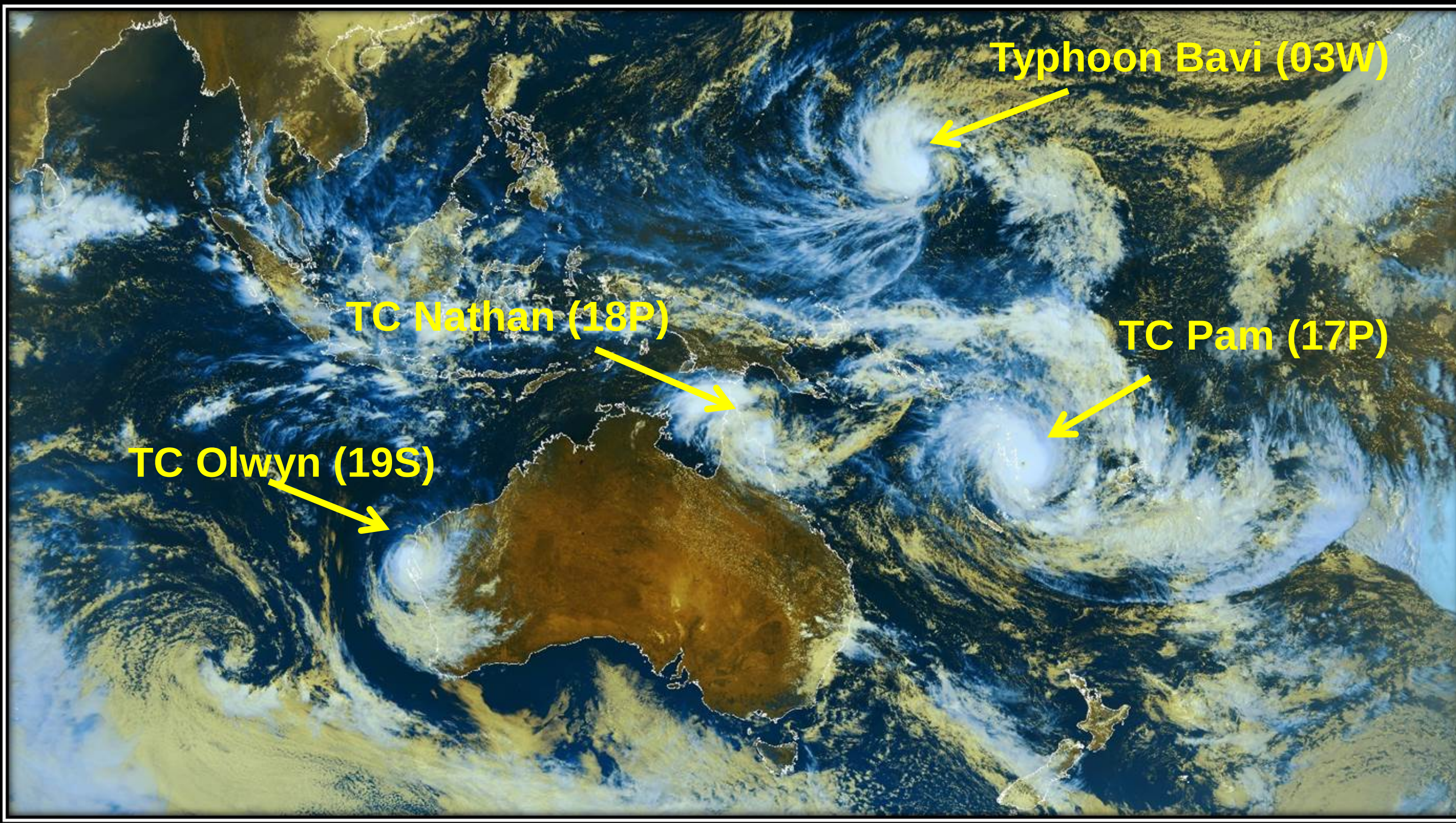
Annual Tropical Cyclone Report
2015



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Cover: Image depicts a rare four-storm situation in March 2015, where JTWC was issuing warnings on Typhoon Bavi (03W) in the western North Pacific, and Tropical Cyclones Pam (17P), Nathan (18P), and Olwyn (19S),

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

The 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 2015 TC season and details operationally or meteorologically significant cyclones noted within the JTWC Area of Responsibility. 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 tactics, techniques and procedure (TTP) development in which members of JTWC were involved.

The major event in the tropics during 2015 was a strong El Nino, with sea surface temperature anomalies reaching +3 degrees Celsius above normal in December with the 3-month running mean anomaly remaining above +2 degrees Celsius from September 2015 to March 2016. The western North Pacific Ocean returned to near normal tropical cyclone activity, with 29 TCs forming in basin, compared to the long term average of 31. Two additional TCs formed in the Central North Pacific and subsequently crossed into the basin. Additionally, 9 of the 29 cyclones attained super typhoon intensity. As expected, long-lived El Nino conditions shifted the mean TC genesis region eastward, causing major DoD installations to experience significant cyclone impacts. Okinawa was impacted by 3 typhoons, Guam and the Commonwealth of the Northern Mariana Islands experienced impacts from 7 cyclones and mainland Japan had 3 cyclones make landfall.

Southern Hemisphere activity remained below the long term average of 28, with 16 cyclones in the south Indian Ocean / western Australia region and 9 in the south Pacific / eastern Australia region. Tropical Cyclone Olwyn (19S) made a direct impact on the USAF solar observatory at Learmonth Australia. Tropical Cyclone Pam (17P) reached a peak intensity of 150 knots as it tracked through the island nation of Vanuatu, resulting in catastrophic damage. The north Indian Ocean experienced normal activity of five cyclones, with 4 in the Arabian Sea and 1 in the Bay of Bengal. The most significant cyclones in the north Indian Ocean were Tropical Cyclone 04A (Chapala) and 05A (Megh) in the Arabian Sea, reaching peak intensities of 130 knots and 110 knots, respectively. Both cyclones followed nearly the same westerly track, passing near or over Socotra before making landfall in central Yemen.

Meteorological satellite data remained the mainstay of the TC reconnaissance mission in the support of the JTWC. Satellite analysts administratively assigned to the 17th Operational Weather Squadron, exploited a wide variety of conventional and microwave satellite data to produce 12,208 position and intensity estimates (fixes), primarily using the USAF Mark IVB and the USN FMQ-17 direct readout systems. Geo-located satellite imagery overlays available via the Automated Tropical Cyclone Forecast (ATCF) system from Fleet Numerical Meteorology and Oceanography Center and the Naval Research Laboratory-Monterey, were also used by JTWC to make TC fixes. This year, JTWC satellite analysts expanded the use of active and passive scatterometer data and began adding 35 knot wind structure information (radii) by quadrant to the position and maximum observed wind speed entries. This effort will assist in creating a more accurate initial state of tropical cyclones for use in numerical model initialization and wind radii forecasting.

The eastward shift in the mean genesis formation region led to numerous long-lived tropical cyclones. As a result, JTWC issued a likely record-breaking 1,193 tropical cyclone warnings throughout its area of responsibility. Additionally, forecast operations experienced two unprecedented periods of four concurrent tropical cyclones. Despite these challenges, JTWC western North Pacific mean forecast errors set new records for all lead times, with day 3 and day 5 errors below 100 nm and 200 nm, respectively, for the first time ever. Behind all these efforts and accomplishments are the dedicated team of men and women, military and civilian at JTWC. Special thanks to the entire JTWC N6 Department for their continued 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 their dedicated TC research; the National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) for satellite reconnaissance support; Dr. John Knaff, 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, and Mr. Mike Frost for their outstanding support and continued development of the ATCF system.

JTWC Personnel 2015

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Mr. Roberto Macais, *Administrative Assistant*

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LCDR Thomas Mills, *Operations Officer*
LT Thai Phung, *Operations Officer*
Mr. Brian Strahl, *Senior Scientist*

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Mr. Andrew Rhoades, *Information Assurance Officer*
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IT2 Isaac Wilson, *Information Technology*
IT3 Sha'nae Wilson, *Information Technology*

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Mr. James Darlow, *Technical Services*

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LT Denie Kiger
LT Dominique Krieger
LT Christopher Machado
LT Justin Van Es
ENS Chi Maxey
ENS Sarah Beemiller
AGC Christopher McKinstry
AG1 Nadine McBee
AG1 Cecil Jordan
AG1 Michael Schmidt

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LT Vincent Chamberlain
LT Thai Phung
LT Nicholas Kutchak
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Mr. Stephen Barlow
Mr. Brian Strahl
Mr. Richard Ballucanag Mr. Aaron Lana

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SSgt Brittany Bermea, *Analyst*
SrA Karen Long, *Analyst*
SrA Francisco Martinez, *Analyst*
SrA Terrance Schalin, *Analyst*
SrA Cheyenne Lembke, *Analyst*
Mr. James Darlow, *Analyst*
Mr. Dana Uehara, *Analyst*

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AG3 Bristol Rigby
AG2 Jack Tracey
AG2 Janie Sherrock
AG2 Jake Wilson
AG3 Christopher Hoole
AGAN Dakota Bennett
AGAA Frandys Ferreras
AGAA Jeremiah Meeker

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Table 1-1

WESTERN NORTH PACIFIC SIGNIFICANT TROPICAL CYCLONES FOR 2015
(01 JAN 2015 - 31 DEC 2015)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS
01W	MEKKHALA	13 JAN / 1800Z	18 JAN / 1800Z	22	70
02W	HIGOS	07 FEB / 0600Z	11 FEB / 1200Z	18	130
03W	BAVI	11 MAR / 1200Z	18 MAR / 0000Z	27	50
04W	MAYSAK	27 MAR / 0000Z	05 APR / 1800Z	40	150
05W	HAISHEN	03APR / 0000Z	06 APR / 1200Z	15	45
06W	NOUL	03 MAY / 0000Z	12 MAY / 0600Z	38	140
07W	DOLPHIN	06 MAY / 1800Z	19 MAY / 1200Z	52	140
08W	KUJIRA	20 JUN / 1200Z	24 JUN / 0000Z	15	50
09W	CHAN-HOM	30 JUN / 1200Z	12 JUL / 1800Z	50	120
10W	LINFA	02 JUL / 0000Z	09 JUL / 1800Z	32	75
11W	NANGKA	03 JUL / 1200Z	18 JUL / 0000Z	59	135
01C	HALOLA	13 JUL / 0000Z	26 JUL / 1200Z	54***	85
12W	TWELVE	23 JUL / 0600Z	25 JUL / 0600Z	9	35
13W	SOUDELOR	30 JUL / 0600Z	08 AUG / 1800Z	39	155
14W	FOURTEEN	02 AUG / 0600Z	04 AUG / 1200Z	10	30
15W	MOLAVE	07 AUG / 0000Z	13 AUG / 1800Z	22	45
16W	GONI	14 AUG / 0000Z	25 AUG / 1200Z	47	120
17W	ATSANI	14 AUG / 0600Z	25 AUG / 0000Z	44	140
03C	KILO	01 SEP / 0600Z	11 SEP / 0000Z	40***	95
18W	ETAU	06 SEP / 1800Z	09 SEP / 0600Z	11	60
19W	VAMCO	13 SEP / 1200Z	14 SEP / 1200Z	5	35
20W	KROVANH	14 SEP / 1800Z	20 SEP / 1200Z	24	100
21W	DUJUAN	21 SEP / 1800Z	29 SEP / 0000Z	30	130
22W	MUJIGAE	01 OCT / 0000Z	04 OCT / 1200Z	15	115
23W	CHOI-WAN	02 OCT / 1200Z	07 OCT / 1800Z	22	70
24W	KOPPU	13 OCT / 0000Z	21 OCT / 0000Z	33	130
25W	CHAMPI	13 OCT / 0600Z	24 OCT / 1800Z	47	125
26W****	TWENTYSIX	22 OCT / 0000Z	22 OCT / 1800Z	4	35
27W	IN-FA	17 NOV / 0000Z	26 NOV / 0000Z	37	120
28W	MELOR	11 DEC / 1200Z	17 DEC / 0000Z	23	125
29W	TWENTYNINE	16 DEC / 1800Z	18 DEC / 0000Z	6	25

* As designated by the responsible RSMC

** Dates are based on the issuance of JTWC warnings on system.

*** Warnings issued by JTWC

**** Post-analysis determined 26W to be a sub-tropical depression

Table 1-2
DISTRIBUTION OF WESTERN NORTH PACIFIC TROPICAL CYCLONES
FOR 1959 - 2015

YEAR	JAN			FEB			MAR			APR			MAY			JUN			JUL			AUG			SEP			OCT			NOV			DEC			TOTALS		
																																					≥64kt	34-63kt	≤33 kt
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	
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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	
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1966		0			0			0			1			2			1			4			9			10			4			5			2			38	
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1967		1			0			2			1			1			1			8			10			8			4			4			1			41	
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1969		1			0			1			1			0			0			3			3			6			5			2			1			23	
	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	2	1	0	2	1	0	2	0	4	4	1	0	1	1	0	0	1	0	13	6	4
1970		0			1			0			0			0			2			3			7			4			6			4			0			27	
	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	1	4	2	1	2	2	0	3	2	1	1	3	0	0	0	0	12	12	3
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	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
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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
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	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
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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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1982		0			0			3			0			1			3			4			5			6			4			1			1			28	
	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	1	2	0	2	2	0	5	0	0	3	2	1	3	0	1	1	0	0	1	0	0	19	7	2
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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	2	3	1	1	1	1	3	2	0	3	2	0	0	2	0	12	11	2
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	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	
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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	
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2004		0			1			1			1			3			5			2			9			3			3			2			2			32	
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2005		1			0			1			1			0			1			4			6			5			3			2			1			25	
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2006		0			0			1			0			1			1			3			8			5			4			2			2			27	
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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	
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2011		0			0			0			2			2			3			4			4			7			1			1			3			27	
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2012		0			1			1			0			1			4			4			5			3			5			2			1			27	
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2013		1			1			0			0			0			4			3			5			8			7			3			1			33	
	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	3	0	1	2	0	2	2	1	4	3	1	6	0	1	1	1	1	0	0	1	15	12	6
2014		2			0			1			2			0			1			4			2			5			1			3			2			23	
	0	1	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	3	1	0	1	1	0	2	2	1	1	0	0	2	1	0	1	0	1	12	8	3
2015		1			1			2			1			2			1			5			4			4			5			1			2			29	
	1	0	0	1	0	0	1	1	0	0	1	0	2	0	0	0	1	0	4	1	0	2	1	1	2	2	0	4	1	0	1	0	0	1	0	1	19	8	2

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 - 2015)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.2	0.1	0.2	0.4	0.8	1.0	2.5	3.4	3.2	2.9	1.5	0.6	16.9
CASES	12	5	12	24	43	59	144	193	184	168	85	37	966
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 - 2015)													
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
MEAN	0.5	0.2	0.5	0.6	1.2	1.8	3.9	5.4	4.9	4.0	2.4	1.2	26.6
CASES	28	14	26	37	66	100	221	310	280	228	139	69	1518

TABLE 1-4 TROPICAL CYCLONE FORMATION ALERTS FOR THE WESTERN NORTH PACIFIC OCEAN 1976 - 2015					
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%
2013	36	31	33	14%	94%
2014	32	23	23	28%	100%
2015	33	29	29	12%	100%
MEAN	35	28	30	21%	93%
CASES	1387	1102	1181		
* Percentage of initial TCFAs not followed by warnings.					

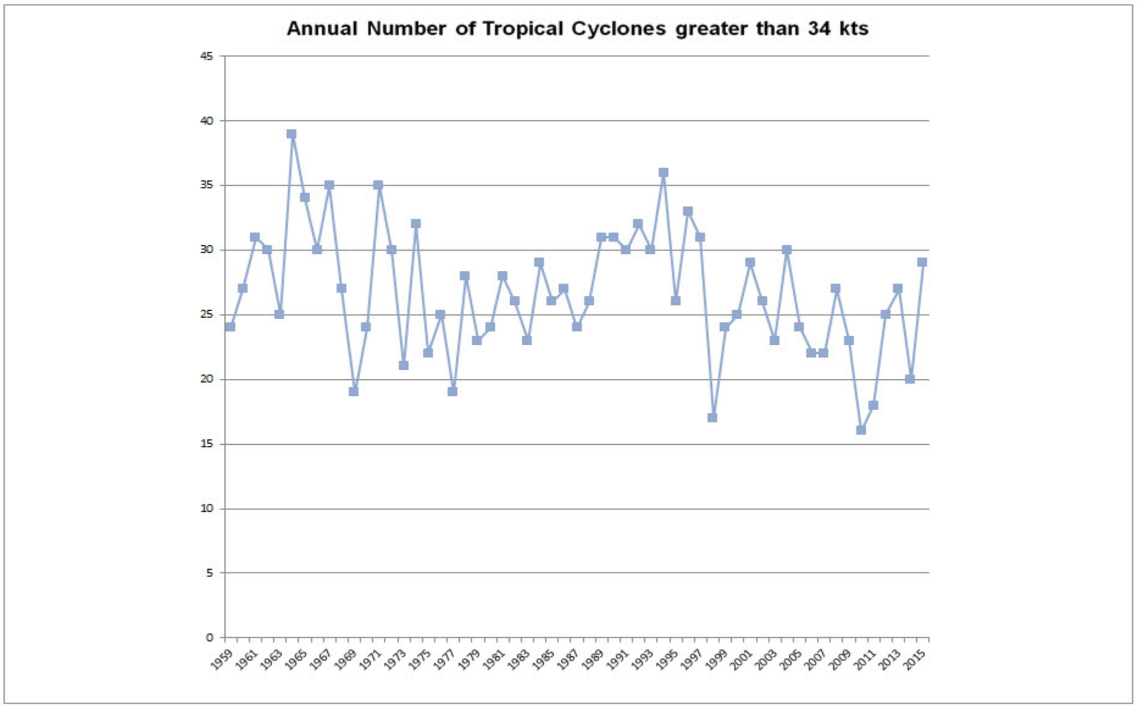


Figure 1-1. Annual number of western North Pacific TCs greater than 34 knots intensity.

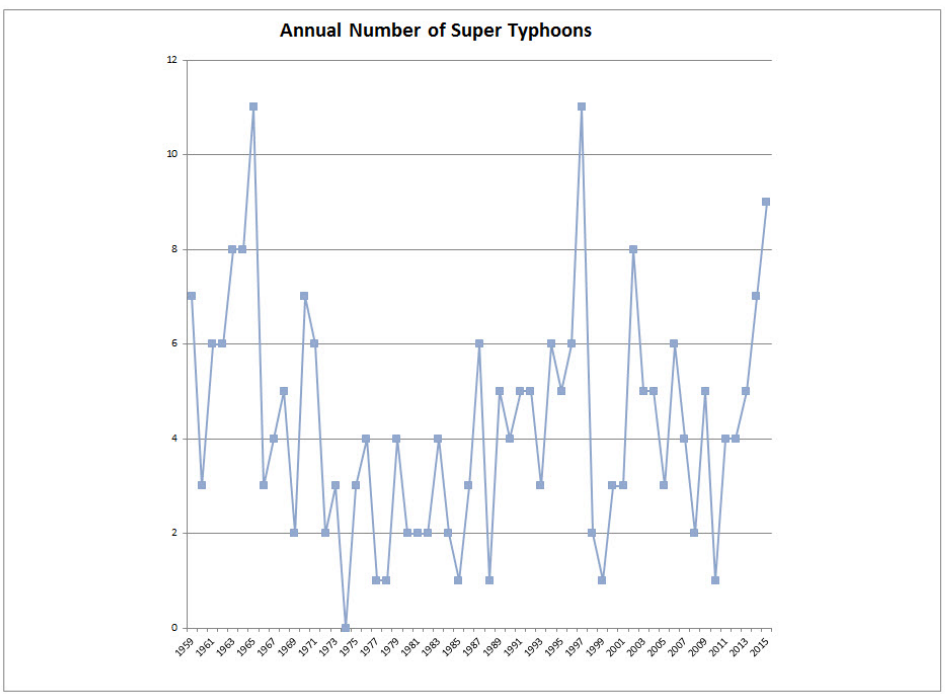
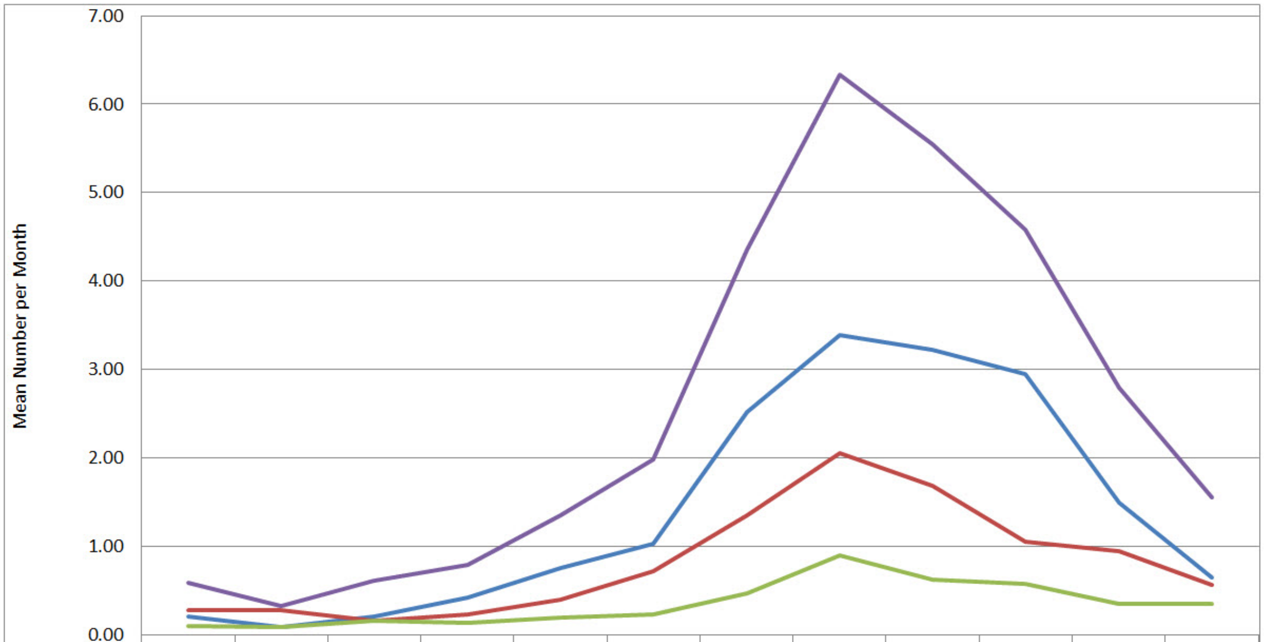


Figure 1-2. Annual number of western North Pacific TCs greater than 129 knots intensity.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
TY AVG	0.21	0.09	0.21	0.42	0.75	1.04	2.53	3.39	3.23	2.95	1.49	0.65
TS AVG	0.28	0.28	0.16	0.23	0.40	0.72	1.35	2.05	1.68	1.05	0.95	0.56
TD AVG	0.11	0.09	0.16	0.14	0.19	0.23	0.47	0.89	0.63	0.58	0.35	0.35
All AVG	0.60	0.33	0.61	0.79	1.35	1.98	4.35	6.33	5.54	4.58	2.79	1.56

Figure 1-3. Average number of western North Pacific TCs (all intensities) by month 1959-2015.

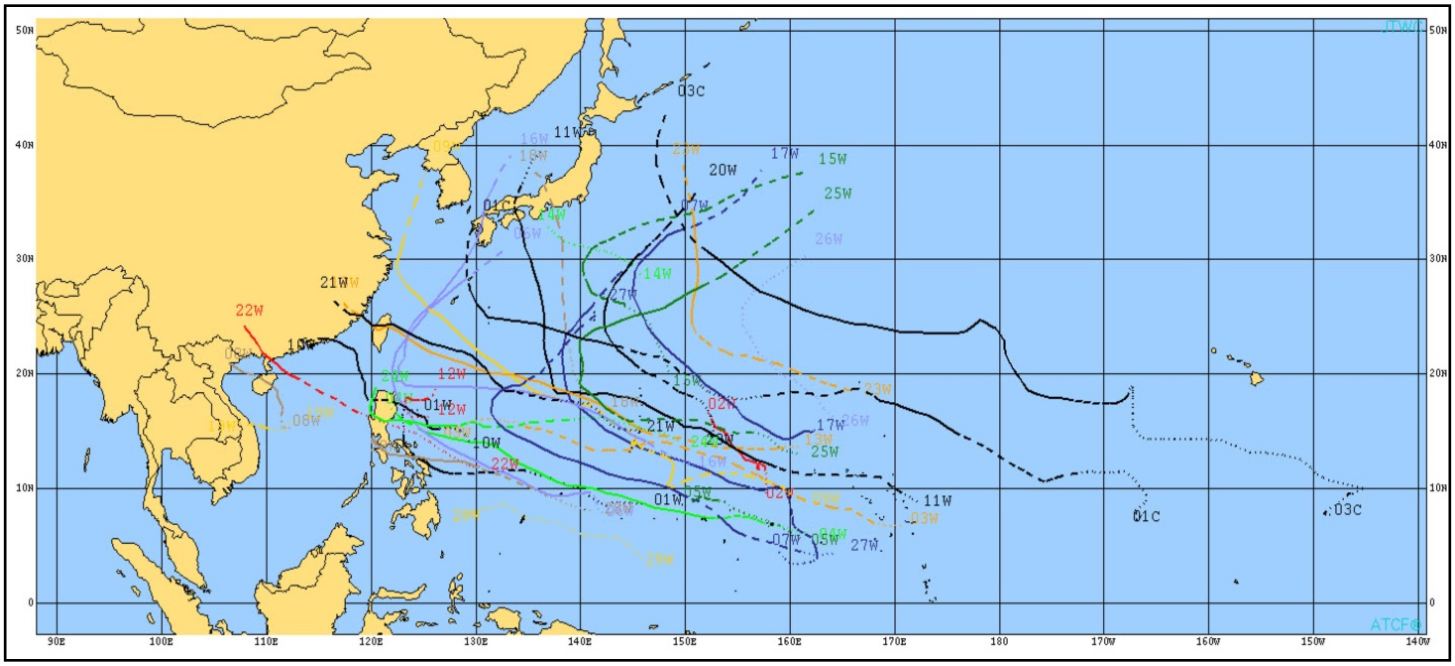


Figure 1-4. Western North Pacific Tropical Cyclones 01W – 29W, 01C and 03C.

01W	TY	MEKKHALA	10 JAN - 20 JAN
02W	ST	HIGOS	05 FEB - 12 FEB
03W	TS	BAVI	10 MAR - 21 MAR
04W	ST	MAYSAK	24 MAR - 07 APR
05W	TS	HAISHEN	02 APR - 07 APR
06W	ST	NOUL	30 APR - 13 MAY
07W	ST	DOLPHIN	06 MAY - 20 MAY
08W	TS	KUJIRA	18 JUN - 24 JUN
09W	TY	CHAN-HOM	27 JUN - 13 JUL
10W	TY	LINFA	30 JUN - 10 JUL
11W	ST	NANGKA	30 JUN - 19 JUL
12W	TS	TWELVE	22 JUL - 26 JUL
13W	ST	SOUDELOR	27 JUL - 09 AUG
14W	TD	FOURTEEN	01 AUG - 05 AUG
15W	TS	MOLAVE	05 AUG - 14 AUG
16W	TY	GONI	11 AUG - 26 AUG
17W	ST	ATSANI	13 AUG - 26 AUG
18W	TS	ETAU	05 SEP - 09 SEP
19W	TS	VAMCO	12 SEP - 15 SEP
20W	TY	KROVANH	14 SEP - 20 SEP
21W	ST	DUJUAN	20 SEP - 30 SEP
22W	TY	MUJIGAE	29 SEP - 05 OCT
23W	TY	CHOI-WAN	30 SEP - 08 OCT
24W	ST	KOPPU	11 OCT - 21 OCT
25W	TY	CHAMPI	11 OCT - 25 OCT
26W	SD	TWENTYSIX	19 OCT - 23 OCT
27W	TY	IN-FA	15 NOV - 26 NOV
28W	TY	MELOR	09 DEC - 17 DEC
29W	TD	TWENTYNINE	12 DEC - 19 DEC
01C	TC	HALOLA	06 JUL - 26 JUL
03C	TC	KILO	17 AUG - 11 SEP

MAXIMUM SUSTAINED SURFACE WIND
—— 64KT (33M/SEC) OR GREATER
– – · 34 TO 63KT (18 TO 32M/SEC)
······ 33KT (17M/SEC) OR LESS

Section 2 Cyclone Summaries

This section presents a synopsis of each cyclone that occurred during 2015 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).

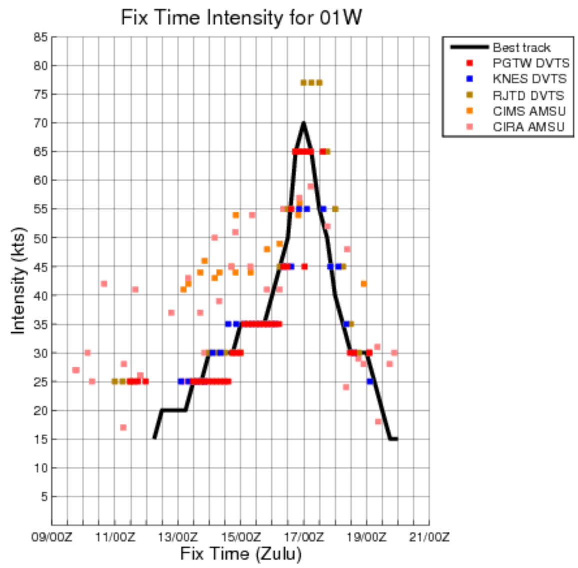
Initial and final JTWC warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

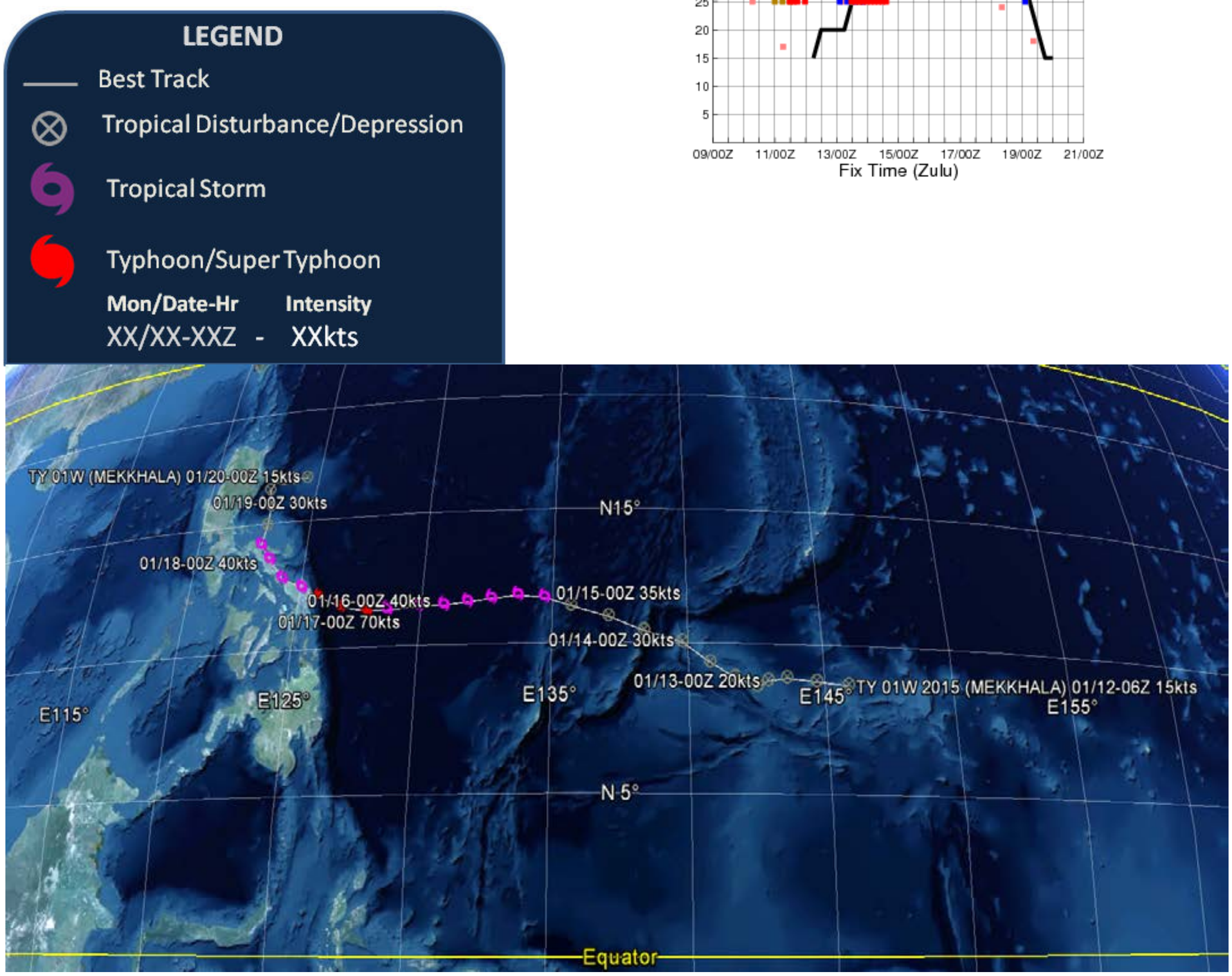
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of 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:
https://metoc.ndbc.noaa.gov/ProductFeeds-portlet/img/jtwc/best_tracks/2015/2015s-bwp/WP_besttracks_2015-2015.kmz

01W TYPHOON MEKKHALA

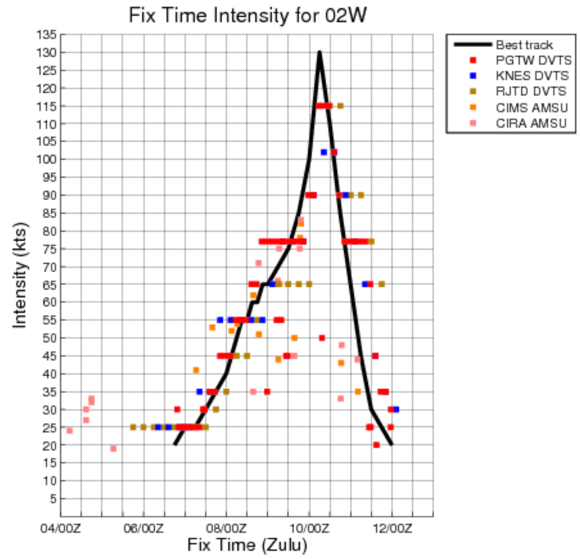
ISSUED LOW:	None
ISSUED MED:	11 JAN / 1100Z
FIRST TCFA:	12 JAN / 2330Z
FIRST WARNING:	13 JAN / 1800Z
LAST WARNING:	18 JAN / 1800Z
MAX INTENSITY:	70
WARNINGS:	22

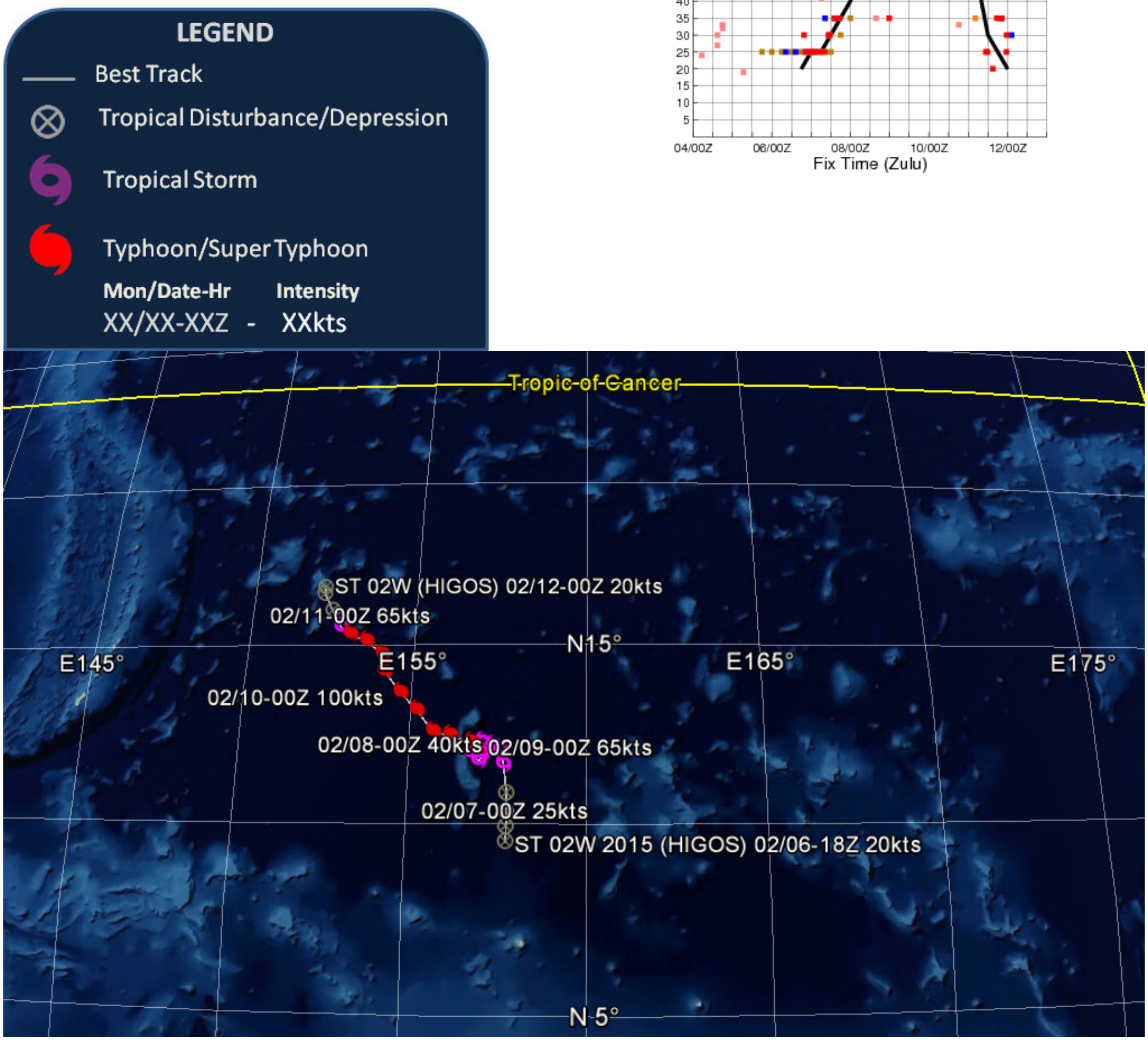




02W SUPER TYPHOON HIGOS

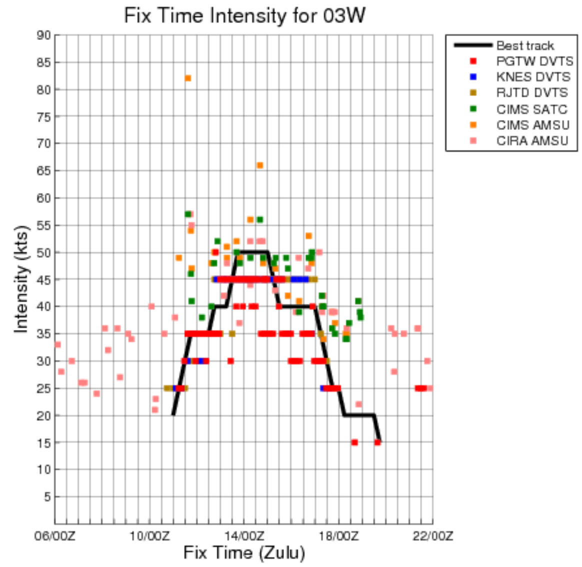
ISSUED LOW:	05 FEB / 0000Z
ISSUED MED:	05 FEB / 0600Z
FIRST TCFA:	06 FEB / 2230Z
FIRST WARNING:	07 FEB / 0600Z
LAST WARNING:	11 FEB / 1200Z
MAX INTENSITY:	130
WARNINGS:	18

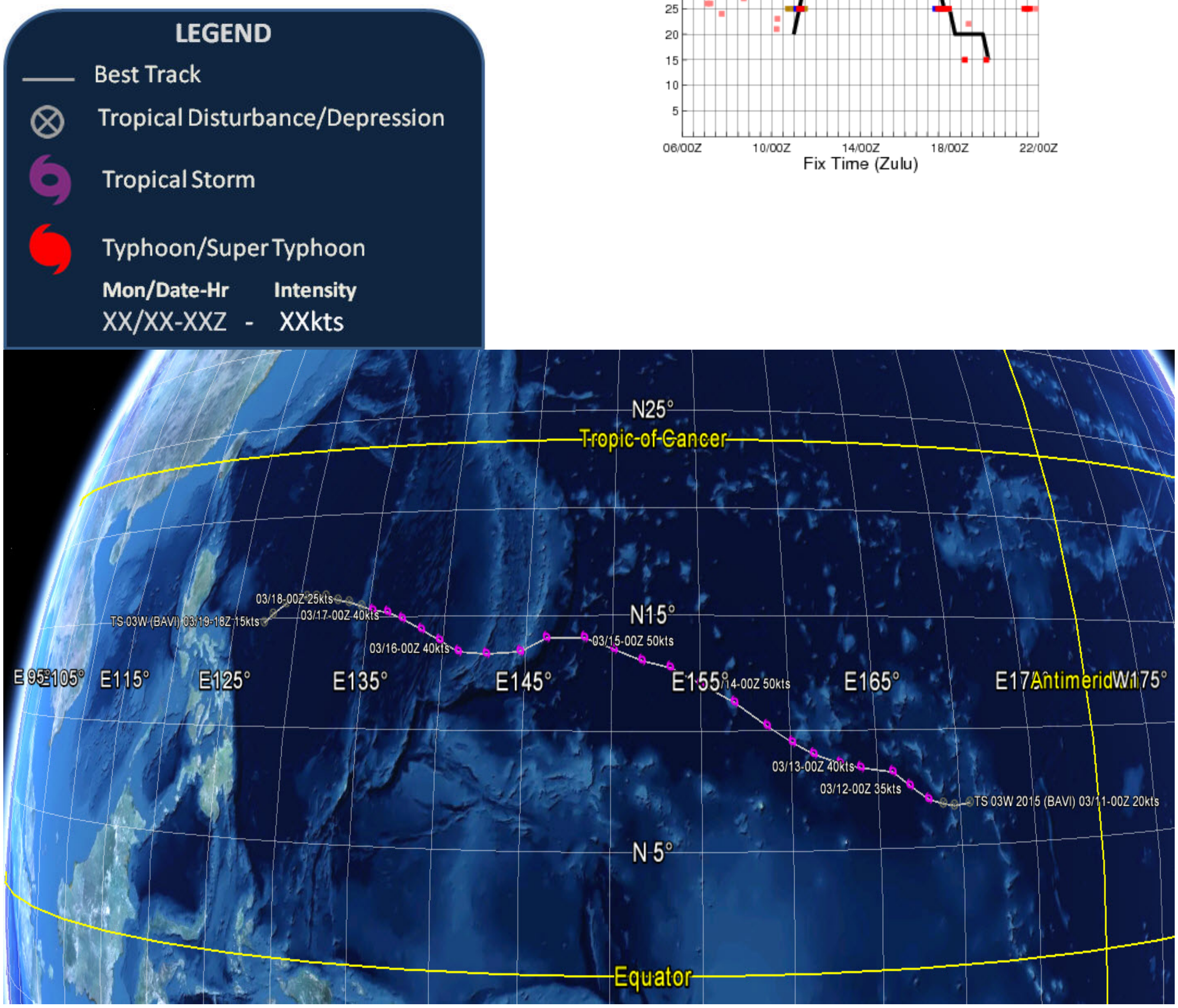




03W TROPICAL STORM BAVI

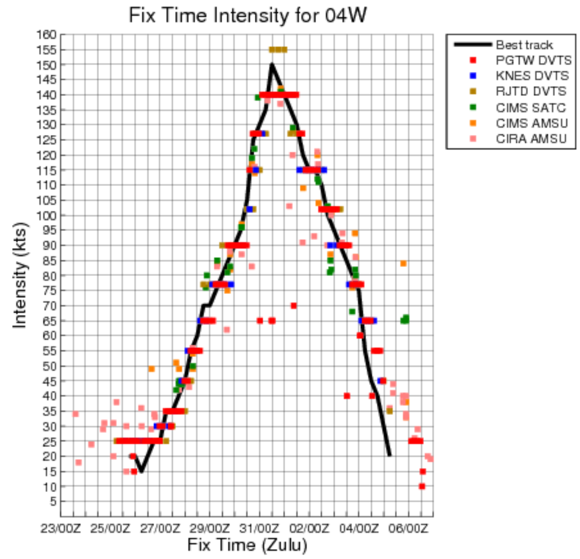
ISSUED LOW:	08 MAR / 2330Z
ISSUED MED:	10 MAR / 0600Z
FIRST TCFA:	11 MAR / 0500Z
FIRST WARNING:	11 MAR / 1200Z
LAST WARNING:	18 MAR / 0000Z
MAX INTENSITY:	50
WARNINGS:	27

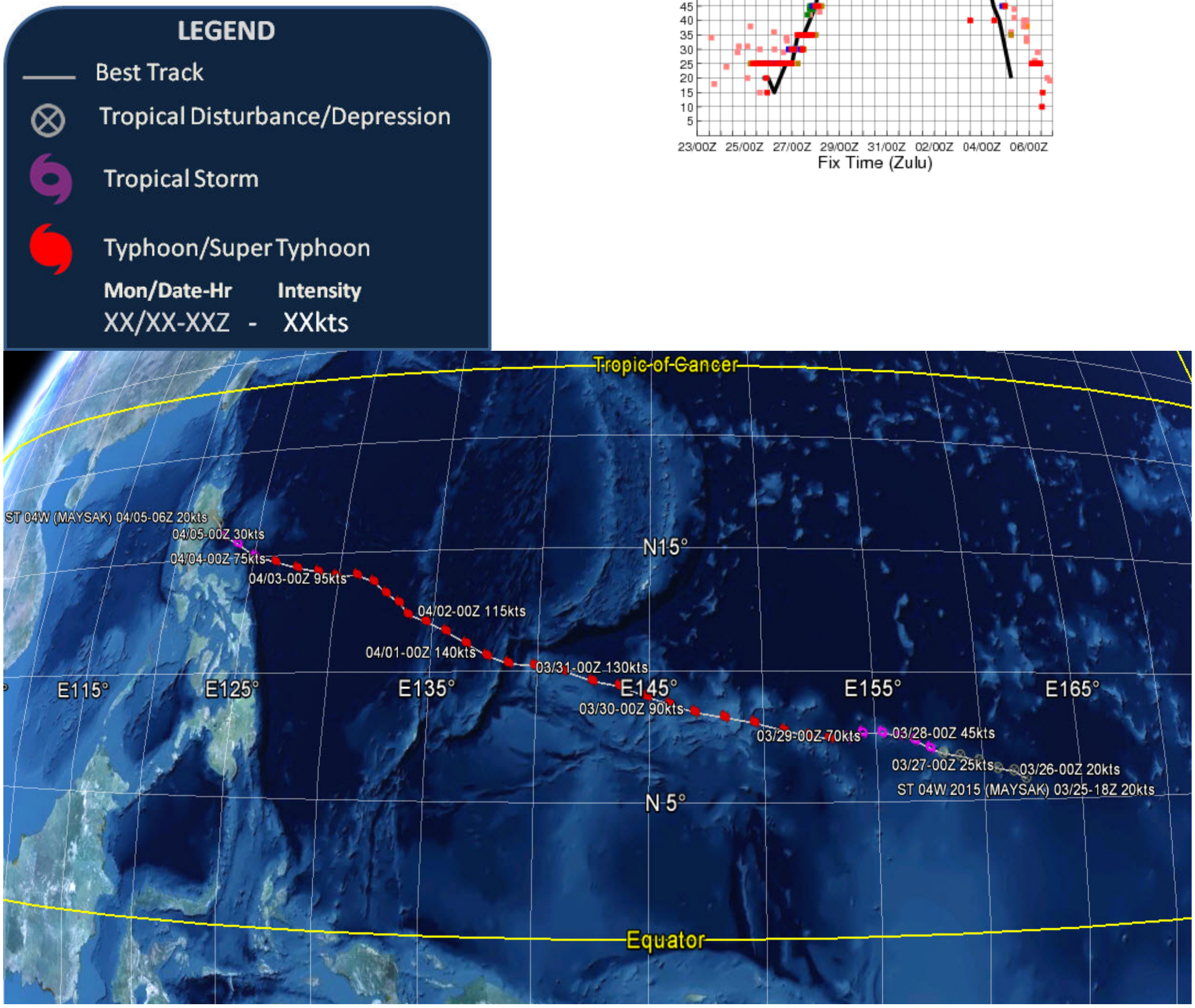




04W SUPER TYPHOON MAYSAK

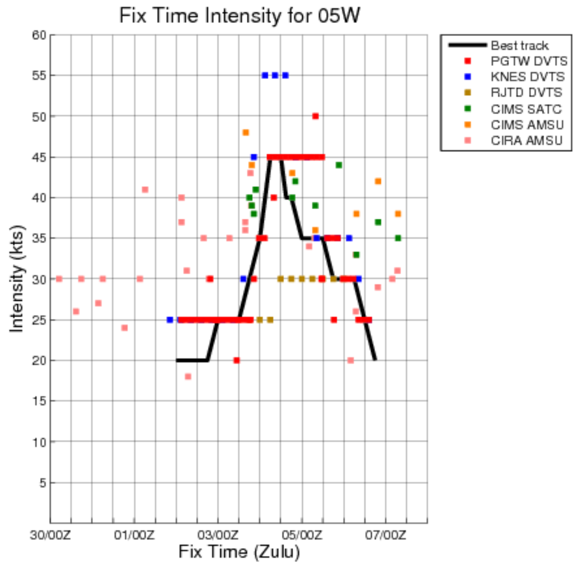
ISSUED LOW:	24 MAR / 0230Z
ISSUED MED:	25 MAR / 1100Z
FIRST TCFA:	26 MAR / 1030Z
FIRST WARNING:	27 MAR / 0000Z
LAST WARNING:	05 APR / 1800Z
MAX INTENSITY:	150
WARNINGS:	40

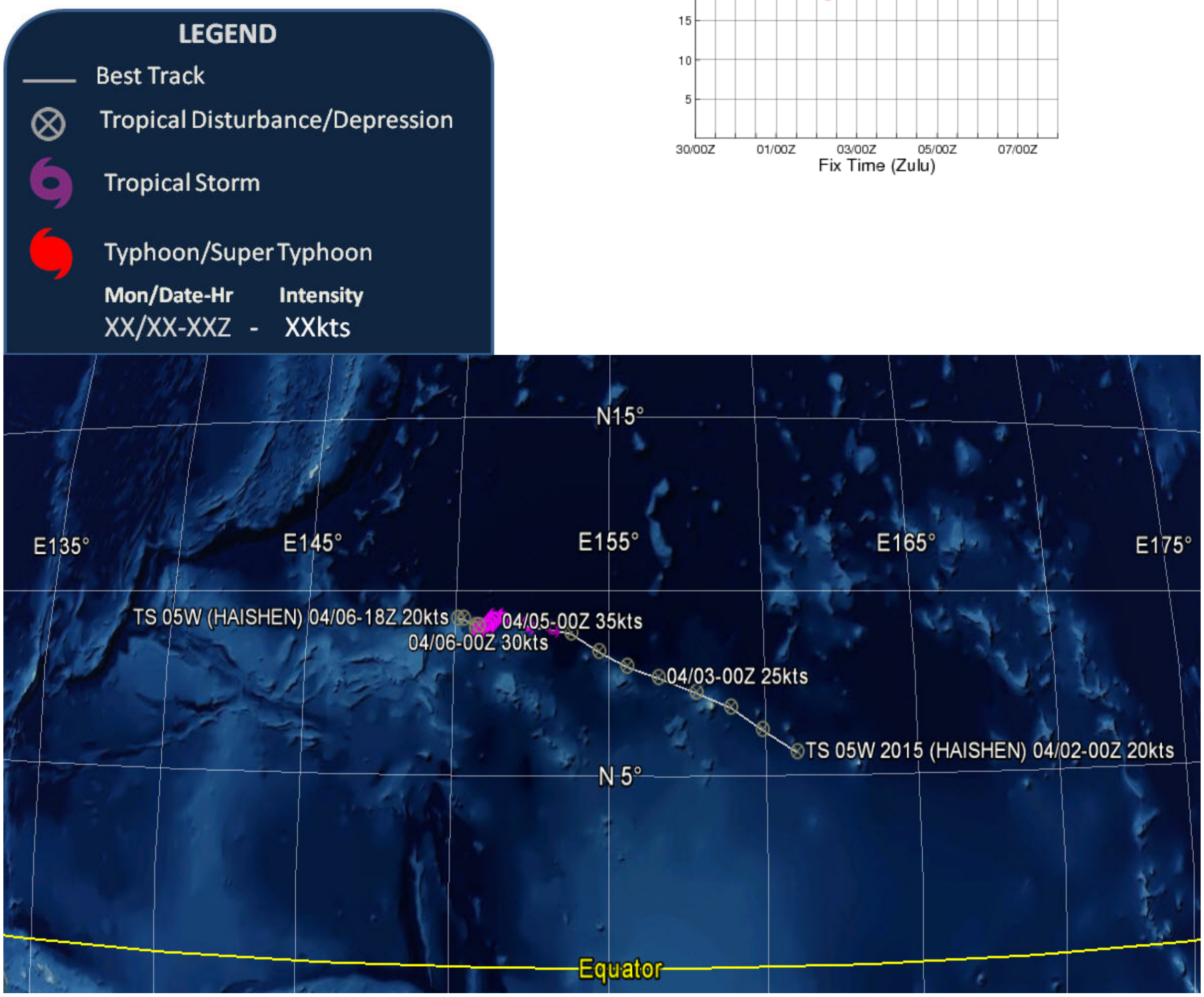




05W TROPICAL STORM HAISHEN

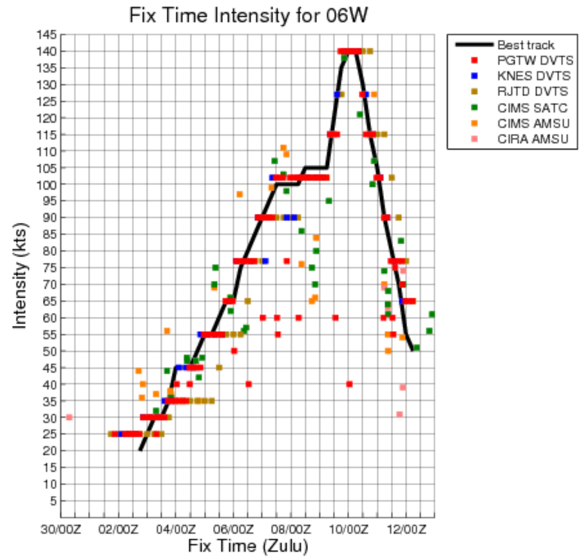
ISSUED LOW:	31 MAR / 0600Z
ISSUED MED:	01 APR / 2330Z
FIRST TCFA:	02 APR / 0530Z
FIRST WARNING:	03 APR / 0000Z
LAST WARNING:	06 APR / 1200Z
MAX INTENSITY:	45
WARNINGS:	15

