ESCAP/WMO Typhoon Committee
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FOR PARTICIPANTS ONLY
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ACTIVITIES OF THE RSMC TOKYO - TYPHOON CENTER IN 2023

(Submitted by the RSMC Tokyo - Typhoon Center)

ACTION REQUIRED:

The Committee is invited to review the activities of the RSMC Tokyo - Typhoon Center in 2023 and future plans.

APPENDIXES:

A) DRAFT TEXT FOR INCLUSION IN SESSION REPORT

B) RSMC Tokyo - Typhoon Center Activity Report 2023 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 2023

1. The Committee noted with appreciation the review of RSMC advisories, products and operational activities and changes made in 2023. It noted the forecast verification results for 17 TCs that reached TS intensity or higher formed in 2023: the forecast track errors of the year of 61 km (72 km in 2022), 110 km (124 km), 165 km (172 km), 249 km (195 km) and 356 km (267 km) for 24-, 48-, 72-, 96- and 120-hour forecasts, respectively, the annual mean Root Mean Squared Errors (RMSEs) for central pressure forecasts of 12.8 hPa (13.7 hPa), 16.9 hPa (19.4 hPa), 18.0 hPa (21.3 hPa), 20.6 hPa (19.4 hPa) and 22.1 hPa (15.5 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 (6.3 m/s), 7.2 m/s (8.7 m/s), 7.9 m/s (8.7 m/s), 9.2 m/s (7.7 m/s) and 10.4 m/s (6.0 m/s) respectively.

2. The Committee noted with appreciation the changes made to RSMC advisories, products and operational/coordination activities in 2023, especially the update to probability-circle radii of TC track forecasts.

3. The Committee noted with appreciation the operation of RSMC Tokyo's Numerical Typhoon Prediction (NTP) website, and noted changes made in 2023 as well as those planned for the near future.

4. The Committee noted with appreciation RSMC Tokyo's maintenance of a dedicated platform for enhanced communication between operational forecasters and RSMC-Tokyo, as well as the sharing of advance-notice updates. In the 2023 typhoon season, 13 inquiries relating to tropical cyclones have been submitted, with related discussion helping to clarify TC status and forecasts.

5. The Committee noted with appreciation the contribution of RSMC Tokyo (which also serves as an International Civil Aviation Organization (ICAO) Tropical Cyclone Advisory Centre (TCAC Tokyo)) to compliance with ICAO Standards and Recommended Practices (SARPs), addressing the provision of TCA information in text, graphical and the ICAO Meteorological Information Exchange Model (IWXXM) 3.0 formats via multi-platform channels such as the TCAC Tokyo website.

6. The Committee noted with appreciation the ongoing contribution of RSMC Tokyo to the regional SSWS, especially the provision of various products including storm surge forecast distribution maps and time-series charts for selected stations, as well as week-range probabilistic wave forecasts for significant wave heights and peak wave periods. The Committee again encouraged Members to make their sea level observation data available in order to support verification activity.

7. The Committee welcomes RSMC Tokyo's efforts in seeking further approaches to increase the benefits of ensemble forecast utilization, including improvement of current operational products.

8. The Committee was pleased to note the progress of the regional radar network development project, under which experimental exchange of radar composite data among Japan, Thailand and Malaysia started in 2016. The project has been expanded, and three more Members (Lao PDR, the Philippines and Viet Nam) joined in 2018. Singapore joined the regional radar data exchange in April 2023. The Committee noted with appreciation the progress made on regional radar data exchanges, especially the creation of a sample regional composite map based on Members' radar data.

9. The Committee was pleased to note the activities of the project for enhancing the utilization of Himawari-8/9 products, under which technical support for developing Rapidly Developing Cumulus Area (RDCA) identification using Himawari-8/9 data is provided. The Committee noted with appreciation the ongoing discussion, support and efforts

contributed by project Members (Malaysia, Singapore, Thailand and Vietnam). The Committee also noted that HCAI (High-resolution Cloud Analysis Information) data and AMV-based Sea-surface Wind data are provided to NMHSs every 10 minutes.

10. The Committee noted with appreciation RSMC Tokyo's publication of Technical Review Nos. 25 and 26 in May and December 2023, respectively, and the Annual Report on the Activities of the RSMC Tokyo - Typhoon Center 2022 in January 2024.

11. The Committee was informed that RSMC Tokyo had started tropical cyclone satellite re-analysis in 2012 for the period from 1981 onward to enable evaluation and improvement regarding the quality of the Current Intensity (CI) number in satellite TC analysis. The Committee was also pleased to note that the Center had completed reanalysis along with basic quality checking (QC) for the period from 1987 to 2016 and had begun to share the whole dataset for this period with Members in December 2023.

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

13. The Committee noted with appreciation that RSMC Tokyo had conducted the 23rd Attachment Training course from 15 to 26 January 2024, hosting four forecasters from Lao PDR, Malaysia, the Philippinesand Vietnam, and three (self-funded) from Hong Kong (China), Macao (China) and the Republic of Korea. In accordance with a decision made at the third joint session of the Panel on Tropical Cyclones (PTC) and the Typhoon Committee, the RSMC Tokyo, ESCAP, WMO, and PTC secretariats invited two forecasters from PTC Members: Saudi Araia and Sri Lanka.

