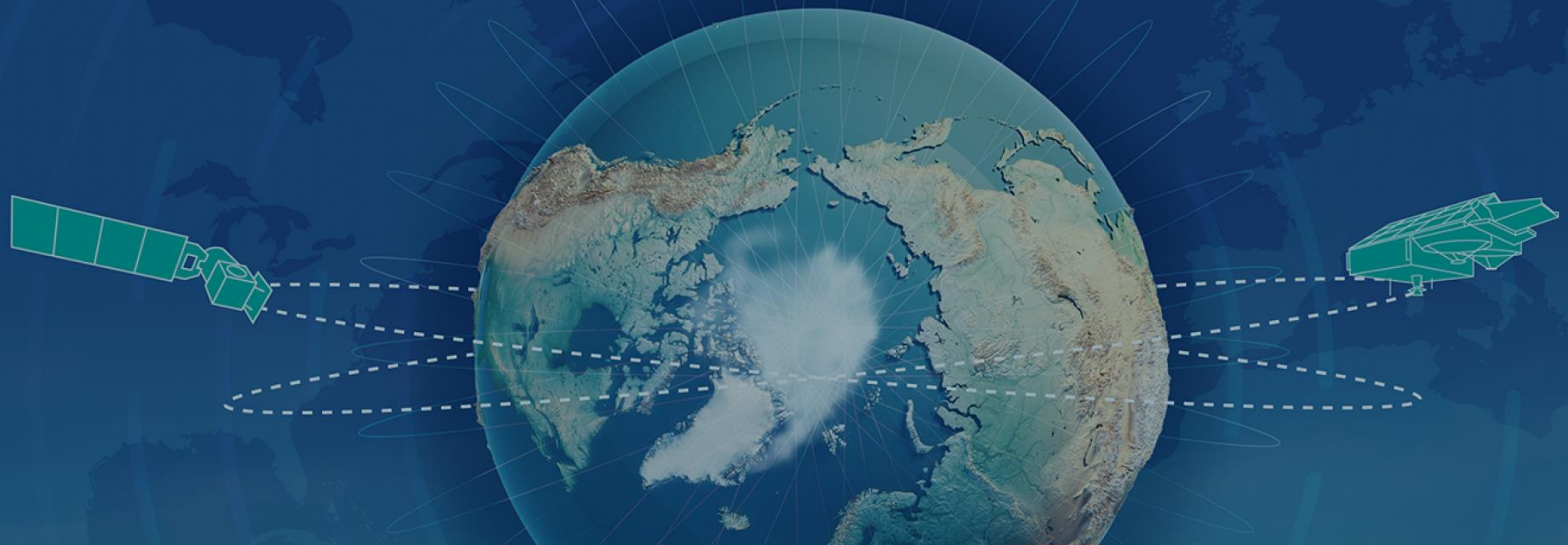

# Greenland Ice Sheet Elevation Change from Radar and Laser Altimetry


Nitin Ravinder[1,2], Andrew Shepherd[2], Inès Otosaka[2], Thomas Slater[2], Alan Muir[3], Lin Gilbert[3]

