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Evaluation of a cosmic-ray neutron sensor network for improved land surface model prediction

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Land surface models describe biogeophysical and biogeochemical processes at the land surface, and represent the lower boundary condition of atmospheric circulation models. Their key role is the quantification of mass and energy fluxes between the land surface and the atmosphere. Predictions with land surface models are affected by many unknown parameters, uncertain meteorological forcings and incomplete process understanding. Measurement data (e.g., soil moisture) can help to improve land surface model predictions. However, soil moisture products obtained from satellite remote sensing are normally available at a very coarse resolution and give information on the upper few centimetres of the soil only. Therefore, the recently developed Cosmic Ray Neutron Sensors (CRNS) are of high interest for predictions by land surface models, because they measure neutron count intensity, which is related to integral soil moisture content at the field scale (about 20 hectares). High resolution land surface models are also able to provide solutions at the same scale. In this study, we investigated whether the assimilation of soil moisture retrievals from CRNS data measured by a network of nine CRNS located in the Rur catchment in Germany (2354 km2) can improve land surface model prediction. The assimilation of soil moisture retrievals from neutron count intensity data was used to update model states and parameters of the land surface model CLM 4.5 over a two year time period, followed by a one year evaluation period without updates. This updating was done with the local ensemble transform Kalman filter. The real world experiment tested the value of CRNS using jackknifing experiments and three different initial soil maps. During the assimilation period, soil moisture predictions generally improved, for a biased soil map from an RMSE of 0.11 cm3/cm3 in the open loop run to 0.03 cm3/cm3 while during the evaluation period soil moisture predictions improved from 0.12 cm3/cm3 to 0.06 cm3/cm3. Improved soil parameters showed also an impact on latent heat and sensible heat flux, particularly during the summer period when evapotranspiration was soil moisture limited. The main conclusion from this study is that a network of CRNS is helpful to improve soil moisture predictions with a land surface model, in spite of the fact that in this study only nine CRNS were available for a catchment of size 2354 km2.