Experimental Investigation of channel avulsion frequency on river deltas under rising sea-levels

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Introduction and Motivation

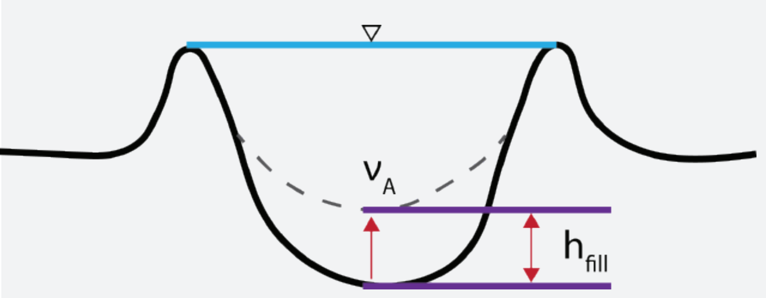
Coastal river deltas are susceptible to drowning via a combination of subsidence and sea-level rise (Syvitski et al., 2009; Higgins et al., 2014). Many river deltas are built by cycles of lobe growth punctuated by abrupt channel shifts., or avulsions, which often reoccur at a similar location and with a regular frequency (Fig 1)(Slingerland and Smith, 2004). However, river avulsions also pose natural hazards to populations living on river deltas (Fig 2).

Fig 1. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) images of yellow river (a) before and (b) after an avulsion.

Fig 2. Damage caused by 2008 Kosi River avulsion in Bihar, India. Image: REUTERS/Krishna Murari Kishan (2008)

How is the avulsion frequency influenced by an increase in sea-level rise?

Avulsion Frequency Theory



$$T_A = \frac{h_{fill}}{V_A}$$

Mohrig et al. (2000); Jerolmack (2009)

Fig 3. Schematic of channel cross section showing the amount of in-channel aggradation (h_{fill}) and the rate of vertical in-channel aggradation (V_A).

Does sea-level rise influence the **amount** or the **rate** of in-channel sedimentation needed to inititate an avulsion?

Experimental Setup and Methods

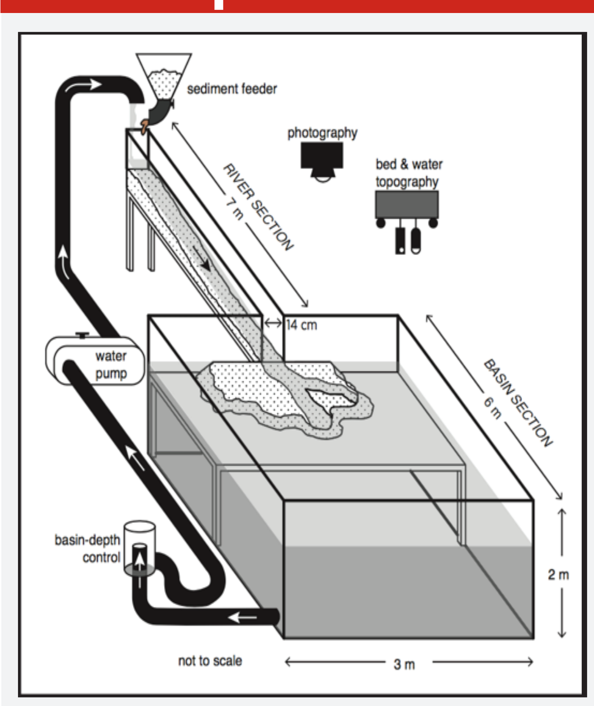


Fig 4. A) Schematic of delta flume with a 7m X 14cm wide alluvial river that empties into a 6m X 3m wide "ocean basin" (Ganti et al., 2016).

