Abstract

River health management mostly depends on high-frequent (daily-scale) monitoring of streamflow and water quality at finer spatial resolutions. However, with the decline in the number of *in situ* monitoring stations owing to their expensive maintenance cost, there is a need to develop the next-generation remote sensing (RS) tools as an alternate approach in rivers and narrow streams for both quantity and quality assessment with better synoptic coverage. These techniques are still in experimental stage worldwide and site-specific which have to be explored for its real field application. To address these issues, this study has developed seven novel optical RS-based hierarchical spectral models, namely, MOD, CMOD, FUS, CFUS, ANNFUS, RFRFUS, and SVRFUS for daily streamflow estimation at 30 m spatial resolution in any ungauged/semi-gauged river reach during non-cloudy period using the enhanced spatiotemporal adaptive reflectance fusion (FUS) of the coarser Aqua-MODIS (MOD) and finer Landsat satellite images. Similarly, for daily Total Suspended Solids (TSS) and Turbidity monitoring in any ungauged/semi-gauged river reach, three novel RS-based models, namely, MOD_T, FUS_T, and $CFUS_T$ are developed. To fill in the monitoring gap left by the defunct streamflow gauging stations in world-rivers as the RS-based virtual stations with very low-cost investment, a novel MIKE11-NAM-HD-CFUS-Altimeter integrated RS-hydrodynamics modeling framework has been proposed, which is applicable both during cloudy and non-cloudy days. The MIKE11-NAM-HD is used for hydrodynamic modeling of streamflow routing and lateral flow generation processes. Similarly, a VPMM-AD(ΨDc)-CFUS-$CFUS_T$ integrated framework has been proposed for establishing remote sensing-based virtual stations at the desired river reaches for daily-scale TSS and Turbidity monitoring. The VPMM-AD(ΨDc) is a physically-based simplified hydrodynamic model for solute transport dynamics in a river applicable under limited cross-section data availability. All the developed models and proposed frameworks are validated for the Brahmani River and Hooghly River in eastern India as the typical case studies. The comparative assessment of the advocated streamflow estimation models reveals that the Frank copula-based fusion (CFUS) model is the best-performing followed by the support vector regression based fusion (SVRFUS) model. Similarly, among the advocated TSS estimation algorithms, the $CFUS_T$ model, that integrates the Frank Copula with the FUS_T model, performs the best. The inherent limitations of the satellite-based altimeters in assessing the river water levels during the low flow period due to land contamination of the echoes and their capability to penetrate through the cloud covers could be best-utilized by the proposed MIKE11-NAM-HD-CFUS-Altimeter integrated modelling framework in almost continuous monitoring daily streamflow in semi-gauged/ungauged river reaches. Moreover, the Frank copula could better describe the TSS-spectral reflectance dynamics in rivers than the conventionally used linear functions. Conclusively, the proposed approaches in this study can be best utilized for near real-time river health monitoring and overall basin-scale water management.

Keywords: Remote Sensing; Rivers; Routing; Streamflow; Ungauged; Water quality