Promoting Technical Exchange of AI Applications in Tropical Cyclone Analysis and Prediction (AOP13 of WGM)

by Expert Team on AI Applications in Tropical Cyclone Analysis and Forecasting (ET-AITC)

Co-chairs:
Yu-heng He (HKO, yhhe@hko.gov.hk)
Munehiko Yamaguchi (JMA, myamagu@mri-jma.go.jp)

Kick-start Workshop for PP1

- A kick-start workshop for the Preliminary Project “Promoting Technical Exchange of AI Applications in Tropical Cyclone Analysis and Forecasting” was held at the Hong Kong Observatory, Hong Kong, China, on 21-22 May 2024.
- 29 experts from 11 Typhoon Committee Members, Chair of TRCG as well as TC Secretariat participated in the workshop. The workshop also invited leading AI development teams from WMO World Meteorological Centre, academia and information technology company to share the latest advancements in AI applications in weather forecasting.

- The participants engaged in technical sharing and in-depth discussions on the developments and applications of AI in tropical cyclone analysis and forecasting. Their presentations covered objective analysis techniques of tropical cyclone, monitoring and forecasting extreme weather events, applications of data-driven models as well as verification.

Recommendations from the Workshop (May 2024)

1. **Develop a platform to facilitate Typhoon Committee Members to share, use and develop AI applications in TC analysis and prediction**
   - Share various products (TC analysis, TC genesis, track forecast, intensity forecast, RI, nowcast, landfalling TCs, sub-seasonal TC forecasting, etc.), including documentation if possible
   - AI expert communication platform (forum), list of AI expert resources
   - AI forecast diagnosis and verification
   - Information sources of various data necessary for AI research and AI models training (e.g. SETCD/HURSAT/digital typhoon)
   - Metadata/Reference papers/publications from Members, academia and non-governmental institutes on AI model research and application
2. **Develop good practices or points to note of running AI models and using the AI products, to shorten the learning curve**
   - Set up expert team under WGM and other working groups
   - Explore potential collaboration with academia, private sector and WMO community
   - To contribute to IWTC in 2026, if possible
3. **Training and capacity building**
   - Organize regular face-to-face or online workshops on experience sharing on running AI models and the use of AI products (with involvement of research community and AI modelling teams)
   - Organize training tailored for the region, including for example hardware setup and practical workshop (e.g. at TRCG roving seminar 2024)
   - Special Theme Topic in IWS and IWTC
   - Invite Members to host research fellowship in AI-related topics
   - Training attachment (train the trainer)

=> HKO then proposed to continue this project as an AOP starting in 2025

Proposal for 2025+

- An AOP **led collaboratively by an Expert Team**, established under TC WGM, with representatives from contributing Members
- The AOP could initially be a **Research-to-Operation** project, also noting the data exchange requirements from Members
- **Scope** of the AOP in the first year (2025) will focus on
  - ✓ Data exchange of TC forecast tracks (both real-time and non-real-time) and the corresponding verification results. Members to contribute relevant products. An online platform for data exchange to be hosted by a Member.
  - ✓ The Expert Team to compile a summarize report on the development and applications of AI models.

✓ Interested Member(s) to host **workshop**(s), and/or organize workshop(s) back-to-back with future TC/WGM meetings

- Scope may be further extended in the coming years
- Endorsed by the 57th Session of the Typhoon Committee (TC57)

Building the ET-AITC – Terms of Reference

- Lead the activities of the WGM Annual Operating Plan (AOP) on Promoting Technical Exchange of Artificial Intelligence (AI) Applications in Tropical Cyclone Analysis and Forecasting.
- Assess and review the applications of AI in tropical cyclone analysis and forecasting.
- Coordinate exchange of tropical cyclone forecast products from AI models among contributing Members and conduct verification of AI products, such as AI models' tropical cyclone forecast tracks.
- Compile and submit to the WGM an annual summary report on AI model development, applications, and performance such as on tropical cyclone track forecasting.
- Assist in organizing workshops to share knowledge and good practices. Liaise with the Training and Research Coordination Group (TRCG) on capacity development activities related to AI modelling.
- Review the ToR of this team and scope of the AOP regularly based on project progress and emerging needs.

