Discharge accelerations in Antarctica inferred from satellite gravimetry

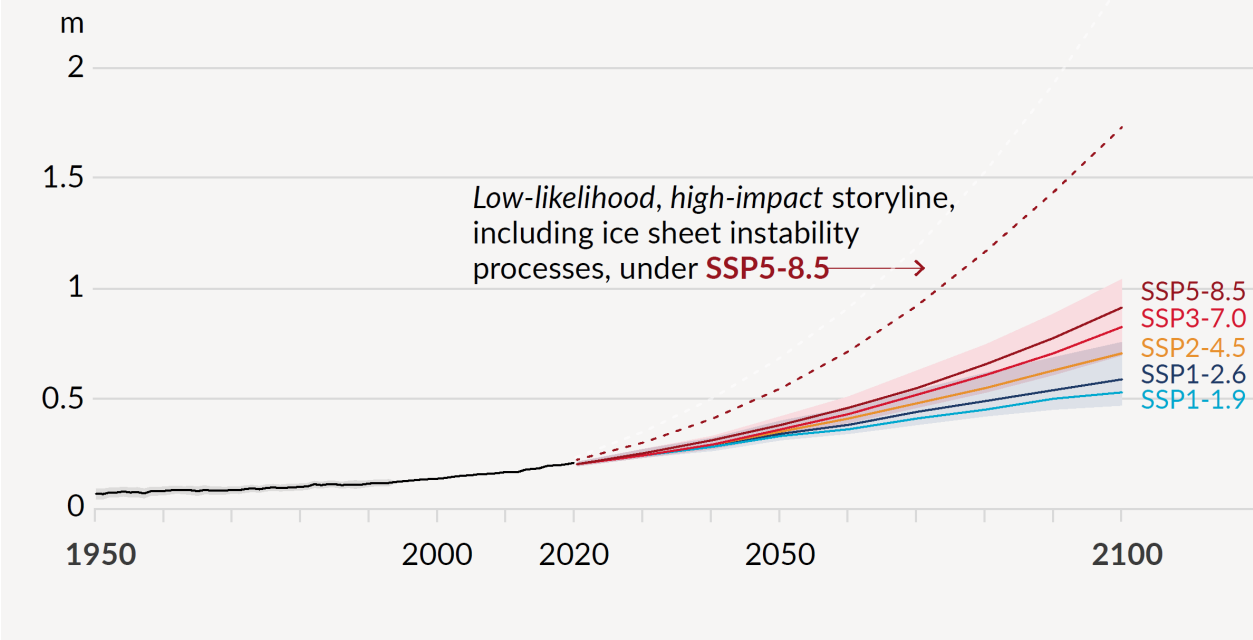
Theresa Diener[1,2], Ingo Sasgen[1], Cécile Agosta[3], Johannes Fürst[2], Matthias Braun[2], Hannes Konrad[4], Xavier Fettweis[5]

Session A9.04.2, 26 May 2022, 11:10 am, ESA LPS 2022, Bonn, Germany

HELMHOLTZ

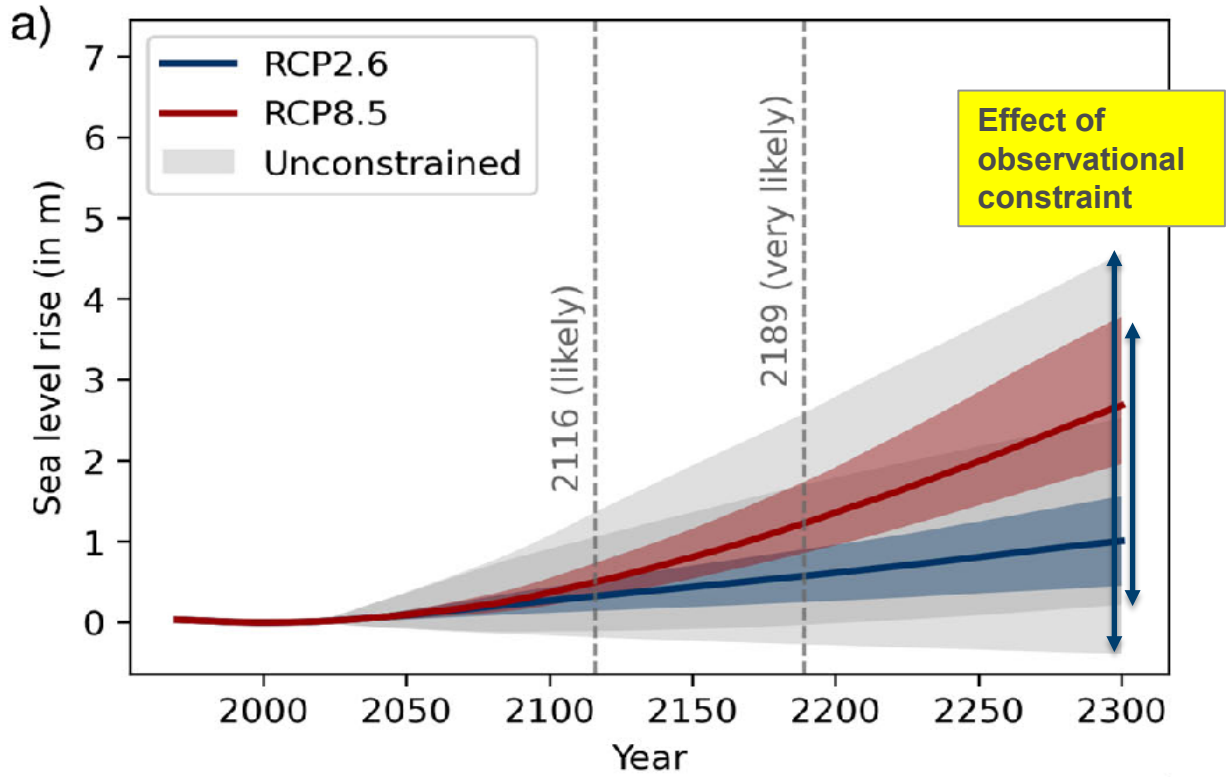
Motivation: constraint on projections?

