DTU Space
National Space Institute

DTU Technical University of Denmark

www.space.dtu.dk

The melting ice sheets – polar changes with global impact

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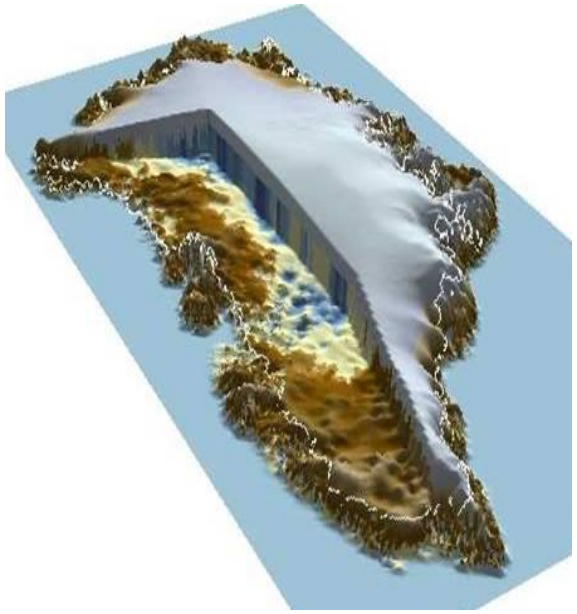
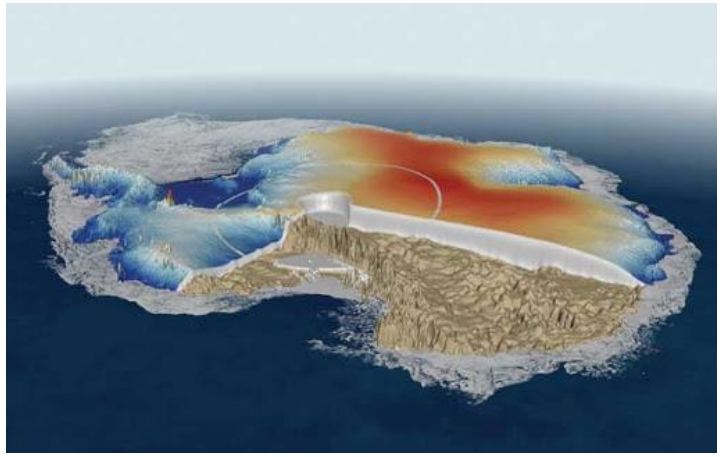
ESA/DTU CryoVEx

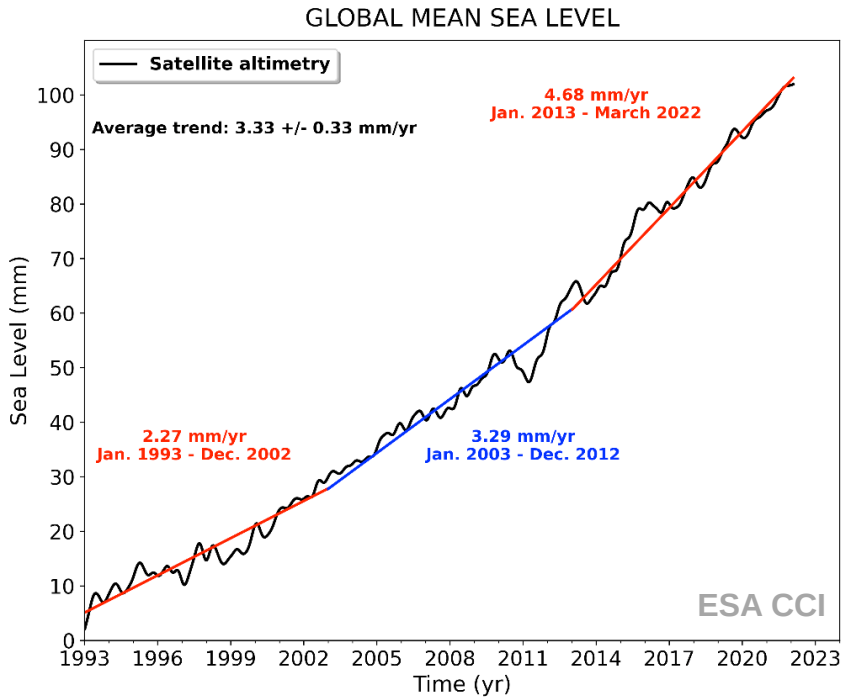
Global sea level rise from ice sheets melt

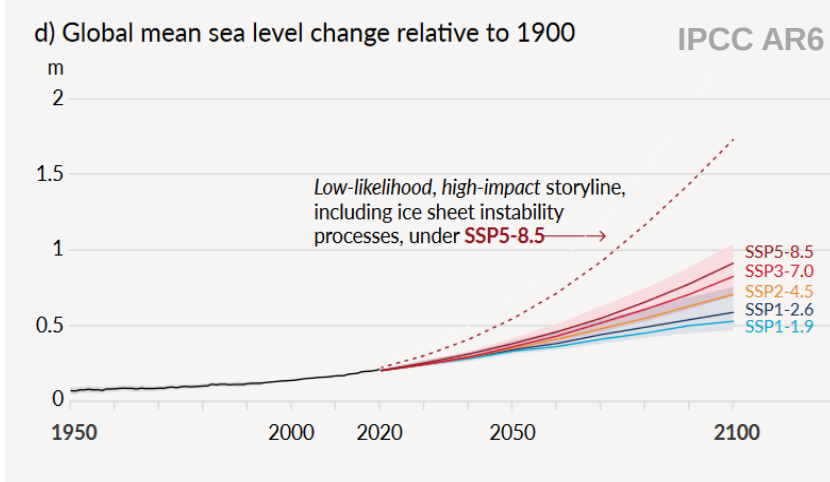


Greenland
7 meter global sea level rise
(if all melted)



Antarctica
57 meter sea level rise
(7x Greenland area)





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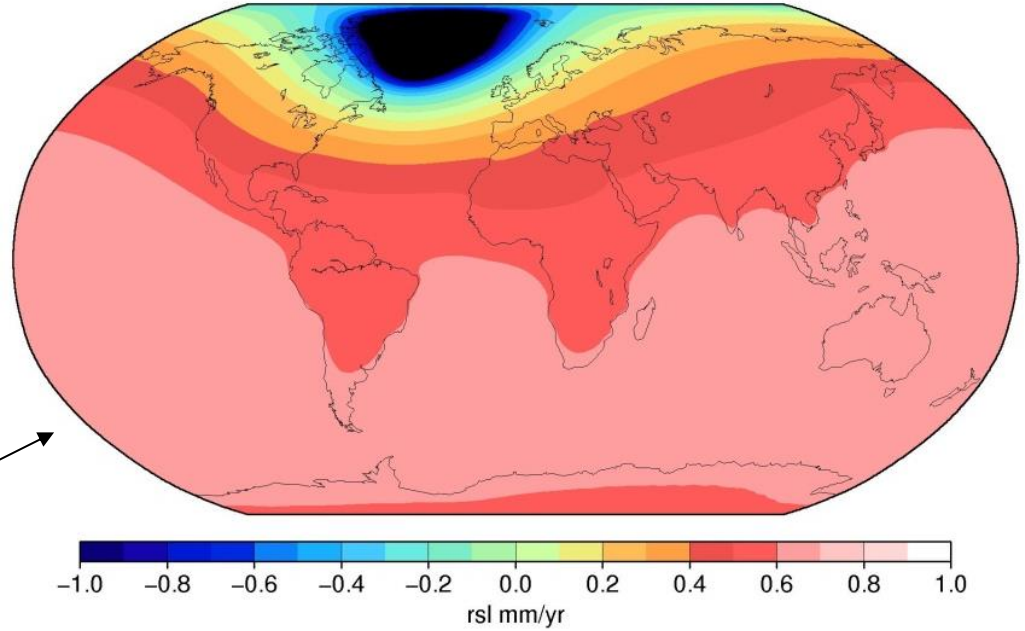
Ice sheet sea level effects not uniform ..

