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TROPICAL CYCLONE PROGRAMME

Report No. TCP-23

TYPHOON COMMITTEE OPERATIONAL MANUAL

METEOROLOGICAL COMPONENT

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GENEVA SWITZERLAND

N O T E

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CHAPTER 1

GENERAL

1.1 Introduction

Typhoons have always been a major threat to the Typhoon Committee region. As a result, they are a common target for meteorological services in the region to monitor, analyse, forecast and warn against.

Under the spirit of international co-operation, a regional programme to mitigate the damage due to tropical cyclones was launched by the Typhoon Committee which was established in 1968. Since its establishment under the auspices of ESCAP in co-operation with WMO, the Typhoon Committee has developed its area of activities to consist of three components, i.e., meteorological, hydrological and disaster prevention and preparedness.

Of these components, the meteorological component aims at improving and upgrading the analysis and forecast used for the routine operation. For this purpose, the Typhoon Committee has arranged a variety of co-operation efforts. One of the epoch-making events in the history of the Committee was the Typhoon Operational Experiment (TOPEX), which was organized for all three components. (The third component was specifically organized as Warning Dissemination and Information Exchange Component).

The Meteorological Component of TOPEX had a co-operation programme where concerted efforts were exerted to analyze and forecast specified typhoons using common technical procedures. The procedures were described in the TOPEX Operational Manual which had been utilized in meteorological services in the Typhoon Committee region during the operational phase of TOPEX.

Activities of the Meteorological Component of the Typhoon Committee – including execution of the meteorological component of TOPEX for three years – had been planned and organized under the Tropical Cyclone Programme (TCP) of the World Meteorological Organization (WMO). The main long-term objective of the TCP is to assist Members in upgrading the capabilities of NMHSs to provide better tropical cyclone, related flood and storm surge forecasts and more effective warnings through regionally coordinated systems, and to encourage Members to establish national disaster prevention and preparedness measures.

As a result of international cooperation and coordination, and with the aid of meteorology and modern technology, such as satellites, weather radars and computers, all tropical cyclones around the globe are now being monitored from their early stages of formation and throughout their lifetime. Six centres designated by WMO as Regional Specialized Meteorological Centres (RSMCs) located in Honolulu, La Reunion, Miami, Nadi (Fiji), New Delhi and Tokyo, as well as other centres of national Meteorological Services carry out these activities. These centres also provide forecasts on the behaviour of tropical cyclones, their movement and changes in intensity and on associated phenomena – principally storm surges and flash floods.

The responsibility of the RSMC Tokyo - Typhoon Center is the provision of information on tropical cyclones for Members of the Typhoon Committee. Information should include formation, movement and development of tropical cyclones and associated meteorological phenomena. In addition, synoptic scale atmospheric situation which affects the behaviour of tropical cyclones should also be prepared by the RSMC Tokyo - Typhoon Center and disseminated to NMCs in the appropriate format for operational processing. The RSMC Tokyo - Typhoon Center should be operational throughout the year and be manned round the clock when a tropical cyclone exists over the region concerned. The RSMC Tokyo - Typhoon Center should also carry out non-operational functions such as training.

In order to implement the RSMC Tokyo - Typhoon Center in the Typhoon Committee region, the Regional Co-operation Programme was discussed and adopted by the Typhoon Committee at its Extraordinary Session (Manila, March 1986). At the same time, the Committee approved a draft of the Typhoon Committee Operational Manual which specifies in more detail the extent and type of activity of the RSMC Tokyo - Typhoon Center and shows the direction of realizing the regional co-operation between Members.

The Operational Manual consists of the text and the appendices. Items included in the text relate to the Typhoon Committee agreement, in particular, basic information for executing meteorological operation, whilst the appendices contain national practices and procedures (it is felt that the Member concerned should have the right to be able to change without having to get prior formal agreement of the Typhoon Committee) together with detailed and technical information for meteorological operation. Information described in WMO official publications such as Manuals is only referred to and not included in this Manual.

Since March 1986, the draft of the Operational Manual has been revised and is still subject to further refinement and revision through experience gained in the use of the Operational Manual. It is also intended that the text of the Manual be updated or revised from time to time by the Typhoon Committee and that each item of information given in the appendices relating to the Manual be kept up to date by the Members concerned.

1.2 Terminology used in the region

1.2.1 General

Typhoon Committee Members

1.2.2 Classification of tropical cyclones*, **

(i)	Low pressure area	(L)
(ii)	Depression or tropical depression	(TD)
(iii)	Tropical storm	(TS)
(iv)	Severe tropical storm	(STS)
(v)	Typhoon	(TY)

1.2.3 Tropical cyclone characteristics

(i) position of centre
(ii) confidence in the centre position
(iii) size and shape of eye, if any
(iv) central pressure
(v) direction of movement
(vi) speed of movement

* "Tropical cyclone" is a generic term that includes tropical depression, tropical storm, severe tropical storm and typhoon.

** Classifications internally used by Members are shown in Appendix 1-B.

(vii) maximum sustained wind
(viii) gusts
(ix) storm radius
(x) gale radius
(xi) storm surge potential for a particular coastal location
(xii) storm tide potential for a particular coastal location

1.2.4 Terms related to the warning and warning system

(i) typhoon season
(ii) tropical cyclone advisory
(iii) tropical cyclone information bulletin
(iv) gale warning
(v) storm warning
(vi) typhoon warning
(vii) visual storm signals
(viii) high sea bulletin
(ix) coastal weather bulletin
(x) bulletin or cyclone warning bulletin

1.3 Meaning of terms used for regional exchange

Average wind speed: Speed of the wind averaged over the previous 10 minutes (mean surface wind) as read from the anemogram or the 3 minutes mean determined with the non-recording anemometer or wind averaged over the previous 1 minute (mean surface wind) at 10 meter height or estimated wind at sea by mariners using the Beaufort scale.

Bulletin: Cyclone warning bulletin

Central pressure of a tropical cyclone: Surface pressure at the centre of the tropical cyclone as measured or estimated.

Centre fix of the tropical cyclone: The estimated location of the centre of a tropical cyclone.

Centre of the tropical cyclone: The centre of the cloud eye, or if not discernible, of the wind/pressure centre.

Confidence in the centre position: Degree of confidence in the centre position of a tropical cyclone expressed as the radius of the smallest circle within which the centre may be located by the analysis. "Position good" implies a radius of 30 nautical miles (55 kilometres) or less. "Position fair", a radius of 30 to 60 nautical miles (55 to 110 km) and "Position poor", a radius of greater than 60 nautical miles (110 km).

Cyclone: Tropical cyclone

Cyclone warning bulletin: A priority message for exchange of tropical cyclone information and advisories.

Direction of movement of the tropical cyclone: The direction towards which the centre of the tropical cyclone is moving.

Extra-tropical cyclone: Low-pressure system which develops in latitudes outside the tropics.

Eye of the tropical cyclone: The relatively clear and calm area inside the circular wall of convective clouds, the geometric centre of which is the centre of the tropical cyclone.

Gale force wind: Average surface wind speed of 34 to 47 knots.

Gale warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of average wind speed in the range of 34 to 47 knots, or wind force 8 or 9 in the Beaufort scale.

Gust: Instantaneous peak value of surface wind speed.

Low pressure area: Region of the atmosphere in which the pressures are lower than those of the surrounding region at the same level. (On the weather map, the low pressure area is denoted with the capital L within the innermost isobar without showing the centre position.)

Maximum sustained wind*: Maximum value of the average wind speed at the surface.

Mean wind speed: Average wind speed.

Reconnaissance aircraft centre fix of the tropical cyclone, vortex fix: The location of the centre of a tropical cyclone obtained by reconnaissance aircraft penetration.

Severe tropical storm: A tropical cyclone with the maximum sustained winds of 48 knots (24.5 m/s, 89 km/h) to 63 knots (32.6 m/s, 117 km/h) near the centre.

Speed of movement of the tropical cyclone: Speed of movement of the centre of the tropical cyclone.

Storm force wind: Average surface wind speed of 48 to 63 knots.

Storm surge: The difference between the actual water level under the influence of a meteorological disturbance (storm tide) and the level which would have been attained in the absence of the meteorological disturbance (i.e. astronomical tide). (Storm surge results mainly from the shoreward movement of water under the action of wind stress. A minor contribution is also made by the hydrostatic rise of water resulting from the lowered barometric pressure.)

Storm tide: The actual sea level as influenced by a weather disturbance. The storm tide consists of the normal astronomical tide and the storm surge.

Storm warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of average wind speeds in the range of 48 to 63 knots or wind force 10 or 11 in the Beaufort scale.

Sub-tropical cyclone: A low pressure system, developing over sub-tropical waters which initially contains few tropical characteristics. With time the sub-tropical cyclone can become tropical.

Sustained wind speed: Average wind speed. Average period of one, three or ten minutes is depending upon the regional practices.

* For converting the wind speeds of different averaging periods such as 1-min, 2-min, 3-min and 10-min, Tropical Cyclone Programme of WMO recommends to follow the guidelines as shown in the Appendix 1-B.

Tropical cyclone: Generic term for a non-frontal synoptic scale cyclone originating over tropical or sub-tropical waters with organized convection and definite cyclonic surface wind circulation. (The term is also used for a storm in the South-West Indian Ocean in which the maximum of the sustained wind speed* is estimated to be in the range of 64 to 90 knots and in the South Pacific and South-East Indian Ocean with the maximum of the sustained over 33 knots.)

Tropical cyclone advisory: A priority message for exchanging information, internationally, on tropical cyclones.

Tropical depression: A tropical cyclone with the maximum sustained winds of 33 knots (17.1 m/s, 61 km/h) or less near the centre.

Tropical disturbance: A non-frontal synoptic scale cyclone originating in the tropics or sub-tropics with enhanced convection and light surface winds.

Tropical storm: A tropical cyclone with the maximum sustained winds of 34 knots (17.2 m/s, 62 km/h) to 47 knots (24.4 m/s, 88 km/h) near the centre.

Tropical wave: A trough or cyclonic curvature maximum in the trade wind easterlies or equatorial westerlies. The wave may reach maximum amplitude in the lower middle troposphere, or may be the reflection of an upper-troposphere cold low or equatorial extension of a mid-latitude trough.

Typhoon: A tropical cyclone with the maximum sustained winds of 64 knots (32.7 m/s, 118 km/h) or more near the centre.

Typhoon force wind: Average surface wind speed of 64 knots or more.

Typhoon warning: Meteorological message intended to warn those concerned of the occurrence or expected occurrence of the mean wind speed of 64 knots (32.7 m/s, 118 km/h) or higher, or wind force 12 in the Beaufort scale.

Visual storm signals: Visual signals displayed at coastal points to warn ships of squally winds, gales and tropical cyclones.

Weather warning: Meteorological message issued to provide appropriate warnings or hazardous weather conditions.

Zone of disturbed weather: A zone in which the pressure is low relative to the surrounding region and there are convective cloud masses which are not organized.

1.4 Units used for regional exchange

(a) The following units/indicators are used for marine purposes:

- (i) Distance in nautical miles, the unit (nm) being stated;
- (ii) Location (position) by degrees and where possible tenths of degrees of latitude and longitude preferably expressed by words;
- (iii) Direction to the nearest sixteen points of the compass or in degree to the nearest ten, given in words;

(iv) Speed (wind speed and speed of movement of tropical cyclones) in knots, the unit (kt) being stated;

(v) Confidence in the centre position in nautical miles (nm) or in position good, fair or poor;

(b) The following units/indicators are used in non-coded segments of exchanges, other than marine bulletins:

(i) Distance in kilometres (km) or nautical miles (nm);

(ii) Location (position) by degrees and tenths of degrees in figures of latitude and longitude and/or bearing on the sixteen point compass and distance from well-known fixed place(s);

(iii) Direction in sixteen points of compass given in figures;

(iv) Speed (wind speed and speed of movement of system) in knots (kt), metres per second (m/s) or kilometres per hour (km/h);

(v) Confidence in the centre position in kilometres (km), nautical miles (nm) or in position good, fair or poor.

1.5 Identification of tropical cyclones

As soon as the wind speed in a tropical cyclone in the responsible area of the RSMC Tokyo - Typhoon Center (between 0°N and 60°N and between 100°E and 180°E) attains 34 knots, it will be given an identification name with a 4-digit number by the RSMC Tokyo - Typhoon Center. Each tropical cyclone should be identified by one of the names in Appendix 1-C, followed by the 4-digit number in brackets, whose number will consist of a year identification and a serial number identification (in two digits each). For example, the first tropical cyclone attaining the 34 knots threshold value in 2000 in the responsible area of the RSMC Tokyo-Typhoon Center will be identified as Damrey (0001). If the life of a tropical cyclone spans two calendar years, it will be accounted for in the year in which it has intensified to the stage where the wind speed has attained the 34 knots threshold value.

1.6 Acronyms

A list of acronyms used in this Operational Manual is shown in Appendix 1-D.

CHAPTER 2

OBSERVING SYSTEM AND OBSERVING PROGRAMME

2.1 Networks of synoptic land stations

The surface and upper-air stations in the regional basic synoptic network are those of the Typhoon Committee Members and are registered in Weather Reporting Volume A - Observing stations (WMO Publication No. 9).

The RSMC Tokyo - Typhoon Center and all Typhoon Committee Members should initiate enhanced observation programmes for their stations in the area within 300 km of the centre of a tropical cyclone of TS intensity or higher. All the observations should be made available to the RSMC Tokyo - Typhoon Center and all Members. Enhanced observations should include:

(i) surface observations - hourly;
(ii) buoy observations - hourly;
(iii) radar observations - hourly;
(iv) upper-air observations - 6-hourly.

2.1.1 Surface observations

All surface stations included in the regional basic synoptic network should make surface observations at the four main standard times of observation, i.e., 0000, 0600, 1200 and 1800 UTC, and at the four intermediate standard times of observation, i.e., 0300, 0900, 1500 and 2100 UTC. Any surface station that cannot carry out the full observational programme should give priority to carrying out the observations at the main standard times. Additional surface observations at hourly intervals may be requested by any Member, whenever a tropical cyclone becomes an imminent threat to the Member, from the stations shown in Appendix 2-A.

2.1.2 Upper-air synoptic observations

All the upper-air stations included in the regional basic synoptic network should carry out radiosonde and radiowind observations at 0000 and 1200 UTC, and radiowind observations at 0600 and 1800 UTC. The radiosonde/radiowind observations carried out at 0000 and 1200 UTC should reach the 30 hPa level for more than 50 per cent of the ascents. The carrying out of the radiosonde/radiowind observations at 0000 and 1200 UTC should receive priority over the radiowind observations at 0600 and 1800 UTC.

Upper-air stations in the areas affected by tropical cyclones of TS intensity or higher should also make radiowind observations at 0600 and 1800 UTC which should aim at reaching the 70 hPa level.

Enhanced upper-air observations given in Appendix 2-B will be made as appropriate whenever a tropical cyclone of TS intensity or higher is centred within 300 km of the station. The minimum required is two observations per day, but for a better understanding of the ambient wind field three or even four ascents per day on some days should be made when possible. All data of these enhanced upper-air observations will be distributed among the Members.

In addition to the upper-air synoptic observations, newly developed observations such as wind profiler observations should be carried out when possible and the data should be made available to the Members.

2.2 Ship and buoy observations

Hourly marine meteorological observations are made by the JMA research vessels (call signs of them are: JPBN and JGQH) in the seas adjacent to Japan and in the western North Pacific.

Upper-air observations are usually made twice a day (00, 12 UTC) on board the JMA research vessel JGQH. Enhanced upper-air observations are carried out six-hourly when these ships are in the vicinity of a tropical cyclone of TS intensity or higher.

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.

Marine meteorological observations, namely air pressure, sea surface temperature, significant wave height and period, are also made by the JMA drifting ocean data buoys every 3 hours in the western North Pacific. When waves are higher than thresholds set beforehand, the buoy changes into the hourly observation mode automatically. All reports are coded in the BUOY code (FM18), and immediately put onto the GTS with the header "SSVB01-19 RJTD".

2.3 Radar observations

It is essential that radar observations continue as long as a tropical cyclone of TS intensity or higher remains within the detection range of the radar. All meteorological centres should co-operate to ensure that the radar observations are transmitted through the GTS to the RSMC Tokyo - Typhoon Center and all Members. Reports will be coded in the BUFR code (FM-94) with RADOB Template (TM316050) and/or the RADOB code (FM 20-VIII).

In case the report is in plain language, the full range of information available at the radar station should be given. The message will therefore include, where available, the confirmation of the determination of the centre, the shape, definition, size and character tendency of the eye, the distance between the end of the outermost band and the centre of the cyclone and the direction and speed of movement with a statement of the interval of time over which the movement was calculated.

Distribution of the radar stations and detailed information on the radar equipment of the Typhoon Committee Members are given in Appendices 2-C and 2-D.

2.4 Meteorological satellite observations

2.4.1 Satellite imagery data and related products

The meteorological satellite information obtained by MTSAT and related products are operated as follows:

(i) full disk data are obtained hourly;
(ii) half disk data in the northern hemisphere are obtained hourly in addition to the full disk data;

(iii) additional half disk data in the northern and southern hemispheres for Atmospheric Motion Vector (AMV) extraction are obtained six-hourly;
(iv) AMV data are derived hourly;
(v) Clear Sky Radiance (CSR) data are derived hourly from the full disk data.

Detailed information is given in Appendix 2-E.

A list of satellite imagery receiving facilities at meteorological centres of the Typhoon Committee Members is given in Appendix 2-F.

2.4.2 SAREP reports

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 by a tropical cyclone is forecasted to be in the responsible area within 24 hours.

2.5 Aircraft observations

Reports from aircraft in flight (AIREPs) in Asia and neighbouring 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.

AIREPs in the north-east Pacific area are also collected by the centres at Honolulu, Washington, etc., and relayed to Tokyo.

AMDAR (Aircraft Meteorological Data Relay) reports are collected by the centre at Tokyo.

All reports will be disseminated in real-time to the RSMC Tokyo - Typhoon Center and to other Members through GTS and AFTN circuits.

2.6 Tropical cyclone passage report

Each Member's tropical cyclone forecast center should compile reliable passage, landfall, near-buoy passage and near-ship passage data, tabulate that data and send it to the Typhoon Committee Secretariat (TCS) within a week after cyclone passage for distribution to other Members. The task is assigned to the focal point for the meteorological component of each Member. A proposed tropical cyclone passage report form is shown in Appendix 2-G.

CHAPTER 3

TROPICAL CYCLONE ANALYSIS AND FORECAST

3.1 Analysis at RSMC Tokyo - Typhoon Center

The RSMC Tokyo - Typhoon Center should produce analyses of various meteorological parameters in chart form and/or in grid point value depending on the facilities of NMCs to process these products. These analyses should include pressure distribution at the sea level and temperature, geo-potential height, humidity and wind at selected pressure levels.

The streamline analysis is indispensable over the tropical region for forecasting tropical cyclones. The RSMC Tokyo - Typhoon Center should produce streamline analyses of the upper and lower atmospheric levels utilizing cloud motion wind, aircraft reports, as well as upper-air observations. Furthermore, the RSMC Tokyo - Typhoon Center should issue analyses of ocean wave and sea surface temperature for the western North Pacific. A list of products provided by the RSMC Tokyo - Typhoon Center is given in Tables 3.1 to 3.3.

The RSMC Tokyo - Typhoon Center should produce additional analyses of the tropical cyclone when it is in the responsible area, based on the enhanced observations. Such analyses should be disseminated in the form of additional bulletins consisting of information on:

(i) position of the tropical cyclone;

(ii) direction and speed of movement;

(iii) central pressure;

(iv) maximum wind and wind distribution.

Various analyses based on MTSAT data other than cloud imagery itself should be produced by the RSMC Tokyo - Typhoon Center. Analysis of sea-surface temperature combining satellite data and in-situ measurements should be prepared every five days. These analyses are useful for the better understanding of the tropical atmosphere and medium-range assessment of forecasting tropical cyclones.

Table 3.1 Chart-form output products transmitted 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	
JCDAS	D' (N.H.)	100hPa (Z, Z anomaly to climatology)	5-day average of analysis	00UTC	GTS
		500hPa (Z, Z anomaly to climatology)			
Ocean Wave	C'' (NW Pacific)	Surface (height, period and direction)	12, 24, 48, 72	00, 12UTC	GTS, JMH

Notes:

(a) Area

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

(b) Contents

Z: geopotential heightζ: vorticityT: temperature
D: dewpoint depression ω: vertical velocity W: wind speed by isotach
A: wind arrowsP: sea level pressure R: rainfall

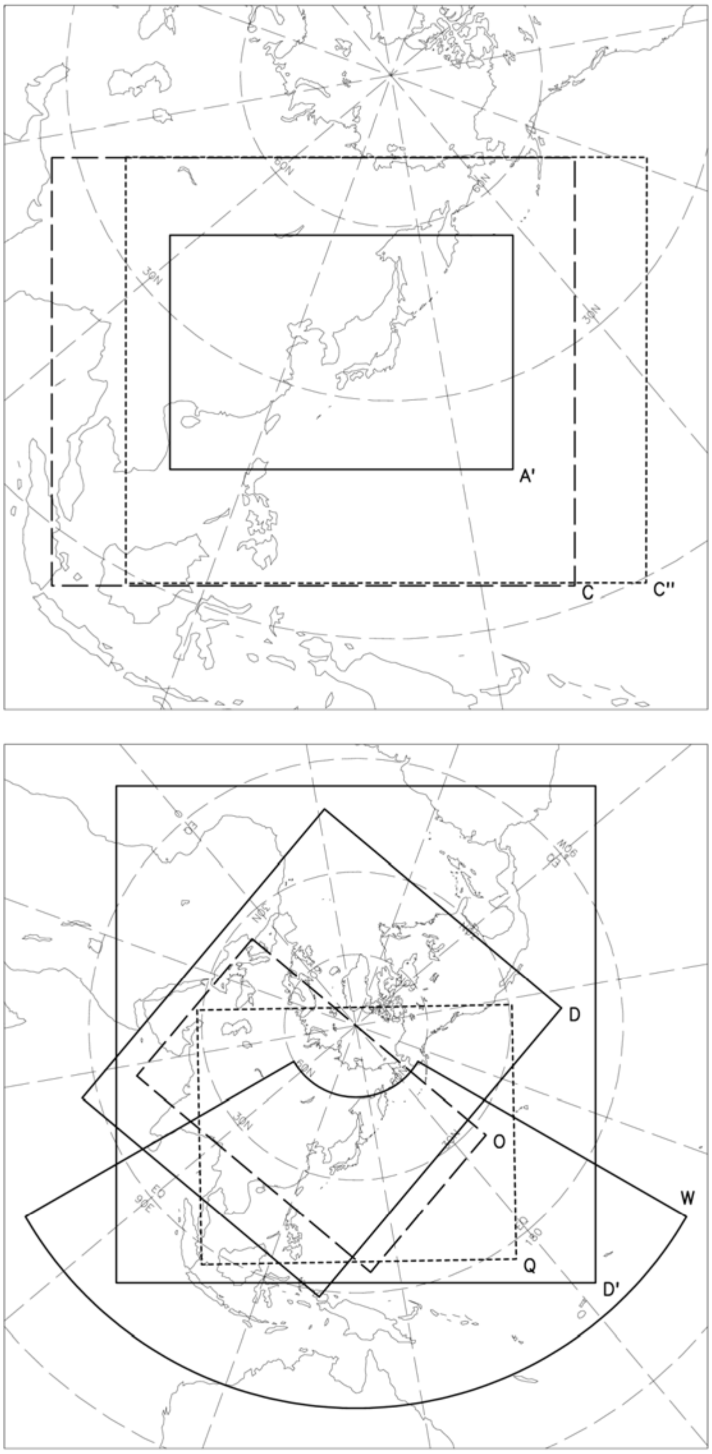


Figure 3.1 **Output areas for facsimile charts transmitted through GTS and radio facsimile JMH**

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/)

3.2 Forecast at RSMC Tokyo - Typhoon Center

The RSMC Tokyo - Typhoon Center should prepare the products for numerical weather prediction shown in Appendix 3-A. These products should be made available to Members in real-time, and should include the following:

(i) deterministic forecast products of a high resolution global model to predict the change in large-scale atmospheric circulation patterns as well as the tropical cyclone movement and intensity

(ii) ensemble forecast products using a lower resolution version of the global model to enable estimation of uncertainties in tropical cyclone movement and intensity as well as to reduce forecast errors by using statistical methods such as ensemble mean.

The RSMC Tokyo - Typhoon Center should also prepare several statistical models for predicting the track of the tropical cyclone and apply the Dvorak method for the prediction of the intensity change of the tropical cyclone. Other relevant synoptic methods should also be applied for predicting the tropical cyclone.

The RSMC Tokyo - Typhoon Center should summarize in a consolidated form all available information and prepare the final forecasts of the tropical cyclone when it exists in the responsible area. These forecasts should include:

(i) 24, 48 and 72-hour forecast position;

(ii) forecast intensity and wind distribution;

(iii) prognostic reasoning;

(iv) tendency assessment if possible.

Furthermore, the RSMC Tokyo - Typhoon Center should prepare a 24-hour ocean wave forecast once a day for the western North Pacific. Storm surge products suitable for the Typhoon Committee region should be provided by the RSMC Tokyo - Typhoon Center. A list of forecast products of the RSMC Tokyo - Typhoon Center, other than alphanumeric form, is shown in Tables 3.1, 3.2 and 3.3.

3.3 Operational analysis and forecast at centres of Typhoon Committee Members

The national meteorological services of Typhoon Committee Members are using various kinds of operational forecast methods for typhoon track. The ones currently used are shown in Appendix 3-B.

The final responsibility for analysis and forecasting development and movement of tropical cyclones in the region will be with the national meteorological services of each of the Members. In order to promote uniformity in the adoption of proven techniques, a sample of such techniques currently used by Members is given in Appendix 3-C.

CHAPTER 4

TROPICAL CYCLONE WARNINGS AND ADVISORIES

4.1 General

The responsibility for warning the human settlements on land which are threatened by a tropical cyclone rests in all cases with the National Meteorological Services (NMS). These national responsibilities are not subject to regional agreement. Therefore, only the cyclone warning systems intended for international users and exchanges among the Typhoon Committee Members are described in this chapter.

4.2 Classification of tropical cyclones[*, **]

Classifications of tropical cyclones for the exchange of messages among the Typhoon Committee Members are given below:

(i)	Low pressure area	(L)	Central position cannot be accurately assessed
(ii)	Tropical depression	(TD)	Central position can be identified, but the maximum sustained wind is 33 kt or less.
(iii)	Tropical storm	(TS)	Maximum sustained wind is between 34 and 47 kt.
(iv)	Severe tropical storm	(STS)	Maximum sustained wind is between 48 and 63 kt.
(v)	Typhoon	(TY)	Maximum sustained wind is 64 kt or more.

4.3 Tropical cyclone advisories

The RSMC Tokyo - Typhoon Center should disseminate six to three-hourly analyses and forecasts of tropical cyclones in the form of bulletins (tropical cyclone advisories - see examples in Appendix 4-A):

(i) analysis of the central position, intensity and wind distribution;

(ii) 24, 48 and 72-hour forecasts of the central position;

(iii) forecasts of intensity and wind distribution;

(iv) prognostic reasoning;

(v) tendency assessment if possible.

[*] "Tropical cyclone" is a generic term that includes tropical depression, tropical storm, severe tropical storm and typhoon.

[**] Classifications internally used by Members are shown in Appendix 1-B.

4.4 Tropical cyclone warnings for the high seas

The World Meteorological Organization (WMO) in its Manual on Marine Meteorological Services sets out the issue of weather and sea bulletins for the high seas in six parts. The first part relates to storm warnings in plain language. Areas of responsibility of each nation for issuing the storm warnings are pre-assigned. The pre-assigned forecast areas of Typhoon Committee Members were agreed upon by Regional Associations II and V (Res. 17 (IV-RA II) and Res.10 (IV-RA V)). Weather forecast areas fixed nationally by individual Typhoon Committee Members are shown in Appendix 4-B.

The radio stations broadcasting tropical cyclone forecasts and warnings for the benefit of the ships on the high seas in the Typhoon Committee Members are listed in Appendix 4-C, where are shown the names of coastal radio stations with their call signs and the area covered by their bulletins. The details are shown in the Manual on Weather Reporting Volume D - Information for Shipping (WMO Publication No. 9).

4.5 Warnings and advisories for aviation

In accordance with the International Civil Aviation Organization (ICAO) Annex 3 - *Meteorological Service for International Air Navigation*/ WMO Technical Regulations (C.3.1), tropical cyclone warnings, required for the international air navigation, are issued by designated meteorological watch offices (MWO) as SIGMET messages. SIGMET messages give a concise description in abbreviated plain language concerning the occurrence and/or expected occurrence of specified en-route weather phenomena, which may affect the safety of aircraft operations, and of the development of those phenomena in time and space. Each MWO provides information for one or more specified flight information regions (FIRs) or upper information regions (UIRs). The boundaries of the FIRs/UIRs are defined in ICAO Air Navigation Plan - Asia and Pacific Region (Doc 9673).

The content and order of elements in a SIGMET message for tropical cyclone shall be in accordance with ICAO Annex 3/WMO Technical Regulations (C.3.1). The data type designator to be used in the WMO abbreviated heading of such messages shall be T1T2 = WC (WMO - No. 386, Manual on GTS refers).

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, international OPMET data banks, and centres operating the ICAO satellite distribution systems (SADIS and ISCS).

The format of the tropical cyclone advisories shall be in accordance with the ICAO Annex 3/WMO Technical Regulations (C.3.1). The data type designator to be used in the WMO abbreviated heading of such messages shall be T1T2 = FK (WMO-No. 386, Manual on GTS, refers).

TCAC Tokyo shall issue updated advisory information for its area of responsibility, for each tropical cyclone, as necessary, but at least every six hours.

CHAPTER 5

TELECOMMUNICATIONS

5.1 General

The basic meteorological telecommunication network for the exchange of forecasts, warnings and observational data will be the Global Telecommunication System (GTS).

5.2 Dissemination of data and products

The RSMC Tokyo - Typhoon Center should have adequate telecommunication facilities for the real-time collection and dissemination of data and products. A large amount of grid point data produced at the RSMC Tokyo - Typhoon Center should be exchanged between the RSMC Tokyo - Typhoon Center and NMCs where adequate circuits for this purpose exist, such as GTS and Internet.

Conventional radio facsimile broadcasts are widely used in the region, though they have some disadvantages, i.e., it takes a long time to transmit a number of charts and received charts are sometimes distorted due to noises. Nevertheless, facsimile broadcasts and reception facilities shall be retained in full operation until telecommunications via satellite is introduced to transmit products both in chart and grid point value form.

5.3 Schedule for exchange of cyclone advisories

Tropical cyclone advisories issued by the RSMC Tokyo - Typhoon Center shall be transmitted at intervals of six to three hours. These messages shall be given high priority.

5.4 Meteorological telecommunication network for the Typhoon Committee region

The network is shown in Figure 5.1 and its present status is summarized in Table 5.1.

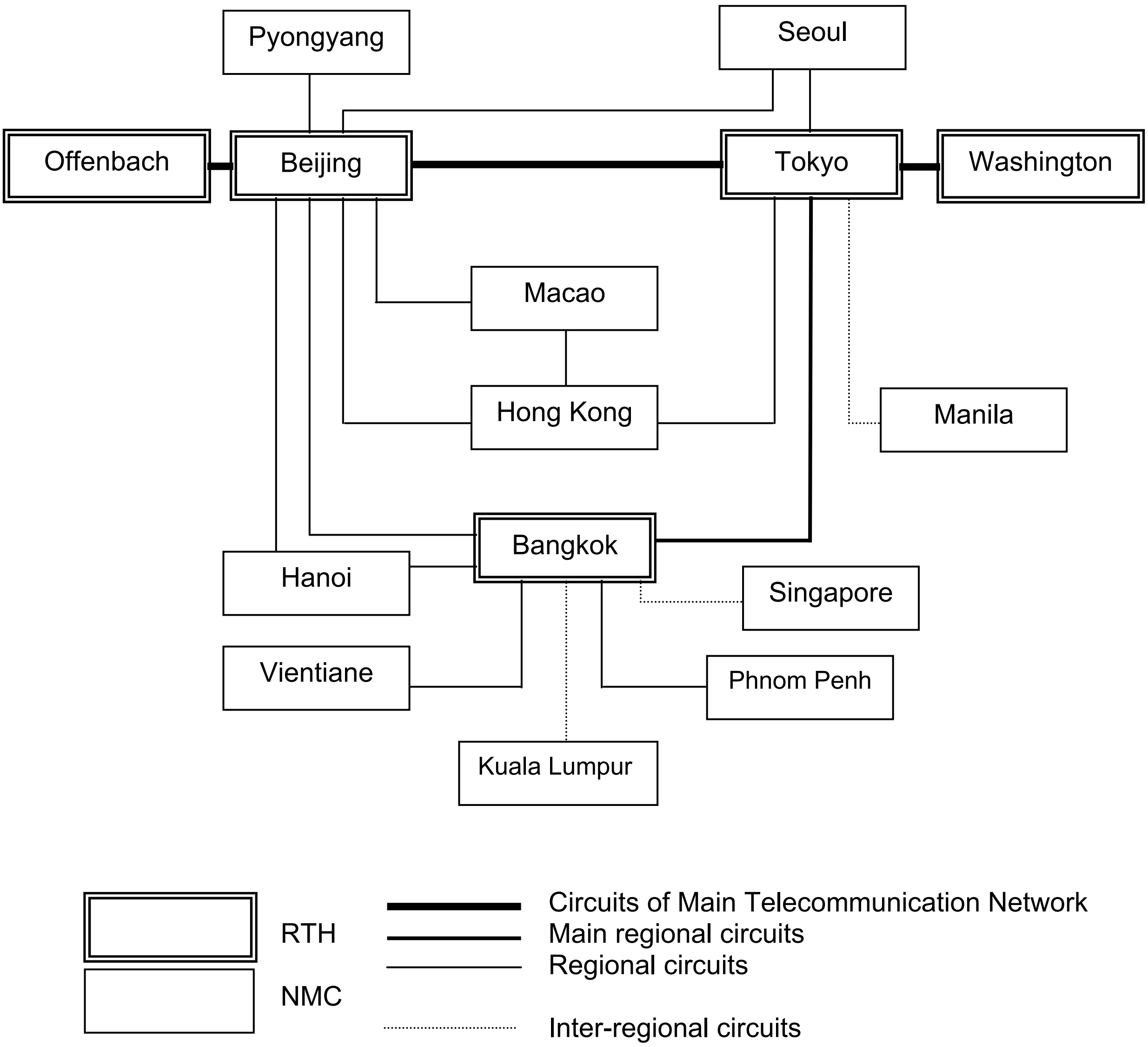


Figure 5.1 Meteorological telecommunication network for the Typhoon Committee

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 3 Mbps/Tokyo 10 Mbps
	Beijing - Offenbach	Cable (FR), 48 kbps (CIR) TCP/IP
	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	Cable (IPLC), 64 kbps, FTP protocol
	Bangkok - Hanoi	Cable (IPLC), 64 kbps, FTP protocol
	Bangkok - Phnom Penh	Internet (VPN)
	Bangkok - Vientiane	Cable (DDN), 64 kbps, FTP protocol
	Beijing - Hanoi	Cable, 75 bauds PC VSAT (Satellite broadcast)
	Beijing - Hong Kong	Cable (SDH), 4 Mbps TCP/IP
	Beijing - Macao	64 kbps leased line
	Beijing - Pyongyang	Cable, 75 bauds; PC VSAT (Satellite broadcast)
	Beijing - Seoul	Cable (FR), 32 kbps (CIR) TCP/IP
	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 (IP-VPN), 64 kbps, socket
Bangkok - Singapore	Cable (IP-VPN), 64 kbps, socket
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 (100.5°E)	Operational data, fax and image distribution
Operated by Japan: MTSAT (140°E)	Operational satellite image distribution

5.5 Addresses, telex/cable and telephone numbers of the tropical cyclone warning centres

A list of addresses of the tropical cyclone warning centres of the Typhoon Committee Members, together with their telex/cable and telephone numbers and e-mail addresses, is given in Appendix 5-A.

