Results from the Ice Sheet Mass Balance Inter-comparison Exercise (IMBIE)

Inès Otosaka on behalf of the **IMBIE Team**
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The Ice Sheet Mass Balance Inter-comparison Exercise

imbie

- International collaboration between polar scientists, co-funded by ESA and NASA
- Reconcile different satellite-based measurements of ice sheet mass balance
- Reduce uncertainties in ice sheet mass balance estimation through community efforts
- Provide critical information on global sea level rise

IMBIE-1 (2011-2014)

- 47 participants
- 8 countries
- Threefold improvement in certainty compared to that of IPCC AR4

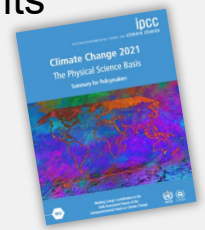
IMBIE-2 (2016-2019)

- 97 participants
- 13 countries
- Twofold increase in number of estimates

IMBIE-3 (2021-)

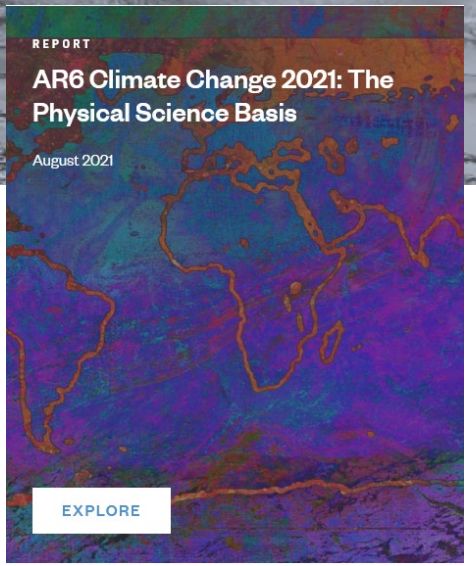
+ New objectives:
- Data from new missions
- Annual updates
- Partitioning SMB/D
- Regional assessments

