventually completing the transition.

Super Typhoon (STY) 19W (Parma)

Super Typhoon (STY) 19W (Parma) formed to the southeast of Guam in the eastern extent of the monsoon trough and tracked westward under the influence of a low- to mid-level subtropical ridge (STR). Parma continued to track over northern Luzon into the Luzon Strait, entered a region of weak steering and retrograded back over Luzon into the Philippine Sea. Parma was eventually captured by a developing STR over southeastern Asia, crossing Luzon for a third time as it slowly drifted westward. The STR continued to strengthen, allowing Parma to increase its track speed westward over Hainan Island, into the Gulf of Tonkin and finally into the northern Vietnam (see Figure 3-5).

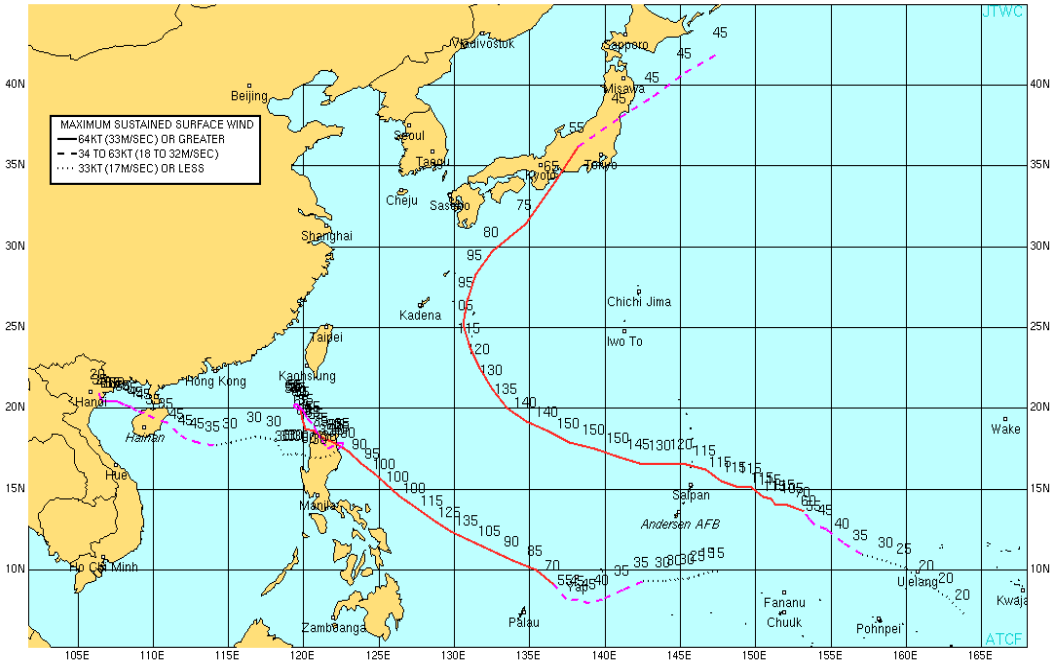


Figure 3-5. Track and intensity of Super Typhoon 19W (Parma) and Typhoon 20W (Melor)

Parma had several forecast challenges, including the presence and potential interaction with Typhoon 20W (Melor), which developed to the east of Parma and tracked westward towards Parma (see Figure 3-5). However, the long period of quasi-stationary movement in a weak steering environment, which led to Parma criss-crossing Luzon three times, was the most challenging portion of the cyclones life cycle. The complex interaction of a weakening Parma as it made the first crossing of Luzon, a mid-latitude low pressure system that was extending south over Taiwan weakening the STR steering, and the development of Melor as it tracked towards Parma all made the track forecast difficult. These elements ultimately were responsible for Parma's multiple tracks over Luzon. As Melor recurved to the northeast, allowing for the low- to mid-level STR to re-develop across the South China Sea into the Philippine Sea, Parma picked up speed towards the west and crossed over Hainan into the Gulf of Tonkin; ultimately dissipating after making landfall over northern Vietnam.

Model guidance remained fairly consistent throughout the life of Parma, however, there were brief periods prior to the initial landfall over Luzon that guidance began to show a possible recurvature scenario as interaction with Melor looked possible in the extended forecast times. The closest point of approach between

Parma and Melor was approximately 650 nautical miles at 06Z on 6 October, while Parma was in the weak steering environment near the strait of Luzon. It is noteworthy to mention that Parma began to move toward the southeast over Luzon for the second time around 05/00Z and continued this southeasterly movement through 07/12Z, for a total of 60 hours, indicating some weak interaction with Melor. This also correlates to the same time as the recurvature of Melor near 20N 135E. Once Melor moved north of the ridge axis, the STR started to rebuild westward over the Philippine Sea and another STR over China started to extend eastward, causing Parma to move across Luzon for the third time as a westward track under the influence of the developing STR's was re-established.

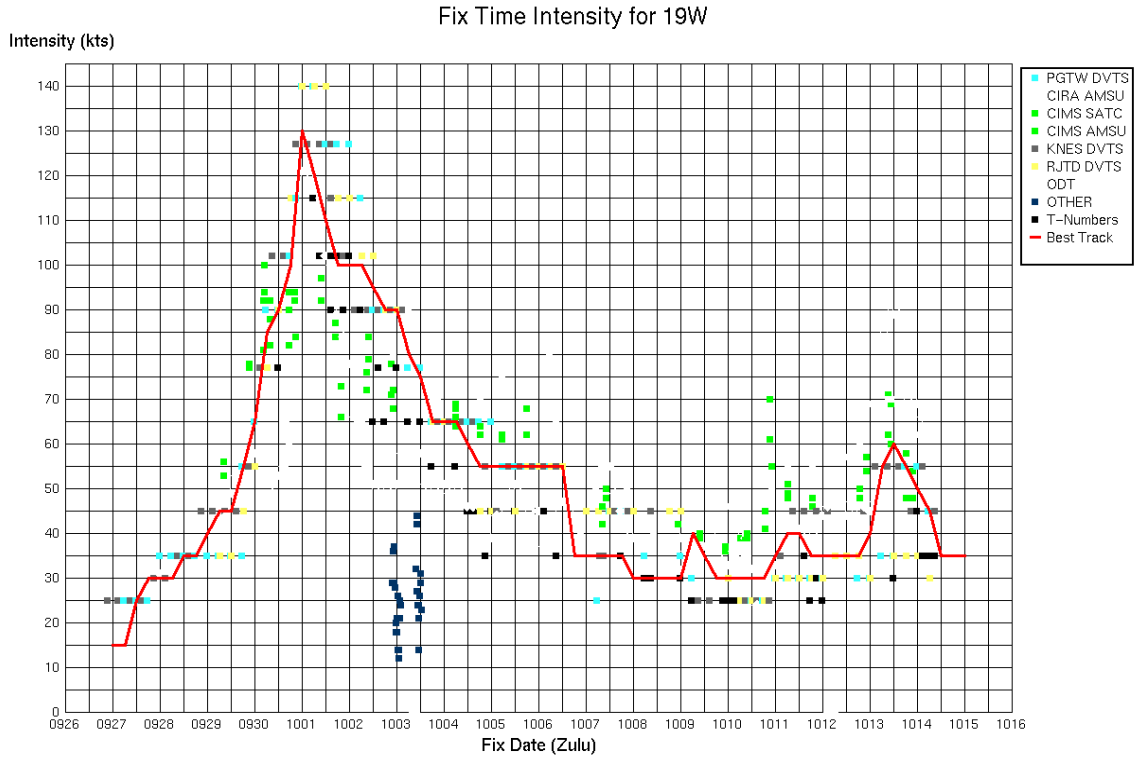


Figure 3-6. Best Track to Fix Intensity Comparison

The intensity forecast for STY Parma from the 00Z forecast on the 1st of October, the only best track position to reach super typhoon strength, through the 06Z forecast on the 3rd of October tended to be over forecast by the available model intensity guidance. At 00Z, forecast number 14 indicated continued intensification through 03/00Z to 145 knots. Post storm analysis showed quite the opposite trend with a continual weakening trend as illustrated in Figure 3-6 through 09/00Z.

The forecasted track speeds in the initial 24 hours following the 01/00Z forecast were spot on with post storm analysis of the best track position; however the forecasts, starting with number 14 through landfall with Luzon, showed a notable decrease in track speed after the first 24 hours. Initial track speeds at 01/00Z were around 12 to 13 knots, but dropped to 8 knots beyond tau 24, with further decreases to 3 to 4 knots by tau 120. This expected decrease in track speed could be the factor that influenced intensity forecasts to be significantly higher than actually observed between 01/00Z and 03/06Z.

Between 01/00Z and 02/12Z intensity guidance tended to over forecast intensity for the first 72 hours, even in light of a continuous weakening trend in best track positions after 01/00Z (Figure 3-7). Throughout the time frame noted, from the maximum intensity of 135 knots at 01/00Z to landfall in Luzon on 03/06Z, the initial best track position intensities were being over estimated by between 10 and 20 knots, according to post

storm analysis. This over estimation at the initial positions likely affected bogus parameters leading intensity guidance to also be skewed to the higher end of the spectrum.

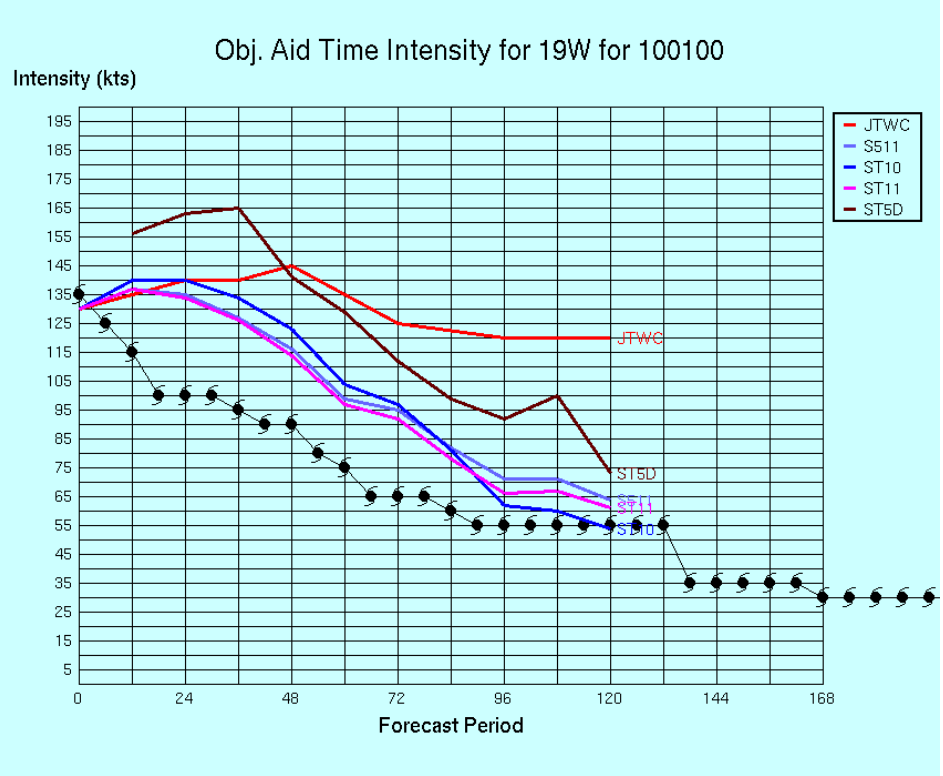


Figure 3-7. Best Track to Intensity Guidance Comparison

It is apparent that a better understanding of direct cyclone interaction is needed, with special focus on the effects when one of the systems involved is in a very weak steering environment. Based on the intensity of Melor at the closest point of approach, effects of environment manipulation by a stronger cyclone (Melor) on a then weaker (Parma) were not adequately apparent in the forecast track of Parma. The second area where more understanding is needed is how we understand the effects on a cyclone (related to intensity) as it approaches the Philippines. Current rules of thumb indicate that the possibility of rapid development is likely in the later portion of the October in the vicinity of Luzon, however this did not verify as illustrated by the graph of JTWC forecasts as compared to the best track values in Figure 3-8.

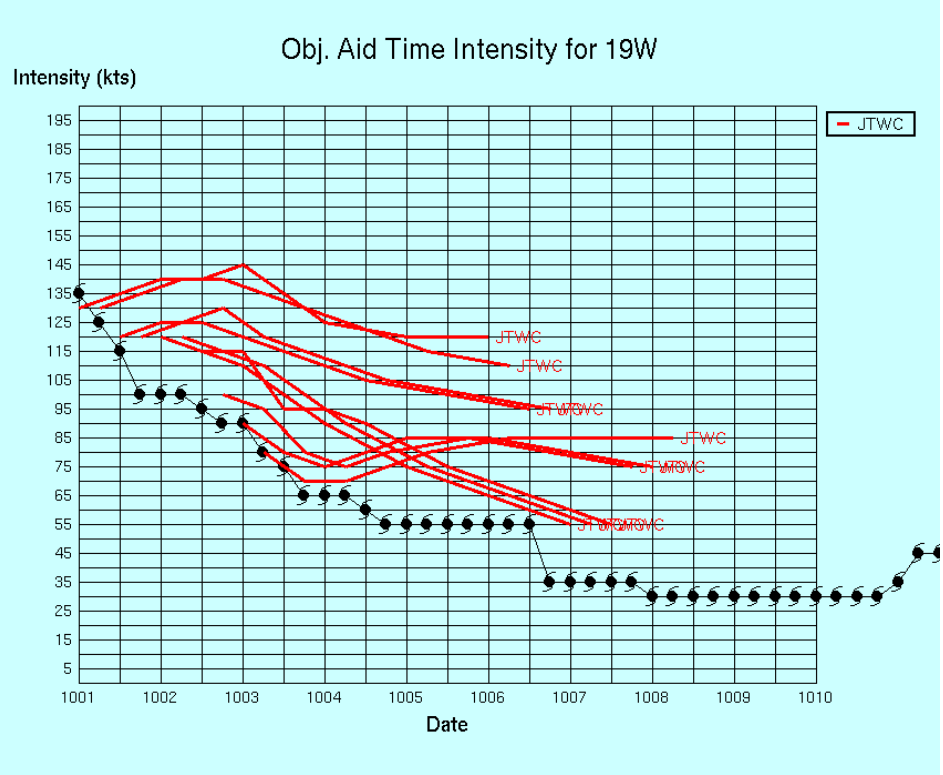


Figure 3-8. JTWC Forecasts to Best Track Intensity Comparison

Super Typhoon 22W (Lupit)

Super Typhoon (STY) 22W (Lupit) formed in the Caroline Islands, and quickly developed into a tropical storm on 14 October 2009 while passing approximately 115 nm south of Guam on a west-northwestward course. By 16 October, the system attained typhoon strength and by 19 October, reached super typhoon intensity in the Philippine Sea. The JTWC forecasts for this cyclone resulted in the diversion or operational voyage change to 6 USN ships. Although Lupit intensified to 140 knots, the cyclone is more noteworthy for its erratic track that included an "S" turn (T1 in Figure 3-9) in the eastern Philippine Sea and a sharp turn to the northeast (T2 in Figure 3-9) near northern Luzon that resulted in large forecast track errors by JTWC and most of the numerical models (Table 3-2).

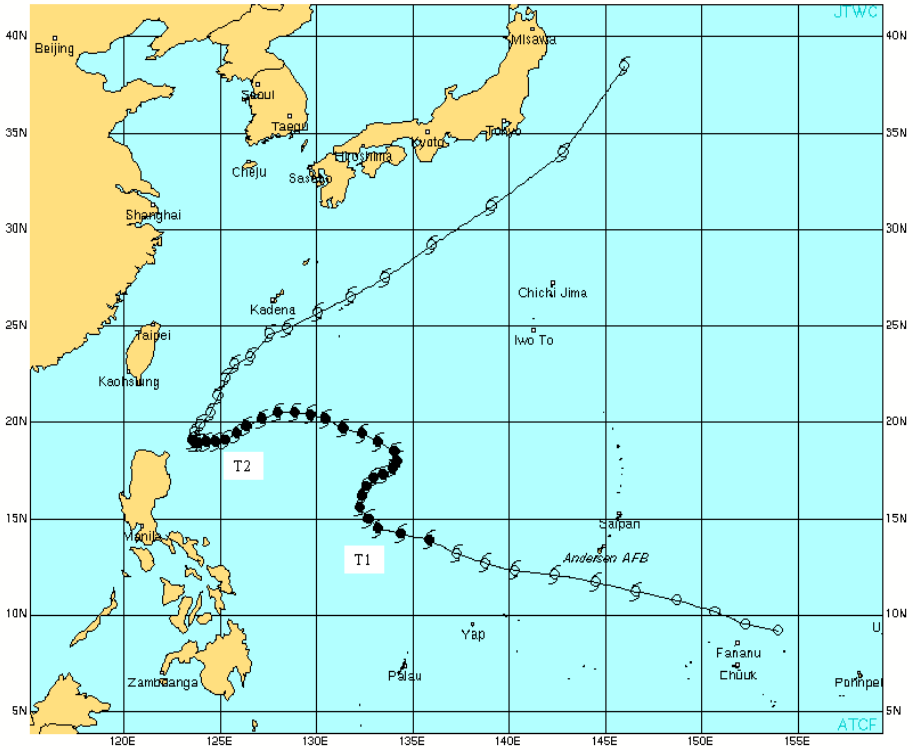


Figure 3-9 Track of Super Typhoon 22W (Lupit)

	24	**36**	**48**	**72**	**96**	**120**
JTWC	74.2	122.3	173.1	282.5	382.6	534.9
CONW	**43.8**	**63.4**	**84.4**	**133.9**	**266.8**	**367.9**
AVNI	44.2	57.9	70.1	112.0	223.9	378.9
EGRI	73.0	116.1	167.8	275.2	429.8	558.4
ECM2	52.6	81.3	117.6	199.4	329.0	509.3
GFNI	56.7	82.7	119.8	181.1	247.1	402.8
NGPI	61.9	88.9	116.1	175.7	234.0	295.1
#CASES	20	19	18	16	14	12

Table 3-2 Homogeneous track errors for STY Lupit

Before Lupit made its first northeastward turn (T1 from Figure 3-9), some of the numerical model forecasts and the model consensus (CONW), indicated a turn would be possible (see Figure 3-10). However, none of the models accurately captured the sharp “S” turn.

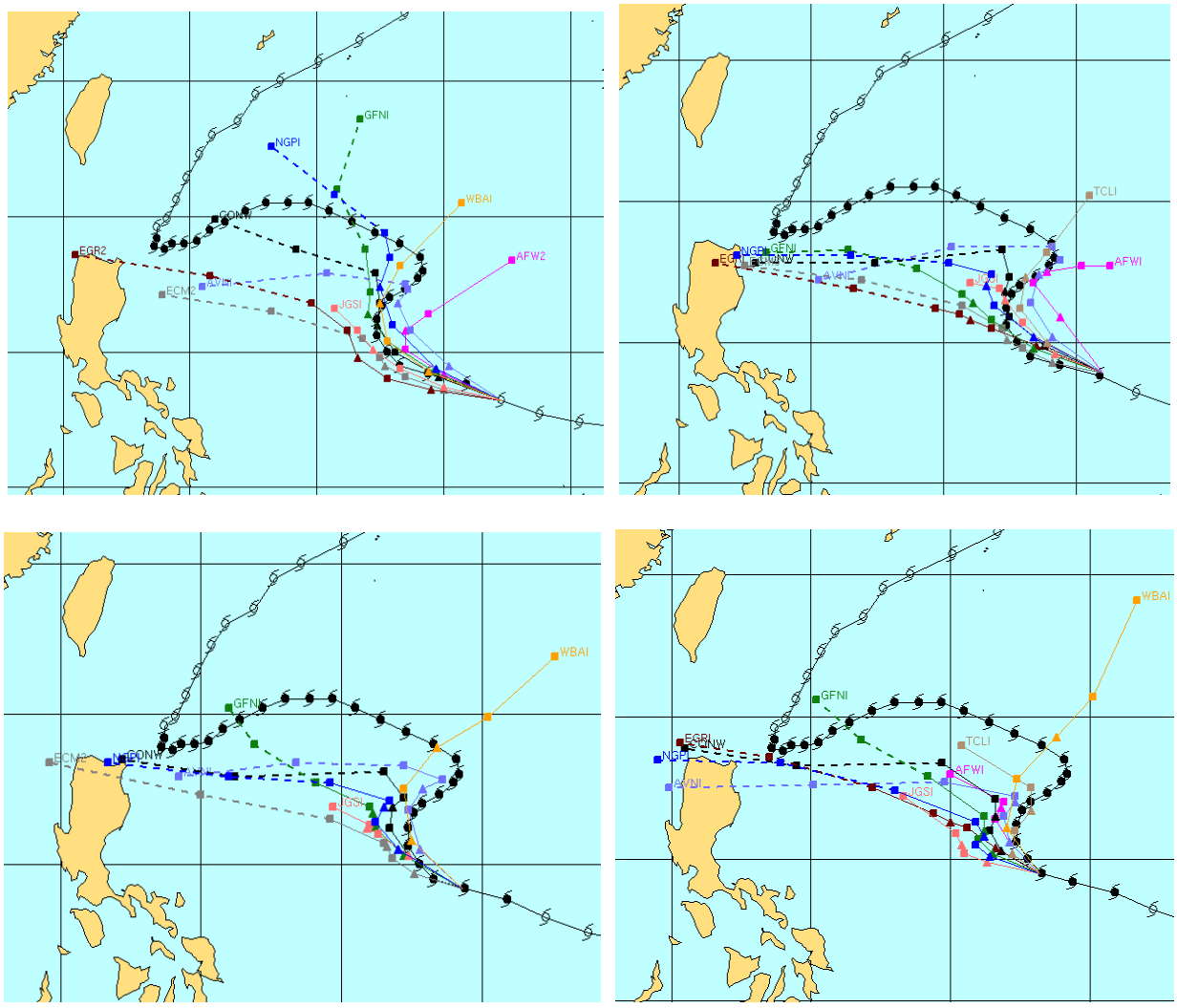


Figure 3-10 Numerical guidance from 00Z, 06Z, 12Z, 18Z on 16 Oct

Over a period of two days, from 16 October through 17 October, the official forecast remained equatorward of CONW (Figure 3-11), remaining in line with the ECMWF model forecast. However, the ECMWF model initially under forecast the strength of a mid-latitude to the north and the cyclone moved in a stair-step fashion in response to the passage of this trough. The official forecast remained biased toward the historically-superior ECMWF (ECMI) and UKMO (EGRI) model solutions and away from those offered by the NOGAPS (NGPI), GFS (AVNI), and GFDN (GFNI) models. There were concerns during the forecast event that the NOGAPS and GFS models were excessively reacting to the passage of the trough and producing apparent movement into the subtropical ridge. However, post-analysis indicates that starting at 16 Oct 0000Z an eastward moving trough in the mid-latitude westerlies did weaken the subtropical ridge close to what NOGAPS and GFS had forecast.

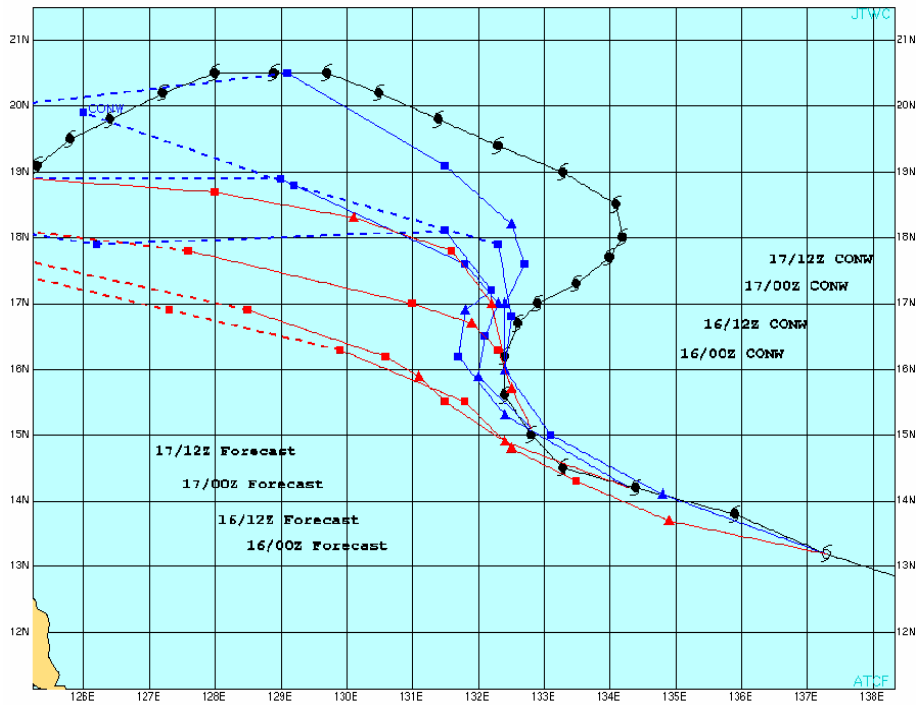
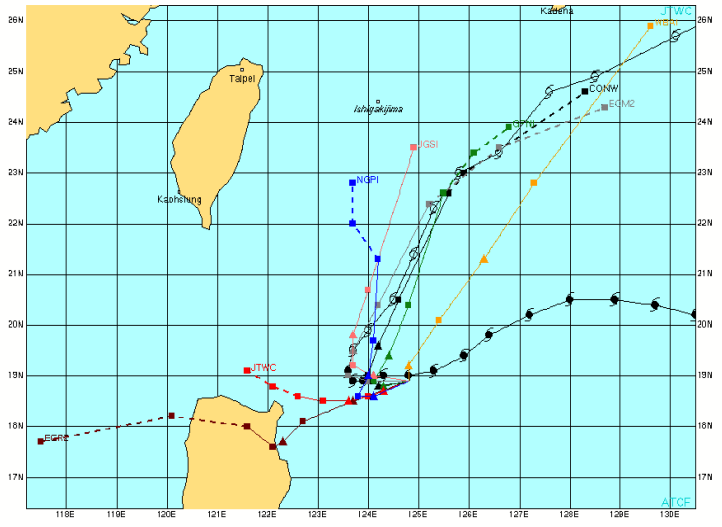
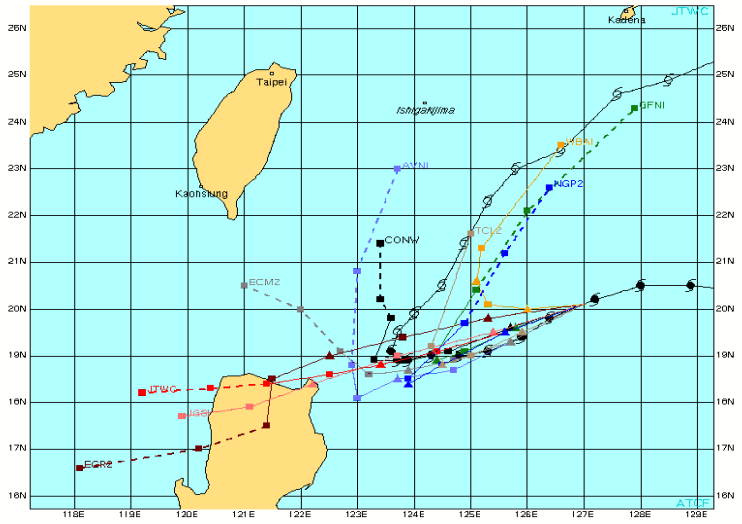


Figure 3-11 Comparison of JTWC official forecasts (red) to the numerical model consensus (blue) for four forecasts starting from 00Z on 16 Oct to 12Z on 17 Oct 2009

The second major event for Lupit occurred around 23 October when the cyclone once again turned sharply to the northeast (T2 in Figure 3-9). As early as 21 October, the NOGAPS, GFDN and GFS models began forecasting a northeast turn scenario, but did so inconsistently. UKMO, JGSM, and beta/advection products continued to depict a west-southwestward track (Figure 3-12).





