Morphological Evolution and the Sustainability of Deltas in the 21st Century

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Research context and aims:

Situated at the dynamic interface between fluvial and coastal processes, deltas are major socioeconomic and ecological centres that are widely recognised as being highly vulnerable to the combined impacts of climate change and increasing levels of human activity. It is critical that morphological research focuses on developing a clearer understanding of how these **synergistic stressors, operating at a variety of temporal and spatial scales**, influence the multidecadal evolution of these dynamic environments. The **Mahanadi delta in India** has been selected as the study site for this research project, as it provides the opportunity to explore a broad range of stressors in a biophysically diverse deltaic landscape. Furthermore, the delta has regularly been highlighted in recent research as one at great risk from climate change and increased anthropogenic interventions within its distributary network (Jena *et al.*, 2014).

Utilising the cellular automata model CAESAR-Lisflood, the overall aim of this study is to develop a methodology to explore the nature of multidecadal morphological change in delta systems under a range of climatic and environmental change scenarios. These scenarios are designed in such a way so as to encapsulate stressors that are common to a broad range of deltaic environments around the world, including: **Sediment starvation**, due to upstream damming and modifications to the distributary network (Syvitski *et al.,* 2009); **Accelerated subsidence**, often due to groundwater and hydrocarbon extraction (Saito *et al.,*2007); **Accelerated eustatic sea-level rise**, as a result of climate change (Zhang and Church, 2012); **Meteorological extremes**, including shifts in large-scale climate indices such as the monsoon, and changes in the magnitude and frequency of short-term events such as tropical cyclones. **As is presented below, this research also aims to meet three distinct objectives:**

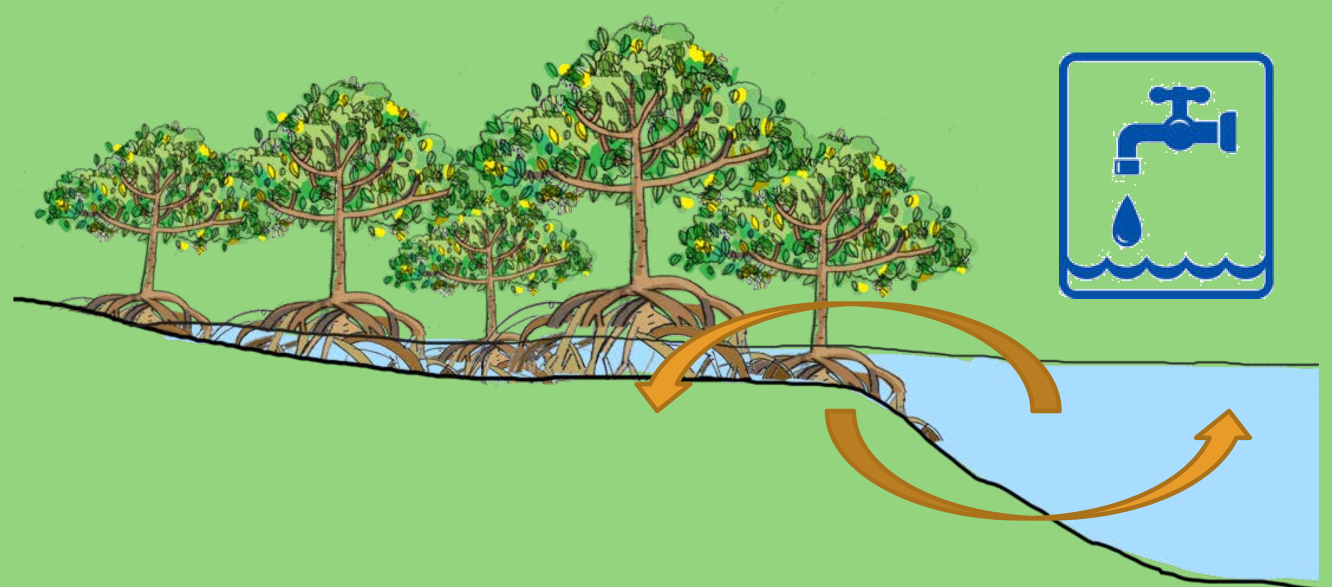
Objective 1: Simulating multidecadal emergent processes in deltaic systems:

Emergent phenomena only become visible at a given scale larger than that of process-form relationships (Schumm and Lichty, 1965).

