Parameter uncertainty of Hydro-glaciological model estimates derived from non-stationary climate conditions

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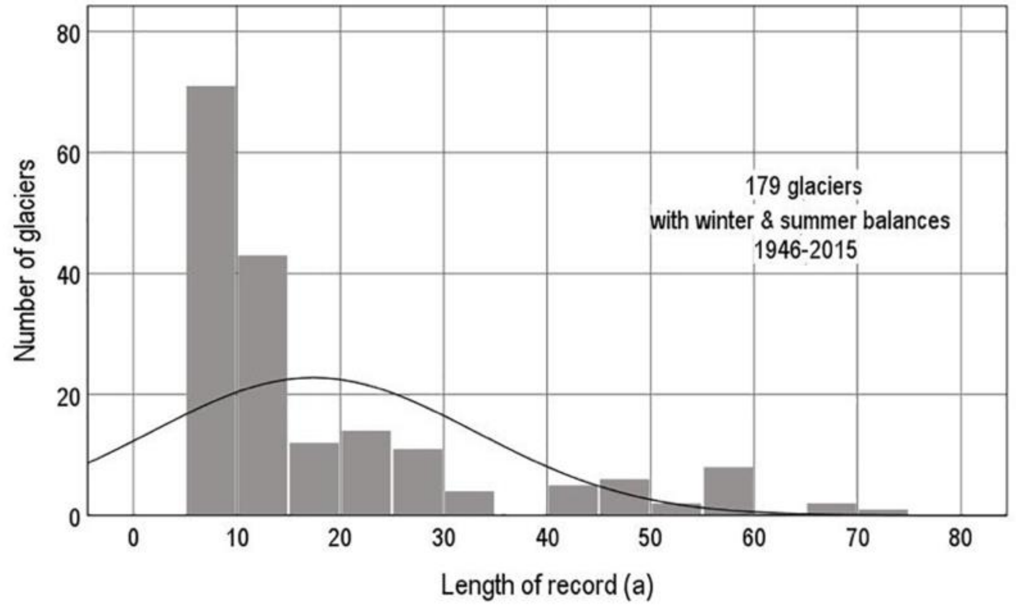
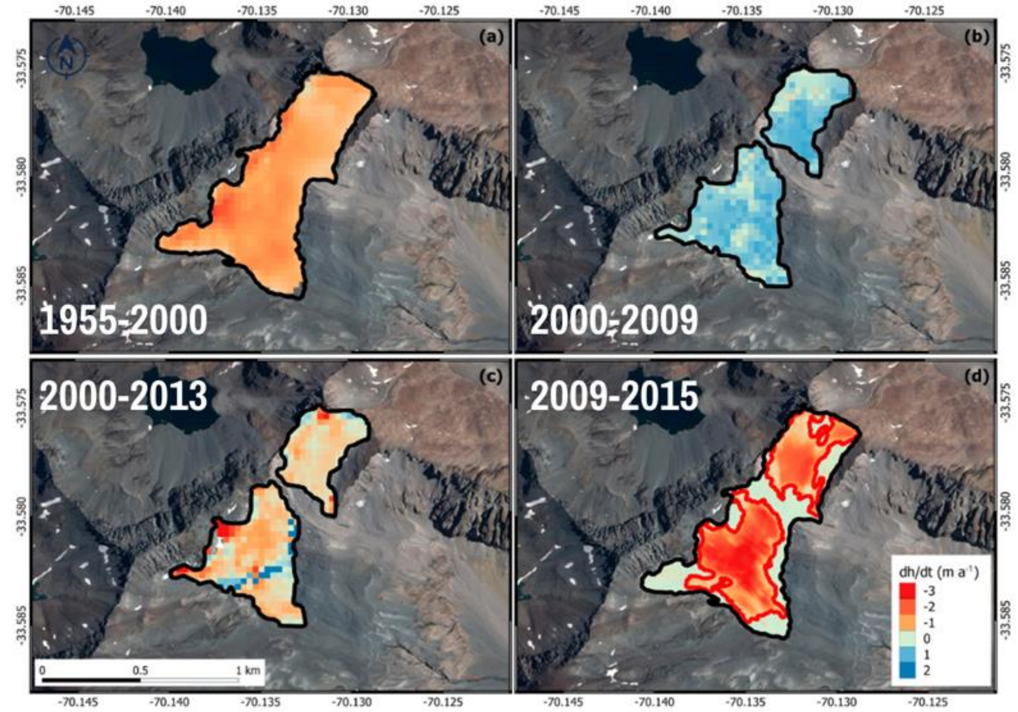
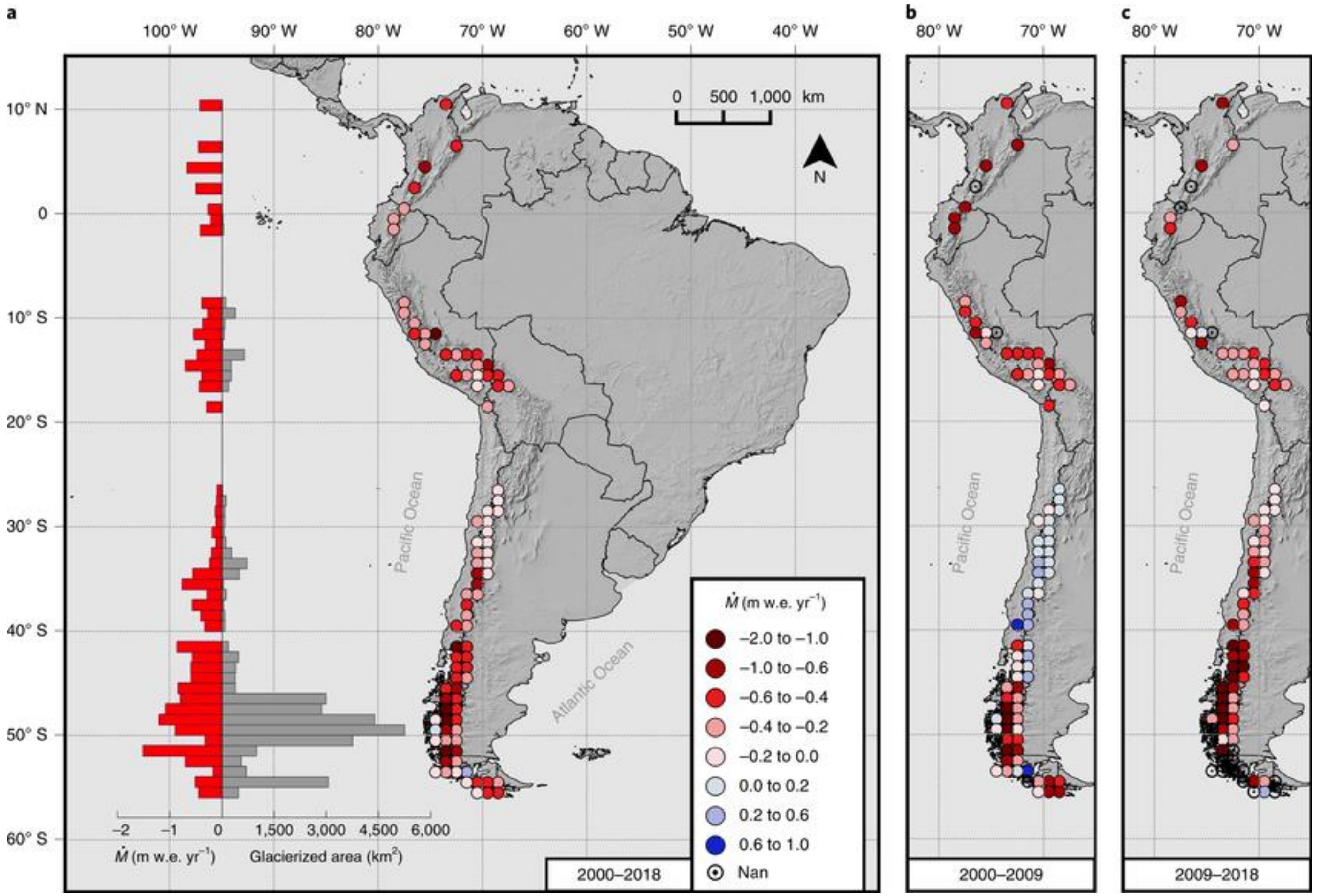
Glaciers in the Andes are retreating (fast), but the actual effect on hydrological regimes is not clear out of the tropics because of high interannual variability

Braithwaite and Hughes (2020)





Farías-Barahona et al. (2019)



Dussaillant et al. (2020)

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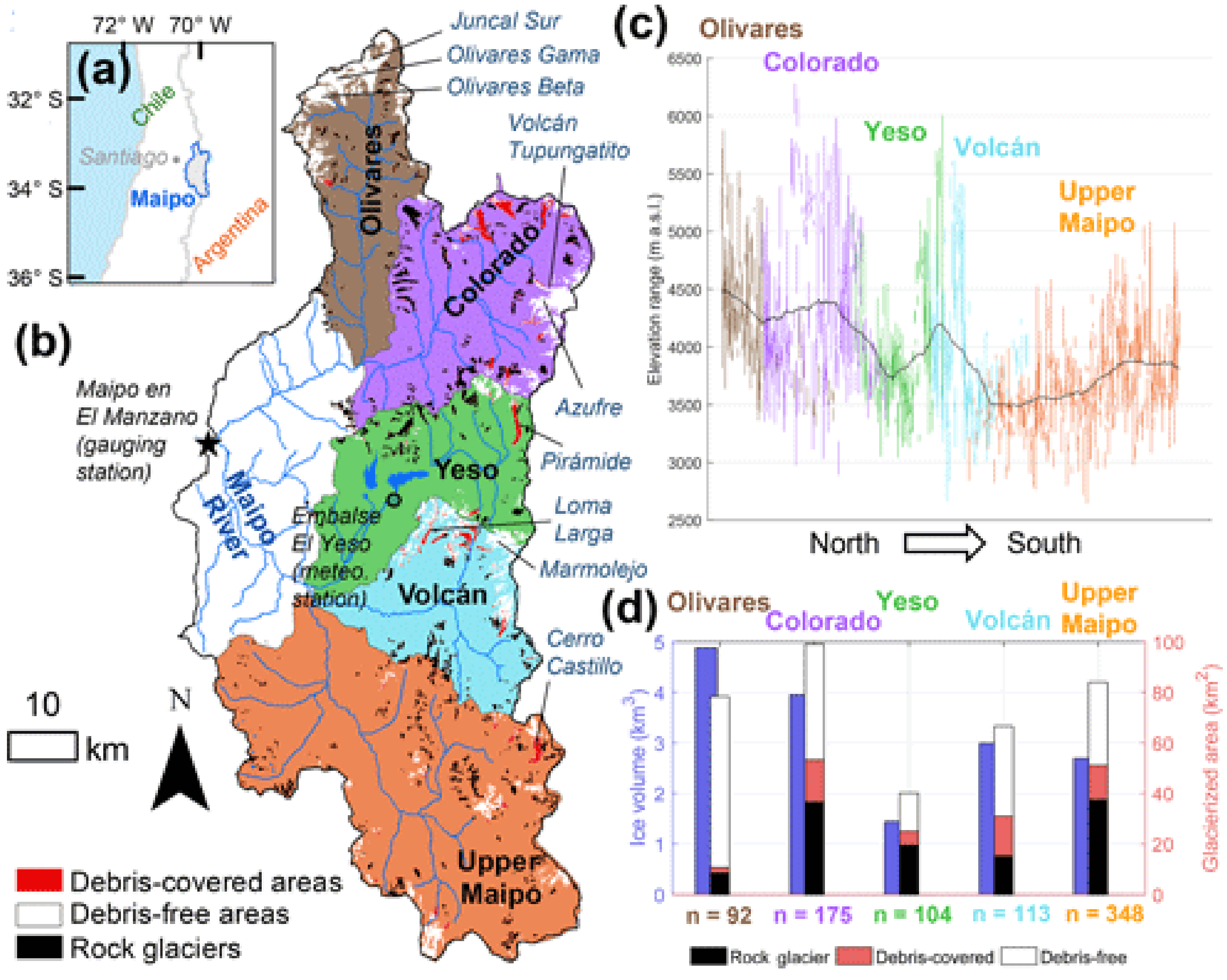
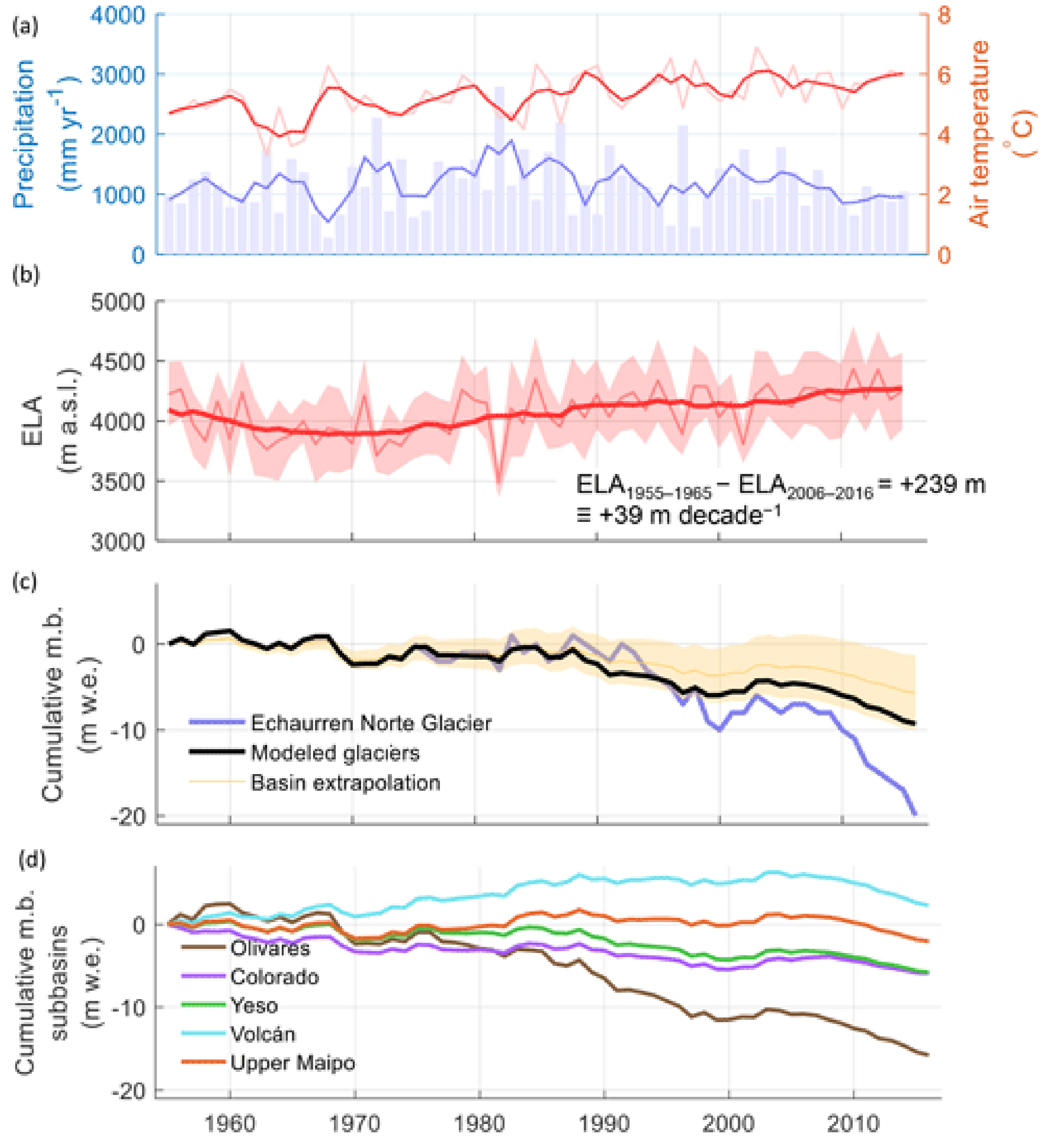
Article | Peer review | Me