14. The Committee noted for RSMC-Tokyo's regular monitoring of observation data exchanges in 2023 as per the Typhoon Committee Operational Manual - Meteorological Component (TOM), with results to be provided by March 2024. The Committee expressed appreciation to all Members providing special observation data to Committee Members in 2023, and further encouraged all Members to conduct additional observation as requested by TOM.

15. The Committee noted with appreciation RSMC Tokyo's contribution to WMO Programmes and related activities, and its promotion of cooperation with other RSMCs for the Tropical Cyclone Programme. These included participation in the Advisory Group on Tropical Cyclones (AG-TC) under the Standing Committee on Disaster Risk Reduction and Public Services (SC-DRR), provision of real-time forecast guidance to Typhoon Committee Members, and contribution to capacity building within the framework of the Severe Weather Forecasting Programme – Southeast Asia (SWFP-SeA) and the Expert Team of Marine Services (ET-MS) under WMO Regional Association II. The Committee also noted with thanks the Center's coordination with adjacent RSMCs for ensuring consistent information delivery across basins.

APPENDIX B:
RSMC Tokyo - Typhoon Center Activity Report 2023 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 Global Telecommunication System (GTS) of World Meteorological Organization (WMO) and the Aeronautical Fixed Telecommunication Network (AFTN). This section reviews RSMC advisories, products and operational activities in 2023 and summarizes changes and future plans.

1.1 Review of RSMC advisories, products and operational activities in 2023

Table 1 shows the total number of RSMC Tropical Cyclone (TC) advisories and information issuances made via GTS in 2023.

✧ **Verification of track forecasts**

Operational track forecasts for 25 TCs that reached Tropical Storm (TS) intensity or higher in 2023 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 61 km (72 km in 2022), 110 km (124 km), 165 km (172 km), 249 km (195 km) and 356 km (267 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. The mean hitting ratios of circles* for 24-, 48-, 72-, 96- and 120-hour forecasts throughout 2023 are 80% (73% in 2022), 76% (72%), 75% (85%), 68% (95%) and 61% (94%), 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 4b 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 17 TCs of 2023. The annual mean RMSEs for central pressure forecasts are 12.8 hPa (13.7 hPa in 2022), 16.9 hPa (19.4 hPa), 18.0 hPa (21.3 hPa), 20.6 hPa (19.4 hPa) and 22.1 hPa (15.5 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 (6.3 m/s in 2022), 7.2 m/s (8.7 m/s), 7.9 m/s (8.7 m/s), 9.2 m/s (7.7 m/s) and 10.4 m/s (6.0 m/s) respectively.

1.2 Changes in RSMC advisories, products and operational activities in 2023

✧ **Update of the probability-circle radii for TC track forecasts**

RSMC Tokyo updated the 70% probability-circle radii in TC track forecasts on RSMC Tokyo's website (https://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/RSMC_HP.htm). Based on recent improvements in forecast accuracy, radii for two days ahead and beyond have been reduced, with those for five days ahead now being up to 40% smaller. The new radii apply to TCs forming after 26th June 2023(Figure 2).

✧

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

✧ **Update to the operational global model**

JMA plans to upgrade its operational Global Spectral Model (GSM) and Global Ensemble Prediction System (GEPS).

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 as part of its contribution to the WMO/ESCAP Typhoon Committee. All the products of the NTP website are listed in Table 5.

2.2 Tropical cyclone advisories for SIGMET in text, graphical and XML formats

As an International Civil Aviation Organization (ICAO) Tropical Cyclone Advisory Centre (TCAC Tokyo), RSMC Tokyo provides tropical cyclone advisories in text, graphical and XML formats, with ICAO Standards and Recommended Practices (SARPs) compliance. TCAs are issued when 1) a tropical cyclone with TS intensity or higher is present in TCAC Tokyo's area of responsibility, or 2) a tropical cyclone is expected to reach TS intensity in the area within 24 hours.

Message details include the following:

✧ Graphical TCAs
- In addition to official RSMC Tokyo TC advisories, TCAs describe areas of cumulonimbus (Cb) associated with tropical cyclones potentially affecting aviation safety as derived from Himawari geostationary satellite data. Graphical TCA information and related specifications are provided via the TCAC Tokyo web resource at https://www.data.jma.go.jp/tca/data/index.html. Graphical TCAs are sent to World Area Forecast Centres (WAFCs) so that they are transmitted through WAFS Internet File Service (WIFS) and Secure Aviation Data Information Service (SADIS) FTP.
- Gale force wind areas are not included for tropical cyclones lower than tropical storm intensity.

✧ ICAO Meteorological Information Exchange Model (IWXXM) 3.0-formatted TCA
- TCAs in a IWXXM form are transmitted via Air Traffic Services (ATS) Message Handling Services (AMHS) and on the TCAC Tokyo website.

