EP33C-1083: Reconciling geomorphic observations with simulations of a modern landslide-dam outburst flood using GeoClaw software

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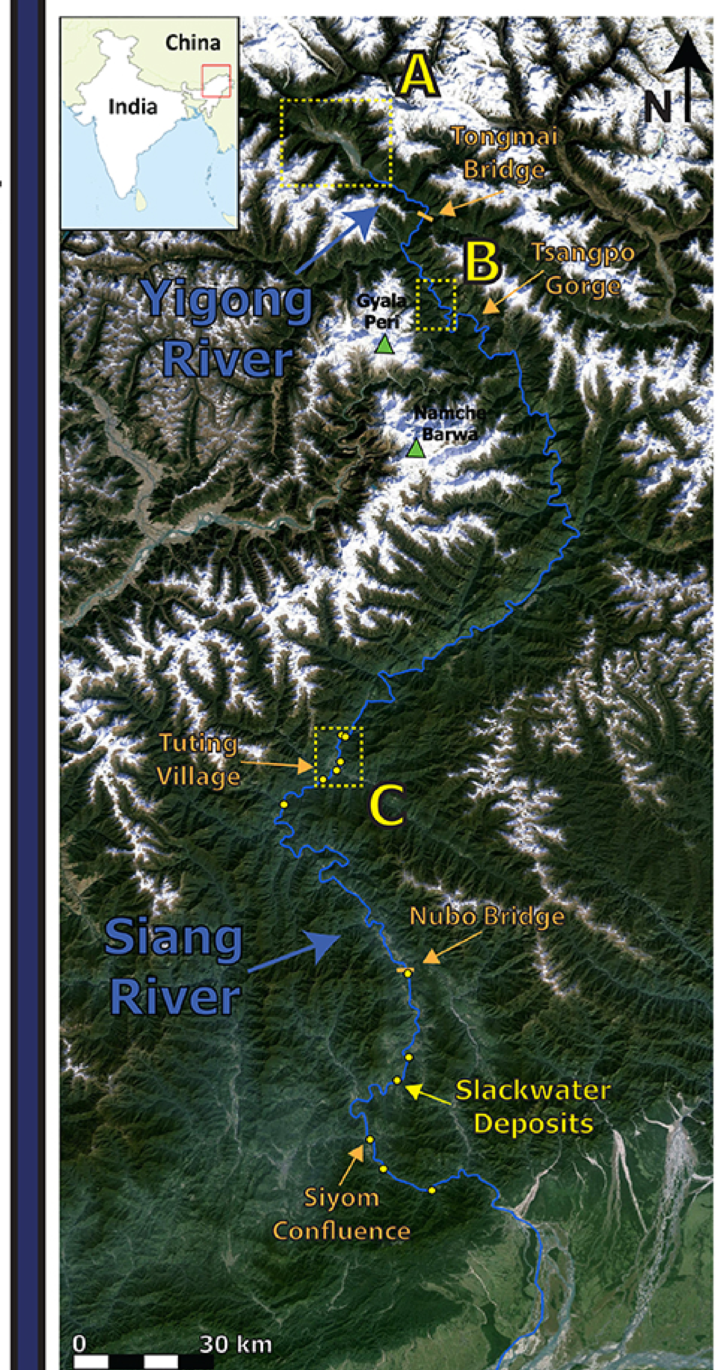
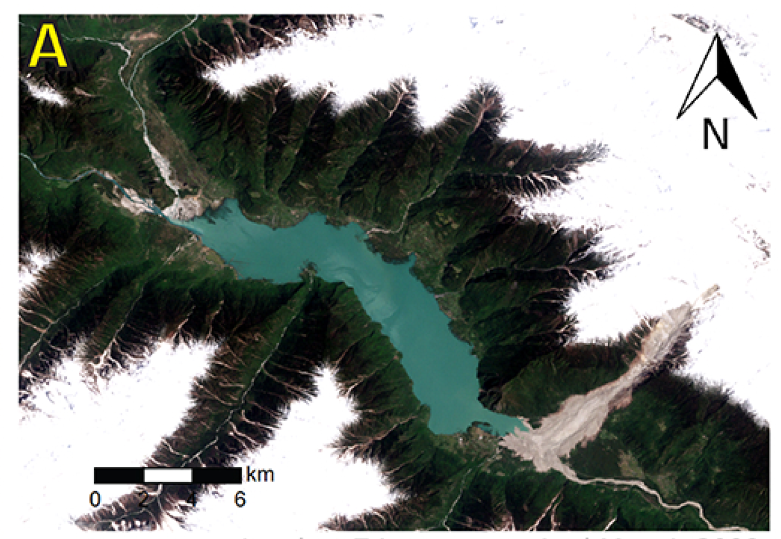
1. Project Overview