- 97 participants
- 13 countries

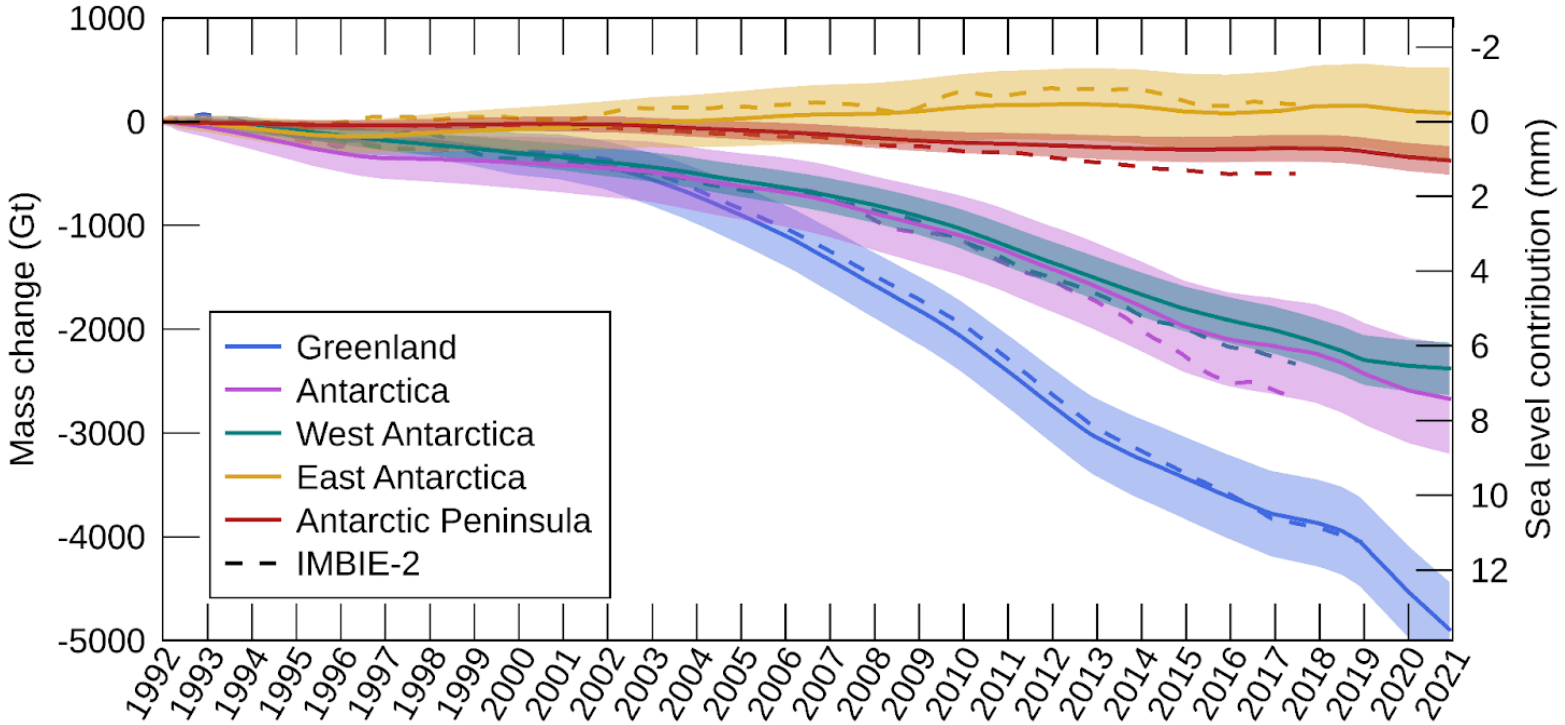


http://imbie.org/

A new dataset prepared for IPCC AR6

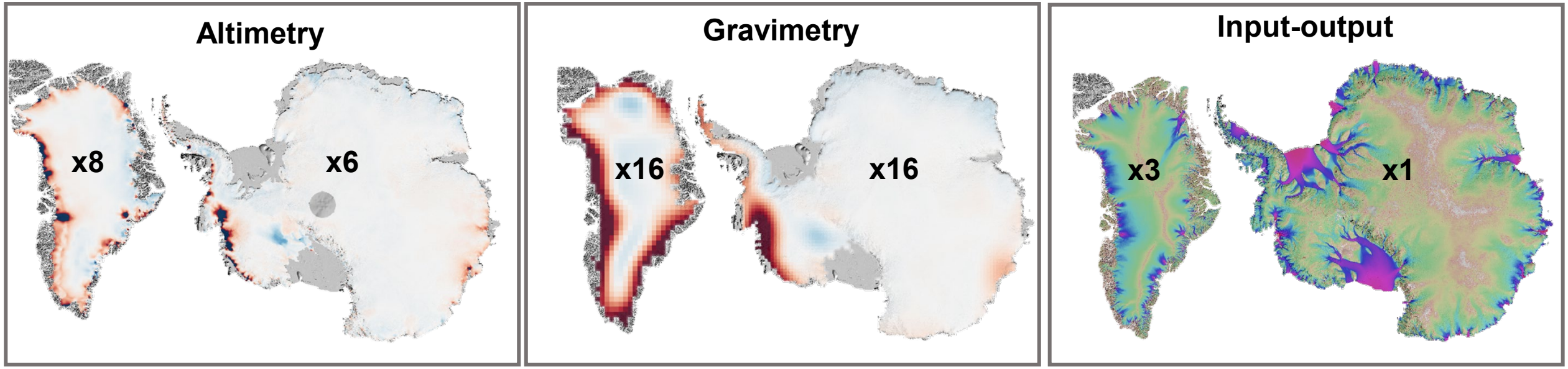


- New dataset prepared for AR6
- Extend time-series for both Greenland and Antarctica
- Includes 50 independent estimates of ice sheet mass balance from 14 satellite missions

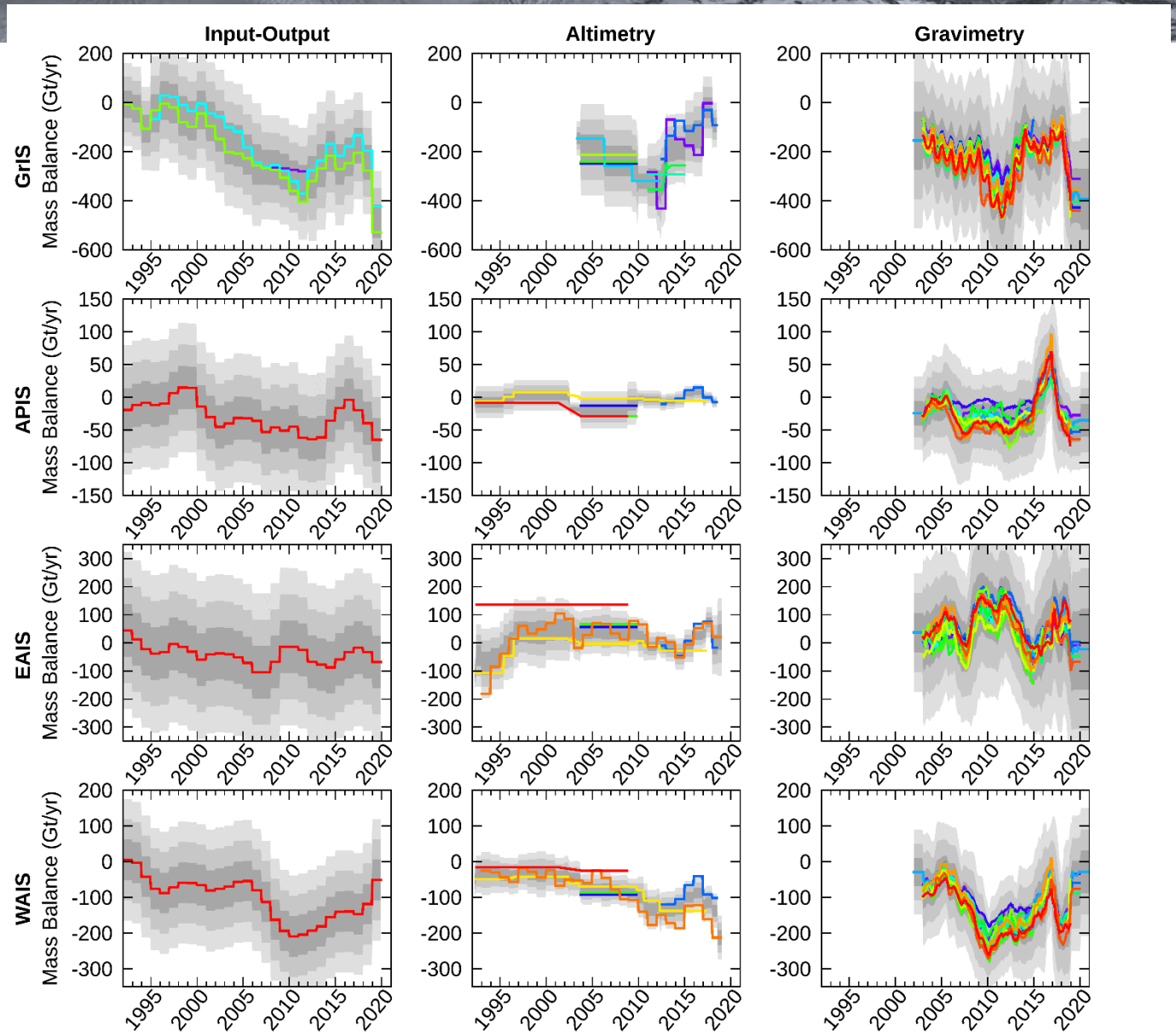


This new assessment includes 50 independent estimates

- 27 estimates for the Greenland Ice Sheet
- 23 estimates for the Antarctic Ice Sheet