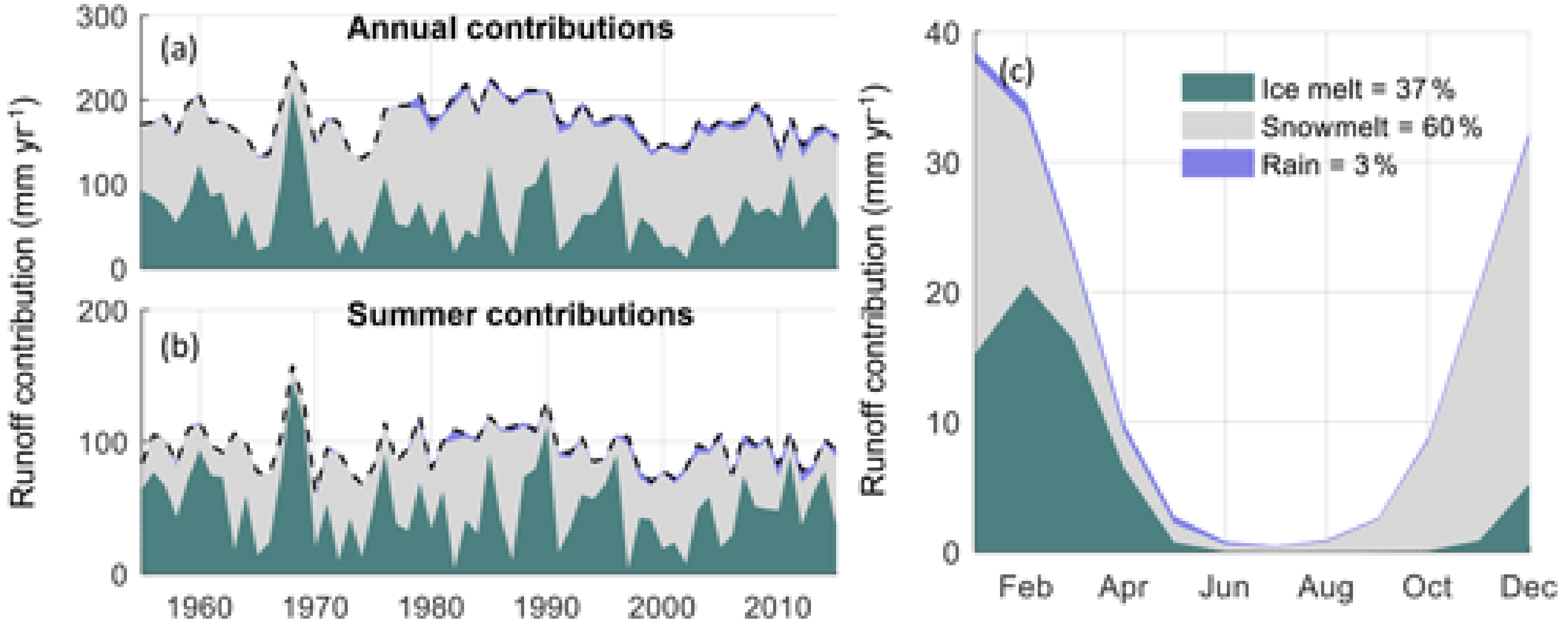
Research article

Glacier runoff variations since 1955 in the Maipo River basin, in the semiarid Andes of central Chile

Álvaro Ayala[1,2,a], David Farías-Barahona[3], Matthias Huss[1,2,4], Francesca Pellicciotti[2,5], James McPhee[6,7], and Daniel Farinotti[1,2]





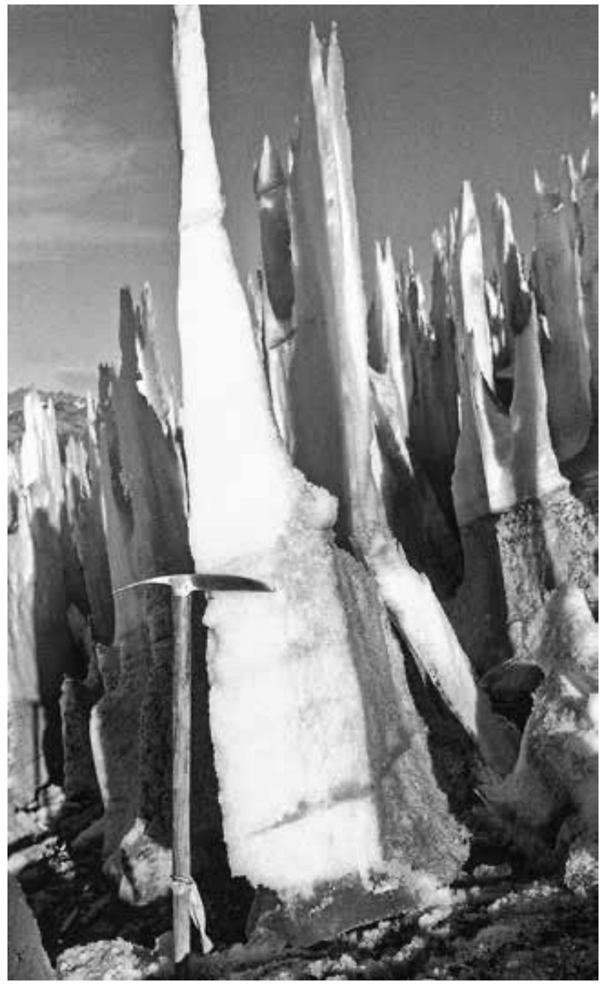


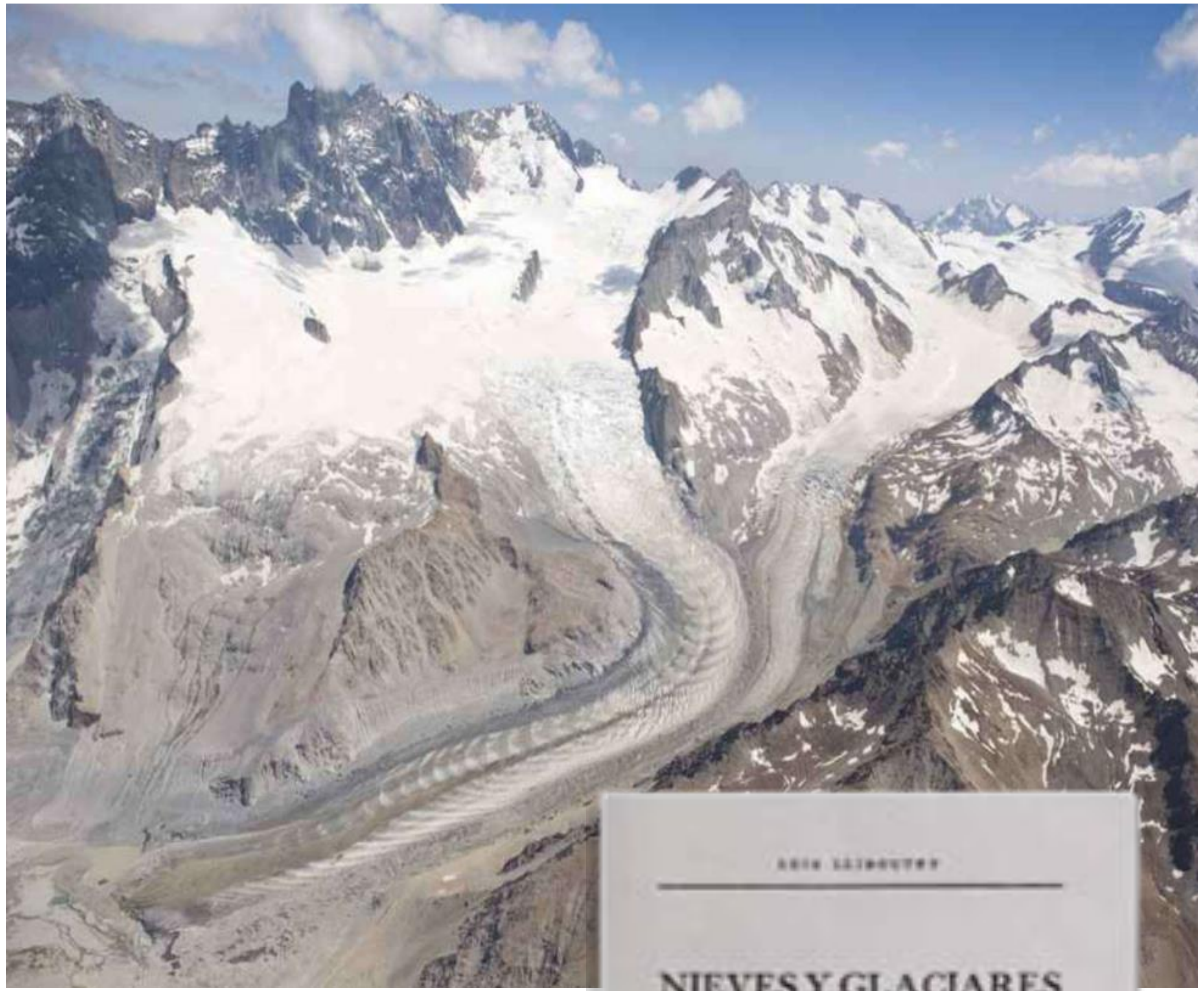
Main questions

- **To what extent are hydroglaciological model parameters transferable accross time (climate conditions)?**
- **What are key determinants for model performance at the glacier-catchment level?**
- **What is the predictive uncertainty derived from parameter uncertainty?**

The Universidad Glacier:

Louis Lliboutry, en 1951.





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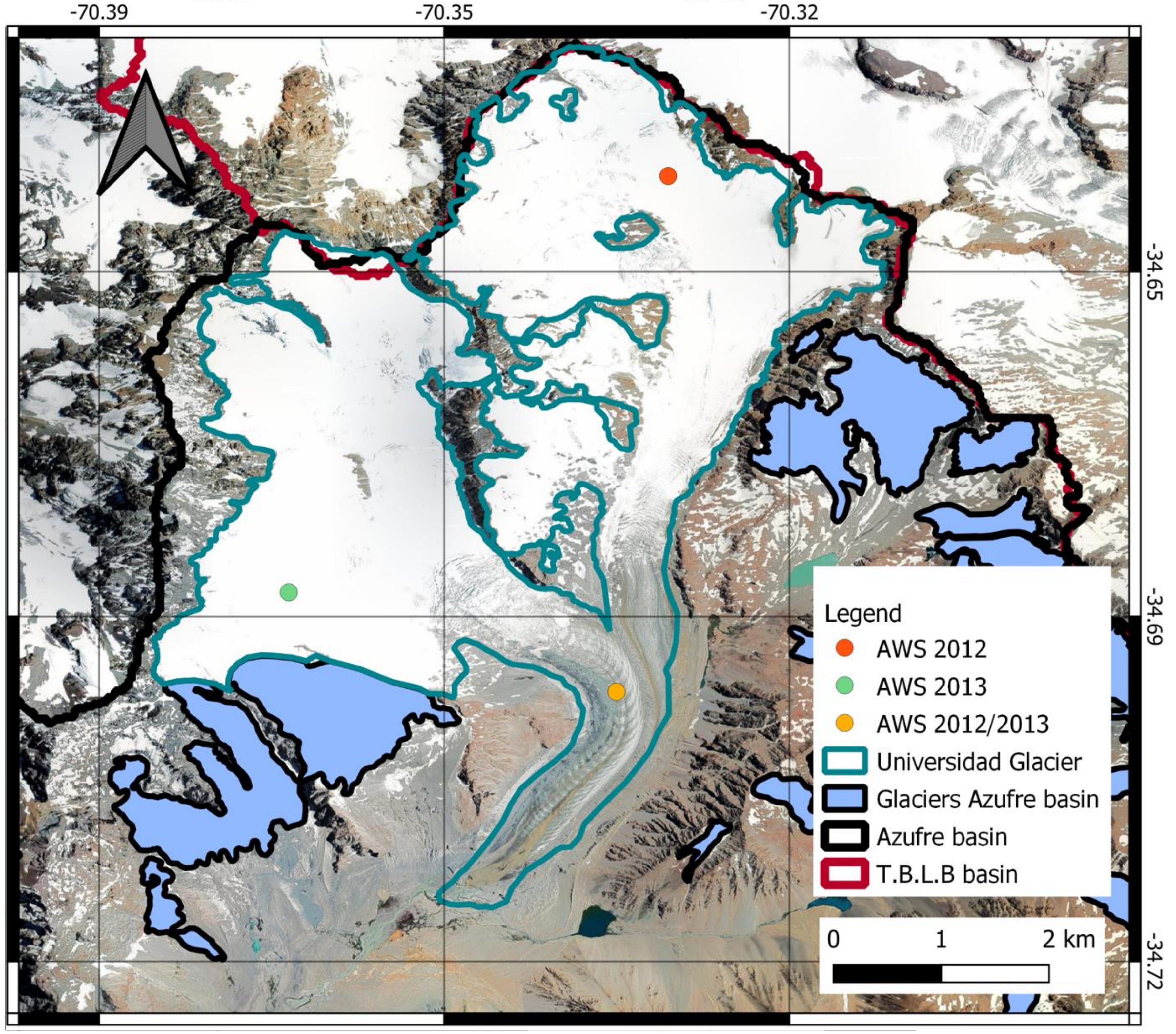
Fundamentos de Glaciología