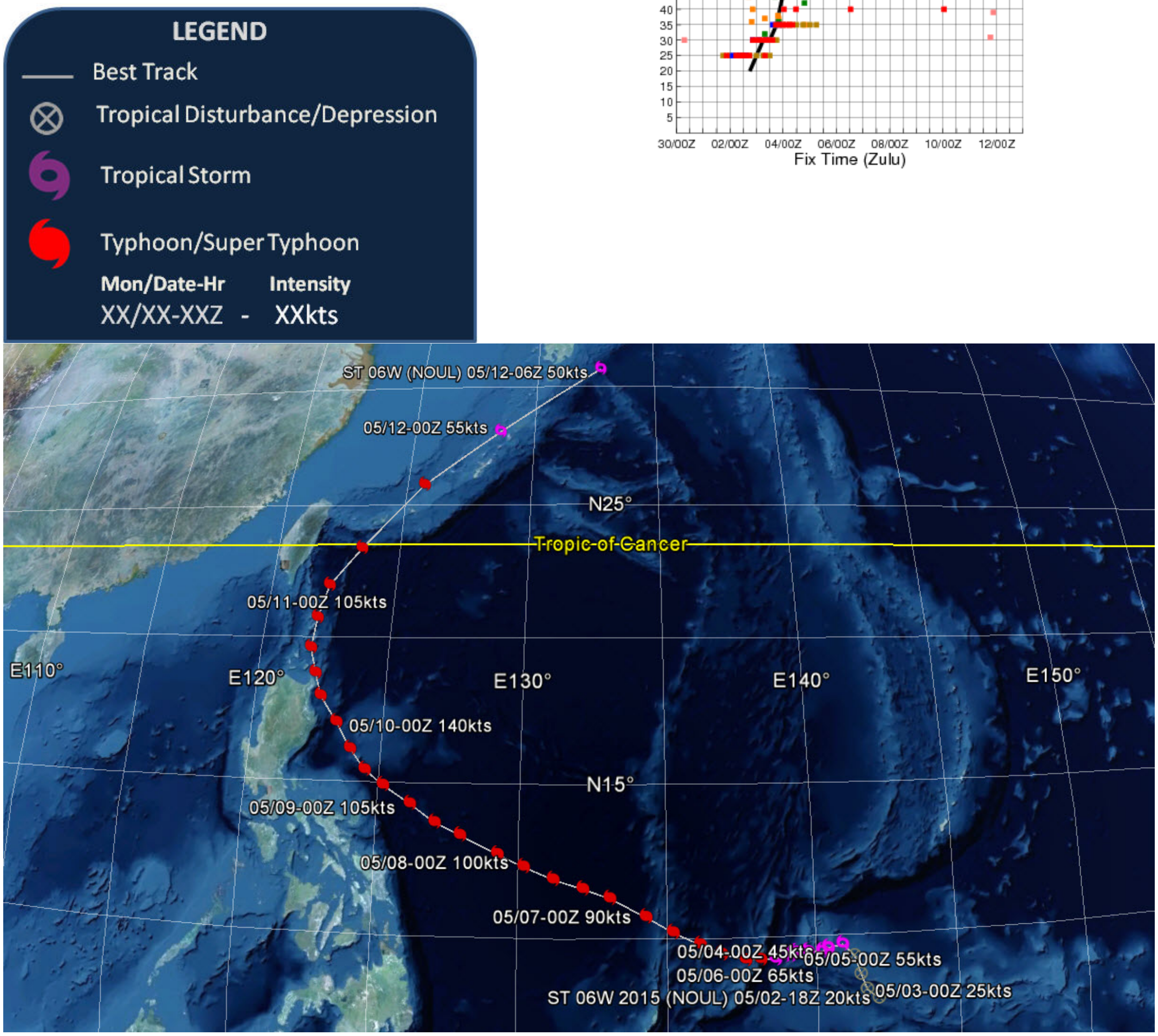




06W SUPER TYPHOON NOUL

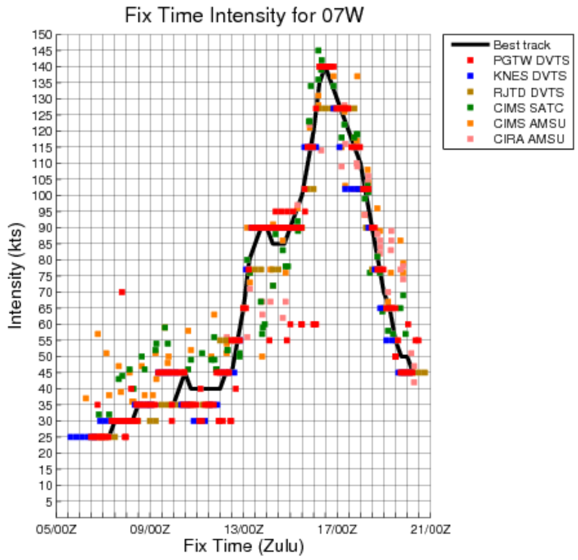
ISSUED LOW:	30 APR / 1400Z
ISSUED MED:	01 MAY / 1900Z
FIRST TCFA:	02 MAY / 0830Z
FIRST WARNING:	03 MAY / 0000Z
LAST WARNING:	12 MAY / 0600Z
MAX INTENSITY:	140
WARNINGS:	38

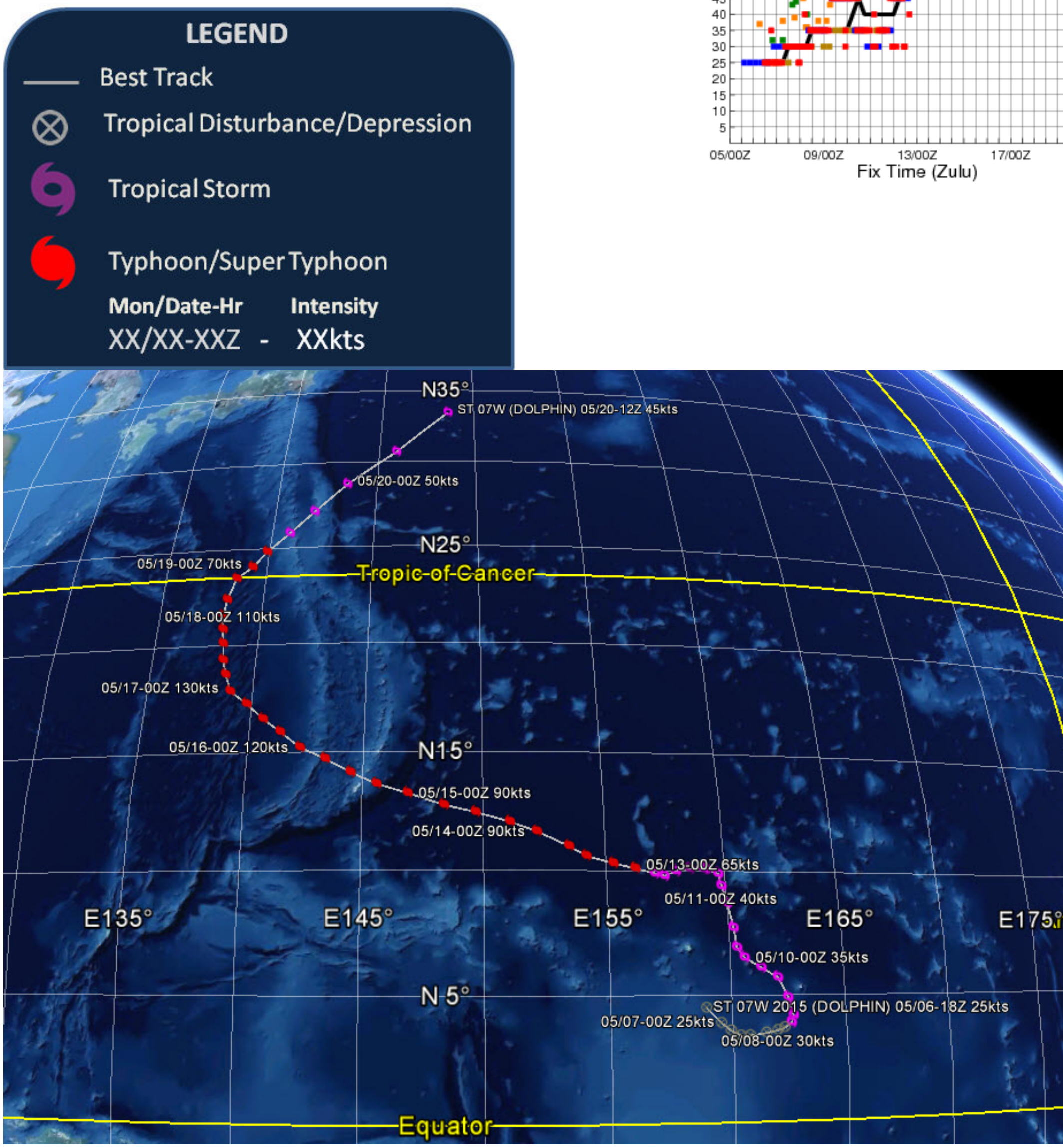




07W SUPER TYPHOON DOLPHIN

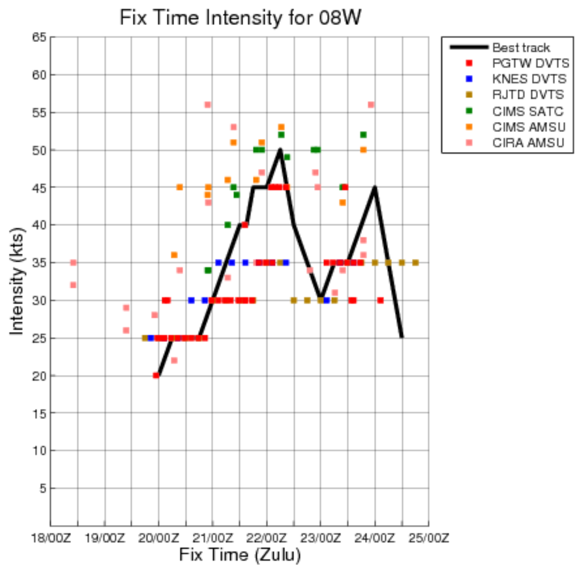
ISSUED LOW:	05 MAY / 0000Z
ISSUED MED:	05 MAY / 1430Z
FIRST TCFA:	06 MAY 0930Z
FIRST WARNING:	06 MAY / 1800Z
LAST WARNING:	19 MAY / 1200Z
MAX INTENSITY:	140
WARNINGS:	52

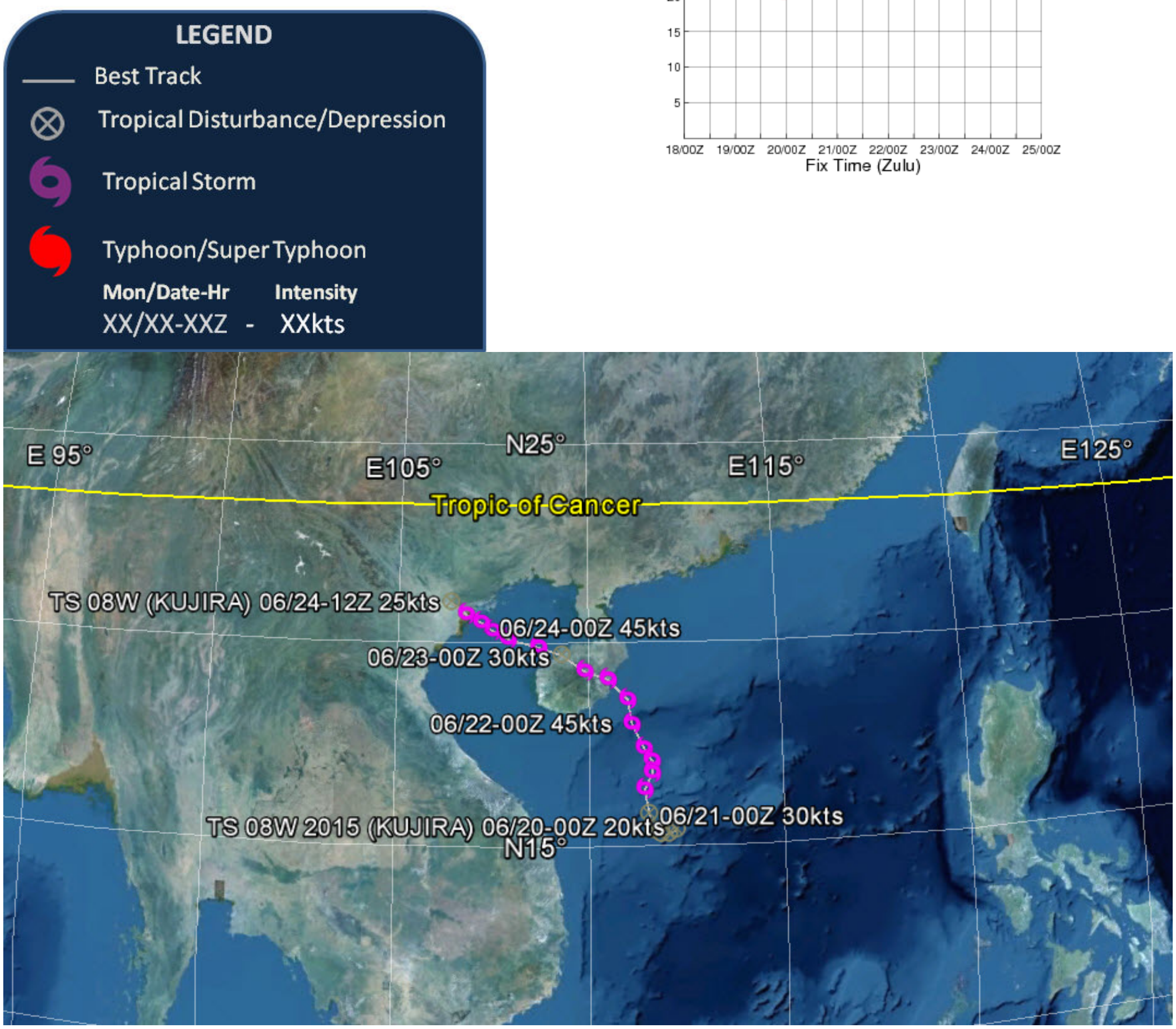




08W TROPICAL STORM KUJIRA

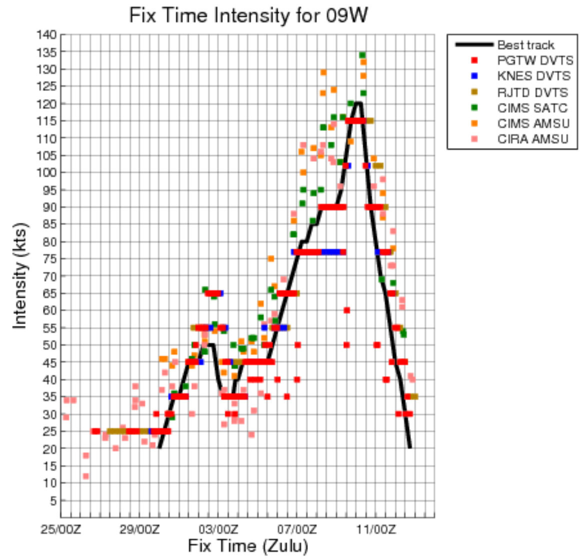
ISSUED LOW:	18 JUN / 2000Z
ISSUED MED:	19 JUN / 0600Z
FIRST TCFA:	20 JUN / 0300Z
FIRST WARNING:	20 JUN / 1200Z
LAST WARNING:	24 JUN / 0000Z
MAX INTENSITY:	50
WARNINGS:	15

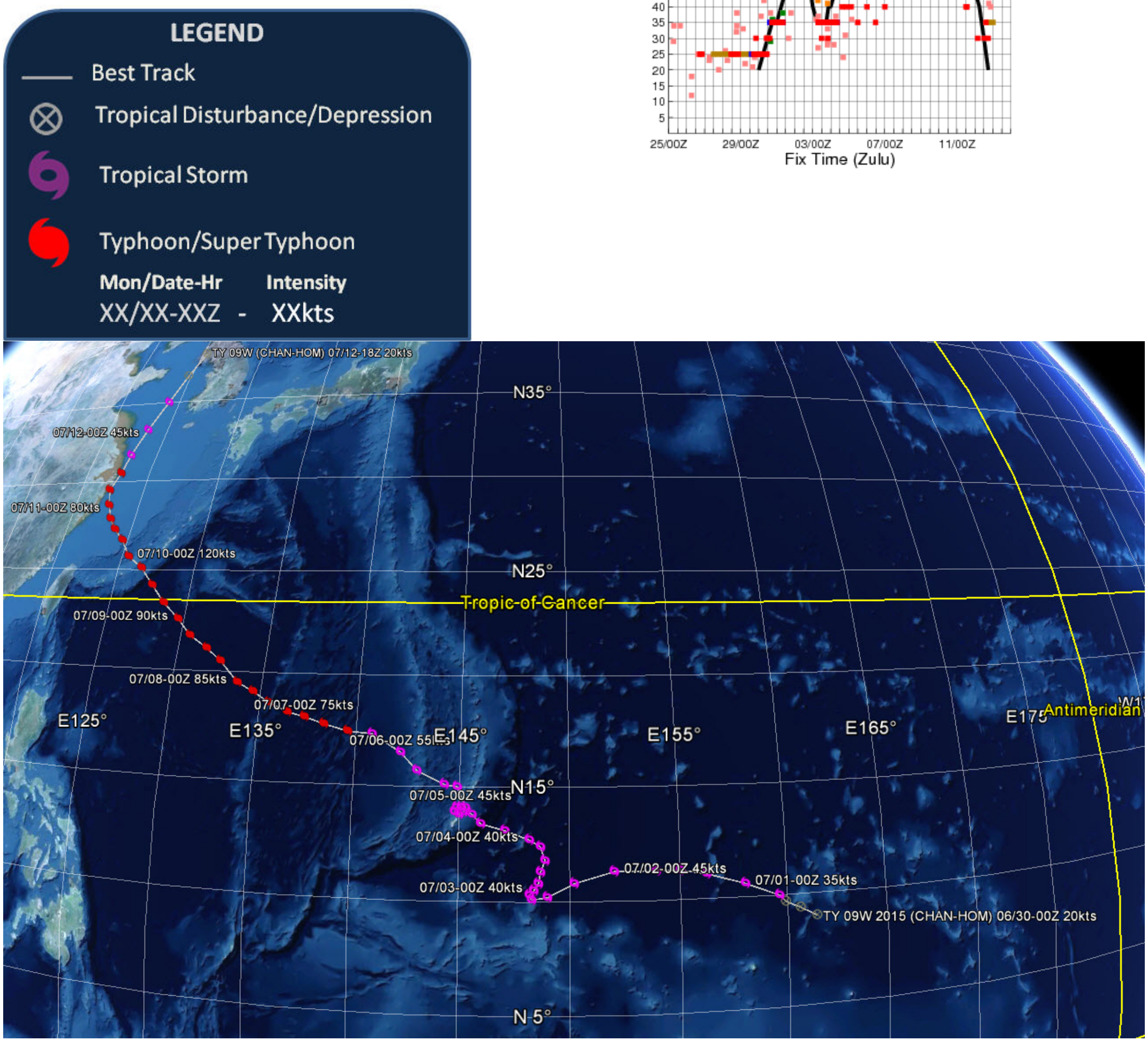




09W TYPHOON CHAN-HOM

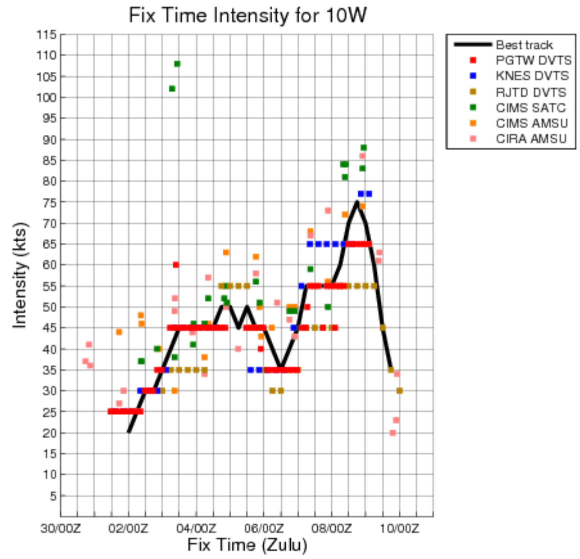
ISSUED LOW:	25 JUN / 1330Z
ISSUED MED:	26 JUN / 2130Z
FIRST TCFA:	29 JUN / 2230Z
FIRST WARNING:	30 JUN / 1200Z
LAST WARNING:	12 JUL / 1800Z
MAX INTENSITY:	120
WARNINGS:	50

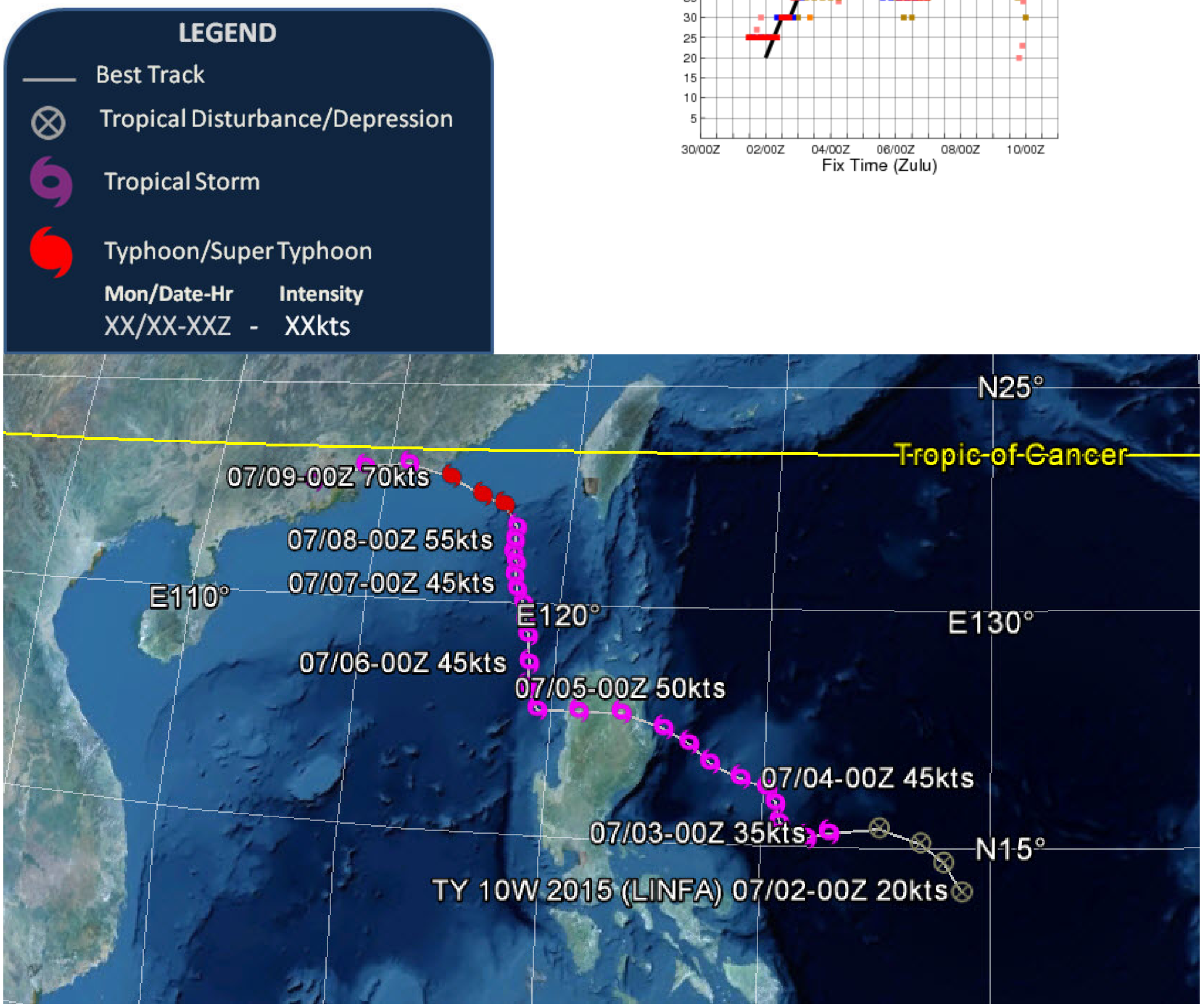




10W TYPHOON LINFA

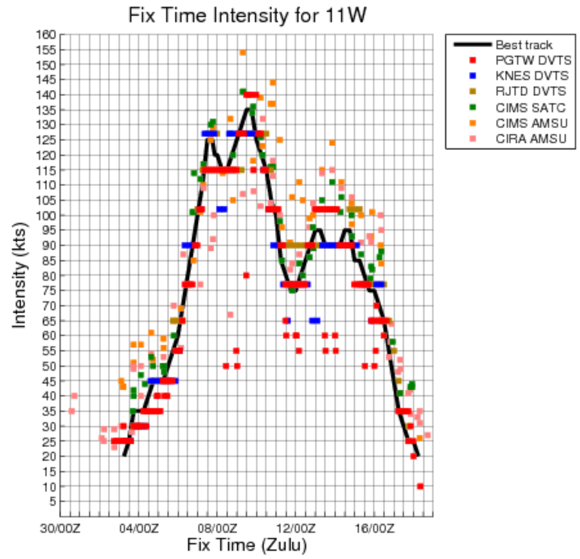
ISSUED LOW:	01 JUL / 0600Z
ISSUED MED:	None
FIRST TCFA:	01 JUL / 1730Z
FIRST WARNING:	02 JUL / 0000Z
LAST WARNING:	09 JUL / 1800Z
MAX INTENSITY:	75
WARNINGS:	32

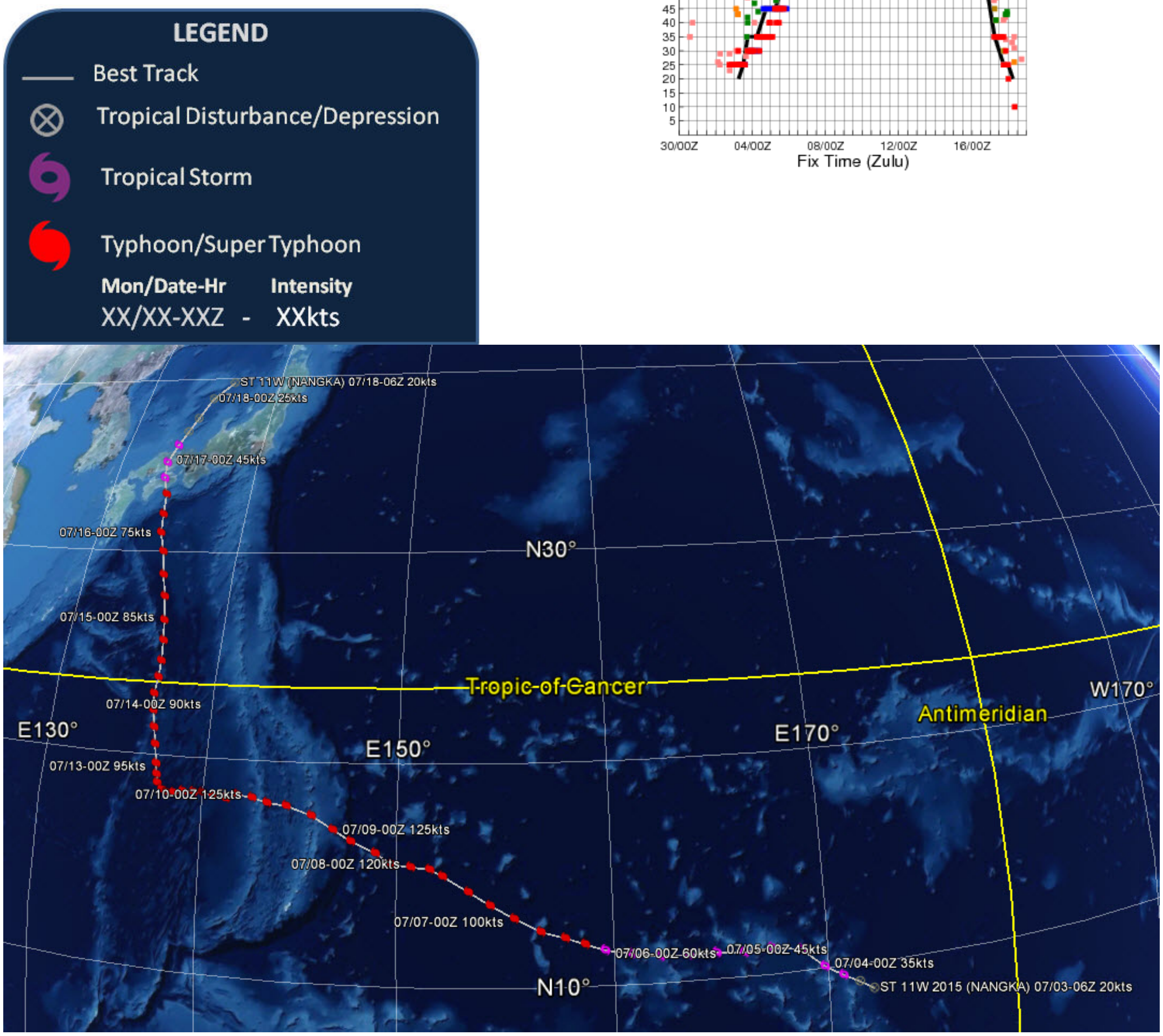




11W SUPER TYPHOON NANGKA

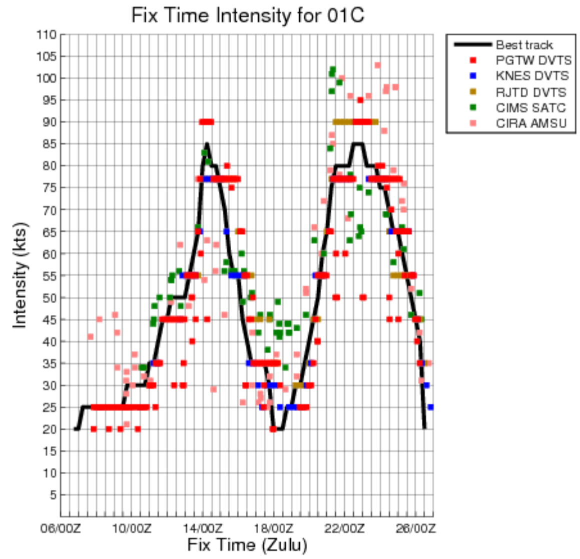
ISSUED LOW:	01 JUL / 0600Z
ISSUED MED:	02 JUL / 2300Z
FIRST TCFA:	03 JUL / 0530Z
FIRST WARNING:	03 JUL / 1200Z
LAST WARNING:	18 JUL / 0000Z
MAX INTENSITY:	135
WARNINGS:	59

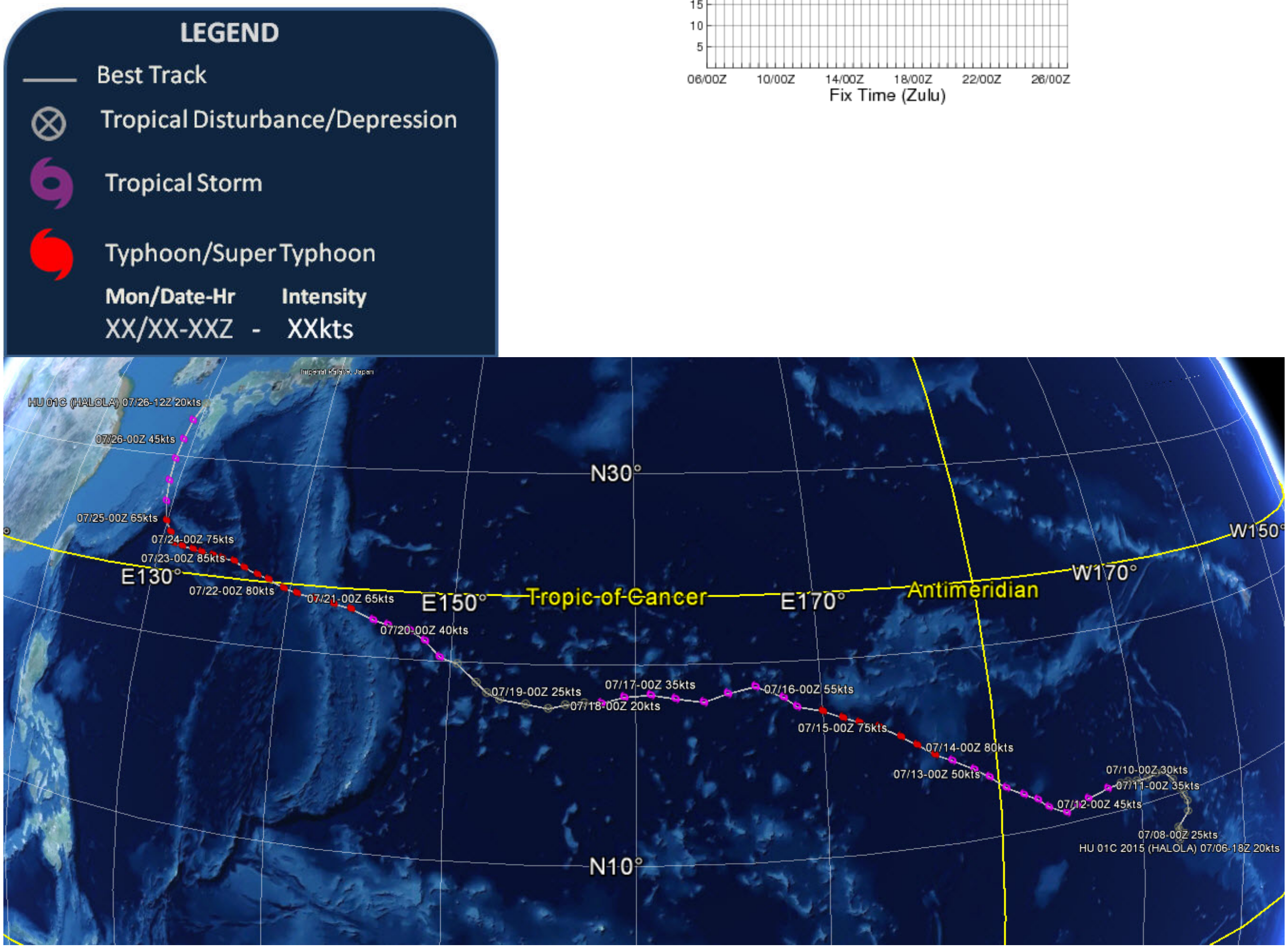




01C HURRICANE HALOLA

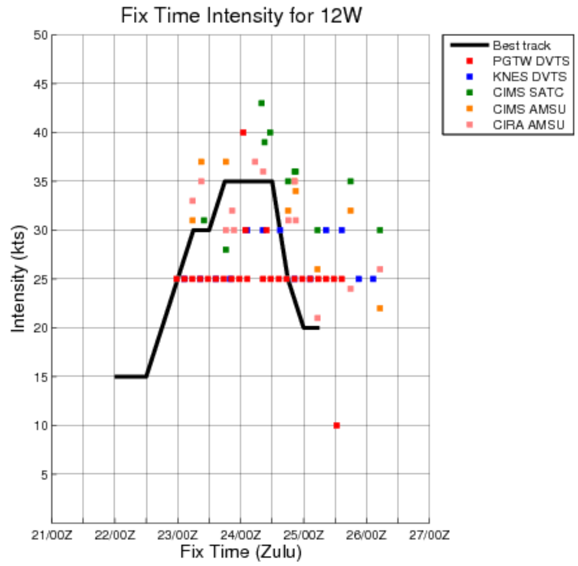
ISSUED LOW:	None
ISSUED MED:	None
FIRST TCFA:	08 JUL / 1730Z
FIRST WARNING:	13 JUL / 0000Z
LAST WARNING:	26 JUL / 1200Z
MAX INTENSITY:	85
WARNINGS:	* 66 (54 PGTW)

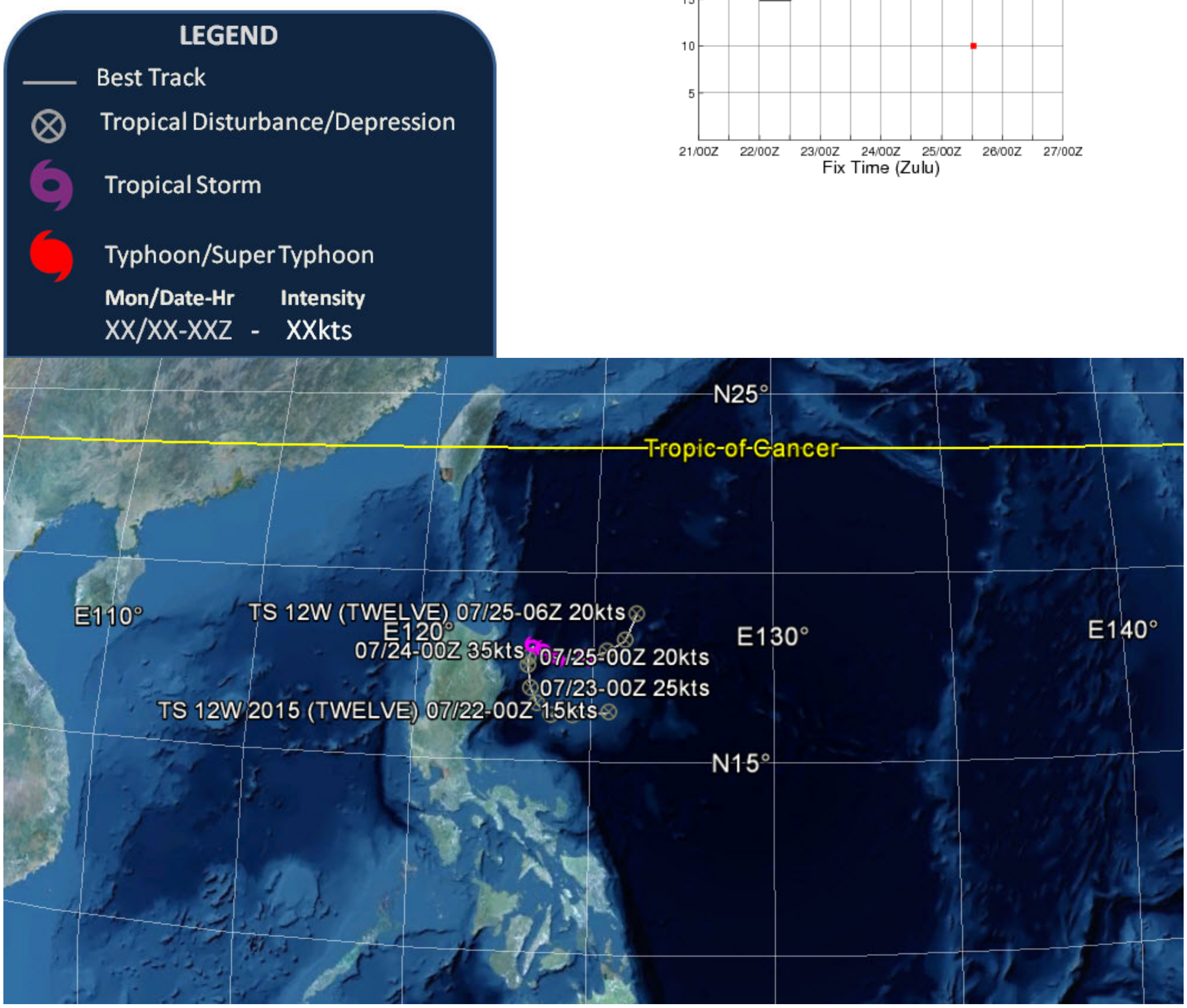




12W TROPICAL STORM TWELVE

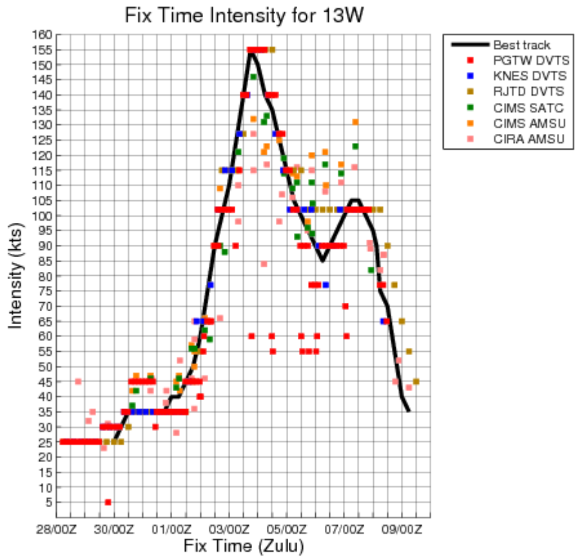
ISSUED LOW:	None
ISSUED MED:	None
FIRST TCFA:	23 JUL / 0130Z
FIRST WARNING:	23 JUL / 0600Z
LAST WARNING:	25 JUL / 0600Z
MAX INTENSITY:	35
WARNINGS:	9

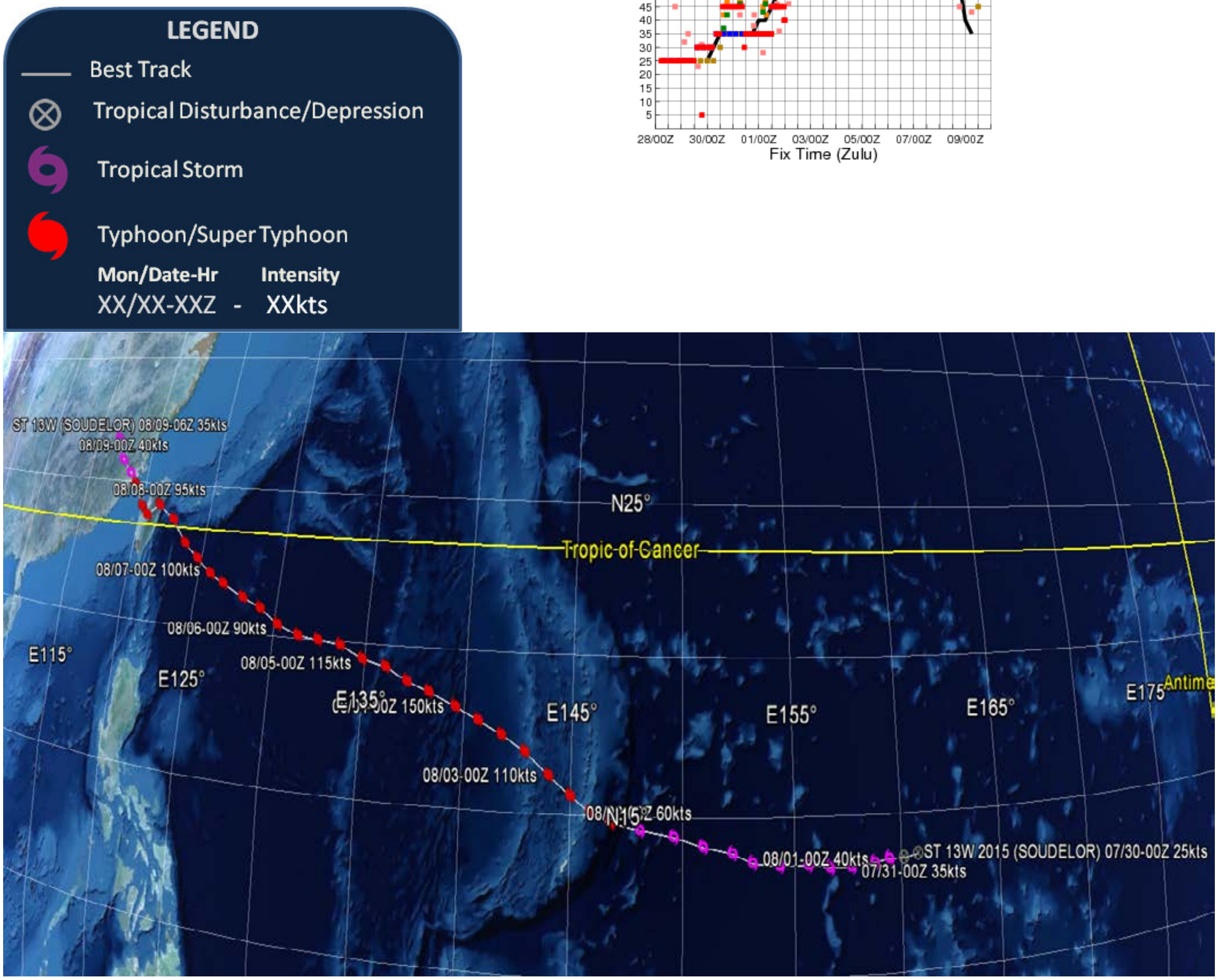




13W SUPER TYPHOON SOUDELOR

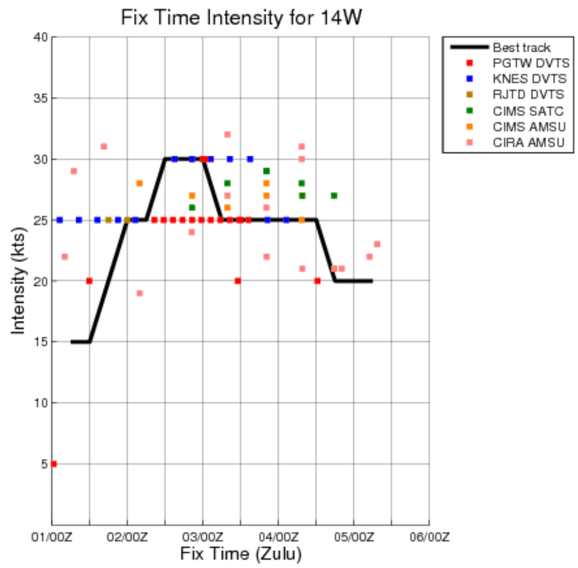
ISSUED LOW:	28 JUL / 2230Z
ISSUED MED:	29 JUL / 0600Z
FIRST TCFA:	29 JUL / 1430Z
FIRST WARNING:	30 JUL / 0600Z
LAST WARNING:	08 AUG / 1800Z
MAX INTENSITY:	155
WARNINGS:	39

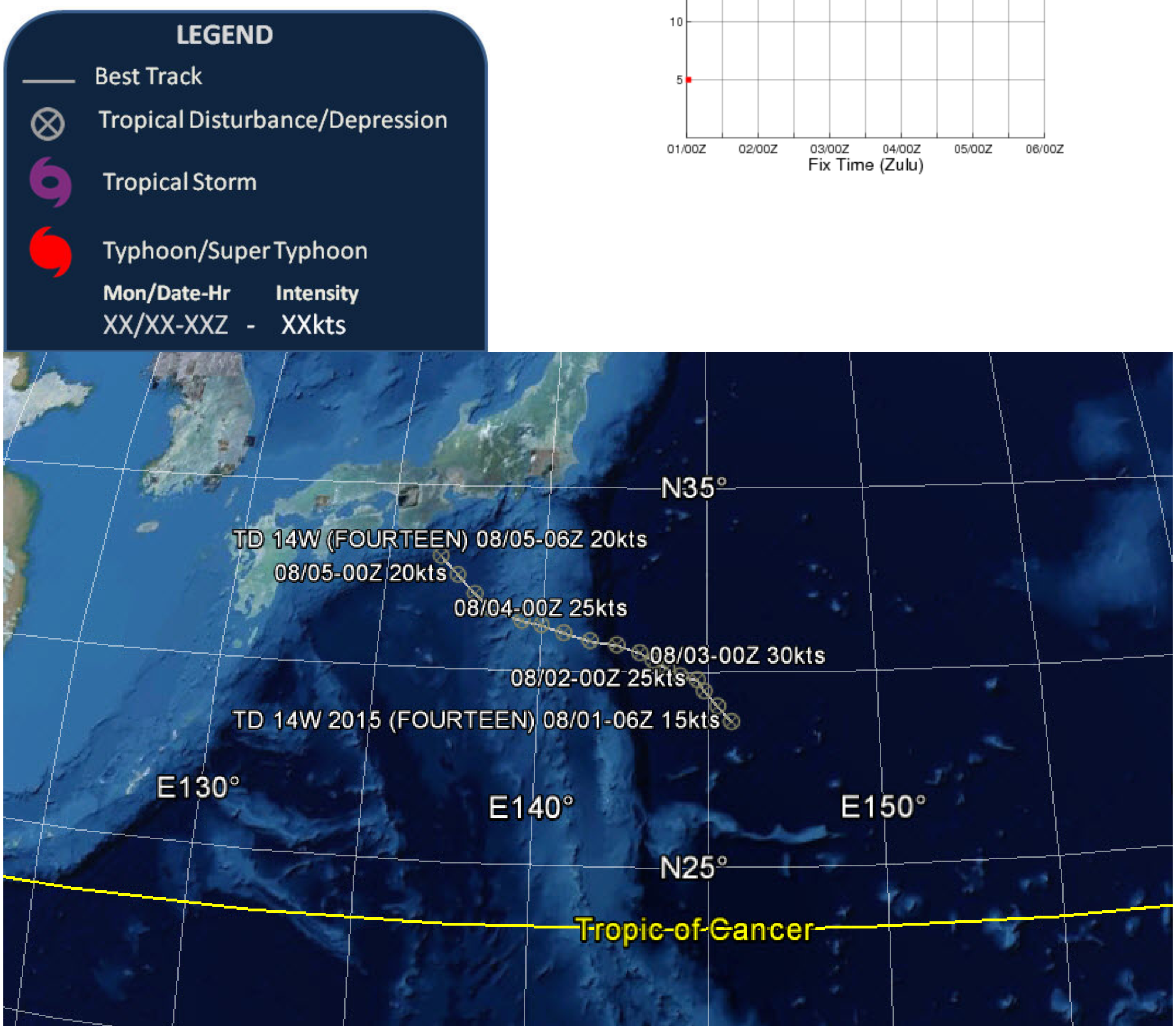




14W TROPICAL DEPRESSION FOURTEEN

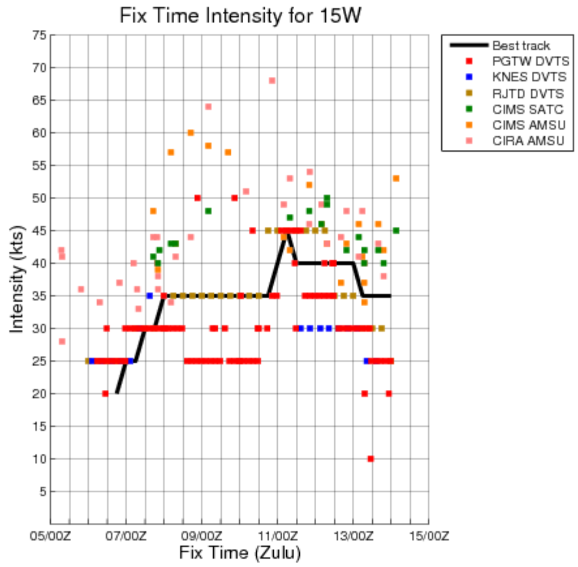
ISSUED LOW:	None
ISSUED MED:	01 AUG / 0600Z
FIRST TCFA:	01 AUG / 1930Z
FIRST WARNING:	02 AUG / 0600Z
LAST WARNING:	04 AUG / 1200Z
MAX INTENSITY:	30
WARNINGS:	10

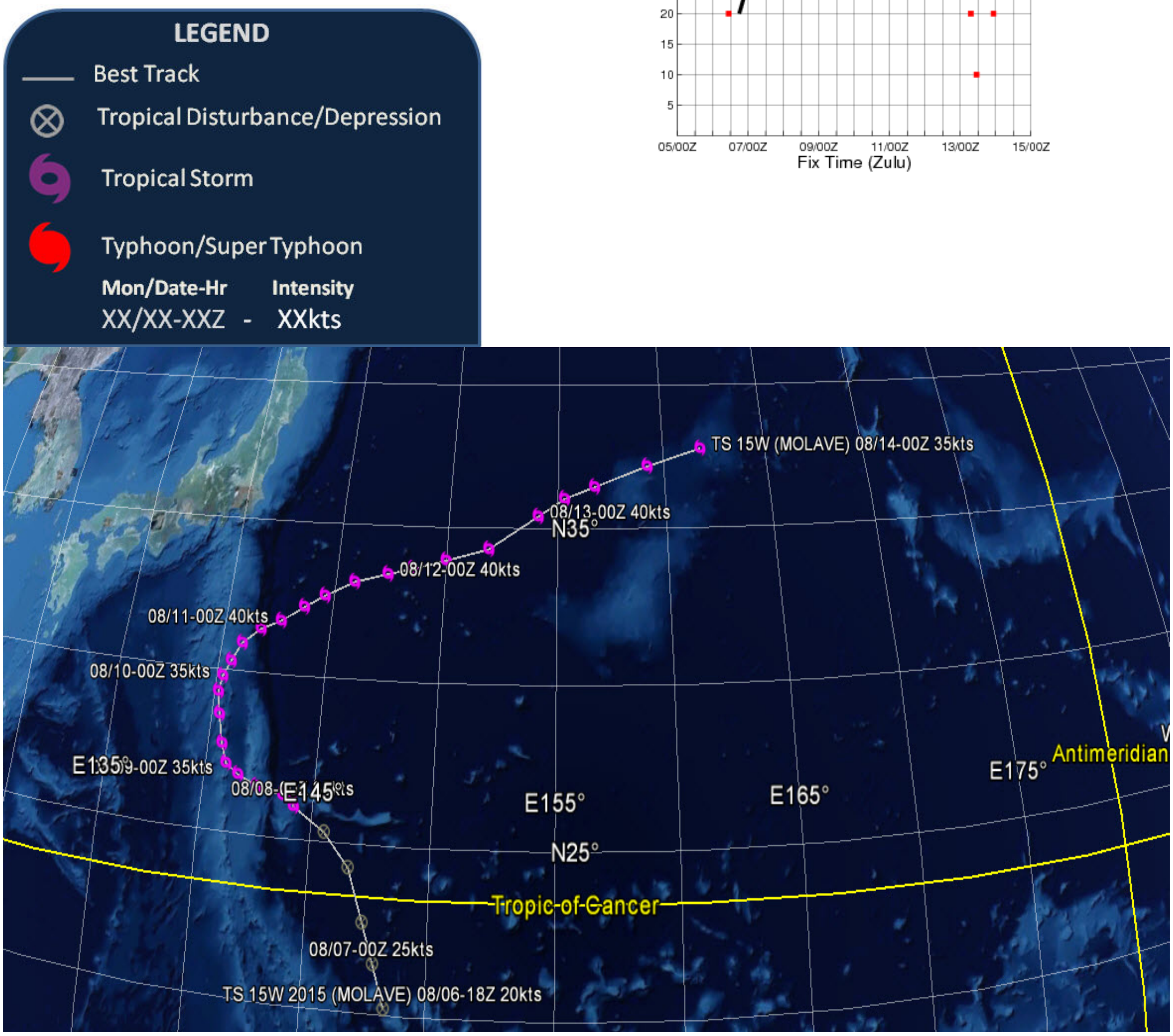




15W TROPICAL STORM MOLAVE

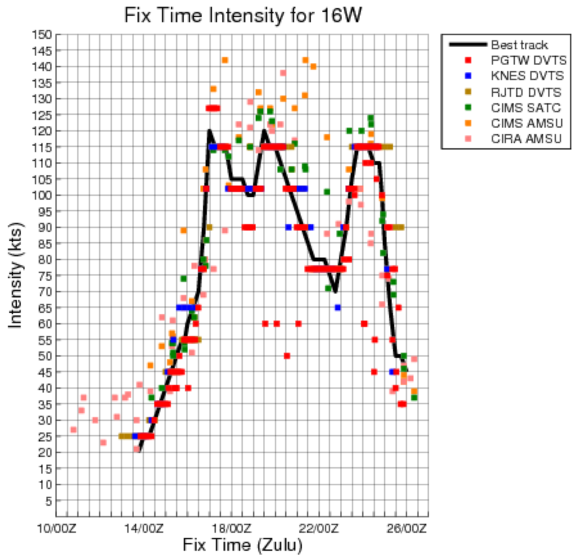
ISSUED LOW:	05 AUG / 1500Z
ISSUED MED:	05 AUG / 2230Z
FIRST TCFA:	06 AUG / 0530Z
FIRST WARNING:	07 AUG / 0000Z
LAST WARNING:	13 AUG / 1800Z
MAX INTENSITY:	45
WARNINGS:	22