Methods overview



Andersen
Colgan
Mouginot
Rignot

Input-Output

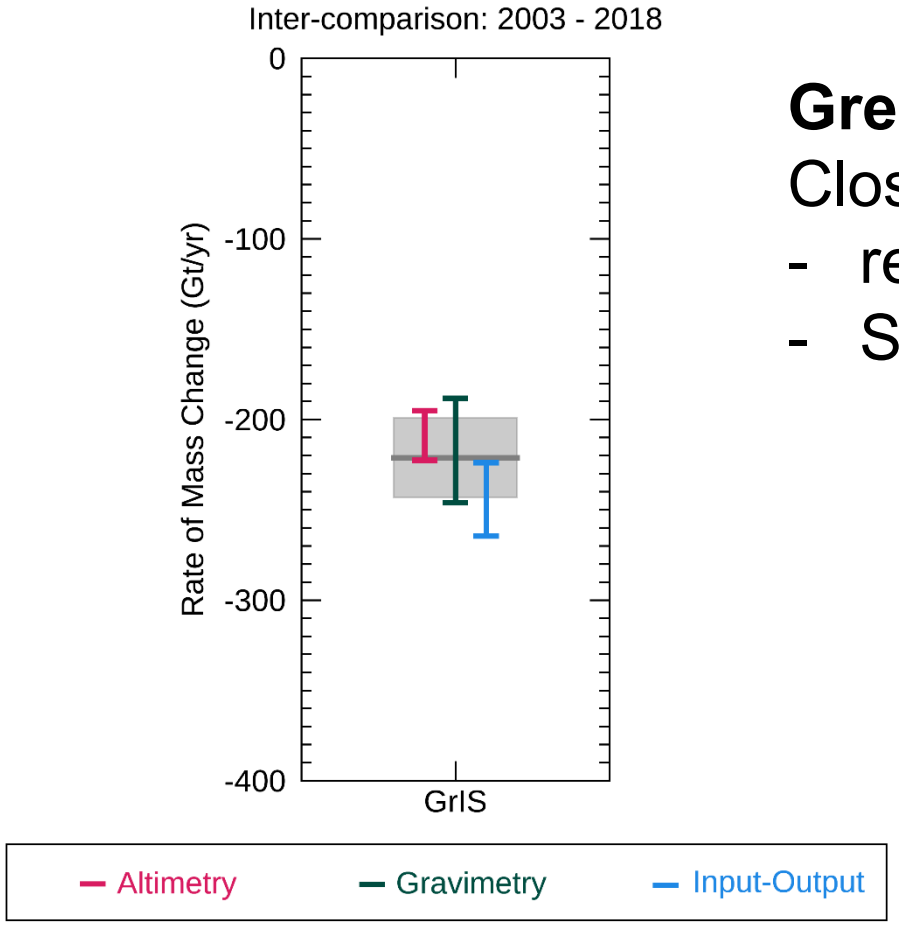
Gourmelen
Gunter
Helm
Khan
McMillan
Nilsson Gardner
Pie
sandberg_sorensen
Schroder
Shepherd
Zwally

Altimetry

Blazquez
Bonin
Forsberg
Gardner Nilsson
Groh
Harig
Horvath
Luthcke
Moore
Save
Schrama
Seo
Velicogna
Vishwakarma
Wiese
Wouters

Gravimetry

Intra-comparison: Altimetry, Gravimetry, Input-Output

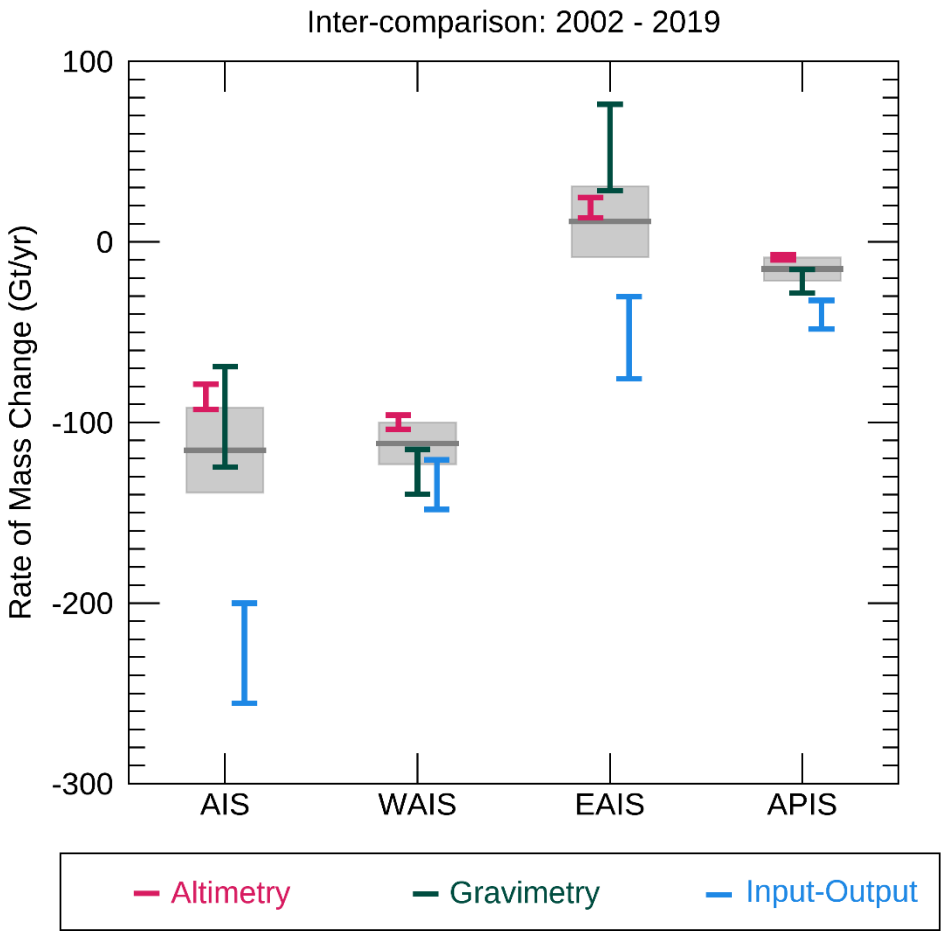


Greenland:

Close agreement between all three techniques:

- reconciled rate of mass loss of 221.1 ± 22.1 Gt/yr
- STD of 18.5 Gt/yr

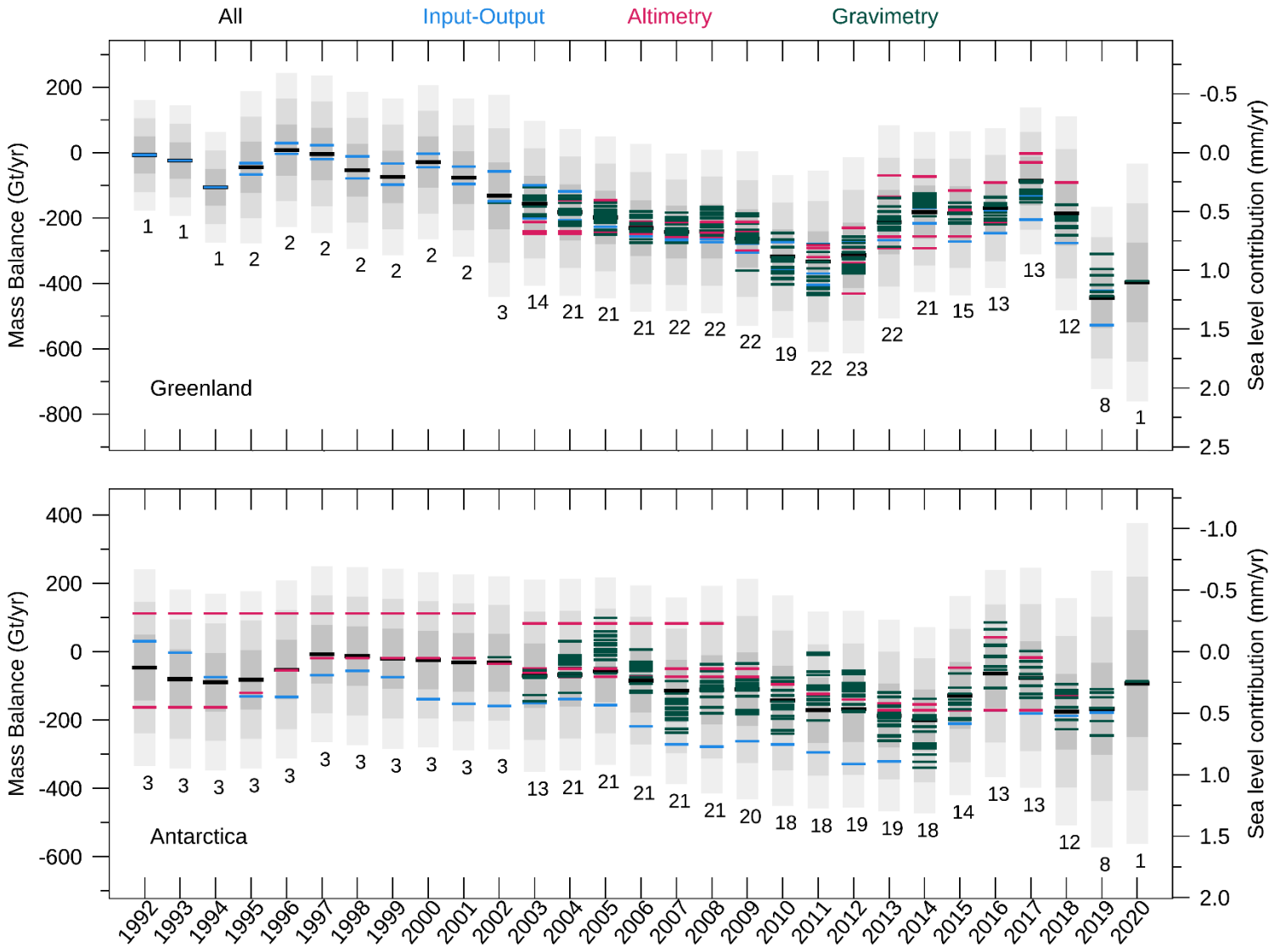
Intra-comparison: Altimetry, Gravimetry, Input-Output



Antarctica:

- Reconciled rate of mass loss of 115.4 ± 23.5 Gt/yr
- Spread of alt, gmb and iom 4 times larger than in Greenland (79.0 Gt/yr)
- Greatest departure at EAIS between gmb and iom (105.3 ± 33.0 Gt/yr)
- At the EAIS, the techniques disagree on the sign of the mass change

Reconciled mass balance estimates

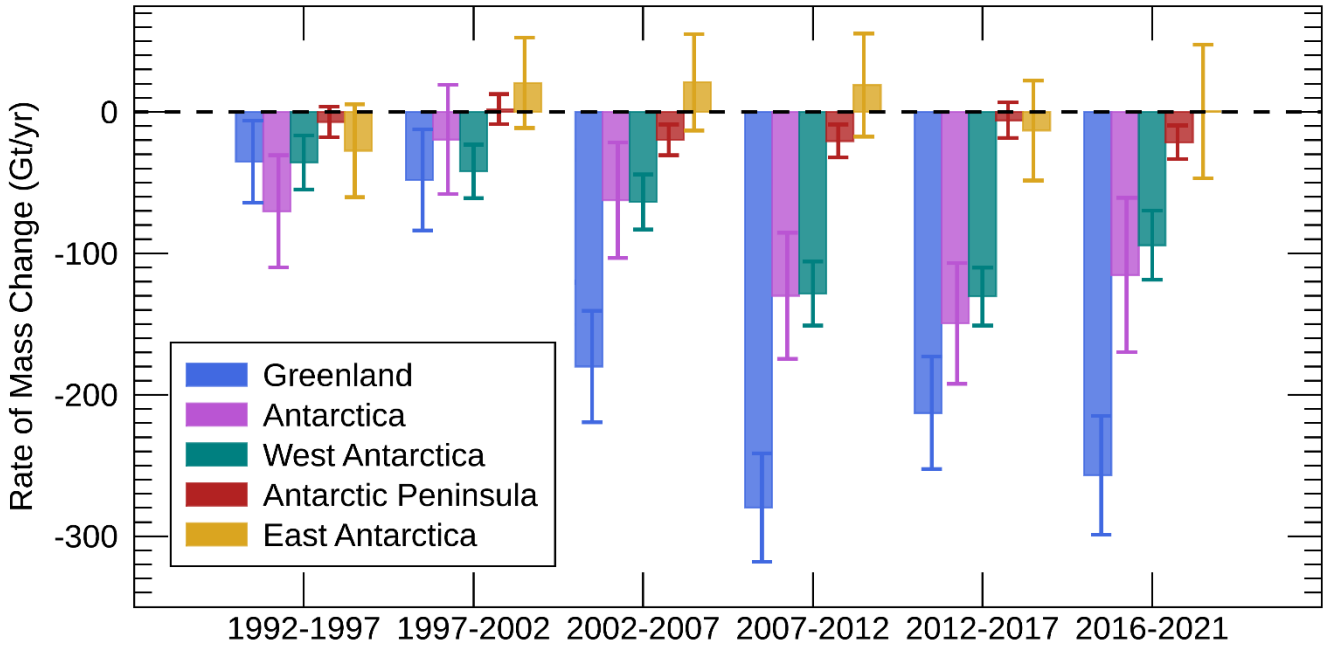


Almost all individual estimates of annual rates of mass balance fall within 1σ of our reconciled estimate given their respective individual errors:

- GrIS 100 %
- AIS 96 %

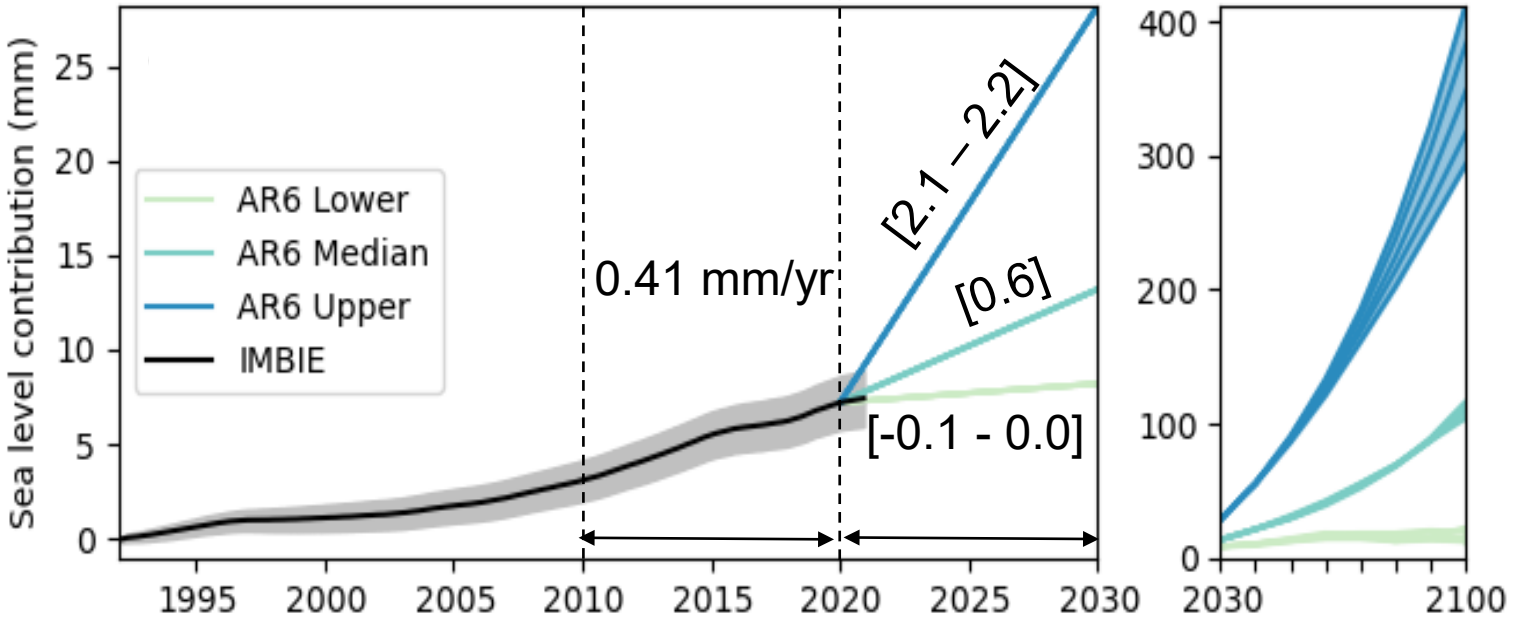
Acceleration of ice losses during our 29-year record

- **Antarctica**: ice losses are dominated by ice discharge at WAIS, EAIS remains close to a state of balance but is the most uncertain component of AIS mass balance
- **Greenland**: large inter-annual variations in mass change during the last five years, ranging from -87 Gt/yr in 2017 to -444 Gt/yr in 2019
- Combined Greenland and Antarctica contributed 21 mm to GMSL since 1992



Comparison to IPCC AR6 projections

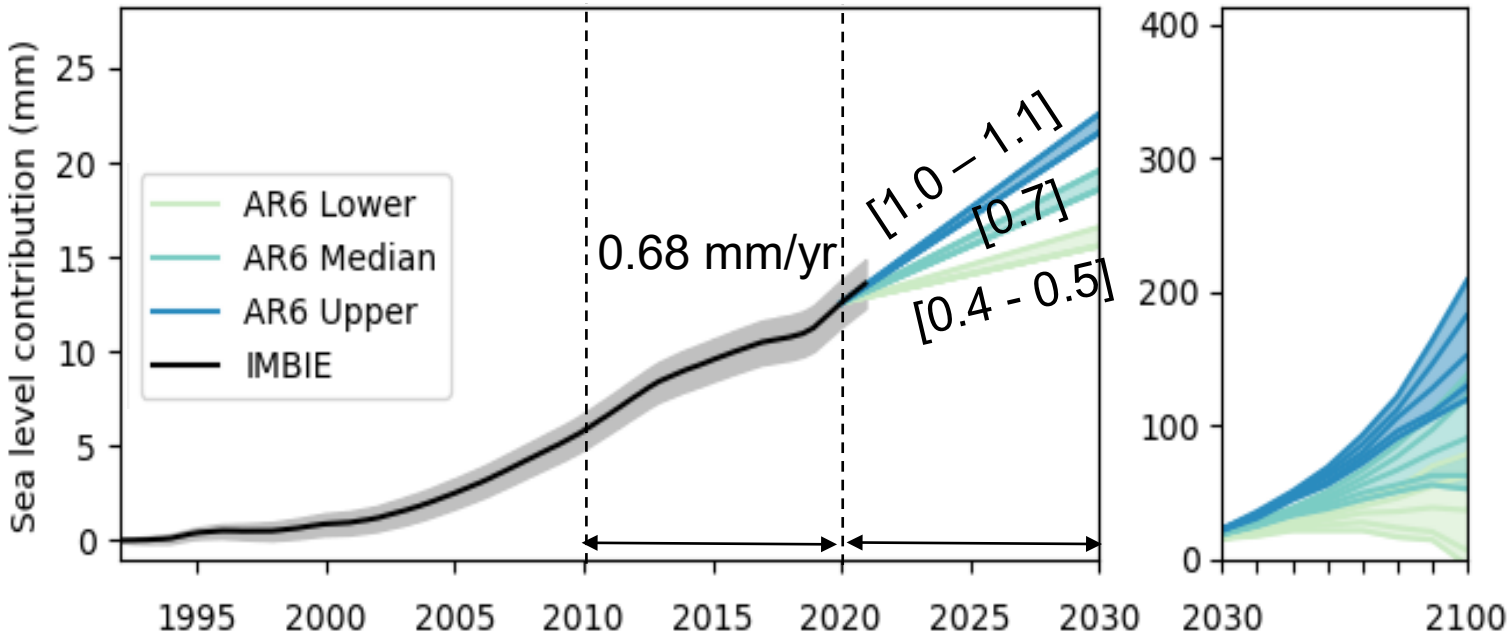
Antarctica



- Observed sea level contribution in the 2010s is closest to the median contribution predicted by the IPCC for 2020s
- Large spread of predicted sea level contribution even in the next decade

