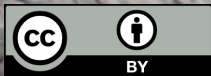


Integrating and assessing Arctic glacier thickness data into Glacier Thickness Database (GlaThiDa) Version 3.0

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GlaThiDa: key facts

- **What is it?** - It is an internationally collected, standardized dataset of glacier thickness from in-situ and remotely sensed observations, based on data submissions, literature review and airborne data from NASA's Operation IceBridge.
- It is a contribution to the working group on "Glacier ice thickness estimation" of the International Association of Cryospheric Sciences (IACS).
- The database is hosted by the World Glacier Monitoring Service (WGMS).

GlaThiDa versions

- GlaThiDa V1 released in 2014
- GlaThiDa V2 released in 2016
- GlaThiDa V3 released in 2019
 - ~3600 ice-thickness surveys have been added to the previous version, making a total of **5181 ice-thickness surveys**.
 - > 3 million thickness measurement points have been added to the previous version, making a total of **3 854 279 point measurements**.

GlaThiDa: how is it structured?

- Structured in three data tables of different levels of detail, which are linked through a GlaThiDa_ID that is unique for a given glacier and survey.
 - T-table: overview table
 - TT-table: ice thickness data averaged over surface elevation bands
 - TTT-table: point data
- For a single glacier there can be multiple entries, each referring to a particular survey (e.g. surveys at different dates, or using different radars).

GlaThiDa: T-Table

Overview table containing information on:

- glacier ID (GlaTHiDa & other databases)
- location (lat, lon; WGS84), area and mean slope of the glacier
- mean and maximum thickness, including accuracies and interpolation method
- survey method and related information
- survey date, date of surface elevation
- investigator, source of the data, funding agency
- References, data flag and remarks

GlaThiDa: TT-Table

Ice thickness data (mean and/or max) averaged over surface elevation bands by given lower and upper boundaries from ice thickness maps or Digital Elevation Models:

- GlaThiDa ID (to link with T-Table)
- lower and upper boundaries of the surface elevation interval
- area and mean slope of each elevation band
- mean and maximum thickness, including accuracies, for each elevation band (based on interpolation)
- data flag and remarks

