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Contribution of remote sensing data to hydrological simulations: case of the Garonne catchment in the South-West of France

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Abstract:(Semi-)Distributed hydrological models often poorly simulate all reservoirs in sub-basins because they rather focus on obtaining a correct streamflow at sub-basin's outlet. In situ networks are point based estimates of a flux and their locations are not always dense enough to validate reservoirs at the model spatial scale. Remote sensing data, however, can provide spatially distributed information on a specific reservoir (with less accuracy than in situ measurements) and are an alternative source of data to calibrate and evaluate model outputs, which can only be performed with (semi-)distributed hydrological models. We present a comparison between remote sensing data and hydrological simulations for the highly anthropized Garonne watershed (~50 000 km^2), located in the south-west of France, in order to cross-compare them (as all of them have different sources of errors). In order to evaluate water resources in all the water cycle reservoirs (snow, aquifer, soil), several remote sensing products are taken into consideration: snow cover area in the Pyrenees from the Moderate-resolution imaging spectroradiometers (MODIS), soil moisture in the first 5 cm from the Soil Moisture and Ocean Salinity mission (SMOS, level-2 product) and total water volumes integrated vertically on the whole soil column from the Gravity Recovery And Climate Experiment (GRACE). Those data are compared with outputs from several hydrological models, each having its specific features: the Soil and Water Assessment Tool (SWAT), a physically based model providing data on a distributed network of sub-basins, the SAFRAN-ISBA-MODCOU (SIM) physically-based model providing data on a regular grid, and the MARTHE 3D hydrodynamic model providing data at the alluvial plain scale. These remote sensing products are used to evaluate the ability of the above-mentioned models to simulate water resources. Only MODIS data have been used for models calibration, and improved modelling of snow extent. The comparison betwenn GRACE and models, shows good correlations (> 0.9 and 0.7 without the seasonal cycle) in yearly and seasonal dynamic of water volume between GRACE and models at the catchment scale, therefore assessing the effectiveness of integrated water stock data in a relatively small catchment given GRACE's low spatial resolution (> 300km). The root mean square difference between GRACE and SWAT is equal to 11% of the SWAT volume change amplitude over the time period. It is equal to 15% when comparing GRACE and SIM. This shows the however good agreement between all datasets, indicating SWAT and SIM physics are sufficient to model the total water volume change. This comparison also confirms

that deep aquifer, which is the most import stock of water, has negligible volume change over the studied time period, compared to other reservoirs.The differences between models and GRACE might be due to the uneven temporal sampling, measurement and processing errors for GRACE and forcing errors and processes not or at least not sufficiently taken into account by models (like anthropic impact) .Snow cover data from MODIS are also well correlated with the SWAT and SIM models when elevation bands are added in mountain areas (Nash-Sutcliffe coef. of 0.53 and Pbias of 3.98), validating both modelling approaches. Furthermore, using MODIS data to re-calibrate the simulations not only allows a better dynamic of snow reservoirs, but also results in improved correlations between simulated and in-situ water fluxes for several sub-basins within the catchment. Finally, comparisons for soil moisture are more difficult to assess, first, due to differences in the soil moisture computation between models and SMOS and, second, due to uncertainties on satellite data and models accuracy. This study also highlights the issue to compare different models with different remote sensing data, as none of them have the same spatial and temporal resolution and accuracy.

***Keywords**:* Remote sensing; hydrological simulations; soil moisture; integrated water stock; snow cover; Garonne catchment