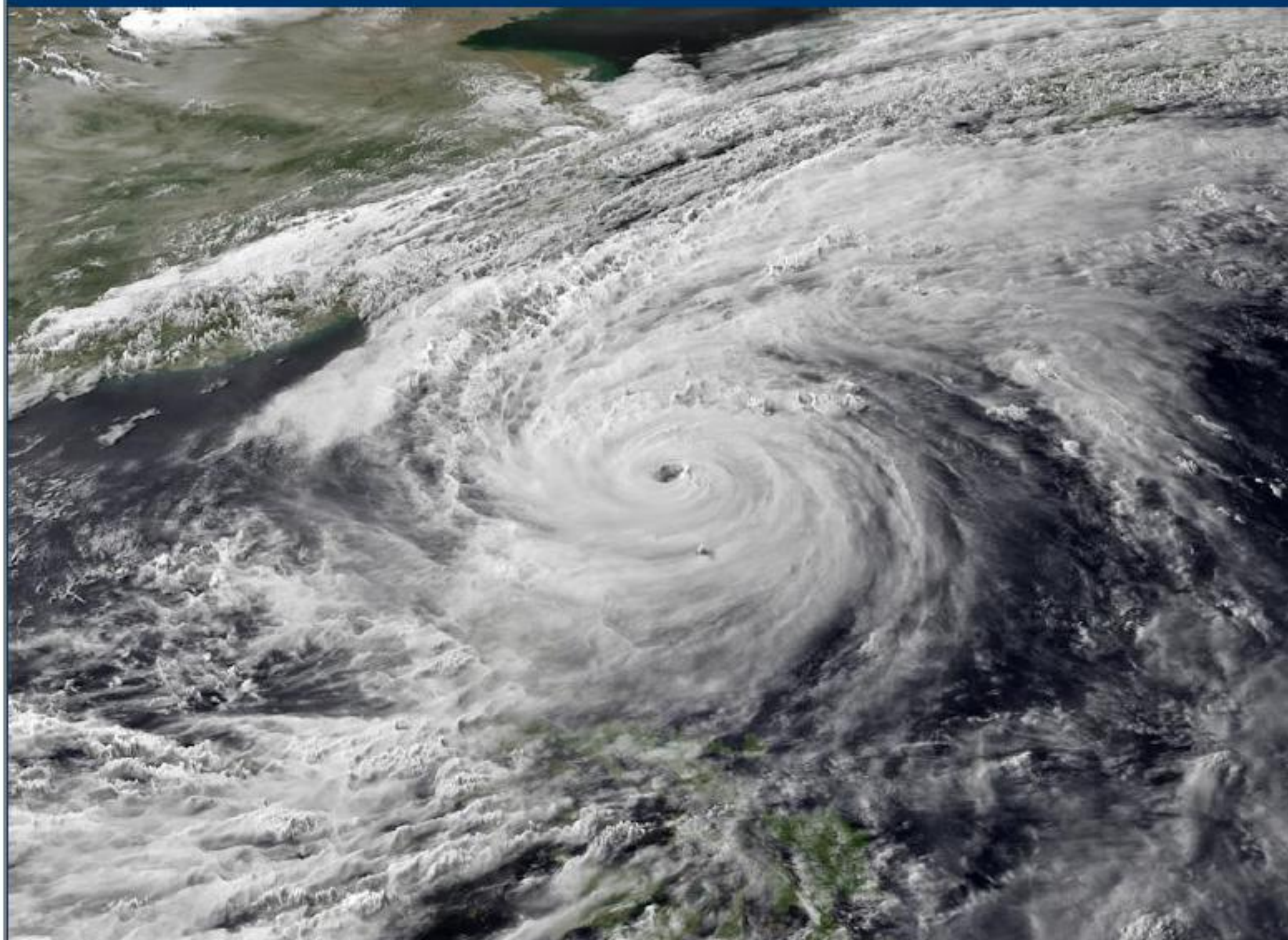
Annual Tropical Cyclone Report
2011



MICHAEL D. ANGOVE

Captain, United States Navy

Commanding Officer

ROBERT J. FALVEY

Director, Joint Typhoon Warning Center

Cover: MODIS image of Typhoon 04W (Songda), taken 27 May, 2011 as the typhoon reached its maximum intensity of 140 knots just northeast of Luzon. Cover image retrieved from http://www.glossusa.com/wp-content/uploads/2011/05/typhoon-songda-5-27-11-800x524.jpg

Executive Summary

The Annual Tropical Cyclone Report (ATCR) is prepared by the staff of the Joint Typhoon Warning Center (JTWC), a jointly manned United States Air Force/Navy organization formally under the operational command of the Commanding Officer, Naval Maritime Forecast Center/Joint Typhoon Warning Center (NMFC/JTWC), Pearl Harbor, Hawaii. During 2011, the Navy Meteorological and Oceanographic (METOC) community reorganization resulted in the stand down of NMFC and a transfer of the Optimal Track Ship Routing (OTSR) and ship weather forecasts (WEAX) missions to Fleet Weather Center, San Diego. This shift in mission, and subsequent Navy Command name change, resulted in JTWC being a stand-alone Navy Command primarily focused on tropical cyclones.

The original JTWC was established on 1 May 1959 when the Joint Chiefs of Staff directed Commander in Chief, U.S. Pacific Command (USCINCPAC) to provide a single tropical cyclone warning center for the western North Pacific region. USCINCPAC delegated the tropical cyclone forecast and warning mission to Commander in Chief, U.S. Pacific Fleet. A subsequent USCINCPAC directive further tasked Commander in Chief, Pacific Air Force to provide for tropical cyclone (TC) reconnaissance support to the JTWC. Currently, JTWC operations are guided by USPACOM Instruction 0539.1 and Pacific Air Forces Instruction 15-101.

This edition of the ATCR documents the TC season and details operationally or meteorologically significant cyclones noted within the JTWC Area of Responsibility. Details are provided to describe operational impacts from tropical cyclones as well as significant challenges and/or shortfalls in the TC warning system. These details are provided to serve as input for future research and development efforts.

Below average tropical cyclone activity continued in the western North Pacific Ocean, continuing a trend that started in 2005, with only 27 TCs observed compared to the long term average of 31. Unlike the previous year, there were four cyclones that reached super typhoon intensity. The TC formation region was displaced north and west again in 2011, a characteristic common during La Nina conditions. Several of these early to mid-season forming TCs exhibited “S” shaped, looping, or generally erratic tracks, with numerous passages near or over Okinawa. In fact, Super Typhoon Songda (04W) passed just west of Kadena Air Base and destroyed the WSR-88D Doppler Weather Radar. As of the writing of this report, the 18 Air Wing at Kadena AB had procured the funding necessary to replace the radar.

The Southern Hemisphere activity also continued a below normal trend, with 21 cyclones observed compared to the long term average of 28 and the Northern Indian Ocean experienced near normal activity with 6 cyclones. Most of the TCs in the Northern Indian Ocean were weak, except TC 06B (Thane), which peaked in intensity just prior to making landfall in southern India at 90 knots.

Weather satellite data remained the mainstay of the TC reconnaissance mission to support the JTWC. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce 11,339 position and intensity estimates (fixes), primarily using the USAF Mark IVB and the USN FMQ-17 satellite direct readout systems. 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 continued to be an invaluable source of information on TC location and intensity. Satellite Operations (SATOPS) continued to advocate for improved satellite reconnaissance capability, including continuation of the Navy Research Labs Coriolis/WindSAT, an ocean surface vector wind capable 43 channel microwave sensor on the Defense Weather Satellite System (DWSS), and exploitation of international remote sensing capabilities, including the Indian Space Research Organizations OceanSAT-2 and the joint Meteo France / Indian Mega Tropiques. Unfortunately, budget cuts within the United States Government resulted in cancellation of DWSS program, so Air Force leadership decided to reduce its Defense Meteorological Satellite Program (DMSP) support from 2 orbits to 1 in order to extend the life of the legacy DMSP satellites.

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. This included evaluation of AFWA's 4 kilometer Weather and Research Forecast (WRF), Mesoscale Ensemble Prediction System (MEPS), and NRLs Coupled Ocean/Atmosphere Mesoscale Prediction System – Tropical Cyclone (COAMPS-TC). Additionally, operational support and enhancements to the ATCF system continued, making development and issuance of tropical cyclone warnings as streamlined as possible for forecasters.

The Techniques Development (TECHDEV) continued their herculean efforts to develop techniques or transition mature research into operations to help improve TC reconnaissance and forecasting. A repeatable TC formation potential process was developed by TECHDEV, tested and implemented in 2011. This checklist will be presented at the 2012 AMS Conference on Hurricanes and Tropical Meteorology. Additionally, TECHDEV acquired a USPACOM sponsored Intern from the University of Hawaii to work on TC genesis and other projects directly related to or supporting operations.

Behind all these efforts are the dedicated team of men and women, military and civilian at JTWC. Special thanks to the entire N6 Department for their outstanding IT support and the administrative and budget staff who worked tirelessly to ensure JTWC had the necessary resources to get the mission done.

A Special thanks also to: FNMOC for their operational data and modeling support; the NRLMRY and ONR 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 outstanding support and continued development of the ATCF system.

JTWC Personnel 2011

Staff
Mr. Robert Falvey, *Director*
LCDR Sarah Follett, *Operations Officer*
Mr. Edward Fukada, *Technical Advisor*

Typhoon Duty Officers (TDO)
LCDR Sarah Follett
Mr. Matt Kucas
LT Natalie Laudier
LT Allan Howard
LTJG Chad Geis
Capt Jay Neese
Mr. Stephen Barlow
Mr. Richard Ballucanag
Mr. Aaron Lana

Satellite Operations
Capt Jay Neese, *OIC Satellite Operations*
TSgt Richard Kienzle, *NCOIC*
Mr. Dana Uehara, *Analyst*
Mr. Todd Brandon, *Analyst*
Mr. James Darlow, *Analyst*
SSgt Jeffrey Quast, *Analyst*
SrA Russell Hathaway, *Analyst*
SrA Maelyn Belmondo, *Analyst*
SrA Michael Lanzetta, *Analyst*
SrA Christina Hough, *Analyst*
SrA Brandon Ross, *Analyst*

Techniques Development
Mr. Matt Kucas, *Techniques Development Chief*
Mr. James Darlow, *Techniques Development-ATCR Editor*

Typhoon Duty Assistants (TDA)
AG3 Christopher Brunner
AG3 Valerie Littlefield
AG2 Alyssa Roth
AG2 Ethan Wright
AGAA Kristin Terrell
AGAA Tyler Terrell
AGAN Vaughan Dill

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Table 1-1

WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 2011 (01 JAN 2011 - 31 DEC 2011)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
01W	-	02 Apr / 0000Z	03 Apr / 0600Z	6	30	1000
02W	-	05 Apr / 0000Z	06 Apr / 0000Z	5	30	1000
03W	Aere	06 May / 0600Z	11 May / 1800Z	23	50	985
04W	Songda	20 May / 0600Z	29 May / 1200Z	38	140	918
05W	Sarika	09 Jun / 0000Z	11 Jun / 0000Z	9	30	1000
06W	Haima	16 Jun / 1800Z	24 Jun / 1800Z	33	35	996
07W	Meari	21 Jun / 1800Z	27 Jun / 0000Z	22	55	982
08W	Ma-On	11 Jul / 1200Z	22 Jul / 0000Z	43	115	937
09W	Tokage	15 Jul / 0600Z	16 Jul / 0000Z	4	30	1000
10W	Nock-Ten	24 Jul / 1800Z	30 Jul / 1200Z	24	65	974
11W	Muifa	25 Jul / 1200Z	08 Aug / 1200Z	57	140	918
12W	Merbok	03 Aug / 0600Z	08 Aug / 1800Z	23	75	967
13W	-	10 Aug / 0000Z	12 Aug / 0000Z	9	30	1000
14W	Nanmadol	22 Aug / 1800Z	31 Aug / 0000Z	35	140	918
15W	Talas	25 Aug / 0600Z	04 Sep / 0000Z	40	55	982
16W	Noru	03 Sep / 0600Z	06 Sep / 1200Z	14	45	989
17W	Kulap	07 Sep / 0600Z	10 Sep / 0000Z	12	40	993
18W	Roke	11 Sep / 1200Z	21 Sep / 1200Z	41	115	937
19W	Sonca	14 Sep / 1800Z	20 Sep / 0000Z	22	90	956
20W	Nesat	23 Sep / 1200Z	30 Sep / 1200Z	29	115	937
21W	Haitang	24 Sep / 1200Z	26 Sep / 1800Z	10	35	996
22W	Nalgae	27 Sep / 0600Z	05 Oct / 1200Z	34	130	926
23W	Banyan	10 Oct / 0000Z	14 Oct / 1800Z	20	30	1000
24W	-	07 Nov / 0600Z	08 Nov / 0600Z	5	25	1004
25W	-	04 Dec / 1200Z	05 Dec / 0000Z	3	25	1004
26W	-	12 Dec / 0600Z	13 Dec / 1200Z	6	25	1004
27W	Washi	13 Dec / 0900Z	19 Dec / 1200Z	26	50	985
* As designated by the responsible RSMC						
** 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 - 2011

YEAR	JAN				FEB				MAR				APR				MAY				JUN			
	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt
1959	0	0	0	0	1	0	1	0	1	0	1	1	1	1	0	0	0	0	0	0	1	0	0	1
1960	1	0	0	1	0	0	0	0	1	0	0	1	1	1	0	0	1	0	1	0	3	2	1	0
1961	1	0	1	0	1	0	1	0	1	1	0	0	1	0	1	0	4	2	1	1	6	1	1	4
1962	0	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0	3	2	0	1	0	0	0	0
1963	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	4	3	1	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	1	2	2	0	0
1965	2	1	1	0	2	0	2	0	1	0	1	0	1	1	0	0	2	1	0	1	4	3	1	0
1966	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	2	0	0	1	1	0	0
1967	1	0	1	0	0	0	0	0	2	1	1	0	1	1	0	0	1	0	1	0	1	1	0	0
1968	0	0	0	0	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	4	2	0	2
1969	1	1	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0
1971	1	0	1	0	0	0	0	0	1	0	1	0	2	2	0	0	5	2	3	0	2	2	0	0
1972	1	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	4	2	2	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	1	0	1	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	0	0	4	1	2	1
1975	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
1976	1	1	0	0	1	0	1	0	0	0	0	0	2	1	1	0	2	2	0	0	2	2	0	0
1977	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	1	1	0	1	0
1978	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3	0	3	0
1979	1	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	2	0	1	1	0	0	0	0
1980	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	4	2	2	0	1	0	1	0
1981	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	1	0	2	2	0	0
1982	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	1	1	0	0	3	1	2	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
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1986	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	2	1	1	0	2	1	1	0
1987	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2	1	1	0
1988	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	3	1	1	1
1989	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	2	2	0	0	2	1	1	0
1990	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	1	1	0	4	2	1	1
1991	0	0	0	0	0	0	0	0	2	1	1	0	1	0	1	0	1	1	0	0	1	1	0	1 0
1992	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0
1993	0	0	0	0	0	0	0	0	2	0	1	1	2	0	0	2	1	0	1	0	2	1	0	1
1994	1	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	2	1	0	1	2	0	2	0
1995	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	0	2	0
1996	1	0	0	1	1	0	0	1	0	0	0	0	2	0	1	1	2	1	1	0	0	0	0	0
1997	1	0	1	0	0	0	0	0	0	0	0	0	2	1	1	0	3	1	2	0	3	3	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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2000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	1	2	0	0	0	0
2001	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	1	0	1	0	2	2	0	0
2002	1	0	1	0	1	1	0	0	1	0	0	1	1	0	0	1	2	1	0	1	3	3	0	0
2003	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	3	1	1	1	2	1	1	0
2004	0	0	0	0	1	0	1	0	1	0	1	0	1	1	0	0	3	2	1	0	5	5	0	0
2005	1	1	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	1	1	0	0
2006	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1	0	0	1	0	1	0
2007	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
2008	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	4	3	1	0	1	1	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	1	1	0
2010	1	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2	1	1	0	3	0	2	1

YEAR	JUL				AUG				SEP				OCT				NOV				DEC				TOTALS			
	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt	Total	≥64 kt	34-63kt	≤33 kt
1959	3	1	1	1	8	5	1	2	9	4	2	3	3	2	1	0	2	2	0	0	2	2	0	0	31	17	7	7
1960	3	2	1	0	9	8	1	0	5	0	4	1	4	4	0	0	1	1	0	0	1	1	0	0	30	19	8	3
1961	5	3	2	0	7	3	1	3	6	5	1	0	7	3	2	2	2	1	0	1	1	1	0	0	42	20	11	11
1962	8	5	1	2	8	7	0	1	7	3	1	3	5	3	1	1	4	3	0	1	2	0	2	0	39	24	6	9
1963	5	3	1	1	4	3	0	1	4	2	2	0	6	5	1	0	0	0	0	0	3	2	1	0	28	19	6	3
1964	8	6	1	1	8	3	5	0	8	5	2	1	7	3	3	1	6	4	2	0	2	1	0	1	44	26	13	5
1965	6	4	1	1	7	3	2	2	9	5	3	1	3	2	0	1	2	1	1	0	1	0	1	0	40	21	13	6
1966	4	3	1	0	9	5	3	1	10	5	3	2	4	1	1	2	5	1	2	2	2	1	0	1	38	20	10	8
1967	8	3	3	2	10	3	4	3	8	5	3	0	4	2	1	1	4	4	0	0	1	0	1	0	41	20	15	6
1968	3	1	2	0	8	3	4	1	4	4	0	0	6	5	1	0	4	4	0	0	0	0	0	0	31	20	7	4
1969	3	2	1	0	3	2	1	0	6	2	0	4	5	4	1	0	2	1	1	0	1	0	1	0	23	13	6	4
1970	3	0	2	1	7	4	2	1	4	2	2	0	6	3	2	1	4	1	3	0	0	0	0	0	27	12	12	3
1971	8	6	2	0	5	3	1	1	7	5	1	1	4	3	1	0	2	1	1	0	0	0	0	0	37	24	11	2
1972	5	4	1	0	5	3	2	0	6	4	1	1	5	4	1	0	2	2	0	0	3	2	1	0	32	22	8	2
1973	7	4	3	0	6	2	3	1	3	2	0	1	4	4	0	0	3	0	3	0	0	0	0	0	23	12	9	2
1974	5	2	3	0	7	2	3	2	5	3	2	0	4	4	0	0	4	2	2	0	2	0	2	0	35	15	17	3
1975	1	0	1	0	6	4	1	1	5	4	1	0	6	3	2	1	3	2	1	0	2	0	2	0	25	14	8	3
1976	4	2	2	0	4	1	3	0	5	4	1	0	0	0	0	0	2	1	1	0	2	0	2	0	25	14	11	10
1977	4	3	0	1	2	0	2	0	5	2	3	0	4	3	1	0	2	2	0	0	1	1	0	0	21	11	8	2
1978	4	3	1	0	8	3	4	1	4	3	1	0	7	4	1	2	4	1	2	1	0	0	0	0	32	15	13	4
1979	5	2	2	1	4	2	0	2	6	3	3	0	3	2	1	0	2	1	1	0	3	1	1	1	28	14	9	5
1980	5	3	1	1	3	2	0	1	7	5	1	1	4	2	2	0	1	1	0	0	1	0	1	0	28	15	9	4
1981	5	2	3	0	8	2	5	1	4	4	0	0	2	1	1	0	3	2	1	0	2	2	0	0	29	16	12	1
1982	4	2	2	0	5	5	0	0	6	3	2	1	4	3	0	1	1	1	0	0	1	1	0	0	28	19	7	2
1983	3	3	0	0	6	2	3	1	3	1	1	1	5	3	2	0	5	3	2	0	2	0	2	0	25	12	11	2
1984	5	4	1	0	7	2	3	2	4	1	3	0	8	5	4	1	3	3	0	0	1	1	0	0	30	16	13	3
1985	1	1	0	0	7	5	2	0	5	3	2	0	5	4	1	0	1	0	1	0	2	1	1	0	27	17	9	1
1986	2	2	0	0	5	4	1	0	2	2	0	0	5	3	2	0	4	2	2	0	3	2	1	0	27	19	8	0
1987	4	4	0	0	4	3	1	0	7	5	1	1	2	2	0	0	3	1	2	0	1	1	0	0	25	18	6	1
1988	2	1	1	0	5	2	3	0	8	2	6	0	4	4	0	0	2	2	0	0	1	0	1	0	27	14	12	1
1989	6	2	3	1	8	3	3	2	4	2	2	0	6	6	0	0	3	3	0	0	2	1	0	1	35	21	10	4
1990	4	2	2	0	5	5	0	0	5	4	1	0	5	2	3	0	4	3	1	0	1	1	0	0	32	21	10	1
1991	4	4	0	0	8	3	3	2	6	4	2	0	3	3	0	0	6	3	3	0	0	0	0	0	32	20	10	2
1992	4	2	2	0	8	4	4	0	5	4	1	0	6	5	1	0	5	3	1	1	0	0	0	0	33	21	11	11
1993	5	3	2	0	8	6	1	1	5	4	1	0	6	3	2	1	4	1	1	2	3	3	0	0	38	21	9	8
1994	9	3	4	2	9	6	3	0	8	4	4	0	7	5	1	1	0	0	0	0	2	1	1	0	41	21	15	5
1995	3	2	1	0	7	4	2	1	7	4	1	2	8	5	1	2	2	0	2	0	3	0	1	2	34	15	11	8
1996	7	6	1	0	10	4	3	3	7	6	1	0	5	2	1	2	6	1	3	2	3	1	1	1	44	21	12	11
1997	4	3	1	0	8	6	1	1	4	3	1	0	6	4	1	1	1	1	0	0	1	1	0	0	33	23	8	2
1998	3	0	1	2	3	2	1	0	8	4	1	3	6	2	1	3	3	0	3	0	4	1	1	2	27	9	8	10
1999	5	1	1	3	9	4	2	3	6	2	4	0	2	1	1	0	3	1	1	1	3	0	0	3	34	12	12	10
2000	8	2	3	3	9	4	3	2	6	4	1	1	3	2	1	0	3	1	1	1	1	1	0	0	34	15	10	9
2001	6	4	1	1	7	3	3	1	5	5	0	0	3	3	0	0	3	1	2	0	4	2	2	0	33	20	9	4
2002	6	3	2	1	8	4	3	1	3	1	2	0	5	3	0	2	1	1	0	0	1	1	0	0	33	18	8	7
2003	2	2	0	0	5	4	1	0	3	3	0	0	6	2	1	3	3	3	0	0	1	0	1	0	27	17	6	4
2004	2	1	1	0	9	6	2	1	3	1	1	1	3	3	0	0	2	2	0	0	2	0	2	0	32	21	9	2
2005	4	1	3	0	6	6	0	0	5	4	1	0	3	2	0	1	2	1	1	0	1	0	1	0	25	18	6	1
2006	3	2	1	0	8	3	4	1	5	3	0	2	4	2	1	1	2	2	0	0	2	1	0	1	27	14	8	5
2007	3	2	1	0	6	3	2	1	5	2	2	1	5	3	2	0	6	3	1	2	0	0	0	0	27	15	8	4
2008	2	2	0	0	5	1	4	0	6	3	3	0	3	0	3	0	3	0	3	0	1	1	0	0	27	12	15	0
2009	3	1	1	1	5	3	2	0	7	4	1	2	4	3	1	0	4	1	1	2	1	0	0	1	28	15	7	6
2010	2	2	0	0	5	2	3	0	4	3	1	0	4	2	2	0	1	0	0	1	1	0	0	1	19	9	6	4
2011	4	2	1	1	4	2	1	1	7	2	5	0	1	0	0	1	1	0	0	1	3	0	1	2	27	7	11	9

1) 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.
2) 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 1-3 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	16.4
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228
TYPHOONS (1959 - 2011)													
	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	2.9	1.5	0.7	17.1
CASES	11	3	10	23	40	56	133	184	174	154	81	35	904
TROPICAL STORMS AND TYPHOONS (1945 - 1958)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.4	0.2	0.5	0.5	0.8	1.6	2.9	4	4.2	3.3	2.7	1.2	22.3
CASES	6	2	7	8	11	22	44	60	64	49	41	18	332
TROPICAL STORMS AND TYPHOONS (1959 - 2011)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.5	0.2	0.4	0.6	1.2	1.7	3.9	5.6	4.9	4.0	2.5	1.2	26.8
CASES	25	12	23	34	63	90	205	296	262	210	133	66	1419

TABLE 1-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976 - 2011					
YEAR	INITIAL TCFAS	TROPICAL CYCLONES WITH TCFAS	TOTAL TROPICAL CYCLONES	PROBABILITY OF TCFA WITHOUT WARNING*	PROBABILITY OF TCFA BEFORE WARNING
1976	34	25	25	26%	100%
1977	26	20	21	23%	95%
1978	32	27	32	16%	84%
1979	27	23	28	15%	82%
1980	37	28	28	24%	100%
1981	29	28	29	3%	97%
1982	36	26	28	28%	93%
1983	31	25	25	19%	100%
1984	37	30	30	19%	100%
1985	39	26	27	33%	96%
1986	38	27	27	29%	100%
1987	31	24	25	23%	96%
1988	33	26	27	21%	96%
1989	51	32	35	37%	91%
1990	33	30	31	9%	97%
1991	37	29	31	22%	94%
1992	36	32	32	11%	100%
1993	50	35	38	30%	92%
1994	50	40	40	20%	100%
1995	54	33	35	39%	94%
1996	41	39	43	5%	91%
1997	36	30	33	17%	91%
1998	38	18	27	53%	67%
1999	39	29	33	26%	88%
2000	40	31	34	23%	91%
2001	34	28	33	18%	85%
2002	39	31	33	21%	94%
2003	31	27	27	13%	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	15%	79%
2010	24	18	19	25%	95%
2011	32	26	27	19%	96%
MEAN	34.9	27.6	29.7	21%	93%
CASES	1255	993	1069		
* Percentage of initial TCFAs not followed by warnings.					

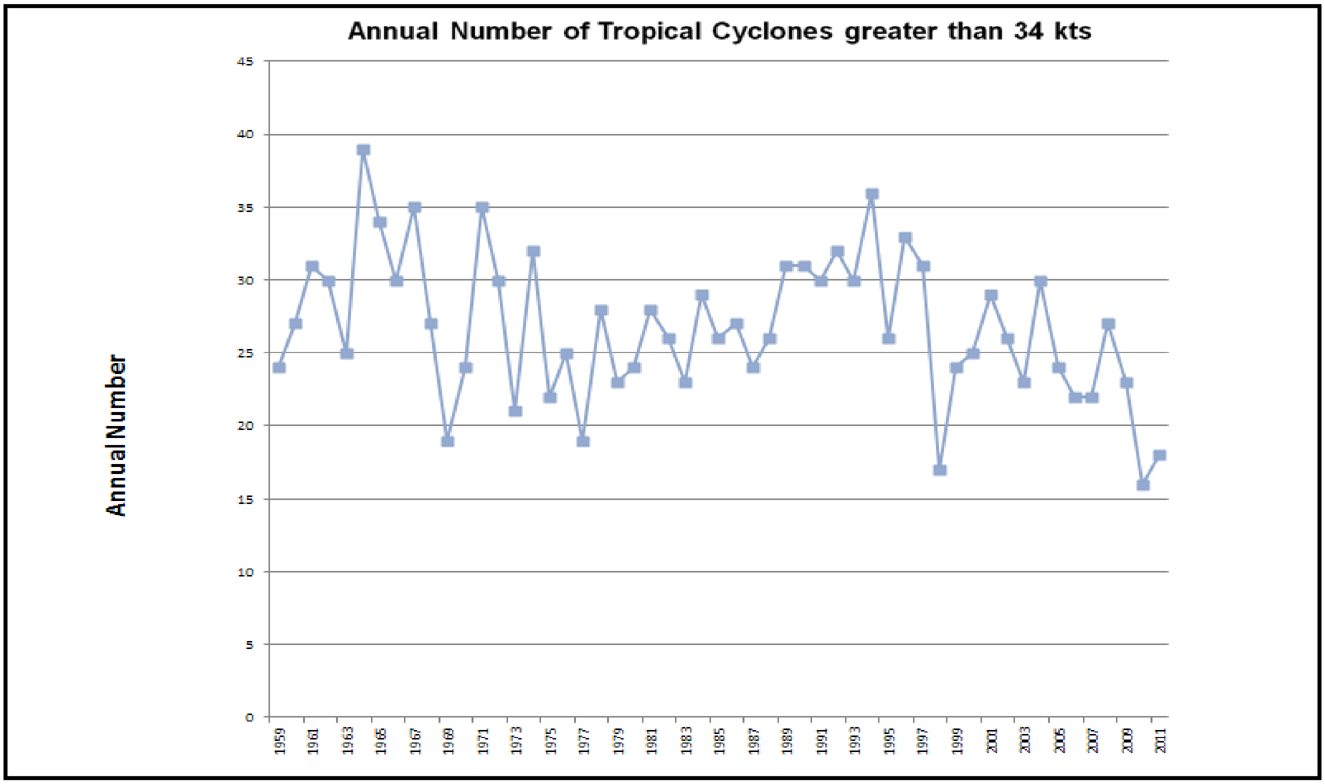


Figure 1-1. Annual number of western North Pacific TCs greater than 34 knots intensity.

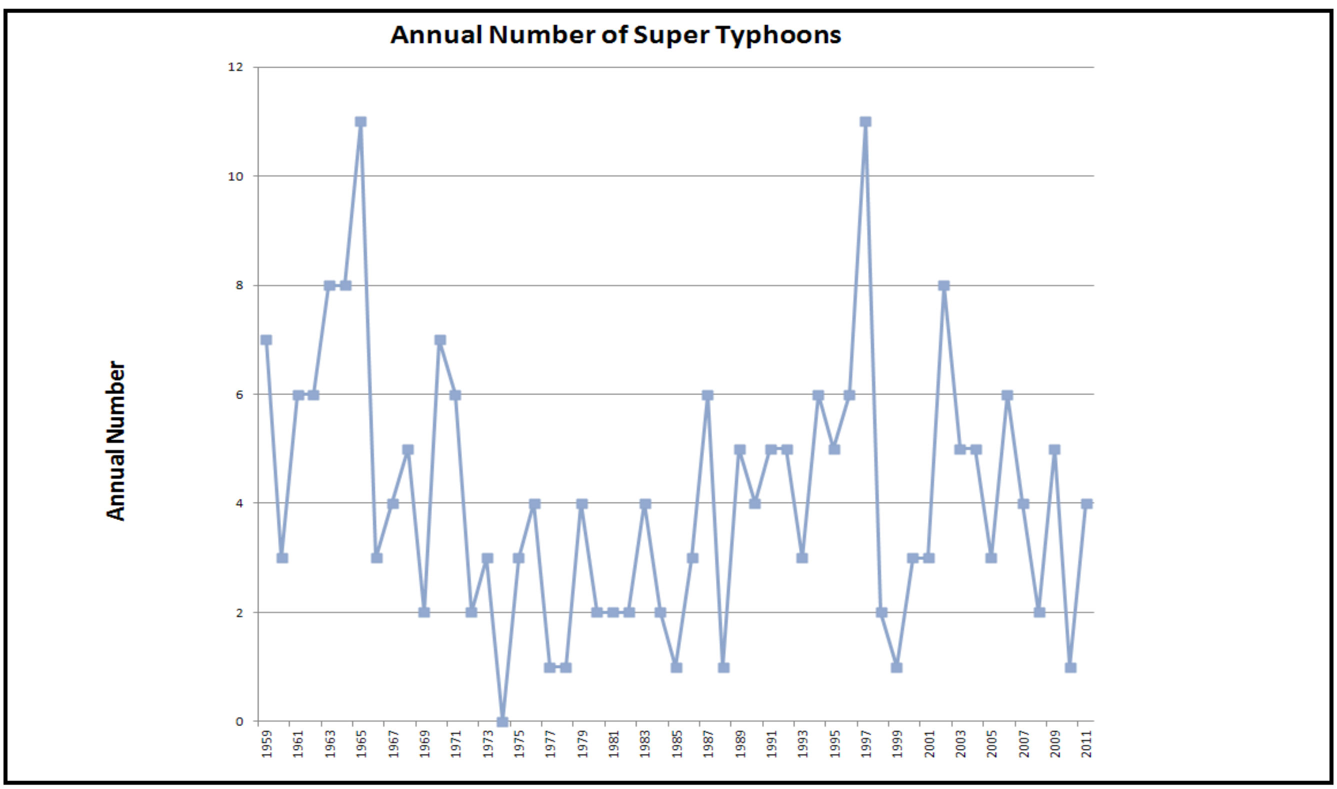
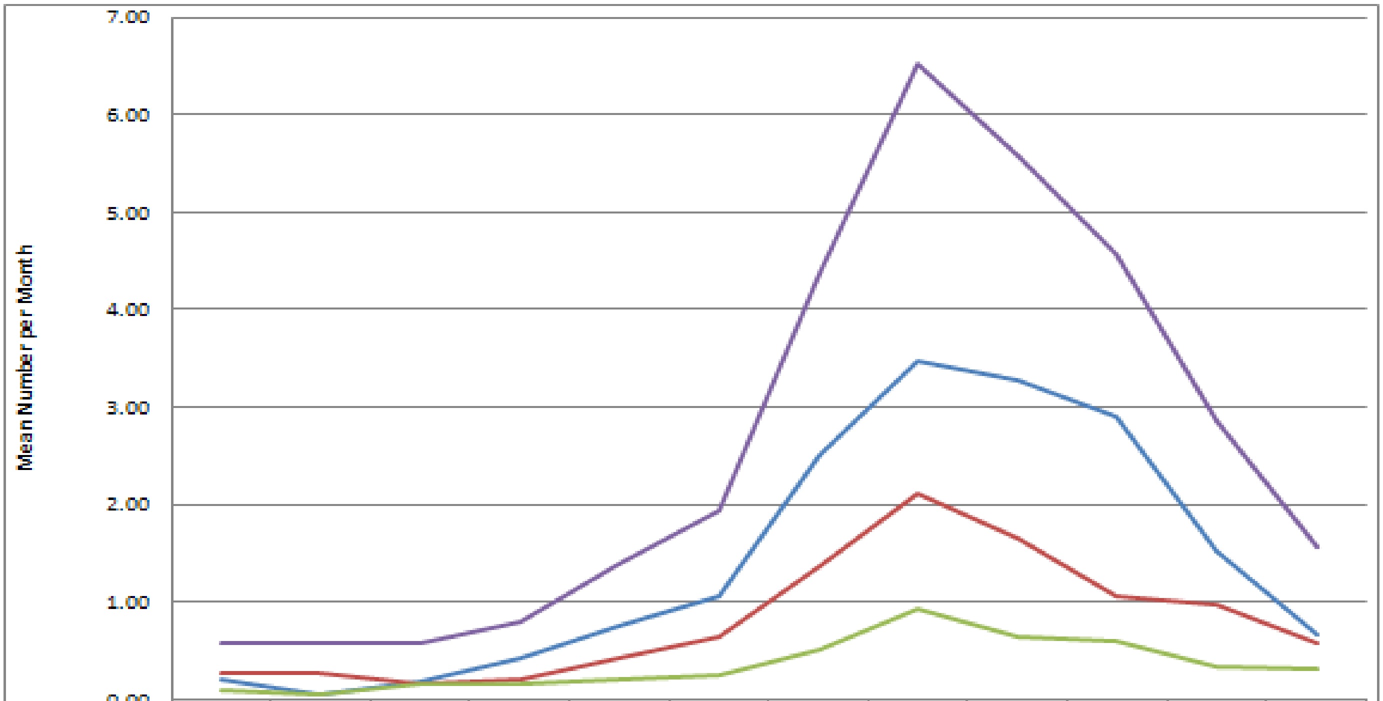


Figure 1-2. Annual number of Western North Pacific TCs greater than 127 knots intensity.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TY AVG	0.21	0.06	0.19	0.43	0.75	1.06	2.51	3.47	3.28	2.91	1.53	0.66
TS AVG	0.26	0.26	0.17	0.21	0.43	0.64	1.36	2.11	1.66	1.06	0.98	0.58
TD AVG	0.09	0.06	0.15	0.15	0.21	0.25	0.51	0.92	0.64	0.60	0.34	0.32
All AVG	0.57	0.57	0.58	0.79	1.40	1.94	4.38	6.51	5.58	4.57	2.85	1.57

Figure 1-3. Average number of Western North Pacific TCs (all intensities) by month 1959-2011.

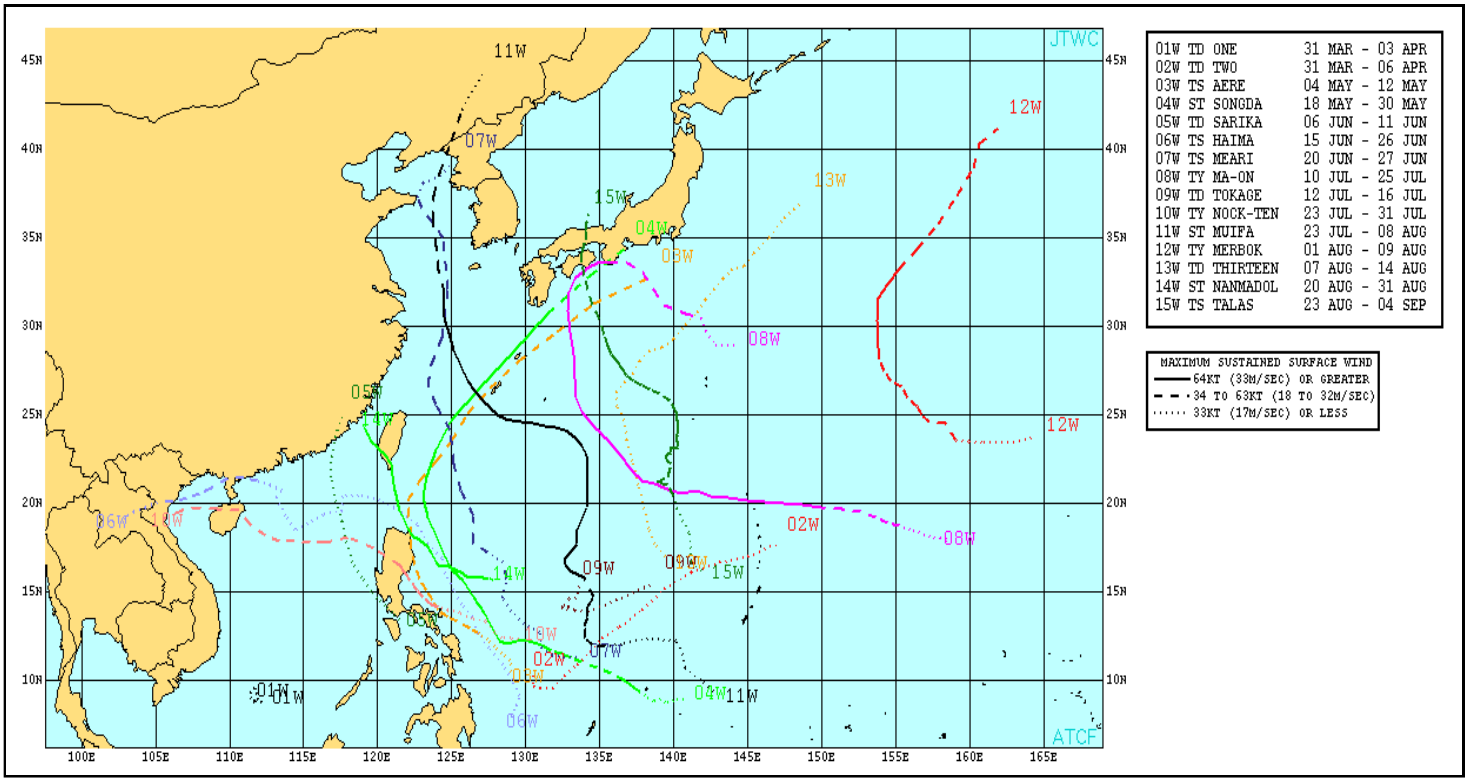


Figure 1-4. Western North Pacific Tropical Cyclones 01W – 15W.

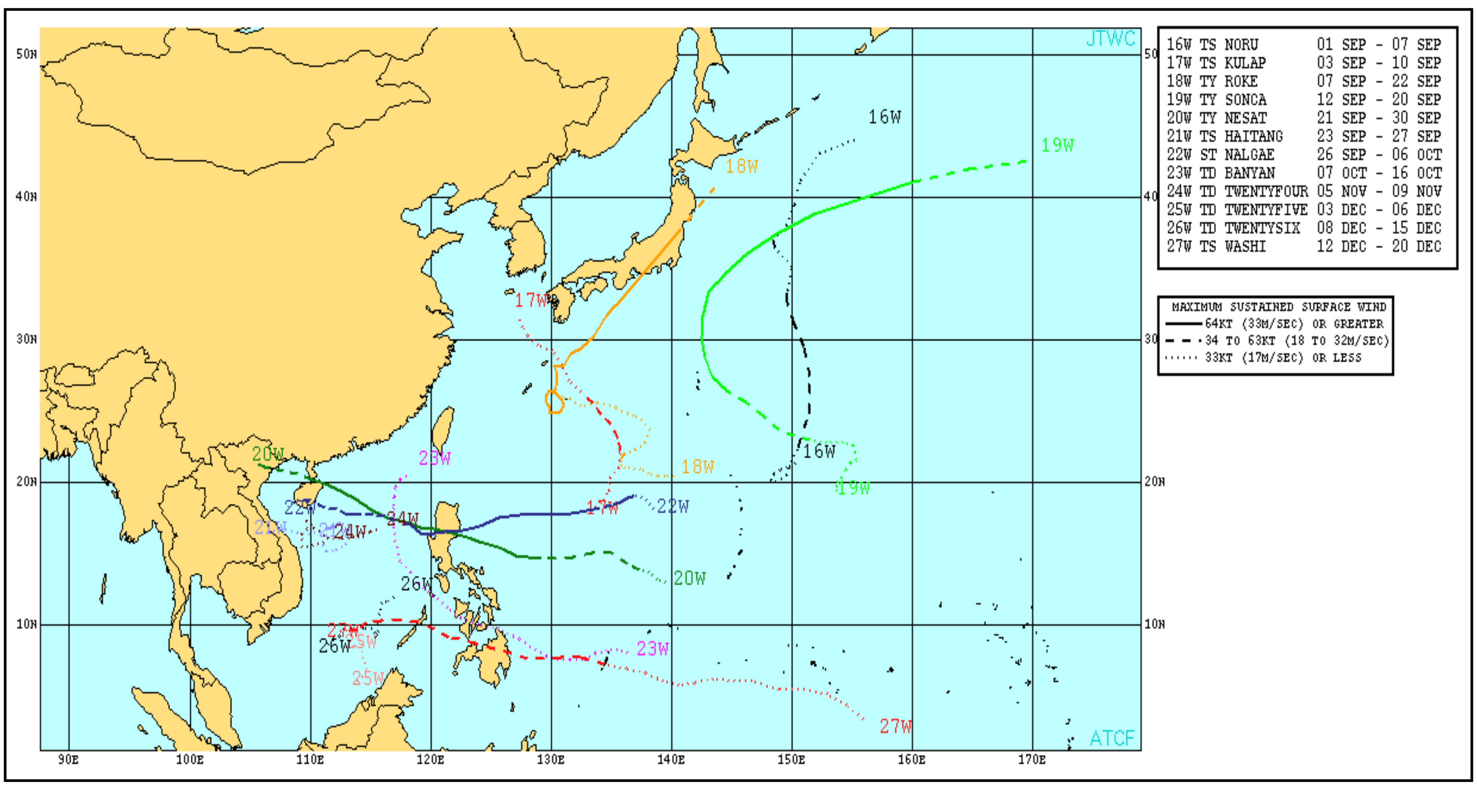


Figure 1-5. Western North Pacific Tropical Cyclones 16W – 27W.

Section 2 Cyclone Summaries

This section presents a synopsis of each cyclone that occurred during 2011 in the western North Pacific Ocean. Each cyclone is presented, with the number and basin identifier used by JTWC, along with the name assigned by RSMC Tokyo.

Dates are also listed when JTWC first designated various stages of pre-warning development: Date of the POOR or LOW potential for development, the date first designated for the increased potential for development (FAIR/MEDIUM classification) and the date when the first Tropical Cyclone Formation Alert was issued. Since JTWC changed its 24 hour tropical cyclone formation potential classification system from “poor, fair, and good” to the probabilistic “low, medium, and high” on 1 June 2011, classification levels for the 2011 Western North Pacific season are a mix of “poor, fair, and good” and “low, medium, and high” classifications. These classifications are defined as follows:

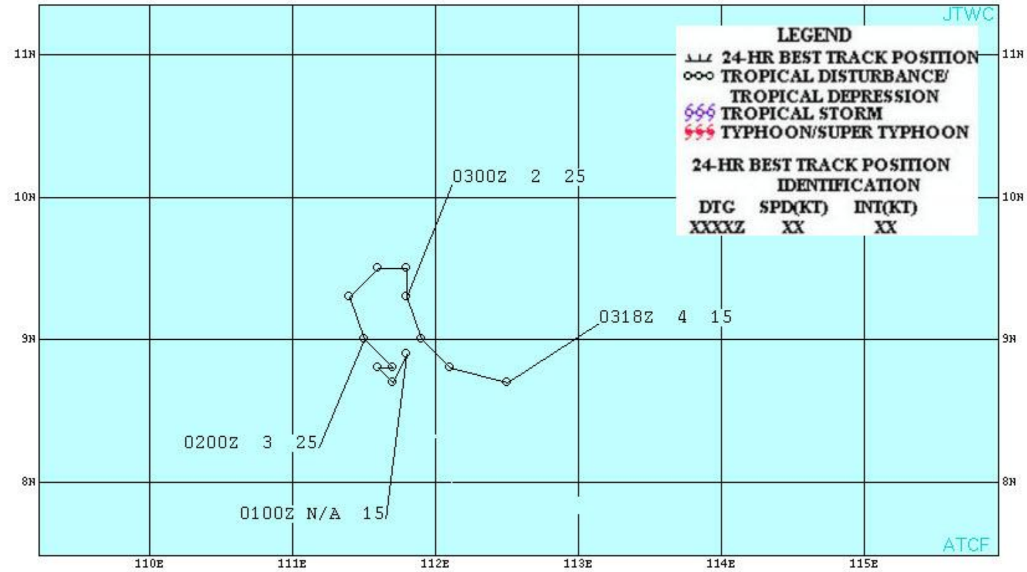
“Poor/Low” formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours.
“Fair/Medium” formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.
“Good/High” formation potential describes an area that is being monitored for development and is either expected to develop within 24 hours or development has already started, but warning criteria have not yet been met. All areas designated as “Good/High” are accompanied by a Tropical Cyclone Formation Alert.

