RIVER MURRAY FLOODPLAIN INUNDATION MODELS (RIM-FIM) FOR THE LOWER-DARLING RIVER SYSTEM, AUSTRALIA

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The Murray Darling Basin Authority needs information about the distribution of inundation at certain flow levels to efficiently plan the delivery of environmental water. One of the models the MDBA have used to assist their planning is the River Murray Floodplain Inundation Model, or RiM-FIM, which uses satellite image observations and digital elevation data to predict the distribution of inundation through a local area at a given stage height of water at a nearby flow gauge. These models are relatively cheap and fast to create compared to more complex models, but they have some characteristics that limit the range of conditions in which they can be best applied. This paper will describe the RiM-FIM method and some of the challenges in developing a model for the Lower Darling River System in inland Australia.

1 INTRODUCTION

The Murray Darling Basin Authority (MDBA) is responsible for planning and implementing the Basin Plan: an adaptive framework for the coordination of water delivery and use to support communities and ecosystems throughout the Basin (http://www.mdba.gov.au/what-we-do/basin-plan). In order to determine the flow required to reach supported ecosystems, but to avoid inundation of towns and properties, the MDBA require a model linking river flows to the extent and depth of inundation of floodplains and surrounding areas.

Hydrodynamic models are being created for a range of catchments in the MDB that will enable predictive analysis of the influence of climatic, hydrological and water management actions on inundation distribution [1] but these are not available for most catchments at this time. In the interim, the MDBA require a relatively low cost framework to support water sharing and delivery decisions that must be made in the short term.

This paper describes the production of River Murray Floodplain Inundation Models (RiM-FIM) for a section of the Lower Darling River system in western New South Wales, Australia. In particular we demonstrate that satellite observations of flooding may not consistently represent the distribution of inundation across the flow range. We then present a new iteration of RIM-FIM which does not use flood observations to constrain the predicted inundation extent.

2 RIVER MURRAY FLOODPLAIN INUNDATION MODEL (RIM-FIM)

The original River Murray Floodplain Inundation Model [2] was created to model the extent of inundation at a range of flow levels along the Murray River between the Hume Dam (Albury Wodonga) and Wellington in South Australia. For these models, cloud-free images were selected showing a range of flood levels from low flows to bank-full and large magnitude flooding, and the extent of flooding shown in these images was correlated to flows measured at the nearest upstream flow gauge. Images were selected on the rising limb of the hydrograph, which typically provide a better correlation to the observed flood extent than images captured after the flood peak, and always more than six months after a larger flood peak to minimise residual water in the images.

A series of additional rules and (usually manual) processing steps were then applied to improve the spatial consistency of predicted commence-to-fill values over large flood extents such as lake beds, and to improve the link between flows and inundated extent. These included removing patches of inundation that are disconnected from the river channel and labelling pixels with the lowest flow at which inundation was observed. The extent of flooding was then interpolated between observations using the ‘marker-based watershed segmentation algorithm’ image morphological processing algorithm [3].

RiM-FIM models have recently been created for several river systems in the southern MDB including the Lower Darling river system [4] and these models included the use of Lidar digital elevation model (DEM) data. Production of these models included the development of an automated process to associate the edge of the inundation mapped in the Landsat images (25m pixels) to the DEM surface heights at 5m resolution, thus creating an image-constrained inundation map at 5m spatial resolution across the extent of a Landsat scene. Flood maps were created for every 1 GL increment in flow between the lowest and highest flows observed in the images.

Reviews of the images used to create the RiM-FIM models indicates that, while the relationship between water height and the extent of inundation shown in the images is 'true' (i.e. the classified images show the location of water at the time of image capture as accurately as we can map it) the distribution of floodwater at the instant of image capture is also specific to the combination of hydrological, climatic and water resource management activities prevailing at that time.

Figure 1 shows the overlay of inundation mapped from three images used to create the RiM-FIM model for the upper reaches of the Lower Darling system. This area is downstream of a lake from which releases are controlled for irrigation purposes.

