# MEMBER REPORT Singapore

ESCAP/WMO Typhoon Committee 19<sup>th</sup> Integrated Workshop Shanghai, China 19 - 22 November 2024

# CONTENTS

# I. Overview of tropical cyclones which have affected/impacted Member's area since the last Committee Session

- 1. Meteorological Assessment (highlighting forecasting issues/impacts)
- 2. Hydrological Assessment (highlighting water-related issues/impact)
- 3. Socio-Economic Assessment (highlighting socio-economic and DRR issues/impacts)
- 4. Regional Cooperation (highlighting regional cooperation and related activities)

# **II. Summary of Progress in Priorities supporting Key Result Areas**

- 1. Hydrological Monitoring and Flood Management
- 2. Data-Driven Probabilistic Rainfall Forecast Guidance for Singapore
- 3. ASEAN Climate Outlook Forum (ASEANCOF) and the Southeast Asia Regional Climate Centre Network (SEA RCC-NETWORK)
- 4. Capability-Building Programme in Subseasonal-to-Seasonal Predictions for Southeast Asia (S2S-SE)
- 5. Singapore's Third National Climate Change Study (V3)
- 6. ASMC-WMO Regional Forum 2024

# I. Overview of tropical cyclones which have affected/impacted Member's area since the last Committee Session

## 1. Meteorological Assessment (highlighting forecasting issues/impacts)

Tropical cyclone activities in the western Pacific Ocean or South China Sea may modify the large-scale monsoonal circulation, thereby influencing the weather patterns in Singapore and the surrounding region. On some occasions, the presence of strong tropical cyclones may bring dry air masses from the Indian Ocean or the Java Sea and suppress the development of rain clouds, leading to fair and warm weather conditions over Singapore.

In the second half of July 2024, Singapore experienced a dry spell<sup>1</sup> of 18 days between 13 and 30 July 2024. During this period, three tropical depressions/storms developed in the South China Sea, in particular, one developed into Super Typhoon Gaemi between 19 and 29 July, which impacted East China and the Philippines. The intensification of both Severe Tropical Storm Prapiroon and Super Typhoon Gaemi induced a strong cross equatorial flow dominating the maritime continent (Figure 1). Consequently, Singapore experienced persistent dry weather conditions, which was exacerbated by the presence of dry air mass drifted from the Indian Ocean and the Java Sea. With little rainfall from around mid-July, many areas across the island registered well below average rainfall (Figure 2).



<sup>&</sup>lt;sup>1</sup> A dry spell is defined as a period of at least 15 consecutive days with daily total rainfall of less than 1.0 millimetre (mm), averaged over islandwide stations with long-term records. The last recorded dry spell in Singapore lasted 17 days from 31 July to 16 August 2019.



Figure 1: Cross equatorial flow in the Maritime Continent as shown by winds at 925hPa from ECMWF 00UTC Analysis during the passage of three storms.



Figure 2: Rainfall anomaly for the period of 16 - 31 July 2024 (left) and 1 - 31 July 2024 (right)

- 2. Hydrological Assessment (highlighting water-related issues/impact) Nil.
- 3. Socio-Economic Assessment (highlighting socio-economic and DRR issues/impacts) Nil.
- 4. Regional Cooperation (highlighting regional cooperation and related activities) Nil.

# **II.** Summary of Progress in Priorities supporting Key Result Areas

# 1. Hydrological Monitoring and Flood Management

#### Main text:

Real-time water level and CCTV monitoring are essential sensors for flood operations in Singapore. Currently, there are more than 1000 water level sensors installed in various waterways around Singapore for monitoring by the Public Utilities Board (PUB), Singapore's national water agency. These water level sensors provide real-time data on water levels in drains and canals, enabling the monitoring of site conditions during heavy rainfall and informing on the flood risk in the various locations. SMS alerts are issued automatically to PUB officers when water level rises above certain thresholds, and SMS alerts from selected water level sensors are available for public subscription to provide early warning on potential flash floods. PUB has also launched a Flood Alerts Telegram channel for the public, to provide heavy rain alerts (from Meteorological Service Singapore) as well as flood risk alerts based on water level sensor measurements.

