Assessing the Role of Soil Moisture and Land Memory in Northern European Extremes Using a Coupled Large-Ensemble Prediction System

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Abstract

Rapid warming is reshaping the hydroclimate of Northern Europe, with spring and summer conditions increasingly characterised by warm, dry spells and increased risk of heatwaves and drought. Land–atmosphere feedback become critical for the onset, persistence, and intensity of extremes, yet they remain imperfectly represented in many operational climate and sub-seasonal to seasonal forecasting systems. This work presents a study using the Norwegian Climate Prediction Model (NorCPM), designed to better represent land–atmosphere interactions. It combines ensemble-based ocean data assimilation with sequential daily assimilation of ESA CCI soil moisture in a loosely coupled configuration, enabling more realistic exchanges of water and energy among land, ocean, and atmosphere. The results demonstrate the added value of incorporating coupled land-surface information into the analysis framework for better understanding and prediction of regional climate extremes. In particular, assimilating soil moisture observations enables the system to more accurately reproduce the lower bounds of soil moisture during drought conditions. This improved representation of land surface states strengthens the simulation of land–atmosphere coupling processes, thereby enhancing the model's ability to capture feedback mechanisms that can amplify heatwaves and dry spells such as the 2018 Scandinavian heatwave.