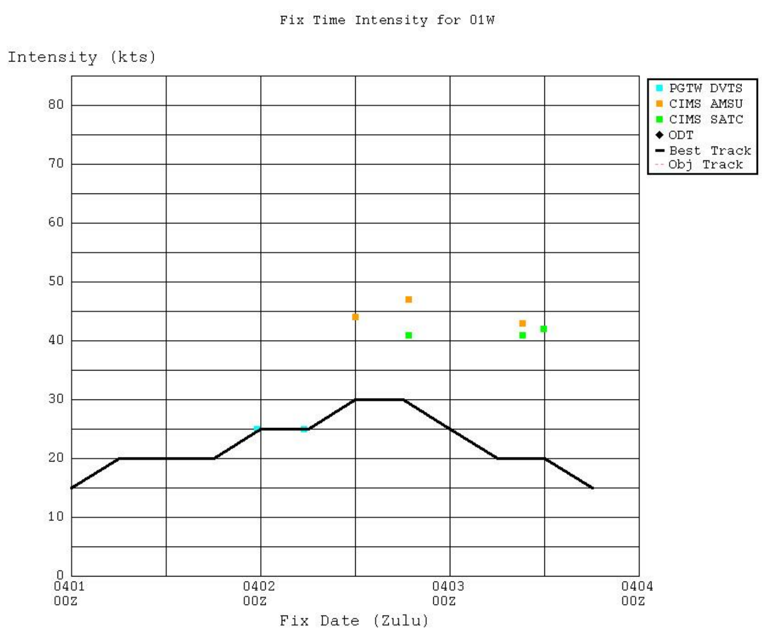
Initial and final JTWC warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

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 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.

Tropical Depression 01W

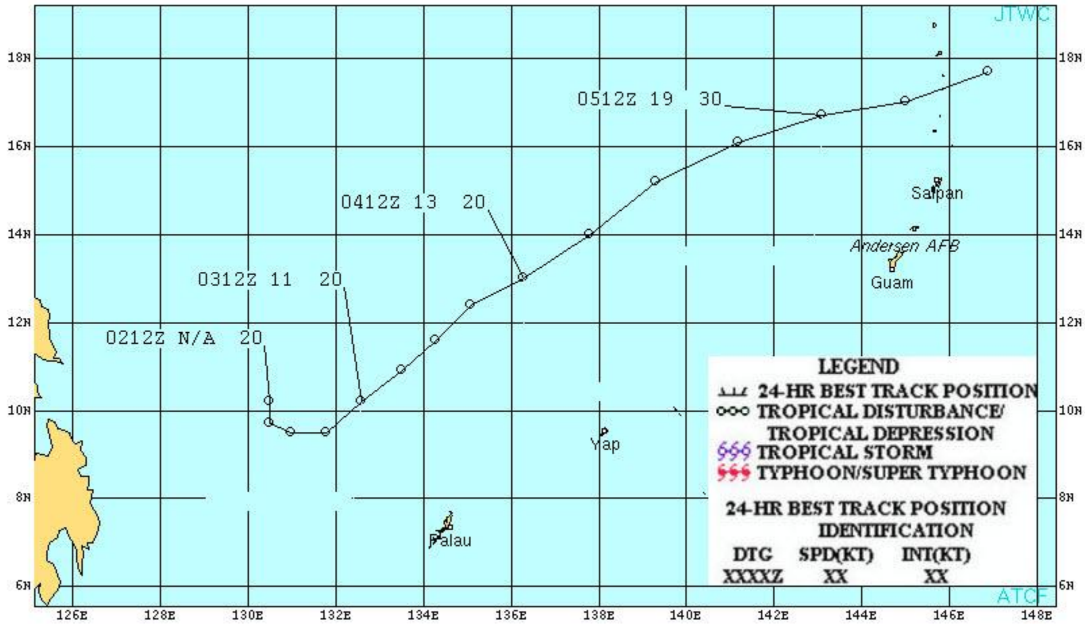
ISSUED POOR:	0600Z 01 Apr 2011
ISSUED FAIR:	1730Z 01 Apr 2011
FIRST TCFA:	2030Z 01 Apr 2011
FIRST WARNING:	0000Z 02 Apr 2011
LAST WARNING:	0600Z 03 Apr 2011
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	6

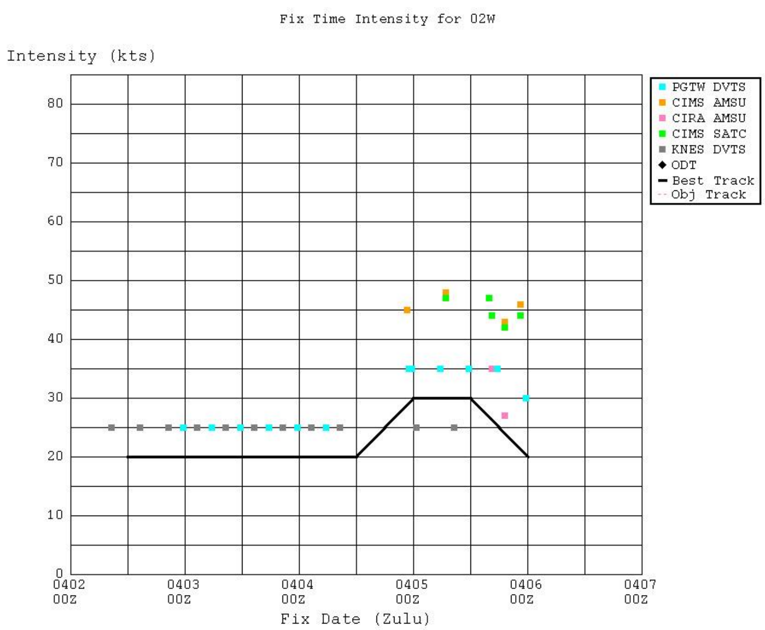




Tropical Depression 02W

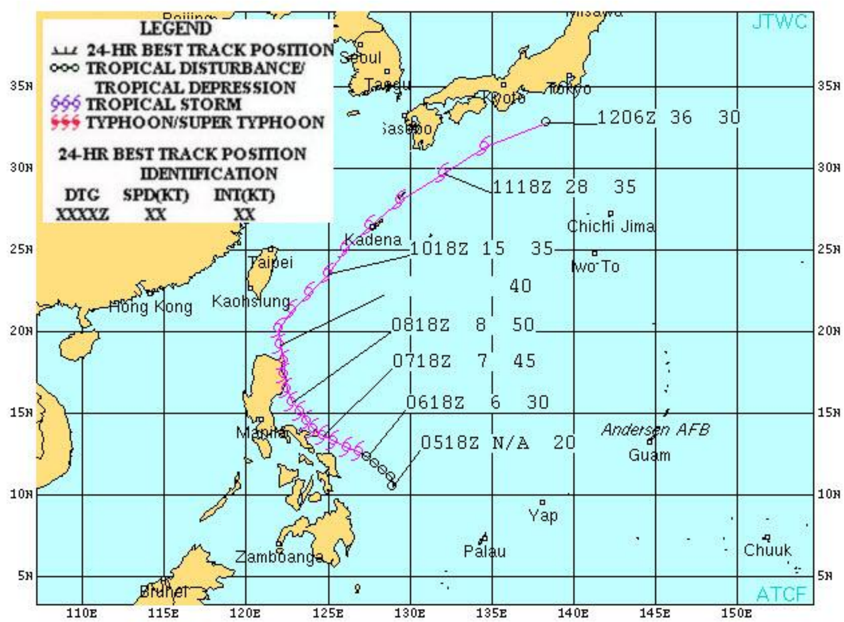
ISSUED POOR:	N/A
ISSUED FAIR:	1730Z 02 Apr 2011
FIRST TCFA:	0000Z 03 Apr 2011
FIRST WARNING:	0000Z 05 Apr 2011
LAST WARNING:	0000Z 06 Apr 2011
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	5

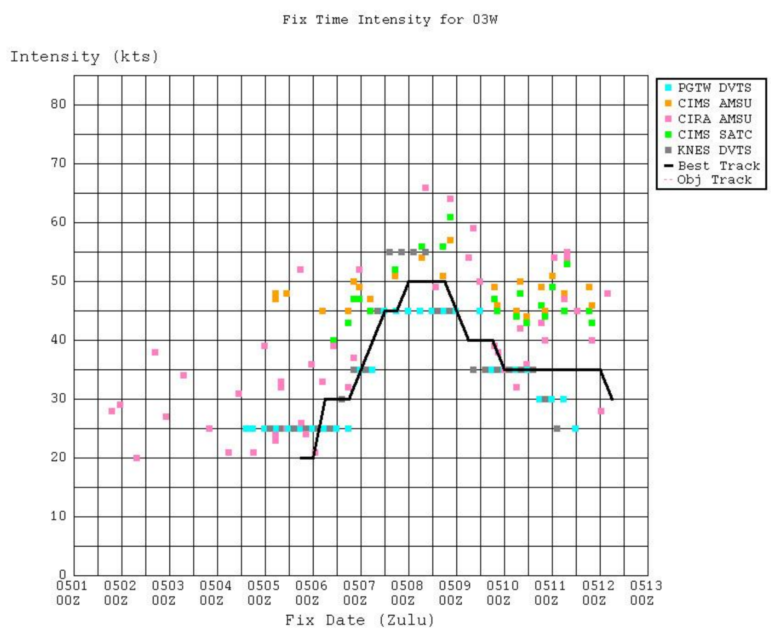




Tropical Storm 03W (Aere)

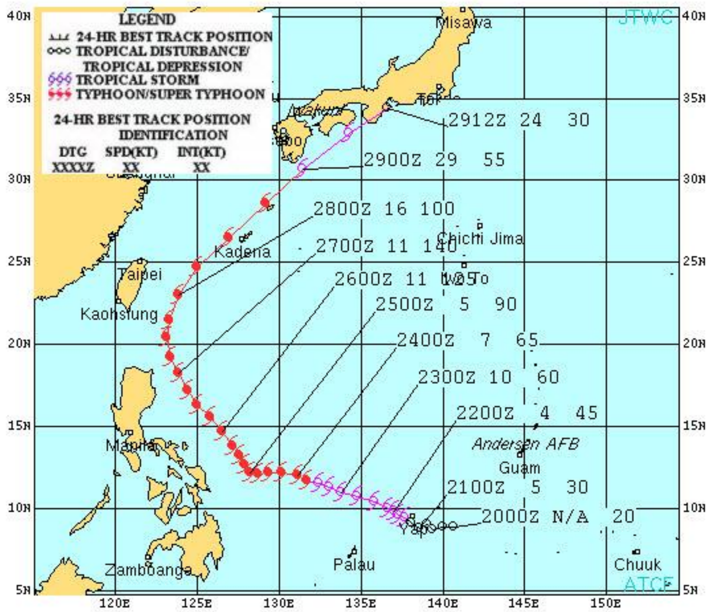
ISSUED POOR: 1800Z 03 May 2011
ISSUED FAIR: 0600Z 04 May 2011
FIRST TCFA: 1400Z 04 May 2011
FIRST WARNING: 0600Z 06 May 2011
LAST WARNING: 1800Z 11 May 2011
MAX INTENSITY: 50Kts
NUMBER OF WARNINGS: 23

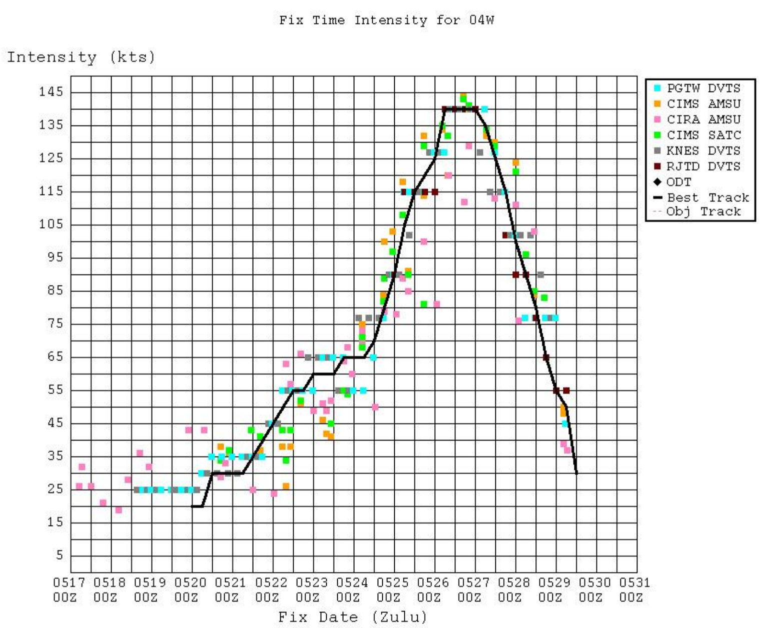




Super Typhoon 04W (Songda)

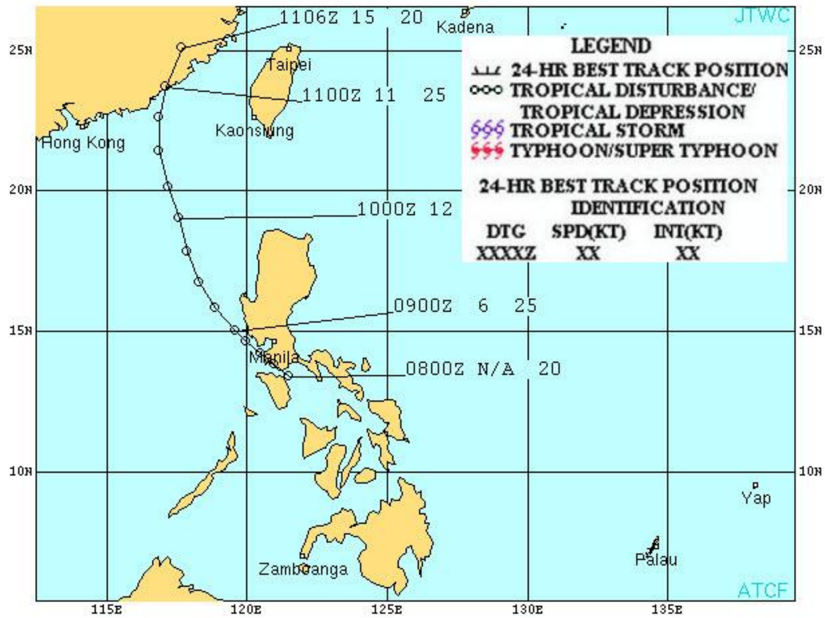
ISSUED POOR:	0330Z 19 May 2011
ISSUED FAIR:	2100Z 19 May 2011
FIRST TCFA:	0100Z 20 May 2011
FIRST WARNING:	0600Z 20 May 2011
LAST WARNING:	1200Z 29 May 2011
MAX INTENSITY:	140 Kts
NUMBER OF WARNINGS:	38

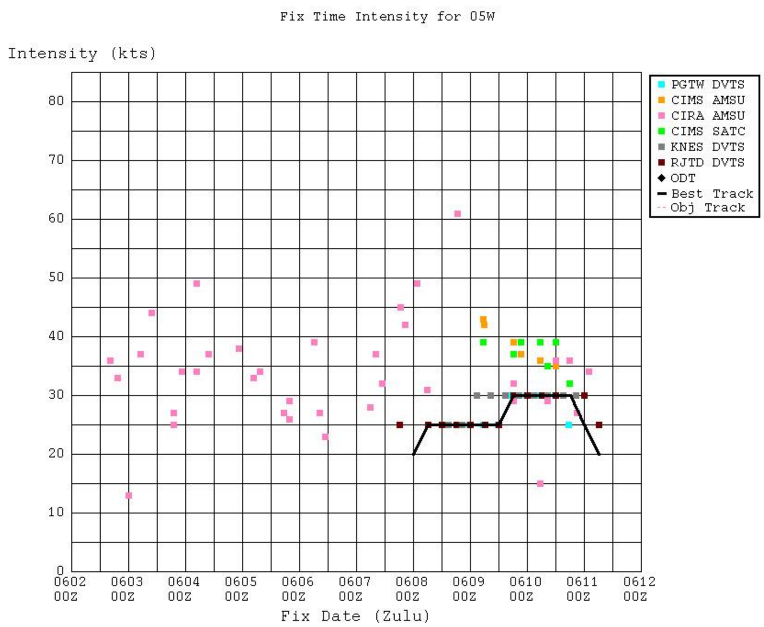




Tropical Depression 05W (Sarika)

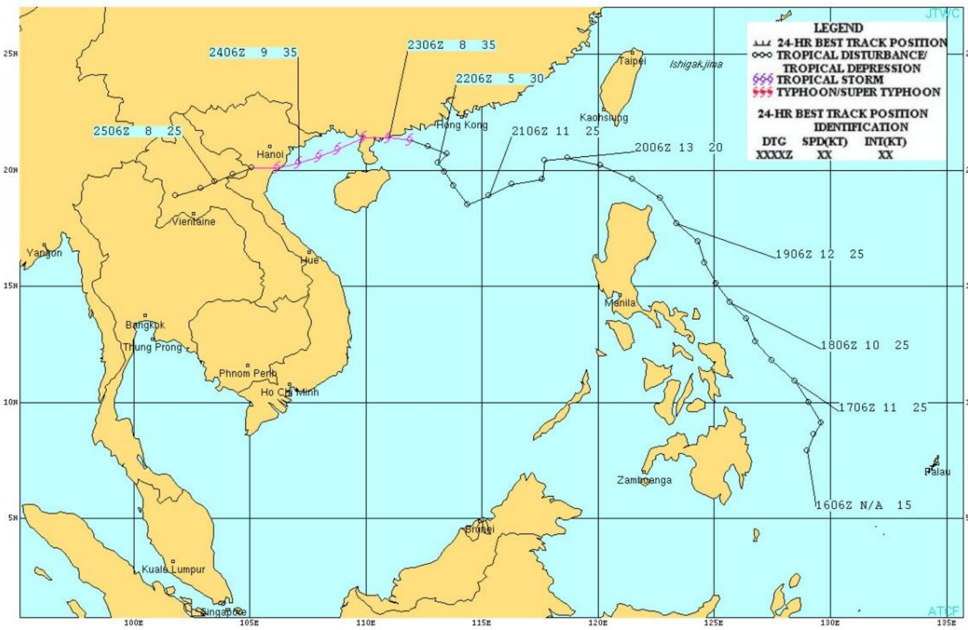
ISSUED LOW:	2100Z 06 Jun 2011
ISSUED MEDIUM:	0600Z 08 Jun 2011
FIRST TCFA:	2000Z 08 Jun 2011
FIRST WARNING:	0000Z 09 Jun 2011
LAST WARNING:	0000Z 11 Jun 2011
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	9

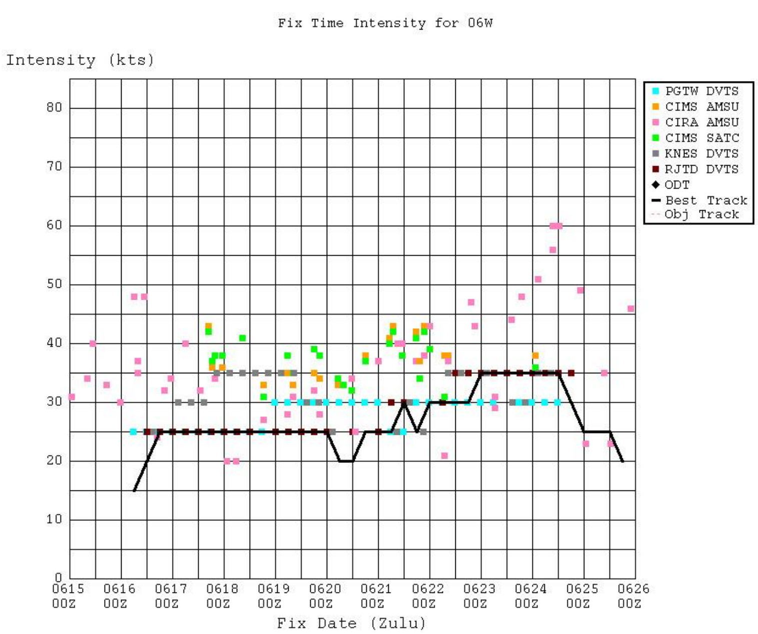




Tropical Storm 06W (Haima)

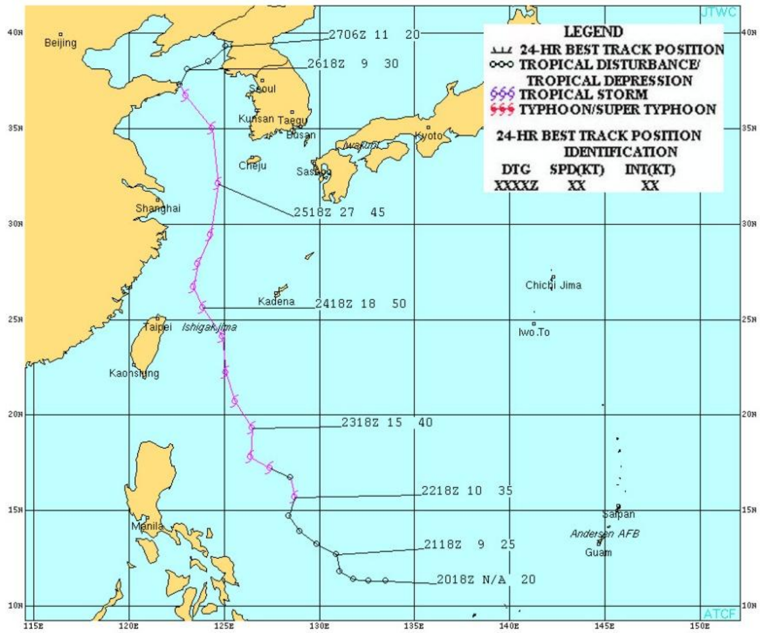
ISSUED LOW:	0600Z 15 Jun 2011
ISSUED MEDIUM:	2030Z 15 Jun 2011
FIRST TCFA:	1630Z 16 Jun 2011
FIRST WARNING:	1800Z 16 Jun 2011
LAST WARNING:	1800Z 24 Jun 2011
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	33

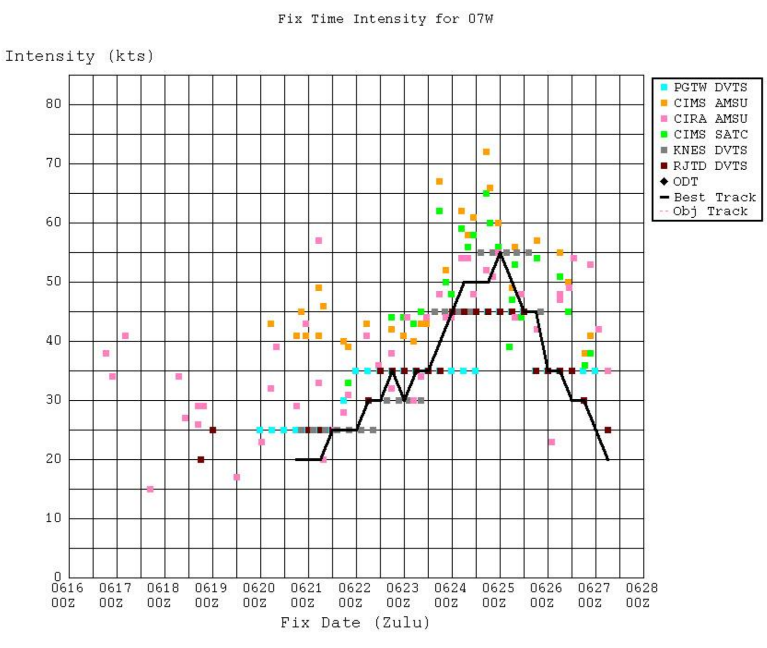




Tropical Storm 07W (Meari)

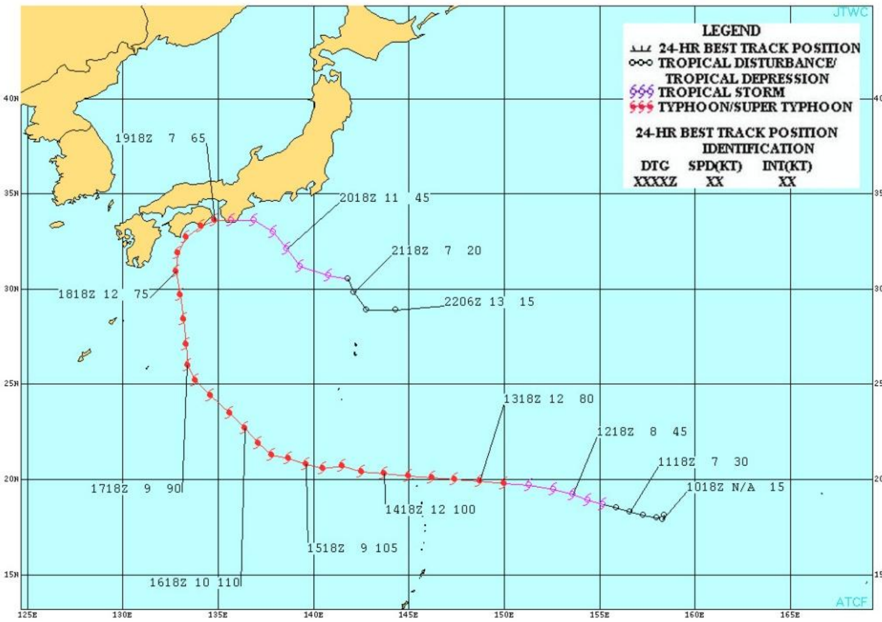
ISSUED LOW: 0600Z 18 Jun 2011
ISSUED MEDIUM: 0600Z 19 Jun 2011
FIRST TCFA: 0300Z 20 Jun 2011
FIRST WARNING: 1800Z 21 Jun 2011
LAST WARNING: 0000Z 27 Jun 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 22

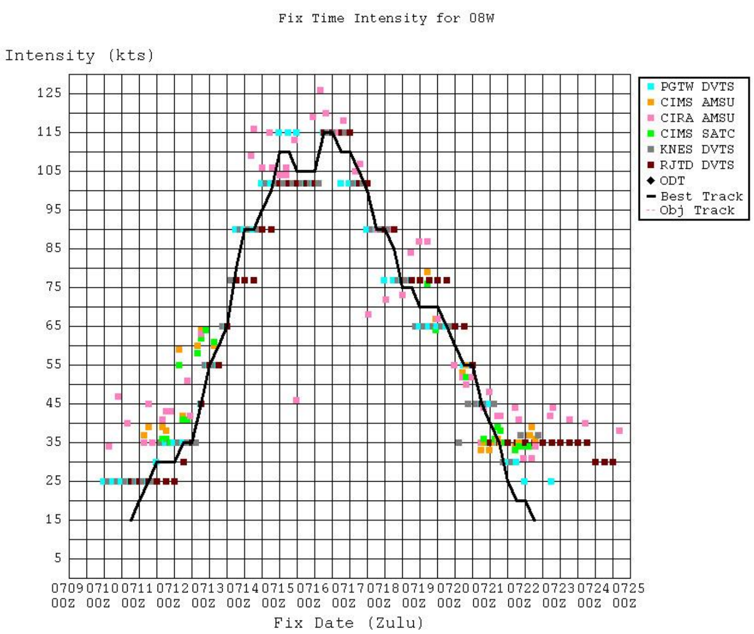




Typhoon 08W (Ma-on)

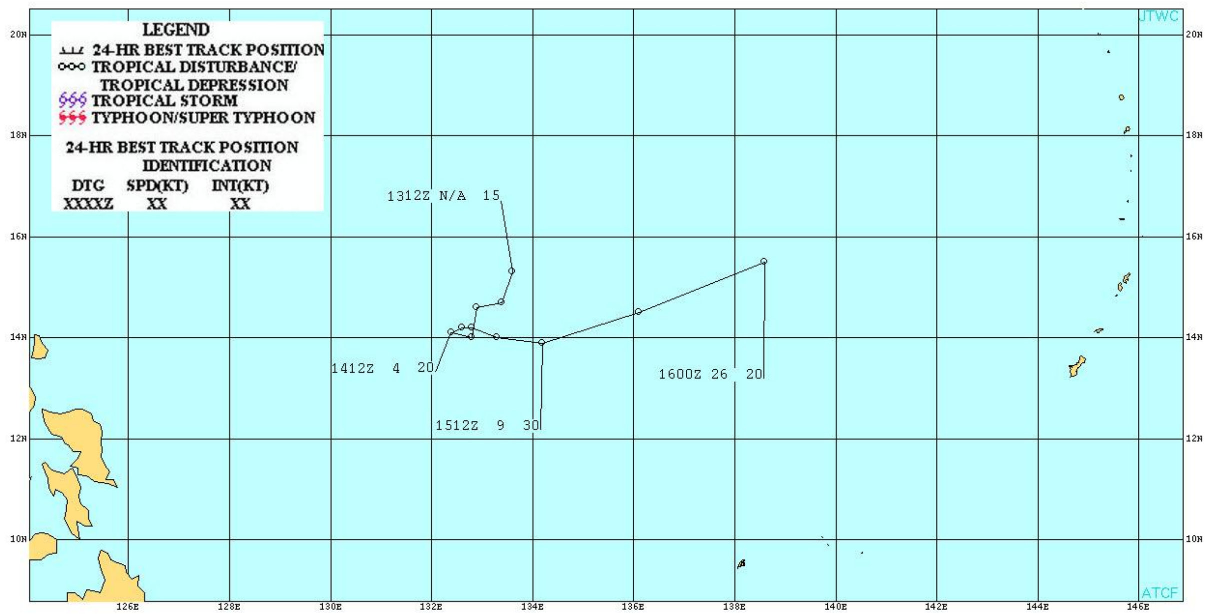
ISSUED LOW: 1800Z 09 Jul 2011
ISSUED MEDIUM: 0600Z 10 Jul 2011
FIRST TCFA: 0600Z 11 Jul 2011
FIRST WARNING: 1200Z 11 Jul 2011
LAST WARNING: 0000Z 22 Jul 2011
MAX INTENSITY: 115 Kts
NUMBER OF WARNINGS: 43

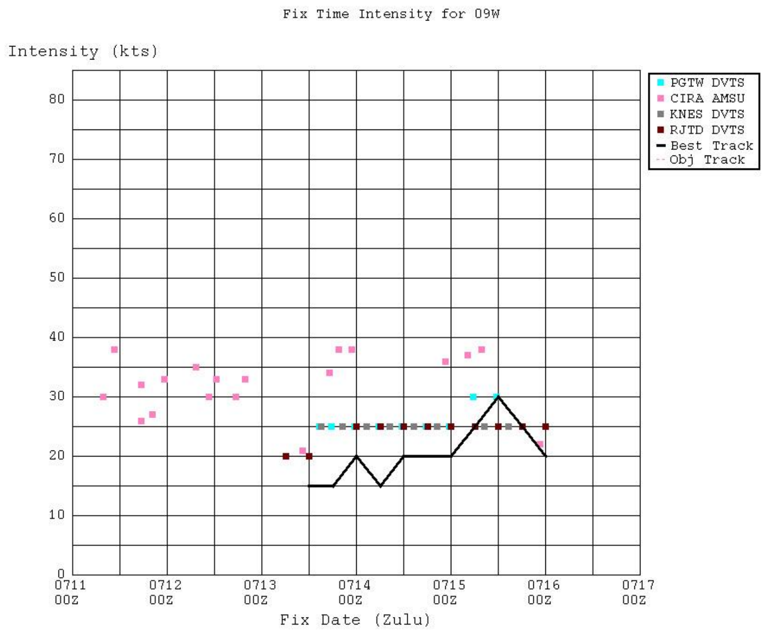




Tropical Depression 09W (Tokage)

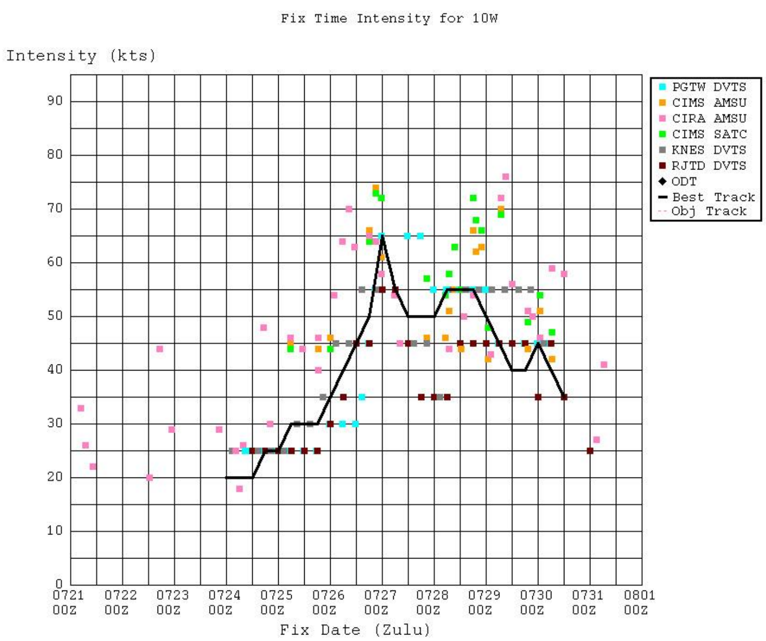
ISSUED LOW:	0600Z 11 Jul 2011
ISSUED MEDIUM:	N/A
FIRST TCFA:	0600Z 14 Jul 2011
FIRST WARNING:	0600Z 15 Jul 2011
LAST WARNING:	0000Z 16 Jul 2011
MAX INTENSITY:	30 Kts
NUMBER OF WARNINGS:	4





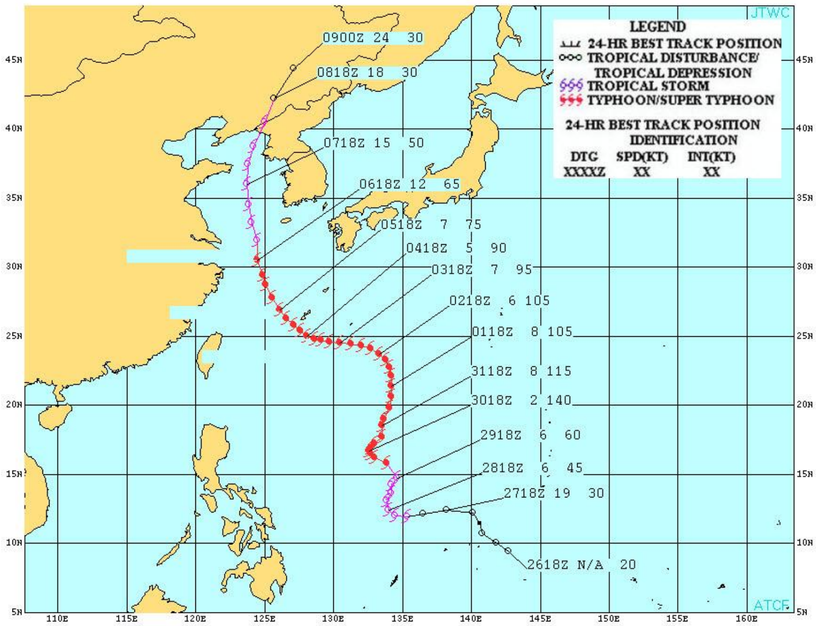
Typhoon 10W (Nock-Ten)

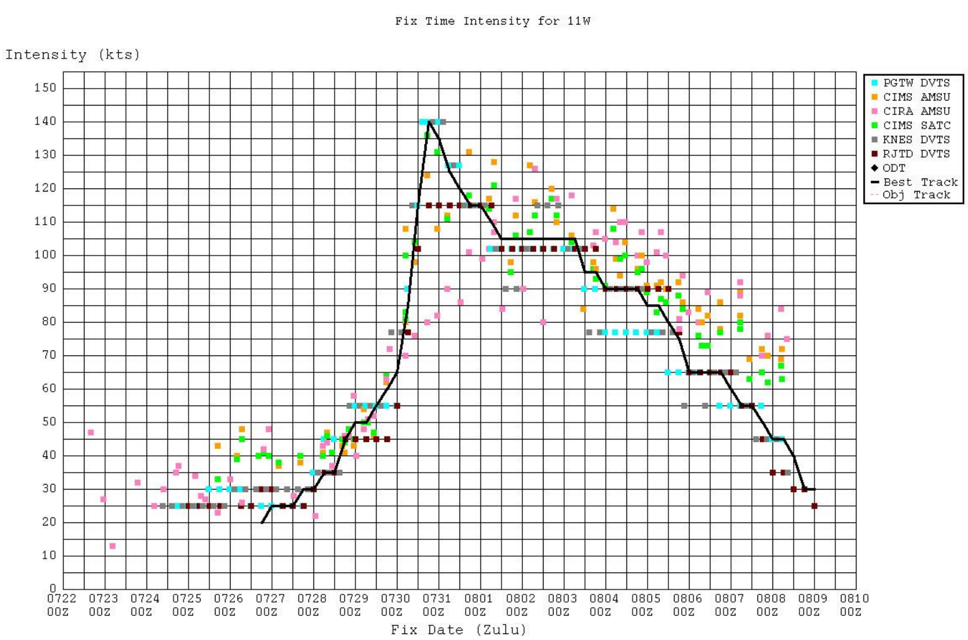
ISSUED LOW: 0600Z 22 Jul 2011
ISSUED MEDIUM: 1900Z 23 Jul 2011
FIRST TCFA: 0630Z 24 Jul 2011
FIRST WARNING: 1800Z 24 Jul 2011
LAST WARNING: 1200Z 30 Jul 2011
MAX INTENSITY: 65 Kts
NUMBER OF WARNINGS: 24



Super Typhoon 11W (Muifa)

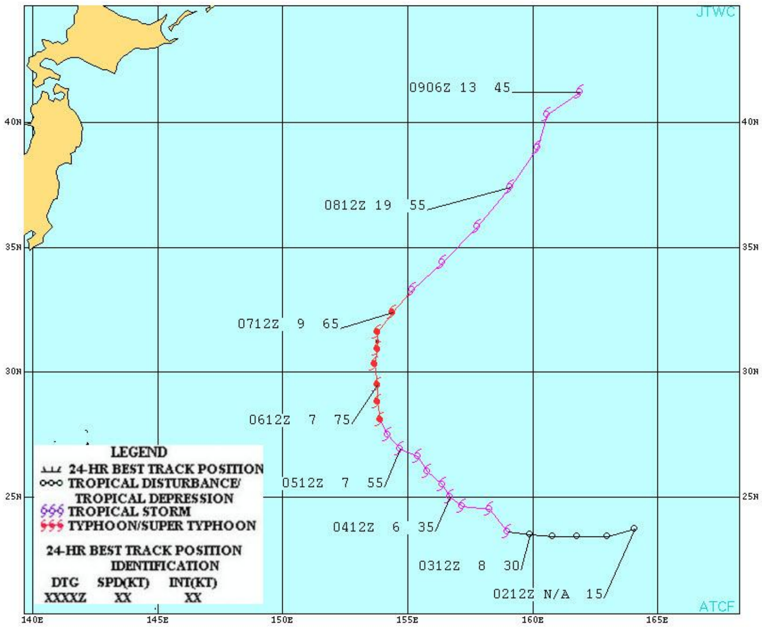
ISSUED LOW: 1930Z 23 Jul 2011
ISSUED MEDIUM: 0600Z 24 Jul 2011
FIRST TCFA: 2300Z 24 Jul 2011
FIRST WARNING: 1200Z 25 Jul 2011
LAST WARNING: 1200Z 08 Aug 2011
MAX INTENSITY: 140 Kts
NUMBER OF WARNINGS: 57

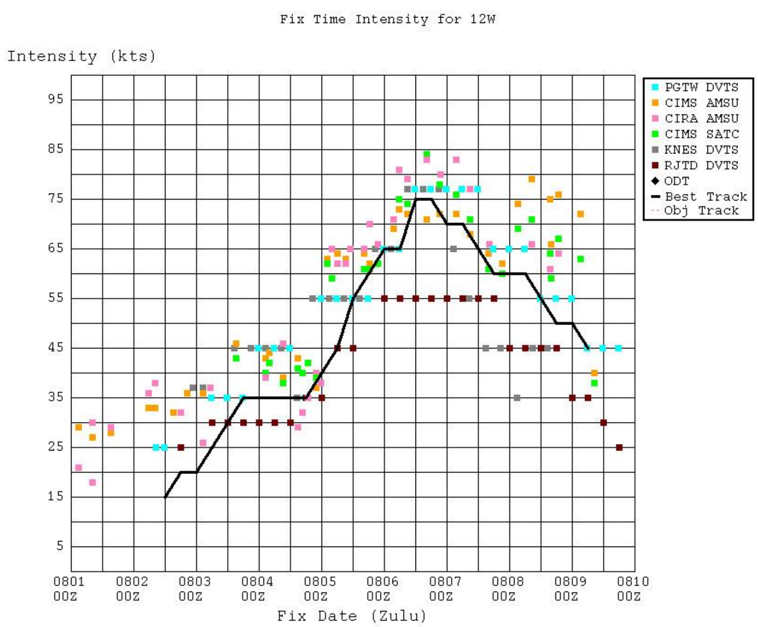




Typhoon 12W (Merbok)

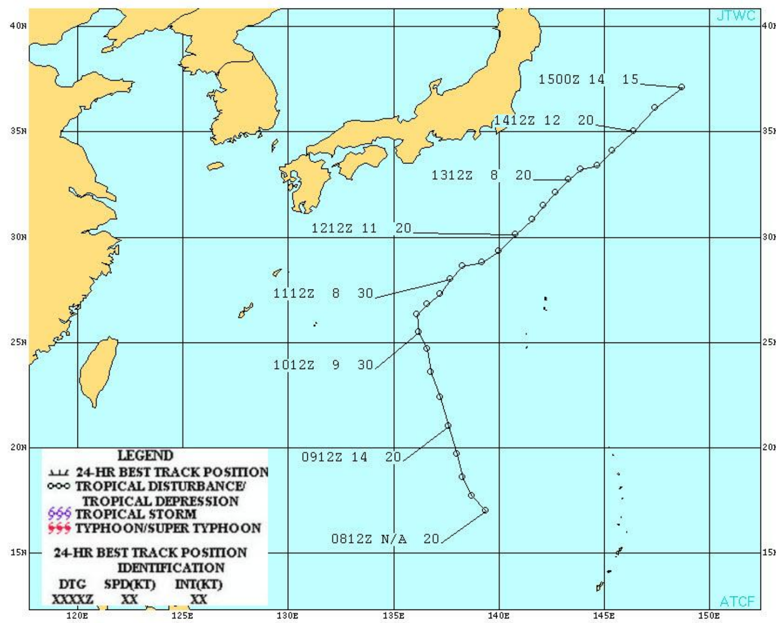
ISSUED LOW:	0030Z 02 Aug 2011
ISSUED MEDIUM:	0600Z 02 Aug 2011
FIRST TCFA:	N/A
FIRST WARNING:	0600Z 03 Aug 2011
LAST WARNING:	1800Z 08 Aug 2011
MAX INTENSITY:	75 Kts
NUMBER OF WARNINGS:	23

