A new bed topography dataset for Greenland out to the continental shelf: BedMachine v3

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1. Overview

- Detailed bed topography and surrounding bathymetry of Greenland are essential for the numerical modelling of ice sheets and ice-ocean interactions with fjord bathymetry controlling the access of warm, salty, subsurface waters of Atlantic origin reaching glacier termini. The most recent Greenland specific datasets include:
  - **B2013** (Bamber et al., 2013): bed + bathymetry.
  - **B2014** (Morlighem et al., 2014): bed (grounded ice + ice-free land).
- A persistent issue with Greenland bed topography products to date is the poor representation of near-coastal bathymetry – this data sparsity resulted in physical discontinuities in B2013 (Fig. 1).

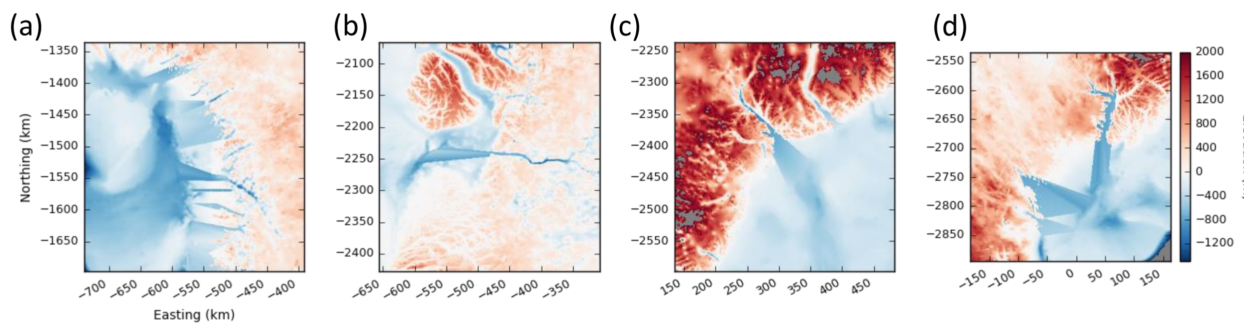


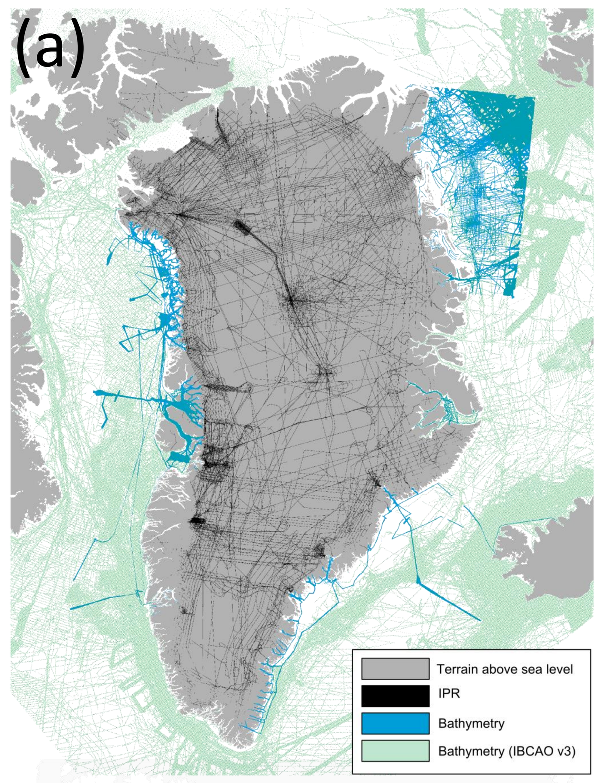
Fig. 1 Physical discontinuities present in near-coastal regions of B2013. Elevations are relative to the WGS84 ellipsoid. See Fig. 3 for geographical locations.

- BedMachine v3 provides seamless high resolution bed topography and bathymetry for Greenland offering major improvements over past products, particularly in near-coastal regions.

2. Data and mapping methods

- Since B2014, additional Ice Penetrating Radar (IPR) tracks are now available following CReSIS Operation IceBridge flights which increased observation coverage and density most noticeably following the 2013 and 2014 campaigns (Fig. 2a).
- In addition to IBCAO v3 (Jakobsson et al., 2012) as combined with B2013/B2014, a variety of additional bathymetric datasets within fjord systems are now available, the most significant coverage being provided through the NASA Oceans Melting Greenland (OMG) Mission.

