

APEC CLIMATE CENTER
2023
Annual Report

APEC CLIMATE CENTER

2023 Annual Report



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Foreword



To address climate disasters, the intensity of which has been increasing across the Asia-Pacific region including Korea, each country must utilize reliable climate prediction information.

Against this backdrop, the APEC Climate Center (hereafter, the Center) has established a climate network among member economies of APEC to generate and exchange the most optimal climate prediction information, while striving to develop shared counter-measures against extreme climate conditions in the Asia-Pacific region.

The year 2023 was of particular significance for anticipated breakthroughs in diverse research initiatives aimed at spearheading advancements in climate prediction across the Asia-Pacific region. The Center enhanced the precision and reliability of multi-model ensemble (MME) seasonal forecasting through the utilization of global climate model information while bolstering usability and competitiveness by integrating cutting-edge artificial intelligence technology. Furthermore, the Center endeavored to address user needs by enhancing the quality and delivery of climate information. We have contributed to long-term forecast production and decision-making in several countries by promptly delivering seasonal prediction information with the desired higher resolution as requested by users.

Simultaneously, the Center has attempted to enhance one-month and three-month forecasting by establishing and strengthening a support system and developing a co-operative relationship with the Korea Meteorological Administration (KMA). Furthermore, academically developed climate forecasting technologies underwent evaluation within the operational settings of the KMA to expedite the application of climate model research outcomes to KMA's operational forecasting, enhance the quality of extreme climate monitoring and prediction information, and establish a robust system for climate change monitoring and analysis, thus bolstering the Center's capacity for early detection of extreme climate conditions. We analyzed future climate changes, crucial for establishing policies on renewable energy and water resource management, and expanded the target area for early detection and warning services regarding wildfires and haze in the Southeast Asia region from the Indonesian Borneo Island to include Malaysia.

In 2023, the Vanuatu-tailored System of Climate services for Agriculture (OSCAR) developed through the UN's Green Climate Fund was successfully transferred to the government of Vanuatu. The Center has conducted training sessions to enhance the climate prediction and information utilization skills of climate forecasting officers from local meteorological agencies in Pacific Island countries. This effort aims to enhance their competence in responding to climate crises, thus contributing to overall improvements in their capabilities.

The Center aspires to establish itself as a premier institution specializing in climate forecasting on a global scale. To achieve this goal, the Center will continue to advance its core technologies for climate forecasting and enhance collaboration with other relevant agencies within the country, including the KMA, as well as with international partners.

Finally, I would like to extend my heartfelt gratitude to all the dedicated employees at the Center whose hard work has led to significant achievements, as well as to the officials from the KMA and partner organizations for their active support of the Center's projects during 2023.

A lush green forest with a lake in the foreground and a large white number '01' on the left.

01

APEC Climate Center

The background image is a lush landscape. On the left, a river flows through a dense forest. A large, vibrant green circular graphic is overlaid on the right side of the image, partially obscuring the forest. The text "Global Climate Characteristics in 2023" is written in white, bold, sans-serif font, centered within the green circle.

Global Climate Characteristics in 2023

Global Climate Characteristics in 2023

Average Annual Temperature

In 2023, the global average temperature was approximately 0.52°C above the normal levels observed between 1991 and 2020, with above-average temperatures recorded across most continents in the Northern Hemisphere [⇒ Figure 1]. Notably, the unprecedented global temperature increase observed since June has surpassed even the highest recorded temperature in 2016 by 0.08°C , thereby making 2023 the hottest year on record. From June to December 2023, each month experienced higher temperatures compared with the corresponding month in the previous year, with July and August being the hottest months ever recorded. Additionally, the summer in the Northern Hemisphere was the warmest on record.

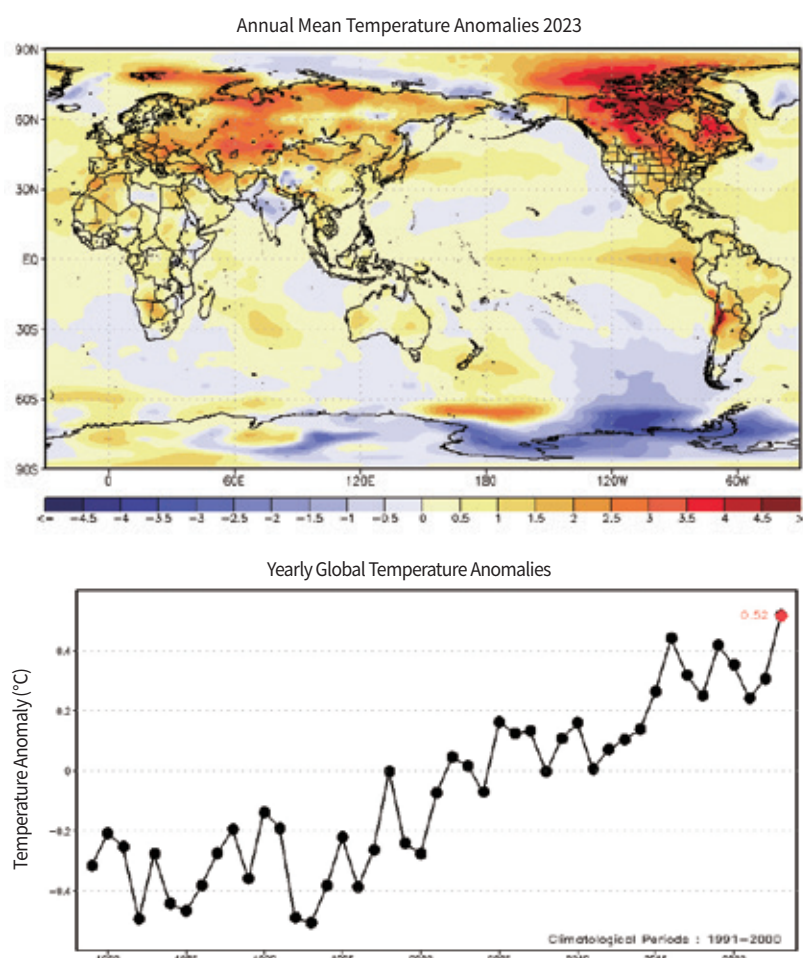


Fig1 Average annual temperature anomaly of 2023 (top) and time series of global annual average temperature anomalies from 1979 to 2023 (bottom). Weather data: 1991–2020, Source: NCEP/NCAR Reanalysis 2.

Various extreme weather events, including heat waves, floods, droughts, and wildfires, were observed worldwide. Northeast Africa and the Middle East regions faced severe droughts, Europe, the United States, and China witnessed unprecedented heat waves, Canada grappled with extensive wildfires, and Australia and South America recorded their highest winter temperatures.

Global Climate Characteristics in 2023

Southeast Asia experienced unusually high temperatures starting in mid-April 2023, resulting in record-breaking heat waves in India, Bangladesh, China, Thailand, and Vietnam. In India, six cities recorded temperatures exceeding 44 °C, while a southern region in Thailand reported a sudden rise in temperature to 45.4 °C, marking the hottest spring ever recorded.

Average Annual Precipitation

In 2023, the average annual precipitation decreased in oceanic regions but increased in terrestrial areas compared with the normal levels observed from 1991 to 2020. East Asia, North Asia, India, East Africa, Southern Europe, and the Mediterranean regions witnessed above-average precipitation, whereas South America, southern parts of North America, and Canada experienced drier conditions than usual [⇒ Figure 2]. Extreme floods and droughts were witnessed throughout the world.

In 2023, there was a rise in the incidence of sudden flash floods, characterized by heavy rainfall within a short period. Cyclone Daniel, the most severe storm ever recorded in the Mediterranean Sea, led to the highest number of fatalities among weather events in 2023. This storm, which was formed as a low-pressure system in the Mediterranean Sea on September 4, 2023, resulted in severe flood damages across Bulgaria, Greece, and Turkey. In Zagora, Greece, a 24-hour precipitation of 1,092 mm was recorded, 55 times the average September precipitation. Meanwhile, in Tsarevo, Bulgaria, the maximum rainfall recorded was 330 mm, equivalent to 40% of the average annual rainfall, occurring within 20 hours. On July 23, Bucks County, Pennsylvania, encountered heavy rainfall of approximately 180 mm within 45 minutes, resulting in 7 fatalities.

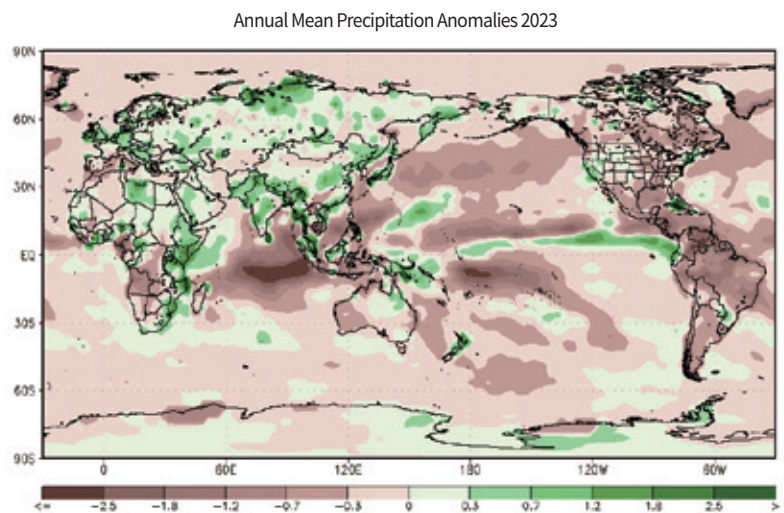


Fig2 Average annual precipitation anomaly of 2023 (mm/day). Weather data: 1991 - 2020, Source: CAMS_OPI.

Global Climate Characteristics in 2023

1) El Niño (La Niña)

Phenomenon characterized by the SST being consistently above (below) average in the central-eastern tropical Pacific region. If the three-month moving average SST deviation exceeds 0.5°C (or falls below -0.5°C) for more than 5 months in the El Niño/La Niña monitoring area (Niño 3.4 region: 5°S – 5°N , 170° – 120°W), the initial month of this occurrence is then defined as the onset of El Niño (La Niña).

Sea Surface Temperature (SST)

In 2023, the global average sea surface temperature steadily increased, with above-average temperatures recorded from April to December [⇒Figure 3]. Elevated sea surface temperatures were noted across several ocean regions, including the Mediterranean Sea, Gulf of Mexico, Caribbean, Indian Ocean, North Pacific, and North Atlantic, primarily attributed to marine heat waves.

La Niña was concluded in the spring of 2023, followed by the emergence of El Niño¹⁾. The World Meteorological Organization (WMO) announced the onset of El Niño at the beginning of July. According to the Niño 3.4 index, the SST of the tropical Pacific Ocean indicated the presence of La Niña from August 2020 to December 2022. The state of La Niña remained in January 2023, during which the Niño 3.4 index was approximately -0.7 . As a result of the swift temperature escalation in the subsequent months, the index transitioned to a positive value in April, peaking at $+1.94$ by December [⇒Figure 3].

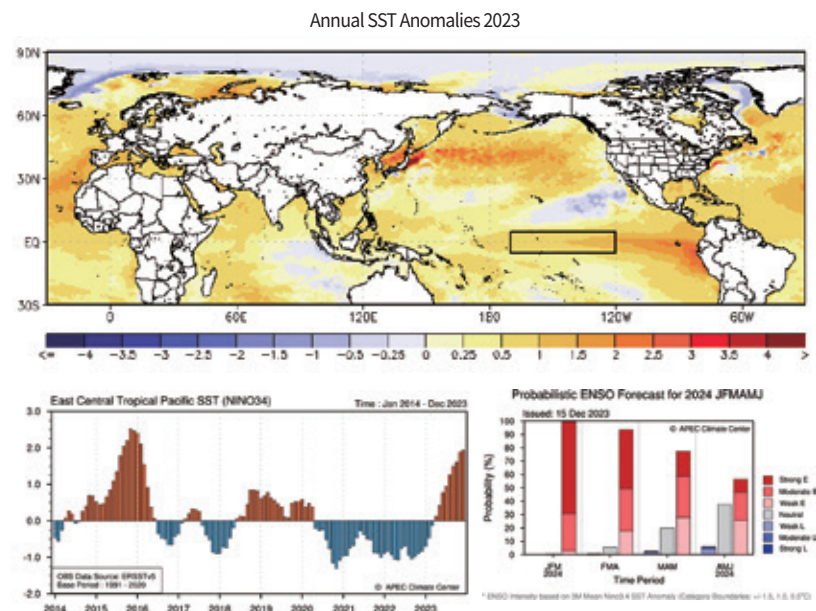


Fig 3 Distribution of global SST average annual deviation in 2023 (top), monthly distribution of the Niño 3.4 index (bottom left), box: El Niño/La Niña monitoring area (Niño 3.4) (Source: NOAA Optimum Interpolation SST V2), APCC ENSO intensity probabilistic forecast (bottom right).

Based on the El Niño forecast provided by APCC, the El Niño conditions are anticipated to persist until the first half of 2024, with the probability of El Niño reaching at least 50% from April to June. Alongside temperature increases attributed to climate change, the El Niño conditions facilitated the heightened global temperatures observed in 2023.



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APEC Climate Center



2023 Featured Achievements

2023 Featured Achievements

1) Multi-Model Ensemble (MME)

To disseminate seasonal forecast data to the Asia-Pacific region, the APCC applies MME techniques to climate prediction models provided by 15 climate prediction agencies from 11 countries. The MME method, by integrating climate forecast models to minimize uncertainty, generally improved the predictive power of various models.

1. Improvement of APCC Climate Information and Services Reflecting User Needs and Conveniences

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APCC has made great efforts to develop and improve the long-term seasonal forecast technology using the Multi-Model Ensemble (MME)¹⁾ and has established a climate prediction system using various global models of the world's leading climate forecast operating and research institutes to provide monthly climate monitoring information and long-term forecast, verification, sub-seasonal forecast information on its platform. The improvement and development of the prediction system have been performed continuously due to user needs, as well as various requests from the APCC Working Group and Model Providers. Therefore, efforts have been made to improve the quality of climate information services along with improving the APCC climate forecast system to reflect the needs of various users and enable users to better understand and utilize climate information.

APCC Homepage Renewal (Dynamic Climate Information Web Services)

APCC opened the renewed APCC website in February 2024. All web pages will be refreshed using the latest web service technology and new designs. We will also apply dynamic web content for MME and individual model forecasts, climate monitoring, and climate indices. The previous static web content, such as figure- or text-based content, will be relocated to the new webpages.

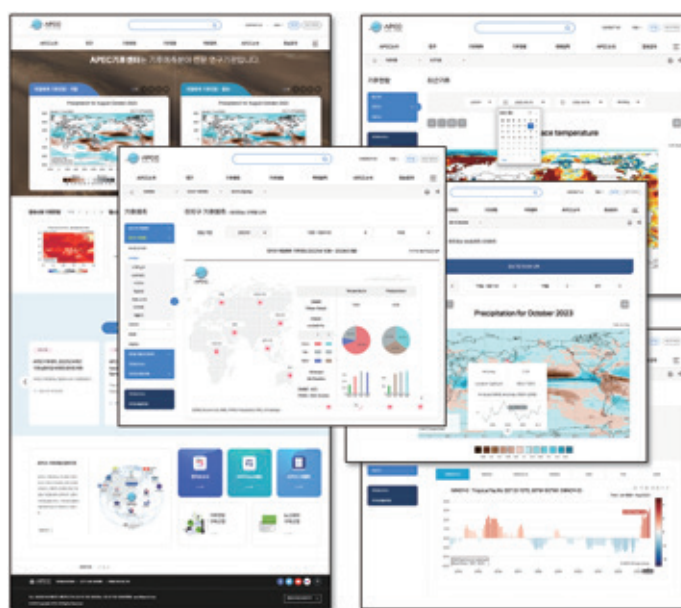


Fig 4 The renewed APCC website and dynamic web contents services for MME and individual model forecasts, climate monitoring, and climate indices

2023 Featured Achievements

APCC Climate Outlook Renewal

APCC redesigned its Seasonal Climate Outlook which provides improved structure and format for users to better understand the contents. The prominent change is applied to the structure of the outlook. While the previous outlook separately provided text descriptions and images, in the new APCC climate outlook, the images and text descriptions are put together in parallel for users to read and understand the contents without any interruptions, such as turning pages. This revamp focused on improving the readability and visibility in describing the MME probabilistic forecast. The colors of temperature and precipitation probability categories are reflected in the text and images of climate forecasts so that users can easily distinguish different probabilities and impacts in the affected areas. The first renewed outlook was rolled out on November 15, 2023.