Global mean sea level change relative to 1900



IPCC, 2021 AR6

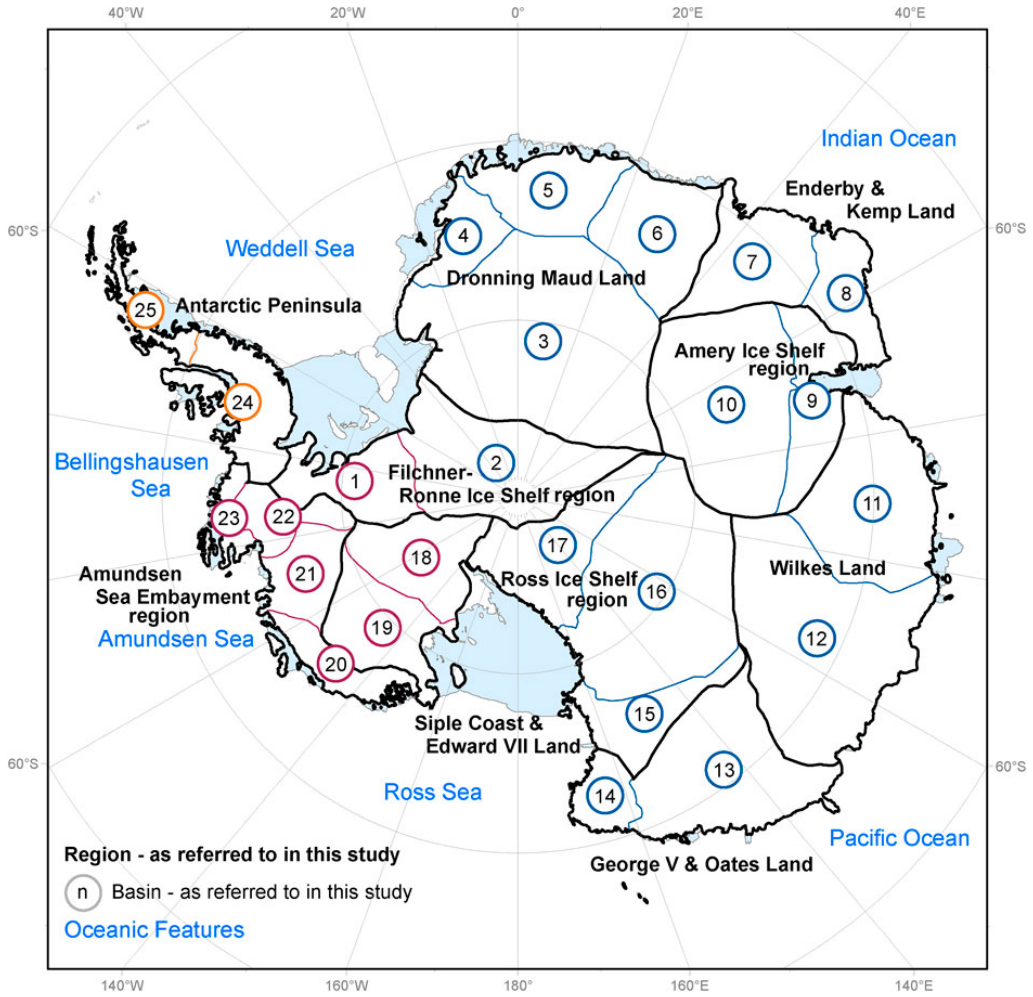
Possible Antarctic contribution



Lowry et al. 2021

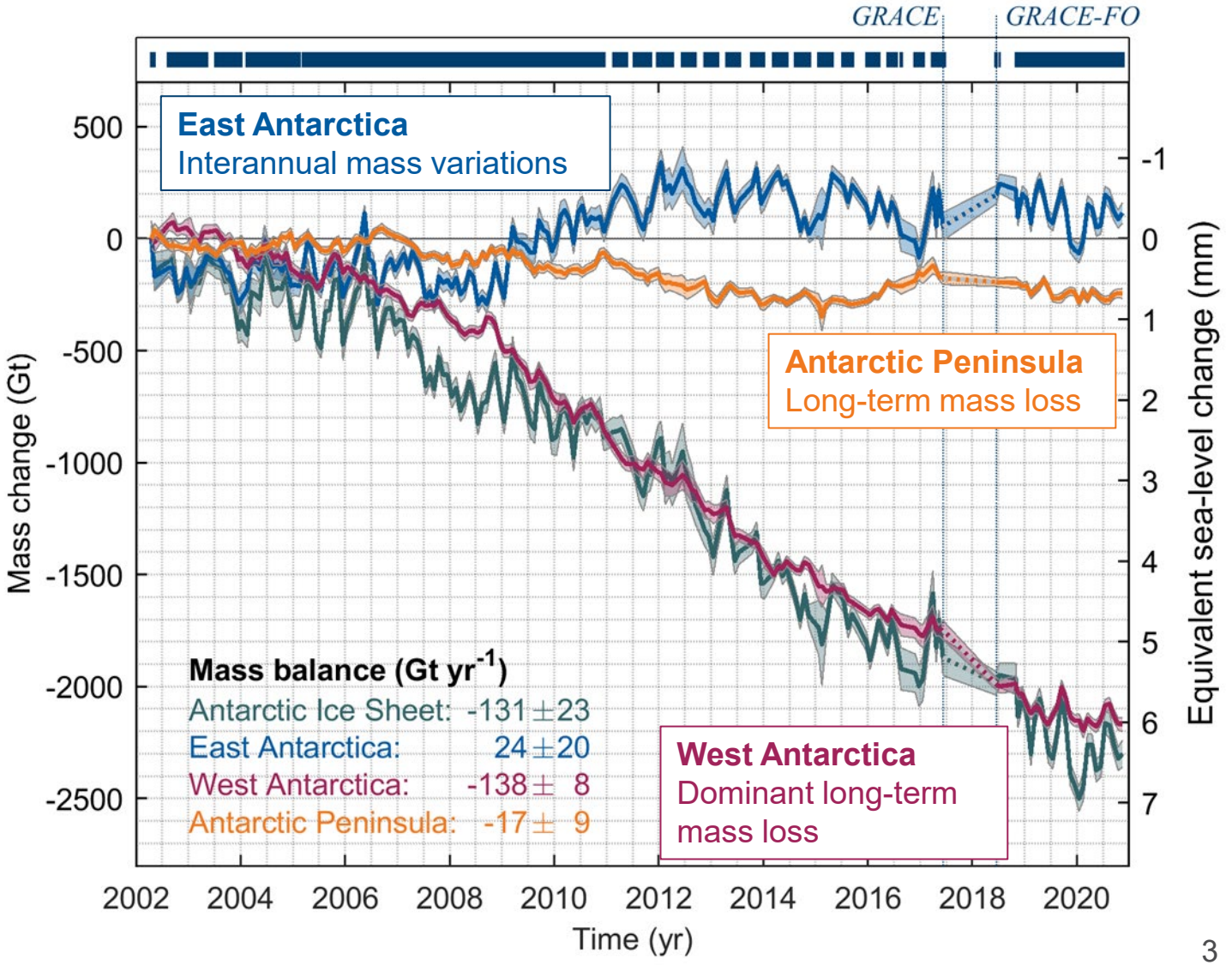
Mass changes in Antarctica from GRACE/GRACE-FO

Antarctic subdivision



25 basins / 10 regions / 3 macro-regions

Time series of mass change



Discharge estimation

Direct estimate (mass budget approach)