[1] University of Leeds

[2] Northumbria University

[3] University College London


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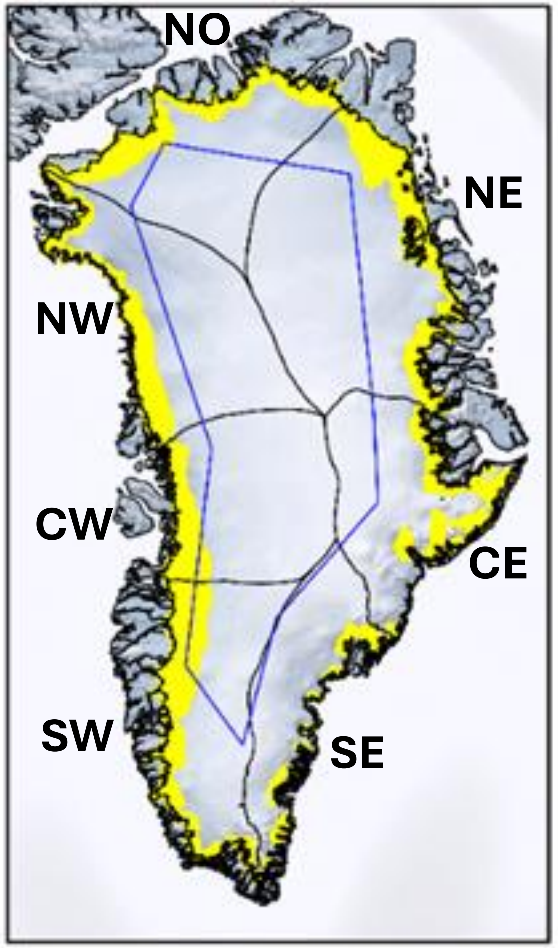
# Outline

- Introduction
- Method
- Sensitivity of Elevation Changes to Processing Parameters
- Agreement between CryoSat-2 and ICESat-2
- Elevation and Volume Changes
- Spatial - Temporal Variability of Differences
- Conclusions

# Introduction

- It is unclear if radar and laser altimeters resolve elevation changes differently

- Past comparisons have been across limited areas (McMillan et al., 2016; Otosaka et al., 2020; Simonsen and Sørensen, 2017; Slater et al., 2021; Sørensen et al., 2015, etc.)




Black: Ice sheet and basins (Mouginot and Rignot, 2019)
Yellow: Ablation zone (Slater et al., 2021)
Blue: CryoSat-2 Mode Mask

