

A Tango between Ice and Sea level



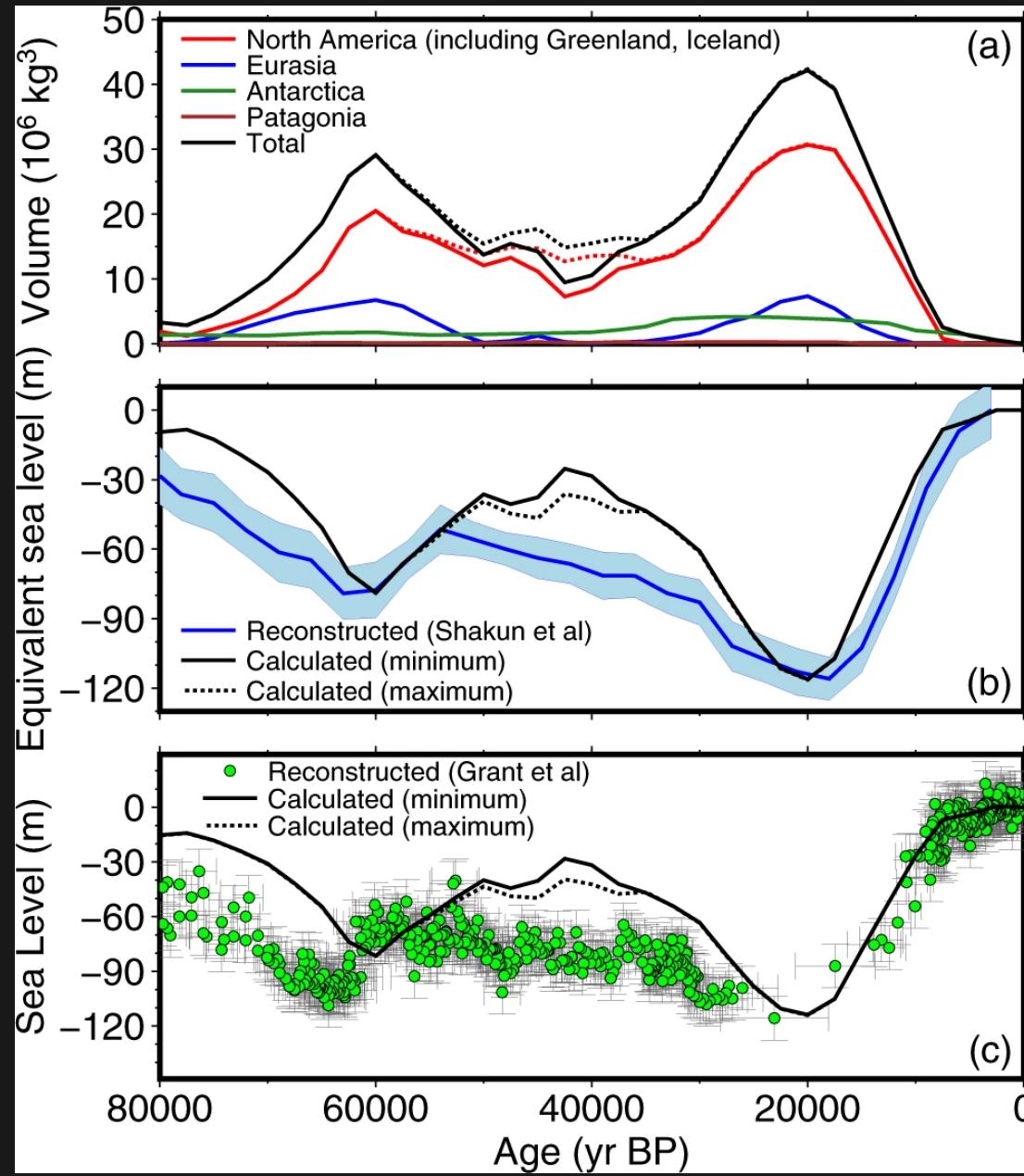
Roelof Rietbroek, with contributions from Ingo Sasgen, Thomas Frederikse, Andreas Groh, Riccardo Riva

Relevant ICCC joint working groups:

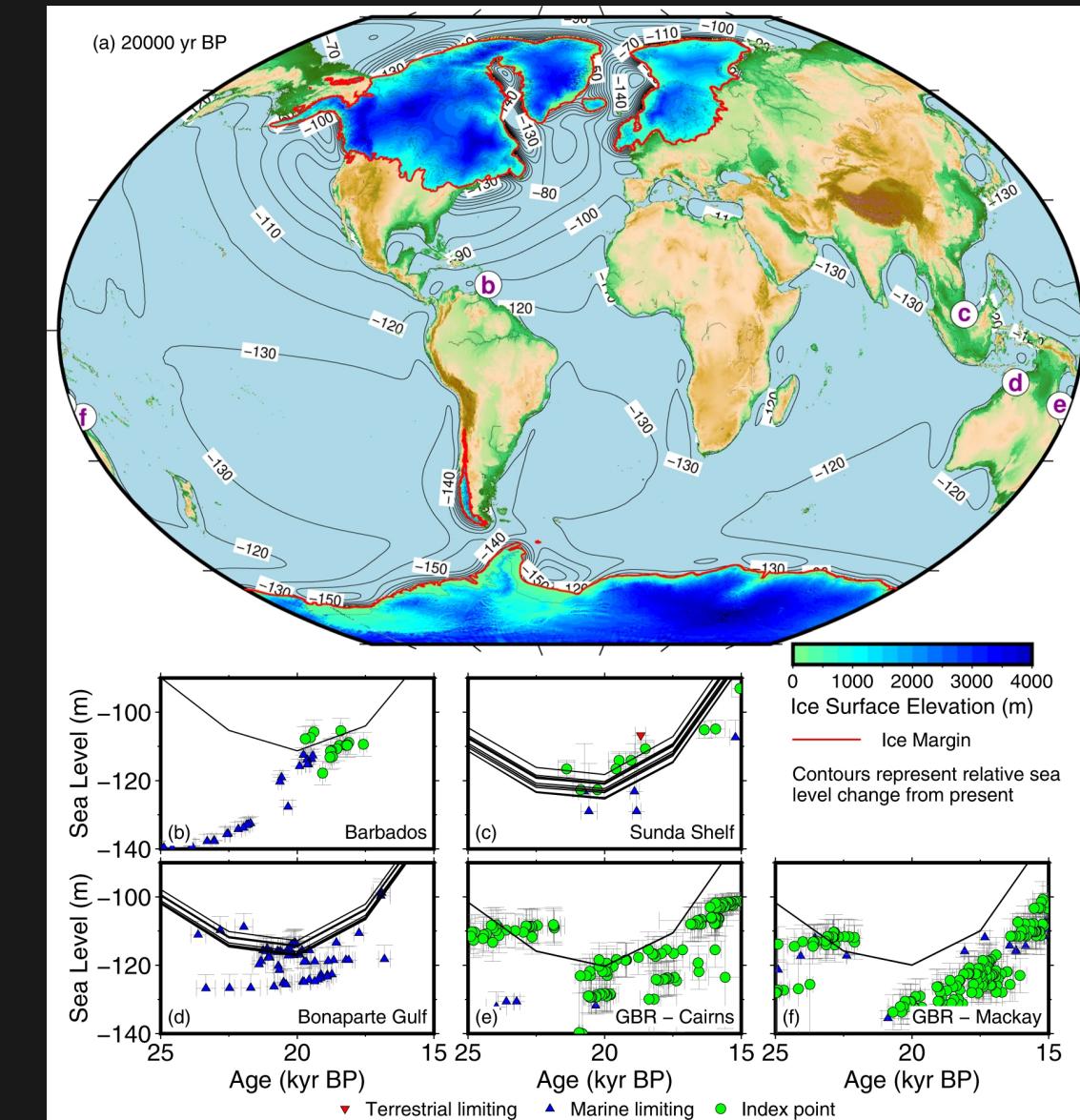
- JWG C.3: Geodesy for the Cryosphere: advancing the use of geodetic data in polar climate modelling
- JWG C.4: Sea level and vertical land motion



