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ACTIVITIES OF THE RSMC TOKYO - TYPHOON CENTER IN 2019

(Submitted by the RSMC Tokyo - Typhoon Center)

ACTION REQUIRED:

The Committee is invited to review the activities of the RSMC Tokyo - Typhoon Center in 2019 and future plans.

APPENDIXES:

A) DRAFT TEXT FOR INCLUSION IN SESSION REPORT

B) RSMC Tokyo - Typhoon Center Activity Report 2019 and future plans

APPENDIX A:
DRAFT TEXT FOR INCLUSION IN THE SESSION REPORT

x.x Review of the activities of the Regional Specialized Meteorological Center (RSMC) Tokyo in 2019

1. The Committee noted with appreciation the review of RSMC advisories, products and operational activities and changes made in 2019. It noted the forecast verification results for 29 TCs that reached TS intensity or higher formed in 2019: the forecast track errors of the year of 80 km (66 km in 2018), 127 km (112 km), 190 km (179 km), 263 km (277 km) and 374 km (409 km) for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively, the annual mean RMSEs for central pressure forecasts of 11.2 hPa (13.8 hPa), 15.1 hPa (18.7 hPa), 17.6 hPa (20.4 hPa), 18.2 hPa and 20.3 hPa for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively, and those for maximum wind speed forecasts for 24-, 48-, 72-, 96- and 120-hour forecasts of 5.1 m/s (5.4 m/s), 7.1 m/s (6.9 m/s), 8.0 m/s (7.3 m/s), 8.4 m/s and 9.3 m/s respectively*.

   * Five-day tropical cyclone intensity forecast has been operational since 14 March 2019; therefore, T1901 and T1902 that formed before 14 March are not included in the above statistics for 96- and 120-hour forecasts of central pressure and maximum wind speed.

2. The Committee noted with appreciation the changes of RSMC advisories, products and operational/coordination activities in 2019, especially the commencement of 5-day tropical cyclone intensity forecasts, revision of probability circle whose radii are an average of approximately 20% smaller than before and express situation-dependent forecast uncertainty more appropriately, and enhanced communication service on a trial basis. It also noted the planned changes, such as the commencement of 5-day forecasts for tropical depressions (TDs) which are expected to become tropical storm (TS) intensity within 24 hours.

3. The Committee expressed its appreciation to the operation of RSMC Tokyo's Numerical Typhoon Prediction (NTP) website and noted the remarkable enhancements made in 2019, such as the commencement of provision of ASWind (Atmospheric motion vector based Sea-surface Wind), probabilistic forecast map for storm winds and Madden-Julian Oscillation and summer monsoon activity, as well as the expansion of contents related to atmospheric circulation data. It also noted the changes planned in the near future.

4. The Committee expressed its appreciation to the continuous contribution of RSMC Tokyo to the regional Storm Surge Watch Scheme (SSWS), especially the provision of various products including storm surge forecast distribution maps, time-series charts at selected stations and multi-scenario storm surge predictions as well as week-range wave forecasts in which probability forecasts on peak wave period in addition to significant wave heights have newly been available since January 2019. The Committee also noted with appreciation that RSMC Tokyo has started provision of astronomical tides estimated by a global ocean tide solution (FES2014)*[1] for 27 stations on 25 February 2019, where sea level observation data is not available. The Committee again encouraged Members to make their sea level observation available to contribute to the verification activity.

5. The Committee noted with appreciation the continuous efforts and progress of RSMC Tokyo's development of tropical cyclone genesis guidance using early Dvorak Analysis and global ensemble.

6. The Committee was pleased to note the progress of the regional radar network development project, whose experimental exchange of radar composite data among RSMC Tokyo, the Thai Meteorological Department (TMD) and the Malaysia Meteorological Department (MMD) started in 2016. The project has been expanded and three more Members, Lao P.D.R., the Philippines and Viet Nam joined in 2018. The Committee noted with appreciation that a technical meeting for experts of the six Members and some countries of interest was held at the JMA headquarters in November

*[1] FES2014 was produced by NOVELTIS, LEGOS, CLS Space Oceanography Division and CNES. It is distributed by AVISO, with support from CNES (http://www.aviso.altimetry.fr/)

2019 to exchange information on experiences and challenges relating to regional radar data exchange and quality control, and to discuss future directions in the field. The Committee also appreciated that the Weather Radar Seminar was jointly held at the JMA headquarters as a platform for the sharing of expertise in radar meteorology expecting to deepen the knowledge in this field.

7. The Committee was pleased to note the activities of the project on enhancing the utilization of Himawari-8/9 products, in which technical support for developing Rapidly Developing Cumulus Area (RDCA) identification using Himawari-8/9 data has been conducted. The committee noted with appreciation that continuous discussion and support were held between experts of MMD and JMA. It also appreciated that a technical web-meeting was held among experts of the Meteorological Service Singapore (MSS), TMD and the Viet Nam Meteorological and Hydrological Administration (VNMHA) on 4 February 2020 to share the outline of RDCA, including the technique for development, wide range of usage and verification methods, and to discuss activities planned in 2020.

8. The Committee noted with appreciation that RSMC Tokyo published the RSMC Tokyo Technical Review No.21 and the Annual Report on the Activities of the RSMC Tokyo Typhoon Center 2018 in April and December 2019, respectively.

9. The Committee was informed that RSMC Tokyo had started tropical cyclone satellite re-analysis in 2012 for the period from 1981 in order to confirm and improve the quality of the Current Intensity (CI) number in the satellite TC analysis, and that the Center has completed the re-analysis for the period from 1987 to present. It was also informed that the re-analysis for the period from 1981 to 1986 is difficult to conduct with accuracy consistent with later events due to the available satellite imagery. Based on this fact and the achievement, the Committee noted with great appreciation that RSMC Tokyo will share the whole dataset for the period from 1987 to present with Members online in 2020; the URL will be announced from RSMC Tokyo in due course.

10. The Committee noted with appreciation that the operation of Himawari-8/9 geostationary meteorological satellites and further welcome the intention of RSMC Tokyo to continue providing Himawari products as well as technical support for using them.

11. The Committee was pleased to note that RSMC Tokyo conducted the 19th Attachment Training from 18 to 29 November 2019, inviting four forecasters from China, Lao PDR, Thailand and Viet Nam and three forecasters (self-funded) from Hong Kong (China), Macao (China) and Malaysia among the Committee Members. Two more forecasters from Bangladesh and Myanmar also participated in the training. In addition, RSMC Tokyo invited a guest lecturer from the India Meteorological Department to give a lecture on the South Asian Monsoon and TCs in the Indian Ocean area.

12. The Committee noted the results of the annual observation exchange monitoring during the period of two tropical cyclones in 2019: Podul (1912) and Mitag (1918), which highlighted the special observation conducted by China, Hong Kong (China), Japan, the Philippines, the Republic of Korea and Thailand during the periods. It expressed its appreciation to the six Members, who provided special observation data to the Committee Members, and further encouraged all the Members to conduct additional observation, as requested by the Typhoon Committee Operational Manual - Meteorological Components (TOM).

APPENDIX B:
RSMC Tokyo - Typhoon Center Activity Report 2019 and future plans

1. RSMC Advisories, Products and Operational/Coordination Activities

The RSMC Tokyo - Typhoon Center provides the Typhoon Committee 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. This section reviews RSMC advisories, products and operational activities in 2019 and summarizes changes and future plans.

1.1 Review of RSMC advisories, products and operational activities in 2019

Table 1 shows the total number of products issued by the Center in 2019.

✧ **Verification of Track Forecasts**

Operational track forecasts for 29 Tropical Cyclones (TCs) that reached Tropical Storm (TS) intensity or higher in 2019 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 80 km (66 km in 2018), 127 km (112 km), 190 km (179 km), 263 km (277 km) and 374 km (409 km) for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively (Table 2).

