Rapid Mass Loss in West Antarctica Revealed by Swarm Gravimetry in the Absence of GRACE

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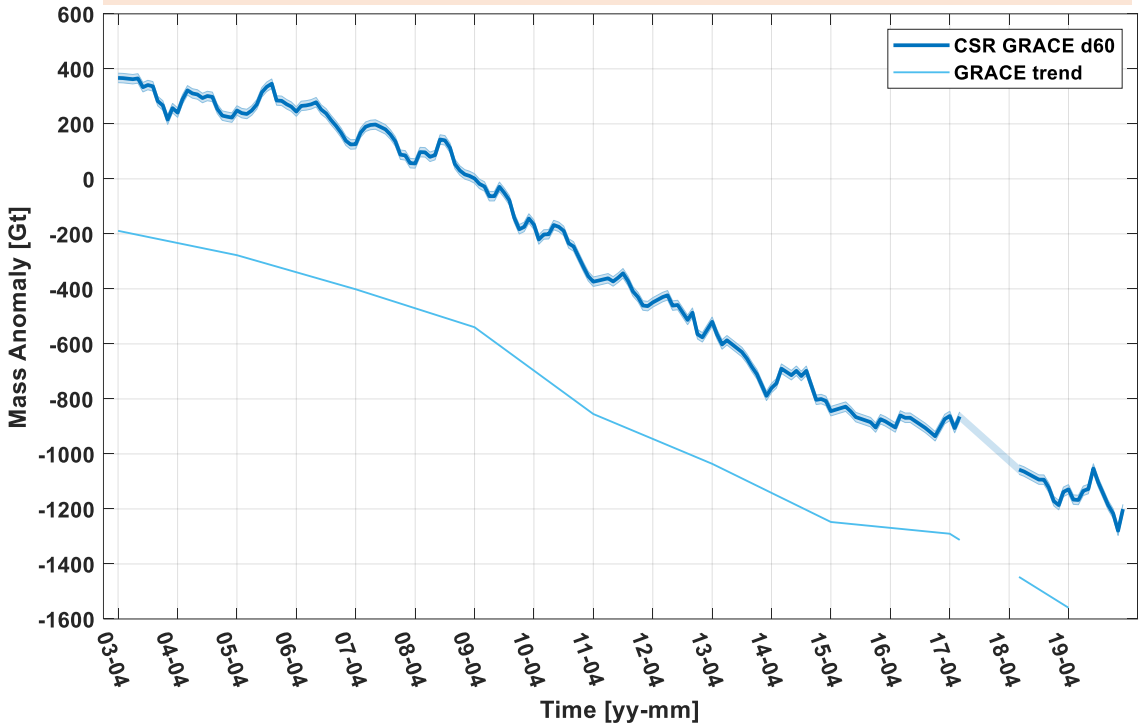
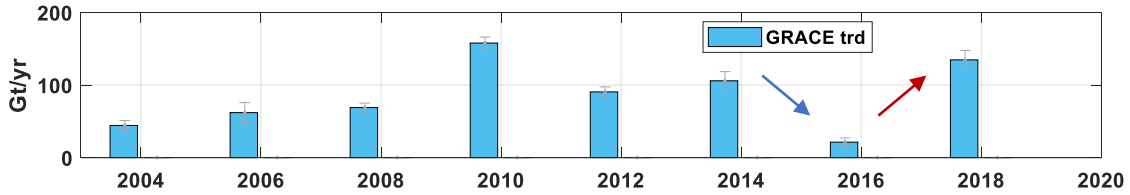
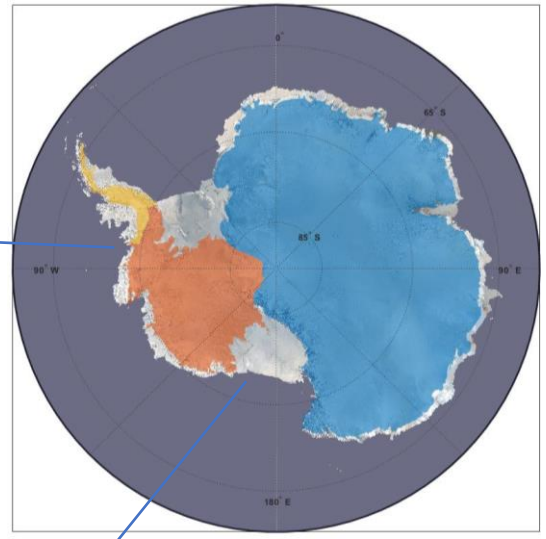
Motivation

