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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 REQUIRED:
The Committee is invited to review and approve the proposed amendments to the TOM.

APPENDIXES:
A) DRAFT TEXT FOR INCLUSION AT SESSION REPORT
B) UPDATE OF THE TYPHOON COMMITTEE OPERATIONAL MANUAL

APPENDIX A:
DRAFT TEXT FOR INCLUSION IN THE SESSION REPORT

x.x Review of Typhoon Committee Operational Manual (TOM)

1. The Session noted that the Typhoon Committee Operational Manual (TOM) rapporteur requests WMO to publish and upload the 2016 edition of TOM on the Tropical Cyclone Programme (TCP) Website as submitted by the Rapporteur, with the amendments given in Appendix XX.

2. The Committee expressed its appreciation to the rapporteur for update of TOM.

APPENDIX B:

UPDATE OF THE TYPHOON COMMITTEE OPERATIONAL MANUAL

1. The Typhoon Committee Operational Manual - Meteorological Component (TOM) has been reviewed and updated every year since its first issue in 1987. The 2016 edition was completed and posted on the WMO website in March 2016 in accordance with the approval of amendments to the 2015 edition by the Typhoon Committee 48th session (22 to 25 February 2016 Honolulu, Hawaii, USA).

2. At the 48th session, the Committee decided that the rapporteur of the Japan Meteorological Agency (JMA) continue arrangements for updating the TOM. In this connection, on 6 September 2016, the rapporteur, Mr. Chiashi Muroi, 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 2017, proposals for updates to the TOM had been submitted by the four focal points of Hong Kong, China, Japan, Macao, China and Thailand.

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

- Update of the information on ship and buoy observations (Chapter 2)
- Update of the information associated with the replacement from MTSAT-2 to Himawari-8/9 of the geostationary meteorological satellite operated by JMA (Chapter 3, Appendix 2-F, Appendix 7-A)
- Update of the information on the meteorological telecommunication network (Chapter 5)
- Update of the information on stations from which enhanced observations are available (Appendix 2-A, Appendix 2-B)
- Update of the information on RSMC Tokyo tropical cyclone prediction models (Appendix 3-A)
- Update of the information on the method for the tropical cyclone analysis and forecasting (Appendix 3-C)
- Update of the information on Non-Hydrostatic Model (NHM) run by HKO (Appendix 3-E)

Annex 1

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

Page	Line	Proposed Amendment	Comments
APPENDICES			
iii	L22	Schedule of Himawari~~MTSAT~~ observation and disseminations	Update of the information associated with the replacement from MTSAT-2 to Himawari-8/9 of the geostationary meteorological satellite operated by JMA
Chapter 2.2			
9	L28	Hourly marine meteorological observations, namely air pressure and sea surface temperature are also made during tropical cyclone seasons by the drifting buoys deployed by Hong Kong, China over the South China Sea with support of the Hong Kong Voluntary Observing Ships. All reports are coded in the BUOY code (FM18), and immediately put onto the GTS with the header "IOBC01 VHHH" and "IOBX02 KWBC" respectively for buoys operated solely by Hong Kong, China and for buoys operated under the Barometer Upgrade Scheme of the Global Drifter Programme of Data Buoy Cooperation Panel of JCOMM.	Addition of the information on the ship and buoy observations operated by HKO
Chapter 3.1			
15	Table 3.2	To be replaced by Annex 1-1	Update of the information on the NWP products provided by JMA
17	Table 3.3	To be replaced by Annex 1-2	Update of the information on the satellite products provided by JMA and revision of the information on the wave data provided by JMA
Chapter 4.5			
20	L19	In accordance with the International Civil Aviation Organization (ICAO) Annex 3 - Meteorological Service for International Air Navigation/-WMO No. 49 Technical Regulations, Volume II: Meteorological Service for International Air Navigation (WMO-No. 49 Vol. 2)~~(C.3.1)~~, tropical	Change of expression of reference documents on warnings and advisories for aviation