Figures 3-12 and 3-13 Model objective aids for STY Lupit on 21 Oct 2009 and 22 Oct 2009

Twenty-four hours later, on 22 October, all of the numerical models JTWC considers skilled, except UKMO, indicated Lupit would recurve poleward (Figure 3-13). Despite increased model agreement, fairly zonal mid-latitude flow and a westward building finger of the subtropical steering ridge (Figure 3-14) still supported a southwestward moving system.

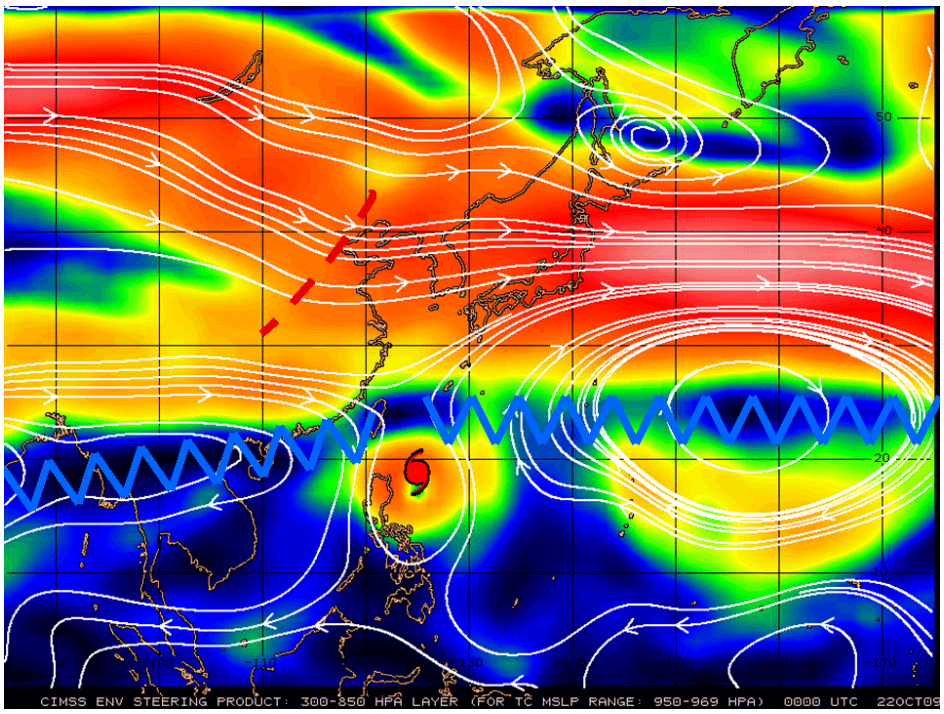


Figure 3-14. CIMSS 300-850mb Deep Layer Mean analysis product for 22OCT09 00Z which depicts weak finger of the subtropical ridge north of the system, an upstream shortwave trough, and a southwestward steering influence. (Courtesy University of Wisconsin)

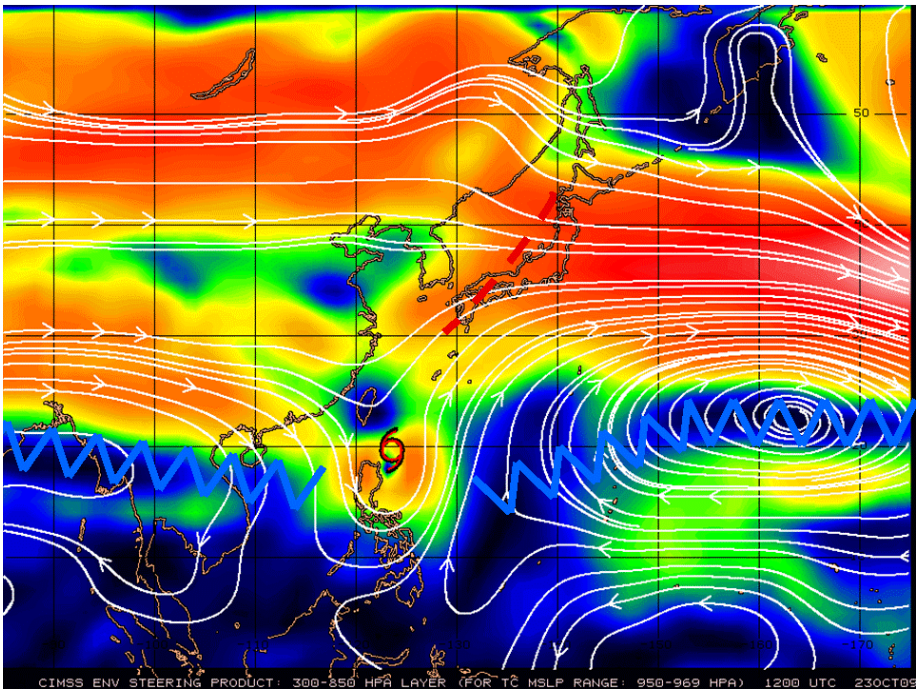


Figure 3-15. CIMSS 300-850mb Deep Layer Mean analysis product for 23OCT09 12Z which shows the effect the shortwave trough had on the strength and orientation of the subtropical ridge and the resultant northward steering influence. (Courtesy University of Wisconsin)

At 0600Z on 23 October, the system had weakened to tropical storm strength and was quasi-stationary east of the Strait of Luzon in the weak steering environment just to the south of a weakness in the subtropical ridge. At this time, just over 48 hours after the models first hinted at a turn to the northeast, the cyclone turned northeastward in response to a shortwave trough in the mid-latitude westerlies and a reorientation of the subtropical ridge (Figure 3-15). JTWC then changed the forecast philosophy for Lupit accordingly.

JTWC was slow to adopt a turn to the northeast for Lupit due to inconsistent model output and the lack of tools necessary for a more precise analysis of the steering mechanisms responsible for the Typhoon's movement. If the extent of the subtropical steering ridge, the depth of the mid-latitude troughs and the interaction between the two were better understood, then a better numerical model initialization and most likely track scenario given the synoptic environment could have been formulated.

Chapter 2 North Indian Ocean Tropical Cyclones

This chapter contains information on north Indian Ocean tropical cyclone activity during 2009 and the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2009. North Indian Ocean tropical cyclone best tracks appear following Table 2-2.

Section 1 Informational Tables

Table 2-1 is a summary of Tropical Cyclone activity in the north Indian Ocean during the 2009 season. Five cyclones occurred in 2009, with only one system reaching intensity greater than 64 knots (TC 02B Aila). Table 2-2 shows the monthly distribution of Tropical Cyclone activity for 1975 - 2009.

Table 2-1

NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 2009

(01 JAN 2009 - 31 DEC 2009)

TC	NAME*	PERIOD**	WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
1B	Bijli	15 - 17 Apr	12	50	985
2B	Aila	24 - 25 May	7	65	974
3B		05 Sep	1	40	992
4A	Phyan	09 - 11 Nov	1	40	992
5B	Ward	11 - 14 Dec	12	45	988

* As Designated by RSMC New Delhi

** Dates are based on Issuance of JTWC warnings on system.

*** MSLP converted from estimated maximum surface winds using Knaff-Zehr wind-pressure relationship

Table 2 - 2

DISTRIBUTION OF NORTH INDIAN OCEAN TROPICAL CYCLONES

FOR 1975 - 2009

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
	010	000	000	000	200	000	000	000	000	100	020	000	330
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
	000	000	000	010	000	010	000	000	010	010	000	010	050
1977	0	0	0	0	1	1	0	0	0	1	0	2	5
	000	000	000	000	010	010	000	000	000	010	000	110	140
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	010	000	000	000	000	010	200	000	220
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
	000	000	000	000	100	010	000	000	011	010	011	000	142
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
	000	000	000	000	000	000	000	000	000	000	010	010	020
1981	0	0	0	0	0	0	0	0	1	0	1	1	3
	000	000	000	000	000	000	000	000	010	000	100	100	210
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
	000	000	000	000	100	010	000	000	000	020	100	000	230
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
	000	000	000	000	000	000	000	010	000	010	010	000	030
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
	000	000	000	000	010	000	000	000	000	010	200	000	220
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
	000	000	000	000	020	000	000	000	000	020	010	010	060
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
	010	000	000	000	000	000	000	000	000	000	020	000	030
1987	0	1	0	0	0	2	0	0	0	2	1	2	8
	000	010	000	000	000	020	000	000	000	020	010	020	080
1988	0	0	0	0	0	1	0	0	0	1	2	1	5
	000	000	000	000	000	010	000	000	000	010	110	010	140
1989	0	0	0	0	1	1	0	0	0	0	1	0	3
	000	000	000	000	010	010	000	000	000	000	100	000	120
1990	0	0	0	1	1	0	0	0	0	0	1	1	4
	000	000	000	001	100	000	000	000	000	000	001	010	112
1991	1	0	0	1	0	1	0	0	0	0	1	0	4
	010	000	000	100	000	010	000	000	000	000	100	000	220
1992	0	0	0	0	1	2	1	0	1	3	3	2	13
	000	000	000	000	100	020	010	000	001	021	210	020	382
1993	0	0	0	0	0	0	0	0	0	0	2	0	2
	000	000	000	000	000	000	000	000	000	000	200	000	200
1994	0	0	1	1	0	1	0	0	0	1	1	0	5
	000	000	010	100	000	010	000	000	000	010	010	000	140
1995	0	0	0	0	0	0	0	0	1	1	2	0	4
	000	000	000	000	000	000	000	000	010	010	200	000	220
1996	0	0	0	0	1	3	0	0	0	2	2	0	8

	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	1 2 0	0 0 0	0 0 0	0 0 0	1 1 0	2 0 0	0 0 0	4 4 0
1997	0	0	0	0	1	0	0	0	1	1	1	0	4
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 1 0	0 0 0	2 2 0
1998	0	0	0	0	2	1	0	0	1	1	2	1	8
	0 0 0	0 0 0	0 0 0	0 0 0	1 1 0	1 0 0	0 0 0	0 0 0	0 1 0	0 1 0	2 0 0	1 0 0	5 3 0
1999	0	1	0	0	1	1	0	0	0	2	0	0	5
	0 0 0	0 1 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 0 0	2 0 0	0 0 0	0 0 0	3 2 0
2000	0	0	0	0	0	0	0	0	0	2	1	1	4
	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 1 0	1 3 0
2001	0	0	0	0	1	0	0	0	1	1	1	0	4
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 1	0 0 0	1 2 1
2002	0	0	0	0	2	0	0	0	0	0	2	1	5
	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 5 0
2003	0	0	0	0	1	0	0	0	0	0	1	1	3
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	2 1 0
2004	0	0	0	0	2	0	0	0	0	2	1	0	5
	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 0 0	1 4 0
2005	2	0	0	0	0	0	0	0	0	2	1	2	7
	0 1 1	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 2 0	0 6 1
2006	1	0	0	1	0	0	1	0	2	0	1	0	6
	0 1 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 2 0	0 0 0	0 1 0	0 0 0	1 5 0
2007	0	0	0	0	1	3	0	0	0	1	1	0	6
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	1 2 0	0 0 0	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	3 3 0
2008	0	0	0	1	0	0	0	0	1	2	2	1	7
	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 1	0 2 0	0 1 0	1 5 1
2009	0	0	0	1	1	0	0	0	1	0	1	1	5
	0 0 0	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 1 0	1 4 0
(1975-2009)													
MEAN	0.2	0.1	0.0	0.2	0.7	0.6	0.1	0.0	0.4	1.0	1.4	0.6	5.0
CASES	6	2	1	7	25	20	2	1	13	35	46	20	178

The criteria used in TABLE 1-6 are as follows:

1) If a tropical cyclone was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month.

2) If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

TABLE 2-2 Legend		
Total month/year		
GTE 64 knots (Typhoon)	34 to 63 knots (Tropical Storm)	LTE 33 knots (Tropical Depression)

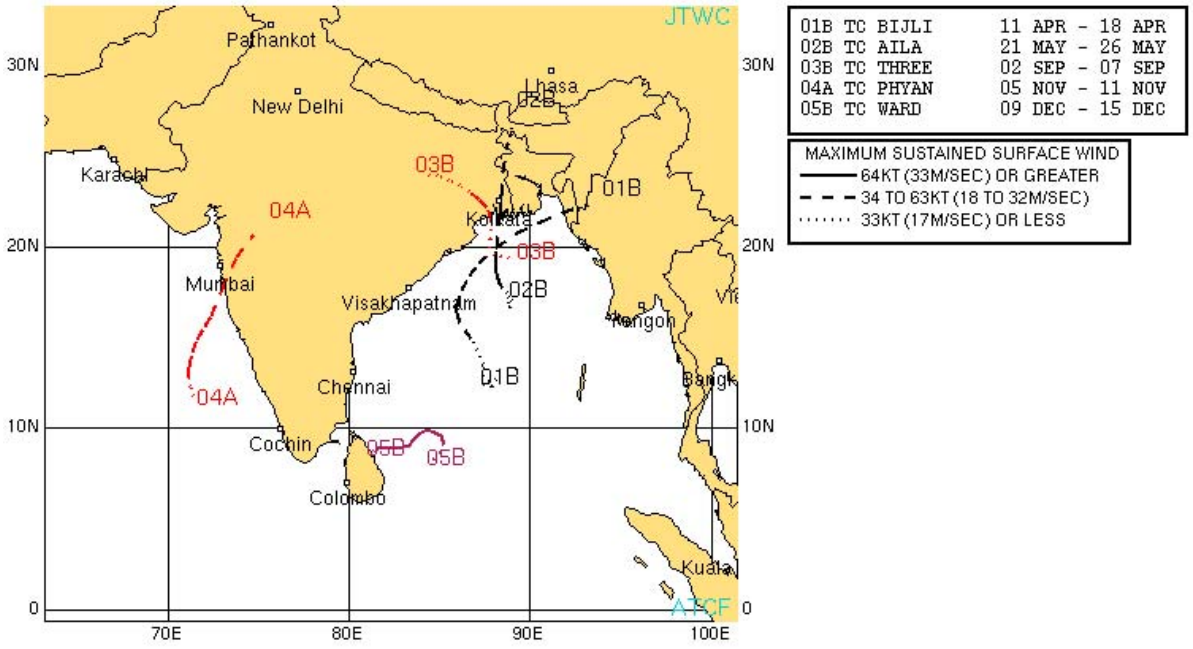


Figure 2-1. North Indian Ocean Tropical Cyclones 01 – 05B.

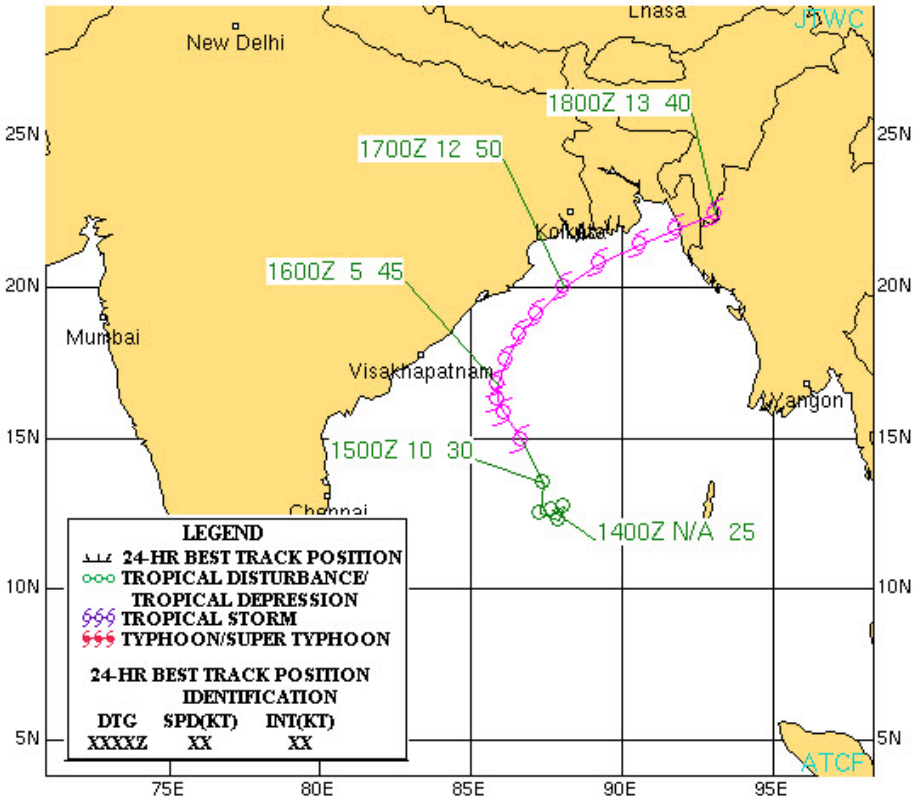
Section 2 Cyclone Summaries

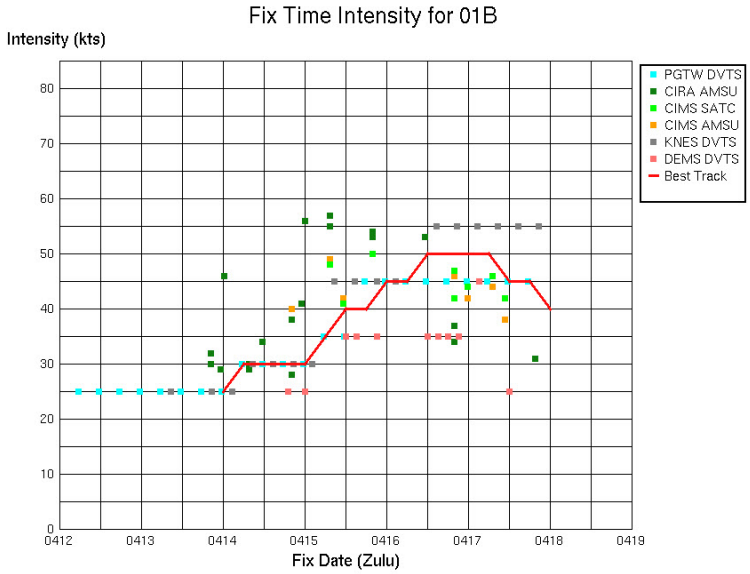
Each cyclone is presented, with the number and basin identifier assigned by JTWC, along with the RSMC assigned cyclone name. Dates are also listed when JTWC first designated various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development/TC expected (Good classification). Furthermore, the first Tropical Cyclone Formation Alert (TCFA), and the first and final warnings dates are also presented with the number of warnings issued by JTWC. Maximum intensity and the number of warnings issued by JTWC are included as well. Landfall over major landmasses and approximate locations are presented as well.

The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track positions are marked by date at 0000 UTC, as well as the beginning and end points. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color coded by fixing agency.

Tropical Cyclone 01B (Bijli)

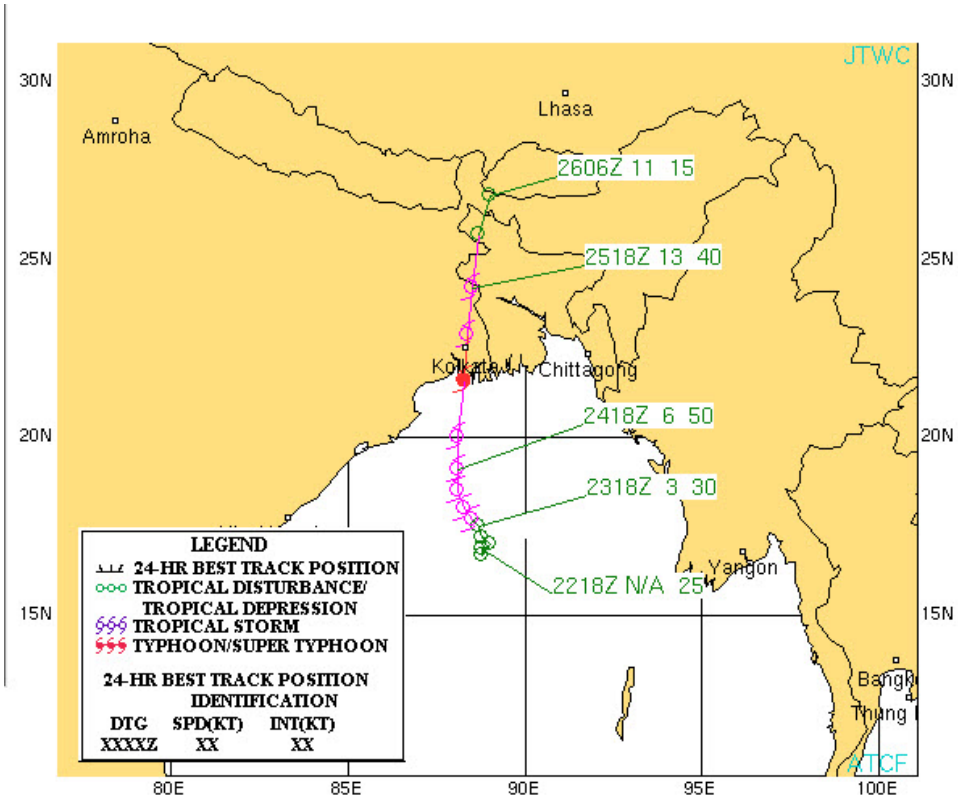
ISSUED POOR:	N/A
ISSUED FAIR:	0600Z 14 Apr 2009
FIRST TCFA:	1100Z 14 Apr 2009
FIRST WARNING:	0000Z 15 Apr 2009
LAST WARNING:	1800Z 17 Apr 2009
MAX INTENSITY:	50 Kts
NUMBER OF WARNINGS:	12

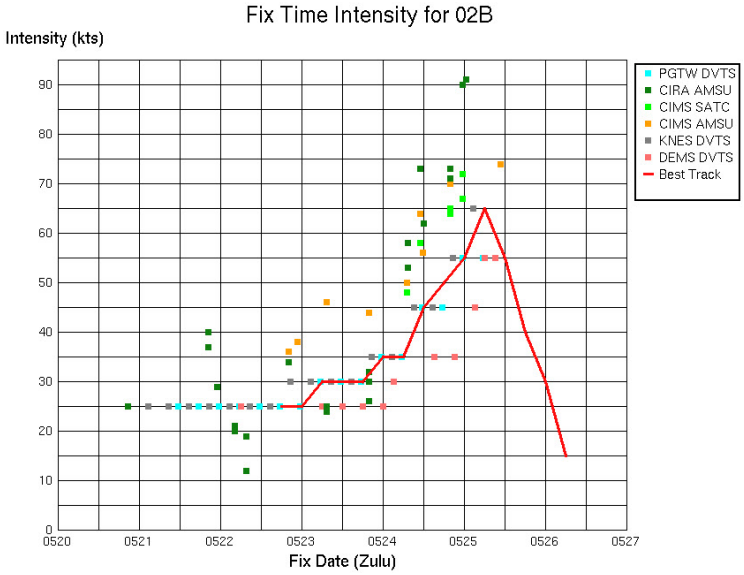




Tropical Cyclone 02B (Aila)

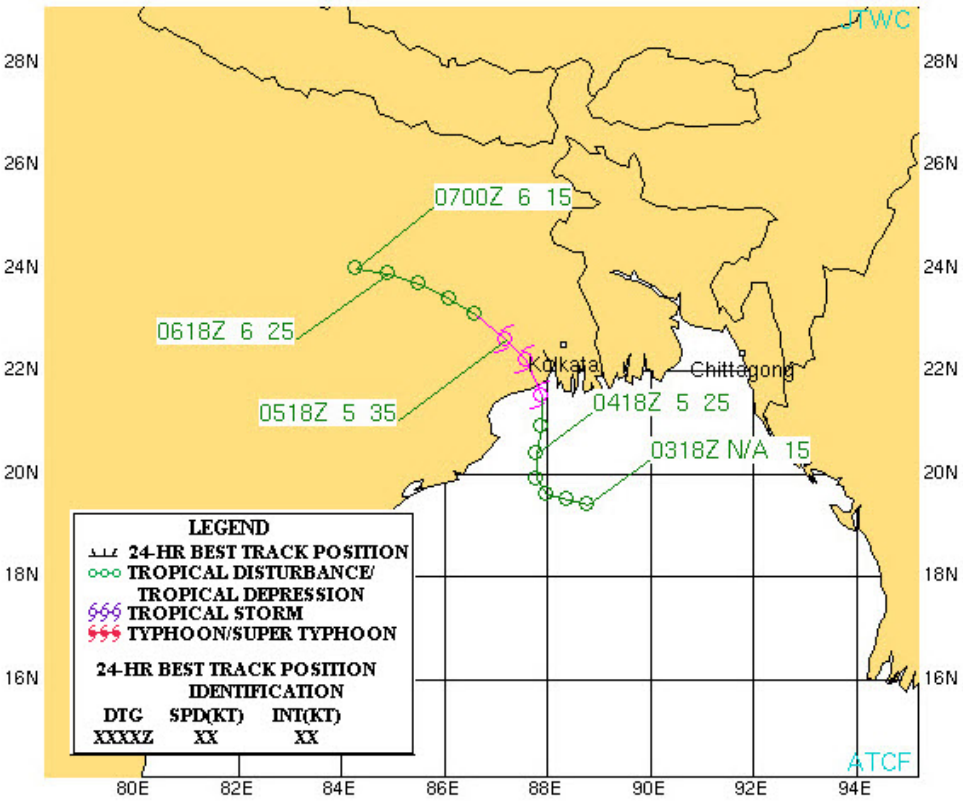
ISSUED POOR:	1800Z 21 May 2009
ISSUED FAIR:	0430Z 22 May 2009
FIRST TCFA:	0600Z 23 May 2009
FIRST WARNING:	0300Z 24 May 2009
LAST WARNING:	1800Z 25 May 2009
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	7

