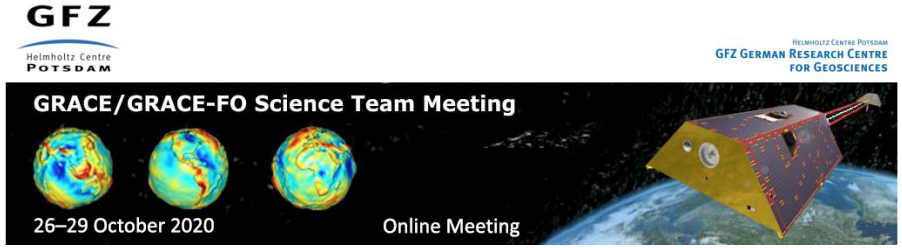


A Prominent Role for GRACE in the Series of IMBIE Studies: Future Plans & Relevant Issues

Erik R. Ivins (Jet Propulsion Lab, California Institute of Technology, Pasadena, CA USA)

Andrew Shepherd (Centre for Polar Observation and Modelling, University of Leeds, Leeds, UK)

A Multidisciplinary Assessment: Ice Sheet Mass Balance Intercomparison Exercise (IMBIE)

- ESA-NASA funded
- Phase 1 (assess ICESat-1 and GRACE overlap period (2003-2010)
- Three methods
  - Input minus Output Method (IOM)
    - Surface Mass Balance (SMB)
    - Flux at ice sheet boundaries
  - GRACE time series (+ GIA correction)
  - Altimetry (+ density conversion)
- Result: Inter-comparative assessments over 1992-2011

A Reconciled Estimate of Ice-Sheet Mass Balance

SCIENCE VOL 338 30 NOVEMBER 2012

A Multidisciplinary Assessment: Ice Sheet Mass Balance Intercomparison Exercise (IMBIE)

- Phase 2-- overlap period doubled (2003-2017)
- Three methods
  - Input minus Output Method (IOM)
    - Surface Mass Balance (SMB) (4 models)
    - Flux at ice sheet boundaries (2 data analysis entries)
  - GRACE time series (+ GIA correction) (15 data analysis entries)
  - Altimetry (+ density conversion) (11 data analysis entries)
  - GIA (12 models)
- Result: Inter-comparative assessments over 1992-2018


Mass balance of the Antarctic Ice Sheet from 1992 to 2017

The IMBIE team*

Article

Mass balance of the Greenland Ice Sheet from 1992 to 2018

https://doi.org/10.1038/s41586-019-1855-2 The IMBIE Team*

IMBIE-2 Greenland and Antarctic Assessments

Executive Committee

- Michiel van den Broeke (SMB)
- Marcus Engdahl,
- Anna Hogg,
- Ian Joughin,
- Gerhard Krinner
- Gorka Moyano
- Sophie Nowicki
- Eric Rignot (Input Output Method)
- Ted Scambos
- Nicole Schlegel
- Ben Smith (Altimetry)
- Isabella Velicogna (GRACE)
- Charles Webb
- Pippa Whitehouse (GIA)

Main new feature: Open subscription for all research groups

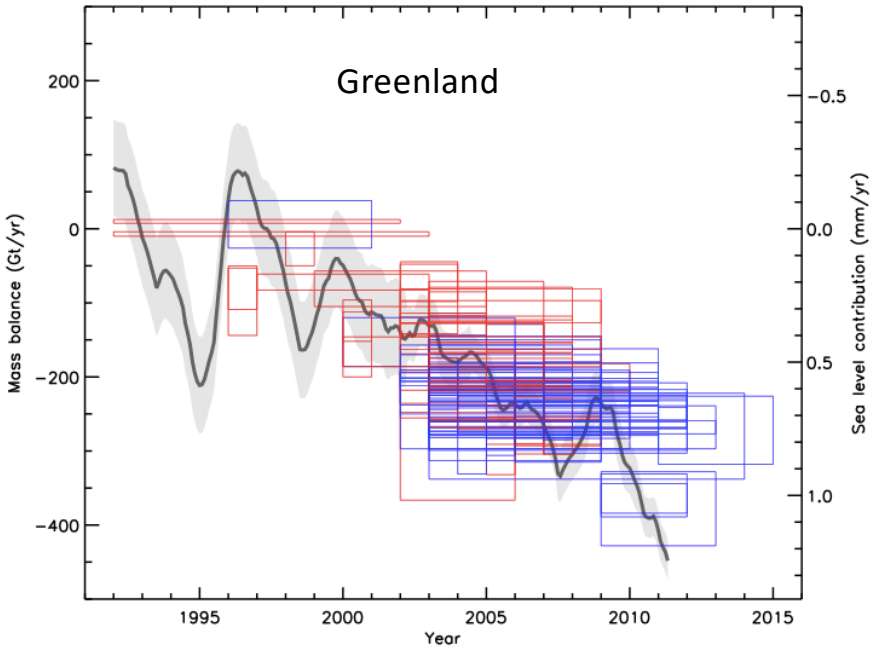
The IMBIE Team (66 named authors) **24 GRACE** **12 GIA**