		cyclone warnings, required for the international air navigation, are issued by designated meteorological watch offices (MWO) as SIGMET messages.	
20	L30	The content and order of elements in a SIGMET message for tropical cyclone shall be in accordance with ICAO Annex 3/WMO-No. 49 Vol. 2 ~~Technical Regulations (C.3.1)~~.	
20	L45	The format of the tropical cyclone advisories shall be in accordance with the ICAO Annex 3/WMO-No. 49 Vol. 2 ~~Technical Regulations (C.3.1)~~.	
Chapter 5.4			
22	Figure 5.1	To be replaced by Annex 1-3	Addition of regional circuits between Bangkok and Offenbach
23	Table 5.1	To be replaced by Annex 1-4	Update of present operational status of the meteorological telecommunication network related to Hong Kong, China, Macao, China, Japan and Thailand
APPENDIX 2-A			
37	p.2	To be replaced by Annex 1-7	Addition of stations from which enhanced surface observation are available in Thailand
APPENDIX 2-B			
38	p.1	To be replaced by Annex 1-8	Addition of stations from which enhanced upper-air observation are available in Thailand
APPENDIX 2-D			
40	p.3	To be replaced by Annex 1-9	Revision of the information of radar stations in Hong Kong, China
APPENDIX 2-F			
67	p.1	To be replaced by Annex 1-10	Update of the information of satellite imagery receiving facilities in Hong Kong, China
APPENDIX 3-A			
71	L6	(a) Global Spectral Model (GSM-16403)	Update of the information of Global Spectral Model
71	L46	Bulk formulationse ~~for sea surface fluxes with similarity functions by Louis (1982) and for land~~ of surface fluxes based on the Monin-Obukhov similarity theory by Beljaars and Holtslag (1991)	
71	L53	Simple Biosphere Model (SiB) by Sellers et al. (1986) and Dai et al. (2003)~~Sato et al. (1989a,b)~~	
APPENDIX 3-B			
81	p.8	To be replaced by Annex 1-11	Revision of description of the Multi-Model Ensemble Technique

			used by Hong Kong, China
APPENDIX 3-C			
108	L34	Deterministic forecasts of tropical cyclone intensity derived from EPS data can also be calibrated using an artificial neural network. The chance of rapid intensification can be estimated using statistical-dynamical methods such as logistic regression and Naïve Bayes classifier with input parameters from deterministic model forecast.	Addition of the information on the model output statistics methods for intensity prediction
108	L39	Rainfall related with the typhoon is~~are~~ roughly divided into the following four categories:~~;~~	Correction of the grammatical error
108	L47	Rainfall amount is~~are~~ predicted by the primitive equation model including cumulus parameterization scheme.	
108	L55	The MOS method is based on the statistical relations between the rainfall amount and the predictors obtained from the NWP products at the grid points. Model precipitation forecast at specific locations due to passage or landfall of tropical cyclones can be calibrated using frequency matching technique. Rainfall forecast from EPS systems can be used to generate the probability of heavy precipitation, various scenarios and their likelihood of occurrence caused by the tropical cyclones.	Addition of the information on the model output statistics method for rainfall prediction
109	L49	1.6.5 Nowcast and ~~V~~very-short range prediction of rainfall by radar observation	Revision of the title of subsection along with the contents of the body
109	L51	Radars are~~is~~ used to detect and track rain bands in tropical cyclones	Revision of the description on the very-short range prediction of
		and severe storms such as thunderstorms. Motion of radar~~rain~~ echoes over successive ~~radar~~ scans, for example, every 6 minutes can be retrieved using methods such as maximum correlation and variational 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.	rainfall by radar observation
109	L58	Accumulated rainfall over a forecast region around 6 to 9 hours	Addition of the information on the very-short range prediction of

