Glacier Mass Balance Intercomparison Exercise

Community estimate of global glacier mass changes from 2000 to 2023

Results & Roadmap

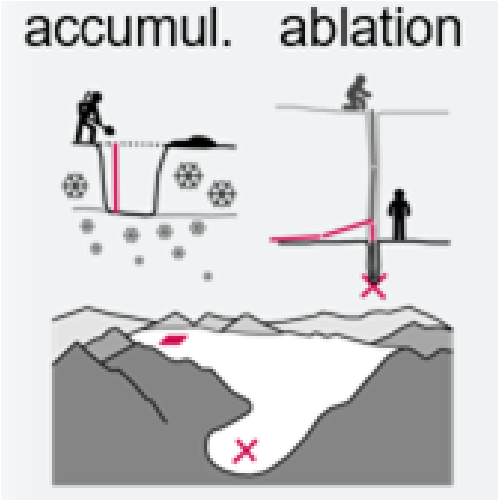
The GlaMBIE Team: Zemp, M.; Jakob, L.; **Dussaillant, Inés;** Nussbaumer, S.U.; Dubber, S.; **Gourmelen, Noel**

Abdullahi, S.; Aðalgeirsdótti, G.; Belart, J.M.; Berthier, E.; Bhambri, R.; Bhattacharya, A.; Björnsson, H.; Blazquez, A.; Bolch, T.; Box, J.; Braun, M.H.; Brun, F.; Burgess, D.O.; Cicero, E.; Colgan, W.T.; Coupry, B.; Cruz Bacca, S.; Dehecq, A.; Döhne, T.; Einarsson, B.; Fan, Y.; Favier, V.; Florentine, C.; Floricioiu, D; Fountain, A.; Fugger, S.; Gardner, A.; Gunnarsson, A.; Hannesdóttir, H.; Haraldsson, H.H.; Harig, C.; Hassan, J.; Hock, R.; Horwath, M.; Howat, I.; Huber, M.; Hugonnet, R.; Huss, M.; Jacob, T.; Jóhannesson, T.; Ke, C.; Keller, C.; Khan, S.A.; King, O.; Kneib, M.; Liang, C.; Lukas, K.; Magnússon, E.; Malz, P.; Marschalk, U.; Masiokas, M.; Mattea, E.; McCarthy, M.; McNabb, R.; Menounos, B.; Miles, E.; Moholdt, G.; Nilsson, J.; O'Neel, S.; Paul, F.; Pellicciotti, F.; Pfeffer, J.; Piermattei, L.; Pitte, P.; Pritchard, M.; Pálsson, F.; Richter, A.; Romero, A.; Roth, A.; Ruiz, L.; Sasgen, I.; Seehaus, T.; Shen, X.; Sigurðsson, O.; Sommer, C.; Suad Corbetta, F.; Sutterley, T.; Thomson, L.I.; Thorsteinsson, T.; Treichler, D.; Velicogna, I.; WGMS, PIs; Welty, E.; Wessel, B.; Willis, M.; Wouters, B.; Zheng, W.; Zhou, X.

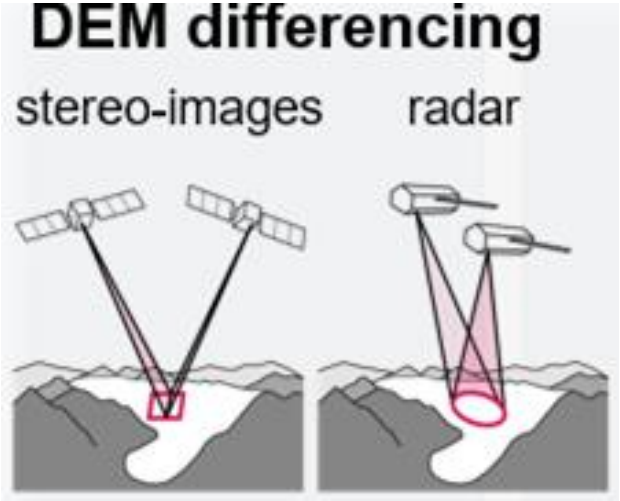
The need for a community estimate

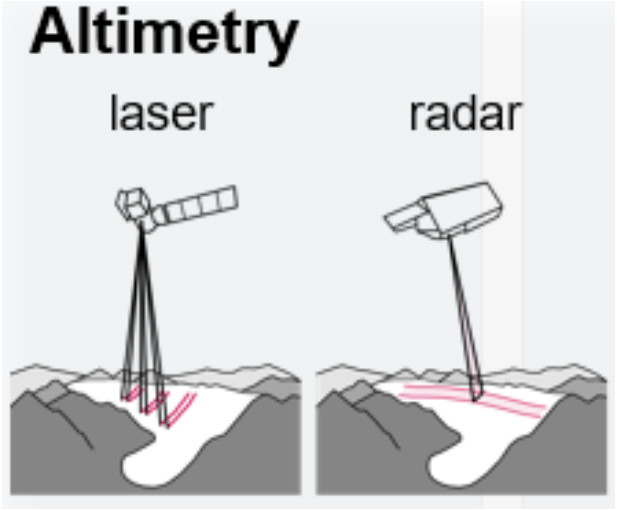
Various observation methods to measure glacier mass changes

GLACIOLOGICAL METHOD



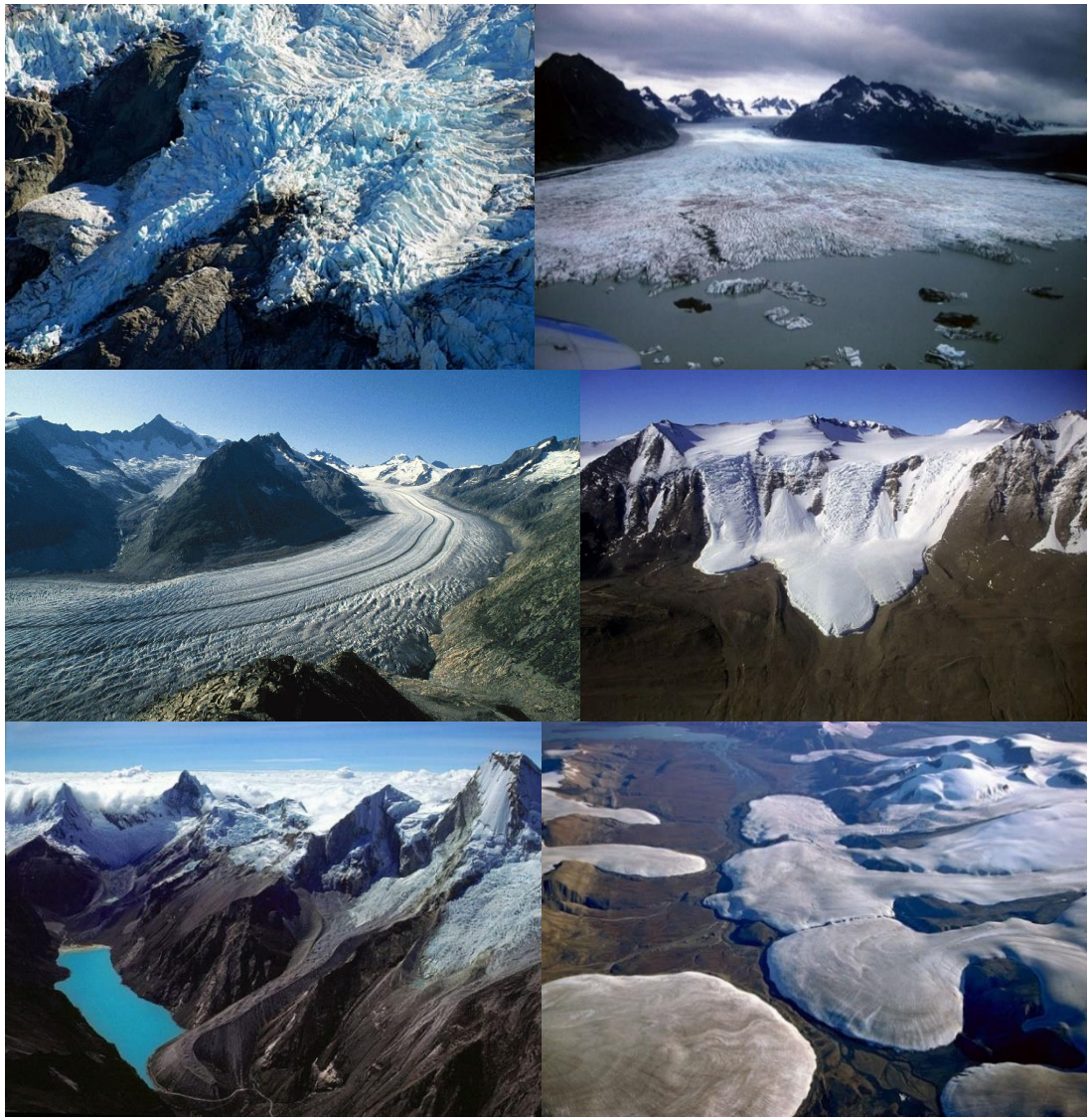
GEODETIC METHODS





GlaMBIE Team (2024, in review)