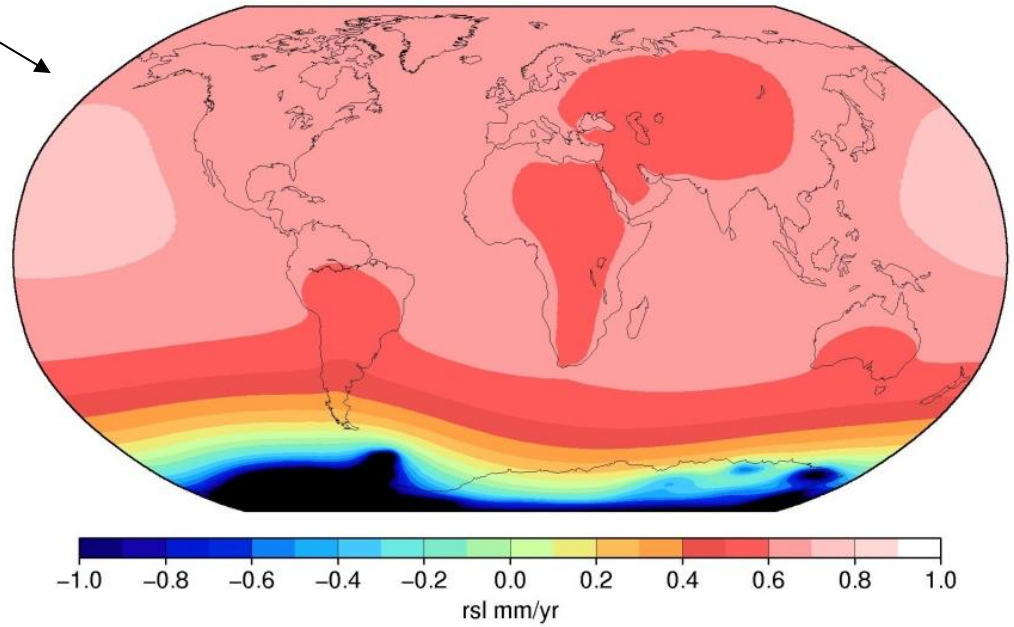
- *Due to changes in gravitation and earth response to changing loads*

- *Effects from Antarctica melt dominating in northern Europe*

Sea level change due to Greenland melt



Sea level change due to Antarctica melt



[V. Barletta, DTU-Space]

Measuring present ice changes – satellites have revolutionized our abilities …

Elevation measurements:

- Radar altimetry (ERS-1, ERS-2, EnviSat, CryoSat, AltiKa ..)
- Laser altimetry (NASA IceSat-1, IceSat-2 ..)

Measures height of the surface from space – few cm accuracy …

***Measurements of gravity field changes**:*

- Satellite-to-satellite ranging (NASA/DLR GRACE 2002-2017, GRACE-FO 2018- ..)

Direct measurement of mass loss of ice sheets and ice caps …

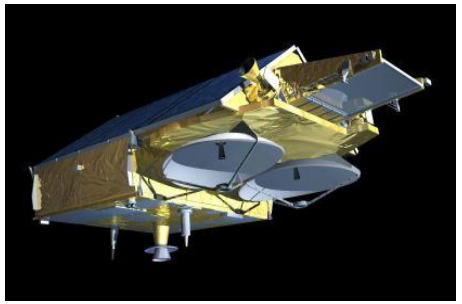
***Measurements of ice flow velocity**:*

- Radar interferometri (ERS, EnviSat, Sentinel-1 ..)

Ice velocity measurements weekly

Also give mass balance .. Input-output ”gate” method

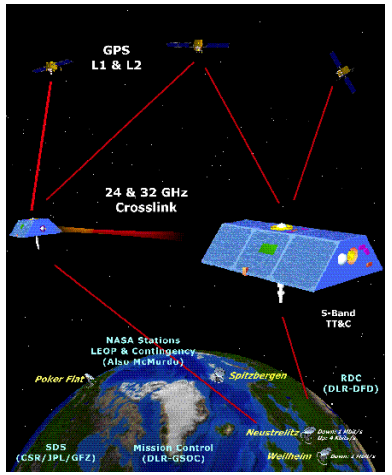
DTU Space leads ESA ”Climate Change Initiative” for Greenland and delivers data to Copernicus Climate Change Service



ESA Cryosat-2 (2010- ..)

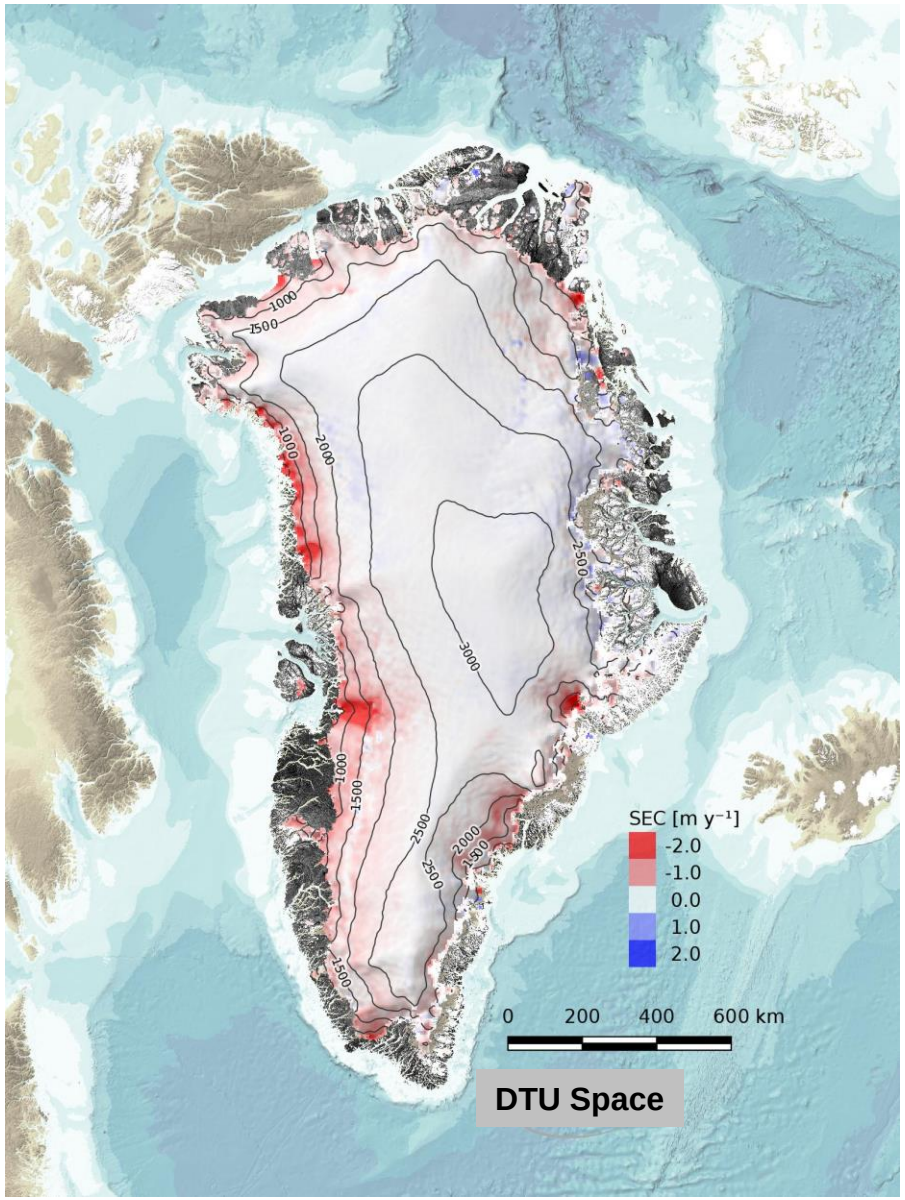
NASA IceSat-1 (2003-9, IceSat-2 (2019-)