		ahead can be obtained by extrapolating the radar echoes along the retrieved motion field and converting their intensity into rainfall amount through the Z-R relationship. By separating the motion field of a tropical cyclone into a translational part and a rotational part, followed by extrapolating the radar echoes based on the rotation and then the translation, the resulting projected radar echoes will result in better rainfall forecast.	rainfall by radar observation
110	L8	The guides for detection of rainfall area are~~is~~ summarized as follows:	Correction of the grammatical error
110	L39	Quantitative precipitation estimate of tropical cyclone using satellite observations can be retrieved through statistical method with the use of other meteorological data. For instance, ground-based radar data can be utilized to derive the reflectivity using neural network for landfalling tropical cyclones with inputs from infra-red and visible channels of the imager data from the geostationary satellites, where the blended reflectivity is then applied to estimate the rainfall amount.	Addition of the information on the very-short range prediction of rainfall by satellite observation
APPENDIX 3-E			
120-122	p.1-p.2	To be replaced by Annex 1-12	Update of the detailed information on Non-Hydrostatic Model (NHM) run by HKO
APPENDIX 5-A			
138	p.2	To be replaced by Annex 1-13	Revision of the contact detail of Macao, China
APPENDIX 5-C			
143	p.3	To be replaced by Annex 1-14	Revision of the table about collection and distribution of information
APPENDIX 5-D			
146		To be replaced by Annex 1-15	Revision of the table of abbreviated headings in accordance with WMO-No.386
APPENDIX 7-A			
156		To be replaced by Annex 1-16	Update of the information associated with the replacement to Himawari-8/9 of the geostationary meteorological satellite operated by JMA

Table 3.2 NWP products (GSM and EPS) provided by RSMC Tokyo - Typhoon Center
(Available at http://www.wis-jma.go.jp/cms/)

Model	GSM	GSM	GSM
Area and resolution	Whole globe, 1.25°×1.25°	20°S–60°N, 60°E–160°W 1.25°×1.25°	Whole globe, 2.5°×2.5°
Levels and elements	10 hPa: Z, U, V, T 20 hPa: Z, U, V, T 30 hPa: Z, U, V, T 50 hPa: Z, U, V, T 70 hPa: Z, U, V, T 100 hPa: Z, U, V, T 150 hPa: Z, U, V, T 200 hPa: Z, U, V, T, ψ, χ 250 hPa: Z, U, V, T 300 hPa: Z, U, V, T, H, ω 400 hPa: Z, U, V, T, H, ω 500 hPa: Z, U, V, T, H, ω, ζ 600 hPa: Z, U, V, T, H, ω 700 hPa: Z, U, V, T, H, ω 850 hPa: Z, U, V, T, H, ω, ψ, χ 925 hPa: Z, U, V, T, H, ω 1000 hPa: Z, U, V, T, H, ω Surface: P, U, V, T, H, R†	10 hPa: Z, U, V, T 20 hPa: Z, U, V, T 30 hPa: Z, U, V, T 50 hPa: Z, U, V, T 70 hPa: Z, U, V, T 100 hPa: Z, U, V, T 150 hPa: Z, U, V, T 200 hPa: Z§, U§, V§, T§, ψ, χ 250 hPa: Z, U, V, T 300 hPa: Z, U, V, T, D 400 hPa: Z, U, V, T, D 500 hPa: Z§, U§, V§, T§, D§, ζ 700 hPa: Z§, U§, V§, T§, D§, ω 850 hPa: Z§, U§, V§, T§, D§, ω, ψ, χ 925 hPa: Z, U, V, T, D, ω 1000 hPa: Z, U, V, T, D Surface: P¶, U¶, V¶, T¶, D¶, R¶	10 hPa: Z*, U*, V*, T* 20 hPa: Z*, U*, V*, T* 30 hPa: Z°, U°, V°, T° 50 hPa: Z°, U°, V°, T° 70 hPa: Z°, U°, V°, T° 100 hPa: Z°, U°, V°, T° 150 hPa: Z*, U*, V*, T* 200 hPa: Z, U, V, T 250 hPa: Z°, U°, V°, T° 300 hPa: Z, U, V, T, D*‡ 400 hPa: Z*, U*, V*, T*, D*‡ 500 hPa: Z, U, V, T, D*‡ 700 hPa: Z, U, V, T, D 850 hPa: Z, U, V, T, D 1000 hPa: Z, U*, V*, T*, D*‡ Surface: P, U, V, T, D*‡, R†
Forecast hours	0–84 every 6 hours and 96–192 every 12 hours for 12UTC initial † Except analysis	0–84 (every 6 hours) § 96–192 (every 24 hours) for 12UTC initial ¶ 90–192 (every 6 hours) for 12UTC initial	0–72 every 24 hours and 96–192 every 24 hours for 12UTC ° 0–120 for 12UTC † Except analysis * Analysis only
Initial times	00, 06, 12, 18UTC	00, 06, 12, 18UTC	00UTC and 12UTC ‡ 00UTC only

