



HAL
open science

THE IMPACT OF COASTLINE ANTHROPOGENIC GEOMORPHOLOGICAL ALTERATIONS ON FLOOD HAZARDS

Sebastián Nash, Cristian Escauriaza, Maria Teresa Contreras, Antoine
Rousseau

► **To cite this version:**

Sebastián Nash, Cristian Escauriaza, Maria Teresa Contreras, Antoine Rousseau. THE IMPACT OF COASTLINE ANTHROPOGENIC GEOMORPHOLOGICAL ALTERATIONS ON FLOOD HAZARDS. CSDMS 2024: Coastlines, Critical Zones and Cascading Hazards: Modeling Dynamic Interfaces from Deep Time to Human Time, May 2024, Montclair, New Jersey, USA, United States. 2024. hal-04577373

HAL Id: hal-04577373

<https://inria.hal.science/hal-04577373v1>

Submitted on 16 May 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial - NoDerivatives 4.0
International License

Introduction

In March 2015, an unprecedented rainfall event occurred in the hyper-arid Atacama Desert of Northern Chile, known as the driest place on Earth. Characterized by scarce vegetation and limited infiltration capacity, the region was hardly prepared for such heavy precipitation. The exceptional magnitude of the rainfall, coupled with **human-induced geomorphological alterations** in both the river channel and the coastline (filled with mine tailings over decades), caused catastrophic damage and loss of life.

Objective: Evaluate the effect of anthropogenic geomorphological alterations on the flood propagation and the associated hazards.

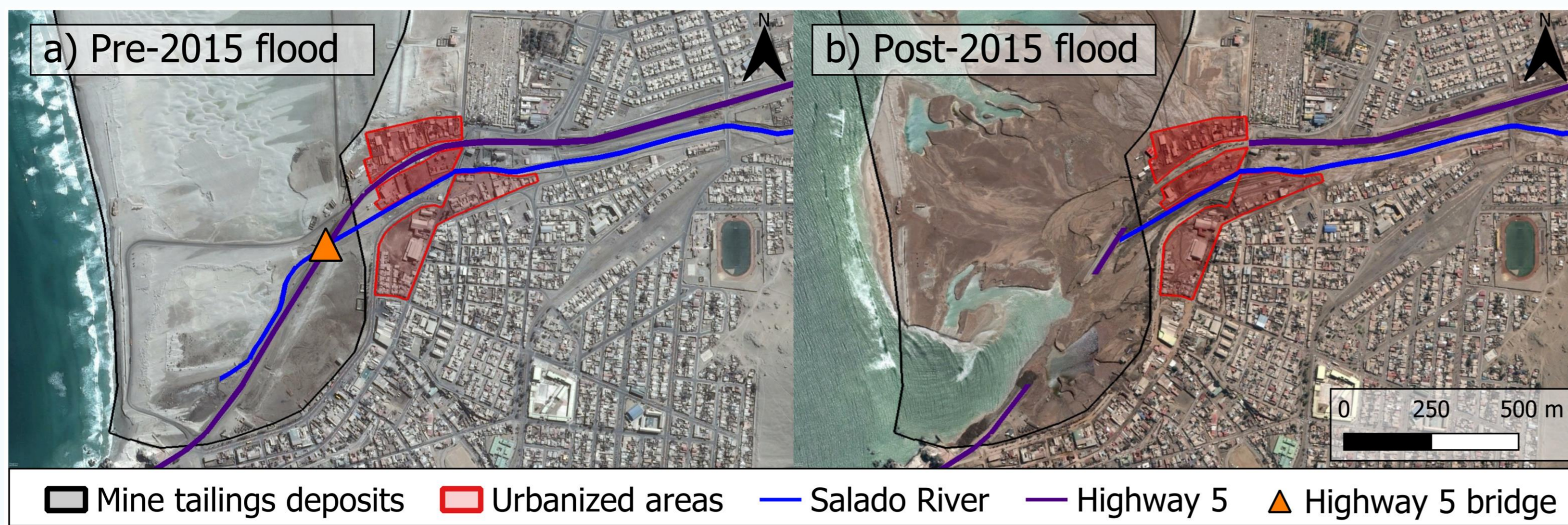


Figure 1: Satellite images captured before and after the flood of March 2015, showing the dramatic topographic changes produced.

Methodology

The event is simulated with a Saint-Venant model coupled with sediment transport and a rheology model [1]. The estimated hydrogram H1 [2], from Figure 2, was used to propagate the flood from the upstream boundary. To isolate the geomorphological alterations effect, the flood is simulated under two scenarios: Pre-2015 flood topography and Post-2015 flood topography.

