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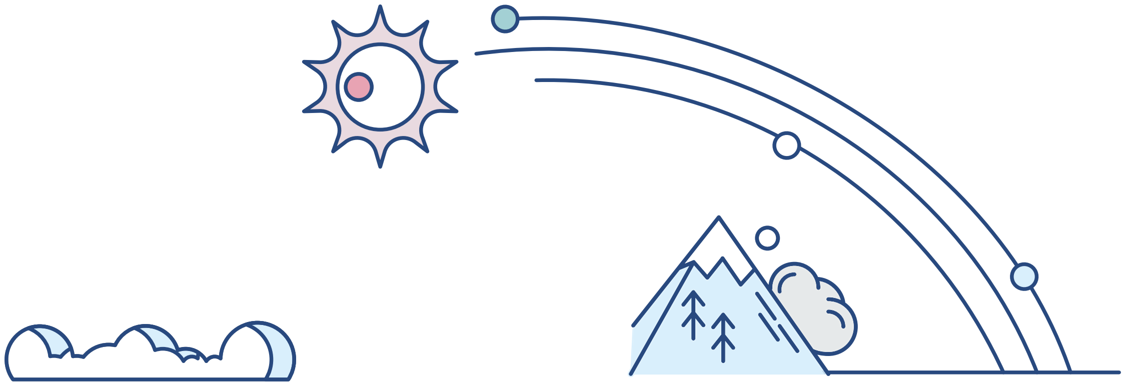

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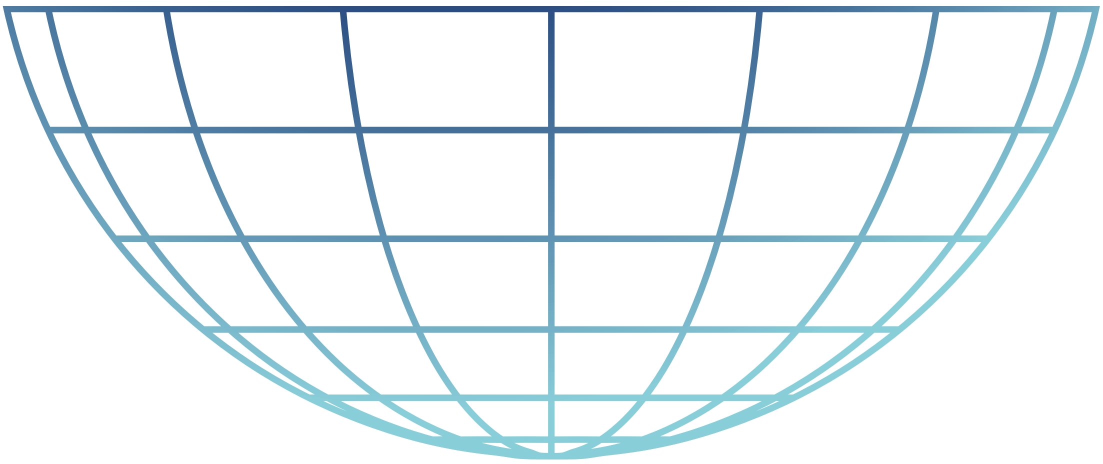
2025 Annual Report APCC



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2025 Annual Report

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Foreword

Responding to the Climate Crisis through Trust and Innovation

The year 2025 served as a stark reminder of the escalating climate crisis, recorded as the third warmest year globally. For the APEC Climate Center (APCC), however, it was a year of profound significance. As the Republic of Korea assumed the APEC chair, APCC celebrated its 20th anniversary, leading international solidarity to address our shared climate challenges.

Building upon two decades of excellence as a leading source of climate information for the Asia-Pacific, 2025 marked a transformative leap forward. We have prioritized digital innovation to fundamentally enhance the quality and reach of our services.

First, we have revolutionized our approach to climate forecasting. By integrating Artificial Intelligence (AI), we transitioned from subjective, heuristic-based methods to a data-driven, automated system. This shift ensures that the climate information we produce remains consistently objective, transparent, and reliable.

Second, we have significantly lowered the barriers to accessing climate data. By integrating disparate information platforms into a single, unified portal, we have created a user-centric environment. This "one-stop" source empowers stakeholders to seamlessly identify and utilize the climate insights necessary for informed decision-making.

Third, we have bridged critical gaps in our technical capabilities. Beyond traditional long-range forecasts, we have secured Subseasonal to Seasonal (S2S) prediction technology—providing vital outlooks for the 14-to-60-day window and effectively closing the gap between short-term weather and seasonal climate. Additionally, we have refined AI-driven techniques for the early detection of extreme climate events, enhancing our proactive response capacity.

Finally, we have fortified national climate resilience through a robust legal and scientific framework. In alignment with the enforcement of the Climate Change Monitoring and Prediction Act, we are producing practical "impact information" for critical sectors like agriculture by leveraging standardized national climate change scenarios. This ensures that our scientific data provides a dependable foundation for national-level crisis management.

As we embark on the 7th Phase (2025–2027) of our strategic mission, APCC will focus on the practical application of our technologies, moving innovations from the laboratory to the field. Building on twenty years of growth, we will continue to serve as a pivotal force protecting humanity from the threats of the climate crisis.

I would like to express my deepest gratitude to our staff for their dedication to change and innovation and to the Korea Meteorological Administration (KMA) and our partner organizations for their unwavering support.

Acting Executive Director, APEC Climate Center (APCC)

Dr. Hyung-Jin Kim

ASIA-PACIFIC ECONOMIC COOPERATION CLIMATE CENTER

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State of the Asia-Pacific Extreme Climate in 2025

State of the Asia-Pacific Extreme Climate in 2025

State of the Asia-Pacific Extreme Climate in 2025

According to the World Meteorological Organization (WMO), 2025 was ranked as the third-hottest year on record. The global average surface temperature was 1.44°C (±0.13°C) above the 1850–1900 baseline. Furthermore, the average temperature over the last three years stood at 1.48°C (±0.13°C) above pre-industrial levels, making it the warmest three-year period to date. Despite the emergence of La Niña in 2025, global warming persisted due to the ongoing accumulation of greenhouse gases in the atmosphere.

The Copernicus Climate Change Service (C3S) has warned that at the current rate of warming, the 1.5°C threshold set by the Paris Agreement could be reached within a decade—a pace more than 10 years ahead of initial projections. This sustained global warming has intensified climate extremes such as heatwaves, heavy snowfall, and torrential rain, leading to severe economic and human losses across the Asia-Pacific region.

North American Cold Wave

In January 2025, two powerful cold waves struck North America. As a result, the average temperature in the U.S. for January was recorded at -1.6°C, making it the coldest January since 1988. On January 21, wind chill temperatures plummeted to -33.3°C at Chicago O'Hare International Airport and -36.1°C in Rockford. On January 22, record lows were broken in Louisiana, with -15.6°C in Lafayette and -16.7°C in New Iberia, marking the lowest temperatures since 1893 and 1948, respectively.

A storm accompanied by heavy snow developed along the Gulf of Mexico, bringing 15–30 cm of accumulated snowfall to low-latitude regions, including Louisiana (New Orleans) and Alabama (Fig. 1). In early January, a cold front from the Arctic moved south through Canada and combined with a powerful blizzard. Subsequently, the weakening of the jet stream caused a disruption of the polar vortex, allowing frigid air to descend into the south-central U.S. and the Gulf Coast. This frigid air collided with warm, moist air masses moving north from the Gulf of Mexico, leading to unprecedented snowfall in these southern regions. This weakening of the polar vortex is widely attributed to climate change, particularly high-temperature anomalies in the Arctic (Fig. 2).

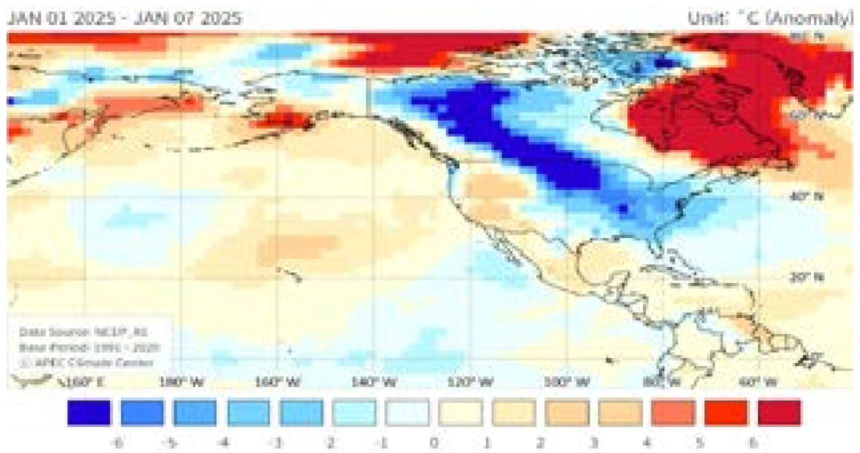


Fig 1 Distribution of mean surface air temperature anomalies, January 1–7, 2025

State of the Asia-Pacific Extreme Climate in 2025

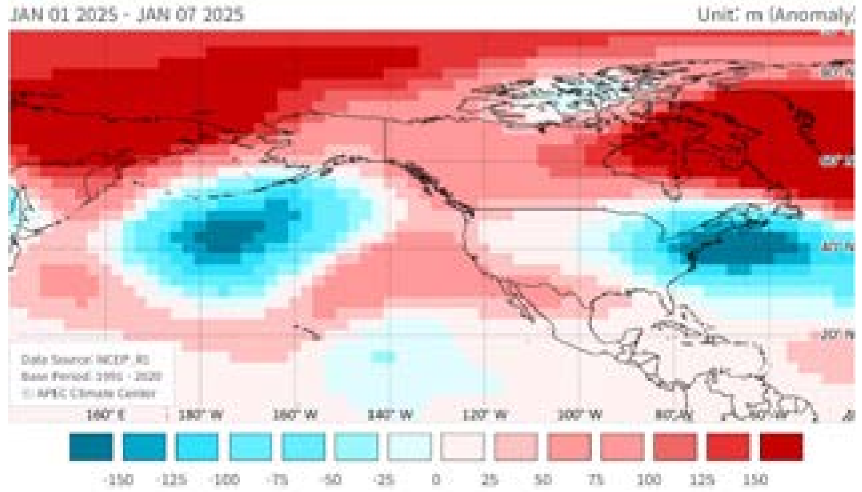


Fig 2 Distribution of mean 500hPa geopotential height anomalies, January 1–7, 2025

Heavy Snowfall in Japan

In early February 2025, extensive regions across Japan, stretching from Hokkaido in the north to Kyushu in the south, experienced unprecedented cold waves and heavy snowfall. Notably, on February 3–4, the city of Obihiro in the Tokachi Plain recorded 120 cm of snow within 12 hours—an unprecedented total for a 12-hour period in Japan's observational history (Fig. 3).

The snowfall resulted in the cancellation of approximately 30 flights, affecting about 2,230 passengers, while expressways and major roads were closed, and train services were suspended. Additionally, over 370 schools implemented temporary closures. Cold air moving from Siberia toward East Asia bifurcates around the northern mountain ranges of the Korean Peninsula before converging over the East Sea. The resulting air-sea interaction, driven by relatively high sea surface temperatures, formed massive cloud bands that triggered the heavy snowfall (Fig. 4).

Furthermore, a marine heatwave—a sustained rise in sea surface temperatures—was observed off the coast of Hokkaido. Numerical model experiments indicated that this marine heatwave augmented precipitation by approximately 50% by facilitating the formation of surface fronts and enhancing atmospheric instability[1)].

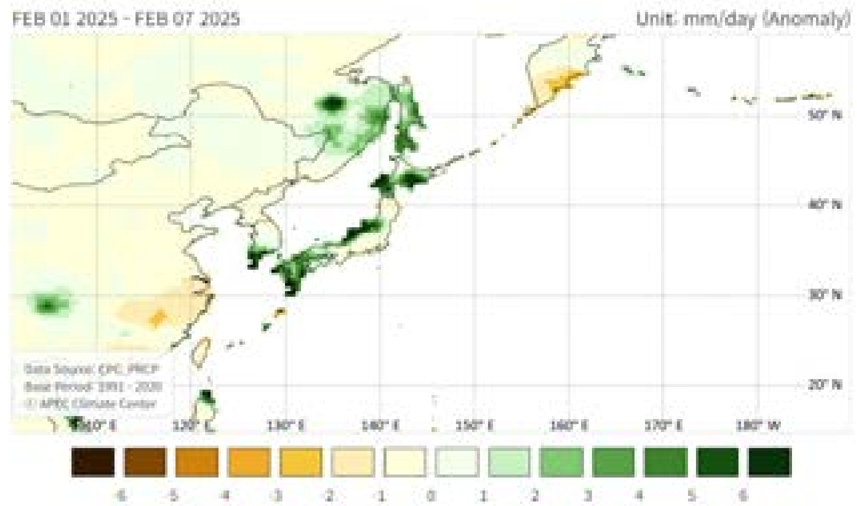


Fig 3 Distribution of mean precipitation anomalies, February 1–7, 2025

1) Hirata, H., K. Tamura, T. Morioka, and T. Sato, 2025:

Mechanisms behind the record-breaking snowfall in Obihiro, Hokkaido, Japan, in February 2025: Roles of atmospheric environment and a marine heatwave. SOLA, 1-9, 21.

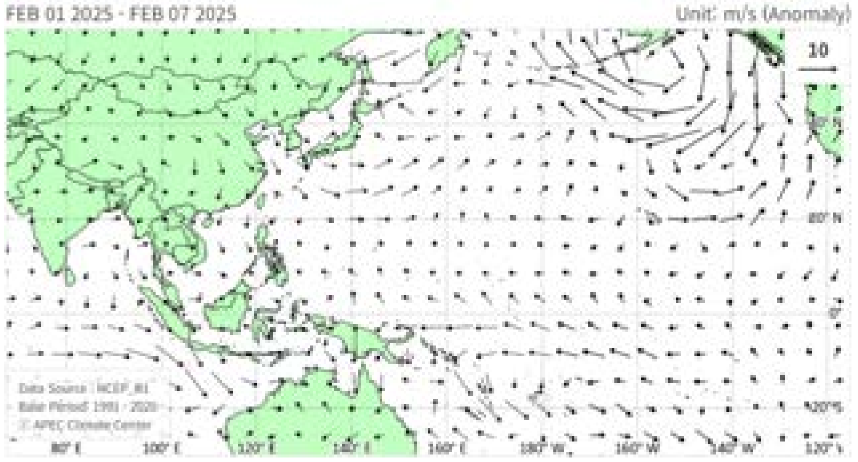


Fig 4 Distribution of mean low-level wind field anomalies, February 1–7, 2025

U.S. Heatwave

In June 2025, an early-season heatwave originated in the U.S. Midwest and spread to the East Coast. Between June 22 and 25 alone, over 100 million people were affected, and 726 counties exceeded previous record highs. New York City reached 38.9°C, a record for June, while temperatures in Boston rose to 37.8°C and Baltimore hit 40.6°C. High humidity elevated heat indices in major cities like New York and Philadelphia to exceed 43.3°C.

The extreme heat caused thermal expansion and buckling—often referred to as "blow-ups"—of highway asphalt in parts of the Midwest and East, leading to significant traffic disruptions. In New Jersey, approximately 150 people were treated for heat exhaustion during a high school graduation ceremony as heat-related illnesses surged (Fig. 5).

A "heat dome" developed as a strong stationary high-pressure system stagnated over the region, trapping hot air near the surface. This heat dome migrated from the Midwest to the East, expanding the scope of the damage. This heatwave event was estimated to be 3 to 5 times more likely due to climate change. Reports indicate that humid heatwaves, driven by the combination of high temperatures and humidity, are being intensified by human-induced climate change along the U.S. East Coast[2].

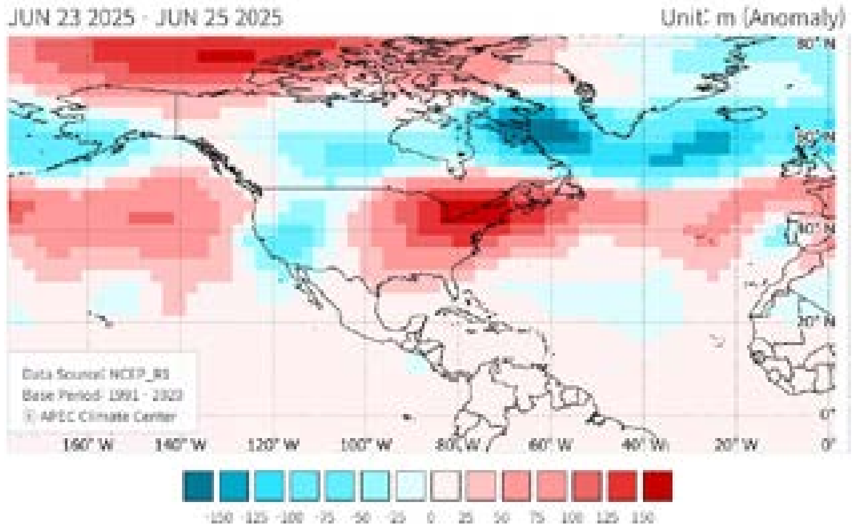


Fig 5 Distribution of mean low-level wind field anomalies, February 1–7, 2025

2) Faranda, D., and T. ALberti, 2025

High temperatures in the June 2025 Eastern USA heatwave exacerbated by human-driven climate change. CLimaMeter. Institut Pierre Simon LapLace, CNRS. https://doi.org/10.5281/zenodo.15746087.

State of the Asia-Pacific Extreme Climate in 2025

Torrential Rain in Southeast and South Asia

The city of Hat Yai in southern Thailand experienced record-breaking rainfall, with an accumulated 630 mm over a three-day period and a daily peak of 335 mm—the heaviest rainfall in 300 years. In Sumatra, Indonesia, Cyclone Senyar made landfall and stalled, triggering floods and landslides that resulted in hundreds of fatalities. Sri Lanka also encountered massive flooding due to Cyclone Ditwah. These events were characterized as complex disasters, in which tropical cyclones and monsoon rains simultaneously struck Thailand, Indonesia, Malaysia, and Sri Lanka.

According to the Thai Meteorological Department (TMD), the torrential rain resulted from a combination of 1) strong low-level convergence and uplift caused by active cyclonic circulation over Thailand and Malaysia (Fig. 6), and 2) strong northeasterly winds from high pressure over the Asian continent gaining moisture over warm seas and hitting the topography of southern Thailand, which intensified orographic lifting (Fig. 7).

Cyclone Senyar, which showed an unusual formation in the Strait of Malacca and northwestern Sumatra in November, stalled and intensified, maintaining a persistent precipitation band over southern Thailand and Malaysia. Analysis suggests that the recent La Niña resulted in relatively high sea surface temperatures and enhanced convective activity in the Western Pacific/Maritime Continent (MC) region. Additionally, the Madden-Julian Oscillation (MJO) index stalled near the Western Pacific/MC after mid-November, strengthening upper-level divergence and low-level convergence, thereby increasing the likelihood of tropical cyclone formation in Southeast Asia.