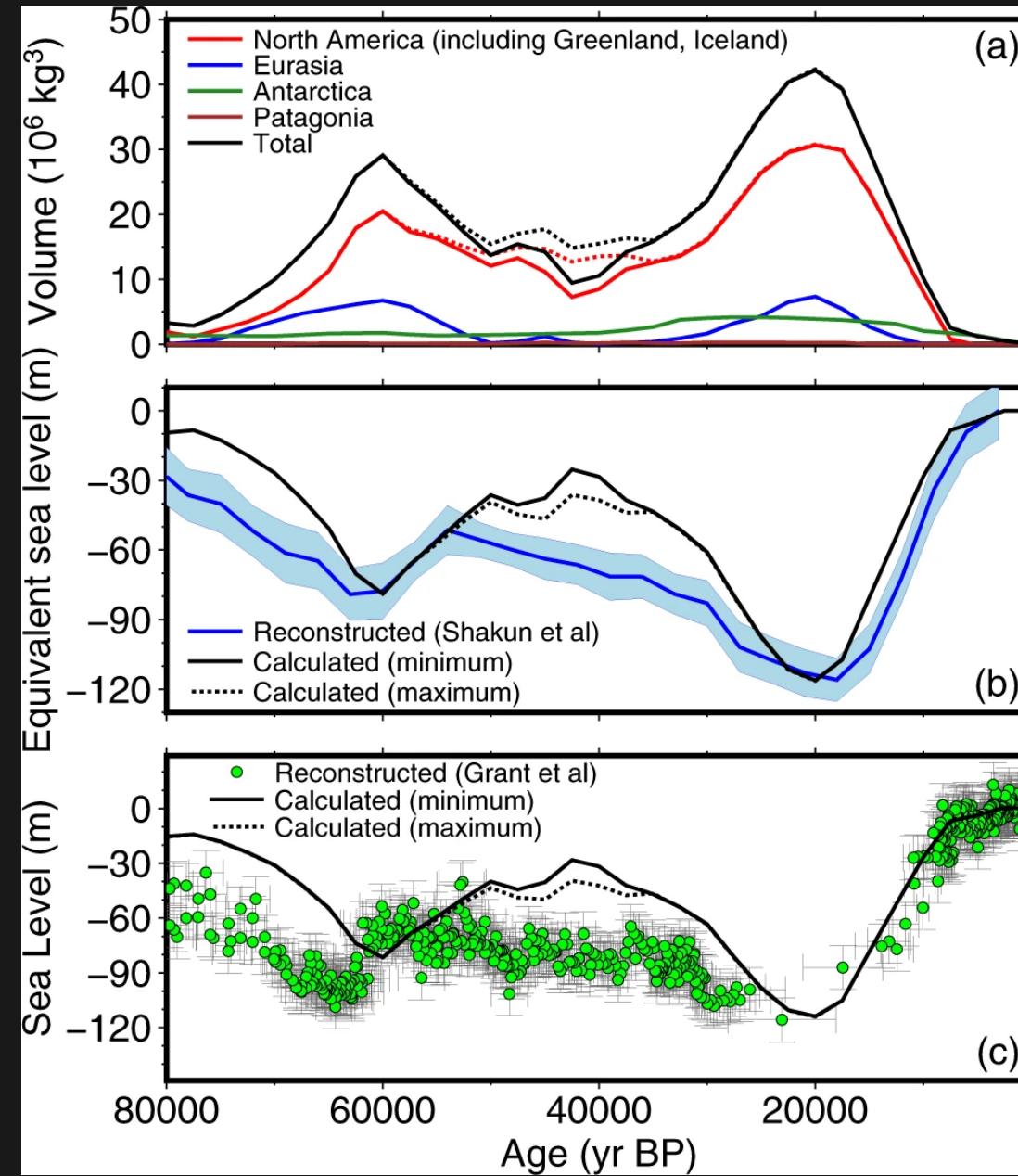
They've been dancing since the last Quaternary (~2.6 Million yrs bp)



