# An improved dataset of ASTER elevation time series in High Mountain Asia to study surge dynamics

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Abstract

Sharing is encouraged

## A. Context and objective

Glacier surges can result in surface elevation changes of more than 100 m in a few months. The ASTER sensor permits to get more than 20 years of global DEMs of high temporal resolution, but with average quality. We developed a processing chain to filter time series of elevation that preserves surge signals and that resample DEMs at monthly interval.

## B. Data

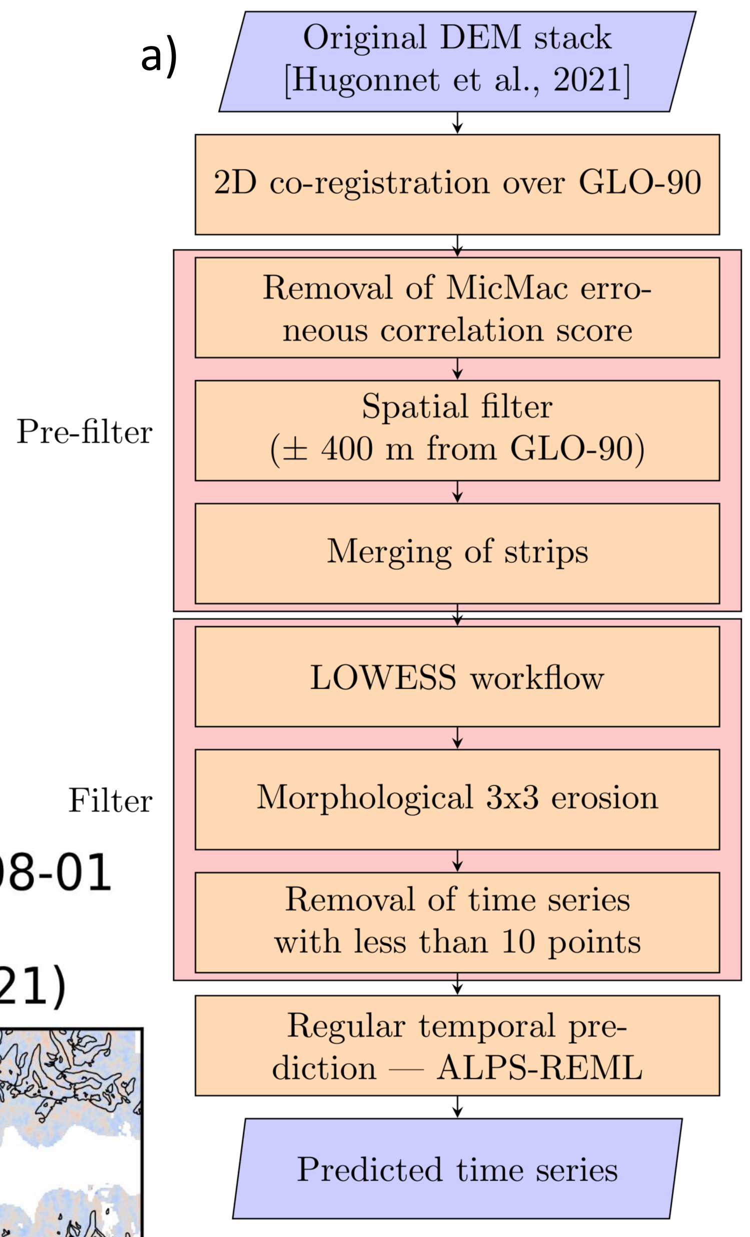
We use unfiltered DEM stacks at 100 m resolution from Hugonnet et al. (2021), covering part of the Karakoram (High Mountain Asia) for about 19 years. The raw time series have a high temporal density : 50 % of intervals are ≤ 13 days, 90% ≤ 2 months. The surface velocities are from the NASA MEaSUREs ITS_LIVE project (Gardner et al., 2022).

## C. Method

The two core steps of our workflow (Fig. 1.a) are:

1) a filter workflow based on the weighted LOWESS method (*scikit-misc* implementation; Derkacheva et al., 2020),

2) a B-spline prediction with automatic hyperparameter optimisation: ALPS – REML method (Shekhar et al., 2021). The LOWESS workflow in in supplementary material online (Suppl. 1).



