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Long-lead station-scale prediction of hydrological droughts in South Korea based on bivariate pattern-based downscaling

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South Korea is susceptible to spring droughts, owing to relatively scarce wintertime precipitation over the region. Capturing climatic variation in boreal winter to spring (December-May) is essential for properly predicting droughts in South Kora. The study investigates the variability and predictability of the South Korean climate during this extended season, based on observations from 60 stations locations and multi-model ensemble (MME) hindcast experiments (1983/1984-2005/2006) archived at the APEC Climate Center (APCC). Multivariate empirical orthogonal function (EOF) analysis results based on observations show that the first two leading modes of winter-to-spring precipitation and temperature variability, which together account for $\sim$ 80% of the total variance, are characterized by regional-scale anomalies covering the whole South Korean territory. The modes were also closely related some of the recurrent large-scale circulation changes in the northern hemisphere during the same season. Consistent with the above, examination of the standardized precipitation evapotranspiration index (SPEI) indicates that drought conditions in South Korea tend to be accompanied by regional-to-continental-scale circulation anomalies over East Asian to the western north Pacific. Motivated by the aforementioned findings on the spatial-temporal coherence among station-scale precipitation and temperature anomalies, a new bivariate and pattern-based downscaling method was developed. The novelty of this method is that precipitation and temperature data were first filtered using multivariate EOFs to enhance their spatial-temporal coherence, before being linked to large-scale circulation variables using canonical correlation analysis (CCA). To test its applicability and to investigate its related potential predictability, a perfect empirical model was first constructed with observed datasets as predictors. Next, a model output statistics (MOS)-typed hybrid dynamical-statistical model was developed, using product from nine one-tier climate models as inputs. Statistically downscaled MME (DMME) precipitation and temperature predictions were compared to those based on raw MME outputs. Limitation and possible causes of error of such a dynamical-statistical model, in the current framework of dynamical seasonal predictions, were also discussed. Finally, the potential of the mothed was assessed in capturing hydrological droughts in South Korea with its fidelity.