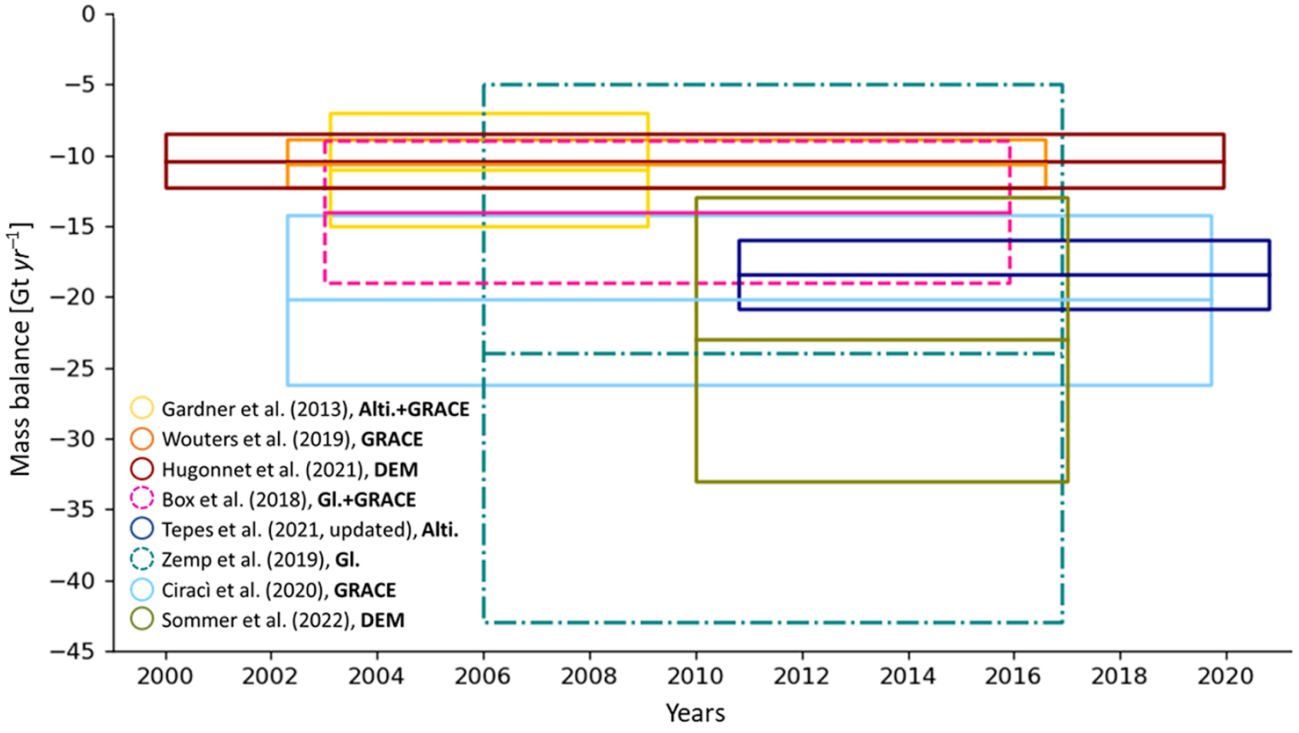
The need for a community estimate



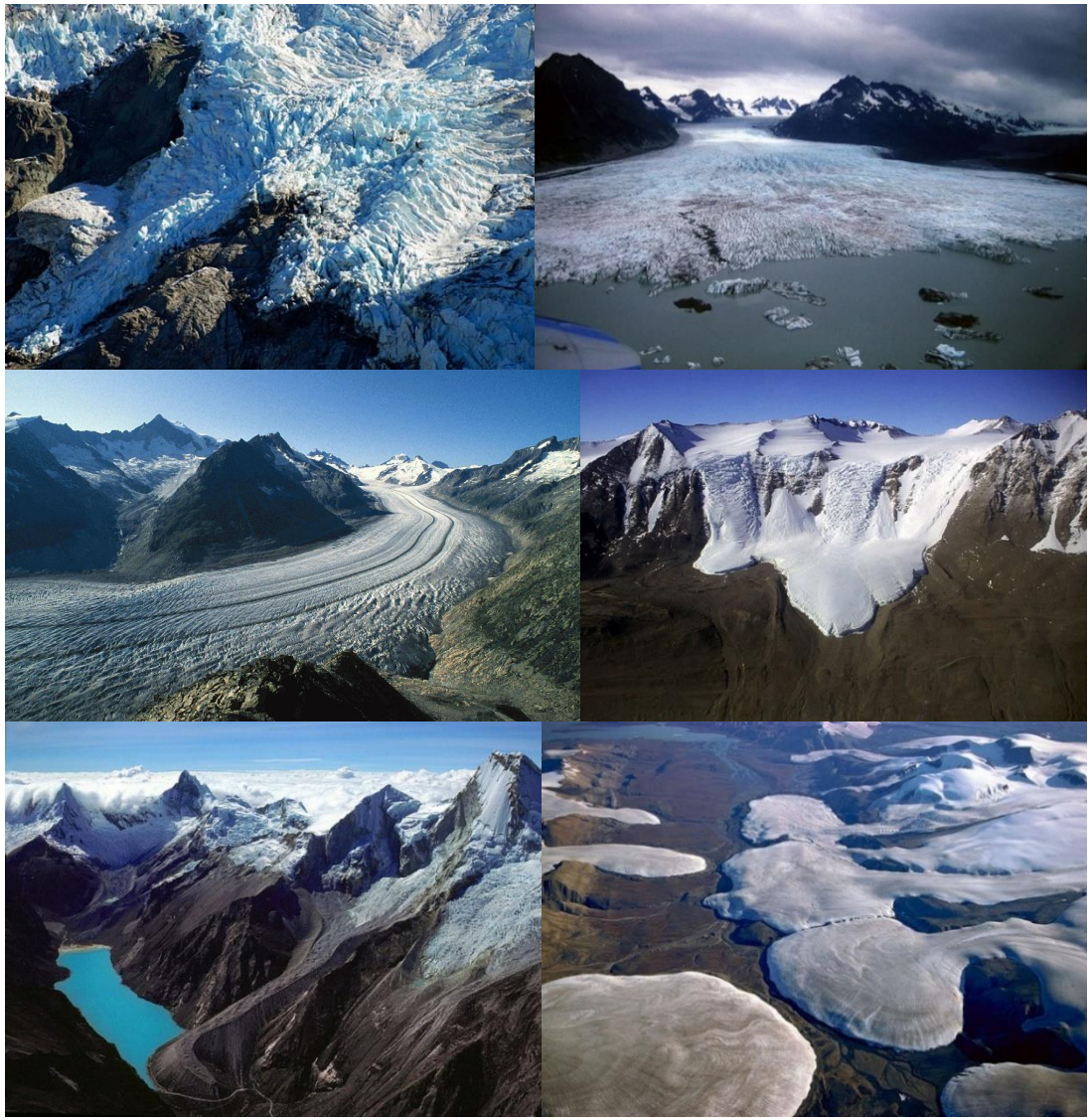
Glaciers Online: https://www.swisseduc.ch/glaciers

= **Large** range of results...

Example: Glacier mass changes in the Russian Arctic



The need for a community estimate



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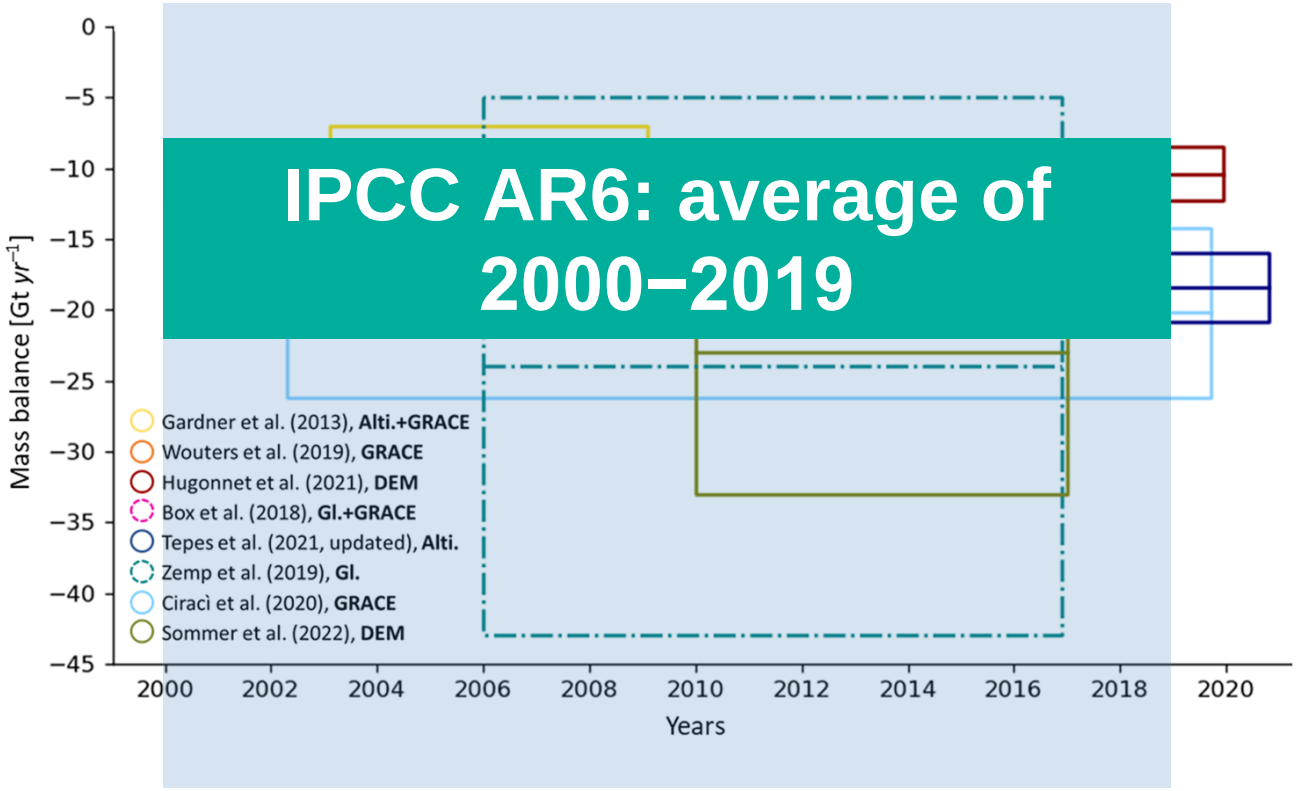
Need for a data-centric approach