✧ **Verification of Track Forecast Probability Circles**

RSMC Tokyo uses track forecast probability circles* to represent TC track forecast uncertainties. Before 12 June 2019, the radius of the circles for all forecast times was statistically determined according to the direction and speed of TC movement based on the results of TC track forecast verification. In addition, those for 96- and 120-hour forecasts were statistically determined according to the confidence level based on the cumulative ensemble spread calculated using the JMA's Ensemble Prediction System (EPS). Since 12 June 2019, RSMC Tokyo has revised the circles by introducing categories only by confidence level based on the cumulative ensemble spread calculated with multi-ensembles from four centers (JMA, ECMWF, NCEP and UKMO) for all forecast times (see Chapter 1.2 for details). The new circles have been applied to T1903 and later TCs. The mean hitting ratios of circles* for 24-, 48-, 72-, 96- and 120-hour forecasts throughout 2019, i.e., previous circles for T1901 - T1902 and new circles for T1903 - T1929, are 69% (82% in 2018), 72% (89%), 75% (82%), 72% (82%) and 80% (78%), respectively (Table 3).

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

✧ **Verification of Intensity Forecasts**

Table 4a and b give the mean errors and root mean square errors (RMSEs) of 24-, 48-, 72-, 96- and 120-hour central pressure (Table 4a) and maximum sustained wind forecasts (Table 4b) for 29 TCs of 2019*. The annual mean RMSEs for central pressure forecasts are 11.2 hPa (13.8 hPa in 2018), 15.1 hPa (18.7 hPa), 17.6 hPa (20.4 hPa), 18.2 hPa and 20.3 hPa for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively, while those for maximum wind speed forecasts for 24-, 48-, 72-, 96- and 120-hour forecasts are 5.1 m/s (5.4 m/s in 2018), 7.1 m/s (6.9 m/s), 8.0 m/s (7.3 m/s), 8.4 m/s and 9.3 m/s respectively.

* Five-day tropical cyclone intensity forecast has been operational since 14 March 2019; therefore, T1901 and T1902 that formed before 14 March are not included in the above statistics for 96- and 120-hour forecasts of central pressure and maximum wind speed.

1.2 Changes in RSMC advisories, products and operational activities in 2019

✧ **Intensity forecast for 96 and 120 hours**

RSMC Tokyo has started providing intensity forecast for 96 and 120 hours from 14 March

2019, based on several tropical cyclone intensity forecast guidance products including the one based on the Statistical Hurricane Intensity Prediction Scheme (SHIPS). The new scheme is known as TIFS (**T**yphoon **I**ntensity **F**orecasting scheme based on **S**HIPS), and the information are added to existing RSMC Tropical Cyclone Advisory for five-day forecast with GTS headings of WTPQ50-55 RJTD.

✧ **Revision of probability circle**

As described in Chapter 1.1, RSMC Tokyo has revised probability circles by introducing categories only by confidence level based on the cumulative ensemble spread calculated with multi-ensembles from four centers for all forecast times. This is based on the result that RSMC Tokyo compared characteristics of probability circles using statistical method, dynamical method consisting of single-ensemble and multi-ensemble use for 2016-2018 data. The revised probability circles are operational since 12 June 2019 and verification was done with tropical cyclone track data for T1903 – T1929; the verification results revealed that mean circle radii reduced by 15-20%, mean hitting ratio of circles reduced and became more appropriate by approaching 70%, and became better situation-dependent radii than those for 2016-2018.

✧ **Enhanced communication**

RSMC Tokyo has started providing a platform in which the Committee Members can post inquiries or comments related to tropical cyclone analyses and forecasts. This service has been available since July 2019 on a trial basis. Based on the Committee Members' request, RSMC Tokyo will also provide Advance Notices on this platform from 2020 and continue the trial for another year to obtain more feedback from the Members.

1.3 Future plans for changes in RSMC advisories, products and operational activities

✧ **End of WTPQ20-25 RJTD distribution**

RSMC Tokyo has currently been providing advisories for both five-day and three-day forecasts with GTS headings of WTPQ50-55 RJTD and WTPQ20-25 RJTD, respectively, considering some users' system transition. WTPQ20-25 RJTD will discontinue during the first quarter of 2021.

✧ **Five-day forecast for TDs that are expected to become TS intensity within 24 hours**

RSMC Tokyo plans to start providing five-day forecasts for tropical depressions (TDs) in September 2020, which are expected to become TS intensity within 24 hours. An example of a bulletin is shown in Table 5.

1.4 Review of RSMC coordination activities

In 2019, TC Pabuk formed in the South China Sea, moved westward and crossed the boundary of the RSMCs Tokyo and New Delhi. Accordingly, RSMC Tokyo communicated with RSMC New Delhi that took over the responsibility for TC advisory issuances.

Procedures of taking over the responsibility for TC advisory issuances for TCs, which cross RSMCs' boundaries, were thoroughly discussed and documented as Standard Operating Procedures (SOP) between RSMCs Honolulu and Tokyo in 2018. As motivated by TC Pabuk, discussion was also held between RSMCs New Delhi and Tokyo in 2019, and documented as SOP after detailed coordination.

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. All the products of the NTP website are listed in Table 6. Changes made in 2019 and those planned in 2020 are as follows.

✧ **Atmospheric motion vector based Sea-surface Wind (ASWind)**

The meteorological satellite center of the Japan Meteorological Agency (JMA/MSC) has developed a method to estimate sea surface winds in the vicinity of tropical cyclones from Hiamwari-8/9. It is named ASWind which Himawari-8/9 provides every 30 minutes for full-disk observation and every 10 minutes for Target Area observation, respectively, with high accuracy for surrounding areas of strong winds (30 kt or higher) due to tropical cyclones. A website of ASWinds is open in which not only the imagery but also data in the SATellite Animation and Interactive Diagnosis (SATAID) format are available.

✧ **Expansion of contents related to atmospheric circulation data**

Previously, charts for Streamline at 200 and 850 hPa, Vertical Wind Shear between 200 and 850 hPa, Divergence at 200 hPa and Vorticity at 850 hPa were available, only for the GSM analysis time. From 24 July 2019, charts for Streamline at 500 hPa, Velocity Potential at 200 hPa, Vertical Velocity in Pressure Coordinate at 500 hPa, Dew Point Depression at 600 hPa, Sea Level Pressure and Genesis Potential Index are newly available with 12-hourly GSM forecast charts up to 132 hours. RSMC Tokyo expects that these charts serve to facilitate understanding of the large-scale atmospheric conditions and development thereof, either favorable or unfavorable for tropical cyclones.

✧ **Madden-Julian Oscillation and summer monsoon activity**

As Madden-Julian Oscillation (MJO) is one of the important intra-seasonal variability which modifies the atmospheric conditions and the potential of tropical cyclogenesis, links to MJO Phase Diagram as well as MJO Hovmöller Diagram are added. Monitoring Indices for the Asian Summer Monsoon, another factor closely linked to tropical cyclogenesis over the western North Pacific, are also added for reference for monsoon activities.

✧ **Probabilistic forecast map for storm winds**

Storm wind (defined as sustained wind upward of 50-kt) probability maps for the western North Pacific region have been developed and available on the NTP website.

✧ **Structure of the website**

Following the upgrades in contents described above, the global navigation for the website has also been reorganized to be easier for use.

✧ **Accuracy Improvement of TC Activity Prediction**

RSMC Tokyo provides two-day and five-day TC Activity Prediction Maps covering its area of responsibility based on ensembles from ECMWF, NCEP, UKMO and JMA, and a multi-center grand ensemble of these four. The maps started with ensembles from ECMWF and UKMO in 2016, and those from JMA and NCEP were added in June and October, 2018, respectively. As more than a year has passed since the start of provision of the maps with the four centers mentioned above, RSMC Tokyo conducted parameter tuning with accumulated data and improved the accuracy. Two-day and five-day TC Activity Prediction Maps with higher accuracy will be operational in March 2020. Maps based on climatological normal will also be added for reference.