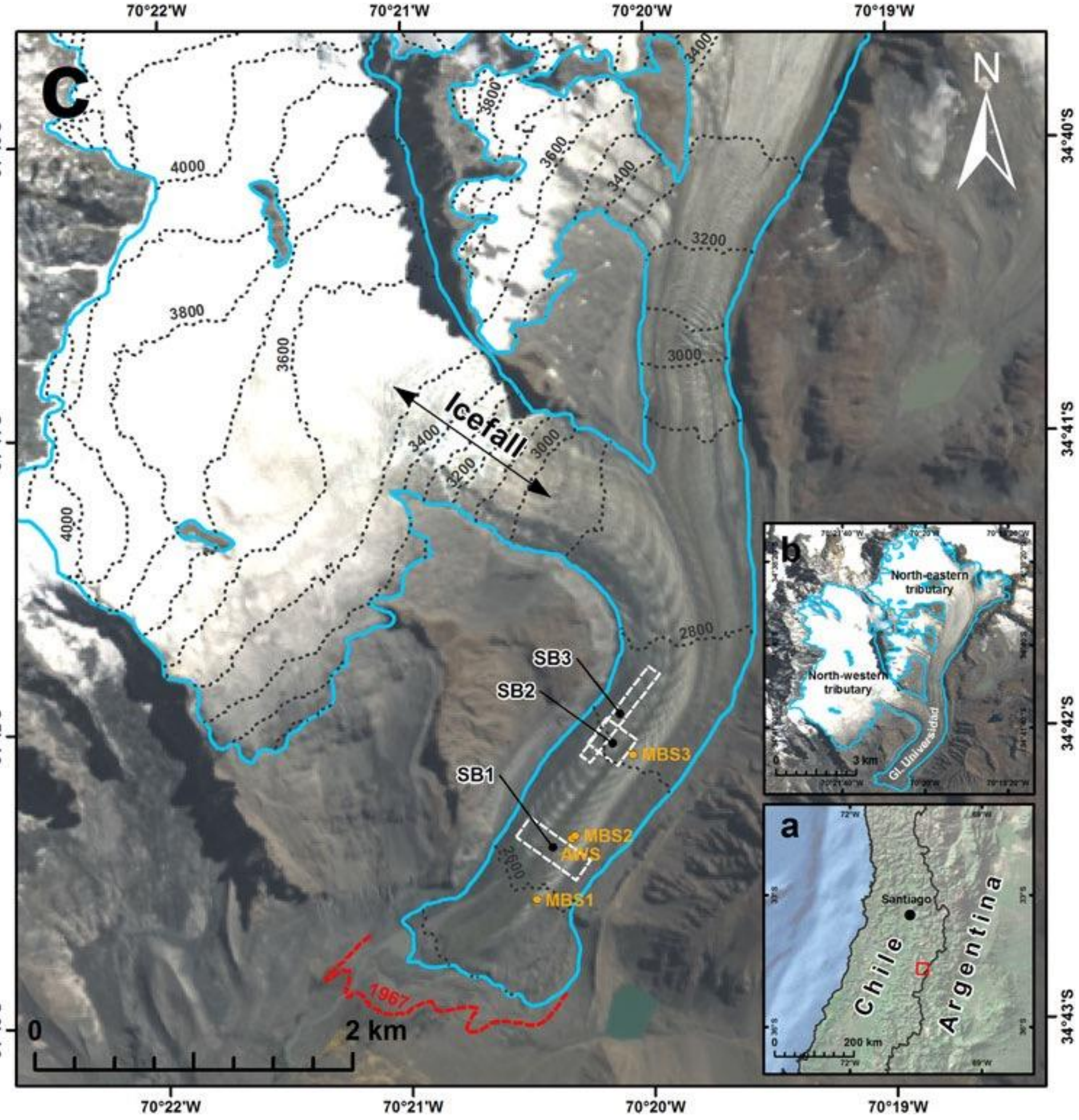
Source: Marc Turrel

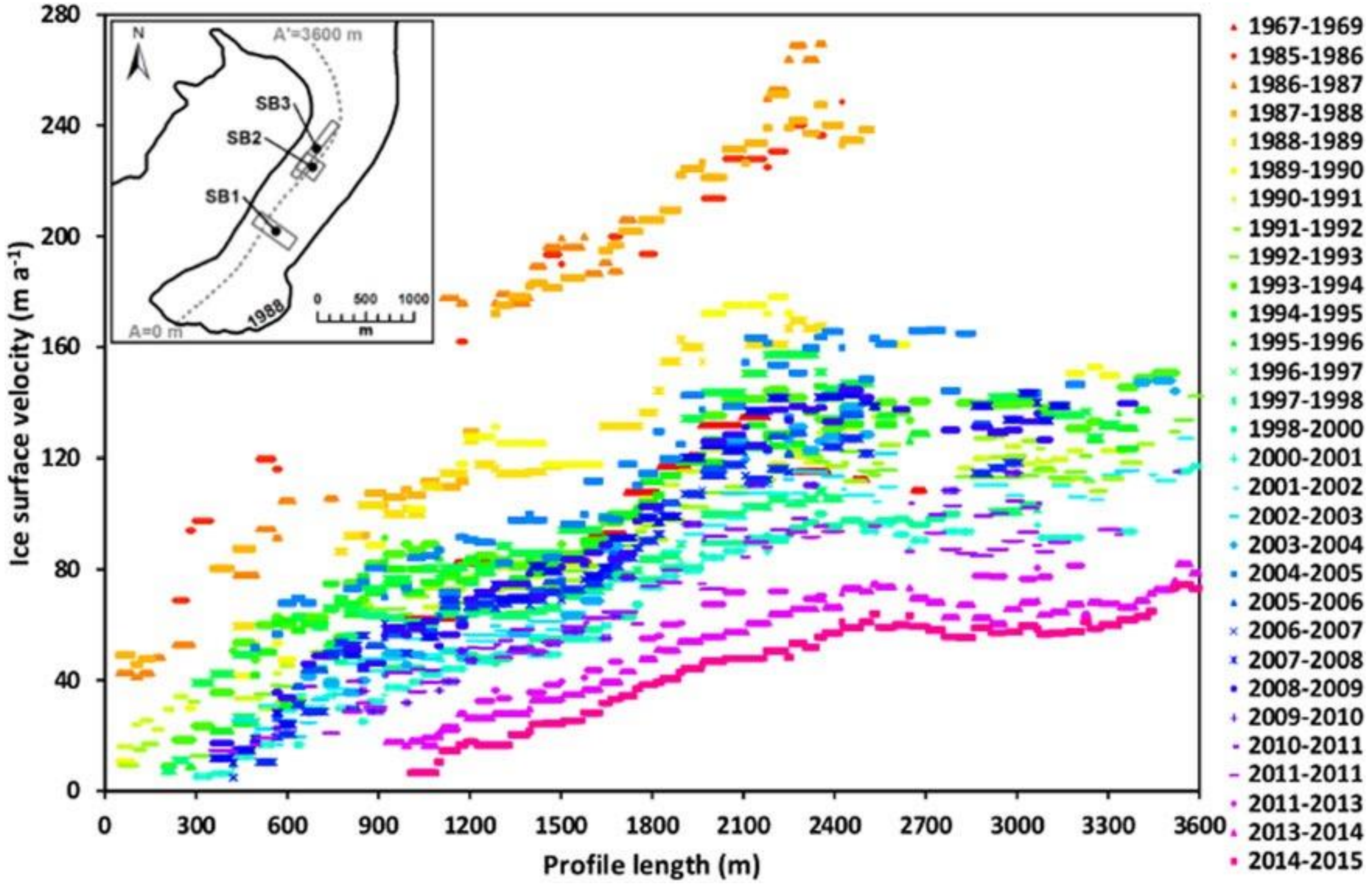
The Universidad Glacier is the largest in the Andes outside Patagonia