- It can be challenging to evaluate **the geomorphic impact of large outburst floods** because they are relatively rare events that aren't often observed directly, but we can **integrate numerical models and observations from the field** to advance our understanding of the role of these events in shaping the landscape
- We use a historical landslide-dam outburst flood event in the eastern Himalaya to develop an approach to investigate the geomorphic impact of outburst floods, including prehistoric megafloods in the region
- We simulate the modern Yigong River landslide-dam outburst flood using depth-averaged 2D shallow water equations in GeoClaw and produce hydraulic conditions downstream that are consistent with observed patterns of erosion and deposition
- Our ongoing work uses GeoClaw to simulate ancient glacial-outburst megafloods (>10^6 m^3/s) to inform our understanding of the role of these events in shaping the Yarlung-Siang-Brahmaputra river valley

2. The Yigong River Landslide-dam outburst flood



- Yigong River in Tibet impounded by massive rockslide-dam (115 Mm^3) in April of 2000
- Impoundment (**pictured below**) lasted 62 days producing a ~3 km^3 lake before a spillway was constructed, reducing its volume by up to ~1 km^3
- Landslide dam failed catastrophically in June after spillway completed, resulting in the second largest outburst flood by volume ever recorded (~2 km^3)
- Flood scoured the Siang R. valley downstream and left many slackwater deposits