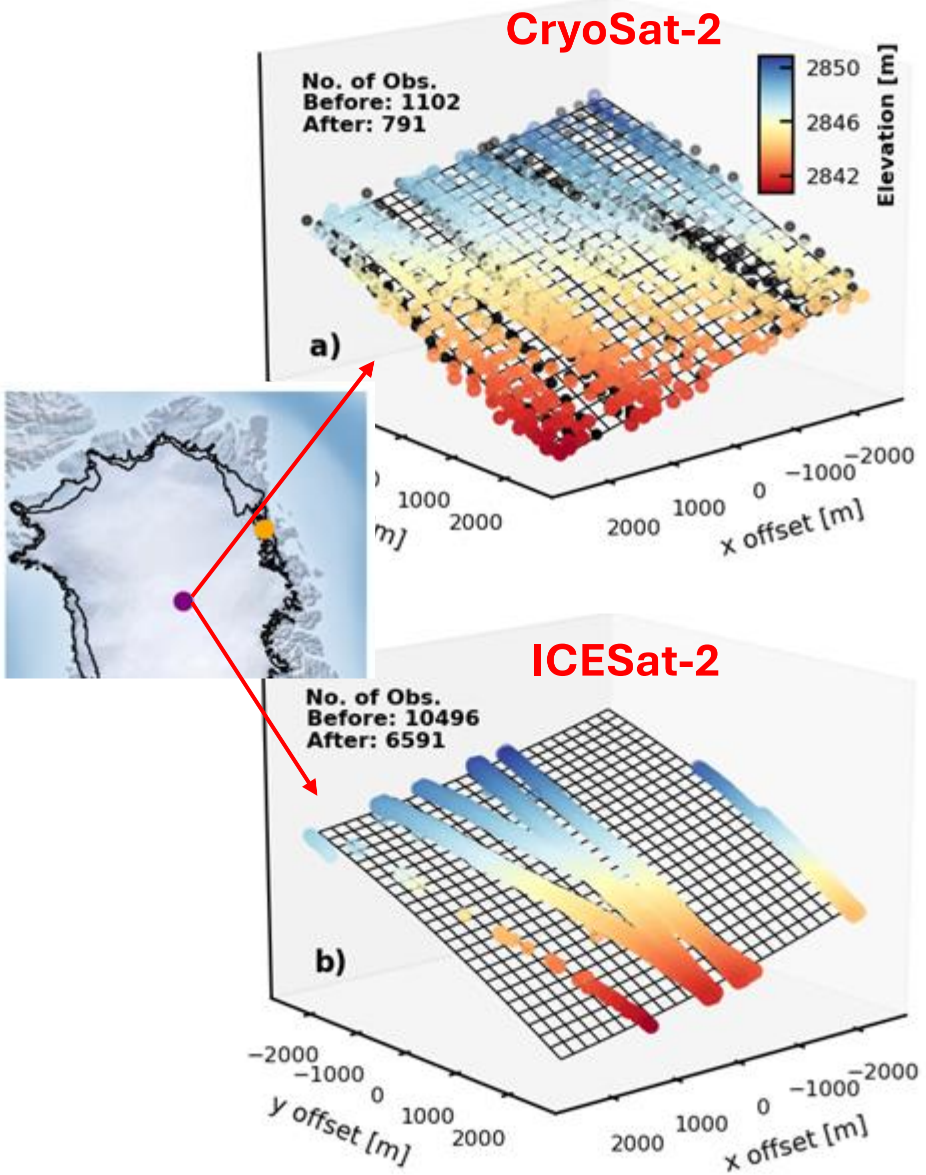
## Along-track Data Products

CryoSat-2: Cryo-TEMPO Baseline B

ICESat-2: ATL06 Version 5

# Method

- We apply the iterative **plane fit method** on 5km x 5km grid
- Processing parameters
  - Outlier exclusion limit (2, 3, 4*SD)
  - Epoch window size (30, 60, 91.25-Day)
  - Interpolation Distance (0, 25, 50 km)
- **We produce 27 ensemble solutions for each mission**
- We calculate:
  - Interannual trends (dh/dt)
  - Seasonal Amplitudes
    - Summer: 1st Apr to 30th Sep
    - Winter: 1st Oct to 31st Mar