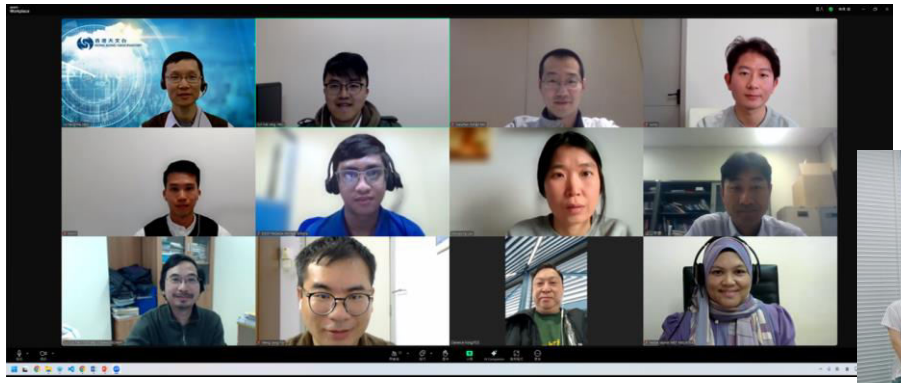
Members of the ET-AITC

Representative	Typhoon Committee Member
Gaozhen NIE	China (CMA)
Ziyao SUN	China (STI)
Yu-heng HE, **co-chair**	Hong Kong, China
Yuk-Sing LUI	Hong Kong, China
Munehiko YAMAGUCHI, **co-chair**	Japan
Kuok Hou HO	Macao, China
Abdul Aizat Nazmi A AZMI	Malaysia
Weng Sang YIP	Malaysia
Michael SIMORA	the Philippines
Woojeong LEE	Republic of Korea
Du Duc TIEN	Socialist Republic of Viet Nam
Eric LAU	United States of America
Clarence FONG	Typhoon Committee Secretariat

(As of September 2025)

Meetings

- Four online meetings have been held to date
  - 2025.02.07
  - 2025.03.21
  - 2025.04.28
  - 2025.08.28



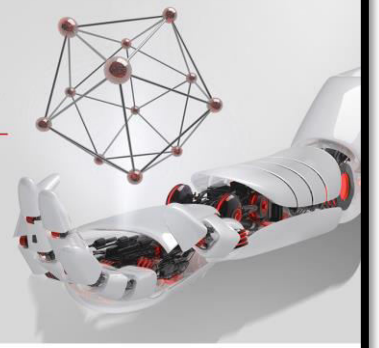
- One face-to-face meeting
  - 24-26 June 2025 (Tokyo, Japan)
  - Presentations on latest advancements by ET Members and invited AI teams
  - Summary of and discussion on verification results in 2024
  - Review of data exchange and further requirements
  - Discussion on future user requirements and work plan 2026-2027
  - Potential collaboration with other WMO programs and initiatives

Current Status and Future Plans for AI Implementation in JMA Systems

RSMC Tokyo
Japan Meteorological Agency (JMA)

ET-AITC Meeting
24-26 June 2025 (Tokyo, Japan)

New Pangu-Weather Trained on Ascend AI chips



HUAWEI

Recent Progress of Fengwu

Presenter: Tao Han
HKUST, CSE, Ph.D
Shanghai AILab

24/06/2025

Current State of AI Application in Typhoon Operational Forecasting at CMA

Gaozhen NIE, Qifeng QIAN, Gaubo ZHOU
National Meteorological Centre
Xiong'an Institute of Meteorological Artificial Intelligence
2025.6.24

Recent technical progress in AI Applications at the Shanghai Typhoon Institute (STI/CMA)

Ziyao Sun
Shanghai Typhoon Institute, China Meteorological Administration, Shanghai, China
Asia-Pacific Typhoon Collaborative Research Center, Shanghai, China
Typhoon Committee Working Group on Meteorology
Expert Team on AI Applications in Tropical Cyclone Analysis and Forecasting (ET-AITC)
First face-to-face meeting
24 -26 June 2025, Tokyo, Japan

LATEST DEVELOPMENTS OF AI MODELLING ON TROPICAL CYCLONE FORECASTING

Expert Team on AI Applications in Tropical Cyclone Analysis and Forecasting (ET-AITC)
First face-to-face meeting
24 June 2025

Yu-heng He
Acting Senior Scientific Officer, Hong Kong Observatory
E-mail: yhhe@hko.gov.hk

Member report:

Investigating potential use of AI models for typhoon forecasting including track, intensity, and ensemble approaches

Typhoon Committee Working Group on Meteorology
Expert Team on AI Applications in Tropical Cyclone Analysis and Forecasting (ET-AITC)
First face-to-face meeting
24 -26 June 2025, Tokyo, Japan

Munehiko Yamaguchi, Yasutaka Ikuta, Shota Yamashita, Takuya Kawabata,
Tsuyoshi Sekiyama, and Takuya Inoue
Meteorological Research Institute, Japan Meteorological Agency (MRI/JMA)

First face to face meeting

Expert Team on AI Applications in Tropical Cyclone Analysis and Forecasting (ET-AITC)

24 June 2024

Mr. Yip Weng Sang (Malaysia) – *Presenter this session*
Ms. Fadila Jasmin Fakaruddin (Malaysia) - *Contributor*

Expert Team on AI Applications in Tropical Cyclone Analysis & Forecasting (6.24.-26./Tokyo)