Table 1. Flow Parameters

	LOW	HIGH
Sediment supply, Qs [m3/sec]	3.9E-07	8.9E-07
Water discharge, Qw [m3/sec]	2.4E-04	3.4E-04
Normal-flow bedslope, S [-]	4.2E-03	4.1E-03
Normal-flow depth, h [mm]	7.5	11.7
Normal-flow Froude number, Fr [-]	0.59	0.43
Normal Shields number, τ*[-]	0.15	0.2
Backwater length scale, h/S [m]	1.8	
Grain size, D [mm]	0.7	
Submerged specific gravity of sediment, R [-]	0.3	

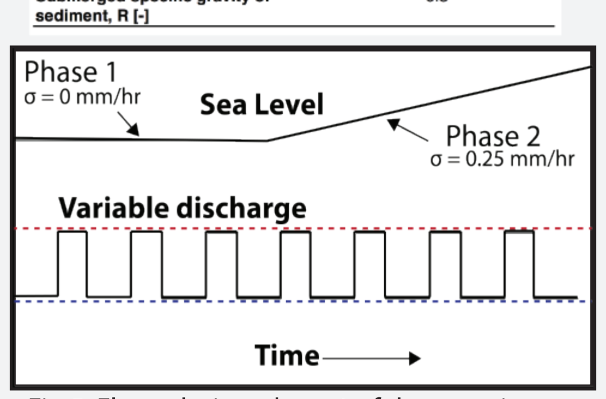


Fig 5. Flows during phase 1 of the experiment were run under constnat sea level and under a rise rate of 0.25 mm/hr for phase 2. Flows were alternated between low and high discharges for both phases.

Time of avulsion (T_A) were identified and determined from images and video captured by overhead cameras before, during and after flows.

An ultrasound distance meter and two laser triangulation sensors were used to measure topography of the delta.

The difference in bed elevation between the inital and final channel scans at avulsion locations were then used to measure the amount of aggradation that occurred (h_{fill}).

Phase 1- Constant Sea Level

Without sea level rise, lobe progradation produced in-channel aggradation andperiodic avulsions every 3.6 +/- 0.9 hours (Fig 6a, 6b, 8a), which corresponded to when channels aggraded to approximately one-half of their flow depth (Fig 6c, 6d, 8b).

Phase 1- Constant Sea Level

With sea level rise (0.25 mm/hr), we observed enhanced aggradation (Fig 6d, 6e), causing channels to aggrade more quickly and avulse more frequently (every 2.1 +/- 0.6 hours) (Fig 8).