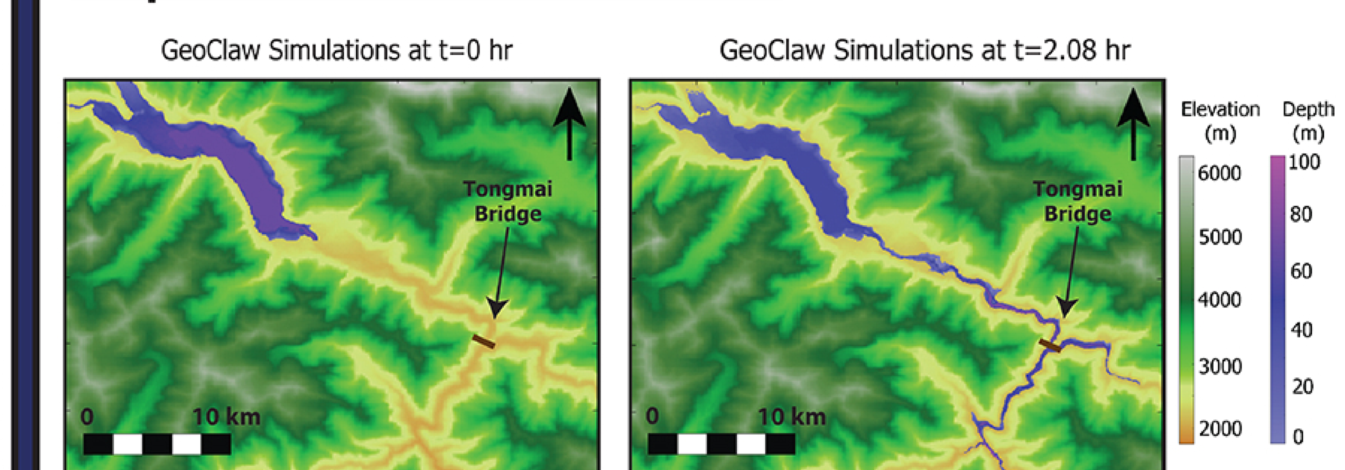


Landsat-7 imagery aquired May 4, 2000

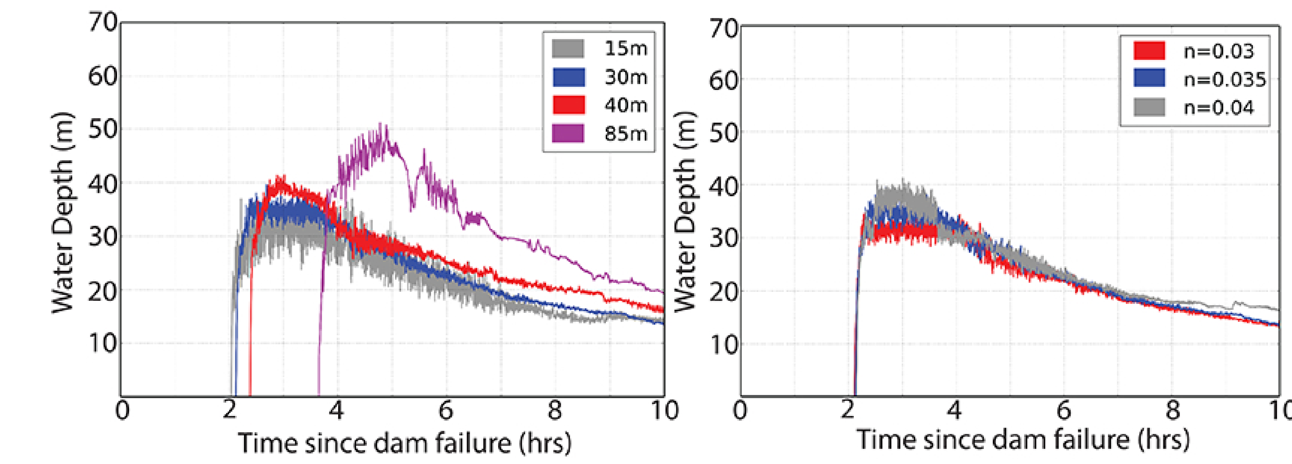
3. GeoClaw: Initialization and tuning

- We simulate the outburst flood in GeoClaw on a custom digital elevation model derived from SRTM 1-arc second (30 m) and 3-arc second (90 m) datasets, and assume instantaneous landslide-dam failure/removal
- Adaptive mesh refinement (AMR) built into GeoClaw allows us to characterize the outburst flood over its entire pathway (>450km) in addition to observing finer details of the flow in refined regions
- We first tested the performance of the model with various maximum grid resolutions and a range of values for the bed roughness parameter, Manning's n (**shown right**)
- A grid-resolution of 30 m was chosen for full simulations of the flood and we refine in regions of interest by a factor of 2 (15m)
- We ran final simulations with the range of best fit dam heights/lake volumes presented in Delaney and Evans (2015)

Snapshots of GeoClaw simulations:

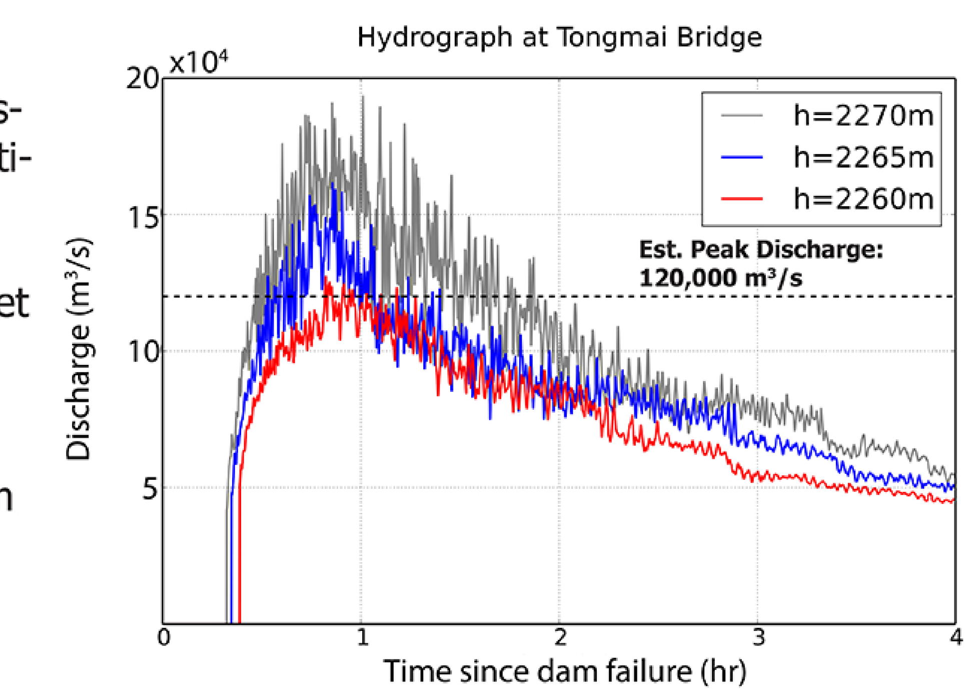


The effect of grid-resolution and Manning's n on depth:



Simulated depth in Tsangpo Gorge ~75 km downstream with varying grid-resolutions from 15m to 85m (**left**), and simulated depth in the gorge with varying roughness values from n=0.03-0.04 (**right**)

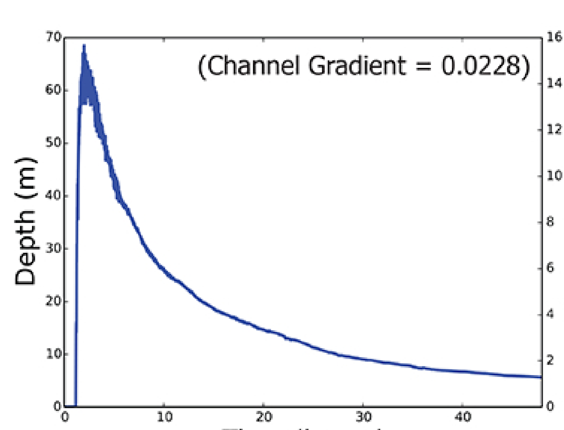
We compare simulated discharge to estimated peak discharge from Shang et al. (2003) at Tongmai Bridge using range of dam heights:

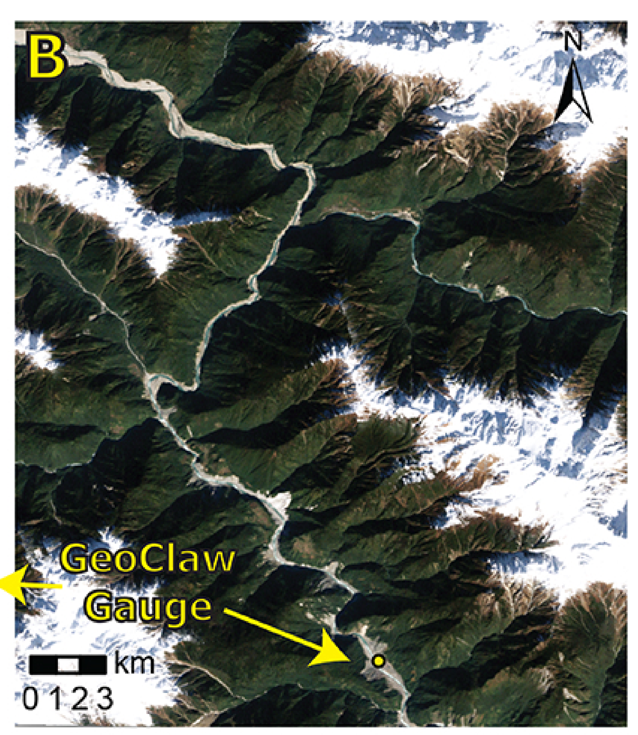


4. GeoClaw results match observed patterns of erosion

Landslides and mass wasting:

- Landsat-7 imagery (**pictured right**) taken shortly after the event illustrates extensive scour and landsliding along the channel just upstream of the Tsangpo Gorge
- Here GeoClaw simulations indicate conditions favorable to erosion for long periods of time; we simulate water depths up to 68 m with bed shear-stresses that peak above 14 kPa