Flow profile

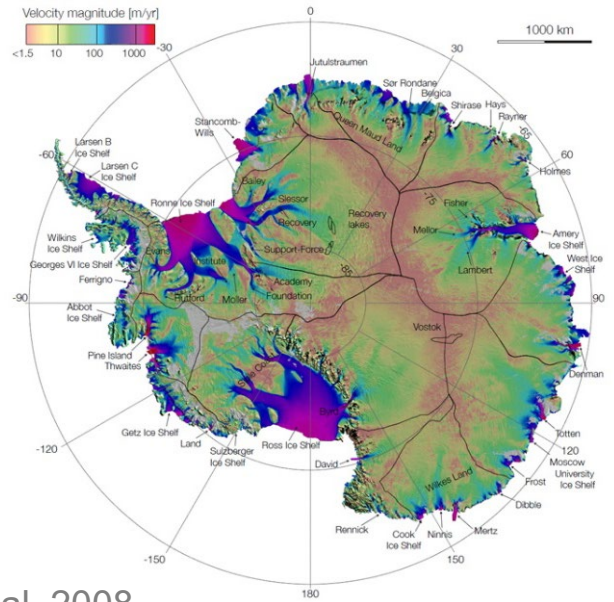
Length of flux gate

$$D = v_{ice} * f * t * L * \varepsilon$$

Surface-ice velocity

Thickness at grounding line

Bulk density



Indirect method

GRACE/GRACE-FO mass storage observations

Surface-mass balance rate

$$\mathrm{G/G\text{-}FO} = \int (\mathrm{SMB} + \mathrm{D})$$

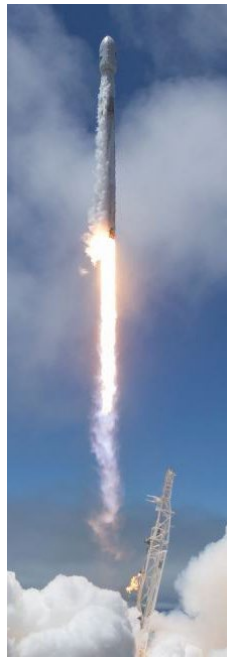
Rate of ice-dynamic discharge

Mass acceleration

$$\mathrm{G/G\ddot{-}FO} = \mathrm{S\dot{M}B} + \dot{\mathrm{D}}$$

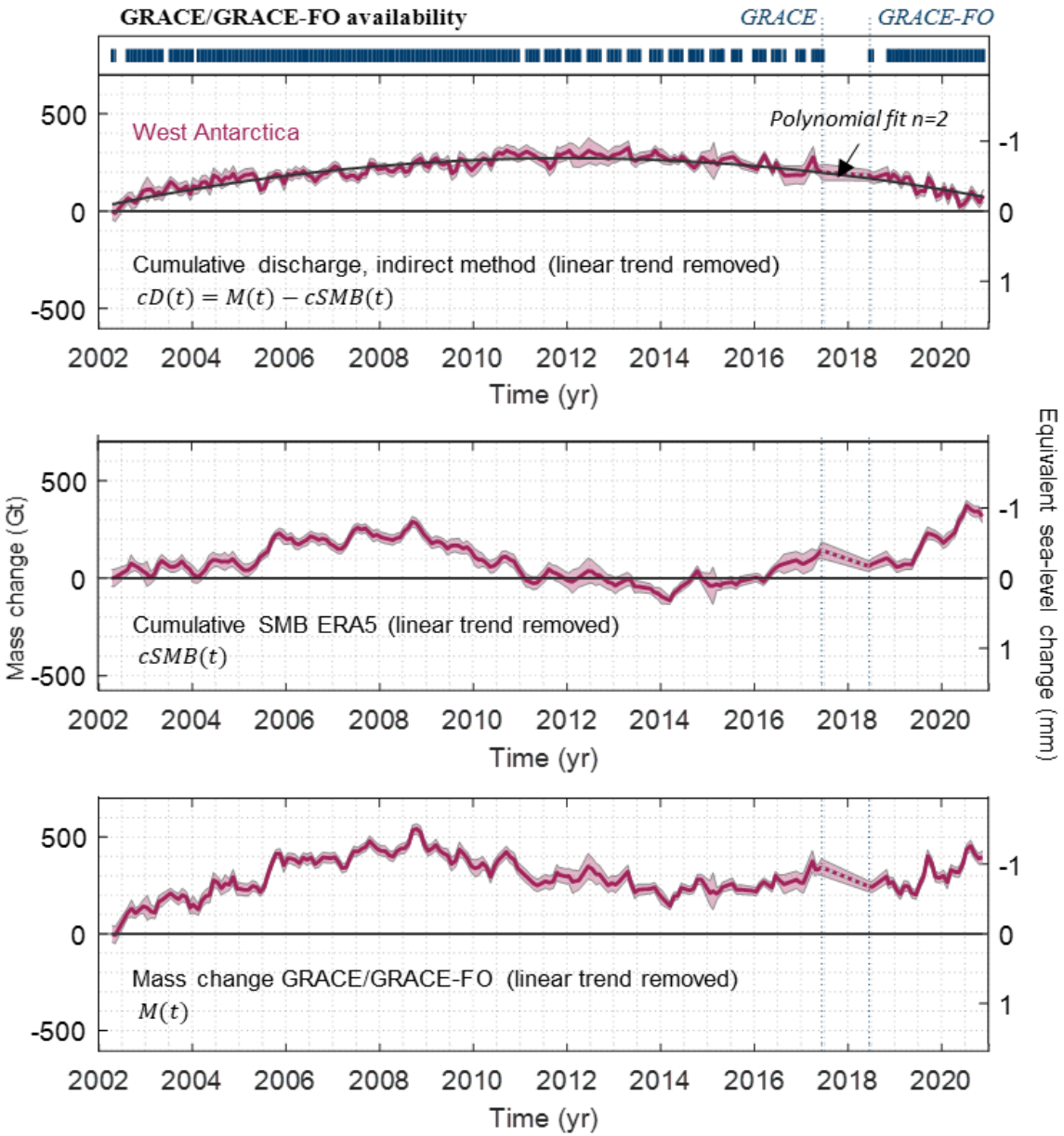
~ accumulation rate

~ $\dot{v}$ Ice stream acceleration



Mouginot et al., 2017, Rignot et al. 2008

Example: West Antarctica



D ~= GRACE/GRACE-FO – SMB

SMB

GRACE/GRACE-FO

Data source and uncertainty

SMB model estimates

- ERA-5 reanalysis (total snowfall, minus snowmelt and evaporation)
- MARv3.6 simulations with different lateral forcing (ECMWF ERA-Interim, MERRA2 and JRA-55)

GRACE/GRACE-FO observations

- 'homemade' solution combination (JPL RL06, GFZ RL06 and CSR RL06)
- Comparison to gridded products (TUD-GravIS, CSR Level 3 data)

Rolling window trends and acceleration differences → SMB systematic

Monthly differences of detrended data → Progatation to trend and acceleration → SMB stochastic

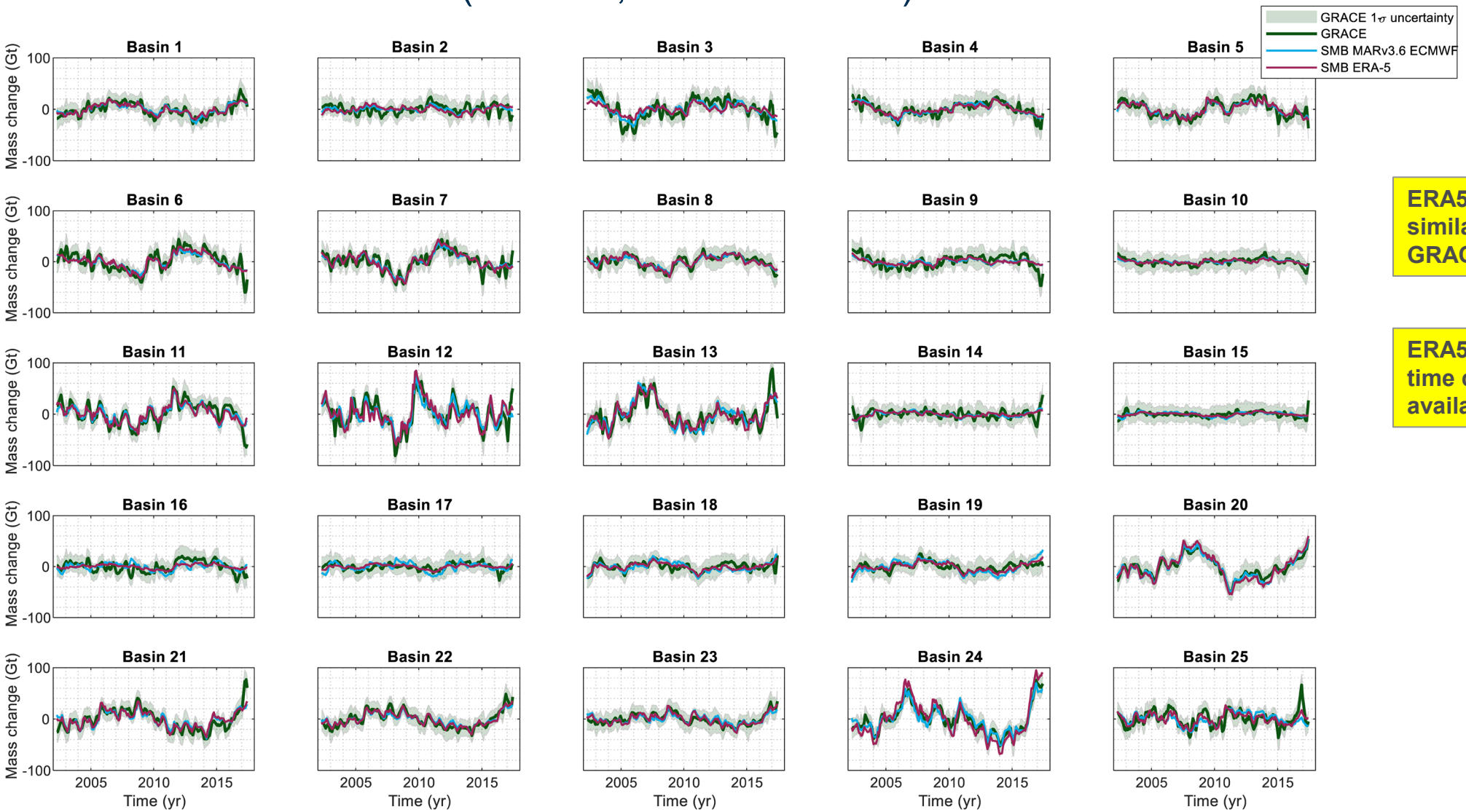
Differences of trends and accelerations between products → systematic

Propagation of coefficient uncertainties to trends and accelerations → stochastic

$\sum$ Total discharge uncertainty

Selection of SMB model

Interannual mass variations (no trend, no acceleration)