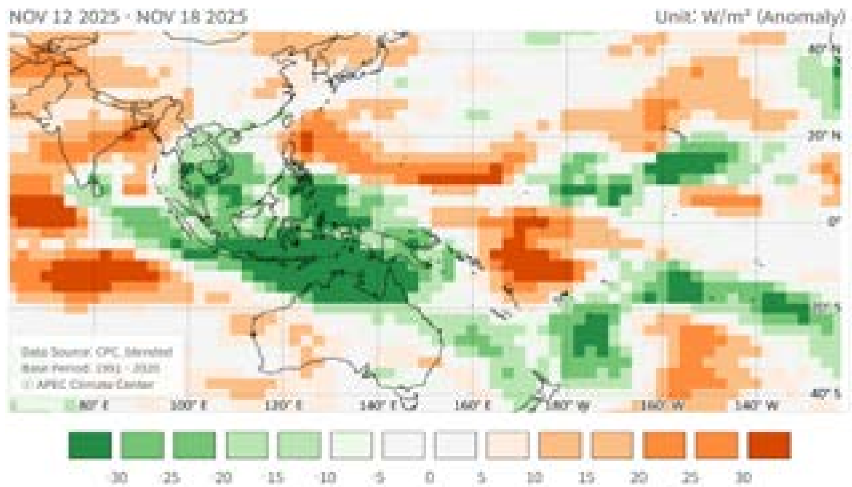


Fig 6 Distribution of mean Outgoing Longwave Radiation (OLR) anomalies, November 12–18, 2025

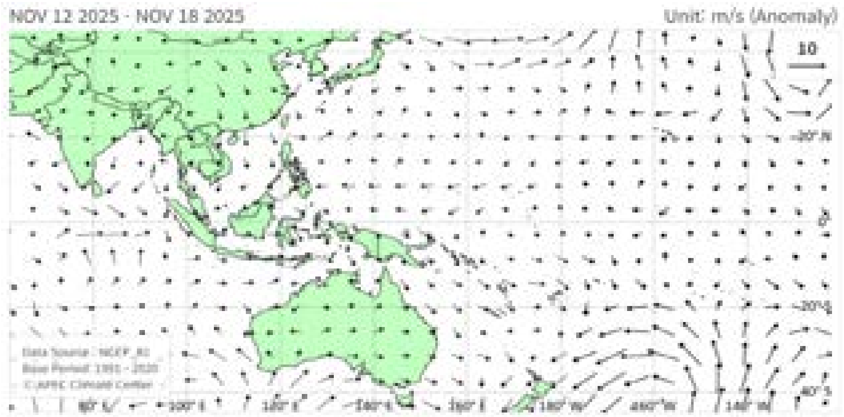


Fig 7 Distribution of mean low-level wind field anomalies, November 12–18, 2025

02

APEC CLIMATE CENTER

Highlighted Achievements in 2025

Highlighted Achievements in 2025

Highlighted Achievements in 2025

1. A New Way of Producing Climate Outlooks: A Data and Rule-Based Systematization

● - Dr. Jin Ho Yoo (jhyoo@apcc21.org)

Climate outlooks serve as core decision-support tools for anticipating future weather-related risks through the analysis of climate variability on seasonal timescales. In regions with high climate vulnerability, such as the Pacific Island Countries, climate outlooks are essential public services that support national climate adaptation strategies and informed decision-making at the community level. Beyond simply presenting forecast results, climate outlooks represent high-value information products that synthesize diverse climate data through expert interpretation and structured narrative, delivering actionable insights to policymakers and practitioners.

However, traditional climate outlook production processes have relied heavily on the experience and qualitative judgment of individual experts. As a result, maintaining consistency and reproducibility across the recurring monthly cycle of large-scale data analysis and document preparation has posed persistent challenges. Variations in interpretation and narrative style depend on the author, while fragmented analysis, writing, and editing hinder the coherent management of the production process. To address these structural limitations and strengthen the sustainability and reliability of climate information services, this initiative transformed the Pacific climate outlook production process into a data- and rule-based automated framework.

The first step involved establishing a quantitative signal detection and regional matching system that reflects the climatological and geographical characteristics of the Pacific region. By systematically reviewing climate outlook documents produced over the past five years, commonly used regional classifications and descriptive conventions were identified and consolidated. Based on this analysis, the surrounding areas of the Pacific Island Countries were standardized into 17 core subregions. Numerical signals derived from probabilistic forecast fields were subsequently mapped to the standardized terminology traditionally used in climate outlook reports—such as 'Strongly Enhanced,' 'Enhanced,' and 'Slight Tendency'—through stringent quantitative interpretation rules. A priority-based decision logic combining probability thresholds and spatial coverage ratios was applied, ensuring consistent signal selection without subjective intervention from individual forecasters.

In parallel, an offline, [1)]large language-model-based narrative automation system was implemented to operate stably within internal computing environments where external network access is restricted. A compact language model was adopted to reflect the characteristics of Pacific Climate Outlooks and their established writing stlye. Additionally, a structured "Prompt Header" approach was introduced to feed signal detection results into the model in a controlled manner. This design minimized arbitrary model interpretation and enabled the automatic generation of concise, objective natural-language descriptions for probabilistic forecasts, sea surface temperature anomalies, and ENSO-related information, all within a consistent narrative and logical structure.

Finally, the entire workflow—from data preprocessing and signal detection to language-model-based narrative generation and [2)]LaTeX-based document assembly—was integrated into a single automated pipeline. An automatic compilation system was developed to faithfully reproduce the layout and visual structure of existing Pacific Climate Outlook documents. Through the execution of a single script, the full sequence from data ingestion to final PDF output is completed in order, resulting in a clearly defined and fully reproducible workflow. This integration established a coherent production structure in which analysis, narrative generation, and document preparation are seamlessly connected.

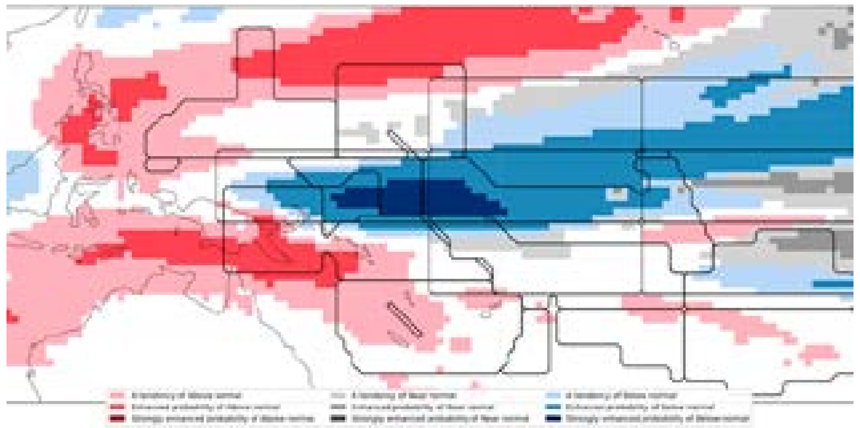


Fig 8 Forecast signals mapped over the subregion masks. Different colors correspond to different signals (category/strength).

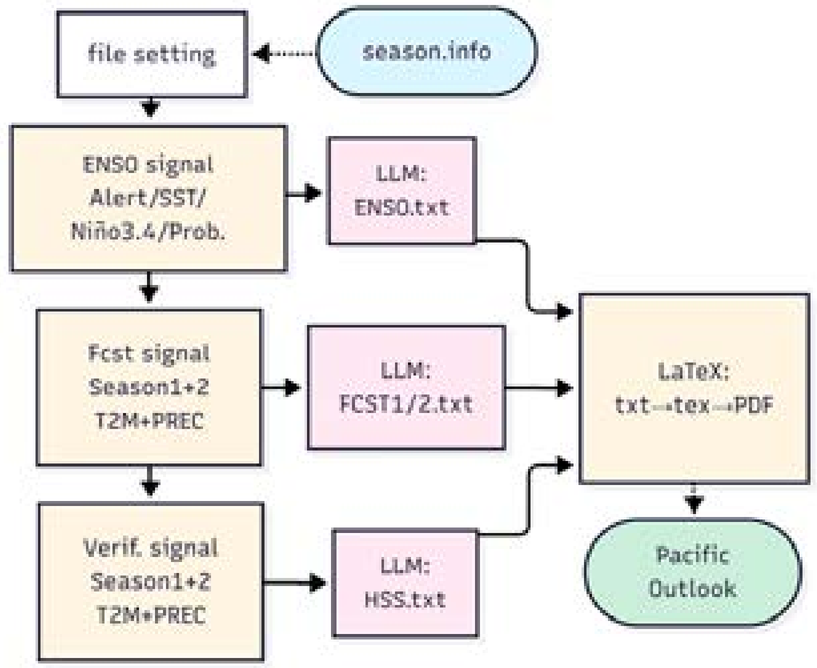


Fig 9 Process flow of integrated outlook generation pipeline

1) LLM (Large Language Model)

An AI language model trained on large amounts of text to generate, summarize, and translate text

2) LaTeX:

A document typesetting system designed for precise formatting of text and mathematical expressions

Highlighted Achievements in 2025

Highlighted Achievements in 2025

2. From Reduction to Reinforcement: Leveraging the Government's Public Website Total Volume Management Policy as a New Leap for Integrated APCC Climate Information Services

● Mr. Sangcheol Kim (sclow@apcc21.org) ● Ms. Jihyeon Shin (jhshin@apcc21.org)
● Mr. Joo Hyung Chung (joohyung@apcc21.org)

The Government's Public Web Total Volume System aims to prevent information redundancy and enhance operational efficiency by systematically managing the number of public websites. While APCC's segmented service structure was effective in delivering specialized climate data, the implementation of this policy presented a strategic opportunity to substantially strengthen inter-service connectivity.

Rather than viewing the total volume limit as a constraint, APCC leveraged it as a pivotal catalyst to integrate and upgrade its climate services into a unified, platform-based architecture. By shifting from siloed services to an integrated User Experience (UX) framework, APCC has established a sustainable and future-proof foundation.

Following a multi-year phased reorganization, APCC successfully finalized the consolidation of its climate services into a single integrated portal in 2025, integrating the main website and the Climate Information Toolkit (CLIK). This process went beyond a simple structural merger; it re-engineered the entire technical architecture to align with the latest digital standards.

◎ Unified Platform Environment: Maximizing operational efficiency by hosting diverse services on a single, modernized infrastructure.
◎ Seamless User Experience: Redesigned service flows to offer a consistent user journey across the homepage and climate tools (Figure 10).
◎ Future-Ready Architecture: Overhauled legacy systems to establish a robust foundation for the efficient linkage of upcoming services (Figure 11).

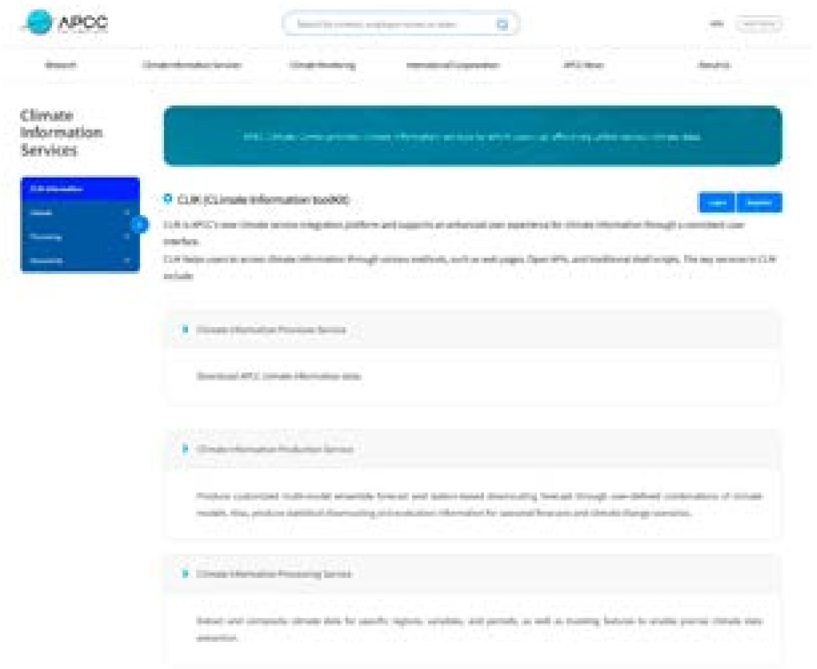


Fig 10 Integrated CLIK on APCC Homepage

Glossary

1) PaaS-TA (Platform as a Service-Technical Architecture):
An open-source-based open PaaS cloud platform developed by the National Information Society Agency (NIA) that controls cloud infrastructure and supports application development, deployment, and operation.

2) K-PaaS (Korean Platform as a Service):
A collective term for cloud platform services and solutions certified for conformity based on the K-PaaS standard model. As the successor standard to PaaS-TA, it aims to vitalize a private sector-led cloud-native ecosystem.

3) aaS (Infrastructure as a Service):
A category of cloud computing where virtualized hardware, operating systems, and libraries are provided as a service, mirroring physical computer resource infrastructure.

4) SSO (Single Sign-On):
An authentication technology that allows users to access multiple applications or websites with a unified set of credentials.

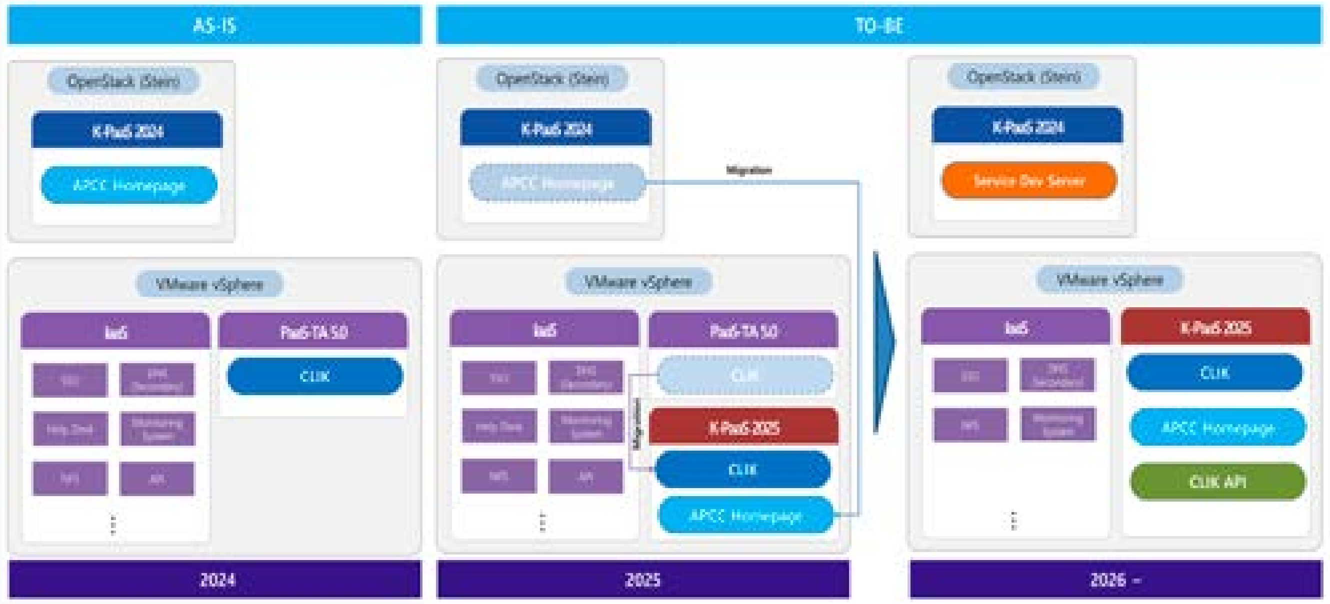


Fig 11 Climate Information Service Architecture

The integrated portal significantly enhances accessibility for all users, from the general public to policymakers and specialized professionals. By providing one-stop access to climate conditions, forecasts, and analytical tools, APCC has bolstered the reliability of its public services.

Operationally, the simplified structure optimizes management efficiency and reduces long-term costs. This integration serves as a benchmark for transforming policy-driven reduction into service advancement, promoting the wider utilization of climate intelligence across all sectors of society.

Highlighted Achievements in 2025

3. Bridging the Gap in Seasonal Prediction: Development of Integrated Subseasonal to Seasonal Forecasting Approaches

● **Dr. Suryun Ham** (suryun01@apcc21.org) ● **Dr. Young-Mi Min** (ymmin@apcc21.org)
● **Dr. Bong-Geun Song** (songbg@apcc21.org) ● **Mr. Soonjo Yoon** (sjyoon@apcc21.org)
● **Dr. Sinil Yang** (siyang@apcc21.org)

Since 2017, the APEC Climate Center (APCC) has established a robust collaborative framework to support the Korea Meteorological Administration (KMA)'s operational one-month forecast by collecting, processing, and providing the latest subseasonal prediction information. This study describes the stable operation of the subseasonal prediction system and the deep learning-based probabilistic temperature forecasting system tailored for this purpose. In addition, the migration and improvement of data collection and forecast production servers were carried out to enhance operational efficiency. Through a case study, the system's performance in predicting detailed weather variability—which cannot be identified through monthly mean values alone—was verified. The results demonstrate the high utility of subseasonal prediction information in capturing intra-monthly variability. To address the limitations of seasonal prediction information in a rapidly changing climate, APCC has pursued the development of a subseasonal prediction system designed to enhance its utilization value.

To develop the APCC subseasonal prediction system, a wide range of global subseasonal-to-seasonal (S2S) prediction datasets were systematically collected and standardized. Using these datasets, we confirmed that the Multi-Model Ensemble (MME) provides stable and superior performance within the subseasonal prediction range. We also confirmed that the APCC's own model, with its diverse component model composition, can further increase the overall contribution to the MME. Furthermore, we evaluated parametric probabilistic prediction methods for temperature and precipitation in order to identify methodologies optimized for the statistical characteristics of each variable. The results indicate that parametric methods outperform non-parametric approaches in terms of quantitative predictive skill and can effectively reduce spatial noise arising from an insufficient ensemble size. Building on these research findings, we established the model configuration and probabilistic methods required for the APCC subseasonal prediction system. The system ingests weekly forecast data from 10 models, including APCC's SCoPS, BOM, NCEP, and HMC, to generate subseasonal prediction products. For the final MME production, the Simple Composite Method (SCM) is used for deterministic forecasts, while the Hybrid Gamma method is employed for probabilistic forecasts. This integrated system allows for the production and display of MME prediction results, initialized to start every Monday. To diversify and enhance the usability of subseasonal information, the study also explored and identified seamless content that integrates subseasonal weekly and monthly forecast information. We identified products that can be delivered immediately, such as integrated monthly/weekly probability distributions and weekly variability information, as well as more advanced products requiring additional technical development, including probabilities of intra-monthly extreme events.