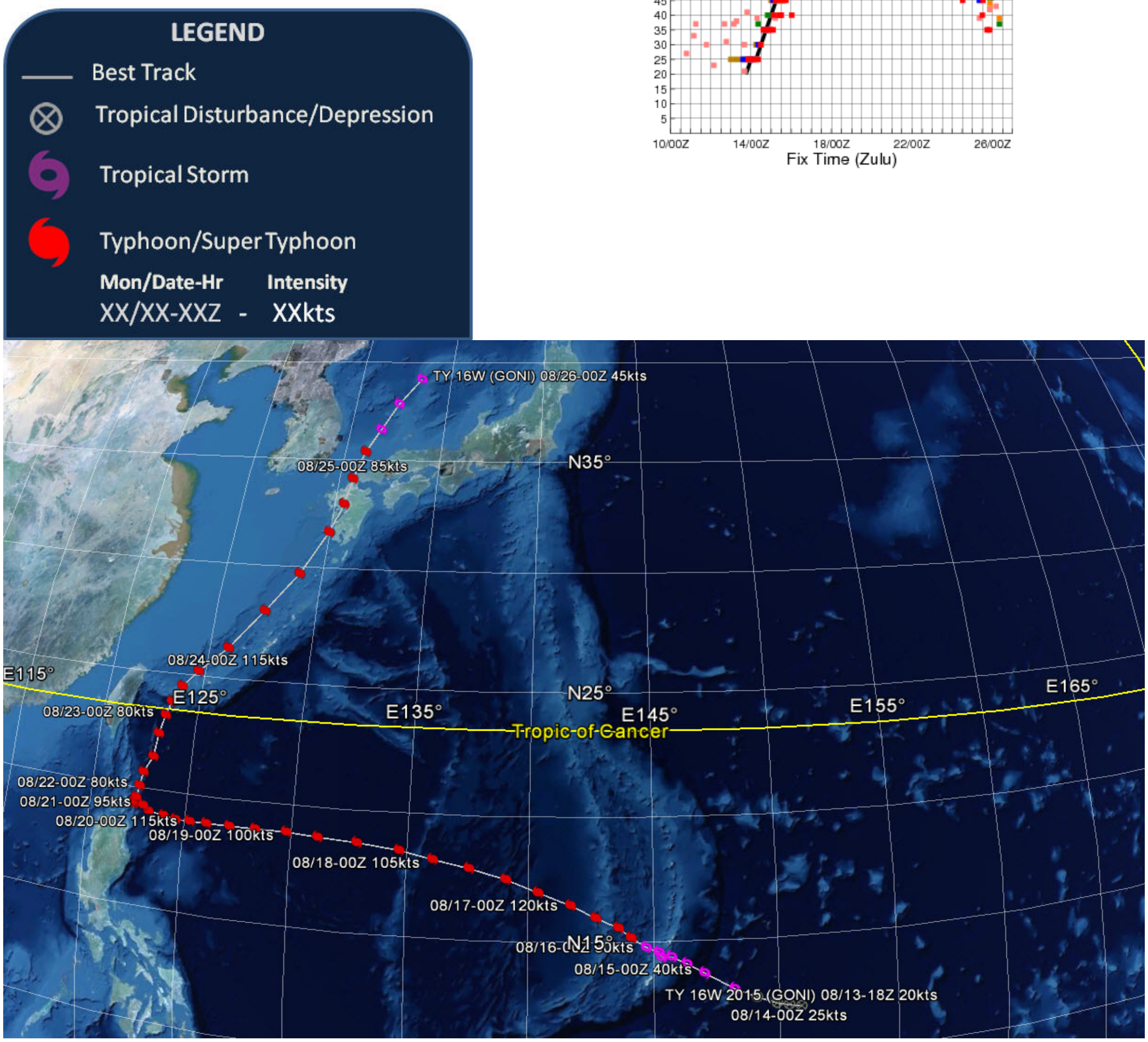




16W TYPHOON GONI

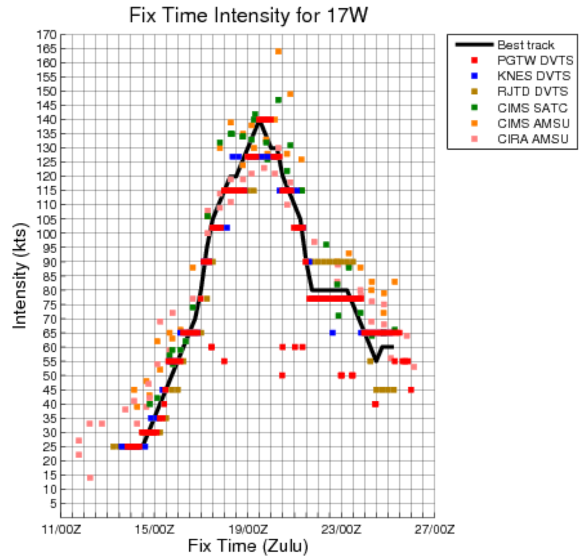
ISSUED LOW:	11 AUG / 2030Z
ISSUED MED:	13 AUG / 0200Z
FIRST TCFA:	13 AUG / 1730Z
FIRST WARNING:	14 AUG / 0000Z
LAST WARNING:	25 AUG / 1200Z
MAX INTENSITY:	120
WARNINGS:	47

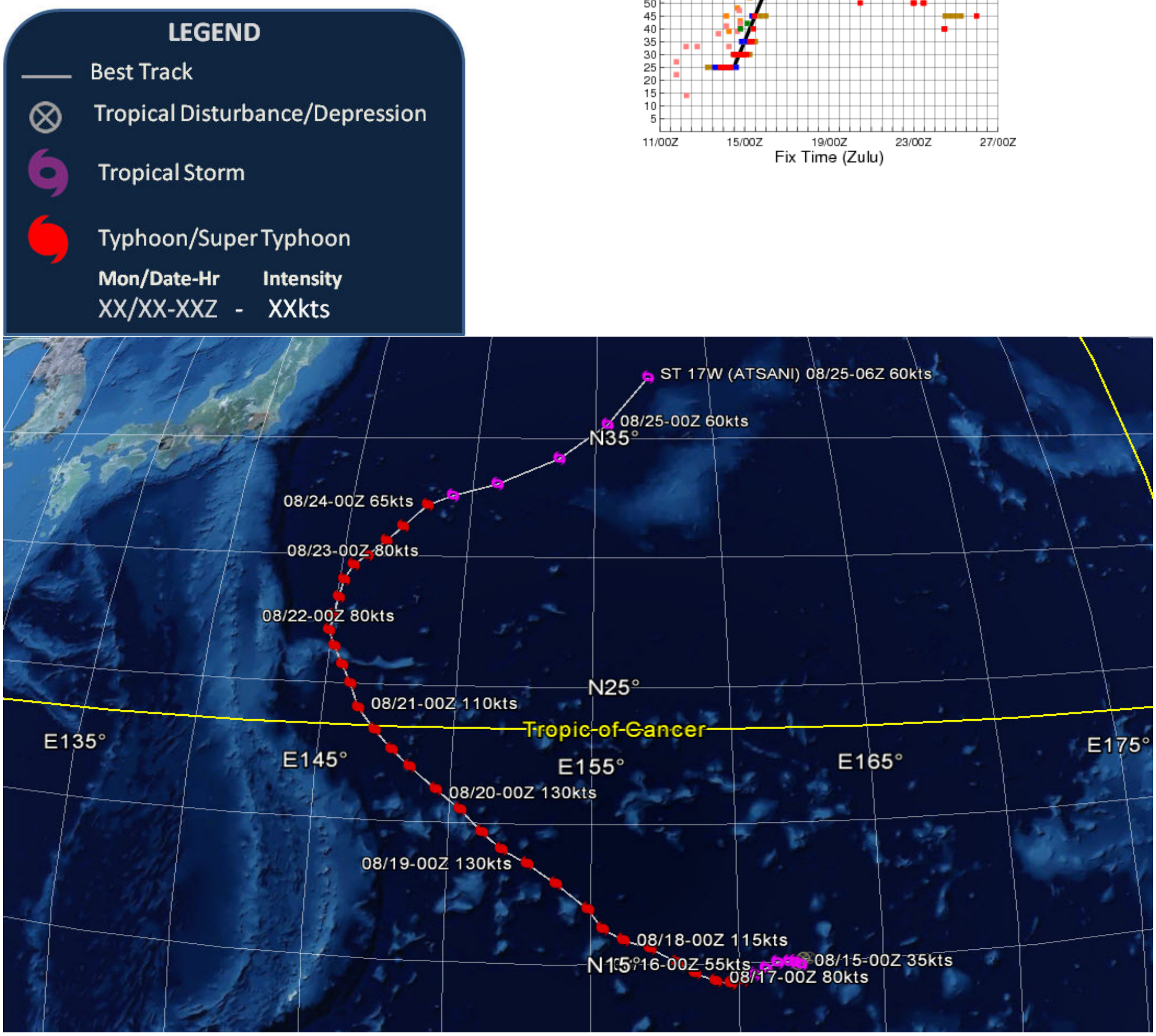




17W SUPER TYPHOON ATSANI

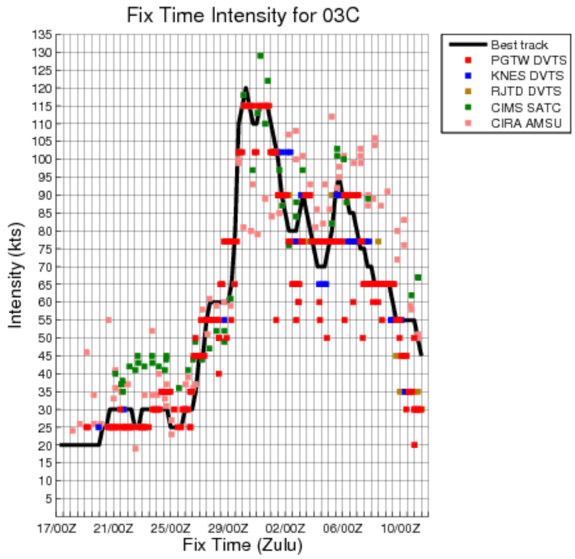
ISSUED LOW:	12 AUG / 0600Z
ISSUED MED:	13 AUG / 0600Z
FIRST TCFA:	13 AUG / 1930Z
FIRST WARNING:	14 AUG / 0600Z
LAST WARNING:	25 AUG / 0000Z
MAX INTENSITY:	140
WARNINGS:	44

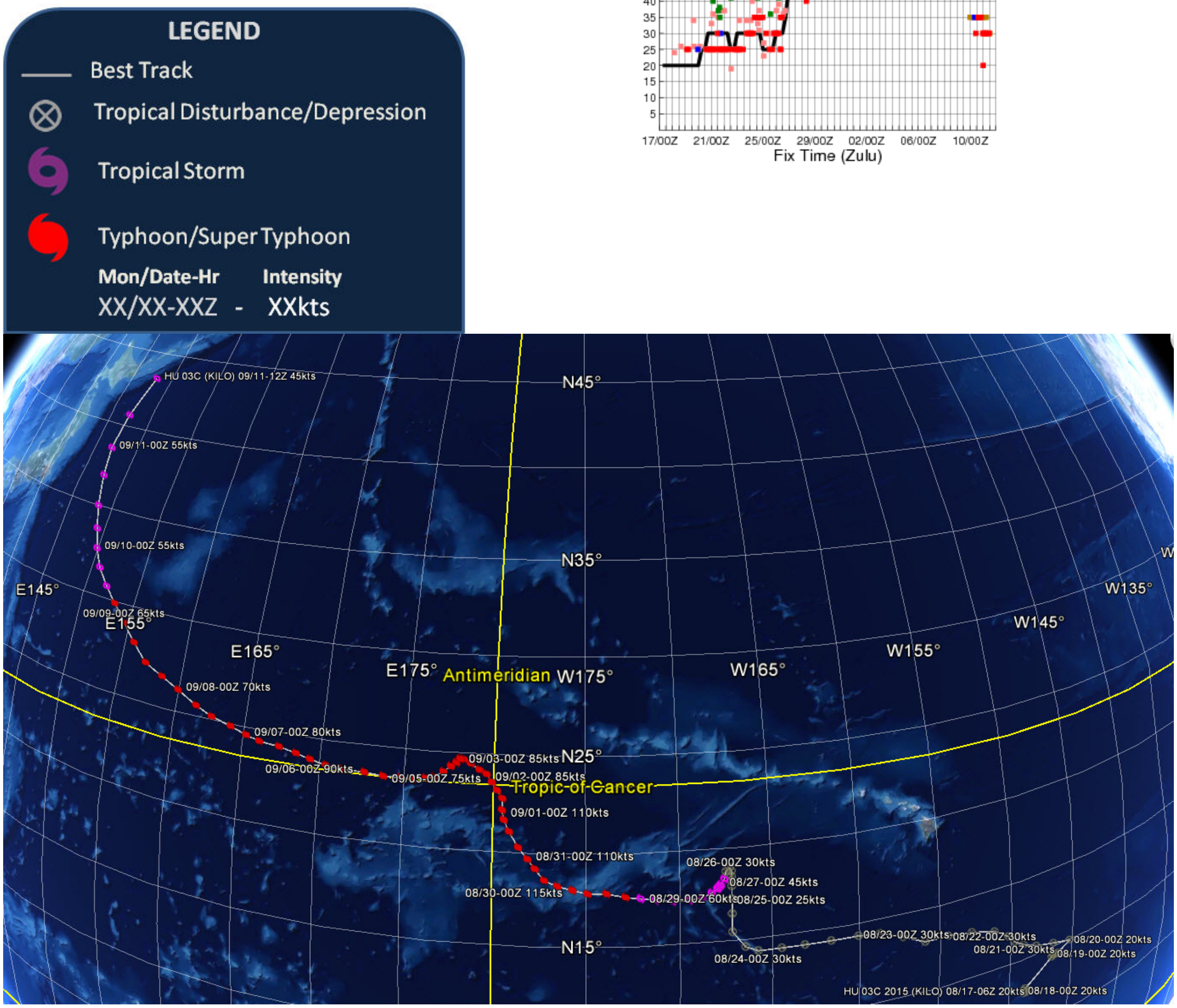




03C HURRICANE KILO

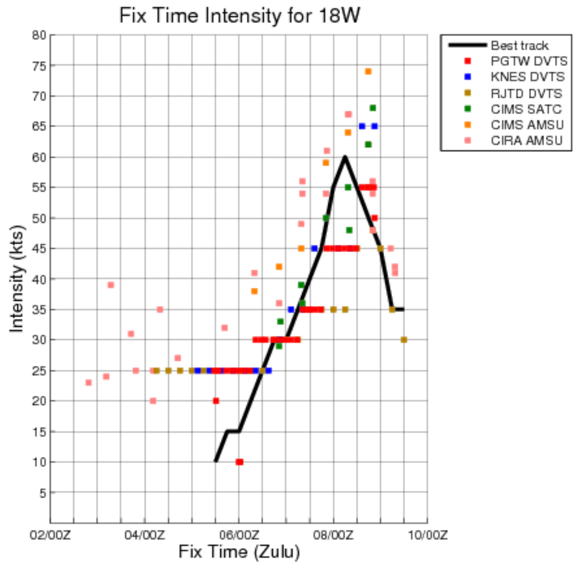
ISSUED LOW:	None
ISSUED MED:	None
FIRST TCFA:	20 AUG / 1730Z
FIRST WARNING:	01 SEP / 0600Z
LAST WARNING:	11 SEP / 0000Z
MAX INTENSITY:	120
WARNINGS:	* 86 (40 PGTW)

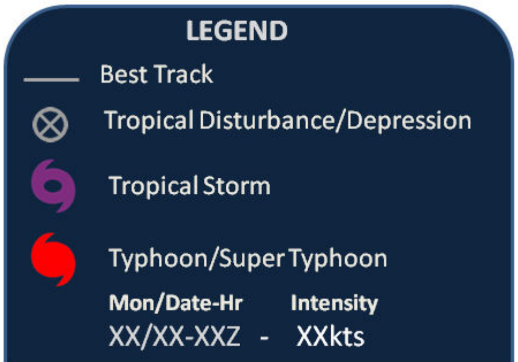


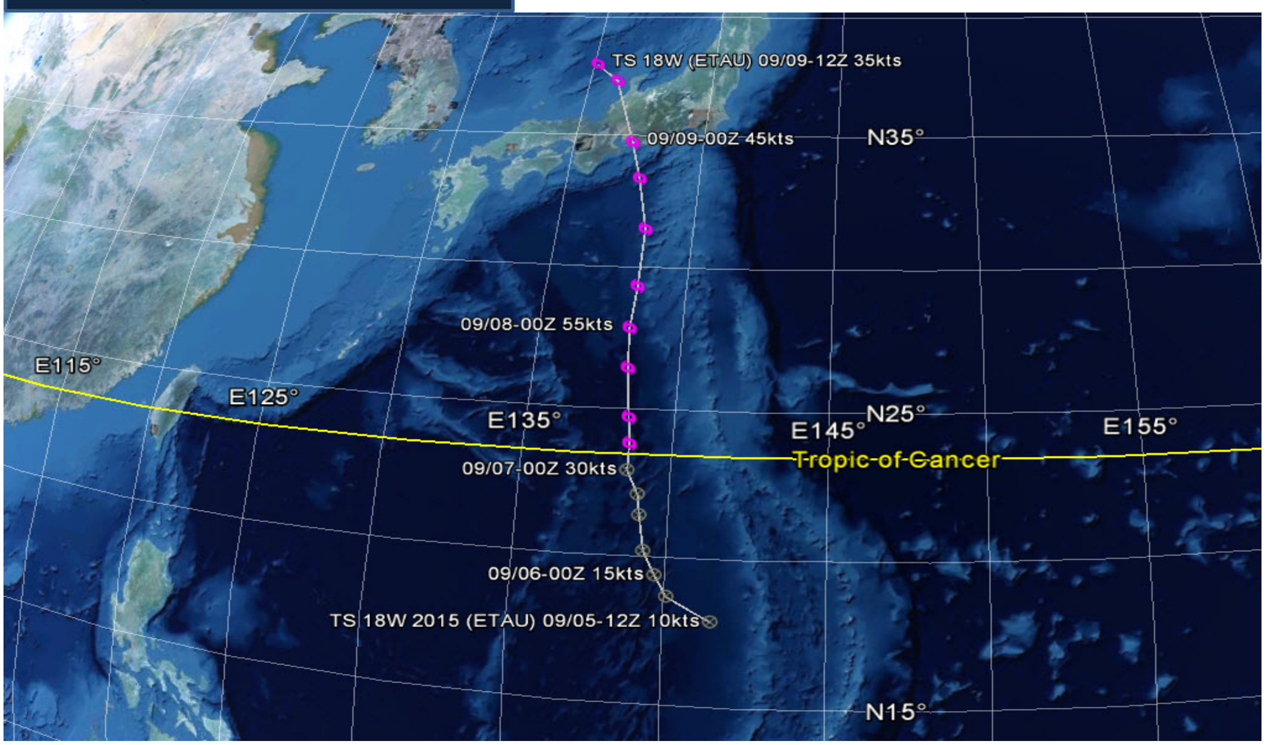


18W TROPICAL STORM ETAU

ISSUED LOW:	05 SEP / 0600Z
ISSUED MED:	None
FIRST TCFA:	06 SEP / 0500Z
FIRST WARNING:	06 SEP / 1800Z
LAST WARNING:	09 SEP / 0600Z
MAX INTENSITY:	60
WARNINGS:	11

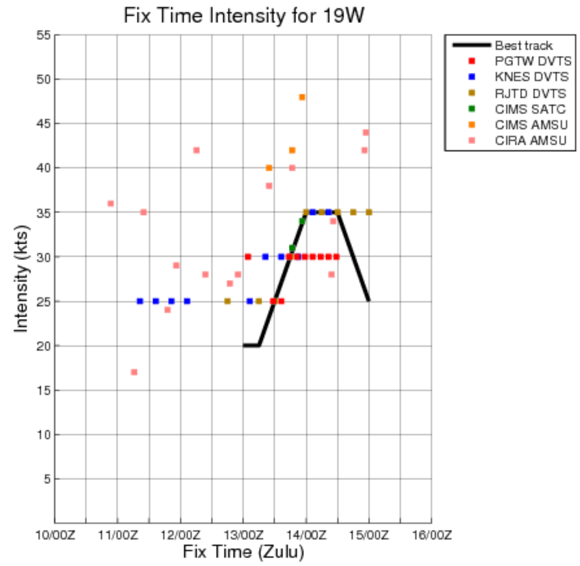


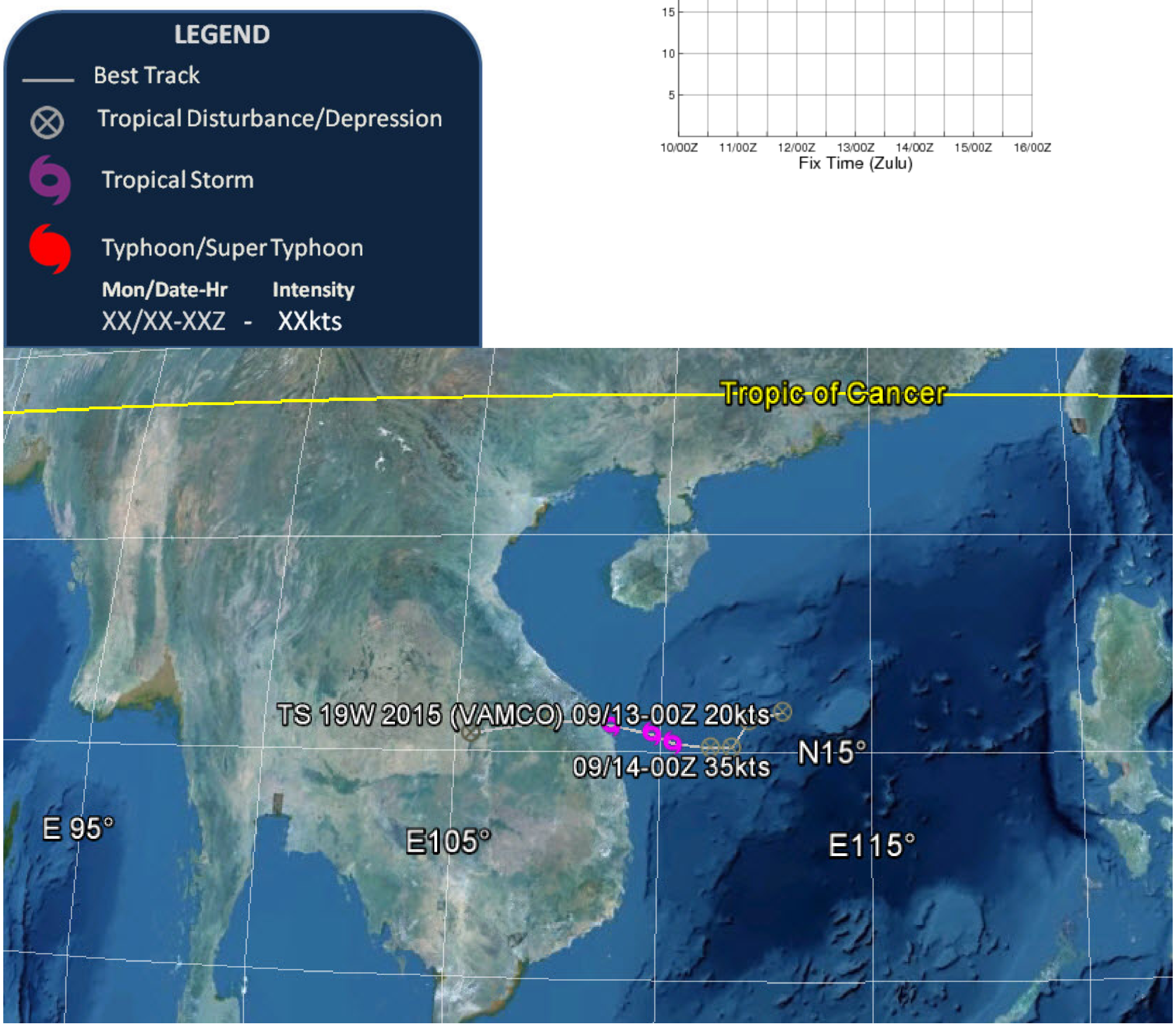




19W TROPICAL STORM VAMCO

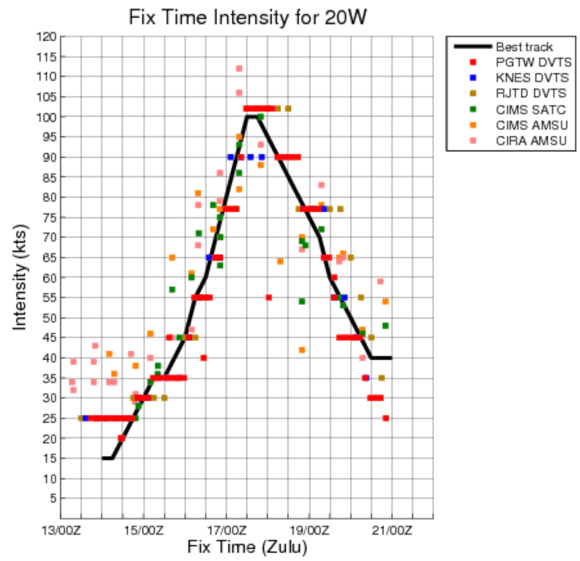
ISSUED LOW:	11 SEP / 0300Z
ISSUED MED:	13 SEP / 0600Z
FIRST TCFA:	13 SEP / 1000Z
FIRST WARNING:	13 SEP / 1200Z
LAST WARNING:	14 SEP / 1200Z
MAX INTENSITY:	35
WARNINGS:	5

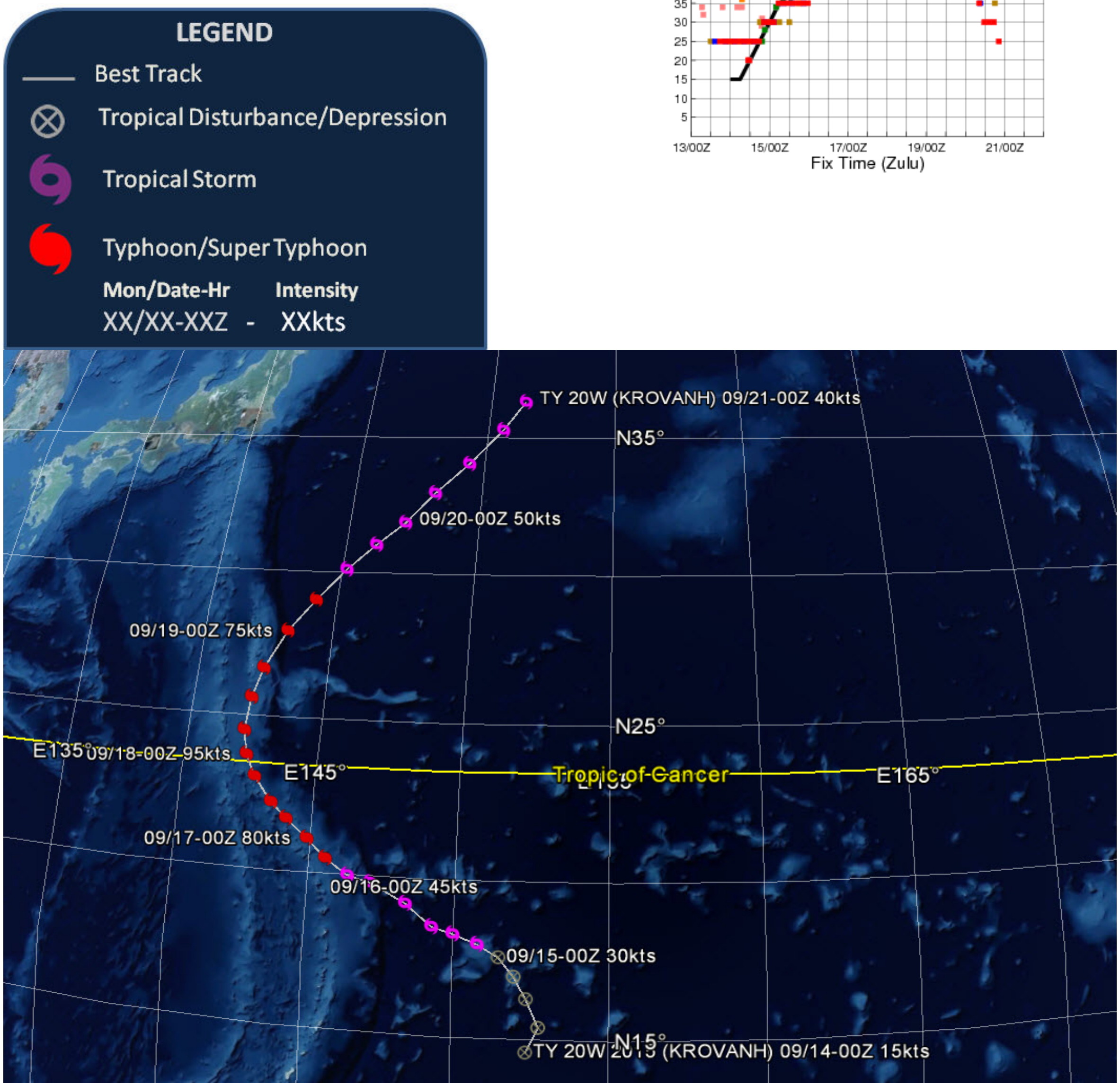




20W TYPHOON KROVANH

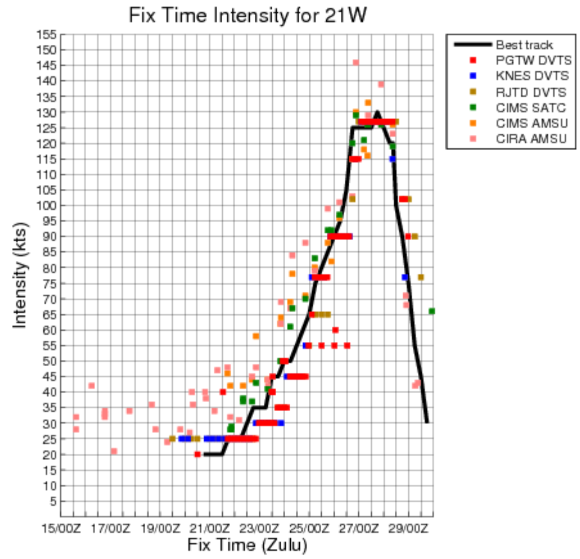
ISSUED LOW:	13 SEP / 1600Z
ISSUED MED:	None
FIRST TCFA:	13 SEP / 1930Z
FIRST WARNING:	14 SEP / 1800Z
LAST WARNING:	20 SEP / 1200Z
MAX INTENSITY:	100
WARNINGS:	24

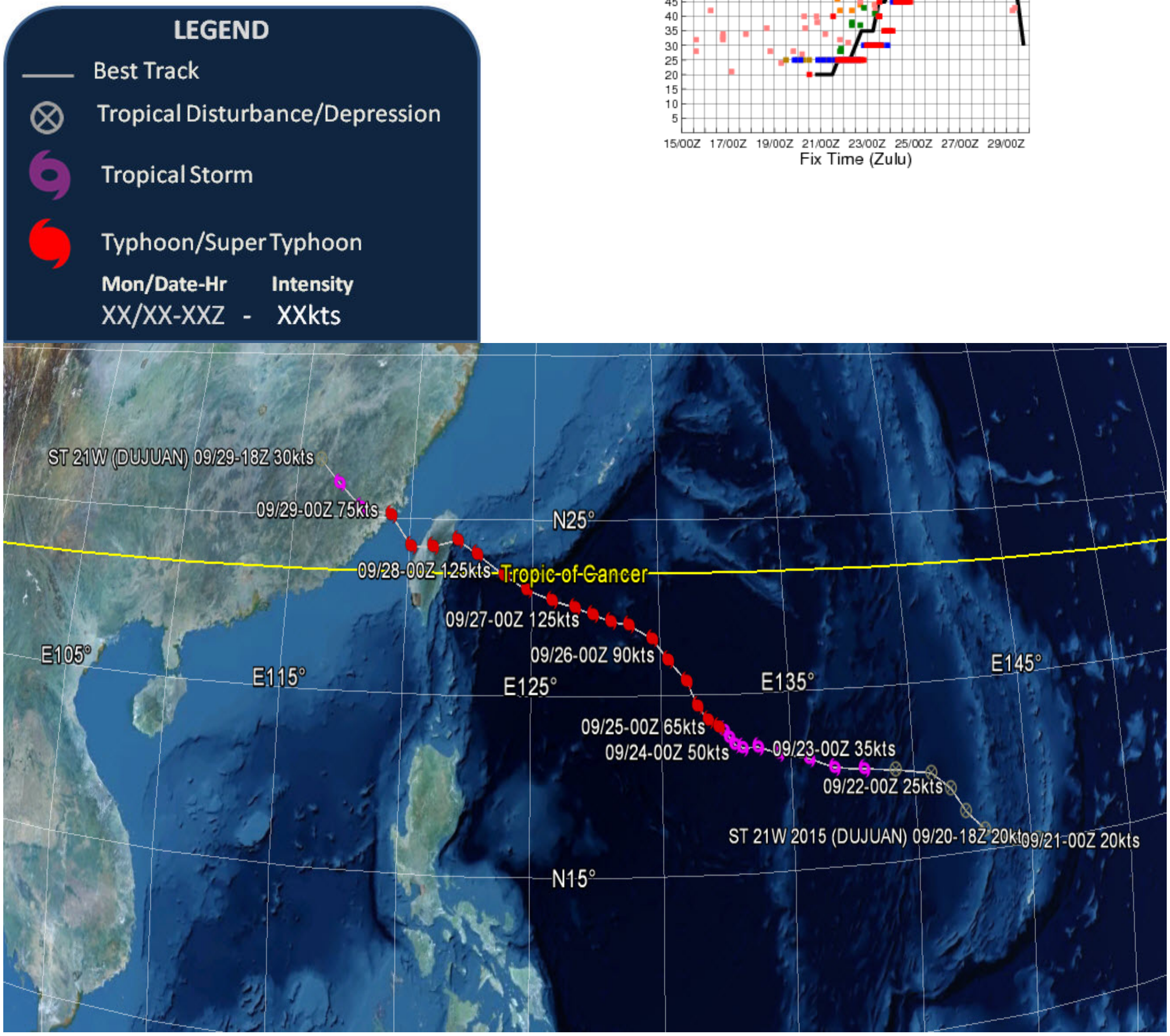




21W SUPER TYPHOON DUJUAN

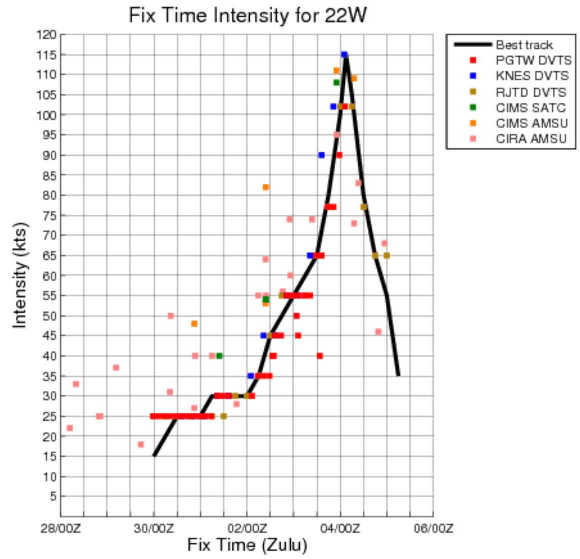
ISSUED LOW:	17 SEP / 0600Z
ISSUED MED:	19 SEP / 1630Z
FIRST TCFA:	20 SEP / 0300Z
FIRST WARNING:	21 SEP / 1800Z
LAST WARNING:	29 SEP / 0000Z
MAX INTENSITY:	130
WARNINGS:	30

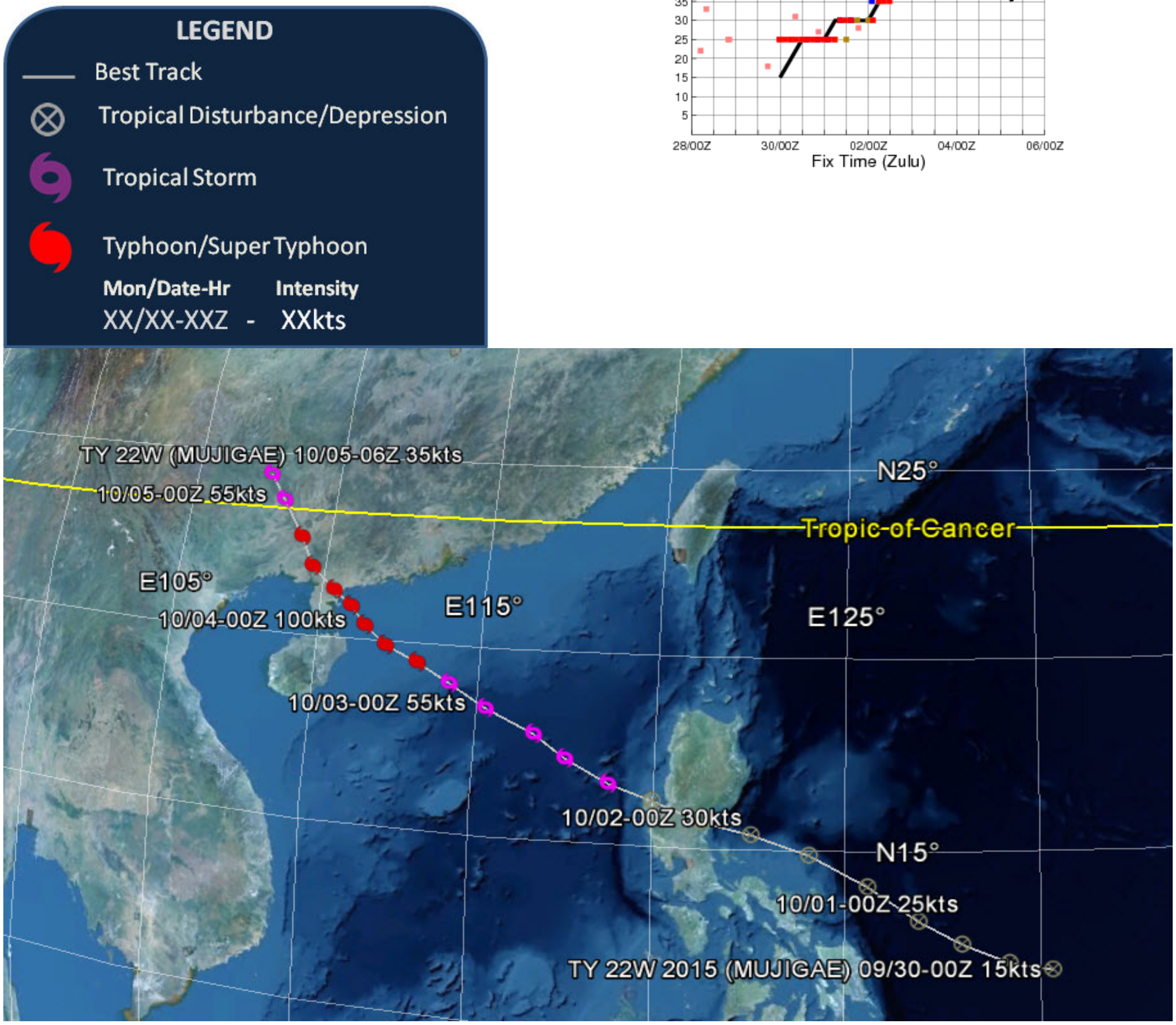




22W TYPHOON MUJIGAE

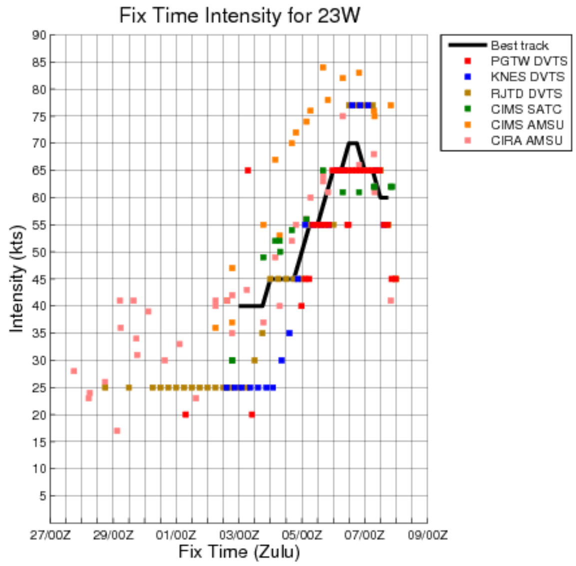
ISSUED LOW:	None
ISSUED MED:	30 SEP / 0030Z
FIRST TCFA:	30 SEP / 0530Z
FIRST WARNING:	01 OCT / 0000Z
LAST WARNING:	04 OCT / 1200Z
MAX INTENSITY:	115
WARNINGS:	15

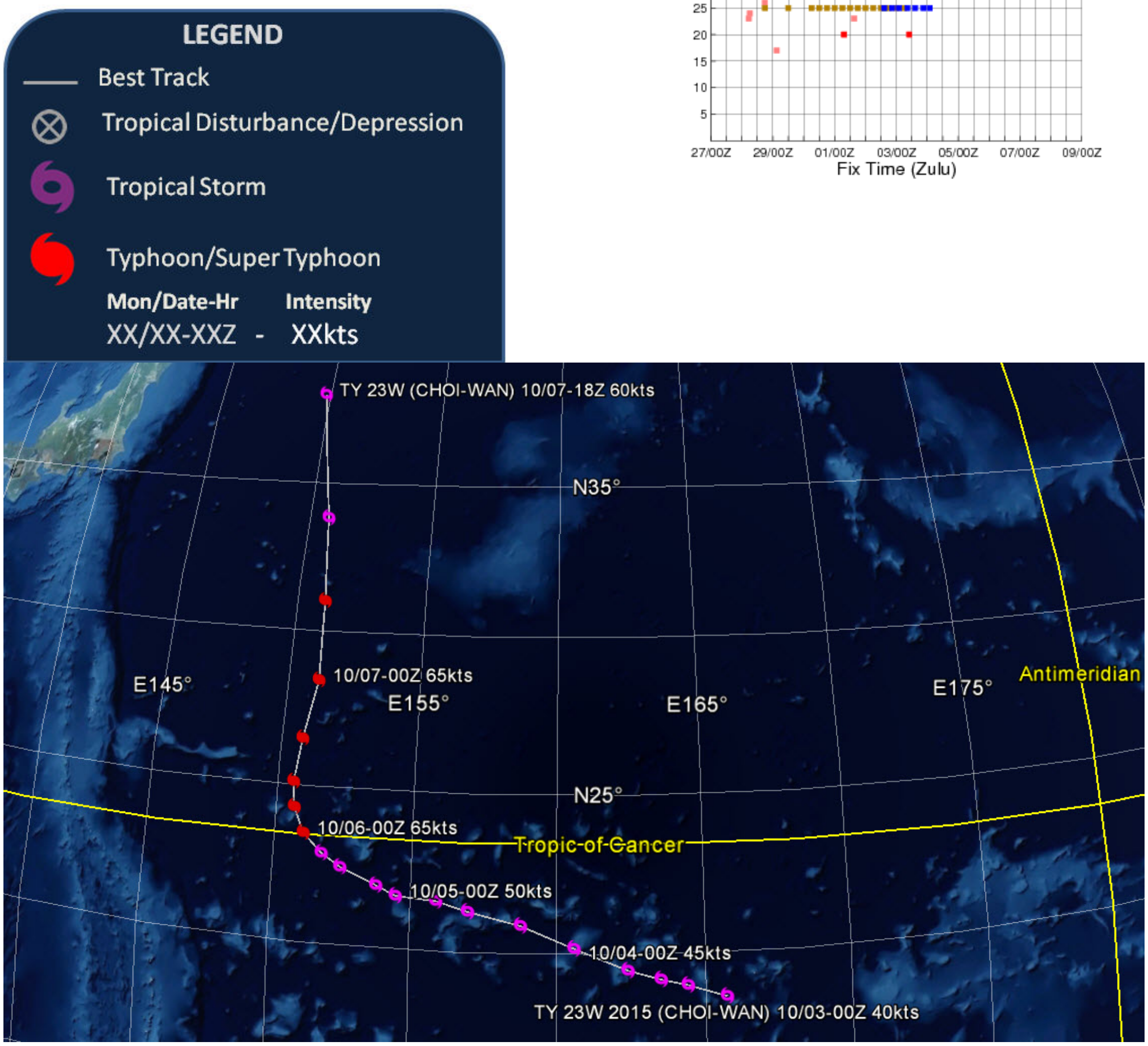




23W TYPHOON CHOI-WAN

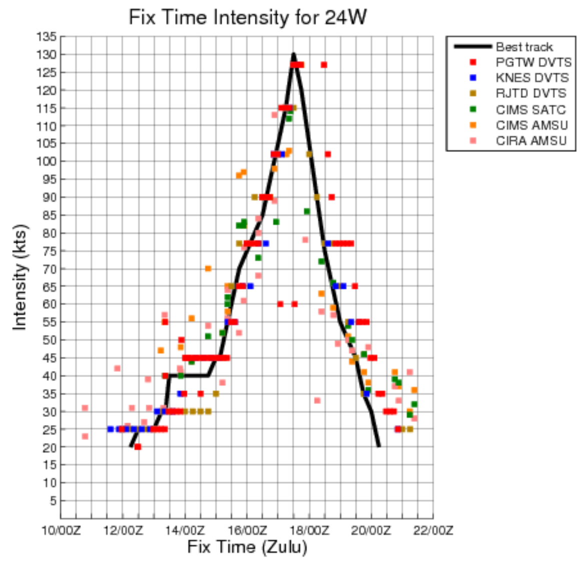
ISSUED LOW:	29 SEP / 0600Z
ISSUED MED:	30 SEP / 0030Z
FIRST TCFA:	02 OCT / 0830Z
FIRST WARNING:	02 OCT / 1200Z
LAST WARNING:	07 OCT / 1800Z
MAX INTENSITY:	70
WARNINGS:	22

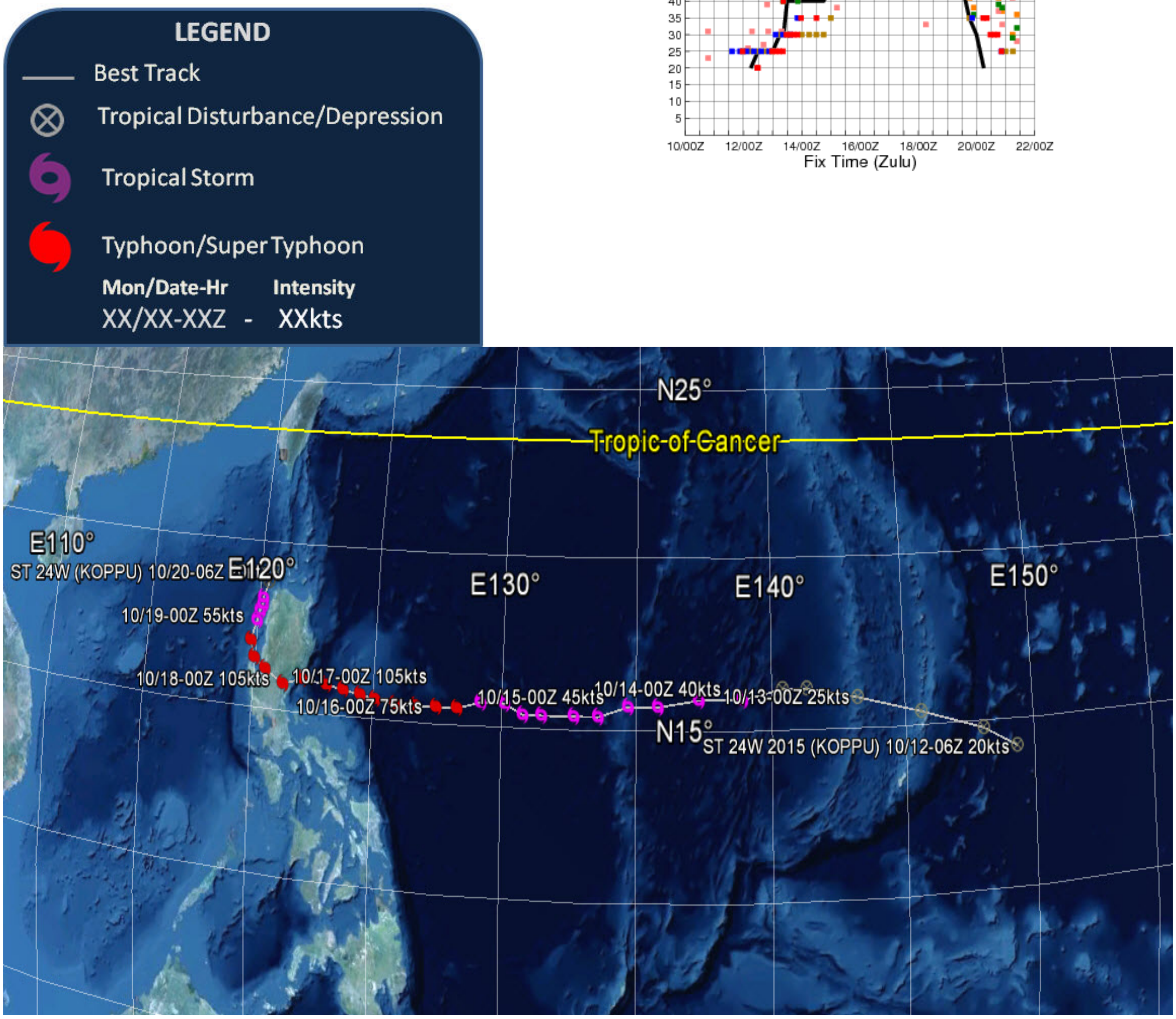




24W SUPER TYPHOON KOPPU

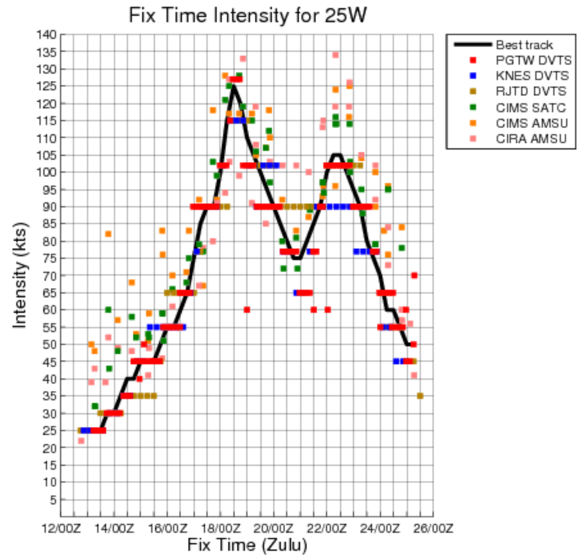
ISSUED LOW:	11 OCT / 0600Z
ISSUED MED:	11 OCT / 1830Z
FIRST TCFA:	12 OCT / 0800Z
FIRST WARNING:	13 OCT / 0000Z
LAST WARNING:	21 OCT / 0000Z
MAX INTENSITY:	130
WARNINGS:	33