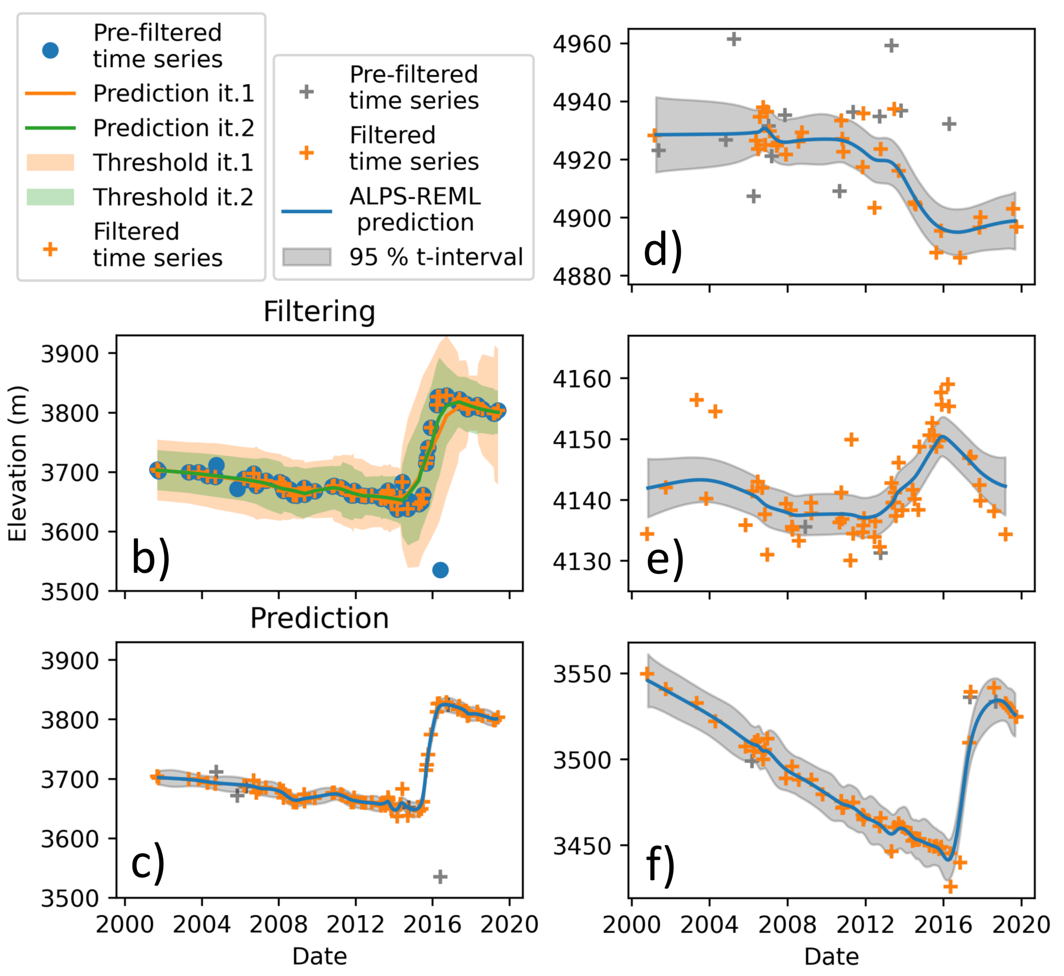
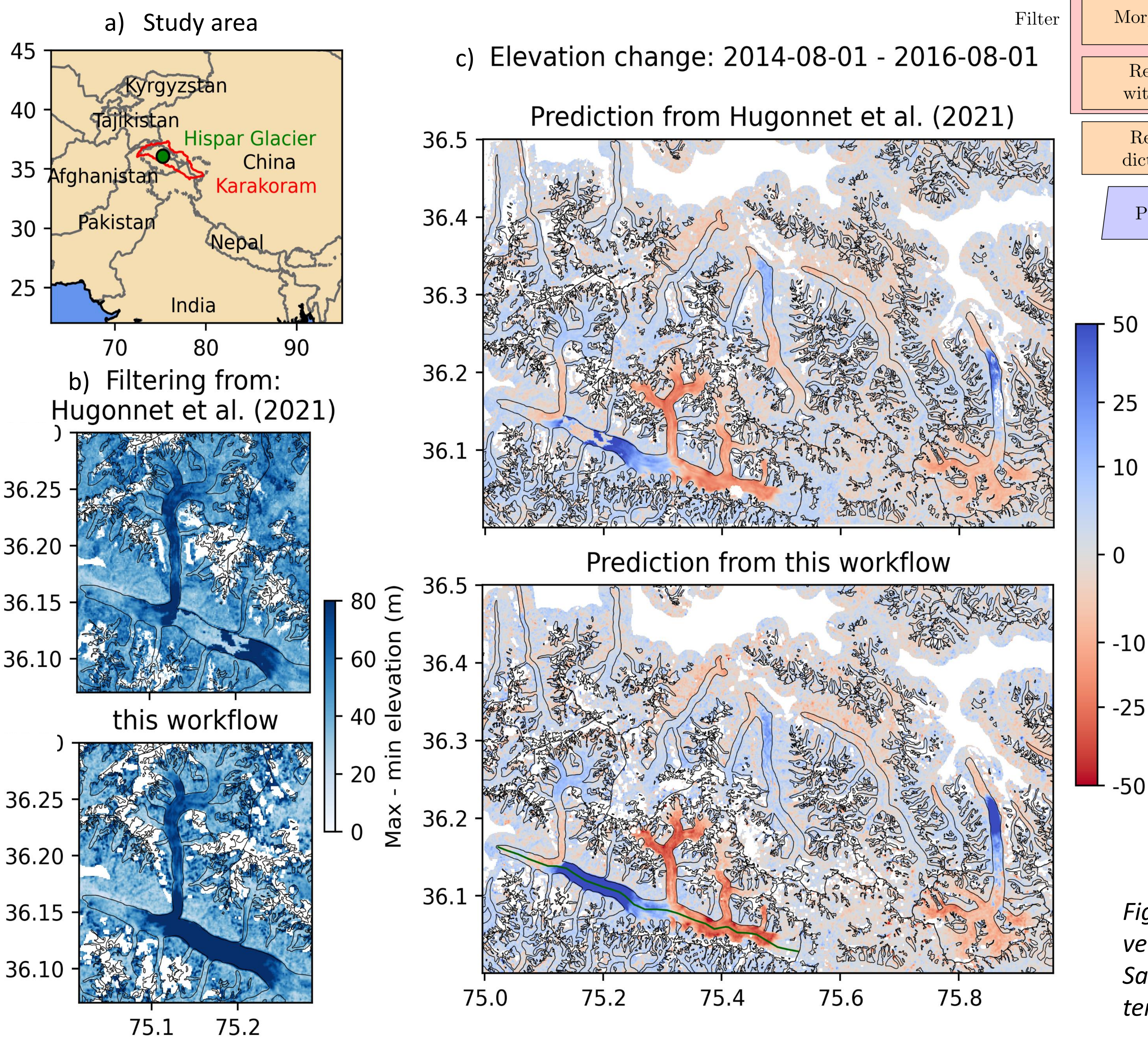




*Fig. 1: Workflow (a), detailed filter (b) and prediction (c) over a same time series, and three other examples of filtering-prediction (d-f)*

*Fig. 2: Study area (a) and comparison of this workflow and the original one (Hugonnet et al., 2021) : filter results (b) and elevation change maps over two years (c). The green centerline on the Hispar glacier (bottom-left of lower c) is related to Fig. 3, starting from the Hispar pass (right).*