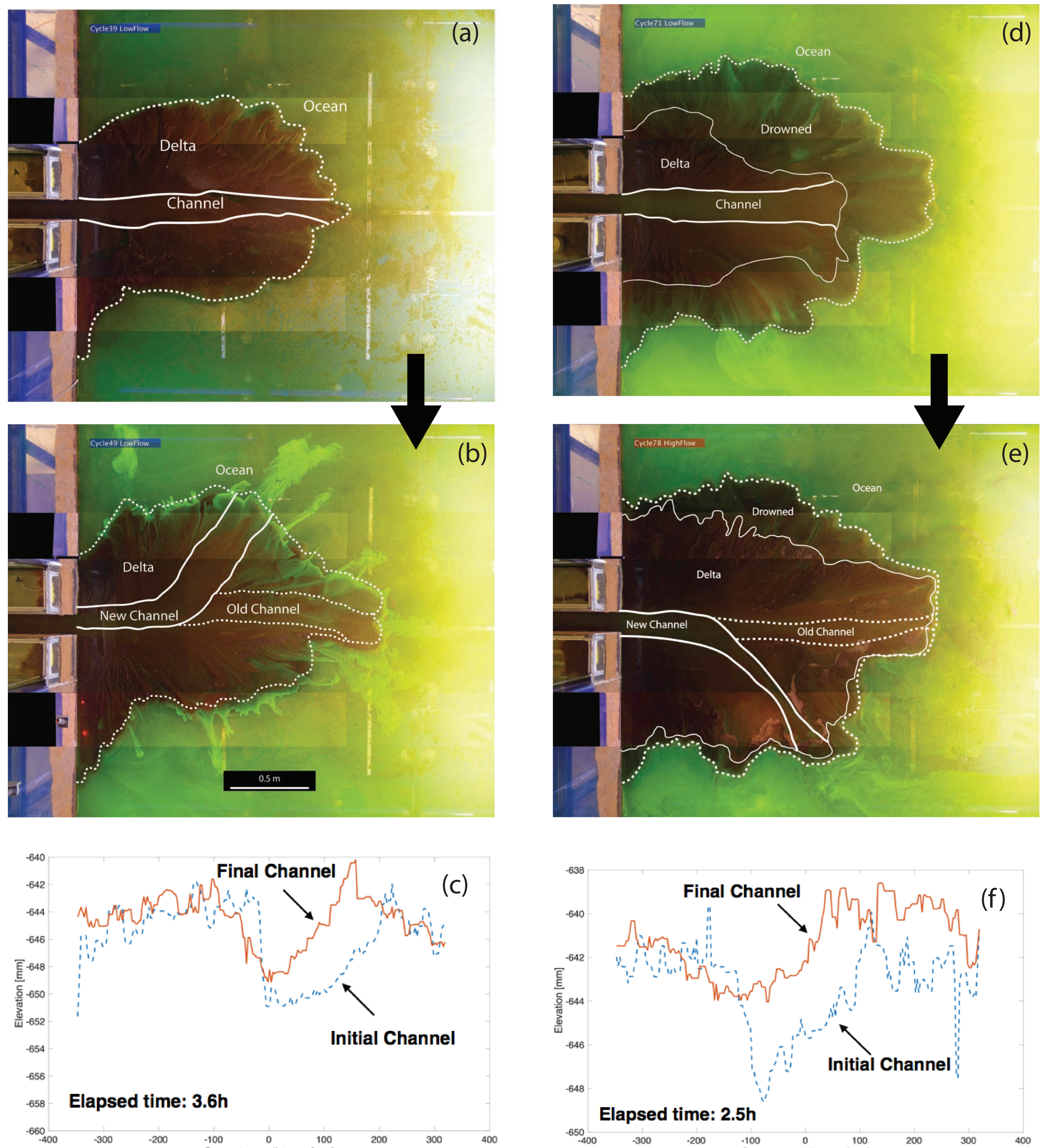


Fig 6. Overhead images of an avulsion cycle for (a and b) phase 1 and (d and e) phase 2. A scale bar is shown in the lower right hand corner of Figure 6b. The solid white line indicates the new channel after avulsion. Channel cross sections for the intial and final channel at the avulsion node for (c) phase 1 and (f) phase 2.

