Third Joint Session
Panel on Tropical Cyclones | Typhoon Committee
(42nd Session of PTC and 47th Session of TC)
9- 13 February 2015
ESCAP - UN Conference Center
Bangkok, Thailand

FOR PARTICIPANTS ONLY
TCS/PTC-TC_3JS/4.1
28 February 2015

ENGLISH ONLY

REPORT ON AMENDMENTS TO THE TYPHOON COMMITTEE OPERATIONAL MANUAL

(submitted by the Rapporteur)

Summary and Purpose of Document:

This document presents draft amendments to the Typhoon Committee Operational Manual - Meteorological Component (TOM) proposed by the Members.

Action Proposed

The Committee is invited to:
Review and approve the proposed amendments to the TOM attached as Annex 1 with necessary modifications.

1. The Typhoon Committee Operational Manual - Meteorological Component (TOM) has been reviewed and updated every year since its first issue in 1987. The 2014 edition was completed and posted on the WMO website in March 2014 in accordance with the approval of amendments to the 2013 edition by the 46th session of the Typhoon Committee (10 to 13 February 2014 Bangkok, Thailand).

2. At the 46th session, the Committee decided that the rapporteur of the Japan Meteorological Agency (JMA) continue arrangements for updating the TOM. In this connection, on 20 August 2014, the rapporteur, Mr Tsukasa Fujita, Head of the JMA Tokyo Typhoon Center invited the focal points of the meteorological component of the Members to provide proposals for updates to the TOM.

3. As of the end of January 2015, proposals for updates to the TOM had been submitted by the five focal points of China, Hong Kong, Macao, Japan and Thailand.

4. Proposed amendments to the TOM are attached as Annex 1 and given below are the major points of the amendments:

- Modification of the definition of terms used for regional exchange (Chapter 1)
- Update of information on technical specifications of the JMA's next generation satellite Himawari-8 (Chapter 2)
- Modification and update of information on Aircraft observations (Chapter 2)
- Update of information on telecommunication network (Chapter 5)
- Update of information on technical specifications of radars of typhoon committee members (Appendix 2-D)
- Update of information on JMA's tropical cyclone prediction models (Appendix 3-A)
- Update of information on HKO's operational procedures of TC satellite analysis and Non-Hydrostatic Model (Appendix 3-C, 3-E)

Annex 1

Draft Amendments to
the Typhoon Committee Operational Manual – Meteorological Component (TOM)
proposed by the Members

Page	Line	Proposed Amendment	Comments
Chapter 1.2			
2	footnote	** Classifications internally used by Members are shown in Appendix 1-~~B~~ A.	Correction of erroneous description. Appendix 1-A and 1-B are exchanged.
Chapter 1.3			
4	L8	Gale force~~ wind~~: Average ~~surface~~ wind speed in the range of 34 knots (17.2 m/s, 62 km/h) to 47 knots (24.4 m/s, 88 km/h), or wind force 8 or 9 in the Beaufort scale.	"Average wind speed" defined in Section 1.3 is used. Different speed units, meters per second (m/s), kilometers per hour (km/h), and Beaufort scale are added.
4	L9	Gale warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of gale force wind ~~average wind speed in the range of 34 to 47 knots, or wind force 8 or 9 in the Beaufort scale~~.	The description is simplified with the terminology, "gale force" defined in Chapter 1.3.
4	L20	Severe tropical storm: A tropical cyclone with the maximum sustained winds at storm force ~~of 48 knots (24.5 m/s, 89 km/h) to 63 knots (32.6 m/s, 117 km/h)~~ near the centre.	Same as the above comment except for "storm force".
4	L24	Storm force~~ wind~~: Average ~~surface~~ wind speed of 48 knots (24.5 m/s, 89 km/h) to 63 knots (32.6 m/s, 117 km/h) or wind force 10 or 11 in the Beaufort scale.	Same as the comment for Line 8 on Page 4.
4	L33	Storm warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of storm force wind~~ average wind speeds in the range of 48 to 63 knots or wind force 10 or 11 in the Beaufort scale~~.	The description is simplified using the defined terminology, "storm force".
5	L24	Tropical storm: A tropical cyclone with the maximum sustained winds at gale force~~ of 34 knots (17.2 m/s, 62 km/h) to 47 knots (24.4 m/s, 88 km/h)~~ near the centre.	Same as the above comment except for "gale force".

5	L30	Typhoon: A tropical cyclone with the maximum sustained winds at typhoon force~~ of 64 knots (32.7 m/s, 118 km/h) or more~~ near the centre.	Same as the above comment except for “typhoon force”.
5	L32	Typhoon force~~ wind~~: Average ~~surface ~~wind speed of 64 knots (32.7 m/s, 118 km/h) or more, or wind force 12 in the Beaufort scale.	Same as the comment for Line 8 on Page 4.
5	L33	Typhoon warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of typhoon force wind~~ the mean wind speed of 64 knots (32.7 m/s, 118 km/h) or higher, or wind force 12 in the Beaufort scale~~ .	Same as the comment for L30 on Page 5.
Chapter 2.2			
9	L11	Marine meteorological observations are made by the Voluntary Observing Ships which are recruited by the Members in accordance with the WMO Voluntary Observing Ship's Scheme. These are generally carried out every six hours and transmitted over the GTS. In addition, marine meteorological observations are reported hourly by on-board automatic weather stations on some of the Voluntary Observing Ships.	The description of Voluntary Observing Ships with automatic weather stations are added.
Chapter 2.4			
10	L8	JMA successfully ~~plans to ~~launched Himawari-8 on 7 October ~~in ~~2014 and plans to start its operation in mid-2015 to replace the current satellite, MTSAT-2. The satellite will feature a new imager with 16 bands as opposed to the 5 bands of the MTSAT series. Full-disk imagery will be obtained every 10 minutes, and rapid scanning at 2.5-minute intervals will be conducted over several regions, one of which will be for targeted observation of tropical cyclones. Its horizontal resolution will also be double that of the MTSAT series. Himawari-8 will not carry a device for direct dissemination system. Instead, JMA will distribute all imagery derived from the satellite	Himawari-8 was successfully launched on 7 October 2014. The information on Himawari-8 is updated.

		to National Meteorological and Hydrological Services (NMHSs) via an Internet cloud service. The Agency also plans to start a HimawariCast service involving the dissemination of primary sets of images for operational meteorological services via a communication satellite. Its current online imagery distribution services (WIS Portal (GISC-Tokyo) and the JMA Data Dissemination System (JDDS)) will be continued ~~imagery from Himawari-8 will be available via the Internet. The Agency will also disseminate a primary set of imagery for operational meteorological services via a commercial telecommunication satellite, and tentatively plans to begin this service in 2015 in parallel with the direct dissemination of imagery from MTSAT-2 via MTSAT-1R which will be terminated after the successful transition to Himawari-8~~.	
10	L15	Further information on Himawari-8 and -9 is available at the website of Meteorological Satellite Center of JMA (http://www.data.jma~~mscweb.kishou~~.go.jp/mscweb/en/himawari89/).	URL is changed.
10	L18	SAREP reports (Part A) are disseminated eight times a day in the following cases from the RSMC Tokyo - Typhoon Center to Typhoon Committee Members through the GTS under the heading of IUCC10 RJTD in the BUFR code (FM 94): (i) when a tropical cyclone of TS intensity or higher is located in the responsible area of the RSMC Tokyo - Typhoon Center; (ii) when a tropical depression existing in the responsible area is forecasted to have an intensity of TS or higher within 24 hours; or (iii) when an area of wind speed of 34 knots or higher caused	The description of SAREP reports issued by HKO is added.

		by a tropical cyclone is forecasted to be in the responsible area within 24 hours. SAREP reports are also issued eight times a day by Hong Kong, China to other meteorological centres through the GTS under the heading of IUCC01 VHHH in the BUFR code (FM 94) when a tropical cyclone is located within 10N to 30N and 105E to 125E.	
Chapter 2.5			
10	L28	Reports from aircraft in flight (AIREPs) in ~~Asia and neighbouring areas~~ the Typhoon Committee Members areas are collected and exchanged according to the Regional OPMET Bulletin Exchange (ROBEX) scheme*. ~~AIREPs are collected by the centres in the Typhoon Committee Members areas and transmitted to the ROBEX centres at Bangkok, Beijing, Hong Kong, Kuala Lumpur and Tokyo.~~	There are many ROBEX centers other than Bangkok, Beijing, Hong Kong, Kuala Lumpur and Tokyo. Also, as ROBEX scheme is mentioned, it is not necessary to explain the detailed data distribution system.
10	L35	AMDAR (Aircraft Meteorological Data Relay) reports are collected by the NHMSs involved in respective AMDAR Programmes and relayed via the GTS to the centre at Tokyo.	The description of AMDAR data relay is modified.
10	L37	All reports will be disseminated in real-time to the RSMC Tokyo - Typhoon Center and to other Members through GTS and AFTN circuits. HKO conducts reconnaissance flights for selected tropical cyclones over the northern part of the South China Sea. Regional data exchange is being arranged.	The description of reconnaissance flights for selected tropical cyclones which will be conducted by HKO is added.
10	footnote	*ICAO ROBEX scheme is the method to exchange operational aeronautical meteorological (OPMET) information. The scheme consists of ROBEX collecting and disseminating centres (ROBEX centres), regional OPMET data banks (RODB), and interregional OPMET gateways (IROG) .	The explanation of ROBEX scheme is added.