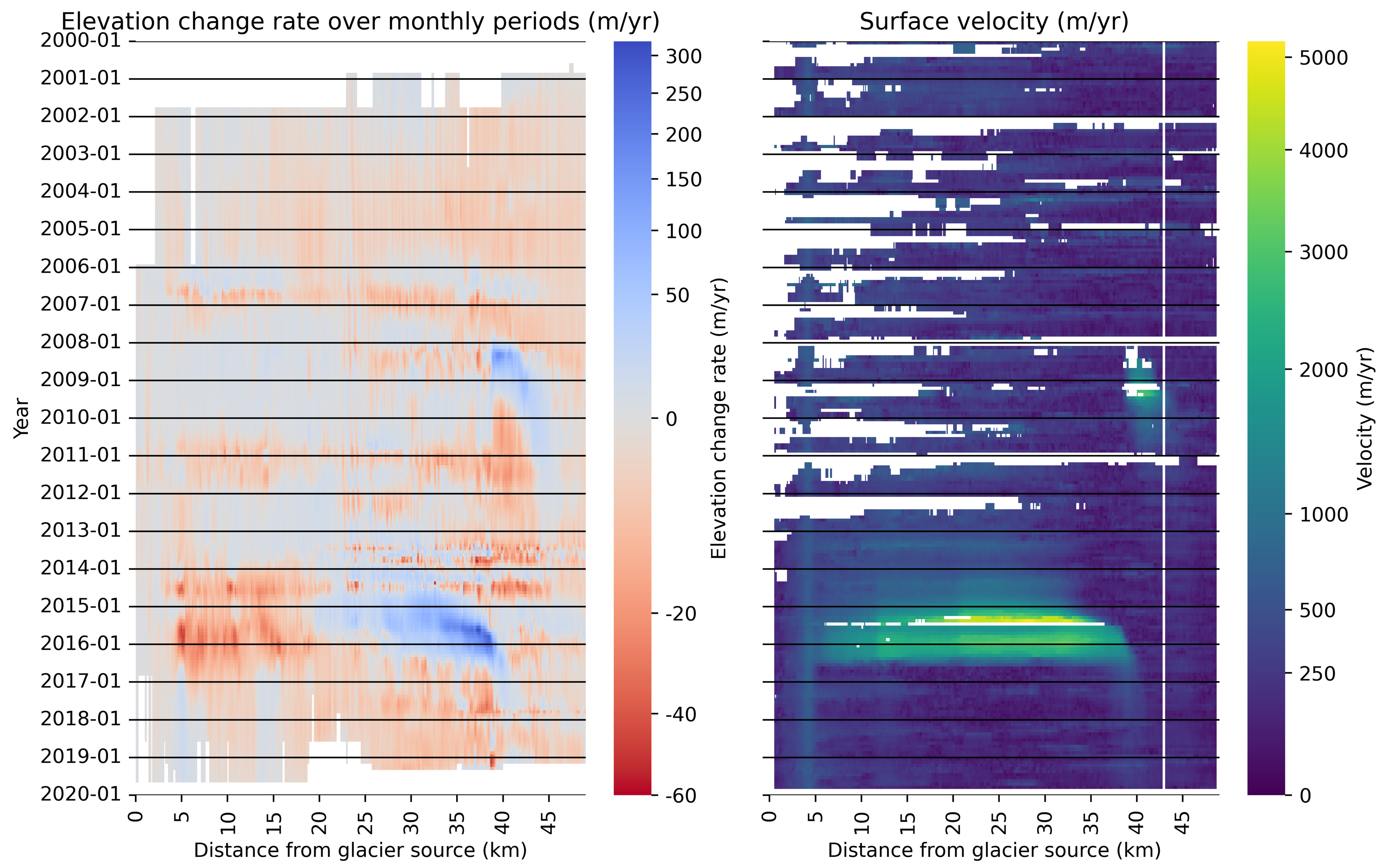



## D. Results and discussion

The filter and prediction methods preserve most of the surge signals, compared to the filtering of the original dataset : unrealistic holes/lower dh in reservoir and receiving areas (Hugonnet et al., 2021; Fig. 2b-c).

- Comments on the LOWESS workflow
  - Moderate sensitivity to noise and overfitting (Fig. 1d,e)
  - Not reliable for particularly noisy ASTER time series in some accumulation areas, steep slopes… (Fig. 2b; time series in Suppl. 2)
- Comments on the prediction – ALPS-REML
  - Surge signals are mostly preserved (Fig. 1c-f & 2c; time series in Suppl. 2)
  - Small "instabilities"/overfitting occurs at dense point clusters (Fig. 1f; time series in Suppl. 2).

*Fig. 3: Hovmöller diagrams – elevation change per month and surface velocities along a centerline of the Hispar glacier (green line, Fig. 2c). Sampling each 100 m. Velocities are monthly averages with a maximum temporal baseline of 100 days.*




## E. Case study : Hispar 2015/16 surge (Fig. 2c; Fig. 3; Suppl. 1)

- Timing, estimated from DEM data only : mid-2014 – mid-2016, similar to Guo et al. (2020) and Paul et al. (2017) with velocities.
- Similar elevation loss timing with Yutmaru/North branch reservoir (time lapse and time series in Suppl. 2). Guo et al. (2020) with velocities point to an onset of Yutmaru first.
- The 2008⁺ gain in thickness around 40⁺ km is the surge of the Kunyang tributary.
- A previously unnoticed early-2014 short elevation rise in receiving area seems to occurs (Suppl. 1 time lapse).
- The elevation changes patterns and values are similar to those of Guo et al. (2020) and Bhambri et al (2022) over the same periods, but our time series permits to restrict the analysis much more precisely on the surge timing (Fig. 2c).
- Spatio-temporal patterns of elevation changes matches those of velocities. The surge-affected area on both diagrams goes up to a serac fall, around 5 km from the Hispar pass, also visible on Fig. 2c.

Hovmöller diagrams of other surge-type glaciers are available in supplement (section 3), including a complete surge cycle.

## F. Conclusion

This workflow is efficient at preserving surge signals automatically. It has a few flaws (overfitting or surge smoothing) depending on the time series qualities. It is applicable at regional scales without tuning. It permits consistent elevation change analysis of surge events with time scales of a few months, rarely explored so far.

# SUPPLEMENT TO THE POSTER: An improved dataset of ASTER elevation time series in High Mountain Asia to study surge dynamics

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April 2024

## 1 LOWESS filter workflow

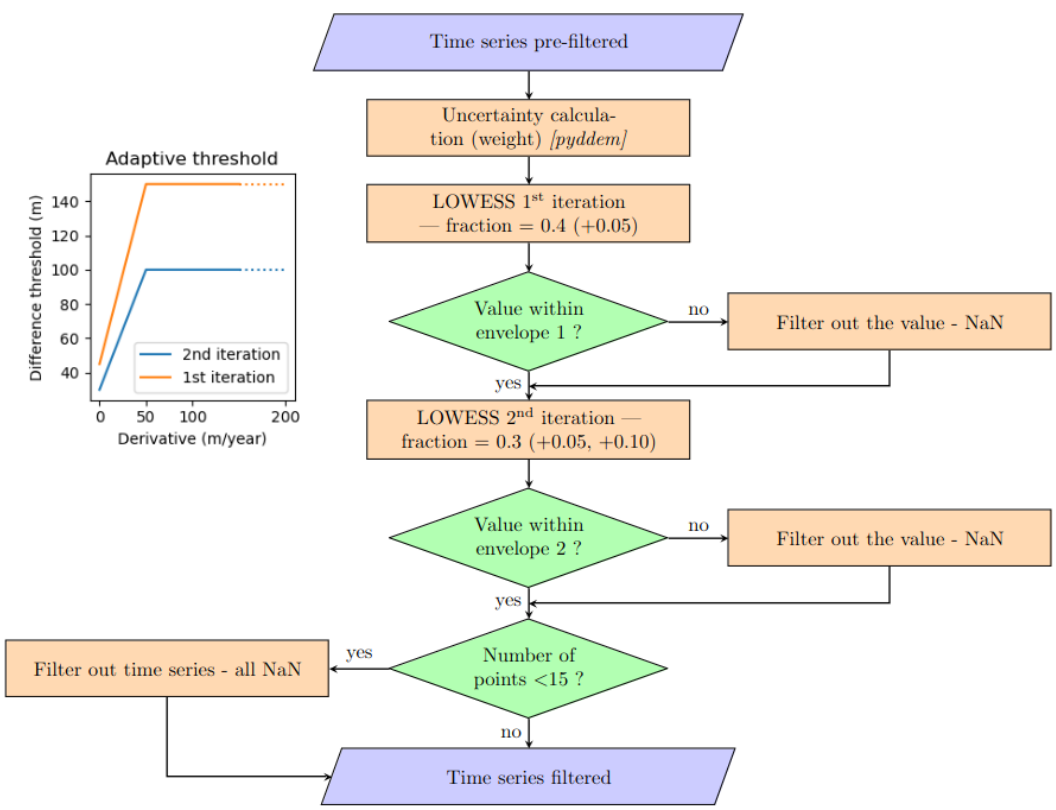


Figure 1: LOWESS part of the filter workflow developped in this study.

