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ACTIVITIES OF THE RSMC TOKYO - TYPHOON CENTER IN 2016

(Submitted by the RSMC Tokyo - Typhoon Center)

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ACTION REQUIRED:

The Committee is invited to review the activities of the RSMC Tokyo - Typhoon Center in 2016.

APPENDIXES:

A) DRAFT TEXT FOR INCLUSION IN SESSION REPORT

B) RSMC Tokyo - Typhoon Center Activity Report 2016

APPENDIX A:
DRAFT TEXT FOR INCLUSION IN THE SESSION REPORT

x.x Review of the activities of the Regional Specialized Meteorological Center (RSMC) Tokyo 2016

1. The Committee was pleased that RSMC Tokyo began providing multi-scenario storm surge predictions as well as ensemble wave forecasts based on the JMA's Typhoon Ensemble Prediction System (TEPS) to the Committee Members, in June and August 2016 respectively. Verification of the storm surge prediction using tidal data available was also conducted. The Committee expressed its gratitude to RSMC Tokyo for provision of storm surge forecasts to the TC Members and sharing information on storm surges through the annual TC attachment training.

2. The Committee with appreciation noted that RSMC Tokyo began providing TC genesis prediction, i.e. Tropical Cyclone Activity Prediction maps using ensembles of ECMWF and UKMO in June 2016.

3. The Committee was informed that RSMC Tokyo started tropical cyclone satellite re-analysis in 2012 for the period from 1981 to confirm and improve the quality of the Current Intensity (CI) number in the satellite TC analysis. Re-analysis for the period from 1987 to 1995 has been completed. In addition, TC satellite analysis datasets for the period from 2004 to 2013 were investigated and the re-analysis was partially completed. RSMC Tokyo plans to complete re-analysis 1987 to 2013 by the end of 2018.

4. The Committee was informed that RSMC Tokyo is continuing experimental provision of TC advisory in CAP format at the JMA website (http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/RSMC_HP.htm) since 12 November 2012.

5. The Committee was pleased that an experimental test of radar data sharing among RSMC Tokyo, Thai Meteorological Department (TMD) and Malaysia Meteorological Department (MMD) were stated in 2016. It also noted with appreciation that a technical meeting was held at the JMA headquarters in November-December 2016 to discuss technical issues to improve data quality of nationwide radar composite maps developed by TMD, to provide technical assistance in application of the JMA's QPE technique to the TMD's radar data, and to identify the way forward.

6. The Committee was informed that RSMC Tokyo, in cooperation with RSMC Honolulu, developed and circulated a draft Tropical Cyclone Forecaster Competency, responding to the discussion at the 66th WMO Executive Council. It noted with appreciation that, in 2017, the RSMCs plan to organize a task team meeting to finalize the competency and discuss how to utilize it for future training activities in the Committee region.

7. The Committee noted with appreciation that RSMC Tokyo completed the comparison study on TC satellite analysis between CMA, HKO, JMA, and JTWC, and developed the final report, including a set of recommendations toward more harmonized TC intensity analysis, in the western North Pacific.

8. The Committee was informed that in March 2016, RSMC Tokyo upgraded graphical Tropical cyclone advisories (TCAs) by using a new Himawari-8 product for identifying Cb areas around TCs.

9. The Committee with pleasure noted that Himawari-9 geostationary meteorological satellite was successfully launched on 2 November 2016. It noted with appreciation that, a series of expert missions were conducted to Cambodia, Malaysia, Singapore, Thailand, Viet Nam, and the Philippines to enhance weather monitoring and forecasting capacity using Himawari-8/9 products. It further welcomed the intention of RSMC Tokyo to continue providing technical supports for Members to utilize Himawari products.

10. The Committee noted with appreciation that RSMC Tokyo published the RSMC Tokyo Technical Review No.18 and the Annual Report on Activities of the RSMC Tokyo in March and December 2016 respectively.

11. The Committee was pleased that RSMC Tokyo conducted the 16th Attachment Training from 15 to 26 August 2016, inviting three forecasters from Lao P.D.R., the Philippines, and Viet Nam. In accordance with the decision of the third joint session of the Panel on Tropical Cyclone (PTC) and the Typhoon Committee, RSMC Tokyo, ESCAP, WMO, and PTC secretariats invited three forecasters from PTC Members, i.e., Oman, Pakistan and Sri Lanka with the Japan Trust Fund. The Committee with pleasure noted that RSMC Tokyo extended the training course by 2 days to provide lectures on TC warning developments with the financial supports of the WMO Secretariat.

APPENDIX B:
Activities of the RSMC Tokyo - Typhoon Center in 2016

1. RSMC Advisories / Products

The RSMC Tokyo - Typhoon Center provides the Typhoon Committee (TYC) Members with a range of products related to tropical cyclones in the western North Pacific and the South China Sea through the GTS and the AFTN. Table 1 shows the total number of products issued by the Center in 2016.

1.1 Track Forecasts

Operational track forecasts for 26 Tropical Cyclones (TCs) that reached Tropical Storm (TS) intensity or higher in 2016 were verified against the Center's analysis data. Figure 1 shows the time series of the annual mean position errors of 24-hour (from 1982), 48-hour (from 1989), 72-hour (from 1997), 96-hour and 120-hour (from 2009) forecasts. The errors of the year are 79 km (72 km in 2015), 142 km (119 km), 243 km (176 km), 316 km (263 km) and 442 km (366 km) for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively (Table 2).

1.2 Track Forecast Probability Circles

RSMC Tokyo has used track forecast probability circles* to represent TC track forecast uncertainties. The radius of the circles is determined based on direction and speed of TC movement and accumulated ensemble spread of the JMA's Typhoon Ensemble Prediction System at each forecast time respectively (RSMC Tokyo – Typhoon Center Technical Review Vol. No.17). In accordance with recent improvements of TC track forecast accuracies, in June 2016, RSMC Tokyo reduced its radius of the circle at each forecast time by approximately 20 up to 40 %. The mean hitting ratios of circles* for 24-, 48-, 72-, 96- and 120-hour forecasts are 78% (89% in 2015), 79% (93%), 79% (94%), 78% (88%) and 69% (83%), respectively (Table 3).

