ECONOMIC AND SOCIAL COMMISSION
FOR ASIA AND THE PACIFIC
AND
WORLD METEOROLOGICAL ORGANIZATION

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Typhoon Committee
Forty-fourth Session
06 to 11 February 2012
Hangzhou, China

REPORT ON AMENDMENTS TO THE TYPHOON COMMITTEE OPERATIONAL MANUAL

(Item 4.6 of the Provisional Agenda)

Submitted by the Rapporteur

Introduction

1. The Typhoon Committee Operational Manual - Meteorological Component (TOM) has been reviewed and updated every year since its first issue in 1987. The 2011 edition was completed and posted on the WMO website in March 2011 in accordance with the approval of amendments to the previous issue by the 43rd session of the Typhoon Committee (17 to 22 January 2011, Jeju, Republic of Korea).

2. At the 43rd session, the Committee decided that the rapporteur of the Japan Meteorological Agency (JMA) would continue arrangements for updating the TOM. In this connection, on 26 September 2011, the rapporteur, Mr Masashi Kunitsugu, Head of the JMA National 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 2012, proposals for updates to the TOM had been submitted by the three focal points of Hong Kong - China, Japan and Republic of Korea.

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

- Update of information on AMV data availability (Chapter 2)
- Inclusion of information on storm surge model products (Chapter 3)
- Update of information on telecommunication network (Chapter 5)
- Update of distribution of radar stations (Appendix 2-C)
- Update of technical specifications of radars in Republic of Korea (Appendix 2-D)
- Inclusion of information on SATAID service provided by DCPC of JMA (Appendix 2-E)
- Update of outline of RSMC Tokyo tropical cyclone prediction models (Appendix 3-A)
- Update of information on operational typhoon track forecast methods of Hong Kong - China and Republic of Korea (Appendix 3-B)
- Update of outline of KMA - Typhoon Dynamic MODELS (Appendix 3-D)
- Update of outline of HKO Non-Hydrostatic Model (Appendix 3-E)
- Update of list of data archived by RSMC Tokyo - Typhoon Center (Appendix 7-A)

Action Proposed

5. The Committee is invited to:

(a) Note the information given in this document,

(b) Review and approve the proposed amendments to the TOM attached as Annex 1 with necessary modifications.

Annex 1

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

Page	Line	Present Description	Proposed Amendment
Chapter 2.4			
9	3	(iv) AMV data are derived three-hourly in the northern hemisphere and six-hourly in the southern hemisphere	(iv) AMV data are derived hourly
Chapter 3.2			
15	24		*<<sentence to be inserted >>* Storm surge products suitable for the Typhoon Committee region should be provided by the RSMC Tokyo - Typhoon Center.
13	Table 3.2		*<<to be replaced by>>* New document (see Annex 1-1)
14	Table 3.3		*<<to be replaced by>>* New document (see Annex 1-2)
Chapter 5.4			
20	6	*<<Telecommunication>>* Beijing 3 Mbps/Tokyo 3 Mbps	Beijing 3 Mbps/Tokyo 10 Mbps
20	9	Washington 1 Mbps/Tokyo 3 Mbps	Washington 1 Mbps/Tokyo 10 Mbps
Chapter 7.2			
25	10	*<<Data to be archived>>* Except for satellite cloud pictures,	Except for satellite imagery data,
Appendix 2-C			
37		*<<Distribution of the radar stations>>*	*<<to be replaced by>>* New document (see Annex 1-3)
Appendix 2-D			
51-52		*<<Technical Specifications of Radars of Republic of Korea>>*	*<<to be replaced by>>* New document (see Annex 1-4)
Appendix 2-E			
62	37	*<<Schedule of MTSAT Observations and Disseminations>>*	*<<sentence to be inserted>>* [SATAID (Satellite Animation and Interactive Diagnosis) Service] http://www.wis-jma.go.jp/cms/sataid/

Appendix 3-A			
72-73		*<<Outline of RSMC Tokyo - Tropical Cyclone Prediction Models>>*	*<<to be replaced by>>* New document (see Annex 1-5)
Appendix 3-B			
79		*<<Operation Typhoon Track Forecast Methods, Hong Kong, China>>*	*<<to be replaced by>>* New document (see Annex 1-6)
89		*<<Operation Typhoon Track Forecast Methods, Republic of Korea >>*	*<<to be replaced by>>* New document (see Annex 1-7)
Appendix 3-D			
134-136		*<<Outline of KMA - Typhoon Dynamic MODELS*	*<<to be replaced by>>* New document (see Annex 1-8)
Appendix 3-E			
137-139		*<<Outline of HKO -* *(1) Operational Regional Spectral Model* *(2) Non-Hydrostatic Model (NHM)>>*	 *<<to be deleted >>* *<<to be replaced by>>* New document (see Annex 1-9)
Appendix 5-C			
161		*<<Collection and Distribution of Information>>*	*<<to be replaced by>>* New document (see Annex 1-10)
Appendix 7-A			
175		*<<LIST OF DATA ARCHIVED BY RSMC TOKYO - TYPHOON CENTER* *(b) MTSAT cloud pictures>>*	*<<to be replaced by>>* New document (see Annex 1-11)
176		*<<Annex>>*	*<< to be deleted >>*