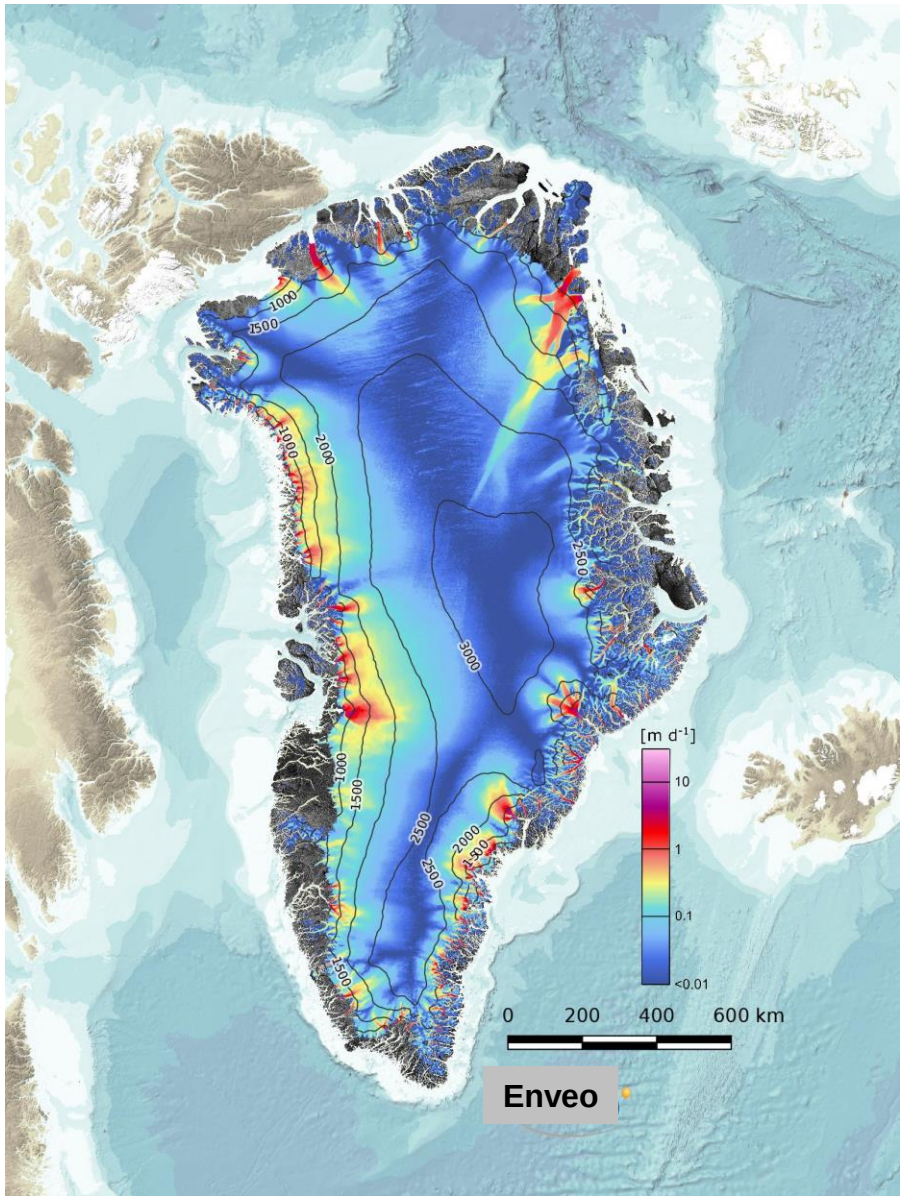
SAR interferometry (Sentinel-1 ..)



NASA/DLR GRACE

Greenland: CryoSat elevation changes and Sentinel-1 ice velocities





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GRACE/GRACE-FO – global mass change mission – hydrology, ice, geodynamics ..

GRACE measure direct mass change at orbit height 480-450 km … monthly gravity field solutions, NASA/DLR

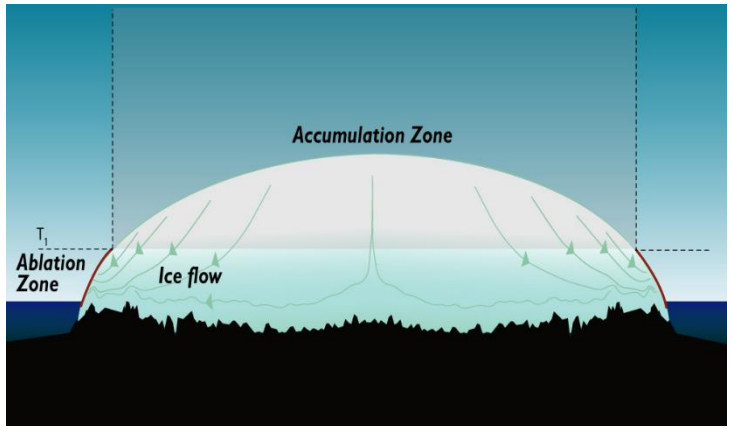
Mascon inversion efficient over ice sheets

