

## 특별세션 1 / English Session 2-1

# Spatiotemporal Characteristics of Mega Asian Dust Events over the Korean Peninsula

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Mega Asian dust events ( $PM_{10} \geq 800 \mu\text{g}/\text{m}^3$ ) represent a significant meteorological hazard to the Korean Peninsula. Conventional alerts, predicated on concentration thresholds alone, inadequately capture diverse threat profiles such as propagation velocity and spatial extent. This study classifies these events based on their spatiotemporal structure to define the unique characteristics of each pattern. A geostatistical spatiotemporal analysis was applied to KMA  $PM_{10}$  data (2002–2023) to classify events into patterns with homogeneous characteristics. The properties of each pattern were then defined by quantifying its spatial clustering (Moran's I, General G) and spatiotemporal scale (e-folding time/distance). The analysis revealed five distinct patterns. For instance, Pattern 5 exhibited the highest peak concentration ( $2586 \mu\text{g}/\text{m}^3$ ) and longest duration (23 hours) but evolved rapidly, forming simultaneous high-concentration clusters in the southern inland and eastern coastal regions. In contrast, Pattern 4 had a widespread (e-folding distance: 58.2 km) and gradual influence, while Pattern 2 was highly localized. Our findings demonstrate that mega dust events are not monolithic but occur in distinct, recurrent patterns. The quantitative metrics for each pattern provide a scientific basis for advancing beyond the current uniform alerts. This facilitates the development of tailored forecasting systems designed for specific threat profiles, such as the 'localized and sudden' threat of Pattern 2 or the 'widespread and persistent' threat of Pattern 4.

**Keywords:** Mega Asian Dust Events, Spatial autocorrelation, Moran's I, General G, e-folding distance

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## 특별세션 1 / English Session 2-2

## Impacts of cool roofs on urban heat island and air quality in Dhaka, Bangladesh: A case modeling study during a heat wave

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This study investigates the impacts of cool roofs on the urban heat island (UHI) and air quality in Dhaka, Bangladesh during an extreme heat wave event occurring in April 2021. A simulation with conventional roofs having an albedo of 0.2 and a simulation with cool roofs having an albedo of 0.8 are conducted using the Weather Research and Forecasting (WRF) model. Cool roofs reduce the 2-m temperature by 0.57 °C in the afternoon (1200–1700 LST) and cause the urban cool island in the daytime. In the afternoon, cool roofs reduce the planetary boundary layer height by 265 m and greatly suppress the urban breeze, reducing the 10-m wind speed by 0.8 m s<sup>-1</sup>. As a result, the near-surface passive tracer (carbon monoxide) concentration increases by 45 ppb (52%) in the afternoon. Cool-roof effects on the UHI and air quality are overall more pronounced in hotter areas. Cool roofs lead to statistically significant decreases in Humidex (–0.19), discomfort index (0.22 °C), and heat index (–0.36 °C) in the afternoon, but all indices remain within the same stress levels. This suggests that additional measures such as urban greenery and other climate-sensitive urban designs are required along with cool roofs for an effective mitigation of urban extreme heat in Dhaka.

**Keywords:** Cool Roof, Urban Heat Island, Air Quality, Urban Breeze, Dhaka

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특별세션 1 / English Session 2-3

## A case study of heavy snowfall on the east coast of South Korea associated with Polar–Low–induced CAD

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During the winter season, the east coast of South Korea occasionally experiences heavy snowfall associated with cold air damming (CAD) events induced by polar lows. This study presents a detailed case analysis of such an event, which was occurred in March 16~17th in 2024, focusing on the meteorological mechanisms, observed precipitation patterns, and regional impacts. Using data from surface observation stations, vertical weather data, and radar measurements, the evolution of the polar low and its interaction with the regional topography were examined. The results indicate that the polar low intensified the cold air mass over the Korean Peninsula, enhancing the lee-side CAD effect along the eastern slopes of the Taebaek Mountains and East sea. Consequently, the Yeongdong region received significantly higher snowfall compared to adjacent areas, while windward regions experienced comparatively lighter precipitation. Temporal analysis showed that the peak snowfall coincided with the strongest northeasterly flow, confirming the role of CAD in modulating precipitation distribution. This case study highlights the importance of understanding polar-low –induced CAD dynamics for operational weather forecasting and disaster preparedness. The findings provide valuable insight into the mechanisms controlling heavy snowfall events along South Korea’s east coast and contribute to improving predictive capabilities for similar future events.