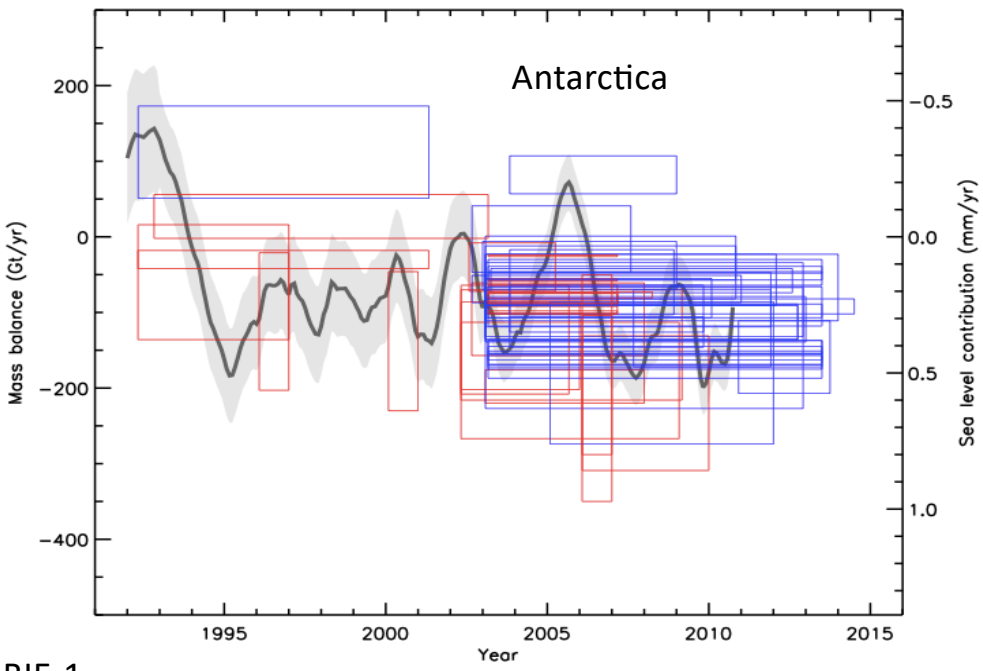
Andrew Shepherd[1] ✉, **Erik Ivins**[2], Eric Rignot[2,3], Ben Smith[4], Michiel van den Broeke[5], **Isabella Velicogna**[2,3], **Pippa Whitehouse**[6], Kate Briggs[1], Ian Joughin[4], Gerhard Krinner[7], Sophie Nowicki[8], Tony Payne[9], Ted Scambos[10], Nicole Schlegel[2], **Geruo A**[3], Cécile Agosta[11], Andreas Ahlstrøm[12], Greg Babonis[13], **Valentina R. Barletta**[14], Anders A. Bjørk[15], **Alejandro Blazquez**[16], **Jennifer Bonin**[17], William Colgan[12], Beata Csatho[13], Richard Cullather[18], Marcus E. Engdahl[19], Denis Felikson[8], Xavier Fettweis[11], **Rene Forsberg**[14], Anna E. Hogg[1], Hubert Gallee[7], Alex Gardner[2], Lin Gilbert[20], Noel Gourmelen[21], **Andreas Groh**[22], **Brian Gunter**[23], Edward Hanna[24], **Christopher Harig**[25], Veit Helm[26], **Alexander Horvath**[27], **Martin Horwath**[22], **Shfaqat Khan**[14], **Kristian K. Kjeldsen**[12,28], Hannes Konrad[29], Peter L. Langen[30], **Benoit Lecavalier**[31], **Bryant Loomis**[8], **Scott Luthcke**[8], Malcolm McMillan[32], **Daniele Melini**[33], Sebastian Mernild[34,35,36,37], **Yara Mohajerani**[3], **Philip Moore**[38], Ruth Mottram[30], Jeremie Mouginot[3,7], Gorka Moyano[39], Alan Muir[20], Thomas Nagler[40], **Grace Nield**[6], Johan Nilsson[2], Brice Noël[5], Ines Otosaka[1], Mark E. Pattle[39], **W. Richard Peltier**[41], Nadège Pie[42], **Roelof Rietbroek**[43], Helmut Rott[40], Louise Sandberg Sørensen[14], **Ingo Sasgen**[26], **Himanshu Save**[42], Bernd Scheuchl[3], **Ernst Schrama**[44], Ludwig Schröder[22,26], **Ki-Weon Seo**[45], Sebastian B. Simonsen[14], Thomas Slater[1], **Giorgio Spada**[46], **Tyler Sutterley**[3], **Matthieu Talpe**[2], **Lev Tarasov**[31], Willem Jan van de Berg[5], **Wouter van der Wal**[44,47], Melchior van Wessem[5], **Bramha Dutt Vishwakarma**[48], **David Wiese**[2], David Wilton[49], Thomas Wagner[50], **Bert Wouters**[5,47] & Jan Wuite[40]