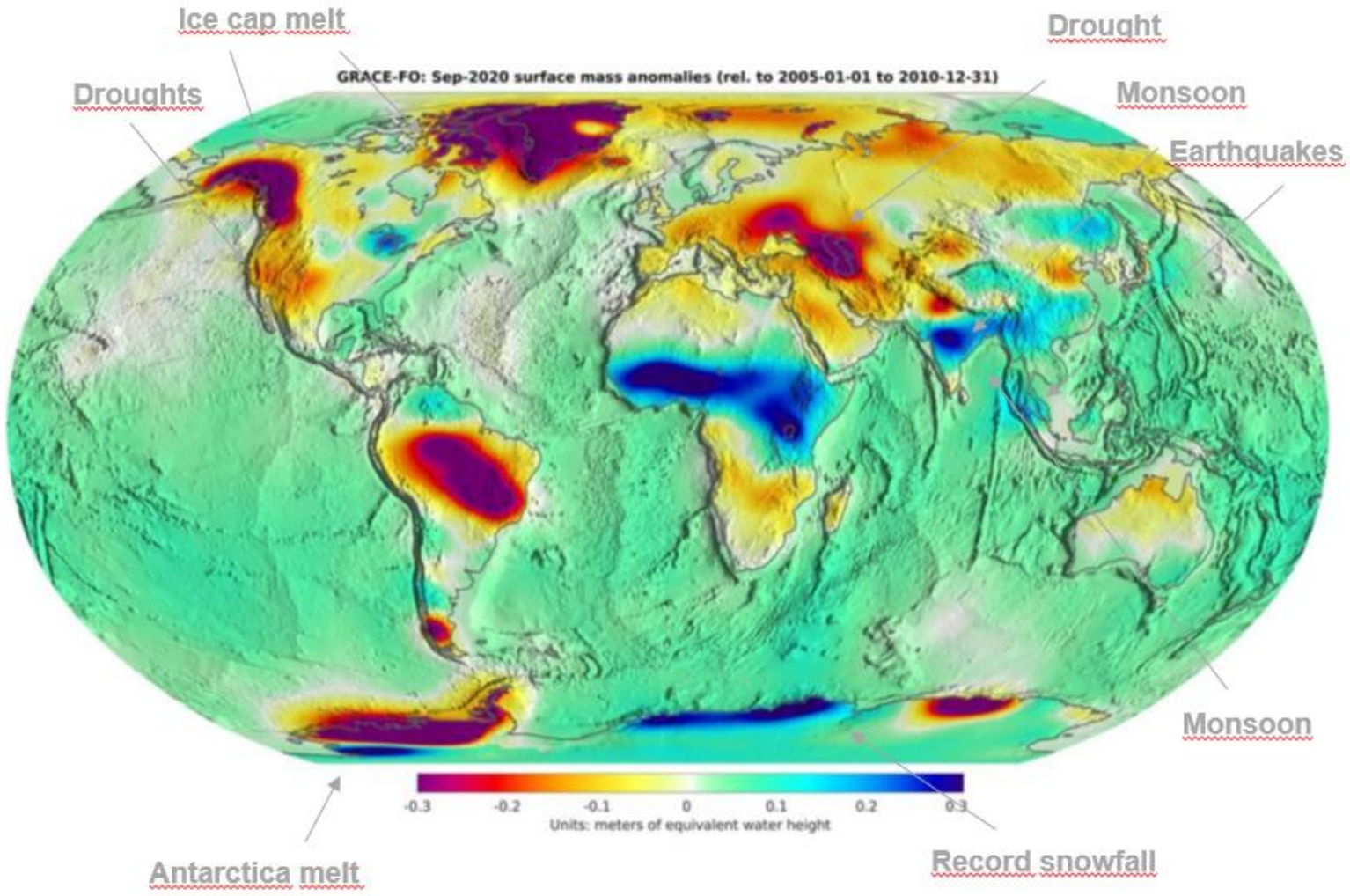
Greenland: - 245 GT/yr

Antarctica: ~ 75 GT/yr

Ice sheets dynamic – snow fall in interior, mass loss by melt, runoff and calving –

Total exchange ~650 GT/yr Greenland, ~2000 GT/yr Antarctica

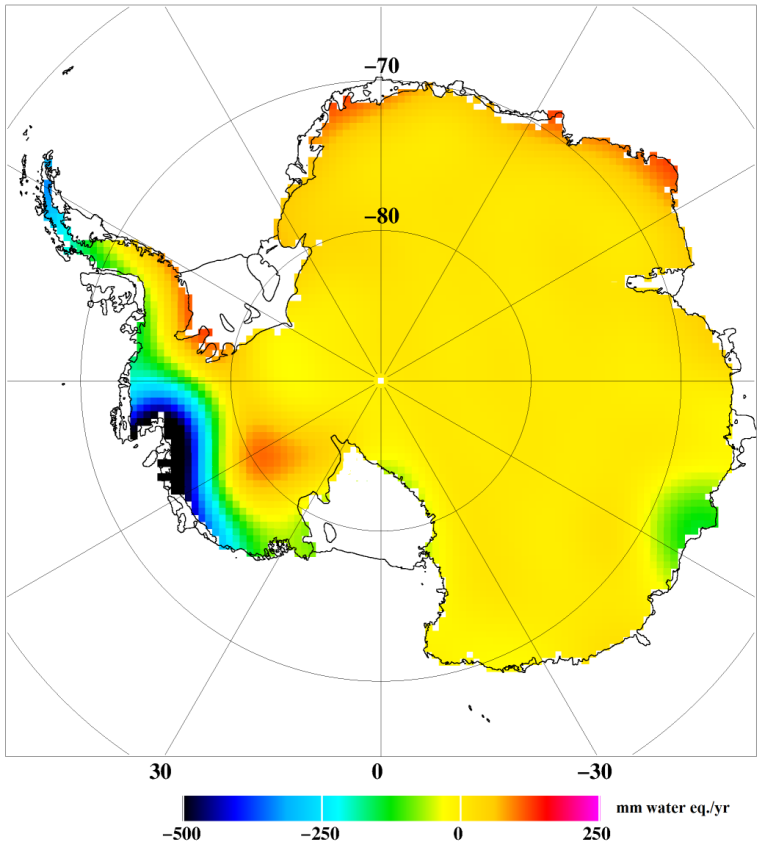


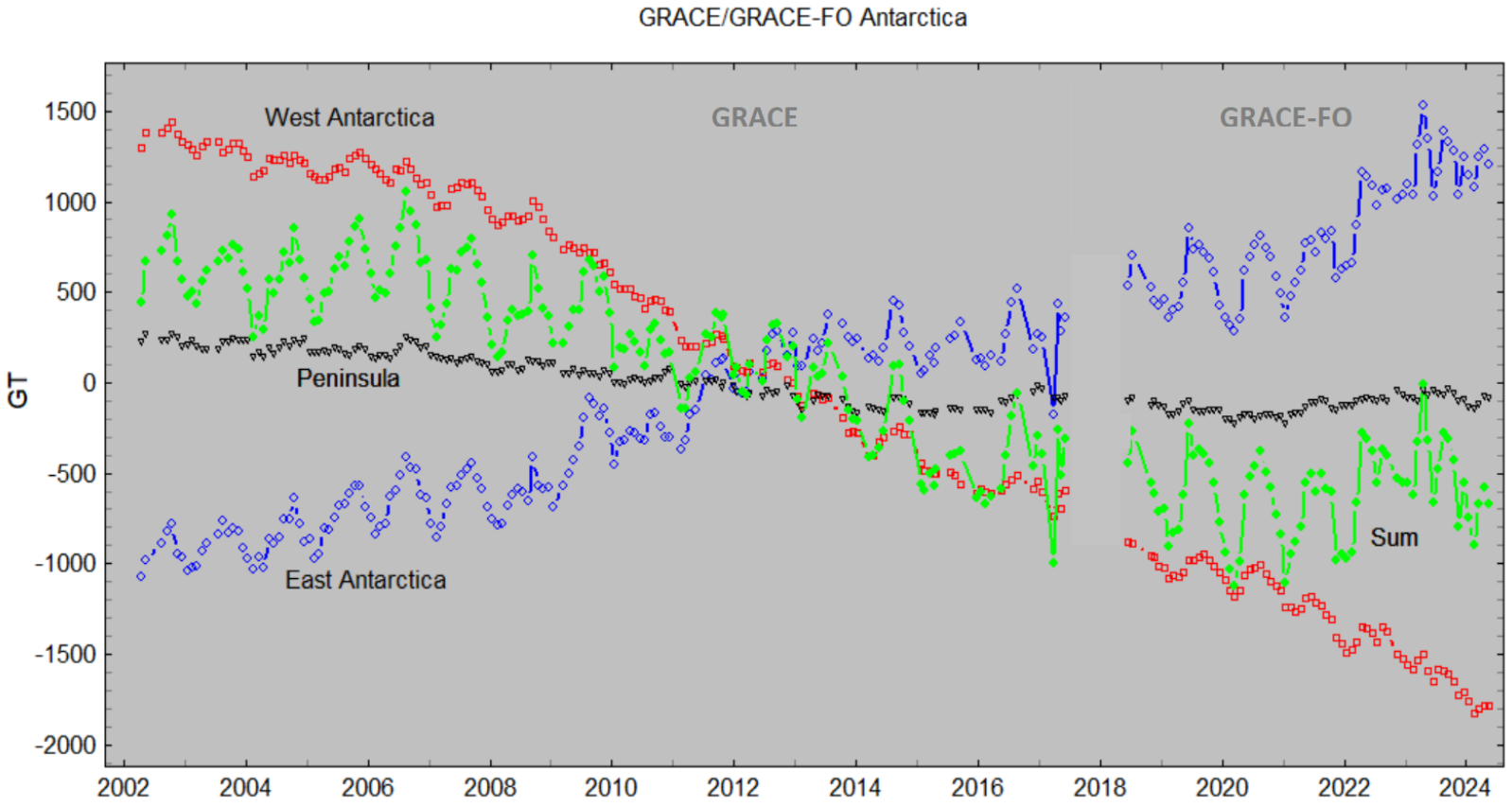


(Rodell, NASA-GSFC)

