Annex IV

JMA/WMO WORKSHOP ON EFFECTIVE TROPICAL CYCLONE WARNING IN SOUTHEAST ASIA

Tokyo, Japan
11-14 March 2014

(COUNTRY REPORT TEMPLATE)

Title of Country Report

Naohisa Koide (Section 1, 2 and 4), Nadao Kono (Section 3), and Kazuhiko Nagata (Section 4)

Japan Meteorological Agency

The Japan Meteorological Agency, since its designation as Regional Specialized Meteorological Centre (RSMC) in 1989, has been providing tropical cyclone (TC) related products to the ESCAP/WMO Typhoon Committee Members. In this report, JMA's operational TC techniques for TC genesis monitoring, intensity analysis, and forecasting, including recent operational/research progress such as the objective TC intensity technique, CLOUD, and ensemble TC genesis forecasts, are summarized. Overview on JMA's warnings related to severe weather phenomena associated TCs (e.g. heavy rain and flooding), including QPE/QPF based index techniques for those warnings are also briefed. The summary of specification of the JMA's NWP and storm surge models are also presented. To further improve its warning messages effectively communicating with users, JMA plans to develop more organized warning systems such as introduction of warning category systems in the future.

A GUIDE TO PREPARE A COUNTRY REPORT AND PRESENTATION

You are kindly requested to provide a written country report (10-15 pages including figures) following the below template. In addition, please note that you are expected to give a 30-minute presentation using a PowerPoint file (including five minute Q&A) on the first day of the workshop in line with your country report. For succinct description, you can just refer to information described in existing written materials available in English via the Internet with the URLs, i.e., in that case, you do not necessarily have to state it within the country report. When you write the country report, please follow notes in square brackets ([ ]).

1. Tropical Cyclone Monitoring, Analysis and Forecasting

1.1 Tropical Cyclone Monitoring

1.1.1 Tropical Cyclogenesis Monitoring

RSMC Tokyo - Typhoon Center (hereafter, "the Centre") closely watches all cloud clusters within its responsible area using MTSAT satellite images as well as deterministic NWP models of major centers available at the Numerical Typhoon Prediction (NTP) Website (https://tynwp-web.kishou.go.jp/), such as ECMWF, NCEP, UKMO and JMA. Once such clusters are organized enough and their cloud system centers (CSCs) are determined, the Centre quantitatively examines the potential for their development into Tropical Storms (TSs), using Early Dvorak Analysis (EDA). Tropical numbers (T-numbers) of those systems determined by EDA, available at NTP Website for Typhoon Committee Members, correspond to the likelihood of their development into TSs (Please refer to 1.2.1. for details on EDA). Streamlines of 850 hPa and 200 hPa are also used for forecasters to understand divergent/convergent atmospheric flows at lower and upper levels respectively.

1.1.2 Tropical Depression (TD) Warnings

The Centre identifies organized convective cloud systems (OCCSs) with CSCs as TDs within its responsible area. Marine warnings are issued, disseminated via telecommunications satellites and the Global Telecommunication System. The warnings are also shown in JMA's Asia-Pacific surface analysis chart (http://www.jma.go.jp/en/g3/), when warning-issued TDs (WTDs) or TDs with 10-minute maximum sustained wind (MSW) of Beaufort scale 7 (28 knots to 33 knots) based on observations, such as SYNOP, SHIP, BUOY and ASCAT, are identified. TDs with 10-minute MSW of less than Beaufort scale 7 are classified as Non-warning issued TDs (NTDs) and are shown in JMA's Asia-Pacific surface analysis chart, whereas no warnings are issued. For TDs expected to reach TS intensity or higher within 24 hours, the Centre issues TC advisories.

1.1.3 Challenges, Needs and Improvement Plans

To further improve the accuracy of TC genesis information and length of its lead time, the Centre has been conducting the evaluation of tropical cyclone genesis prediction, using TIGGE data, up to a medium range timescale under the North Western Pacific Tropical Cyclone Ensemble Forecast Project (NWP-TCEFP). In 2013, predictive skills of Ensemble Prediction Systems (EPSs) of ECMWF, JMA, NCEP and UKMO were evaluated for TCs formed for the period, July to October from 2009 to 2012. The results show that all EPSs have potential to predict TC genesis with a lead time of at least five days, and more in some cases. Further evaluations will be conducted from 2014 through 2015, to assess the potential for the development of TC genesis information using EPSs.

1.2 Tropical Cyclone Analysis

1.2.1 Parameters and Methods

[Please describe analyzed Tropical Cyclone (TC) parameters and methods used for analysis by filling out the below table.]

Parameter	Time (UTC)	Methods	Other sources
Likelihood of development of OCCSs into TSs	00, 06, 12, 18	JMA operationally uses Early Dvorak Analysis (EDA) to determine likelihood of development of OCCSs into TSs. EDA consists of detection of OCCSs and classification of T-numbers. OCCSs are identified whenever meeting one of	Deterministic NWP models of major centers (e.g. ECMWF, NCEP, UK, JMA), 850 hPa and

		the four features described in Tsuchiya et al. (2001). T-number (0.0, 0.5, 1.0, 1.5 or 2.0) of an OCCS is assigned in accordance with the number of their cloud features meeting the conditions given in Tsuchiya et al. (2001). To ensure the continuity of EDA with Dvorak analysis (1984), the EDA's classification of T-number is developed based on the Pattern T-number chart of Dvorak (1984). A likelihood of development of an OCCS into a TS is determined based on the EDA's T-number (Kishimoto 2008).	200 hPa streamlines
Dvorak Intensity (CI, T, DT, PT, MET number)	00, 06, 12, 18	The Dvorak (1984) EIR method has been operational since March 1987 to estimate TC intensity. Dvorak CI number is converted into Central Pressure (CP) as well as MSW according to Koba et al. (1991). The following rules (Koba et al. 1989) are applied to reduction in CI number after landfall. 1) When a TC makes landfall and the T-number decreases immediately, the CI-number also decreases immediately. 2) When a TC makes landfall within 12 hours after reaching its peak T-number and the T-number continues to decrease, the corresponding CI number decreases at the same rate. 3) When a TC shows signs of redevelopment after 1) or 2) is applied, determination of the CI number follows the original Dvorak rule.	As complement to Dvorak analysis, CPs estimated from TC warm core intensities observed by the Advanced Microwave Sounding Unit-A (AMSU-A) (Oyama 2014) and MSW estimated from multi-channel microwave imager data (Sakuragi et al. 2014, Hoshino and Nakazawa (2007)) are available for forecasters.
Center Position, Accuracy of center position, Direction & speed of movement	00, 03, 06, 09, 12, 15, 18, 21	Center positions estimated by using satellite images are adjusted, when other estimation methods which utilize surface observations are considered more reliable.	
Central pressure, Maximum sustained wind speed, maximum gust wind speed, R50 (50 kt radii), R30 (30 kt radii)	00, 03, 06, 09, 12, 15, 18, 21	CP and MSW estimated by using Dvorak method are adjusted so that final CP/MSW are consistent with weather map analysis with full utilization of all observational data available (SYNOP, SHIP, BUOY, ASCAT, OSCAT, etc.). R30 and R50 are determined based on ASCAT/OSCAT, if available, and/or the statistical relationship between CP and R50 selected by TC size.	