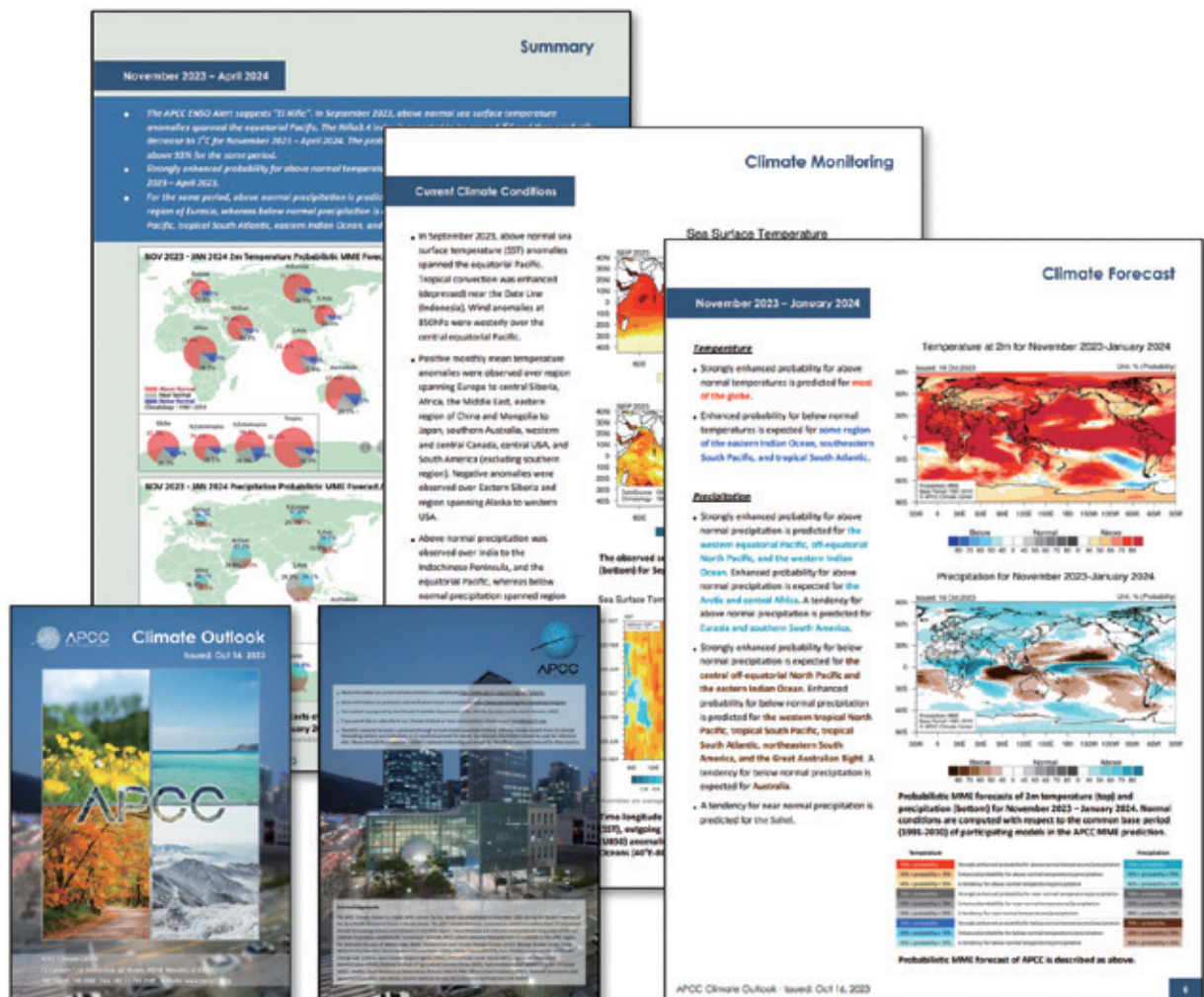


Fig 5 APCC's redesigned Climate Outlook

2023 Featured Achievements

2) Boreal Summer Intraseasonal Oscillation (BSISO)

Convection phenomenon that occurs in the Indian Ocean with a 15–60 day cycle and propagates northward while exhibiting Rossby wave-like character. This phenomenon affects the onset of the Asian summer monsoon season, atmospheric circulation, and weather.

Changes to APCC Boreal Summer Intraseasonal Oscillation (BSISO) Forecasts

There have been a few changes in BSISO²⁾ forecasts since 2023. APCC began to provide BSISO impact anomaly for up to four weeks and expanded its area to 50° N with the expectation that this data will help users seeking medium-range forecasts in the Asian monsoon region. The NOAA Outgoing Longwave Radiation (OLR) data, input data of the APCC BSISO monitoring index, have no longer been provided since September 17, 2023; therefore, APCC plans to revise the input OLR data from the following year. The OLR input data will be revised from NOAA to CPC blended, and the BSISO service will commence in May of next year after reorganizing the system.

• BSISO Impact Anomaly

[TOP](#)

The BSISO impact anomaly shows the expected local impacts of the BSISO activity over the Asian monsoon region in 1–3 weeks. This is the reconstructed field based on composite of the historical BSISO index (1991–2020) for various variables such as temperature, precipitation, wind field, and other relevant variables.

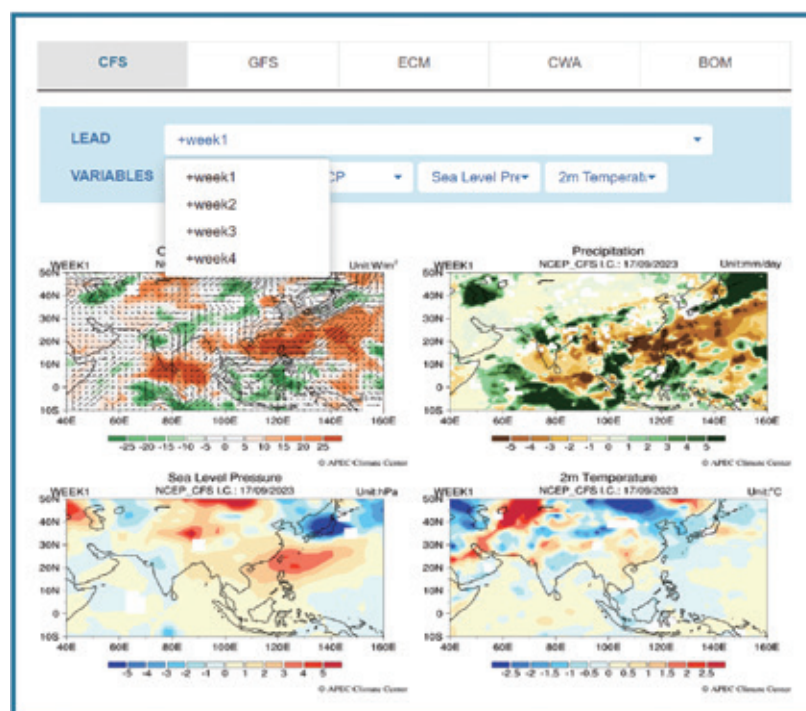


Fig 6 Example of APCC BSISO forecast impact anomaly on the website

2023
Featured
Achievements

Regional Expansion of the APCC Fire and Haze Early Warning System (FHEWS)

The region of APCC FHEWS was expanded to four regions in Malaysia and its expanded forecasts are available through the APCC website from October 2023. The forecast period aligns with the dry season in Malaysia, February–April, based on the 6-month forecast from the APCC Multi-Model Ensemble (MME). The forecast information will be updated from October to January on the 20th of each month.

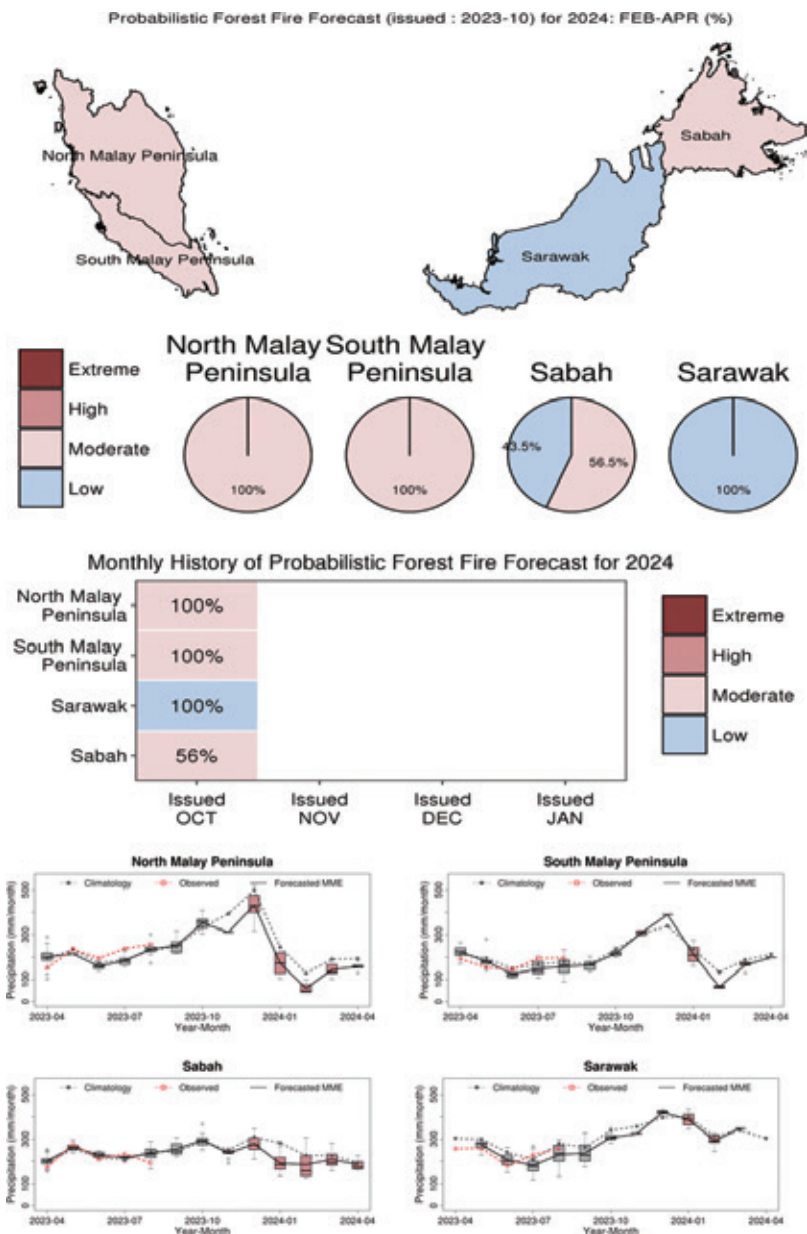


Fig 7 The results of Malaysia FHEWS (Issued: 2023-10)

2023 Featured Achievements

2. What is the Optimal Use of Forecast Information for Long-range Forecasting?

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Over the past several years, APCC has made efforts to improve the accuracy of the KMA's long-range forecast by establishing a cooperation system with the KMA and strengthening its support system. Long-range forecasting can be broadly divided into the data production stage to produce the forecast, that is "observation analysis / climate model operation / long-range forecast technology development" and the forecast information production stage "forecaster comprehensive analysis / service, publicity," which the APCC has connected the two. Therefore, based on the existing APCC-KMA cooperation system, there is a need to further expand the role of APCC in long-range forecasting. To this end, it is necessary to improve long-range forecast practical prediction technology and use existing technologies or improved climate forecasts. We aim to lay the foundation for producing objective predictive information by selecting and processing data (with good predictive value). This is differentiated from other R&D projects that involve research and development with long-range forecasting and aims to contribute improving domestic long-range forecasts through continuous domestic long-range forecast production and improvement and utilization of practical forecasting technologies.

Long-range forecasting requires technological development and improvement in the data production and forecast information production stages, and developing strategy to directly apply it to practice through linking the two is also necessary. Model forecast information are essential for producing long-range forecasts, and there is a need to improve long-range forecast technology for practical application. Therefore, this study improves accuracy by improving seasonal and intra-seasonal long-range forecasting technology and integrates past long-range forecasting experience and scattered information (based on existing observation and model data) to provide objective predictions that can be used in long-range forecasting in Korea. The goal is to establish a foundation for information production.

The ultimate goal of this task is "traceable, reproducible, and physically intuitive predictions," which is what WMO pursues for objective seasonal forecasts. To make objective predictions, it is necessary to understand the model predictability itself, select the optimal model for Korea's long-range forecast, and, based on this, select and integrate observation and monitoring data. Ultimately, to integrate observation and model-based information ① Korea's main climate monitoring elements in winter were selected and their usability was diagnosed, and ② a plan for combining Korea's main climate monitoring elements and model information in winter was presented.

In December, when the correlation between winter ENSO and tropical precipitation is high, the process of ENSO-related tropical precipitation inducing wave propagation in the mid-latitudes and anticyclonic anomalies around the Korean Peninsula was most evident and well reproduced in the model. However, In January, the correlation between ENSO and Indian Ocean precipitation decreased compared with that in December, and the response of western Pacific and central Pacific precipitation, which are highly correlated with ENSO, did not appear to be wave propagation from the tropics, however, the model simulated it similarly to December, which differs from observation. February was similar to January; however, some wave propagation from the tropics occurred in response to precipitation in the western Pacific.

2023 Featured Achievements

Although the fall Arctic sea ice is used as a predictor in predicting temperatures in Korea in the winter, there are limitations in using sea ice as a predictor as the decreasing trend of sea ice is very strong. If the linear trend is not considered, the correlation between Korea's monthly temperature and sea ice in winter is not significant, and even if the linear trend is considered, the correlation with Korea's winter temperature is low. Therefore, using the vertical warming distribution of the Arctic atmosphere was proposed as an alternative. The seasonal prediction model can predict whether an Arctic deep warming will occur; however, the associated atmospheric response can simulate regardless of the type of warming event.

As an important climate monitoring element for the mid-latitude continent, we analyzed ways to utilize the rate of snow cover on the Eurasian continent in the autumn to determine winter temperatures. In the case of the rate of snow cover on the Eurasian continent in the autumn, the trend should be removed and used as a monitoring factor. In early winter, the model reproducibility in response to snow cover is reliable as temperature changes due to snow cover and surface albedo are reproduced relatively well. On the other hand, in late winter, the mid/upper atmospheric response due to surface heat flux is not well reproduced in the model's historical reproduction period, hence, in this case, long-range observation-based monitoring factors become more important.

In this study, in addition to improving accuracy through the improvement of seasonal and intra-seasonal long-range forecasting technology, we integrated past long-term forecasting experience and scattered information (based on existing observation and model data) to provide objective forecast data that can be used in long-range forecasting in Korea, which may contribute to improving the predictability of the KMA's long-range forecasts.

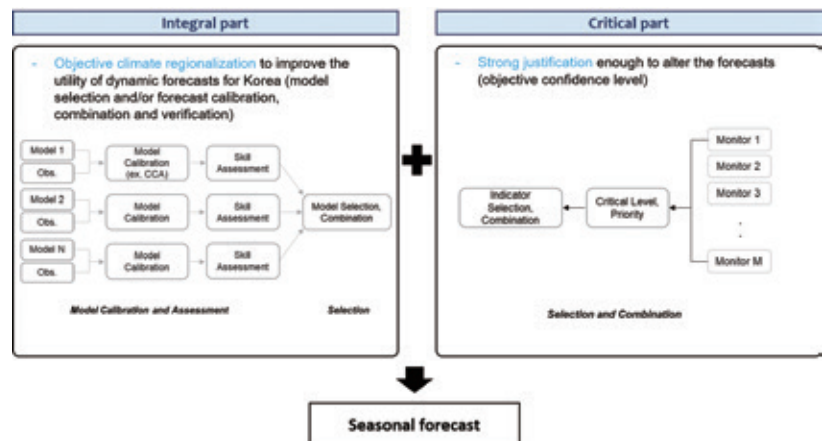


Fig 8 Schematic diagram showing the linkage of integral part with critical part for objective seasonal forecast

2023 Featured Achievements

1) energy power generation potentials

Theoretical estimates produced from natural resources.

2) high-carbon scenario

A future scenario to be unsuccessful in reducing CO₂.

3. Projection of Drought and Renewable Energy Generation Under Future Global Warming

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Global warming is progressing rapidly due to indiscriminate carbon dioxide emissions by human activities, and along with this, extreme weather events, such as heat waves, cold waves, droughts, and heavy rains, are becoming more frequent. Droughts are becoming more serious due to global warming; indeed, three record-breaking droughts have occurred in Korea in the past 10 years. To proactively respond to more severe drought, it is necessary to analyze the climate change impact on drought considering various climate factors and using future climate change scenario data.

To alleviate global warming, global efforts are underway to switch from fossil fuel-dependent energy systems to renewable energy systems, such as solar and wind power generation. However, wind and solar energy generation, which depend on climate conditions, may be vulnerable to future climate change, which may affect the operation of future low-carbon energy supply systems. Therefore, it is necessary to determine how wind and solar energy generation changes due to climate change.

For the future drought projections over the Korean Peninsula, we used a high-resolution (25km) East Asian standard climate change scenario and analyzed the near- and far-future projections of the agricultural drought index (SEDI). The SEDI evaluates the standardized evapotranspiration deficit considering the actual evapotranspiration, which is the interaction between the atmosphere and soil. In the high-carbon scenario, droughts will become more severe in the distant future (2081–2100) than in the near future (2021–2040) compared with the present climate (1985–2014). Especially, the drought is projected to become worsen in the fall (September–May) rather spring (March–May) seasons. In the [high-carbon scenario^{2\)}](#), droughts are projected to intensify in the second half of the 21st century as the increase in the amount of water vapor that the atmosphere can absorb becomes more pronounced due to rapidly rising temperatures in both spring and fall seasons. In particular, precipitation will increase in spring compared with the present climate, but in fall. The humid southerly winds blowing into South Korea decreased along with precipitation, thereby exacerbating droughts in fall compared with spring. As for the intensity of drought, severe droughts are projected to be more frequent in the southern region in spring, extreme droughts are more frequent in Seoul and Gyeonggi. In fall, extreme droughts are expected to be very frequent in the southern region. Exceptional droughts, which rarely occur, are projected to occur in central and northern regions rather than southern regions in spring and fall.

For the analysis of future renewable energy generation projection, the change in [solar and wind power generation potential^{1\)}](#) was analyzed using the high-resolution (1km) standard scenario of climate change on the Korean Peninsula. The average solar power generation potential across the country in spring will decrease toward the second half of the 21st century (2081–2100) compared with the present climate (2000–2019), and the decreasing tendency is negligibly small in the low-carbon scenario after the second half of the 21st century; however, a significant decrease in the high-carbon scenario is projected. In addition, the national average solar power generation potential in summer and fall is projected to be negligibly small in both low-carbon and high-carbon scenarios. On the other hand, in both scenarios in winter, a significant decrease is projected after the second half of the 21st century (2041–2080) and is projected to be greater in the high-carbon scenario.

2023 Featured Achievements

3) low-carbon scenario

A future scenario to realize the CO₂ reduction in the atmosphere.

This decrease is related to the fact that the high temperature becomes more severe in the high-carbon scenario during the same period compared with the [low-carbon scenario](#)³⁾ and thus the energy generation efficiency of solar cells significantly decreases. In winter, in addition to the high temperature, wetter southerly wind influence increases, thereby increasing the total amount of clouds on the Korean Peninsula and decreasing solar radiation energy reaching the surface. In terms of wind power generation potential, negligibly small changes are projected in both high-carbon and low-carbon scenarios until the middle half period of the future climate change scenario in spring, fall, and winter. In the second half, there is a significant decrease in the wind power generation potential in both scenarios, and a greater decrease is projected, especially in high-carbon scenarios. This decrease is related to the change in atmospheric circulation due to future climate change caused by global warming, thereby increasing the influence of the southwesterly wind in spring and the northeasterly wind in fall and winter in the second half of the 21st century. This reduces the northwesterly wind, the main wind blowing over the Korean Peninsula in the present climate, thereby decreasing wind speed and wind power generation potential.

Therefore, it is necessary to consider the impact of future climate change at the stage of establishing policy plans related to future water management and renewable energy, which suggests that carbon-neutral policies must be successful to mitigate the impact of climate change.