Example: Glacier mass changes in the Russian Arctic



Glacier Mass Balance Intercomparison Exercise

glambie

European Space Agency

esa

GlaMBIE consortium

glambie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earthwave

THE UNIVERSITY of EDINBURGH

RAGMAC Community
(Researchers & Participants)

Scientific Advisory Committee
(RAGMAC Co-Chairs)

IACS

- Etienne Berthier
- Matthias Braun
- Fanny Brun
- Alex Gardner
- Regine Hock
- Geir Moholdt
- Bert Wouters

Stakeholder Board

- Intergovernmental Panel on Climate Change
- American Meteorological Society
- World Meteorological Organisation
- Copernicus Climate Change Service
- International Association of Cryospheric Sciences
- US National Aeronautics and Space Administration
- Ice Sheet Mass Balance Intercomparison Experiment
- Horizon 2020, Horizon Europe projects
- International Cryosphere Climate Initiative

Project Objectives

- Define a set of criteria to standardise the assessment and its uncertainty
- Collect and analyse regional assessments from the community across the range of available methods
- Produce and publish a consensus estimate at regional and global levels
- Work will lead to a set of recommendations for standardised future assessments

Community effort

to generate a
reconciled estimate
of glacier mass changes
at regional and global levels based on
all observational sources

RAGMAC

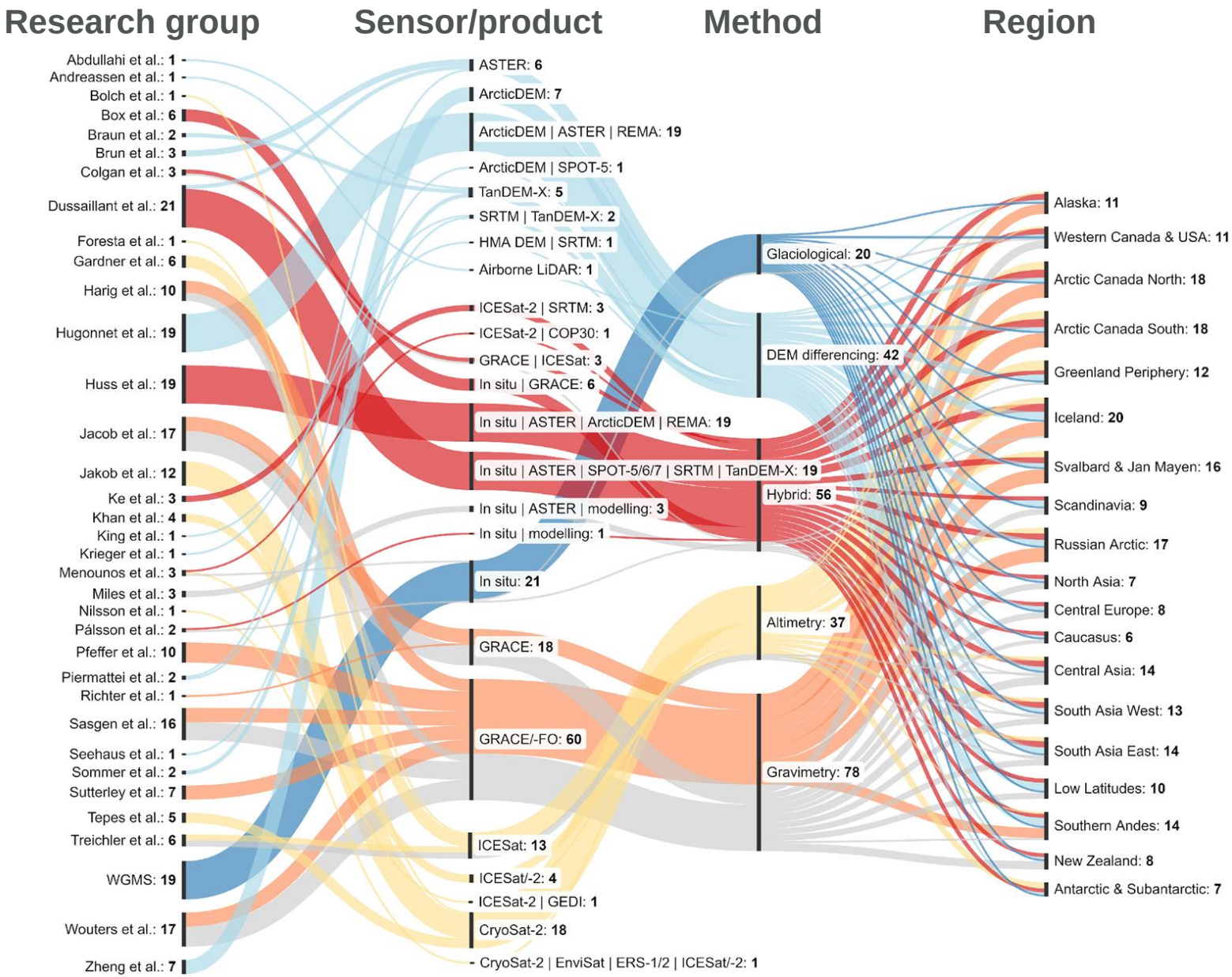
Regional Assessment of Glacier Mass Change

IACS
International Association of Cryospheric Sciences

Building on **existing activities** and **network**

esa

Community input to GlaMBIE



35 research groups

21 sensor combinations

4 observational methods

- Glaciological
- DEM differencing
- Altimetry
- Gravimetry
- & (Hybrid)

19 glacier regions

233 mass change estimates

period **2000 – 2023**

GlaMBIE Team (2024, in review)

The GlaMBIE approach workflow in a nutshell

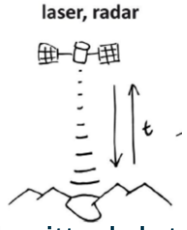
WITHIN methods

1

Compile data at best resolution and unit

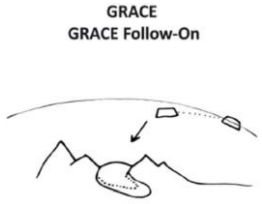
Homogenize data (space, time, units, area)

Altimetry



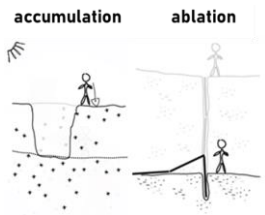
Submitted datasets

Gravimetry



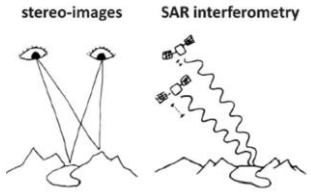
Submitted datasets

Glaciological



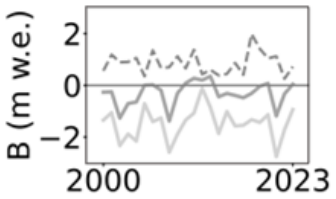
Submitted datasets

DEM differencing



Submitted datasets

1 **Select & homogenize**
(time, space, unit)



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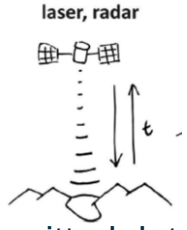
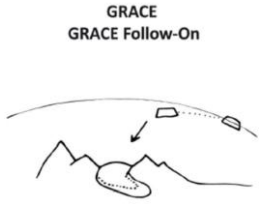
2 Separate temporal variability and long-term trend