1.2.2 Challenges, Needs and Improvement Plans

To minimize the subjectivity of Dvorak analysis, the Centre developed an algorithm to derive T-numbers covering both EDA and Dvorak analysis stages (Kishimoto et al., 2013). This is referred to as Cloud Grid Information Objective Dvorak Analysis (CLOUD). What is remarkable technique employed in CLOUD is its utilization of TC Cloud Grid Information (CGI; a product operationally produced by JMA's Meteorological Satellite Center (MSC) since 2007) to accurately identify convective cloud areas. CLOUD uses TC center positions and cloud patterns manually determined by operational forecasters. Verification study from 2011 to August 2013 indicate that CLOUD T-numbers are as accurate as their manual counterparts and can be used as final T-numbers except in the cases of: 1) CGI identification of convective cloud areas significantly different from manually

identified ones; 2) low concentration of convective cloud areas around a TC center; 3) shear patterns; or 4) rapid intensification. These shortcomings of CLOUD can be overcome by adopting manually determined PT (Pattern T) or MET (Model Expected T-number) data as appropriate. CLOUD will be operational in 2014. Although CLOUD increases the objectivity of TC analysis and reduces the burden of operational forecasters, its accuracy still largely depends on the appropriate manual determination of TC central positions and cloud patterns, and the correct choice of the final T-number among CLOUD, PT and MET data. To ensure appropriate use of CLOUD by forecasters, continuous training on algorithm of CLOUD as well as Dvorak analysis (1984) is necessary.

1.3 Tropical Cyclone Forecasting

1.3.1 Parameter and Method

Parameter	Issu-ance Time (UTC)	Lead time (hours)	Methods
Track (center position, radius of probability circle, direction and speed of movement)	00, 06, 12, 18	24, 48, 72, 96, 120	Track forecasts are mainly based on deterministic and ensemble NWP models of JMA and other major centers such as ECMWF, NCEP and UKMO. Radius of probability circle through 72h is determined in accordance with the verification results of past TC track errors, whereas those for 96h and 120h track forecasts depend on ensemble spread of the JMA's Typhoon Ensemble Prediction System (Yamaguchi and Komori 2009, Kishimoto 2010).
Central pressure, Maximum sustained wind, R50 (50 kt radii), R30 (30 kt radii), Maximum gust wind speed	00, 06, 12, 18	24, 48, 72	TC intensity forecasts are made by forecaster's comprehensive analysis mainly based on deterministic NWP models of JMA and ECMWF, CI-CP development curves of similar past cases, a statistical relationship between SST and potential minimum sea level pressures, and statistical 5 day TC intensity forecasts. R50 is forecasted based on CP-R50 development curve determined by TC size.

1.3.2 Challenges, Needs and Improvement Plans

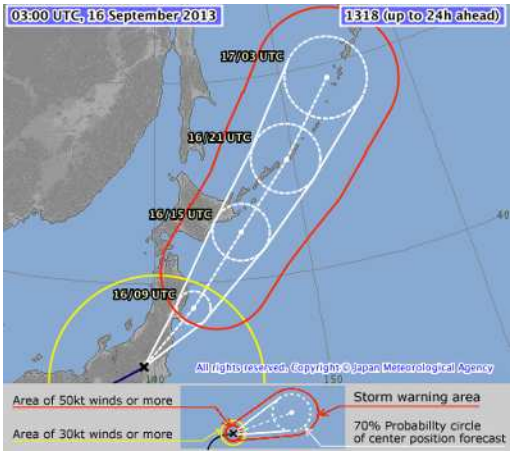
The Centre mainly uses the JMA global NWP model, with reference to those of other major centers, to make official tropical cyclone forecasts. However, the accuracy of TC intensity forecasts by the JMA's model is not enough due to lack of resolution and biases in the direction and speed of TC track forecasts by the model. These weak points sometimes degrade the official forecasts of the Centre. To improve TC track forecasts, the Centre continues to make efforts to further refine its model, while pursuing a research on better use of NWP results from major centers such as ECMWF and UKMO. Furthermore, the Centre is investigating ways to represent uncertainties of TC forecasts and the possibility to develop probabilistic tropical cyclogenesis information, based on ensemble NWP systems.

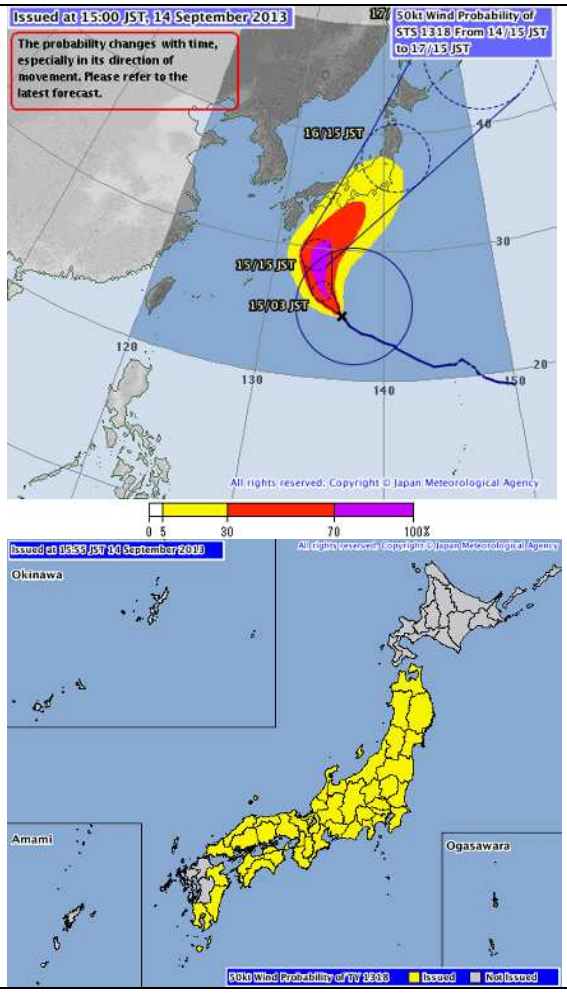
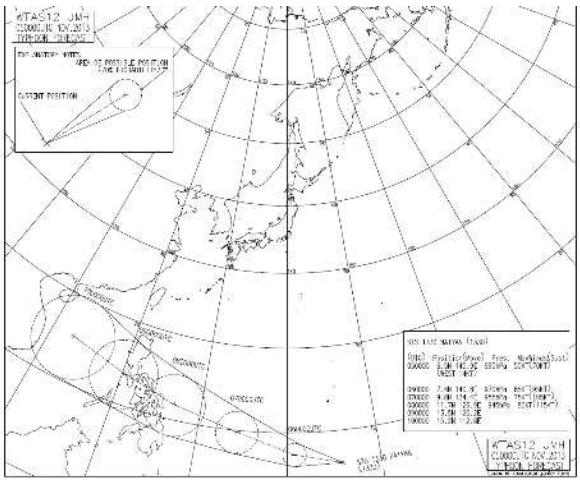
1.4 Tropical Cyclone Products

1.4.1 TC Products

Listed below are JMA's TC products for domestic users. TC products of the Centre for international users are provided in Annual Report on Activities of the RSMC Tokyo - Typhoon Center (http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/annualreport.html) and Typhoon Committee Operational Manual (http://www.wmo.int/pages/prog/www/tcp/operational-plans.html).