Evan Gowan et al. 2021

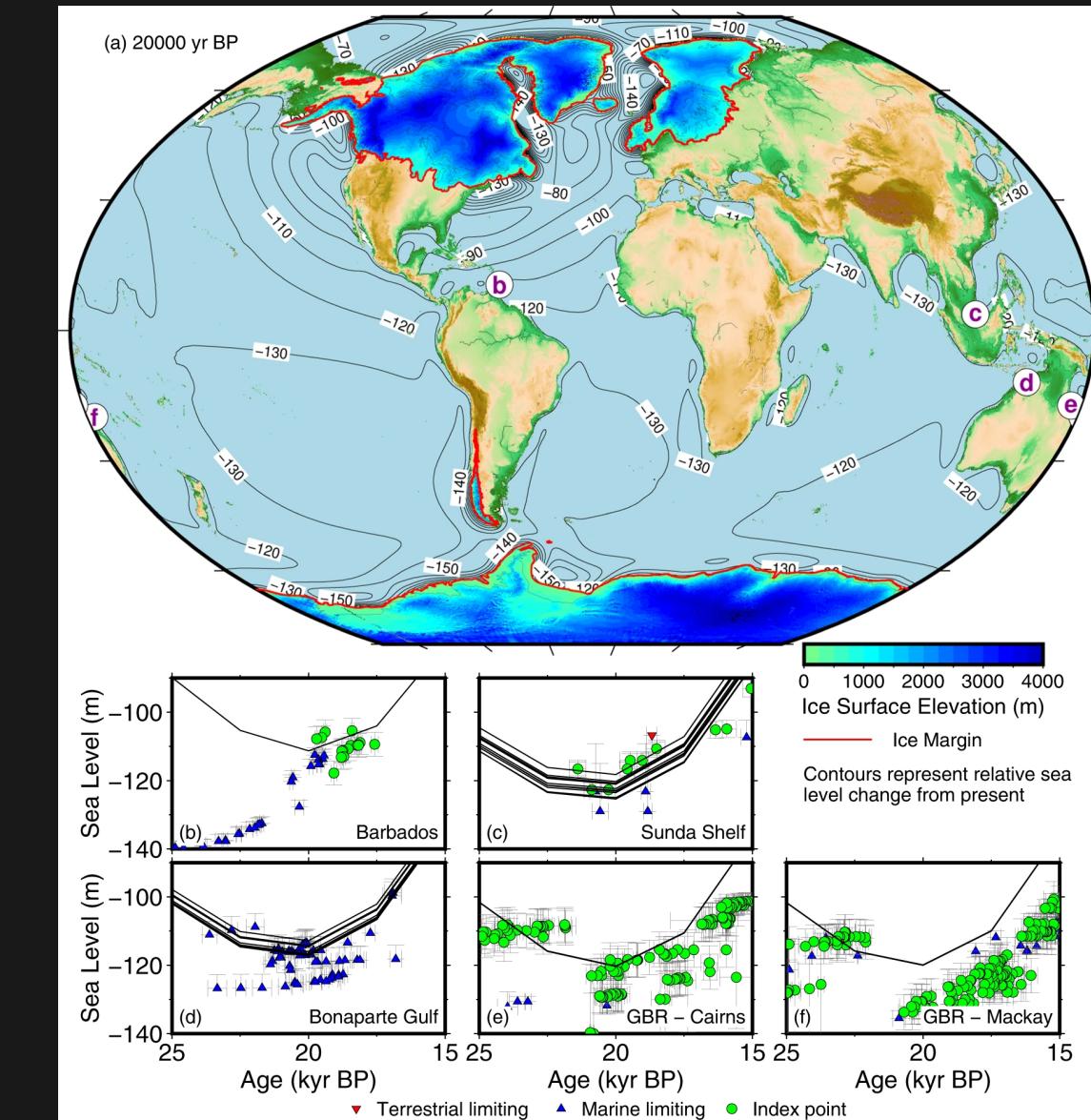


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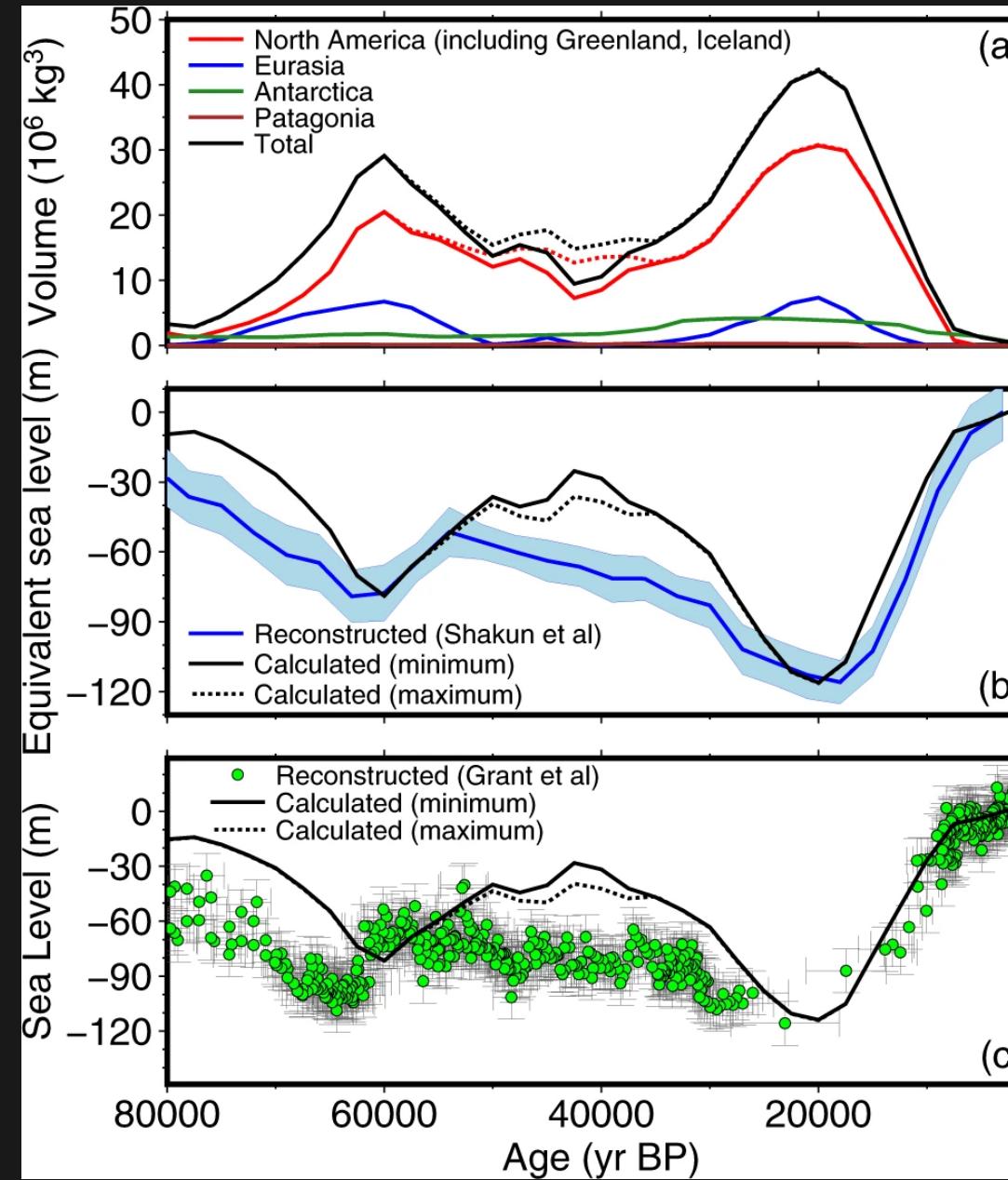