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 † 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	GSM	Mid-range EPS
Area and resolution	20°S–60°N, 80°E–200°E 2.5°×2.5° (to be terminated in March 2012)	Whole globe, 2.5°×2.5°
Levels and elements	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 500 hPa: Z, U, V, T, D, ζ 700 hPa: Z, U, V, T, D, ω 850 hPa: Z, U, V, T, D, ω Surface: P, U, V, T, D, R	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	0–36 every 6 hours, 48, 60, and 72	0–192 every 12 hours
Initial times	00UTC and 12UTC	12UTC

Model	GSM	GSM
Area and resolution	5S-90N and 30E-165W, Whole globe 0.25° × 0.25°	5S-90N and 30E-165W, Whole globe 0.5° × 0.5°
Levels and elements	Surface: U, V, T, H, P, Ps, R, Cla, Clh, Clm, Cll	10 hPa: Z, U, V, T, H, ω 20 hPa: Z, U, V, T, H, ω 30 hPa: Z, U, V, T, H, ω 50 hPa: Z, U, V, T, H, ω 70 hPa: Z, U, V, T, H, ω 100 hPa: Z, U, V, T, H, ω 150 hPa: Z, U, V, T, H, ω 200 hPa: Z, U, V, T, H, ω, ψ, χ 250 hPa: Z, U, V, T, H, ω 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 800 hPa: Z, U, V, T, H, ω 850 hPa: Z, U, V, T, H, ω, ψ, χ 900 hPa: Z, U, V, T, H, ω 925 hPa: Z, U, V, T, H, ω 950 hPa: Z, U, V, T, H, ω 975 hPa: Z, U, V, T, H, ω 1000 hPa: Z, U, V, T, H, ω Surface: U, V, T, H, P, Ps, R, Cla, Clh, Clm, Cll
Forecast hours	0– 84 (every 6 hours) and 90–216 (every 24 hours) are also available for 12 UTC Initial time.	0– 84 (every 6 hours) and 90–216 (every 24 hours) are also available for 12 UTC Initial time.
Initial times	00, 06, 12, 18 UTC	00, 06, 12, 18 UTC

Notes: Z: geopotential height U: eastward wind V: northward wind
T: temperature D: dewpoint depression H: relative humidity
ω: vertical velocity ζ: vorticity ψ: stream function
χ: velocity potential P: sea level pressure Ps: pressure
R: rainfall Cla: total cloudiness Clh: cloudiness (upper layer)
Clm: cloudiness (middle layer) Cll: cloudiness (lower layer)

