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Assimilation of leaf area index and surface soil moisture satellite observations into the SIM hydrological model over France

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Hydrological models have a variety of uses, including flood and drought prediction and water management. The SAFRAN-ISBA-MODCOU (SIM) hydrological model consists of three stages: An atmospheric analysis (SAFRAN) over France, which forces a land surface model (ISBA-A-gs), which then provides drainage and runoff inputs to a hydrological model (MODCOU). The river discharge from MODCOU is validated using observed river discharge over France.

Data assimilation (DA) combines a short model forecast from the past with observations to improve the estimate of the model state. The ISBA-A-gs representation of soil moisture and its influence by vegetation can be improved by assimilating surface soil moisture (SSM) and leaf area index (LAI) observations respectively. The Advanced Scatterometer (ASCAT) on board the MetOP satellite measures a low-frequency microwave signal, which is used to retrieve daily SSM over France. The SPOT-VGT sensor observes LAI over France at a temporal frequency of about 10 days. The Simplified Extended Kalman (SEKF) filter combines the model and observed variables by weighting them according to their respective accuracies. Although the SEKF makes incorrect linear assumptions, past experiments have shown that it improves on the model estimates of SSM and LAI. However, due to nonlinearities in the land surface model, improvements in SSM and LAI do not imply improved soil moisture fluxes (drainage, runoff and evapotranspiration).

This study indirectly examines the impact of the SEKF on the soil moisture fluxes using the MODCOU hydrological model. The ISBA-A-gs model appears to underestimate the LAI for grasslands in winter and spring, which results in an underestimation (overestimation) of evapotranspiration (drainage and runoff). The excess water flowing into the rivers and aquifers contributes to an overestimation of the MODCOU discharge. Assimilating LAI observations slightly increases the LAI analysis in winter and spring and therefore reduces the drainage and runoff, which in turn improves the MODCOU discharge estimates. However, assimilating SSM results in spurious increases in drainage and runoff in winter due to the nonlinear behaviour of ISBA-A-gs near the field capacity. This degrades the MODCOU discharge estimates. This problem is partly resolved by imposing a minimum on LAI for grasslands, which prevents the evapotranspiration (drainage and runoff) from becoming too low (too high) in winter.

It is recommended that improvements are made to the ISBA-A-gs representation of LAI, especially in winter. It is also likely that MODCOU over-estimates river discharge because it cannot take into account anthropogenic features such as dams.