Model	One-week EPS
Area and resolution	Whole globe, 2.5°×2.5°
Levels and elements	250 hPa: μU, σU, μV, σV 500 hPa: μZ, σZ 850 hPa: μU, σU, μV, σV, μT, σT 1000 hPa: μZ, σZ Surface: μP, σP
Forecast hours	0–192 every 12 hours
Initial times	00, 12UTC

Table 3.3 List of other products provided by RSMC Tokyo - Typhoon Center
(Available at http://www.wis-jma.go.jp/cms/)

Data	Contents / frequency (initial time)
Satellite products	High density atmospheric motion vectors (BUFR) ~~(a) MTSAT-2 (VIS, IR, WV), 60S-60N, 90E-170W~~ ~~VIS: every hour (00-09, 21-23 UTC), IR and WV: every hour~~ ~~(b)~~ Himawari-8 (VIS, IR, WVx3: every hour), 60S-60N, 90E-170W ~~VIS: every hour (Northern Hemisphere: 00-09, 21-23 UTC;~~ ~~Southern Hemisphere: 00-08, 21-23 UTC), IR and WV: every hour~~ ~~(c) METEOSAT-7 (VIS, IR, WV)~~ ~~VIS: every 1.5 hours between 0130 and 1500 UTC~~ ~~IR and WV: every 1.5 hours~~ Clear Sky Radiance (CSR) data (BUFR) ~~(a) MTSAT-2 (IR, WV) radiances and brightness temperatures~~ ~~averaged over cloud-free pixels: every hour~~ ~~(b)~~ Himawari-8 radiances and brightness temperatures averaged over cloud-free pixels: every hour
Tropical cyclone Information	Tropical cyclone related information (BUFR) • tropical cyclone analysis data (00, 06, 12 and 18 UTC)
Wave data	Global Wave Model (GRIB2) • significant wave height • prevailing wave period • wave direction Forecast hours: 0–84 every 6 hours (00, 06 and 18UTC) 0–84 every 6 hours and 96-192~~264~~ every 12 hours (12 UTC)
Observational data	(a) Surface data (TAC/TDCF) SYNOP, SHIP, BUOY: Mostly 4 times a day (b) Upper-air data (TAC/TDCF) TEMP (parts A-D), PILOT (parts A-D): Mostly twice a day
Storm surge	Storm surge model for Asian area · storm surge distribution (map image) · time series charts (at requested locations) The plotted values are storm surges, predicted water levels, astronomical tides, surface winds, and sea level pressures. Forecast hours: 0–72 every 3 hours (00, 06 12, and 18UTC) Only in the case of a tropical cyclone being in the forecast time (Available at https://tynwp-web.kishou.go.jp/)
SATAID service	(a) Satellite imagery (SATAID) Himawari-8 (b) Observation data (SATAID) SYNOP, SHIP, METAR, TEMP (A, B) and ASCAT sea-surface wind (c) NWP products (SATAID) GSM (Available at http://www.wis-jma.go.jp/cms/sataid/)

