Advanced flood inundation modelling and wetland connectivity analysis

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Extended Abstract

Floodplain inundation modelling becomes increasingly important for flood forecasting and river basin management for engineering, ecological and environmental perspectives. While flooding is disastrous from economic and social point of view, it is the single most beneficial component for ecological and biodiversity values of floodplain wetlands. Flood flows provide an opportunity for off-stream wetlands to be connected to the main river channel. The high biodiversity found in many unregulated floodplain systems are thought to be largely dependent upon these ‘flood pulses’. An important issue for the management of wetlands on river-floodplain ecosystem is to acquire knowledge of the extent, timing, duration and frequency of inundation and their hydrological connectivity to the main channel.

In the past, hydrodynamic models of mostly one-dimensional (1-D) and two-dimensional (2-D) regular grid types were used to simulate flood height and inundation extent. While these models are sufficiently accurate for small study areas with fine raster grid size, the results are often distorted for a large floodplain because of coarse grid size in the model. In order to produce the flood mapping necessary to support floodplain disaster management and ecological impact assessment, hydrodynamic modellings have to be sufficiently detailed and flexible to properly capture the river networks, tributaries and floodplain wetlands. With the rapid advancement in computer technology and numerical simulation methods, flexible mesh (rectangular and triangular grids of variable size) hydrodynamic modellings become most efficient tool for flood inundation modelling and wetland connectivity analysis.

This paper presents the results from an analysis undertaken using two dimensional (2-D) regular grid model (MIKE21) and flexible grid model (MIKE21 FM) for flood mapping and quantifying hydrological connectivity between floodplain water bodies in a large and topographically complex river basin with numerous wetlands of ecological and cultural value. The Fitzroy catchment in Western Australia was selected for this case study. The hydrodynamic modelling domain covers an area of 35,000 km^2 encompassing land subject to inundation. The regular grid model consists of approximately 4.3 million model mesh with the size of 8100 m^2 (90 m × 90 m). The flexible grid model consists of approximately 2.1 million model mesh with minimum and maximum size of 93 m^2 and 8.1×10^6 m^2, respectively. Light Detection And Ranging (LiDAR) surveyed 1 m grid elevation data were used to parameterise river networks in the model and Shuttle Radar Topographic Mission (SRTM) derived 30 m elevation data were used for floodplain topography. Hydraulic roughness parameters were estimated using a land use map, which was developed using a combination of aerial photography, topographic maps and Google Earth imagery. For a computational time step of 5 sec, the rectangular grid model takes about 16 days of computer time for the simulation of a 40-day flood while the flexible mesh model takes about 2 days for the same flood event. On average, the flexible mesh model runs eight times faster on GPU compared to the rectangular grid model for this case study. It is worth mentioning that the regular grid model is built on a finite-difference implicit scheme and runs on CPU machine only, while the flexible grid model is built on a finite-volume explicit scheme and is able to run on both CPU and GPU machines. The model was calibrated using a combination of stream gauge data and flood inundation maps derived from satellite imagery.

The study evaluates the MIKE21 FM model performances in terms of accuracy of the results compared to the MIKE21 regular grid model. Simulated water levels on the floodplain were compared with observed data at 3 gauging stations on the Fitzroy River. Inundation area were evaluated using the Moderate Resolution Imaging Spectroradiometer (MODIS) and Landsat imagery. The results show the MIKE21 FM model better simulates spatial and temporal inundation across the floodplain compared to regular grid model. We found that the regular grid model grossly overestimates the inundation area during the receding flood. While the flexible mesh model better simulates the receding flood, the overestimation issue is not fully resolved. As the MIKE21 FM model can utilise multi-core parallel computing facilities, the computational time is significantly less compared to the MIKE21 regular grid model. One notable advantage of flexible mesh modelling is its ability to represent the natural meandering of river network and flood runners using a combination of rectangular and triangular grids. Another major advantage is using smaller grids for the areas of interest and larger grids for less important areas.

Model simulated water depths were combined with land topography to identify floodplain pathways that connect off-stream wetlands with rivers. The connectivity of 30 selected wetlands to the main river channel was evaluated for floods of 2, 10 and 25 return periods and varying flow hydrographs. The duration of connection of the individual wetlands to the main river channel varied from 1 to 40 days depending on flood magnitude, with some wetlands only connecting to the main river channel during large floods. Topographic relief, location on the floodplain, and magnitude and duration of the flood were found to be key factors governing the level of connectivity, and the relationship between return period of flood and inundated area was found to be non-linear. The findings of this research will facilitate future research in inundation modelling and hydrological connectivity analysis.

Keywords: Floods, hydrological connectivity, MIKE21 FM, MODIS, wetlands