Annual Tropical Cyclone Report

2012

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Commanding Officer

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Cover: Photographic image of Super Typhoon 26W (Bopha).
Taken 2 December, 2012 from the International Space Station. Courtesy of NASA.

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 under the command of the Commanding Officer, Joint Typhoon Warning Center.

The original JTWC was established on 1 May 1959 when the Joint Chiefs of Staff directed Commander-in- Chief, US 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, Pacific Fleet. A subsequent USCINCPAC directive further tasked Commander, Pacific Air Force to provide for tropical cyclone (TC) reconnaissance support to the JTWC. Currently, JTWC operations are guided by USPACOM Instruction 0539.1 and Pacific Air Forces Instruction 15-101.

This edition of the ATCR documents the 2012 TC season and details operationally or meteorologically significant cyclones noted within the JTWC Area of Responsibility (AOR). Details are provided to describe either significant challenges and/or shortfalls in the TC warning system and to serve as a focal point for future research and development efforts. Also included are tropical cyclone reconnaissance statistics and a summary of tropical cyclone research or technique development that members of JTWC were involved.

Continued below average tropical cyclone activity was observed in the western North Pacific Ocean, with only 27 TCs observed compared to the long term average of 31. There were four cyclones that reached super typhoon intensity. The TC formation region shifted eastward when compared to 2011 and displayed characteristics common during ENSO neutral conditions. Many of the 2012 TCs exhibited “S” shaped, looping, or generally erratic tracks, especially in the east Philippine Sea and South China Sea. Okinawa suffered three direct hits between late August and late September by Typhoon Bolaven (16W), Super Typhoon Sanba (17W), and Super Typhoon Jelawat (18W) with five other passages within 150 miles. Guam was again spared from direct tropical cyclone impacts, with Typhoon Sanvu (03W) passing just west of the island as a weak tropical storm. Department of Defense (DoD) bases in South Korea and mainland Japan were impacted by four and three tropical cyclones, respectively.

The Southern Hemisphere activity also continued a below normal trend, with 21 cyclones observed compared to an average of 28. A large majority of Southern Hemisphere cyclones occurred in the south Indian Ocean, with only four in the South Pacific, five around Australia and 12 occurring east of 100 degrees east longitude. The Northern Indian Ocean experienced near normal activity with 4 cyclones, with two in the Arabian Sea and two in the Bay of Bengal. All of the cyclones in the Northern Indian Ocean were weak, with peak winds of 50 knots or less.

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 over 8,500 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 were also used by JTWC to make TC fixes thus providing additional data for TC location and intensity.

JTWC also continues to utilize radar derived TC position information from numerous U.S. owned/operated weather radars as well as from international sources. Antenna site selection and budget challenges have delayed the replacement of the WSR-88D Doppler Weather Radar at Kadena AB that was destroyed in 2011 by Super Typhoon Songda.

In 2012, the Air Force cancelled the Defense Weather Satellite System program. As a result, the Joint Requirements Oversight Council identified 12 DoD Meteorological and Oceanographic (METOC) collection requirement gaps. Several identified gaps relate to tropical cyclone reconnaissance, including Ocean Surface

Vector Winds (OSVW), Tropical Cyclone Intensity, and Theater Weather Imagery. A space based environmental monitoring analysis of alternatives is currently underway to identify mitigation strategies for these gaps. Additionally, the announcement from the Japan Meteorological Agency that future geostationary satellites (Himawari 8 and 9) will not have a direct readout capability has caused JTWC to engage with Air Force, Navy, and NOAA to ensure critical western North Pacific geostationary satellite data will be available for TC reconnaissance when Himawari 8 becomes operational. The Air Forces' Mark IVB system had several upgrades in 2012, including adding a second geostationary satellite dish, receipt and processing of NOAA's NPP Suomi, China Meteorological Administration's FengYun 3A/3B, and Korea Meteorological Administration's COMS-1.

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 (ONR), Air Force Weather Agency (AFWA), and National Oceanic and Atmospheric Administration (NOAA) Line Offices for continued development of TC reconnaissance tools, numerical models and forecast aids. JTWC also funded upgrades to the GFDN model, as well as, adaptation of intensity forecast aids (SHIPS-RI and LGEM) for use in the U.S. Pacific Command (USPACOM) AOR.

The Techniques Development Branch (TECHDEV) remained the voice of JTWC to the research and development community. They worked with researchers from the University of Hawaii, University of Arizona, Naval Post Graduate School, and other agencies on a variety of promising projects. They helped JTWC refine its TC formation potential process via the Low-Medium-High checklist. This process and checklist was presented at the 2012 American Meteorological Service Conference on Hurricanes and Tropical Meteorology. TECHDEV also worked on product enhancements, including displaying JTWC products in Google Earth.

Behind all these efforts are the dedicated team of men and women, military and civilian at JTWC. Special thanks to the entire JTWC 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 in extremely volatile financial times.

A Special thanks also to: FNMOC for their operational data and modeling support; the NRLMRY and ONR for its dedicated TC research; the NOAA National Environmental Satellite, Data, and Information Service for satellite reconnaissance support; 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 2012

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Mr. Robert Falvey, *Director*
LCDR Sarah Follett, *Operations Officer*
LT Chad Geis, *Operations Officer*
Mr. Edward Fukada, *Technical Advisor*
Mr. James Darlow
Mr. Matt Kucas
Mr. Brian Strahl

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LT Chad Geis
LTJG Joshua Carter
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Mr. Aaron Lana
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Capt Spring Clegg, *OIC Satellite Operations*
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TSgt Jeffrey Quast, *Analyst/NCOIC*

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SrA Andrew Casper, *Analyst*
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SrA Karen Long, *Analyst*
SrA Julian McAllister, *Analyst*
SrA Cody Newcomer, *Analyst*
A1C Savas Rivera, *Analyst*
Mr. James Darlow, *Analyst*
Mr. Dana Uehara, *Analyst*

Geophysical Technician (GT)
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AG2 James Spruill
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AG2 Alyssa Roth
AG3 Valerie Littlefield
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AG3 Tyler Terrell
AG3 Vaughan Dill
AG3 Candice Sullivan
AGAN Bristol Rigby
AGAA Heather Johnston
AGAA Christian Wilcox
AGAA Jack Tracey
AGAR Jake Wilson

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Table 1-1

WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 2012 (01 JAN 2012 - 31 DEC 2012)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
01W	-	17 Feb / 1200Z	17 Feb / 1800Z	2	25	1004
02W	Pakhar	29 Mar / 0000Z	31 Mar / 1200Z	11	60	978
03W	Sanvu	21 May / 0600Z	27 May / 0600Z	25	80	963
04W	Mawar	31 May / 1800Z	05 Jun / 1800Z	21	105	944
05W	Guchol	11 Jun / 0000Z	19 Jun / 1200Z	35	130	926
06W	Talim	17 Jun / 1800Z	21 Jun / 0000Z	14	50	985
07W	Doksuri	26 Jun / 1200Z	30 Jun / 0000Z	15	40	993
08W	Khanun	15 Jul / 1200Z	19 Jul / 0000Z	15	55	982
09W	Vicente	20 Jul / 1800Z	24 Jul / 0000Z	14	115	937
10W	Saola	28 Jul / 0000Z	03 Aug / 0000Z	25	90	956
11W	Damrey	28 Jul / 1800Z	02 Aug / 1800Z	21	80	963
12W	Haikui	02 Aug / 1800Z	08 Aug / 0000Z	22	65	974
13W	Kirogi	04 Aug / 1800Z	09 Aug / 1800Z	21	45	989
14W	Kai-Tak	12 Aug / 1200Z	17 Aug / 1800Z	22	65	974
15W	Tembin	19 Aug / 0000Z	30 Aug / 0000Z	45	120	933
16W	Bolaven	20 Aug / 0000Z	28 Aug / 1800Z	36	125	929
17W	Sanba	10 Sep / 1800Z	17 Sep / 0600Z	27	155	907
18W	Jelawat	20 Sep / 1200Z	30 Sep / 1800Z	42	140	918
19W	Ewiniar	24Sep / 0000Z	29 Sep / 1200Z	23	55	982
20W	Maliksi	30Sep / 1200Z	03 Oct / 1800Z	14	45	989
21W	Gaemi	01 Oct / 1200Z	06 Oct / 1200Z	21	55	982
22W	Prapiroon	07 Oct / 1200Z	19 Oct / 0000Z	47	105	944
23W	Maria	14 Oct / 0600Z	19 Oct /1200Z	22	55	982
24W	Son-Tinh	23 Oct / 1800Z	29 Oct / 0000Z	22	105	944
25W	-	14 Nov / 0600Z	14 Nov / 1800Z	3	25	1004
26W	Bopha	25 Nov / 1800Z	09 Dec / 0000Z	54	150	911
27W	Wukong	24 Dec / 1800Z	26 Dec / 1200Z	13	35	996

* 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 - 2012

																																					Total		
																																					≥64kt	34-63kt	≤33 kt
YEAR	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC			TOTALS		
1959		0			1			1			1			0			1			3			8			9			3			2			2			31	
	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	5	1	2	4	2	3	2	1	0	2	0	0	2	0	0	17	7	7
1960		1			0				1		1			1			3			3			9			5			4			1			1			30	
	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	2	1	0	2	1	0	8	1	0	0	4	1	4	0	0	1	0	0	1	0	0	19	8	3
1961		1			1			1			1			4			6			5			7			6			7			2			1			42	
	0	1	0	0	1	0	1	0	0	0	1	0	2	1	1	1	1	4	3	2	0	3	1	3	5	1	0	3	2	2	1	0	1	1	0	0	20	11	11
1962		0			1			0			1			3			0			8			8			7			5			4			2			39	
	0	0	0	0	1	0	0	0	0	1	0	0	2	0	1	0	0	0	5	1	2	7	0	1	3	1	3	3	1	1	3	0	1	0	2	0	24	6	9
1963		0			0			1			1			0			4			5			4			4			6			0			3			28	
	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	3	1	0	3	1	1	3	0	1	2	2	0	5	1	0	0	0	0	2	1	0	19	6	3
1964		0			0			0			0			3			2			8			8			8			7			6			2			44	
	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	2	0	0	6	1	1	3	5	0	5	2	1	3	3	1	4	2	0	1	0	1	26	13	5
1965		2			2			1			1			2			4			6			7			9			3			2			1			40	
	1	1	0	0	2	0	0	1	0	1	0	0	1	0	1	3	1	0	4	1	1	3	2	2	5	3	1	2	0	1	1	1	0	0	1	0	21	13	6
1966		0			0			0			1			2			1			4			9			10			4			5			2			38	
	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	1	0	0	3	1	0	5	3	1	5	3	2	1	1	2	1	2	2	1	0	1	20	10	8
1967		1			0			2			1			1			1			8			10			8			4			4			1			41	
	0	1	0	0	0	0	1	1	0	1	0	0	0	1	0	1	0	0	3	3	2	3	4	3	5	3	0	2	1	1	4	0	0	0	1	0	20	15	6
1968		0			1			0			1			0			4			3			8			4			6			4			0			31	
	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	2	1	2	0	3	4	1	4	0	0	5	1	0	4	0	0	0	0	0	20	7	4
1969		1			0			1			1			0			0			3			3			6			5			2			1			23	
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1970		0			1			0			0			0			2			3			7			4			6			4			0			27	
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1971		1			0			1			2			5			2			8			5			7			4			2			0			37	
	0	1	0	0	0	0	0	1	0	2	0	0	2	3	0	2	0	0	6	2	0	3	1	1	5	1	1	3	1	0	1	1	0	0	0	0	24	11	2
1972		1			0			1			0			0			4			5			5			6			5			2			3			32	
	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	2	0	4	1	0	3	2	0	4	1	1	4	1	0	2	0	0	2	1	0	22	8	2
1973		0			0			0			0			0			0			7			6			3			4			3			0			23	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	2	3	1	2	0	1	4	0	0	0	3	0	0	0	0	12	9	2
1974		1			0			1			1			1			4			5			7			5			4			4			2			35	
	0	1	0	0	0	0	0	1	0	0	1	0	1	0	0	1	2	1	2	3	0	2	3	2	3	2	0	4	0	0	2	2	0	0	2	0	15	17	3
1975		1			0			0			1			0			0			1			6			5			6			3			2			25	
	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	4	1	1	4	1	0	3	2	1	2	1	0	0	2	0	14	8	3
1976		1			1			0			2			2			2			4			4			5			0			2			2			25	
	1	0	0	0	1	0	0	0	0	1	1	0	2	0	0	2	0	0	2	2	0	1	3	0	4	1	0	0	0	0	1	1	0	0	2	0	14	11	10
1977		0			0			1			0			1			1			4			2			5			4			2			1			21	
	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	3	0	1	0	2	0	2	3	0	3	1	0	2	0	0	1	0	0	11	8	2
1978		1			0			0			1			0			3			4			8			4			7			4			0			32	
	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	3	1	0	3	4	1	3	1	0	4	1	2	1	2	1	0	0	0	15	13	4
1979		1			0			1			1			2			0			5			4			6			3			2			3			28	
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1980		0			0			1			1			4			1			5			3			7			4			1			1			28	
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1981		0			0			1			1			1			2			5			8			4			2			3			2			29	
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1982		0			0			3			0			1			3			4			5			6			4			1			1			28	
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1983		0			0			0			0			0			1			3				6		3			5			5			2			25	
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1985		2			0			0			0			1			3			1			7			5			5			1			2			27	
	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	1	0	0	5	2	0	3	2	0	4	1	0	0	1	0	1	1	0	17	9	1
1986		0			1			0			1			2			2				2		5			2			5			4			3			27	
	0	0	0	1	0	0	0	0	0	1	0	0	1	1	0	1	1	0	2	0	0	4	1	0	2	0	0	3	2	0	2	2	0	2	1	0	19	8	0
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1988		1			0			0			0			1			3			2			5			8			4			2			1			27	
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1989		1			0			0			1			2			2			6			8			4			6			3			2			35	
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1993		0			0			2			2			1			2			5			8			5			6			4			3			38	
	0	0	0	0	0	0	0	1	1	0	0	2	0	1	0	1	0	1	3	2	0	6	1	1	4	1	0	3	2	1	1	1	2	3	0	0	21	9	8
1994		1			0			1			0			2			2			9			9			8			7				0		2			41	
	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0	3	4	2	6	3	0	4	4	0	5	1	1	0	0	0	1	1	0	21	15	5
1995		1			0			0			0			1			2			3			7			7			8			2			3			34	
	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	1	0	4	2	1	4	1	2	5	1	2	0	2	0	0	1	2	15	11	8
1996		1			1			0			2			2			0			7			10			7			5			6			3			44	
	0	0	1	0	0	1	0	0	0	0	1	1	1	1	0	0	0	0	6	1	0	4	3	3	6	1	0	2	1	2	1	3	2	1	1	1	21	12	11
1997		1			0			0			2			3			3			4			8			4			6			1			1			33	
	0	1	0	0	0	0	0	0	0	1	1	0	1	2	0	3	0	0	3	1	0	6	1	1	3	1	0	4	1	1	1	0	0	1	0	0	23	8	2
1998		0			0			0			0			0			0			3			3			8			6			3			4			27	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	2	1	0	4	1	3	2	1	3	0	3	0	1	1	2	9	8	10
1999		1			1			0			3			0			1			5			9			6			2			3			3			34	
	0	1	0	0	1	0	0	0	0	2	1	0	0	0	0	1	0	0	1	1	3	4	2	3	2	4	0	1	1	0	1	1	1	0	0	3	12	12	10
2000		0			0			0			0			4			0			8			9			6			3			3			1			34	
	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	2	3	3	4	3	2	4	1	1	2	1	0	1	1	1	1	0	0	15	10	9
2001		0			1			0			1			1			2			6			7			5			3			3			4			33	
	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0	0	4	1	1	3	3	1	5	0	0	3	0	0	1	2	0	2	2	0	20	9	4
2002		1			1			1				1		2			3			6			8			3			5			1			1			33	
	0	1	0	1	0	0	0	0	1	0	0	1	1	0	1	3	0	0	3	2	1	4	3	1	1	2	0	3	0	2	1	0	0	1	0	0	18	8	7
2003		1			0			0			1			3			2			2			5			3			6			3			1			27	
	0	1	0	0	0	0	0	0	0	1	0	0	1	1	1	1	1	0	2	0	0	4	1	0	3	0	0	2	1	3	3	0	0	0	1	0	17	6	4
2004		0			1			1			1			3			5			2			9			3			3			2			2			32	
	0	0	0	0	1	0	0	1	0	1	0	0	2	1	0	5	0	0	1	1	0	6	2	1	1	1	1	3	0	0	2	0	0	0	2	0	21	9	2
2005		1			0			1			1			0			1			4			6			5			3			2			1			25	
	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1	3	0	6	0	0	4	1	0	2	0	1	1	1	0	0	1	0	18	6	1
2006		0			0			1			0			1			1			3			8			5			4			2			2			27	
	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	2	1	0	3	4	1	3	0	2	2	1	1	2	0	0	1	0	1	14	8	5
2007		0			0			1			0			1			0			3			6			5			5			6			0			27	
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2008		1			0			0			1			4			1			2			5			6			3			3			1			27	
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2009		0			0			0			0			2			2			3			5			7			4			4			1			28	
	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0	1	1	1	3	2	0	4	1	2	3	1	0	1	1	2	0	0	1	15	7	6
2010		1			0			1			0			0			0			2			5			4			4			1			1			19	
	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	2	3	0	3	1	0	2	2	0	0	0	1	0	0	1	9	6	4
2011		0			0			0			2			2			3			4			4			7			1			1			3			27	
	0	0	0	0	0	0	0	0	0	0	0	2	1	1	0	0	2	1	2	1	1	2	1	1	2	5	0	0	0	1	0	0	1	0	1	2	7	11	9
2012		0			1			1			0			1			4			4			5			3			5			2			1			27	
	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	2	2	0	3	1	0	4	1	0	2	1	0	2	3	0	1	0	1	0	1	0	15	10	2

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 - 2012)													
	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	0.6	17.0
CASES	11	3	10	23	41	58	136	188	176	156	82	35	919
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 - 2012)													
	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	26.7
CASES	25	12	23	34	64	94	209	301	265	215	134	67	1443

TABLE 1-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976 - 2012					
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%
2012	31	26	27	16%	96%
MEAN	34.8	27.5	29.6	21%	93%
CASES	1286	1019	1096		
* Percentage of initial TCFAs not followed by warnings.					

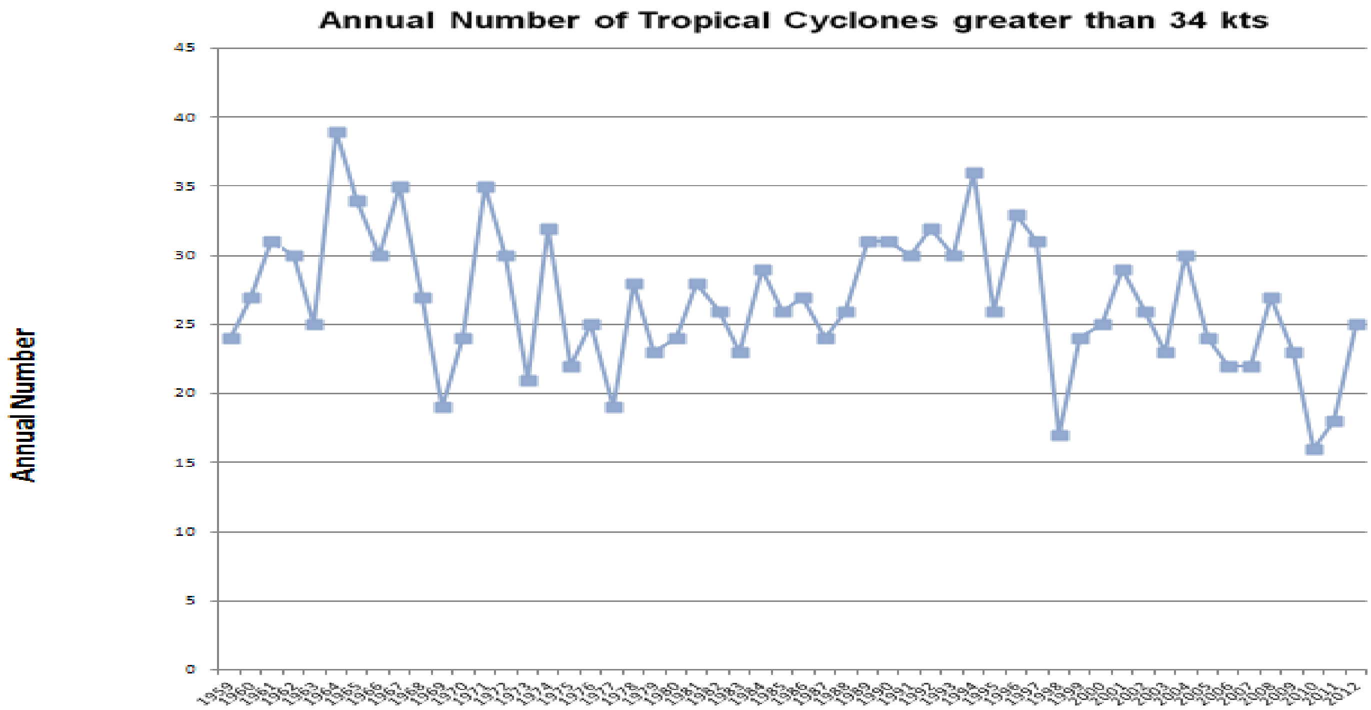


Figure 1-1. Annual number of western North Pacific TCs greater than 34 knots intensity.

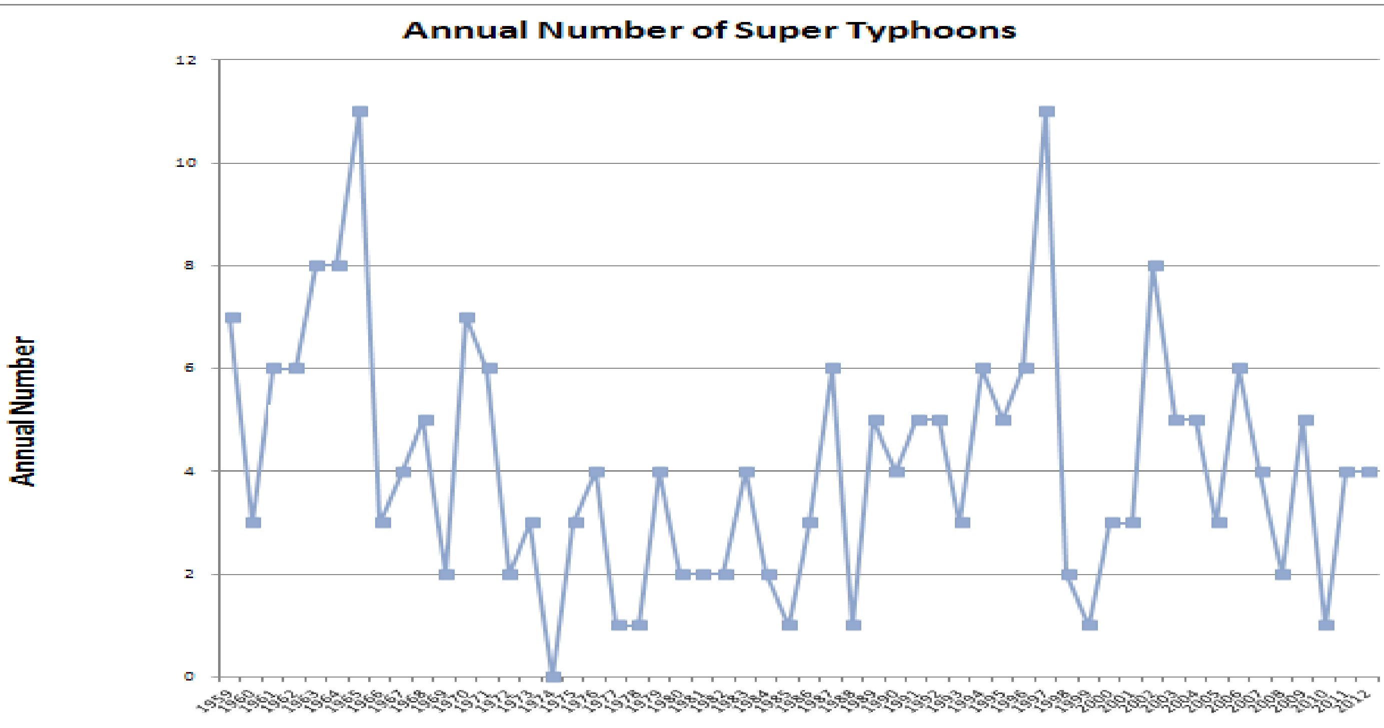
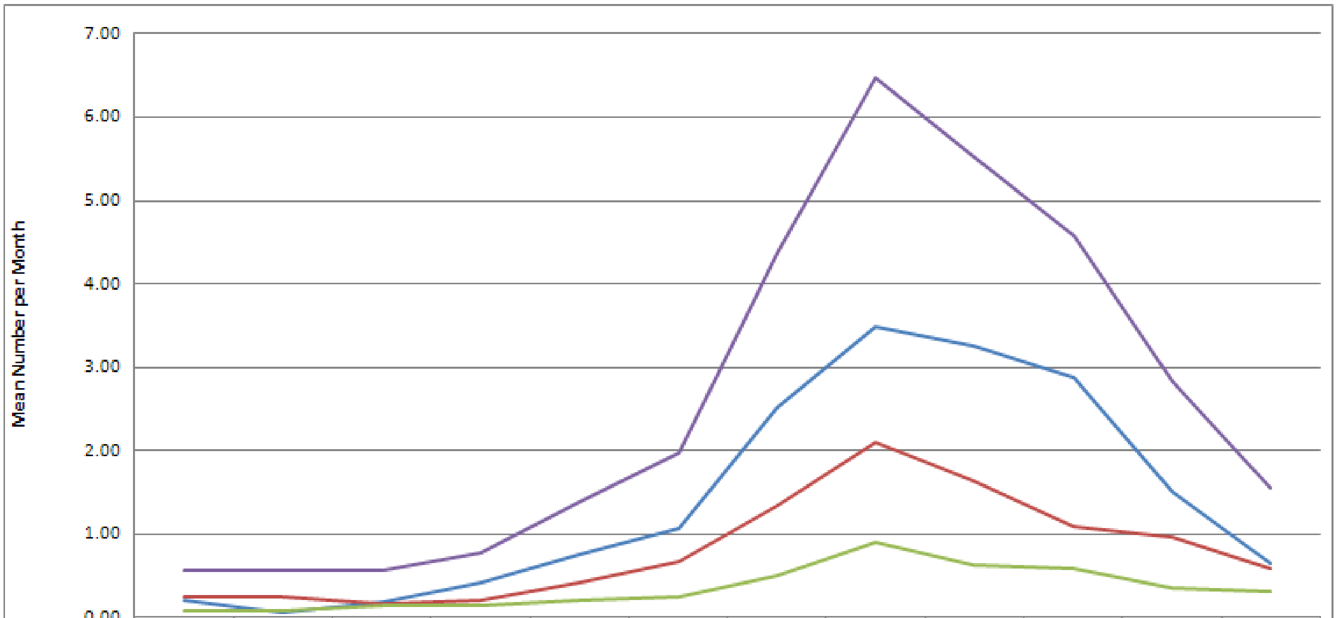


Figure 1-2. Annual number of Western North Pacific TCs greater than 127 knots intensity.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TY AVG	0.20	0.06	0.19	0.43	0.76	1.07	2.52	3.48	3.26	2.89	1.52	0.65
TS AVG	0.26	0.26	0.17	0.20	0.43	0.67	1.35	2.09	1.65	1.09	0.96	0.59
TD AVG	0.09	0.07	0.15	0.15	0.20	0.24	0.50	0.91	0.63	0.59	0.35	0.31
All AVG	0.56	0.56	0.57	0.78	1.39	1.98	4.37	6.48	5.54	4.57	2.83	1.56

Figure 1-3. Average number of Western North Pacific TCs (all intensities) by month 1959-2012.

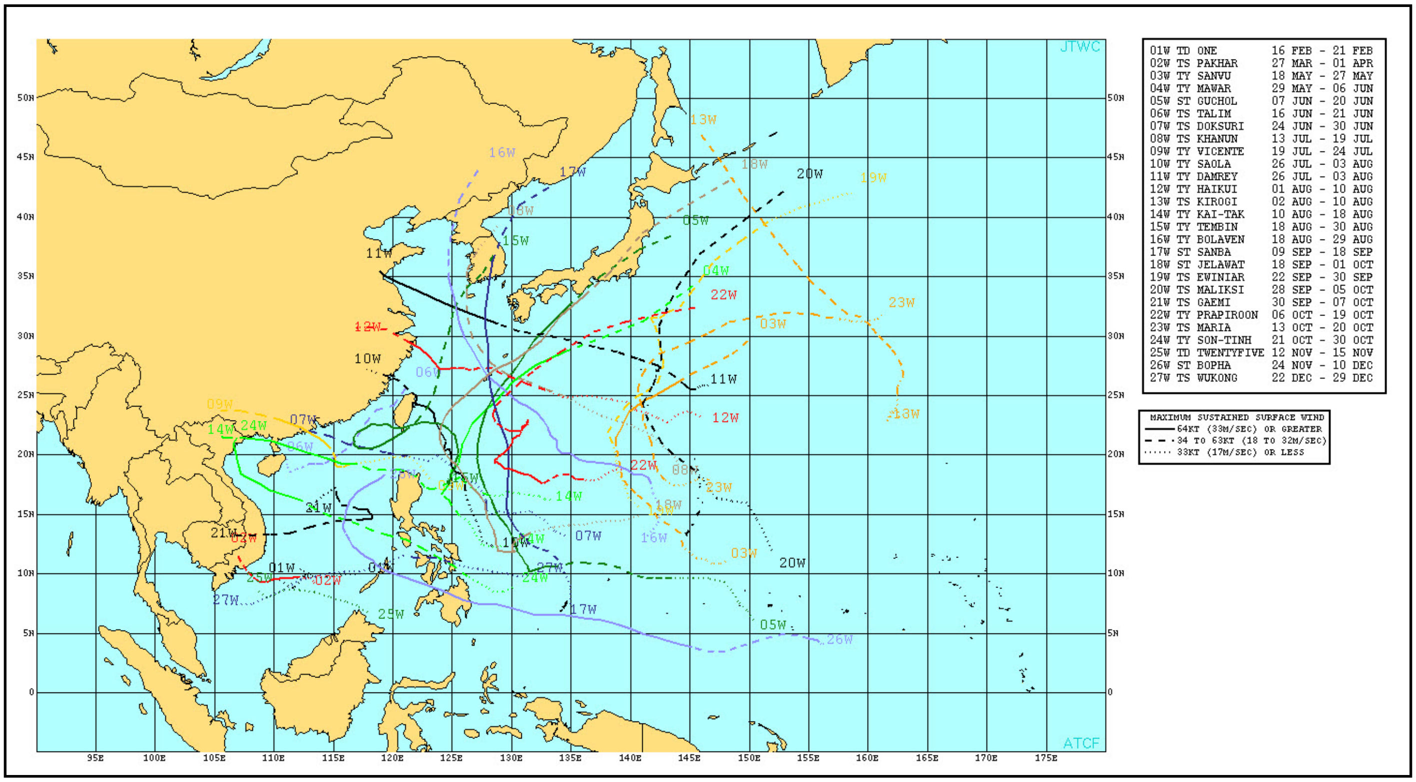


Figure 1-4. Western North Pacific Tropical Cyclones 01W – 27W.

Section 2 Cyclone Summaries

This section presents a synopsis of each cyclone that occurred during 2012 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 Regional Specialized Meteorological Center (RSMC) Tokyo.

Dates are also listed when JTWC first designated various stages of pre-warning development: LOW, MEDIUM, and HIGH (concurrent with TCFA). These classifications are defined as follows:

“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. All areas designated as “High” are accompanied by a Tropical Cyclone Formation Alert (TCFA).

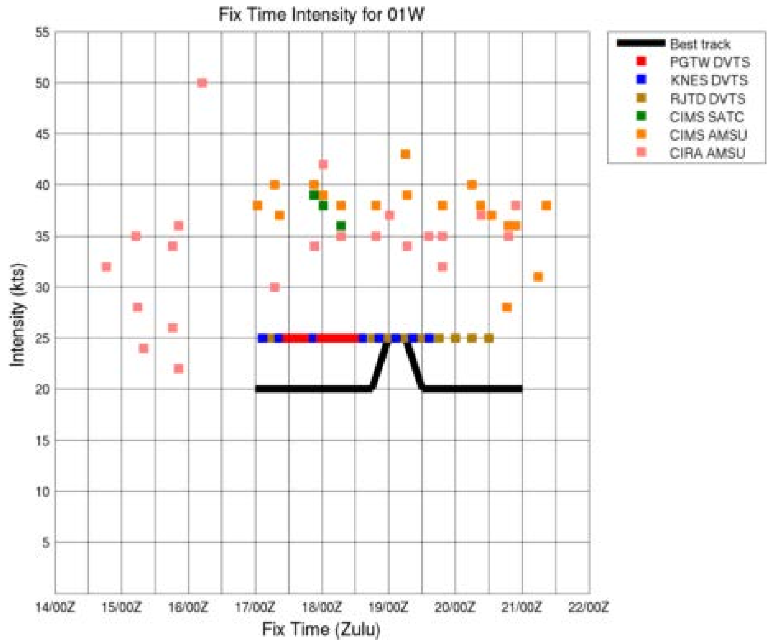
Initial and final JTWC warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

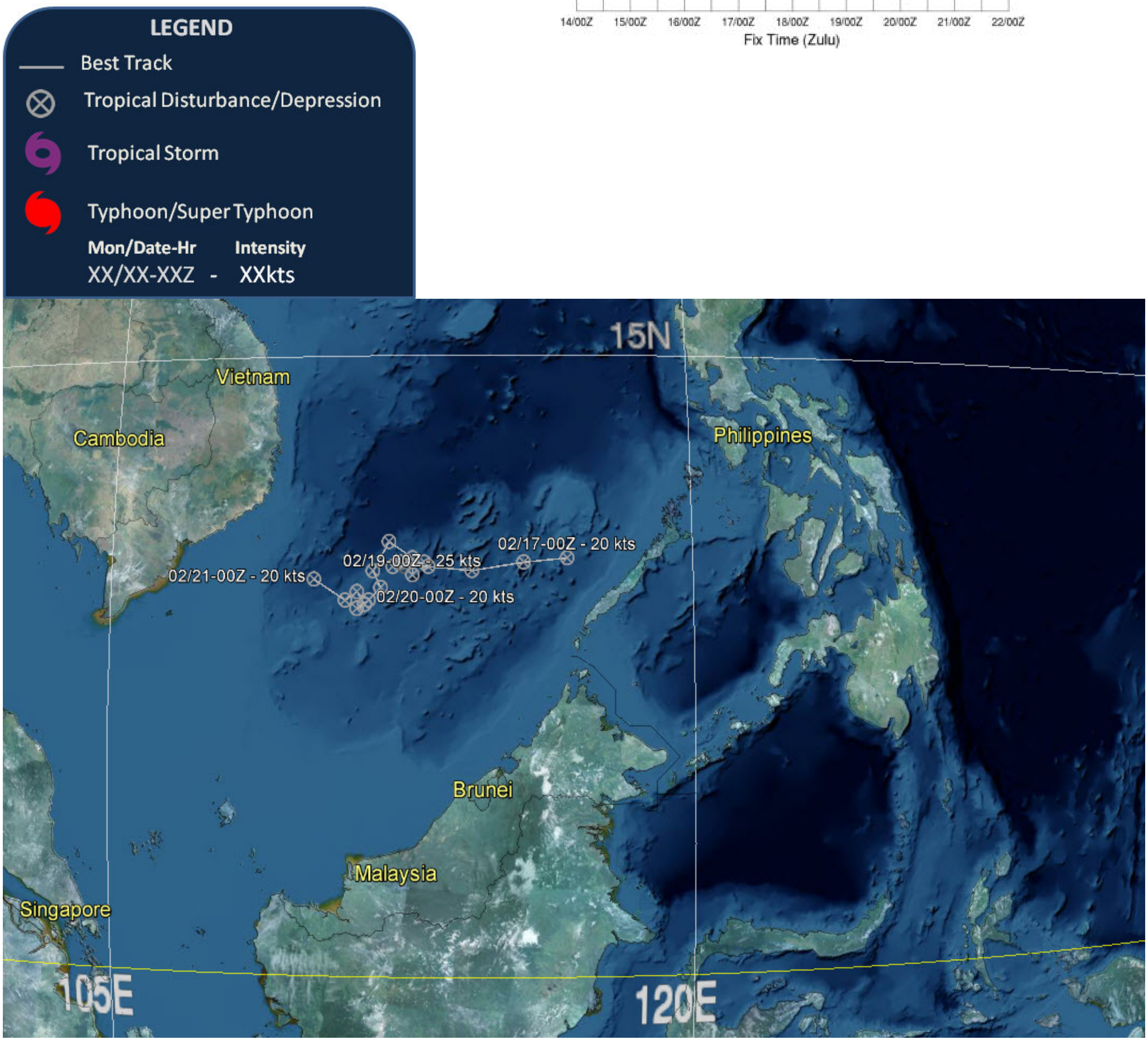
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of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

In addition, if this document is viewed as a pdf, each map has been hyperlinked to the appropriate keyhole markup language (kmz) file that will allow the reader to access and view the best-track data interactively on their computer using Google Earth software. Simply hold the control button and click the map image. The link will open, allowing the reader to download and open the file. Users may also retrieve kmz files for the entire season from:
http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/2012/2012-kmzs/

Tropical Depression 01W

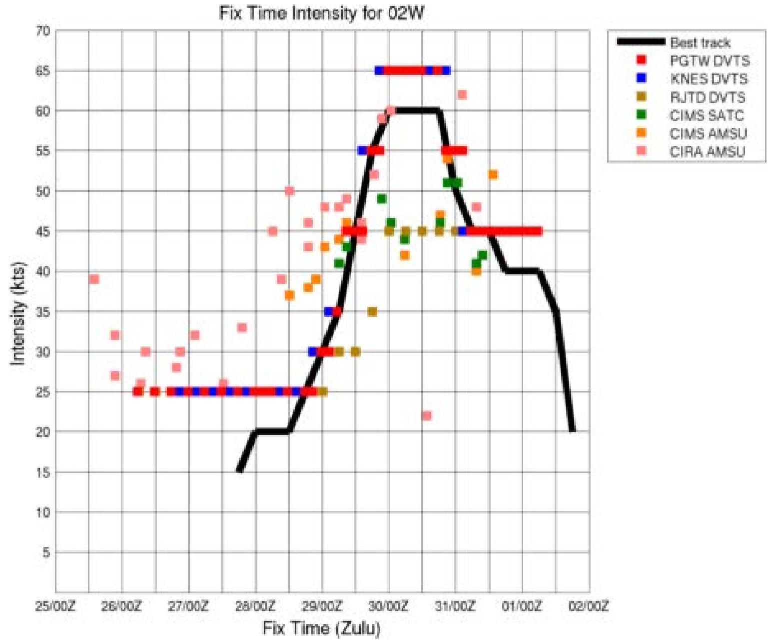
ISSUED LOW:	0600Z 17 Feb 2012
ISSUED MED:	N/A
FIRST TCFA:	N/A
FIRST WARNING:	1200Z 17 Feb 2012
LAST WARNING:	1800Z 17 Feb 2012
MAX INTENSITY:	25 Kts
WARNINGS:	2

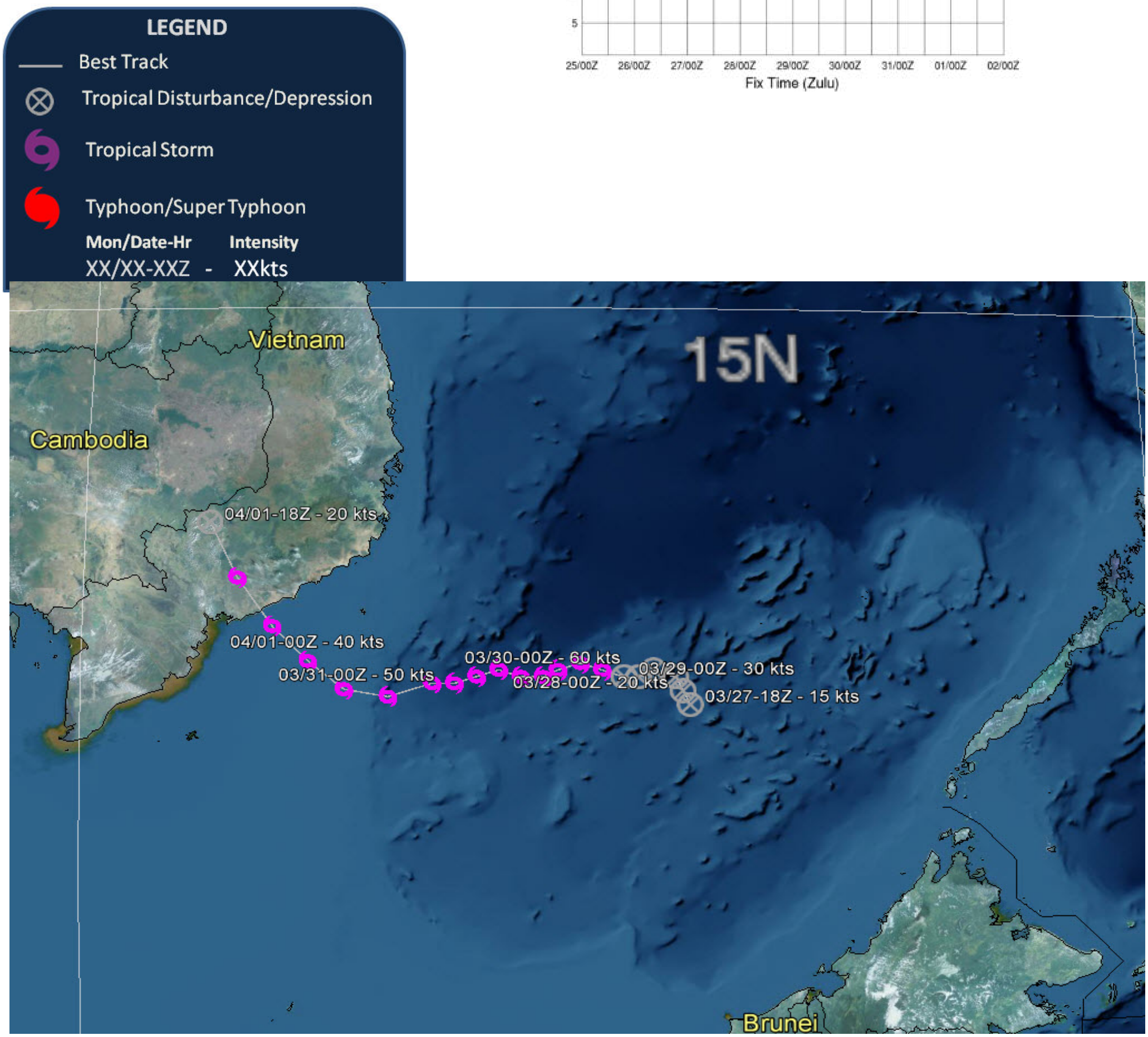




Tropical Storm 02W (Pakhar)

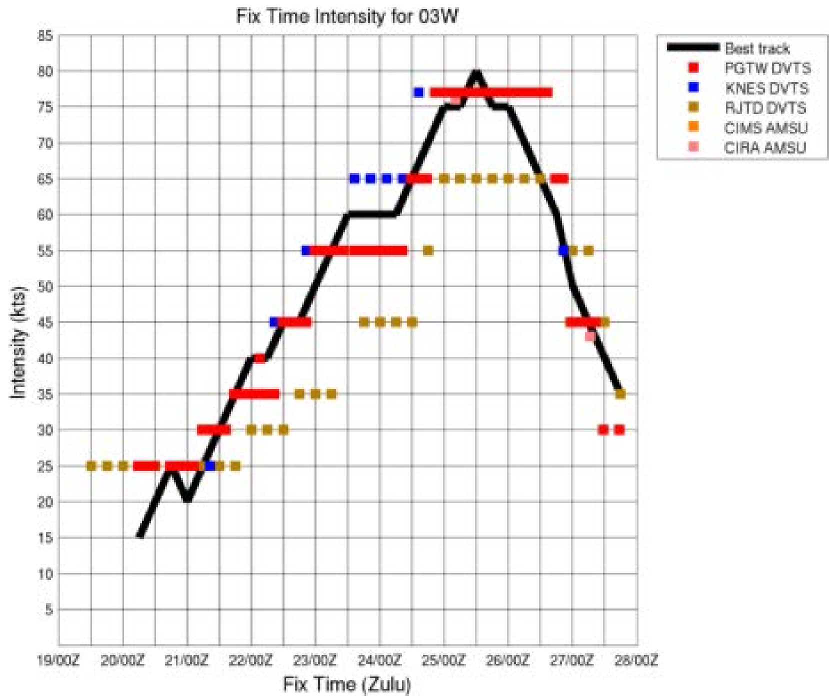
ISSUED LOW:	0430Z 26 Mar 2012
ISSUED MED:	1930Z 26 Mar 2012
FIRST TCFA:	0300Z 28 Mar 2012
FIRST WARNING:	0000Z 29 Mar 2012
LAST WARNING:	1200Z 31 Mar 2012
MAX INTENSITY:	60 Kts
WARNINGS:	11

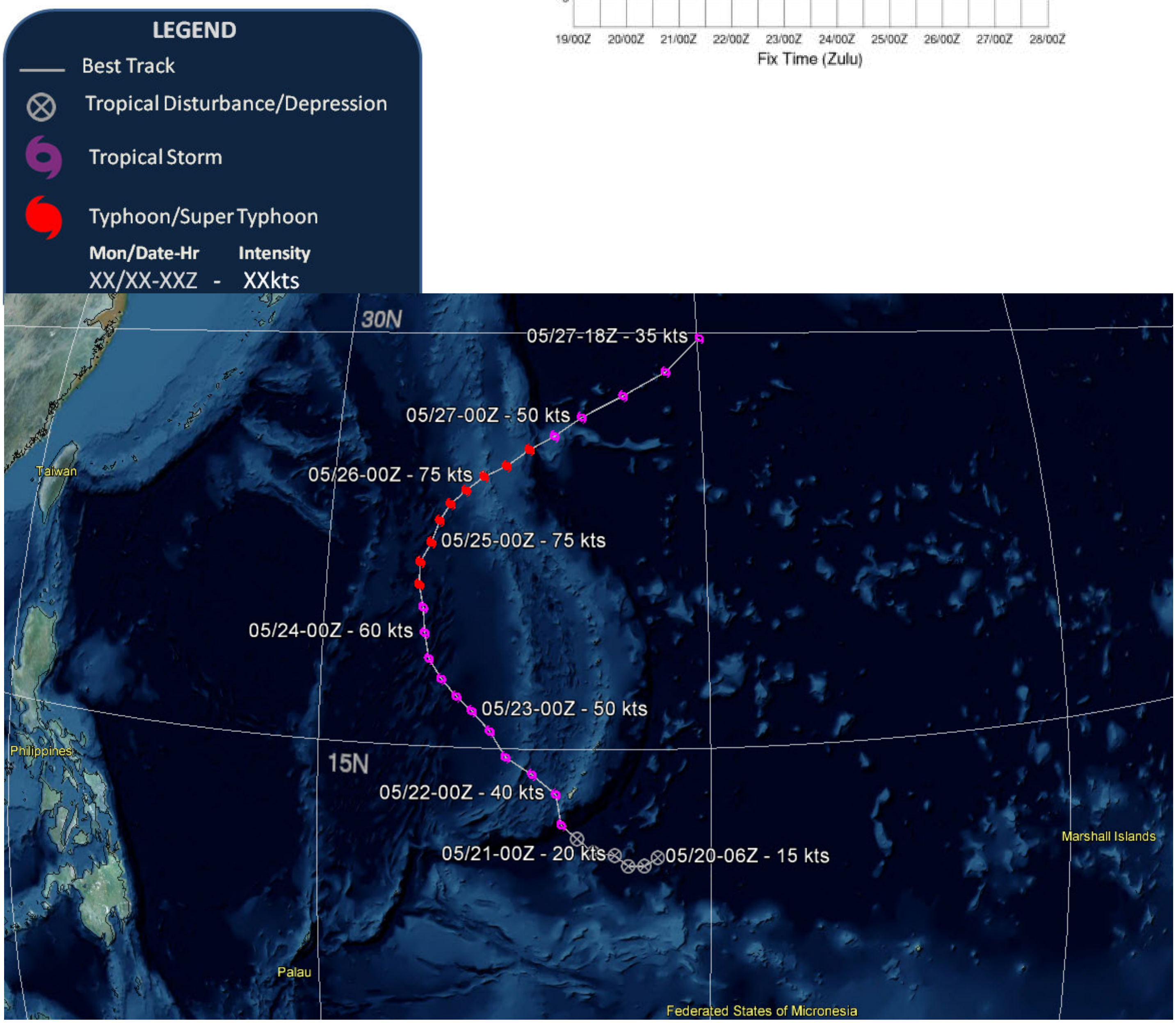




Typhoon 03W (Sanvu)

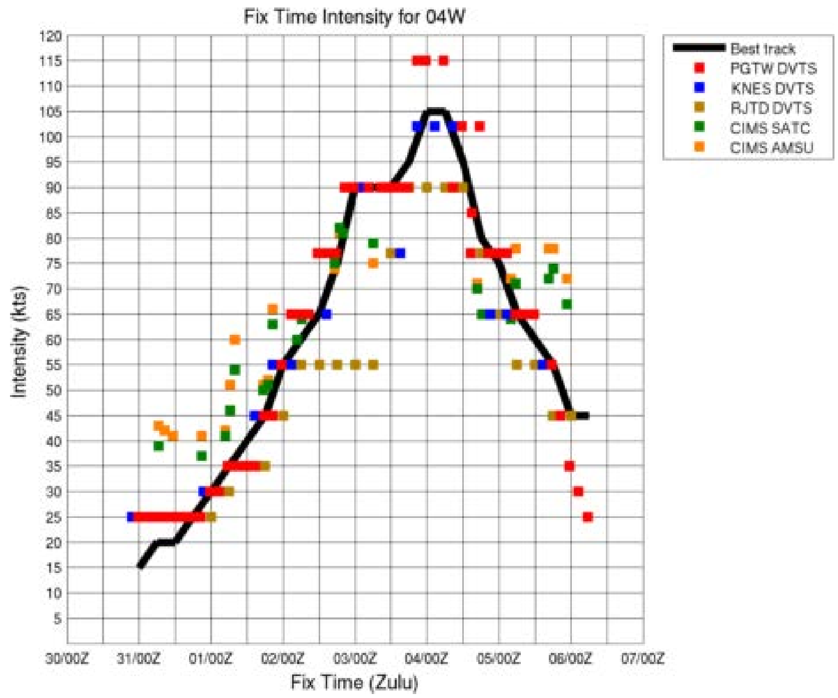
ISSUED LOW:	2200Z 18 May 2012
ISSUED MEDIUM:	0600Z 19 May 2012
FIRST TCFA:	2000Z 20 May 2012
FIRST WARNING:	0600Z 21 May 2012
LAST WARNING:	0600Z 27 May 2012
MAX INTENSITY:	80Kts
WARNINGS:	25

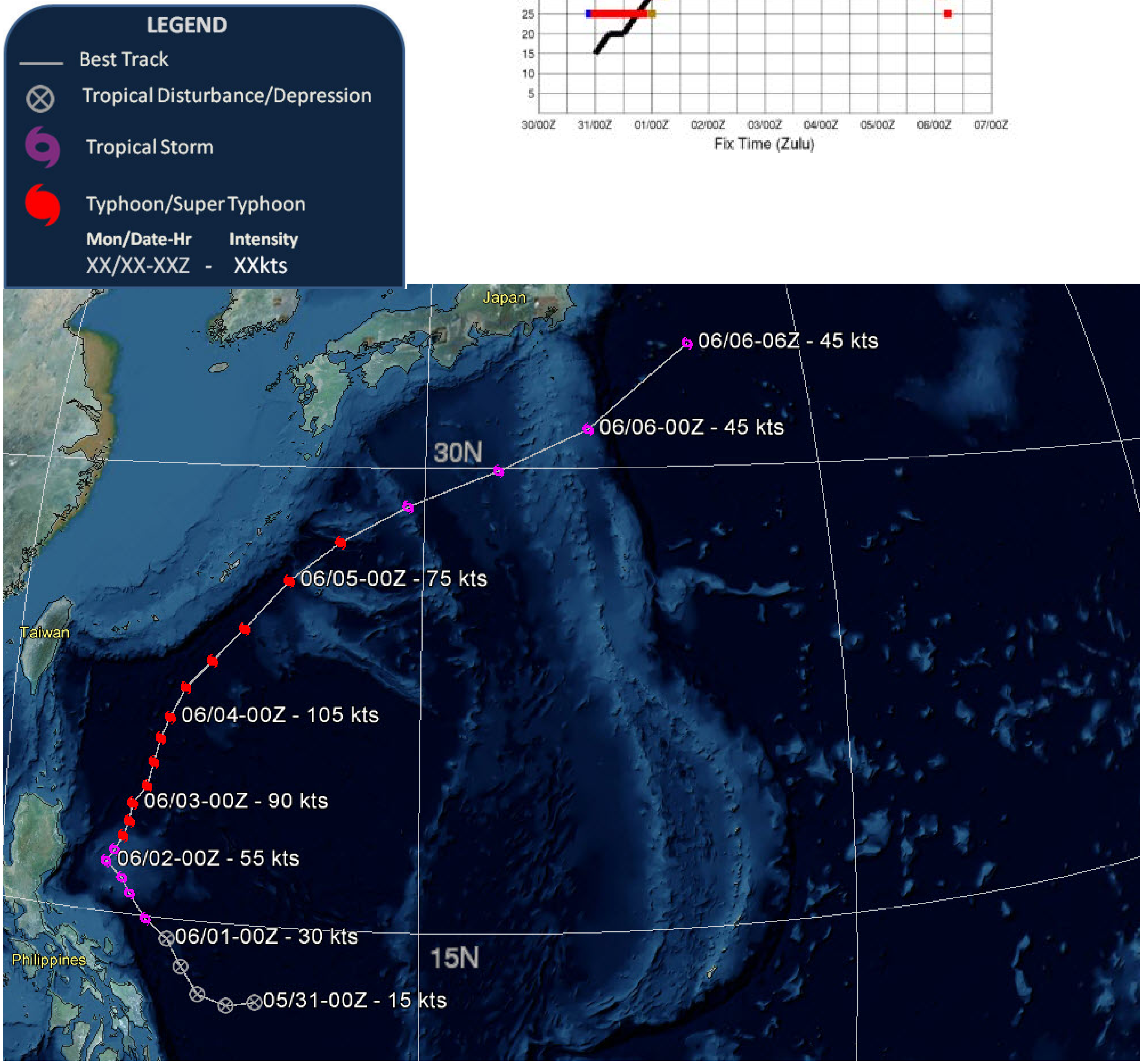




Typhoon 04W (Mawar)

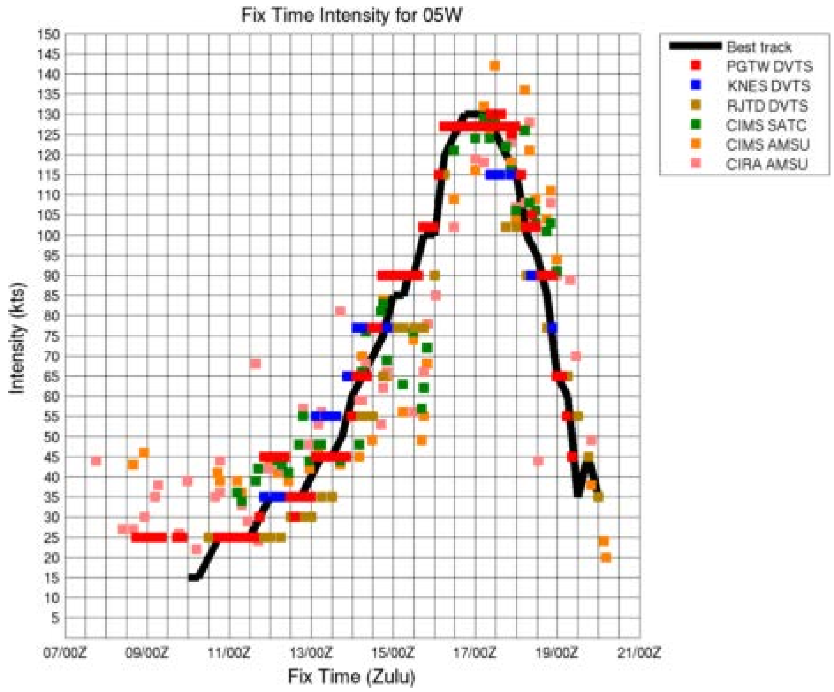
ISSUED LOW:	1330Z 29 May 2012
ISSUED MEDIUM:	1000Z 30 May 2012
FIRST TCFA:	2200Z 30 May 2012
FIRST WARNING:	1800Z 31 May 2012
LAST WARNING:	1800Z 05 Jun 2012
MAX INTENSITY:	105 Kts
WARNINGS:	21

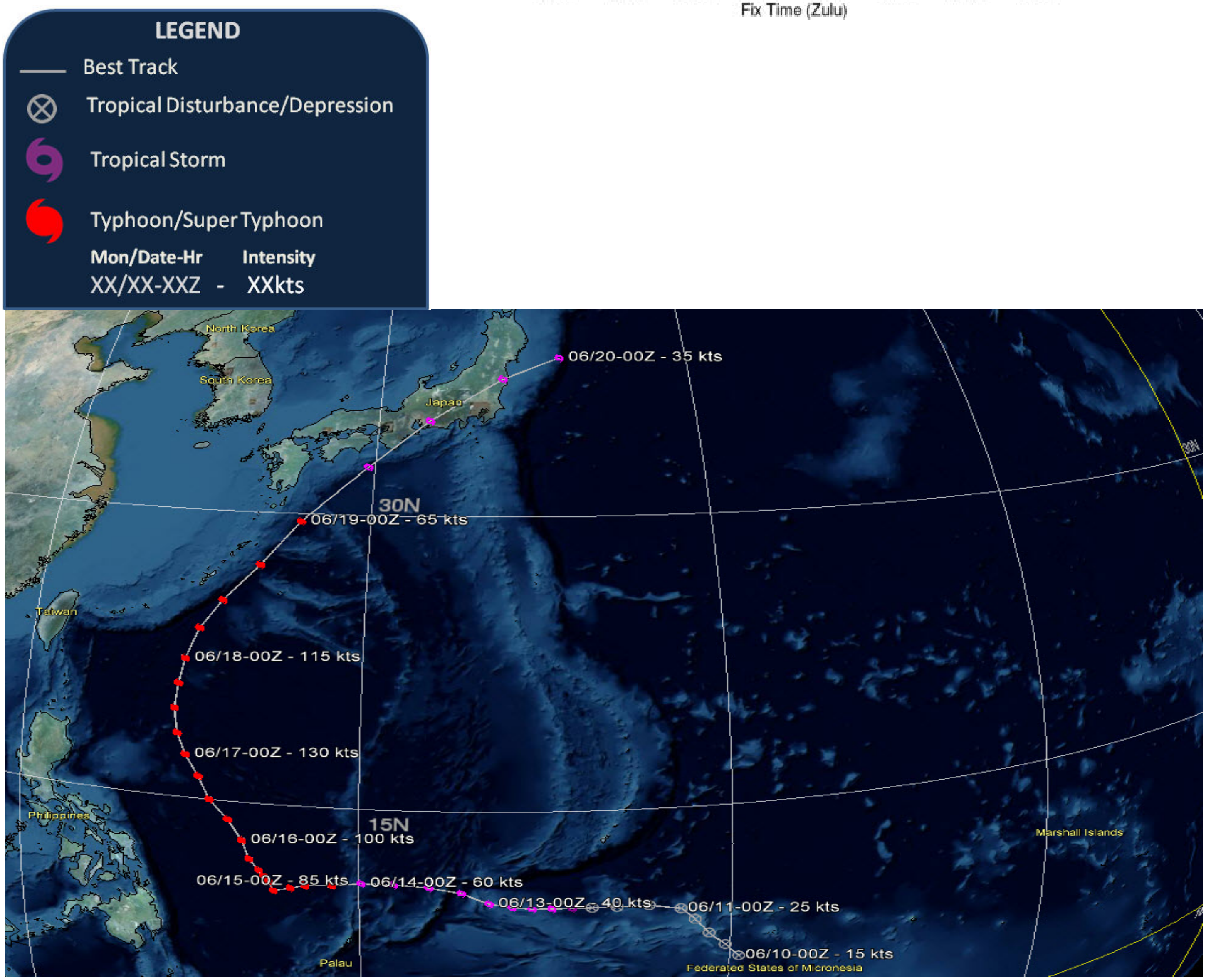




Super Typhoon 05W (Guchol)