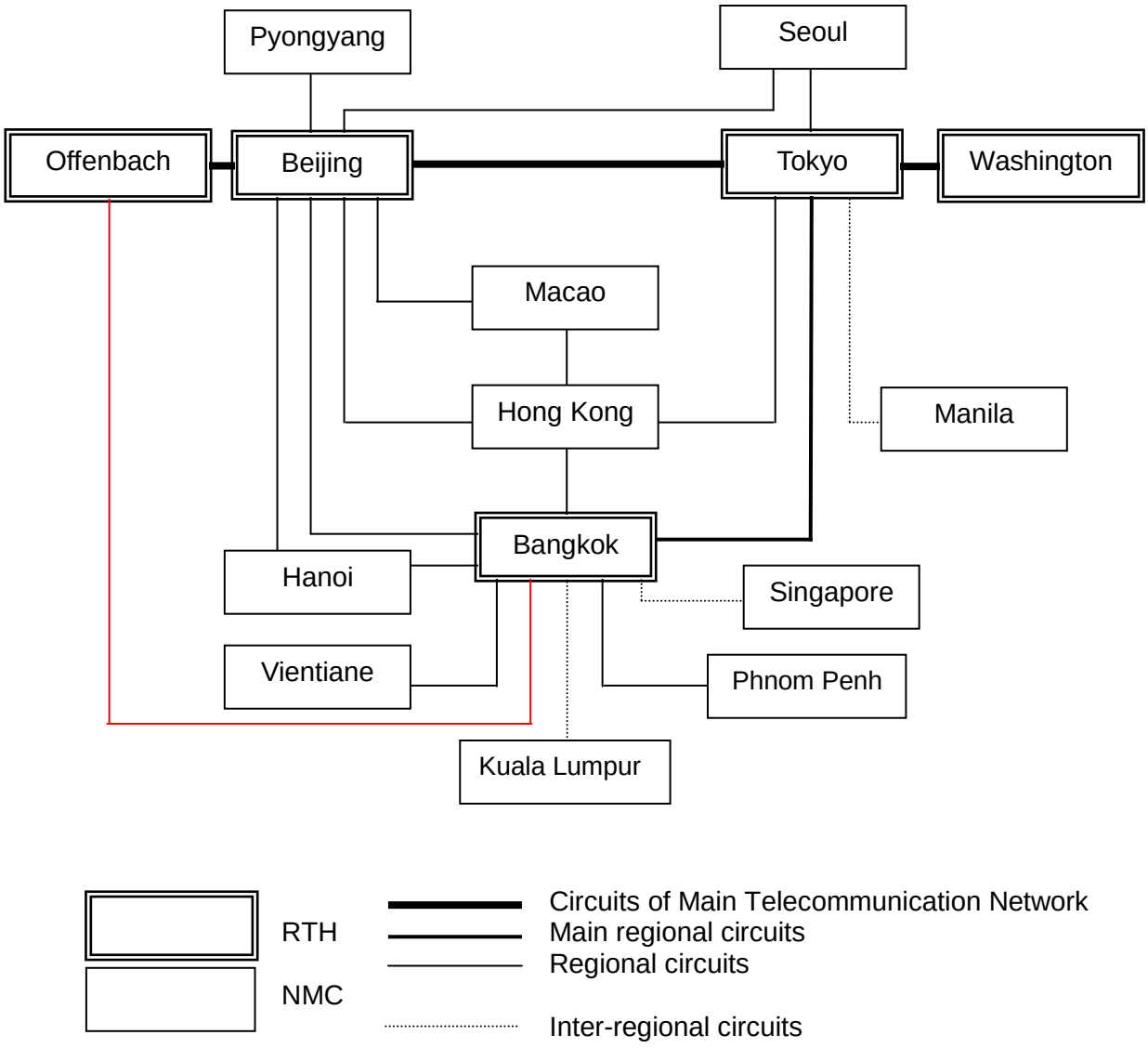

Figure 5.1 Meteorological telecommunication network for the Typhoon Committee

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 16 Mbps/Tokyo 10 Mbps
Beijing - Offenbach	Cable (FR), 48 kbps (MPLS) TCP/IP Beijing 16 Mbps/Offenbach 50 Mbps
Washington - Tokyo	Cable (MPLS), TCP/IP Washington 50 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 CMACast (Satellite broadcast)
Bangkok - Hanoi	64 kbps leased line, FTP protocol
Bangkok – Hong Kong	Internet, FTP protocol
Bangkok - Phnom Penh	Internet (VPN), TCP/IP
Bangkok - Vientiane	Cable (DDN), 64 kbps, Internet, FTP protocol
Beijing - Hanoi	64 kbps leased line, CMACast (Satellite broadcast)
Beijing - Hong Kong	Cable (MSTP), 4 Mbps TCP/IP CMACast (Satellite broadcast)
Beijing - Macao	2Mbps leased line CMACast (Satellite broadcast)
Beijing - Pyongyang	64 kbps leased line,; CMACast (Satellite broadcast)
Beijing - Seoul	Cable (FR), 32 kbps (CIR) TCP/IP
Beijing - Vientiane	CMACast (Satellite broadcast)
Hong Kong - Macao	Internet (VPN)~~ISDN, 128 kbps, TCP/IP~~
Tokyo - Hong Kong	Cable (MPLS), TCP/IP