✧ **TC intensity forecast guidance TIFS**

As described in Chapter 1.2, RSMC Tokyo has been operating TC intensity forecasts based on a guidance scheme named TIFS. RSMC Tokyo plans to share TIFS intensity prediction results on the NTP website from March 2020.

✧ **Real-time verification results**

RSMC Tokyo has currently been conducting real-time verification internally and newly plans to share some of the contents with TC Members on the NTP website from March 2020. The contents will be limited to RSMC Tokyo's official forecasts, prediction results of global models already on the NTP website, and prediction results of some intensity guidance

schemes, for track and intensity (central pressure and maximum wind speed) forecasts.

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 the NTP website. Also, TCG is sent to WAFCs, so that they are transmitted through WIFS and Secure SADIS FTP. 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 Typhoon Committee region

Since 2011, RSMC Tokyo has been providing products to support storm surge prediction, within the framework of the Storm Surge Watch Scheme (SSWS), in response to the results of the survey conducted in 2009 after the devastating storm surge disaster caused by Cyclone Nargis in 2008 (Hasegawa et al. 2017).

Products include storm surge forecast distribution maps, time-series charts at selected stations, multi-scenario storm surge predictions and week-range wave forecasts based on JMA Wave Ensemble system (WENS). JMA's storm surge model runs on a daily basis, even when no TCs exist in the area of responsibility, for providing information on storm surges generated by monsoon winds or extra-tropical cyclones (see Annex B Table 6 for specifications). Multi-scenario storm surge predictions give predictions based on RSMC Tokyo TC advisory and five additional TC scenarios extracted from the JMA's GEPS using cluster analysis. 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 are increased upon requests from the Committee Members. As of January 2020, time-series storm surge predictions are provided to 78 stations; USA (1), the Philippines (10), Viet Nam (20), Hong Kong China (6), Macao China (1), Republic of Korea (11), Thailand (2), Malaysia (17), Cambodia (4) and Singapore (6). Time series of storm surge predictions are provided on top of astronomical tides for stations calculated from hourly tidal observational data for a few years that are provided by Members. In addition, since February 2019, for stations where those observational data are not available, astronomical tides and storm tides have also become available by adopting a global ocean tide solution (FES2014).

Annual verification results of the storm surge products are regularly published in Annual Report on Activities of the RSMC Tokyo since 2015. Statistical verification is conducted for stations where sea level observations are available in University of Hawaii Sea Level Center (UHSLC) data base. The verification continues to be enhanced with results for high-impact storm surge cases, in addition to statistical verification.

Week-range wave forecasts created using its global WENS are provided on the NTP website. WENS covers most of the global region and has a 1.25-degree grid resolution. It is run twice a day at 00 and 12 UTC and enables prediction of ocean wave conditions up to 264 hours ahead with 27 members.

RSMC Tokyo is working on upgrading the storm surge model; the new model uses finite volume method (FVM) with an unstructured (triangular) grid. As the new model can largely save the resources, RSMC Tokyo will increase the grid resolution around coastal regions from 2 minutes to 1 minute, expand the model domain to cover most of its area of responsibility, and increase the number of multi-scenario prediction using whole members of GEPS.

3.2 Enhanced use of Ensemble Forecast

RSMC Tokyo has been working for enhancement of use of Ensemble Forecast 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 Committee Members. Based on the assessment research using the TIGGE (THORPEX Interactive Grand Global Ensemble) datasets, RSMC Tokyo has provided ensemble TC track guidance of ECMWF and NCEP to the Committee Members on a real-time basis through the NTP website since October 2015.

As described in 2.1, RSMC Tokyo started providing two-day and five-day Tropical Cyclone Activity Prediction Maps covering its area of responsibility based on ensembles from the ECMWF, UKMO and their consensus in 2016. The number of ensemble models used for consensus was expanded to four in 2018, by adding those of NCEP and JMA, and a multi-center grand ensemble (MCGE). The maps display potential tropical cyclone activity in terms of percentage of ensemble members in which TC-like vortices are represented within 300 km of a certain location during the relevant forecast time. RSMC Tokyo has recently conducted parameter-tuning and products with higher accuracy will be available in March 2020, also with maps based on climatological normal, aiming at helping forecasters identify and monitor areas in which tropical cyclones could form within two- and five-day periods.

The probability circle radii for all forecast times were statistically determined according to the direction and speed of TC movement based on the results of recent TC track forecast verification. In addition, those for 96- and 120-hour forecasts were statistically determined according to the confidence level based on the cumulative ensemble spread from GEPS. RSMC Tokyo has revised probability circles in TC track forecasts in June 2019, by introducing categories only by confidence level based on the cumulative ensemble spread calculated with multi-ensemble from the four centers for all forecast times. This is based on the result that RSMC Tokyo compared characteristics of probability circles using statistical method, dynamical method consisting of single-ensemble and multi-ensemble use for 2016-2018 data.

3.3 Development of regional radar network

The Development of Regional Radar Network is a project of the Working Group on Meteorology of the Typhoon Committee. Technical assistance provided through this project includes development of a national (domestic) radar network, radar data quality control, application of composite as well as quantitative precipitation estimation (QPE) techniques to the nationwide radar network. So far Thailand and Malaysia have been actively working on these items, through several technical meetings and workshops and hourly regional radar composite imagery is available on RSMC Tokyo NTP website at https://tynwp-web.kishou.go.jp/Analysis/Radar/index.html. This imagery is produced using radar composite data exchanged experimentally among the Members since 2016.

This project has been expanded and three more Members, Lao P.D.R., the Philippines and Viet Nam, have joined in 2018. Technical meetings were held at the JMA headquarters in October 2018 and November 2019 for experts of participating Members, including the new Members, to exchange information on experiences and challenges relating to regional radar

data exchange and quality control, and to discuss future directions in the field. In addition, a Weather Radar Seminar was jointly held at the JMA headquarters in November 2019 as a platform for the sharing of expertise in radar meteorology expecting to deepen the knowledge in this field.

3.4 Enhancement of Utilization of Himawari-8/9

The Enhancement of Utilization of Himawari-8/9 is a project of the Working Group of Meteorology of the Typhoon Committee. Technical assistance provided through this project includes developing Rapidly Developing Cumulus Area (RDCA) detection technique using Himawari8/9 products. A technical meeting was held with experts from Malaysia at JMA headquarters in October 2018 to exchange information on recent progress and ideas for advanced products in the field. Technical support and communication between Malaysia and RSMC Tokyo continued via e-mails in 2019. In addition, the first technical meeting was held via WebEx with other participants such as Singapore, Thailand and Viet Nam in February 2020.

3.5 Cross-cutting activities with ICHARM

Enhancement of disaster risk reduction against heavy rain in collaboration with an Annual Operating Plan (AOP) of Working Group on Hydrology (WGH), led by ICHARM, is undertaken by RSMC Tokyo for Working Group on Meteorology (WGM) side. RSMC Tokyo has currently been providing various data of JMA's NWP model to ICHARM so that ICHARM can test the effectiveness and figure out which data to use for the project. In parallel, RSMC Tokyo has also been under discussion with ICHARM about the way for sharing knowledge and experience on awareness raising.