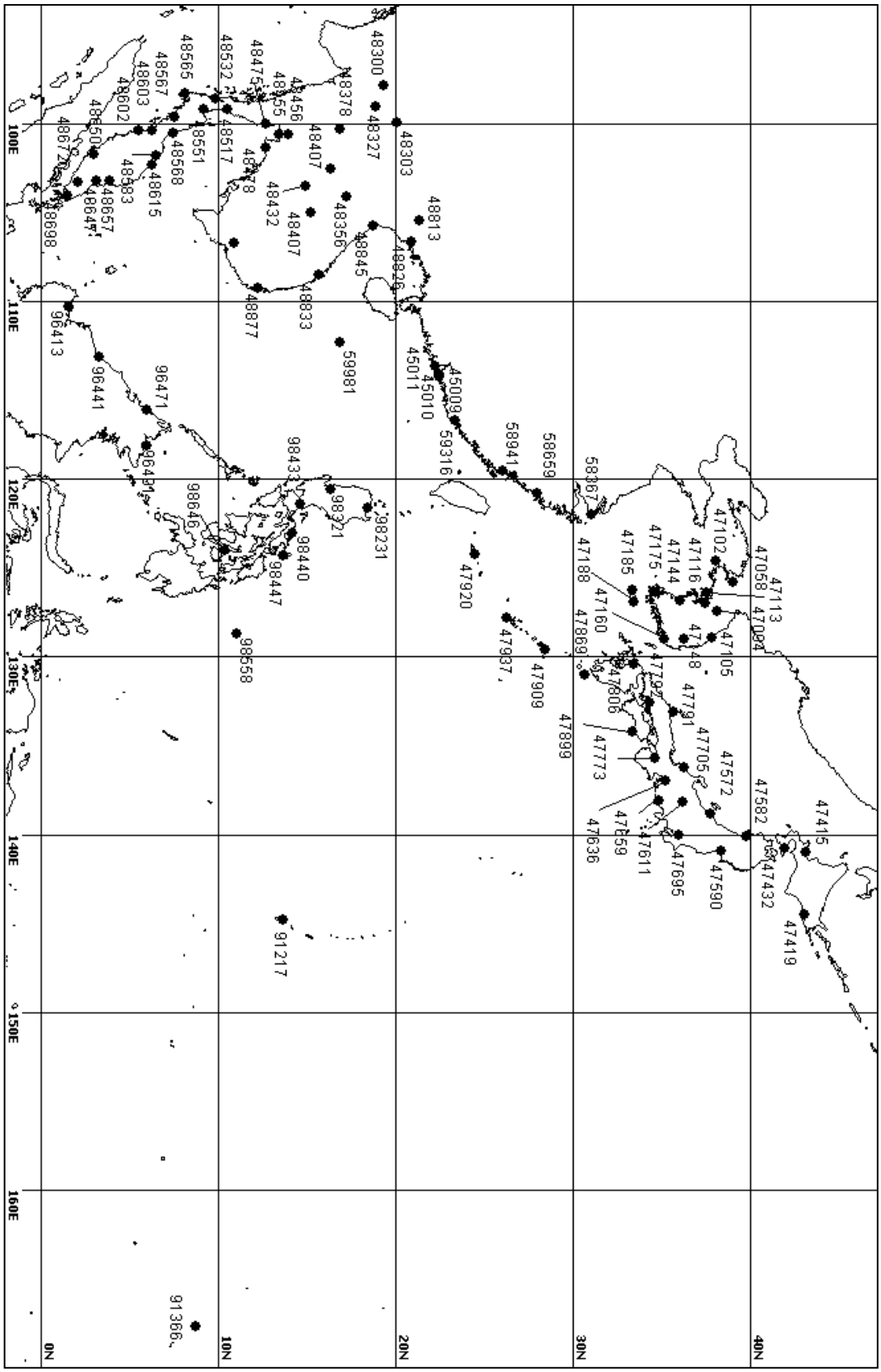
The prefixes μ and σ represent the average and standard deviation of ensemble prediction results respectively.
The symbols °, *, ¶, §, ‡ and † indicate limitations on forecast hours or initial time as shown in the tables.

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) 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) MTSAT-2 (IR, WV) 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 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 (map image) • storm surge distribution 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/)

Annex 1-3
APPENDIX 2-C

DISTRIBUTION OF THE RADAR STATIONS OF TYPHOON COMMITTEE MEMBERS



Name of the Member **Republic of Korea - 1**

NAME OF STATION		Gosan	Seongsan	Gangneung	Oseongsan	Baengnyeong-do
SPECIFICATIONS	Unit					
Index number		47185	47188	47105	47144	47102
Location of station		33° 17′ N 126° 09′ E	33° 23′ N 126° 52′ E	37° 49′ N 128° 51′ E	36° 00′ N 126° 47′ E	37° 58′ N 124° 37′ E
Antenna elevation	m	101	68	99	231	188
Wave length	Cm	10.9	10.8	10.5	10.9	5.3
Peak power of transmitter	kW	750	750	750	750	250
Pulse length	μs	1.0; 4.5	1.0; 4.5	1.0; 4.5	1.0; 4.5	1.0; 2.0
Sensitivity minimum of receiver	dBm	-112	-112	-112	-112	-108
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.0	1.0	1.0	1.0	1.0
Detection range	km	250 (volume) 500 (lowest tilt)	250, 500	280, 500	240, 480	256, 480
Scan mode in observation 1. Fixed elevation 2. CAPPI 3. Manually controlled		1, 2	1, 2	1, 2	1, 2	1, 2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2	2	2	2
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. Hourly 2. 3-hourly 3. Others		3 (continuous)	3 (continuous)	3 (continuous)	3 (continuous)	3 (continuous)
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Republic of Korea - 2**