The water level sensors are complemented by a network of more than 500 CCTVs to provide up-todate visuals of the conditions at various locations, in particular at locations with potential flood risk such as low-lying areas and past flooded locations.

PUB has in recent years enhanced its flood response and rainfall forecasting capabilities. These include rolling out new flood response vehicles (as part of Quick Response Teams for floods) which are better equipped to drive through floodwaters, and the use of a rainfall nowcasting system incorporating X-band radars to provide rainfall forecasts at street-scale resolution up to 90-minute lead time. The system is currently able to achieve 74% accuracy in terms of probability of detection (POD) for the 30-minute lead time forecasts at 500m resolution.

The rainfall forecasts complement the monitoring of real-time site conditions with the use of water level sensors and CCTVs, enabling PUB to deploy its Quick Response Teams early to where there could be potential flooding, to keep the public out of harm's way.

Meanwhile, PUB's flood response vehicles can wade through water 70cm deep, slightly above knee level, and are fitted with a Global Positioning System tracker and cameras that live-stream footage back to PUB's Joint Operations Centre. They also carry flood mitigation equipment such as portable flood barriers that officers on board can deploy to divert floodwaters from roads so that traffic remains passable or render assistance to affected home/business owners.

PUB is now working towards further improving the accuracy of rainfall forecasts in terms of POD and quantitative precipitation forecasts (QPF), as well as addressing the forecasting of convective rainfall events which can form quickly and bring about intense rainfall. With better QPF, the rainfall forecasts can subsequently help to improve parallel efforts by PUB on the development of flood models and machine learning models to provide forecasted flood maps, as well as forecasted water level and discharge in the waterways, to further enhance flood and reservoir operations for flood management.



Figure 3: Interactive map of water level sensors data available to the general public



Figure 4: Interactive map of CCTVs (left) and sample real-time CCTV image (right)

#### Identified opportunities/challenges, if any, for further development or collaboration:

There is ongoing effort to explore the development of composite radar datasets, which incorporate MSS S-band & C-band radars with PUB's X-band radar data, to further enhance rainfall forecasting for Singapore.

#### **Priority Areas Addressed:**

Meteorology

• Enhance the capacity to monitor and forecast typhoon activities particularly in genesis, intensity, and structure change.

<u>Hydrology</u>

• Improve typhoon-related flood (including riverine flood, flash flood, urban flood, and coastal flood) monitoring, data collection and archiving, quality control, transmission, processing, and sharing framework.

#### Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please 🗸 the
	related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	1
Warning dissemination and communication	1
Preparedness and response capabilities	1

#### **Contact Information:**

Member: Singapore Name of contact for this item: Mr. YAU Wing Ken Telephone: +65-67313212 Email: yau\_wing\_ken@pub.gov.sg

# 2. Data-Driven Probabilistic Rainfall Forecast Guidance for Singapore

#### Main text:

Despite advances in NWP, rainfall forecasting remains a key challenge for Singapore. Deterministic NWP rainfall forecasts do not capture the uncertainties associated with convective processes in the deep tropics, while probabilistic information derived from NWP ensembles may be unreliable due to limitations on ensemble sizes. To address this challenge, MSS is developing AI/ML rainfall prediction models across spatial and time scales to complement existing NWP systems.

One potential application involves using machine-learned regional synoptic weather patterns to constrain rainfall forecasts. Characteristic patterns of moisture and wind in the region around Singapore at 0 UTC have been identified by means of a self-organising map (SOM) and K-means clustering of ERA5 reanalysis data. Regional and local rainfall observations were then stratified according to the synoptic patterns identified. Potentially useful probabilistic information, such as the probability of heavy rain (Figure. 5) or the range of rainfall associated with each weather regime (Figure. 6), may be extracted from this stratified rainfall observation dataset. Compared to NWP, this is a computationally inexpensive method of producing probabilistic rainfall forecast guidance.