TCAC Tokyo contributes to annual ICAO Asia and Pacific (APAC) SIGMET tests by issuing tropical cyclone advisory test messages.

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 (https://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).

As described in 2.1, RSMC Tokyo provides Members with graphical SSWS products via the

NTP website. These include storm surge forecast distribution maps and time-series charts for selected stations (Table 5). To predict storm surges for the regional SSWS, RSMC Tokyo runs a storm surge watch scheme model four times a day, even when no TCs exist in the area of responsibility, providing information on surges generated by monsoon winds or extra-tropical cyclones.

Stations for storm surge time-series predictions have been increased upon requests from the Committee Members. As of January 2024, 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 have been 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) and Global Sea Level Observing System (GLOSS) data base. The verification continues to be enhanced with results for high-impact storm surge cases, in addition to the statistical verification.

As well as storm surge forecast products, RSMC Tokyo provides week-range wave forecast products based on the JMA Wave Ensemble System (WENS) via the NTP website (Table 5). WENS covers most of the global region (grid resolution: 0.5 degrees; ensemble members: 51), running at 00 and 12 UTC daily to predict conditions such as wave height and wave period up to 264 hours ahead.

3.2 Enhanced use of ensemble forecasts

RSMC Tokyo works to enhance operational use of ensemble forecasts by Committee Members. Such forecasts are currently used for:

- ✧ Provision of ensemble TC track guidance from ECMWF, NCEP, UKMO and JMA via the NTP website.
- ✧ Provision of two- and five-day tropical cyclone activity prediction (TCAP) maps displaying percentages of ensemble members in which TC-like vortices are represented within 300 km of a certain location during the relevant forecast time. Provision via the NTP website started in 2016, and accuracy improvement based on parameter-tuning was introduced in 2020 along with addition of climatological normal maps.
- ✧ Probability circles show the range into which the center of a TC is expected to move with 70% probability at each validation time. Since June 2019, the radius for all forecast times has been determined using the multiple ensemble method, which is solely premised on confidence levels based on cumulative ensemble spread calculated using ECMWF, NCEP and UKMO global EPSs in addition to GEPS.

3.3 Development of Regional Radar Network

Development of Regional Radar Network is a project of the Typhoon Committee's Working Group on Meteorology. Technical assistance provided via the project includes development of a domestic radar network, radar data quality control and application of composite as well as quantitative precipitation estimation (QPE) techniques to the nationwide radar network. As a result of activities conducted in collaboration with Thailand and Malaysia (such as participation in technical meetings and workshops), an experimental radar data exchange involving these

nations and Japan was initiated in 2016 and has since expanded in terms of Member numbers. Hourly regional radar composite imagery based on the exchange data is available on the RSMC Tokyo NTP website at https://tynwp-web.kishou.go.jp/Analysis/Radar/index.html.
In 2018, Lao PDR, the Philippines and Viet Nam joined the project, and technical meetings were held at JMA headquarters in 2018 and 2019. Based on the 2019 meeting, a sample regional composite map consisting of participating Members' radar data was produced in 2021 to demonstrate the usefulness of regional radar data exchange. Members at an online technical meeting held in November 2021 reviewed project achievements and highlighted their current situations along with challenges in radar. The discussions underlined the significance of data exchanges within the regional radar network and engagement in technical collaboration. Members also reviewed the current direction and plans for data exchange under the Southeast Asian radar project at workshops in February and October 2023. Coordination for data exchanges between JMA and Members has been ongoing. The Guide to Quantitative Precipitation Estimation (QPE) Program was finalized by Thailand, Malaysia and Japan in July 2022.

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 Himawari-8/9 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, and technical support and communication between Malaysia and RSMC Tokyo has conducted via e-mails.
An online technical meeting was also held with Members from Singapore, Thailand and Viet Nam in February 2020 to give an outline of RDCA detection, including technical aspects and the wide range of usage and verification methods implemented. Members also considered potential RDCA applications and data suitable for verification. In 2021, Japan experts considered future initiatives, including another meeting in February 2022, to promote the adoption of RDCA detection techniques.
Since the 2022 meeting, JMA has provided source code for RDCA detection with Singapore, Thailand and Vietnam, reviewed the development status of each country along with that of Malaysia, and provided support for related activities.

The High-resolution Cloud Analysis Information (HCAI) satellite-derived product based on data from the Advanced Himawari Imager (AHI) units on the Himawari-8/-9 satellites includes information on cloud mask (including dust mask), snow and ice mask, cloud top height, cloud type and quality control. HCAI data are provided to National Meteorological and Hydrological Services (NMHSs) via the JMA Data Dissemination System (JDDS) every 10 minutes in addition to AMV-based Sea-surface Wind data.