- **Ice sheet interior:** bed elevations derived from various IPR surveys from 1993-2014 (e.g. CReSIS) – kriging interpolation (Fig. 2b).
- **Outlet glaciers**: constrained using mass conservation (Morlighem et al., 2014, 2016).
- **Ice free topography**: integration of the GIMP DEM (Howat et al., 2014).
- **Bathymetry**: data from various surveys (see Fig. 2a) - spline interpolation coupled with Rtopo-2 (Schaffer et al., 2016).
- **Unsurveyed fjords**: synthetic fjord geometry (Williams et al., 2017) (Section 3).



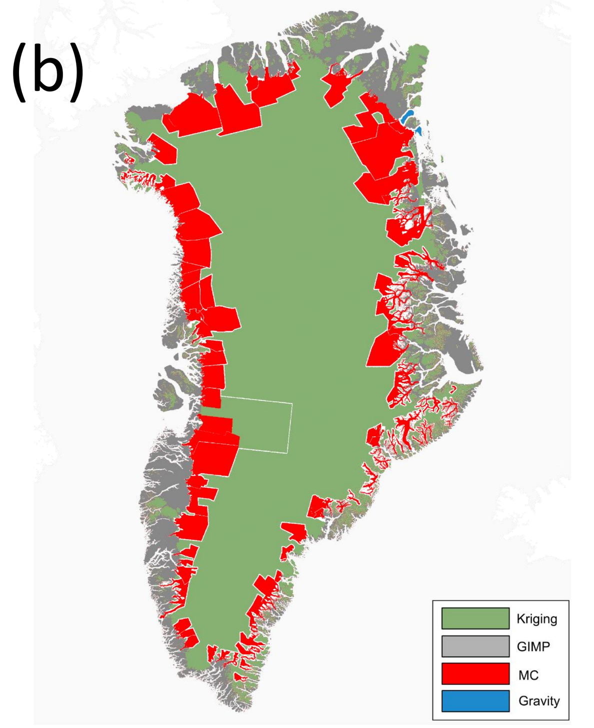


Fig. 2 (a) Observation coverage used in BedMachine v3 – bathymetry in past compilations only used IBCAO v3 (b) Main data integration methods for grounded/floating ice.

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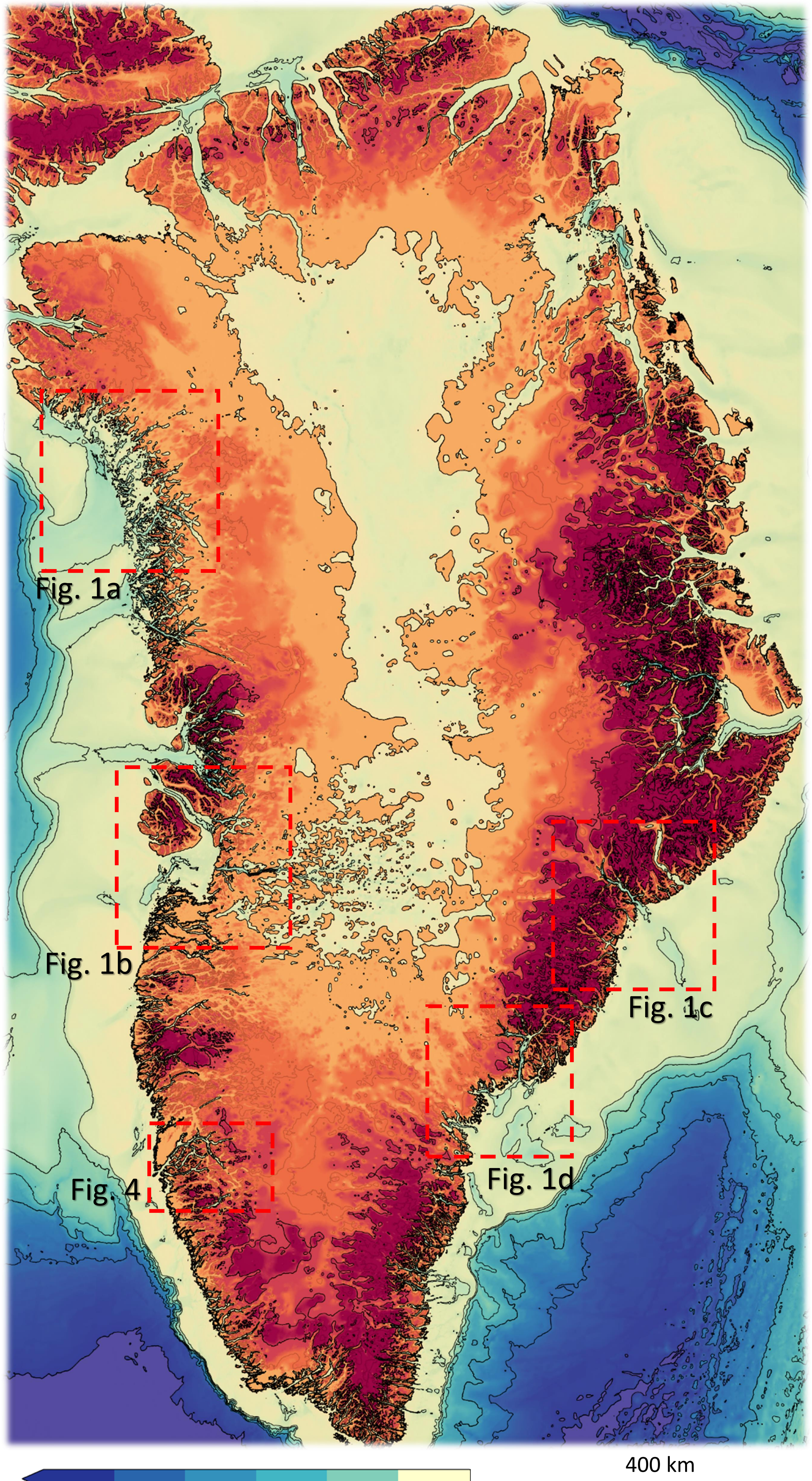