Evan Gowan et al. 2021

- Sealevel <-> ice volume

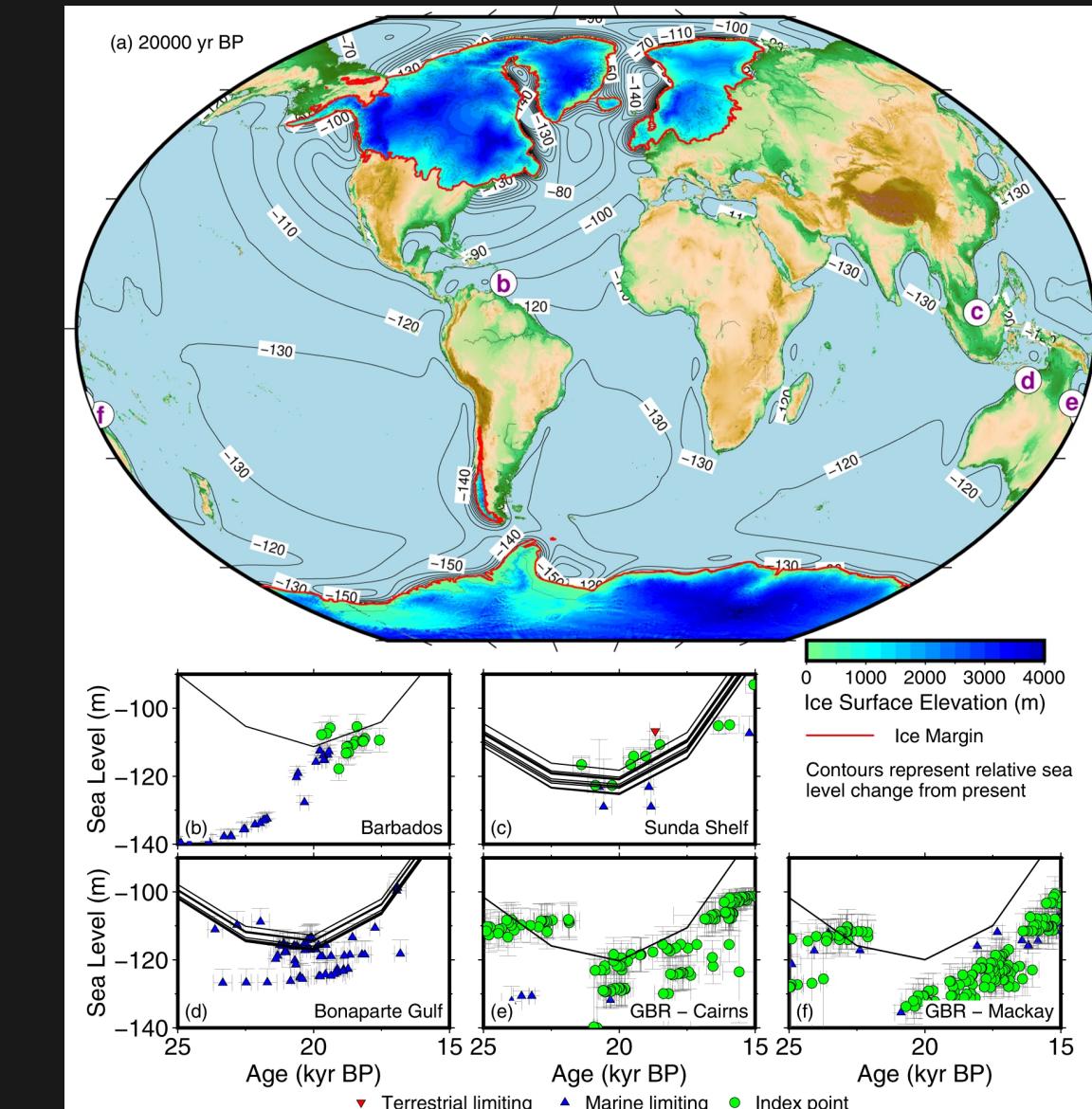


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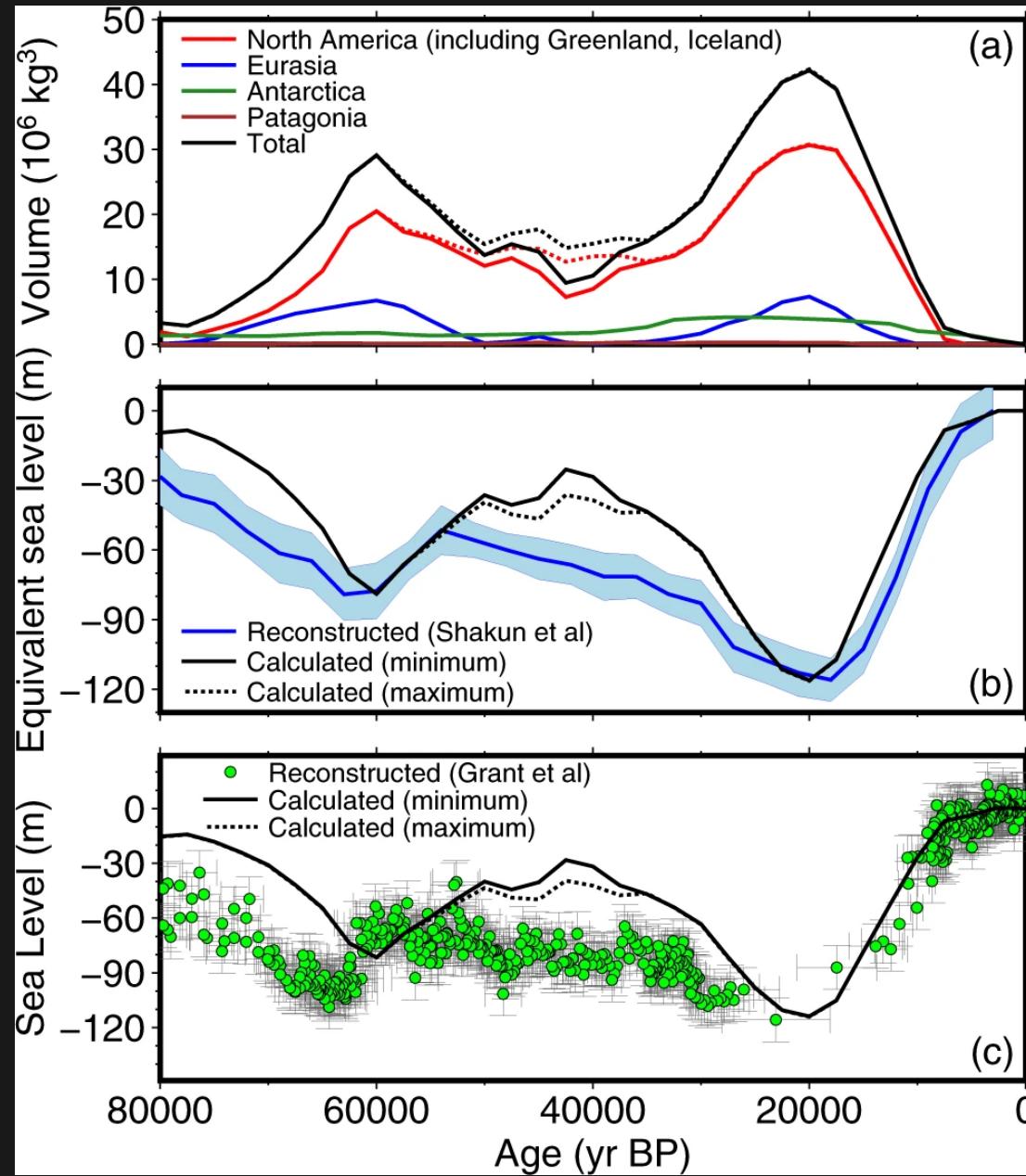


[Evan Gowan et al. 2021](#)

- Sealevel <-> ice volume
- How do we know? sea level indicators and proxies: corals, oxygen isotopes,..