5.6 Abbreviated headings of tropical cyclone advisories and warnings

The abbreviated headings of meteorological messages containing tropical cyclone advisories issued by the RSMC Tokyo - Typhoon Center shall be:

(i) analysis and forecast - WTPQ20 RJTD through WTPQ25 RJTD;

(ii) prognostic reasoning - WTPQ30 RJTD through WTPQ35 RJTD;

(iii) five-day track forecast - WTPQ50 RJTD through WTPQ55 RJTD;

(iv) numerical prediction - FXPQ20 RJTD through FXPQ25 RJTD.

The abbreviated headings of meteorological bulletins used for the exchange of tropical cyclone warnings by the Typhoon Committee Members are given in Appendix 5-B.

5.7 Exchange of information related to tropical cyclones

Collection and dissemination of observational and processed data plus warnings related to tropical cyclones at Regional Telecommunication Hubs (RTHs) and National Meteorological Centres (NMCs) are summarized in Appendix 5-C.

The meanings of the symbols used in abbreviated headings in the meteorological messages transmitted to the GTS are listed in Appendix 5-D. The details are described in the Manual on the Global Telecommunication System (WMO Publication No. 386) and Weather Reporting Volume C - Transmissions, Chapter I Catalogue of Meteorological Bulletins (WMO Publication No. 9).

CHAPTER 6

MONITORING AND QUALITY CONTROL OF DATA

6.1 Quality control of observational data

National Meteorological Centres will make additional efforts to ensure that all observational data disseminated during periods of cyclone threat to the area are specifically free from errors. Wherever appropriate, verification of reports or of elements of reports will be requested of the observing station and communication channels will be kept open to facilitate this, particularly in cases where an enhanced observing programme is being carried out.

In the exchange of data during periods of cyclone threat, queries concerning reports on which there is doubt should be addressed to the relevant National Meteorological Centre.

Examples of message format for inquiry on doubtful and garbled reports are shown in Appendix 6-A.

6.2 Monitoring of exchange of information

Monitoring will be carried out by the RSMC Tokyo - Typhoon Center and all Typhoon Committee Members in accordance with their standard procedures. Special attention will be given to identification of deficiencies during the cyclone season in the flow of observational data and processed information relating to cyclone analysis and forecast with a view to appropriate remedial action.

The Members will inform the RSMC Tokyo - Typhoon Center of any shortcomings in the flow of data (raw and processed) and also indicate any requirements over and above those already agreed upon for tropical cyclone warning purposes.

Regular monitoring at the RSMC Tokyo - Typhoon Center should be made twice a year for appropriate periods when enhanced observations are carried out. Special monitoring may be made depending on the situation.

The procedure of regular monitoring is shown in Appendix 6-B.

6.3 Verification

Immediately after the dissipation of a tropical cyclone of TS grade or stronger, the RSMC Tokyo - Typhoon Center should disseminate a report on the tropical cyclone in the form of bulletins to provide Members with data needed for verification, such as position and intensity of the tropical cyclone (see the example in Appendix 6-C):

After the end of each typhoon season, each Member will conduct the verification for its analyses and forecasts and send the report to the RSMC Tokyo - Typhoon Center in accordance with the standard procedure as shown in Appendix 6-D. Verification sheets for positioning of the centre, prediction of movement, and analysis and forecast of intensity of a tropical cyclone are shown in Appendix 6-E.

The RSMC Tokyo - Typhoon Center should summarize the reports issued in a year and the results of verification conducted by Members. It should publish an annual report with respect to tropical cyclones and activities of the RSMC Tokyo - Typhoon Center and Members. The report should also identify specific areas where further co-operative research needs to be carried out by Members.

CHAPTER 7

ARCHIVAL OF DATA

7.1 Data to be archived by Typhoon Committee Members

Members should establish tropical cyclone data files and information services nationally, archiving all appropriate available data.

7.2 Data to be archived by RSMC Tokyo - Typhoon Center

The RSMC Tokyo - Typhoon Center should archive as far as possible tropical cyclone related data received at the centre. The data set should be produced during the period when tropical cyclone(s) is (are) in the range of 1,000 km around Typhoon Committee Members. Except for satellite imagery data, all data should be recorded by the RSMC Tokyo - Typhoon Center preferably on electronic media. A proposed list of data to be archived by the RSMC Tokyo - Typhoon Center is shown in Appendix 7-A.

7.3 Exchange of archived data

Whenever possible Members should supply the RSMC Tokyo - Typhoon Center with all additional data requested by the RSMC Tokyo - Typhoon Center. The RSMC Tokyo - Typhoon Center should make available the archived data to Members on request for use in research, studies, investigations and training. As to distribution, similar arrangements should be made as for the TOPEX data sets which were provided by the Japan Meteorological Agency to Typhoon Committee Members (one set each) with financial assistance from UNDP. The detailed arrangements for exchange of data should be agreed upon bilaterally. Request for data sets by non-Typhoon Committee Members should be made through the WMO Secretariat upon payment of net cost (for electronic media, copying, handling, postal fees, etc.) by the requesting WMO Members.

In accordance with the directive of the WMO Executive Council (EC-XLV), (Geneva, June 1993) an international format for the archiving of tropical cyclone data is to be used by all RSMCs with activity specialization in tropical cyclones.

Complete historical data using the international format given in Appendix 7-B will be made available for research applications. RSMC Tokyo - Typhoon Center will provide such data to the Director of the National Climatic Data Center (NCDC), USA.

The Tropical Cyclone Programme (TCP) Division of the WMO Secretariat has the responsibility for the maintenance of the format, including assignment of the source codes to appropriate organizations, and authorizing additions and changes.

GUIDELINES FOR CONVERTING BETWEEN VARIOUS WIND AVERAGING PERIODS IN TROPICAL CYCLONE CONDITIONS

This note is based on recommendations from Harper et al. (2010) and extracts from Knaff and Harper (2010), providing advice on why, when and how “wind averaging conversions” can be made.

a) Why Convert Wind Speeds?

From the observational perspective, the aim is to process measurements of the wind so as to extract an estimate of the **mean** wind at any time and its **turbulence** properties. From the forecasting viewpoint, the aim is, given a specific wind speed metric derived from a process or product, to usefully predict other metrics of the wind. Typically these needs revolve around the concept of the mean wind speed and an associated peak gust wind speed; such that the statistical properties of the expected level of wind turbulence under **different exposures** can be used to permit useful conversions **between peak gust wind speed** estimates.

b) When to Convert Wind Speeds?

Wind speed conversions to account for varying averaging periods only apply in the context of a maximum (peak gust) wind speed of a given duration observed within some longer interval. Simply measuring the wind for a shorter period of time at random will not ensure that it is always higher than the mean wind (given that there are both lulls and gusts). It is important that all wind speed values be correctly identified as an estimate of the **mean wind** or an estimate of a **peak gust**.

Once the mean wind is reliably estimated, the random effects of turbulence in producing higher but shorter-acting wind gusts, typically of greater significance for causing damage, can be estimated using a “gust factor”. In order for a gust factor to be representative, certain conditions must be met, many of which may not be exactly satisfied during a specific weather event or at a specific location:

- Wind flow is turbulent with a steady mean wind speed (**statistically stationary**);
- Constant surface features exist within the period of measurement, such that the boundary layer is in equilibrium with the underlying surface roughness (**exposure**);
- The conversion assumes the mean wind speed and the peak gust wind speed are at the same **height** (e.g. the WMO standard observation height +10 m) above the surface.

c) How to Convert Individual Point-Specific Wind Speeds

Firstly, the mean wind speed estimate V should be explicitly identified by its averaging period T_o in seconds, described here as V_{To} , e.g.

V_{600} is a 10-min averaged mean wind estimate;
V_{60} is a 1-min averaged mean wind estimate;
V_3 is a 3-sec averaged mean wind estimate.

Next, a peak gust wind speed should be additionally prefixed by the gust averaging period τ , and the time period over which it is observed (also termed the **reference period**), described here as $V_{\tau,To}$, e.g.

$V_{60,600}$ is the highest 1-min mean (peak 1-min gust) within a 10-min observation period;
$V_{3,60}$ is the highest 3-sec mean (peak 3-sec gust) within a 1-min observation period.

The “gust factor” $G_{\tau,To}$ then relates as follows to the mean and the peak gust:

$$V_{\tau,To} = G_{\tau,To}\, V \,,$$

where the (true) mean wind V is estimated on the basis of a suitable sample, e.g. V_{600} or V_{3600}.

On this basis, Table 1 provides the recommended near-surface (+10 m) conversion factors $G_{\tau,To}$ between typical peak gust wind averaging periods, which are a strong function of the exposure class because the turbulence level varies depending on the surface roughness. Table 1 only provides a range of indicative exposures for typical forecasting environments and Harper et al. (2010) or WMO (2008) should be consulted for more specific advice regarding particular types of exposures - especially if it is intended to calibrate specific measurement sites to “standard exposure”.

Table 1 Wind speed conversion factors for tropical cyclone conditions (after Harper et al. 2010).

Exposure at +10 m		Reference Period T_o (s)	Gust Factor $G_{\tau,To}$				
Class	Description		*Gust Duration* τ (s)				
			3	*60*	*120*	*180*	*600*
In-Land	Roughly open terrain	3600	1.75	1.28	1.19	1.15	1.08
		600	1.66	1.21	1.12	1.09	1.00
		180	1.58	1.15	1.07	1.00	
		120	1.55	1.13	1.00		
		60	1.49	1.00			
Off-Land	Offshore winds at a coastline	3600	1.60	1.22	1.15	1.12	1.06
		600	1.52	1.16	1.09	1.06	1.00
		180	1.44	1.10	1.04	1.00	
		120	1.42	1.08	1.00		
		60	1.36	1.00			
Off-Sea	Onshore winds at a coastline	3600	1.45	1.17	1.11	1.09	1.05
		600	1.38	1.11	1.05	1.03	1.00
		180	1.31	1.05	1.00	1.00	
		120	1.28	1.03	1.00		
		60	1.23	1.00			
At-Sea	> 20 km offshore	3600	1.30	1.11	1.07	1.06	1.03
		600	1.23	1.05	1.02	1.00	1.00
		180	1.17	1.00	1.00	1.00	
		120	1.15	1.00	1.00		
		60	1.11	1.00			

Some example applications of the above recommendations are:

- To estimate the expected "off-land" 3-sec peak gust in a 1-min period, multiply the estimated "off-land" mean wind speed by 1.36
- To estimate the expected "off-sea" 3-sec peak gust in a 10-min period, multiply the estimated "off-sea" mean wind speed by 1.38
- To estimate an "at-sea" 1-min peak gust in a 10-min period, multiply the estimated "at-sea" mean wind speed by 1.05

Note that it is not possible to convert from a peak gust wind speed back to a **specific** time-averaged mean wind – only to the **estimated true mean** speed. Hence to estimate the "off-sea" mean wind speed given only a peak observed gust of 1-min duration (τ = 60 s) measured in a 10-min period (T_o = 600 s), multiply the observed 1-min peak gust by (1/1.11) = 0.90. This does not guarantee that the estimated mean wind will be the same as the 10-min averaged wind at that time but, because the 10-min average is normally a reliable estimate of the true mean wind, it will likely be similar. In all cases, measurement systems should aim to reliably measure the mean wind speed and the standard deviation using a sample duration of not less than 10-min (WMO 2008), i.e. V_{600}. Additional shorter averaging periods and the retaining of peak information should then be targeted at operational needs.

d) Converting Between Agency Estimates of Storm Maximum Wind Speed *Vmax*

This is a slightly different situation from converting a point specific wind estimate because the concept of a storm-wide maximum wind speed *Vmax* is a metric with an associated spatial context (i.e. anywhere within or associated with the storm) as well as a temporal fix context (at this moment in time or during a specific period of time). While it may be expressed in terms of any wind averaging period it remains important that it be unambiguous in terms of representing a mean wind or a peak gust. Agencies that apply the WMO standard 10-min averaged *Vmax* wind have always applied a wind-averaging conversion to reduce the maximum "sustained" 1-min wind value (a 1-min peak gust) that has been traditionally associated with the Dvorak method (Dvorak 1984, Atkinson and Holliday 1977)2. As noted in the previous section, it is technically not possible to convert from a peak gust back to a specific time-averaged mean wind – only to the estimated true mean wind speed. However, in Harper et al. (2010) a practical argument is made for nominal conversion between $Vmax_{60}$ and $Vmax_{600}$

2 As detailed in Harper et al. (2010), this traditional assumption is without a firm basis.

values via an hourly mean wind speed reference, and the recommendations are summarised in Table 2.

It can be noted that the recommended conversion for at-sea exposure is about 5% higher than the “traditional” value of 0.88 (WMO 1993), which is more appropriate to an off-land exposure. This has special implications for the Dvorak method because “at sea” is the typical exposure of interest where such conversions have been traditionally applied.

Table 2 Conversion factors between agency estimates of maximum 1-min and maximum 10-min averaged tropical cyclone wind speed *Vmax*. (after Harper et al. 2010).

$Vmax_{600}=K\ Vmax_{60}$	At-Sea	Off-Sea	Off-land	In-Land
K	0.93	0.90	0.87	0.84

e) References

Atkinson, G.D., and C. R. Holliday, 1977: Tropical cyclone minimum sea level pressure/maximum sustained wind relationship for the Western North Pacific. *Mon. Wea. Rev.,* **105**, 421-427.

Dvorak, V.F., 1984: Tropical cyclone intensity analysis using satellite data. NOAA Tech. Rep. NESDIS 11, *National Oceanic and Atmospheric Administration*, Washington, DC, 47 pp.

Knaff, J.A. and B.A. Harper, 2010: Tropical cyclone surface wind structure and wind-pressure relationships. In: Proc. WMO IWTC-VII, *World Meteorological Organization* , Keynote 1,La Reunion, Nov.

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*, TCP Sub-Project Report, WMO/TD-No. 1555.

WMO 1993: Global guide to tropical cyclone forecasting. Tropical Cyclone Programme Report No. TCP-31, *World Meteorological Organization*, WMO/TD – No. 560, Geneva.

WMO 2008: Guide to meteorological instruments and methods of observation. *World Meteorological Organization* , WMO-No. 8, 7th Ed, 681pp.

APPENDIX 1-B

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 (ST)	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

APPENDIX 1-C

LIST OF NAMES FOR TROPICAL CYCLONES ADOPTED BY THE TYPHOON COMMITTEE FOR THE WESTERN NORTH PACIFIC OCEAN AND THE SOUTH CHINA SEA

(Valid as of 2012)

Contributed by	I	II	III	IV	V
	Name	Name	Name	Name	Name
Cambodia	Damrey	Kong-rey	Nakri	Krovanh	Sarika
China	Haikui	Yutu	Fengshen	Dujuan	Haima
DPR Korea	Kirogi	Toraji	Kalmaegi	Mujigae	Meari
Hong Kong, China	Kai-tak	Man-yi	Fung-wong	Choi-wan	Ma-on
Japan	Tembin	Usagi	Kammuri	Koppu	Tokage
Lao PDR	Bolaven	Pabuk	Phanfone	Champi	Nock-ten
Macao, China	Sanba	Wutip	Vongfong	In-fa	Muifa
Malaysia	Jelawat	Sepat	Nuri	Melor	Merbok
Micronesia	Ewiniar	Fitow	Sinlaku	Nepartak	Nanmadol
Philippines	Maliksi	Danas	Hagupit	Lupit	Talas
RO Korea	Gaemi	Nari	Jangmi	Mirinae	Noru
Thailand	Prapiroon	Wipha	Mekkhala	Nida	Kulap
U.S.A.	Maria	Francisco	Higos	Omais	Roke
Viet Nam	Son-Tinh	Lekima	Bavi	Conson	Sonca
Cambodia	Bopha	Krosa	Maysak	Chanthu	Nesat
China	Wukong	Haiyan	Haishen	Dianmu	Haitang
DPR Korea	Sonamu	Podul	Noul	Mindulle	Nalgae
Hong Kong, China	Shanshan	Lingling	Dolphin	Lionrock	Banyan
Japan	Yagi	Kajiki	Kujira	Kompasu	Washi
Lao PDR	Leepi	Faxai	Chan-hom	Namtheun	Pakhar
Macao, China	Bebinca	Peipah	Linfa	Malou	Sanvu
Malaysia	Rumbia	Tapah	Nangka	Meranti	Mawar
Micronesia	Soulik	Mitag	Soudelor	Rai	Guchol
Philippines	Cimaron	Hagibis	Molave	Malakas	Talim
RO Korea	Jebi	Neoguri	Goni	Megi	Doksuri
Thailand	Mangkhut	Rammasun	Atsani	Chaba	Khanun
U.S.A.	Utor	Matmo	Etau	Aere	Vicente
Viet Nam	Trami	Halong	Vamco	Songda	Saola

Replaced names

Aere	for	Kodo	(2002)
Morakot	for	Hanuman	(2002)
Matmo	for	Chataan	(2004)
Nuri	for	Rusa	(2004)
Peipah	for	Vamei	(2004)
Molave	for	Imbudo	(2004)
Noul	for	Pongsona	(2006)
Dolphin	for	Yanyan	(2006)
Mujigae	for	Maemi	(2006)
Mirinae	for	Sudal	(2006)
Lionrock	for	Tingting	(2006)
Fanapi	for	Rananim	(2006)
Pakhar	for	Matsa	(2007)
Doksuri	for	Nabi	(2007)
Haikui	for	Longwang	(2007)
Sanba	for	Chanchu	(2008)
Maliksi	for	Bilis	(2008)
SonTinh	for	Saomai	(2008)
Leepi	for	Xangsane	(2008)
Mangkhut	for	Durian	(2008)
Atsani	for	Morakot	(2011)
Champi	for	Ketsana	(2011)
In-fa	for	Parma	(2011)
Rai	for	Fanapi	(2012)

Corrected spelling

Megkhla	to	Mekkhala	(2002)
Kularb	to	Kulap	(2002)
Ramasoon	to	Rammasun	(2002)
Vipa	to	Wipha	(2002)
Kaemi	to	Gaemi	(2008)
Chebi	to	Jebi	(2008)
Noguri	to	Neoguri	(2008)
Changmi	to	Jangmi	(2008)
Koni	to	Goni	(2008)
SonTinh	to	Son-Tinh	(2008)

OPERATIONAL PROCEDURES FOR THE ASSIGNMENT OF NAMES OF TROPICAL CYCLONES

(a) RSMC Tokyo – Typhoon Center will assign a name each time a 4-digit identification number is to be assigned. That is, names on the Typhoon Committee list will only be given to tropical cyclones of tropical storm strength or above. Each tropical cyclone should be identified by its name followed by the 4-digit number in brackets. The same names and numbers should also be used in bulletins issued by the Tokyo Tropical Cyclone Advisory Centre under the umbrella of the International Civil Aviation Organization (ICAO) as well as in bulletins for Meteorological Area (METAREA)-XI of the Global Maritime Distress and Safety System (GMDSS) issued by both China and Japan. This would contribute to the standardization of the usage of names of tropical cyclones as was desired by the Typhoon Committee.

(b) The exchange of observational data should be promoted as much as possible in addition to what is already exchanged among the warning centres and the meteorological services in the region, to ensure that RSMC Tokyo – Typhoon Center would benefit from the best possible data and information needed for it to carry out its work.

(c) On the operation of the name list, the names will be assigned following the pre-determined order. The name would remain unchanged throughout the life history of the tropical cyclone. To avoid confusion, tropical cyclones given a name before crossing the Date Line and entering the western North Pacific should be assigned a number by RSMC Tokyo – Typhoon Center but should not be assigned a new name in the Typhoon Committee list. RSMC Honolulu Hurricane Center will continue the use of the tropical cyclone names assigned by RSMC Tokyo – Typhoon Center when tropical cyclones cross the Date Line from west to east.

(d) The names and numbers assigned by RSMC Tokyo – Typhoon Center will be used by all Typhoon Committee Members when issuing warning bulletins intended for the international community including the press, aviation and shipping.

(e) The Typhoon Committee, as the authority to maintain the list, shall review the list of names and its operation regularly at its annual sessions as the need arises.

(f) Members may request the retirement of a name from the list particularly in case of tropical cyclones causing extensive destruction or for other reasons. Such notification shall be made preferably within a year of the event. The decision to retire names should be made at the regular review at annual sessions of the Typhoon Committee.

APPENDIX 1-D

LIST OF ACRONYMS USED IN THE OPERATIONAL MANUAL - METEOROLOGICAL COMPONENT -

AFTN	Aeronautical Fixed Telecommunication Network
AIREP	Aircraft En-route Report
APT	Automatic Picture Transmission
ASDAR	Aircraft to Satellite Data Relay
DPSK	Differential Phase-Shift Keying
EIR	Enhanced Infrared
ESCAP	Economic and Social Commission for Asia and the Pacific
FAX	Facsimile
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
GTS	Global Telecommunication System
HRPT	High Resolution Picture Transmission
IR	Infrared
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Warning Centre
LTP	Long Term Plan
MANAM	Manual Amendment
MDUS	Medium Scale Data Utilization Station
MOS	Model Output Statistics
MSL	Mean Sea Level
MTI	Moving Target Indicator
MTSAT	Multi-functional Transport Satellite
NESDIS	National Environmental Satellite, Data and Information Service
NMC	National Meteorological Centre
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OPMET	Operational Meteorological Data
RADOB	Report of ground radar weather observation
RMC	Regional Meteorological Centre
ROBEX	Regional OPMET Bulletin Exchange
RSMC	Regional/Specialized Meteorological Centre
RTH	Regional Telecommunication Hub
SDUS	Small Scale Data Utilization Station
S.VISSR	Stretched VISSR
SAREP	Report of synoptic interpretation of cloud data obtained by a meteorological satellite
SST	Sea Surface Temperature
TC	Typhoon Committee
TCP	Tropical Cyclone Programme
TEMP	Upper-level pressure, temperature, humidity and wind report from a land station
TOPEX	Typhoon Operational Experiment
UNDP	United Nations Development Programme
UTC	Universal Time Coordinated
VIS	Visible
VISSR	Visible and Infrared Spin Scan Radiometer
WMC	World Meteorological Centre
WMO	World Meteorological Organization
WWW	World Weather Watch

APPENDIX 2-A

LIST OF STATIONS FROM WHICH ENHANCED SURFACE OBSERVATIONS ARE AVAILABLE

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

Cambodia

China

(54):	662,	753,	776,	836,	843,	857,	863,	929,	945	
(58):	040,	150,	238,	251,	265,	345,	362,	457,	472,	477
	543,	556,	569,	646,	659,	660,	666,	754,	834,	847,
	911,	921,	927,	944						
(59):	096,	117,	134,	278,	287,	293,	316,	431,	456,	493,
	501,	632,	644,	658,	663,	673,	758,	838,	845,	855,
	948,	981								

Democratic People's Republic of Korea

(47):	003,	005,	008,	014,	016,	020,	022,	025,	028,	031,
	035,	037,	039,	041,	045,	050,	052,	055,	058,	060,
	061,	065,	067,	068,	069					

Hong Kong, China

(45): 007

Japan

(47):	401,	407,	409,	412,	418,	420,	421,	426,	430,	570,
	575,	582,	584,	590,	600,	604,	605,	610,	624,	629,
	636,	648,	651,	655,	662,	675,	678,	740,	741,	746,
	750,	765,	772,	778,	800,	807,	815,	817,	827,	830,
	843,	887,	891,	893,	895,	909,	918,	927,	936,	945,
	971,	991								

Lao People's Democratic Republic

Macao, China

(45): 011

Malaysia

(48):	601,	615,	620,	647,	650,	657,	665	
(96):	413,	421,	441,	449,	465,	471,	481,	491

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,	327,	328,	331,	353,	354,	356,	375,	378,
	379,	381,	400,	407,	431,	432,	453,	456,	462,	465,
	477,	480,	500,	517,	532,	551,	565,	567,	568,	569,
	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).

APPENDIX 2-B

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
radiosonde observations supplemented by wind profiler observations at 06 and 18 UTC when necessary

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, 407, 453, 480, 500, 551, 565, 568

USA

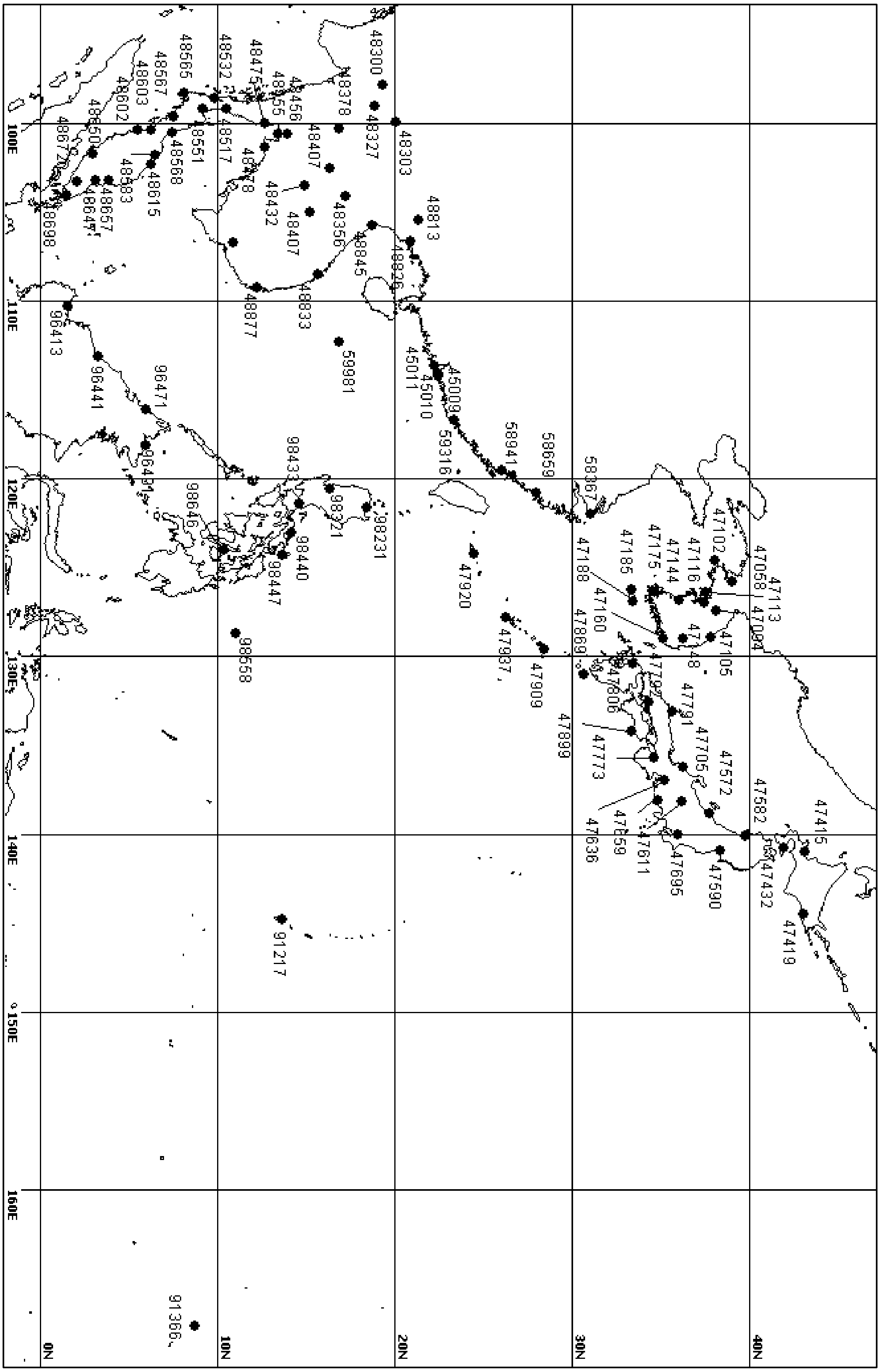
(91): 212, 334, 348, 366, 376, 408, 413

Viet Nam

(48): 820, 855, 900

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

DISTRIBUTION OF THE RADAR STATIONS OF TYPHOON COMMITTEE MEMBERS



APPENDIX 2-D, p.1

TECHNICAL SPECIFICATIONS OF RADARS OF TYPHOON COMMITTEE MEMBERS

Name of the Member **China**

NAME OF STATION		Shanghai	Wenzhou	Fuzhou	Shantou	Xishadao
SPECIFICATIONS	Unit					
Index number		58367	58659	58941	59316	59981
Location of station		31° 02´ N 121° 57´ E	27° 51´ N 120° 49´ E	25° 59´ N 119° 32´ E	23° 17´ N 116° 44´E	16° 50´ N 112° 20´ E
Antenna elevation	m	68	294	652.5	196.7	8.5
Wave length	cm	10.6	10.6	10.4	10.4	10.6
Peak power of transmitter	kW	500	500	500	500	500
Pulse length	μ s	1	3.0	1.0	1	3
Sensitivity minimum of receiver	dBm	-110	-110	-109	-109	-110
Beam width (Width of over -3dB antenna gain of maximum)	deg	2.0	2.0	2.0	1.2	2.0
Detection range	km	600	600	600	600	600
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		1 2 3	1 2 3	1 2 3	1 2 3	2
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2	2	2	2
Doppler processing 1.Yes, 2.No		2	2	1	1	2
Display 1.Digital, 2.Analog		1	1	1	1	2
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		1	1	1	1	1
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Democratic People's Republic of Korea**

NAME OF STATION		Pyongyang				
SPECIFICATIONS	Unit					
Index number		47058				
Location of station		39° 02′ N 125° 47′ E				
Antenna elevation	m	90				
Wave length	cm	3.2				
Peak power of transmitter	kW	150				
Pulse length	μ s	1, 2				
Sensitivity minimum of receiver	dBm	-132				
Beam width (Width of over -3dB antenna gain of maximum)	deg	44				
Detection range	km	300				
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		 1 2 3				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2				
Doppler processing 1.Yes, 2.No		2				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		1				
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1				

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

NAME OF STATION		Tai Mo Shan	Tate's Cairn			
SPECIFICATIONS	Unit					
Index number		45009	45010			
Location of station		22° 25´ N 114° 07´ E	22° 22´ N 114° 13´ E			
Antenna elevation	m	968	583			
Wave length	cm	10.6	10.3			
Peak power of transmitter	kW	650	500			
Pulse length	μ s	1.0/1.8	0.8/2.0			
Sensitivity minimum of receiver	dBm	-117	-110			
Beam width (Width of over -3dB antenna gain of maximum)	deg	0.9(H) 0.9(V)	1.8			
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			

Name of the Member **Japan - 1**

NAME OF STATION		Sapporo /Kenashiyama	Kushiro /Kombumori	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	5.61	5.64
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	2.6
Sensitivity minimum of receiver	dBm	-109/-112	-110/-113	-108/-111	-108/-111	-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)	1.1(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	2
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		1	1	1	1	1
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)		1	1	1	1	1

Name of the Member **Japan - 2**

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	1.1/2.7	2.6	2.6
Sensitivity minimum of receiver	dBm	-109/-113	-109/-113	-109/-113	-114	-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) 1.1(V)	1.0(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	2
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		1	1	1	1	1
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)		1	1	1	1	1

Name of the Member **Japan - 3**

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

Name of the Member **Japan - 4**

NAME OF STATION		Fukuoka /Sefurisan	Tanegashima /Nakatane	Naze /Funchatoge	Naha /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	315.7	208.2	535.5
Wave length	cm	5.60	5.60	5.66	5.60	5.61
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	1.1/2.7	1.1/2.7	2.6	1.0/2.5	1.1/2.7
Sensitivity minimum of receiver	dBm	-109/-112	-108/-112	-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	2	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		1	1	1	1	1
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				
SPECIFICATIONS	Unit					
Index number		45011				
Location of station		22.1599N 113.5624E				
Antenna elevation	m	183				
Wave length	cm	3.4				
Peak power of transmitter	kW	200				
Pulse length	μ s	0.4, 0.8, 1.0, 2.0				
Sensitivity minimum of receiver	dBm	-113				
Beam width (Width of over -3dB antenna gain of maximum)	deg	1°				
Detection range	km	128				
Scan mode in observation 1. Fixed elevation 2. CAPPI 3. Manually controlled		3				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2				
Doppler processing 1.Yes, 2.No		1				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1. Hourly 2. 3-hourly 3. Others		3				
PRESENT STATUS 1.Operational 2.Not operational (for research etc.)		2				

Name of the Member **Malaysia - 1**

NAME OF STATION		Alor Star	Kota Bharu	Kuala Lumpur (Sepang)	Kuala Lumpur (Subang)	Kluang
SPECIFICATIONS						
Index number		48603	48615	48650	48647	48672
Location of station		6° 11´ N 100° 24´ E	6° 10´ N 102° 17´ E	2° 51´ N 101° 40´ E	3° 07´ N 103° 13´ E	2° 01´ N 103° 19´E
Antenna elevation	m	24	33	25	32	113
Wave length	cm	10	10	10	10	10
Peak power of transmitter	kW	650	650	750	650	650
Pulse length	μ s	0.8 and 2	2	1 and 3	2	0.8 and 2
Sensitivity minimum of receiver	dBm	-110 (.8 μs) -113 (2 μs)	-113	-110 (.8 μs) -115 (3 μs)	-113	-110 (.8 μs) -113 (2 μs)
Beam width (Width of over -3dB antenna gain of maximum)	deg	2	2	1	2	2
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		2	2	2	2	2
Doppler processing 1.Yes, 2.No		2	2	1	2	2
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 (every 10 mins)	3 (every 10 mins)	3 (every 5 mins)	3 (every 10 mins)	3 (every 10 mins)
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1 (from May 2005)	1	1	1	1 (from Apr 2005)