Table 1: Simulations carried out for the analysis.

Topography	Initial condition	Border Condition
Pre-2015	Dry-Bed	H1
Post-2015	Dry-Bed	H1

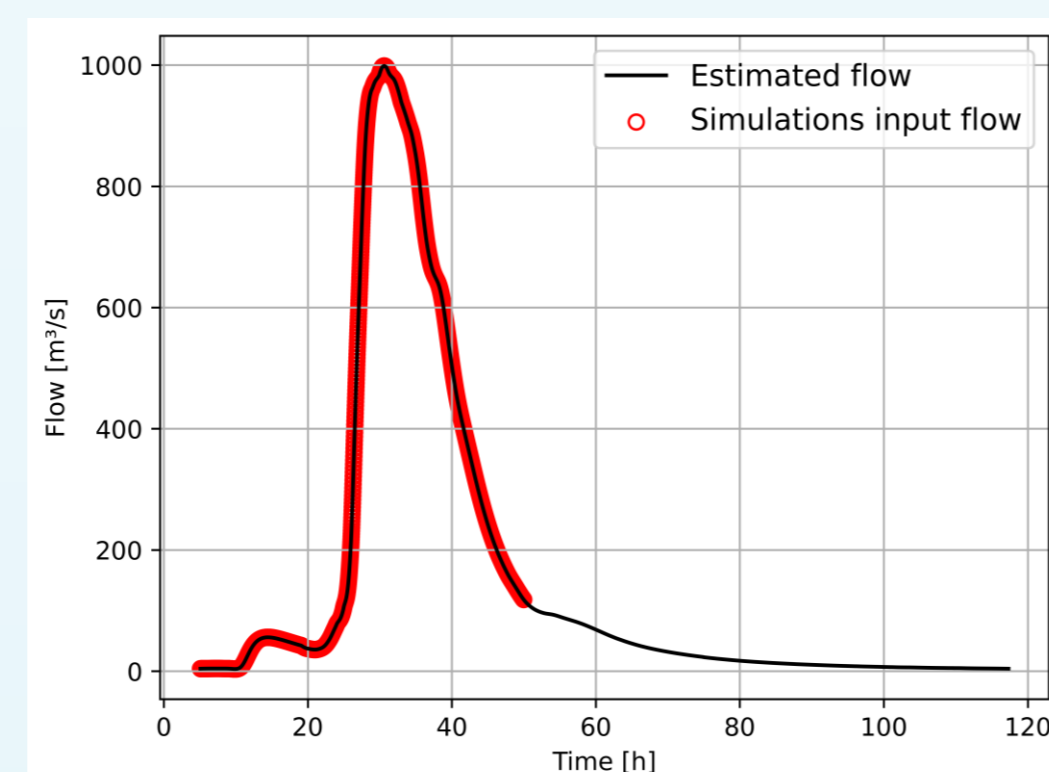


Figure 2: Estimated hydrogram for the event.

Results: Flood extent

Numerical results evidence that, with the pre-2015 topography, a blockage effect occurs where the sea outflow is impeded by the mining tailings and nearby infrastructure along the channel. This creates an upstream stagnation zone and redirects the flood towards the city center. In this case, the inundated area increases in 12% at a watershed level.