GRACE(FO) observed West Antarctic Ice Sheet (WAIS) mass anomalies



Biennial trend (every two year)





Ice mass loss rate (biennial):

2003~2015 ↗ 50~150Gt/yr

2015~2017 ↘ ~20Gt/yr

Data gap

2017~2019 ↗ ~130Gt/yr

?!

Mass loss rate abruptly changed

- Rapid ice mass loss **signal?**
- An inter-mission **bias (**low mass loss rate)?

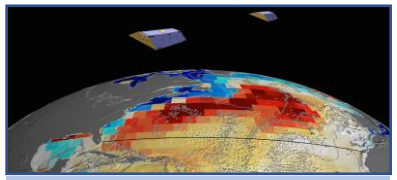
Method

Swarm mission spans the GRACE and GRACE-FO time.
Can we use lower resolution Swarm gravity solutions to patch the gap and resolve the puzzle?

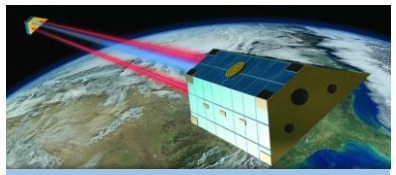
Main ingredient: Swarm kinematic orbit

Method: Modified Decorrelated Acceleration Approach

Quality: good overlap up to d/o 12, 1 order of magnitude worse at degree 20 (w.r.t. GRACE(FO)) .

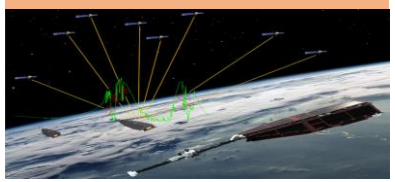


2003-2017 (GRACE)



2003-now (GRACE-FO)

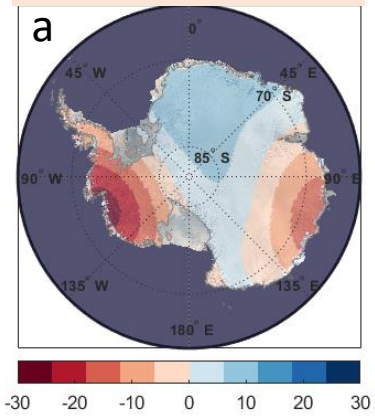
2013-now (Swarm)



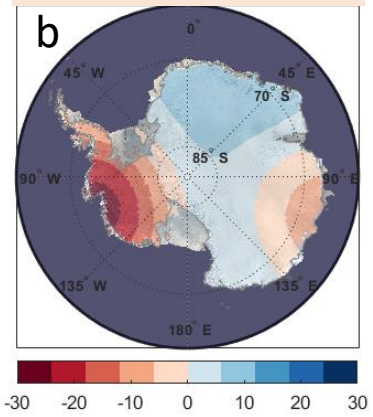
Credit: NASA/ESA

Antarctica Trend map (2015-2020)