3.5 Cross-cutting activities with ICHARM

Enhancement of disaster risk reduction against heavy rain in collaboration with an Annual Operating Plan (AOP) of the Working Group on Hydrology (WGH), led by ICHARM, is undertaken by RSMC Tokyo for the Working Group on the 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. From 2021, RSMC Tokyo has provided one-month and three-month ensemble NWP model data.
In addition, a number of favorable practices related to effective public awareness were adopted in 2023. By way of example, during a prolonged period of heavy rain caused by a stationary front over wide areas of Japan in July, JMA (a meteorological body) and the country's Ministry of Land, Infrastructure and Transportation (a hydrological body) held a joint press conference to call for early evacuation due to the possibility of flooding from large rivers based on rainfall

forecasts, thereby providing a united authoritative front to the public.

4. Publications

4.1 Technical review

RSMC Tokyo published “Upgrade of JMA's Storm Surge Prediction for the WMO Storm Surge Watch Scheme (SSWS) in 2022” in Technical Review No. 25 in May 2023, and “JMA 30-year Dvorak Reanalysis for the Western North Pacific” in No. 26 in December 2023. The information 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 2022 in January 2024, 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 2016 has been completed. RSMC Tokyo started to share the whole dataset for 1987 – 2016 with Members from December 2023.

5.2 Himawari-8/9

JMA's Himawari-8/9 geostationary meteorological satellites are both equipped with optimized Advanced Himawari Imagers (AHIs). The Agency aims to provide a stable and continuous satellite observation with redundancy based on operation of these satellites to support disaster risk reduction in East Asia and the western Pacific until 2029. Himawari-8 was chiefly used for observation from 7 July 2015 onward, with Himawari-9 in a back-up role. These roles were switched on 13 December 2022, placing Himawari-9 in the main observational role and Himawari-8 as back-up. In particular the satellites are expected to support unprecedented prevention and mitigation of tropical cyclone-related disasters in the above target areas. 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.

The 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 the end of December 2023 JMA had taken registrations from 22 NMHSs in RA II and RA V and opened the service to the 19 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.

In March 2023, JMA contracted the manufacture of Himawari-10 as a follow-on to, Himawari-8/9, with initial operation scheduled for FY 2029. Himawari-10 will carry the visible/infrared imager (Geostationary Himawari Imager: GHMI), infrared sounder (Geostationary Himawari Sounder: GHMS). The GHMS is intended to improve JMA's services in extreme weather monitoring, nowcasting and numerical weather prediction. Ongoing evolution is planned for the Himawari satellite series to address universal concerns around climate-related issues such as heavy rain, droughts and floods across East Asia and the Western Pacific.

5.3 Updates to the operational global model

JMA upgraded its Global Spectral Model (GSM) and Global Ensemble Prediction System (GEPS) on 14 March 2023. Enhancements included: increased GSM horizontal resolution (20 to 13 km); a change of the source data set for orographic ancillary files from GTOPO30 to MERIT DEM + RAMP2; revision of physical processes for variables including non-orographic gravity waves, boundary layers, orographic drag and radiation; enhancement for lake surface processing; revision of global snow depth analysis; assimilation of Suomi-NPP and NOAA-20/VIIRS AMVs; and expansion of the two-tiered sea surface temperature approach using the Seasonal Ensemble Prediction System from tropical and sub-tropical oceans to the whole globe for GEPS.

These updates have enhanced the accuracy of typhoon forecasts. The average improvement of typhoon track prediction errors for 2021 typhoons was approximately 6% over a period of 72 hours.

6. Typhoon Committee Attachment Training at RSMC Tokyo

The RSMC Tokyo – Typhoon Center has organized the 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 Member countries of the Panel on Tropical Cyclones have also been hosted since 2015. The course is set as a Category 2 Unit of the Tropical Cyclone Forecast Competency in the Typhoon Committee Region specifications.

The 23rd course was held at JMA Headquarters from 15 to 26 January 2023. The center welcomed Mr. YIP Kai Hou from Hong Kong, China, Ms. Akhom Thamalangs (Lao PDR), Ms. Leong KA Ieng Bowie (Macau, China), Ms. Nur Zu Ira binti Bohari (Malaysia), Ms. Mary Grace M. Castañeda (Philippines), Mr. Myung Sub Shin (Republic of Korea), Ms. Shaikhah Amr Al-Saiary (Saudi Arabia), Mr. Athdath Waduge Susantha Janaka Kumara (Sri Lanka) and Ms. Nguyen Thi Thanh Binh (Vietnam). Researchers and Japanese experts from the Typhoon Committee's Hydro and Disaster Risk Reduction group along with a weathercaster were invited as presenters, with the expectation that the training would give forecasters broader perspectives in the field and contribute to the UN's EW4ALL initiative.

7. Regular monitoring of exchange information

In accordance with the ESCAP/WMO Typhoon Committee Operational Manual (TOM), RSMC Tokyo monitors observational data exchanges twice a year. The state of 2023 exchanges are currently being assessed, with final monitoring results to be circulated by March 2024.