Comparison to IPCC AR6 projections

Greenland



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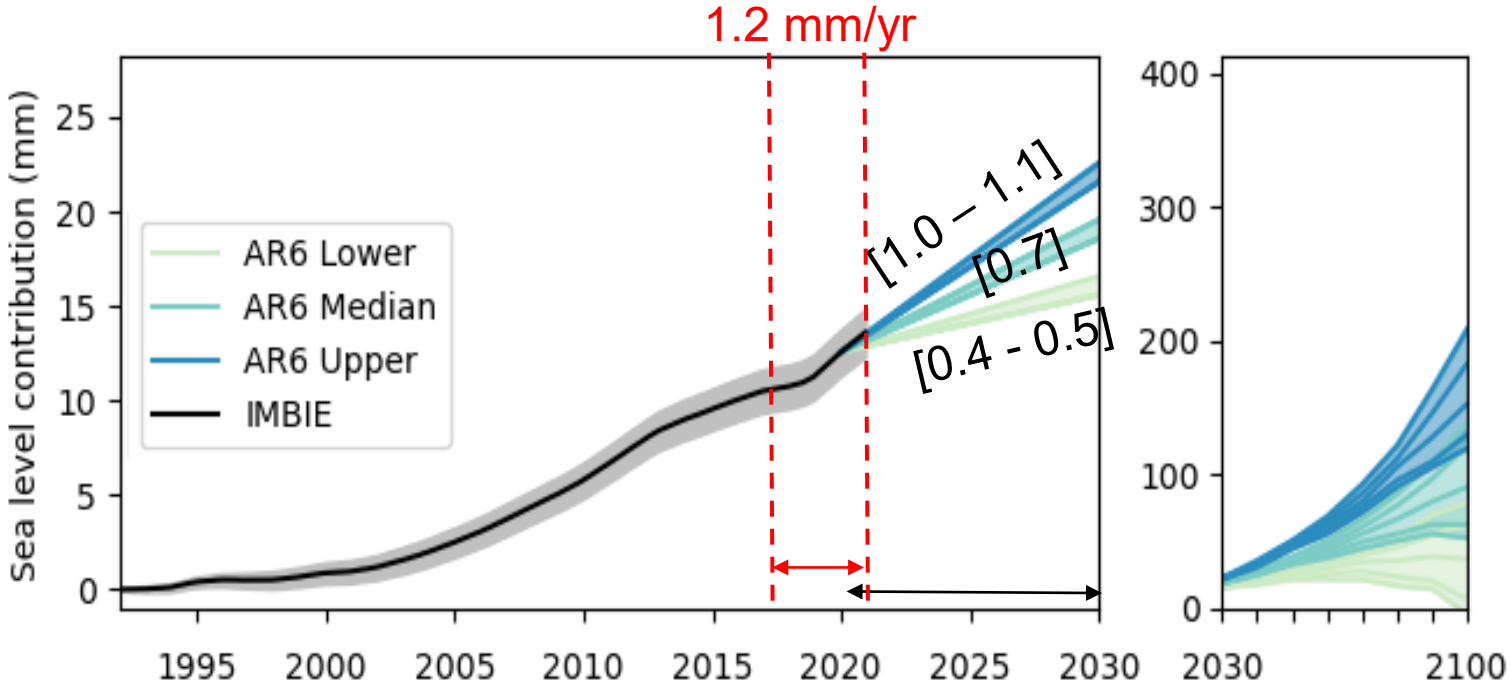
Greenland



- Observed sea level contribution in the 2010s is closest to the median contribution predicted by the IPCC for 2020s
- But between 2017 and 2021, Greenland ice losses accelerated to 1.2 mm/yr which corresponds to the upper range of predictions

IMBIE-3 recent progress and next steps

IMBIE-3 (2021-)

+ New objectives:
- Data from new missions
- Annual updates
- Partitioning SMB/D
- Regional assessments

We have received ~30 new submissions for the next annual update (1992 to 2021) including:

- Altimetry estimates using ICESat-2 data
- Gravimetry estimates
- Input-Output estimates
- SMB models outputs
- GIA modelled estimates

IMBIE-3 recent progress and next steps

IMBIE-3 (2021-)