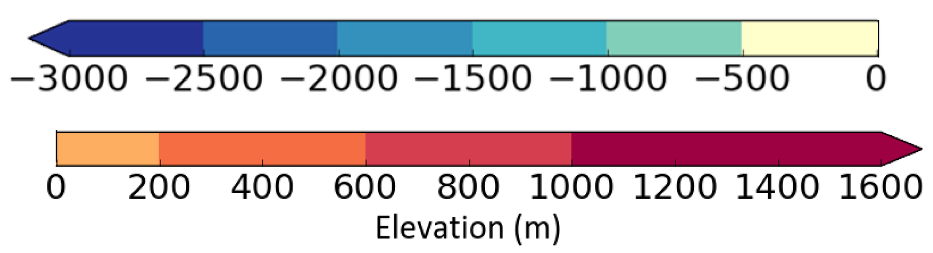

Fig. 3 BedMachine v3. Contours are shown every 1000 m above and every 500 m below sea level. All elevations are relative to mean sea level.

3. Synthetic fjords

- Despite increased bathymetric data coverage, many fjords remain unsurveyed.
- To constrain bathymetry in the absence of any other information, we generate synthetic fjord bathymetry (Williams et al., 2017), imposing parabolic cross-profile geometry.
- Fjord edges are constrained by bed or ice free ground elevations – centreline elevations trend downslope from known elevations at the head of the fjord to the nearest bathymetric observations to the mouth.
- Where sparse observations are available along the fjord, the synthetic profile accounts for these data.
- Until more observations become available, this introduces a best estimate of fjord bathymetry based on glaciological processes.

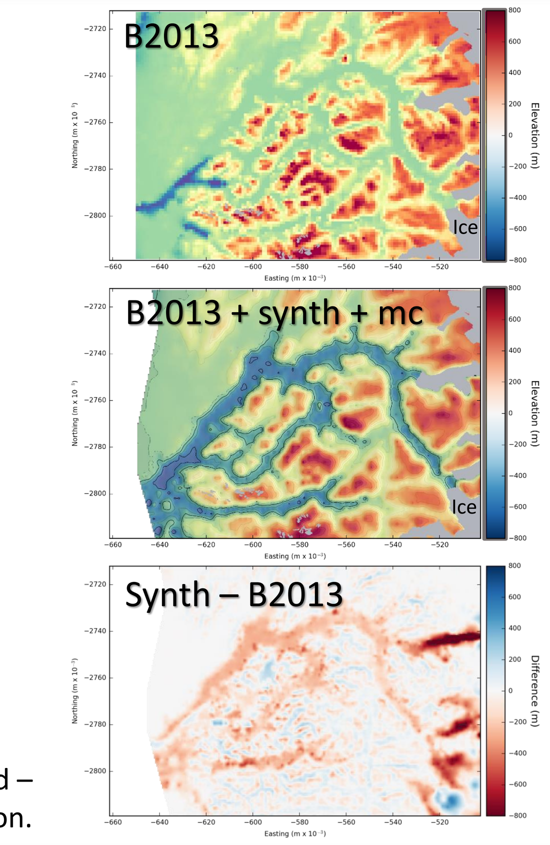

Fig. 4 Application of the synthetic fjord method + mass conservation in Godthåbsfjord – see Fig. 3 for geographic location.