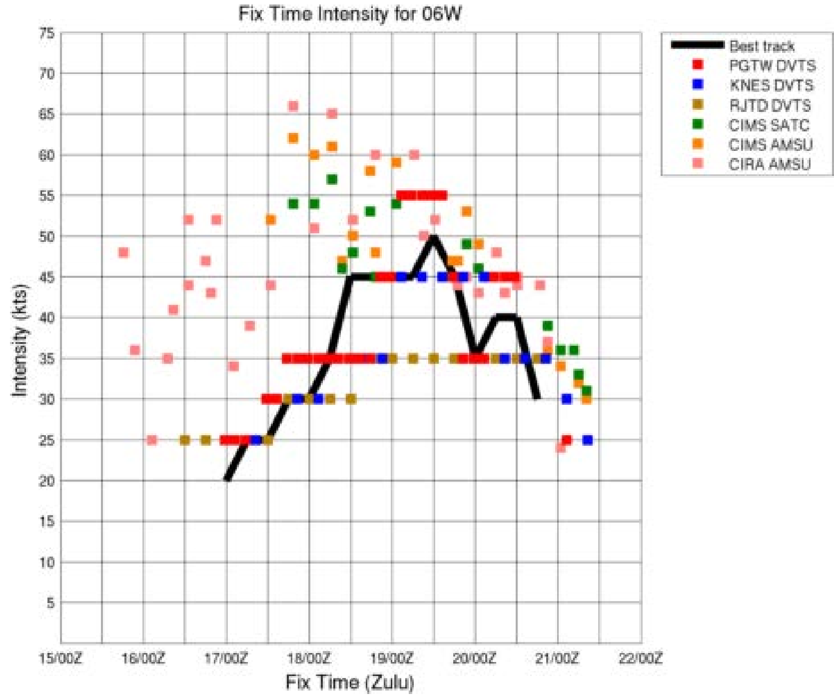
ISSUED LOW:	2030Z 07 Jun 2012
ISSUED MEDIUM:	0300Z 07 Jun 2012
FIRST TCFA:	2030Z 08 Jun 2012
FIRST WARNING:	0000Z 11 Jun 2012
LAST WARNING:	1200Z 19 Jun 2012
MAX INTENSITY:	130 Kts
WARNINGS:	35

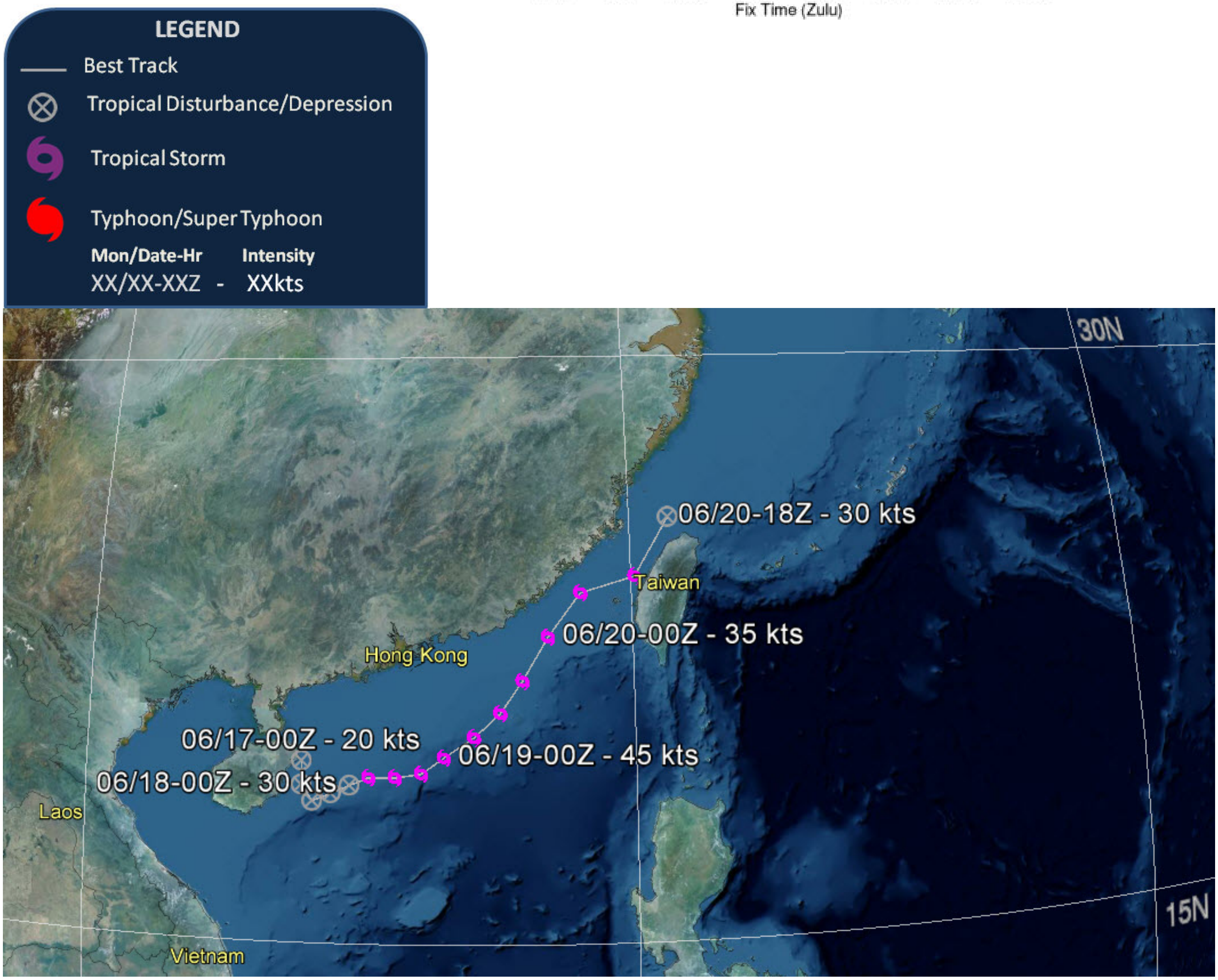




Tropical Storm 06W (Talim)

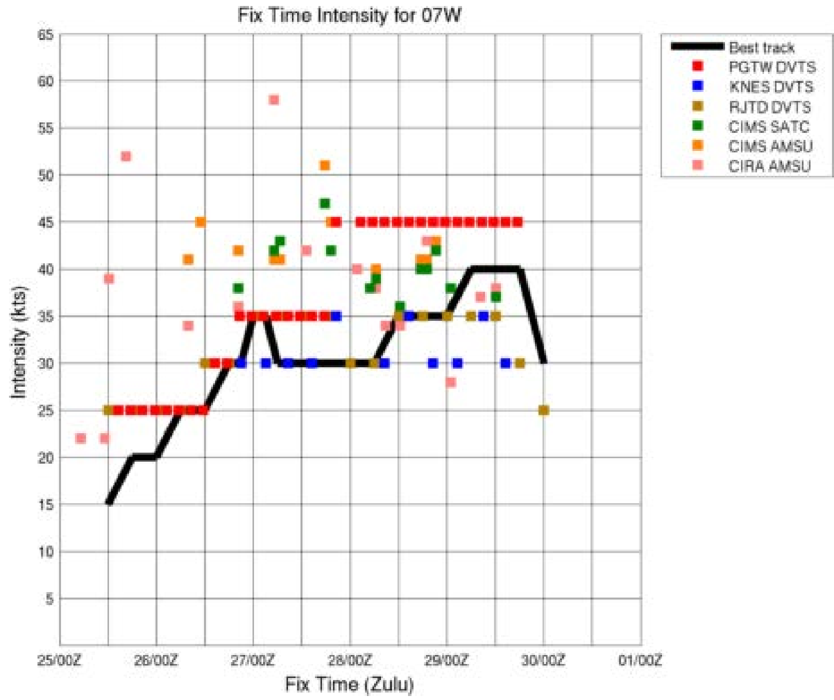
ISSUED LOW:	0600Z 16 Jun 2012
ISSUED MEDIUM:	2130Z 16 Jun 2012
FIRST TCFA:	1130Z 17 Jun 2012
FIRST WARNING:	1800Z 17 Jun 2012
LAST WARNING:	0000Z 21 Jun 2012
MAX INTENSITY:	50 Kts
WARNINGS:	14

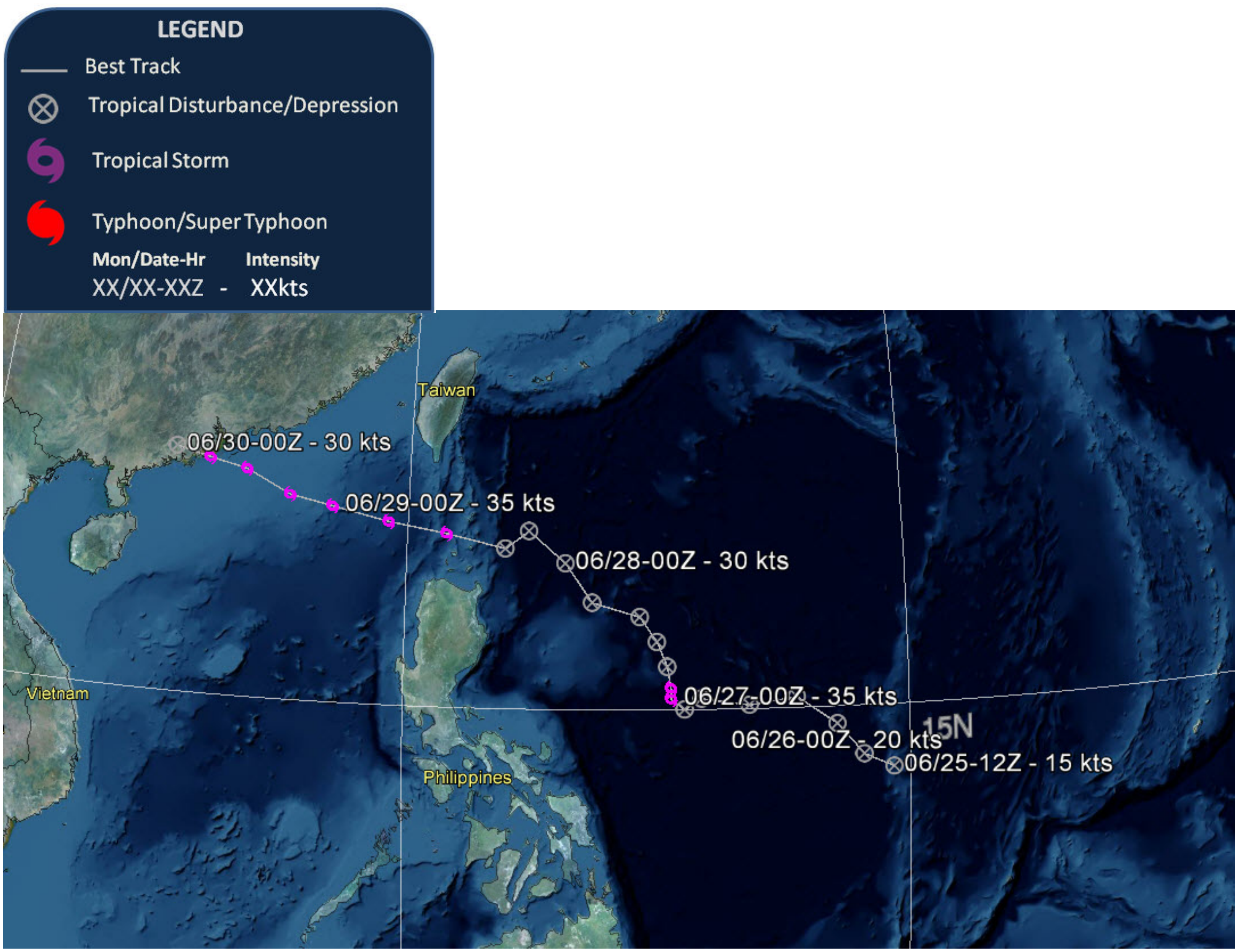




Tropical Storm 07W (Doksuri)

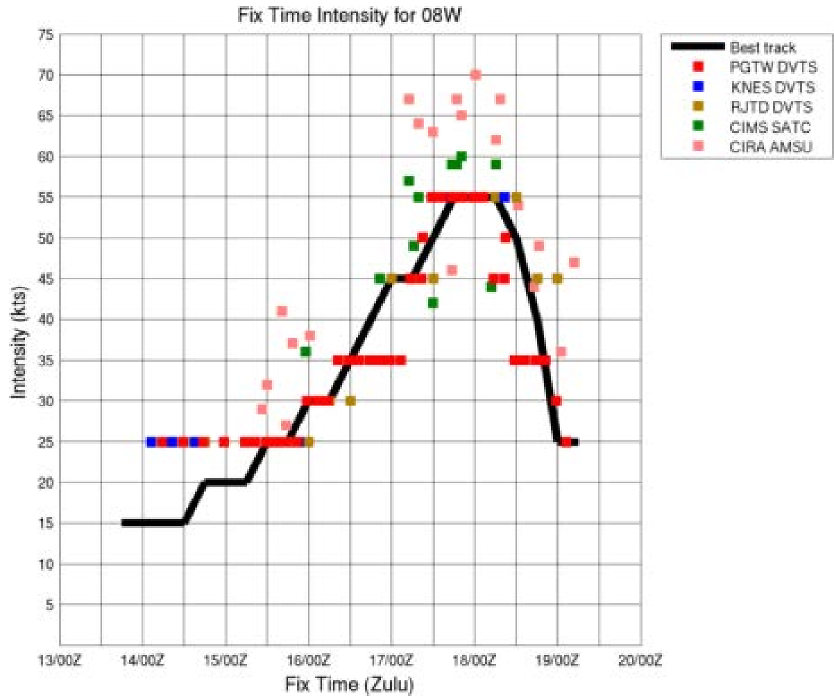
ISSUED LOW: N/A
ISSUED MEDIUM: 0600Z 25 Jun 2012
FIRST TCFA: 1700Z 25 Jun 2012
FIRST WARNING: 1200Z 26 Jun 2012
LAST WARNING: 0000Z 30 Jun 2012
MAX INTENSITY: 40 Kts
WARNINGS: 15

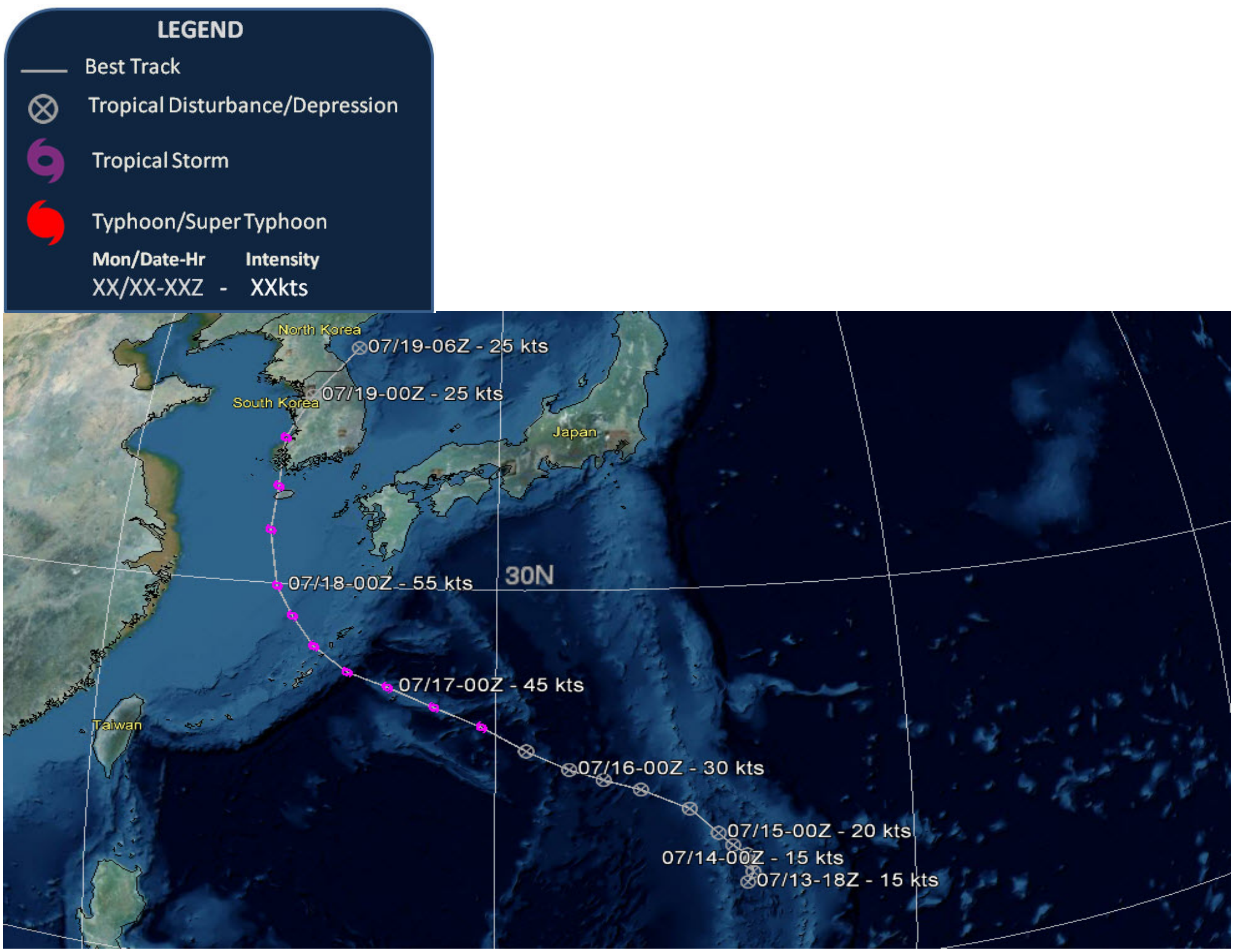




Tropical Storm 08W (Khanun)

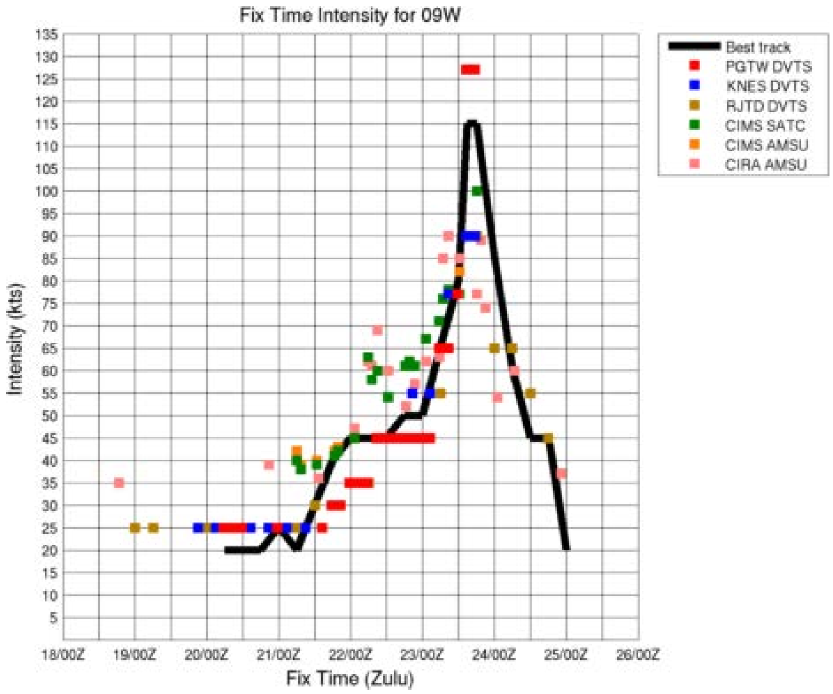
ISSUED LOW:	0230Z 14 Jul 2012
ISSUED MEDIUM:	0600Z 14 Jul 2012
FIRST TCFA:	0430Z 15 Jul 2012
FIRST WARNING:	1200Z 15 Jul 2012
LAST WARNING:	0000Z 19 Jul 2012
MAX INTENSITY:	55 Kts
WARNINGS:	15

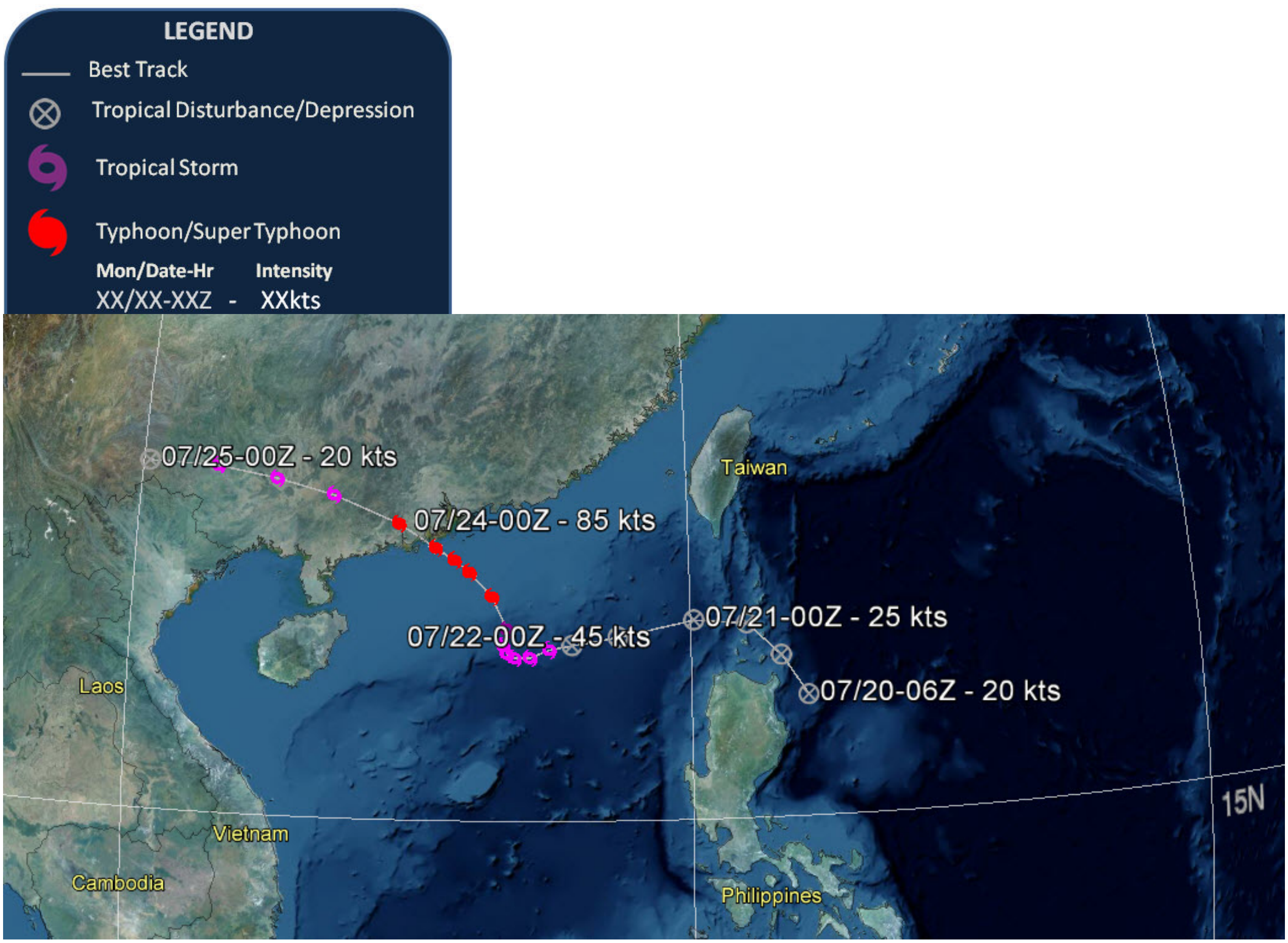




Typhoon 09W (Vicente)

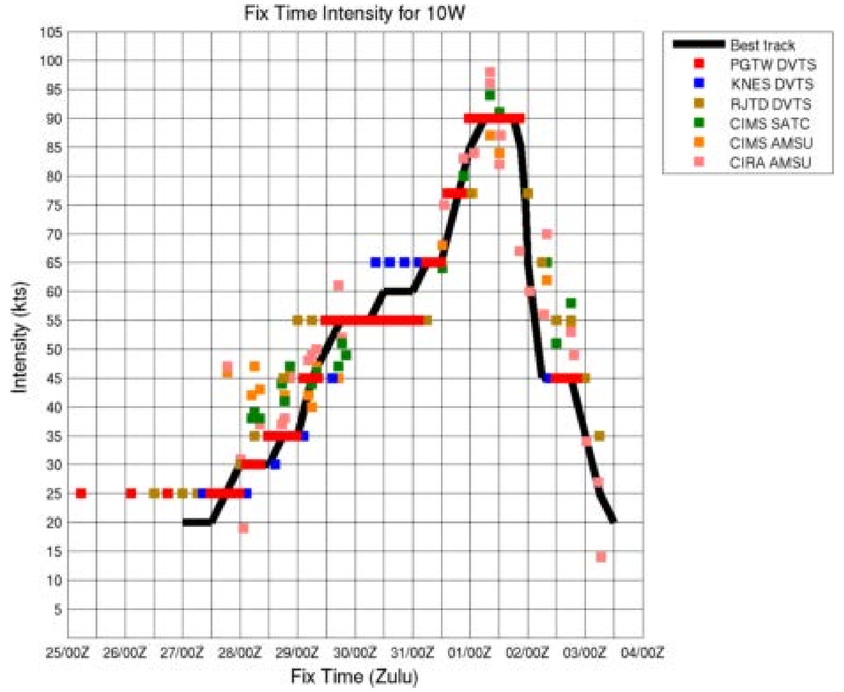
ISSUED LOW: 1500Z 17 Jul 2012
ISSUED MEDIUM: 1800Z 18 Jul 2012
FIRST TCFA: 0800Z 20 Jul 2012
FIRST WARNING: 1800Z 20 Jul 2012
LAST WARNING: 0000Z 24 Jul 2012
MAX INTENSITY: 115 Kts
WARNINGS: 14

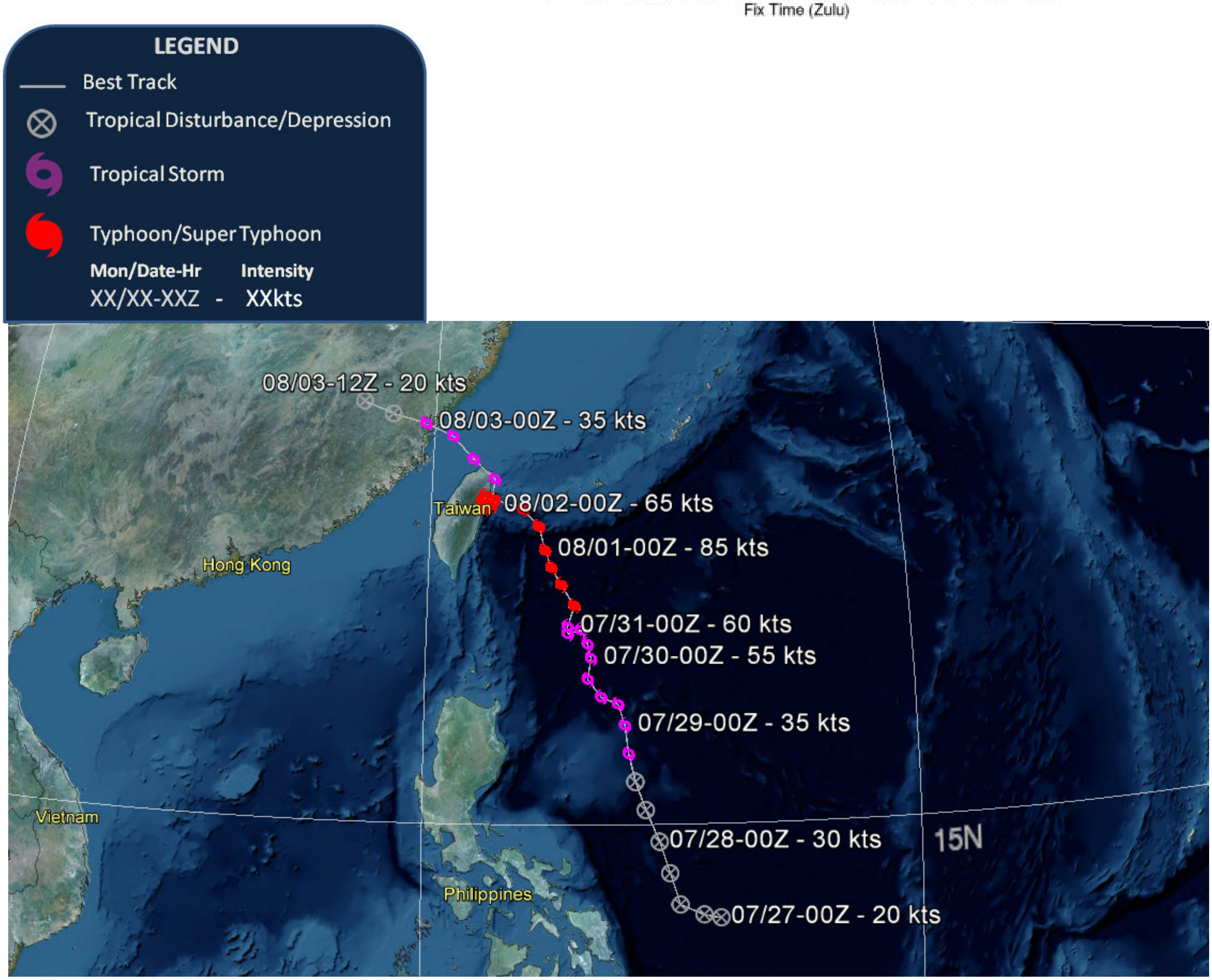




Typhoon 10W (Saola)

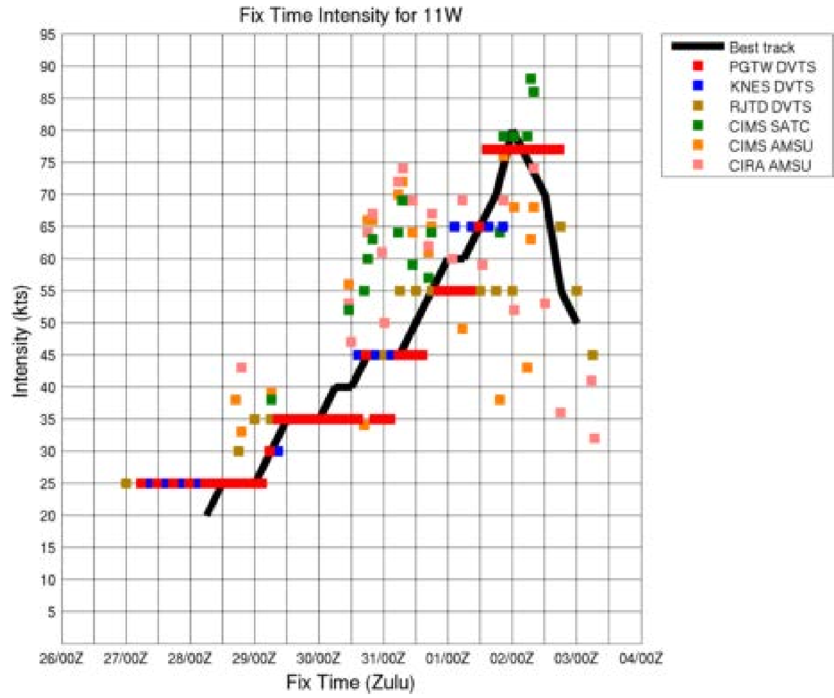
ISSUED LOW:	0130Z 25 Jul 2012
ISSUED MEDIUM:	0600Z 26 Jul 2012
FIRST TCFA:	1400Z 27 Jul 2012
FIRST WARNING:	0000Z 28 Jul 2012
LAST WARNING:	0000Z 03 Aug 2012
MAX INTENSITY:	90 Kts
WARNINGS:	25

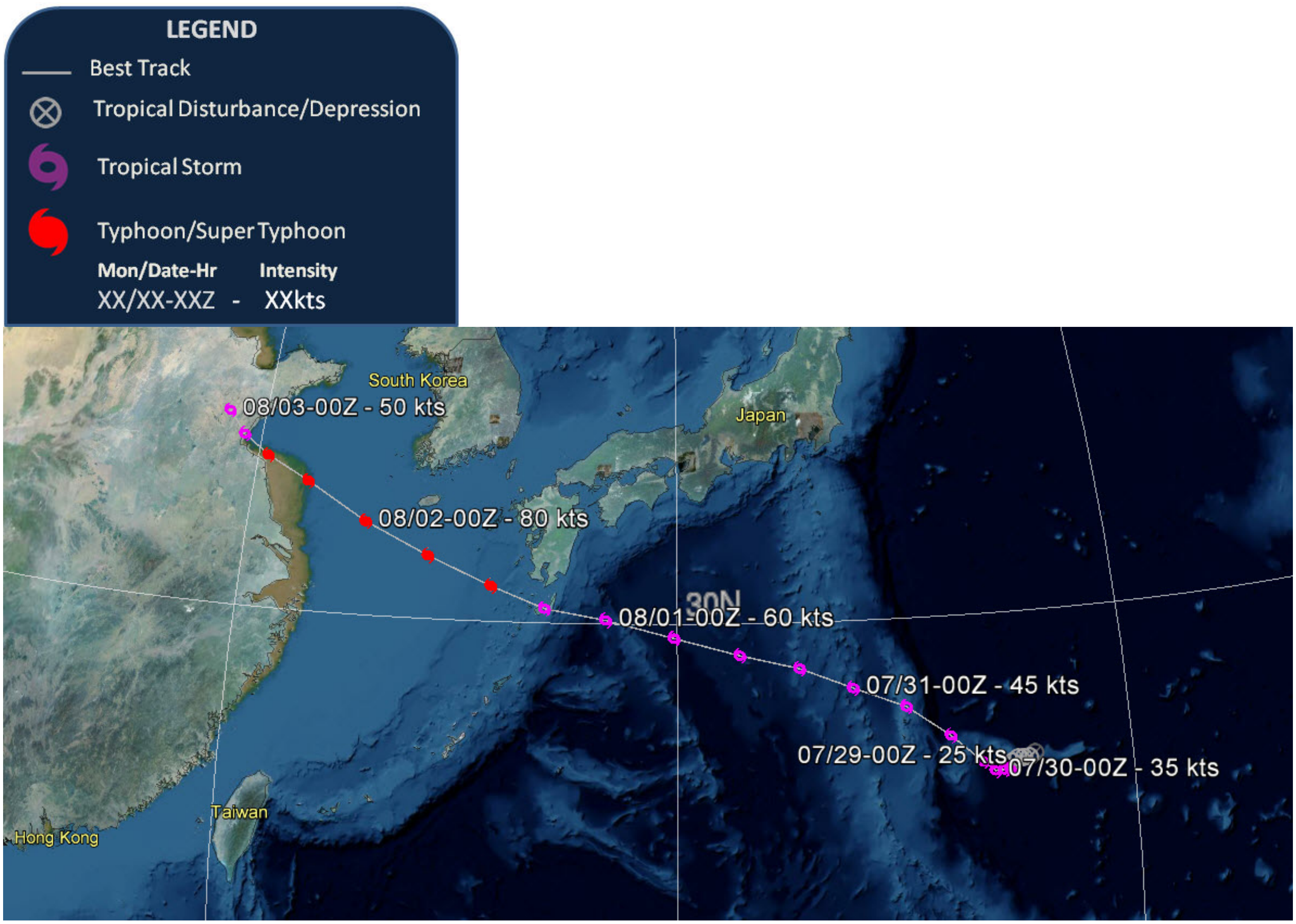




<u>**Typhoon 11W (Damrey)**</u>

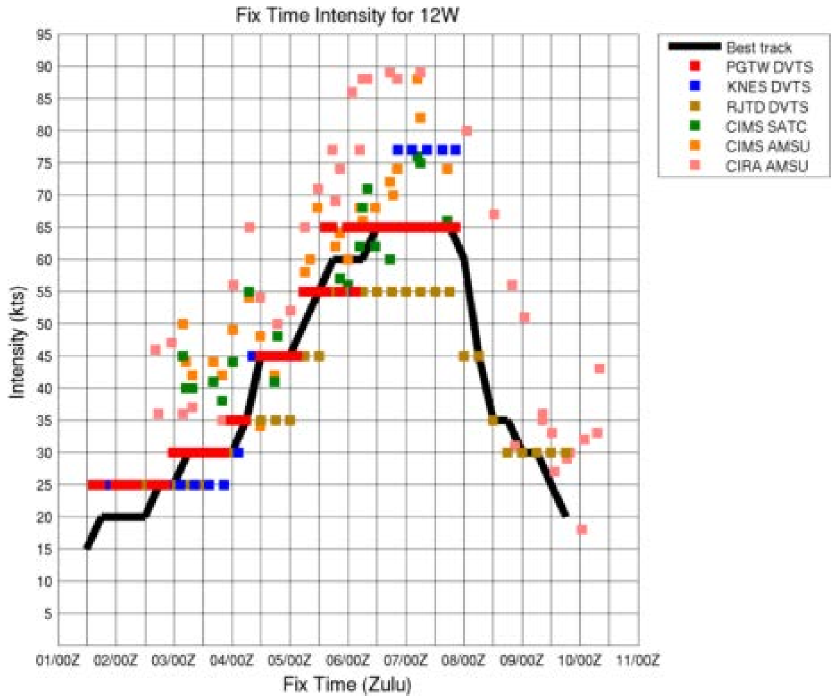
ISSUED LOW:	0200Z 27 Jul 2012
ISSUED MEDIUM:	1430Z 27 Jul 2012
FIRST TCFA:	0600Z 28 Jul 2012
FIRST WARNING:	1800Z 28 Jul 2012
LAST WARNING:	1800Z 02 Aug 2012
MAX INTENSITY:	80 Kts
WARNINGS:	21

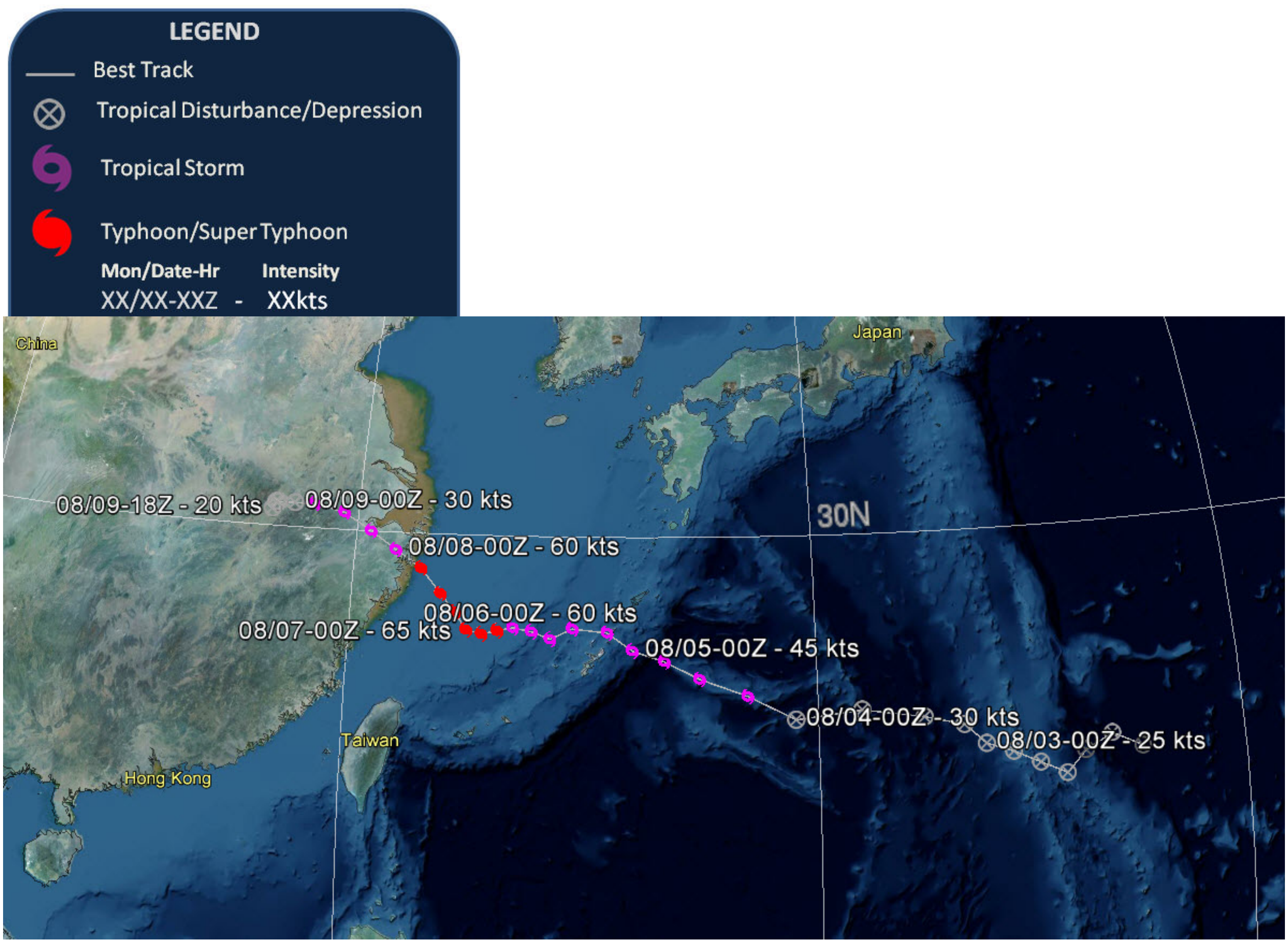




Typhoon 12W (Haikui)

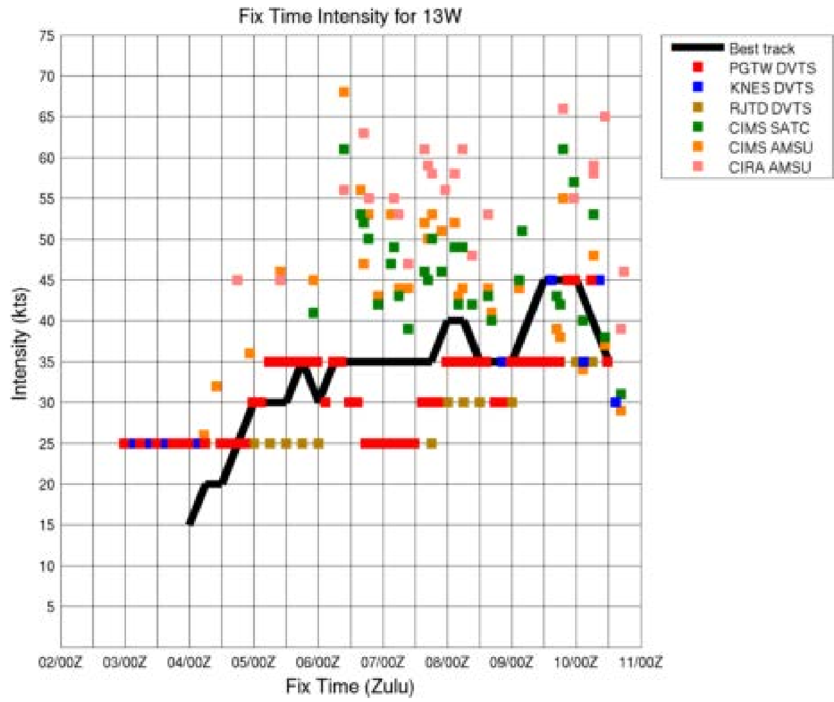
ISSUED LOW:	0930Z 01 Aug 2012
ISSUED MEDIUM:	1300Z 01 Aug 2012
FIRST TCFA:	2200Z 01 Aug 2012
FIRST WARNING:	1800Z 02 Aug 2012
LAST WARNING:	0000Z 08 Aug 2012
MAX INTENSITY:	65 Kts
WARNINGS:	22

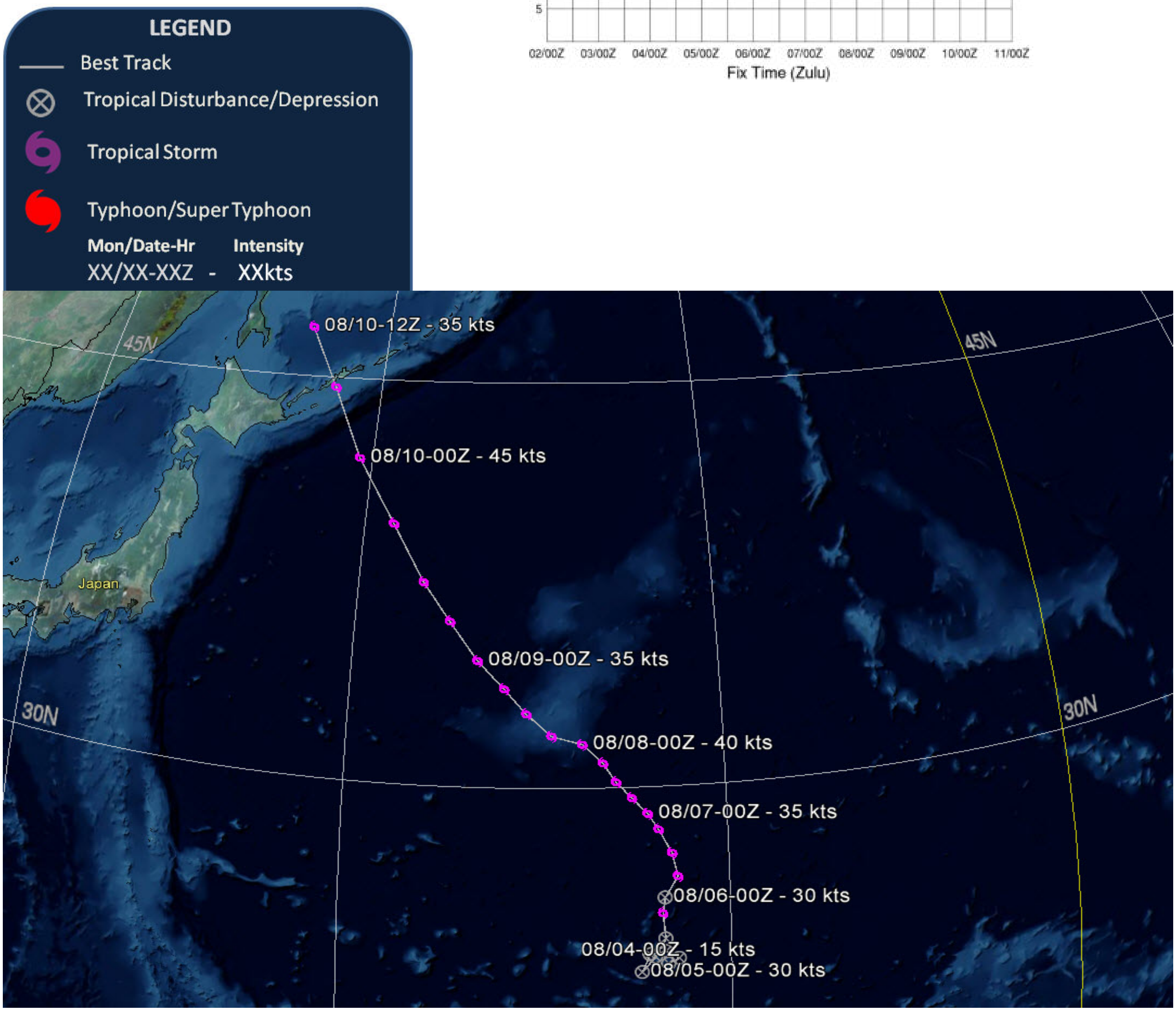




Tropical Storm 13W (Kirogi)

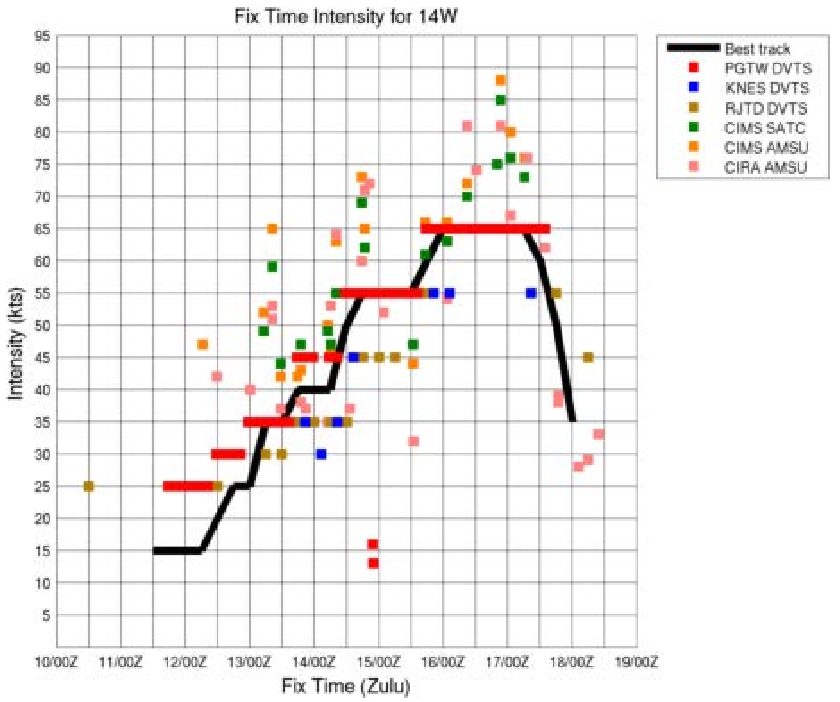
ISSUED LOW:	N/A
ISSUED MEDIUM:	2230Z 02 Aug 2012
FIRST TCFA:	1100Z 04 Aug 2012
FIRST WARNING:	1800Z 04 Aug 2012
LAST WARNING:	1800Z 09 Aug 2012
MAX INTENSITY:	45 Kts
WARNINGS:	21

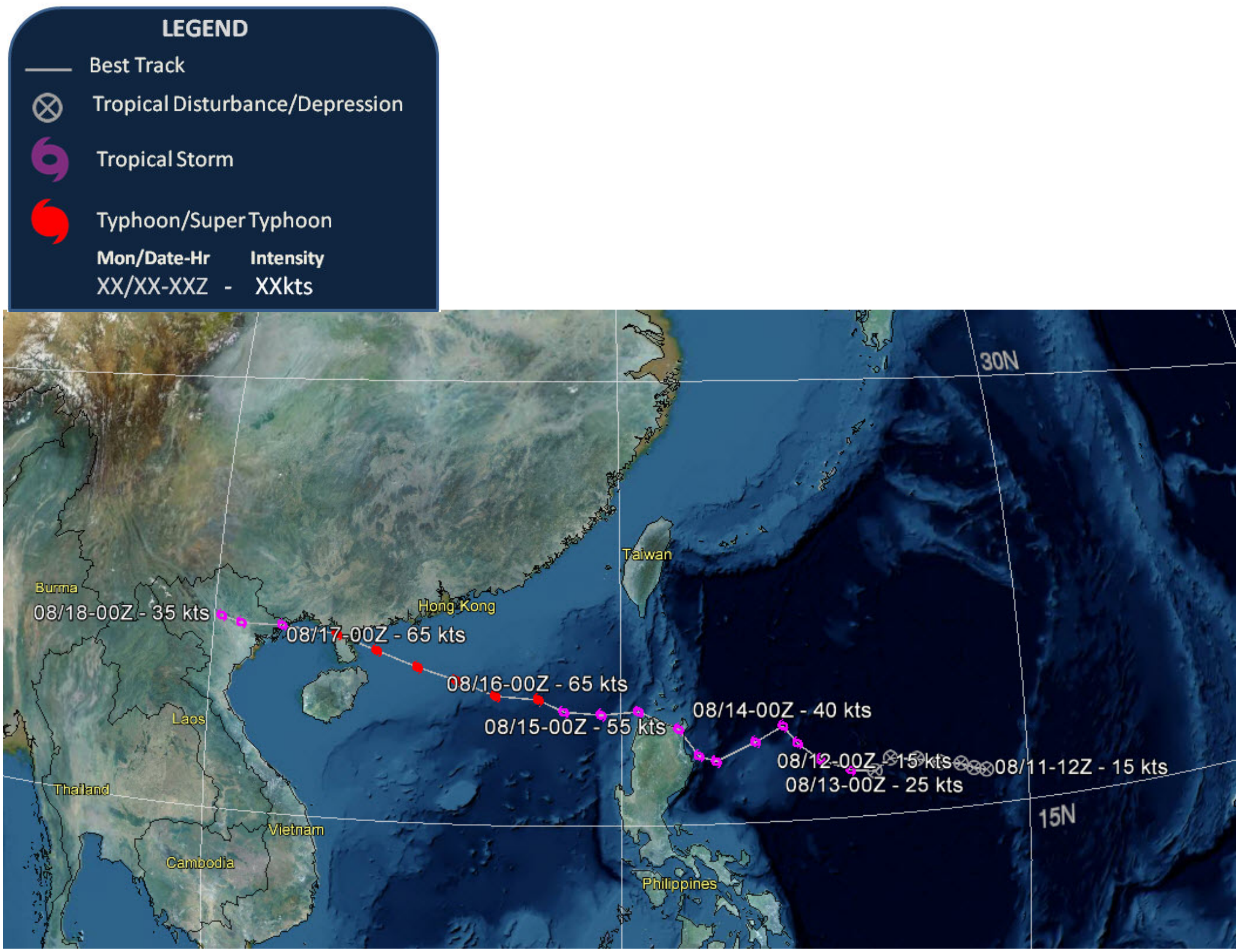




Typhoon 14W (Kai-Tak)

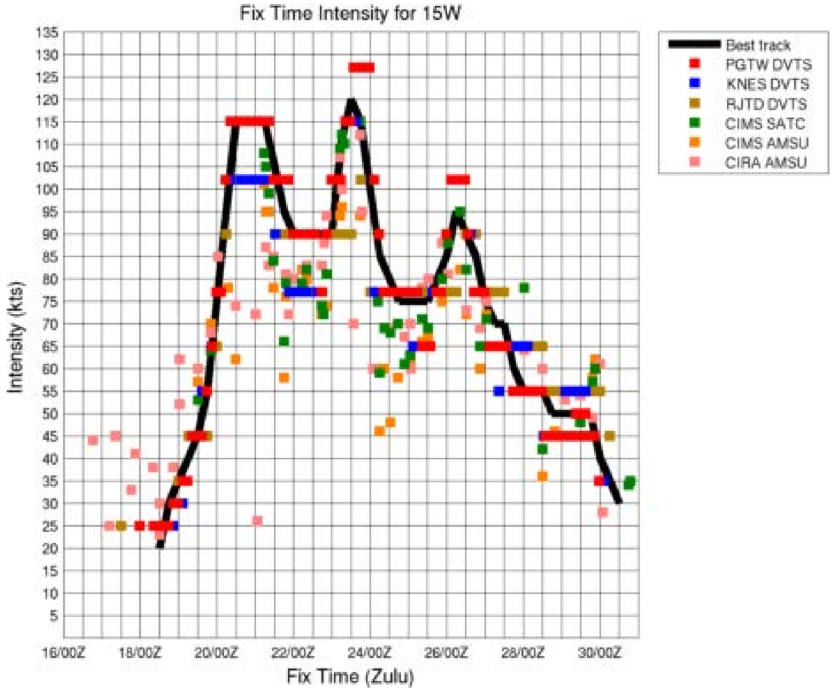
ISSUED LOW:	0600Z 10 Aug 2012
ISSUED MEDIUM:	1800Z 11 Aug 2012
FIRST TCFA:	0700Z 12 Aug 2012
FIRST WARNING:	1200Z 12 Aug 2012
LAST WARNING:	1800Z 17 Aug 2012
MAX INTENSITY:	65 Kts
WARNINGS:	22

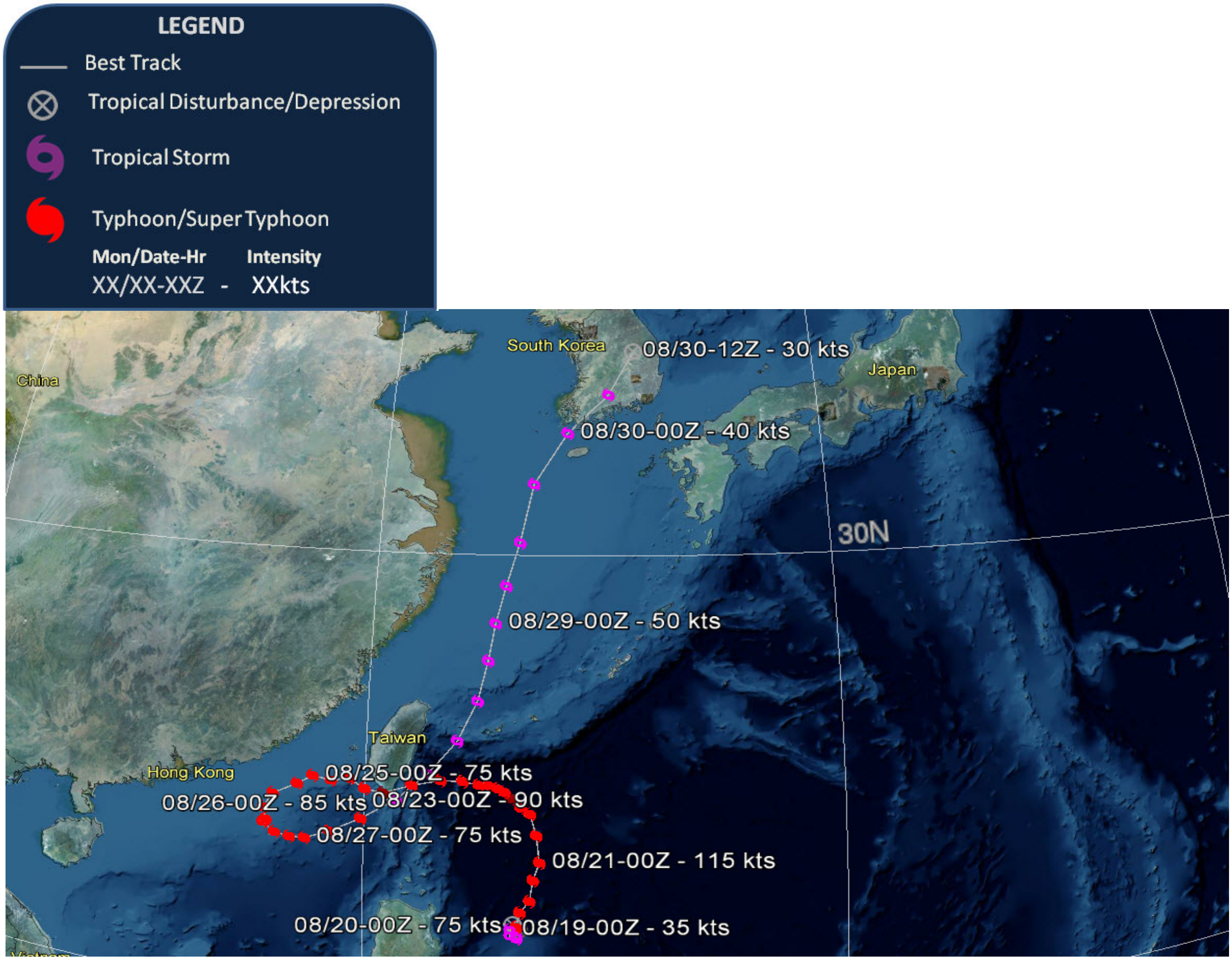




Typhoon 15W (Tembin)