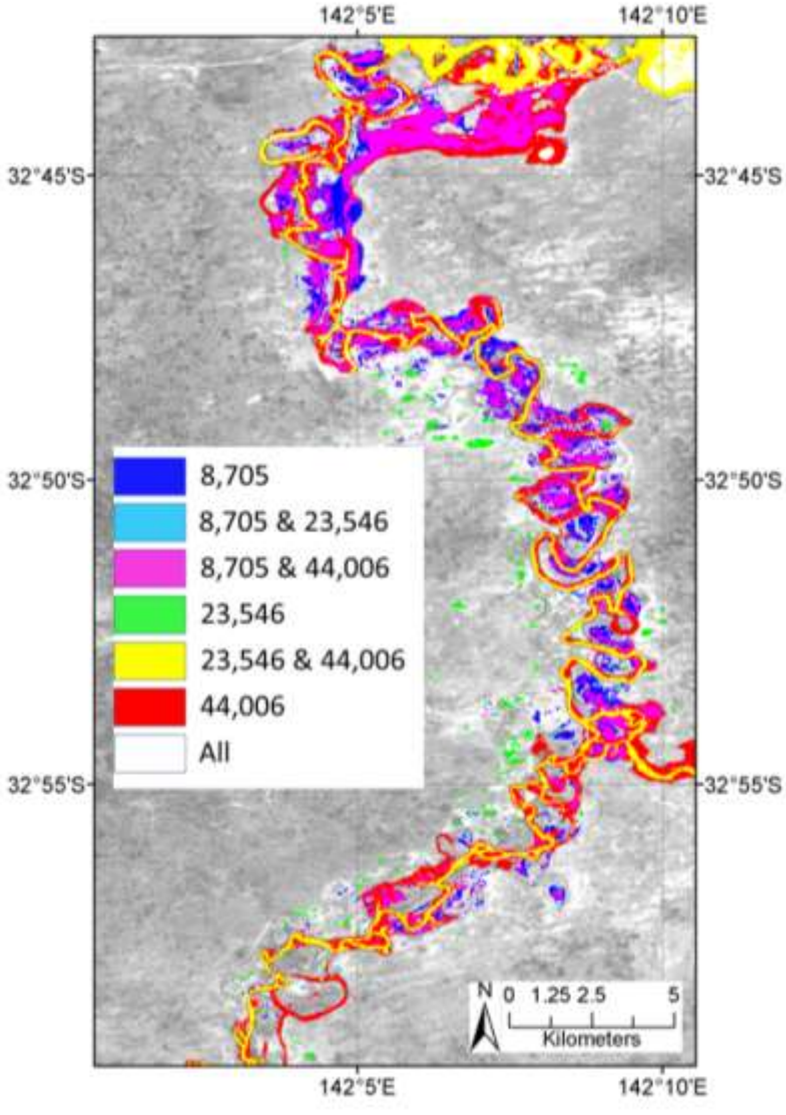

Figure 1. Overlay of flooding in the north of the Lower Darling River System at 8,705 ML (24 January 2010), 23,546 ML (25 June 1990) and 44.006 ML (21 October 1998) per day at the Weir 32 flow gauge. Inundation is observed on days of low flow in areas that remain dry in larger magnitude floods.

On the days of image capture flows at Weir 32 (the main flow control structure upstream of the lake) were 8,705 ML per day (blue; image captured on 24 January 2010), 23,546 ML per day (green; 25 June 1990), and 44,006 ML per day (red; 21 October 1998), with mixed colours showing where floods overlap. Despite the wide range of flow levels represented in this Figure, areas of primary colour remain because each flood can inundate a unique area of the floodplain. Areas in blue, for example, were mapped as water only in the lowest magnitude flood. This can occur from natural phenomena such as changes in flow resistance from vegetation in the channels [5] or on the floodplain [6] between floods, differences in the pattern and amount of soil moisture over time, or the manipulation of floodwater by landholders and water managers. In this region we suspect that inconsistencies are largely the result of manipulation of outflows from the upstream lake, especially at low flows, though no record of outflows from the lake was available to us. While some of the processes in the RiM-FIM method attempt to account for these inconsistencies, variations such as these can still affect the outcomes of image-constrained flood models.

3 DEM-FIM

The latest iteration of RiM-FIM eliminates the use of flood observations except in the validation process, and determines inundation distribution using only the DEM data (Figure 2). This method, which we call DEM-FIM, is based on fluvial geomorphological features of meandering river floodplains [7, 8] and on the conclusion of Wolman & Leopold [9] that similar features along a length of river are often formed by floods of a similar magnitude.