4. Publications

4.1 Technical Review

RSMC Tokyo published *Determining Probability-Circle Radii of Tropical Cyclone Track Forecasts with Multiple Ensembles*, *Operational Use of the Typhoon Intensity Forecasting Scheme Based on SHIPS (TIFS) and Commencement of Five-day Tropical Cyclone Intensity Forecasts* and *Utilization of Estimated Sea Surface Wind Data Based on Himawari-8/9 Low-level AMVs for Tropical Cyclone Analysis* as its Technical Review No. 21 in April 2019, which is available on the Center's website at:
https://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/techrev.htm.

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

RSMC Tokyo published Annual Report on the Activities of the RSMC Tokyo - Typhoon Center 2018 in December 2019, which is available on the Center's website at:
https://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. Re-analysis for the period from 1987 to present has been completed, though it was figured out that the re-analysis from 1981 to 1986 is difficult to conduct with accuracy consistent with later events due to the available satellite imagery. RSMC Tokyo will share the whole dataset for the period from 1987 to present with Members online in 2020; the URL will be announced from RSMC Tokyo in due course.

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 features 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.

On 2 November 2016, Himawari-9 was launched as the follow-on satellite to Himawari-8. After a period of in-orbit testing, Himawari-9 began serving as back-up to Himawari-8 on 10 March 2017 and will continue in this role until the planned switchover in or around 2022. This dual combination of new-generation satellites will support JMA's stable provision of continuous satellite observation data for the Asia-Oceania region until 2029.

The Advanced Himawari Imager (AHI) on board Himawari-8/9 is capable of frequent and flexible observation, providing Full-Disk images of the earth every 10 minutes and regional images with shorter periodicity. In regional monitoring, Target Area observation provides imagery covering an area of approximately 1,000 km x 1,000 km every 2.5 minutes with flexibility for location changes. This rapid observation provides superior insight for extreme events such as tropical cyclones and volcanic eruptions. One example of the use for tropical cyclones is ASWind, as described in Chapter 2.1, which is used operationally by RSMC Tokyo for sea surface winds estimation in the vicinity of tropical cyclones.

Since January 2018, JMA has launched an international service called HimawariRequest service, allowing NMHSs to request Target Area observations, within a framework of a WMO RA II (Asia) regional project in collaboration with WMO RA V (South-West Pacific) Members. As of 5 February 2020, JMA had taken registrations from 21 NMHSs in RA II and RA V and opened the service to the 17 whose preparations for request submission were complete. The service has been introduced upon requests to monitor tropical cyclones, volcanic ash from eruptions and forest fire. Further information on HimawariRequest, including a service description and registration form, is available on the JMA website at https://www.jma.go.jp/jma/jma-eng/satellite/HimawariRequest.html. JMA expects the service to support disaster risk reduction activities in the region based on the monitoring of tropical cyclones and other extreme events.

5.3 Updates on the operational global data assimilation system

JMA's operational global NWP system has significantly been improved in December 2019. All-sky radiance assimilation of microwave imager (AMSR2/GCOM-W, GMI/GPM, SSMIS/DMSP F-17, F-18, WindSat/Coriolis, MWRI/FY-3C) as well as microwave water-vapor sounder (GMI/GPM, MHS/NOAA-19, Metop-A, -B) have started. Assimilation of ASCAT/Metop-C ocean surface wind data also started. The data assimilation system for JMA Global Spectral Model (GSM) has been upgraded with introduction of a hybrid 4D-Var method. These upgrades will improve the accuracy of GSM's initial conditions that will result in improvements in the accuracy of typhoon prediction by GSM, i.e., the accuracy of typhoon track forecasts over the western North Pacific in short range forecasts as well as realistic total column water vapor analysis and forecasts of TC intensification.

6. Typhoon Committee Attachment Training at RSMC Tokyo

The 19th ESCAP/WMO Typhoon Committee Attachment Training course was held at JMA Headquarters from 18 to 29 November 2019. The RSMC Tokyo – Typhoon Center has organized ESCAP/WMO Typhoon Committee Attachment Training courses every year since 2001 with the support of the WMO Tropical Cyclone Programme and the Typhoon Committee in order to advance the tropical cyclone (TC) analysis and forecasting capacity of Committee Members. Forecasters from the Member countries of the Panel on Tropical Cyclones have also been invited since 2015. In 2019, the Center welcomed; Mr. Md. Bazlur Rashid from Bangladesh, Dr. Xinyan Lyu from China, Dr. Yin Lam Ng from Hong Kong, Ms. Sinthaly Chanthana from Lao PDR., Mr. Chan Wa Lok from Macao, Ms. Maziah Binti Mat from Malaysia, Ms. Ni Ni Khine from Myanmar, Ms. Premwadee Traitangwong from Thailand and Ms. Hien Thi Thu Vo from Viet Nam, as well as guest lecturer Dr. Balachandran Sethurathinam from the India Meteorological Department. The training focused on practical knowledge and skills related to operational TC analysis and forecasting via lectures and exercises. The TC analysis course covered a range of subjects including interpretation of satellite imagery and Dvorak analysis techniques involving the use of SATAID, and other analysis techniques based on microwave imagery, Doppler radar data and sea-surface Atmospheric Motion Vector data. TC forecasting subjects included techniques involving the use of various types of guidance and information sources along with storm surge and wave forecasting. Presentations and exercises were also provided on public weather services, including the setting of warning criteria based on disaster statistics, key roles of quantitative precipitation estimation and forecasting techniques, appropriate provision of disaster risk reduction (DRR) information, and forecast skill evaluation, to enhance capacity in the development and implementation of effective warning systems in collaboration with DRR operators. Dr. Balachandran Sethurathinam also gave a lecture on the South Asian Monsoon and TCs in the Indian Ocean area. All attendees gave presentations to help JMA staff understand the current status of their meteorological and hydrological services, including those relating to TCs and warnings.

RSMC Tokyo plans to remove the limit of the number of nominations for each Member for self-funded participants, i.e., forecasters with financial support will still be up to one for each Member (in other words, WMO TCP and TCTF will cover four forecasters from four Members), but two or more forecasters can be accepted from the same Member if RSMC Tokyo can accommodate and as long as they are self-funded. As for the budget of the training, RSMC Tokyo coordinated with the Training and Research Coordination Group (TRCG) to submit a proposal to increase, from TRCG side for the 52nd annual session, in order to partially cover the reduction in WMO TCP support and inflation in recent years.

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 2019, two typhoons, Podul (1912) and Mitag (1918), were selected for the regular monitoring. The target Members of the monitoring are the Philippines, China, Hong Kong (China), Macao (China), Viet Nam, Lao PDR, Cambodia and Thailand (Podul, 1912) and the Philippines, Japan, China, Republic of Korea and Democratic People's Republic of Korea (Mitag, 1918). The result showed that China (TEMP), Hong Kong (TEMP and RADOB), Japan (SYNOP and SHIP), Republic of Korea (TEMP), the Philippines (SYNOP and TEMP) and Thailand (SYNOP and TEMP) conducted frequent observation during the period and shared data with the Committee Members through GTS. Results of the monitoring are available on the GISC Tokyo Server at: http://www.wis-jma.go.jp/monitoring/data/monitoring/.

8. Implementation Plan

Table 7 shows the implementation plan of the Center for the period from 2019 to 2023.