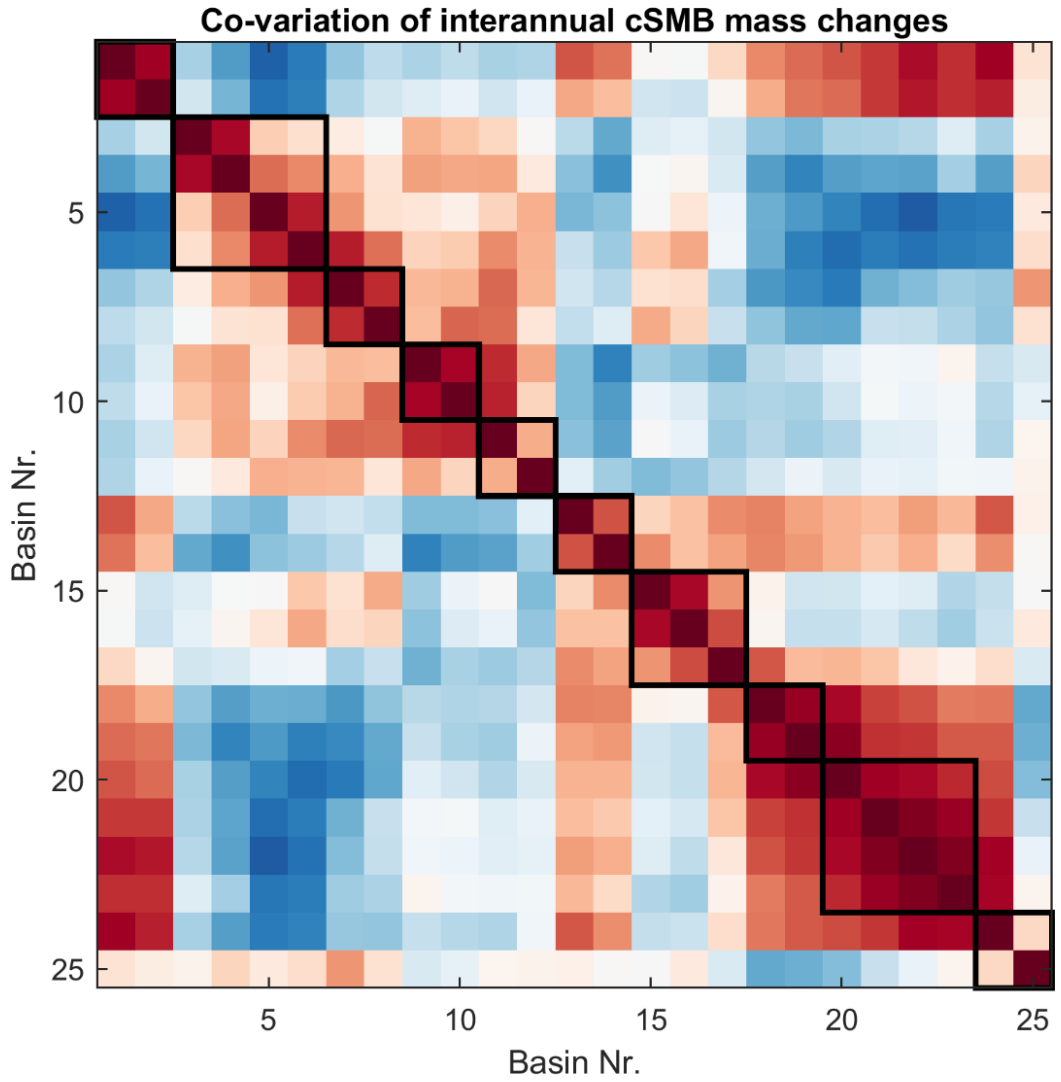


ERA5 and MAR3.6 similar agreement with GRACE/GRACE-FO

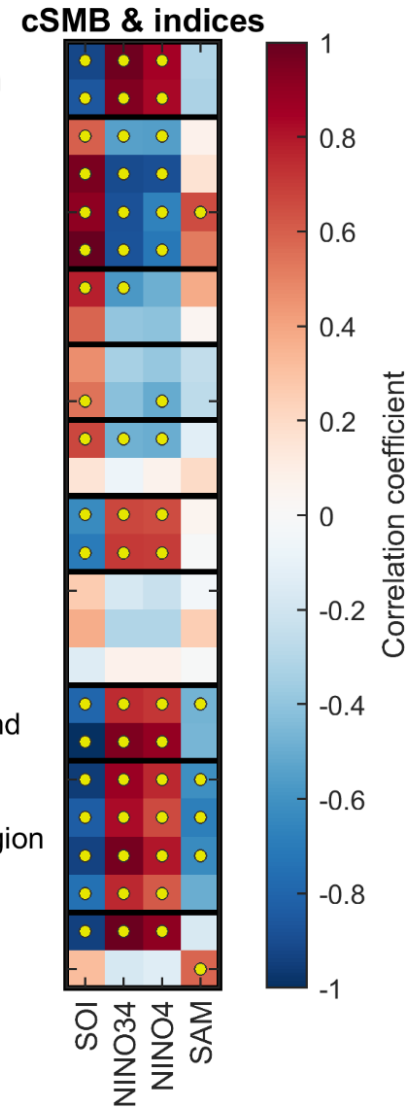
ERA5 preferred for time coverage / availability