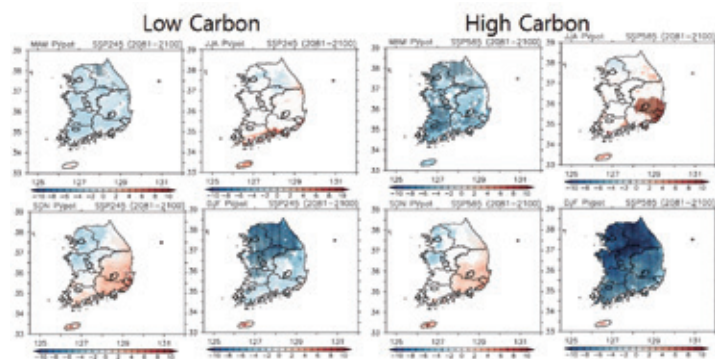


Fig 9 Change in seasonal mean solar power generation potentials under a future (left) low-carbon and (right panels) high-carbon scenario relative to present climate over long-term (2081~2100) period

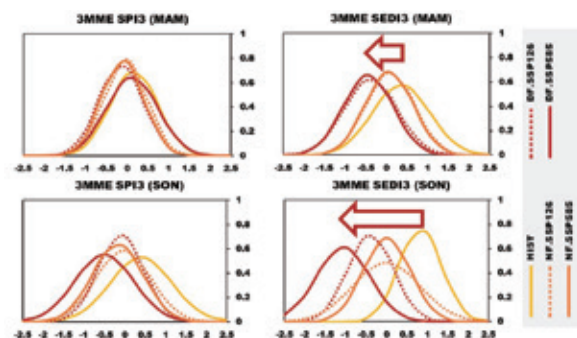


Fig 10 PDF distribution for SPI3 and SEDI3 in spring and fall.

Detailed regional data on the changes in renewable energy power generation potential due to future climate change is expected to be used to establish future regional renewable energy policies. Furthermore, the drought index shows that droughts in the entire Korean Peninsula will become more severe compared with the present in the high-carbon scenario. It is expected that the future projection data on droughts can be used to mitigate damage by preparing in advance for severe droughts through linkage with other fields, such as water resources and agriculture.

2023 Featured Achievements

1) Testbed

A testbed refers to an environment or system where the effect of new technologies or products can be tested. In the collaborative development system for KMA's climate model, the testbed evaluates the outcomes from R&D, verifies which research can be operationalized, and performs a coordinating for the direction of technology integration.

2) Non-Fungible Testbed (NFT)

NFT, a concept inspired by the economic term referring to non-fungible tokens in the realm of virtual assets, means a unique and irreplaceable role that can be fulfilled only by APCC, which has both environments and research capacities.

4. The Establishment and Utilization of the Testbed¹⁾ for KMA's Climate Model: Non-Fungible Testbed (NFT)²⁾ in the Climate Modeling Market

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As the scale of damages from natural disasters caused by abnormal climate conditions increases, the climate prediction that can anticipate such events in advance has become more important. To predict the rapidly changing climate more accurately, it is essential to have climate prediction models with state-of-the-art techniques capable of reflecting these changes. However, due to a lack of domestic modeling infrastructure, there have been challenges in directly applying the techniques to the operational forecast. In response to this, consensus has been reached on the necessity for collaborative efforts among academia, research institutions, and government agencies and there was a collective decision to jointly develop the KMA climate prediction model (GloSea6) to enhance the quality of climate predictions. As one of the key strategies, the role of a testbed for the transition of research to operation (R2O) has become prominent. APCC is engaged in joint development by playing a bridging role as a testbed to expedite the operationalization of newly developed prediction techniques.

For the developed prediction techniques to be applied in actual operational settings, it is essential to assess their effects in the same environment as the operational conditions. Therefore, the operationalization assessment in the testbed is conducted under conditions identical to those in the actual operational environment. This evaluation considers both scientific effectiveness and technical efficiency to ensure a stable operational forecast. APCC has established an environment capable of conducting plenty of quasi-operational prediction experiments, and our expertise has been solidified through the accumulation of multi-year research on using GloSea6. In other words, APCC as the testbed, plays an irreplaceable role in the Korea climate prediction modeling area for its comprehensive capabilities in both experimental environment and research competence.

The technologies to be evaluated through the testbed are determined based on the roadmap established through consensus among APCC, the Korea Meteorological Administration (KMA), and the National Institute of Meteorological Sciences (NIMS).

This year, two technologies were applied, namely ① the loosely coupled initialization technique developed at Ulsan National Institute of Science and Technology (UNIST) and ② a sub-seasonal-scale climate prediction technology based on sea ice physics processes developed at Pusan National University (PNU). These technologies were transferred to APCC for practical application assessment after development in the academic community.

The loosely coupled initialization technique is an atmosphere-ocean coupled initialization method designed to minimize errors caused by initial imbalances in model fields, the application of which improved the predictability of climate factors influencing summer precipitation. Additionally, there was a positive effect on the simulation of phenomena related to tropical variability during winter. From a technical perspective, the application of the loosely coupled initialization technique was reviewed in terms of operational time and stability. In conclusion, this technique is deemed suitable for practical implementation in operational settings.

2023 Featured Achievements

In the optimization evaluation of sea ice parameterization, the effects of parameters within the sea ice physical processes were validated, and optimization approaches were proposed. Based on research results from PNU, sensitivity experiments were conducted on parameters analyzed to influence winter temperature in East Asia. Adjusting parameters within the sea ice physics did not significantly improve the predictability of East Asian winter temperature. However, improvements were observed in the teleconnection between Arctic and East Asian winter temperatures. Additionally, the operational time and stability were evaluated to review the technical efficiency. The results of the two developed technologies were communicated to operational institutions. Based on these outcomes, two technologies will be applied in the operational system in 2024.

The APCC's testbed bridges climate model developers and operational agencies, accelerating the cyclical process of "basic technique development → operationalization assessment → enhanced operational forecast". The testbed has become a hub for domestic collaboration that facilitates the practical use of climate model research outcomes. We intend to continue supporting and collaborating with institutions in operating the APCC's testbed to bridge the gap between research and development and operational forecast.

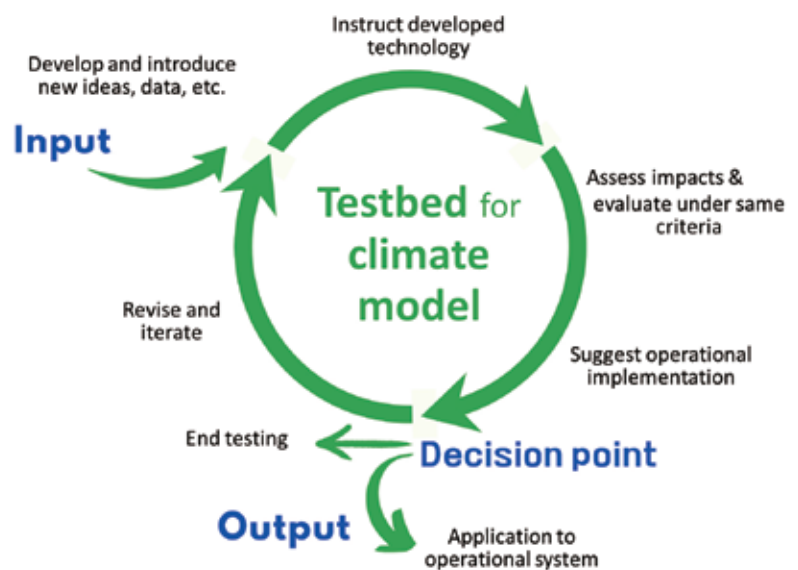


Fig11 Concept of testbed for climate model

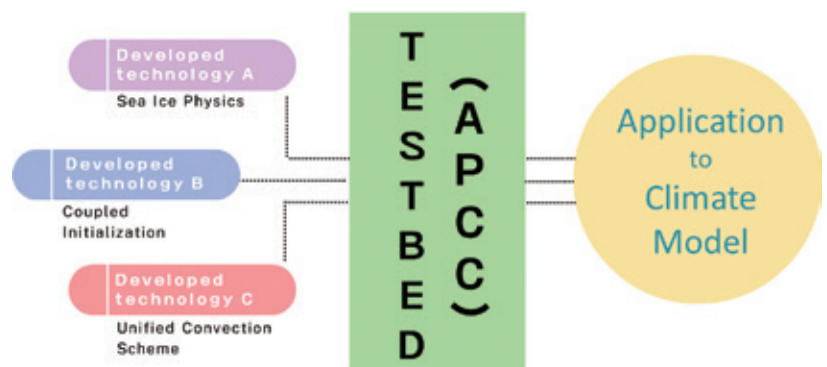


Fig12 Role of APCC as testbed

2023 Featured Achievements

5. Construction and Utilization of Climate forecast model Evaluation & Management system by APCC (CrEMA)

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The Korea Meteorological Administration (KMA) adopted the Global Seasonal Forecast System (GloSea) through collaboration with the United Kingdom Met Office (UKMO) in 2014 and is operating the GloSea version 6 (GloSea6). KMA is advancing its prediction system to produce better climate forecasts in collaboration with academic societies and the APEC Climate Center (APCC) as the research partner of KMA. The operationalization of techniques should be decided upon based on the consistent verification criteria. Therefore, the standard verification framework is needed to assess the techniques developed objectively and comprehensively and ensure fairness. To address this, APCC is constructing the Climate forecast model Evaluation & Management system by APCC (CrEMA), which consists of two parts, namely skill assessment of various climate variables and diagnostics for major climate variability. The former was developed in 2022 and presents the prediction skill of deterministic and probabilistic forecasts, while the latter was developed in 2023 and diagnoses the reproducibility of most variability in the model environment based on El Niño-Southern Oscillation (ENSO), Madden-Julian Oscillation (MJO), and the East Asian summer monsoon (EASM). To expand the diagnostic area, diagnostic metrics for sea ice over the Arctic, boreal summer intraseasonal oscillation (BSISO), and East Asia winter monsoon will be developed in 2024.

The CrEMA diagnostic metrics were designed concerning the CLIVAR ENSO metrics and CLIVAR MJOWG diagnostics, which evaluate the specific climate variability of coupled models such as CMIP and are reorganized into the factors suitable for climate prediction diagnosis. The CrEMA diagnostic metrics are categorized into performance, process, and teleconnection, which aims to provide comprehensive evaluation information for each climate mode. The results are expressed in a scorecard format, indicating relative skill differences compared with the reference model, and present the level of the current operation model and effectiveness of the developed technology. The goal of the CrEMA is to identify improvements and weaknesses in the model briefly and suggest ways to improve the model based on process-based metrics.

The CrEMA diagnostic system was applied to GloSea6 to diagnose ENSO, MJO, and EASM, which are the major climate variables in the tropical and mid-latitudes. As a result of the ENSO diagnosis, the equatorial SST mean and seasonal variation and ENSO bias (strong intensity, strong seasonality, and rapid release of phase locking characteristics) were improved. The coupling errors between atmosphere-ocean variables in the equatorial Pacific were identified; the Taux-SSH coupling error during the La Niña development period may contribute to the decrease in La Niña prediction performance, and the sharp decline in heat flux during the El Niño decaying period may contribute to the rapid termination of El Niño. The basic properties of ENSO, except for ENSO duration, are overall improved, which affects the improvement of the average prediction accuracy and teleconnection of ENSO. Temperature patterns associated with ENSO fluctuations have shown global and East Asian region improvements. However, the simulation accuracy of precipitation patterns has diminished. This decline is attributed to GloSea6's dry bias in the equatorial Pacific and a strong double ITCZ. Rectifying the systematic errors in equatorial precipitation may not only ameliorate these biases but also improve the teleconnection-influenced precipitation field associated with ENSO.

2023
Featured
Achievements

As a result of the MJO diagnosis, eastward motion performance was improved in the maritime continent, known as the MJO prediction barrier, possibly because the moisture dry bias in the lower layer of the oceanic continent has been improved, which in turn improved the cold bias and vertical diabatic heating of the relevant temperature range. However, there is a degradation in the lower-level moisture convergence performance over the Indian Ocean. Although this did not directly impact the eastward propagation performance of the MJO, future improvements remain warranted, considering its association with the warm bias in the Indian Ocean. The performance of the MJO-related upper-level simulation has decreased overall, including the deterioration of the upper-level divergence structure associated with MJO and eastward expansion of the Pacific tropical jet. The eastward expansion of the jet influenced teleconnection, ultimately causing the PNA region to shift eastward. In this regard, efforts to improve upper-level simulation performance are essential for model enhancement.

As a result of the MJO diagnosis, the sub-seasonal variability of the summer rainfall moving north to East Asia was partially improved and the strength and variability of the Northwest Pacific high were improved; however, the east-west expansion of the Northwest Pacific and the East Asian jet are under-estimated. Teleconnections between EASM and tropical/extratropical climate modes showed improved El Niño remote teleconnections, yet, additional improvements are needed for La Niña and Indian Ocean teleconnections. Furthermore, the local ocean-atmosphere feedback in the subtropical North Pacific Ocean, which plays a crucial role in the tropics-midlatitude teleconnection, was overly simulated compared with observations and hence requires further analysis and adjustments.

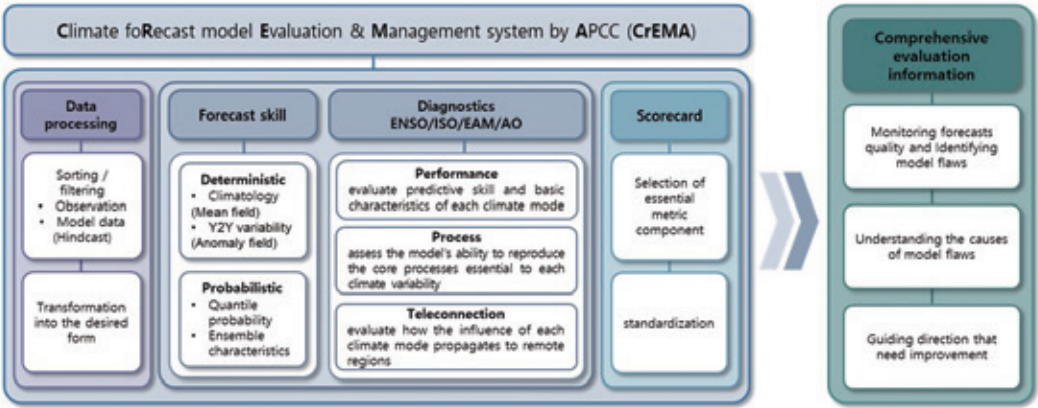


Fig13 Schematic diagram exploring the structure and function of CrEMA

2023 Featured Achievements

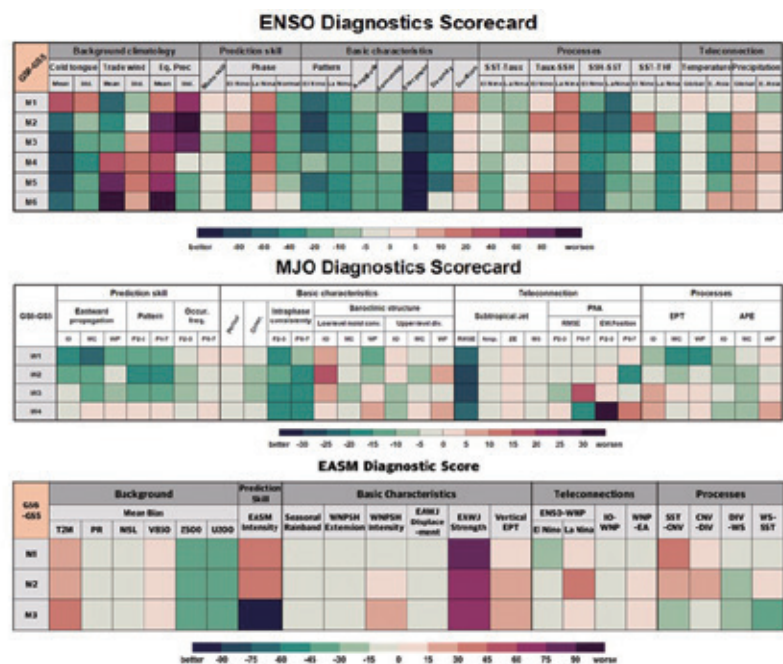


Fig14 CrEMA diagnostics scorecards which represents relative skill difference between GloSea6 and GloSea5

CrEMA is an integrated system that encompasses the entire process related to evaluation, including data preprocessing, skill assessment for climate variables, diagnostics of various climate variability, and presentation of evaluation information, and aims to generate comprehensive evaluation information for the KMA climate prediction system, providing a state of the current forecasting capabilities. Additionally, CrEMA offers the improvement on the information (scorecards) of the developed model, demonstrating the effectiveness of research and development (R&D) outcomes. These results can be used as the basis for selecting the developed technology for operationalization, and the standardized evaluation information derived from continuous model improvements can be utilized as systematic historical records for climate prediction system management. CrEMA can play a crucial role in producing integrated evaluation information, offering insights into the current state of climate predictions, facilitating effective research and development, and providing a basis for decision-making regarding the implementation of advanced technologies in operational systems.