8. Ties with WMO Programmes/activities and tropical cyclone RSMCs

The Advisory Group on Tropical Cyclones (AG-TC) under the Standing Committee on Disaster Risk Reduction and Public Services (SC-DRR) supports the delivery of globally consistent services on tropical cyclones. Representatives of RSMCs and TCWCs, including the RSMC Tokyo – Typhoon Center, attended two meetings held in 2023, and the Group's activities have included submitting recommendations to the third session of the WMO Services Commission (SERCOM-3). The Center also contributes to the Severe Weather Forecasting Programme – Southeast Asia (SWFP-SeA) as a participating organization, providing meteorological data for operational purposes and supporting capacity building. Representatives of the Center attended the Climate Risk and Early Warning Systems (CREWS) / SWFP-SeA In-country Training Workshop on Severe Weather in Cambodia as trainers in October 2023.

The Expert Team on Marine Services (ET-MS) under the Working Group Services initiative of WMO Regional Association (RA) II held a workshop at JMA headquarters in December 2023 to assess the current status of storm surge information in the regions concerned and discuss future directions for service improvement.

The third Joint Session of TC and PTC (February 2015) recommended establishing a cooperative mechanism to promote the transfer of technical expertise between TC and PTC Members. In this regard, a representative from the Center gave a presentation during a forecaster training course held online by RSMC New Delhi in April 2023.

Guidelines on responsibility transfer have been exchanged between RSMC Tokyo and RSMC New Delhi and between RSMC Tokyo and RSMC Honolulu to ensure information delivery when a named tropical cyclone crosses the boundary of each area of responsibility.

9. Implementation plan

Table 6 shows the implementation plan of the Center for the period from 2023 to 2027.

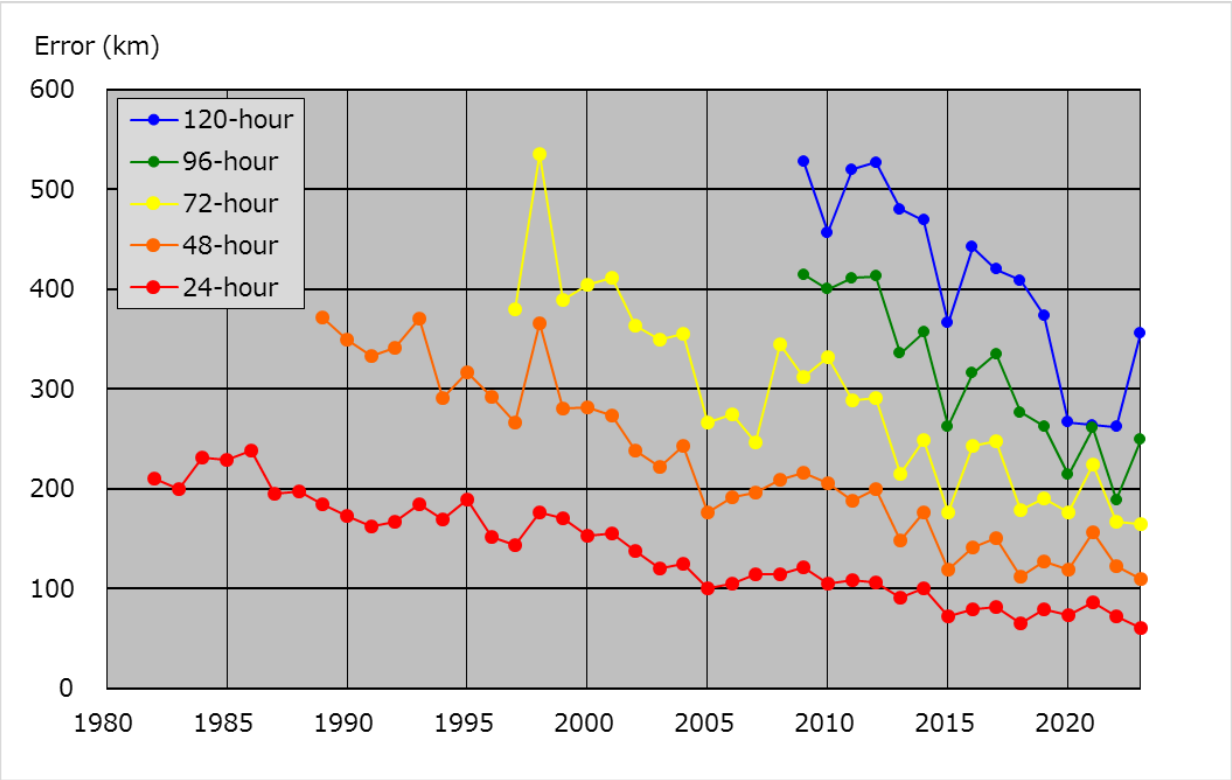

Figure 1 Annual mean position errors of track forecasts
Vertical axis: position error (km), Horizontal axis: year