## 2 Hispar time series

Hispar 2000-2019 time lapse of elevation change : https://youtu.be/PFQdwCmGpnM.

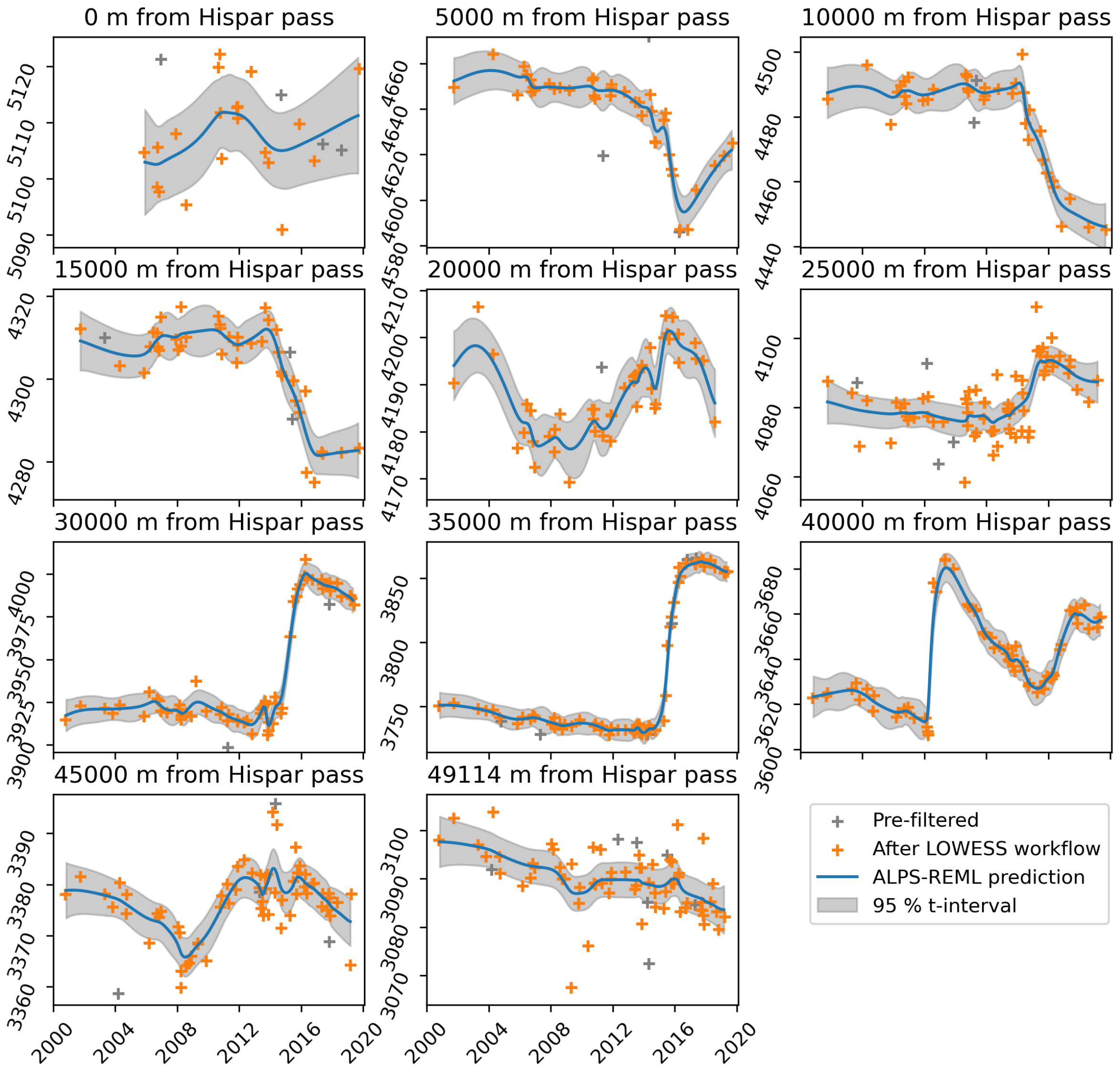


Figure 2: Time series processed each 5 km along the Hispar centerline of the poster (Fig. 3 here). The y-axis is the elevation (m), and the x-axis the dates.

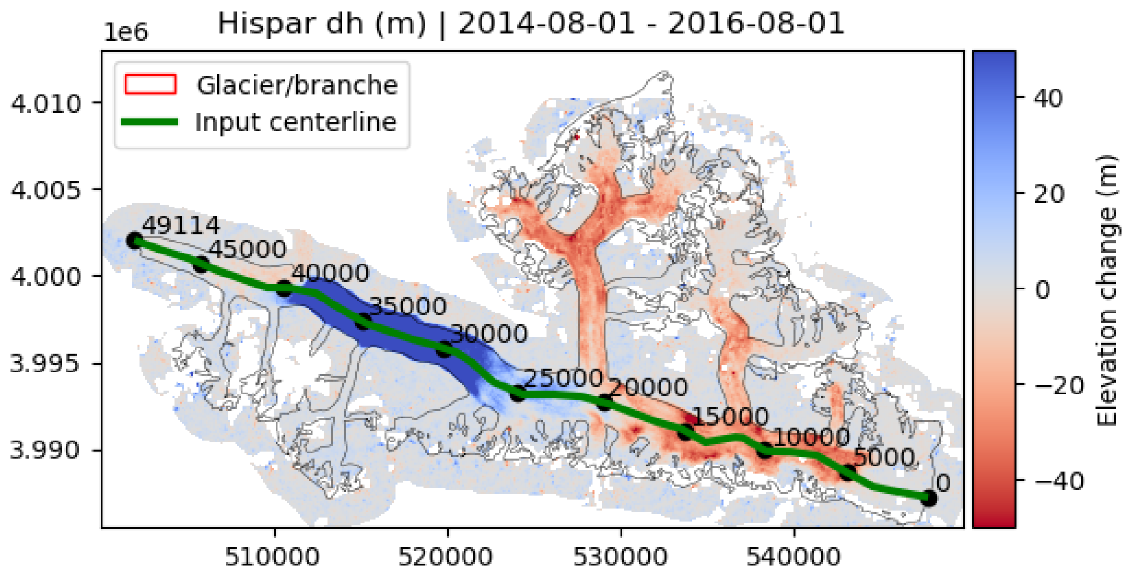


Figure 3: Elevation change map during surge with sampling coordinates of Fig. 2 and corresponding distance along centerline (in meter).