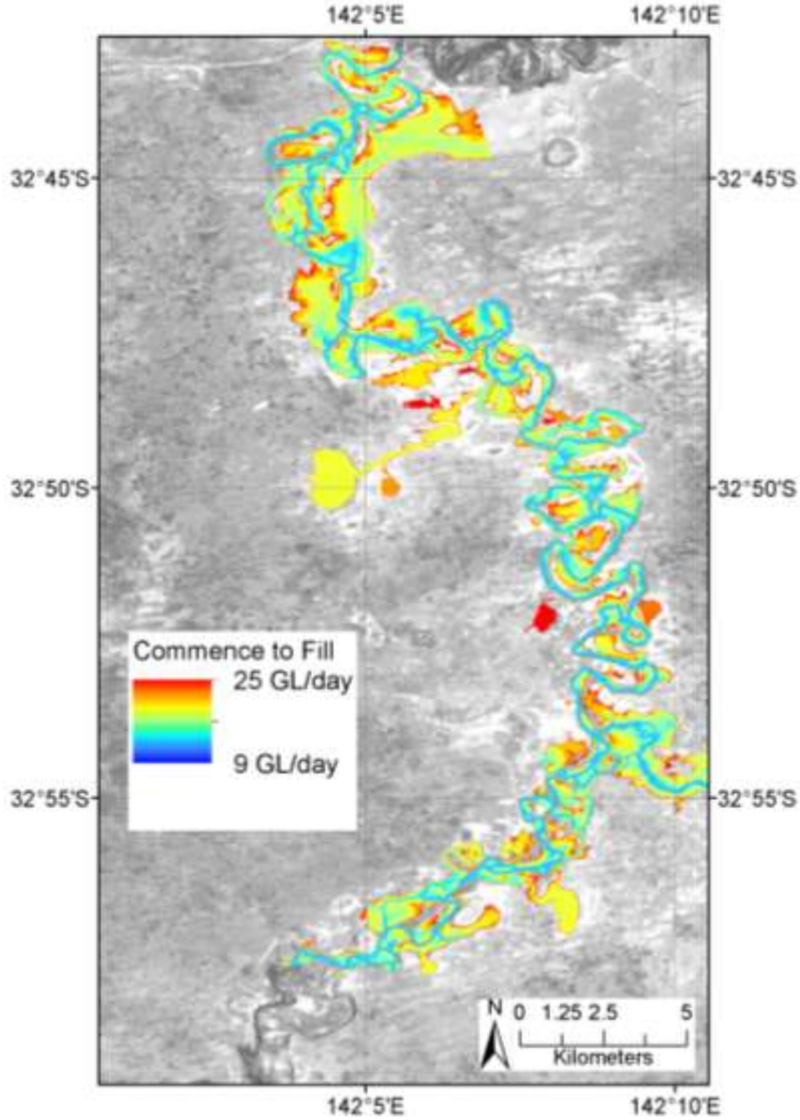

Figure 2. DEM-FIM model showing commence to fill flow at Weir 32.

In this river system the DEM-FIM method is based on meander bend scrolls, which are assumed to be related by their shared inundation history and can thus be used to determine a notional bank-full water height for a given river reach. Meander bends are manually identified and their elevations are measured, ensuring that they descend consistently along the channel to produce a descending bank-full water height surface. These heights are then extrapolated laterally across the floodplain to produce a water height surface at measured stage heights associated with 1 GL flow increments at Weir 32. Inundation at each height is mapped as the area below the water height surface that is connected to the river channel.

The DEM-FIM model for the study reach shows commence to fill flow levels between 9 GL and 25 GL per day at Weir 32 (Figure 2). In contrast with the flood observations across a similar flow range (Figure 1) the DEM-FIM results are more spatially consistent in that commence-to-fill flow levels tend to increase away from the main channel and all patches of inundation are connected to the river channel by open water.

4 APPLICATION AND LIMITATIONS

RiM-FIM models have certain advantages in that they are computationally relatively simple to create compared to hydrodynamic models, and that constraining inundation predictions with satellite observations can provide a useful guide to modelling in certain conditions, particularly on very flat landscapes where predicting the distribution of floodwater for a given flow using elevation data alone is problematic. For these reasons, the MDBA have requested RiM-FIM models for a range of river systems in recent years.

RiM-FIM models also have a range of limitations including that they are 'steady state' and, unlike hydrodynamic models [1], are not readily able to demonstrate the effect of water management options on floodwater distribution. Variations in antecedent conditions and water management activities can also have a significant influence on the distribution of flooding observed in the images used to constrain the models, which influences the representation of floodwater distribution across the range of flows being modelled as we have demonstrated here.

Using only high resolution DEM data can overcome some of the issues associated with imagery-related artefacts in flood models of the Lower Darling River system. While DEM-FIM appears to provide results that are internally consistent, it too has limitations. Predicting inundation using only DEM data ignores other features that may influence floodwater distribution such as changes in flow resistance over time [5, 6] and wetting behaviors that may alter floodwater spread as the system becomes saturated. The accuracy of DEM-FIM models in terms of their representation of known flow/inundation relationships, and their suitability for use in managing flows in the Lower Darling system, is currently being assessed.

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