03

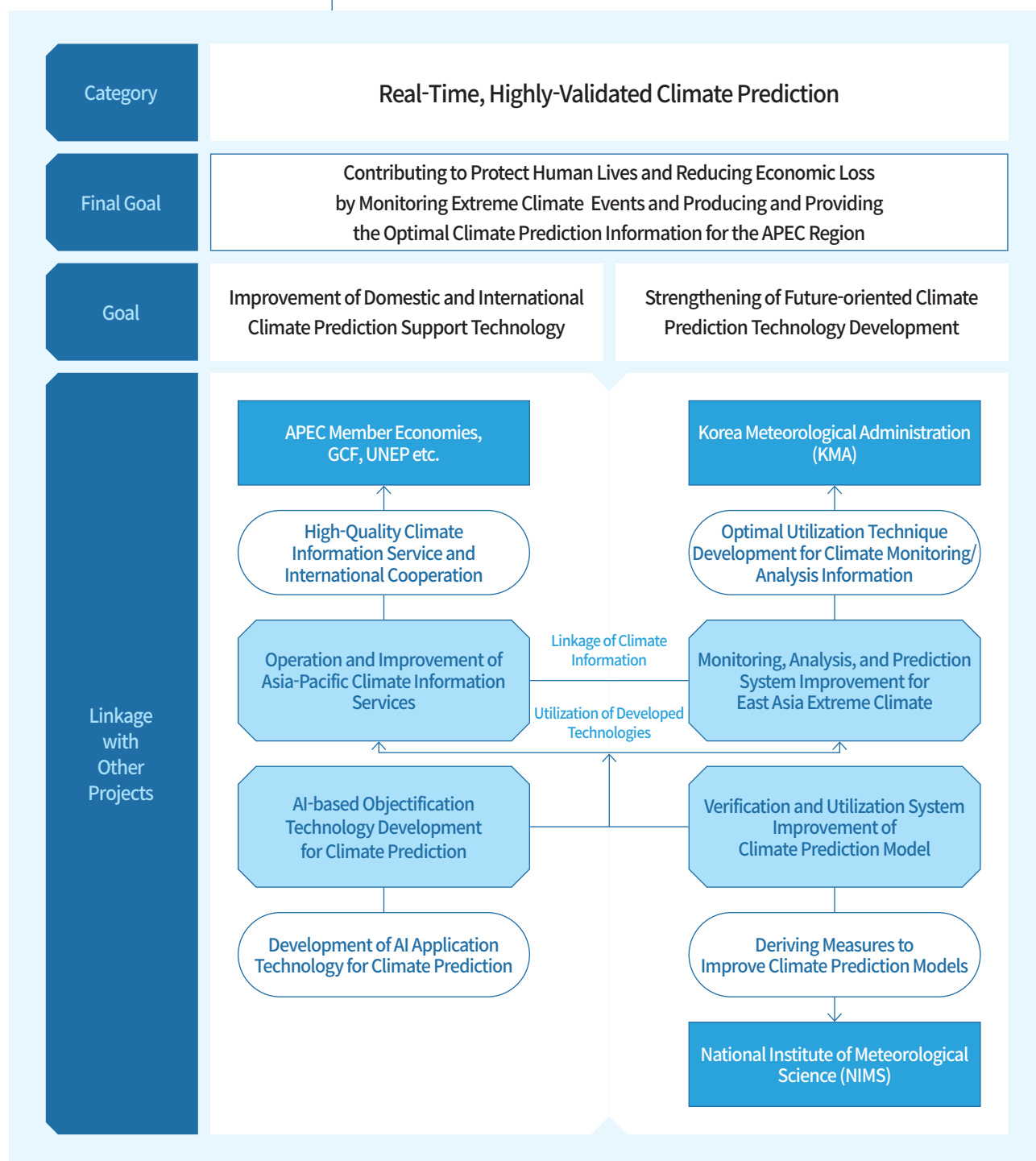
APEC Climate Center



2023 Research Projects

2023 Research Projects

Improving the Structure of Climate Information Service for the Asia-Pacific Region and Establishing an Innovation System for Climate Prediction Technology to Strengthen Climate Crisis Response Capacity



2023 Research Projects

1) Multi-Model Ensemble (MME)

To disseminate seasonal forecast information to the Asia-Pacific region, APCC applies MME techniques to climate prediction models provided by 15 climate prediction agencies from 11 countries. The MME method, by integrating climate forecast models to minimize uncertainty, improved the predictive power of various models.

2) Boreal Summer Intraseasonal Oscillation (BSISO)

Convection phenomenon that occurs in the Indian Ocean with a 15–60-day cycle and propagates northward while exhibiting Rossby wave-like character. This phenomenon affects the onset of the Asian summer monsoon season, atmospheric circulation, and weather.

3) El Niño-Southern Oscillation (ENSO)

An irregularly periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of much of the tropics and subtropics. The warming phase of the sea temperature is known as El Niño, while the cooling phase as La Niña.

4) Seamless Coupled Prediction System (SCoPS)

APCC's global seasonal forecast system.

1. Real-Time, Highly Validated Climate Prediction

Overhauling the Asia-Pacific Climate Service and Establishing Climate Prediction Technological Innovation System to Strengthen Climate Crisis Response Capabilities

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

..... Securing APCC MME competitiveness and strengthening user support for climate information service

Project 1 Establishment of High-resolution Multi-model Ensemble (MME) Sub-seasonal to Seasonal (S2S) Prediction Framework and Diversification of Web Contents to Strengthen the Usability of APCC Climate Information

Dr. Bong-Geun Song songbg@apcc21.org

1) Background and Relevance

- Provision of real-time, high-quality climate forecast data for the Asia-Pacific region through the stable operation of and improvement in the APCC climate prediction system.
- To improve the usability of APCC climate forecast data and strengthen MME¹⁾ competitiveness, a base system should be constructed to extend the forecast time scale to S2S and upgrade climate information web contents.

2) Main Results

A Operation of APCC climate prediction system and provision of forecast information

- MME seasonal forecast: Sending climate forecasts in English and Korean to all countries/Pacific Islands/East Asia around the 15th of every month
- MME probabilistic forecast from selected models for East Asian region: Provision of forecast information on the website around the 15th of every month
- BSISO²⁾ sub-seasonal forecast: BSISO information production and provision (May–October)
- ENSO³⁾ alert: Provision of updated information twice on the 15th and last day of each month
- SCoPS⁴⁾ seasonal forecast: Monthly forecast production and MME participation
- Fire and haze early warning: Production and provision of precipitation and fire forecast warnings in Indonesia (April–July) and Malaysia (October–January)
- Production of presentation files for KMA's seasonal forecast discussion to deliver the MME's seasonal forecast for South Korea

B Improvements of APCC climate prediction system

- APCC Climate Outlook Renewal.
 - Improved structure and format for users to better understand the contents.
- Improvement in BSISO sub-seasonal forecast system.
 - Extension of BSISO impact anomaly domain (10S–40N, 40E–160E → 10S–50N, 40E–160E) and forecast period (up to 3 weeks → 4 weeks).

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- Improvement in Fire and haze early warning system.
 - Updates of input data (higher resolution individual model and observed precipitation data), regional expansion to Malaysia.
- Dynamic climate information web services.
 - Dynamic web content services for APCC MME and individual model forecasts, climate monitoring, and climate indices.

C Linear trend bias correction of temperature at 2 m of APCC MME

- Comparisons of long-term trend temperature between seasonal forecast and observation in East Asia.
- Development of real-time seasonal forecast temperature correction based on the long-term trend analysis.

D Establishment of APCC MME sub-seasonal forecast Framework

- Establishment of MME sub-seasonal forecast operation infrastructure.
- Establishment of infrastructure for producing SCoPS sub-seasonal forecast data.

E International cooperation and policy support in the climate sector

- Operation of WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble ([LC-LRF MME](#)), support for quarterly Global Seasonal Climate Update ([GSCU](#)) publication, and support for WMO Regional Climate Outlook Forums ([RCOF](#)).
- Operation of WMO Sub-seasonal-to-Seasonal prediction ([S2S](#)) International Coordination Office ([ICO](#)).
- Participation in the IPCC Sixth Assessment Report ([AR6](#)) Working Group 1 ([WG1](#)) expert committee.

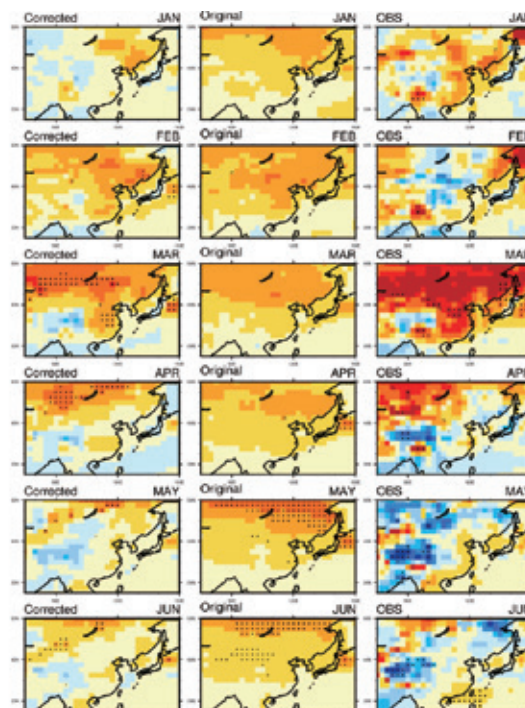


Fig15 Monthly (January-June) spatial patterns of (left) corrected forecast, (middle) original forecast, and (right) observation of 2-m temperature anomalies averaged from 2013 to 2022 (dot: 10 percentile of both side)

2023 Research Projects

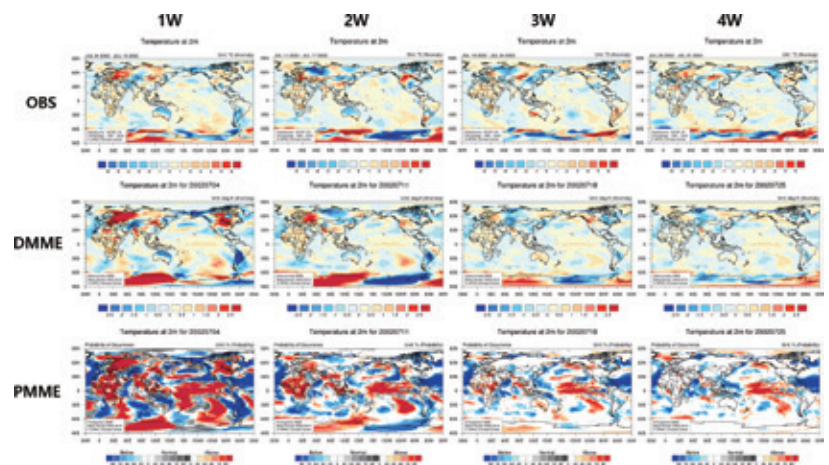


Fig16 Observations (top) and 1~4 weeks MME subseasonal deterministic (middle) and probabilistic (bottom) forecasts during 4~25 July 2022

3) Expected Implications

- Provision of high-quality climate forecast information services through stable operation and continuous system improvement.
- Strengthening the efficiency and usability of the APCC climate forecast information and support for long-range forecast.
- Strengthening the international climate network through cooperation with APCC MME participating institutions, WMO, IPCC, etc.

Project 2 Development of APCC Dynamic Climate Information Services

Dr. Hyunrok Lee tank@apcc21.org

1) Background and Relevance

- Service Operation: To promote stable operation and improvement of APCC climate information services based on the operation plan.
- User support: To expand user support for the APCC climate information service through the reinforcement of Open APIs and online tutorial services on the climate service platform.
- Establishment of dynamic climate information service: To establish a monitoring/prediction/verification information provision homepage incorporating dynamic web technology which includes the integration of the homepage and climate service platform, as well as providing a pilot service of user-customized high-resolution climate prediction data in the platform.

2) Main Results

A Stable operation and improvement of APCC climate information services

- Stable operation of climate information services
 - Stable operation of APCC climate information services (homepage, APCC climate service platform, etc.) (constantly).

2023 Research Projects

- Establishment of climate information service operation plan and its regular inspection for efficient management of climate information service (monthly).
- Improvement and application of countermeasures against security vulnerabilities to strengthen the security of climate information services.
- Continuous monitoring through the information service monitoring system.
- Support for related tasks necessary for the stable and efficient operation of climate information services (EA, Web quality control, public data, etc.).
- Expansion of reanalysis data services through the climate information service platform.
 - NCEP1/2 reanalysis data provision service.
- Enhancement of climate data processing service user interface and Open API on the climate information service platform
 - Strengthening of climate data processing service interface for user convenience.
 - Design and development of Open APIs for climate information dynamic display and mashup services.
 - Providing dynamic verification information in the climate information service platform.
- Strengthening of online tutorial services for the climate Information service platform.
 - Increased user convenience through the development of improved user interfaces.

B Establishment of dynamic climate information service

- Construction of APCC Homepage providing monitoring/prediction/verification information using dynamic web technology.
 - Collection and analysis of requirements for information, display functions, etc., to be provided in dynamic climate information service.
 - Design of web application interfaces and overall page layouts using dynamic web technology.
 - Development of homepage and climate data processing modules linked to the APCC homepage.
- Establishment of integration framework for homepage/climate information service platform.
 - Design of an integration system for the homepage/climate information service platform.
 - Development of the prototype for the integration of the homepage/climate information service platform.
- Development and beta service of user customized high-resolution MME prediction.

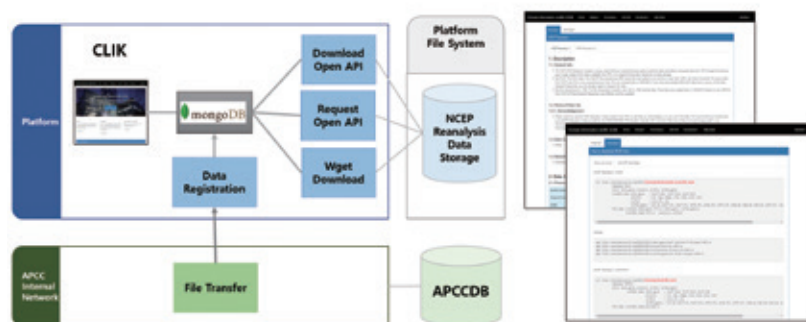


Fig17 NCEP1/2 Reanalysis Data Service on the APCC Climate Information Service Platform

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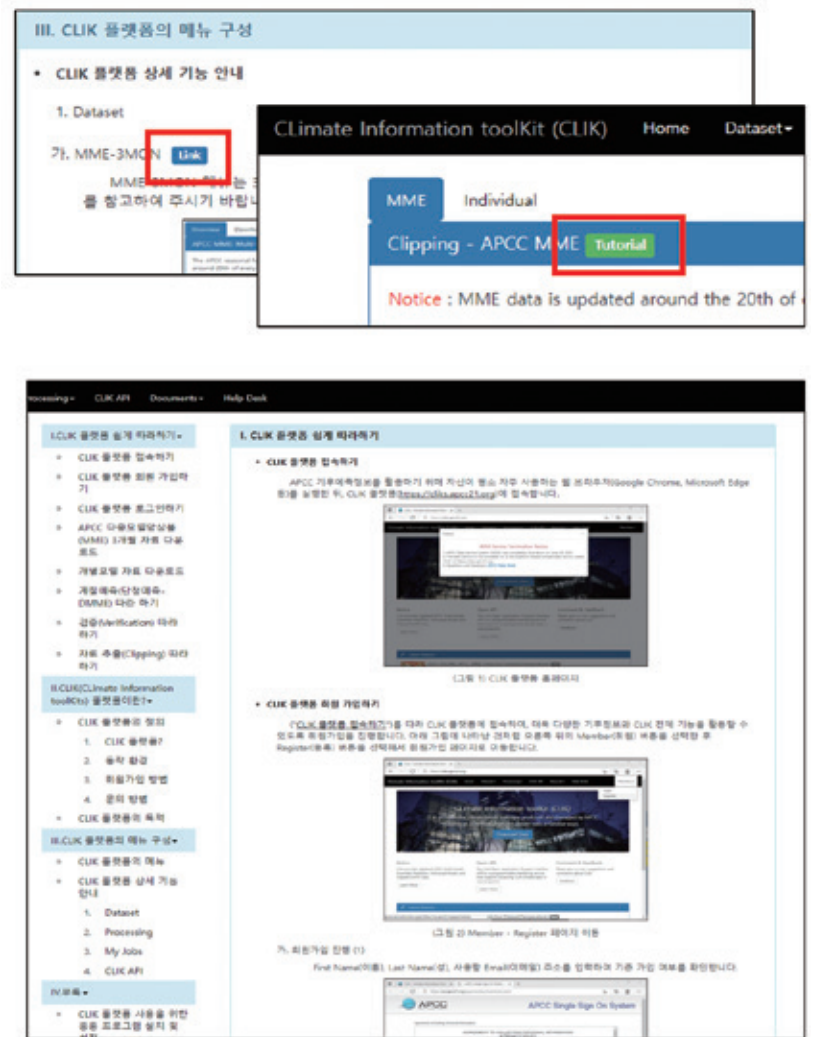


Fig18 Enhancement of Online User Tutorial

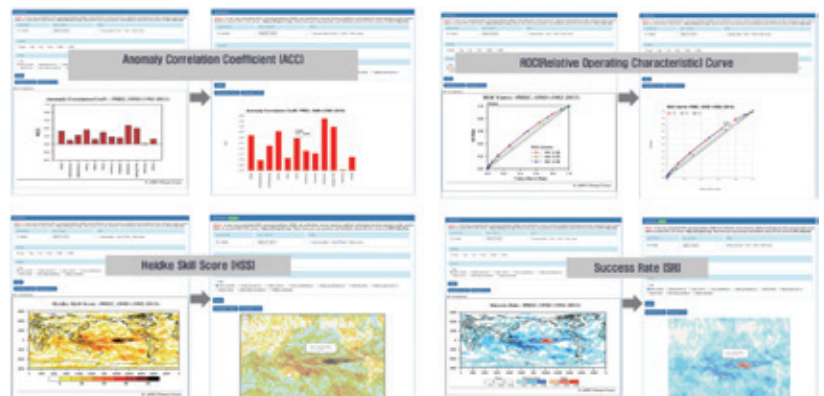


Fig19 APCC Dynamic Climate Information Services in the CLIK platform

2023 Research Projects



Fig20 APCC Homepage Development

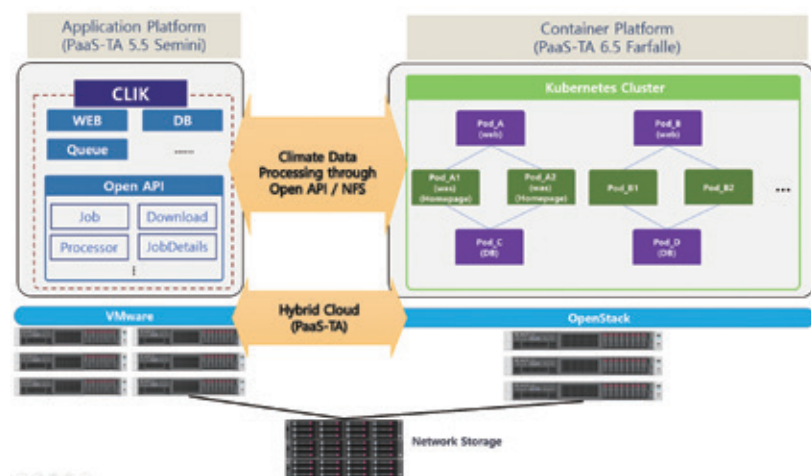


Fig21 APCC Homepage/CLIK Platform Integration

※ Pod is the most basic deployment unit in Kubernetes and is a unit that includes containers.

3) Expected Implications

- Enhance user access convenience and climate information provision by expanding climate data, delivering dynamic climate information, and ensuring secure and consistent channels for climate information delivery.
- Provide support to domestic private and public institutions, as well as the Asia-Pacific region, through the climate information service platform for the production, processing, and provision of climate forecasting and verification data.
- Anticipate improved operational stability, scalability, and budget efficiency for the APCC climate information service through the utilization of platform technology in climate information services.