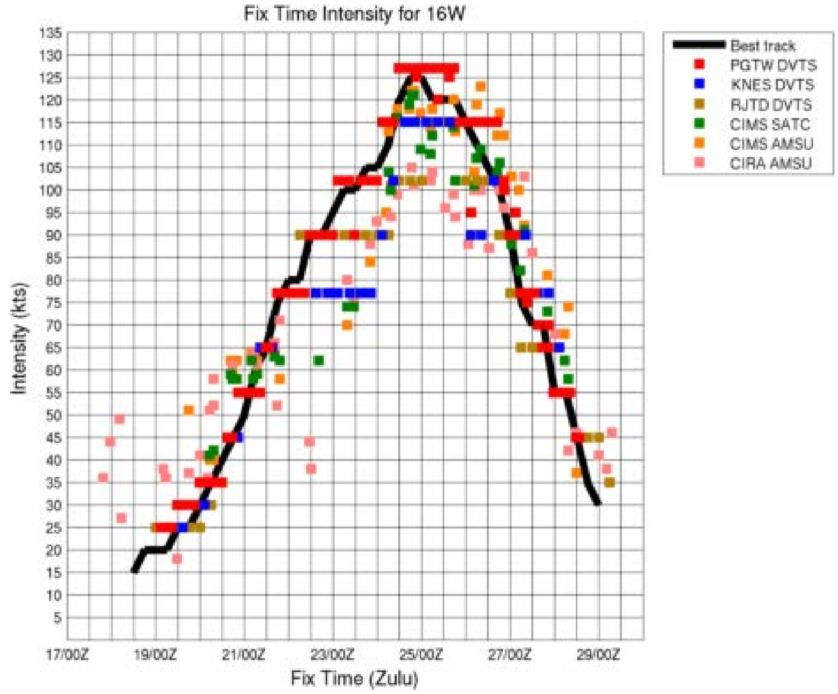
ISSUED LOW:	0600Z 17 Aug 2012
ISSUED MEDIUM:	2100Z 17 Aug 2012
FIRST TCFA:	1800Z 18 Aug 2012
FIRST WARNING:	0000Z 19 Aug 2012
LAST WARNING:	0000Z 30 Aug 2012
MAX INTENSITY:	120 Kts
WARNINGS:	45

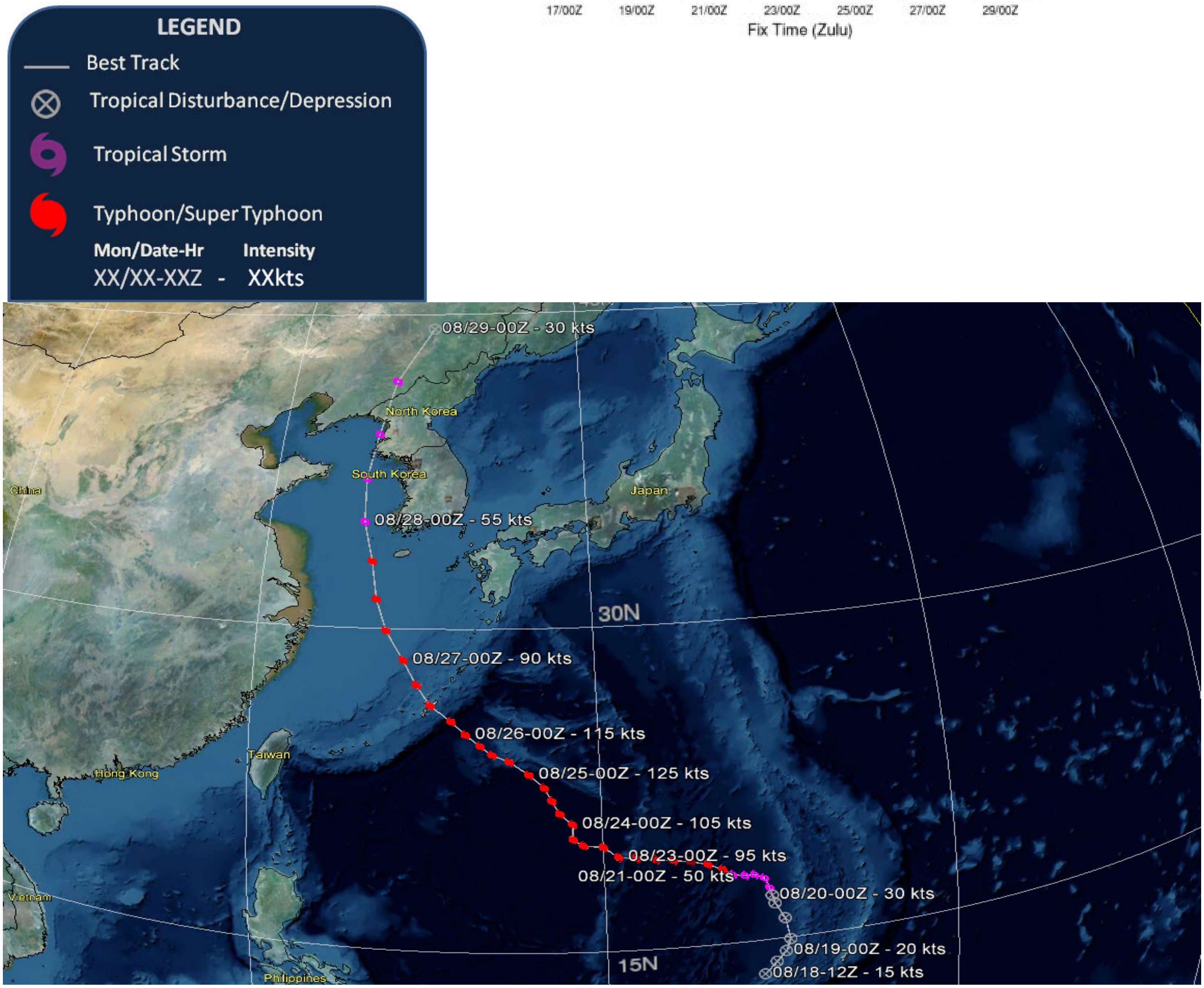




<u>**Typhoon 16W (Bolaven)**</u>

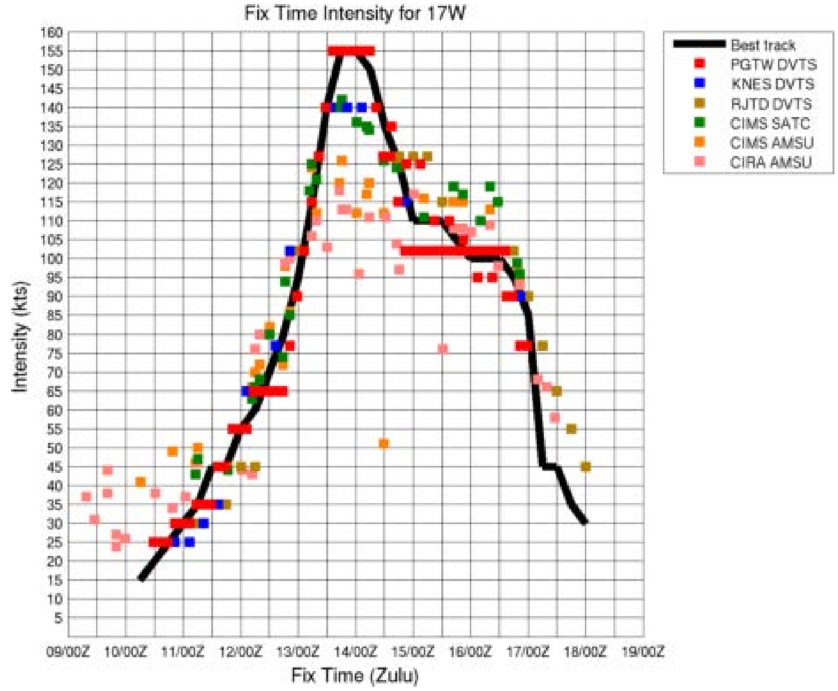
ISSUED LOW:	0600Z 18 Aug 2012
ISSUED MEDIUM:	0600Z 19 Aug 2012
FIRST TCFA:	1000Z 19 Aug 2012
FIRST WARNING:	0000Z 20 Aug 2012
LAST WARNING:	1800Z 28 Aug 2012
MAX INTENSITY:	125 Kts
WARNINGS:	36

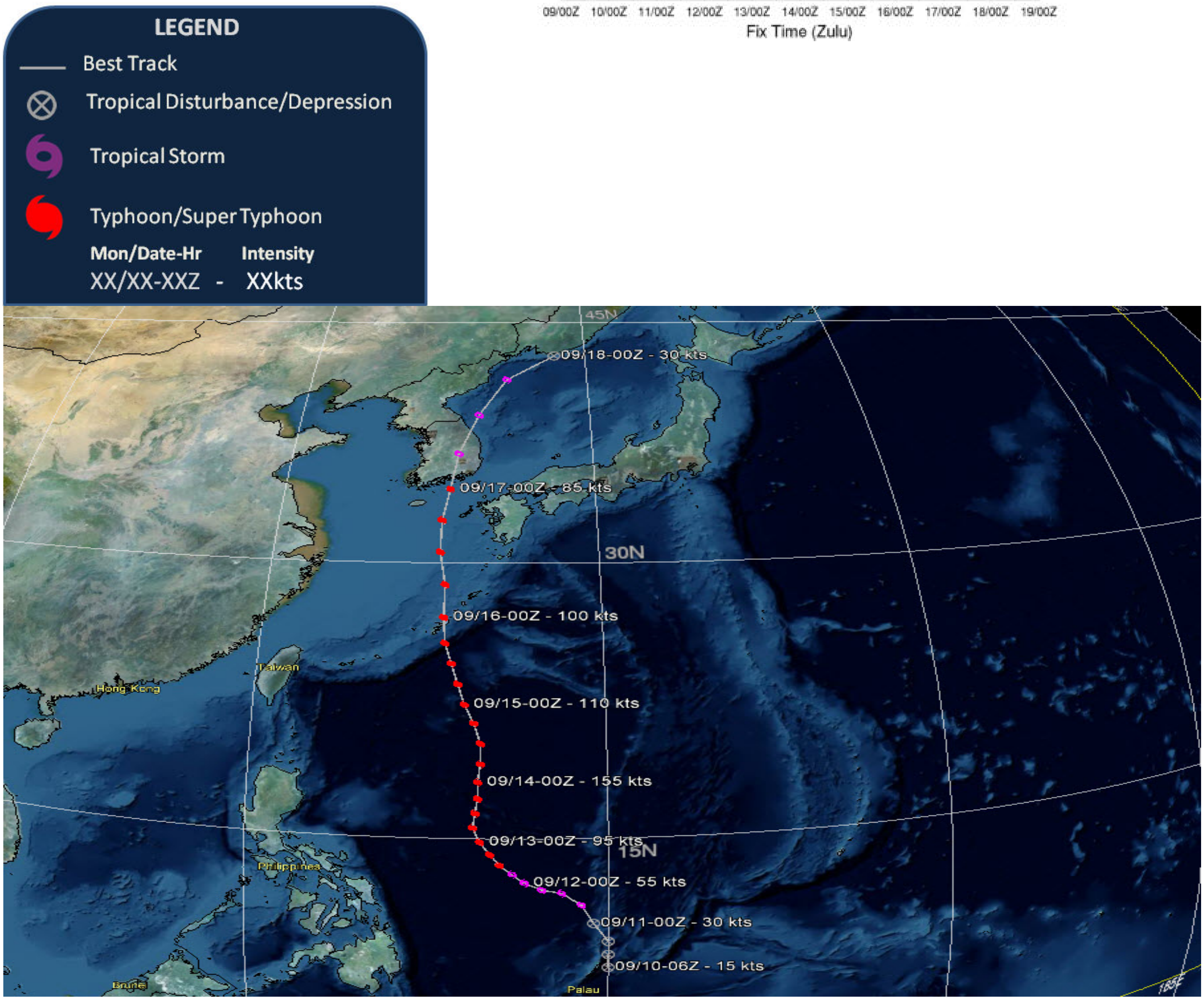




Super Typhoon 17W (Sanba)

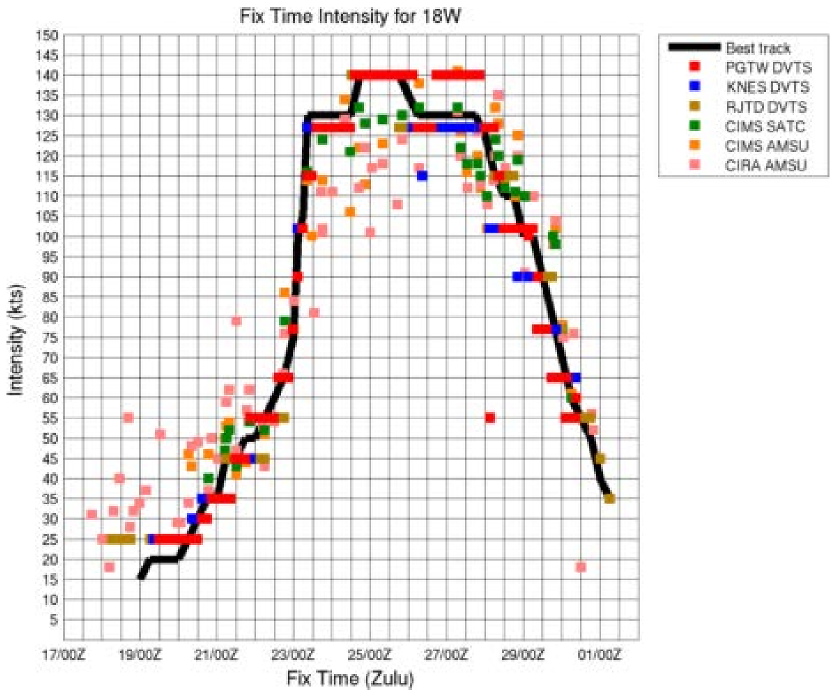
ISSUED LOW:	N/A
ISSUED MEDIUM:	1900Z 09 Sep 2012
FIRST TCFA:	1400Z 10 Sep 2012
FIRST WARNING:	1800Z 10 Sep 2012
LAST WARNING:	0600Z 17 Sep 2012
MAX INTENSITY:	155 Kts
WARNINGS:	27

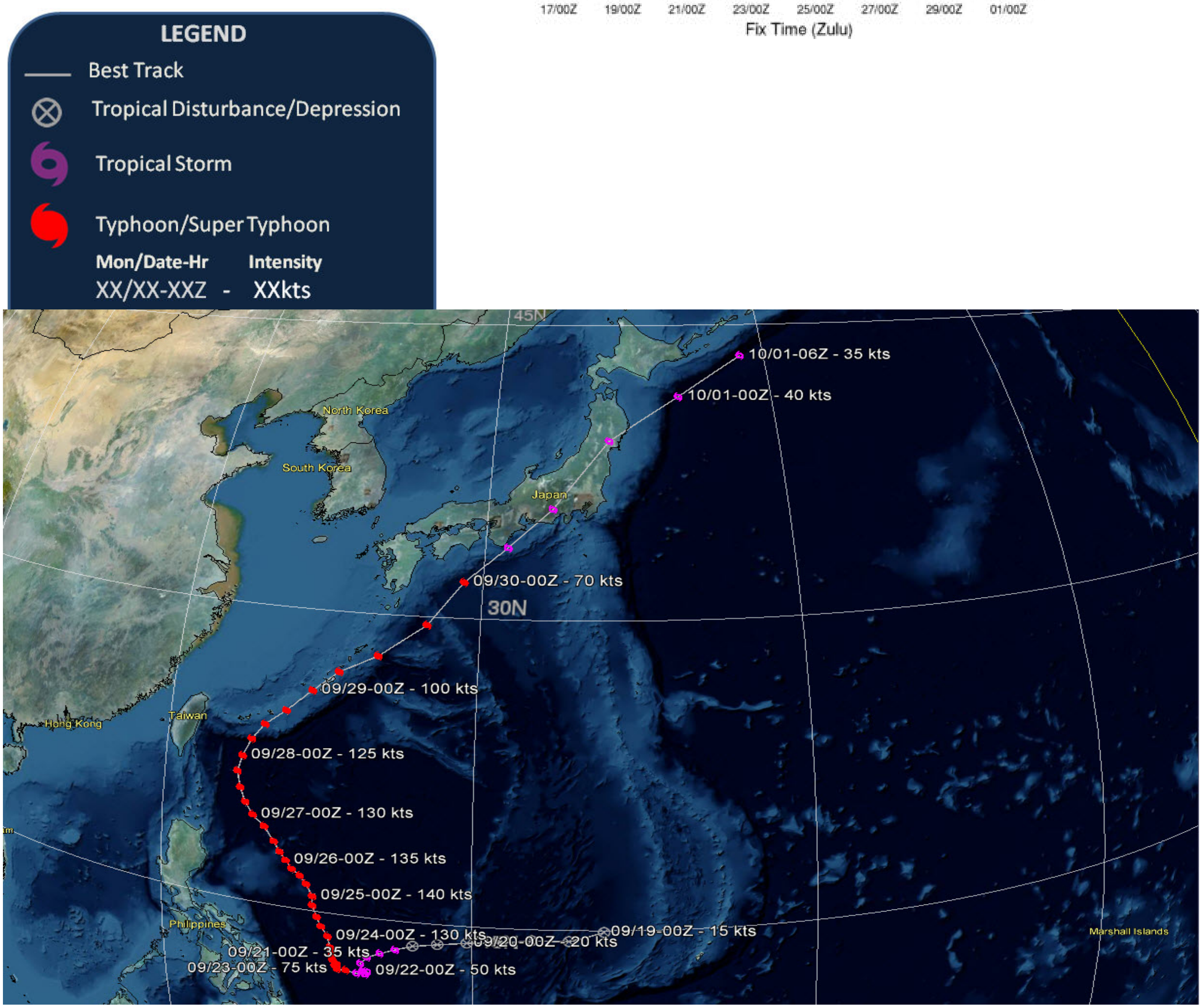




Super Typhoon 18W (Jelawat)

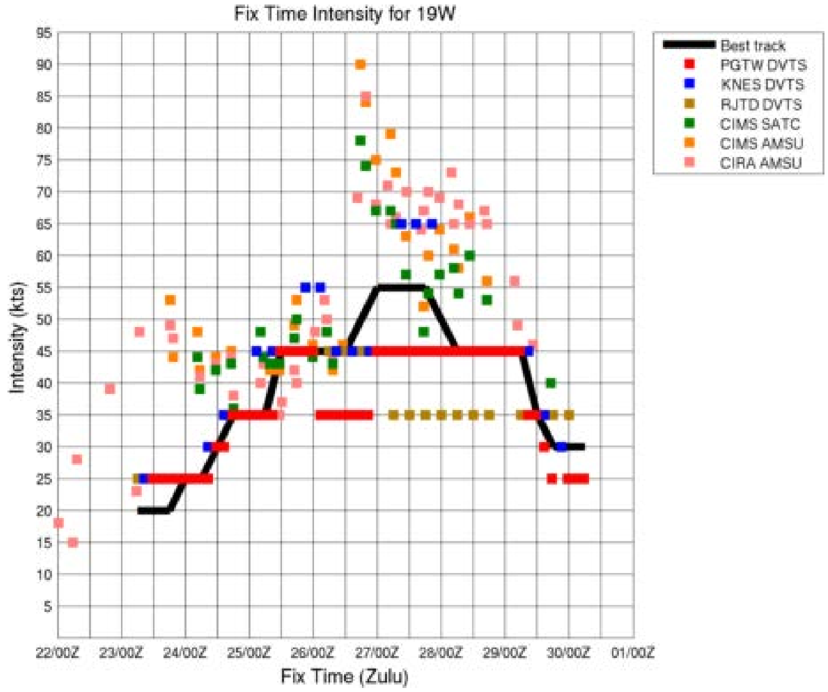
ISSUED LOW:	1800Z 17 Sep 2012
ISSUED MEDIUM:	0800Z 19 Sep 2012
FIRST TCFA:	2300Z 19 Sep 2012
FIRST WARNING:	1200Z 20 Sep 2012
LAST WARNING:	1800Z 30 Sep 2012
MAX INTENSITY:	140 Kts
WARNINGS:	42

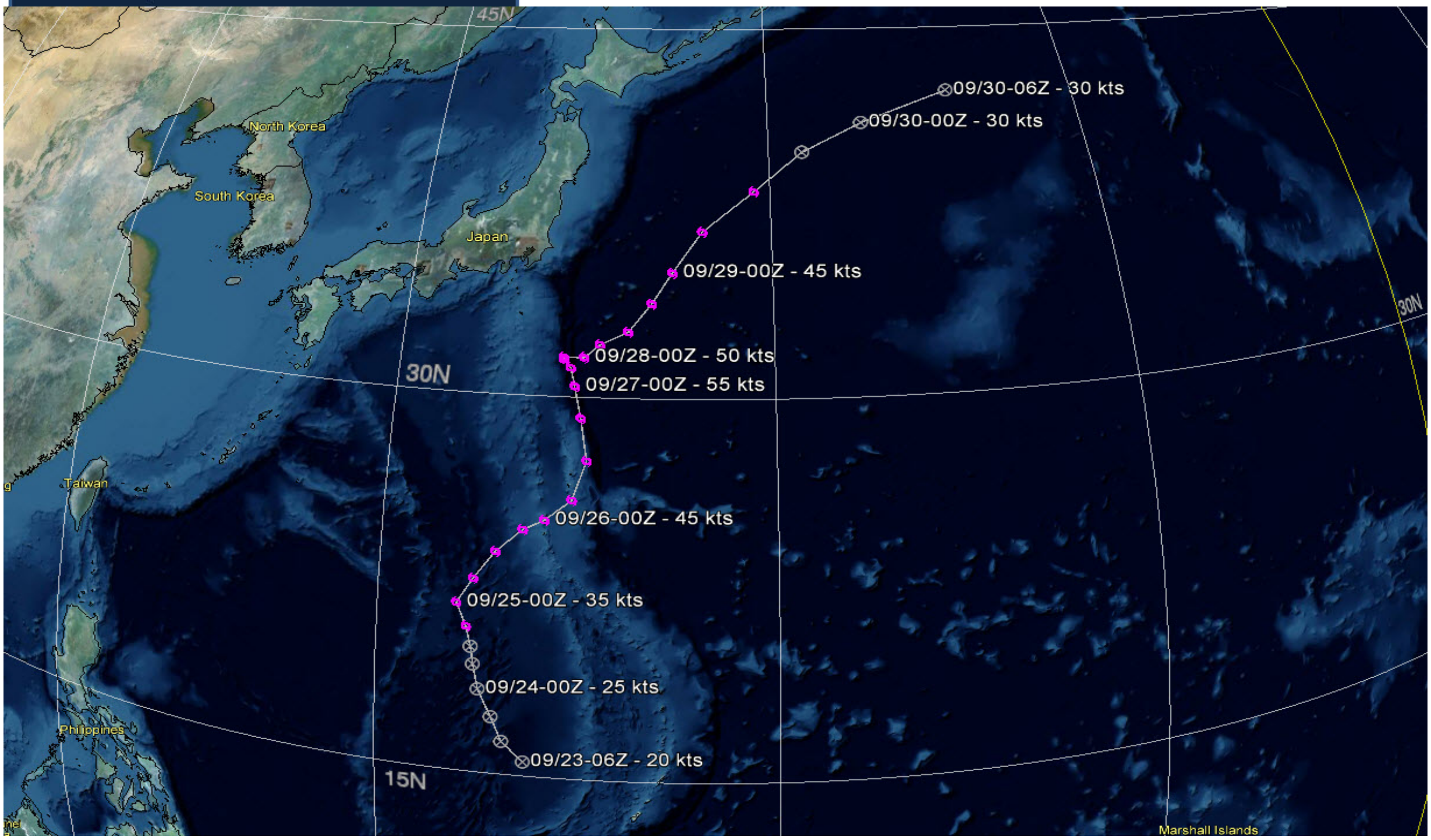




Tropical Storm 19W (Ewiniar)

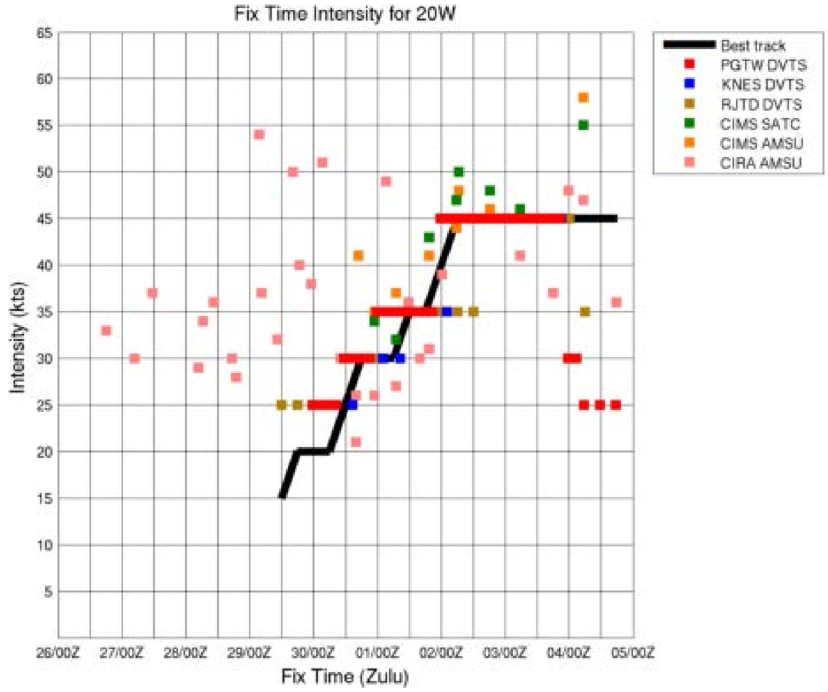
ISSUED LOW:	2330Z 22 Sep 2012
ISSUED MEDIUM:	0600Z 23 Sep 2012
FIRST TCFA:	1230Z 23 Sep 2012
FIRST WARNING:	0000Z 24 Sep 2012
LAST WARNING:	1200Z 29 Sep 2012
MAX INTENSITY:	55 Kts
WARNINGS:	23

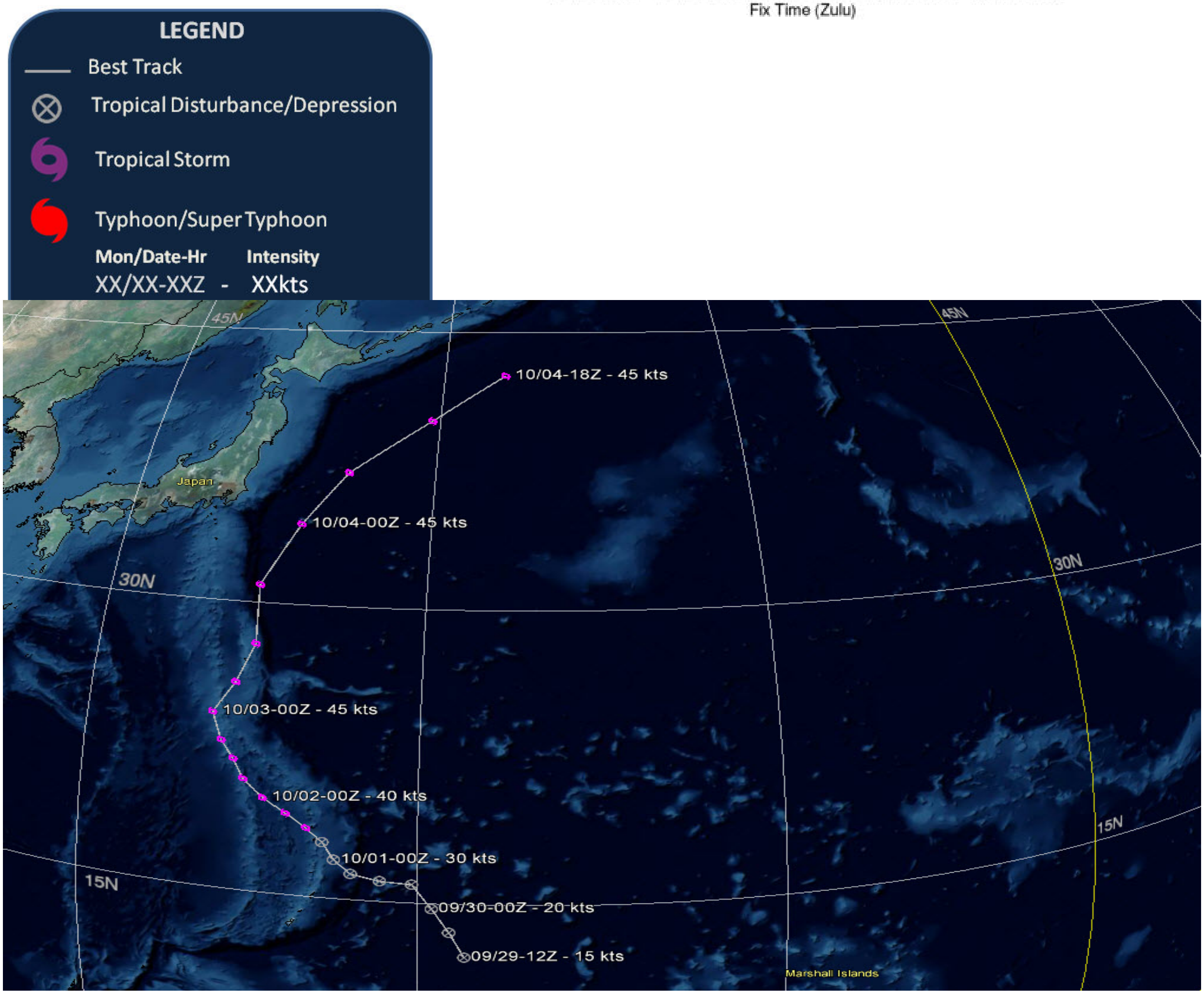




Tropical Storm 20W (Maliksi)

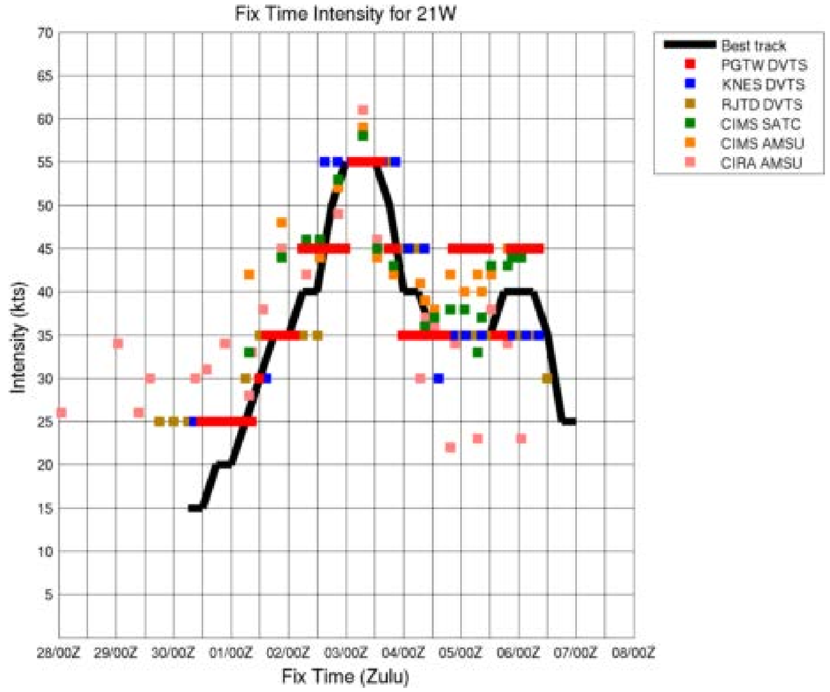
ISSUED LOW:	0600Z 28 Sep 2012
ISSUED MEDIUM:	0600Z 29 Sep 2012
FIRST TCFA:	0200Z 30 Sep 2012
FIRST WARNING:	1200Z 30 Sep 2012
LAST WARNING:	1800Z 03 Oct 2012
MAX INTENSITY:	45 Kts
WARNINGS:	14

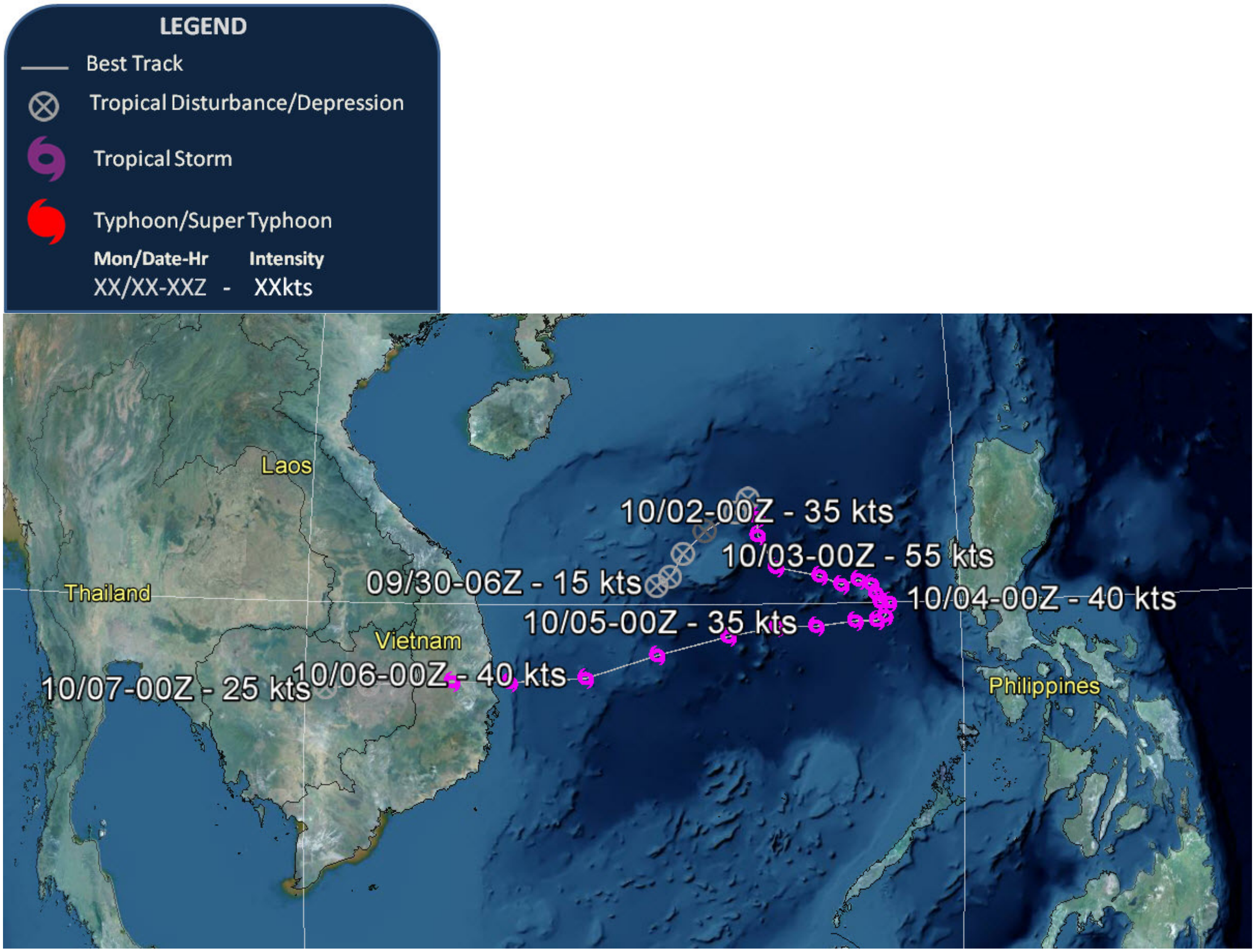




Tropical Storm 21W (Gaemi)

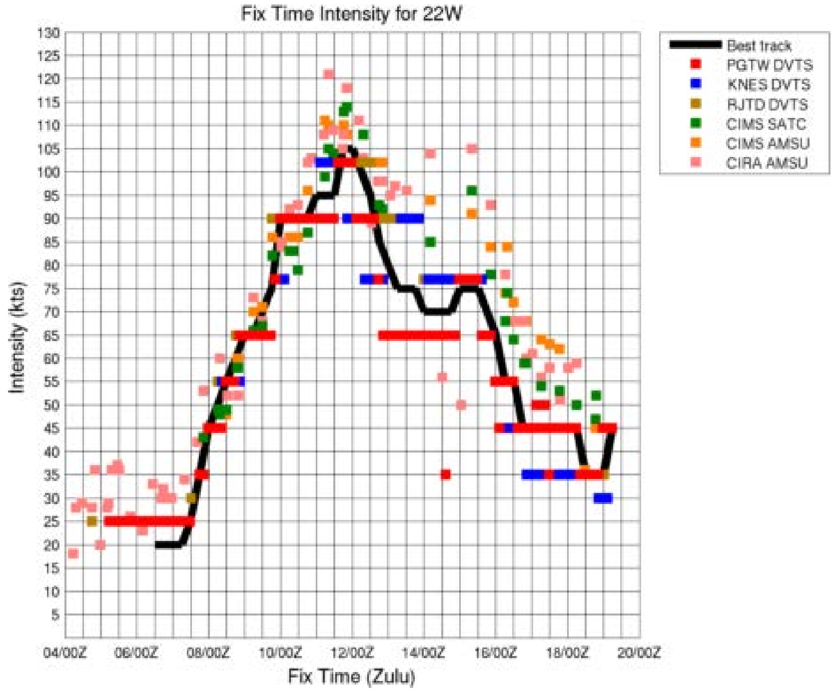
ISSUED LOW:	0600Z 29 Sep 2012
ISSUED MEDIUM:	0600Z 30 Sep 2012
FIRST TCFA:	1200Z 30 Sep 2012
FIRST WARNING:	1200Z 01 Oct 2012
LAST WARNING:	1200Z 06 Oct 2012
MAX INTENSITY:	55 Kts
WARNINGS:	21

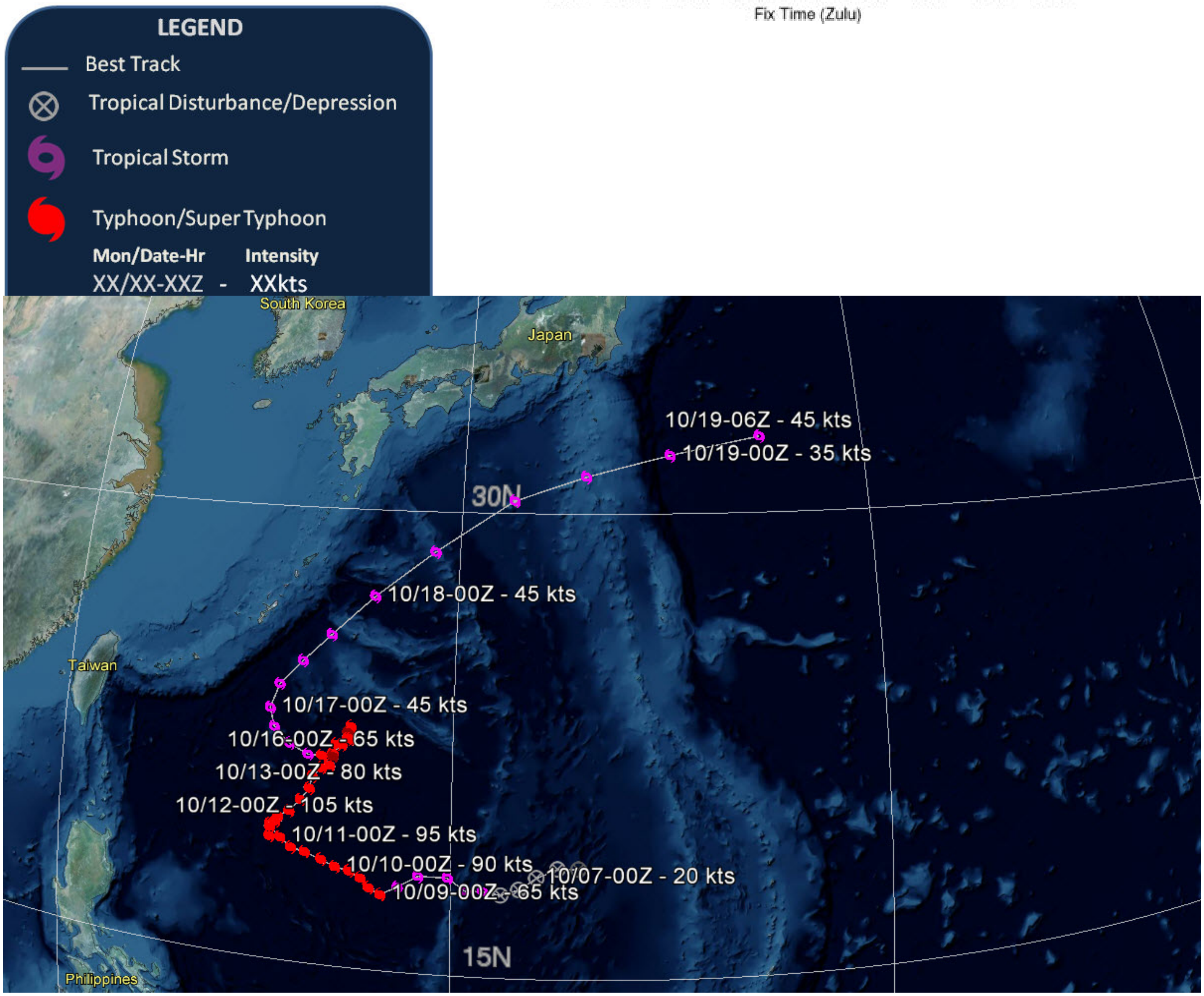




Typhoon 22W (Prapiroon)

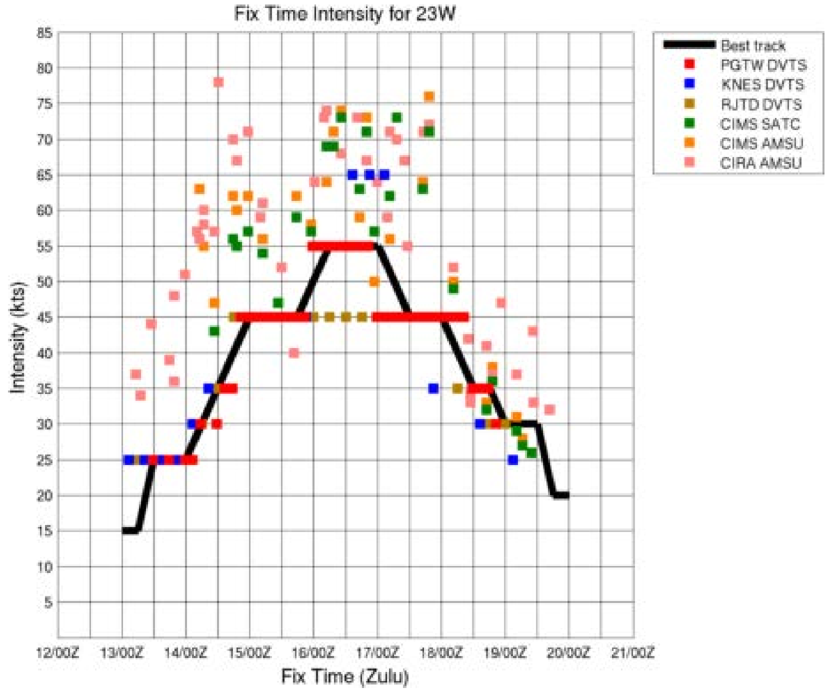
ISSUED LOW:	N/A
ISSUED MEDIUM:	0600Z 05 Oct 2012
FIRST TCFA:	1730Z 06 Oct 2012
FIRST WARNING:	1200Z 07 Oct 2012
LAST WARNING:	0000Z 19 Oct 2012
MAX INTENSITY:	105 Kts
WARNINGS:	47

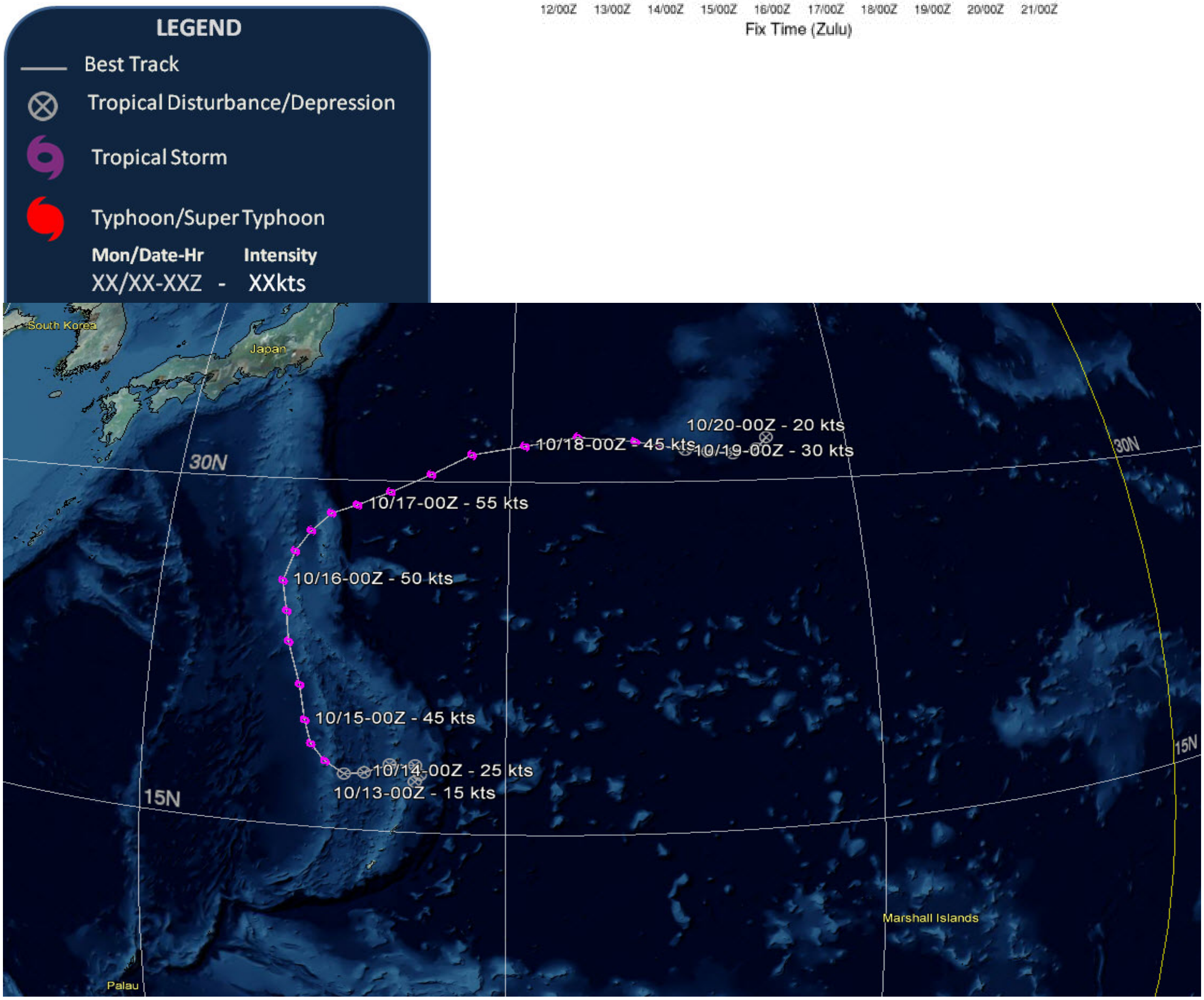




Tropical Storm 23W (Maria)

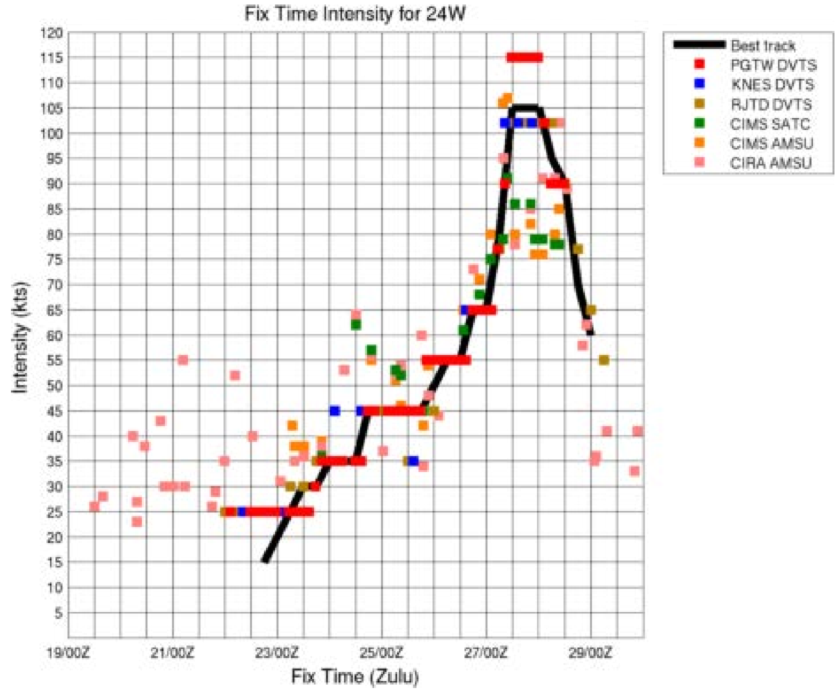
ISSUED LOW:	0600Z 13 Oct 2012
ISSUED MEDIUM:	N/A
FIRST TCFA:	0000Z 14 Oct 2012
FIRST WARNING:	0600Z 14 Oct 2012
LAST WARNING:	1200Z 19 Oct 2012
MAX INTENSITY:	55 Kts
WARNINGS:	22

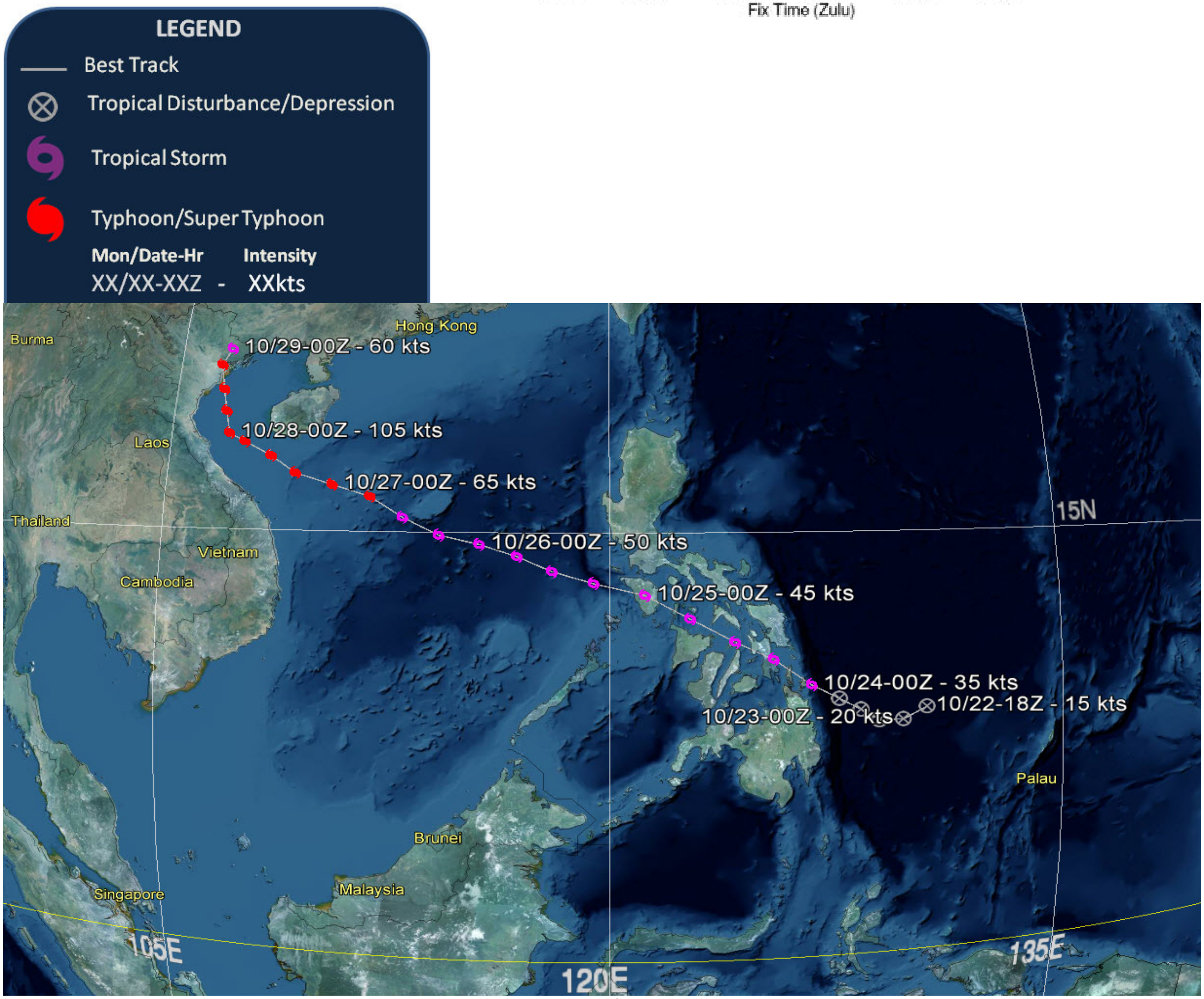




Typhoon 24W (Son-Tinh)

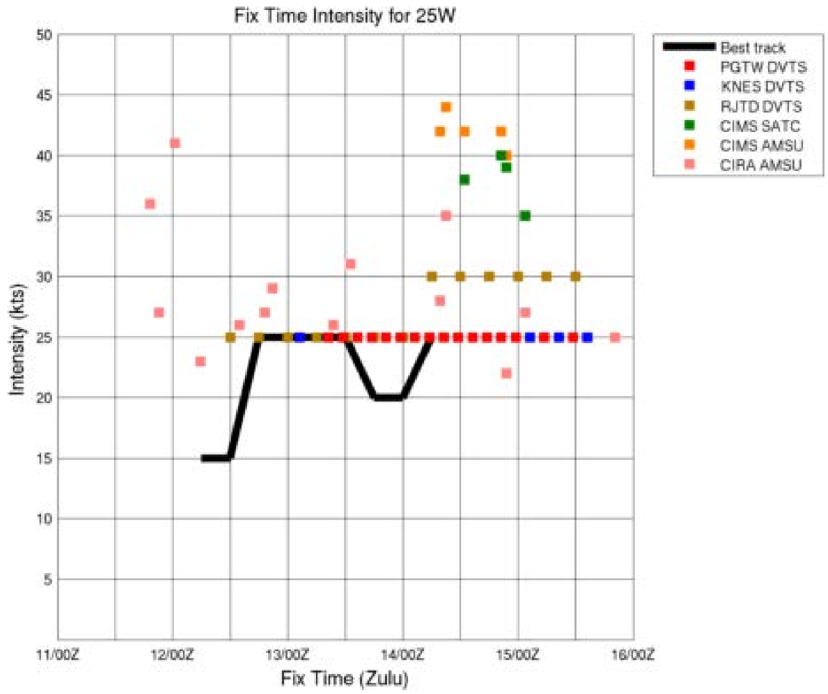
ISSUED LOW:	0930Z 21 Oct 2012
ISSUED MEDIUM:	0600Z 22 Oct 2012
FIRST TCFA:	1030Z 22 Oct 2012
FIRST WARNING:	1800Z 23 Oct 2012
LAST WARNING:	0000Z 29 Oct 2012
MAX INTENSITY:	105 Kts
WARNINGS:	22

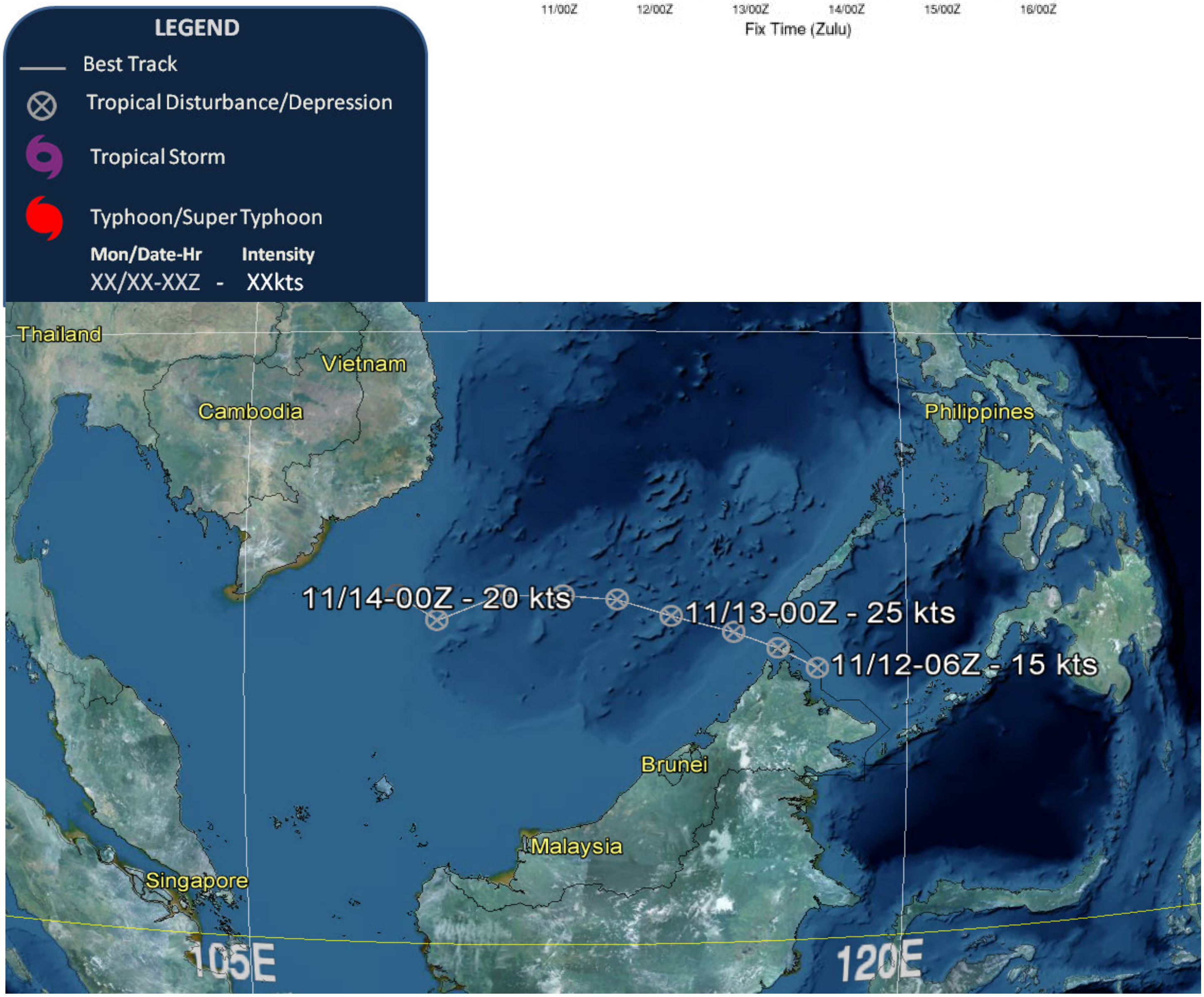




Tropical Depression 25W

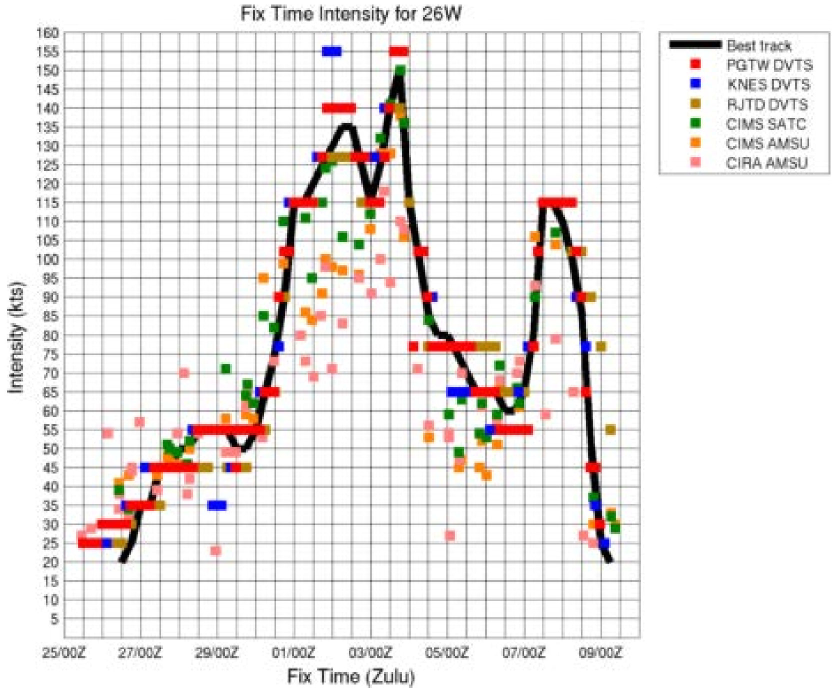
ISSUED LOW:	1430Z 12 Nov 2012
ISSUED MEDIUM:	N/A
FIRST TCFA:	1430Z 13 Nov 2012
FIRST WARNING:	0600Z 14 Nov 2012
LAST WARNING:	1800Z 14 Nov 2012
MAX INTENSITY:	25 Kts
WARNINGS:	3

