Greenland Monthly Mass Trends Determined Using a Bayesian Hierarchical Modelling Approach

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Attributing global sea level rise to its component parts

The Challenge

- The Greenland Ice Sheet (GrIS) has been a key **contributor to increases** in the Global Mean Sea Level since 1998.[1]
- Altimetry, gravimetry and mass budget techniques operate at different spatial and temporal resolutions using disparate observations (fig.1).

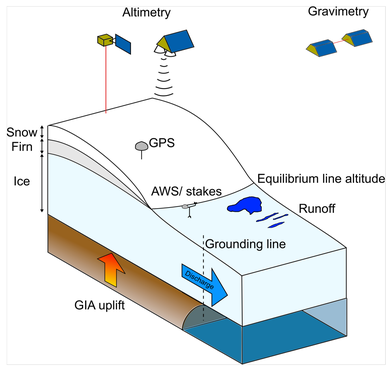

Fig. 1 – An overview of GrIS processes (including GIA) and methods used to observe them

- Each technique uses geophysical forward model output to resolve for unobserved processes e.g. Surface Mass Balance (SMB), firn compaction, Glacio-Isostatic Adjustment (GIA).
- This can introduce hard to quantify **uncertainties** and **biases** into the results.
- A key challenge is to **combine** these diverse observations in a **statistically rigorous manner**.
- Here, a Bayesian Hierarchical Model (BHM) approach, as recently applied over Antarctica[2], is used to produce a **data-driven estimate of ice sheet mass balance for the GrIS from 2003 onwards.**

Bayesian Hierarchical Framework Methodology

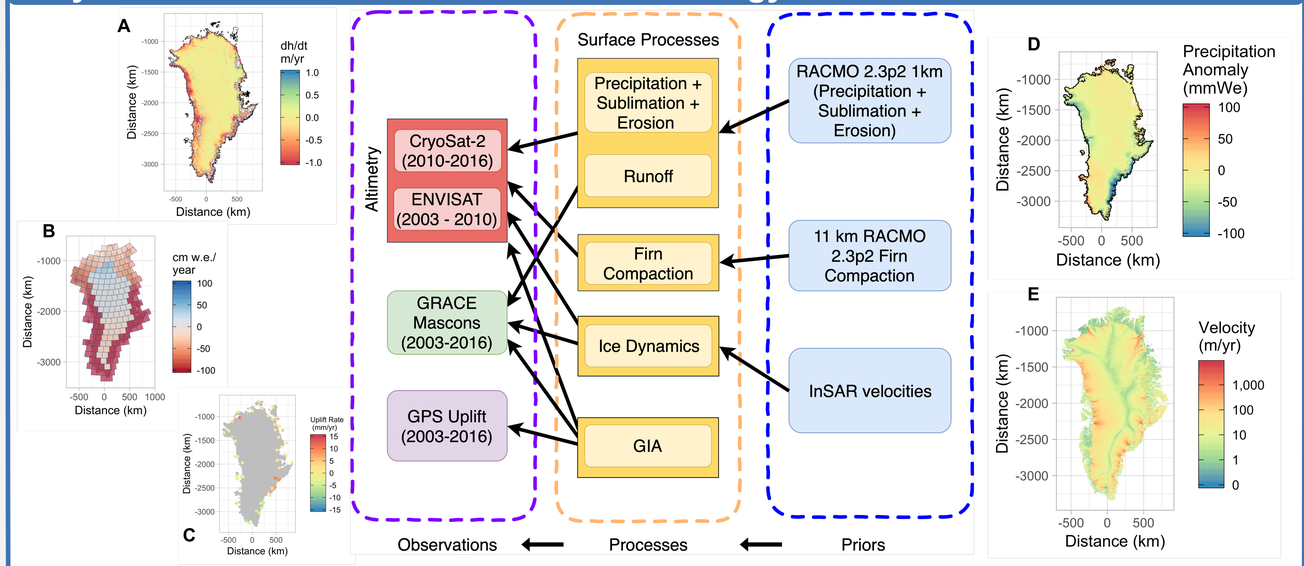

Fig. 2 – Diagram of GrIS BHM setup (center). A) CryoSat-2 linear 2010-2017 $\Delta h/\Delta t$ trend B) NASA GSFC Mascon mass trend for July 2007. C) GPS vertical uplift rates for 2013[3] D) RACMO 2.3p2 Precipitation anomalies for July 2007 w.r.t 1958-2002 baseline[4]. E) MEaSUREs ice sheet velocity[5]

Preliminary Results – Jakobshaven Isbræ

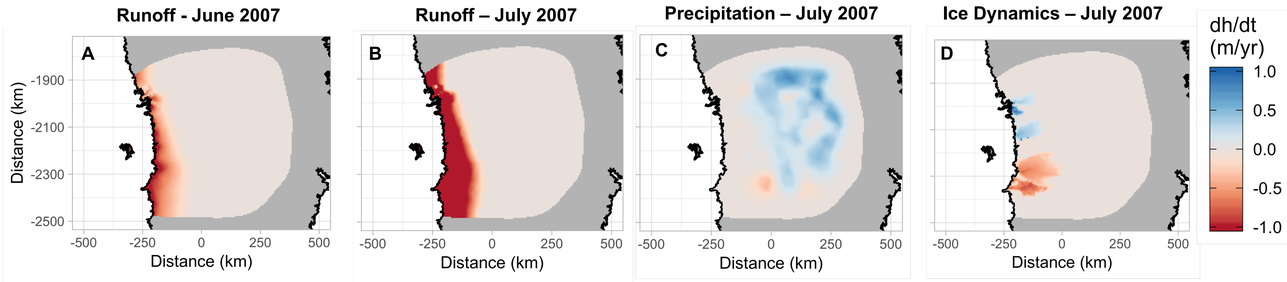

Fig. 3 - BHM monthly solutions of ice sheet elevation change due to: A) Runoff in June 2007 B) Runoff in July 2007 C) Precipitation in July 2007 D) Ice Dynamics in July 2007. The BHM solution captures the onset of runoff during the summer months and its spread up to the ELA. Additionally, the dynamic thinning of Jakobshaven Isbræ is being captured in the ice dynamics process.

Discussion

- Preliminary results demonstrate the BHM methodology is able to **solve for ice sheet latent processes at a monthly scale**.
- Moving from an annual (used in Antarctica[2]) to a monthly time step has enabled the statistical framework to resolve **seasonal process cycles such as runoff** (fig. 3A & 3B).
- Prior knowledge about ice dynamics and surface processes provide enough information to effectively separate observations into processes which are **co-incident in space and occur at similar densities** (e.g. Ice Dynamics and Runoff).
- When applied to whole ice sheet, **SMB** latent process field can be used as an **independent data-driven validation** against forward geophysical models (e.g. RACMO, MAR), which exhibit noticeable variation at the basin scale.
- GIA forward model solutions can have large impacts on basin scale ice mass trends[6]. The BHM data-driven **GIA solution will provide an independent validation to these forward models**.

Future Work

- Calculate monthly mass trends and constituent components for 2003 onwards at the drainage basin scale.[7]
- Extend the time series from 2010 until the present day using a combination of **CryoSat-2 swath $\Delta h/\Delta t$ data and NASA GSFC Mascons**.
- Investigate ability to incorporate field observations of SMB.[8]
- Extend the time series into the next decade by utilizing data from **ICESat-2 and GRACE-FO**.

Acknowledgements

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