AI based weather prediction systems in KMA

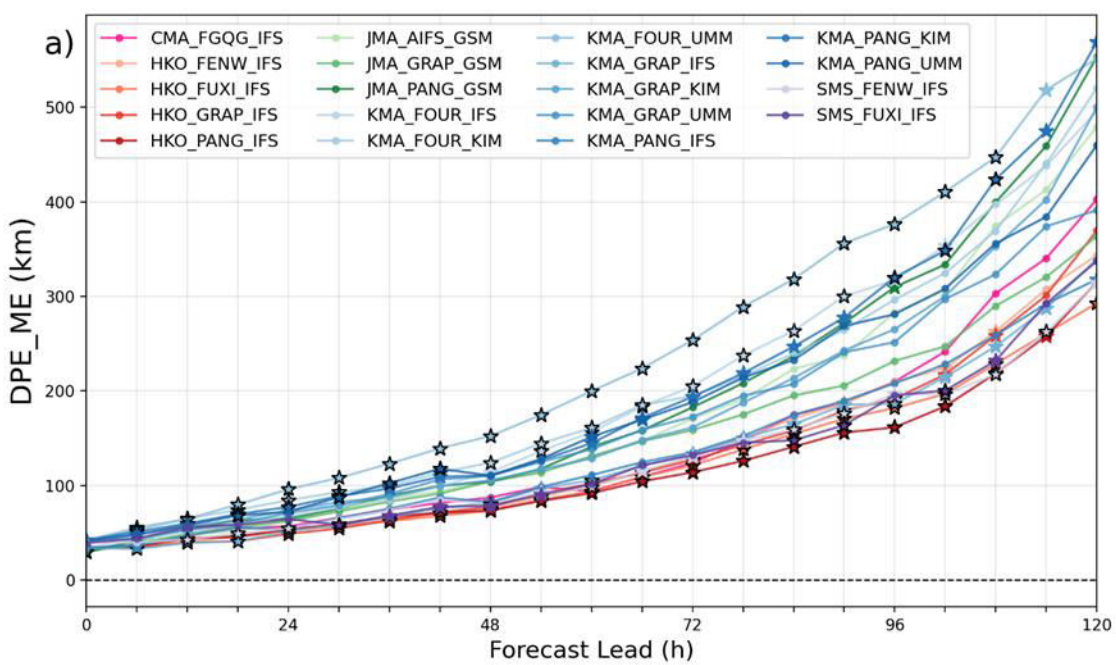
[1]**Woojeong Lee**, [1]Seonghee Won, [1]SiWoo Lee, [2]JeongHoon Joe
[1]National Typhoon Center/KMA, [2]AI Meteorological Research Division NIMS/KMA

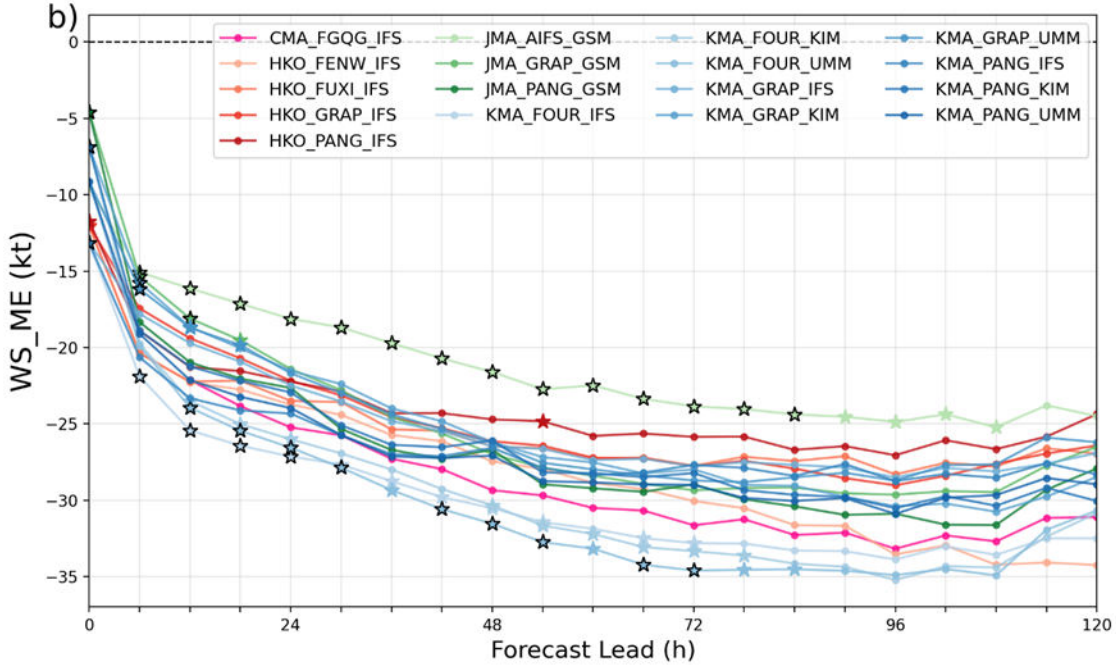
ET-AITC multi-model dataset

- A dataset of 19 AI models' tropical cyclone forecasts were submitted by CMA, HKO, JMA, KMA, and SMS (Shanghai Meteorological Service, whose data is provided via STI).
- CMA: Fengqing (initialized by IFS)
- HKO: Fengwu, Fuxi, Graphcast, Pangu-Weather (initialized by IFS)
- JMA: AIFS, Graphcast, Pangu-Weather (initialized by GSM)
- KMA: FourCastNet, Graphcast, Pangu-Weather (initialized by IFS/KIM/UM)
- SMS: Fengwu, Fuxi (initialized by IFS)

