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An observation-based approach for global runoff estimation: exploiting satellite soil moisture and Grace

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Water is at the centre of economic and social development; it is vital to maintain health, grow food, manage the environment, produce renewable energy, support industrial processes and create jobs. Despite the importance of water, to date over one third of the world's population still lacks access to drinking water resources and this number is expected to increase due to climate change and outdated water management. As over half of the world's potable water supply is extracted from rivers, either directly or from reservoirs, understanding the variability of the stored water on and below landmasses, i.e., runoff, is of primary importance. Apart from river discharge observation networks that suffer from many known limitations (e.g., low station density and often incomplete temporal coverage, substantial delay in data access and large decline in monitoring capacity), runoff can be estimated through model-based or observation-based approaches whose outputs can be highly model or data dependent and characterised by large uncertainties.

On this basis, developing innovative methods able to maximize the recovery of information on runoff contained in current satellite observations of climatic and environmental variables (i.e., precipitation, soil moisture, terrestrial water storage anomalies and land cover) becomes mandatory and urgent. In this respect, within the European Space Agency (ESA) STREAM Project (SaTellite based Runoff Evaluation And Mapping), a solid "observational" approach, exploiting space-only observations of Precipitation (P), Soil Moisture (SM) and Terrestrial Water Storage Anomalies (TWSA) to derive total runoff has been developed and validated. Different P and SM products have been considered. For P, both in situ and satellite-based (e.g., Tropical Rainfall Measuring Mission, TRMM 3B42) datasets have been collected; for SM, Advanced SCATterometer, ASCAT, and ESA Climate Change Initiative, ESA CCI, soil moisture products have been extracted. TWSA time series are obtained from the latest Goddard Space Flight Center's global mascon model, which provides storage anomalies and their uncertainties in the form of monthly surface mass densities per approximately 1°x1° blocks.

Total runoff estimates have been simulated for the period 2003-2017 at 5 pilot basins across the world (Mississippi, Amazon, Niger, Danube and Murray Darling) characterised by different physiographic/climatic features. Results proved the potentiality of satellite observations to estimate runoff at daily time scale and at spatial resolution better than GRACE spatial sampling. In particular, by using satellite TRMM 3B42 rainfall data and ESA CCI soil moisture data, very good runoff estimates have been obtained over Amazon basin, with a Kling-Gupta efficiency (KGE) index greater than 0.92 both at the closure and over several inner stations in the basin. Good results found for Mississippi and Danube are also encouraging with KGE index greater than 0.75 for both the basins.