Recent Changes in Ice Mass Balance of the Amundsen Sea Embayment

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Intercomparison of Mass Balance Estimates for the Amundsen Sea Embayment (ASE) from four independent techniques:

1. GRACE time-variable gravity: (2002–2014)

2. Mass Budget Method (MBM): (1992–2013)

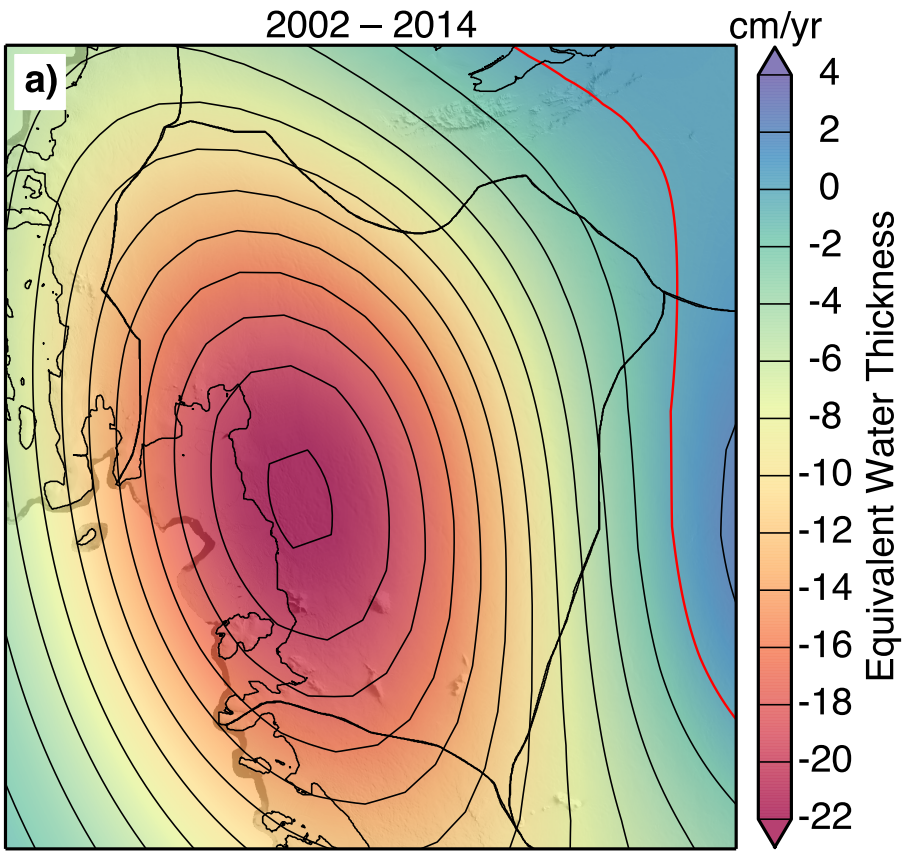
3. ICESat laser altimetry/Operation IceBridge ATM and LVIS: (2003–2011)