APPENDIX 2-D, p.10

Name of the Member **Malaysia - 2**

NAME OF STATION		Kuantan	Butterworth	Kuching	Bintulu	Kota Kinabalu
SPECIFICATIONS						
Index number		48657	48602	96413	96441	96471
Location of station		3° 47´ N 103° 13´ E	5° 28´ N 100° 23´ E	1° 29´ N 110° 20´ E	3° 13´ N 113° 04´ E	5° 56´ N 116° 03´E
Antenna elevation	m	32	20	57	151	27
Wave length	cm	10	10	5	5	5
Peak power of transmitter	kW	650	650	250	250	250
Pulse length	μ s	2	2	2	2	2
Sensitivity minimum of receiver	dBm	-113	-113	-113	-113	-113
Beam width (Width of over -3dB antenna gain of maximum)	deg	2	2	1.6	1.6	1.6
Detection range	km	400	400	250	250	250
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		2	2	2	2	2
Doppler processing 1.Yes, 2.No		2	2	2	2	2
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 (every 10 mins)	3 (every 10 mins)	3 (every 10 mins)	3 (every 10 mins)	3 (every 10 mins)
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Malaysia - 3**

NAME OF STATION		Sandakan				
SPECIFICATIONS						
Index number		96491				
Location of station		5° 54´ N 118° 04´ E				
Antenna elevation	m	28				
Wave length	cm	5				
Peak power of transmitter	kW	250				
Pulse length	μ s	2				
Sensitivity minimum of receiver	dBm	-113				
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.6				
Detection range	km	250				
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2				
Doppler processing 1.Yes, 2.No		2				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		3 (every 10 mins)				
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1				

Name of the Member **Philippines - 1**

NAME OF STATION	Unit	Aparri	Baguio	Virac	Tanay	Daet
SPECIFICATIONS	Unit					
Index number		98231	98321	98447	98433	98440
Location of station		18° 22′ N 121° 37′ E	16° 20′ N 120° 34′ E	13° 38′ N 124° 19′ E	14° 34′ N 121° 21′ E	14° 08′ N 122° 59′ E
Antenna elevation	m	16	2256	248	650.36	12.5
Wave length	cm	5.65	10.5	10.5	10.5	10.5
Peak power of transmitter	kW	250	500	500	500	500
Pulse length	μ s	2	4/ 0.5	3	3	3
Sensitivity minimum of receiver	dBm					
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.5	2.2	2.2	2.2	2.2
Detection range	km	400	400	400	400	400
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		Automatic Azimuth scan and mode 3 elv	Automatic Azimuth scan and mode 3 elv	Automatic Azimuth scan and mode 3 elv	Automatic Azimuth scan and mode 3 elv	Automatic Azimuth scan and mode 3 elv
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2	2	2	2
Doppler processing 1.Yes, 2.No		2	2	2	2	2
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		1 occasionally every 30 minutes	1 occasionally every 30 minutes	1 occasionally every 30 minutes	1 occasionally every 30 minutes	1 occasionally every 30 minutes
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Philippines - 2**

NAME OF STATION		Mactan	Guiuan			
SPECIFICATIONS	Unit					
Index number		98646	98558			
Location of station		10° 18´ N 123° 58´ E	11° 02´ N 128° 44´ E			
Antenna elevation	m	33	66			
Wave length	cm	10.5	10.5			
Peak power of transmitter	kW	500	500			
Pulse length	μ s	3	3			
Sensitivity minimum of receiver	dBm					
Beam width (Width of over -3dB antenna gain of maximum)	deg	2.2	2.2			
Detection range	km	400	400			
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		Automatic Azimuth scan and mode 3 elv	Automatic Azimuth scan and mode 3 elv			
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2	2			
Doppler processing 1.Yes, 2.No		2	2			
Display 1.Digital, 2.Analog		1	1			
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		1 occasionally every 30 minutes	1 occasionally every 30 minutes			
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1			

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	μ s	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	μ s	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

Name of the Member **Republic of Korea - 3**

NAME OF STATION		Korean Aviation Meteorological Agency				
SPECIFICATIONS	Unit					
Index number		47113				
Location of station		37° 28´ N 126° 21´ E				
Antenna elevation	m	145				
Wave length	cm	5.32				
Peak power of transmitter	kW	250				
Pulse length	μ s	1.0; 2.0				
Sensitivity minimum of receiver	dBm	-110				
Beam width (Width of over -3dB antenna gain of maximum)	deg	0.53				
Detection range	km	30, 480				
Scan mode in observation 1. Fixed elevation 2. CAPPI 3. Manually controlled		1, 2				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		2				
Doppler processing 1.Yes, 2.No		1				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1. Hourly 2. 3-hourly 3. Others		3 (continuous)				
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1				

Name of the Member **Singapore**

NAME OF STATION		Changi				
SPECIFICATIONS	Unit					
Index number		48698				
Location of station		1° 22´ N 103° 59´ E				
Antenna elevation	m	35				
Wave length	cm	10				
Peak power of transmitter	kW	750				
Pulse length	μ s	1 or 3				
Sensitivity minimum of receiver	dBm	-110				
Beam width (Width of over -3dB antenna gain of maximum)	deg	< 1				
Detection range	km	480				
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1				
Doppler processing 1.Yes, 2.No		1				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		3 (continuous)				
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1				

Name of the Member **Thailand - 1**

NAME OF STATION		Mahong Son	Chiang Rai	Chiang Mai	Sakol Nakon	Phitsanulok
SPECIFICATIONS	Unit					
Index number		48300	48303	48327	48356	48378
Location of station		19° 18′ N 97° 50′ E	19° 55′ N 99° 50′ E	18° 47′ N 98° 59′ E	17° 09′ N 104° 08′ E	16° 46′ N 100° 16′ E
Antenna elevation	m	292	440	337	198	56
Wave length	cm	3	5	5	5	5
Peak power of transmitter	kW	200	250	250	250	25
Pulse length	μ s	0.5&1	0.8&2	0.8&2	0.8&2	0.8&2
Sensitivity minimum of receiver	dBm	-108	-108	-106	-108	-106
Beam width (Width of over -3dB antenna gain of maximum)	deg	2	1.1	1.1	1.1	1.1
Detection range	km	120	240	240	240	240
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2, 3	2, 3	2, 3	2,3	2, 3
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.Hourly 2.3-hourly 3.Others		1, 3	1, 3	1, 3	1, 3	1, 3
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Thailand - 2**

NAME OF STATION		Khon Khaen	Ubol	Surin	Bangkok	Donmuang
SPECIFICATIONS	Unit					
Index number		48381	48407	48432	48455	48456
Location of station		16° 27′ N 102° 47′ E	15° 14′ N 105° 01′ E	14° 53′ N 103° 29′ E	13° 23′ N 100° 36′ E	13° 55′ N 100° 36′ E
Antenna elevation	m	215	155	175	60	45
Wave length	cm	10	5	10	3	10
Peak power of transmitter	kW	500	250	500	25	500
Pulse length	μ s	0.8&2	0.8&2	0.8&2	0.5&1	0.8&2
Sensitivity minimum of receiver	dBm	-106	-108	-106	-108	-106
Beam width (Width of over -3dB antenna gain of maximum)	deg	2.2	1.1	2.1	2.5	1.2
Detection range	km	240	240	240	60	240
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2, 3	2, 3	2, 3	2, 3	2, 3
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.Hourly 2.3-hourly 3.Others		1, 3	1, 3	1, 3	1, 3	1, 3
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Thailand - 3**

NAME OF STATION		Hua Hin	Rayong	Chumporn	Ranong	Surat Thani
SPECIFICATIONS	Unit					
Index number		48475	48478	48517	48532	48551
Location of station		12° 35′ N 99° 57′ E	12° 38′ N 101° 21′ E	10° 29′ N 99° 11′ E	9° 47′ N 98° 36′ E	9° 08′ N 99° 09′ E
Antenna elevation	m	30	32	28	45	33
Wave length	cm	10	5	5	3	10
Peak power of transmitter	kW	500	500	250	200	500
Pulse length	μ s	0.8&2	0.882	0.8&2	0.5&1	0.8&2
Sensitivity minimum of receiver	dBm	-106	-106	-108	-108	-106
Beam width (Width of over -3dB antenna gain of maximum)	deg	2.1	1.1	1.1	2	2.2
Detection range	km	240	240	240	120	240
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2, 3	2, 3	2, 3	2, 3	2, 3
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.Hourly 2.3-hourly 3.Others		1, 3	1, 3	1, 3	1, 3	1, 3
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	2	1

Name of the Member **Thailand - 4**

NAME OF STATION		Phuket	Trang	Sathing Pra (Songkla)	Narathiwat	
SPECIFICATIONS	Unit					
Index number		48565	48567	48568	48583	
Location of station		8° 08´ N 99° 19´ E	7° 31´ N 99° 37´ E	7° 26´ N 100° 27´ E	6° 25´ N 101° 49´ E	
Antenna elevation	m	281	40	30	29	
Wave length	cm	5	3	5	3	
Peak power of transmitter	kW	250	200	250	200	
Pulse length	μ s	0.852	0.5&1	0.8&2	0.5&1	
Sensitivity minimum of receiver	dBm	-106	-108	-106	-108	
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.1	2	1.1	2	
Detection range	km	240	120	240	120	
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2, 3	2, 3	2, 3	2, 3	
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	
Doppler processing 1.Yes, 2.No		1	1	1	1	
Display 1.Digital, 2.Analog		1	1	1	1	
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		1, 3	1, 3	1, 3	1, 3	
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	

Name of the Member **USA**

NAME OF STATION		Guam	Kwajalein			
SPECIFICATIONS	Unit					
Index number		91217	91366			
Location of station		13° 33´ N 144° 50´ E	8° 44´ N 167° 44´ E			
Antenna elevation	m	110	30			
Wave length	cm	10.6	10.0			
Peak power of transmitter	kW	750	500			
Pulse length	μ s	1.57/ 4.5	0.8			
Sensitivity minimum of receiver	dBm	-113	-107			
Beam width (Width of over -3dB antenna gain of maximum)	deg	0.96	1.0			
Detection range	km	399	250			
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		2	2			
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	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 6-minute continuous	3 continuous			
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1			

Name of the Member **Viet Nam – 1**

NAME OF STATION		Phu Lien	Viet Tri	Vinh	Tam Ky	Nha Trang
SPECIFICATIONS	Unit					
Index number		48826	48813	48845	48833	48877
Location of station		20.48 °N 106.38 °E	21.18 °N 105.25 °E	18.40 °N 105.41 °E	15.34 °N 108.28 °E	12.13 °N 109.12 °E
Antenna elevation	m	140	56	27	40	52
Wave length	cm	5.3	5.3	5.3	5.6	5.6
Peak power of transmitter	kW	250	250	250	250	250
Pulse length	μ s	2	2	2	0.8;2.0	0.8;2.0
Sensitivity minimum of receiver	dBm	-110	-110	-110	-113	-113
Beam width (Width of over -3dB antenna gain of maximum)	deg	1.1	1.1	1.1	1	1
Detection range	km	384	384	384	480	480
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		1,3	1,3	1,3	1,2,3	1,2,3
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1	1	1	1	1
Doppler processing 1.Yes, 2.No		2	2	2	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		1, 3	1, 3	1, 3	1, 3	1, 3
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		1	1	1	1	1

Name of the Member **Vietnam - 2**

NAME OF STATION		Nha Be				
SPECIFICATIONS	Unit					
Index number						
Location of station		10° 49´ N 106° 43´ E				
Antenna elevation	m	25				
Wave length	cm	5.6				
Peak power of transmitter	kW	250				
Pulse length	μ s	0.4; 0.8; 2.0				
Sensitivity minimum of receiver	dBm	-122				
Beam width (Width of over -3dB antenna gain of maximum)	deg	1				
Detection range	km	480				
Scan mode in observation 1.Fixed elevation 2.CAPPI 3.Manually controlled		1, 2, 3				
DATA PROCESSING						
MTI processing 1.Yes, 2.No		1				
Doppler processing 1.Yes, 2.No		1				
Display 1.Digital, 2.Analog		1				
OPERATION MODE (When tropical cyclone is within range of detection) 1.Hourly 2.3-hourly 3.Others		1, 3				
PRESENT STATUS 1.Operational 2.Not operational(for research etc.)		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/mtsat1r/4.2HRIT_1.pdf)

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/mtsat1r/4.3LRIT.pdf)

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/ds.html

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

[MSC real-time satellite imagery webpage]
http://mscweb.kishou.go.jp/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/

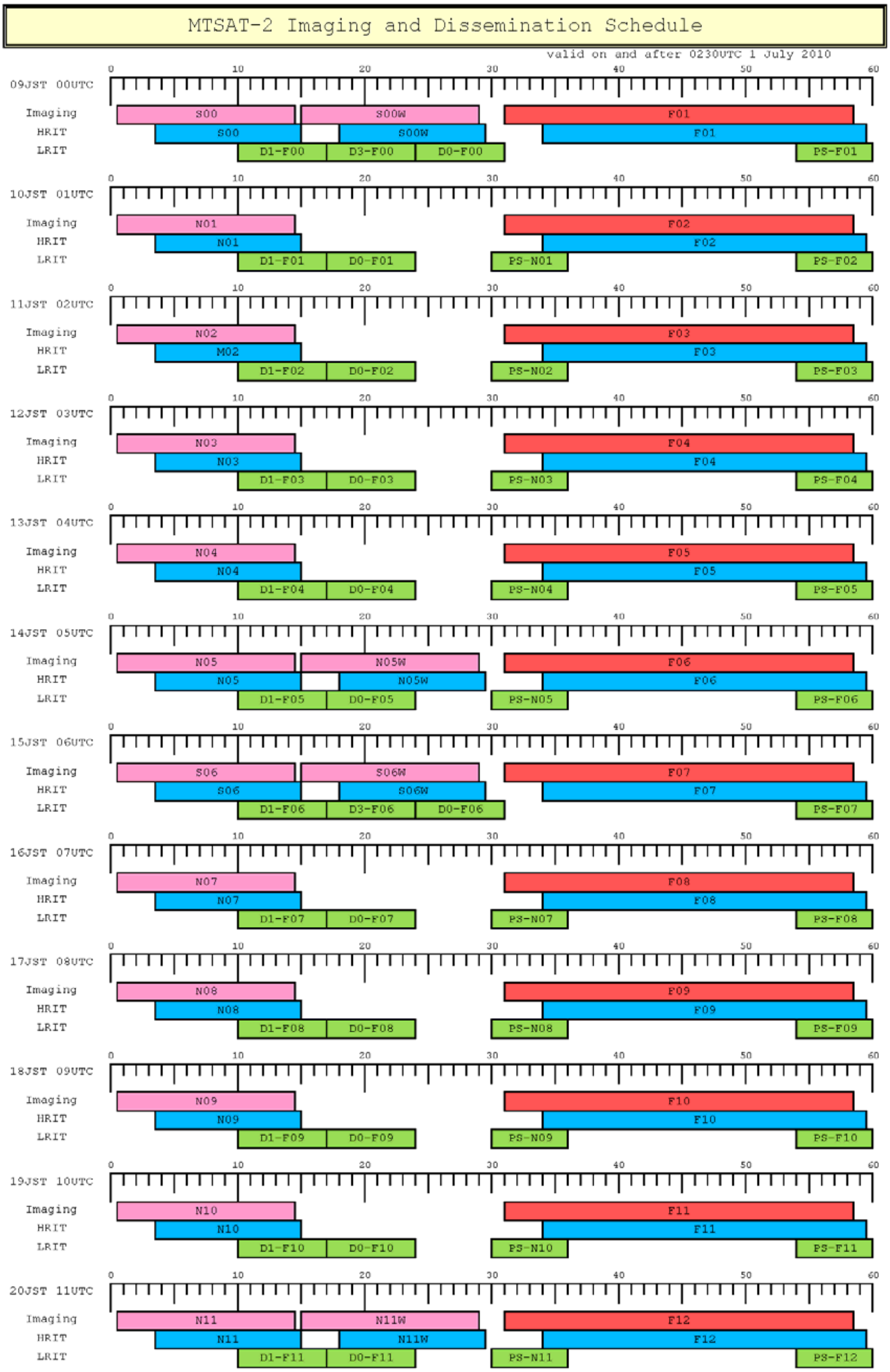


Figure 2-E.1 Time Table for Operation of MTSAT-2 (1/5)

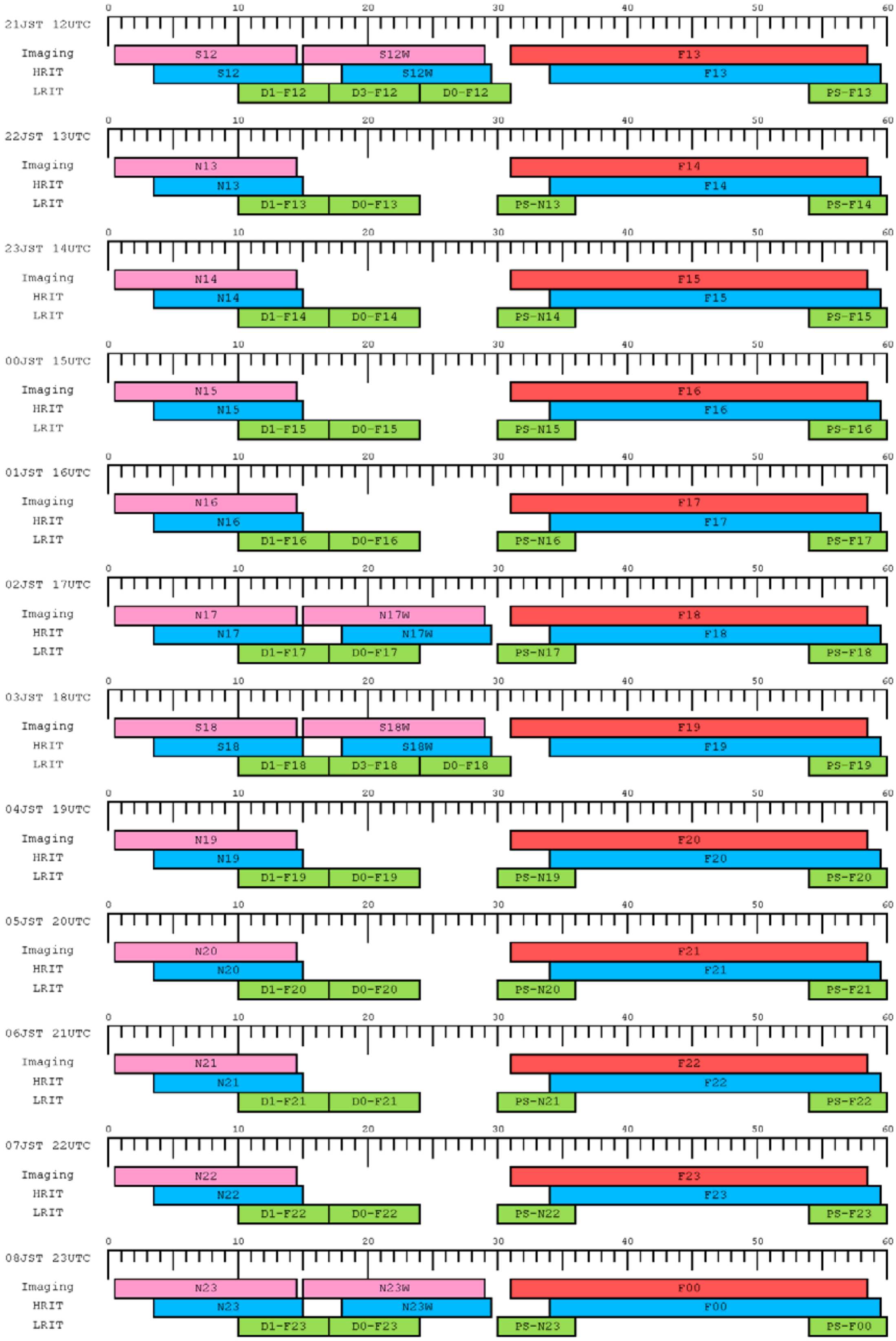


Figure 2-E.1 Time Table for Operation of MTSAT-2 (2/5)

A. Notes

- This timetable is effective from 0230 UTC on 1 July 2010.

- For updated information on the dissemination timetable, please refer to MANAM, which is disseminated via MTSAT-1R and is also available on our web site.

Via MTSAT-1R
HRIT: MANAM is sent along with imagery of N02 and N08
(shown as “N02” or “N08” on a sky-blue ground in the timetable)
LRIT: MANAM is sent along with imagery of PS-N02 and PS-N08
(shown as “PS-N02” or “PS-N08” on a green ground in the timetable)

Website:
URL: http://mscweb.kishou.go.jp/operation/index.htm

Fig 2-E.1 Time Table for Operation of MTSAT-2 (3/5)

B. Legend

- Observation (full disk/half disk)
- HRIT
- LRIT

C. Symbols

hh: hours in UTC

1. Observation

Symbol	Observation	Explanation of symbol
Fhh	Hourly full disk	F: hourly Full-disk observation
Nhh	Hourly Northern Hemisphere	N: hourly Northern-hemisphere observation
NhhW	Special observations for wind extraction	W: Wind extraction; S: Southern-hemisphere observation. Every 6 hours (00, 06, 12, 18 UTC), two Northern-hemisphere and two Southern-hemisphere observations will be performed before and after the full-disk observation respectively. As an example, observations for wind extraction around 12 UTC are N11, N11W, F12, S12 and S12W.
Shh		
ShhW		

2. HRIT Dissemination

Symbol	Observation	Explanation of symbol
Fhh	Hourly full disk	F: hourly Full-disk observation
Nhh	Hourly Northern Hemisphere	N: hourly Northern-hemisphere observation
NhhW	Special observations for wind extraction	W: Wind extraction; S: Southern-hemisphere observation. Every 6 hours (00, 06, 12, 18 UTC), two Northern-hemisphere and two Southern-hemisphere observations will be performed before and after the full-disk observation respectively. As an example, observations for wind extraction around 12 UTC are N11, N11W, F12, S12 and S12W.
Shh		
ShhW		

3. LRIT Dissemination

Symbol	Observation	Explanation of symbol
D1-Fhh	Full disk	D1: Full-Disk imagery, Infrared-ch1; F: hourly Full-disk observation
D3-Fhh		D3: Full-Disk imagery, Infrared-ch3; F: hourly Full-disk observation
PS-Fhh		PS: Polar-Stereographic imagery; F: hourly Full-disk observation; N: hourly Northern-hemisphere observation. There are three different sets of polar-stereographic imagery covering East Asia, northeast Japan and southwest Japan.
PS-Nhh	Northern Hemisphere	

Figure 2-E.1 Time Table for Operation of MTSAT-2 (4/5)

D. Data disseminated in LRIT

Imagery / Observation	Polar-stereographic projection (PS-Fhh / PS-Nhh)						Full disk	
	East Asia				Northeast Japan	Southwest Japan		
	Visible	Infrared-ch1	Infrared-ch3	Infrared-ch4	Visible	Visible	Infrared-ch1 (D1-Fhh)	Infrared-ch3 (D3-Fhh)
F00	D	D	D		D	D	D	D
F01	D	D	D		D	D	D	
N01	D	D	D		D	D		
F02	D	D	D		D	D	D	
N02	D	D	D		D	D		
F03	D	D	D		D	D	D	
N03	D	D	D		D	D		
F04	D	D	D		D	D	D	
N04	D	D	D		D	D		
F05	D	D	D		D	D	D	
N05	D	D	D		D	D		
F06	D	D	D		D	D	D	D
F07	D	D	D		D	D	D	
N07	D	D	D		D	D		
F08	(D)	D	D	(D)	(D)	(D)	D	
N08	(D)	D	D	(D)	(D)	(D)		
F09	(D)	D	D	(D)	(D)	(D)	D	
N09	(D)	D	D	(D)	(D)	(D)		
F10		D	D	D			D	
N10		D	D	D				
F11		D	D	D			D	
N11		D	D	D				
F12		D	D	D			D	D
F13		D	D	D			D	
N13		D	D	D				
F14		D	D	D			D	
N14		D	D	D				
F15		D	D	D			D	
N15		D	D	D				
F16		D	D	D			D	
N16		D	D	D				
F17		D	D	D			D	
N17		D	D	D				
F18		D	D	D			D	D
F19		D	D	D			D	
N19		D	D	D				
F20		D	D	D			D	
N20		D	D	D				
F21	(D)	D	D	(D)	(D)	(D)	D	
N21	(D)	D	D	(D)	(D)	(D)		
F22	(D)	D	D	(D)	(D)	(D)	D	
N22	(D)	D	D	(D)	(D)	(D)		
F23	D	D	D		D	D	D	
N23	D	D	D		D	D		

Legend

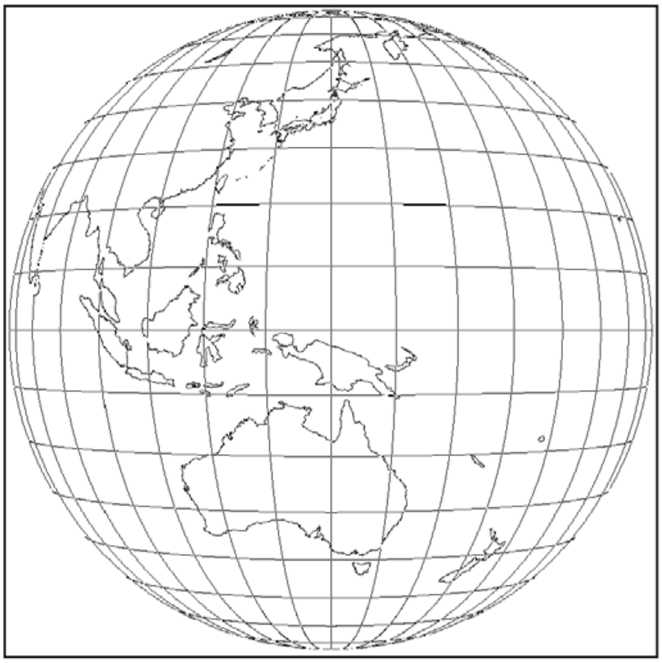
D: Dissemination

(D): Visible images are disseminated when the days are long enough, while infrared-ch4 images are disseminated when days are shorter. See MANAM for the latest information.

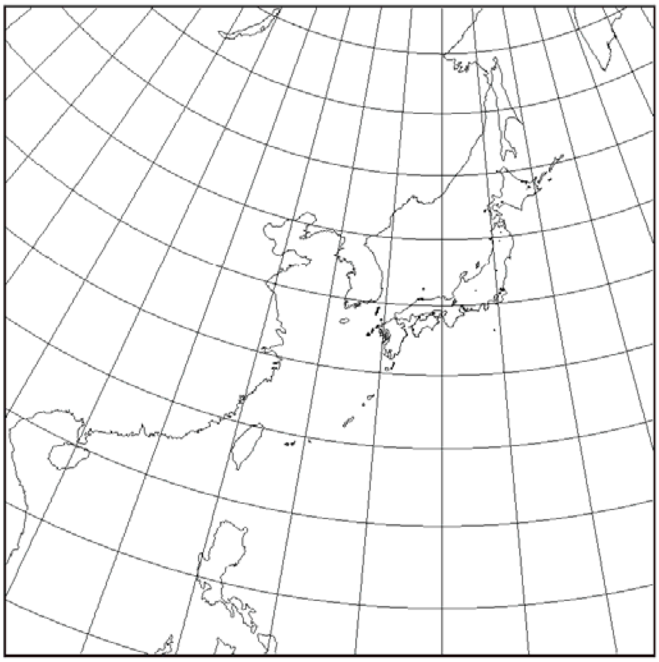
E. Observation channels of the MTSAT-1R imager

Channel	Wavelength
Infrared-	
ch1	10.3-11.3 μm
ch2	11.5-12.5 μm
ch3	6.5-7.0 μm
ch4	3.5-4.0 μm
Visible	0.55-0.90 μm

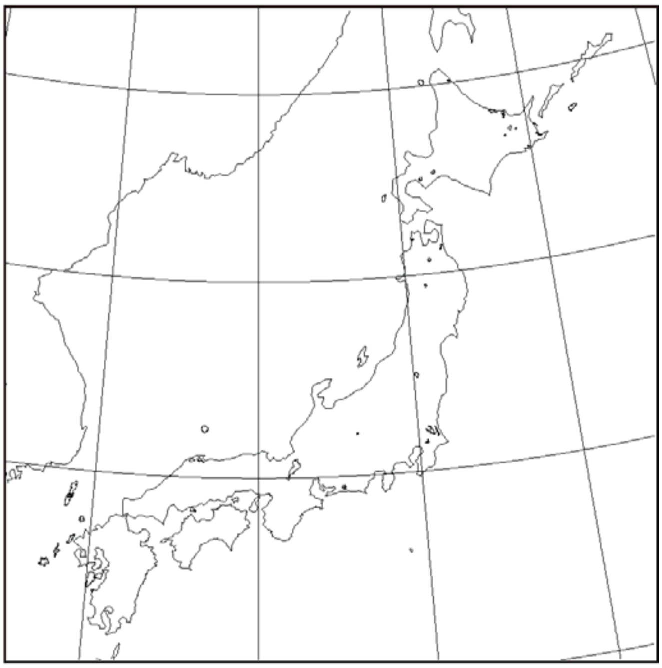
Figure 2-E.1 Time Table for Operation of MTSAT-2 (5/5)



Full earth's Disk of normalized geostationary projection



Polar-stereographic projection covering East Asia



Polar-stereographic projection covering the north-east of Japan

Polar-stereographic projection covering the south-west of Japan

Figure 2-E. 2 LRIT Images

SATELLITE IMAGERY RECEIVING FACILITIES AT TYPHOON COMMITTEE MEMBERS

Member	Station		MTSAT 1. M-DUS 2. S-DUS	NOAA 1. HRPT 2. APT	Meteosat 1. P-DUS
Cambodia					
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, 2 1, 2 1, 2 1, 2 1, 2 1, 2 1, 2 1, 2 1, 2 1 2	1, 2 2	
Democratic People's Republic of Korea	Pyongyang	(39.0°N, 125.8°E)	1,2	1	
Hong Kong, China*	Kowloon	(22.3°N, 114.2°E)	1, 2	1	
Japan	Minamitorishima Osaka	(24.3°N, 154.0°E) (34.7°N, 135.5°E)	2 1, 2		

*Hong Kong, China receives AQUA (MODIS), FY-1 (CHRPT), FY-2 (S-VISSR), and TERRA (MODIS).

Member	Station		MTSAT 1. MDUS 2. SDUS 3. Movie	NOAA 1. HRPT 2. APT	Meteosat 1. P-DUS
Lao People's Democratic Republic					
Macao, China*	Macao	(22.2°N, 113.5°E)	1	1	
Malaysia	Petaling Jaya	(3.1°N, 101.7°E)	1, 2	1	
Philippines	Quezon City	(14.7°N, 121.0°E)	1, 2	1	
	Cagayan de Oro City	(8.5°N, 124.6°E)	2		
	Pasay City	(14.5°N, 121.0°E)	2		
	Cebu	(10.3°N, 124.0°E)	2		
Republic of Korea*	Seoul	(37.6°N, 127.0°E)	1, 2	1	
	Incheon Int. Airport	(37.3°N, 126.3°E)	2, 3		
	Munsan	(37.9°N, 126.8°E)			1
	Seosan	(36.8°N, 126.5°E)		1	
	Pusan	(35.1°N, 129.0°E)	2, 3		
	Pusan Kimhae Air	(35.2°N, 126.9°E)	2, 3		
	Kwangju	(35.2°N, 126.9°E)	2		
	Taejon	(36.4°N, 127.4°E)	2, 3		
	Kangnung	(37.5°N, 130.9°E)	2, 3		
	Cheju	(33.5°N, 126.5°E)	2, 3		
	Taegu	(35.9°N, 128.6°E)	2, 3		
	Taegu/Air Traffic	(35.9°N, 128.7°E)	2, 3		
	Chonju	(35.8°N, 127.2°E)	2, 3		
	Chongju	(36.6°N, 127.4°E)	2, 3		
	Ullung-Do	(37.5°N, 130.9°E)	2, 3		
	Mokpo	(34.8°N, 126.4°E)	3		
	Chunchon	(37.9°N, 127.7°E)	3		
	Masan	(35.2°N, 128.6°E)	3		
	Tongyong	(34.9°N, 128.4°E)	3		
	Inchon	(37.5°N, 126.6°E)	3		
	Huksando	(34.7°N, 125.5°E)	2, 3		
	Suwon	(37.3°N, 127.0°E)	3		
	Sokcho	(38.3°N, 128.6°E)	3		
	Pohang	(36.0°N, 129.4°E)	3		
	Kunsan	(36.0°N, 126.7°E)	3		
	Baengnyeong-do	(37.9°N, 124.6°E)	3		
Singapore*	Changi Airport	(1.4°N, 104.0°E)	1	1	1
Thailand	Bangkok	(13.7°N, 100.6°E)	1, 2	1	
USA	Guam	(13.4°N, 144.6°E)	1, 2	1	
Viet Nam	Hanoi	(21.0°N, 105.5°E)	1, 2	2	
	Ho Chi Ming City	(10.5°N, 106.4°E)		2	

* Macao, China receives AQUA (MODIS), FY-1D (CHRPT), FY-2 (S-VISSR) and TERRA (MODIS).
* Republic of Korea receives AQUA (MODIS, AIRS, AMSU, AMSR-E), FY-1 (CHRPT) and TERRA (MODIS).
* Singapore receives AQUA (MODIS), FY2B (S-VISSR), FY-1 (CHRPT) and TERRA (MODIS).

