DUAL-CRYO | Workshop on Dual-Band Altimetry of the Cryosphere
Online (Webex) | 13-14 January 2021 | 14:00 - 17:30 GMT

Greenland ice sheet mass balance 1992-2020 from radar altimetry

Sebastian B. Simonsen[1], Valentina R. Barletta[1], William Colgan[2] and Louise Sandberg Sørensen[1]

[1]Technical University of Denmark, Lyngby, Denmark
[2]Geological Survey of Denmark and Greenland, Copenhagen, Denmark

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esa

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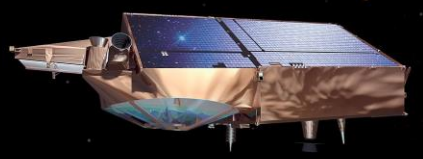
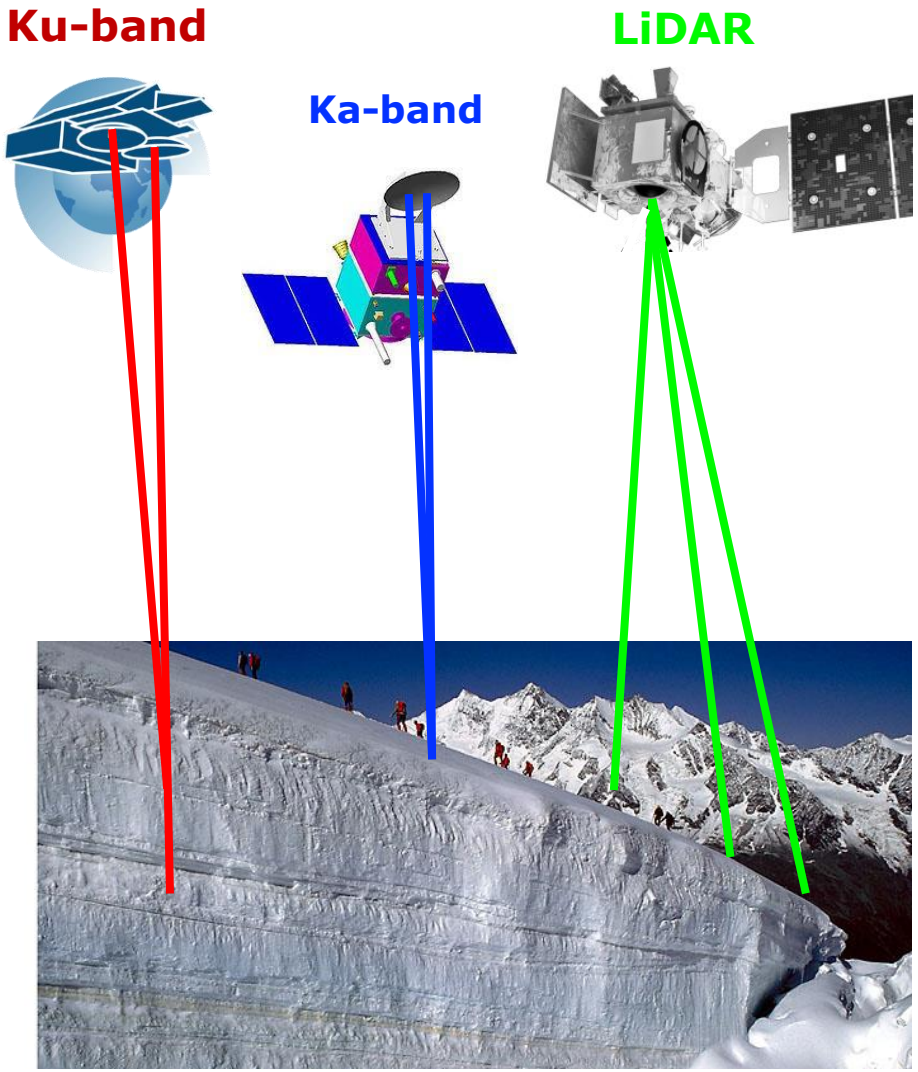
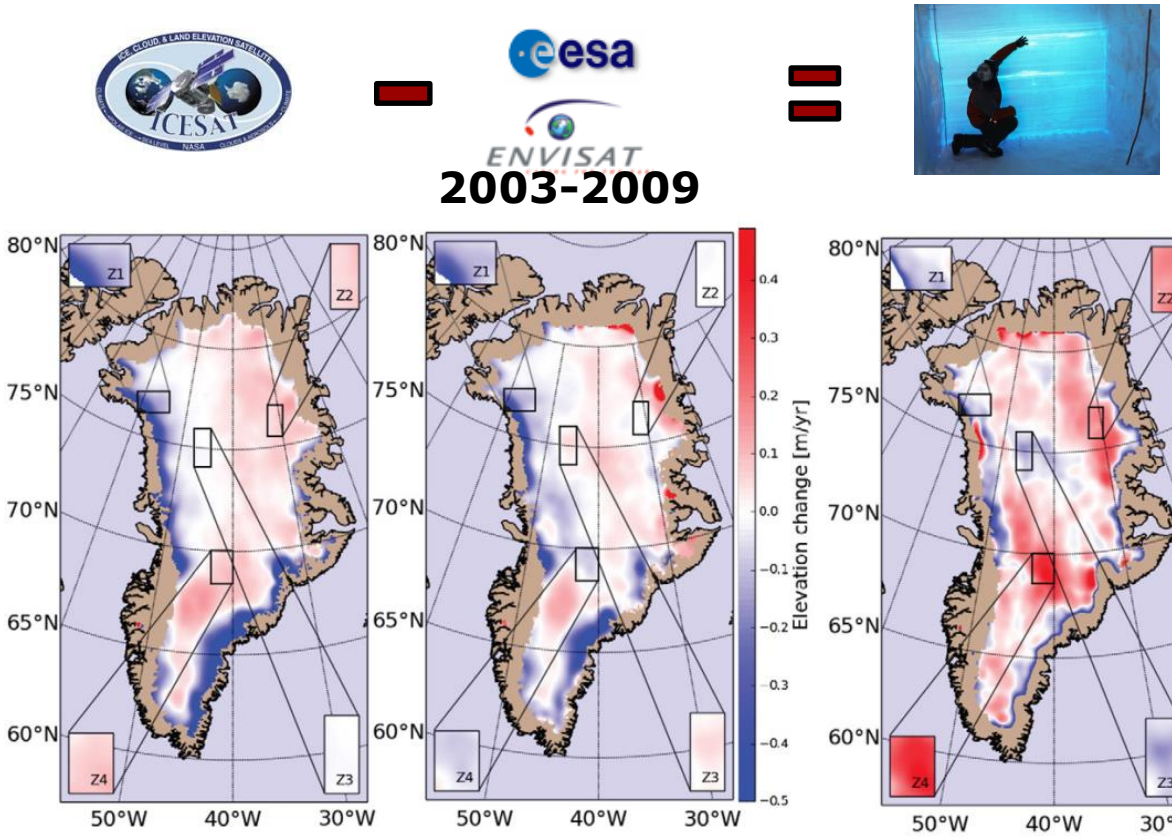
DTU Space
National Space Institute

DTU Technical University of Denmark



Greenland ice sheet altimetry





ICESat
~ -240 Gt/yr

Envisat
~ -177 Gt/yr

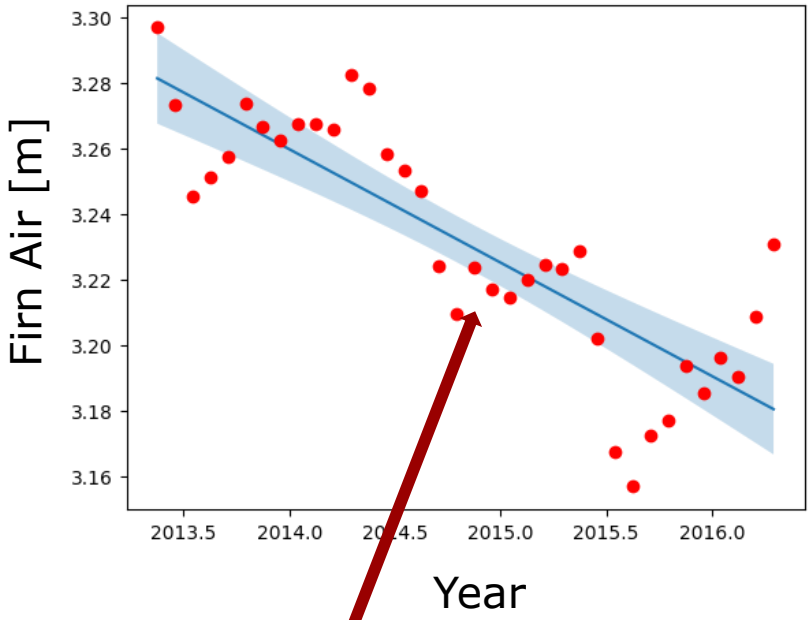
= "Penetration"
~63 Gt/yr

Envisat-derived elevation changes of the Greenland ice sheet, and a comparison with ICESat results in the accumulation area