Verification of AI models

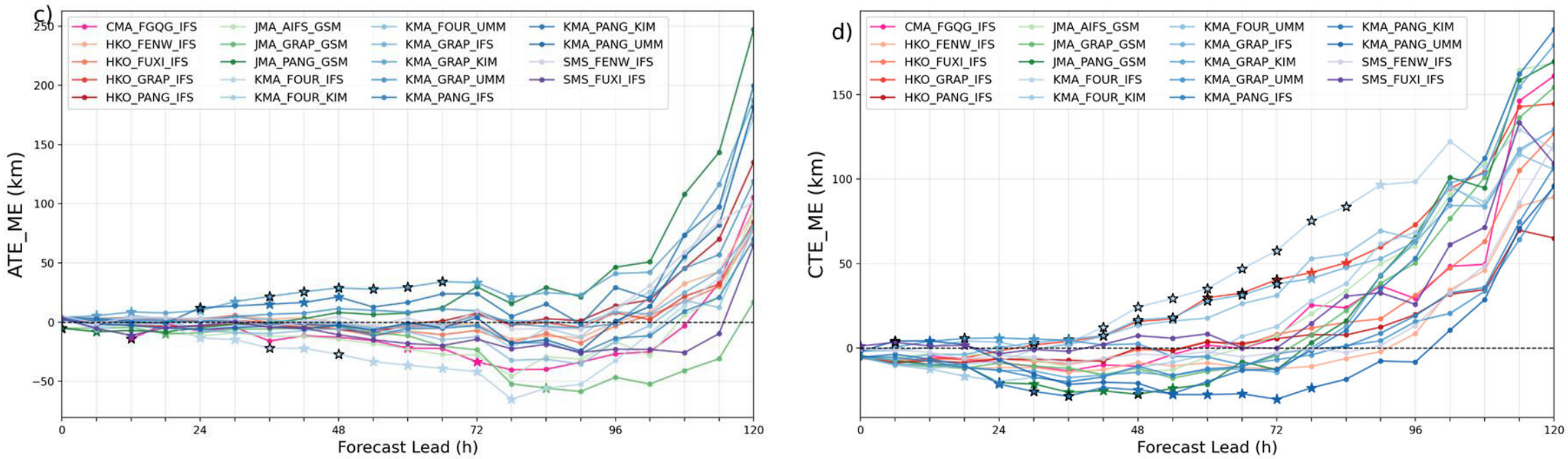
- Contribution from Woojeong Lee / KMA.
- Cover the 2024 Western North Pacific typhoon season.
- Verified against best tracks by RSMC Tokyo





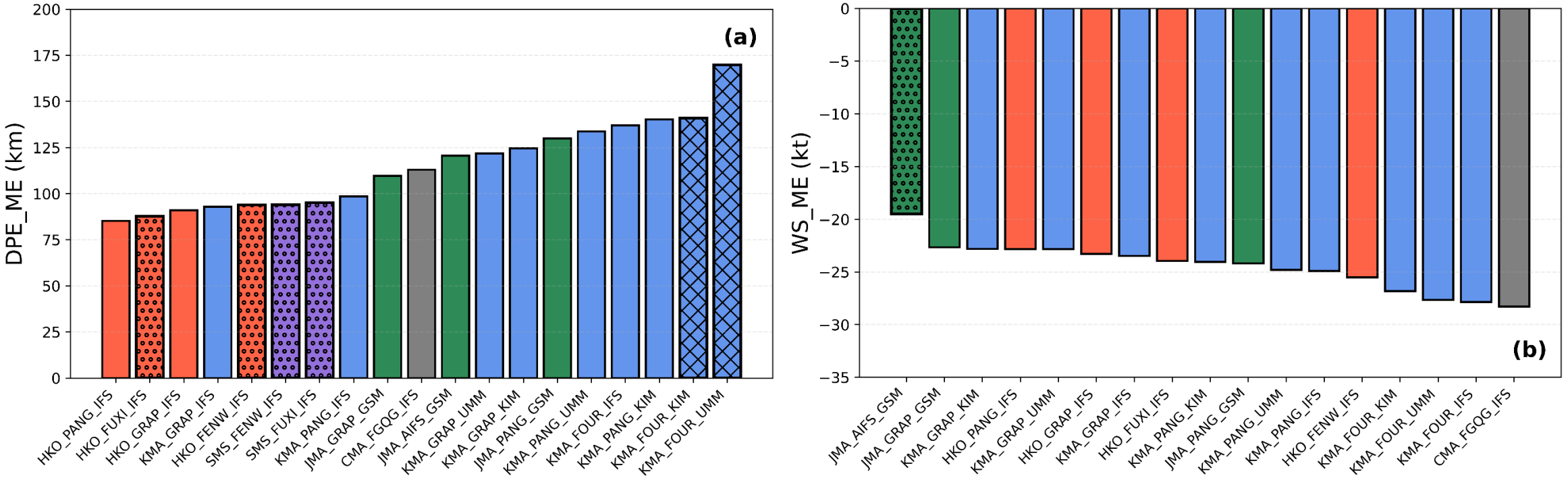
- Several models showed comparatively high skill for direct position error (DPE) throughout the forecast range.
- For intensity forecasts, all models tended to underestimate the maximum sustained wind speed.