55 % are engaged with the GRACE time series

IMBIE-2

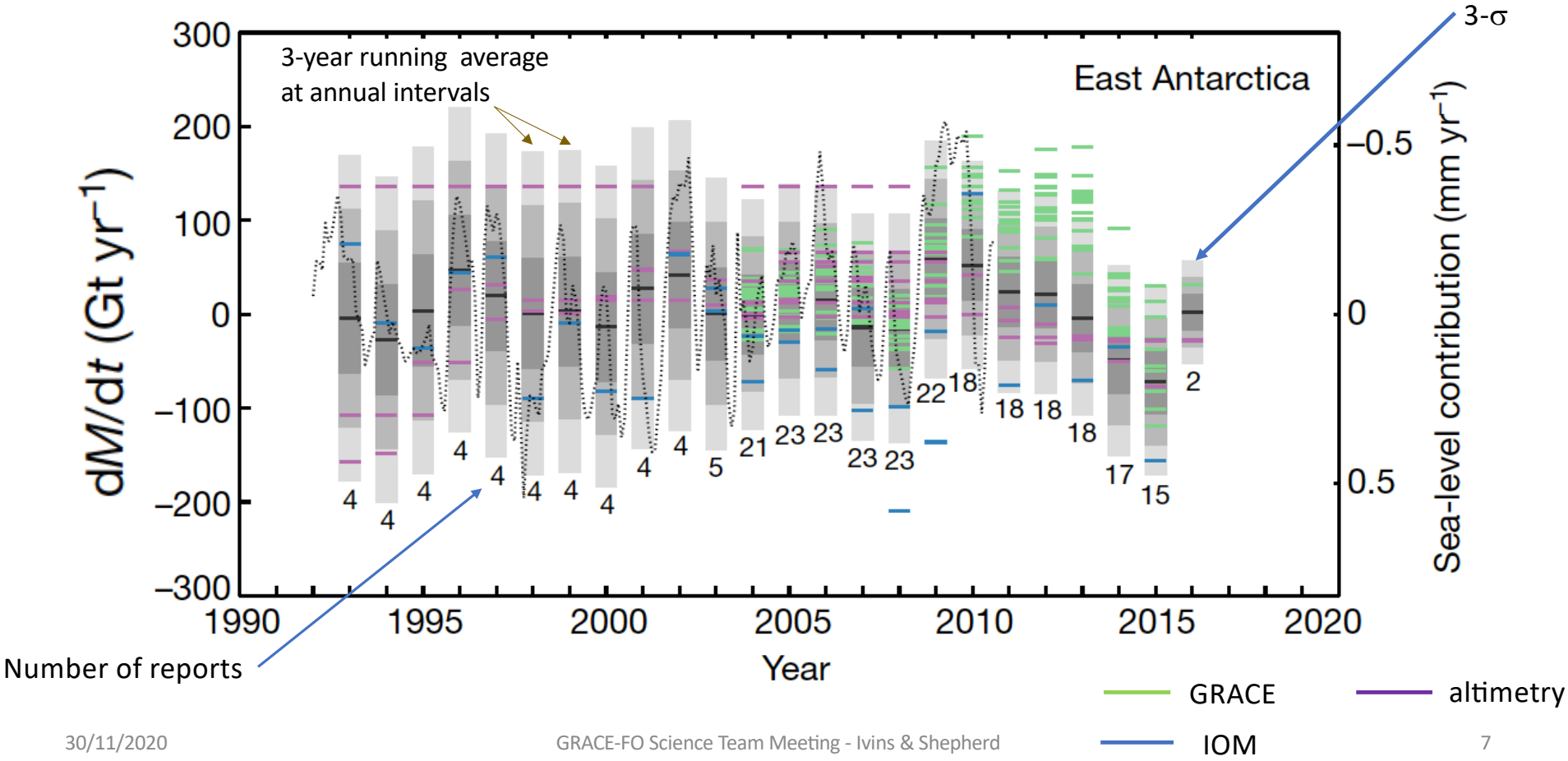
*(slide prepared for **December 2016** AGU by Andy Shepherd)*





- 52 new estimates of Greenland mass balance since IMBIE-1
- 34 new estimates of Antarctica mass balance since IMBIE-1
- Note the density of new trend estimates intensifies in 2002.