Latest GRACE / GRACE-FO results – Antarctica

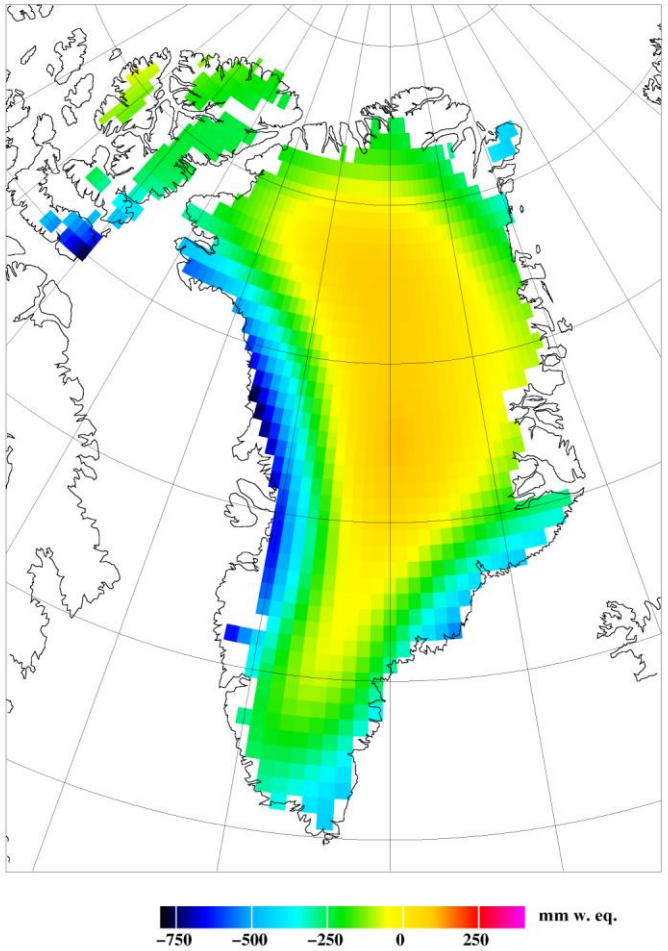
231 monthly epochs, CSR release 6.1, geocenter model, C_{20}/C_{30} from SLR, GIA model P. Whitehouse