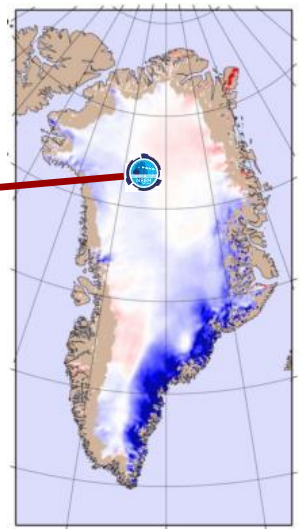
L.S. Sørensen, S.B. Simonsen,R. Meister, R. Forsberg, J.F. Levinsen, and T. Flament

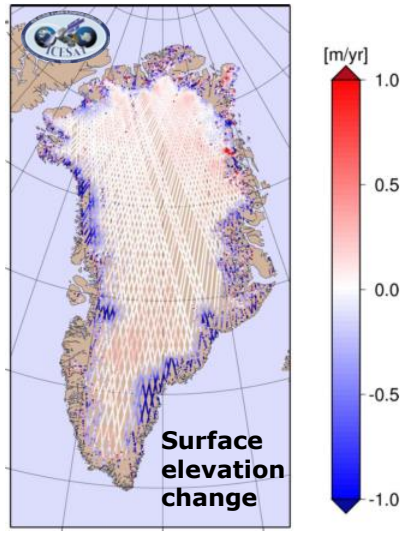
Remote Sensing of Environment (2015) (doi:10.1016/j.rse.2014.12.022)

Greenland ice sheet mass balance - Lidar altimetry



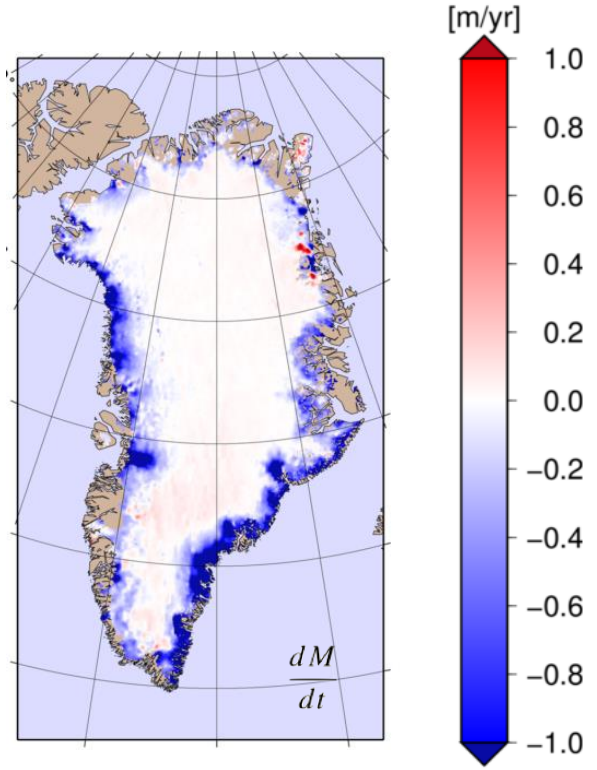
$$\frac{dH}{dt} = \frac{\dot{b}}{\rho} + w_c + w_{ice} + \frac{\dot{b}_m}{\rho} + w_{br} - u_s \frac{dS}{dx} - u_b \frac{dB}{dx}$$





$$\frac{dM}{dt} = \frac{dH^{\text{ICESat}}_{\text{corrected}}}{dt}\tilde{\rho},$$

$$* \tilde{\rho} =$$



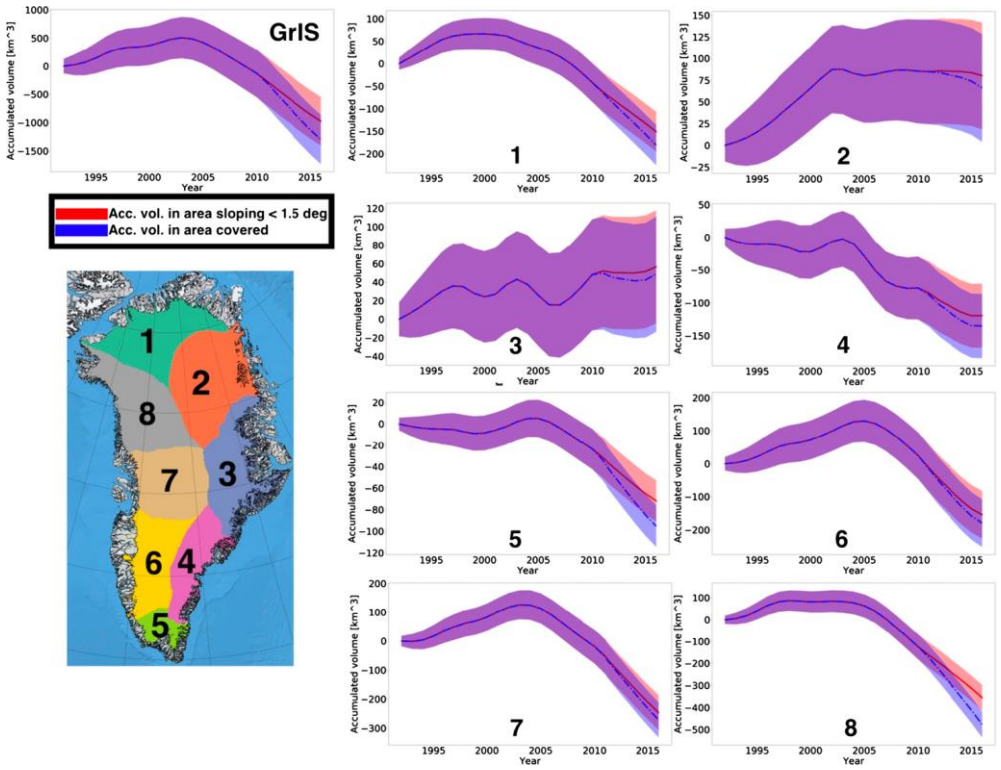
LS Sørensen, SB Simonsen, et al.

Mass balance of the Greenland ice sheet (2003–2008) from ICESat data – the impact of interpolation, sampling and firn density