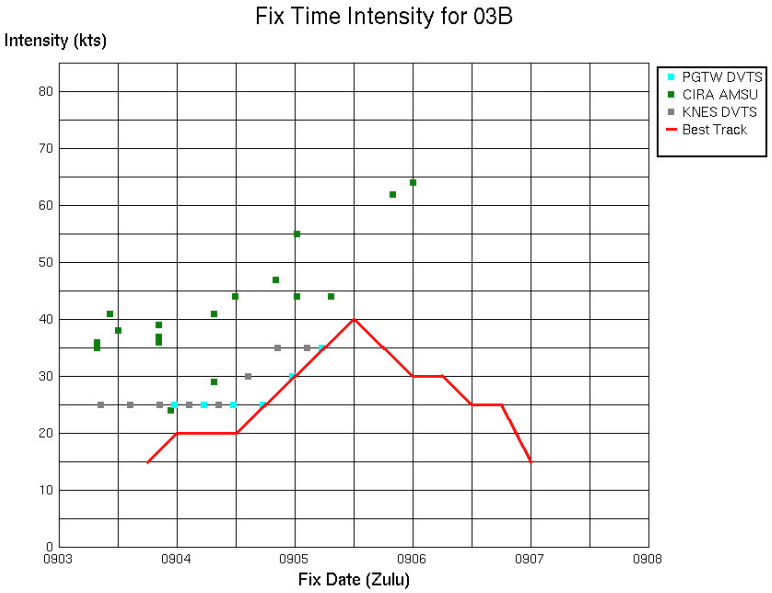




Tropical Cyclone 03B

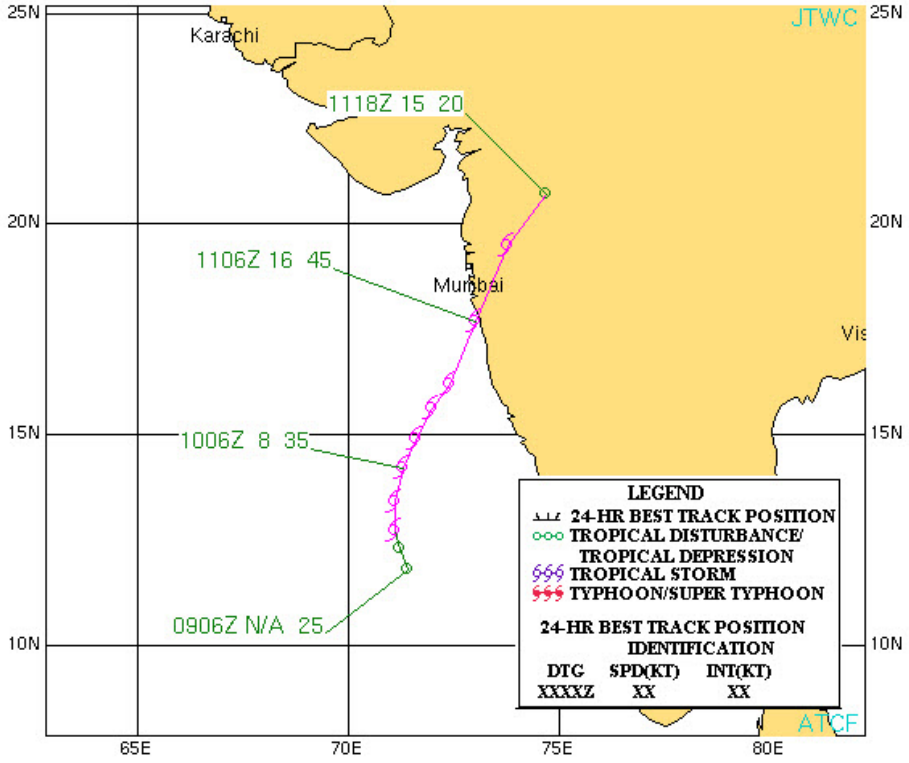
ISSUED POOR: 1200Z 04 Sep 2009
ISSUED FAIR: 1800Z 04 Sep 2009
FIRST TCFA: 0030Z 05 Sep 2009
FIRST WARNING: 0600Z 05 Sep 2009
LAST WARNING: 0600Z 05 Sep 2009
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 1

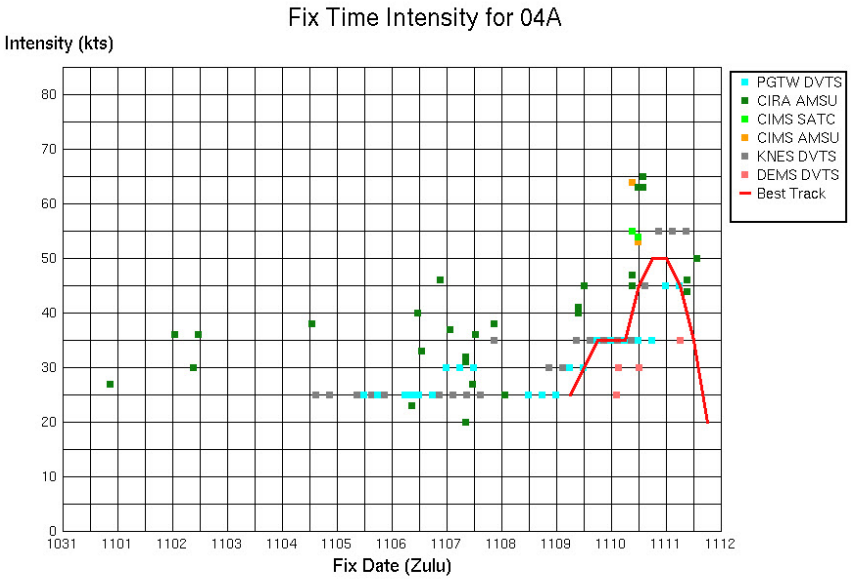




Tropical Cyclone 04A (Phyan)

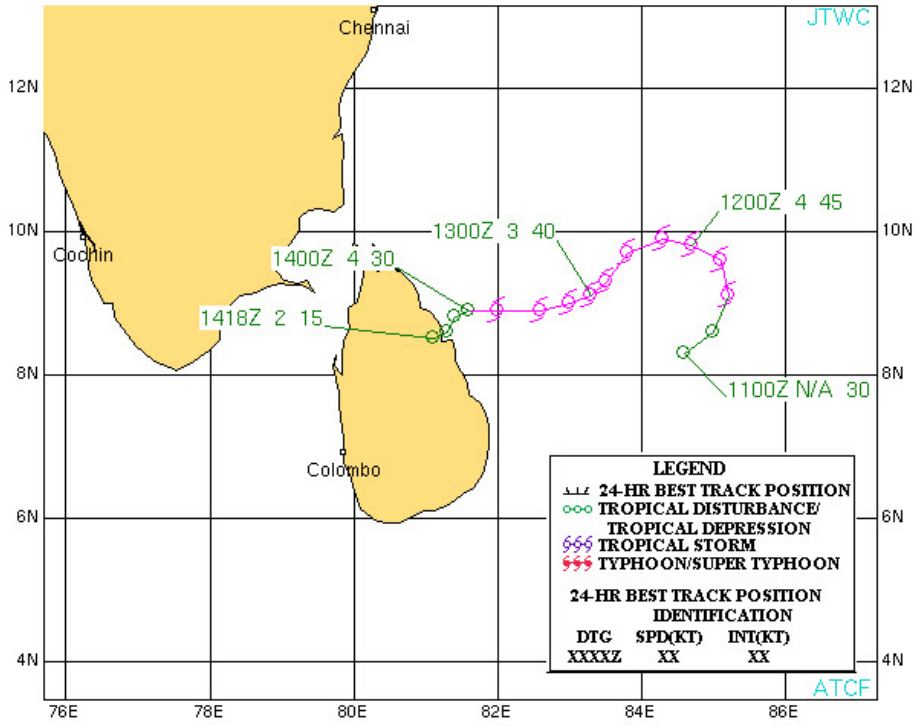
ISSUED POOR: 1800Z 04 Nov 2009
ISSUED FAIR: 1500Z 06 Nov 2009
FIRST TCFA: 0900Z 09 Nov 2009
FIRST WARNING: 1800Z 09 Nov 2009
LAST WARNING: 1200Z 11 Nov 2009
MAX INTENSITY: 50 Kts
NUMBER OF WARNINGS: 8

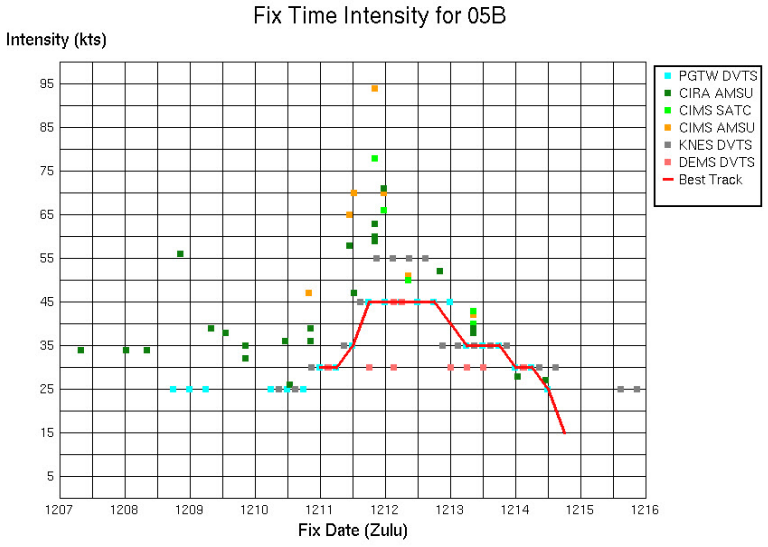




Tropical Cyclone 05B (Ward)

ISSUED POOR:	N/A
ISSUED FAIR:	1030Z 10 Dec 2009
FIRST TCFA:	0530Z 11 Dec 2009
FIRST WARNING:	1200Z 11 Dec 2009
LAST WARNING:	0600Z 14 Nov 2009
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	12





Chapter 3 South Pacific and South Indian Ocean Tropical Cyclones

This chapter contains information on South Pacific and South Indian Ocean TC activity that occurred during the 2009 tropical cyclone season (1 July 2008 – 30 June 2009) and the monthly distribution of TC activity summarized for 1975 - 2009.

Section 1 Informational Tables

Table 3-1 is a summary of TC activity in the Southern Hemisphere during the 2009 season. Table 3-2 provides the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2009.

Table 3-1

SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 2009

(01 JULY 2008 - 30 JUNE 2009)

TC	NAME	PERIOD	WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)**
01S	Asma	16 - 21 OCT	10	55	981
02S	Anika	18 - 20 NOV	6	60	977
03S	Bernard	19 - 20 NOV	3	40	992
04S	Cinda	17 - 21 DEC	9	55	981
05S	Billy	18 - 27 DEC	19	110	940
06S	Dongo	9 - 12 JAN	7	55	981
07P	Charlotte	11 JAN	1	40	992
08S	Eric	18 - 20 JAN	5	40	992
09S	Fanele	19 - 22 JAN	9	115	936
10S	Dominic	25 - 27 JAN	7	50	985
11P	Hettie	28 - 29 JAN	2	35	996
12P	Ellie	31 JAN - 1 FEB	3	35	996
13S	Gael	2 - 10 FEB	16	120	933
14S	Freddy	6 - 9 FEB	8	55	981
15P	Innis	17 - 18 FEB	3	40	992
16S	Hina	21 - 24 FEB	6	65	974
17S	Gabrielle	2 - 4 MAR	6	35	996
18P	Hamish	5 - 12 MAR	14	135	921
19S		9 - 10 MAR	2	35	996
20P	Joni	11 - 13 MAR	6	55	981
21P	Ken	17 - 19 MAR	4	50	985
22S	Ilsa	17 -23 MAR	13	100	948
23P	Jasper	24 - 25 MAR	4	45	988
24S	Izilda	24 - 26 MAR	7	65	974
25P	Lin	4 - 5 APR	4	55	981
26S	Jade	4 - 10 APR	16	65	974
27S	Kirrily	26 - 28 APR	5	45	988

***As Designated by TCWC Perth, Darwin, Brisbane, RSMC La Reunion, or RSMC Nadi, Fiji

**MSLP converted from estimated maximum winds using Knaff-Zehr wind pressure relationship. Number of warnings includes amended warnings.

Table 3-2

DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

FOR 1958 – 2009

YEAR	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTALS
1958 - 1977 AVERAGE*													
-	-	-	-	0.4	1.5	3.6	6.1	5.8	4.7	2.1	0.5	-	24.7
1981 - 2009													
1981	0	0	0	1	3	2	6	5	3	3	1	0	24
1982	1	0	0	1	1	3	9	4	2	3	1	0	25
1983	1	0	0	1	1	3	5	6	3	5	0	0	25
1984	1	0	0	1	2	5	5	10	4	2	0	0	30
1985	0	0	0	0	1	7	9	9	6	3	0	0	35
1986	0	0	1	0	1	1	9	9	6	4	2	0	33
1987	0	1	0	0	1	3	6	8	3	4	1	1	28
1988	0	0	0	0	2	3	5	5	3	1	2	0	21
1989	0	0	0	0	2	1	5	8	6	4	2	0	28
1990	2	0	1	1	2	2	4	4	10	2	1	0	29
1991	0	0	1	1	1	3	2	5	5	2	1	1	22
1992	0	0	1	1	2	5	4	11	3	2	1	0	30
1993	0	0	1	1	0	5	7	7	2	2	2	0	27
1994	0	0	0	0	2	4	8	4	9	3	0	0	30
1995	0	0	0	0	2	2	5	4	5	4	0	0	22
1996	0	0	0	0	1	3	7	6	6	4	1	0	28
1997	1	1	1	2	2	6	9	8	3	1	3	1	38
1998	1	0	0	3	2	3	7	9	6	6	0	0	37
1999	1	0	1	1	1	6	6	8	7	2	0	0	33
2000	0	0	0	0	0	3	6	5	7	6	0	0	27
2001	0	1	0	0	1	1	4	6	2	5	0	1	21
2002	0	0	0	2	4	1	4	5	4	2	3	0	25
2003	0	0	1	0	2	5	5	7	5	2	1	1	29
2004	0	0	0	1	1	3	6	3	7	1	1	0	23
2005	0	0	1	1	2	2	7	7	4	2	0	0	26
2006	6	5	5	3	0	0	0	0	0	1	2	1	23
2007	0	0	0	0	1	2	2	5	6	6	1	1	24
2008	1	0	0	0	3	4	7	5	6	3	0	0	29
2009	0	0	0	1	2	2	7	4	8	3	0	0	27
(1981 - 2009)													
MEAN	0.5	0.3	0.5	0.8	1.6	3.1	5.7	6.1	4.9	3.0	0.9	0.2	27.6
CASES	15	8	14	22	45	90	166	177	141	88	26	7	799

* (GRAY, 1978)

The criteria used in TABLE 3-2 are as follows:

1) If a TC was first warned on during the last two days of a particular month and continued into the next month for longer than two days, then that system was attributed to the second month

2) If a TC was warned on prior to the last two days of a month, it was attributed to the first month, regardless of how long the system lasted.

3) If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that system was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for only two days, then it was attributed to the second month.

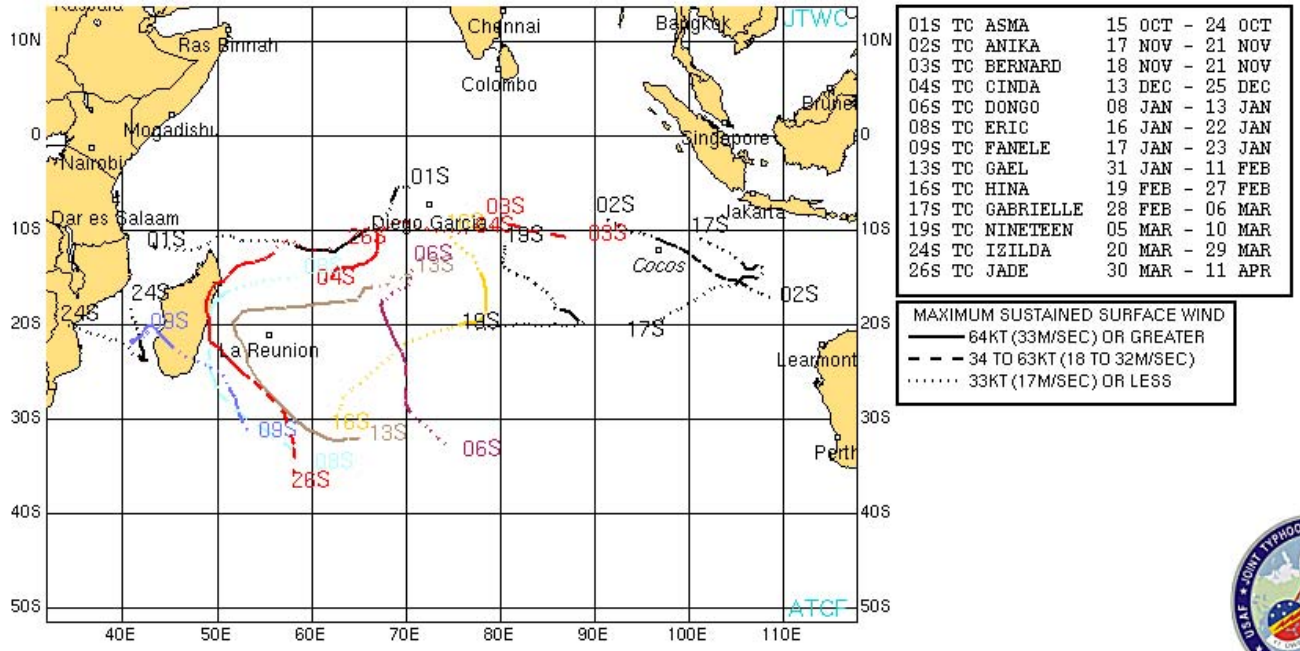


Figure 3-1. Southern Indian Ocean Tropical Cyclones 15 Oct 2008 – 11 Apr 2009.

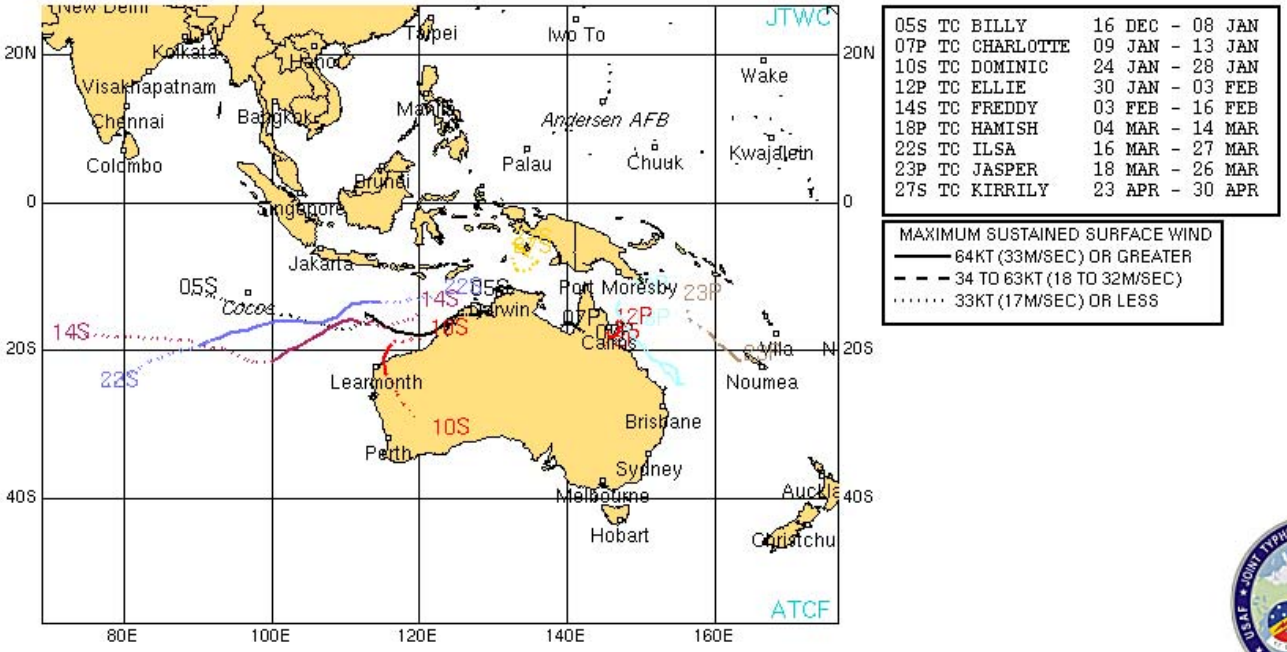


Figure 3-2. Australia Region Tropical Cyclones 16 Dec 2008 - 30 Apr 2009.

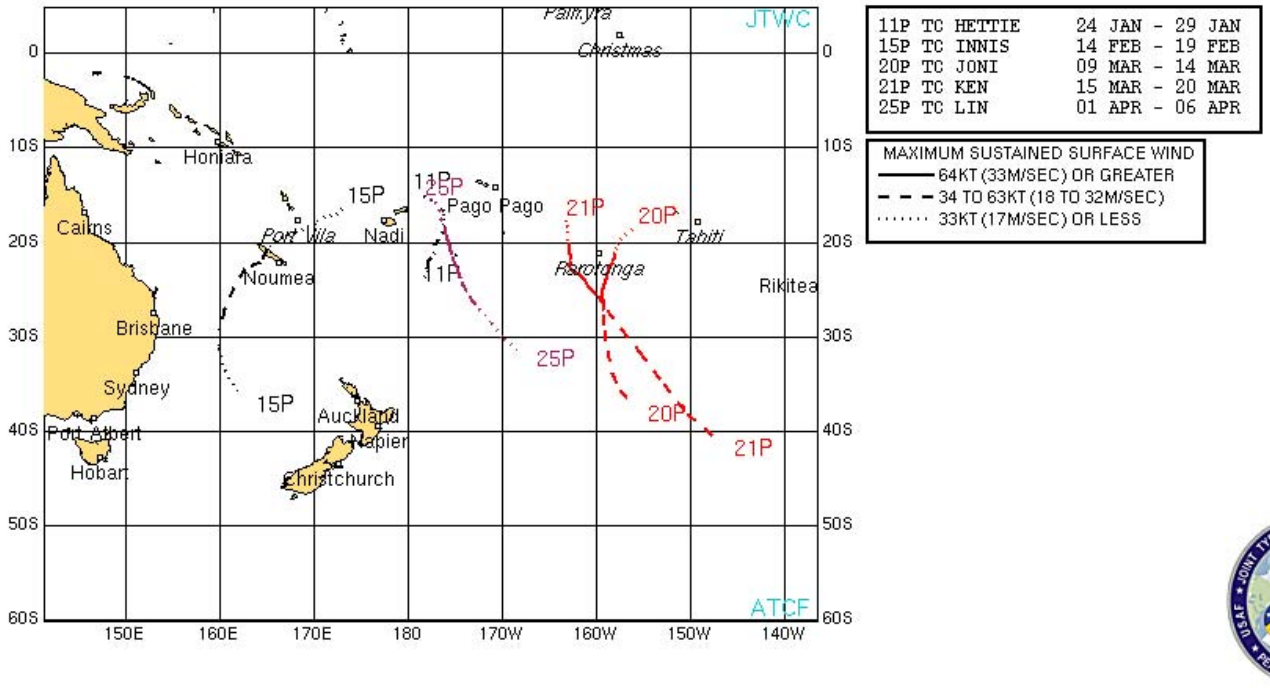


Figure 3-3. Southern Pacific Tropical Cyclones 24 Jan 2009 - 06 Apr 2009.

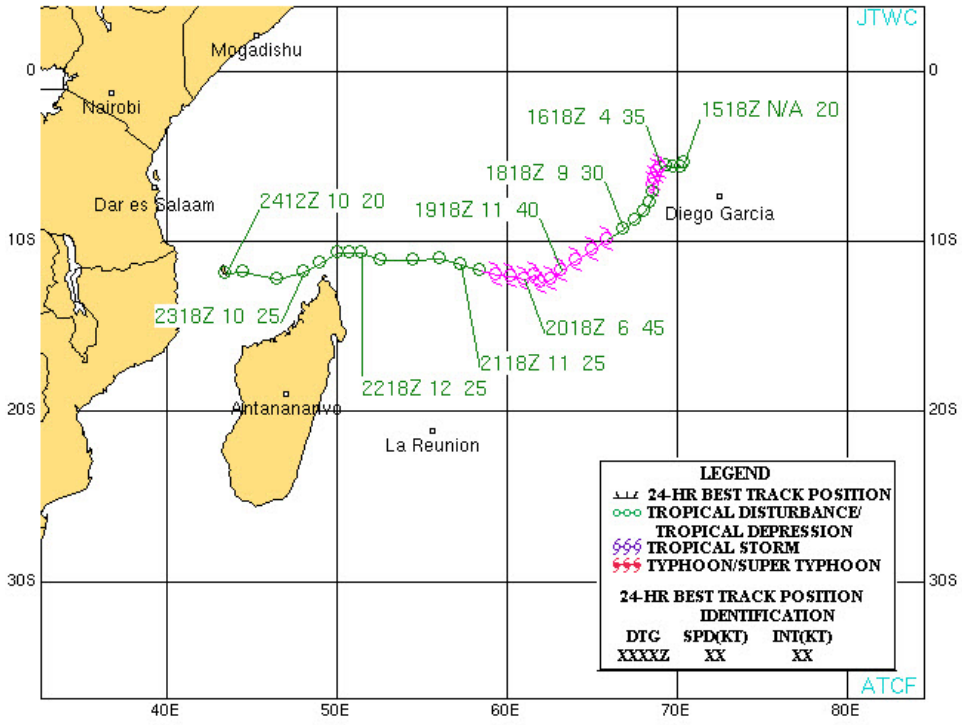
Section 2 Cyclone Summaries

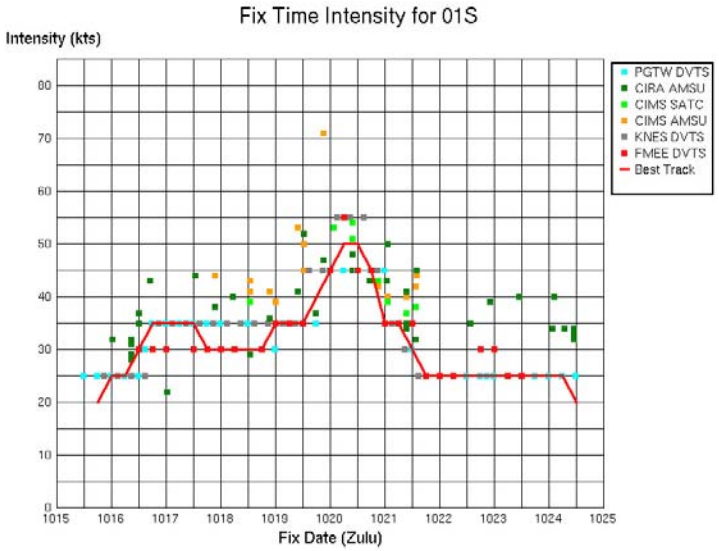
Each cyclone is presented, with the number and basin identifier assigned by JTWC, along with the RSMC assigned cyclone name. Dates are also listed when JTWC first designated various stages of development; as an area of interest (Poor classification), increased potential for development (Fair classification) and development/TC expected (Good classification). Furthermore, the first Tropical Cyclone Formation Alert (TCFA), and the first and final warnings dates are also presented with the number of warnings issued by JTWC. Maximum intensity and the number of warnings issued by JTWC are included as well. Landfall over major landmasses and approximate locations are presented as well.

The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track positions are marked by date at 0000 UTC, as well as the beginning and end points. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color coded by fixing agency.