Altimetry



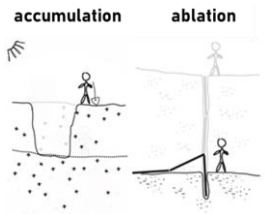
Submitted datasets

Gravimetry



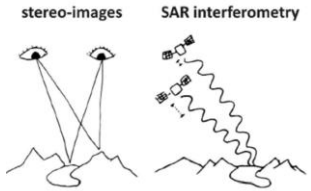
Submitted datasets

Glaciological

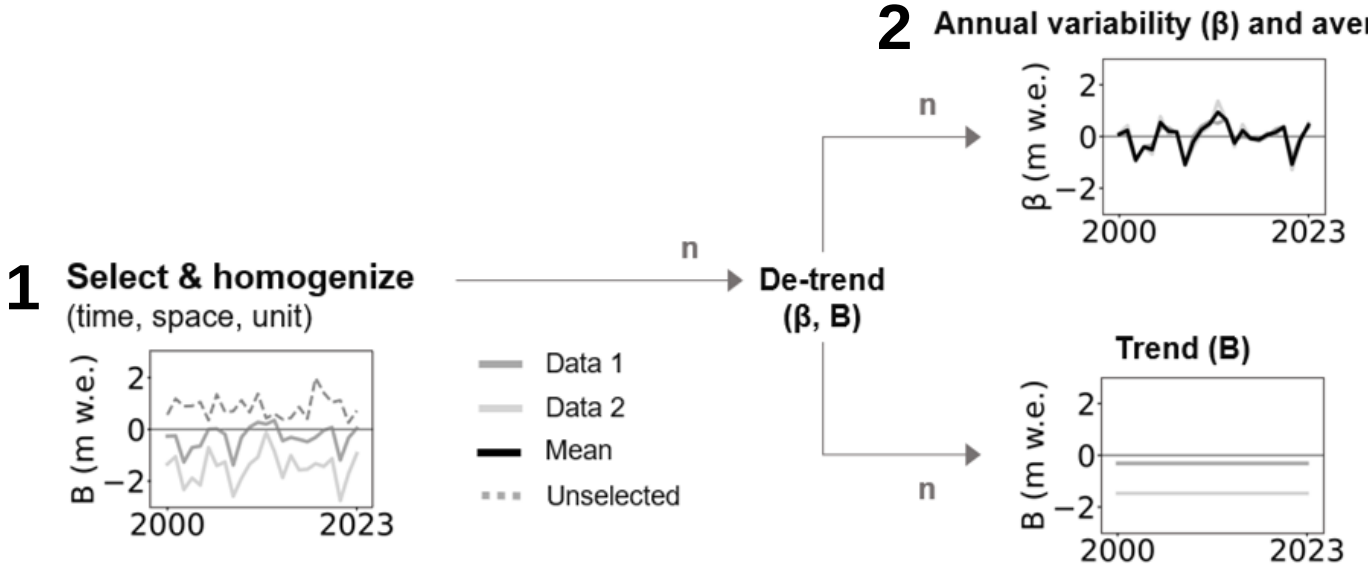


Submitted datasets

DEM differencing



Submitted datasets



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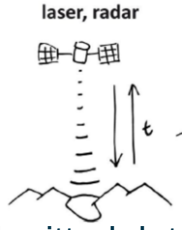
2 Separate temporal variability and long-term trend

3 Combine datasets within methods

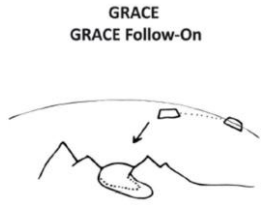
Altimetry



Submitted datasets

Combined Altimetry solution

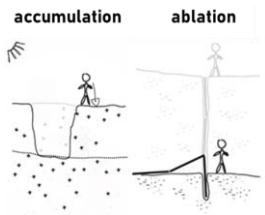
Gravimetry



Submitted datasets

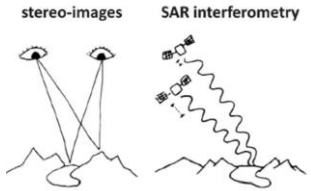
Combined Gravimetry solution

Glaciological



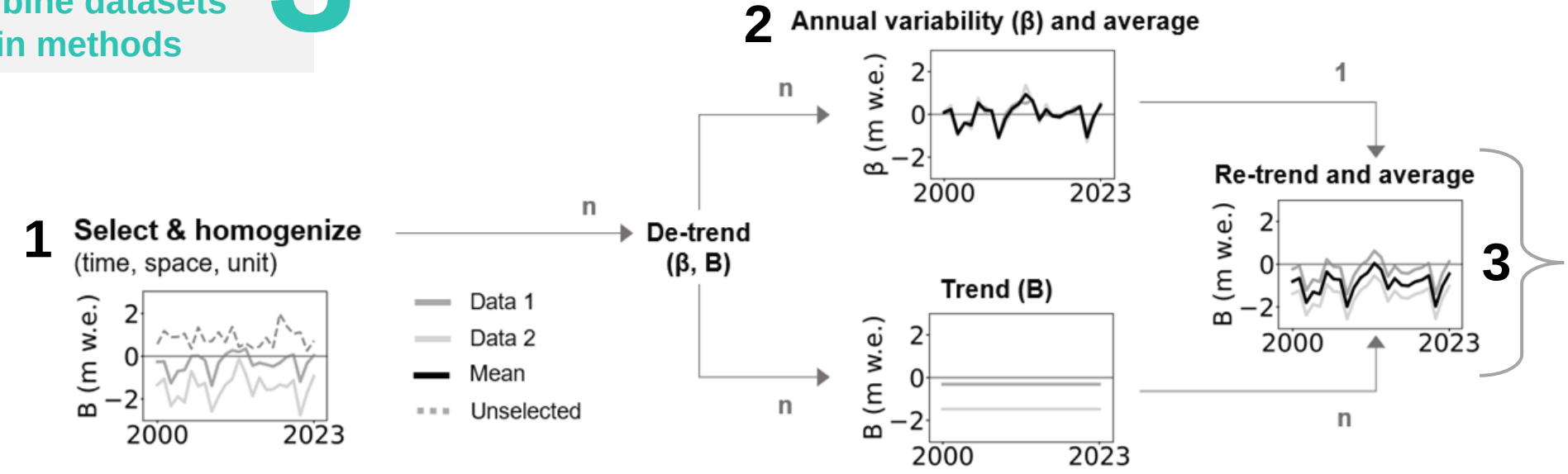
Submitted datasets

DEM differencing



Submitted datasets

Combined DEM differencing & glaciological solution



Combined solution

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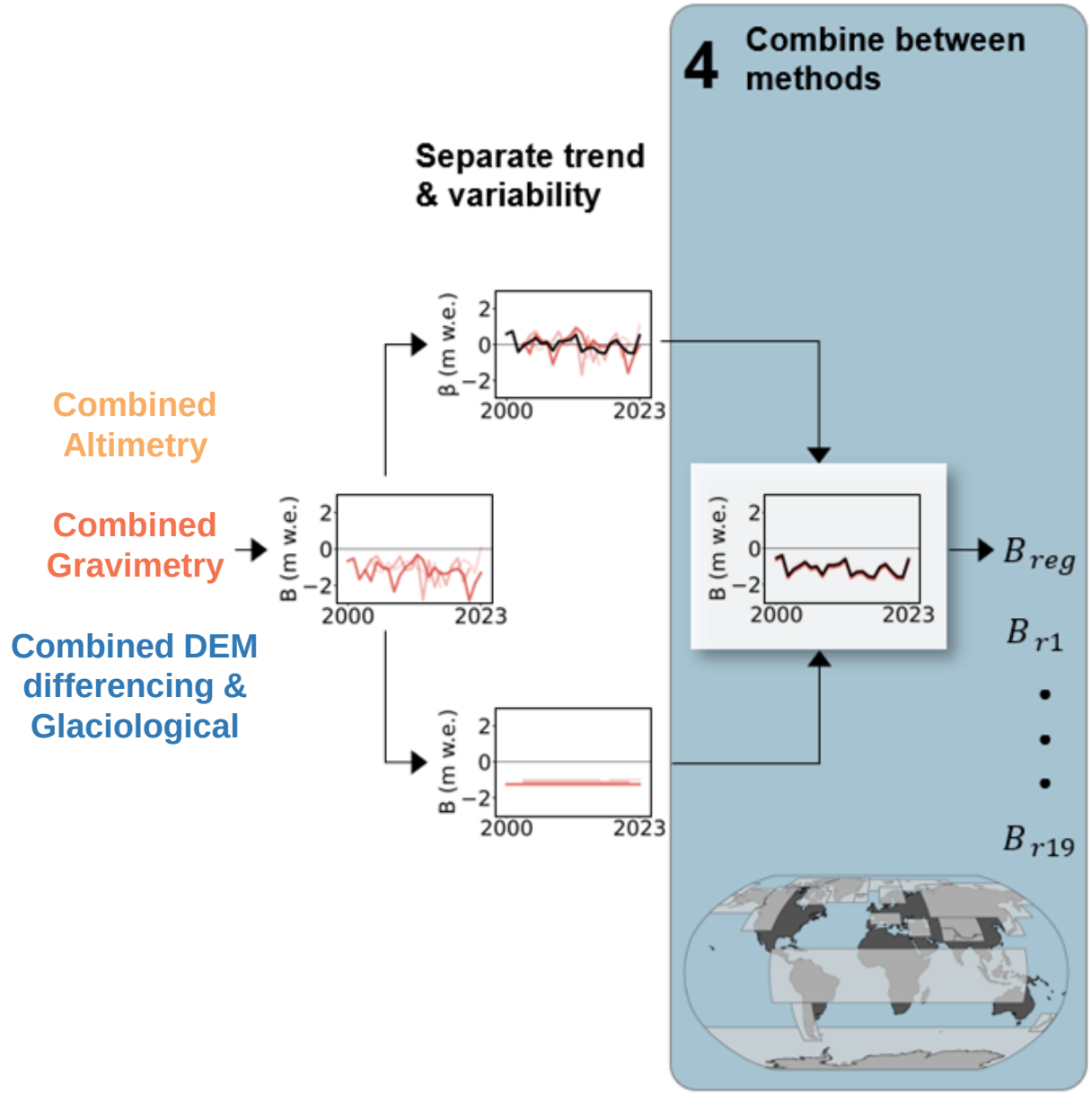
3 Combine datasets within methods

BETWEEN methods

4 Combine between methods into regional estimates



The GlaMBIE approach workflow in a nutshell

WITHIN methods

1 Compile data at best resolution and unit

Homogenize data (space, time, units, area)