Example report for East Antarctic Ice Sheet

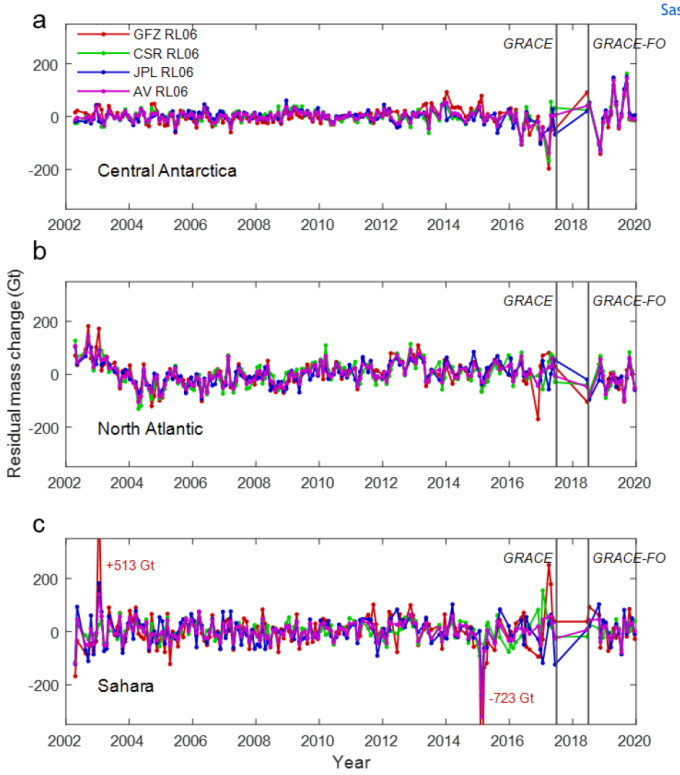


GRACE-GRACE-FO continuity:

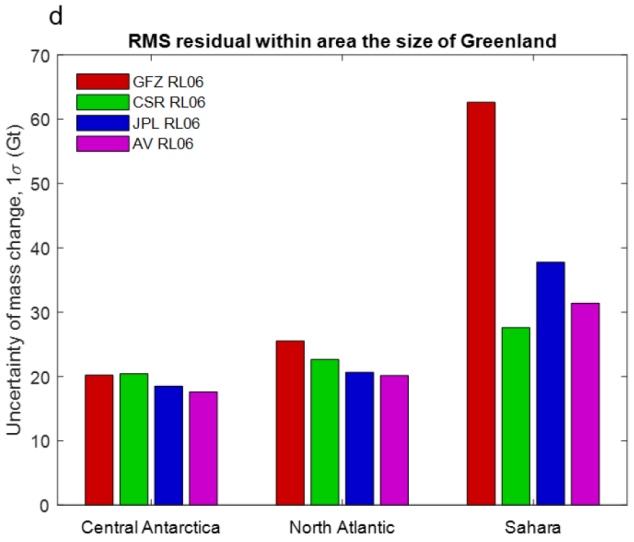
Assessment of Greenland Mass balance by Ingo Sasgen

Additional support from:

- elastic load-mass induced crustal motions (?)
- Support from SLR multiple satellite laser ranging solutions (Sosnica et al. 2015; Bonin et al., 2018).



Sasgen et al., 2020, Commun. Earth Environ. 1(8), https://doi.org/10.1038/s43247-020-0010-1.