Chapter 3.1			
13	Table3.1	To be replaced by Annex 1-1	Surface weather analysis / forecast and typhoon forecast charts are added.
14	Figure 3.1	To be replaced by Annex 1-2	
Chapter 4.5			
20	L29	The designated Tropical Cyclone Advisory Centre (TCAC) Tokyo shall monitor the development of tropical cyclones in its area of responsibility, as determined in the ICAO Air Navigation Plan - Asia and Pacific Region (Doc 9673) and issue advisory information concerning the position of the cyclone centre, its direction and speed of movement, central pressure and maximum surface wind near the centre. The tropical cyclone advisories shall be disseminated to the MWOs by TCAC Tokyo in its area of responsibility. In addition, the tropical cyclone advisories shall be disseminated to other TCACs, whose areas of responsibility may be affected, to the World Area Forecast Centres (WAFC) London and Washington, and international OPMET data banks~~, and centres operating the ICAO satellite distribution systems (SADIS and ISCS)~~.	ISCS is no longer in operation, and SADIS is operated by WAFC London. There is no need to mention satellite distribution system here.
Chapter 5.4			
23-24	Table 5.1	To be replaced by Annex 1-3	
Appendix 1-A			
		To be replaced by Annex 1-4.	To be replaced by Appendix 1-B. Correction of description.
Appendix 1-B			
		To be replaced by Appendix 1-A.	Correction of erroneous description
Appendix 2-D			
4-8		To be replaced by Annex 1-5	New Doppler radar systems have been installed at three radar sites. Correction of description.
Appendix 2-E			
1		To be replaced by Annex 1-6	MDUS、SDUS services will terminate in November 2015. URL is changed.
4	L10	Website: URL: http://www.data.jma~~mscweb.kishou~~.go.jp/mscweb/en/operation/~~ind~~	URL is changed.

		~~ex.htm~~	
Appendix 2-F			
1	footnote	*Hong Kong, China receives AQUA (MODIS), ~~FY-1 (CHRPT)~~ NPP(CrIs, VIIRS, ATMS), FY-2 (S-VISSR), and TERRA (MODIS).	Information on the satellites from which Hong Kong and Macao receive data is updated.
2	footnote	* Macao, China receives ~~AQUA (MODIS), FY-1D (CHRPT), FY-2 (S-VISSR) and TERRA (MODIS)~~FY-2D, FY-2E (S-VISSR) Stretched VISSR.	
Appendix 3-A			
		To be replaced by Annex 1-7	JMA updated tropical cyclone prediction models in March 2014.
Appendix 3-B			
1	Table	To be replaced by Annex 1-8	Information on CMA's Typhoon Track Prediction model is updated.
5	Table	To be replaced by Annex 1-8	Some of the information is deleted.
7		Delete	
Appendix 3-C			
11	L26	1.6.5 Very-short range prediction of rainfall by radar observation Radar is used to detect and track tropical cyclones ~~for detecting and tracking the typhoon~~ and severe storms such as thunderstorms. Motion of rain echoes over successive radar scans, for example, every 6 minutes can be retrieved using methods such as maximum correlation and optical flow constraint. Rainfall amount can be estimated based on the Z-R relationship, which is the relationship between radar rain reflectivity and the rainfall amount. Such relationship can be determined based on historical data or dynamically calibrated using real-time radar data and rain-gauge data. This radar-based nowcasting method is useful provided that the rain intensity, the movement direction and the speed of rain echoes in a short span of time are largely constant. Accumulated rainfall over a forecast region around 6 to 9 hours ahead can be obtained by extrapolating the radar echoes along the retrieved motion	The description of radar observation is modified in more detail.

		field and converting their intensity into rainfall amount through the Z-R relationship. ~~From the relation between the echo intensity and the precipitation, the amount of rainfall is estimated. The method is used provided that the intensity change, the movement direction and the speed of echoes in a short span of time are estimated over the experimental area. Rainfall in a short span of time is watched by the time-sequential radar observation.~~	
Annex 1		To be replaced by Annex 1-9	Information on TC satellite analysis procedure at HKO is updated.
Annex 4		To be replaced by Annex 1-10	
Appendix 3-E			
		To be replaced by Annex 1-11	Information on HKO NHM is updated.
Appendix 4-B			
2	title	WEATHER FORECAST AREAS (~~DALIAN~~ TIANJIN)	Correction of description.
5	note	NOTE: The pecked lines enclose the area for which the Hong Kong Observatory issues warnings of tropical cyclones.	Correction of erroneous description.
Appendix 4-C			
	Table	To be updated as shown in Annex 1-12	Correction of description.
Appendix 5-A			
1		To be updated as shown in Annex 1-13	Information of China and Hong Kong is updated.
Appendix 5-C			
1	title	COLLECTION AND DISTRI~~I~~BUTION OF INFORMATION RELATED TO TROPICAL CYCLONES	Correction of erroneous description.
2-3		To be replaced by Annex 1-14	
Appendix 5-D			
1		To be replaced by Annex 1-15	The description of SAREP reports issued by HKO is added.

Table 3.1 Chart-form products provided by RSMC Tokyo - Typhoon Center for regional purposes

~~Model~~	Area	Contents and Level	Forecast hours	Initial time	Availability
~~Global Analysis/Forecast Models~~	A' (Far East)	500hPa (Z, ζ)	Analysis	00, 12UTC	GTS
			24, 36	00, 12UTC	GTS, JMH
		500hPa (T), 700hPa (D)	24, 36	00, 12UTC	GTS, JMH
		700hPa (ω), 850hPa (T, A)	Analysis	00, 12UTC	GTS
			24, 36	00, 12UTC	GTS, JMH
		Surface (P, R, A)	24, 36	00, 12UTC	GTS, JMH
	C (East Asia)	300hPa (Z, T, W, A)	Analysis	00UTC	GTS
		500hPa (Z, T, A)	Analysis	00, 12UTC	GTS, JMH
		500hPa (Z, ζ)	48, 72	00, 12UTC	GTS
		700hPa (Z, T, D, A)	Analysis	00, 12UTC	GTS
		700hPa (ω), 850hPa (T, A)	48, 72	12UTC	GTS
		850hPa (Z, T, D, A)	Analysis	00, 12UTC	GTS, JMH
		Surface (P, R)	24, 48, 72	00, 12UTC	GTS, JMH
			96, 120	12UTC	JMH
	O (Asia)	500hPa (Z, ζ)	96, 120, 144, 168, 192	12UTC	GTS
		850hPa (T), Surface (P)			
	Q (Asia Pacific)	200hPa (Z, T, W), Tropopause (Z)	Analysis	00, 12UTC	GTS
		250hPa (Z, T, W)	Analysis, 24	00, 12UTC	
		500hPa (Z, T, W)		00, 12UTC	
	D (N.H.)	500hPa (Z, T)	Analysis	12UTC	GTS
	W (NW Pacific)	200hPa (streamline)	Analysis, 24, 48	00, 12UTC	GTS
		850hPa (streamline)		00, 12UTC	
~~Ocean Wave~~	C'' (NW Pacific)	~~Surface~~ Ocean Wave (height, period and direction)	12, 24, 48, 72	00, 12UTC	GTS, JMH
~~SST~~	C	Sea Surface Temperature	Daily analysis	-	JMH
	C'2 (Asia Pacific)	Surface(P)	Analysis	00,06,12, 18UTC	GTS, JMH
			24	00, 12UTC	
			48		
		Surface(Typhoon Forecast)	12,24,48,72	00,06,12, 18UTC	
			24,48,72,96, 120		JMH

Notes:

(a) Area

A', C, O, Q, D, W, ~~and~~ C'' and C'2 are illustrated in Figure 3.1.