Table 1 Monthly and annual total numbers of products issued by the RSMC Tokyo - Typhoon Center in 2019

Product	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
IUCC10	31	72	0	0	0	13	93	288	189	177	273	91	1227
WTPQ20-25	36	77	0	0	0	22	118	318	234	193	300	95	1393
WTPQ30-35	20	38	0	0	0	9	58	156	114	95	147	47	684
WTPQ50-55	2	26	0	0	0	22	118	318	234	193	300	95	1308
FXPQ20-25	18	38	0	0	0	10	58	156	114	95	147	47	683
FXPQ30-35	18	38	0	0	0	6	52	154	114	95	147	47	671
FKPQ30-35	18	38	0	0	0	11	58	156	115	96	147	47	571
AXPQ20	2	1	0	1	0	0	0	3	2	6	6	4	25

Notes:

IUCC10 RJTD	SAREP (BUFR format)
WTPQ20-25 RJTD	RSMC Tropical Cyclone Advisory for Three-day Forecast
WTPQ30-35 RJTD	RSMC Prognostic Reasoning
WTPQ50-55 RJTD	RSMC Tropical Cyclone Advisory for Five-day Forecast
FXPQ20-25 RJTD	RSMC Guidance for Forecast by Global Model
FXPQ30-35 RJTD	RSMC Guidance for Forecast by Global Ensemble Prediction System
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 2019

Tropical Cyclone			24-hour Forecast				48-hour Forecast				72-hour Forecast				96-hour Forecast				120-hour Forecast			
			Mean (km)	S.D. (km)	Num.	Impr. (%)	Mean (km)	S.D. (km)	Num.	Impr. (%)	Mean (km)	S.D. (km)	Num	Impr. (%)	Mean (km)	S.D. (km)	Num	Impr. (%)	Mean (km)	S.D. (km)	Num	Impr. (%)
TS	Pabuk	(1901)	64	26	10	53	99	39	6	46	137	22	2	74	-	-	0	-	-	-	0	-
TY	Wutip	(1902)	61	41	30	59	91	49	26	71	142	72	22	68	196	119	18	67	388	108	14	46
TS	Sepat	(1903)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Mun	(1904)	114	10	4	-6	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Danas	(1905)	150	106	14	45	288	120	10	58	455	102	6	63	608	15	2	72	-	-	0	-
TS	Nari	(1906)	133	11	2	55	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Wipha	(1907)	47	27	11	68	45	14	6	83	41	18	2	91	-	-	0	-	-	-	0	-
TY	Francisco	(1908)	59	27	14	76	87	39	10	86	124	46	6	89	312	20	2	80	-	-	0	-
TY	Lekima	(1909)	68	35	30	64	139	70	26	58	198	114	22	59	286	132	18	51	351	171	14	49
TY	Krosa	(1910)	58	28	37	58	102	60	33	68	154	89	29	66	215	141	25	67	286	190	21	67
STS	Bailu	(1911)	89	56	14	56	106	33	10	75	147	37	6	74	214	66	2	50	-	-	0	-
TS	Podul	(1912)	137	38	4	27	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Lingling	(1913)	56	34	20	74	120	69	16	76	179	90	12	73	196	176	8	74	260	146	4	80
TS	Kajiki	(1914)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Faxai	(1915)	66	48	17	73	83	49	12	84	119	41	7	84	267	67	3	66	-	-	0	-
TS	Peipah	(1916)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Tapah	(1917)	55	24	12	71	83	41	8	86	97	45	3	90	-	-	0	-	-	-	0	-
TY	Mitag	(1918)	63	19	17	69	83	39	13	84	191	83	9	78	220	100	5	85	230	0	1	88
TY	Hagibis	(1919)	64	30	26	58	105	56	22	71	156	67	18	73	278	104	14	57	463	96	10	41
TY	Neoguri	(1920)	196	118	13	8	388	91	8	21	976	94	3	-55	-	-	0	-	-	-	0	-
TY	Bualoi	(1921)	55	30	21	64	124	40	16	63	222	47	12	62	328	50	8	62	352	72	4	77
STS	Matmo	(1922)	65	25	2	40	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Halong	(1923)	110	137	22	41	117	116	18	66	199	100	13	57	476	316	9	10	829	460	5	5
TY	Nakri	(1924)	51	26	17	54	79	27	13	73	126	48	9	75	128	40	5	74	86	0	1	88
TY	Fengshen	(1925)	145	85	18	53	261	112	14	64	315	214	9	66	212	100	5	65	369	0	1	67
TY	Kalmaegi	(1926)	117	72	18	36	141	68	14	56	251	41	10	26	473	153	6	13	516	40	2	62
STS	Fung-wong	(1927)	131	32	6	33	401	30	2	-81	-	-	0	-	-	-	0	-	-	-	0	-
TY	Kammuri	(1928)	80	38	35	61	130	73	31	69	194	122	27	70	263	168	23	73	365	211	19	73
TY	Phanfone	(1929)	49	30	18	80	61	30	14	87	67	35	10	90	96	61	6	91	197	9	2	95
Annual Mean (Total)			80	66	432	58	127	95	328	69	190	144	237	68	263	173	159	65	374	226	98	64

Notes: S.D. means standard deviation of operational forecast errors.
Num. means numbers of forecasts.
Impr. indicates the ratios of position errors in operational forecasts to those in CLIPER predictions.

Table 3 Mean hitting ratios (%) and radii (km) of 70% probability circles issued for track forecasts for the TCs in 2019

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)
TS	Pabuk	(1901)	90	10	94	100	6	181	100	2	250	-	0	-	-	0	-
TY	Wutip	(1902)	83	30	100	88	26	184	91	22	256	100	18	430	100	14	609
TS	Sepat	(1903)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
TS	Mun	(1904)	25	4	106	-	0	-	-	0	-	-	0	-	-	0	-
TS	Danas	(1905)	57	14	118	20	10	222	17	6	333	0	2	482	-	0	-
TS	Nari	(1906)	0	2	102	-	0	-	-	0	-	-	0	-	-	0	-
TS	Wipha	(1907)	91	11	93	100	6	144	100	2	185	-	0	-	-	0	-
TY	Francisco	(1908)	71	14	82	90	10	144	100	6	241	100	2	426	-	0	-
TY	Lekima	(1909)	80	30	91	54	26	162	68	22	259	61	18	389	79	14	580
TY	Krosa	(1910)	76	37	81	76	33	143	72	29	226	72	25	315	86	21	435
STS	Bailu	(1911)	64	14	101	100	10	176	100	6	284	100	2	482	-	0	-
TS	Podul	(1912)	50	4	125	-	0	-	-	0	-	-	0	-	-	0	-
TY	Lingling	(1913)	65	20	90	75	16	164	83	12	272	88	8	426	100	4	625
TS	Kajiki	(1914)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
TY	Faxai	(1915)	71	17	100	100	12	176	100	7	286	100	3	463	-	0	-
TS	Peipah	(1916)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
TY	Tapah	(1917)	92	12	93	100	8	160	100	3	235	-	0	-	-	0	-
TY	Mitag	(1918)	88	17	89	100	13	152	56	9	235	80	5	348	100	1	519
TY	Hagibis	(1919)	73	26	82	73	22	144	72	18	216	57	14	315	40	10	422
TY	Neoguri	(1920)	31	13	114	0	8	194	0	3	309	-	0	-	-	0	-
TY	Bualoi	(1921)	81	21	86	38	16	144	42	12	232	50	8	315	100	4	532
STS	Matmo	(1922)	100	2	83	-	0	-	-	0	-	-	0	-	-	0	-
TY	Halong	(1923)	77	22	109	83	18	204	100	13	331	44	9	475	40	5	639
TY	Nakri	(1924)	82	17	84	92	13	135	89	9	202	100	5	270	100	1	370
TY	Fengshen	(1925)	33	18	90	14	14	155	44	9	251	80	5	359	100	1	519
TY	Kalmaegi	(1926)	44	18	116	79	14	196	80	10	285	33	6	398	50	2	519
STS	Fung-wong	(1927)	33	6	108	0	2	153	-	0	-	-	0	-	-	0	-
TY	Kammuri	(1928)	43	35	81	61	31	145	67	27	230	70	23	322	79	19	468
TY	Phanfone	(1929)	83	18	82	100	14	128	100	10	204	100	6	278	100	2	370
Annual Mean (Total)			69	432	93	72	328	162	75	237	249	72	159	363	80	98	509