4. Envisat radar altimetry: (2002–2010)

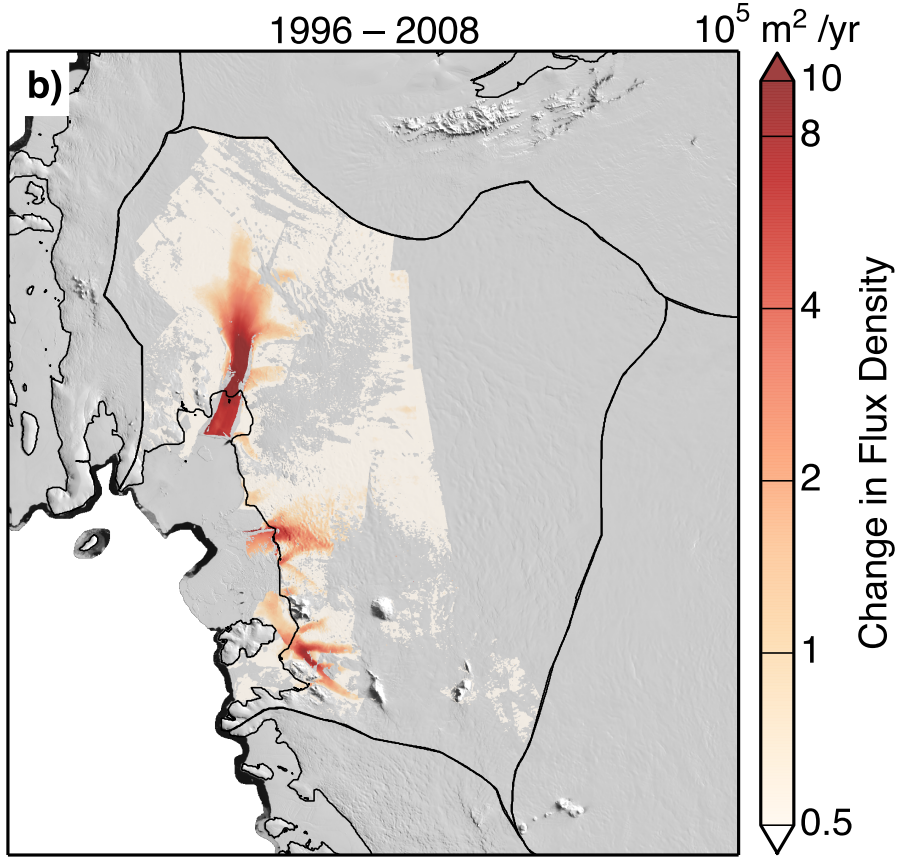
Sutterley et al. submitted, GRL (2014)

GRACE Time-Variable Gravity and Mass Budget

Trend in GRACE Mass Anomaly



Change in ASE ice flux density



Sutterley et al. submitted, GRL (2014)

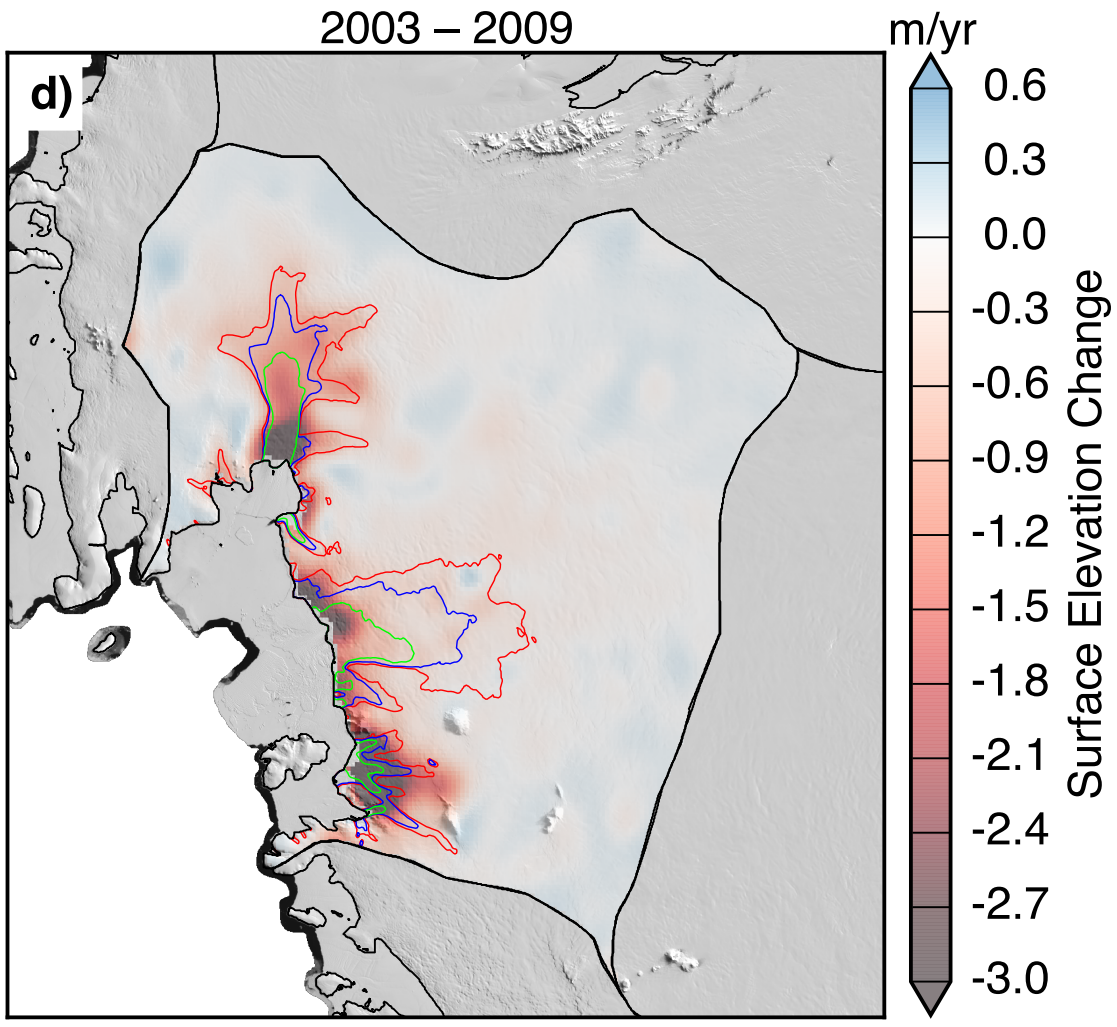
ICESat and Operation IceBridge Altimetry