Meanwhile, to include SCoPS as one of the contributing models, we developed a real-time subseasonal forecast system that produces 60-day forecasts every week, based on monthly seasonal forecasts. However, given the relatively old development baseline of SCoPS and its lower skill compared to other MME participating models, there is a clear need to reduce its systematic errors. To reduce land-related initial errors, which are critical for subseasonal prediction, we developed a soil moisture initialization technique for SCoPS and quantitatively evaluated its impact. We also examined how improvements in oceanic and atmospheric initial conditions influence prediction performance on both subseasonal and seasonal time scales. On the basis of these results, we have initiated pilot operations of the newly established APCC subseasonal prediction system to provide enhanced forecast information. We plan to develop display systems for weekly prediction products and select highly useful content for operational dissemination.

Subseasonal prediction provides forecast information on timescales ranging from 2 to 8 weeks and is rapidly gaining value for applications across a wide range of sectors, including disaster prevention, agricultural management, and hydrological and energy operations. However, due to the inherent characteristics of the forecast lead time, subseasonal prediction remains highly challenging, as both sensitivity to initial conditions and signals from external forces are relatively weak. The newly developed APCC subseasonal prediction system is expected to play a vital role in climate information services for the Asia-Pacific region through sustained operation and improvement. In particular, the expanded subseasonal forecast information is anticipated to support disaster prevention efforts and climate risk management that relies on forecast-based decision-making..

Highlighted Achievements in 2025

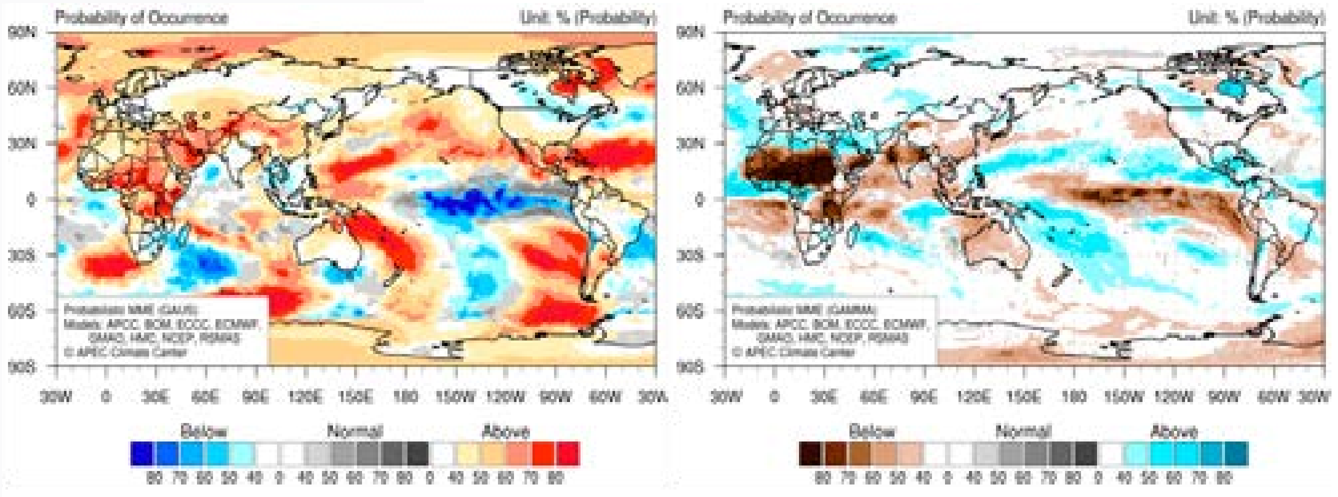


Fig 12 Probabilisic forecasts of 3-4 week mean temperature and precipitation produced by the subseasonal prediction system

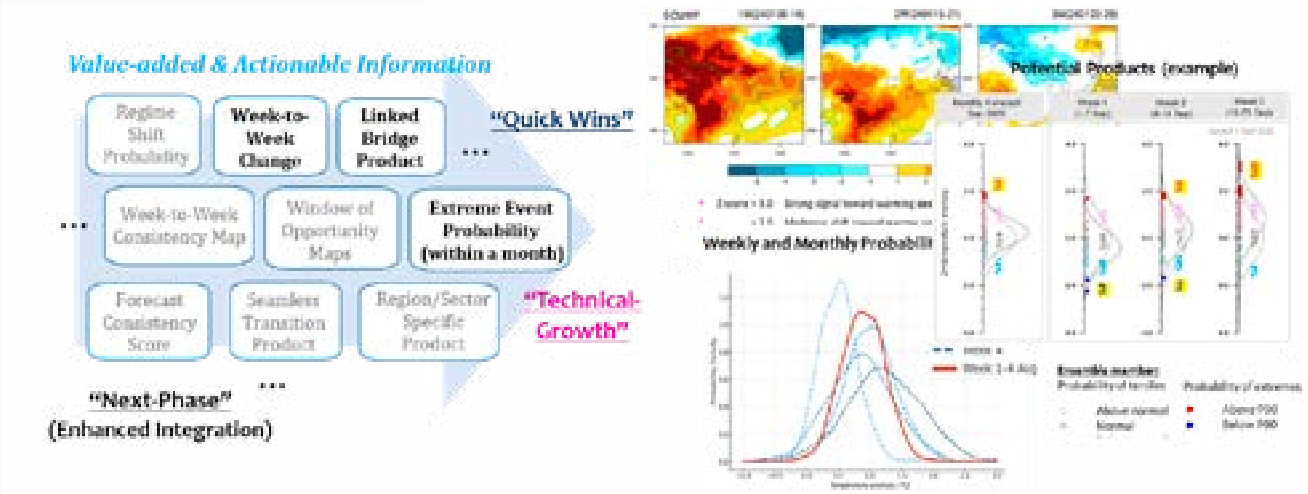


Fig 13 Example of potential contents to bridge subseasonal and seasonal (monthly) forecasts.

Highlighted Achievements in 2025

4. Initiative for Developing an East Asia Climate Extremes Dataset!

● Dr. Yun-Young Lee (yyalee@apcc21.org) ● Dr. Miae Kim (miaekim@apcc21.org)
● Dr. Uran Chung (uchung@apcc21.org)

The most critical and fundamental step in developing AI models for predicting climate extremes is the systematic construction of training data. However, defining climate extremes is challenging in the initial stages of data construction because definitions vary by meteorological element, and criteria differ depending on research objectives or regions. Consequently, a systematically organized and classified [1] inventory of major climate extreme phenomena is now needed. Establishing such an inventory is essential for enhancing the reproducibility and utility of future AI-based prediction research. Furthermore, it holds significant meaning as it promotes the qualitative and quantitative expansion of East Asian climate extreme research by lowering the barrier to data access for researchers in academia and related organizations.

The primary achievement of this research is the establishment of a sharing system that systematizes climate extreme data and analysis codes for the East Asia region (21–48°N, 114–141°E) via the [2]GitHub repository 'EastAsiaClimateExtremes' (https://github.com/yyalexlee/EastAsiaClimateExtremes). The main components are as follows:

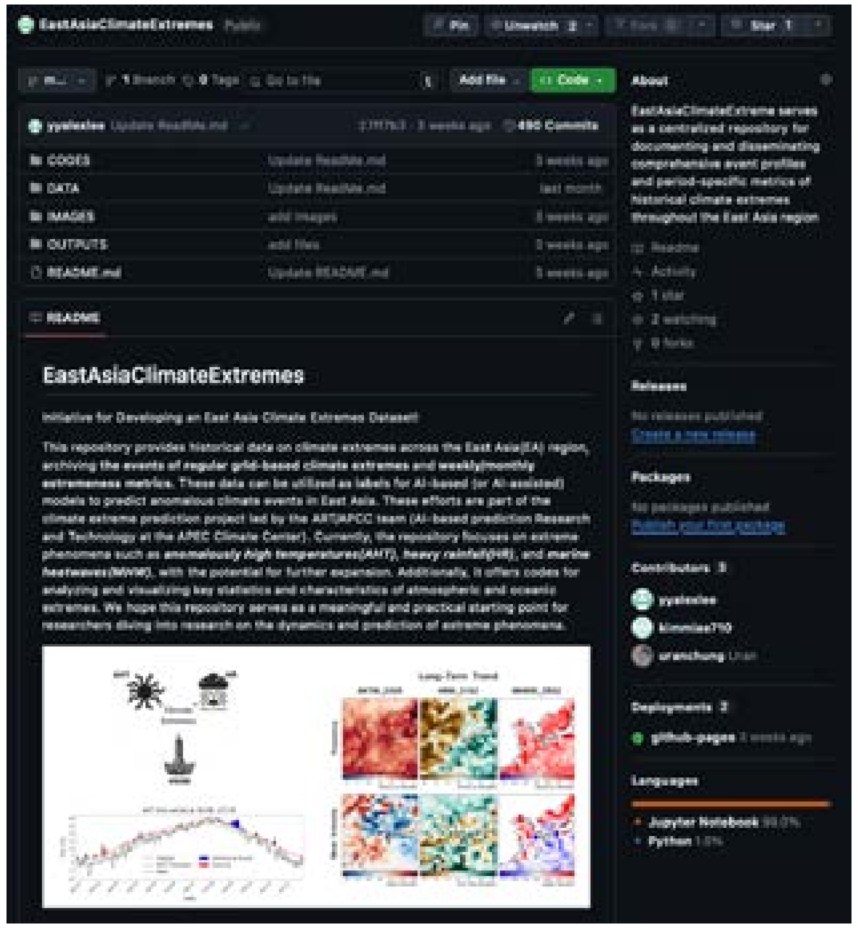


Fig 14 Screenshot of EastAsiaClimateExtreme GitHub repository page (https://github.com/yyalexlee/EastAsiaClimateExtremes)

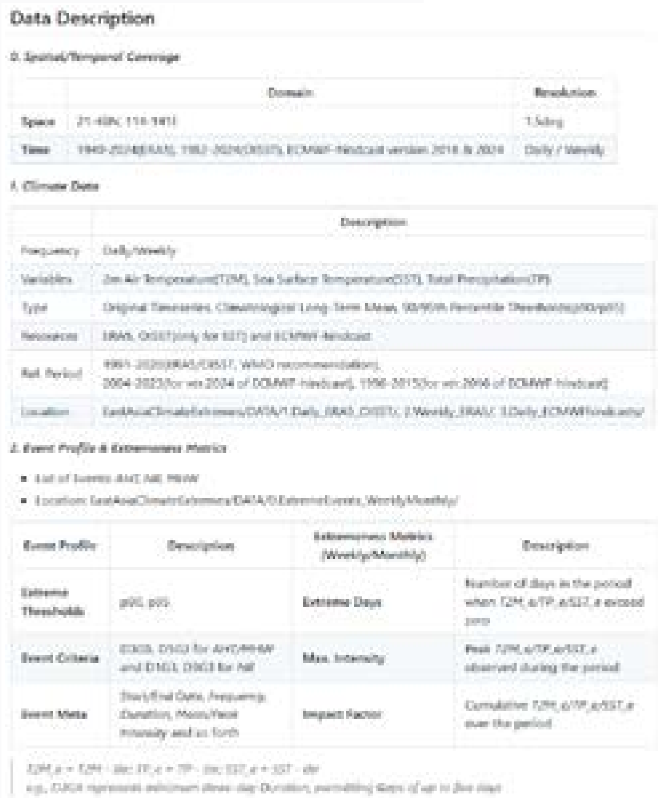
Glossary

1) Climate Extremes Inventory:

Refers to a 'comprehensive information system' established by identifying extreme weather events within a specific scope (spatial and temporal) and quantifying the data according to standardized methods.

2) GitHub Repository

A web-based storage space used to store and share a project's source code and version history.



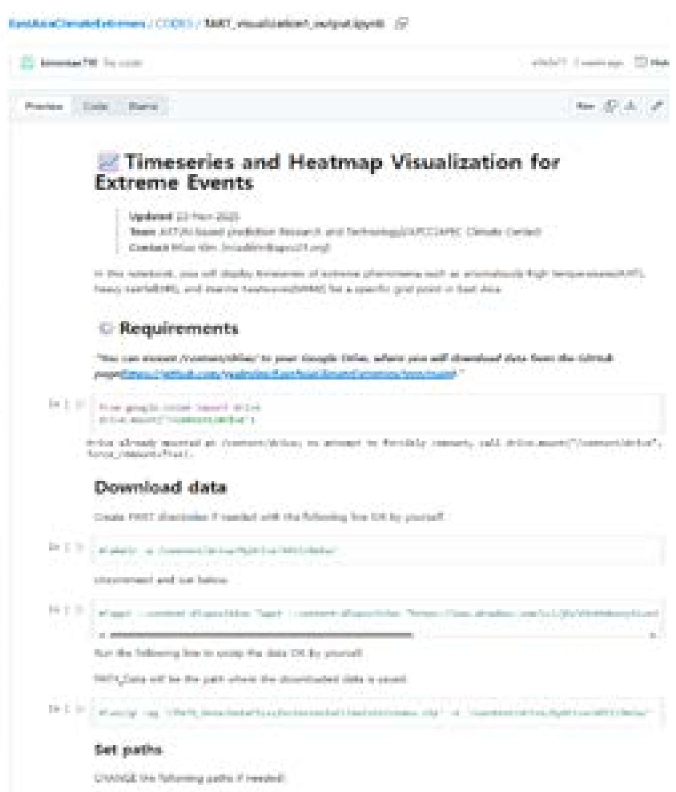


Fig 15 Detailed metadata provided by the EastAsiaClimateExtreme GitHub repository

Fig 16 Sample [3]Jupyter Notebook scripts supporting statistical analysis, visualization, and data storage

◎ Construction of Long-term East Asian Climate Extremes Data: Utilizing observation-based reanalysis data such as ERA5 and OISST, along with ECMWF-hindcast dynamical model data, major extreme phenomena including Anomalously High Temperatures (AHT), Heavy Rainfall (HR), and Marine Heatwaves (MHW) were quantified on a long-term, grid basis.

◎ Inclusion of Grid-based Detailed Extreme Indices: Daily and weekly climatological normals and percentile thresholds (90th/95th) were calculated. Based on these, detailed profiles including occurrence frequency, duration, mean and max intensity, and impact factors, as well as weekly extremeness metrics, were generated.

◎ Provision of Analysis Tools and Flexibility: Through Python-based Jupyter Notebooks, the system provides codes that allow for the reproduction of the entire workflow, from data loading to extreme event calculation, storage, and visualization using time-series graphs or heatmaps. Additionally, it is designed with a flexible structure that allows users to easily modify the research domain, variables, and time periods to suit their needs.

This system is expected to substantially contribute to the analysis of mechanisms behind East Asian climate extremes and the improvement of prediction accuracy.

◎ **Acceleration of AI Research: The constructed inventory can be immediately utilized as training and labeling data as well as validation datasets for AI-based climate prediction models, thereby increasing research efficiency.**

◎ **Ease of Model Evaluation: By providing both observation-based data and Global Circulation Model (GCM) data, this system facilitates performance comparisons and evaluations between AI models and existing dynamical models.**

◎ **Provision of Research Collaboration Infrastructure: The distribution via a public repository and the provision of reproducible code will create an environment where researchers can collaborate on a single platform based on a 'common baseline dataset.'**

Glossary

3) Jupyter Notebook:

An all-in-one analysis tool that combines code, execution results (graphs), and documentation in a single document.

Highlighted Achievements in 2025

5. Maximizing the Utility of Agro-Climate Impact Information: Developing 5 Enhanced Indices for Field Application

● Dr. Shin, Yonghee (shin.yonghee@apcc21.org)

As the climate crisis accelerates and agricultural environments undergo rapid transformations, the importance of agricultural impact information utilizing National Climate Change Standard Scenarios (SSP) is more critical than ever. However, the eight agricultural impact indices that were previously used had limitations in accurately reflecting actual field demands and the changing technical environment. For instance, terms like 'Plant Period' and 'Crop Period' were vague and seldom used in the field. Moreover, simplified calculation methods that merely aggregated days above a base temperature failed to reflect the diversity of growth environments. Technically, while scenario data is provided on a 'daily' basis, existing models for 'Chill Units' (such as the Utah model) required hourly meteorological data, resulting in significant compatibility challenges. Furthermore, indices like 'Cooling Degree Days' were criticized for low practical utility, as they overlooked the reality that most farmers rarely operate cooling facilities due to prohibitive operating costs. Accordingly, this study precisely diagnosed the limitations of the existing indices through consultations with experts from various fields, including the Korea National University of Agriculture and Fisheries, the National Institute of Animal Science, and the National Institute of Horticultural and Herbal Science, and developed improvement plans that ensure both data availability and practical applicability in the agricultural field.

This achievement holds significant scientific meaning as it represents a paradigm shift from a simple listing of meteorological statistics to precise prediction models that reflect the biological characteristics of crops. In particular, we introduced a 'Phenological Model (Cesaraccio et al.)' capable of sophisticatedly predicting dormancy break and flowering times of fruit trees using only daily data. Furthermore, by standardizing disparate growth indices into 'Growing Degree Days (GDD)' and 'Growing Season Length (GSL)' and establishing clear calculation criteria, we have enhanced the objectivity and reliability of assessments on the impact of climate change. From a socio-economic perspective, the development of 'Facility Heating Degree Days,' specialized for energy management on smart farms and greenhouses, provides a basis for calculating winter heating cost savings and greenhouse gas reduction effects. In addition, the 'Livestock Heat Index (THI),' an improvement over the simple temperature-humidity index, provides precise 5-level risk warnings ranging from 'Normal' to 'Fatal' by livestock type (cattle, pigs, chickens). This is expected to directly contribute to stabilizing farm household income and strengthening national food security by preemptively preventing mass livestock mortality caused by summer heatwaves.

We conducted a thorough analysis of the existing eight agricultural impact indices, reorganized overlapping or low-utility indicators, and refined them into five core indices that maximize field usability. The specific results are as follows:

1. Scientific Standardization and Integration of Crop Growth Indices

Overlapping concepts such as 'Growing Degree Days' and 'Effective Accumulated Temperature' were unified into 'Growing Degree Days (GDD),' and the unit was standardized from the unofficial 'degree-day' to the internationally accepted '°C·day' to enhance data reliability.

Highlighted Achievements in 2025

Vague terms like 'Plant Period' and 'Crop Period,' which were uncommon in the field, were abolished and replaced with 'Growing Season Length (GSL),' which reflects actual crop growth characteristics. Specifically, GSL established quantitative calculation criteria by defining the start date as "when the daily average temperature remains above 5°C for 5 consecutive days" and the end date as "when it remains below 5°C for 5 consecutive days," enabling precise prediction of changes in cultivation periods due to climate change.