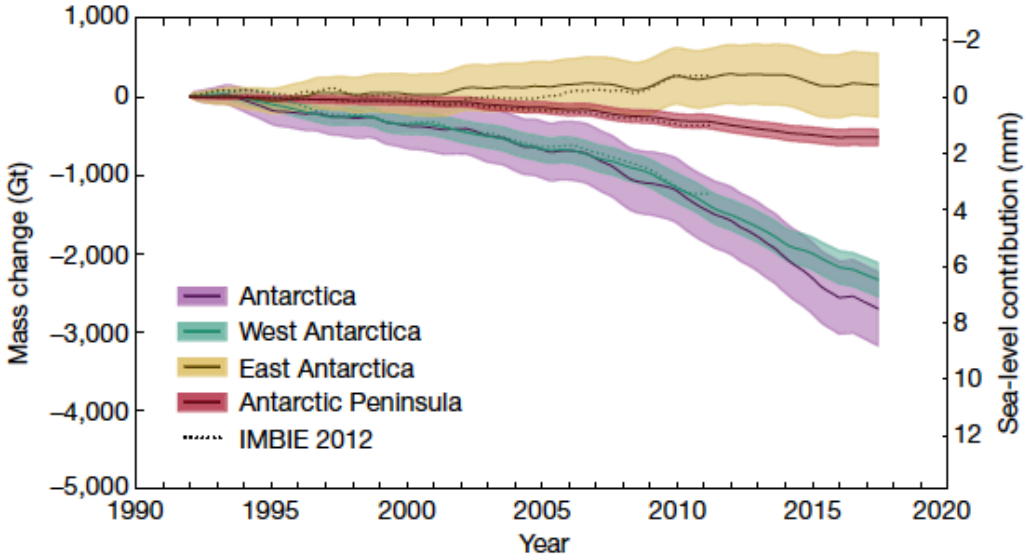


Antarctica Ice Sheet: All Methods:

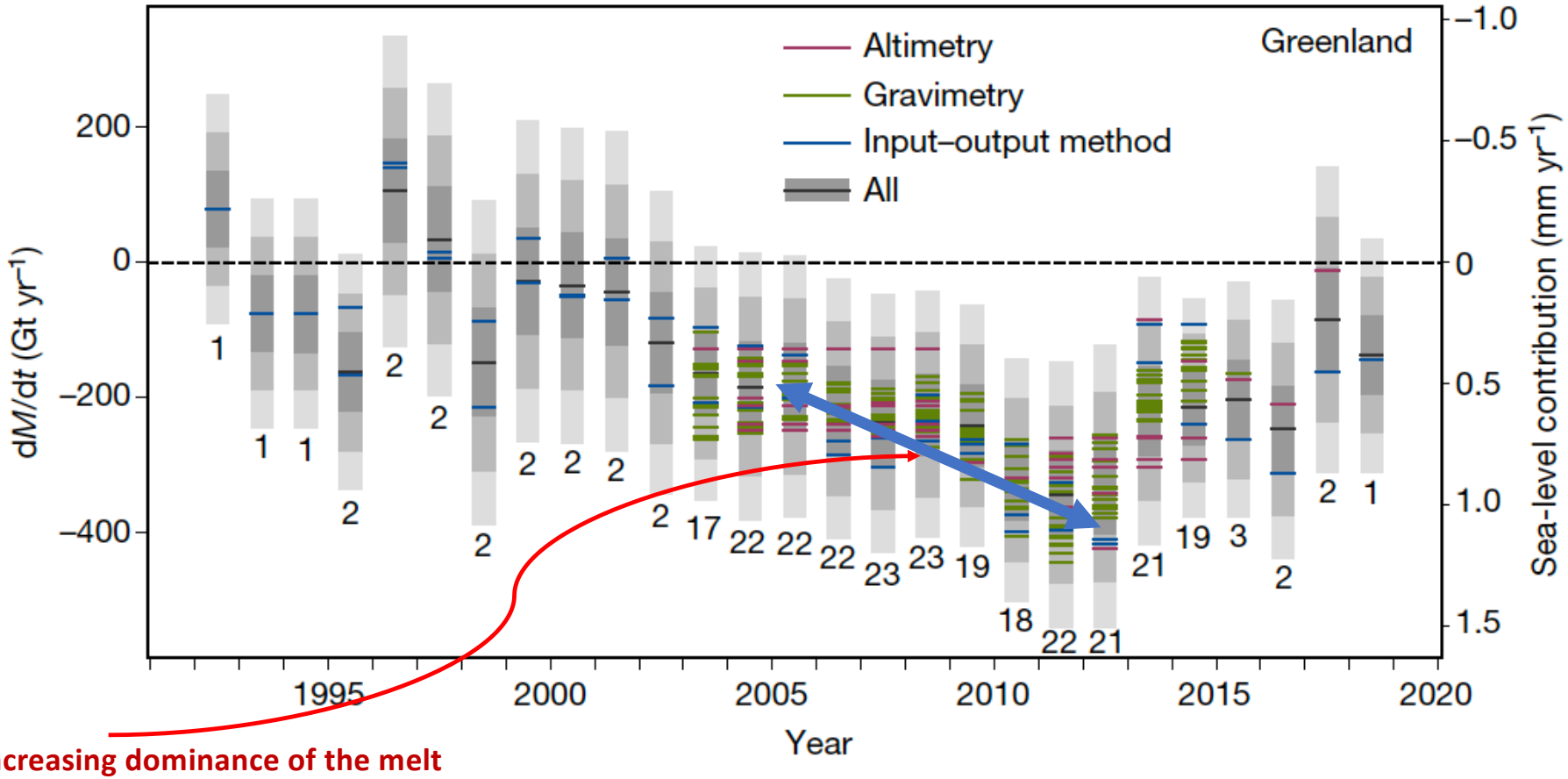
(via time series to GRACE termination)