Figure 5: Probabilities of rainfall in the region surrounding Singapore associated with typical weather patterns of moisture and wind.



Figure 6: Three-hourly rainfall (range) in Singapore associated with typical weather patterns.

#### Identified opportunities/challenges, if any, for further development or collaboration:

Better uncertainty estimates for rainfall arising from this study can help guide operational meteorologists and other stakeholders on the range of possible scenarios under each weather regime. Further work is necessary to ascertain the value of this data-driven probabilistic information on top of NWP ensemble forecasts and to improve its usability.

#### **Priority Areas Addressed:**

Meteorology

• Develop and enhance typhoon analysis and forecast techniques from nowcast to mediumrange, and seasonal to long-range prediction.

#### Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please 🗸 the
	related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	1
Warning dissemination and communication	
Preparedness and response capabilities	

#### **Contact Information:**

Member: Singapore Name of contact for this item: Dr. Peter HENG Telephone: +65 6241 6485 Email: peter\_heng@nea.gov.sg

# 3. ASEAN Climate Outlook Forum (ASEANCOF) and the Southeast Asia Regional Climate Centre Network (SEA RCC-NETWORK)

#### Main text:

#### a. ASEANCOF

#### Background

The ASEAN Climate Outlook Forum (ASEANCOF) was established in 2013, following the support at the 35th Meeting of the ASEAN Sub-Committee on Meteorology and Geophysics (ASCMG, July 2013). ASEANCOF provides collaboratively developed and consensus-based seasonal climate outlooks and related information on a regional scale, including risk assessment of heightened tropical cyclone activities and the associated atmospheric circulation anomalies. These activities support decision-making to manage climate-related risks and support sustainable development. The hosting of ASEANCOF sessions is rotated among ASEAN Member States and supported by the Meteorological Service Singapore (MSS), as host of the ASEAN Specialised Meteorological Centre (ASMC).

#### ASEANCOF-22 meeting

The most recent ASEANCOF-22 meeting was conducted as a hybrid session for the June-August (JJA) summer monsoon season of 2024. The forum was hosted by the Lao PDR's Department of Meteorology and Hydrology, with support from RIMES, MSS/ASMC, the UK Met Office, and WMO. The forum consisted of two days pre-COF training, where the UK Met Office conducted training on the basics of seasonal prediction, followed by RIMES on the use of the seasonal prediction tool: FOCUS (the training was in-person only). During the training, discussions were held on further implementation of objective outlooks in ASEANCOF. The following two days were conducted in a hybrid session, with presentations on the national and global outlooks by the ASEAN NMHSs and select GPCs, presentation of the ASEANCOF consensus outlook, and presentations and discussion sessions by climate information users around ASEANCOF-22's theme of climate services for The ASEANCOF-22 Consensus agriculture. Outlook was published late Mav 2024 (https://asmc.asean.org/events-twenty-second-session-of-the-asean-climate-outlook-forumaseancof-22/). From the report, for JJA 2024 tropical cyclone frequency was predicted to be below average around the Philippine Sea and the Bay of Bengal, and near average around South China Sea.

The next session, ASEANCOF-23, will be held at the end of November 2024 in online format, and will include a review of the ASEANCOF-22 outlook.

Detailed meeting reports are available at <u>http://asmc.asean.org/asmc\_asean\_conf\_about/</u>

## b. SEA RCC-Network

The Southeast Asia Regional Climate Centre Network (SEA RCC-Network) is an operational platform for delivery of climate services. The Network complements the ASEANCOF, which is primarily a platform for sharing best practices and improving the process of consensus-building for climate outlooks. An RCC-Network for the region was first proposed at the WMO RA V 16th Session (Jakarta, May 2014), and covers ten Southeast Asian countries in two WMO Regional Associations (RA), RA II and RA V. The SEA RCC-Network entered the demonstration phase in November 2017.