Product Name	Issuance Time	Contents

Information on Developing Tropical Cyclone	00, 06, 12, 18	Issued when there is a TC expected to develop into TS and affect Japan within 24 hours. Analytic results and one-day forecasts of TC positions and intensities are included.
Typhoon Information (Tropical Cyclone Genesis)	00, 06, 12, 18	Issued to inform the genesis of a TS in the western North Pacific. It includes the position and the time of the TS genesis.
Typhoon Information	00, 03, 06, 09, 12, 15, 18, 21 (When a TC is expected to affect Japan) Every hour (When a TC is expected to have severe impacts on Japan)	Detailed information on analysis and forecasts of a TC in a text and graphical format are issued. 
Typhoon Information (General Information)	2 to 3 times per day (When a TC is expected to affect Japan) 4 to 8 times per day (When a TC is expected to have severe impacts on Japan)	Issued to inform current status and outlook of a TC, as well as precaution statements in terms of disaster mitigation. It consists of the following components. 1) Headline Points to be noted particularly by disaster management authorities and mass media 2) Current status and forecasts of a TC 3) Warning statements on potential severe phenomena such as heavy rain, strong wind, high wave and storm surge.
Typhoon Information (landfall)	When a TC makes landfall	Issued to inform the position and the time of a TC landfall.
50 kt wind probability	00, 06, 12, 18, 21	50 kt wind probability are issued for sub-divisions where the probability is expected to exceed 0.5 percent within 72 hours.

		
WTAS	00, 06, 12, 18	Issued for fishery. 

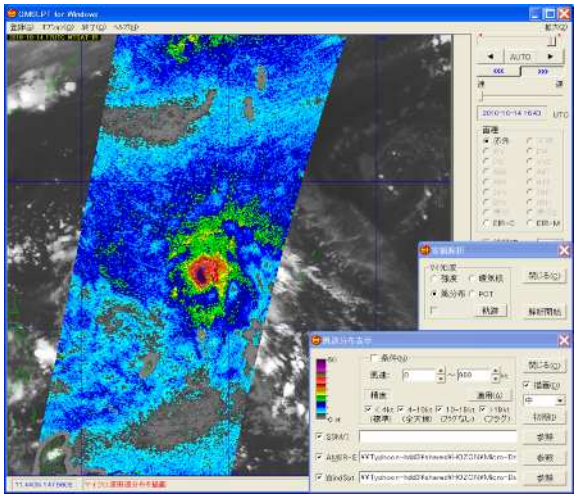
1.4.2 Challenges, Needs and Improvement Plans

The Centre represents uncertainties of TC track forecasts using probability circles as shown in 1.4.1. To further improve the representation of uncertainties, the Centre is exploring the way for better representation of probabilistic information extracted from ensemble NWP systems. The Centre is also investigating the possibilities of provision of five-day TC intensity forecasts, information of post tropical cyclones and 64-kt wind areas.

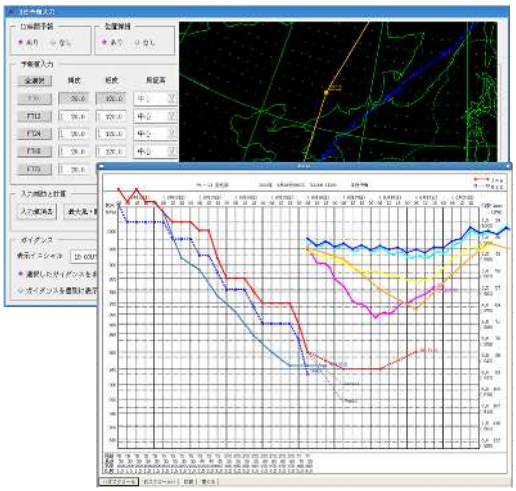
1.5 Computing Platform (including software)

For TC monitoring and satellite-based analysis, JMA uses SATAID (Satellite Animation and

Interactive Diagnosis) system developed by its own. It is equipped with multiple functions, not only for EDA and Dvorak analysis but also for daily weather analysis, including overlay of a variety of data such as SYNOP, SHIP, TEMP, METAR, AWS, radar, NWP outputs, etc. Results of Dvorak analysis with SATAID are provided to the JMA's weather analysis system called TKS. On TKS platform, TC analysis is conducted by using Dvorak analysis as well as other observations available. TKS also provides forecasters with the platform to make TC forecasts and TC related products.



SATAID



TKS

2 Numerical Weather Prediction Status for Effective Warning

[In this section, you are invited to provide summaries on your NWP status for effective warnings.]

2.1 NWP in Operational Use

Model	Domain (square degree)	Resolution (horizontal & vertical)	Initial Time (UTC)	Forecast Range (hours)	Run by (own/ foreign centers)
Global Spectral Model	Global	TL959 (~20 km) VL: 60	00, 06, 12, 18	84 (00, 06, 18 UTC) 264 (12 UTC)	Own
One-week Ensemble Prediction System (51 members)	Global	TL319 (~55 km) VL: 60	12	264	Own
Typhoon Ensemble Prediction System (11 members)	Global	TL319 (~55 km) VL: 60	00, 06, 12, 18	132	Own
Meso-scale Model	817 x 661 (horizontal grids)	5 km VL: 50	00, 03, 06, 09, 12, 15, 18, 21	39	Own
Local Forecast Model	1581 x 1301 (horizontal grids)	2 km VL: 50	Every hour	9	Own

2.2 Application Techniques of NWP Products for Operational Forecasts

The following is a summary description on JMA's application techniques for very short range and short range forecasts for precipitation. Details are described in Chapter 4 of OUTLINE OF THE OPERATIONAL NUMERICAL WEATHER PREDICTION AT THE JAPAN METEOROLOGICAL AGENCY (http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2013-nwp/index.htm).

1) Very Short Range Forecast

JMA issues Quantitative Precipitation Forecast (QPF) for hourly precipitation with the spatial

resolution of 1 km, up to 6 hours ahead, every half hour. The QPF product is based on Quantitative Precipitation Estimate (QPE) for hourly precipitation made every half hour using the nationwide weather radar and rain gauge network consisting of 46 weather radars and about 10,000 rain gauges. Two forecasting methods are used: one is extrapolation of precipitation systems of QPE with consideration of development and decay of the systems due to orographical effects, and the other is precipitation forecasts by the Meso-scale Model (MSM). For short lead time, extrapolation forecasts are more skillful than MSM. However, it rapidly becomes less skillful as lead times get longer, and the accuracy of MSM forecasts exceed that of the extrapolation forecasts for forecasting a few hours or longer. Considering such characteristics, JMA merges the two forecasts with weighting factors according to lead times to maximize the forecasting skill.

2) Short Range Forecast

To utilize NWP outputs for operational weather forecasting, JMA has operationally produced NWP-based guidance products for various kinds of parameters, such as mean/maximum precipitation, probability of precipitation, maximum/minimum temperature and wind speed, in short forecasting ranges up to 84 hours. To cope with frequent model upgrading, JMA uses guidance techniques of adaptively correcting statistical relationships between NWP outputs and corresponding observations: Kalman Filter (KF) and Neural Network (NRN). KF is applied for many parameters such as temperature, mean precipitation and wind. Since KF tends to underestimate the probability of extreme phenomena a frequency bias correction scheme is applied to outputs of KF. NRN has advantage of analyzing non-linear phenomena. Categorized weather is one of the forecast guidance parameters which NRN is applied to. JMA's guidance products are listed in Table 4.6.1 in OUTLINE OF THE OPERATIONAL NUMERICAL WEATHER PREDICTION AT THE JAPAN METEOROLOGICAL AGENCY.