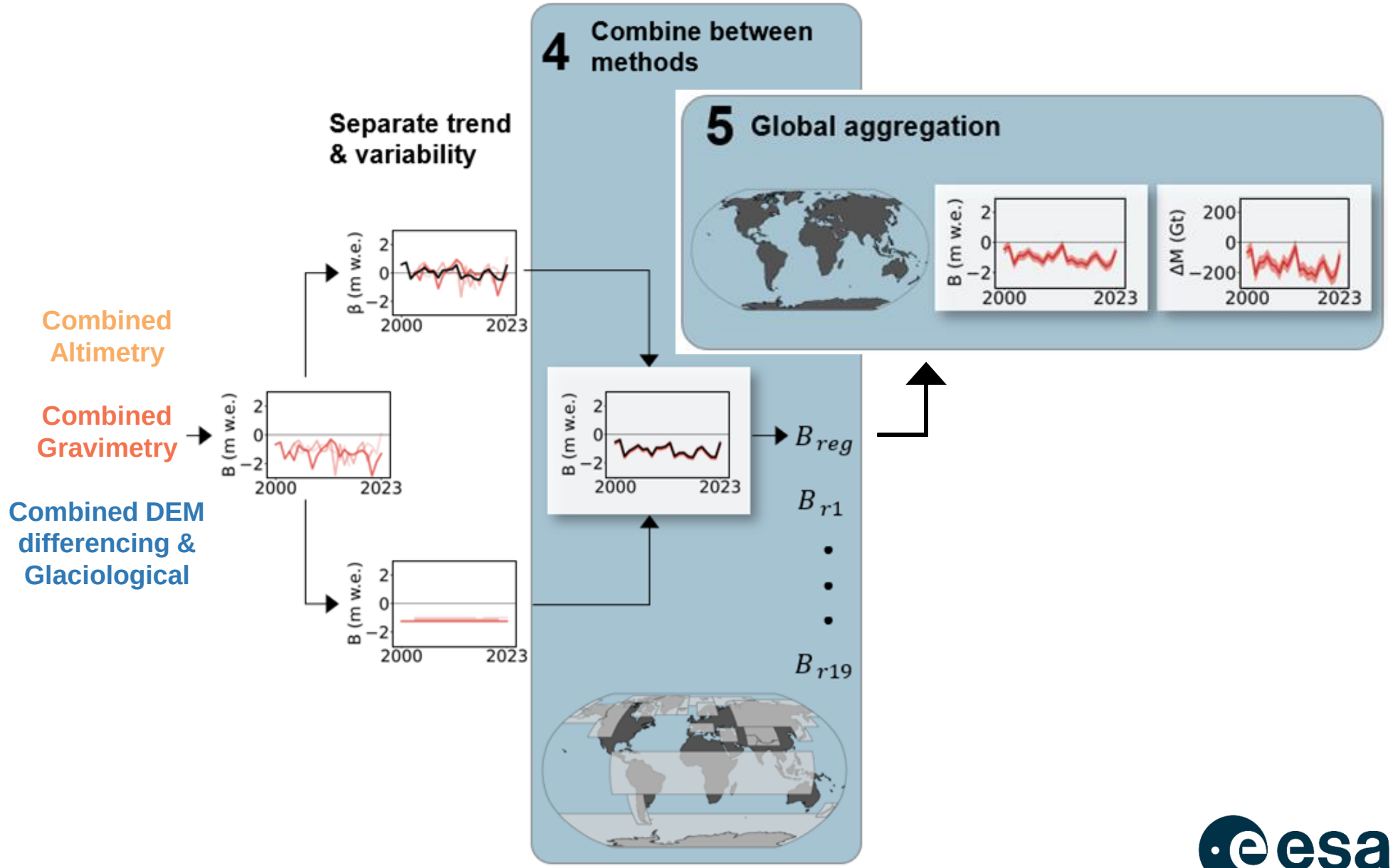
2 Separate temporal variability and long-term trend

3 Combine datasets within methods

BETWEEN methods

4 Combine between methods into regional estimates

5 Sum up to global estimates



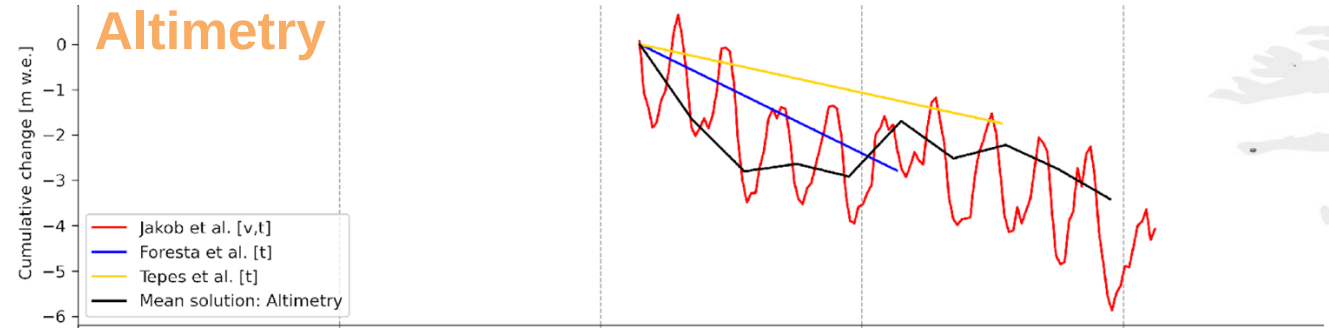
Data submissions and results | e.g. Iceland

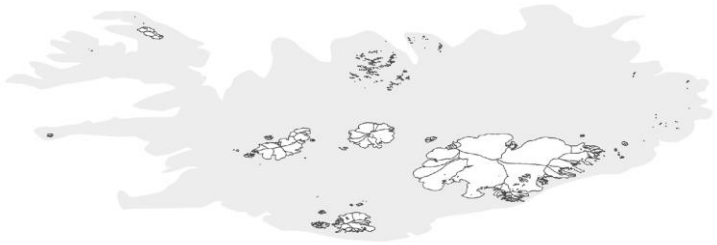
1 Compile data at best resolution and unit

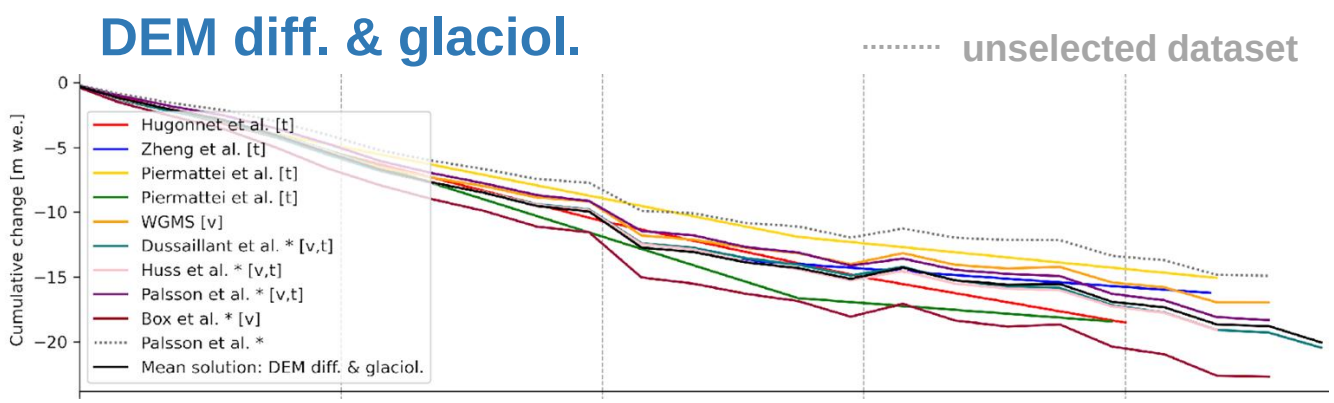
Homogenize data (space, time, units, area)

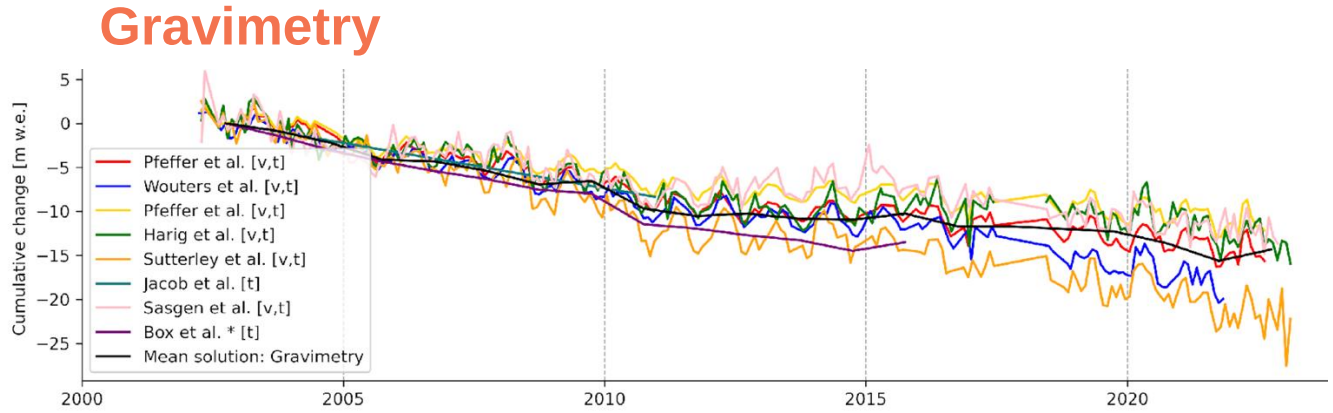
2 Separate temporal variability and long-term trend