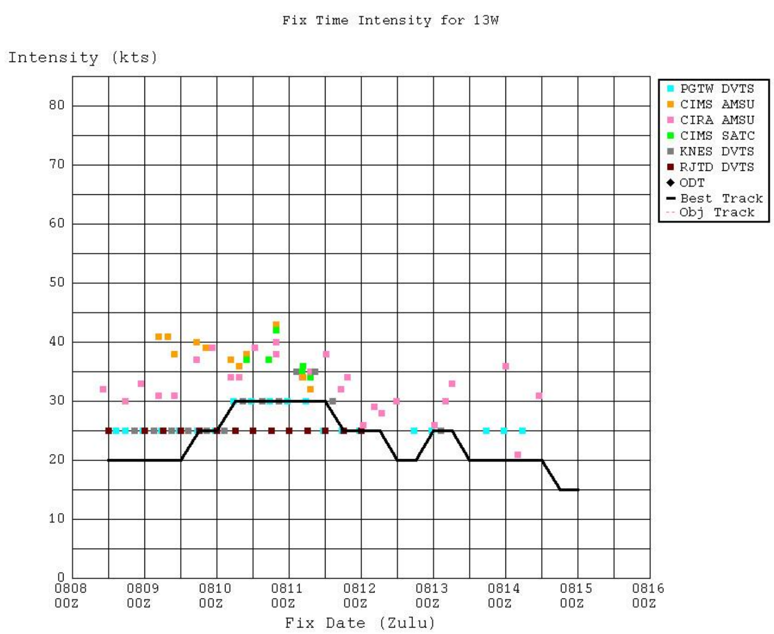




Tropical Depression 13W

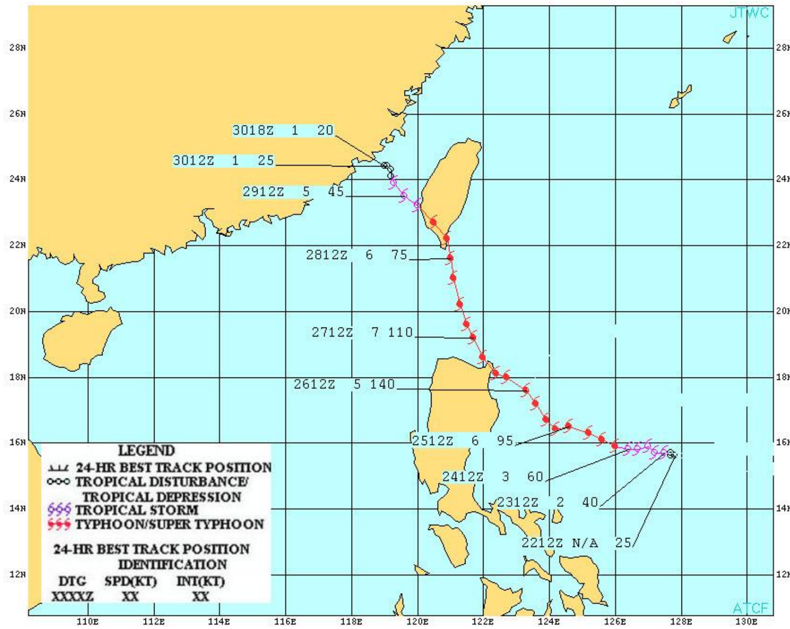
ISSUED LOW: N/A
ISSUED MEDIUM: 1730Z 08 Aug 2011
FIRST TCFA: 2200Z 08 Aug 2011
FIRST WARNING: 0000Z 10 Aug 2011
LAST WARNING: 0000Z 12 Aug 2011
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 9

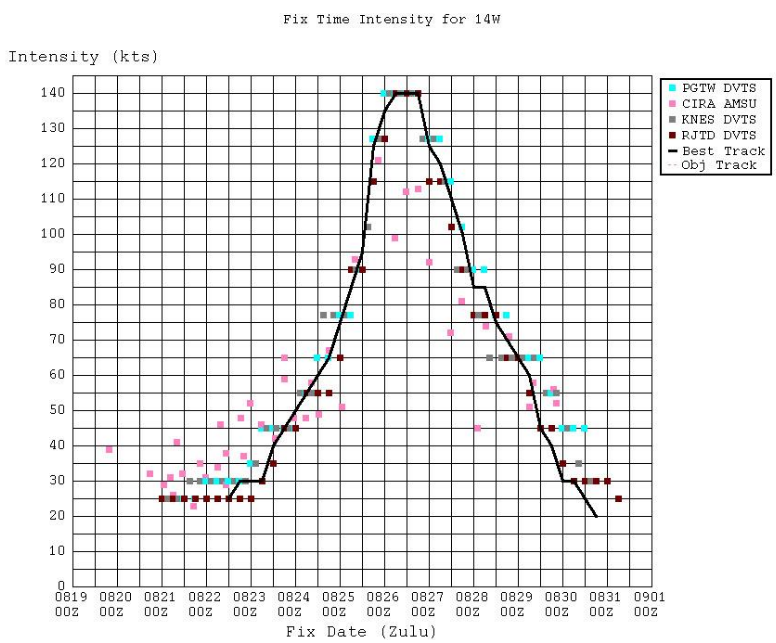




Super Typhoon 14W (Nanmadol)

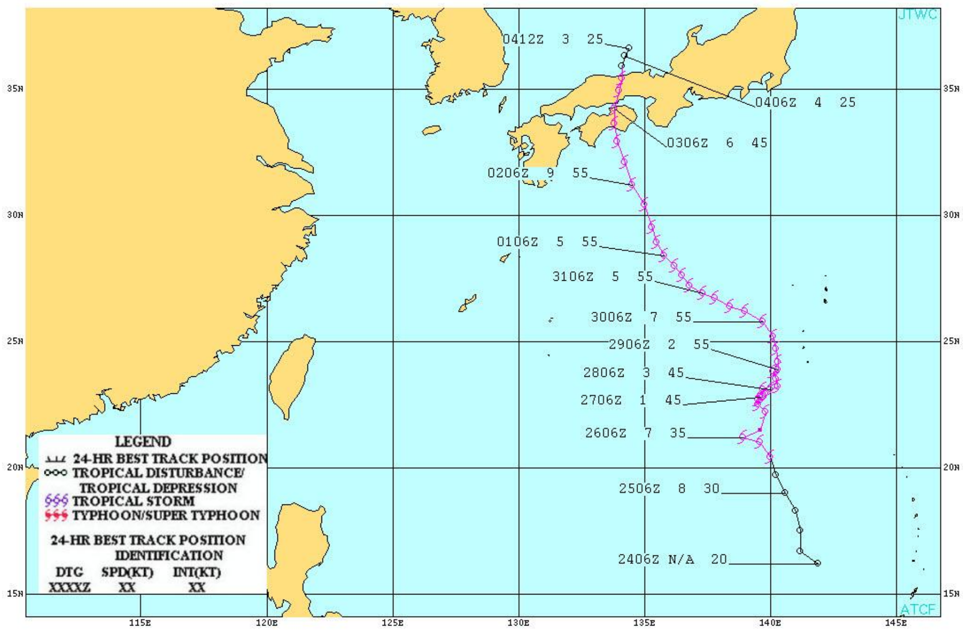
ISSUED LOW: 0600Z 20 Aug 2011
ISSUED MEDIUM: 2000Z 20 Aug 2011
FIRST TCFA: 1400Z 21 Aug 2011
FIRST WARNING: 1800Z 22 Aug 2011
LAST WARNING: 0000Z 31 Aug 2011
MAX INTENSITY: 140 Kts
NUMBER OF WARNINGS: 35

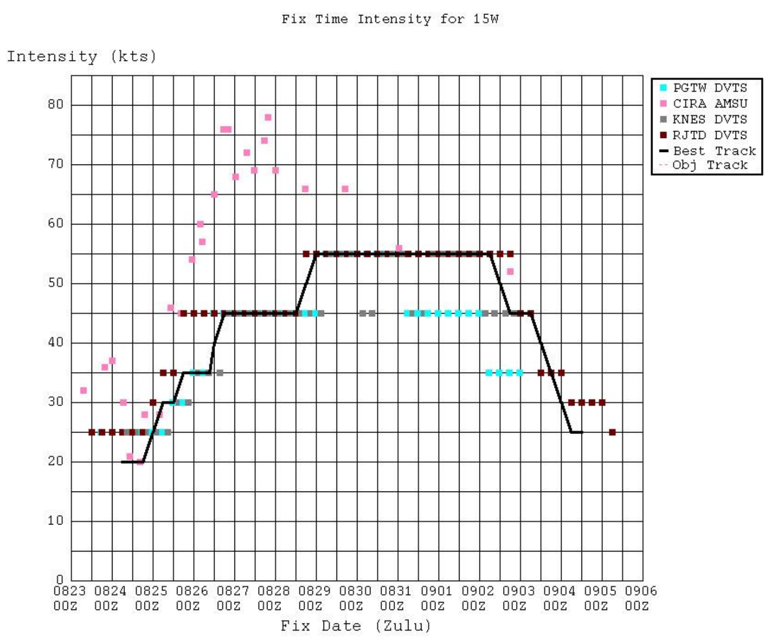




Tropical Storm 15W (Talas)

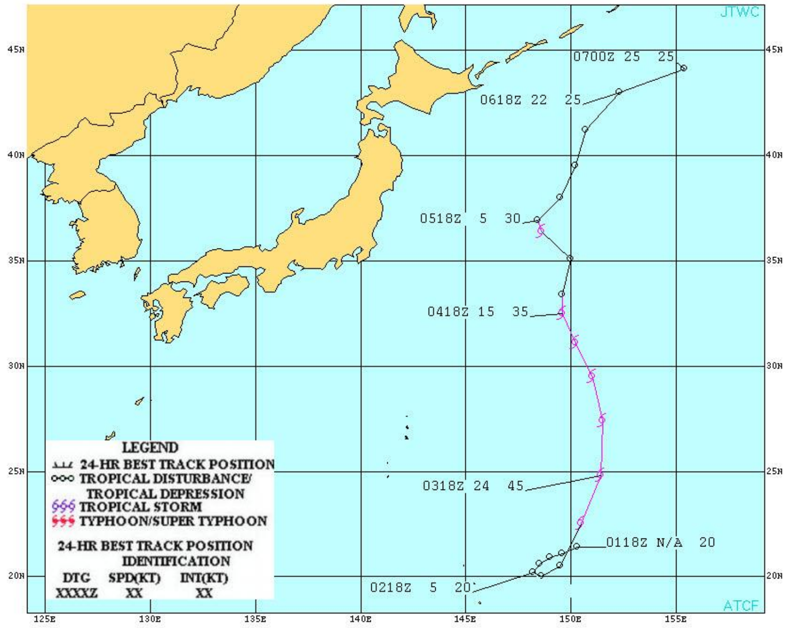
ISSUED LOW: N/A
ISSUED MEDIUM: 2300Z 22 Aug 2011
FIRST TCFA: 1530Z 23 Aug 2011
FIRST WARNING: 0600Z 25 Aug 2011
LAST WARNING: 0000Z 04 Sep 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 40

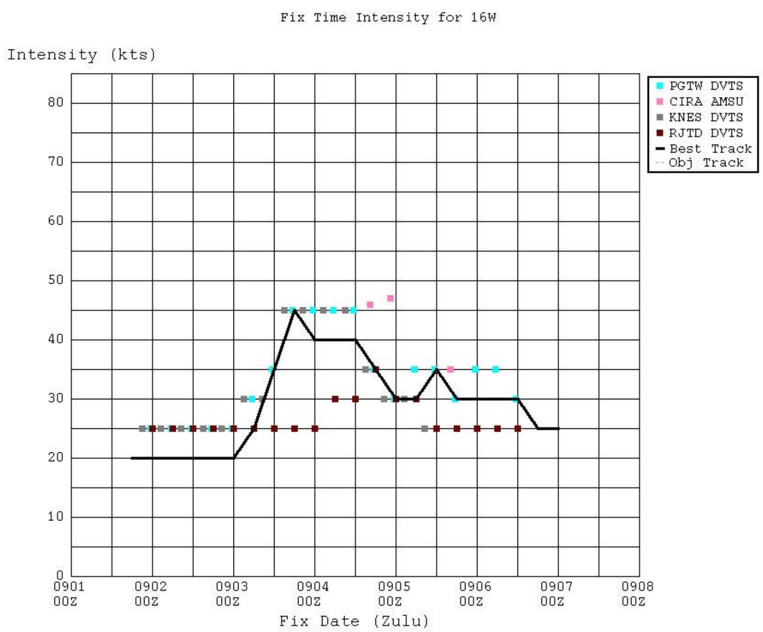




Tropical Storm 16W (Noru)

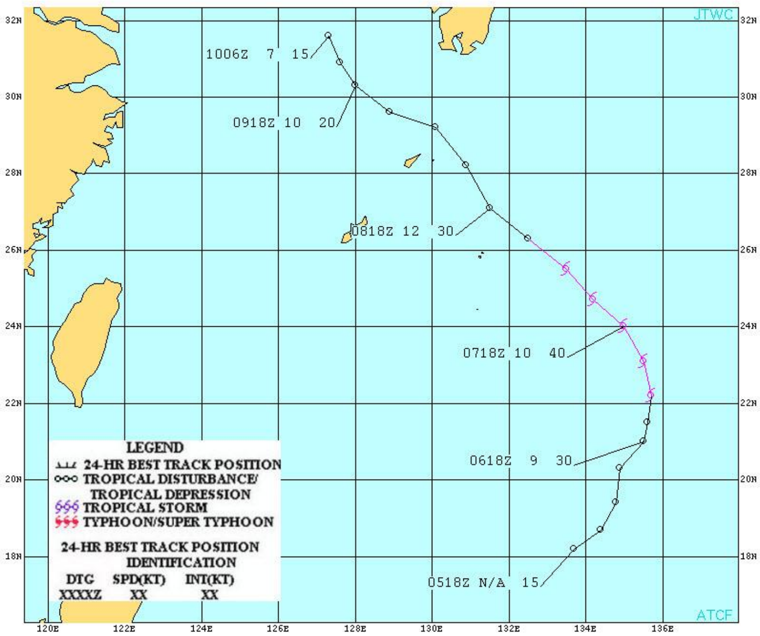
ISSUED LOW:	1500Z 01 Sep 2011
ISSUED MEDIUM:	0600Z 02 Sep 2011
FIRST TCFA:	1000Z 02 Sep 2011
FIRST WARNING:	0600Z 03 Sep 2011
LAST WARNING:	1200Z 06 Sep 2011
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	14

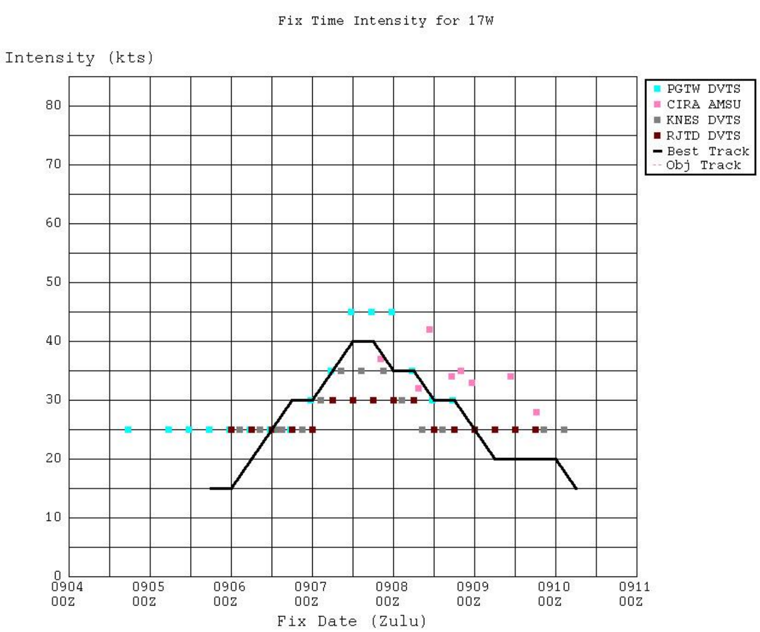




Tropical Storm 17W (Kulap)

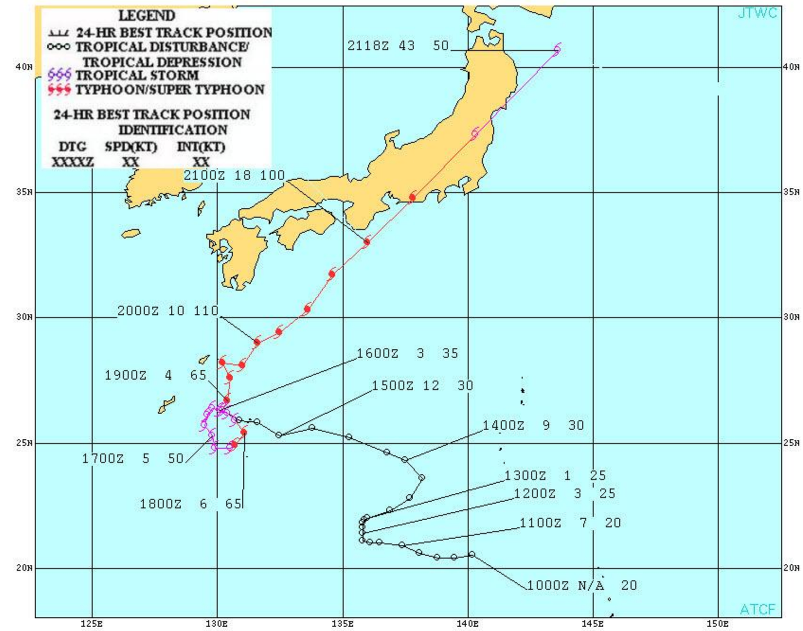
ISSUED LOW:	2200Z 04 Sep 2011
ISSUED MEDIUM:	0600Z 06 Sep 2011
FIRST TCFA:	0000Z 07 Sep 2011
FIRST WARNING:	0600Z 07 Sep 2011
LAST WARNING:	0000Z 10 Sep 2011
MAX INTENSITY:	40 Kts
NUMBER OF WARNINGS:	12



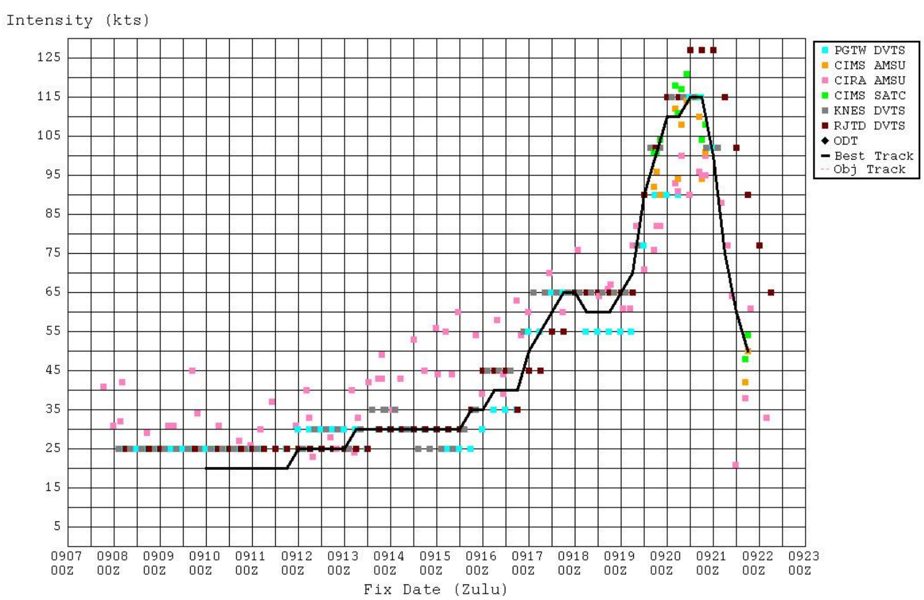


Typhoon 18W (Roke)

ISSUED LOW: 0130Z 08 Sep 2011
ISSUED MEDIUM: 0600Z 08 Sep 2011
FIRST TCFA: 2030Z 10 Sep 2011
FIRST WARNING: 1200Z 11 Sep 2011
LAST WARNING: 1200Z 21 Sep 2011
MAX INTENSITY: 115 Kts
NUMBER OF WARNINGS: 41

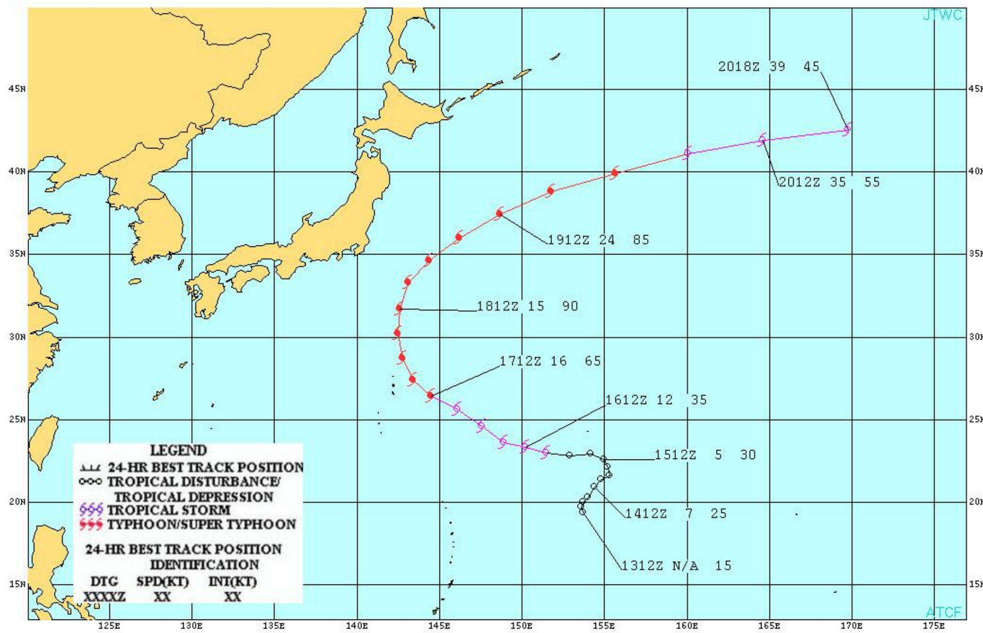


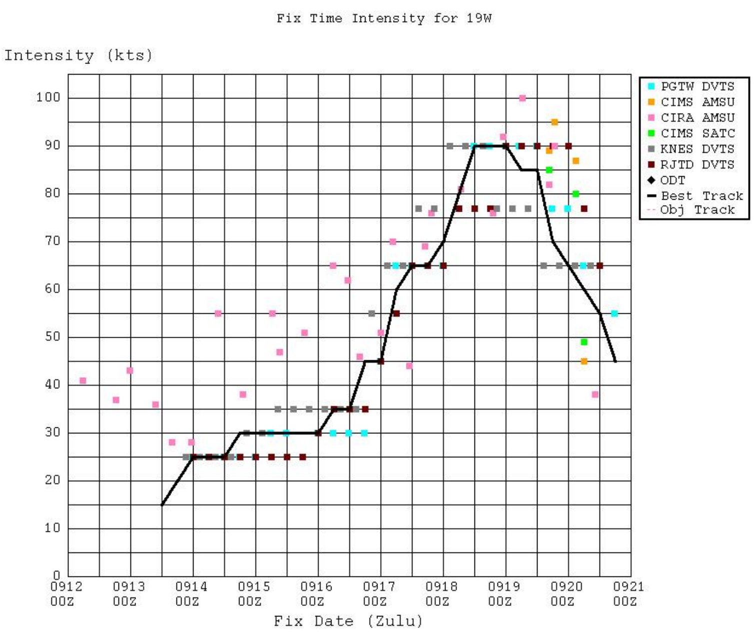
Fix Time Intensity for 18W



Typhoon 19W (Sonca)

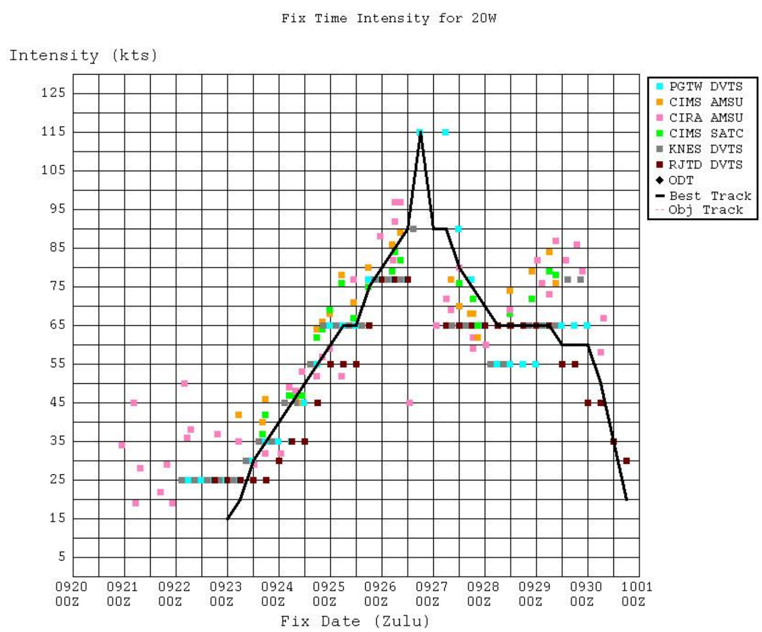
ISSUED LOW:	0000Z 13 Sep 2011
ISSUED MEDIUM:	0000Z 14 Sep 2011
FIRST TCFA:	1430Z 14 Sep 2011
FIRST WARNING:	1800Z 14 Sep 2011
LAST WARNING:	0000Z 20 Sep 2011
MAX INTENSITY:	90 Kts
NUMBER OF WARNINGS:	22





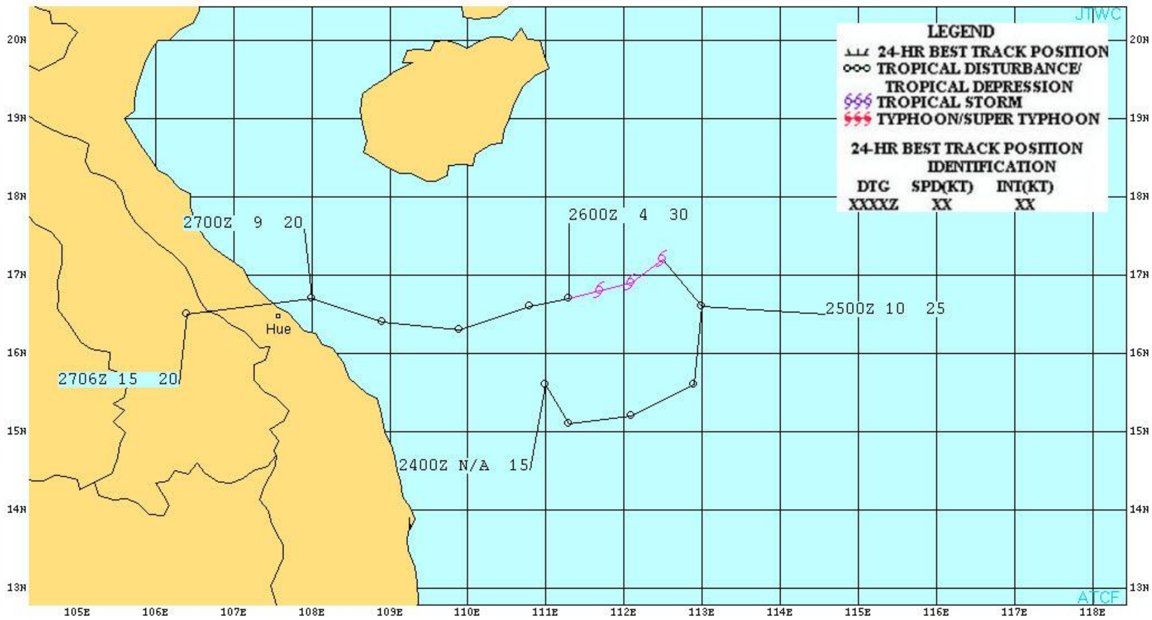
Typhoon 20W (Nesat)

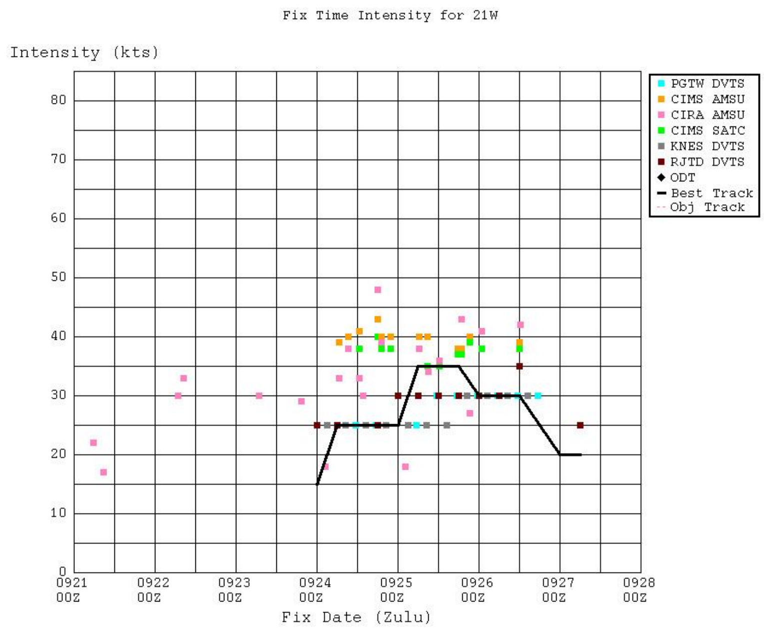
ISSUED LOW:	0600Z 21 Sep 2011
ISSUED MEDIUM:	0130Z 22 Sep 2011
FIRST TCFA:	2000Z 22 Sep 2011
FIRST WARNING:	1200Z 23 Sep 2011
LAST WARNING:	1200Z 30 Sep 2011
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	29



Tropical Storm 21W (Haitang)

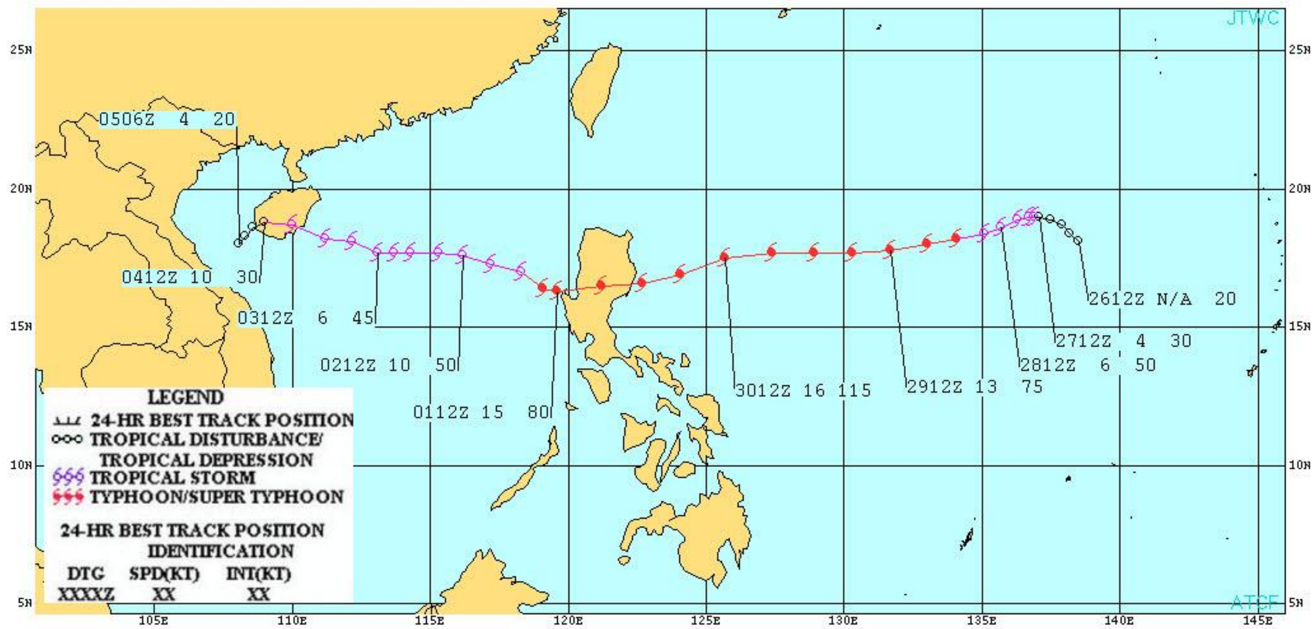
ISSUED LOW: 1500Z 21 Sep 2011
ISSUED MEDIUM: N/A
FIRST TCFA: 0500Z 24 Sep 2011
FIRST WARNING: 1200Z 24 Sep 2011
LAST WARNING: 1800Z 26 Sep 2011
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 10

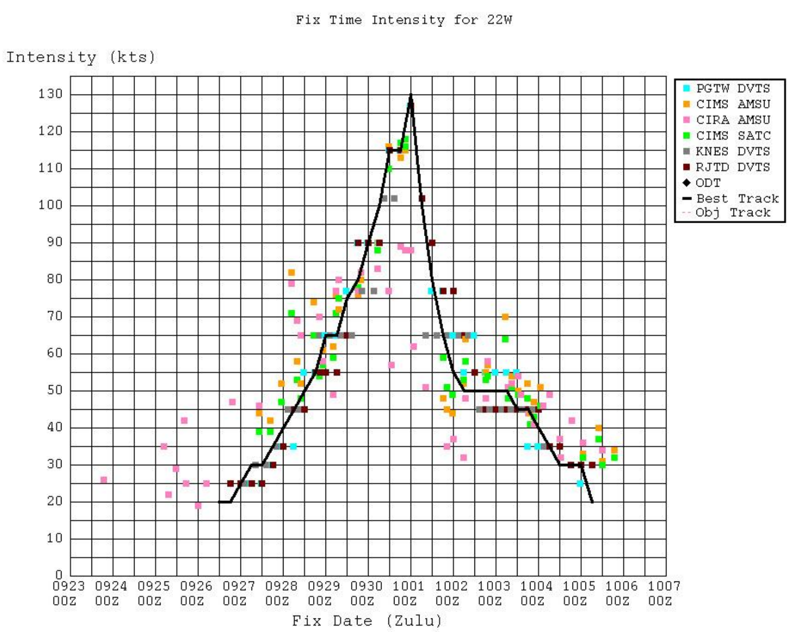




Super Typhoon 22W (Nalgae)

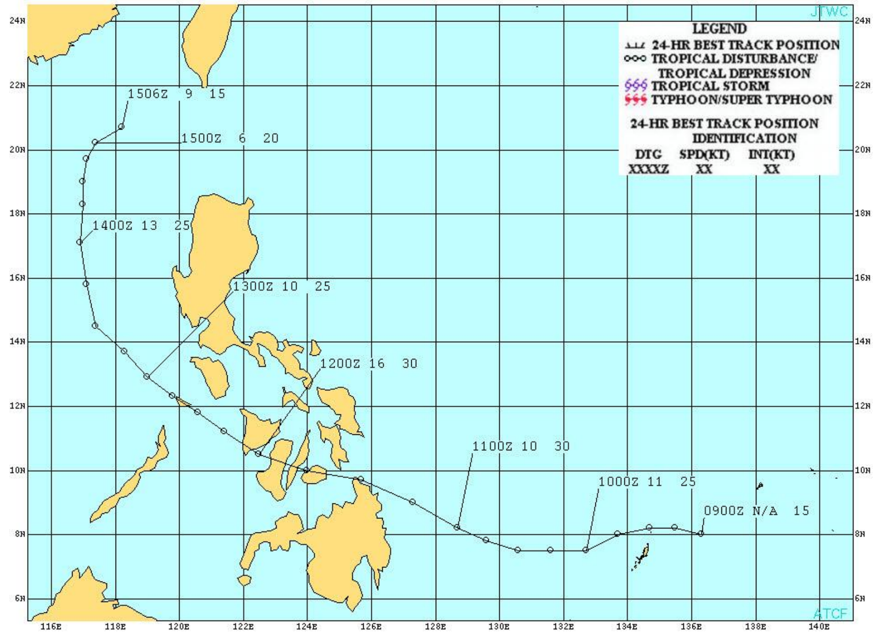
ISSUED LOW:	2330Z 26 Sep 2011
ISSUED MEDIUM:	N/A
FIRST TCFA:	0600Z 27 Sep 2011
FIRST WARNING:	0600Z 27 Sep 2011
LAST WARNING:	1200Z 05 Oct 2011
MAX INTENSITY:	130 Kts
NUMBER OF WARNINGS:	34

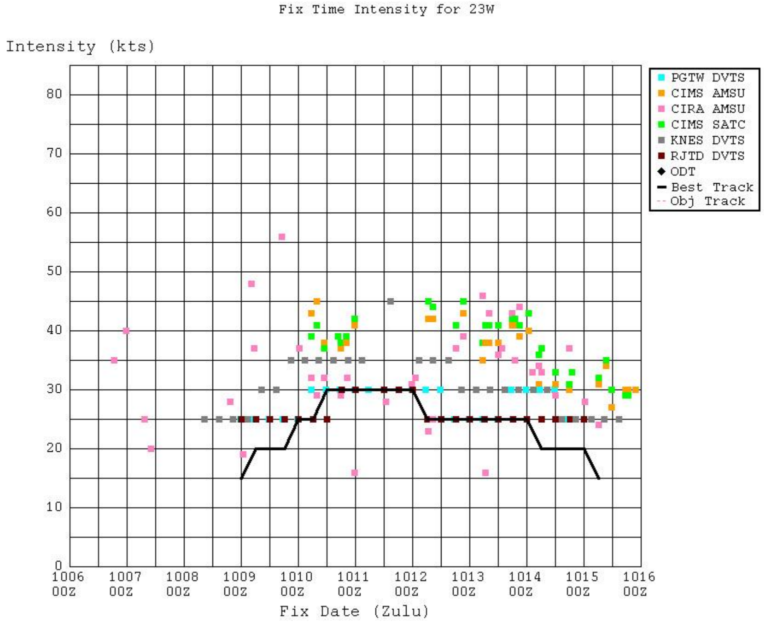




Tropical Depression 23W (Banyan)

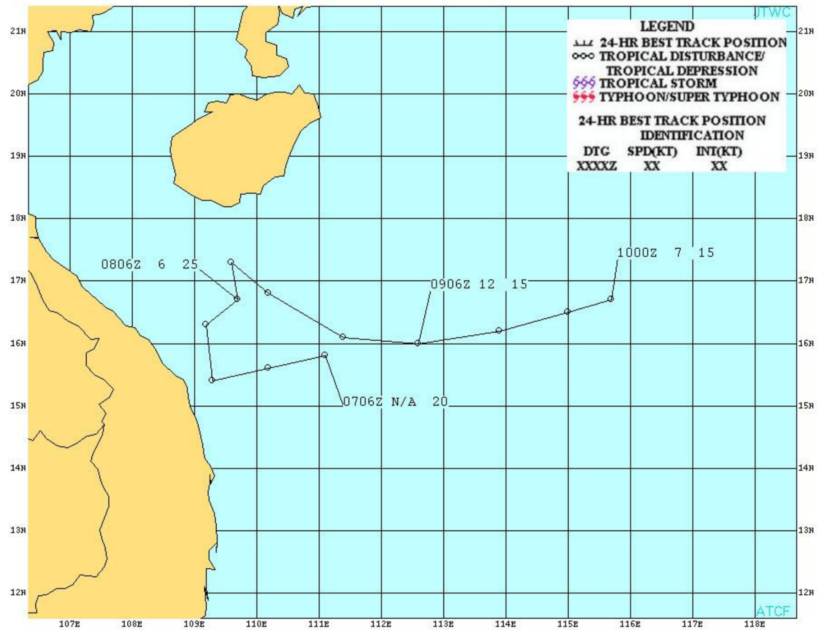
ISSUED LOW: 0600Z 07 Oct 2011
ISSUED MEDIUM: 2100Z 08 Oct 2011
FIRST TCFA: 1800Z 09 Oct 2011
FIRST WARNING: 0000Z 10 Oct 2011
LAST WARNING: 1800Z 14 Oct 2011
MAX INTENSITY: 30 Kts
NUMBER OF WARNINGS: 20

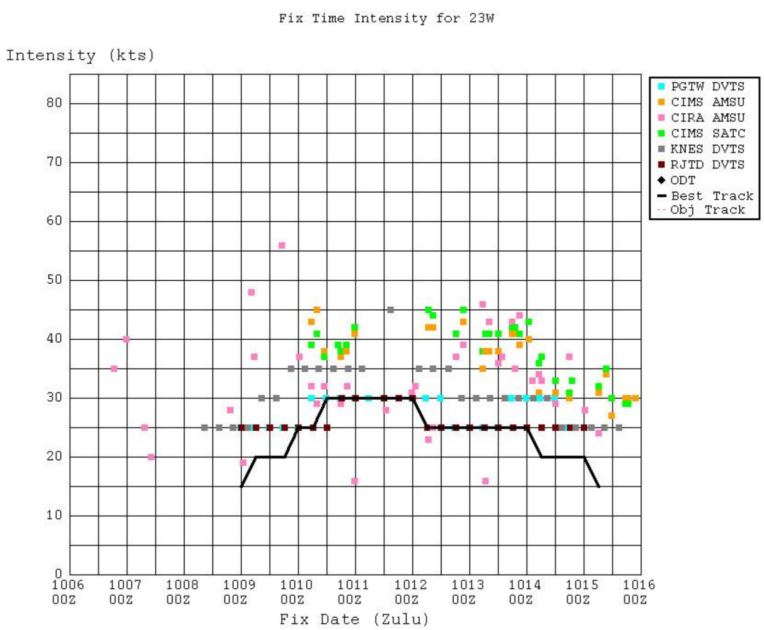




Tropical Depression 24W

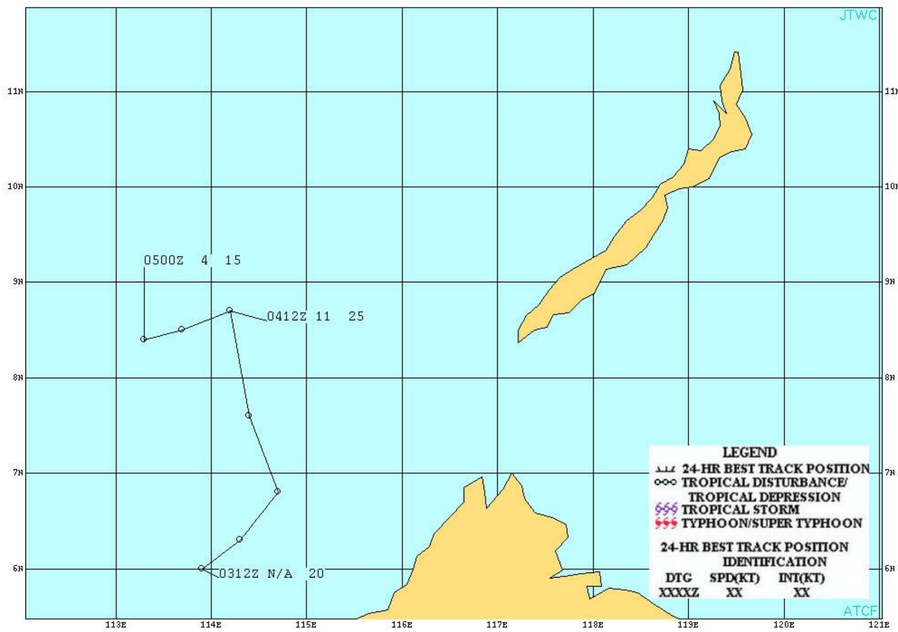
ISSUED LOW: 0600Z 05 Nov 2011
ISSUED MEDIUM: 0030Z 06 Nov 2011
FIRST TCFA: 2230Z 06 Nov 2011
FIRST WARNING: 0600Z 07 Nov 2011
LAST WARNING: 0600Z 08 Nov 2011
MAX INTENSITY: 25 Kts
NUMBER OF WARNINGS: 5

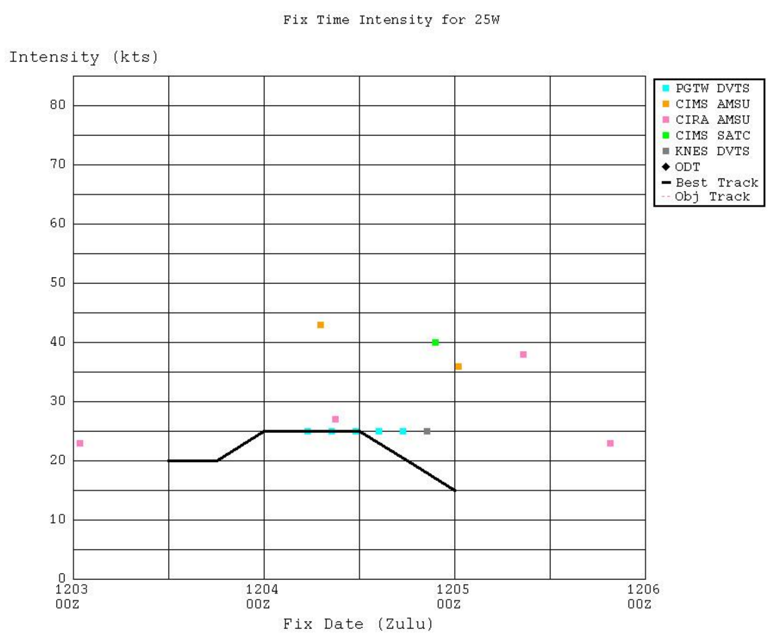




Tropical Depression 25W

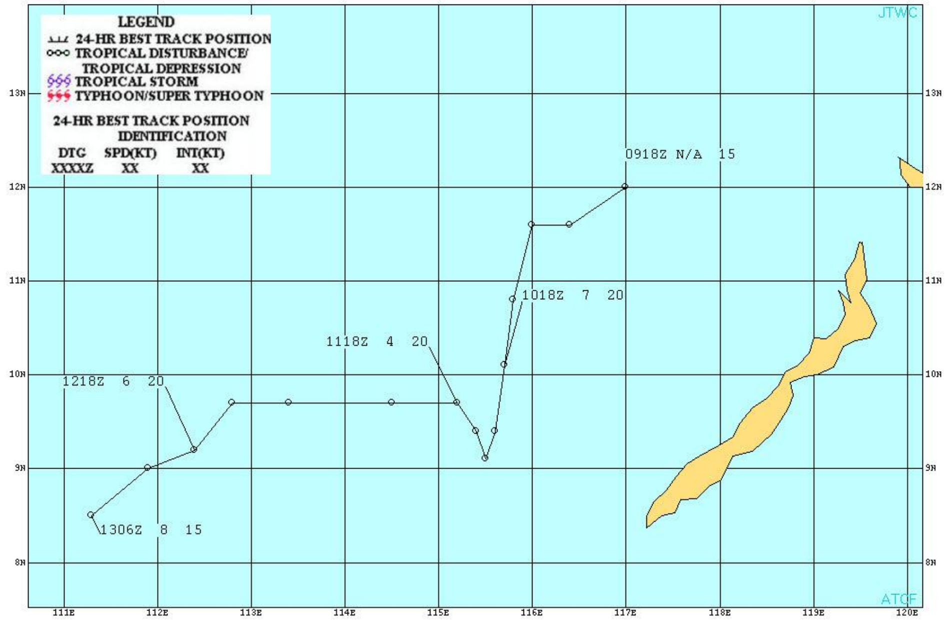
ISSUED LOW:	N/A
ISSUED MEDIUM:	2330Z 03 Dec 2011
FIRST TCFA:	0800Z 04 Dec 2011
FIRST WARNING:	1200Z 04 Dec 2011
LAST WARNING:	0000Z 05 Dec 2011
MAX INTENSITY:	25 Kts
NUMBER OF WARNINGS:	3