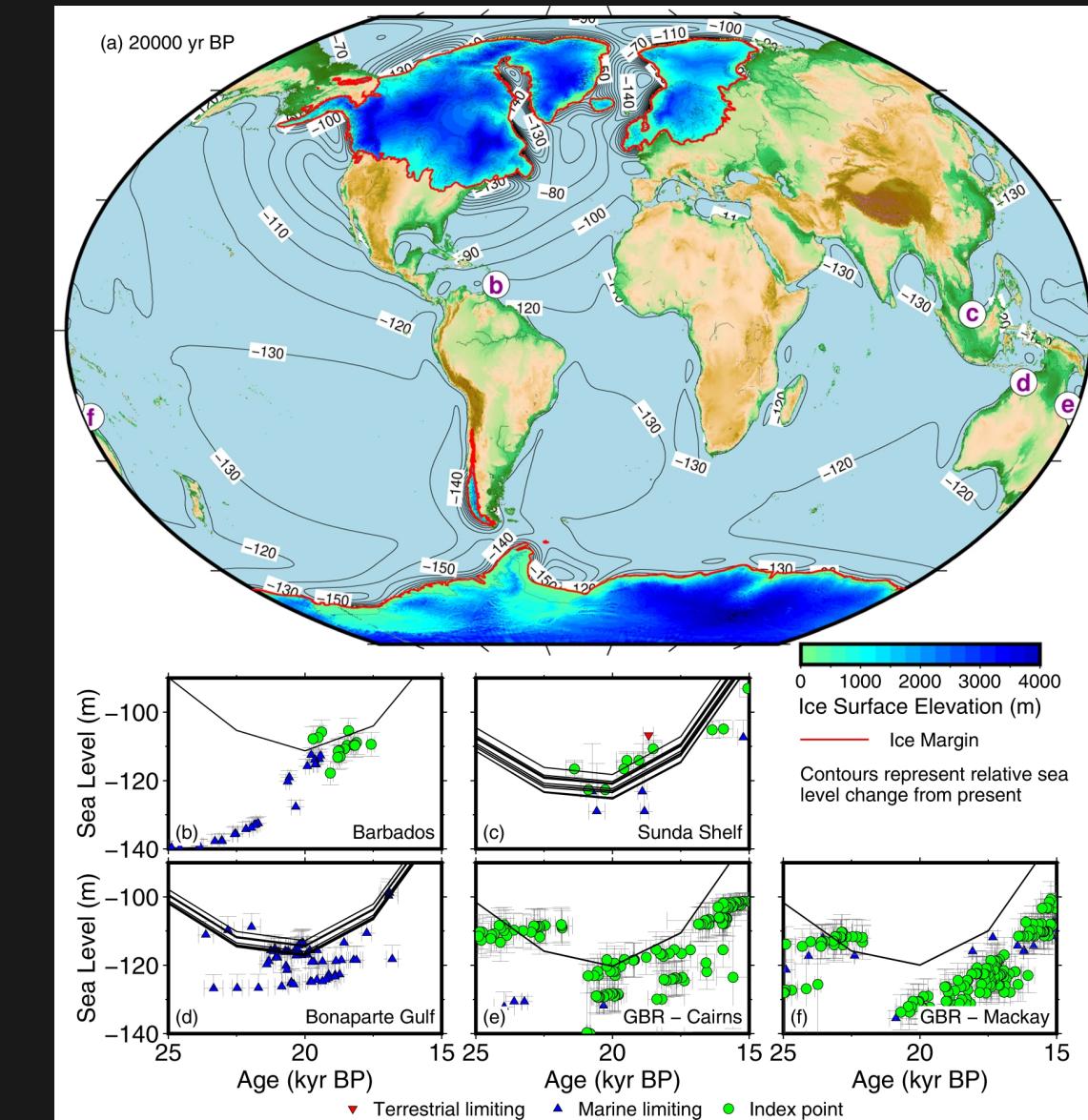


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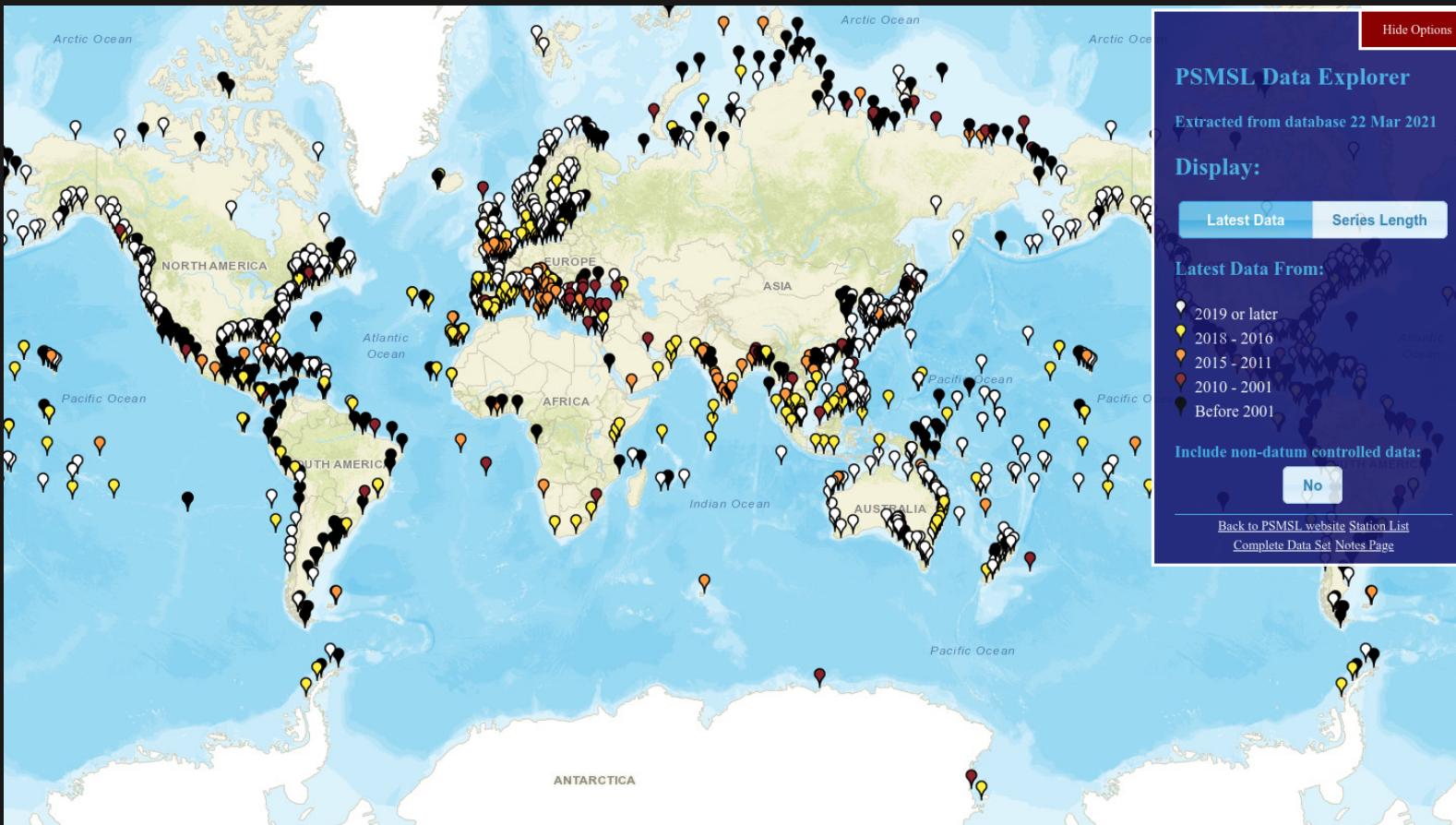


[Evan Gowan et al. 2021](#)

- Sealevel <-> ice volume
- How do we know? sea level indicators and proxies: corals, oxygen isotopes,..
- Challenge is to reconcile sea level indicators with physics of glacial isostatic adjustment



Direct observations of sea level: Tide Gauges



Tide gauge locations from the Permanent Service of Mean Sea level (PSMSL).

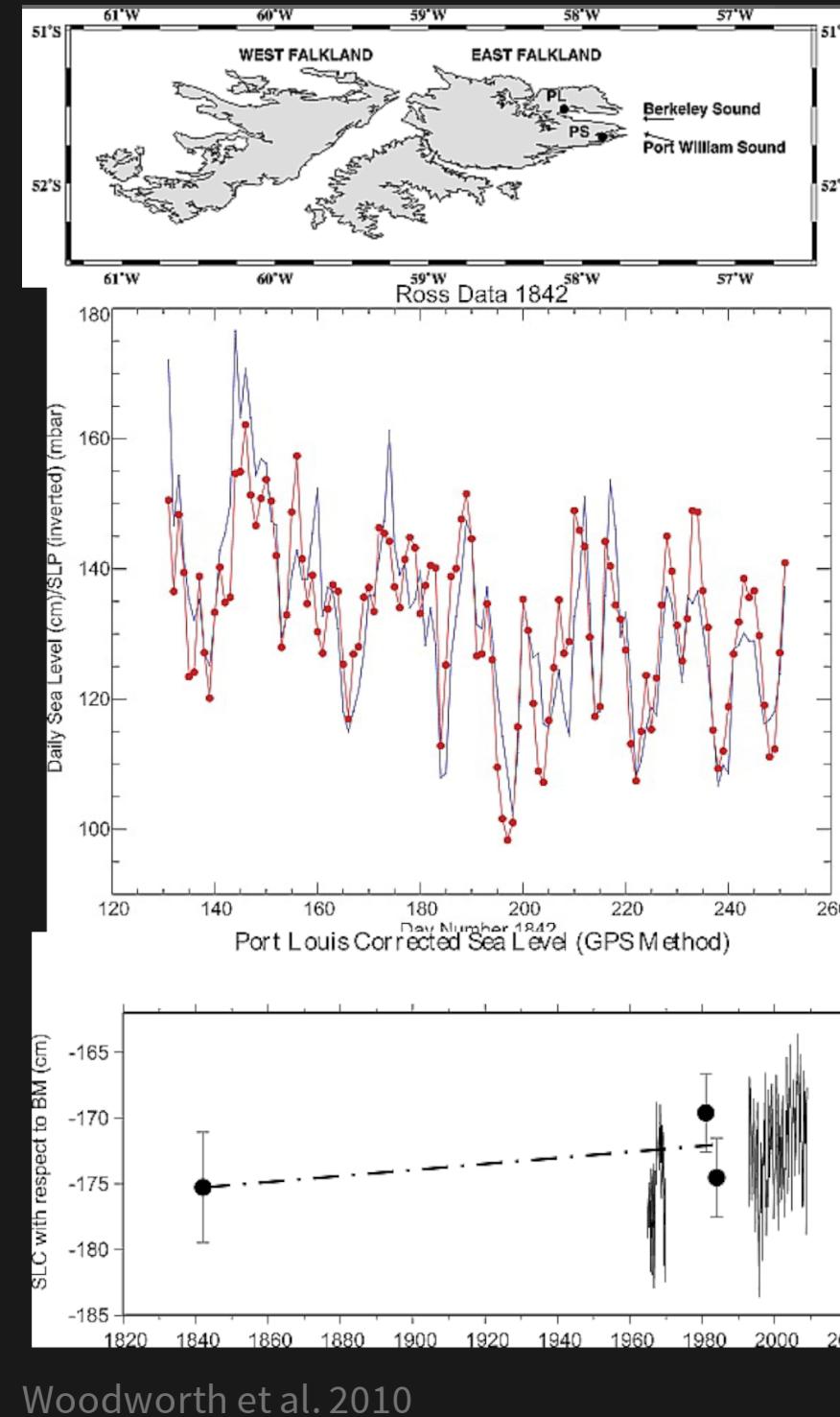


Inspection of a Greenland TG, 1926, Credit: NOAA

- Some tide gauge records go back to the 18-19th century!
- Useful for charting tides, but also **relative sea level** rise
- 'Asymmetrical' coverage (space and time)



James Clark Ross' voyage of research and discovery in the Southern Ocean (1839-1843)