3 Combine datasets within methods





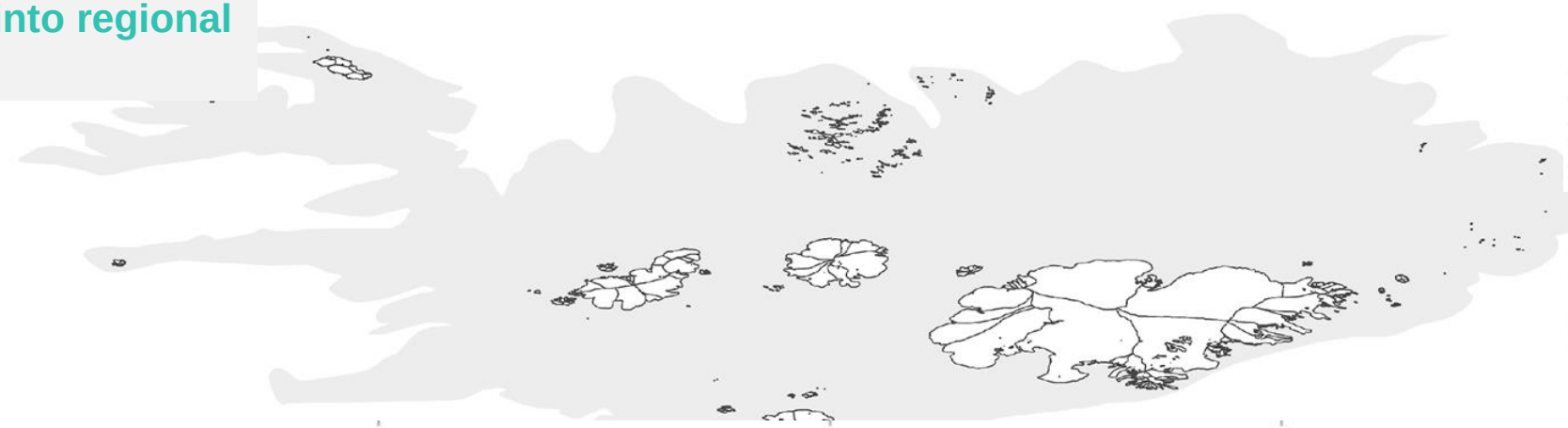


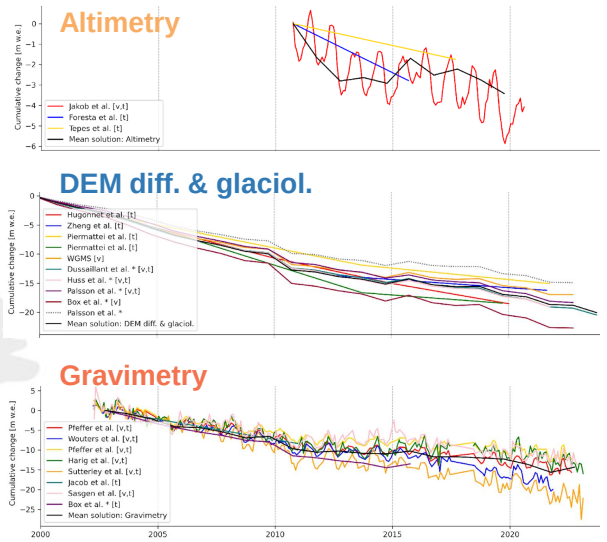


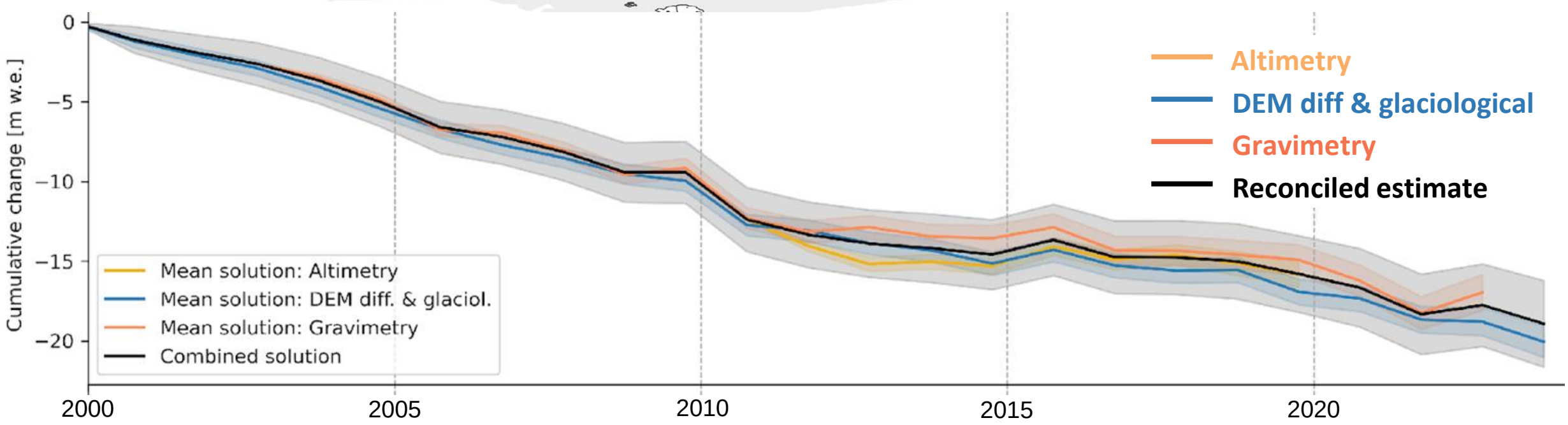
Data submissions and results | e.g. Iceland

4

Combine between methods into regional estimates







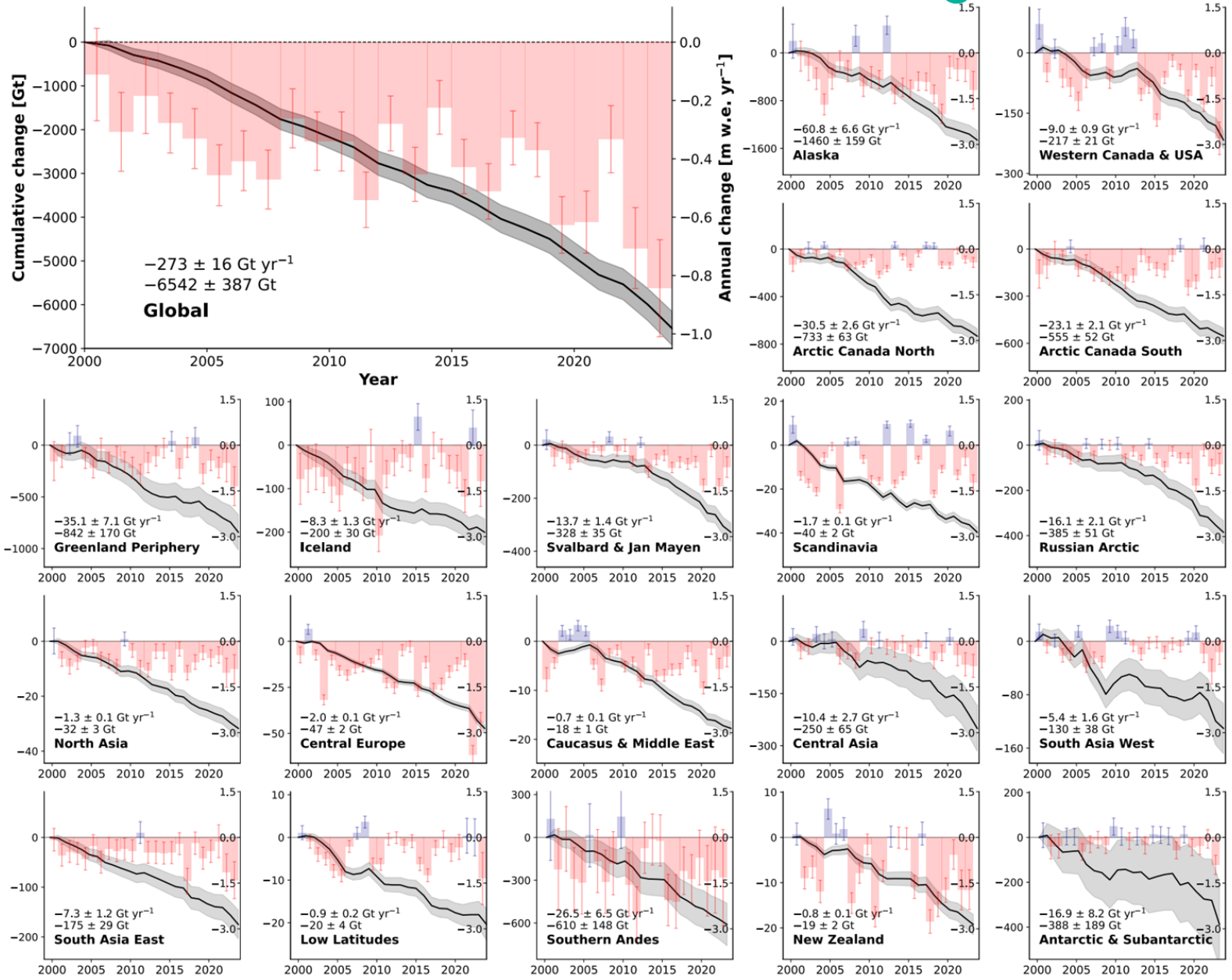
Regional glacier mass changes 2000–2023

Continued mass loss
in all regions

Increased mass loss
in second half period in 14 out of 19 regions

Systematic bias
between DEM diff & glacial. (more negative) and Altimetry (less negative)

Altimetry & Gravimetry only in regions with large glacier covers



GlaMBIE Team (2024, in review)

Global glacier mass changes 2000–2023

glambie

Sum up to global estimates **5**

2000–2023:

-6,500 ± 325 Gt

-275 ± 15 Gt per year

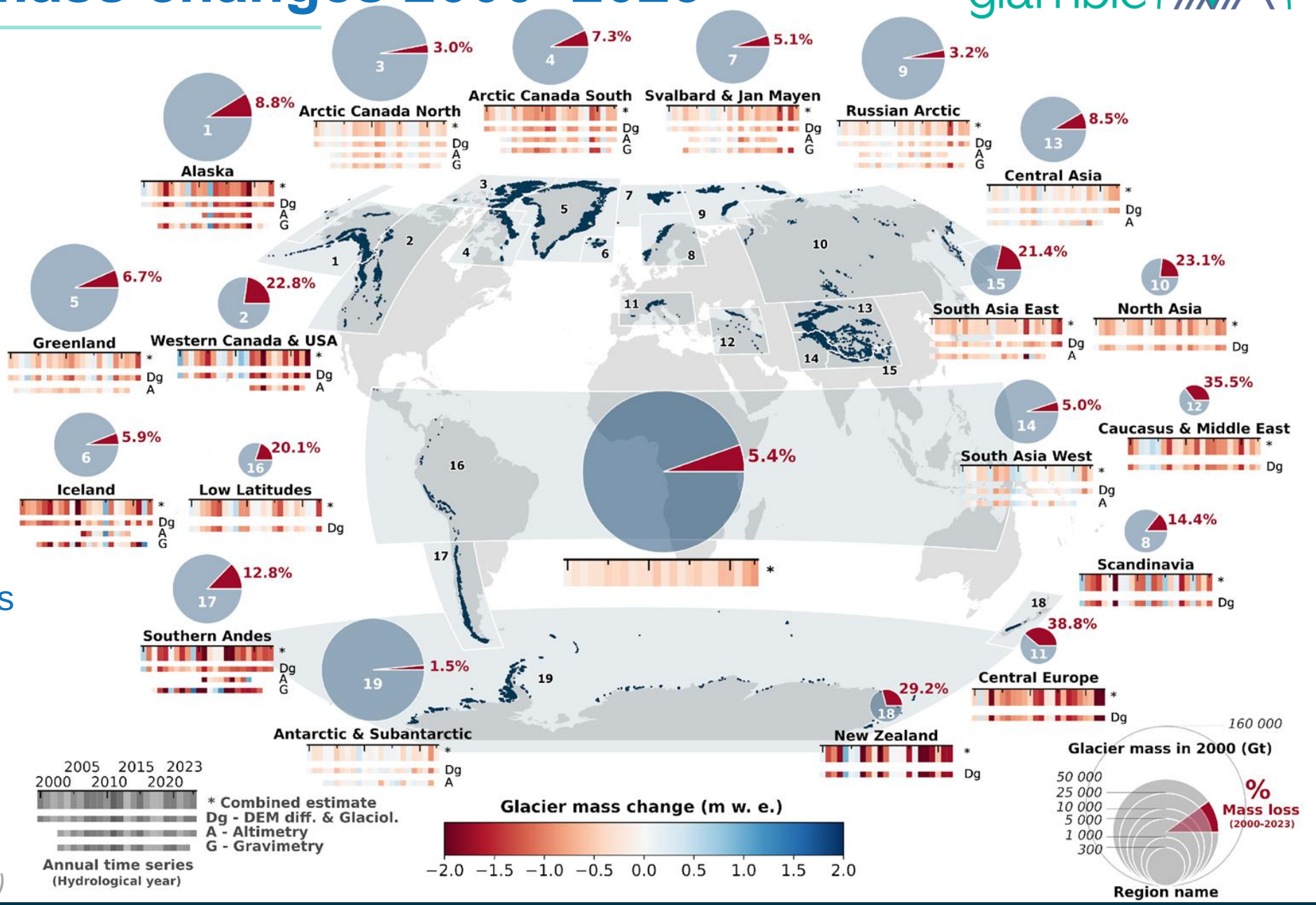
+ 0.70 mm SLE per year

Since 2000:

-5.4% global volume loss

regionally between

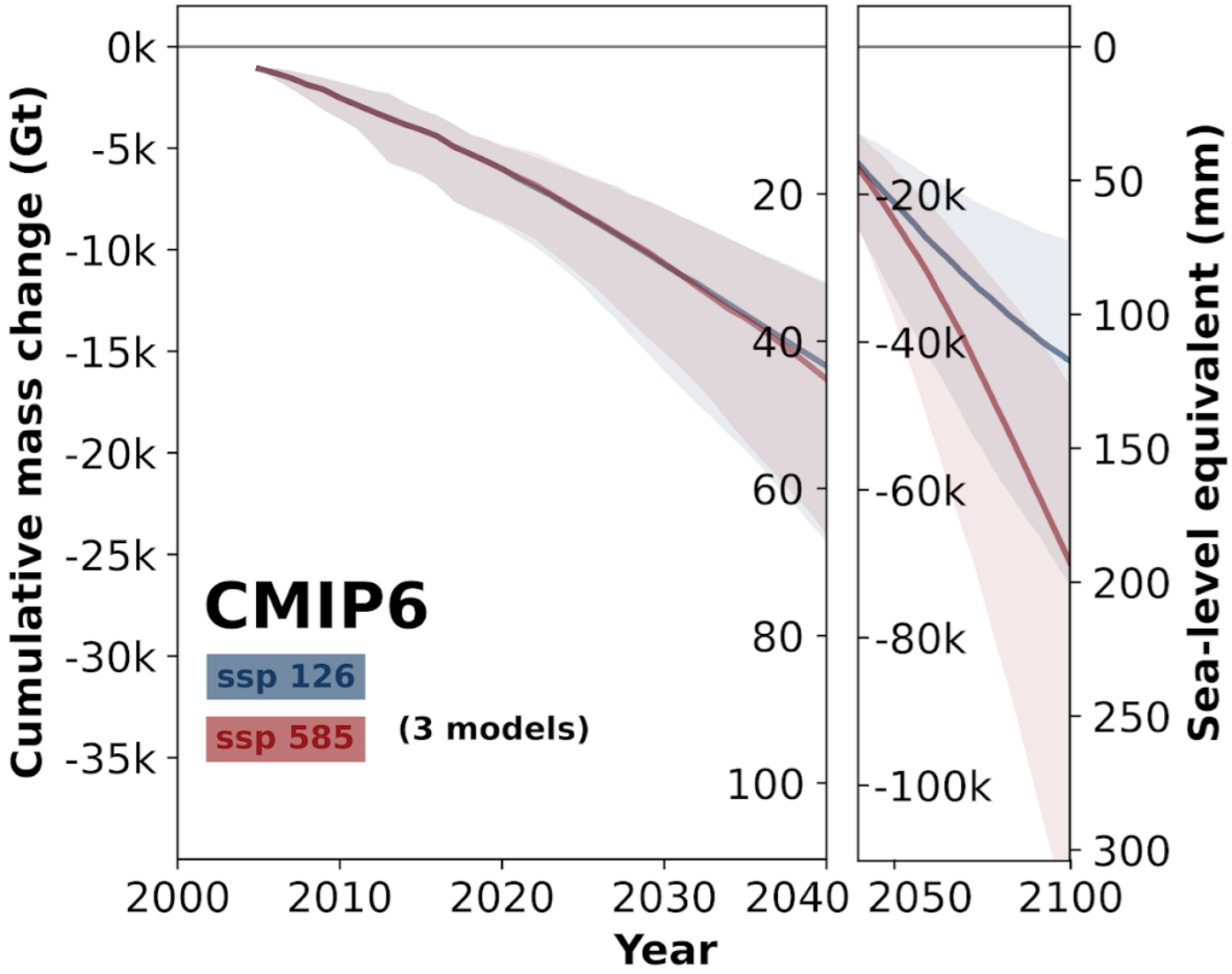
-2% (Ant.) and **-39%** (Alps)



GlaMBIE Team (2024, in review)

(Ice volumes from Farinotti et al. 2019)

Reconciled observation versus model ensemble



Zekollary et al., (2024, in review)