(b) Contents

Z: geopotential height — ζ: vorticity — T: temperature
D: dewpoint depression — ω: vertical velocity — W: wind speed by isotach
A: wind arrows — P: sea level pressure — R: rainfall

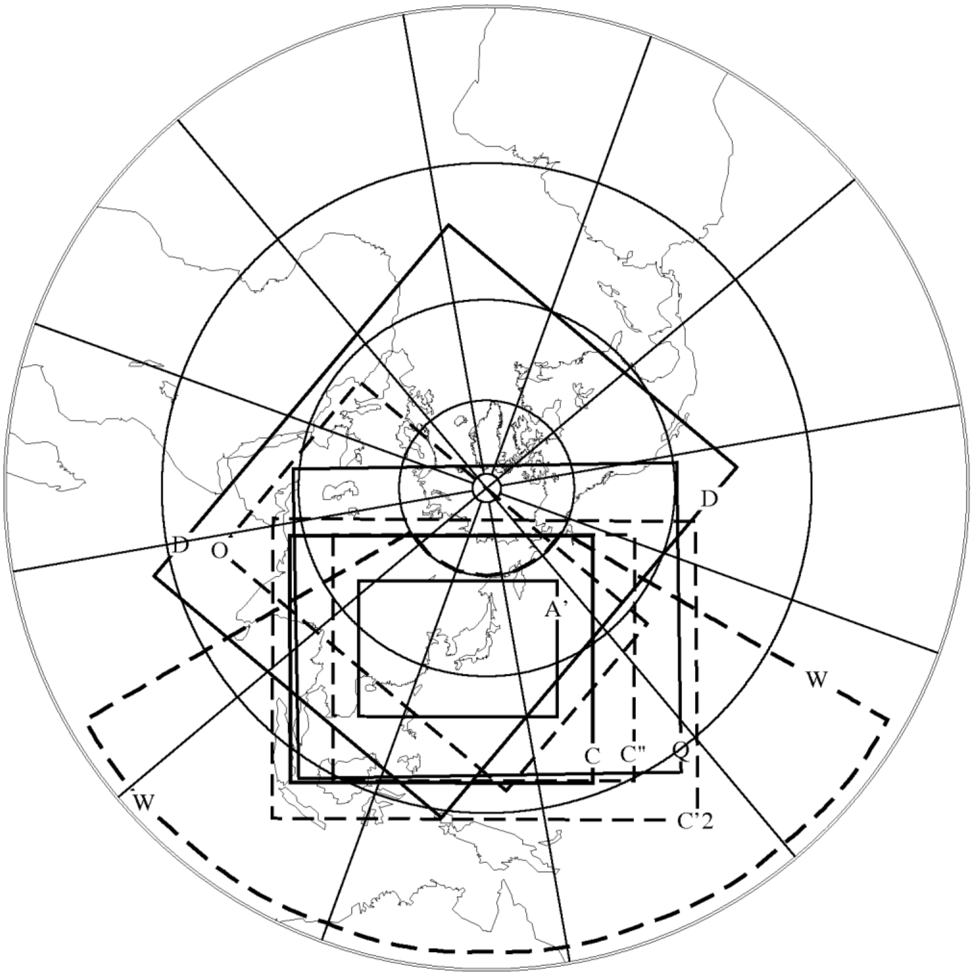

Figure 3.1 Output areas for facsimile charts transmitted through GTS and radio facsimile JMH

Table 5.1: Present operational status of the meteorological telecommunication network for the Typhoon Committee region

1.	Main Telecommunication Network	Present Operational Status
	Beijing - Tokyo	Cable (MPLS), TCP/IP Beijing 48 Mbps/Tokyo 10 Mbps
	Beijing - Offenbach	Cable (FR), 48 kbps (MPLS) TCP/IP Beijing 48 Mbps/Offenbach ~~8~~50 Mbps
	Washington - Tokyo	Cable (MPLS), TCP/IP Washington 1 Mbps/Tokyo 10 Mbps
2.	Main regional circuit	
	Tokyo - Bangkok	Cable (MPLS), TCP/IP Tokyo 2 Mbps/Bangkok 128 kbps
3.	Regional circuits	
	Bangkok - Beijing	64 kbps leased line
	Bangkok - Hanoi	64 kbps leased line
	Bangkok – Hong Kong	Internet, FTP protocol
	Bangkok - Phnom Penh	Internet (VPN)
	Bangkok - Vientiane	Cable (DDN), 64 kbps, FTP protocol
	Beijing - Hanoi	~~Cable, 75 bauds~~ 64 kbps leased line ~~PC VSAT~~ CMACast (Satellite broadcast)
	Beijing - Hong Kong	Cable (~~SDH~~ MSTP), 4 Mbps TCP/IP
	Beijing - Macao	~~64 kbps~~ 2 Mbps leased line
	Beijing - Pyongyang	~~Cable, 75 bauds~~ 64 kbps leased line; ~~PC VSAT~~ CMACast (Satellite broadcast)
	Beijing - Seoul	Cable (FR), 32 kbps (CIR) TCP/IP
	Beijing - Vientiane	CMACast (Satellite broadcast)
	Hong Kong - Macao	ISDN, 128 kbps, TCP/IP
	Tokyo - Hong Kong	Cable (MPLS), TCP/IP Tokyo 2 Mbps/Hong Kong 1 Mbps

Tokyo - Seoul	Cable, 128 kbps, TCP/IP

4. Inter-regional circuits

Bangkok - Kuala Lumpur	Cable (MPLS), TCP/IP 64 kbps ~~leased line~~
Bangkok - Singapore	Cable (MPLS), TCP/IP 64 kbps ~~leased line~~
Tokyo - Manila	Cable (MPLS), TCP/IP Tokyo 2 Mbps/Manila 64 kbps

5. RTH radio broadcast

Bangkok	1 FAX
~~Beijing~~	~~1 FAX (Shanghai)~~
Tokyo	1 FAX

6. Satellite broadcast

Operated by China: Asiasat~~-2~~4 (~~100.5~~122.2°E)	Operational data, fax and image distribution
Operated by Japan: MTSAT (140°E)	Operational satellite image distribution

Annex 1-4
APPENDIX 1-~~B~~ A

CLASSIFICATIONS OF TROPICAL CYCLONES IN THE WESTERN NORTH PACIFIC INTERNALLY USED BY MEMBERS

	Maximum sustained winds (knots)	34 - 47	48 - 63	64 -		
Typhoon Committee	10 min	Tropical Storm (TS)	Severe Tropical Storm (STS)	Typhoon (TY)		
China	2 min	TS	STS	64 - 80 TY	81 - 99 Severe Typhoon (STY)	100 - Super Typhoon (Super TY)
Hong Kong, ~~/~~China	10 min	TS	STS	64 – 80 TY	81 - 99 Severe Typhoon (ST)	100 - Super Typhoon (Super T)
Japan	10 min	TS	STS	64 - 84 TY	85 - Very Strong TY	105 - Violent TY
U.S.	1 min	TS		64 - 129 TY		130 - Super TY

Name of the Member **Japan - 1**

NAME OF STATION		Sapporo /Kenashiyama	Kushiro /Komburi	Hakodate /Yokotsudake	Sendai	Akita
SPECIFICATIONS	Unit					
Index number		47415	47419	47432	47590	47582
Location of station		43° 08′ N 141° 01′ E	42° 58′ N 144° 31′ E	41° 56′ N 140° 47′ E	38° 16′ N 140° 54′ E	39° 43′ N 140° 06′E
Antenna elevation	m	749.0	121.5	1141.7	98.2	55.3
Wave length	cm	5.61	5.61	~~5.59~~ 5.60	5.61	5.59
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	1.1/2.6	1.1/2.6	1.1/2.6	1.0/2.6	1.1/2.6
Sensitivity minimum of receiver	dBm	-109/-112	-110/-113	-108/-111	-108/-111	-108/-112
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.1(H) 1.1(V)	1.1(H) 1.0(V)	1.0(H) 1.0(V)	1.0(H) 1.0(V)	1.0 (H) 0.9 (V)
Detection range	km	400	400	400	400	400
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2	2	2	2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	1
Doppler processing 1.Yes, 2.No		1	1	1	1	1
Display 1.Digital, 2.Analog		1	1	1	1	1
OPERATION MODE (When tropical cyclone is within range of detection)		1	1	1	1	1

1.Hourly 2.3-hourly 3.Others					
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)	1	1	1	1	1

