

Quantifying Glacier Mass Change in the Western Pamirs (2003–2024): Insights from High-Resolution DEM Time Series

Haruki Hagiwara¹, Evan Miles^{2, 3, 4}, Achille Jouberton^{1, 3, 5}, Francesca Pellicciotti¹



1: Institute of Science and Technology Austria, Klosterneuburg, Austria, 2: Glaciology and Geomorphodynamics Group, Institute of Geography, University of Zurich, Zurich, Switzerland, 3: Mountain Hydrology and Mass Movements, Swiss Federal Institute for Snow, Forest, and Landscape Research, Birmensdorf, Switzerland, 4: Department of Geosciences, University of Fribourg, Fribourg, Switzerland, 5: Institute of Environmental Engineering, ETH Zurich, Zurich, Switzerland

Motivation

The Pamir Mountains serve as a vital water tower, supplying water to the Amu Darya basin, one of the most vulnerable to climate change [1].

More precise analysis is limited due to

- Sparse in-situ data
- Spatiotemporally variable climate conditions in temperature and precipitation [2]
- Complex glaciological processes (e.g., debris-cover [3], surge [4])

Previous ASTER-based geodetic mass balance assessments indicate [5,6]:

- Increasing mass loss trend since the early 2000s
- Challenges for measuring smaller glaciers and over short time periods.

This study analyzes geodetic data from 2003 to 2024, leveraging high-resolution stereo satellite imagery (SPOT5, SPOT6, Pléiades) to assess 21st-century mass balance trends. Our research questions are:

- Do independent stereo data confirm spatio-temporal glacial change patterns derived from the ASTER data?
- How has glacier mass balance changed since 2019?

Methodology

1. Stereo satellite datasets and study site

Datasets cover the Sangvor area, at the headwaters of the Amu Darya River basin, Tajikistan (Fig. 1).

- SPOT5-HRS with 5/10 m resolution on Aug 6, 2003 (Western area) and Sep 18, 2006
- SPOT6/7 with 1.5 m resolution on Aug 21/Sep 21, 2014 (mono images) and Sep 29, 2019
- Pléiades with 0.5 m resolution on Sep 11, 2022 and Sep 2, 2024

2. DEMs and elevation change rate

DEMs were generated with More-Global-Matching method based on the steps in the NASA Ames Stereo Pipeline [5].

All DEMs were resampled to 10m by the bilinear method, coregistered, and bias corrected (incl. jitter).

Outlier filtering ($>3\sigma$ in each 50m elevation bin) and global hypsometric interpolation were applied to dh/dt maps.

Uncertainty calculation method follows [4].