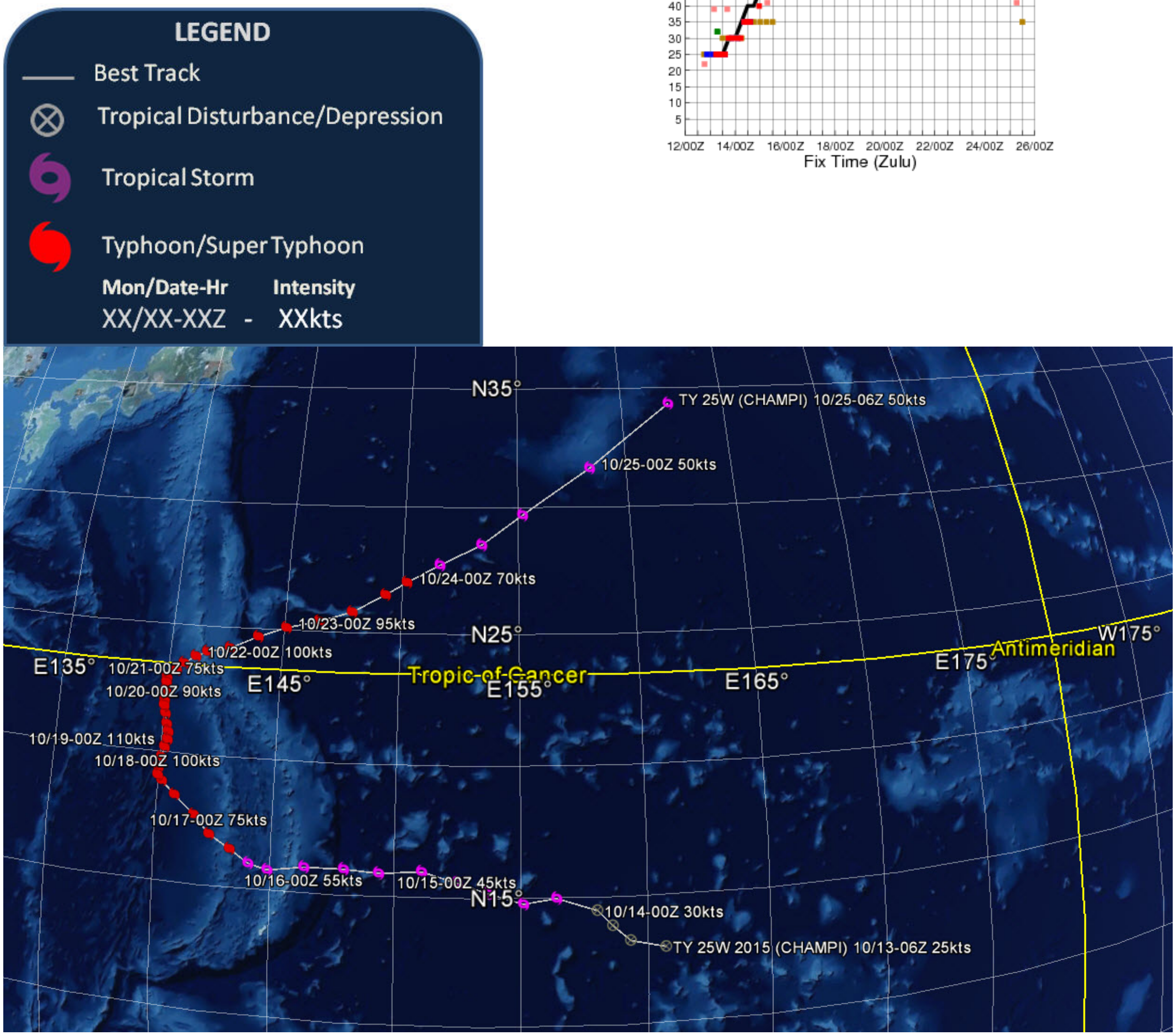




25W TYPHOON CHAMPI

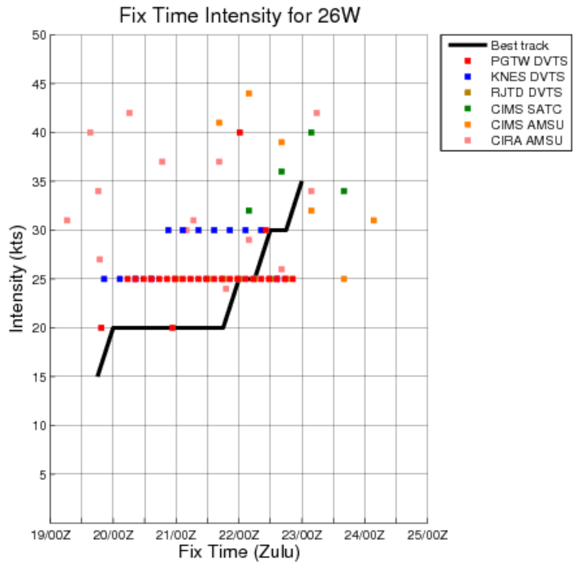
ISSUED LOW:	12 OCT / 1430Z
ISSUED MED:	12 OCT / 2130Z
FIRST TCFA:	13 OCT / 0230Z
FIRST WARNING:	13 OCT / 0600Z
LAST WARNING:	24 OCT / 1800Z
MAX INTENSITY:	125
WARNINGS:	47

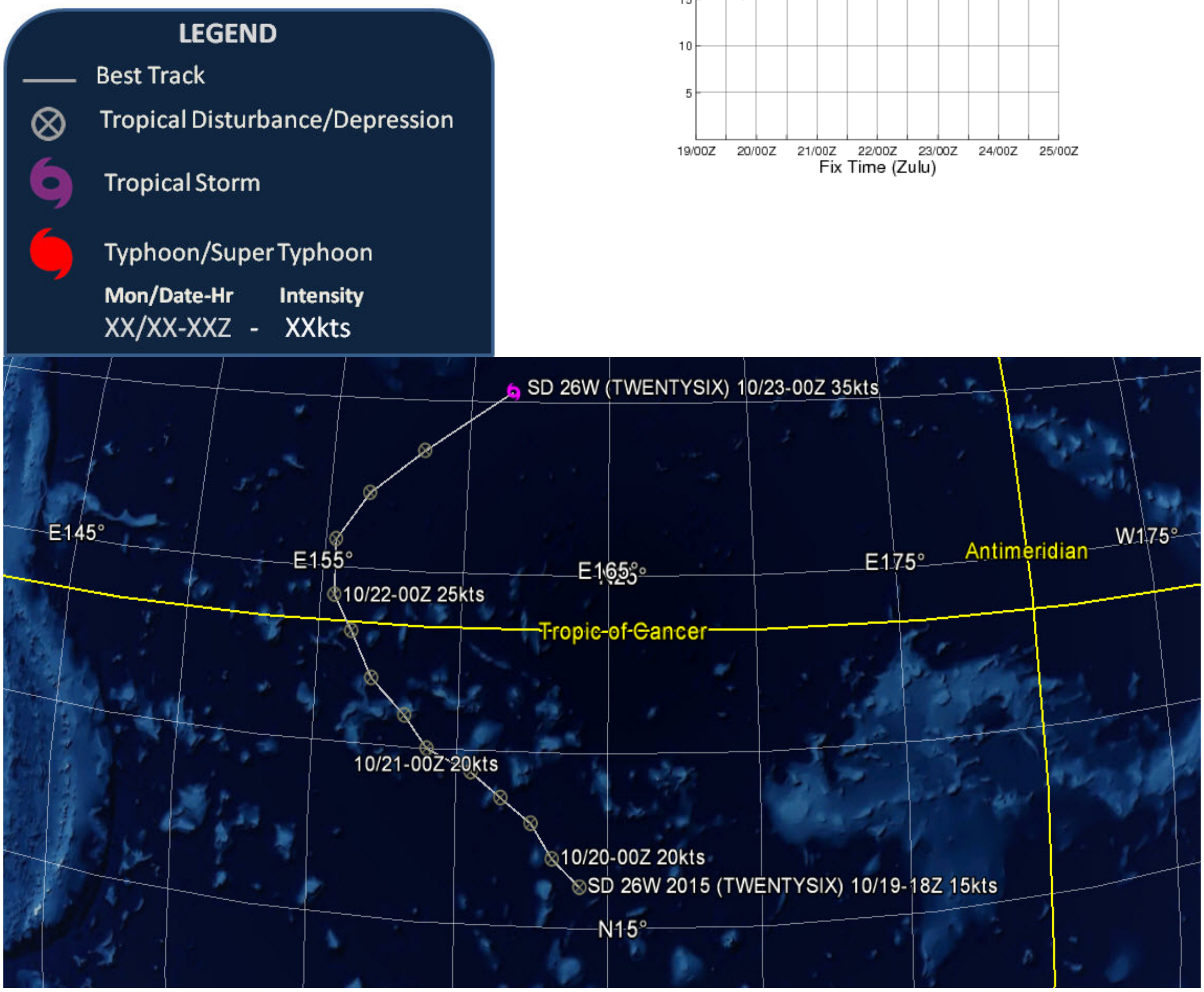




26W SUBTROPICAL DEPRESSION TWENTYSIX*

ISSUED LOW:	20 OCT / 0600Z
ISSUED MED:	20 OCT / 1630Z
FIRST TCFA:	20 OCT / 2230Z
FIRST WARNING:	22 OCT / 0000Z
LAST WARNING:	22 OCT / 1800Z
MAX INTENSITY:	35
WARNINGS:	4

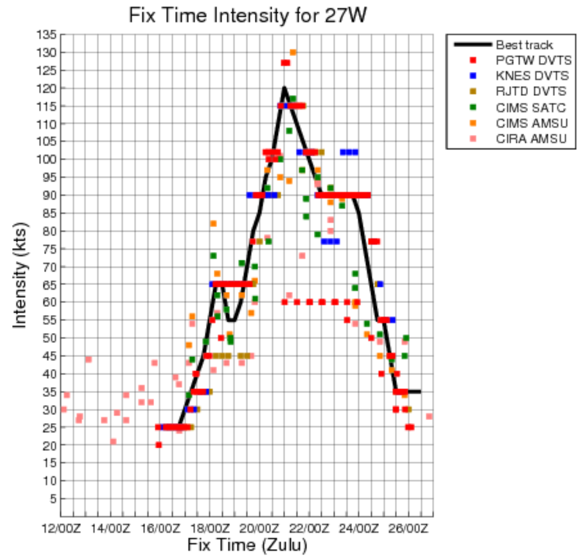


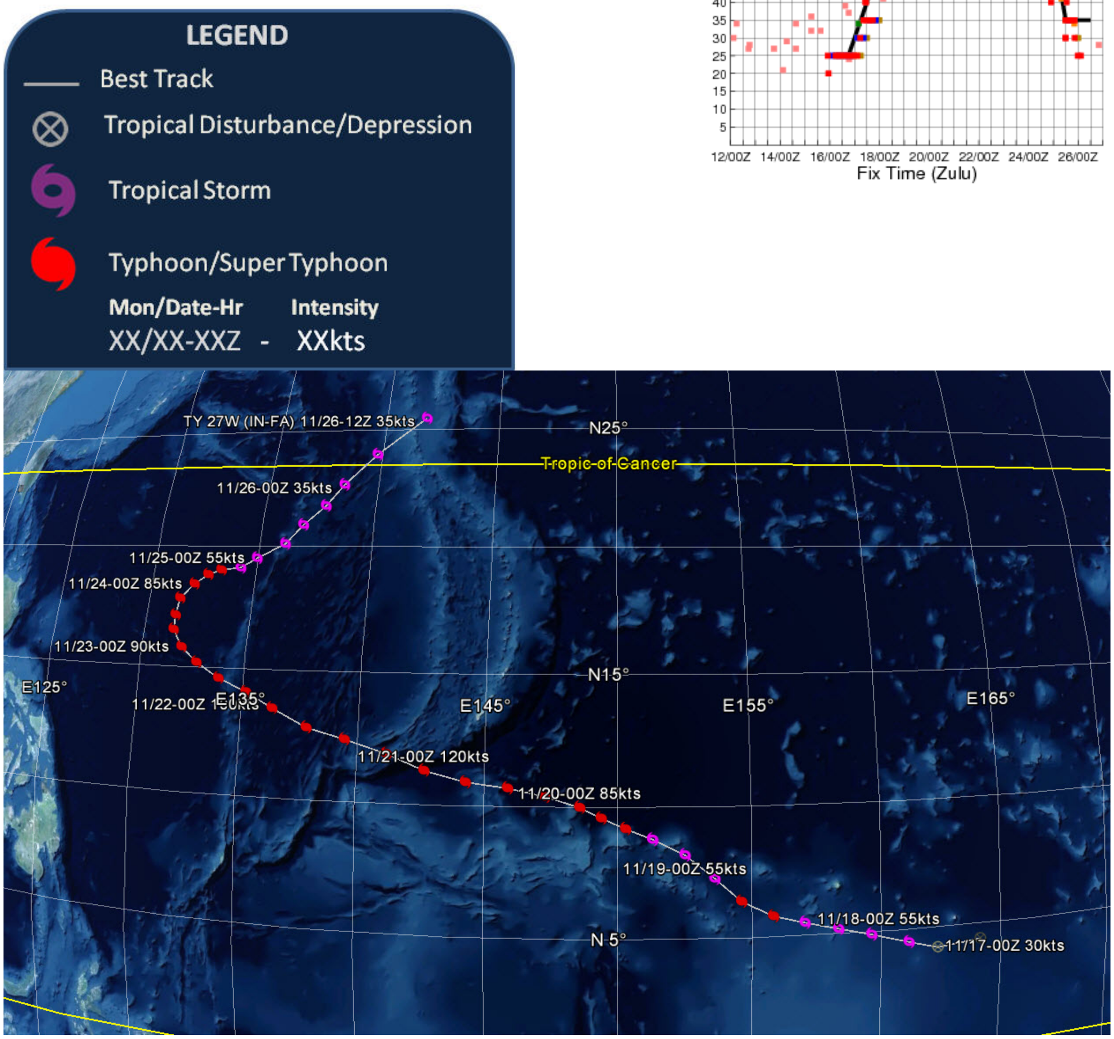


* Post-analysis determined 26W to be a sub-tropical depression

27W TYPHOON IN-FA

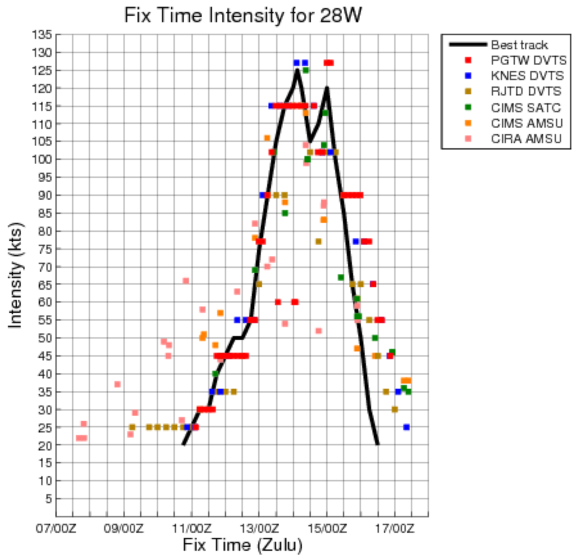
ISSUED LOW:	14 NOV / 0600Z
ISSUED MED:	16 NOV / 0600Z
FIRST TCFA:	16 NOV / 0800Z
FIRST WARNING:	17 NOV / 0000Z
LAST WARNING:	26 NOV / 0000Z
MAX INTENSITY:	120
WARNINGS:	37

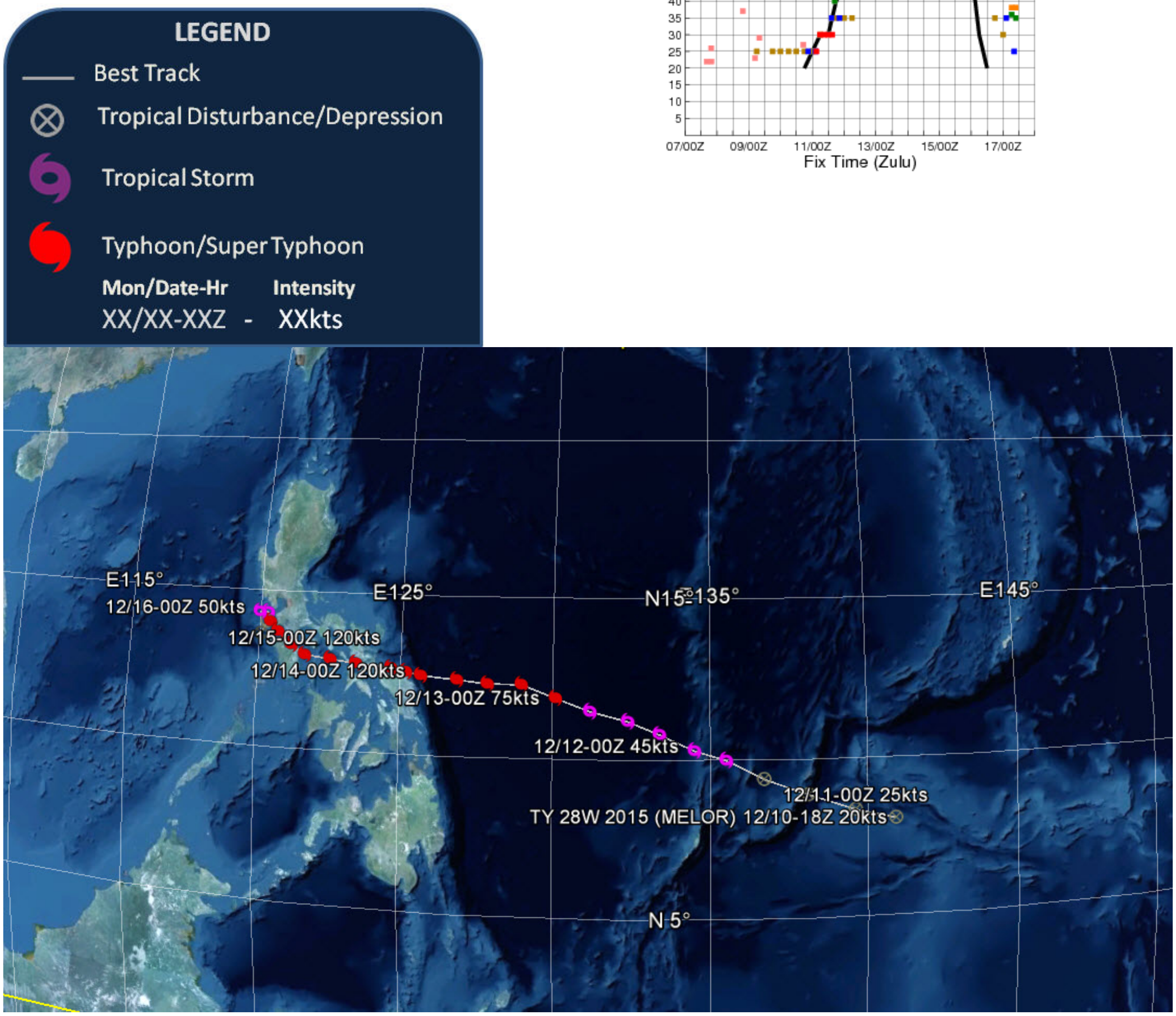




28W TYPHOON MELOR

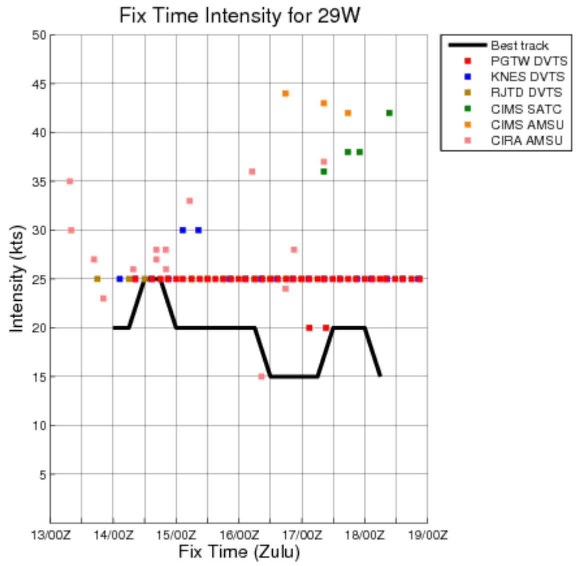
ISSUED LOW:	10 DEC / 0600Z
ISSUED MED:	10 DEC / 2200Z
FIRST TCFA:	11 DEC / 0530Z
FIRST WARNING:	11 DEC / 1200Z
LAST WARNING:	17 DEC / 0000Z
MAX INTENSITY:	125
WARNINGS:	0

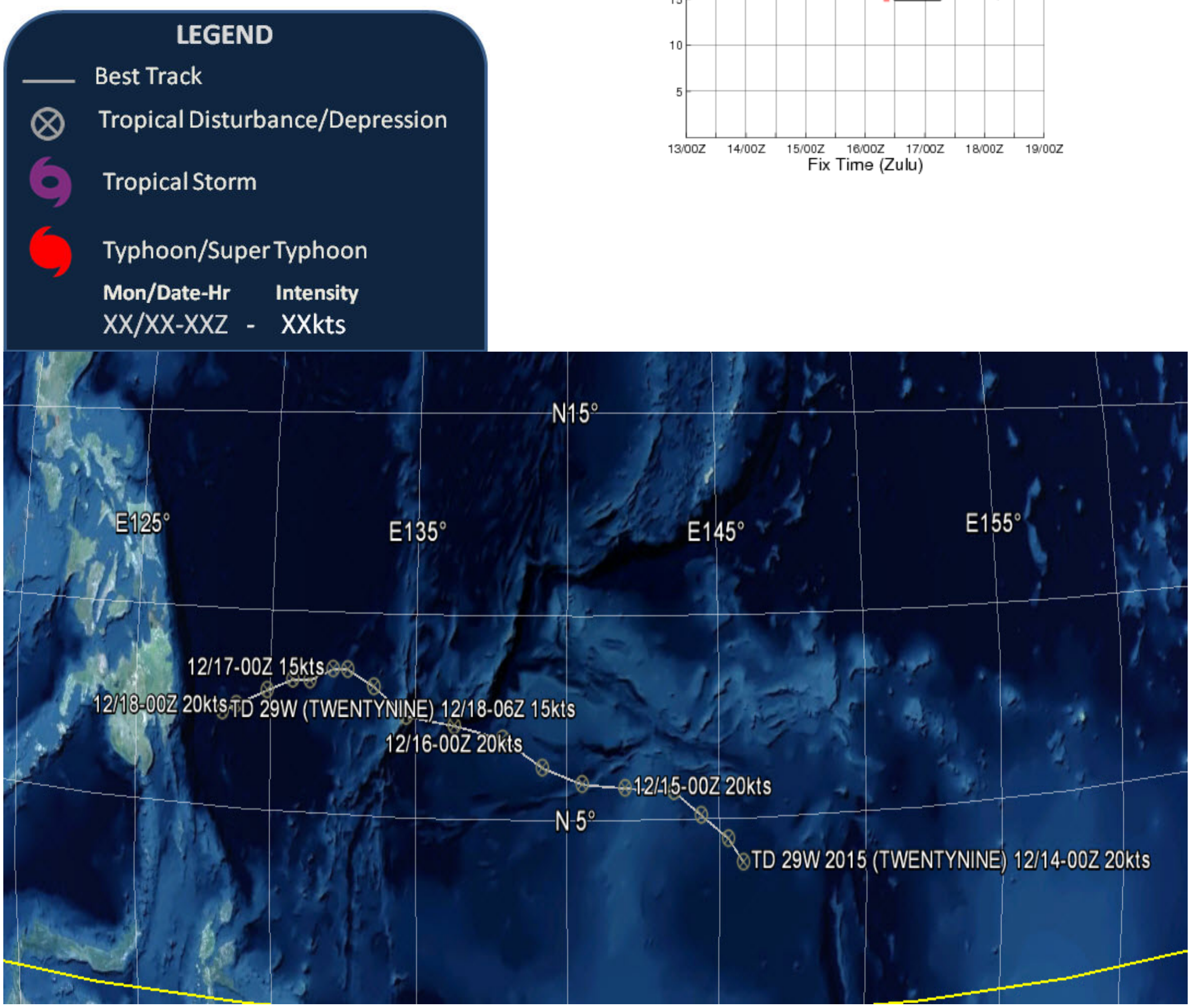




29W TROPICAL DEPRESSION TWENTYNINE

ISSUED LOW:	13 DEC / 1830Z
ISSUED MED:	14 DEC / 0030Z
FIRST TCFA:	15 DEC / 1730Z
FIRST WARNING:	16 DEC / 1800Z
LAST WARNING:	18 DEC / 0000Z
MAX INTENSITY:	25
WARNINGS:	6





Section 3 Detailed Cyclone Reviews

Typhoon 09W (Chan-Hom)

Typhoon 09W (CHAN-HOM) – Binary interaction case study

I. Overview

Typhoon (TY) 09W (Chan-Hom) developed during an active phase of the Madden-Julian Oscillation (MJO), just south of Kosrae, Federated States of Micronesia, on 27 June 2015. The system initially tracked poleward under the influence of a subtropical ridge to the east prior to transitioning to a westward trajectory under the influence of a second subtropical ridge to the north. The cyclone began to intensify, reaching tropical storm intensity while closing in on the Marianas Islands. On 02 July, prior to reaching the Marianas Island chain, the low-level circulation center (LLCC) and the associated convection decoupled and the system weakened as the LLCC shifted poleward and eastward. Figure 1-5 depicts the JTWC and JMA preliminary track analyses, both of which show the abrupt change in motion just east of the Marianas Islands. The satellite fix history and best track intensity analyses for TY 09W (Figure 1-6) depict two separate intensity peaks occurring during the storm's lifespan. On 03 July, vertical structure improved and TY 09W resumed a northwestward trajectory. The typhoon began to intensify at a nearly climatological rate, followed by a period of rapid intensification from 09 to 10 July. TY 09W reached a peak intensity of 120 knots just west of Okinawa, Japan, on 10 July at 00Z. As the typhoon approached the eastern coast of China near Shanghai, it rounded the southwestern periphery of the subtropical ridge and accelerated north-northeastward. The system made landfall in North Korea before dissipating.

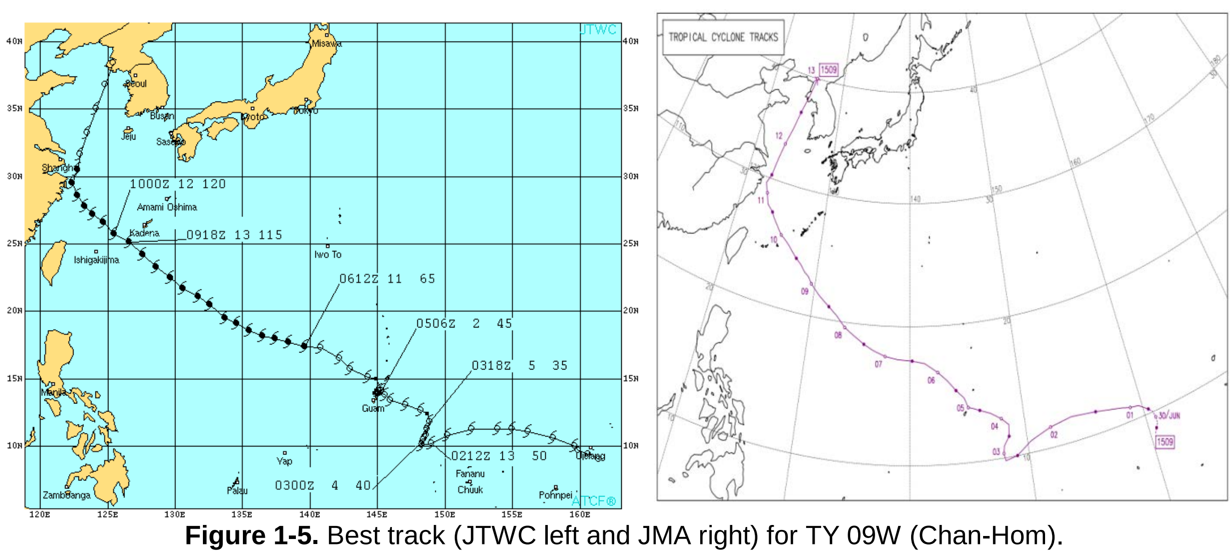


Figure 1-5. Best track (JTWC left and JMA right) for TY 09W (Chan-Hom).

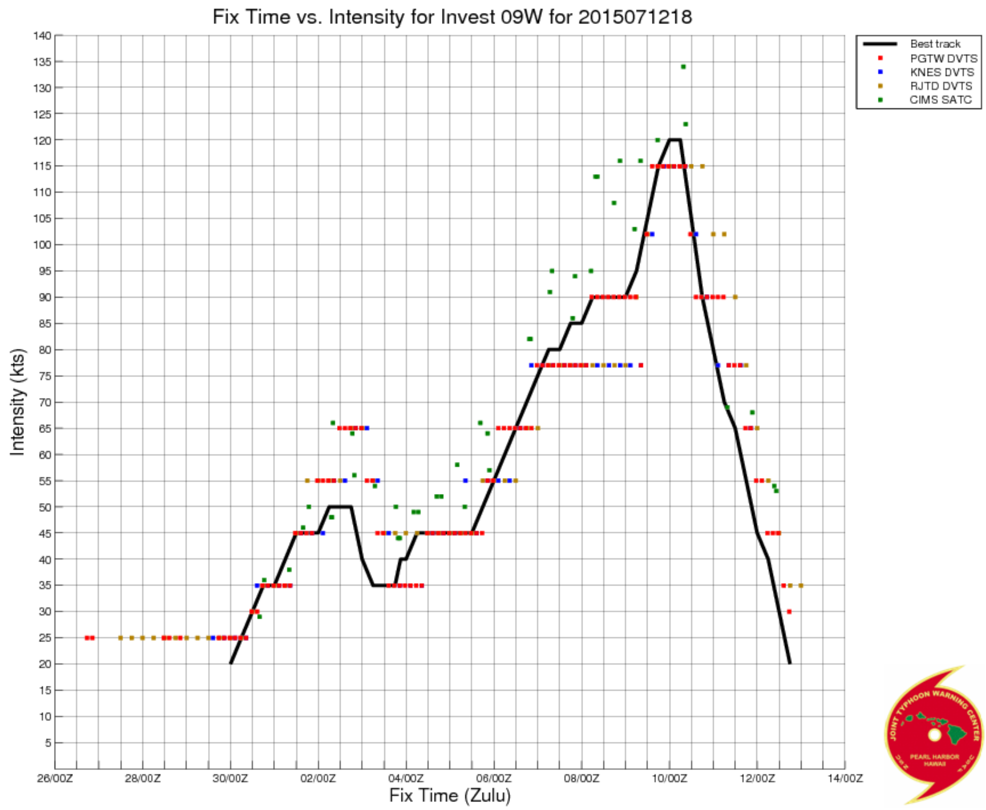


Figure 1-6. Fix history vs best track intensity graphic for TY 09W showing two intensity peaks bracketing a period of weakening that occurred between 02 and 03 July.

II. Initial development

TY 09W's incipient vortex was enhanced by a strong westerly surge analyzed to the south of the disturbance. The system quickly consolidated under favorable environmental conditions, and a Tropical Cyclone Formation Alert was issued on 29 June at 2200Z. The circulation continued to intensify as it tracked northward towards Ujelang, and met the warning threshold intensity of 25 knots on 30 June at 1200Z. Figures 1-7 and 1-8 illustrate the system's development in scatterometer and microwave imagery. These images suggest that the low-level circulation spun up with relatively limited associated deep convection, which was primarily confined to the northern and western peripheries. TY 09W continued to steadily intensify through 02 July, when a noteworthy period of weakening was observed.

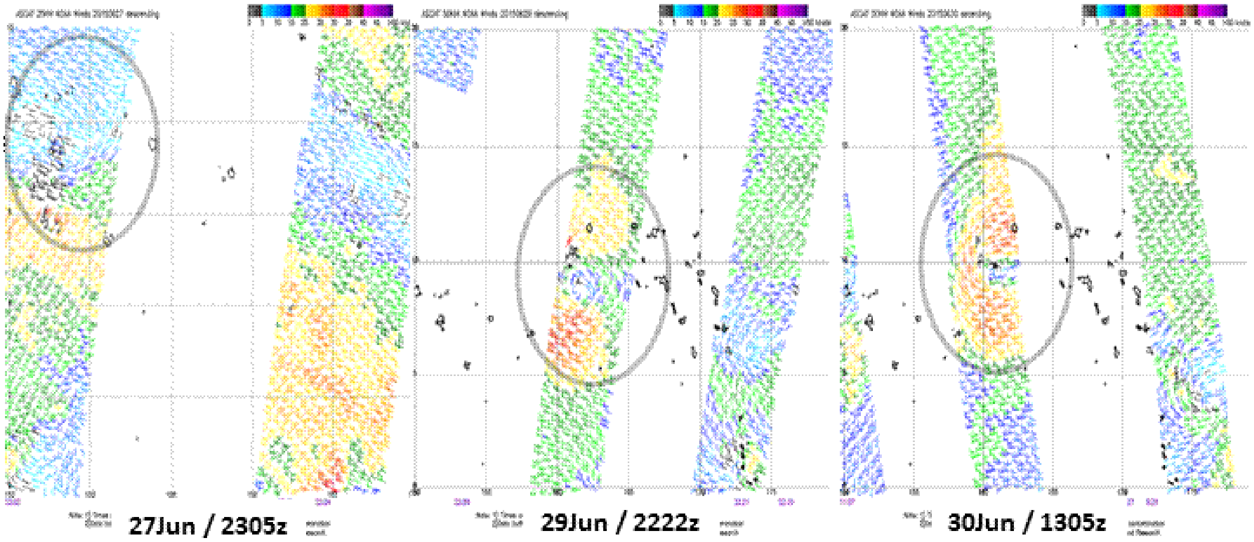


Figure 1-7. Scatterometer progression of TY 09W from approximate initial invest time (left), to Tropical Cyclone Formation Alert time (middle), to first warning time (right) (data source: NOAA NESDIS STAR).

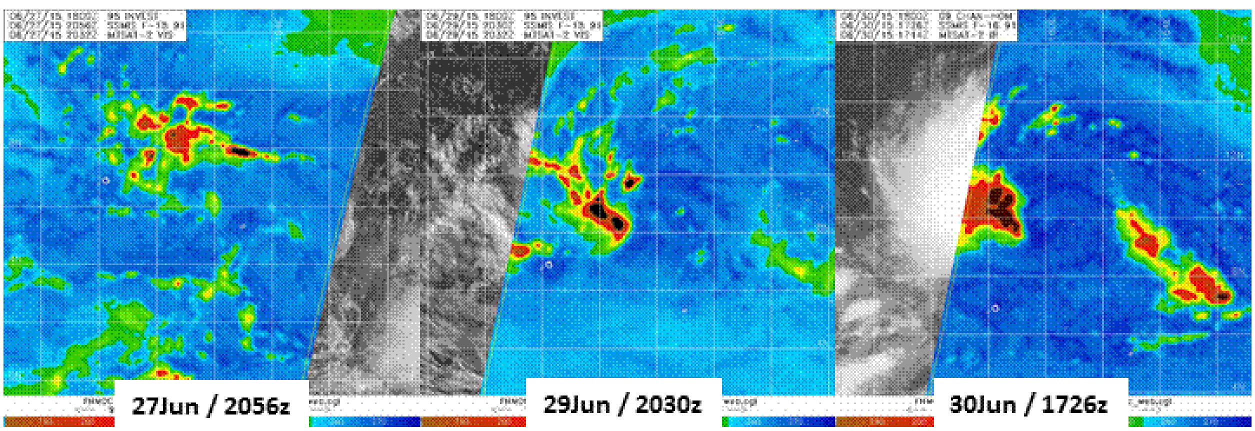


Figure 1-8. SSMIS microwave progression of TY 09W from approximate initial invest time (left), to Tropical Cyclone Formation Alert time (middle), to first warning time (right) (data source: FNMOC).

III. Intermediate weakening phase (02 through 03 July)

TY 09W weakened slightly between 18Z on 02 July and 12Z on 03 July as convection decoupled from the LLCC and the storm track shifted abruptly poleward and eastward. Scatterometer and visible satellite data depict changes in the storm and environmental structure observed during this period. Figure 1-9 shows two scatterometer passes from 03 July. The image on the left shows a defined LLCC with stronger winds along the southern periphery. The latter pass on the right misses the center, but it does show significant troughing extending to the west with a strong 30- to 40-knot westerly surge along the southern periphery of the trough. Storm-centered Himawari-8 visible imagery from 03 July (Figure 1-10) clearly depicts a convectively-decoupled system with a fully-exposed LLCC.

Decoupling of deep convection from TY 09W's low-level circulation and subsequent weakening observed during the 02 through 03 July time period, may be attributable to two factors. The first factor is the observed interaction between TY 09W and a disturbance (Invest 94W) located to the west of the typhoon (southwest of Guam). Invest 94W approached TY 09W as it tracked eastward along a strong low to mid-level westerly wind surge. During real-time analysis, this disturbance was thought to have fully dissipated as it encountered the much stronger typhoon, but post-storm analysis indicates that the circulation remained somewhat intact as it interacted and eventually merged with TY 09W. This complex interaction may have altered the vertical alignment and storm-relative vertical wind shear and divergence patterns over TY 09W. The second potential contributing factor to the observed weakening period was the presence of a Tropical Upper Tropospheric Trough (TUTT) cell just north of TY 09W, which likely increased subsidence and vertical wind shear over the cyclone. The following sections detail the observed interactions between TY 09W and the TUTT cell to the north.

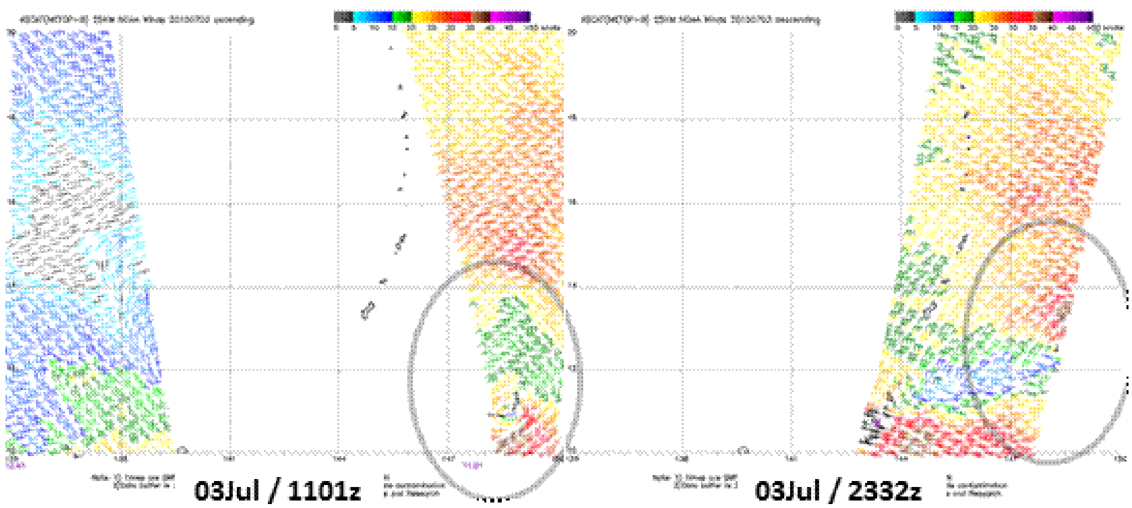


Figure 1-9. Scatterometer imagery showing the LLCC of TY09W with troughing extending to the west and a strong 30-40 knot westerly wind surge to the south (data source: NOAA NESDIS STAR).

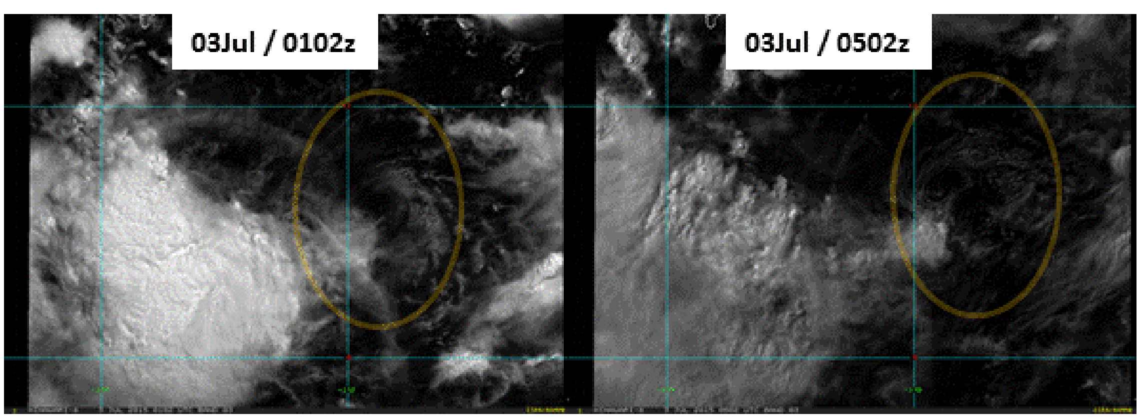


Figure 1-10. Himawari-8 storm centered imagery showing a fully-exposed LLCC moving poleward and eastward.

Interaction with Invest 94W

Time series of CIMSS 850MB relative vorticity (figure 1-11) and Himawari-8 satellite imagery (figure 1-12) depict the binary interaction between Invest 94W and Typhoon 09W. These data show the two circulations approaching one another prior to Typhoon 09W's observed convective decoupling and poleward track shift. Both datasets confirm TY 09W as the primary circulation, with Invest 94W gradually merging in. The third Himawari-8 image in figure 1-12 (from 03 July) shows the partially-exposed low-level circulation of Typhoon 09W and associated deep convection, originating from both the original circulation and from former Invest 94W, positioned along the western and eastern peripheries. The vorticity time series indicates reconsolidation of TY 09W as the system passed through and to the west of the Marianas Islands.

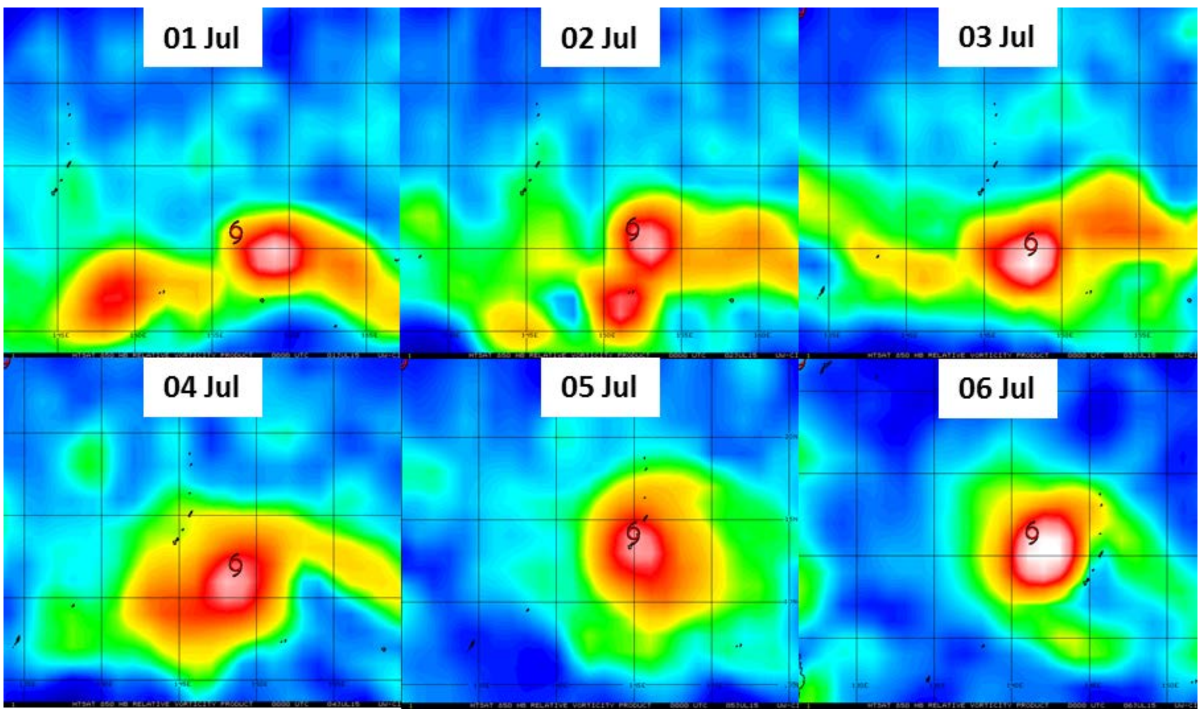


Figure 1-11. CIMSS 850MB relative vorticity showing the binary interaction progression from 01 July through 06 July (data source: University of Wisconsin, CIMSS).

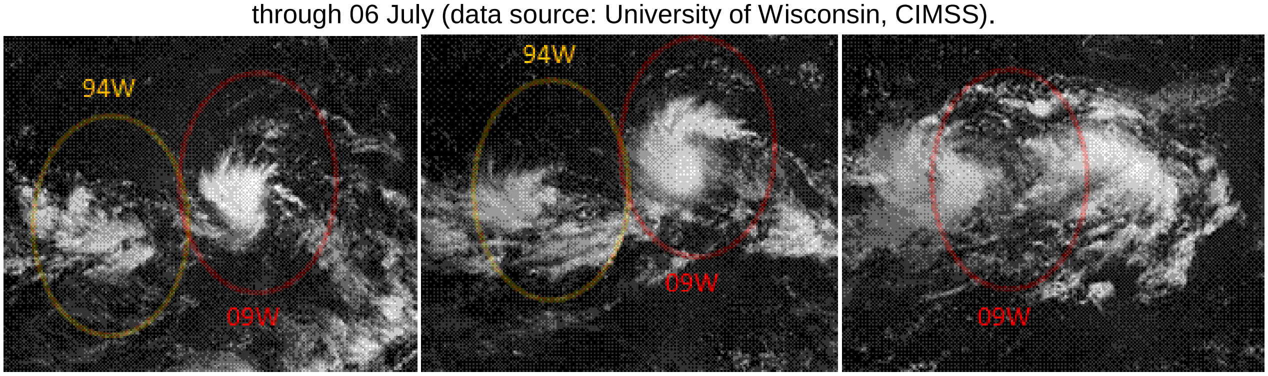


Figure 1-12. Himawari-8 visible imagery showing the binary interaction progression from 30 June (left), to 31 June (middle), to 03 July (right).

Interaction with TUTT

As TY 09W interacted with Invest 94W, a TUTT cell and trailing upper-level trough developed between the two circulations. A streamline analysis of CIMSS mid-upper layer, satellite-derived wind data (figure 1-13) shows the TUTT and associated convergent flow over the Typhoon. This trough may have developed, at least in part, from the interaction between the anticyclonic outflow regions above Invest 94W and TY 09W or through induction by a more extensive TUTT to the north. While a full accounting of the upper trough's formation mechanism is beyond the scope of this review, it is an interesting topic for additional study. The TUTT cell and trough appear to have induced subsidence aloft and northeasterly flow across TY 09W, which suppressed and sheared convection from the LLCC toward the southeast.

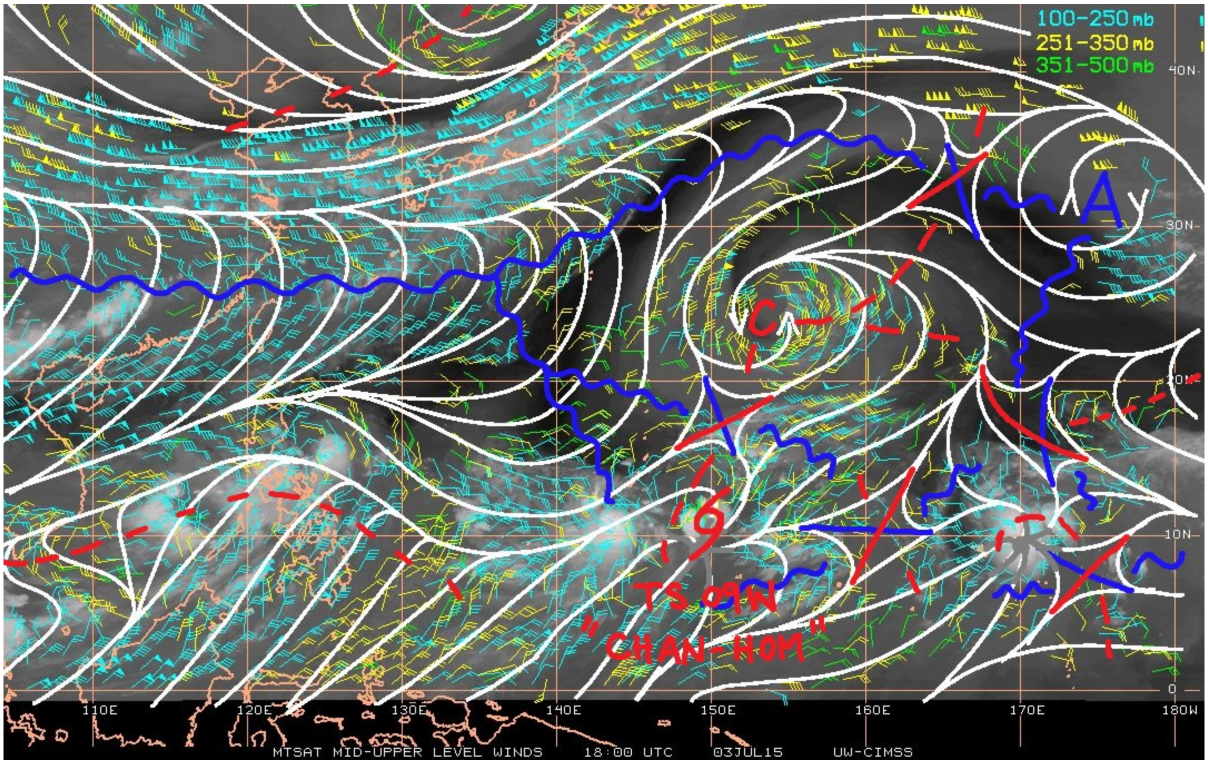


Figure 1-13. CIMSS mid-upper layer winds with JTWC Satellite Operations streamline analysis for 18Z on 03 July. This analysis shows a TUTT cell and trailing trough located poleward and across TY 09W, with convergence over the system (data source: University of Wisconsin, CIMSS).

IV. Reconsolidation and Peak Intensity.

Typhoon 09W reconsolidated and intensified from 04 July onward, after the noted interactions with Invest 94W and the upper-level trough were complete. A Himawari-8 visible image and a scatterometer pass from 05 July (figure 1-14) show a reconsolidated system with developing central convection and a tight LLCC. The system regained typhoon status on 06 July.

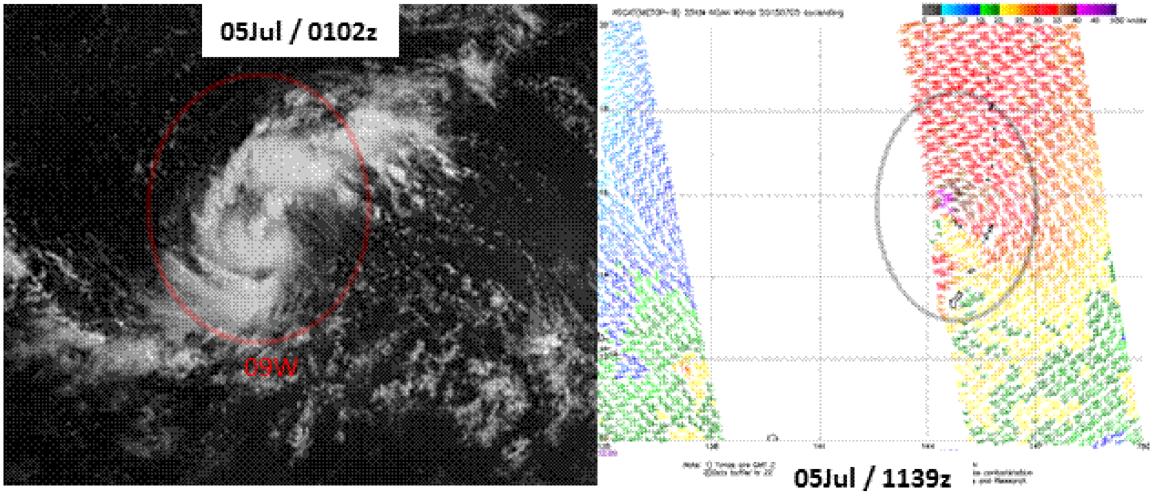


Figure 1-14. Left: Himawari-8 visible image of Typhoon 09W as it reconsolidated just west of the Marianas Islands. Right: Scatterometer image of the LLCC of the reconsolidated storm (data source: NOAA NESDIS STAR).

Following reconsolidation, Typhoon Chan-Hom resumed its northwestward track under the steering influence of the deep layered sub-tropical ridge to the north. The system continued to intensify, with a period of rapid intensification observed from 090600Z through 100000Z. The estimated intensity increased from 90 knots to a peak of 120 knots. Figure 1-15 shows the system as it passed through the Ryukyu Island chain on 091800Z at 115 knots.

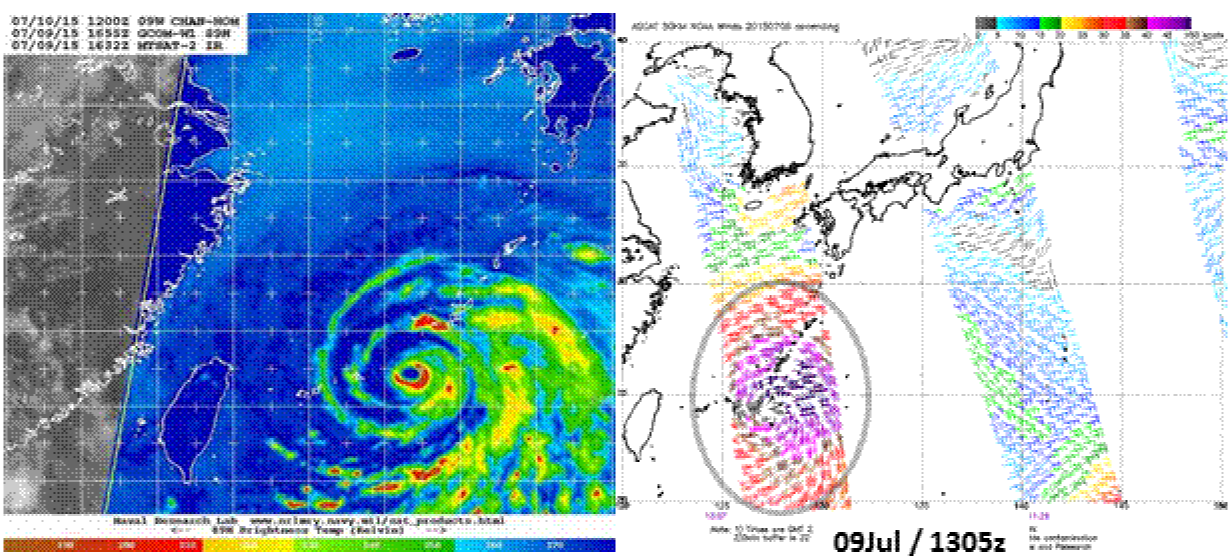


Figure 1-15. Left: AMSR-2 microwave image of Typhoon 09W passing through Ryukyu Islands at peak intensity (data source: NRL). Right: Scatterometer image from the same timeframe (data source: NOAA NESDIS STAR).

V. Dissipation

As Typhoon Chan-Hom approached the eastern coast of China, near Shanghai, it reached the western extent of the steering sub-tropical ridge and turned poleward around the ridge axis. Deteriorating environmental conditions resulted in steady weakening as TY 09W recurved toward the Korean Peninsula. Microwave and scatterometer data (Figure 1-16) show deterioration and weakening of the low-level circulation prior to landfall and eventual dissipation over North Korea.