* Track forecast probability circle: a circular area within which a TC is expected to be located with a probability of 70% at each forecast time.

1.3 Intensity Forecasts

Table 4 gives the mean errors and root mean square errors (RMSEs) of 24-, 48- and 72-hour central pressure (Table 4a) and maximum sustained wind forecasts (Table 4b) for 26 TCs of 2016. The annual mean RMSEs for central pressure forecasts are 14.6 hPa (13.7hPa in 2015), 21.5 hPa (19.1 hPa) and 23.4 hPa (21.2 hPa) for 24-, 48- and 72-hour forecasts, respectively, while those of maximum wind speed forecasts for 24-, 48- and 72-hour forecasts are 6.5 m/s (5.9 m/s in 2015), 8.9 m/s (8.2 m/s) and 10.0 m/s (9.0 m/s), respectively.

2. Web-based RSMC TC Products

2.1 Numerical Typhoon Prediction (NTP) website

Since October 2004, RSMC Tokyo has operated the Numerical Typhoon Prediction (NTP) website (https://tynwp-web.kishou.go.jp/) as part of its contribution to the WMO/ESCAP Typhoon Committee. On 15 June 2016, the products detailed below were added to the site.

- ✧ **Tropical Cyclone Activity Prediction**

  RSMC Tokyo provides two-day and five-day Tropical Cyclone Activity Prediction Maps covering its area of responsibility based on ensembles from the European Centre for Medium-Range Weather Forecasts (ECMWF), the UK Met Office (UKMO) (See paragraph 3.2).

- ✧ **TC Track Ensembles from ECMWF, NCEP and UKMO**

  TC track predictions from ECMWF, NCEP and UKMO ensemble systems are provided in addition to JMA's Typhoon Ensemble Prediction System to help forecasters develop TC track forecast scenarios in consideration of related uncertainty.

✧ **Weighted Consensus of Satellite TC Intensity Estimates**

A Weighted consensus TC intensity estimates produced using the Dvorak technique and warm core intensity observation data from the Advanced Microwave Sounding Unit-A (AMSU-A) of the NOAA- and MetOp-series polar-orbiting satellites are also provided. These estimates are more accurate than those produced using the Dvorak technique, providing additional reliable information for TC intensity forecasting.

✧ **Detailed Historical Logs of Dvorak Analysis**

Detailed logs of Dvorak analysis, including Cloud Pattern, DT, MET, PT, Final-T and CI data, are provided to help forecasters understand TC intensity estimates from RSMC Tokyo.

✧ **Multi-scenario Storm Surge Prediction & Ensemble Ocean Wave Prediction**

The new Multi-scenario Storm Surge Prediction product provides storm surge forecasts based on RSMC Tokyo official advisories and five additional tropical cyclone track scenarios derived from JMA's Typhoon Ensemble Prediction System (TEPS) using cluster analysis. As storm surge prediction is sensitive to tropical cyclone track scenarios, the product helps forecasters estimate related uncertainty in consideration of track forecast errors (For more details, see paragraph 3.1).

2.2 Tropical cyclone advisories for SIGMET in graphical format

In August 2015, RSMC Tokyo, as the ICAO TCAC, started providing graphical tropical cyclone advisories (hereinafter referred to as TCG) according to MODEL TCG in Appendix 1 of ICAO Annex 3. In March 2016, it started providing the graphical tropical cyclone advisories using a new Himawari product identifying Cb associated with tropical cyclones potentially affecting aviation safety. TCG is being provided through the website where the specifications and text format advisories are also available (http://www.data.jma.go.jp/fcd/tca/data/index.html). This website is linked to Numerical Typhoon Prediction website (https://tynwp-web.kishou.go.jp/). Also, TCG is sent to WAFCs, so that they are transmitted through WIFS, Secure SADIS FTP and SADIS. WMO AHLs of the bulletin are PZXE (01-06) RJTD.

TCG is issued, together with text advisories, when 1) a tropical cyclone with Tropical Storm (TS) intensity or higher exists in the area of responsibility of RSMC Tokyo, or 2) a tropical cyclone is expected to reach TS intensity in the area within 24 hours. In the second case, gale force wind area is not to be presented in TCG.

2.3 Experimental version of TC advisory in CAP format

RSMC Tokyo has provided the experimental provision of TC advisory in CAP format at the website (http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/RSMC_HP.htm) since 12 November 2012.

3. RSMC Tokyo-led activities

3.1 Regional storm surge watch scheme suitable for the TYC region

In response to the results of the survey in 2009, RSMC Tokyo has been providing distribution maps since 1 June 2011 and time-series charts of storm surges since 5 June 2012 on the NTP website. Since 13 January 2016, the storm surge model has experimentally been run on a daily basis, regardless of the existence of TCs in the responsible area, for providing information on storm surges generated by monsoon winds or extra-tropical cyclones.

In 2016, RSMC Tokyo began providing multi-scenario storm surge predictions. In addition to storm surge prediction based on RSMC Tokyo TC advisory, predictions with five different TC scenarios extracted from the JMA's Typhoon Ensemble System (TEPS) using cluster analysis were included. Maximum storm surges at each grid among the above 6 scenarios during the entire forecast period are also provided.

Stations for storm surge time-series predictions have been increased on requests from the Members. As of the end of 2016, time-series storm surge predictions are provided to 68 stations; USA(1), the Philippines (10), Viet Nam (20), Hong Kong China (6), Macao China (1), Republic of Korea (11), Thailand (2), and Malaysia (17). In response to request for station addition, 10 stations (4 in Cambodia and 6 in Singapore) are scheduled to be added in early 2017. Time series of storm surge predictions are provided on top of astronomical tides for stations where hourly tidal observational data for a few years are provided by Members concerned. At 17 stations out of the 68 stations, only storm surge is plotted. In 2017, RSMC Tokyo plans to provide astronomical tides estimated by an ocean tide model such as OTIS (OSU Tidal Inversion Software) at these 17 stations, in order for forecasters to estimate storm tide in time series charts, although it will be less accurate than the estimated values from observed data.

