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Towards a seamless probabilistic flood inundation modelling capability across the disaster response timeline

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Abstract: Floods constitute the second-most deadly natural hazard in Australia, only exceeded by heatwaves. Predictions of flood inundation is key to mitigating the loss of human life and minimizing negative socio-economic and environmental impacts of flooding. A probabilistic approach to flood inundation is required to be able to consider various sources of uncertainty and quantify the confidence in the results. This will enable decision-makers to identify the most flood-prone areas with high confidence and employ flood mitigation measures effectively, thus reducing the potential downstream impacts. Also, a seamless approach is necessary because different stages of flood response require different types of information for a variety of stakeholders. For example, short-term forecasts of a few days are needed for immediate response and evacuation planning, while seasonal forecasts are used for longer-term planning and resource allocation during the recovery phase. Our aim is to develop a seamless probabilistic flood inundation modelling capability (ProFIM) which will provide the likelihood of the extent and depth of a flood across the Prevention, Preparedness, Response and Recovery timeline.

The ProFIM workflow to produce probabilistic flood inundation forecasts includes four main steps. Firstly, we run a land surface model (currently the Australian Landscape Water Balance model (AWRA-L v7)) forced with gridded outputs from climate forecast models (e.g., the Australian Community Climate and Earth-System Simulator (ACCESS) weather models) to produce ensemble runoff. Secondly, we utilize a river routing scheme (i.e., the CaMa-Flood (Catchment-based Macro-scale Floodplain) model) to simulate the movement of water across the landscape, and then produce ensemble water level simulations along river reaches also considering river geometry uncertainties. Thirdly, we produce probabilistic flood inundation mapping based on ensemble water levels and high-resolution DEMs (i.e., 30-m Bureau's Geofabric SRTM derived hydrologically enforced DEM and 1-5 m locally acquired airborne LiDAR derived DEM) using the HAND (Height above the Nearest Drainage) approach. Lastly, we validate the flood inundation maps generated by ProFIM using satellite imagery (e.g., Sentinel-1 Synthetic Aperture Radar (SAR) and Sentinel-2 optical images) and assimilate remote sensing data to improve the accuracy of the flood mapping.

We assessed the ProFIM workflow for the flood-prone Hawksbury-Nepean Valley region, where probabilistic flood inundation maps generated for four flood events occurring in February 2020, March 2021, and March & July 2022 were compared to satellite observations. The overall agreements between modelled and satellite-derived flood inundation maps are all above 90%. The main difference occurred in vegetated areas and narrow river channels which is potentially due to the uncertainties in the earth observation information. We also showed that the flood extent boundaries and spatial depth can be significantly improved by using LiDAR-derived DEM.

This study demonstrates a repeatable and scalable ProFIM workflow that has the potential to be implemented in the operational settings nationally, across flood-prone Australian catchments. ProFIM will be used to generate short to medium-term flood forecasts, ranging from a few days up to several weeks or even seasonal projections for decision support. It will also be used in decadal projections to support planning to identify projected changes in event severity and frequency. Overall, the implementation of the ProFIM workflow presented in this study holds promising implications for enhancing flood forecasting and planning efforts at various timescales in Australia.

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