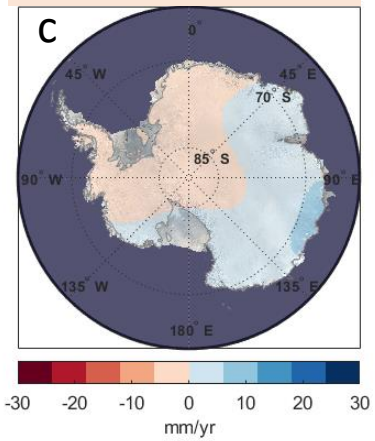
Swarm d20



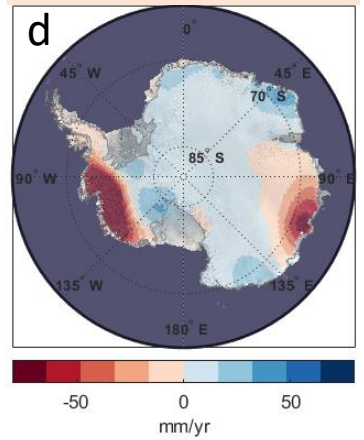
GRACE(FO) d20



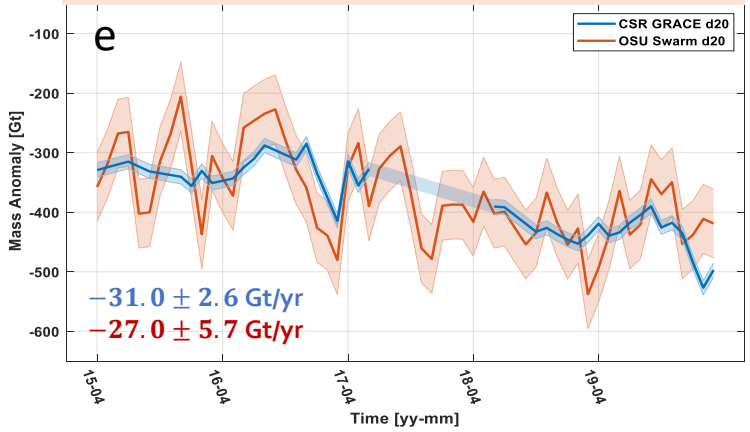
Swarm – GRACE(FO)



GRACE(FO) d60



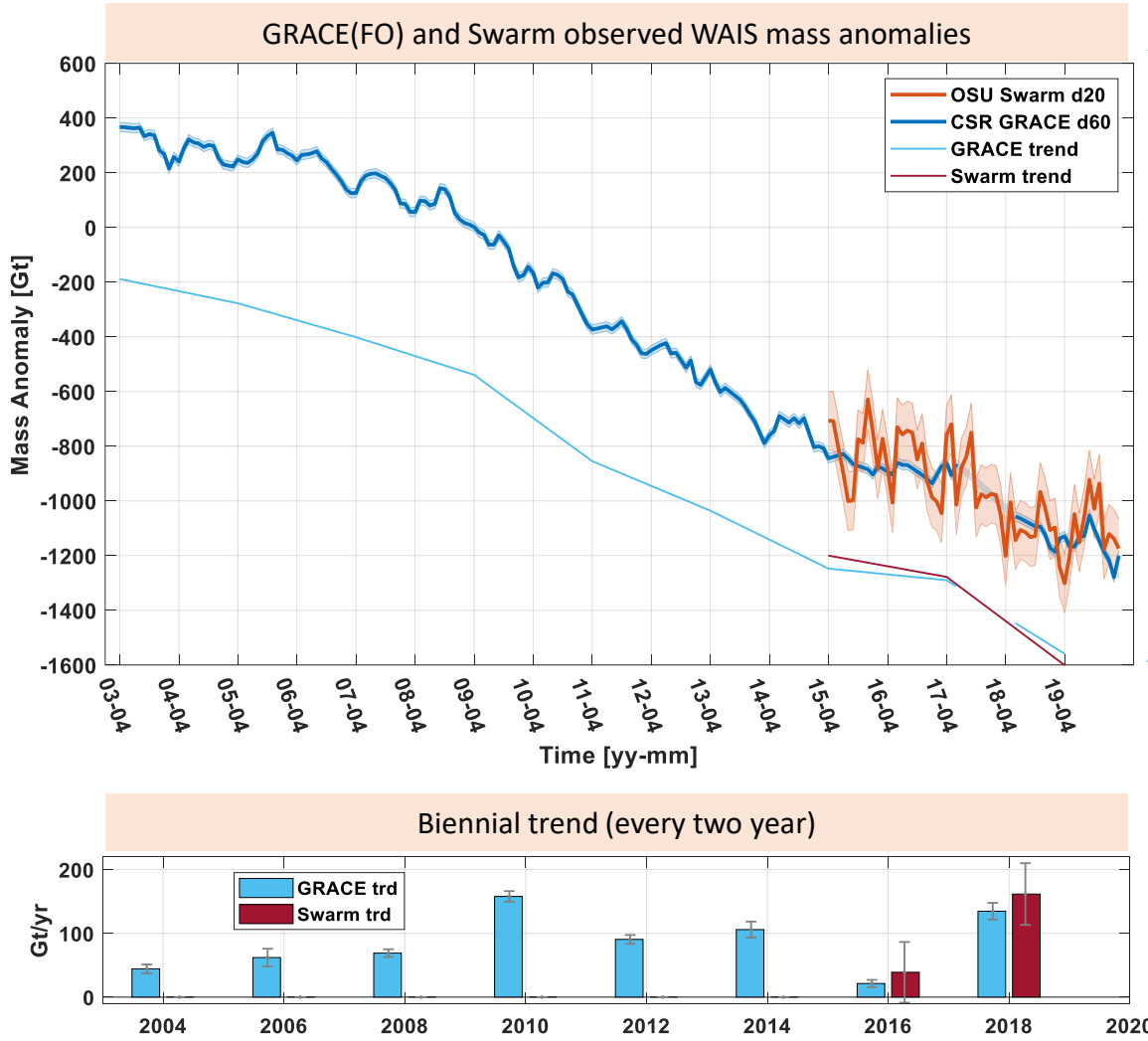
WAIS apparent mass anomalies (d20)