2.3 Challenges, Needs and Improvement Plans

The specifications of the JMA ensemble systems are scheduled to be modified as follows:

One-week Ensemble Prediction System (to be implemented in February 2014)
Horizontal Resolution: TL319 -> TL479
Initial Time: 12 UTC -> 00 and 12 UTC
Members: 51 -> 27

Typhoon Ensemble Prediction System (to be implemented in March 2014)
Horizontal Resolution: TL319 -> TL479
Members: 11 -> 25

3. Storm Surge

[You are invited to describe your operational activity on storm surge information.]

1) Storm Surge Information

a. (Issuing) b. not issuing

(For those who answered "b." in 1))

2) What is the reason?

a. No use (inland / no storm surge) b. No forecast are available

c. Other ( )

(For those who answered "a." in 1))

3) How the information is issued?

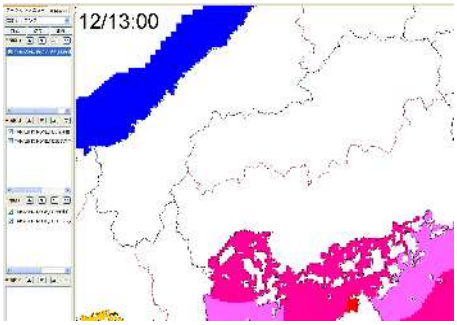
a. (Independent storm surge information) b. Included in TC information

c. Other ( )

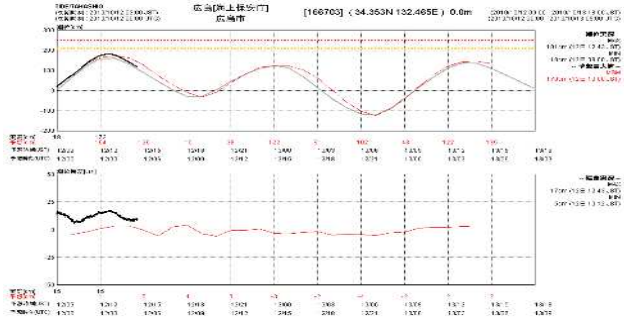
4) What products (observations /forecasts) are referred to?

When large storm surges are expected, caused by typhoons or mid-latitude low pressure systems, storm surge information (warning/advisory) is produced based on results of the JMA's storm surge model. Model results are provided to forecasters as horizontal maps as well as time sequences of predicted storm surges and water levels at tidal stations, together with observations at about 187 stations.

Examples are shown below:



Storm surge forecast



Water level at a tidal station

5) If your Service runs a storm surge model by yourself, please describe the way in detail.

Model	Domain and resolution	Forecast Range (hours)	Frequency	Considered factors (Tide/ensemble/ inundation, etc.)
Japan Area	20.0N-50.0N 117.4E-150.0E 1 km-16 km (adaptive Mesh)	Up to 39 hours	8 times/day (3 hourly)	Tides: linearly added Artificial ensemble Inundation: not predicted
Asian Area	0.0-46.0N 95.0E-160.0E 2'(~3.7 km)	Up to 72 hours	4 times/day (6 hourly)	Time sequences of predicted surges are provided at stations as requested from Members. Tides: linearly added Inundation: not predicted

6) In case your Service issue storm surge forecast without your own model, please briefly explain the operational procedure.

4. Effective Warnings

4.1 Emergency Response for TC Disasters

4.1.1 Legal Framework for TC Disaster Management

Please see page 8, 11, 14, 15 and 18 of the brochure DISASTER MANAGEMENT IN JAPAN (http://www.bousai.go.jp/1info/pdf/saigaipanf_e.pdf). JMA is one of the Designated Government Organizations.

4.1.2 Emergency Response Mechanism

Please see page 20 and 21 of the brochure, DISASTER MANAGEMENT IN JAPAN.

4.1.3 Organs Responsible for Warnings and Evacuation Orders

Severe Weather Phenomena	Organs responsible for Warnings	Organs responsible for Evacuation Orders
Tropical Cyclone	Null	Null
Heavy Rain (Sediment Disaster)	**Sediment Disaster Alert** JMA (Local Meteorological Offices (LMOs)) Prefectural Governments **Heavy Rain (Sediment Disaster)** JMA (LMOs) Prefectural Governments	Mayor of municipality
Heavy Rain (Inundation)	JMA (LMOs)	
Strong Wind		
Storm Surge		
River Flood	Designated River Forecasts Class A: JMA (LMOs) Water and Disaster Management Bureau of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) Class B : JMA (LMOs) Prefectural Governments Flood warnings/advisories For all the other rivers other than the above, JMA is responsible for flood warnings/advisories.	

4.2 Warnings/Advisories for Severe Weather Phenomena

[You are invited to provide details on warnings/advisories for tropical cyclones as well as associated severe weather phenomena, i.e., heavy rainfall, strong wind, flood, inundation and storm surge, in the following formats respectively.]

4.2.1 Tropical Cyclone

Warnings/Advisories and corresponding emergency responses	JMA issues warnings for disasters/phenomena associated with TCs, such as heavy rain, strong winds and storm surge, but not for TCs themselves. Please see details of respective warnings/advisories below.
Potential Disaster Risks	Null
Target (warning areas)	Null
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	Null
Criteria/Thresholds	Null
Contents of Warning/Advisory Message	Null
Sample Warning/Advisory Message	Null

4.2.2 Heavy Rain

JMA issues two kinds of heavy rain warnings depending on risks of subsequent disasters, i.e., sediment disaster and inundation.

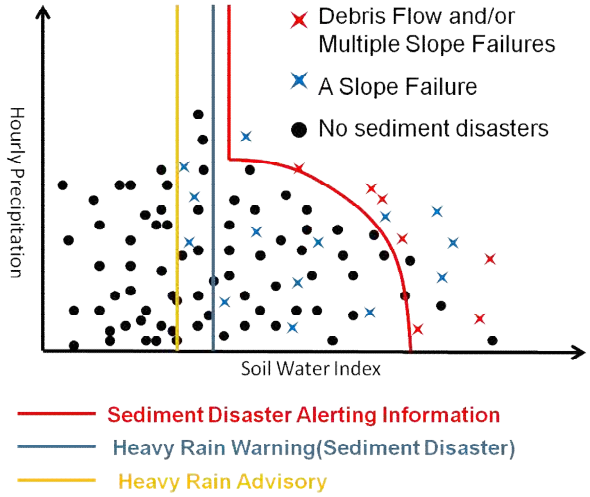
Heavy Rain Warnings/Advisories (Sediment Disaster)