Furthermore, RSMC Tokyo began providing week-range wave forecasts created using its global Wave Ensemble System (WENS) on the NTP website in August 2016. The products consist of data on ensemble mean/3rd quantile/maximum wave heights, probability of wave heights exceeding 2, 3, 4, 5 and 6 m, and ensemble spread. Boxplot data and information on probabilities exceeding a certain level for selected stations are also provided on the site. WENS covers most of the global region and has a 1.25-degree grid resolution. It is run once a day at 12 UTC and enables prediction of ocean wave conditions up to 264 hours ahead with 27 members.

3.2 Enhanced use of Ensemble Forecast

RSMC Tokyo implements this project as part of the World Weather Research Program (WWRP) and Tropical Cyclone Program (TCP), North Western Pacific Tropical Cyclone Ensemble Forecast Project (NWP-TCEFP) to enhance operational use of ensemble forecast by the Typhoon Committee Members. The project explored the potential for ensemble systems for operational TC forecasts using the TIGGE (THORPEX Interactive Grand Global Ensemble) datasets. In 2014, operational global medium-range ensemble predictions of TC genesis were systematically evaluated. The global ensembles used were ECMWF, JMA, NCEP and UKMO for the period from 2010 to 2013. It was found that operational global medium-range ensembles are capable of providing guidance on TC genesis predictions extending into the second week. In accordance with the outcome, RSMC Tokyo requested ECMWF, UKMO, and NWS to provide their ensemble TC products to the Committee Members on a real-time basis. Since October 2015, RSMC Tokyo has provided ensemble TC track guidance of ECMWF and NCEP to the Committee Members through the NTP website.

In 2016, RSMC Tokyo began providing two-day and five-day Tropical Cyclone Activity Prediction Maps covering its area of responsibility based on ensembles from the European Centre for Medium-Range Weather Forecasts (ECMWF), UKMO and their consensuses. The maps display potential tropical cyclone activity in consideration of the probability that a TC will be present within 300 km of a certain location during the relevant forecast time. The products are intended to help forecasters identify and monitor areas in which tropical cyclones could form within two- and five-day periods.

To explore the potential of TC intensity prediction using ensembles, the Coupled Hurricane Intensity Prediction System (CHIPS), which is a simplified axisymmetric TC model combined with a 1D ocean model using TC surrounding parameters including SST and vertical wind shear as its input data, was tested. Through a verification study using the TIGGE archive for a period from 2012 to 2014, the consensus (ensemble mean) of the multiple CHIPS predictions is found to provide better forecast skills than that of single model-based predictions in general. However the ensemble means of CHIPS do not necessarily predict TC intensity change well and the ensemble spreads do not well capture uncertainty of TC intensity predictions.

3.3 Development of regional radar network

The Development of Regional Radar Network is one of the projects of the Working Group on Meteorology (WGM) to develop a regional radar network in Southeast Asia. Toward this goal, as its first step, RSMC Tokyo has been providing technical assistance to the Thai Meteorological Department (TMD) for its development of the national radar network since 2011. From 2012 to 2015, TMD, with technical supports of RSMC Tokyo, worked on the application of the JMA's radar quality control and composite techniques as well as the quantitative precipitation estimation (QPE) technique to its nationwide radar network. In 2016, the project was extended to include Malaysia Meteorological Department (MMD) and an experimental test of radar data sharing among the three countries was conducted. Also a follow-up technical meeting between TMD and JMA was held at the JMA Headquarters in November-December 2016 to discuss technical issues to be addressed to improve data quality of nationwide radar composite maps developed by TMD, to provide technical assistance in application of the JMA's QPE technique to the TMD radar data, and to identify the way forward, including further expansion of this project to other Members of interest such as Lao P.D.R., Viet Nam, the Philippines in the future. In connection with the project, bilateral training workshop between MMD and JMA was held at the JMA Headquarters in December 2016 to discuss on recent progress in the development of radar composite map developed by MMD and challenges on quality control of radar data and Quantitative Precipitation Estimation (QPE).

3.4 Tropical Cyclone Forecaster Competency

At the 66th World Meteorological Organization (WMO) Executive Council, the need for development of the tropical cyclone (TC) forecaster competencies by regional tropical cyclone committees under the initiative of the Reginal Specialized Meteorological Centres (RSMCs) was stressed, in order to ensure the quality of tropical cyclone forecasting services and to meet the users' requirements. The 47th session of the Typhoon Committee (Bangkok, 2015) requested RSMCs Tokyo and Honolulu to develop draft TC forecaster competency as Annual Operating Plan of its Working Group on Meteorology.

RSMCs Honolulu and Tokyo reviewed 1) the WMO International TC Competencies Regional Association (RA) V (version 1.3), and 2) TC Competency developed by the Hurricane Committee Task Team submitted to the RA IV Hurricane Committee in 2014. Since the latter originated from the first one, contents of these documents are quite similar, except that the latter has the competency requirement for non-forecast offices which primarily interprets provided forecasts for use in an advisory capacity to the emergency services, local media etc (Category 3). At the 10th Integrated Workshop of the Typhoon Committee (Malaysia, October 2015), RSMCs Tokyo and Honolulu reported that both versions describe a list of requirements comprehensively enough to be used as a draft of the TC forecast competencies for the ESCAP/WMO Typhoon Committee. The RSMCs also indicated that all the Typhoon Committee Members have dedicated Meteorological Services, and thus a category for non-forecast offices, namely Category 3 of the Hurricane Committee version would not need to be included into the Typhoon Committee version. In addition, it should be considered that some Typhoon Committee Members still rely on TC forecasts of the RSMCs or other agencies to issue their TC information, TC competency requirements for such Members need to be included.

In October 2016, RSMCs Honolulu and Tokyo circulated the draft version of TC forecast competency, which was developed largely based on the WMO International TC Competencies Regional Association (RA) V (version 1.3). Views of Members were collected. Also, for further discussion, focal points on this matter were set up. In 2017, RSMCs plan to hold a task team meeting, preferably before its TC season, to finalize a draft TC forecast competency and to propose how to utilize the competency for future capacity building, such as trainings, in the region.