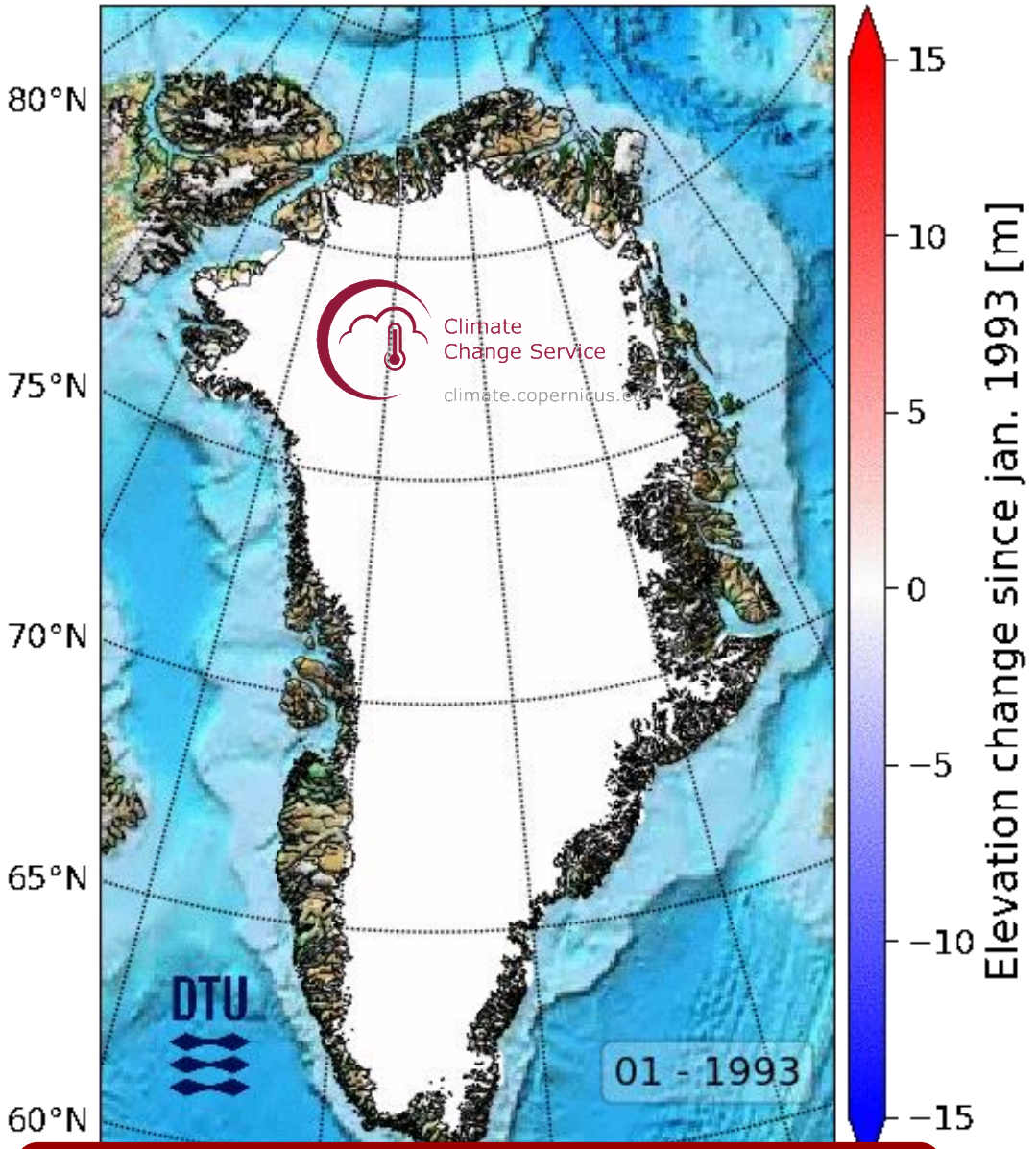
The Cryosphere (2011) doi: 10.5194/tc-5-173-2011

25+ years of Greenland Ice Sheet elevation change - Elevation Change

ice sheets greenland cci



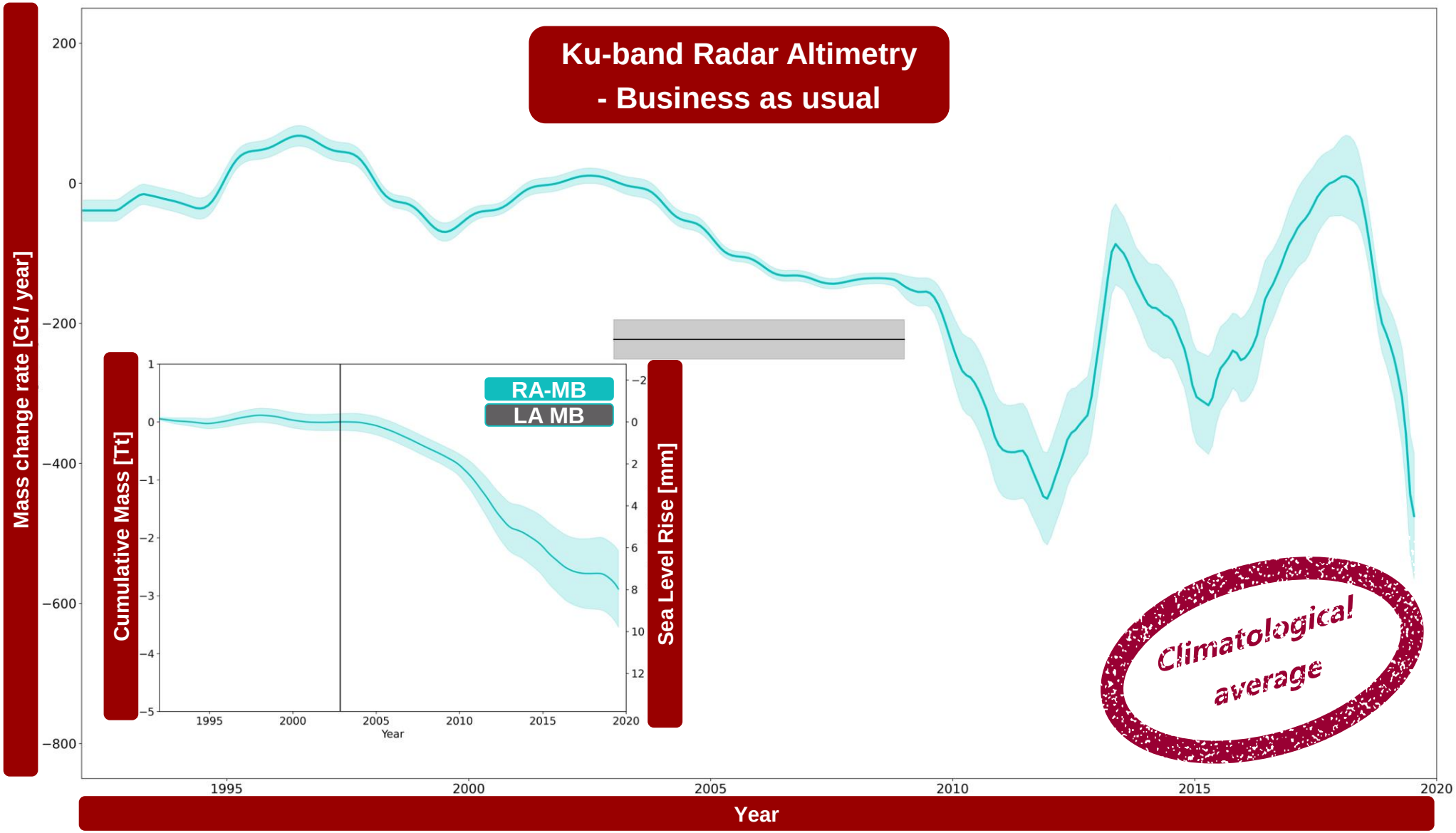
LS Sørensen, SB Simonsen, R Forsberg, K Khvorostovsky, R Meister and ME. Engdahl (2018) **25 years of elevation changes of the Greenland Ice Sheet from ERS, Envisat, and CryoSat-2 radar altimetry** Earth and Planetary Science Letters, Vol. 495, doi: 10.1016/j.epsl.2018.05.015