Intra-basin mass correlation and climatic drivers

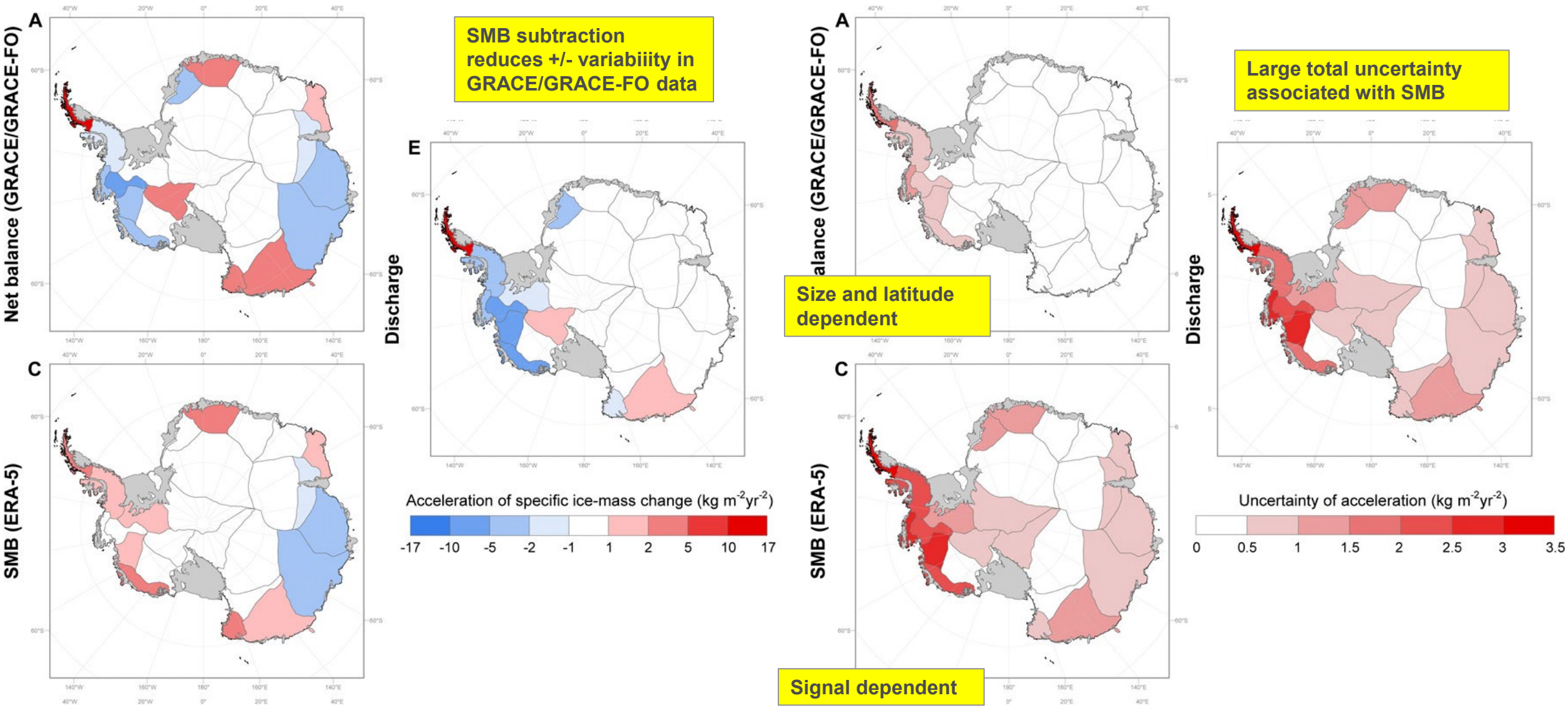
Between basins



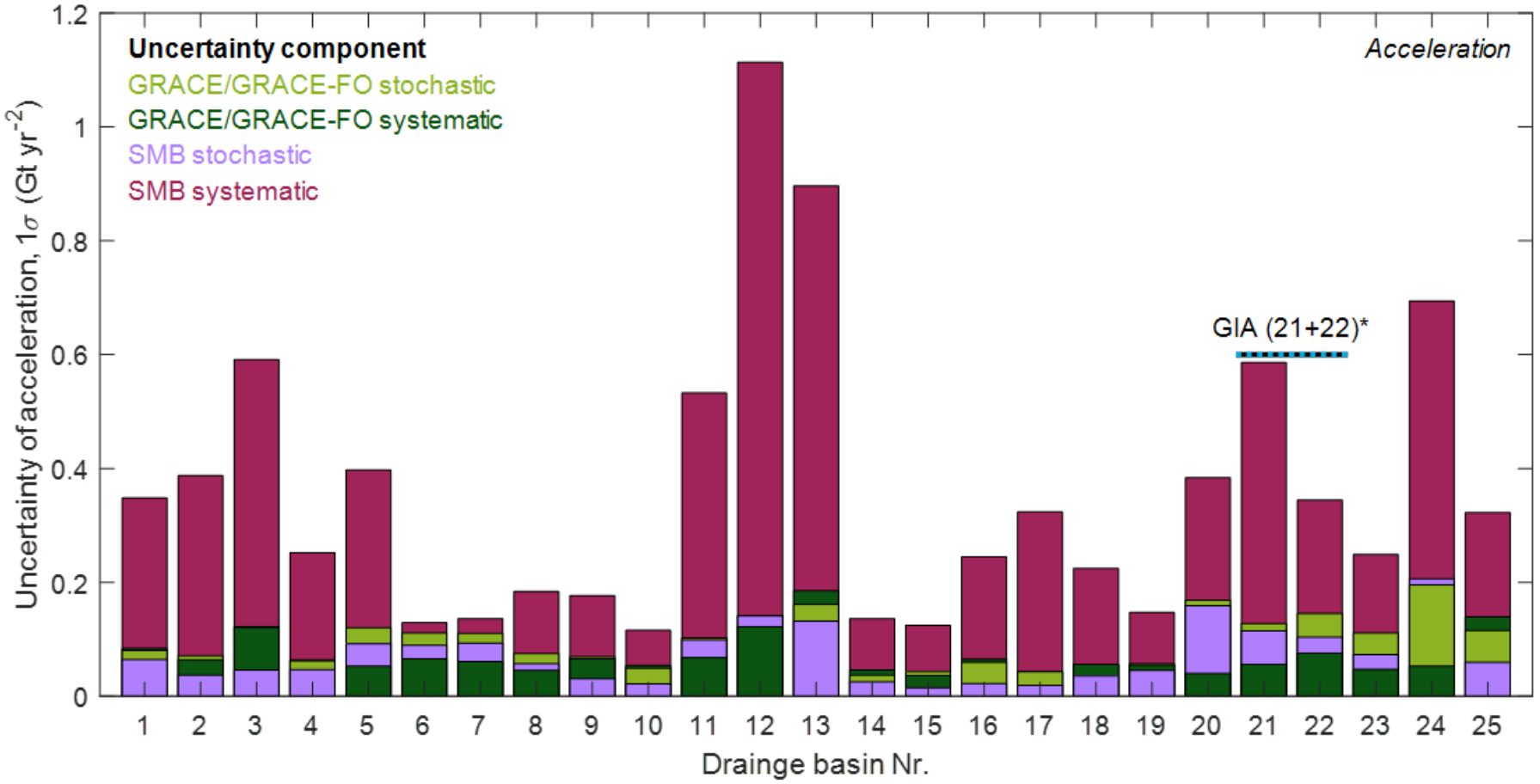
With climate indices



Mass change acceleration and uncertainties



Uncertainty components of acceleration

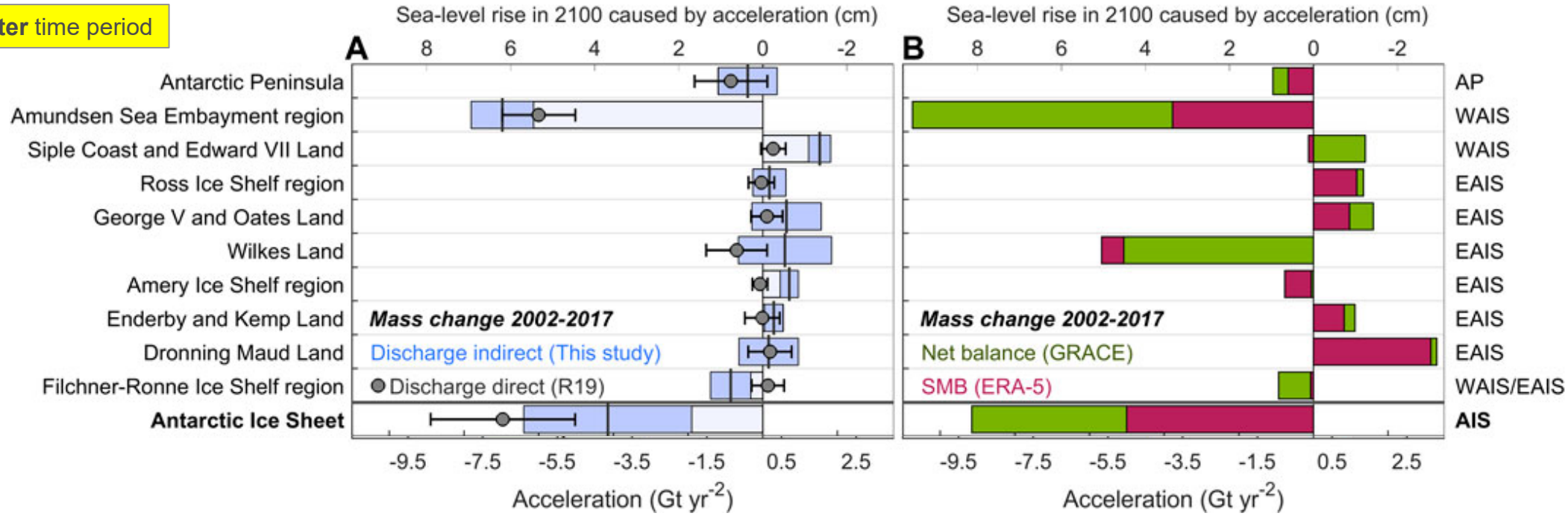


→ SMB systematic uncertainties are dominant

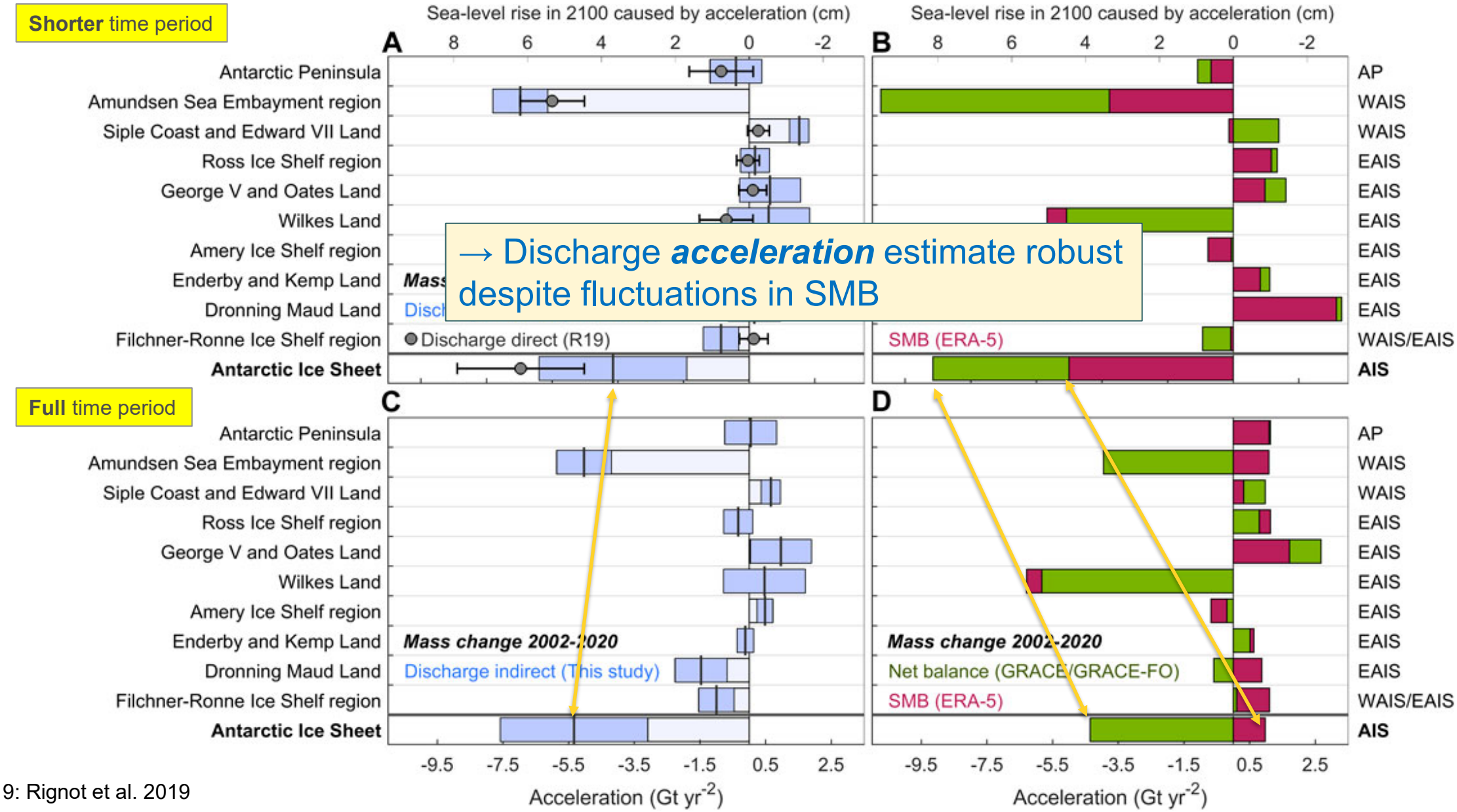
* Barletta et al. 2018

Regional discharge acceleration

Shorter time period

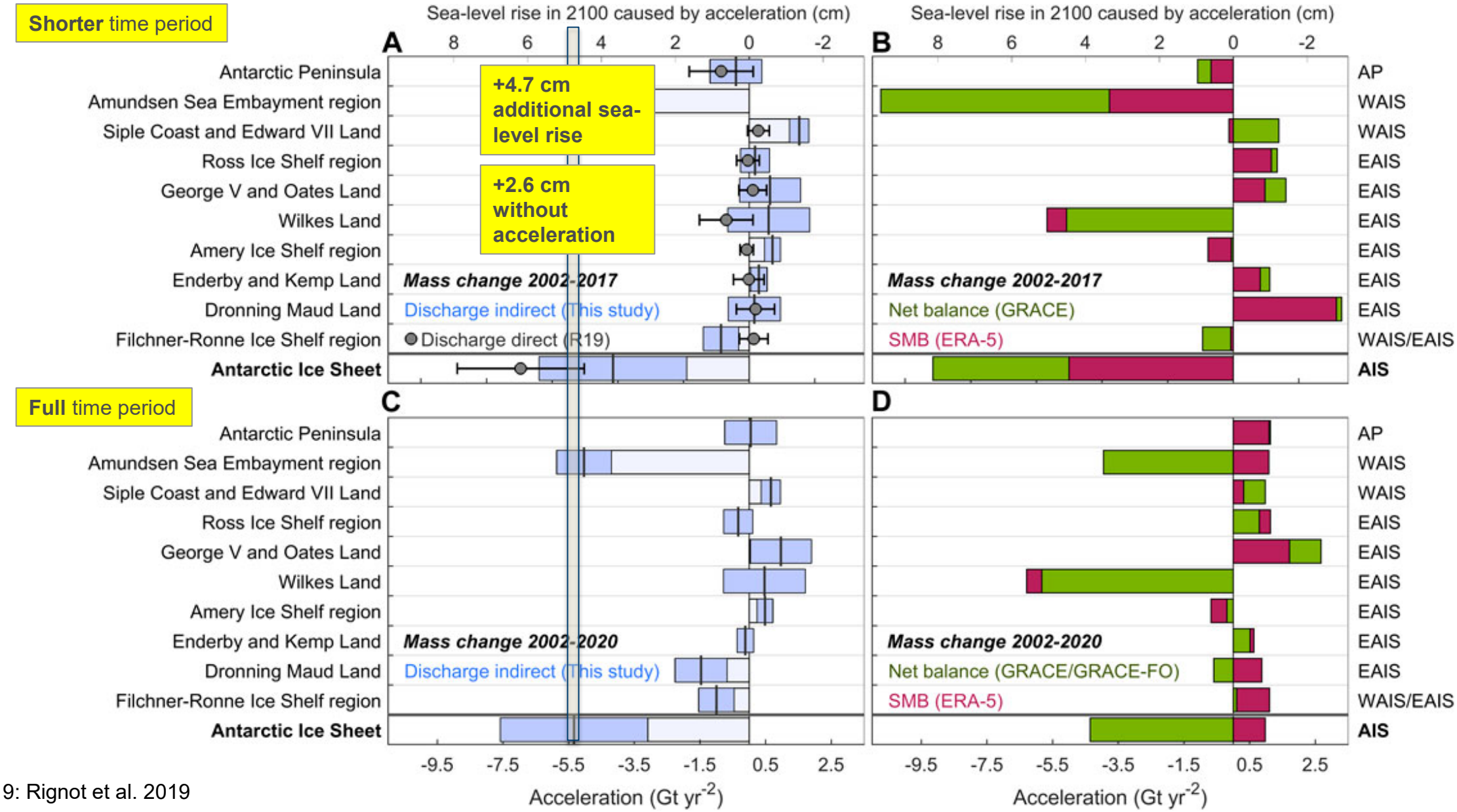


Regional discharge acceleration



R19: Rignot et al. 2019

Regional discharge acceleration



R19: Rignot et al. 2019

Summary

- **Indirect discharge acceleration estimate possible** from GRACE/GRACE-FO and SMB, with similar accuracy as the direct approach
- **Accuracy limited by SMB uncertainties** mainly, but reconciliation possible
- **Amundsen Sea Embayment and Bellingshausen Sea region** confirmed dominant sources of **dynamic acceleration**
- GRACE/GRACE-FO mass loss accelerations apparent in **East Antarctica** caused **mainly** by **SMB variations**
- *Extrapolation* suggests contribution of **7.6 ± 2.9 cm** to **sea-level rise by 2100**, **with discharge acceleration** (4.7 ± 2.8 cm acceleration only)
- More than **two times larger than** the purely **linear extrapolation** of current mass loss trends **(2.9 ± 0.6 cm only linear extrapolation)**