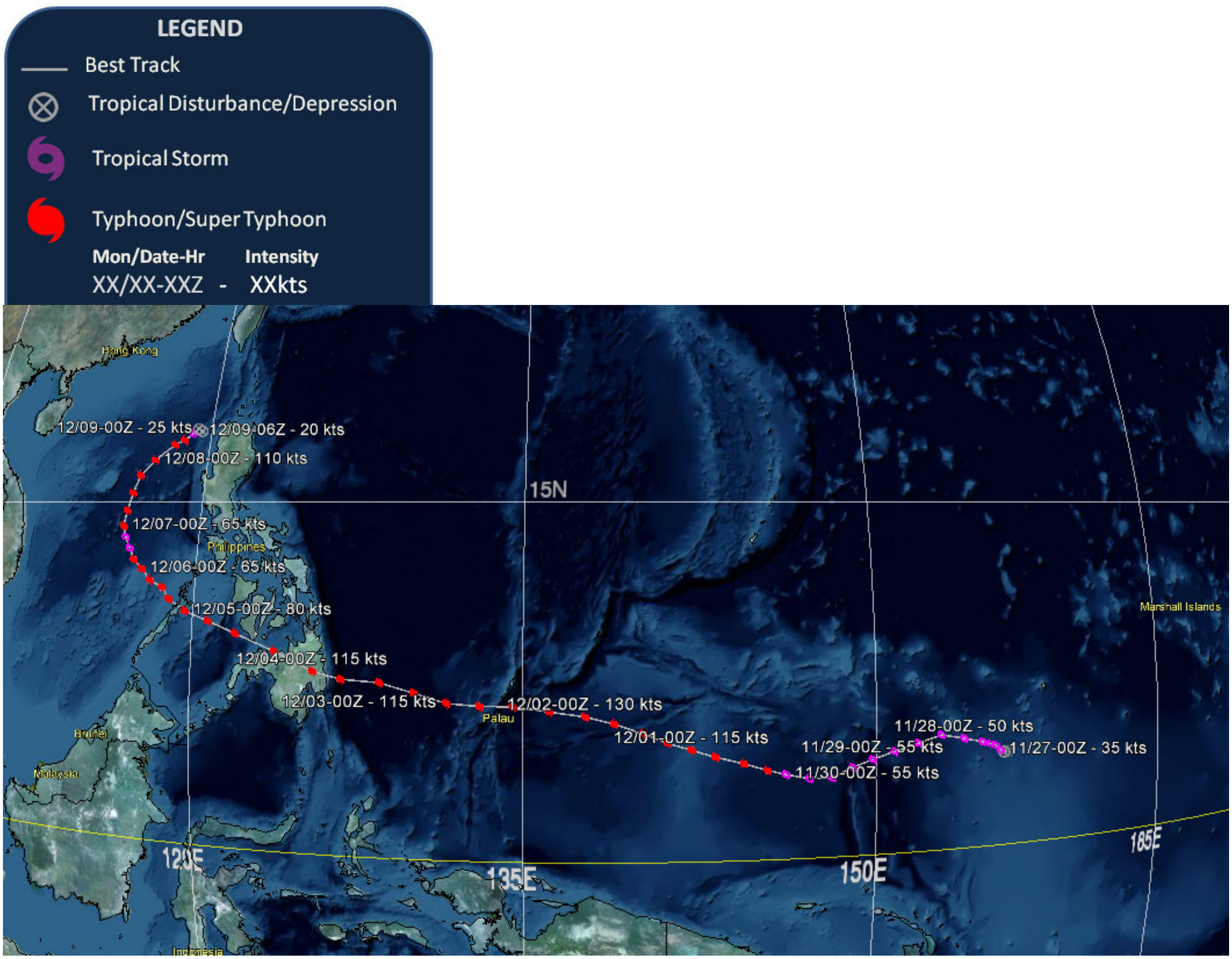




Super Typhoon 26W (Bopha)

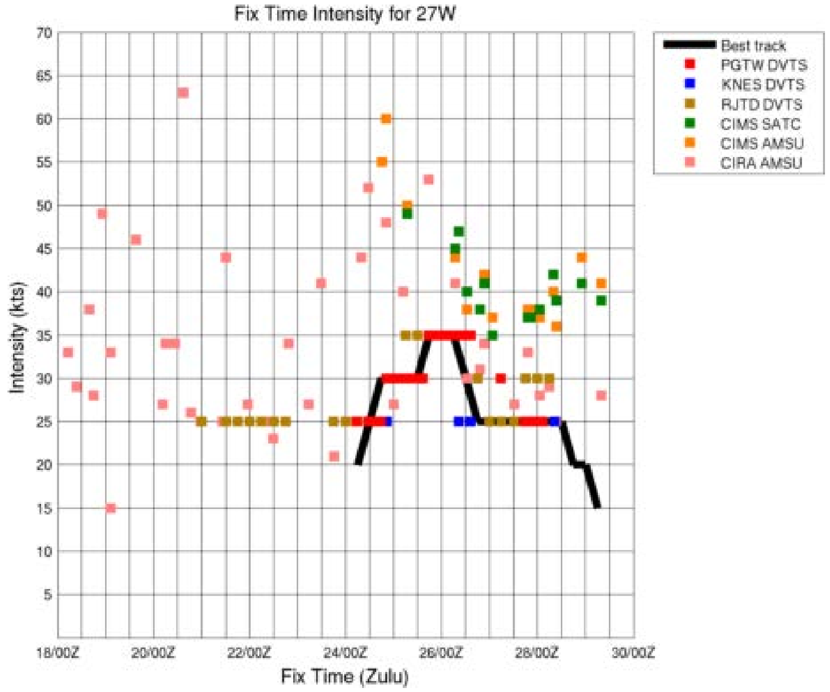
ISSUED LOW:	0600Z 23Nov 2012
ISSUED MEDIUM:	1730Z 24Nov 2012
FIRST TCFA:	1700Z 25Nov 2012
FIRST WARNING:	1800Z 25Nov 2012
LAST WARNING:	0000Z 09Dec 2012
MAX INTENSITY:	150 Kts
WARNINGS:	54

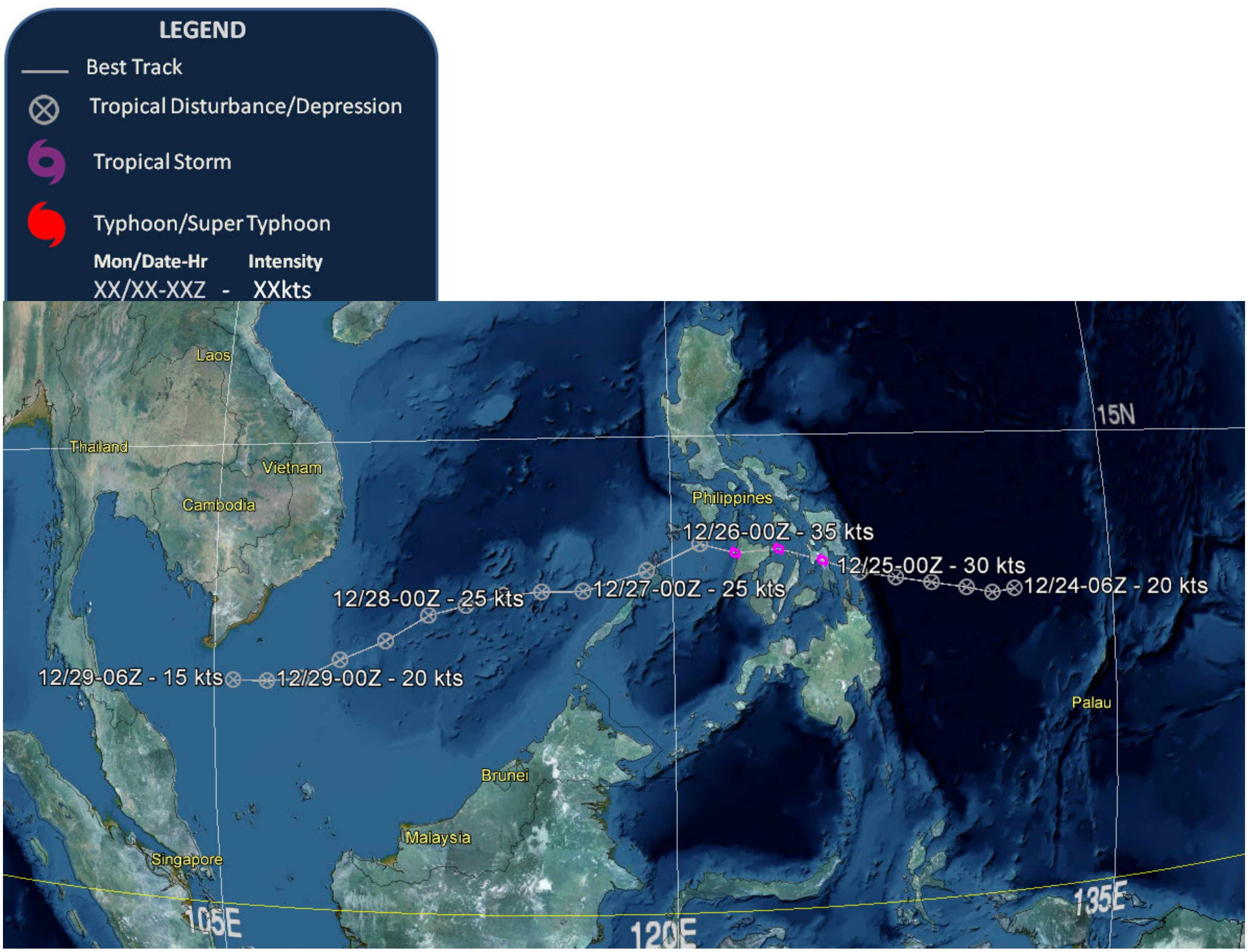




Tropical Storm 27W (Wukong)

ISSUED LOW:	1400Z 20 Dec 2012
ISSUED MEDIUM:	N/A
FIRST TCFA:	1530Z 24 Dec 2012
FIRST WARNING:	1800Z 24 Dec 2012
LAST WARNING:	1200Z 28 Dec 2012
MAX INTENSITY:	35 Kts
WARNINGS:	13





Section 3 Detailed Cyclone Reviews

This section highlights operationally or meteorologically significant cyclones noted within the JTWC AOR. 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 05W (Guchol)

Super Typhoon (STY) 05W (Guchol) formed from a disturbance embedded within the eastern end of the monsoon trough to the southeast of Guam in early June 2012. JTWC issued its first warning on this cyclone on 11 June 2012 at 0000Z. Guchol slowly intensified for the first four days of its lifecycle while tracking westward along the southern periphery of the subtropical ridge (STR). The cyclone subsequently took an abrupt north-northwestward turn around the western periphery of the STR after 0000Z on 15 June 2012, and rapidly intensified to super typhoon intensity (130 knots) during the following 36-hour period. The system remained a super typhoon for 48 hours under the influences of favorable upper-level outflow and passage over very warm water. After 1200Z on 17 June 2012, Guchol began to slowly weaken as it tracked over slightly cooler sea surface conditions north of 20° latitude, but remained an intense typhoon, primarily due to favorable upper-level conditions, until reaching approximately 30° north latitude. As the cyclone finally interacted with a mid-latitude baroclinic zone north of 30°, cold air advection, increased vertical wind shear and passage over a much cooler sea surface induced rapid weakening prior to landfall along the southern coast of Honshu. Extra-tropical transition had begun as the cyclone made landfall. The low-level circulation tracked south of the Japanese Alps before exiting back into the Pacific Ocean as an extra-tropical low.

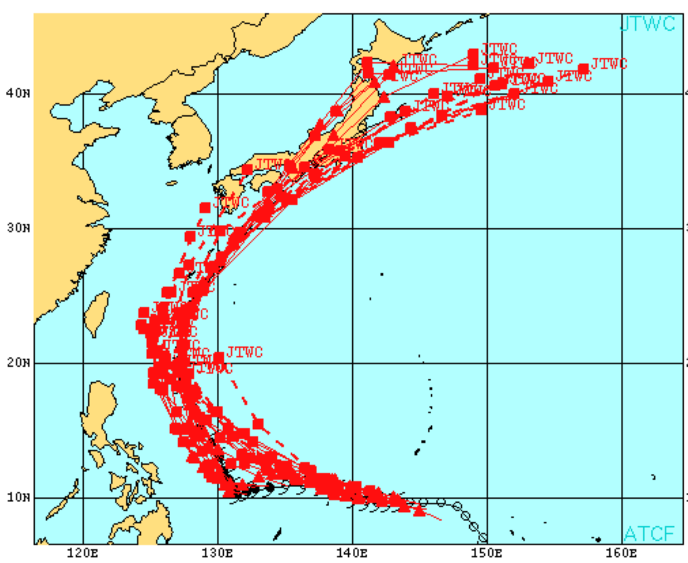


Figure 1-5. All JTWC forecasts for STY 05W.

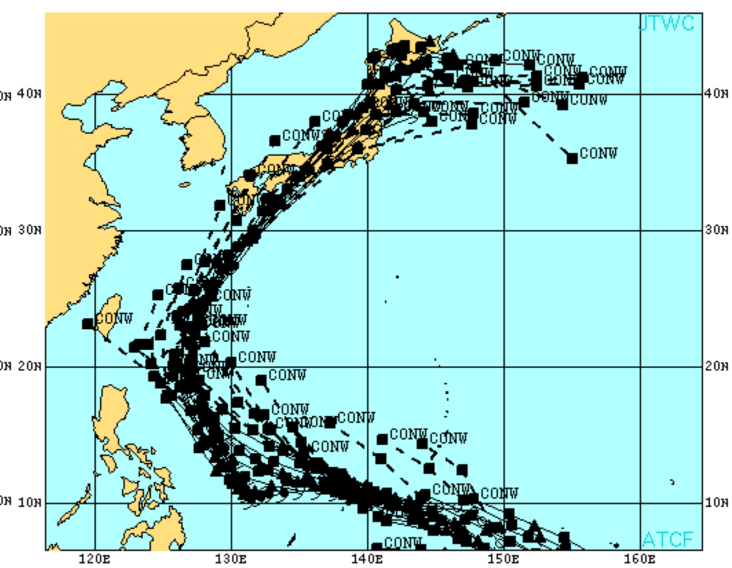


Figure 1-6. All model consensus (CONW) forecasts for STY 05W.

Synoptic analysis and numerical model guidance early in the cyclone's lifecycle indicated that STY 05W would likely recurve in the Philippine Sea. However, as the system tracked westward along the southern periphery of the STR, the timing and location of recurvature became difficult to predict. Extended model guidance suggested a smooth and steady recurvature around the steering ridge, well to the east of its eventual turn point. The models developed a trough across central Asia and predicted it to track eastward, causing a slight weakening of the western extent of this steering ridge (Figure 1-7). This weakening indicated the cyclone would recurve slowly and steady around the ridge. However, the model-forecasted trough was significantly weaker and had a less meridional extent than the actual trough that developed (Figure 1-8). Subsequent model runs began to forecast a more accurate orientation of the mid-latitude trough and a consequently sharper turn about 24 to 36 hours prior to the observed recurvature. However, even these shorter range forecasts did not predict as sharp a turn as was later observed. The stronger than predicted trough altered the flow along the western periphery of the steering ridge and allowed 05W to track farther to the west, resulting in a sharper poleward turn than models indicated. Following the turn, the model consensus (CONW) quickly settled on a track to the east of Okinawa, with a few forecasts during early stages of recurvature depicting a track slightly to the west of the island. The JTWC forecast tracks (Figure 1-5) remained consistent for the next several days, correctly indicating that the cyclone would remain east of Okinawa and crest the subtropical ridge axis at approximately 22°N.

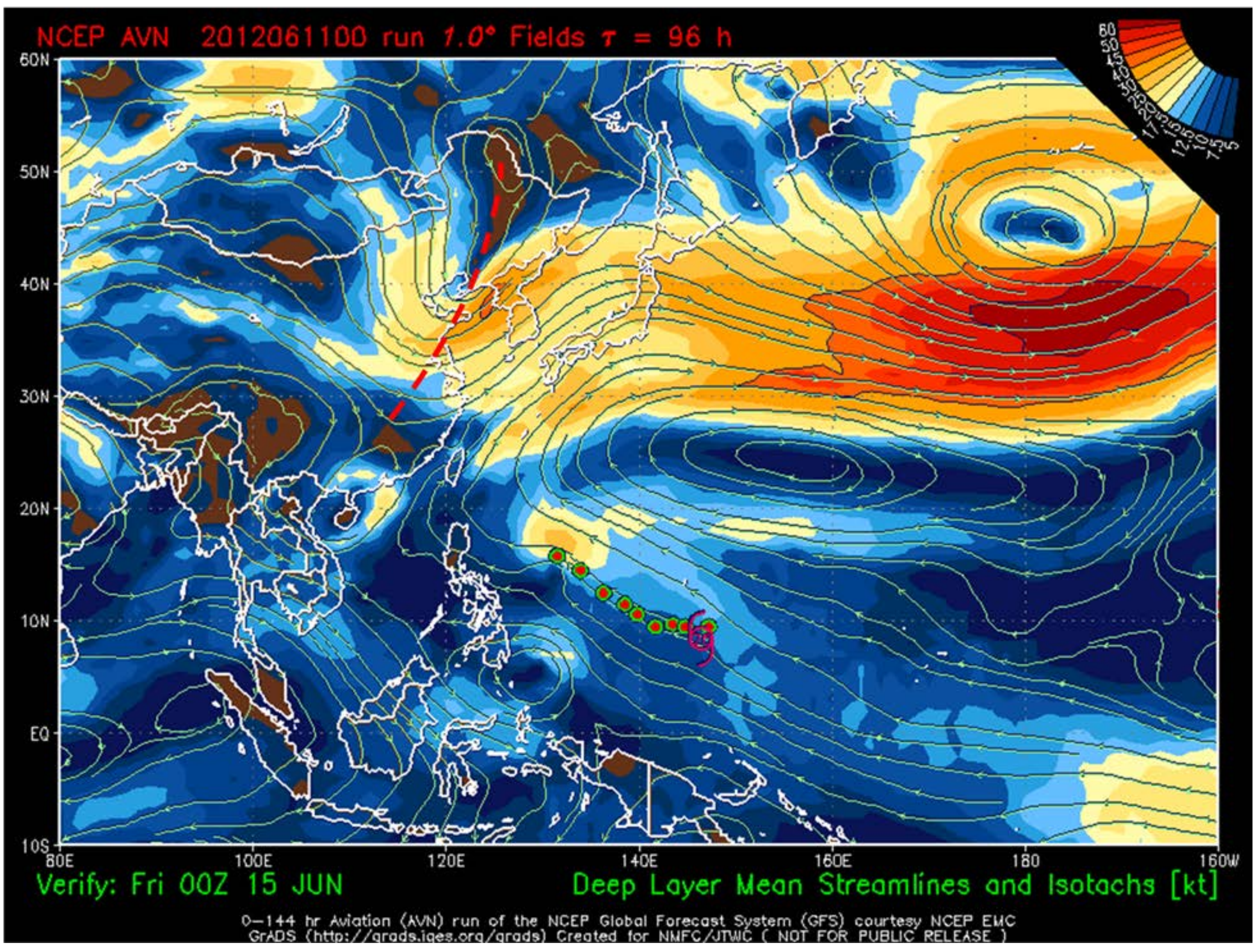


Figure 1-7. GFS 96-hour deep layer mean flow forecast from 11 June 2012 at 0000Z. The forecast time (15 June 2012 at 0000Z) is the time at which STY 05W initially began recurvature.

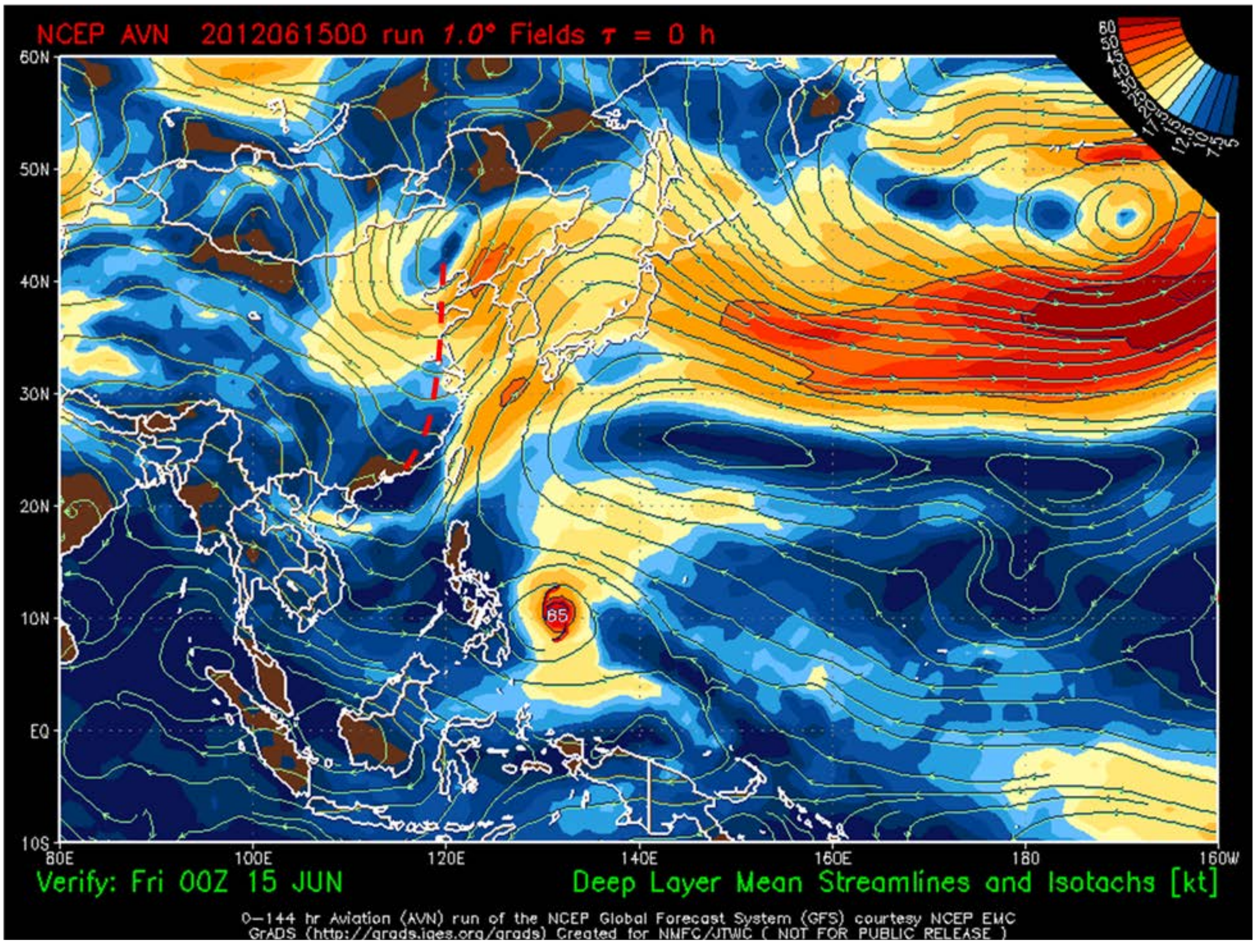


Figure 1-8. GFS deep layer mean flow analysis from 15 June 2012 at 0000Z, the time at which STY 05W initially began recurvature.

As STY 05W approached Japan, early model forecasts suggested that the cyclone would track along the eastern coast of Honshu Island and remain to the south of the highest portions of the Japanese Alps. JTWC initially assessed these forecasts to be consistent with the analyzed steering environment and anticipated interaction of a transitory mid-latitude trough with the STR. However, model guidance abruptly shifted poleward, indicating that STY 05W would track over southwestern Honshu into the Sea of Japan (SOJ) before turning eastward and passing over Misawa Air Base (Figure 1-6) in response to a change in the forecasted mid-latitude trough to a more meridional orientation. JTWC forecasts remained to the south of and faster than CONW based on the assessment of the synoptic environment and a historical trend for tropical cyclones to track inside of and faster than CONW during extra-tropical transition. However, with CONW consistently showing STY 05W crossing Japan into the SOJ, JTWC shifted the forecast track to match the model forecast orientation (Figure 1-10). This shift would prove to be unrepresentative of the cyclone's eventual track along the southern portion of the Alps and over Tokyo (Figure 1-9), which was depicted in earlier JTWC forecasts. Both JTWC and CONW track forecast errors for STY 05W from first to final warning are provided in Table 1-5.

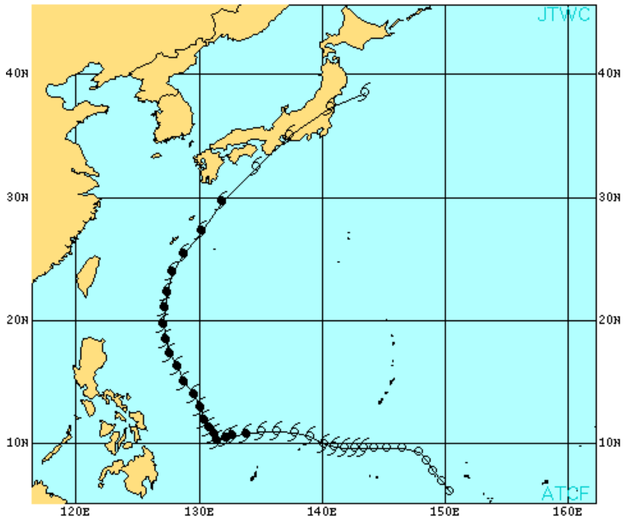


Figure 1-9. Complete track of STY 05W (Guchol**).**

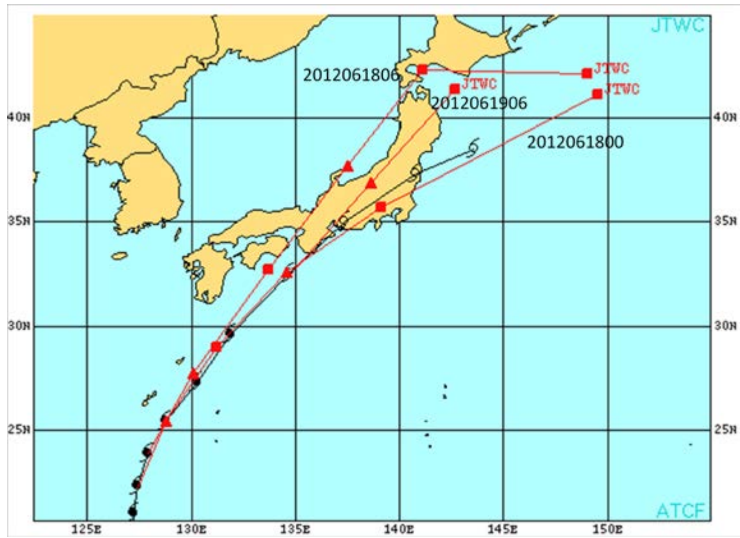


Figure 1-10. JTWC forecasts for 00Z on 18 June 2012, 06Z on 18 June 2012, and 06Z on 19 June 2012.

	TAU 24	TAU 48	TAU 72	TAU 96	TAU 120
JTWC (05W)	59 nm	100 nm	142 nm	205 nm	297 nm
CONW	57 nm	96 nm	156 nm	267 nm	320 nm
Cases	31	27	23	19	15
JTWC (2012)	50	89	127	163	224
CONW	48	84	127	166	214
Cases	535	439	340	248	177

Table 1-5. JTWC and CONW (model consensus) forecast track errors (homogeneous sample) for STY 05W and the entire 2012 western North Pacific TC season (red).

Forecasting the intensity of STY 05W throughout the cyclone's life cycle was another major challenge. As indicated in Table 1-5, there were significant intensity forecast errors at extended forecast times. Although JTWC intensity forecasts for the cyclone outperformed statistical-dynamical intensity model guidance (e.g., ST11), the average errors exceeded seasonal averages by 10 knots. The intensity forecast effort was complicated, at least in part, by difficulties associated with real-time intensity analysis. Figure 1-11 shows fix and best track intensities throughout the lifecycle of 05W. Starting on 11 June at 1200Z, the graph indicates a large variability in fix intensities, with the analyzed best track intensity – consistent with an average of these fix values - steadily increasing through 13 June at 1200Z. After that time, the system underwent a period of rapid intensification (RI) through 16 June at 1200Z. Early forecasts did not originally call for the RI event due to a large variability in intensity model guidance and a noted slow pace of intensification while the cyclone was moving along the southern periphery of the STR. However, there were some early indications of RI in the operational GFDN output and the experimental COAMPS-TC output (Figure 1-12).

	TAU 24	TAU 48	TAU 72	TAU 96	TAU 120
JTWC (05W)	11 knots	17 knots	23 knots	31 knots	31 knots
ST11	10 knots	13 knots	25 knots	39 knots	40 knots
Cases	24	20	16	12	12
JTWC (2012)	11	15	17	20	22
ST11	11	16	19	22	24
Cases	513	421	322	225	160

Table 1-6. JTWC and ST11 intensity forecast errors (homogeneous sample) for STY 05W and the entire 2012 western North Pacific TC season (red).

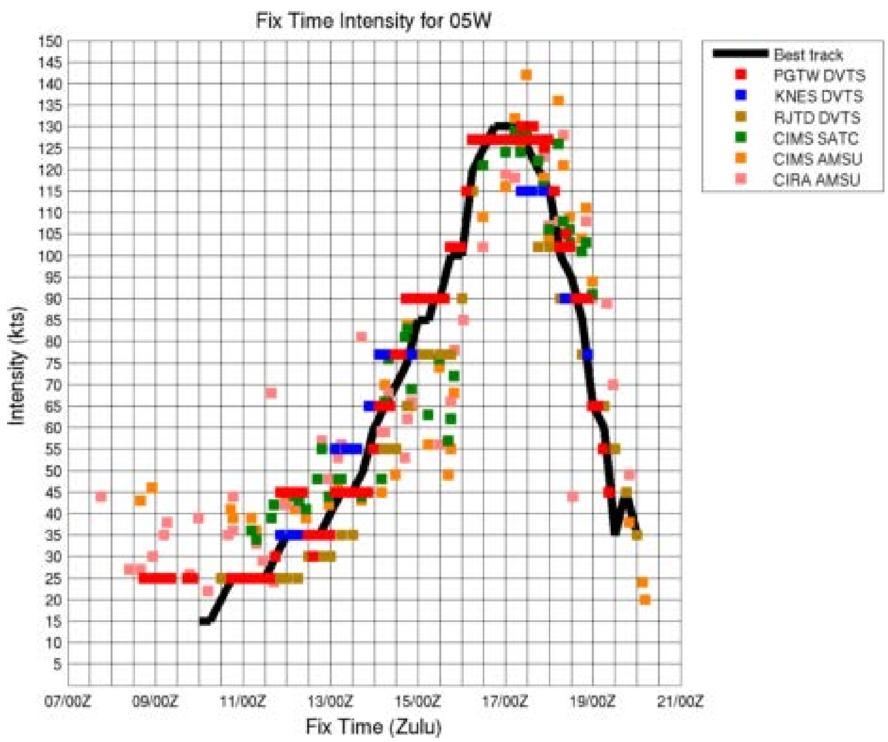
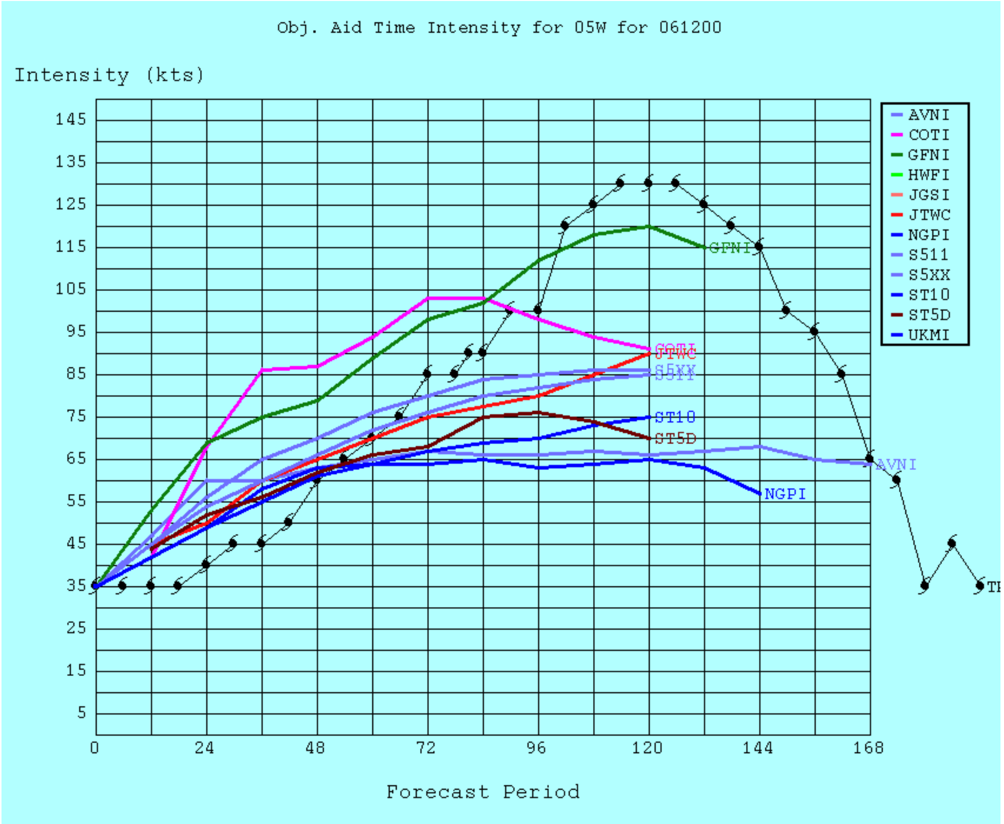


Figure 1-11. Graph of fix intensities compared to the best track intensities for STY 05W over the life cycle of the system.



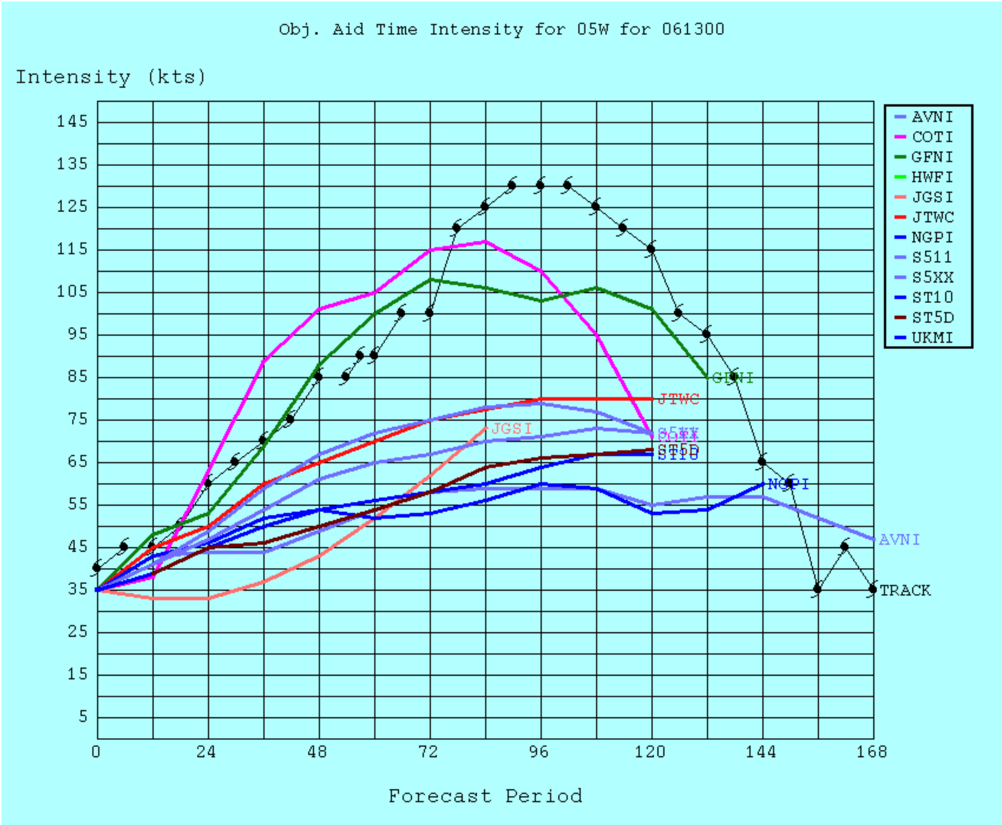


Figure 1-12. Graphs of model intensity forecasts from 00Z on 12 June (top) and 00Z on 13 June (bottom), showing GFDN (green) and COAMPS-TC (pink) indications of RI.

In summary, STY 05W presented three major forecast challenges: an abrupt poleward recurvature around the STR axis, rapid intensification, and a post-recurvature track over southern Honshu that was not forecast well by numerical model guidance.

Beginning with the abrupt recurvature, it became clear during post-storm analysis that the intensity, orientation, and motion of the developing mid-latitude trough were crucial influences on the recurvature track of 05W. Early model guidance incorrectly forecasted both the strength and orientation of the approaching mid-latitude trough as well as its interaction with and influence on the steering ridge. Closer inspection of the pressure field associated with the trough may have helped forecasters to anticipate a turn earlier than the 24 to 36 hours lead time the models fields were able to distinguish, and ultimately lead to a greater lead time on the projected turn.

Rapid intensification remains a difficult forecasting challenge complicated by the sensitivity of intensity forecasts to initial best track intensities and the influences of synoptic patterns on the cyclone's outflow. Large variability in both subjective and objective satellite intensity estimates for 05W prior to 15 June suggests that forecasters may have set best track intensities too low in real-time and, consequently, under estimated the intensification rate. It was not until post-storm analysis that the best track intensities were adjusted upward, consistent with higher Dvorak estimates from 14 June at 0000Z through the 16^{th} at 0000Z. Post storm investigation also indicates the mesoscale models (GFDN and COAMPS-TC) provided some indications that RI was possible, illustrating the need for continued support for and development of mesoscale models.

The final major forecast challenge associated with 05W relates to the difficulty of predicting how the low-level circulation center would track as it interacted with the mountainous region of Honshu. As noted earlier in this report, JTWC forecasts for the system remained well south of the consensus of available model guidance for a significant period of time. JTWC incorrectly shifted the track prior to landfall, taking the system into the Sea of Japan and then eastward through northern Honshu. After the storm made landfall it quickly weakened and tracked along the southern portion of the Japan Alps, then over the Kanto Plain and back into the Pacific Ocean. The complexity of this track forecasting problem appears to be related to the approach angle, intensity at landfall, orientation of the steering elements, and interaction between the low pressure center embedded within the mid-latitude trough and the tropical cyclone. Although the JTWC analysis of the steering influences indicated a track along the coast of Honshu as the most likely scenario, the overwhelming influence of the model guidance became too difficult to contradict and forced a philosophy change in the track forecast just prior to landfall. Inspection of model forecasts reveals that excessive, forecasted direct cyclone interaction (E-DCI) between the tropical cyclone and the low-pressure center associated with the mid-latitude trough likely contributed to the noted poleward shift in forecast tracks. Model-forecasted interaction between the cyclone and rugged terrain over central Honshu may have also factored into this shift. An initial review of published literature indicates little research into the effects of Japanese terrain on tropical cyclone tracks. The implications of terrain on the intensity of a system are more established, and in this case, the weakening of the system was appropriately forecast as the system tracked over Japan despite complications associated with the track forecast.

Tropical Storm 07W (Doksuri)

Tropical Storm (TS) 07W (Doksuri) was selected for review due to the presence of multiple weak, cyclonically-rotating meso-vortices (MV) which persisted throughout the life of this cyclone. MV were observed in multiple storms which formed in the Philippine Sea during the 2012 WPAC season (e.g., 09W, 10W, 14W, 24W). Sippel et al. (2005) note that these MV are common in multiple basins, including the Atlantic and Gulf of Mexico, and are often noted in Tropical Prediction Center discussions. MV present a significant operational challenge in determining the “correct” low-level circulation center (LLCC), a key parameter for the accurate initialization of numerical models and the basis of the subsequent forecast. The uncertainty in the 07W fixes is evident in the working best track presented in Figure 1-13 (background), where yellow dots represent position fixes deemed erroneous at that time due to the presence of MV. Potentially significant errors in estimating the LLCC are reflected in the model bogus information, and are subsequently carried out through the model forecast. Therefore, it follows that improvements in the JTWC analysis of tropical cyclones when MV are present would result in an improved model representation of a storm’s position, and ultimately, in improved JTWC forecasts. For comparison, the official JTWC post-analysis is also shown in figure 1-13 (foreground), and will be discussed in further detail below.

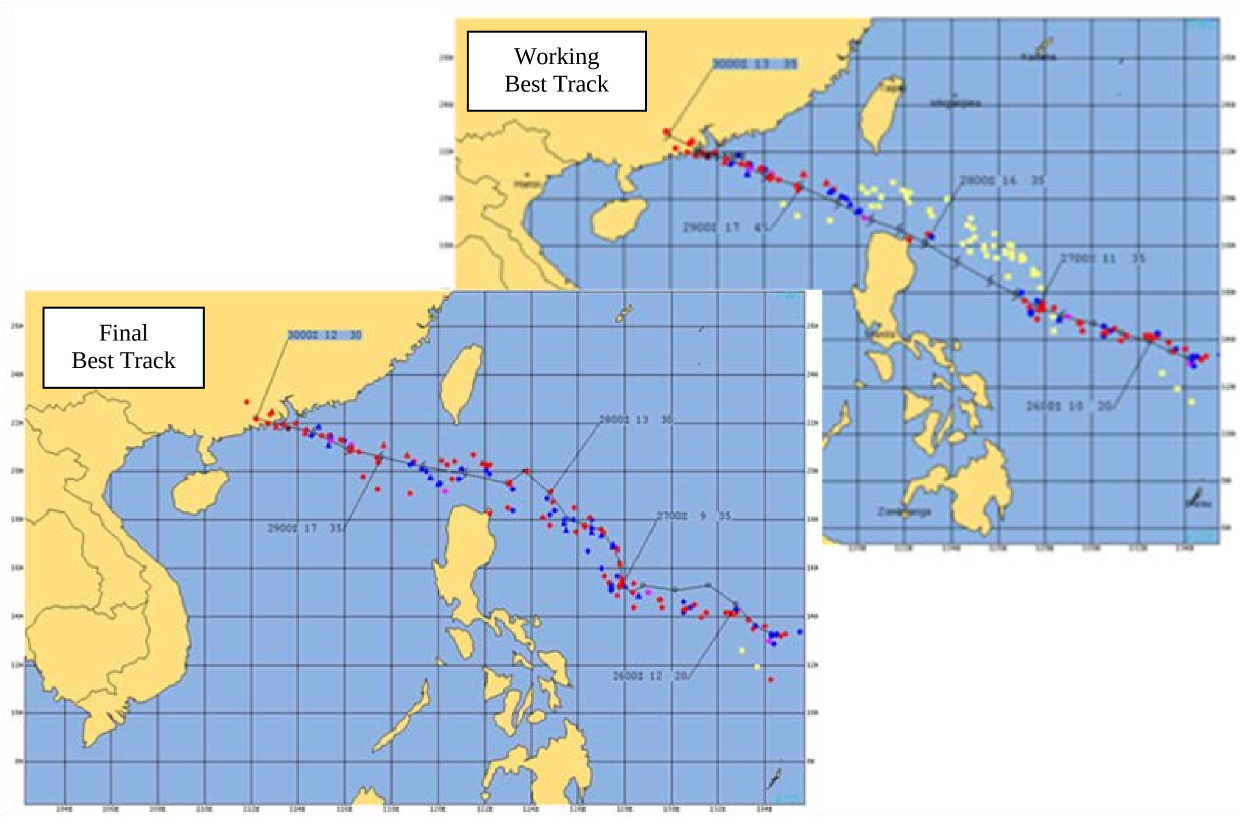


Figure 1-13. TS 07W (Doksuri) Initial best track (background) and final best track (foreground) with position fixes shown. 00Z positions for 26-30 June are notated.

An important consideration when MV are present is the possibility of binary interaction. TS 10W (Malou) was the subject of a storm review in the 2010 JTWC ATCR due to such binary interaction of MV. In that case, JTWC failed to recognize the secondary circulation(s), and the binary interaction contributed to large forecast track and intensity errors. Unlike TS 10W (Malou), the obvious presence of MV in TS 07W was quickly detected, and forecasts accounted for MV impacts on track and intensity. The average 48- and 72- hour track forecast error was 115 and 156nm, respectively.

TS 07W was first warned on as a tropical depression at 12Z, June 26. Prior to the initial warning, a dominant mesoscale convective system (MCS) with MV to the northeast was evident in the 260632Z multi-spectral satellite imagery (MSI) (Figure 1-14, left). A 260901Z 91GHz SSMIS microwave image (Figure 1-14, right) reveals the chaotic nature of the flow. The imposing MCS in the MSI is easily assumed to be associated with the LLCC, however, the large-scale cloud lines in the SSMIS image instead appear to flow into an elongated area of weaker winds.

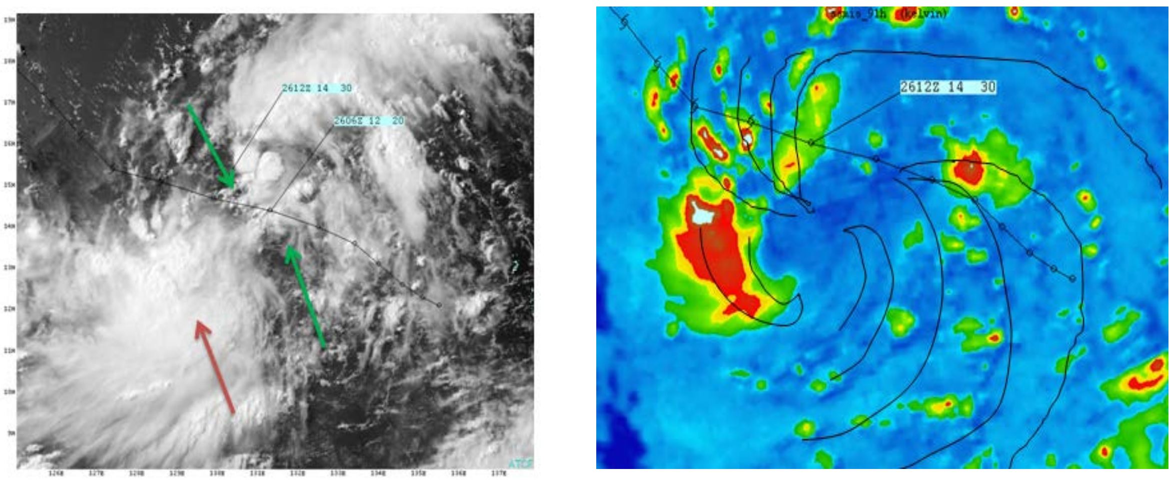


Figure 1-14. 260632Z MSI image (left) with red arrow indicating the MCS, and green arrows indicating probable mesoscale vortices. 260901Z SSMIS 91GHz image (right) with subjective flow analysis.

Shortly after 270200Z, MSI (Figure 1-15, left) revealed a well-defined MV had popped out of the eastern flank of the MCS and proceeded to move almost due north. Because it came from the area of deepest convection, the forecaster assessed this to be the true LLCC, and best-tracked accordingly. Several additional pieces of data subsequently supported this decision. A 270848Z 91GHz microwave SSMIS image (Figure 1-15, right) depicted flow which had consolidated towards this weak, exposed LLCC. Also, a 280906Z WINDSAT pass (not shown) suggested at least two circulation centers, with the easternmost (corresponding to the exposed LLCC) appearing to be the dominant circulation. This MV eventually rotated cyclonically and disappeared under the cloud cover of the larger MCS. Over the course of 07W's lifecycle, MV continued this pattern of exposure from the MCS, cyclonic rotation about the MCS, and eventual disappearance under the deep convective cloud mass.

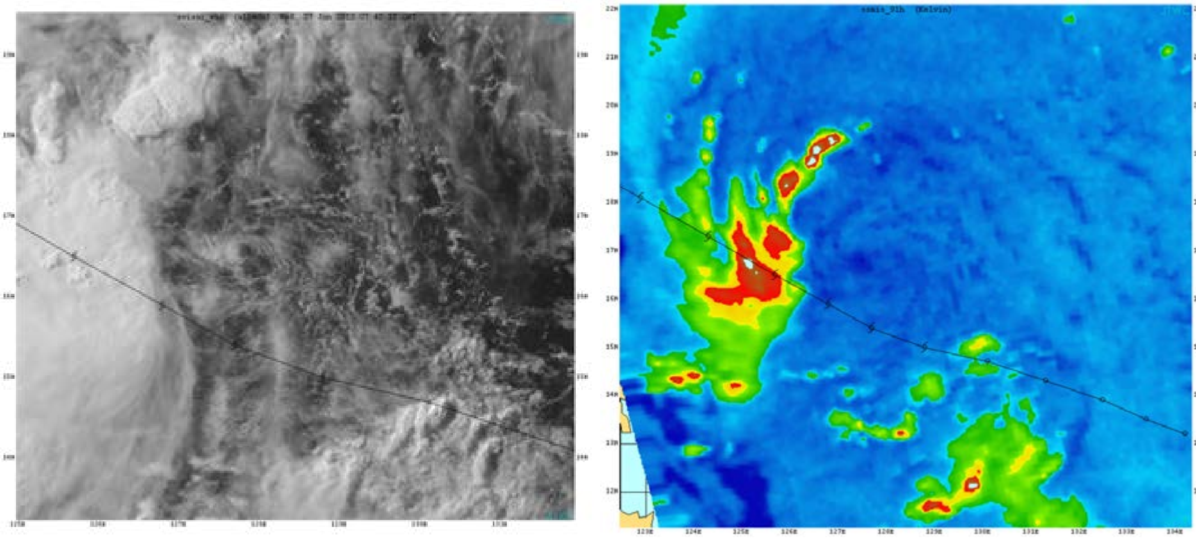


Figure 1-15. 270732Z MSI image (left) and 270848Z 91GHz SSMIS image (right).

At times, the LLCC appeared to be associated with individual meso-vortex signatures, while at other times the data indicated the MCS as the dominant center, such as in Figure 1-16, where the meso-vortex off the northern tip of Luzon does not appear in the corresponding OSCAT flow field.

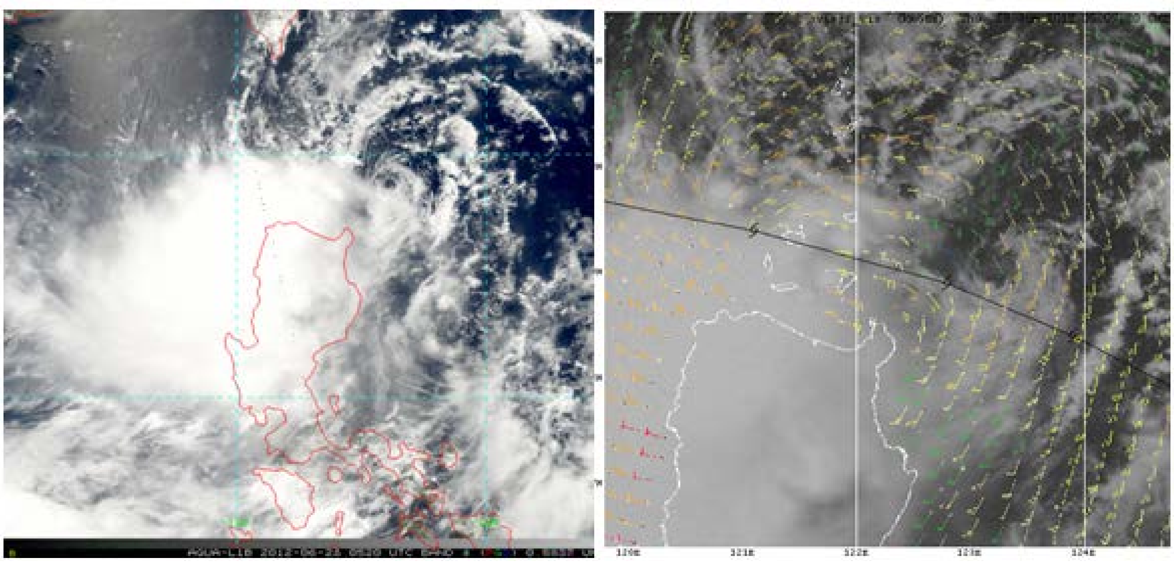


Figure 1-16. 280520Z True Color image (left) and 280402Z OSCAT wind vectors (right).

The lesson learned from 07W is that in the presence of MV, not only should the forecaster weigh the impact of binary interaction on track and intensity, but the safest best-track and bogus practice is to select the centroid of the larger circulation which contains the MV. A centroid position better represents the true motion and ensures that the best track is not erroneously assigned to a fleeting exposed LLCC, particularly given the coarse temporal resolution of available data. Forecasters should ensure clarity in the prognostic reasoning message that the presence of MV and the best-track position may not directly correlate to a visible exposed LLCC. It is only after extensive post-storm analysis of all available data that one can evaluate the true center of circulation. The uncharacteristically ragged final best track shown in Figure 1-13 (foreground) emphasizes the complexity of 07W. Prior to entering the South China Sea, the system lacked organization and reached a peak intensity of only 35 knots. The obvious presence of MV suggests that environmental factors prevented the consolidation of competing vortices. After careful analysis, the final best track reflects several “jumps” between vortices. To more accurately depict these discontinuities, several intermediate (3-hourly) fixes were added to the record.

There are several recommendations that could aid JTWC forecasters in assessing the initial TC state, particularly when MV are present. First, a higher resolution vector analysis would provide greater detail of small-scale flow around tropical cyclones. The current suite of scatterometry platforms has a maximum resolution of 25km. One research group at BYU has developed a technique to produce Ultra-High Resolution (UHR) scatterometry imagery from the existing ASCAT retrievals. This 10km resolution imagery provides much finer detail, as seen in Figure 1-17. Originally developed for sea-ice applications, more needs to be done to assess the verification of this product for tropical cyclones. Secondly, while observations are sparse over the open oceans, and manned reconnaissance is almost non-existent, more and more countries are adding observing networks, including radar. For example, the Philippines recently launched the Nationwide Operational Assessment of Hazards (NOAH) website with four radars previously unavailable to JTWC, and plans for five more radars in the near term. Data mining and acquisition are key components of ongoing and future JTWC collaborations. Finally, as mesoscale models continue to progress towards higher resolutions, it is possible that such models may be capable of resolving small-scale details such as MV, even without such circulations in the intialization conditions from the parent global model. Whether or not mesoscale models can accurately depict MV and diagnose binary interaction is a subject of further investigation for numerical modelers.

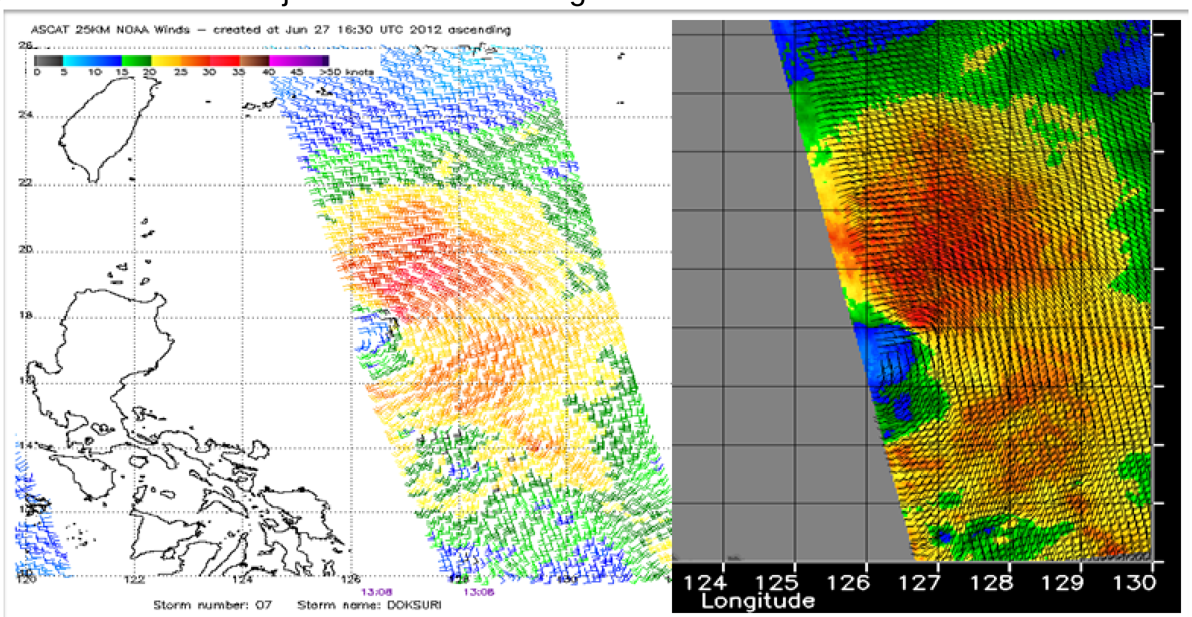


Figure 1-17. Comparison of traditional ASCAT vs. UHR product from BYU.

REFERENCES

Sippel, J.A., J. W. Nielsen-Gammon, and S. Allen, 2005: The multiple-vortex nature of tropical cyclongenesis. *Mon. Wea. Rev.,* **134**, 1796-1814.

Typhoon 09W (Vicente)

Typhoon (TY) 09W (Vicente) developed within the monsoon trough in the Luzon Strait on 21 July 2012. TY 09W began its lifecycle as a disorganized tropical disturbance, with multiple low-level meso-vortices observed in visible and microwave satellite imagery. On 20 July 2012 at 1200Z, the cyclone consolidated into a single low-level vortex and began tracking westward along the southern periphery of an elongated extension of the deep-layered subtropical ridge. The following day, an upper-level anticyclone developed over the system, significantly enhancing upper-level outflow and supported the cyclone's intensification into a tropical storm.