Tropical Cyclone 01S (Asma)

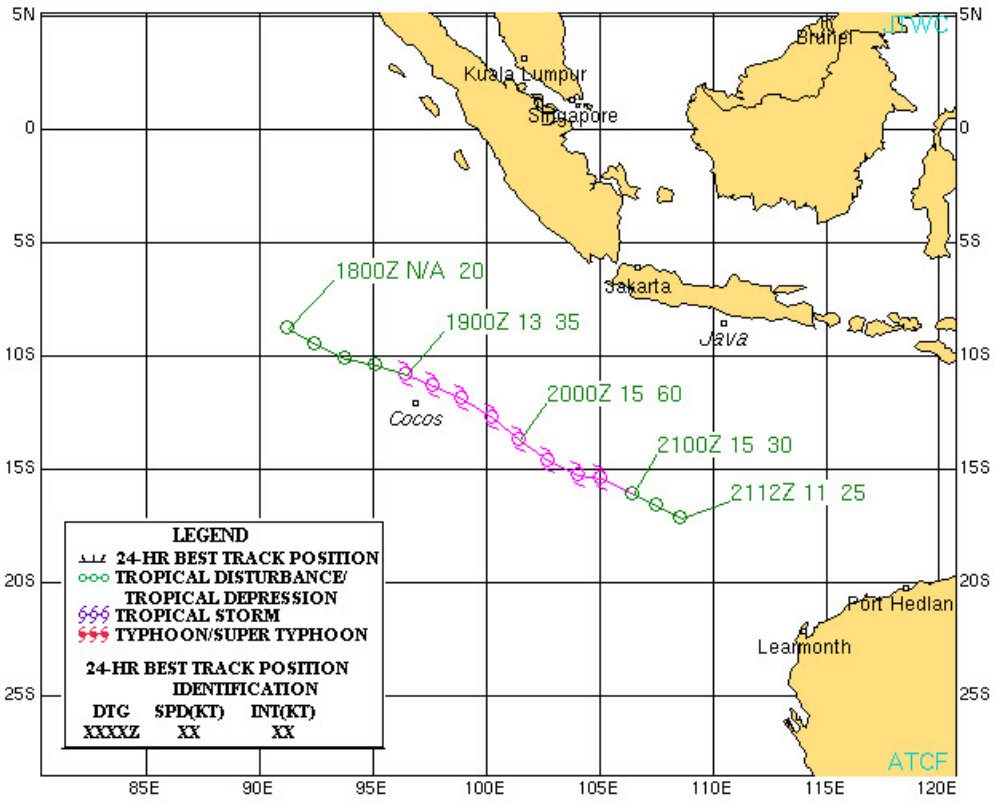
ISSUED POOR:	1230Z 15 Oct 2008
ISSUED FAIR:	0200Z 16 Oct 2008
FIRST TCFA:	1630Z 16 Oct 2008
FIRST WARNING:	1800Z 16 Oct 2008
LAST WARNING:	0600Z 21 Oct 2008
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	10

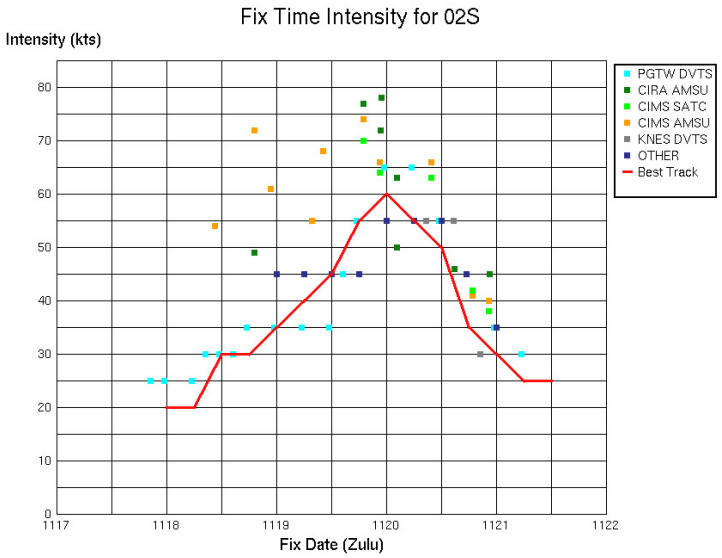




Tropical Cyclone 02S (Anika)

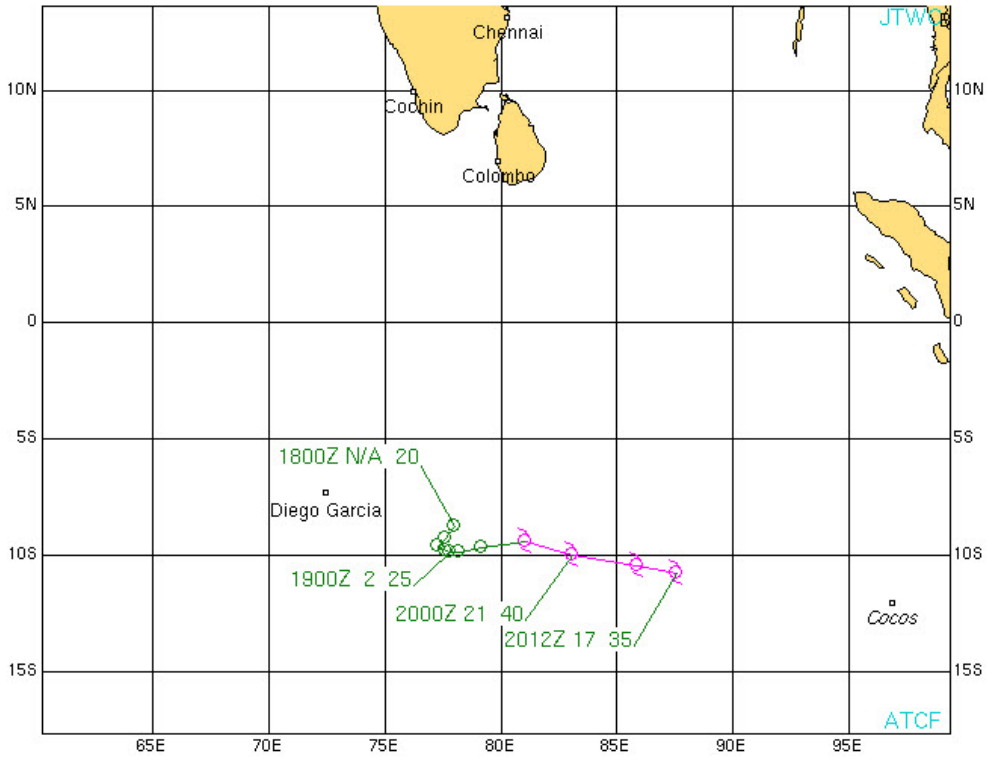
ISSUED POOR: 0130Z 18 Nov 2008
ISSUED FAIR: 0630Z 18 Nov 2008
FIRST TCFA: 0930Z 18 Nov 2008
FIRST WARNING: 1800Z 18 Nov 2008
LAST WARNING: 1800Z 20 Nov 2008
MAX INTENSITY: 60 Kts
NUMBER OF WARNINGS: 6

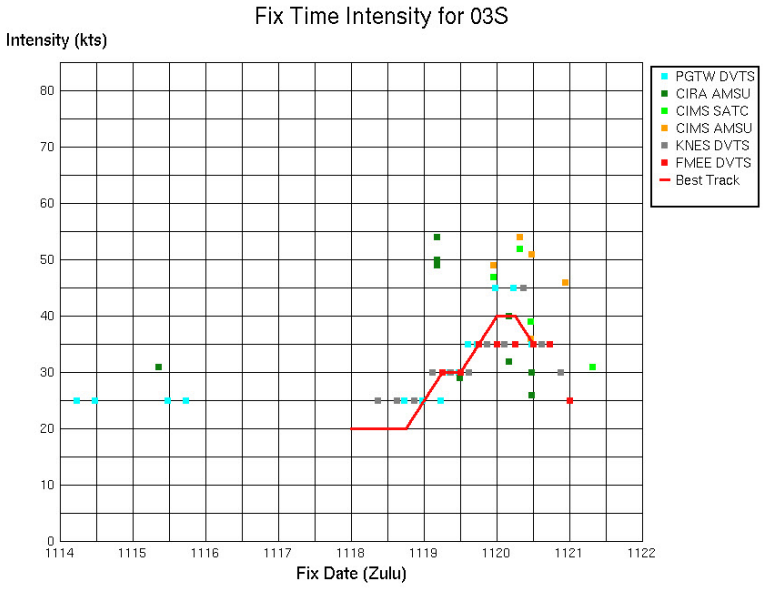




Tropical Cyclone 03S (Bernard)

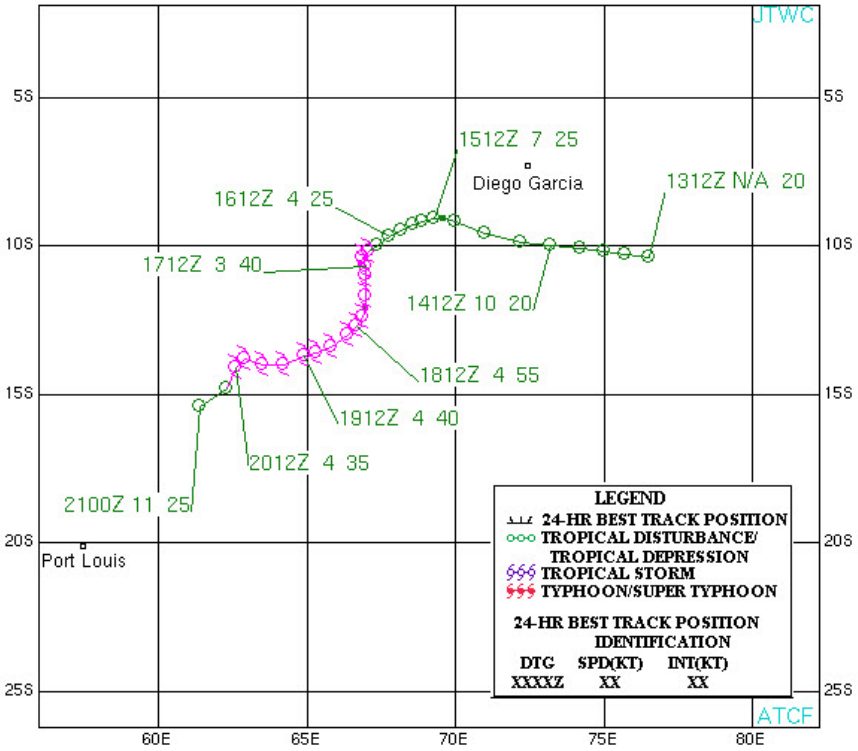
ISSUED POOR:	1800Z 15 Nov 2008
ISSUED FAIR:	N/A
FIRST TCFA:	0830Z 19 Nov 2008
FIRST WARNING:	1800Z 19 Nov 2008
LAST WARNING:	1800Z 20 Nov 2008
MAX INTENSITY:	40 Kts
NUMBER OF WARNINGS:	3

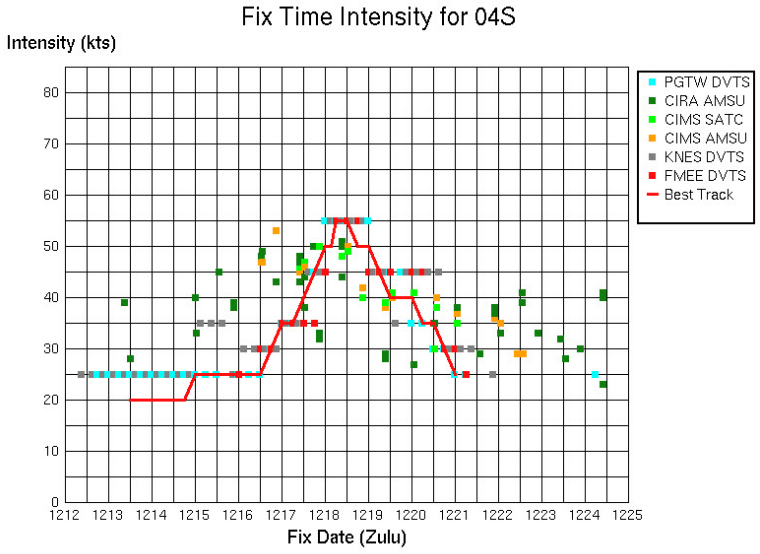




Tropical Cyclone 04S (Cinda)

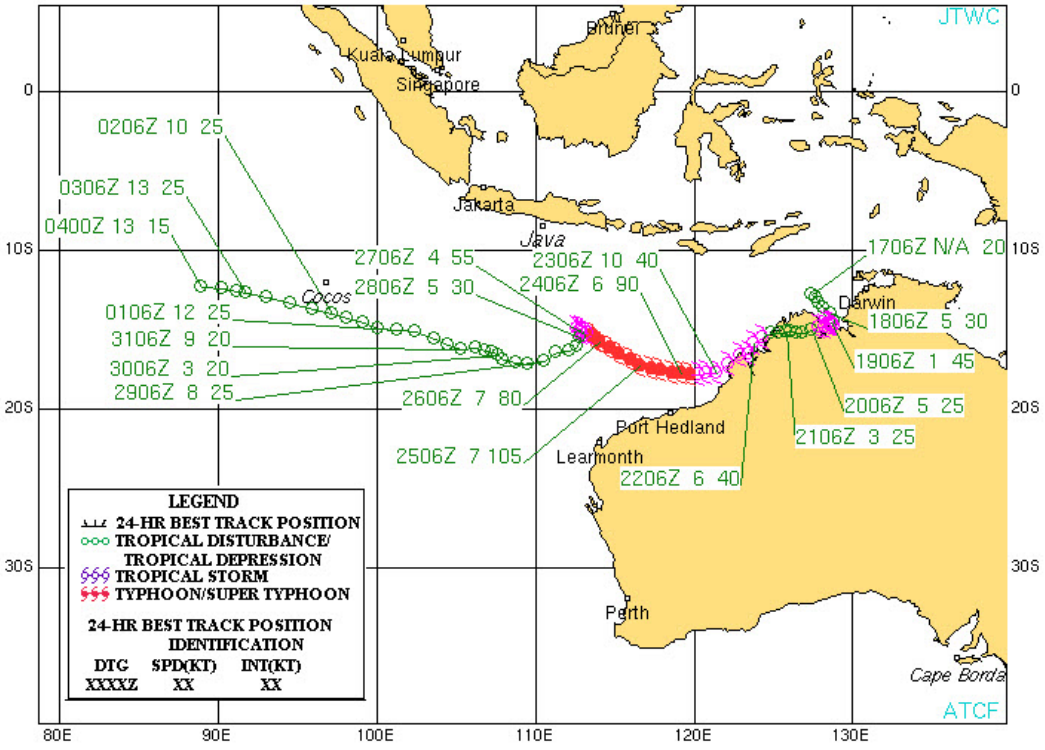
ISSUED POOR:	N/A
ISSUED FAIR:	1200Z 13 Dec 2008
FIRST TCFA:	2200Z 16 Dec 2008
FIRST WARNING:	0000Z 17 Dec 2008
LAST WARNING:	0000Z 21 Dec 2008
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	9

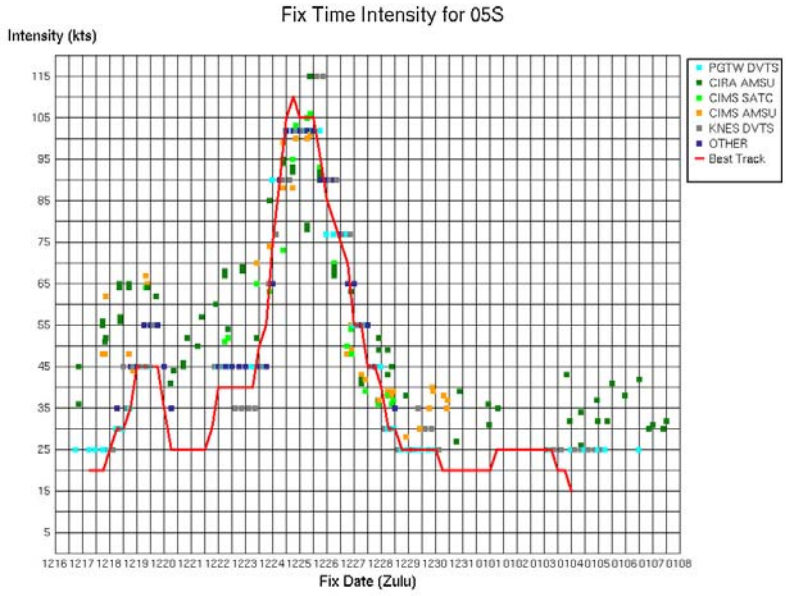




Tropical Cyclone 05S (Billy)

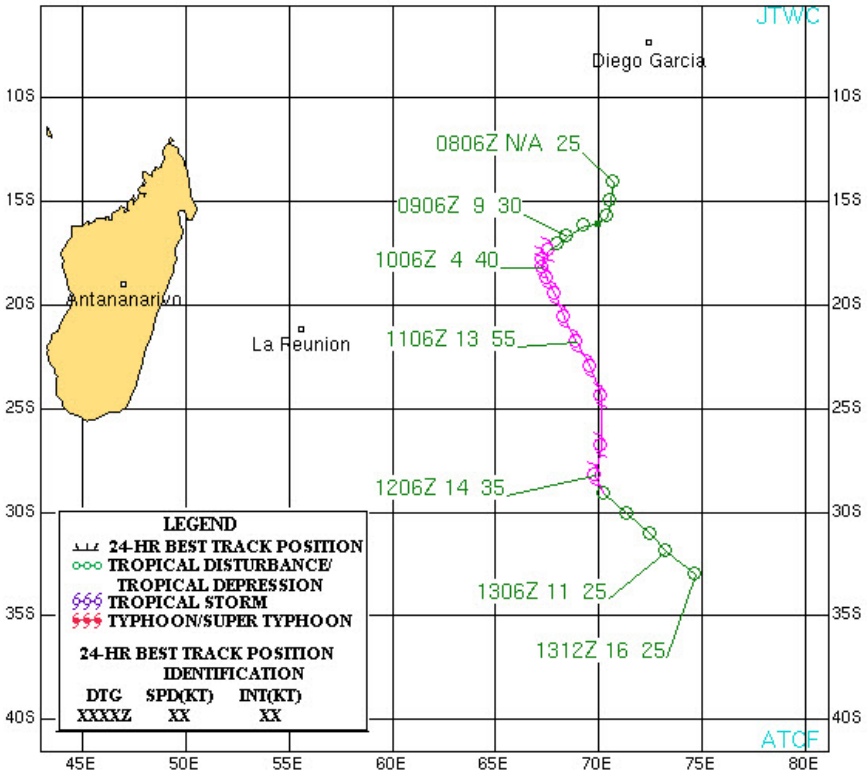
ISSUED POOR: 1800Z 16 Dec 2008
ISSUED FAIR: N/A
FIRST TCFA: 0830Z 18 Dec 2008
FIRST WARNING: 1200Z 18 Dec 2008
LAST WARNING: 0600Z 27 Dec 2008
MAX INTENSITY: 110 Kts
NUMBER OF WARNINGS: 19

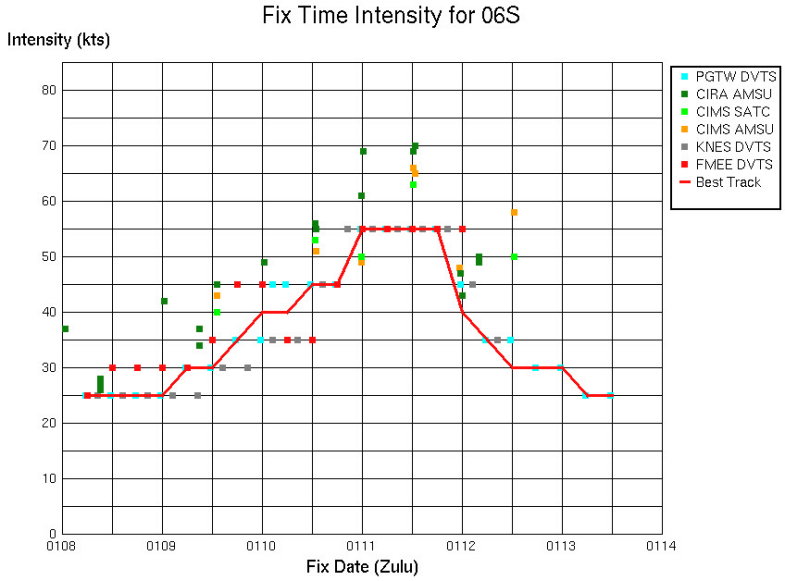




Tropical Cyclone 06S (Dongo)

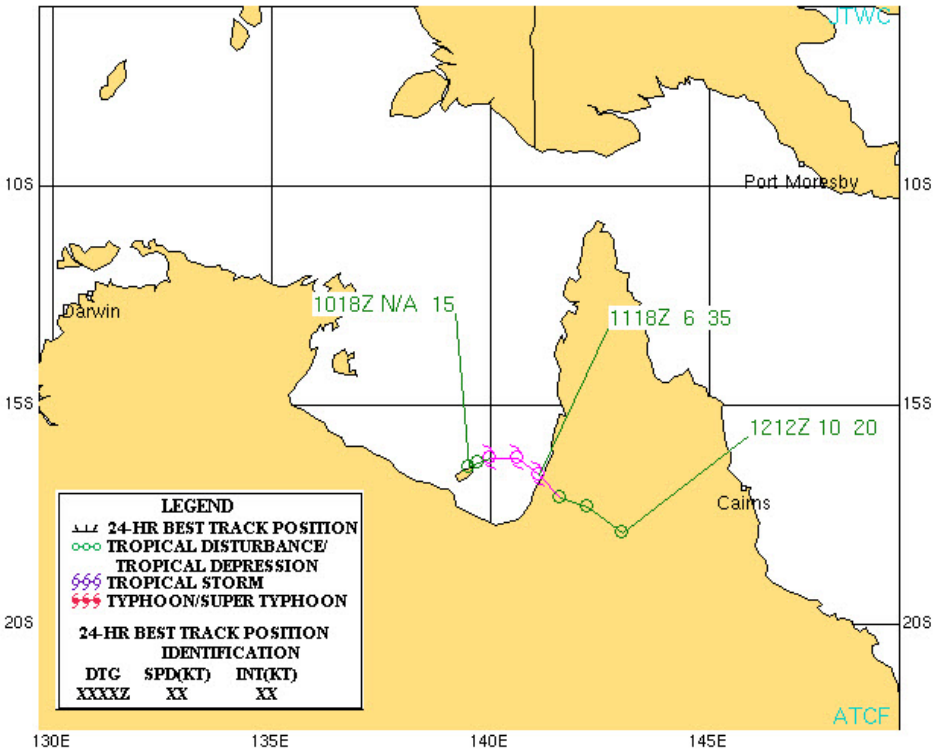
ISSUED POOR: 0300Z 8 Jan 2009
ISSUED FAIR: 0830Z 8 Jan 2009
FIRST TCFA: 1500Z 8 Jan 2009
FIRST WARNING: 1200Z 9 Jan 2009
LAST WARNING: 1200Z 12 Jan 2009
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 7

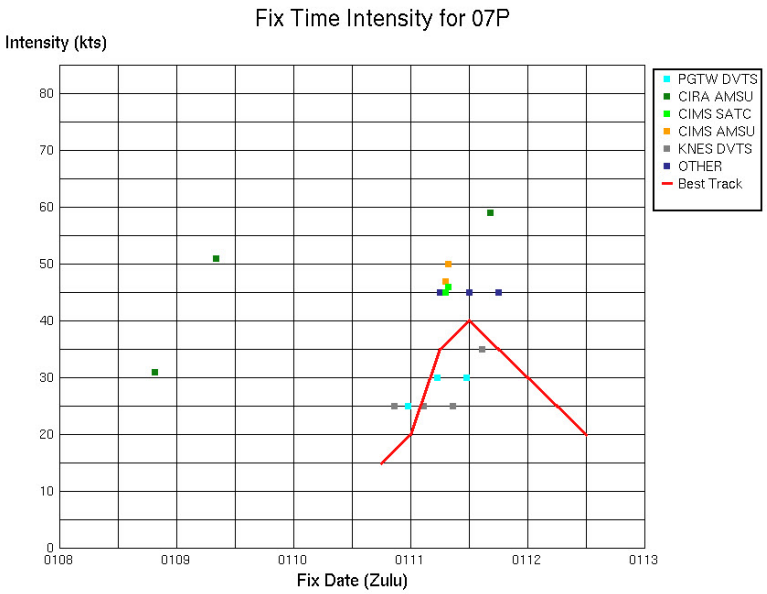




Tropical Cyclone 07P (Charlotte)

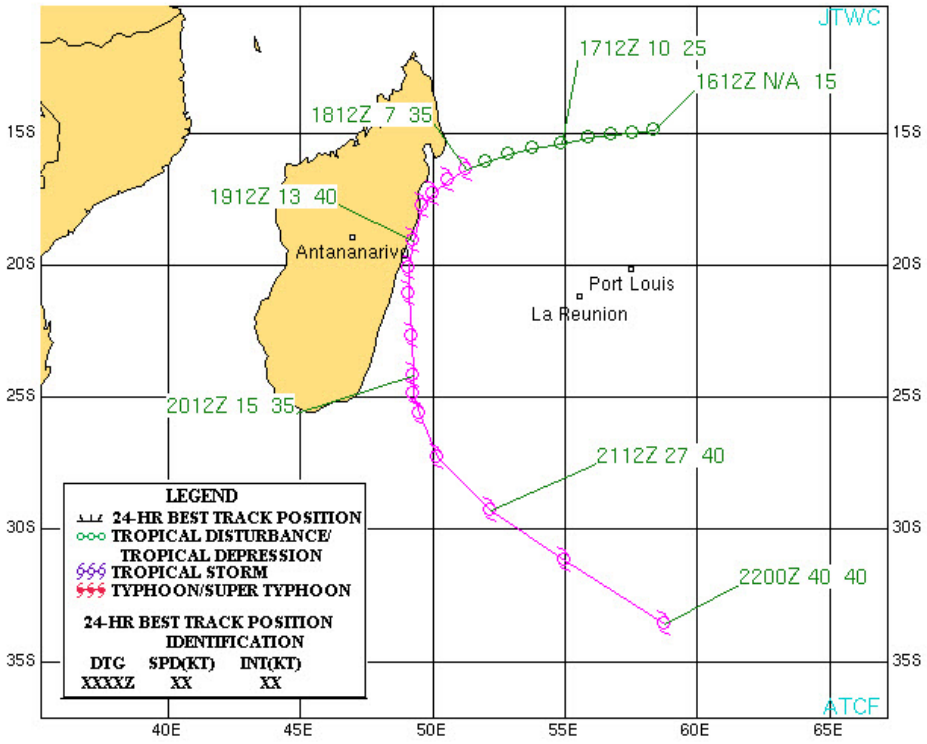
ISSUED POOR:	1500Z 9 Jan 2009
ISSUED FAIR:	N/A
FIRST TCFA:	0100Z 11 Jan 2009
FIRST WARNING:	0600Z 11 Jan 2009
LAST WARNING:	0600Z 11 Jan 2009
MAX INTENSITY:	40 Kts
NUMBER OF WARNINGS:	1

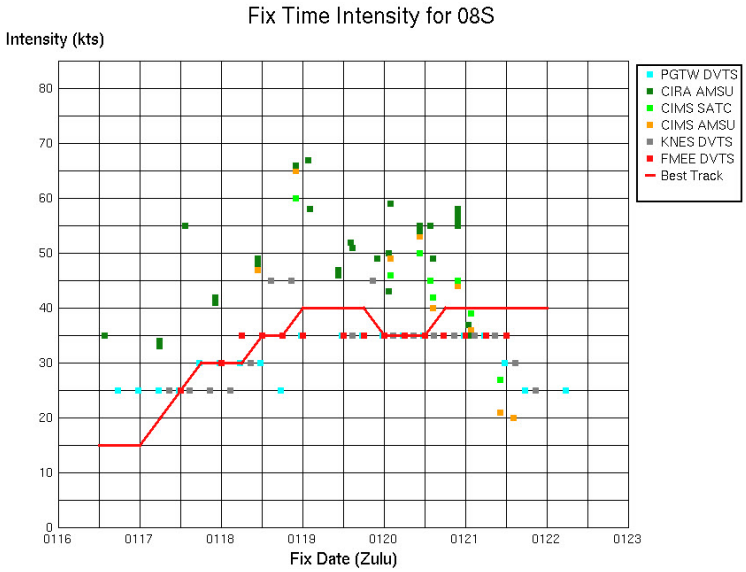




Tropical Cyclone 08S (Eric)