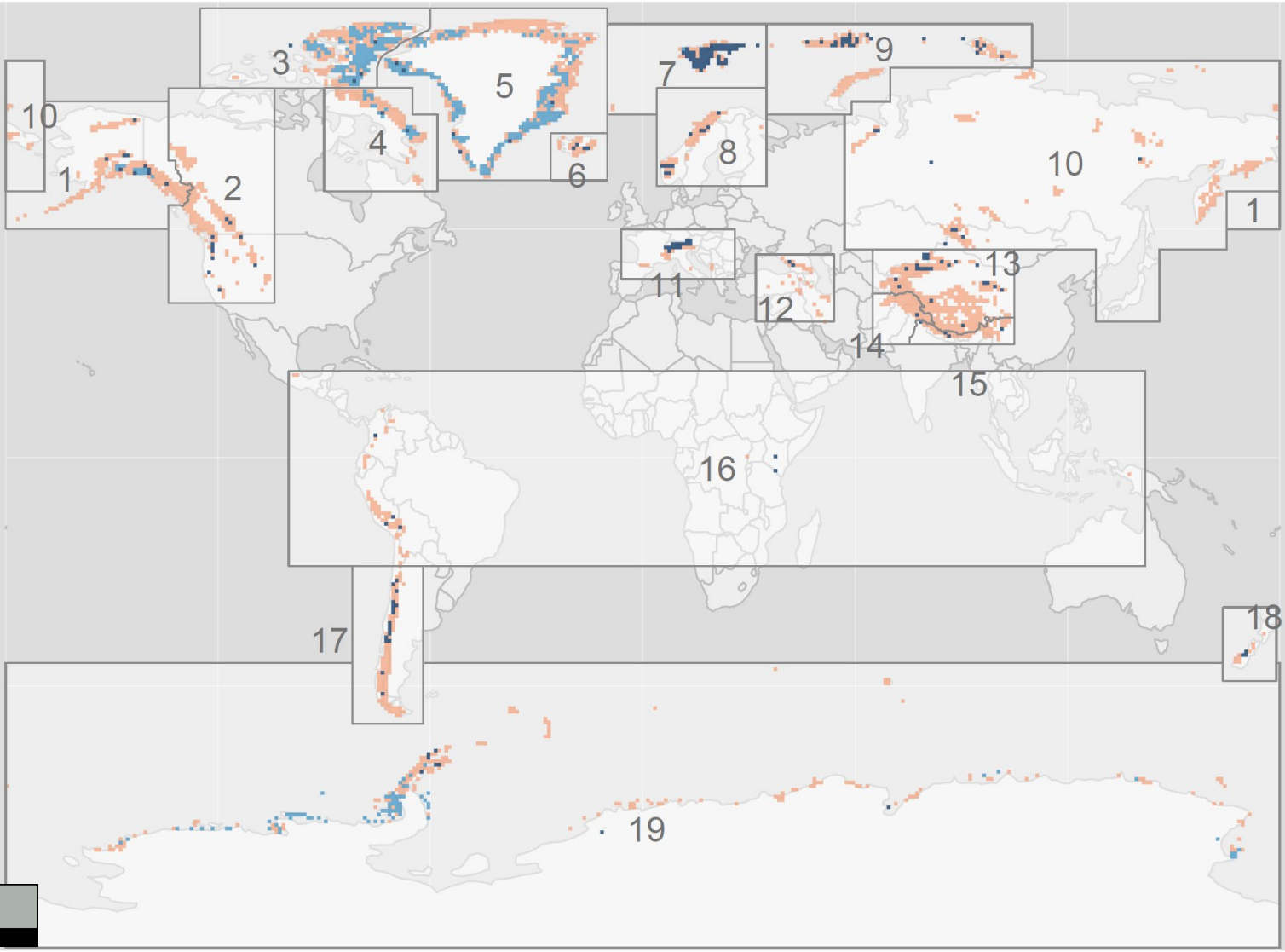
GlaThiDa: TTT-Table

Contains point data, including:

- GlaThiDa ID (to link with T-Table)
- point ID, coordinates (lat, lon) and date
- point elevation (pref. a.s.l.)
- thickness and uncertainty
- data flag and remarks

GlaThiDa 3.0 coverage (GTN-G glacier regions)

Legend: RGI (orange), GlaThiDa (IceBridge) (light blue), GlaThiDa (other) (dark blue)



GlaThiDa 3.0: Number of surveys and measurement points by survey method

Method	Surveys	Points	Thickness (m)	Years
Radar (airborne)	4 624	3 064 055	104–456	1968–2017
Radar (terrestrial)	412	700 066	87–330	1970–2018
Radar (both or unknown)	25	87 481	179–323	2006–2016
Seismic	43	31	218–440	1953–1993
Drilling	18	35	40–135	1935–2007
Electromagnetic	2	2 611	47–86	2002–2002
Unknown	17	0		

Technical (data management) improvements

GlaThiDa fulfills (and surpasses) the FAIR principles (Findable, Accessible, Interoperable and Reusable for both machines and people), by using open-source metadata formats and software tools to:

- Describe and continuously validate the structure and contents of the data, facilitating dialogue with (and bug reports by) data users.
- Maximize data access and interoperability by using universal text-based file formats.
- Automatically track changes to the data following modern data management best-practices, using the distributed version-control system git.