32 mechanistic scenarios – designed to explore the biophysical impacts of an individual stressor – and 53 synergistic scenarios – designed to explore the combined impacts of multiple stressors – will be input into two catchment models in CAESAR-Lisflood. The scenarios have been designed to represent possible changes **to sediment supply, subsidence rates, sea-level and meteorological factors, under a range of climatic pathways**. Two time periods are investigated: **2015-2045** and **2045-2075.** The two catchments modelled represent that of the most morphologically-active channel in the delta, the **Devi River**; and that of a channel in which morphological activity has decreased; the **Mahanadi River**.

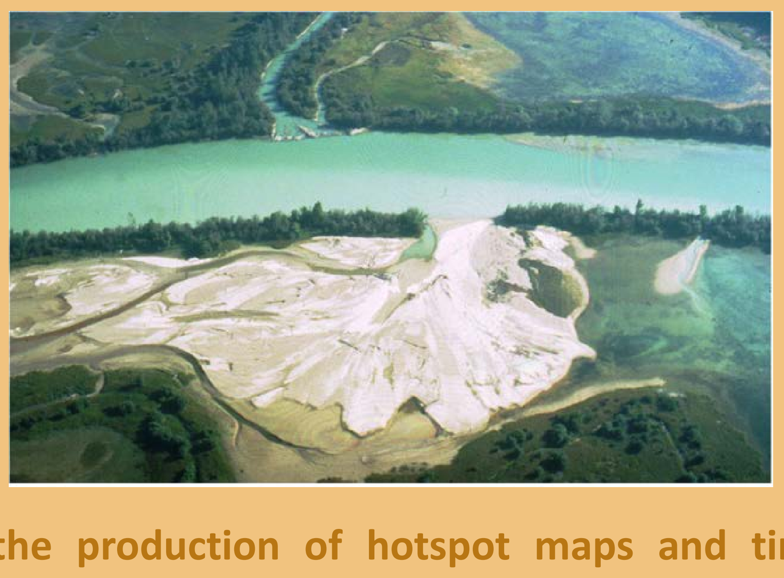
CAESAR-Lisflood is able to simulate the synergistic impacts of both long-term, slow morphological processes and extreme, short-term events. It is hoped this investigation will **enhance our understanding of how emergent processes influence the multidecadal evolution of deltaic environments**, and how they may lead to the crossing of morphodynamic **critical thresholds** under increasing conditions of climatic stress. Compared to terrestrial systems, there are relatively few studies that focus on the successful simulation of long-term emergent phenomena in coastal catchments, and even fewer in deltas.

Objective 2: Integrating morphological modelling within the broader biophysical system