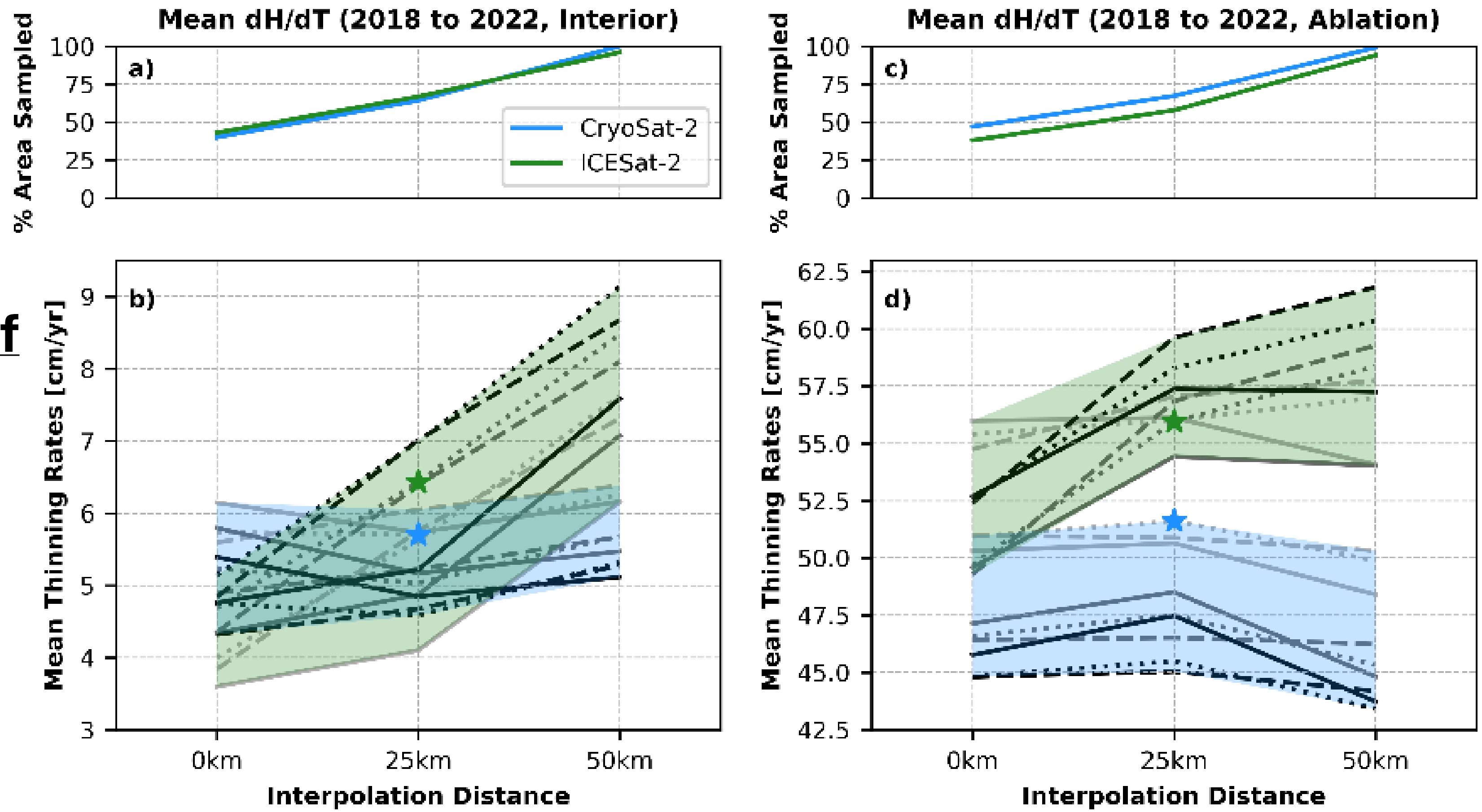


# Sensitivity of Interannual Elevation Trends

Interannual trends are mainly influenced by **interpolation distance**.

- Orbits affect the level of influence (spatial sampling)