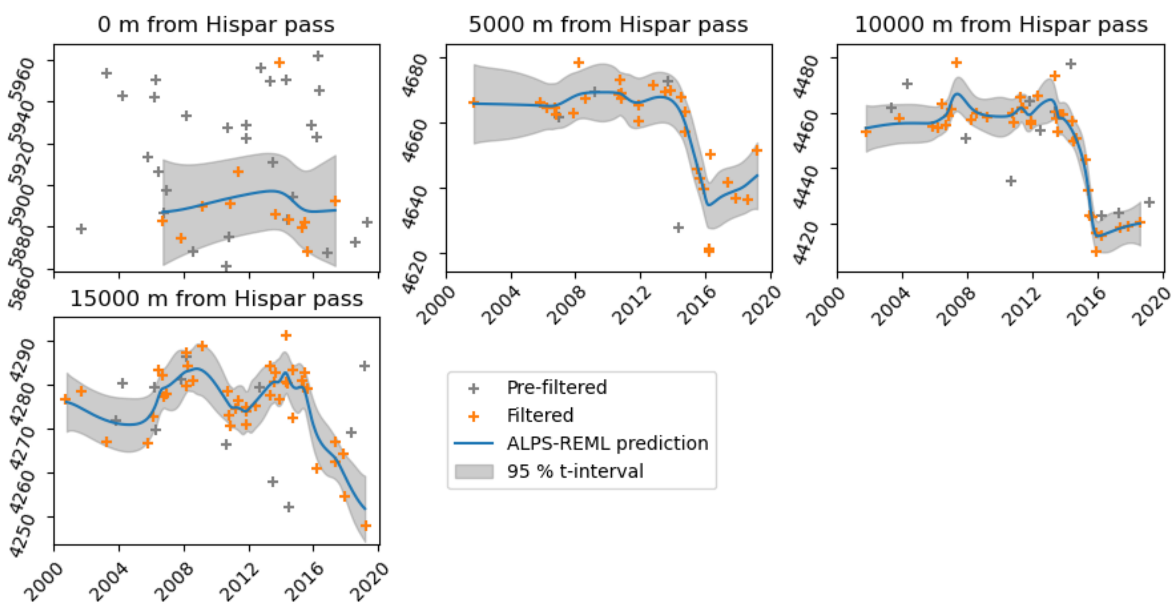


Figure 4: Time series processed each 5 km along the Yutmaru tributary centerline (Fig. 5). The y-axis is the elevation (m), and the x-axis the dates.

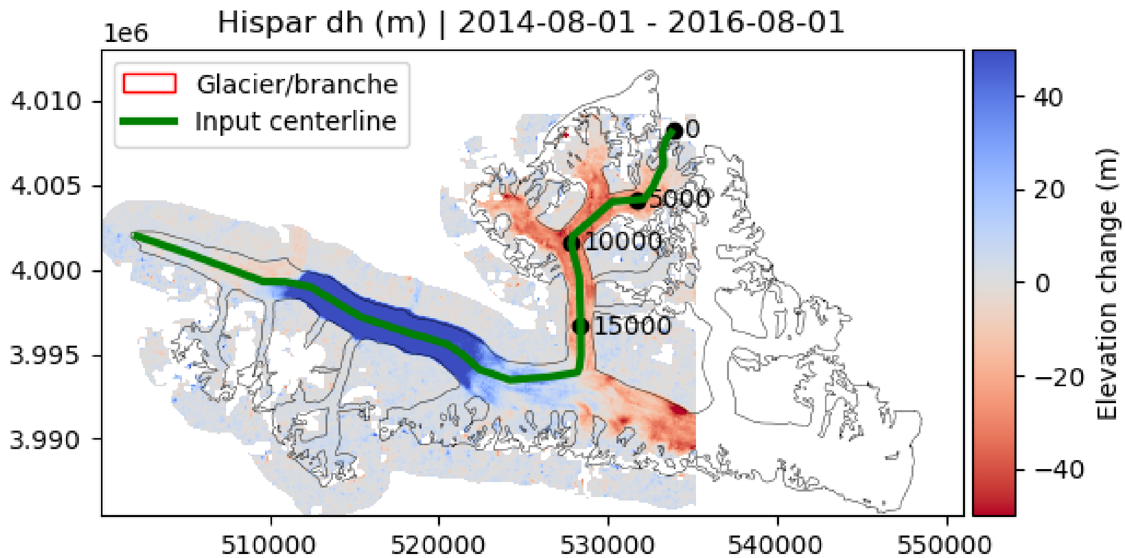


Figure 5: Elevation change map during surge with sampling coordinates of Fig. 4 and corresponding distance along centerline (in meter).

# 3 Hovmöller diagrams

Coordinates on maps are in the UTM43N projection (EPSG:32643; metric unit). Hovmöller diagrams are computed with a bilinear sampling each 100m along the centerline in green on the maps.

## 3.1 Yazghil Glacier (RGI2000-v7.0-G-14-21865)

Yazghil 2000-2019 time lapse of elevation change : https://youtu.be/69utI5EA7Gk.