Around 1200Z on 22 July, a mid-latitude trough extending equatorward from Mongolia through east-central China weakened the steering ridge, inducing quasi-stationary storm motion followed by an abrupt northward turn (see Figure 1-18). As the system moved northward, poleward outflow increased significantly toward upper-level troughs analyzed to the north and to the east of 09W, both of which are evident in the GFS model upper-level analysis shown in figure 1-18. By 23 July at 0600Z, 09W had intensified into a typhoon with a well-defined eye. Shortly thereafter, typhoon 09W underwent a period of explosive deepening, peaking at a maximum estimated intensity of 115 knots at approximately 23/1500Z – an increase of 50 knots is just nine hours.[1]

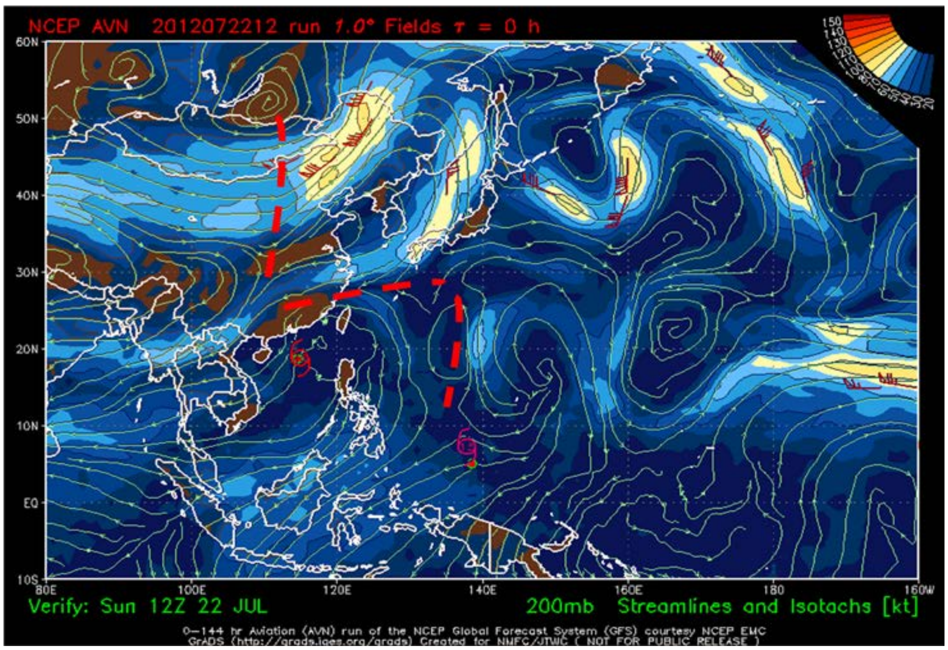


Figure 1-18. GFS 200 mb flow analysis from 22 July 2012 at 1200Z.

TY 09W made landfall approximately 70 nm west of Hong Kong at 23/2100Z with an estimated over-water intensity of 115 knots, making it the strongest typhoon to affect the Hong Kong metropolitan area in over ten years. According to the online International Business Times, the cyclone took three lives and caused extensive damage in Southern China (International 2012). The cyclone tracked well inland with its low-level circulation mostly intact before dissipating north of Hanoi, Vietnam, over a day after it made landfall (Figure 1-19).

[1] In order to capture the peak intensity of TY 09W following the cyclone's rapid intensification, an off-synoptic hour best track position and intensity estimate was inserted into the best track data record for 23/1500Z.

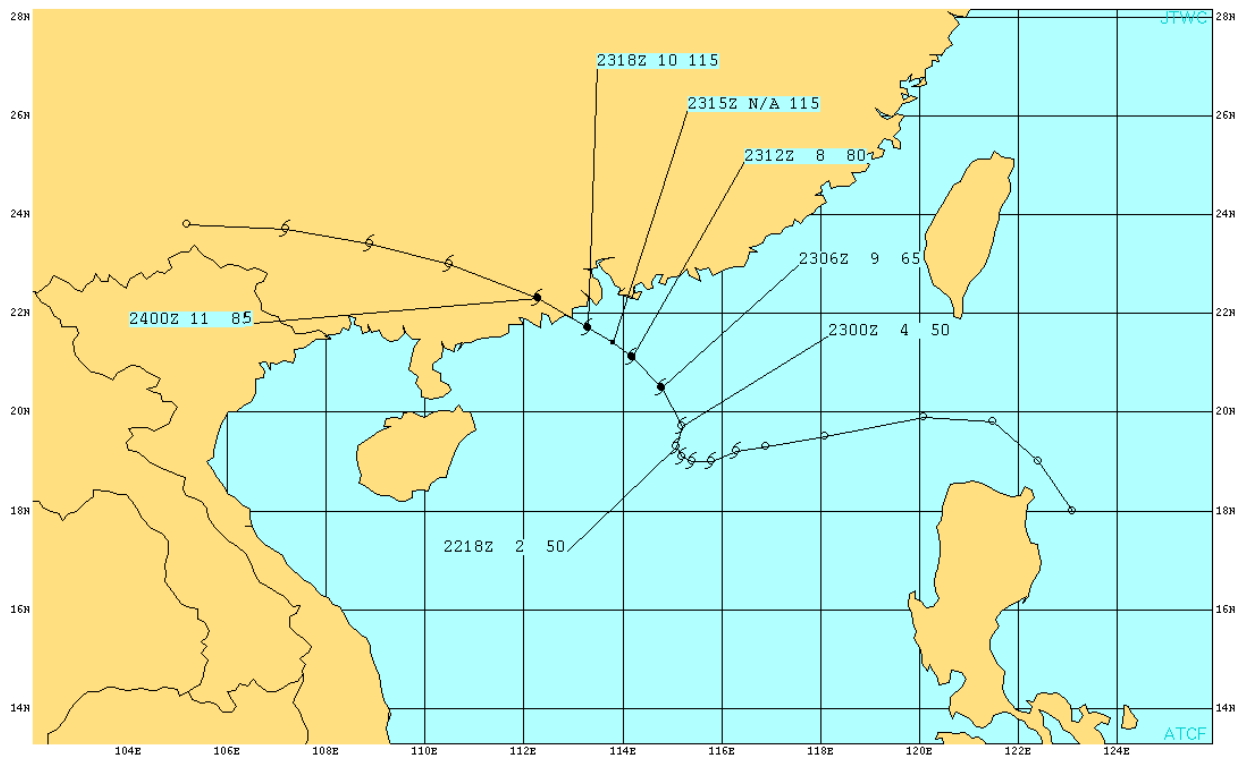


Figure 1-19. Final JTWC best track for TY 09W. Labels show best track times, translational speeds, and intensities.

The poleward deflection and subsequent rapid intensification of TY 09W were not predicted by any of the available numerical model track forecast guidance (Figure 1-20), subsequently, the statistical-dynamical intensity model guidance (Figure 1-21), did not capture the rapid intensification associated with the influence of upper-level troughs to the north and east of the cyclone. JTWC's subjective forecasts for both track and intensity favored the objective forecast data. The original forecast philosophy called for the system to track generally westward towards the Leizhou Peninsula, China, and intensify to moderate tropical storm intensity before making landfall. The mid-latitude trough ultimately responsible for the poleward deflection was not expected to weaken the deep-layer subtropical steering ridge significantly.

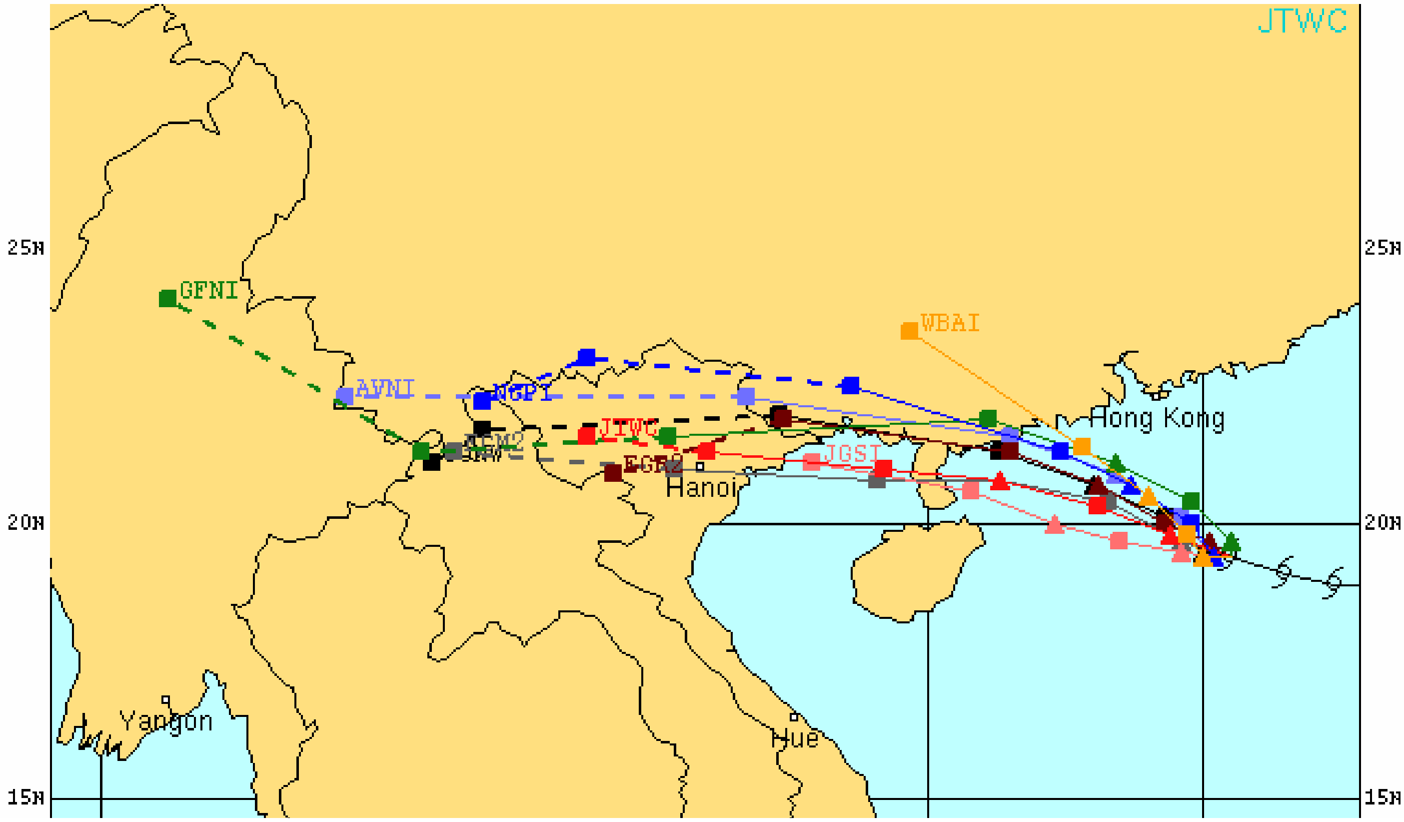


Figure 1-20. Multi-model consensus track forecasts for TY 09W from 22 July 2012 at 0000Z

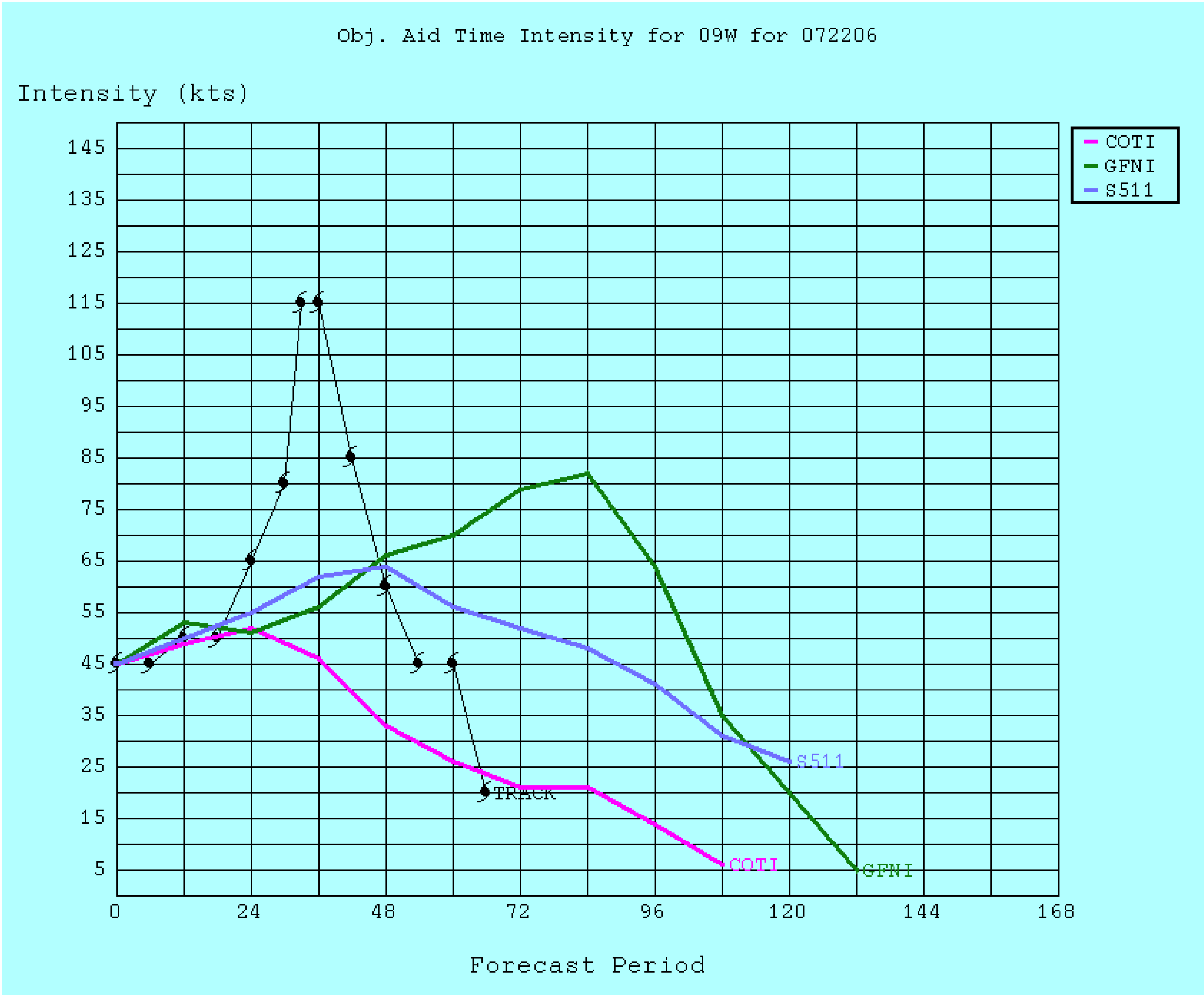


Figure 1-21. Interpolated GFDN and COAMPS-TC dynamical and S511statistical-dynamical intensity forecasts for TY 09W from 22 July 2012 at 0600Z and verifying best track intensities (in black).

As mentioned earlier, it appears that a significant increase in the poleward outflow following the poleward deflection in track was the dominant factor driving rapid intensification (RI) of TY 09W. The values of other environmental variables, including weak vertical wind shear (05-10 knots) and very warm sea surface temperatures (30-33° Celsius) (Figure 1-22), provided for further intensification throughout the RI period. Post-storm analysis indicated strong outflow was induced by a deepening tropical upper tropospheric trough (TUTT) to the east of the system (Figure 1-23) and a second TUTT to the north. A sudden increase in upper-level outflow was indeed evident in water vapor animation that showed an increased stream of cirrus into the two upper-level troughs.

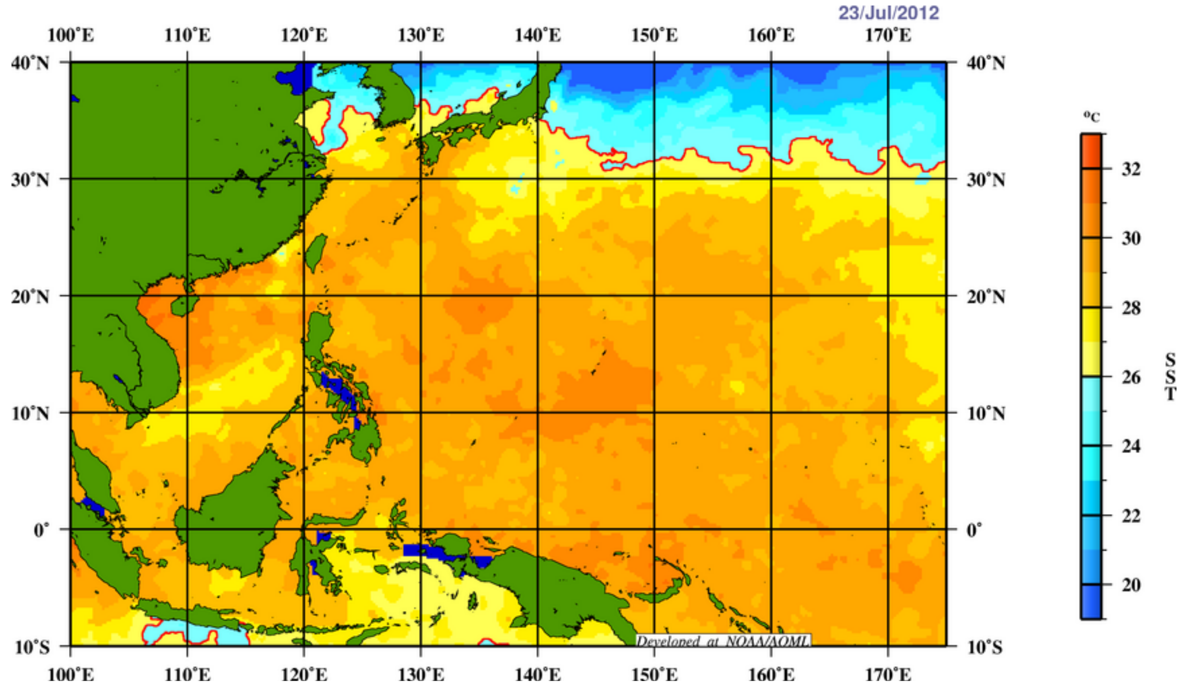


Figure 1-22. SST during 23 July 2012. Note the pool of very warm water off the coast of Hong Kong

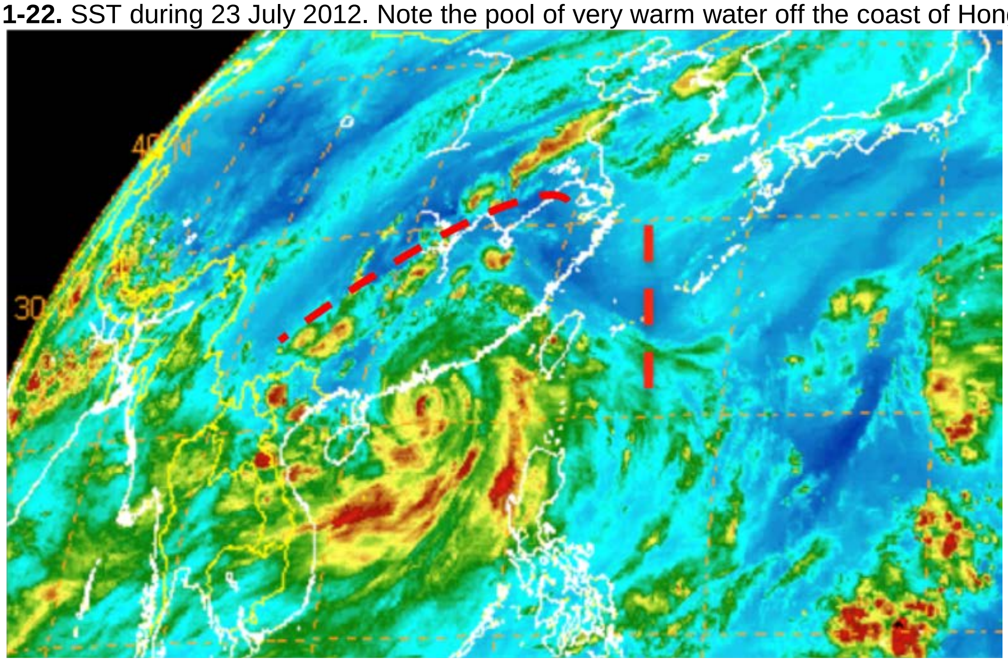


Figure 1-23. Water vapor image of TY 09W and the surrounding region showing two tropical upper-tropospheric troughs – one to the north and one to the east of the rapidly intensifying typhoon

Given the unexpected shift in track and RI of TY 09W, further study of this case is warranted. Future work could address the following questions. Were the poleward deflection of TY 09W and subsequent rapid intensification linked to the same dynamical mechanism? Was there anything unique about the strength and positioning of the TUTT cells that interacted with this system and did upper-level model fields accurately depict their formation? Finally, did any other large-scale environmental factors, such as intraseasonal oscillations, contribute to the noted track or intensity changes?

This case clearly illustrates that RI of tropical cyclones remains a difficult and complex forecast problem. While some of the factors that influence rapid intensity changes are generally understood (SST, shear, outflow, etc.), the details of role of the TUTT remain difficult to assess and difficult to capture in numerical models.

References

[1] International Business Times. Aug 2012. Web. 24 Aug. 2012.

Chapter 2 North Indian Ocean Tropical Cyclones

This chapter contains information on north Indian Ocean TC activity during 2012 and the monthly distribution of TC activity summarized for 1975 - 2012. North Indian Ocean tropical cyclone best tracks appear following Table 2-2.

Section 1 Informational Tables

Table 2-1 is a summary of TC activity in the north Indian Ocean during the 2012 season. Four cyclones occurred in 2012, with not one system reaching intensity greater than 64 knots. Table 2-2 shows the monthly distribution of Tropical Cyclone activity for 1975 - 2012.

Table 2-1

NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 2012

(01 JAN 2012- 31 DEC 2012)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)***
01A	Murjan	24 Oct / 1200Z	25 Oct / 1800Z	6	35	996
02B	Nilam	29 Oct / 1200Z	31 Oct / 1200Z	9	50	985
03B	-	17 Nov / 1800Z	19 Nov / 0000Z	6	35	996
04A	-	23 Dec / 0000Z	24Dec / 1200Z	7	35	996
* 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 - 2012

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total ≥64kt	Total 34-63kt	Total ≤33 kt
													TOTALS		
	1	0	0	0	2	0	0	0	0	1	2	0	6		
1975	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
	0	0	0	1	0	1	0	0	1	1	0	1	5		
1976	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
	0	0	0	0	1	1	0	0	0	1	0	2	5		
1977	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
	0	0	0	0	1	0	0	0	0	1	2	0	4		
1978	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
	0	0	0	0	1	1	0	0	2	1	2	0	7		
1979	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
	0	0	0	0	0	0	0	0	0	0	1	1	2		
1980	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
	0	0	0	0	0	0	0	0	1	0	1	1	3		
1981	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
	0	0	0	0	1	1	0	0	0	2	1	0	5		
1982	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
	0	0	0	0	0	0	0	1	0	1	1	0	3		
1983	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
	0	0	0	0	1	0	0	0	0	1	2	0	4		
1984	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
	0	0	0	0	2	0	0	0	0	2	1	1	6		
1985	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
	1	0	0	0	0	0	0	0	0	0	2	0	3		
1986	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
	0	1	0	0	0	2	0	0	0	2	1	2	8		
1987	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
	0	0	0	0	0	1	0	0	0	1	2	1	5		
1988	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
	0	0	0	0	1	1	0	0	0	0	1	0	3		
1989	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
	0	0	0	1	1	0	0	0	0	0	1	1	4		
1990	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
	1	0	0	1	0	1	0	0	0	0	1	0	4		
1991	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
	0	0	0	0	1	2	1	0	1	3	3	2	13		
1992	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
	0	0	0	0	0	0	0	0	0	0	2	0	2		
1993	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
	0	0	1	1	0	1	0	0	0	1	1	0	5		
1994	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
	0	0	0	0	0	0	0	0	1	1	2	0	4		
1995	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
	0	0	0	0	1	3	0	0	0	2	2	0	8		
1996	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
	0	0	0	0	1	0	0	0	1	1	1	0	4		
1997	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
	0	0	0	0	2	1	0	0	1	1	2	1	8		
1998	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
	0	1	0	0	1	1	0	0	0	2	0	0	5		
1999	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
	0	0	0	0	0	0	0	0	0	2	1	1	4		
2000	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
	0	0	0	0	1	0	0	0	1	1	1	0	4		
2001	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
	0	0	0	0	2	0	0	0	0	0	2	1	5		
2002	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
	0	0	0	0	1	0	0	0	0	0	1	1	3		
2003	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
	0	0	0	0	2	0	0	0	0	2	1	0	5		
2004	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
	2	0	0	0	0	0	0	0	0	2	1	2	7		
2005	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
	1	0	0	1	0	0	1	0	2	0	1	0	6		
2006	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
	0	0	0	0	1	3	0	0	0	1	1	0	6		
2007	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
	0	0	0	1	0	0	0	0	1	2	2	1	7		
2008	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
	0	0	0	1	1	0	0	0	1	0	1	1	5		
2009	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
	0	0	0	0	2	1	0	0	0	1	1	0	5		
2010	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
	0	0	0	0	0	1	0	0	0	1	3	1	6		
2011	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
	0	0	0	0	0	0	0	0	0	2	1	1	4		
2012	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 1 0	0 1 0	0	4	0
						(1975-2012)									
MEAN	0.2	0.1	0.0	0.2	0.7	0.6	0.1	0.0	0.3	1.0	1.3	0.6	5.1		
CASES	6	2	1	7	27	22	2	1	13	39	51	22	193		

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.

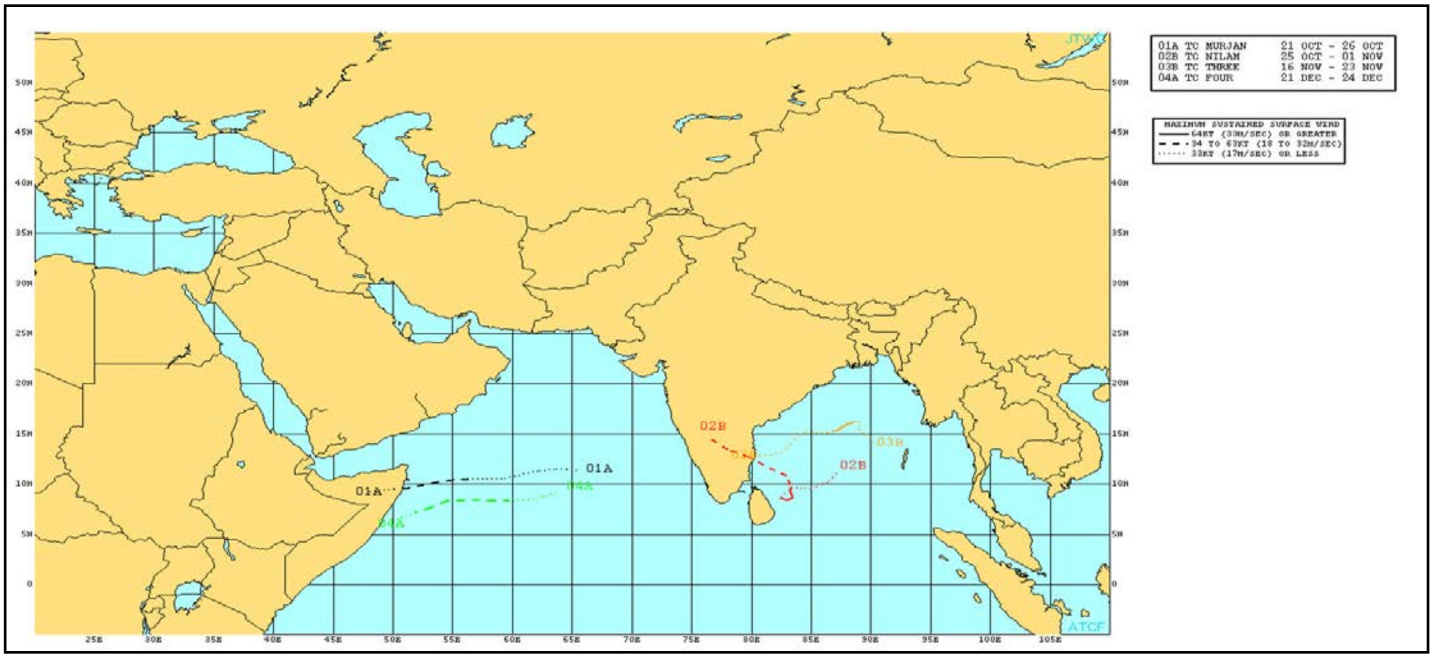


Figure 2-1. North Indian Ocean Tropical Cyclones.

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:

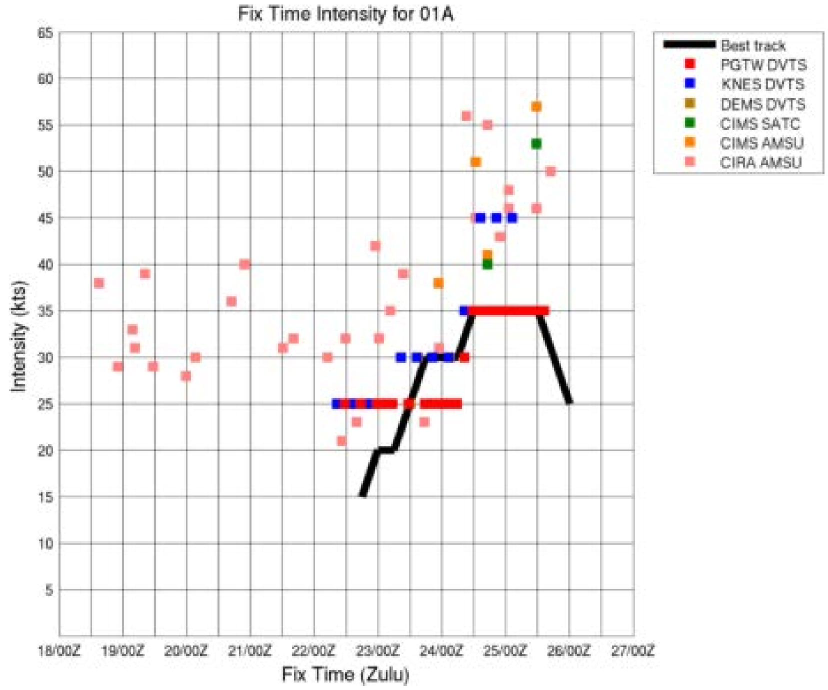
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

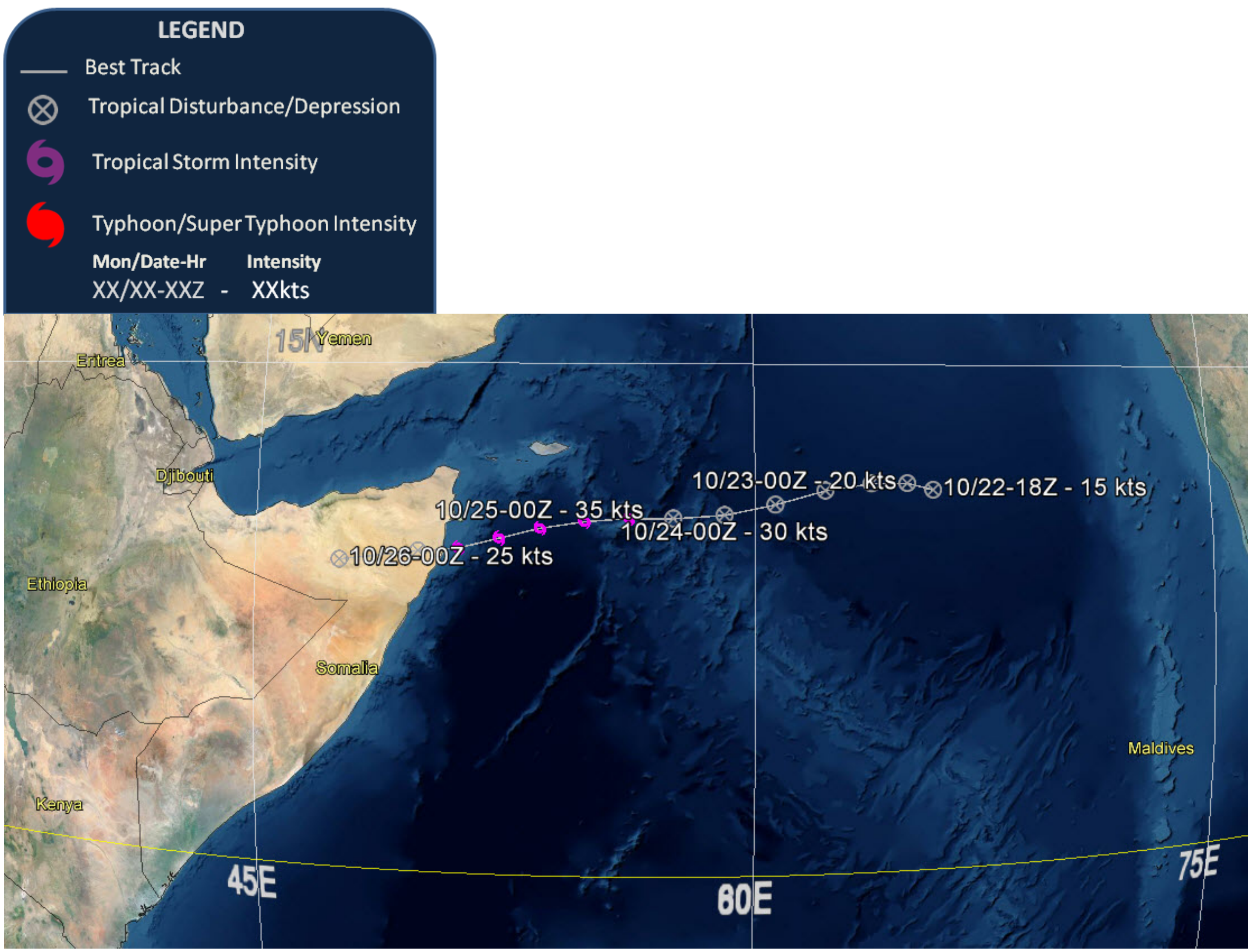
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of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

In addition, if this document is viewed as a pdf, each map has been hyperlinked to the appropriate keyhole markup language (kmz) file that will allow the reader to access and view the best-track data interactively on their computer using Google Earth software. Simply hold the control button and click the map image; the link will open allowing the reader to download and open the file. Users may also retrieve kmz files for the entire season from:
http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/2012/2012-kmzs/

Tropical Cyclone 01A (Murjan)

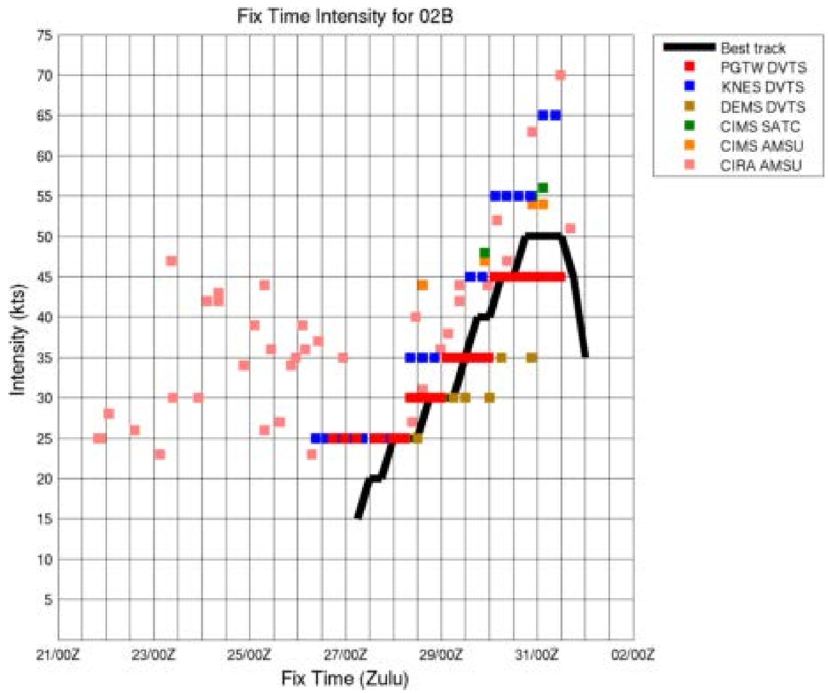
ISSUED LOW: 0900Z 22 Oct 2012
ISSUED MEDIUM: 1600Z 23 Oct 2012
FIRST TCFA: 2000Z 23 Oct 2012
FIRST WARNING: 1200Z 24 Oct 2012
LAST WARNING: 1800Z 25 Oct 2012
MAX INTENSITY: 35 Kts
WARNINGS: 6

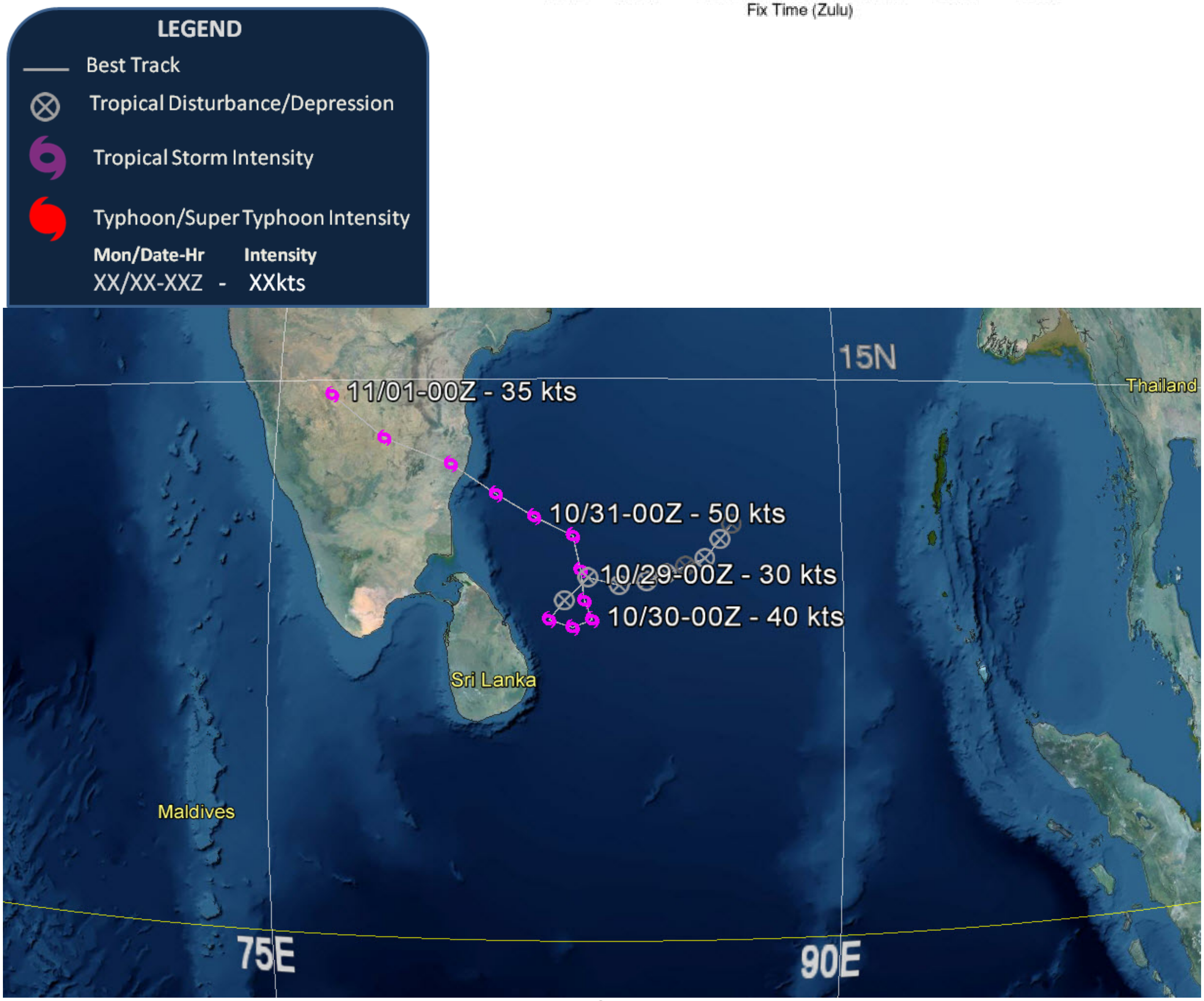




Tropical Cyclone 02B (Nilam)

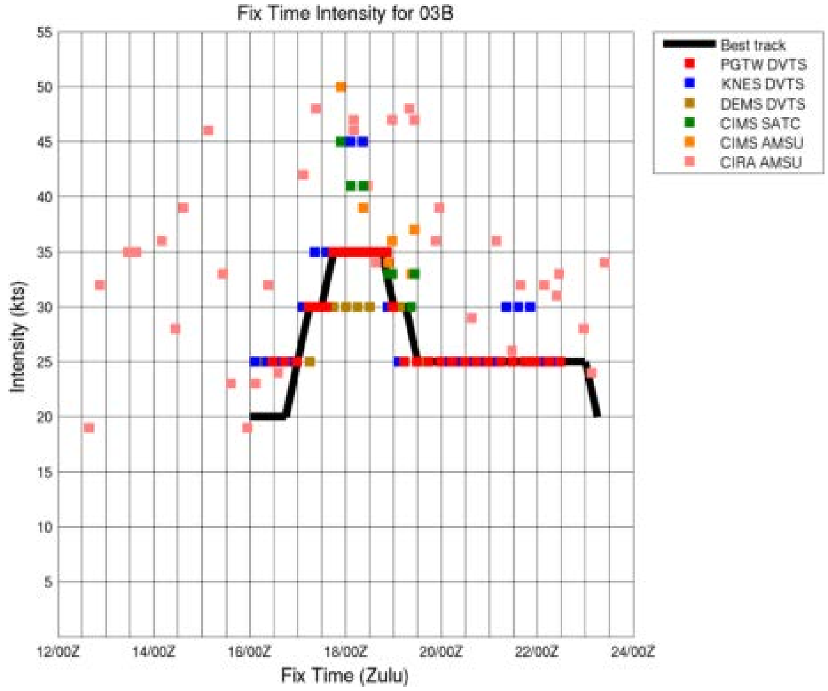
ISSUED LOW:	2100Z 23 Oct 2012
ISSUED MEDIUM:	0600Z 26 Oct 2012
FIRST TCFA:	0330Z 29 Oct 2012
FIRST WARNING:	1200Z 29 Oct 2012
LAST WARNING:	1200Z 31 Oct 2012
MAX INTENSITY:	50 Kts
WARNINGS:	9

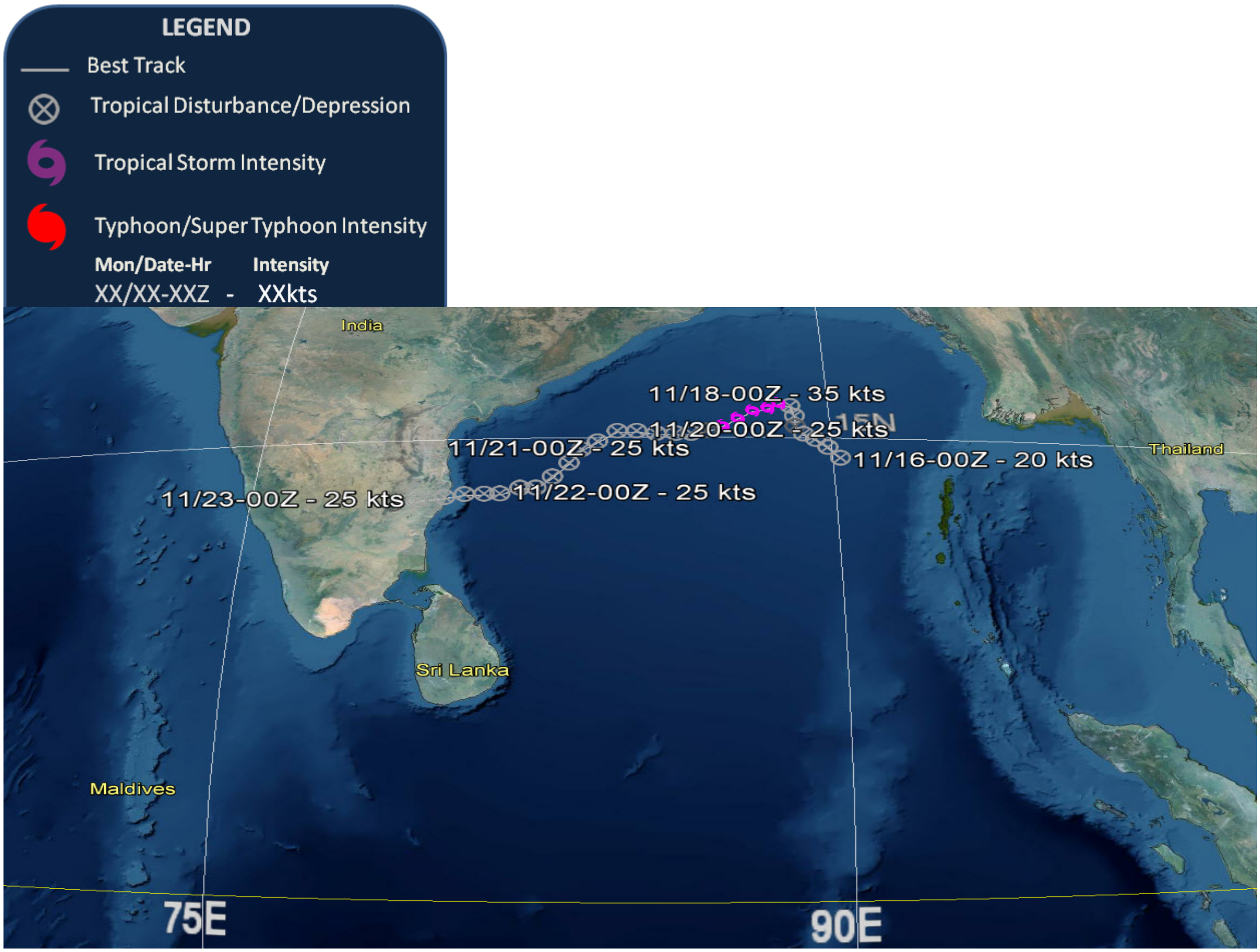




Tropical Cyclone 03B

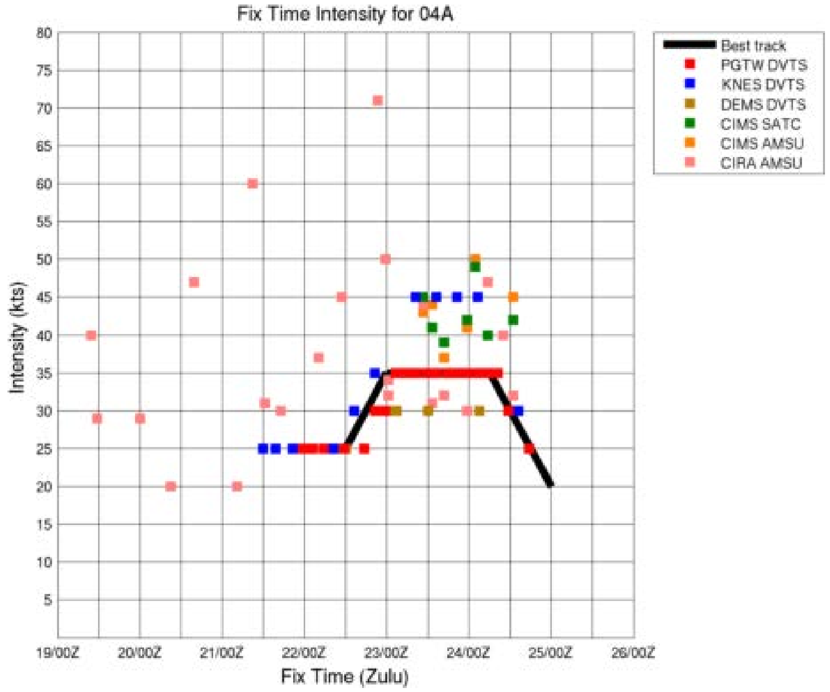
ISSUED LOW:	0300Z 16 Nov 2012
ISSUED MEDIUM:	0030Z 17 Nov 2012
FIRST TCFA:	0800Z 17 Nov 2012
FIRST WARNING:	1800Z 17 Nov 2012
LAST WARNING:	0000Z 19 Nov 2012
MAX INTENSITY:	35 Kts
WARNINGS:	6

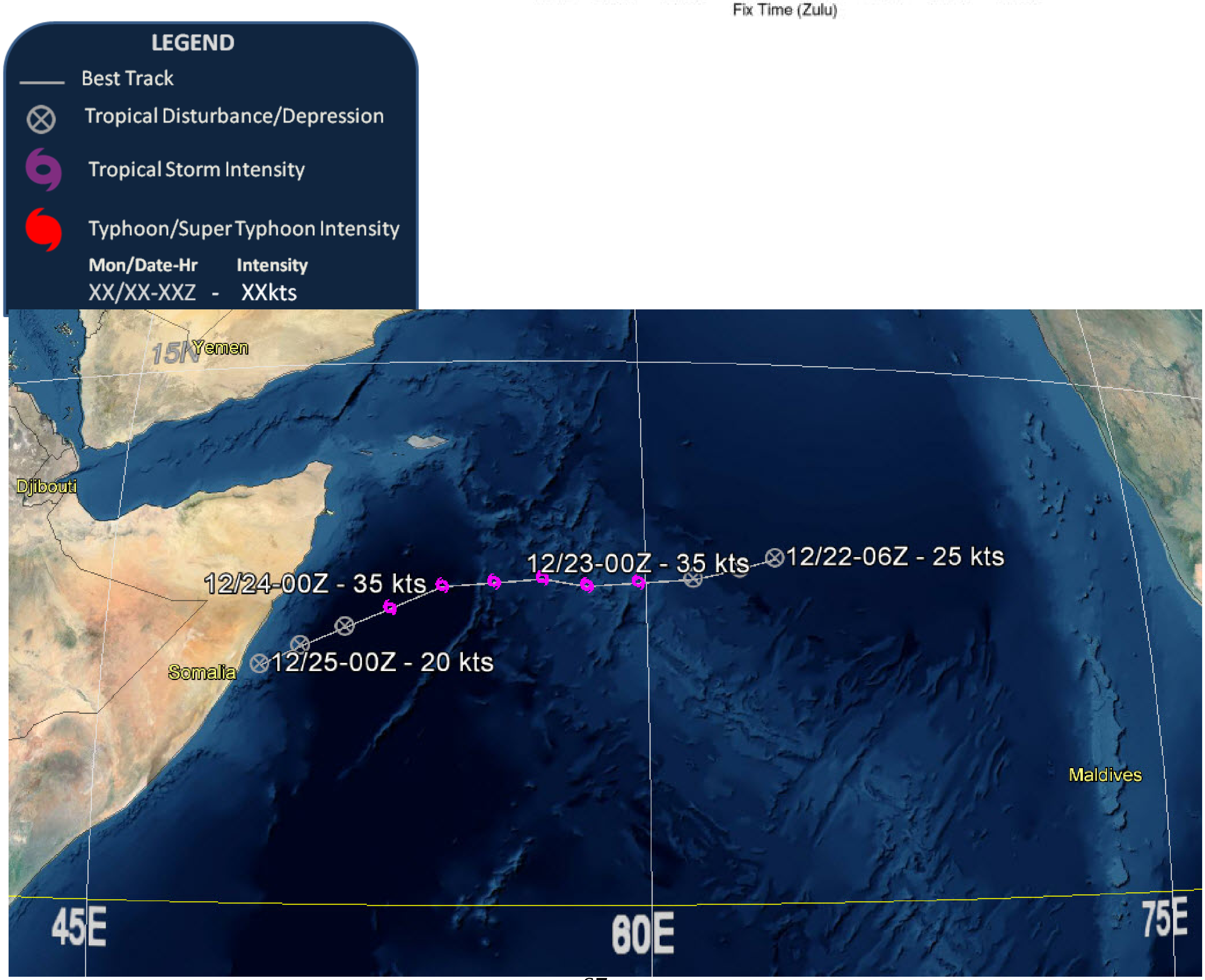




Tropical Cyclone 04A

ISSUED LOW:	0000Z 21 Dec 2012
ISSUED MEDIUM:	1300Z 21 Dec 2012
FIRST TCFA:	1800Z 22 Dec 2012
FIRST WARNING:	0000Z 23 Dec 2012
LAST WARNING:	1200Z 24 Dec 2012
MAX INTENSITY:	35 Kts
WARNINGS:	7





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 2012 tropical cyclone season (1 July 2011 – 30 June 2012) and the monthly distribution of TC activity summarized for 1975 - 2012.

Section 1 Informational Tables

Table 3-1 is a summary of TC activity in the Southern Hemisphere during the 2012 season.

Table 3-1

SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 2012

(01 JULY 2011- 30 JUNE 2012)

TC	NAME*	PERIOD		WARNINGS ISSUED	EST MAX SFC WINDS KTS	MSLP (MB)**
01S	Alenga	05 Dec / 0000Z	09 Dec / 0000Z	11	95	952
02S	Two	06 Dec / 0600Z	07 Dec / 0600Z	3	35	996
03S	Grant	25 Dec / 0000Z	27 Dec / 0000Z	5	60	978
04S	Benilde	28 Dec / 0600Z	04 Jan / 0600Z	15	90	956
05S	Chanda	07 Jan / 1800Z	08 Jan /1800Z	3	35	996
06S	Heidi	10 Jan / 1800Z	11 Jan / 1800Z	5	65	974
07S	Ethel	19 Jan / 0000Z	22 Jan / 1200Z	8	70	970
08S	Funso	19 Jan / 0600Z	28 Jan / 1800Z	21	115	937
09S	Iggy	25 Jan / 1200Z	02 Feb / 1200Z	26	70	970
10P	Jasmine	04 Feb / 0600Z	15 Feb / 1800Z	24	115	937
11P	Cyril	06 Feb / 1200Z	08 Feb / 0000Z	4	55	982
12S	Giovanna	09 Feb / 1200Z	21 Feb / 0000Z	25	120	933
13S	Hilwa	14 Feb / 0600Z	22 Feb / 0600Z	18	40	993
14S	Irina	29 Feb / 0000Z	10 Mar / 0000Z	21	60	978
15S	Fifteen	29 Feb / 1800Z	01 Mar / 1800Z	3	35	996
16S	Koji	07 Mar / 0600Z	12 Mar / 0600Z	11	75	967
17S	Lua	13 Mar / 0600Z	17 Mar / 1200Z	12	95	952
18P	Daphne	TC not forecast by JTWC due to TCC			55	982
19P	Nineteen	07 May / 0000Z	07 May / 1200Z	2	30	1000
20S	Kuena	06 Jun / 0000Z	07 Jun / 1200Z	4	55	982
21P	Twenty-One	29 Jun / 1200Z	30 Jun / 0000Z	2	35	996

*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 provides the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2012.

Table 3-2

DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES

FOR 1958 - 2012

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 - 2012													
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
2012	0	0	0	0	0	4	5	6	2	1	1	2	21
(1981 - 2012)													
MEAN	0.3	0.1	0.3	0.7	1.6	3.2	5.9	6.3	4.8	3.0	0.8	0.3	27.0
CASES	9	3	9	21	50	101	188	201	155	95	25	8	865

* (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.

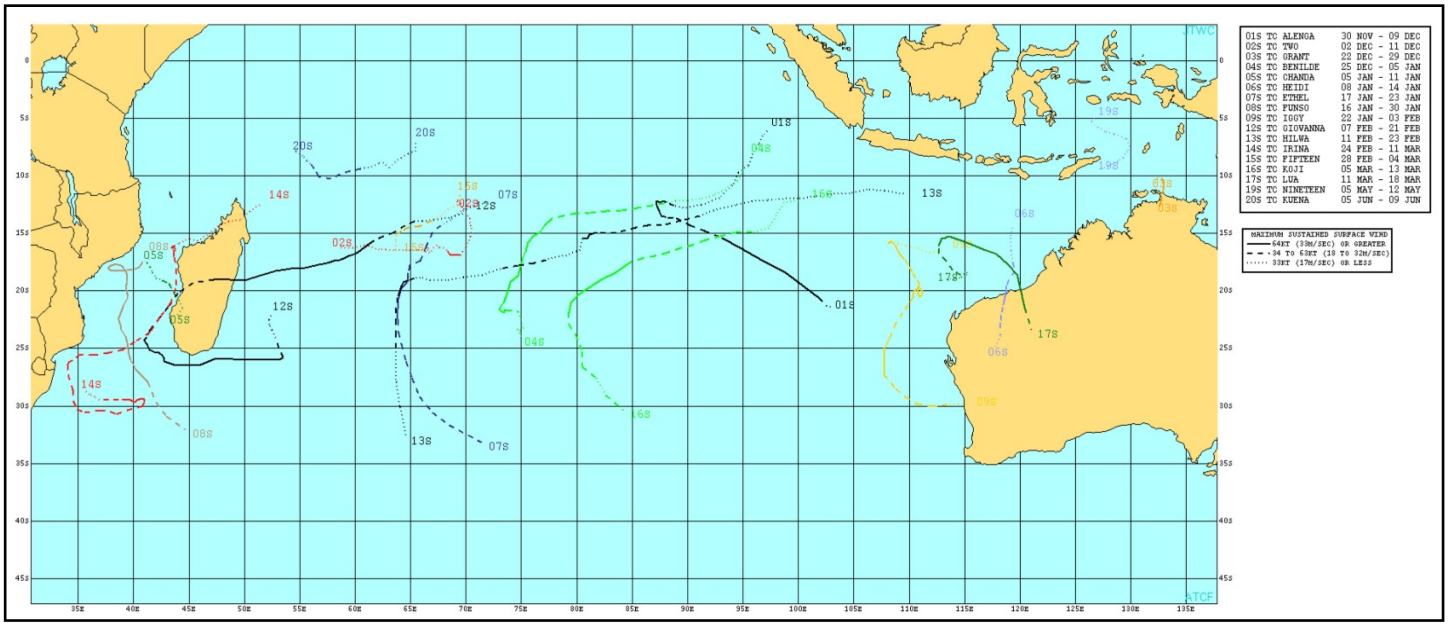


Figure 3-1. Southern Indian Ocean Tropical Cyclones.

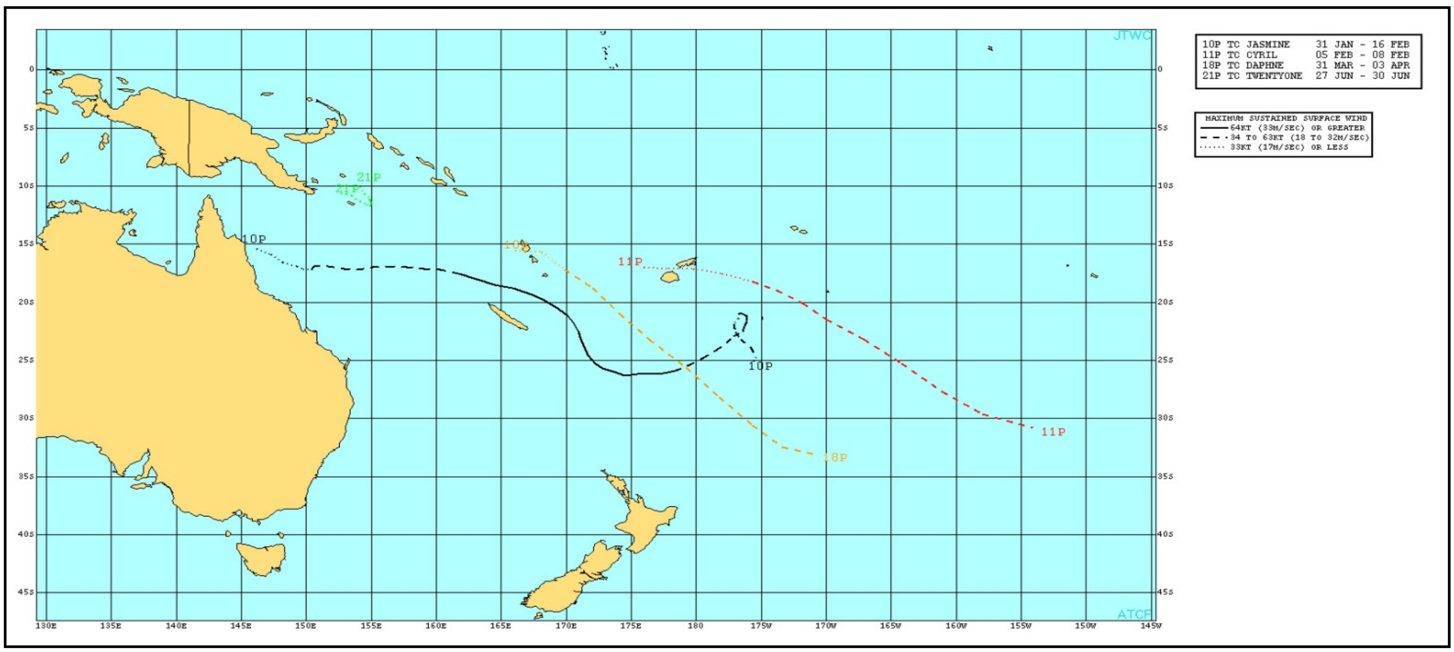


Figure 3-2. Southeast Pacific Ocean Tropical Cyclones.