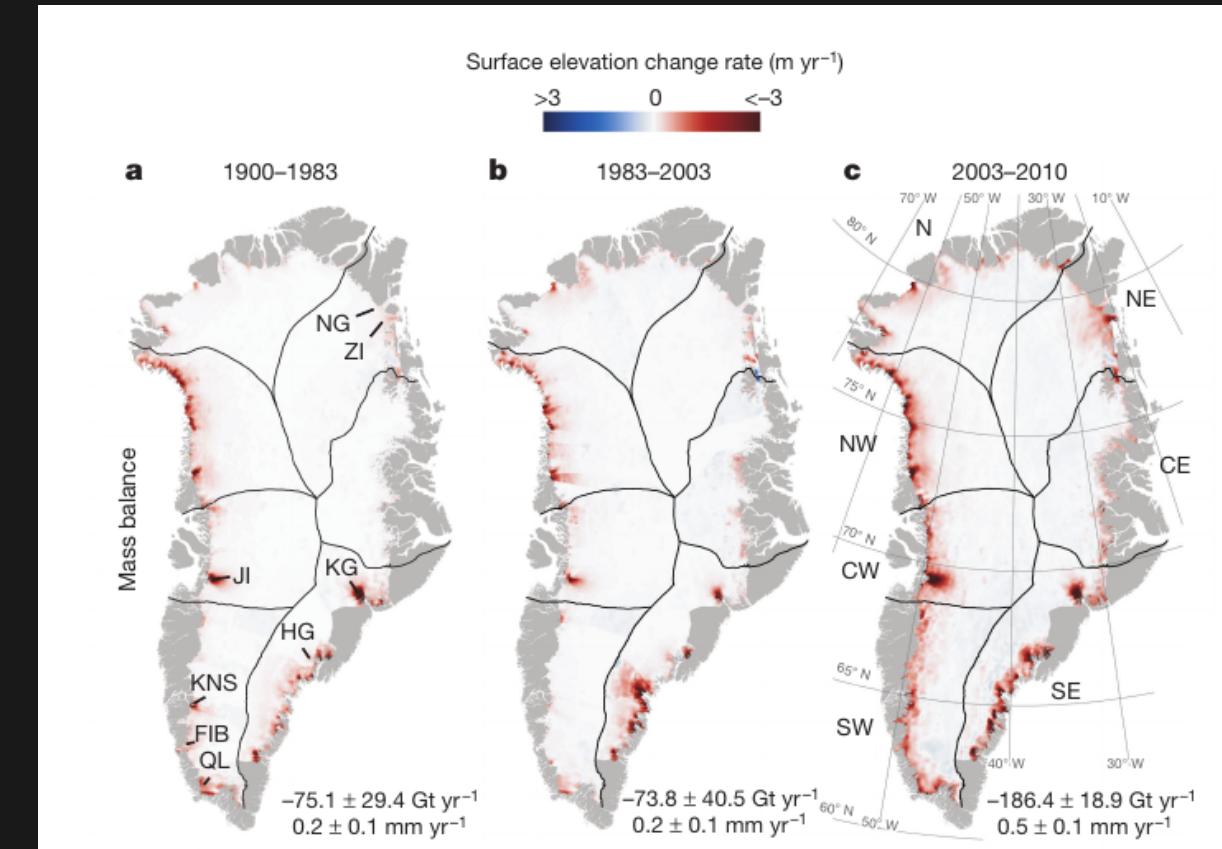
Woodworth et al. 2010

- Take home message: Make benchmarks as indestructible as possible
- 19th century sea level observations (~1 year) in the Falklands (Port Louis)
- Corrections needed: air pressure (IB), Glacial Isostatic Adjustment
- Connecting the history series to more recent records yields a trend estimate of 1.23 ± 0.22 mm/yr (Woodworth et al. 2010)

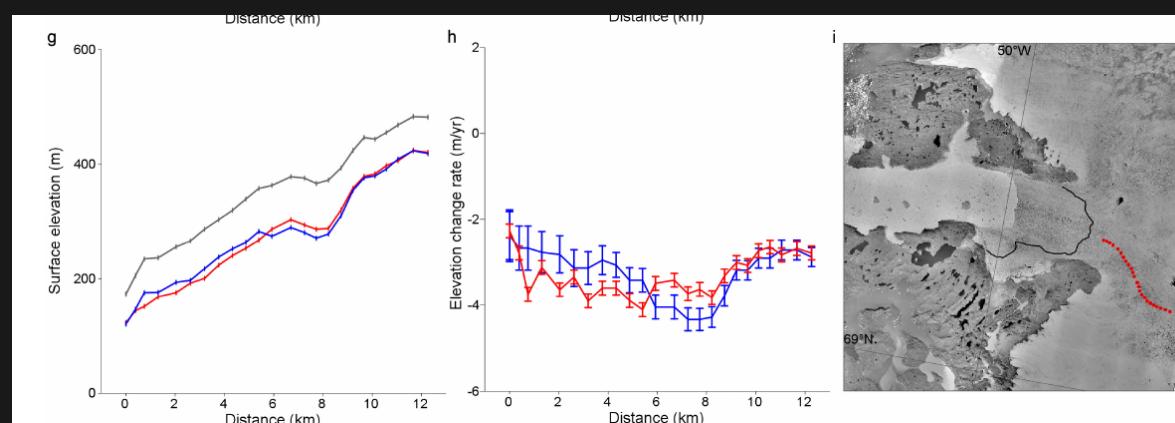


Using areal photography of Greenland to estimate glacier changes (Kjeldsen et al. 2015)

- Areal photographic evidence from the 80's provide early snapshots of the glacier ice extents
- Use geometric relationship to map front locations to glacier mass change
- Identify ice fronts and lateral moraines in DEM to estimate the ice extent in 1900
- Shows and accelerated mass balance from $-75 \pm 29 \text{ Gt yr}^{-1}$ (1900-1983) to $-186 \pm 19 \text{ Gt yr}^{-1}$ (2003-2010)



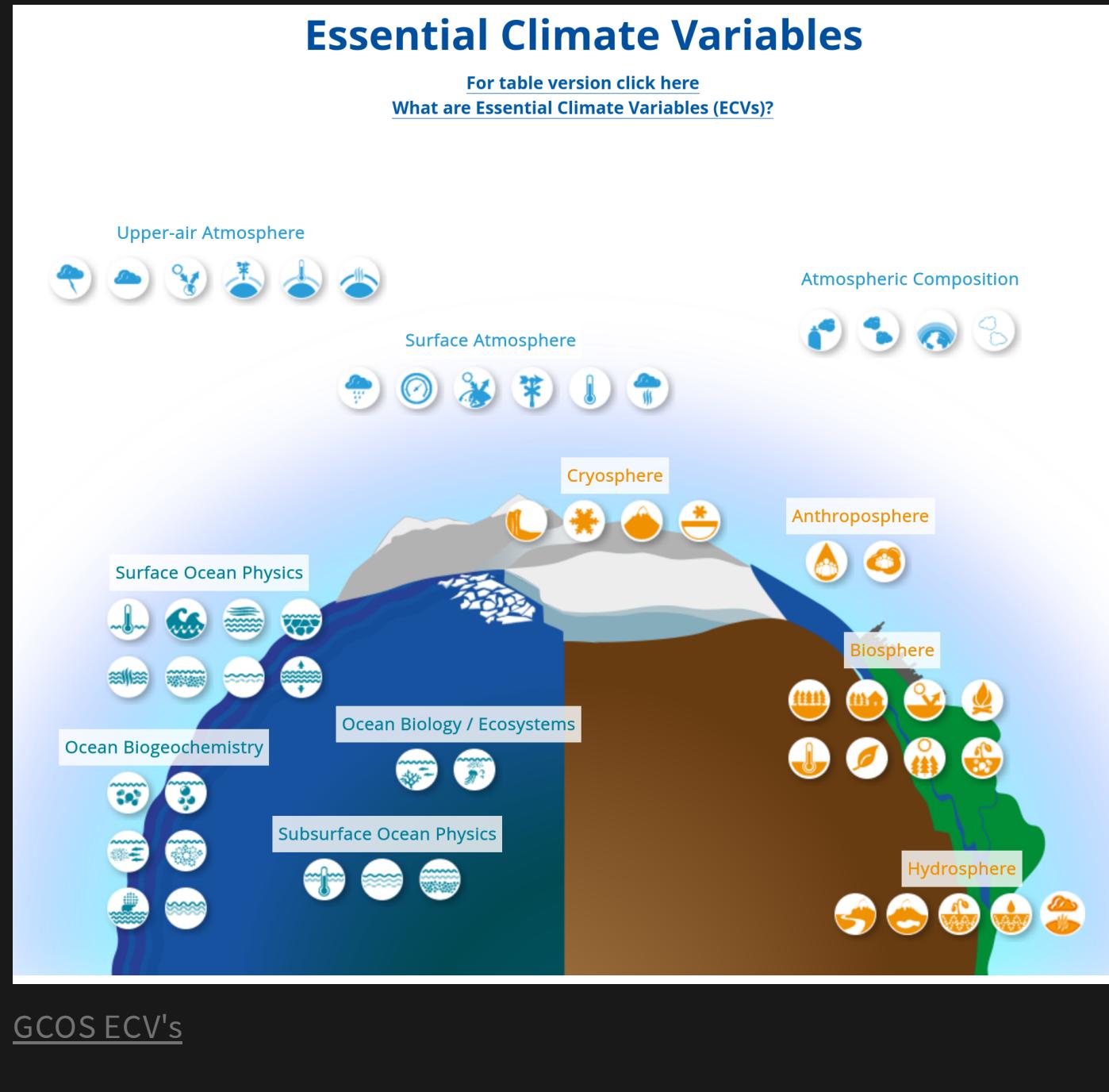
[Kjeldsen et al. 2015](#), Greenland mass change since 1900



[Kjeldsen et al. 2015](#), Photogrammetric DEM from (1978-1987) overlaid with ice surface elevation from the Nasa Airborne Topographic Mapper (2003)



Sea level and ice sheets as Essential Climate Variables



- Not just for scientific purposes, but monitoring ECV's inform policy on mitigation and adaptation decision
- **Ice sheets and Ice shelves**
 - Surface elevation
 - Ice velocity
 - Ice mass change
 - Grounding lines and thickness
- **Sea level**
 - global mean sea level
 - regional sea level
 - but missing: vertical land motion