Data:

- ICESat
- IceBridge ATM
- IceBridge LVIS

Procedures:

- Cloud filtering and saturation corrections
- ICBC from Ewert (2012) and Urban (2005)
- Least-Squares fit a time-variable polynomial surface to 1 km patches



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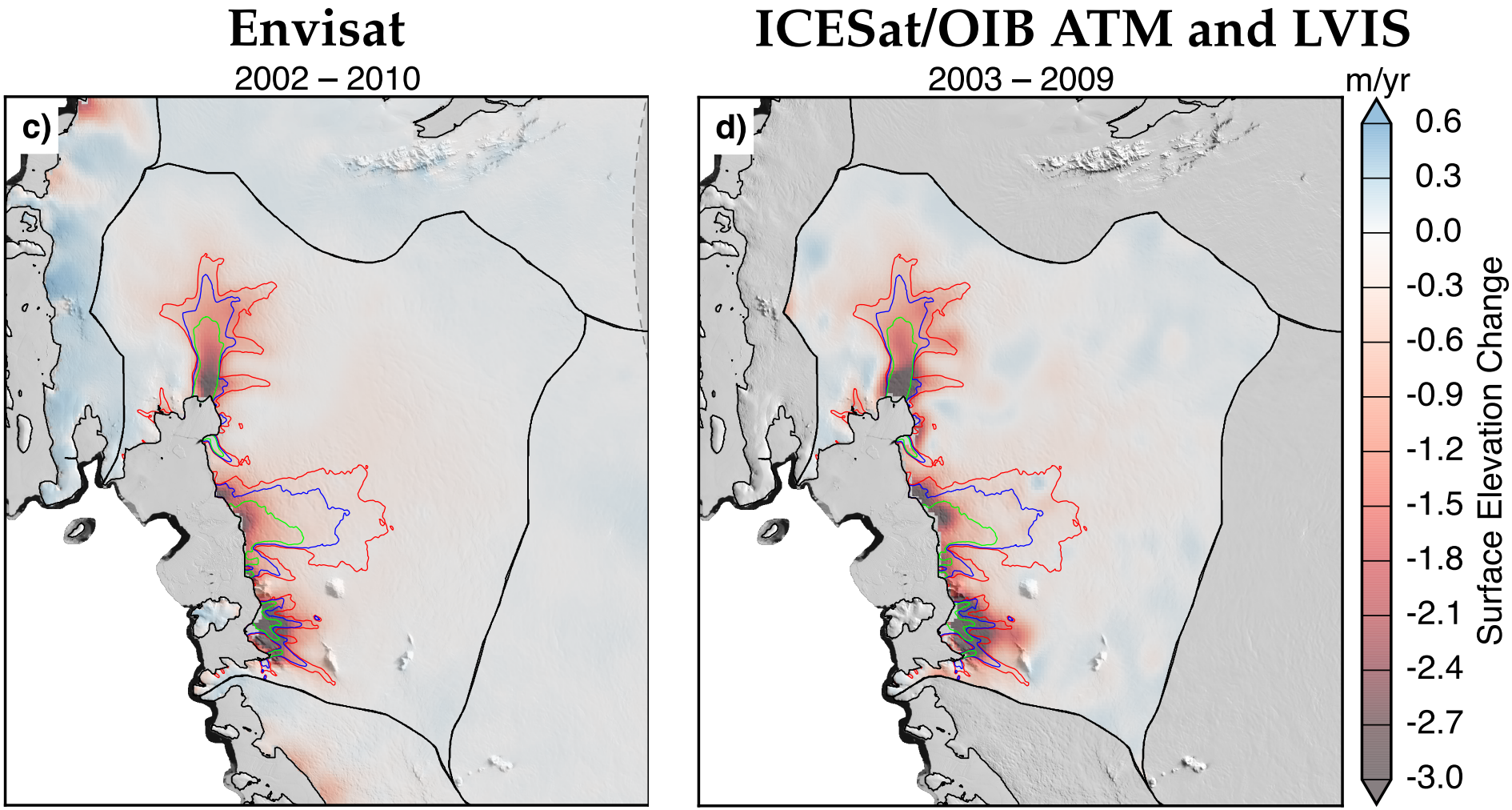


