Assimilating SMOS brightness temperatures into a conceptual spatially distributed hydrological model for improving flood and drought forecasting at large scale.

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Motivated by climate change and its impact on the scarcity or excess of water in many parts of the world, several agencies and research institutions have taken initiatives in monitoring and predicting the hydrologic cycle at a global scale. Such a monitoring/prediction effort is important for understanding the vulnerability to extreme hydrological events and for providing early warnings. This can be based on an optimal combination of hydro-meteorological modelling and remote sensing that consists in using satellite measurements as forcing or calibration data or for regularly updating the model states or parameters. Many advances have been made in these domains and the near future will bring new opportunities with respect to remote sensing as a result of the ever increasing number of spaceborne sensors enabling the large scale monitoring of water resources at unprecedented temporal and spatial resolution. In addition to such advances in terms of monitoring capacities, there is a tendency to continuously refine and render more complex physically-based hydrologic models in order to better capture the hydrologic processes at hand. However, this may not necessarily be beneficial for large-scale hydrology, as computational efforts and data requirements are increasing significantly. As a matter of fact, a novel thematic science question that is to be investigated is whether a flexible conceptual model can match the performance of a more complex physically-based model for hydrologic simulations at large scale.

In this context, the main objective of this study is to investigate how innovative techniques that allow for the observation of soil moisture variation (via Brightness Temperature observations) from satellite data can help in reducing errors and uncertainties in large scale conceptual hydro-meteorological modelling.

A spatially distributed conceptual hydrologic model has been set up based on recent developments of the SUPERFLEX modelling framework. With its limited computational and data requirements, this model is ideally suited for operational hydrology covering large areas. Using as forcings the ERA-Interim public dataset and coupled with the CMEM radiative transfer model, SUPERFLEX is capable of predicting runoff, soil moisture, and SMOS-like brightness temperature time series. Such a model is traditionally calibrated using in situ discharge measurements. In this study we first designed a multi-objective calibration procedure based on both discharge measurements and SMOS-derived brightness temperature observations in order to evaluate the added value of remotely sensed soil moisture data in the calibration process.

Next, SMOS-derived brightness temperature observations are sequentially assimilated into the SUPERFLEX model in “forecasting mode”. For this experiment, the Local Ensemble Transform Kalman Filter (LETKF) is used and the meteorological forcing (ERA interim-based rainfall and air and soil temperature simulations) are perturbed to generate the forecast ensemble. Each time a SMOS observation is available, the SUPERFLEX simulations are stopped, the Brightness Temperature map is assimilated, the SUPERFLEX state variables related to the water content in the various soil layers are updated and the model simulations are continued until a new SMOS observation is available.

As a test case we set up the SUPERFLEX model for the Murray-Darling catchment in Australia (~ 1 Million km^2). The assimilation experiment is carried out over the time period 2010-2016 using more than 4000 SMOS observations.
When compared to in situ soil moisture measurements, predictions yielded by the calibrated model show a good agreement resulting in correlation coefficients exceeding 70 % and Root Mean Squared Errors below 1 %.
In “forecasting mode”, our experiment shows that the assimilation of SMOS brightness temperature observations substantially improves soil moisture forecasts as the forecast soil moisture time series is compared to corresponding in situ measurements.