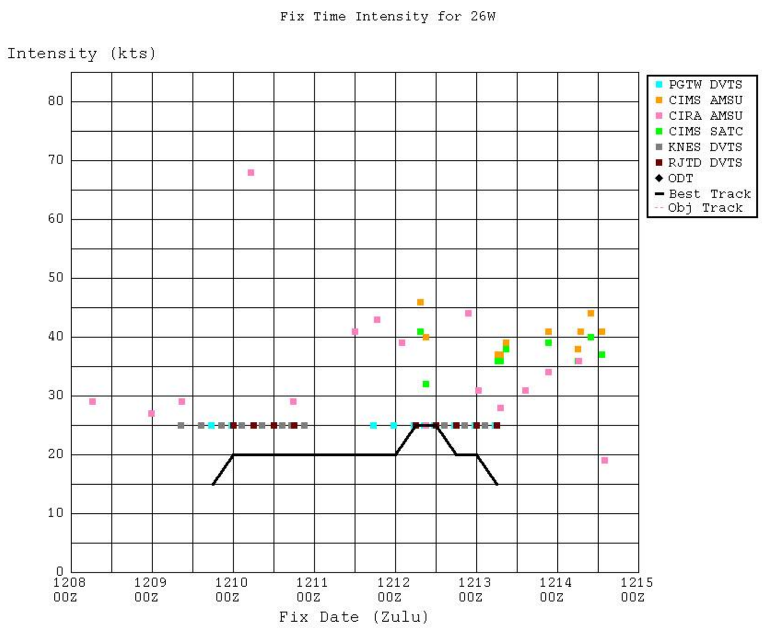




Tropical Depression 26W

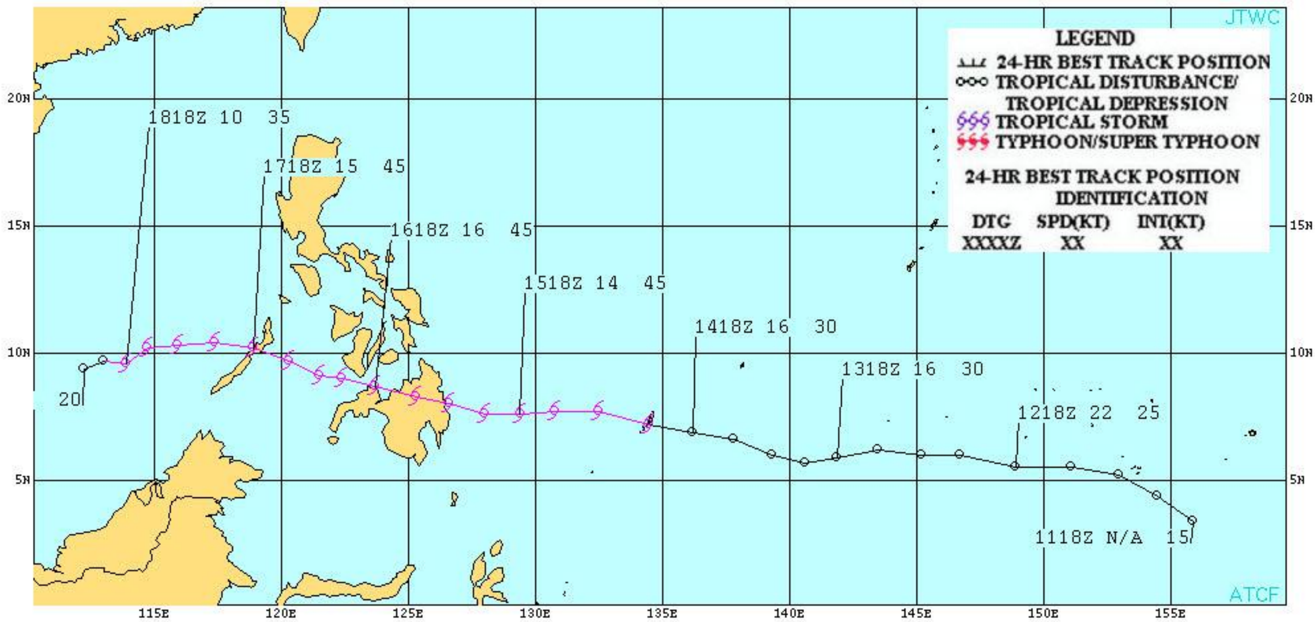
ISSUED LOW: 1000Z 09 Dec 2011
ISSUED MEDIUM: 1500Z 09 Dec 2011
FIRST TCFA: 0900Z 10 Dec 2011
FIRST WARNING: 0600Z 12 Dec 2011
LAST WARNING: 1200Z 13 Dec 2011
MAX INTENSITY: 25 Kts
NUMBER OF WARNINGS: 6

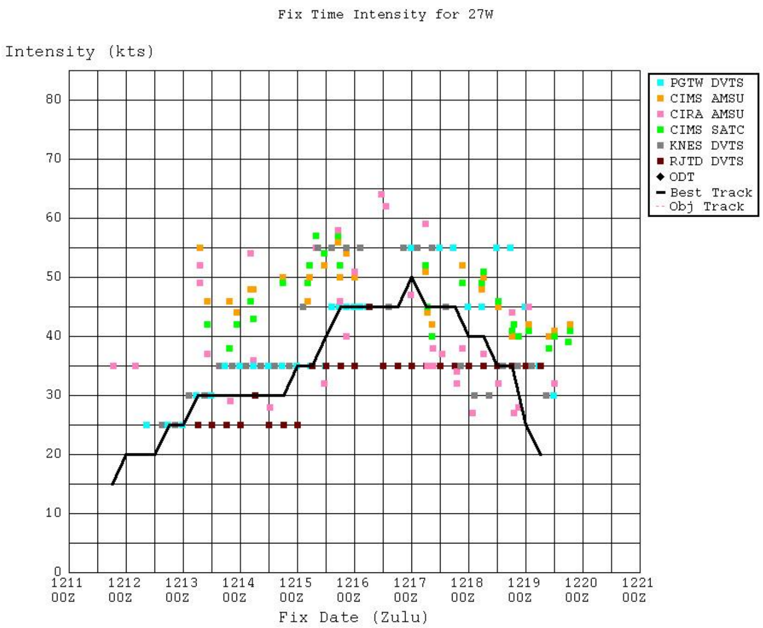




Tropical Storm 27W (Washi)

ISSUED LOW: N/A
ISSUED MEDIUM: 2200Z 12 Dec 2011
FIRST TCFA: 0230Z 13 Dec 2011
FIRST WARNING: 0900Z 13 Dec 2011
LAST WARNING: 1200Z 13 Dec 2011
MAX INTENSITY: 50 Kts
NUMBER OF WARNINGS: 26





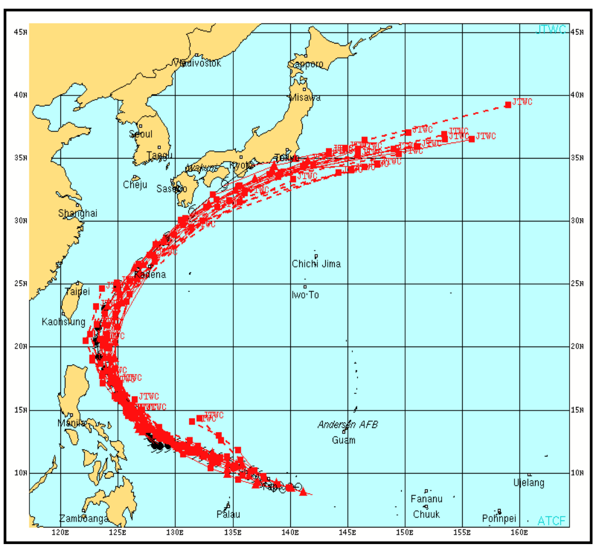
This section highlights operationally or meteorologically significant cyclones noted within the JTWC Area of Responsibility. Details are provided to describe operational impacts from tropical cyclones as well as significant challenges and/or shortfalls in the TC warning system. These details are provided to serve as input for future research and development efforts.

Super Typhoon 04W (Songda) proved to be a relatively easy forecast event however, extensive damage and fatalities occurred on the island of Okinawa.

Super Typhoon 14W (Nanmadol) was not forecast well for either track or intensity. Forecasts were created with the expectation that direct-cylone interaction would occur with TS 15W (Talas) however, the interactions never occurred or were at the least very minimal. This non-interaction resulted in STY 14W moving west vice east and rapidly intensifying. Post analysis suggests that the minimal interaction of both STY 14W and TS 15W with the Tropical Upper Tropospheric Trough may have been a factor in this event.

Super Typhoon 04W (Songda)

Super Typhoon (STY) 04W (Songda) formed east of Palau in late May and rapidly intensified to a peak of 140 knots as it re-curved east of the Philippines and Taiwan. Songda subsequently weakened to 80 knot intensity under the influence of increasing vertical wind shear as it passed approximately 40 nautical miles to the north-northwest of Okinawa at 28/1400Z. The cyclone brushed along the southern coast of Honshu before completing extra-tropical transition and accelerating eastward into the central North Pacific as a baroclinic low pressure system.



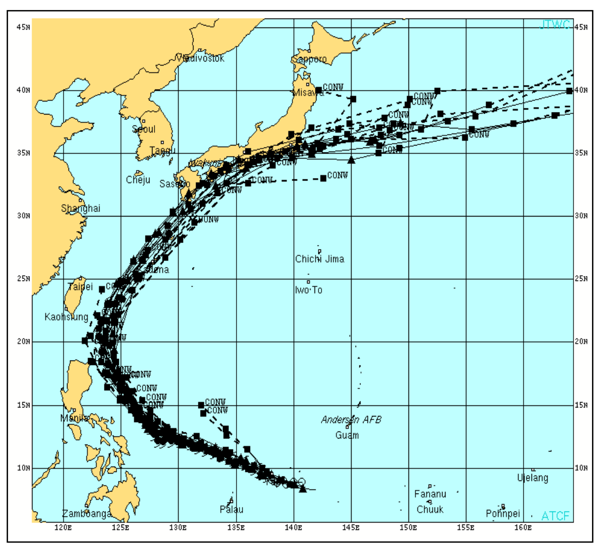


Figure 1-6. All JTWC STY04W official track forecasts. Figure 1-7. All model consensus (CONW) forecasts for STY 04W.

STY 04W followed a highly predictable track around the periphery of a persistent subtropical steering ridge and into the mid-latitude westerly flow pattern. JTWC official track forecasts for the cyclone were accurate and consistent (Figure 1-6) while the numerical model consensus forecasts were equally consistent (Figure 1-7). Consequently, forecast track error (FTE) statistics for 04W were 50-67% lower than the 2011 JTWC average FTE from tau 72 to tau 120

(Table 1-5). JTWC capitalized on a noted slow bias in numerical model track forecasts for recurving cyclones that clear the steering ridge axis by forecasting more rapid northeastward post-recurvature acceleration than CONW (see tau 96 and tau 120 statistics for JTWC and CONW in Table 1-5).

Although overall track forecast error statistics for STY 04W are quite impressive, JTWC consistently forecasted the cyclone to pass south of the island of Honshu, while several CONW forecasts showed the system tracking along the coast. JTWC attempted to capitalize on another observed numerical model forecast tendency, namely a delayed eastward turn into the westerly flow pattern for systems that enter the mid-latitude baroclinic zone. However, the steering ridge maintained the orientation predicted by the numerical guidance. As noted earlier, the system did graze the southern tip of Honshu as it completed extra-tropical transition, bringing heavy rainfall and flooding to mainland Japan.

	Tau 24	Tau 48	Tau 72	Tau 96	Tau 120
JTWC (04W)	49 nm	63 nm	64 nm	64 nm	125 nm
CONW	45 nm	51 nm	55 nm	80 nm	139 nm
Cases	31	27	23	19	15
JTWC (2011)	61 nm	93 nm	128 nm	175 nm	251 nm
CONW	56 nm	85 nm	122 nm	166 nm	236 nm
Cases	454	364	289	223	162

Table 1-5. JTWC and CONW (model consensus) forecast track errors (homogeneous sample) for STY 04W and the entire 2011 western North Pacific TC season (red).

Like the track forecasts, JTWC official intensity forecasts were fairly accurate (Table 1-6). In the extended taus, JTWC forecast intensity errors were lower than the Statistical Typhoon Intensity Prediction Scheme guidance (ST11). Additionally, JTWC intensity forecast errors for STY 04W bested JTWC western North Pacific TC seasonal average errors for forecast tau 48 to tau 96 by 12-27%.

	Tau 24	Tau 48	Tau 72	Tau 96	Tau 120
JTWC (04W)	13 knots	15 knots	17 knots	16 knots	25 knots
ST11	11 knots	13 knots	18 knots	21 knots	26 knots
Cases	31	27	23	19	15
JTWC (2011)	12 knots	17 knots	22 knots	22 knots	25 knots
ST11	11 knots	17 knots	21 knots	22 knots	22 knots
Cases	417	327	259	192	137

Table 1-6. JTWC and ST11 intensity forecast errors (homogeneous sample) for STY 04W (blue) and the entire 2011 western North Pacific TC season (red).

A cursory review of JTWC wind structure forecasts for Kadena Air Base also reflected a precise and consistent forecast approach. This is exemplified by the 25/1200Z warning graphic (Figure 1-8), which showed a closest point of approach (CPA) of 6nm at 28/16Z (the actual CPA was approximately 40 nm at 28/14Z) and also showed 64-knot wind radii over Okinawa by 28/12Z. A peak sustained wind of 74 knots was recorded at Kadena Air Base at 28/1318Z.

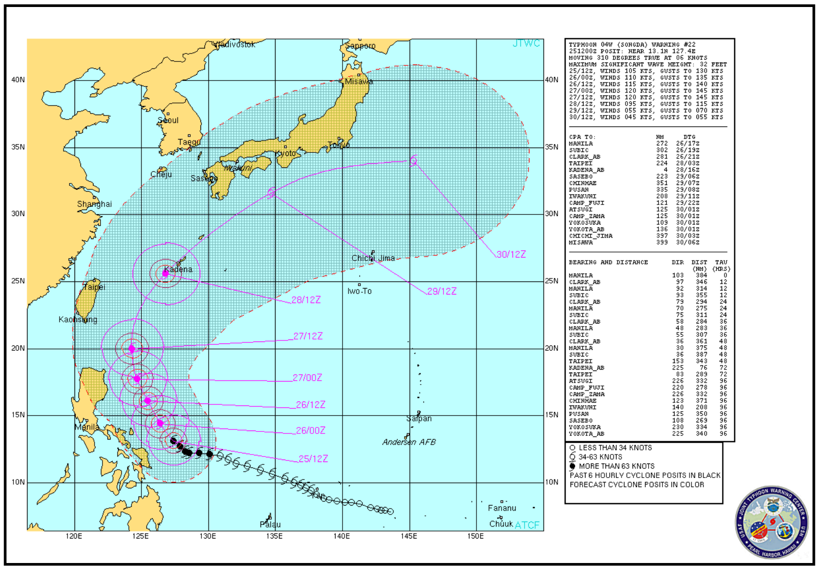


Figure 1-8. 25/1200Z warning graphic for STY 04W (2011).

Despite its high degree of predictability, STY 04W produced major impacts across the western North Pacific Ocean as it tracked near land. The Philippine government's National Disaster Risk Reduction and Management Council reported that heavy rains associated with the outer spiral bands produced flash floods and landslides across the Northern Philippines resulting in four fatalities[1] (Figure 1-9). Intense winds and heavy rains over Okinawa (Figure 1-10) produced nearly $300 million in damage[3] and left 57 people injured[4], but there were fortunately no reported fatalities.

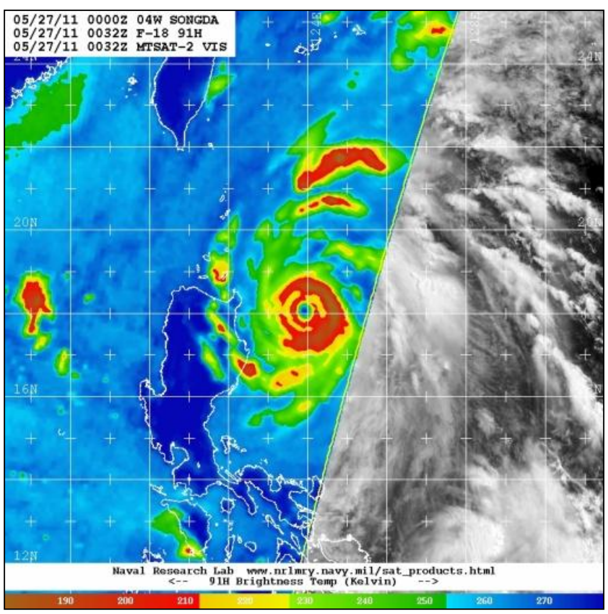


Figure 1-9. May 27 0032Z SSMIS image of STY 04W east of the Philippines (image courtesy NRL TC webpage).

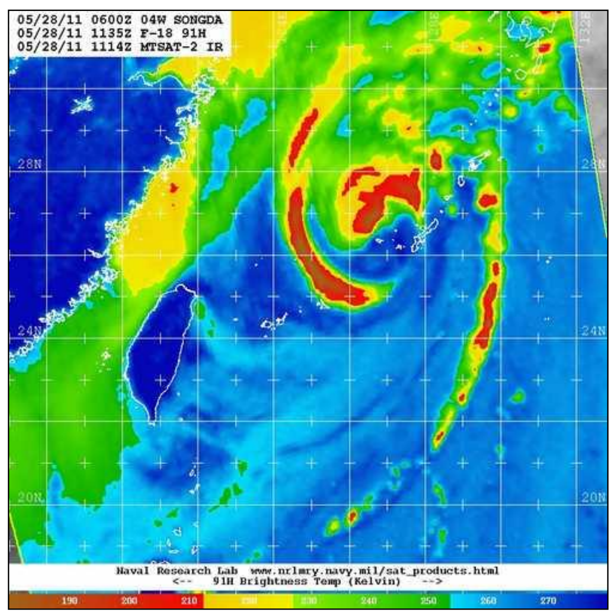


Figure 1-10. May 28 1135Z SSMIS image showing STY 04W impacting Okinawa (image courtesy NRL TC webpage).

As STY 04W weakened and underwent extra-tropical transition, it continued to produce heavy rain and flooding with 13 fatalities[5] reported in mainland Japan. In the Tokyo region, approximately 400,000 people were evacuated while repair and radiation containment operations were suspended at the crippled Fukushima nuclear plant, still reeling after the tsunami disaster just a few months earlier.[6] Operations at Kadena Air Base were put on hold with major airframes (E-3Bs, KC/RC-135s, F-15s, P-3s, UC-12s) evacuating to safe havens before STY 04W impacted the island. The base weather station recorded maximum winds at 28/1318Z with southerly winds of 74 knots gusting to 95 knots, but the base sustained only minor damage. However, the Doppler weather radar was completely destroyed (Figure 1-11).

Figure 1-11. Kadena Air Base Doppler weather radar, damaged by passage of STY 04W.

Due to the importance of the radar to the resource protection of Department of Defense personnel and assets on the island of Okinawa, the Air Force has funded the replacement of the radar. While it is too early to ascertain the final cost to replace the Kadena Doppler radar, initial estimates from the Kadena Weather Flight Commander, Capt. Paslay, indicate that the radar will not be replaced until May 2012 at the earliest and possibly as late as July 2012, well into the western North Pacific tropical cyclone season.

STY 14W was clearly an atypically predictable western North Pacific system due to the static steering environment and exceptionally consistent dynamic model guidance throughout the system's lifecycle. Consequently, JTWC track, intensity, and wind radii forecasts were highly accurate overall. However, the successful and unsuccessful applications of forecasting thumb-rules in this case illustrate the need for more complete guidance to help the forecaster identify potential model track forecast errors in real-time. Additionally, this system highlights the requirement for stable, precise dynamical model guidance to protect assets as well as the importance of accurate advanced warning of local impacts to minimize loss of life and property.

References

[1] NDRRMC Update SitRep No. 15 on Typhoon "Chedeng" (Songda) (PDF). *National Disaster Risk Reduction and Management Council*. National Disaster Coordinating Council. May 31, 2011. http://ndcc.gov.ph/attachments/article/215/NDRRMC%20Update%20Sitrep%20No.%2015%20CHEDENG31May2011,%206PM.pdf. Retrieved August 4, 2011.

[2] **(Japanese)** Unattributed (May 28, 2011). 台風1102号 沖縄：久米島灯台 風速55メートル". 吟遊詩人の戯言. http://gurizuri0505.halfmoon.jp/20110528/29502. Retrieved July 2, 2011.

[3] **(Japanese)** Unattributed (June 23, 2011). 保険支払い２０億円に 台風２号. Okinawa Times. http://www.okinawatimes.co.jp/article/2011-06-23_19539/. Retrieved July 2, 2011.

[4] Unattributed (May 29, 2011). 57 Injured in Okinawa, Tokyo Next. *Accuweather*. Star Tribune. http://www.startribune.com/weather/122801604.html. Retrieved July 2, 2011.

[5] Unattributed (June 3, 2011). Typhoon Songda Floods Strike Japan Disaster Zone. Earthweek. http://www.earthweek.com/2011/ew110603/ew110603e.html. Retrieved July 5, 2011.

[6] **(Japanese)** Unattributed (May 30, 2011). 台風２号：県内で車水没、１人死亡 新居浜では避難勧告 ／愛媛 - 毎日新聞. おもっしょい愛媛. http://ehime.gourmet47.info/modules/news/index.php?page=clipping&clipping_id=4798. Retrieved July 5, 2011.

Super Typhoon 14W (Nanmadol)

Super Typhoon (STY) 14W (Nanmadol) formed within the monsoon trough east of the Philippines and began tracking west-northwestward toward Luzon in a complex steering environment dominated by a subtropical ridge to the north and east. The cyclone steadily developed into a tropical storm by 23 August 2011 at 1200Z and reached typhoon intensity just thirty hours later. 14W then took a poleward turn around the steering ridge and rapidly intensified to reach super typhoon status by 26 August at 0000Z under the favorable environmental influences of low vertical wind shear, excellent dual-channel outflow enhanced by a TUTT cell to the northeast, and passage over a region of high ocean heat content. The intensification rate exceeded four Dvorak T-numbers in 2.5 days, almost double the standard intensification rate of one T-number per day cited by Dvorak (Dvorak 1984[2]). STY 14W clipped the northeast tip of Luzon and then moved across the southern coast of Taiwan before dissipating in the Taiwan Strait, just prior to making landfall in China's Fujian Province. The cyclone reportedly caused at least 35 deaths and $34.5M damage in the Philippines (NDRRMC 2011[4]), at least 1 death and $500M damage in Taiwan (*Typhoon* 2011[5]; *Nanmadol affects* 2011[7]), and 2 deaths and $48.5M damage in China (*Nanmadol causes* 2011[6]).

While Nanmadol intensified to an estimated intensity of 140 knots and caused significant loss of life and property damage, from a forecaster's perspective the cyclone is also noteworthy for the numerical models' and JTWC track forecasts' erroneous depiction of a northeastward turn well to the east of the area eventually impacted by the cyclone. This tendency in both the model and subjective forecasts began during the cyclone's development stage in the Philippine Sea and lasted well into its mature stage in the Luzon Strait (Figure 1-12).

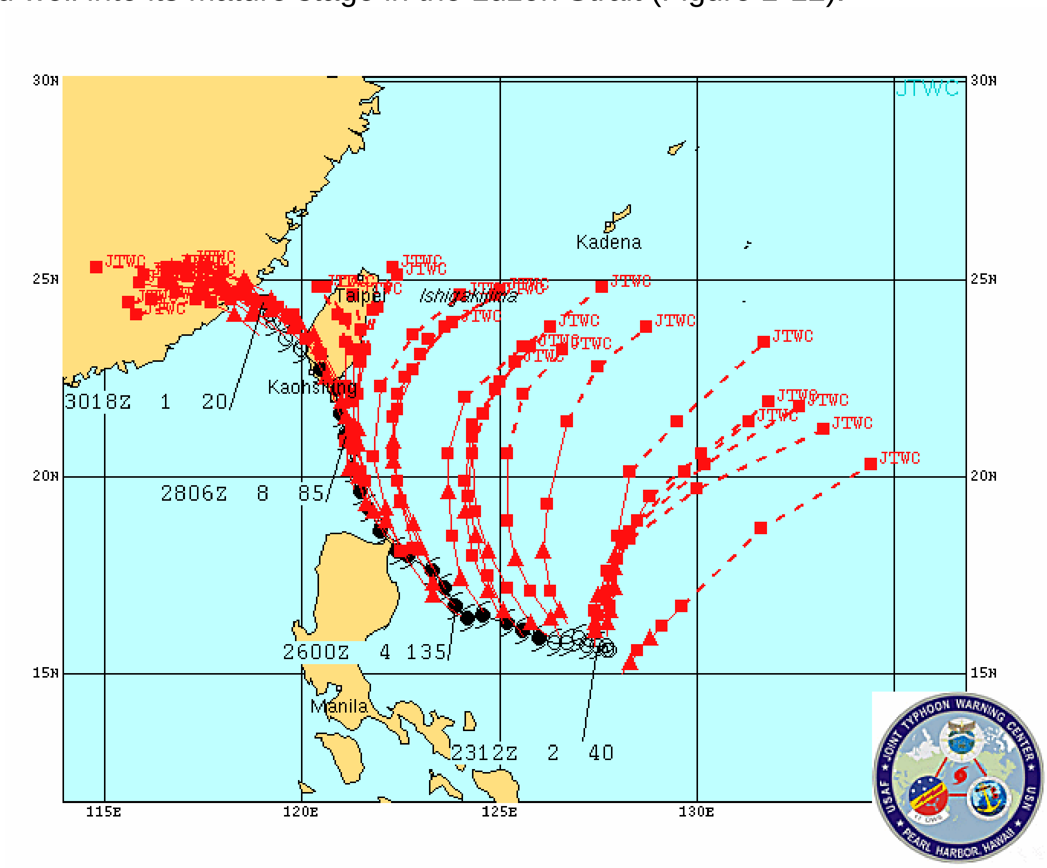


Figure 1-12. JTWC track forecasts versus best track for STY 14W.

JTWC forecast strategy encourages consistency with the model consensus, CONW, and adjusting for known model consensus member error tendencies. Additionally, given the ECMWF's model superior performance in track forecasting during recent TC seasons, as described in ECMWF Newsletter No. 118 – Winter 2008/09 (Fiorino 2008[3]), forecasters often hedge their forecasts toward that model's interpolated vortex tracker. These forecasting guidelines have helped JTWC to minimize average track errors over the past several seasons. However, this case showed how these guidelines may break down in "small model spread, large model error" scenarios. Indeed, JTWC track forecast errors for STY 14W were the highest for a single cyclone during the 2011 western North Pacific typhoon season (Figure 1-13). In this case, the UKMET office global model exhibited smaller track forecast errors than all other available models (Figure 1-14). reason for the model's superior performance is not entirely clear.

Average Forecast Track Errors (NM)					
	Forecast tau 24	Forecast tau 48	Forecast tau 72	Forecast tau 96	Forecast tau 120
JTWC	59	114	200	296	462
CONW	44	97	165	251	345
EGRI (UKMET)	49	80	109	149	226
AVNI (GFS)	52	118	209	275	311
ECMI (ECMWF)	49	96	156	244	410
#CASES	17	14	12	10	7
JTWC (Season)	62	93	129	177	252
PACOM Goals	25	50	75	100	150

Figure 1-13. Average track forecast errors for STY 14W (computed only for cases in which all listed model vortex trackers/forecasts are available), average JTWC forecast track errors for the entire western North Pacific 2011 TC season, and newly-established US PACOM track forecast error goals.

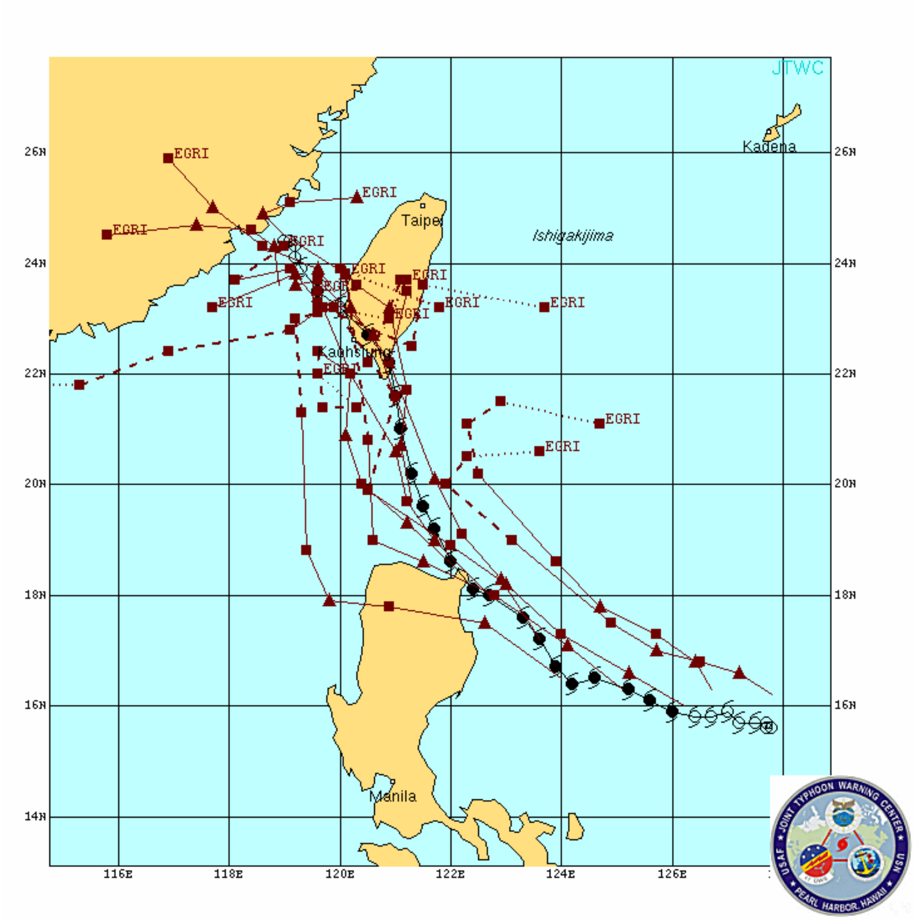


Figure 1-14. EGRI (interpolated UKMET global model) track forecasts versus best track for STY 14W.

STY 14W formed in a complex steering environment with a near equatorial ridge to the southeast and an extension of the subtropical ridge to the north, in addition to its development near a second cyclone developing to the east within the same, broad monsoon trough. Excessive DCI between STY 14W and TS 15W appeared to have occurred mostly in the early period of all model forecasts. This interaction between cyclones in the numerical models caused both STY 14W and TS 15W to shift further east in the model forecasts than what actually occurred. This errant "shift" in the broad area of troughing associated with both systems caused the synoptic pattern (including evolution of mid-latitude troughing to the north) to shift as well, leading the models to forecast north-northeastward tracks when, in reality, each system moved north-northwestward. For example, Figure 1-15 shows the GFS 72-hour surface wind field forecast from the 23 August 2011 1200Z run where STY 14W is depicted well to the northeast of Luzon and its verifying position much farther to the west. A similar displacement is noted for TS 15W.

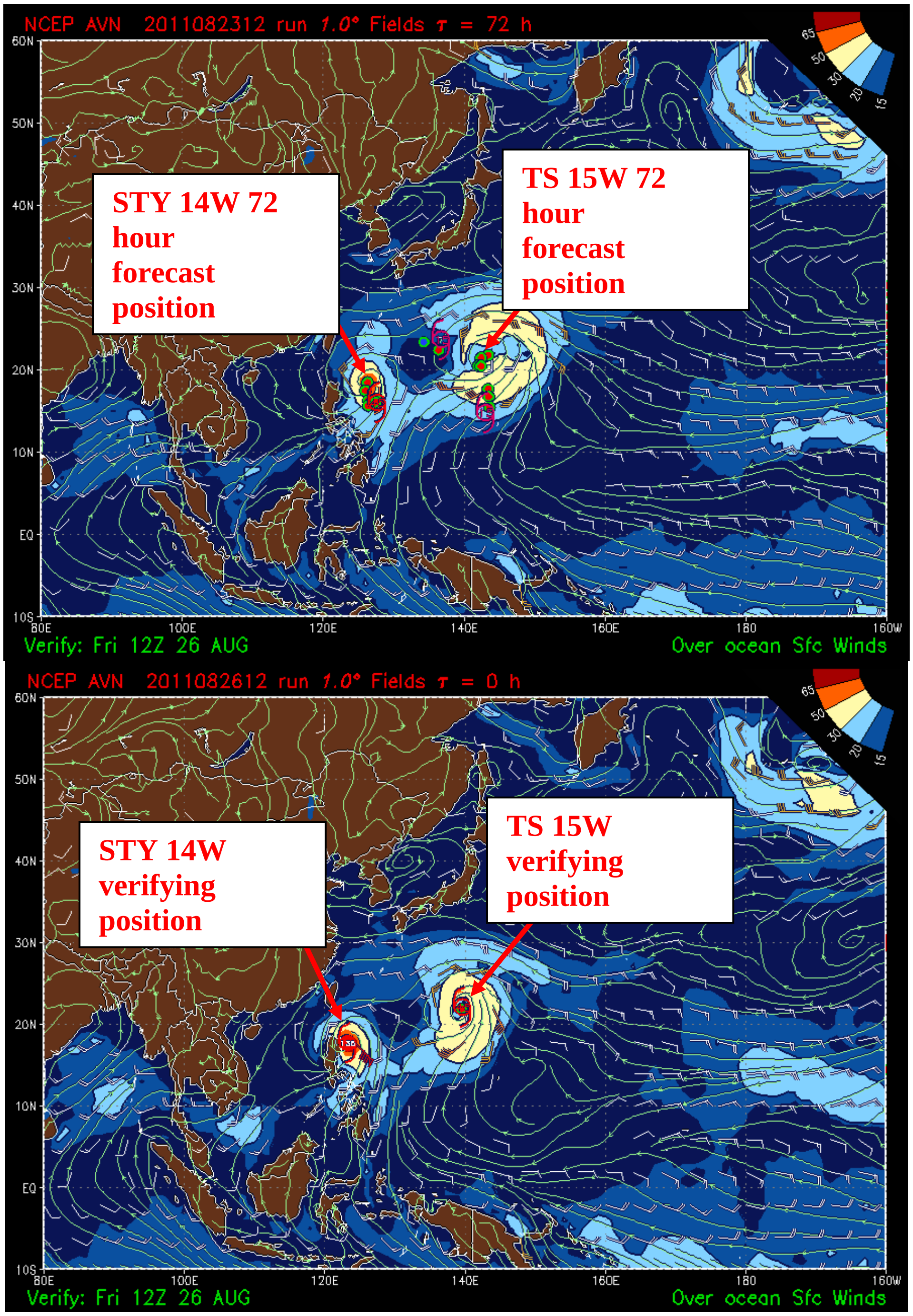


Figure 1-15. GFS 72-hour surface wind field forecast from 23 Aug 2011 at 12Z (top) and verifying analysis from 26 Aug 2011 at 12Z (bottom)

Erroneous eastward shifts were also noted in the NOGAPS and ECMWF model fields (not shown) from the same period. In contrast, following a few early forecasts for 14W, the UKMET model field (the EGRR vortex tracker's parent model), did not exhibit this errant eastward "shift" (Figure 1-16).

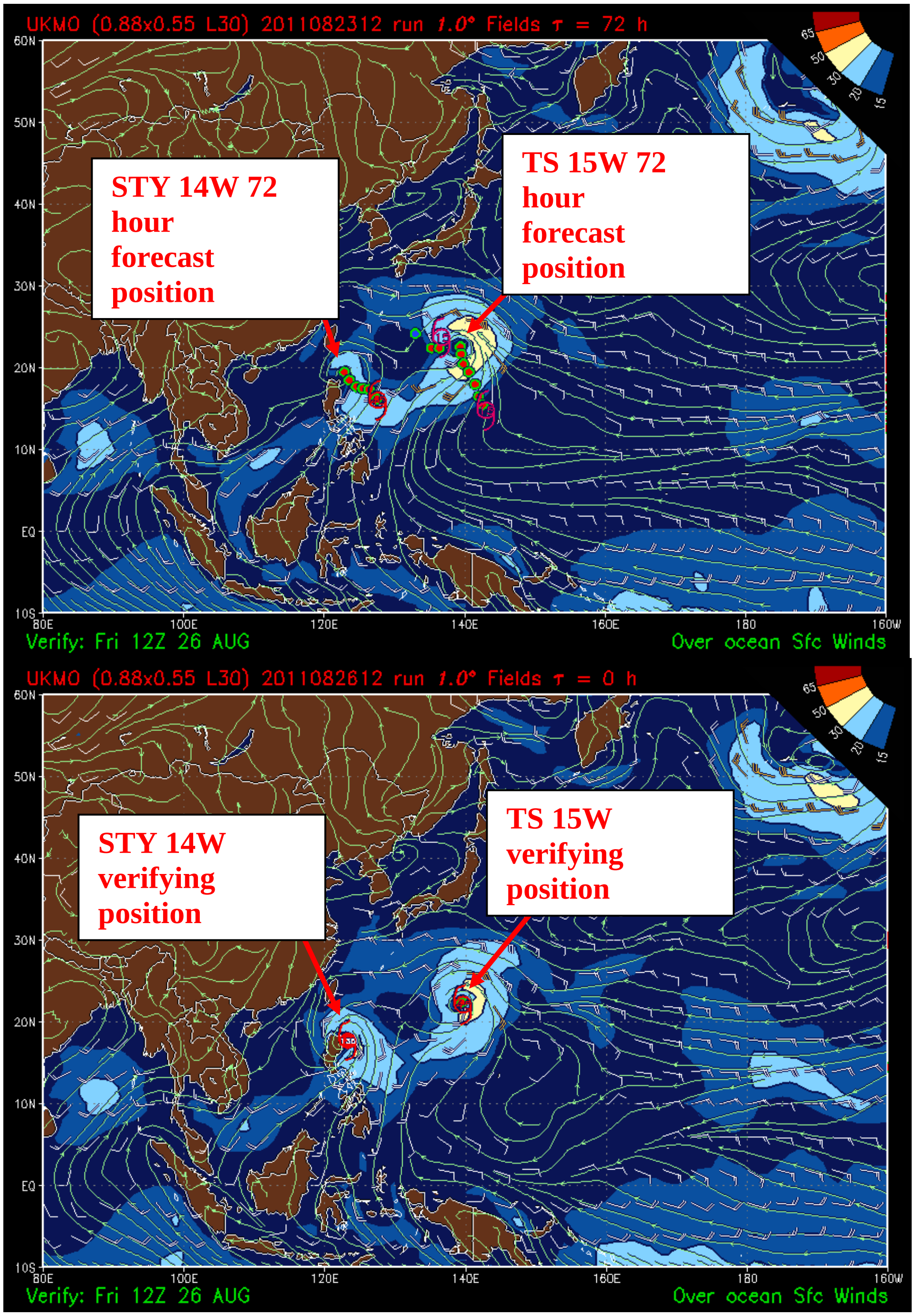


Figure 1-16. UK MET Office global model 72-hour surface wind field forecast from 23 Aug 2011 at 12Z (top) and verifying analysis from 26 Aug 2011 at 12Z (bottom)

It is possible that the numerical models' poor handling of the TUTT cell analyzed poleward of STY 14W also contributed to errant track forecasts. Figure 1-17 shows the GFS model 72 hour forecast of the upper level wind field from the 23 August 2011 1200Z run and the verifying analysis on 26 August 2011 at 1200Z. The model forecasted the TUTT cell to fill, but the TUTT cell maintained a closed circulation throughout the forecast period (figure 1-18). The observed track, which fell to the left (west) of the initial numerical model forecasts, is consistent with the TC-TUTT cell interaction conceptual model for TUTT cells positioned to the right of a TC proposed by Patla et al. (2009[8]).

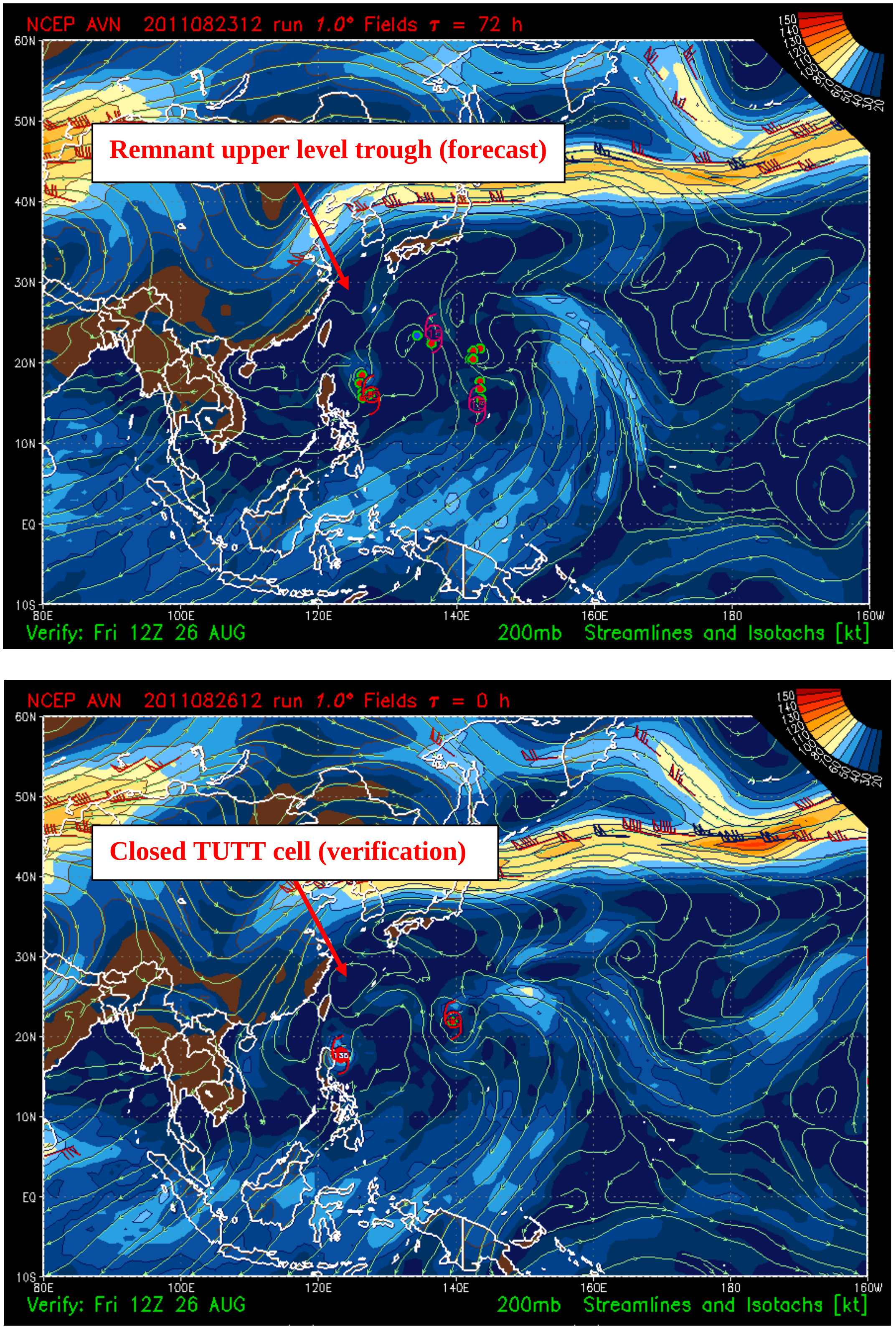


Figure 1-17. GFS 72-hour upper level (200 mb) wind field forecast from 23 Aug 2011 at 12Z (top) and verifying analysis from 26 Aug 2011 at 12Z (bottom).