3.5 Harmonization of Tropical Cyclone Intensity Analysis

The Typhoon Committee published Assessment Report on Impacts of Climate Change on Tropical Cyclone Frequency and Intensity in the Typhoon Committee Region in 2010. The report concluded that "For TC Intensity, differences in best track datasets available for WNP do not allow for a convincing detection of a long term trend in TC intensity change in this basin when compared with variability from natural causes." Responding to the Report, Best-track Consolidation Meeting, which was attended by representatives from HKO, RSMC Tokyo, Joint Typhoon Warning Center (JTWC) and Shanghai Typhoon Institute (STI)/CMA, was held in Hong Kong, China, December 2010. The meeting concluded that large differences of maximum sustained wind speed (MSW) among the centers were mainly caused by the different conversion from CI-number to MSW while there was no large difference in their CI-numbers. Also, it was found very difficult to verify MSW due to considerable uncertainty inherent in observational data and different wind-averaging period. The meeting recommended that the Centers were encouraged to exchange digitized CI numbers of historical TCs if they are available for CI number comparison. In accordance with the recommendation, CI-number comparison was implemented as a WGM project, Harmonization of Tropical Cyclone Intensity Analysis under the Working Group on Meteorology. In 2014, after working for the digitization of CI numbers for the period from 2004-2014, CMA, HKO, JTWC, and RSMC Tokyo exchanged CI numbers. In 2015, cyclone-by-cyclone CI number comparison was conducted by RSMC Tokyo and preliminary findings were presented at the 10th Integrated Workshop in October 2015.

In 2016, RSMC Tokyo drafted and finalized the final report, including the following recommendations, in consultation with the experts of CMA, HKO, and JTWC, toward harmonized TC intensity analysis in the western North Pacific. The final report is available at http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/Final_Report_Harmonization_Tropical_Cyclone_Intensity_Estimate.pdf.

Recommendation 1: Operational TC Centers are encouraged to incorporate Dvorak reanalysis process into operational procedures of TC analysis.

Recommendation 2: Typhoon Committee Members are encouraged to promote sharing of surface observations on a real-time basis within the region.

Recommendation 3: Microwave satellite imageries providing information on TC structures under dense overcasts should be used to make appropriate cloud pattern recognition.

Recommendation 4: Operational TC Centers are encouraged to implement reanalysis of satellite TC intensity estimates using Dvorak technique, if resources, particularly experienced TC analysts, are available, in order to develop long term homogeneous satellite TC intensity datasets.

Recommendation 5: Operational TC Centers are encouraged to utilize objective satellite TC intensity estimates such as objective Dvorak techniques (e.g. ADT, CLOUD) and satellite intensity consensus (e.g. SATCON), as reference for operational TC intensity analysis.

4. Publications

4.1 Technical Review

RSMC Tokyo published *Development of a product based on consensus between Dvorak and AMSU tropical cyclone central pressure estimates at JMA*, and *Tropical Cyclone Central Pressure Estimation Using Doppler Radar Observations at JMA* as its Technical Review No. 18 in March 2016, which is available on the Center's website at http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev.htm.

4.2 Annual Report on Activities of the RSMC Tokyo - Typhoon Center

RSMC Tokyo published Annual Report on the Activities of the RSMC Tokyo - Typhoon Center 2015 in December 2016, which is available on the Center's website at http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/annualreport.html.

5. Other related activities

5.1 Tropical Cyclone Satellite Re-analysis

Responding to the discussions of the Seventh WMO International Workshop on Tropical Cyclones (IWTC-VII La Reunion, France, 15-20, November 2010), and the 2nd international IBTrACS Workshop (Honolulu, Hawaii, 11-13 April 2011) held in conjunction with the WMO sponsored International Workshop on Satellite Analysis of Tropical Cyclones (IWSATC) (Honolulu, Hawaii, 13-16 April 2011), RSMC Tokyo started tropical cyclone satellite re-analysis in 2012 for the period from 1981 to confirm and improve the quality of the Current Intensity (CI) number in the satellite TC analysis. In 2016, re-analysis for the period from 1987 to 1995 was completed. In addition, satellite analysis datasets for the period from 2004 to 2013 were investigated and the re-analysis was partially completed. RSMC Tokyo continues to work on the TC satellite re-analysis to complete re-analysis from 1987 to 2013 by the end of 2018.

5.2 Himawari-8/9

The Himawari-8 geostationary meteorological satellite operated by JMA began operation at 02 UTC on 7 July 2015. Himawari-8 is the world's first new-generation satellite of its kind, featuring significant improvements in terms of the number of observation bands, data capture periodicity and spatial resolution as compared to the previous generation. These enhancements are expected to support unprecedented prevention and mitigation of typhoon -related disasters in the East Asia and Western Pacific regions. JMA runs two services for the provision of Himawari-8 imagery. One is the HimawariCast service, by which primary sets of imagery are disseminated for operational meteorological services via a communication satellite. The other is the HimawariCloud service, by which full sets of imagery are delivered to National Meteorological and Hydrological Services (NMHSs) via an Internet cloud service. In addition, JMA continuously provides Himawari-8 imagery in SATAID format via the WIS/GISC Tokyo server with its automatic downloader.

In 2015 and 2016, to enhance the Members' weather monitoring and forecasting capacity using Himawari-8 imagery, JMA has conducted expert missions to Cambodia, Malaysia, Singapore, Thailand, Viet Nam, the Philippines. In addition, ASEAN Sub-Committee on Meteorology and Geophysics (ASCMG) Satellite Rainfall Estimation Workshop was held in Singapore from 28 to 30 March 2016 to provide trainings on Himawari-8 data/product to forecasters of the NMHSs of the ASEAN countries.

On 2 November 2016, Himawari-9 was launched as the follow-on satellite to Himawari-8. The satellite was put into in-orbit and will be stand-by as backup for Himawari-8, with which it shares identical specifications. This will help to ensure the stability of the satellite observation system for the East Asia and Western Pacific regions for 15 years.