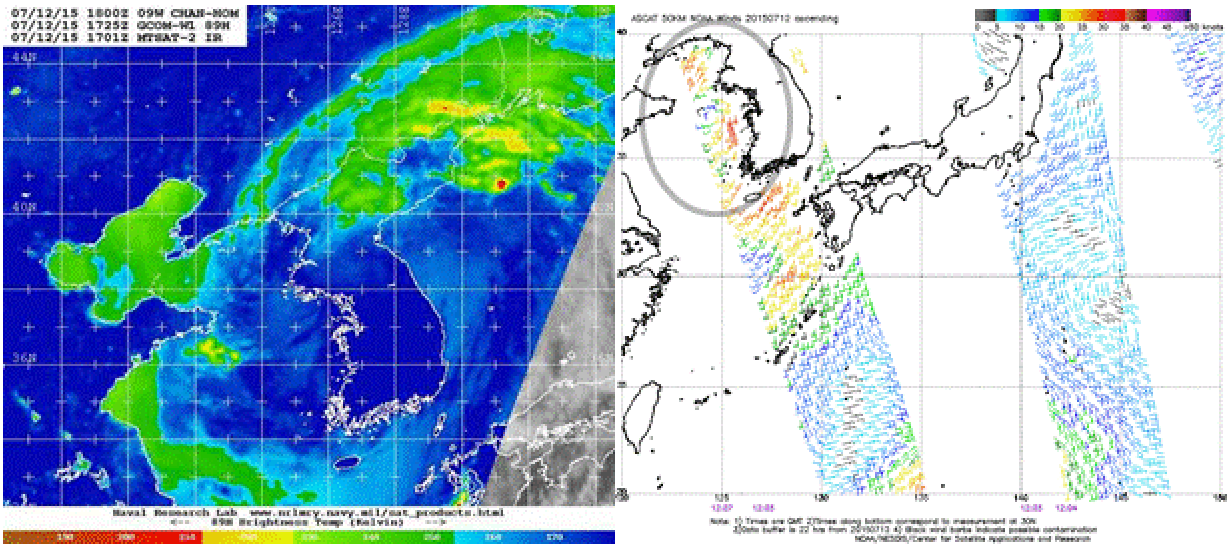


Figure 1-16. Left: AMSR-2 microwave image of Typhoon 09W dissipating as it moves into North Korea (data source: NRL). Right: Scatterometer image from the same timeframe (data source: NOAA NESDIS STAR).

VI. Conclusion

Typhoon 09W presents an interesting case of binary interaction and small-scale, upper-level flow features and their impacts on TC track and intensity. Although the JTWC track and intensity forecasts “missed” the abrupt poleward turn and temporary weakening discussed in this review, mesoscale models, particularly HWRF, did provide more accurate predictions of the short term track and intensity changes observed during the merger period. Given that the interactions driving these observed track and intensity changes were complex and occurred on a small spatial scale, it is promising to note the models’ ability to simulate these features, at least in part. The complexity and scale of these interactions also highlight TY 09W as a useful case for future model development and verification studies.

Chapter 2 North Indian Ocean Tropical Cyclones

This chapter contains information on north Indian Ocean TC activity during 2015 and the monthly distribution of TC activity summarized for 1975 - 2015. 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 2015 season. Five cyclones occurred in 2015, with two systems reaching an intensity greater than 64 knots. Table 2-2 shows the monthly distribution of Tropical Cyclone activity for 1975 - 2015.

Table 2-1

NORTH INDIAN OCEAN SIGNIFICANT TROPICAL CYCLONES FOR 2015

(01 JAN 2015- 31 DEC 2015)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS
01A	ASHOBAA	07 Jun / 0600Z	11 Jun / 1800Z	19	55
02B	KOMEN	29 Jul / 0000Z	30 Jul / 0600Z	6	45
03A	THREE	09 Oct / 1800Z	11 Oct / 0600Z	7	35
04A	CHAPALA	28 Oct / 1800Z	03 Nov / 1800Z	25	130
05A	MEGH	05 Nov / 0600Z	10 Nov / 0000Z	20	100

* As designated by the responsible RSMC

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

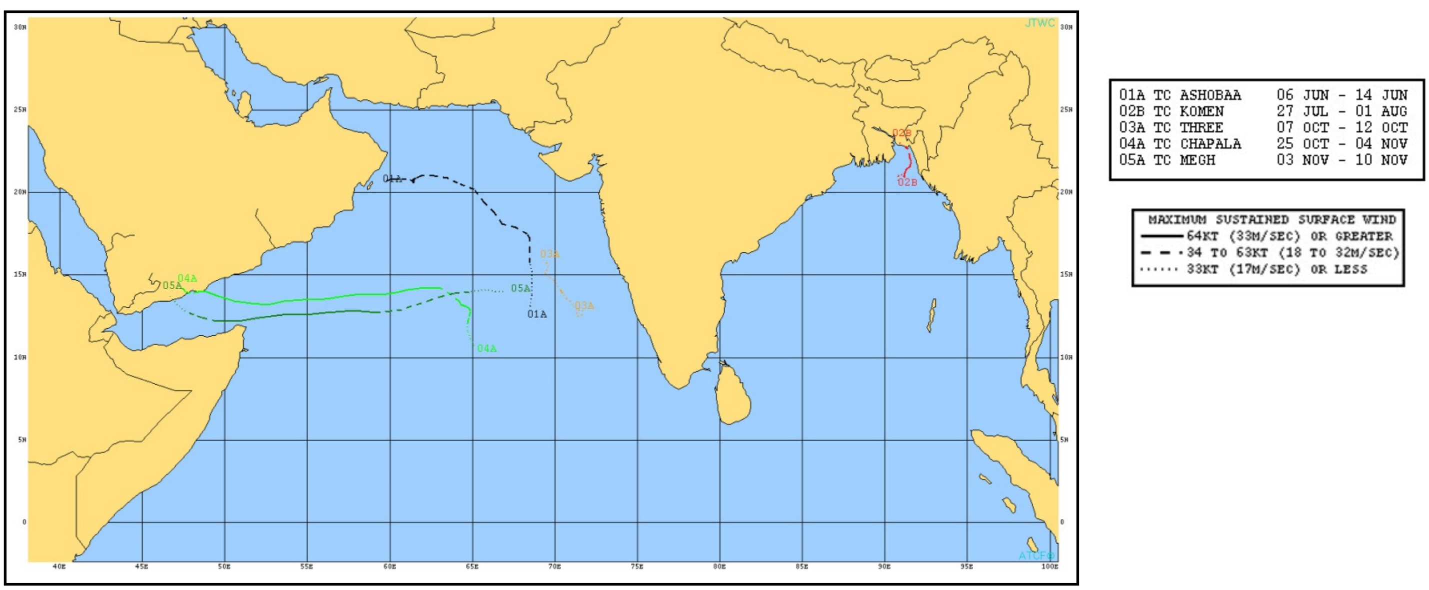


Figure 2-1. North Indian Ocean Tropical Cyclones.

Table 2 - 2
DISTRIBUTION OF NORTH INDIAN OCEAN TROPICAL CYCLONES
FOR 1975 - 2015

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
	0	0	0	0	1	0	0	0	0	1	3	1	6		
2013	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	1 0 0	2 1 0	1 0 0	4	2	0
	1	0	0	0	0	0	1	0	0	2	1	0	5		
2014	0 1 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 0 0	0 0 0	2 0 0	0 1 0	0 0 0	2	3	0
	0	0	0	0	0	1	1	0	0	2	1	0	5		
2015	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 1 0	0 1 0	0 0 0	0 0 0	1 1 0	1 0 0	0 0 0	2	3	0
(1975-2014)															
MEAN	0.2	0.0	0.0	0.2	0.7	0.6	0.1	0.0	0.3	1.1	1.4	0.6	5.1		
CASES	7	2	1	7	28	23	4	1	13	44	56	23	209		

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:

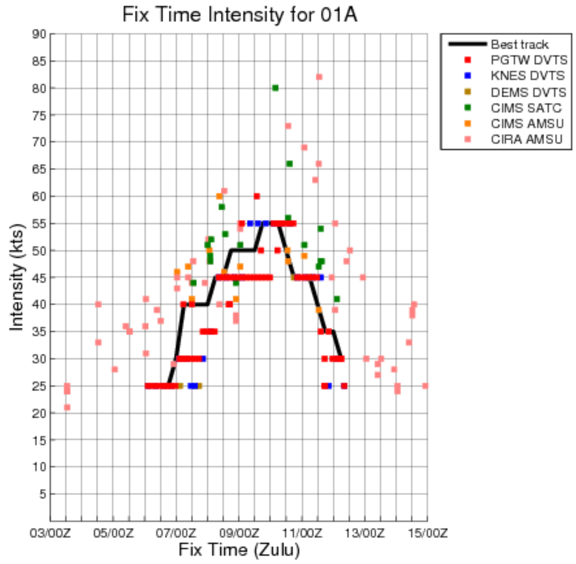
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

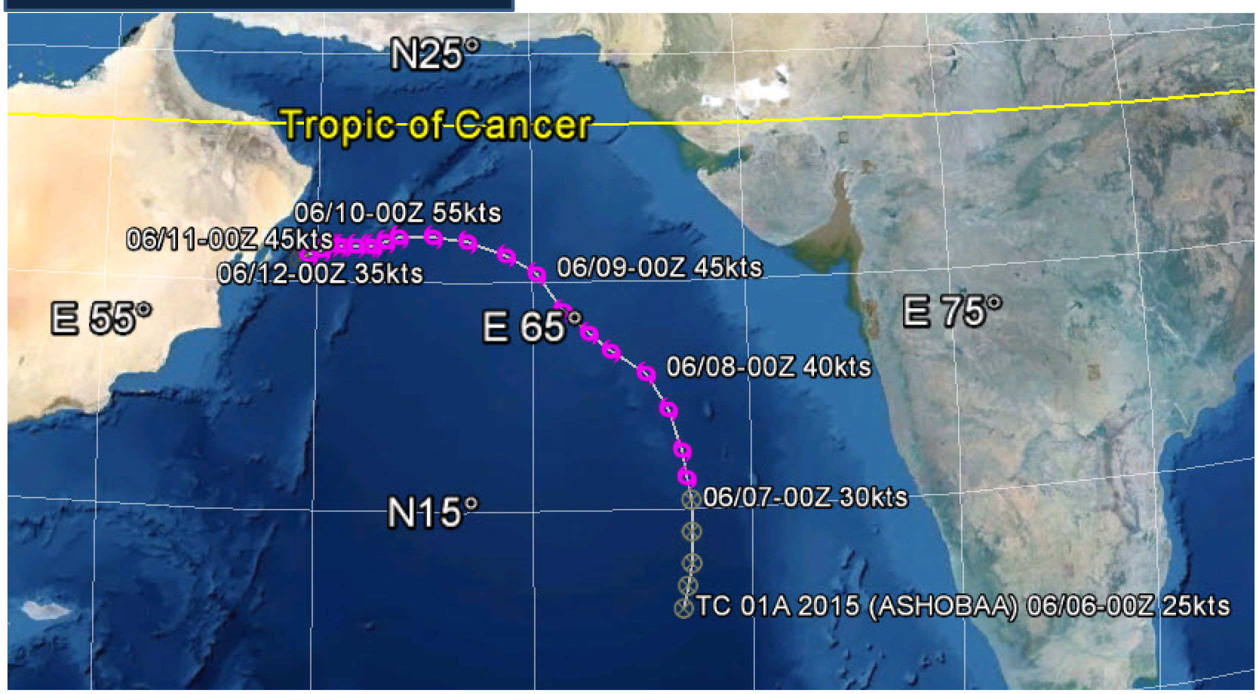
The JTWC post-event reanalysis best track is also provided for each cyclone. Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of 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:
https://metoc.ndbc.noaa.gov/ProductFeeds-portlet/img/jtwc/best_tracks/2015/2015s-bio/IO_besttracks_2015-2015.kmz

01A TROPICAL CYCLONE ASHOBAA

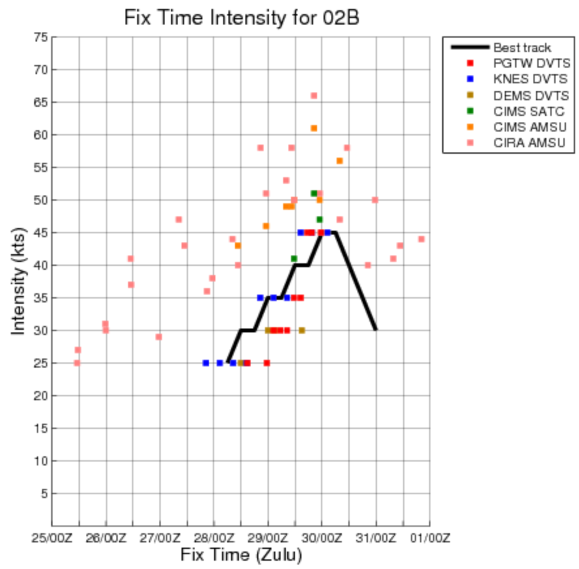
ISSUED LOW:	03 JUN / 1800Z
ISSUED MED:	05 JUN / 0630Z
FIRST TCFA:	06 JUN / 1100Z
FIRST WARNING:	07 JUN / 0600Z
LAST WARNING:	11 JUN / 1800Z
MAX INTENSITY:	55
WARNINGS:	19

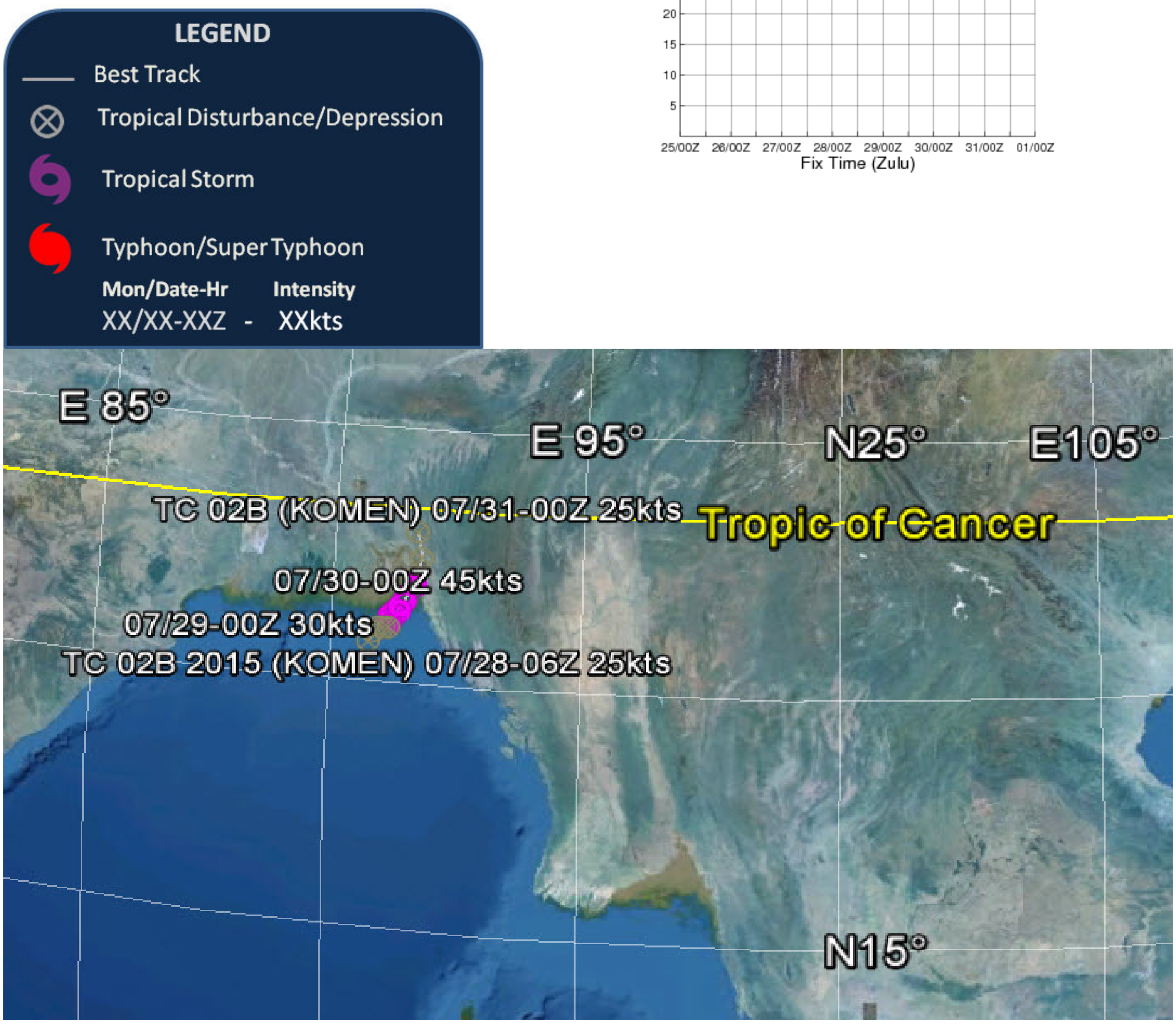




02B TROPICAL CYCLONE KOMEN

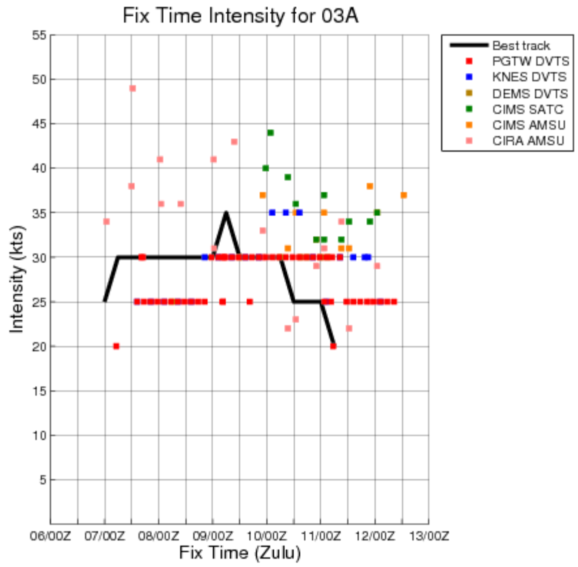
ISSUED LOW:	None
ISSUED MED:	27 JUL / 0000Z
FIRST TCFA:	28 JUL / 1930Z
FIRST WARNING:	29 JUL / 0000Z
LAST WARNING:	30 JUL / 0600Z
MAX INTENSITY:	45
WARNINGS:	6

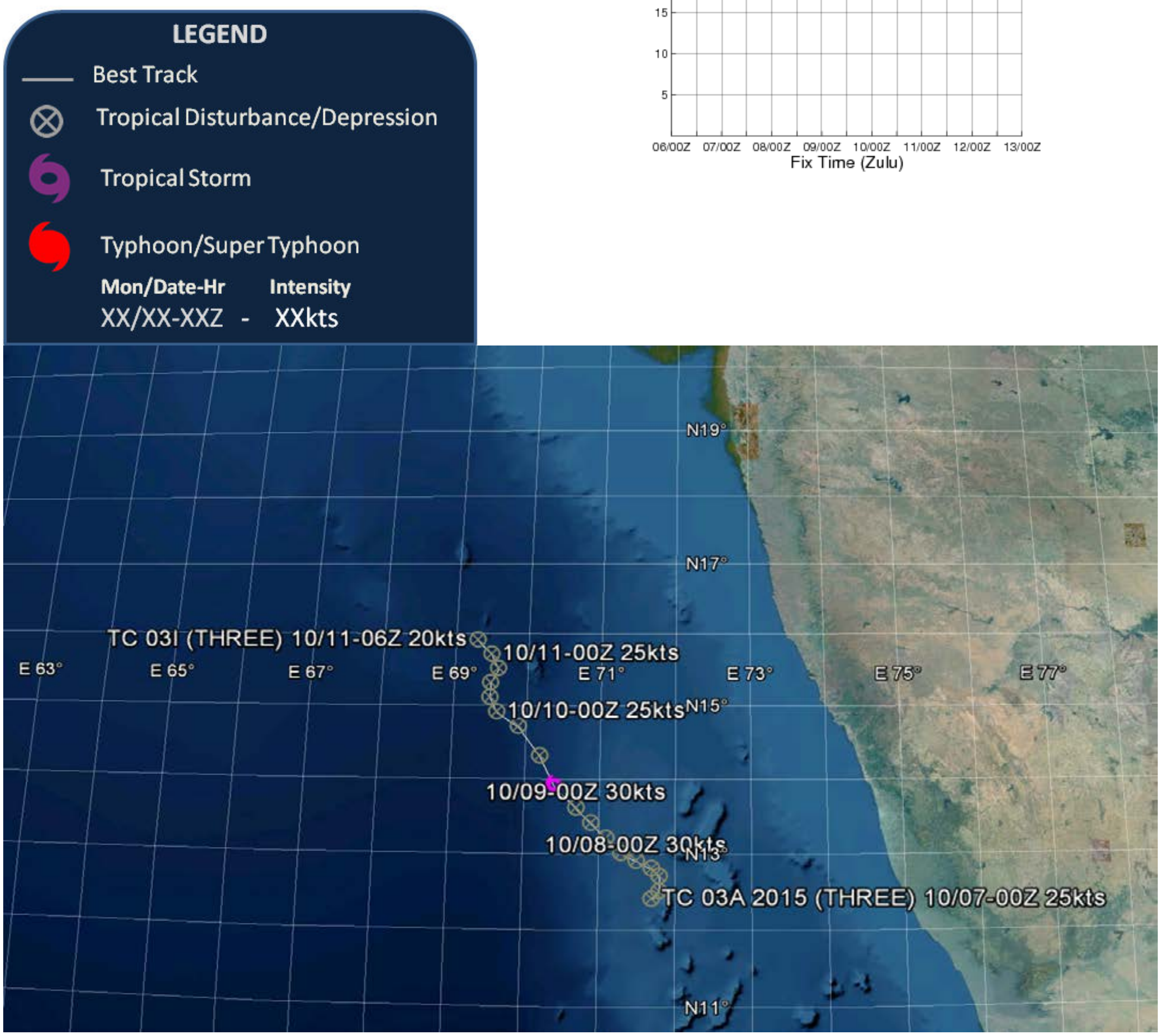




03A TROPICAL CYCLONE THREE

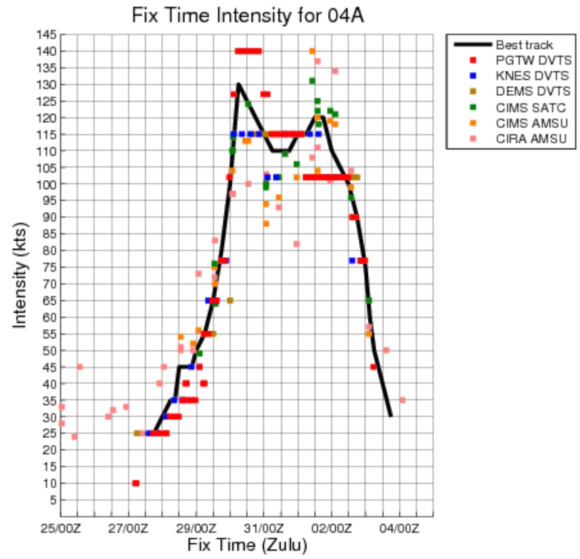
ISSUED LOW:	07 OCT / 0530Z
ISSUED MED:	07 OCT / 1800Z
FIRST TCFA:	07 OCT / 2200Z
FIRST WARNING:	09 OCT / 1800Z
LAST WARNING:	11 OCT / 0600Z
MAX INTENSITY:	35
WARNINGS:	7

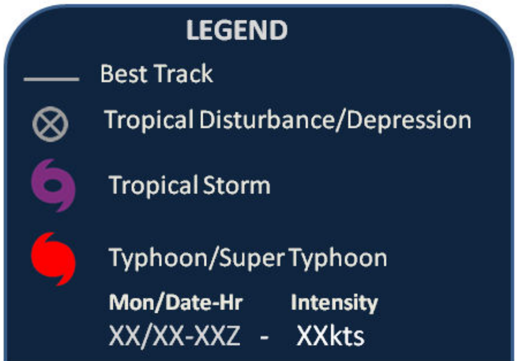


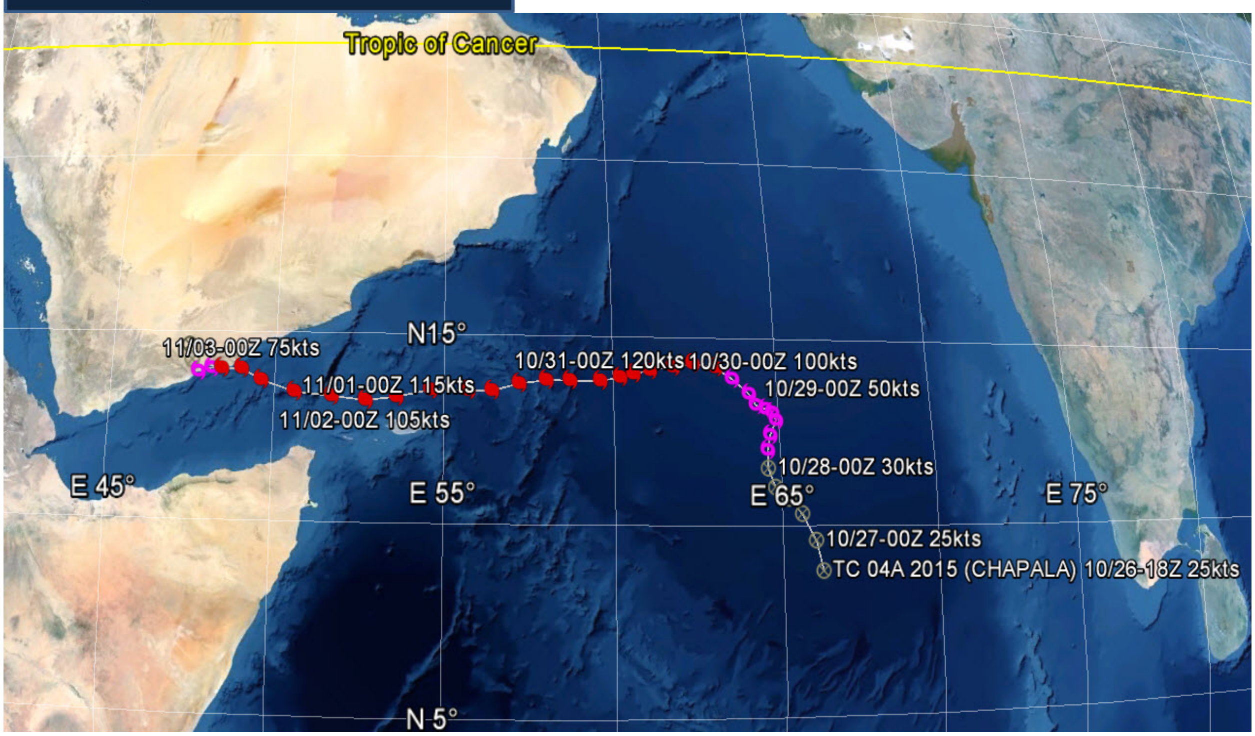


04A TROPICAL CYCLONE CHAPALA

ISSUED LOW:	25 OCT / 1100Z
ISSUED MED:	26 OCT / 1100Z
FIRST TCFA:	28 OCT / 0700Z
FIRST WARNING:	28 OCT / 1800Z
LAST WARNING:	03 NOV / 1800Z
MAX INTENSITY:	130
WARNINGS:	25

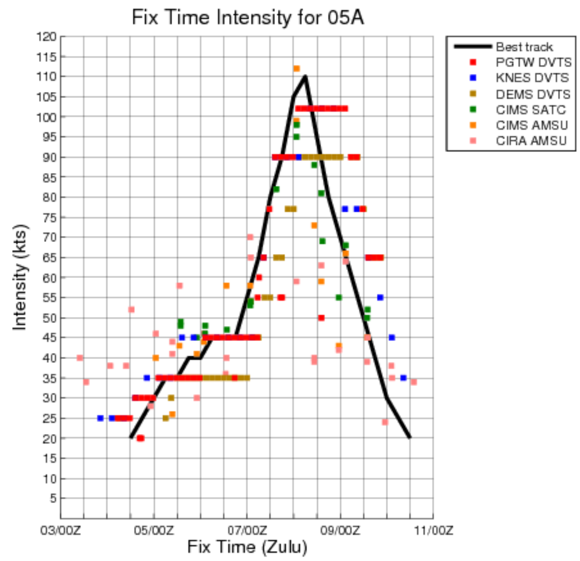


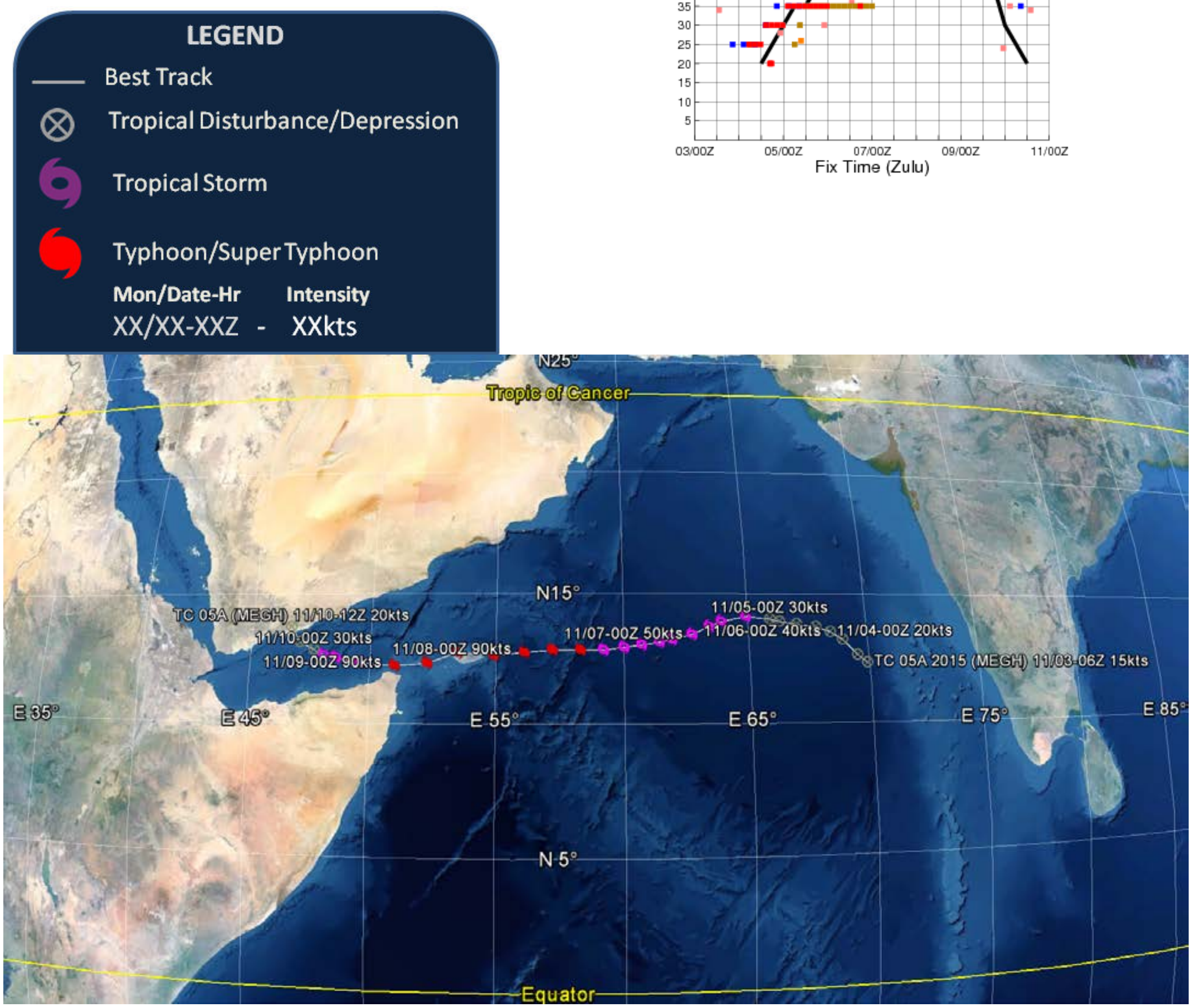




05A TROPICAL CYCLONE MEGH

ISSUED LOW:	03 NOV / 1800Z
ISSUED MED:	04 NOV / 1000Z
FIRST TCFA:	05 NOV / 0230Z
FIRST WARNING:	05 NOV / 0600Z
LAST WARNING:	10 NOV / 0000Z
MAX INTENSITY:	110
WARNINGS:	20





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 2015 tropical cyclone season (1 July 2014 – 30 June 2015) and the monthly distribution of TC activity summarized for 1975 - 2015.

Section 1 Informational Tables

Table 3-1 is a summary of TC activity in the Southern Hemisphere during the 2015 season.

Table 3-1

SOUTHERN HEMISPHERE TROPICAL CYCLONES FOR 2015

(01 JULY 2014- 30 JUNE 2015)

TC	NAME*	PERIOD**		WARNINGS ISSUED	EST MAX SFC WINDS KTS
01S	ADJALI	16 NOV / 1800Z	19 NOV/ 1800Z	7	70
02S	TWO	28 NOV / 1200Z	29 NOV / 1200Z	3	35
03S	BAKUNG	11 DEC / 1800Z	13 DEC / 0600Z	4	40
04S	KATE	25 DEC / 0000Z	31 DEC / 1200Z	15	105
05S	BANSI	11 JAN / 0600Z	18 JAN / 1800Z	16	140
06S	CHEDZA	16 JAN / 0000Z	18 JAN / 0000Z	5	50
07P	NIKO	20 JAN / 1800Z	24 JAN / 0600Z	8	55
08S	DIAMONDRA	26 JAN /1800Z	29 JAN / 0600Z	6	45
09S	EUNICE	27 JAN / 1800Z	02 FEB / 1200Z	13	140
10P	OLA	30 JAN / 1800Z	03 JAN / 0600Z	8	85
11S	FUNDI	06 FEB / 1800Z	08 FEB / 1800Z	5	55
12P	LAM	16 FEB / 1800Z	19 FEB / 1800Z	7	100
13P	MARCIA	18 FEB / 0000Z	20 FEB/ 0600Z	6	125
14S	GLENDA	24 FEB / 0600Z	28 FEB / 0600Z	9	55
15S	FIFTEEN	05 MAR / 1200Z	07 MAR / 0600Z	5	35
16S	HALIBA	08 MAR / 1800Z	10 MAR / 0600Z	4	40
17P	PAM	09 MAR / 0600Z	15 MAR / 1200Z	22	150
18P	NATHAN	10 MAR / 1800Z	24 MAR / 0600Z	28	100
19S	OLWYN	11 MAR / 0600Z	13 MAR / 1200Z	9	90
20P	REUBEN	21 MAR / 1200Z	23 MAR / 0000Z	4	45
21S	IKOLA	05 APR / 1800Z	08 APR / 0600Z	6	115
22S	JOALANE	06 APR / 0000Z	12 APR / 0600Z	14	90
23P	SOLO	10 APR / 0000Z	12 APR / 0000Z	5	55
24S	QUANG	28 APR /1800Z	01 MAY / 1200Z	10	120
25P	RAQUEL	30 JUN / 1200Z	04 JUL / 0000Z	11	45

* As designated by the responsible RSMC

** Dates are based on the issuance of JTWC warnings on the system.

Table 3-2 provides the monthly distribution of Tropical Cyclone activity summarized for 1975 - 2015.

Table 3-2													
DISTRIBUTION OF SOUTH PACIFIC AND SOUTH INDIAN OCEAN TROPICAL CYCLONES													
FOR 1958 - 2015													
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 - 2015													
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
2013	0	0	0	1	1	4	7	5	2	3	1	0	24
2014	0	0	0	1	1	4	5	4	6	3	0	0	24
2015	0	0	0	0	2	2	5	5	6	4	0	1	25
(1981 - 2015)													
MEAN	0.3	0.1	0.3	0.7	1.5	3.2	5.9	6.1	4.8	3.0	0.7	0.3	26.8
CASES	9	3	9	23	54	111	205	215	169	105	26	9	938
* (GRAY, 1978)													

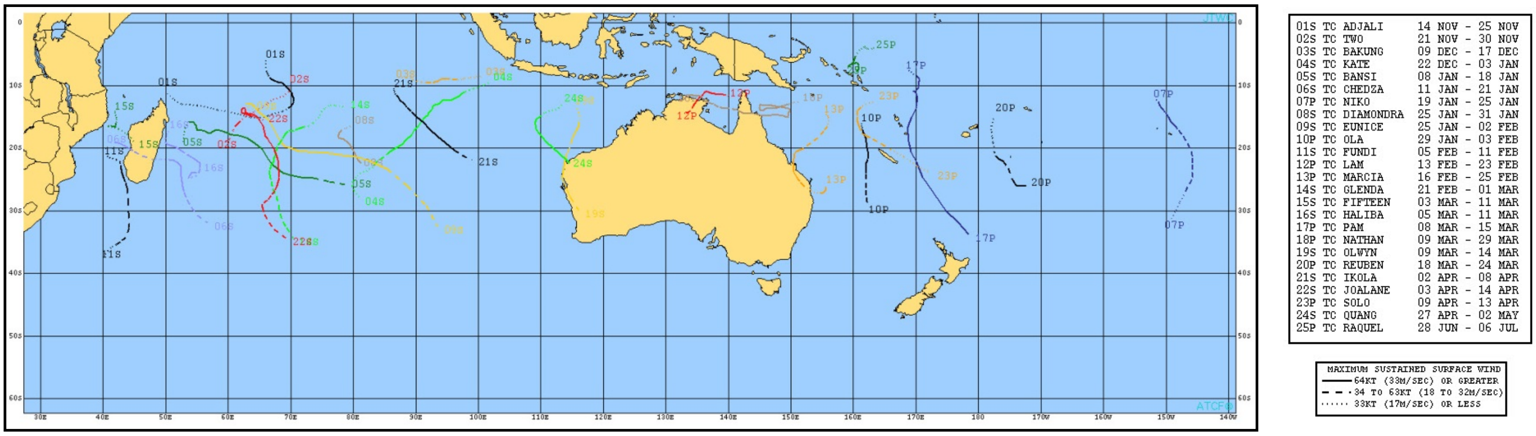


Figure 3-1. Southern Hemisphere Tropical Cyclones.

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.

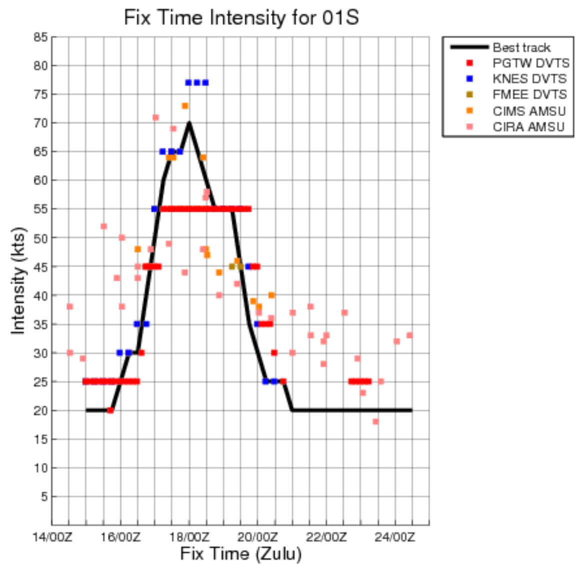
The first Tropical Cyclone Formation Alert (TCFA) and the initial and final warning dates are also presented with the number of warnings issued by JTWC. Landfall over major landmasses with approximate locations is presented as well.

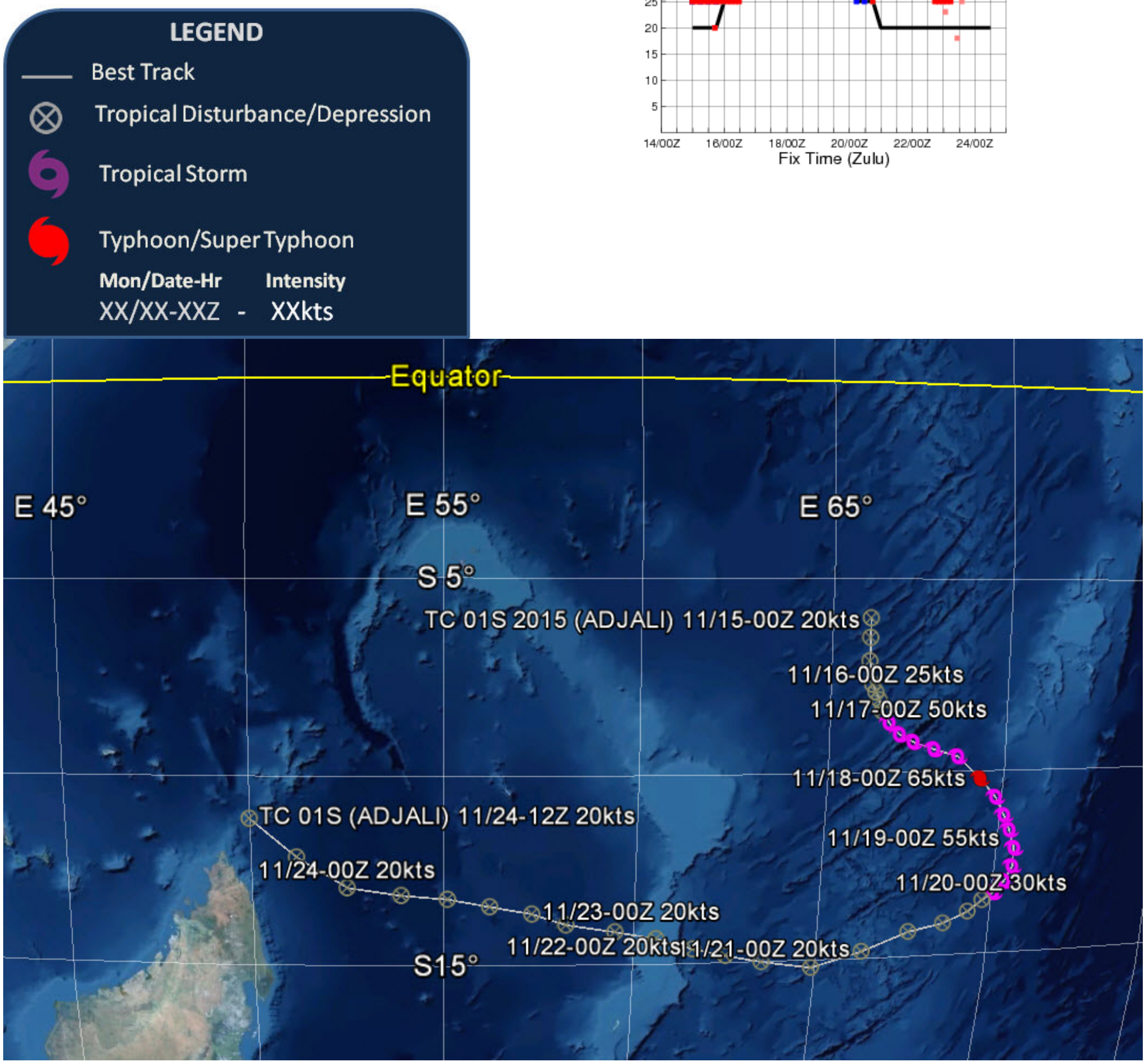
Data included on the best track are position and intensity noted with cyclone symbols and color coded track. Best track position labels include the date-time, track speed in knots, and maximum wind speed in knots. A graph of best track intensity versus time is presented. Fix plots on this graph are color 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:
https://metoc.ndbc.noaa.gov/ProductFeeds-portlet/img/jtwc/best_tracks/2015/2015s-bsh/SH_besttracks_2015-2015.kmz

01S TROPICAL CYCLONE ADJALI

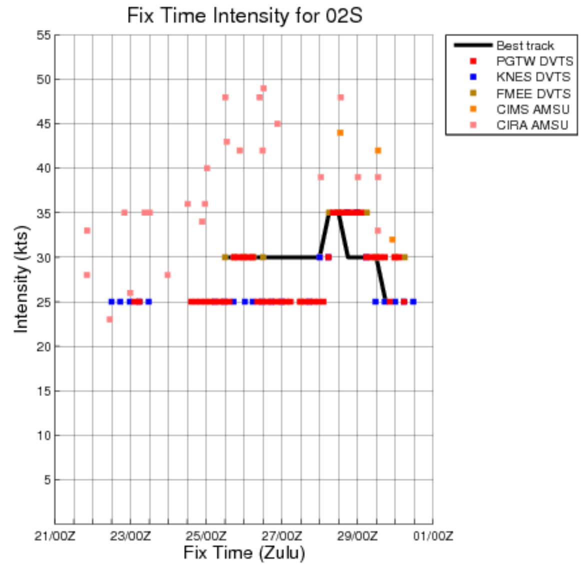
ISSUED LOW:	None
ISSUED MED:	14 NOV / 0700Z
FIRST TCFA:	16 NOV / 1330Z
FIRST WARNING:	16 NOV / 1800Z
LAST WARNING:	19 NOV / 1800Z
MAX INTENSITY:	70
WARNINGS:	7

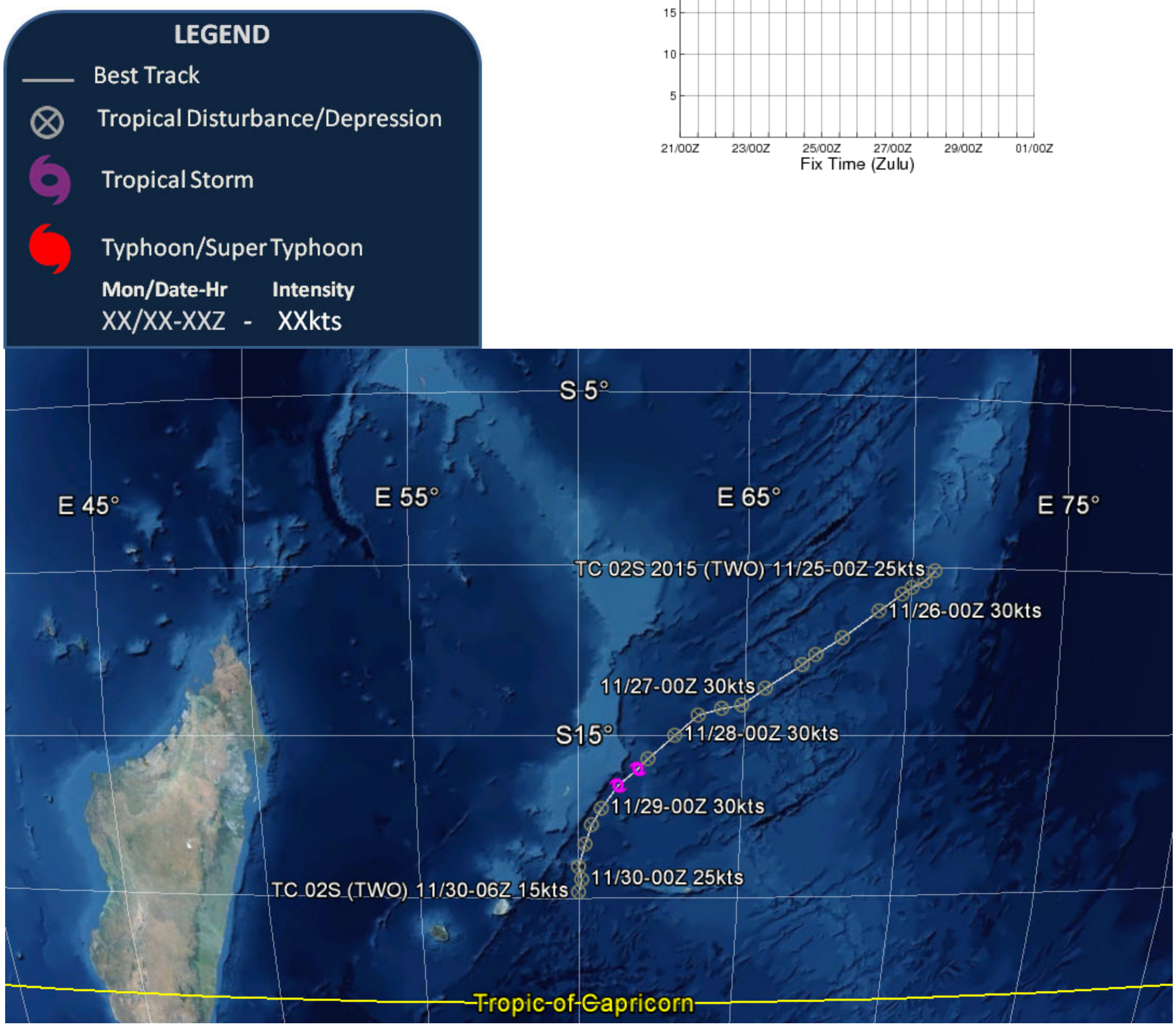




02S TROPICAL CYCLONE TWO

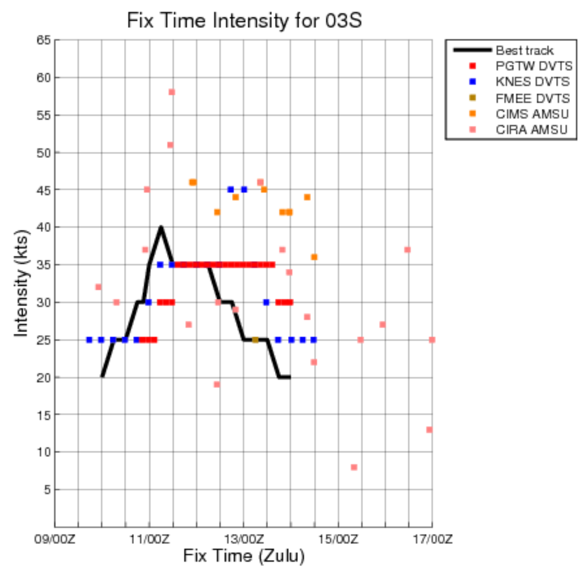
ISSUED LOW:	22 NOV / 1800Z
ISSUED MED:	25 NOV / 0630Z
FIRST TCFA:	27 NOV / 0730Z
FIRST WARNING:	28 NOV / 1200Z
LAST WARNING:	29 NOV / 1200Z
MAX INTENSITY:	35
WARNINGS:	3

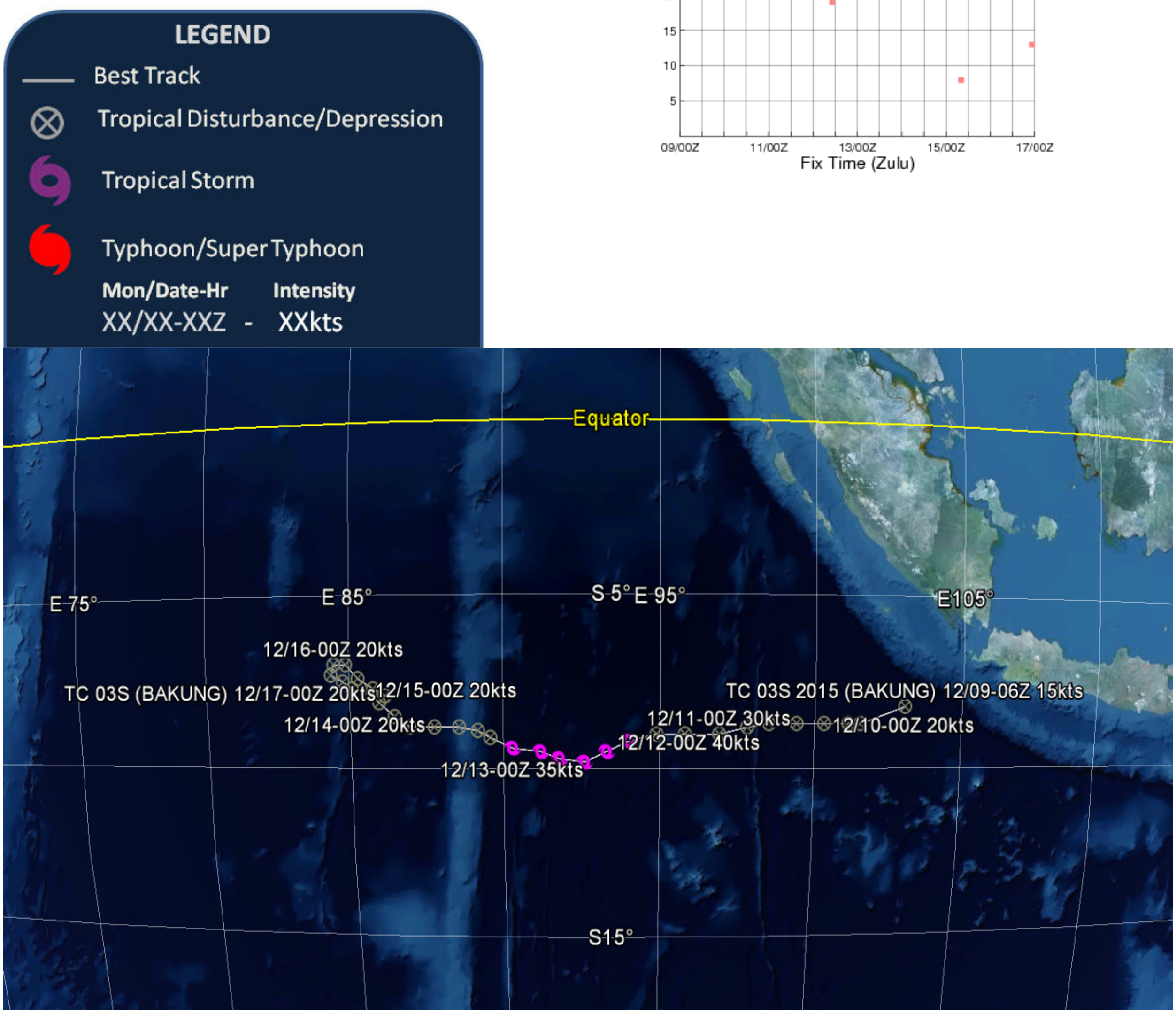




03S TROPICAL CYCLONE BAKUNG

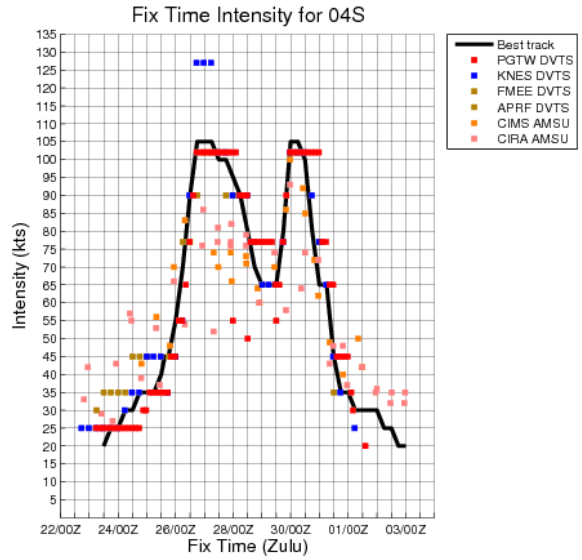
ISSUED LOW:	None
ISSUED MED:	10 NOV / 0730Z
FIRST TCFA:	11 DEC / 0230Z
FIRST WARNING:	11 DEC / 1800Z
LAST WARNING:	13 DEC / 0600Z
MAX INTENSITY:	40
WARNINGS:	4