NAME OF STATION		Tokyo /Kashiwa	Niigata /Yahikoyama	Fukui /Tojimbo	Nagano /Kurumayama	Shizuoka /Makinohara
SPECIFICATIONS	Unit					
Index number		47695	47572	47705	47611	47659
Location of station		35° 52′N 139° 58′E	37° 43′N 138° 49′E	36° 14′N 136° 09′E	36° 06′N 138° 12′E	34° 45′N 138° 08′E
Antenna elevation	m	74.0	645.0	107.0	1937.1	186.0
Wave length	cm	5.59	5.61	5.59	5.64	5.66
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	1.1/2.6	1.0/~~2.6~~ 2.5	1.1/2.7	1.0/2.6	1.1/2.6
Sensitivity minimum of receiver	dBm	-109/-113	-109/-113	-109/-113	-110/-114	-110/-113
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.0(H) 1.0(V)	1.0(H) 1.0(V)	1.1(H) 1.0(V)	1.1(H) 1.0V)	1.1(H) 1.1(V)
Detection range	km	400	400	400	400	400
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2	2	2	2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	1
Doppler processing 1.Yes, 2.No		1	1	1	~~2~~ 1	~~2~~ 1
Display 1.Digital, 2.Analog		1	1	1	1	1
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly		1	1	1	1	1

2.3-hourly 3.Others					
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)	1	1	1	1	1

NAME OF STATION		Nagoya	Osaka /Takayasuyama	Matsue /Misakayama	Hiroshima /Haigamine	Murotomisaki
SPECIFICATIONS	Unit					
Index number		47636	47773	47791	47792	47899
Location of station		35° 10′ N 136° 58′ E	34° 37′ N 135° 39′ E	35° 33′ N 133° 06′ E	34° 16′ N 132° 36′ E	33° 15′ N 134° 11′E
Antenna elevation	m	73.1	497.6	553.0	746.9	198.9
Wave length	cm	~~5.59~~ 5.60	5.61	5.61	5.59	5.60
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	1.1/2.6	1.0/2.6	1.1/2.6	1.1/2.7	1.1/2.6
Sensitivity minimum of receiver	dBm	-108/-112	-108/-112	-109/-112	-109/-111	-109/-113
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.0(H) 1.0(V)	1.1(H) 1.1(V)	1.0(H) 1.1(V)	1.1(H) 1.0(V)	1.0(H) 1.0(V)
Detection range	km	400	400	400	400	400
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2	2	2	2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	1
Doppler processing 1.Yes, 2.No		1	1	1	1	1
Display 1.Digital, 2.Analog		1	1	1	1	1
OPERATION MODE (When tropical cyclone is within range of detection)		1	1	1	1	1

1.Hourly 2.3-hourly 3.Others					
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)	1	1	1	1	1

NAME OF STATION		Fukuoka /Sefuri ~~san~~ yama	Tanegashima /Nakatane	Naze /Funchatoge	~~Naha~~ Okinawa /Itokazu	Ishigakijima /Omotodake
SPECIFICATIONS	Unit					
Index number		47806	47869	47909	47937	47920
Location of station		33° 26′N 130° 21′E	30° 38′N 130° 59′E	28° 24′N 129° 33′E	26° 09′N 127° 46′E	24° 26′N 124° 11′E
Antenna elevation	m	982.7	290.5	318.8	208.2	~~535~~ 533.5
Wave length	cm	5.60	~~5.60~~ 5.61	5.66	~~5.60~~ 5.61	5.61
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	1.1/2.7	1.1/2.7	1.1/2.6	1.0/2.5	1.1/2.7
Sensitivity minimum of receiver	dBm	-109/-112	-108/-112	-109/-113	-109/-113	-107/-111
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.0(H) 1.0(V)	1.1(H) 1.0(V)	1.1(H) 1.0(V)	1.0(H) 1.0(V)	1.1(H) 1.1(V)
Detection range	km	400	400	400	400	400
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2	2	2	2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	1
Doppler processing 1.Yes, 2.No		1	1	1	1	1
Display 1.Digital, 2.Analog		1	1	1	1	1
OPERATION MODE (When tropical cyclone is within range of detection)		1	1	1	1	1

1.Hourly 2.3-hourly 3.Others					
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)	1	1	1	1	1

Name of the Member **Macao, China**

NAME OF STATION		TAIPA GRANDE	ZHUHAI-MACAO RADAR			
SPECIFICATIONS	Unit					
Index number		45011				
Location of station		22.1599N 113.5624E	22.0240N 113.3756E			
Antenna elevation	m	183	250			
Wave length	cm	3.4	~10			
Peak power of transmitter	kW	200	> 800			
Pulse length	μ s	0.4, 0.8, 1.0, 2.0	0.5, 1.57, 4.5			
Sensitivity minimum of receiver	dBm	-113	-114 for 4.5us -111 for 1.57us			
Beam width (Width of over -3dB antenna gain of maximum)	deg	1°	< +/- 0.01°			
Detection range	km	128	230/460			
Scan mode in observation 1. Fixed elevation 2. CAPPI 3. Manually controlled		3	3			
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2			
Doppler processing 1.Yes, 2.No		1	1			
Display 1.Digital, 2.Analog		1	1			
OPERATION MODE (When tropical cyclone is within range of detection)		3	3			

1. Hourly 2. 3-hourly 3. Others					
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)	2	1			

SCHEDULE OF MTSAT OBSERVATIONS AND DISSEMINATIONS

1. IMAGER observations

IMAGER observations are as follows:

(a) full-disk observations are made hourly;
(b) half-disk observations of northern hemisphere are made hourly in addition to the full-disk observations;
(c) additional half disk data in the northern and southern hemispheres for Atmospheric Motion Vector (AMV) extraction are made six-hourly.

2. Dissemination Services for Medium-scale Data Utilization Station (MDUS) Users

High Rate Information Transmission (HRIT) is available as dissemination service for MDUS users.
Technical specifications of HRIT are given in
JMA HRIT Mission Specification Implementation (Issue 1.2, 1 Jan. 2003)
(http://www.jma.go.jp/jma/jma-eng/satellite/introduction/4_2HRIT.pdf)

This service will terminate in November 2015.

3. Dissemination Services for Small-scale Data Utilization Stations (SDUS) Users

Low Rate Information Transmission (LRIT) is available as dissemination service for SDUS users. Visible imagery of full earth's disk of normalized geostationary projection has been disseminated via LRIT since 1 July, 2010. Technical specification of LRIT is given in JMA LRIT Mission Specification Implementation (Issue 7, 1 Jul. 2010).
(http://www.jma.go.jp/jma/jma-eng/satellite/introduction/4_3LRIT.pdf)

This service will terminate in November 2015.

4. Internet Service for National Meteorological and Hydrological Services (NMHSs)

Besides the direct broadcasting, JMA provides satellite imagery through the Internet FTP for NMHSs. Detailed information of this service is shown in the following webpage:
http://www.jma.go.jp/jma/jma-eng/satellite/nmhs~~ds~~.html

[JMA real-time satellite imagery webpage]
http://www.jma.go.jp/en/gms/

[MSC real-time satellite imagery webpage]
http://ds.data.jma~~mscweb.kishou~~.go.jp/mscweb/data/sat_dat/~~index.htm~~

~~[MSC real-time satellite imagery webpage (for selected areas)]~~
~~http://mscweb.kishou.go.jp/sat_dat/img/reg/sat_img.htm~~

[SATAID (Satellite Animation and Interactive Diagnosis) Service]
http://www.wis-jma.go.jp/cms/sataid/

OUTLINE OF RSMC TOKYO - TROPICAL CYCLONE PREDICTION MODELS

(a) Global Spectral Model (GSM-~~1110~~ 1403)

Data Assimilation:
- Four-dimensional variational (4D-Var) data assimilation method with 6-hours assimilation window using 3 to 9-hours forecast by GSM as first-guess field
- Data cut-off at 2.3 hours from synoptic time for prediction model, at 7.8 ~ 11.8 hours from synoptic time for assimilation cycle
- Dynamic quality control considering temporal and spatial variabilities
- Reduced Gaussian grid, roughly equivalent to 0.1875° x 0.1875° in latitude and longitude (~20km grid)
- Model p-sigma hybrid levels (~~60~~ 100) + surface (1)

(bogusing of tropical cyclones)
- Axis-symmetric structure based on Frank's (1977) empirical formula with parameters prescribed on forecasters' analysis mainly applying the Dvorak method to MTSAT imagery
- Asymmetric structure derived from first-guess field (prediction using GSM)
- Bogus structure is given as pseudo-observation data to the analysis for the prediction model

Operation:
(schedule)
Four times a day (0000, 0600, 1200 and 1800 UTC)
(integration time)
84 hours from 0000, 0600 and 1800 UTC, and 264 hours from 1200 UTC