NAME OF STATION		Jindo	Gwangdeok -san	Myeonbong -san	Gwanaksan	Gudeoksan
SPECIFICATIONS	Unit					
Index number		47175	47094	47148	47116	47160
Location of station		34° 28′ N 126° 19′ E	38° 07′ N 127° 26′ E	36° 10′ N 128° 59′ E	37° 26′ N 126° 57′ E	35° 07′ N 128° 59′ E
Antenna elevation	m	497	1064	1127	640	547
Wave length	cm	10.3	10.3	5.3	11	11
Peak power of transmitter	kW	750	750	250	850	850
Pulse length	μs	1.0; 2.5	1.0; 4.5	0.83; 2.5	1.0; 4.5	1.0; 4.5
Sensitivity minimum of receiver	dBm	-112	-112	-112	-114	-114
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.0	1.0	1.0	1.0	1.0
Detection range	km	240, 480	250, 500	200	240, 480	240, 480
Scan mode in observation 1. Fixed elevation 2. CAPPI 3. Manually controlled		1, 2	1, 2	1, 2	1, 2	1, 2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2	2	2	2
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. Hourly 2. 3-hourly 3. Others		3 (continuous)	3 (continuous)	3 (continuous)	3 (continuous)	3 (continuous)
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

OUTLINE OF RSMC TOKYO - TROPICAL CYCLONE PREDICTION MODELS

(a) Global Spectral Model (GSM-1110)

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 5.6 ~ 11.6 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
- Model p-sigma hybrid levels (60) + 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 216 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 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 by Smith (1990)
- Bulk formulae for surface fluxes with similarity functions by Louis (1982)
- Vertical diffusion with the level-2 closure model by Mellor and Yamada (1974) with moist effect included
- Gravity wave drag by Palmer et al. (1986) and Iwasaki et al. (1989)
- Simple Biosphere Model (SiB) by Sellers et al. (1986) and Sato et al. (1989a,b)

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
- A stochastic physics scheme to represent model uncertainties
  - Perturbed parameterized tendencies of u, v, T and q

Ensemble size:

11

Operation:

(schedule)

Four times a day (0000, 0600, 1200 and 1800 UTC)

(tropical cyclone conditions that can trigger model prediction)

- a tropical cyclone of TS intensity or higher exists in the area of responsibility (0°N - 60°N, 100°E - 180°E)
- a tropical cyclone is expected to reach TS intensity or higher in the area within the next 24 hours
- 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
- TL319 spectral discretization in the horizontal direction
- Reduced Gaussian grid, roughly equivalent to 0.5625° x 0.5625° in latitude and longitude (~55km grid)
- Finite differencing on 60 p-sigma hybrid levels in the vertical direction

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

Item	Method	Type of output
Name of the method Description of the method	Non-Hydrostatic Model (NHM) See Appendix 3-E	Tropical cyclone position forecasts, surface and upper level prognoses up to 72 hours from the 10-km NHM, and up to 15 hours from the 2-km NHM. Tropical cyclone forecast guidance bulletins based on the 10-km NHM will be disseminated through the GTS when a tropical cyclone is within 10N to 30N and 105E to 125E.

Name of the Member **Republic of Korea**

Item	Method	Type of output
Name of the method	**Global Data Assimilation and Prediction System (GDAPS)**	TC positions up to 252 hours at 00/12 UTC and 72 hrs at 06/18 UTC
Description of the method	Governing equations: Non-hydrostatic Vertical resolution: 70 levels in hybrid coordinate. Model top 80 km Horizontal representation: Spherical latitude-longitude. Resolution 0.234° latitude and 0.352° longitude. Initialization: 4DVAR (See Appendix 3-D (1))	
Name of the method	**Regional Data Assimilation and Prediction System (RDAPS)**	TC positions up to 72 hours at 00/06/12/18 UTC
Description of the method	Governing equations: Non-hydrostatic Vertical resolution: 70 levels in hybrid coordinate. Model top 80 km Horizontal resolution: Spherical rotated latitude-longitude. Resolution 0.11°. Initialization: 4DVAR Boundary condition: Specified from GDAPS with 3-hr interval (See Appendix 3-D (2))	
Name of the method	**Double Fourier-series BAROtropic typhoon model (DBAR)**	6 hourly TC position up to 72 hours at 00/06/12/18 UTC
Description of the method	Governing equation: Shallow water equations Domain: Global Resolution: 0.3515° Initial field: global analysis from GDAPS 4DVAR (See Appendix 3-D (3))	

OUTLINE OF KMA - Typhoon Dynamic MODELS

(1) < Global Data Assimilation and Prediction System (GDAPS) >

Initial field:

(analysis)

4DVAR (Resolution: 0.833° latitude and 1.25° longitude)

(bogusing)

winds and sea level pressure generated by empirical formulas and observations

(initialization) 4DVAR

Operation:

(schedule)

four times (00, 06, 12, 18UTC) a day

(integration time)

252 hours at 00, 12UTC and 72 hours at 06, 18 UTC

Prediction model:

(dynamics)

Non-hydrostatic

(vertical resolution)

70 levels in hybrid coordinate

(horizontal resolution)

Spherical latitude-longitude with 0.234° latitude and 0.352° resolution

Time integration:

Two time-level semi-Lagrangian advection with a pressure correction semi-implicit time stepping method using a Helmoltz solver to include non-hydrostatic terms.