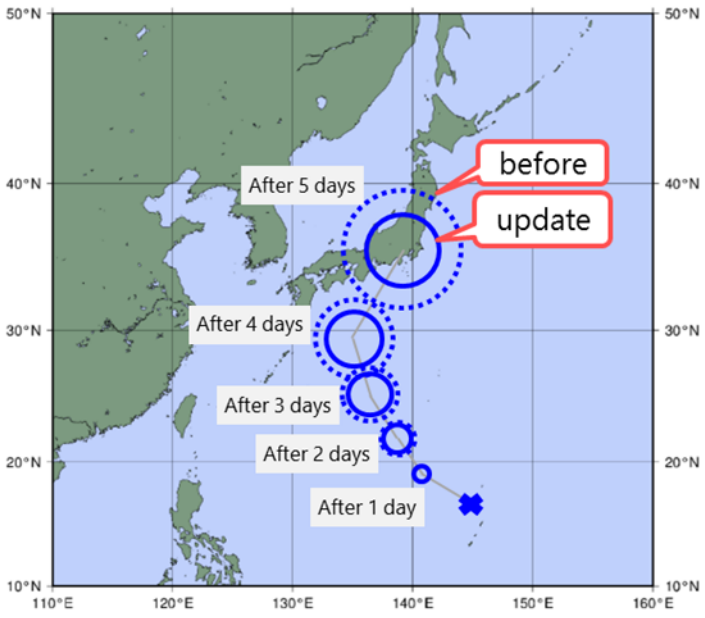

Figure 2: Example of center position and radius of probability circle

Table 1 Monthly and annual total numbers of products issued by the RSMC Tokyo - Typhoon Center in 2023

Product	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
IUCC10	0	0	0	27	96	72	138	336	108	153	4	12	946
WTPQ30-35	0	0	0	19	50	37	77	177	57	80	5	8	510
WTPQ50-55	0	0	0	37	101	76	156	359	118	164	8	17	1036
FXPQ20-25	0	0	0	18	50	37	77	177	57	80	4	8	508
FXPQ30-35	0	0	0	18	50	37	77	177	57	80	4	8	508
FKPQ30-35	0	0	0	18	51	37	77	177	57	80	4	8	509
AXPQ20	9	0	0	0	0	0	1	1	1	3	7	0	22

Notes:

IUCC10 RJTD	SAREP (BUFR format)
WTPQ30-35 RJTD	RSMC Prognostic Reasoning
WTPQ50-55 RJTD	RSMC Tropical Cyclone Advisory
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 2023

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	Sanvu	(2301)	67	21	2	27	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Mawar	(2302)	43	29	50	66	98	43	46	71	158	91	42	75	210	156	38	80	240	237	34	83
TY	Guchol	(2303)	38	23	20	68	90	64	16	71	174	107	12	65	250	86	8	63	406	31	4	9
STS	Talim	(2304)	38	16	9	69	72	24	5	80	170	0	1	81	-	-	0	-	-	-	0	-
TY	Doksuri	(2305)	46	29	28	66	79	41	24	69	144	48	20	43	232	102	16	15	323	133	12	17
TY	Khanun	(2306)	53	42	49	61	101	85	45	73	161	133	41	75	271	158	37	68	419	193	33	59
TY	Lan	(2307)	33	28	33	71	44	26	29	85	68	33	25	85	121	49	21	78	192	74	17	69
TY	Dora	(2308)	71	42	8	57	118	35	4	44	-	-	0	-	-	-	0	-	-	-	0	-
TY	Saola	(2309)	59	26	34	62	100	40	30	73	141	38	26	76	210	69	22	71	307	82	18	63
STS	Damrey	(2310)	52	27	14	85	70	62	10	91	109	30	6	90	320	137	2	75	-	-	0	-
TY	Haikui	(2311)	119	90	25	26	251	144	21	8	385	180	17	12	626	195	13	15	1046	176	9	10
TS	Kirogi	(2312)	139	30	10	46	216	48	6	67	314	45	2	72	-	-	0	-	-	-	0	-
TS	Yun-yeung	(2313)	128	42	8	52	256	81	4	56	-	-	0	-	-	-	0	-	-	-	0	-
TY	Koinu	(2314)	64	34	34	47	107	65	30	68	134	78	26	79	178	78	21	84	215	115	17	86
TY	Bolaven	(2315)	73	59	24	43	148	138	20	61	218	194	16	73	331	247	12	76	597	199	8	72
TS	Sanba	(2316)	98	41	4	53	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Jelawat	(2317)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
Annual Mean (Total)			61	49	352	59	110	91	290	69	165	128	234	72	249	179	190	70	356	264	152	68