<table>
<tr>
<td>Warnings/Advisories and corresponding emergency responses</td>
<td>The following table summarizes recommended emergency responses by municipalities and residents when heavy rain warnings/advisories are issued (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).
<table>
<tr><th>Type</th><th>Expected Phenomena</th><th>Emergency responses</th></tr>
<tr><td>Emergency Warning (Sediment Disaster)</td><td>・ Heavy rainfall with a level of intensity observed only once every few decades in predicted in association with a typhoon or similar.
・ Heavy rainfall is predicted in association with a typhoon expected to have a level of intensity observed only once every few decades or an extra tropical cyclone with comparable intensity.</td><td>(Municipal responses)
・ Immediately urging residents to take all possible steps for self-protection.
・ Alerting residents to the issuance of an Emergency Warnings and highlight the exceptionally dangerous situation.
(Resident responses)
・ Taking immediate action for self-protection (head to an evacuation center, or if it is dangerous to go outside, evacuate to a safer place within the building.)</td></tr>
<tr><td>Warning (Sediment Disaster)</td><td>Catastrophic weather conditions which are likely to cause severe disasters of sorts listed in “Potential Disaster Risks”.</td><td>(Municipal responses)
・ Urging residents to evacuate
・ Issuing evacuation advisories and orders to areas as necessary.
・ Preparing for emergency response.
・ Issuing evacuation preparedness information to trigger evacuation of people requiring assistance.
・ Establishing evacuation centers.
・ Disseminating warnings to residents.
(Resident responses)
・ Starting voluntary and early evacuation or follow evacuation advisories or orders.
・ For Storm Warnings, evacuating to a safe place.
・ Reporting abnormalities to municipalities and other authorities.
・ Staying away from hazardous</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td></td><td></td><td>places.
・ Preparing for evacuation.</td></tr>
<tr><td>Advisory (Sediment Disaster)</td><td>Disastrous weather conditions which are likely to cause disasters of sorts listed in “Potential Disaster Risks”.</td><td>(Municipal responses)
・ Patrolling areas requiring caution.
・ Advising residents to pay attention.
・ Monitoring weather bulletins and information on rainfall conditions.
・ Preparing to call out relevant officials.
(Resident responses)
・ Checking emergency supplies.
・ Checking evacuation routes and centers.
・ Checking windows and storm shutters.
・ Monitoring weather bulletins on TV, radio and JMA’s website.</td></tr>
</table>

Sediment Disaster AlertTogether with heavy rain warnings, Sediment Disaster Alerts are issued jointly by LMOs and prefectural govenments, when sediment-related damage caused by heavy rain is considered likely within the next few hours, and thus necessary emergency responses such as evacuation orders should be implemented immediately.
</td></tr>
<tr><td>Potential Disaster Risks</td><td>Landslides, debris flows</td></tr>
<tr><td>Target (warning areas)</td><td>Individual municipality</td></tr>
<tr><td>Meteorological variables/index used for criteria/threshold for warnings/advisories</td><td>
<table>
<tr><th>Type</th><th>Meteorological variables/indices</th></tr>
<tr><td>Emergency Warning</td><td>・ 48-hour precipitation amount
・ 3-hour precipitation amount
・ Soil Water Index*</td></tr>
<tr><td>Warning</td><td>Soil Water Index</td></tr>
<tr><td>Advisory</td><td>Soil Water Index</td></tr>
<tr><td>Sediment Disaster Alert</td><td>・ Hourly/3-hour precipitation amount
・ Soil Water Index</td></tr>
</table>
*Soil Water Index: an indicator of amount of water (i.e. rainfall) stored in soil. Higher index values indicate an increased risk of sediment-related disasters.
</td></tr>
</table>

Criteria/Thresholds	**Type**	**Criteria**
	Emergency warning	Please see the following JMA's website (http://www.jma.go.jp/jma/en/Emergency_Warning/Relationships_between_criteria_and_indices.pdf) (Example of Hiroshima City) 48-hour precipitation amount: 434 mm 3-hour precipitation amount: 155 mm Soil Water Index: 266
	Warning	Criteria for heavy rain warnings (sediment disasters) for individual municipalities in a prefecture are determined through the following procedure. The same procedure is also applied to other types of hazards including strong wind, flood, and storm surge, when one type of meteorological values/indices is used as the warning criterion. 1. The following datasets are collected from a prefectural government. - Datasets of disasters of interest, i.e., sediment disasters, roughly for the last ten years. - Criteria used for triggering emergency responses by relevant disaster management authorities. 2. The magnitude/scale of sediment disasters to be alerted by heavy rain warnings (e.g., scale of landslide, or the number of landslides during an event) is tentatively determined for?? sub-prefectural area. 3. Several draft warning criteria are selected bearing in mind the followings. 1) To minimize the probability of missing severe events. 2) To minimize the probability of issuing false alarms for frequently occurring events. 3) To ensure consistent criteria for neighboring sub-prefectural areas under a similar geographical and climatological setting. 4. Draft warning criteria are proposed to the prefectural government including relevant disaster management authorities. In addition to differences between draft criteria and those used for their emergency responses, expected warning frequency of respective draft criteria are also provided, so that the most suitable criteria in terms of efficiency and effectiveness of their emergency responses will be formulated. 5. Agreed warning criteria are reflected to its Local Disaster Management Plan and announced to the general public through mass media. (Example of Hiroshima City) Soil Water Index: 108
	Advisory	Same as that of warning except for the step 2. Instead of step 2 above, the minimum magnitude/scale of the disasters included in the dataset is tentatively set as the target for advisory. (Example of Hiroshima City) Soil Water Index: 82
	Sediment Disaster Alert	Criteria for sediment disaster alert, based on Soil Water Index and hourly precipitation amount, are determined as a Critical Line (CL), a boundary between past cases

<table>
<tr>
<td></td>
<td>
<table>
<tr>
<td></td>
<td>without sediment disasters and ones which needed emergency responses. CLs are calculated with Radial Basis Function Network. The below is an example of CL curve.
 
</td>
</tr>
</table>
</td>
</tr>
<tr>
<td>Contents of Warning/Advisory Message</td>
<td>
<table>
<tr><th>Type</th><th>Content</th></tr>
<tr><td>Emergency warning</td><td>➢ Issuance time
➢ Warning statements on potential disasters including warning areas and period of warning in effect
➢ Potential disasters (Sediment disaster and/or Inundation)
➢ Quantitative forecasts (period of warning in effect)</td></tr>
<tr><td>Warning</td><td>➢ Issuance time
➢ Warning statements on potential disasters including warning areas and period of warning in effect
➢ Potential disasters (Sediment disaster and/or Inundation)
➢ Quantitative forecasts (period of warning in effect)</td></tr>
<tr><td>Advisory</td><td>➢ Issuance time
➢ Warning statements on potential disasters including warning areas and period of warning in effect
➢ Warning status (e.g., downgrading to advisory)
➢ Potential disasters (Sediment disaster and/or Inundation)
➢ Quantitative forecasts (period of advisory in effect)</td></tr>
<tr><td>Sediment Disaster Alert</td><td>➢ Issuance time
➢ Explanatory note on potential risks
➢ Targeted municipalities
➢ Actions required</td></tr>
</table>
</td>
</tr>
</table>

Sample Warning/Advisory Message	Heavy Rain Warning issued by the Choshi LMO at 18:32 JST on 15 Oct. 2013 Warning statement ・ Heavy rain warning (sediment disaster) for the northeast and south region in Chiba prefecture. Target area: Chiba City. Period of warning/advisory in effect Warning (Sediment Disaster): 9 pm of 15 Oct. to 9 am of 16 Oct. Advisory: until noon of 16 Oct. Peak precipitation: 3 am to 6 am of 16 Oct. Maximum hourly precipitation: 80 mm

Heavy Rain Warnings/Advisories (Inundation)