125, 250 and 500 m/yr ice speeds (Rignot et al., 2011)

Sutterley et al. submitted, GRL (2014)

Large differences in spatial and temporal resolution

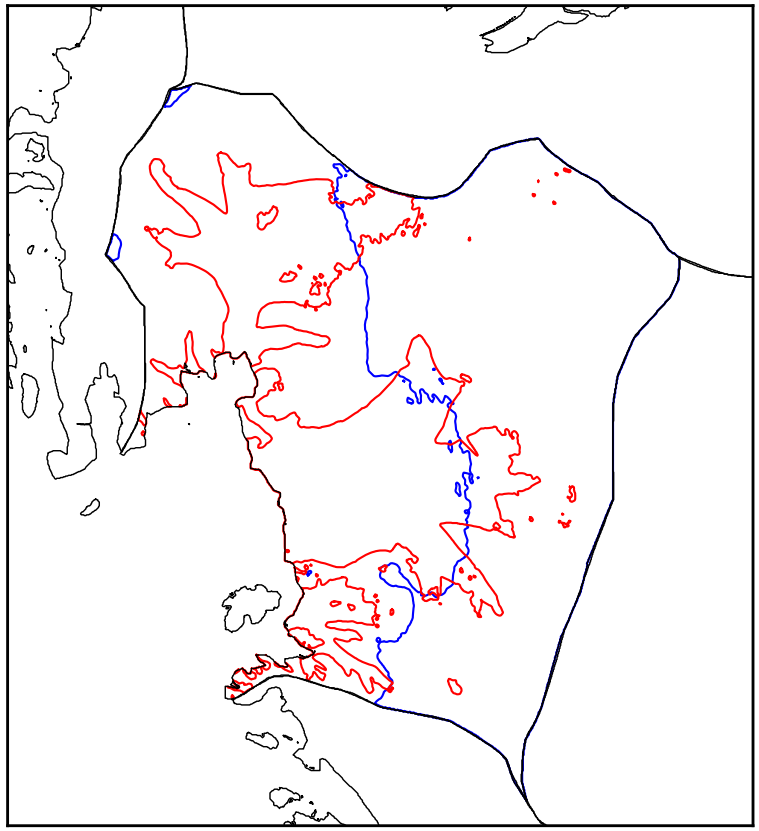
Compare the basin-averaged time series for each technique:

1. Mass Balance: dM/dt [Gt/yr]
2. Mass Anomaly: $M(t)$ [Gt]
3. Average Mass Balance Rate: dM/dt [Gt/yr]
4. Change in Mass Balance Rate: d^2M/dt^2 [Gt/yr^2]