**Keywords:** East Coast, CAD, snowfall

## 특별세션 1 / English Session 2-4

## Synoptic systems and domain size influence the effectiveness of spectral nudging in simulations of extreme precipitation

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Spectral nudging (SN) is an effective method of preventing drift from large-scale background conditions in regional climate models by retaining circulations with the wavelengths longer than a specified threshold. Quantifying the effects of SN on extreme precipitation simulations can contribute to improving model performance and mitigating associated impacts. In this study, we conducted sensitivity experiments to assess how synoptic characteristics and domain size influence the effectiveness of SN in simulating extreme precipitation events. The Weather Research and Forecasting (WRF) model version 4.4 was employed at a convection-permitting simulation. Three extreme precipitation events that occurred over South Korea during the warm season and involved transient extratropical cyclones were selected for analysis. Results show that the application of SN improves simulation performance by maintaining large-scale background conditions consistent with observations. However, the degree of improvement varies depending on the synoptic characteristics and domain configuration. Specifically, the effect of SN is more pronounced in cases dominated by upper-level troughs and strong baroclinicity, compared with cases in which surface processes played a more significant role. Additionally, when the horizontal scale of the dominant wave systems is sufficiently resolved within the domain, the effectiveness of SN become more evident. Based on these findings, we suggest that applying SN to domains approximately 3,000 km wide in the zonal direction is an effective configuration for simulating extreme precipitation over South Korea. This study highlights the importance of considering both synoptic-scale characteristics and domain size when applying SN in regional climate simulations of extreme precipitation.

**Keywords:** Kilometer-scale modeling; Spectral nudging; Extreme precipitation

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## 특별세션 1 / English Session 2-5

# Disentangling the contributions of cloud microphysical properties on regional precipitation with explainable machine learning

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Cloud-to-precipitation transition involves complex microphysical and dynamic interactions among cloud particles. However, understanding of this process remains limited due to the scarcity of direct observational data and the challenges in identifying statistically significant precipitation-inducing factors. In this study, we used machine learning that can estimate daytime precipitation for the East Asian mid-latitude and tropical warm pool regions in 2023 using geostationary satellite data, and analyzed the relative contributions of the input variable using SHAP (SHapley Additive exPlanations). Results show that the relative contributions are related to regional cloud dynamics. Ice water path and the reflectance differences between the visible (0.47–0.64  $\mu\text{m}$ ) and near-infrared (1.6  $\mu\text{m}$ ) channels (indicating cloud phase and particle size) were relatively important for the East Asian mid-latitude light-to-moderate rain (0.5–10 mm/h), while the near-infrared channel (1.37  $\mu\text{m}$ ) and the brightness temperature difference between 6.2  $\mu\text{m}$  and 9.6  $\mu\text{m}$  (indicating the upper-tropospheric humidity) for the East Asian mid-latitude heavy rain (over 10 mm/h). In the tropical warm pool region, the ice water path was the most dominant variable for light-to-moderate rain followed by cloud optical thickness, while the visible channel differences with the near-infrared channel (0.86  $\mu\text{m}$ ) (indicating clouds presence) for estimation of heavy rain. These results demonstrate that the optimal cloud properties and environmental predictors for satellite-based precipitation retrieval vary by regions and intensities.

**Keywords:** Precipitation, Cloud microphysics, Geostationary Satellite, Machine Learning

## 특별세션 1 / English Session 2-6

# Regionalization of Hydrological Model Parameters Using Machine Learning and Observational Big Data

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Hydrological models are essential for managing water resources, forecasting floods, and assessing climate change impacts. However, accurate parameter estimation remains a major challenge, particularly for ungauged basins where direct calibration is not feasible. To address this, parameter regionalization techniques have been developed to transfer parameters from gauged to ungauged basins.

In this study, we integrate big data and machine learning to improve parameter regionalization in the Simplified Water Balance Model (SWBM), a widely used conceptual rainfall–runoff model. Using Caravan runoff observations, we first obtain the best-performing parameters at gauged sites. Tree-based machine learning models are then trained to estimate parameters at ungauged sites by capturing relationships between site-specific climatic and hydrometeorological features and the calibrated parameters. We further apply explainable machine learning methods, including feature importance analysis and SHAP values, to identify the most influential predictors for parameter transferability.

The results demonstrate the potential of combining big data with machine learning to enhance the applicability of hydrological models in ungauged basins. By leveraging open-source datasets, the proposed approach can be readily applied to other hydrological models. Moreover, enhanced parameter regionalization ultimately leads to more reliable runoff predictions, improved water resource management, and greater climate resilience across diverse regions.

**Keywords:** Regionalization, Big Data, Simplified Water Balance Model, Machine Learning, Hydrological Modeling