<table>
<tr><td>Warnings/Advisories and corresponding emergency responses</td><td>The following table summarizes recommended emergency responses by municipalities and residents when heavy rain warnings/advisories are issued (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).
<table>
<tr><th>Type</th><th>Expected Phenomena</th><th>Emergency responses</th></tr>
<tr><td>Emergency Warning (Inundation)</td><td>Same as heavy rain warnings/advisories relevant to sediment disasters (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).</td><td rowspan="3">Same as heavy rain warnings/advisories relevant to sediment disasters (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).</td></tr>
<tr><td>Warning (Inundation)</td><td>Same as heavy rain warnings/advisories relevant to sediment disasters</td></tr>
<tr><td>Advisory (Inundation)</td><td>Same as heavy rain warnings/advisories relevant to sediment disasters</td></tr>
</table></td></tr>
<tr><td>Potential Disaster Risks</td><td>Inundation of houses, loads and farming lands, etc.</td></tr>
<tr><td>Target (warning areas)</td><td>Individual municipality</td></tr>
<tr><td>Meteorological variables/index used for criteria/threshold for warnings/advisories</td><td>
<table>
<tr><th>Type</th><th>Meteorological variables/indices</th></tr>
<tr><td>Emergency Warning</td><td>Same as those for heavy rain warnings/advisories relevant to sediment disasters.</td></tr>
<tr><td>Warning</td><td>・ 3-hour precipitation amount
・ Hourly precipitation amount</td></tr>
<tr><td>Advisory</td><td>・ 3-hour precipitation amount
・ Hourly precipitation amount</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Criteria/Thresholds</td><td>
<table>
<tr><th>Type</th><th>Criteria</th></tr>
<tr><td>Emergency warning</td><td>Same as those for heavy rain warnings/advisories relevant to sediment disasters</td></tr>
<tr><td>Warning</td><td>The same procedure for heavy rain warnings relevant to sediment disasters is applied to inundation disasters.
(Example of South area of Shizuoka City)
Plain land: 3-hour precipitation amount 110 mm
Others: hourly precipitation amount 100 mm</td></tr>
<tr><td>Advisory</td><td>The same procedure as those of heavy rain advisory relevant to sediment disasters is applied to inundation disasters.
(Example of South area of Shizuoka City)
Plain land: 3-hour precipitation amount 70 mm
Others: hourly precipitation amount 70 mm</td></tr>
</table>
</td></tr>
<tr><td>Contents of Warning/Advisory Message</td><td>Same as those of heavy rain warnings/advisories relevant to sediment disasters</td></tr>
<tr><td>Sample Warning/Advisory Message</td><td>Heavy Rain Warning issued by the Choshi LMO at 18:32 JST on 15 Oct. 2013
Warning statement
・ Heavy rain warning (inundation) for lowlands and water level rise of rivers in Chiba Prefecture.
Target area: Chiba City.
Period of warning/advisory in effect
Warning (Inundation): 9 pm of 15 Oct. to 9 am of 16 Oct.
Advisory: until noon of 16 Oct.
Peak precipitation: 3 am to 6 am of 16 Oct.
Maximum hourly precipitation: 80 mm</td></tr>
</table>

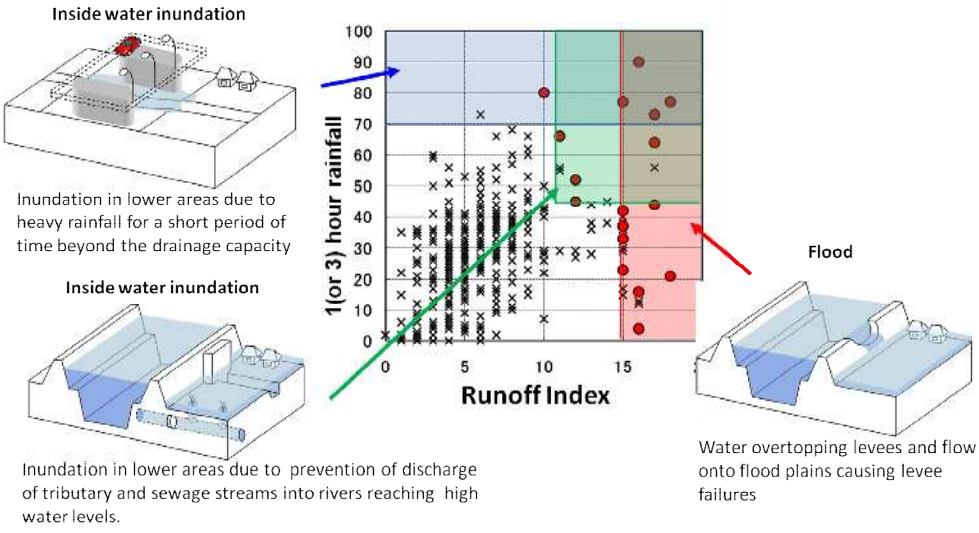
4.2.3 Strong Wind

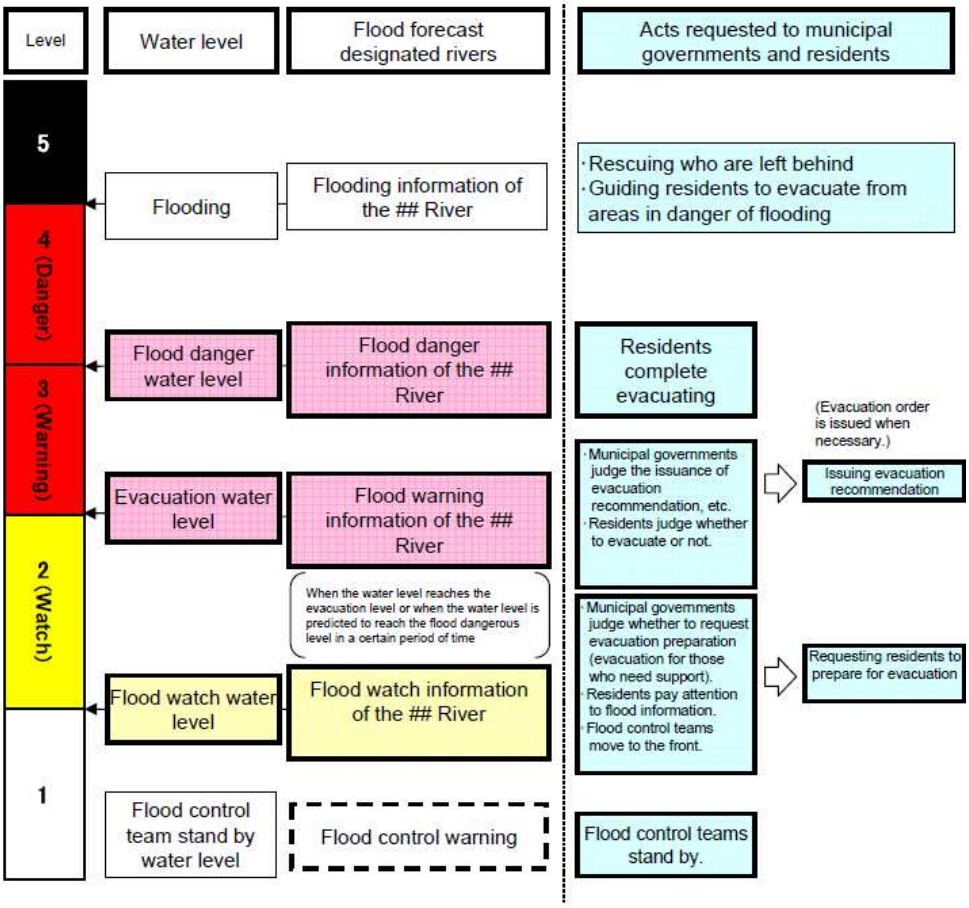
<table>
<tr><td>Warnings/Advisories and corresponding emergency responses</td><td>
<table>
<tr><th>Type</th><th>Expected Phenomena</th><th>Emergency responses</th></tr>
<tr><td>Emergency warning</td><td>Storm in association with a typhoon expected to have a level of intensity observed only once every few decades or an extra-tropical cyclones with comparable intensity.</td><td rowspan="3">Same as heavy rain warnings/advisories relevant to sediment disasters (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).</td></tr>
<tr><td>Warning</td><td>Same as heavy rain warnings relevant to sediment disasters</td></tr>
<tr><td>Advisory</td><td>Same as heavy rain advisories relevant to sediment disasters</td></tr>
</table>
</td></tr>
<tr><td>Potential Disaster Risks</td><td>Damage to houses, buildings, agricultural crops and maritime disaster</td></tr>
<tr><td>Target (warning areas)</td><td>Individual municipality</td></tr>
</table>