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 2023

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	Sanvu	(2301)	100	2	106	-	0	-	-	0	-	-	0	-	-	0	-
TY	Mawar	(2302)	84	50	70	78	46	124	76	42	199	76	38	281	82	34	407
TY	Guchol	(2303)	95	20	67	63	16	118	58	12	194	50	8	280	50	4	426
STS	Talim	(2304)	89	9	80	100	5	148	100	1	222	-	0	-	-	0	-
TY	Doksuri	(2305)	93	28	87	92	24	142	90	20	204	63	16	258	50	12	315
TY	Khanun	(2306)	84	49	76	71	45	123	66	41	182	46	37	244	30	33	312
TY	Lan	(2307)	91	33	70	93	29	126	100	25	203	100	21	282	100	17	360
TY	Dora	(2308)	63	8	103	100	4	164	-	0	-	-	0	-	-	0	-
TY	Saola	(2309)	82	34	81	80	30	145	88	26	218	91	22	276	67	18	342
STS	Damrey	(2310)	100	14	109	100	10	210	100	6	296	50	2	370	-	0	-
TY	Haikui	(2311)	60	25	115	48	21	210	29	17	296	15	13	370	0	9	463
TS	Kirogi	(2312)	10	10	120	50	6	213	50	2	296	-	0	-	-	0	-
TS	Yun-yeung	(2313)	38	8	120	50	4	213	-	0	-	-	0	-	-	0	-
TY	Koinu	(2314)	79	34	93	73	30	160	81	26	231	86	21	295	88	17	383
TY	Bolaven	(2315)	75	24	95	70	20	177	63	16	259	58	12	343	25	8	455
TS	Sanba	(2316)	50	4	96	-	0	-	-	0	-	-	0	-	-	0	-
TS	Jelawat	(2317)	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-
Annual Mean (Total)			80	352	86	76	290	148	75	234	217	68	190	284	61	152	370

Table 4a Root mean square errors and mean errors of central pressure forecasts for the TCs in 2023

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	Sanvu	(2301)	2.0	2.8	2	87	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Mawar	(2302)	3.6	17.8	50	-2	2.8	22.4	46	1	-2.7	21.2	42	-6	-5.1	21.3	38	-10	-3.4	21.6	34	5
TY	Guchol	(2303)	6.0	9.0	20	-8	2.8	7.2	16	42	-6.3	8.5	12	37	-15.6	18.8	8	-25	-21.3	21.9	4	-4
STS	Talim	(2304)	1.1	2.4	9	75	-2.0	3.2	5	70	-25.0	25.0	1	-52	-	-	0	-	-	-	0	-
TY	Doksuri	(2305)	-2.2	10.3	28	41	-0.9	12.0	24	41	0.3	13.2	20	40	4.4	14.9	16	32	0.8	13.1	12	20
TY	Khanun	(2306)	0.4	9.5	49	-6	-1.2	14.4	45	-10	-4.1	17.3	41	-6	-2.6	20.5	37	-27	0.3	24.2	33	-62
TY	Lan	(2307)	0.4	11.7	33	-17	-0.5	13.4	29	8	-4.0	11.8	25	12	-9.8	13.1	21	-55	-10.1	14.1	17	-90
TY	Dora	(2308)	-1.9	7.3	8	72	-4.5	7.5	4	78	-	-	0	-	-	-	0	-	-	-	0	-
TY	Saola	(2309)	5.1	17.9	34	-1	4.0	21.3	30	18	-2.2	19.9	26	24	5.4	22.8	22	24	17.7	26.7	18	27
STS	Damrey	(2310)	-0.6	6.4	14	14	2.4	6.2	10	61	5.7	6.5	6	77	9.5	10.1	2	68	-	-	0	-
TY	Haikui	(2311)	3.2	10.9	25	21	3.6	13.7	21	19	4.8	14.8	17	-5	15.8	19.4	13	-46	15.8	18.8	9	-21
TS	Kirogi	(2312)	-3.2	3.9	10	73	-5.3	6.0	6	84	-4.0	4.0	2	92	-	-	0	-	-	-	0	-
TS	Yun-yeung	(2313)	-2.5	3.2	8	38	-4.5	4.6	4	69	-	-	0	-	-	-	0	-	-	-	0	-
TY	Koinu	(2314)	7.1	13.1	34	28	16.8	21.5	30	-9	19.4	24.9	26	-44	19.2	27.1	21	-90	15.8	28.7	17	-135
TY	Bolaven	(2315)	-3.3	17.1	24	12	-0.5	20.3	20	33	5.9	19.5	16	34	7.1	22.6	12	15	-0.6	15.7	8	18
TS	Sanba	(2316)	-2.0	2.4	4	73	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Jelawat	(2317)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
Annual Mean (Total)			1.8	12.8	352	13	2.5	16.9	290	18	0.7	18.0	234	12	1.5	20.6	190	-6	2.4	22.1	152	-9

Impr. indicates the ratios of RMSEs of operational forecasts to those of SHIFOR predictions.