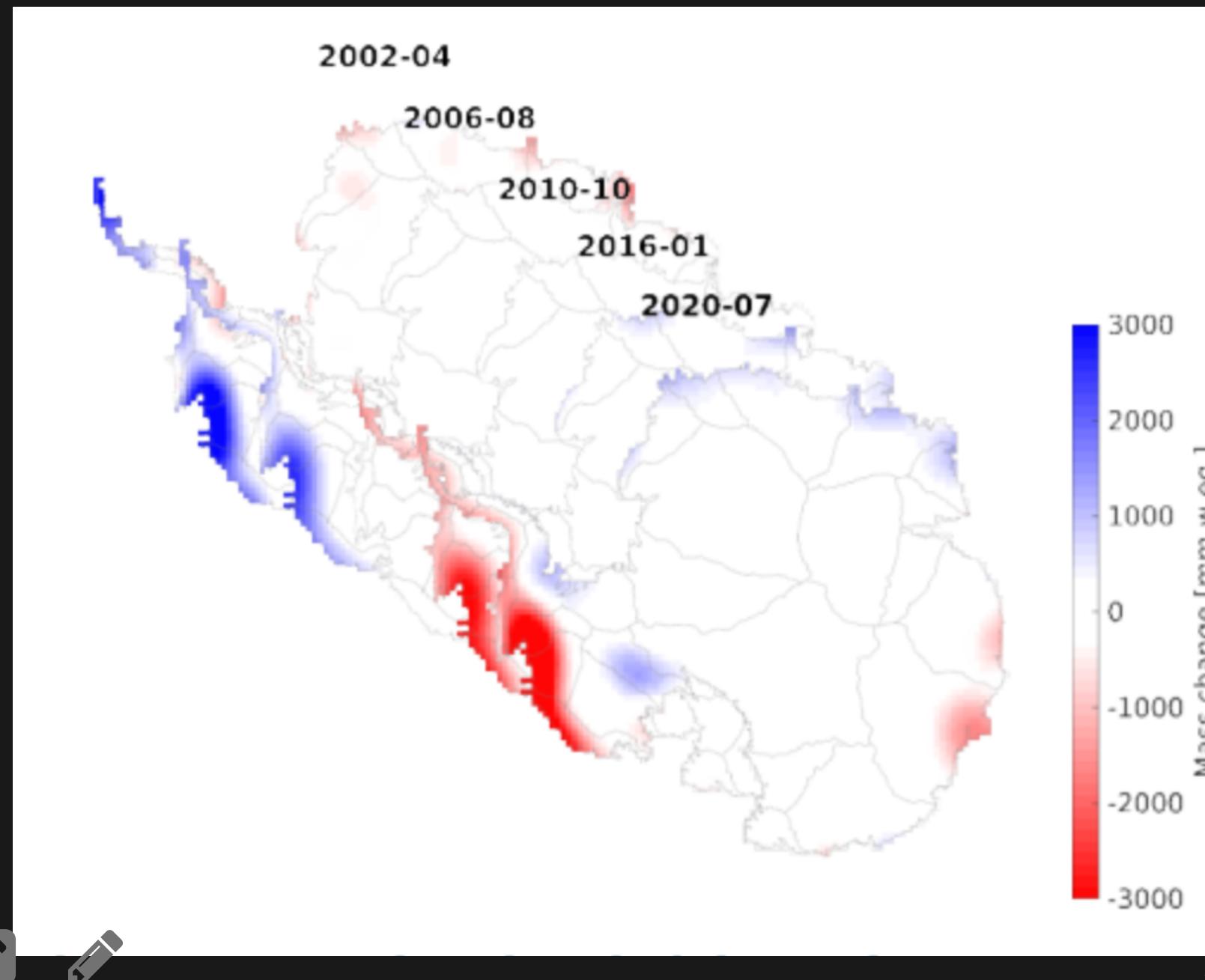
Example: Antarctic Ice mass changes from the Climate Change Initiative

- Monthly products based on GRACE/GRACE-FO solutions of release CSR RL06
- [Download and visualize \[https://data1.geo.tu-dresden.de/ais_gmb\]\(https://data1.geo.tu-dresden.de/ais_gmb\)](https://data1.geo.tu-dresden.de/ais_gmb)