**25 km maximises overlap of estimates between both missions**

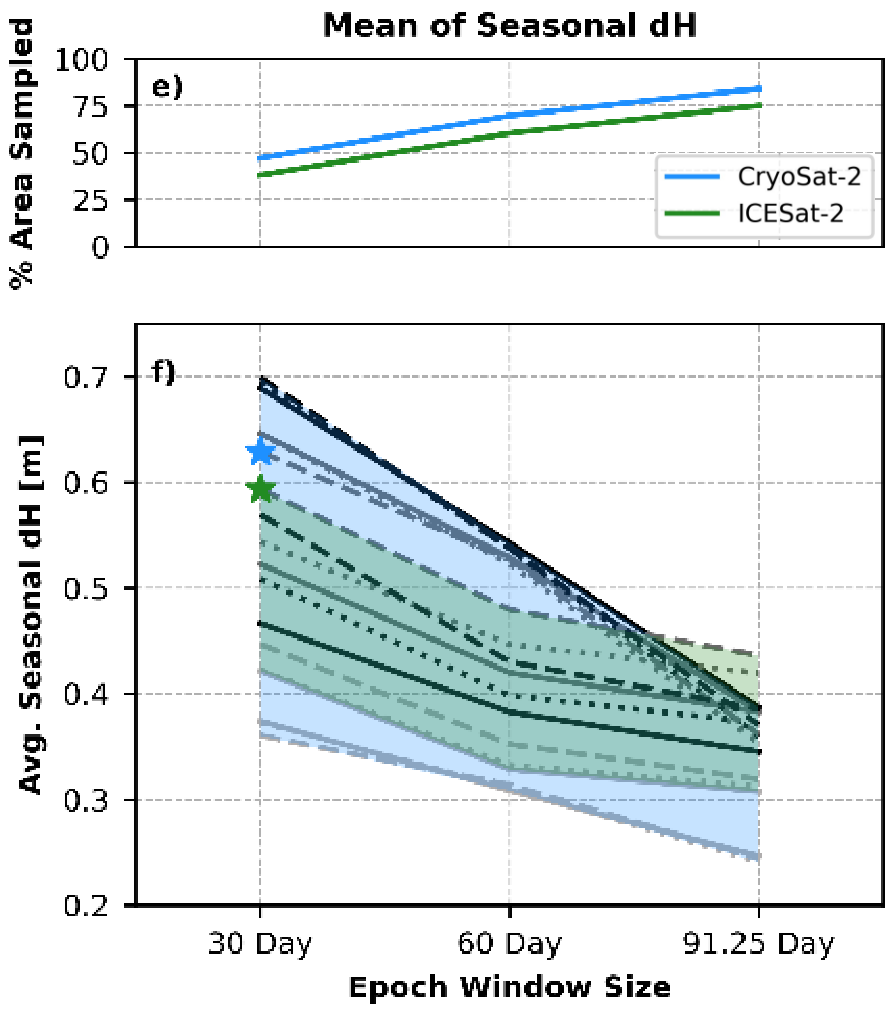


# Sensitivity of Seasonal Elevation Changes

Seasonality of elevation changes is primarily influenced by **<u>epoch window size</u>** (temporal sampling).

- Outlier exclusion limit has a secondary influence.
- <u>Smaller epoch window and larger outlier exclusion limit is better suited</u>