Prediction model:
(dynamics)
- Hydrostatic, primitive, semi-Lagrangian-form equations
- Semi-implicit time integration
- TL959 spectral discretization in the horizontal direction
- Reduced Gaussian grid, roughly equivalent to 0.1875° x 0.1875° in latitude and longitude (~20km grid)
- Finite differencing on ~~60~~ 100 p-sigma hybrid levels in the vertical direction
- Horizontal diffusion by linear second-order Laplacian

(physics)
- Arakawa-Schubert (1974) cumulus parameterization with modifications by Moorthi and Suarez (1992), Randall and Pan (1993) and Kuma and Cho (1994)
- ~~Prognostic cloud water scheme~~ PDF-based cloud parameterization by Smith (1990)
- Bulk formulae for sea surface fluxes with similarity functions by Louis (1982) and for land surface fluxes based on the Monin-Obukhov similarity theory by Beljaars and Holtslag (1991)
- Vertical diffusion with the level-2 closure model by Mellor and Yamada (1974) with moist effect included
- Orographic ~~G~~gravity wave drag parameterization by Palmer et al. (1986) and Iwasaki et al. (1989)
- Non-orographic gravity wave parameterization by Scinocca (2003)
- Simple Biosphere Model (SiB) by Sellers et al. (1986) and Sato et al. (1989a,b)

- Shortwave radiation scheme based on a two-stream delta-Eddington approximation radiation transfer method (Joseph et al. 1976)
- Longwave radiation scheme based on a two-stream absorption approximation radiation transfer method (Yabu 2013)

Boundary conditions:
(SST)
0.25° x 0.25° daily analysis with climatic seasonal trend

(b) Typhoon Ensemble Prediction System (TEPS)

Initial condition:
Interpolation of the initial condition for GSM plus ensemble perturbations

Methods to make ensemble perturbations:
- Singular vector (SV) method to generate initial perturbations
  - Linearized model and its adjoint version based on those adopted in 4-D variational calculus, which consist of full dynamics of Eulerian integrations and full physical processes containing representations of surface fluxes, vertical diffusion, gravity wave drag, large-scale condensation, long-wave radiation and deep cumulus convection
  - T63 (~180 km grid) spectral discretization in the horizontal direction
  - Finite differencing on 40 p-sigma hybrid levels in the vertical direction
  - Two types of SV spatial area (fixed as the Northwestern Pacific and movable as within a 750-km-radius of ~~the~~ a predicted TC's position in one-day forecasting) introduced
- A stochastic physics scheme to represent model uncertainties
  - Perturbed parameterized tendencies of u, v, T and q

Ensemble size:
~~11~~ 25

Operation:
(schedule)
Up to ~~F~~four times a day (0000, 0600, 1200 and 1800 UTC)
(tropical cyclone conditions that can trigger model prediction)
- ~~a~~ A tropical cyclone of TS intensity or higher ~~exists~~ is present in the area of responsibility (0°~~N~~ - 60°N, 100°E - 180°~~E~~)
- ~~a~~ A tropical cyclone is expected to reach TS intensity or higher in the area within the next 24 hours
- ~~a~~ A tropical cyclone of TS intensity or higher is expected to move into the area within the next 24 hours

(maximum number of predictions)
Three for each synoptic time (0000, 0600, 1200 and 1800 UTC)
(integration time)
132 hours
(domain)
globe

(Prediction model)
- Lower-resolution version of the GSM
- TL~~319~~ 479 spectral discretization in the horizontal direction
- Reduced Gaussian grid, roughly equivalent to ~~0.5625~~ 0.375° x ~~0.5625~~ 0.375° in latitude and longitude (~~~55~~ 40km grid)
- Finite differencing on 60 p-sigma hybrid levels in the vertical direction

OPERATIONAL TYPHOON TRACK FORECAST METHODS
USED BY TYPHOON COMMITTEE MEMBERS

Name of the Member **China**

Item	Method	Type of output
Name of the method	Global Numerical Model of Typhoon Track Prediction (GMTTP)	Track position up to 120h, interval is 6h
Description of the method	a) Forecast domain of GMTTP: Global b) Vertical resolution: 60L c) Horizontal resolution: T639 d) Time integration: Semi-Lagrangian e) Physical processes: Short wave radiation: morcrette,1991 Long wave radiation: Fouquart and Bonnel,1988 Turbulence diffusion: Louis et al.,1982 cumulus convection: mass flux scheme(tiedtke,1989) cloud physics: prognostic cloud scheme (Tiedtke;1993) Surface physical processes: 4 level model (Viterbo and Beljaars, 1995)	

Name of the Member **Hong Kong, China**

Item	Method	Type of output
~~Name of the method~~	~~**Regression method**~~	
~~Description of the method~~	~~The mean 24-hr movement of each tropical cyclone centered in each 5-degrees square is correlated with that 24 hours ago to derive regression equations for forecasting.~~ ~~Independent variables: Present and past 24-hour positions~~ ~~Domain : 5° - 25°N, 105° - 145°E~~ ~~Frequency of forecast : 4 times a day~~	~~24, 48, 72 and 96-hr movement forecasts~~
~~Name of the method~~	~~**The space mean method**~~	
~~Description of the method~~	~~The space mean technique is based on the concept of steering. Space mean charts are prepared by the computer to depict the smoothed basic flows at various upper levels with the circulation of the tropical cyclone and other small-scale eddies removed.~~ ~~Input: Surface, 700, 500 and 300 hPa data covering the area 0° - 65°N, 65° - 165°E~~	~~Space mean charts and 24-hour movement forecast~~
Name of the method	**The Multi-Model Ensemble Technique**	
Description of the method	An unweighted position and motion vector consensus of the tropical cyclone forecast tracks given by the global models of the UKMO (EGRR), Japan Meteorological Agency (JMA), National Centers for Environmental Prediction (NCEP) and European Centre for Medium-Range Weather Forecasts (ECMWF). Frequency of forecast: 2 times a day References: [1] James S. Goerss, 2000: Tropical Cyclone Track Forecasts Using an Ensemble of Dynamical Models, Monthly Weather Review, Vol. 128, p.1187-1193. [2] Russell L. Elsberry, James R. Hughes, and Mark A. Boothe, 2008: Weighted Position and Motion Vector Consensus of Tropical Cyclone Track Prediction in the Western North Pacific, Monthly Weather Review, Vol. 136, p.2478-2487.	24, 48, and 72-hr forecast positions

THE TROPICAL CYCLONE ANALYSIS AND FORECASTING TECHNIQUE
USING SATELLITE DATA

The tropical cyclone analysis and forecasting technique using satellite data developed by Vernon F. Dvorak (Dvorak, 1984) is mainly used for TC warnings. The methods are described in the Global Guide to Tropical Cyclone Forecasting at the WMO/TCP website (http://www.wmo.int/pages/prog/www/tcp/TCF/GlobalGuide.html).

Detailed operational satellite-based analysis of TCs used by the RSMC Tokyo, CMA, HKO and U. S. Joint Typhoon Warning Center (JTWC) are attached in Annex 2-5 to this Appendix.

The objective techniques developed by the TC research community, including the Advanced Dvorak Technique (ADT), the Advanced Microwave Sounding Unit method (AMSU), the Automated Rotational Center Hurricane Eye Retrieval algorithm (ARCHER), the SATellite CONsensus approach (SATCON), passive microwave (PMW) applications, and the Multiplatform TC Surface Wind Analysis (MTCSWA), are described in Appendix C of the Proceedings of the International Workshop on Satellite Analysis of Tropical Cyclones held in Honolulu, Hawaii, USA 13–16 April 2011 (http://www.wmo.int/pages/prog/www/tcp/documents/TCP-52_IWSATC_proceedings_en.pdf)

OPERATIONAL TYPHOON SATELLITE ANALYSIS
USED BY METEOROLOGICAL CENTERS

Organization	Method	Detailed Description of Methods
RSMC Tokyo	Dvorak (1984), Early-stage Dvorak Analysis (Tsuchiya et al. 2001, Kishimoto 2008) for the TCs in generation stage	Annex2 (http://www.wmo.int/pages/prog/www/tcp/documents/APPENDIX3-CANNEX2JMA.pdf)
CMA	Real time analysis: Before 2012: Simplified Dvorak technique. Since 2012: Dvorak (1984). Best track analysis: 1) Mathematical morphology (TC center location) and Convective Core Extraction technique (TC intensity estimation) 2) Use of real time satellite analysis issued by various centers as reference.	Annex3a (http://www.wmo.int/pages/prog/www/tcp/documents/APPENDIX3-CANNEX3CMA.pdf) Annex 3b (http://www.wmo.int/pages/prog/www/tcp/documents/APPENDIX3-CANNEX3CMA.pdf)
HKO	Dvorak (1984) ADT version 7.2.2 of McIDAS used as reference A modified version of the original scheme by Dvorak is adopted during the weakening stage of TC.	Annex4 (http://www.wmo.int/pages/prog/www/tcp/documents/APPENDIX3-CANNEX4HKO.pdf)
JTWC	Dvorak (1984), Subtropical intensity technique (Hebert and Poteat, 1975)	Annex5 (http://www.wmo.int/pages/prog/www/tcp/documents/APPENDIX3-CANNEX5JTWC.pdf)