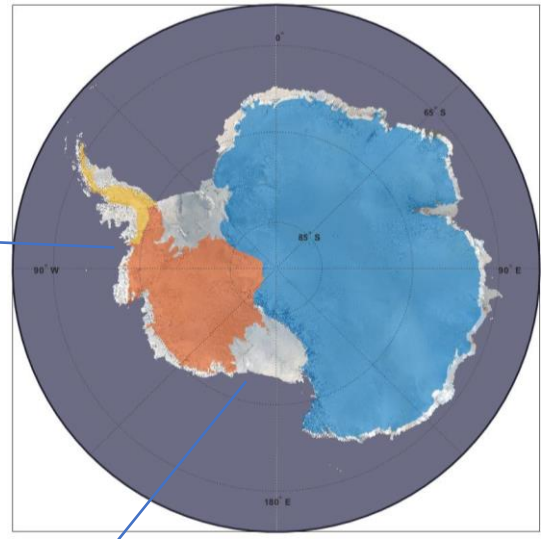


Swarm(a) vs GRACE (b): trend differences within several mm/yr
D20(b) vs D60 (d): captured main features but lost details
WAIS time series: Swarm is noisier but has good agreement with GRACE(FO) observations, CC=0.78.

(*no leakage correction*)

Result





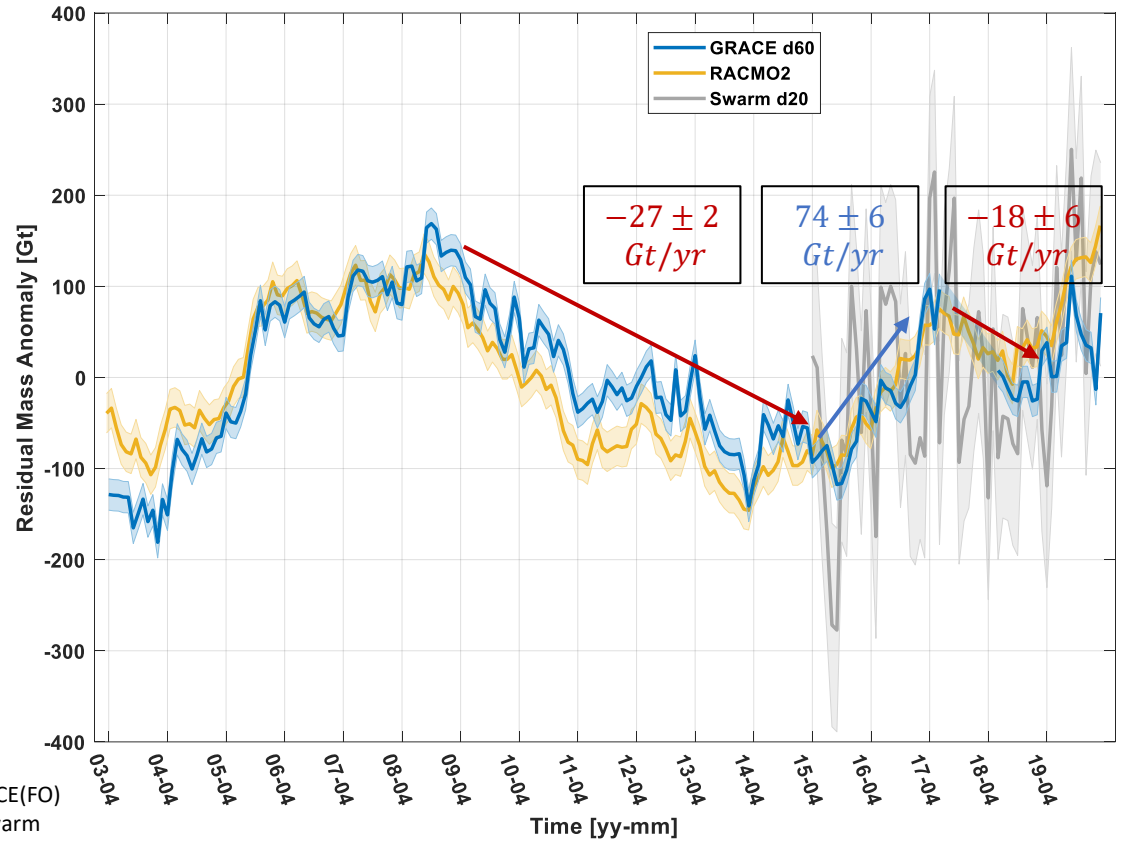
Biennial trend	GRACE(FO) [Gt/yr]	Swarm [Gt/yr]
