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Converging Deep Learning and Numerical Prediction for Skillful Subseasonal Soil Moisture and Flash Drought Forecasting

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Global warming is accelerating drought onset, causing more frequent flash drought events. These events occur at the subseasonal timescale in which rapid decreases in root-zone soil moisture (RZSM) increase risks of crop failure, wildfire, and heat stress globally. However, forecasting soil moisture and flash droughts at lead times beyond 2 weeks remains a significant challenge. Recently, machine learning methods with historical reanalysis data have shown improved forecast accuracy compared to state-of-the-art numerical weather prediction methods, but they can only produce skillful forecast within 10 days. Here we show that a convergence forecast model combining a deep learning approach with subseasonal retrospective forecasts (reforecast) from numerical models produces skillful subseasonal soil moisture and flash drought forecasts at lead times beyond 2 weeks. We train a deep learning architecture on combinations of reanalysis and reforecast from 2000 to 2015 and validate results during the testing period from 2018 to 2019. The subseasonal forecast skill of soil moisture of the convergence forecast model is much higher than those of current state-of-the-art numerical forecast models, deep learning bias corrected numerical forecast models, or the reanalysis-based deep learning models, which showed no skill after 2 weeks lead time. The convergence model also showed significantly improved performance for predicting flash droughts compared to the original or deep learning bias corrected numerical forecast models or reanalysis-based deep learning models. A permutation analysis indicates that reanalysis precursors and soil moisture reforecast at lead times within 2 weeks both contribute significantly to the forecast skill at longer lead times. The convergence forecast model provides accurate and efficient subseasonal soil moisture and flash drought forecasting and is promising for accurately forecasting key variables and extreme events at the subseasonal timescale.