OPERATIONAL PROCEDURES OF TC SATELLITE ANALYSIS AT HONG KONG OBSERVATORY

1. INTRODUCTION

The Hong Kong Observatory (HKO) has long been using manual Dvorak analysis (1984) on satellite imagery for operational estimation of the intensity of tropical cyclones (TCs). Once a potential TC is suspected to soon form, a Dvorak analysis will be performed as often as deemed appropriate for assessing the current intensity of the TC. For TCs within 0-36 N, 100-140 E, Dvorak analysis will be performed at least for 00, 06, 12 and 18 UTC imageries. For TCs within the HKO area of responsibility (viz. 10-30 N, 105-125 E), additional analysis will be performed for 03, 09, 15 and 21 UTC imageries. Operational position and intensity are provided in Hong Kong Tropical Cyclone Warning for Shipping and local tropical cyclone warnings for the public.

A post-season reanalysis of storms is carried out and the information is incorporated into the TC best track dataset. HKO's best track records started as early as 1884, but more complete records were kept since 1961. HKO produces best tracks for TCs within 0-45 N, 100-160 E until 1960 and 0-45 N, 100-180 E from 1961 onward. The maximum 10-minute surface mean wind and the minimum pressure of TCs are given in the best track dataset at 6-hourly intervals.

2. LOCAL VARIATIONS TO DVORAK (1984)

The Enhanced IR Dvorak technique has been in use operationally in HKO since early 1980s. Prior to that, the Dvorak analysis was initially carried out using the visible imageries. ~~For reporting and warning purposes, a conversion factor of 0.9 was adopted in Hong Kong to convert 1-minute mean winds from the Dvorak wind table into 10-minute mean winds.~~

While there is no formal reference in the Dvorak technique about its application to TCs making landfall, Dvorak analysis is being applied in Hong Kong to TCs over the sea as well as over land. Beginning the TC season of 2014, a modified version of the original scheme by Dvorak for the weakening stage of TCs is followed (Shum and Chan, 2013). The original scheme only gives direction on handling CI-number when the TC weakens but no explicit guidance is given when the TC stops weakening and the final T-number has flattened for some period of time. In the modified scheme, when the final T-number has already plateaued for more than 12 hours, CI is held the same as the final T-number. For weakening TCs over land, there is no need to hold CI constant for 12 hours. Instead, it is immediately held 0.5 higher than the final T-number.

According to Dvorak (1984), the eye adjustment factor is determined using the eye temperature and the coldest surrounding ring temperature that meets the "narrowest width" requirement. This "narrowest width" requirement has been relaxed in 2014 following Dvorak (1995), i.e. the surrounding ring temperature is defined as any cold band surrounding the eye, regardless of width.

Currently, no Dvorak analysis will be performed after a TC has transitioned into an extratropical low. Extratropical systems are not included in the HKO best tracks.

3. UNIFORMITY IN APPLICATION OF DVORAK TECHNIQUE

The HKO forecasters will carry out Dvorak analysis and fill in the tropical cyclone analysis worksheet as described in the appendix of Dvorak (1984) during operation. SAREP reports in BUFR format, including information such as CI and the final T-number, are issued eight times a day to other meteorological centres when a TC enters within the HKO area of responsibility. ~~but the information such as the current intensity (CI) or T-numbers are not being reported outside of HKO and digitized.~~

~~According to Step 9 in Dvorak (1984)~~ Prior to the introduction of the modified weakening rules described in the preceding section, the CI of a TC would ~~is to~~ be held constant for 12 hours) during ~~the~~ initial weakening ~~of a TC~~ according to Dvorak (1984). Normally, the HKO forecasters followed this weakening rule even when the TC had~~s~~ made landfall or ~~is~~ was crossing large landmasses such as the Philippines. However, the forecasters ~~may~~ could ignore ~~this~~ the rule for landfalling TCs on a case-by-case basis ~~and discussion is being made in HKO about whether to allow the final T-number to decrease once the centre of the TC hits land~~.

4. CHANGES IN PROCEDURES OVER TIME

~~There has been little change to the procedures over the years.~~

Following Harper et al. (2010), a conversion factor of 0.93 was adopted in Hong Kong from February 2013 to convert 1-minute mean winds from the Dvorak wind table into 10-minute mean winds for reporting and warning purposes. Prior to that, a fixed conversion factor of 0.9 had been used.

5. DETERMINATION OF TC FINAL INTENSITY

In determining the final intensity of a TC, surface wind and pressure reports are regarded as ground truth but the quality of the observations are also taken into account (for example, pressure reported by ships can sometimes be suspicious). For TCs over the ocean where such observations are sparse, Dvorak analysis is used as the main tool for TC intensity determination. Other satellite intensity estimates, e.g. wind scatterometer, ADT, etc., are used as references.

Tropical cyclone's central pressure is estimated based on the surface pressure reported by land stations and ships, reconnaissance aircraft reports when available and Dvorak analysis via the wind-pressure conversion table.

The maximum surface mean wind speed is estimated based on the surface winds reported by land stations and ships, Doppler wind observations from radars, reconnaissance aircraft reports when available and Dvorak analysis. Estimates from wind scatterometer data, ADT, SATCON and the Multi-platform Tropical Cyclone Surface Wind Analysis by NOAA are also referenced.

6. INFLUENCES OF TECHNOLOGICAL ADVANCEMENTS ON DVORAK ANALYSIS

One notable influence is due to the advent of microwave imageries in recent years. Microwave imageries are less frequently available, but can serve as a supplement to Dvorak analysis. They enable the forecasters to see through clouds and view rainbands and eye of the TCs even when obscured by upper-level clouds, thereby helping to reveal the best pattern (e.g. banding versus shear or an eye pattern under a central cold cover) to use in the Dvorak classification. In addition, sea-level winds measured by ~~QuikSCAT and~~ ASCAT or previously QuikSCAT serve as a check on the location and strength of TCs.

7. ANCILLARY DATA CONSIDERED IN PRODUCING FINAL SATELLITE INTENSITY ESTIMATE

Since 2009, HKO has incorporated the "Advanced Dvorak Technique (ADT)" developed by the University of Wisconsin-Madison / Cooperative Institute for Meteorological Satellite Studies (CIMSS) as an objective reference tool for weather forecasters. ADT makes use of computer- based algorithms to objectively identify cloud pattern types, calculate the eye/convective cloud temperatures, apply selection rules, and derive intensity estimate for TC. One advantage of this tool is that it can be fully automated. The ADT is presently applied to the TC positions determined by the forecasters.

Scatterometer winds such as ASCAT or previously Quik~~Scat~~SCAT, NOAA Multiplatform satellite surface wind analysis, images from microwave sensors available in the NRL website (http://www.nrlmry.navy.mil/TC.html), other resources from the web such as satellite-derived winds and dropwindsonde observations are also referenced by HKO forecasters.

8. PRESSURE WIND RELATIONSHIP IN USE

The empirical relationship between CI, the minimum sea level pressure (MSLP) for the Western North Pacific Basin and the 1-minute maximum mean wind speed (MWS) given in Dvorak (1984) is in operational use at HKO. A conversion factor of 0.93 is applied to convert the 1-minute mean winds to 10-minute mean winds. ~~There have not been any changes regarding the above over the years, but HKO is currently considering adopting the new conversion factor of 0.93 as proposed in WMO/TD-No. 1555.~~

Conversion of the Dvorak CI number to MSLP and MWS

CI Number	MWS (10-minute mean in knots)	MSLP (hPa)
1.0	23	
1.5	23	
2.0	~~27~~28	1000
2.5	~~31~~33	997
3.0	~~41~~42	991
3.5	~~49~~51	984
4.0	~~59~~60	976
4.5	~~69~~72	966
5.0	~~81~~84	954
5.5	~~92~~95	941
6.0	~~103~~107	927
6.5	~~114~~118	914
7.0	~~126~~130	898
7.5	~~139~~144	879
8.0	~~153~~158	858

9. SYSTEMS TO ENTER THE BEST TRACK RECORDS

Best tracking has been carried out by HKO officers who have rich experience in TC operation. The best tracks are determined independently from the operational environment. An advantage of best tracks over operational tracks is that the analyst can look back and forth to ensure a more reasonable and consistent track. References are also made to additional information such as tropical cyclone passage reports and best track data issued by RSMC Tokyo, which are not available operationally. Currently, there is no periodic re-visit of the best track record from previous years - this is only done on an ad-hoc and need-only basis.