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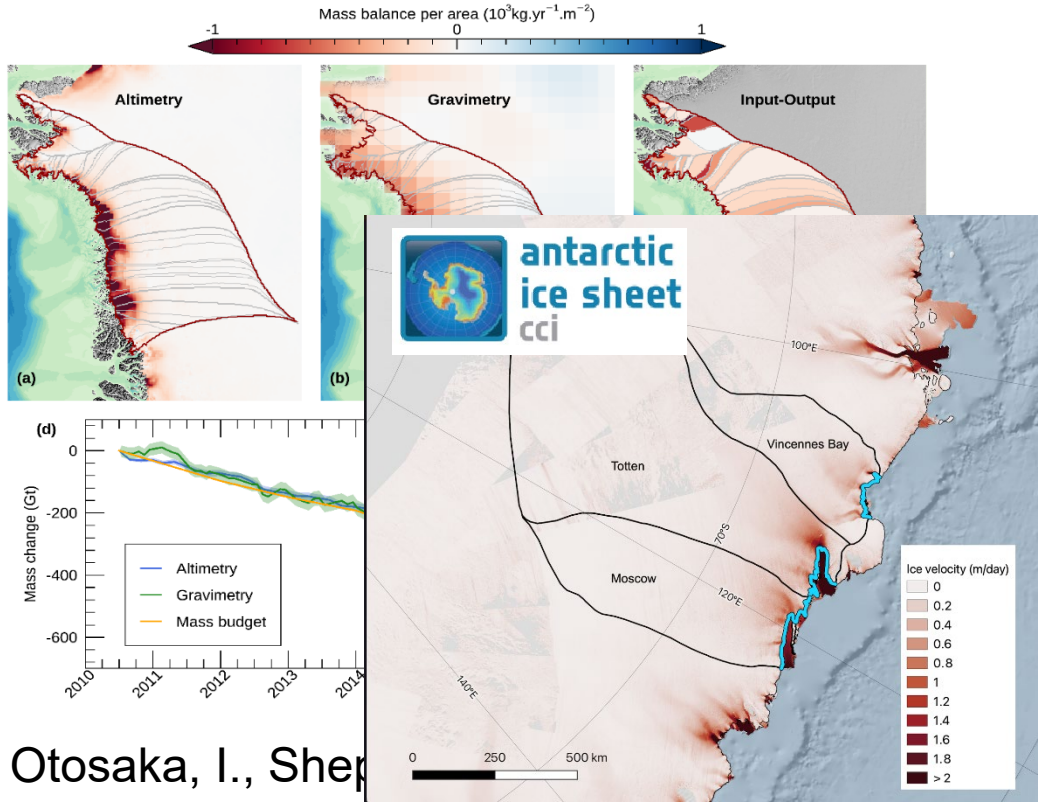
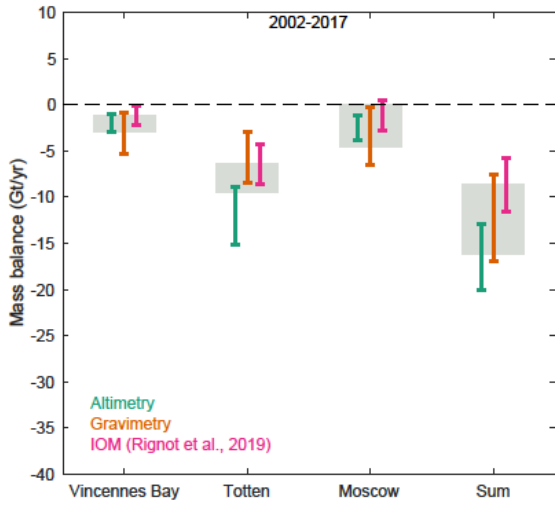
Regional Assessments: two case studies in preparation





Otosaka, I., Shep
J., Fettweis, X.

Slater, T., Doehne, T., Floricioiu, D., Gilbert, L.,Groh, A., Krieger, L., Horwath, M., Muir, A., Nagler, T., Shepherd, A., Wuite, J.

IMBIE Executive Committee



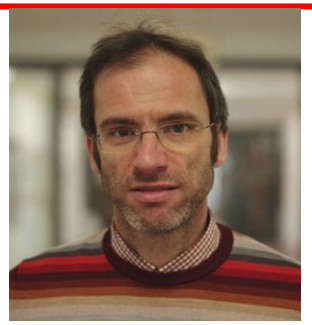

Andrew Shepherd, Inès Otosaka, Erik Ivins, Nicole Schelgel






Ben Smith, Isabella Velicogna, Eric Rignot, Michiel van den Broeke, Sophie Nowicki,Tony Payne





Charles Amory, Michalea King, Martin Horwath, Louise Sandberg Sørensen, Karen Simon

Marcus Engdahl

Mark Pattle

Thematic Working Groups

	New missions	Partitioning	Regional	IOM	ALT	GMB	GIA	SMB
Bridging the GRACE/GRACE-FO gap	●					●	●	
Radar/Laser altimetry comparisons	●				●			
Partitioning (GIA & SMB, combining RA, GMB, IOM)		●		●	●	●	●	●
Regional – NW GrIS	●		●	●	●	●	●	●
Regional – Totten	●	●	●	●	●	●	●	●
Regional – APIS	●		●	●	●	●	●	●
Inter-comparison – EAIS	●		●	●	●	●	●	●
Error budget				●	●	●	●	●
Hybrid Assessments				●	●	●	●	●

Conclusions and Next steps

- Greenland and Antarctica contributed 21 mm to GMSL between 1992 and 2020
- Ice losses have accelerated over this 29-year record, and the rate of ice loss is now 5 times higher in Greenland and 25 % higher in Antarctica compared to the early 1990s
- The ice sheets' contribution to sea level is closest to the median contribution predicted by IPCC for the next decade and will contribute between 148 and 272 mm to GMSL by 2100

- We have new objectives for IMBIE-3, including using data from new missions and performing regional assessments
- We have started the IMBIE 2022 mass balance assessment, which will cover the years 1992 - 2021
- We will soon be organising thematic working groups on topics of high relevance for ice sheet mass balance estimation, stay tune for this!

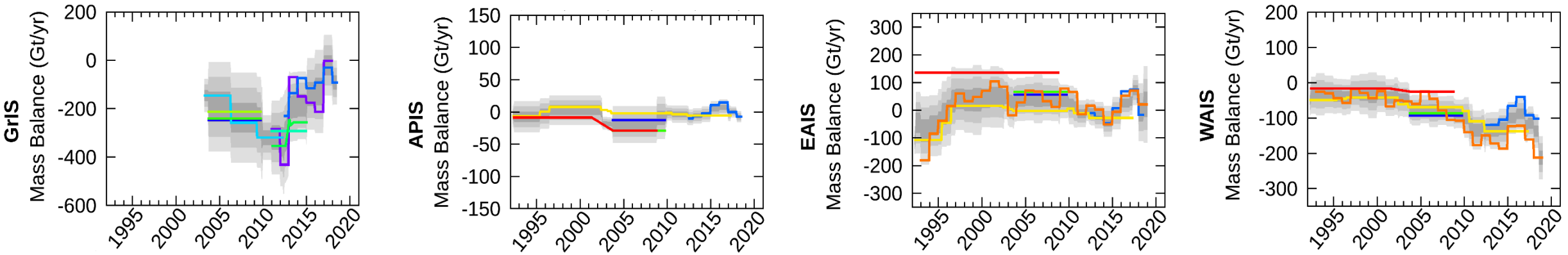
Methods overview

IMBIE participants submitted either time-series of relative mass change or of rate of mass change and associated uncertainties.