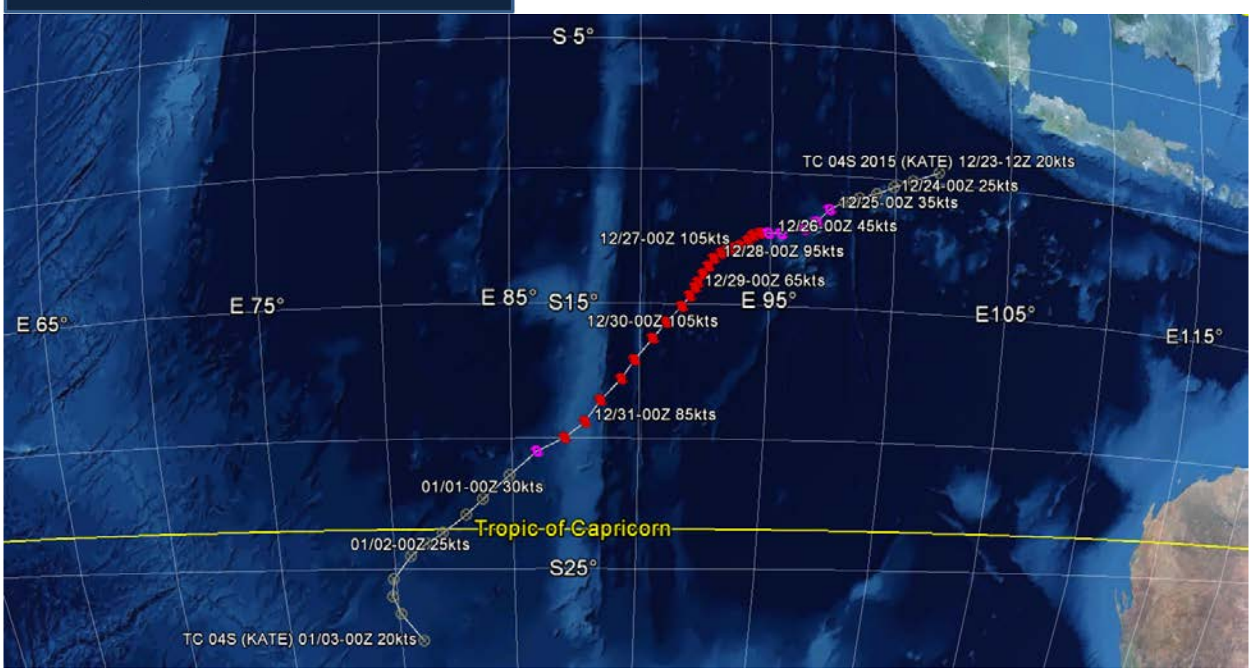




04S TROPICAL CYCLONE KATE

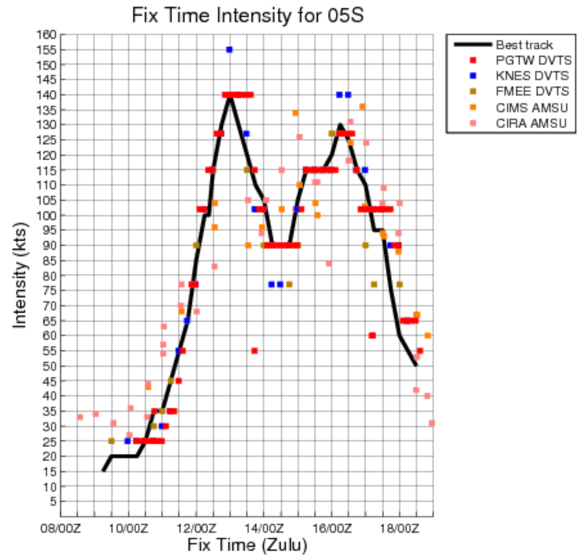
ISSUED LOW:	23 DEC / 0600Z
ISSUED MED:	23 DEC / 1200Z
FIRST TCFA:	23 DEC / 2100Z
FIRST WARNING:	25 DEC / 0000Z
LAST WARNING:	31 DEC / 1200Z
MAX INTENSITY:	105
WARNINGS:	15

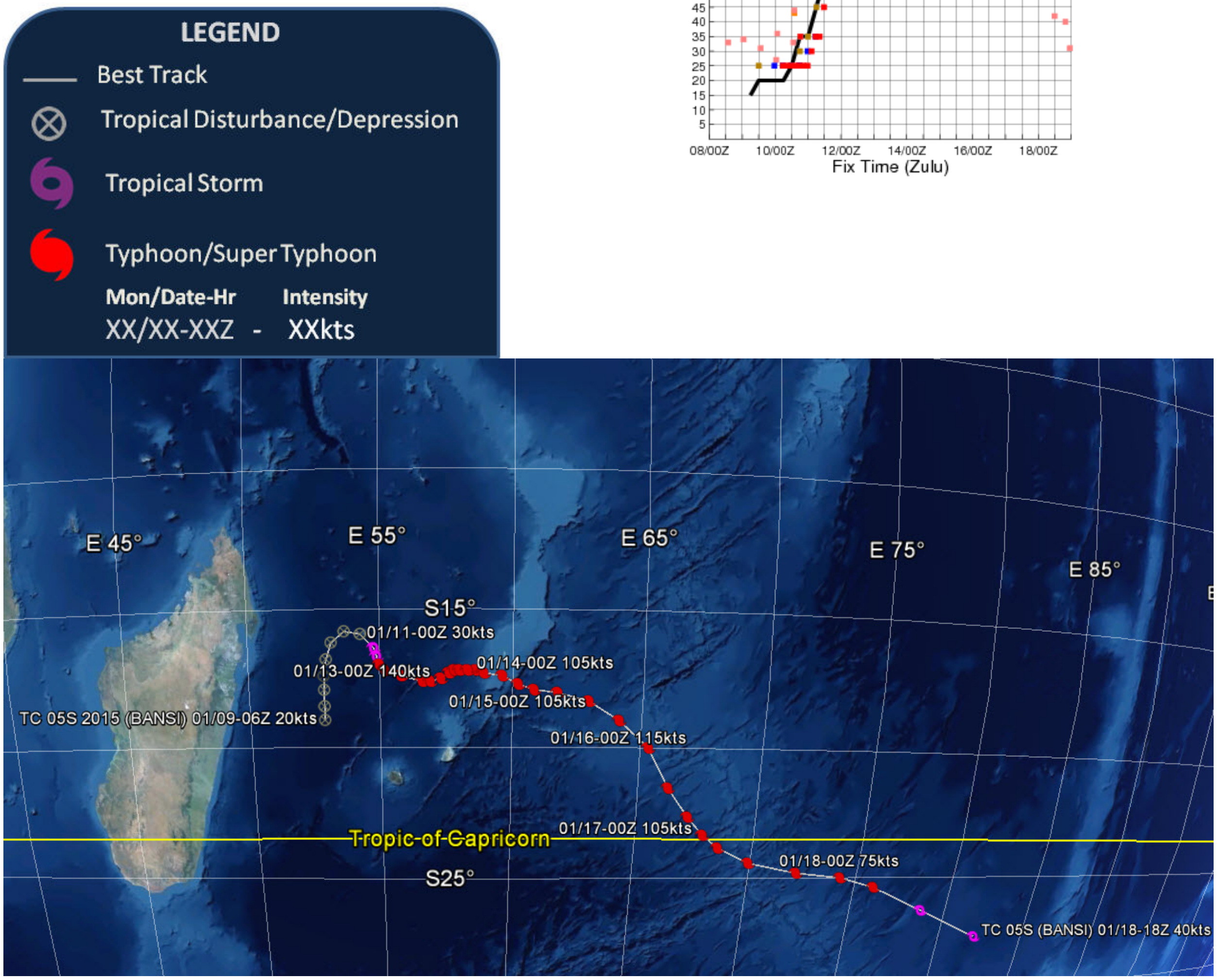




05S TROPICAL CYCLONE BANSI

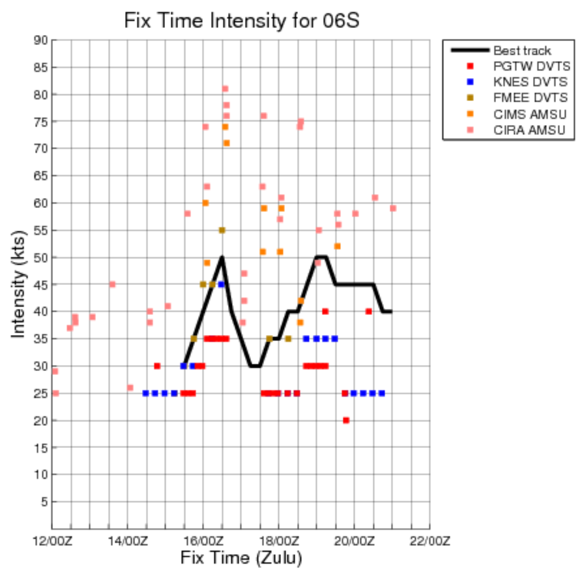
ISSUED LOW:	10 JAN / 0230Z
ISSUED MED:	10 JAN / 1800Z
FIRST TCFA:	11 JAN / 0200Z
FIRST WARNING:	11 JAN / 0600Z
LAST WARNING:	18 JAN / 1800Z
MAX INTENSITY:	140
WARNINGS:	16

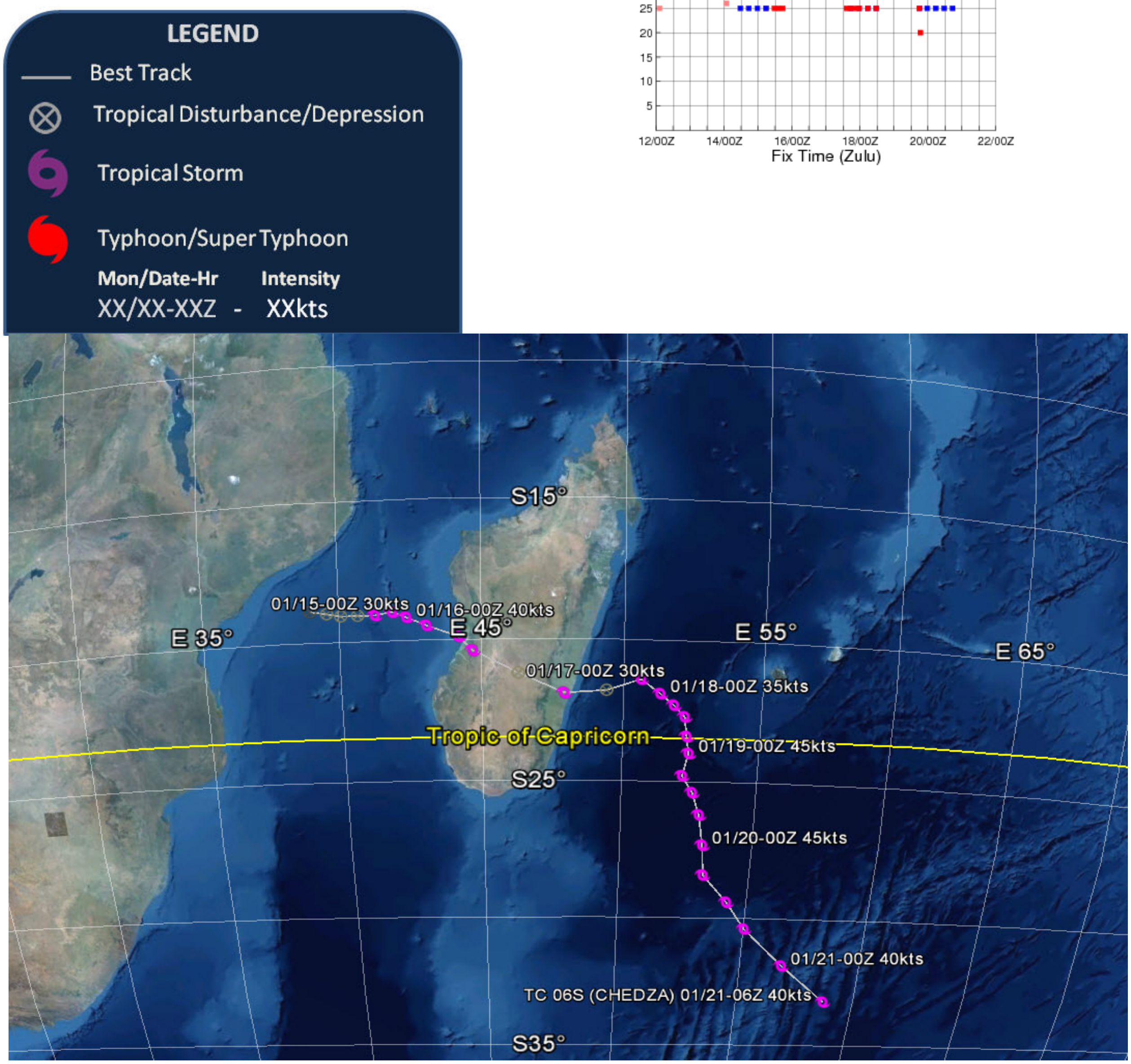




06S TROPICAL CYCLONE CHEDZA

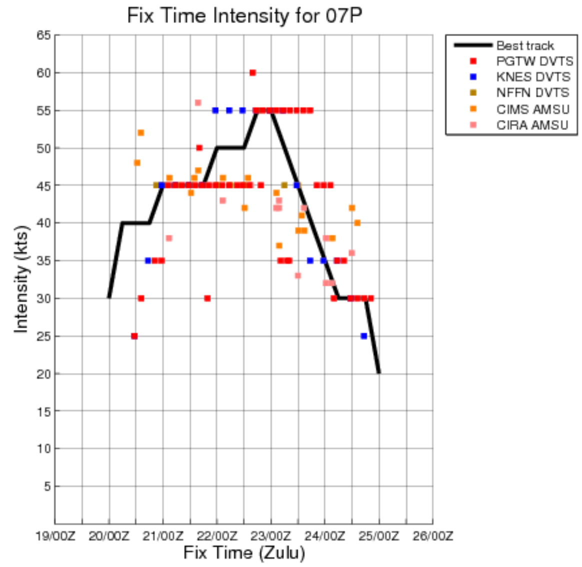
ISSUED LOW:	12 JAN / 1800Z
ISSUED MED:	15 JAN / 1000Z
FIRST TCFA:	15 JAN / 1630Z
FIRST WARNING:	16 JAN / 0000Z
LAST WARNING:	18 JAN / 0000Z
MAX INTENSITY:	50
WARNINGS:	5

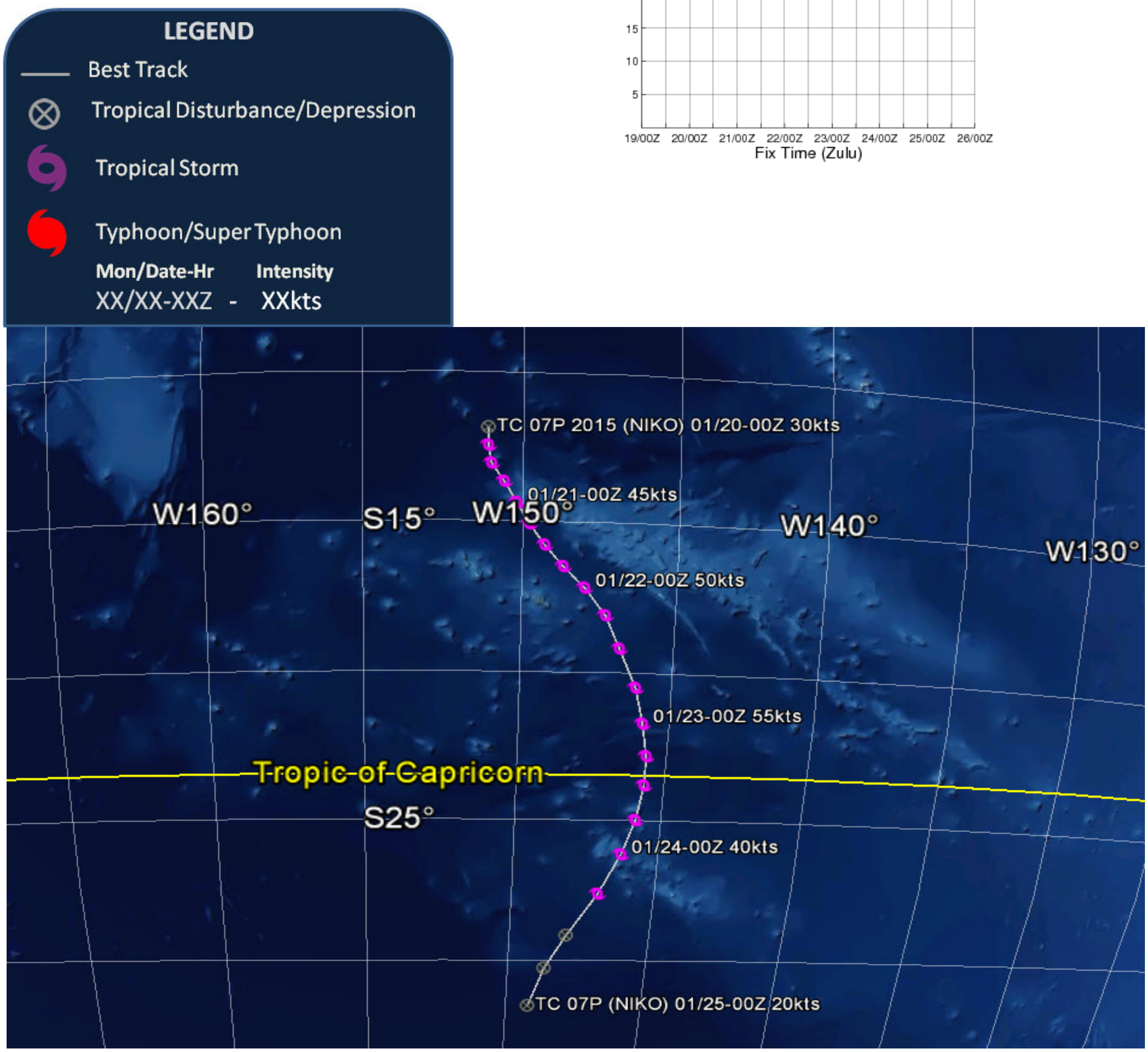




07P TROPICAL CYCLONE NIKO

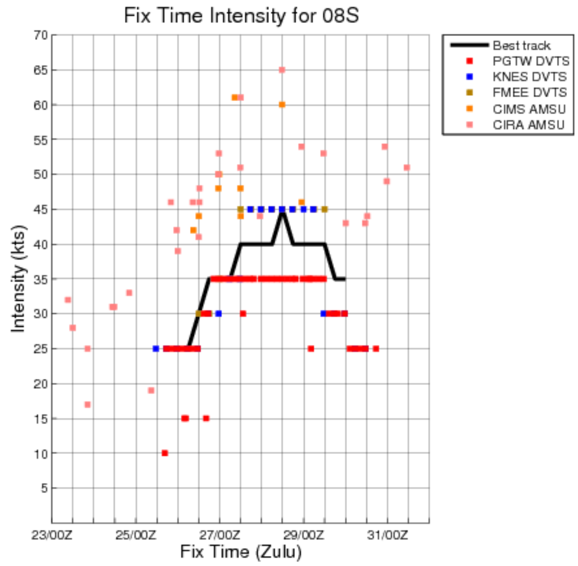
ISSUED LOW:	None
ISSUED MED:	20 JAN / 1230Z
FIRST TCFA:	20 JAN / 1530Z
FIRST WARNING:	20 JAN / 1800Z
LAST WARNING:	24 JAN / 0600Z
MAX INTENSITY:	55
WARNINGS:	8

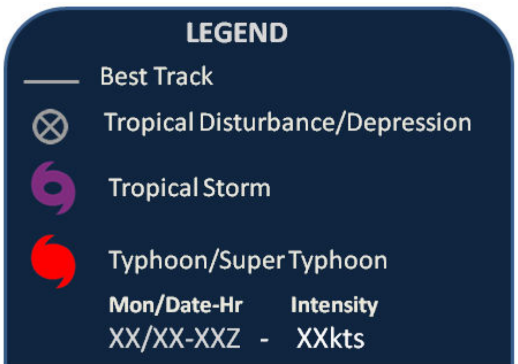


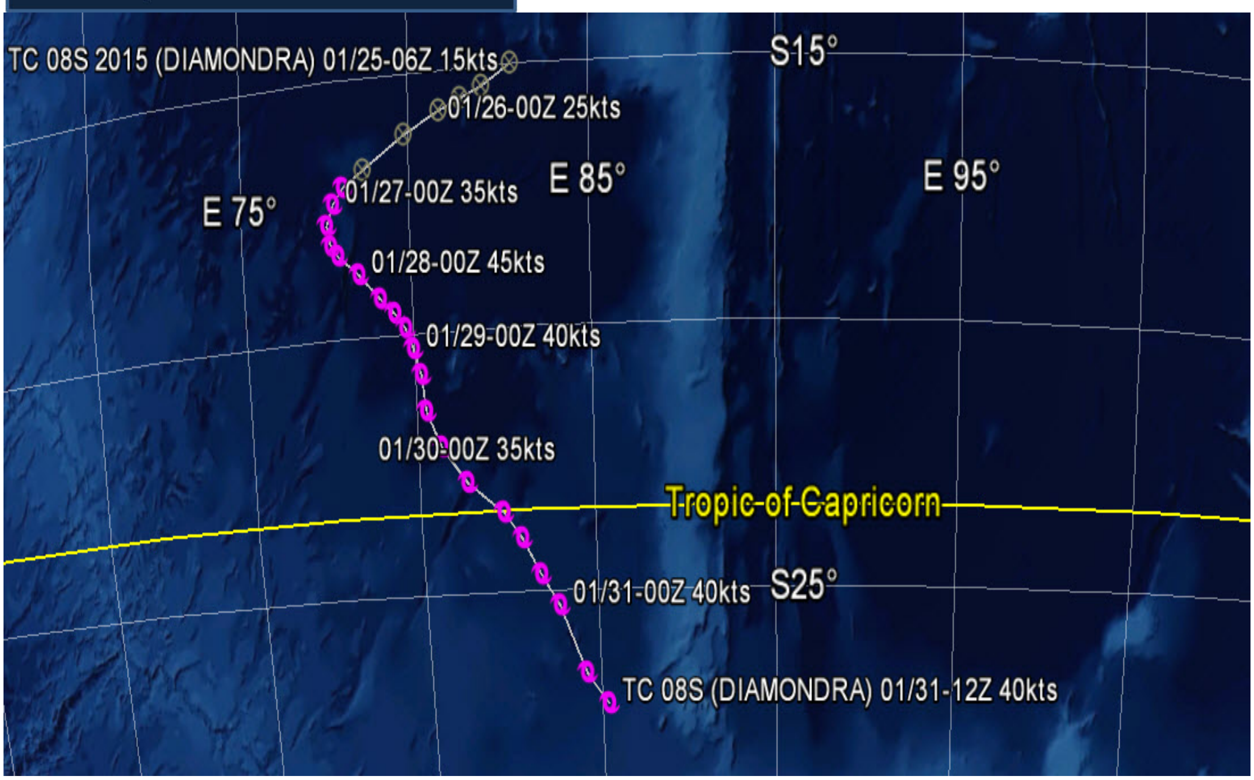


08S TROPICAL CYCLONE DIAMONDRA

ISSUED LOW:	25 JAN / 1800Z
ISSUED MED:	26 JAN / 0000Z
FIRST TCFA:	26 JAN / 1300Z
FIRST WARNING:	26 JAN / 1800Z
LAST WARNING:	29 JAN / 0600Z
MAX INTENSITY:	45
WARNINGS:	6

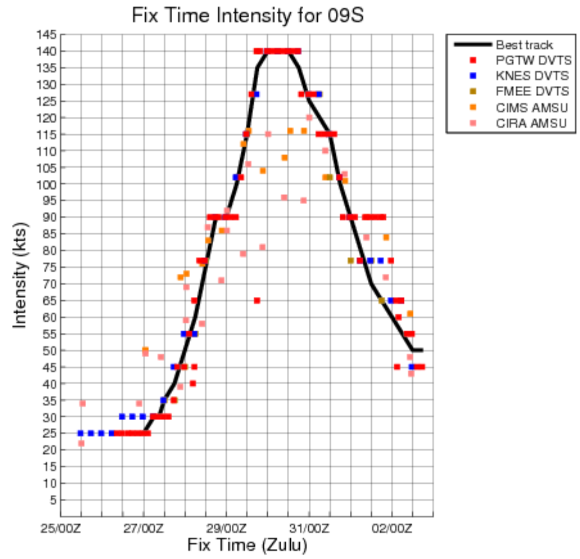


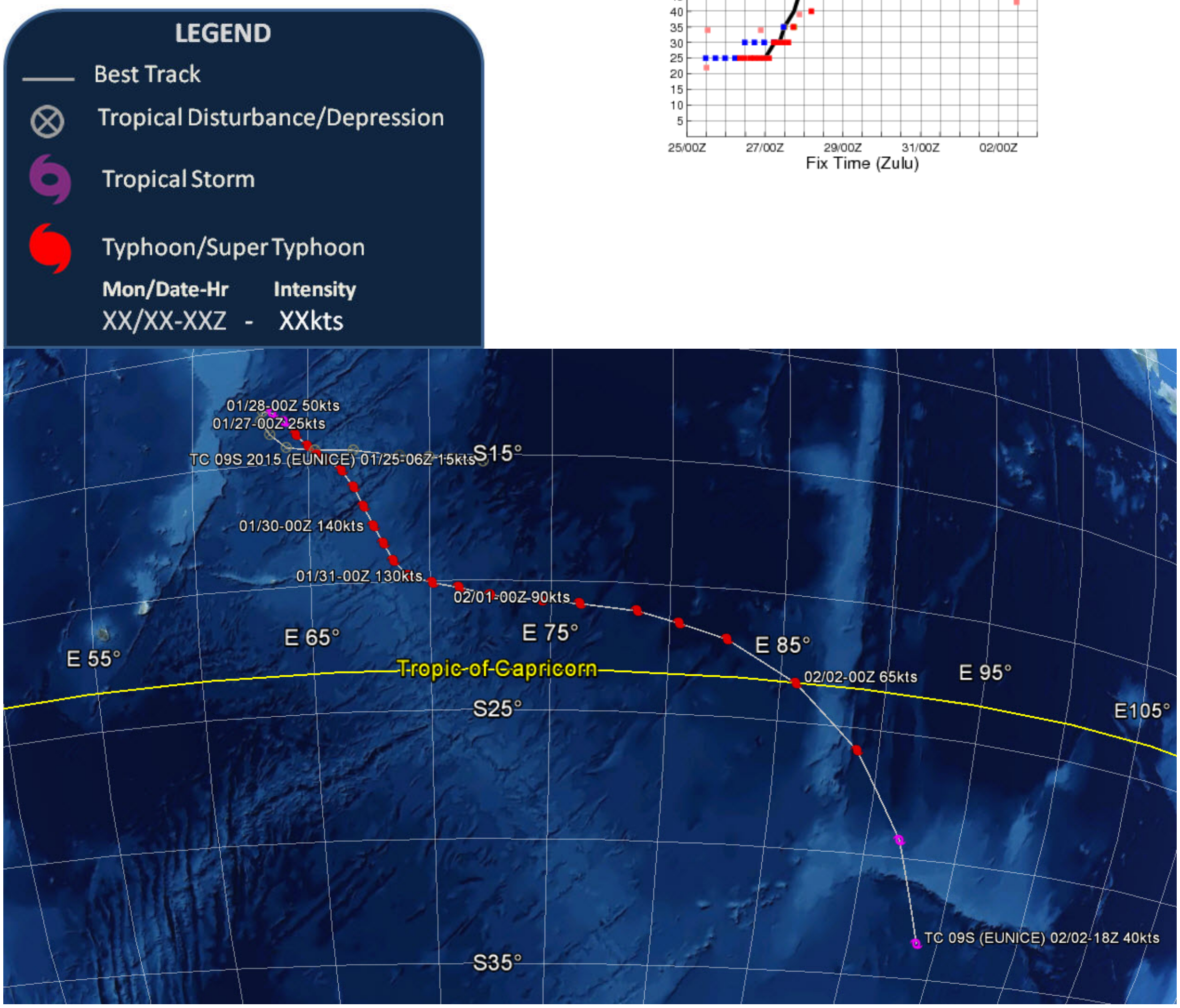




09S TROPICAL CYCLONE EUNICE

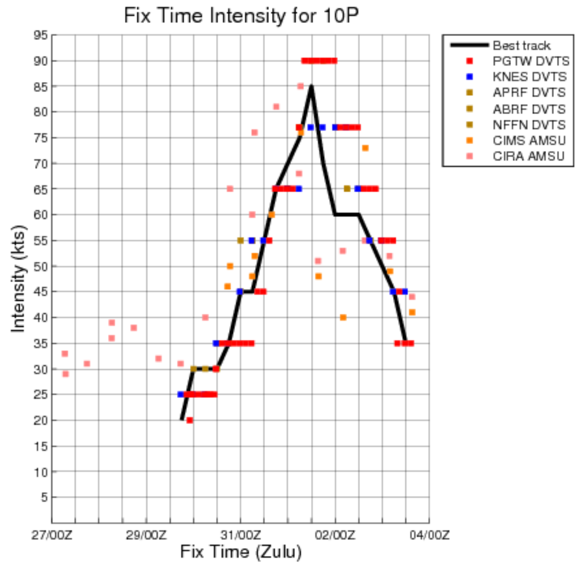
ISSUED LOW: 25 JAN / 1800Z
ISSUED MED: 26 JAN / 1330Z
FIRST TCFA: 27 JAN / 0930Z
FIRST WARNING: 27 JAN / 1800Z
LAST WARNING: 02 FEB / 1200Z
MAX INTENSITY: 140
WARNINGS: 13

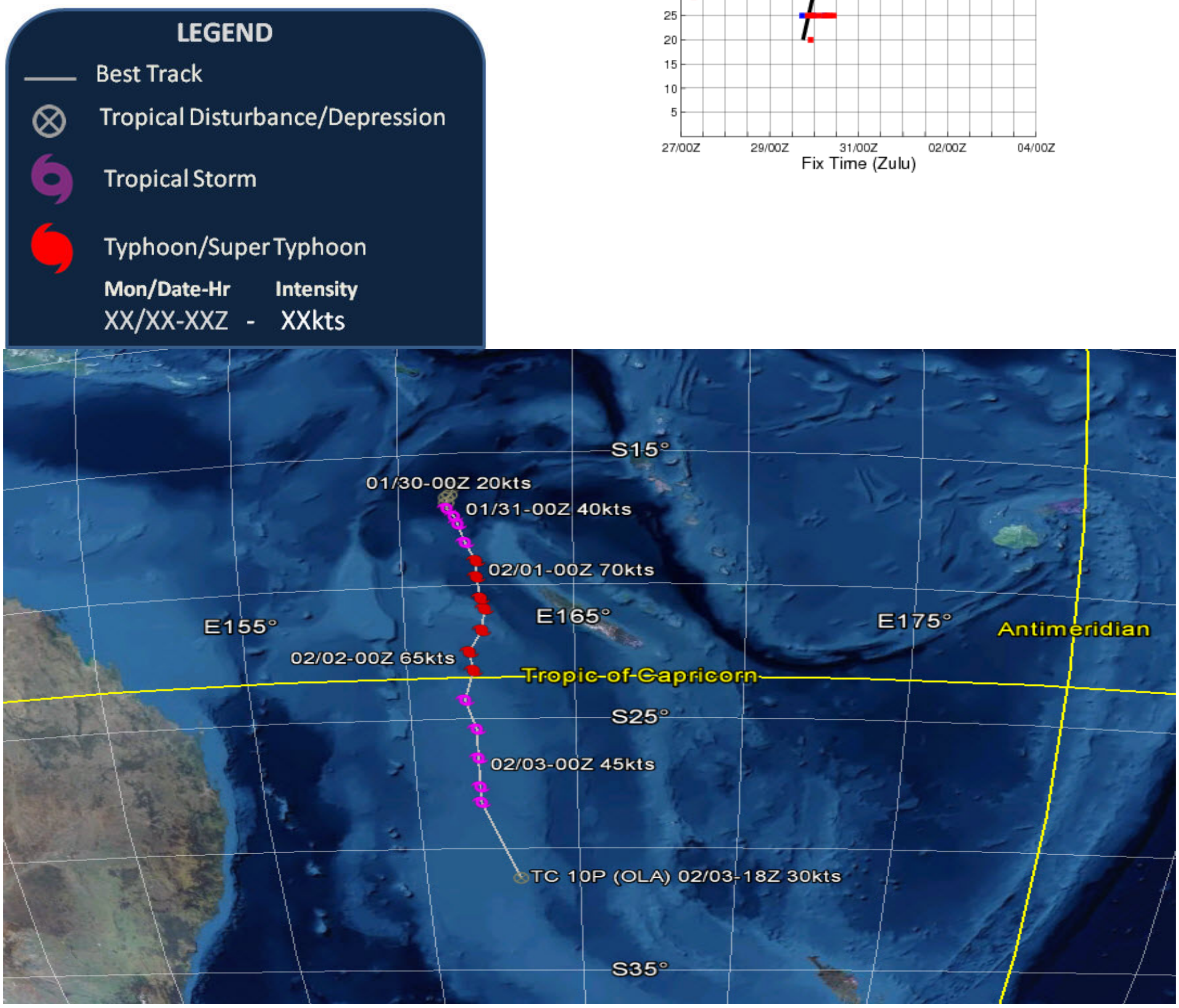




10P TROPICAL CYCLONE OLA

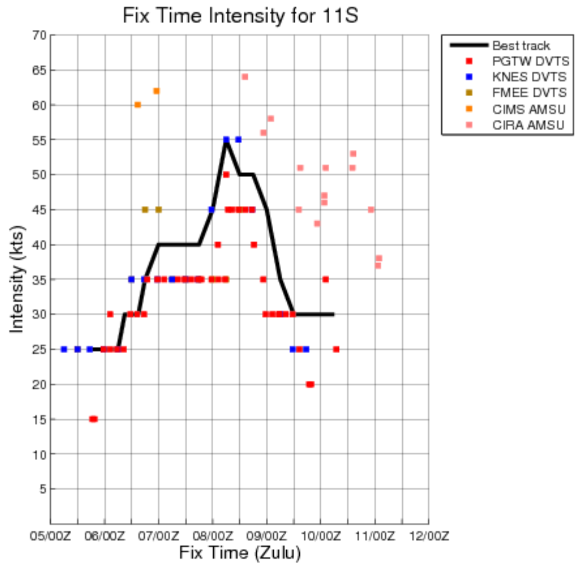
ISSUED LOW:	29 JAN / 0600Z
ISSUED MED:	29 JAN / 2100Z
FIRST TCFA:	30 JAN / 1030Z
FIRST WARNING:	30 JAN / 1800Z
LAST WARNING:	03 FEB / 0600Z
MAX INTENSITY:	85
WARNINGS:	8

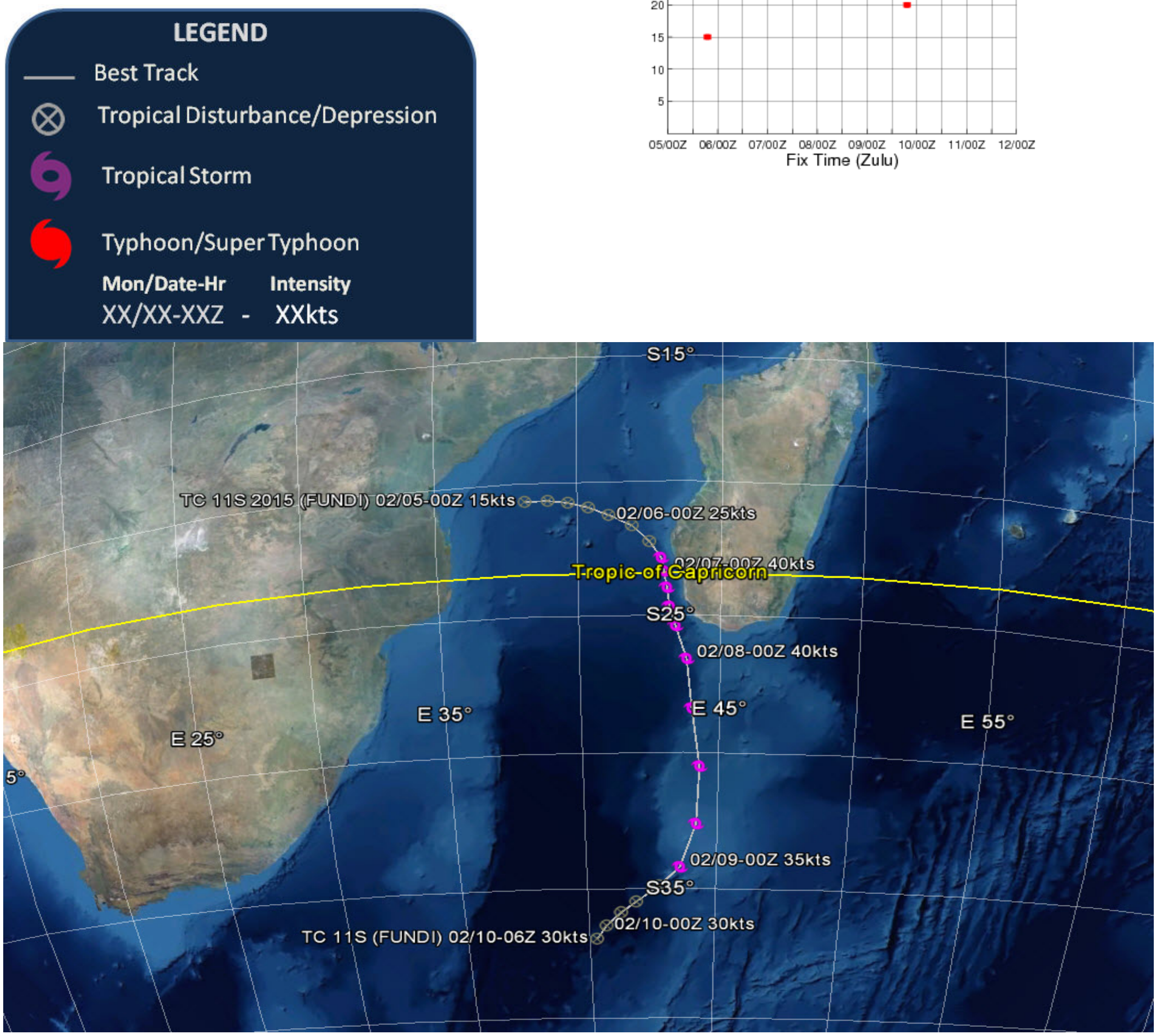




11S TROPICAL CYCLONE FUNDI

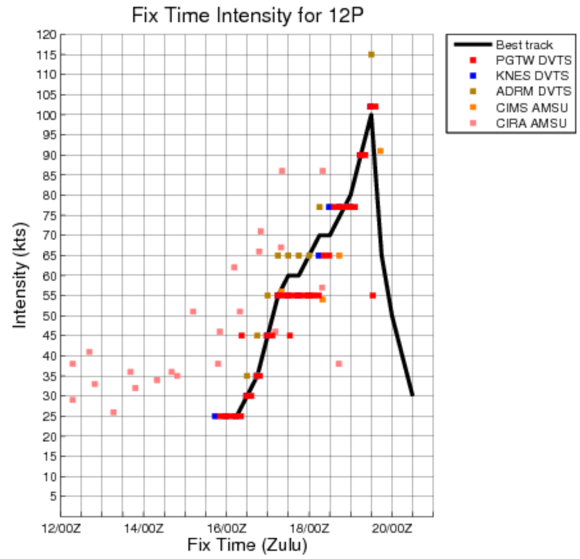
ISSUED LOW:	05 FEB / 1800Z
ISSUED MED:	06 FEB / 0100Z
FIRST TCFA:	06 FEB / 0900Z
FIRST WARNING:	06 FEB / 1800Z
LAST WARNING:	08 FEB / 1800Z
MAX INTENSITY:	55
WARNINGS:	5

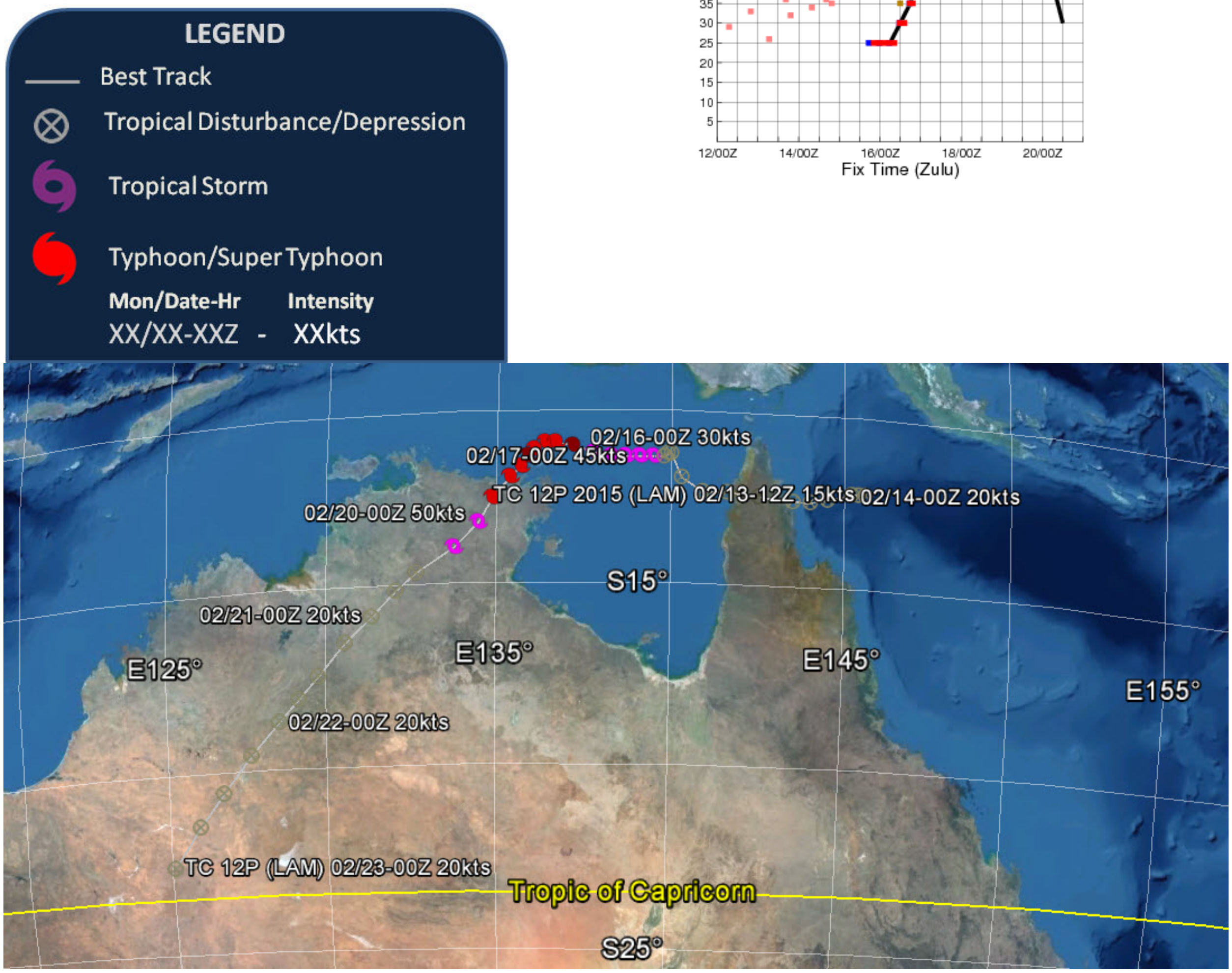




12P TROPICAL CYCLONE LAM

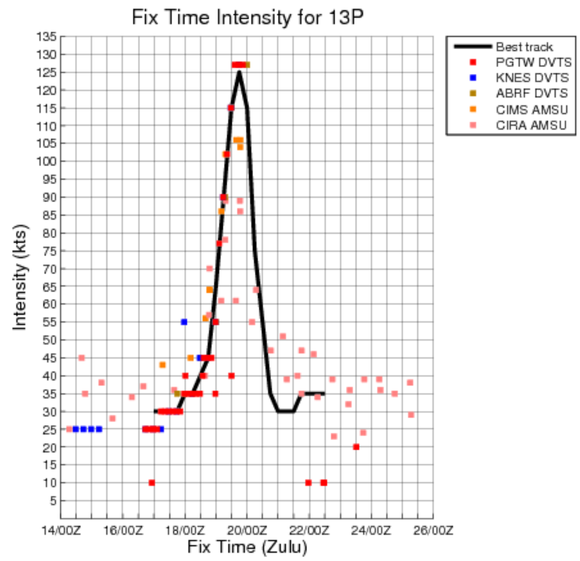
ISSUED LOW:	12 FEB / 2000Z
ISSUED MED:	None
FIRST TCFA:	16 FEB / 0600Z
FIRST WARNING:	16 FEB / 1800Z
LAST WARNING:	19 FEB / 1800Z
MAX INTENSITY:	100
WARNINGS:	7

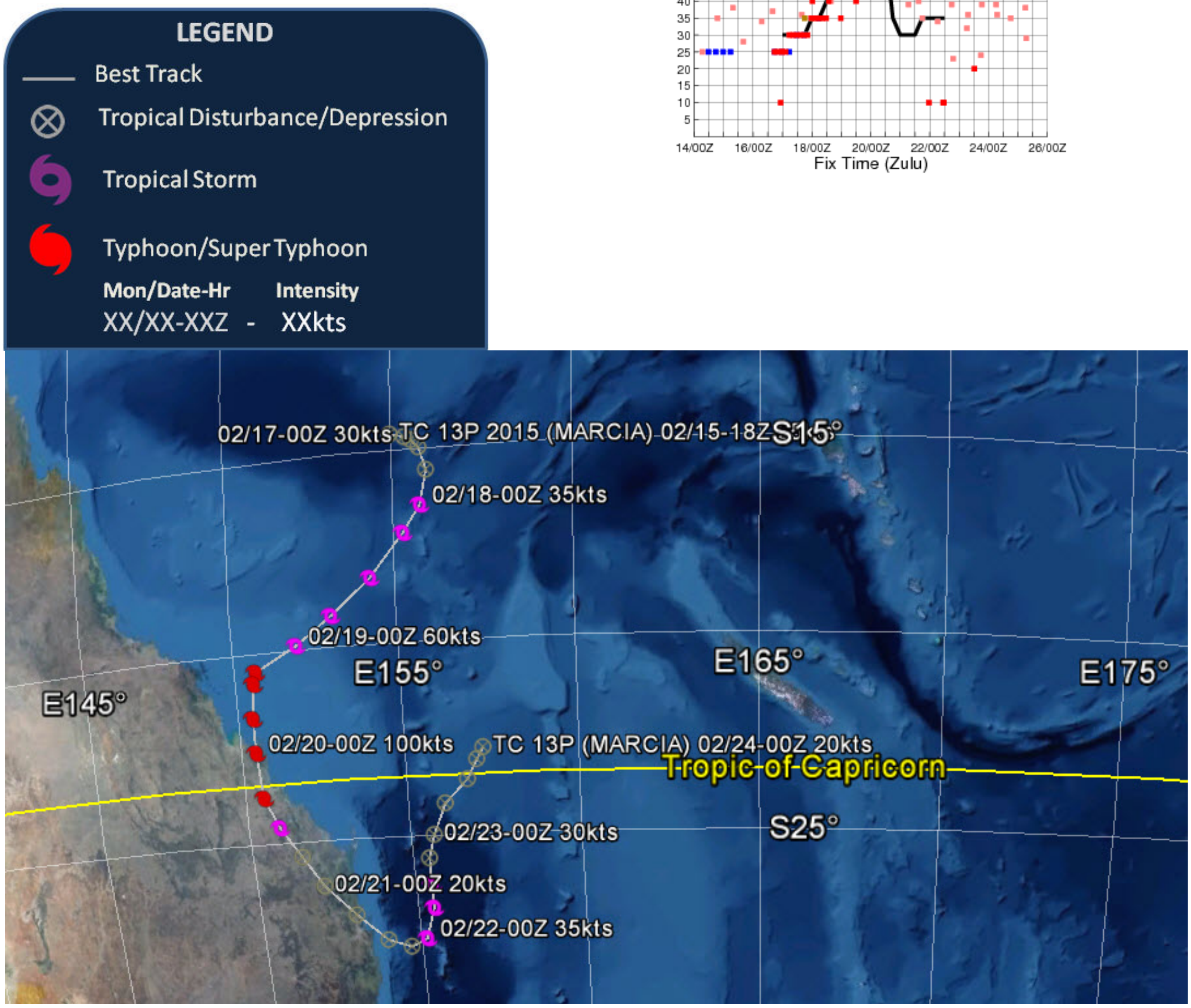




13P TROPICAL CYCLONE MARCIA

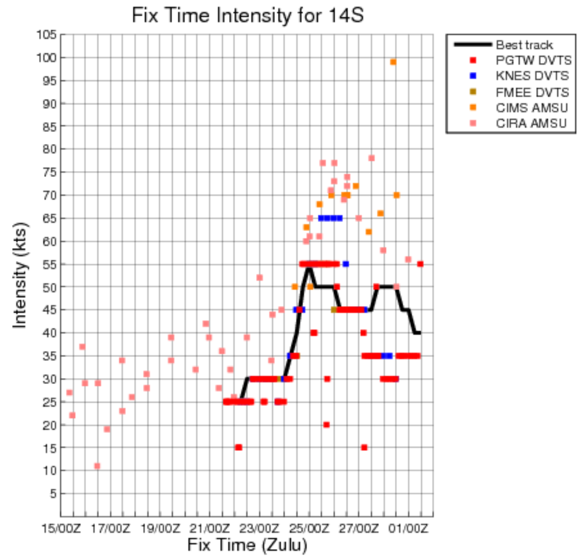
ISSUED LOW:	16 FEB / 0600Z
ISSUED MED:	16 FEB / 2130Z
FIRST TCFA:	17 FEB / 0530Z
FIRST WARNING:	18 FEB / 0000Z
LAST WARNING:	20 FEB / 0600Z
MAX INTENSITY:	125
WARNINGS:	6

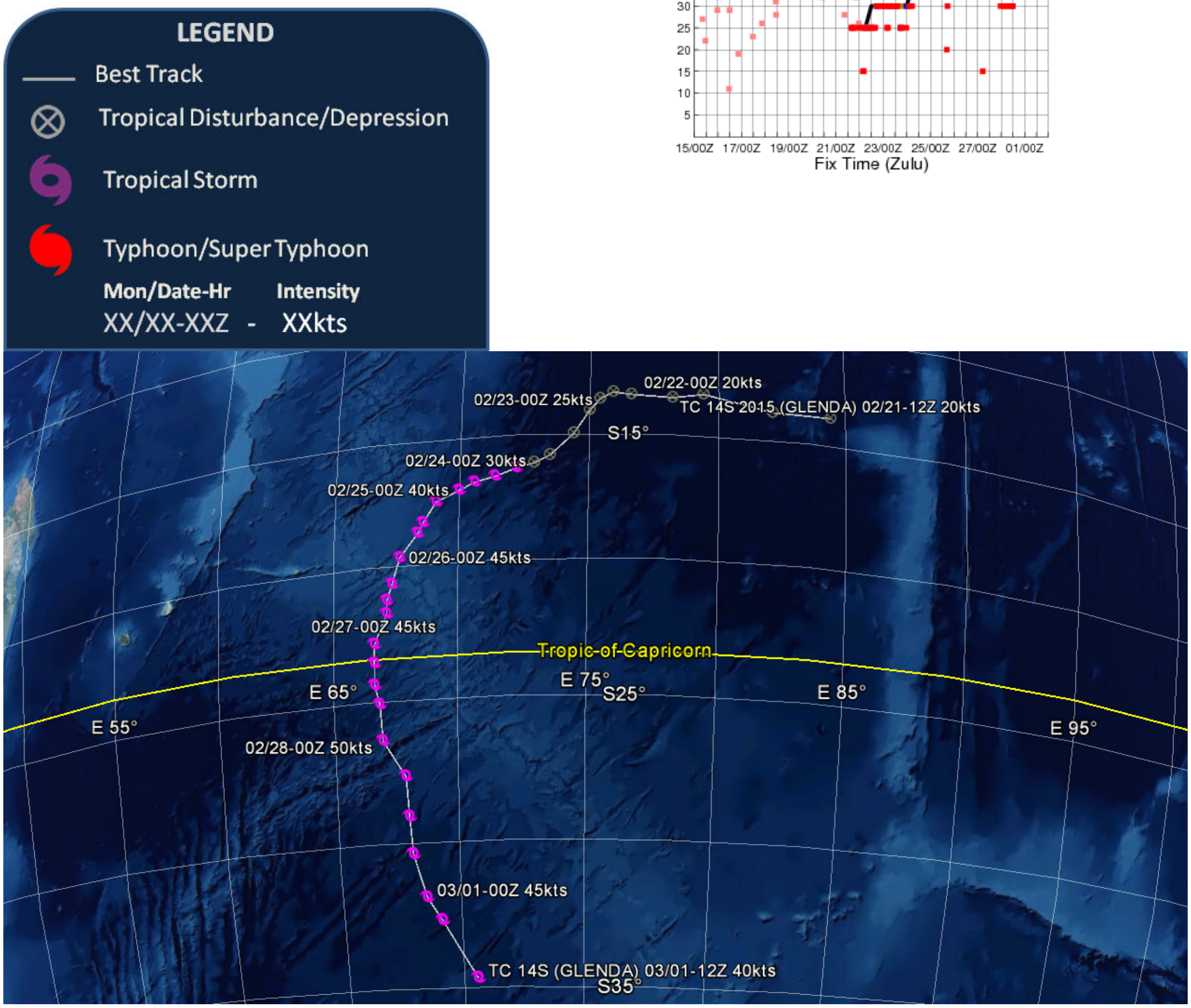




14S TROPICAL CYCLONE GLENDA

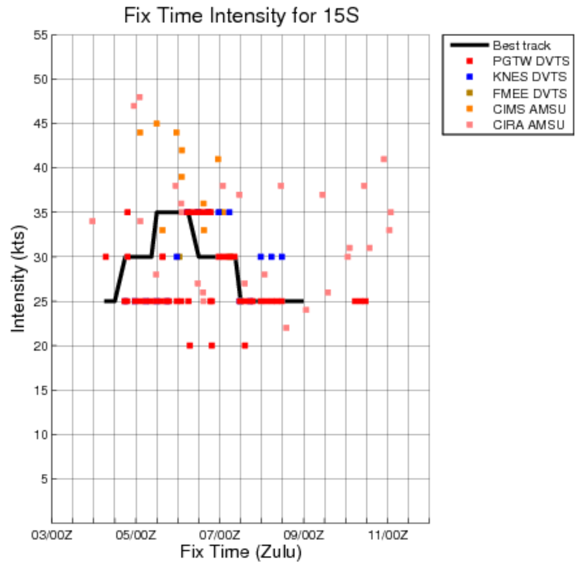
ISSUED LOW:	15 FEB / 1800Z
ISSUED MED:	22 FEB / 0630Z
FIRST TCFA:	22 FEB / 1400Z
FIRST WARNING:	24 FEB / 0600Z
LAST WARNING:	28 FEB / 0600Z
MAX INTENSITY:	55
WARNINGS:	9

