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Moderation of ensemble covariances for data assimilation of satellite-based water level observations into flood modelling

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Satellite imagery has proved useful for obtaining information on water levels in flood events. Microwave frequencies are generally more useful for flood detection than visible-band sensors because of their all-weather day-night capability. Specifically, the future SWOT mission, with Ka-band interferometry, will be able to provide direct Water Level Observations (WLOs), and current and future Synthetic Aperture Radar (SAR) sensors can provide information of flood extent, which, when intersected with a Digital Elevation Model (DEM) of the floodplain, provides indirect WLOs. By either means, satellite-based WLOs can be assimilated into a hydrodynamic model to decrease forecast uncertainty and further to estimate river discharge into the flooded domain and model parameters. However, studies on assimilation of real satellite-based WLOs into flood models are still sparse.

For 2D high resolution flood modelling, the data assimilation (DA) techniques based on Monte Carlo implementations of the Kalman filter (Ensemble Kalman Filters; EKFs) provide a minimum variance estimator. The performance of ensemble techniques depends on the quality of both the observations to be assimilated and the correctness of the several covariance matrices involved, which serve to convey the observation information (innovations) to elsewhere in the studied domain. Here we evaluate how some of the particularities of flood models may hamper the straightforward implementation of EKFs for operational assimilation of satellite-based WLOs. Specifically, the filter may become hyper-sensitive to observations in minor tributaries, and the specific network connectivity of braided flooded domains (e.g. converging tributaries or urban domains) indicate that straightforward spatial localization (Euclidean distance-based covariance moderation) is just not sound.

Here we discuss these problems by assimilating real WLOs obtained from a 7-image sequence from the COSMO-Skymed (CSK) constellation X-band SAR, in a flood that occurred in November 2012 in the lower Severn-Avon rivers, Southwest UK (perhaps the most detailed sequence of SAR-based WLOs of a flood event currently existing in the world). We evaluate the effect of moderating the covariance matrices, to counteract the abovementioned problems, on the assimilation-constrained dynamic footprints of the flood forecast.