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.

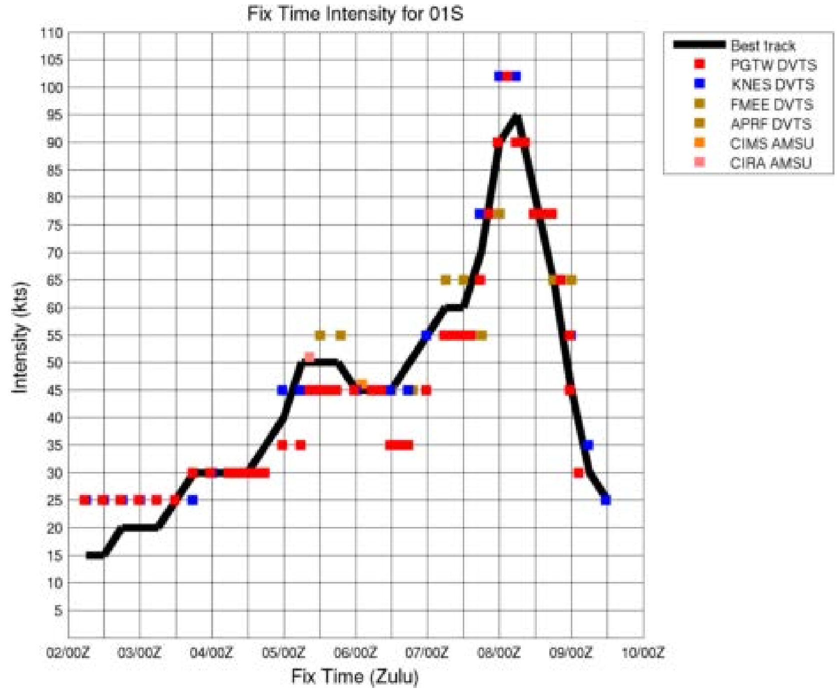
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

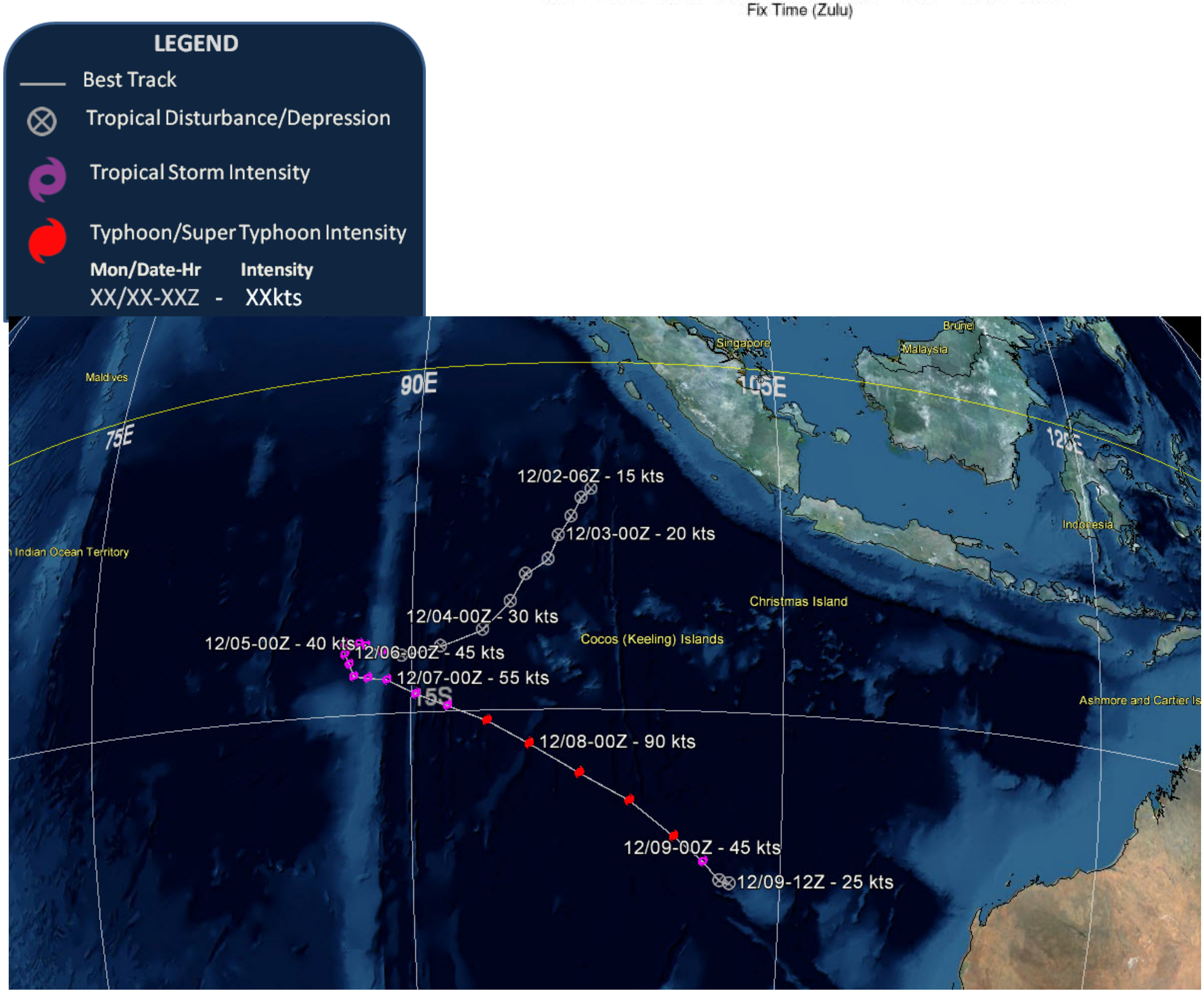
Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color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

In addition, if this document is viewed as a pdf, each map has been hyperlinked to the appropriate keyhole markup language (kmz) file that will allow the reader to access and view the best-track data interactively on their computer using Google Earth software. Simply hold the control button and click the map image; the link will open allowing the reader to download and open the file. Users may also retrieve kmz files for the entire season from:
http://www.usno.navy.mil/NOOC/nmfc-ph/RSS/jtwc/best_tracks/2012/2012-kmzs/

Tropical Cyclone 01S (Alenga)

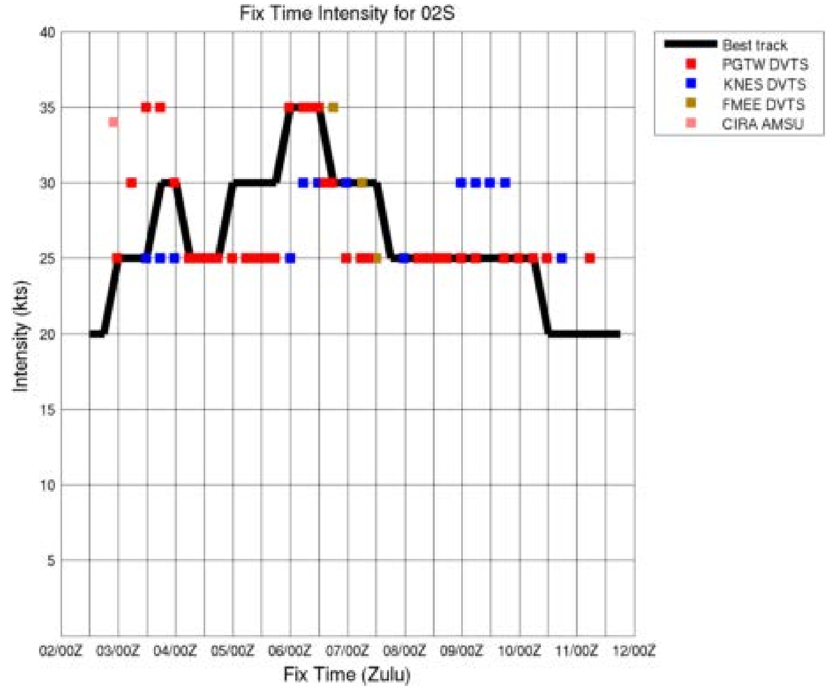
ISSUED LOW:	0030Z 02 Dec 2011
ISSUED MEDIUM:	1730Z 02 Dec 2011
FIRST TCFA:	2030Z 03 Dec 2011
FIRST WARNING:	0000Z 05 Dec 2011
LAST WARNING:	0000Z 09 Dec 2011
MAX INTENSITY:	95 Kts
WARNINGS:	11

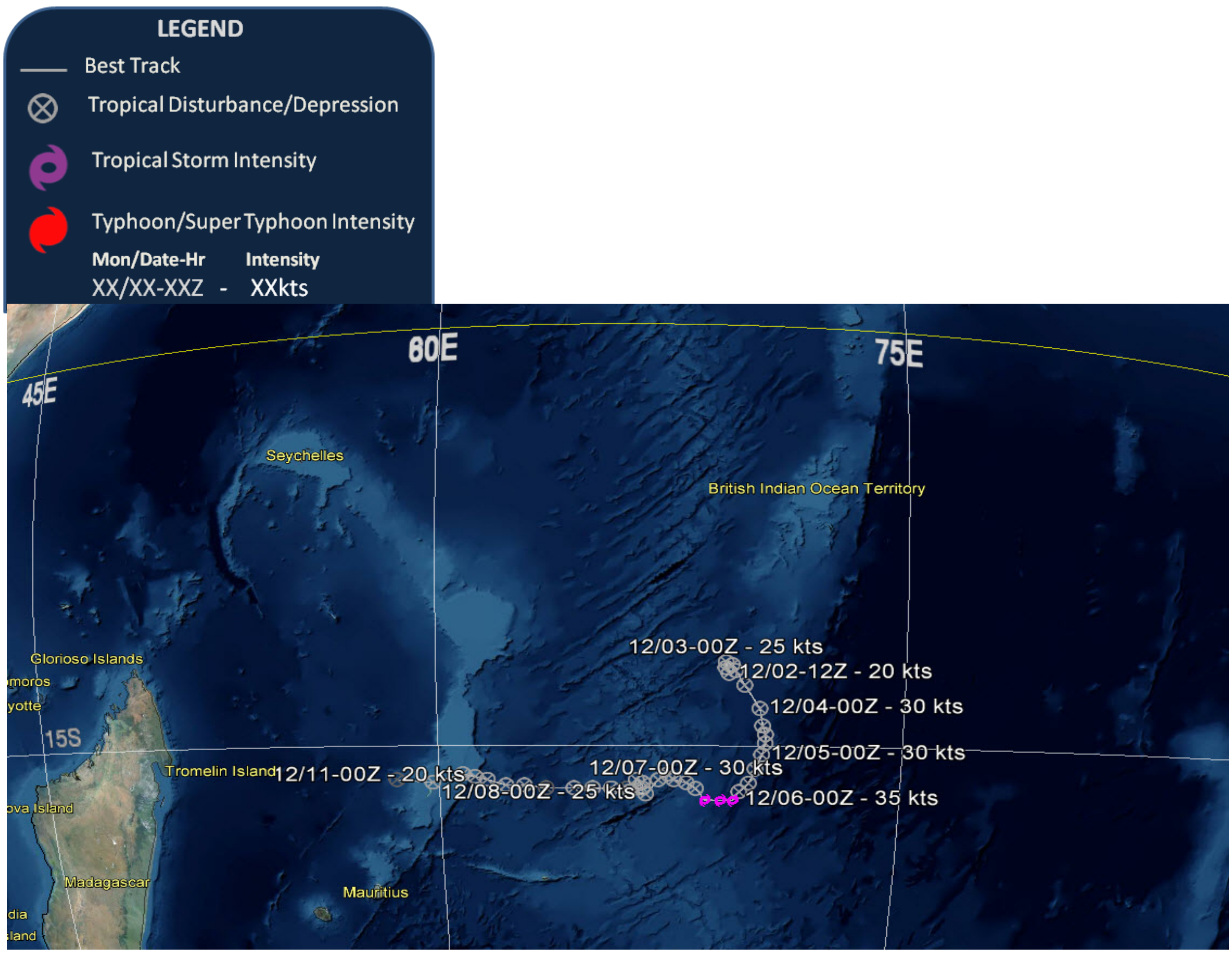




Tropical Cyclone 02S

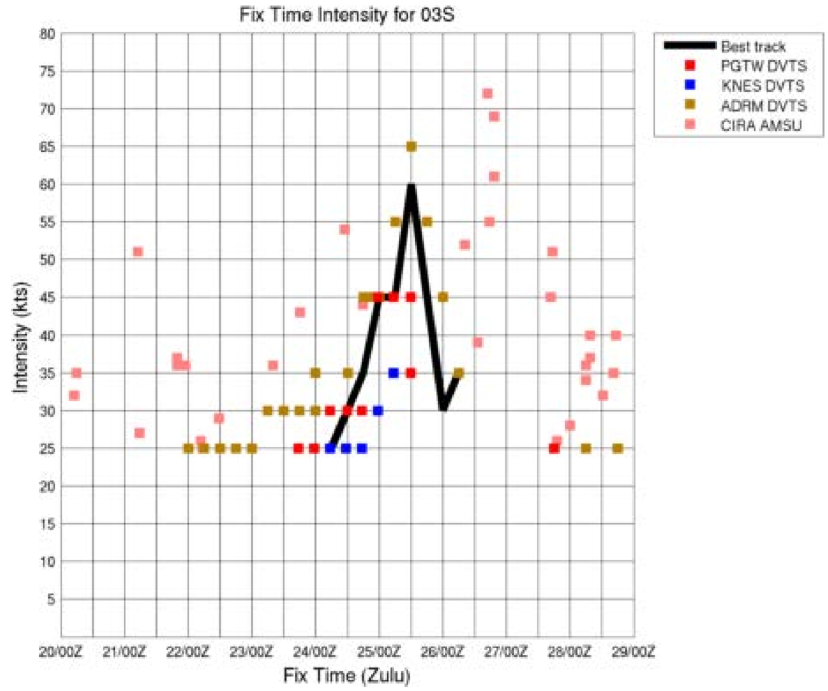
ISSUED LOW:	1800Z 28 Nov 2011
ISSUED MEDIUM:	0130Z 06 Dec 2011
FIRST TCFA:	0300Z 06 Dec 2011
FIRST WARNING:	0600Z 06 Dec 2011
LAST WARNING:	0600Z 07 Dec 2011
MAX INTENSITY:	35 Kts
WARNINGS:	3

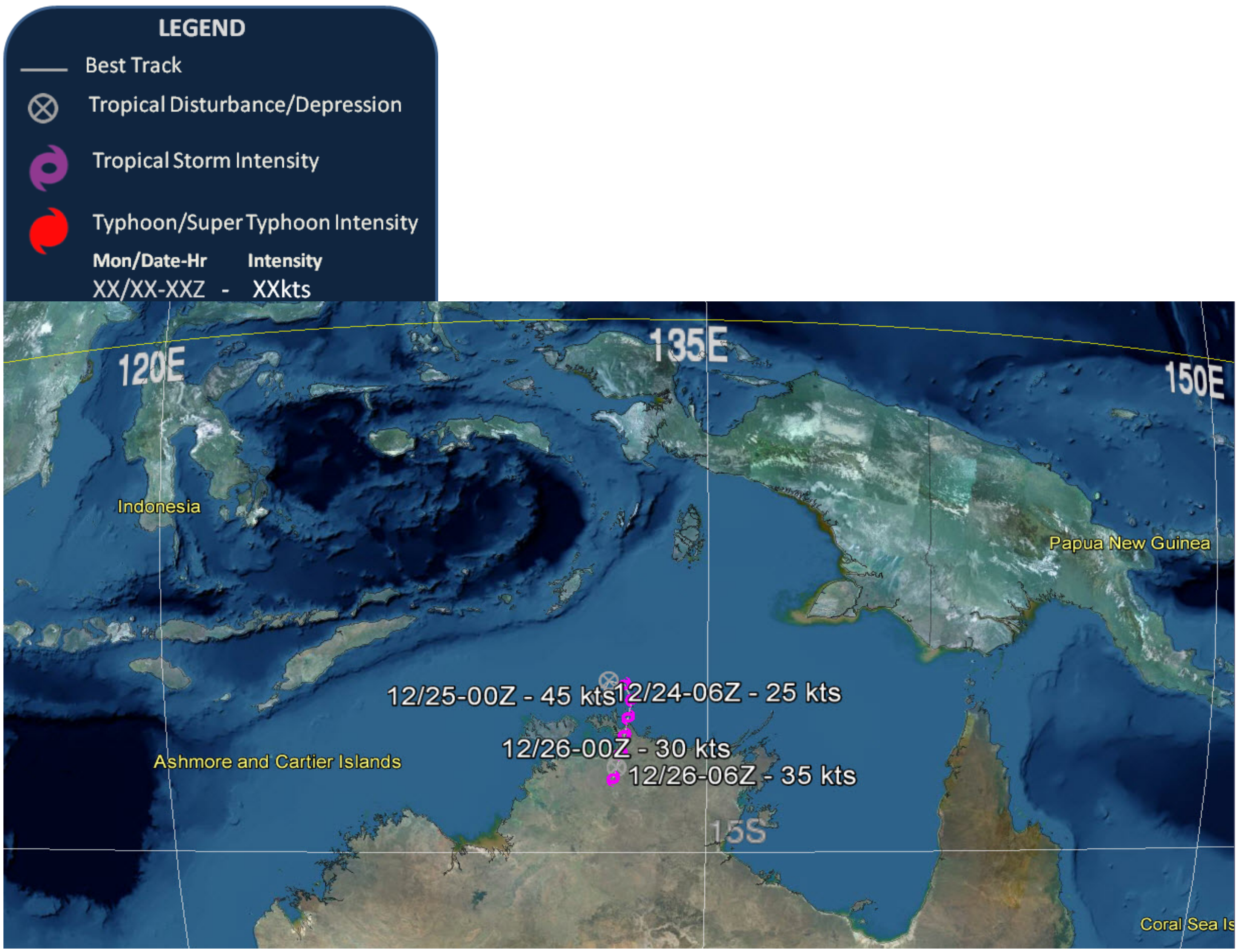




Tropical Cyclone 03S (Grant)

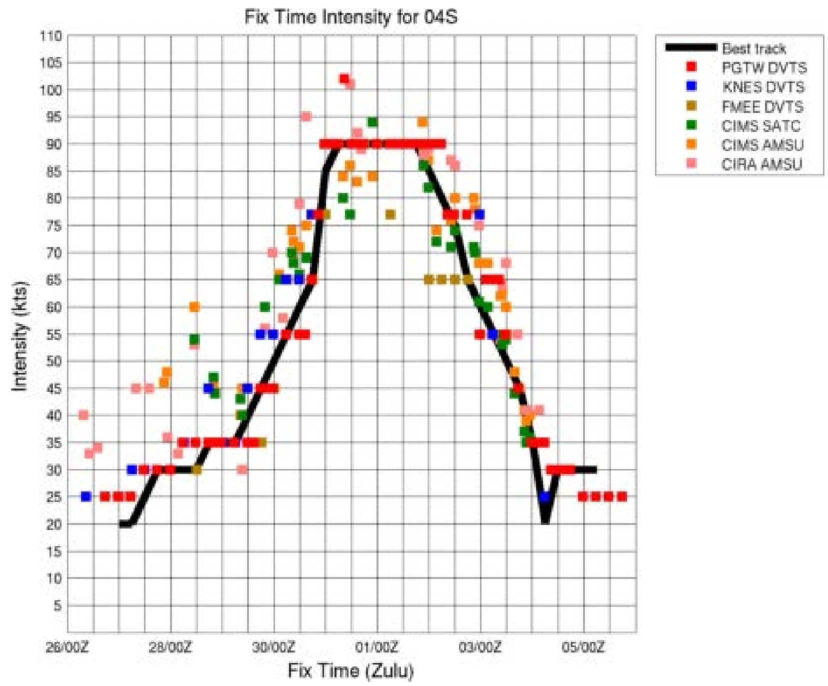
ISSUED LOW:	1800Z 20 Dec 2011
ISSUED MEDIUM:	1800Z 21 Dec 2011
FIRST TCFA:	1430Z 24 Dec 2011
FIRST WARNING:	0000Z 25 Dec 2011
LAST WARNING:	0000Z 27 Dec 2011
MAX INTENSITY:	60 Kts
WARNINGS:	5

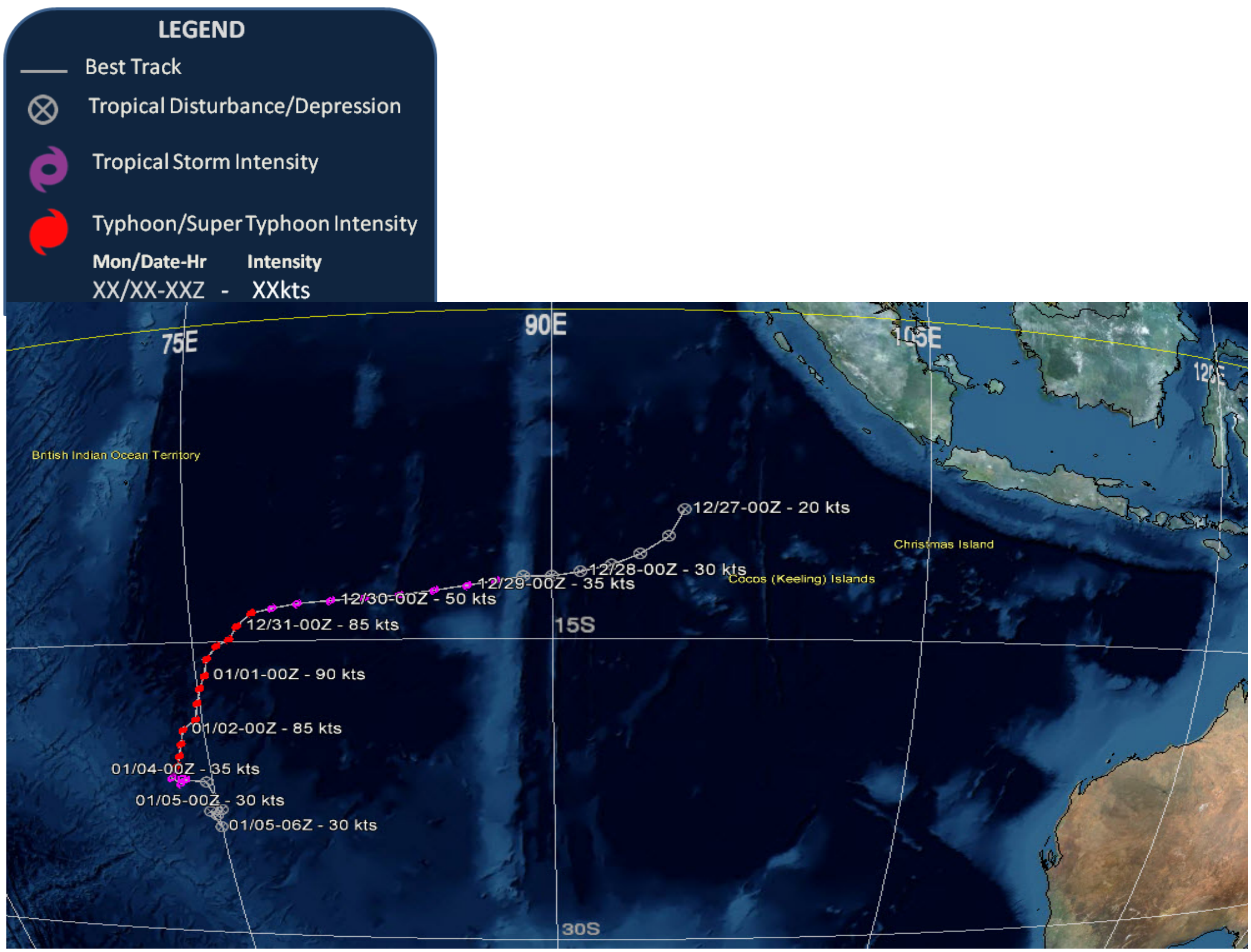




Tropical Cyclone 04S (Benilde)

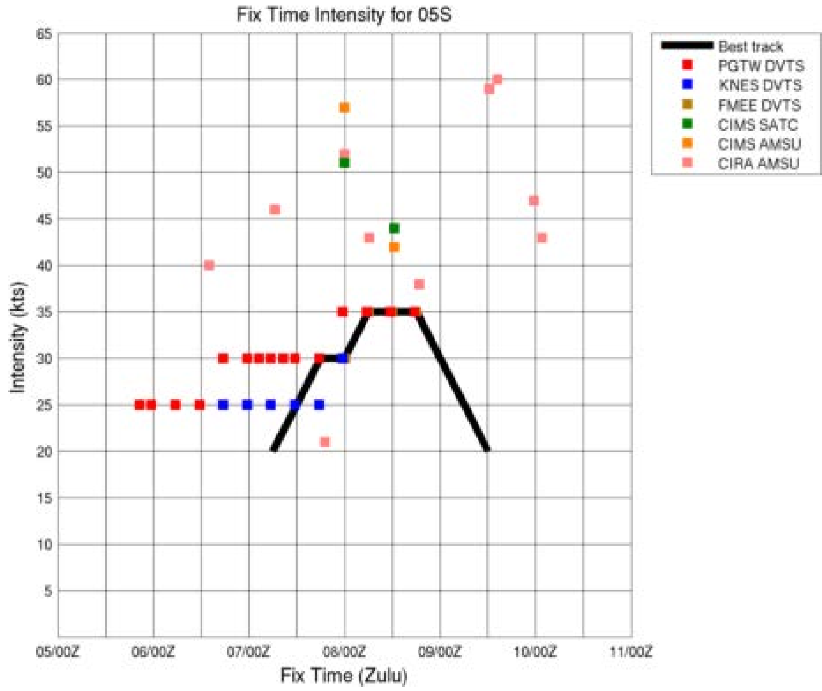
ISSUED LOW:	1800Z 26 Dec 2011
ISSUED MEDIUM:	1000Z 27 Dec 2011
FIRST TCFA:	0200Z 28 Dec 2011
FIRST WARNING:	0600Z 28 Dec 2011
LAST WARNING:	1200Z 04 Jan 2012
MAX INTENSITY:	90 Kts
WARNINGS:	15

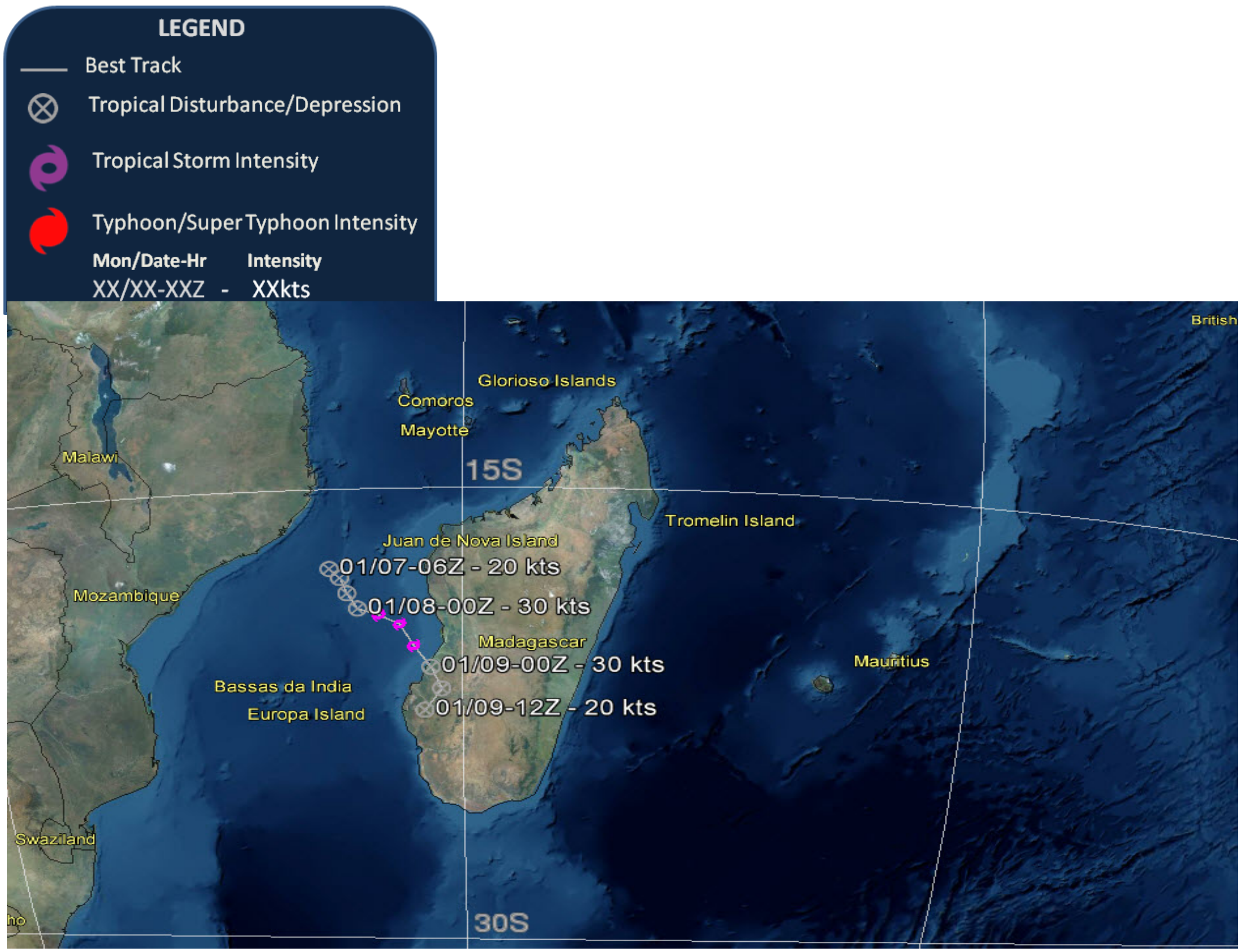




Tropical Cyclone 05S (Chanda)

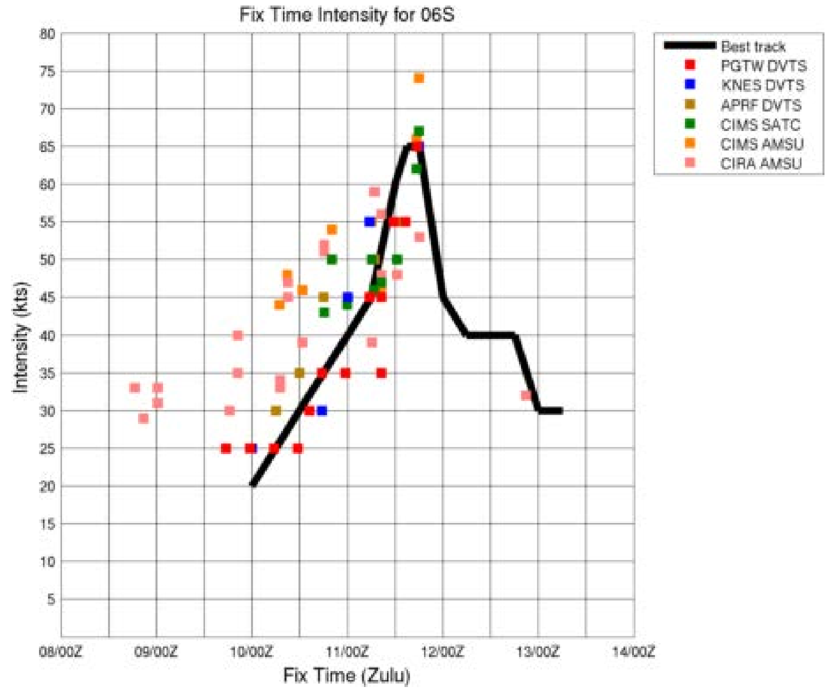
ISSUED LOW:	0900Z 05 Jan 2012
ISSUED MEDIUM:	1800Z 05 Jan 2012
FIRST TCFA:	1930Z 06 Jan 2012
FIRST WARNING:	1800Z 07 Jan 2012
LAST WARNING:	1800Z 08 Jan 2012
MAX INTENSITY:	35 Kts
WARNINGS:	3





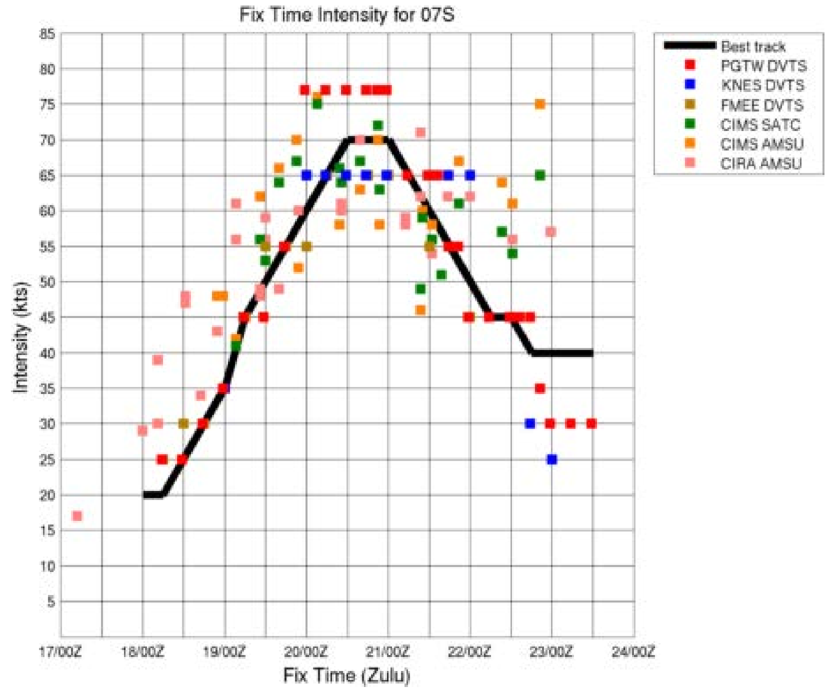
Tropical Cyclone 06S (Heidi)

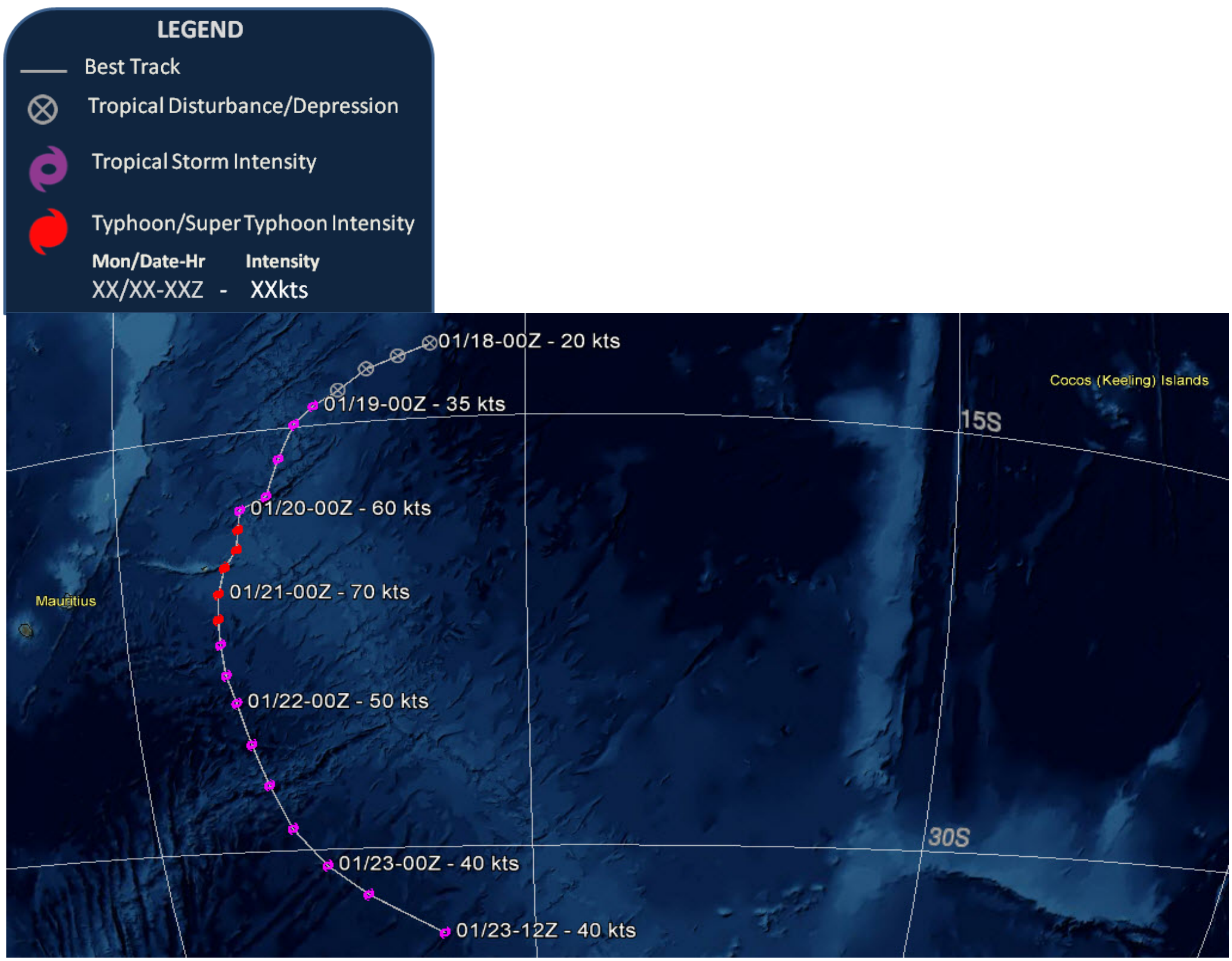
ISSUED LOW:	1400Z 09 Jan 2012
ISSUED MEDIUM:	1800Z 09 Jan 2012
FIRST TCFA:	0900Z 10 Jan 2012
FIRST WARNING:	1800Z 10 Jan 2012
LAST WARNING:	1800Z 11 Jan 2012
MAX INTENSITY:	65 Kts
WARNINGS:	5



Tropical Cyclone 07S (Ethel)

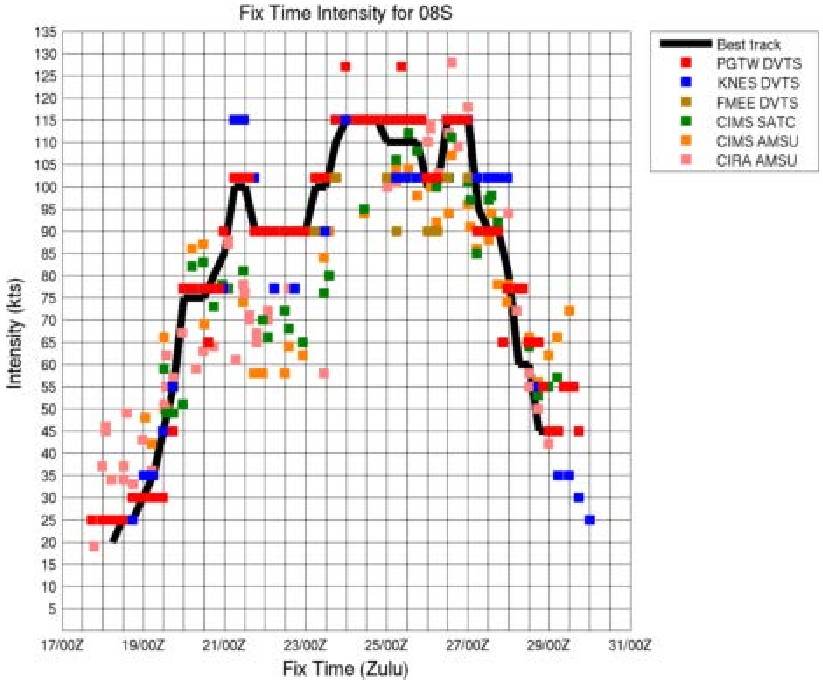
ISSUED LOW: 1800Z 17 Jan 2012
ISSUED MEDIUM: 0300Z 18 Jan 2012
FIRST TCFA: 1900Z 18 Jan 2012
FIRST WARNING: 0000Z 19 Jan 2012
LAST WARNING: 1200Z 22 Jan 2012
MAX INTENSITY: 70 Kts
WARNINGS: 8

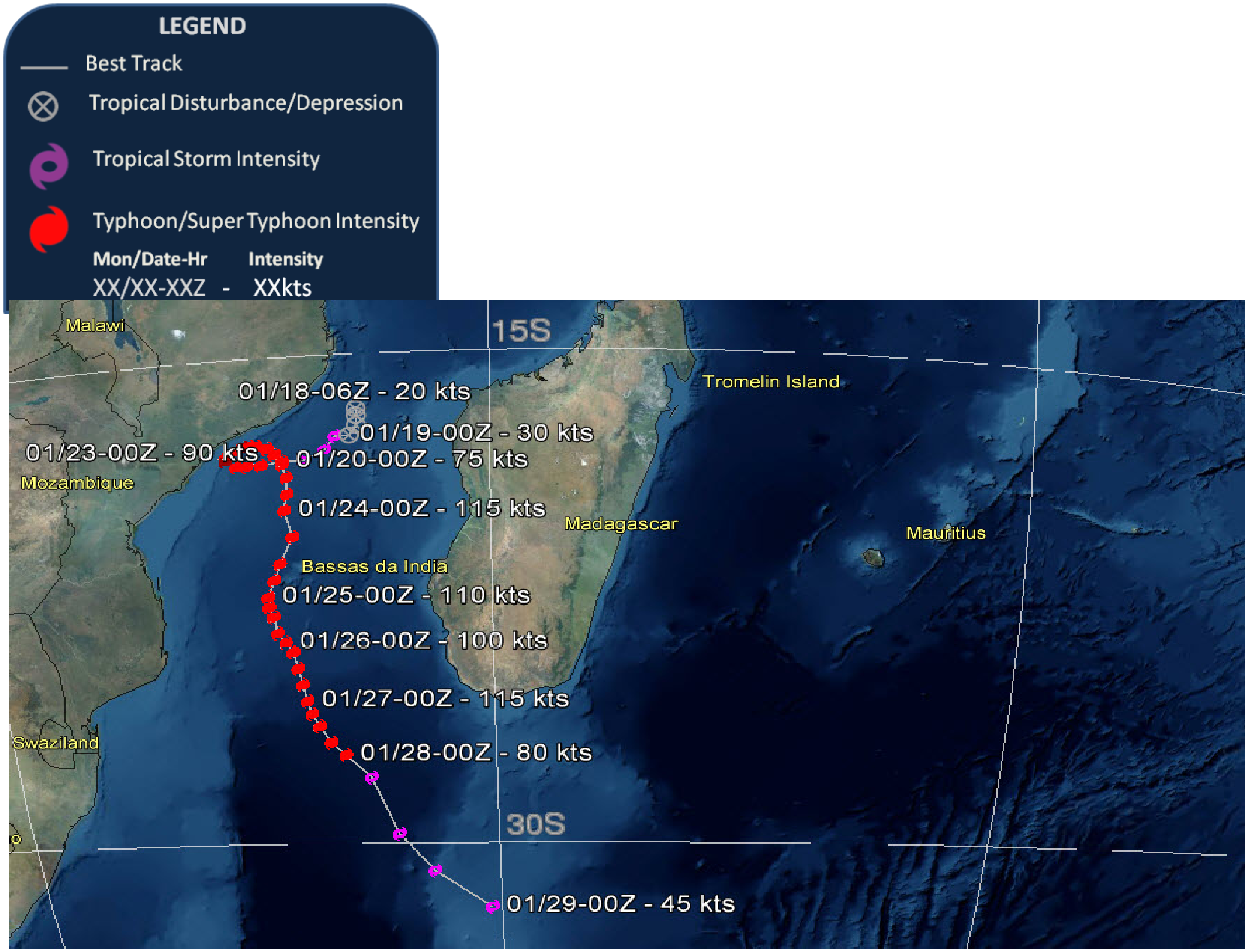




Tropical Cyclone 08S (Funso)

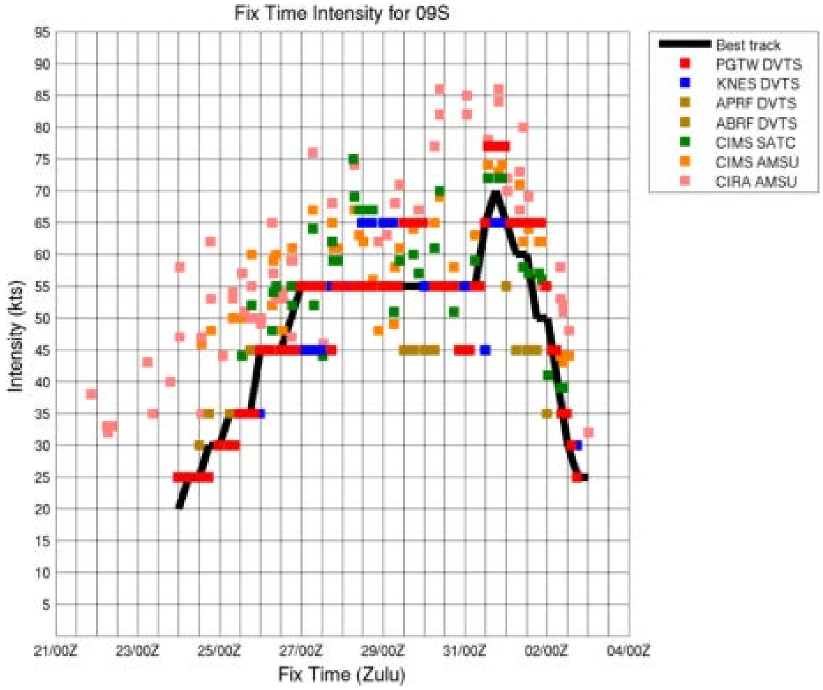
ISSUED LOW: N/A
ISSUED MEDIUM: 1800Z 17 Jan 2012
FIRST TCFA: 1930Z 18 Jan 2012
FIRST WARNING: 0600Z 19 Jan 2012
LAST WARNING: 1800Z 28 Jan 2012
MAX INTENSITY: 115 Kts
WARNINGS: 21

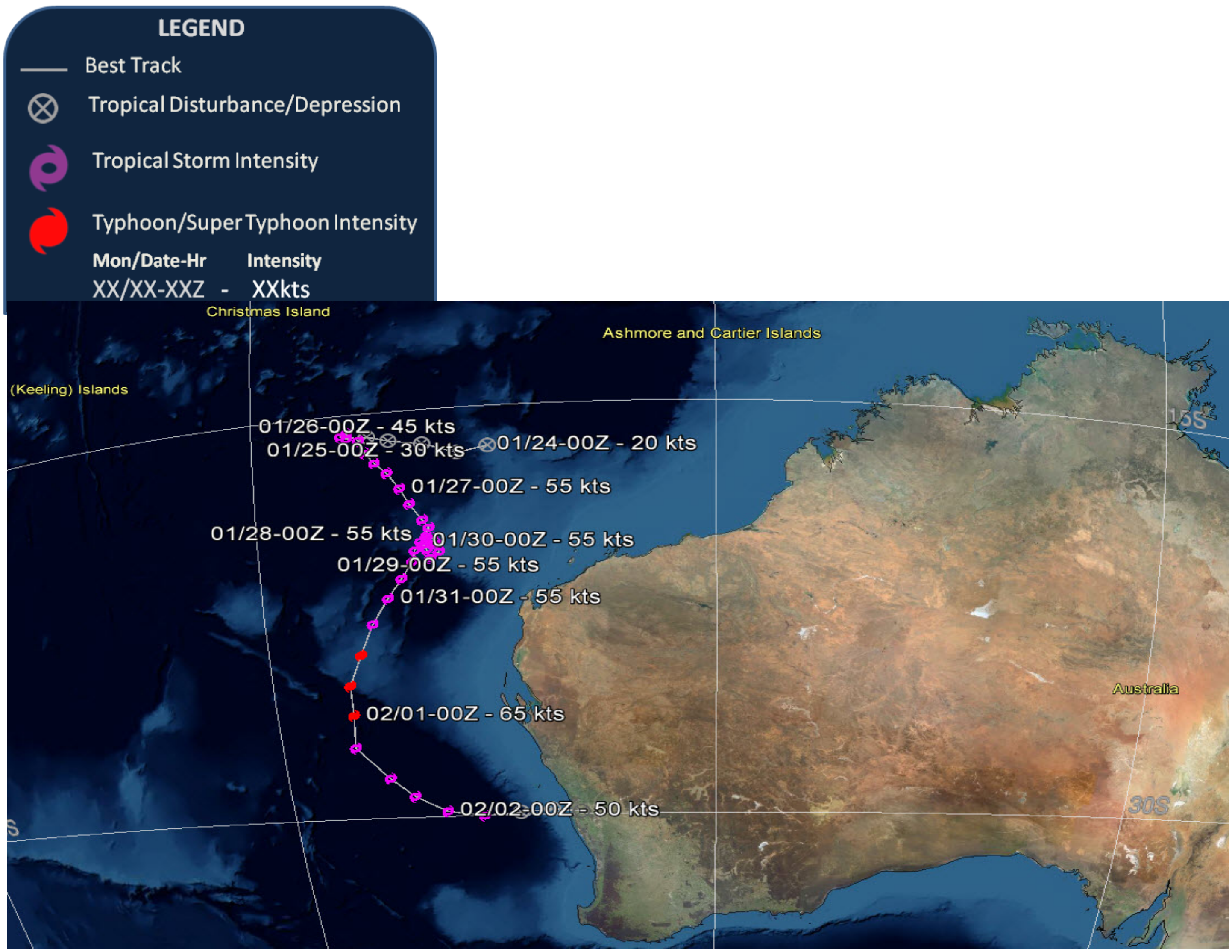




Tropical Cyclone 09S (Iggy)

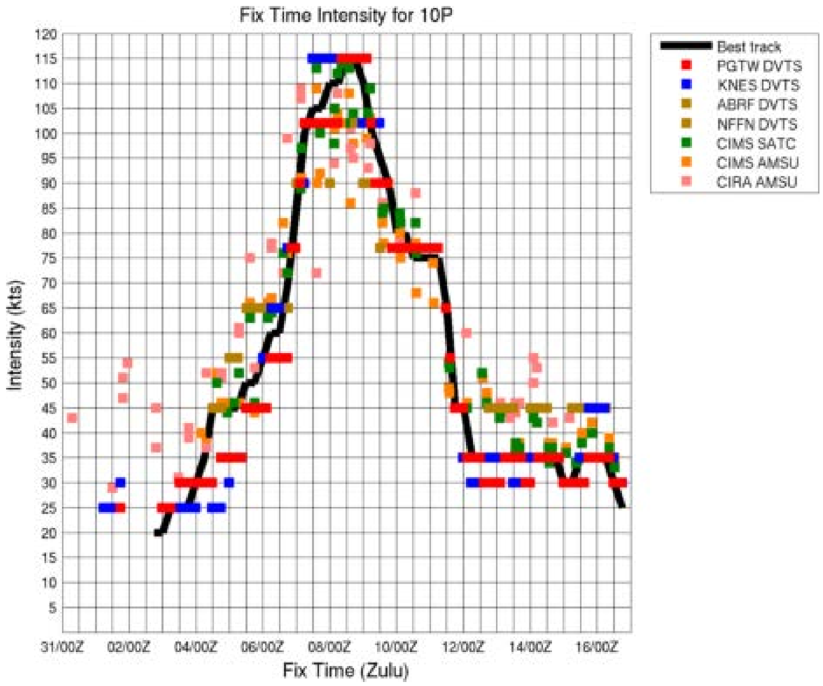
ISSUED LOW:	1200Z 22 Jan 2012
ISSUED MEDIUM:	1800Z 23 Jan 2012
FIRST TCFA:	1100Z 24 Jan 2012
FIRST WARNING:	1200Z 25 Jan 2012
LAST WARNING:	1200Z 02 Feb 2012
MAX INTENSITY:	70 Kts
WARNINGS:	26

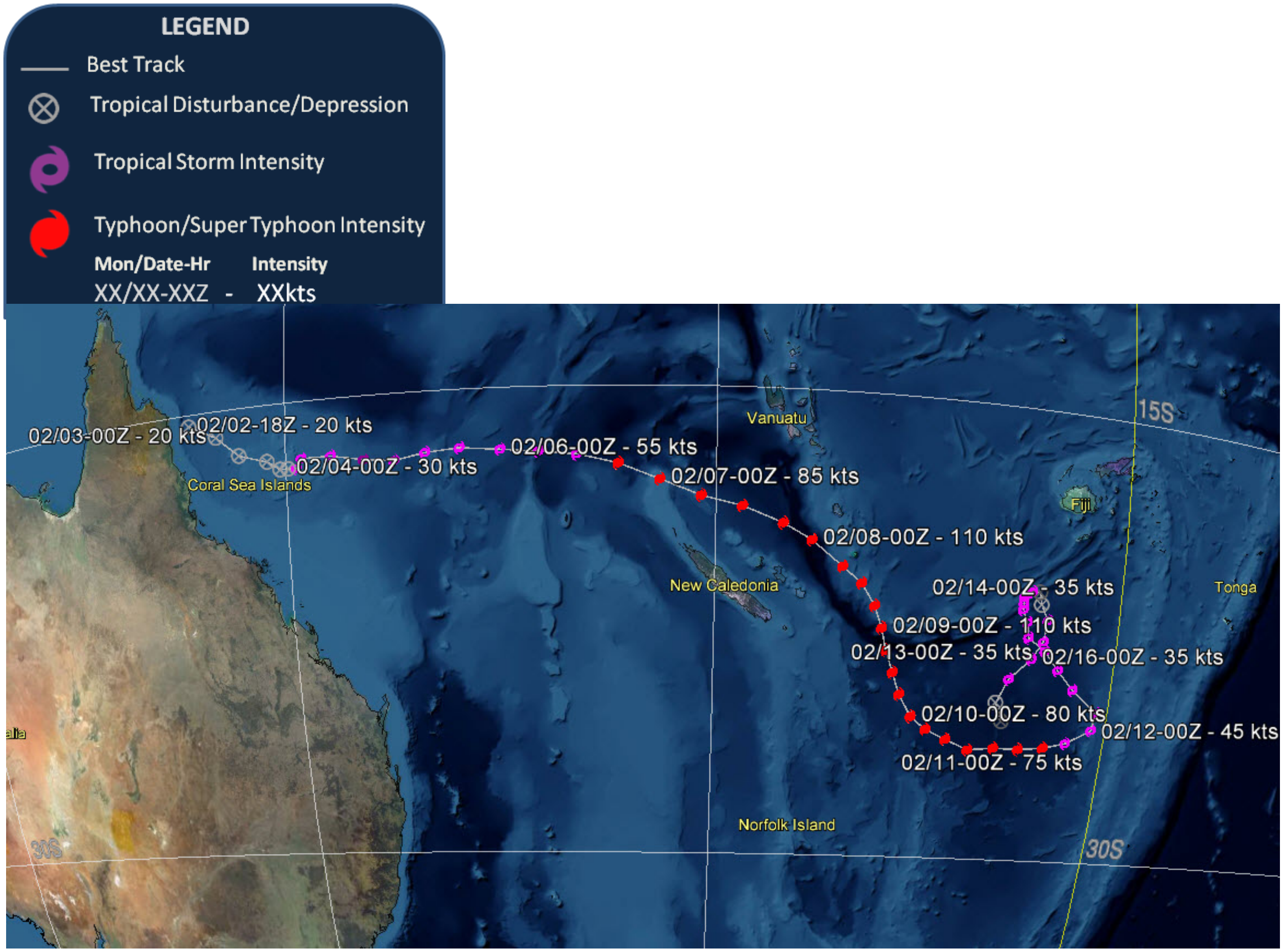




Tropical Cyclone 10P (Jasmine)

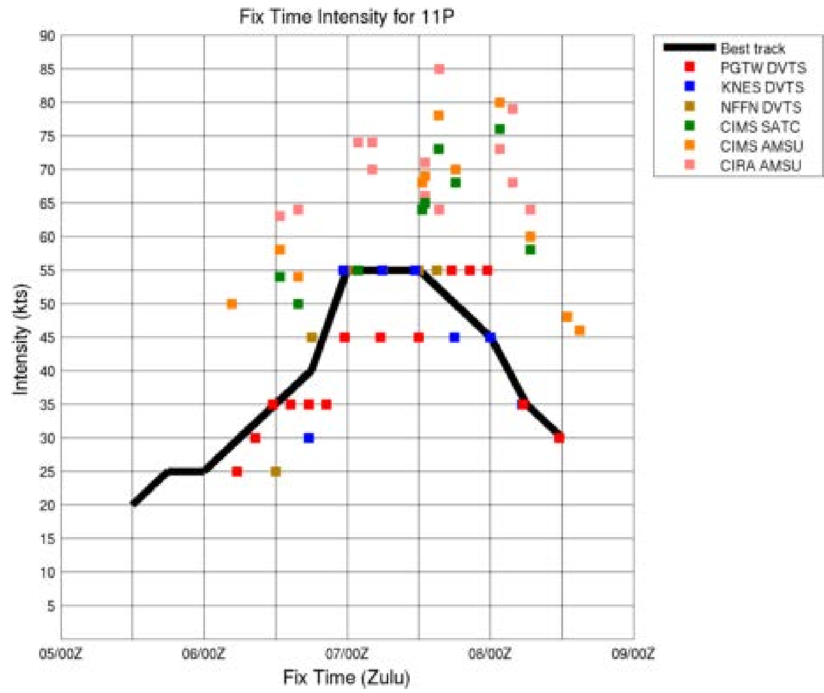
ISSUED LOW:	0600Z 31 Jan 2012
ISSUED MEDIUM:	2000Z 01 Feb 2012
FIRST TCFA:	2000Z 02 Feb 2012
FIRST WARNING:	0600Z 04 Feb 2012
LAST WARNING:	1800Z 15 Feb 2012
MAX INTENSITY:	115 Kts
WARNINGS:	24