4. Results and discussion

- Accounting for scale corrections, this new bed topography yields a total ice volume of 2.99±0.02 10^6 km^3 or 2.7437±0.02 10^6 Gt, assuming an ice density of 916.7 kg m^{-3}
- BedMachine v3 suggests that the Greenland ice sheet has a total sea level rise potential of 7.43±5 m – 8 cm larger than stated in Stocker et al., 2013.
- The inclusion of new bathymetric data has had significant impacts on bed/bathymetry transitions (Fig. 5) – previous datasets such as B2013, for which these data were absent, relied upon manual lowering of bathymetry.
- Prior to OMG, few glaciers in SE Greenland could be mapped using MC – this is now possible with the new data providing the required constraints (Figs. 5b and 5c).

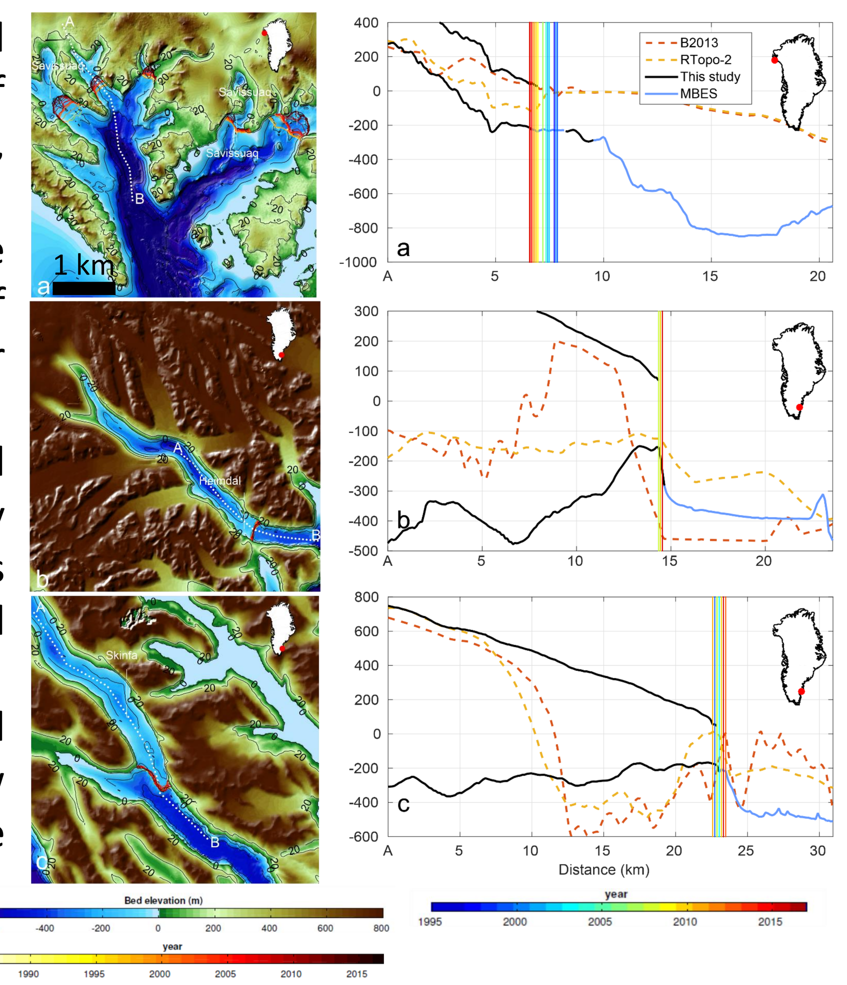

Fig. 5 Bed/bathymetry elevation and long profiles comparing changes in elevation between past Greenland bed/bathymetry datasets for (a) the region of Savissuaq Gletscher, (b) Heimdal Gletscher and (c) Skinfaxe. Glacier terminus positions through time are also indicated.

5. Application and dataset access

- BedMachine v3 offers new opportunities to consider basal conditions, processes and the impact of the ocean on glacier dynamics.
- The dataset will be updated as new data become available.
- Final product will be available as an Operation IceBridge Earth Science Dataset at the National Snow and Ice Data Center (NSIDC).

6. Literature

Bamber et al., 2013. The Cryosphere, 7. **(CReSIS) Gogineni et al., 2001**. J. Geophys. Res.-Atmos., 106. **Howat et al., 2014**. The Cryosphere, 8. **Jakobsson et al., 2012**. Geophys. Res. Lett., 39. **Morlighem et al., 2014**. Nat. Geo. Sci., 7. **Morlighem et al., 2016**. Oceanography, 29. **OMG Mission, 2016**. **Schaffer et al., 2016.** Earth Syst. Sci. Data, 8. **Stocker et al., 2013.** Climate Change 2013: *The Physical Science Basis*. **Williams et al.**, 2017. The Cryosphere, 11.