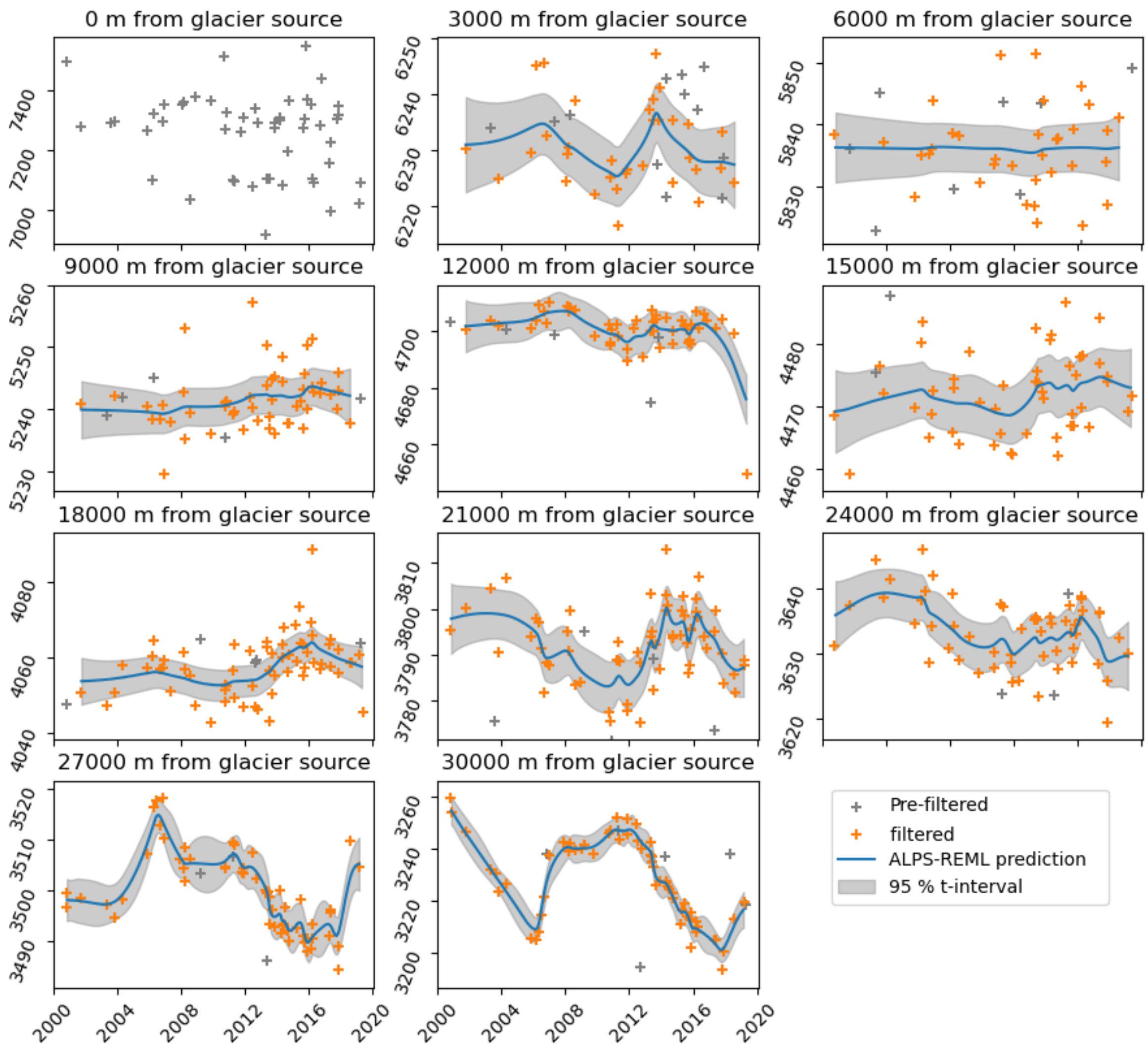


Figure 6: Time series processed each 3 km along the Yazghil glacier centerline. The time series quality show some limits of the LOWESS and ALPS-REML algorithms/parameters. The y-axis is the elevation (m), and the x-axis the dates. Sampling points are in Fig. 8

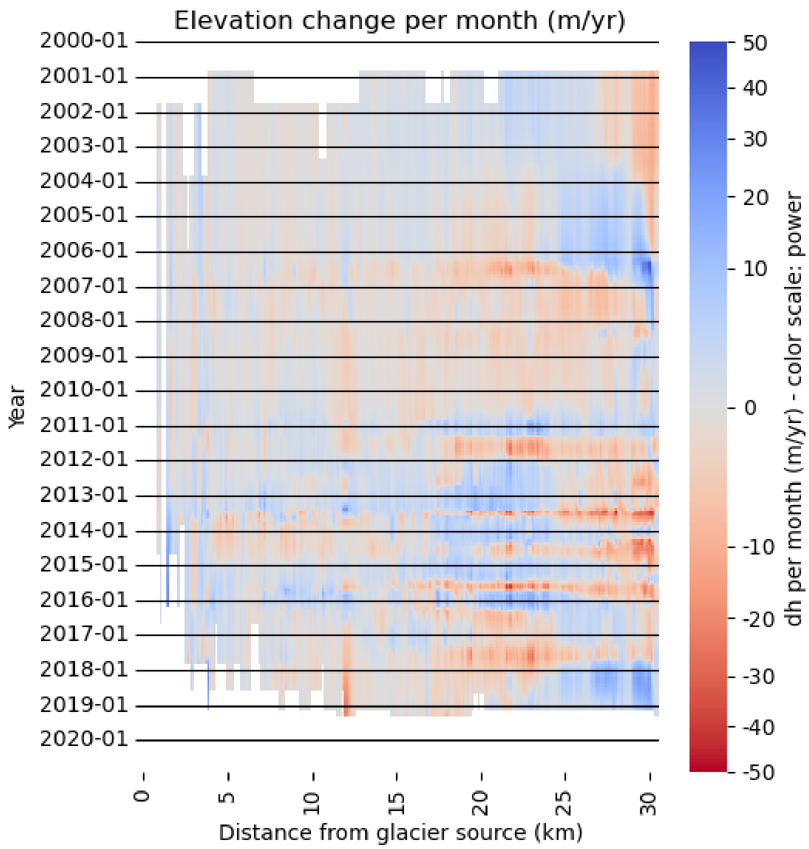


Figure 7: R. Bhambri et al. 2017 mentions a surge in 2006 and a recurrent surge cycle of approx. 8 years. It seems it started probably around two years before, and it may have started another surge in 2016. A full surge cycle may be captured here with visible reservoir and receiving areas, and a dynamic balance line around 25 km.

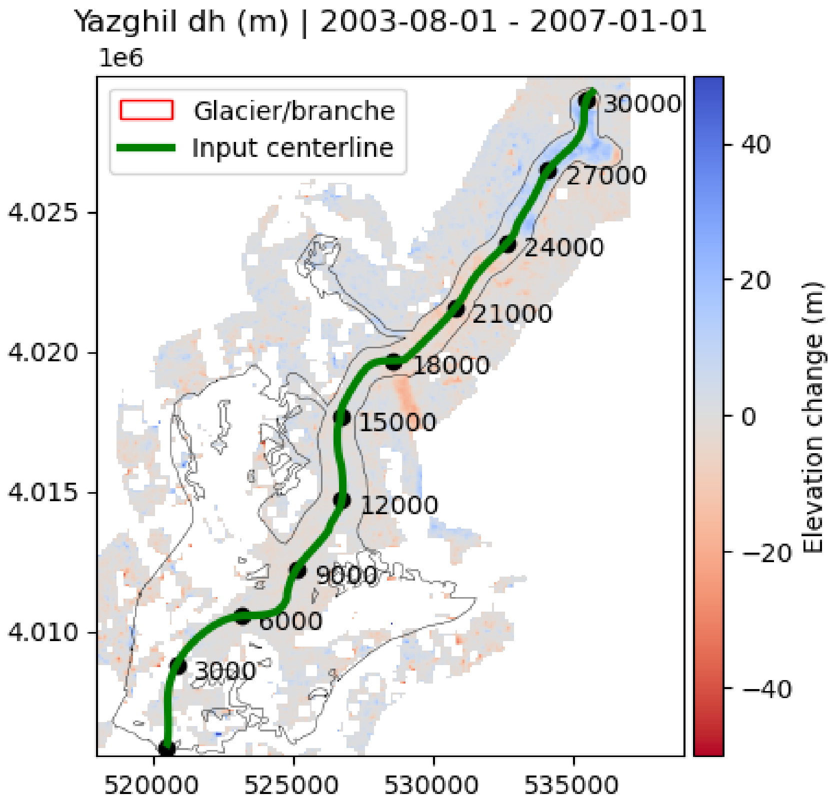


Figure 8: Elevation change map during the estimated surge phase of 2003. Labels correspond to Fig. 6.