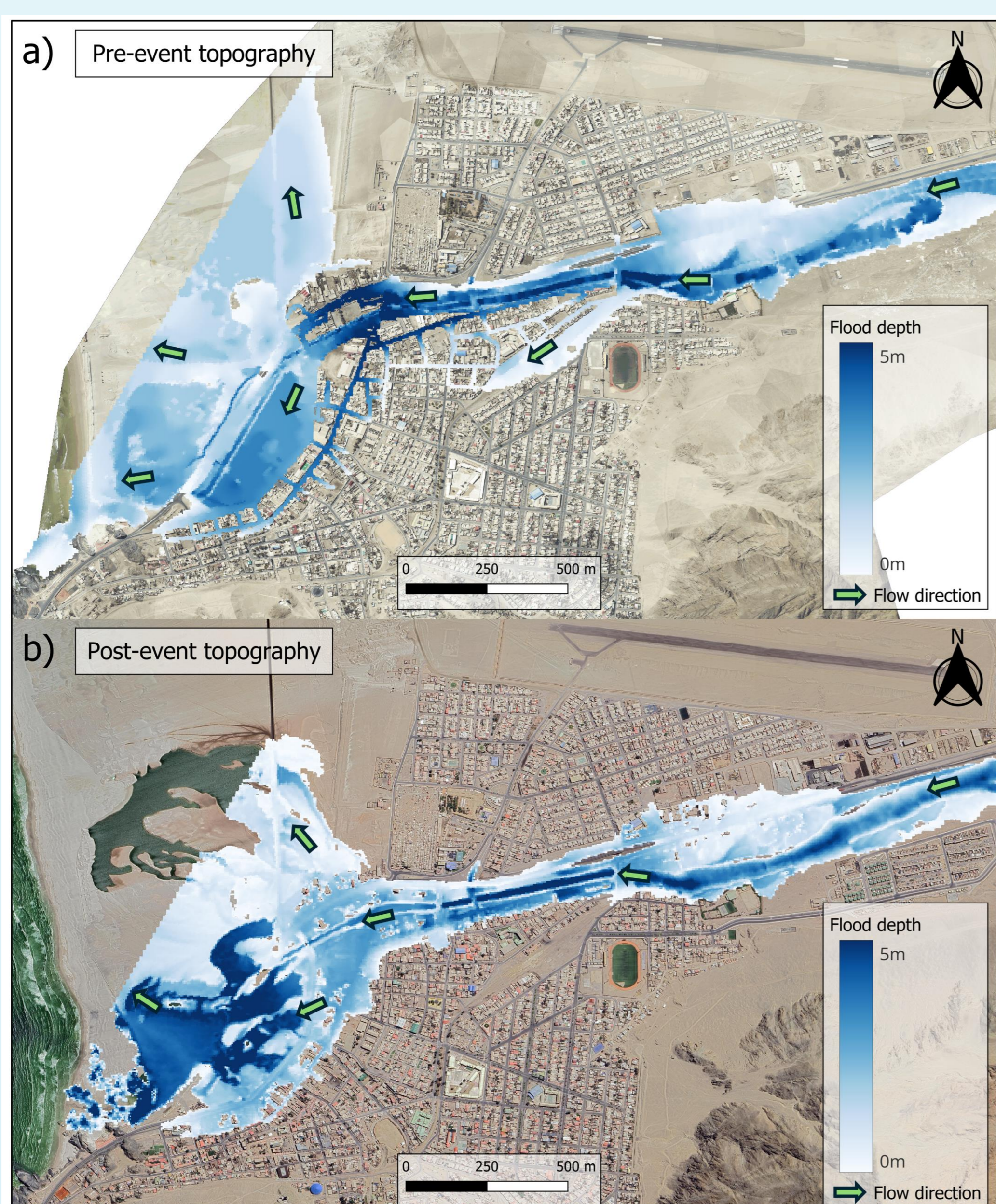


Figure 3: Flood propagation showing a flow rerouting towards the city center for the pre-2015 topography.

Hazards

The pre-2015 topography presents a larger area with High Hazard as one moves away from the channel thalweg, evidencing a **spatial expansion of the hazard**.