Table 4a Root mean square errors and mean errors of central pressure forecasts for the TCs in 2019

Tropical Cyclone			24-hour Forecast				48-hour Forecast				72-hour Forecast				96-hour Forecast				120-hour Forecast			
			Error (hPa)	RMSE (hPa)	Num.	Impr. (%)	Error (hPa)	RMSE (hPa)	Num.	Impr. (%)	Error (hPa)	RMSE (hPa)	Num.	Impr. (%)	Error (hPa)	RMSE (hPa)	Num.	Impr. (%)	Error (hPa)	RMSE (hPa)	Num.	Impr. (%)
TS	Pabuk	(1901)	-1.6	2.7	10	47	-4.3	5.0	6	42	-5.0	5.8	2	29	-	-	0	-	-	-	0	-
TY	Wutip	(1902)	5.2	14.4	30	29	10.4	17.4	26	36	15.0	18.3	22	35	-	-	0	-	-	-	0	-
TS	Sepat	(1903)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Mun	(1904)	-0.5	1.7	4	77	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Danas	(1905)	-0.9	1.7	14	73	-2.4	3.9	10	69	-1.5	2.6	6	87	-2.0	2.8	2	89	-	-	0	-
TS	Nari	(1906)	4.0	4.0	2	35	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Wipha	(1907)	-0.4	2.8	11	63	0.2	2.5	6	82	-2.0	2.0	2	90	-	-	0	-	-	-	0	-
TY	Francisco	(1908)	1.6	7.1	14	56	-0.3	6.9	10	32	-4.0	7.9	6	56	-17.5	17.7	2	48	-	-	0	-
TY	Lekima	(1909)	4.1	7.9	30	42	5.3	14.9	26	23	11.1	21.3	22	-1	13.2	21.4	18	-5	11.3	14.4	14	0
TY	Krosa	(1910)	-6.3	10.8	37	-14	-12.7	15.4	33	-104	-13.6	16.4	29	-311	-12.5	14.8	25	-274	-9.4	12.7	21	-117
STS	Bailu	(1911)	-2.3	4.7	14	52	-5.1	7.4	10	65	-2.7	6.0	6	81	2.0	2.8	2	92	-	-	0	-
TS	Podul	(1912)	-2.5	2.6	4	78	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Lingling	(1913)	0.9	10.5	20	19	7.2	16.1	16	13	10.0	21.0	12	-24	11.3	14.8	8	-82	10.5	10.5	4	7
TS	Kajiki	(1914)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Faxai	(1915)	7.5	8.6	17	20	13.0	15.5	12	-15	18.9	22.0	7	-96	14.3	15.5	3	33	-	-	0	-
TS	Peipah	(1916)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Tapah	(1917)	2.8	6.5	12	13	2.5	9.0	8	-8	-3.3	5.8	3	-13	-	-	0	-	-	-	0	-
TY	Mitag	(1918)	-4.4	6.1	17	24	-5.1	7.1	13	46	-8.4	10.6	9	46	-12.2	14.0	5	45	-7.0	7.0	1	76
TY	Hagibis	(1919)	1.3	18.2	26	17	1.4	12.9	22	43	-1.7	7.3	18	65	-5.4	7.2	14	66	-14.5	17.5	10	-27
TY	Neoguri	(1920)	6.8	11.8	13	8	19.5	22.4	8	-155	17.3	18.1	3	-43	-	-	0	-	-	-	0	-
TY	Bualoi	(1921)	-4.8	12.2	21	-1	-4.7	11.8	16	28	-8.7	16.4	12	7	-16.9	18.6	8	14	-26.2	26.6	4	9
STS	Matmo	(1922)	4.0	4.5	2	72	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Halong	(1923)	2.5	15.9	22	36	8.4	25.2	18	33	9.3	27.9	13	30	6.8	17.6	9	20	4.6	11.0	5	62
TY	Nakri	(1924)	-4.0	6.6	17	29	-6.8	10.3	13	38	-4.2	8.4	9	51	-5.8	8.8	5	52	-21.0	21.0	1	18
TY	Fengshen	(1925)	2.6	5.6	18	49	4.1	8.2	14	49	5.0	8.0	9	19	5.0	8.7	5	34	-5.0	5.0	1	83
TY	Kalmaegi	(1926)	-0.4	10.4	18	-18	-4.1	14.8	14	-4	2.9	18.3	10	-34	14.7	16.9	6	-69	10.5	16.3	2	-2
STS	Fung-wong	(1927)	-3.5	4.0	6	58	-7.5	8.3	2	55	-	-	0	-	-	-	0	-	-	-	0	-
TY	Kammuri	(1928)	-12.7	17.4	35	-9	-17.0	21.7	31	-10	-21.3	25.5	27	-32	-25.6	29.6	23	-58	-28.8	32.5	19	-73
TY	Phanfone	(1929)	-2.9	11.8	18	11	0.8	12.0	14	39	0.2	7.2	10	65	-5.2	5.3	6	80	-7.0	7.1	2	81
Annual Mean (Total)			-0.8	11.2	432	20	-0.8	15.1	328	21	-0.9	17.6	237	14	-5.1	18.2	141	2	-9.5	20.3	84	-14

Impr. indicates the ratios of RMSEs of operational forecasts to those of SHIFOR predictions.
Five-day tropical cyclone intensity forecast has been operational since 14 March 2019; therefore, T1901 and T1902 that formed before 14 March are not included in this statistics for 96- and 120-hour forecasts.

Table 4b Root mean square errors and mean errors of maximum sustained wind forecasts for the TCs in 2019