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EDITED BY

Thomas V. Schuler
University of Oslo, Norway

REVIEWED BY

Jonathan L. Bamber
University of Bristol, United Kingdom

Anthony MEMIN
Université Côte d'Azur, France

The editor and reviewers' affiliations are the latest provided on their Loop research profiles and may not reflect their situation at the time of review.

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Front. Earth Sci., 24 December 2021 | https://doi.org/10.3389/feart.2021.741789

Acceleration of Dynamic Ice Loss in Antarctica From Satellite Gravimetry

Theresa Diener[1,2], Ingo Sasgen[2]*, Cécile Agosta[3], Johannes J. Fürst[1], Matthias H. Braun[1], Hannes Konrad[4] and Xavier Fettweis[5]

[1]Department of Geography and Geosciences, Institute of Geography, Friedrich-Alexander Universität Erlangen-Nürnberg, Erlangen, Germany
[2]Division of Glaciology, Alfred-Wegener-Institut Helmholtz-Zentrum Für Polar- und Meeresforschung, Bremerhaven, Germany
[3]Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Gif-sur-Yvette, France
[4]Satellite-based Climate Monitoring, Deutscher Wetterdienst, Offenbach am Main, Germany
[5]Department of Geography, SPHERES research unit, University of Liège, Liège, Belgium