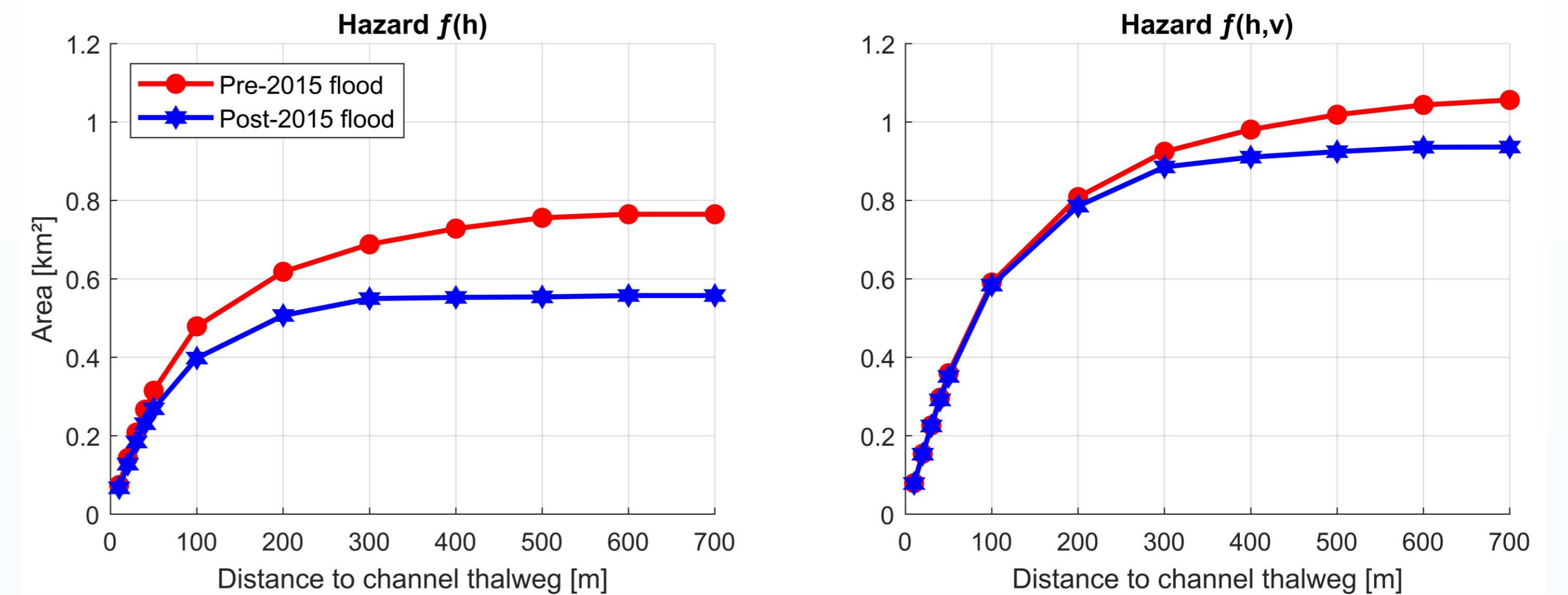


Figure 4: Area affected by a high hazard as a function of the distance to the channel thalweg.

Forces

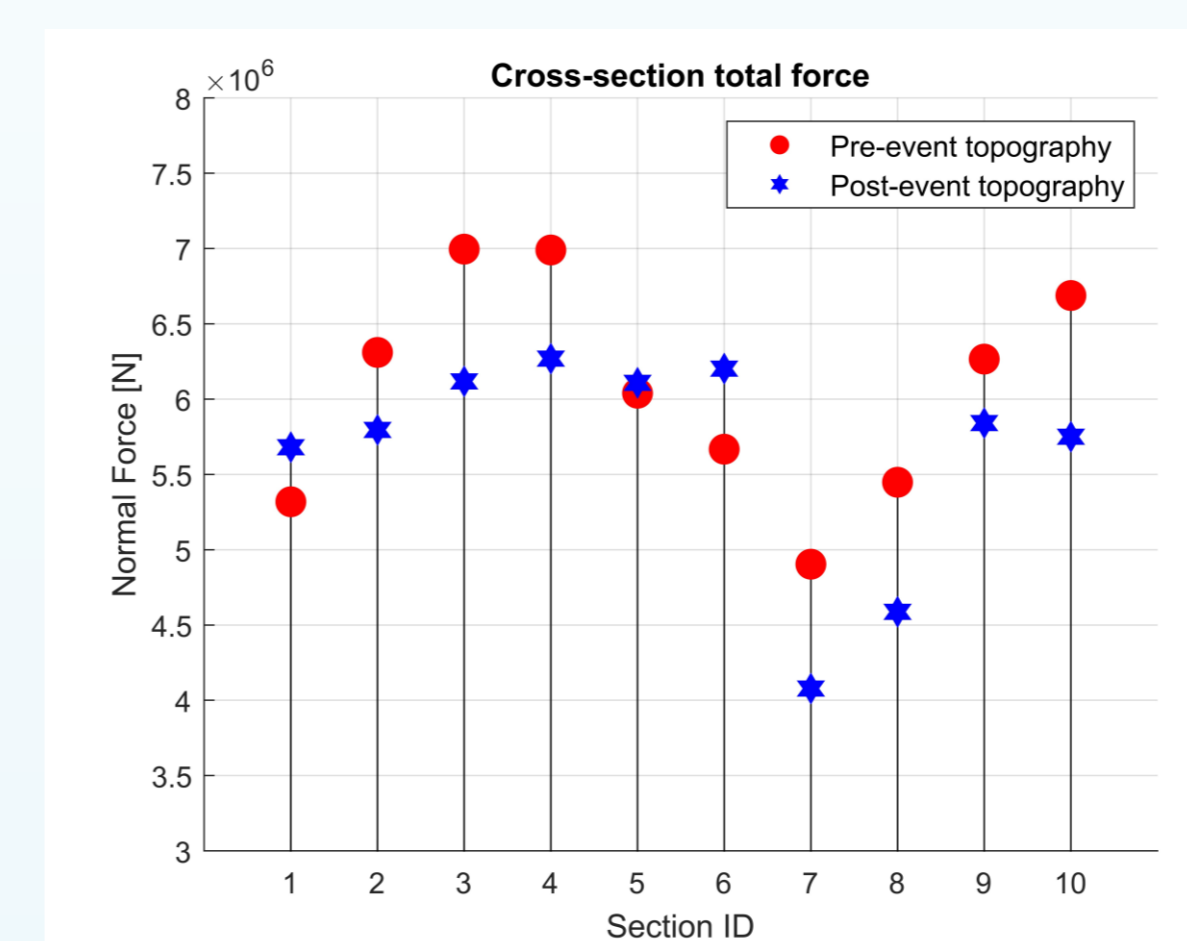


Figure 5: Total force exerted by the flow over 10 channel cross-sections.