2003~2015 ↗	50~160	
2015-2017 ↘	21.3 ± 5.7	38.9 ± 47.5
2017-2019 ↗	134.6 ± 13.0	161.5 ± 48.4

- Rapid ice mass loss **signal?** ✓
- An inter-mission **bias?** ✗

What is the origin of the observed abrupt change?
What is the climate driver?

Origin and climate driver

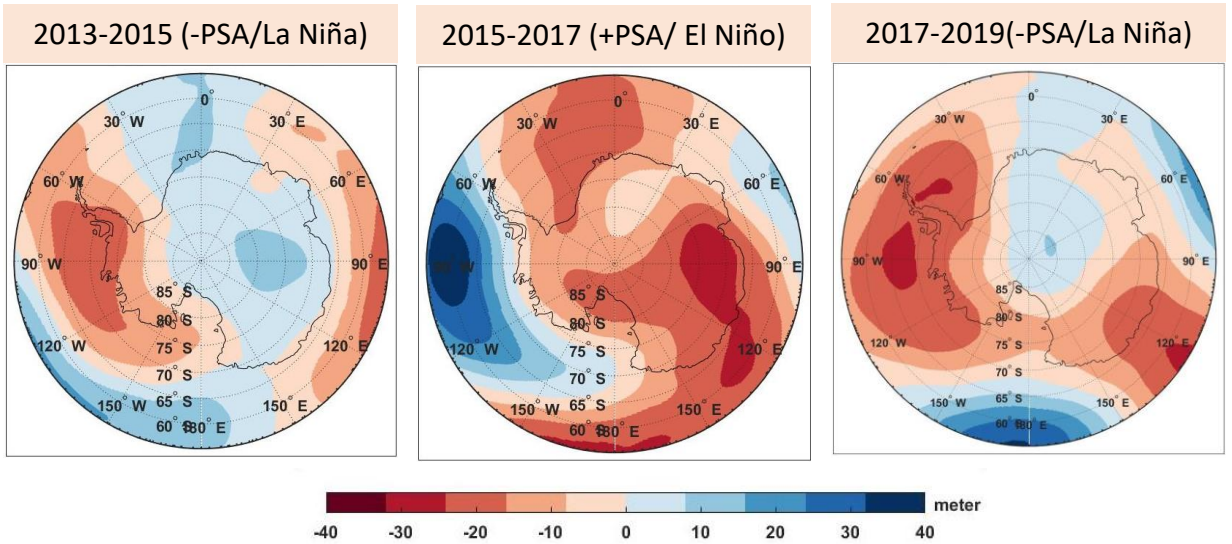
WAIS inter-annual mass anomalies
(rm trd, ann, semi-ann)