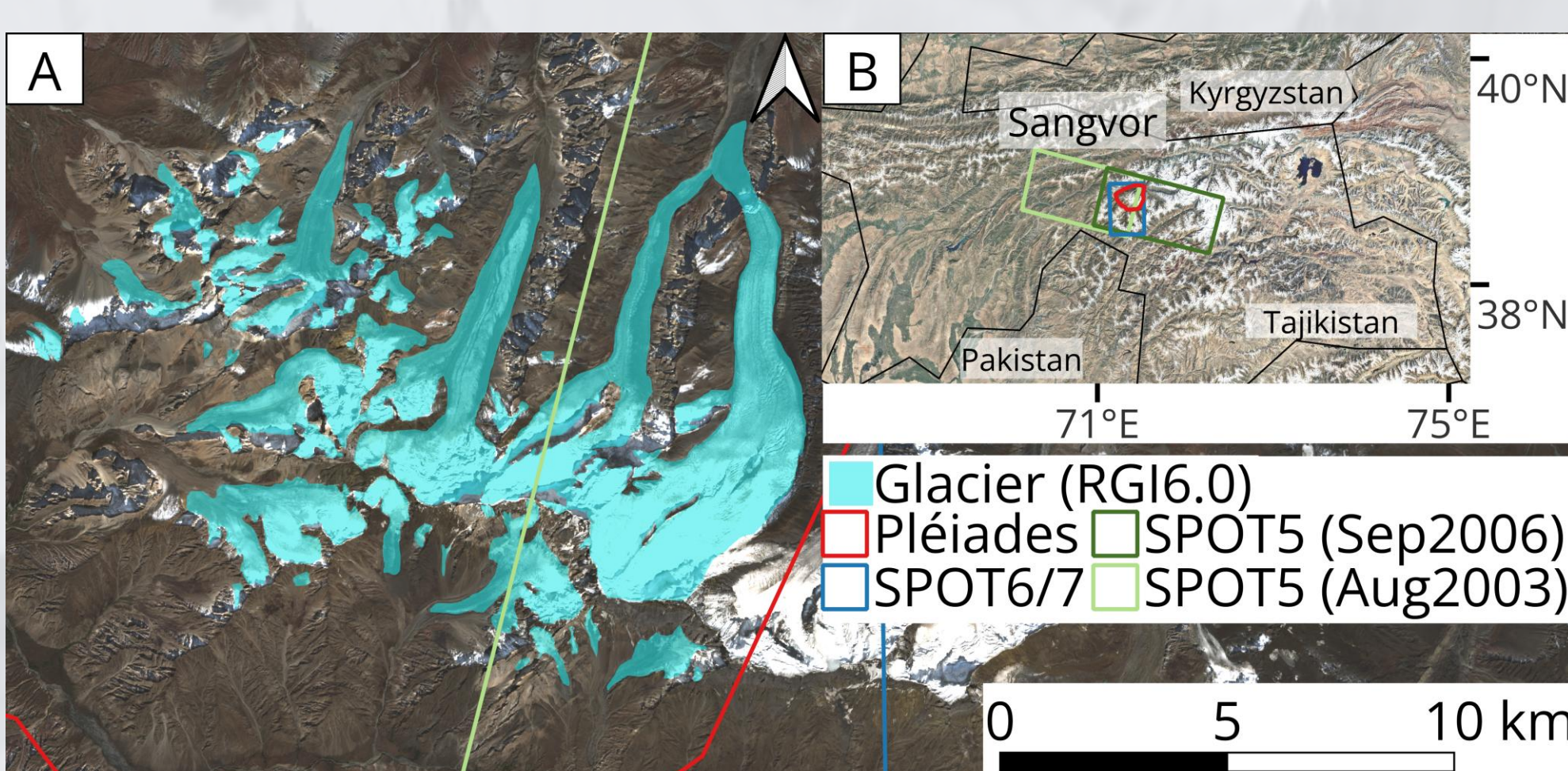


Fig. 1: Details of the study area and dataset coverages

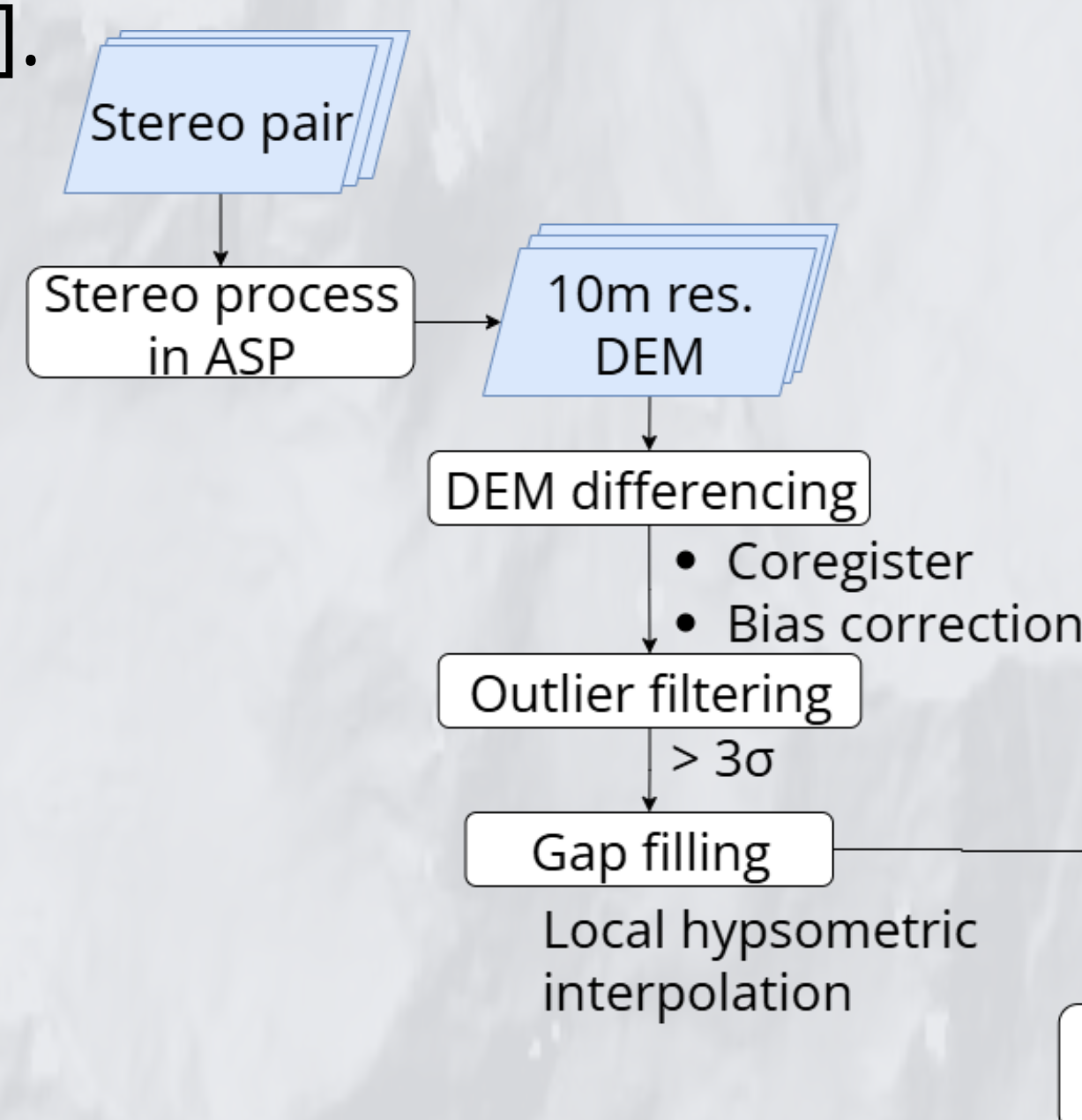


Fig. 2: Process flowchart to calculate dh/dt and uncertainty

Result & Outlook

Mean elevation change rates (dh/dt)