2023 Research Projects

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

- Development of optimal utilization techniques for information on prediction, monitoring and analysis

Project 3 Improving Long-range Forecasts through Enhanced Forecast Skills and Integrated Information

Dr. OkYeon Kim oykim@apcc21.org

1) Background and Relevance

- There is a need to continuously develop forecast information utilization technology to improve the KMA's long-range forecast.
- Model prediction information must be selected and corrected in consideration of model reproducibility on the variability and impact of winter monitoring factors.
- It is necessary to select quantifiable indicators through analysis of model prediction characteristics and prepare a method that can be used for forecasting.

2) Main Results

A Improving and integrating monitoring factor information for long-range forecasts

- Analysis of Korea's winter monitoring factors (tropical ocean, Arctic Sea ice, and Eurasian snow cover).
 - Analysis of the main modes of variation in tropical precipitation in winter and related atmospheric circulation fields.
 - Proposal to analyze the utility of Arctic Sea ice and use the vertical structure of the Arctic atmosphere as an alternative monitoring factor.
 - Analysis of East Asian atmospheric circulation field characteristics and utilization according to Eurasian snow cover in autumn
- Proposal of a plan to utilize monitoring factors considering model reproducibility.
 - The model does not differentiate responses according to precipitation region and period and has limitations in simulating waves on the Eurasian continent.
 - The model simulates a similar atmospheric circulation response regardless of the differences in vertical depth of Arctic warming.
 - The model simulates the atmospheric response of the Eurasian continent due to snow cover being weaker than observation.

B KMA's 1/3-month long-range forecast practical cooperation

- Development of long-range forecast content that reflects the needs of forecasters.
 - After 3 weeks of forecasting, limitations were identified in considering the trend of the 500hPa altitude forecast field.
 - When selecting ensemble forecast data, the performance of temperature and precipitation probability forecasts in Korea is expected to improve.
 - Confirmation of the possibility of using MJO information of a specific phase to predict temperature for the 3rd week of winter on the Korean Peninsula

2023 Research Projects

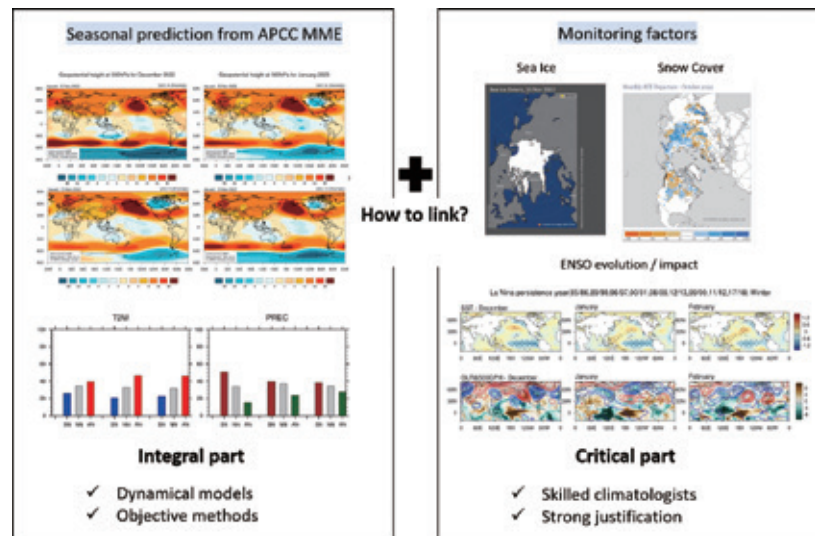


Fig22 Three-month long-range forecast from the linkage with model predictions from APCC MME and observation-based monitoring factors

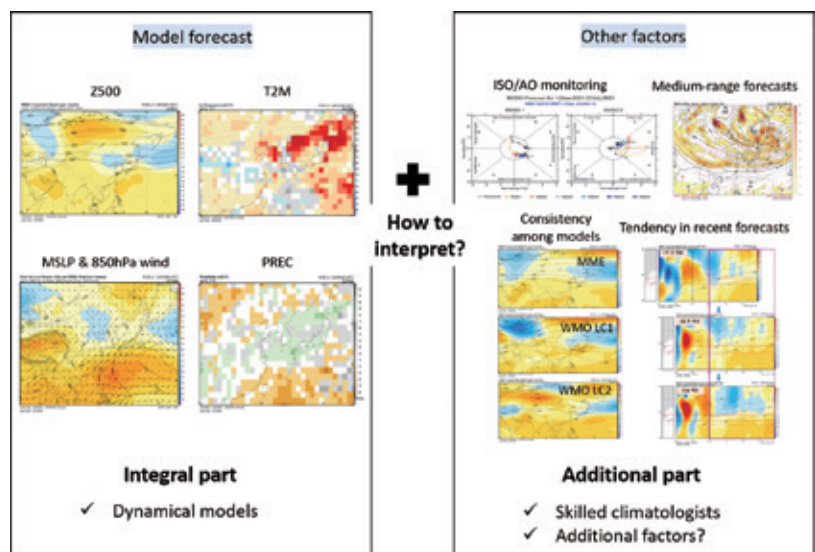


Fig23 One-month long-range forecast from the interpretation with model prediction and additional factors

3) Expected Implications

- Ongoing practical support related to the KMA's long-range forecast production work.
- Used as basis for objective judgement in the long-range forecast production process.
- Expansion of long-range forecast content according to technical development.

2023 Research Projects

1) North Pacific Oscillation (NPO)

One of the atmospheric teleconnection patterns occurred in North Pacific Ocean. NPO is characterized by a north-south seesaw in sea-level pressure over the North Pacific Ocean.

Project 4 Enhancing Climate Information and Establishing Integrated Information System to Cope with Extreme Climates

Dr. Seon Tae Kim seontae.kim@apcc21.org

1) Background and Relevance

- Reliable predictions of extreme climate events (heat waves, cold waves, droughts, torrential rains, etc.) globally and on the Korean Peninsula, which have recently become more frequent and stronger due to global warming, are essential for coping with and adapting to climate change.
- APCC contributes to producing reliable long-term forecasts by developing observational climate predictors (El Niño-Southern Oscillation, Indian Ocean, sea ice, snow cover, Arctic Oscillation, etc.) that are closely related to monthly and seasonal temperature and precipitation variation in Korea.
- The relationship between the Korean climate and its predictors changes, and the use of predictors based on simple correlations has limitations in improving predictor-based prediction skills.
- For the various climate predictors to contribute to improving long-term predictions and preparing for extreme climate events, effective methods are needed to improve prediction utilization and reliability.
- To adapt to and prepare for climate change, research is needed on extreme climate events on the Korean Peninsula and the climate change impact on renewable energy power generation.
- There is a need to develop and improve the Climate Analysis System (CAS) to provide rapid analysis and information related to extreme climate events.

2) Main Results

A Improvement of analysis-based climate monitoring/prediction information

- Providing methods to improve prediction skills through the use of dynamical processes of summer temperature predictors.
 - Monitoring a strong South Asian monsoon index in June for a positive value of the European Z500 predictor in March and monitoring snow depth in Central Asia in April and SST in the Gulf of Mexico in June for its negative value increase the reliability of temperature prediction for the Korean Peninsula in July.
 - The reliability of July temperature prediction can be enhanced by monitoring the South Asian monsoon index in June when the tropical SST triple predictor in April is in a positive phase, and by monitoring the tropical SST triple in May when the predictor is in a negative phase.
 - It was confirmed that prediction reliability was improved through monitoring of the dynamic process for each preceding.
- Improving climate monitoring and analysis information by proposing a new winter climate predictor for Korea and presenting its related teleconnection.
 - ENSO, a major winter climate predictor, has high temperature and precipitation predictive skills in Korea in December, but low in January.
 - The North Pacific Oscillation (NPO)¹⁾ in December was delayed by one month in its effect on January temperature variability in Korea.
 - The anticyclonic circulation that occurs over the mid-latitude North Pacific under the influence of NPO decreases precipitation in the western North Pacific, while the East Asian high pressure continues until January through upper-level teleconnection.

2023 Research Projects

2) Standardized Precipitation Index (SPI)

Estimating the deficit of precipitation.

3) Standardized Evapotranspiration Deficit Index (SEDI)

Estimating the real evapotranspiration between air and land.

- The easterly wind anomalies located in the south of the NPO-related high pressure weakens the mid-latitude jet, which is characterized by the mean westerly wind, while the wind-evaporation-sea surface temperature feedback causes the sea surface temperature in the near-sea region of Korea to rise, thereby facilitating the increase in Korea's January temperature.
- The use of the December NPO index as a climate predictor for January temperature in Korea can improve predictive skills compared with ENSO

B Analysis of renewable energy power generation and drought projections in the Korean Peninsula in a future climate change

- Analysis of seasonal mean changes in solar and wind power generation potential due to future climate change
 - There is no significant change in solar power generation potential in spring, summer, and fall in the low-carbon scenario; however, in the high-carbon scenario, there is a significant decrease in spring and winter.
 - In the high-carbon scenario, the significant decrease in spring-averaged solar power generation potential in the second half of the 21st century compared to the present climate is due to the increase in temperature attributed to global warming, while the decrease in winter is due to the significant increase in temperature and is associated with increased cloudiness due to the increased influence of southwesterly winds, thereby decreasing solar radiation amount to reach the earth surface.
 - Wind power generation potential did not show statistically significant changes in spring and summer under the low-carbon scenario, but showed a significant decrease in fall and winter in the western and southern regions of South Korea, respectively, in the second half of the 21st century. In contrast, in the high-carbon scenario, significant decreases were seen in almost all regions in spring and fall and in southern part of South Korea in winter.
 - The decrease in wind energy power generation potential is due to the greater influence of southwesterly winds in spring and winter and northeasterly winds in fall in the second half of the 21st century, thereby decreasing wind speed compared with the present climate and wind power generation potential.
- Analysis of drought projections on the Korean Peninsula in future climate change
 - Using the [Standardized Precipitation Index \(SPI\)^{2\)}](#) and [Standardized Evapotranspiration Deficit Index \(SEDI\)^{3\)}](#), we analyzed future changes in the drought over south Korea.
 - It was projected that spring and fall drought in south Korea will worsen more in SEDI than SPI in the future since the latter index better reflects the effects of global warming, such as temperature rise.
 - Drought is projected to intensify in fall than spring and in the high-carbon scenario than the low-carbon scenario.
 - Due to rapidly rising temperatures in future climate change, demand in the atmosphere will exceed evapotranspiration, making droughts more severe than in the present climate.
 - In spring, precipitation increases under future global warming compared with the present climate; however in fall, the southerly wind blowing into Korea weakens and precipitation decreases, which results in more droughts in the fall than spring

C Improving climate monitoring system and expanding climate analysis services to enhance user convenience

- Automated monitoring and analysis information providing service for APCC seasonal prediction discussion.
 - Provision of observational monitoring information for the past 3 months based on the time of forecast discussion.
 - Providing the latest external monitoring information (various ocean/atmospheric variability, Arctic Sea ice, snow cover, etc.).
- Extraction of observational climate predictors of interest and their related composite analysis service.
 - Providing the results of the composite analysis of a climate predictor.

2023 Research Projects

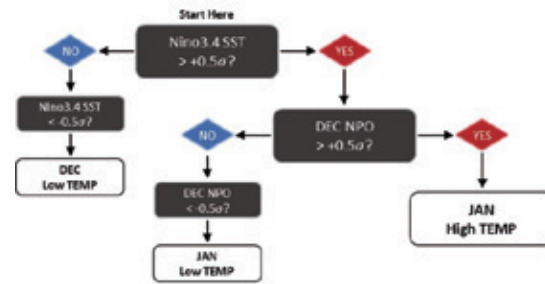


Fig24 Flowchart of decision process for implementing the December NPO and ENSO to determine the Korean temperature anomalies in winter (December and January).

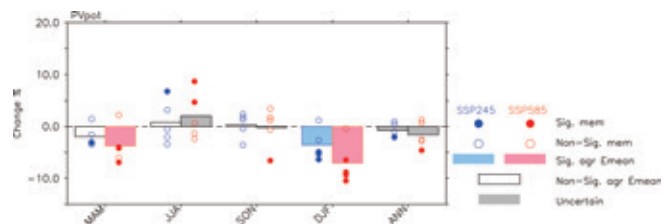


Fig25 Box plots for change in seasonal and annual mean solar power generation potentials under a future low-carbon (blue) and high-carbon (red) scenario over long-term (2081-2100) period relative to present climate.

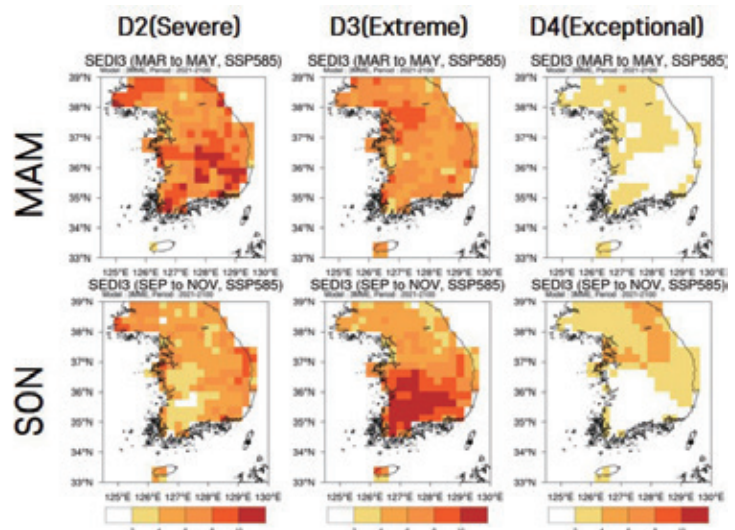


Fig26 Spatial Distribution of D2 (Severe), D3 (Extreme), D4 (Exceptional) Drought for (upper) MAM and (lower) SON season during 2021-2100 in high-carbon scenario.

3) Expected Implications

- Utilization of climate analysis information related to the North Atlantic and South Asian pressure systems for long-term forecasting on South Korea.
- Enhanced ability of APCC and preparedness for future climate change by providing impacts of climate change on South Korea related to extreme precipitation and typhoons.
- Contributing to the production of objective long-term forecasts by preparing a predictor importance evaluation system.
- Contributing to efficient climate analysis and response to extreme climate issues through the establishment of an integrated climate monitoring and analysis system.

2023 Research Projects

1) Artificial Intelligence

The ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent agents (e.g., humans).

2) Sub-seasonal to Seasonal (S2S) timescales

predictions of the time range between 2 weeks and 2 months.

3) Deep Learning

A machine learning technique that teaches computers to do what comes naturally to humans.

4) Semi-Supervised Learning

A machine learning technique that uses both labeled and unlabeled data to train a model.

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

..... Development of AI application technology suitable for climate prediction

Project 5 The Development Of Artificial Intelligence¹⁾-Based Technologies for Objective Climate Prediction

Dr. Seongkyu Lee geoslegend@apcc21.org

1) Background and Relevance

- Global companies and the ECMWF are developing and testing AI-based 14-day weather forecast models; however, the application of AI to climate forecasting is in its infancy.
- Research is needed to improve the predictability of [sub-seasonal to seasonal \(S2S\) timescales](#)²⁾ through development of AI-based climate prediction technologies for objective climate prediction.

2) Main Results

A Analysis of the sensitivity of model performance to expanding data

- Sensitivity analysis based on data sampling techniques.
 - Selection of the input dataset for the deep learning model by sampling technique (e.g., filter method, wrapper method, and embedded method)
 - Test deep learning model on selected input data.
 - Sensitivity analysis of model inputs by sampling technique.
 - Understanding of the impact of the data organization and the sampling techniques on AI learning.

B Improvement of model architectures with training techniques, hyperparameter optimization, and uncertainty analysis

- Construction of U-NET-based experimental models
 - Residual U-Net, Attention U-Net, Residual+Attention U-Net.
- Analysis of the predictability of ECMWF temperature at 2 m maximum ([TMAX](#)) and precipitation ([PREC](#))
 - Attention U-Net > Residual+Attention U-Net > Residual U-Net.
- Application of hyperparameter optimization algorithm and sensitivity analysis by hyperparameter combination

C Application of semi-supervised learning techniques and sensitivity analysis of the [deep learning](#)³⁾ model

- Development and testing of an image-based AI model for MJO phase classification
 - Selection of fully-connected ([FC](#)) layers with less overfitting and AI models.
 - Evaluation of model accuracy against independent test data and identification of misclassifications.
- Development and testing of models based on semi-supervised learning techniques
 - Implementation and testing of Pseudo-Label, Mean teacher algorithms.
 - Analysis of results by input variables, AI model, and [semi-supervised learning](#)⁴⁾ algorithms.

2023 Research Projects

5) Explainable Artificial Intelligence

A set of processes and methods that allows human users to comprehend the results and output created by machine learning algorithms.

- Sensitivity analysis of climate forecasts using semi-supervised learning
 - Experiment with models based on data conditions when applying semi-supervised learning.
 - Predictive modeling of MJO index with lead time and testing of application of semi-supervised learning.

④ Explainable artificial intelligence (XAI)⁵⁾, model structure analysis, and model improvement

- Visualization and analysis of the structure of the deep learning model
 - Loss surface visualization analysis.
 - Visualization and analysis of features in deep learning models.
- Analysis of the internal structure and the parameters of the deep learning models
 - Analysis of the hyperparameter and the parameter definitions in deep learning models.
 - Analysis of the predictability of the models with hyperparameter tuning experiments.
- Improvement of the structure of deep learning models and testing their predictability
 - Design experimental models that consider attention mechanisms, expansion of the data and the number of layer filters, feature collapse analysis, etc.
 - Improvement of the models through redesigning the section where the features collapse in the models.
 - HSS evaluation of deep learning models using ASOS data in South Korea.
- Improvement of a model by comparing XAI results
 - Before-and-after analysis of semi-supervised learning for MJO phase classification model.