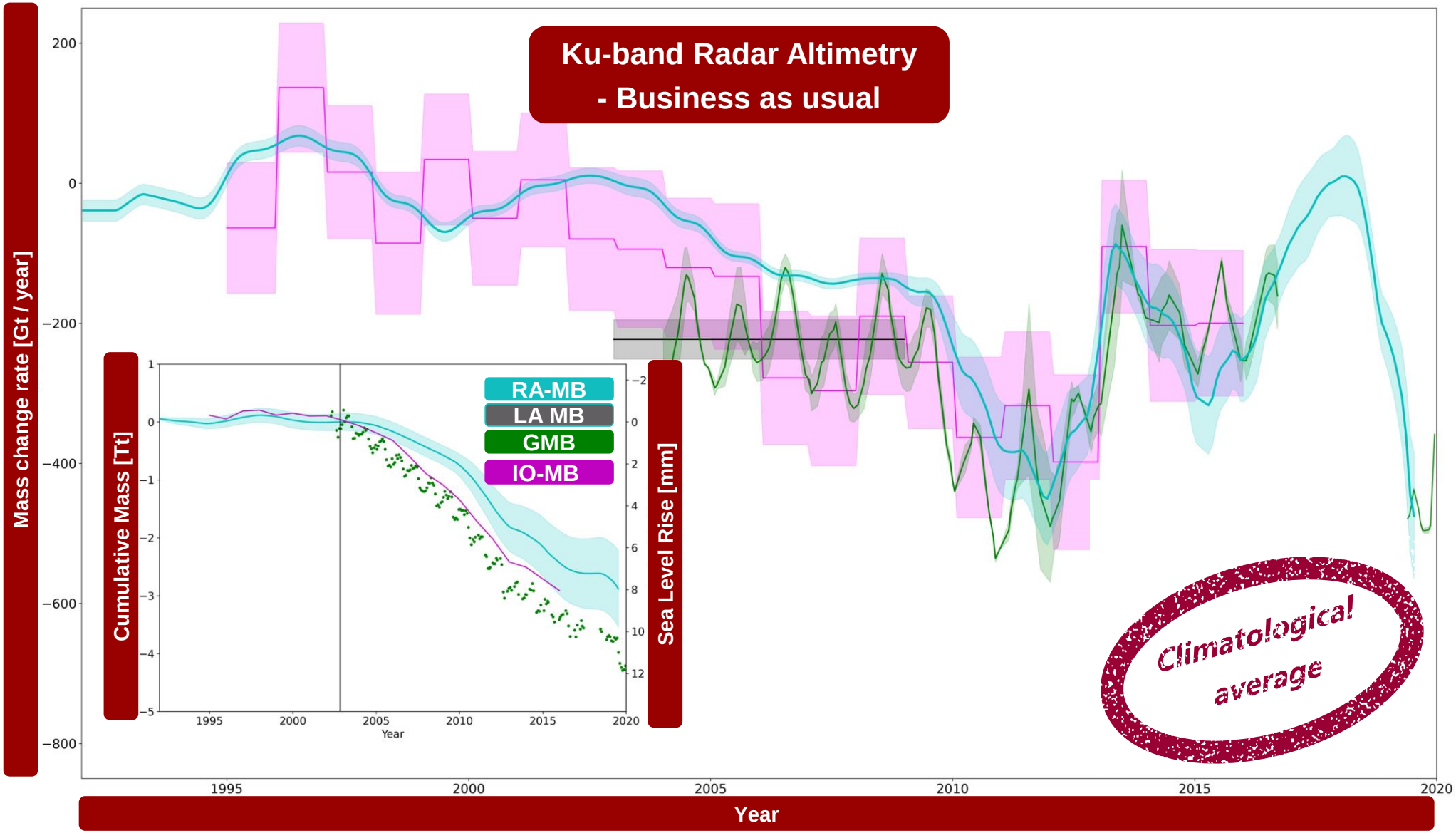
Available at https://cds.climate.copernicus.eu/

DOI: 10.24381/cds.056d0df7

Greenland ice sheet mass balance - Radar altimetry

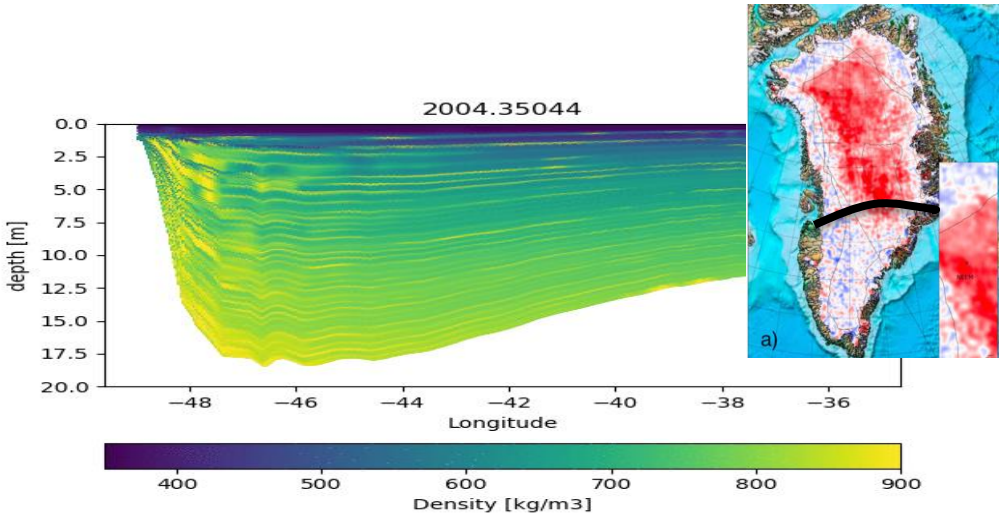


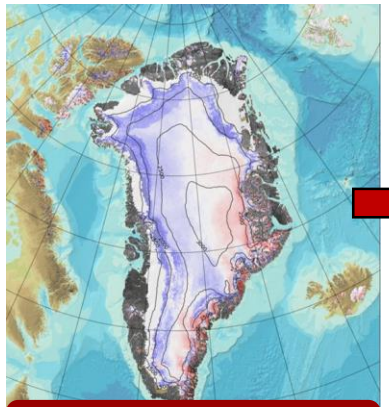
Greenland ice sheet mass balance - Radar altimetry



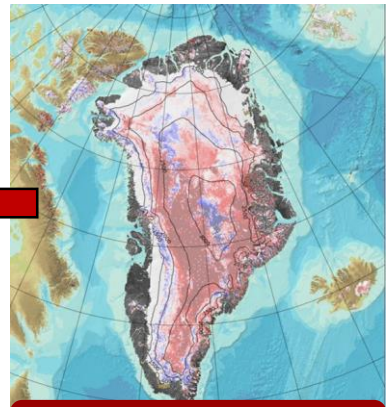
Greenland ice sheet mass balance - Surface penetration challenges

Firn modelling approach



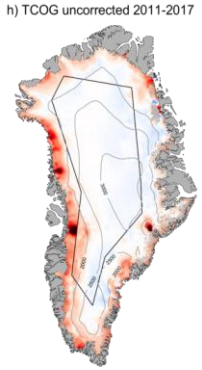


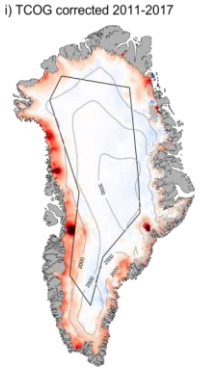
Firn compaction

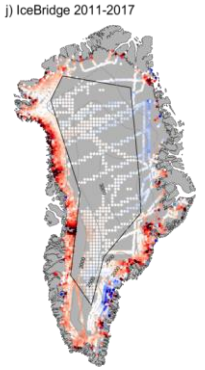


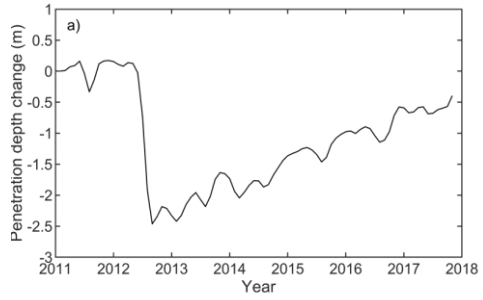
Radar scattering

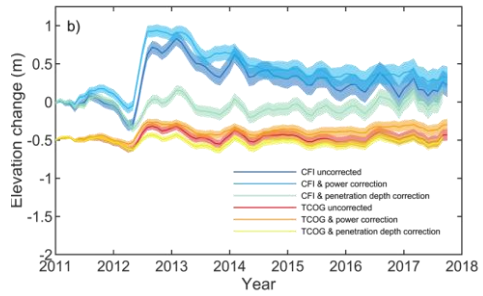
Radar processing approach











$$P_R(t) = P_T(t) * P_{FS}(t) * P_D(t)$$

Pulse received at the antenna

Transmitted pulse shape

Flat surface impulse response

Distribution of Bs-power with depth and surface roughness height

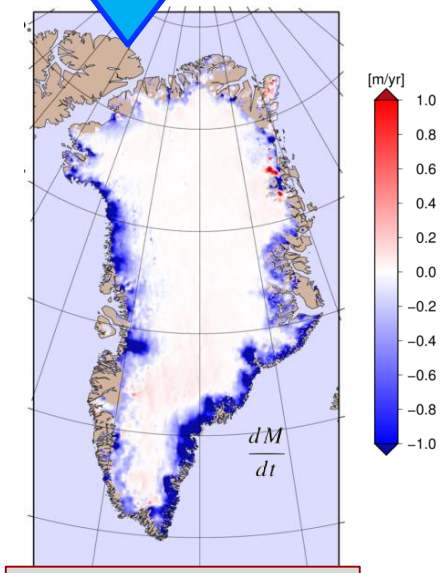
Compensating Changes in the Penetration Depth of Pulse-Limited Radar Altimetry Over the Greenland Ice Sheet

T Slater , A Shepherd, M McMillan, TWK Armitage , I Otosaka, and RJ Arthern.