Comparison

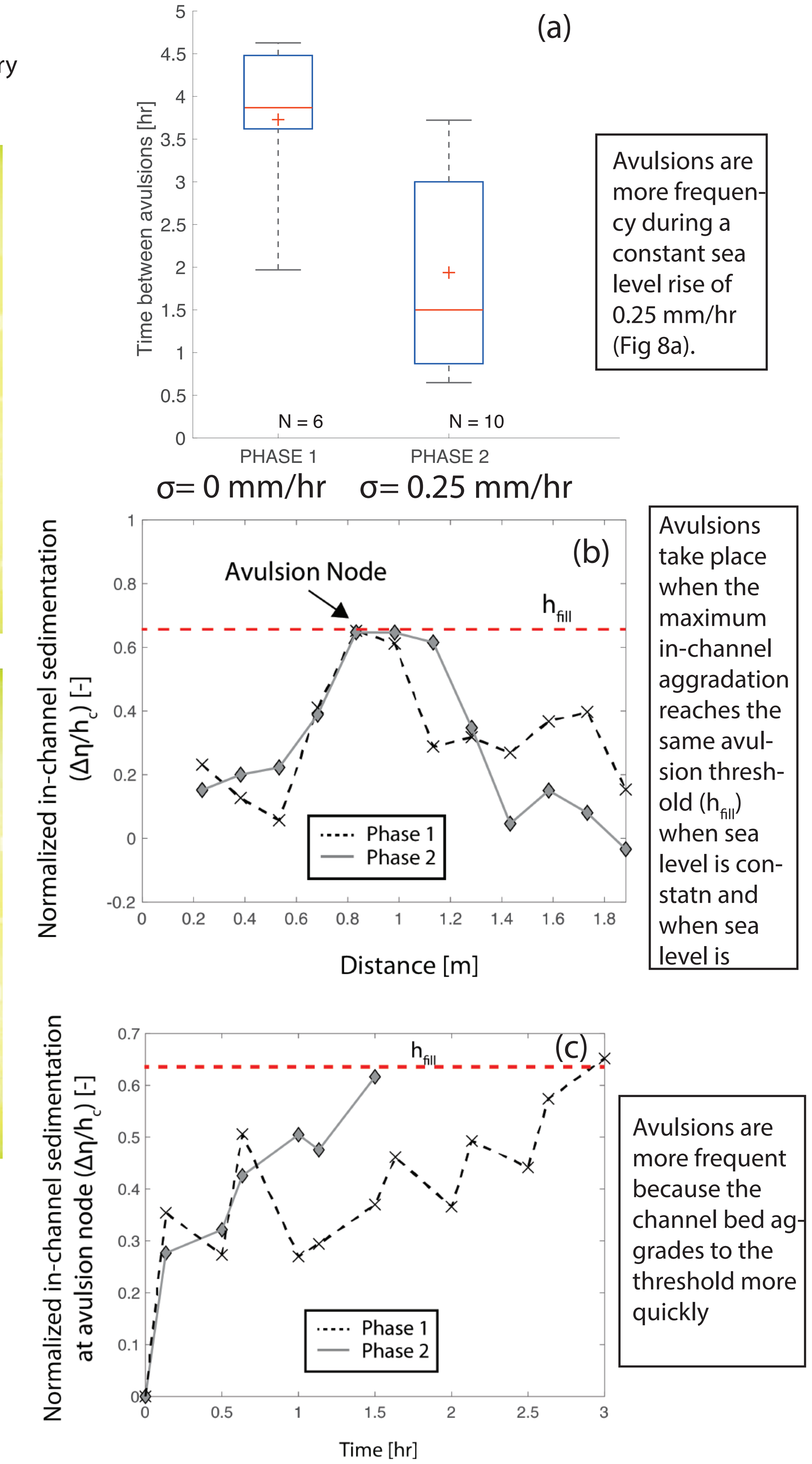


Fig 8. **(a)** Box plot of time between avulsions (hr) for phase 1 and phase 2 of the experiment. Six avulsions were identified in pahse 1 and 10 avulsions were identified in phase 2. **(b)** Normalized in-channel sedimentation through distance downstream. The dashed red line represents the critical amount of in-channel sedimentation needed to initiate an avulsion (h_{fill}). **(c)** Normalzied in-channel sedimentation through time.

References

Ganti, V., A. J. Chadwick, H.J Hassenruck-Gudipati, and M.P. Lamb (2016), Avulsion cycles and their stratigraphic signature on an experimental back-water-controlled delta, J. Geophys. Res. Earth Surf., 121.

Higgins, S.A., Overeem, I. Steckler, MS.S, Syvitski, J.P.M., Seeber, L., Akhter, S.H., (2014). InSAR measurements of compaction and subsidence in the Ganges-Brahmaputra Delta, Bangladesh. J. Geophys. Res. F Earth Surf. 119 1768-1781

Jerolmack, D.J., 2009. Conceptual framework for assessing the response of delta channel networks to Holocene sea level rise. Quat. Sci. Rev. 28, 1786-1800.

Slingerland, R. L., and N.D. Smith (2004), River avulsion and deposits, Annu. Rev. Earth Planet. Sci., 32 257-285

Syvitski, J.P.M., et al. (2009), Sinking deltas due to human activities, Na. Geosci., 2, 681-686.

Acknowledgements

Much thanks to Aisha Morris, Rolf Norgaard, Megan Brown, and UNAVCO/RESESS for their support.

This material is based upon work supported by the National Science Foundation under grant No. 1261833. Any opinions, findings, and conclusions or recommendations expressed in this material are thsoe of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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