Tropical Cyclone			24-hour Forecast				48-hour Forecast				72-hour Forecast				96-hour Forecast				120-hour Forecast			
			Error (m/s)	RMSE (m/s)	Num.	Impr. (%)	Error (m/s)	RMSE (m/s)	Num.	Impr. (%)	Error (m/s)	RMSE (m/s)	Num.	Impr. (%)	Error (m/s)	RMSE (m/s)	Num.	Impr. (%)	Error (m/s)	RMSE (m/s)	Num.	Impr. (%)
TS	Pabuk	(1901)	0.8	1.8	10	43	3.0	3.5	6	-1	2.6	3.6	2	-45	-	-	0	-	-	-	0	-
TY	Wutip	(1902)	-3.3	6.1	30	25	-5.2	7.9	26	33	-7.1	8.2	22	44	-	-	0	-	-	-	0	-
TS	Sepat	(1903)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Mun	(1904)	0.0	0.0	4	100	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Danas	(1905)	1.1	1.7	14	29	1.8	2.4	10	1	1.7	2.1	6	38	1.3	1.8	2	71	-	-	0	-
TS	Nari	(1906)	0.0	0.0	2	100	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Wipha	(1907)	0.5	2.2	11	19	0.4	1.1	6	73	2.6	2.6	2	59	-	-	0	-	-	-	0	-
TY	Francisco	(1908)	-0.2	3.8	14	52	0.8	4.2	10	25	3.4	5.8	6	19	11.6	11.6	2	-4	-	-	0	-
TY	Lekima	(1909)	-2.1	4.8	30	39	-2.4	7.3	26	35	-3.9	9.8	22	28	-4.0	9.6	18	29	-3.7	7.1	14	53
TY	Krosa	(1910)	3.8	5.5	37	-43	6.7	8.1	33	-100	8.8	9.4	29	-228	10.0	10.5	25	-322	9.9	10.8	21	-306
STS	Bailu	(1911)	1.7	3.2	14	26	2.8	4.1	10	45	1.3	3.2	6	67	-1.3	1.8	2	85	-	-	0	-
TS	Podul	(1912)	5.1	5.5	4	18	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Lingling	(1913)	-1.7	5.7	20	6	-4.0	8.2	16	17	-4.7	9.2	12	18	-5.1	6.4	8	18	-4.5	4.6	4	-30
TS	Kajiki	(1914)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Faxai	(1915)	-3.9	4.3	17	3	-6.6	7.2	12	6	-10.7	11.7	7	-69	-12.9	14.0	3	-120	-	-	0	-
TS	Peipah	(1916)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Tapah	(1917)	-1.9	3.9	12	22	-1.6	4.4	8	40	1.7	3.0	3	12	-	-	0	-	-	-	0	-
TY	Mitag	(1918)	2.9	3.4	17	0	3.8	4.3	13	14	5.1	5.6	9	12	8.2	8.5	5	-5	7.7	7.7	1	18
TY	Hagibis	(1919)	-0.3	6.5	26	23	0.5	4.6	22	52	2.0	3.8	18	60	2.9	3.6	14	60	6.7	7.4	10	-23
TY	Neoguri	(1920)	-4.2	6.6	13	10	-12.9	14.1	8	-44	-15.4	15.9	3	-254	-	-	0	-	-	-	0	-
TY	Bualoi	(1921)	0.9	4.8	21	-5	0.8	4.7	16	7	1.7	6.1	12	0	4.2	5.1	8	0	8.4	8.6	4	-52
STS	Matmo	(1922)	-6.4	6.6	2	32	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Halong	(1923)	-0.9	6.2	22	26	-3.0	9.3	18	32	-3.0	9.8	13	33	-3.1	7.9	9	16	-3.6	7.7	5	19
TY	Nakri	(1924)	2.4	3.9	17	5	3.8	5.6	13	12	1.4	5.5	9	0	3.1	4.6	5	-27	12.9	12.9	1	-193
TY	Fengshen	(1925)	-0.6	3.0	18	47	-1.5	4.3	14	49	-2.9	4.4	9	52	-3.1	4.9	5	32	0.0	0.0	1	100
TY	Kalmaegi	(1926)	0.0	7.1	18	-10	1.3	9.4	14	-7	-4.4	11.5	10	-27	-12.0	12.7	6	-24	-11.6	13.2	2	-69
STS	Fung-wong	(1927)	1.3	2.8	6	61	2.6	3.6	2	24	-	-	0	-	-	-	0	-	-	-	0	-
TY	Kammuri	(1928)	3.4	5.5	35	1	5.1	7.2	31	3	6.2	7.3	27	7	7.7	8.7	23	-6	9.6	10.8	19	-29
TY	Phanfone	(1929)	0.6	7.6	18	5	-1.3	9.0	14	6	-1.3	5.6	10	27	1.3	1.8	6	73	3.9	4.1	2	57
Annual Mean (Total)			0.1	5.1	432	17	0.1	7.1	328	17	0.2	8.0	237	16	2.3	8.4	141	2	4.9	9.3	84	-27

Impr. indicates the ratios of RMSEs of operational forecasts to those of SHIFOR predictions.
Five-day tropical cyclone intensity forecast has been operational since 14 March 2019; therefore, T1901 and T1902 that formed before 14 March are not included in this statistics for 96- and 120-hour forecasts.

Table 5 Example of RSMC Tropical Cyclone Advisory

five-day forecast for TDs that are expected to become TS intensity within 24 hours (Subject to change)

Example of a new bulletin for TD expected to become TS intensity within 24 hours	Example of an existing WTPQ5x bulletin for TD expected to become TS intensity within 24 hours
WTPQ50 RJTD 211800 RSMC TROPICAL CYCLONE ADVISORY NAME TD ANALYSIS PSTN 211800UTC 06.9N 139.6E FAIR MOVE WNW 14KT PRES 1002HPA MXWD 030KT GUST 045KT FORECAST 12HF 220600UTC 07.9N 137.6E 45NM 70% MOVE WNW 11KT PRES 1002HPA MXWD 030KT GUST 045KT 24HF 221800UTC 09.2N 135.3E 60NM 70% MOVE WNW 12KT PRES 1000HPA MXWD 035KT GUST 050KT 48HF 231800UTC 10.5N 129.7E 90NM 70% MOVE W 14KT PRES 994HPA MXWD 045KT GUST 065KT 72HF 241800UTC 11.6N 124.0E 140NM 70% MOVE W 14KT PRES 992HPA MXWD 050KT GUST 070KT 96HF 251800UTC 12.5N 119.0E 200NM 70% MOVE W 07KT PRES 990HPA MXWD 055KT GUST 080KT 120HF 261800UTC 13.5N 116.3E 280NM 70% MOVE WNW 07KT PRES 985HPA MXWD 060KT GUST 085KT =	WTPQ50 RJTD 211800 RSMC TROPICAL CYCLONE ADVISORY NAME TD ANALYSIS PSTN 211800UTC 06.9N 139.6E FAIR MOVE WNW 14KT PRES 1002HPA MXWD 030KT GUST 045KT FORECAST 24HF 221800UTC 09.2N 135.3E 60NM 70% MOVE WNW 12KT PRES 1000HPA MXWD 035KT GUST 050KT =

Table 6 Products of RSMC Tokyo via NTP website

Products	Frequency	Details
RSMC Advisories		
RSMC TC Advisory	At least 8 times/day	• RSMC Tokyo – Typhoon Center's TC analysis and forecasts up to 120-hours (linked to the JMA website at https://www.jma.go.jp/en/typh/)
Storm Wind Probability Map	4 times/day	• Probabilistic forecast map for sustained wind upward of 50-kt for 1, 2, 3, 4 and 5 days ahead
Prognostic Reasoning	4 times/day	• RSMC Tokyo Tropical Cyclone Prognostic Reasoning (WTPQ3X)
Operational Remarks		• Advance notice on TC status change from RSMC Tokyo – Typhoon Center
Graphical TC Advisory	4 times/day	• Graphical TC Advisory including RSMC Tokyo – Typhoon Center's TC analysis, track and intensity forecasts up to 24-hours and horizontal extents of cumulonimbus cloud and cloud top height associated with TCs potentially affecting aviation safety (linked to the Tropical Cyclone Advisory Center Tokyo website at https://www.data.jma.go.jp/fcd/tca/data/index.html)
Remote Sensing		
Satellite Analysis	At least 4 times/day	• Results and historical logs of RSMC Tokyo – Typhoon Center's TC analysis conducted using satellite images (Conventional Dvorak analysis and Early-stage Dvorak analysis)
Satellite Imagery	Up to 142 times/day	• Satellite imagery of Himawari-8/9 (linked to the JMA website at https://www.jma.go.jp/en/gms/smallc.html?area=6&element=0&mode=UTC)
Satellite Microwave Products		• TC snapshot images • Warm-core-based TC intensity estimates • Weighted consensus TC intensity estimates made using Dvorak analysis and satellite microwave warm-core-based intensity estimates
Sea-surface AMV (ASWind)	Every 10 / 30 minutes	• AMV-based Sea-surface Wind in the vicinity of TC (linked to Meteorological Satellite Center's web site: http://www.data.jma.go.jp/mscweb/en/product/product/aswind/monitor/aswind.php)
Radar	Every hour	• Radar composite imagery of the Typhoon Committee Regional Radar Network
Atmospheric Circulation		
Weather Charts	4 times/day	• Weather maps for surface analysis, 24- and 48-hour forecasts (linked to the JMA website at https://www.jma.go.jp/en/g3/)
NWP Multi Center Weather Charts	Twice/day	• Mean sea level pressure and 500 hPa Geopotential height (up to 168 hours) of deterministic NWP models from nine centers (BoM, CMA, CMC, DWD, ECMWF, KMA, NCEP, UKMO and JMA)
JMA GSM Analysis and Forecast	4 times/day	• Upper-air analysis and forecast data based on JMA-GSM - Streamlines at 850, 500 and 200 hPa - Divergence at 200 hPa - Velocity potential at 200 hPa - Vertical Velocity in Pressure Coordinate at 500 hPa - Dew Point Depression at 600 hPa - Curvature Vorticity at 850 hPa - Vertical wind shear between 200 and 850 hPa - Sea Level Pressure - Genesis Potential Index
MJO Phase Diagram	Daily	• MJO phase and amplitude diagram and MJO Hovmöller diagram (linked to the Tokyo Climate Center web site: https://ds.data.jma.go.jp/tcc/tcc/products/clisys/mjo/monitor.html https://ds.data.jma.go.jp/tcc/tcc/products/clisys/ASIA_TCC/mjo_cross.html)