6. Typhoon Committee Attachment Training at RSMC Tokyo

RSMC Tokyo has run the ESCAP/WMO Typhoon Committee Attachment Training courses every year since 2001 with the support of the WMO Tropical Cyclone Programme (TCP) and the Typhoon Committee in order to advance the tropical cyclone forecasting capacity of Committee Members. Forecasters from the Panel on Tropical Cyclones (PTC) have also been hosted since 2015 to enhance training collaboration between PTC and the Typhoon Committee.

The 16th ESCAP/WMO Typhoon Committee Attachment Training 2016 course was held at JMA Headquarters from 15 to 26 August 2016. The 2016 attendees were Mr. Thatsana Chanvilay from Lao PDR, Ms. Shelly Jo Igpuara Ignacio from the Philippines, Ms. Ton Thi Thao from Vietnam, Mr. Nasser Said Abdullah Al Ismaili from Oman, Mr. Habib Rehmat from Pakistan, and Mr. Ponna Handi Chaminda De Silva from Sri Lanka. The training focused on imparting practical knowledge and skills relating to operational tropical cyclone analysis and forecasting via lectures and exercises using the Satellite Analysis and Viewer Program (SATAID). The course covered a range of subjects including Dvorak analysis, interpretation of microwave data, quantitative precipitation estimation (QPE), quantitative precipitation forecasting (QPF) and storm surge forecasting. All attendees gave presentations to help JMA staff understand the current status of their meteorological and hydrological services. In 2016, two-day sessions on warning coordination were introduced, with focus on how to determine warning thresholds using disaster statistics and meteorological datasets based on a past tropical cyclone event in Japan.

7. Regular Monitoring of the exchange information

In accordance with the ESCAP/WMO Typhoon Committee Operational Manual (TOM), RSMC Tokyo carried out regular monitoring of the exchange of observational data twice a year. For 2015, two typhoons, Goni (1515) and Mujigae (1522), were selected for the regular monitoring. Results of the monitoring are available on the WMO WIS GISC Server.

8. Implementation Plan

Table 6 shows the implementation plan of the Center for the period from 2016 to 2020.

Table 1 Monthly and annual total numbers of products issued by the RSMC Tokyo - Typhoon Center in 2016

Product	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
IUCC10	0	0	0	0	0	14	102	314	250	239	101	51	1071
WTPQ20-25	0	0	0	0	0	28	119	352	284	286	127	55	1251
WTPQ30-35	0	0	0	0	0	8	28	86	71	71	31	14	309
WTPQ50-55	0	0	0	0	0	0	22	80	70	62	14	17	265
FXPQ20-25	0	0	0	0	0	28	116	346	278	282	124	54	1228
FKPQ30-35	0	0	0	0	0	14	58	173	139	141	62	27	614
AXPQ20	2	0	0	0	0	0	0	2	9	6	5	3	27

Notes:

IUCC10 RJTD	SAREP (BUFR format)
WTPQ20-25 RJTD	RSMC Tropical Cyclone Advisory
WTPQ30-35 RJTD	RSMC Prognostic Reasoning
WTPQ50-55 RJTD	RSMC Tropical Cyclone Advisory for five-day track forecast
FXPQ20-25 RJTD	RSMC Guidance for Forecast
FKPQ30-35 RJTD	Tropical Cyclone Advisory for SIGMET
AXPQ20 RJTD	RSMC Tropical Cyclone Best Track

Table 2 Mean position errors of track forecasts for the TCs in 2016

Tropical Cyclone			24-hour Forecast				48-hour Forecast				72-hour Forecast				96-hour Forecast				120-hour Forecast			
			Mean (km)	S.D. (km)	Num.	EO/EP (%)	Mean (km)	S.D. (km)	Num.	EO/EP (%)	Mean (km)	S.D. (km)	Num	EO/EP (%)	Mean (km)	S.D. (km)	Num	EO/EP (%)	Mean (km)	S.D. (km)	Num	EO/EP (%)
TY	Nepartak	(1601)	60	45	21	35	92	49	17	22	156	52	13	22	327	94	9	35	508	127	5	40
TS	Lupit	(1602)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
STS	Mirinae	(1603)	71	53	4	16	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
STS	Nida	(1604)	68	25	9	40	133	33	4	31	-	-	0	-	-	-	0	-	-	-	0	-
STS	Omais	(1605)	76	48	19	28	141	72	15	37	214	66	10	30	124	62	6	11	144	26	2	8
TS	Conson	(1606)	108	52	20	37	145	74	16	19	187	82	12	15	492	105	8	32	907	102	4	44
STS	Chanthu	(1607)	168	54	12	42	330	99	8	39	792	74	4	86	-	-	0	-	-	-	0	-
TS	Dianmu	(1608)	52	30	3	67	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Mindulle	(1609)	90	74	12	19	212	75	8	40	388	141	4	31	-	-	0	-	-	-	0	-
TY	Lionrock	(1610)	102	58	33	43	165	106	29	30	225	118	25	21	267	118	21	17	449	96	17	24
TS	Kompasu	(1611)	141	60	3	11	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Namtheun	(1612)	48	21	11	30	51	27	7	9	340	94	3	16	-	-	0	-	-	-	0	-
TS	Malou	(1613)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Meranti	(1614)	63	31	17	58	138	95	13	69	169	108	9	52	214	29	5	58	302	0	1	-
TS	Rai	(1615)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Malakas	(1616)	73	44	27	42	174	113	23	33	275	150	19	28	385	174	15	26	506	216	11	24
TY	Megi	(1617)	73	16	15	55	111	30	11	47	160	37	7	42	167	44	3	26	-	-	0	-
TY	Chaba	(1618)	65	38	21	23	110	48	17	18	222	66	13	26	424	79	9	32	651	128	5	17
STS	Aere	(1619)	98	39	13	45	203	63	9	29	312	31	5	18	514	0	1	-	-	-	0	-
TY	Songda	(1620)	64	32	15	14	120	44	11	9	310	54	7	15	782	92	3	23	-	-	0	-
TY	Sarika	(1621)	30	13	18	17	104	33	14	19	168	46	10	24	197	37	6	23	220	26	2	-
TY	Haima	(1622)	52	28	23	26	87	46	19	23	128	47	15	23	178	30	11	20	220	36	7	19
TY	Meari	(1623)	137	99	13	36	297	198	9	46	1000	114	5	103	2066	0	1	-	-	-	0	-
TS	Ma-on	(1624)	136	66	4	28	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
STS	Tokage	(1625)	72	30	6	19	65	19	2	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Nock-ten	(1626)	58	42	20	30	85	55	16	22	103	41	12	17	127	47	8	12	115	65	4	13
Annual Mean (Total)			79	55	339	32	142	101	248	26	243	192	173	26	316	242	106	23	442	232	58	24

Notes: S.D. means standard deviation of operational forecast errors.
Num. means numbers of forecasts.
EO/EP indicates the ratio of EO (mean position error of operational forecasts) to EP (mean position error of forecasts by the persistency forecast).