Table 1 | Rates of ice-sheet mass change

	1992–1997 (Gt yr^{-1})	1997–2002 (Gt yr^{-1})	2002–2007 (Gt yr^{-1})	2007–2012 (Gt yr^{-1})	2012–2017 (Gt yr^{-1})	1992–2011 (Gt yr^{-1})	1992–2017 (Gt yr^{-1})
EAIS	11 ± 58	8 ± 56	12 ± 43	23 ± 38	−28 ± 30	13 ± 50	5 ± 46
WAIS	−53 ± 29	−41 ± 28	−65 ± 27	−148 ± 27	−159 ± 26	−73 ± 28	−94 ± 27
APIS	−7 ± 13	−6 ± 13	−20 ± 15	−35 ± 17	−33 ± 16	−16 ± 14	−20 ± 15
AIS	−49 ± 67	−38 ± 64	−73 ± 53	−160 ± 50	−219 ± 43	−76 ± 59	−109 ± 56



Greenland Mass Balance

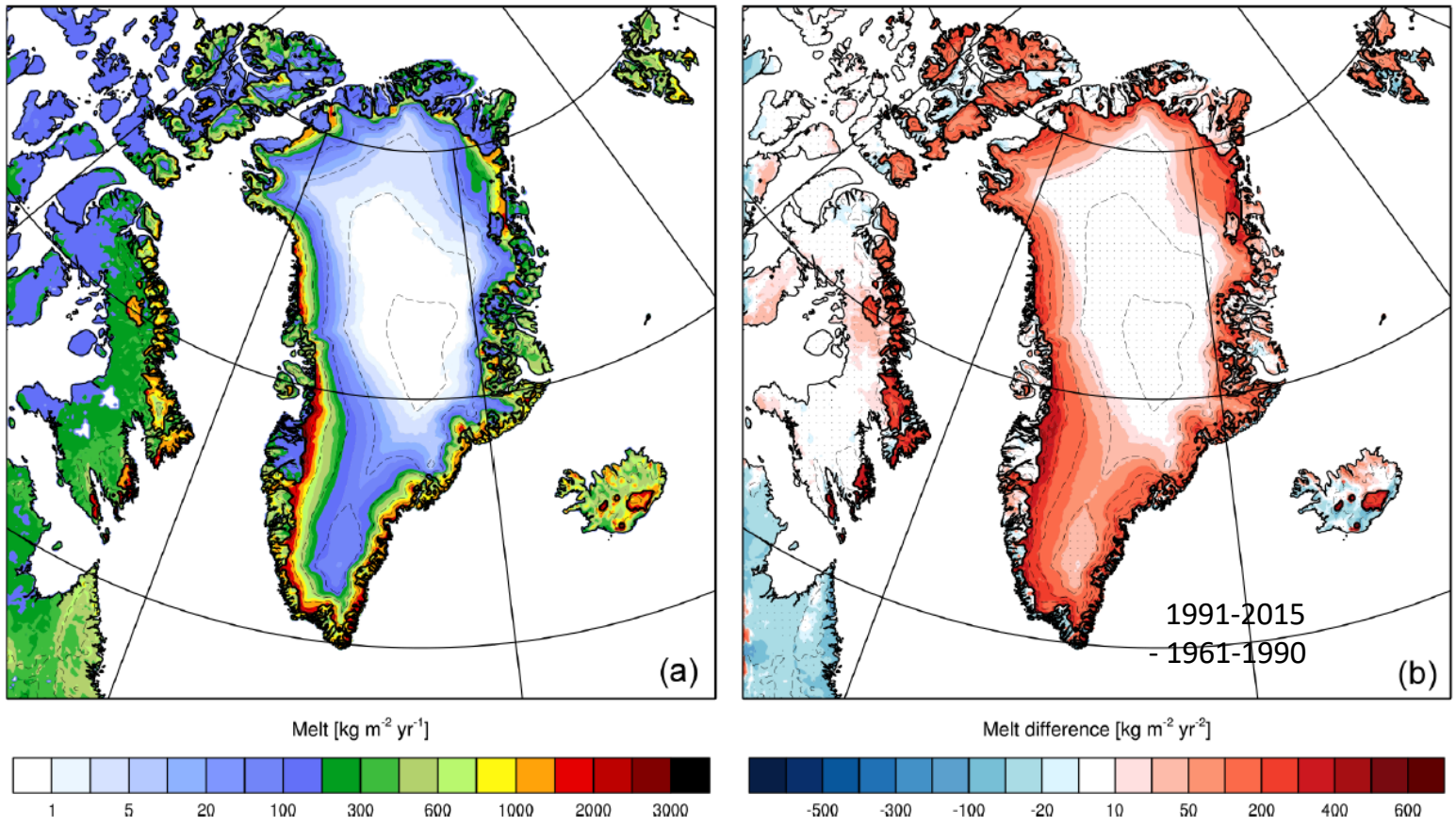


Years of increasing dominance of the melt runoff component of SMB

A Trajectory for Greenland?