Altimetry Mass Balance

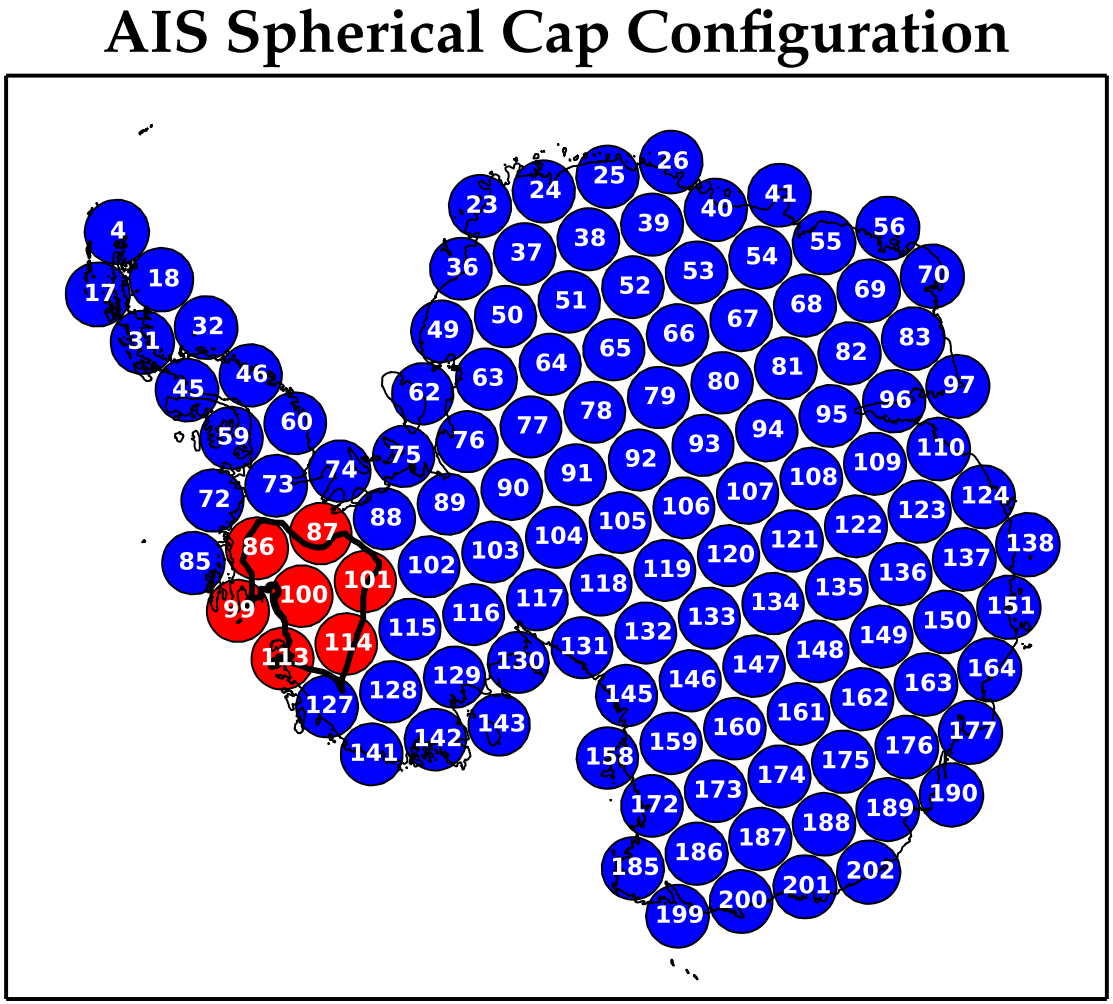
Assume mass changes are primarily due to ice dynamics for ASE

- Correlation of $d\mathrm{h}/d\mathrm{t}$ with velocity and flux density change
- 87% loss for velocities >50 m/yr
- 97% losses below 1300m elevation
- Using: $\rho = 900\ \mathrm{kg/m^3}$
- Very large uncertainties in available firn correction models