	Tokyo 2 Mbps/Hong Kong 1 Mbps
Tokyo - Seoul	Cable (MPLS), TCP/IP Tokyo 10 Mbps/Seoul 4 Mbps

4. Inter-regional circuits

Bangkok - Kuala Lumpur	Cable (MPLS), TCP/IP 64 kbps
Bangkok - Singapore	Cable (MPLS), TCP/IP 64 kbps
Bangkok - Offenbach	Internet, FTP protocol
Tokyo - Manila	Cable (MPLS), TCP/IP Tokyo 2 Mbps/Manila 64 kbps

5. RTH radio broadcast

Bangkok	1 FAX
Tokyo	1 FAX

6. Satellite broadcast

Operated by China: Asiasat-4 (122.2°E)	Operational observations, warnings, NWP products, satellite image and fax distribution
Operated by Japan: HimawariCast (JCSAT-2, 154°E)	Operational satellite image, NWP~~and data~~ products, in-situ observation data and ASCAT ocean surface wind data distribution

7. Internet Cloud Service

Operated by Japan: HimawariCloud	Operational satellite image in full resolutions and bands

Philippines

(98): 132, 133, 135, 222, 232, 233, 324, 325, 328, 329,
330, 333, 336, 425, 427, 428, 429, 430, 431, 432,
434, 435, 437, 440, 444, 446, 447, 526, 531, 536,
538, 543, 546, 548, 550, 555, 558, 618, 630, 637,
642, 644, 646, 648, 653, 741, 746, 747, 748, 751,
752, 753, 755, 836, 851

Republic of Korea

(47): 090, 095, 098, 099, 100, 101, 102, 105, 106, 108,

112, 114, 115, 119, 121, 127, 129, 130, 131, 133,
135, 136, 137, 138, 140, 143, 146, 152, 155, 156,

159, 162, 165, 168, 169, 170, 175, 184, 185, 189,
192

Thailand

(48): 300, 303, 310, 327, 328, 329, 330, 331, 351, 352,
353, 354, 356, 357, 372, 375, 376, 378, 379, 380,
381, 383, 400, 403, 405, 407, 425, 426, 430, 431,
432, 437, 450, 453, 455, 456, 459, 462, 465, 477,
478, 480, 500, 501, 517, 532, 551, 552, 561, 564,
565, 566, 567, 568, 569, 570, 580, 583

USA

(91): 203, 212, 258, 317, 324, 334, 339, 348, 353, 356,
366, 367, 369, 371, 376, 378, 408, 413, 425, 434

Viet Nam

(48): 820, 826, 839, 845, 848, 855, 870, 877, 900, 914,
917, 918, 920

Note: Name, latitude, longitude and elevation of these stations are included in Weather Reporting, Volume A - Observing Stations (WMO Publication No. 9).

LIST OF STATIONS FROM WHICH ENHANCED UPPER-AIR OBSERVATIONS ARE AVAILABLE

The following stations will make 6-hourly upper-air observations when they are within 300 km of the centre of a tropical cyclone of TS intensity or higher:

Cambodia

China

(54): 857
(57): 083, 494, 972
(58): 150, 457, 847
(59): 316, 758, 981

Democratic People's Republic of Korea

(47): 041, 058

Hong Kong, China

(45): 004
upper-air observations are made by wind profiler at 06 and 18 UTC normally, but radiosondes will be launched when warranted by local wind conditions

Japan

(47): 401, 412, 418, 582, 600, 646, 678, 741, 778, 807, 827, 909, 918, 945, 971*, 991*
* except 18 UTC