The best track intensity will not normally differ too much from the warning intensity. Strong evidence is required for large changes in intensity.

REFERENCES

Dvorak, V.F., 1984: Tropical cyclone intensity analysis using satellite data. *NOAA Tech. Rep.* **11**, 45 pp.

Dvorak, V.F., 1995: Tropical clouds and cloud systems observed in satellite imagery: Tropical cyclones. Workbook Vol. 2, 359 pp.

Harper, B.A., J.D. Kepert and J.D. Ginger, 2010: Guidelines for converting between various wind averaging periods in tropical cyclone conditions. World Meteorological Organization, WMO/TD-No. 1555.

Shum, C.T., S.T. Chan, 2013: Application of Dvorak Technique during the weakening stage of tropical cyclones. Tropical Cyclone Research and Review, 2013, **2(4)**, 207-221.

Outline of HKO – Non-Hydrostatic Model (NHM)

Name of the method:
Non-Hydrostatic Model (NHM)

Description of the method:

HKO operates the NHM system based on JMA-NHM (Saito *et al.* 2006) with horizontal resolution at 10-km and 2-km to provide forecasts up to 72 hours and 15 hours ahead respectively (Wong 2010).

In NHM, a 3-dimensional variational data assimilation (3DVAR) system is used to generate the initial condition on model levels using the following meteorological observations:

(A) GTS

SYNOP, SHIP and BUOY	synoptic stations, ship and buoy data
TEMP and PILOT	radiosonde and pilot data
AMDAR and AIREP	aircraft data
AMV	atmospheric motion vectors from MTSAT-2
ATOVS	retrieved temperature profiles from NOAA
ASCAT	retrieved surface wind over ocean surface

(B) Internet

~~(i) NCEP global high resolution daily sea surface temperature analysis at 0.083 degree resolution~~

~~(ii)~~ Retrieved total precipitable water over ocean surface from SSM/I and AMSR-E

(C) Regional data exchange

Data from automatic weather stations over the south China coastal areas

(D) Local data

(i) Tropical cyclone bogus data from forecasters' analysis during TC situations
(ii) Automatic weather station data
(iii) Wind profiler data
(iv) Doppler weather radar data
(v) Radar retrieved wind data (u and v) on 1-5 km levels based on multiple weather radars in Hong Kong and the Pearl River Delta region, China
(vi) GPS total precipitable water vapour

The 3DVAR analysis for 10-km NHM is produced eight times a day at 00, 03, 06, 09, 12, 15, 18, and 21 UTC. Hourly analysis is performed for the 2-km NHM.

Specifications of the forecast model are given in the following table:

Basic equations	Fully compressible non-hydrostatic governing equations
Vertical coordinates	Terrain following height coordinates system
Forecast parameters	wind (u,v,w), 3-dimensional pressure, potential temperature, specific humidity of water vapour, cloud water, cloud ice, rain water, hail/graupel and snow
Map projection	Mercator
Number of grid points	10-km NHM: 585x405, 50 levels

	2-km NHM: 305x305, 60 levels
Forecast range	10-km NHM: 72 hours 2-km NHM: 15 hours
Initial condition	Analysis from NHM 3DVAR on model levels
Boundary condition	For 10-km NHM, 3-hourly interval boundary data including horizontal wind, temperature, relative humidity, geopotential height and surface pressure from ~~JMA Global Spectral Model~~ECMWF IFS forecast at horizontal resolution of 0.125 degree in latitude/longitude and on ~~21~~ 25 pressure levels (1000, ~~975,~~ 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, ~~and~~ 10, 7, 5, 3, 2 and 1 hPa) For 2-km NHM, hourly interval boundary data provided from 10-km NHM forecasts
Nesting configuration	One-way nesting
Topography and land-use	USGS GTOPO30 (30 second data smoothed to 1.5 times of horizontal resolution) USGS Global Land Cover Characterization (GLCC) 30 second data
Dynamics	Non-hydrostatic governing equations solved by time-splitting horizontal-explicit-vertical-implicit (HEVI) scheme using 4-order centred finite difference in flux form
Moisture process	Kain-Fritsch convective parameterization (JMA-NHM version) Three ice bulk microphysics scheme
Surface process	Flux and bulk coefficients: Beljaars and Holtslag (1991) Stomatal resistance and temporal change of wetness included 4-layer soil model to predict ground temperature and surface heat flux.
Turbulence closure model and planetary boundary layer process	Mellor-Yamada-Nakanishi-Niino Level 3 (MYNN-3) (Nakanishi and Niino, 2004) with partial condensation scheme (PCS) and implicit vertical turbulent solver. Height of PBL calculated from virtual potential temperature profile.
Radiation	Long wave radiation process follows Kitagawa (2000) Short wave radiation process using Yabu and Kitagawa (2005) Prognostic surface temperature included; Cloud fraction determined from PCS.

Reference

Beljaars, A. C. M., and A. A. M. Holtslag, 1991: Flux parameterization and land surfaces in atmospheric models. *J. Appl. Meteor.*, **30**, 327-341.

Kitagawa, H., 2000: Radiation process. *NPD Report No. 46*, Numerical Prediction Division, JMA, 16-31. (in Japanese)

Nakanishi, M. and H. Niino, 2004: Improvement of the Mellor-Yamada level 3 model with condensation physics: Its de-sign and verification. *Bound.-Layer Meteor.*, **112**, 1-31.

Saito, K., T. Fujita, Y. Yamada, J. Ishida, Y. Kumagai, K. Aranami, S. Ohmori, R. Nagasawa, S. Kumagai, C. Muroi, T. Kato, H. Eito, and Y. Yamazaki, 2006: The Operational JMA Nonhydrostatic Mesoscale Model. *Mon. Wea. Rev.*, **134**, 1266-1298.

Wong, W.K., 2010: Development of Operational Rapid Update Non-hydrostatic NWP and Data Assimilation Systems in the Hong Kong Observatory, *3rd International Workshop on Prevention and Mitigation of Meteorological Disasters in Southeast Asia*, 1-4 March 2010, Beppu, Japan. [Reprint available at http://www.hko.gov.hk/publica/reprint/r882.pdf]

Yabu, S., S. Murai, and H. Kitagawa, 2005: Clear-sky radiation scheme. *NPD Report No. 51*, Numerical Prediction Division, JMA, 53-64. (in Japanese)

Annex 1-12
APPENDIX 4-C

STATIONS BROADCASTING CYCLONE WARNINGS FOR SHIPS ON THE HIGH SEAS

Station		Call sign of coastal radio station	Area covered
Member	Station		
China	Shanghai	XSG	Bohai Sea, Huanghai Sea, Donghai Sea, Shanghai Port, Taiwan Straits and sea around Taiwan province
	~~Dalian~~ Tianjin	XSZ	North and Central Huanghai Sea and Bohai Sea
	Guangzhou	XSQ	Taiwan Straits, Bashi Channel, Nanhai Sea and Beibu Wan Gulf
Hong Kong, China	Hong Kong	Broadcast via NAVTEX on 518 kHz*	Waters inside the boundary line: 30N 105E to 30N 125E to 10N 125E, to 10N 105E, to 30N 105E
Japan	Hokkaido	JNL	Hokkaido area
	Shiogama	JNN	Sendai area
	Yokohama	JGC	Tokyo area
	Nagoya	JNT	Nagoya area
	Kobe	JGD	Kobe area
	Hiroshima	JNE	Hiroshima area
	Niigata	JNV	Niigata area
	Maizuru	JNC	Maizuru area
	Moji	JNR	Fukuoka area
	Kagoshima	JNJ	Kagoshima area
	Okinawa	JNB	Okinawa area
Malaysia	Port Penang	LY 3010	Strait of Malacca*
	Labuan	OA 3010	South China Sea*
	Miri	OE 3010	South China Sea*
			*within 300nm from station
Philippines	Manila	DZR, DZG, DSP, DZD, DZF, DFH, DZO, DZN, DZS	Pacific waters inside the boundary line: 25N 120E to 25N 135E, to 5N 135E, to 5N 115E, to 15N 115E, to 21N 120E, to 20N 120E
	San Miguel	NPO	North Pacific waters east of 160E; Philippine Sea, Japan Sea, Yellow Sea, East China Sea, South China Sea
Republic of Korea	Seoul	HLL	East Sea, Yellow Sea, Jeju, Chusan, Nagasaki, and Kagoshima areas
Thailand	Bangkok	HSA, HSJ	Gulf of Thailand, West coast of Southern Thailand, Strait of Malacca and South China Sea
U.S.A.	Honolulu, Hawaii	KMV-99	Pacific Ocean
Viet Nam	Dannang	XVT 1-2	Basco Gulf, Blendong Sea and Gulf of Thailand
	Halphong	XVG 5, 9	*ditto*
	Ho Chi Minh Ville	XVS 1, 3, 8	*ditto*
	Nha Trang	XVN 1, 2	*ditto*

*Coast station VRX closed on 1 October 2006.