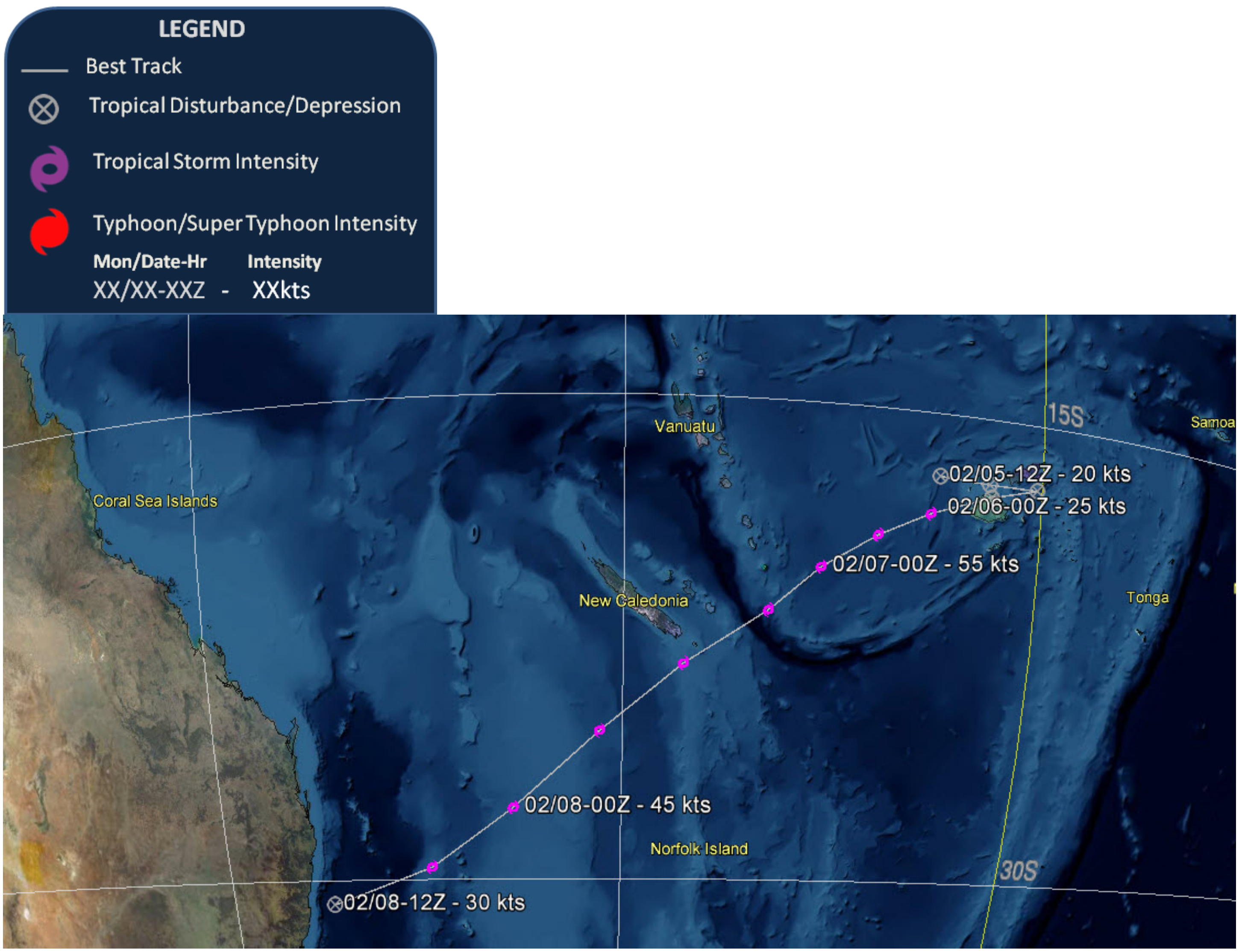




Tropical Cyclone 11P (Cyril)

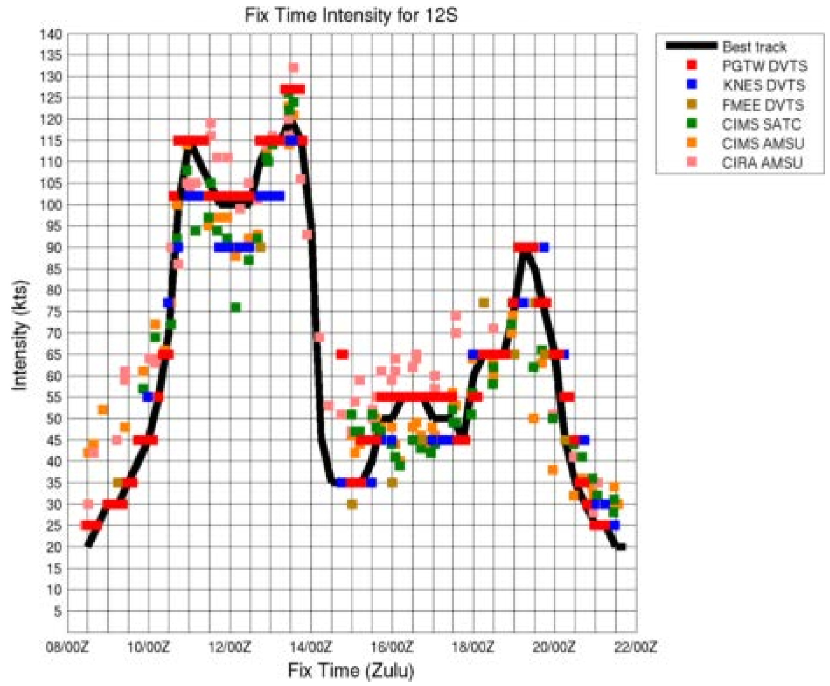
ISSUED LOW:	N/A
ISSUED MEDIUM:	0600Z 06 Feb 2012
FIRST TCFA:	0930Z 06 Feb 2012
FIRST WARNING:	1200Z 06 Feb 2012
LAST WARNING:	0000Z 08 Feb 2012
MAX INTENSITY:	55 Kts
WARNINGS:	4

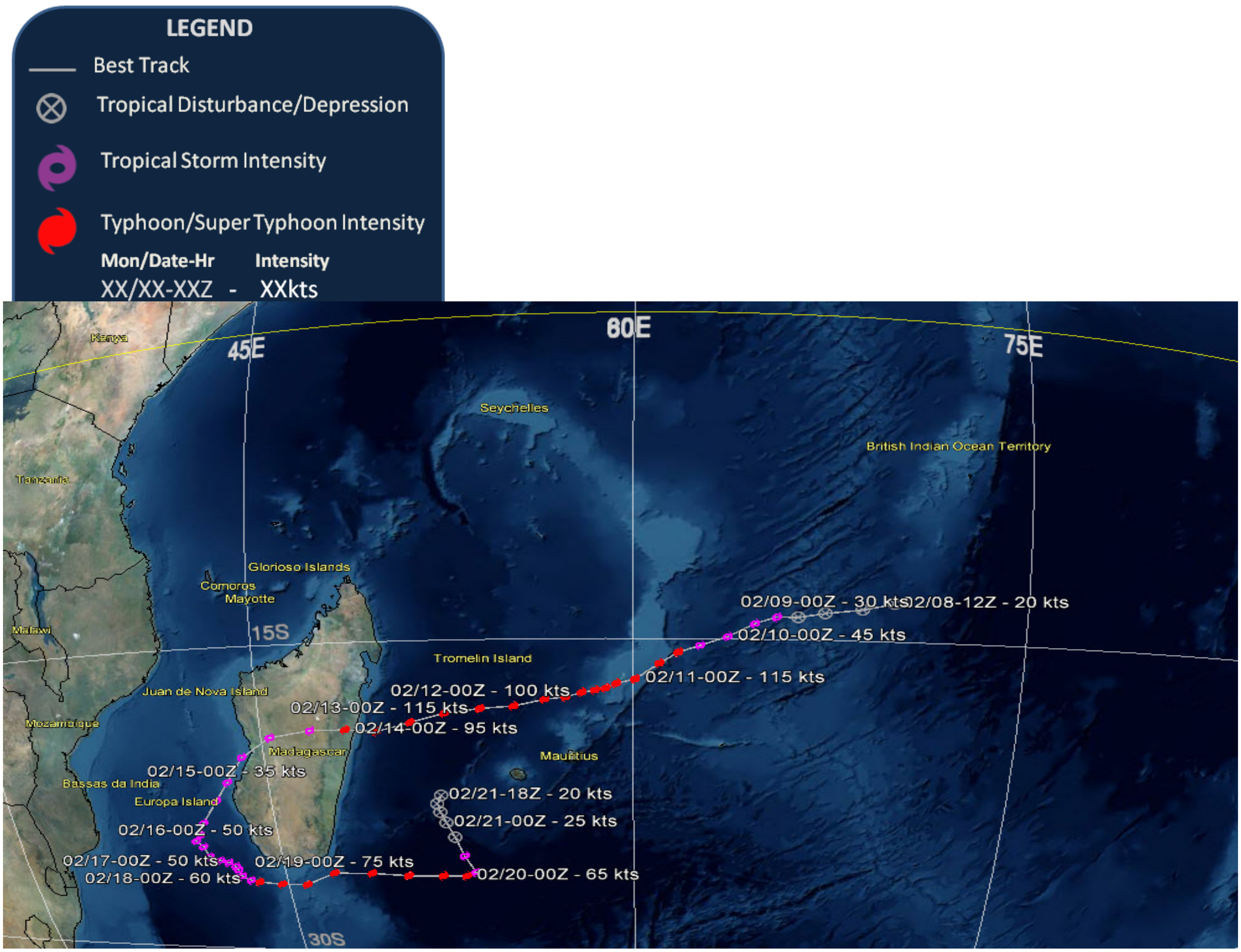




Tropical Cyclone 12S (Giovanna)

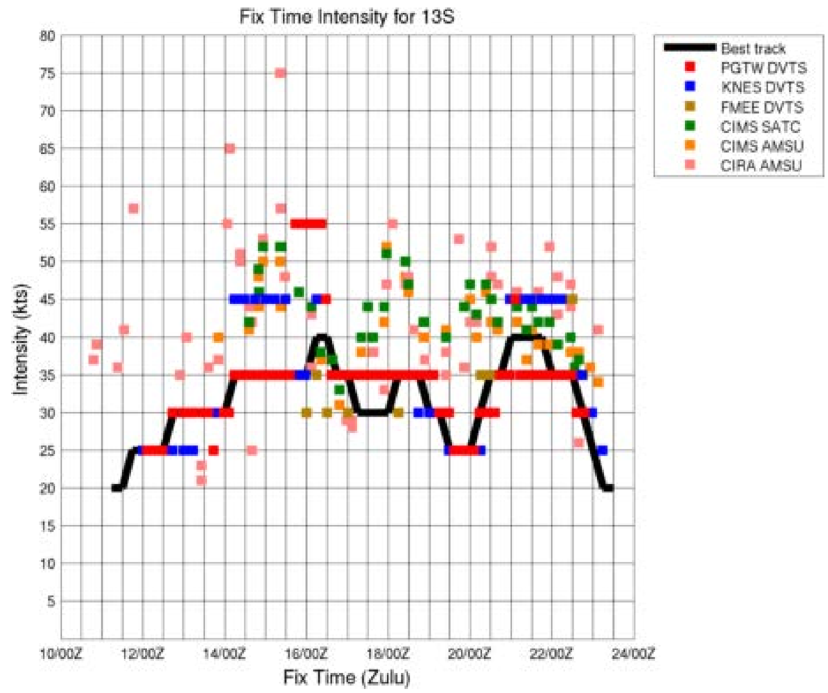
ISSUED LOW:	1330Z 08 Feb 2012
ISSUED MEDIUM:	1800Z 08 Feb 2012
FIRST TCFA:	2330Z 08 Feb 2012
FIRST WARNING:	1200Z 09 Feb 2012
LAST WARNING:	0000Z 21 Feb 2012
MAX INTENSITY:	25 Kts
WARNINGS:	120

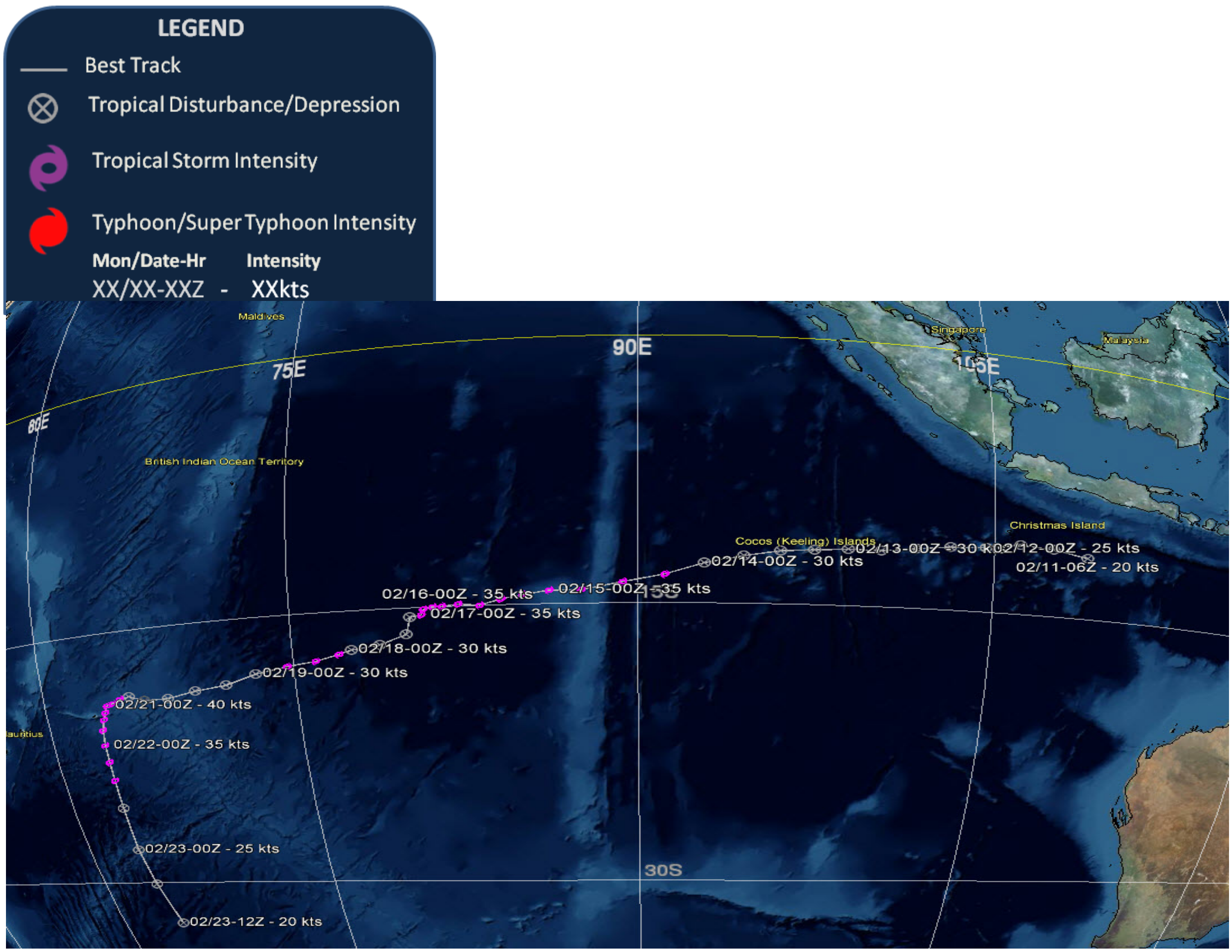




Tropical Cyclone 13S (Hilwa)

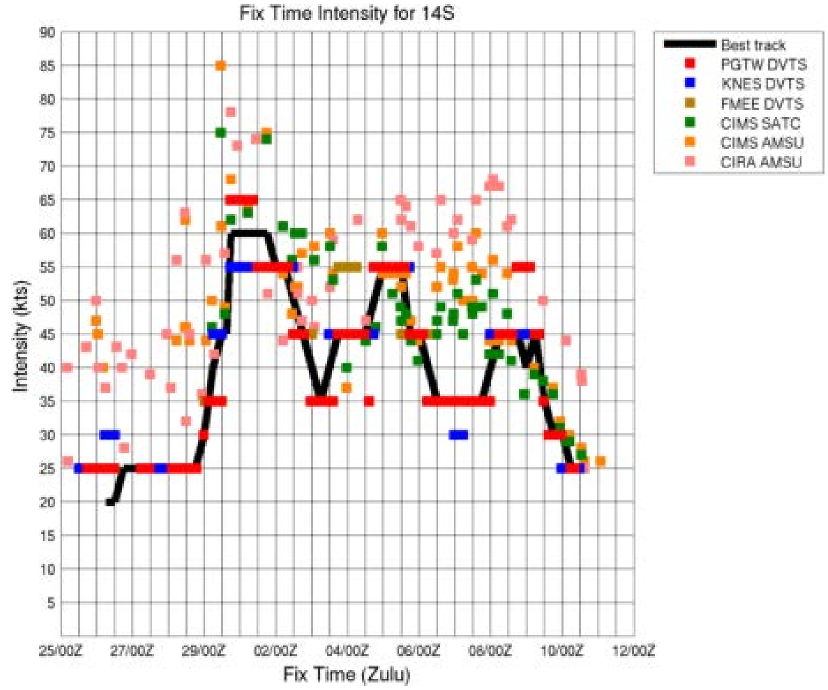
ISSUED LOW:	0600Z 11 Feb 2012
ISSUED MEDIUM:	1800Z 12 Feb 2012
FIRST TCFA:	1600Z 13 Feb 2012
FIRST WARNING:	0600Z 14 Feb 2012
LAST WARNING:	0600Z 22 Feb 2012
MAX INTENSITY:	40 Kts
WARNINGS:	18

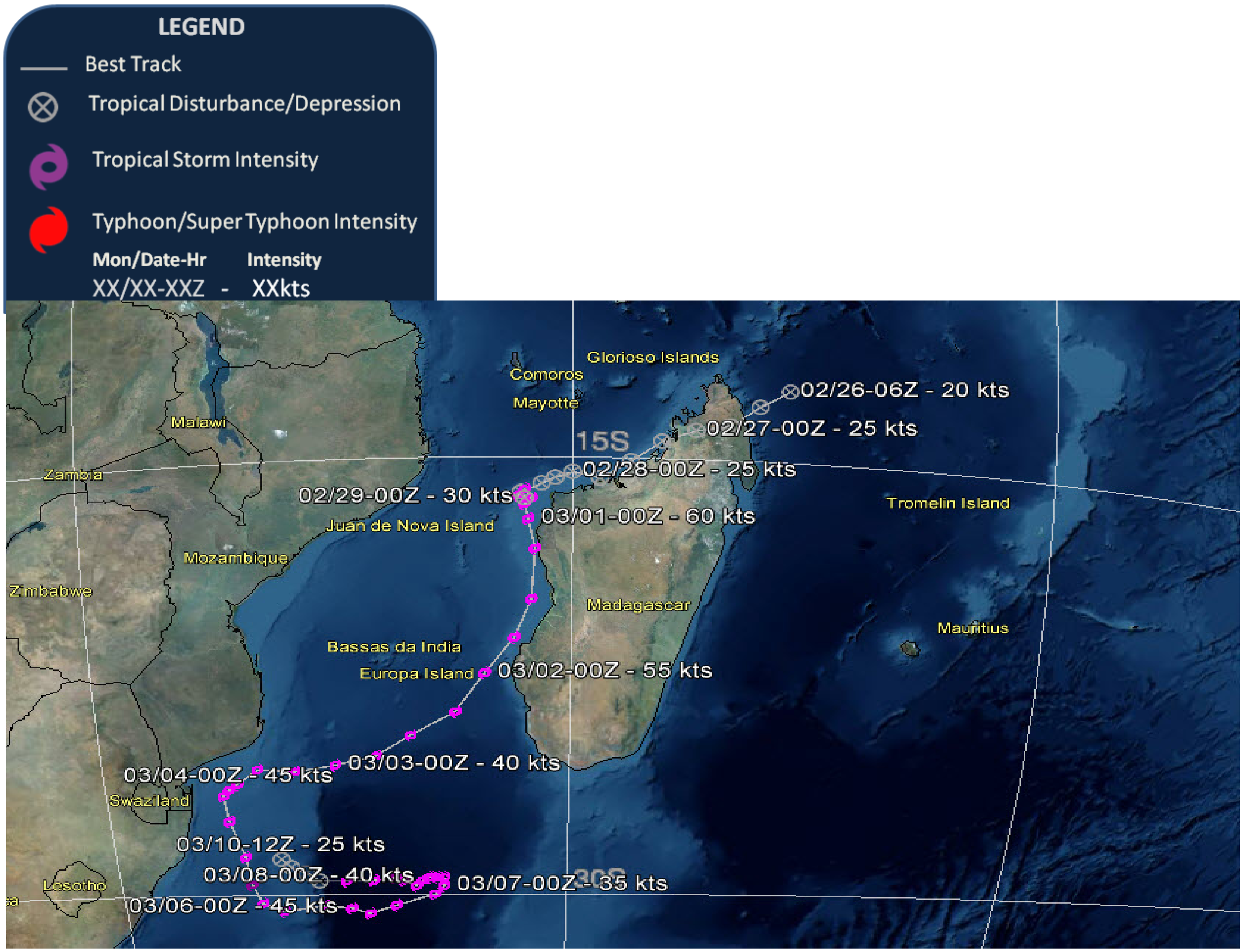




Tropical Cyclone 14S (Irina)

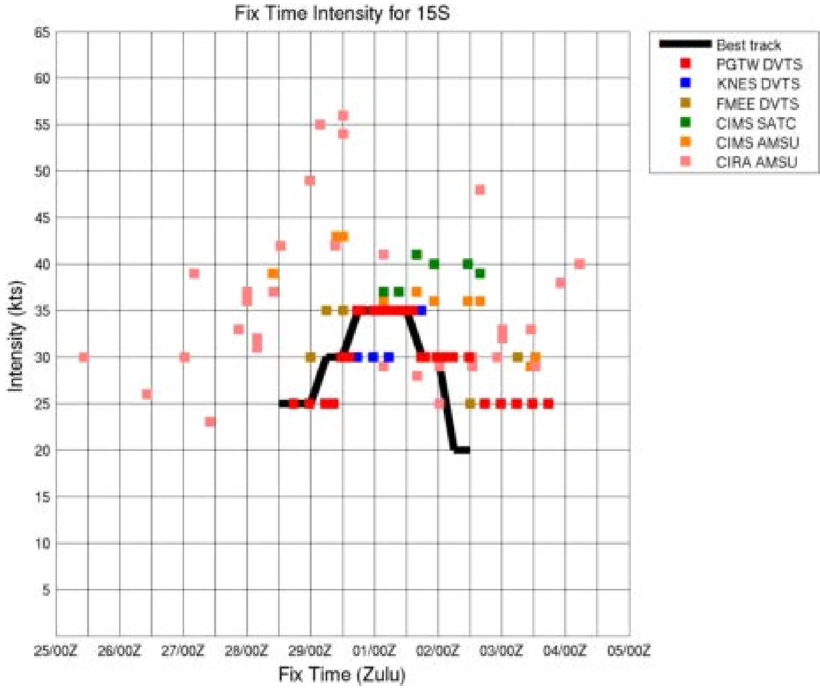
ISSUED LOW: N/A
ISSUED MEDIUM: 1800Z 25 Feb 2012
FIRST TCFA: 0130Z 26 Feb 2012
FIRST WARNING: 0000Z 29 Feb 2012
LAST WARNING: 0000Z 10 Mar 2012
MAX INTENSITY: 60 Kts
WARNINGS: 21

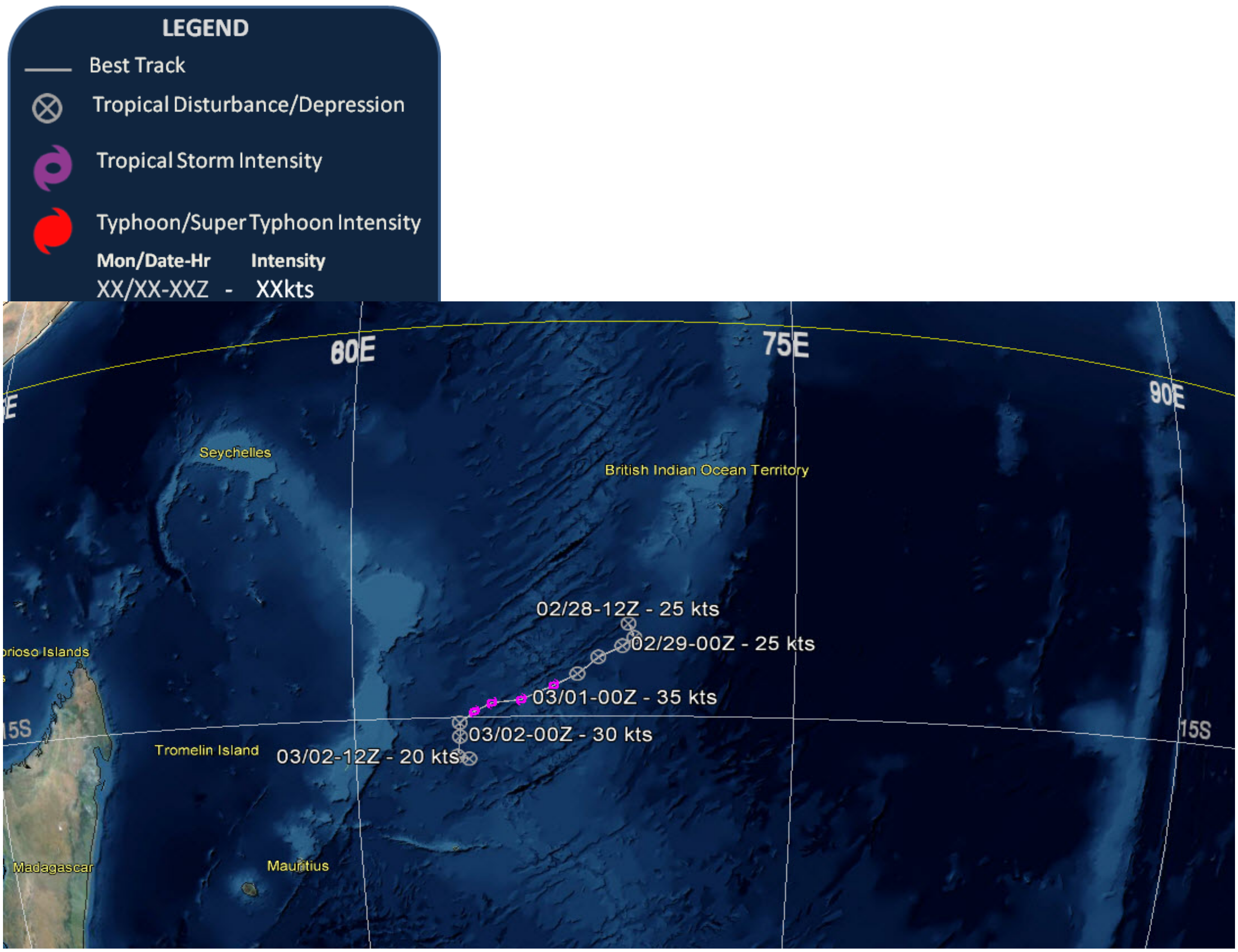




Tropical Cyclone 15S

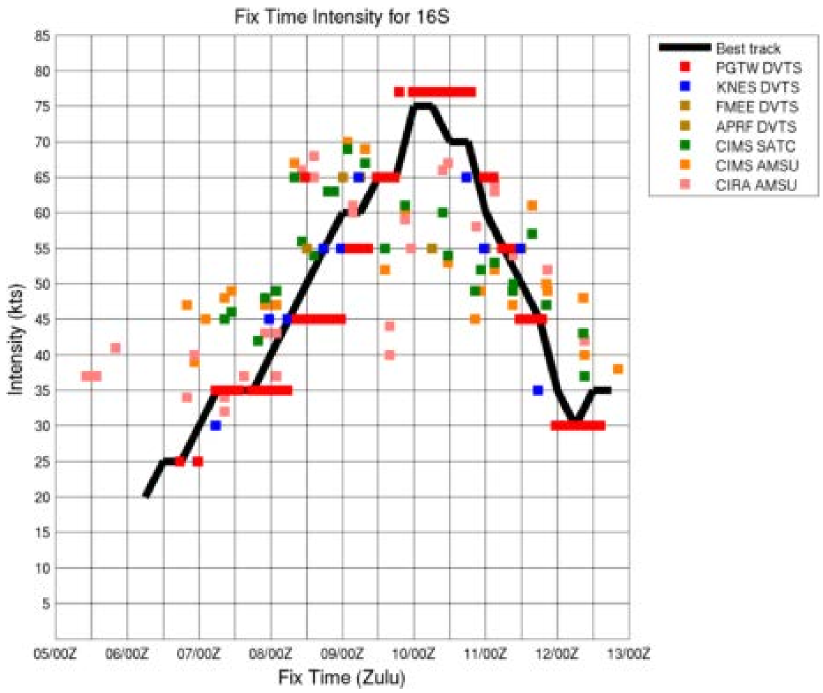
ISSUED LOW:	1800z 23 Feb 2012
ISSUED MEDIUM:	1800Z 28 Feb 2012
FIRST TCFA:	0800Z 28 Feb 2012
FIRST WARNING:	1800Z 29 Feb 2012
LAST WARNING:	1800Z 01 Mar 2012
MAX INTENSITY:	35 Kts
WARNINGS:	3

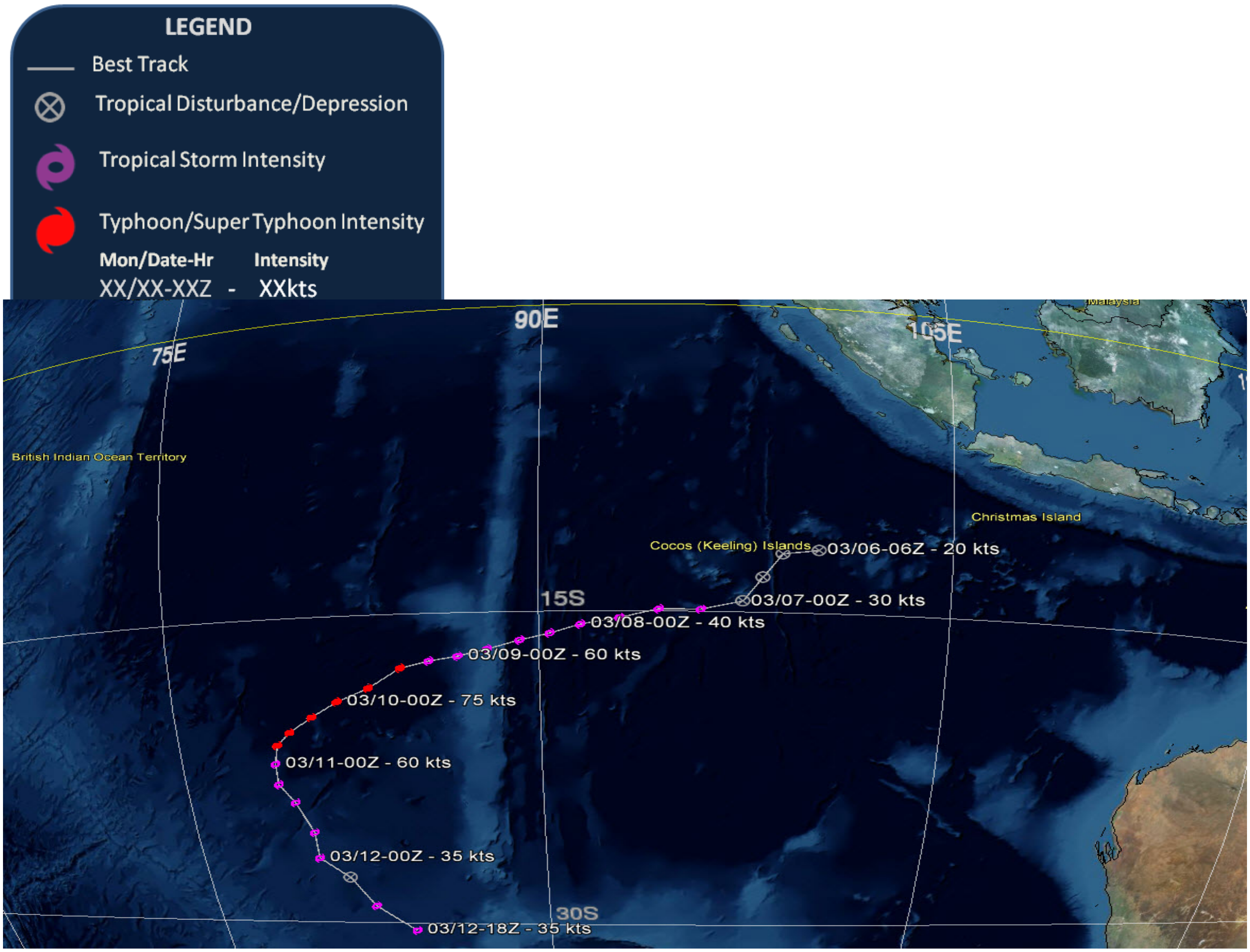




Tropical Cyclone 16S (Koji)

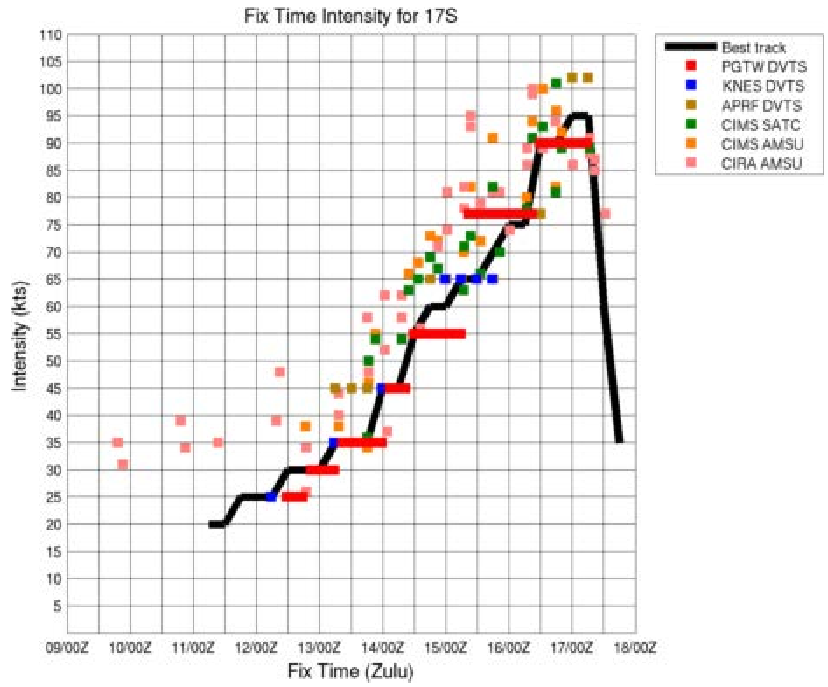
ISSUED LOW: 1800Z 05 Mar 2012
ISSUED MEDIUM: 1800Z 06 Mar 2012
FIRST TCFA: 0500Z 07 Mar 2012
FIRST WARNING: 0600Z 07 Mar 2012
LAST WARNING: 0600Z 12 Mar 2012
MAX INTENSITY: 75 Kts
WARNINGS: 11

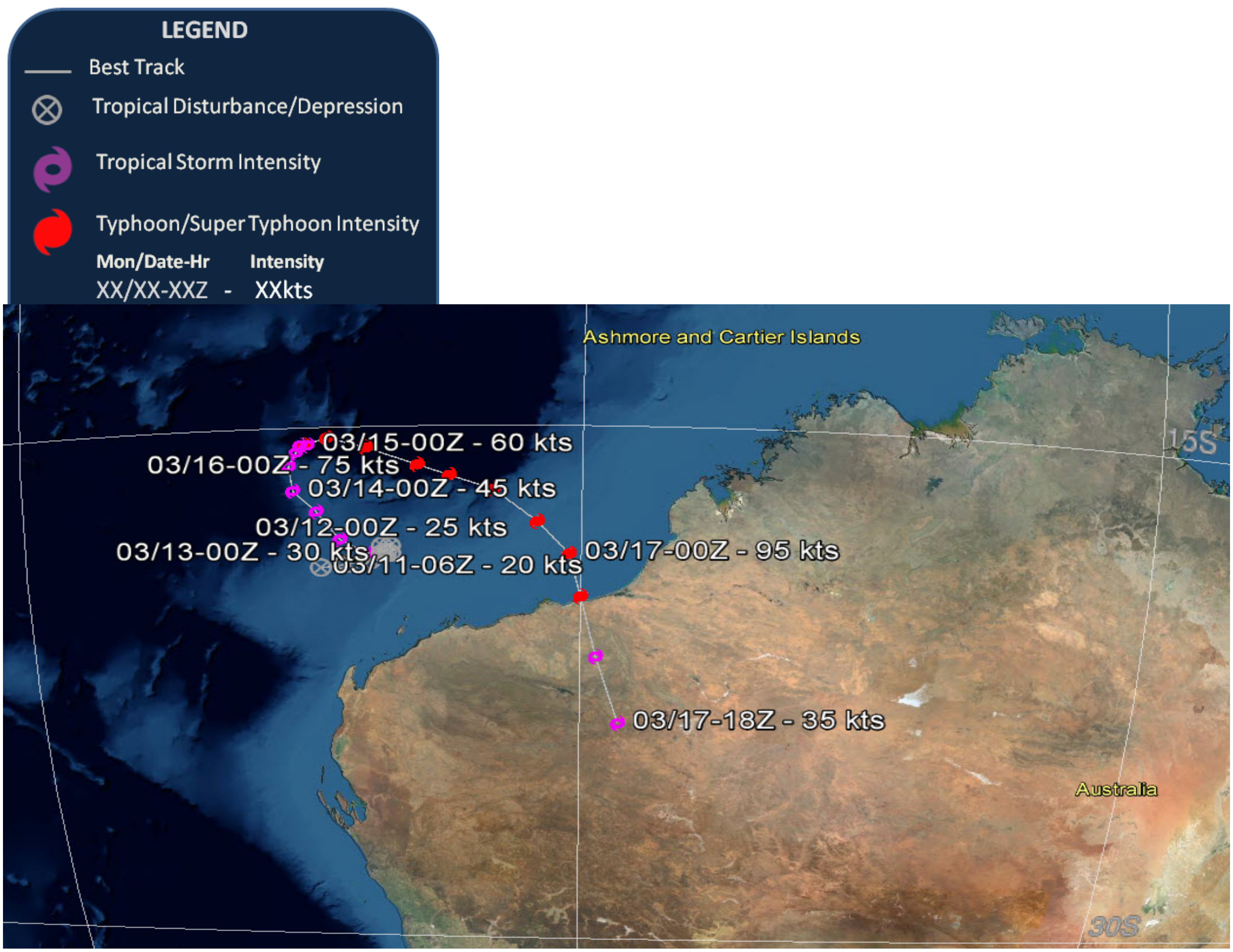




Tropical Cyclone 17S (Lua)

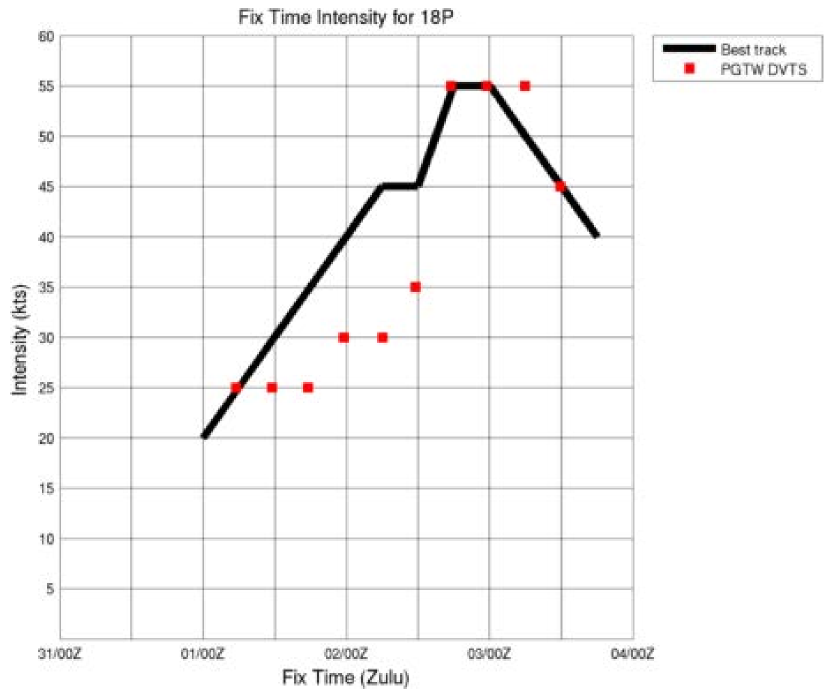
ISSUED LOW:	0000Z 09 Mar 2012
ISSUED MEDIUM:	1000Z 12 Mar 2012
FIRST TCFA:	2300Z 12 Mar 2012
FIRST WARNING:	0600Z 13 Mar 2012
LAST WARNING:	1200Z 17 Mar 2012
MAX INTENSITY:	95 Kts
WARNINGS:	12

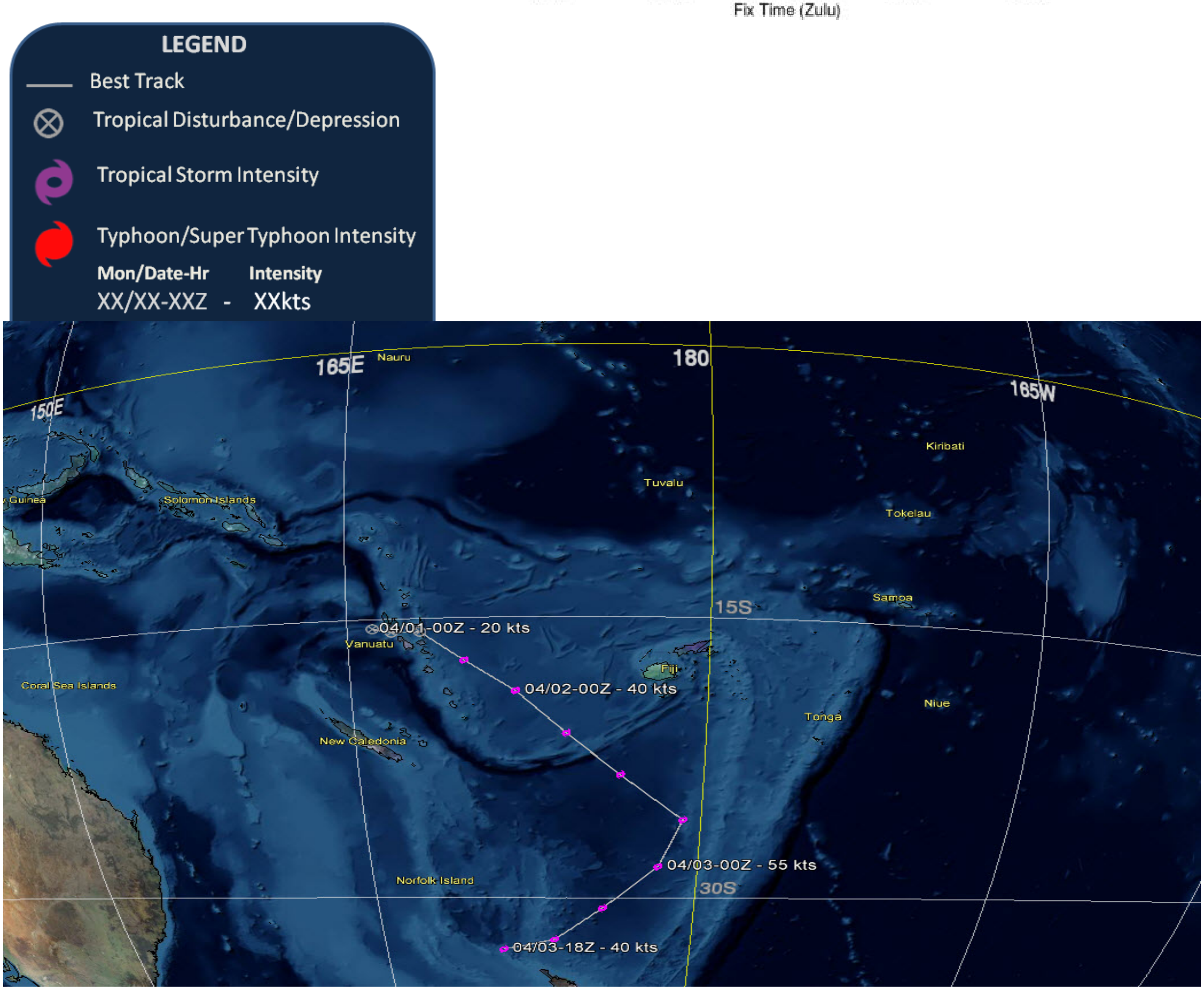




Tropical Cyclone 18P (Daphne)

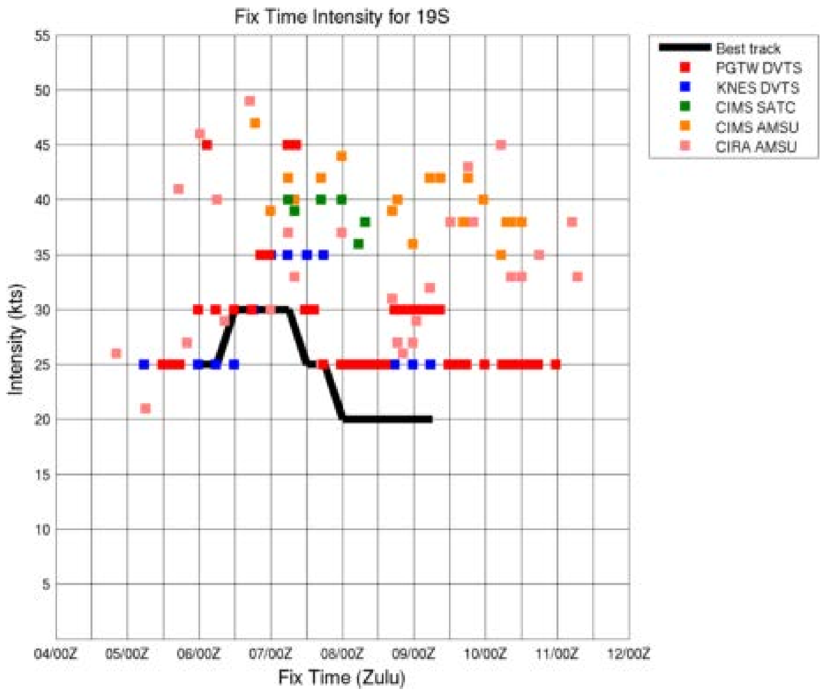
Regional Specialized Meteorology Center, Fiji warnings were used/distributed by Fleet Weather Center Norfolk during JTWC Continuation of Operations Plan (COOP) execution during the 2012 Tropical Cyclone Conference.

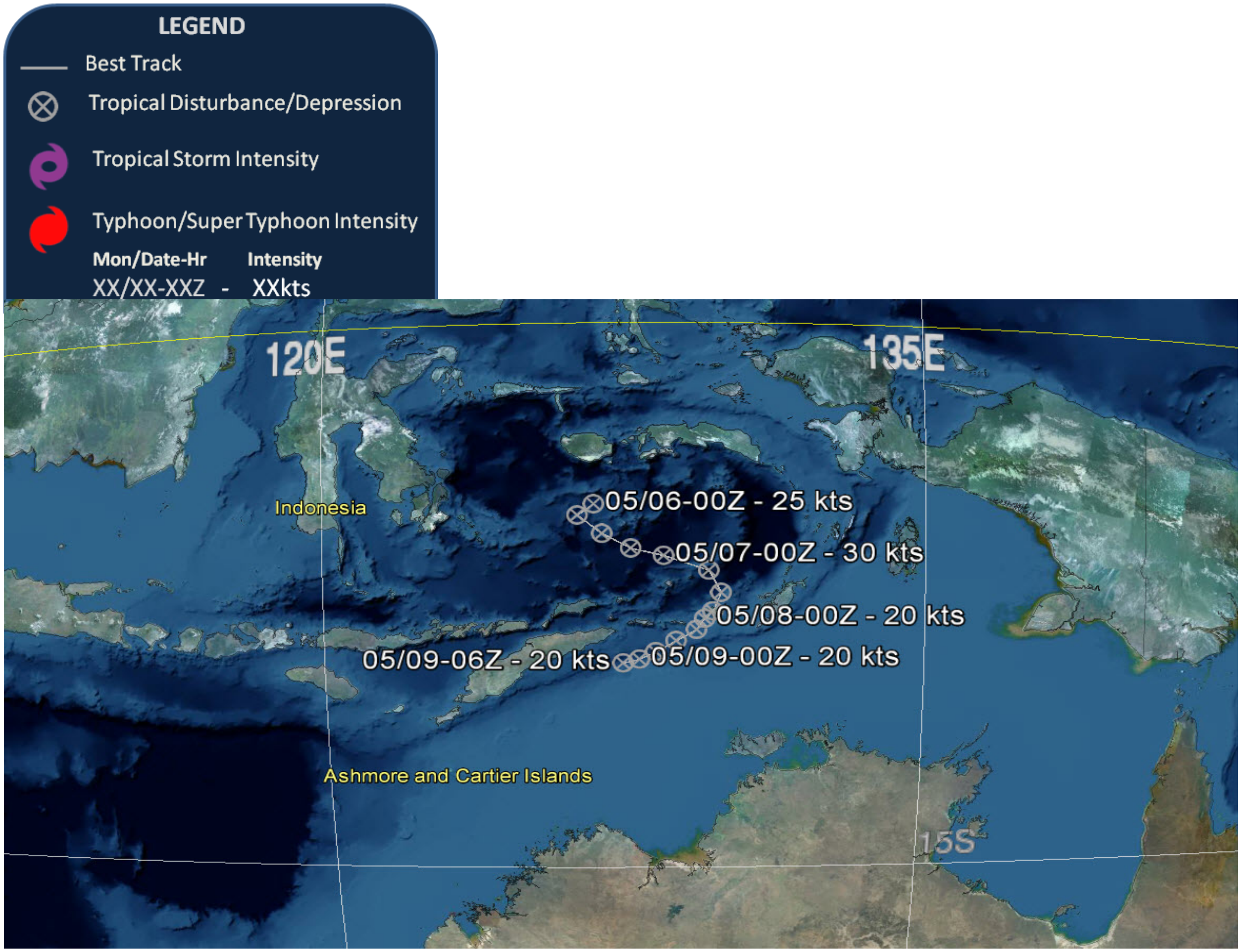




Tropical Cyclone 19S

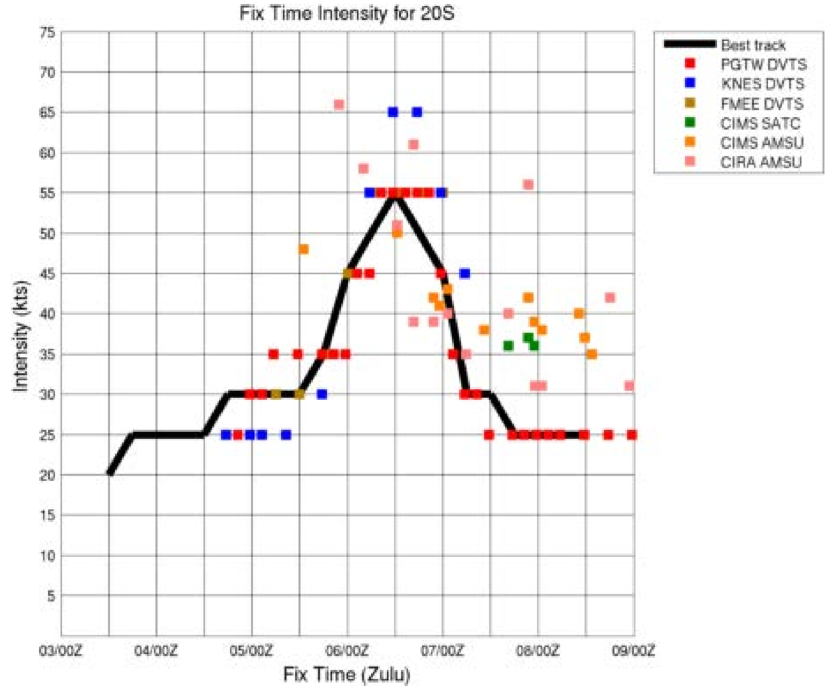
ISSUED LOW:	0730Z 05 May 2012
ISSUED MEDIUM:	1800Z 05 May 2012
FIRST TCFA:	1730Z 06 May 2012
FIRST WARNING:	0000Z 07 May 2012
LAST WARNING:	1200Z 07 May 2012
MAX INTENSITY:	30 Kts
WARNINGS:	2

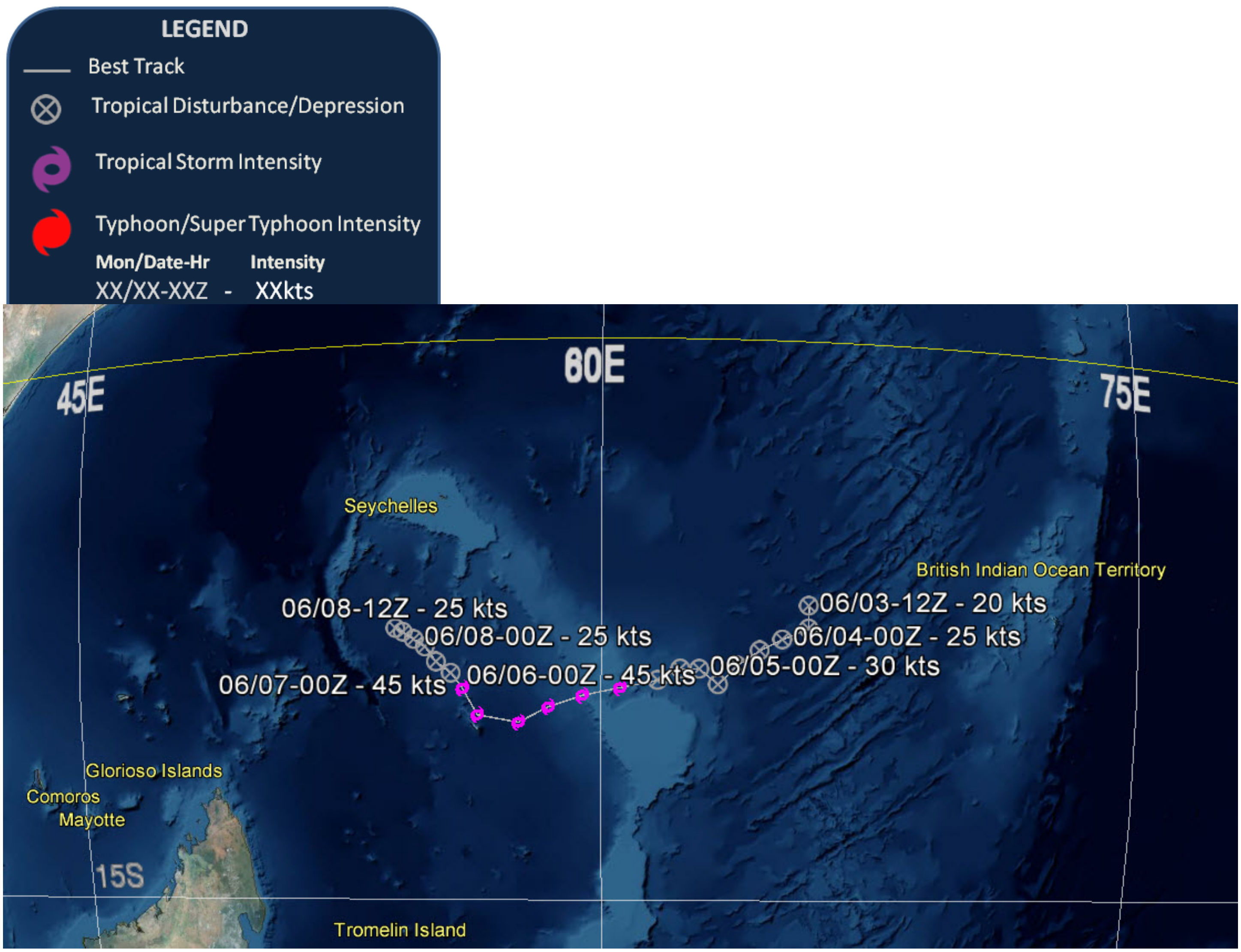




Tropical Cyclone 20S (Kuena)

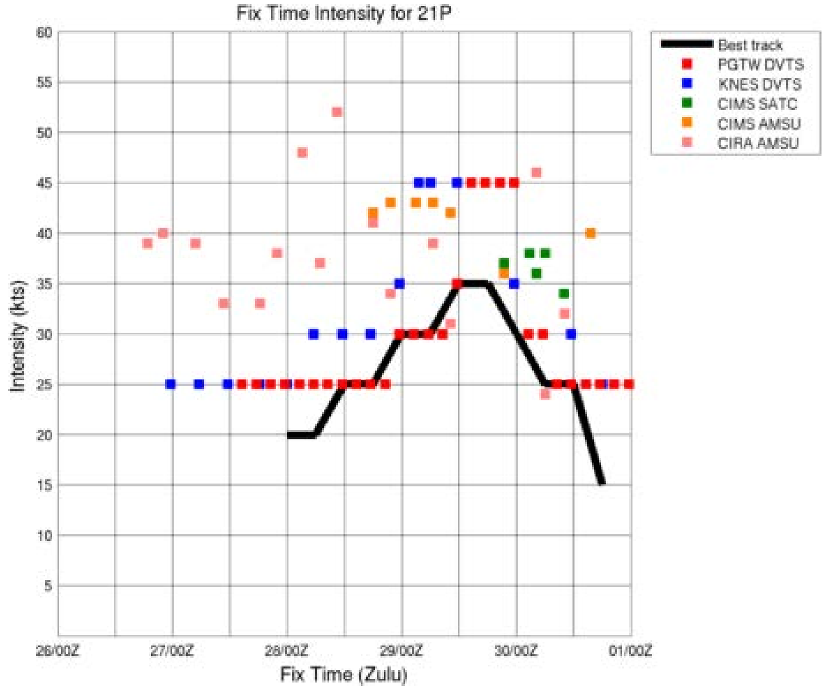
ISSUED LOW:	2030Z 04 Jun 2012
ISSUED MEDIUM:	1100Z 05 Jun 2012
FIRST TCFA:	2130Z 05 Jun 2012
FIRST WARNING:	0000Z 06 Jun 2012
LAST WARNING:	1200Z 07 Jun 2012
MAX INTENSITY:	55 Kts
WARNINGS:	4

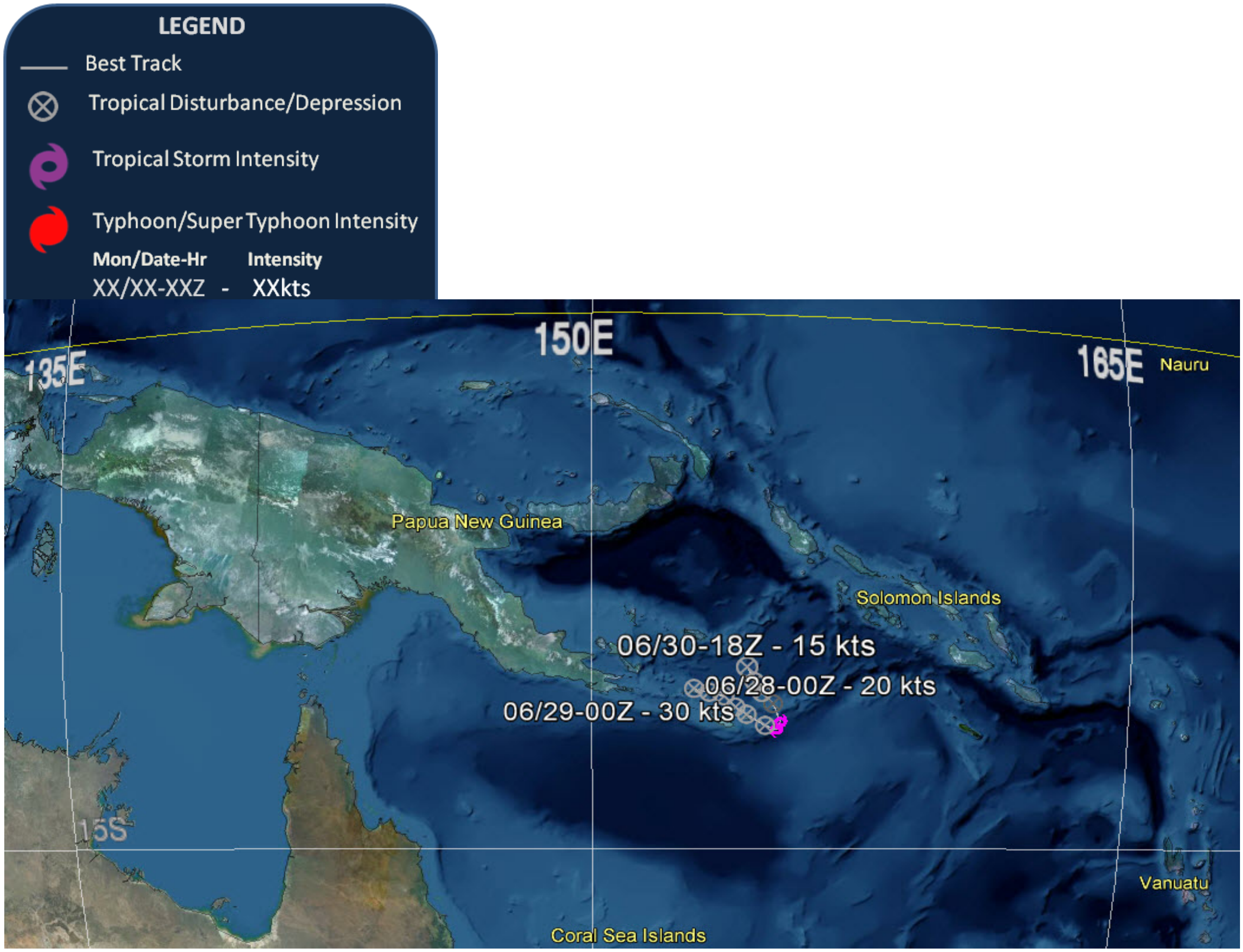




Tropical Cyclone 21P

ISSUED LOW:	1930Z 27 Jun 2012
ISSUED MEDIUM:	0600Z 30 Jun 2012
FIRST TCFA:	1000Z 29 Jun 2012
FIRST WARNING:	1200Z 29 Jun 2012
LAST WARNING:	0000Z 30 Jun 2012
MAX INTENSITY:	35 Kts
WARNINGS:	2





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 2012 year ended with slightly below average storms in the western North Pacific Ocean and near average in the North Indian Ocean. The Southern Hemisphere produced a below average number of storms with only 21 storms reaching 35 knots or greater. Satellite analysts exploited a wide variety of conventional and microwave satellite data to produce 8,526 position and intensity estimates. A total of 4,751 fixes were made using microwave imagery, amounting to over half of the total number of fixes. The USAF primary weather satellite direct readout system, Mark IVB, and the USN FMQ-17 continued to be invaluable tools in the TC reconnaissance mission. Section 2 tables depict fixes produced by JTWC 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 2012				
Tropical Cyclone		Visible/ Infrared	Microwave/ Scatterometry	Total
01W		33	29	62
02W	Pakhar	61	49	110
03W	Sanvu	69	107	176
04W	Mawar	56	82	138
05W	Guchol	88	148	236
06W	Talim	33	34	67
07W	Doksuri	37	44	81
08W	Khanun	40	51	91
09W	Vicente	43	52	95
10W	Saola	73	81	154
11W	Damrey	58	85	143
12W	Haikui	71	91	162
13W	Kirogi	61	84	145
14W	Kai-Tak	49	68	117
15W	Tembin	100	165	265
16W	Bolaven	80	153	233
17W	Sanba	65	102	167
18W	Jelawat	90	131	221
19W	Ewiniar	55	107	162
20W	Maliksi	39	49	88
21W	Gaemi	58	77	135
22W	Prapiroon	113	176	289
23W	Maria	56	90	146
24W	Son-Tinh	64	59	123
25W		21	13	34
26W	Bopha	111	161	272
27W	Wukong	43	43	86
DND		204	119	323
Totals		1871	2450	4321
Percentage of Total		43.30%	56.70%	100

TABLE 4-2

NORTH INDIAN OCEAN (BAY OF BENGAL/ARABIAN SEA) FIX SUMMARY FOR 2012

Tropical Cyclone		Visible/ Infrared	Microwave/ Scatterometry	Total
01A	Murjan	33	48	81
02B	Nilam	46	52	98
03B		54	59	113
04A		28	36	64
DND		38	28	66
Totals		199	223	422
Percentage of Total		47.16%	52.84%	100

TABLE 4-3

SOUTH PACIFIC & SOUTH INDIAN OCEAN FIX SUMMARY FOR 2012

Tropical Cyclone		Visible/ Infrared	Microwave/ Scatterometry	Total
01S	Alenga	63	89	152
02S		70	106	176
03S	Grant	43	17	60
04S	Benilde	62	82	144
05S	Chanda	39	10	49
06S	Heidi	31	39	70
07S	Ethel	44	80	124
08S	Funso	100	149	249
09S	Iggy	85	139	224
10P	Jasmine	126	125	251
11P	Cyril	21	43	64
12S	Giovanna	109	189	298
13S	Hilwa	90	154	244
14S	Irina	116	188	304
15S		40	49	89
16S	Koji	51	92	143
17S	Lua	44	64	108
18P	Daphne	20	0	20
19P		52	70	122
20S	Kuena	51	63	114
21P		31	32	63
DND		417	298	715
Totals		1705	2078	3783
Percentage of Total		45.07%	54.93%	100

Section 3: 2012 Automated Fix Assessment

In an effort to assess the utility of automated satellite position and intensity fixes, the JTWC Techniques Development team and Satellite Operations Flight analyzed data from 2010, 2011, and 2012 for the western Pacific Ocean and Indian Ocean basins. Subjective Dvorak fix data from PGTW and KNES along with objective Dvorak fix data from Advanced Dvorak Technique (ADT), CIRA AMSU, CIMMS AMSU, and SATCON were compared to JTWC official best track data. Our assessment is that automated fixes have continued to improve over the past three years, and each fix method can be used to aid the JTWC analysis and forecast process. However, due to various errors and biases of each product based on intensity and basin, the application of objective fix data varies for different TC scenarios. Therefore, a process is underway to develop rules of thumb for determining where and when analysts and forecasters can effectively use each objective method.