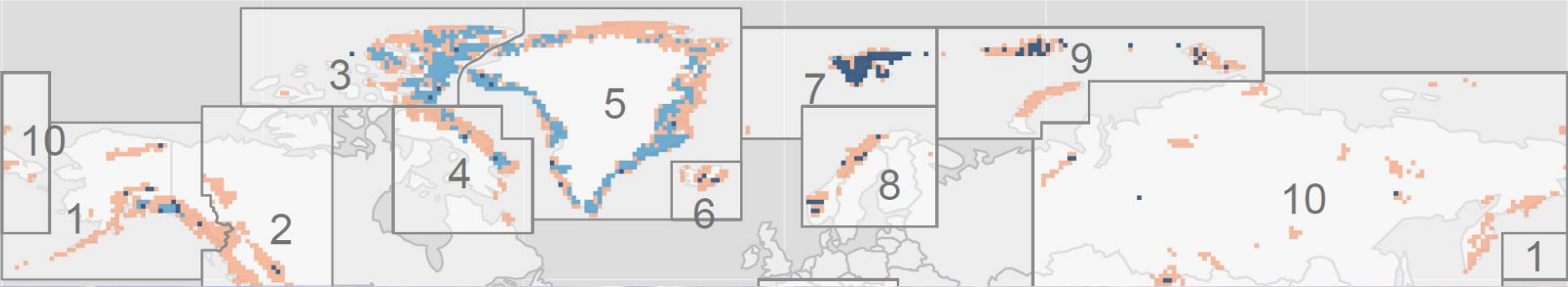
Assessing GlaThiDa Arctic-related data

- GlaThiDa 2.0 was assessed within INTAROS Work Package 2.1 (Assessment of existing Arctic Observing Systems and identification of essential gaps relative to essential Arctic variables and stakeholders needs):
 - “GlaThiDa database is lacking a more homogeneous coverage of the various glacier regions of the Arctic.”
 - “The number of glaciers with ice-thickness measurements reported to the GlaThiDa dataset is very low for both Alaska and Iceland.”
 - “We encourage the people in charge of the IceBridge Operation to collect, in every region, cross-sectional glacier profiles in addition to centerline profiles”.

Assessing GlaThiDa Arctic-related data

- A large portion of the new (V3.0) data corresponds to Arctic glaciers and ice caps (see next slide), and some of them have been collected under H2020 INTAROS project.
- The region having experienced the largest increase in coverage has been Svalbard, where the number of covered glaciers has increased from 79 (V2) to 232 (V3) out of 1,615 (RGI6.0), and the corresponding area of the glaciers with thickness measurements from 9,582 (V2) to 26,318 (V3) out of 33,959 km² (RGI6.0).
- Though the number of covered glaciers in Alaska is still low, the area of glaciers with point measurements has increased $\times 5$, which is $\sim 24\%$ of the total glacierized area.

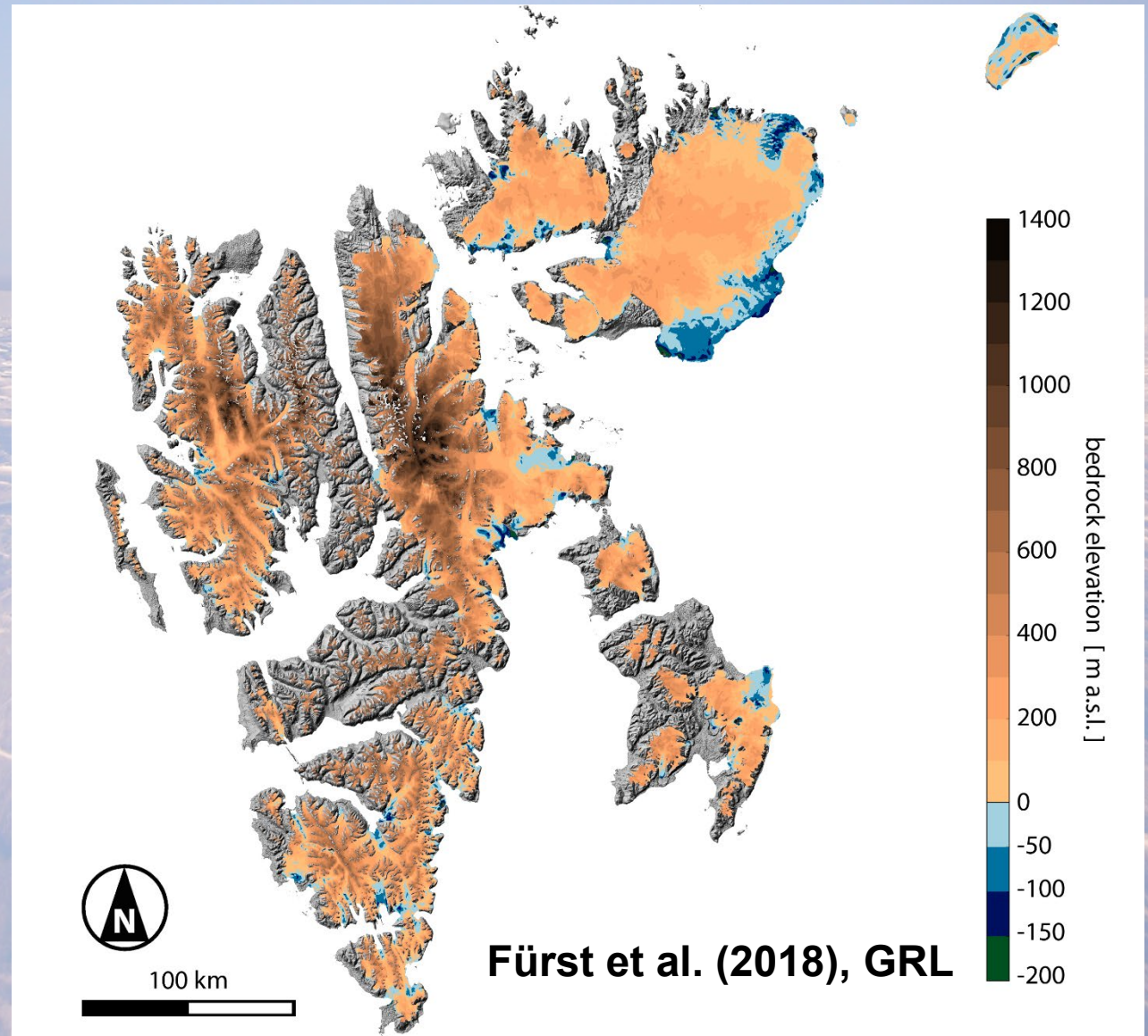
GlaThiDa 2.0 & 3.0 vs. RGI Arctic Coverage