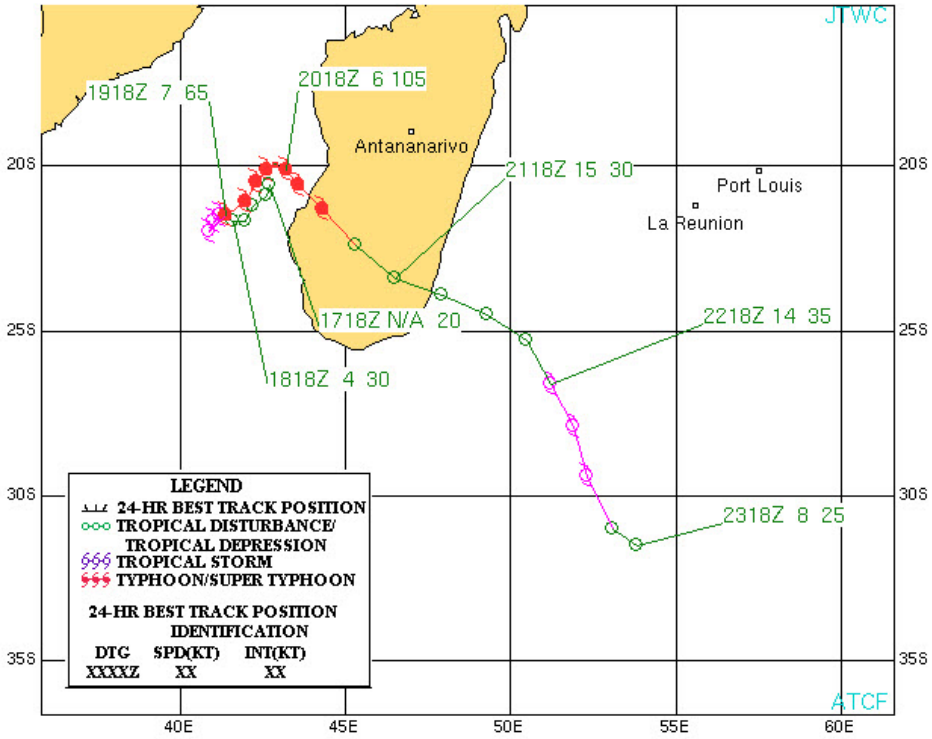
ISSUED POOR: 1800Z 16 Jan 2009
ISSUED FAIR: 1330Z 17 Jan 2009
FIRST TCFA: 1900Z 17 Jan 2009
FIRST WARNING: 1200Z 18 Jan 2009
LAST WARNING: 1200Z 20 Jan 2009
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 5

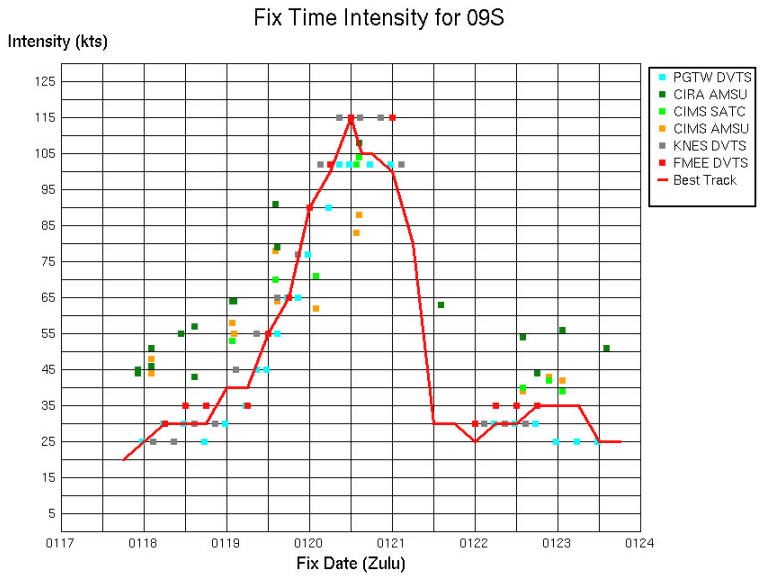




Tropical Cyclone 09S (Fanele)

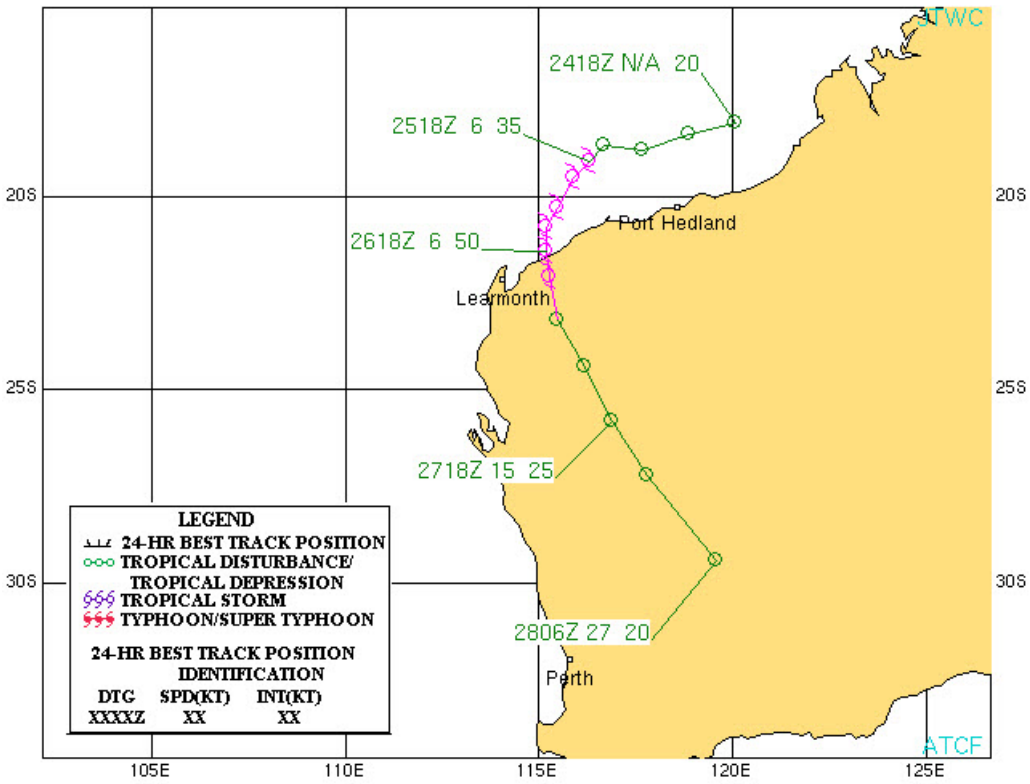
ISSUED POOR:	1930Z 17 Jan 2009
ISSUED FAIR:	N/A
FIRST TCFA:	0530Z 18 Jan 2009
FIRST WARNING:	0000Z 19 Jan 2009
LAST WARNING:	1800Z 22 Jan 2009
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	9

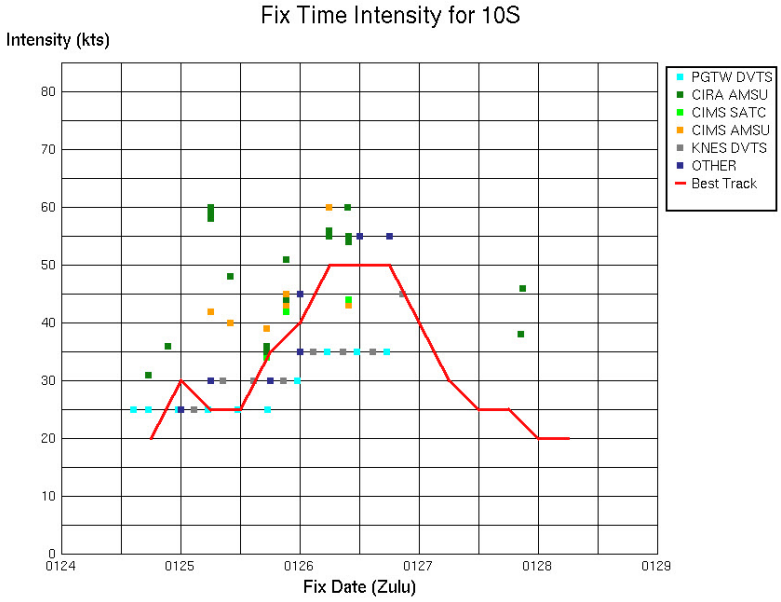




Tropical Cyclone 10S (Dominic)

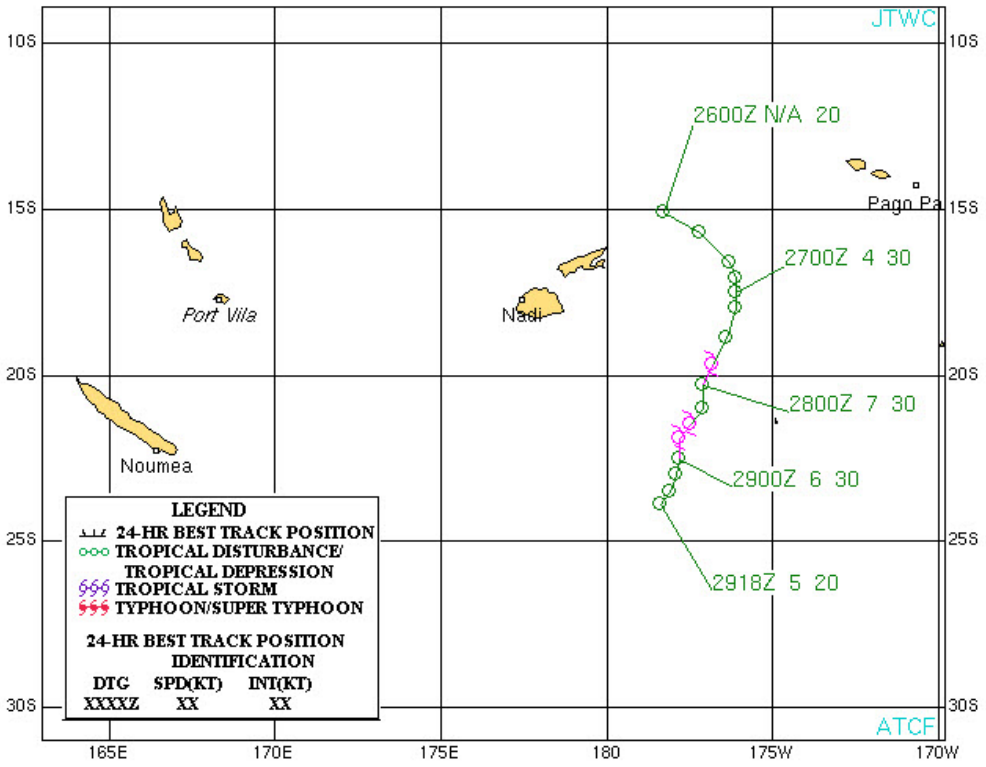
ISSUED POOR: 1800Z 24 Jan 2009
ISSUED FAIR: 0100Z 25 Jan 2009
FIRST TCFA: 0700Z 25 Jan 2009
FIRST WARNING: 1200Z 25 Jan 2009
LAST WARNING: 0000Z 27 Jan 2009
MAX INTENSITY: 50 Kts
NUMBER OF WARNINGS: 7

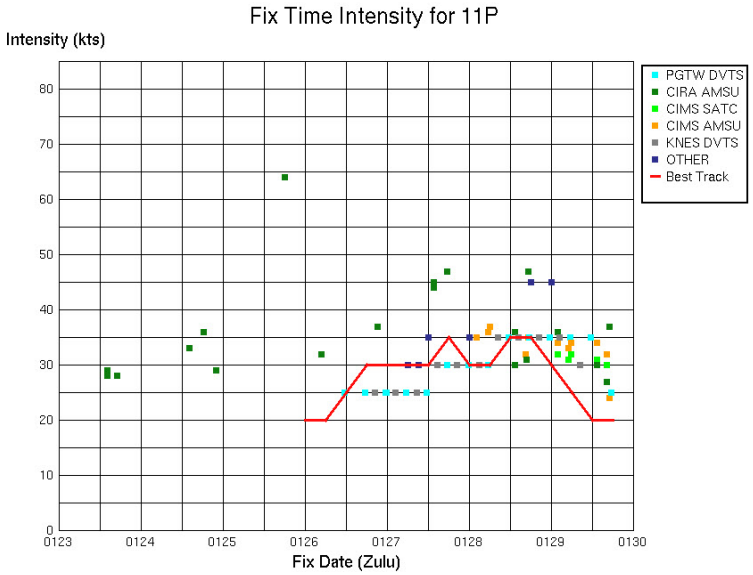




Tropical Cyclone 11P (Hettie)

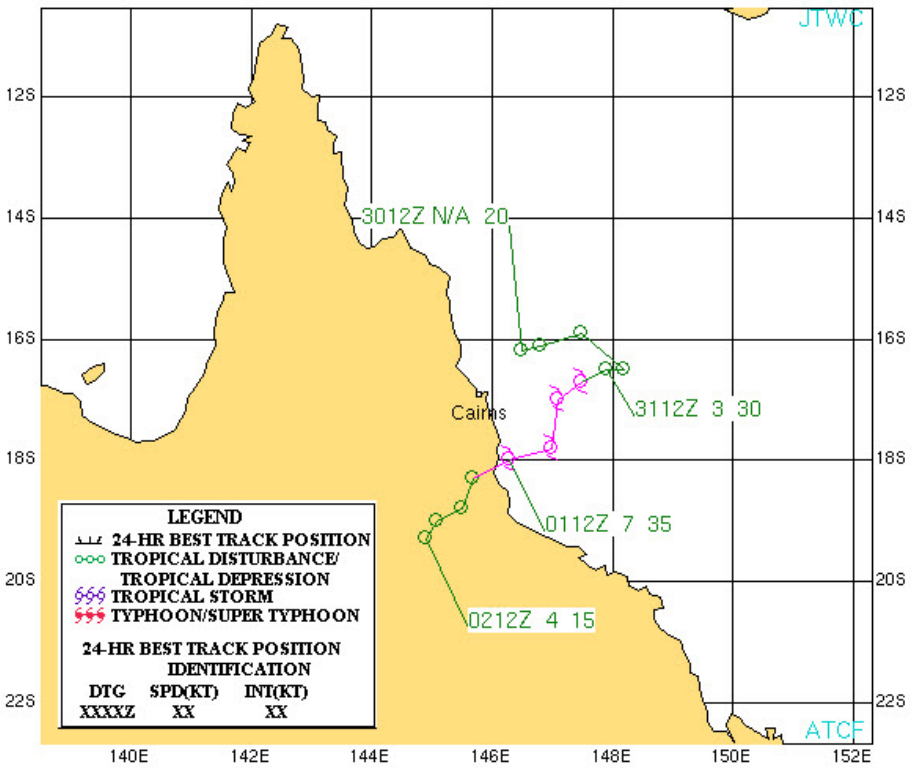
ISSUED POOR: 2230Z 23 Jan 2009
ISSUED FAIR: 1400Z 26 Jan 2009
FIRST TCFA: 0200Z 27 Jan 2009
FIRST WARNING: 1200Z 28 Jan 2009
LAST WARNING: 0000Z 29 Jan 2009
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 2

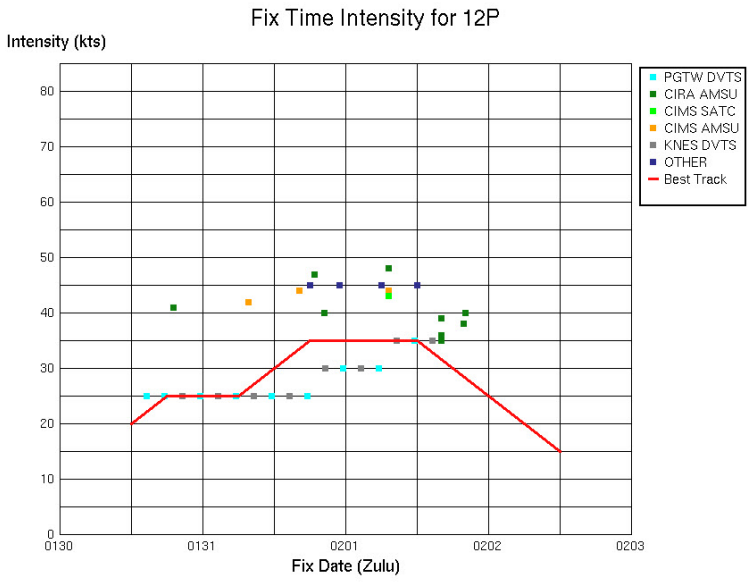




Tropical Cyclone 12P (Ellie)

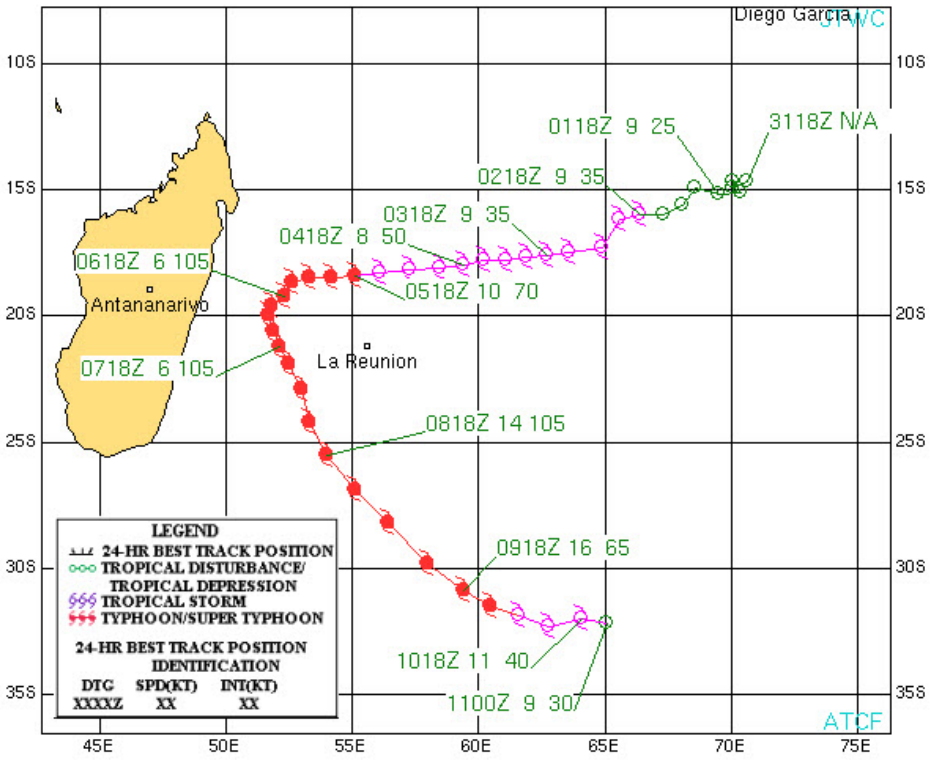
ISSUED POOR:	N/A
ISSUED FAIR:	2000Z 30 Jan 2009
FIRST TCFA:	N/A
FIRST WARNING:	1800Z 31 Jan 2009
LAST WARNING:	1800Z 1 Feb 2009
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	3

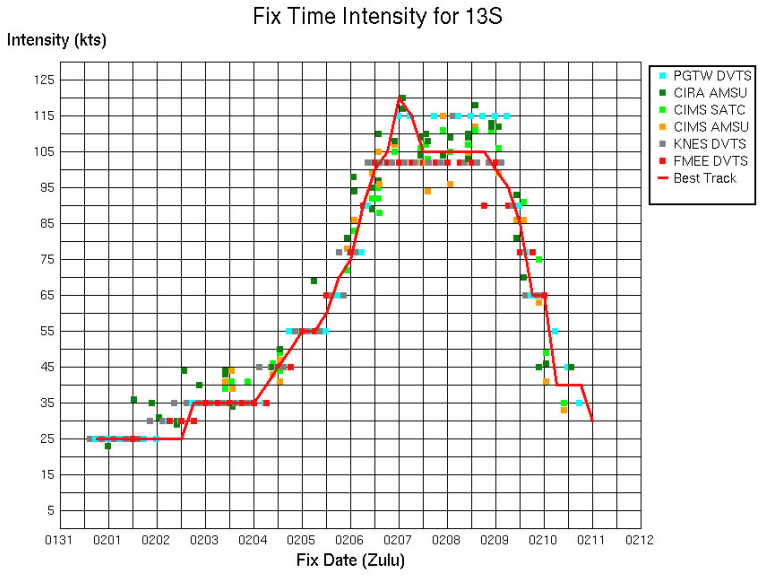




Tropical Cyclone 13S (Gael)

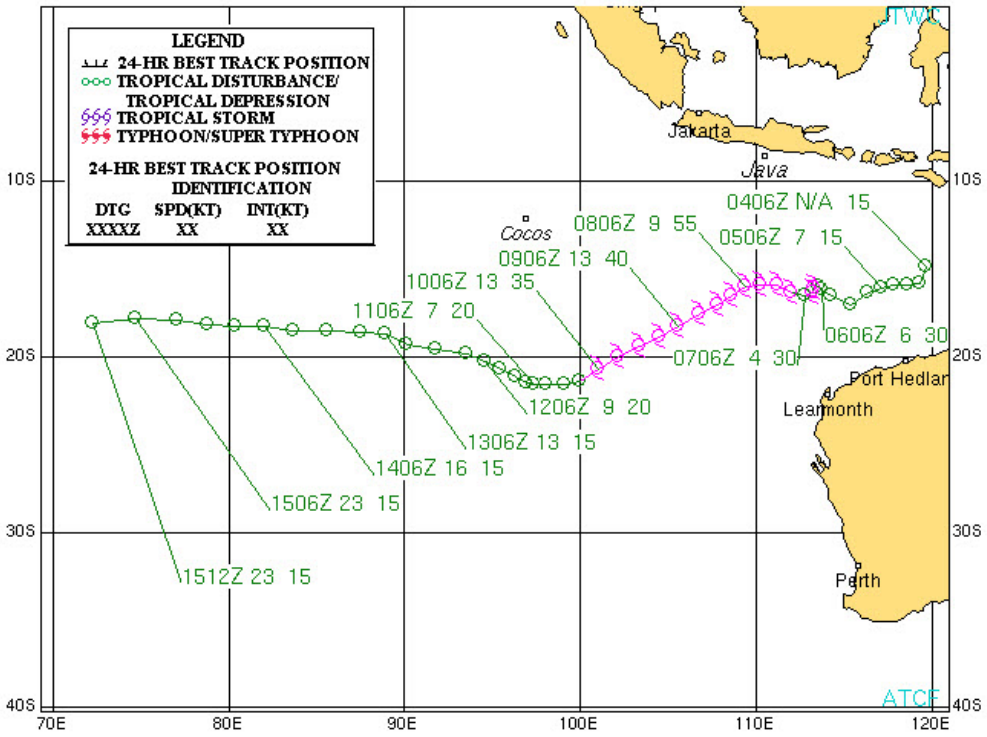
ISSUED POOR:	0100Z 1 Feb 2009
ISSUED FAIR:	0200Z 2 Feb 2009
FIRST TCFA:	0700Z 02 Feb 2009
FIRST WARNING:	1800Z 02 Feb 2009
LAST WARNING:	0000Z 10 Feb 2009
MAX INTENSITY:	120 Kts
NUMBER OF WARNINGS:	16

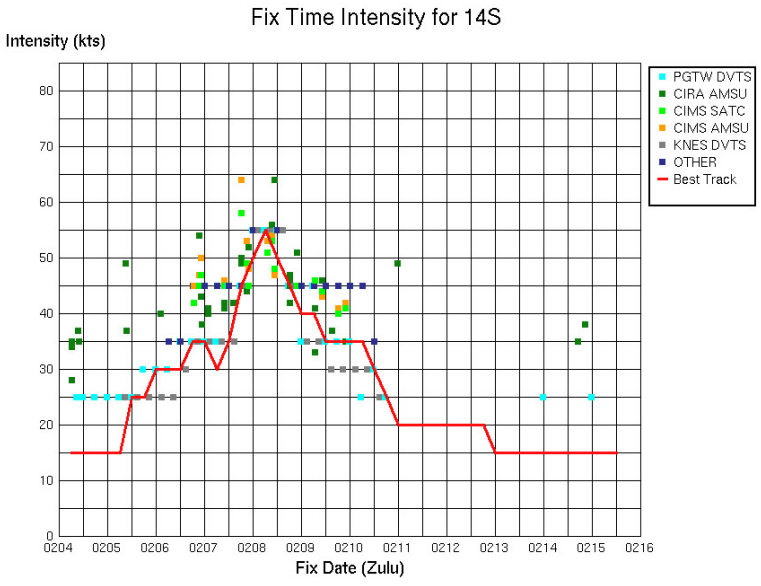




Tropical Cyclone 14P (Freddy)

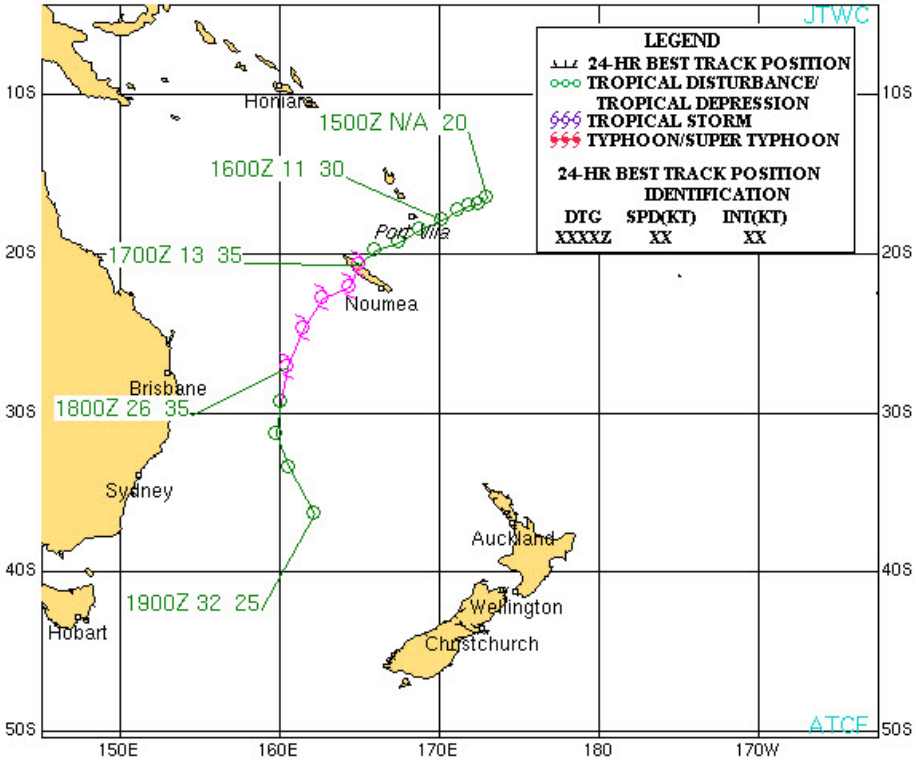
ISSUED POOR:	1800Z 3 Feb 2009
ISSUED FAIR:	1330Z 5 Feb 2009
FIRST TCFA:	0130Z 6 Feb 2009
FIRST WARNING:	1200Z 6 Feb 2009
LAST WARNING:	1800Z 9 Feb 2009
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	8

