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Optimizing SAR-based Flood Extent Assimilation for Improved Flood Inundation Forecasts

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Floods can have extremely expensive and often fatal consequences, thereby necessitating accurate flood inundation forecasts for increased preparedness and resilience. In an operational forecasting scenario, inflow uncertainties propagated from precipitation forecasts dominate and lead to inherently erroneous predictions of flood inundation, frequently impeding their application to rescue and response operations. Thus, it is expected that assimilating independent inundation observations, from Synthetic Aperture Radar (SAR) sensors for example, may reduce the inherent uncertainty in hydraulic modelling. The increasing number of SAR satellites, with their all-weather/all-day imaging capabilities, have increased the probability of monitoring flood dynamics from space. SAR-based flood extents were previously used to indirectly retrieve floodplain water levels in conjunction with digital elevation models. However, studies highlighted this process as an additional source of uncertainty, leading to the development of algorithms for the direct assimilation of flood extent into hydraulic flood inundation forecasting chains. The efficiency of flood extent assimilation is keenly sensitive to the spatiotemporal observation characteristics, and so the expected improvement in the forecast strongly depends on the acquisition timing with respect to the position of the flood wave. In this study, numerical experiments were used to simulate multiple spatiotemporal SAR acquisition scenarios, to identify the optimum measurement design for targeted satellite acquisition, to best facilitate flood extent assimilation. A particle filter based flood extent assimilation framework was developed using the hydraulic model LISFLOOD-FP, and implemented for the 2011 flood event in the Clarence Catchment, Australia. An operational forecasting scenario was emulated for the open loop model ensemble, with the consideration of temporally correlated, variance changing uncertainties in inflows, simulating hydrological model forecasts. The impact of assimilating flood extent at reaches exhibiting uniform flow behaviour, with different combinations of first visit and revisit intervals were investigated. Results indicate that the optimum timing and frequency of targeted SAR acquisitions differs with respect to reach hydraulic characteristics and that images acquired after the peak is observed in the channel are most informative for the forecast. Note that the maximum inundation extent in the floodplain always follows the channel peak, and therefore, post-peak images with respect to the within reach flood wave could improve predictions during the peak in the floodplain. Moreover, a single image assimilated at a reaches exhibiting more diffusive flow behaviour just after the peak, could result in improvements comparable to the assimilation of multiple images elsewhere. Findings from the study will allow the optimal utilization of SAR imagery to overcome localized model uncertainties, and help to maximize the accuracy of

inundation forecasts.

- **Keywords:** Flood inundation modelling, flood extent assimilation, SAR, data assimilation, hydraulic modelling, forecast uncertainty