2. Efficiency in Facility Agriculture Energy Management and Advancement of Fruit Tree Models

'Heating Degree Days,' which simply accumulated temperature differences, was upgraded to 'Facility Heating Degree Days (HDD),' specialized for energy management in smart farms and greenhouses. Based on the critical growth temperature for each crop (5°C for cold-tolerant, 10°C for heat-loving), this accurately calculates heating demand to maintain optimal internal environments, supporting farmers in planning heating cost reductions. Conversely, 'Cooling Degree Days (CDD)' was excluded due to its low utility, as farmers rarely use cooling systems due to cost constraints.

3. Strengthening Response Capabilities in Livestock Sector to Prevent Mortality

The simple 'Temperature Humidity Index' was renamed 'Livestock Heat Index (THI)' to allow farmers to intuitively recognize risks, and its functions were significantly enhanced. Applying the US NRC (National Research Council) formula, we quantified livestock heat stress based on daily average temperature and humidity. Instead of providing just an index value, we improved it to provide 5-level risk information (Normal-Caution-Warning-Danger-Fatal) based on thresholds for each livestock type (cattle, pigs, chickens). This supports livestock farmers in taking preemptive measures to prevent mass losses during heatwaves.

Category	Existing Indices (8 types)	Improved Indices (5 types)	Major Changes
Integration	Growing Degree Days	Growing Degree Days	Unification of names and formulas
	Effective Accumulated Temperature		
	Plant Period	Growing Season Length	Establishment of start/end date criteria
	Crop Period		
Refinement	Heating Degree Days Cooling Degree Days(Deleted)	Facility Heating Degree Days	Specialized for greenhouse energy management
	Temperature Humidity Index	Livestock Heat Index	Provision of 5-level risk information by livestock type
Method Change	Chill Units	Chill Days / Anti-Chill Days	Application of phenological model using daily data

Table 1 Comparison of Agricultural Impact Indices Improvement

The five improved impact indices go beyond simple meteorological statistics to provide practical decision-support information directly linked to productivity improvement and management stability in the agricultural field.

First, it enables data-driven precision agriculture planning. By utilizing the standardized 'Growing Degree Days (GDD)' and the quantitatively calculated 'Growing Season Length (GSL),' farmers can accurately forecast optimal timings for each growth stage, from germination to flowering and harvest. This allows farmers to determine the appropriate timing for fertilization and irrigation to enhance product quality and scientifically assess shifts in suitable cultivation areas or the feasibility of double cropping due to climate change, enabling preemptive preparation of future cropping systems.

Second, it contributes to energy efficiency and cost reduction for facility farmers. The newly introduced 'Facility Heating Degree Days (HDD)' accurately predicts winter heating energy demand for greenhouses by considering the critical growth temperature for each crop. This not only assists smart farms and facility horticulture farmers in significantly reducing energy costs by minimizing unnecessary heating but also serves as a crucial basis for quantitatively assessing the impact of greenhouse gas reduction in the agricultural sector at the national level.

Third, it minimizes agricultural damage from meteorological disasters. 'Chill Days,' which reflect daily meteorological data, provide sophisticated predictions for fruit tree dormancy break and flowering times, enabling preparation against spring frost damage caused by abnormal low temperatures. Additionally, the 'Livestock Heat Index (THI),' which reflects thresholds for each livestock type (cattle, pigs, chickens), provides specific risk information in 5 levels (Normal to Fatal). This significantly strengthens the risk management capabilities of livestock farmers by mitigating livestock stress and preventing mass mortality during summer heatwaves.

Highlighted Achievements in 2025

6. Evaluation of Heatwave and Drought Predictability Using DCPP Prediction Models over East Asia

● Ms. Daeun Jeong (downy@apcc21.org) ● Dr. Hyun-Ju Lee (asteria1104@apcc21.org)

Recently, East Asia has experienced a rapid increase in the frequency and intensity of extreme hydrometeorological disasters, such as heatwaves, droughts, and floods, driven by the acceleration of climate change. To proactively respond to the climate crisis and minimize socio-economic damage, securing reliable mid-to-long-term prediction information on a decadal scale is essential. In particular, the Decadal Climate Prediction Project [1](DCPP), a core initiative of the World Climate Research Programme (WCRP), is an innovative system that projects the climate for the next decade by incorporating observed initial conditions into climate models. While its potential for global climate risk management is highly recognized, systematic diagnosis and verification of its performance regarding East Asian extremes remain insufficient. Therefore, this study aims to precisely diagnose the characteristics and limitations of the DCPP prediction system. By providing essential baseline data for enhancing forecast reliability and developing bias correction technologies, this research seeks to contribute to establishing an effective framework for climate disaster response.

All five DCPP prediction systems consistently exhibit positive biases (model values exceeding observations) across East Asia when predicting heatwave frequency indices of warm days [2](TX90p) and warm nights [3](TN90p). These indices show high sensitivity to warming, with biases intensifying as forecast lead time increases. In contrast, the intensity indices—annual maximum of daily maximum temperature [4](TXx) and annual maximum of daily minimum temperature [5](TNx)—generally show negative biases (model values lower than observations). The upward trends in heatwave indices simulated by the models are overestimated compared to observations, with particularly pronounced increases in TX90p and TN90p after the 2000s. Predictability analysis indicates that frequency-based indices exhibit higher skill than intensity-based indices; notably, MPI-ESM1-2-HR demonstrates high correlations and low errors for heatwave frequency indices. In contrast, CMCC-CM2-SR5 shows low predictive skill across all heatwave indices, with negative correlations for TN90p. Overall, models exhibiting relatively robust predictive performance may allow the direct use of uncorrected forecasts, whereas models characterized by strong warming trends and substantial biases would require bias correction based on observed trends.

The drought prediction performance of the DCPP systems was rigorously evaluated through both deterministic and probabilistic verification, spanning lead times from individual years to multi-year averages of three, five, and nine years. While most models exhibited a positive precipitation bias, predictive performance improved significantly when transitioning from single-year forecasts to multi-year average assessments. These results empirically demonstrate that the DCPP systems possess a distinct strength in capturing the long-term decadal mean state rather than predicting the specific climate variability of a single year. Furthermore, the study revealed clear discrepancies in performance among the models depending on the verification framework utilized. Specifically, MIROC6 demonstrated the highest skill in deterministic verification, whereas CanESM5 excelled in probabilistic verification. These distinct performances are attributed to the unique error characteristics and internal physical mechanisms inherent in each individual climate model. Consequently, the findings indicate that a uniform bias correction approach applied across all models is insufficient for fundamentally enhancing the accuracy of DCPP-based drought information. Instead, the research emphasizes the necessity of implementing customized calibration methods that account for the specific prediction characteristics and error profiles of each model.

Glossary

1) DCPP:
Decadal Climate Prediction Project

2) TX90p (Warm days):
Number of days when daily maximum temperature is greater than the 90th percentile

3) TN90p (Warm nights):
Number of days when daily minimum temperature is greater than the 90th percentile

4) TXx:
Annual maximum value of daily maximum temperature

5) TNx:
Annual maximum value of daily minimum temperature

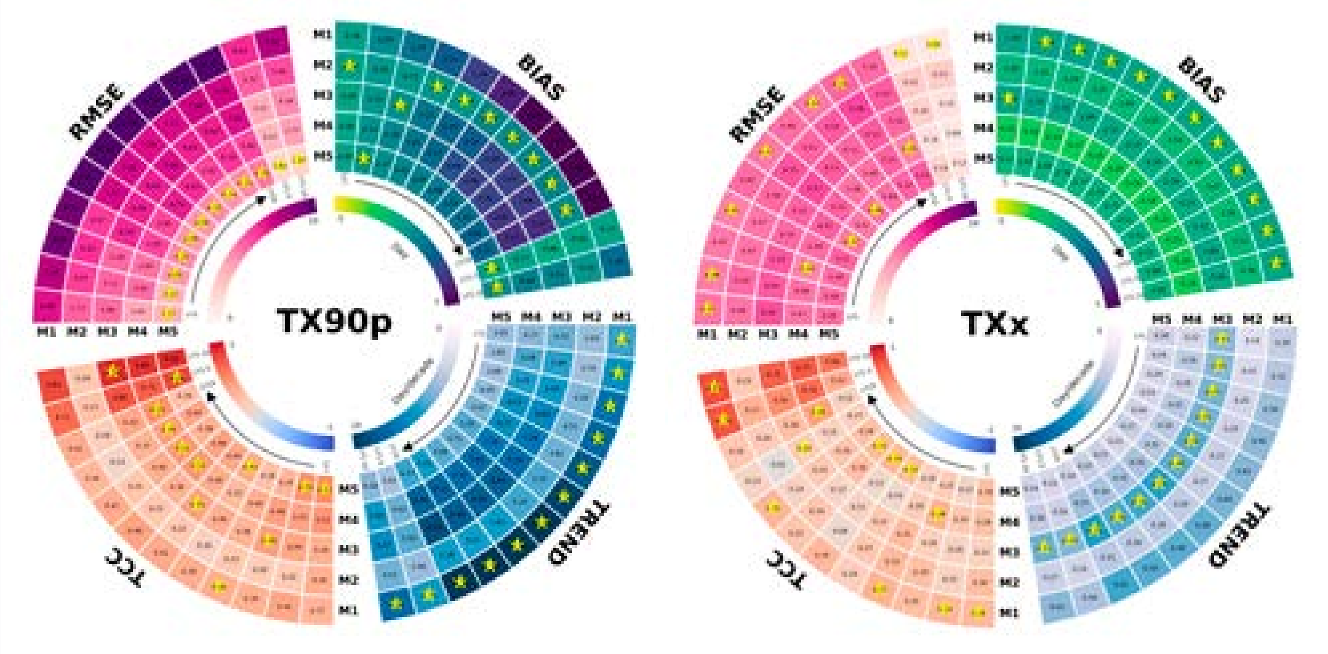


Fig 17 Mean bias, decadal trend, temporal correlation and root mean squared error of detrended heat indices (TX90p and TXx) between ERA5 reanalysis data and DCPP hindcast model data over East Asia for June-August. M1, M2, M3, M4 and M5 denote CanESM5, CMCC-CM2-SR5, HadGEM3-GC3.1-MM, IPSL-CM6A-LR and MPI-ESM1.2-HR, respectively. Yellow stars are marked on the models with the lowest absolute bias, highest trend, highest correlation and the lowest error.

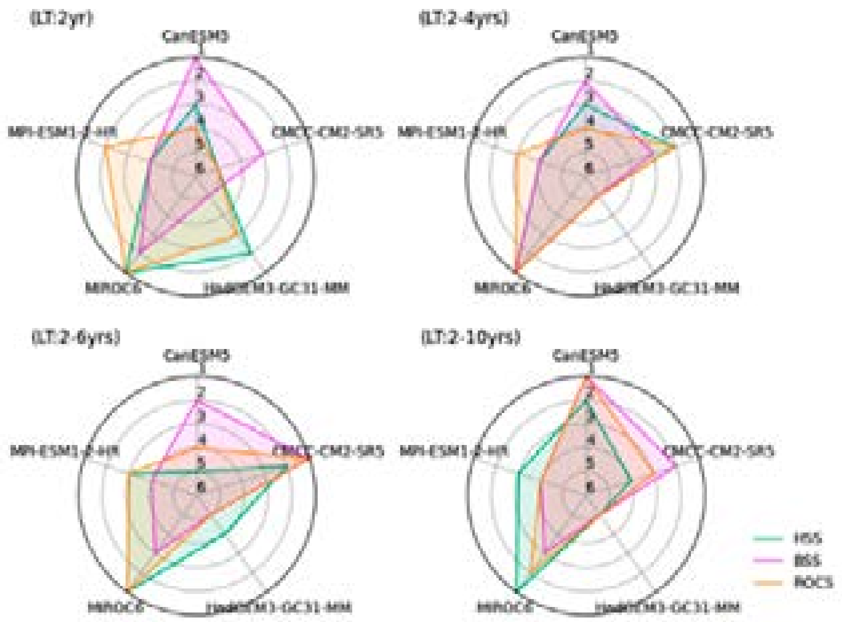


Fig 18 Comparison of Multi-model Verification Scores (ROCS, BSS, and HSS) for East Asian Drought Prediction across Lead-time Windows.

Highlighted Achievements in 2025

Characteristics(Model)	Description	Strategy/Direction
Good ROCS/HSS but poor BSS (MIROC6, MPI-ESM1-2-HR)	Preserve rank information to keep high ROCS	**Quantile mapping** of SPI6 at each lead window
High BSS but modest ROCS/HSS (CanESM5, (partly CMCC-CM2-SR5))	Sharpening rather than further bias removal	**Down-weight** when they strongly disagree with high-ROCS models
Weak across all metrics (HadGEM3-GC31-MM)	Limited potential added value from bias correction	Heavily down-weight / only for quantifying **uncertainty**
Skillful (ROCS) for **longer averaging windows**	Time-scale aware (preserving low-frequency signal)	Treat **each lead window** with its own calibration parameters

Fig 19 Diagnostic Characteristics of DCPP Models and Corresponding Customized Bias Correction Strategies

This study scientifically identified the applicability and limitations of the DCPP system in predicting extreme climate in the East Asia region. In particular, by revealing the different error characteristics and the degree to which each model reflects the warming trend, this study provided essential foundational data for the future development of model-specific bias correction techniques. This is expected to fundamentally enhance the reliability of climate prediction information and serve as a scientific foundation for more sophisticated climate disaster response systems and the establishment of national climate policies.

03

APEC CLIMATE CENTER

Research Projects in 2025

Research Projects in 2025

Practical implementation of climate information services and strengthening research and development capabilities to address the climate crisis in the Asia-Pacific region

Annual Strategic Objectives	Year 1 (2025)	Year 2 (2026)	Year 3 (2027)
	Building the Foundation for the Expansion of Climate and Climate Change Information in the Asia-Pacific Region	Advancing the Deployment of Climate Crisis Response Technologies and the Establishment of an Information System in the Asia-Pacific Region	Enhancing Extreme Climate Services and Solidifying International Leadership in Climate Crisis Response in the Asia-Pacific Region

분류	사업종류	과제명
1. Operation and Technical Development of Real-Time, Highly Validated Climate Prediction System for the Asia-Pacific Region	1-1. Operation and Improvement of Asia-Pacific Climate Information Services	Project 1: Enhancing the effectiveness of MME seasonal forecasts for responding to extreme climate
		Project 2: Development of advanced subseasonal-to-seasonal forecasting approaches enabling seamless prediction
		Project 3: Enhancement of Seasonal Prediction Information Systems and Development of Subseasonal Prediction Infrastructure in the Asia-Pacific Region
	1-2. Monitoring, Analysis And Prediction System Improvement for Extreme Climate in East Asia	Project 4: Technology Development for Annual-to-Decadal (A2D) Extreme Climate Outlooks in the Asia-Pacific Region
		Project 5: Advanced Downscaling for High-resolution Climate Information and Sectoral Applications (I)
	1-3. Artificial Intelligence (AI)-based Objectification Technology Development for Climate Prediction	Project 6: Exploring Artificial Intelligence Techniques for Better Forecast of Climate Extremes
	1-4. Improvement of the Verification and Utilization Framework for Climate Prediction Models	Project 7: Development of a Verification Framework and Expansion of Testbeds for Advancing Climate Prediction Models
2. Green Climate Fund (GCF) Supported Projects	2-1. Joint Project with the UN Environment Programme (UNEP)	Project 8: Enhancing Climate Information and Knowledge Services for Resilience in 5 Island Countries of the Pacific Ocean

1. Operation and Technical Development of Real-Time, Highly Validated Climate Prediction System for the Asia-Pacific Region

- Practical implementation of climate information services and strengthening research and development capabilities to address the climate crisis in the Asia-Pacific region

1-1. Operation and Improvement of Asia-Pacific Climate Information Services

- Generating operational seasonal and subseasonal forecasts to effectively address climate extremes in the Asia-Pacific region

Project 1. Enhancing the Effectiveness of MME Seasonal Forecasts for Responding to Extreme Climate

● Dr. Jinho Yoo (jhyoo@apcc21.org)

1) Background and Relevance

- With the intensification of climate change leading to more frequent climatic extremes such as heatwaves and floods, conventional tercile-based seasonal forecasts (above/near/below normal) alone have exhibited limitations in supporting effective responses to extreme events. This necessitates the interpretation and expansion of seasonal prediction information from both extreme and physical perspectives.
- Previous evaluations of MME prediction skill have mainly relied on hindcast datasets, resulting in a limited understanding of the characteristics and reliability of real-time forecasts that reflect recent and rapid climate change trends. Accordingly, it is imperative to explore new predictive products for responding to extreme climate events using the large ensemble datasets of the APCC MME, and to gradually enhance the interpretability and usability of seasonal forecast information through the diagnostic analysis of major climate modes.

2) Main Results

A. Development of Predictive Information for Extreme Climate Response

- Climate distribution analysis and probabilistic forecast evaluation: Distributional characteristics of observational and climate prediction data were analyzed, and various bias correction methods were applied to establish foundational methodologies for extending seasonal predictions toward extreme and physically based perspectives.
- Integrated analysis of monthly precipitation, precipitation frequency, and intensity: Relationships between monthly total precipitation and precipitation frequency and intensity were examined to diagnose regional differences in precipitation mechanisms relevant to extreme rainfall characteristics.

B. Diagnostics of Major Climate Modes in MME Seasonal Predictions

- Evaluation of oceanic and atmospheric climate mode predictability: Predictability of major climate modes, including the tropical Pacific (ENSO), North Atlantic, Indian Ocean (IOD, IOB), and atmospheric indices (AO, NAO, etc.), was assessed for both hindcast and real-time forecast periods.
- Analysis of real-time forecast datasets: Real-time forecast data accumulated since 2012 were analyzed to examine climate mode prediction characteristics under operational conditions and to compare them with hindcast-based assessments.

C. Operation and Improvement of Operational Climate Prediction Systems

- Enhancement of the MME system: A new model from Pukyong National University (PKNU) was incorporated, improvements to existing models (CWA, CMCC, METFR)

Research Projects in 2025

were reflected, and the hindcast climatological period was extended to 1993–2016 (24 years) to better capture recent climate variability.

- Automation of climate outlook production: Automation of the entire outlook production process—including signal detection, text generation, and document assembly—was implemented to improve operational efficiency and consistency.
- Improvement of the ENSO alert system: Alert criteria were refined by considering the development and decay phases of ENSO events, enabling clearer communication of event evolution.
- Improvement of the BSISO subseasonal prediction system: An in-house input data processing system was established to respond to changes in external data acquisition environments, thereby enhancing the stability of subseasonal operational forecasting.
- Enhancement of the Fire and Haze Early Warning System (FHEWS): High-resolution (1°×1° grid) fire risk prediction products were pilot-produced to supplement existing region-based information and to evaluate operational applicability.
- Domestic and international collaboration: Forecast products were provided in support of the KMA's three-month outlook, and global GPC datasets were standardized and disseminated through the operation of the WMO Lead Centre for Seasonal Prediction Multi-Model Ensembles (LC-SPMME).