TROPICAL CYCLONE PASSAGE REPORT FORM

TROPICAL CYCLONE PASSAGE REPORT FORM

TC Name (RSMC No.) ______________

Station/ buoy/ship Number	Minimum Sea Level Pressure		Maximum Sustained Wind		Peak Gust		Rainfall	
	hPa	Time Observed (UTC)	(10-min ave.) m/sec	Time Observed (UTC)	m/sec	Time Observed (UTC)	Amount mm	Date Observed

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

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: 31L c) Horizontal resolution: T213 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 **China**

Item	Method	Type of output
Name of the method Description of the method	Statistical dynamic method (SD-90) a. Basic equations: $du/dt - fv = F_1$ $dv/dt + fu = F_2$ Where u and v are velocity components of typhoon center; F_1,F_2 represent the mean effects of the pressure gradient and some other forces in the vortex area, given out by: $F_1 + b_1^{(1)} + b_2^{(1)} t + b_3^{(1)} t^2$, $F_2 + b_1^{(2)} + b_2^{(2)} t + b_3^{(2)} t^2$, Here $b_i^{(j)}$ (i=1,2,3; j=1,2) represents 6 random variables, which are statistically obtained from samples over 30-year period (1961-1990). The 24-hr numerical forecast height values at 500 hPa are used as predictors. b. Domain: West of the Northwest Pacific area from 15°N-40°N, 115°E-140°E c. Frequency of forecast: Twice a day 06Z, 18Z up to 72-hr	12,24,36,48,60 and 72-hr forecast positions

Name of the Member **China**

Item	Method	Type of output
Name of the method	Consensus forecast method using the canonical correlation	12,24,36,48,60 and 72-hr forecast positions
Description of the method	a. Basic equations: $X = a_0 + \sum a_i x_i$ $Y = b_0 + \sum b_i y_i$ Where X and Y are longitude and latitude of forecast typhoon position, respectively. x_i and y_i (i=1,2,3,4) are forecast longitude and latitude obtained by four sub-models: Japanese numerical model, SD-85 method, CLIPER method and Shanghai Composite Statistical method. a_i and b_i (i=1,2,3,4) are regression coefficients obtained by canonical correlation method. b. Domain: West of the Northwest Pacific area from 15°N-40°N, 115°E-140°E c. Frequency of forecast: Twice a day 06Z, 18Z up to 72-hr	

Name of the Member **Democratic People's Republic of Korea**

Item	Method	Type of output
Name of the method	Northern Hemisphere Model of Typhoon Track Prediction (NHMTTP)	Every 3 hours up to 168 hours
Description of the method	Governing equation: primitive equations Forecast domain of NHMTTP: Northern Hemisphere Resolution: T63L14 Time integration scheme: Semi-implicit Integration method: nudging of ECMWF prediction data 24 hourly. Physical processes: - radiation considering short and long wave - Kuo-type cumulus convection - Large scale condensation - Surface physical processes - PBL by K model - Fourth order diffusion Frequency of forecast: twice a day (00 and 12 UTC) Objective analysis: 3DVAR Initialization: digital filter	

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

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 **Hong Kong, China**

Item	Method	Type of output
Name of the the method Description of the method	**Persistence and climatology method** Forecasts are based on linear extrapolation (without acceleration) from the past 12-hour position of tropical cyclones and their modal directions and speeds as given by climatology. Equal weight is given to both elements. This method is sometimes referred to as the 1/2 (P + C) method. Independent variables : Present and past 12-hour positions Historical variables : Climatological model directions and speeds in 2.5 degree squares Domain : 5° ~ 30° N, 105° ~ 150° E Frequency of forecast : 4 times a day Reference : Chin, P.C., 1972: Tropical cyclone climatology for the China Seas and Western Pacific., Royal Observatory Technical Memoir, No. 11.	24, 48, 72 and 96-hr movement forecasts
Name of the the method Description of the method	**Analog** The analog method is based on the concept that a storm with certain characteristics (time of year, position, direction and speed) will move in the same way as past storms with similar characteristics. Therefore, the method searches through histropical storm tracks and identify those that fall within certain pre-defined "windows" of these characteristics. These storms are called analog storms. The analog forecast is then the average of all the forecast positions of the analog storms. Input : Date, latest position of current storm, 6-hour direction and speed or (T-6h) position of current storm, radius of acceptance circle. Frequency of forecast : 4 times a day. Reference : Hope, J.R., and C.J. Neumann, 1970 : An operational technique for relating the movement of existing tropical cyclones to past tracks., Mon. Wea. Rev., 98, 925-935.	6-hourly forecast positions and movement up to 72 hrs, list of analog storms (-48 to +72 hours positions)

Name of the Member **Japan**

Item	Method	Type of output
Name of the method	**PC method**	12, 24, 36 and 48-hr forecast position
Description of the Method	PC method is based on the fact that the typhoon movement is highly correlated with the parameters related to to the persistence (P) and climatology (C). Prediction equations used are the regression equations with predictors derived from potential predictors by employing a stepwise screening procedure. Forecast domains are shown below. Independent equations are given for the periods of January to June, July to September and October to December for the domain N and January to August and September to December for the domain S and W. Independent variables: a) Day of year b) The present and 12, 24 and 48-hr past positions and central pressures c) Zonal and meridional components of the velocity and acceleration of the typhoon movement. Domain: N: 20°-35°N, 120°-150°E S: 0°-20°N, 120°-150°E W: 0°-25°N, 100°-120°E Frequency of forecast: 4 times or more a day. Reference: Aoki, T., 1979: A statistical prediction of the tropical cyclone position based on persistence and climatological factor in the western North Pacific (the PC method). Geophys. Mag., 38, 17-27.	
Name of the method	**Analogue method**	
Description of the method	This method is based on the selection of analogue historical samples by referring to historical typhoon track data. For each past typhoon, past position closest to the present typhoon position is slightly shifted to the present typhoon position. By calculating the sum of the distances between 12-, 24-, 36- and 48-hour past positions of the present and past typhoons, respectively, ten past typhoon tracks (with the smallest ten sums of the distances) are selected. Domain: 0°-50°N, 100°-180°E. Frequency of forecast: 4 times per day.	

Name of the Member **Japan**

Item	Method	Type of output
Name of the method	The global spectral model (GSM)	
Description of the method	See Appendix 3-A (a)	
Name of the method	Typhoon Ensemble Prediction System (TEPS)	
Description of the method	See Appendix 3-A (b)	

Name of the Member **Philippines**

Item	Method	Type of output
Name of the method	**Barotropic model (500 hPa–level)**	24, 48 and 72–hr forecast positions
Description of the method	The model was based on the non–divergent barotropic vorticity equation given by $$\nabla^2 \frac{\partial\psi}{\partial t} = J(\nabla^2\psi + f, \psi) \qquad (1)$$ Equation (1) is solved numerically for $\partial\psi/\partial t$ using the sequential relaxation technique. Prediction of the future values of the stream function is made using the centered time difference formula. $$\psi(t+\Delta t) = \psi(t-\Delta t) + 2\frac{\partial\psi}{\partial t}\Delta t \qquad (2)$$ where Δt is the time increment which was taken to be 30 minutes. Domain: Asian area 20°S to 44°N 92°E to 180°E Grid net: Rectangular grid net with 23 × 17 grid points at 2.5° × 2.5° grid distance Initial data: (a) Initial 500 hPa grid point data of GSM received from RSMC Tokyo – Typhoon Center (b) "Deep layer mean winds" calculated from available initial GSM wind fields at 850, 500 and 200 hPa levels Time integration : Centered Independent variables : Boundary stream function Time–dependent variables : Inner stream function Frequency of forecast : Twice a day (06 and 18 UTC)	
Name of the method	**Persistence (P) method**	12 and 24–hr forecast positions
Description of the method	This method (as adopted in this paper) is based on the assumption that in the next 24–hour, the tropical cyclone will move in the same direction and speed as it did during the past 12–hour. Independent variables : Present and 12–hr past positions Frequency of forecast : 4 times a day (00, 06, 12 and 18 UTC) Domain : 0°–25°N, 115°–135°E	

Name of the Member **Philippines**

Item	Method	Type of output
Name of the method	**Climatology (C) method**	12 and 24–hr forecast positions
Description of the method	In this method it is assumed that a given tropical cyclone will move in all probability in the mean direction and speed of all cyclones that have been located in approximately the same latitude and longitude during the month of previous years. The 24–hour latitude ($C\phi_{24}$) and longitude ($C\lambda_{24}$) forecast position of the tropical cyclone may be expressed as: $C\phi_{24} = \phi_0 + \Delta\phi C \cdots\cdots$ $C\lambda_{24} = \lambda_0 + \Delta\lambda C \cdots\cdots$ where: $C\phi_{24}$, $C\lambda_{24}$, ϕ_0 and λ_0 are as defined above, $\Delta\phi C$, $\Delta\lambda C$ = 24–hour latitudinal and longitudinal tropical cyclone displacements, respectively, taken from the 24–hour Typhoon Displacement Tables. Frequency of forecast: 4 times a day (00,06,12 and 18UTC) Domain: 0°–25°N, 115°–135°E	
Name of the method	**(P+C)/2 method**	12 and 24–hr forecast positions
Description of the method	This is merely average of Persistence (P) and Climatology (C) forecasts, or, $\lambda\phi_{24} = (P\phi_{24} + C\phi_{24})\ /2 \cdots\cdots$ $\lambda\lambda_{24} = (P\lambda_{24} + C\lambda_{24})\ /2 \cdots\cdots$ where: $\lambda\phi_{24}$, $\lambda\lambda_{24}$ = 24–hr forecast position Other terms are defined in previous two methods. Frequency of forecast: 4 times a day (00, 06, 12 and 18 UTC)	

Name of the Member **Philippines**

Item	Method	Type of output
Name of the method	**Weighted persistence and climatology (AMADORE 1)**	12 and 24–hr forecast positions
Description of the method	Unequal weights are given to Persistence and Climatology forecasts. Only one set of weighting factors was derived from a 3–year tropical cyclone data for the whole western North Pacific and South China Sea areas. $W\phi_{24} = 0.6\ (P\phi_{24}) + 0.4\ (C\phi_{24})$ .... (1) $W\lambda_{24} = 0.8\ (P\lambda_{24}) + 0.2\ (C\lambda_{24})$ .... (2) where: $W\phi_{24}$, $W\lambda_{24}$ = 24–hour forecast position Other terms are as defined above.	
Name of the method	**FERASPER method ***	
Description of the method	This statistical technique is based on the observations that tropical cyclones that cross the Philippines actually moved to the right of the axis of maximum pressure falls making an angle of about 15 degrees. Domain is bounded by 10°N, 20°N, 120°E and 135°E A. <u>Parameters used:</u> Predictands (Dependent variables) ϕ_{12} = 12 hour forecast position in degrees latitude λ_{12} = 12 hour forecast position in degrees longitude ϕ_{24} = 24 hour forecast position in degrees latitude λ_{24} = 24 hour forecast position in degrees longitude Predictors (Independent variables) ϕ_0 = Initial position in degrees latitude at chart time λ_0 = Initial position in degrees longitude at chart time	

* : Temporarily decommissioned due to shutdown of Clark Air Base Station from where 700 hPa height data are obtained. FERASPER method is to be replaced by "BAGYO".

Name of the Member **Philippines**

Item	Method	Type of output
	ΔP_M = 24–hour pressure change, Manila (98429) at chart time ΔP_B = 24–hour pressure change, Basco (98135) at chart time ΔP_N = 24–hour pressure change, Naha (47936) at chart time $\Delta\phi_{-12}$ = Past 12–hour latitude displacement, positive (+) for Northward displacement $\Delta\lambda_{-12}$ = Past 12–hour longitude displacement, positive (+) for Westward displacement H_C = Latest 700 hPa height in geopotential meters at Clark Air Base (98327) H_I = Latest 700 hPa height in geopotential meters at Ishigakijima (47918) B. <u>Set of Regression Equations</u> Predicted 12–hour Displacement: $\phi_{12} = 2.1715 + 0.8697\,(\phi_0) + 0.6591\,(\Delta\phi_{-12}) - 0.0415\,(\Delta P_M) - 0.0593\,(\Delta P_B) - 0.0433\,(\Delta P_N)$ $\lambda_{12} = -5.563 + 0.911\,(\lambda_0) - 0.3799\,(\Delta\lambda_{-12}) + 0.0469\,(\Delta P_M) - 0.0578\,(\Delta P_B) - 0.00048\,(H_C) + 0.0054\,(H_I)$ Predicted 24–hour Displacement $\phi_{24} = 4.596 + 0.7543\,(\phi_0) + 0.973\,(\Delta\phi_{-12}) - 0.0785\,(\Delta P_M) - 0.0911\,(\Delta P_B) - 0.1087\,(\Delta P_N)$ $\lambda_{24} = -26.91 + 0.8526\,(\lambda_0) - 0.5365\,(\Delta\lambda_{-12}) - 0.1274\,(\Delta P_B) - 0.0229\,(\Delta P_N) - 0.00292\,(H_C) + 0.0164\,(H_I) + 0.0752\,(\Delta P_M)$ Frequency of forecast: 4 times a day (00, 06, 12 and 18 UTC)	

Name of the Member **Philippines**

Item	Method	Type of output
Name of the method	**Analog ("BAGYO")**	
Description of the method	"BAGYO" is an analog method of predicting tropical cyclone tracks using data base from the years 1884–1989. The forecast is based on finding past storms which appeared during a similar time of year and geographic region and which exhibited characteristics similar to those of the storm under consideration, such as speed and heading. Time and space characteristics are identified and displaced to a common origin. Bias translation is applied to the cluster of analog storm positions at various forecast intervals. The forecast is solved by taking the weighted mean of storm positions 24–, 48– and 72–hour after the common origin of the analog storms. The weight used is the rank of the analog cyclone which depends on the characteristics of the analog storm. Probability ellipses are also computed. Independent variables: Weighted mean of 24–, 48– and 72– hour storm positions Domain: Bounded by 10°N, 30°N, 110°E and 135°E Frequency of forecast: 4 times a day (00, 06, 12 and 18 UTC)	

Name of the Member **Philippines**

Item	Method	Type of output
Name of the method	In addition to methods mentioned above, other objective methods currently being used in the Philippines are (a) Veigas Miller, (b) Arakawa, (c) Analogue (Typhoon), (d) Kalman and (e) WPCLPR by Yiming Xu and C.J. Neumann. The average of the results of all objective techniques is considered as the objective forecast. If some of the objective forecast tracks depart greatly from the majority, these are disregarded in the averaging process. The official tropical cyclone track forecast is the arithmetical average of the subjective and objective forecasts for 12 and 24 hours. During critical situations, storm strike probability is also used to minimize overwarning and as an additional tool in forecasting landfall of typhoons. Mean tropospheric wind field calculated from three levels is also used as a guide in determining the steering current for tropical cyclone movement. The data used in the calculations are from the Global Spectral Model (GSM) products of JMA at 850, 500 and 200 hPa levels, with the same domain for the barotropic model.	

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))	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**Extrapolation method (XTRP)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Forecast speed and direction are computed by taking the difference between the current and 12-hour old positions of the tropical cyclone. - Frequency of Forecast : 4 times a day	
Name of the the method	**Climatology method (CLIM)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Employ time and location windows relative to the current position of the tropical cyclone to determine which historical storm will be used to compute the forecast. - The historical database is from 1945-1981 for the Northwest Pacific, and from 1900 to 1990 for the rest of JTWC's AOR. - Objective intensity forecasts are available from these databases. - Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these databases. - Frequency of Forecast : 4 times a day	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**Analog method**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	A revised Typhoon Analog 1993 (TYAN93) picks the top matches with the basin Climatology of historical tropical cyclone best tracks. - Matches are based upon the differences between the direction and speed of the superimposed historical best track positions and the past direction and speed of the cyclone. - Forecast direction and speed are calculated from the 12-hour old position to the current position and the 24-hr old position to the current position. - Separate comparisons are made for climatology cyclone tracks classified as "straight," "recurver" and "other". There is also a "total" group, that includes the top matches without regard to classification of tracks. - The space window is +/- 35 days from the current position. - The space window is +/- 2.5 degrees latitude and +/- 5 degrees longitude from the current position. - Frequency of Forecast : 4 times a day	
Name of the the method	**Climatology and Persistence method (CLIPER or CLIP)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	A statistical regression technique based on climatology, current position, and 12-hour and 24-hour past movement. - Is the baseline against which forecast skill is measured. - Uses third-order regression equations, and is based on the work of Xu and Neumann (1985). - Frequency of Forecast : 4 times a day	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**Colorado State University model (CSUM)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	A statistical-dynamical technique based on the work of Matsumoto (1984). - Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAP 500-hPa analyses, and heights from the 24-hr and 48-hr NOGAPS 500-hPa prognoses. - Height values from 200-hPa fields are substituted for storms that have an intensity exceeding 90 kt and are located north of the subtropical ridge. - Three distinct sets of regression eqations are used depending on whether the storm's direction of motion falls into "below", "on", or "above" the subtropical ridge categories. - Frequency of forecast: 4 times a day	
Name of the the method	**JTWC92 or JT92**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	A statistical-dynamical model for the North West Pacific Ocean which uses the deep-layer mean height field derived from the NOGAPS forecast fields. - Deep-layer mean height fields are spectrally truncated to wave numbers 0 through 18 prior to use in JTWC92. - Separate forecasts are made for each position. - The 00Z and 12Z tropical forecasts are based upon the previous 12-hour old synoptic time NOGAPS forecasts. - The 06Z and 18Z tropical forecasts are based on the previous 00Z and 12Z NOGAPS forecasts, respectively. - Frequency of forecast: 4 times a day	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**NOGAPS Vortex Tracking Routine (NGPS/X)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Tropical cyclone vorticies are tracked in NOGAPS by converting the 1000-hPa u and v wind component fields into isogons. - The intersection og isogons are either the center of a cyclonic or anticyclonic circulation, or a col. - The tracking program starts at the last known location of the cyclone – a warning position. Based on this position and the last known speed and direction of movement, the program hunts for the next cyclonic center representing the tropical cyclone. - Frequency of forecast: 2 times a day	
Name of the the method	**Geophysical Fluid Dynamics Model – NAVY (GFDN/X)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	This model is an adaptation of the Geophysical Fluid Dynamics Model used by the National Center for Environmental Prediction (NCEP). - This model uses a triple-nested movable mesh with 18 sigma levels. - The outer mesh domain covers a 75 degrees x 75 degrees area with a horizontal resolution of 1 degree and is fixed for the duration of the model ru. - The 10 degrees x 10 degrees middle and a 5 degrees x 5 degrees inner (resolution 1/6 degrees) nested meshes move with thr cyclone. - Based on global analysis and an initialization message, the TC is removed from the global analysis, and replaced by a synthetic vortex which has an asymmetric (beta-advection) component added. - The model outputs TC track forecasts and maximum isotach swaths indicating the location of maximum winds in relation to the TC track. - Frequency of forecast: 2 times a day	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**FNMOC Beta and Advection Model (FBAM)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	This model is an adaptation of the Beta and Advection model used by the National Center for Environmental Prediction (NCEP). - The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. - The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind Fields which are a weited average of the wind fields computed for the 1000-hPa to 100-hPa levels. - The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave an "effective radius" propagating in response to the horizontal graient of the coriolis parameter, beta. - The forecast blends in a persistence bias for the first 12 hours. - Frequency of forecast: 4 times a day	
Name of the the method	**Medium Beta and Advection Model (MBAM)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Similar to FBAM, but the steering is computed from the NOGAPS wind fields which are a weighted average of the wind fields computed for the 850-hPa to 500-hPa levels. - Frequency of forecast: 4 times a day	
Name of the the method	**Shallow Beta and Advection Model (SBAM)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Similar to FBAM, but the steering is computed from the NOGAPS wind fields which are a weighted average of the wind fields computed for the 850-hPa to 700-hPa levels. Frequency of forecast: 4 times a day	

Name of the Member **USA**

Item	Method	Type of output
Name of the method	**Half Persistence and Climatology (HPAC)**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	Forecast positions generated by equally weighting the forecasts given by XTRP and CLIM. - Frequency of forecast: 4 times a day	
Name of the the method	**Dynamic Average**	12-, 24-, 36-, 48-, and 72-hr forecast positions
Description of the method	A simple average of all dynamic forecast aids: NOGAPS (NGPS), Bracknell (EGRR), JMA Typhoon Model (JTYM), JT92, FBAM, and CSUM. - Frequency of forecast: 4 times a day	

Name of the Member **Viet Nam**

Item	Method	Type of output
Name of the method Description of the method	Barotropic Model Governing equations: Three primitive equations formulated on a discrete grid in geographical coordinates. Dependent variables: geopotential height **H** (m), zonal **U** (m/s) and meridional **V** (m/s) components of wind. Domain: Two nested domains. The outermost forecasting domain is fixed and extends from 20 °S to 60°N, 60 °E to 180 °E with horizontal resolution 1.25° (121 x 81 grid points). The inner domain is vortex - centered, movable consisting of 20 x 20 grid points with resolution of 0.25 degrees. Approximation schemes: centered finite difference for spatial approximation, Adams-Bashforth for time integration. Boundary conditions are fixed. Initial global fields **H, U, V** are obtained from global analysis of Japan Meteorological Agency (JMA). Vortex initialisation scheme: bogus vortex is constructed based on the assumption that the storm motion is equal to the vector sum of the large scale environmental flow plus the vortex asymmetry (Smith and Ulrich, 1990; Smith, 1991; Smith and Weber, 1993; Weber and Smith, 1995; Davidson and Weber, 2000). A number of modifications had been done to this scheme for better representing characteristics of tropical cyclone motion near Viet Nam. Frequency of forecast: twice a day (for base times 00 UTC and 12 UTC) when a tropical storm is acting in the South China Sea.	Tropical cyclone positions (latitude, longitude) for +12h, +24h, +36h and +48h ahead

Name of the Member **Viet Nam**

Item	Method	Type of Output
Name of the method Description of the method	Barotropic model (referred to as WBAR model) with vortex initialization scheme **Governing Equations**: a set of shallow water equations that formulated in a geographical coordinate system **Data Domain**: Area of 161 x 101 grid points from 60^0E to 180^0E and from -5^0S to 55^0N with spatial resolution of 0.75^0 x 0.75^0 in lat-long **Initial Conditions**: predifined 850-200mb DLM wind and height operational objective analyses and forecasts of Global Spectral Model (GSM) of Japan. Geopotential height is provided in the form of deviation from a mean distribution. **Boundary Conditions**: time-dependent boundary **Integration Scheme**: An Euler forward step and a third-order Adams-Bashforth step are used for the first two time steps, while all other time steps are Adams-Bashforth steps of third-order. **Integration Step**: the model time steps are variable and determined automatically by evaluation of the Courant-Friedrich-Levy criterion using the current wind and height fields. **Integration Domain**: is storm-relative circular domain and movable . **Vortex initialization scheme**: consists of a post-analysis of the predifined 850-200mb DLM wind components of the operational objective analyses and forecasts of GSM model and the construction of synthetic vortex using the information provided that by the operational TC advisories. The analysis procedure is based on the methodology of Weber and Smith (1995) and is similar to the operational vortex enhancement scheme used in TC-LAPS model. **Frequency of forecast**: Twice times a day when existing any tropical cyclone over the East Sea	12h, 24h, 36h and 48h forecast position of tropical cyclone

SAMPLES OF THE OPERATIONAL PROCEDURES AND METHODS FOR THE TROPICAL CYCLONE ANALYSIS AND FORECASTING

1. The methods of tropical cyclone analysis and forecasting

1.1 Judgement on tropical cyclone formation

1.1.1 Satellite analysis

See Appendix 3-C, p.15 (Sec. 2.2)

1.1.2 Radar analysis

See Appendix 3-C, p.14 (Sec. 2.1)

1.1.3 Upper air analysis

The following conditions may be assessed on an operational basis by means of upper air and streamline analyses (at the 850, 500 and/or 300 hPa levels). If the replies to the following questions are "yes" in at least one of the following cases, formation of a storm is expected.

1. Does the synoptic scale upper divergence exist over the tropical disturbance? The upper divergence favours the development of disturbance into storm.

2. Are the high level anticyclone and the warm core starting to be established or have they developed over the disturbance? These indications show a storm formation empirically.

3 Are the convergence of the moist air and the definite organized circulation observed (say, at the 850 hPa level) over the disturbance? These features show a storm formation empirically.

1.1.4 Synoptic surface analysis

The following conditions may be assessed on an operational basis in the vicinity of the disturbance by means of the surface analysis.

1. Existence of a region of the surface pressure less than 1,000 hPa?

2. Existence of a region of the surface pressure fall more than 5 hPa per 24 hours.

3. Existence of a region of the surface mean wind more than 10 m/sec.

Any existence of the region mentioned above may favour a storm formation.

1.1.5 Sea surface temperature (SST) analysis

A large area of SST greater than or equal to 26°C in the vicinity of the disturbance is necessary for the formation and development of the typhoon.

1.2 Identification of tropical cyclone / typhoon position

1.2.1 Determination of typhoon position by means of extrapolation

Central position of the typhoon can be estimated by extrapolation. This extrapolation is based on the persistence of typhoon movement in the past.

1.2.2 Radar data analysis

See Appendix 3-C, p.14 (Sec.2.1)

1.2.3 Satellite analysis

See Appendix 3-C, p.15 (Sec. 2.2)

1.2.4 Surface map analysis

(1) The distance intersection method (with pressure profile)

We assume that the strength, scale and pressure profile of the typhoon remains unchanged.

Procedure

Step 1. Read the surface pressure at point A and measure the distance from point A to the typhoon center in the pressure profile chart (Fig. 3-C.1) prepared at the previous map time. Draw the arc with the distance obtained (Fig.3-C.4).

Step 2. Same work for several points.

Step 3. The arcs do not always intersect at one point. The typhoon center must be obtained as the average of the intersecting points.

Remarks:

a. This method is not used in case of rapid development or weakening of the typhoon, or when the typhoon has come near to land because the pressure profile will change.

b. When the isobar of the typhoon is not circular, this method will produce some error.

Note: Determination of the pressure profile

1. The pressure profile of the typhoon is determined by using surface pressure data on the surface map at the previous map time. The obtained pressure profile is used to fix the position of the typhoon at next map time.

2. The pressure (P) – distance (r) relation of the typhoon is expressed approximately by the following empirical formula:

$$P(r) = P_\infty - \frac{\Delta P}{1 + r / r_0}$$

Where P_∞ (= 1015 hPa) is the pressure outside the typhoon, ΔP is the difference between P_∞ and the P_{CN} (central pressure), and r_0 is the distance of the isobar ($P_{CN} + ½\Delta P$) from the typhoon center.

This $P_\infty - r$ relation is expressed by a line on Takahashi's diagram (Fig.3–C.1).

3. Procedures for the determination of the typhoon pressure profile are as follows.

Step 1. The distance r_A from the typhoon center, CN, to station A on the surface map (see Fig.3–C.2) is measured. Point A is plotted on Fig.3–C.1 (r_A is abscissa, P_A in ordinate).
Step 2. The same is done for points B, C ···· F.
Step 3. Point CN (r_{CN} = 0, P_{CN}) is plotted on Fig.3–C.1.
Step 4. A line as shown in Fig.3–C.1 is drawn. This line expresses the pressure profile of the typhoon at the analyzed time.

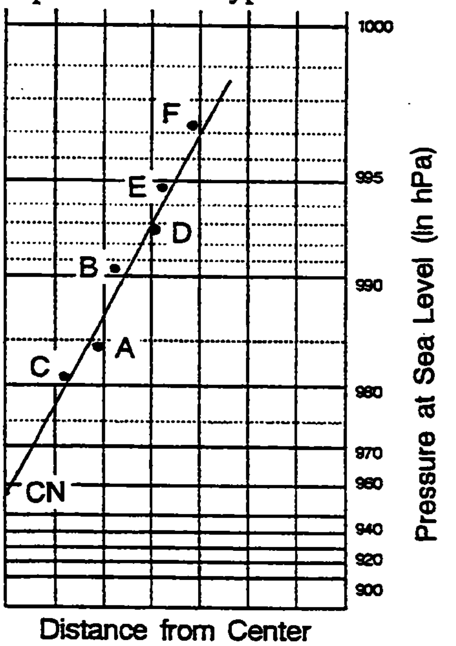


Fig.3–C.1 Graph for determining the centre reading of a typhoon

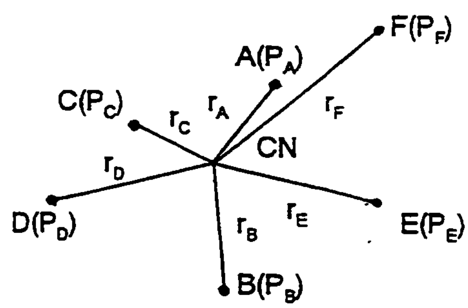


Fig.3–C.2 Measurement of the distance between the typhoon centre and surface observation stations

(2) Circular center method.

In the case of the circular typhoon, first, draw perpendicular bisectors between points of equal pressure. The bisectors for various couples of such points may not always pass one point, but form a polygon. The center of the polygon is regarded as the typhoon center (Fig. 3-C.5).

Remark:

a. When the isobar of the typhoon is not circular, this method will produce some errors. However, this method is preferable when another method cannot be used.
b. When the typhoon is moving fast, or when the typhoon is close to land, the errors become large because the isobar of the typhoon is not circular.
c. It is advisable not to use the data that are located far from the center.

(3) Inflow angle method

Using the wind directions reported by ships or land stations within the circulation of the tropical cyclone, the wind center can be determined by assuming that the wind profile is symmetrical and that the angle of inflow is constant at 20 degrees. The procedure to locate the eye is therefore to draw straight lines from the above points at an angle of 110° + θ° where θ is the direction of the reported wind. The centroid of the polygon formed by these straight lines can be regarded as the tropical cyclone's eye.

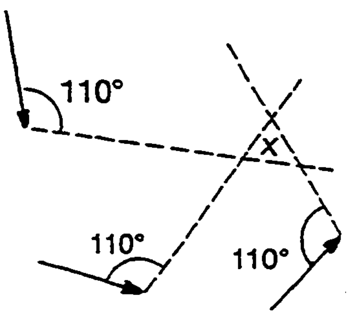


Fig. 3–C.3 Arrows indicate the wind directions at some ships or stations within the circulation of a tropical cyclone. The dotted lines are drawn at an angle of 110° + θ° where θ is the direction of the reported wind.

(4) Surface map analysis over land area

In case of the typhoon passing over the land area, reports of occurrence time of minimum pressure, the rapid changes in wind directions should be used to determine the accurate course of the typhoon.

When there is a notable weakening of the typhoon or deformation of the pressure field caused by the orographic influence, the data should be used with care. The surface pressure change during three hours can be used for tracing the typhoon movement.

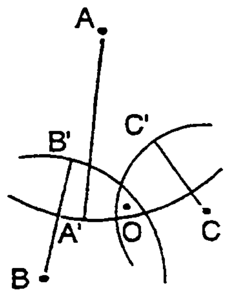


Fig. 3-C.4 Explanation of the distance intersecting method (1).

Point O is the center of typhoon.

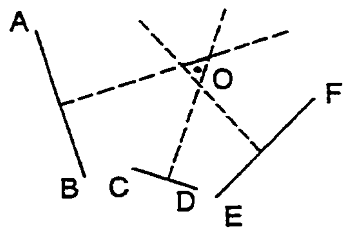


Fig. 3-C.5 Explanation of the distance intersecting method(2).

Dotted lines are perpendicular bisectors of lines AB, CD and EF connecting equal pressure points. Point O is the center of typhoon.

1.3 Assessment of tropical cyclone / typhoon intensity

1.3.1 Satellite analysis

See Section 2.2.

1.3.2 Radar observation

See Section 2.1.

1.3.3 Surface map analysis

See Section 1.2.4.

1.3.4 Estimation of maximum wind by using the empirical relation between central pressure and maximum wind

The observation of the maximum wind is scarcely made over the sea area. Therefore, the maximum wind speed must be estimated from the central pressure using some formula. As an example, the formula given by Atkinson and Holliday (1977) is shown below.

The maximum sustained surface wind speed is obtained by applying the minimum sea level pressure to the following regression equation:

$$V_m = 6.7 (1010 - P_c)^{0.644}$$

where V_m is the maximum sustained (1 min) wind speed (kt) and P_c the minimum sea level pressure (hPa). In this study, 28 years of maximum wind measurements made at coastal and island stations in the western North Pacific were collected and analyzed (see Fig. 3–C.6). (After G. D. Atkinson and C. R. Holliday, 1977: Mon. Wea. Rev. 105, 421–427)

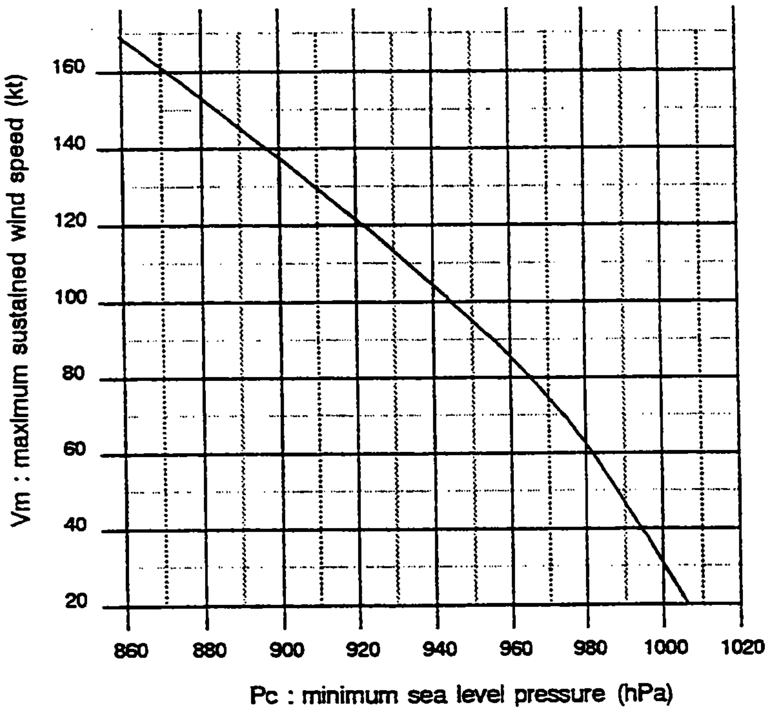


Fig. 3–C.6 The maximum sustained wind (one minute mean) *vs* the minimum sea level pressure.

1.4 Prediction of tropical cyclone / typhoon movement

1.4.1 Best typhoon track

1. Decide the best typhoon track up to now.

2. Check some indications of special movement, such as slow–down, meander and looping.

1.4.2 Persistence method (Extrapolation)

The persistence method is based upon the assumption that the velocity of the typhoon is unchanged, i.e., the simple extrapolation.

1.4.3 Prediction by the statistical method

The statistical methods are effective when the typhoon shows simple movement. PC method, Arakawa's method and NHC's CLIPER may be included in the category of the statistical method.

Various statistical methods are used by Typhoon Committee members. These methods are described in Appendix 3–A "Operational typhoon track forecast methods used by Typhoon Committee members".

1.4.4 Prediction by analogue method

The analogue method may be used for the prediction of the typhoon movement, provided that in the historical data one can find a typhoon similar to the present one in regard to the movement, intensity and large–scale environmental situation.

1.4.5 Prediction by dynamical method

Basically, two approaches can be attempted, i.e.,

1) Prediction by two–dimensional model such as the barotropic model.

2) Prediction by the three–dimensional model with a special emphasis on the treatment of the typhoon.

Three–dimensional model

The three–dimensional model used for the typhoon prediction with real data may essentially be similar to the ordinary high resolution operational numerical weather prediction model. Outline of the RSMC typhoon model is described in Table 3.2 (b). However, since we have only incomplete initial observation to depict the sharp profile of typhoon fields (i.e., velocity, temperature, pressure, height and humidity), we cannot help but estimating the typhoon fields from limited data to fit assumed profiles. The lack of initial data may sometimes cause a poor performance of numerical typhoon prediction model.

Ordinary NWP models are also utilized for the prediction of typhoon movement in the lower and middle latitudes. The accuracy of the prediction by these models may be limited due to the insufficient resolution to represent tropical cyclone.

1.4.6 Synoptic method

1.4.6.1 Analysis of the general field

1. Watch the behavior of the subtropical anticyclone, easterly wave and other disturbances which will affect the movement of the typhoon.

2. Watch significant changes in the surrounding situation around the typhoon.

3. Watch the behavior of the westerly trough near the recurving point expected.

4. Examine the influence of the changes in the general field on the typhoon movement.

1.4.6.2 Steering method

The steering method is based upon the experience that the typhoon moves approximately along the steering current. Prediction is made by the following steps.

Step 1. Make the streamline analysis at 500 and 300 hPa.

Step 2. Find the steering current (V_s: large scale current around the typhoon).

Step 3. Find the difference D between the typhoon speed V_T and V_s ($D = V_s - V_T$).