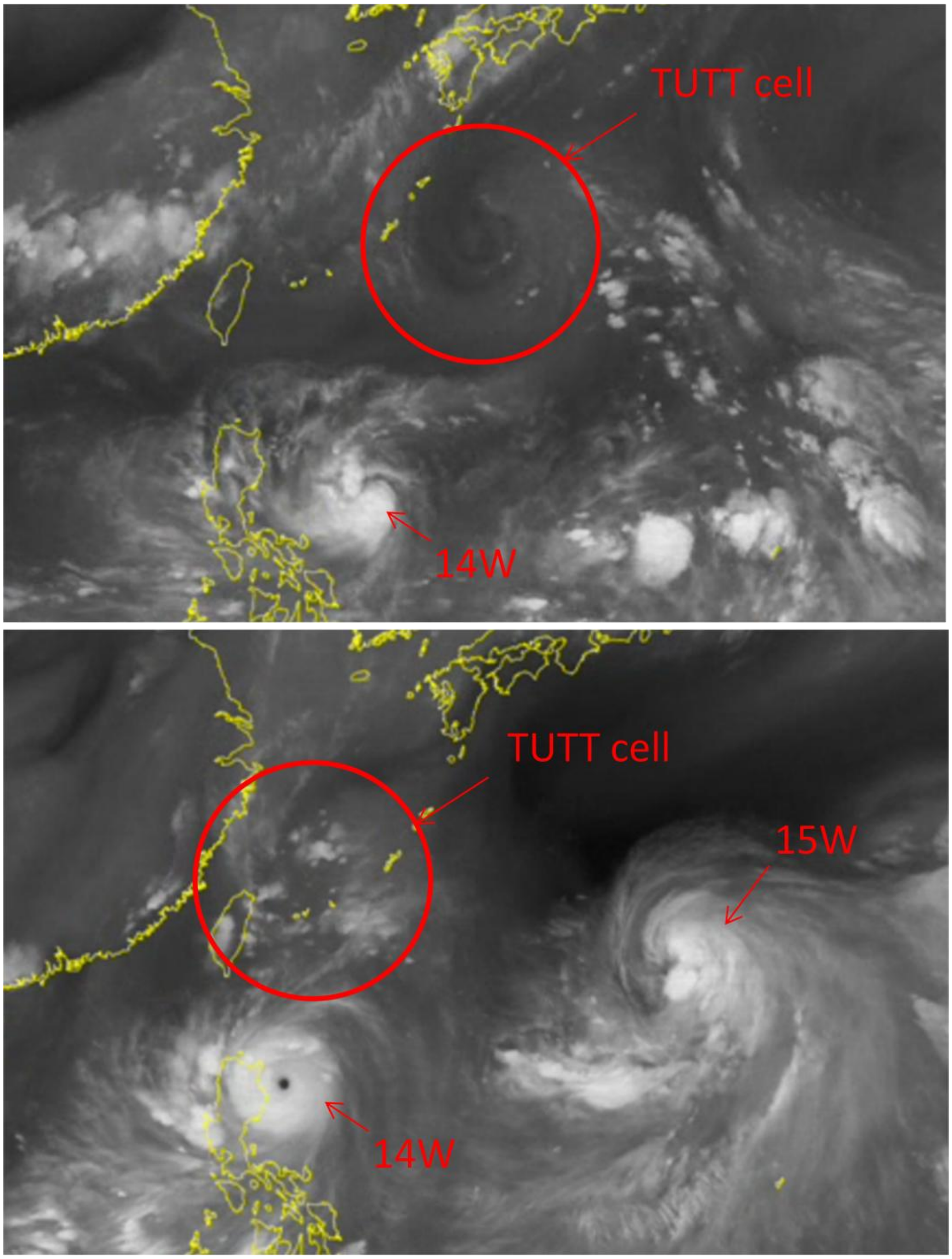


Figure 1-18. MTSAT satellite imagery (water vapor) from 23 Aug 2011 at 12Z (top) and 26 Aug 2011 at 12Z (bottom) showing the presence of a closed upper level circulation (TUTT cell) poleward of STY 14W throughout the period

In hindsight, it is difficult to argue that JTWC forecasters should have recognized excessive DCI (E-DCI) in the majority of the numerical model solutions given the complex steering environment and lack of guidance to identify excessive DCI cases in real-time. This case demonstrates a need to develop automated tools that may be applied to identify such cases of E-DCI in real-time. During its lifespan, STY 14W never came to within 700 NM of 15W, a recognized separation distance at which direct cyclone interaction may occur between two tropical circulations (Carr 1997[1]). A study to determine how rules-of-thumb for DCI critical separation distances may be applied in real-time, especially in the context of model forecasts, could also provide useful forecast guidance in future cases akin to that of STY 14W.

This case further demonstrates the potential impact of TUTT cells on tropical cyclone motion. JTWC began testing the TC-TUTT interaction conceptual model proposed by Patla et al. (2009[8]) during real-time forecasting operations late in the 2011 western North Pacific TC season. This conceptual model, and further work that builds on the study from which it is derived, may help forecasters identify and adjust for TUTT cell-related model error tendencies in future forecast scenarios.

References

[1]Carr, L. E., III and R. L. Elsberry, 1998: Objective diagnosis of binary tropical cyclone interactions for the western North Pacific basin. *Mon. Wea. Rev.*, **126**, 1734-1740.

[2]Dvorak, V.F.,1984: Tropical cyclone intensity analysis using satellite data. NOAA Technical Report NESDIS 11, U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Environmental Satellite Data and Information Service, Washington, DC, 47 pp.

[3]Fiorino M., 2008: Record-setting performance of the ECMWF IFS in medium-range tropical cyclone track prediction. ECMWF Newsletter, No. 118 – Winter 2008/09.

[4]NDRRMC Update SitRep No. 27 on Typhoon "Mina" (Nanmadol) (PDF). *National Disaster Risk Reduction and Management Council*. National Disaster Coordinating Council. September 5, 2011.
http://www.ndrrmc.gov.ph/attachments/article/280/NDRRMC%20UPDATE%20re_%20Sitrep%2027%20TY%20_MINA_%20(NANMADOL)%2005SEPT2011.pdf. Retrieved September 5, 2011.

[5]*Typhoon floods Taiwan, heads to China.* Fairfax Media.
http://news.brisbanetimes.com.au/breaking-news-world/typhoon-floods-taiwan-heads-to-china-20110829-1jhh0.html. Retrieved 29 August 2011.

[6]*Nanmadol causes est. $200 to $500 million in Taiwan; Talas to hit Japan as Category 2.* EQECAT. http://www.eqecat.com/catWatchREV/secureSite/report.cfm?id=368. Retrieved 2 September 2011.

[7]*Nanmadol affects bullet trains, batters E China province.* Xinhua News Agency.
http://news.xinhuanet.com/english2010/china/2011-09/01/c_131091103.htm. Retrieved 2 September 2011.

[8]Patla, J. E., D. Stevens, and G. M. Barnes, 2009: A conceptual model for the influence of TUTT cells on tropical cyclone motion in the Northwest Pacific Ocean. *Wea. Forecasting*, **24**, 1215-1235.

Chapter 2 North Indian Ocean Tropical Cyclones

This chapter contains information on north Indian Ocean tropical cyclone activity during 2011 and the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2011. 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 2011 season. Six cyclones occurred in 2011, with only one systems reaching intensity greater than 64 knots. Table 2-2 shows the monthly distribution of Tropical Cyclone activity for 1975 - 2011.

Table 2-1

NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 2011

(01 JAN 2011- 31 DEC 2011)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
01A	-	11 Jun / 1200Z	12 Jun / 0600Z	4	35	996
02B	-	19 Oct / 0600Z	19 Oct / 1200Z	2	35	996
03A	Keila	02 Nov / 0000Z	02 Nov / 1800Z	4	55	928
04A	-	07 Nov / 1800Z	09 Nov / 1200Z	8	35	996
05A	-	26 Nov / 0000Z	30 Nov / 0600Z	17	35	996
06B	Thane	25 Dec / 1800Z	30 Dec / 0600Z	19	90	956

* As designated by the responsible RSMC

** 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 - 2011

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS (Total) ≥64kt	34-63kt	≤33 kt
1975	1	0	0	0	2	0	0	0	0	1	2	0	6		
	0 1 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	1 0 0	0 2 0	0 0 0	3	3	0
1976	0	0	0	1	0	1	0	0	1	1	0	1	5		
	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 1 0	0	5	0
1977	0	0	0	0	1	1	0	0	0	1	0	2	5		
	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	1 1 0	1	4	0
1978	0	0	0	0	1	0	0	0	0	1	2	0	4		
	0 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 1 0	2 0 0	0 0 0	2	2	0
1979	0	0	0	0	1	1	0	0	2	1	2	0	7		
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 1 1	0 1 0	0 1 1	0 0 0	1	4	2
1980	0	0	0	0	0	0	0	0	0	0	1	1	2		
	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 0 0	0 1 0	0 1 0	0	2	0
1981	0	0	0	0	0	0	0	0	1	0	1	1	3		
	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 1 0	0 0 0	1 0 0	1 0 0	2	1	0
1982	0	0	0	0	1	1	0	0	0	2	1	0	5		
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 2 0	1 0 0	0 0 0	2	3	0
1983	0	0	0	0	0	0	0	1	0	1	1	0	3		
	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 1 0	0 1 0	0 0 0	0	3	0
1984	0	0	0	0	1	0	0	0	0	1	2	0	4		
	0 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 1 0	2 0 0	0 0 0	2	2	0
1985	0	0	0	0	2	0	0	0	0	2	1	1	6		
	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	0 1 0	0 1 0	0	6	0
1986	1	0	0	0	0	0	0	0	0	0	2	0	3		
	0 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	0 0 0	0 2 0	0 0 0	0	3	0
1987	0	1	0	0	0	2	0	0	0	2	1	2	8		
	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 2 0	0 0 0	0 0 0	0 0 0	0 2 0	0 1 0	0 2 0	0	8	0
1988	0	0	0	0	0	1	0	0	0	1	2	1	5		
	0 0 0	0 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	1 1 0	0 1 0	1	4	0
1989	0	0	0	0	1	1	0	0	0	0	1	0	3		
	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	1	2	0
1990	0	0	0	1	1	0	0	0	0	0	1	1	4		
	0 0 0	0 0 0	0 0 0	0 0 1	1 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 1	0 1 0	1	1	2
1991	1	0	0	1	0	1	0	0	0	0	1	0	4		
	0 1 0	0 0 0	0 0 0	1 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 0 0	2	2	0
1992	0	0	0	0	1	2	1	0	1	3	3	2	13		
	0 0 0	0 0 0	0 0 0	0 0 0	1 0 0	0 2 0	0 1 0	0 0 0	0 0 1	0 2 1	2 1 0	0 2 0	3	8	2
1993	0	0	0	0	0	0	0	0	0	0	2	0	2		
	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 0 0	2 0 0	0 0 0	2	0	0
1994	0	0	1	1	0	1	0	0	0	1	1	0	5		
	0 0 0	0 0 0	0 1 0	1 0 0	0 0 0	0 1 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	1	4	0
1995	0	0	0	0	0	0	0	0	1	1	2	0	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 1 0	0 1 0	2 0 0	0 0 0	2	2	0
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
2010	0	0	0	0	2	1	0	0	0	1	1	0	5		
	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 0 0	1 0 0	0 1 0	0 0 0	3	2	0
2011	0	0	0	0	0	1	0	0	0	1	3	1	6		
	0 0 0	0 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 3 0	1 0 0	1	5	0
(1975-2011)															
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	5.1		
CASES	6	2	1	7	27	22	2	1	13	37	50	21	189		

1) 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.
2) 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.

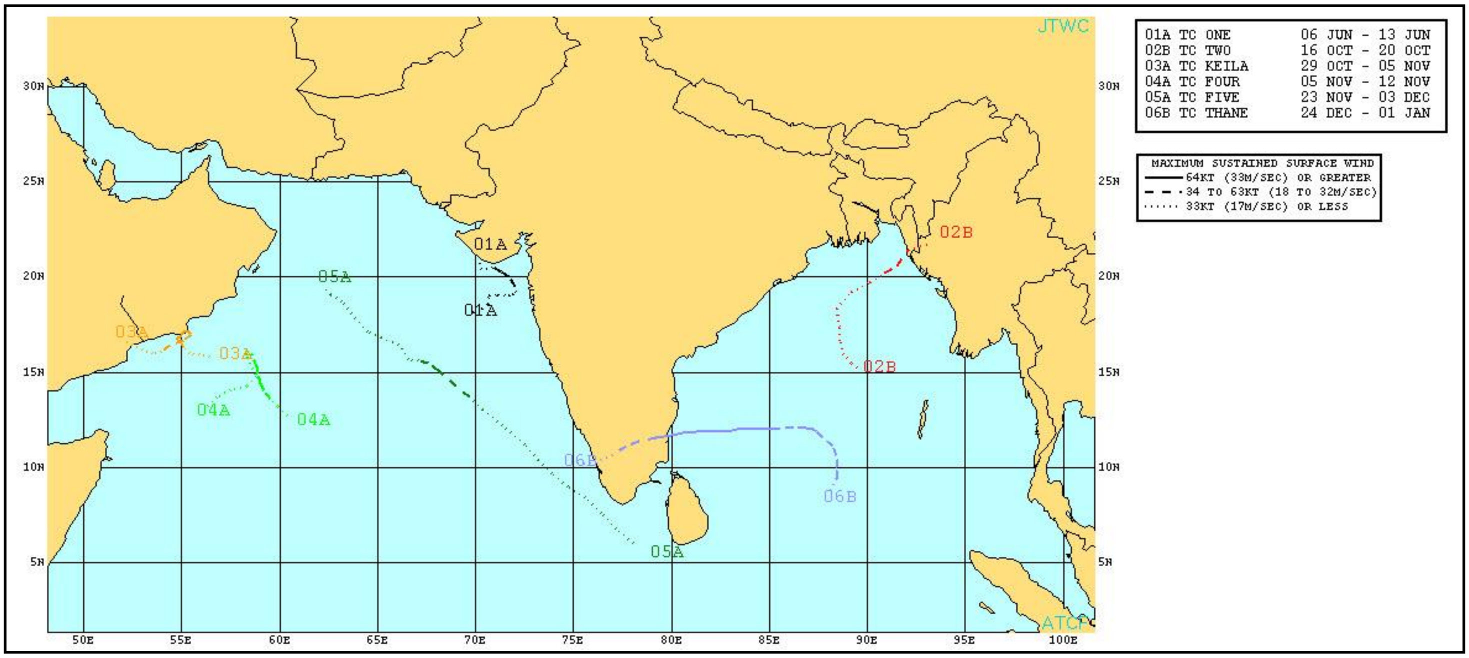


Figure 2-1. North Indian Ocean Tropical Cyclones.

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 Low and Medium[1] stages of development:

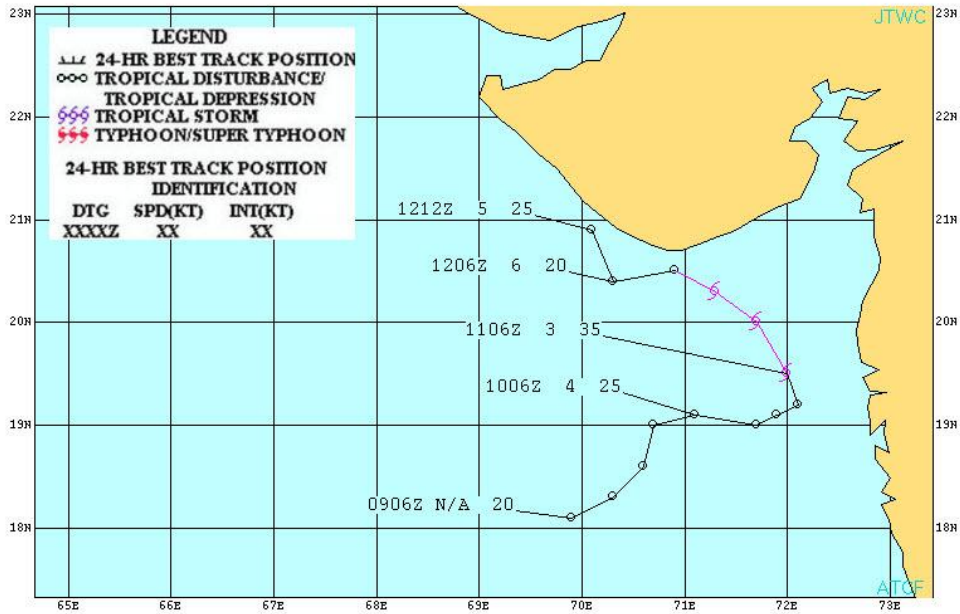
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

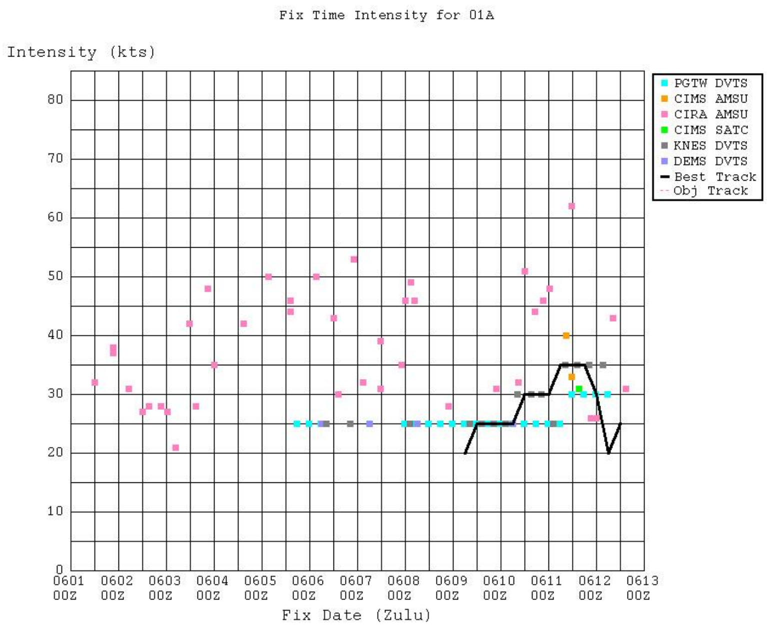
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of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

[1] Low" formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours. "Medium" formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.

Tropical Cyclone 01A

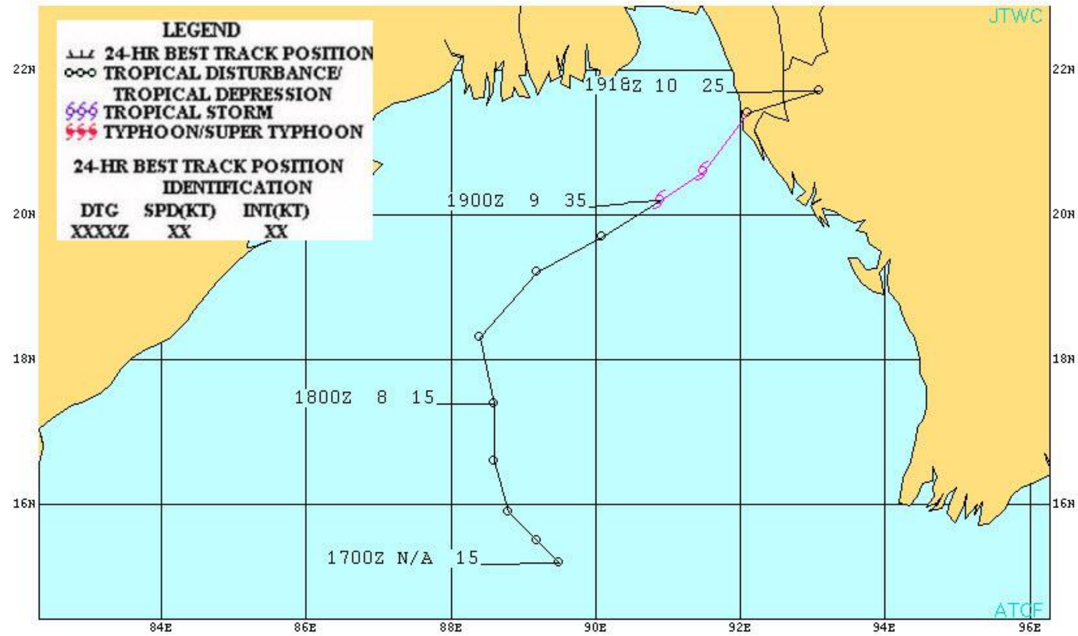
ISSUED LOW:	1230Z 04 Jun 2011
ISSUED MEDIUM:	1800Z 05 Jun 2011
FIRST TCFA:	2230Z 08 Jun 2011
FIRST WARNING:	1200Z 11 Jun 2011
LAST WARNING:	0600Z 12 Jun 2011
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	4

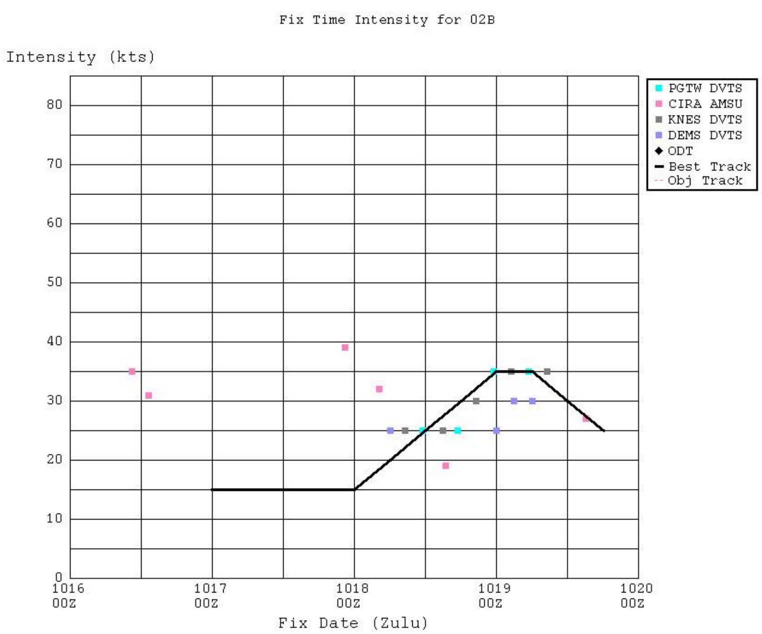




Tropical Cyclone 02B

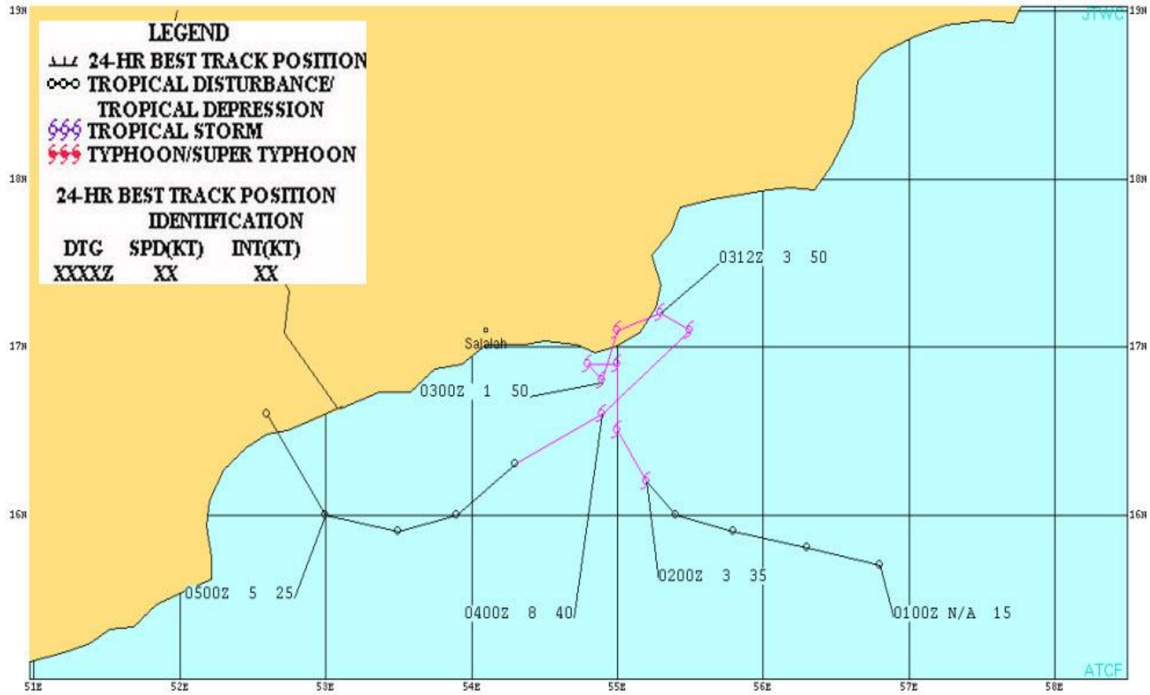
ISSUED LOW: 1800Z 16 Oct 2011
ISSUED MEDIUM: 0300Z 18 Oct 2011
FIRST TCFA: 2230Z 18 Oct 2011
FIRST WARNING: 0600Z 19 Oct 2011
LAST WARNING: 1200Z 19 Oct 2011
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 2

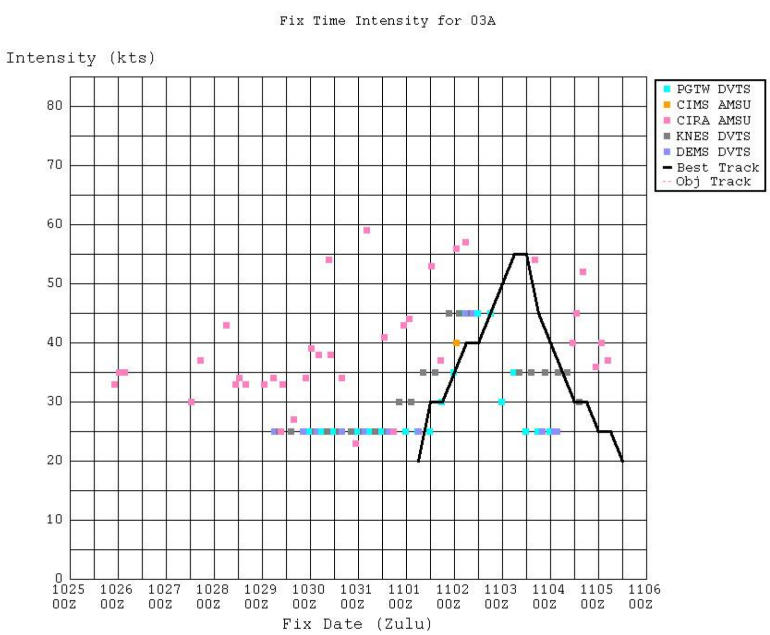




Tropical Cyclone 03A (Keila)

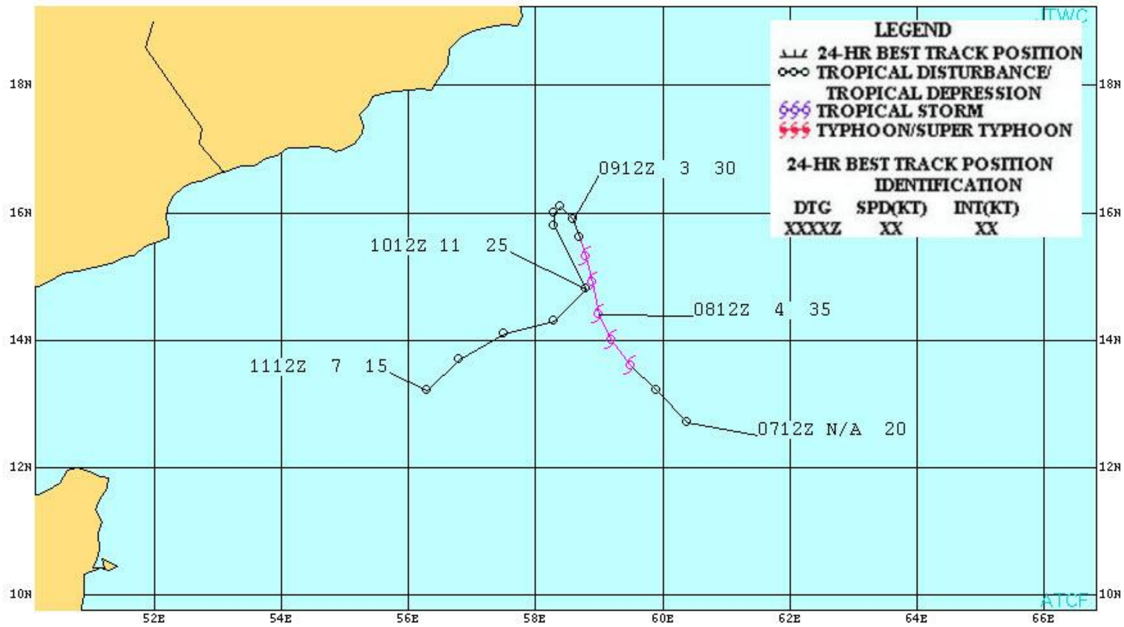
ISSUED LOW: N/A
ISSUED MEDIUM: 1800Z 01 Nov 2011
FIRST TCFA: 1900Z 01 Nov 2011
FIRST WARNING: 0000Z 02 Nov 2011
LAST WARNING: 1800Z 02 Nov 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 4

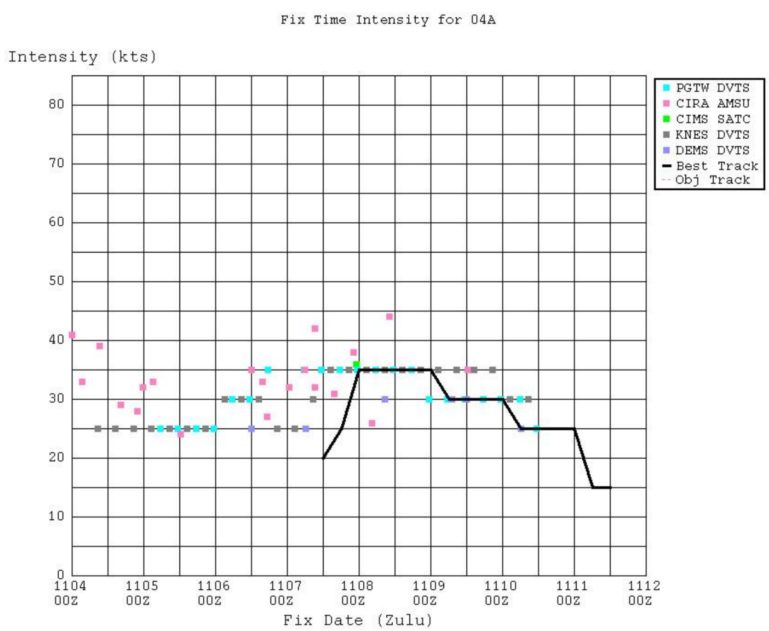




Tropical Cyclone 04A

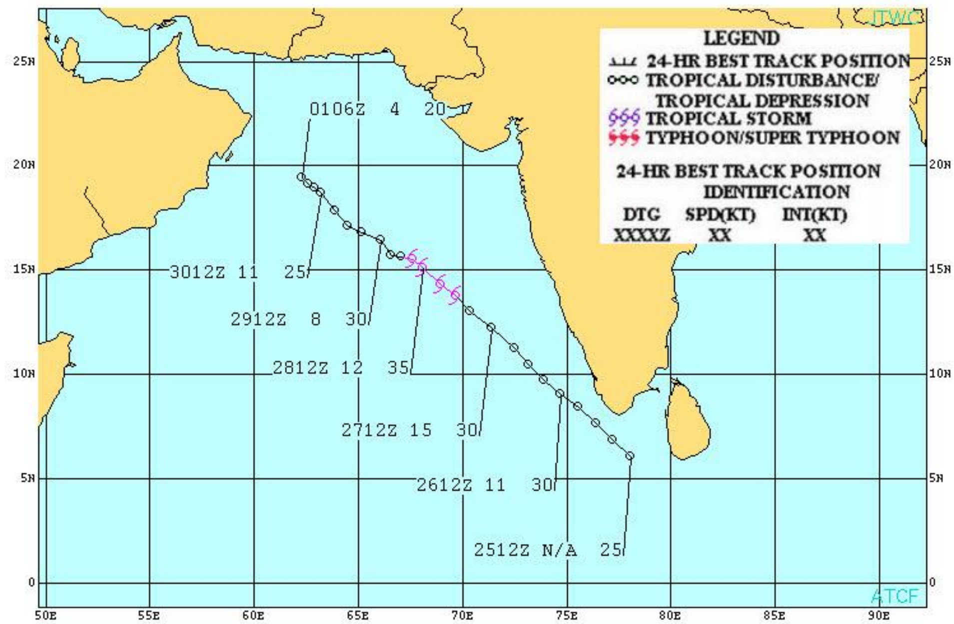
ISSUED LOW:	1800Z 04 Nov 2011
ISSUED MEDIUM:	1800Z 05 Nov 2011
FIRST TCFA:	2000Z 06 Nov 2011
FIRST WARNING:	1800Z 07 Nov 2011
LAST WARNING:	1200Z 09 Nov 2011
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	8

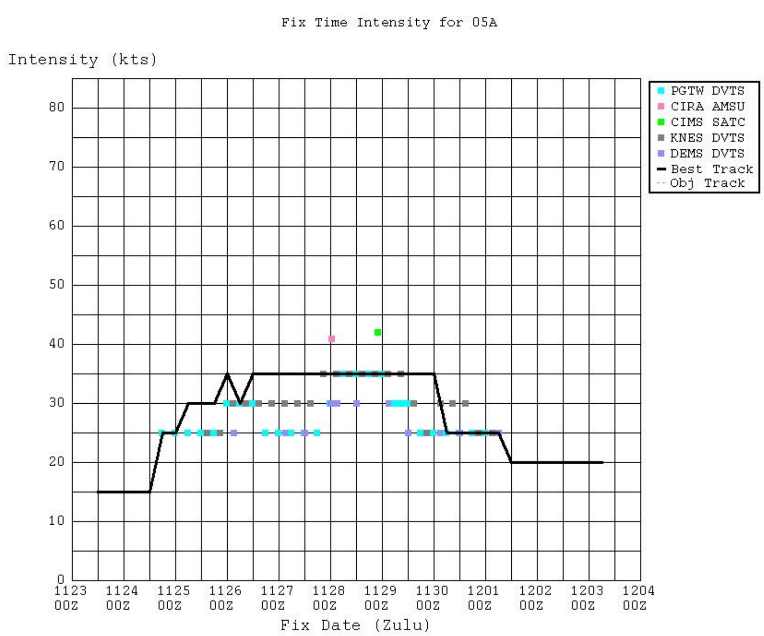




Tropical Cyclone 05A

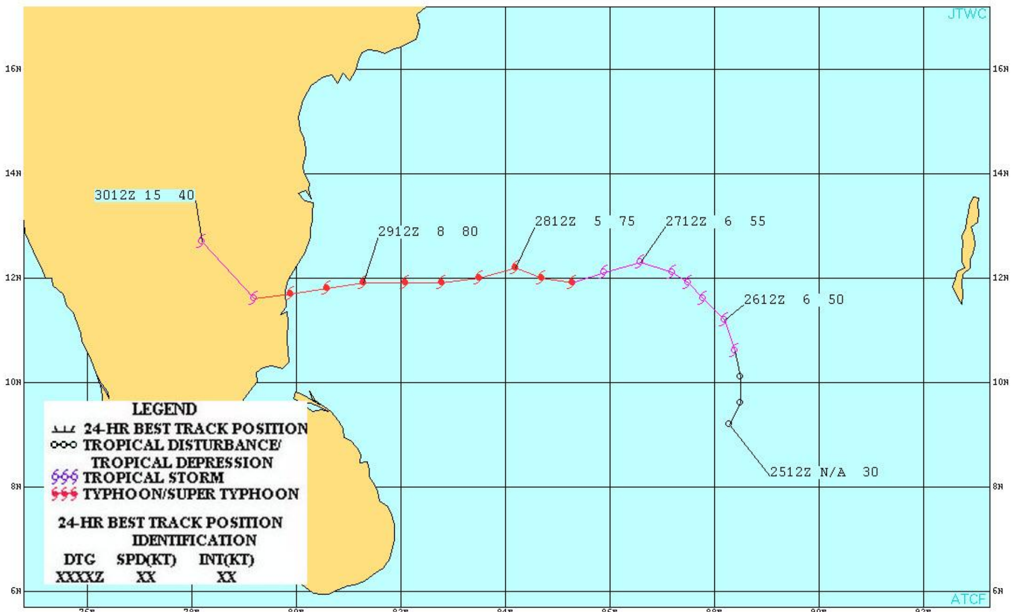
ISSUED LOW:	0130Z 23 Nov 2011
ISSUED MEDIUM:	1800Z 24 Nov 2011
FIRST TCFA:	0800Z 25 Nov 2011
FIRST WARNING:	0000Z 26 Nov 2011
LAST WARNING:	0000Z 30 Nov 2011
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	17

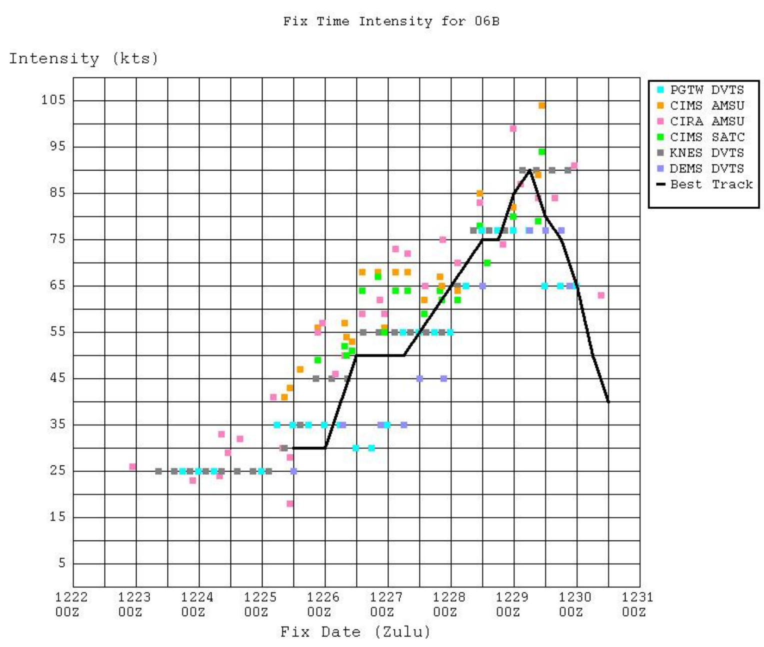




Tropical Cyclone 06B (Thane)

ISSUED LOW: 0300Z 22 Dec 2011
ISSUED MEDIUM: 0200Z 24 Dec 2011
FIRST TCFA: 1100Z 25 Dec 2011
FIRST WARNING: 1800Z 25 Dec 2011
LAST WARNING: 0600Z 30 Dec 2011
MAX INTENSITY: 90 Kts
NUMBER OF WARNINGS: 19





Tropical Cyclone 03A (Keila) is detailed in this report as post analysis indicates significant underestimation of intensity and misplacement of location during the event. This report details surrounding the significant revision to track and intensity of this cyclone conducted in post-event review.

Tropical Cyclone 03A (Keila)

Tropical Cyclone (TC) 03A (Keila) formed within the monsoon trough over the western Arabian Sea before consolidating into a very small TC and tracking slowly poleward toward the southeast coast of Oman during the first week of November. Extensive post-analysis of TC 03A identified a number of inaccurate position and intensity estimates, which resulted in major best track revision.

At the final warning time of 02/1800Z, the real-time best track position was placed onshore based on infrared satellite fixes from PGTW and KNES, extrapolation of past movement, and wind observations from Salalah, Oman (OOSA). Nearly all subjective Dvorak fixes between 02/18Z and 03/21Z were located either over land or very near the coast of Oman. However, post-analysis utilizing microwave satellite imagery indicated that TC 03A remained offshore at 02/1800Z and continued to track over water for the next 24 hours.

Figure 2-2 below depicts a segment of the original best track in red from 02/00Z (first warning) to 02/18Z (final warning) with arrows indicating the adjustments made to formulate the final best track (in black). The operational best track indicated a generally poleward track into Oman. However, post-analysis suggests that TC 03A followed a more erratic track including two small loops.

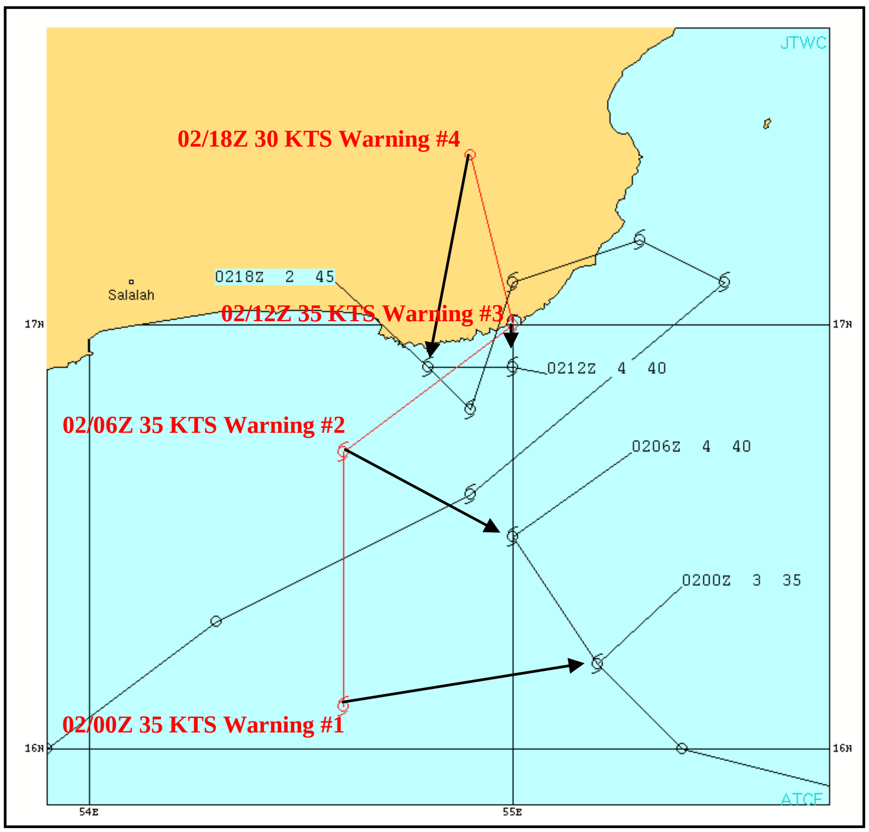


Figure 2-2. Final best track for TC 03A (black) with original best track (red).

Although post-event adjustments to real-time best track position were significant, this review focuses on particularly noteworthy revisions to best track intensity estimates for the 48-hour period beginning on November 2 at 0000Z (JTWC's first warning time). Post-event review indicates that several factors contributed to erroneous intensity assessments during this period:

- Inaccurate Dvorak intensity estimates due to interaction with land
- Inadequate microwave position and intensity estimation techniques
- Lack of a conceptual model for pressure gradients in very small cyclones

A detailed discussion of these factors and recommendations for new tools and techniques to address future challenges follow.

The revised best track positions formulated during post-analysis indicate that TC 03A tracked along the coast of Oman throughout the 02/18Z to 04/00Z period. All agencies (PGTW, KNES and DEMS) reported Dvorak current intensity estimates of T2.5 or lower during this period as deep convection weakened and became increasingly fragmented over the inland portion of the circulation. This weakening is clearly evident in a 03/1145Z enhanced infrared satellite image (Figure 2-3). However, a nearly coincident 03/1218Z SSMI 85 GHz image (Figure 2-4) showed tightly-wrapped deep convective banding over a well-organized low-level circulation center.

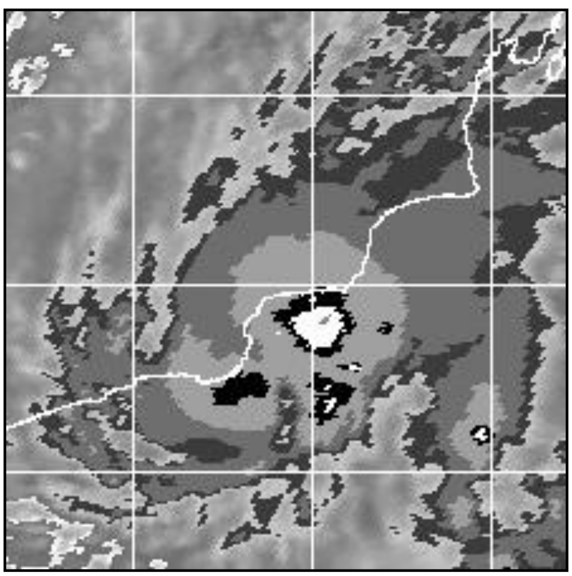


Figure 2-3. Meteosat-7 enhanced Infrared image with BD enhancement (03/1145Z).

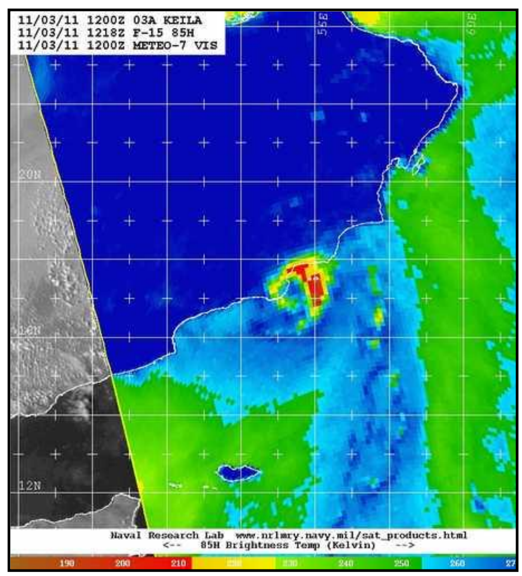


Figure 2-4. SSMI 85 GHz image (03/1218Z).