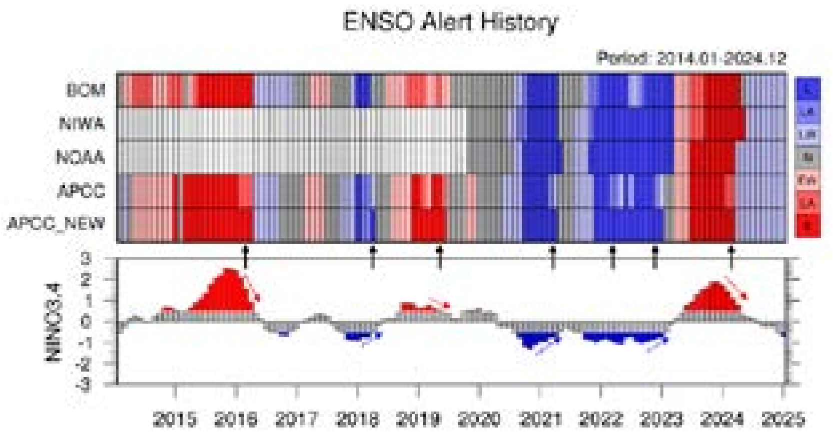


Fig 20 Comparative Analysis of ENSO Alert History: Global Institutions vs. APCC (Pre- and Post-System Revision) based on Niño 3.4 and SOI Indices

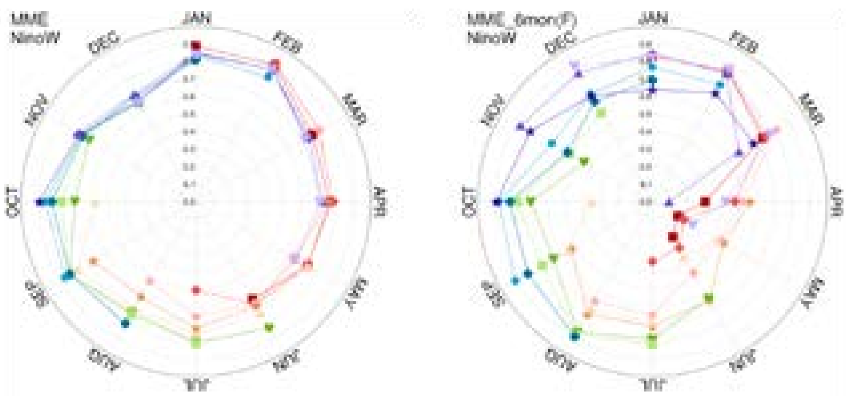


Fig 21 Monthly Prediction Skill of the Niño West Index: Comparison between MME Hindcast (Left) and Forecast (Right)

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3) Expected Implications

- The gradual expansion of seasonal prediction information from extreme and physical perspectives will contribute to improved proactive decision-making and response capacities in sectors such as agriculture, water resources, and disaster management.
- Provision of information on prediction characteristics and limitations of major climate modes will enable forecasters and users to interpret and utilize MME seasonal forecasts more appropriately.
- Stable and efficient delivery of high-quality climate prediction information across the Asia-Pacific region will be achieved through system enhancements, including expanded model participation, updated climatological periods, and increased automation.

Project 2. Development of Advanced Subseasonal-to-Seasonal Forecasting Approaches Enabling Seamless Prediction

● Dr. Suryun Ham (suryun01@apcc21.org)

1) Background and Relevance

- There is an increasing need to develop a system that overcomes the limitations of conventional seasonal prediction by providing weekly subseasonal information capable of capturing rapid short-term variability. This is essential for the early detection and proactive response to extreme climate events occurring on short timescales.
- The objective is to establish a system that collects subseasonal forecast information on a weekly basis to produce reliable subseasonal predictions based on a multi-model ensemble (MME) approach. Furthermore, the project aims to develop integrated subseasonal-to-seasonal (S2S) utilization technologies to lay the foundation for advancing toward seamless prediction.

2) Main Results

A. Development of integrated subseasonal-to-seasonal (S2S) forecasting approaches

- Establishment of an APCC S2S MME prediction system
  - · Configuration of MME participating models and establishment of a visualization system
  - · Comparative evaluation and selection of optimal probabilistic forecasting techniques for subseasonal prediction
  - · Development of an MME subseasonal prediction system and real-time pilot operation of subseasonal forecasts
  - · Identification of integrated S2S utilization prediction content based on predictability and usability for seamless forecasting
- Production and provision of one- and three-month forecast information
  - · Production of KMA S2S MME forecast data to support the KMA one-month outlook (weekly)
  - · Production of East Asian extreme climate information for the APCC webpage (monthly)

B. Operation and improvement of the APCC in-house model (SCoPS) for subseasonal forecasting

- Establishment of an operational SCoPS subseasonal prediction system and production of real-time weekly prediction data
  - · Establishment of a seasonal prediction data production system
- Optimization of atmosphere-ocean and land surface initial conditions for SCoPS and identification of improvement strategies
  - · Development of land surface initialization techniques and evaluation of their impacts
  - · Analysis of forecast error characteristics related to atmosphere-ocean initial conditions

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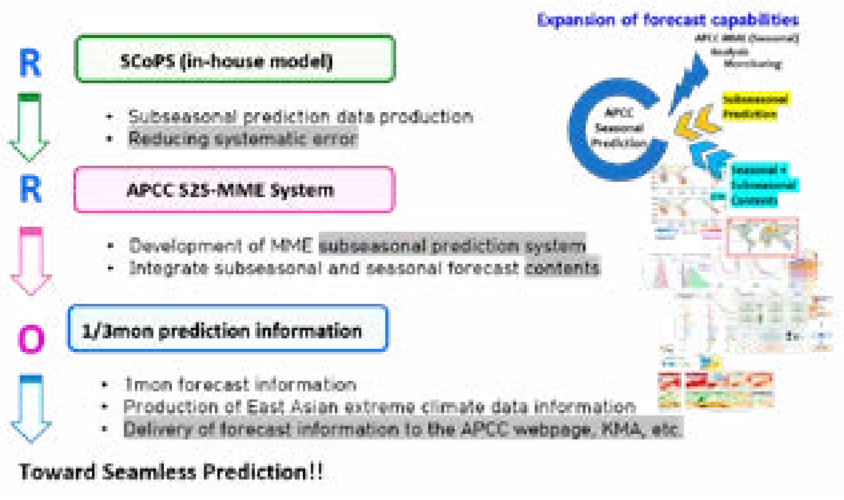

Fig 22 Conceptual framework and project schematic for the subseasonal-to-seasonal (S2S) forecast utilization system

3) Expected Implications

- Strengthening medium- and extended-range forecast support for the KMA and the Asia-Pacific region by providing subseasonal-to-seasonal (S2S) forecast information
- Enhancing the uniqueness and competitiveness of APCC climate prediction services through the integration of subseasonal-to-seasonal (S2S) forecasting technologies

Project 3. Enhancement of Seasonal Prediction Information Systems and Development of Subseasonal Prediction Infrastructure in the Asia-Pacific Region

- Mr. Sangcheol Kim (sclow@apcc21.org)

1) Background and Relevance

- Service Operations: To ensure service continuity through the stable operation of APCC climate information services based on established operational plans and platform modernization.
- User Support: To provide users with a unified gateway by integrating the homepage and climate information tools into a single website system, thereby strengthening inter-service connectivity and establishing a foundation for further expansion.
- Policy Compliance: To comply with the government's web governance policy by streamlining the operational system and reorganizing dispersed services into an integrated user interface (UI).
- High-Resolution Verification Service: To implement a pilot service that provides user-tailored verification information to enhance the utilization and accessibility of high-resolution MME seasonal forecast information.
- Service Domain Expansion: To proactively establish a platform-based environment for providing sub-seasonal forecast information, thereby expanding the scope of climate adaptation support in the Asia-Pacific region.

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2) Main Results

A. User-Customized High-Resolution MME Seasonal Prediction & Verification Pilot Service

- Designed and developed the technical framework for user-customized high-resolution MME seasonal prediction and verification
- Implemented the high-resolution MME seasonal prediction and verification pilot service and collected user feedback (official service launch planned for 2026)

B. Stable Operation and Improvement of APCC Climate Information Services

- Modernized the cloud operating environment by transitioning from PaaS-TA[1], which is scheduled to end technical support, to the latest K-PaaS[2]
- Enhanced the Homepage-CLIK integrated interface and established a unified web address system to achieve web quota targets
- Developed and implemented a new service for accessing user-selected regions on the homepage
- Ensured the stable operational management of climate information services:

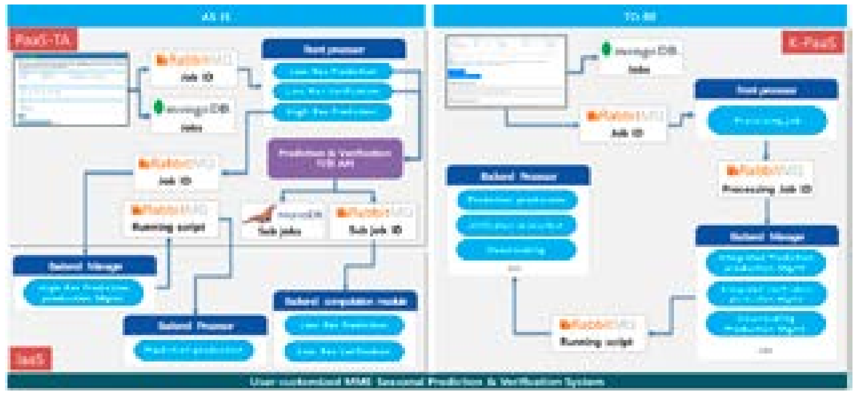

Fig 23 User-customized MME Seasonal Prediction & Verification System

Fig 24 User-customized MME Seasonal Prediction & Verification service UI (Front & End)

Glossary

1) PaaS-TA (Platform as a Service-Technical Architecture):

An open-source-based open PaaS cloud platform developed by the National Information Society Agency (NIA). It controls cloud infrastructure and supports application development, deployment, and operation.

2) K-PaaS (Korean Platform as a Service):

A collective term for cloud platform services and solutions certified for conformity based on the K-PaaS standard model open source. As the successor standard to PaaS-TA, it aims to invigorate a private sector-led cloud-native ecosystem.

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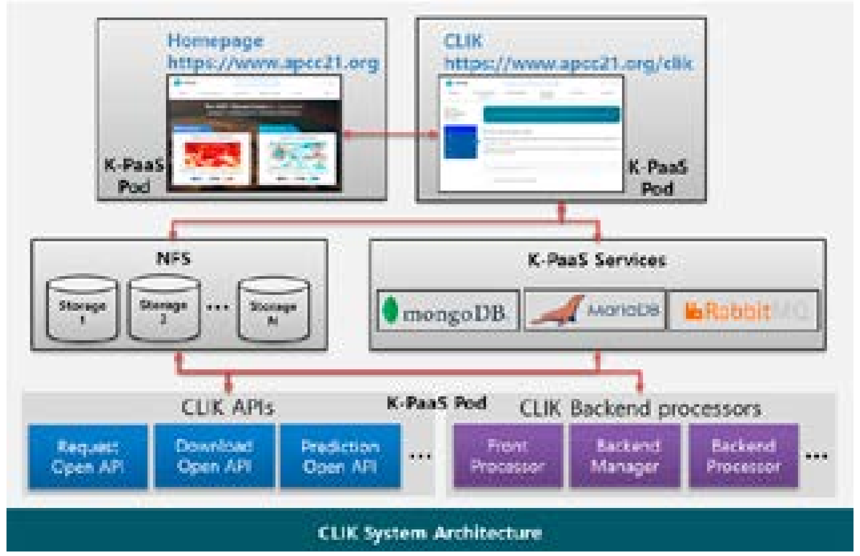

Fig 25 CLIK system architecture

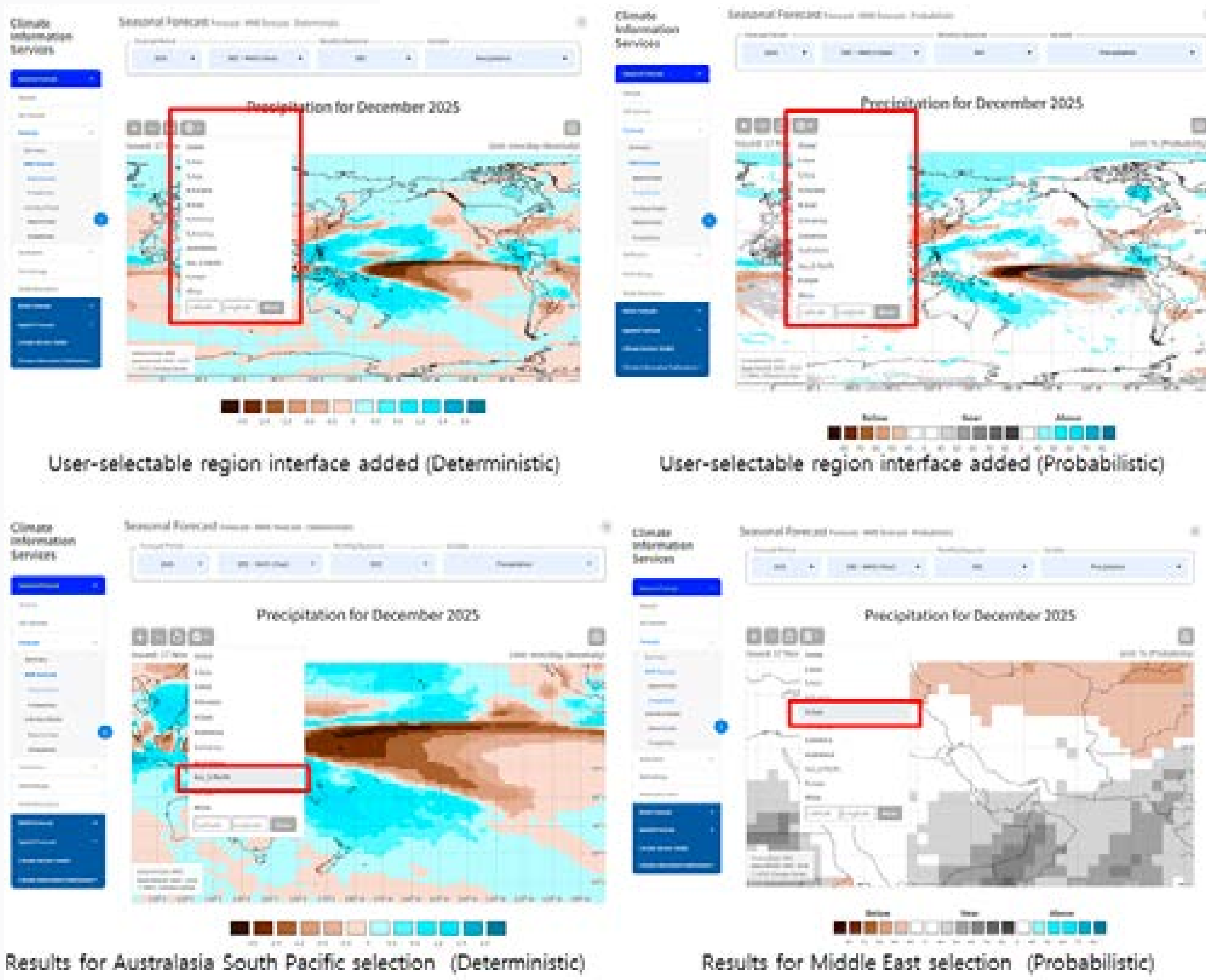

Fig 26 User-selected region access service

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3) Expected Implications

- Establishment of a consistent climate information delivery channel through the integration of the official website and CLIK
- Enhancement of climate forecast information utilization through high-resolution MME seasonal prediction and verification, as well as website services providing access to user-selected regions
- Improvement of operational stability, scalability, and budget efficiency through service integration and platform modernization

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1-2. Monitoring, Analysis and Prediction System Improvement for Extreme Climate in East Asia

• Evaluating annual-to-decadal (A2D) extreme climate predictability and producing high-resolution downscaled data to improve the quality and utilization of climate change information in the Asia-Pacific region.

Project 4. Technology Development for Annual-to-Decadal (A2D) Extreme Climate Outlooks in the Asia–Pacific Region)

● Dr. OkYeon Kim (oykim@apc21.org)

1) Background and Relevance

- Anthropogenic climate change has led to the escalation of extreme climate-related disasters to a critical level.
- In the Asia–Pacific region, extreme climate events associated with climate change are increasing, and consequently, related socio-economic risks are also growing. Therefore, reliable A2D forecast information on the occurrence of extreme climate events is essential to support proactive policy decisions for climate change adaptation and response.

2) Main Results

A. Developing storylines for A2D extreme climate outlooks in the Asia–Pacific region

- Selected atmospheric, oceanic, and land-surface factors associated with observed extreme climate events (high-impact events, HI events; heat waves/cold waves, drought/heavy rainfall).
  · Selected atmospheric, oceanic, and land-surface factors associated with the regional characteristics of extreme climate events through statistical and dynamical analyses (considering relationships with variability and frequency over the A2D period).
  · Analyzed the sensitivity (e.g., duration, intensity) of the relationship between extreme events and the selected factors, and examined the underlying causes and mechanisms.
  · Prioritize the selected factors according to duration, intensity, and related characteristics.

B. Developing bias-correction methods for A2D extreme climate outlooks in the Asia–Pacific region

- Analyzed the predictability of extreme climate events in A2D climate data (deterministic and probabilistic).
  · Evaluated regional predictability of extreme climate events at A2D scales (e.g., annual, 5-year, and 10-year).
  · Identified the characteristics of extreme events with high forecast skill (e.g., average of maximum values over a fixed period—1, 5, or 10 years—frequency, intensity, and duration).