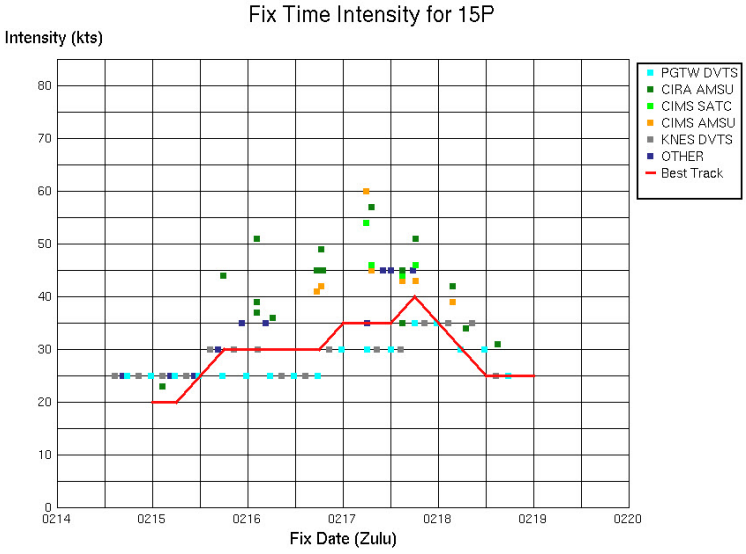




Tropical Cyclone 15P (Innis)

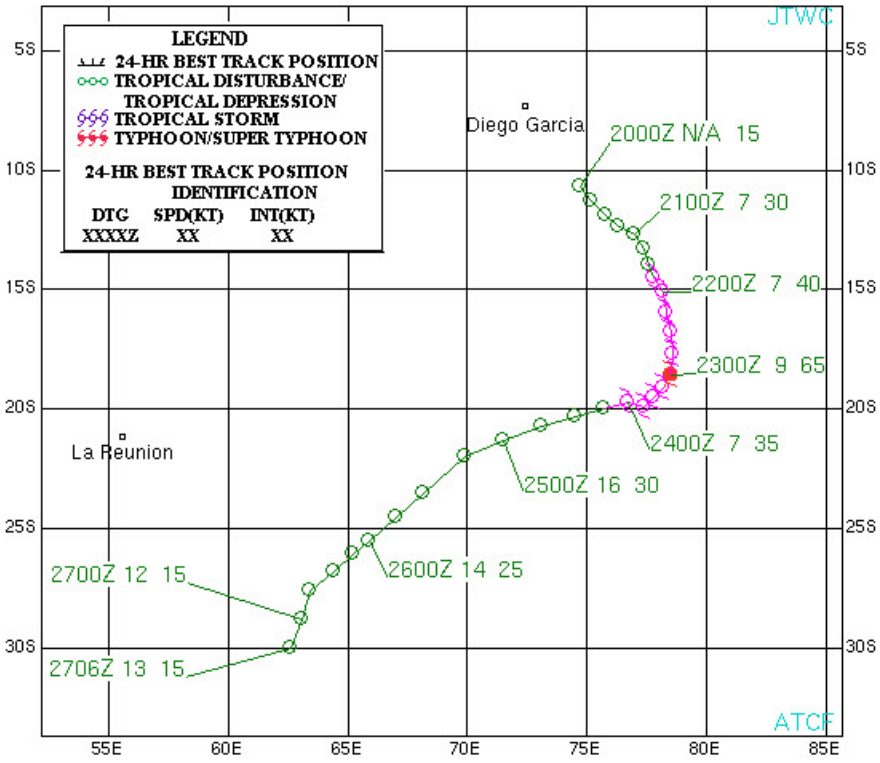
ISSUED POOR: 0600Z 15 Feb 2009
ISSUED FAIR: N/A
FIRST TCFA: 2100Z 15 Feb 2009
FIRST WARNING: 0000Z 17 Feb 2009
LAST WARNING: 0000Z 18 Feb 2009
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 3

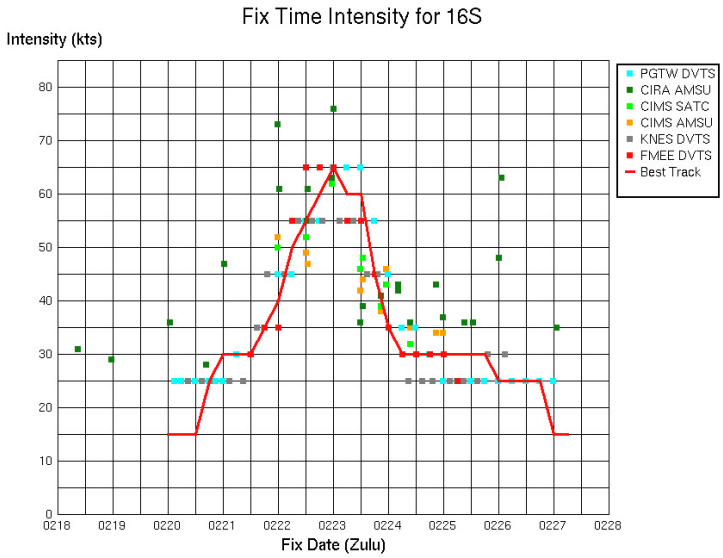




Tropical Cyclone 16S (Hina)

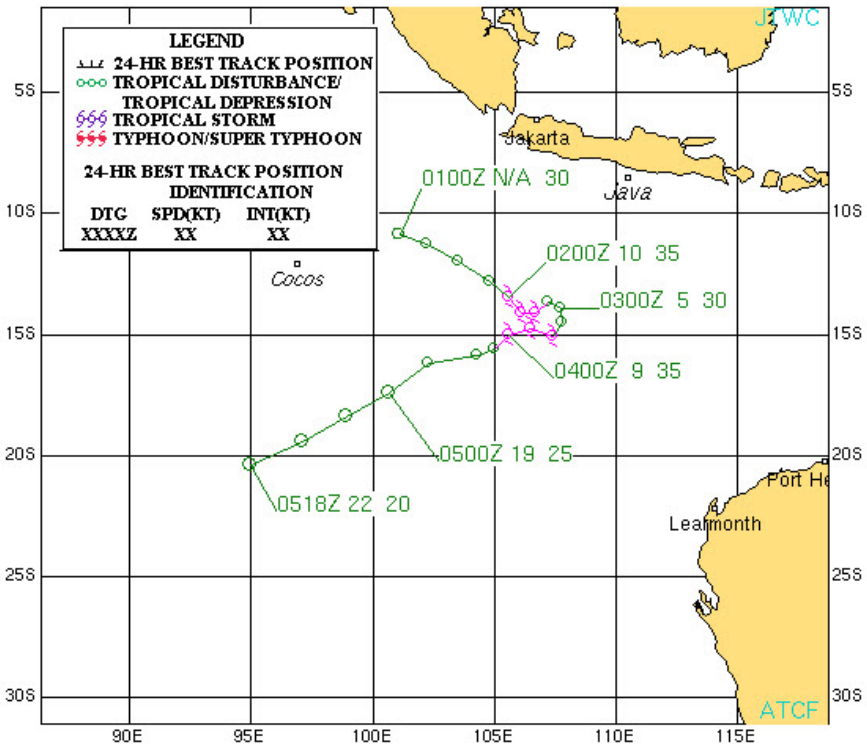
ISSUED POOR: 1200Z 20 Feb 2009
ISSUED FAIR: 2100Z 20 Feb 2009
FIRST TCFA: 0700Z 21 Feb 2009
FIRST WARNING: 1800Z 21 Feb 2009
LAST WARNING: 0000Z 24 Feb 2009
MAX INTENSITY: 65 Kts
NUMBER OF WARNINGS: 6

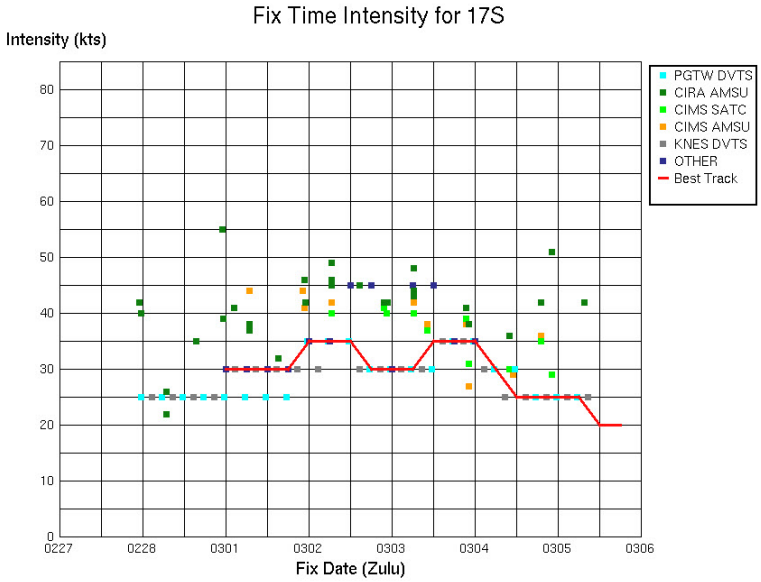




Tropical Cyclone 17P (Gabrielle)

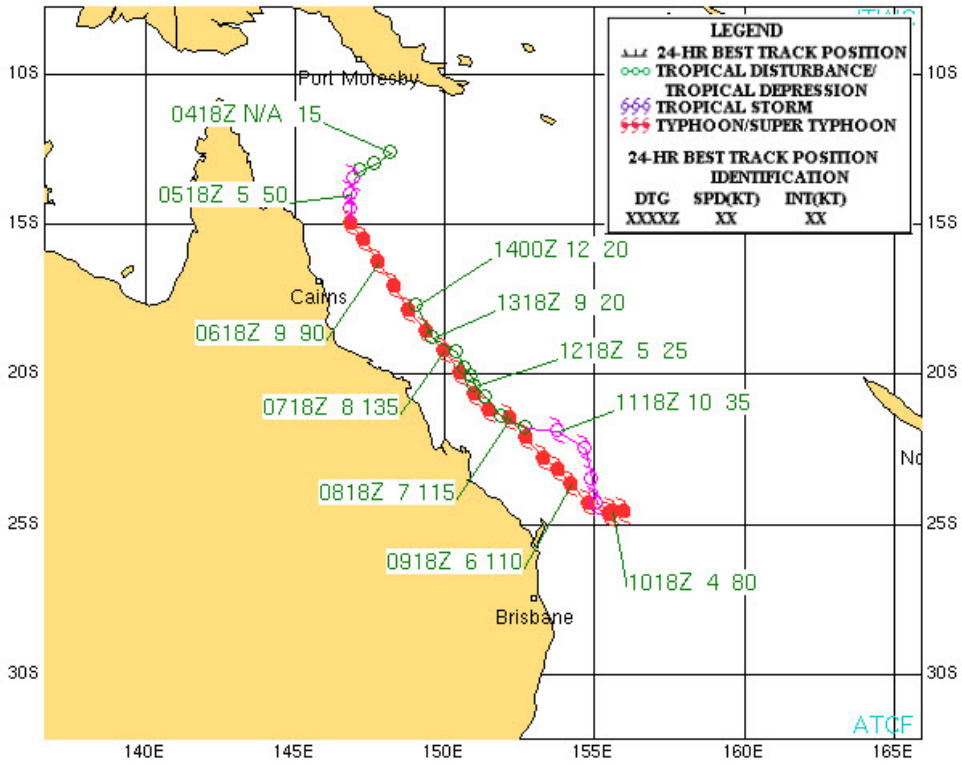
ISSUED POOR: 1800Z 28 Feb 2009
ISSUED FAIR: 0000Z 01 Mar 2009
FIRST TCFA: 1400Z 01 Mar 2009
FIRST WARNING: 0000Z 02 Mar 2009
LAST WARNING: 0600Z 04 Mar 2009
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 6

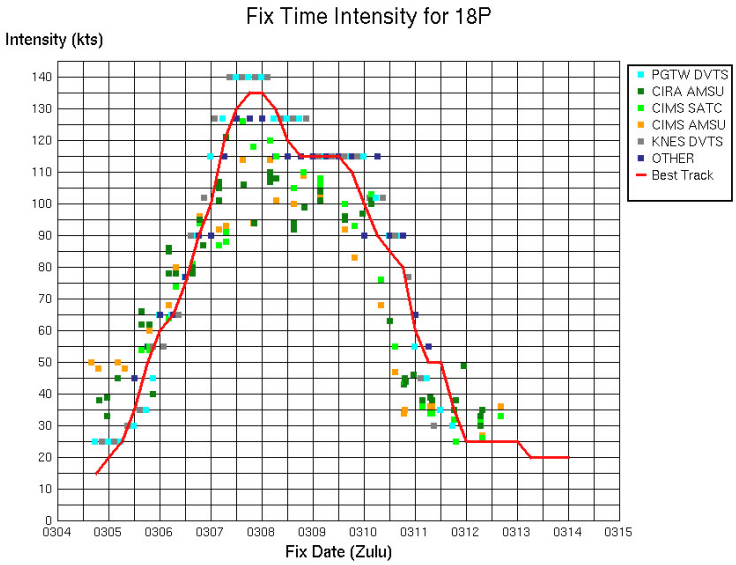




Tropical Cyclone 18P (Hamish)

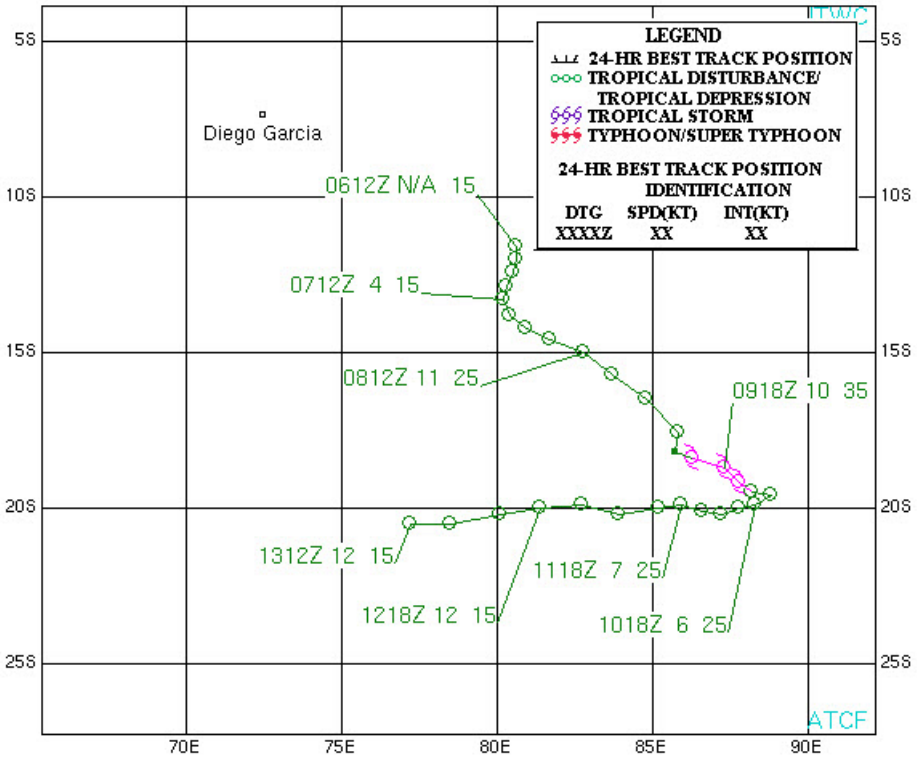
ISSUED POOR:	N/A
ISSUED FAIR:	2030Z 04 Mar 2009
FIRST TCFA:	0930Z 04 Mar 2009
FIRST WARNING:	1200Z 05 Mar 2009
LAST WARNING:	0000Z 12 Mar 2009
MAX INTENSITY:	135 Kts
NUMBER OF WARNINGS:	14

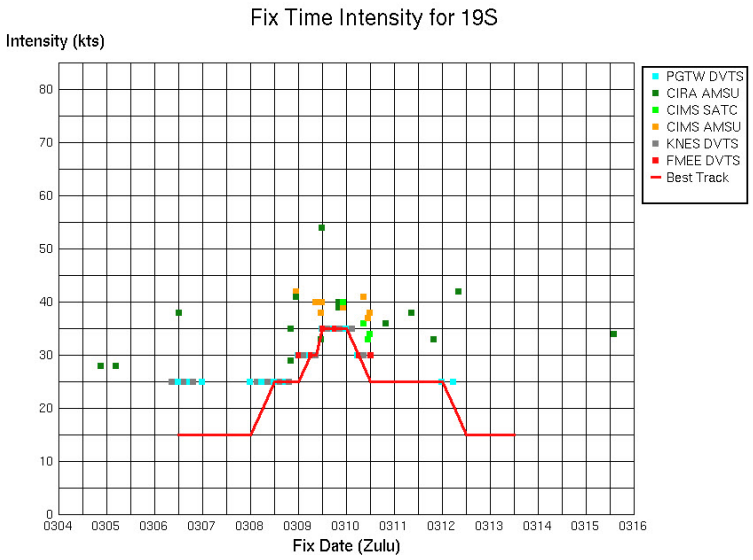




Tropical Cyclone 19S

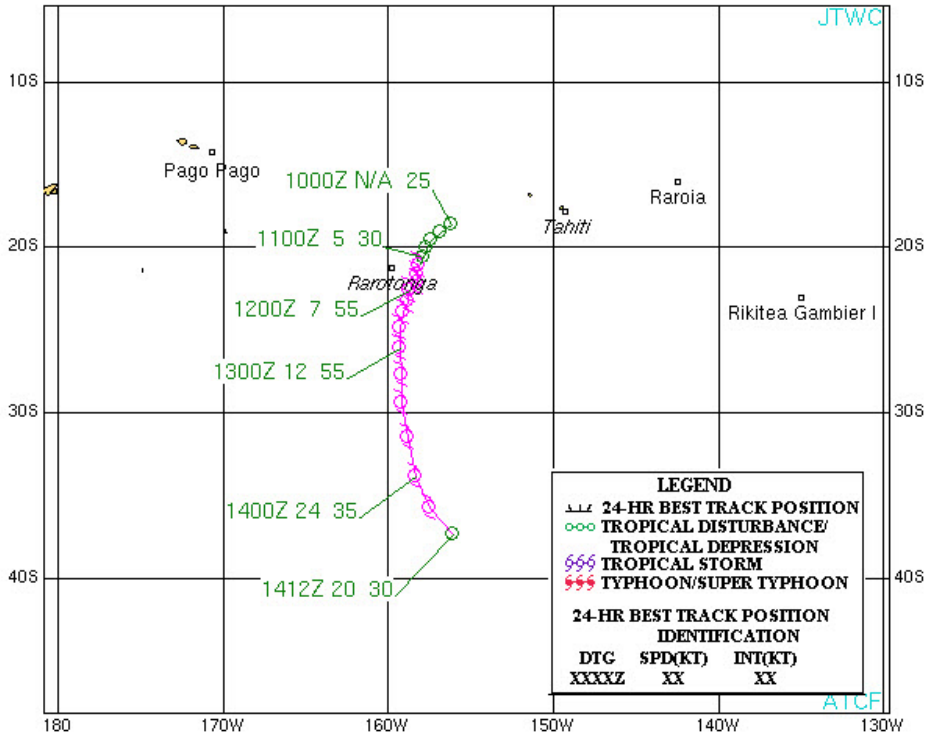
ISSUED POOR: 0630Z 08 Mar 2009
ISSUED FAIR: 1800Z 08 Mar 2009
FIRST TCFA: 0130Z 09 Mar 2009
FIRST WARNING: 1200Z 09 Mar 2009
LAST WARNING: 0000Z 10 Mar 2009
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 2

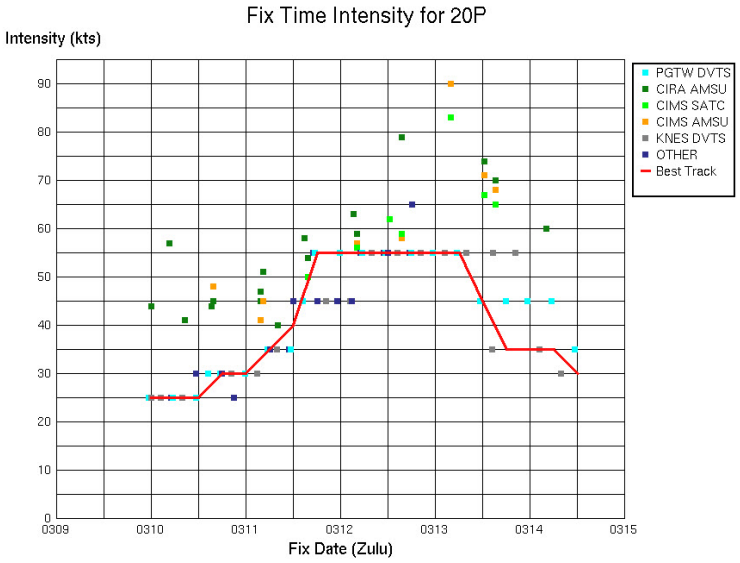




Tropical Cyclone 20P (Joni)

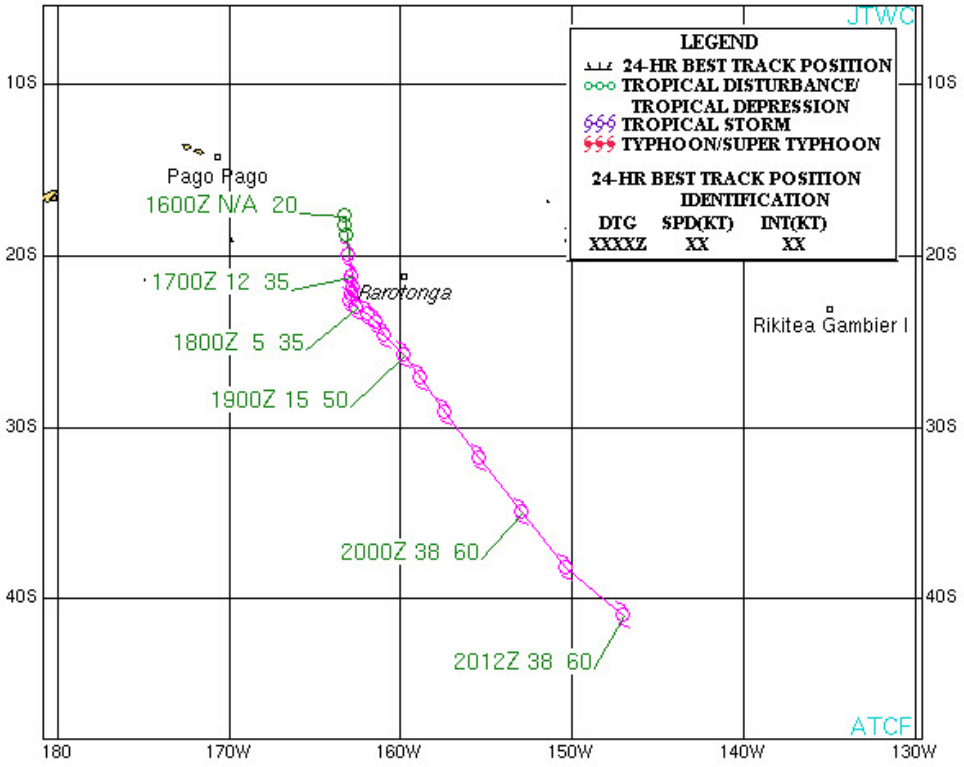
ISSUED POOR: N/A
ISSUED FAIR: N/A
FIRST TCFA: 0200Z 10 Mar 2009
FIRST WARNING: 0600Z 11 Mar 2009
LAST WARNING: 0600Z 13 Mar 2009
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 6

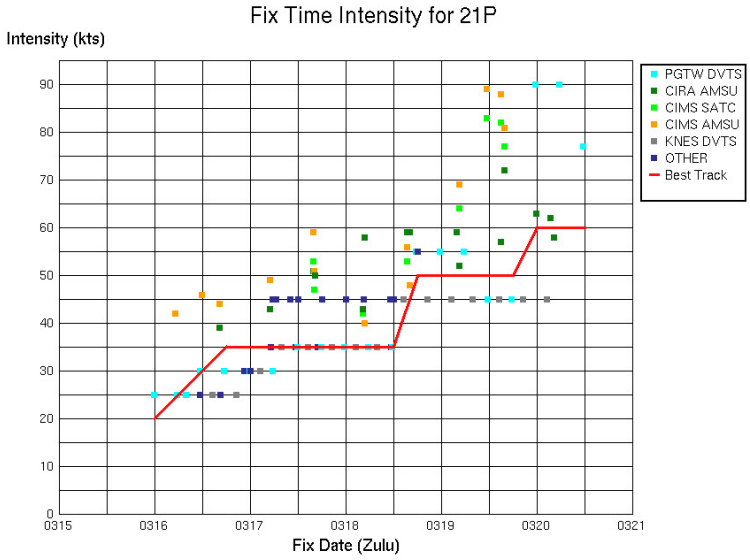




Tropical Cyclone 21P (Ken)

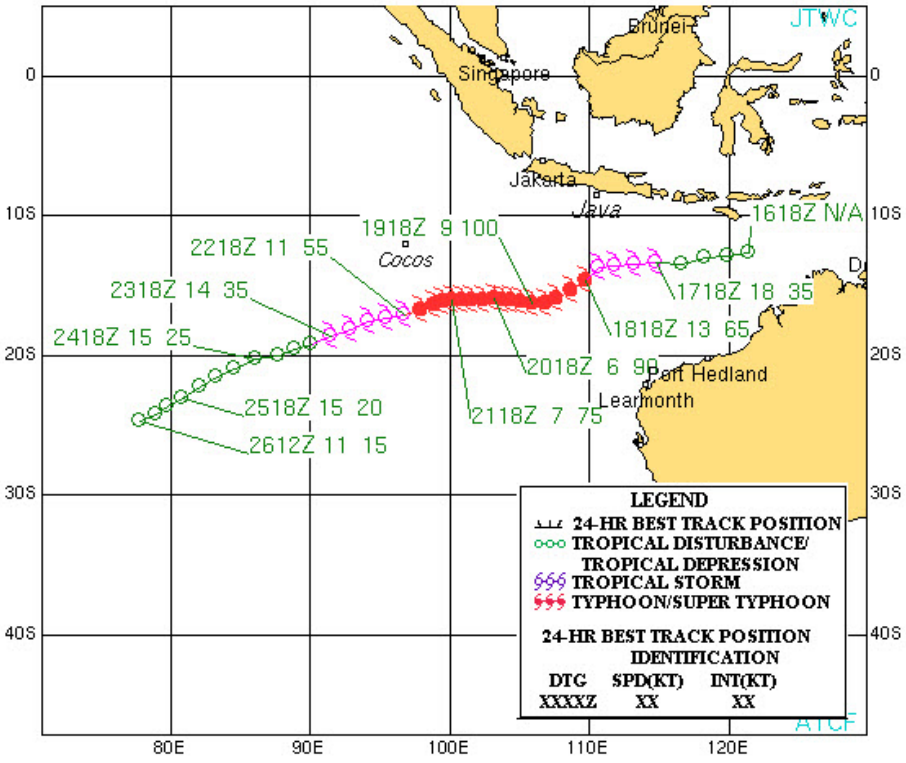
ISSUED POOR: N/A
ISSUED FAIR: 0800Z 16 Mar 2009
FIRST TCFA: 1300Z 16 Mar 2009
FIRST WARNING: 1200Z 17 Mar 2009
LAST WARNING: 0000Z 19 Mar 2009
MAX INTENSITY: 50 Kts
NUMBER OF WARNINGS: 4