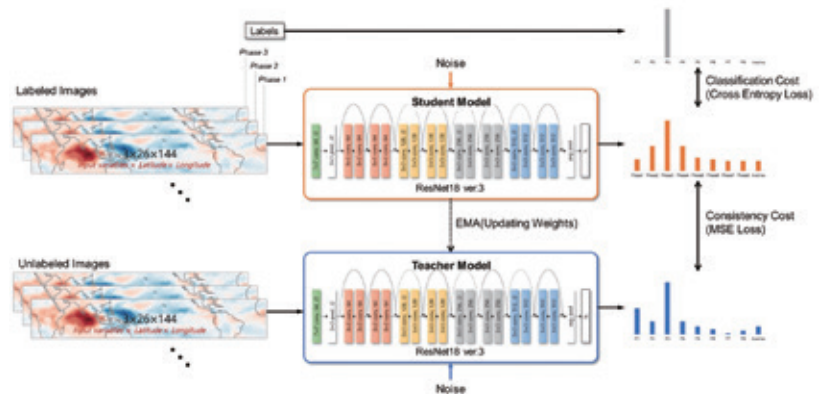


Fig27 Diagram of modified ResNet18 model version 3 based on semi-supervised learning

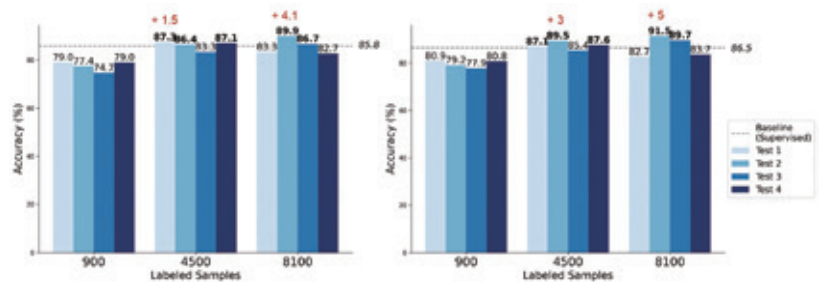


Fig28 Comparison of the performance of the models after applying semi-supervised learning: RMM (left) and VPM (right) variable

2023 Research Projects

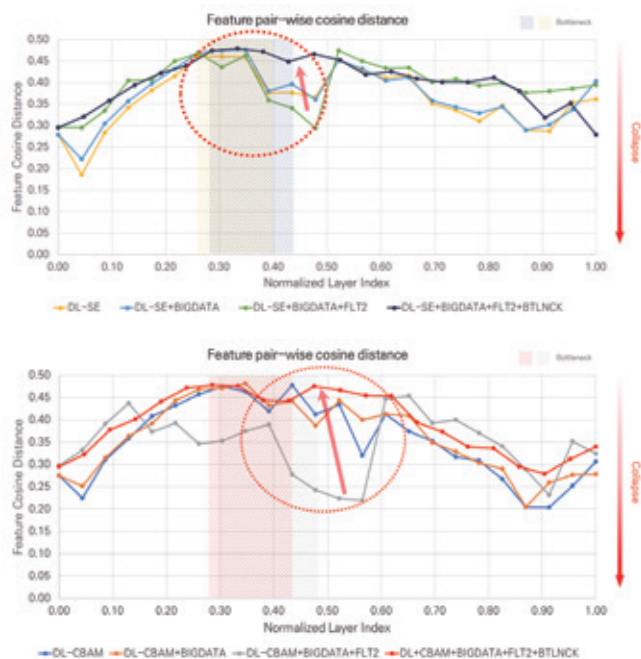


Fig29 Results of the feature pair-wise cosine distance analysis of the deep learning models with SE block (up) and CBAM block (bottom) after changing the bottleneck block

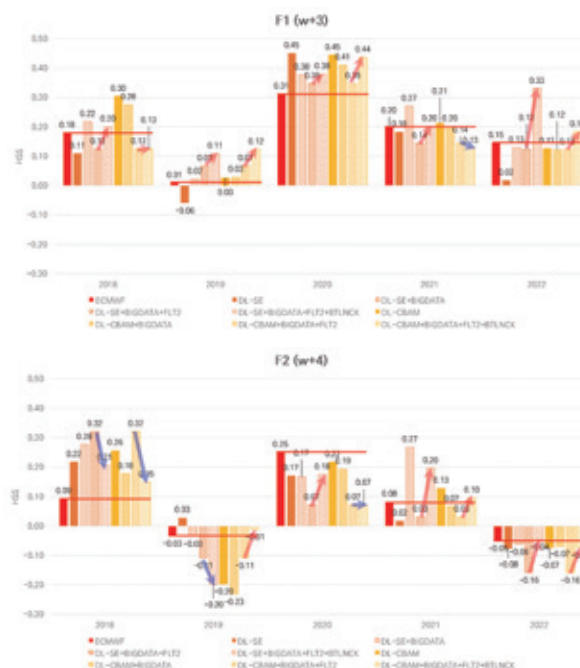


Fig30 Results of HSS assessment of lead time F1 (W+1) (up) and lead time F2 (W+3) (bottom) for 8 models

3) Expected Implications

- Contribute to improving climate prediction performance in S2S timescales by utilizing advanced AI technologies.
- Contribute to the technological development of climate forecast fields in S2S timescales through the enhancement of AI-based climate prediction technologies.

2023 Research Projects

1-4. Verification and Utilization System Improvement of Climate Prediction Model

..... Establishment of an Effective Improvement System for the National Climate Prediction Model

Project 6 Testbed Construction and Development of Its Utilization Technology for the National Climate Prediction Model

Dr. Sun-Hee Shin SSh222@apcc21.org

1) Background and Relevance

— Reliable climate forecast hinges on a continuous commitment to improving the prediction system. This undertaking involves the following: ① Strategies to enhanced land surface process; ② suggestions for the practical applicability of specific techniques to the operational forecast (testbed); ③ establishing a consistent and systematic evaluation framework through a diagnostic assessment of key climate variabilities in climate prediction models.

2) Main Results

A Development of model improvement techniques based on diagnosing the characteristics of KMA GloSea6 land model

- Improvement of river routing model (TRIP) in GloSea6
 - Diagnosing the characteristics of GloSea6-TRIP, identifying excessive river storage from river mouth due to the low-resolution, and proposing higher resolution for river routing model.
 - Collecting and developing input/output data for the high-resolution TRIP and designing modules for implementation.
 - Assessing the effectiveness of applying the high-resolution TRIP and confirming the improvements in river flow and discharge and expectations for enhanced atmosphere-ocean interactions.

B Suggestions for the practical applicability of specific techniques to the operational forecast (testbed)

- Sensitivity experiments and optimization evaluation of parameters within sea ice physics processes scientific/technical efficacy review
 - Conducting single/multiple parameter adjustment sensitivity experiments.
 - Proposing a 10% reduction in snow albedo and establishing scientific justification for a realistic snow albedo.
 - Proposing a 10% increase in ice albedo and confirming the improvement in arctic-midlatitude teleconnections.
- Experimenting with coupled initialization techniques in the operational environment, scientific/technical efficacy review
 - Confirming the improvement of the seasonal predictability of East Asian summer rainfall and in predicting factors influencing the East Asian summer monsoon.
 - Confirming the seasonal predictability of tropical variability in winter, improvement in precipitation, mean/variability of lower-level winds, and MJO eastward propagation performance.
 - Verifying technical stability when applied in operational settings.

2023 Research Projects

© Comprehensive assessment of major climate variabilities in KMA GloSea6

- Construction of standard verification frame, namely the Climate forecast model Evaluation & Management system by APCC (CrEMA)
 - Selection of key climate prediction factors and composition of standard diagnostic evaluation metrics.
 - Development of calculation modules and graphic modules for individual metric elements based on ENSO/MJO/EASM diagnostic metrics.
 - Development of scorecards based on the quantification of ENSO/MJO/EASM diagnostic metrics.
- Applying the CrEMA to KMA GloSea6 re-forecasts
 - Improvement of biases in equatorial SST mean and interannual variability, ENSO bias confirmation, and verification of errors in equatorial Pacific atmospheric-oceanic dynamic coupling.
 - Confirmation of improved MJO eastward propagation performance due to enhancements in the oceanic-continental mid-lower layer vertical structure, suggesting the need for improvement in Indian Ocean lower-level moisture convergence.
 - Partial improvement in the seasonal/interannual variability prediction of East Asian summer monsoon rainfall, verification of improvements in the North Pacific subtropical high variability, and suggestion of the need for improvement in the tropical jet stream.



Fig31 A framework for developing model technology and diagnosing joint development technology to improve KMA GloSea6

3) Expected Implications

- The results of high-resolution TRIP in KMA GloSea6 can be useful in improving seasonal prediction due to more accurate air-sea interaction and in applied and policy research on water resources.
- Testbed has proposed guidelines to implement coupled initialization and optimizing sea-ice physics in the current KMA GloSea6. This will contribute to enhancing R2O efficiency for the improvement of the climate prediction system.
- The comprehensive assessments of major climate variabilities (ENSO/MJO/ENSO) have been conducted by applying the CrEMA diagnostic system to KMA-GloSea6, which will be utilized to identify the model's weaknesses and provide guidance for the model's improvement.

2023 Research Projects

2. Green Climate Fund (GCF) Supported Projects

APCC is participating in the Green Climate Fund (GCF) support 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 has been promoted since its establishment.

2-1. Project Initiated by the Secretariat of the Pacific Regional Environment Program (SPREP)

- Improving risk management & decision-making capabilities for meteorological disasters caused by climate change and extreme climate through the use of climate information

Project 7 Climate Information Services for Resilient Development Planning in Vanuatu

Dr. Jong Ahn Chun jachun@apcc21.org

1) Background and Relevance

- Essential use of climate information to effectively respond to disasters caused by climate change and enhance climate resilience in Vanuatu.
- Strengthening climate information services across five key sectors (tourism, agriculture, infrastructure, water resources, and fisheries) to promote resilient development and sustainable growth of local communities.
- The first delivery partners for GCF projects in Korea (15th board meeting).
- The web-based agricultural climate information service is a crucial tool for decision-making support.

2) Main Results

A Development of the Agricultural Climate Information Service System

Completion of the 3-phase tailored system of Climate Services for Agriculture (OSCAR) system, accessible at <https://oscar.gov.vu/>.

Key features include:

- Application of Gap-filling techniques to enhance the quality of observational meteorological information, providing accurate and reliable weather data.
- Digitalization of paper soil maps and development of electronic soil maps, improving access and utilization of soil-related information.
- Enhanced accessibility of the OSCAR system through mobile pages, enabling agricultural workers to use vital climate data anytime and anywhere.
- Provision of various APCC seasonal forecast data and ENSO warning information, offering critical inputs for agricultural planning and management.
- Automatic production of the Agromet-Bulletin, delivering up-to-date climate information related to agriculture.

2023 Research Projects

B Collection of Agricultural Meteorological Information for Optimal Crop Cultivation

- Conducting cultivation experiments and additional soil analysis for various crops such as peanuts, corn, and tomatoes, to determine optimal growing conditions
- These experiments and analyses enhance the accuracy of agricultural meteorological information, laying the foundation for establishing region-specific crop cultivation strategies.

C Hosting Workshops and Official Handover of the OSCAR

- Developing a sustainable operation and effective management system for the OSCAR system through the Train of Trainers (ToT) program.
- Official handover of the OSCAR system in August 2023, supporting its autonomous management and operation.
- Conducting invitational training programs for key stakeholders in Vanuatu to educate them on the importance and usage of the OSCAR system.
- Participating in international conferences such as PMC, PICOF, and COP28 and conducting side events to enhance the global recognition of the OSCAR system, emphasizing its significance through high-level meetings with Vanuatu's Minister of Climate Change, the Director of Meteorology, and other key national entities.
- Introduction and demonstration of the OSCAR system's features and benefits in the field.

D Development of the Crop-Climate Diary (CCD)

- Development of a crop productivity estimation model using computer vision techniques, providing more accurate and efficient methods for assessing agricultural productivity.
- Construction of offline maps of Vanuatu using Super-resolution techniques, enhancing the visual representation and analysis of agricultural data and contributing to the optimization of crop production in the region.



Fig32 OSCAR Intensive Training Program Completion Ceremony: (From left to right) Mr. Igor Michel, Ms. Moirah Matou, Mr. Do-Shick Shin (Executive Director of APCC), Mr. Pakoa Leo, and Mr. John Ruben Celebrate the Successful Conclusion of the Program (July 20 2023, APCC)

2023 Research Projects



Fig33 Official Handover Ceremony of the OSCAR (August 11 2023, Vanuatu)

3) Expected Implications

- The project is expected to enable Vanuatu to respond more effectively to climate change and enhance its climate resilience Strengthening climate information services in various sectors to promote the resilient development of local communities and lay the foundation for a sustainable future
- APCC's participation in the GCF project elevates the international role and contribution of domestic research institutions
- The agricultural climate information service is expected to enhance decision-making support in agriculture, leading to improved agricultural productivity and sustainability

2-2. Project Initiated by the UN Environment Program (UNEP)

Project 8 Enhancing Climate Information and Knowledge Services for Resilience In 5 Island Countries of the Pacific Ocean

Dr. Jinho Yoo jhyoo@apcc21.org

1) Background and Relevance

- The value of climate prediction and services are enormous for the 5 Pacific countries, the most vulnerable to the climate change and extreme climate events.
- We support enhancing climate services in the 5 Pacific Island countries through improving climate prediction system for the Pacific Islands and enhancing capacity for climate prediction of national hydrological and meteorological services (NHMSs)

2023 Research Projects

2) Main Results

- A Improving climate prediction system for the Pacific islands (PICASO) for the 5 countries**
- Renovating predictors for seasonal rainfall using recent relationships and collection of global climate models in APCC Multi Model Ensemble.
 - Considering recent climate variability and characteristics of climate models, 40% of seasonal rainfall predictor has been replaced.
 - Predictor selection for the monthly rainfall.
 - A total of 60% of monthly rainfall predictors have been identified and remainders will be completed in 2024.
- B Supporting the capacity building in climate prediction**
- Conducting 2 face to face trainings and 1 visiting program
 - The joint Regional Training Workshop in February (Fiji) and December (Cook Islands) for understanding the new feature of climate prediction tool and its use. A total of 33 NHMS staff participated.
 - The Young Scientist Support Program (YSSP) was held in October. A total of 4 NHMSs staff from Cook Islands, Marshall Islands, Niue, Tuvalu were invited to APCC for a month. The Participants gained skills on Climate Data Analysis using the Python programming.



Fig34 The Participants of the joint Regional Training Workshop in Cook Islands (December 2023)



Fig35 The Participants of the Young Scientist Support Program (YSSP) (October 2023, APCC Building)

3) Expected Implications

- Improving the performance of climate prediction tool by considering recent characteristics of climate variability in the Pacific.
- Enhancing climate services of the Pacific Island countries through better understanding and skills in climate data analysis and prediction.



04

APEC Climate Center



APCC Introduction

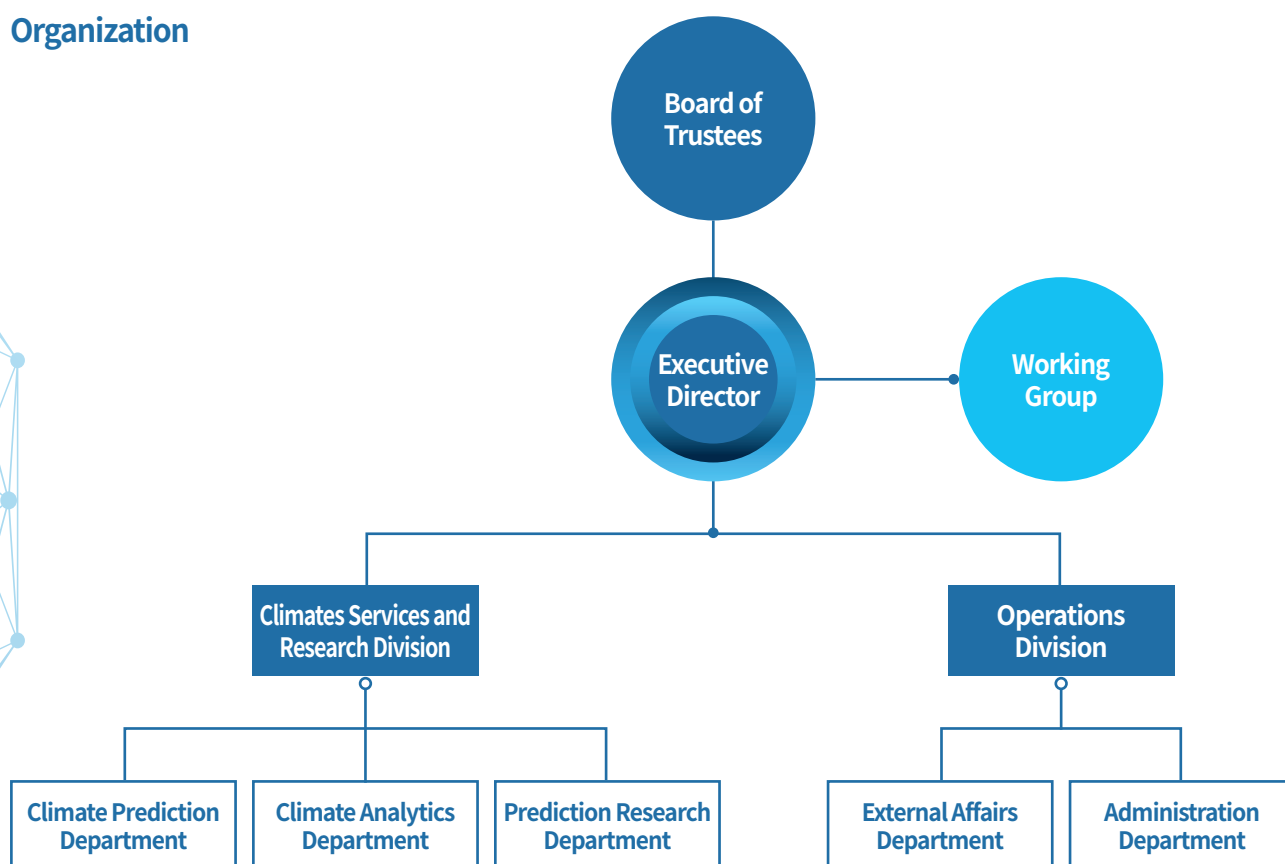
APCC Introduction



APEC Climate Center

APCC enhances the socio-economic well-being of member economies by utilizing up-to-date scientific knowledge and applying innovative climate prediction techniques.

Organization



Goal	Enhancing Climate Prediction Services through Innovative Research and Technology		
	Climate Prediction Department	Climate Analytics Department	Prediction Research Department
Goal	Operation of Climate Prediction Systems and Provision of Climate Information Services for the Asia-Pacific Region	Monitoring and Analysis of Extreme Climate and Operational Seasonal and Subseasonal Prediction	Development of Innovative Climate Prediction Techniques
Function	- Provision of timely and reliable climate prediction - Strengthening climate information services for the Asia-Pacific region	- Supporting Operational Seasonal and Subseasonal Prediction - Effective response to extreme climate events through in-depth monitoring and analysis of climate variability	- Development of multi-model based regional seasonal prediction techniques - Analysis of subseasonal variability and predictability - Development of multi-model based subseasonal prediction techniques



05

APEC Climate Center



2023 News

1.