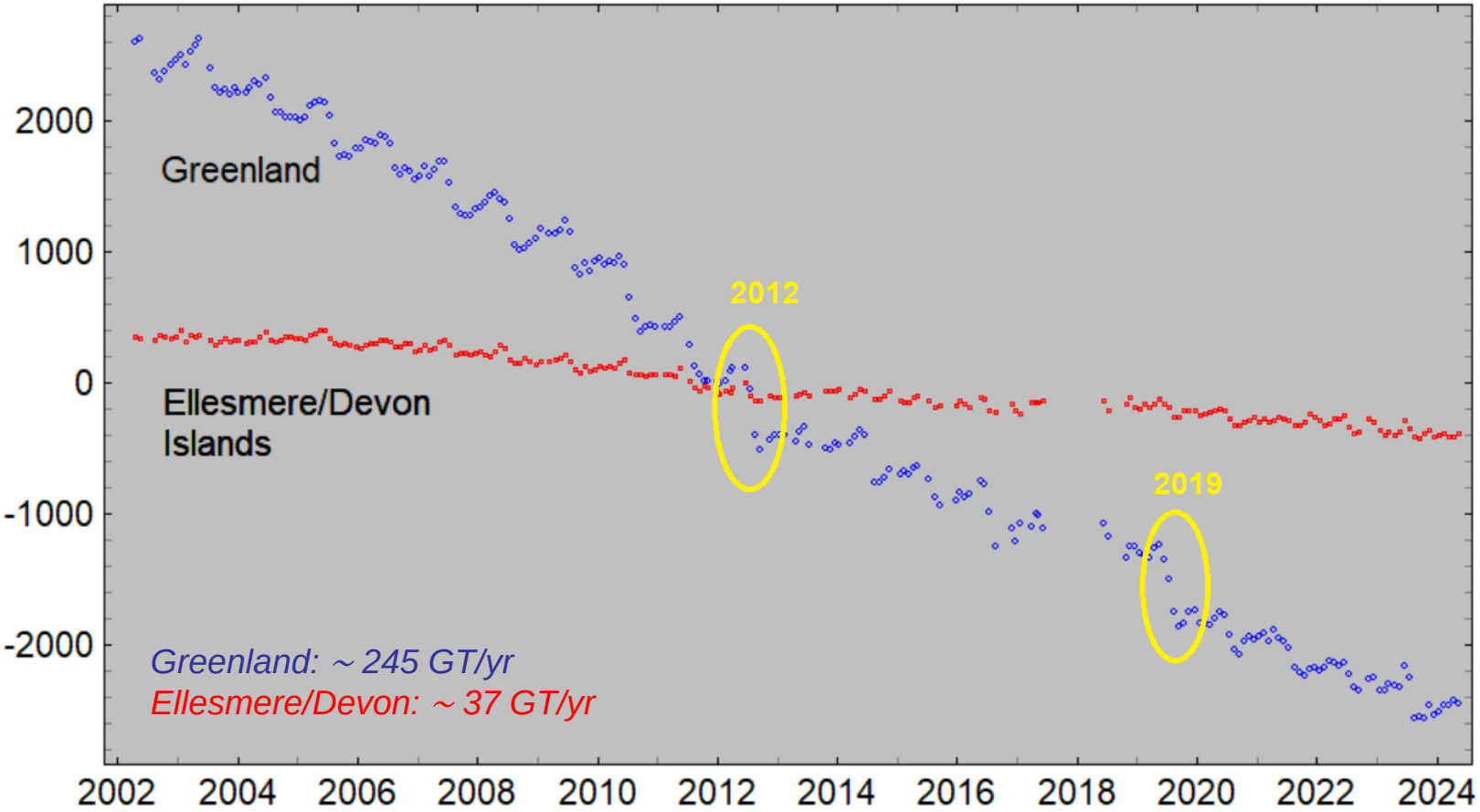




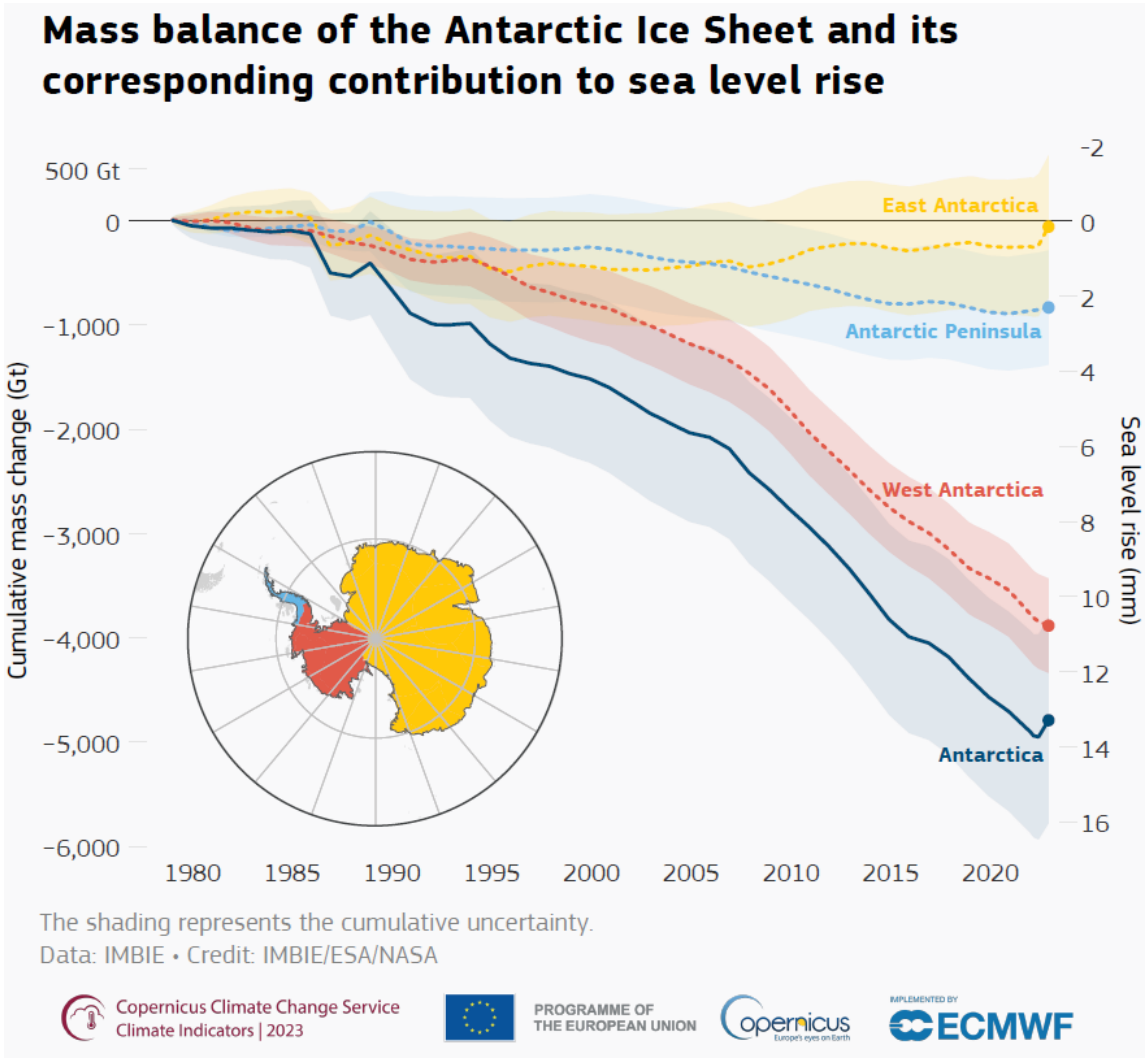
East Antarctica ~ 98 GT/yr, West Antarctica ~ -154 GT/yr
Antarctic Peninsula ~ -154 GT/yr, ***Total: ~ - 74 GT/yr***

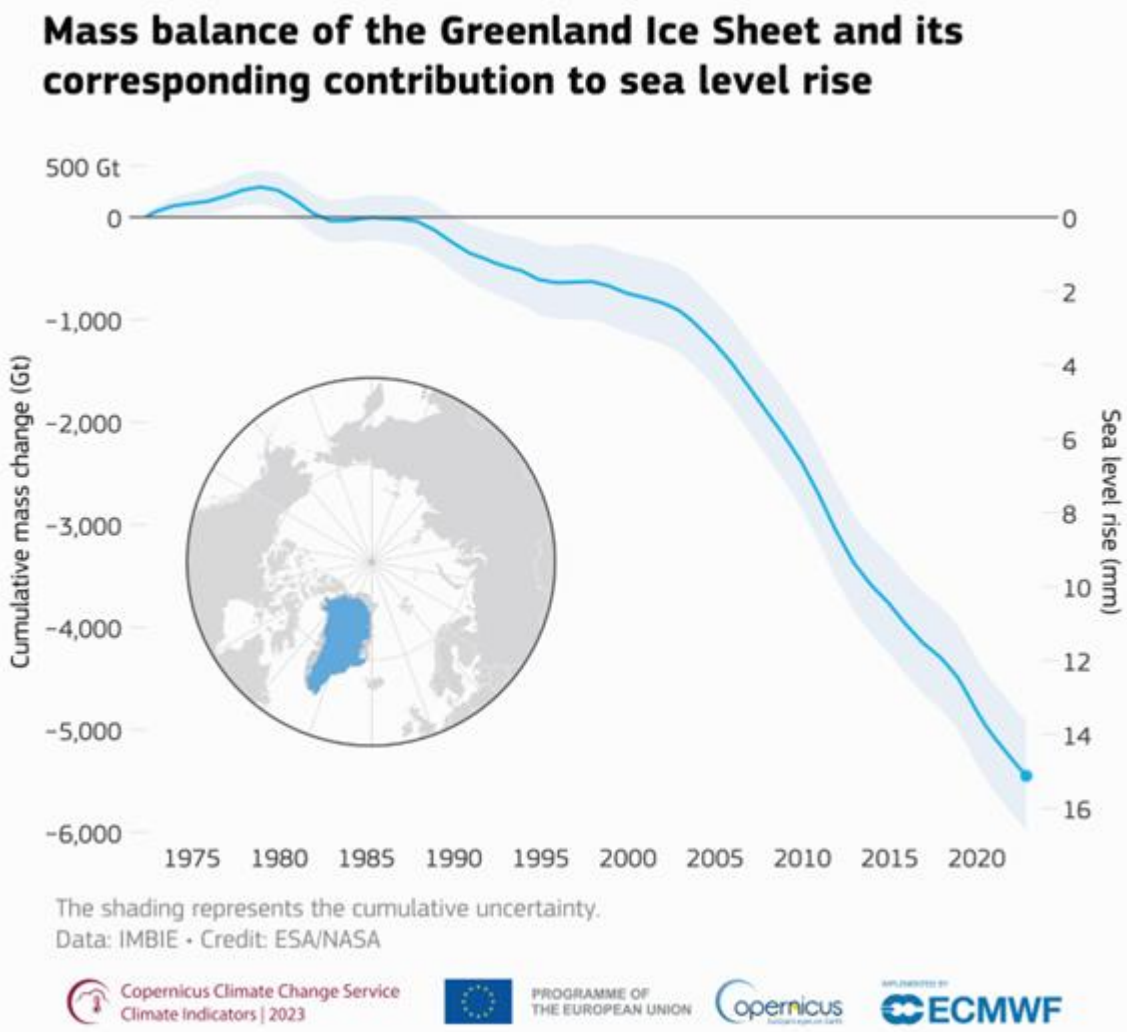
Latest GRACE / GRACE-FO results – Greenland – with record ice melt years





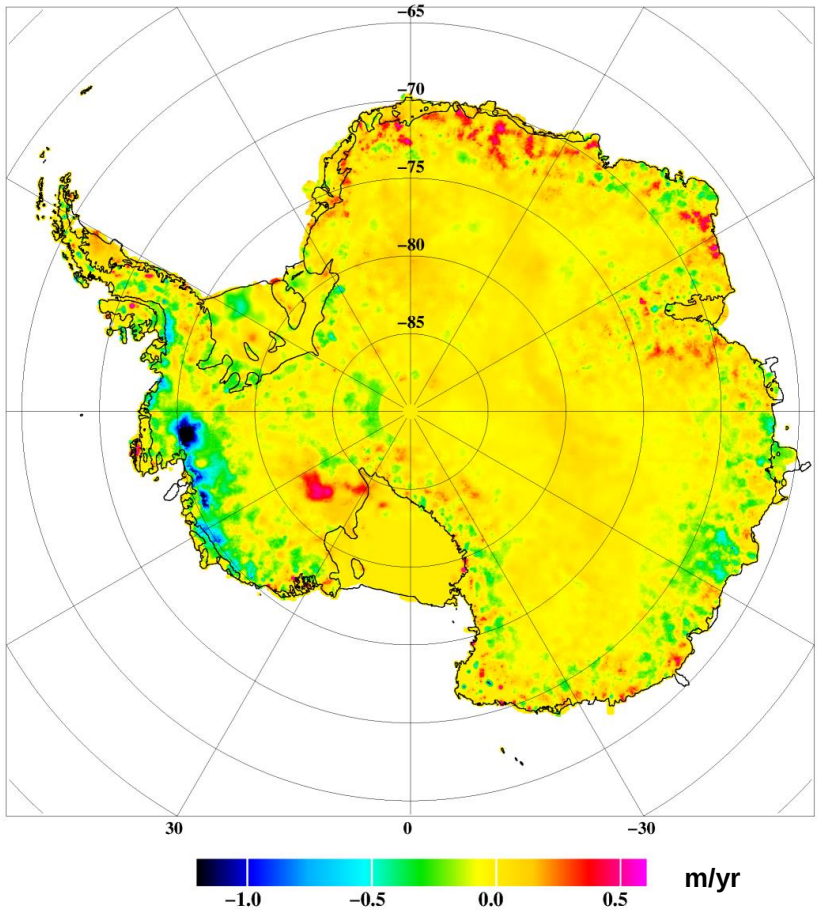
Going back in time – early space missions and in-situ data (IMBIE)