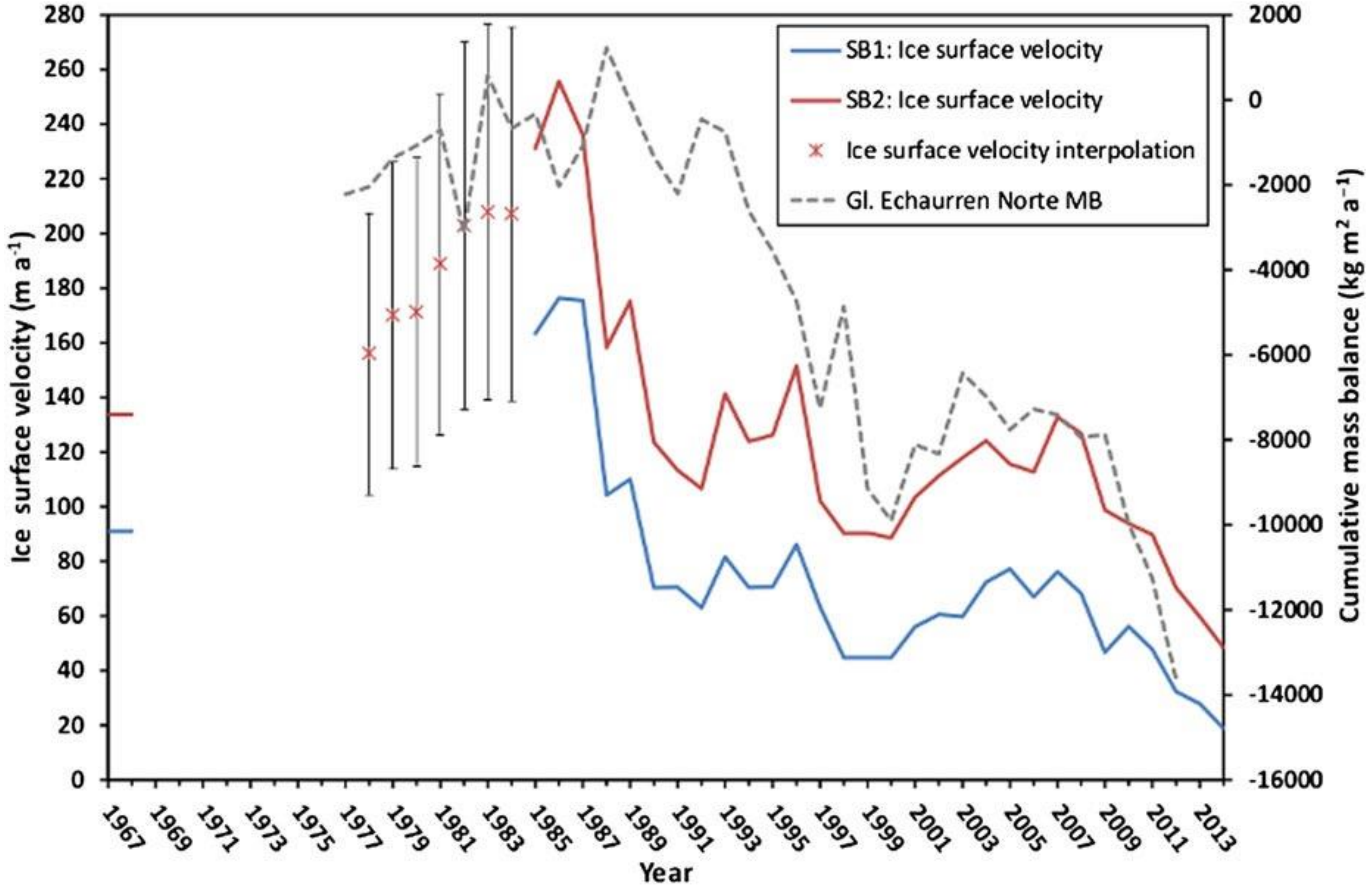
Surface area: 26,7 km2

M.A.P. approx. 1500 mm







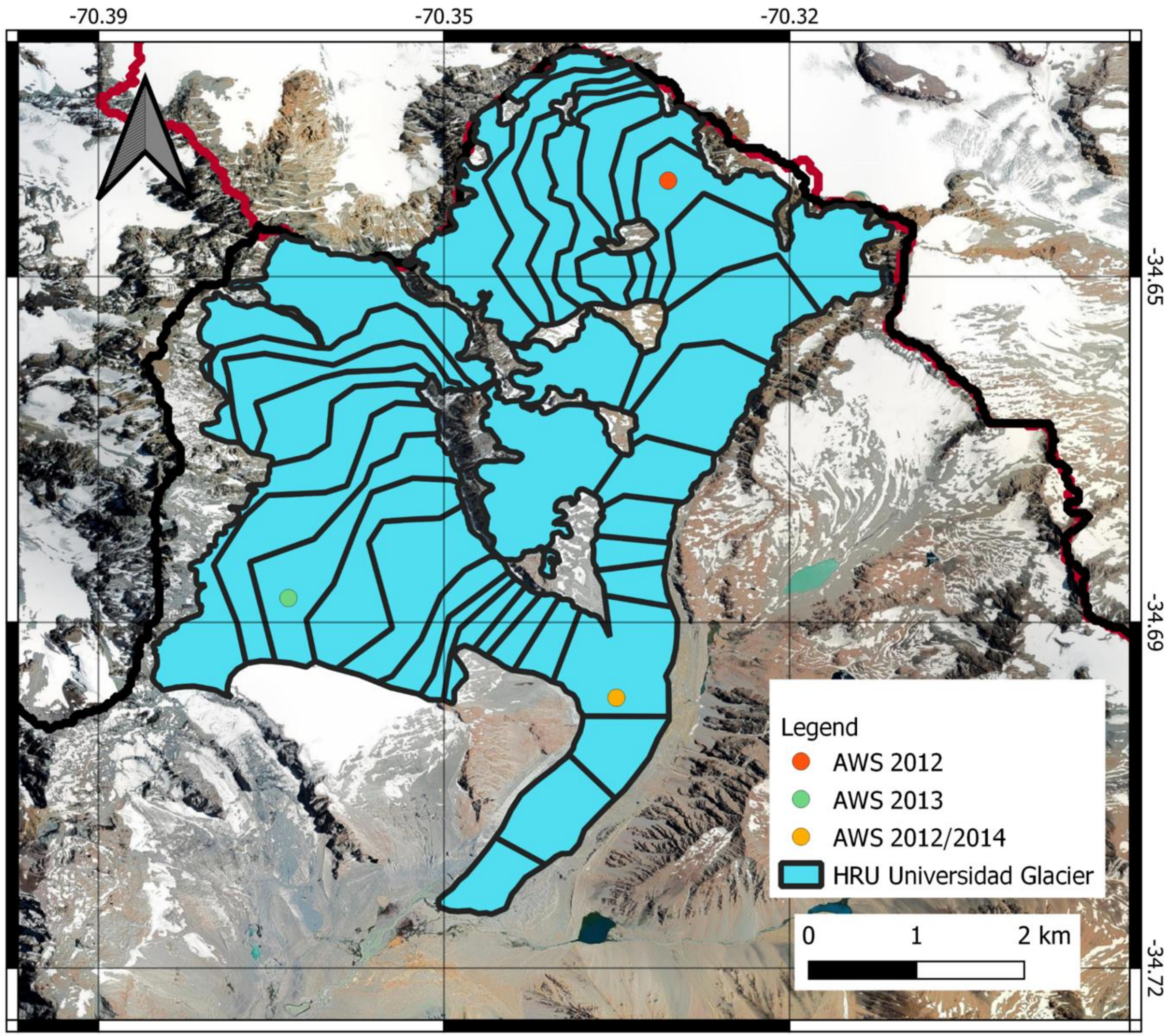


Wilson et al. (2016)

A moderate retreat since 1960's, but a clear pattern of diminishing ice velocity

Hydroglaciological modeling with CRHM

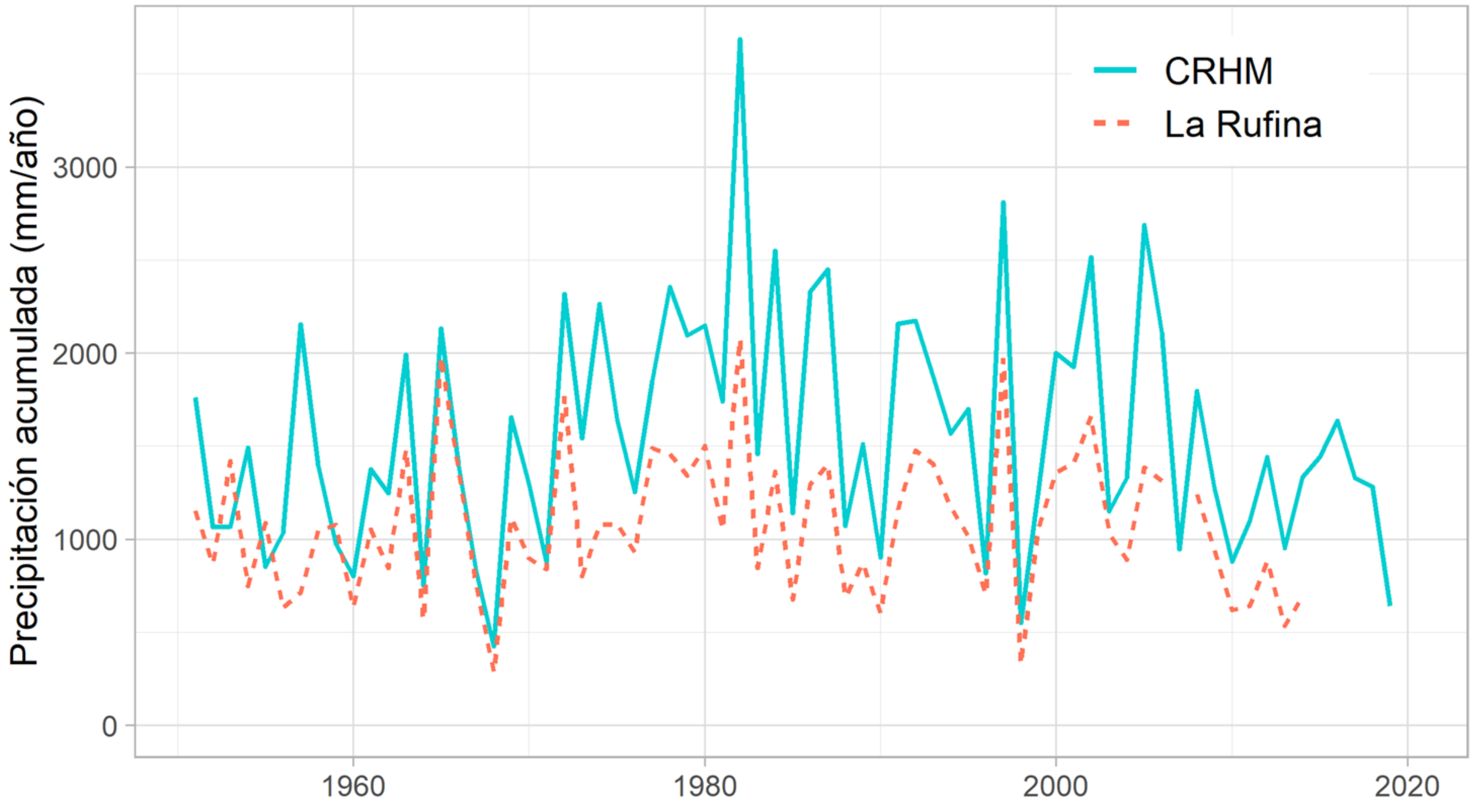
- Energy balance, blowing snow, avalanching
- 35 HRU based on elevation bands; orientation fairly homogeneous given glacier geometry
- Ice thickness updated “offline” with Dh parameterization
- Decreasing ice albedo trend-0.014/decade (Shaw et al., 2020)

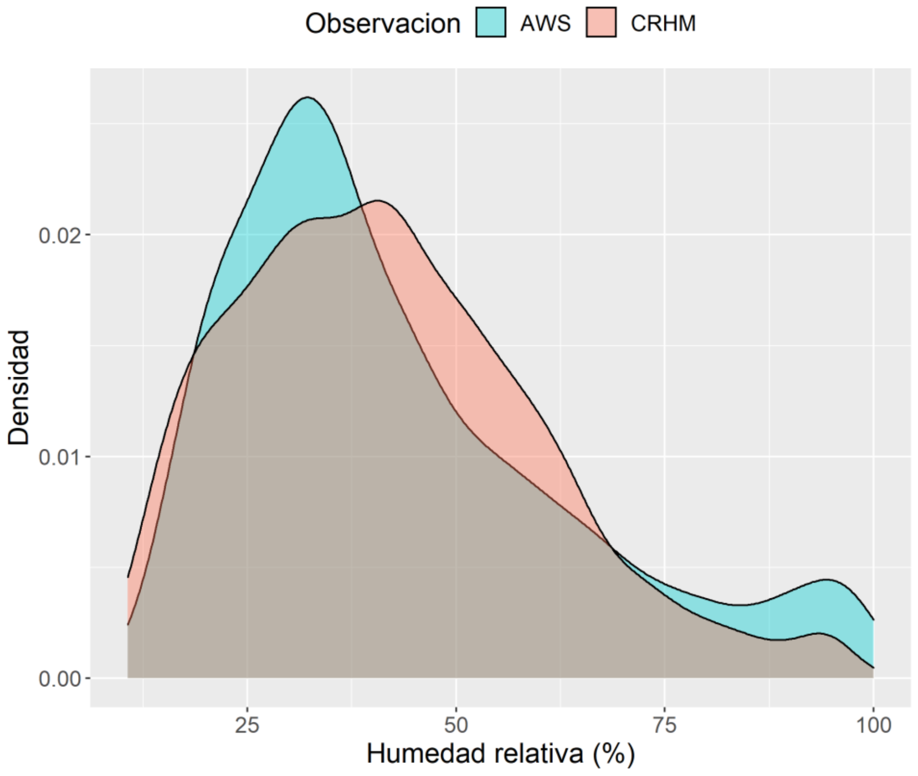


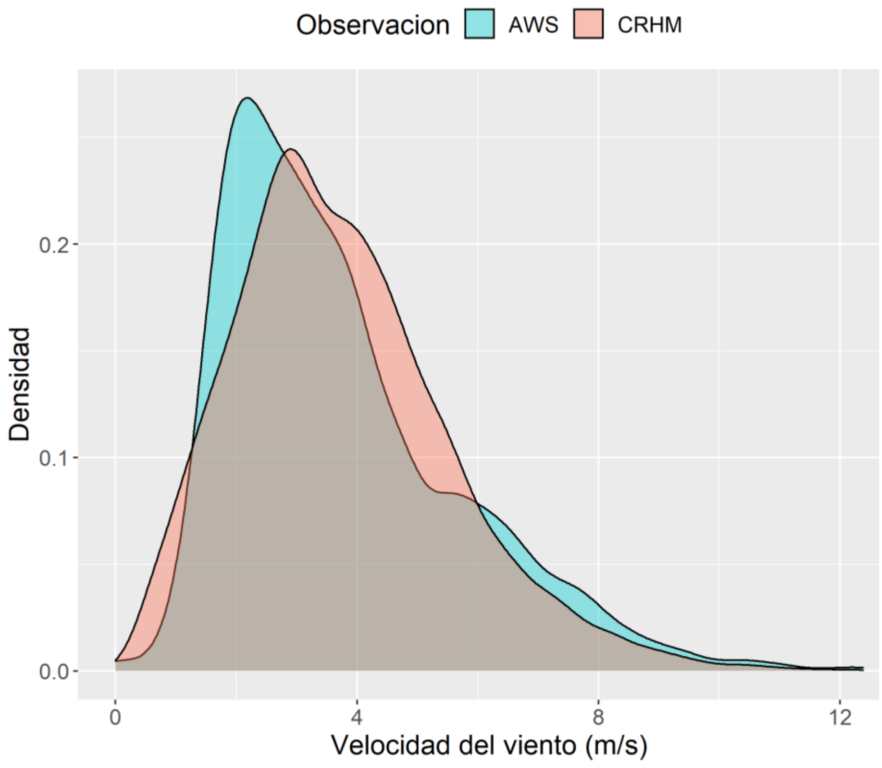
Forcing data

- Precipitation and temperature from ERA-Land at hourly time-step, bias-corrected through obs. based CR2met.

- Synthetic wind and relative humidity series generated from AWS data.





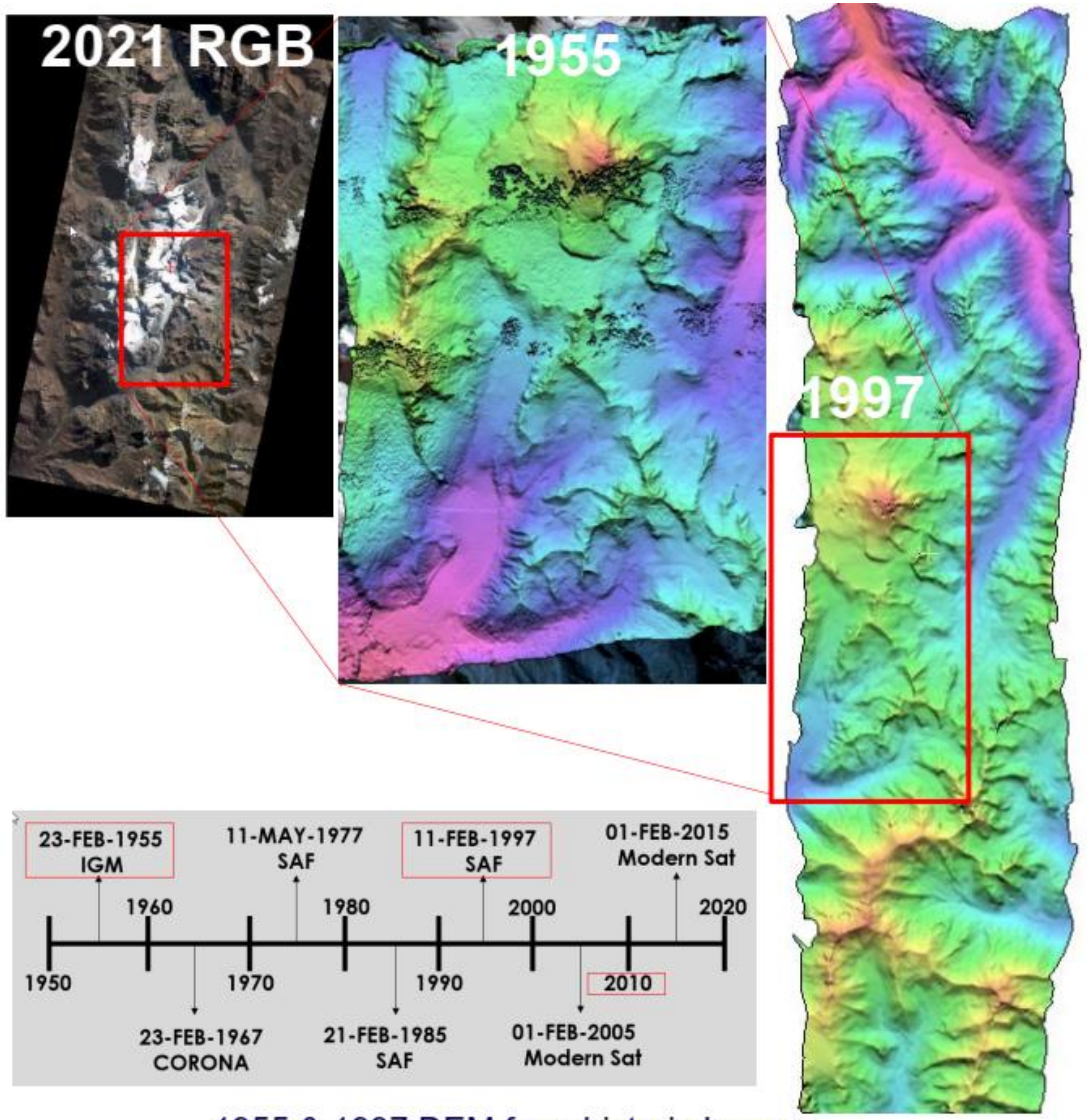


Extended geodetic mass balance estimations

- Scarcity of glaciological mass balance observations due to difficult field conditions. Only 2012-2014.