We apply a consistent processing scheme to all submitted datasets:

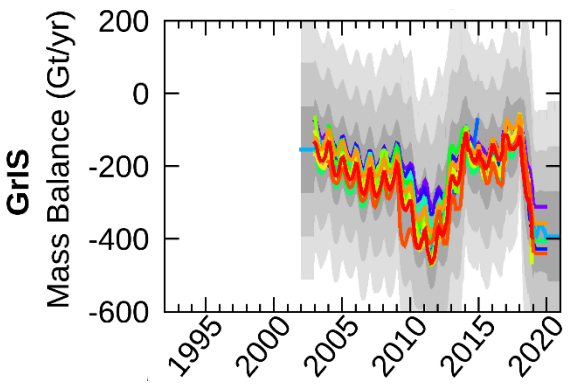
1. Computing time-series of mass trends for all datasets submitted as time-series of relative mass change
2. Aggregating time-series of mass trends within each class of satellite observations
3. Combining the altimetry, gravimetry and mass budget time-series of mass trends
4. Generating the final reconciled cumulative time-series of mass change

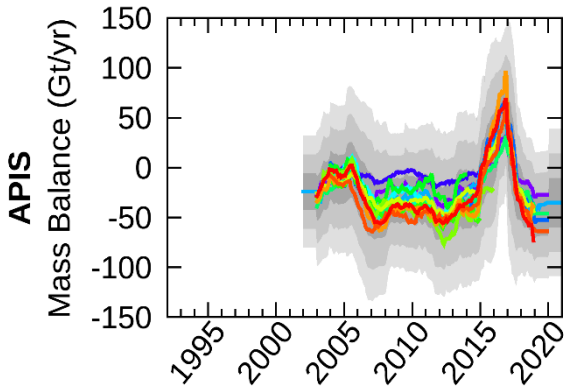
Intra-comparison: Altimetry

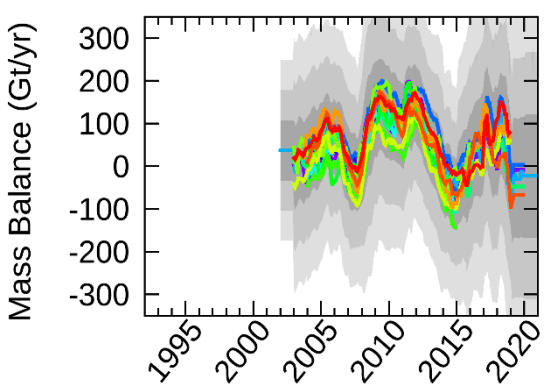


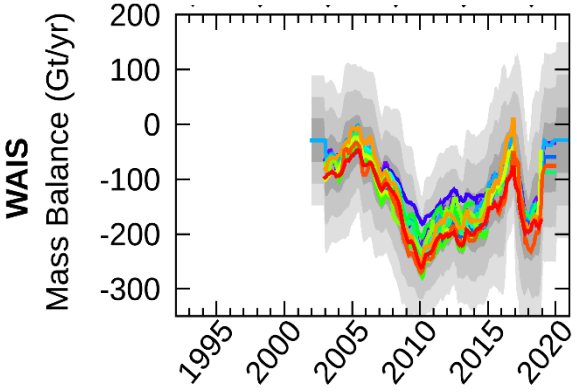
- Solutions were derived from radar altimetry, laser altimetry, or a combination of both
- Cover the period 2003 to 2018 for Greenland and 1992 to 2019 for Antarctica
- Varying temporal resolutions from 1 month to 7.1 years
- In Greenland, better agreement among laser solutions (56.1 Gt/yr, 2004-2010) compared to radar solutions (102.3 Gt/yr, 2013-2015)
- In Antarctica, good agreement for both radar (max 53.5 Gt/yr at WAIS, 2013-2019) and laser solutions (max 56.8 Gt/yr at EAIS, 2004-2009)

Intra-comparison: Gravimetry









Blazquez
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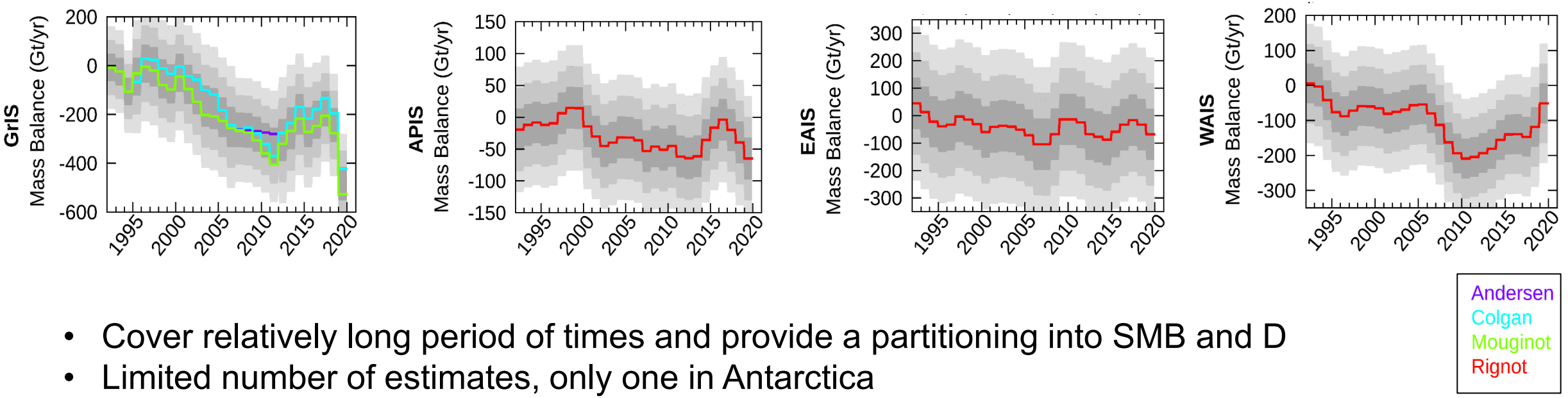
Wiese
Wouters

- Includes highest number of estimates
- Includes GRACE-FO data for the first time
- Cover the period 2002 to 2020 for both ice sheets at monthly resolution
- Good agreement in Greenland (35.8 Gt/yr, 2012-2014) and Antarctica (41.3 Gt/yr, 2004-2014)

Intra-comparison: Input-Output Method



- Cover relatively long period of times and provide a partitioning into SMB and D
- Limited number of estimates, only one in Antarctica
- Cover the period 1992 to 2019 for both ice sheets at annual resolution
- Good agreement in Greenland (28.1 Gt/yr, 2007-2011)

Comparison to IMBIE-2

- Only small differences (< 35 Gt/yr) with IMBIE-2 over their overlap periods
- Differences originate from updated datasets and updated processing scheme (inverse-error weighting applied to both ice sheets)