The pre-2015 topography has shown to increase the total normal force in 7 cross-sections out of 7. On average, there is an increase of 430 kN per section. Thus, this topographic condition **increased the destructive power of the event**.

Conclusions

- The anthropogenic alterations to the coastal geomorphology played a major role during the propagation of the 2015 flood in Atacama, increasing the affected area, expanding the hazards and increasing the strength of the flow.
- Alterations to coastal geomorphology can play an important role upstream.

Upscaling models

Classical Saint-Venant models are **very time consuming** because of the fine-scale topographic information needed by the model. Simulations presented here lasted 8 days, only to simulate 2 days of the flood.

In the context of urban floods, the flood can be simulated over a coarse grid, adding fine-scale topographic features at a subgrid scale through a porosity parameter. With this technique, simulations speedup can be from a factor of 10 to 1,000.

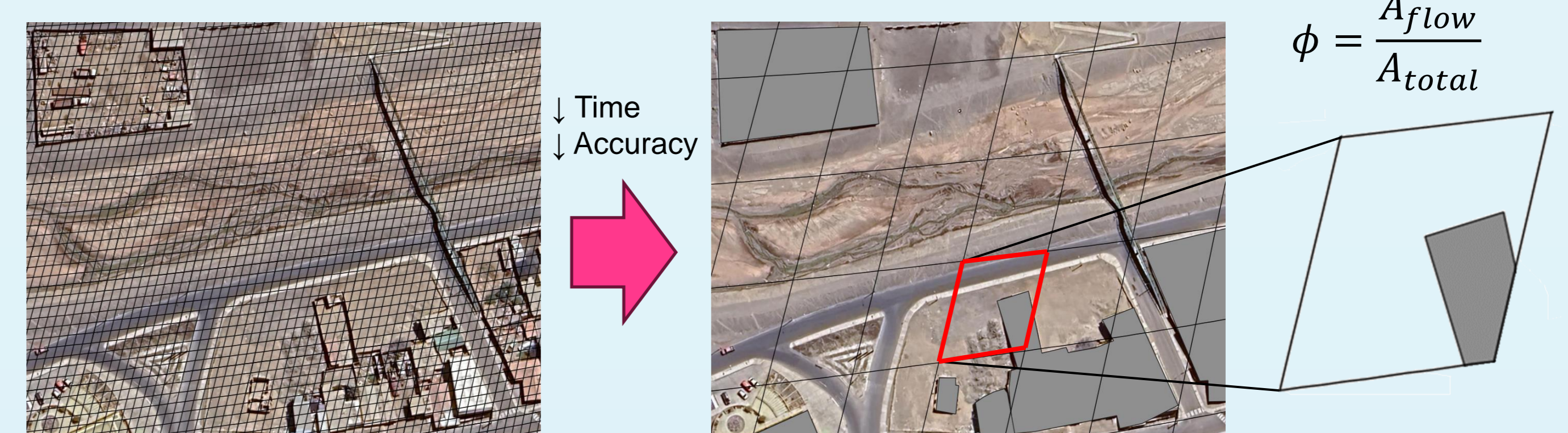


Figure 6: Porosity concept for urban flood modelling using coarse grids.

References

- Contreras, M. T. and Escauriaza, C. (2020). "Modeling the effects of sediment concentration on the propagation of flash floods in an Andean watershed." *Natural Hazards and Earth System Sciences*, 20(1), 221–241.
- Wilcox, A. C., Escauriaza, C., Agredano, R., Mignot, E., Zuazo, V., Otárola, S., Castro, L., Gironás, J., Cienfuegos, R., and Mao, L. (2016). "An integrated analysis of the March 2015 Atacama floods." *Geophysical Research Letters*, 43(15), 8035–8043.

Acknowledgements

This work was supported by CIGIDEN, INRIA through the FLOTTE associated team, and the supercomputing infrastructure of the NLHPC (ECM-02).