The dynamic stability of the Antarctic Ice Sheet is one of the largest uncertainties in projections of future

https://doi.org/10.3389/feart.2021.741789

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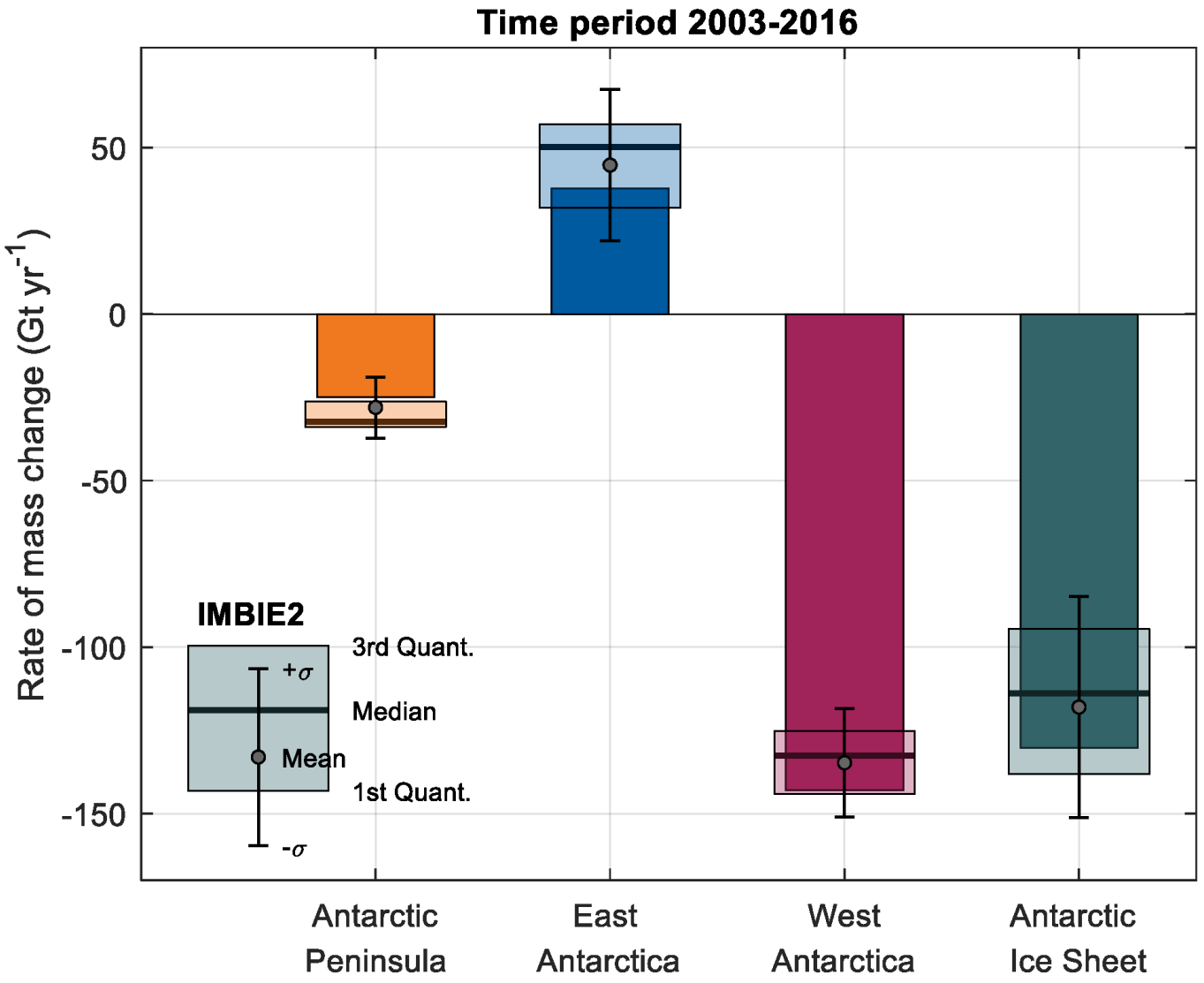
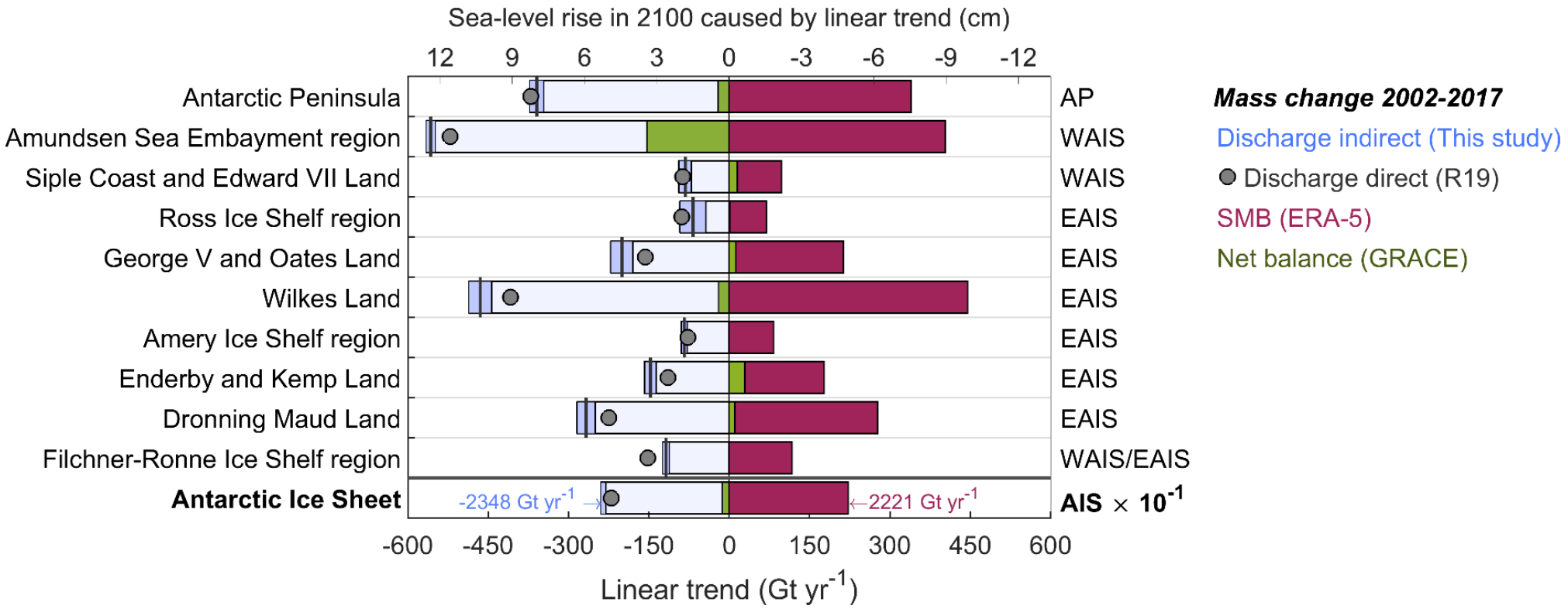
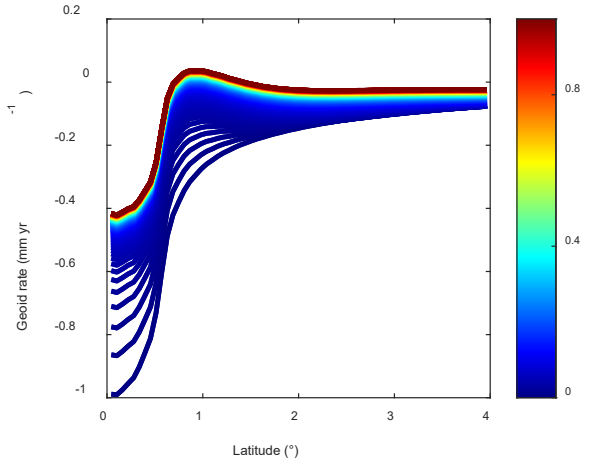
Comparison to IMBIE2 assessment