As a group of centres (nodes), the SEA RCC-Network collectively fulfils the four mandatory functions of an RCC, namely long-range forecasting led by Singapore (MSS), climate monitoring led by the Philippines (PAGASA), operational data services led by Indonesia (BMKG), and training led

by all three partners. Singapore is the current coordinator of the Network. Within the monitoring and long-range forecasting functions, assessments of tropical cyclone activities are included as deliverables by either the lead node or a contributing consortium member.

Following the start of the demonstration phase for the SEA RCC-Network, the 3 nodes have since provided pilot products for long-range forecast, climate data services, and monitoring through their respective portals. These sites can be accessed from the recently updated main page of the SEA RCC-Network (<u>https://www.mss-int.sg/sea-rcc-network/</u>). Since the demonstration phase, monthly climatology for TC tracks and a two-week outlook are included on the website (<u>https://www.mss-int.sg/sea-rcc-network/long-range-forecasting/tropical-cyclone/fortnightly-outlook</u>) provided by PAGASA. In 2023, the domain of the TC outlook was expanded to include more of the Bay of Bengal, to better support western Mainland Southeast Asia. The expansion of the TC track climatology to cover all Southeast Asia is still pending. The SEA RCC-Network has also implemented a Climate Watch System. This Climate Watch initially focuses on the 1-month SPI, however, is expected to be expanded to other variables, including heightened risk of TC development, in the future.

#### Identified opportunities/challenges, if any, for further development or collaboration:

With the incorporation of objective seasonal outlooks in ASEANCOF, this provides the opportunity to improve the seasonal outlooks, including additional tailored products for the region. However, this shift requires all NMHSs in the region to be involved in the process, which in turn requires training. Training during ASEANCOF-22 highlighted some reluctance in moving towards a more objective seasonal outlook, partly related to the current ASEANCOF outlooks outperforming the initial MME (with regard to rainfall and temperature prediction).

#### **Priority Areas Addressed:**

Meteorology

• Develop and enhance typhoon analysis and forecast techniques from nowcast to mediumrange, and seasonal to long-range prediction.

Kev	<b>Pillars</b> of	f UN's Earl	v Warnings	for All (	(EW4All	) Initiative Addressed:
	1 11161 5 01		, ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	IVI INII (		, inductive readinessed.

Key Pillars of EW4All	Please 🗸 the
	related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	<i>√</i>
Warning dissemination and communication	
Preparedness and response capabilities	

#### **Contact Information:**

Member: Singapore Name of contact for this item: Dr. Thea TURKINGTON Telephone: +65 6488 1850 Email: thea\_turkington@nea.gov.sg

# 4. Capability-Building Programme in Subseasonal-to-Seasonal Predictions for Southeast Asia (S2S-SEA)

## Main text:

MSS, as host of the ASEAN Specialised Meteorological Centre (ASMC), conducts a Capability-Building Programme in Subseasonal-to-Seasonal Predictions for Southeast Asia (S2S-SEA). S2S-SEA is a multi-year series of workshops to equip the NMHSs with the knowledge and skills to deliver S2S predictions to end-users. The S2S predictions typically span timescales of 2 weeks to 2 months and has the potential to provide warnings for extreme rainfall events, caused by tropical storms or otherwise, but requires further studies.

During the final S2S SEA workshop (S2S SEA IV in August 2023), participants discussed the usefulness of continued discussion on S2S predictions. The ASMC Fortnightly discussion session was proposed: 30-minute discussion every two weeks covering a review of the previous regional S2S outlook, high impact events, relevant climate drivers, and the outlook for the upcoming two weeks (including predicted tropical cyclone activity).

#### Identified opportunities/challenges, if any, for further development or collaboration:

The ASMC fortnightly discussion session around subseasonal prediction is being trialed every second Wednesday. Potential for a small number of additional participants to join.

#### **Priority Areas Addressed:**

Meteorology

• Develop and enhance typhoon analysis and forecast techniques from nowcast to mediumrange, and seasonal to long-range prediction.

#### DRR

• Enhance Members' disaster risk reduction techniques and management strategies.

# Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	
Detection, observation, monitoring, analysis, and forecasting	<i>√</i>
Warning dissemination and communication	
Preparedness and response capabilities	

#### **Contact Information:**

Member: Singapore Name of contact for this item: Dr Thea TURKINGTON Telephone: +65 6488 1850 Email: <u>thea turkington@nea.gov.sg</u>

# 5. Singapore's Third National Climate Change Study (V3)

## Main text:

The Centre for Climate Research Singapore (CCRS), under MSS, released the findings of the Third National Climate Change Study (V3) in January 2024. Based on a selected set of global climate models from IPCC AR6, V3 downscales the projections to higher resolutions of 8km over Southeast Asia and 2km over Singapore using CCRS' customised Regional Climate Model. V3 projects higher temperatures, more wet and dry extremes, and accelerating increase in mean sea levels for Singapore and Southeast Asia by the end of the century. V3 data forms the basis for deeper research in climate impacts science for Singapore, including the areas of sea level rise, water resources and flood management to strengthen flood and coastal resilience. MSS is making available the data and findings of V3 to ASEAN member states. This is in line with one of ASMC's roles in supporting the scientific understanding and prediction of climate change and its impacts within the Southeast Asia region. More information about V3 reports can be found at <u>https://www.mss-int.sg/v3-climate-projections</u>.

#### Identified opportunities/challenges, if any, for further development or collaboration:

The V3 result can be harnessed by the ASEAN member states for improving resilience against coastal protection (including storm inundation risk and storm surge), extreme rainfall and flooding in relation to climate change. New opportunities to collaborate with the ASEAN region and beyond in making use of V3 climate projections for the region through collaborations of mutual interest are welcomed.

## **Priority Areas Addressed:**

Hydrology

• Develop capacity in projecting the impacts of climate change, urbanization and other human activities on typhoon-related flood disaster vulnerability and water resource availability.

#### Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please 🗸 the
	related pillar(s)
Disaster risk knowledge and management	<i>✓</i>
Detection, observation, monitoring, analysis, and forecasting	
Warning dissemination and communication	
Preparedness and response capabilities	1

#### **Contact Information:**

Member: Singapore Name of contact for this item: Dr. Sandeep SAHANY Telephone: +65 9372 1553 Email: <u>sandeep\_sahany@nea.gov.sg</u>

# 6. ASMC – WMO Regional Forum 2024

## Main text:

MSS, as the host of The Association of Southeast Asia Nations (ASEAN) Specialized Meteorological Centre (ASMC), and WMO jointly organised the inaugural ASMC - WMO Regional Forum in Singapore, from 4 to 6 September 2024. Titled "Towards a Weather-Ready and Climate-Resilient ASEAN", the Forum brought together global, regional and national leaders and partners from across the climate services value chain to focus on how climate services, including high-resolution regional climate projections and early warning systems, can better support climate change adaptation and disaster risk reduction in Southeast Asia. The Forum also discussed how effective and inclusive early warning systems can mitigate the impact of extreme weather and climate events, especially in light of the Early Warnings for All (EW4All) initiative. Key highlights of the Forum included:

- Deep dive into findings relevant to Southeast Asia from the 2023 WMO State of the Climate Reports for the South-West Pacific and Asia, with keynote address by Prof. Celeste Saulo, Secretary-General of the WMO and panel discussion on supporting ASEAN member states in translating climate information into actions.
- Keynote presentations on climate change projections for Southeast Asia and the United Nations Early Warnings for All (EW4All) initiative
- Technical Forums on Adapting to Climate Change in Southeast Asia, and Early Warning Systems as an Adaptive Measure: Panellists discussed about the current challenge and disaster riskscape in the Southeast Asia, the opportunity and on supports for NMHSs and ASEAN Member States in achieving EW4All.