Verification results



- For along track error (ATE), most models showed near-zero values up to 24 hours.
- However, by 120 hours all models produced positive ATEs, reflecting a general tendency to overestimate typhoon forward speed.
- For cross track error (CTE), most models initially exhibited a slight left-of-track bias, which gradually shifted to a right-of-track displacement with longer lead times.
- Note that the sample size is limited.

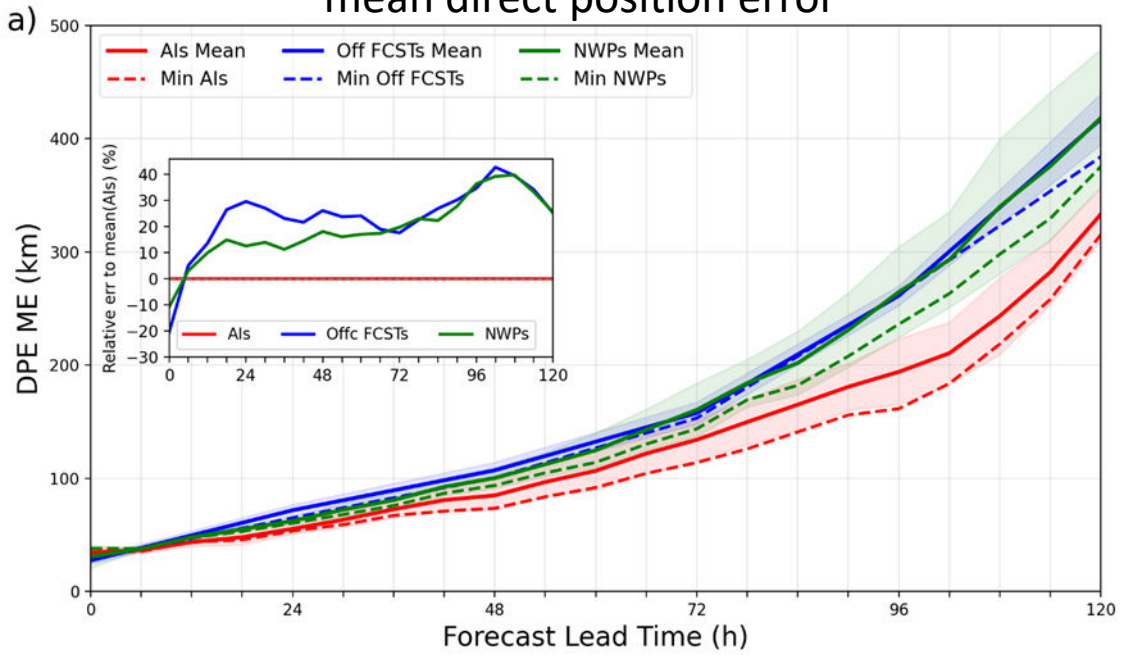
Verification results



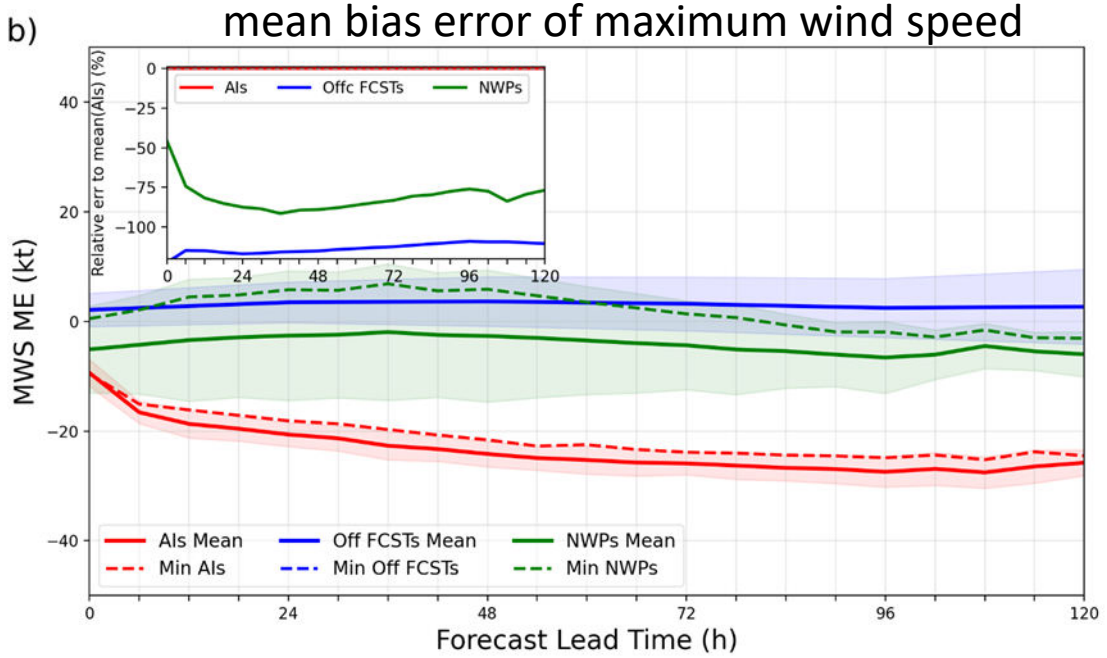
Forecast performance for all 19 AI-TC forecast configurations, using the mean DPE_ME (left) and WS_ME (right) averaged over 0-120 h with equal sample sizes. Models are ordered left to right by increasing error magnitude and color-coded by contributing institution: red (HKO), blue (KMA), green (JMA), purple (SMS), and gray (CMA).