Region	Name	v2 (count)	v3 (count)	RGI (count)	v2 (km ²)	v3 (km ²)	RGI (km ²)
1	Alaska	14	41	27108	4469	21141	86725
3	Arctic Canada, North	239	476	4556	57783	72351	105111
4	Arctic Canada, South	24	251	7415	10633	13943	40888
5	Greenland Periphery	295	1361	20261	51290	63594	130071
6	Iceland	4	4	568	2161	2161	11060
7	Svalbard and Jan Mayen	79	232	1615	9582	26318	33959
9	Russian Arctic	22	32	1069	3606	5716	51592
	Total Arctic	677	2397	62592	139524	205224	459406

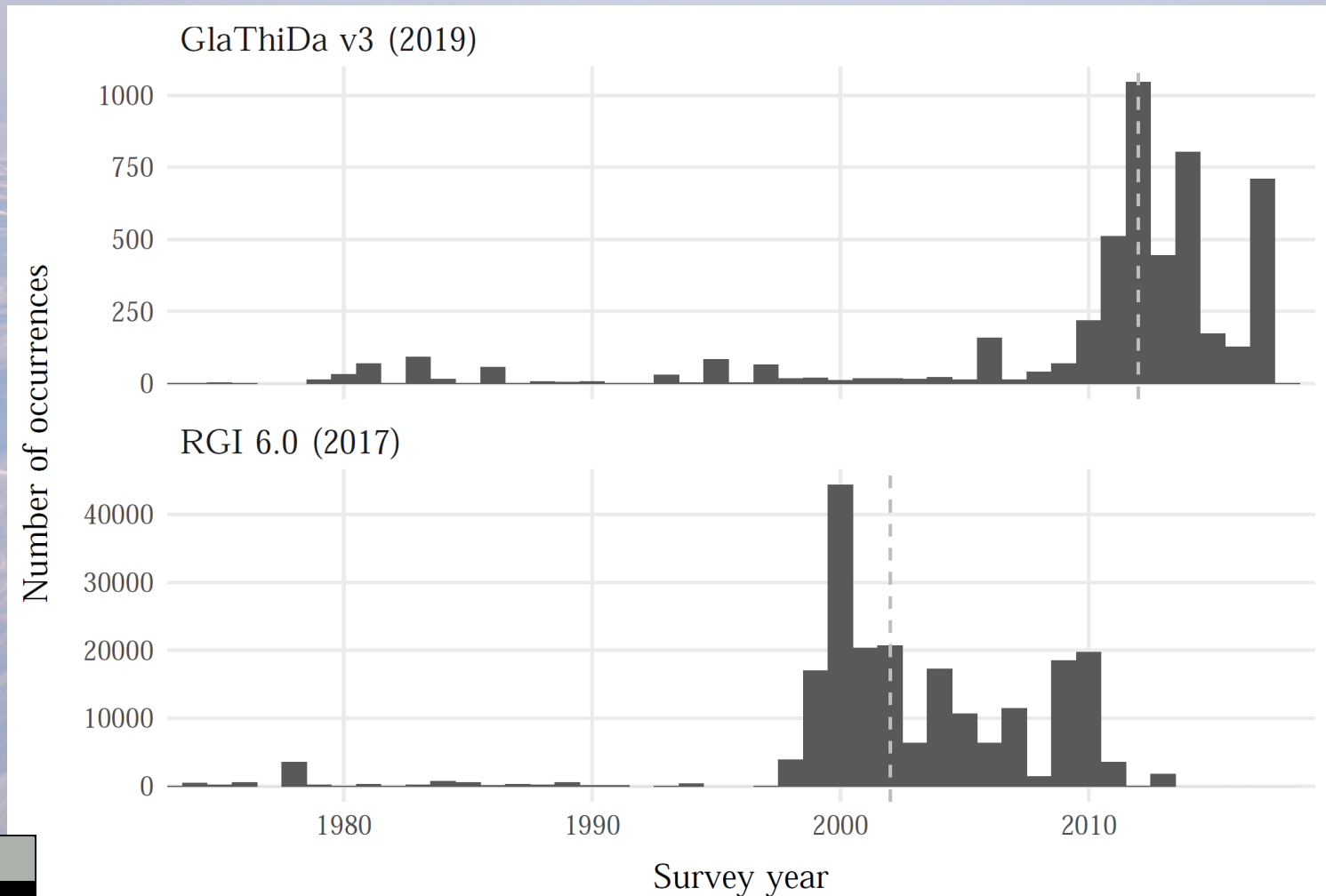
A sample application: Svalbard bed map

Inversion-based bed reconstruction using more than 1 million point measurements, totalling more than 8,700 km of thickness profiles.



A time-frame issue

The median survey year for RGI glacier outlines is 2002, a decade earlier than the 2012 median for GlaThiDa surveys.



Conclusions and outlook

- GlaThiDa has a great potential as reference dataset for
 - Calibrating and validating regional/global glacier volume estimates.
 - Input data to numerical models.
- Addition of new data is expected, but
 - Operation IceBridge, the source of 61% of the thickness point measurements in GlaThiDa, is ending operation in 2020. Thus, future updates to GlaThiDa may not include as many new measurements as the latest version.
 - However, RGI 6.0 does not include glaciers on the Antarctic Peninsula mainland and in the McMurdo Dry Valleys, so data for those glaciers were not included in GlaThiDa v3, and will be added in a future version.