<table>
<tr><td>Meteorological variables/indices used for criteria/thresholds for warnings/advisories</td><td>10-minute average wind speed (m/s)</td></tr>
<tr><td>Criteria/Thresholds</td><td>
<table>
<tr><th>Type</th><th>Criteria</th></tr>
<tr><td>Emergency warning</td><td>Please see the following JMA’s website (http://www.jma.go.jp/jma/en/Emergency_Warning/Relationships_between_criteria_and_indices.pdf)</td></tr>
<tr><td>Warning</td><td>The procedure for determination of warning criteria is same as those for heavy rain warnings/advisories relevant to sediment disasters. One of the examples used as indicators for magnitude/scale of storm disasters is the number of damaged houses.
(Example of Hiroshima City)
20 m/s (land), 25 m/s (at sea)</td></tr>
<tr><td>Advisory</td><td>Same as above.
(Example of Hiroshima City)
12 m/s (land), 15 m/s (at sea)</td></tr>
</table>
</td></tr>
<tr><td>Contents of Warning/Advisory Message</td><td>Same as heavy rain warnings/advisories relevant to sediment disasters except for not including statements on potential disasters.</td></tr>
<tr><td>Sample Warning/Advisory Message</td><td>Gust Advisory issued by Choshi LMO at 10:28 JST on 15 Oct. 2013
Warning Statement:
Caution for inundation at lowlands, rise of water level of rivers, gusts, high waves, hazardous winds such as tornadoes, and lightning strike in Chiba Prefecture
Target area; Chiba City.
Warning status: likely to be upgraded to warning after 9 am of 16 Oct.
Period of warning/advisory in effect
Warning: 9 pm of 15 Oct. to 9 am of 16 Oct.
Advisory: 9 pm of 15 Oct. to noon of 16 Oct.
Wind direction: northeast in the evening of 15 Oct. and northwest later.
Maximum mean wind speed: 23 m/s (land), 25 m/s (at sea)</td></tr>
</table>

4.2.4 River Flood

<table>
<tr><td>Warnings/Advisories and corresponding emergency responses</td><td>
<table>
<tr><th>Type</th><th>Expected Phenomena</th><th>Emergency responses</th></tr>
<tr><td>Warning</td><td>Same as heavy rain warnings relevant to sediment disaster</td><td rowspan="2">Same as heavy rain warnings/advisories relevant to (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).</td></tr>
<tr><td>Advisory</td><td>Same as heavy rain advisories relevant to sediment disaster</td></tr>
<tr><td>River Flood Forecasts for Designated Rivers</td><td>Issued only for major rivers, jointly by either MLIT (Class A river) or prefectural governments (Class B) when there is a risk of river flooding due to heavy rains</td><td>The forecast represents the degree of risk with five warning levels determined by water levels. Corresponding emergency responses required by municipal governments and residents are shown at どこそこ</td></tr>
</table>
</td></tr>
</table>

Potential Disaster Risks	Flood, dike break, washout of bank, Inundation, etc.
Target (warning areas)	Individual Municipality
Meteorological variables/indices used for criteria/thresholds for warnings/advisories	**Warnings/Advisories** ・ Hourly precipitation amount ・ 3-hour precipitation amount ・ Runoff Index **River Flood Forecasts for Designated Rivers** ・ Water levels of rivers
Criteria/Thresholds	**Warnings/Advisories** The procedures for determination of criteria for river flood warnings/advisories are mostly same as others. Criteria for river flood warnings/advisories are based on 1- (or 3-) hour precipitation amounts and/or Runoff Index (RI) depending on types of disasters, i.e. inside water inundations or river floods. For river floods, criteria are based on RIs, whereas those for inside water inundations are based on 1- (or 3-) hour precipitation amounts and/or RI.  **River Flood Forecasts for Designated Rivers** Warning levels based on water levels are determined depending on expected degree of flood risks in consideration with corresponding actions to be taken by river management authorities and residents. Those criteria are proposed by river management authorities and determined through the coordination with relevant municipalities. Below is an example.

<table>
<tr><td></td><td> 
</td></tr>
<tr><td>Contents of Warning/Advisory Message</td><td>Warnings/Advisories
Same as warnings/advisories for strong winds

River Flood Forecasts for Designated Rivers
➢ Issuance time
➢ Warning statements on observed and forecasted warning levels, and municipalities/areas with warnings in effect.
➢ Observations and forecasts of precipitation and water levels</td></tr>
<tr><td>Sample Warning/Advisory Message</td><td>Warnings/Advisories
Heavy Rain Warning issued by Choshi LMO at 18:32 JST on 15 Oct. 2013
・ Be cautious for water level rise of rivers in Chiba Prefecture.
Target area: Chiba City
Warning (flood): 9 pm of 15 Oct. to 9 am of 16 Oct.
Advisory (flood): until noon of 16 Oct.</td></tr>
</table>