Verification results

mean direct position error



mean bias error of maximum wind speed

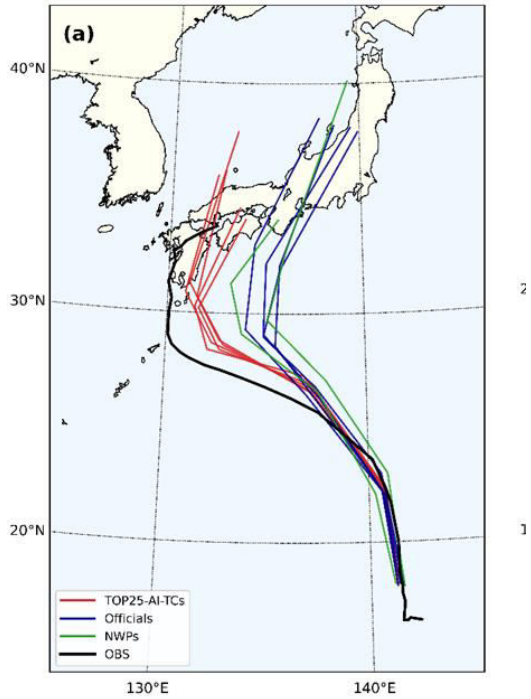


- To evaluate the practical utility of AI-based typhoon forecasts, a homogeneous comparison of forecast performance of selected representative AI-based models against official operational forecasts and traditional NWP models.
- AI models produced the smallest mean position errors, with the advantage becoming increasingly pronounced at longer lead times.
- AI models systematically underestimated TC intensity. Official forecasts and NWP models maintained smaller biases, often more than 50% lower than those of AI systems.
- These findings highlight a marked contrast: AI-based models already provide superior skill in TC track prediction in the medium range, but remain limited in capturing TC intensity.

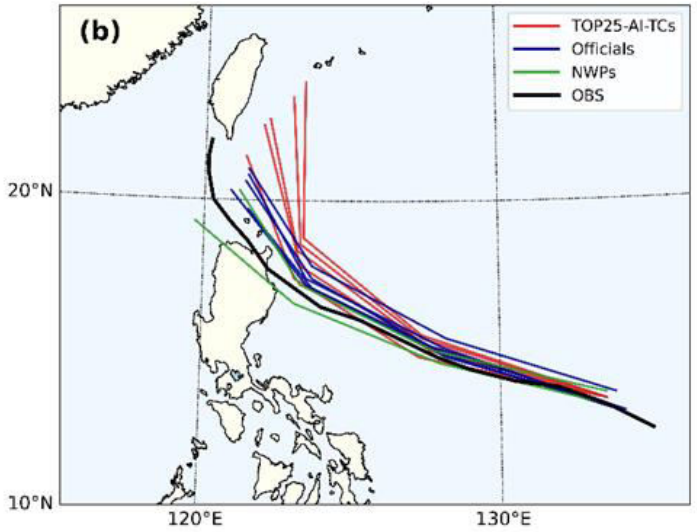
Case study

AI vs NWP

Typhoon Shanshan (T2410)
2024.08.23 12 UTC init.



Typhoon Usagi (T2425)
2024.11.12 00 UTC init.



- There are cases where a group of forecasts produced by AI-based weather models differ from those of numerical weather prediction (NWP) models.
- In the case of Shanshan, the AI weather models were able to predict the track relatively well, but in the case of Usagi, all of the AI weather models showed a northward bias.
- It is possible that phenomena not represented in the 0.25-degree training data—such as mesoscale convection—are influencing the storm track.

Evaluation of AI-based tropical cyclone forecasts in the western North Pacific: Insights from the 2024 Typhoon Committee ET-AITC multi model dataset

Woojeong Lee [a], Munehiko Yamaguchi[b], Yu-heng He[c], Yuk-Sing Lui[c], Ziyao Sun[d], Xuliang Fan[e] and Gaozhen Nie[f]

[a] *National Typhoon Center, Korea Meteorological Administration (KMA), Jeju, Republic of Korea*

[b] *Meteorological Research Institute, Japan Meteorological Agency, Tsukuba, Ibaraki, Japan*

[c] *Hong Kong Observatory, Hong Kong, China*

[d] *Shanghai Typhoon Institute, China Meteorological Administration/Asia-Pacific Typhoon Collaborative Research Center, Shanghai, China*

