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Can we monitor groundwater head variation from space? Coupling ERS spaceborne microwave observations to groundwater dynamics

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The objective of this study is to investigate whether the time series of a remote sensing based soil moisture product, referred as the European Remote Sensing Soil Water Index (ERS SWI), correlates to in-situ observations of groundwater heads; and can thus be used for groundwater head prediction. As a test-bed we used the Rhine-Meuse basin, where we have collected thousands of groundwater head time series. Here we performed a correlation analysis between the time series of groundwater heads and ERS SWI spatio-temporal maps of profile soil moisture content. Results show that there is a significant correlation between ERS SWI and groundwater heads. Correlation is strongest in areas with shallow groundwater. The correlation improves for most areas, including those with deep groundwater tables, if we account for the lag time (i.e. the response time of water from the upper unsaturated soil moisture zone to the saturated deeper groundwater bodies) by adding a time delay to the correlation analysis.

We further investigated the possibility of using the ERS SWI to predict or estimate groundwater heads in two exercises in which we used the ERS SWI as the input of a transfer function-noise (TFN) model. (1) As a first exercise we focused on forecasting in time. For this, we calibrated the parameters of a TFN model to the head time series within the period 1995-2000 by embedding it in a Kalman filter algorithm. Once calibrated, we validated the TFN one-step-ahead forecasts for the period 2004-2007 in order to assess their prediction skill in time. (2) In a second exercise, we focused on spatio-temporal prediction. Here, we sampled the calibrated TFN parameters, derived in the first exercise, from a few selected head measurement locations. We then used these sampled TFN parameters to fit a spatial regression model with landscape attributes derived from a digital elevation model as input. The fitted regression model was subsequently used to estimate TFN parameters in all observation locations. Given these estimated TFN parameters, we predicted groundwater heads with the TFN model (also using the ERS SWI time series), and evaluated these against observations.

Results of both exercises are promising. The model results can reproduce the observed groundwater head time series reasonably well, especially in shallow groundwater areas where soil moisture dynamics are the major cause of groundwater head fluctuations. We argue that ERS SWI products should be considered as an important source of information for the assessment of large-scale groundwater dynamics in data-poor environments, especially in areas without field-measured groundwater head data.