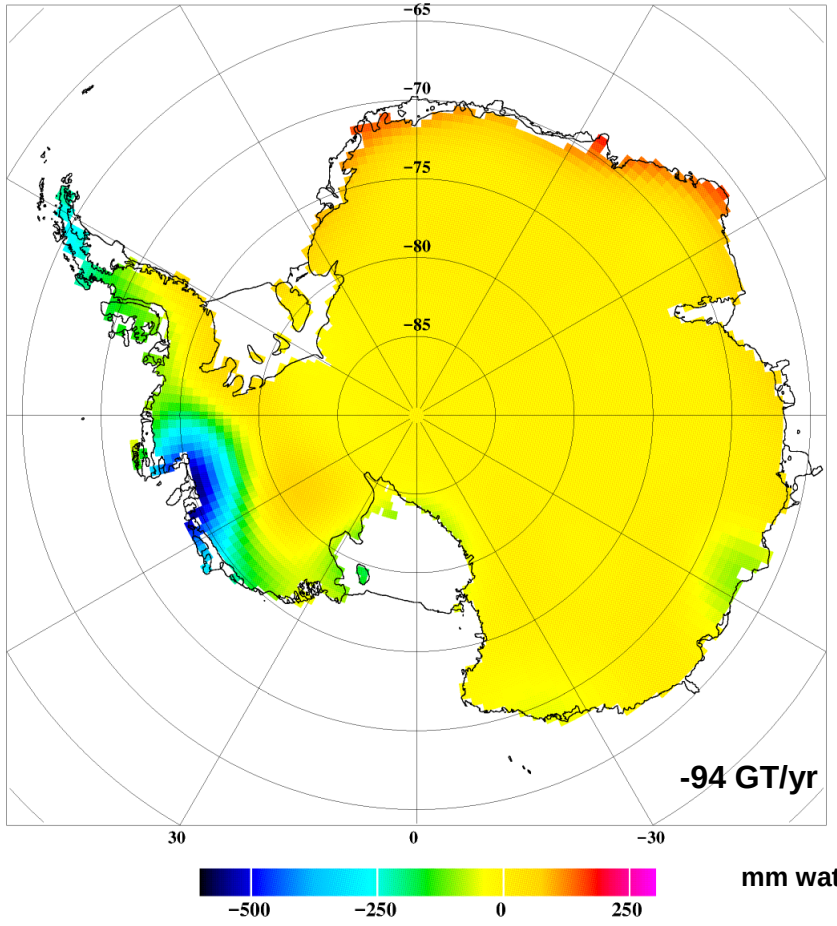


Increasing the spatial resolution: Combining space methods

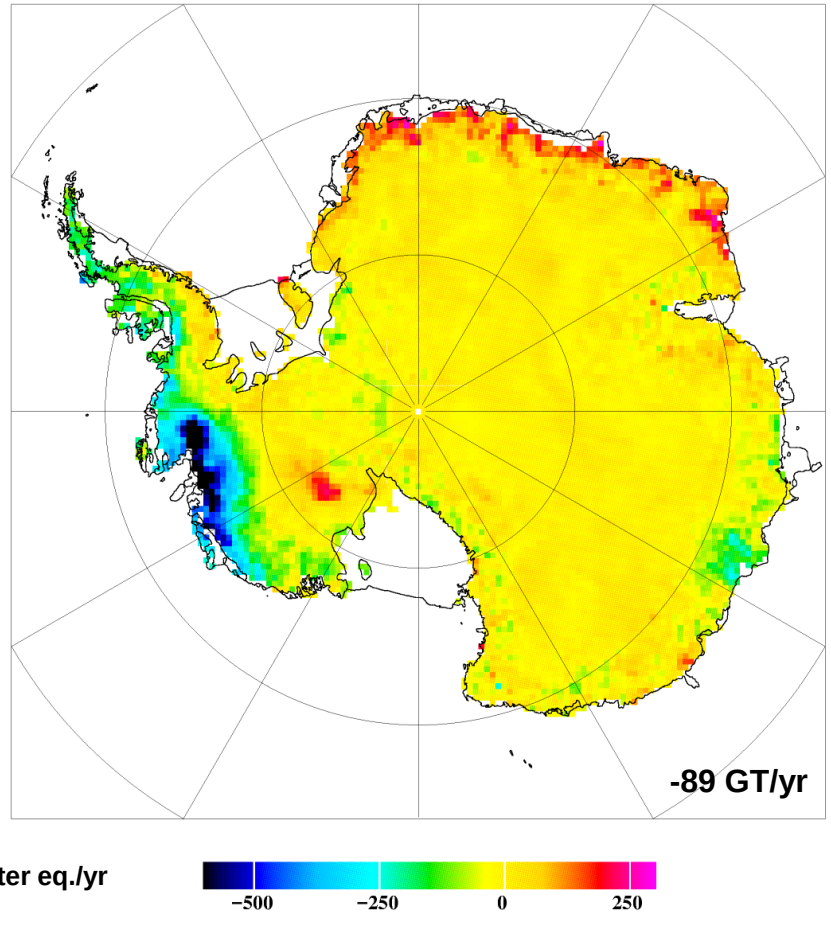
CryoSat 2010-16: 5 km res dh/dt (stacking)



GRACE-only inversion 2010-16 (CSR R6, Geruo GIA)