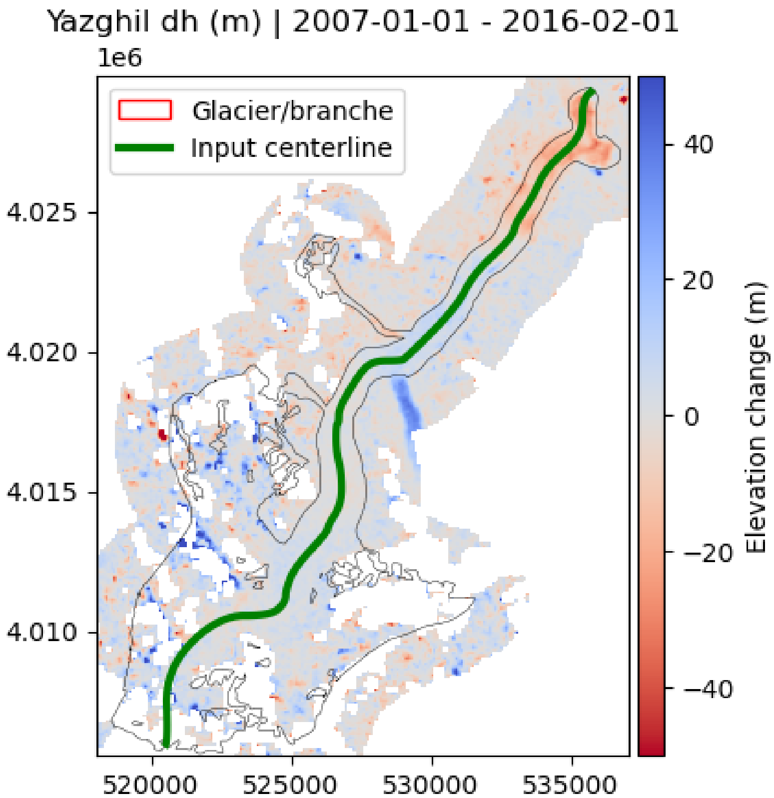


Figure 9: Elevation change map during the estimated quiescent phase.

## 3.2 Unnamed glacier (RGI2000-v7.0-G-14-12163)

Unnamed 2000-2019 time lapse of elevation change : https://youtu.be/JZ68PeA2VOI.

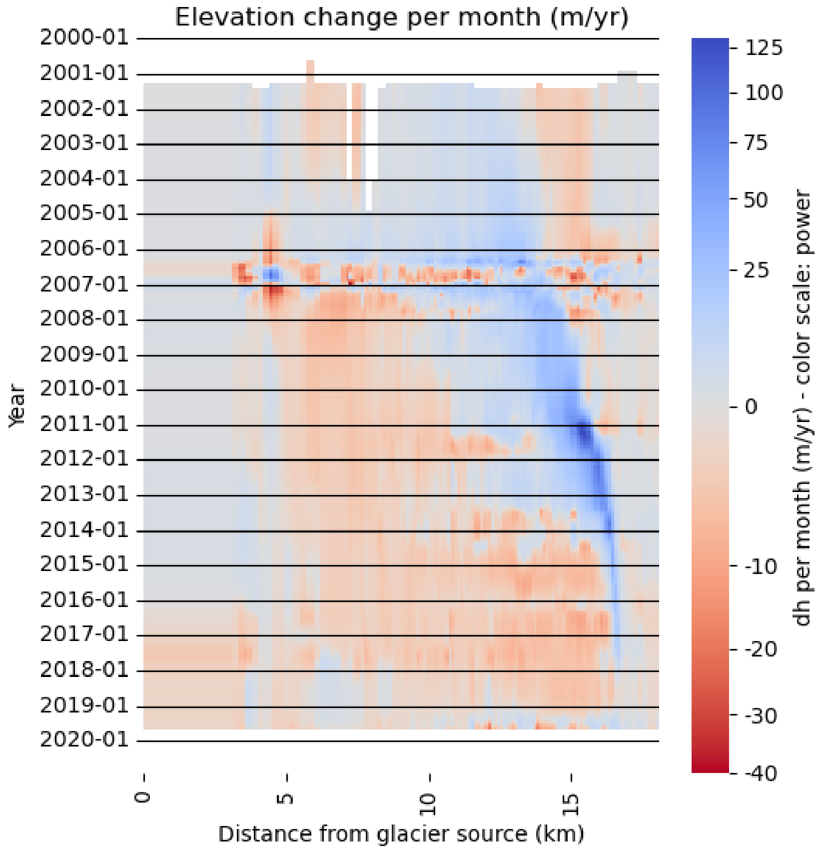


Figure 10: Surge of a surge-type glacier assessed in several inventories (Guo et al. 2022; Guillet et al. 2022).

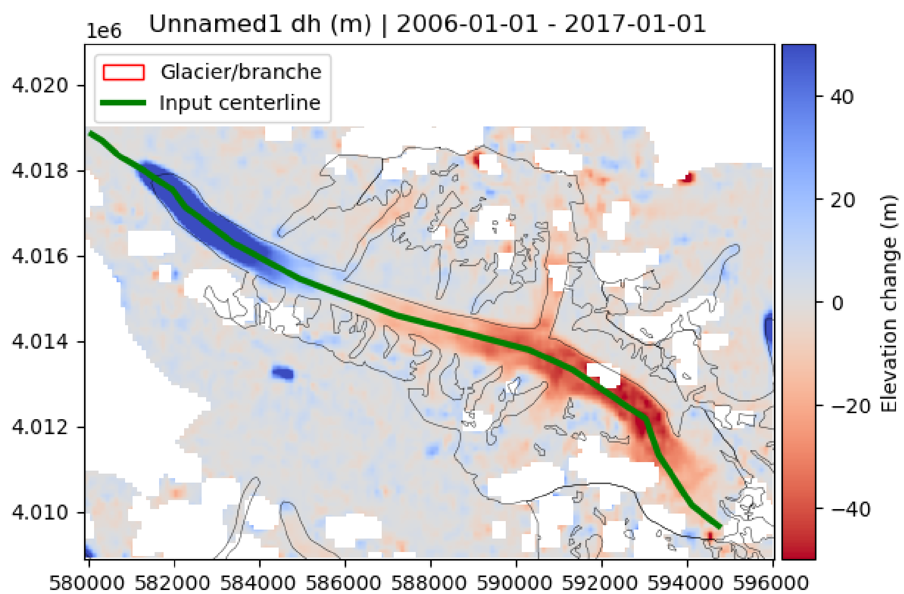


Figure 11: Elevation change map during the estimated surge phase.