C. Providing monitoring and analysis information on extreme climate and responding to climate issues

- Monitored extreme weather/climate events in the Asia–Pacific region and analyzed their causes.
- Prepared climate anomaly reports for relevant ministries and agencies

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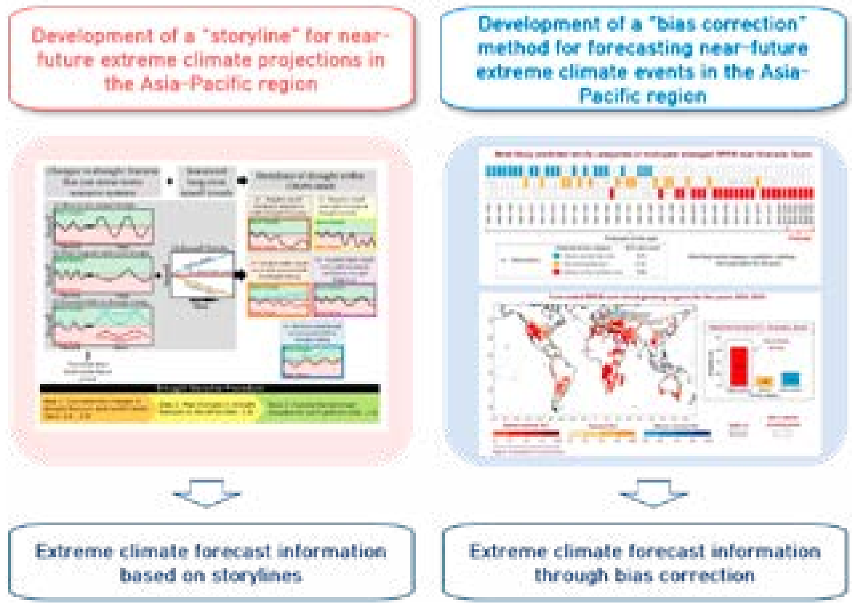

Fig 27 Overview of research content

3) Expected Implications

- Strengthening of research capacity for international collaborative research through DCPP-related studies and international exchanges.
- Creation of opportunities to participate in future DCPP initiatives.
- Establishment of a scientific foundation for responding to the new climate regime by developing A2D-scale climate prediction technologies.
- Provision of climate-risk prediction information applicable to long-term climate-change adaptation policy planning in sectors such as agriculture and hydrology.

Project 5. Advanced Downscaling for High-resolution Climate Information and Sectoral Applications (Ⅰ)

● Dr. Seongkyu Lee (geoslegend@apcc21.org)

1) Background and Relevance

- Global Climate Models[1] (GCMs) possess limitations in spatial resolution, which restrict their applicability in regional-scale disaster risk assessment and policy formulation. Therefore, it is necessary to develop high-resolution climate change scenario downscaling technologies that reflect local and regional climate characteristics.
- Through statistical and deep learning–based downscaling methods, this initiative seeks to overcome the resolution limitations of climate data and, based on evaluations of national standard climate change scenarios, provide region-specific climate projection information, thereby strengthening climate change adaptation measures and policy response capacities.

2) Main Results

A. Generation of satellite-based high-resolution gridded data, algorithm development, and quality control

Glossary

1) Global Climate Model (GCM):

A physics-based climate prediction model that numerically simulates the interactions among the major components of the Earth system—such as the atmosphere, oceans, land surface, and cryosphere—in order to scientifically project past, present, and future global climate change.

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- Constructed training datasets based on multiple satellite products (GPM IMERG, CMORPH, PERSIANN, CHIRPS)
- Developed machine-learning models (XGBoost, Random Forest), generated training results, and optimized AI models
- Produced high-resolution precipitation gridded data using AI-based models

※ A machine-learning model was developed and trained to generate highly accurate satellite-based precipitation gridded data for the pilot region (Jeju Island), demonstrating robust predictive performance overall.

B. Development of multivariate downscaling core technologies

- Produced 1-km observed gridded temperature and precipitation data for the pilot region (Jeju Island) by applying Ordinary Cokriging (OCOK), Simple Cokriging (SCOK), and Universal Cokriging (UCOK) methods
- Analyzed prediction accuracy (R2, RMSE) for temperature and precipitation for each cokriging method using Leave-One-Out Cross-Validation (LOOCV)[2]

※ For Jeju Island, which features complex topographic and climatic characteristics, the UCOK method showed the highest R2 and the lowest RMSE, indicating superior overall predictive performance.

C. Development of AI-based downscaling technologies to enhance the usability of climate change projection data

- Constructed and tested downscaling models based on the EDSR framework using ERA-5 and topographic data (DEM)
- Built datasets and performed comparative analysis of downscaling accuracy considering spatial interpolation[3] methods (Nearest Neighbor, Bilinear, Bicubic) and downscaling factors (×2, ×4, ×8)
- Assessed accuracy using ASOS observations instead of image-based evaluation metrics (PSNR, SSIM)

※ Deep learning–based downscaling models incorporating topographic data significantly improved temperature downscaling performance across the East Asia region.

D. Analysis and evaluation of high-resolution (500 m) gridded data

- Evaluated simulation performance for high-resolution grids considering spatial resolution (500 m vs. 1 km) and radius of influence (1.3 km vs. 2 km)
- Verified spatial consistency (Moran's I) and assessed simulation performance (KGE)
- Produced and analyzed future climate projection data for extreme indices (1 km vs. 500 m)

※ The 500-m model generally showed higher accuracy than the 1-km model, and improvements in predictive performance were more clearly attributed to increased spatial resolution than to changes in the radius of influence.

E. Development of improvement measures for sector-specific impact indices based on national standard climate change scenarios

- Reviewed the current utilization status and redefined the concepts of eight agricultural sector impact indices
- Formulated improvement plans for the eight agricultural sector impact indices

※ The eight agricultural impact indices were ultimately reorganized into five indices by categorizing them into groups such as index integration, name change, sector change, and change of use through working-level meetings and expert advisory consultations regarding the improvement of agricultural impact indices.

Glossary

2) LOCV (Leave-One-Out Cross-Validation):

A validation method in which predictions are performed using all but one observation, and the predictive performance is evaluated by repeatedly comparing the prediction with the excluded observation.

3) Interpolation:

A method for estimating unobserved values that lie between observed data points based on already observed values.

Fig 28 Summary of Research on the Development of Region-Specific Downscaling Core Technologies

3) Expected Implications

- By developing region-specific downscaling core technologies capable of reflecting local climate characteristics and complex topography, this study establishes a technical foundation for producing high-resolution climate projection gridded data.
- By standardizing downscaling core technologies and a framework for evaluating their applicability to national standard climate change scenarios, this study builds a foundation for utilizing baseline data in region-specific climate change impact and adaptation studies as well as climate disclosure.
- This study contributes to future downscaling of climate change scenario data and enhances climate change response policy formulation at national and local government levels by accumulating region-specific downscaling technologies.

Research
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1-3. Artificial Intelligence (AI)-based Objectification Technology Development for Climate Prediction

• Development of an artificial intelligence model designed to produce reliable predictive information on extreme climate events

Project 6. Exploring Artificial Intelligence Techniques for Better Forecast of Climate Extremes

● Dr. Yun-Young Lee (yyalee@apcc21.org)

1) Background and Relevance

- It is essential to proactively prepare for extreme climate events, which are becoming more frequent due to global warming, and to strengthen capabilities for responding to the climate crisis.
- We aim to develop an AI-based prototype model with a 3–4-week lead time to address the limitations of existing forecasting systems regarding climate extremes and to advance sub-seasonal prediction technologies.

2) Main Results

A. AI Prototype Development for 3–4-Week Prediction of Climate Extremes
We developed AI models to predict heatwaves, heavy rainfall, and marine heatwaves with a lead time of 3 to 4 weeks, aiming to mitigate risks associated with increasingly frequent climate hazards.

- Anomalous High Temperature:
  We adopted a bias-correction approach to improve ECMWF ensemble forecasts. Experiments utilizing an [3]Attention [2]UNet with binary labeling demonstrated the most realistic spatial probability patterns, successfully improving prediction skill compared to raw ECMWF outputs.
- Heavy Rainfall:
  A [5]ResNet-LSTM was constructed to effectively capture spatiotemporal patterns. The application of [4]multi-task learning (simultaneously predicting rainfall amount and extreme rainfall days) and the use of temporally decomposed input variables (10–60-day oscillations) significantly enhanced prediction accuracy.
- Marine Heatwaves:
  We designed a [6]SwinUNet model that extracts signals from large-scale ocean-atmosphere variables. By implementing a weighted loss function to prioritize extreme events and integrating multi-modal data such as river discharge, the model consistently outperformed the ECMWF baseline in detecting anomalously warm ocean grids.

B. Infrastructure for Climate Analysis and Research.

- To provide systematic support for future research, we established the "EastAsiaClimateExtremes" GitHub repository (https://github.com/yalexle/EastAsiaClimateExtremes). This platform archives grid-based historical climate extreme event profiles (derived from ERA5 and OISST) and provides code for calculating daily and weekly extremeness indices, which can serve as analysis-ready labels for training new AI models. This infrastructure is designed to lower entry barriers for researchers and facilitate interdisciplinary collaboration.

Glossary

1) Deep Learning:
An AI technique inspired by the human brain's neural networks. It learns complex patterns and rules from vast amounts of historical climate data to predict future weather phenomena.

2) UNet:
A deep learning architecture specialized in extracting spatial features to segment images. In this study, it is used as the foundational model for learning the spatial distribution patterns of anomalous high temperatures and marine heatwaves.

3) Attention UNet:
An advanced model that combines UNet with an "attention" mechanism. This allows the model to focus more intensively on important high-impact spatial features, improving the detection accuracy for heatwaves compared to the standard UNet.

4) Multi-task Learning
A technique where an AI learns multiple related tasks simultaneously (e.g., rainfall amount and the number of rainy days). This mutual learning process helps improve overall prediction accuracy.

5) ResNet-LSTM:
A deep learning architecture that combines "ResNet" (excellent at capturing spatial features in images) and "LSTM" (specialized in remembering time sequences). It is effective for analyzing patterns that change over both space and time.

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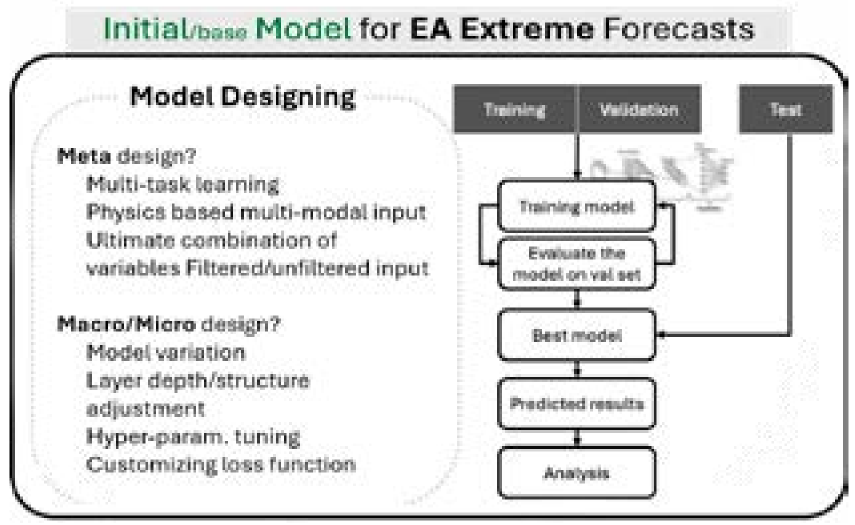

Fig 29 Experimental design of AI model variations to derive a prototype model for predicting climate extremes. (Right) Schematic of the process for deriving the optimal AI model.

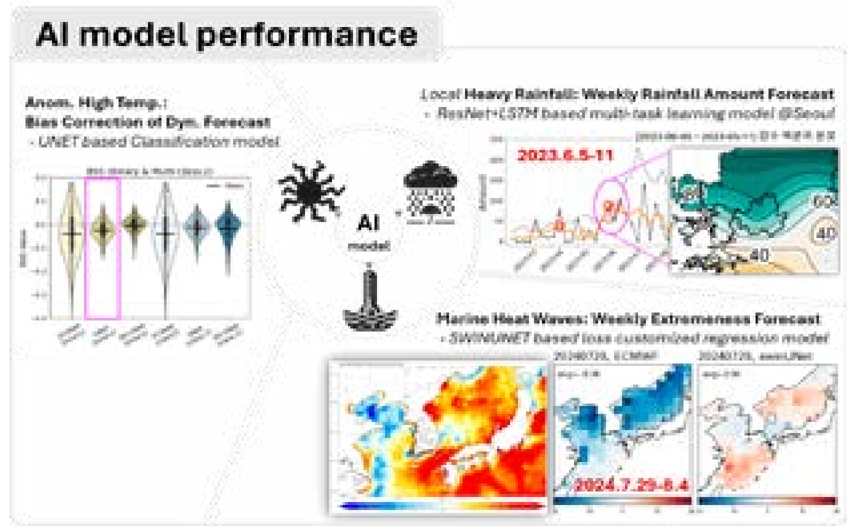

Fig 30 Performance of the AI prototype model for predicting East Asian climate extremes: (Left) Anomalous high temperature, (Top Right) Heavy rainfall, (Bottom Right) Marine heatwaves

3) Expected Implications

- Enhancing Climate Service Quality: Improving the accuracy of early warning systems for climate extremes and optimizing climate risk management across various industrial sectors.
- Establishing a Foundation for Adopting Future Technologies: Based on the developed AI prototype models, laying the groundwork for integrating future technologies such as probabilistic prediction and [7] Explainable AI (XAI).
- Vitalizing the Climate Extremes Research Ecosystem: Lowering entry barriers for subsequent research and promoting interdisciplinary collaboration through the open sharing of data and code inventories.

Glossary

6) SwinUNet:
An advanced model applying the latest technology (Swin Transformer) to process information over wide areas efficiently. It is optimized for detecting complex temperature changes in the ocean.

7) Explainable AI (XAI):
A technology that visually presents the "reasons" and "evidence" behind an AI's prediction, helping humans understand "why" a specific forecast was made.

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1-4. Improvement of the Verification and Utilization Framework for Climate Prediction Models

• Development of an advanced assessment system aimed at improving the performance of the Korea Meteorological Administration's operational climate forecasting models

Project 7. Development of a Verification Framework and Expansion of Testbeds for Advancing Climate Prediction Models

● Dr. Sun-Hee Shin (ssh222@apcc21.org)

1) Background and Relevance

- To enhance the predictive performance and operational applicability of the Korea Meteorological Administration (KMA) climate prediction system, timely and systematic verification of state-of-the-art climate model development techniques is essential. In particular, a robust framework for quantitatively evaluating and assessing the reliability of newly developed algorithms and physical parameterizations against existing operational models is required for their effective transfer into forecasting systems.

- The climate prediction model testbed serves as a core infrastructure that enables rapid testing and evaluation of model improvement technologies developed by KMA and the academic community. It plays a critical role in verifying the predictive skill and physical consistency of new techniques from an operational perspective. Furthermore, this project aims to develop diagnostic and evaluation systems using real-time forecast data while enhancing the versatility and sustainability of the verification framework through the expansion of verification components and structural improvements.

2) Main Results

A. Testbed Operation for Proactive Verification and Operational Transition of Advanced Climate Prediction Technologies

- Evaluation of the Operational Utility of High-Resolution Forecast Data from the KMA Climate Prediction System (GC3.2)
  · The climate simulation performance of high-resolution forecast data from the operational climate prediction system is evaluated, and its applicability to operational forecasting is quantitatively assessed.
  · Based on the simulation skill for summer extreme precipitation and winter extreme temperature events, the seasonal prediction utility of high-resolution forecast data is analyzed, providing a scientific basis for the operational adoption of a high-resolution ensemble prediction system.
- Assessment of the Operational Applicability of the High-Resolution River Runoff Model (TRIP)
  · Quasi-operational experiments are conducted using the climate prediction system (GC3.2) coupled with the high-resolution TRIP model.
  · Changes in prediction skill associated with freshwater effects and corresponding atmospheric and oceanic responses are analyzed to diagnose operational feasibility.

B. Expansion of the Verification Framework to Enhance Forecast Reliability

- Development of a Performance Evaluation Framework for Forecast Data of the KMA Climate Prediction System (GC3.2)
  · An automated verification system is implemented to support routine and consistent performance assessment of forecast data, enabling systematic evaluation of both deterministic and probabilistic forecast performance.

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  · The framework is designed to diagnose seasonal prediction skill systematically and to analyze the system's response characteristics to structural or configuration-related issues, thereby supporting a comprehensive assessment of forecast performance.
- Diagnosis of Climate Mode Prediction Characteristics in GC3.2 Forecast Data
  · Prediction characteristics of major climate modes are diagnosed using forecast data, including summer modes (the Circumglobal Teleconnection (CGT) and Pacific–Japan (PJ) patterns) and winter modes (the Eurasian pattern (EU) and North Atlantic Oscillation (NAO)).
  · The reliability of forecast data is assessed through a comparative analysis of simulation characteristics between hindcast and forecast datasets.
  · Strategies for the utilization of long-range forecasts are suggested based on the diagnosed prediction characteristics of the climate prediction system.
- Development of an Automated Seasonal Verification System Based on Quasi-Operational Testbed Experiments
  · Diagnostic metrics applicable to quasi-operational testbed experiments are designed for Arctic climate variability and East Asian summer and winter monsoon systems, and an automated seasonal verification framework is developed to establish a consistent performance evaluation environment.
  · In preparation for the introduction of the next-generation climate prediction system, hindcast seasonal experiment datasets for the latest model version (GC5.0) are collected and analyzed, and supporting evidence for operational transition is provided through the diagnosis of prediction performance and physical processes.

Fig 31 Testbed Operation and Expansion of the Verification Framework for Climate Prediction Model Improvement

3) Expected Implications

- Provision of quantitative scientific bases to support operational decision-making for the adoption of climate model improvements within the KMA climate prediction system.
- Enhancement of the versatility and long-term sustainability of the climate model verification framework through flexible application across seasons and climate modes.
- Contribution to improved long-range forecast accuracy and strengthened predictive capability for extreme climate events through enhanced seasonal climate mode prediction skill.
- Strengthening collaboration between KMA and related research institutions, facilitating rapid operational implementation of research outcomes and advancing APCC's capacity in climate model diagnostics and evaluation.

Research Projects in 2025

2. Green Climate Fund (GCF)-Supported Projects

• APCC is participating in the Green Climate Fund (GCF)-supported projects by being recognized by the international community for its climate-related expertise and knowledge acquired through the climate information provision service projects in the Asia-Pacific region, which have been promoted since its establishment.

2-1. Joint Project With The UN Environment Programme (UNEP)

Project 8. Enhancing Climate Information and Knowledge Services for Resilience in Five Island Countries of the Pacific Ocean

● Dr. Jinho Yoo (jhyoo@apcc21.org)

1) Background and Relevance

- Pacific Island Countries, particularly the five Small Island States (Cook Islands, Marshall Islands, Niue, Palau, and Tuvalu), are among the most vulnerable to climate change and climate variability; however, their capacity for climate prediction and preparedness remains very limited.
- This project aims to support the five Pacific Island Countries in better responding to extreme climate events by improving tailored climate prediction and early warning technologies designed for the Pacific region.
- In addition, the project seeks to strengthen the climate prediction capabilities of the national meteorological services (NMSs) of the five Pacific Island Countries through the continuous operation of training and capacity-building programs.