IEEE 2019, DOI: 10.1109/tgrs.2019.2928232

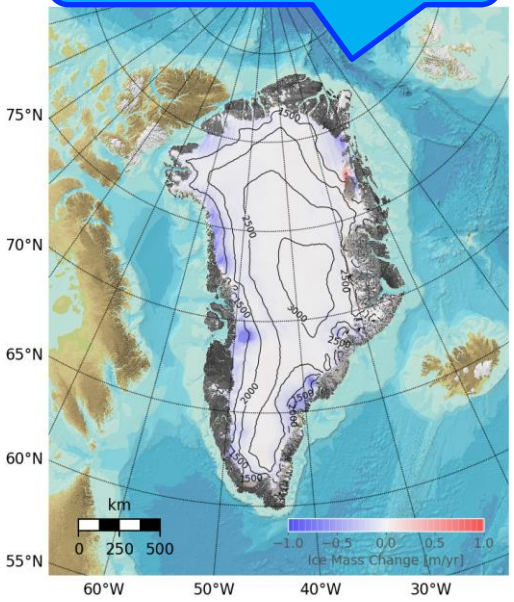
Greenland ice sheet mass balance
- Surface penetration challenges and an alternative correction approach.

We know the mass balance in the ICEsat-era



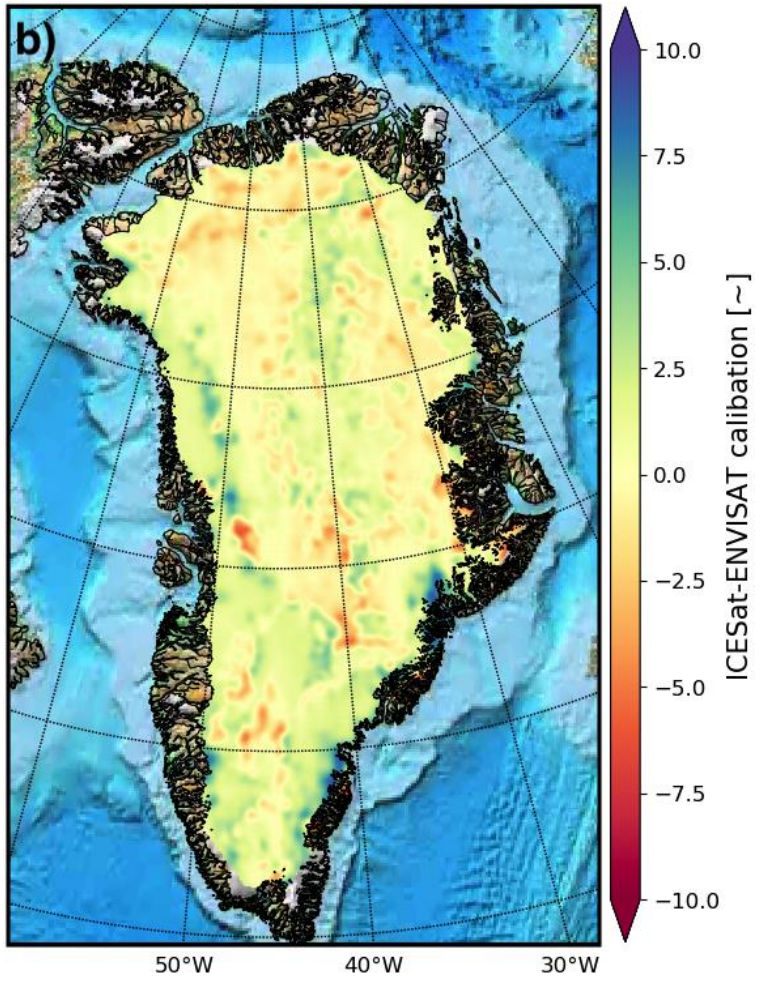
LS Sørensen, SB Simonsen, K Nielsen, P Lucas-Picher, G Spada, G Adalgeirsdottir, R Forsberg, R., and CS Hvidberg **Mass balance of the Greenland ice sheet (2003–2008) from ICESat data – the impact of interpolation, sampling and firn density** The Cryosphere (2011) doi: 10.5194/tc-5-173-2011

An initial guess for the Radar based MB, by simple snow/ice approximations



$$ICE_{Scale} = \frac{Mass\ balance\ _{ICESat}}{Mass\ balance\ _{Radar}}$$

=

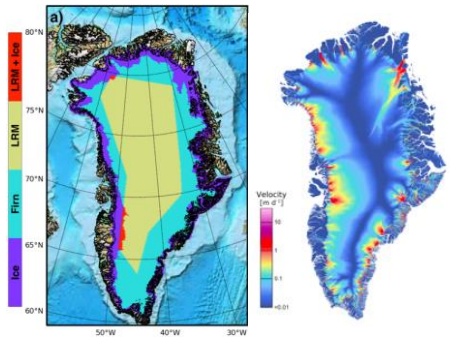


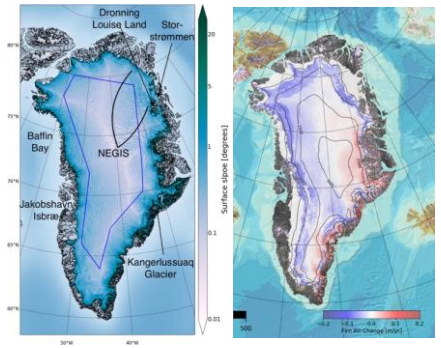
Greenland ice sheet mass balance

Ku-band Radar Altimetry
- Business as usual

Supervised machine learning

- Nearest Neighbors
- Decision Tree
- AdaBoost





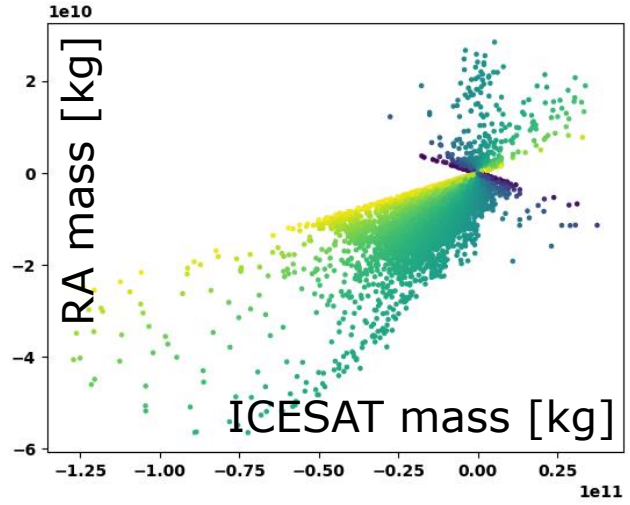
Mass change rate [Gt / year]

Cumulative Mass [Tt]

Sea Level Rise [mm]