Chapter 5 Techniques Development Summary

Section 1: Background

The JTWC Techniques Development (TECHDEV) team facilitates operations and improves TC analyses and forecasts through scientific study, techniques development, information technology exploitation, data evaluation, and process improvement. This section of the 2012 ATCR provides a brief overview of scientific and operational resource projects conducted by the JTWC TECHDEV team during 2012 as well as a preview of future work.

Section 2: 2012 Projects

Classifying TC genesis potential

TECHDEV analyzed “Deviation Angle Variance (DAV)” data provided by the University of Arizona (project lead: Dr. Elizabeth Ritchie) for western North Pacific tropical disturbances between August and December, 2012. The DAV technique indicates tropical cyclogenesis potential by quantifying the convective symmetry of tropical disturbance cloud clusters derived from infrared radiance data (Piñeros et al. 2008; Piñeros et al. 2010). Previous work has demonstrated that symmetrical tropical cloud clusters with associated DAV values below a threshold value are more likely to develop into self-sustaining TCs than more asymmetric cloud clusters with associated DAV values that above the threshold (Piñeros et al. 2010).

DAV values derived from MT-SAT infrared satellite data were presented to JTWC forecasters within an hour of each image time via an interactive, password-protected web interface during the western North Pacific TC season (figure 1). These data were evaluated in real-time by JTWC Geophysical Technicians and forecasters as part of the tropical disturbance monitoring process, and were incorporated into the JTWC “LMH Worksheet” as an experimental parameter (Kucas and Darlow 2012). DAV data for specific best track locations were also provided to JTWC to facilitate in-depth, post-season evaluation.

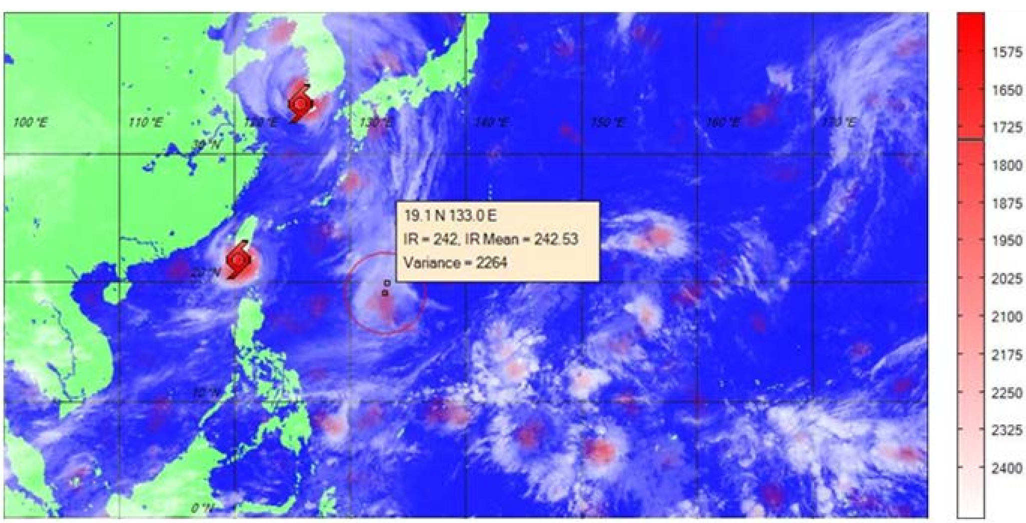


Figure 5-1: Sample image from the interactive DAV website developed by the University of Arizona research team. The interface allows forecasters to retrieve DAV values by clicking on any target point within the image. The solid line shows the DAV threshold value (1750) determined through prior study.

Post-season analysis indicated that DAV values for developing cyclones infrequently dropped below the previously-cited genesis threshold value of 1750 prior to or at first warning times. However, setting a higher threshold DAV value yielded a 100% probability of detection with a false alarm rate, for classified invests, of approximately 15%. Further work is needed to determine if these promising results, obtained from setting a higher threshold, are repeatable. TECHDEV plans to continue evaluating the DAV technique during the upcoming 2013 western North Pacific TC season.

Operational review of Genesis Potential Index (GPI)

Evaluation of the Naval Research Laboratory (Dr. Melinda Peng) and University of Hawai'i (Drs. Tim Li and Bing Fu, and Duane Stevens) tropical cyclone genesis potential index (GPI) continued in 2012. The GPI routine applies an empirically-derived equation relating the near-disturbance 800mb vorticity anomaly, 750 mb zonal wind gradient (both derived from NOGAPS/NAVGEM global model output), and near-disturbance TRMM three-hour average satellite-derived rain rates to tropical cyclogenesis potential (Fu et al. 2011; Peng et al. 2011;Bing Fu, personal correspondence). Genesis potential index (GPI) values that exceed a threshold value (0.2) indicate that a TC is likely to form within a 24 to 48 hour forecast period, while values below the threshold indicate that development is unlikely. JTWC provided real-time best track data to the GPI research team and subsequently reviewed real-time GPI model data provided by the University of Hawaii from June through September, 2012. Results continued to be favorable, with GPI generally increasing in the lead-up to formation for developing cyclones, and decreasing over time for non-developers. The GPI model will be implemented at JTWC during the upcoming 2013 western North Pacific TC season for a final evaluation and eventual integration into the routine TC formation forecasting process.

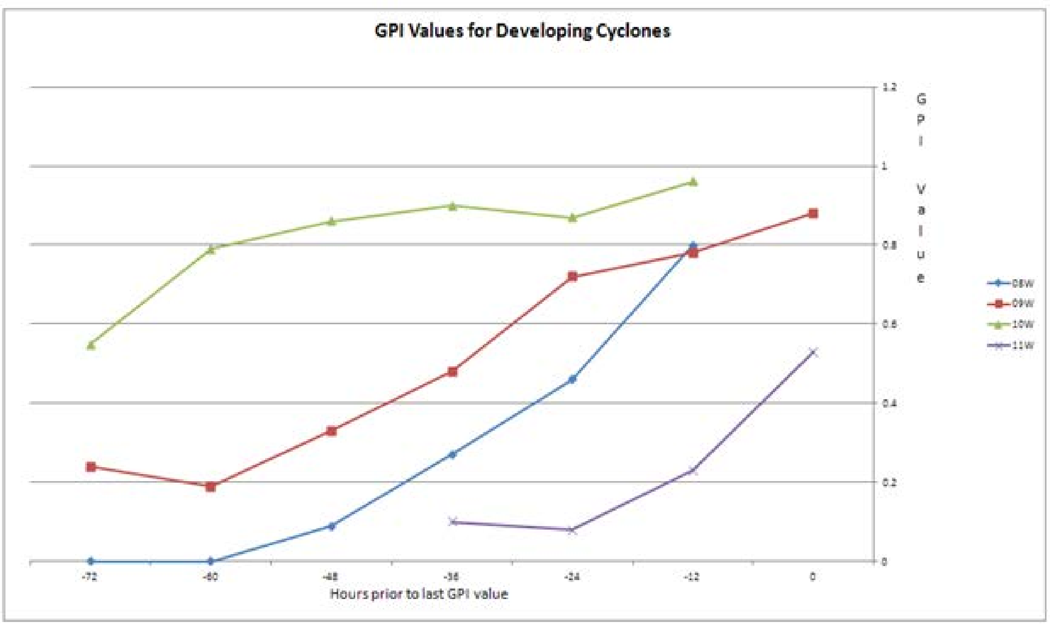


Figure 5-2. Genesis Potential Index (GPI) calculated in near real-time for the 72 hour period preceding formation (first warning) time on tropical cyclones 08W through 11W (July 2012). Operational and after-the-fact evaluation once again indicated that GPI trends are a useful indicator of either imminent TC formation or dissipation of non-developing disturbances.

Operational review of the Naval Postgraduate School Long Lead Tropical Cyclone Formation Model

Dr. Thomas Murphree and Mr. David Meyer of the Naval Postgraduate School have developed a statistical-dynamical model to forecast tropical cyclogenesis probabilities in the western North Pacific basin at 0 to 90-day lead-times. Based on the results of previous tropical cyclogenesis studies, the researchers hypothesized that tropical cyclones will most likely form where the values of a specific set of large-scale environmental factors (LSEFs) – namely, SST, vertical wind shear, relative humidity, relative vorticity, Coriolis parameter, and divergence aloft (a proxy for vertical velocity) - exceed key thresholds. Performing a backward stepwise regression on LSEF values extracted from NCEP reanalysis data and tropical cyclogenesis locations derived from JTWC best tracks, the researchers derived an equation set that relates the probability of tropical cyclogenesis to the values of all LSEFs at a given location (2.5 degree square areas) across the western North Pacific basin. In a follow-on study, LSEF values calculated from National Centers for Environmental Prediction Climate Forecast System Reanalysis (CFSR) data were used to update the predictive statistical equation set derived in the initial study. The resulting statistical-dynamical forecasting system, a blend of the LSEFs derived from a lagged-ensemble of CFSv2 climate model forecasts and the derived equations relating LSEFs to TC formation probability, predicts tropical cyclone formation probabilities at 0 to 90-day lead times (Murphree and Meyer 2012, personal correspondence; Meyer 2013).

From July through November, 2012, the NPS research team provided one-day and four-day tropical cyclone formation probability values to JTWC via the Naval Postgraduate School Collaborative Learning & Research Portal. Forecast data were presented for the western North Pacific basin in graphical format (see figure below). JTWC also received one-week and two-week formation probability forecasts prepared for the Climate Prediction Center's Global Tropics Hazards product discussion.

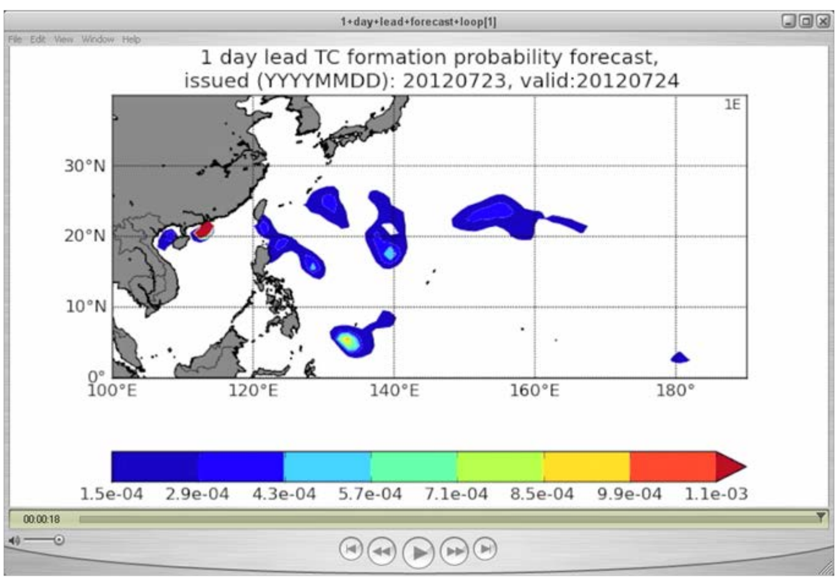


Figure 5-3: Example NPS tropical cyclone formation probability forecast graphic for a one-day forecast lead time.

One-day lead formation probability data were collected for ten classified invests that developed into tropical cyclones (17W - 26W) and twenty invests that did not develop during the evaluation period. These values were recorded at each synoptic time by JTWC Geophysical Technicians as part of the tropical disturbance monitoring process, and were incorporated into the JTWC "LMH Worksheet" as an experimental parameter (Kucas and Darlow 2012). The results of our analysis suggested that short-term formation probability products, when considered in context of other available data either subjectively or via the JTWC Low-Medium-High worksheet, may improve invest development potential classification recommendations. Likewise, for classified invest areas, development into a tropical cyclone was somewhat more likely to occur within areas of enhanced formation probabilities highlighted in the one- and two-week lead forecasts. TECHDEV will continue to evaluate the model's formation probability forecasts, and associated modifications recommended by JTWC and implemented by the research team, during the upcoming 2013 western North Pacific TC season.

ECMWF ensemble: Forecasting formation, track, and intensity

Dr. Russell Elsberry, Ms. Mary Jordan (Naval Postgraduate School – NPS), and Dr. Hsiao-Chung Tsai (visiting scientist to NPS from the Taiwan Central Weather Bureau), provided tropical cyclone track and intensity forecasts for one to four week lead times and tropical cyclone track and intensity forecast clusters derived from ECMWF ensemble model forecasts to JTWC via the Naval Postgraduate School Collaborative Learning & Research Portal from August through December, 2012 (Elsberry et al. 2011; Tsai and Elsberry, 2013). Thirty-two day ensemble forecast data were recorded at each synoptic time by JTWC Geophysical Technicians as part of the tropical disturbance monitoring process, and were incorporated into the JTWC "LMH Worksheet." In addition, TECHDEV conducted a subjective, post-season evaluation of these forecast products. Our analysis indicated that the forecasts provide useful indications of tropical cyclone formation potential and forecast track probabilities. JTWC will work closely with the research group to improve the prediction scheme, particularly to reduce a relatively high TC formation false-alarm rate, provide in-season feedback, and conduct a full post-season evaluation of the ensemble forecast data for the 2013 western North Pacific TC season.

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 20 km horizontal resolution for a global tropical domain and at 4 km horizontal resolution for selected areas. Ensemble member forecasts are initialized with atmospheric fields from three global models: the UK Met Office Unified model, GFS, and the Canadian Global Model. Model physics and boundary conditions are also varied for each member run (Hacker et al, 2011; Kuchera et al, 2012).

AFWA recently transitioned the MEPS ensemble into operations, dedicating two, 4 km storm-centered domain runs (one at 0000Z, another at 1200Z) to modeling tropical disturbances and cyclones upon request from JTWC. Ensemble output is provided in the form of model output graphics (figure 4), significant weather probabilities, and tropical cyclone vortex trackers for both the 20 km global tropical domain and requested 4 km runs. JTWC, in cooperation with AFWA (project lead Mr. Evan Kuchera), will conduct a full evaluation of MEPS ensemble performance for tropical cyclone forecasting during the 2013 western North Pacific TC season.

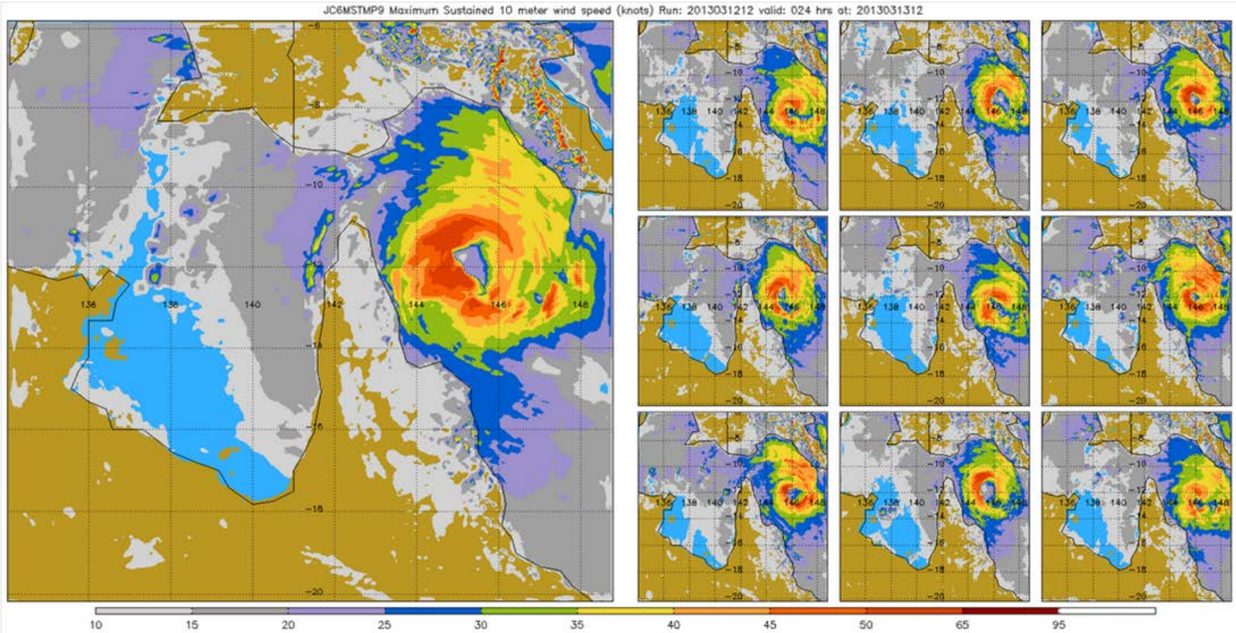


Figure 5-4: Example 24-hour surface wind speed forecast from the ten members of the AFWA MEPS ensemble. The control run is shown in the large panel at left, and forecasts from the other nine members depicted in the smaller "stamp charts" to the right. The ensemble accurately depicted rapid development of tropical disturbance 96P into a tropical cyclone within the 24 hour forecast period.

Global Tropics Hazards product

JTWC TECHDEV continued to provide medium-range 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.

JTWC Product KMLs

TECHDEV has developed KML data files containing track, intensity, and formation data for tropical cyclone warnings and tropical cyclone formation alerts (TCFAs) generated within the Automated Tropical Cyclone Forecasting system (ATCF). These KML files are available on JTWC web pages for all TCFAs and tropical cyclones in warning status.

Mesoscale models

Recent studies and statistics suggest that state-of-the-art mesoscale models are producing increasingly skillful predictions of tropical cyclone intensity and structure. Recognizing this trend, JTWC renewed its focus on incorporating mesoscale model output into the forecast process in 2012. A summary of ongoing and future work to both apply mesoscale model forecast output to real-time forecasting and to develop new operational applications for these data is provided in Section 4.

Section 3 Future projects

The year ahead promises several developments in analysis and forecasting at JTWC. In addition to continuing several projects highlighted in section 2 of this summary, TECHDEV will pursue the following:

- **Electronic streamline analysis:** JTWC currently produces streamline analyses of upper and gradient-level winds for its forecast area of responsibility twice daily (0000Z and 1200Z). These analyses are hand-drawn on paper charts, and subsequently scanned for uploading to DoD METOC web sites. Beginning in 2013, JTWC will hand-analyze these data on electronic tablets, facilitating the generation and transfer of analysis data and enabling JTWC and its customers to overlay streamlines in geospatial data display systems.

- **Cyclone phase worksheet**: TECHDEV will evaluate and implement a first-of-its-kind worksheet to guide cyclone phase classifications (tropical, subtropical, or extra-tropical) based on subjective analysis of readily available datasets.

- **Tropical cyclone data plots:** The production and distribution of several, manually-generated tropical cyclone data plots will be fully automated ahead of the western North Pacific TC season using computer programs and procedures developed by TECHDEV. Additional TC data plots will be provided for the JTWC Decision Support website.

Section 4 Summary of mesoscale models: Current use and future development

The JTWC is actively evaluating the application of mesoscale models for TC track and intensity forecasting. Current plans are to evaluate operational forecasts from all mesoscale models available to JTWC and develop a multi-model consensus from a subset of skilled mesoscale models with the goal of improving TC intensity forecasts.

Operational global models running at horizontal resolutions between 13-50 km have been shown to simulate the synoptic scale factors responsible for tropical cyclone track motion well (e.g., average 2012 five-day errors for GFS, ECMWF, and NOGAPS were 260, 267 and 290 nm, respectively). However, the spatial and temporal resolutions are too coarse to adequately resolve fine-scale TC inner core processes responsible for driving intensity change. Mesoscale models capable of higher resolution (typically considered to be below 10 km) have existed for many years. For example, JTWC has been using forecasts from the Geophysical Fluid Dynamics Lab (GFDL) – Navy version model (*a.k.a.,* GFDN) since 1996 (Kurihara et al., 1995). Despite having higher resolution, single mesoscale model intensity forecast skill has shown little to no significant improvement over the past decade. Because of this lag, TC intensity forecast improvement is currently the number one priority among all U.S. TC forecast centers (Oceanic and Atmospheric Research, 2013). Accurately modeling TC intensity is a complex problem that is particularly challenging in the JTWC AOR due to the large number of systems that experience rapid intensification (RI) during their lifecycles (since 2001, 51% of all Western Pacific (WPAC) systems reaching tropical storm strength or greater experienced RI).

More recently, higher resolution mesoscale models (3-5 km) have been introduced, using the latest advanced schemes to simulate the physical processes taking place at these fine scales. As a result, deterministic mesoscale models are beginning to indicate improved intensity forecast skill. JTWC believes a multi-model consensus (MESOCON) of skillful mesoscale models may improve forecasts of TC intensity and structure, and may additionally allow for statistical characterization of forecast uncertainty that translates to forecast confidence. JTWC has a history of successfully applying a multi-model consensus methodology, with operational consensus track forecasts dating back to the early 2000's (Goerss et al, 2004). Given recent improvements in mesoscale model capabilities, JTWC TECHDEV plans to test various combinations of archived mesoscale model TC forecasts (vortex trackers) to develop an optimal mesoscale model consensus.

Furthermore, the expansion of high performance computational resources is increasing the viability of delivering mesoscale model ensembles and associated ensemble trackers for use in the mesoscale consensus for intensity and track forecasting. This mixed model consensus will be available to JTWC forecasters for initial evaluation during the 2013 calendar year.

JTWC evaluated several mesoscale models during the 2012 season. First, the Naval Research Lab Monterey (NRLMRY) experimental COAMPS-TC model (COTC), using GFS lateral boundary conditions, has been under evaluation since 2010. COTC received numerous enhancements throughout the year, and is expected to become fully operational at FNMOC by June, 2013. A pre-operational version of this model (identified as COFN) using NOGAPS/NAVGEM boundary conditions (the operational Navy global model transitioned from NOGAPS to NAVGEM in March, 2013) became available to JTWC for test and evaluation beginning in September, 2012. The current configuration of both models includes a storm-following inner nest with 5 km horizontal resolution (Doyle et al., 2012). After COFN becomes fully operational at FNMOC, NRLMRY plans to continue running the experimental COTC for their development efforts, and will make this output available to JTWC for continued evaluation.

Due to the sustained efforts of the Hurricane Forecast Improvement Program (HFIP) and NOAA's Environmental Modeling Center (EMC), the Hurricane WRF model was extended to cover the western North Pacific Ocean (WPAC) domain in May 2012, for evaluation by JTWC. Aside from a lack of ocean coupling, the WPAC HWRF configuration is the same as used in the Atlantic Basin, with a storm-following inner grid at 3 km horizontal resolution (Gopalakrishnan, et al., 2012). Both COAMPS-TC models and HWRF are run for JTWC invest areas (*i.e.,* prior to reaching Tropical Depression status), providing valuable guidance to forecasters leading up to the initial warning time.

TWRF is an adaption of the WRF-ARW model tuned specifically for TC rainfall over Taiwan by the Taiwan Central Weather Bureau (CWB). This model has fixed nests of 5 and 15 km horizontal resolution centered over Taiwan and a larger 45 km nest covering the WPAC (Hsiao, L.-F. et al., 2012). Although primarily designed to improve TC-related precipitation forecasting, the CWB has provided TWRF forecasts to JTWC for evaluation. Given the small coverage of the fixed high-resolution domain, TWRF may have limited applicability to a JTWC MESOCON.

TC forecasts from The Australian Community Climate and Earth-System Simulator (ACCESS-TC) model are provided by the Australian Bureau of Meteorology for systems around Australia as well as the WPAC. ACCESS-TC boundary conditions are provided by the Unified UKMet model, uses 4DVAR data assimilation, and has an inner-most grid at approximately 12 km resolution (ABOM, 2010).

The operational GFDN model for 2012 was the 2011 version of the GFDL model, with ocean coupling provided by a high-resolution version of the 3-D Princeton Ocean Model (POM). GFDN is run for all JTWC basins at FNMOC using the NAVGEM for initial and boundary conditions, while GFDL is run operationally by NCEP using the GFS global model, for the Atlantic and Eastern Pacific basins in support of the National Hurricane Center. Both GFDL and GFDN have a storm-following inner nest at approximately 9 km resolution. Plans are underway to upgrade GFDN to match the current operational GFDL configuration for the 2013 season. This upgrade consisted of numerous improvements in the physics and convective schemes. Additionally, a parallel test run of an experimental higher-resolution (6 km) GFDN with improved microphysics and ocean coupling is also being discussed for 2013, adding another potential member to a MESOCON.

During forecast operations, JTWC evaluates all available model data during the forecast process, however, track forecast error statistics for mesoscale models typically lag those of the global models. This trend has become more apparent over the past 3-5 years due to substantial improvements made to global models. Therefore, the primary focus of mesoscale model use at JTWC focuses on intensity forecasting. Intensity statistics for the aforementioned models in 2012 are listed below. With the exception of GFDN, these models are considered "experimental", and their availability has varied widely due to computational resource availability, ongoing changes to core code, product dissemination issues *etc*. Typically, a homogeneous comparison of interpolated models (*i.e.*, the model output available to JTWC at forecast time) would be presented; however, due to the availability issues noted, late-arriving models often miss the interpolation cut-off time, leading to a reduced sample size. Instead, non-homogenous statistics are presented for the parent model trackers, and readers are cautioned not to make direct comparisons between models based on these statistics.

MODEL	Tau 12	Tau 24	Tau 36	Tau 48	Tau 72	Tau 96	Tau 120
ACES	15 kts	17 kts	19 kts	20 kts	25 kts	N/A	N/A
	260 cases	239 cases	219 cases	195 cases	143 cases		
COFN	17 kts	18 kts	18 kts	21 kts	19 kts	20 kts	17 kts
	120 cases	99 cases	72 cases	62 cases	44 cases	35 cases	21 cases
COTC	14 kts	16 kts	17 kts	20 kts	20 kts	21 kts	24 kts
	505 cases	465 cases	424 cases	376 cases	286 cases	200 cases	137 cases
GFDN	12 kts	15 kts	18 kts	19 kts	22 kts	24 kts	26 kts
	551 cases	507 cases	459 cases	401 cases	302 cases	218 cases	151 cases
HWRF	10 kts	14 kts	17 kts	19 kts	22 kts	24 kts	28 kts
	536 cases	497 cases	454 cases	414 cases	319 cases	229 cases	166 cases
TWRF	24 kts	24 kts	25 kts	26 kts	29 kts	N/A	N/A
	386 cases	354 cases	320 cases	286 cases	208 cases		

Table 5-1: 2012 Non-Homogeneous Mesoscale Model Intensity Forecast Errors

In 2013, JTWC will continue to collaborate with groups such as NRLMRY, the Hurricane Forecast Improvement Project (HFIP) and the National Unified Operational Prediction Capability (NUOPC), to name a few, and leverage work in mesoscale models to improve TC intensity forecasting through consensus development. Additionally, JTWC will continue collaborating with partners in the modeling community to evaluate and provide feedback on mesoscale model performance.

This year, NRLMRY plans to run an experimental version of a COTC ensemble (approximately 10 members) for a limited number of cases in the WPAC, contingent on computational resources. Additionally, JTWC will be adding the Air Force Weather Agency (AFWA) Mesoscale Ensemble Prediction System (MEPS) into the evaluation process, as discussed in the future project section above. These mesoscale ensembles produce an ensemble tracker that could contribute to the growing list of consensus and multi-member mesoscale ensembles and provide benefit to the JTWC MESOCON.

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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 2012 season, and contrasts it with annual verification statistics from previous years.

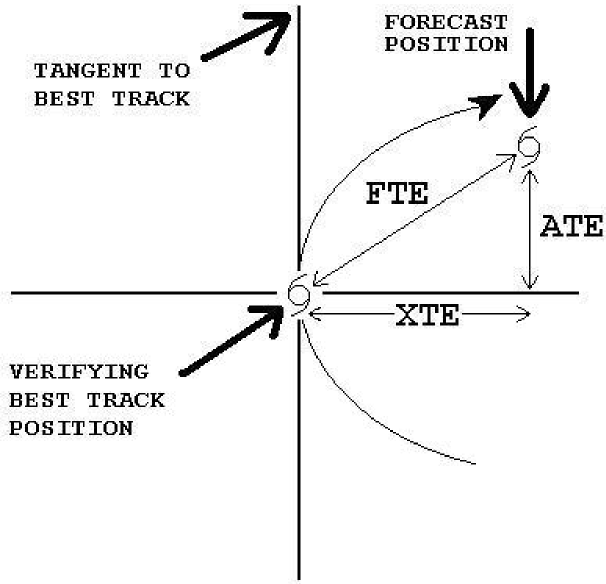

Figure 6-1. Definition of cross-track error (XTE), along track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of track) and the ATE is positive (ahead of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

TABLE 6-1
MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC TROPICAL CYCLONES FROM 1959 - 2012

	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
2012	535	48	50	30	34	439	87	89	52	61	340	121	127	67	93	248	160	163	82	123	178	218	224	105	176
Avg (1978-2012)	580	86	96	54	67	467	168	179	102	125	368	263	268	151	188	198	158	226	121	164	144	202	298	157	216
5yr Avg	419	50	60	34	42	330	96	105	62	72	253	155	159	90	111	176	158	224	125	159	131	202	300	167	209

(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.

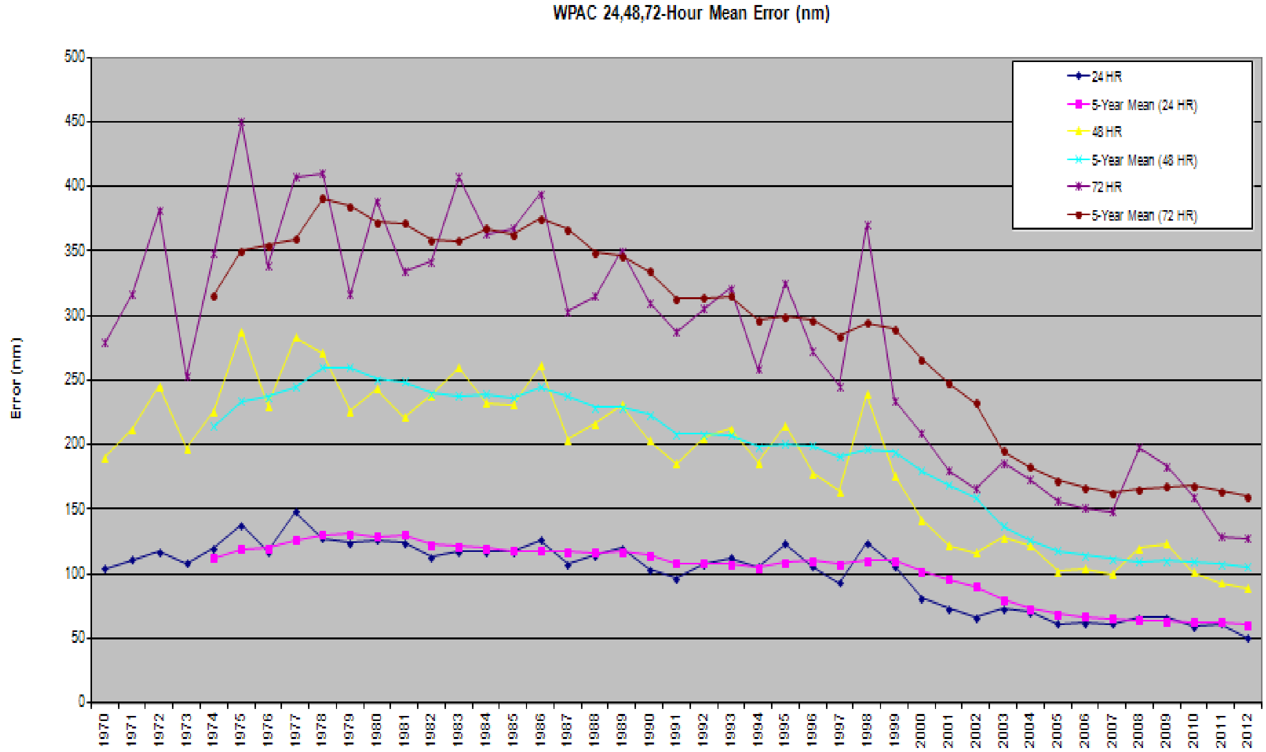

Figure 6-2. Graph of JTWC track forecast errors and five year running mean errors for the western North Pacific at 24, 48, and 72 hours.

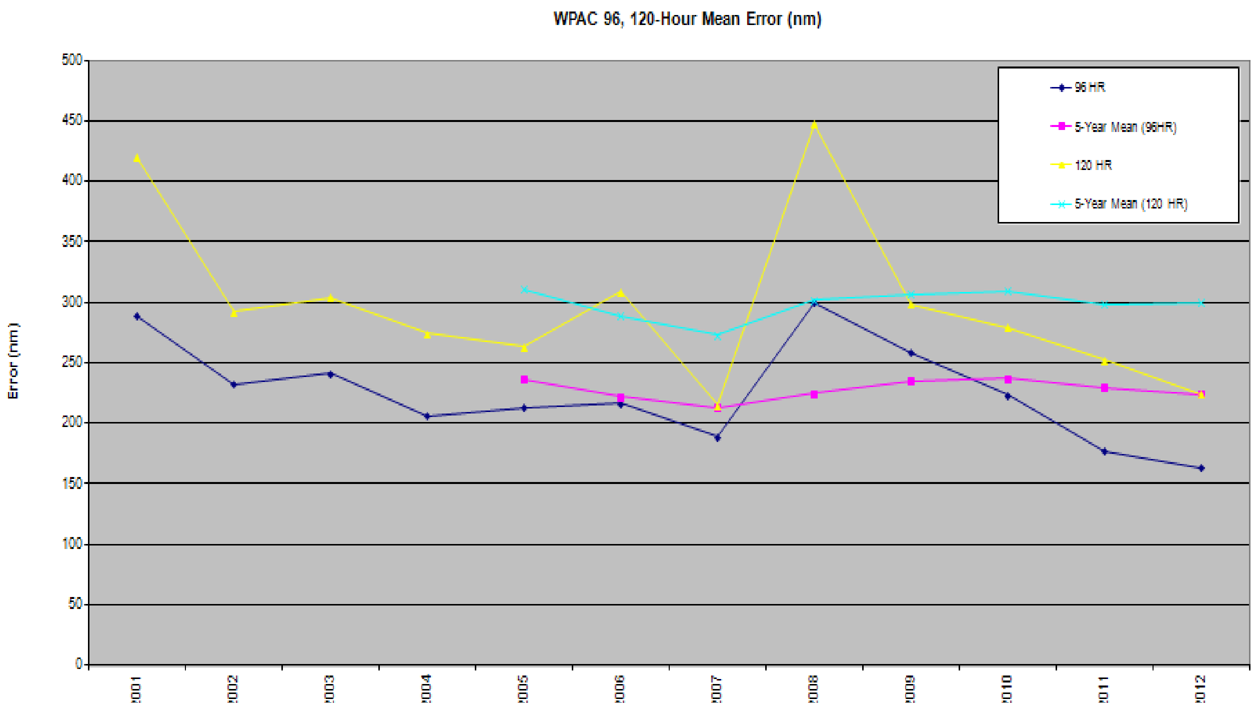

Figure 6-3. Graph of JTWC track forecast errors and five year running mean errors for the western North Pacific at 96 and 120 hours.

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

TROPICAL CYCLONES FROM 1985-2012

	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
2012	19	67	38	42	7	51	34	31	3	30	22	15	0				0			
Avg (1985-2012)	46	96	68	53	29	163	112	94	16	252	173	143								
5Yr Avg	42	68	39	45	26	108	62	72	15	166	79	137								

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

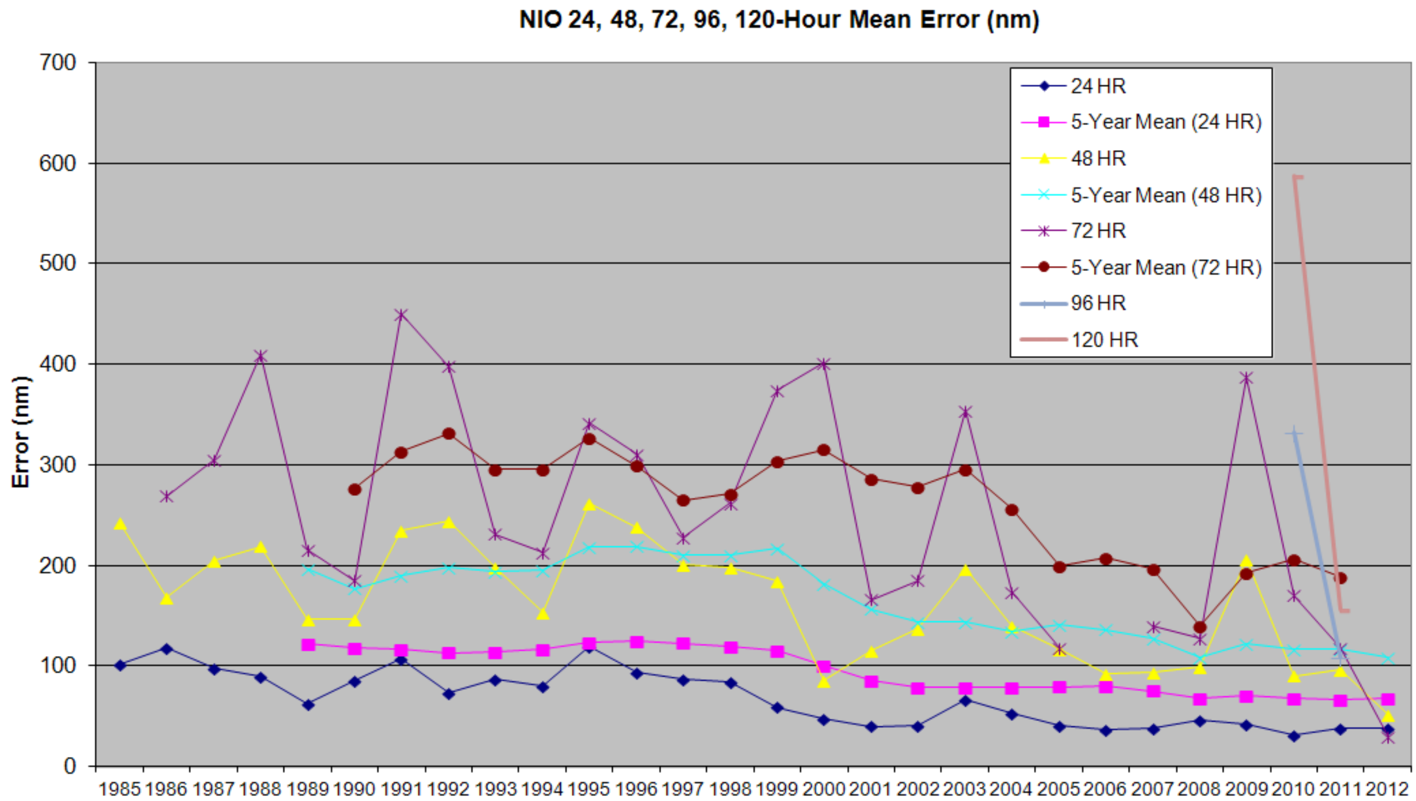

Figure 6-4. Graph of JTWC track forecast errors and five year running mean errors for the north Indian Ocean at 24, 48, 72, 96, and 120 hours.

TABLE 6-3 MEAN FORECAST ERRORS (NM) FOR SOUTHERN HEMISPHERE TROPICAL CYCLONES 1985 - 2012																				
	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	75	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
2012	187	58	33	41	145	99	53	72	117	149	71	116	91	202	96	162	64	272	149	192
Avg	238	98	56	69	187	183	104	128	55	197	116	136								
5Yr Avg	198	62	37	42	152	105	62	69	74	124	70	84								

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

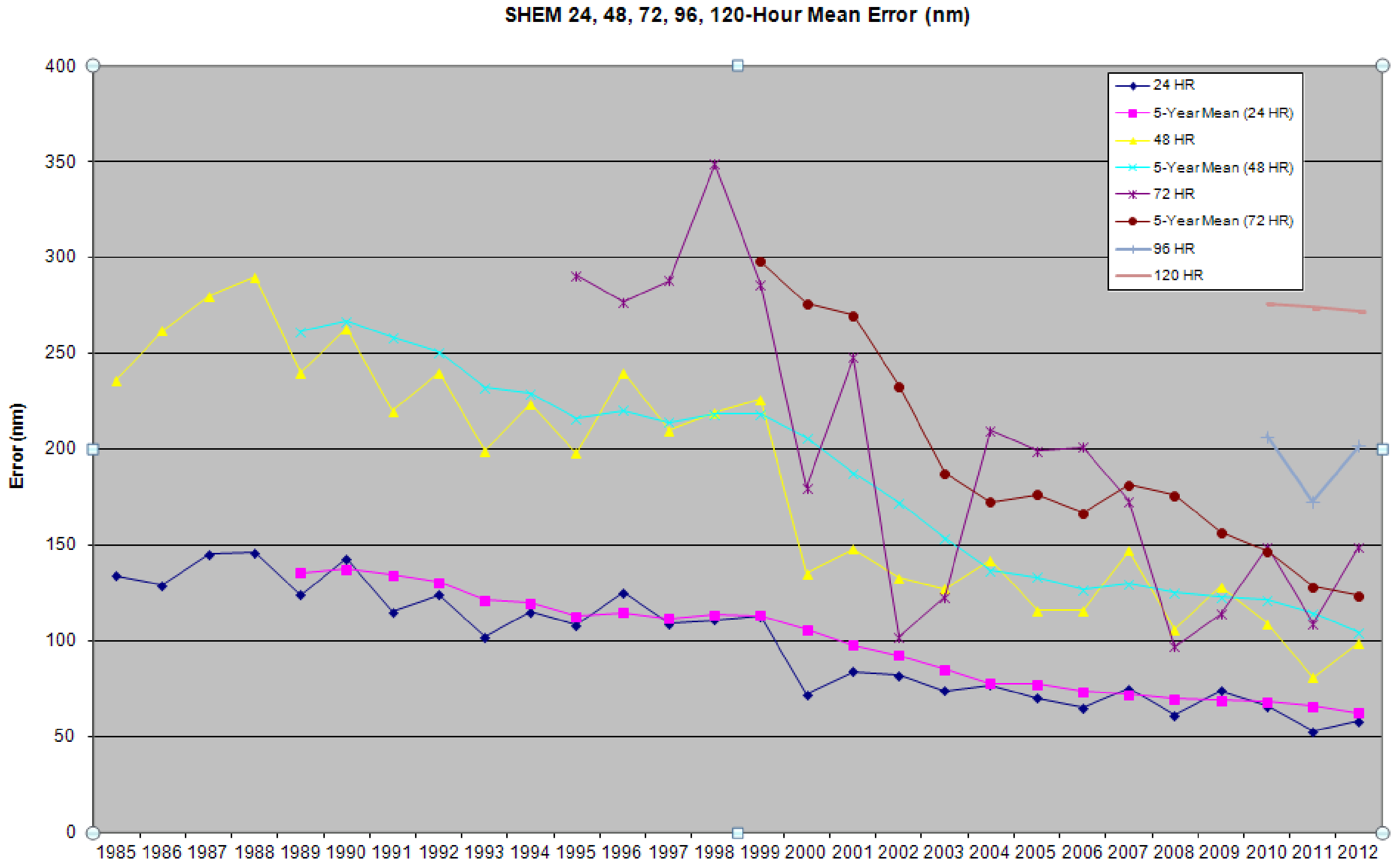

Figure 6-5. Graph of JTWC track forecast errors for the Southern Hemisphere at 24, 48, 72, 96, and 120 hours.

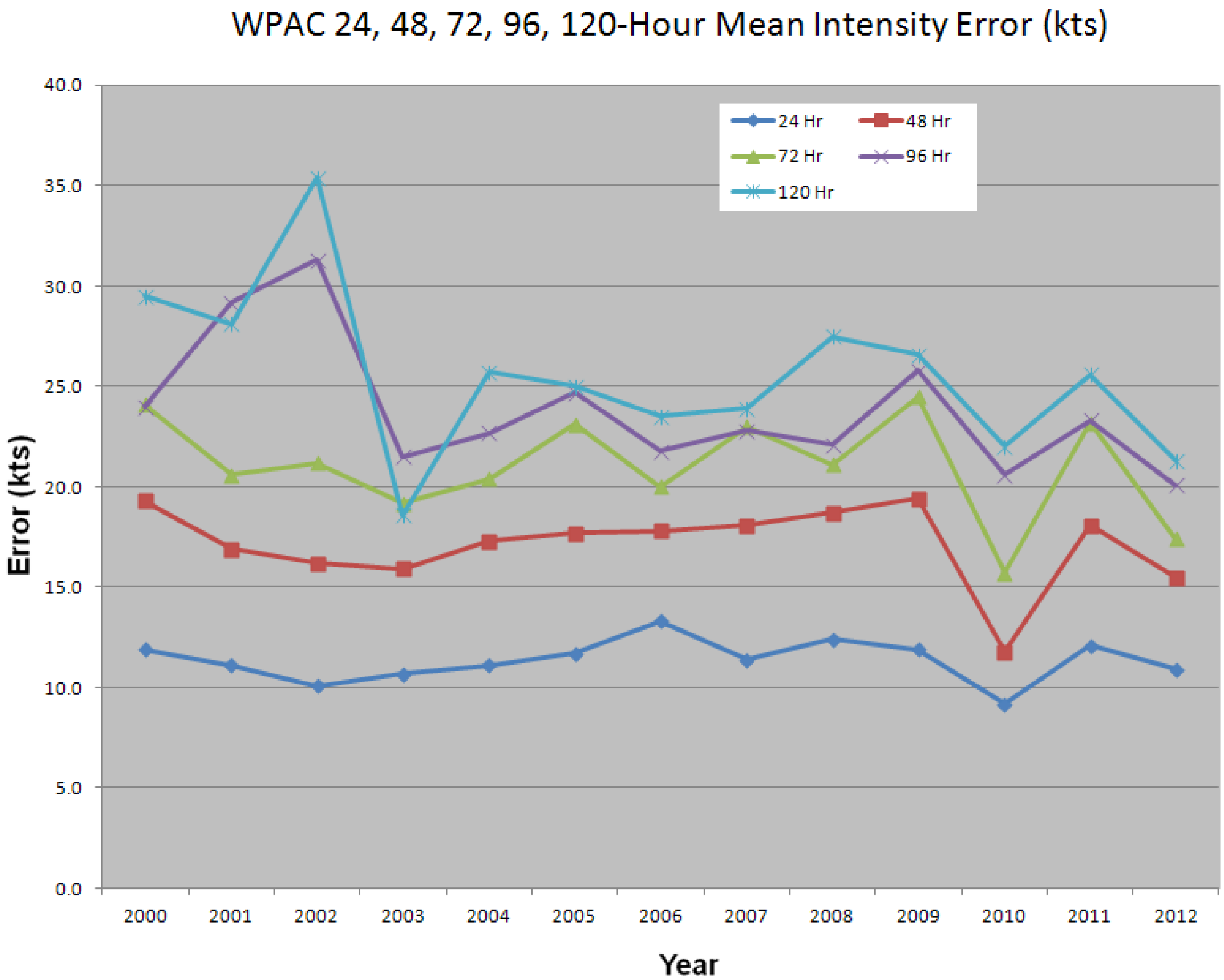

Figure 6-6. Graph of JTWC intensity forecast errors for the western North Pacific at 24, 48, 72, 96, and 120 hours.

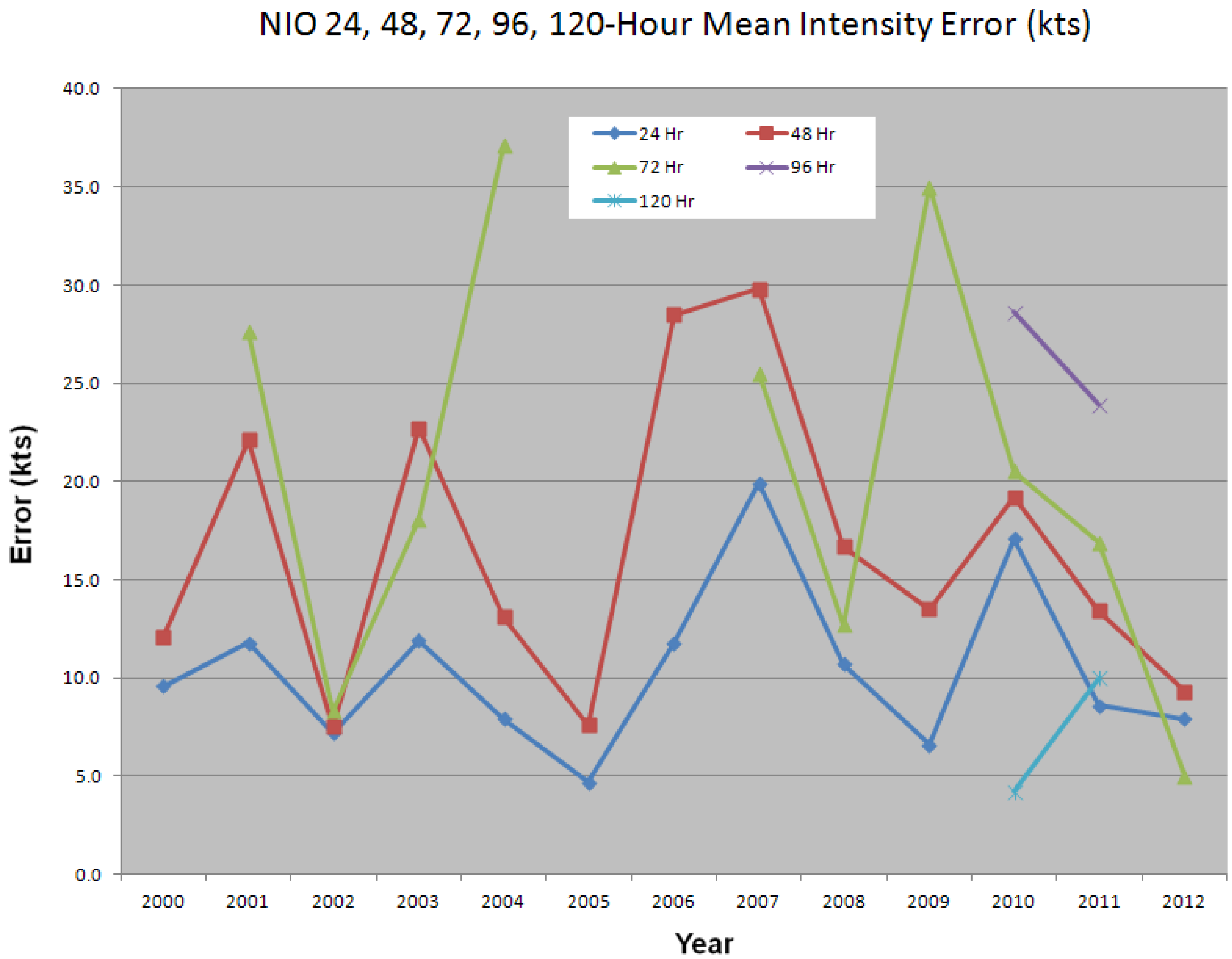

Figure 6-7. Graph of JTWC intensity forecast errors for the North Indian Ocean at 24, 48, 72, 96, and 120 hours.

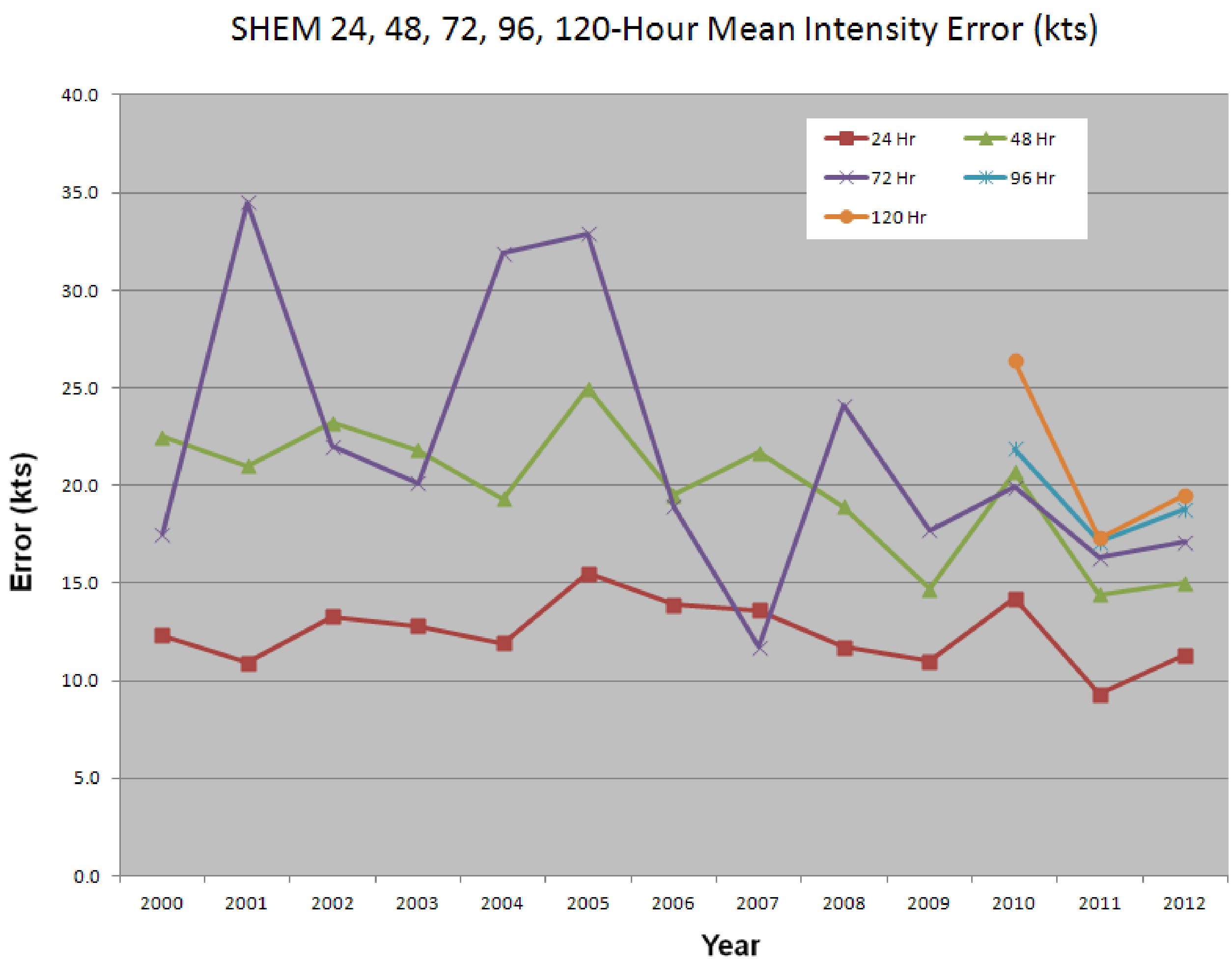

Figure 6-8. Graph of JTWC intensity forecast errors for the Southern Hemisphere at 24, 48, 72, 96, and 120 hours.