**30-day** epoch window and **3*SD** outlier limit retains much of the seasonality



# Agreement between CryoSat-2 and ICESat-2 Elevation changes

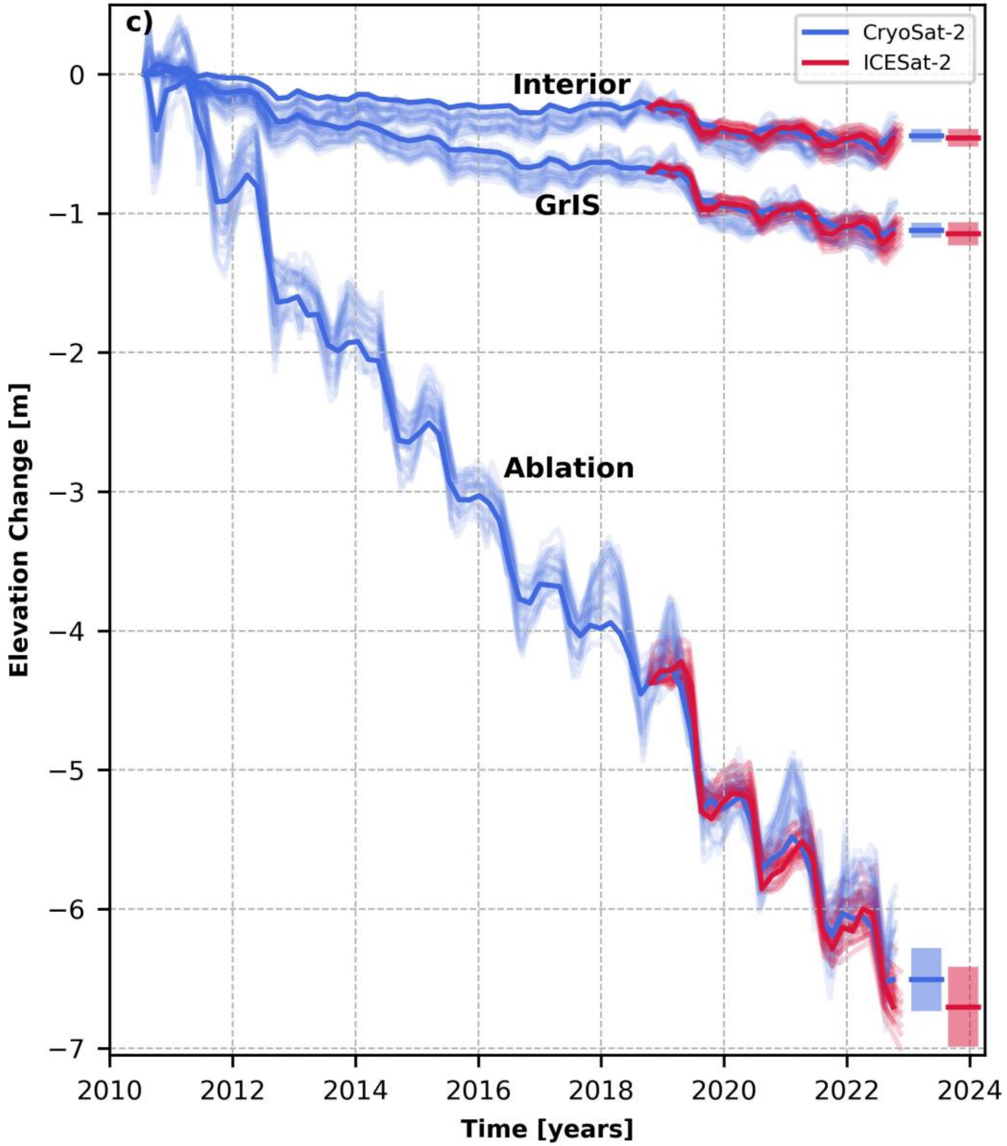
## Bi-monthly time series

| Region | RMSD [cm] | $R^2$ |
|---|---|---|
| GrIS | 5.4 | 0.9 |
| Interior | 5.0 | 0.75 |
| Ablation | 12.6 | 0.97 |