4.2.5 Storm Surge

<table>
<tr><td>Warnings/Advisories and corresponding emergency responses</td><td>
<table>
<tr><th>Type</th><th>Expected Phenomena</th><th>Emergency responses</th></tr>
<tr><td>Emergency Warning</td><td>Storm in association with a typhoon or extra-tropical cyclone expected to have a level of intensity observed only once every few decades or an extra-tropical cyclones with comparable intensity</td><td>Same as heavy rain warnings/advisories (http://www.jma.go.jp/jma/en/Emergency_Warning/examples_of_responses.png).</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>Warning</td><td>Same as heavy rain warnings relevant to sediment disasters</td><td rowspan="2"></td></tr>
<tr><td>Advisory</td><td>Same as heavy rain advisories relevant to sediment disasters</td></tr>
</table>
</td></tr>
<tr><td>Potential Disaster Risks</td><td>Inundation, damage of ships, shore facilities including ones for fishery, etc.</td></tr>
<tr><td>Target (warning areas)</td><td>Individual municipality</td></tr>
<tr><td>Meteorological variables/indices used for criteria/thresholds for warnings/advisories</td><td>Tidal level</td></tr>
<tr><td>Criteria/Thresholds</td><td>
<table>
<tr><th>Type</th><th>Criteria</th></tr>
<tr><td>Emergency warning</td><td>Emergency warning is issued when severe typhoons or extra-tropical cyclones stated in Section 4.2.1 are expected to hit Japan. Please see the following JMA’s website (http://www.jma.go.jp/jma/en/Emergency_Warning/Relationships_between_criteria_and_indices.pdf)</td></tr>
<tr><td>Warning</td><td>Same as heavy rain warnings, except for the step 3. Detailed rules for criteria for storm surge warnings vary depending on situations of municipalities. For areas with coastal levees, in general, criteria are set either at heights of coastal levees or expected maximum water levels when coastal levees are constructed. For areas without coastal levees, water levels of past severe coastal disasters or the lowest height of quay walls within the area are used as criteria.
(Example of Hiroshima City)
Tidal level: 2.5 m elevation</td></tr>
<tr><td>Advisory</td><td>Same as that for heavy rain advisory.
(Example of Hiroshima City)
Tidal level: 2.1 m elevation</td></tr>
</table>
</td></tr>
<tr><td>Contents of Warning/Advisory Message</td><td>Same as strong wind warnings/advisories</td></tr>
<tr><td>Sample Warning/Advisory Message</td><td>Storm Surge Warning issued by Akita LMO at 16:50 JST on 3 April 2012
Warning statement: Warning for storm, high waves and storm surge in Akita Prefecture.
Target Area: Akita City
Period of warning/advisory in effect:
Warning: 9 pm of 3 April to 6 am of 3 April
Advisory: 6 pm of 3 April to noon of 4 April
Peak of storm surge: 3 am of 4 April
Maximum tidal level: 1.5 m height above sea level</td></tr>
</table>

4.3 Supporting Meteorological Information for Warning/Advisory Messages

[Please describe supporting meteorological information which provides supplementary explanation on warning/advisory messages to support emergency responses of recipients, if any.]

Name of Information	Potential Disaster Risks	Target (areas)	Issuance (update) Time	Contents
Bulletin	All kind of disasters	Nationwide, Region, Prefecture	Bulletins are issued to call public's attention to weather conditions prior to the issuance of Warnings/Advisories and/or to supplement the Warnings.	1. Issuance time 2. Explanatory note 3. Current and expected condition of typhoons or lows 4. Quantitative forecasting e.g. for rainfall amounts and wind speeds 5. Alarming disasters
Bulletins on Exceptionally Heavy Downpours	Inundation, sediment disaster, flood	Points or sub-municipal area.	Bulletins on Exceptionally Heavy Downpours are issued when downpour that happens only once in several years observed or analyzed in one hour.	1. Issuance time 2. Observation time and station 3. Hourly precipitation amount

4.4 Institutional Coordination

4.4.1 Coordination with Disaster Management Authorities

Warning Coordination	JMA visits prefectures and municipalities and asks the following items to improve the warnings/advisories, so that they are utilized more for their disaster management activities. - What disaster management activities conducted before and during natural disasters. - What triggered their disaster management activities. - Needs for improvement of the warnings/advisories.
Needs from Disaster Management Authorities	Disaster management authorities often ask for further improvements in forecasting accuracies and resolutions, and warning messages supporting their decision making, for the effectiveness and efficiency of their emergency operations, as well as more easy-to-understand warning messages.

4.4.2 Partnership and Coordination with Media

Warning Coordination	Whenever new warnings/bulletins are developed or important updates of existing warnings/bulletins are made, their contents and technical details, such as means of dissemination and their formats, are determined in consideration with requests from mass media through coordination meetings with mass media.
Needs from Media	JMA's bulletins/warnings are complexly systematized and not necessarily user-friendly, thus reduction of the complexity are sometimes requested from mass media.

4.5 Challenges (and Future Plan)

JMA has improved its warning system through the technical developments and refinements of warning messages. For example, since June 2012, JMA has included, into its warning messages, short statements in comparison with past major disasters so that people intuitively understand expected severity of disasters from their experience (e.g., “heavy rainfall equivalent to that of XXXX disaster in 20XX”, “unprecedented rainfall”, etc). However, such continued effort for years has led to make JMA’s bulletins/warnings complex enough for users to request JMA to improve its warning system. In order to re-organize its warning in a more systematic and user-friendly manner, JMA is developing an idea for a new framework for its warning system including the introduction of a unified warning category system for all types of meteorological/hydrological disasters for which JMA is responsible for issuance of warnings. In addition, JMA plans to promote the use of 2-dimentional products, such as 5-km-mesh Soil Water Index Product, for the decision making of disaster management authorities, as complement information to its warning messages.

Reference

Hoshino, S. and T. Nakazawa, 2007: Estimation of Tropical Cyclone's Intensity Using TRMM.TMI Brightness Temperature Data, J. Meteor. Soc. of Japan, Vol. 85, No. 4, 437 – 454.

Japan Meteorological Agency, 2013: OUTLINE OF THE OPERATIONAL NUMERICAL WEATHER PREDICTION AT THE JAPAN METEOROLOGICAL AGENCY, WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION (http://www.jma.go.jp/jma/jma-eng/jma-center/nwp/outline2013-nwp/index.htm).

Kishimoto, K., 2008: Revision of JMA's Early Stage Dvorak Analysis and Its Use to Analyze Tropical Cyclones in the Early Developing Stage, RSMC Tokyo - Typhoon Center Technical Review No. 10, 1 – 12.

Kishimoto, K., 2010: JMA's Five-day Tropical Cyclone Track Forecast, RSMC Tokyo – Typhoon Center Technical Review, No. 12 55 - 63.

Kishimoto, K., M. Sasaki, and M. Kunitsugu, 2013: Cloud Grid Information Objective Dvorak Analysis (CLOUD) at the RSMC Tokyo - Typhoon Center, Typhoon Center Technical Review No. 15, 1 – 15.

Koba, H., S. Osano, T. Hagiwara, S. Akashi and T. Kikuchi, 1989: Determination of the intensity of typhoons passing over the Philippines (in Japanese) . J. Meteor. Res., 41, 157 – 162.

Koba, H., T. Hagiwara, S. Osano and S. Akashi, 1991: Relationships between CI Number and Minimum Sea Level Pressure/Maximum Wind Speed of Tropical Cyclones, Geophysical Magazine, Vol. 44, No. 1, 15 – 25.

Oyama, R., 2014: Algorism and Validation of Tropical Cyclone Central Pressure Estimation Method using Warm Core Intensity Observed by the Advanced Microwave Sounding Unit-A (AMSU-A), Typhoon Center Technical Review No. 16 (in preparation).

Sakuragi, T., S. Hoshino, N. Kitabatake, 2014: Development and Verification of Tropical Cyclone Intensity Estimation Method Reflected Asymmetric Distribution of TRMM/TMI Brightness Temperature, Typhoon Center Technical Review No. 16 (in preparation).

Tsuchiya, A., T. Mikawa and A. Kikuchi, 2001: Method of Distinguishing Between Early Stage Cloud Systems that Develop into Tropical Storms and Ones that Do Not, Geophysical Magazine Series 2, Vol. 4, Nos. 1 – 4, 49 – 59.

Yamaguchi, M, T. Komori, 2009: Outline of the Typhoon Ensemble Prediction System at the Japan Meteorological Agency, RSMC Tokyo – Typhoon Center Technical Review No. 11, 14 - 24.