APEC Climate Symposium
2023

The APEC Climate Center, in collaboration with the Central Weather Administration of Chinese Taipei, Chung-Hua Institution for Economic Research, International Climate Development Institute, and Taiwan Climate Service Partnership, jointly organized the APEC Climate Symposium 2023. The symposium took place from October 18 (Wednesday) to October 20 (Friday) at the International Conference Hall of the Central Weather Administration in Taipei. The event was conducted both on-site and online, with the participation of over 220 attendees from 34 countries including 14 APEC member economies.

Under the theme “Enhancing Energy Security in a Changing Climate for a Resilient Future in APEC,” the symposium featured expert presentation sessions and panel discussions addressing topics such as enhancing energy security using climate information, renewable and clean energy to adapt climate change, and policy efforts or best practices to enhance energy security. As the symposium was commenced, Mr. Do-Shick Shin, Executive Director of APCC, stated that the global temperature has soared causing unprecedented extreme climate events and highlighted the importance of understanding and appropriately utilizing climate information for the APEC region to transition towards renewable energy and a low-carbon regime.

Chia-Ping Cheng, Administrator of Central Weather Administration, shared that in 2021, CWA established the Taiwan Climate Service Partnership with six non-profit organizations to play a coordinating role in the international development of climate services. He emphasized the need for user involvement in scientific and research processes to promote climate service facilitation and called for increased awareness of climate risks through discussions and dialogues.

The keynote speech was delivered by Dr. Noboru Koshizuka, the President of the Weather Business Consortium in Japan, on the challenges and opportunities of climate services for promoting energy transition toward achieving 2050 net-zero target. Dr. Koshizuka stressed the global impact of climate change on industries and economies, highlighting the importance of global warming measurements for carbon-neutral cities and emphasized the significance of digital technology in mitigation and adaptation aspects and introduced a model for developing an optimized process for smart city development to achieve carbon neutrality.

1.

APEC Climate Symposium
2023

Following the keynote speech, three sessions covered expert presentations on topics such as enhancing energy security using climate information, renewable and clean energy to adapt climate change, and best practices or policy efforts to enhance energy security. The symposium included presentations from various stakeholders, including those from solar and wind energy companies, member economies, and regional organizations for efforts to enhance energy security.

A panel discussion focused on policy recommendations and discussions regarding energy transition and energy security in the context of climate change adaptation. Experts from organizations, such as the Institute for Energy Economics and Financial Analysis, Asia-Pacific Energy Research Centre, energy and climate consulting firms, and academic community, gathered to engage in in-depth discussions on current challenges and opportunities for enhancing energy security. The experts touched on various topics, including the socioeconomic value of renewable and clean energy, South Korea's renewable energy policies and projects, reducing vulnerabilities in energy supply and demand, the interconnection of climate science and energy security, and key issues for companies to achieve carbon neutrality.

The APEC Climate Center aims to strengthen the network of experts from relevant agencies worldwide for effective climate data utilization in socioeconomic activities through the APEC Climate Symposium. The APEC Climate Symposium is an annual event that has been held since 2005 and the symposium results are reported to the APEC community. The theme of each symposium is aligned with APEC's yearly priorities. The 2023 symposium addressed the priority of the United States, the APEC host economy, by focusing on enhancing energy security. The topic for the 2024 symposium will be selected considering the priorities of the APEC host economy, Peru. More detailed information on the presentations and discussions from the 2023 APEC Climate Symposium can be found on the APEC Climate Center's official website.

2.

APCC Working Group Meeting 2023



The APCC Working Group meeting for the year 2023 took place on October 17th, with the participation from 11-member economies. The meeting was held in a hybrid format, allowing both in-person and virtual attendance, at the conference room of the Central Weather Administration of Chinese Taipei. The APCC Working Group is a key stakeholder and major client of APCC's climate information services. The primary objective of the annual meeting is to enhance APCC's climate information services and facilitate the sharing of climate prediction and service-related issues among member economies. In 2023, the meeting received support from the Central Weather Administration of Chinese Taipei, coinciding with the APEC Climate Symposium 2023.

Chaired by Dr. Jinyoung Rhee, Director of Climate Service and Research Division at APCC, the meeting was attended by representatives from 11-member economies, namely Australia, Canada, Japan, Korea, Indonesia, Malaysia, Papua New Guinea, the Philippines, Thailand, Vietnam, and Chinese Taipei. Each member shared insights into the impacts of extreme climate phenomena, utilizing climate prediction information for response measures. Additionally, the meeting provided a platform to exchange information on how each country employs APCC's climate information and services.

Dr. Chin-Tzu Fong, Deputy Administration of the Central Weather Administration, emphasized the deepening significance of climate prediction information amid worsening extreme climate patterns and highlighted the three consecutive years of severe drought in Chinese Taipei due to recent La Niña phenomena, affecting various sectors such as agriculture and energy. Dr. Fong expressed hope for collaborative efforts in achieving sustainable development in the APEC region through multi-lateral cooperation with the APCC Working Group.

Dr. Jinyoung Rhee from APCC presented various research and project activities undertaken by APCC in the past year and shared information regarding the expansion of the APCC wildfire and haze early warning system to Malaysian region starting from October 2023. She also discussed improvements, including the expansion of the BSISO ([Boreal Summer Intraseasonal Oscillation](#)) impact anomaly zone from 40N to 50N. Director Rhee emphasized APCC's goal of developing a seamless MME prediction system and expressed the desire for bilateral and multi-lateral cooperation research from 2025 onwards and encouraged the active efforts and participation of the working group members in these initiatives.

3.

The 5th APCC MME Model Providers' Meeting



The APCC MME (Multi-Model Ensemble) Climate Prediction System, a flagship initiative of the APEC Climate Center (APCC) since its establishment, has been providing climate prediction data from 15 institutions across 11 economies worldwide. Since its beginning in 2014, APCC has been hosting the APCC MME Model Providers' Meeting biennially. During these meetings, model providers share information on data production, validation results, and improvement plans for individual models. The meetings also serve as a platform for discussing the future direction of enhancements of the APCC MME prediction system.

The 5th APCC MME Model Providers' Meeting took place over three days from August 29 (Tuesday) to August 31 (Thursday) at the APEC Climate Center. Representatives from nine institutions, namely Australian Bureau of Meteorology, the United States National Weather Service, the Hydrometeorological Center of the Russian Federation, Environment and Climate Change Canada, the Euro-Mediterranean Center on Climate Change, Japan Meteorological Agency, Central Weather Administration of Chinese Taipei, National Institute of Meteorological Sciences at Korea Meteorological Administration, and the National Institute of Agricultural Sciences in Korea. During the meeting, they shared recent improvements and future plans for the APCC MME participating models.

Also, APCC shared the status of APCC MME prediction system including its improvements and development plans and the plan for establishing S2S MME system briefly and requested participation from the members. The APCC plan for the S2S MME system was explained in-depth in a subsequent discussion session chaired by Dr. Jinyoung Rhee, Director of Climate Service and Research Division of APCC. As part of the improvement strategies for the APCC MME prediction system, APCC introduced the construction of the S2S MME prediction system based on the experiences of operating the APCC MME prediction system and S2S prediction research and network. Dr. Rhee also emphasized APCC's commitment to producing and providing seamless prediction data through the establishment of these systems, seeking opinions and approval from member institutions. Additionally, APCC requested member institutions to consider adopting a policy for the public release of individual institution data, aligning with the global trend where organizations, including World Meteorological Organization (WMO), adopt data release policies that encompass public interest as well as commercial use.

The meeting concluded with the election of the Co-Chair for the upcoming term, and Dr. Mingyue Chen from the United States National Weather Service's Climate Prediction Center was appointed as the Co-Chair for the 6th APCC MME Model Providers' Meeting.

4.

The Official Handover Ceremony of the Van-KIRAP tailOred System of Climate services for AgRiculture (OSCAR)



The APEC Climate Center (APCC) held the Official Handover Ceremony of the Van-KIRAP tailOred System of Climate services for AgRiculture (OSCAR) on 11 August 2023. The OSCAR system is a Vanuatu Customized Climate Information Services-based Decision Support System (DSS) for farmers. The Official Handover Ceremony was attended by around 50 participants, including the Vanuatu Minister of Climate Change Adaptation, and key high-ranking and working-level officials from local government related to agriculture, weather, and climate.

APCC officially transferred the OSCAR to the Vanuatu Meteorology and Geo-Hazards Department (VMGD), laying the foundation for the sustainable provision and operation of climate services in Vanuatu. Based on this, APCC will promote follow-up projects to steadily strengthen the field utilization of the OSCAR.

5.

The Joint Regional Training Workshop Held by APCC and UNEP

The APCC and UNEP co-hosted a Joint Regional Training Workshop on “Strengthening Climate Information Services and Multi-hazard Early Warning System (MHEWS) for Anticipatory Action from Prediction to Early Action” from December 4–8, 2023.

The 5 Pacific Island Countries targeted through this program are the Cook Islands, Niue, Palau, the Republic of the Marshall Islands (RMI), and Tuvalu.

The workshop was held as part of the UNEP CIS-Pac5 (GCF FP147) Project activities, “Enhancing Climate Information and Knowledge Services for Resilience in 5 Island Countries of the Pacific Ocean”. APCC is participating in this program as one of the technical partners.

APCC, to enhance climate resilience in the Pacific through improved climate prediction services, provided lectures on understanding climate information and hands-on sessions on utilizing the Pacific Island Countries Advanced Seasonal Outlook (PICASO) System.

6.

APCC Shared Its Experiences and Accomplishments in Response to Climate Change in Vanuatu's Agricultural Sector at the COP28 Conference



Four delegates from the APEC Climate Center (APCC), including Mr. Do-Shick Shin, the Executive Director, and Dr. Jong Ahn Chun, a Research Fellow, attended the COP28 Conference in Dubai, UAE, from December 4th to 10th, 2023. They were invited by the Secretariat of the Pacific Regional Environment Programme (SPREP) to participate in response to climate change initiatives in the Pacific Islands.

At the COP28 Conference, a side event titled “Harnessing Climate Information Services: The Success Story of the OSCAR System and Agromet Bulletins” took place at the Moana Blue Pacific Pavilion on December 8th, 2023. Mr. Do-Shick Shin opened the event with a keynote speech, followed by Dr. Jong Ahn Chun, who highlighted the tailored System of Climate Services for Agriculture (OSCAR), developed by APCC in the Green Climate Fund (GCF)-supported project. This system has been successfully implemented in Vanuatu in collaboration with the Vanuatu Meteorology & Geo-Hazards Department (VMGD) and the Department of Agriculture and Rural Development (DARD).

Additionally, Mr. Do-Shick Shin engaged in a high-level meeting with the SPREP's Director General and senior officials from Pacific Island Countries. The discussion focused on identifying follow-up projects in climate information services, leveraging the success of the OSCAR.

7.

APCC Held 2023 Young Scientist Program for Pacific Islands Countries



The APEC Climate Center (APCC) held a specialized 4-week training course titled “2023 Young Scientist Support Program”, from the 4th–31st of October. APCC invited four Meteorology Service Officers from four Pacific Islands countries: The Republic of Marshall Islands, the Cook Islands, Niue, and Tuvalu.

The program, funded by the UNEP CIS Pac-5 project, consisted of courses focusing on cultivating climate data analysis skills of the officers to enhance climate resilience in the Pacific region.

APCC will continue its efforts to respond to climate change through similar programs.



8.

APCC Participated in the Joint Regional Training Workshop for ROK PI Clips and GCF-UNEP FP 147 Project



Meteorological Services from around the Pacific have gathered in Nadi, Fiji for the Joint Regional Training for the Republic of Korea-Pacific Islands Climate Prediction Services Project ([ROK PI CLIPS](#)) Phase 2 and GCF- UNEP FP147 Project, from 28 February to 2 March 2023.

The workshop is co-hosted by the Fiji Meteorological Services, Secretariat of the Pacific Regional Environment Program ([SPREP](#)), Pohang University of Science Technology ([POSTECH](#)) through the support of ROK PI CLIPS Project Phase 2 and the APEC Climate Center ([APCC](#)) through the UNEP CIS-Pac5 Project ([GCF FP147](#)). The workshop was attended by 20 National Meteorological and Hydrological Services ([NMHS](#)) officers, from 14 countries around the Pacific.

Lectures on tropical climates and climate information as well as hands-on exercises were provided during the workshop. Extended functions of PICASO were also introduced, and the NHMS staff could produce a climate outlook using PICASO on the last day of the workshop.

9.

APCC Hosted the 4th Climate Prediction Workshop in 2023



The APEC Climate Center hosted the “4th APCC Climate Prediction Workshop” on June 26 and 27, 2023 with the theme of “Status of Anomalous Climate Prediction Technology and its Utilization”. The workshop, attended by approximately 150 participants from academia, research institutes, and other relevant organizations in Korea, took place at BEXCO in Haeundae, Busan. During the workshop, 4 expert presentation sessions and panel discussions were facilitated.

Since 2020, the APEC Climate Center has been actively contributing to the development and achievements of domestic climate prediction technology by regularly organizing climate prediction workshops. The 4th APCC Climate Prediction Workshop held this year aimed to enhance understanding of recent characteristics of extreme climates related to climate change. Additionally, by addressing the current status and prospects of extreme climate prediction technology development, including new technologies, it also aimed to lead research in the development of extreme climate prediction technology and elevate the value of prediction information through discussions on sector-specific applicability of extreme climate prediction information and crisis management strategies related to natural disasters.

Immediately following the workshop, a special session organized by the Korea Meteorological Administration was held to commemorate the release of the IPCC Sixth Assessment Report. During this session, key findings from the leadership team of the 6th IPCC were shared, providing insights into the latest trends and results in international climate science.

Table the Contents of the 4th Climate Prediction Workshop in 2023

Event	Session Theme
Keynote Speech	Value of Extreme Climate Prediction Information in the era of Climate Crisis
Session 1	Recent Monitoring and Analysis of Extreme Climate Worldwide and in Korea
Session 2	Development and Utilization of Extreme Climate Prediction Technology
Session 3	Utilization of Extreme Climate Prediction Information in Sectors
Panel Discussion	Value and Expansion of the Utilization of Extreme Climate Prediction Information

9.

APCC Hosted the 4th Climate Prediction Workshop in 2023

The keynote session of the 4th Climate Prediction Workshop centered around the theme of **the value of extreme climate prediction information in the era of climate crisis**. Dr. Cho Chun-ho, the former Director General of the National Institute of Meteorological Sciences, and Dr. Nam Jae-jak, the Director of the Korea Precision Agriculture Institute, delivered keynote presentations. In his keynote speech, Dr. Cho emphasized that the Earth has reached a critical threshold due to an increase in greenhouse gases resulting from human activities and highlighted the risks not only in climate change but also in various aspects such as biodiversity, new substances, land-use changes, and food security. Director Nam conveyed that proactive responses in sectors like agriculture and industry could sufficiently address climate change mitigation and adaptation possibilities and emphasized that detailed climate information in the context of climate crisis could be utilized in the restructuring of the food industry, the design of agricultural disaster insurance, estimation of global agricultural production changes, and formulation of food security policies. He underscored the importance of providing crucial information for these areas. Moreover, he stressed the importance of urging public attention and encouraging societal changes conveying a positive message about these possibilities.

Session 1, titled **“Recent Monitoring and Analysis of Extreme Climate Worldwide and in Korea”**, consisted of five expert presentations focusing on the status and impacts of extreme climate occurrences globally and on the Korean Peninsula. The presentations also covered observational-based analysis of extreme climate characteristics and their causes, as well as the analysis of extreme climate characteristics related to climate change. Dr. Kim Suntae, Research Fellow of Climate Analytics Department in APCC, introduced the global climate in 2022, highlighting severe extreme climates such as the European heatwave and record-breaking rainfall in Pakistan. Mr. Hwang Ho-seong from the Korea Meteorological Administration, presented the extreme climate events and characteristics in South Korea for 2022, noting the severe drought in the southern part and the significant threat posed by the powerful typhoon Heenamho.

The second session focused on **the development and utilization of anomalous climate prediction technology**. Five expert presentations covered topics such as extreme climate prediction technology utilizing climate models and statistical methods, integration of multiple prediction information, AI-based extreme climate prediction technology, and the development and application of early detection technology for extreme climates. The presentations discussed the development status of extreme climate prediction technology using new technologies, such as deep learning and artificial intelligence, limitations and applicable scope of applying deep learning technology in climate prediction, and research cases for establishing a climate service system for flood and drought on a seasonal scale.

Session 3, titled **“Utilization of Extreme Climate Prediction Information in Specific Sectors”**, featured three presentations from relevant agencies on the applicability of extreme climate prediction information in agriculture, water resources, and fisheries, as well as crisis management approaches for sector-specific weather-related disasters. The presentations covered flood prediction technology development and utilization for adapting to natural disasters by the National Disaster Management Research Institute, customized early warning services for weather risk management in agriculture by the National Institute of Agricultural Sciences, and the impact of climate change-induced abnormal sea temperatures on the fisheries industry and the establishment of monitoring and prediction infrastructure by the National Institute of Fisheries Science.

9.

APCC Hosted the 4th Climate Prediction Workshop in 2023

In the final panel discussion of the workshop, six experts from relevant agencies discussed the value and expansion of the utilization of extreme climate prediction information. Dr. Jinyoung Rhee, the Head of the Climate Services and Research Division at the APEC Climate Center, delivered a keynote presentation on the necessity and key elements of climate crisis and extreme climate prediction technology development. Key elements proposed for extreme climate prediction included seamless climate prediction information, region-specific monitoring and prediction of extreme climates, application technologies for sector-specific extreme climate prediction information, and the development of a system for providing extreme climate prediction information.

The panel of experts emphasized that macroscopic and microscopic/event-based aspects of extreme climate prediction must be considered together and suggested the advancement of prediction system technology, improvement of the extreme climate monitoring system, enhanced understanding of extreme climate phenomena, and the development of prediction techniques using AI. While the incidents of extreme events are increasing due to climate change, the intensity varies regionally, and understanding the impact of natural variability is crucial. The panel stressed that systematic improvement of predictability and enhancement of utilization of prediction information should be driven by institutions, highlighted the low utilization and understanding of climate information in disaster management at the local government level, emphasized the importance of connecting service providers with users, and agreed that close communication and collaboration with relevant agencies are essential from the development stage to increase the utility of prediction information.