### 3.3 Braldu glacier (RGI2000-v7.0-G-14-21584)

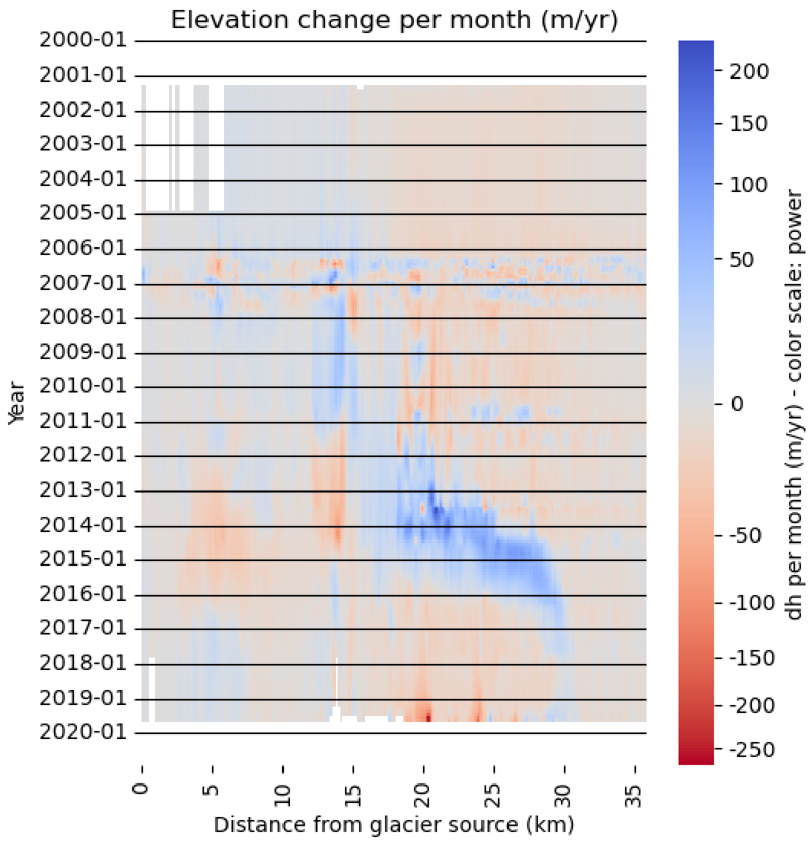


Figure 12: Surge of the Braldu glacier, on a centerline covering only one tributary among the reservoir areas.

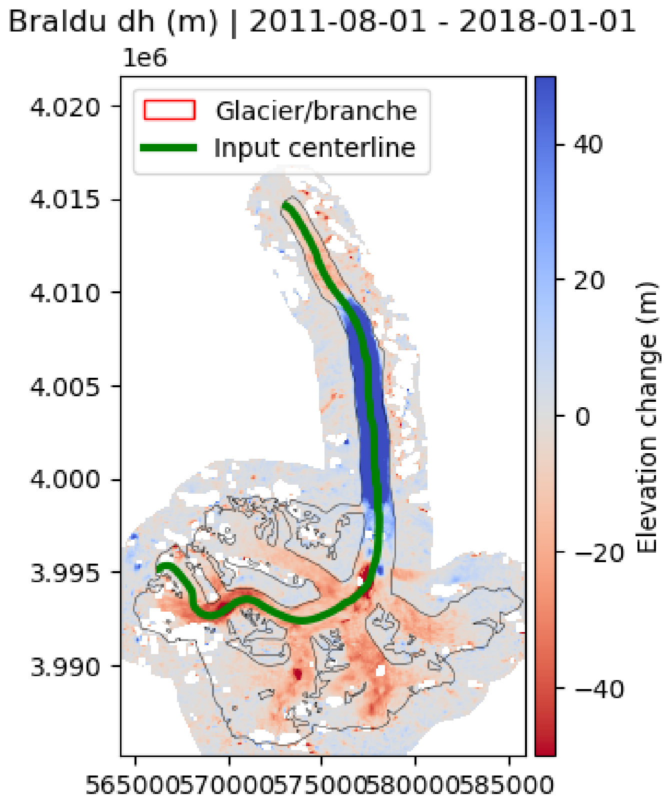


Figure 13: Elevation change map during the estimated surge phase.

### 3.4 Unnamed glacier (RGI2000-v7.0-G-14-22107)

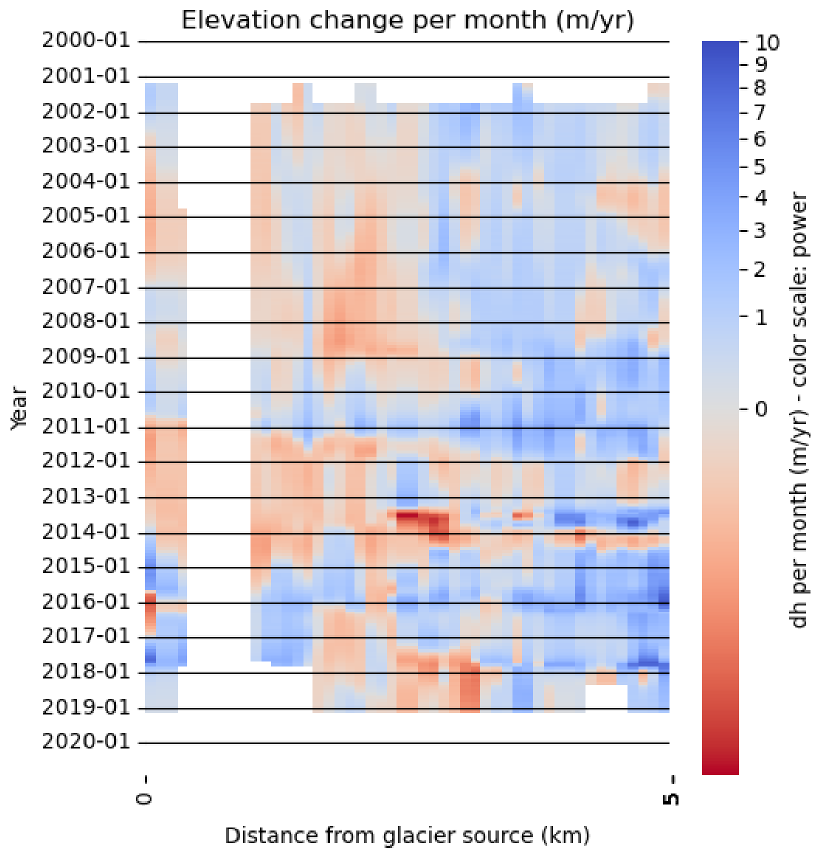


Figure 14: Limit case where the result seems barely usable over this short timescale.

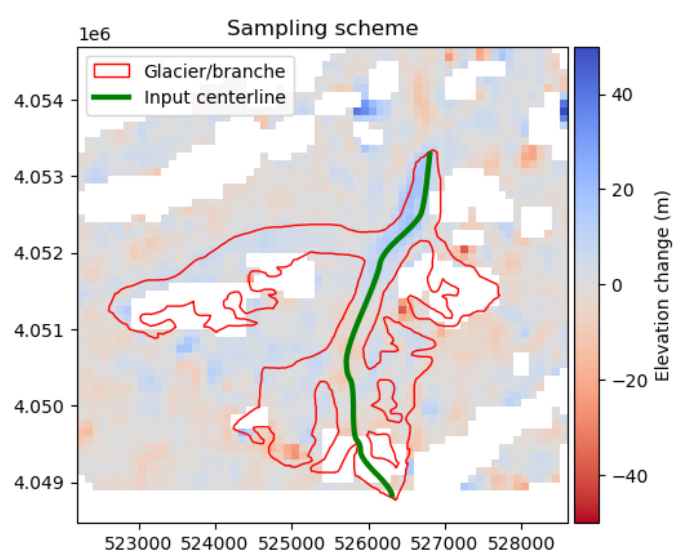


Figure 15: Map of the glacier. Elevation changes are at arbitrary dates and does not represent a surge period.

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