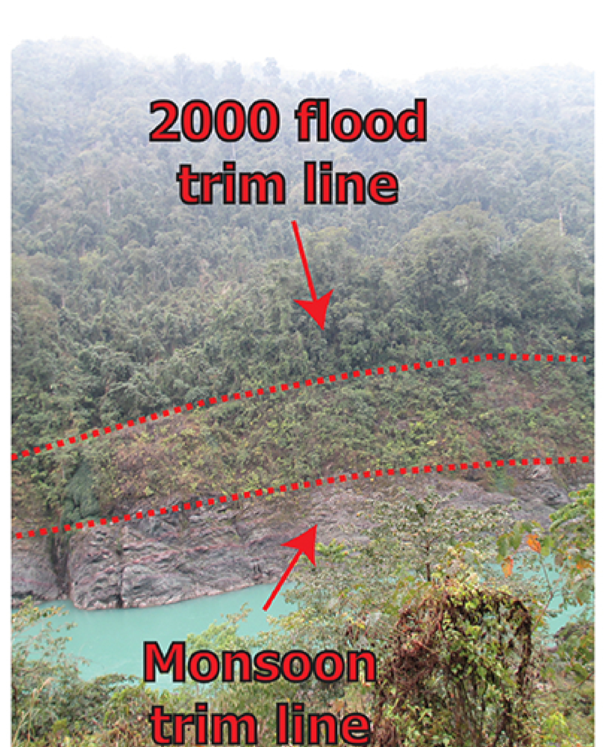


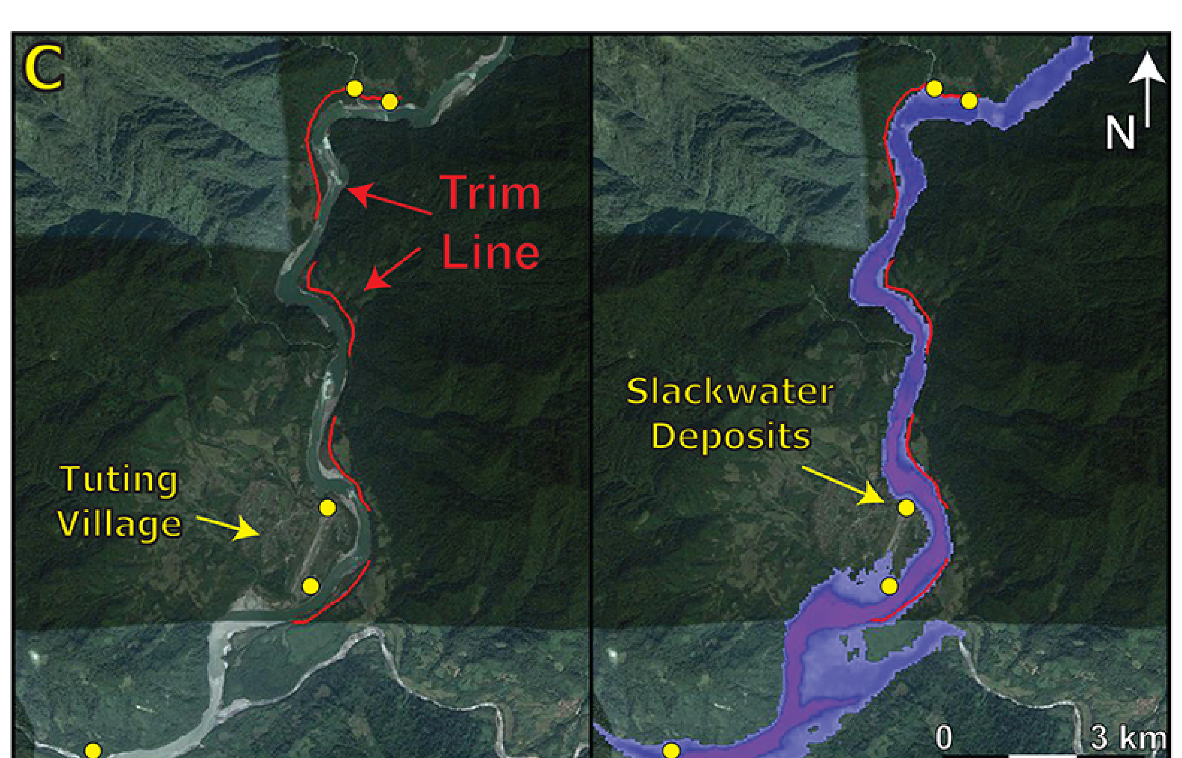


Landsat-7 imagery aquired November 15, 2001

Flood scour and trim line:

- Flood left behind a high-water mark or trim line (**pictured below**) preserved over time in vegetation growth along the flood pathway
- We surveyed these marks and mapped over 60 km of trim line remotely with Google Earth imagery; simulated inundation with the best fit dam height (h=2265 m) are consistent with these geomorphic features:





Google Earth Imagery

5. Simulated inundation matches observed patterns of deposition

Identifying Slackwater Deposits in the Field:

- We mapped and observed 12 slackwater deposits in hydraulically sheltered areas such as terraces and local tributaries
- Pictured **right**: large slackwater deposit near entrance of Siyom tributary and close-up of laminations present in deposits

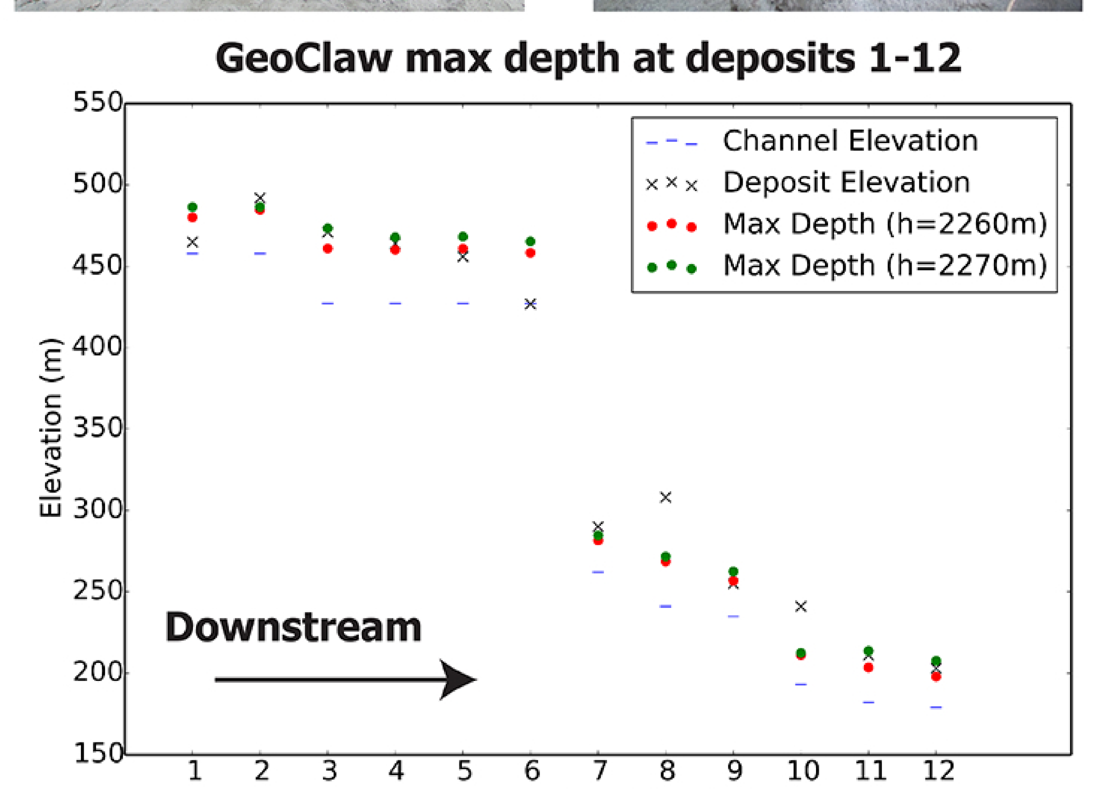
GeoClaw results at location of deposits:

- We ran GeoClaw simulations with the range of dam heights/lake volumes and evaluated which models sufficiently inundated locations of observed deposits:

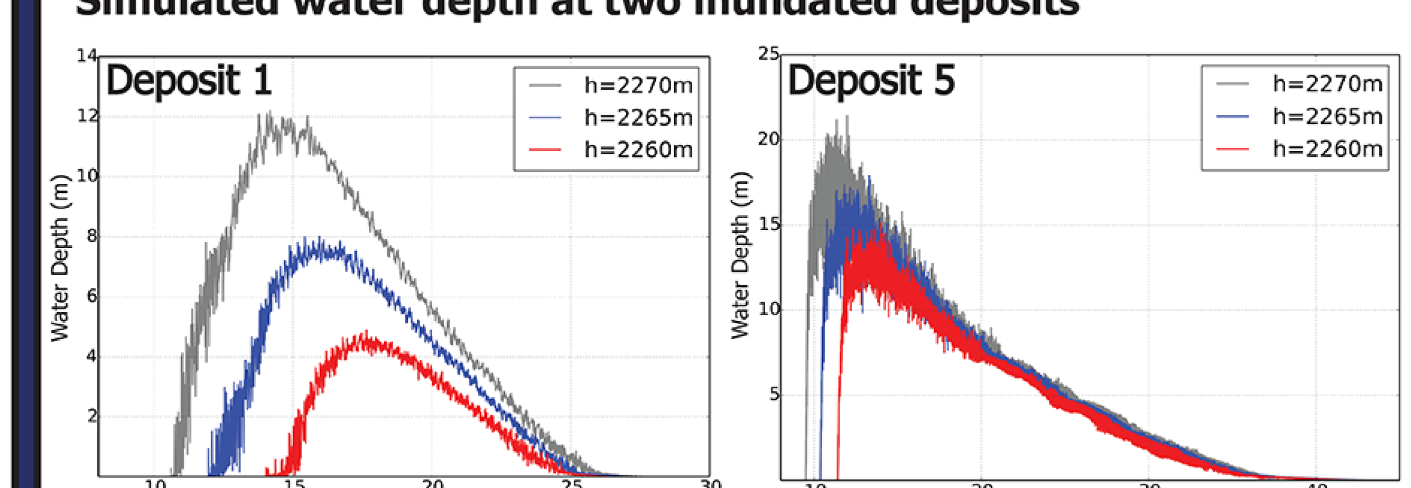
Dam Height (m.a.s.l.)	Impounded Volume on SRTM 3" (km^3)	Peak Discharge at Tongmai Bridge (m^3/s)	No. of Inundated Slackwater Deposits
2260	1.79	1.27×10^5	4/12
2265	2.05	1.61×10^5	6/12
2270	2.32	1.93×10^5	8/12

Right: Simulated stage at locations of observed deposits 1-12 using minimum and maximum dam heights; Deposits 1, 5, 6, and 9 were sufficiently inundated by the full range of dam heights

GeoClaw max depth at deposits 1-12



Simulated water depth at two inundated deposits



Potential sources of error:

1) Innaccurate GPS positions of slackwater deposits along the channel
2) Relatively coarse (30m) resolution of SRTM1" dataset
3) Lack of base flow component in GeoClaw; monsoon stage not accurately represented by base of DEM

6. Conclusions

- **GeoClaw accurately simulates observed hydraulic conditions** at Tongmai Bridge with the range of published credible dam heights/lake volumes
- GeoClaw simulations indicate sustained high-depths and bed shear-stresses in steep parts of the channel where the flood triggered landslides
- Despite uncertanties GeoClaw simulations inundate a majority of surveyed flood deposits using the range of dam heights/lake volumes
- GeoClaw is a suitable tool to investigate the impact of high-magnitude outburst floods on the landscape

7. Future Work

- More sophisticated dam breach scenarios will be explored in the near future to examine the effect of different rates of dam removal
- Simulations of the Bridge of the Gods flood (Columbia River, Washington USA) will be performed to test the performance of GeoClaw with higher-resolution topographic datasets as well as a base flow component
- GeoClaw simulations will be used to investigate ancient megaflood events sourced from the Yarlung River in the eastern Himalaya

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