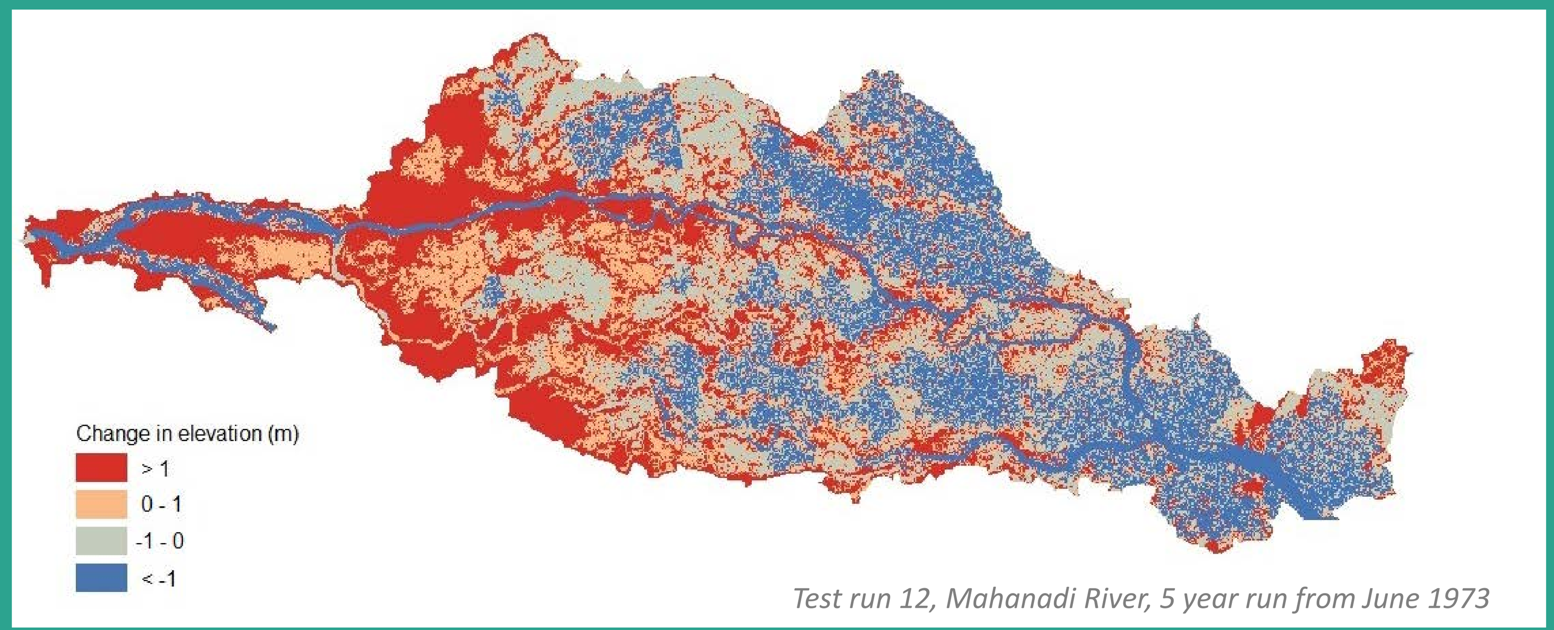
A novel aspect of this research is that it aims to identify important connections between the morphological system and certain ecosystem services that influence the habitability of the delta, such as **water quality, nutrient distribution** and **habitat cover**. In this way this study aims to provide a route towards developing a methodology that produces multidecadal morphological projections in a delta, whilst also gaining a better understanding of how the **whole biophysical system** operates under increasing conditions of environmental stress.

Objective 3: Providing outputs that are directly useful to stakeholders



It is hoped that the production of hotspot maps and time series data, could contribute towards the development of **climate-resilient adaption strategies** in the Mahanadi region. Furthermore, this study provides **a platform to investigate the viability of potential engineering strategies** that could enhance the habitability of a given location, with a particular focus on re-naturalising the channel network.

Preliminary results and next steps:



Test run 12, Mahanadi River, 5 year run from June 1973

At this early stage of the modelling process the current focus is to calibrate the models for both the Mahanadi and Devi River catchments using historical data. Daily river flows from 1972-2012 have been obtained from the Central Water Commission[1]. **Daily sediment loads** of fine (< 0.075 mm), medium and coarse grains (> 0.2 mm), have also been obtained[2] for the period 1973 - 2012. Both data records are taken from a gauging station at Tikarapara, 110 km upstream of the catchments. Preliminary runs such as in the image above are **currently simulating enhanced rates of aggradation and erosion**, and displaying inaccurate flood depths in some regions of the delta plain. **Adjustments to model parameters** are therefore being made before the first scenarios are tested (commencing summer 2016).

References: Jena, P.P. *et al.* (2014) *Journal of Hydrology* 517:847-862; Saito, Y. *e t al.* (2007) *Land Ocean Interaction in the Coastal Zone* 2: 3–9; Schumm, S.A. and Lichty, R.W. (1965) Time, space and causality in geomorphology, *American Journal of Science* 263: 110-119; Syvitski , J.P.M. *et al.,* (2009) *Nature Geoscience,* 2: 681-686 ; Zhang, X. and Church, J.A. (2012) *Geophys. Res. Lett.,* 39 **Data sources: 1 -** courtesy of Sugata Hazra, Rahul Sharma and the WRIS; 2 - courtesy of Rahul Sharma and the WRIS **Images (L-R):** Telegraph India (2014); Lawrence Solomon (2012); Bay Delta Conservation Plan (2011); Go_Greener_Oz (2007); NASA (2013); Scientia Salon (2015); Mangrove Action Project (2016); seddepseq.co.uk (2016).