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Drought occurrence in key regions of soil moisture-atmosphere interaction in temperate Eurasia

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In an atmospheric general circulation drought-forming anomaly the nonlinear relationship between soil moisture and evapotranspiration play an important role in transitional (sub-humid and semi-dry) moisture regime. In this study the preceding soil moisture deficit was linked to the following low standardized precipitation index (SPI) indicating atmospheric drought in two major land-atmosphere coupling regions over Eurasia – Northern Eurasian Plains (NEP) and Plains and Uplands of Northeastern China (PUNEC). Spring season was under consideration as the most significant for crop development failure due to lack of moisture and the most predictable due to prolonged soil memory after major hydrological event of the year – the snowmelt. The Global Energy and Water Exchanges (GEWEX) project deliverables and Climate Prediction Center (CPC) soil moisture data were used after validation with agrometeorological station data. It was shown that May droughts in NEP and PUNEC occur after regional negative soil moisture anomaly in early spring in significantly high proportion of cases for the study period 1985-2019. The soil moisture anomaly is leading to drought when the specific circulation pattern is formed as shown by the composite analysis. Importantly, the circulation pattern is Eurasia-broad with upstream blocking ridge centered in NEP and anticyclone formation in PUNEC. Both ridge and anticyclone are persistent and characterized by low cloudiness, reduced moist static energy (also due to reduction in evapotranspiration by low soil moisture) and low large scale and convective precipitation. That is why low SPI events often co-occur in two study regions. Atmospheric models tend to agree that atmospheric processes do respond to negative anomalies in surface moisture conditions in NEP and PUNEC and positive feedback of soil drought on the atmosphere is largely responsible for enabling atmospheric aridity extremes. The reasons for the simultaneous early spring moisture deficits in two regions are to be searched in the features of winter general circulation which lead to reduced snow accumulation and/or snowmelt regime with lower than average water infiltration to the soil. European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble seasonal forecast skill was also explored. SPI skill scores in April are indicating better forecast in NEP than in PUNEC but skill decreases sharply in May in NEP while remaining high till June in PUNEC. Further prospects for improving meteorological, hydrological and agricultural drought forecasting and forecast post-processing methodology for the regions of study are discussed.

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