A report by WMO on the forum can be found here: <u>https://wmo.int/media/news/towards-weather-ready-and-climate-resilient-asean</u>



Figure 8: (From left) Prof. Celeste Saulo, WMO Secretary-General; Ms Grace Fu, Singapore's Minister for Sustainability and the Environment and Minister-in-charge of Trade Relations; Ms Koh Li-Na, Assistant Chief Executive/Director General Meteorological Service at the opening of the ASMC-WMO Regional Forum on 4 September 2024.

#### Identified opportunities/challenges, if any, for further development or collaboration:

The Forum provided a platform for regional collaboration in climate change adaptation and disaster risk reduction, including the implementation of hydrology-related projects and achieving EW4All. Implication of climate change on tropical cyclone activity and extreme rainfall events in the Southeast Asia region could be explored at similar platforms in the future.

#### **Priority Areas Addressed:**

DRR

- Enhance Members' disaster risk reduction techniques and management strategies.
- Promote international cooperation of DRR implementation project.

#### Key Pillars of UN's Early Warnings for All (EW4All) Initiative Addressed:

Key Pillars of EW4All	Please ✓ the related pillar(s)
Disaster risk knowledge and management	1
Detection, observation, monitoring, analysis, and forecasting	<i>√</i>
Warning dissemination and communication	<i>√</i>
Preparedness and response capabilities	<i>√</i>

#### **Contact Information:**

Member: Singapore Name of contact for this item: Mr. CHONG Wei Ming Telephone: +65-65457195 Email: CHONG\_Wei\_Ming@nea.gov.sg

# Appendix I - Priority Areas of Working Groups for the Strategic Plan 2022-2026

WG	Priorities
	1. Strengthen the cooperation between TRCG, WGM, WGH, and WGDRR to
	develop impact-based forecasts, decision-support and risk-based warning.
TANAL	2. Strengthen cross-cutting activities among working groups in the Committee.
Integrated	3. Enhance collaborative activities with other regional/international
	frameworks/organizations, including technical cooperation between TC/AP-TCRC
	and TC/PTC cooperation mechanism.
	4. Enhance the capacity to monitor and forecast typhoon activities particularly in
	genesis, intensity and structure change.
	5. Develop and enhance typhoon analysis and forecast techniques from nowcast to
	medium-range, and seasonal to long-range prediction.
	6. Enhance and provide typhoon forecast guidance based on NWP including
	ensembles, weather radar and satellite related products, such as QPE/QPF.
Meteorology	7. Promote communication among typhoon operational forecast and research
	communities in Typhoon Committee region.
	8. Enhance training activities with TRCG, WGH, and WGDRR in accordance with
	Typhoon Committee forecast competency, knowledge sharing, and exchange of
	latest development and new techniques.
	9. Enhance RSMC capacity to provide regional guidance including storm surge, in
	response to Member's needs.
	10. Improve typhoon-related flood (including riverine flood, flash flood, urban
	flood, and coastal flood) monitoring, data collection and archiving, quality control,
	transmission, processing, and sharing framework.
	11. Enhance capacity in typhoon-related flood risk management (including land-
	use management, dam operation, etc.) and integrated water resources management
	and flood-water utilization.
Hudualaan	12. Strengthen capacity in effective flood forecasting and impact-based early
Hydrology	warning, including hazard mapping and anticipated risk based on methodological
	and hydrological modelling, and operation system development.
	13. Develop capacity in projecting the impacts of climate change, urbanization and
	other human activities on typhoon-related flood disaster vulnerability and water
	resource availability.
	14. Increase capacity in utilization of advanced science and technology for
	typhoon-related flood forecasting, early warning, and management.
	15. Provide reliable statistics of mortality and direct disaster economic loss caused
DRR	by typhoon-related disasters for monitoring the targets of the Typhoon Committee.
	16. Enhance Members' disaster risk reduction techniques and management
	strategies.
	17. Evaluate socio-economic benefits of disaster risk reduction for typhoon-related
	disasters.
	18. Promote international cooperation of DRR implementation project.
	19. Share experience/knowhow of DRR activities including legal and policy
	framework, community-based DRR activities, methodology to collect disaster-
	related information.