MB= SMB + D, SMB:D $\approx 10:1$ at inter-annual scale

The dramatic change in the precipitation (enhanced → anomalous low) explains the transition observed by Swarm and GRACE(FO)

Residual Geopotential height at 500 hPa



Dominated by the Pacific-South America (PSA) patterns

- high (low) pressure anomalies persist at the Pacific sector
- Air flow: high (blue) → low (red) pressure
- -PSA /La Niña low precipitation, +PSA/ El Niño rich precipitation

The shift from +PSA to –PSA, coupled with the unusually pronounced El Niño to La Niña transition, are the main driver.

Summary

- The rapid ice mass loss in WAIS paused in 2015 and lasted until the end of GRACE mission in2017.
- The critical 1-year GRACE(FO) intermission data gap raises the question of whether the reduced mass loss rate persists
- The lower resolution Swarm gravimetry data show good agreement with GRACE(FO) in WAIS, i.e., high correlation (0.78) and consistent trend estimates.
- Swarm data efficiently bridge the GRACE/GRACE-FO data gap and reveal that WAIS has returned to the rapid mass loss state that prevailed prior to 2015 during the GRACE(FO) intermission data gap.
- The changes in precipitation patterns, driven by the climate cycles (e.g. PSA and ENSO), further explain and confirm the dramatic shifts in the WAIS mass loss regime implied by the Swarm observations.

More details can be found in our paper:
Zhang et al., 2021 GRL. https://doi.org/10.1029/2021GL095141