Additionally, a series of microwave satellite images (Figures 2-5 to 2-7) from the 02/1800Z to 03/1200Z indicate that TC 03A maintained a well-organized structure with tightly-wrapped convective banding during the period. Based on empirical observations, this convective signature is typically indicative of a 45-55 knot system.

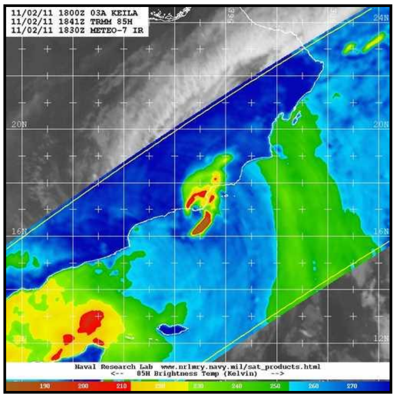


Figure 2-5. 021841Z TRMM image.

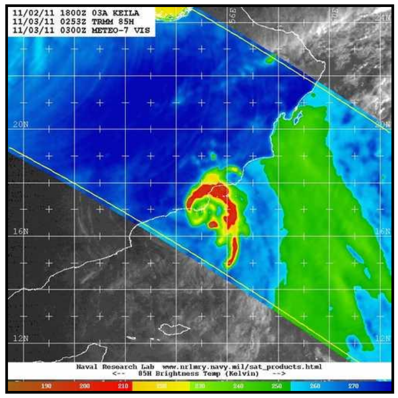


Figure 2-6. 030253Z TRMM image.

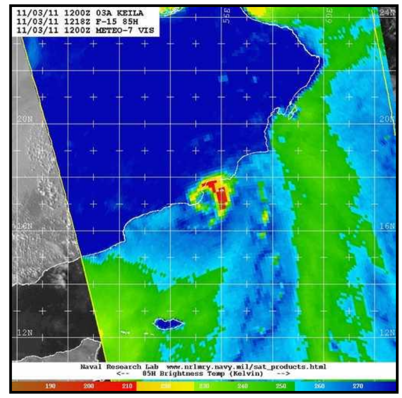


Figure 2-7.031218Z SSMI image.

Although scatterometer data (Figures 2-8 and 2-9) was limited due to the close proximity of the system to land, associated imagery did show 35-40 knot maximum sustained surface winds along the southeastern periphery of TC 03A between 03/05Z and 03/20Z. Even higher wind speeds could be expected near the center of the cyclone.

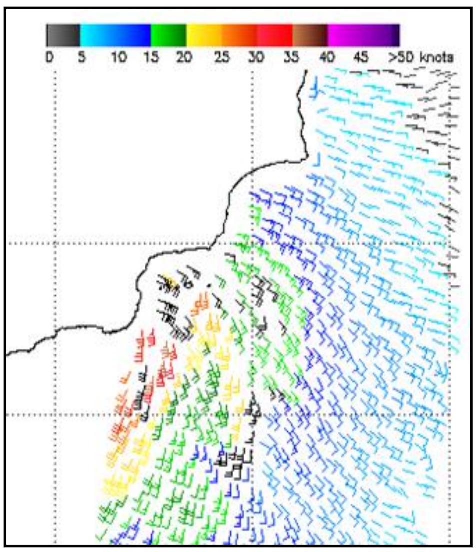


Figure 2-8. ASCAT image 03/0525Z.

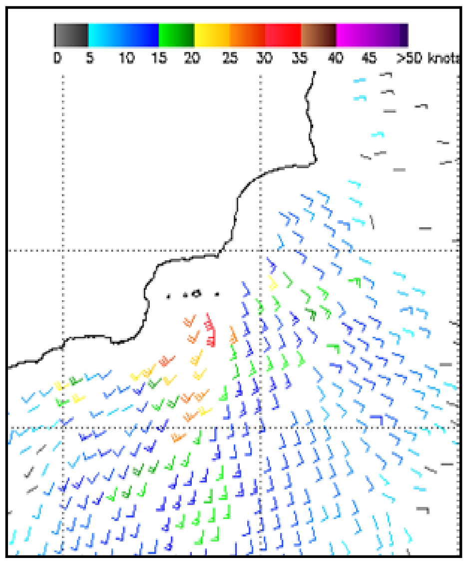


Figure 2-9. OceanSAT image 03/1937Z.

Surface observations (Table 2-3) available during the 02/18Z to 04/00Z period were limited to two reporting stations (OOSA and KQTH) and one drifting buoy. These observations were all taken within 70 nm of the cyclone's center and seemed to suggest a weaker system consistent with the subjective Dvorak values, which ranged from 25 to 30 knots (T1.0-2.0). The apparent disparity between the noted microwave imagery (suggesting a well defined and intense cyclone) and these observations suggests that the cyclone's maximum wind area was very small and/or that the surface wind speeds were reduced by frictional effects over land. In order to assess the validity of the revised best track intensity estimates that ranged from 45-55 knots, efforts were made to derive an intensity estimate from available sea level pressure (SLP) data. First, calculations using the SLP data and a modified Rankine vortex formulation from Depperman (1947[2]) yielded sustained wind estimates of approximately 20 knots gusting to 30 knots. Second, applying wind-pressure relationships (WPRs) from Harper, 2002[5] (figure 2-10) and a Δp of 33 mb (environmental pressure of 1014 mb minus an estimated central pressure of 981 mb) yields a maximum sustained wind speed estimate of 22 to 35 knots (one-minute wind speed average). Both calculations were assessed as being too low, especially considering the actual winds reported at OOSA were higher. Supporting this perspective, Holland (1980[6]) showed that the wind and SLP gradients within small TCs like TC 03A can significantly exceed those used to derive the WPRs discussed in Harper (2002[5]).

	OOSA winds	OOSA SLP	KQTH winds	KQTH SLP
02/18Z	330/25G36 kts	1002 mb	-------	-------
03/00Z	310/17 kts	1002 mb	020/17 kts	1008 mb
03/06Z	340/26G37 kts	1005 mb	020/19G24 kts	1011 mb
03/12Z	340/24G34 kts	1003 mb	020/18G27 kts	1009 mb
03/18Z	350/20 kts	1007 mb	-------	-------
04/00Z	-------	-------	-------	-------

Table 2-3. Surface wind and sea level pressure obs from Salalah (OOSA) and Thumrait (KQTH), Oman.

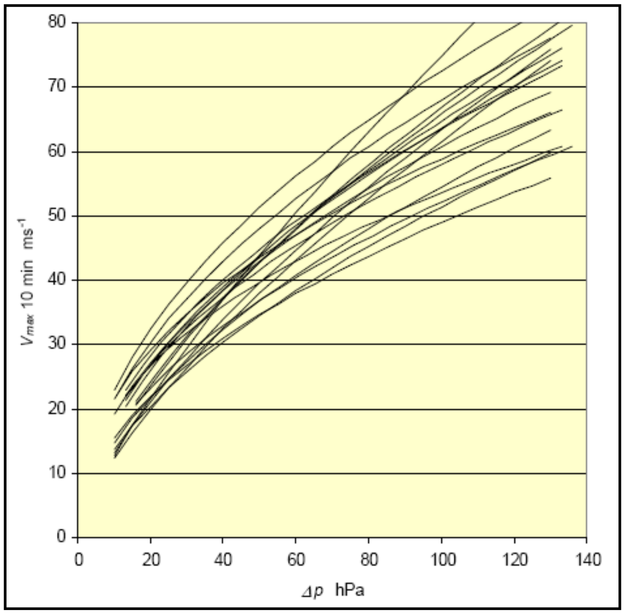


Figure 2-10. WPRs calculated from formulas published in peer-reviewed research between 1939 and 2002 (from Harper, 2002).

To reconcile seeming incongruent Dvorak, microwave satellite, scatterometer, and observational data, we considered that the Dvorak method often underestimates the intensity of very small TCs as well as those that pass over and in close proximity to land, resulting in a "dramatic weakening of the cloud pattern and warming of cloud tops" (Dvorak, 1984[3]). Given this noted weakness in the Dvorak method, the level of convective organization observed in microwave imagery, and wind speed estimates derived from observations, best track intensities for the 02/18Z to 04/00Z period were increased significantly during post-analysis. We speculate that land interaction disrupted the cloud pattern over the western semi-circle of TC03A throughout this period, yielding low Dvorak estimates despite strong low-level organization. The very small size of this system may have also contributed to low Dvorak estimates. Real-time and post-analysis intensity estimates for TC 03A are summarized in Table 2-4.

DTG	Original Best Track Intensity	Real-time Dvorak (PGTW)	Revised Best Track Intensity	After-the-fact Dvorak
02/18Z	30 knots	Overland	45 knots	2.5/3.0
03/00Z	25 knots	1.5/2.0	50 knots	2.5/3.0

03/06Z	30 knots	1.5/2.0	55 knots	2.0/2.5
03/12Z	25 knots	1.0/1.5	50 knots	2.5/2.5
03/18Z	25 knots	1.5/1.5	45 knots	1.5/2.5
04/00Z	25 knots	1.0/1.0	40 knots	N/A

Table 2-4. PGTW Dvorak real-time and after-the-fact intensity fixes and best-track.

Figure 2-11 further highlights the disparity between subjective Dvorak estimates and final best track (post-analysis) intensity estimates for TC 03A. This disparity is most significant during the 02/1800Z to 04/0000Z period, highlighted with a yellow box.

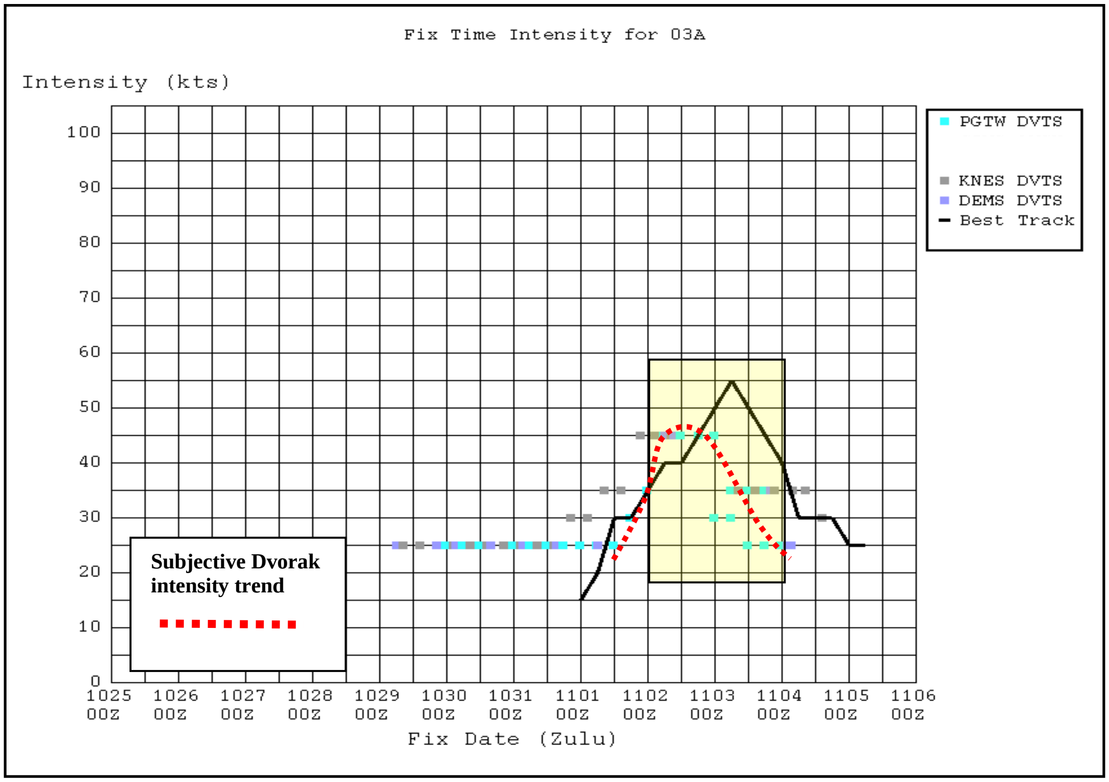


Figure 2-11. Fix Time Intensity Graph with subjective intensity fixes and trend line.

Given inconsistencies among analysis methods, data, and wind-pressure relationships discussed in this summary, it is clear that more work is needed to help satellite analysts and forecasters formulate accurate intensity analyses. First, a comprehensive subjective method to derive TC position and intensity estimates from available microwave satellite imagery to mitigate noted weaknesses in the existing Dvorak methodology for cyclones passing near and over land is needed. The Japan Meteorological Agency has developed methods (Hoshino 2007[4]; Nishimura 2007[9]; Yoshida 2011[10]) to extend the Dvorak technique specifically using AMSR-E (now non-operational) and TRMM microwave imagery. Additionally, the Naval Research Laboratory in Monterey is currently working on an objective microwave fix methodology and other efforts have been undertaken to qualitatively assess rapid intensification using 37 GHz microwave imagery (Kieper, 2008[7]). However, there is no documented, comprehensive technique available to consistently and accurately assess TC position and intensity using all available microwave imagery. Such a method would complement the Dvorak technique for cyclones passing over data sparse open-ocean areas within the JTWC forecast AOR. Second, a tool to derive intensity estimates from sea-level pressure data using an appropriate, forecaster-selected wind-pressure relationship based on observed cyclone structure is needed to provide more consistent information to operational customers.

References

[1]Demuth, Julie L., Mark DeMaria, John A. Knaff, 2006: Improvement of Advanced Microwave Sounding Unit Tropical Cyclone Intensity and Size Estimation Algorithms. *J. Appl. Meteor. Climatol.*, **45**, 1573–1581.

[2]Depperman, C.E., 1947: Not. To the origin and structure of Philippine typhoon's. Bull Amer. Met. Coc. 28. 399-404

[3]Dvorak, Vernon F., 1984: A Workbook on Tropical Clouds and Cloud Systems Observed in Satellite Imagery, Volume II. NAVEDTRA 40971, Stennis Space Center, Mississippi.

[4]Hoshino, Shunsuke, Nakazawa, Tetsuo, 2007: Estimation of Tropical Cyclone's Intensity Using TRMM/TMI Brightness Temperature Data, Journal of the Meteorological Society of Japan, Vol. 85, No. 4, pp. 437 – 454, Meteorological Society of Japan.

[5]Harper, B. A., 2002: Tropical cyclone parameter estimation in the Australian region: Wind–pressure relationships and related issues for engineering planning and design—A discussion paper. Systems Engineering Australia Party Ltd. (SEA) for Woodside Energy Ltd., SEA Rep. J0106-PR003E, 83 pp.

[6]Holland, Greg J., 1980: *An Analytic Model of the Wind and Pressure Profiles in Hurricanes. Monthly Weather Review, 108, 1212-1218.*

[7]Kieper, M., 2008: A Technique for Anticipating Initial Rapid Increases in Intensity in Tropical Cyclones, Using 37 GHz Microwave Imagery. Extended Abstract: http://ams.confex.com/ams/pdfpapers/140605.pdf, *AMS 28th Conference on Hurricanes and Tropical Meteorology*, Wyndham Orlando Resort, Orlando, FL, 28 April – 2 May.

[8]Knaff, John A., Raymond M. Zehr, 2007: Reexamination of Tropical Cyclone Wind–Pressure Relationships. *Wea. Forecasting*, **22**, 71–88.

[9]Nishimura, Shuji, Yoshida, Shiro, Endo, Takeshi, Otsubo, Kohei, Mori, Koki, Saito, Sadao, Kato, Koji, Oyama, Ryo, Shimizu, Akihiro, Asano, Junichi, 2007: Analysis of tropical cyclones with microwave satellite imagery, Meteorological Satellite Center Technical Note No. 49, Meteorological Satellite Center, 91 – 125.

[10]Yoshida, Shiro, Sakai, Makoto, Shouji, Akiko, Hirohata, Masaya, Shimizu, Akihiro, 2011: Estimation of Tropical Cyclone Intensity Using Aqua/AMSR-E Data, Meteorological Satellite Center Technical Review No. 13, Meteorological Satellite Center, 1 – 36.

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 2011 tropical cyclone season (1 July 2010 – 30 June 2011) and the monthly distribution of TC activity summarized for 1975 - 2011.

Section 1 Informational Tables

Table 3-1 is a summary of TC activity in the Southern Hemisphere during the 2011 season. Table 3-2 provides the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2011.

Table 3-1

SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 2011

(01 JULY 2010 - 30 JUNE 2011)

TC	NAME*	PERIOD		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)**
01S	-	26 Oct / 1200Z	28 Oct / 0600Z	5	35	996
02S	Anggrek	30 Oct / 1800Z	04 Nov / 0600Z	10	55	982
03S	Abele	29 Nov / 1200Z	03 Dec /1800Z	10	80	963
04P	Tasha	24 Dec / 1800Z	25 Dec / 0600Z	2	40	993
05P	Vania	11 Jan / 1800Z	15 Jan / 0600Z	8	55	982
06S	Vince	12 Jan / 1200Z	16 Jan / 1200Z	8	45	989
07P	Zelia	14 Jan / 0000Z	17 Jan / 1800Z	9	95	952
08P	Wilma	22 Jan / 0000Z	28 Jan / 1200Z	14	115	937
09P	Anthony	23 Jan / 0000Z	30 Jan / 1200Z	8	55	982
10S	Bianca	25 Jan/ 1200Z	29 Jan /1800Z	13	95	952
11P	Yasi	30 Jan/ 0000Z	03 Feb/ 0000Z	9	135	922
12P	Zaka	06 Feb / 1800Z	07 Feb / 1800Z	3	45	989
13S	Bingiza	09 Feb / 1800Z	17 Feb / 1800Z	18	100	948
14S	Fourteen	11 Feb / 1200Z	12 Feb / 0000Z	2	35	996
15S	Carlos	15 Feb / 1800Z	26 Feb / 0000Z	20	65	974
16S	Diane	16 Feb / 0000Z	22 Feb / 0000Z	13	80	963
17P	Atu	21 Feb / 1800Z	23 Feb / 1800Z	11	115	937
18S	Cherono	17 Mar / 0600Z	19 Mar / 1800Z	6	45	989
19P	Bune	23 Mar / 1800Z	23 Mar / 1800Z	11	75	967
20S	Twenty	02 Apr / 0000Z	04 Apr / 1200Z	6	35	996
21S	Errol	15 Apr / 0000Z	18 Apr / 1200Z	10	55	982

*As designated by the responsible RSMC

**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 - 2011													
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 - 2011													
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	0	0	0	1	2	1	6	5	5	3	0	0	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
2010	0	0	0	0	2	4	5	6	5	2	0	0	24
2011	0	0	0	1	1	2	6	7	2	2	0	0	21
(1981 - 2010)													
MEAN	0.3	0.1	0.3	0.7	1.6	3.1	5.9	6.3	4.9	3.0	0.8	0.2	27.2
CASES	9	3	9	21	50	97	183	195	153	94	24	6	844
* (GRAY, 1978)													

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.

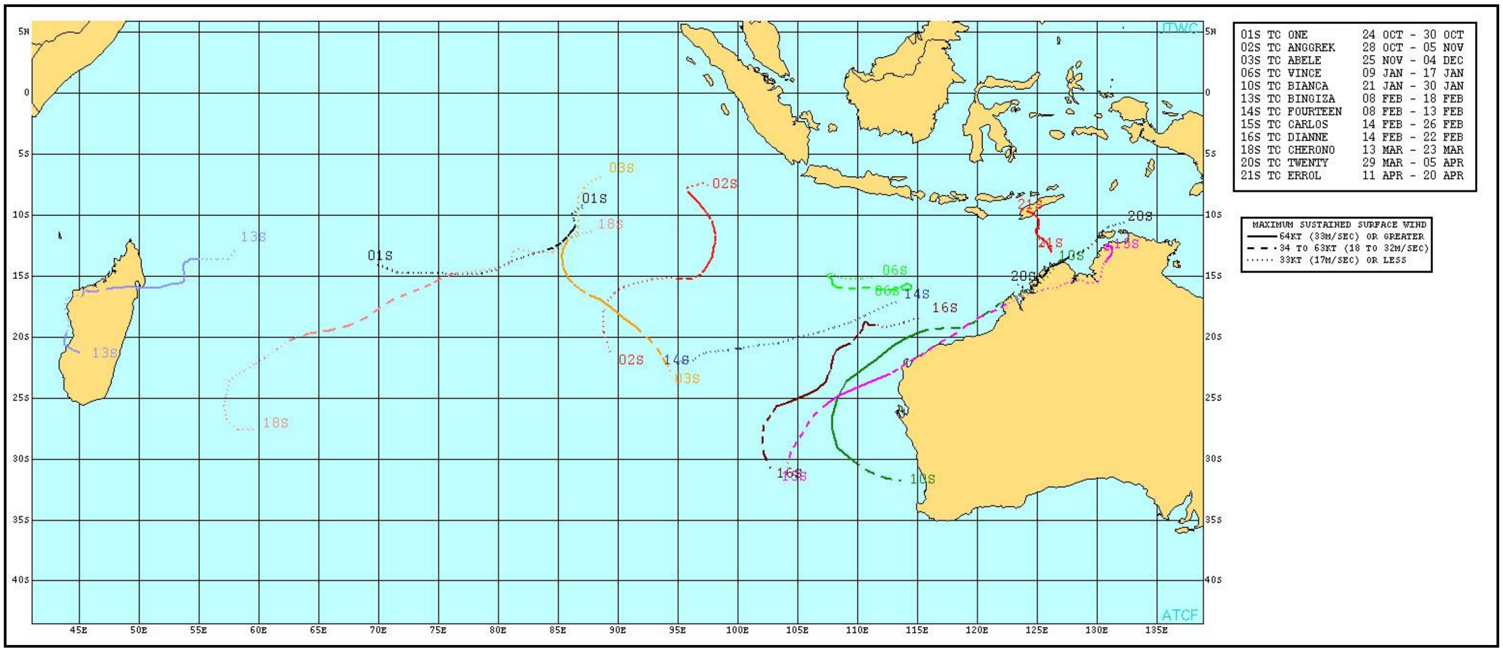


Figure 3-1. Southern Indian Ocean Tropical Cyclones.

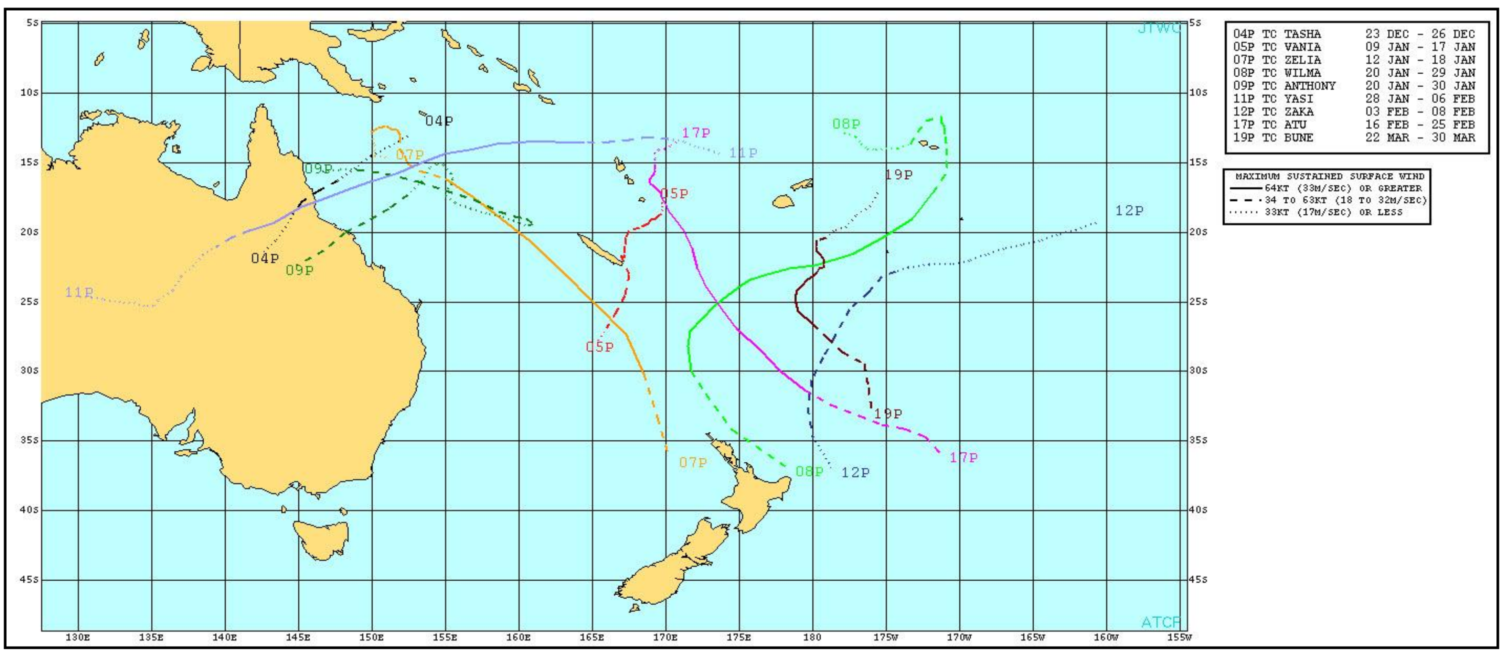


Figure 3-2. Southeast Pacific Ocean Tropical Cyclones.

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).

Since JTWC changed its 24 hour tropical cyclone formation potential classification system from “poor, fair, and good” to the probabilistic “low, medium, and high” on 1 June 2011, classification levels for the 2011 Southern Hemisphere season followed the old system. These classifications are defined as follows:

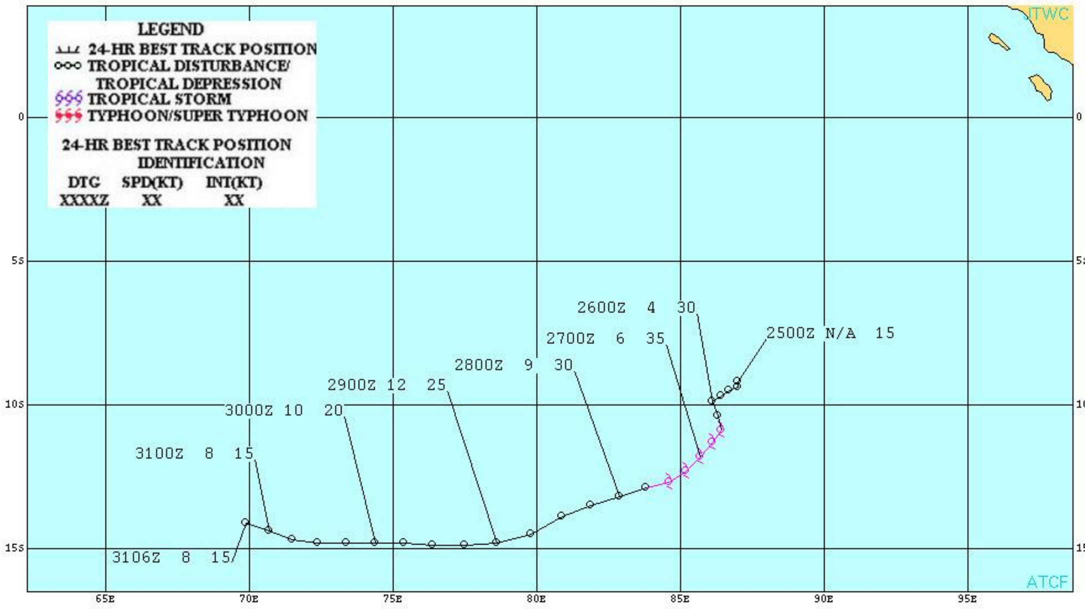
“Poor” formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours.
“Fair” formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.
“Good” formation potential describes an area that is being monitored for development and is either expected to develop within 24 hours or development has already started, but warning criteria have not yet been met. All areas designated as “Good” are accompanied by a Tropical Cyclone Formation Alert.

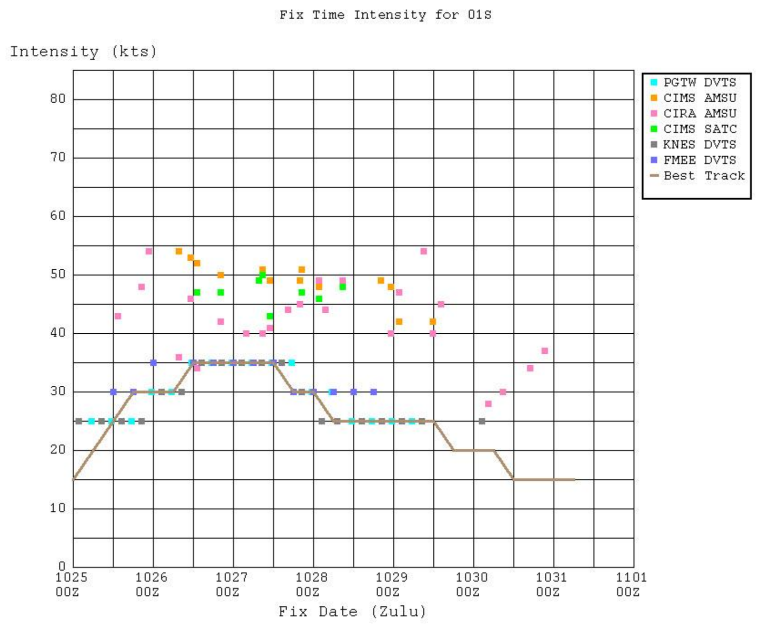
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

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 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

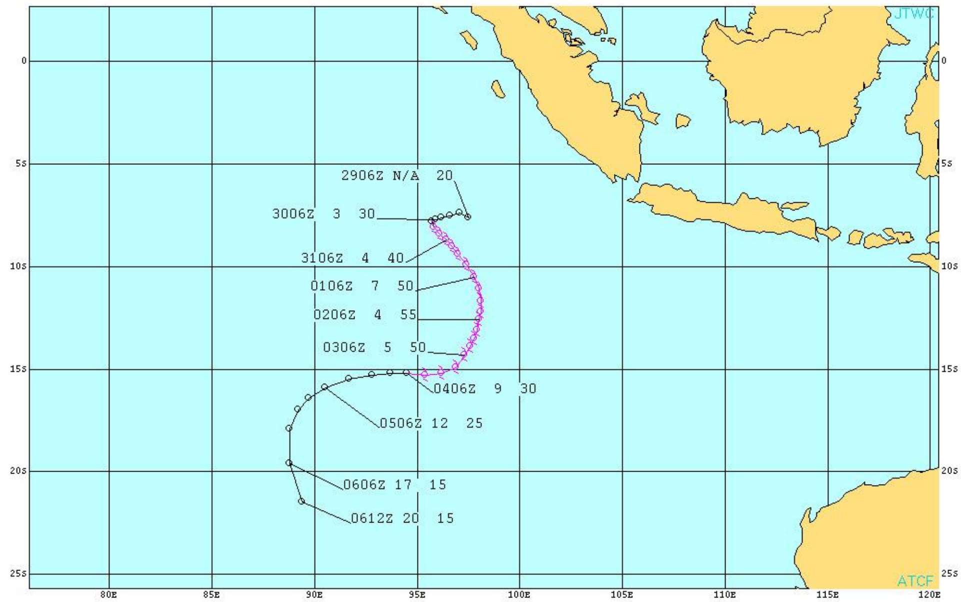
ISSUED POOR:	1400Z 25 Oct 2010
ISSUED FAIR:	N/A
FIRST TCFA:	2300Z 25 Oct 2010
FIRST WARNING:	1200Z 26 Oct 2010
LAST WARNING:	0600Z 28 Oct 2010
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	5

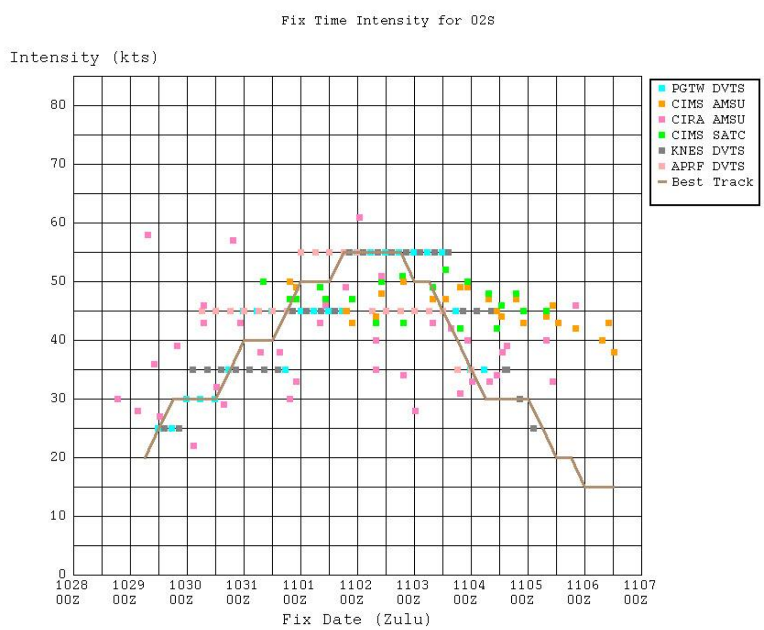




Tropical Cyclone 02S (Anggrek)

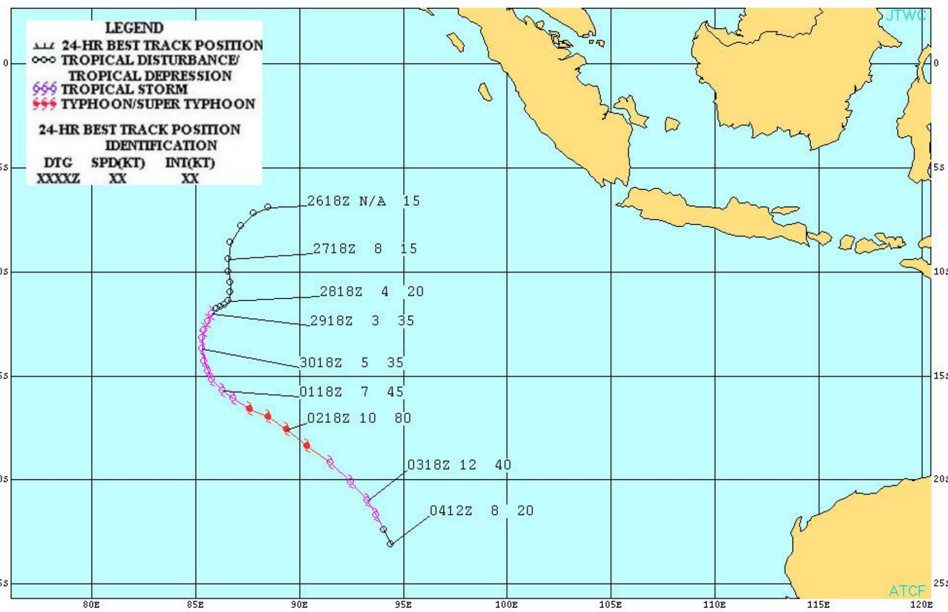
ISSUED POOR:	N/A
ISSUED FAIR:	1800Z 29 Oct 2010
FIRST TCFA:	2200Z 29 Oct 2010
FIRST WARNING:	1800Z 30 Oct 2010
LAST WARNING:	0600Z 04 Nov 2010
MAX INTENSITY:	55 Kts
NUMBER OF WARNINGS:	10

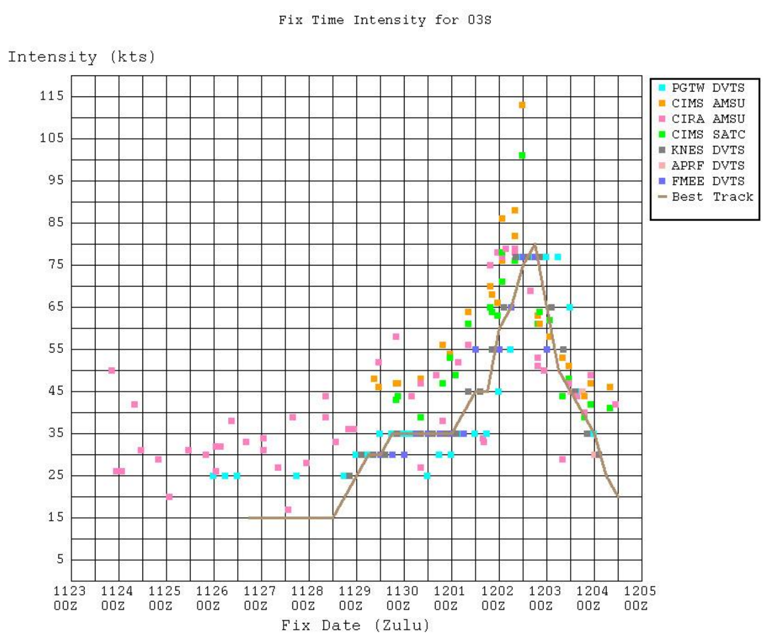




Tropical Cyclone 03S (Abele)

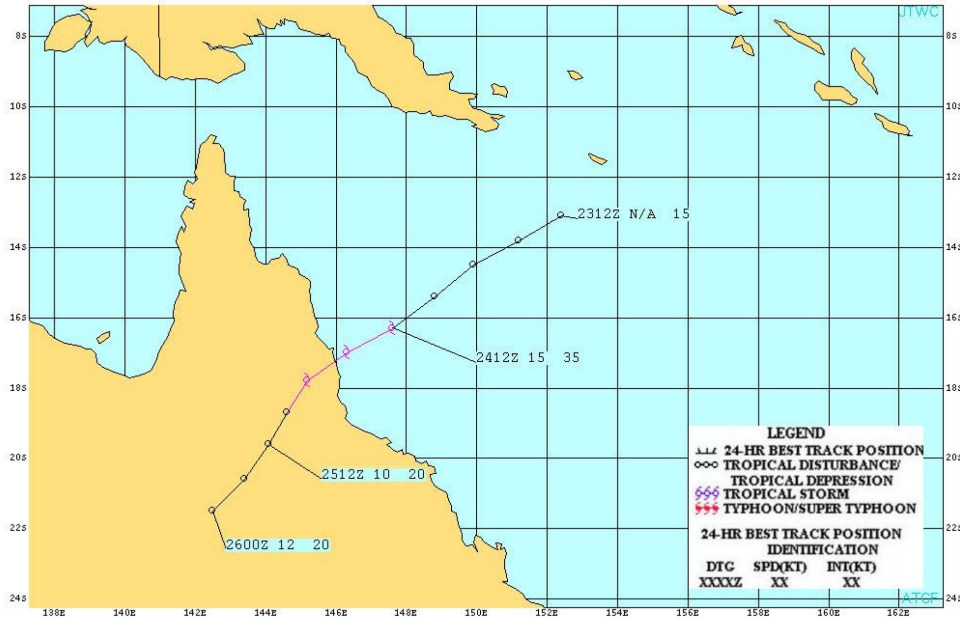
ISSUED POOR:	0130Z 26 Nov 2010
ISSUED FAIR:	1800Z 26 Nov 2010
FIRST TCFA:	2300Z 28 Nov 2010
FIRST WARNING:	1200Z 29 Nov 2010
LAST WARNING:	1800Z 03 Dec 2010
MAX INTENSITY:	80 Kts
NUMBER OF WARNINGS:	10

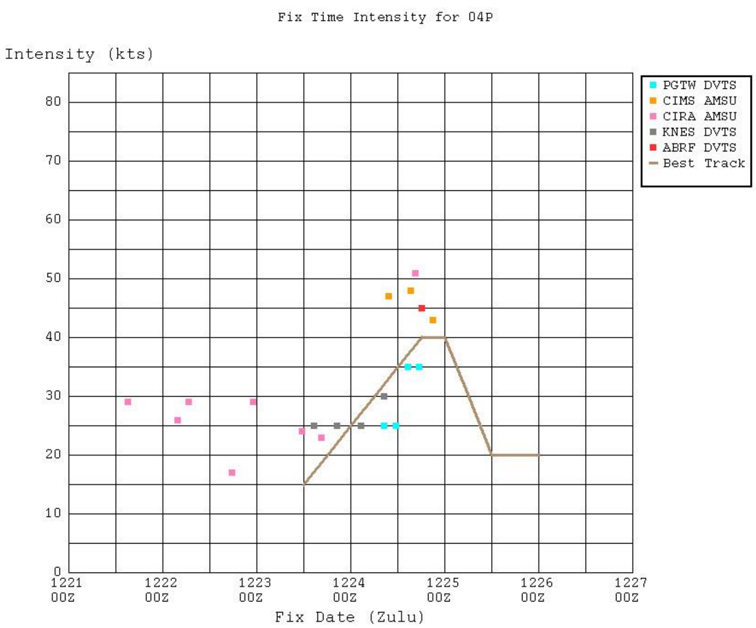




Tropical Cyclone 04P (Tasha)

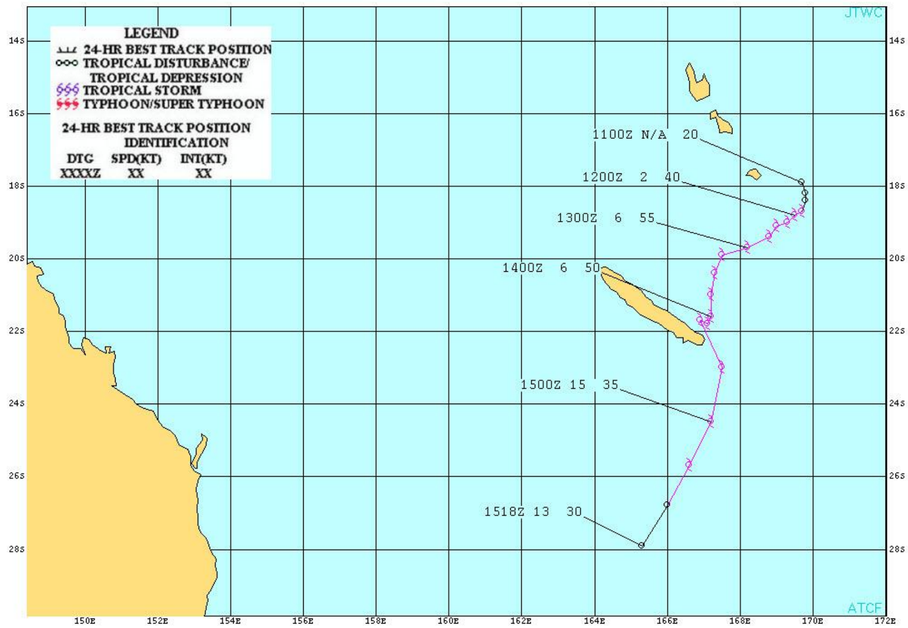
ISSUED POOR: N/A
ISSUED FAIR: 1030Z 24 Dec 2010
FIRST TCFA: 1600Z 24 Dec 2010
FIRST WARNING: 1800Z 24 Dec 2010
LAST WARNING: 0600Z 25 Dec 2010
MAX INTENSITY: 40 Kts
NUMBER OF WARNINGS: 2

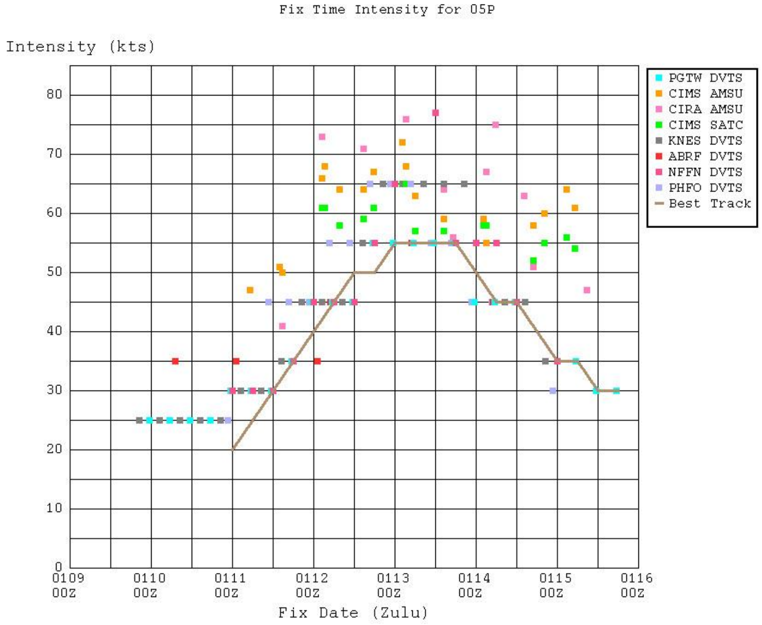




Tropical Cyclone 05P (Vania)