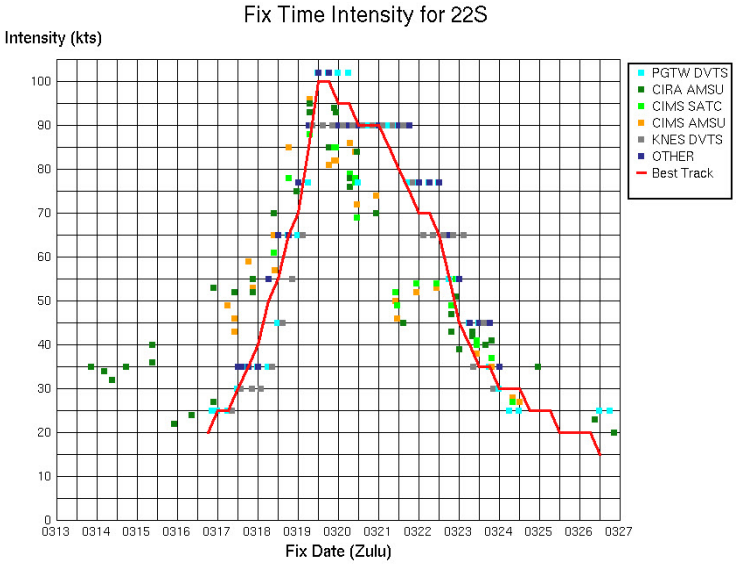




Tropical Cyclone 22S (Ilsa)

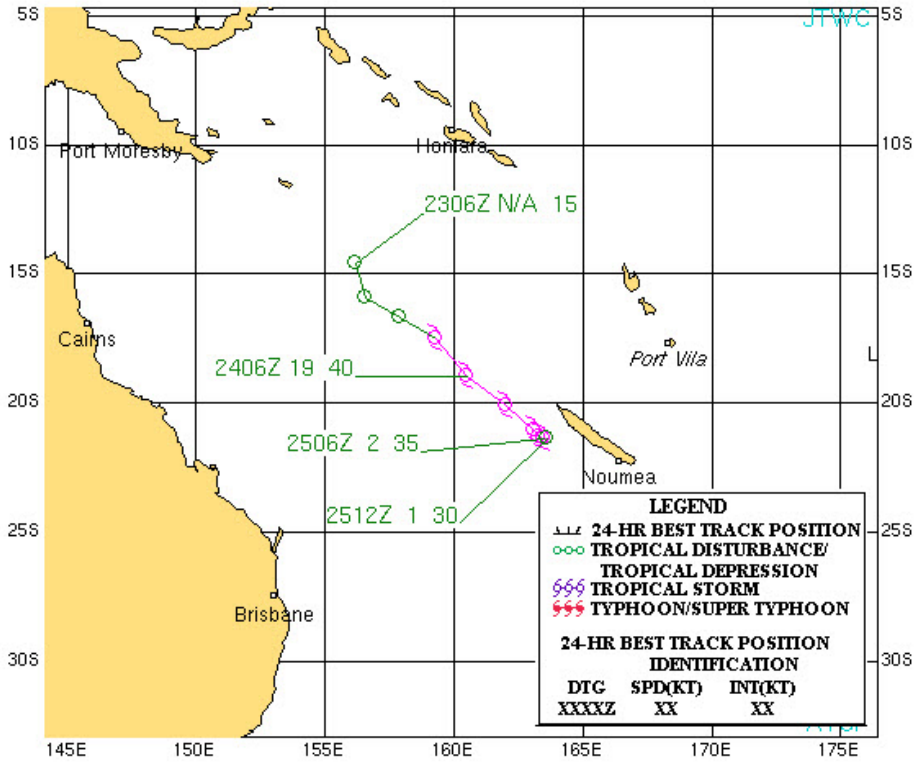
ISSUED POOR:	0000Z 17 Mar 2009
ISSUED FAIR:	1800Z 17 Mar 2009
FIRST TCFA:	2000Z 17 Mar 2009
FIRST WARNING:	1800Z 17 Mar 2009
LAST WARNING:	1800Z 23 Mar 2009
MAX INTENSITY:	100 Kts
NUMBER OF WARNINGS:	13

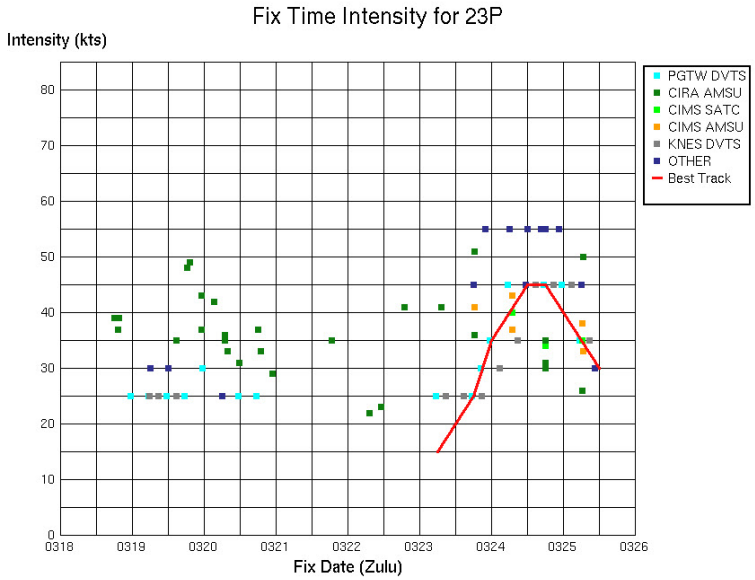




Tropical Cyclone 23P (Jasper)

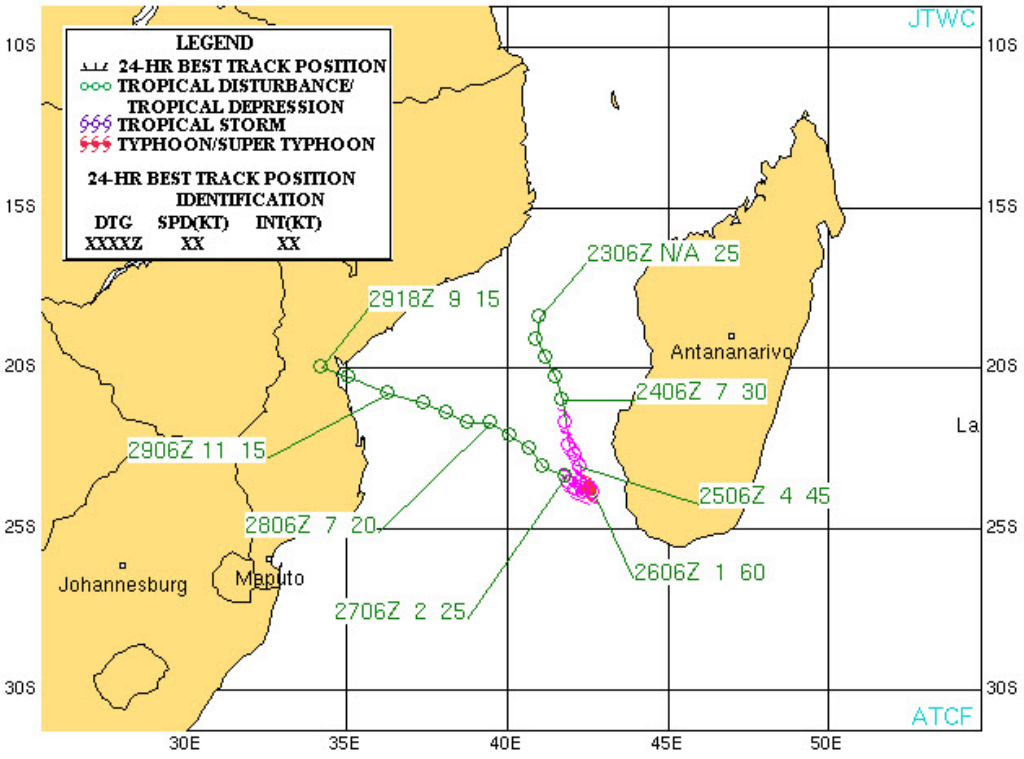
ISSUED POOR:	0600Z 23 Mar 2009
ISSUED FAIR:	N/A
FIRST TCFA:	2200Z 23 Mar 2009
FIRST WARNING:	0000Z 24 Mar 2009
LAST WARNING:	1200Z 25 Mar 2009
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	4

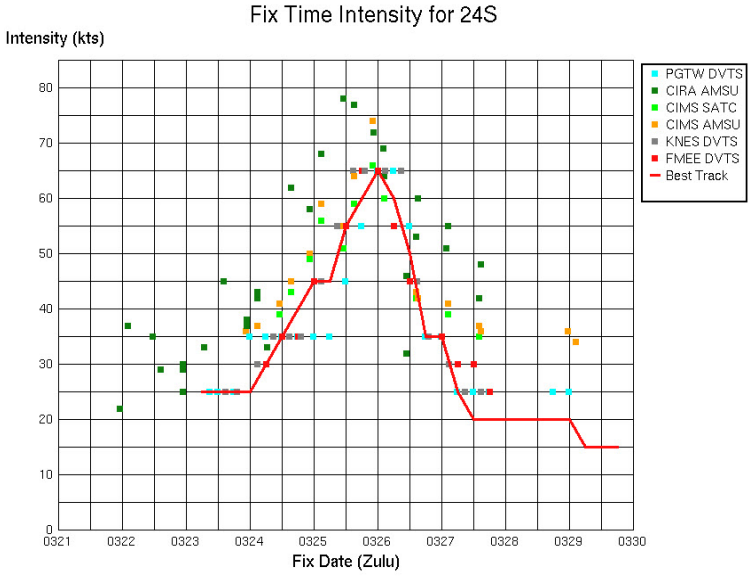




Tropical Cyclone 24S (Izilda)

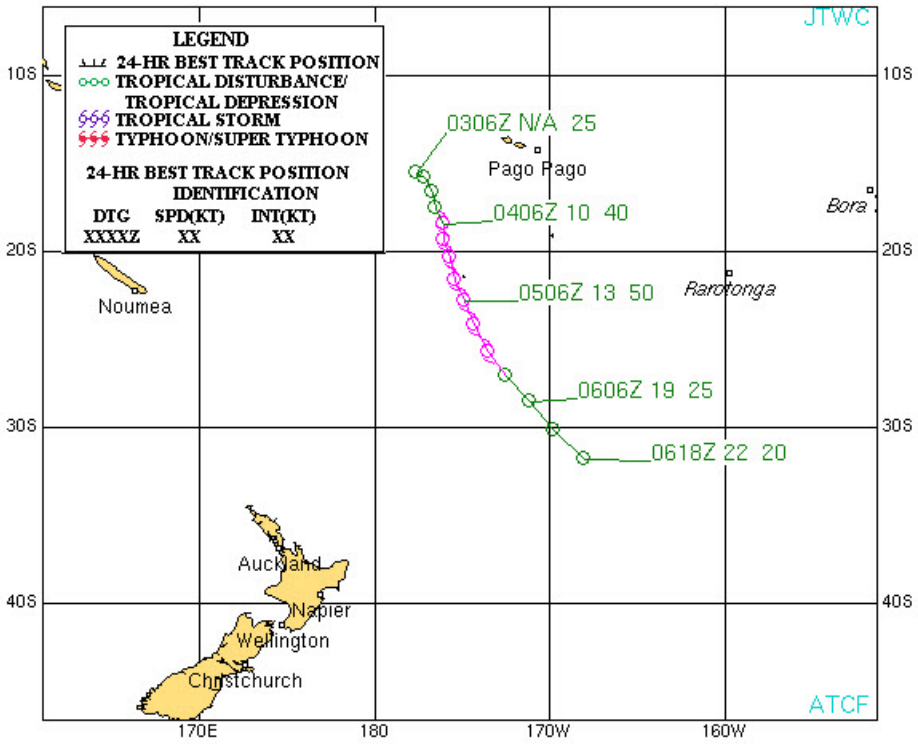
ISSUED POOR: 0300Z 22 Mar 2009
ISSUED FAIR: N/A
FIRST TCFA: 1100Z 23 Mar 2009
FIRST WARNING: 0600Z 24 Mar 2009
LAST WARNING: 1800Z 26 Mar 2009
MAX INTENSITY: 65 Kts
NUMBER OF WARNINGS: 7

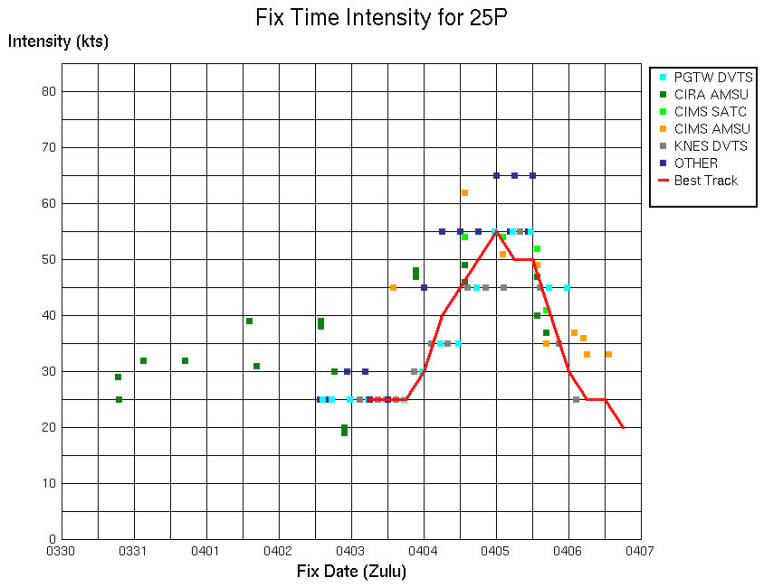




Tropical Cyclone 25P (Lin)

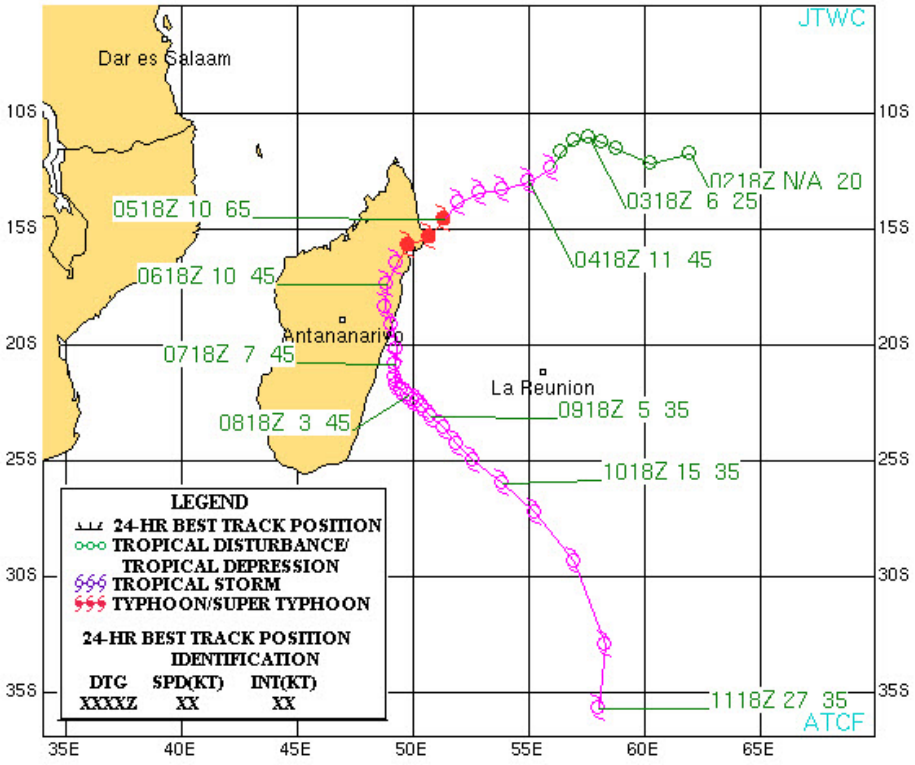
ISSUED POOR:	1600Z 02 Apr 2009
ISSUED FAIR:	2330Z 03 Apr 2009
FIRST TCFA:	N/A
FIRST WARNING:	0300Z 04 Apr 2009
LAST WARNING:	1200Z 05 Apr 2009
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	4

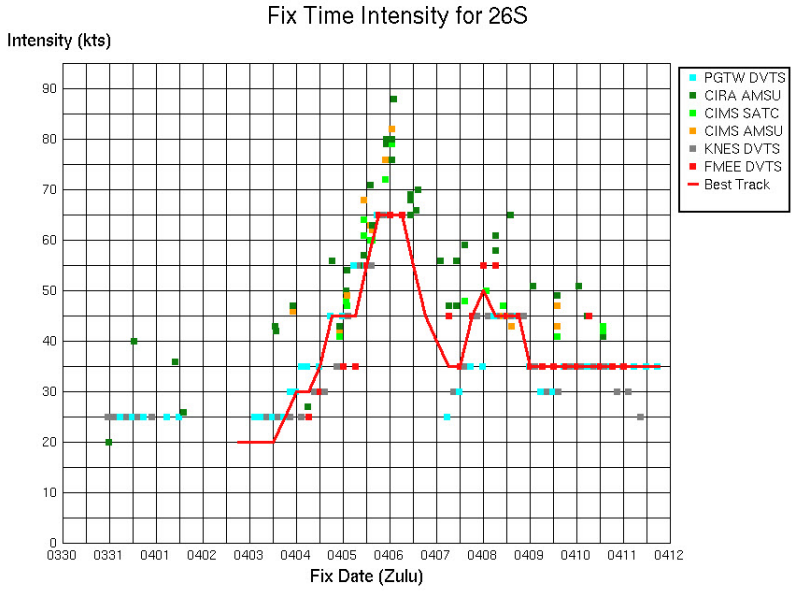




Tropical Cyclone 26S (Jade)

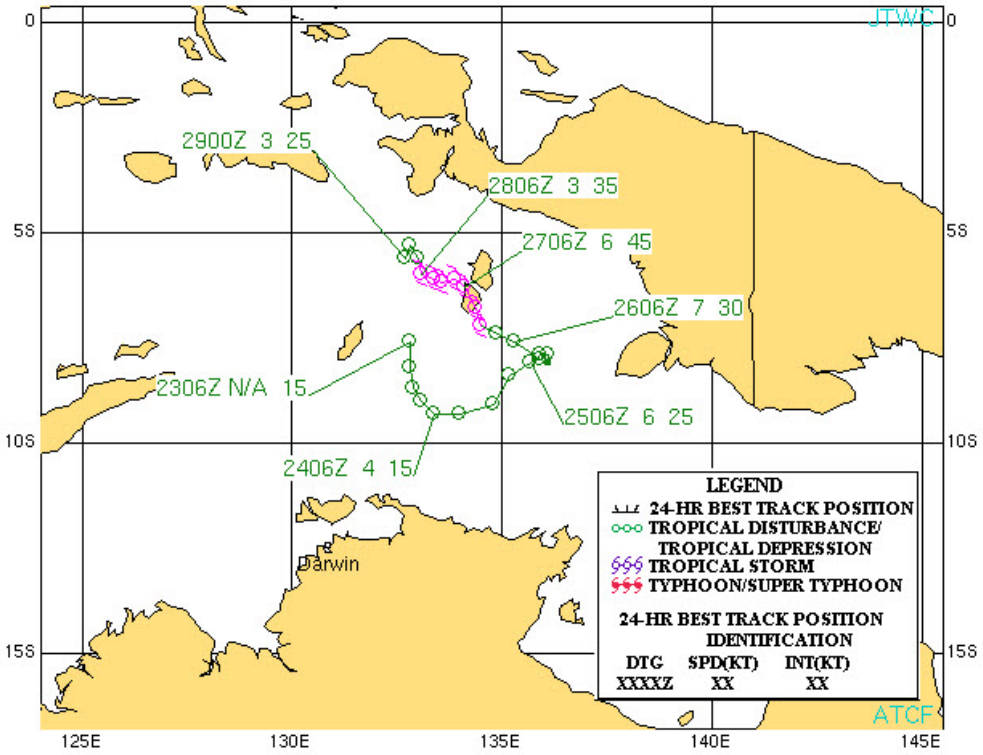
ISSUED POOR:	0730Z 31 Mar 2009
ISSUED FAIR:	2200Z 03 Apr 2009
FIRST TCFA:	0030Z 04 Apr 2009
FIRST WARNING:	0600Z 04 Apr 2009
LAST WARNING:	1800Z 10 Apr 2009
MAX INTENSITY:	65 Kts
NUMBER OF WARNINGS:	16

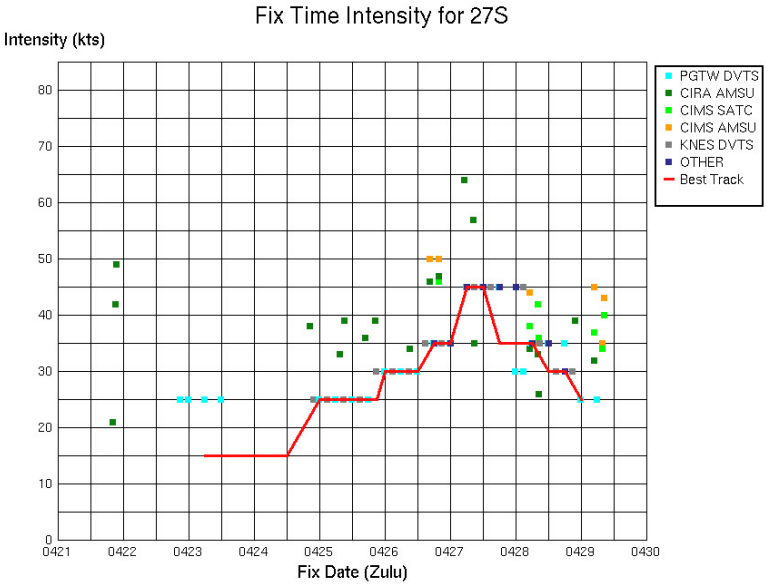




Tropical Cyclone 27S (Kirrily)

ISSUED POOR:	N/A
ISSUED FAIR:	1530Z 25 Apr 2009
FIRST TCFA:	0100Z 26 Apr 2009
FIRST WARNING:	1800Z 26 Apr 2009
LAST WARNING:	1800Z 28 Apr 2009
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	5





Chapter 4 Tropical Cyclone Fix Data

Section 1 Background

Weather satellite data continued to be the mainstay for the TC reconnaissance mission at the JTWC. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce nearly 11,300 position and intensity estimates. A total of 6,371 fixes were done using microwave imagery, amounting to over half of the total number of fixes. The USAF primary weather satellite direct readout system, Mark IVB, and the USN FMQ-17 continued to be invaluable tools in the TC reconnaissance mission. The following tables depict the fixes produced by our satellite analysts broken down by basin and storm numbers. Following the final numbered storm for each section is a depiction of the fixes for did not develop (DND) areas that were monitored and never reached warning criteria.

Section 2 Fix summary by basin

NORTHERN INDIAN OCEAN FIX SUMMARY FOR 2009				
Tropical Cyclone		**Visible / Infrared**	**Microwave**	**Total**
01B	Bijli	48	62	110
02B	Aila	41	53	94
03B		31	38	69
04A	Phyan	48	60	108
05B	Ward	62	40	102
DND'S		141	89	230
Totals		**371**	**342**	**713**
Percentage of Total		**52.03%**	**47.97%**	

WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 2009				
Tropical Cyclone		**Visible / Infrared**	**Microwave**	**Total**
01W	Kujira	61	111	172
02W	Chan-Hom	91	152	243
03W	Linfa	75	95	170
04W	Nangka	44	67	111
05W	Soudelor	37	32	69
06W		32	44	76
07W	Molave	52	71	123
08W	Goni	103	85	188
09W	Morakot	59	96	155
10W	Etau	68	101	169
11W	Vamco	97	180	277
12W	Krovanh	50	105	155
13W	Dujuan	81	123	204
14W	Mujigae	34	52	86
15W	Choi-Wan	71	130	201
16W	Koppu	38	53	91
17W	Ketsana	47	64	111
18W		49	34	83
19W	Parma	141	225	366
20W	Melor	83	116	199
21W	Nepartak	48	66	114
22W	Lupit	106	218	324
23W	Mirinae	80	130	210
24W		20	20	40
25W		30	45	75
26W	Nida	100	175	275
27W		37	28	65
28W		27	31	58
01C	Maka	72	101	173
02C		46	42	88
DND		572	316	888
Totals		**2451**	**3108**	**5559**
Percentage of Total		**44.09%**	**55.91%**	

SOUTH PACIFIC & SOUTH INDIAN OCEAN FIX SUMMARY FOR 2009				
Tropical Cyclone		**Visible / Infrared**	**Microwave**	**Total**
01S	Asma	41	76	117
02S	Anika	37	45	82
03S	Bernard	102	166	268
04S	Cinda	41	40	81
05S	Billy	178	273	451
06S	Dongo	154	134	288

07P	Charlotte	21	25	46
08S	Eric	44	73	117
09S	Fanele	47	103	150
10S	Dominic	29	47	76
11P	Hettie	30	46	76
12P	Ellie	28	43	71
13S	Gael	83	142	225
14S	Freddy	90	175	265
15P	Innis	36	65	101
16S	Hina	59	105	164
17S	Gabrielle	47	81	128
18P	Hamish	75	116	191
19S		78	78	156
20P	Joni	37	73	110
21P	Ken	37	79	116
22S	Ilsa	82	141	223
23P	Jasper	32	40	72
24S	Izilda	52	84	136
25P	Lin	32	53	85
26S	Jade	79	116	195
27S	Kirrily	55	82	137
DND'S		470	420	890
Totals		**2096**	**2921**	**5017**
Percentage of Total		**41.78%**	**58.22%**	

Chapter 5 Techniques Development Project Summary

Section 1 Background

The JTWC Techniques Development (Tech Dev) team's mission is to facilitate operations and improve TC analyses and forecasts through scientific study, technology transition, techniques development, information technology exploitation, data evaluation, and process improvement. This section provides a brief overview of scientific and operational resource development projects initiated by the JTWC Tech Dev team during 2009 and continuing into 2010, as well as a look ahead to future projects.

Section 2 Scientific development

Classifying TC genesis potential: JTWC Tech Dev is developing a standardized process to transition classification of tropical cyclone genesis potential of poor, fair, and good to genesis probability of low, medium, and high based on a set of primary development indicators or combinations of secondary indicators. The goal of this project is to provide objective development criteria for operational application by the 2011 western North Pacific typhoon season.

Incorporating automated intensity estimates: This project evaluates performance of automated intensity estimates provide by various agencies in the JTWC AOR and provides recommendations for operational application of these data. Evaluation will be based on documented performance and biases relative to historical subjective Dvorak, in-situ, and final best track intensity estimates.

Applying ensemble model forecast data: Given recent improvements in ensemble modeling systems and the resultant potential to more accurately quantify TC track and intensity forecast uncertainty based on these data, JTWC forecasters are increasingly applying ensemble model output during the forecast process. JTWC Tech Dev is laying the framework to evaluate performance of TC ensemble model forecasts for tropical cyclones having occurred within the JTWC AOR over the past several seasons. It is a JTWC goal to make near real-time ensemble model output more accessible in the Automated Tropical Cyclone Forecast (ATCF) system.

Predicting rapid intensification (RI): JTWC Tech Dev is evaluating recently documented methods to interrogate statistical intensity guidance and microwave satellite imagery and apply these data to the RI prediction problem. Our goal is to develop a repeatable process to improve both qualitative and quantitative prediction of RI at 12-36 hour lead times.