Reconciled observation versus model ensemble

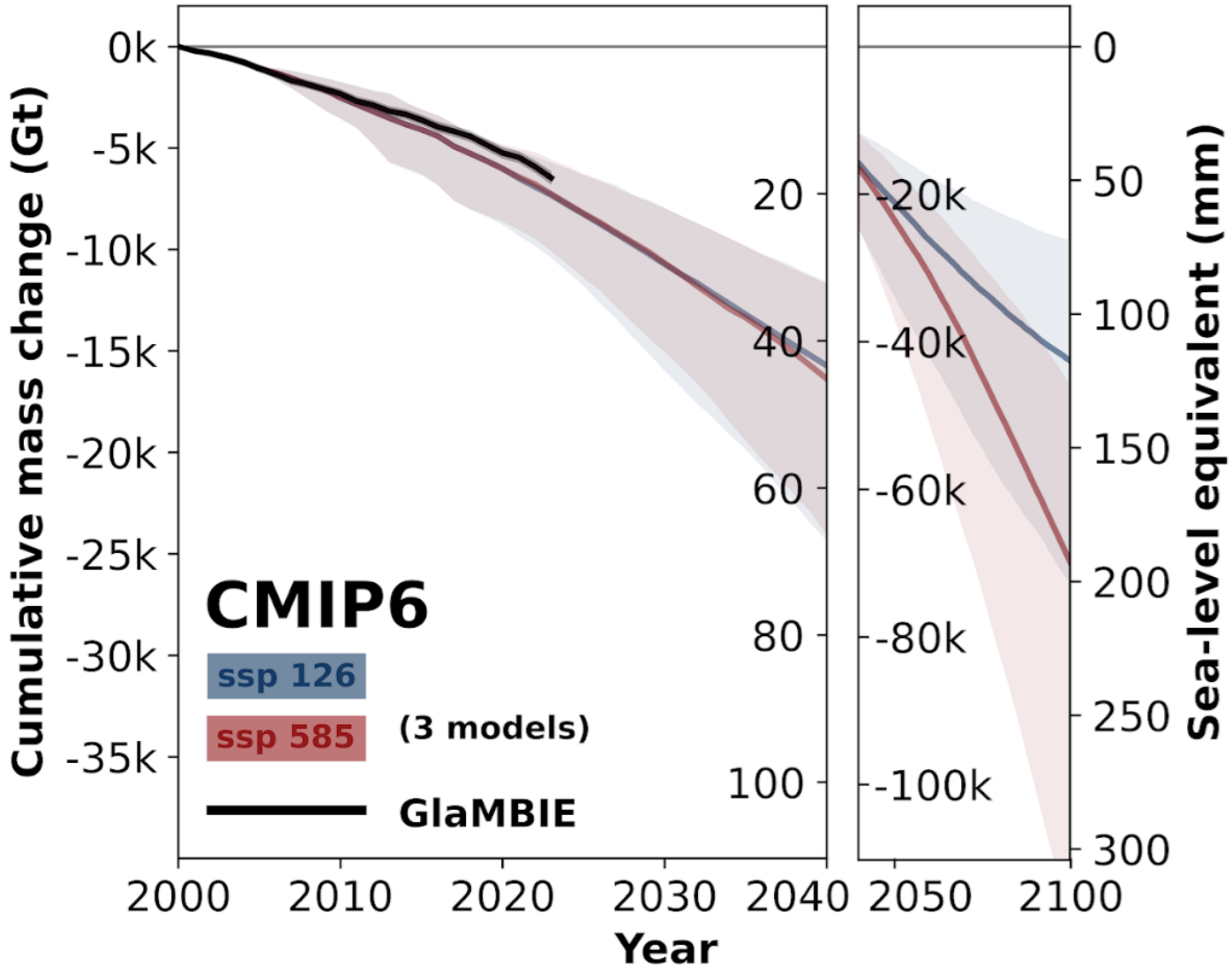
Observations

Follow about the median of
model ssp scenarios

Models predict

1.5 to 3 times
more mass loss by 2040

3.5 to 15 times
more mass loss by 2100
strongly dependent on ssp



Zekollary et al., (2024, in review)

Take home message

Since 2000, glaciers lost

5.4% of their global volume

almost 40% in Central Europe

Glaciers can loose

3.5 to 15 times more

mass loss by 2100

Need for future research

Differences between observation methods

Differences between observations and models

etc...

glambie

*** Community based estimate ***

of glacier mass changes

combining all observational sources

esa

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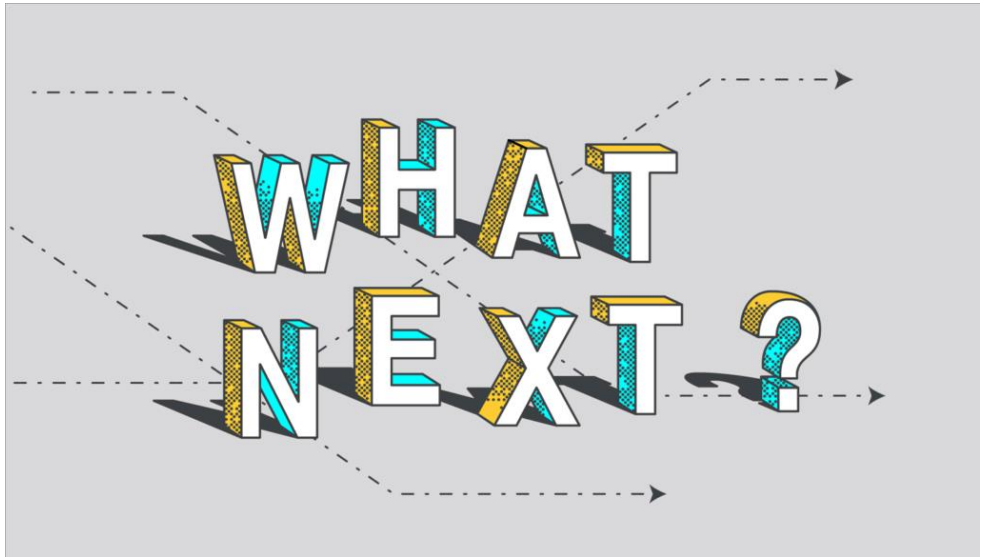

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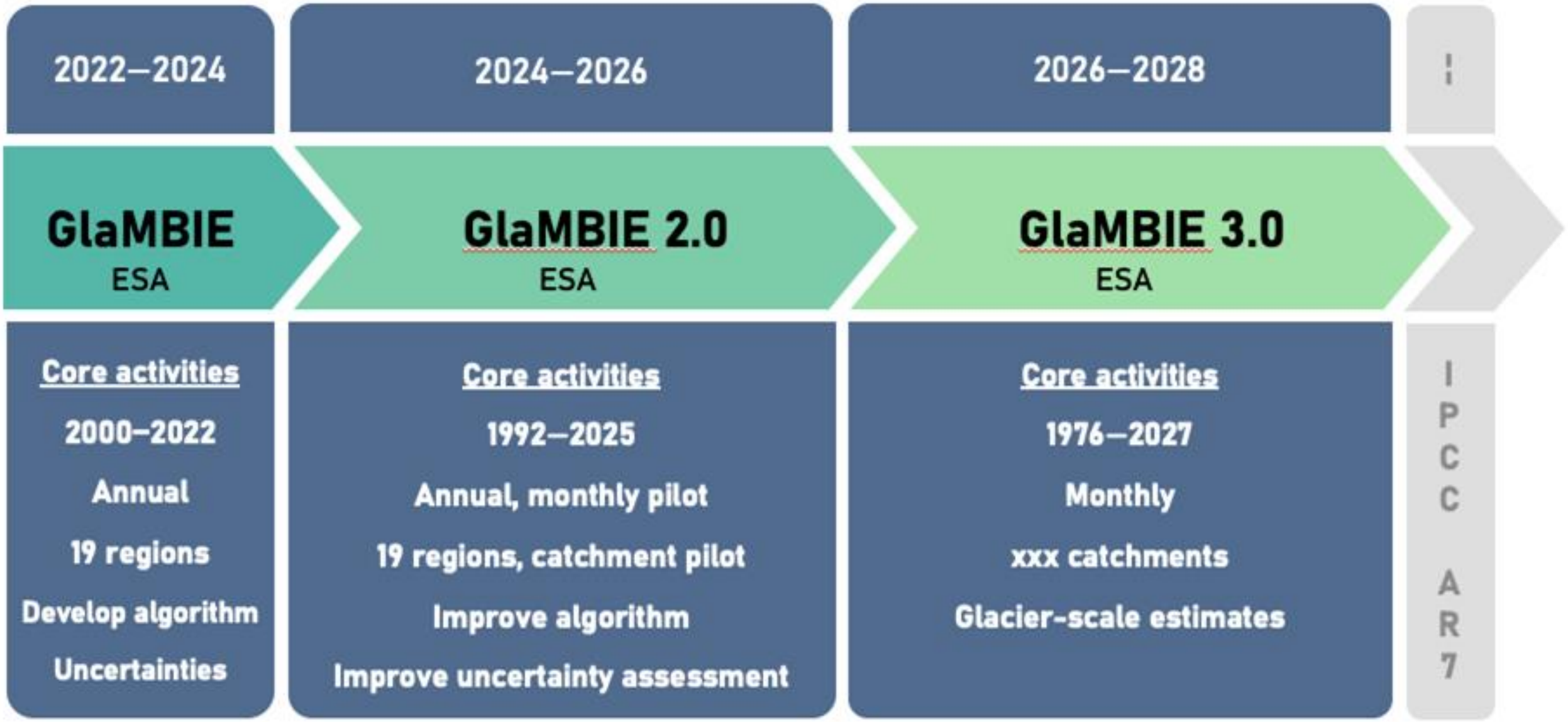
GlaMBIE follow-up



GlaMBIE “satellite” studies

Sensors and techniques

DEM differencing: tapping the full potential of DEM differencing from multiple spaceborne sensors

Radar altimetry: improved seasonal estimates from radar altimetry

Gravimetry : improved estimates from spaceborne gravimetry including geophysical corrections.

In-situ: expand glaciological monitoring programs to all regions and push to real-time.

Apparent systematic differences between Altimetry and DEM differencing

Thematics

- Increasing the availability of **glacier-specific mass balance** solutions - move GlaMBIE towards this goal
- **Model hindcasting & forecasting:** collaboration with the modelling community for comparison of observations and scenario runs in the 20th and early 21st century (e.g., 2000−2025).
- **Mass-balance components:** improve understanding and quantification of mass-balance components (surface, internal, basal, and frontal) and of mass changes below lake and sea levels.

Method and auxiliary datasets

- **Density conversion:** improve glacier density conversion for annual and seasonal geodetic surveys.
- **Uncertainty:** homogenization and improvement of uncertainty estimates for glacier mass-change assessments from different sources.
- **Catchments:** revise glacier regions and complement with hydrological catchments.
- **Glacier area changes:** update and improvement of glacier area change estimates from improved glacier mass-change assessments.
- **Glacier inventory:** development of multi-temporal global glacier inventory for improved glacier mass-change assessments.

Glacier Mass Balance Intercomparison Exercise (GlaMBIE)

A community effort to reconcile measurements of glacier mass balance

https://glambie.org/