LIST OF ADDRESSES, TELEX/CABLE AND TELEPHONE NUMBERS OF THE TROPICAL CYCLONE WARNING CENTERS IN THE REGION

Centre	**Mailing address**	**Telex/cable, Telephone, fax numbers**
China		
National Meteorological Center China Meteorological Adm. (Director: ~~Jiao Meiyan~~ Bi Baogui)	No. 46 Zhongguancun Nandajie, Beijing 100081	Tel.: (+86) (10) ~~6840 6169~~ 5899 5809 Cable: 2894 Fax: (+86) (10) 6217 ~~5928~~ 2956 E-mail: ~~jiaomy~~ bibg@cma.gov.cn
Hong Kong, China		
Central Forecasting Office Hong Kong Observatory (Attn. Mr. L.S. Lee ~~K.C. Tsui~~)	134A Nathan Road Tsim Sha Tsui Kowloon Hong Kong, China	~~Telex: 54777 GEOPH HX~~ Tel.: (+852) 2926 8371 (Office hours) (+852) 2368 1944 (24 hours) Fax: (+852) 2721 5034 (24 hours) E-mail: ~~kctsui~~lslee@hko.gov.hk

Type of Data	Heading	Receiving station TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
Enhanced Upper-air observation	UKTH01 VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
	ULTH01 VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
	UETH01 VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
	USVS01 VNNN	BB	TD	NN	TD	TD	TD	O	BB	BB	BB	
	UKVS01 VNNN	BB	TD	NN	TD		TD	O	BB	BB	BB	
	ULVS01 VNNN	BB	TD	NN	TD	TD	TD	O	BB	BB	BB	
	UEVS01 VNNN	BB	TD	NN	TD	TD	TD	O	BB	BB	BB	
	URPA10 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	URPA11 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	URPA12 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	URPA14 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	URPN10 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	UZPA13 PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	UZPN13 KNHC	*		TD	TD		TD	BB	BB	BB	BB	
	UZPN13 KWBC	*	TD	TD	TD		TD	BB	BB	BB	BB	
	UZPN13 PGTW	*	TD	TD	TD		TD	BB	BB	BB	BB	
Enhanced ship observation	SNVB20 VTBB			O				BB	BB	BB	BB	
	SNVB20 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVD20 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVE20 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVX20 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVB21 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVD21 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVE21 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVX21 RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	SNVX20 RPMM	MM	TD	TD	TD	O	TD	BB		BB	BB	
	SNVX20 VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	
	SNVX20 VNNN	BB	TD	NN	TD		TD	O	BB	BB	BB	
Enhanced radar observation	SBCI30 BABJ	BJ	O	BJ	TD	TD	TD	BJ	BB	BB	BB	
	SCCI30 BABJ		O	BJ	BJ			BB	BB	BB	BB	
	SBCI60 BCGZ		O	BJ				BJ	BB	BB	BB	
	SCCI60 BCGZ	HH	O	BJ				BB	BB	BB	BB	
	SBHK20 VHHH	HH	HH	BJ	O	TD		BB	BB	BB	BB	
	ISBC01 VHHH	HH	HH	HH	O	TD	TD		BB	BB	BB	
	ISBC01 RJTD	O	TD	TD	TD	TD	TD		BB	BB	BB	
	SDKO20 RKSL						O					

	SDMS20	WMKK	BB	TD	KK	TD			BB	O	BB	BB
	SDPH20	RPMM	MM	TD	TD	~~O~~		TD	BB		BB	BB
	SDTH20	VTBB	BB	TD	O	TD			BB	BB	BB	BB
	SDVS20	VNNN	BB	TD	NN	TD	TD		O	BB	BB	BB

Type of Data	Heading		Receiving station TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
			*										
Satellite guidance	TPPN10	PGTW			TD	TD			BB	BB	BB	BB	
	TPPN10	PGUA	*		TD	TD			BB	BB	BB	BB	
	TPPA1	RJTY	*	TD	TD	TD	TD		BB	BB	BB	BB	
	TPPA1	RODN	*	TD	TD	TD	TD		BB	BB	BB	BB	
	IUCC10	RJTD	O	TD	TD	TD	TD	TD		BB	BB	BB	
	IUCC01	VHHH	HH	HH	HH	O							
Tropical Cyclone Forecast	FXPQ01	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXPQ02	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXPQ03	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXPQ20	VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	
	FXPQ20	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ21	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ22	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ23	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ24	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ25	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	FXPQ29	VTBB			O								
	FXPH20	RPMM	MM	TD	TD	TD	O	TD	BB	BB	BB	BB	
	FXSS01	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXSS02	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXSS03	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	FXSS20	VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	
Warning	WDPN31	PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WDPN32	PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WHCI28	BCGZ			BJ	BJ			BJ	BB	BB	BB	
	WHCI40	BABJ	BJ	O	BJ	BJ			BJ	BB	BB	BB	
	WSPH	RPMM	*	TD	TD	TD	O	TD	BB	BB	BB	BB	
	WTMU40	VMMC	BJ	MC	BJ	BJ			BB	BB	BB	BB	O
	WTPN21	PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPN31	PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPN32	PGTW	*	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPH20	RPMM	MM	TD	TD	TD	O		BB		BB	BB	
	WTPH21	RPMM			TD		O		BB		BB	BB	
	WTPQ20	VHHH	HH	HH	BJ	O		TD	BB	BB	BB	BB	
	WTSS20	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	
	WTTH20	VTBB	BB	TD	O	TD			BB	BB	BB	BB	
	WTVS20	VNNN			NN	BJ			O	BB	BB	BB	

	WTPQ20	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB
	WTPQ21	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB
	WTPQ22	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB
Continued to the next page	WTPQ23	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB
	WTPQ24	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB

TABLE of Abbreviated headings (TTAAii CCCC)

TT	Data designator
FX	Miscellaneous forecasts
SB	Radar reports PART A
SC	Radar reports PART B
SD	Radar reports (PART A and PART B)
SN	Synoptic reports (non-standard hours)
TP	Satellite guidance
UA	Aircraft reports (AIREP)
UE	Upper-level observation, PART D
UK	Upper-level observation, PART B
UL	Upper-level observation, PART C
US	Upper-level observation, PART A
WD	Prognostic reasoning for typhoon
WH	Hurricane warnings
WO	Other warnings
WC	Tropical cyclone(SIGMET)
WT	Tropical cyclone warnings
WW	Warning and weather summary

ii	Data distribution area
01-19	Global
20-39	Regional
40-89	National

TABLE of Abbreviated Headings
(TTAAii CCCC) for BUFR

TTAAii CCCC	Data type
ISBC01 VHHH	Radar reports
IUCC01 VHHH	SAREP reports
ISBC01 RJTD	Radar reports
IUCC10 RJTD	SAREP reports

AA	Geographic designator
CI	China
HK	Hong Kong
JP	Japan
KO	Republic of Korea
KP	Cambodia
LA	Lao People's Democratic Republic
MS	Malaysia
MU	Macao
PA	Pacific
PH	Philippines
PN	North Pacific area
PQ	Western North Pacific
PW	Western Pacific area
SS	South China Sea area
TH	Thailand
VS	Viet Nam

CCCC	Location indicator
BABJ	Beijing
BCGZ	Guangzhou
KWBC	Washington
PGFA	Guam (F.W.C)
PGTW	Guam (JTWC)
PGUM	Guam (Agana)
RJTD	Tokyo
RJTY	Yokota
RKSL	Seoul
RKSO	Osan
RODN	Okinawa / Kadena AB
RPMK	Clark AB
RPMM	Manila / Intl.
VDPP	Phnom Penh
VHHH	Hong Kong
VLIV	Vientiane
VMMC	Macao
VNNN	Hanoi
VTBB	Bangkok
WMKK	Kuala Lumpur