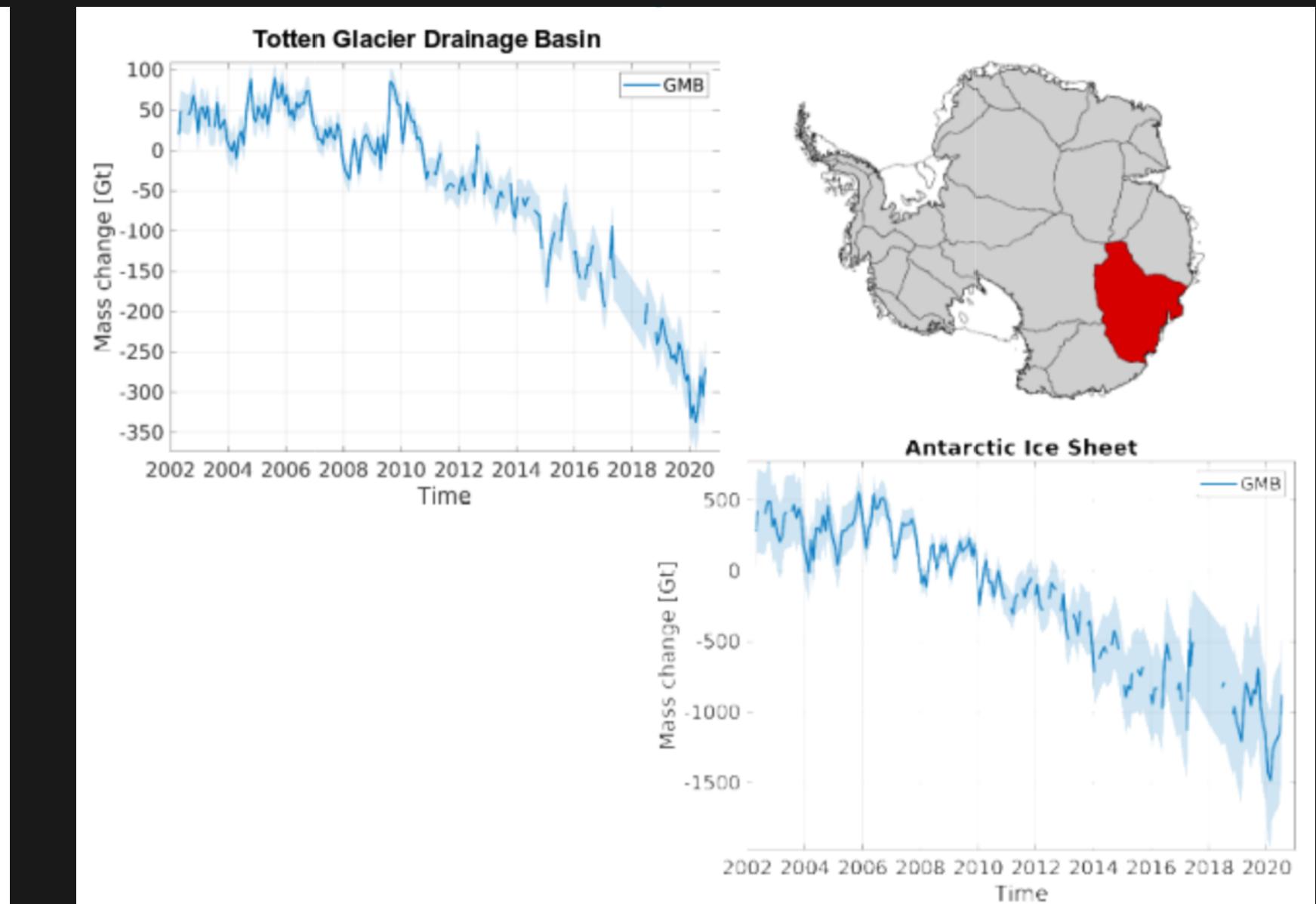
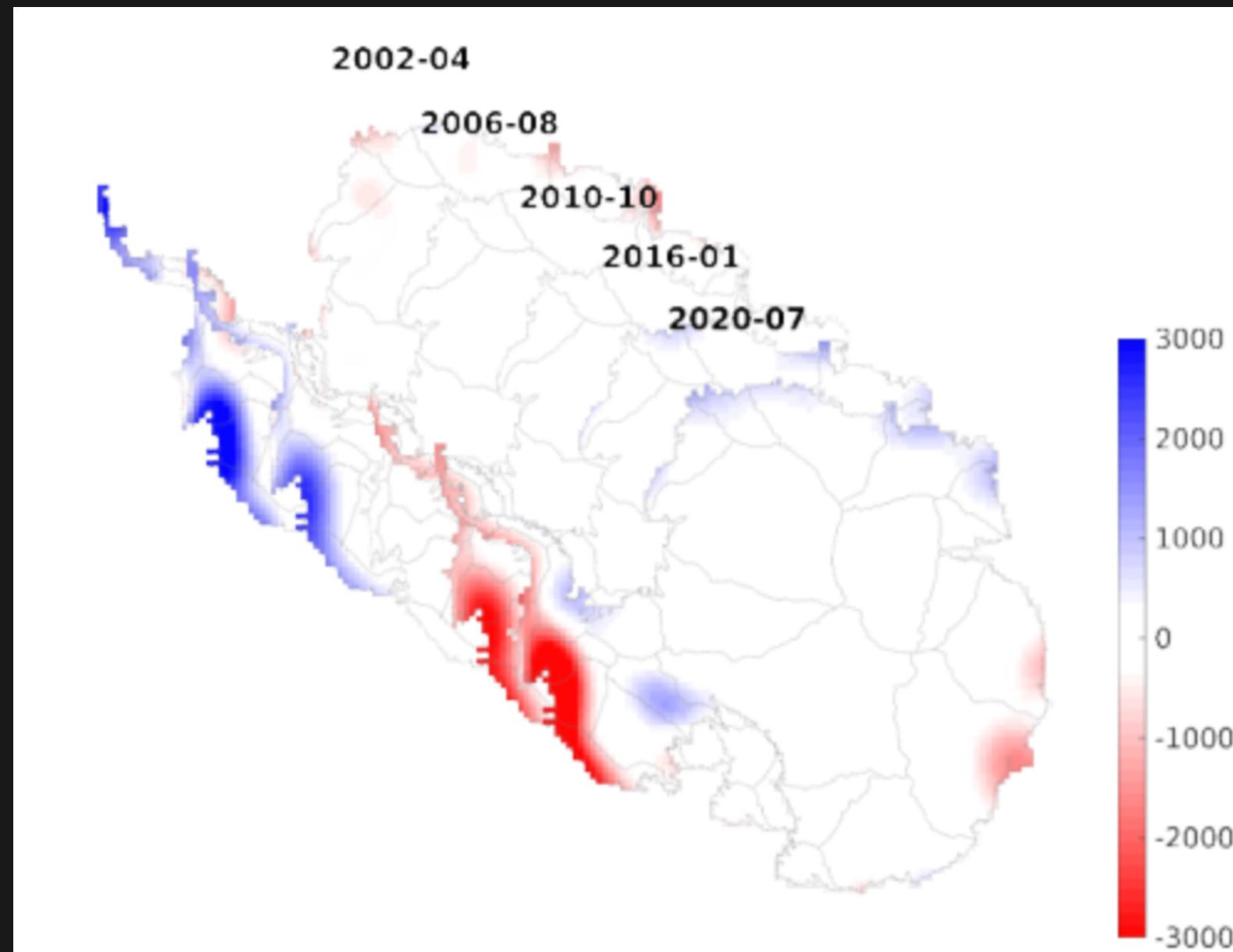
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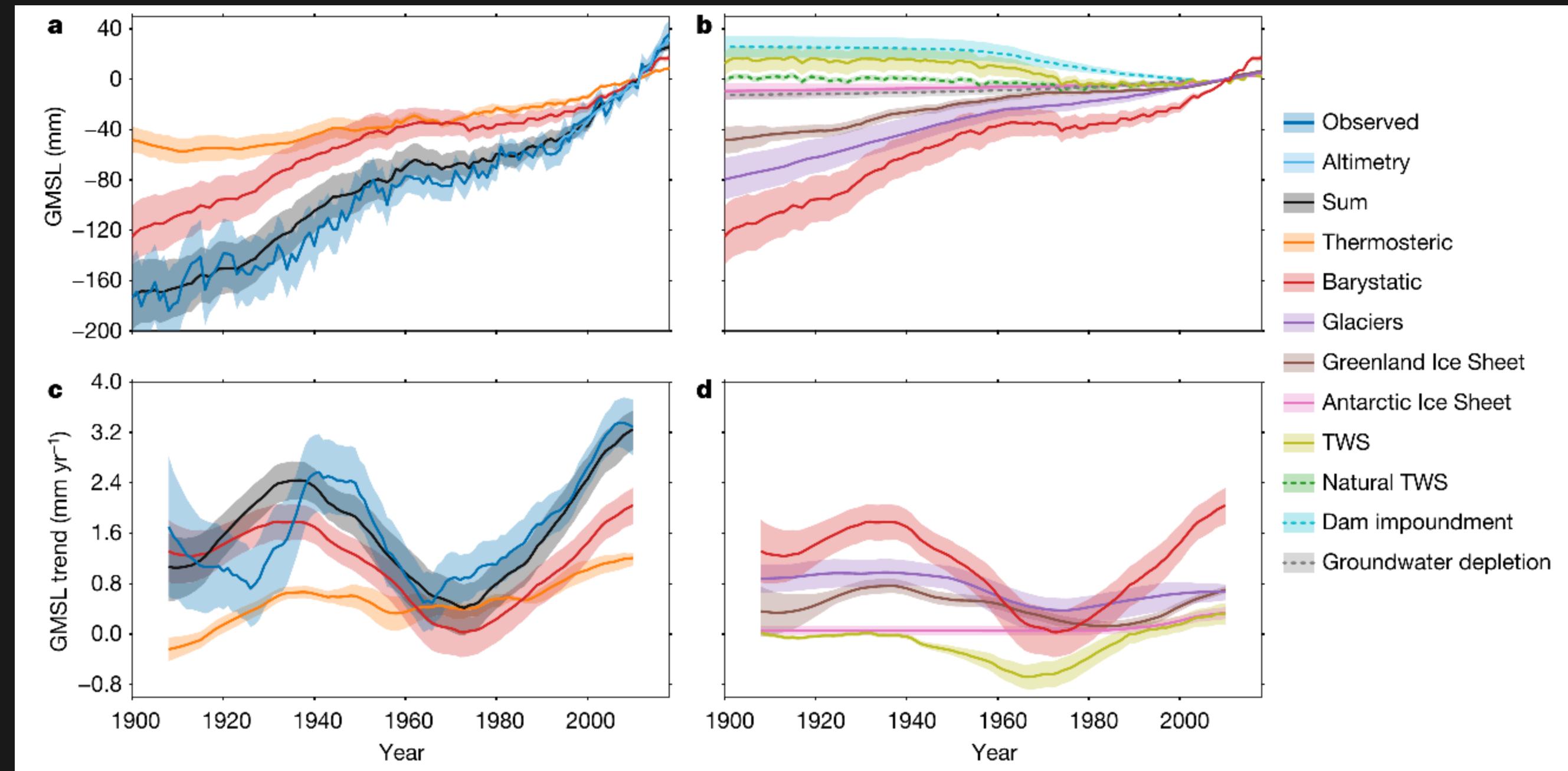
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Partitioning global sea level

- Highlight Paper Thomas



From global to regional sea level



A Tango between Ice and Sea level, R. Rietbroek, ICCC Workshop, 29-31 March 2020

UNIVERSITY
OF TWENTE.



Regional sea level

- Highlight recent paper on Atlantic



Looking in the future

- Highlight paper by Aimee? (projections)
- Future strategies: are we taking enough advantage of geodetic data? Move into climate sciences, but also move in
- Keeping projections in check: What would we like to have as a future observation system?
- The future of computing: Cloud versus local computing
- Making research accessible

Boundaries of geophysical observation systems? New ideas for next gen of scientists

discuss ICCC & JWG's

JWG.3 is about 1) enhancing the use of geodetic data in ice sheet and glacier modeling, 2) understanding requirements of modelling community and 3) exploring potential of future geodetic observables.