Physics:

(diffusion)

2nd-order horizontal diffusion of surface winds, specific humidity and potential temperature

2nd-order vertical diffusion of winds only between 500 and 150 hPa in the tropics

(surface flux and boundary layer)

Met Office Surface Exchange Scheme (MOSES II; Cox et al., 2001)

Non-local boundary layer scheme (Lock et al., 2000)

(cumulus convection)

Mass flux convection with CAPE closure, momentum transports and convective anvils

(microphysics)

Mixed phase precipitation (Wilson and Ballard, 1999)

(radiation)

Edwards-Slingo (1996) radiation scheme with non-spherical ice spectral files

Products:

location (lat./lon.), central pressure, maximum tangential winds, every 6 hr up to 252 hours

(2) < Regional Data Assimilation and Prediction System (RDAPS) >

Data assimilation:

(objective analysis)

4DVAR

(bogusing of tropical cyclones)

winds and sea level pressure generated by empirical formulas and observations

Dynamics:

(basic equations)

non-hydrostatic

(domain)

East Asia region

(vertical levels)

70 levels and 80km top

Physics:

(diffusion)

none

(surface flux and boundary layer)

Met Office Surface Exchange Scheme (MOSES II; Cox et al., 2001)

Non-local boundary layer scheme (Lock et al., 2000)

(cumulus convection)

Mass flux convection with CAPE closure, momentum transports and convective anvils

(microphysics)

Mixed phase precipitation (Wilson and Ballard, 1999)

(radiation)

Edwards-Slingo (1996) radiation scheme with non-spherical ice spectral files

Initial conditions:

4DVAR

Boundary conditions:

specified from GDAPS with the previous time

Frequency of forecast:

four times a day (00, 06, 12, 18 UTC)

Products:

location (lat./lon.), central pressure, and maximum tangential winds every 6 hr
up to 72 hours

(3) < Double Fourier-series BARotropic typhoon model (DBAR) >

Initial field:

Analysis from a GDAPS (4DVAR)
Height field obtained by solving the balance equation

Operation:

(schedule)

Four times (00, 06, 12, and 18 UTC) a day

(Integration time)

72 hours from 00, 06, 12, and 18 UTC

Prediction model:

(dynamics)

shallow water equations

(horizontal resolution)

grid (lat*lon): 512*1024, ~0.3515° x 0.3515° spacing

(vertical level)

1 level

(spectral transform method)

double Fourier series

Products:

6-hourly TC location (lat./lon.) in the western North Pacific up to 72 hours

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

(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

Type of Data	Heading		Receiving station TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
Enhanced	UKTH01	VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
Upper-air	ULTH01	VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
observation	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	SNVB20	VTBB			O				BB	BB	BB	BB	
ship	SNVB20	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
observation	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	SBCI30	BABJ	BJ	O	BJ	TD	TD	TD	BJ	BB	BB	BB	
radar	SCCI30	BABJ		O	BJ	BJ			BB	BB	BB	BB	
observation	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			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	

(b) MTSAT imagery data

High Rate Information Transmission (HRIT) Data:

Kind of data: MTSAT high resolution digital imagery data

Data format: "JMA HRIT Mission Specification Implementation", Issue 1.2, 1 Jan. 2003

(http://www.jma.go.jp/jma/jma-eng/satellite/mtsat1r/4.2HRIT_1.pdf)

Resolution: 1 km (VIS) and 4 km (IR) at the sub-satellite point

Channel and wavelength (micrometers):

VIS: 0.55 - 0.90
IR1: 10.3 - 11.3
IR2: 11.5 - 12.5
IR3: 6.5 - 7.0
IR4: 3.5 - 4.0

Brightness level: 10 bits (1,024 gradations)

Meteorological Satellite Center Monthly Report (CD-ROM):

Kinds of data: MTSAT images of SATAID and PNG formats. (http://mscweb.kishou.go.jp/product/library/report/index.htm)

Area coverage:

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