Table 4b Root mean square errors and mean errors of maximum sustained wind forecasts for the TCs in 2023

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	Sanvu	(2301)	-1.3	1.8	2	76	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TY	Mawar	(2302)	0.3	6.2	50	6	0.6	8.1	46	19	1.9	7.2	42	40	2.6	7.1	38	47	2.7	7.4	34	49
TY	Guchol	(2303)	-1.5	3.8	20	13	-0.5	4.3	16	40	2.6	4.8	12	39	7.1	8.4	8	-56	10.3	10.4	4	-613
STS	Talim	(2304)	0.3	1.9	9	53	2.1	3.3	5	23	15.4	15.4	1	-1011	-	-	0	-	-	-	0	-
TY	Doksuri	(2305)	0.6	4.3	28	39	-0.4	5.6	24	43	-0.5	4.9	20	61	-3.2	7.0	16	49	-1.5	5.9	12	47
TY	Khanun	(2306)	1.6	5.0	49	-5	2.6	7.3	45	9	4.1	8.8	41	7	4.0	10.3	37	-13	2.3	12.9	33	-75
TY	Lan	(2307)	-0.7	5.1	33	-1	-1.1	6.0	29	28	-0.6	5.5	25	41	1.6	4.9	21	40	1.8	4.3	17	31
TY	Dora	(2308)	1.0	6.0	8	65	4.5	6.7	4	64	-	-	0	-	-	-	0	-	-	-	0	-
TY	Saola	(2309)	-1.4	5.6	34	31	-0.9	6.5	30	49	1.1	6.6	26	54	-0.7	8.9	22	47	-5.7	12.1	18	40
STS	Damrey	(2310)	-0.4	3.1	14	12	-1.3	3.4	10	41	-3.0	3.5	6	63	-5.1	5.8	2	48	-	-	0	-
TY	Haikui	(2311)	2.6	5.3	25	13	1.2	5.3	21	31	0.3	5.4	17	25	-5.9	7.1	13	4	-5.4	7.5	9	1
TS	Kirogi	(2312)	2.6	3.6	10	45	3.9	5.0	6	68	2.6	2.6	2	88	-	-	0	-	-	-	0	-
TS	Yun-yeung	(2313)	1.6	2.0	8	-6	3.2	3.4	4	32	-	-	0	-	-	-	0	-	-	-	0	-
TY	Koinu	(2314)	-3.5	6.0	34	10	-8.7	11.4	30	-10	-11.5	13.9	26	-15	-12.2	15.8	21	-30	-11.3	16.1	17	-41
TY	Bolaven	(2315)	0.6	6.0	24	-2	-0.4	7.2	20	26	-2.3	6.6	16	43	-3.0	8.1	12	35	1.0	6.0	8	37
TS	Sanba	(2316)	2.6	3.2	4	-31	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
TS	Jelawat	(2317)	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-	-	-	0	-
Annual Mean (Total)			0.1	5.1	352	17	-0.4	7.2	290	26	-0.2	7.9	234	30	-0.6	9.2	190	22	-0.8	10.4	152	14

Impr. indicates the ratios of RMSEs of operational forecasts to those of SHIFOR predictions.

Table 5 Products of RSMC Tokyo via the 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/bosai/map.html#contents=typhoon&lang=en)
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)
Advance Notice		• Advance notice on TC status change from RSMC Tokyo – Typhoon Center *Supplemental information to RSMC advisories (It may not be provided in certain situations and should not be considered as an official RSMC advisory and/or its replacement)
TC Advisory	4 times/day	• TC Advisory in text, graphical and xml formats 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/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/bosai/map.html#contents=himawari&lang=en)
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: https://www.jma.go.jp/jma/jma-eng/satellite/jdds.html)
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/bosai/weather_map/#lang=en)
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 intensity (TIFS monitor)	4 times/day	• TIFS (Typhoon Intensity Forecast scheme based on SHIPS) Monitor
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
TC Verification	4 times/day	• Verification results of RSMC Tokyo's official forecasts as well as NWP model and guidance predictions
Marine Forecast		
Storm Surge Forecasts	4 times/day	• Distribution of storm surge for RSMC Tokyo – Typhoon Center TC track forecasts and probabilistic products (ensemble mean, maximum, third quartile, spread and exceeding probabilities) of storm surge EPS from GEPS ensemble members (up to 132 hours) • Time-series storm surge forecast charts (plume diagrams, box plots and exceeding probabilities) for RSMC Tokyo – Typhoon Center TC track forecasts and 51 TC track forecasts from GEPS ensemble members (up to 132 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 Wave Ensemble System (WENS) (up to 264 hours) • Time-series representations with box plots for wave height/period and probability of exceeding various wave height/period thresholds based on WENS (up to 264 hours)

Table 6 Implementation Plans of the RSMC Tokyo - Typhoon Center (2023 - 2027)

PRODUCT	2023	2024	2025	2026	2027	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
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
RSMC Guidance for Forecast						4 times/day up to 132 hrs (GSM and GEPS)
Web-based RSMC Advisories / Products						
Numerical Typhoon Prediction Website						
Tropical Cyclone Advisory in text, graphical and XML formats						
Experimental CAP Tropical Cyclone Advisory						
Others						
RSMC Tropical Cyclone Best Track						
Annual Report						Publication
Technical Review						Publication (as necessary)
Tropical Cyclone Reanalysis						
Communication platform						(Full operation started in 2021)

SUPPORTING ACTIVITY	2023	2024	2025	2026	2027	REMARKS
Attachment Training						The 24th training course will be conducted in 2025 1Q.
Data archive						
Monitoring of data exchange						
Dissemination of products via GISC Tokyo						