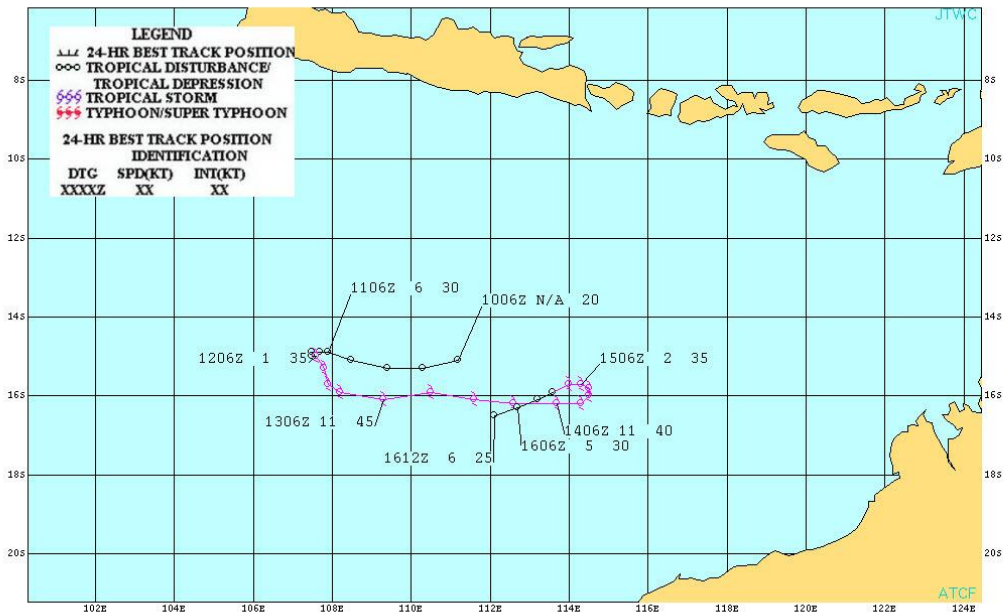
ISSUED POOR: 0800Z 08 Jan 2011
ISSUED FAIR: 0600Z 10 Jan 2011
FIRST TCFA: 0200Z 11 Jan 2011
FIRST WARNING: 1800Z 11 Jan 2011
LAST WARNING: 0600Z 15 Jan 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 8

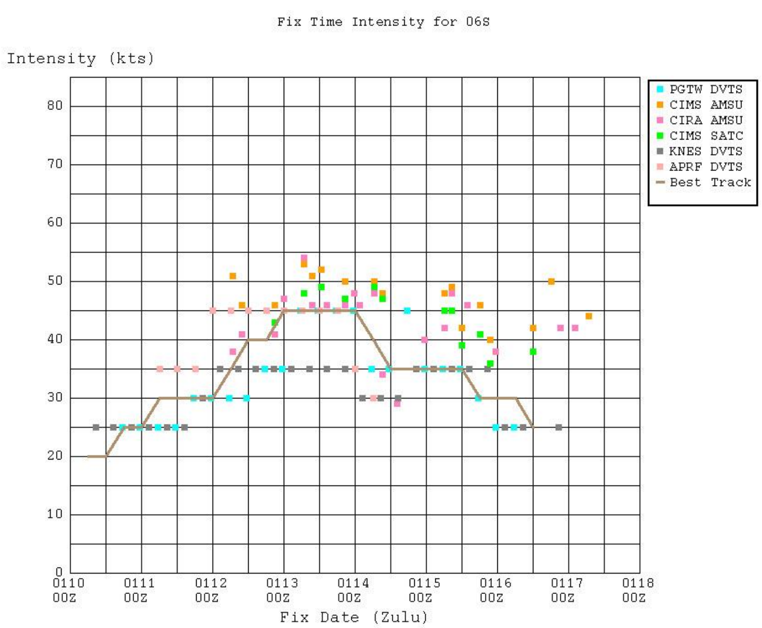




Tropical Cyclone 06S (Vince)

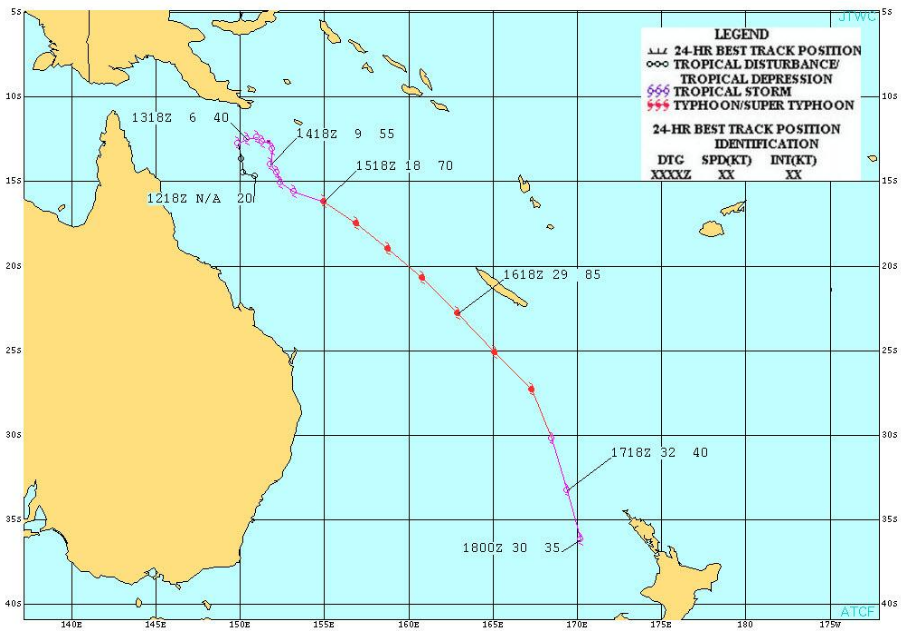
ISSUED POOR:	0930Z 10 Jan 2011
ISSUED FAIR:	1800Z 10 Jan 2011
FIRST TCFA:	0800Z 11 Jan 2011
FIRST WARNING:	1200Z 12 Jan 2011
LAST WARNING:	1200Z 16 Jan 2011
MAX INTENSITY:	45 Kts
NUMBER OF WARNINGS:	8

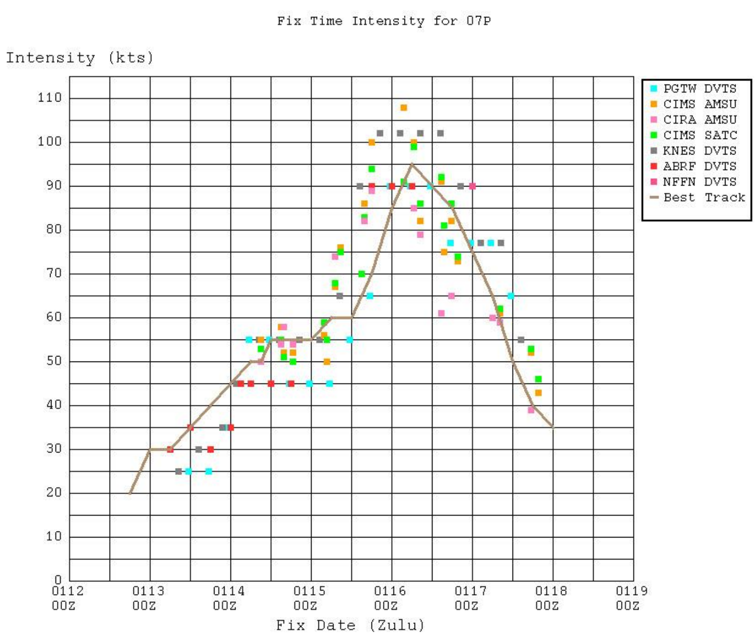




Tropical Cyclone 07P (Zelia)

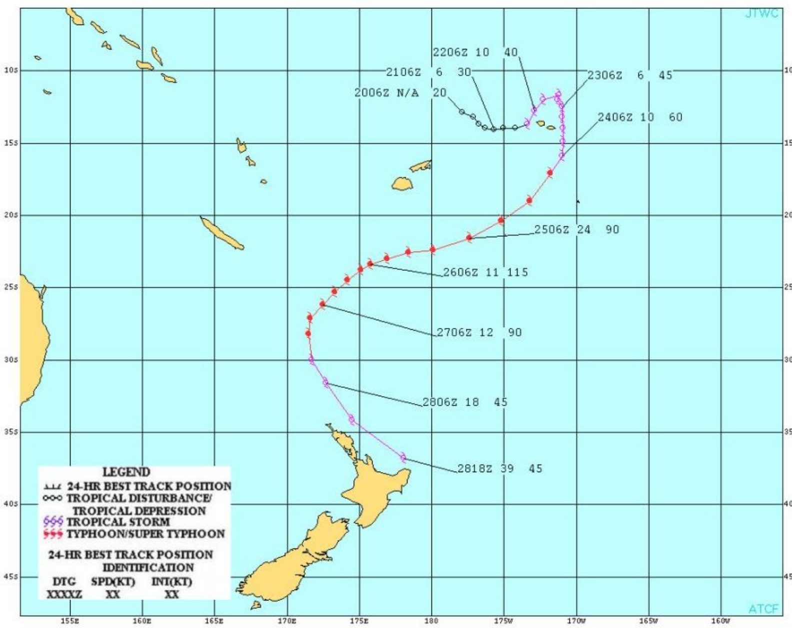
ISSUED POOR: N/A
ISSUED FAIR: 0600Z 13 Jan 2011
FIRST TCFA: 1000Z 13 Jan 2011
FIRST WARNING: 0000Z 14 Jan 2011
LAST WARNING: 1800Z 17 Jan 2011
MAX INTENSITY: 95 Kts
NUMBER OF WARNINGS: 9

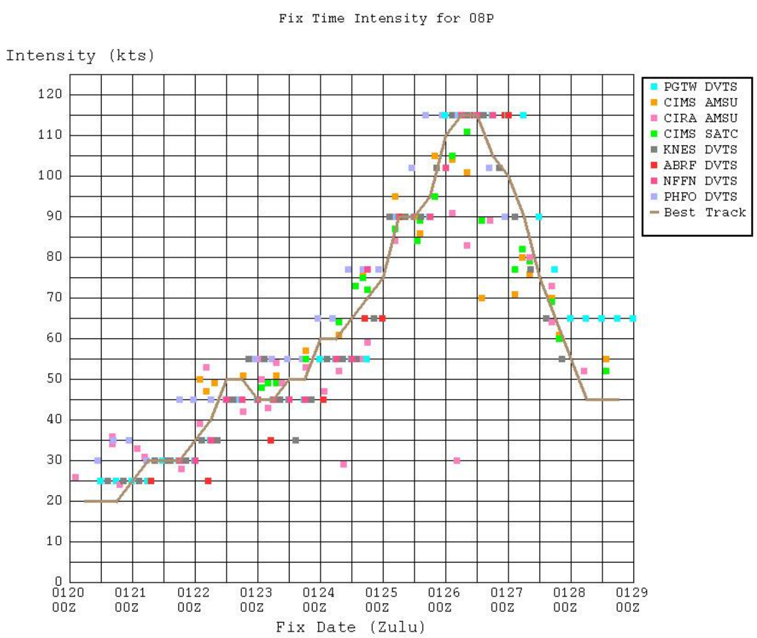




Tropical Cyclone 08P (Wilma)

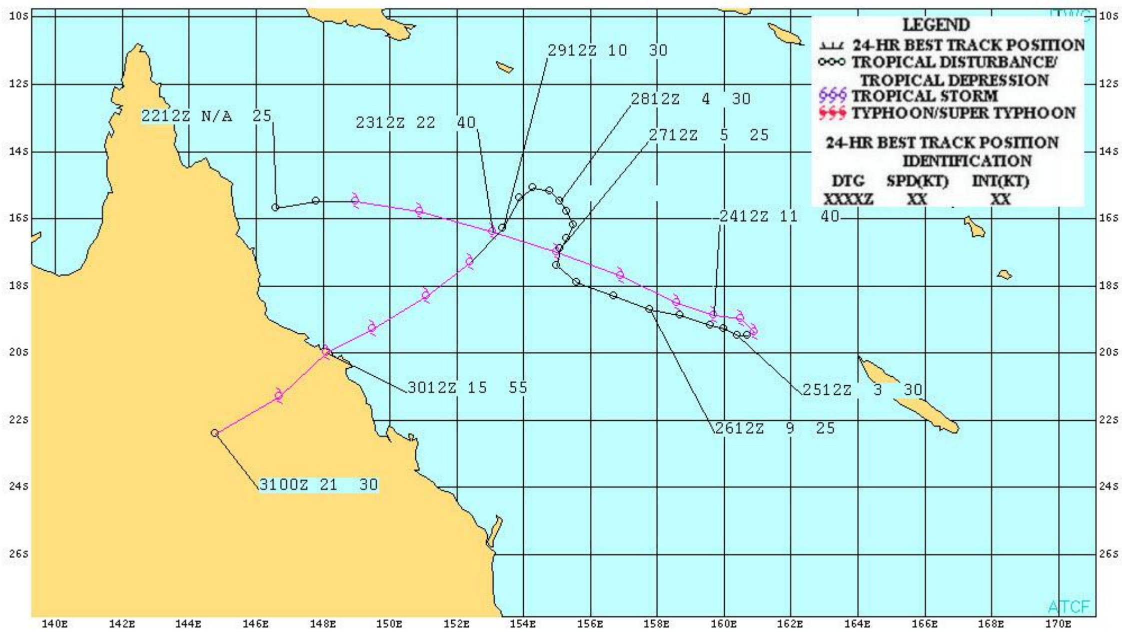
ISSUED POOR:	1300Z 20 Jan 2011
ISSUED FAIR:	0130Z 21 Jan 2011
FIRST TCFA:	1700Z 21 Jan 2011
FIRST WARNING:	0000Z 22 Jan 2011
LAST WARNING:	1200Z 28 Jan 2011
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	14

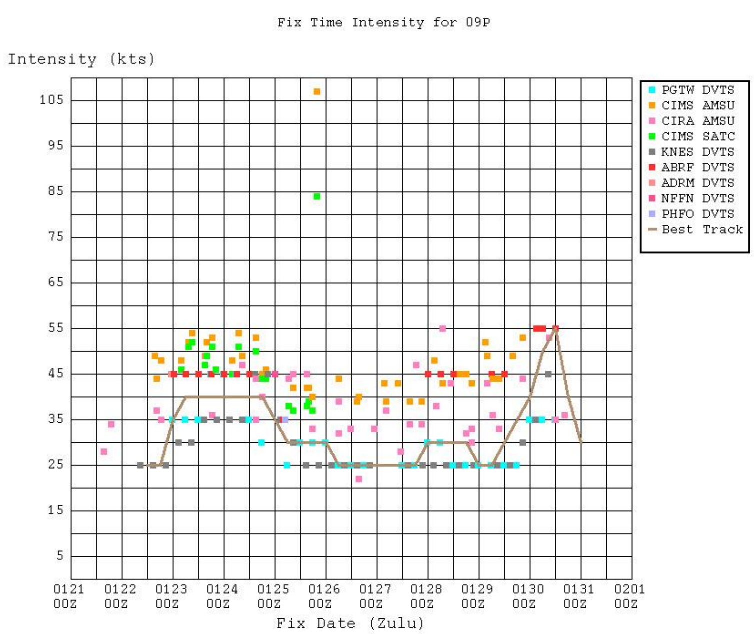




Tropical Cyclone 09P (Anthony)

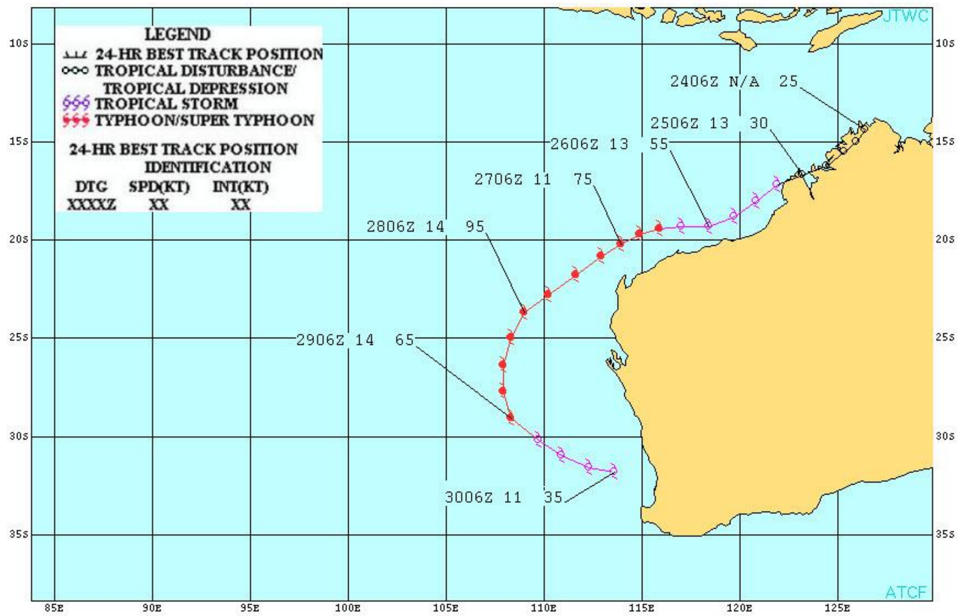
ISSUED POOR: 1730Z 21 Jan 2011
ISSUED FAIR: 0600Z 22 Jan 2011
FIRST TCFA: N/A
FIRST WARNING: 0000Z 23 Jan 2011*
LAST WARNING: 1200Z 30 Jan 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 8
* No JTWC warnings issues from 1200Z 25 Jan 2011- 0000Z 30 Jan 2011

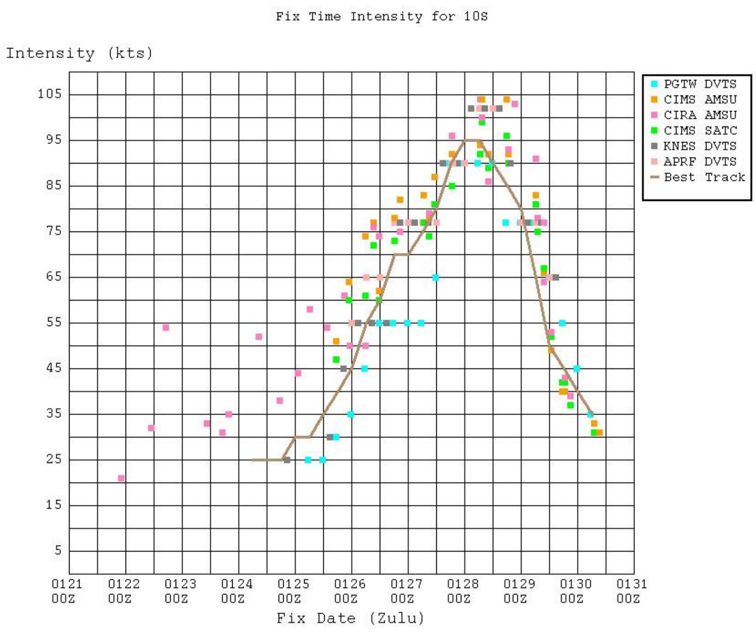




Tropical Cyclone 10S (Bianca)

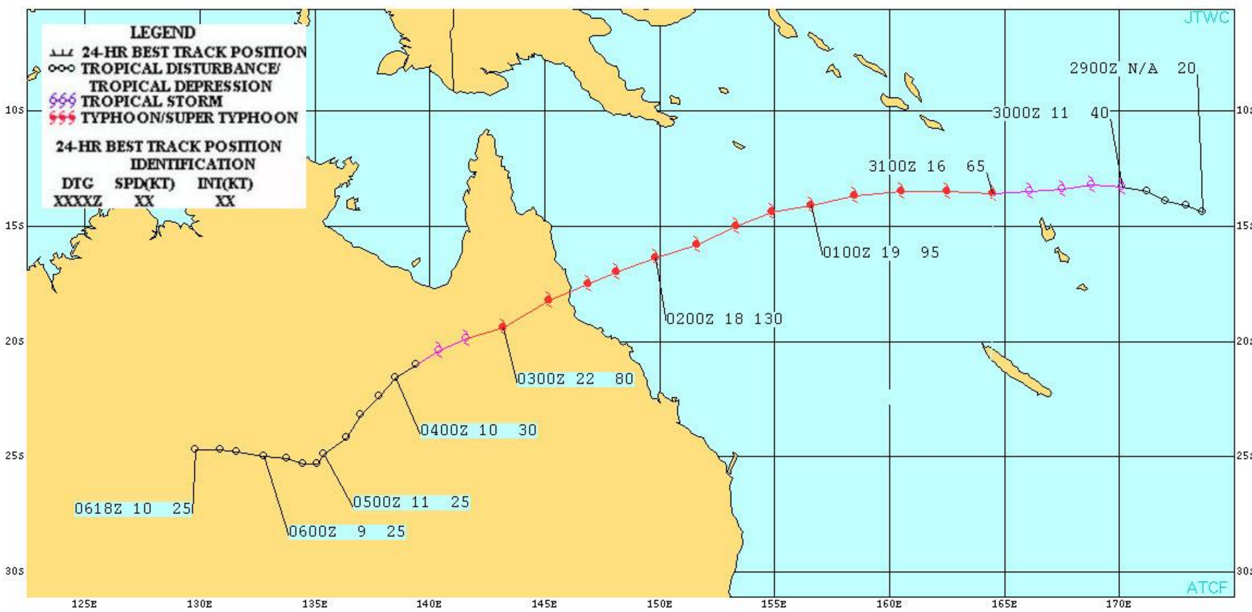
ISSUED POOR:	N/A
ISSUED FAIR:	0530Z 23 Jan 2011
FIRST TCFA:	1230Z 24 Jan 2011
FIRST WARNING:	1200Z 25 Jan 2011
LAST WARNING:	1800Z 29 Jan 2011
MAX INTENSITY:	95 Kts
NUMBER OF WARNINGS:	13

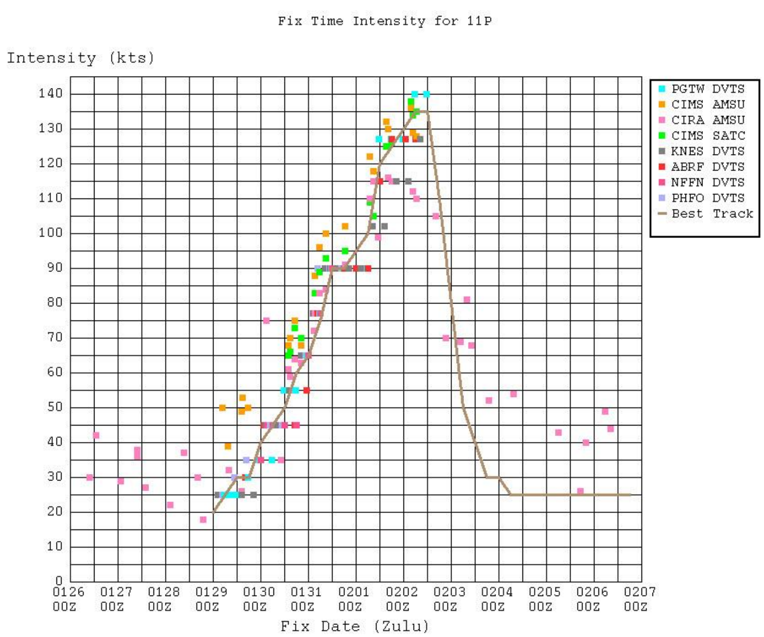




Tropical Cyclone 11P (Yasi)

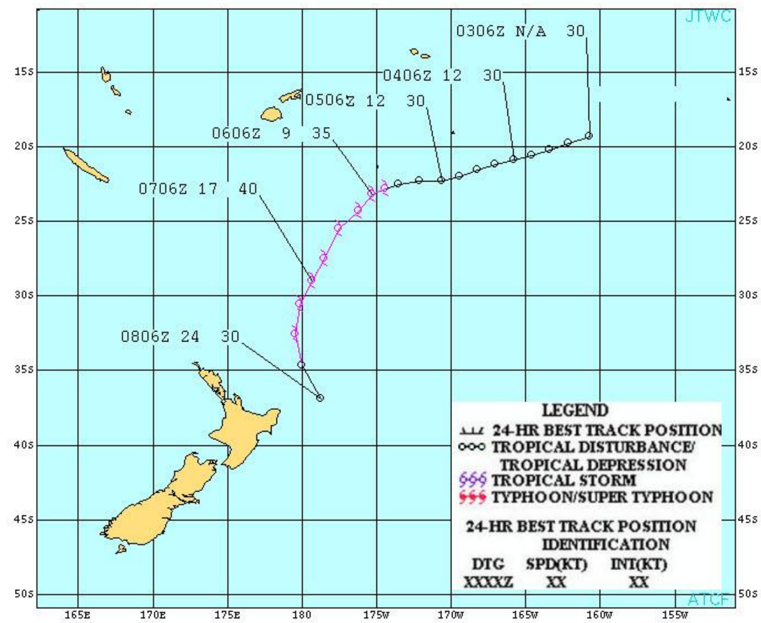
ISSUED POOR:	1800Z 25 Jan 2011
ISSUED FAIR:	1400Z 29 Jan 2011
FIRST TCFA:	1700Z 29 Jan 2011
FIRST WARNING:	0000Z 30 Jan 2011
LAST WARNING:	0000Z 03 Feb 2011
MAX INTENSITY:	135 Kts
NUMBER OF WARNINGS:	9

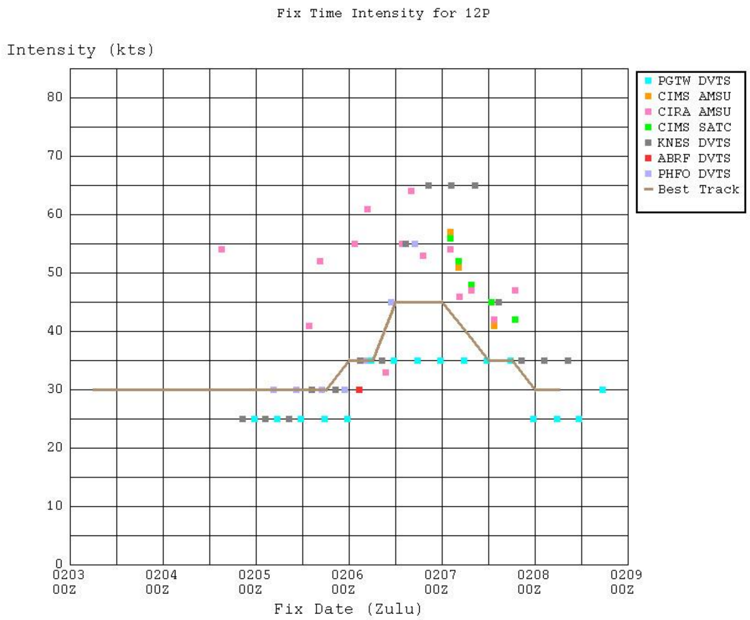




Tropical Cyclone 12P (Zaka)

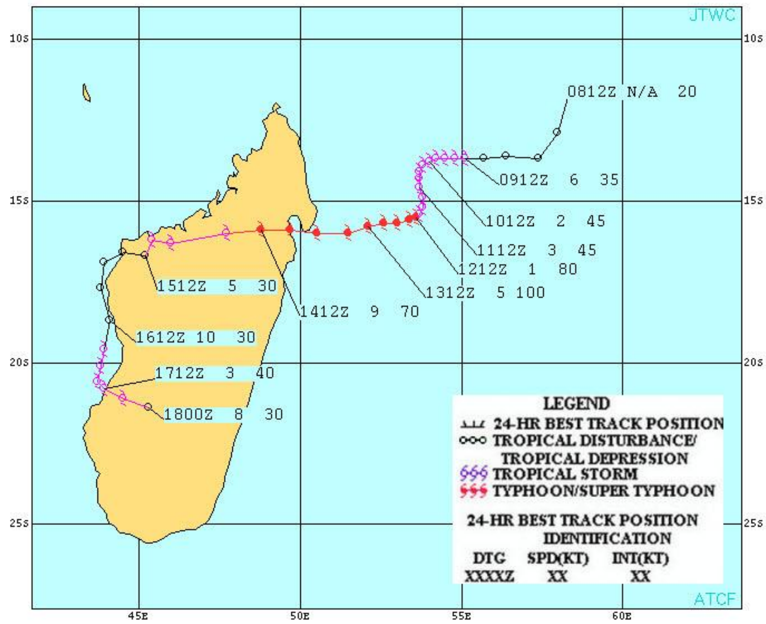
ISSUED POOR: 0400Z 04 Feb 2011
ISSUED FAIR: 2230Z 05 Feb 2011
FIRST TCFA: 0530Z 06 Feb 2011
FIRST WARNING: 1800Z 06 Feb 2011
LAST WARNING: 1800Z 07 Feb 2011
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 3

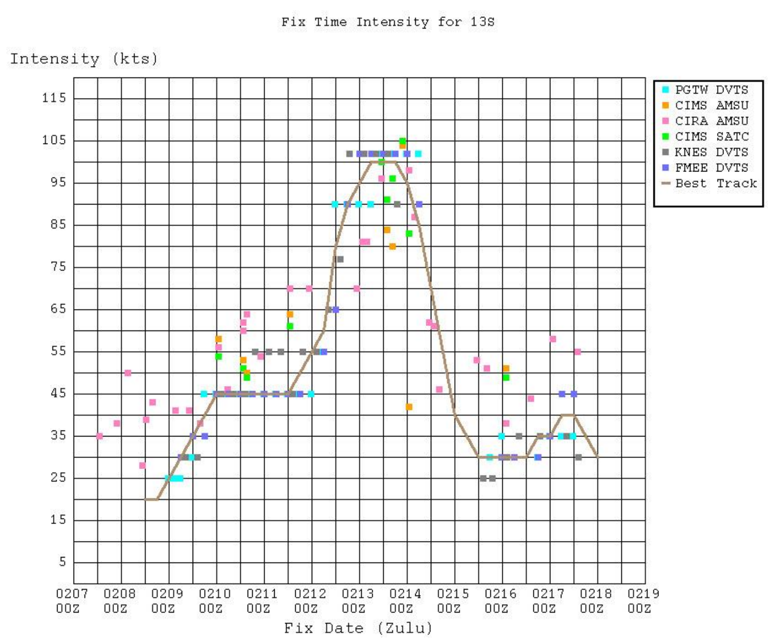




Tropical Cyclone 13S (Bingiza)

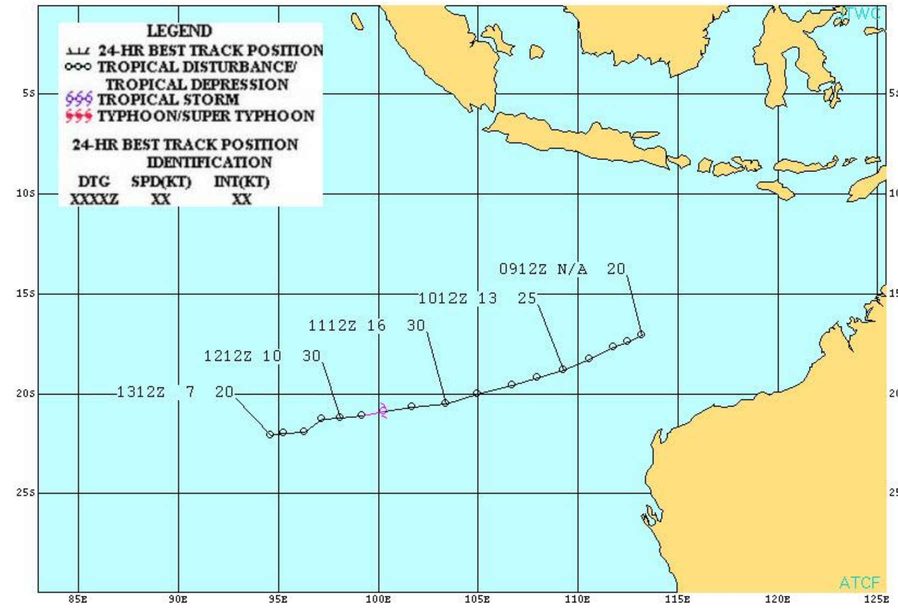
ISSUED POOR:	2030Z 08 Feb 2011
ISSUED FAIR:	0800Z 09 Feb 2011
FIRST TCFA:	1430Z 09 Feb 2011
FIRST WARNING:	1800Z 09 Feb 2011
LAST WARNING:	1800Z 17 Feb 2011
MAX INTENSITY:	100 Kts
NUMBER OF WARNINGS:	18

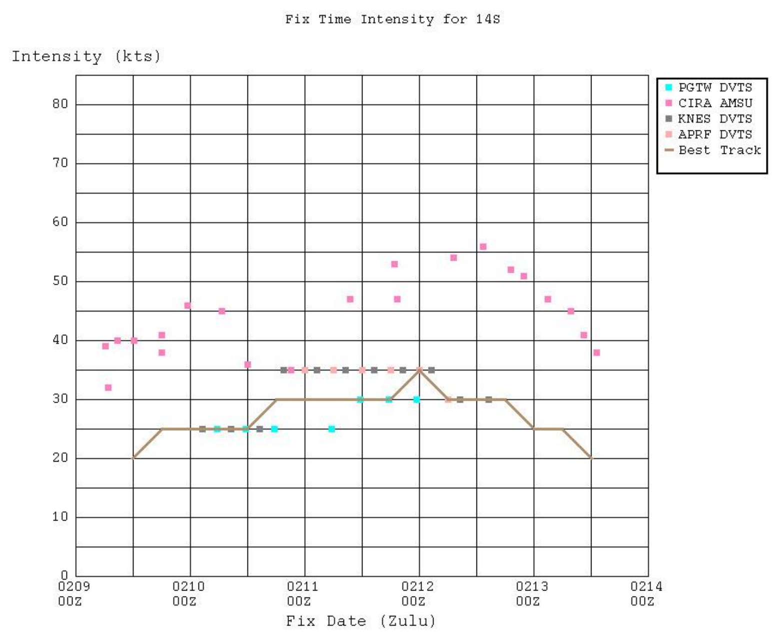




Tropical Cyclone 14S

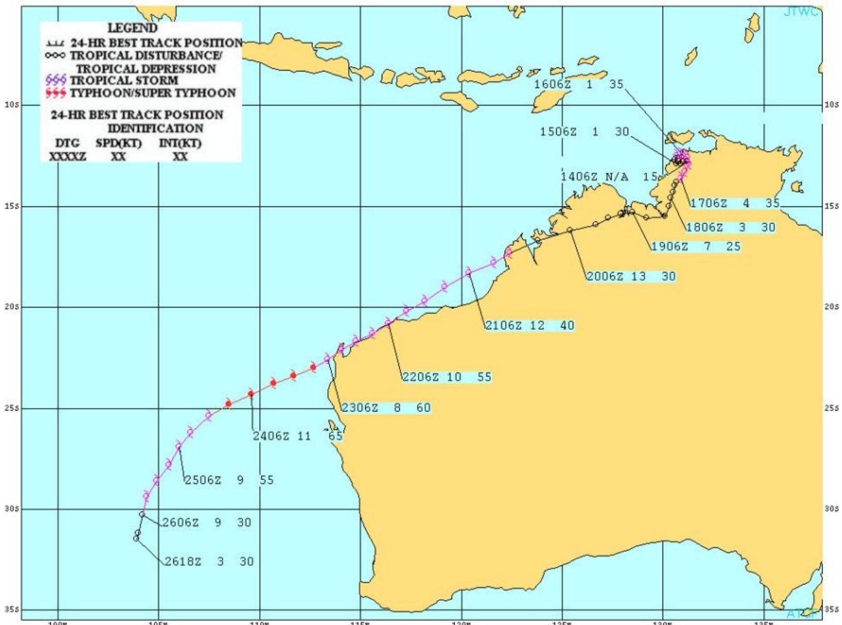
ISSUED POOR: 0800Z 09 Feb 2011
ISSUED FAIR: 2300Z 09 Feb 2011
FIRST TCFA: 2230Z 10 Feb 2011
FIRST WARNING: 1200Z 11 Feb 2011
LAST WARNING: 0000Z 12 Feb 2011
MAX INTENSITY: 35 Kts
NUMBER OF WARNINGS: 2

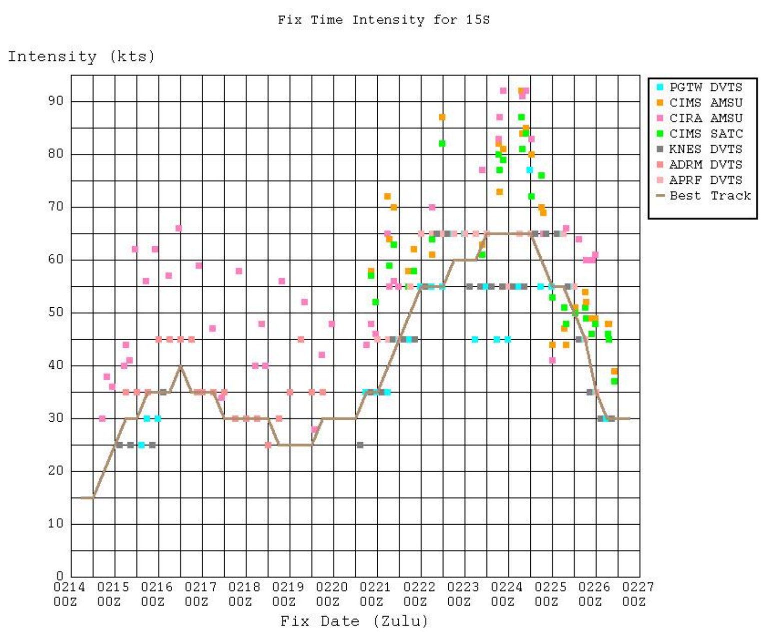




Tropical Cyclone 15S (Carlos)

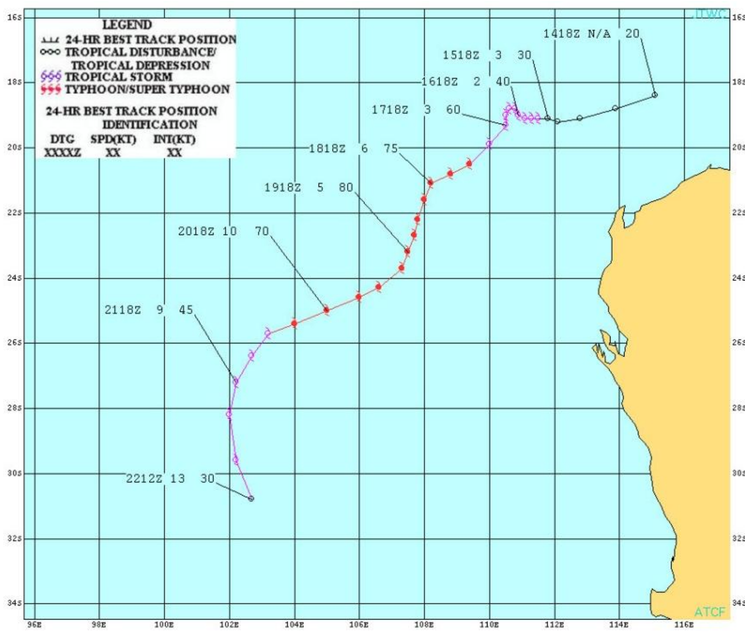
ISSUED POOR: N/A
ISSUED FAIR: N/A
FIRST TCFA: 0730Z 15 Feb 2011
FIRST WARNING: 1800Z 15 Feb 2011
LAST WARNING: 0000Z 26 Feb 2011
MAX INTENSITY: 65 Kts
NUMBER OF WARNINGS: 20
* TC was closed from 0600Z 17 Feb 2011- 1800Z 20 Feb 2010

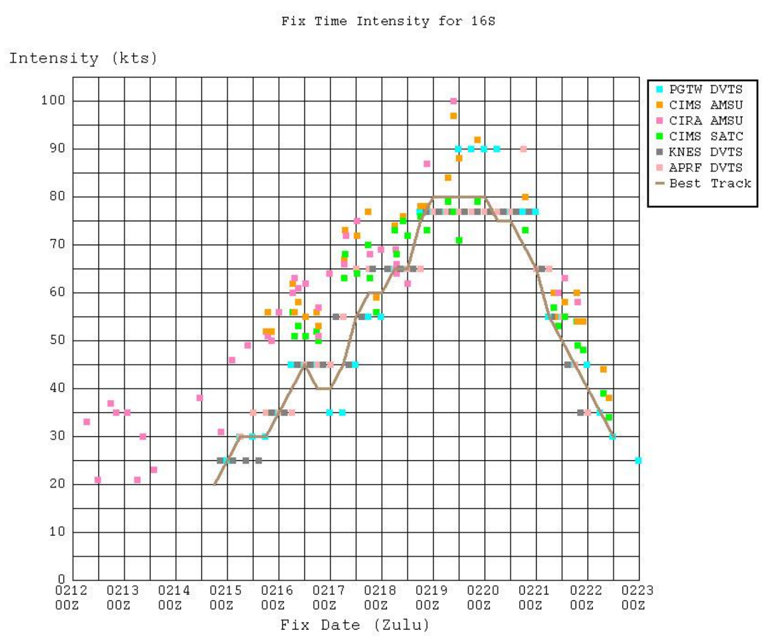




Tropical Cyclone 16S (Diane)

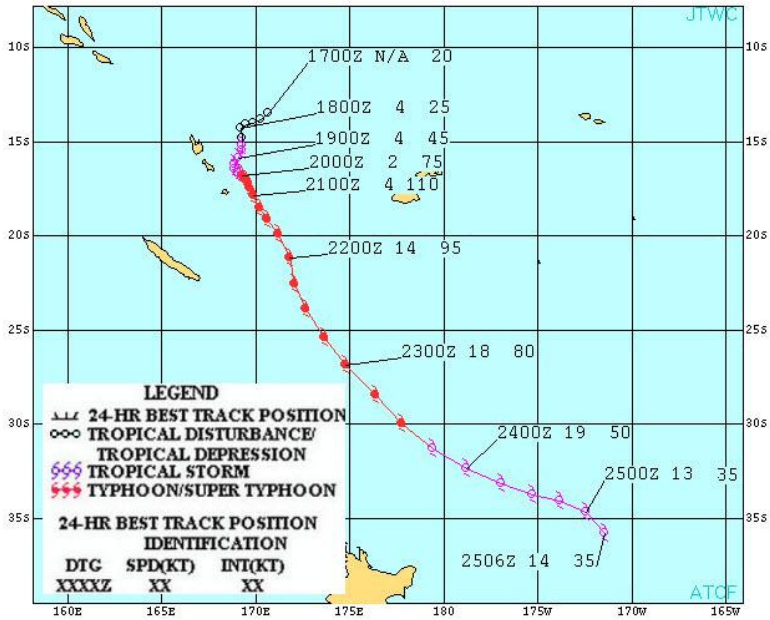
ISSUED POOR:	N/A
ISSUED FAIR:	1000Z 14 Feb 2011
FIRST TCFA:	0230Z 15 Feb 2011
FIRST WARNING:	0000Z 16 Feb 2011
LAST WARNING:	0000Z 22 Feb 2011
MAX INTENSITY:	80 Kts
NUMBER OF WARNINGS:	13

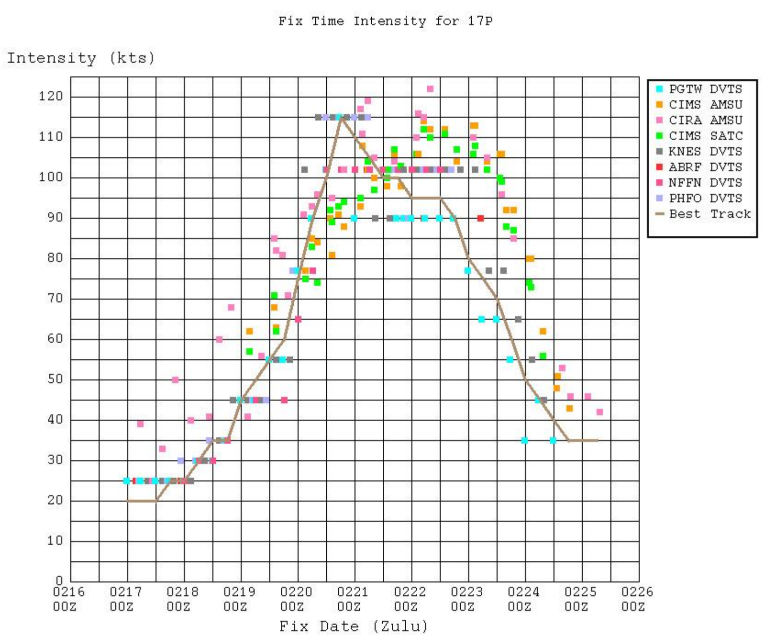




Tropical Cyclone 17P (Atu)

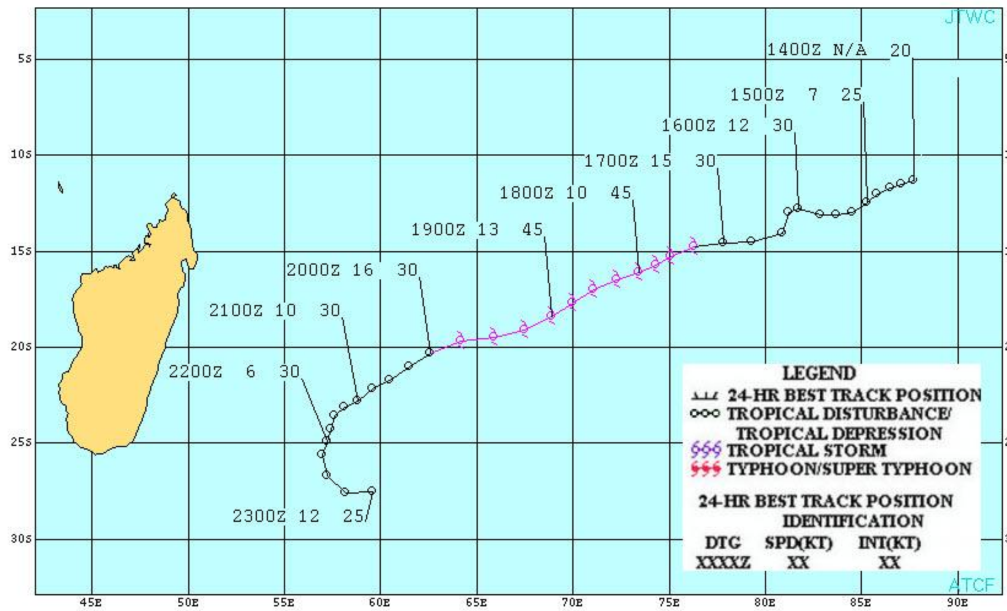
ISSUED POOR:	0030Z 17 Feb 2011
ISSUED FAIR:	2100Z 17 Feb 2011
FIRST TCFA:	0530Z 18 Feb 2011
FIRST WARNING:	1800Z 21 Feb 2011
LAST WARNING:	1800Z 23 Feb 2011
MAX INTENSITY:	115 Kts
NUMBER OF WARNINGS:	11