[e] *Shanghai Central Meteorological Observatory, Shanghai, China*

[f] *China Meteorological Administration, Beijing, China*

Corresponding author: Munehiko Yamaguchi, myamagu@mri-jma.go.jp

ABSTRACT

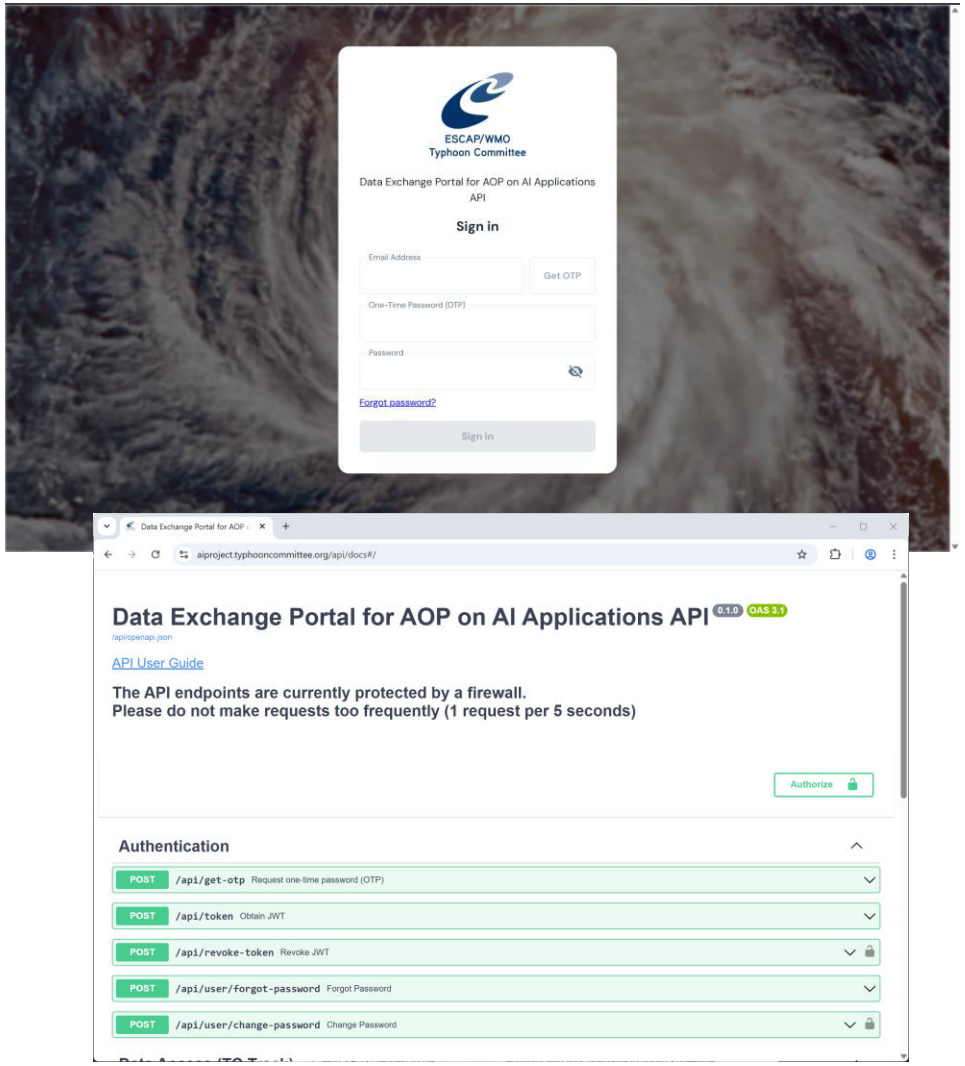
Artificial intelligence (AI)–based tropical cyclone (TC) forecasts (AI-TC forecasts) for the 2024 western North Pacific season were evaluated using model datasets provided through the Expert Team on AI Applications on Tropical Cyclone Analysis and Forecasting (ET-AITC) under the ESCAP/WMO Typhoon Committee. AI-TC forecasts refer to TC track and intensity predictions obtained by applying objective vortex-tracking algorithms to outputs of AI-based global weather forecasting models (AI-WFMs). Nineteen forecast configurations submitted by Members were verified against best-track data from RSMC Tokyo. Model performance was assessed by individual configuration, underlying AI-WFM, and initial conditions (IC). Both AI-WFM and IC influenced forecast skill, with AI-WFM generally more important. The top 25% of AI-TC forecasts (TOP25-AI-TC) had track errors comparable to or smaller than those from numerical weather prediction (NWP) models and official forecasts. For about 68% of 2024 typhoon cases, these TOP25-AI-TC produced lower mean position errors than NWPs, with statistically significant improvement in ~32% of cases. In contrast, AI-TC intensity forecasts exhibited a substantial low bias, with ~73% performing worse than NWPs. This underestimation persisted throughout the forecast period, although AI-TC forecasts showed skill for rapid weakening events. As AI-WFMs continue to evolve, the shared AI-TC forecasts through ET-AITC provide a foundation for evaluating and improving performance. These results demonstrate strong potential for AI-WFMs in TC track forecasting but highlight the need for bias correction, model development, and broader data sharing to support operational use in intensity prediction.