Step 4. Estimate the typhoon position in the next map time using V_s and D at the present map time.

The present method can be used only for 12–hour or 24–hour prediction, because the change of the steering current is not predicted.

1.4.6.3 Prediction based upon the time change of pressure or height

This method is based upon the experience that the typhoon moves toward the area of maximum pressure (height) fall. The analysis of the field of pressure change ΔP and height change ΔZ in a certain time interval Δt is useful for predicting the direction of the typhoon movement. Time interval Δt of 1, 3, 12, or 24 hour is usually used for ΔP and that of 12 or 24 hour for ΔZ.

This method is useful when the pressure fall area takes a form like a tongue as shown in Fig. 3–C.7.

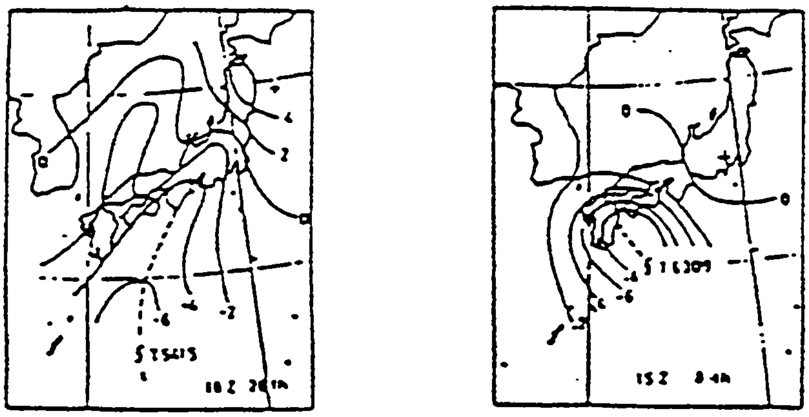


Fig. 3–C.7 Typical pattern of the 12–hour pressure change.

1.5 Prediction of tropical cyclone / typhoon intensity

1.5.1 Extrapolation method

The central pressure can be predicted by extrapolation of central pressure on "time change curve of central pressure by Eye data".

1.5.2 Satellite analysis

See Section 2.2

1.5.3 Synoptic method

1. When the radius of the eye is reduced and the eye becomes more distinct, the typhoon is developing.

2. When the wind distribution becomes more symmetric with respect to the circulation center, the typhoon is developing.

3. When the temperature in the lower troposphere becomes high near the typhoon center, the typhoon will develop.

4. When the wind distribution becomes asymmetric, the typhoon will decay.

5. The typhoon tends to decay when it moves into the midlatitude upper westerlies.

6. The typhoon tends to decay when the colder air flows into the lower part of the typhoon.

1.5.4 The sea surface temperature

1. When a typhoon stays over the ocean of the sea surface temperature more than 26°C, the typhoon tends to maintain the present intensity or develop.

2. When a typhoon moves into the colder sea surface area (less than 26°C), the typhoon tends to decay.

1.5.5 Radar observation

See Appendix 3-C, p.14 (Sec. 2.1).

Notes: Life cycle of the typhoon

a. Formation stage
The rate of the pressure change may fluctuate and the wind distribution may be asymmetric.

b. Development stage
The amount of pressure fall increases with respect to time. The intensification of the maximum wind is more remarkable than the expansion of the strong wind zone.

c. Mature stage
A typhoon acquires a quasi-steady state with only random fluctuations in the central pressure and maximum wind speed. However, the strong wind zone still expands.

d. Decay stage
Asymmetry in the pressure and wind field becomes more pronounced.

1.5.6 Numerical weather prediction

High-resolution NWP global models, including EPS systems, are generally becoming more reliable with skills comparable to the subjective forecasts issued by the forecasters. They can provide useful guidance material for estimating intensity category and trend.

1.5.7 Model output statistics (MOS) method

The NWP intensity predictions can be further improved using MOS methods by establishing the statistical relationship between the analyzed intensity and forecast intensity output by the models. For example, based on the regression of model forecast central pressure against the best-track data in past years, a set of best-estimated parameters can be derived to correct the real-time NWP forecasts. Deterministic forecasts of tropical cyclone intensity derived from EPS data can also be calibrated using an artificial neural network.

1.6 Prediction of rainfall

Rainfall related with the typhoon are roughly divided into the following four categories;
1) vortical rain near the typhoon center,
2) orographic rainfall,
3) rainfall caused by the outer-band, and
4) rainfall caused by front in the higher latitude region.

1.6.1 Numerical weather prediction

Rainfall are predicted by the primitive equation model including cumulus parameterization scheme. The predicted precipitation is, in general, smaller than the observed one, though the predicted rainfall area generally agrees well with the observed rainfall area. It should be noted that the model sometimes yields the erroneous small-scale (two grid noise) concentration of heavy rainfalls.

1.6.2 MOS method: Model Output Statistics

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.

1.6.3 Statistical prediction of rainfall

The statistical method is based on the statistical relations between the rainfall amount and various parameters of the typhoon such as the wind speed and the wind direction.

Example: the empirical formula used to predict rainfall in Japan is shown below.

$$RAIN(I, J, K) = V(I, J) \times C(I, J) \times 0.33 \times 0.08 \quad \cdots \text{ orographic rainfall}$$

$$VR(I, J) = 0.8 \times ST \times \exp\left\{ \frac{50}{ST} \cdot \left(\frac{R(I, J)}{100} \right)^2 \right\}$$

$\cdots$ vortical rain near typhoon center

$$V(I, J) = ST(I) - (ST(I)-10) \times \frac{R(I, J)}{SZ}$$

$\cdots$ wind speed related typhoon region

RAIN : orographic rainfall
V : wind speed (m/sec)
C : orographically induced vertical velocity (unit: 10 hPa/hour) by wind speed of 1 m/sec
VR : vortical rain (mm/hour)
ST : maximum wind (m/sec)
R : distance from the center of typhoon (km)
SZ : radius of the wind speed zone over 15 m/sec (km)
I,J,K : time, region and wind direction (16 point) related to such element as V, ST, R and C

1.6.4 Analogue method

The analogue method can be used if the typhoon similar to the present one regarding the trajectory and intensity is found in the past data.

1. Select analogous typhoon.

2. The prediction of rainfall is made by referring to the rainfall amount of the selected analogous typhoon.

3. The predicted rainfall amount is adjusted by comparing the predicted amount with the actual one.

1.6.5 Very-short range prediction of rainfall by radar observation

Radar is used for detecting and tracking the typhoon and severe storms such as thunderstorms. From the relation between the echo intensity and the precipitation, the amount of rainfall is estimated. This 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.

1.6.6 Very-short range prediction of rainfall by satellite observation

Qualitative analysis of rainfall area can be done using satellite picture. For the quantitative analysis techniques of rainfall area and amount, digital image data must be used.

The guides for detection of rainfall area is summarized as follows:

1. Identification of convective cloud area and the thickest and/or coldest “point” area of deep convective clouds

a. Draw the outlines of convective clouds.
Try to discriminate cirrus anvil from convective cloud. Cirrus anvils of deep convective clouds are seen at the 200 hPa downwind areas of the clouds.

b. Detect the “point” maximum rainfall area by examining the highest and/or coldest area in IR picture and shadows of overshooting Cb tops in VIS picture. In the case of Cb with cirrus anvil, the “point” area is usually near the upwind sharp end of the Cb cloud.

2. Analysis of movement and evolution of convective cloud and Cb cluster

Life times of Cb’s with size of 50 – 100 km including anvil are 3 – 6 hours and those of Cb clusters are about 12 hours.
Note that convective clouds in IR picture tend to continue to appear cold (white) even a few hours after convective activity and rainfall reached the peak.

3. Comparison of satellite analysis with radar analysis

Analyze rainfall area out of radar detection range by referring to the relation between satellite and radar analyses within the radar detection range.

4. Microwave sensors from satellites

Rainfall amount and probability of precipitation can be predicted using microwave sensors from satellites.

1.7 Prediction of wind

1.7.1 Synoptic method

1. The distribution of wind within the typhoon area is resultant of gradient wind and isallobaric wind in the first approximation. However, calculation of the isallobaric wind is not easy in operational basis, therefore it is obtained approximately by adding the velocity of typhoon movement to the gradient wind.

2. The maximum wind near the moving typhoon center is usually observed in the right hand side of the direction of movement. The distribution of wind speed accompanying the typhoon may be expressed as follows:

Vmax in the right semicircle = Vmax in the left semicircle x K,
where K is 1.2 to 1.4.

3. Predict the wind over the target area taking into consideration the features mentioned in 1. and 2.

4. The wind field over land is usually modified by the topography, therefore it is necessary to research topographic effect beforehand.

5. The gust is greater around the convective cloud in mature stage, therefore it is necessary to watch the convective cloud by radar and satellite.

1.7.2 Statistical method

1. Wind velocity at a given point is extrapolated from the profile of the wind over the typhoon area. For example, an empirical formula for the wind speed distribution within the typhoon area over Japan is shown below;

$$V = ST - (ST - 10) \times R / SZ$$

where V = wind speed (m/sec),
ST = maximum wind speed (m/sec),
R = distance from the typhoon center (km),
SZ = radius of the wind speed zone over 15 m/sec.

2. The change of maximum wind speed due to the land effect in the experimental area should be investigated by the statistical method.

3. The maximum gust speed is given by $V_{max} \times K$, where V_{max} is the maximum sustained wind and K is 1.1 to 1.5. However, for the weakened typhoon in lower latitudes, K will be increased to 2 to 3.

1.7.3 Analogue method

This method is applied to the typhoon which is found to be similar to the one in historical data in terms of the trajectory and the intensity. Wind distribution around the present typhoon is assumed similar to that of the typhoon found in historical data.

1.8 Prediction of storm surge

1.8.1 General explanation

The storm surge is caused by pressure drop near the storm center and by surface drag due to the strong wind accompanying the storm. The surge due to the latter effect depends strongly on the angle between the wind and the axis of the bay. The actual tide is the sum of the astronomical tide and the storm surge.

In order to estimate the tide, predict

i) the place and the time of landfall,

ii) the minimum central pressure and the maximum wind of the storm at the time of landfall and

iii) the storm trajectory relative to the axis of the bay concerned.

There are two methods, i.e., dynamical method and statistical method. An example of the dynamical method is the SPLASH model. A detailed report about the SPLASH model is found in the reference. It is helpful for operational purpose to calculate the surge beforehand using the dynamical method for storms with various intensity and trajectory.

1.8.2 An example of statistical method

The following regression equation is used in Japan to predict the maximum storm surge.

$$h = A (P_0 - P_c) + B V_{max}^2 \cos\theta,$$

where, h is surge (cm) and P_0 the mean monthly pressure (hPa). The terms P_c and V_{max} are the minimum central pressure and the maximum wind of the storm at the time of landfall, respectively. The term θ denotes the angle between the wind and the axis of the bay. The magnitude of constant A is close to unity since the hydrostatic pressure fall by 1 hPa generates a rise of sea level of about 1 cm. The magnitude of constant B is specified for each bay, because the area size, depth and configuration of bays are not the same. The regression coefficients must be determined from tide gauge data over the long period.

Reference
WMO (1973): Present Techniques of Tropical Storm Surge Prediction, Report on marine science affairs report No.13.

2. The application of radar and satellite observation data in tropical cyclone analysis and forecasting

2.1 Radar observation data

Radar observation and RADOB report are used for the operation.

2.1.1 Judgement on tropical cyclone formation

The features of the curved echoes, spiral bands and the eye show the stage of the tropical storm.

2.1.2 Identification of typhoon position

When the radar data reported by WMO code are used to fix the central position of the typhoon, the accuracy code in the RADOB must be confirmed. Accuracy code is classified into three categories: 1) good (within 10 km), 2) fair (10–30 km) and 3) poor (30–50 km).

2.1.3 Some features indicating the change in typhoon intensity

The following features should be noted in radar observation.

1. The distinct eye and reduction of eye size show the typhoon development. The indistinct shape of the eye and the expansion of the diameter of the eye observed over the sea show the decay of the typhoon.

2. Remarkable echo developing near the center shows the typhoon development. The reduction of area and intensity of convective echo near the center over the sea shows typhoon decay.

3. Typical configuration of the spiral band shows the typhoon development.

4. Increase of stratified echo shows the decay of the typhoon.

5. When the typhoon center reaches the middle latitudes and the echoes are organized into the pattern like ● or λ, the typhoon is changing into the extratropical cyclone.

Note:

a) Regular calibration of radar should be carried out. Technical specification of radars of Typhoon Committee Members shown in Appendix 2–E should be consulted when reports from these radars are used.

b) When the reports from two or more radar sites are received, the report from the sites using 10 cm radar is used first in the tropics. If the type of the radars are same, the report from the site nearest to the typhoon is used first and the report with better accuracy is used next.
In addition, past radar reports from the same site should be evaluated for accuracy against the past track of the typhoon.

c) Typhoon track fixed by radar should be smoothed. Since the typhoon track fixed by radar reports often shows irregular fluctuation over a short span of time, any small–scale irregularities should be eliminated using the smoothing method.

2.2 Satellite analysis

2.2.1 Judgement on tropical cyclone formation,
Identification of tropical cyclone / typhoon position,
Assessment of tropical cyclone / typhoon intensity and
Prediction of tropical cyclone / typhoon intensity

After its operational application over a long time in many tropical cyclone forecast centers, it has been found that Dvorak's technique is very useful for the satellite analysis operation of tropical cyclones.

Therefore, the explanation of the satellite data application technique for the operations in this section is considered to be fulfilled by referring to the material in Dvorak's article which is attached to this Manual as an annex of Appendix 3–C.

2.2.2 Prediction of tropical cyclone / typhoon movement

2.2.2.1 Cloud features indicating future storm movement

When cloud features mentioned below are found, change of movement should be noted.

1. Deep convective cloud clusters developing around CSC.

   Storm moves toward them. When they are seen in front of (in the rear of) CSC, storm movement accelerates (decelerates). Storm does not move toward the Cb–free sector of the storm.

2. The elongation of storm cloud system.

   Storm tends to change its movement direction to the orientation of its long axis.

3. Northward extension of cirrus shield.

   This feature indicates northward component of future storm movement. North–eastward extension of cirrus is often seen when the recurvature of westward moving storm takes place.

On the other hand, when cloud features stated above are not seen or when cloud features mentioned below are observed, persistence of the present movement may be expected.

1. Axially symmetric cloud pattern.

2. Multidirectional cirrus outflow.

2.2.2.2 Identification of cloud features indicating environmental situation affecting future storm movement.

Environmental cloud features sometimes indicate large scale situation affecting future storm movement.

1. North–south oriented active convective cloud band moving westward in the subtropical high.

   This cloud band indicates westward extension or intensification of the subtropical high.

2. Southward extension of the cloud system associated with midlatitude westerly trough seen to the northwest of the storm.

   When this extension is significant, northward movement of the storm is expected.

Remark:

Short–period variation of cloud features associated with the storm and in environmental area often misleads forecast of future storm movement.

THE TROPICAL CYCLONE ANALYSIS AND FORECASTING TECHNIQUE USING SATELLITE DATA

This is extracted from NOAA Technical Report NESDIS 11 described by Vernon F. Dvorak in September 1984.

Figure 1-4 shows diagrams outlining the steps used for analyzing both EIR pictures (Figures 1 and 2) and VIS pictures (Figures 3 and 4). Figure 5 is a worksheet to be used for the analysis. The figures are followed by detailed instructions for each step of the technique.

These instructions include the techniques for the analysis of the formation, central position and intensity of the tropical cyclone as well as for the prediction of its intensity.

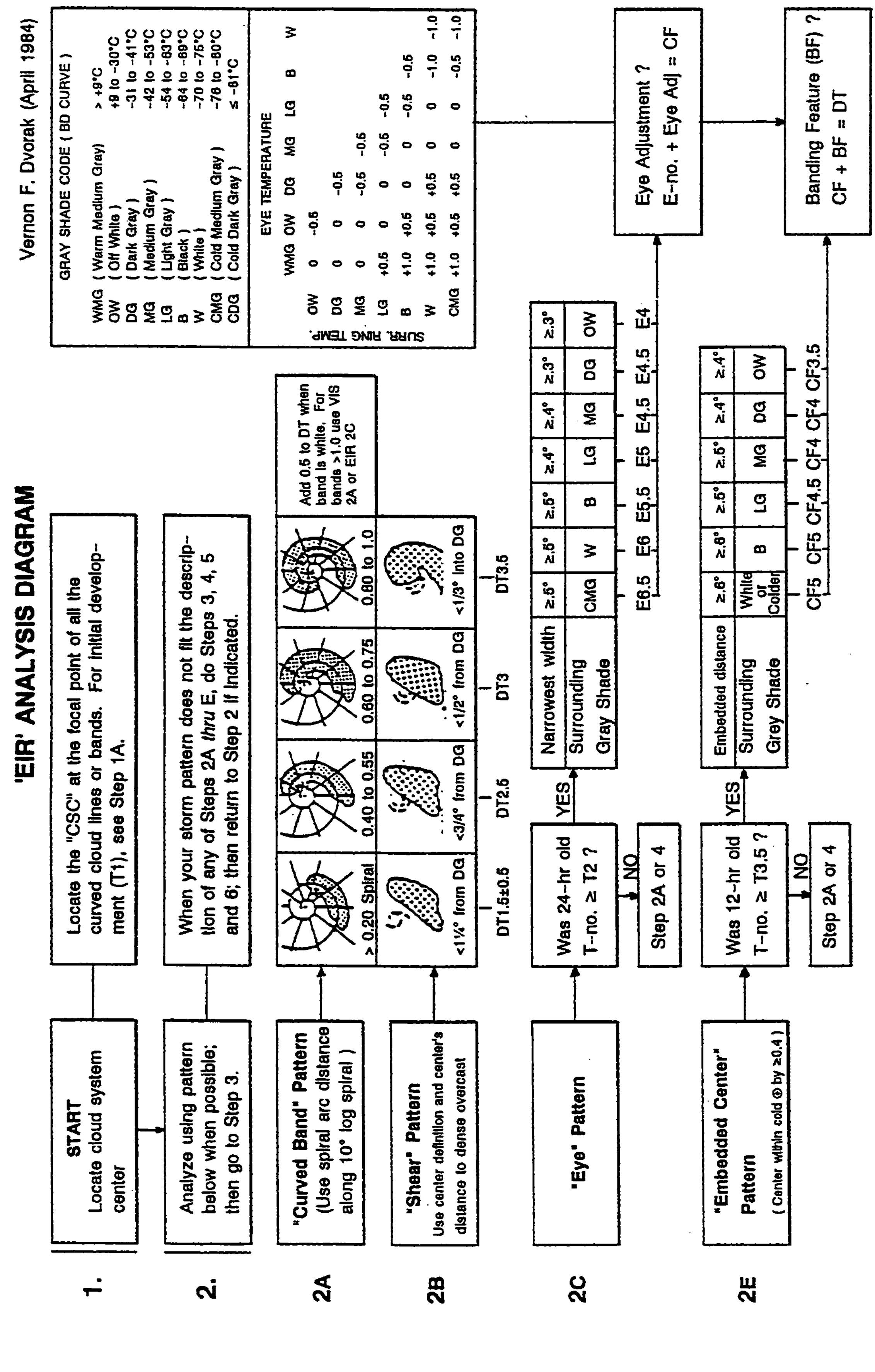


Figure 1. EIR Analysis Diagram, Part 1.

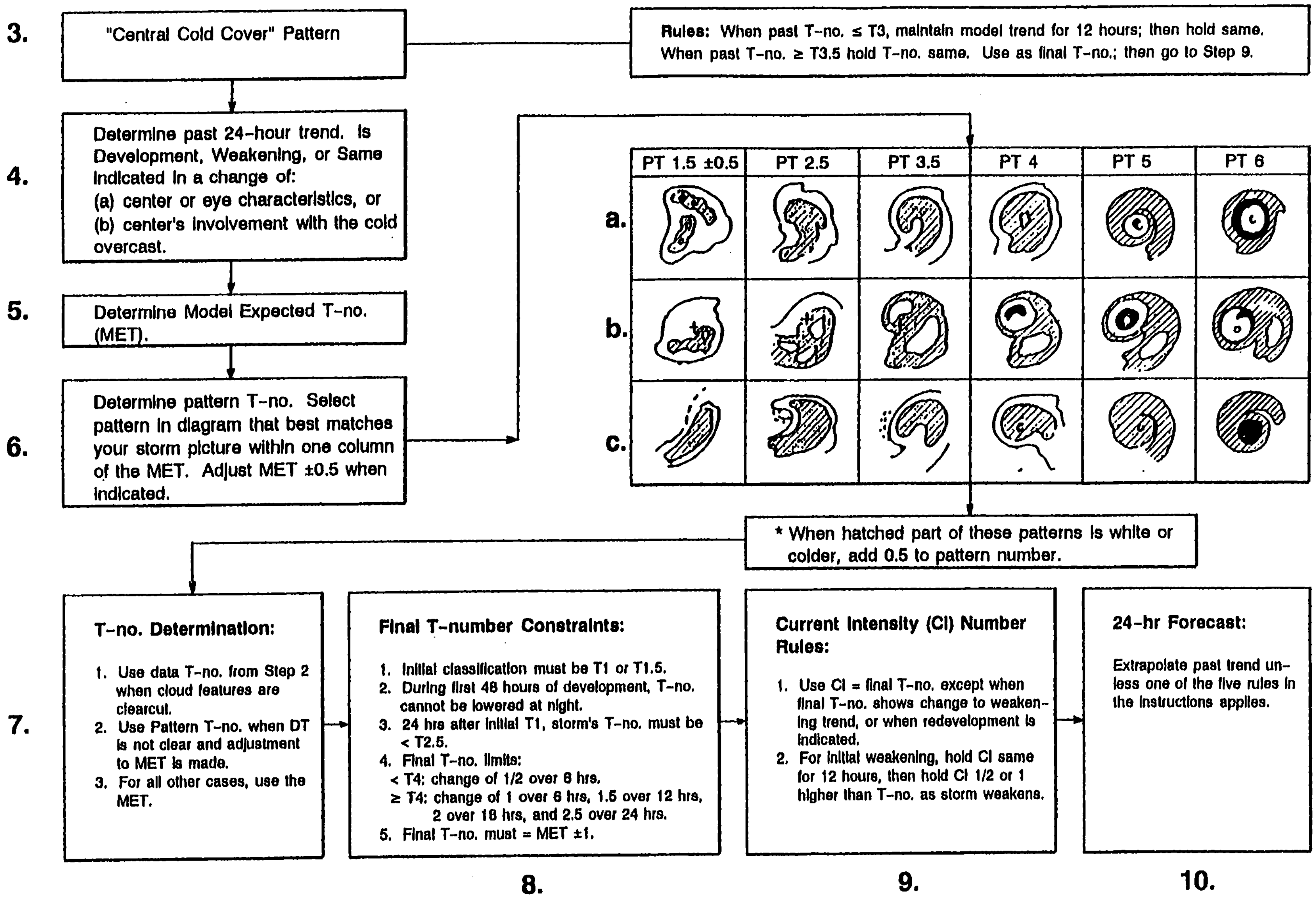


Figure 2. EIR Analysis Diagram, Part 2.

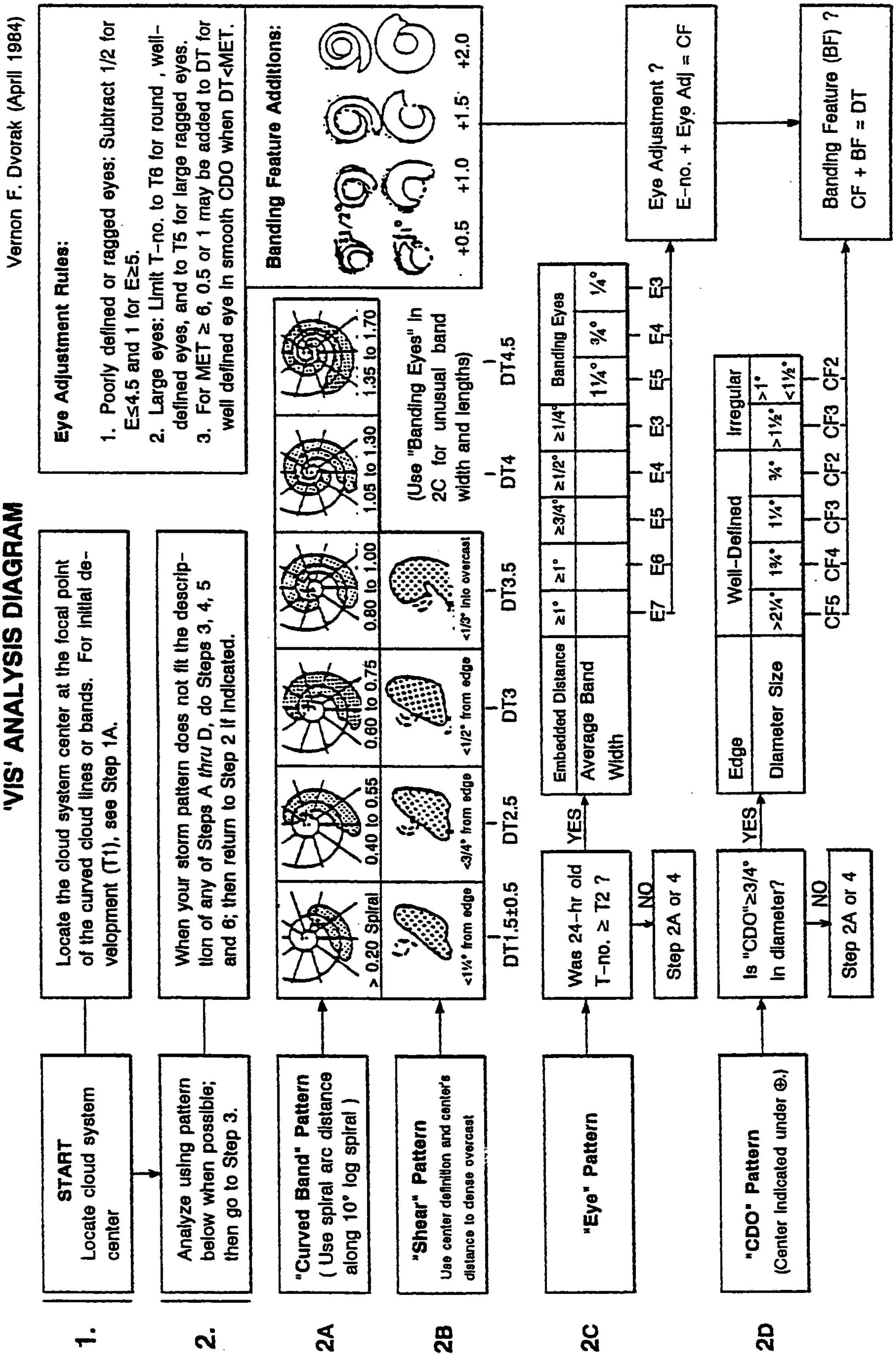


Figure 3 VIS Analysis Diagram, Part 1.

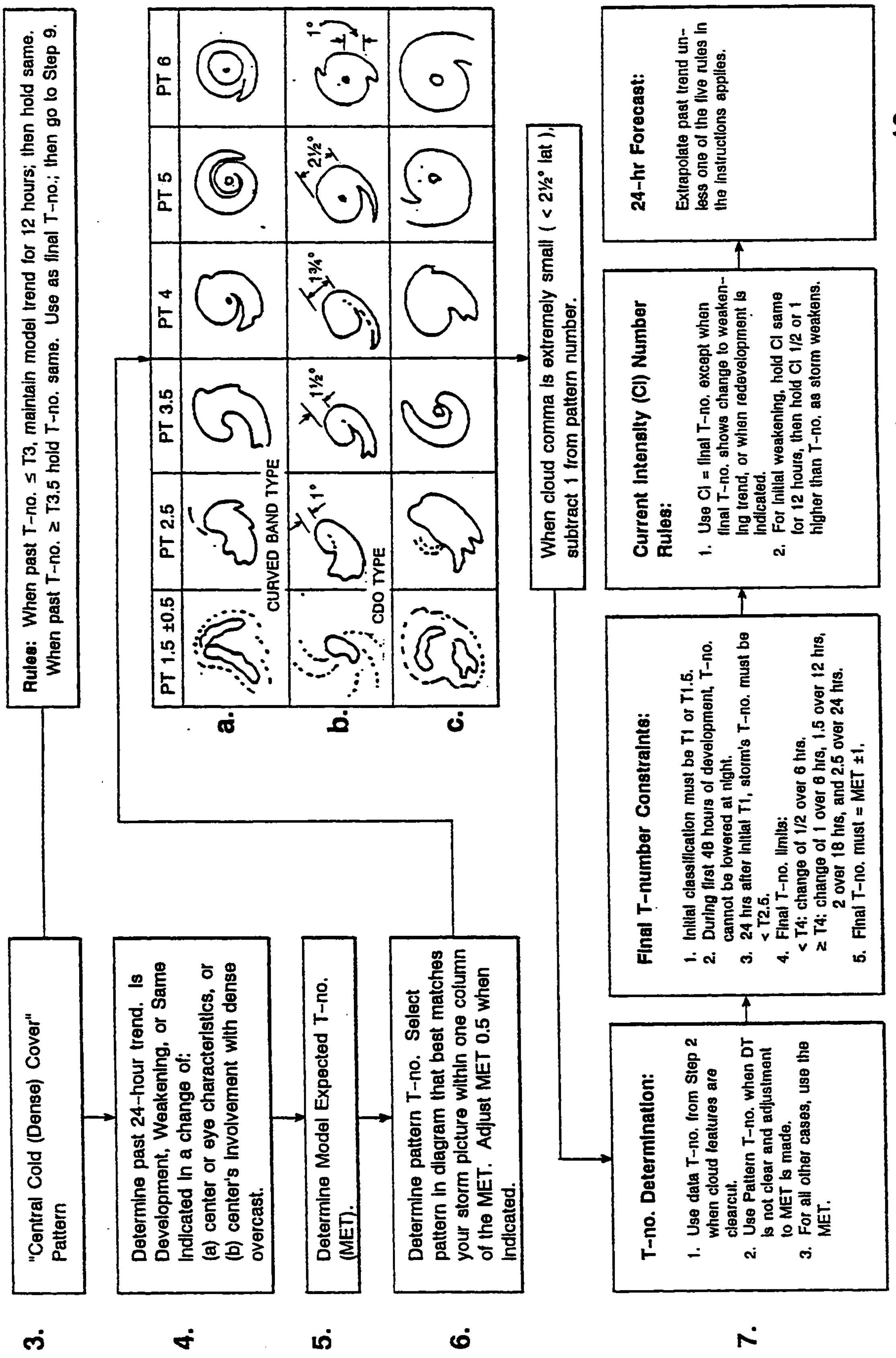


Figure 4. VIS Analysis Diagram, Part 2.

TROPICAL CYCLONE ANALYSIS WORKSHEET

Vernon F. Dvorak
June 1983

T-NUMBER ESTIMATE FROM MEASUREMENTS FOR DATA T-NUMBER (DT) COMPUTATION

T-NUMBER ESTIMATE FROM MODEL (AND DT CONSTRAINTS)

STEP -	1		2A,B				2C				2D	2E	Data T-Number			3	4	5	6	7,8	9	10		INITIALS
DESCRIPTION -	Location		Curved Band or Shear				Eye		ENo+EAdj=CF		CDO	Emb Centr	Computation			CCC	Trend	MET	PAT	FT	CI	24-Hr Fcst		
Rules -	Locate Cloud System Center at focal point of cloud curvature		Use Spiral Arc Length				(VIS) Use Embedded Distance	(EIR) Use Surrounding Temperature	From Rules	Eye Definition	Use Size Central Dense Overcast	(EIR) Use Surrounding Temperature	CF + BF = DT			Use Rules Central Cold Cover	24 Hr change D-developing W-weakening S-same	Model Expected T-Number	Pattern T-Number	Use Rules Final T-Number	Current Intensity Number	Adj Model Fcst if nec. Last Rule Used	Forecast Intensity Number	
DATE/TIME	LAT	LONG	DT1.5	DT2.5	DT3.5	DT4.5			ENo	EAdj			CF	BF	DT									

Figure 5. Analysis Worksheet

INTENSITY ANALYSIS PROCEDURES AND RULES

STEP 1. Locate the Cloud System Center (CSC)

The cloud system center is defined as the focal point of all the curved lines or bands of the cloud system. It can also be thought of as the point towards which the curved lines merge or spiral.

Procedures:

(1) The CSC is located at the center of the eye or at the center of curvature of a partial eye wall when one of these features is observed.

(2) When the CSC is not obvious, locate the model expected CSC. Draw a line along the "curved band axis" through the most dense (coldest) portion of the band. The axis should roughly parallel the concave (inner) overcast boundary of the band. Locate the model expected center location in relation to the curved band. (See plus symbols in diagram in Step 2A.) The center is located near the inner (concave) edge of the band on the counterclockwise end (comma head) portion of the band. Locate tightly curved lines, merging lines, or CDO near the point where the center is expected to fall. The CSC is located at the center of curvature, near the point of mergence or at the center of CDO (for CDO of ≤ 1½° latitude in size). For large CDO's, the center is sometimes defined by an arc of overshooting cloud tops or in an isolated cluster of convective tops. When not visible, use (3) below.

(3) When features are not visible at the expected CSC, or when the curved band is not apparent, use the circle method. The method consists of first drawing lines following the cloud line curvature or curved boundaries that fall within the curve of the curved band axis, and then fitting circles to the lines with tightest curvature. The CSC is located at the center of the area common to the circles. For relatively circular embedded center patterns of > T3.5 intensity, fit a log 10° spiral overlay to the curved band axis to locate center.

(4) When a cloud minimum wedge is visible on the concave side of the band near its middle, the CSC is located at the midpoint of a line drawn between the deepest cloud minimum incursion of the wedge and the counterclockwise extremity of the curved band axis. This method is frequently used with EIR pictures. In EIR pictures, the center is often located in the tight gradient near the coldest part of the pattern.

(5) When the location of the CSC is unclear, or could be placed at different locations, use all the methods above along with an extrapolation from the past track positions in making the final decision.

(6) When more than one well–defined CSC is apparent, use the one defined by the strongest appearing, lowest level cloud lines that best fits the past track of the storm. When strong vertical shear is apparent, remember that the upper level (dense) clouds will not be centered directly over the low–level center, but will be displaced with the CSC on the tight temperature gradient (sharp boundary) side of the dense cloud pattern.

Step 1A. Initial Development

The earliest signs of tropical cyclone development are observed about 1½ days before a disturbance reaches tropical storm strength. At this time, the disturbance is classified a T1. A T1 is first used when a cluster of deep layer convective clouds showing line or band curvature has the following three properties.

(1) It has persisted for 12 hours or more.

(2) It has a cloud system center defined within an area having a diameter of 2½° latitude or less which has persisted for 6 hours.

(3) It has an area of dense, cold (DG or colder) overcast* of >1½° in extent that appears less than 2° from the center. The overcast may also appear in cumulonimbus lines the curve around the center.

