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Development of a deep learning-based method for estimating surface soil moisture at high spatial resolution from Sentinel-1 satellite data

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Soil moisture content is an important hydrological and climatic variable with applications in a wide range of domains. The high spatial variability of soil moisture cannot be well captured from conventional point-based in-situ measurements. Remote sensing offers a feasible way to observe spatial pattern of soil moisture from regional to global scales. Microwave remote sensing has long been used to estimate Surface Soil Moisture Content (SSMC) at lower spatial resolutions (>1km), but few accurate options exist in the higher spatial resolution (<1km) domain. This study explores the capabilities of deep learning in the high-resolution domain of remotely sensed SSMC by using a Convolutional Neural Network (CNN) to estimate SSMC from Sentinel-1 acquired Synthetic Aperture Radar (SAR) imagery. The developed model incorporates additional SSMC predictors such as Normalized Difference Vegetation Index (NDVI), temperature, precipitation, and soil type to yield a more accurate estimation than traditional empirical formulas that focus solely on the conversion of backscatter signals to relative soil moisture. This also makes the developed model less sensitive to site-specific conditions and increases the model applicability outside the training domain. The model is developed and tested with in-situ soil moisture measurements in Denmark from a dense network maintained by HOBE (Danish Hydrological Observatory). The unique advantage of the developed model is its transferability across climate zones, which has been historically absent in many prior models. This would open up opportunities for high-resolution soil moisture mapping through remote sensing in areas with relatively few soil moisture gauges. A reliable high-resolution soil moisture platform at good temporal resolution would allow for more precise erosion modelling, flood forecasting, drought monitoring, and precision agriculture.