Clustering-based Diagnostic Technique of Korean ensemble model forecasts for wintertime cold surge prediction

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Cold surges are major wintertime weather systems in East Asia that cause widespread socio-economic impacts, including human casualties and damage to agriculture, industry, transportation, and energy sectors. Over Korea, cold surges typically occur when the intensified Siberian High expands southward into East Asia, strengthening northerly winds and advecting cold air masses toward the Korean Peninsula. This process often results in a rapid temperature drop within one to two days. However, variations in synoptic-scale pressure patterns lead to differences in surge intensity, duration, and associated impacts. To investigate the characteristics of different cold-surge types, this study applied the K-means clustering method to classify cold surge events into four clusters. Analysis of sea level pressure (SLP) patterns showed that all clusters share a common feature: a pronounced expansion of the Siberian High into East Asia. Nevertheless, distinct large-scale circulation differences were identified among clusters over the Eurasian continent. Furthermore, a diagnostic and forecasting tool was developed using data from the Korean Integrated Model (KIM) ensemble prediction system to provide cold-surge type information. In the ensemble classification procedure, cold-surge occurrence (On/Off) was first determined based on SLP and temperature criteria. For forecasts classified as “On,” the predicted SLP patterns were compared with the four predefined cluster patterns to assign a surge type. If the predicted pattern did not match any cluster, it was categorized as “No-class.”
For the cold-surge events of 22 January 2025 and 17 February 2025, 10-day forecasts were conducted using initial conditions five days prior to onset. Results indicate that all ensemble members successfully predicted cold-surge occurrence on the actual event dates. As the surges persisted, cluster classification was also achieved. Although these events exhibited mixed characteristics across multiple clusters—resulting in less distinct cluster identification in five-day lead forecasts—the ensemble system demonstrated reasonable predictive skill, including the transition of some members to “Off” as the surges weakened.

Keywords: Korean Integrated Model (KIM), East Asian cold surges, K-means clustering, Ensemble prediction