The cloud system center will be defined in one of the following ways:

(1) Curved band, a dense (DG or colder) overcast band that shows some curvature around a relatively warm (cloud minimum) area. It should curve at least one–fifth the distance around a 10° log spiral. Cirrus, when visible, will indicate anticyclonic shear across the expected CSC. (See diagrams, Step 6, PT 1.5 pattern types.)

(2) Curved cirrus lines indicating a center of curvature within or near a dense, cold (DG or colder) overcast. (See Figure 4, Step 6, PT 1.5b.)

(3) Curved low cloud lines showing a center of curvature within 2° of a cold (DG or colder) cloud mass. (See diagrams, Step 2B, DT 1.5 pattern.)

In many cloud clusters that eventually develop, the northern boundaries shows a straightening about 1½ days prior to the T1 classifications. During the organizing stage of the T1 pattern, there may be extreme variability in the cloud pattern. In most developments at the T1 stage, strong upper–level horizontal anticyclonic shear will be indicated across the disturbance center when curved cirrus lines are present to reveal the shear. These upper–level clouds may indicate patterns far more advanced than T1 at the time of the initial classification. These patterns do not involve deep tropospheric circulations at this time and will be short lived. This means that the Day–2 data T–number may at times be less than Day–1's, but still development is indicated as long as the DT is 2 or more. There may also be times during the first two days of development when cirrus or convective clouds are almost absent, showing little pattern during the nighttime hours. This usually does not mean the storm is weakening. The rule is to never lower the T–number at night during the first 24 hours of development. A flat boundary rotating clockwise across the north side of the pattern throughout the period is a good sign of development. Note that a classification of T1 forecasts tropical storm intensity (T2.5) 36 hours after the T1 observation only when the environment is expected to remain favorable. A minus symbol is used after the T1 to indicate a T1 pattern that is not expected to develop. (See Step 11.)

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* The amount of cold overcast may decrease during the subsequent nighttime hours making it crucial that the analyst watch for the required amount of overcast when it occurs.

STEP 2. Determine the Pattern Type that Best Describes your Disturbance and Measure Cloud Features as Indicated

The manner in which the cloud system center is defined determines the pattern type to be analyzed. The pattern types listed below are described on the following pages. When the cloud pattern being analyzed does not resemble one of the patterns, proceed to Step 3.

Step 2A.	"Curved Band" Pattern
Step 2B.	"Shear" Pattern
Step 2C.	"Eye" Pattern
Step 2D.	Central Dense Overcast (CDO) Pattern
Step 2E.	Embedded Center Pattern

General Analysis Rules:

1. When short-interval pictures are available, use the average measurement of all of the pictures with well-defined features taken within the 3 hour period ending at analysis time.

2. When two or more T-number estimates are made from the same picture, use the estimate closest to the MET.

3. When in doubt concerning ambiguous features, bias the analysis toward the MET.

Step 2A. Curved Band Pattern

The intensity estimate determined from this pattern type is derived by measuring the arc length of the curved band fitted to a 10° logarithm spiral overlay. (A circle will give the same answer most of the time.) The intensity values that relate to the curved band length are given in the analysis diagrams, Figures 1, 3. Curved band measurements may be used with both VIS and EIR pictures until an intensity of DT 4.5 is reached. For EIR patterns greater than DT 3.5 use measurements from VIS diagram.

The spiral overlay is fitted to the curvature of the dense (cold) band by first drawing a line along the "curved band axis" and then fitting the spiral curve to the line drawn. The curved band axis is defined as the axis of the coldest overcast gray shade (most dense clouds) within the cloud band. The line should roughly parallel the overcast edge on the concave side of the band. When the band indicates two possible axes, use the one with tightest curvature. Cellular cold globs that do not fall in line with the curve of the comma band are ignored when drawing the line. Fit the spiral to the line drawn on the picture and measure the spiral arc length of dense (cold) band that follows the spiral curve.

In EIR patterns (like those in Figure 2, Step 6, Row b), the cold comma band will often show warm breaks through its middle. These breaks will appear to be almost clear in the VIS picture. When this occurs, draw the comma axis as though it were continuous through the breaks paralleling the edge of the cloud minimum incursion into the concave side of the band. As the curved band pattern evolves it will usually be defined by the dark gray shade of the BD curve, but may at times appear defined in warmer or colder shades of gray. At times the boundaries of the band must be interpreted from its form in previous pictures.

During the first 2 days of development (T1 to T2), the amount of overall band curvature may change excessively, very little, or even decrease somewhat for short periods even through typical development is occurring. For this reason, the tendency should be to raise the T–number by one during the first 24 hours of development as long as the band remains curved enough for T2 and clear signs of weakening or rapid development are not apparent. It is also important to allow at least 24 hours to pass between a T2 and a T4 classification. Even though the coiling process has been observed to be faster than this at times, the surface pressure does not fall accordingly.

During the T2.5 ot T3 stage, a tightly curved band ≤ 1¼° diameter of curvature observed within the curve of the broad curved band can also be used as an indicator of tropical storm intensity. This is evidence that the wall cloud is forming. This tight curvature at weak tropical storm intensity is often ragged in appearance but will have deep–layer convective cloudiness on nearly opposite sides of a system center.

Step 2B. Shear Patterns

Shear patterns appear in pre–hurricane stages of development when vertical shear prevents the cold clouds from bending around the cloud system center as they do in the curved band patterns. The pattern may also appear after the hurricane stage has weakened to a pre–hurricane pattern because of increasing vertical shear.

The intensity estimate determined from this pattern type is derived by (1) the way in which the cloud system center is defined and (2) the distance between the low cloud center and the dense, cold overcast. For shear patterns associated with tropical storm intensity (T2.5 to T3.5), the center will be defined by parallel, circularly curved low cloud lines with a diameter of about 1.5° latitude or less. They indicate a center either near the edge or under the edge of a dense, cold (DG or colder) overcast cloud mass (see patterns in Step 2B, Figures 1, 3). During the weaker stages of development (T1.5 ± 0.5), the low cloud center will either be poorly defined in spiral lines within 1.25° of the cold overcast, circularly defined but some distance (>1.25° latitude) from the cold overcast clouds, or circularly defined near a small amount (<1½° diameter) of dense overcast.

Step 2C. Eye Pattern

Eye patterns are analyzed in this step only when the eye falls near the point of the expected cloud system center, and after a T2 or greater pattern has been observed 24 hours prior to the current observation.

The eye is defined as one of the following:

(1) A warm (dark) spot in a dense, cold (OW or colder) overcast. (When more than one dark spot appears near the CSC, use the center closest to the expected center location.)

(2) A point in a dense, cold (OW or colder) overcast centered within the curvature of a colder (denser) band that curves at least halfway around the point with a diameter of curvature of 1½° latitude or less.

(3) A spiral band wrapped around a relative warm (dark) spot with a diameter of curvature of 1½° latitude or less. The band must curve at least 1.0 the distance around the 10° log spiral curve. (See pattern labeled DT 4 in Figure 3, 2A.)

The analysis of the eye pattern involves three computations: The eye number (E), the eye adjustment factor (Eye Adj), and the banding features (BF) number. The equation is: CF + BF = DT (data T–number), where CF = E no. + Eye Adj.

1. EIR only (See 2. for VIS)

a. E (eye) number

To get the E or eye number, first determine the coldest gray shade that surrounds the relatively warm spot. Make certain that the minimum width of this gray shade meets the "narrowest width" requirement shown in the diagram. When a spiral eye is defined, use the average width of the spiral band to determine the narrowest width criteria.

b. Eye Adjustment Factor

The eye adjustment factor is determined by using the graph in Figure 6. The graph is a plot of eye temperatures versus the temperature of the coldest ring or spiral that completely encircles the eye. This provides an adjustment of ±0.5, ±1, or 0 to the "E" number. No plus adjustment can be made for large eyes (≥ 3/4° diameter within the surrounding gray shade) or elongated eyes. When no previous subtraction was made, 0.5 is subtracted for elongated eyes having E numbers of ≥ 4.5. Elongated eyes are defined as those having a short axis of < 2/3 the long axis within the surrounding gray shade.

c. Banding Feature (BF)

The BF addition is used with EIR pictures only when the T–number estimate without the BF is lower than the model expected T–number. It is defined only for patterns of CF4 or more that contain a clearcut comma tail band that:

(1) curves 1/4 or more of the distance around the central features or comma head,

(2) is cold (MG or colder), and

(3) has a warm wedge (DG or warmer) between the tail and the central features that cuts at least halfway through the pattern for patterns a and b, Figure 7, and at least 2/3 the way for pattern c.

2. VIS only (See 1 above for EIR)

a. **The E (eye) number** is obtained by measuring the distance the eye is embedded in dense overcast clouds. The embedded distance of the eye is measured outward from the center of the eye to the nearest outside edge of the dense overcast for small (<30 nm) eyes. For large eyes, measure outward from the inner wall of the eye. When a banding-type eye is indicated, the arc length of the band around the eye and the average width of the band surrounding the eye are important to the intensity determination, as indicated in the diagram. See analysis diagram (Figure 3, 2C) for the relationships between E-number and embedded distance (eye in CDO), and for band width (banding eye).

b. **The eye adjustment** factor is determined by the definition, shape, and size of the eye. The eye is well-defined by either its blackness or by a well-defined boundary. To be well-defined, the eye should be dark or black. Remember that a very high or very low sun angle may reduce the eye definition unrealistically, and that high-resolution pictures may show a poorly defined eye that would not appear in the low-resolution pictures for which the technique was defined. A poorly defined eye is one that is barely visible. A ragged eye is one with a very uneven boundary with little circularity. VIS eye adjustment rules are as follows. (1) For poorly defined or ragged eyes, subtract 1/2 number for E numbers of ≤ 4.5 and subtract 1 number when E ≥ 5. When analyzing patterns with poorly defined eyes especially in high-resolution pictures, also check the CDO size. Use the estimate which is most consistent with the MET. (2) For large eyes, limit the maximum T-number to T6 for round, well-defined eye patterns, and to T5 or lower for all other large-eyed patterns. And, (3) the E-number may also be adjusted upward by either 0.5 or 1.0 when the eye is well-defined, circular and embedded in a very smooth, very dense appearing canopy. The addition is made only when the data T-number is lower than the MET and the storm's past history gives an expected T-number of T6 or more. The general rule for the eye adjustment factor is: When an adjustment is not clearcut, use the guidance of the MET to make the final decision.

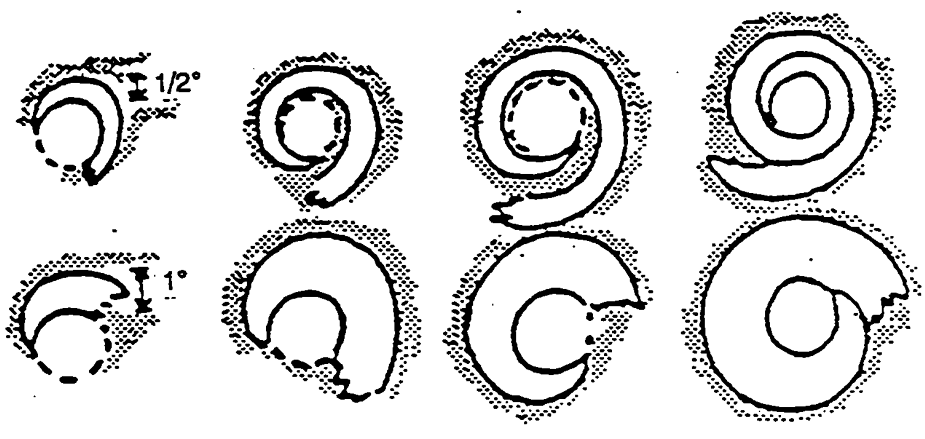
c. **The BF adjustment** is often an important factor when VIS pictures are used. It is defined as a dense, mostly overcast band that curves quasi-circularly at least 1/4 the distance around the central feature. Bands that curve evenly around an inner BF may also be counted. The amount of the BF term ranges from .5 to 2.5. It depends on the width of the band and the amount the band curves evenly around the central features, as shown in Figure 8. A BF term is not used for pre-hurricane patterns when the curved dense band concept in Step 2A is used. However, it is still needed for CDO patterns and all hurricane patterns when indicated. For banding eye patterns use the central coil (once around the eye) as the CF and add the BF as indicated. This pattern type is rarely used for DT of greater than 4.5.

		EYE TEMPERATURE						
		WMG	OW	DG	MG	LG	B	W
	OW	0	−0.5					
	DG	0	0	−0.5				
SURROUNDING	MG	0	0	−0.5	−0.5			
RING	LG	+0.5	0	0	−0.5	−0.5		
TEMPERATURE	B	+1.0	+0.5	0	0	−0.5	−0.5	
	W	+1.0	+0.5	+0.5	0	0	−1.0	−1.0
	CMG	+1.0	+0.5	+0.5	0	0	−0.5	−1.0

Figure 6. Eye Adjustment Graph. Rules: (1) For large or elongated eyes, use values to the right of the diagonal line only; (2) for elongated eye patterns ≥ 4.5, subtract 0.5 when no other subtraction was made.

a. Add 1/2 no. b. Add 1/2 no. c. Add 1 no.

Figure 7. EIR Banding Features. Add to the CF only when the data T–no. is lower than the MET.



BF = 1/2 BF = 1 BF = 1½ BF = 2

Figure 8. VIS Banding Features.

Step 2D. CDO Patterns (VIS only)

CDO patterns are defined when a dense, solid–looking mass of clouds covers the cloud system center and lies within the curve of the system's comma band. Both its size and the sharpness of its boundary are important to the analysis. A well–defined CDO has an abrupt edge on at least one side of the cloud mass. An irregular CDO appears within the curve of the comma band but has ragged boundaries and uneven texture. Generally, well–defined CDO's that measure about 1° latitude in their narrowest width are associated with tropical storm intensities while those measuring 2° latitude or more are associated with hurricanes. The size – CF number relationship is given in the analysis diagram, Figure 3. Examples of CDO's are shown in Figure 4, Step 6b. For CDO patterns, the analysis equation is CF + BF = DT. Banding features (BF) are usually added to the CF term for CDO patterns. The BF's are described above in 2C, 2c.

Step 2E. Embedded Center Patterns (EIR only)

Embedded center patterns are analyzed when the storm has had a previous history of a T3.5 or greater intensity and when the CSC is clearly indicated to be within a cold overcast (OW or colder). Curved cloud lines or bands within the cold overcast as well as the outer curved bands will indicate the location of the CSC within the overcast. A 10° logarithmic spiral can often be fitted to the system's pattern to help locate the CSC in patterns of hurricane intensity. (See Step 2A for fitting spiral.)

The analysis of this pattern is similar to the eye pattern analysis except that no eye adjustment factor is added. Determine the coldest overcast in which the CSC is embedded the required distance. This yields the central feature number (CF). Then add a banding feature (BF) adjustment when indicated. The equation being CF + BF = DT.

STEP 3. Central Cold Cover (CCC) Pattern

The CCC pattern is defined when a more or less round, cold overcast mass of clouds covers the storm center or comma head obscuring the expected signs of pattern evolution. The outer curved bands and lines usually weaken with the onset of CCC. When using VIS pictures, substitute the word "dense" for "cold". It is only rarely that the CCC pattern is used with VIS pictures since the CDO or curved lines are usually visible through the thin cirrus clouds. When the CCC persists (see rules in diagram, Step 3), development has been arrested until signs of development or weakening once again appear in the cloud features. Care should be exercised under the following conditions:

(1) Do not confuse a CCC pattern with a very cold comma pattern. A very cold (usually white) pattern is indicated by a very cold (very smooth texture) comma tail and head with some indication of a wedge in between. Curved cirrus lines or boundaries usually appear around the cold pattern and not around the CCC pattern. The very cold pattern for T–numbers of T3 or less warrant an additional 1/2 number in intensity estimate and often indicates rapid growth.

(2) Do not assume weakening in a CCC pattern when the coma tail begins to decrease in size. It is common to observe the tail decreasing in size at the onset of the CCC. Also the CCC often warms as the eye of the T4 pattern begins to be carved out by a warm incursion into the side of the cold overcast. This signals the resumption of pattern evolution (intensification) even though some warming is evident.

STEP 4. Determine the Trend of the Past 24-hour Intensity Change

The trend of the past 24–hour intensity change is determined qualitatively by comparing the cloud features of the current picture with those in the 24–hour old picture of the storm. In general, a disturbance has developed when its center appears better defined with no change in the relation to the dense clouds of the disturbance or is more involved with dense overcast clouds. More precise definitions for development, weakening or steady state changes are given below.

The storm has developed (D):

(1) Curved band pattern: Curved band coils farther around the CSC.

(2) CDO pattern: CDO becomes larger or an increase in banding features is noted.

(3) Shear pattern: CSC becomes more tightly defined in curved cloud lines or appears closer to the dense overcast.

(4) Eye pattern: Eye is more embedded, more distinct (warmer), less ragged, or is surrounded by colder (smoother textured) clouds, or more banding features.

(5) No significant warming (darkening) of the cloud system is noted. By significant, it is meant that a change that is not diurnal (near sunset), which lasts for more than 3 hours, and is great enough to lower the T–number.

The storm has weakened (W):

(1) The storm has weakened when its cloud pattern indicates a persistent trend opposite to those listed in (1) – (5) above. Watch in particular for patterns that become sheared out (elongated with time) or for patterns undergoing nondiurnal warming (lowering) of their cloud tops.

The storm has become steady state (S):

(1) When a central cold cover appears in a T3.5 or greater storm or has persisted for more than 12 hours in a weaker storm; or

(2) When the CSC's relationship to the cold clouds has not changed significantly; or

(3) When there are conflicting indications of both development and weakening.

STEP 5. The Model Expected T-number (MET)

The MET is determined by using the 24-hour old T-number, the D, S, or W decision in Step 4, and the past amount of intensity change of the storm. When the growth rate has not been established in the case of new developments or reversals in trend, assume a past rate of change of one T-number per day. Equations for determining the MET are given below.

MET = 24-hour old T-number + (0.5 to 1.5) when D was determined.

MET = 24-hour old T-number - (0.5 to 1.5) when W was determined.

MET = 24-hour old T-number when S was determined.

Rapid or slow past rates of change are established when two consecutive analyses showing rapid or slow pattern evolution are observed at 6-hour or more intervals, or when one observation accompanied by signs of strong intensification or weakening is observed (see Step 10).

STEP 6. The Pattern T-number (PT)

The pattern T-number is used primarily as an adjustment to the MET when an adjustment is indicated. The PT-number is determined by choosing the pattern that best matches your storm picture from either the model expected T-number column or the column on either side of it. When the pattern being analyzed looks more like the pattern in the column to the right or left of the MET column, then raise or lower the MET 0.5 to determine the PT.

STEP 7. Rules for Determining the T-number

Use the data T-number (DT) when the cloud feature measurements are clearcut. Use the pattern T-number (PT) when the DT is not clear and the pattern is understandable. When neither the DT or the PT is clear, use the Model Expected T-number (MET).

STEP 8. Final T-number

This step provides the constraints within which the final T-number must fall. In other words, when the T-number gotten from Step 7 does not fall within the stated limits, it must be adjusted to the limits. The constraints hold the final T-number change to 1.5 during the first 24 hours of development; to 2 numbers in 24 hours for T-numbers T2 to T4 (i.e., 1/2 number over a six hour period); and to 2.5 numbers over a 24 hour period for changes in storms of T4 or greater intensity (i.e., 1 number over a six hour period, 1½ numbers in 12hours, 2 in 18 hours, and 2.5 in 24 hours). In general for storms of hurricane intensity, the final T-number must be within one number of the model expected T-number (MET). The constraints are listed in the diagram. The rules also prohibit the lowering of the T-number at night during the first 48 hours of development because the diurnal changes in clouds often give deceptive indications of weakening at this time.

STEP 9. Current Intensity (CI) Number

The CI number relates directly to the intensity of the storm. The empirical relationship between the CI number and the storm's wind speed is shown in Figure 9.

CI Number	MWS (Knots)	MSLP (Atlantic)	MSLP (NW Pacific)
1	25 K		
1.5	25 K		
2	30 K	1009	1000
2.5	35 K	1005	997
3	45 K	1000	991
3.5	55 K	994	984
4	65 K	987	976
4.5	77 K	979	966
5	90 K	970	954
5.5	102 K	960	941
6	115 K	948	927
6.5	127 K	935	914
7	140 K	921	898
7.5	155 K	906	879
8	170 K	890	858

Figure 9. The empirical relationship between the current intensity number (CI), the maximum mean wind speed (MWS), and the minimum sea level pressure (MSLP) in tropical cyclones. The MSLP values for the NW Pacific were recommended in Shewchuck and Weir (1980). The unit of the MSLP is hPa.

After each intensity analysis, the previous analyses of the storm should be reviewed in the light of the current data. When an error was made in the previous day's analysis, correct the T–number to provide a more accurate model–expected intensity. The correction may at times alter the current intensity analysis.

The CI number is the same as the T–number during the development stages of a tropical cyclone but is held higher than the T–number while a cyclone is weakening. This is done because a lag is observed between the time a storm pattern indicates weakening has begun and the time when the storm's intensity decreases. In practice, the CI number is not lowered until the T–number has shown weakening for 12 hours or more. The CI number is then held one higher than the T–number as the storm weakens. (Hold the CI number 1/2 number higher when the T–number shows a 24 hour decrease of 1/2 number.) When redevelopment occurs, the CI number is not lowered even if the T–number is lower than the CI number. In this case, let the CI number remain the same until the T–number increases to the value of the CI number.

STEP 10. The 24–hour Intensity Forecast (FI)

The Forecast Intensity (FI) is an extrapolation forward of the past 24 hr change in T–number (not to exceed 1½ T–number per day) unless the cyclone's cloud pattern or its environment indicates a change in one of the following. Remember that the FI number is similar to a forecast CI number in that for a forecast of weakening the FI number is held one or 1/2 number higher than the forecast T–number.

Step 10A. Strong Unfavorable Signs for Future Development within the Cloud Pattern

(1) Persistent warming of cloud pattern for more than 12 hours even though other features may indicate intensification.

(2) A central cold cover that persists for more than 3 hours.

(3) The storm's convective clouds are becoming involved with a field of stratocumulus clouds in the path of the storm.

(4) The cirrus cloud lines of the storm indicate less curvature because of increasing strong unidirectional flow aloft across the storm.

(5) The cloud pattern is undergoing increasing elongation (defomation) with time.

Rule 10A: When strong unfavorable signs are observed, forecast (either) no further development or reduce the past development rate of the storm by half. The changes in the environment listed in 10B should play a role in this judgment.

Step 10B. Strong Unfavorable Signs for Future Development within the Environment

The disturbance is entering an unfavorable environment such that the storm will soon become involved with the following:

(1) Stratocumulus clouds.

(2) Land.

(3) Southward–moving cirrus appearing less than 10° latitude to the north or west of the storm.

(4) Increasing unidirectional flow across the storm pattern.

(5) A southward surge of the westerlies in the upstream environment of a disturbance. The surge is observed as either jet stream cirrus pointing southward northwest or north of the disturbance or as curved cloud lines or bands bowed toward the disturbance moving southward becoming more convective or remaining convective with time. Watch for areas of increasing convection. The band structure may be very weak at first. The environment is considered unfavorable when a broadscale cyclonically curved cloud band is within 25° latitude of a westward–moving disturbance. When the clouds of the disturbance indicate signs of upper–level westerly shear the probability of arrested growth is increased.

Rule 10B: When the storm is entering an unfavorable environment, forecast slow development (1/2 T–number per day) for developing disturbances; or when signs are strong in both the disturbance (10A) and the environment, forecast no development.

Step 10C. Strong Favorable Signs for Future Development within the Cloud Pattern

(1) Two successive observations of 24–hour changes that indicate rapid development. (The observations should be at least 6 hours apart.)

(2) One observation of rapid development and either (a) a cold pattern (white or colder); (b) cold (dense) comma tail pattern such as those shown in Figure 2, Step 6b; (c) or signs of two or three strong outflow channels. That is, cirrus bands extending some distance out from the disturbance. This is also observed as a fanning out of the cirrus to the south or east of rapidly developing storms.

Rule 10C: When strong favorable signs are observed, forecast rapid development in a developing disturbance of ≤ T5.5 that is not expected to peak or enter one of the environments listed in Step 10B. Never forecast an intensity greater that in T7.

Step 10D. Favorable Signs for Future Development within the Environment

The disturbance is moving away from the conditions described in Step 10B. A disturbance leaving an unfavorable environment as described in 10B(5) is indicated by jet stream cirrus pointing more northward than previously or as curved cloud bands in the broad scale environment to the north of the storm bowing more away from the disturbance or dissipating in time.

Rule 10D: When a storm is leaving an unfavorable environment and it had weakened as a consequence of the unfavorable environment, forecast rapid development until the storm reaches its previous intensity and then forecast the previous rate of change. If the rate of development had decreased because of the unfavorable environment, forecast a resumption of the previous rate of development. When a storm had originally been developing in an unfavorable environment, forecast an increase to one T–number/day in the rate of development as the storm moves into the more favorable environment.

Step 10E. Signs of "Peaking"

Most storms reach their maximum intensity 4 to 6 days after T1 classification has been made. The day of peaking often depends on the direction of motion of the storm; northward moving in 4 days, westward moving in 6 days, and all others in 5 days. The signs of peaking observed in a storm's cloud pattern are a general warming of the cloud tops (less smoothness in texture), or a more or less circular pattern having an absence of peripheral convective clouds or bands.

Rule 10E: If the signs of peaking are observed at or after the time of expected peaking, forecast no change in intensity.

STEP 11 (Optional)

Encode the intensity estimate using the code in Figure 10 below. The code is self–explanatory except for the PLUS and MINUS (indications of ongoing change). These are used only when the cloud pattern of a disturbance or its environment indicates a change in trend will occur during the succeeding 24–hour period, or when rapid change is forecast. The PLUS is used either to forecast development when a past trend of W or S is indicated in the code or to forecast rapid development when a D was shown. A MINUS is used in the code either to forecast weakening when a past trend of D or S is indicated in the code or to forecast rapid weakening when a W was shown. When the past trend as indicated by D, S, or W is expected to continue for the next 24 hours, the space is left blank.

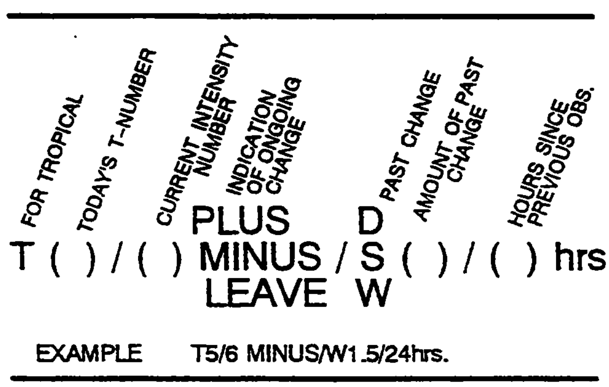


Figure 10. Code to be used for communicating satellite intensity estimations and forecast.

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) <u>GTS</u>

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) <u>Internet</u>
(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) <u>Regional data exchange</u>
Data from automatic weather stations over the south China coastal areas

(D) <u>Local data</u>
(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 forecast at horizontal resolution of 0.5 degree in latitude/longitude and on 21 pressure levels (1000, 975, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 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

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EXAMPLES OF ADVISORIES ISSUED FROM RSMC TOKYO - TYPHOON CENTER

RSMC Tropical Cyclone Advisory

```
WTPQ20 RJTD 271200
RSMC TROPICAL CYCLONE ADVISORY
NAMETY 0815 JANGMI (0815)
ANALYSIS
PSTN271200UTC 21.3N 124.4E GOOD
MOVENW 13KT
PRES910HPA
MXWD115KT
GUST165KT
50KT120NM
30KT240NM
FORECAST
24HF281200UTC 24.7N 121.1E 75NM 70%
MOVENW 12KT
PRES950HPA
MXWD080KT
GUST115KT
48HF291200UTC 27.3N 121.3E 160NM 70%
MOVEN 07KT
PRES980HPA
MXWD060KT
GUST085KT
72HF301200UTC 29.3N 124.9E 220NM 70%
MOVEENE 09KT
PRES994HPA
MXWD035KT
GUST050KT =
```

RSMC Guidance for Forecast

```
D20080927152930
FXPQ20 RJTD 271200
RSMC GUIDANCE FOR FORECAST
NAME TY 0815 JANGMI (0815)
PSTN 271200UTC 21.3N 124.4E
PRES  910HPA
MXWD 115KT
FORECAST BY  GLOBAL MODEL
TIME    PSTN       PRES    MXWD
             (CHANGE FROM T=0)
T=06 22.0N 124.0E -002HPA +001KT
T=12 23.0N 123.4E  000HPA +004KT
T=18 24.5N 122.7E -003HPA +013KT
T=24 25.0N 121.3E +009HPA -005KT
:
:
T=72 29.5N 125.8E +040HPA -039KT
T=78 29.5N 127.6E +039HPA -040KT
T=84 29.7N 129.7E +039HPA -039KT
T=90 ///// ////// /////// //////=
```

RSMC Prognostic Reasoning

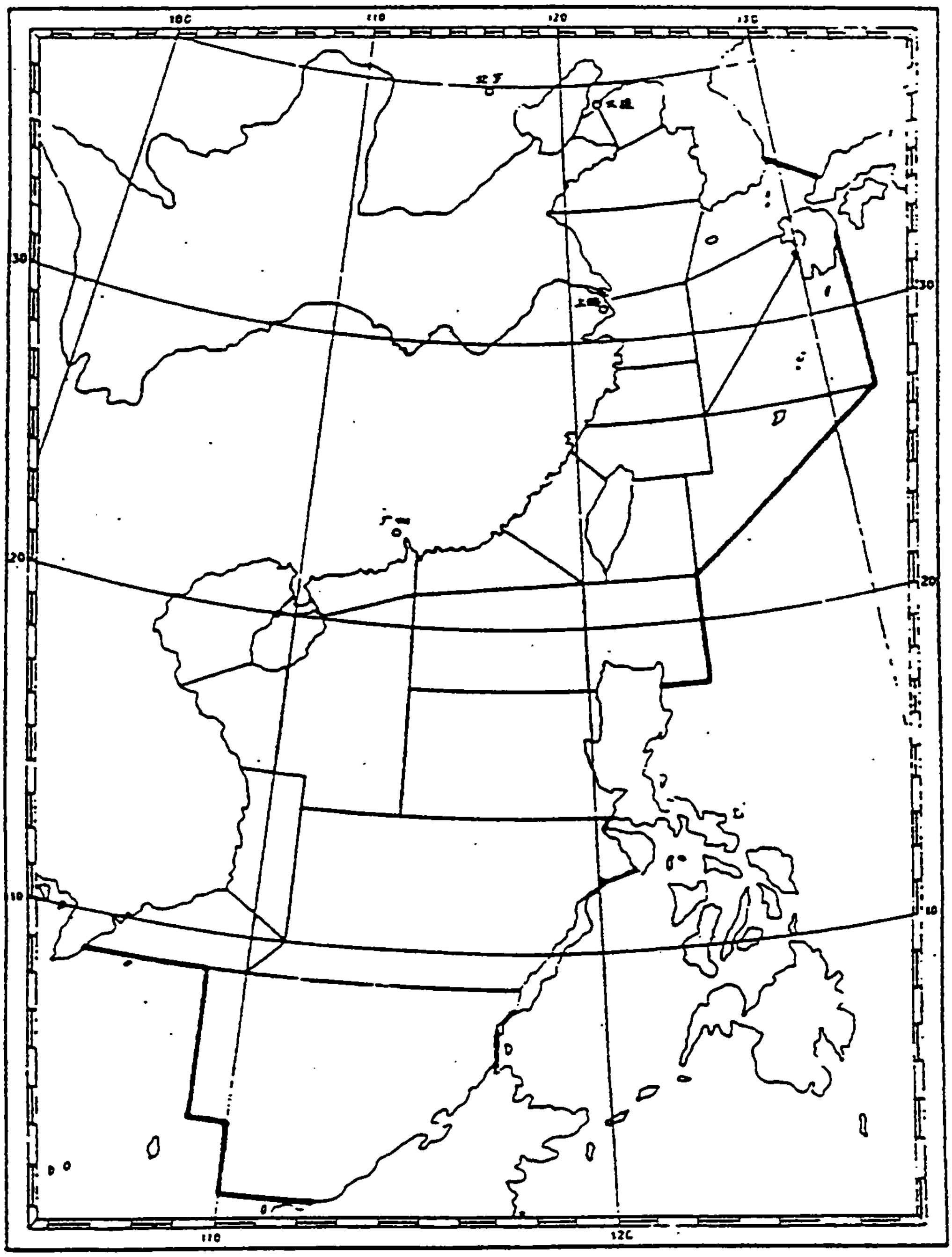
WTPQ30 RJTD 250600
RSMC TROPICAL CYCLONE PROGNOSTIC REASONING
REASONING NO. 4 FOR STS 0815 JANGMI (0815)
1.GENERAL COMMENTS
REASONING OF PROGNOSIS THIS TIME IS SIMILAR TO PREVIOUS ONE.
POSITION FORECAST IS MsAINLY BASED ON NWP AND PERSISTENCY.
2.SYNOPTIC SITUATION
NOTHING PARTICULAR TO EXPLAIN.
3.MOTION FORECAST
POSITION ACCURACY AT 250600 UTC IS FAIR.
STS WILL DECELERATE FOR THE NEXT 24 HOURS.
STS WILL MOVE NORTHWEST FOR THE NEXT 48 HOURS THEN MOVE
GRADUALLY TO WEST-NORTHWEST.
4.INTENSITY FORECAST
STS WILL BE GRADED UP TO TY WITHIN 24 HOURS.
STS WILL DEVELOP BECAUSE SPIRAL CLOUD BANDS HAVE BECOME WELL
ORGANIZED AND CYCLONE WILL STAY IN HIGH SST AR
EA.
FI-NUMBER WILL BE 4.5 AFTER 24 HOURS.=

RSMC Tropical Cyclone Advisory for Five-day Track Forecast

WTPQ50 RJTD 190000
RSMC TROPICAL CYCLONE ADVISORY
NAME TY 0910 VAMCO (0910) UPGRADED FROM STS
ANALYSIS
PSTN 190000UTC 17.3N 157.5E GOOD
MOVE E SLOWLY
PRES 970HPA
MXWD 065KT
GUST 095KT
50KT 40NM
30KT 180NM NORTHEAST 120NM SOUTHWEST
FORECAST
24HF 200000UTC 18.0N 156.9E 70NM 70%
MOVE ALMOST STATIONARY
PRES 960HPA
MXWD 075KT
GUST 105KT
48HF 210000UTC 18.7N 156.5E 110NM 70%
MOVE ALMOST STATIONARY
PRES 950HPA
MXWD 080KT
GUST 115KT
72HF 220000UTC 21.2N 155.9E 160NM 70%
MOVE N 06KT
PRES 950HPA
MXWD 080KT
GUST 115KT
96HF 230000UTC 24.5N 154.4E 240NM 70%
MOVE NNW 09KT
120HF 240000UTC 29.2N 153.5E 375NM 70%
MOVE N 12KT =