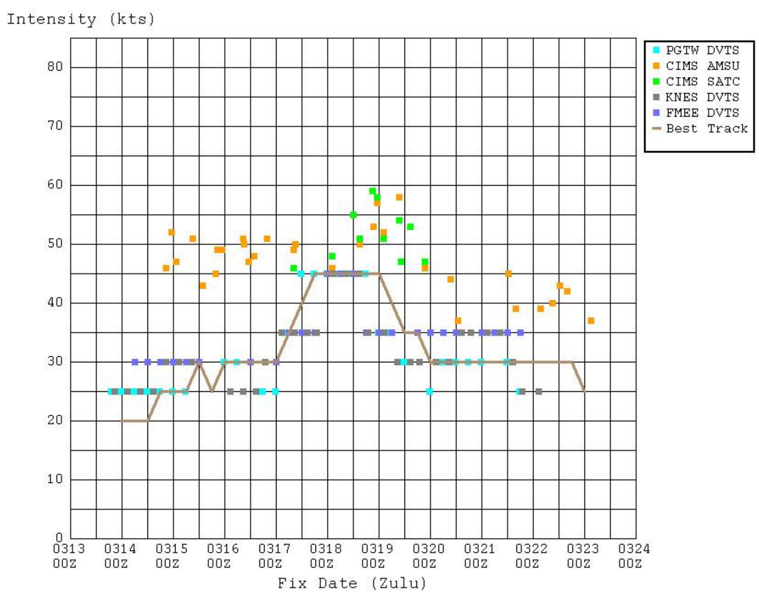


Tropical Cyclone 18S (Cherono)

ISSUED POOR: 1800Z 12 Mar 2011
ISSUED FAIR: 1000Z 14 Mar 2011
FIRST TCFA: 2200Z 16 Mar 2011
FIRST WARNING: 0600Z 17 Mar 2011
LAST WARNING: 1800Z 19 Mar 2011
MAX INTENSITY: 45 Kts
NUMBER OF WARNINGS: 6

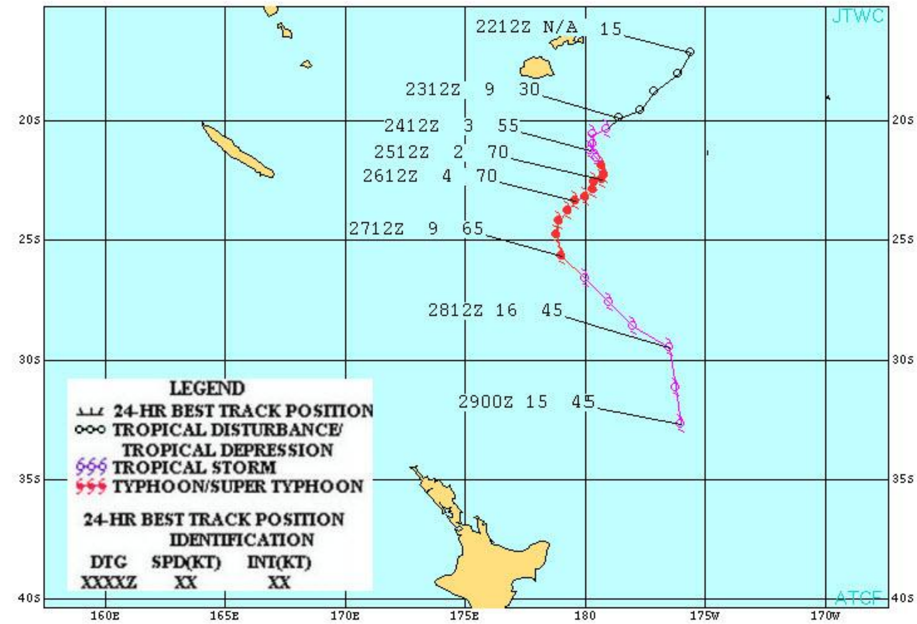


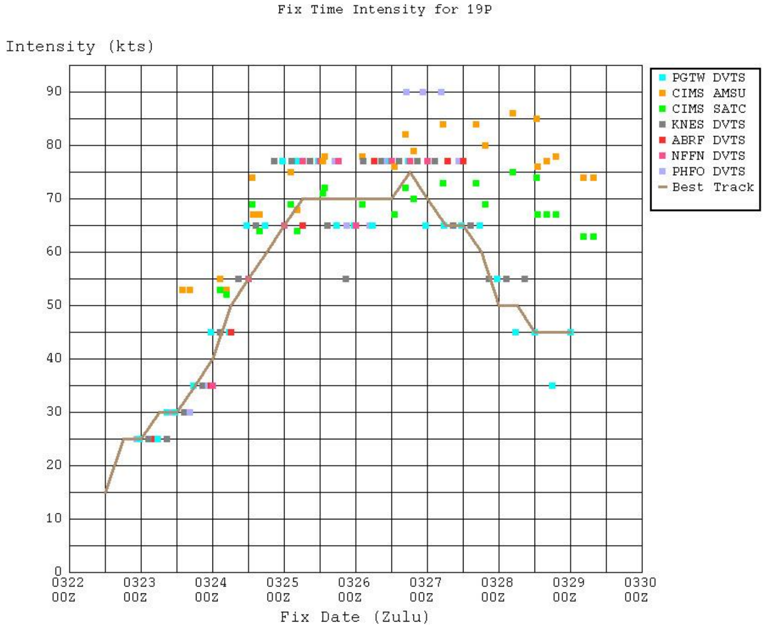
Fix Time Intensity for 18S



Tropical Cyclone 19P (Bune)

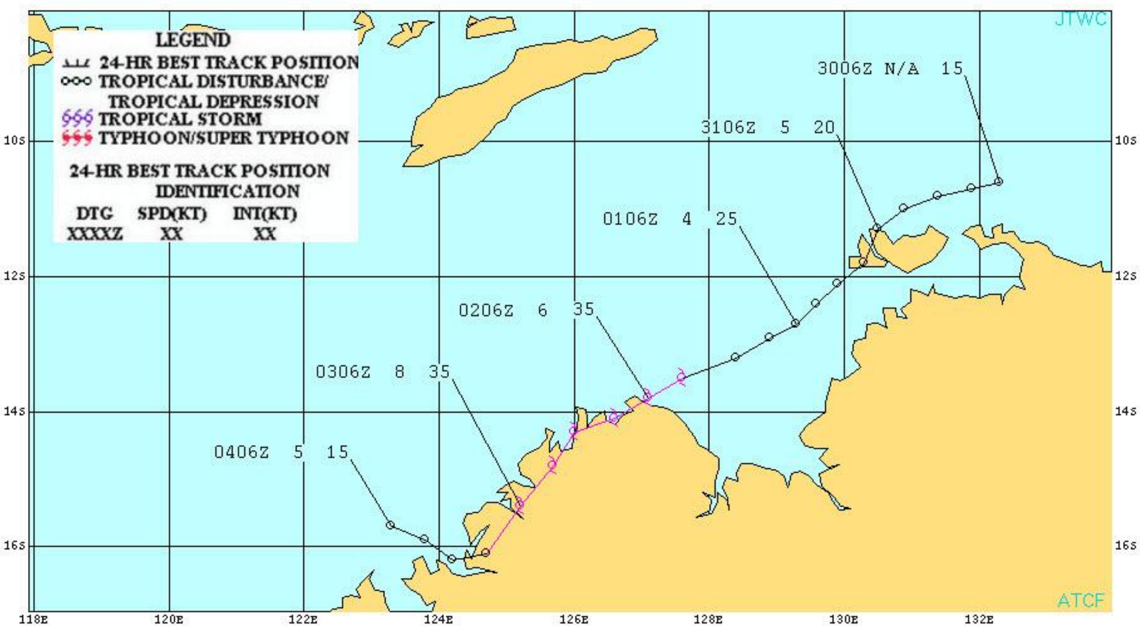
ISSUED POOR:	1930Z 22 Mar 2011
ISSUED FAIR:	0030Z 23 Mar 2011
FIRST TCFA:	0930Z 23 Mar 2011
FIRST WARNING:	1800Z 23 Mar 2011
LAST WARNING:	1800Z 28 Mar 2011
MAX INTENSITY:	75 Kts
NUMBER OF WARNINGS:	11

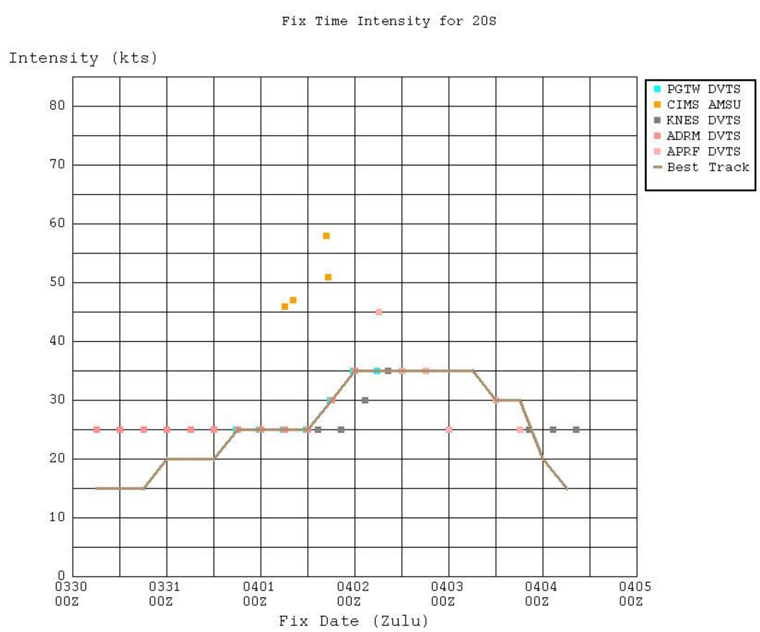




Tropical Cyclone 20S

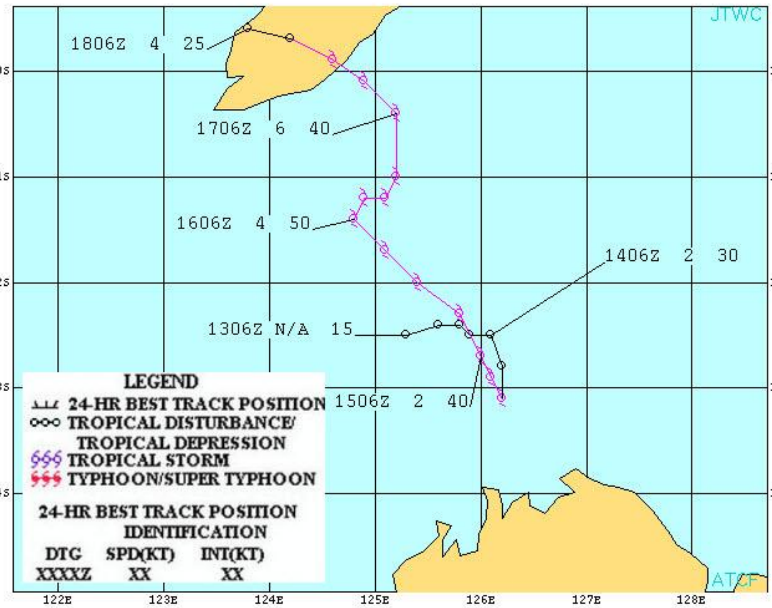
ISSUED POOR:	2230Z 29 Mar 2011
ISSUED FAIR:	0100Z 01 Apr 2011
FIRST TCFA:	1630Z 01 Apr 2011
FIRST WARNING:	0000Z 02 Apr 2011
LAST WARNING:	1200Z 04 Apr 2011
MAX INTENSITY:	35 Kts
NUMBER OF WARNINGS:	6

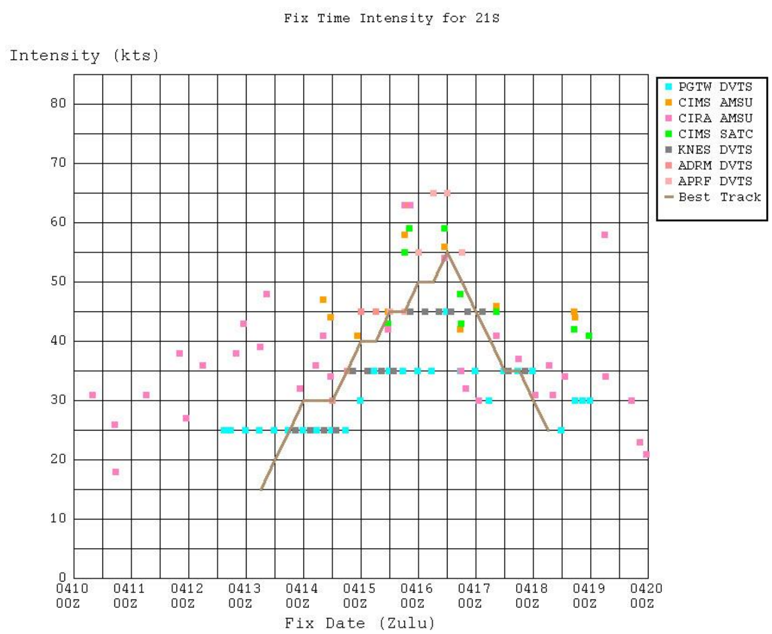




Tropical Cyclone 21S (Errol)

ISSUED POOR: 1500Z 12 Apr 2011
ISSUED FAIR: 0630Z 14 Apr 2011
FIRST TCFA: 2130Z 14 Apr 2011
FIRST WARNING: 0000Z 15 Apr 2011
LAST WARNING: 1200Z 18 Apr 2011
MAX INTENSITY: 55 Kts
NUMBER OF WARNINGS: 10





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. The 2011 year brought a rebound to near average storms after last year's below average numbers of storms in all three ocean basins, the Western North Pacific Ocean, North Indian Ocean, and Southern Hemisphere. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce 11,339 position and intensity estimates. A total of 6,199 fixes were made using microwave imagery, amounting to almost half of the total number of fixes, the ratio of microwave imagery used dropped significantly this year due to the loss NASA's AMSR-E and degradation and eventual loss of NOAA-16 AMSU. 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, stratified by basin and storm number. Following the final numbered storm for each section, is a value representing the number of fixes for invests considered as Did Not Develop (DND) areas. DNDs are areas that were fixed on but did not reach warning criteria.

Section 2 Fix summary by basin

Table 4-1

WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 2011

Tropical Cyclone		Visible/Infrared	Microwave/Scatterometry	Total
01W	N/A	20	29	49
02W	N/A	22	17	39
03W	Aere	61	84	145
04W	Songda	93	138	231
05W	Sarika	23	28	51
06W	Haima	76	60	136
07W	Meari	77	57	134
08W	Ma-On	110	246	356
09W	Tokage	38	25	63
10W	Nock-Ten	53	100	153
11W	Muifa	123	233	356
12W	Merbok	66	137	203
13W	N/A	52	113	165
14W	Nanmadol	85	127	212
15W	Talas	104	180	284
16W	Noru	60	54	114
17W	Kulap	48	34	82
18W	Roke	108	215	323
19W	Sonca	52	103	155
20W	Nesat	69	80	149
21W	Haitang	28	52	80
22W	Nalgae	67	131	198
23W	Banyan	65	51	116
24W	N/A	33	37	70
25W	N/A	10	10	20
26W	N/A	42	57	99
27W	Washi	57	91	148
DND		601	388	989
Totals		**2243**	**2877**	**5120**
Percentage of Total		**43.81%**	**56.19%**	

Table 4-2 NORTH INDIAN OCEAN FIX SUMMARY FOR 2011				
Tropical Cyclone		Visible/Infrared	Microwave/Scatterometry	Total
01A		47	33	80
02B		20	16	36
03A	Keila	61	46	107
04A		62	69	131
05A		66	96	162
06B	Thane	67	50	117
DND		111	34	145
Totals		**434**	**344**	**778**
Percentage of Total		**55.78%**	**44.22%**	

Table 4-3 SOUTH PACIFIC & SOUTH INDIAN OCEAN FIX SUMMARY FOR 2011				
Tropical Cyclone		Visible/Infrared	Microwave/Scatterometry	Total
01S		48	58	106
02S	Anggrek	64	86	150
03S	Abele	72	91	163
04P	Tasha	14	5	19
05P	Vania	57	55	112
06S	Vince	50	71	121
07P	Zelia	36	49	85
08P	Wilma	69	102	171
09P	Anthony	65	67	132
10S	Bianca	41	58	99
11P	Yasi	68	60	128
12P	Zaka	32	54	86
13S	Bingiza	75	78	153
14S		33	45	78
15S	Carlos	94	80	174
16S	Diane	65	104	169
17P	Atu	62	125	187
18S	Cherono	71	119	190
19P	Bune	61	120	181
20S		35	10	45
21S	Errol	55	41	96
DND		1296	1500	2796
Totals		**2463**	**2978**	**5441**
Percentage of Total		**45.27%**	**54.73%**	

Chapter 5   Techniques Development 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, techniques development, information technology exploitation, data evaluation, and process improvement. This section of the 2011 ATCR provides a small sampling of scientific and operational resource projects conducted by the JTWC Tech Dev team during 2011 and a look at ongoing and future work.

In 2011, JTWC was fortunate to have Mr. Owen Shieh, a University of Hawaii PhD candidate, as a USPACOM sponsored intern. Mr. Shieh completed a large portion of the Typhoon Duty Officer training to familiarize himself with operations and to aid in keeping his research focused on operational needs.

Section 2: 2011 Projects

Classifying TC genesis potential: In support of JTWC's shift to a probabilistic genesis forecast nomenclature, Techniques Development designed a guided process and associated worksheet to classify genesis potential as low, medium, and high based on a number of commonly-observed factors associated with TC genesis.

- "Low" formation potential describes an area that is being monitored for development, but is unlikely to develop within the next 24 hours.
- "Medium" formation potential describes an area that is being monitored for development and has an elevated potential to develop, but development will likely occur beyond 24 hours.
- "High" formation potential describes an area that is being monitored for development and is either expected to develop within 24 hours or development has already started, but warning criteria have not yet been met. Like areas previously assessed as "Good", all areas designated as "High" is accompanied by a Tropical Cyclone Formation Alert.

This new process is "trigger-based," i.e. if certain factors or combinations of factors exist, then the forecaster is advised to upgrade or downgrade development potential on the appropriate analysis bulletin (ABPW or ABIO). This approach represents a departure from the point-based TCFA checklist and is the first known attempt at JTWC to provide formal guidance for determining TC development potential for all tracked disturbances. This process also provides a framework for developing future guided forecasting techniques. In the year ahead, JTWC Techniques Development will investigate how to apply this method to forecasting tropical cyclone rapid intensification (RI).

Operational review of Genesis Potential Index (GPI): Researchers at the Naval Research Laboratory (Dr. Melinda Peng) and the University of Hawai'i (Drs. Tim Li, Bing Fu, and Duane Stevens) have developed a tropical cyclone genesis potential index (GPI) derived from the 850mb vorticity anomaly, 300mb air temperature anomaly, and variation in zonal wind with latitude at the 750mb level associated with tropical disturbances analyzed in NOGAPS model output fields (Fu et al. 2011; Peng et al. 2011). Genesis potential index (GPI) values that exceed a threshold value (0.2) indicate that a TC is likely to form within the 24 to 48 hour forecast period, while values below the threshold indicate development is unlikely. JTWC conducted an operational review of real-time GPI data in August and September 2011. Our review suggested that the GPI model could become an important addition to the forecaster's genesis prediction toolset.

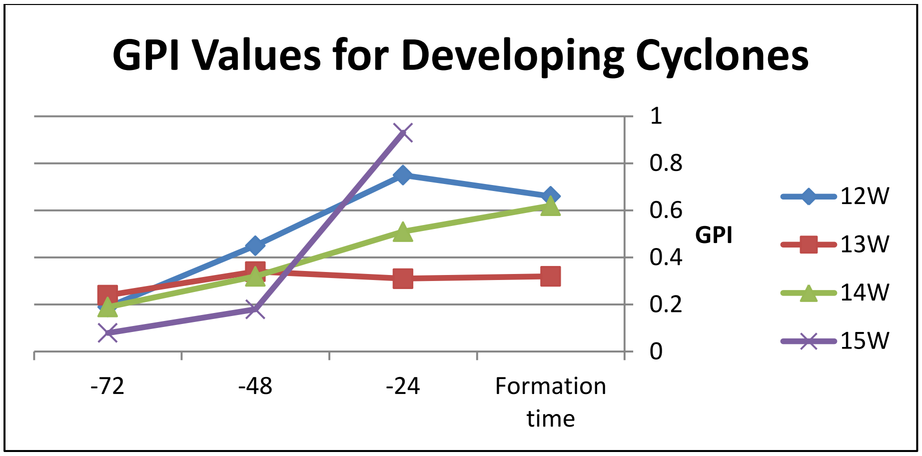


Figure 5-1. NOGAPS Genesis Potential Index (GPI) calculated in near real-time for the 72 hour period preceding formation (first warning) time on tropical cyclones 12W through 15W (August 2011).

Evaluation of AFWA Mesoscale Ensemble Prediction System (MEPS): The Air Force Weather Agency's ten member Mesoscale Ensemble Prediction System ("MEPS") is comprised of forecast output from the Weather Research and Forecasting (WRF) model run at 4 km horizontal resolution and initialized with atmospheric fields from four global models: the UK Met Office model, GFS, NOGAPS, and the Canadian Global Model. Model physics and boundary conditions are also varied for each member run. The MEPS system has been used to forecast probabilities of key weather phenomena/thresholds occurring at military installations for some time. An initial effort to evaluate the system's potential as a tropical cyclone modeling tool - a joint effort between AFWA (its ensemble team led by Mr. Evan Kuchera) and JTWC - is now underway. Preliminary observations suggest that the ensemble may provide skillful track and intensity forecasts for tropical cyclones as well as probabilistic forecasts of significant weather associated with tropical cyclones at DoD assets across the JTWC forecast area of responsibility.

Predicting the impact of TUTT cells on tropical cyclone motion: Patla et al, 2009 documented several cases of Tropical Upper Tropospheric Trough (TUTT) cells influencing tropical cyclone motion. The study indicated that TUTT cells with sufficient vorticity, vertical depth, and proximity to nearby tropical cyclones may significantly alter TC track through direct interaction between TUTT cell and TC circulations. A conceptual model to help JTWC forecasters predict potential TUTT cell-TC interactions and determine appropriate TC track forecast adjustments remains under evaluation at JTWC.

Global Tropics Hazards product: JTWC Tech Dev continued to provide weekly tropical cyclone forecasts for the Climate Prediction Center's weekly Global Tropics Hazards (GTH) Assessment. The subjective GTH Assessment provides US Government interests a two week outlook of potential tropical cyclone formation areas across the global tropics. This is the first-ever mid-range TC prediction capability to support USPACOM.

Google Earth Meteorological Information Interface (GEMInI): JTWC Tech Dev continued to update GEMInI, 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. Efforts to improve GEMINI in 2011 included adding JTWC track forecast and scatterometer data overlays and tools for the JTWC Decision Support Branch, including tsunami and earthquake data.

Forecast process checklists: JTWC Tech Dev developed multiple checklists to guide the forecast process. These checklists have improved continuity of effort and sharpened forecasters' focus on key meteorological features that impact forecasts.

Section 3 Future projects

Classifying TC genesis probability: Tech Dev will evaluate ongoing efforts at the University of Arizona (project lead Dr. Elizabeth Ritchie) to determine the potential for tropical cyclogenesis through inspection of convective symmetry around tropical disturbance cloud clusters as measured from infrared satellite imagery (Piñeros et al. 2008; Piñeros et al. 2010). The prediction method, funded by the Office of Naval Research (ONR) and supported by the National Oceanographic Partnership (NOPP), will be tested during real-time operations during the upcoming western North Pacific typhoon season.

Rapid intensification (RI) prediction methodology: JTWC Tech Dev will evaluate a subjective method to forecast tropical cyclone RI based on a number of commonly-observed factors that are associated with intensification, such as model trends, upper-level outflow potential, and sea water thermal characteristics. By applying this new forecasting method, JTWC aims to improve quantitative RI prediction, particularly at 12-36 hour lead times.

New intensity forecast tools: The Cooperative Institute for Research in the Atmosphere (CIRA) will provide SHIPS-RI index (Kaplan et al. 2010) and Logistic Growth Equation Model (LGEM) (DeMaria 2008) output to the JTWC for evaluation during calendar year 2012. Techniques Development will facilitate the exchange of data and feedback by coordinating with the CIRA project leads, Dr. Mark DeMaria and Dr. John Knaff.

Long-lead TC genesis prediction: JTWC is working with Dr. Russell Elsberry and Ms. Mary Jordan (Naval Postgraduate School) and Dr. Hsiao-Chung Tsai (Taiwan Central Weather Bureau) to schedule operational evaluation of a tropical cyclogenesis prediction method that applies vortex clustering to tropical cyclones forecasted by member runs of the 32-day ECMWF forecast ensemble (Elsberry et al. 2011). JTWC Tech Dev is also collaborating with Dr. Tom Murphree and Mr. David Meyer from the Naval Postgraduate School to evaluate their 0 to 90-day lead statistical-dynamical tropical cyclone activity prediction system. Extended range TC genesis forecasts are expected to improve JTWC's input for the CPC Global Tropics Hazards product, increase tropical cyclone development potential classification lead-times, and aid new Decision Support efforts.

References

DeMaria, M., 2008: A simplified dynamical system for tropical cyclone intensity prediction. *Mon. Wea. Rev.*, **137**, 68-82.

Elsberry, R. L., M.S. Jordan, and F. Vitart, 2011: Evaluation of the ECMWF 32-day ensemble predictions during 2009 season of western North Pacific tropical cyclone events on intraseasonal timescales. *Asia-Pacific J. Atmos. Sci*., **47**, 305-318.

Fu, B., M.S. Peng, T. Li, and D.E. Stevens, 2011: Developing versus nondeveloping disturbances in the North Atlantic and Western North Pacific. Part II: the Western North Pacific. *Mon. Wea. Rev.*, in press.

Kaplan, J., M. DeMaria, and J.A. Knaff, 2010: A revised tropical cyclone rapid intensification index for the Atlantic and eastern North Pacific basins. *Wea. Forecasting*, **25**, 220-241.

Patla, J. E, D.E. Stevens, and G.M. Barnes, 2009: A Conceptual Model for the Influence of TUTT Cells on Tropical Cyclone Motion in the Northwest Pacific Ocean. *Wea. Forecasting*, **24**, 1215-1235.

Peng, M.S., B. Fu, T. Li, and D.E. Stevens, 2011: Developing versus non-developing disturbances for tropical cyclone formation: Part I: North Atlantic. *Mon. Wea. Rev.*, in press.

Piñeros, M. F., E.A. Ritchie, and J.S. Tyo, 2008: Objective measures of tropical cyclone structure and intensity change from remotely sensed infrared image data. IEEE Transactions in Geoscience and Remote Sensing, vol. 46, issue 11, part 1, pp. 3574-3580.

Piñeros, M.F., E.A. Ritchie, and J.S. Tyo, 2010: Detecting tropical cyclone formation from satellite infrared imagery. *Preprints, AMS 29th Conf. on Hurricanes and Tropical Meteorology,* Tucson, 9-14 May.

Chapter 6 Summary of Forecast Verification

Verification of warning position and intensities at 24-, 48-, and 72-, 96-, 120-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 2011 season, and contrasts it with annual verification statistics from previous years.

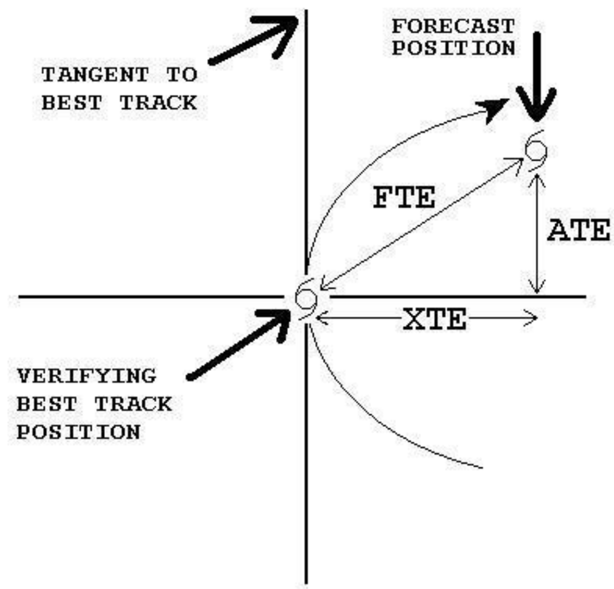


Figure 6-1. Definition of cross-track error (XTE), along track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of track) and the ATE is positive (ahead of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

Section 1 Annual Forecast Verification

TABLE 6-1 MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FROM 1959 - 2011																									
	24-Hour					48-Hour					72-Hour					96-Hour					120-Hour				
Year (Note)	Cases	TY Mean Error	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases	TY Mean Error	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases	TY Mean Error	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases (1)	TY Mean Error	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)	Cases (1)	TY Mean Error	TC Mean Error (3)	Cross Track Mean Error (2)	Along Track Mean Error (2)
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	191		289	169	200	139		420	237	299
2002	657	50	66	37	47	535	94	116	67	79	421	144	166	88	120	260		232	107	183	201		292	131	230
2003	602	59	73	41	52	495	119	128	68	94	397	186	186	89	147	238		241	107	197	173		304	126	249
2004	766	52	70	41	48	646	94	122	69	84	537	180	173	95	121	328		206	111	147	242		274	147	195
2005	507	41	61	38	38	407	81	102	59	72	316	138	156	76	120	168		213	106	164	111		263	122	200
2006	512	47	62	39	40	405	85	104	61	73	327	133	151	77	112	206		216	115	155	141		309	167	222
2007	343	45	61	24	42	260	72	100	58	69	189	89	148	83	102	105		189	107	127	63		215	117	155
2008	354	45	66	38	46	261	104	120	75	78	192	201	198	110	140	138		300	163	219	87		447	246	313
2009	498	46	66	35	47	395	102	123	65	90	303	179	183	102	130	227		258	145	183	174		298	158	213
2010	253	57	59	33	42	192	101	101	63	65	140	157	160	95	102	92	154	223	134	147	54	154	279	174	179
2011	455	56	61	36	43	365	85	93	54	66	290	117	129	74	91	177	159	177	103	121	164	233	252	150	163
Avg (1978-2011)	582	87	97	55	68	468	171	181	103	127	369	267	272	153	191	194	157	231	124	168	141	194	305	161	220
5yr Avg	381	50	63	33	44	295	93	107	63	74	223	149	164	93	113	148	157	229	130	159	108	194	298	169	205

(1) JTWC extended warning period from 72hrs to 120hrs in 2001. 96-hour and 120-hour data is not available prior to 2001.
(2) Cross-track and along-track errors were adopted by the JTWC in 1986. Right angle errors (used prior to 1986) were recomputed as cross-track errors after-the fact to extend the data base.
(3) Mean forecast errors for all warned systems in Northwest Pacific.

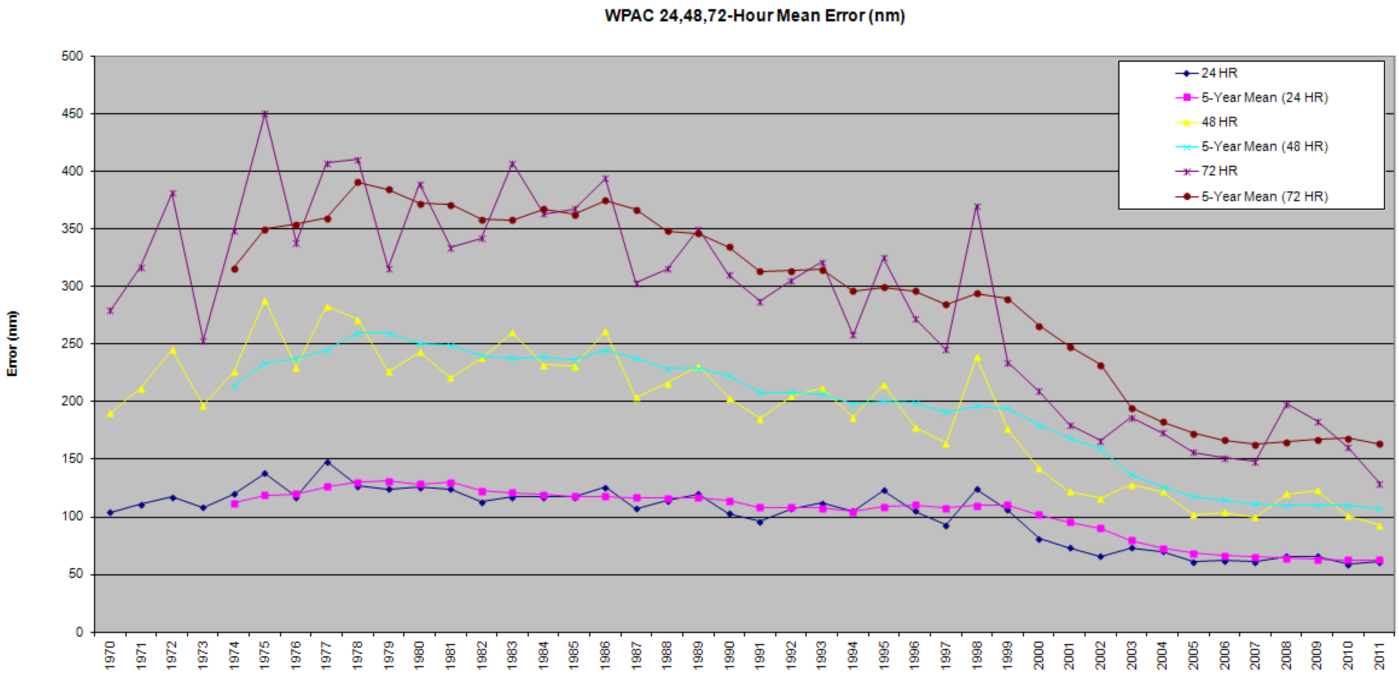


Figure 6-2. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 24, 48, and 72 hours.

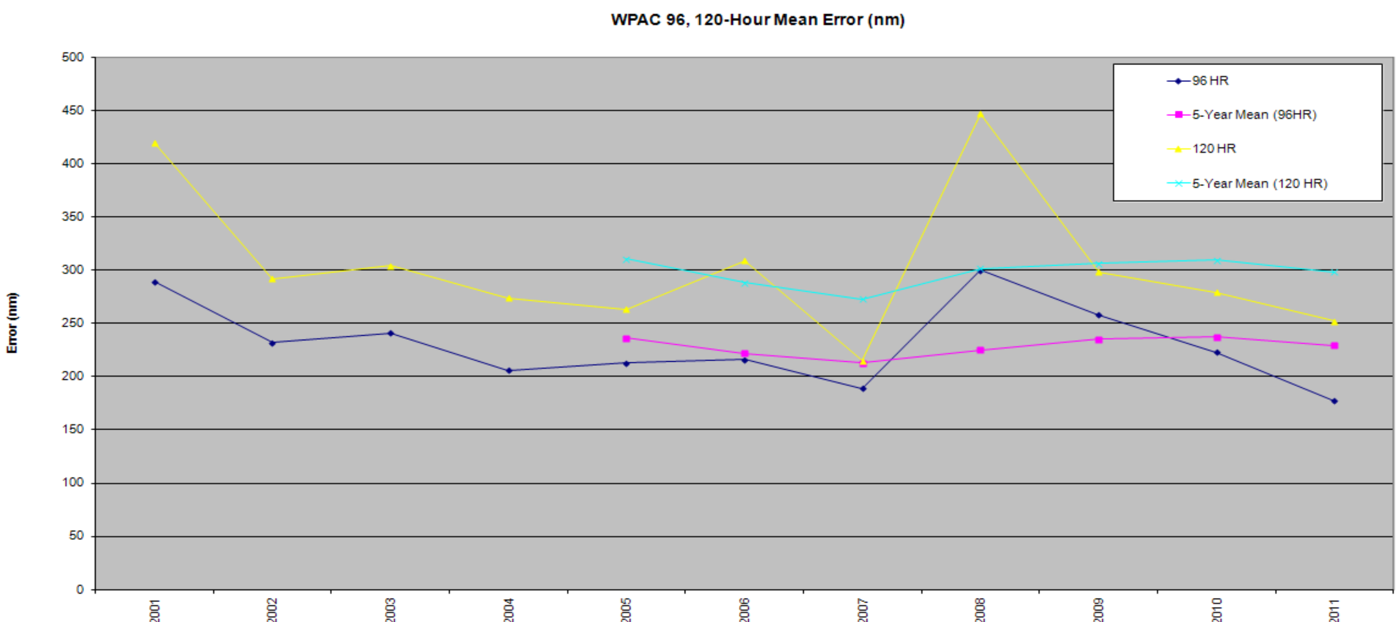


Figure 6-3. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 96 and 120 hours.

Table 6-2
MEAN FORECAST TRACK ERRORS (NM) FOR NORTH INDIAN OCEAN

TROPICAL CYCLONES FROM 1985-2011

	24-HOUR				48-HOUR				72-HOUR				96-HOUR				120-HOUR			
YEAR (Notes)	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error
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	(1)							
2010	63	52	31	33	42	90	67	44	22	170	116	84	11	332	175	259	6	587	154	545
2011	46	56	38	34	35	96	59	63	23	118	59	87	12	108	44	95	4	156	65	118
Avg (1985-2010)	47	97	69	54	30	167	115	96	16	261	179	148								
5Yr Avg	46	66	39	44	30	117	66	79	16	188	93	153								

(1) JTWC extended warning period from 72hrs to 120hrs in 2010. 96-hour and 120-hour data is not available prior to 2010.

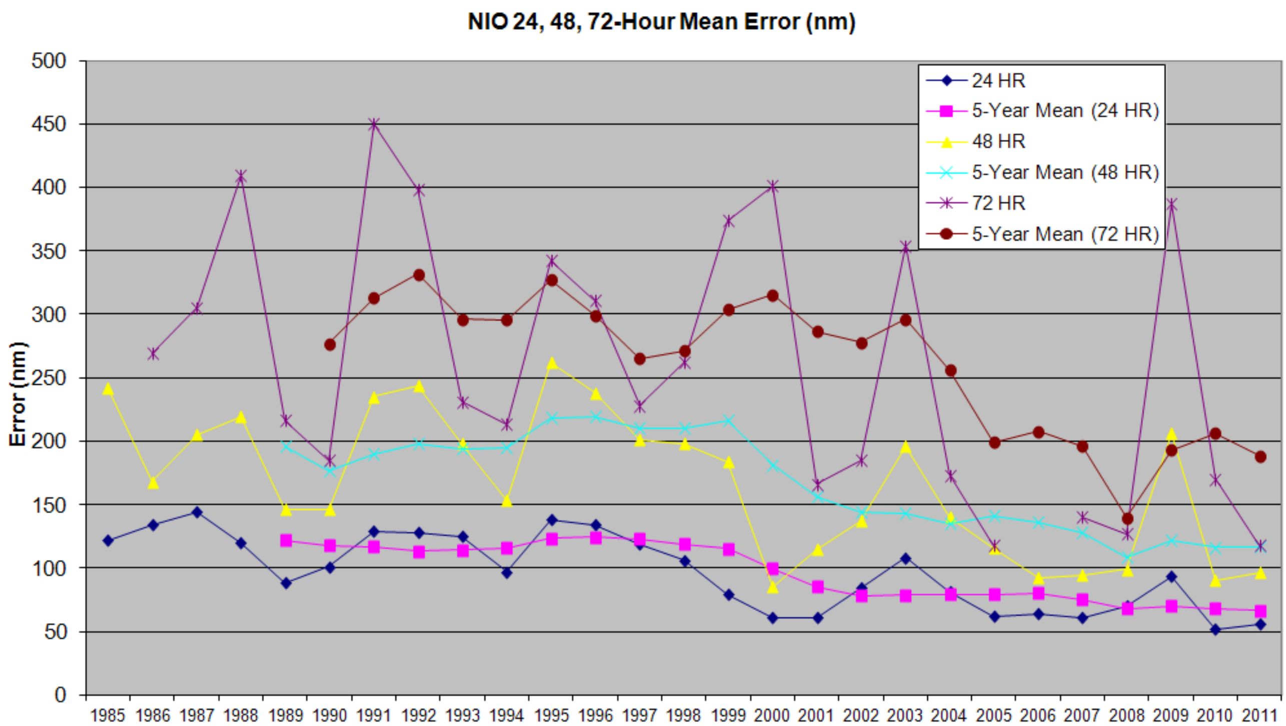


Figure 6-4. Graph of JTWC forecast errors and five year running mean errors for the north Indian Ocean at 24, 48, and 72 hours.

TABLE 6-3
MEAN FORECAST ERRORS (NM) FOR SOUTHERN HEMISPHERE TROPICAL CYCLONES 1985 - 2011

	24-Hour				48-Hour				72-Hour				96-Hour				120-Hour			
Year (Notes)	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error
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	(1)							
2010	206	66	40	45	161	109	67	57	125	149	76	109	89	207	117	145	64	276	159	191
2011	164	53	32	34	127	81	50	54	88	109	62	76	54	173	114	107	31	274	205	151
Avg (1985-2010)	240	100	57	70	188	186	106	130	52	200	118	138								
5Yr Avg	198	66	39	44	150	114	67	75	51	128	85	75								

(1) JTWC extended warning period from 72hrs to 120hrs in 2010. 96-hour and 120-hour data is not available prior to 2010.

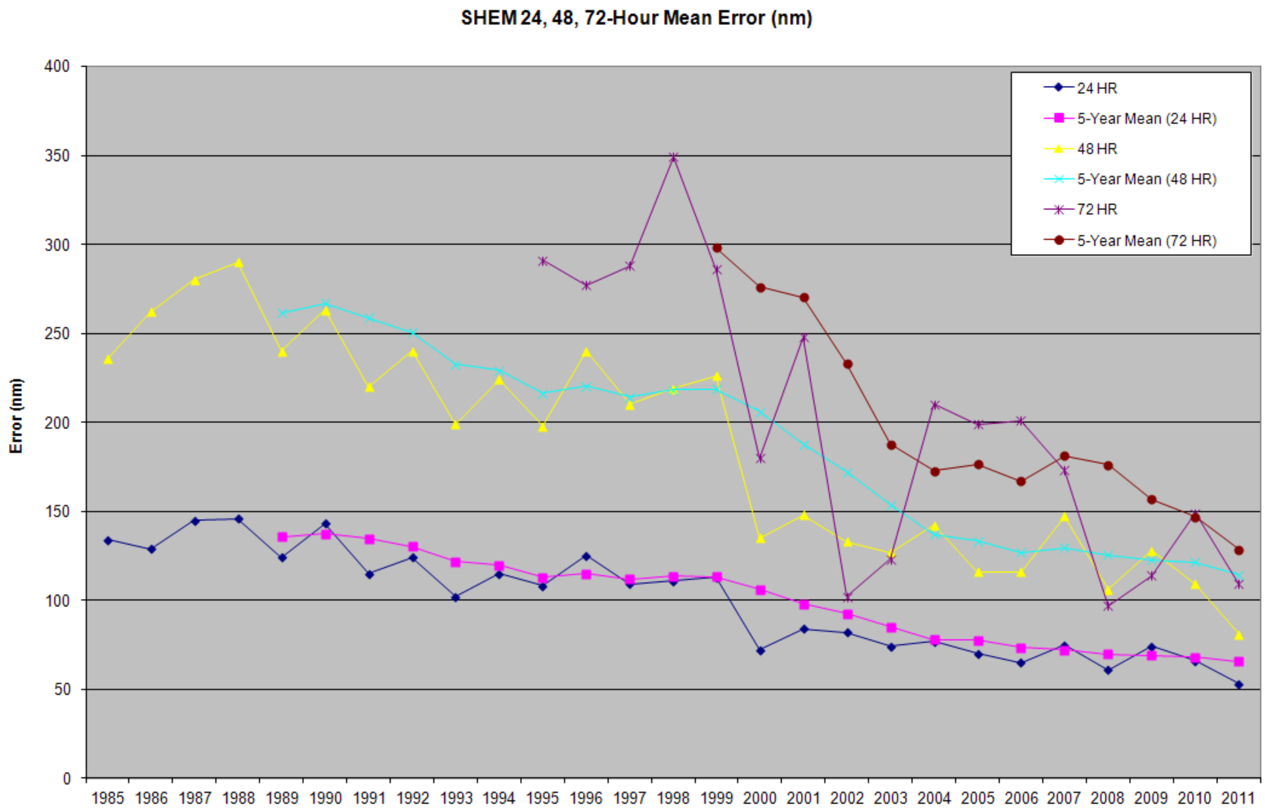


Figure 6-5. Graph of JTWC forecast errors for the Southern Hemisphere at 24, 48, and 72 hours.