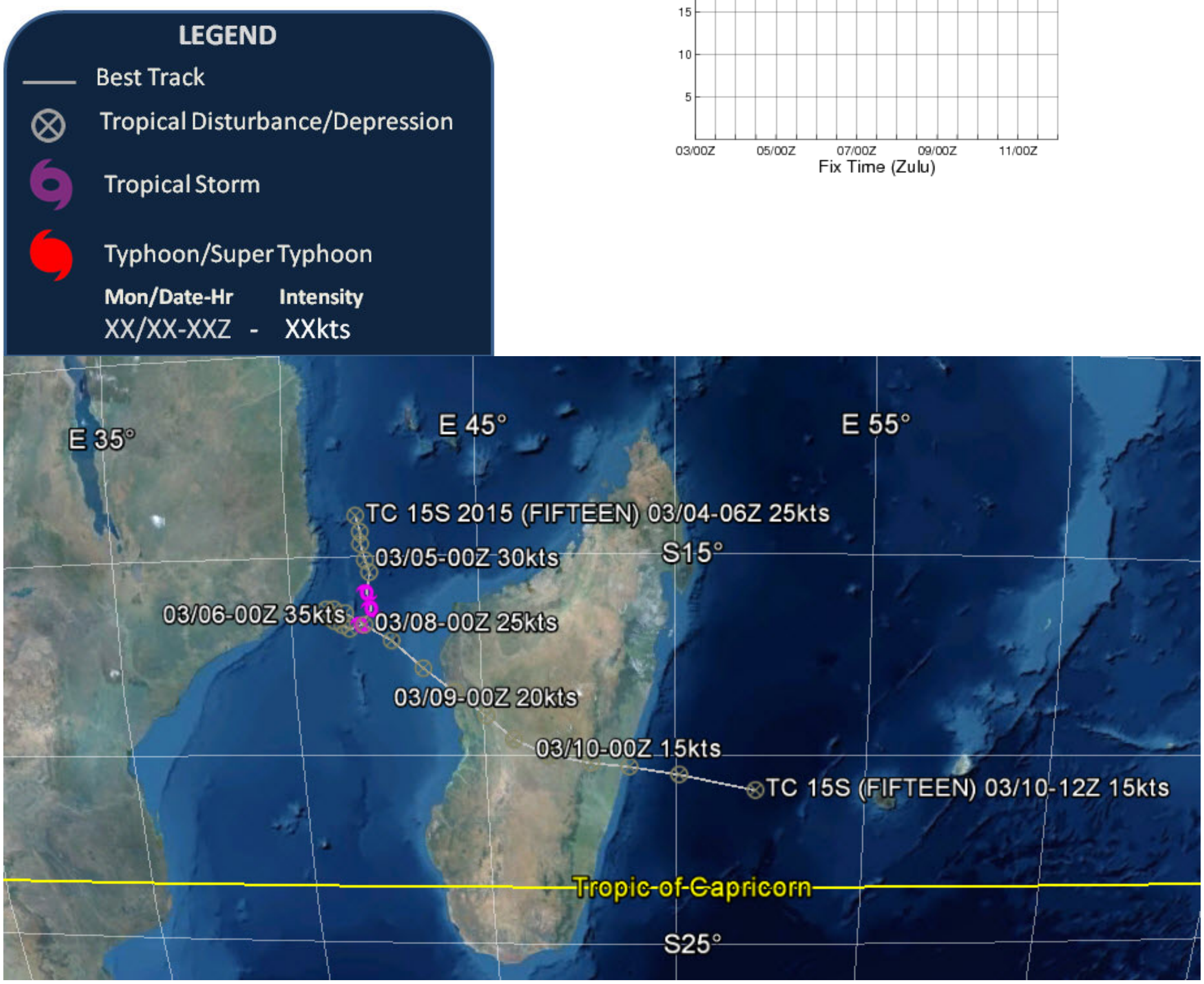




15S TROPICAL CYCLONE FIFTEEN

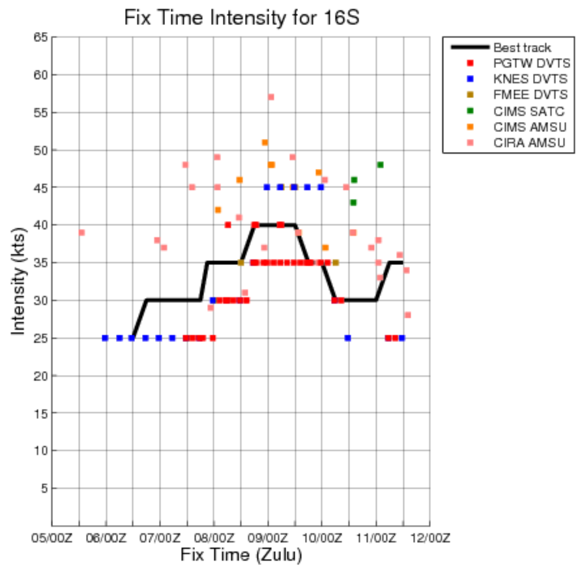
ISSUED LOW:	04 MAR / 1430Z
ISSUED MED:	04 MAR / 1800Z
FIRST TCFA:	04 MAR / 2200Z
FIRST WARNING:	05 MAR / 1200Z
LAST WARNING:	07 MAR / 0600Z
MAX INTENSITY:	35
WARNINGS:	5

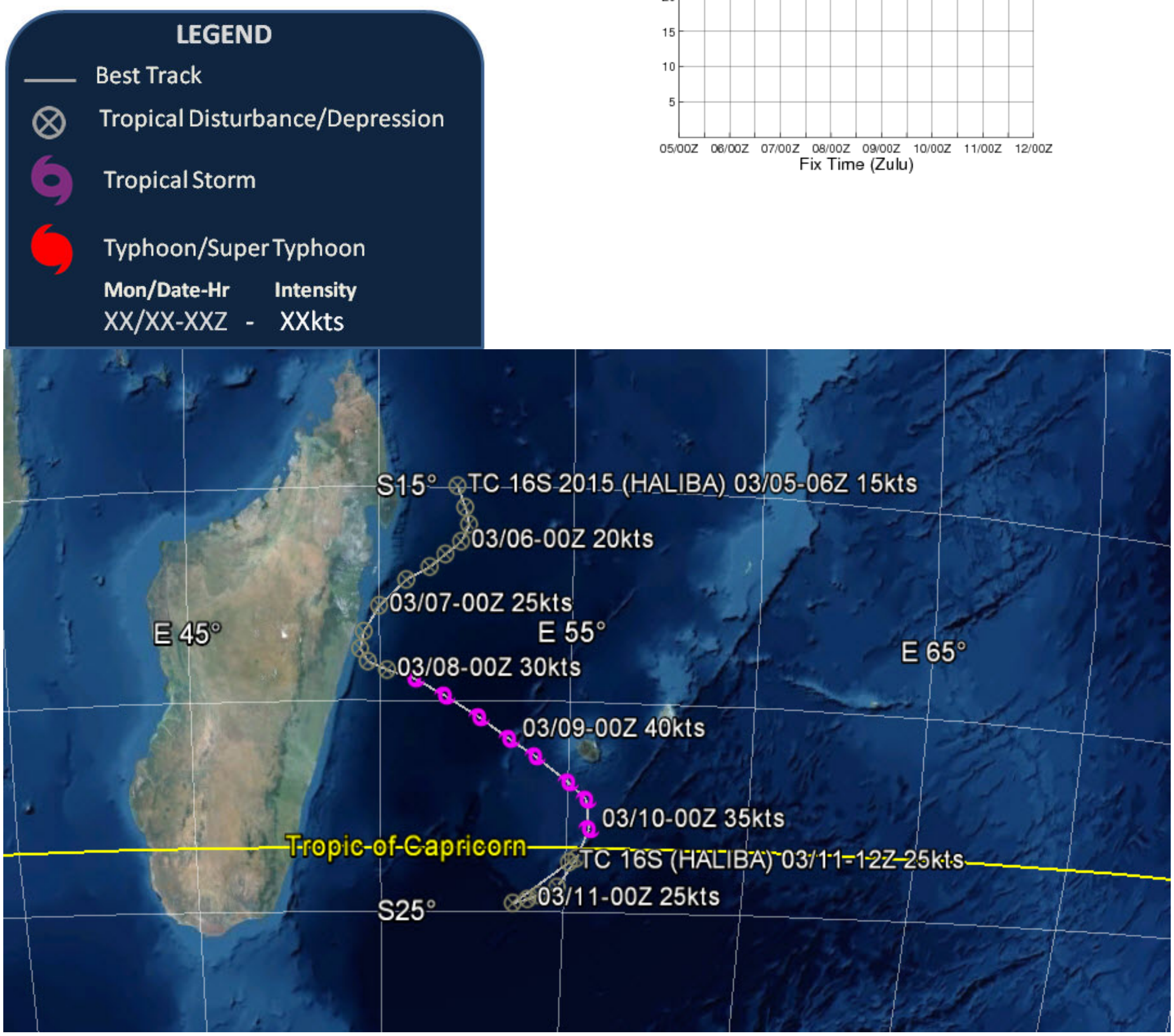




16S TROPICAL CYCLONE HALIBA

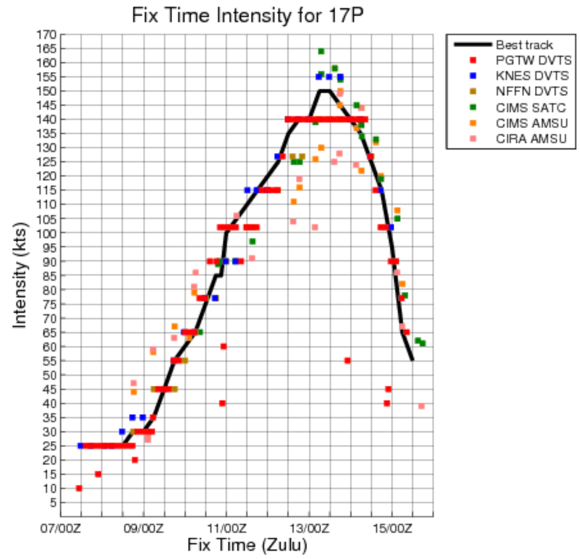
ISSUED LOW:	05 MAR / 1800Z
ISSUED MED:	07 MAR / 2230Z
FIRST TCFA:	08 MAR / 0230Z
FIRST WARNING:	08 MAR / 1800Z
LAST WARNING:	10 MAR / 0600Z
MAX INTENSITY:	40
WARNINGS:	4

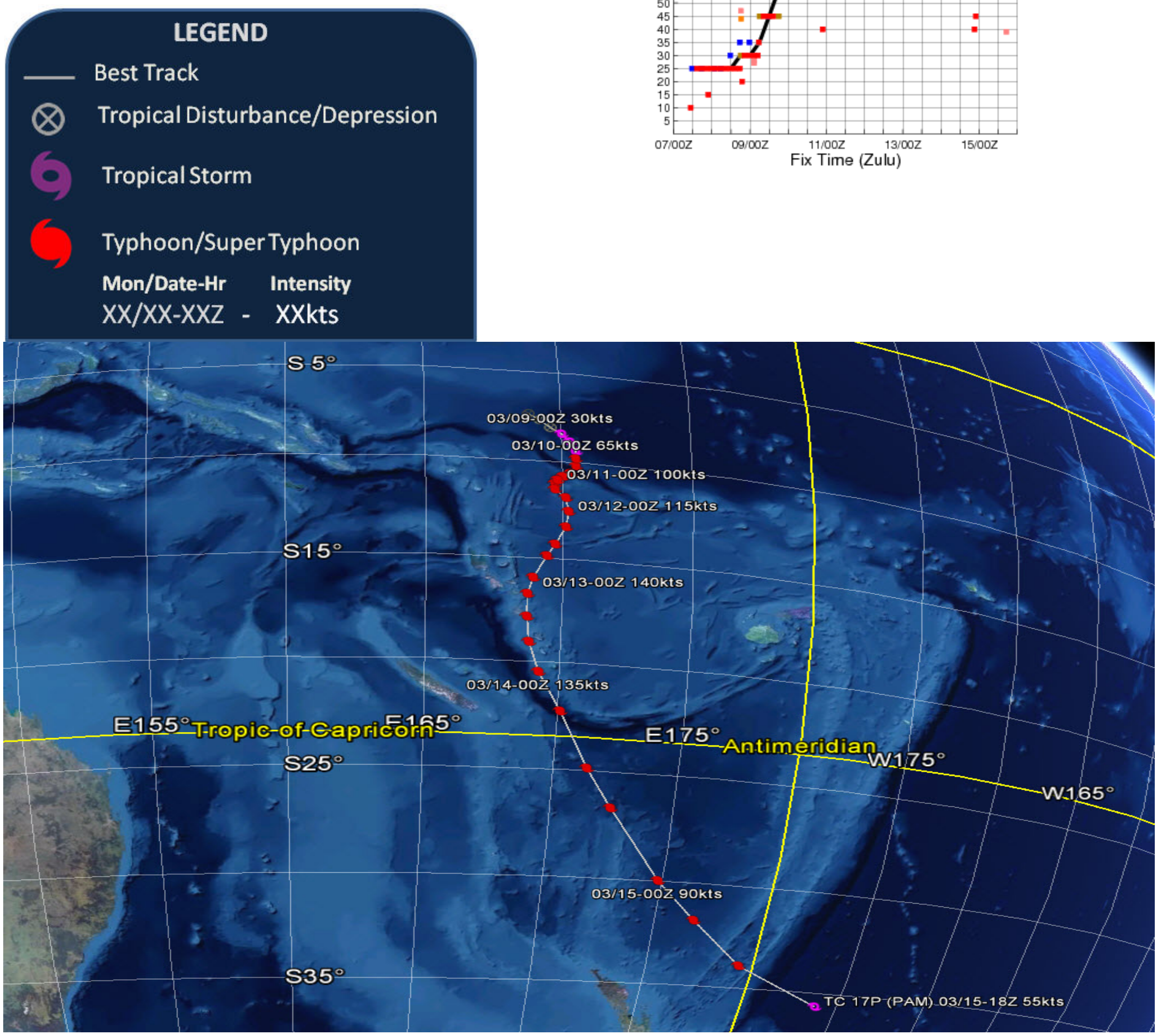




17P TROPICAL CYCLONE PAM

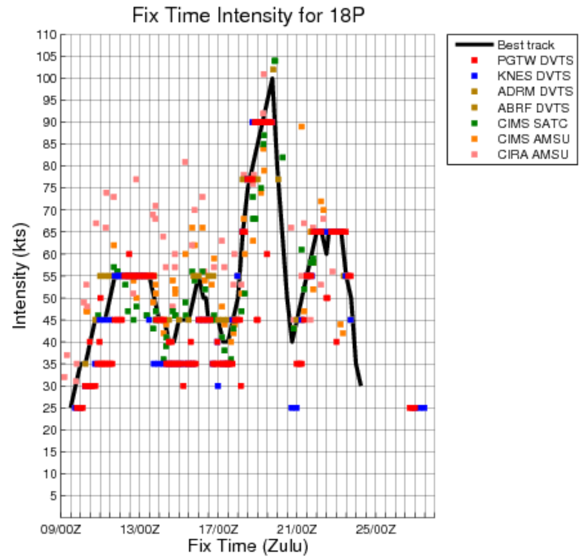
ISSUED LOW:	06 MAR / 0600Z
ISSUED MED:	06 MAR / 2130Z
FIRST TCFA:	08 MAR / 2300Z
FIRST WARNING:	09 MAR / 0600Z
LAST WARNING:	15 MAR / 1200Z
MAX INTENSITY:	150
WARNINGS:	22

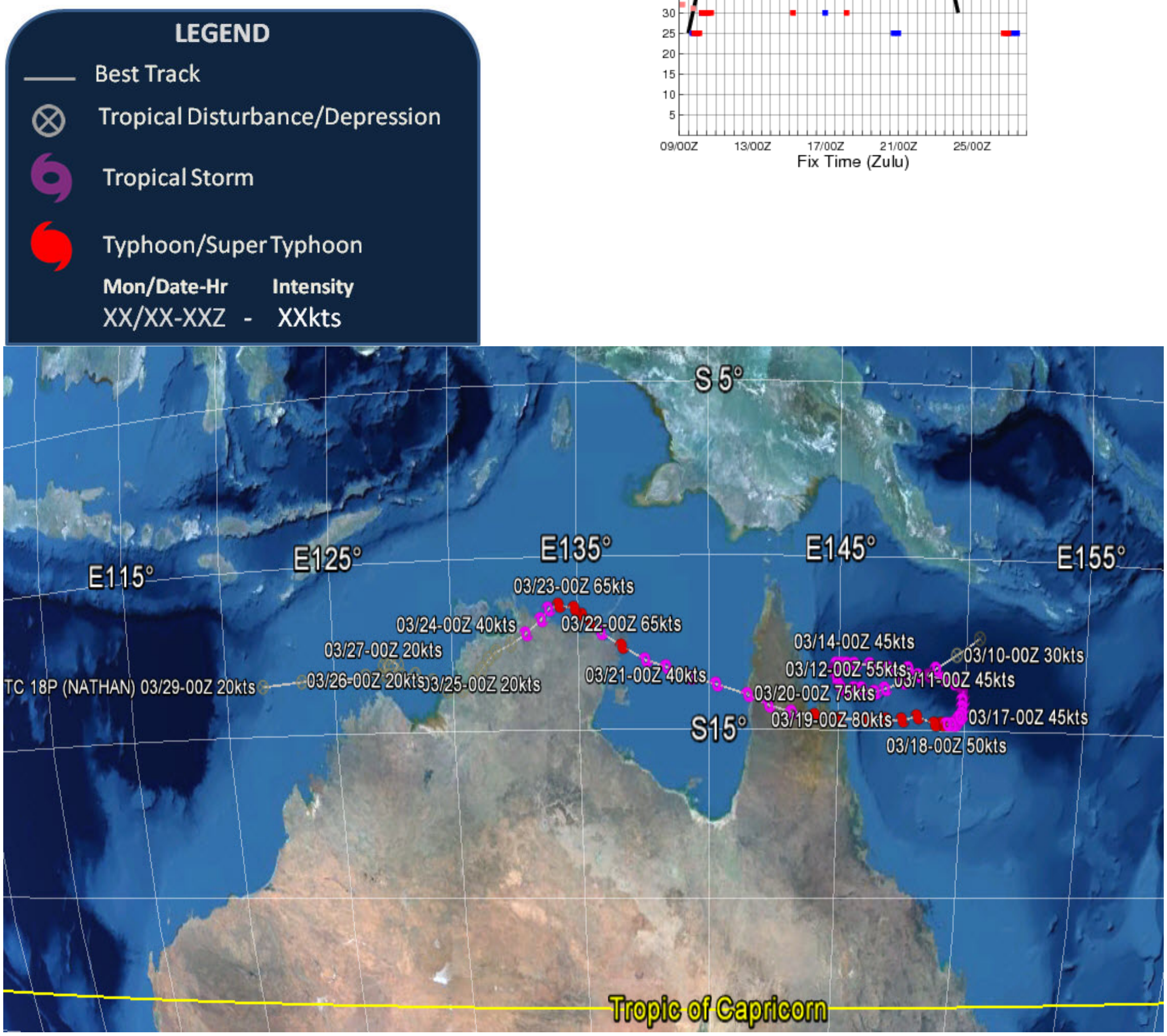




18P TROPICAL CYCLONE NATHAN

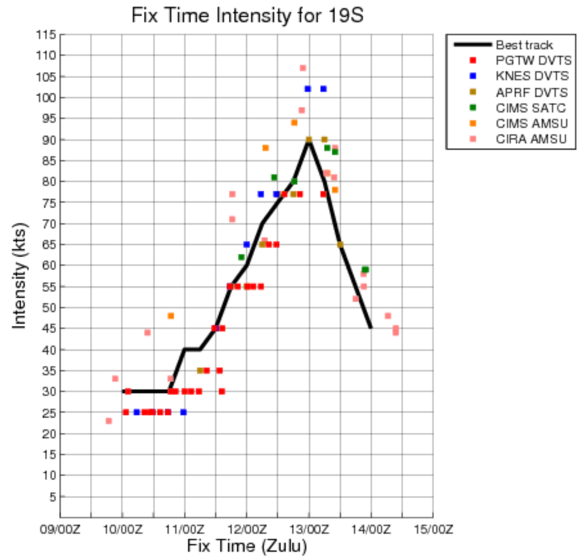
ISSUED LOW:	None
ISSUED MED:	09 MAR / 2200Z
FIRST TCFA:	10 MAR / 0300Z
FIRST WARNING:	10 MAR / 1800Z
LAST WARNING:	24 MAR / 0600Z
MAX INTENSITY:	100
WARNINGS:	28

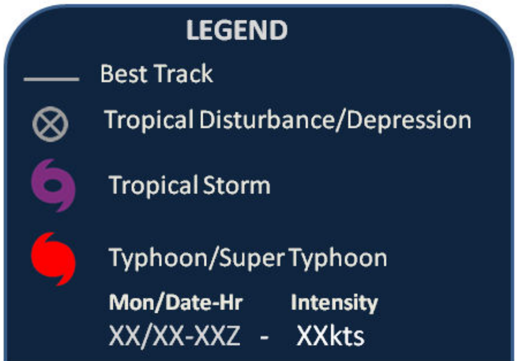


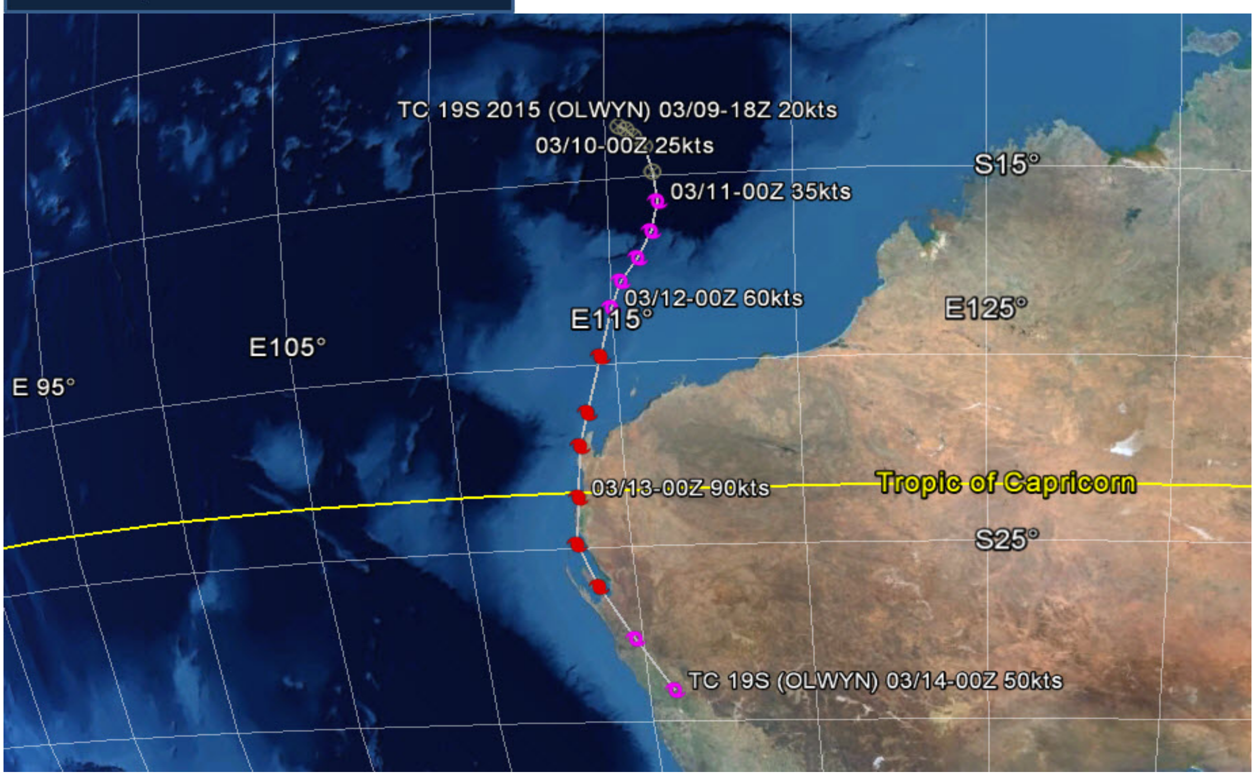


19S TROPICAL CYCLONE OLWYN

ISSUED LOW:	None
ISSUED MED:	10 MAR / 0530Z
FIRST TCFA:	10 MAR / 2300Z
FIRST WARNING:	11 MAR / 0600Z
LAST WARNING:	13 MAR / 1200Z
MAX INTENSITY:	90
WARNINGS:	9

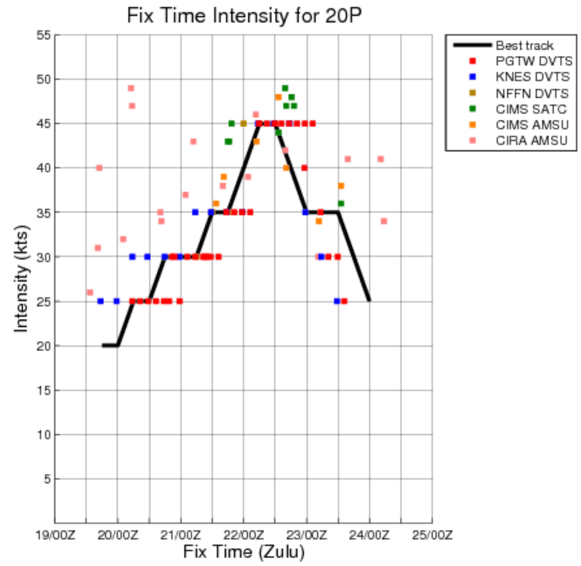


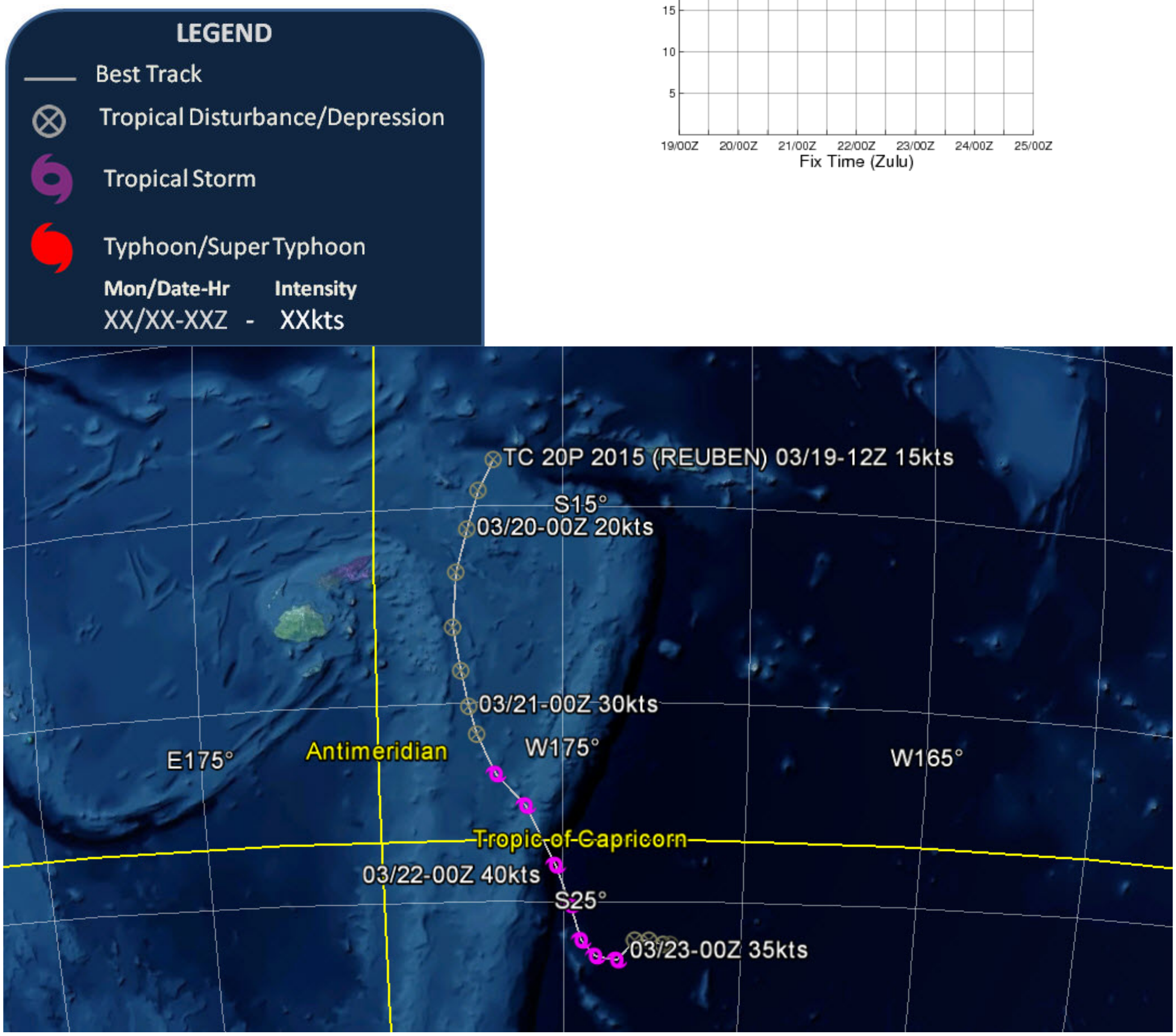




20P TROPICAL CYCLONE REUBEN

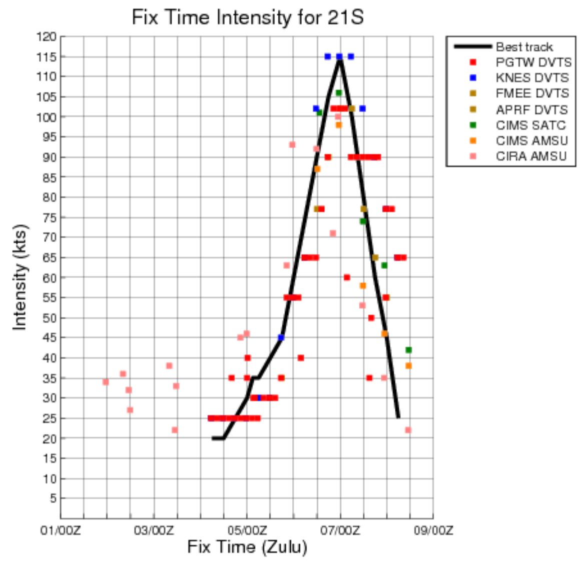
ISSUED LOW:	20 MAR / 0600Z
ISSUED MED:	20 MAR / 2200Z
FIRST TCFA:	21 MAR / 0130Z
FIRST WARNING:	21 MAR / 1200Z
LAST WARNING:	23 MAR / 0000Z
MAX INTENSITY:	45
WARNINGS:	4

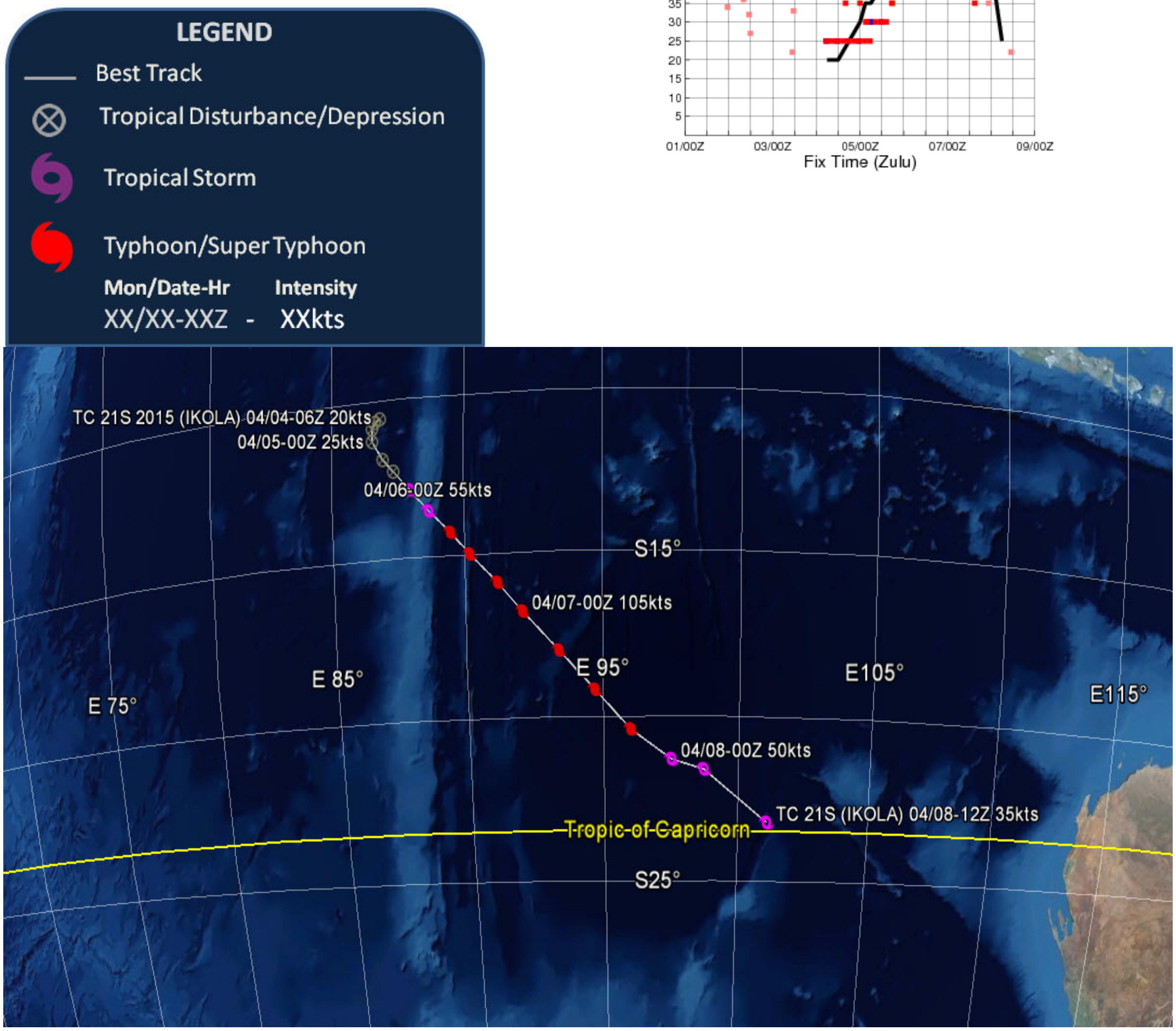




21S TROPICAL CYCLONE IKOLA

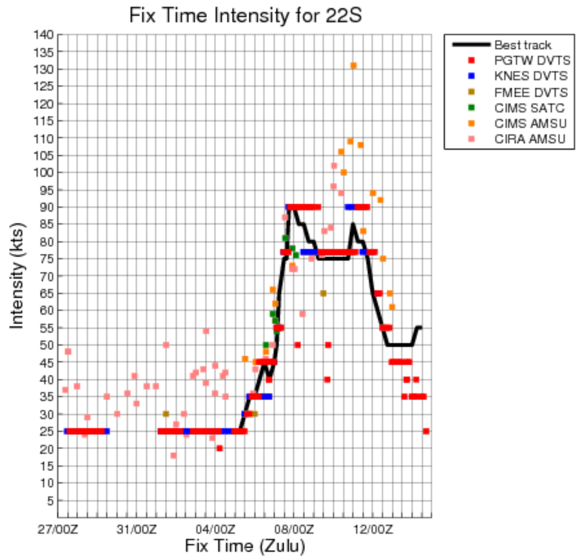
ISSUED LOW:	04 APR / 1800Z
ISSUED MED:	05 APR / 1800Z
FIRST TCFA:	None
FIRST WARNING:	06 APR / 1800Z
LAST WARNING:	08 APR / 0600Z
MAX INTENSITY:	115
WARNINGS:	6

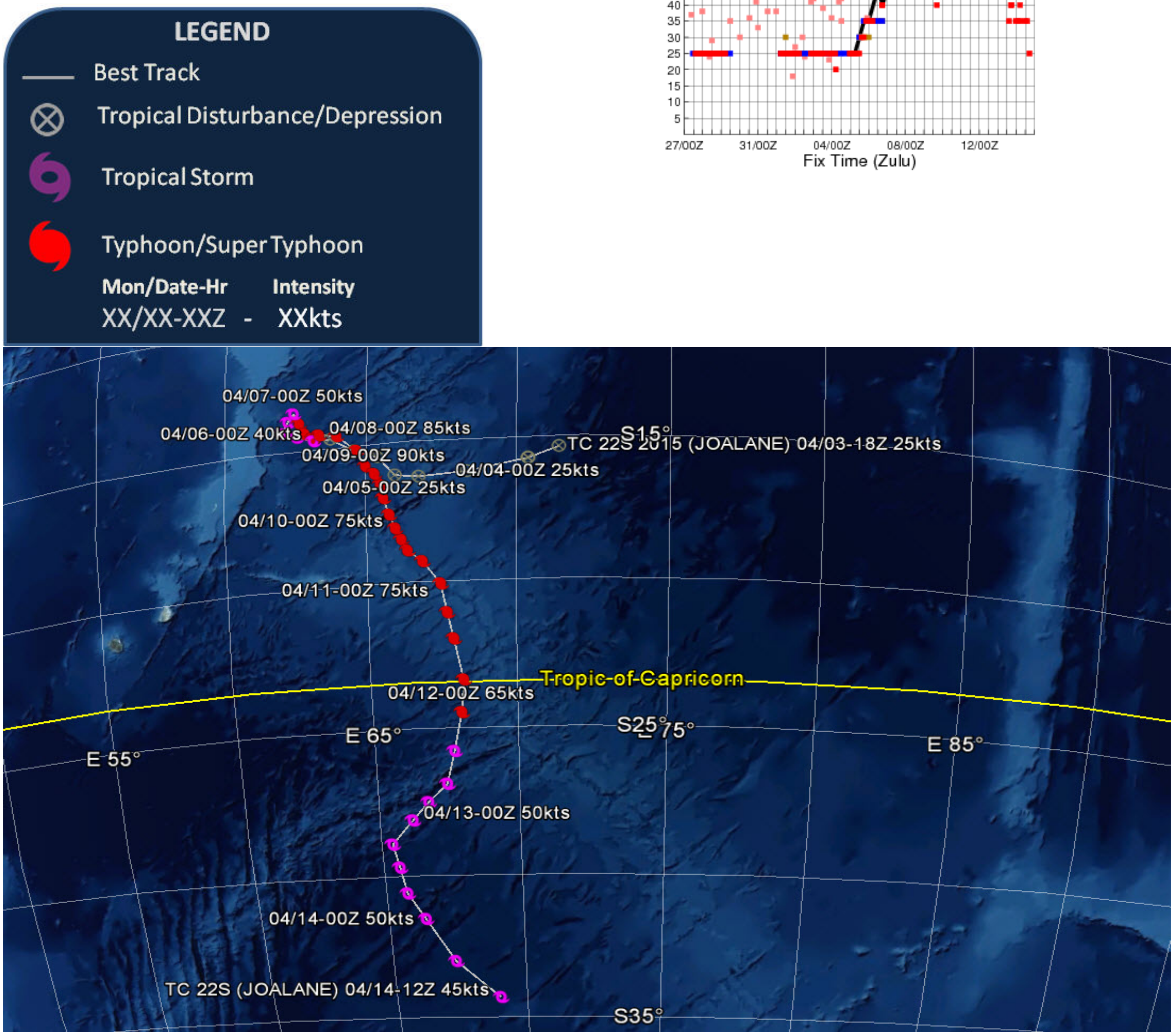




22S TROPICAL CYCLONE JOALANE

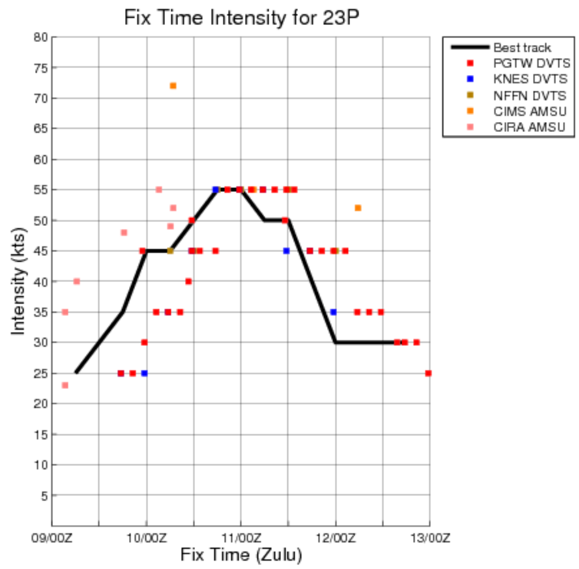
ISSUED LOW:	02 APR / 1800Z
ISSUED MED:	05 APR / 1800Z
FIRST TCFA:	05 APR / 2100Z
FIRST WARNING:	06 APR / 0000Z
LAST WARNING:	12 APR / 0600Z
MAX INTENSITY:	90
WARNINGS:	14

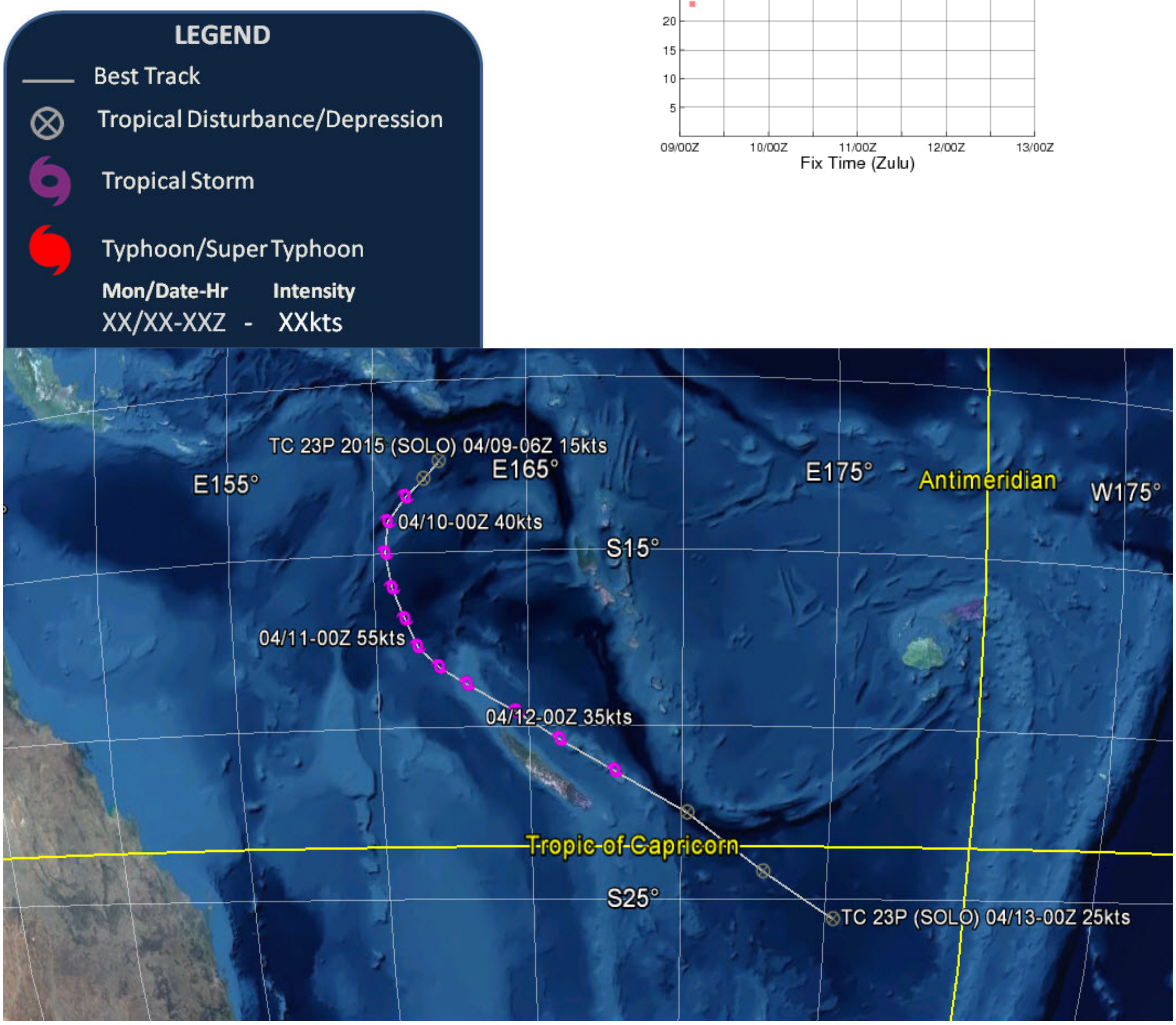




23P TROPICAL CYCLONE SOLO

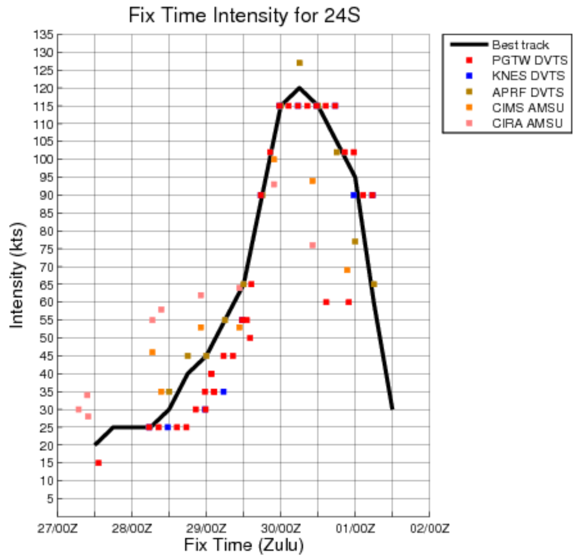
ISSUED LOW:	None
ISSUED MED:	None
FIRST TCFA:	09 APR / 1930Z
FIRST WARNING:	10 APR / 0000Z
LAST WARNING:	12 APR / 0000Z
MAX INTENSITY:	55
WARNINGS:	5

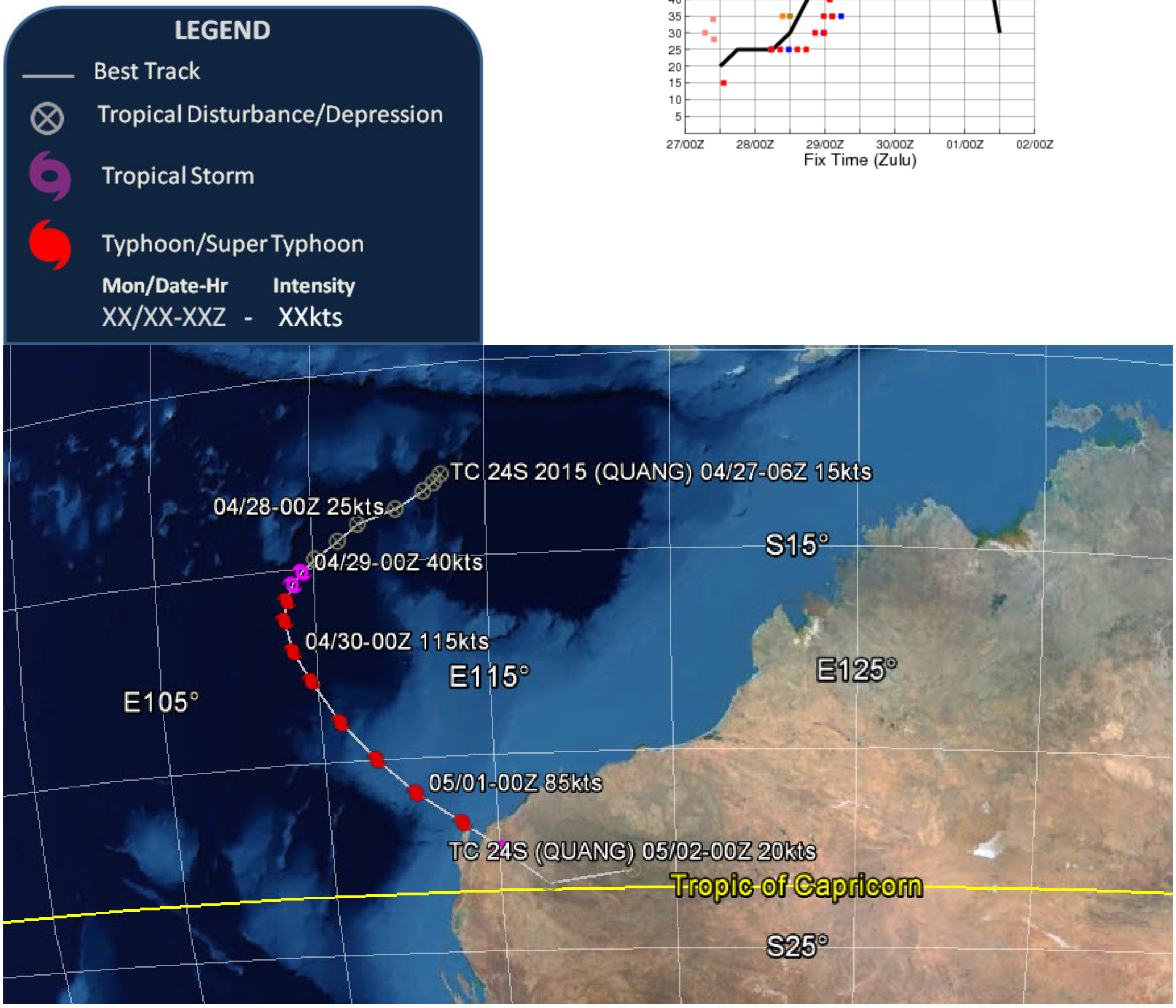




24S TROPICAL CYCLONE QUANG

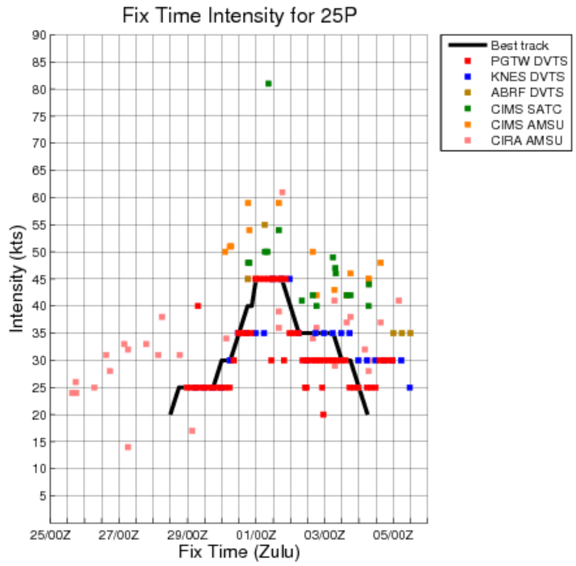
ISSUED LOW:	27 APR / 0930Z
ISSUED MED:	27 APR / 1800Z
FIRST TCFA:	28 APR / 0900Z
FIRST WARNING:	28 APR / 1800Z
LAST WARNING:	01 MAY / 1200Z
MAX INTENSITY:	120
WARNINGS:	10

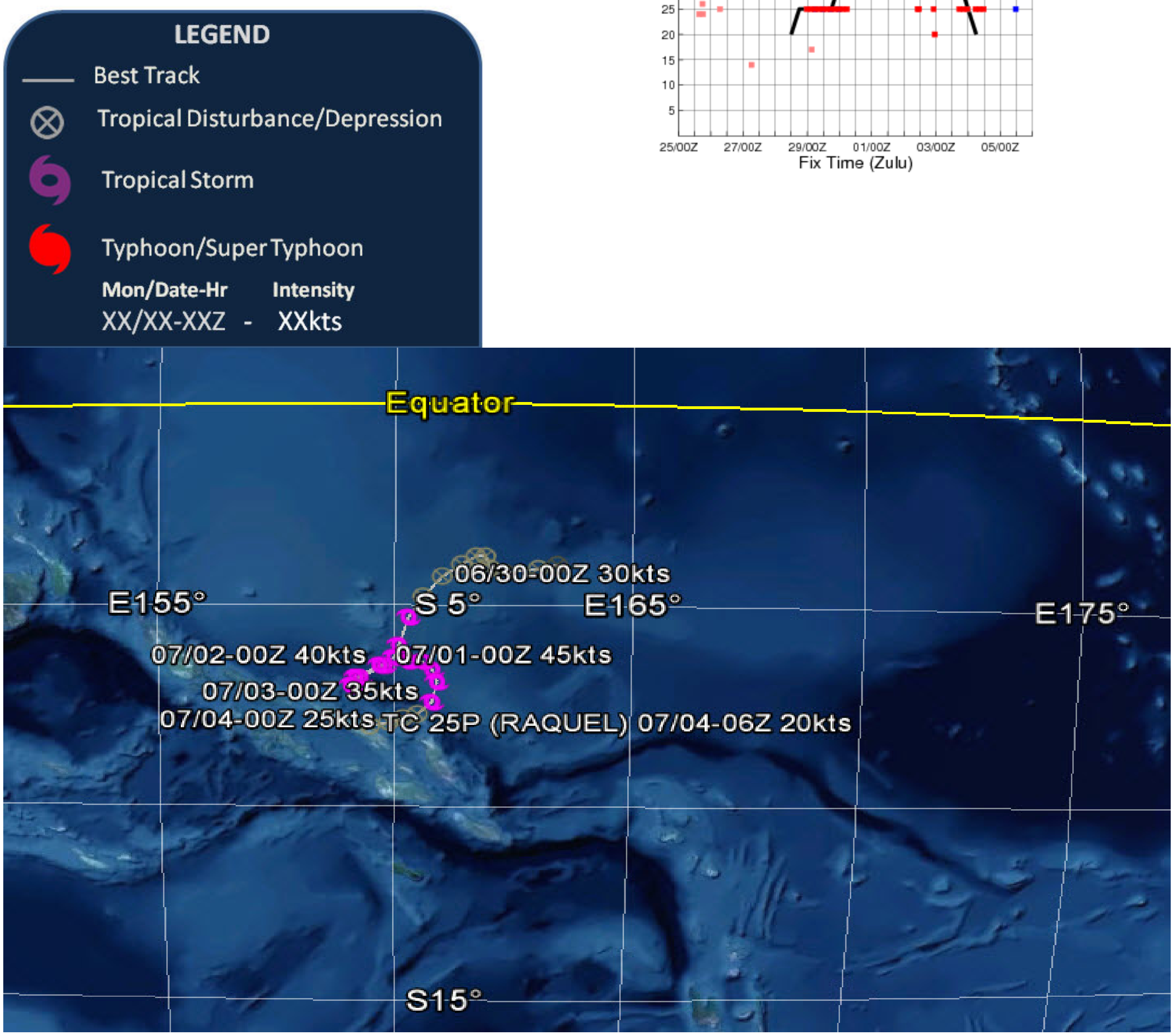




25P TROPICAL CYCLONE RAQUEL

ISSUED LOW:	28 JUN / 0600Z
ISSUED MED:	28 JUN / 1700Z
FIRST TCFA:	30 JUN / 0200Z
FIRST WARNING:	30 JUN / 1200Z
LAST WARNING:	04 JUL / 0000Z
MAX INTENSITY:	45
WARNINGS:	11





Chapter 4 Tropical Cyclone Fix Data

Section 1 Background

Meteorological satellite data continued to be the mainstay for the TC reconnaissance mission at JTWC. JTWC satellite analysts produced 12,208 position and intensity estimates. A total of 7852 of those 12,208 fixes were made using microwave imagery, amounting to just over 64 percent 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 supporting 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. The total count of DND fixes was 1801 for all basins, which account for approximately 15% of all fixes in 2015 (Note: An increase of 6% from 2014).

