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Retrieving the irrigation actually applied at district scale: assimilating high-resolution Sentinel-1-derived soil moisture data into a FAO-56-based model

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Irrigation is the most water consuming activity in the world. Knowing the timing and amount of irrigation that is actually applied is therefore fundamental for water managers. However, this information is rarely available at all scales and is subject to large uncertainties due to the wide variety of existing agricultural practices and associated irrigation regimes (full irrigation, deficit irrigation, or over-irrigation). To fill this gap, we propose a two-step approach based on 15 m resolution Sentinel-1 (S1) surface soil moisture (SSM) data to retrieve the actual irrigation at the weekly scale over an entire irrigation district. In a first step, the S1-derived SSM is assimilated into a FAO-56-based crop water balance model (SAMIR) to retrieve for each crop type both the irrigation amount (I_{dose}) and the soil moisture threshold ($SM_{threshold}$) at which irrigation is triggered. To do this, a particle filter method is implemented, with particles reset each month to provide time-varying $SM_{threshold}$ and I_{dose}. In a second step, the retrieved $SM_{threshold}$ and I_{dose} values are used as input to SAMIR to estimate the weekly irrigation and its uncertainty. The assimilation approach (SSM-ASSIM) is tested over the 8000 hectare Algerri-Balaguer irrigation district located in northeastern Spain, where in situ irrigation data integrating the whole district are available at the weekly scale during 2019. For evaluation, the performance of SSM-ASSIM is compared with that of the default FAO-56 irrigation module (called FAO56-DEF), which sets the $SM_{threshold}$ to the critical soil moisture value and systematically fills the soil reservoir for each irrigation event. In 2019, with an observed annual irrigation of 687 mm, SSM-ASSIM (FAO56-DEF) shows a root mean square deviation between retrieved and in situ irrigation of 6.7 (8.8) mm $week^{-1}$, a bias of +0.3 (-1.4) mm $week^{-1}$, and a Pearson correlation coefficient of 0.88 (0.78). The SSM-ASSIM approach shows great potential for retrieving the weekly water use over extended areas for any irrigation regime, including over-irrigation.