River delta floodplains: diffusive deposition, crevasse splays, or avulsions?

Jaap H. Nienhuis
Physical Geography, Utrecht University, Utrecht, NL
j.h.nienhuis@uu.nl

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Introduction

During floods, rivers can deposit sediments on their floodplains, but can also erode new channels that later heal (crevasse splays) or form an entirely new channel (avulsions). Close to the coast, in deltaic floodplains, the style of flooding is highly heterogeneous, yet carries important implications for the timescales, length scales, and styles of delta growth.

In deltas, avulsions do not occur until some distance upstream from the river mouth, called the avulsion length (Mohrig et al., 2000; Slingerland & Smith, 2004; Jerolmack & Swenson, 2007). Despite significant recent interest (Kleinhans et al., 2008; Chatanantavet et al., 2012; Hajek & Edmonds, 2014; Toonen et al., 2016; Moran et al., 2017; Chamberlain et al., 2018), avulsion mechanisms and their implications for avulsion lengths and delta size are still poorly understood.

Here we hypothesize that levee breaches result in river delta avulsions depending on two competing controls: floodplain roughness and the water level head between the channel and the floodplain. If the channel-to-floodplain water level head gradually increases away from the river mouth, this would set a preferential minimum distance for river delta avulsions at a location with a critical water level difference.

Methods

Here we use Delft3D to investigate channel-floodplain interactions, and simulate responses from crevasse splays to avulsions including the effects of vegetation and soil consolidation (Nienhuis et al., 2018). We compare these responses to observed floodplain features from the Lafourche lobe of the Mississippi River Delta.

Results

Model simulations show that crevasse splays heal because floodplain aggradation reduces the water surface slope, decreasing water discharge into the flood basin (Nienhuis et al., 2018). Easily erodible and unvegetated floodplains increase the likelihood for channel avulsions. Denser vegetation and less potential for soil consolidation results in small crevasse splays that are efficient sediment traps but that are also short-lived.

We also find a strong dependence of avulsion occurrence on water level head. A high water level head between the channel and the floodplain increases avulsion likelihood. Here, the flow velocities exceed a threshold and erosion dominates floodplain deposition. A low water level head on the other hand tends to heal crevasses and leave only small splays.

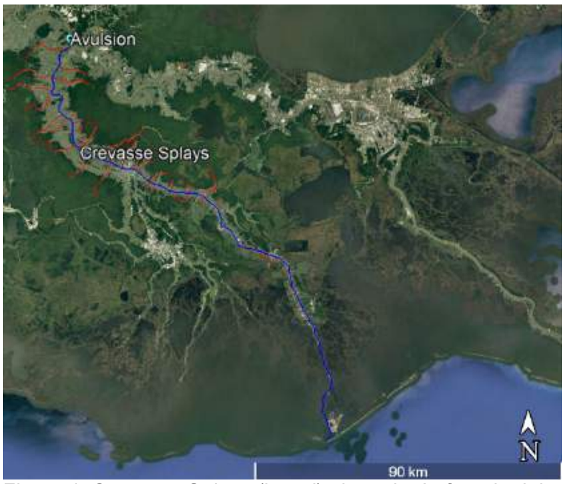

Figure 1. Crevasse Splays (in red) along the Lafourche lobe (in blue) of the Mississippi River Delta. The Avulsion node is marked in green.

We compare these simulated floodplain features to observed the Lafourche lobe of the Mississippi River Delta (Fig. 1). Here the avulsion length is approximately 125 km (Chamberlain et al., 2018).

From the mouth (at 125 km) up to the avulsion node (at 0 km), we find that the elevation difference between the natural levee and the adjacent floodplain increases upstream (Fig. 2). Assuming most floodplains form at or near flood water levels, this would indicate gradually increasing water level heads with distance upstream. We analyzed crevasse splays and found that crevasse splay length also generally increases with distance from the mouth (at 125 km) (Fig. 2). Because river avulse when conditions for crevasse splays are exceeded, it is likely that the Lafourche avulsion formed by a critical water level head that occurred during flood.

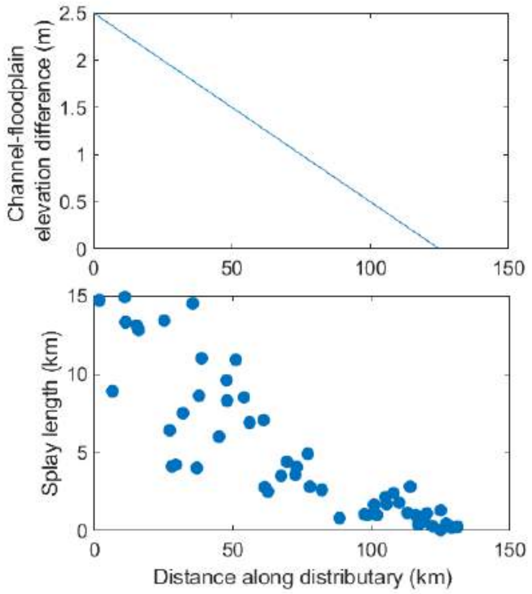

Figure 2. Crevasse Splay Length as a function of distance from the avulsion node (at 0 km) up to the modern river mouth (at 125 km).

Conclusions

Preliminary analysis of the Lafourche lobe of the Mississippi River Delta suggests that crevasse splay size and avulsion locations are dependent on the channel-floodplain water level head, in accordance with our Delft3D simulations. Combined, these investigations will help us understand river delta avulsions and provide critical new insights into controls on large-scale delta morphology and small-scale floodplain and fluvial sedimentology.

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