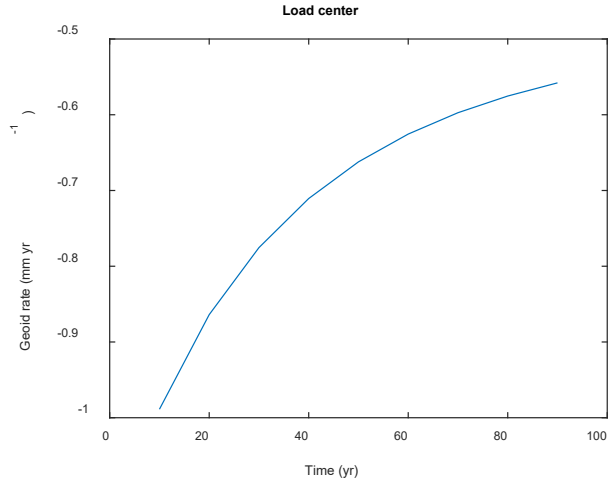


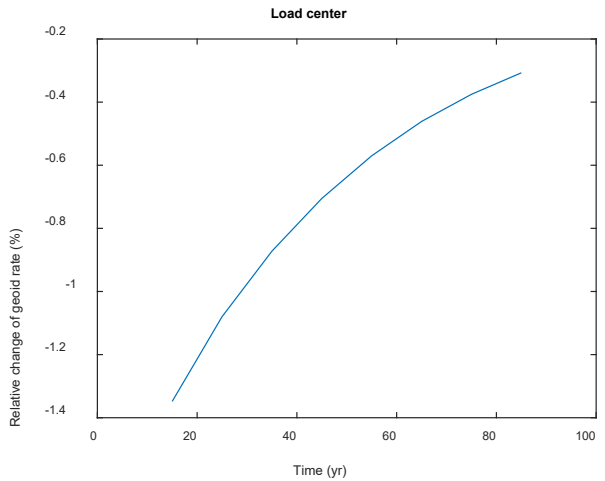
Discharge rate estimate

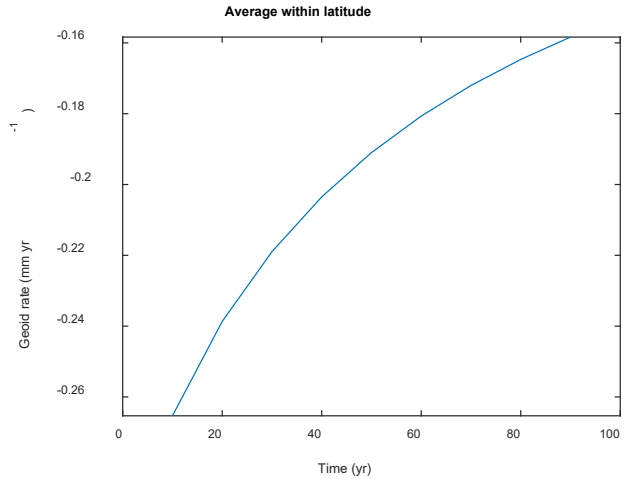


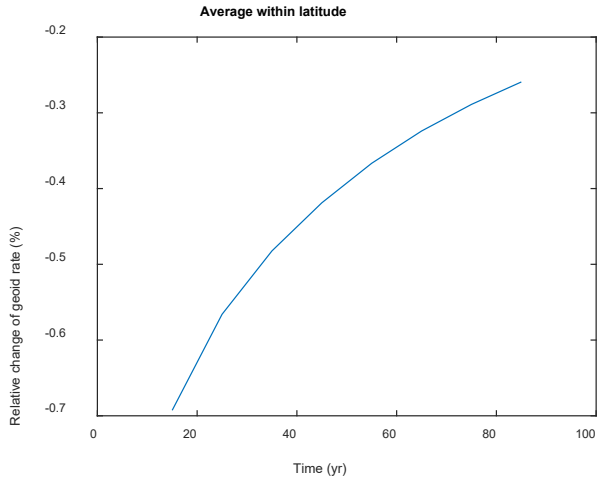
Acceleration of glacial-isostatic adjustment





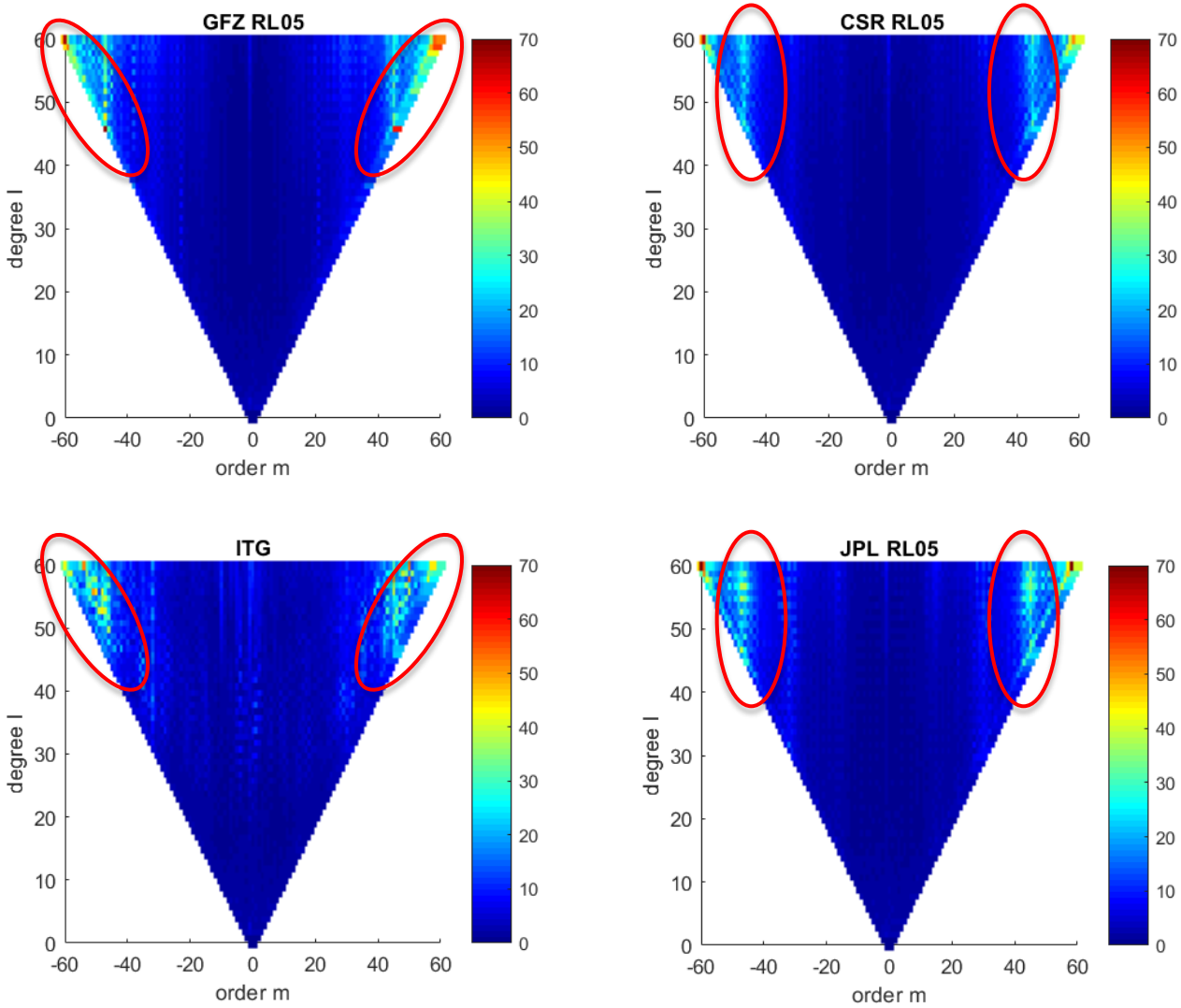




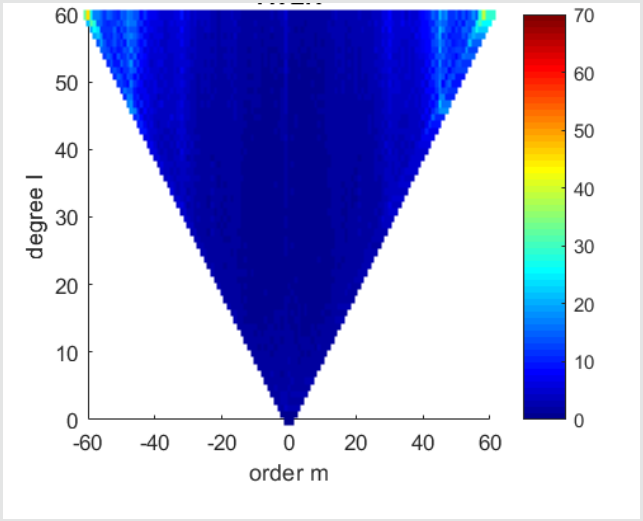


Combination and inversion using spectral methods

Degree-power spectra of GRACE coefficients for a single month



Uncertainty-weighted average solution



→ Spectral inversion method makes use GRACE error structure