RA-MB
LA MB
GMB
IO-MB

Year

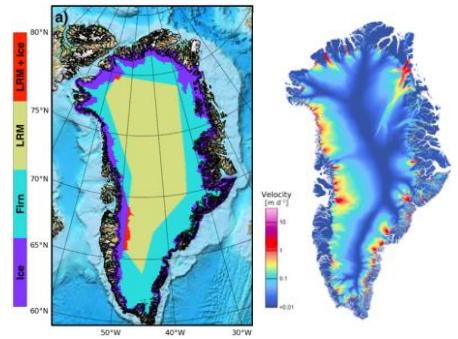


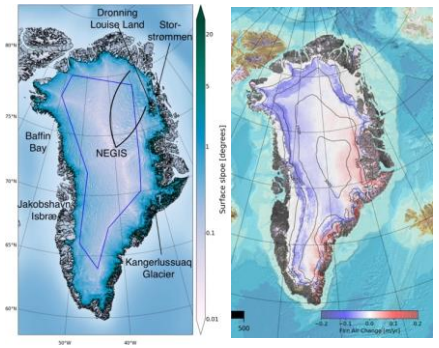
Greenland ice sheet mass balance

Ku-band Radar Altimetry
- Calibrated time series

Supervised machine learning

- Nearest Neighbors
- Decision Tree
- AdaBoost

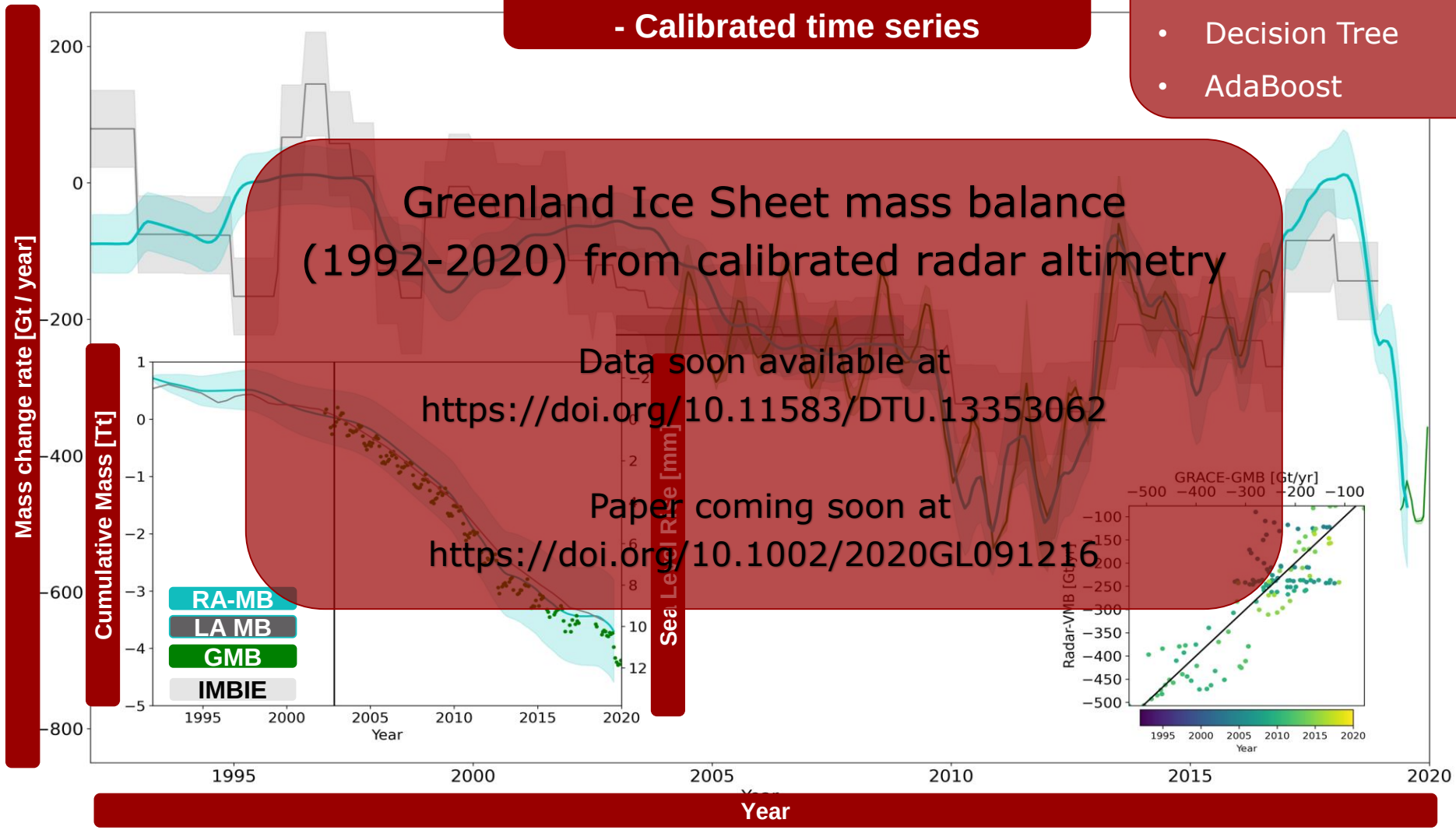




Greenland Ice Sheet mass balance (1992-2020) from calibrated radar altimetry

Data soon available at
https://doi.org/10.11583/DTU.13353062

Paper coming soon at
https://doi.org/10.1002/2020GL091216



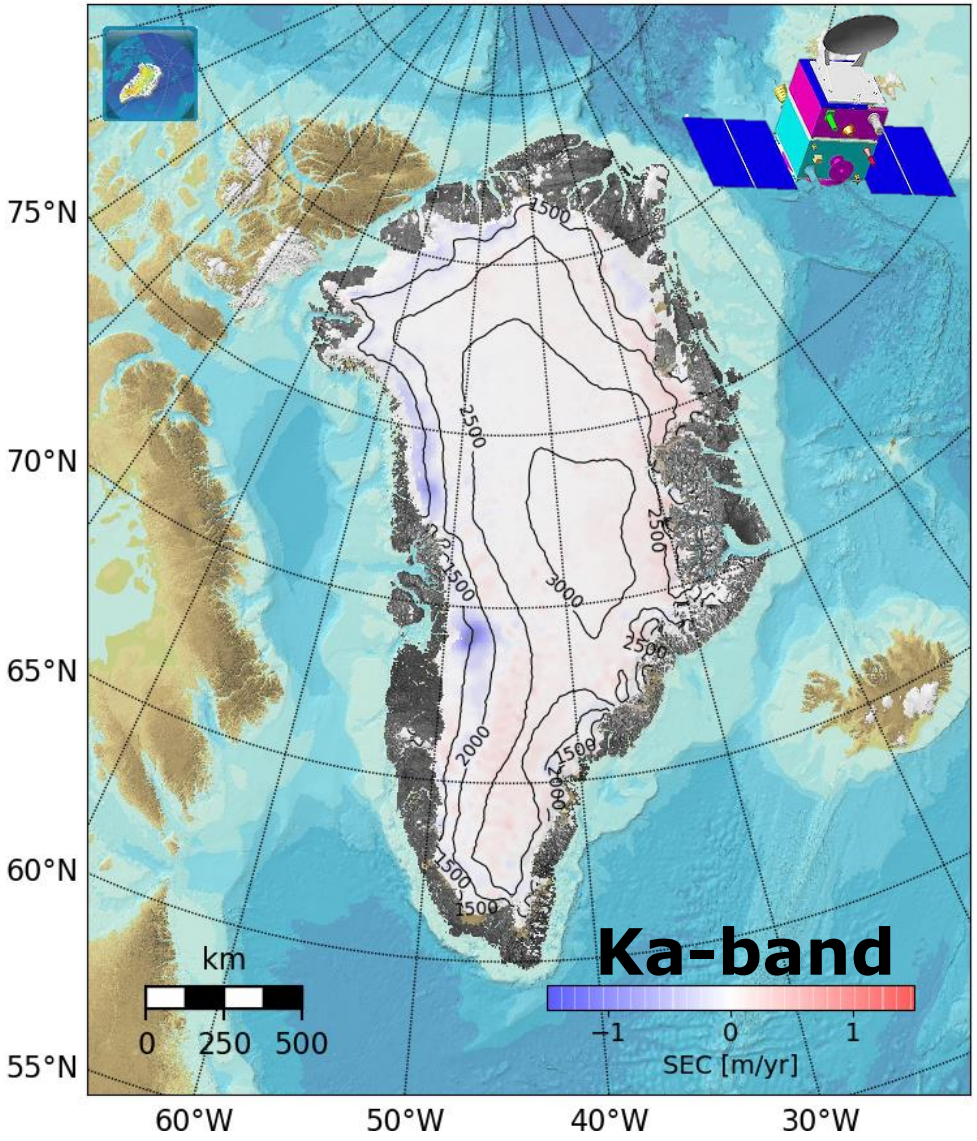
Greenland ice sheet mass balance from 1992- 2020:

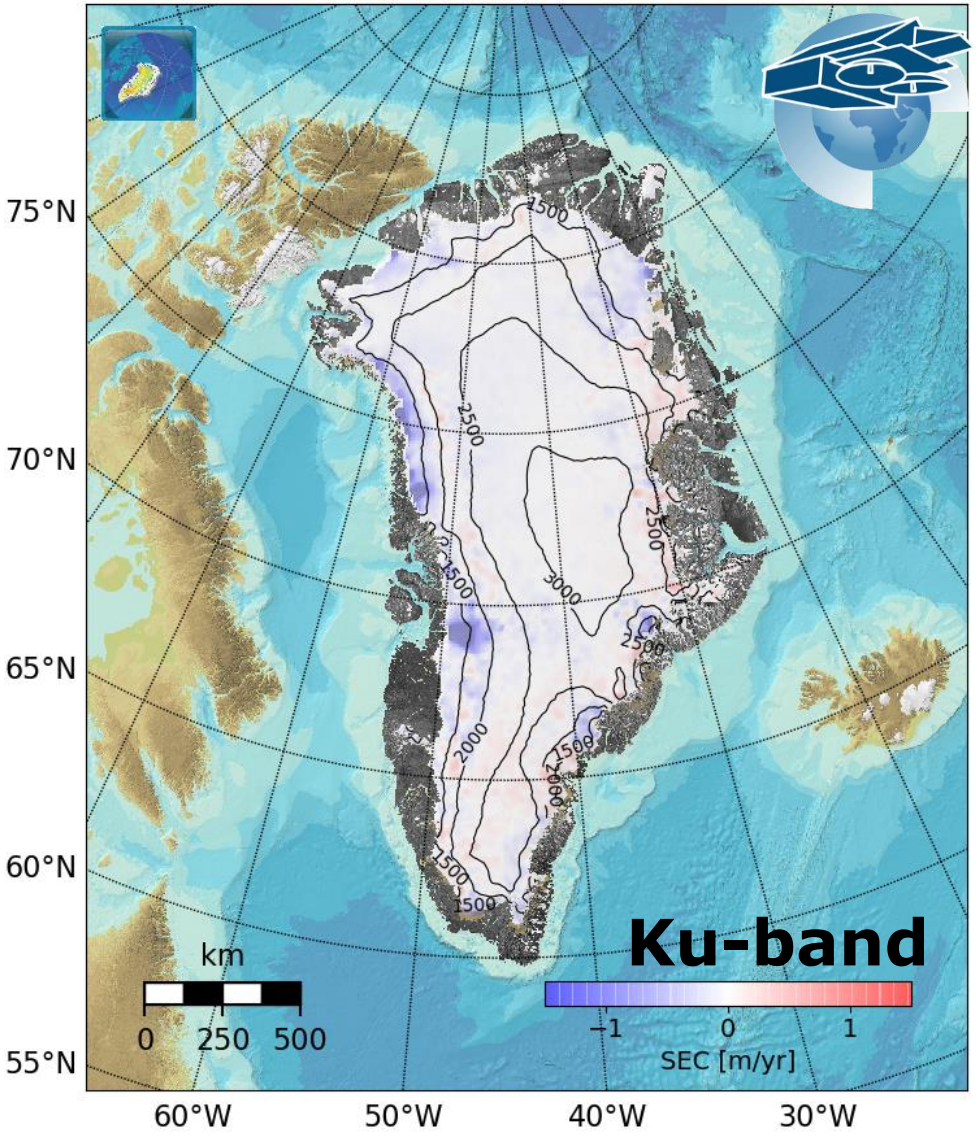
12.1±2.3 mm sea-level equivalent since 1992

More than 80% of this contribution occurring after 2003

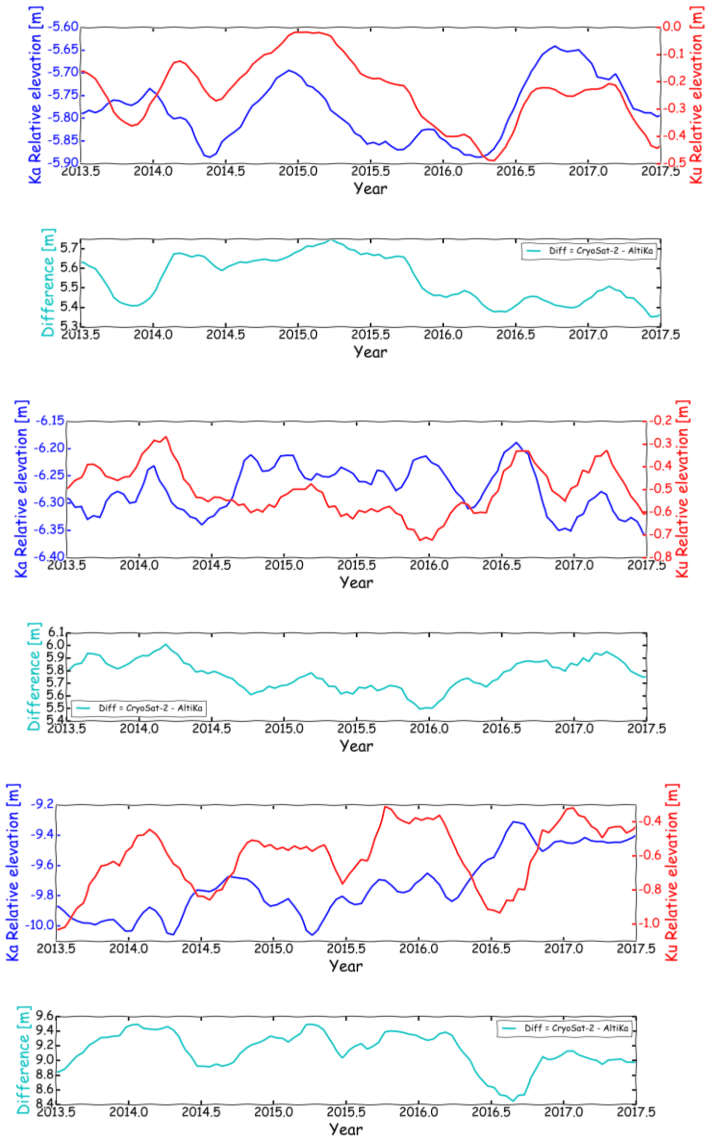
Greenland ice sheet mass balance - Radar altimetry