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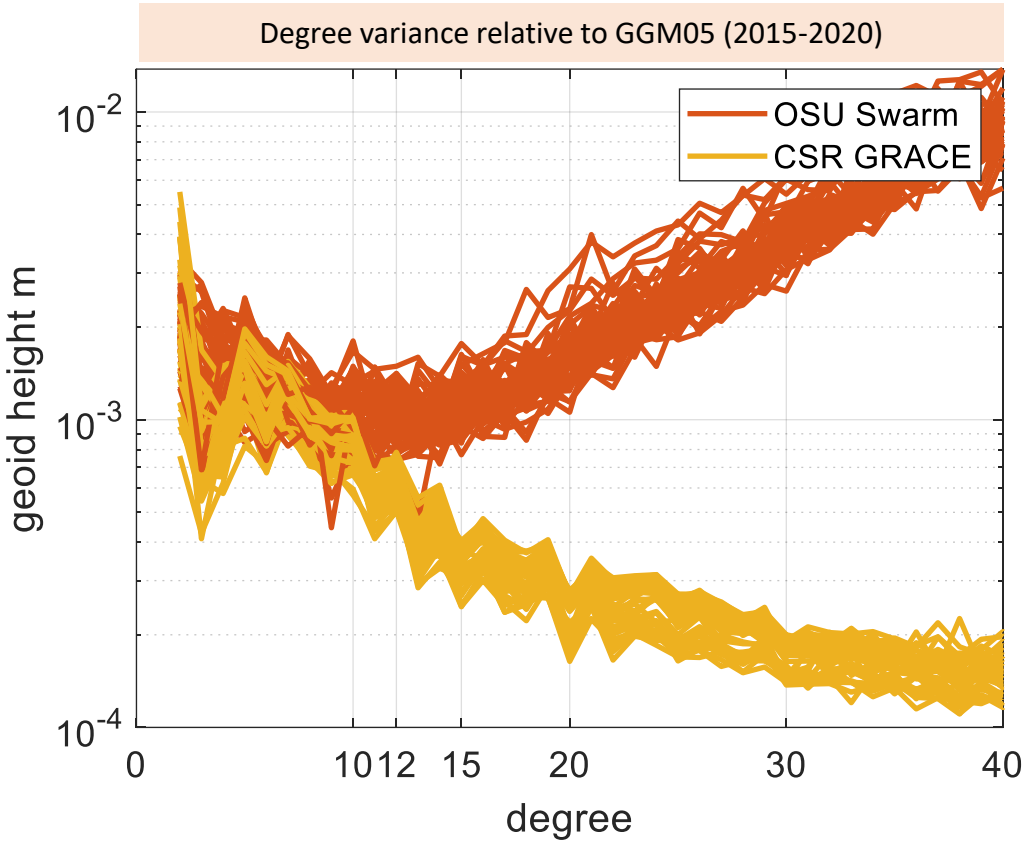
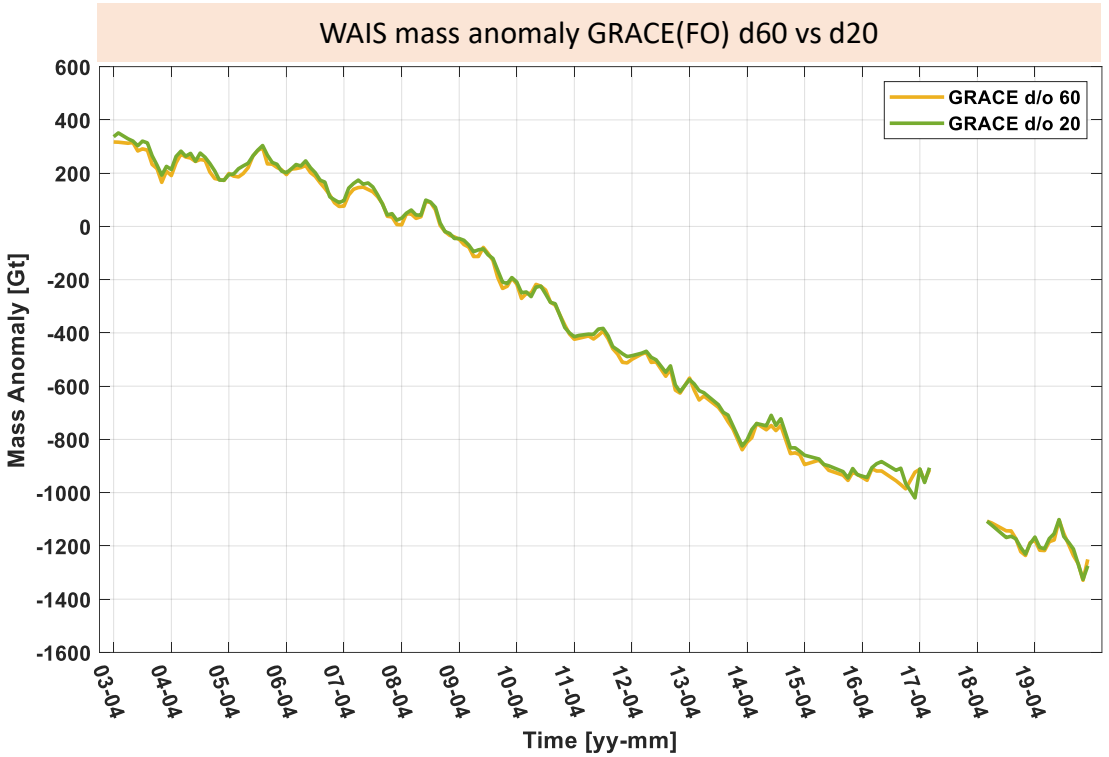
Extra slides





WAIS mass anomaly time series estimated from GRACE/GRACE-FO with different maximum degree (degree 60 in yellow and 20 in green). 300km/1100km (degree 60/20) Gaussian smoothing, and forward modeling (FM) leakage reduction are applied.

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