Section 2 Fix summary by basin

TABLE 4-1 WESTERN NORTH PACIFIC OCEAN FIX SUMMARY FOR 2015				
Tropical Cyclone	**Name**	**Visible/Infrared**	**Microwave/Scatterometry**	**Total**
01W	MEKKHALA	66	121	187
02W	HIGOS	49	124	173
03W	BAVI	86	218	304
04W	MAYSAK	100	197	297
05W	HAISHEN	41	89	130
06W	NOUL	99	170	269
07W	DOLPHIN	114	218	332
08W	KUJIRA	37	54	91
09W	CHAN-HOM	122	230	352
10W	LINFA	76	120	196
11W	NANGKA	134	252	386
12W	TWELVE	22	61	83
13W	SOUDELOR	101	163	264
14W	FOURTEEN	34	45	79
15W	MOLAVE	66	128	194
16W	GONI	101	186	287
17W	ATSANI	100	194	294
18W	ETAU	33	51	84
19W	VAMCO	13	12	25
20W	KROVANH	59	93	152
21W	DUJUAN	67	100	167
22W	MUJIGAE	45	66	111
23W	CHOI-WAN	59	54	113
24W	KOPPU	69	94	163
25W	CHAMPI	100	160	260
26W	TWENTYSIX	26	40	66
27W	IN-FA	82	130	212
28W	MELOR	47	67	114
29W	TWENTYNINE	40	36	76
DND		**107**	**128**	**235**
Totals		**2095**	**3601**	**5696**
Percentage of Total		**36.78%**	**63.22%**	**100**

TABLE 4-2 NORTH INDIAN OCEAN (BAY OF BENGAL/ARABIAN SEA) FIX SUMMARY FOR 2015				
Tropical Cyclone	**Name**	**Visible/Infrared**	**Microwave/ Scatterometry**	**Total**
01A	ASHOBAA	54	121	175
02B	KOMEN	41	41	82
03A	THREE	43	62	105
04A	CHAPALA	65	101	166
05A	MEGH	53	82	135
DND		**105**	**104**	**209**
Totals		**361**	**511**	**872**
Percentage of Total		**41.40%**	**58.60%**	**100**

TABLE 4-3 SOUTH PACIFIC & SOUTH INDIAN OCEAN FIX SUMMARY FOR 2015				
Tropical Cyclone	**Name**	**Visible/Infrared**	**Microwave/ Scatterometry**	**Total**
01S	ADJALI	88	202	290
02S	TWO	55	130	185
03S	BAKUNG	39	71	110
04S	KATE	91	223	314
05S	BANSI	78	149	227
06S	CHEDZA	49	90	139
07P	NIKO	36	78	114
08S	DIAMONDRA	43	102	145
09S	EUNICE	60	122	182
10P	OLA	39	82	121
11S	FUNDI	45	103	148
12P	LAM	49	66	115
13P	MARCIA	57	96	153
14S	GLENDA	65	151	216
15S	FIFTEEN	47	78	125
16S	HALIBA	34	108	142
17P	PAM	63	141	204
18P	NATHAN	131	242	373
19S	OLWYN	33	63	96
20P	REUBEN	35	72	107
21S	IKOLA	44	77	121
22S	JOALANE	124	234	358
23P	SOLO	27	54	81
24P	QUANG	33	55	88
25P	RAQUEL	51	78	129
DND		**484**	**873**	**1357**
Totals		**1900**	**3740**	**5640**
Percentage of Total		**33.69%**	**66.31%**	**100**

Section 1: Operational Priorities

The top operational priority of the Joint Typhoon Warning Center remains the sustained development and support of The Automated Tropical Cyclone Forecast System (ATCF). ATCF is the DOD's primary toolkit for analyzing and forecasting tropical cyclones (TCs), and is the principal software platform through which emerging research transitions into JTWC operations. Without ATCF, JTWC could not generate TC formation alerts or warnings. The systems tracks all TC activity and invest areas, automatically processes objective forecasting aids, produces TC formation alert, warning text and graphical products, and provides core capabilities for analyzing TCs and their environment. Additionally, ATCF provides JTWC Contingency of Operations Plan (COOP) backup capabilities to Fleet Weather Center (FWC)-Norfolk and analytic support to FWC-San Diego for tasks such as setting TCCOR, forecasting on-station wind speed, designating Optimum Track Ship Routing (OTSR) "MODSTORM" locations, and preparing diverts and advisories. JTWC upgraded to the latest version of ATCF (v5.7) in June 2015. This upgrade incorporated new data displays such as composite microwave imagery overlays and radar, and a host of other improvements to the efficiency of data entry, processing, and filtering. The v5.8 release scheduled for July, 2016 incorporates numerous new guidance products and visualizations to improve JTWC's analysis, forecast, and use of TC structure information, as discussed in Section 2.

JTWC has also prioritized integrating a state-of-the-art platform to facilitate visualization and evaluation of meteorological data. In 2015, the Commander, US Navy Meteorology Oceanography Command authorized acquisition of the National Weather Service (NWS) Advanced Weather Interactive Processing System (AWIPS-II) as the Navy's next-generation weather display and analysis system for JTWC, FWC-Norfolk and FWC-San Diego. JTWC technical services staff is facilitating incorporation of the AWIPS-II system into operations by developing standard operating procedures and site-specific applications. An initial operating capability (IOC) is scheduled in 2017. Although AWIPS II promises a generational leap in data synthesis capabilities, it cannot currently replicate ATCF functionality.

Section 2: Research and Development Priorities

The top 6 JTWC needs for R&D, as outlined in the 2015 annual report of the Office of the Federal Coordinator for Meteorological Services and Supporting Research – Tropical Cyclone Working Group are:

1. Deterministic and probabilistic forecast guidance for tropical cyclone intensity change, particularly the onset, duration, and magnitude of rapid intensification events and eyewall replacement cycles, as well as over-water rapid weakening events
2. Techniques to improve the utility and exploitation of microwave satellite, ocean surface vector winds (OSVW), and radar data for fixing tropical cyclones (e.g. develop a "Dvorak-like "technique using microwave imagery), or for diagnosing RI, ETT, ERC, etc.
3. Accurate deterministic and probabilistic guidance to improve TC track forecast skill, particularly with respect to identification and reduction of large error outliers, (e.g., accelerating recurvers

and stalling storms) and large direction errors (e.g., loops), and on specific forecast problems, including interactions between upper-level troughs and tropical cyclones, track forecasts near/over land--especially elevated terrain, and extratropical transition.

4. Enhancements to the operational environment that increase forecaster efficiency by expediting analysis, forecast, coordination, and/or communication activities. In particular, transitioning of successful guidance products to integrated operational forecast systems such as the ATCF or AWIPS.
5. Probabilistic guidance for the timing of TC genesis as well as forecast track, intensity and structure of pre-genesis tropical disturbances. Guidance should be given for both the short-range (0-48hours) and the medium-range (48-120 hours), and exhibit a high probability of detection and a low false alarm rate.
6. Techniques to diagnose and predict the formation of TCs via transition of non-classical disturbances, *e.g.* monsoon depressions, subtropicals, hybrids, etc., and to forecast track, intensity, and structure prior to TC transition.

Section 3: Technical Development Projects

JTWC personnel have collaborated on numerous efforts to evaluate promising R&D efforts and to transfer mature projects into operations.

1. TC Wind Structure

a. TC wind structure post-analysis QA/QC

JTWC limits quality control of final best data to position and intensity due to finite manpower resources and the lack of an "off-season" during which to perform the post-analysis. The absence of quality-controlled TC structure data (i.e., radius of 34-, 50-, and 64-knot winds) for the R&D community has restricted JTWC's capability to create new products that could improve analyses and forecasts of these important parameters. In 2015, NRL Monterrey funded an initial effort to post-analyze TC wind structure in the western North Pacific basin for 2014 and 2015. The fruits of this effort include the development of new techniques, highlighted below, which are designed to improve the accuracy of JTWC wind structure and to automate the lengthy process of recording these data. JTWC is seeking funding to continue post analysis of wind structure in the future and to extend this work to other basins.

b. Forecast Wind Radii Consensus (RVCN)

Sampson and Knaff (2015) evaluated the feasibility of applying a consensus of numerical model forecast output to predict tropical cyclone gale-force wind radii. The consensus technique, RVCN, is comprised of interpolated wind radii forecasts from four dynamical models: GFS, GFDL, HWRF, and ECMWF. Sampson and Knaff (2015) showed the wind radii consensus to be more skillful than individual members and more accurate than, and on-par with, the DRCL (climatology and persistence) method in the Atlantic and eastern North Pacific basins, respectively.

The RVCN method was incorporated into JTWC's ATCF system for evaluation in the western North Pacific, Indian Ocean, and southern hemisphere in 2015. Verification of the technique's accuracy in these basins is pending, but anecdotal evidence suggests that RVCN provides reasonable tropical cyclone wind field forecasts in these new basins as well. Evaluation will continue in 2016.

RVCN
AHNI
GHTI
HHFI
EMXI

Table 5-1. Primary objective aids comprising the experimental JTWC tropical cyclone wind radii (RVCN) consensus (as of Spring 2016).

c. Wind Radii Analysis Consensus (RCON)

Analyzed TC structure parameters (e.g. R34, R50, and R64) are critical numerical weather prediction inputs, and form the basis for subsequent forecast wind radii values used to generate the forecast error swath graphic as well as TCCOR setting guidance. Due to infrequent and/or incomplete scatterometer overpasses and the lack of in-situ observational data throughout the JTWC AOR, TC structure analysis has a high degree of uncertainty, with a well-known small bias for large TCs and frequent step function-like growth in the non-quality controlled best tracks. Sampson et al (manuscript in development) developed a consensus of equally weighted R34 estimates (AMSU, Dvorak wind radii (Knaff et al, 2016), 6-hour NWP forecasts, and agency scatterometry radii fixes). Preliminary evaluations indicate that the consensus verifies well against independent 2014 best-track values, while greatly reducing small bias and smoothing the growth curve. JTWC will begin real-time evaluation of the RCON in 2016.

d. Dynamically sized swath of potential gale force winds based on GPCE

TC forecast wind radii are used to compute the swath of potential 34 knot winds. Strahl et al (2016) discuss an ongoing effort to evaluate an ATCF v5.7 option that scales the swath by the ratio of Goerss Predicted Consensus Error (GPCE) to GPCE Climatology. Preliminary findings indicate the JTWC swath size is reduced in high certainty scenarios, as expected, thereby increasing potential operation area. However, in cases of extreme uncertainty, typically during recurvature, the swath size can become unrealistically large. JTWC is seeking funding to update the along-across track version of GPCE, i.e., GPCE-AX, which could alleviate this issue and render the dynamically sized swath feasible for future operational implementation.

2. Tropical cyclone intensity change

a. Intensity Consensus (S5YY & S5XX)

The S5YY intensity consensus was unchanged in 2015, while STIPS forecast members generated from the discontinued Weber and AFWA WRF model forecasts were removed from the S5XX consensus. Current members of each consensus technique are listed in table 5-2.

S5YY Western North Pacific intensity consensus	S5XX Indian Ocean / Southern Hemisphere intensity consensus

DSHN (SHIPS)	AVS5 (STIPS)
DSHA (SHIPS)	JGS5 (STIPS)
GFNI	NVS5 (STIPS)
COTI	UKS5 (STIPS)
CHII	GFNI
HWFI	COTI
RI30	CHII

Table 5-2. Primary objective aids comprising the operational JTWC tropical cyclone intensity (S5YY and S5XX) consensuses (as of Spring 2015).

b. Weighted Analog Intensity Technique – extension to 7 days

JTWC continued to evaluate 5-day intensity and intensity spread forecasts from the Weighted Analog Intensity Technique throughout 2015. Additionally, the technique's developers, Dr. Hsiao-Chung Tsai and Dr. Russell Elsberry, expanded the model to predict tropical cyclone intensity and intensity spread out to 7 days (Tsai and Elsberry 2015). Operational evaluation of the expanded 7-day analog technique, the first intensity forecast-specific prediction technique available for the 6 and 7-day forecast period, is planned for calendar year 2016.

3. Application of environmental satellite data

a. Evaluation of automated intensity fix estimates

JTWC Satellite Operations and Technical Services personnel completed a statistical analysis of subjective Dvorak intensity estimates generated by meteorological agencies and automated tropical cyclone intensity estimates provided by the National Environmental Satellite, Data, and Information Service (NESDIS), the Cooperative Institute for Meteorological Satellite Studies (CIMSS), and the Cooperative Institute for Research in the Atmosphere (CIRA). The study specifically focused on the subjective Dvorak, AMSU (Demuth et al. 2004; Herndon and Velden 2004), Advanced Dvorak (Olander and Velden 2007), and satellite consensus (Velden et al. 2006) techniques. Results and recommendations for real-time data application were provided to JTWC forecasters. Of particular note, automated satellite consensus (SATCON) estimates were confirmed to be approximately as accurate and reliable as heavily-referenced Dvorak intensity estimates. SATCON estimates are weighted averages of individual CIMSS AMSU, SSMIS, and ADT estimates. Based on the noted favorable performance, forecasters were advised to increase consideration of SATCON estimates as skillful independent data during the tropical cyclone intensity analysis process. SATCON data will also continue to be included on fix history decision support plots provided to JTWC's DoD customers and researchers for cyclones in tropical cyclone formation alert and warning status (figure 5-1).

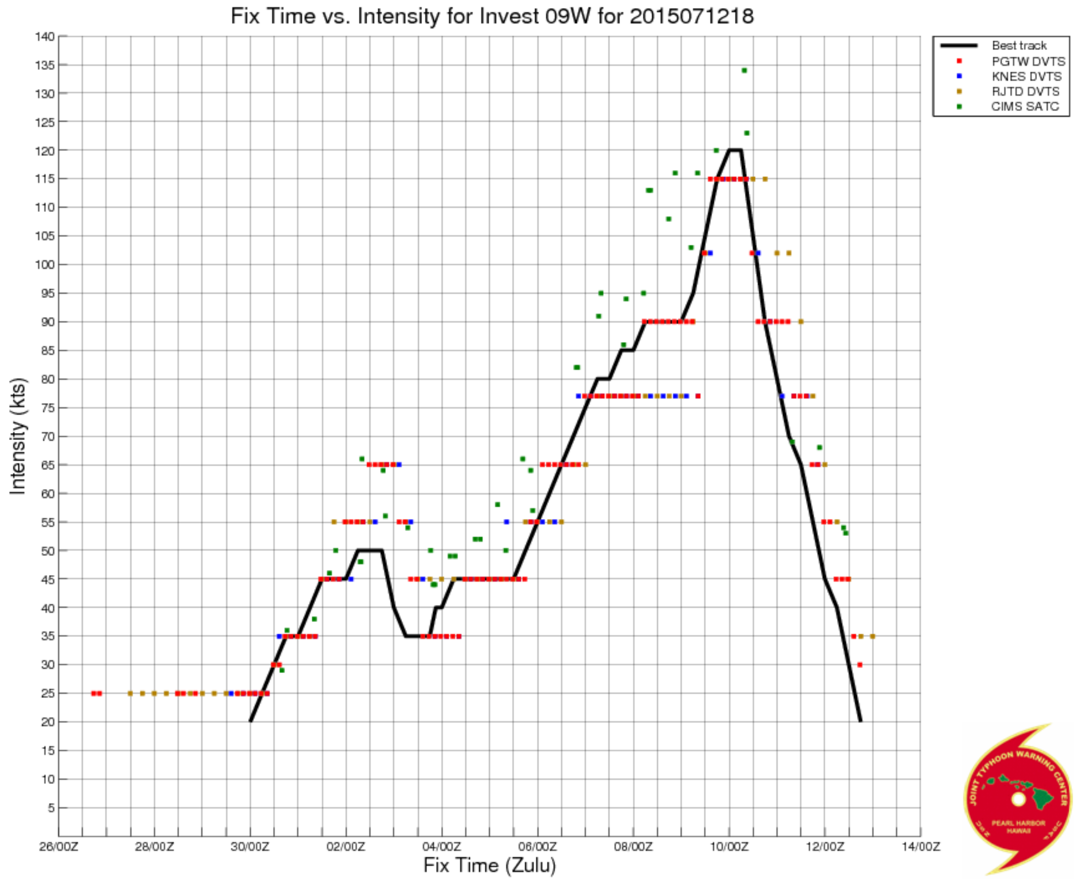


Figure 5-1. Sample fix history decision support graphic for TC 09W (2015). These graphics illustrate the best track intensity analysis along with the individual intensity estimates that are typically considered to be the primary basis for the analysis, currently agency subjective Dvorak (DVTS) and satellite consensus (SATC) estimates.

b. Himawari data integration

The Japan Meteorological Agency replaced MTSAT with Himawari as its primary operational geostationary meteorological satellite on 07 July 2015. Data from the new satellite are available to JTWC through the Mark-IVB and FMQ-17 satellite data processing systems and the Automated Tropical Cyclone Forecast system (ATCF). Satellite Analysts apply Himawari-8 imagery to generate Dvorak position and intensity fixes for tropical cyclones that occur in the western Pacific Ocean, north and south of the equator. Imagery from the Himawari-8 satellite are available at more frequent intervals (every ten minutes) than MTSAT imagery, which allows Satellite Analysts to closely track the evolution of transient atmospheric phenomena and to formulate intensity estimates from imagery recorded nearer to synoptic times. The JTWC Satellite Operations team is eager to apply additional features of the Himawari-8 dataset, including a broader spectrum of channels, to tropical cyclone analysis in the years ahead.

4. Improved and extended tropical cyclone forecast track guidance

a. CONW

The track consensus remained unchanged in 2015, with the members listed in table 5-3.

CONW	Model Type
NVGI	Global
EGRI	Global
JGSI	Global
GFNI	Mesoscale
AVNI	Global
ECMI	Global
COTI	Mesoscale
JENI	Ensemble
HWFI*	Mesoscale
AEMI	Ensemble

Table 5-3. Primary objective aids comprising the operational JTWC tropical cyclone track (CONW) consensus (as of Spring 2016).

In addition to the official consensus, JTWC reviews other model guidance, including the GFDL Ensemble, ECMWF-EPS, ACCESS-TC, TWRF, CMC, ARPEGE, MEPS, and the NRL Monterrey experimental COAMPS-TC (using GFS initial and boundary conditions). The UK Met Office global ensemble, MOGREPS, and the Air Force Global Air-Land Weather Exploitation Model (GALWEM) will be available to typhoon duty officers beginning in 2016.

* NCEP operationalized HWRF in all JTWC basins beginning in 2015.

b. Acquisition and evaluation of ECMWF ensemble

JTWC began processing the ECMWF ensemble mean vortex tracker for operational application during calendar year 2015. A post-season statistical evaluation indicated that average track forecast accuracy for the ensemble mean was on-par with the multi-model consensus average through the 120 hour forecast time and slightly more accurate than the consensus average at 144 and 168 hours. These results support incorporation of the ECMWF ensemble into the suite of prospective 7-day forecasting aids as well the CONW.

c. Evaluation of seven-day forecasting capability

JTWC continues to evaluate the feasibility of six- and seven-day TC track and intensity forecasting within the agency's primary forecast basins. An analysis of western North Pacific and southern hemisphere tropical cyclone multi-model consensus (CONW) track forecast errors over the past three seasons (figure 5-2) indicates generally consistent model performance through tau 144 (six days). The mean tau 144 forecast error of 266 nm is approximately equivalent to the mean tau 120 forecast error observed just a few years ago, suggesting that steady improvements in numerical forecast models have extended the period throughout which accurate TC track forecasting is possible. On the other hand, mean forecast error jumps to 367 nm at tau 168 and varies more significantly from year-to-year and basin-to-basin. More work is necessary to determine if model upgrades and incorporation of the ECMWF ensemble mean forecast track into operations, discussed earlier in this report, will reduce variability at the tau 168 in the years ahead. It is not yet possible to asses intensity forecast skill at 6 and 7 days due a lack of intensity forecast guidance, although a preliminary evaluation should be possible later this year as the 7-day Weighted Analog Intensity (WANI) technique is implemented on an experimental basis.

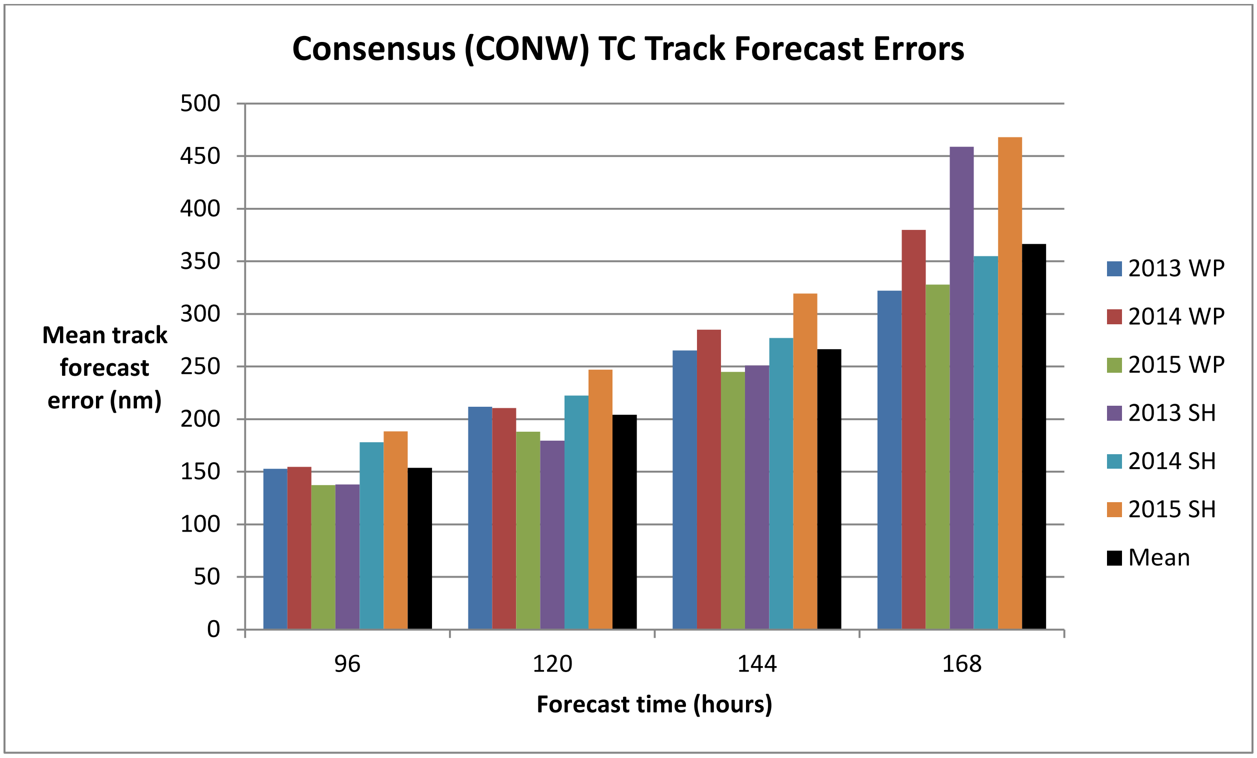


Figure 5-2. Mean CONW western North Pacific (WP) and southern hemisphere (SH) TC track forecast errors in nautical miles for the extended forecast period (96 to 168 hours) during the past three seasons.

5. Enhancements to the operational environment

a. Geospatial data display tool

JTWC Technical Services incorporated model analysis fields into a geospatial data interface developed with the Google Maps Javascript API. The interface enables expedient visual inspection of both hand-analyzed and model-analyzed surface and upper-tropospheric flow patterns. Additional datasets such as model forecast fields will be incorporated into the interface during the upcoming calendar year.

Section 4: Other Scientific Collaborations

1. Joint Hurricane Testbed

JTWC is collaborating with principal investigators of two 2015-2017 JHT funded projects

a. Passive Microwave Data Exploitation via the NRL Tropical Cyclone Webpage (R. Bankert, J. Cossuth, and K. Richardson (NRL-MRY))

The goal of this project is to improve the utility of the NRL TC webpage used by JTWC, NHC, CPHC, and other global TC forecast agencies and researchers, via the following efforts:

- Enhance the near-realtime 37 and 85/89/91 GHz H/V/PCT/color imagery products for all global TCs

- Populate an archive of historical passive microwave data since 1987. A standardized database of both digital data and image products will be generated and made available to the TC community to compliment the near-realtime data.
- A study and application of a more sophisticated parallax correction scheme will be created to provide increased confidence in the initialization of the TC center.
- Revised color tables will be revised to improve visualization of TCs.

b. Improvement and Implementation of the Probability-based Microwave Ring Rapid Intensification Index for NHC/JTWC Forecast Basins (H. Jiang (FIU) and K. Musgrave (CSU/CIRA))

The goals of this project include adding two additional 37 GHz predictors to the probability-based RI index, as well as implementing and tuning this product to all JTWC forecast basins

2. Hurricane Forecast Improvement Project (HFIP)

JTWC has significantly benefited from work performed under the auspices of the HFIP, particularly with respect to the significant improvements in data assimilation, numerical TC track and intensity forecasting, rapid intensification prediction, ensemble modeling, and tropical cyclogenesis forecasting. JTWC maintains ongoing collaborative efforts with HFIP modeling teams from COAMPS-TC, HWRF, and GFDL.

Section 5: Scientific and technical exchanges

Participating in national and international-level meetings and conducting technical exchanges with members of the scientific community are essential to the success of JTWC's strategic development efforts. A summary of JTWC's 2015 conference attendance and technical exchange meetings follows.

- Interdepartmental Hurricane Conference (Mar 2015).
- Naval Research Laboratory 6.2/6.4 Program Review (Mar 2015).
- Technical Exchange with NRL-MRY and Japan Meteorological Agency (Apr 2015)
- ESCAP/WMO Typhoon Committee 10th Integrated Workshop (Oct 2015).
- NCEP Production Suite Review (Dec 2015).

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Velden, C. S., D. C. Herndon, J. P. Kossin, J. D. Hawkins and M. DeMaria, 2006: Consensus estimates of tropical cyclone intensity using integrated multispectral (IR and MW) satellite observations. Preprints, 27th Conf. on Hurr. and Trop. Meteor., Monterey, CA, Amer. Meteor. Soc.

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 2015 season, and contrasts it with annual verification statistics from previous years.

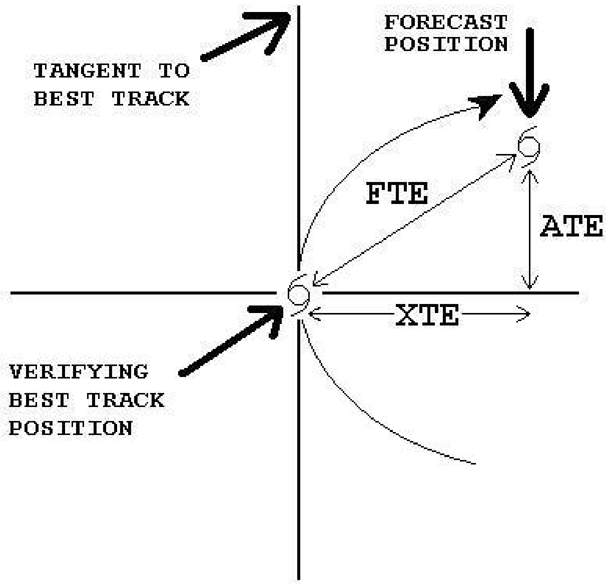

Figure 6-1. Definition of cross-track error (XTE), along track error (ATE), and forecast track error (FTE). In this example, the forecast position is ahead of and to the right of the verifying best track position. Therefore, the XTE is positive (to the right of track) and the ATE is positive (ahead of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

Section 1 Annual Forecast Verification

TABLE 6-1
MEAN FORECAST ERRORS (NM) FOR WESTERN NORTH PACIFIC
TROPICAL CYCLONES FROM 1959 - 2015

	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
2013	448	39	46	29	31	332	65	74	47	49	232	96	102	61	71	152	156	156	92	105	87	248	240	142	161
2014	406	49	49	29	34	362	81	82	48	56	258	119	123	71	85	200	164	167	102	111	146	218	227	147	146
2015	669	32	42	26	29	561	52	67	42	44	469	80	98	57	68	382	122	137	81	94	303	171	185	107	132
Avg (1978-2015)	573	82	92	52	64	462	160	171	97	119	363	250	255	144	180	207	153	211	115	152	151	207	282	152	202
5yr Avg	503	45	50	30	34	412	74	81	49	55	318	107	116	66	82	232	152	160	92	111	176	218	226	130	156

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

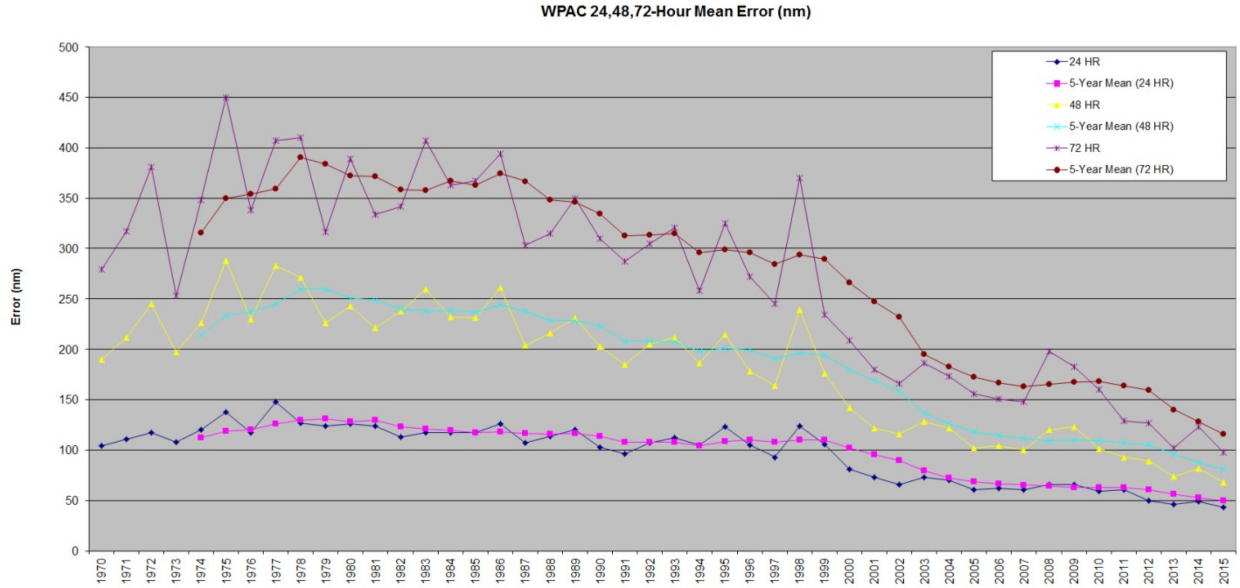

Figure 6-2. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 24, 48, and 72 hours.

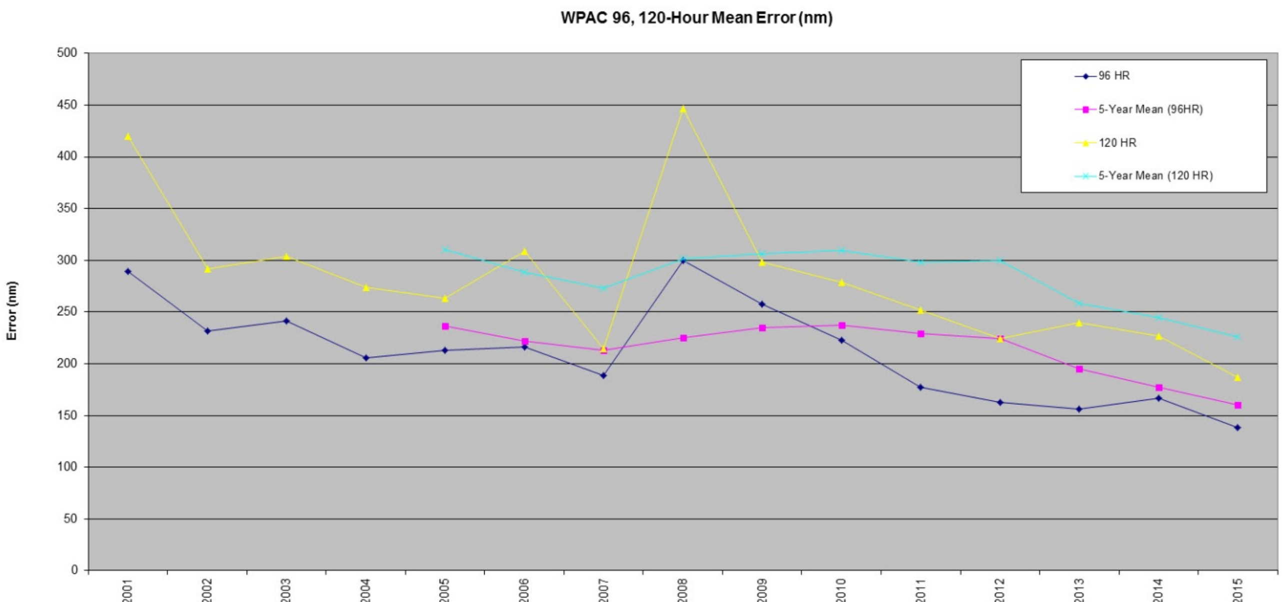

Figure 6-3. Graph of JTWC forecast errors and five year running mean errors for the western North Pacific at 96 and 120 hours.

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

TROPICAL CYCLONES FROM 1985-2015

	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								
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			
2013	99	49	27	37	75	80	37	66	52	102	61	69	32	138	68	109	17	207	104	167
2014	59	40	27	26	40	55	36	36	25	76	52	45	16	136	101	84	8	182	139	112
2015	62	38	22	27	44	75	49	49	31	115	74	76	19	156	104	108	7	209	126	159
Avg (1985-2015)	49	91	64	51	32	154	105	89	18	236	161	135	15	174	98	131	7	268	118	220
5Yr Avg	57	50	30	33	40	71	43	49	27	88	54	58	16	135	79	99	7	189	109	139

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

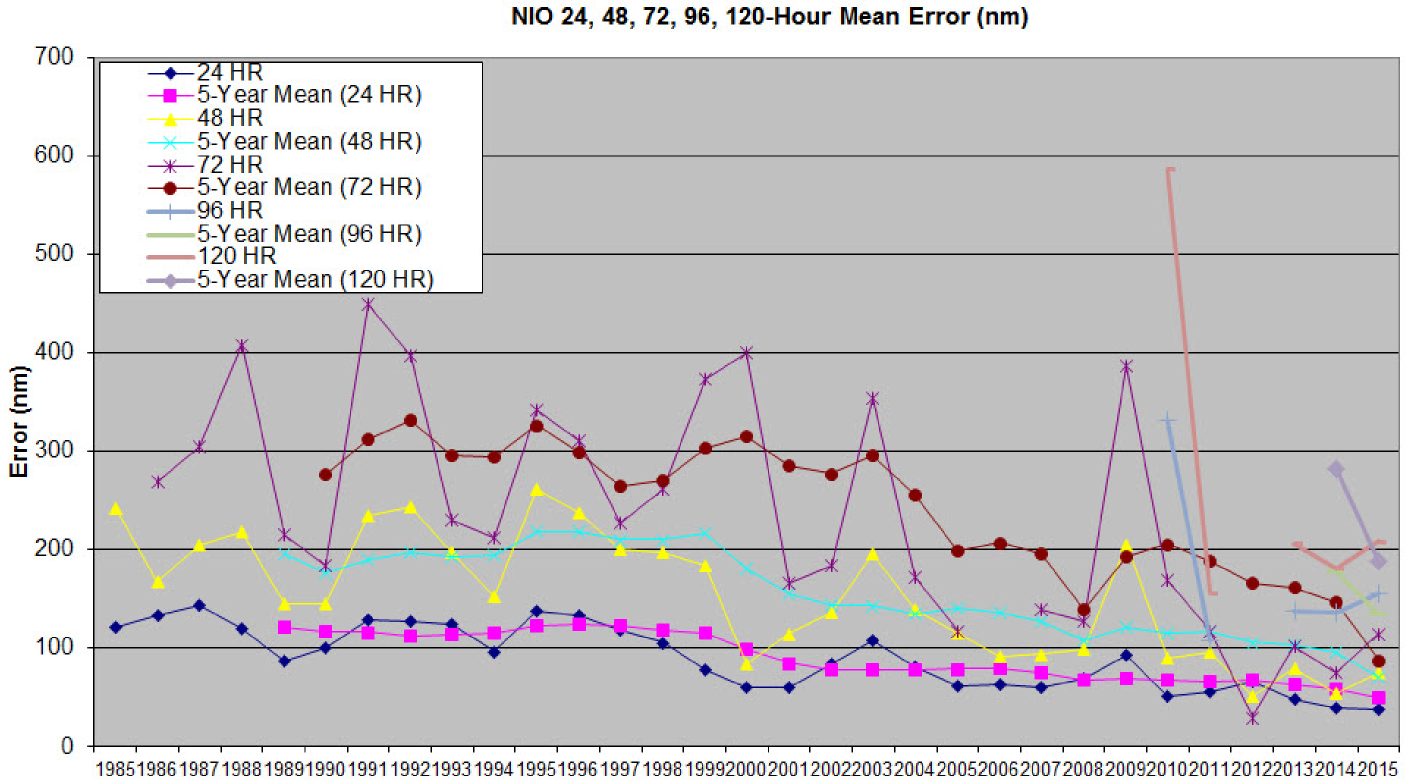

Figure 6-4. Graph of JTWC forecast errors and five year running mean errors for the north Indian Ocean at 24, 48, 72, 96, and 120 hours. (Note: No 96 HR, 120 HR data for 2012)

TABLE 6-3 MEAN FORECAST ERRORS (NM) FOR SOUTHERN HEMISPHERE TROPICAL CYCLONES 1985 - 2015																				
	24-Hour				48-Hour				72-Hour				96-Hour				120-Hour			
Year (Notes)	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error	Cases	Mean Error	Cross Track Mean Error	Along Track Mean Error
1985	257	134	79	92	193	236	132	169												
1986	227	129	77	86	171	262	164	169												
1987	138	145	90	94	101	280	138	153												
1988	99	146	83	98	48	290	144	246												
1989	242	124	73	84	186	240	136	166												
1990	228	143	74	105	177	263	152	178												
1991	231	115	69	75	185	220	129	152												
1992	230	124	64	91	208	240	129	177												
1993	225	102	57	74	176	199	114	142												
1994	345	115	68	77	282	224	134	147												
1995	222	108	55	82	175	198	108	144	53	291	190	169								
1996	298	125	67	90	237	240	129	174	46	277	133	221								
1997	499	109	72	82	442	210	135	163	150	288	175	248								
1998	305	111	52	85	245	219	108	169	81	349	171	261								
1999	322	113	64	80	245	226	132	159	59	286	164	198								
2000	313	72	45	47	245	135	86	84	58	180	139	94								
2001	147	84	44	61	113	148	86	105	11	248	197	133								
2002	200	82	43	60	146	133	75	93	5	102	41	91								
2003	279	74	37	57	221	127	68	90	37	123	54	99								
2004	277	77	45	52	233	142	89	92	47	210	102	162								
2005	214	70	44	44	170	116	77	72	41	199	117	136								
2006	191	65	37	46	140	116	69	79	32	201	101	151								
2007	186	74.9	41	52	131	147	80	105	3	173	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								
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
2013	216	49	28	34	175	80	45	54	140	114	63	78	103	138	72	101	69	166	76	131
2014	180	53	28	39	132	90	47	65	95	133	64	102	69	162	83	122	50	198	98	147
2015	185	51	29	35	137	87	48	60	88	123	75	76	55	188	121	108	37	287	201	147
Avg (1985-2015)	234	94	53	66	183	174	99	121	63	186	109	129	77	178	101	124	53	246	148	160
5Yr Avg	186	53	30	37	143	87	49	61	106	126	67	90	74	173	97	120	50	239	146	154

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

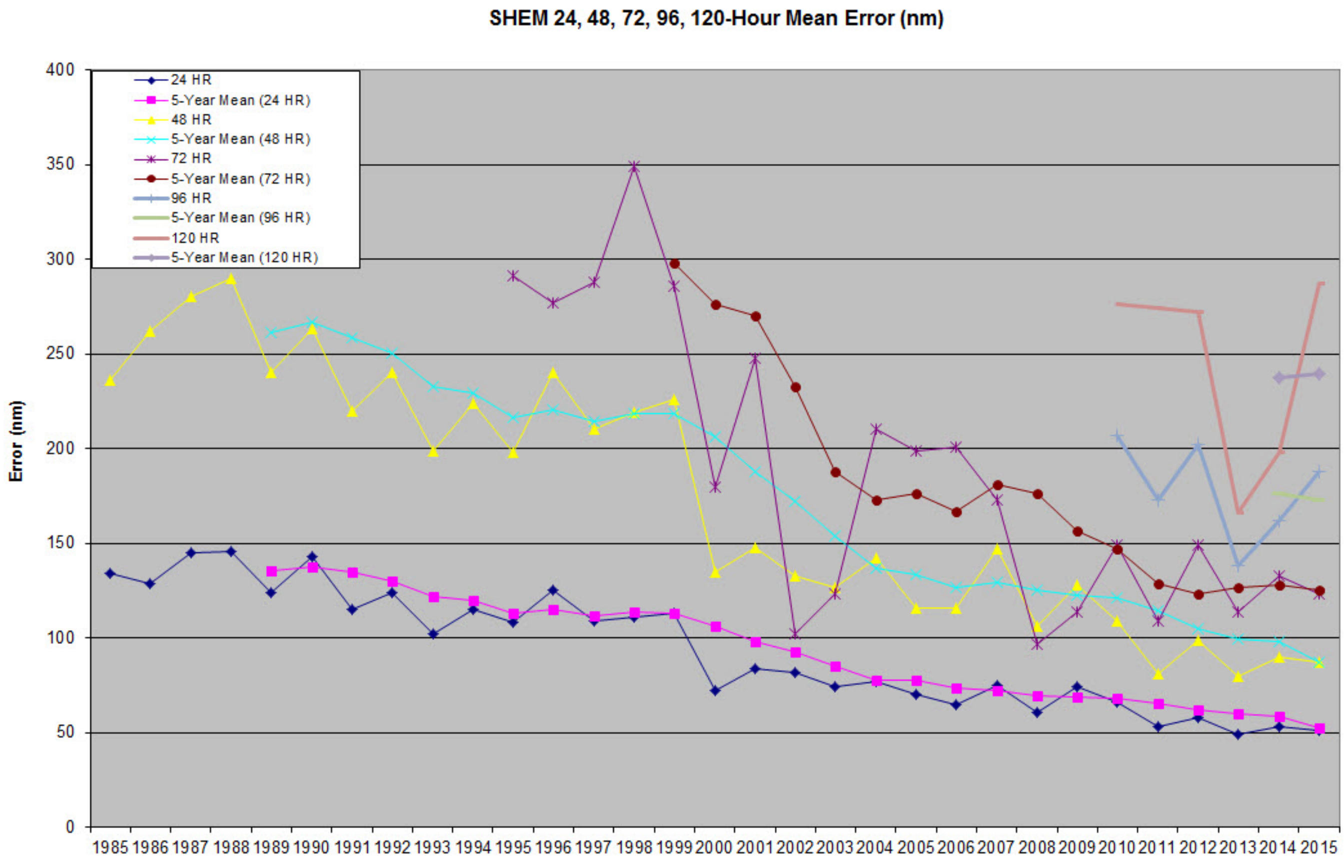

Figure 6-5. Graph of JTWC forecast errors for the Southern Hemisphere at 24, 48, 72, 96, and 120 hours.

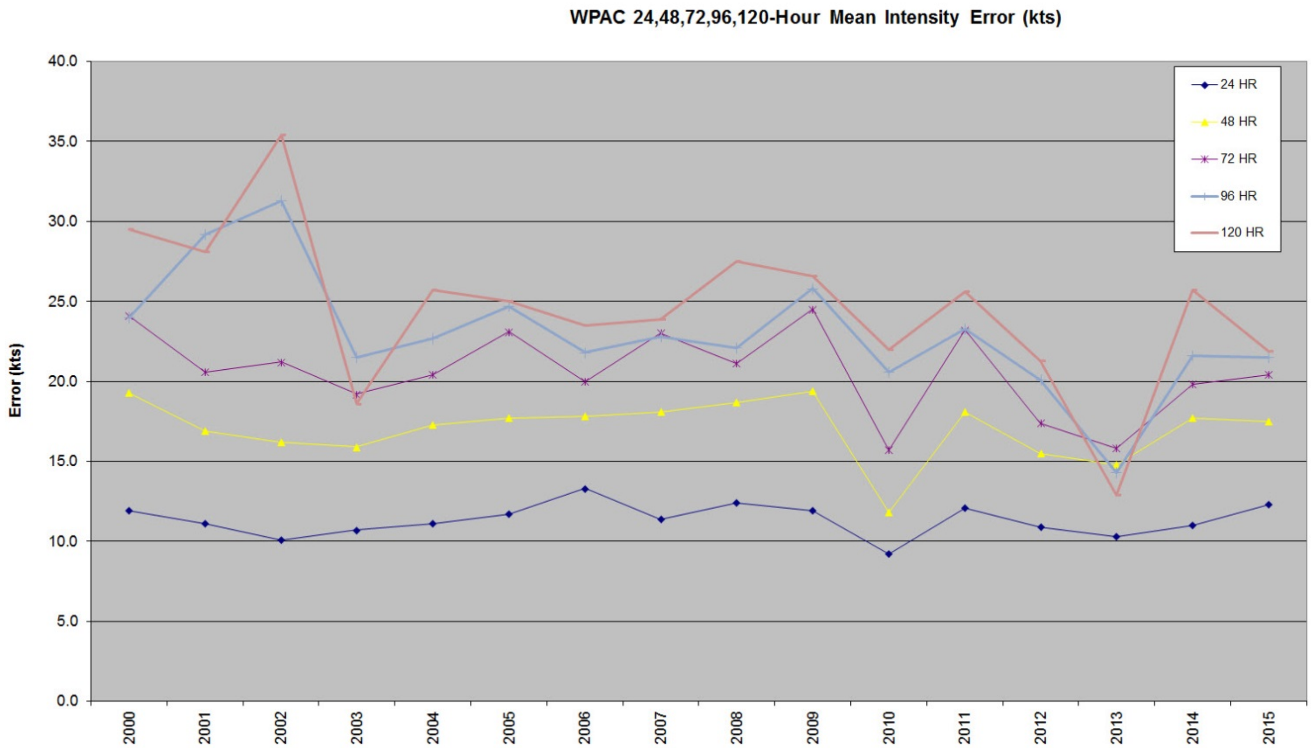

Figure 6-6. Graph of JTWC intensity forecast errors for the western North Pacific at 24, 48, 72, 96, and 120 hours.

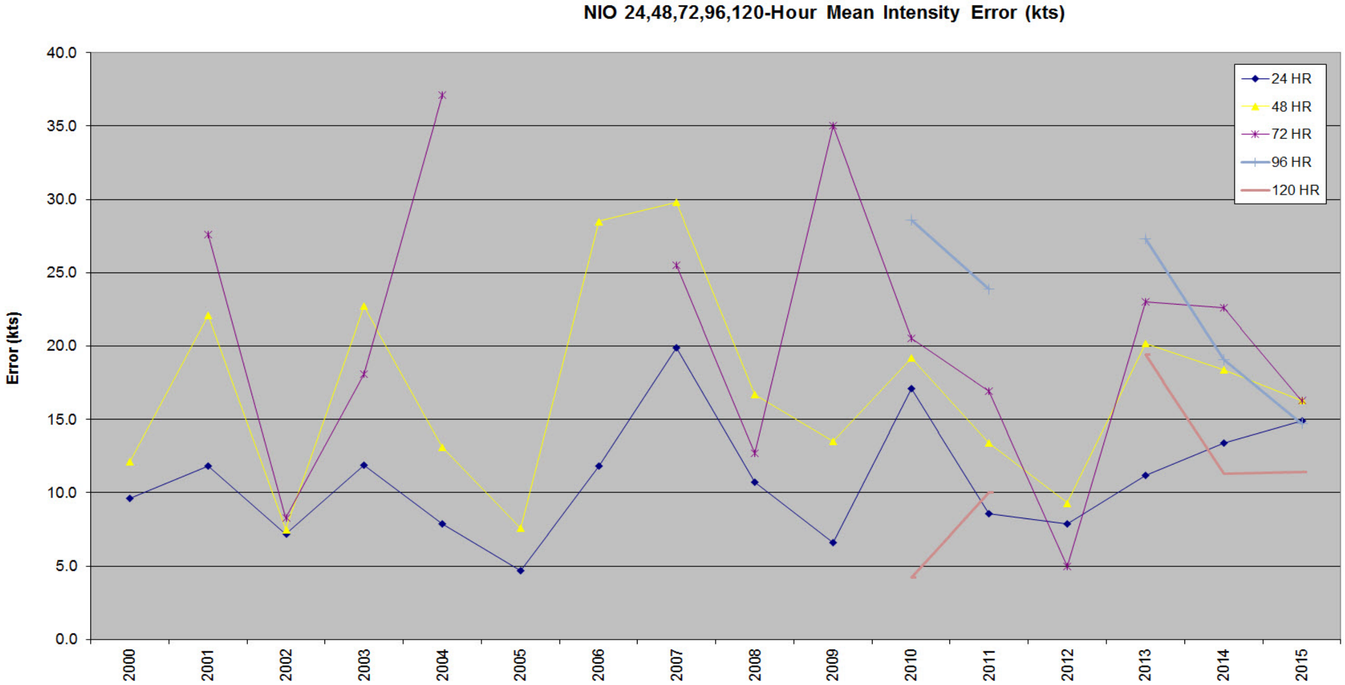

Figure 6-7. Graph of JTWC intensity forecast errors for the North Indian Ocean at 24, 48, 72, 96, and 120 hours. (Note: No 96 HR, 120 HR data for 2012)

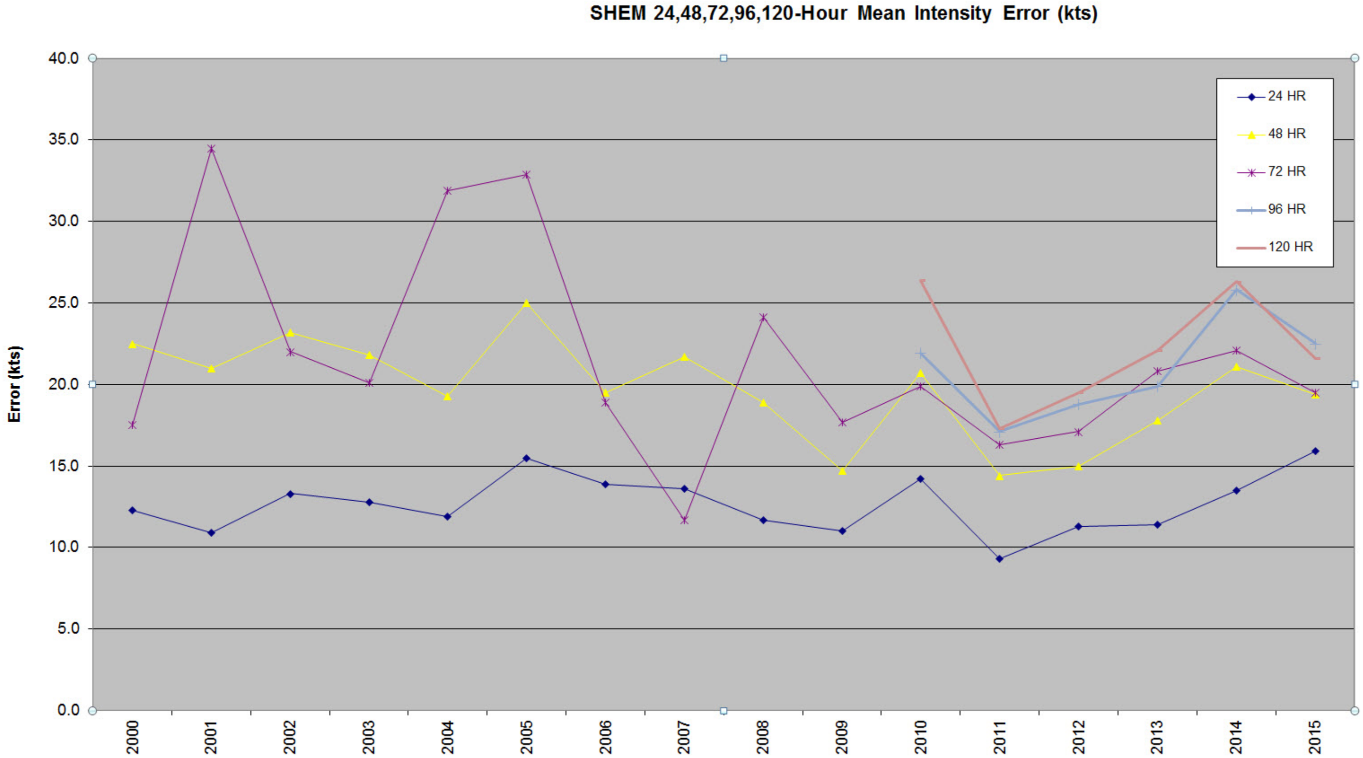

Figure 6-8. Graph of JTWC intensity forecast errors for the Southern Hemisphere at 24, 48, 72, 96, and 120 hours.