Improving extratropical transition forecasts: Predicting the timing of extratropical transition and associated changes in track direction, track speed, and storm structure present significant challenges, particularly for long lead (3 to 5 day) forecasts. JTWC Tech Dev is developing a methodology that will help the forecaster to more efficiently interpret synoptic analyses and numerical model forecast indicators to improve the extratropical forecast.

Anticipating TUTT cell impacts on TC motion: Dissertation research published by Maj Jason Patla (PhD) in 2008 documented several case studies of TUTT cell influences on tropical cyclone motion. Maj Patla's work suggests that TUTT cells with sufficient vorticity, vertical depth, and proximity to nearby TCs may significantly impact TC track and recommends application of an observation-based methodology to forecast the likelihood of TC track deviation due to anticipated TUTT cell interaction. JTWC Tech Dev is testing this methodology and developing guidelines for its operational application at JTWC.

Examining numerical model singular vector output: Understanding current model singular vector sensitivities can help the forecaster identify synoptic features that will impact future tropical cyclone motion. Additionally, the impact of singular vector sensitivities on numerical model forecasts can be visualized through inspection of ensemble model output. JTWC Tech Dev is finding ways to effectively incorporate these considerations into the forecast process.

Section 3 Operational resource development

Identification of numerical model forecast outliers: It is imperative that the JTWC forecaster recognizes numerical model "outliers" in real-time while simultaneously applying sound meteorological reasoning to the forecast in order to avoid large track forecast errors. JTWC Tech Dev is documenting cases of large numerical model and JTWC forecast outliers by examining individual storm statistics, visualizing model forecast tracks, and conducting regular storm reviews. These studies will allow us to build upon existing operational guidelines for recognizing numerical model forecast errors and minimizing their negative impact on subjective forecasts.

Google Earth Meteorological INformation Interface (GEMINI): GEMINI is a scalable meteorological data display platform for tropical cyclone analysis and forecasting using the Google Earth software application. The objective of GEMINI is to improve speed and ease of weather data retrieval and to enhance multisource data comparison. JTWC Tech Dev has developed and incorporated numerous data overlays into GEMINI, to include ship and buoy observations, skew-t data, radar imagery, geostationary and microwave satellite data, as well as JTWC TC best tracks and forecast tracks, and DoD asset information. Future versions of GEMINI will further incorporate satellite fixes, objective aids, model data, model ensemble tracks, and more.

Section 4 Future projects

In addition to the topics discussed above, JTWC Tech Dev is interested in pursuing further work in the following areas during 2010:

- Optimizing the operational model consensus through closer evaluation of individual numerical model performance and other methods
- Deriving track probability data from ensemble TC track forecasts
- Improving the ATCF objective best track technique through objective analysis of position, intensity, and wind radii fix performance
- Determining the impact of TC bogus parameters on bogused numerical models and minimizing the negative impacts of errant forecaster bogus inputs on model forecast performance
- Instituting a subject matter expert (SME) program to improve analysis and forecast processes and enhance forecaster and satellite analyst training
- Evaluation of research that predicts tropical cyclone genesis from geostationary satellite imagery

Chapter 6 Summary of Forecast Verification

Verification of warning position and intensities at 24-, 48-, and 72-hour forecast periods are made against the final best track. The (scalar) track forecast, along-track and cross track errors (illustrated in Figure 6-1) were calculated for each verifying JTWC forecast. These data are included in this chapter. This section summarizes verification data for the 2009 season, and contrasts it with annual verification statistics from previous years.

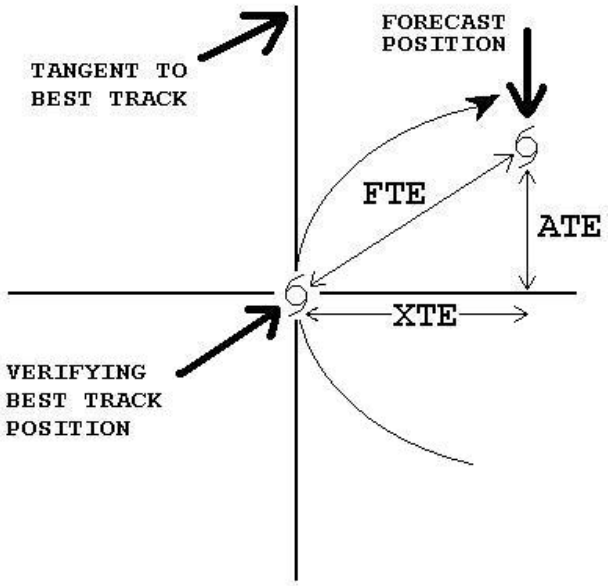


Figure 6-1. Definition of cross-track error (XTE), along track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of track) and the ATE is positive (ahead of the best track). Adapted from Tsui and Miller, 1988.

TABLE 6-1

MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC

TROPICAL CYCLONES FROM 1959 - 2009

	24-Hour					48-Hour					72-Hour				
Year (Notes)	Cases (1)	TY (2)	TC (4)	Cross Track (3)	Along Track (3)	Cases (1)	TY (2)	TC (4)	Cross Track (3)	Along Track (3)	Cases (1)	TY (2)	TC (4)	Cross Track (3)	Along Track (3)
1959		117					267								
1960		177					354								
1961		136					274								
1962		144					287					476			
1963		127					246					374			
1964		133					284					429			
1965		151					303					418			
1966		136					280					432			
1967		125					276					414			
1968		105					229					337			
1969		111					237					349			
1970		98	104				181	190				272	279		
1971		99	111	64			203	212	118			308	317	177	
1972		116	117	72			245	245	146			382	381	210	
1973		102	108	74			193	197	134			245	253	162	
1974		114	120	78			218	226	157			256	348	245	
1975		129	138	84			279	288	181			442	450	290	
1976		117	117	71			232	230	132			336	338	202	
1977		140	148	83			266	283	157			290	407	228	
1978		120	127	71	87		241	271	151	194		459	410	218	296
1979		113	124	76	81		219	226	138	146		319	316	182	214
1980		116	126	76	86		221	243	147	165		362	389	230	266
1981		117	124	77	80		215	221	131	146		342	334	219	206
1982		114	113	70	74		229	238	142	162		337	342	211	223
1983		110	117	73	76		247	260	164	169		384	407	263	259
1984		110	117	64	84		228	232	131	163		361	363	216	238
1985		112	117	68	80		228	231	138	153		355	367	227	230
1986		117	126	70	85		261	261	151	183		403	394	227	276
1987		101	107	64	71		211	204	127	134		318	303	186	198
1988	353	107	114	58	85	255	222	216	103	170	183	327	315	159	244
1989	585	107	120	69	83	458	214	231	127	162	343	325	350	177	265
1990	551	98	103	60	72	453	191	203	110	148	334	299	310	168	225
1991	673	93	96	53	69	570	187	185	97	137	467	298	287	146	229
1992	890	97	107	59	77	739	194	205	116	143	610	295	305	172	210
1993	744	102	112	63	79	596	205	212	117	151	469	320	321	173	226
1994	920	96	105	56	76	762	172	186	105	131	623	244	258	152	176
1995	521	105	123	67	89	409	200	215	117	159	315	311	325	167	240
1996	868	85	105	56	76	707	157	178	89	134	604	252	272	137	203
1997	905	86	93	55	76	783	159	164	87	134	665	251	245	120	202
1998	354	127	124	58	98	257	263	239	127	178	189	392	370	201	274
1999	433	88	106	59	74	300	150	176	102	119	191	225	234	139	155
2000	605	75	81	45	57	467	136	142	80	98	363	205	209	118	144
2001	627	66	73	42	49	512	114	122	75	78	395	169	180	110	120

2002	657	50	66	37	47	535	94	116	67	79	421	144	166	88	120
2003	602	59	73	41	52	495	119	128	68	94	397	186	186	89	147
2004	766	52	70	41	48	646	94	122	69	84	537	180	173	95	121
2005	507	41	61	38	38	407	81	102	59	72	316	138	156	76	120
2006	512	47	62	39	40	405	85	104	61	73	327	133	151	77	112
2007	343	45	61	24	42	260	72	100	58	69	189	89	148	83	102
2008	354	45	66	38	46	261	104	120	75	78	192	201	198	110	140
2009	498	46	66	35	47	395	102	123	65	90	303	179	183	102	130
Averages (1978-2009)	603	89	100	56	70	485	175	187	106	131	383	275	280	157	197

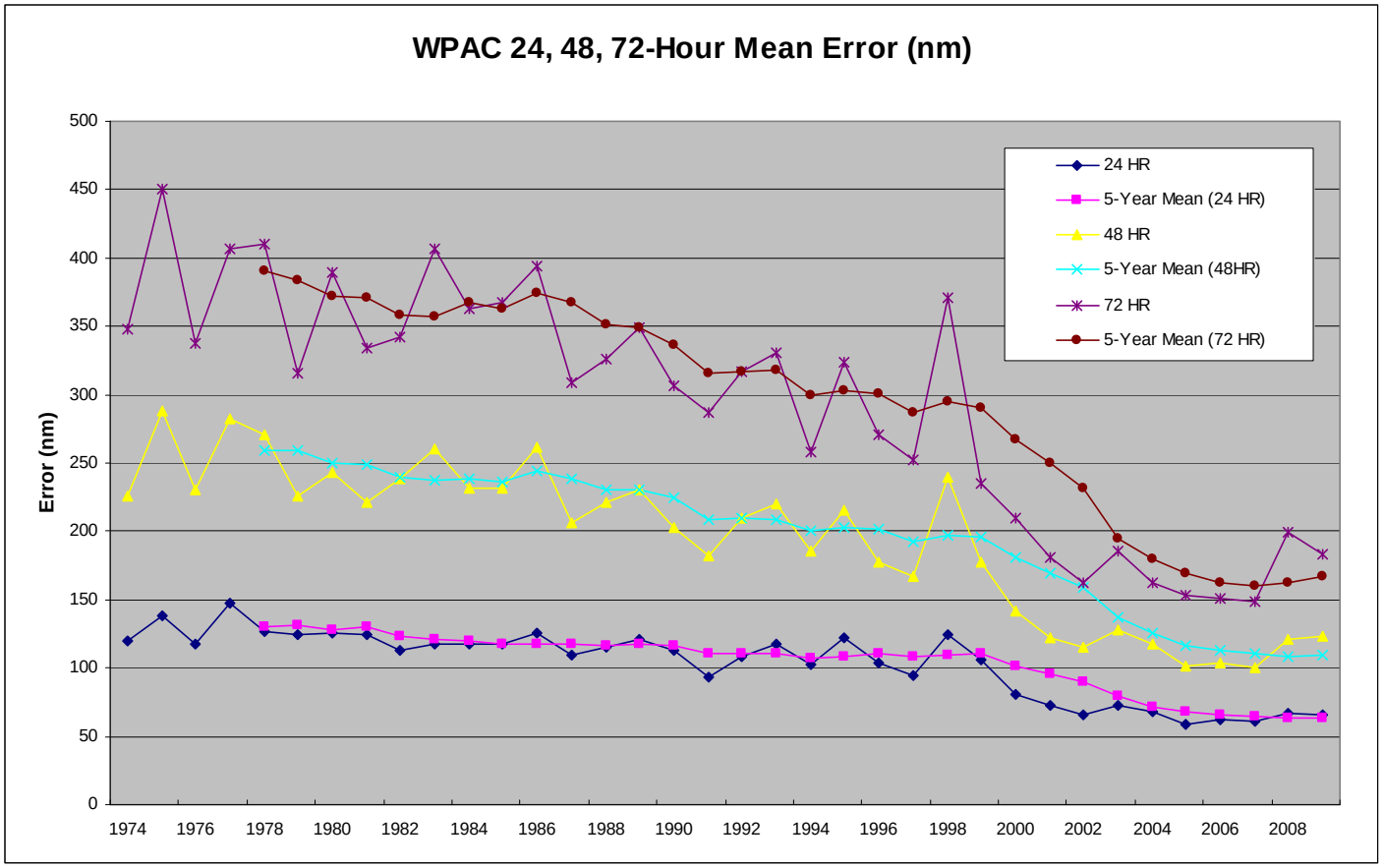


Figure 6-2. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 24, 48, and 72 hours.

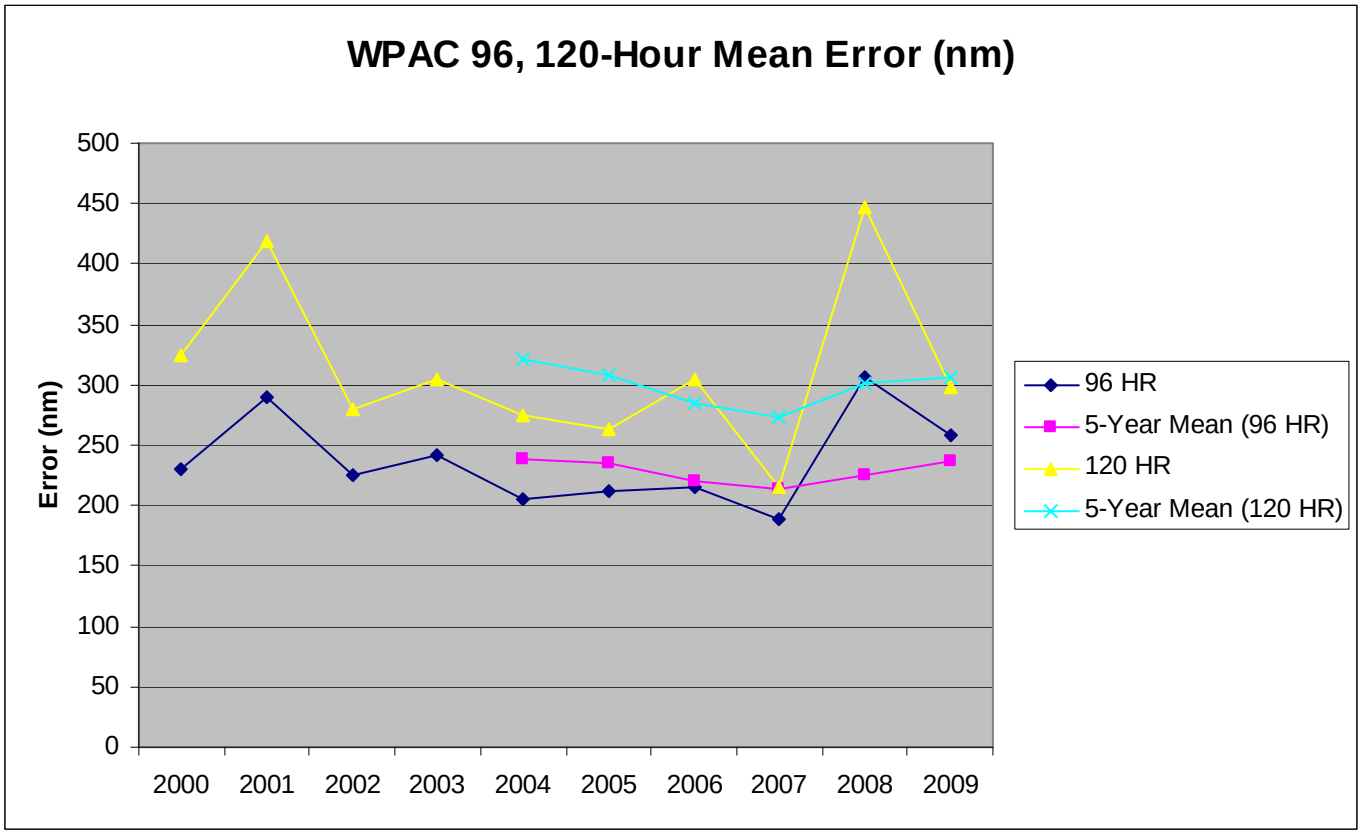


Figure 6-3. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 96 and 120 hours.

Table 6-2

MEAN FORECAST TRACK ERRORS (NM) FOR NORTH INDIAN OCEAN

TROPICAL CYCLONES FROM 1985-2009

	24-HOUR				48-HOUR				72-HOUR			
YEAR (Notes)	Cases	Track	CROSS TRACK	ALONG TRACK	Cases	Track	CROSS TRACK	ALONG TRACK	Cases	Track	CROSS TRACK	ALONG TRACK
1985	30	122	102	53	8	242	119	194	0			
1986	16	134	118	53	7	168	131	80	5	269	189	180
1987	54	144	97	100	25	205	125	140	21	305	219	188
1988	30	120	89	63	18	219	112	176	12	409	227	303
1989	33	88	62	50	17	146	94	86	12	216	164	11
1990	36	101	85	43	24	146	117	67	17	185	130	104
1991	43	129	107	54	27	235	200	89	14	450	356	178
1992	149	128	73	86	100	244	141	166	62	398	276	218
1993	28	125	87	79	20	198	171	74	12	231	176	116
1994	44	97	80	44	28	153	124	63	13	213	177	92
1995	47	138	119	58	32	262	247	77	20	342	304	109
1996	123	134	94	80	85	238	181	127	58	311	172	237
1997	42	119	87	49	29	201	168	92	17	228	195	110
1998	55	106	84	51	34	198	135	106	17	262	188	144

1999	41	79	59	38	22	184	130	116	10	374	309	177
2000	24	61	47	26	16	85	69	37	1	401	399	38
2001	41	61	40	37	31	115	71	71	22	166	44	154
2002	30	84	41	63	18	137	92	83	10	185	92	133
2003	37	108	66	69	31	196	115	132	7	354	210	252
2004	46	81	53	52	36	140	95	85	9	173	144	86
2005	67	62	41	40	49	116	71	73	18	118	35	109
2006	19	64	37	44	13	92	58	60	0	-	-	-
2007	38	61	38	36	23	94	56	65	10	140	92	93
2008	59	70	46	44	38	99	71	55	24	127	94	127
2009	25	93	42	74	10	206	79	169	1	387	102	373
Averages (1985-2009)	46	100	72	55	30	173	119	99	16	271	187	154

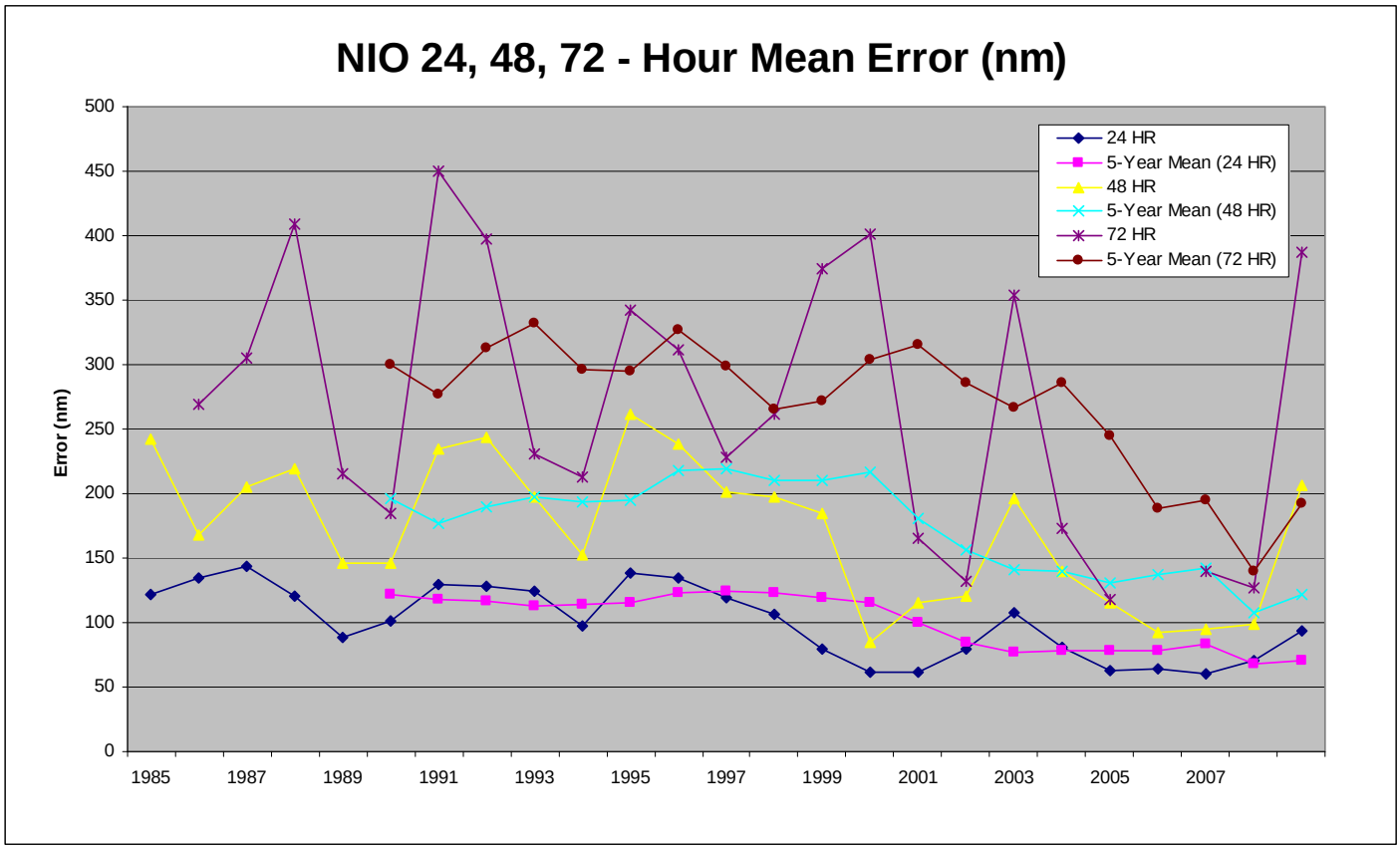


Figure 6-4. Graph of JTWC forecast errors and five year running mean errors for the north Indian Ocean at 24, 48, and 72 hours.

TABLE 5-3
MEAN FORECAST ERRORS (NM) FOR SOUTHERN HEMISPHERE TROPICAL CYCLONES 1985 - 2009

	24-Hour				48-Hour				72-Hour			
Year (Notes)	Cases	Track	Cross	Along	Cases	Track	Cross	Along	Cases	Track	Cross	Along
1985	257	134	79	92	193	236	132	169				
1986	227	129	77	86	171	262	164	169				

1987	138	145	90	94	101	280	138	153				
1988	99	146	83	98	48	290	144	246				
1989	242	124	73	84	186	240	136	166				
1990	228	143	74	105	177	263	152	178				
1991	231	115	69	75	185	220	129	152				
1992	230	124	64	91	208	240	129	177				
1993	225	102	57	74	176	199	114	142				
1994	345	115	68	77	282	224	134	147				
1995	222	108	55	82	175	198	108	144	53	291	190	169
1996	298	125	67	90	237	240	129	174	46	277	133	221
1997	499	109	72	82	442	210	135	163	150	288	175	248
1998	305	111	52	85	245	219	108	169	81	349	171	261
1999	322	113	64	80	245	226	132	159	59	286	164	198
2000	313	72	45	47	245	135	86	84	58	180	139	94
2001	147	84	44	61	113	148	86	105	11	248	197	133
2002	200	82	43	60	146	133	75	93	5	102	41	91
2003	279	74	37	57	221	127	68	90	37	123	54	99
2004	277	77	45	52	233	142	89	92	47	210	102	162
2005	214	70	44	44	170	116	77	72	41	199	117	136
2006	191	65	37	46	140	116	69	79	32	201	101	151
2007	186	74.9	41	52	131	147.2	80	105	3	173.1	146	73
2008	269	61	38	40	211	106	64	72	27	97	53	65
2009	166	74	42	51	118	128	74	89	14	114	89	54
Averages (1985-2009)	244	103	58	72	192	194	110	136	44	209	125	144

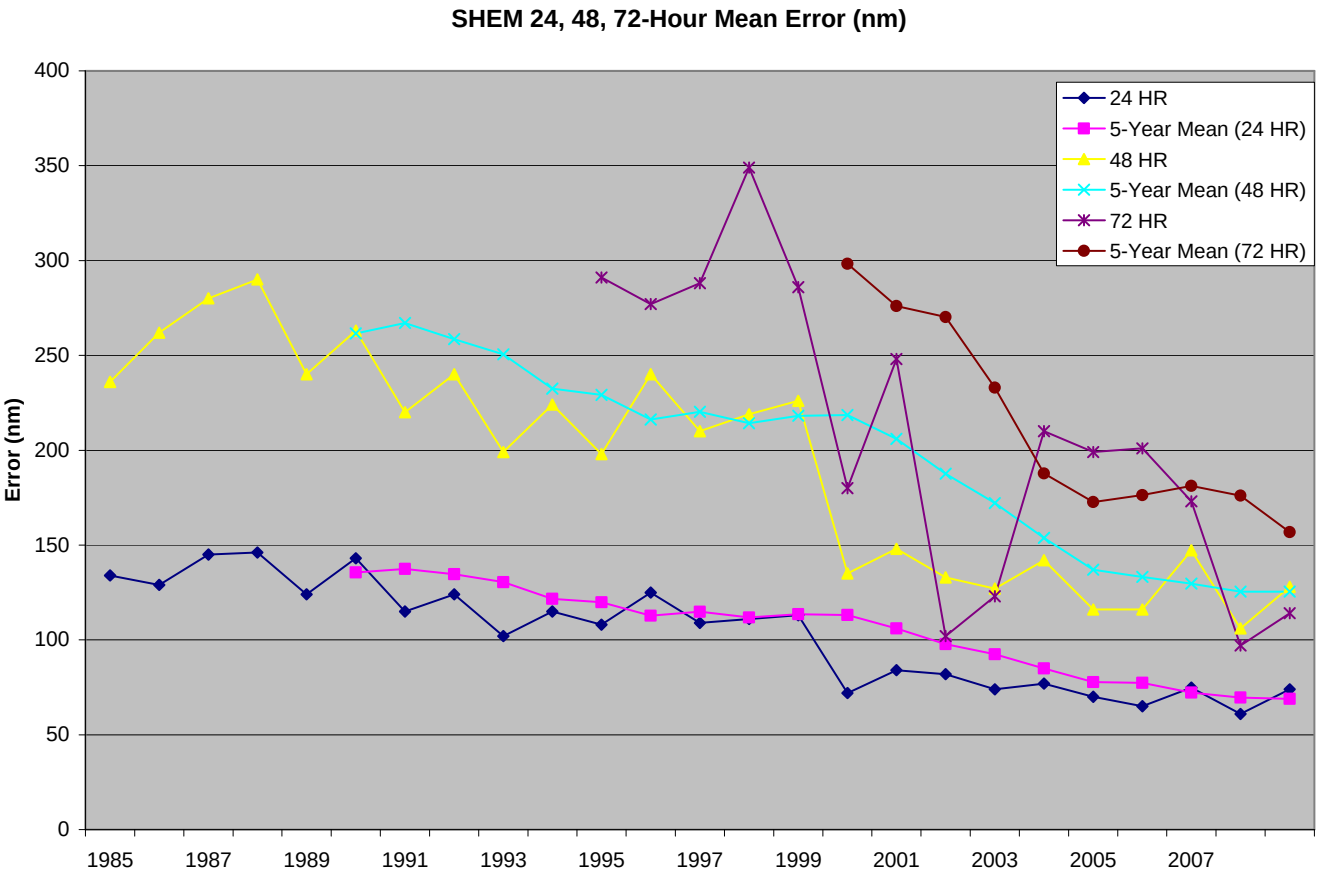


Figure 6-5. Graph of JTWC forecast errors and five year running mean errors for the Southern Hemisphere at 24, 48, and 72 hours.