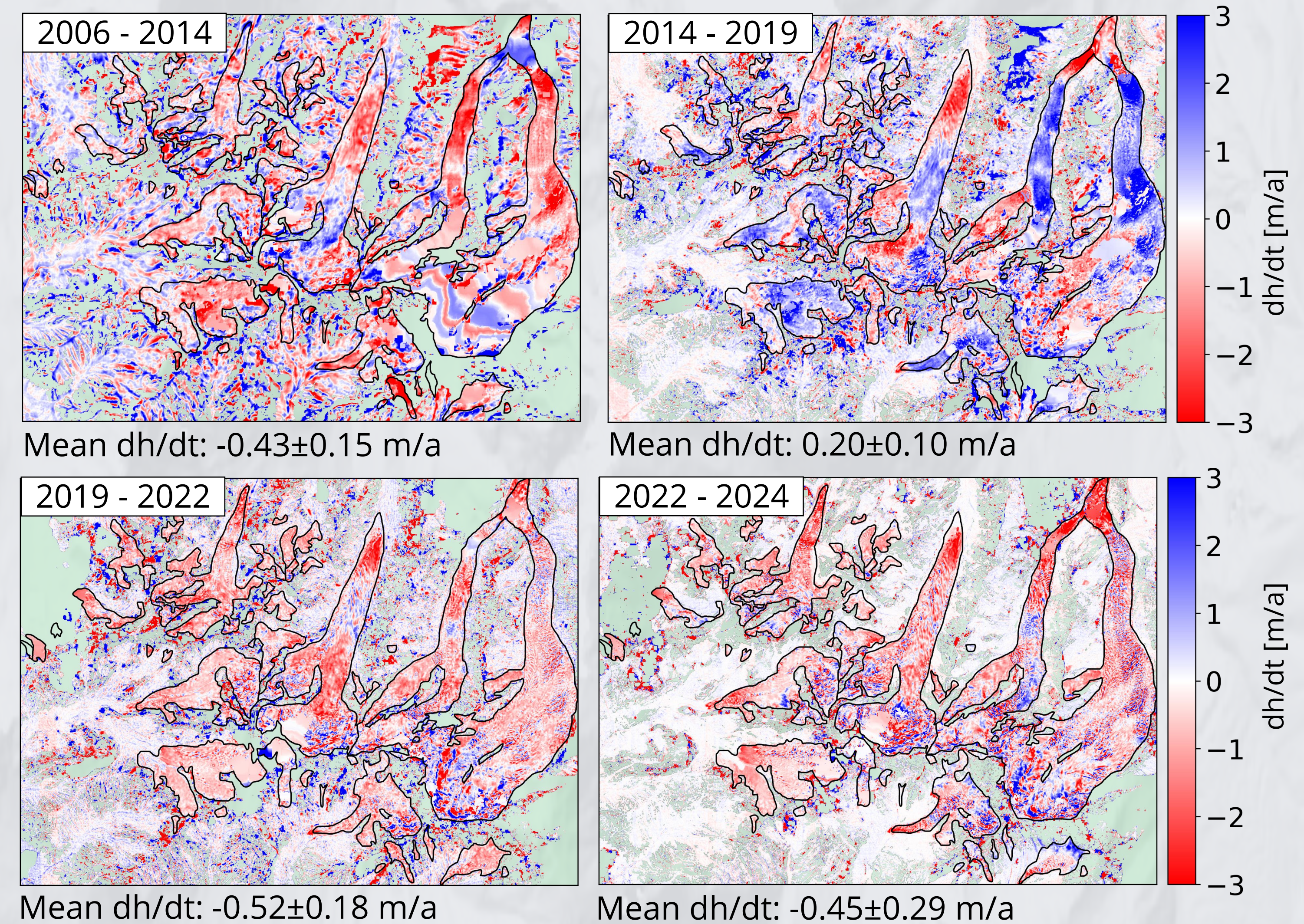


Fig. 3: Elevation change rate maps in each period since 2006

Elevation change rates for the entire period are -0.37 ± 0.090 m/a (2003-2024, western region (Fig. 1)) and -0.24 ± 0.076 m/a (2006-2024).

Until 2019, our results show:

- The rate is consistent with the previous study [6] (Fig. 4): 0.22 ± 0.10 m/a (2003-2019) and 0.21 ± 0.10 m/a (2006-2019).
- Elevation increase at the terminus (Fig. 3, 2006-2014) may indicate glacier surge.
- The positive elevation change from 2014 to 2019 could be caused by higher precipitation (Fig. 5).

Since 2019, Glaciers have been thinning more rapidly (Fig. 3).

- Possibly caused by lower precipitation (Fig. 5).