Lao People's Democratic Republic

Macao, China

Malaysia

(48): 601, 615, 650, 657
(96): 413, 441, 471, 481

Philippines

(98): 223, 433, 444, 618, 646, 573

Republic of Korea

(47): 090, 102, 122, 138, 158, 169, 185

Thailand

(48): 327, 354, 378, 407, 431, 453, 480, 500, 551, 565, 568

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

NAME OF STATION		Tai Mo Shan	Tate's Cairnm			
SPECIFICATIONS	Unit					
Index number		45009	45010			
Location of station		22° 25´ N 114° 07´ E	22° 21´ N 114° 13´ E			
Antenna elevation	m	968	582			
Wave length	cm	10.6	10.3			
Peak power of transmitter	kW	650	650			
Pulse length	μ s	1.0/1.8	1.0/2.0			
Sensitivity minimum of receiver	dBm	-117	-114			
Beam width (Width of over -3dB antenna gain of maximum)	deg	0.9(H) 0.9(V)	0.9			
Detection range	km	500	500			
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2			
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) 1.Hourly 2.3-hourly 3.Others		3 (Continuous)	3 (Continuous)			
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)		1	1			

SATELLITE IMAGERY RECEIVING FACILITIES AT TYPHOON COMMITTEE MEMBERS

Member	Station		Himawari 1. Himawari Cloud 2. Himawari Cast	NOAA 1. HRPT 2. APT	Meteosat 1. P-DUS
Cambodia			1, 2		
China	Beijing Shanghai Shenyan Guangzhou Cheng-chou Cheng-tu Lan-chou Kunming Changsha Nanjing Harbin	(39.9°N, 116.4°E) (31.1°N, 121.4°E) (41.8°N, 123.6°E) (23.1°N, 113.3°E) (34.7°N, 113.7°E) (31.2°N, 114.0°E) (36.1°N, 103.9°E) (25.0°N, 102.7°E) (28.2°N, 113.1°E) (32.0°N, 118.8°E) (45.8°N, 126.8°E)	1	1, 2 2	
Democratic People's Republic of Korea	Pyongyang	(39.0°N, 125.8°E)		1	
Hong Kong, China*	Kowloon	(22.3°N, 114.2°E)	1, 2 ~~Receiving Himawari-8 (replacement of MTSAT) via Internet download and HimawariCast~~	1	
Japan	Minamitorishima	(24.3°N, 154.0°E)	2		

*Hong Kong, China receives AQUA (MODIS), NPP(CrIs, VIIRS, ATMS), FY-2 (S-VISSR), and TERRA (MODIS).

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

Item	Method	Type of output
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 European Centre for Medium-Range Weather Forecasts (ECMWF)~~UKMO (EGRR)~~, Japan Meteorological Agency (JMA), National Centers for Environmental Prediction (NCEP) and the United Kingdom Meteorological Office (UKMO)~~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. [3] Y.T. Tam, W.K. Wong and M.Y. Chan, 2015: Error Characteristics of Numerical Weather Prediction Model Ensemble in Tropical Cyclone Track Prediction. [http://www.weather.gov.hk/publica/reprint/r1167.pdf]	24, 48, 72, 96 and 120-hr forecast positions

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 Himawari-8~~MTSAT-2~~
ATOVS	retrieved temperature profiles from NOAA
Ocean surface wind	scatterometer wind retrieval data from ASCAT, RAPID-SCAT and HY2A
Dropsonde	tropical cyclone wind observations from DOTSTAR
IASI	temperature and humidity retrieval profile data from EUMETSAT Metop IASI (Infrared Atmospheric Sounding Interferometer)

(B) Regional data exchange
Data from automatic weather stations over the south China coastal areas

(C) Local data
(i) Automatic weather station data
(ii) Wind profiler data
(iii) Doppler weather radar data
(iv) 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
(v) 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	10-km NHM: Lambert Conformal 2-km NHM: Mercator
Number of grid points	10-km NHM: 841x515, 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 ECMWF IFS forecast at horizontal resolution of 0.125 degree in latitude/longitude and on 25 pressure levels (1000, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10,7,5,3,2 and 1 hPa) For 2-km NHM, 3-hourly interval boundary data provided from ECMWF IFS~~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	Tiedtke-based bulk mass flux~~Kain-Fritsch~~ convective parameterization (HKO~~JMA-NHM~~ version) Three ice bulk microphysics scheme
Surface process	Flux and bulk coefficients: Land: Beljaars and Holtslag (1991) Sea: Wong, Sumdin and Lai (2010) 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 2.5~~3~~ (MYNN-2.5~~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.