2) Main Results

A. Commencement of the Development of Country-Specific Applied Climate Prediction Products

- Based on the unique characteristics of each island country and the potential use of climate prediction information, the project has initiated the selection and development of applied climate prediction products to support decision-making in climate-sensitive sectors:
  · Cook Islands: Small-scale river streamflow prediction
  · Marshall Islands and Tuvalu: Drought early warning
  · Palau: Reservoir dam water level prediction
  · Niue: Wildfire risk prediction

B. Support for Enhancing Climate Prediction Capacity in Pacific Island Countries

- One in-person training program hosted at the APEC Climate Center:
  · September – Young Scientist Support Program (YSSP) (1-month duration; 4 participants from 4 countries): Advanced climate data analysis training, focusing on the relationships between large-scale climate variability and regional climate characteristics

C. Development and Testing of a Prototype Mobile Application for Early Warning

- Deployment of a pilot version of a mobile application designed to provide early warning information—such as heavy rainfall risk—based on satellite observations, and the collection of country-specific feedback.
  · Verification of system reliability and functionality through communication and coordination with NMSs and relevant agencies in each country.

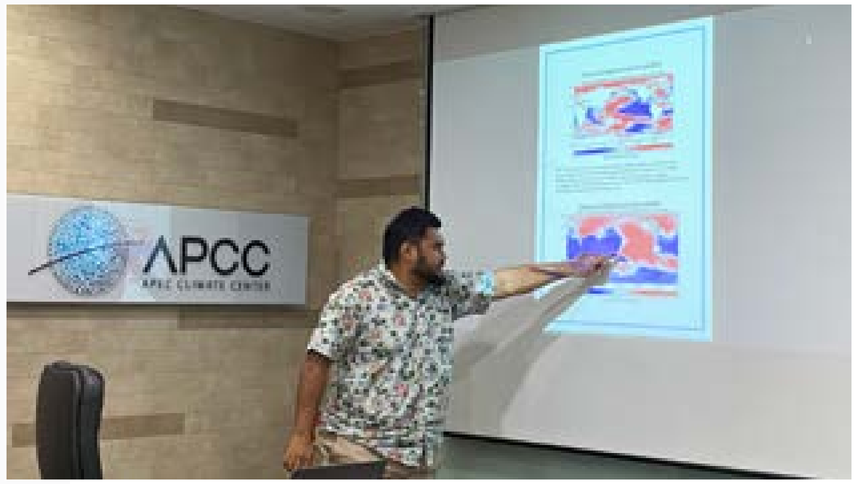


Fig 32 Final presentation of YSSP climate data analysis

Fig 33 YSSP participants and APCC team members

3) Expected Implications

- Enhancement of climate prediction and application capacities in the five Pacific Island Countries, leading to improved country-specific climate services.
- Expansion of the utilization of APCC's climate prediction information and increased contributions to climate resilience and climate services across the Asia-Pacific region.

04

APEC CLIMATE CENTER

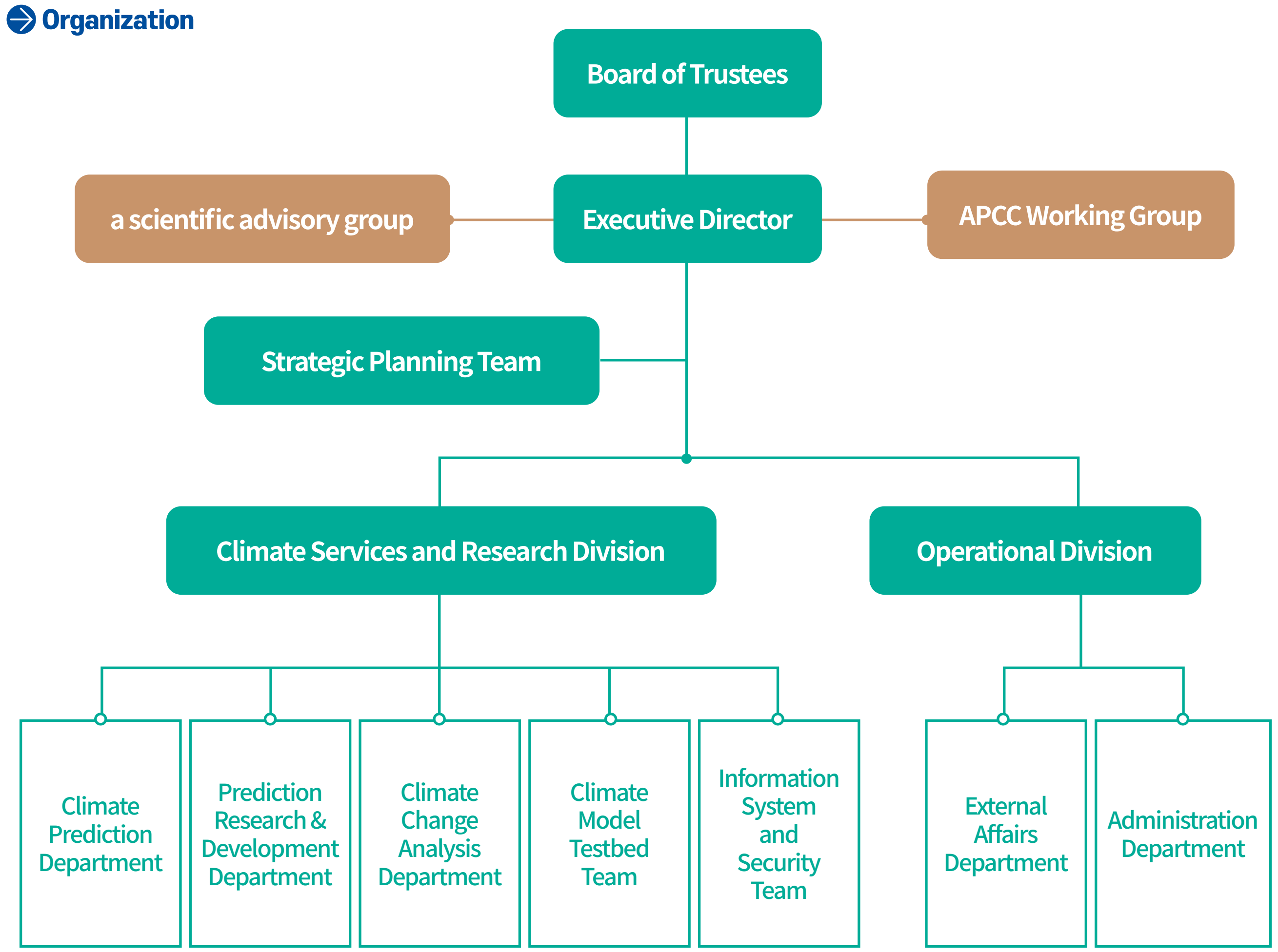
Introduction to APCC

APCC Introduction

APEC Climate Center

APCC enhances the socio-economic well-being of its member economies by fostering cooperation in developing climate and climate change monitoring and prediction technologies, as well as promoting the effective use of related climate information.

Organization



Name	Main Tasks
Strategic Planning Team	Responsible for project planning and evaluation, management assessment of public institutions, ESG initiatives, and conducting customer satisfaction surveys and the Project Real-Name System.
Climate Prediction Department	Operates Multi-Model Ensemble (MME), BSISO, and SCoPS seasonal predictions; manages the WMO MME Lead Center, ESGF, and APCC website; and supports the Korea Meteorological Administration (KMA) with three-month outlooks.
Prediction Research & Development Department	Develops sub-seasonal prediction technologies and systems; enhances SCoPS; operates the SCoPS sub-seasonal prediction system; develops AI-based climate prediction models; and supports KMA's one-month outlooks.
Climate Change Analysis Department	Analyzes decadal variability and conducts climate change detection and attribution; produces downscaled climate change scenarios; and facilitates international cooperation with the IPCC and UNFCCC.
Climate Model Testbed Team	Evaluates technologies for improving climate models using testbeds; verifies climate prediction performance; and advances the KMA's climate prediction model evaluation system
Information System and Security Team	Operates and manages IT infrastructure, networks, and information security, while providing technical support for system and network users.

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APCC Marks 20th Anniversary with APEC Climate Symposium 2025

Marking the Republic of Korea's chairmanship of APEC, the APCC successfully hosted the '2025 APEC Climate Symposium' to celebrate its 20th anniversary in Busan from 7 to 9 August 2025. Under the theme "Addressing APEC's Climate Challenges: Complexity of Climate Change Adaptation and the Way Forward," the event was co-hosted with the Korea Meteorological Administration (KMA) and Busan Metropolitan City. The event gathered around 180 climate scientists, policymakers, and representatives from APEC member economies and international organizations from 26 countries, to explore scientific solutions and enhance coordination between science and policy to address the climate crisis. This symposium was significant for reflecting on APEC's achievements over the past 20 years as a climate information hub in the Asia-Pacific region and declaring a vision for leading future climate responses.

The symposium commenced with the "APCC 20th Anniversary Ceremony." Key dignitaries, including Acting Executive Director Hyung-jin Kim, KMA Administrator Dong-eon Jang, Vice Mayor of Busan Jun-seung Lee, and APEC Secretariat Executive Director Eduardo Pedrosa, delivered welcome remarks, praising APEC's journey from its inception in Busan in 2005 to becoming a leading climate prediction institution in the region. During the subsequent vision declaration ceremony, key figures participated in an LED touch performance, pledging to play a pivotal role in future climate change responses based on the achievements of the last two decades. Additionally, the awards ceremony for the "Climate Crisis Short-form Video Contest," designed to convey the value of climate science to the public, added meaning to the event by raising public awareness of climate change. During the keynote session, IPCC Chair Jim Skea and Director Axel Timmerman of the IBS Center for Climate Physics emphasized that "overcoming the limits of climate adaptation requires an integrated approach that encompasses social aspects such as health and poverty, alongside the refinement of scientific prediction," thereby enriching the academic discourse of the symposium.

The main sessions of the symposium were organized around two key pillars: "Climate Prediction and Attribution," representing recent advancements in climate science, and "Adaptation and Cooperation," offering practical solutions. In the first session, various attempts to reduce climate model uncertainty and increase prediction reliability were shared. Dr. Doug Smith from the UK Met Office emphasized the importance of accounting for model errors. Professor Yu Kosaka from the University of Tokyo pointed out the discrepancy between observed La Niña-like trends and model-predicted El Niño-like warming, analyzing the tropical Pacific as a key factor in prediction uncertainty. Professor Seung-Ki Min from POSTECH presented his research on the impact of human-induced warming on typhoons and extreme precipitation through high-resolution simulations. Professor Yukiko Imada from the University of Tokyo introduced various event attribution methods to bridge the gap between complex climate data and decision-making, while Professor Ted Shepherd drew significant attention by proposing "Physical Climate Storylines," an innovative approach to support rational decision-making under uncertain future conditions.

The second session featured concrete discussions on how climate science can converge with other sectors such as health, agriculture, and climate finance to enhance social resilience. Professor Ho Kim from Seoul National University proposed applying the "Health in All Policies (HiAP)" concept to climate action. Dr. Toshichika Iizumi from Japan's National Agriculture and Food Research Organization (NARO) presented research on global crop yield forecasting. Professor Hyungjun Kim from KAIST emphasized that climate change is a complex crisis caused by human activity, advocating for an integrated adaptation approach that considers interconnected sectors like the water-food-energy nexus, encompassing socio-economic scenarios and Earth system models. Meanwhile, Dr. Martin Okata from the Asian Development Bank (ADB) presented ADB's plans to integrate climate risk into development decision-making and expand climate finance investments, offering practical implementation strategies.

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The panel discussion, which concluded the symposium, reaffirmed that "integration and cooperation" are key to responding to the climate crisis. Experts agreed on the need to elevate climate change adaptation to a standing agenda within APEC and to facilitate data sharing and the exchange of scientists among member economies. Notably, the "APEC Member Economy Knowledge Sharing Session" showcased APCC's effective cooperative network, with China, Indonesia, Thailand, Vietnam, and member economies presenting best practices in climate adaptation using climate information and services.

The APEC Climate Symposium 2025 reaffirmed APCC's role not just as a provider of climate information, but as a bridge connecting science, policy, and society, and as an enduring partner to the Asia-Pacific climate community. Moving forward, APCC remains committed to expanding customized climate services that meet the needs of member economies, building upon its 20 years of achievement.

APCC SENAMHI Collaboration: Improving National Climate Information Services to Enhance the Climate Resilience of Rural Communities in Peru

Since its establishment, the APCC has pursued a wide range of international cooperation activities aimed at promoting climate information utilization and strengthening climate change response capacities among APEC member economies. As climate risks have intensified, global demand for practical climate information services and field-oriented capacity-building approaches has increased. These approaches are designed to be directly applied by local communities, moving beyond the mere provision of climate data.

In this regard, APCC, in partnership with a private-sector climate service provider, Weatherpia Co., Ltd., has implemented a climate information service cooperation project in Peru funded by the Korea International Cooperation Agency (KOICA). The project aims to link APCC's expertise in climate prediction and climate information services with policy priorities and user needs in Peru, with a particular focus on enhancing climate resilience in the agricultural sector.

The project was initially implemented from 2024 to May 2025 under the title "Strengthening Climate Resilience in Peru through Enhanced Climate Information Services and Capacity Building for Climate Change Monitoring and Prediction." This phase focused on establishing a medium- to long-term roadmap and defining phased implementation directions to support climate resilience in Peru.

During this phase, APCC conducted field-based assessments to examine the full cycle of agricultural climate information, including production, dissemination, and utilization. Through interviews and surveys with the Peruvian National Meteorological and Hydrological Service (SENAMHI), agricultural institutions, local governments, and farmers, the project analyzed how climate information is used in agricultural decision-making and identified key constraints. Common challenges included disparities in observation infrastructure across regions, limitations in the timing and format of information delivery, and the need for improved communication and training for farmers.

Based on these findings and SENAMHI's policy priorities, APCC consolidated key issues and outlined strategic directions for future cooperation, resulting in a set of prioritized candidate activities to guide the subsequent phase of the project.

Building on the outcomes of the Track-1 project, the APCC consortium was selected for Track 2 (pilot stage) of the KOICA Country Program. The Track 2 project commenced in December 2025 and focuses on applying the previously identified plans and recommendations in real-world settings while establishing a foundation for the sustained use of climate information services.

The Track 2 project, titled "Improving national climate information services for enhancing climate resilience of rural communities in Peru," aims to implement agricultural climate information systems, specifically the Agroclimatic Management Platform (PGA), in three selected regions of Peru and to strengthen the practical capacities of SENAMHI, farmers, and related institutions involved in producing, delivering, and using climate information. Through these efforts, the project seeks to enhance climate resilience at the community level.

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Implemented from December 2025 to October 2027, the project includes key activities such as (i) establishing and improving PGAs through region-specific customization; (ii) conducting capacity-building programs for farmers and relevant stakeholders; (iii) installing Automatic Weather Stations (AWS) and assessing observation environments; (iv) improving the efficiency of SENAMHI's meteorological and climate data platforms; and (v) strengthening the technical capacity of meteorological and climate service professionals.

Through this project, APCC aims to support the stable integration of climate information services tailored to local conditions, while helping SENAMHI and local communities establish a foundation for independently producing and utilizing climate information beyond the project period. The experience and lessons gained through this collaboration are expected to serve as a reference for future international cooperation initiatives in other countries and regions.

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APCC Successfully Concludes Young Scientist Support Program 2025 Advanced Course for Pacific Island Countries

The APCC successfully conducted the 2025 Young Scientist Support Program (YSSP 2025) from September 3 (Wednesday) to September 30 (Tuesday), 2025, at its headquarters in Haeundae, Busan. As part of the "Enhancing Climate Information and Knowledge Services for Resilience in Five Pacific Island Countries (CIS-Pac5)" project—proposed by the United Nations Environment Programme (UNEP) and funded by the Green Climate Fund (GCF)—this initiative invited four operational climate forecasters from the National Meteorological and Hydrological Services (NMHSs) of four Pacific Island Countries (PICs): the Cook Islands, the Republic of the Marshall Islands, Tuvalu, and Niue.

The primary objective of the program was to strengthen the analytical and operational capacity of staff in Pacific Island countries, which are highly vulnerable to climate change. The curriculum was specifically designed to empower participants to apply scientific reasoning to local climate problems using global data sources and advanced analytical methods.

The most significant change in this year's program was the emphasis on "continuity of training." APCC selected participants who had completed the basic courses held over the past two years (2023–2024) and designed an "Advanced Course" that goes beyond foundational knowledge and skills. Skilled professionals from the four Pacific nations gathered at APCC for a four-week residential training program consisting of lectures and practical sessions.

The curriculum focused on immediate application in their daily operations. Participants moved beyond basic Python skills to master techniques for directly collecting and processing vast amounts of climate data, such as global reanalysis data. Furthermore, they underwent intensive training in climate statistical techniques, including correlation and regression analysis, to identify the impact of large-scale climate drivers—such as El Niño and La Niña—on their local climate. This process maximized the quality of training by combining invited lectures from external experts, including those from Pukyong National University, with dedicated mentoring by APCC's internal researchers.

All participants completed independent research reports analyzing their countries' rainfall patterns and climate variability using the analysis techniques learned during the training. This experience is expected to contribute to enhanced forecast accuracy and policy application at each national meteorological service in the future. Having proven the program's effectiveness through high participant satisfaction rates, APCC plans to systematically operate both basic and advanced courses in the future. Through this, APCC intends to continuously expand the network of climate experts equipped with data analysis skills in the Pacific region and further solidify science-based partnerships for responding to the climate crisis.

