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Vita Ayoub, Renaud Hostache, Marco Chini, Ramona Pelich, Carole Delenne,
Patrick Matgen

► To cite this version:

Vita Ayoub, Renaud Hostache, Marco Chini, Ramona Pelich, Carole Delenne, et al.. Assimilation of probabilistic flood maps into large scale hydraulic models to retrieve missing river geometry data using a tempered particle filter. IGARSS 2023 - 2023 IEEE International Geoscience and Remote Sensing Symposium, Jul 2023, Pasadena, United States. hal-04378319

HAL Id: hal-04378319

<https://hal.science/hal-04378319>

Submitted on 8 Jan 2024

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Paper Title: ASSIMILATION OF PROBABILISTIC FLOOD MAPS INTO LARGE SCALE HYDRAULIC MODELS TO RETRIEVE MISSING RIVER GEOMETRY DATA USING A TEMPERED PARTICLE FILTER

Authors:

1. Vita Ayoub, Luxembourg Institute of Science and Technology
2. Renaud Hostache, Institut de Recherche pour le développement
3. Marco Chini, Luxembourg Institute of Science and Technology
4. Ramona Pelich, Luxembourg Institute of Science and Technology
5. Patrick Matgen, Luxembourg Institute of Science and Technology
6. Carole Delenne, Université de Montpellier

Abstract :

As climate change worsens, intensified natural events are expected to happen in the future. Among these events, floods can be the most destructive and can cause significant damages on many levels. It is therefore necessary to put in place cost-effective flood forecasting models in order to obtain accurate dynamic simulations for flood risk assessment. However, current models are affected with large uncertainties and need to be constrained with independent data that must be acquired from *in situ* measurements or remote sensing derived observations. If the network of hydrometric stations was well developed, flow rate and/or stage time series should be provided at a relatively sufficient spatial and temporal coverages and used as inputs for flood models. However, in many areas around the world, stream gauges are sparsely distributed and can be lacking in ungauged basins [85]. To compensate the lack of *in situ* data, we propose to exploit earth observation (EO) and particularly make use of Synthetic Aperture Radar (SAR) imagery due to its ability to provide frequent updates of flooded areas at a large scale, regardless of atmospheric conditions. Moreover, the specular reflection of the emitted backscatter on open water bodies allows a relatively straightforward detection of water on the SAR image. Thus, these images hold an added value and a potential to improve the predictive accuracy of flood forecasting models through data assimilation (DA). Widely used in the fields of hydrology, hydraulics and geosciences, DA aims to optimally combine uncertain model predictions and uncertain observations. This relies on the estimation of optimal model states and/or parameters and allows thereby for the reduction of model uncertainties. DA can be carried out sequentially, for example in near-real time, by updating model states and/or parameters using observations as they become available, or in a reanalysis by assimilating all observations at once, i.e., retrospectively.

Another major challenge tied to the hydrodynamic modelling is the lack of hydraulic parameter data that are needed as inputs, such as the riverbed shape and elevation. While the knowledge of such information is critical for flood models, it is rarely available from remote sensing observations, digital elevation models (DEMs), or ground data measurements. Most studies have estimated river discharges and depths assuming the bathymetry and bed roughness to be known *a priori*. The complexity of implementing DA to estimate these hydraulic parameters have long been seen has a pitfall.

In this study, we propose to assimilate probabilistic flood maps derived from SAR data into the SW2D-DDP model, a 2-dimensional shallow water equations model with depth-dependent porosity, in order to retrieve the unknown bathymetry of a river. The porosity functions in this model, enable a straightforward representation of the riverbed geometry using porosity parameters. We assume the bed shape to be trapezoidal, and the bed roughness to be known a priori. The DA framework is thus based on integrating PFMs into the SW2D-DDP model via a Tempered Particle Filter (TPF) and takes into account the SAR observation and the SW2D-DDP model related uncertainties. The data assimilation algorithm is applied using as a test case the 2012 flood event that hits the Severn River around the city of Tewkesbury at the confluence of the Severn and Avon Rivers. We thus proposed to retrieve via data assimilation a simplified spatially distributed riverbed geometry (i.e., riverbed depth) along with the model downstream boundary condition in the form of a rating curve. The results are very encouraging as the model predictions reach water level RMSEs below 0.5 m as a result of the assimilation although the retrieved river depths are not matching the real one.