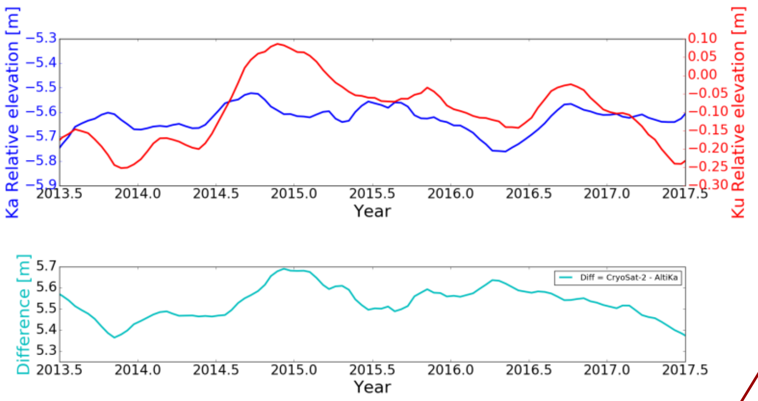
2013-2017

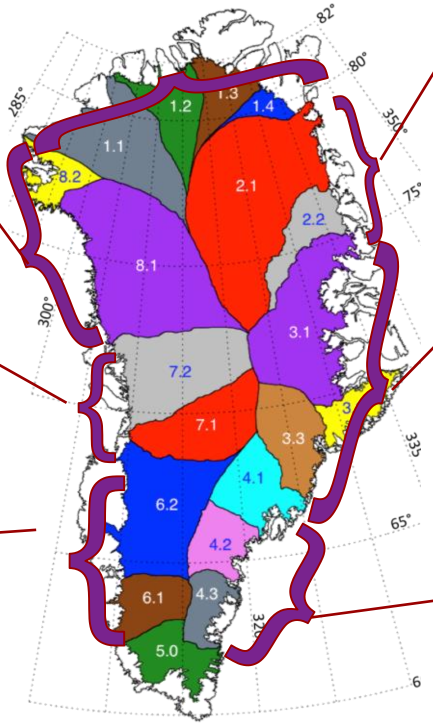


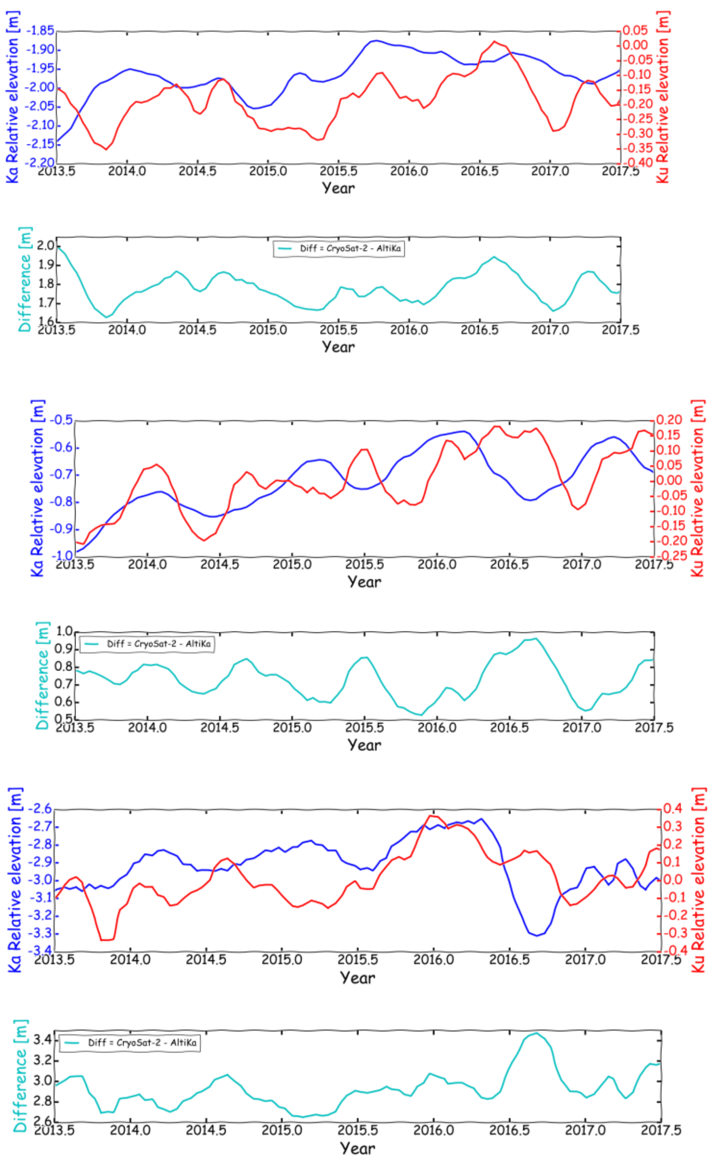


Greenland ice sheet mass balance - Radar altimetry

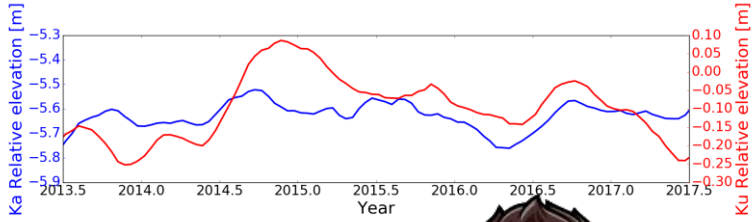


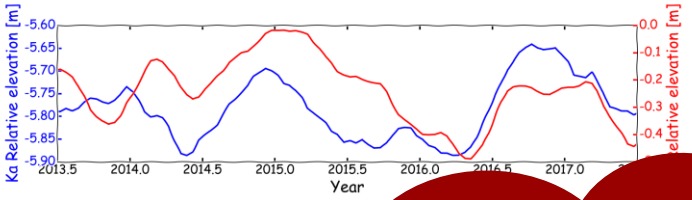


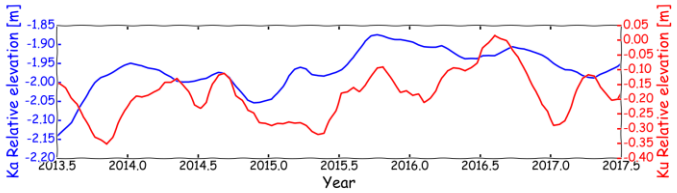


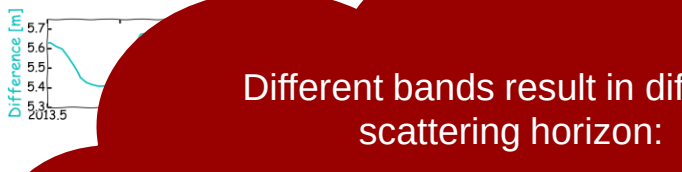


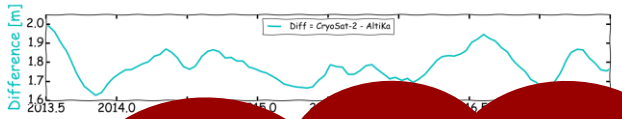
Greenland ice sheet mass balance - Radar altimetry

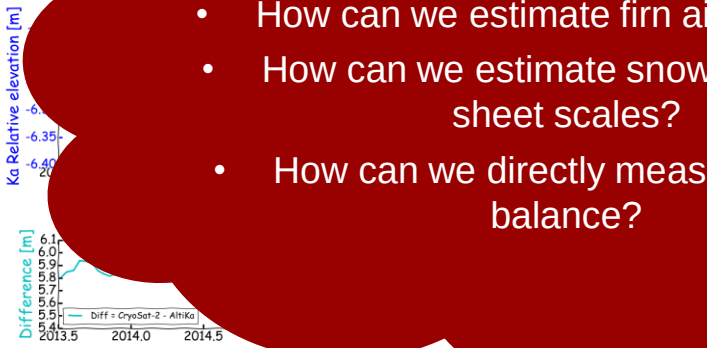


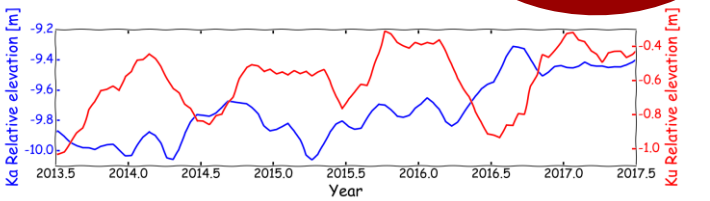


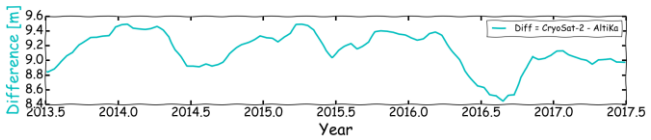


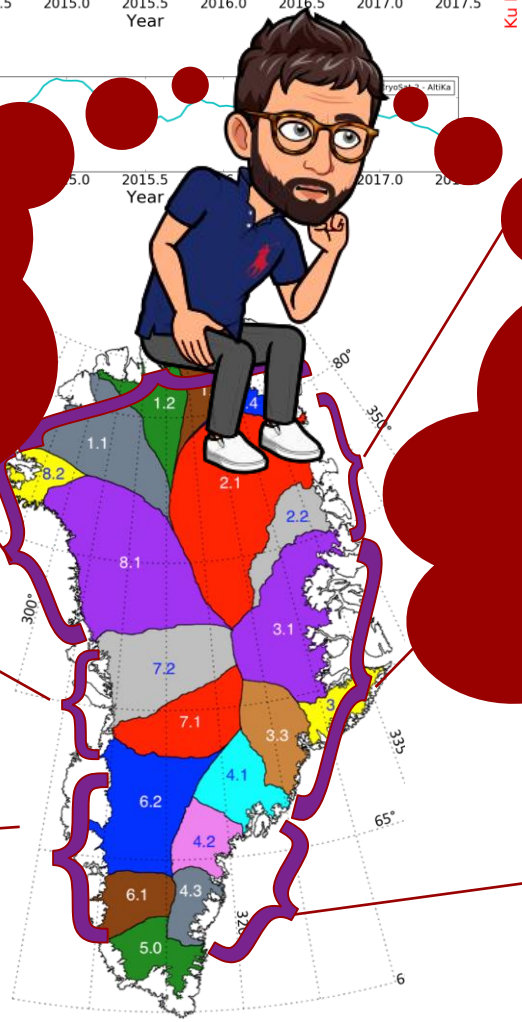


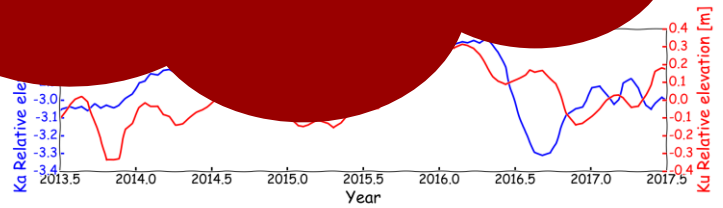


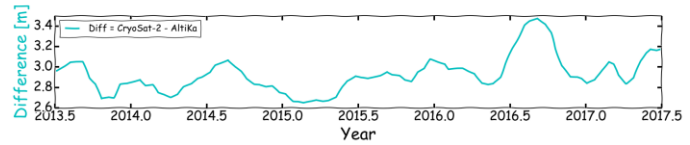












Different bands result in different scattering horizon:

- How can we estimate firn air content?
- How can we estimate snowfall on ice sheet scales?
- How can we directly measure mass balance?

Technical challenges for dual radar altimeters:

- How to ensure comparable footprint-size?
- How to ensure co-located measurements?
- How does the surface roughness effect the measurement?


DTU