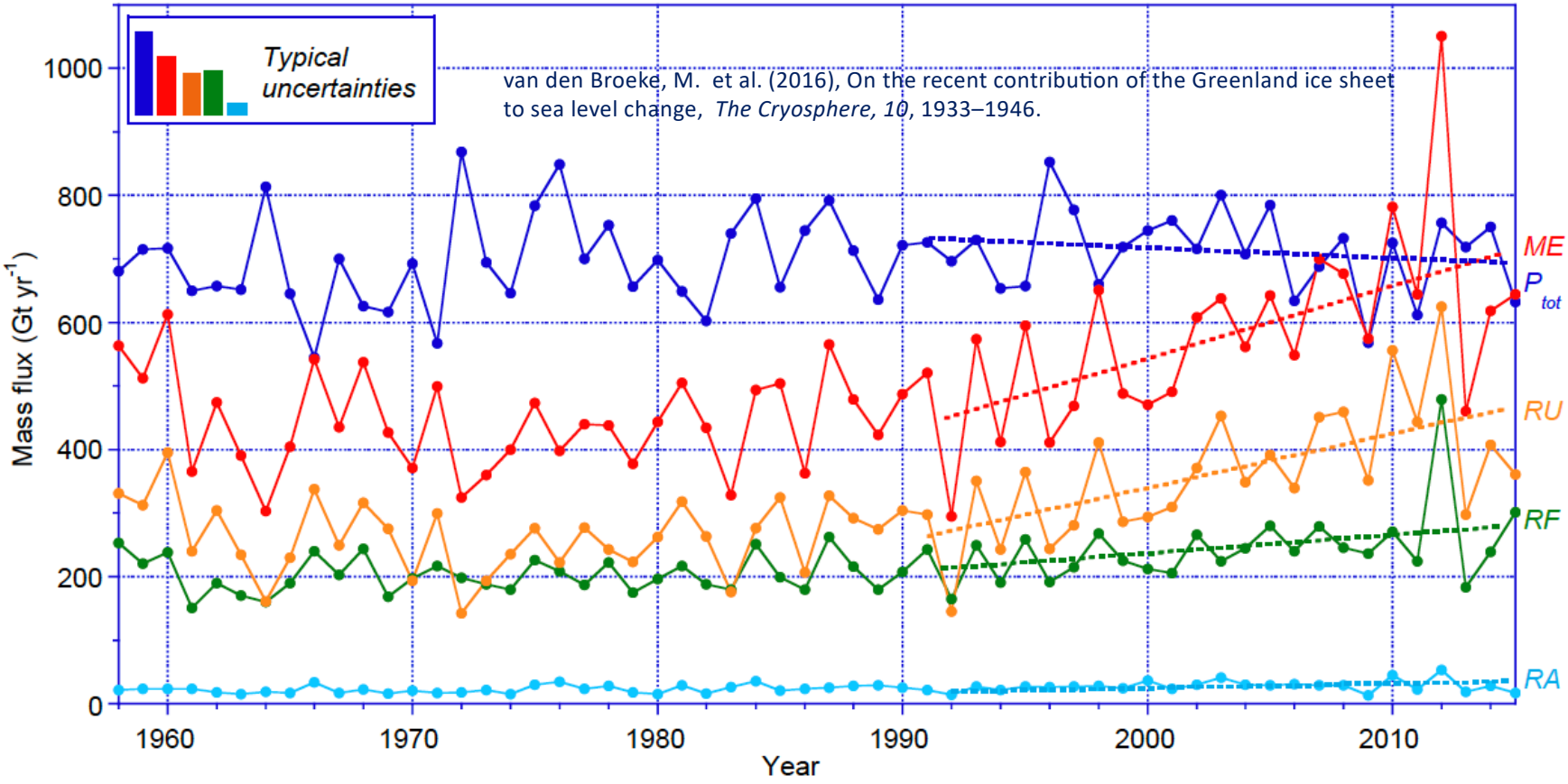
Melt rate averaged over 1961-1990

Increase in melt rate after 1990

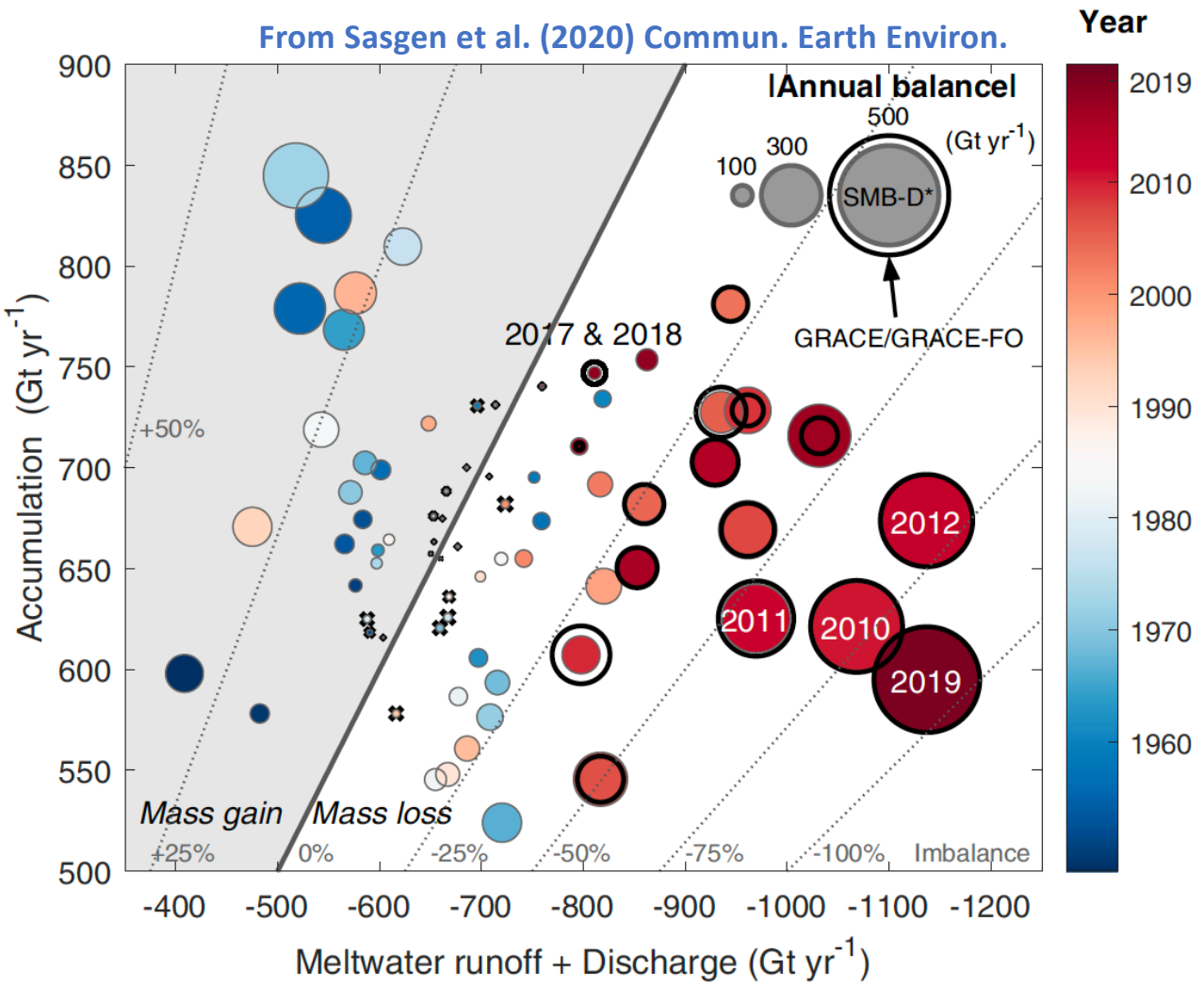


From:
van den Broeke, M. et al. (2016), On the recent contribution of the Greenland ice sheet to sea level change, *The Cryosphere, 10*, 1933–1946.

Disambiguation of SMB Components



Greenland Annual Mass Balance: A Trajectory?



Preliminary Goals for IMBIE-3

- Report 2019 year mass balance for Greenland by March 2021
- Strive for Basin-by-Basin Assessments
- Emphasis on SMB Inter-comparisons
- Currently desire Feedback: Please contact erik.r.ivins@jpl.nasa.gov and A.Shepherd@leeds.ac.uk
- Similar Analysis Procedure to IMBIE-2 except the goal now is to create Annual Reports