- Reprocessed aero-photogrammetric data enabled an extended geodetic mass balance time series, back to 1955.

Year	Mission	DEM source
1955	Hykon	Topographic map IGM
1985	SAF CH30	Original data
1997	GEOTEC	Original data
2000	SRMT	Farr and Kobrick. (2000)
2005	ASTER	Hugonnet et al. (2021)
2010	ASTER	Hugonnet et al. (2021)
2015	ASTER	Hugonnet et al. (2021)
2019	ASTER	Hugonnet et al. (2021)



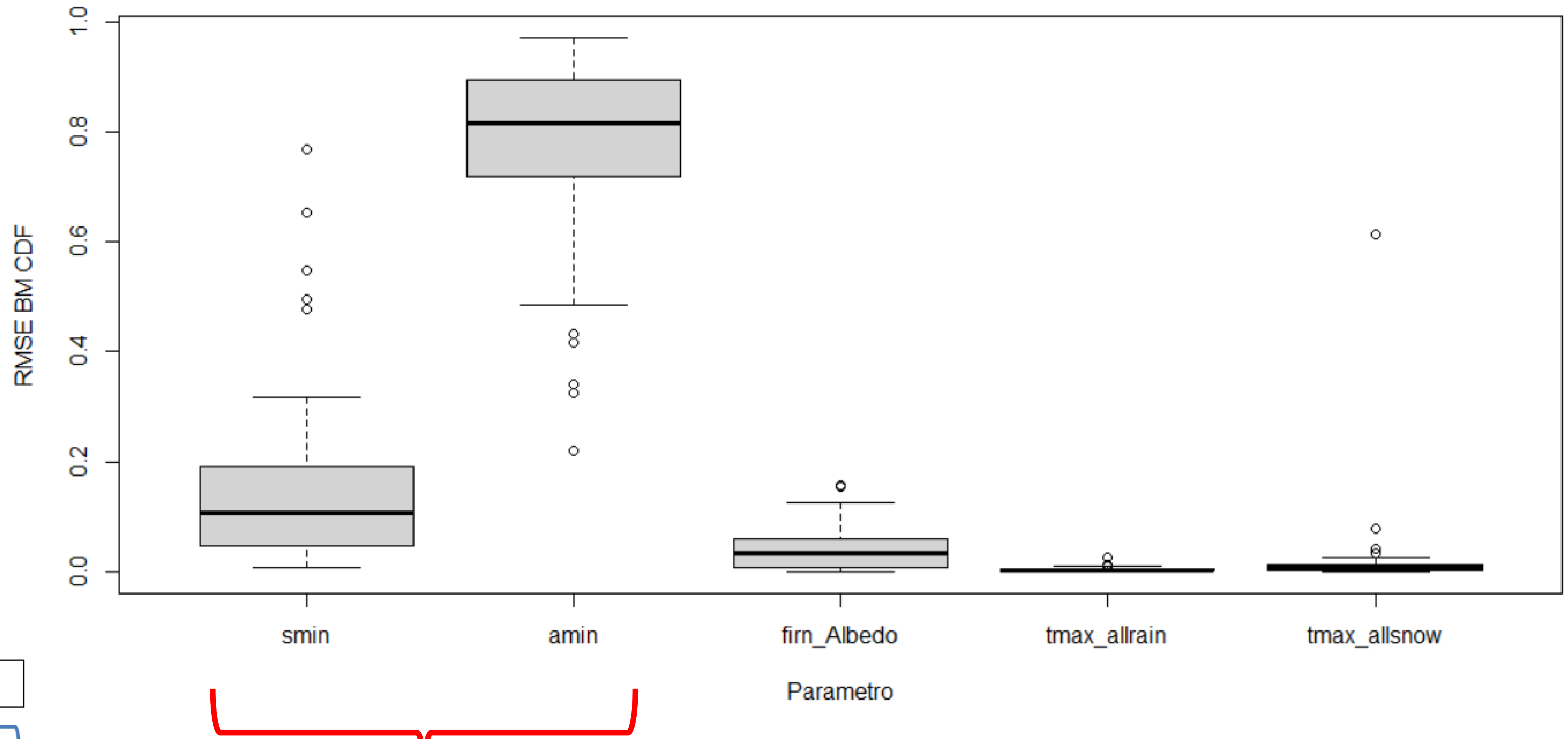
1955 & 1997 DEM from historic Images

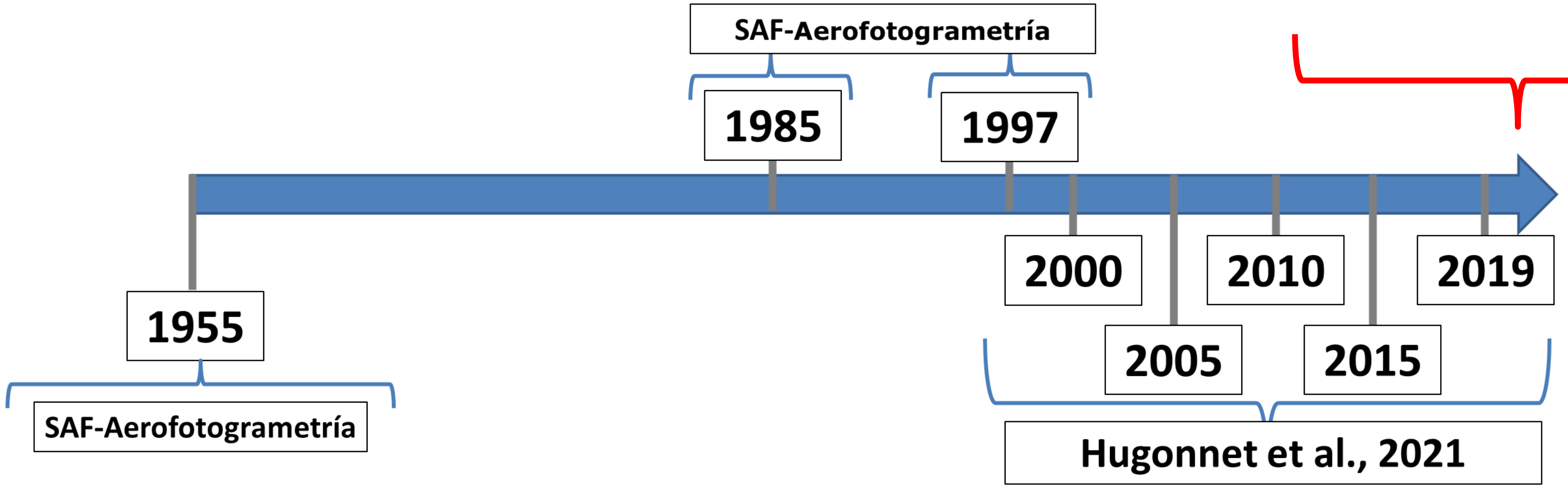
Mahmoud & Fernández 2021

Which model parameters are most sensitive to mass balance calculations?

- DELSA Sensitivity Analysis (Rakovec 2014) points to:
  Minimum snow albedo (amin)
  Snow fall threshold for albedo reset (smin).

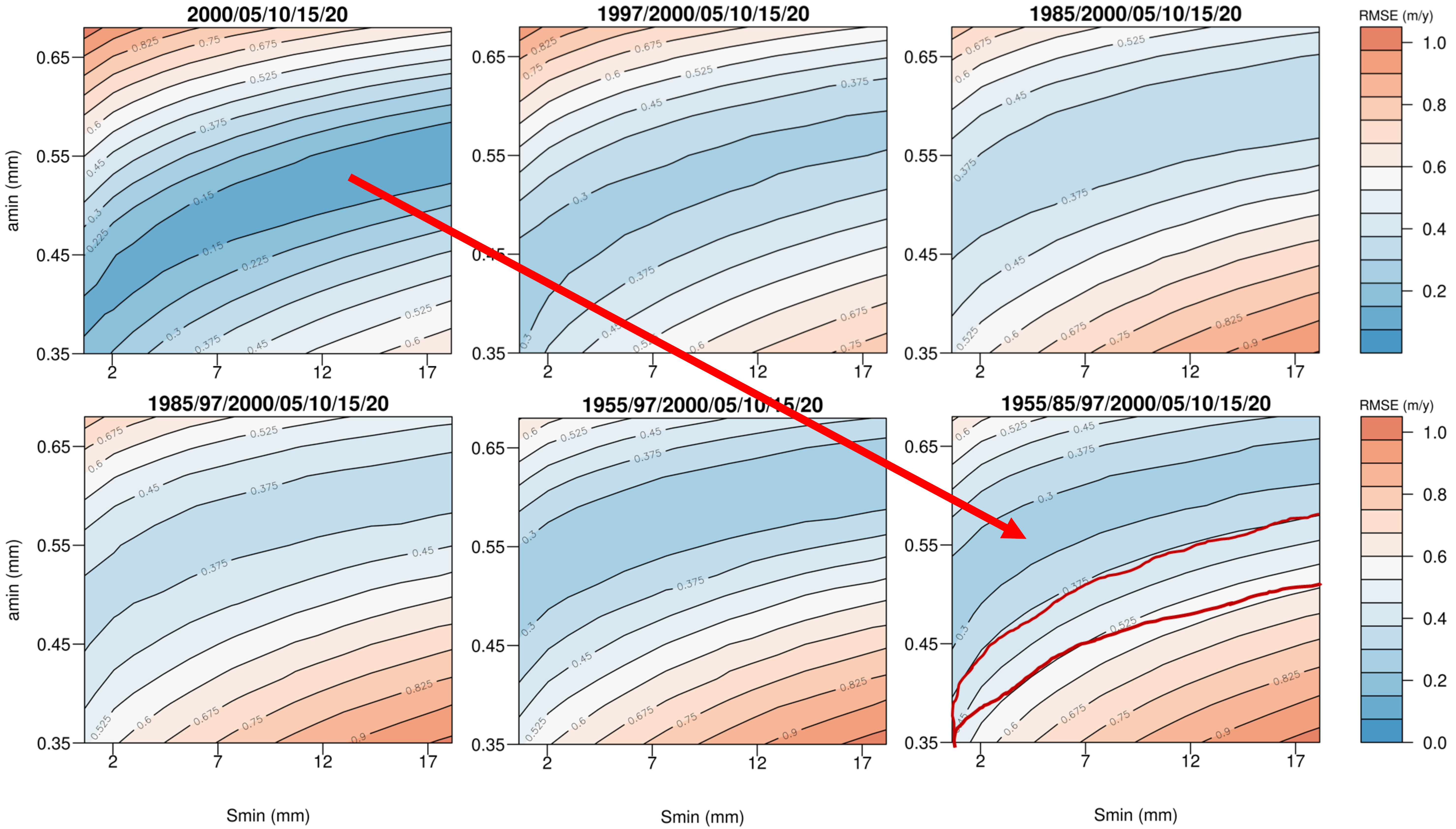
- Latin Hypercube response surface to explore parameter behavior w.r.t. mass balance time series.





$$\text{RMSE M. B.} = \sqrt{\frac{1}{m}\sum_{j=1}^{m}\left(\Delta h_{ref,j} - \Delta h_{sim,j}\right)}$$

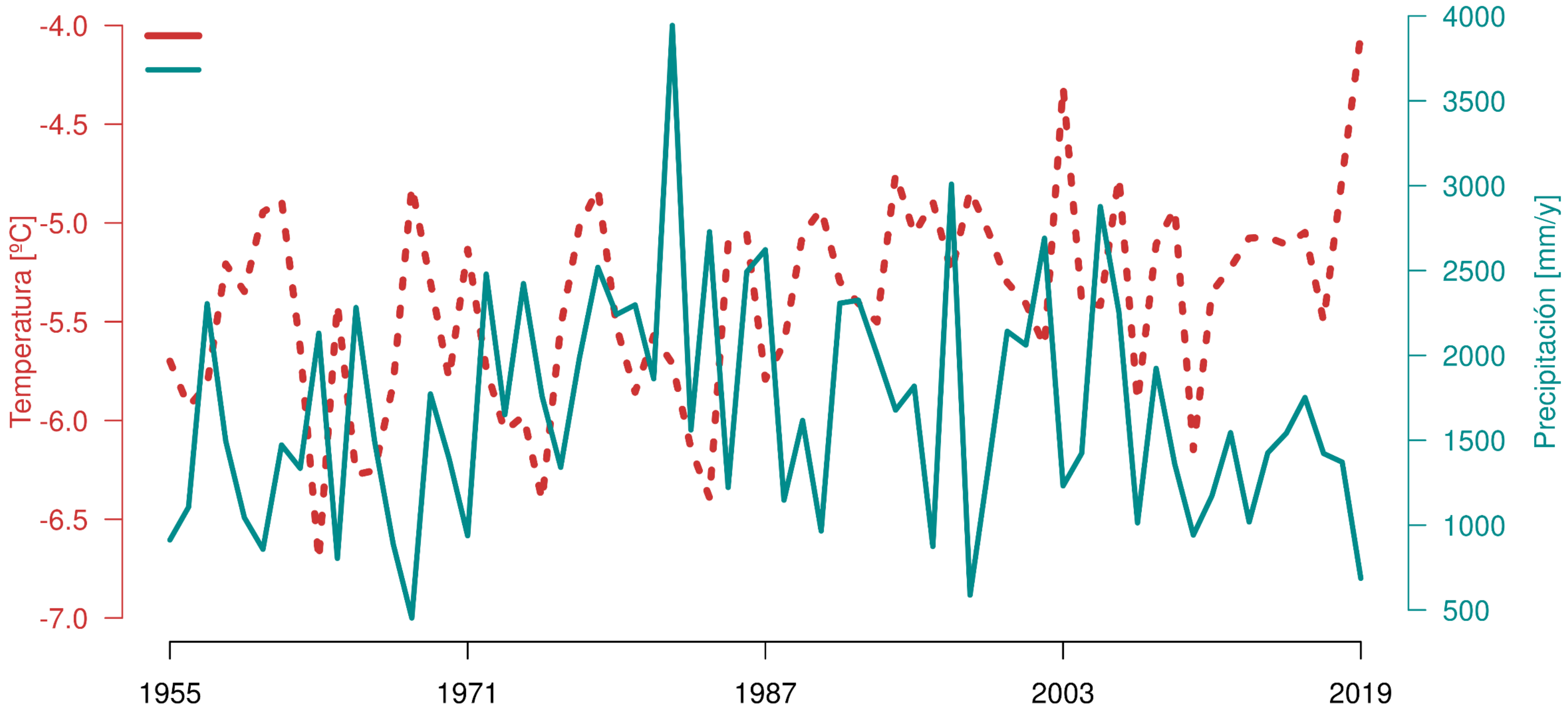
Calibration results show a shift in response surface to higher albedo -> less available energy for ablation