Envisat: radar altimetry signal losses along coasts

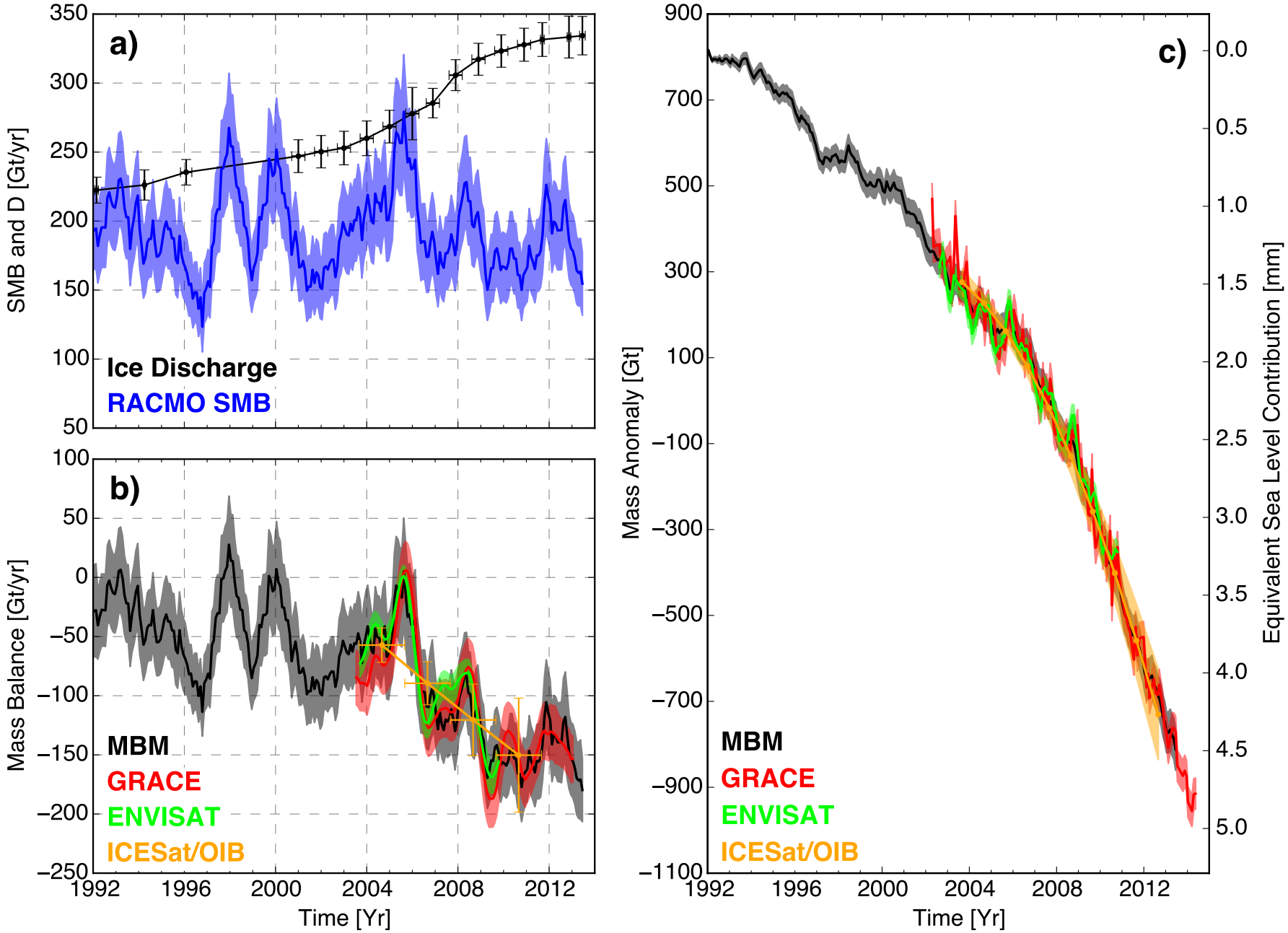
Least-Squares Mascons



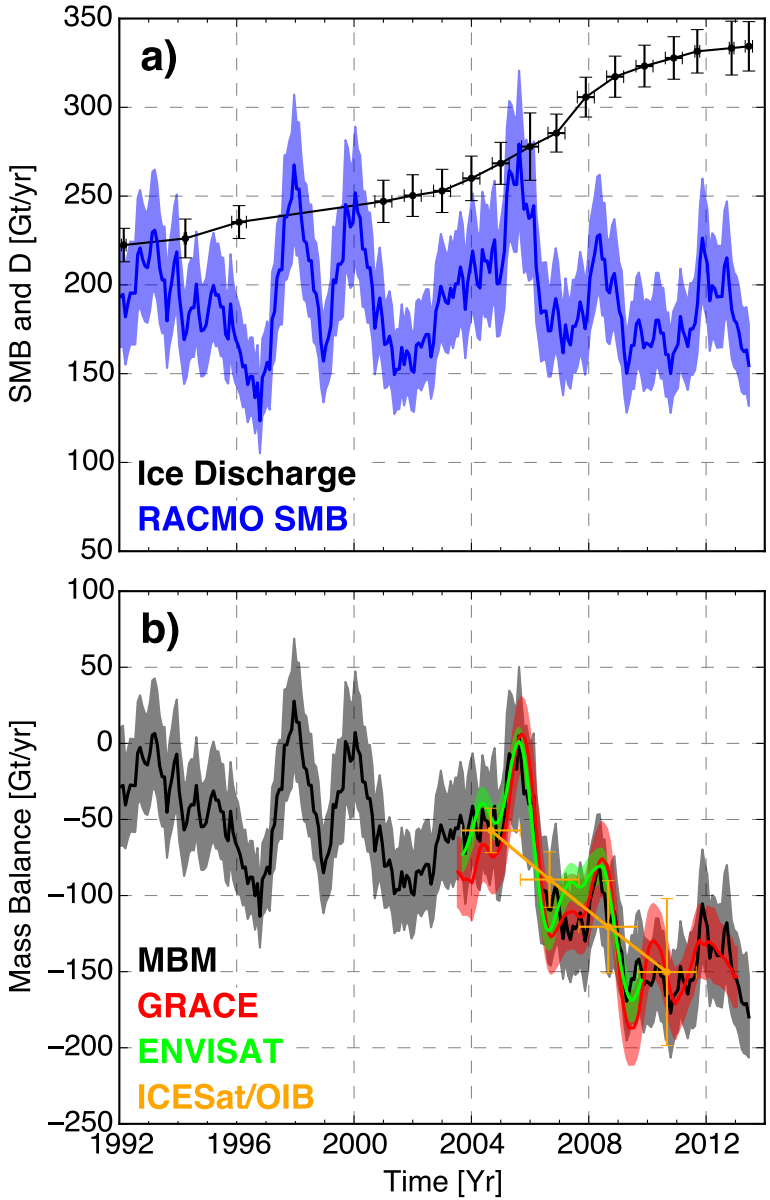
Procedure:

- Cover Antarctica with a set of spherical caps
- Fit to GRACE data
- ASE time series = sum of red mascons

Mass Balance of Amundsen Sea Embayment (ASE)



Mass Balance of Amundsen Sea Embayment (ASE)



ASE Regional Mass Balance Rates

Dataset	Date Range	Average Mass Balance Rate [Gt/yr]	Change in Mass Balance Rate [Gt/yr^2]
GRACE	2003 – 2009	-90 ± 8	-16.4 ± 2.6
MBM	2003 – 2009	-89 ± 4	-19.6 ± 2.2
Envisat	2003 – 2009	-81 ± 6	-18.6 ± 2.3
ICESat/OIB	2003 – 2009	-89 ± 12	-15.9 ± 7.6
GRACE	2003 – 2011	-104 ± 7	-15.5 ± 1.7
MBM	2003 – 2011	-105 ± 3	-18.0 ± 1.5
ICESat/OIB	2003 – 2011	-105 ± 14	-15.7 ± 6.1
GRACE	2003 – 2013	-108 ± 7	-11.7 ± 1.3
MBM	2003 – 2013	-110 ± 3	-13.6 ± 1.2
MBM	1992 – 2013	-83 ± 2	-6.1 ± 0.3

Change in RACMO SMB not statistically significant over 1992 – 2013 (-0.2 ± 0.3 Gt/yr^2)

Cumulative losses:

1160 ± 30 Gt over 2002–2013 (3.2 ± 0.1 mm SLE)

1630 ± 30 Gt over 1992–2013 (4.5 ± 0.1 mm SLE)

Conclusions

1. Four methods agree at the regional scale in terms of mass loss and acceleration in loss

2. Operation IceBridge campaign-style measurements sufficient to extend the ICESat derived time-series of mass balance in time and maintain a record of ice mass balance in the region

3. Results reconcile independent mass balance estimates in a setting dominated by changes in ice dynamics with significant variability in surface mass balance

4. Significant fluctuations in SMB signals average out after a couple of decades