Table 3 Mean hitting ratios (%) and radii (km) of 70% probability circles issued for track forecasts for the TCs in 2016

Tropical Cyclone			24-hour Forecast			48-hour Forecast			72-hour Forecast			96-hour Forecast			120-hour Forecast		
			Ratio (%)	Num.	Radius (km)	Ratio (%)	Num.	Radius (km)	Ratio (%)	Num.	Radius (km)	Ratio (%)	Num.	Radius (km)	Ratio (%)	Num.	Radius (km)
TY	Nepartak	(1601)	86	21	104	100	17	197	100	13	254	100	9	424	40	5	500
TS	Lupit	(1602)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
STS	Mirinae	(1603)	75	4	93	-	0	-	-	0	-	-	0	-	-	0	-
STS	Nida	(1604)	100	9	119	100	4	204	-	0	-	-	0	-	-	0	-
STS	Omais	(1605)	79	19	117	67	15	214	90	10	298	100	6	330	100	2	602
TS	Conson	(1606)	60	20	113	75	16	200	75	12	267	13	8	350	0	4	468
STS	Chanthu	(1607)	17	12	119	13	8	212	0	4	245	-	0	-	-	0	-
TS	Dianmu	(1608)	100	3	130	-	0	-	-	0	-	-	0	-	-	0	-
TY	Mindulle	(1609)	92	12	139	63	8	232	25	4	296	-	0	-	-	0	-
TY	Lionrock	(1610)	64	33	119	66	29	224	80	25	348	81	21	462	82	17	536
TS	Kompasu	(1611)	67	3	136	-	0	-	-	0	-	-	0	-	-	0	-
TY	Namtheun	(1612)	100	11	96	100	7	188	67	3	377	-	0	-	-	0	-
TS	Malou	(1613)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
TY	Meranti	(1614)	82	17	108	69	13	197	78	9	251	100	5	444	100	1	648
TS	Rai	(1615)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
TY	Malakas	(1616)	81	27	116	70	23	207	58	19	292	80	15	499	64	11	583
TY	Megi	(1617)	100	15	110	100	11	204	100	7	257	100	3	315	-	0	-
TY	Chaba	(1618)	86	21	115	100	17	224	92	13	339	56	9	469	20	5	602
STS	Aere	(1619)	46	13	101	33	9	179	20	5	256	0	1	315	-	0	-
TY	Songda	(1620)	80	15	121	91	11	230	100	7	368	0	3	482	-	0	-
TY	Sarika	(1621)	100	18	100	93	14	188	100	10	248	100	6	315	100	2	370
TY	Haima	(1622)	96	23	109	100	19	202	100	15	259	100	11	315	100	7	370
TY	Meari	(1623)	54	13	115	44	9	222	0	5	285	0	1	444	-	0	-
TS	Ma-on	(1624)	50	4	134	-	0	-	-	0	-	-	0	-	-	0	-
STS	Tokage	(1625)	83	6	105	100	2	204	-	0	-	-	0	-	-	0	-
TY	Nock-ten	(1626)	85	20	102	100	16	185	100	12	247	100	8	326	100	4	370
Annual Mean (Total)			78	339	112	79	248	207	79	173	290	78	106	409	69	58	510

Table 4 Root mean square errors and mean errors of central pressure (4a: left) and maximum sustained wind (4b: right) forecasts for the TCs in 2016

Tropical Cyclone			24-hour Forecast			48-hour Forecast			72-hour Forecast		
			Error (hPa)	RMSE (hPa)	Num.	Error (hPa)	RMSE (hPa)	Num.	Error (hPa)	RMSE (hPa)	Num.
TY	Nepartak	(1601)	7.4	20.5	21	15.2	35.8	17	16.4	45.8	13
TS	Lupit	(1602)	-	-	0	-	-	0	-	-	0
STS	Mirinae	(1603)	8.8	10.2	4	-	-	0	-	-	0
STS	Nida	(1604)	-11.1	15.5	9	-26.2	27.0	4	-	-	0
STS	Omais	(1605)	-3.6	7.6	19	-8.7	11.4	15	-15.0	15.2	10
TS	Conson	(1606)	-5.9	9.9	20	-13.7	17.5	16	-19.2	21.6	12
STS	Chanthu	(1607)	2.2	5.7	12	-1.1	6.1	8	-4.7	8.8	4
TS	Dianmu	(1608)	3.3	5.8	3	-	-	0	-	-	0
TY	Mindulle	(1609)	0.3	5.0	12	2.6	5.9	8	-1.7	2.7	4
TY	Lionrock	(1610)	-4.5	10.4	33	-6.8	15.5	29	-4.1	13.2	25
TS	Kompasu	(1611)	-3.3	3.8	3	-	-	0	-	-	0
TY	Namtheun	(1612)	-5.5	17.2	11	-9.3	20.8	7	-6.7	8.5	3
TS	Malou	(1613)	-	-	0	-	-	0	-	-	0
TY	Meranti	(1614)	3.8	23.2	17	6.1	35.6	13	-1.8	37.6	9
TS	Rai	(1615)	-	-	0	-	-	0	-	-	0
TY	Malakas	(1616)	-0.9	9.4	27	1.7	7.4	23	8.9	15.4	19
TY	Megi	(1617)	-14.1	19.7	15	-13.6	20.2	11	-5.7	9.6	7
TY	Chaba	(1618)	7.9	20.1	21	15.0	23.0	17	15.0	22.5	13
STS	Aere	(1619)	-6.5	12.9	13	-14.4	21.6	9	-21.0	21.1	5
TY	Songda	(1620)	17.3	22.1	15	27.3	30.9	11	20.0	25.5	7
TY	Sarika	(1621)	-7.4	13.9	18	-11.7	21.1	14	-20.9	26.4	10
TY	Haima	(1622)	0.6	9.0	23	-0.4	13.7	19	-3.5	17.8	15
TY	Meari	(1623)	1.5	13.0	13	8.9	18.4	9	12.0	12.6	5
TS	Ma-on	(1624)	-4.0	4.0	4	-	-	0	-	-	0
STS	Tokage	(1625)	-3.7	4.4	6	-5.0	5.1	2	-	-	0
TY	Nock-ten	(1626)	6.8	19.2	20	16.5	29.1	16	16.2	29.8	12
Annual Mean (Total)			-0.3	14.6	339	0.4	21.5	248	0.1	23.4	173