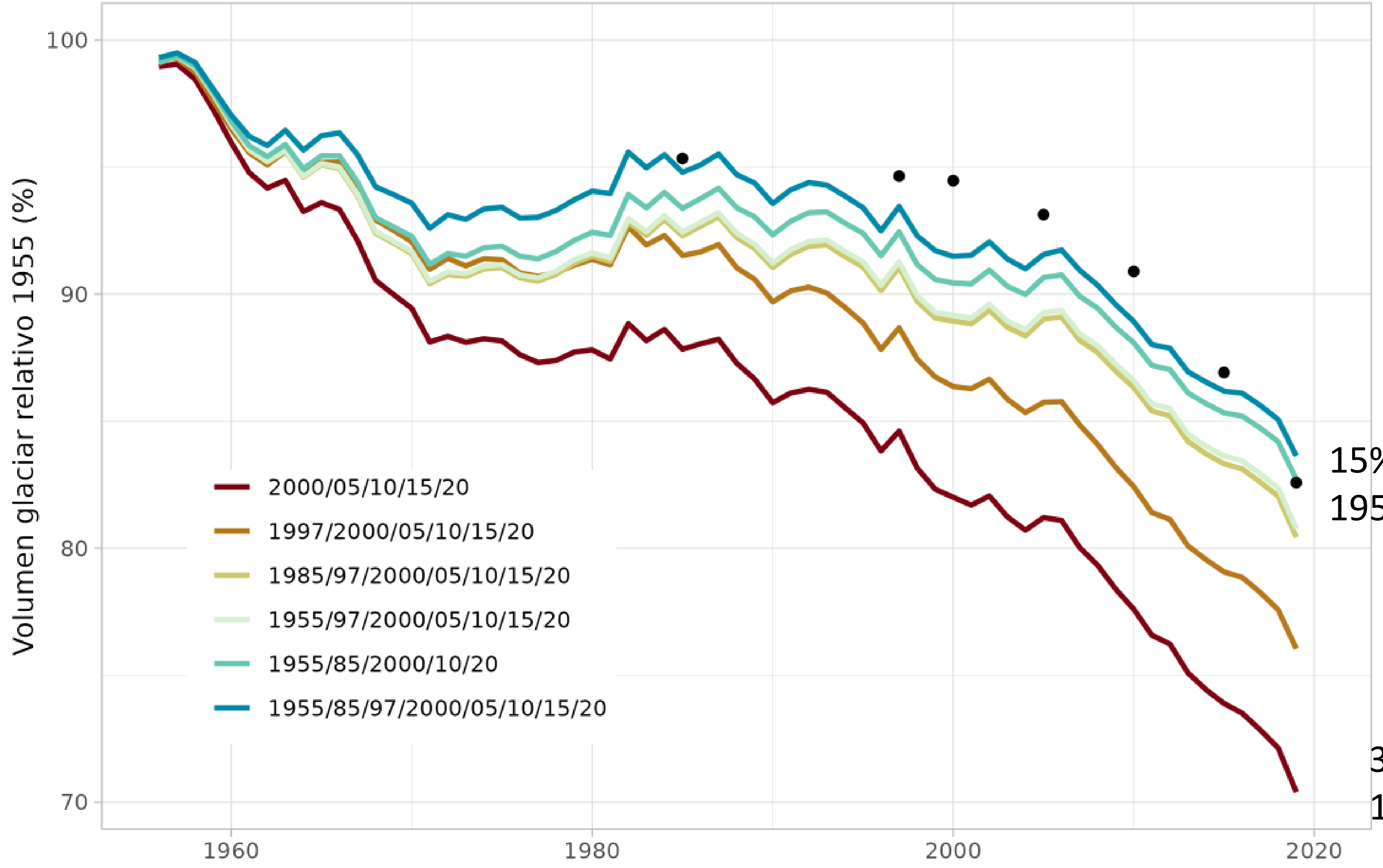


Running the model with different amin values

MB data from the last two decades requires very high ablation from the model

Prior two decades show a much gentler retreat…

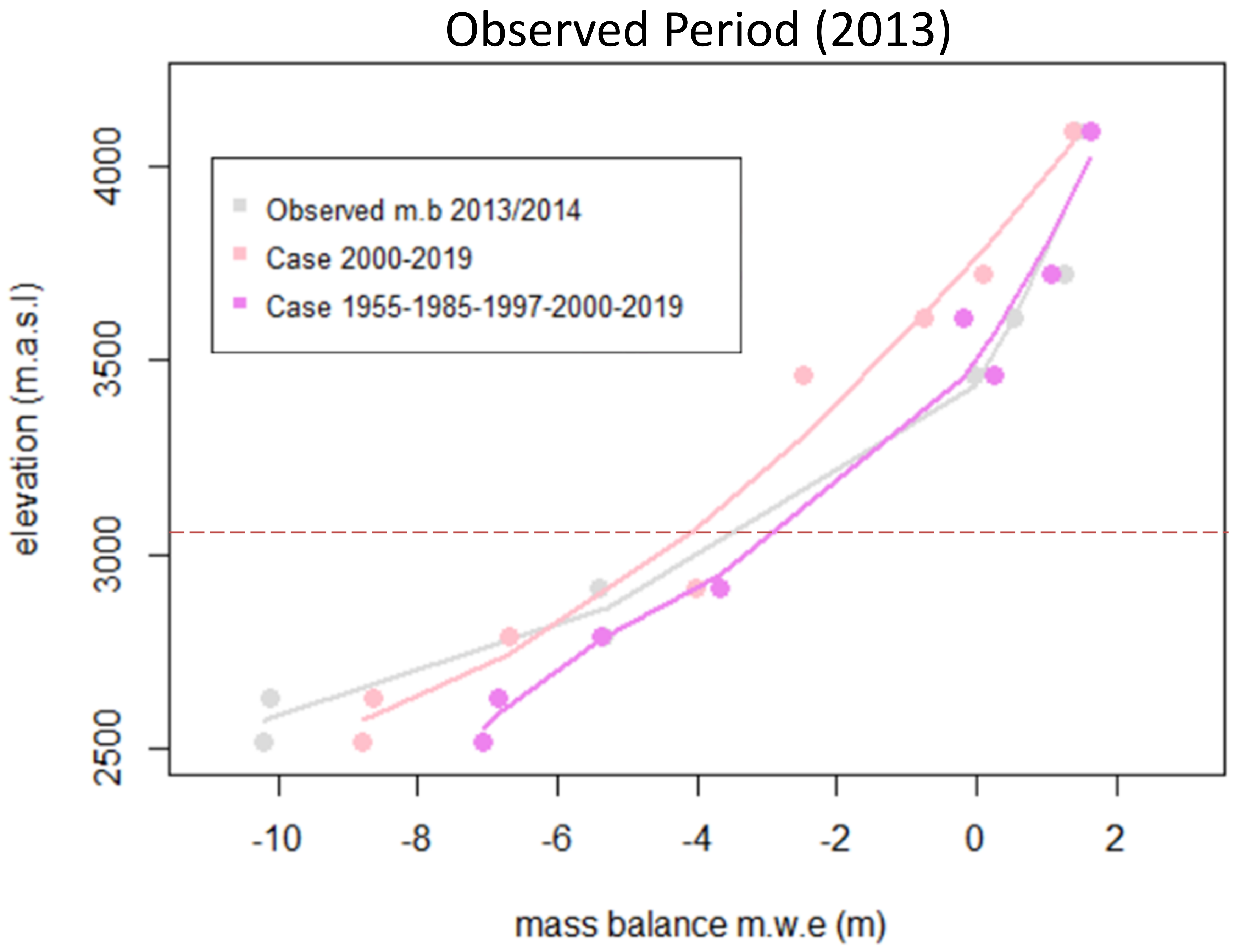


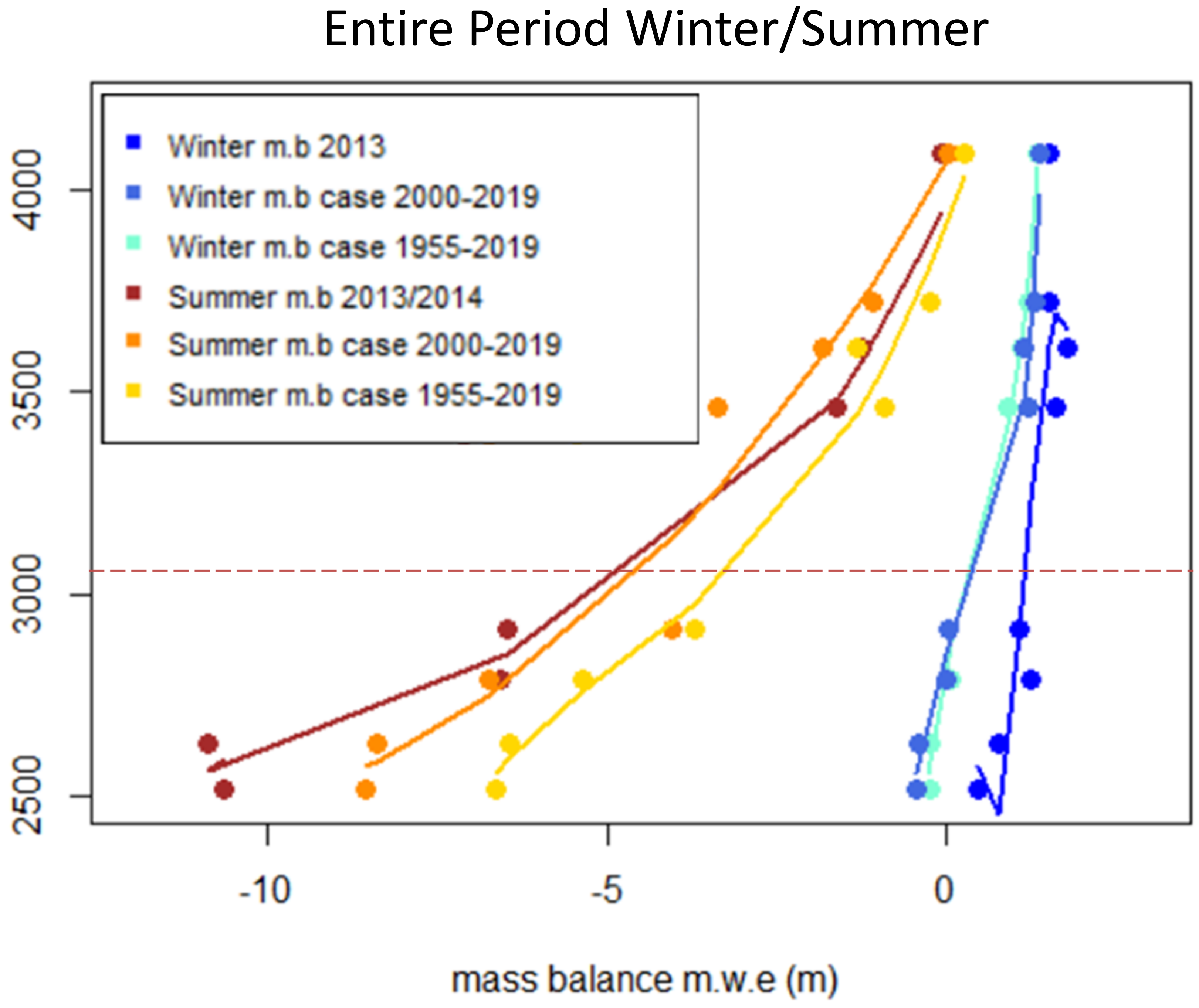


15% decrease w.r.t. 1955

30% decrease w.r.t. 1955

Running the model with different amin values





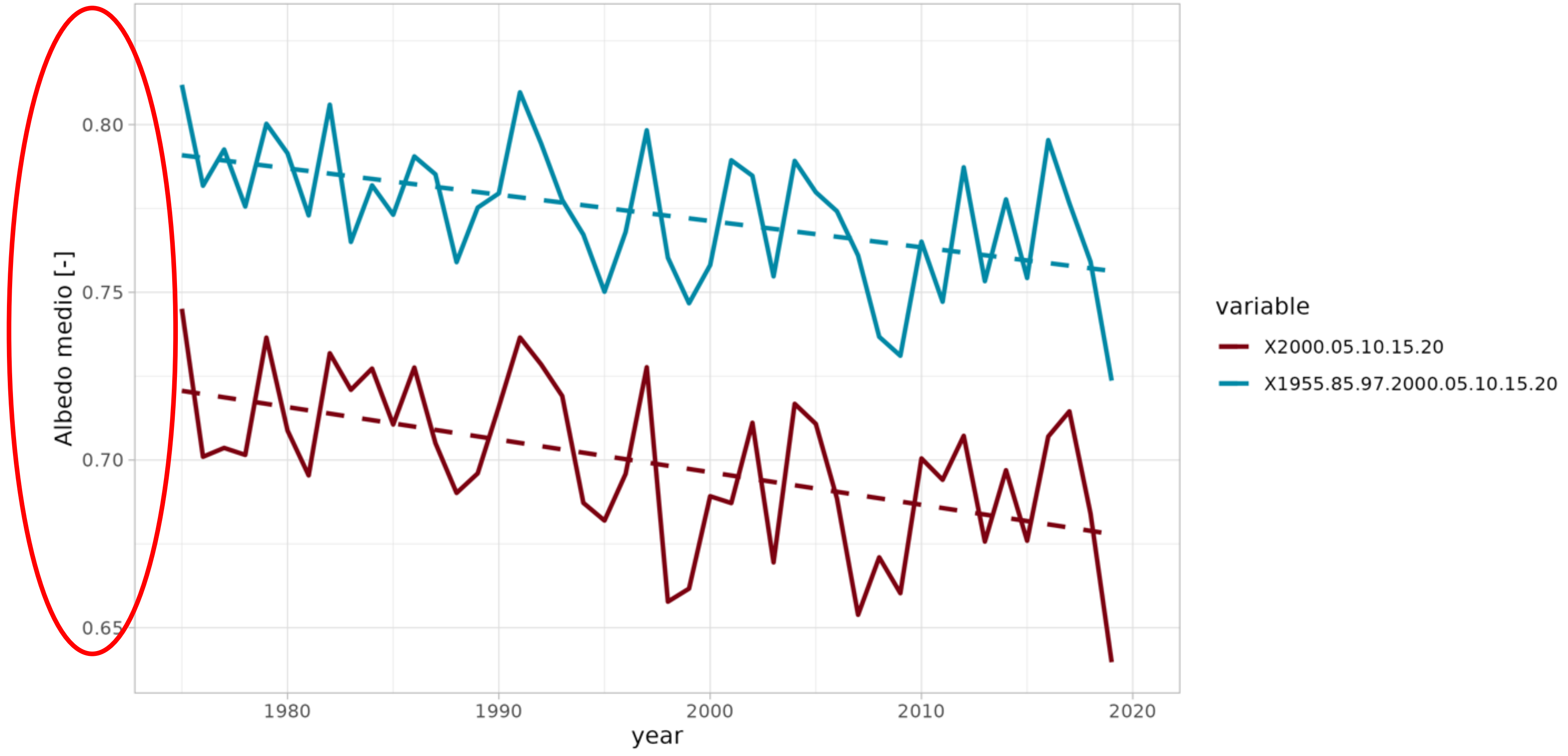
Do these results make sense at all? When comparing end-of-summer glacier wide albedo with satellite estimates, it seems the calibrated values are not very good

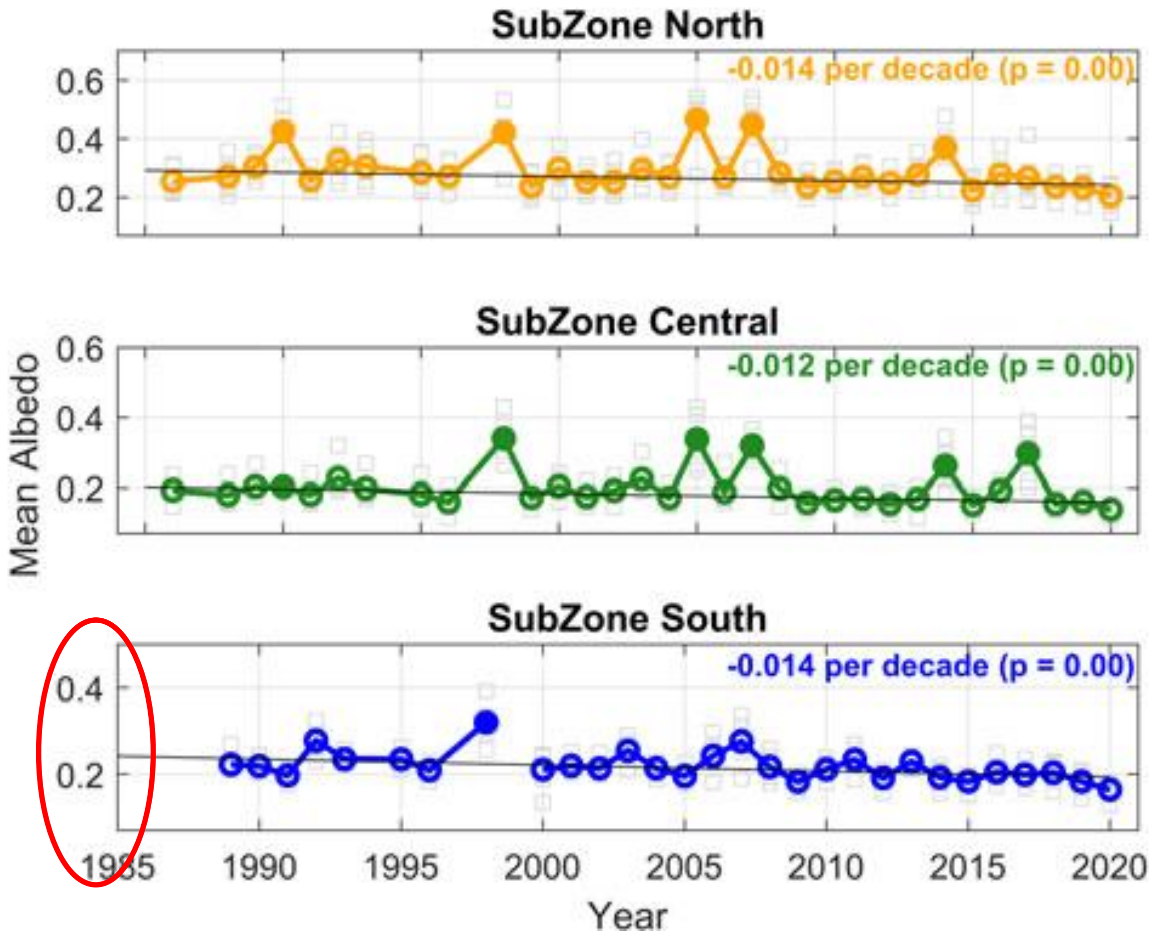
Journal of Glaciology

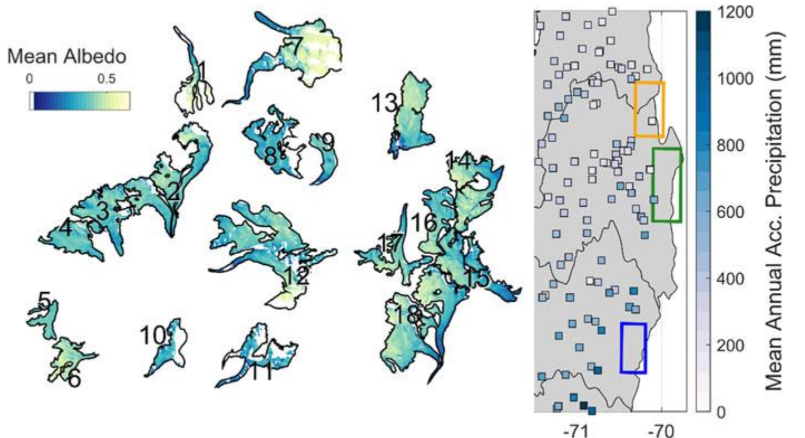