Asian Monsoon Monitoring Indices	Daily, only during Apr. - Oct.	• Time series of vertical wind shear, OLR and other indices associated with SW Asian Monsoon (linked to the Tokyo Climate Center web site: https://ds.data.jma.go.jp/tcc/tcc/products/clisys/ASIA_TCC/monsoon_index.html)
Ocean Condition		
SST	Once/day	• Sea surface temperature and related differences from 24 hours ago
TCHP	Once/day	• Tropical cyclone heat potential and related differences from 24 hours ago
Numerical TC Prediction		
Track Bulletin	4 times/day	• RSMC Tokyo Tropical Cyclone Track Forecast Bulletin - Track forecast by GSM (FXPQ2X) - Track forecast by GEPS (FXPQ3X)
TC Track Prediction	4 times/day	• TC track prediction of deterministic NWP models from nine centers (BoM, CMA, CMC, DWD, ECMWF, KMA, NCEP, UKMO and JMA) and a related consensus • TC track prediction of EPS models from four centers (ECMWF, NCEP, UKMO and JMA)
TC Activity Prediction	Twice/day	• Two- and five-day TC activity prediction maps based on EPS models from four centers (ECMWF, NCEP, UKMO and JMA) and a related consensus
Marine Forecast		
Storm Surge Forecasts	4times/day	• Distribution maps of storm surge for RSMC Tokyo – Typhoon Center's TC track forecast and each of five TC track forecasts selected from GEPS ensemble members and maximum storm surge among these six TC track forecasts (up to 72 hours) • Time-series storm surge forecast charts for RSMC Tokyo – Typhoon Center's TC track forecast and each of five TC track forecasts selected from GEPS ensemble members (up to 72 hours)
Ocean Wave Forecasts	Twice/day	• Distribution maps for ensemble mean, maximum, probability of exceeding various thresholds and ensemble spread of wave height and period based on the Wave Ensemble System (WENS) (up to 264 hours) • Time-series representations with box-and-whisker plots for wave height/period and probability of exceeding various wave height/period thresholds based on the WENS (up to 264 hours)

Table 7 Implementation Plans of the RSMC Tokyo - Typhoon Center (2019 - 2023)

PRODUCT	2019	2020	2021	2022	2023	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 Advisories / Bulletins						
RSMC Tropical Cyclone Advisory	———	———	———	———	———	8 times/day Five-day TC intensity forecast has started on 14 March 2019.
SAREP (for tropical cyclones, BUFR)	———	———	———	———	———	8 times/day Position of cloud sytem center, etc. 4 times/day Dvorak intensity
RSMC Prognostic Reasoning	———	———	———	———	———	4 times/day
Operational Remarks	———	———	———	———	———	
RSMC Guidance for Forecast	———	———	———	———	———	4 times/day up to 132 hrs (GSM and GEPS)
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	2019	2020	2021	2022	2023	REMARKS
Attachment Training	———	———	———	———	———	The 20th Training will be conducted in March 2021.
Data archive	———	———	———	———	———	
Monitoring of data exchange	———	———	———	———	———	
Dissemination of products via GISC Tokyo	———	———	———	———	———	

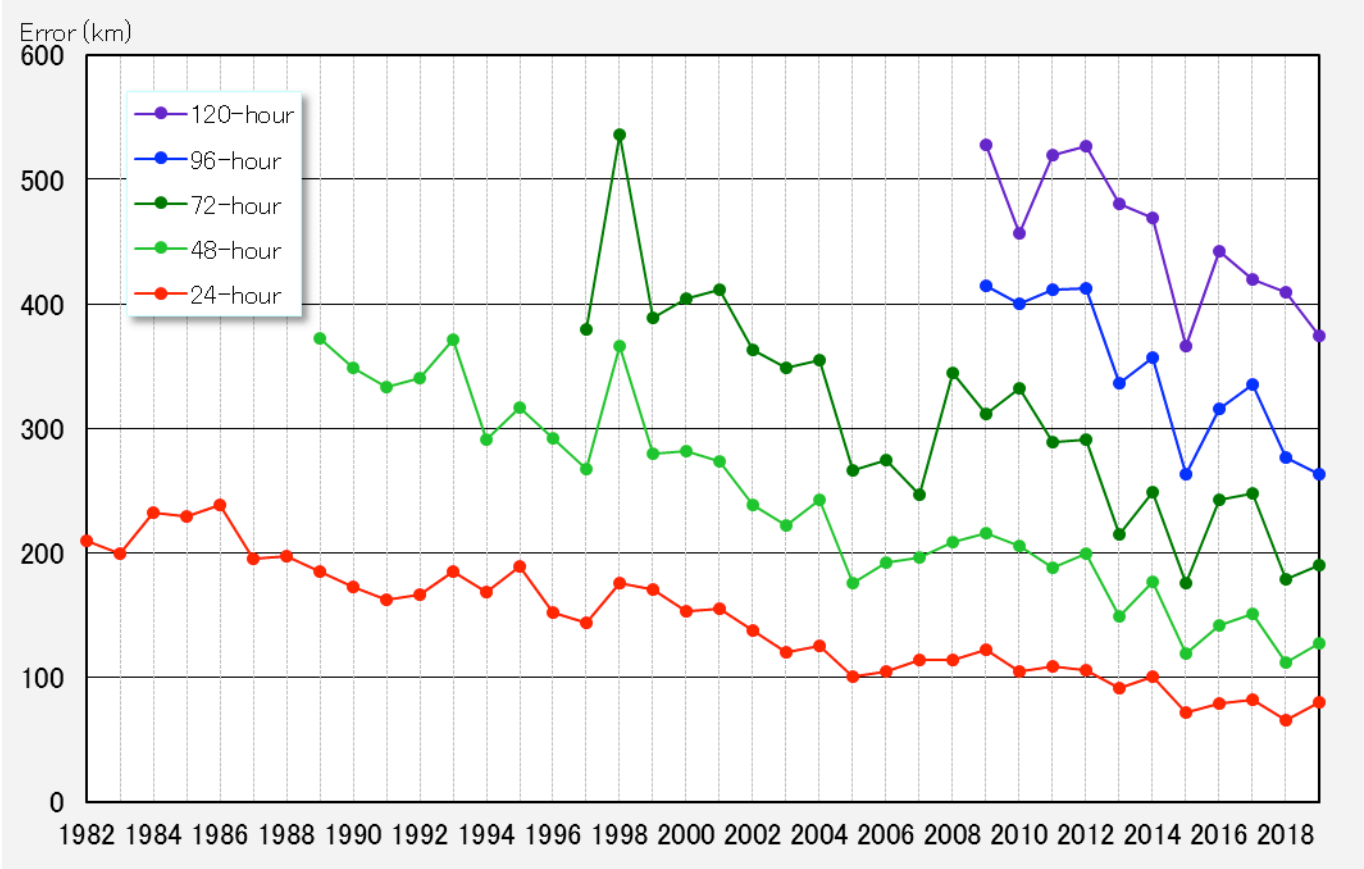

Figure 1 Annual mean position errors of track forecasts

Vertical axis: position error (km), Horizontal axis: year