Tropical Cyclone			24-hour Forecast			48-hour Forecast			72-hour Forecast		
			Error (m/s)	RMSE (m/s)	Num.	Error (m/s)	RMSE (m/s)	Num.	Error (m/s)	RMSE (m/s)	Num.
TY	Nepartak	(1601)	-0.9	7.1	21	-2.1	12.3	17	-1.4	16.2	13
TS	Lupit	(1602)	-	-	0	-	-	0	-	-	0
STS	Mirinae	(1603)	-3.2	4.3	4	-	-	0	-	-	0
STS	Nida	(1604)	6.9	9.5	9	14.8	15.5	4	-	-	0
STS	Omais	(1605)	0.9	4.0	19	2.6	5.4	15	5.1	6.0	10
TS	Conson	(1606)	5.4	6.7	20	9.5	10.9	16	13.1	14.3	12
STS	Chanthu	(1607)	0.0	3.5	12	1.6	4.0	8	1.9	5.0	4
TS	Dianmu	(1608)	0.9	2.6	3	-	-	0	-	-	0
TY	Mindulle	(1609)	-2.4	3.4	12	-4.8	5.5	8	-5.8	5.9	4
TY	Lionrock	(1610)	1.9	4.5	33	2.1	6.4	29	2.1	5.3	25
TS	Kompasu	(1611)	0.0	0.0	3	-	-	0	-	-	0
TY	Namtheun	(1612)	4.0	8.0	11	7.0	9.9	7	2.6	3.3	3
TS	Malou	(1613)	-	-	0	-	-	0	-	-	0
TY	Meranti	(1614)	-0.3	9.3	17	-1.8	11.3	13	0.9	14.3	9
TS	Rai	(1615)	-	-	0	-	-	0	-	-	0
TY	Malakas	(1616)	-0.2	4.8	27	-0.7	3.9	23	-3.8	7.3	19
TY	Megi	(1617)	7.4	9.2	15	6.3	8.9	11	4.4	6.4	7
TY	Chaba	(1618)	-2.1	8.0	21	-4.8	7.8	17	-4.4	7.7	13
STS	Aere	(1619)	4.2	7.7	13	8.9	12.8	9	12.3	12.5	5
TY	Songda	(1620)	-6.2	8.3	15	-8.9	10.2	11	-5.5	8.3	7
TY	Sarika	(1621)	5.1	8.3	18	7.9	11.3	14	12.9	14.6	10
TY	Haima	(1622)	0.2	4.3	23	1.1	6.4	19	3.3	8.5	15
TY	Meari	(1623)	-2.6	7.0	13	-5.4	9.0	9	-6.2	6.5	5
TS	Ma-on	(1624)	0.0	0.0	4	-	-	0	-	-	0
STS	Tokage	(1625)	0.9	2.6	6	1.3	1.8	2	-	-	0
TY	Nock-ten	(1626)	-3.6	6.4	20	-5.8	10.0	16	-5.8	10.6	12
Annual Mean (Total)			0.8	6.5	339	0.9	8.9	248	1.4	10.0	173

Table 5 Products of RSMC Tokyo via NTP website

Products	Frequency	Contents
NWP Weather Map TC track guidance	Twice/day	Mean sea level pressure and 500 hPa Geopotential height (up to 72 hours at 00 TC, up to 168 hours at 12 UTC) of nine major NWP centers (BoM, MSC, CMA, DWD, KMA, UKMO, NCEP, ECMWF and JMA)
TC track guidance	Twice/day	TC track guidance of nine deterministic NWP models (BoM, MSC, CMA, DWD, KMA, UKMO, NCEP, ECMWF and JMA), ensemble TC track guidance of JMA's TEPS, ECMWF, UKMO, and NCEP
TC Activity Prediction map	Twice/day	TC genesis probability maps of the ensembles of ECMWF and UKMO, and their consensus.
EDA Analysis	4 times/day	Center position and its accuracy, T number
Sea Surface Temperature	once/day	Sea Surface Temperature in the area of responsibility
Tropical Cyclone Heat Potential	once/day	Tropical Cyclone Heat Potential in the area of responsibility
Vertical Wind Shear	4 times/day	Vertical Wind Shear of initial fields of the JMA's global model
Satellite Microwave Products		Microwave TC snapshot (37GHz(H,V,PCT), 89GHz(H,V,PCT), AMSU-based TC intensity(Central pressure, Maximum sustained wind), Consensus TC intensity estimates using Dvorak CI-number and AMSU-based TC intensity.
Storm Surge Prediction	4 times/day	Multi-scenario storm surge prediction maps (up to 72 hours ahead) and time series storm surge prediction at 68 stations (up to 72 hours ahead),
Ensemble ocean wave prediction	once/day	ensemble mean/3rd quantile/maximum wave heights, probability of wave heights exceeding 2, 3, 4, 5 and 6 m.
Stream line	4 times/day	Stream line (850 hPa, 200 hPa) based on initial fields of the JMA's global model
Graphical Tropical Cyclone Advisory for SIGMET	4 times/day	Center position, Maximum sustained wind speed, Direction and speed of movement, Central pressure, height and area of CB associated with a TC