Article

Glacier albedo reduction and drought effects in the extratropical Andes, 1986–2020

Thomas E. Shaw[1,2], Genesis Ulloa[3], David Farías-Barahona[4], Rodrigo Fernandez[3], Jose M. Lattus[3,5] and James McPhee[2,6]

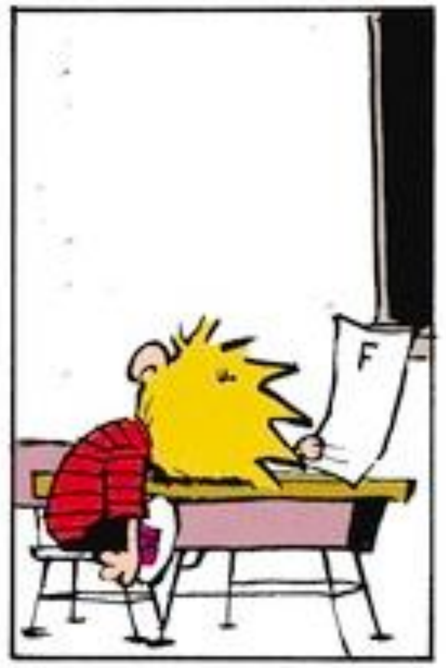


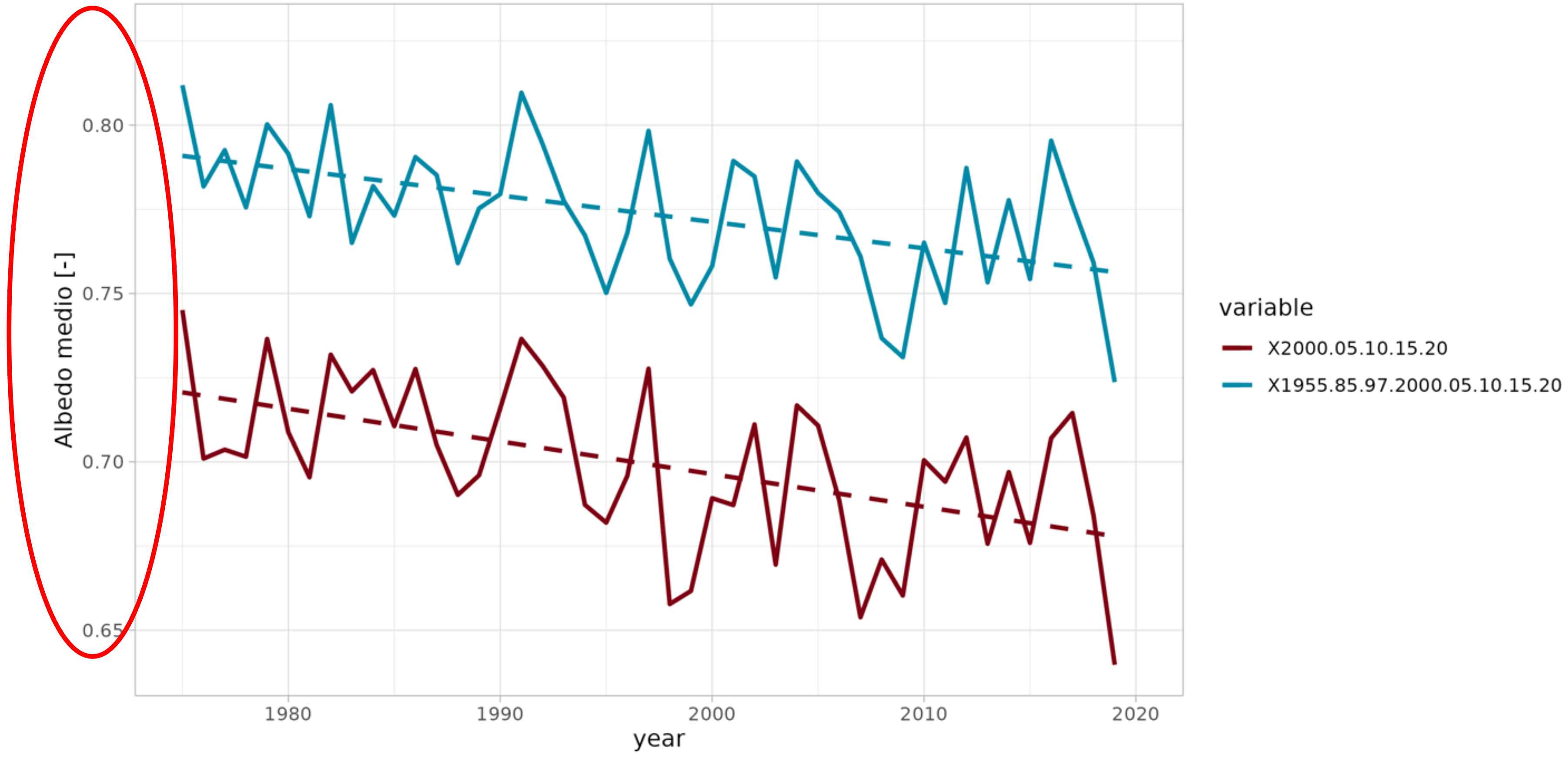




We get a trend (which is expected), but our glacier-wide albedo values are high compared to Shaw et al. (2021)

Do these results make sense at all? When comparing end-of-summer glacier wide albedo with satellite estimates, it seems the calibrated values are not very good





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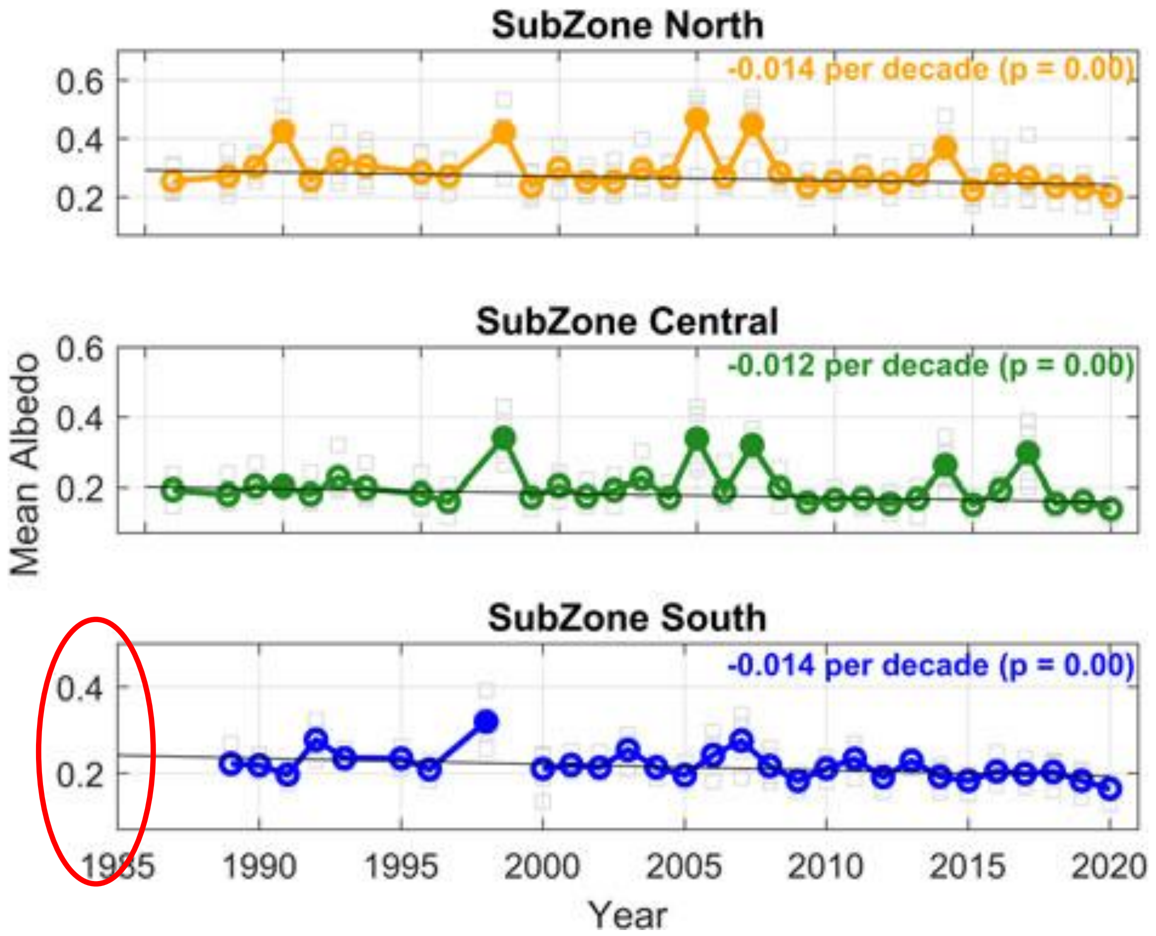