ECMWF, 2015: Convection. *IFS Documentation CY41R1*, Part IV, Chapter 6, ECMWF, 73-90. [Available at http://www.ecmwf.int/en/forecasts/documentation-and-support/changes-ecmwf-model/ifs-documentation]

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]

Wong, W.K., S. Sumdin and E.S.T. Lai, 2010: Development of Air-Sea Bulk Transfer Coefficients and Roughness Lengths in JMA Non-hydrostatic Model and Application in Prediction of an Intense Tropical Cyclone. *SOLA*, **6**, 065-068.

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

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Annex 1-14
APPENDIX 5-C, p.3

Type of Data	Heading		Receiving station TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
			*										
Satellite	TPPN10	PGTW			TD	TD			BB	BB	BB	BB	
guidance	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	
	IUCC010	VHHH	HH	HH	HH	O							
	IUCC02	VHHH	HH	HH	HH	O							
	IUCC03	VHHH	HH	HH	HH	O							
	IUCC04	VHHH	HH	HH	HH	O							
Tropical	FXPQ01	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
Cyclone	FXPQ02	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
Forecast	FXPQ03	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
	FXPQ20	VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	HH
	FXPQ21	VHHH	HH	HH		O							
	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	HH
	FXSS02	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
	FXSS03	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
	FXSS20	VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	HH
	FXSS21	VHHH	HH	HH		O							
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	HH
	WTSS20	VHHH	HH	HH	BJ	O			BB	BB	BB	BB	HH
	WTTH20	VTBB	BB	TD	O	TD			BB	BB	BB	BB	
	WTVS20	VNNN			NN	BJ			O	BB	BB	BB	
Continued to	WTPQ20	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
the next page	WTPQ21	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	

Annex 1-15
APPENDIX 5-D

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	Marine/Coastal flood~~Hurricane~~ warnings
WO	Other warnings
WC	Tropical cyclone(SIGMET)
WT	Tropical cyclone warnings
WW	Warning and weather summary

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

~~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 RJTD	Radar reports
ISBC01 VHHH	Radar reports
IUCC01-04 VHHH	SAREP reports
IUCC10 RJTD	SAREP reports
~~ISBC01 RJTD~~	~~Radar reports~~
~~IUCC10 RJTD~~	~~SAREP reports~~

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

LIST OF DATA ARCHIVED BY RSMC TOKYO - TYPHOON CENTER

(a) Level II-b

Kinds of data: Surface, ship, buoy, upper-air, RADOB, aircraft, ASDAR, advisory warning, SAREP, SATEM, SATOB, TBB grid value and cloud amount (GMS);

Area coverage: SATEM : 90°E ~ 180°E and 0° ~ 45°N

SATOB, TBB grid value and cloud amount : area covered by Himawari series~~MTSAT~~

Other data : within the area of 80°E ~ 160°W and 20°S ~ 60°N

(b) Himawari imagery data

Himawari Standard Data (HSD):

Kind of data: Himawari full-spec imagery data

Data format: Himawari Standard Format (http://www.data.jma.go.jp/mscweb/en/himawari89/space_segment/hsd_sample/HS_D_users_guide_en_v12.pdf)

Meteorological Satellite Center Monthly Report (DVD):

Kinds of data: Himawari images in SATAID and PNG formats. (http://www.data.jma.go.jp/mscweb/en/product/library/report/)

Area coverage:
SATAID: 115°E ~ 150°E and 15°N ~ 50°N
PNG: Full earth disk as seen from 140°E

(c) Level III-a

Kinds of data: Grid point data of the objective analysis obtained by the global objective analysis system in RSMC.

Area coverage: Global area covered by 1.25 X 1.25 latitude-longitude grid system.

Time of analysis: 00, 06, 12 and 18 UTC

Element and layer:

Surface: Sea surface pressure (Ps), temperature (Ts), dew point depression (Ts - Tds), wind (Us, Vs);

Specific pressure levels (1000 - 10 hPa):
Geopotential height (Z), temperature (T), wind (U, V);