SIGNIFICANCE STATEMENT

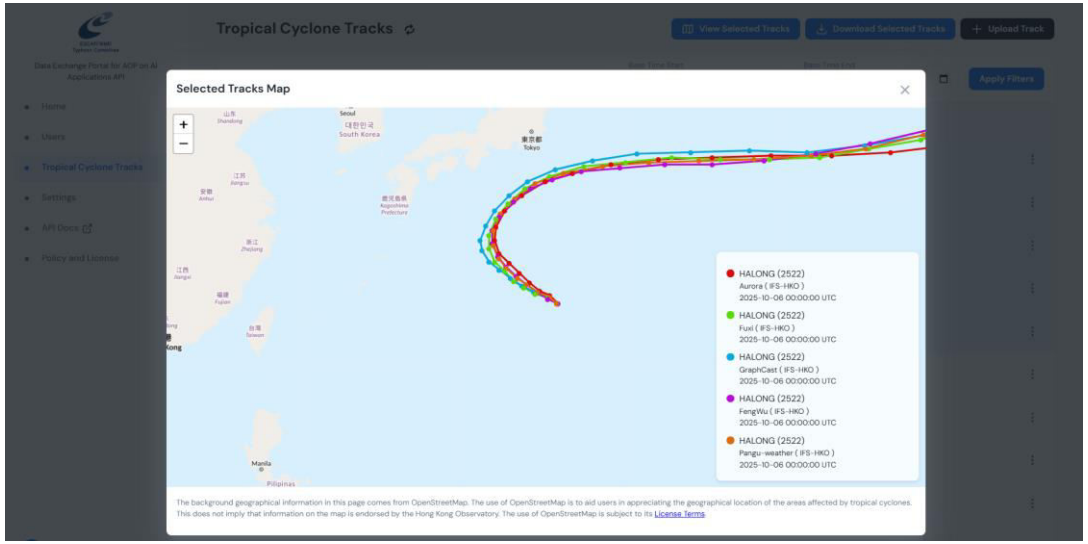
This study is the first international effort to compare AI-based tropical cyclone forecasts contributed by many institutions, using 19 datasets shared through the WMO Typhoon Committee. The results show that AI forecasts can rival or exceed traditional models in predicting storm tracks, while intensity prediction remains a known weakness. The analysis also indicates that the design of the AI model has a greater impact on forecast skill than the initial conditions used. Continued multi-year evaluations and shared platforms, supported by international collaboration, are expected to contribute to improving TC forecast performance in the future.

A manuscript has been prepared and submitted for peer review.

Data Exchange Platform



- A closed and secured web platform for Members of the ET.
- Facilitate real-time and none-real-time data exchange (as contributing Members would choose), and archival of TC forecast tracks from a number of AI models.
- In 2025 TC season, HKO has been providing TC tracks from AI models in real time.
- Provide both API access and quick visualization.
- Developed and operated on behalf of Typhoon Committee by HKO.



Data Exchange Policy

The **primary objective** of this AOP is to share findings, including verification results and good practices, to explore how AI-based tropical cyclone analysis and forecasting can be effectively utilized in the future. Given this objective, it is important to be mindful on the use of data being exchanged.

- Data will be exchanged among Typhoon Committee Members with representatives in the Expert Team.
- Data exchanged for this AOP will not be provided to third parties.
- The data will only be used for the purposes of this AOP and will not be utilized for any purposes beyond the scope of this AOP. For example, data exchange arrangement is intended to support the research activities under this AOP and not for operational tropical cyclone forecasting.
- Acknowledgement will be given on using the data from this AOP.

(Discussed and agreed by the ET on 26 June 2025)

Collaboration with other programs/initiatives

- This AOP is closely tied to various WMO programs and initiatives
- Advisory Group on Tropical Cyclones (AG-TC)
- Participation in IWTC
- WIPPS Pilot Project
  - Outcomes from this initiative will benefit the community, and will be fed into *the technical guidelines on the use of AI* to be drafted by INFCOM

Future requirements and work plan 2026-2027

- Continue TC forecast verification for 2025 for TC forecasts up to lead time of 240 hours.
- Inter-comparison of TC analysis using satellite-based AI estimates for TC location and intensity.
- Verification for weak TC or tropical disturbance (e.g. Tropical Depression, Tropical Storm, Tropical Low).
- To consider verification of pre-genesis tracks, pending further discussion on the tracking and identification of potential TCs/lows.
- Verification of TC genesis (e.g. how many days prior to formation have the TC been forecasted by AI models).
- Case studies of individual TCs.

Activity Report

- A detailed activity report for 2025 has been prepared, as a joint efforts of all Members of ET-AITC, available here.
- The report is being submitted to WGM.

Future events

- Upcoming Workshop and Expert Team meeting in Shanghai on 21–23 April 2026
- 2-day Workshop (21-22/4), 1-day ET meeting (23/4)
- Targeted participants
  - All ET-AITC members
  - Representatives from TC Member
  - TC Secretariat
  - Invited speakers from leading AI model development teams
  - May consider inviting relevant researchers from institutes and universities

Thank you!