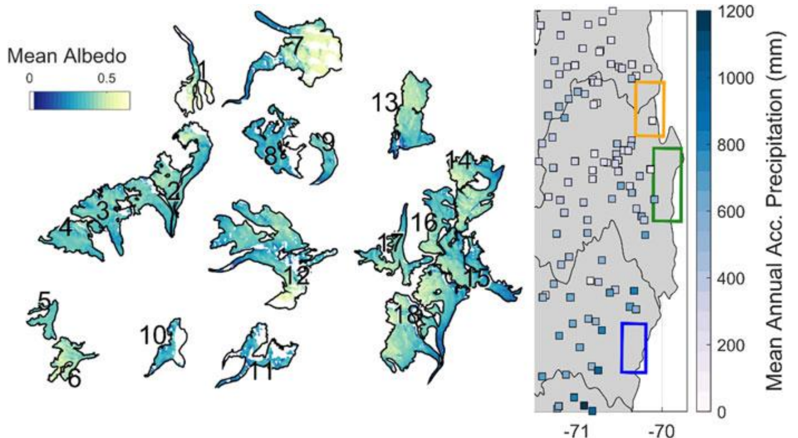

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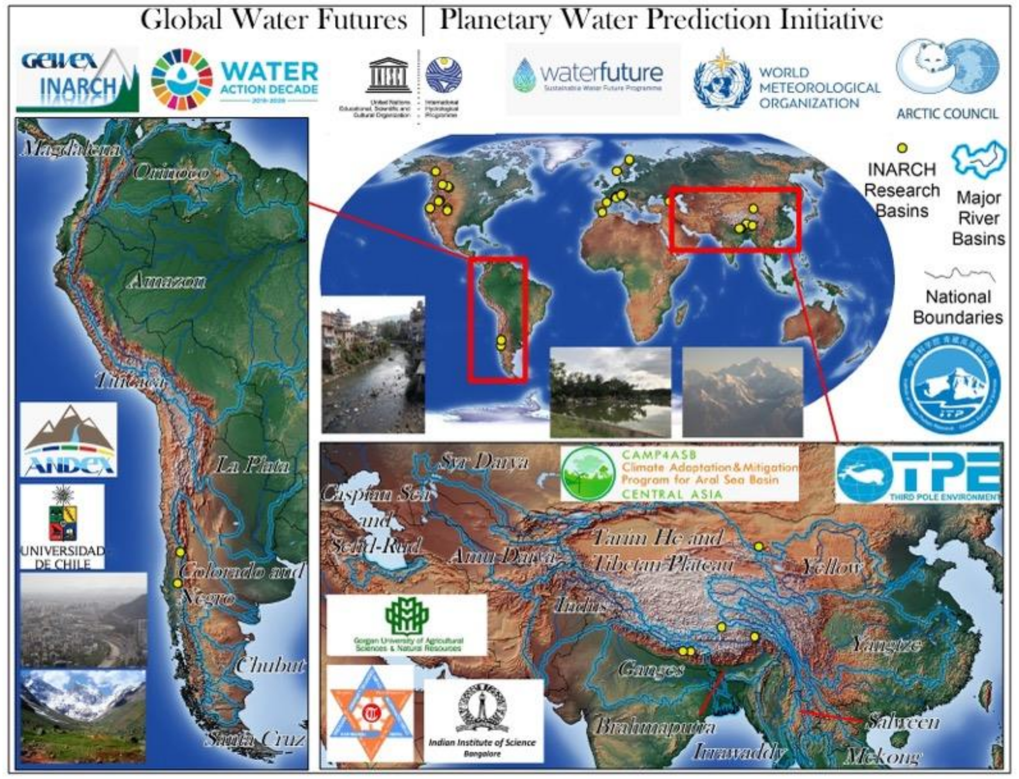
Next steps

Back to the drawing board: known unknowns?

- Geodetic MB affected by higher ice flow velocity in 1980´s?
- Overall underestimation of winter mass balance? Snowfall, redistribution to accumulation area?

Systematize workflow as template for larger modelling effort encompassing largest glaciers in the region (e.g Shaw et al. 2021 + Ayala et al. 2020 + others)



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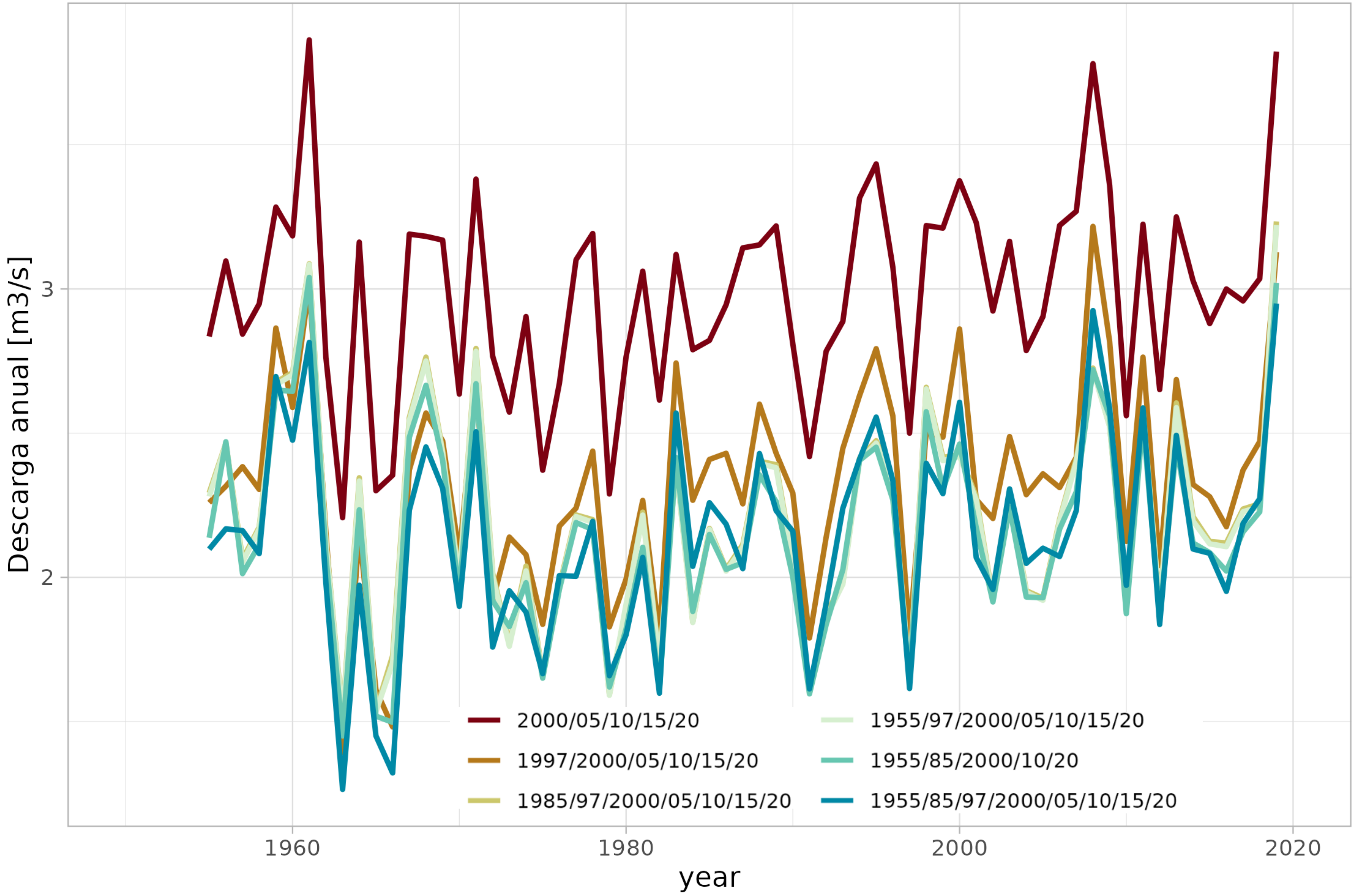
Resultados

Cambio escorrentía

- El modelo 2000-2020 posee una escorrentía de 3.0 m3/s promedio, mientras que el modelo 1955-2020 contribuye con 2.1 m3/s, i.e, un 39% de diferencia.

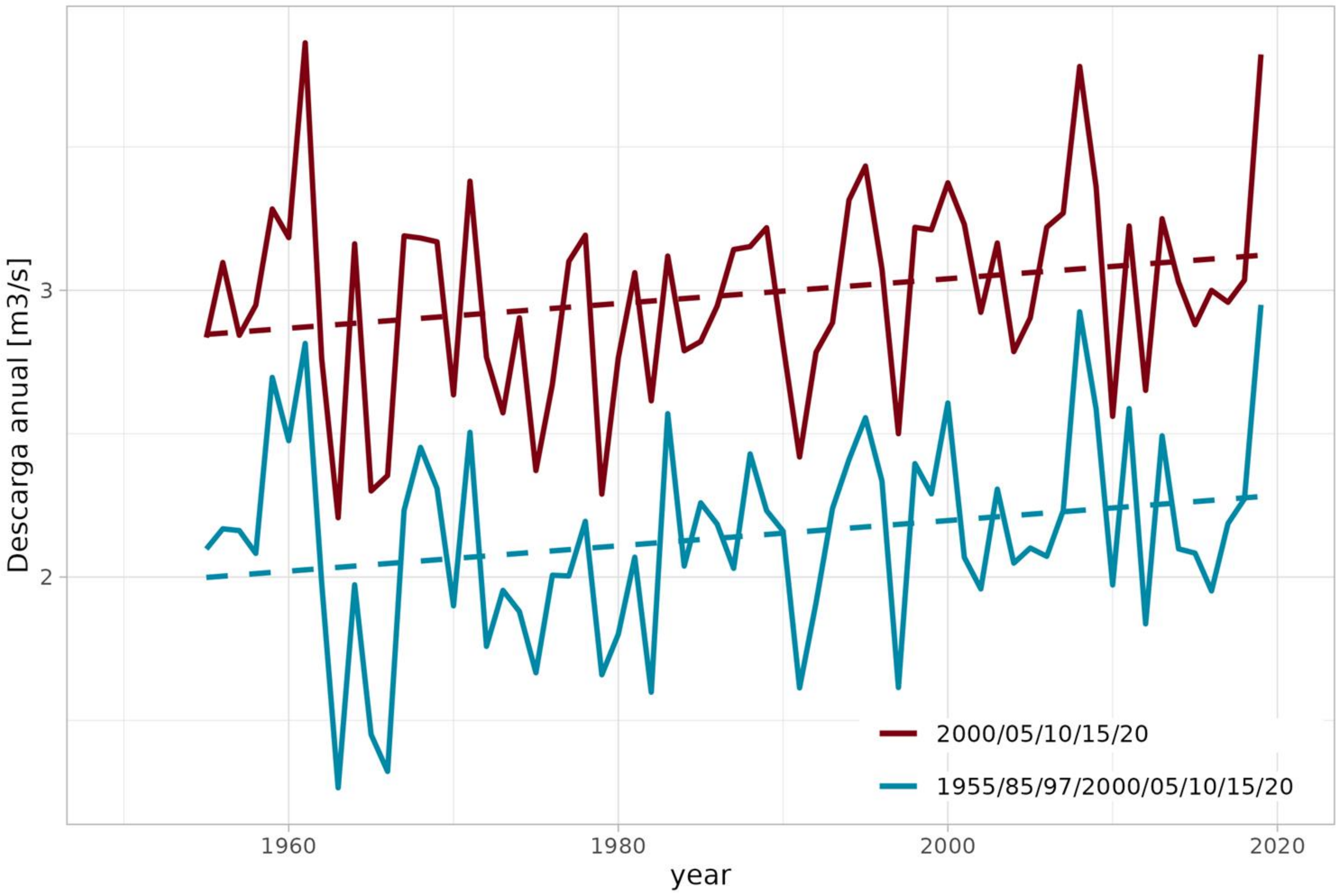
- Respecto a estudios similares, el glaciar tiene una escorrentía de 2,700 mm/yr. En comparación para el Río Maipo, los glaciares aportaron 2,260 mm/yr (Ayala et al. 2019).



Resultados

Cambio escorrentía

- En ambos modelos se aprecia una leve tendencia creciente de 0.04 m3/decada (p-value 0.04)



Resultados

Cambio escorrentía

- En ambos modelos se aprecia una leve tendencia creciente de 0.04 m3/decada (p-value 0.04)
- Desde 1975, se aprecia una clara tendencia (p-value < 0.01) en el aumento en la escorrentía de deshielo.
- Mientras para el modelo 1955-2020 se obtiene un crecimiento de 0.12 m3/decada, en el modelo 2000-2020 se tiene un aumento de 0.18 m3/decada.