Table 6 Implementation Plans of the RSMC Tokyo - Typhoon Center (2016 - 2020)

PRODUCT	2016	2017	2018	2019	2020	REMARKS
Satellite Observation						
Himawari- 8/9	—	—	—	—	—	Every 10 minutes (Full-disk) Every 2.5 minutes (Target area)
Cloud motion wind (BUFR)	—	—	—	—	—	24 times/day
RSMC TC Advisory						
RSMC Tropical Cyclone Advisory	—	—	—	—	—	8 times/day
SAREP (for tropical cyclones, BUFR)	—	—	—	—	—	8 times/day Position of cloud sytem center, etc. 4 times/day Dvorak intensity
RSMC Prognostic Reasoning	—	—	—	—	—	2 times/day
RSMC Guidance for Forecast	—	—	—	—	—	4 times/day up to 84 hrs ahead (GSM) 4 times/day up to 132 hrs ahead (TEPS(-2016)/GEPS(2017-))
Web-based RSMC Advisories / Products						
Numerical Typhoon Prediction Website	—	—	—	—	—	
Graphical Tropical Cyclone Advisory	—	—	—	—	—	
Experimental CAP Tropical Cyclone Advisory	—	—	—	—	—	
Others						
RSMC Tropical Cyclone Best Track	—	—	—	—	—	
Annual Report	—	—	—	—	—	Publication
Technical Review	…	…	…	…	…	Publication (as necessary)
Tropical Cyclone Reanalysis	—	—	—	—	—	
SUPPORTING ACTIVITY	**2016**	**2017**	**2018**	**2019**	**2020**	**REMARKS**
Attachment Training	—	—	—	—	—	
Data archive	—	—	—	—	—	
Monitoring of data exchange	—	—	—	—	—	
Dissemination of products via GISC Tokyo	—	—	—	—	—	

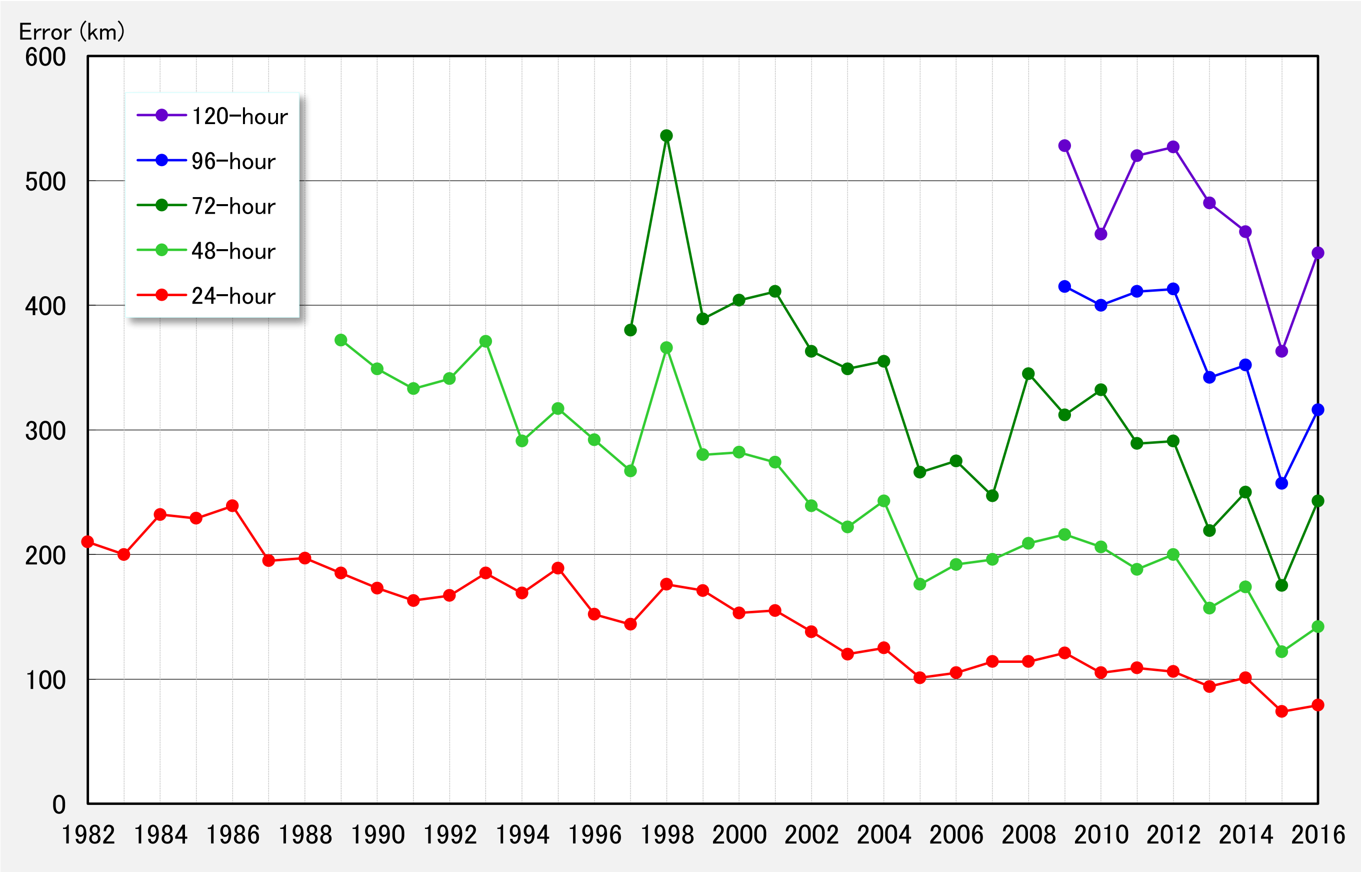

Figure 1 Annual mean position errors of track forecasts
Vertical axis: position error (km), Horizontal axis: year