Further info

- <https://www.gtn-g.ch/glathida> (archived versions)
- <https://gitlab.com/wgms/glathida> (development version, issue tracker)
- Gärtner-Roer et al. (2014). A database of worldwide glacier thickness observations. *Global and Planetary Change*, 122, 330-344, doi:10.1016/j.gloplacha.2014.09.003.
- Welty et al. (2020). Worldwide version-controlled database of glacier thickness observations. Submitted to *Earth System Science Data*.

Acknowledgements

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To the WGMS, for making possible the data compilation, archiving and dissemination

Assessment of GlaThiDa Arctic data done under EU H2020 project INTAROS (RIA 727890)



Thank you for your attention

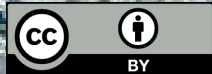


Photo: © Glaciers online · J. Alean · M. Hambrey

Appendix

Icebridge data incorporated into GlaThiDa

- Pre-IceBridge MCoRDS L2 Ice Thickness, Version 1 - Arctic and Antarctica, 1993-2007
- IceBridge HiCARS 1 L2 Geolocated Ice Thickness, Version 1 - Antarctica, 2009-2010
- IceBridge HiCARS 2 L2 Geolocated Ice Thickness, Version 1 - Antarctica, 2010-2013
- IceBridge MCoRDS L2 Ice Thickness, Version 1 – Arctic and Antarctica, 2009-2017
- IceBridge PARIS L2 Ice Thickness, Version 1 – Greenland, spring 2009
- IceBridge WISE L2 Ice Thickness and Surface Elevation, Version 1 – Alaska, spring 2012