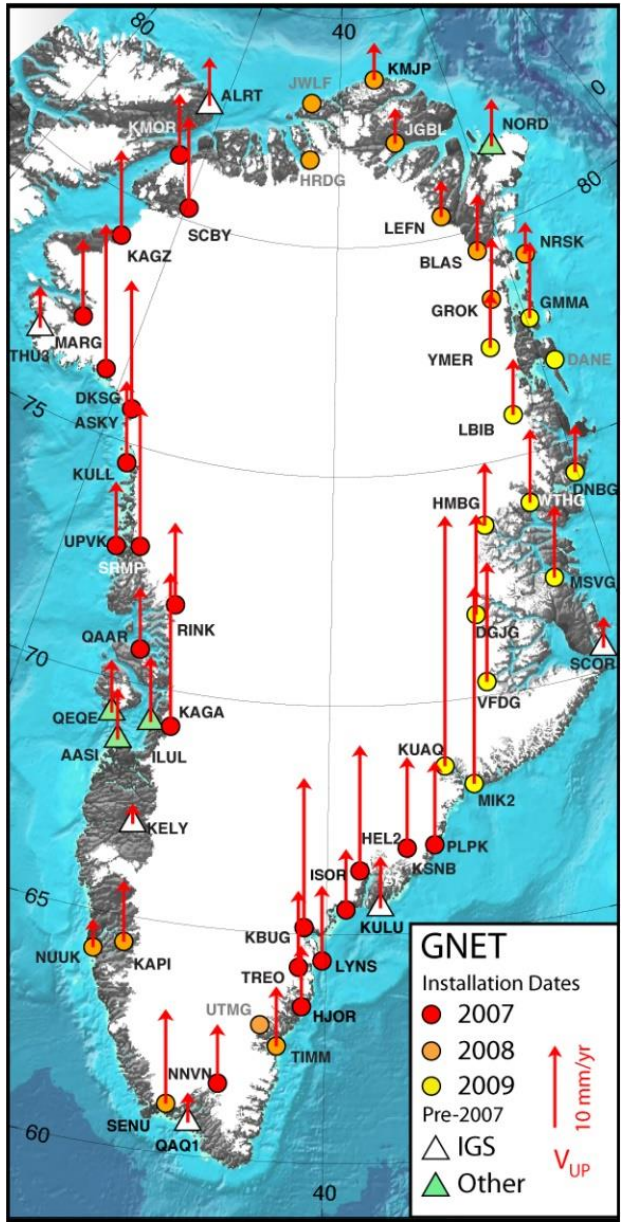


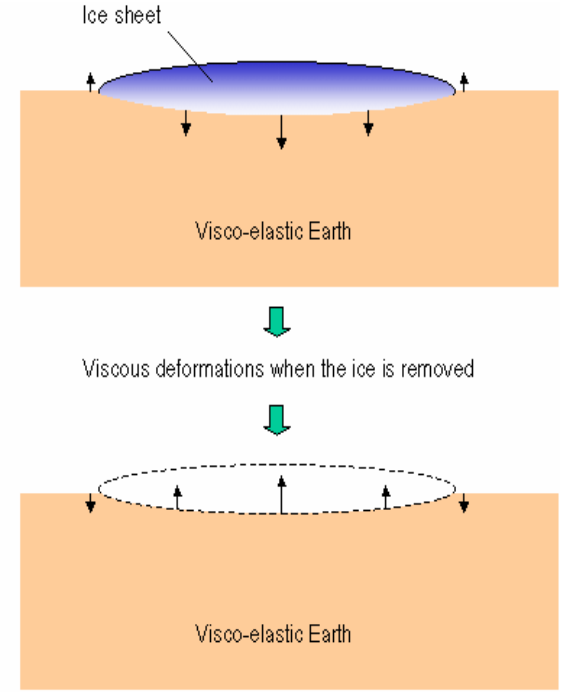
Joint inversion GRACE + CryoSat

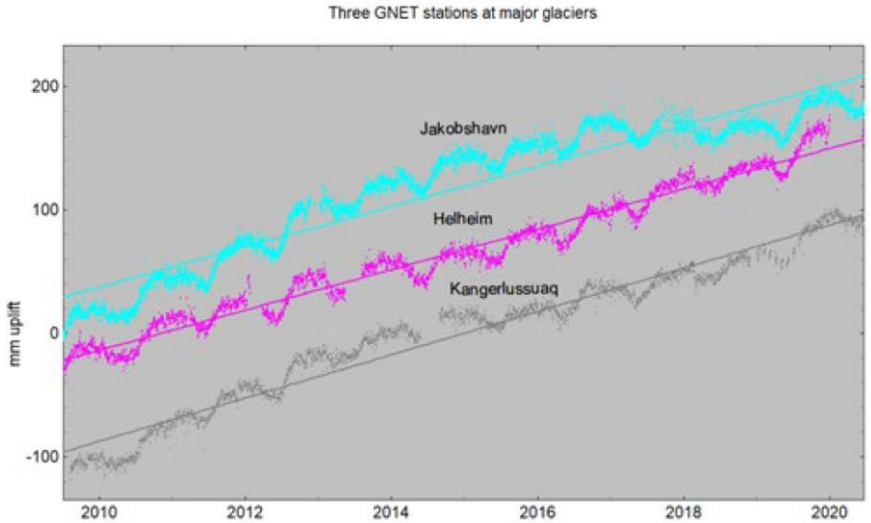


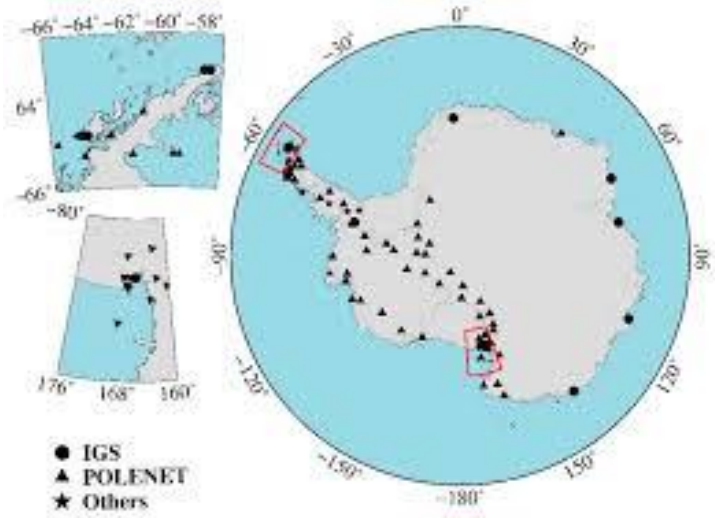
mm water eq./yr

GNSS land uplift – in-situ metworks for monitoring ice sheets









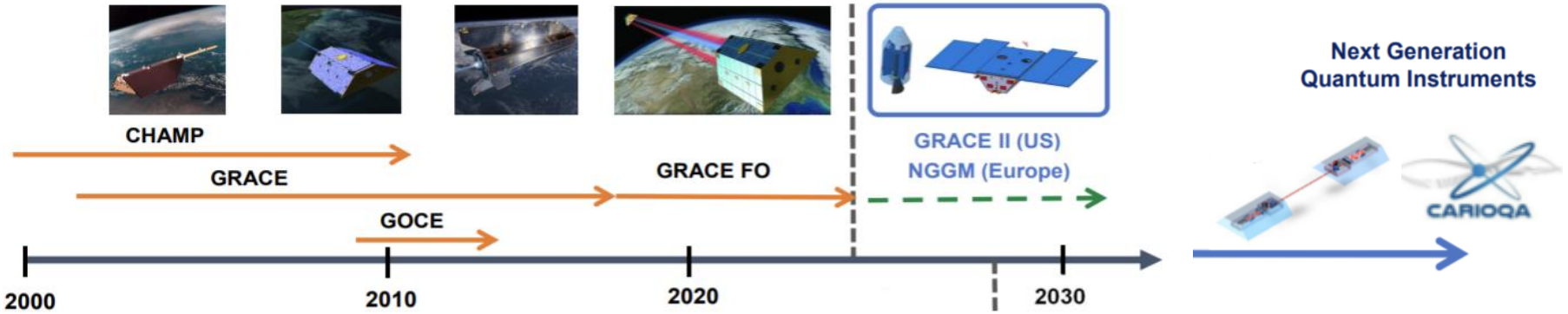
Summary

- Space based monitoring of the ice sheets efficient – *give the "ground truth" for climate models*
- Icesheet monitoring show multi-year and decadal changes, and record melt summers (in Greenland)
- Antarctica melt decadal variations – *relatively modest melt rates (yet)*

New missions help ice sheet monitoring: CRISTAL, Sentinels NG. NISAR, HARMONY … + *RINGS*

Improved future gravity missions: higher accuracy and resolution

- NASA GRACE-C + ESA NGGM = MAGIC (double satellite pair, .. 2032?)
- EU/ESA and NASA/JPL – Cold Atoms Quantum Pathfinder missions … 2030?



Thanks for your attention

DTU/ONERA first quantum gravity survey, Greenland 2023