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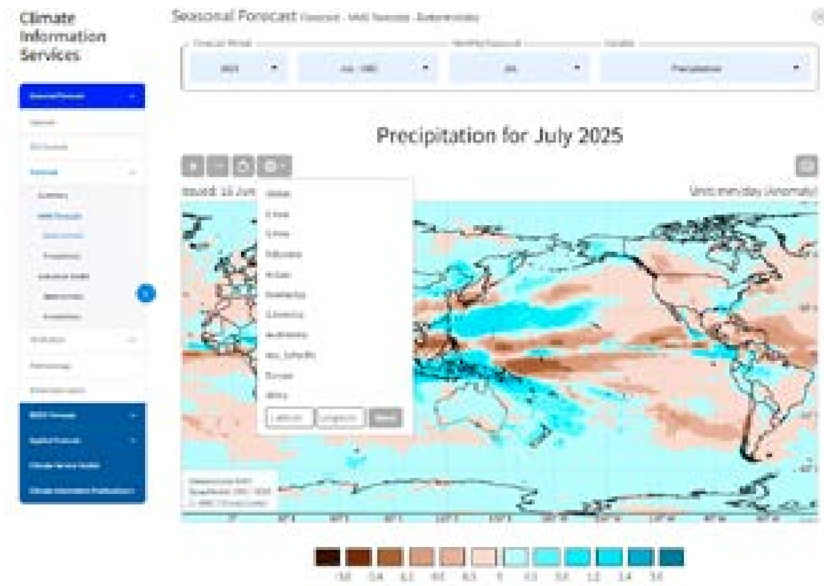
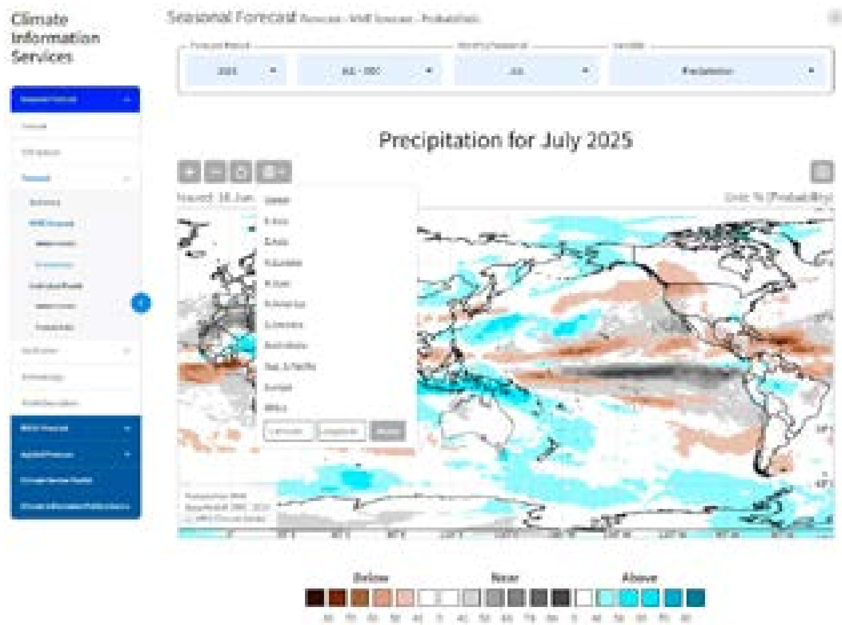
APCC Enhances Seasonal Forecast Service with Customized Regional Climate Information

The APEC Climate Center (APCC) has launched a new service integrated into its official website to provide localized climate information as part of its standard seasonal forecast offerings.

The newly implemented capabilities enhance the global seasonal forecast service by allowing users to select specific regions within both the deterministic and probabilistic Multi-Model Ensemble (MME) forecast pages.

With this upgrade, APCC now offers tailored regional climate information that better meets user needs, significantly improving the usability and applicability of its seasonal forecasts.





<APCC Website (www.apcc21.org)>

· Climate Information Services > Seasonal Forecast > Forecast > MME forecast > Deterministic

· Climate Information Services > Seasonal Forecast > Forecast > MME forecast > Probabilistic

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Dr. Jong An Chun from APCC introduced the OSCAR platform during COP30

At the request of the Government of Vanuatu, Dr. Jong An Chun from the APEC Climate Center (APCC) participated in the Moana Blue Pacific Pavilion side events on November 19, 2025, during COP30 held in Brazil. During the session, he introduced the OSCAR (tailored system of climate services for agriculture) platform. APCC highlighted its ongoing collaborations with Pacific Island countries and emphasized the importance of localized climate services to strengthen climate resilience in vulnerable regions. During the event, APCC presented the impacts of the OSCAR system implemented under the GCF-funded Van-KIRAP project in Vanuatu.

APCC also shared plans to further expand OSCAR-driven climate-smart agriculture services across the Pacific Island countries in partnership with SPREP and regional agricultural agencies. This effort aims to help more countries integrate climate information into policy development, agricultural research, and farming practices.

Through its engagement at COP30, APCC reiterated that climate-informed agriculture is essential for advancing global climate adaptation efforts. The Center affirmed its commitment to strengthening regional and international cooperation to support communities most affected by climate change.

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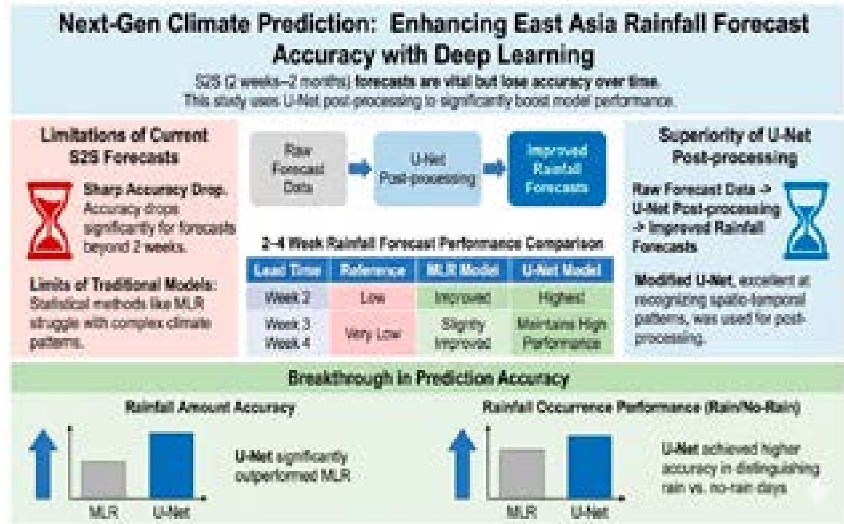
APCC Research Team Enhances Climate Disaster Prediction in East Asia Using AI Techniques

A research study by the APEC Climate Center (APCC) research team, led by Dr. Uran Chung, titled "Advancing Subseasonal to Seasonal (S2S) Multi-Model Ensemble Precipitation Prediction in East Asia: Deep Learning-Based Post-Processing for Improved Accuracy," has been published online in the internationally renowned journal Heliyon.
(https://www.sciencedirect.com/science/article/pii/S2405844024119640)



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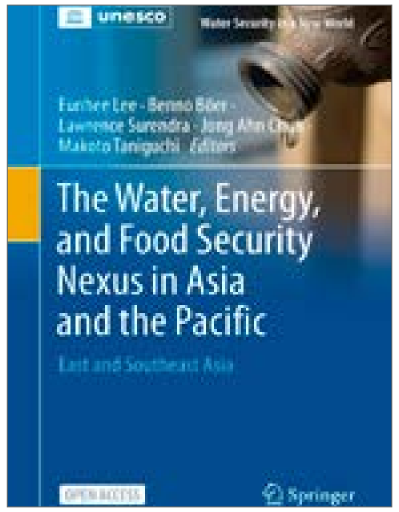
Dr. Jong Ahn Chun of the APCC contributed as an author to the UNESCO-published book, 'The Water-Energy-Food Nexus Approach in Asia and the Pacific.'

Dr. Jong Ahn Chun from the APEC Climate Center (APCC) contributed as an author to the UNESCO-published book 'The Water-Energy-Food Nexus Approach in Asia and the Pacific,' which is part of the 'Water Security in a New World' series.



Recently, the water-energy-food (WEF) nexus approach has garnered significant attention as a cornerstone for achieving sustainable development.
Effective policy decisions and governance require a comprehensive understanding of the intricate interconnections among these three critical elements.

Moreover, the increasing economic integration in Asia and the Pacific—regions highly vulnerable to climate change—has underscored the necessity of conducting nexus-based analyses at the regional scale.
Addressing challenges related to water, energy, and food security through this approach is critical for developing sustainable solutions.
(https://link.springer.com/book/10.1007/978-3-031-12495-2)

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Publication of the APCC 2024 Annual Report

The APCC has released its 2024 Annual Report in both Korean and English.
This report provides a comprehensive overview of the center's key achievements and milestones attained throughout 2024. The report is available for public download on the official APCC website.

APCC

06

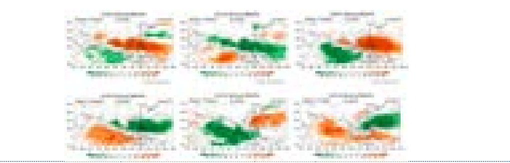
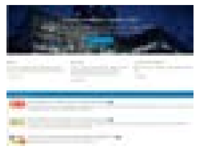
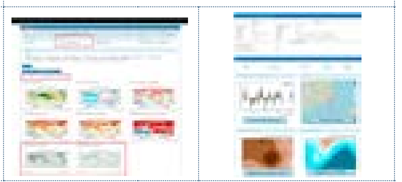
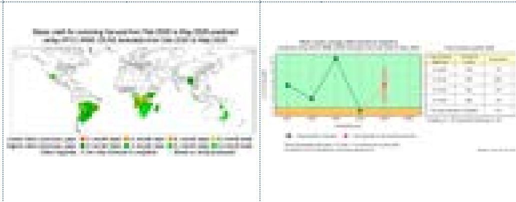
APEC CLIMATE CENTER

APPENDIX

APPENDIX 1

APCC Climate Information Services

APCC (www.apcc21.org) provides comprehensive climate information services to end-users around the world.

Services	Function	Screen	Contents
Provision of Climate Information	Seasonal Forecast (Climate forecast for 3 or 6 months)		• APCC provides high-quality 6-month climate outlooks, updated monthly, for APEC member economies and climate-related agencies worldwide. (https://apcc21.org/ser/global/outlookSummary.do?lang=en)
	BSISO (Boreal Summer Intraseasonal Oscillation) Forecast		• The BSISO is one of the dominant phenomena over the Asian summer monsoon region. The BSISO monitoring index for 15 to 60 days is provided via the APCC homepage in real time. (https://apcc21.org/prediction/bsiso/intro?lang=en)
	Climate Monitoring		• APCC presents information on major climate variables, including droughts, floods, and atmospheric circulation, on a weekly, monthly, and seasonal basis. (https://apcc21.org/ser/high.do?lang=en)
Customized Climate Information Service	APCC Climate Services Platform (https://apcc21.org/clik) 	Provision 	APCC Climate Services Platform enabling the provision of climate information services by which users can effectively utilize various climate data · Provision Service : A platform-based climate data service that allows downloading APCC climate information in various formats.
		Production 	· Production Service : A service that enables users to select climate models, variables of prediction, regions, and analysis techniques online to produce MME climate prediction information and statistically downscaled information for desired areas.
		Processing 	· Processing Service : A service enabling the extraction of the values of climate variables in user-desired areas or periods from a large amount of climate data in a variety of data formats
Use of Climate Information	SEA Fire and Haze Early Warning System (FHEWS)		• APCC provides an independently developed fire and haze EWS, which translates 6-month precipitation data into fire danger ratings to prevent dangerous forest fires and haze. 1. Indonesia: Available annually from April to July (https://www.apcc21.org/prediction/fhewsid) 2. Malaysia: Available from October to March every year (https://www.apcc21.org/prediction/fhewsmy)
	Global Crop Yield Forecast Service		• APCC provides yield forecasts for major producing countries for the world's four major crops (maize, rice, wheat, and soybean) on the 20th of every month, utilizing APCC MME seasonal forecast data. (https://www.apcc21.org/prediction/naro_methodology?lang=en)

APPENDIX 2

APCC Multi-Model Ensemble Participating Model

The APEC Climate Center (APCC) disseminates high-quality climate forecast information based on the multi-model ensemble (MME) on the 15th of every month. Currently, 16 operational institutes from 11 countries participate in the APCC MME. Real-time forecasts by the APCC MME are provided on the APCC homepage monthly (https://www.apcc21.org/?lang=en).

1. Introduction of New MME Members and Model Upgrades

The CGCMv1.0 model developed by Pukyong National University (PKNU) was registered as a new MME provider in 2024 and has officially participated in APCC MME forecasting since February 2025. In addition, model upgrades implemented by CWA, METFR, and CMCC in 2025 have further strengthened the overall configuration of the MME system.

2. Extension of the Hindcast Base Period

To comply with the recommendations of the World Meteorological Organization (WMO) and to better reflect recent climate variability, the hindcast base period for the MME prediction system was extended from 1991–2010 (20 years) to 1993–2016 (24 years). This update has been applied to forecasts issued since August 2025.

3. Enhancement of the ENSO Alert System

The APCC ENSO Alert System was revised to clearly distinguish between the developing and decaying phases of ENSO events by introducing a slope condition for the Oceanic Niño Index (ONI). As a result, during the decaying phase, a clear "Final" alert is issued instead of downgrading the status to "Watch" or "Alert." This revised criterion has been applied since the October 2025 forecast.

4. Provision of High-Resolution Verification Information

To improve the accuracy of forecast performance evaluations, the verification framework was upgraded from a low-resolution (2.5°) to a high-resolution (1.0°) system. In addition, observational and reanalysis datasets used for verification, excluding SST, were standardized to ERA5 to ensure physical and dynamical consistency. High-resolution verification results have been officially provided since December 2025.

APPENDIX 3

Boreal Summer IntraSeasonal Oscillation (BSISO)

APCC produces Boreal Summer IntraSeasonal Oscillation (BSISO) monitoring and forecast information daily from May to October.

◎**Definition :** BBSISO represents a large circulation system, generated in the tropical Indian Ocean, with prominent gradual northward propagation. It affects the Asian summer monsoon, atmospheric circulation, and weather with a period of 15–60 days.

◎**Modes:** BBSISO consists of two modes: BSISO1 represents the canonical northward propagating variability with a 30–60 day period, and BSISO2 corresponds to the northward/northwest propagating variability with a period of 10–30 days.

◎**System:** Currently, APCC operates BSISO with five models from four institutes: [1]NCEP, [2]ECMWF, [3]CWA, and [4]BOM

1. Update of the CWA Model

With the upgrade of the participating model from the Central Weather Administration (CWA) of Taiwan from TCWB1T1.1 to CWACFSv2 in May 2025, both the horizontal and vertical resolutions have been enhanced.

2. Enhancement of the BSISO Input Data Processing System

Since 2025, APCC has enhanced its in-house BSISO input data processing system by directly collecting and preprocessing the required input data, thereby enabling a broader range of prediction models to participate in the BSISO forecasting system with minimal additional effort.

Glossary

1) NCEP

National Centers for Environmental Prediction

2) ECMWF

European Centre for Medium-Range Weather Forecasts

3) CWA

Central Weather Administration

4) BOM

Bureau of Meteorology

APPENDIX 4

Research Papers

1. *Yoo-Rim Jung, Woo-Seop Lee, 09 January 2025:*
Influence of the boreal summer intraseasonal oscillation on temperature and precipitation in South Korea, Atmospheric Science Letters Volume 26 Issue 1, https://doi.org/10.1002/asl.1282

2. *Soo-Jin Sohn, Hae-Jeong Kim, Sun-hee Shin, Jin Ho Yoo, Johan Lee, Kyung-On Boo, and Yu-Kyung Hyun, 01 February 2025:*
Sharing Small Resources and Making Joint Efforts for the Improvement of a Climate Prediction Model in South Korea, Bulletin of the American Meteorological Society, PP. 79–83, https://doi.org/10.1175/BAMS-D-23-0150.1

3. *Yoo-Bin Yhang, Chang-Mook Lim & Daeun Jeong, 20 February 2025:*
APEC climate center multi-model ensemble dataset for seasonal climate prediction, Scientific Data 12, 303(2025), https://doi.org/10.1038/s41597-025-04643-3

4. *Yooju Jeon, Sunyong Kim, Soo-Jin Sohn, Suhee Han, and Sangwon Moon, 01 April 2025:*
Toward a Sustainable and Resilient Society through Enhanced ENSO Response and Preparedness, Bulletin of the American Meteorological Society, E571–E575, https://doi.org/10.1175/BAMS-D-25-0024.1

5. *Sinil Yang, Hyo-Jun Bae, Mark Bourassa, Chaehyeon Chelsea Nam, Steven Cocke, DW Shin, Benjamin W Barr, Hyodae Seo, Dong-Hyun Cha, Min-Ho Kwon, 11 April 2025:*
Sea spray effects on typhoon prediction in the Yellow and East China Seas: case studies using a coupled atmosphere-ocean-wave model for Lingling (2019) and Maysak (2020), Bulletin of the American Meteorological Society, Environmental Research Letters, Volume 20, Number 5, https://doi.org/10.1088/1748-9326/adc616

6. *F. Vitart, A. W. Robertson, A. Brookshaw, N. Caltabiano, C. A. S. Coelho, E. de Coning, P. A. Dirmeyer, D. I. V. Domeisen, L. Hirons, H. J. Kim, H. Lin, A. Kumar, A. Molod, J. Robbins, Z. Segele, C. M. Spillman, C. Stan, Y. Takaya, S. Woolnough, C. J. White, and T. Wu, 01 May 2025:*
The WWRP/WCRP S2S project and its achievements, Bulletin of the American Meteorological Society, E791–E808, https://doi.org/10.1038/s41597-025-04643-3

7. *Seon Tae Kim, Woo-Seop Lee, Eun-Jeong Lee, Young-Hwa Byun & Jin-Uk Kim, 19 June 2025:*
Impact of future climate change on the photovoltaic power generation potential over South Korea, Theoretical and Applied Climatology, Volume 156, article number 379 (2025), https://doi.org/10.1007/s00704-025-05611-y

8. *Yoojin Kim, Chang-Mook Lim, Bong-Geun Song, Jin Ho Yoo, February 2025:*
Long-term Trend Correction of Seasonal Forecast of East Asian Air Temperature in APCC MME, Atmosphere-Korea, Volume 35 Issue 1, Pages.147-161, https://koreascience.or.kr/article/JAKO202506454003815.page

9. *Suyeon Moon, Seul-Hee Im, OkYeon Kim and Woo-Seop Lee, 8 July 2025:*
Recent Changes in the Subseasonal Influence of the Western Pacific Pattern on Winter Temperature over South Korea, Environmental Research Letters, Volume 20, Number 8, https: /doi.org/10.10 8/1748-9326/ade897

10. *OkYeon Kim, Woo-Seop Lee, 10 July 2025:*
Enhancing Seasonal Predictability of the East Asian Summer Monsoon via Optimized Multi-Model Ensembles, Scientific Reports volume 15, Article number: 24912 (2025), https://doi.org/10.1038/s41598-025-08794-6

11. *Sunyong Kim, Jin Ho Yoo, 30 August 2025:*
Delayed impacts of North Pacific Oscillation on wintertime surface air temperature in East Asia, Climate Dynamics, Volume 63 article number 344 (2025), https://doi.org/10.1007/s00382-025-07828-z

12. *Young - Mi Min, Chang - Mook Lim, Jin - Ho Yoo, Hyung - Jin Kim, Vladimir N. Kryjov ,Daeun Jeong, A - Young Lim, Suryun Ham, Mingyue Chen , Yi Xiao , Normand Gagnon, Ryan Muncaster, Pang - Yen Liu, Andrea Borrelli, Hee - Sook Ji, Johan Lee, Sera Jo, Dmitry Kiktev, Mikhail Tolstykh, Vadim Matyugin, Peter McLean, and Andrea M. Molod, 03 September 2025:*
A Diachronic Assessment of Advances in Seasonal Forecasting: Evolution of the APCC Multi-Model Ensemble Prediction System Over the Last Two Decades, Geophysical Research Letters, Volume 52 Issue 17, https://doi.org/10.1029/2025GL116416

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