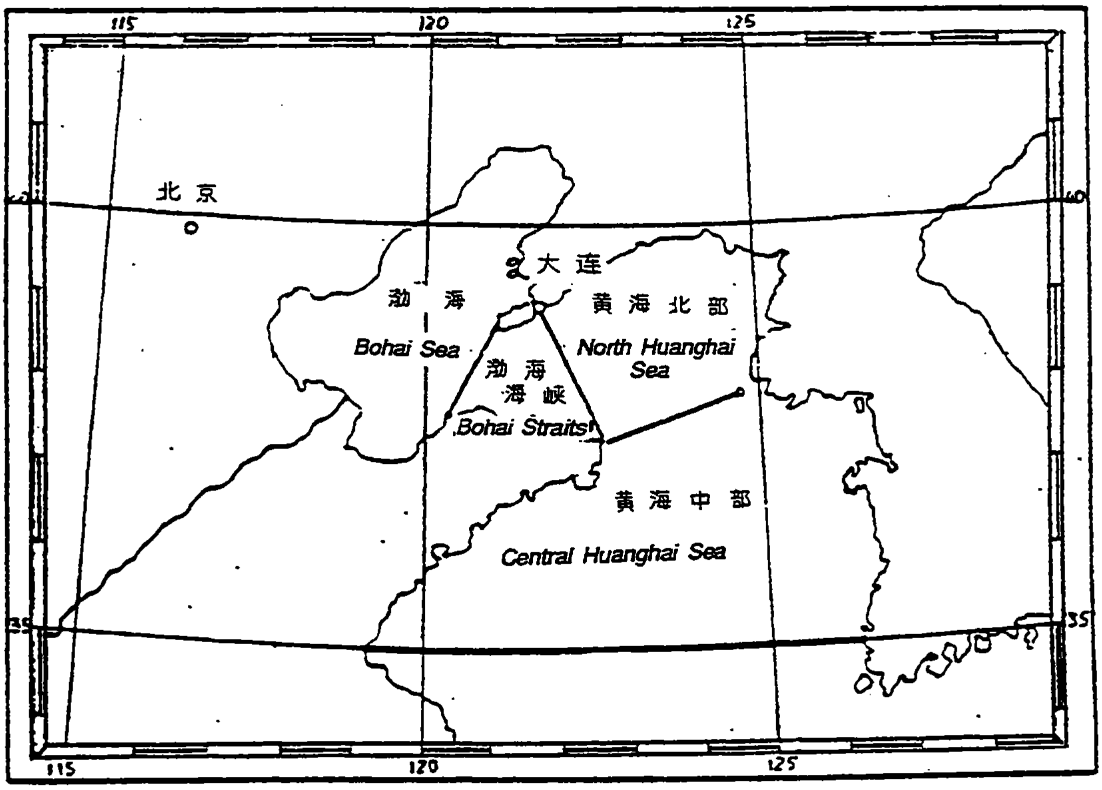
WEATHER FORECAST AREAS

CHINA



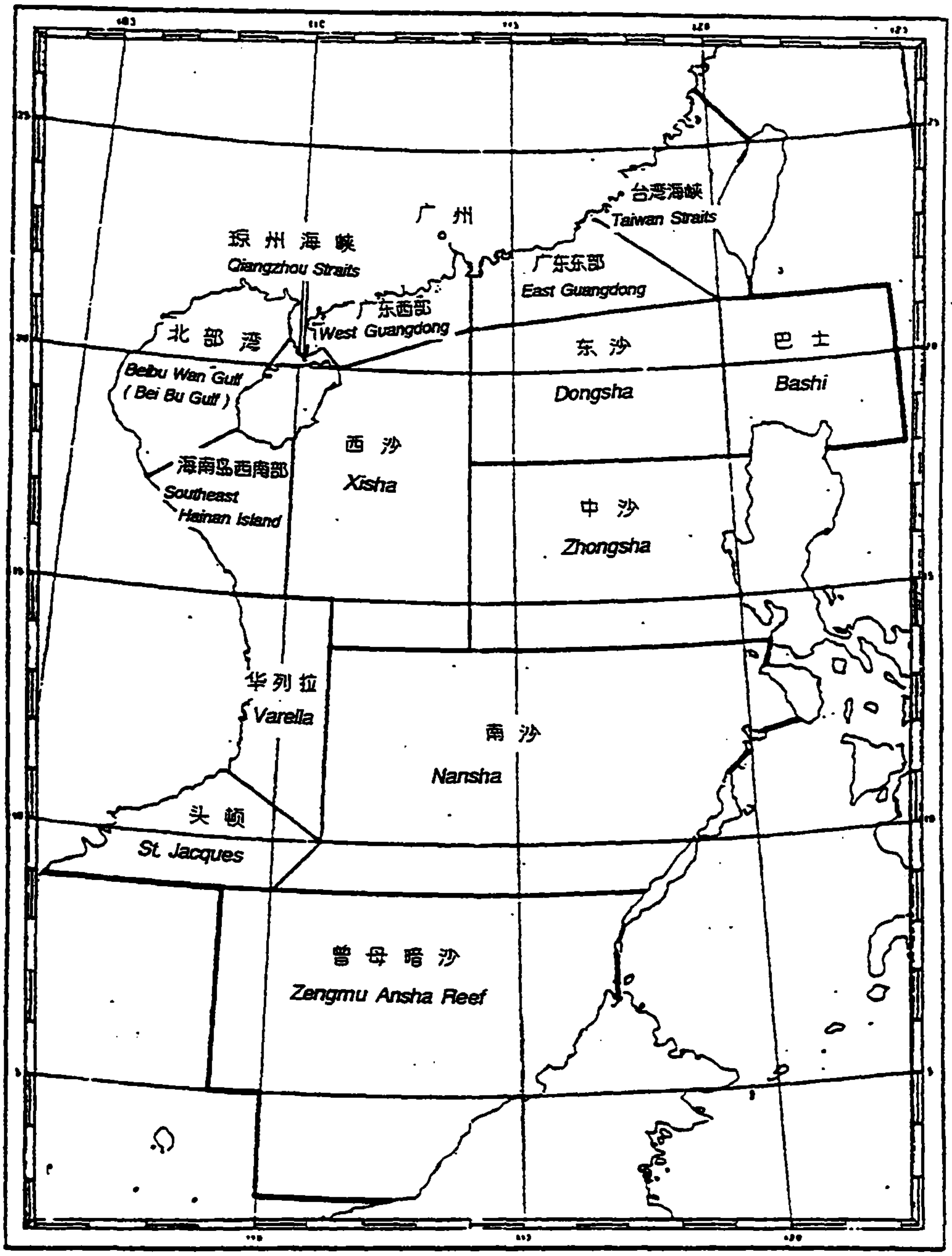
CHINA

WEATHER FORECAST AREAS (DALIAN)



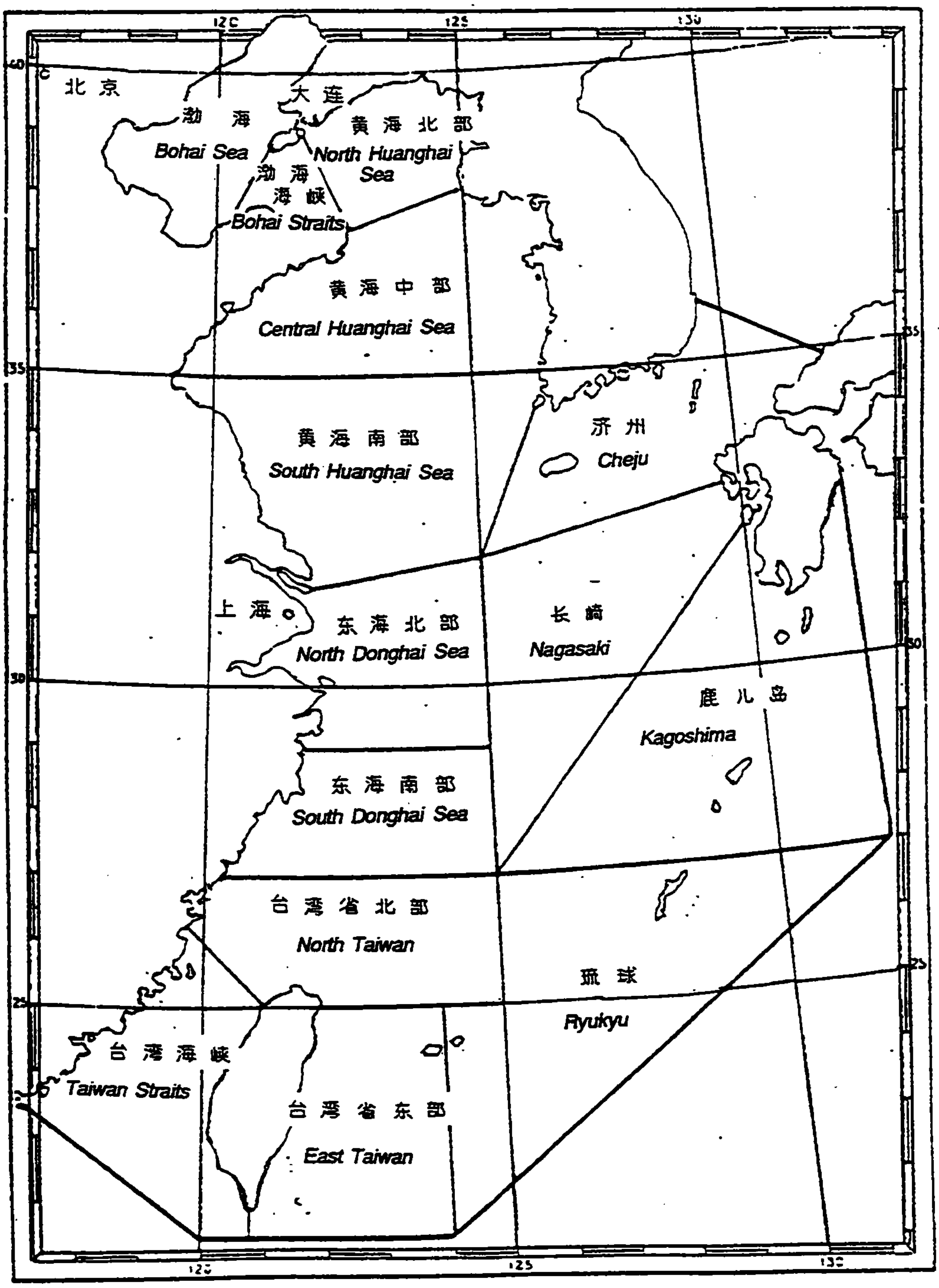
CHINA

WEATHER FORECAST AREAS (GUANGZHOU)



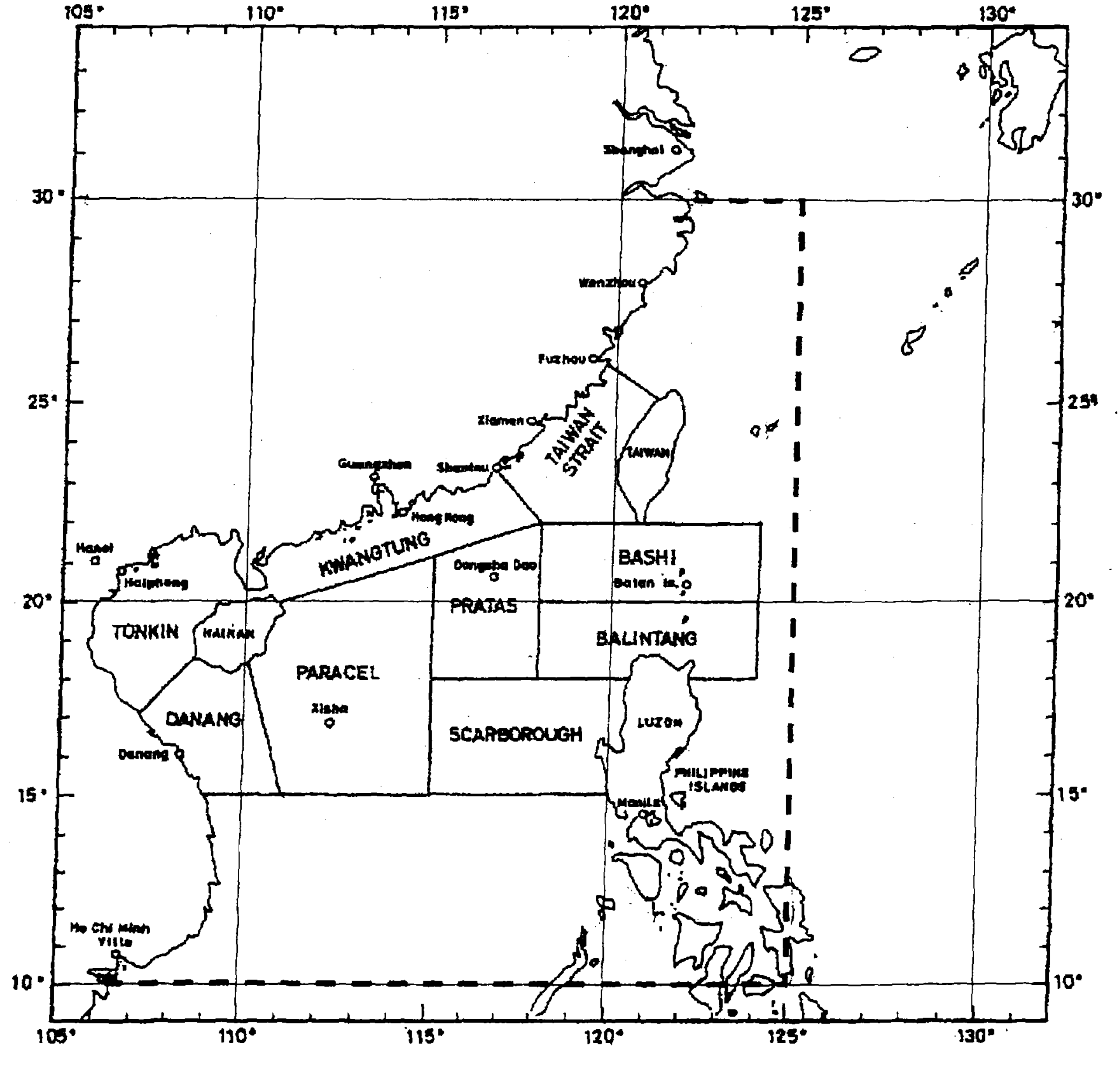
CHINA

WEATHER FORECAST AREAS (SHANGHAI)



HONG KONG, CHINA

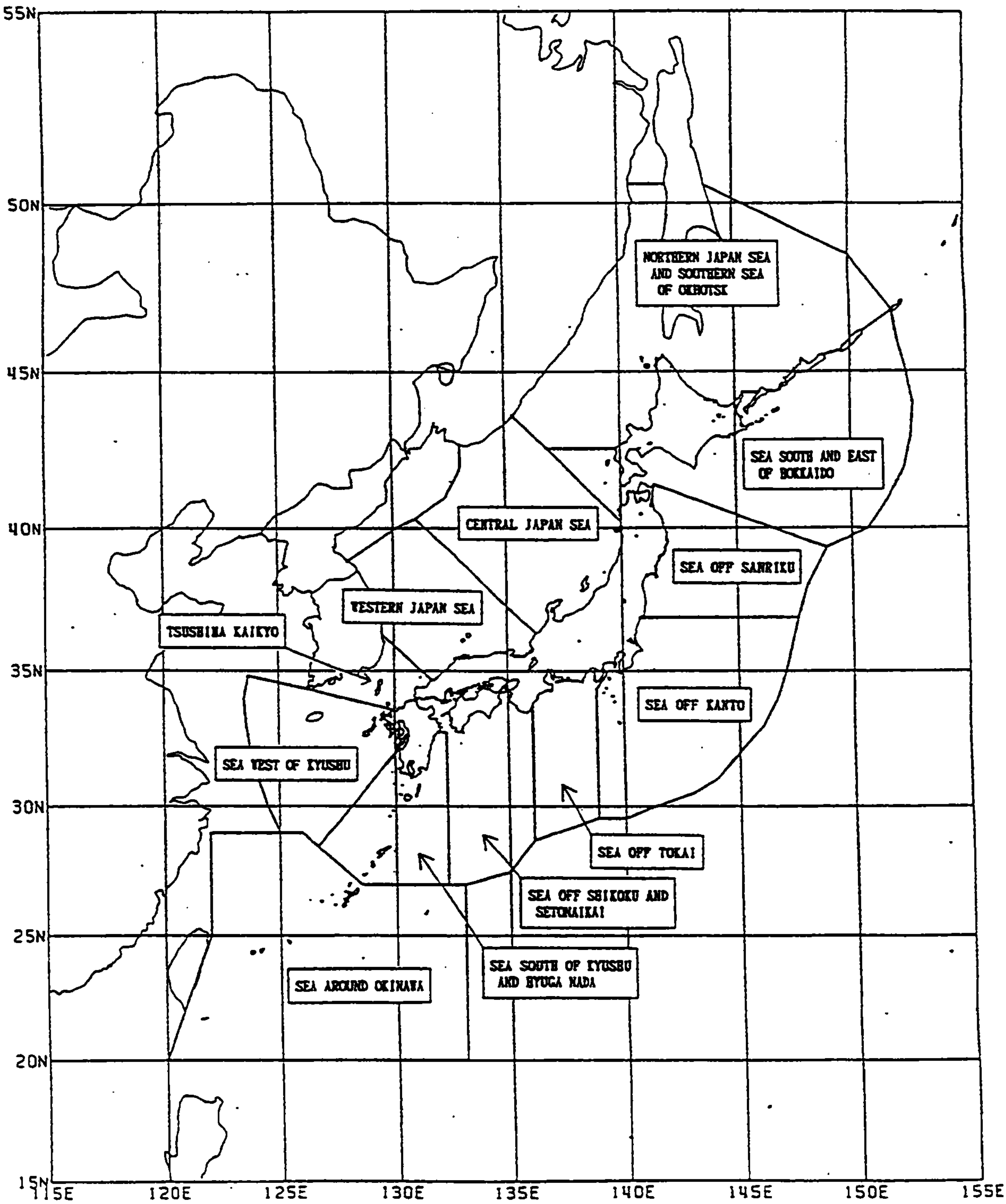
WEATHER FORECAST AREAS



NOTE: The pecked line enclose the area for which the Hong Kong Observatory issues warnings of tropical cyclones.

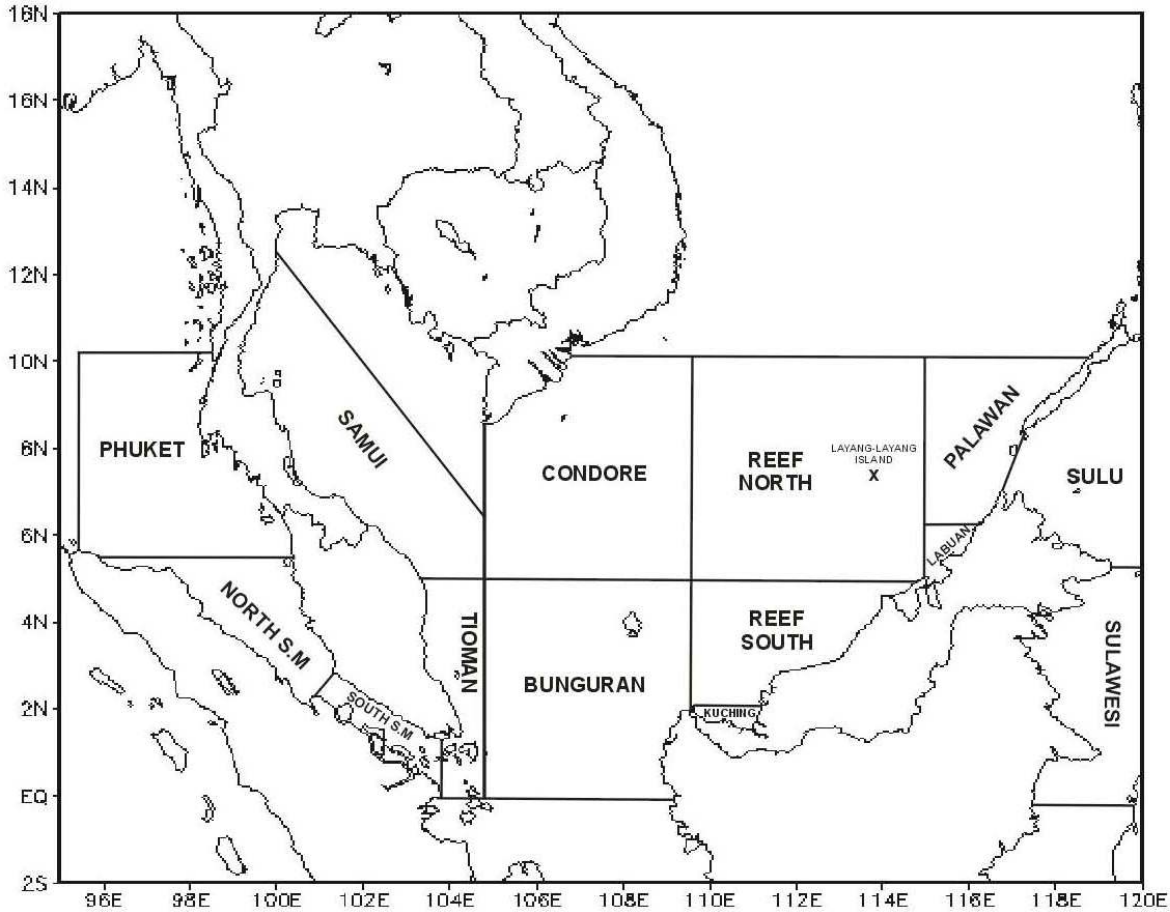
JAPAN

WEATHER FORECAST AREAS



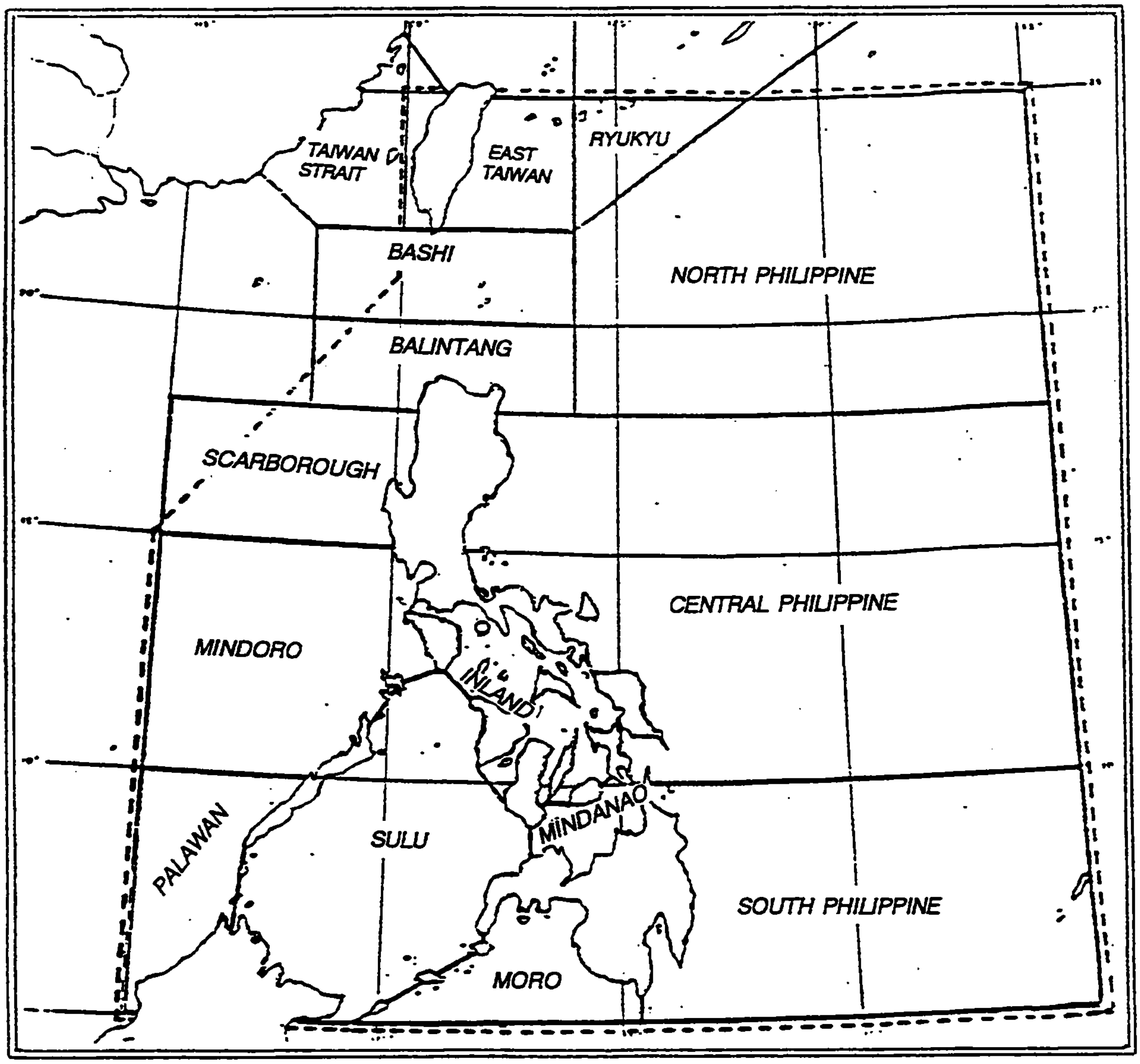
MALAYSIA

WEATHER FORECAST AREAS



PHILIPPINES

WEATHER FORECAST AREAS

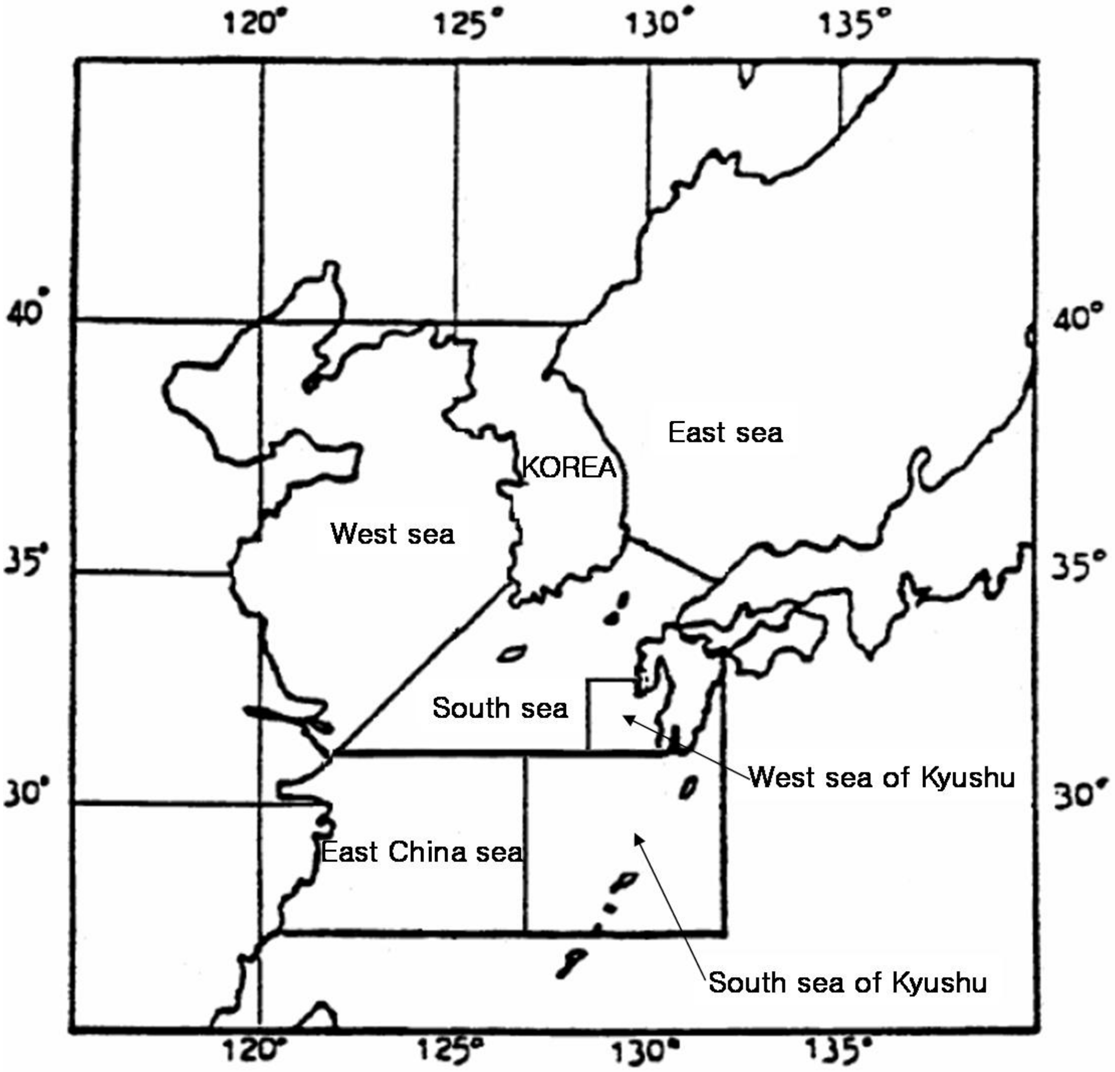


NOTE: INLAND area includes Sibuyan, Samar, Visayan and Camotes Seas.

Boundary of area covered by storm warnings issued by the Philippines Weather Bureau.

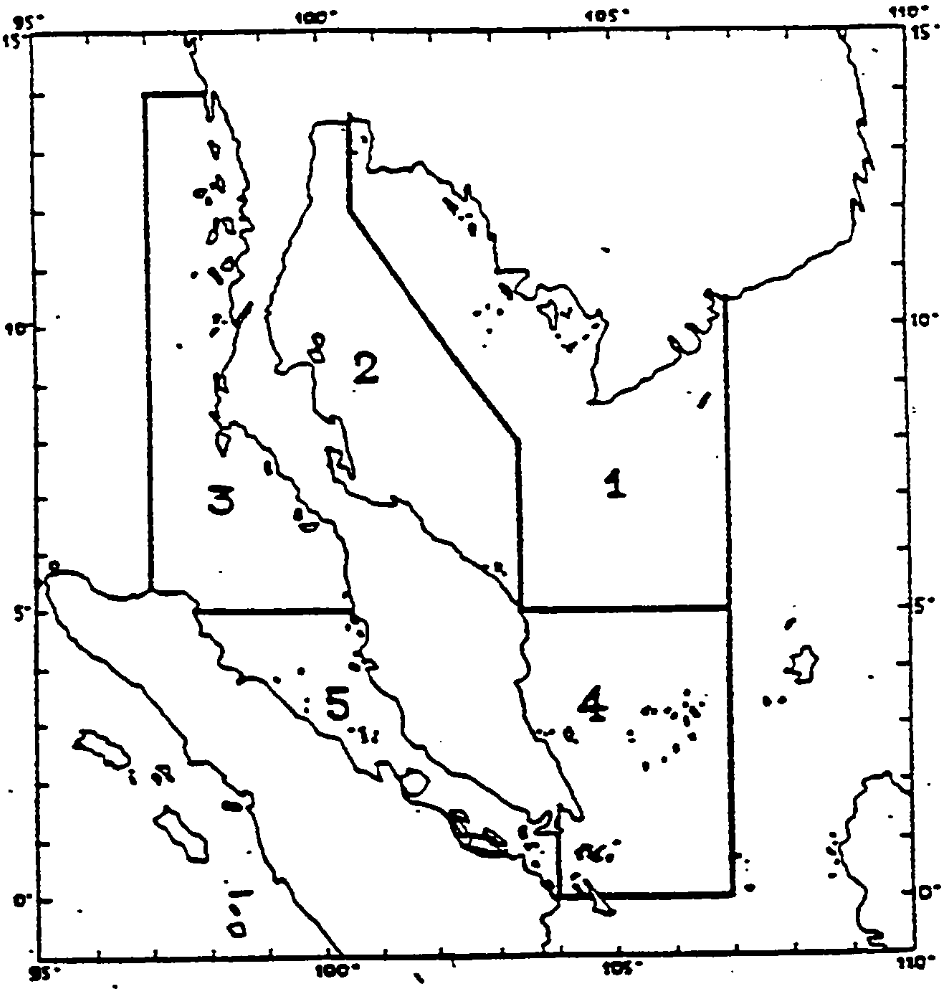
REPUBLIC OF KOREA

WEATHER FORECAST AREAS



THAILAND

WEATHER FORECAST AREAS



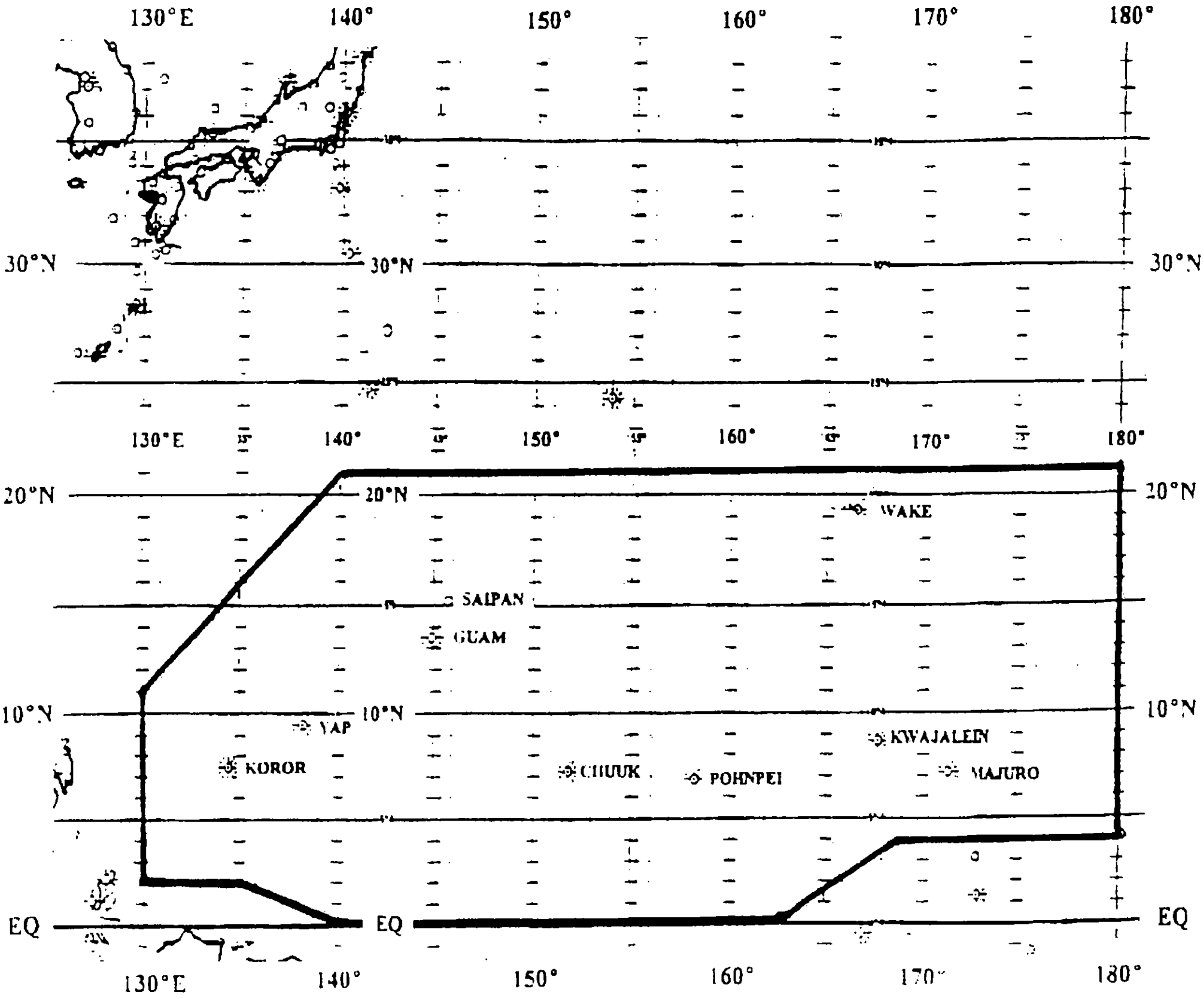
Note :