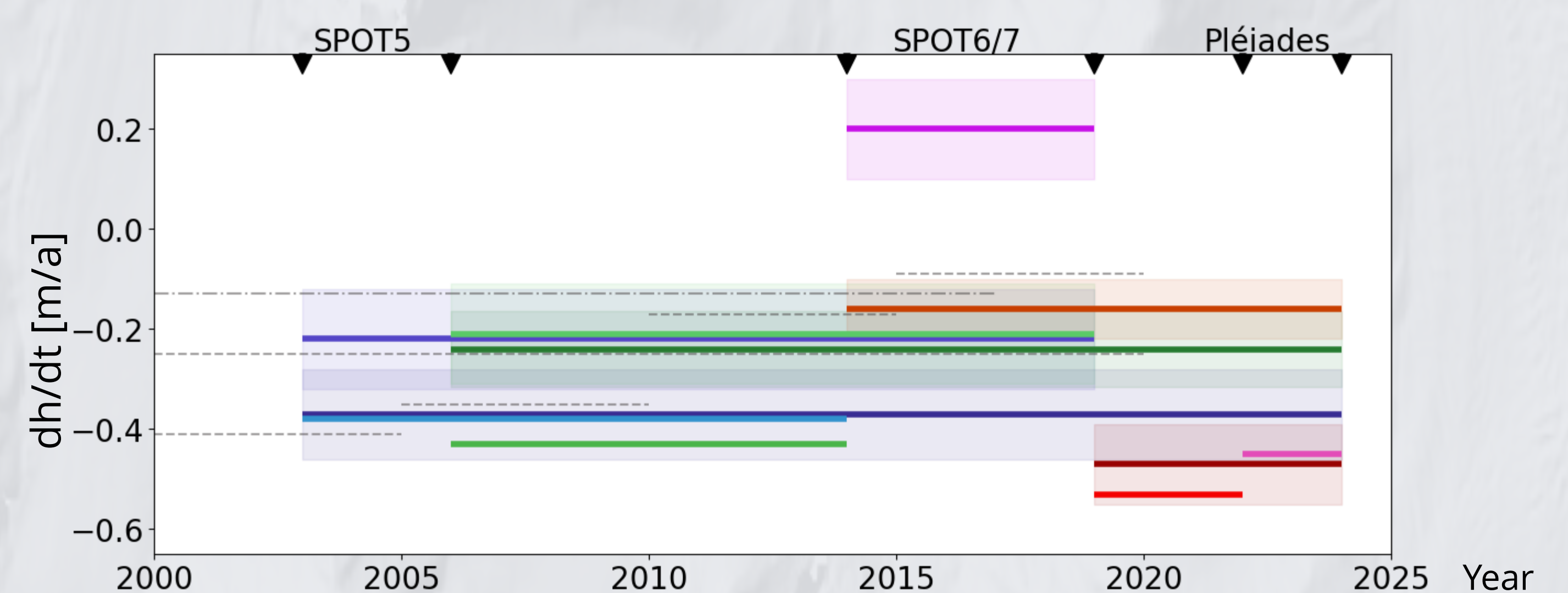


Fig. 4: Mean elevation change rates and uncertainty per period

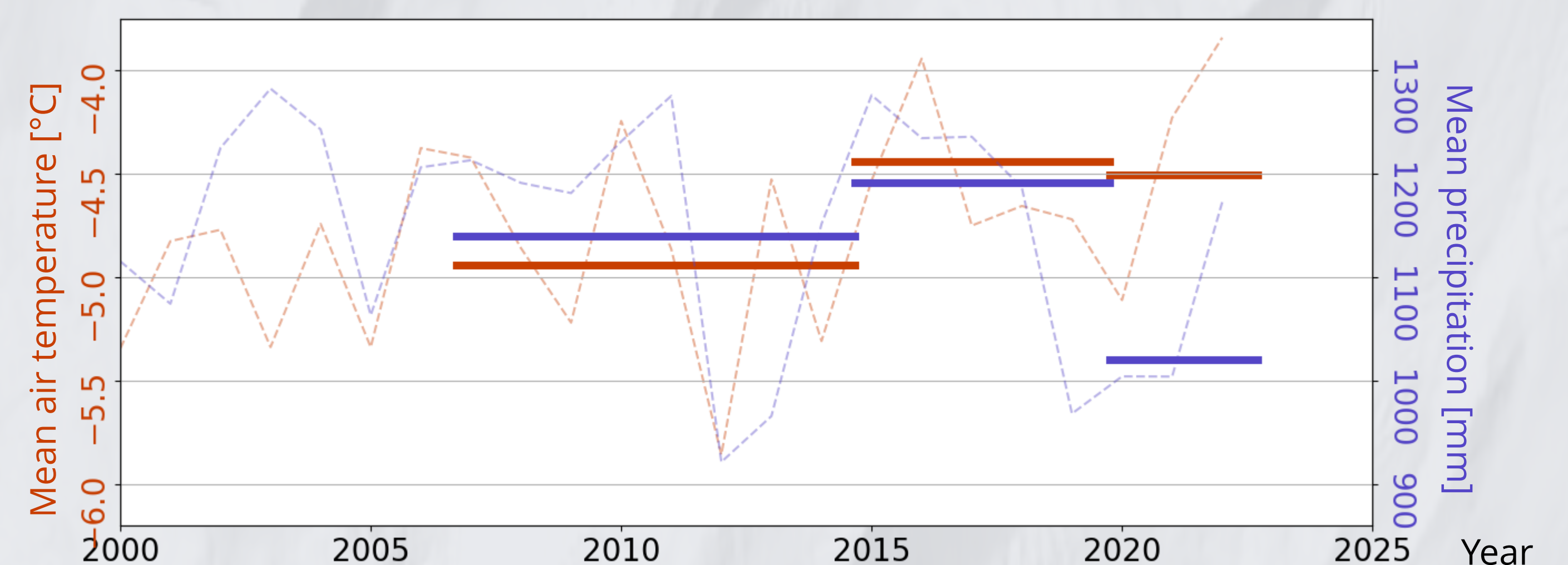


Fig. 5: Meteorological data at an AWS point within the area downscaled ERA5 re-analysis data [8]
Mean for calendar years (dashed lines) and periods (solid lines)

Outlook and discussions:

- Reconsideration of DEM processing methods and switch to more robust uncertainty calculations.
- Assessment of the mass balance signatures of surging vs. non-surging glaciers in the study region.

Acknowledgement

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