The APEC Climate Center aims to contribute to the development of climate prediction by annually sharing the latest research results and expert knowledge on climate prediction through the Climate Prediction Workshop, fostering in-depth discussions on the direction of climate prediction technology development.

10.

Busan Climate Change Consortium Seminar in 2023

Since 2021, the APEC Climate Center, in collaboration with Busan Metropolitan City, Busan Regional Meteorological Administration, and Busan Research Institute, has formed the Busan Climate Change Consortium. This initiative aims to foster collaboration between public, private, and academic entities in Busan to share climate change science and policies, jointly address Busan's efforts towards net zero by 2050, and tackle climate change issues in the region. As part of its joint efforts, the Busan Climate Change Consortium, aligned with the World Climate Industry Expo 2023, organized a seminar on May 26 at BEXCO, located in Haundae-gu, Busan.

The seminar, attended by a total of 115 participants, including industry representatives, academia, and stakeholders from the consortium member organizations, focused on the climate crisis and industry responses. The event featured a keynote speech regarding the scientific significance of recent climate change based on the 6th IPCC Assessment Report and its impact on industries, practical cases of carbon capture and storage technology, rural responses to the climate crisis, and the outlook for the maritime industry in achieving carbon neutrality.

11.

APCC Hosted the 2023 APCC Climate Information Service User Workshop

The 2023 Climate Information Service User Workshop was hosted on July 12–14, 2023. APCC has been hosting this workshop since 2017 to expand the usability of climate information services produced and provided by the APCC and to strengthen its domestic contribution. A total of 15 university and graduate students majoring in climate-related department participated in this workshop that featured theoretical lectures on climate prediction, climate change and its analysis, and comprehensive practice using the APCC Climate Information Tool Kit ([CLIK](#)). APEC Climate Center will continue to host user-participatory programs to secure new users and provide better services to meet their demand.

12.

A Parliamentary Seminar on Climate Prediction and Response Utilizing AI Technology

On July 18, 2023, Mr. Do-Shick Shin, Executive Director of the APEC Climate Center, participated in a seminar on Utilizing AI Technology for Climate Prediction and Response, held at the National Assembly. Executive Director Do-Shick Shin addressed the increasing risks of unprecedented extreme climate phenomena globally and discussed the effective utilization of climate prediction data to address these challenges with the theme 'Disseminating the Value of Climate Prediction Information for Future Society'. The event was co-hosted by Representative Lee Joohwan and Representative Hong Sukjoon. Attendees included policymakers, relevant government officials, experts from affiliated agencies, and stakeholders, totaling approximately 40 participants. The seminar aimed to assess the status of climate prediction and AI technology, examining ways to enhance the production of better climate prediction information and improve technological capabilities to respond to abnormal climate conditions.

13.

APCC Held a Policy Meeting Related to the Climate Issues of the Busan Region by Inviting a Member of the National Assembly

APCC held a policy meeting related to the climate issues of the Busan region by inviting Mr. Lee Joohwan, a member of the National Assembly in Korea at the APCC building on March 31, 2023.

The extreme climate caused by recent climate change may lead to urban flooding and other natural disasters. At the policy meeting, the severity of damage to local industries and citizens due to heat waves and tropical nights was shared. The participants of the policy meeting discussed future cooperation plans among the National Assembly, Korean Meteorological Administration (KMA), and APCC to strengthen climate crisis response capabilities with the goal of disaster prevention and damage reduction in local communities.

14.

Parliamentary Debate on Achieving Net-Zero in the Agricultural Sector, 2023

To share the status of carbon net zero implementation strategies in the agricultural sector and discuss effective ways to achieve the goals, a parliamentary debate was held on March 16 at the National Assembly Hall. The event was hosted by Representative Jung Hee-yong from the Agriculture, Food, Rural Affairs, Oceans and Fisheries Committee, organized by the Ministry of Agriculture, Food, and Rural Affairs, and supported by the APEC Climate Center and Greenlabs. Representatives Jung Hee-yong and Song Eon-seok attended the opening ceremony. The debate, chaired by President Kim Chang-gil of the Korea Rural Economic Institute, featured discussions from Kim Chan-ho, CEO of Greenlabs Financial; Lee Gil-jae, Head of the Climate Change Response Team at the Korea Agriculture Technology Promotion Agency; Lee Yoo-kyung, Researcher at the National Institute of Animal Science; Jung Hak-gyun, Senior Research Fellow at the Korea Rural Economic Institute; and Kim Gyu-ho, Legislative Researcher at the National Assembly Research Service. The participants engaged in a lively discussion on policy directions concerning the implementation status of carbon neutrality in the agricultural sector and government measures in line with the national greenhouse gas reduction goals set by the 2030 Nationally Determined Contributions (NDC).

15.

APCC-Seoul National University Asia Center Signs Memorandum of Understanding

On May 12th, 2023, the APEC Climate Center (APCC) and Seoul National University Asia Center signed a memorandum of understanding (MOU) at the APEC Climate Center. The purpose of this collaboration is to maximize the utilization of climate information for climate change response and sustainable development in the Asian region, including South Korea. Mr. Do-Shick Shin, Executive Director of APCC represented APCC, and Director Park Soo-Jin represented Seoul National University Asia Center during the signing of the MOU.

The collaboration is expected to encompass joint efforts in various areas, such as utilizing climate analysis and prediction information for food security through agriculture and water resource management, cooperation on projects related to water resource security and carbon reduction, and collaborative initiatives in monitoring a healthy and sustainable ecological-social system and responding to climate change, both domestically and internationally.

16.

APCC-Korea Power Exchange Signs Memorandum of Understanding

On June 14, 2023, the APEC Climate Center (APCC) and Korea Power Exchange signed an MOU at the Korea Power Exchange located in the city of Naju. The MOU aims to strengthen cooperation in recognizing the significant impact of climate information on the stable production and supply management of national essential industries, particularly in the field of electricity generation. The ceremony was attended by the heads of both organizations. Through this agreement, both parties commit to enhancing collaboration in utilizing climate prediction information for energy security responses, exchanging climate change-related information domestically and internationally, and jointly promoting projects in these areas.

17.

APCC-Japan National Agriculture and Food Research Organization (NARO) Signs Agreement for Operational Collaboration Based on Joint Research

Since 2017, the APEC Climate Center (APCC) and the Institute for Agro-Environmental Science, a part of Japan's National Agriculture and Food Research Organization (NARO), have been engaged in joint research focused on developing a model for predicting global crop yield variations based on seasonal forecasts and establishing an information service system for predicting crop yields. Utilizing the system developed through this collaborative research, APCC plans to provide predictive information on crop yield variations for major crops in each country 3 months before harvest.

To facilitate the operational aspects of the jointly developed system, APCC and NARO have formalized their commitment to operational collaboration through a written agreement. This agreement is effective from April 2023 to December 2027.

06

APEC Climate Center

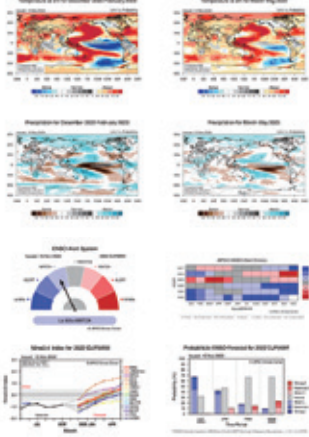
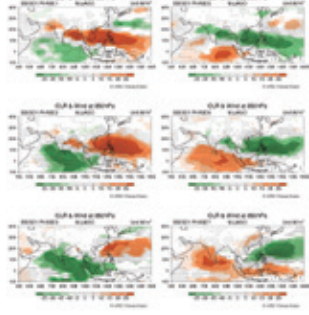
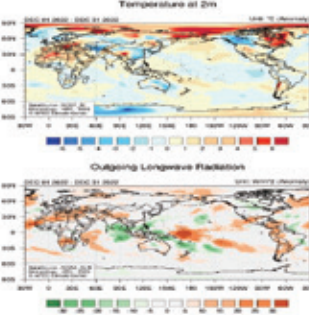
The background is a composite image. The top half shows a starry night sky with a gradient from dark purple to deep blue. The bottom half shows a sunset over the ocean, with a bright orange and red sky reflecting on the water. A large, semi-transparent blue circle is overlaid on the right side of the image, partially covering the starry sky and the sunset. The word "APPENDIX" is written in white, bold, sans-serif capital letters across the middle of the circle.

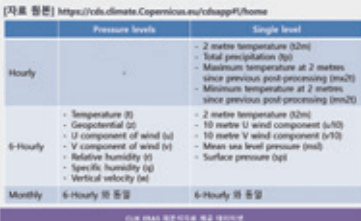
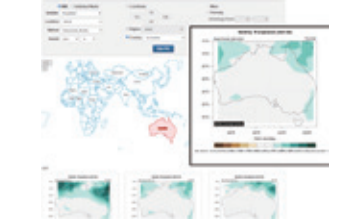
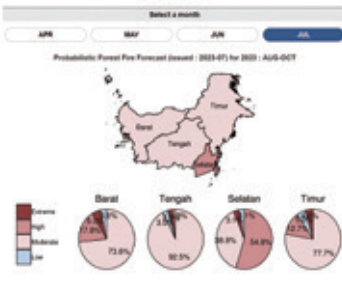
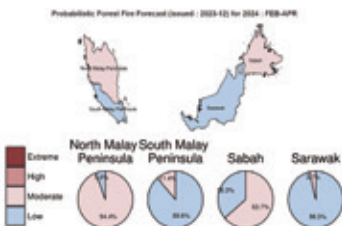
APPENDIX

APPENDIX 1.

APCC Climate Information Services

APCC (www.apcc21.org) provides 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 around the world. https://apcc21.org/ser/global/outlookSummary.do?lang=en
	BSISO (Boreal Summer Intraseasonal Oscillation) Forecast		The BSISO is the one of the dominant phenomena over the Asian summer monsoon region. The BSISO monitoring index for 15 to 60 days is provided through APCC homepage in real time. https://apcc21.org/ser/meth.do?lang=ko
	Climate Monitoring		APCC presents information on major climate variables, including droughts, floods, and atmospheric circulation, which can affect people's daily lives. https://apcc21.org/ser/high.do?lang=en

Services	Function	Screen	Contents
Customized Climate Information Service	APCC Climate Services Platform (CLIK: CLimate Information toolkit) https://cliiks.apcc21.org 	Provision  Production  Processing 	APCC Climate Services Platform provides climate information services by which users can effectively utilize various climate data. • Provision Service: A platform-based climate data service that allows for the downloading of APCC climate data in various formats. • 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 Service: A service that allows for the extraction of values of climate variables in users. — desired areas or periods from a large amount of climate data in a variety of data formats.
	SEA Fire and Haze Early Warning System (FHEWS) - Indonesia SEA Fire and Haze Early Warning System (FHEWS) - Malaysia	 	which translates 6-month precipitation data into four fire danger ratings based on the relationship between the precipitation amount and CO₂ emissions. These data will be utilized to prevent dangerous forest fires and haze. 1. Indonesia https://www.apcc21.org/prediction/fhewsid?lang=en 2. Malaysia https://www.apcc21.org/prediction/fhewsm?lang=en

APPENDIX 2.

APCC Multi-Model Ensemble Participating Model

1) ECCC

Environment and Climate Change
Canada

2) HMC

Hydrometeorological Centre of Rus-
sia

3) JMA

Japan Meteorological Agency

4) KMA

Korea Meteorological Administration

The APCC disseminates high-quality climate forecast information based on the MME on the 15th of every month. Currently, 15 operational institutes from 11 countries participate in the APCC MME. Real-time forecasts by APCC MME are provided on the APCC homepage every month (<https://www.apcc21.org>).

Improvements in the APCC MME Prediction and Monitoring Information

APCC redesigned its Seasonal Climate Outlook which provides more improved structure and format for users to better understand the contents. The prominent change is applied in the structure of the outlook; while the previous outlook provided text descriptions and images separately, in the new version of APCC climate outlook, images and text descriptions are put together for users to read and understand the contents without any interruptions, such as turning pages. Especially, this revamp focused on the better readability and visibility of descriptions on the MME probabilistic forecast. The colors of temperature and precipitation probability categories are reflected in the texts as well as image of climate forecasts so that the users can easily distinguish different probabilities and impacts in the affected areas. The first renewed outlook was rolled out on November 15, 2023.

APCC launched the renewed APCC website in February 2024. All web pages will be refreshed using the latest web service technology and new design. We will also apply dynamic web contents for MME and individual model forecasts, climate monitoring, and climate indices.

Improvement of Participating Models of APCC MME

In 2022, four models from ECCC¹⁾, HMC²⁾, JMA³⁾, and KMA⁴⁾ were upgraded. These models were successfully applied to MME after some evaluation and enhanced the MME's forecast performance.



<APCC Multi-Model Ensemble Participating Model>

APPENDIX 3.

Boreal Summer IntraSeasonal Oscillation (BSISO)

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

The APCC produces Boreal Summer IntraSeasonal Oscillation (BSISO) monitoring and forecast information daily from May to October. BSISO represents a large circulation system, generated in the tropical Indian Ocean, with prominent gradual northward propagation and affects the Asian summer monsoon, atmospheric circulation, and weather and has a 15–60-day period. BSISO consists of two modes, namely BSISO1, which represents the canonical northward propagating variability with a 30–60-day period, and BSISO2, which corresponds to the northward/northwest propagating variability, with a period of 10–30 days. Each BSISO is classified into eight phases with primary convection cell location. Currently, APCC operates BSISO with five models from four institutes, namely NCEP¹⁾, ECMWF²⁾, CWA³⁾, and BOM⁴⁾.

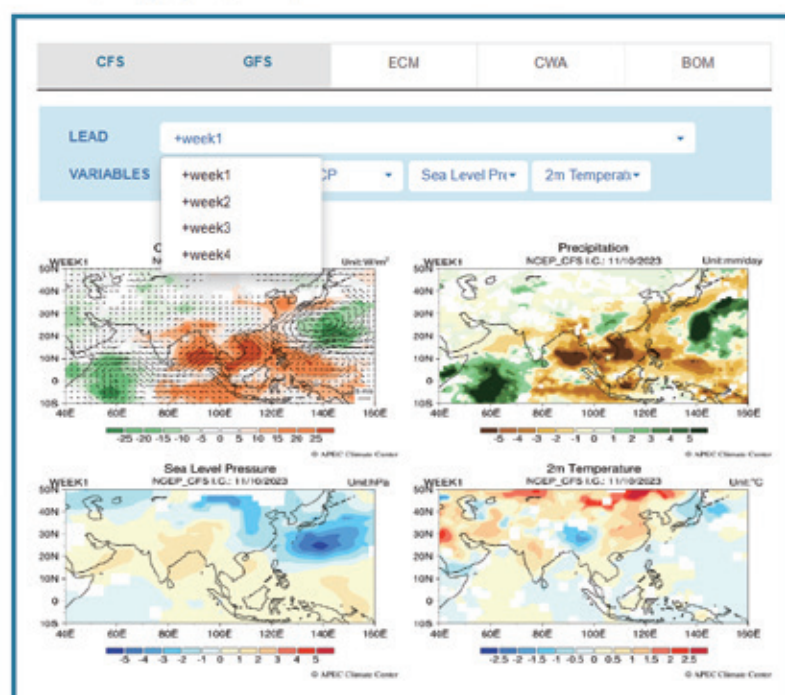
In 2022 APCC changed the climatological base period from 1981–2010 to 1991–2020 for all BSISO contents, including monitoring, forecast, and impact fields to follow the WMO recommendation to use the most recent 30-year period as the climatological standard normal. The graphics on the BSISO website were also reformatted to increase readability and visibility.

In 2023, APCC started to provide BSISO impact anomaly for up to four weeks and expand its area to 50 degrees north with the expectation that this information will help users who seek medium-range forecasts in the Asian monsoon region. The NOAA Outgoing Longwave Radiation (OLR) data, input data of the APCC BSISO monitoring index, have no longer been provided since September 17, 2023. Therefore, APCC intends to change the input OLR data from next year. The OLR input data will be changed from NOAA to CPC blended data, and the BSISO service will commence in May of next year after reorganizing the system.

• BSISO Impact Anomaly

TGP

The BSISO impact anomaly shows the expected local impacts of the BSISO activity over the Asian monsoon region in 1-3 weeks. This is the reconstructed field based on composite of the historical BSISO index (1991-2020) for various variables such as temperature, precipitation, wind field, and other relevant variables.



<Example of APCC BSISO forecast impact anomaly on the website>

APPENDIX 4.

Research Papers

1. OkYeon Kim, Chang-Mook Lim, 16 June 2023

Predictability of the Western North Pacific Subtropical High and associated East Asian monsoon rainfall in APCC Multi-modal, JGR Atmospheres Volume 128 Issue 13, <https://doi.org/10.1029/2023JD038476>

2. Suryun Ham, Yeomin Jeong, Jin Ho Yoo, Somin Lim, Heesook Ji & Yu-Kyung Hyun, 30 October 2023

What is the effect of atmospheric initial condition inconsistency between the hindcasts and real-time forecasts?, Climate Dynamics, Online First, <https://doi.org/10.1007/s00382-023-06972-8>

3. Imgook Jung, Syewoon Hwang, Jaepil Cho, 30 January 2023

Comparative Evaluation of Reproducibility for Spatio-temporal Rainfall Distribution Downscaled Using Different Statistical Methods, Journal of The Korean Society of Agricultural Engineers Volume 65 Issue 1, PP. 1-13, <https://doi.org/10.5389/KSAE.2023.65.1.001>

4. Seon Tae Kim, Woo-Seop Lee, Il-Won Jung, Jeong-Min Han, Young-Hwa Byun, Jin-Uk Kim, 14 Apr 2023

Change in Extreme Precipitation by Watersheds of South Korea Under Future Shared Socio-Economic Pathway (SSP) Scenarios, Journal of Climate Change Research 2-23, Volume 14, No. 2, PP.83-93 (11 pages), <https://doi.org/10.15531/KSCCR.2023.14.2.083>

5. Uran Chung, Jinyoung Rhee, Miae Kim, Soo-Jin Sohn, 30 June 2023

Investigating Data Preprocessing Algorithms of a Deep Learning Postprocessing Model for the Improvement of Sub-Seasonal to Seasonal Climate Predictions, Korean Journal of Agricultural and Forest Meteorology, Volume 25 Issue 2, PP. 80-98, <https://doi.org/10.5532/KJAFM.2023.25.2.80>



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