Division of forecasting areas:

Area 1 : Gulf of Thailand East coast to latitude 5°N and longitude 107°E
Area 2 : Gulf of Thailand West coast to latitude 5°N
Area 3 : West coast of Southern Burma below latitude 14°N and West coast of Southern Thailand to latitude 5°N
Area 4 : East coast of the Malay Peninsula from latitude 5°N to the Equator
Area 5 : The Strait of Malacca

NATIONAL WEATHER SERVICE OFFICE, GUAM, USA

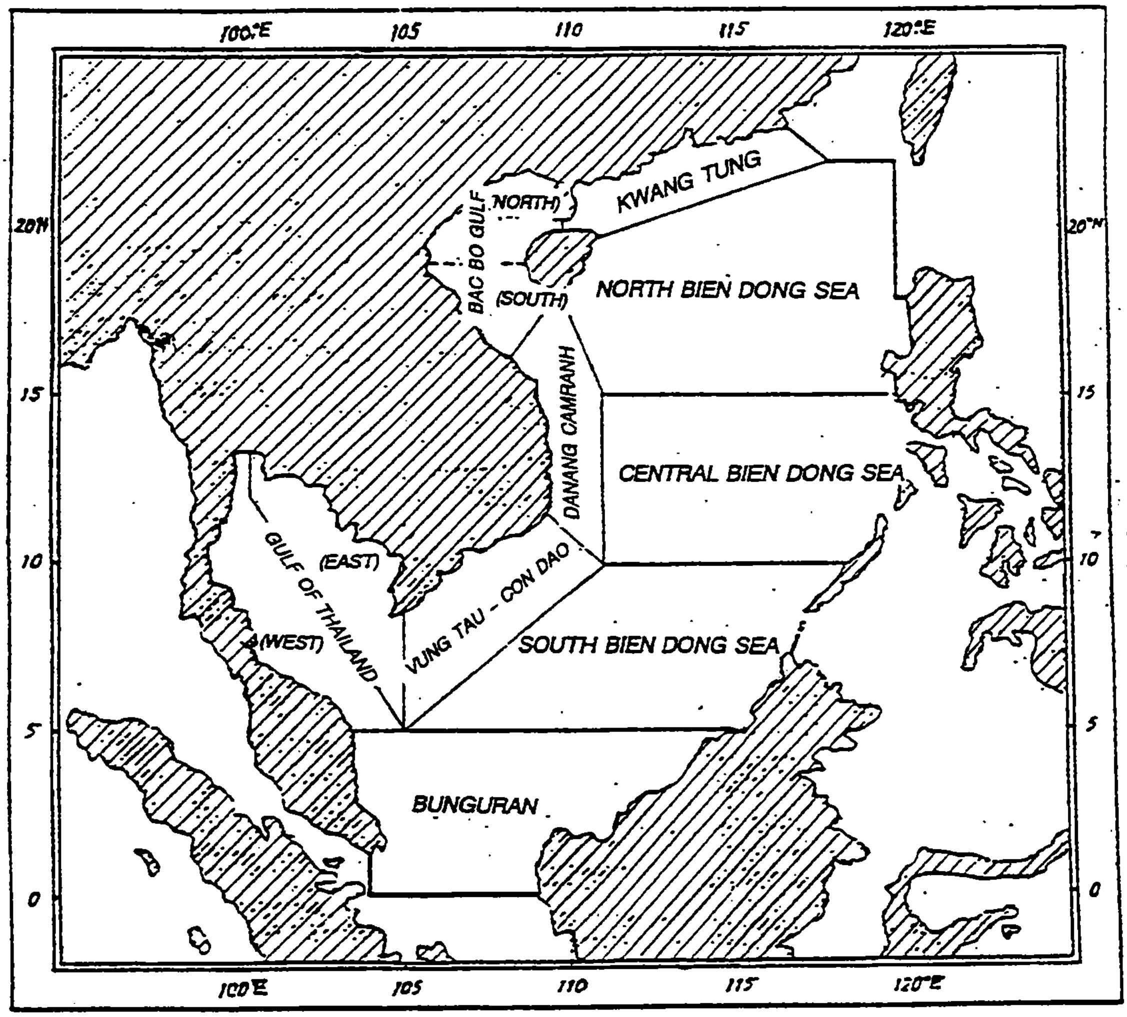
AREA OF RESPONSIBILITY



Note: Within this Area of Responsibility tropical cyclone watch and warning products, based on
tropical cyclone forecasts issued by the Joint Typhoon Warning Center, are provided by
National Weather Service Office, Guam.

VIET NAM

WEATHER FORECAST AREAS



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	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 Labuan Miri	LY 3010 OA 3010 OE 3010	Strait of Malacca* South China Sea* 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
Cambodia		
Attn. Mr Ly Chana Deputy Director Department of Agricultural Hydraulics and Hydrometeorology	Norodom Boulevard	Tel.: (+855) 15 913081 Fax: (+855) 23 26345
Attn. Mr Hun Kim Hak Chief of Cambodian National Airport	Pochentong	Tel/Fax:(+855) 23 66193 66192 NMC 66191
China		
National Meteorological Center China Meteorological Adm. (Director: Jiao Meiyan)	No. 46 Zhongguancun Nandajie, Beijing 100081	Tel.: (+86) (10) 6840 6169 Cable: 2894 Fax: (+86) (10) 6217 5928 E-mail: jiaomy@cma.gov.cn
Democratic People's Republic of Korea		
Mr Ko Sang Bok Director Central Forecast Research Insitute State Hydrometeorological Adm.	Oesong-dong Central District	Telex: 38022 TCT KP Tel.: (+850) (2) 321 4539 Fax: (+850) (2) 381 4410
Hong Kong, China		
Central Forecasting Office Hong Kong Observatory (Attn. Mr. 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@hko.gov.hk
Japan		
Forecast Division Forecast Department Japan Meteorological Agency (Director: A. Muranaka)	1-3-4 Otemachi Chiyoda-ku Tokyo 100-8122	Telex: 2228080 METTOKJ (24 hours) Tel.: (+81) (3)3211 8303 (00 - 09 UTC on weekdays) (+81) (3) 3211 7617 (24 hours) Fax: (+81) (3) 3211 8303

Lao People's Democratic Republic

Ministry of Agriculture and Forestry, Department of VIENTIANE Meteorology and Hydrology	P.O. Box 811 Vientiane	Telex: 4306 ONU VTELS Cable: UNDEVPRO

Macao, China

Meteorological and Geophysical Bureau (Director: Fong Soi Kun)	P.O. Box 93 Macao, China	Tel.: (+853) 88986273 Fax: (+853) 28850773 E-mail: meteo@smg.gov.mo

Malaysia

Malaysian Meteorological Dep. (Central Forecast Office, Director: Mr. Saw Bun Liong)	Jalan Sultan 46667 Petaling Jaya Selangor Malaysia	Tel.: (+60) (3) 7967 8116 (+60) (3) 7967 8119 Fax: (+60) (3) 7955 0964 E-mail: cfo@met.gov.my

Philippines

Weather Branch PAGASA (Weather Services Chief: Ellaquim A. Adug)	Asia TrustBank Bldg. 1424 Quezon Avenue Quezon City 3008	Telex: 66682 WXMLA PN Tel.: (+63) (2) 922 1996 Cable: 66682 WX MLA Fax: (+63) (2) 922 5287 (24 hours)

T C S

Secretary: Olavo Rasquinho	Avenida de 5 de Outubro Coloane, Macau	Tel: (853) 8 8010531 Fax: (853) 8 8010530 E-mail: olavo@typhooncommittee.org

Republic of Korea

National Typhoon Center
Korea Meteorological Adm.
(Chief Executive: Tae Ryong Kim)
1662-1 Hannam-ri, Namwon-eup, Seogwipo,
Jeju, 699-942, Republic of Korea

Tel.: (+82) (64) 801-0200
Fax: (+82) (64) 805-0366

Thailand

Thai Meteorological Department (Director-General: Mr. Suparerk Tansriratanawong) suparerk@metnet.tmd.go.th	4353 Sukhumvit Road Bangkok 10260	Telex: 72004 DEPMETE TH Tel.: (+66) (2) 399 1425 Tel.: (+66) (2) 399 1426 E-mail:
Weather Forecast Bureau Thai Meteorological Department (Director: Mr. Somchai Baimoung) somchaib@metnet.tmd.go.th	4353 Sukhumvit Road Bangkok 10260	Telex: 72004 DEPMETE TH Tel.: (+66)(2) 398 9801 Fax: (+66)(2) 398 9836 Tel&Fax:(+66)(2) 399 4012-4 E-mail:
Meteorological Telecommunication and Information Division Thai Meteorological Department (Director: Kumpol Luengpetngam) kumpol@metnet.tmd.go.th	4353 Sukhumvit Road Bangkok 10260	Tel.: (+66)(2) 399 4555 Fax: (+66)(2) 398 9861 (+66)(2) 399 4597 (+66)(2) 399 4598 E-mail:

USA

National Weather Service (Genevieve Miller, Meteorologist in charge)	3232 Hueneme Road Barrigada Guam 96913	Tel.: (+1-671) 472 0944 Fax: (+1-671) 472 7405
RSMC Honolulu (Director: Jim Weyman)	2525 Correa Road Suite 250 Honolulu, HI 96822	Tel.: (+1-808) 973-5272 Fax: (+1-808) 973-5271

Viet Nam

Forecast Division Forecast Department Hydro-Meteorological Service (Director: Nguyan Cong Thanh)	4 Dan Thai Than Hanoi	Tel.: (+84) (4) 264020 Fax: (+84) (4) 254278

ABBREAVIATED HEADINGS FOR THE TROPICAL CYCLONE WARNINGS

Member	Abbreviated WMO Communication Headings
Cambodia	
China	WTPQ20 BABJ
Democratic People's Republic of Korea	
Hong Kong, China	WTPQ20 VHHH, WTSS20 VHHH
Japan	WTPQ20 RJTD, WTPQ21 RJTD, WTPQ22 RJTD, WTPQ23 RJTD, WTPQ24 RJTD, WTPQ25 RJTD
Lao People's Democratic Republic	
Macao, China	For domestic dissemination only and WTMU40 VMMC
Malaysia	For domestic dissemination only
Philippines	WTPH20 RPMM, WTPH21 RPMM
Republic of Korea	WTKO20 RKSL
Singapore	WTSR20 WSSS
Thailand	WTTH20 VTBB
USA	WTPQ31 - 35 PGUM
Viet Nam	WTVS20 VNNN

COLLECTION AND DISTRIIBUTION OF INFORMATION RELATED TO TROPICAL CYCLONES

Type of Data	Heading		Receiving station										
			TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
Enhanced surface observation	SNCI30	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	SNHK20	VHHH	HH	HH	BJ	O		TD	BB	BB	BB	BB	
	SNJP20	RJTD	O	TD	TD	TD		TD	BB	BB	BB	BB	
	SNKO20	RKSL	SL	TD	TD	TD		O	BB	BB	BB	BB	
	SNLA20	VLIV	BB	BB	IV				BB	BB	O	BB	
	SNMS20	WMKK	BB	BB	KK	BJ			BB	O	BB	BB	
	SNMU40	VMMC		MC	BJ	BJ		TD	BB	BB	BB	BB	O
	SNPH20	RPMM	MM	TD	TD	TD	O	TD	BB	BB	BB	BB	
	SNTH20	VTBB	BB	TD	O	TD		TD	BB	BB	BB	BB	
	SNVS20	VNNN	BB		NN	BJ			O	BB	BB	BB	
Enhanced upper-air observation	USCI01	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	USCI03	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	USCI05	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	USCI07	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	USCI09	BABJ	BJ	O	BJ	BJ	TD	TD	BJ	BB	BB	BB	
	UKCI01	BABJ	BJ	O	BJ	BJ		TD	BJ	BB	BB	BB	
	ULCI01	BABJ	BJ	O	BJ	BJ		TD	BB	BB	BB	BB	
	ULCI03	BABJ	BJ	O	BJ	BJ		TD	BB	BB	BB	BB	
	ULCI05	BABJ	BJ	O	BJ	BJ		TD	BB	BB	BB	BB	
	ULCI07	BABJ	BJ	O	BJ	BJ		TD	BB	BB	BB	BB	
	ULCI09	BABJ	BJ	O	BJ	BJ		TD	BJ	BB	BB	BB	
	UECI01	BABJ	BJ	O	BJ	BJ		TD	BB	BB	BB	BB	
	USHK01	VHHH	HH	HH	BJ	O	TD	TD	BB	BB	BB	BB	
	UKHK01	VHHH	HH	HH	BJ	O		TD	BB	BB	BB	BB	
	ULHK01	VHHH	HH	HH	BJ	O		TD	BB	BB	BB	BB	
	UEHK01	VHHH	HH	HH	BJ	O		TD	BB	BB	BB	BB	
	USJP01	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	UKJP01	RJTD	O	TD	TD	TD		TD	BB	BB	BB	BB	
	ULJP01	RJTD	O	TD	TD	TD		TD	BB	BB	BB	BB	
	UEJP01	RJTD	O	TD	TD	TD		TD	BB	BB	BB	BB	
	USKO01	RKSL	SL	TD	TD	TD	TD	O	BB	BB	BB	BB	
	UKKO01	RKSL	SL	TD	TD	TD		O	BB	BB	BB	BB	
	ULKO01	RKSL	SL	TD	TD	TD		O	BB	BB	BB	BB	
	UEKO01	RKSL	SL	TD	TD	TD		O	BB	BB	BB	BB	
	USMS01	WMKK	BB	TD	KK	TD	TD	TD	BB	O	BB	BB	
	UKMS01	WMKK	BB	TD	KK	TD	TD	TD	BB	O	BB	BB	
	ULMS01	WMKK	BB	TD	KK	TD	TD	TD	BB	O	BB	BB	
	UEMS01	WMKK	BB	TD	KK	TD	TD	TD	BB	O	BB	BB	
	USPH01	RPMM	MM	TD	TD	TD	O	TD	BB		BB	BB	
	UKPH01	RPMM	MM	TD	TD	TD	O	TD	BB		BB	BB	
	ULPH01	RPMM	MM	TD	TD	TD	O	TD	BB		BB	BB	
Continued to	UEPH01	RPMM	MM	TD	TD	TD	O	TD	BB		BB	BB	
the next page	USTH01	VTBB	BB	TD	O	TD	TD	TD	BB	BB	BB	BB	

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			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		TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
			Receiving station										
			*										
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	
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	

Type of Data	Heading		Receiving station TD	BJ	BB	HH	MM	SL	NN	KK	IV	PP	MC
Warning	WTPQ25	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTKO20	RKSL	SL	TD	TD	TD		O	BB	BB	BB	BB	
Prognostic Reasoning	WTPQ30	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ31	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ32	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ33	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ34	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ35	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
Five-day track forecast	WTPQ50	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ51	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ52	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ53	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ54	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
	WTPQ55	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	
Others Best track	AXPQ20	RJTD	O	TD	TD	TD	TD	TD	BB	BB	BB	BB	

Note: Meaning of abbreviation

O	:	Data originating centre
TD	:	Data transmitting centre - Tokyo
BJ	:	- Beijing
BB	:	- Bangkok
HH	:	- Hong Kong
MM	:	- Manila
SL	:	- Seoul
NN	:	- Hanoi
KK	:	- Kuala Lumpur
IV	:	- Vientiane
PP	:	- Phnom Penh
MC	:	- Macao
*	:	Places other than described above

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
WS	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
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

EXAMPLE OF THE MESSAGE FORMAT FOR INQUIRY ON DOUBTFUL AND GARBLED REPORTS

Example 1. Inquiry on a doubtful report

BMBB01 VTBB 220245
RJTD
PLEASE CHECK THE FOLLOWING REPORT

BULLETIN	SNTH20 VTBB
DATE AND TIME	210200
LOCATION	48300
CONTENT	SECTION 1, 2ND GROUP: 80540

REGARDS
RSMC TOKYO =

Example 2. Inquiry on a garbled report

BMRR01 RPMM 210425
RJTD
AHD SNPH20 RPMM 210400 =

PROCEDURES OF REGULAR MONITORING AT RSMC TOKYO - TYPHOON CENTER

1. Monitoring period

The two appropriate periods are selected from the one year starting on 1st November and ending on 31st October of the subsequent year. Each period will be up to five consecutive days.

2. Items of monitoring

The reception time of reports at RSMC Tokyo should be monitored. The types of reports to be monitored are:

(i) hourly surface observations (SYNOP code),

(ii) hourly ship and buoy observations (SHIP and BUOY codes),

(iii) 6-hourly upper-air observations (TEMP and PILOT codes),

(iv) hourly radar observations (BUFR and/or RADOB codes).

3. Format of monitoring results

Samples of format of monitoring results are shown in Fig. 6-B.1 to Fig 6-B.4.

4. Distribution of monitoring results

The monitoring results should be distributed once a year by RSMC Tokyo - Typhoon Center to Typhoon Committee Secretariat and its Members by the end of every year. A copy will be forwarded to WMO Secretariat. Members can also retrieve the data from the Internet server of JMA (ddb.kishou.go.jp) by using FTP. A password to connect the FTP server by using anonymous FTP is issued to Members in consultation with JMA.

RECEPTION TIME OF SYNOP REPORTS

NOV. 07 2001 PAGE : 1

Location	00 UTC	01 UTC	02 UTC	03 UTC	04 UTC	05 UTC	06 UTC	07 UTC	08 UTC	09 UTC	10 UTC	11 UTC	12 UTC	13 UTC	14 UTC	15 UTC	16 UTC	17 UTC	18 UTC	19 UTC	20 UTC	21 UTC	22 UTC	23 UTC
45007	0006			0307			0608			0909			1208			1507			1806			2111		
45011	0026						0646						1236						1833			2114		
47090	0012			0312			0612			0912			1212			1512			1812			2110		
47095	0012			0312			0612			0912			1212			1512			1812			2107		
47100	0012			0312			0612			0912			1212			1512			1812					
47101	0012			0312			0612			0912			1212			1512			1812					
47105	0012			0312			0612			0912			1212			1512			1812					
47108	0012			0312			0612			0912			1212			1512			1812					
47112	0012			0312			0612			0912			1212			1512			1812			2140		
47114	0012			0312			0612			0912			1212			1512			1812					
:																								
:																								

Fig. 6-B.1 Format of monitoring results for SYNOP

RECEPTION TIME OF SHIP/BUOY REPORTS

NOV. 11 2001 PAGE : 5

Location	00 UTC	01 UTC	02 UTC	03 UTC	04 UTC	05 UTC	06 UTC	07 UTC	08 UTC	09 UTC	10 UTC	11 UTC	12 UTC	13 UTC	14 UTC	15 UTC	16 UTC	17 UTC	18 UTC	19 UTC	20 UTC	21 UTC	22 UTC	23 UTC
JPBN																								
JCCX	0008	0105		0310	0404	0504	0609	0704	0804	0909	1005		1211	1307	1404	1516								
JDWX																								
JFDG																								
JGQH	0004	0101	0201	0304	0401	0501	0606	0701	0801	0904	1001	1101	1204	1301	1401	1505	1601	1701						
JIVB																								
21002																								
21004																								
22001																								
:																								
:																								

Fig. 6-B.2 Format of monitoring results for SHIP and BUOY

RECEPTION TIME OF UPPER-AIR REPORTS

NOV. 07 2001 T: TEMP/TEMP SHIP P: PILOT/PILOT SHIP

	00 UTC					06 UTC					12 UTC					18 UTC				
Location	PART	A	B	C	D	PART	A	B	C	D	PART	A	B	C	D	PART	A	B	C	D
JPBN																				
JPBN																				
JCCX																				
JCCX																				
JDWX																				
JDWX																				
JGQH																				
JGQH																				
JIVB																				
JIVB																				
45004		T0044	T0044	T0044	T0044							T1238	T1238	T1238	T1238					
45004		P0044	P0044	P0044	P0044		P0710	P0710	P0710	P0710		P1238	P1238	P1238	P1238		P1850	P1850		
47122		T0127	T0127	T0127	T0127		T0727	T0727	T0734	T0734		T1327	T1327	T1327	T1327		T1927	T1927	T1927	T1927
47122																				
47138		T0127	T0127	T0127	T0127							T1327	T1327	T1327	T1327					
47138																				
47158		T0127	T0127	T0127	T0127							T1327	T1327	T1327	T1327					
47158																				
47185		T0127	T0127	T0127	T0127							T1327	T1327	T1327	T1327					
47185																				
47401		T0024	T0025	T0057	T0059							T1233	T1235	T1259	T1259					
47401							P0616	P0618									P1814	P1815		
47412		T0027	T0029	T0104	T0106							T1237	T1239	T1253	T1254					
47412							P0618	P0618									P1824	P1826		
:																				
:																				

Fig. 6-B.3 Format of monitoring results for TEMP and PILOT

RECEPTION TIME OF RADAR REPORTS

NOV. 07 2001 PAGE : 1

Location	00 UTC	01 UTC	02 UTC	03 UTC	04 UTC	05 UTC	06 UTC	07 UTC	08 UTC	09 UTC	10 UTC	11 UTC	12 UTC	13 UTC	14 UTC	15 UTC	16 UTC	17 UTC	18 UTC	19 UTC	20 UTC	21 UTC	22 UTC	23 UTC
45009																								
45010																								
47106																								
47116																								
47144																								
47160																								
47185																								
47415																								
47418																								
47419																								
:																								
:																								

Fig. 6-B.4 Format of monitoring results for Radar reports

EXAMPLE OF BEST TRACK REPORT

```
AXPQ20 RJTD 060400
RSMC TROPICAL CYCLONE BEST TRACK
NAME 9009 TASHA (9009)
PERIOD FROM JUL2612UTC TO AUG0100UTC
2612 20.0N 119.6E 1002HPA  //KT  2618 19.6N 120.0E 1000HPA  //KT
2700 19.2N 120.2E 1000HPA  //KT  2706 18.8N 120.2E 1000HPA  //KT
2712 18.6N 119.8E 1000HPA  //KT  2718 18.6N 119.2E 1000HPA  //KT
2800 18.6N 118.3E  996HPA  35KT  2806 18.6N 118.0E  992HPA  40KT
2812 18.7N 117.6E  990HPA  45KT  2818 18.8N 117.4E  990HPA  45KT
2900 18.9N 117.2E  990HPA  45KT  2906 18.8N 116.5E  985HPA  50KT
2912 18.8N 116.0E  985HPA  50KT  2918 19.0N 116.0E  985HPA  50KT
3000 19.4N 115.5E  980HPA  55KT  3006 20.1N 115.8E  980HPA  55KT
3012 21.4N 115.8E  980HPA  55KT  3018 22.0N 116.0E  980HPA  55KT
3100 23.6N 115.1E  985HPA  50KT  3106 25.0N 114.7E  990HPA  45KT
3112 25.5N 114.4E  996HPA  35KT  3118 25.8N 114.3E  998HPA  //KT
0100 26.2N 114.6E 1000HPA  //KT
REMARKS
TD   FORMATION   AT JUL2612UTC
FROM TD  TO TS   AT JUL2800UTC
FROM TS  TO STS  AT JUL2906UTC
FROM STS TO TS   AT JUL3106UTC
FROM TS  TO TD   AT JUL3118UTC
DISSIPATION      AT AUG0106UTC=
```

STANDARD PROCEDURES FOR THE VERIFICATION OF TYPHOON ANALYSIS AND FORECAST AT NATIONAL METEOROLOGICAL CENTRES

1. General

Each Member will verify each typhoon which affects it and summarize the verification made in a year

2. Basis for verification

The best initial typhoon position, central pressure and maximum sustained wind as determined from a post-analysis conducted by the RSMC.

3. Points for verification

(1) Error statistics in each method (bias and standard deviation) by using common work sheets as shown in Appendix 6-E. Statistical computations involve positioning of the centre, prediction of movement, and analysis and forecast of intensity of a tropical cyclone.

(2) Discussion of following points;

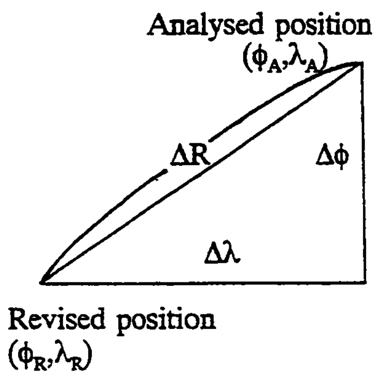
- (i) relative merits of each technique,
- (ii) effects of inaccuracies on the forecast,
- (iii) effects of meagreness of available relevant real-time observations,
- (iv) variation from one geographical area to another,
- (v) climatological factors in climatological and/or statistical method,
- (vi) large-scale circulation pattern for giving rise to extremely poor prediction performance.

Verification sheet for positioning of the centre, prediction of movement, and analysis and forecast of intensity of tropical cyclones

Typhoon ....(..............)...

Method ....

Date	Analysed position		Revised position		Error		
	ϕ_A	λ_A	ϕ_R	λ_R	$\Delta\phi$	$\Delta\lambda$	ΔR



$$\Delta R = a\sqrt{\left(\cos\phi_R \cdot \Delta\lambda \cdot \frac{\pi}{180}\right)^2 + \left(\Delta\phi \cdot \frac{\pi}{180}\right)^2} \quad \text{(km)}$$

ΔR ; Error in analysed position (km)
a ; Radius of the earth, 6371 km
ϕ, λ ; Latitude and longitude
ϕ, λ, $\Delta\phi$, $\Delta\lambda$ are measured in degree.

Remark ; For RADOB and RADAR position verification, interpolated position of reviced track at fixed observation time should be used.

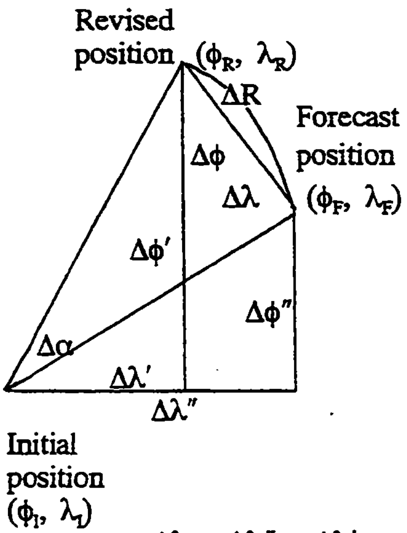
Note; ΔR can also be measured directly on the verification map.

Verification sheet for positioning of the centre, prediction of movement, and analysis and forecast of intensity of tropical cyclones

Typhoon ....(............)

Method .... Forecast period 24–hour / 48–hour (check one)

Initial Date	Initial position		Forecast position		Revised position		Errors				
	ϕ_I	λ_I	ϕ_F	λ_F	ϕ_R	λ_R	$\Delta\phi$	$\Delta\lambda$	ΔR	$\Delta\alpha$	ΔSP



$\Delta\lambda = \Delta\lambda'' - \Delta\lambda'$

$\Delta\phi = \Delta\phi' - \Delta\phi''$

$$\Delta R = a\sqrt{\left(\cos\phi_I \cdot \Delta\lambda \cdot \frac{\pi}{180}\right)^2 + \left(\Delta\phi \cdot \frac{\pi}{180}\right)^2} \quad \text{(km)}$$

$$\Delta\alpha = \tan^{-1}\frac{\Delta\phi''}{\cos\phi_I \cdot \Delta\lambda''} - \tan^{-1}\frac{\Delta\phi'}{\cos\phi_I \cdot \Delta\lambda'}$$

$$\Delta SP = a\left\{\sqrt{(\cos\phi_I \cdot \Delta\lambda'')^2 + (\Delta\phi'')^2} - \sqrt{(\cos\phi_I \cdot \Delta\lambda')^2 + (\Delta\phi')^2}\right\}/\Delta t$$

(km/hour)

ΔR ; Error in prediction position (km)
$\Delta\alpha$; error in predicted direction of movement in degrees in azimuth angle
ΔSP ; Error in the speed of movement
$\Delta\phi'$, $\Delta\phi''$, $\Delta\lambda'$, $\Delta\lambda''$ are measured in degrees.
Δt ; forecast period (hour)
$\Delta\alpha$ is positive if forecast is to the right of the actual path.

Note ; ΔR, $\Delta\alpha$ and ΔSP can also be measured directly on the verification map.

Verification sheet for positioning of the centre, prediction of movement, and analysis and forecast of intensity of tropical cyclones

Typhoon ....(..........)

	Analysis			24–hour forecast			48–hour forecast		
Method	....			....			....		
Date	P_a	P_r	ΔP_a	P_f	P_r	ΔP_f	P_f	P_r	ΔP_f

Note :

P_r : Revised central pressure

P_a : Analysed central pressure, $\Delta P_a = P_a - P_r$

P_f : Predicted central pressure, $\Delta P_f = P_f - P_r$

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

(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

(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 (P_s), temperature (T_s), dew point depression (T_s - T_{ds}), wind (U_s, V_s);

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

Specific pressure levels (1000 - 300 hPa):
Dew point depression (T-T_d).

GLOBAL TROPICAL CYCLONE TRACK AND INTENSITY DATA SET - REPORT FORMAT

Position	Content
1- 9	Cyclone identification code composed by 2 digit numbers in order within the cyclone season, area code and year code. 01SWI2000 shows the 1st system observed in South-West Indian Ocean basin during the 2000/2001 season. Area codes are as follows: ARB = Arabian Sea ATL = Atlantic Ocean AUB = Australian Region (Brisbane) AUD = Australian Region (Darwin) AUP = Australian Region (Perth) BOB = Bay of Bengal CNP = Central North Pacific Ocean ENP = Eastern North Pacific Ocean ZEA = New Zealand Region SWI = South-West Indian Ocean SWP = South-West Pacific Ocean WNP = Western North Pacific Ocean and South China Sea
10-19	Storm Name
20-23	Year
24-25	Month (01-12)
26-27	Day (01-31)
28-29	Hour- universal time (at least every 6 hourly position -00Z,06Z,12Z and 18Z) Latitude indicator: 1=North latitude; 2=South latitude
31-33	Latitude (degrees and tenths)
34-35	Check sum (sum of all digits in the latitude)
36	Longitude indicator: 1=West longitude; 2=East longitude
37-40	Longitude (degrees and tenths)
41-42	Check sum (sum of all digits in the longitude)
43	position confidence* 1 = good (<30nm; <55km) 2 = fair (30-60nm; 55-110 km) 3 = poor (>60nm; >110km) 9 = unknown
Note*	Confidence in the center position: Degree of confidence in the center position of a tropical cyclone expressed as the radius of the smallest circle within which the center may be located by the analysis. **"position good"** implies a radius of less than 30 nm, 55 km; "position fair", a radius of 30 to 60 nm, 55 to 110km; and "position poor", radius of greater than 60 nm, 110km.
44-45	Dvorak T-number (99 for no report)
46-47	Dvorak CI-number (99 for no report)
48-50	Maximum average wind speed (whole values) (999 for no report).
51	Units 1=kt, 2=m/s, 3=km per hour.
52-53	Time interval for averaging wind speed (minutes for measured or derived wind speed, 99 if unknown or estimated).
54-56	Maximum Wind Gust (999 for no report)

57 Gust Period (seconds, 9 for unknown)

58 Quality code for wind reports:
- 1=Aircraft or Dropsonde observation
- 2=Over water observation (e.g. buoy)
- 3=Over land observation
- 4=Dvorak estimate
- 5=Other

59-62 Central pressure (nearest hectopascal) (9999 if unknown or unavailable)

63 Quality code for pressure report (same code as for winds)

64 Units of length: 1=nm, 2=km

65-67 Radius of maximum winds (999 for no report)

68 Quality code for RMW:
- 1=Aircraft observation
- 2=Radar with well-defined eye
- 3=Satellite with well-defined eye
- 4=Radar or satellite, poorly-defined eye
- 5=Other estimate

69-71 Threshold value for wind speed (gale force preferred, 999 for no report)

72-75 Radius in Sector 1: 315°-45°

76-79 Radius in Sector 2: 45°-135°

80-83 Radius in Sector 3: 135°-225°

84-87 Radius in Sector 4: 225°-315°

88 Quality code for wind threshold
- 1=Aircraft observations
- 2=Surface observations
- 3=Estimate from outer closed isobar
- 4=Other estimate

89-91 Second threshold value for wind speed (999 for no report)

92-95 Radius in Sector 1: 315°-45°

96-99 Radius in Sector 2: 45°-135°

100-103 Radius in Sector 3: 135°-225°

104-107 Radius in Sector 4: 225°-315°

108 Quality code for wind threshold (code as for row 88)

109-110 Cyclone type:
- 01= tropics; disturbance (no closed isobars)
- 02= <34 knot winds, <17m/s winds and at least one closed isobar
- 03= 34-63 knots, 17-32m/s
- 04= >63 knots, >32m/s
- 05= extratropical
- 06= dissipating
- 07= subtropical cyclone (nonfrontal, low pressure system that comprises initially baroclinic circulation developing over subtropical water)
- 08= overland
- 09= unknown

111-112 Source code (2 - digit code to represent the country or organization that provided the data to NCDC USA. WMO Secretariat is authorized to assign number to additional participating centers, organizations)
- 01 RSMC Miami-Hurricane Center
- 02 RSMC Tokyo-Typhoon Center
- 03 RSMC-tropical cyclones New Delhi
- 04 RSMC La Reunion-Tropical Cyclone Centre
- 05 Australian Bureau of Meteorology
- 06 Meteorological Service of New Zealand Ltd.

07 RSMC Nadi-Tropical Cyclone Centre
08** Joint Typhoon Warning Center, Honolulu
09** Madagascar Meteorological Service
10** Mauritius Meteorological Service
11** Meteorological Service, New Caledonia
12 Central Pacific Hurricane Center, Honolulu

Note** no longer used

Headings 1-19 Cyclone identification code and name; 20-29 Date time group;
30-43 Best track positions;
44-110 Intensity, Size and Type;
111-112 Source code.