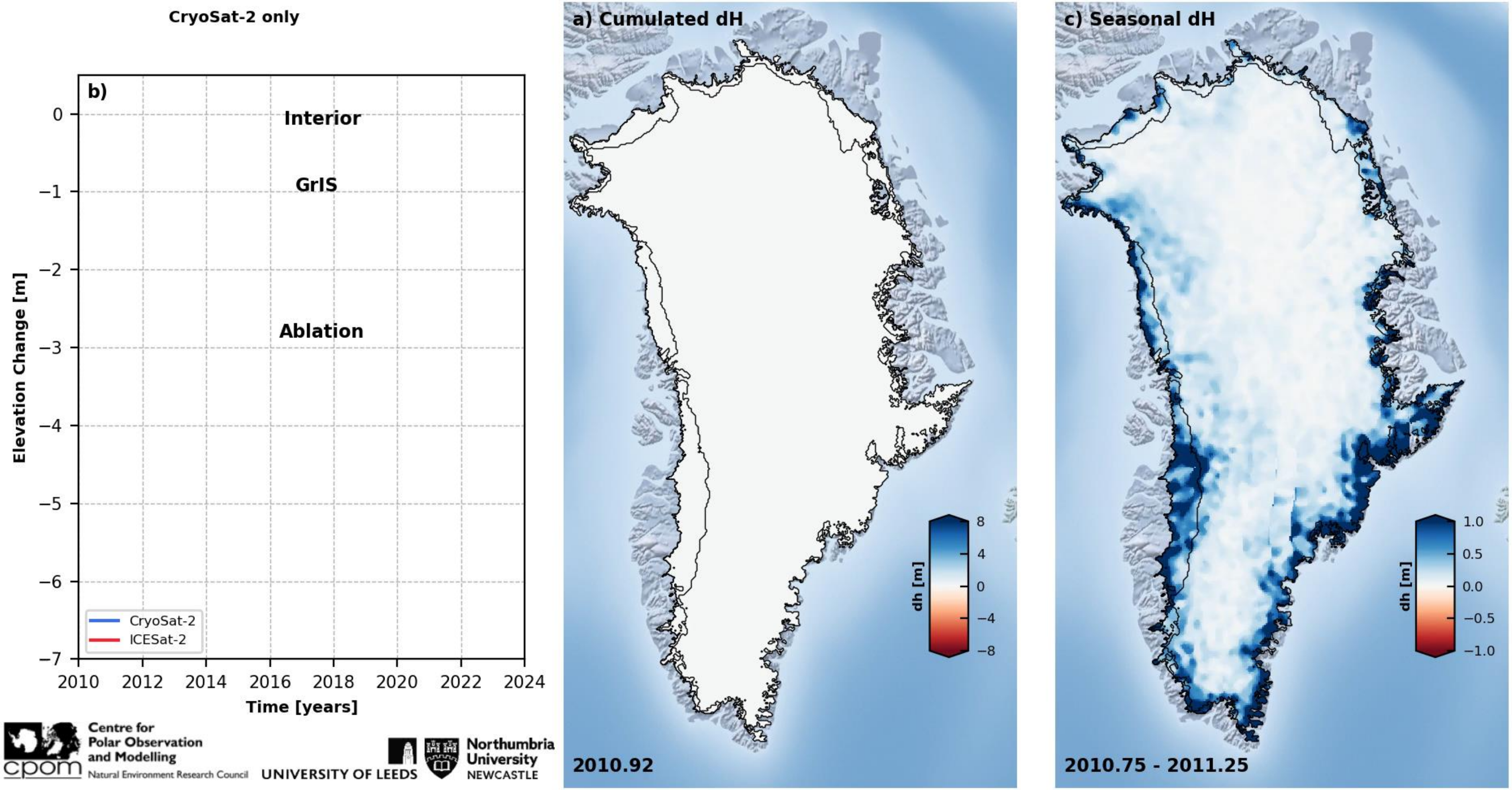
## Trends & Seasonal changes

- Agree within respective uncertainties

| Region | Difference in Trends [cm/yr] | Difference in seasonality [cm] |
|---|---|---|
| GrIS | -0.3 ± 1.8 | - |
| Interior | -0.2 ± 1.5 | - |
| Ablation | 3.3 ± 6.0 | 3.5 ± 38.0 |



# Elevation changes from CryoSat-2 and ICESat-2

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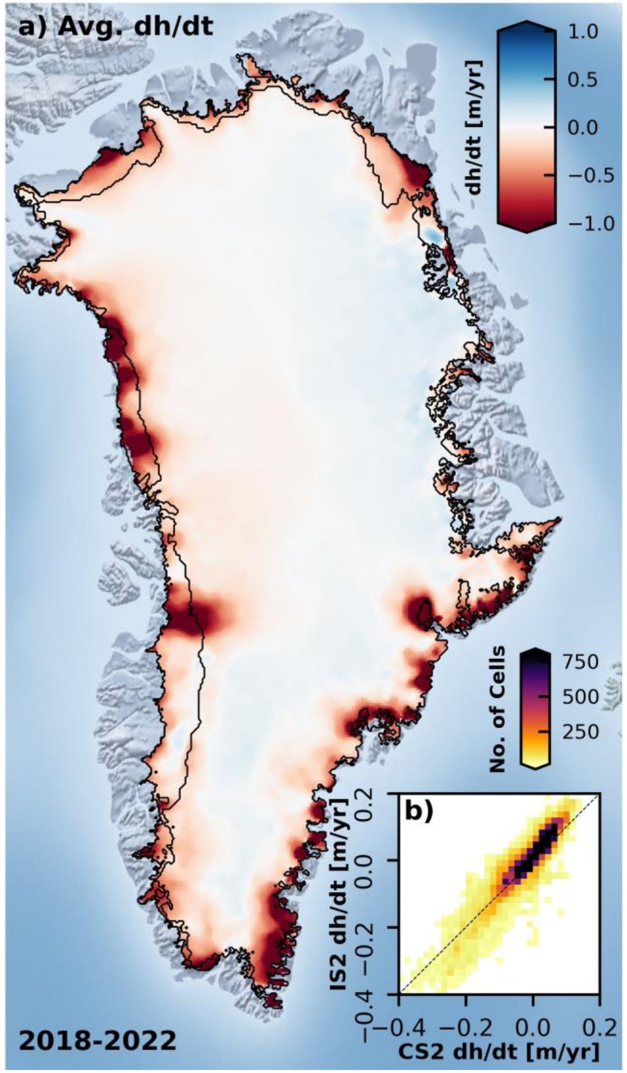
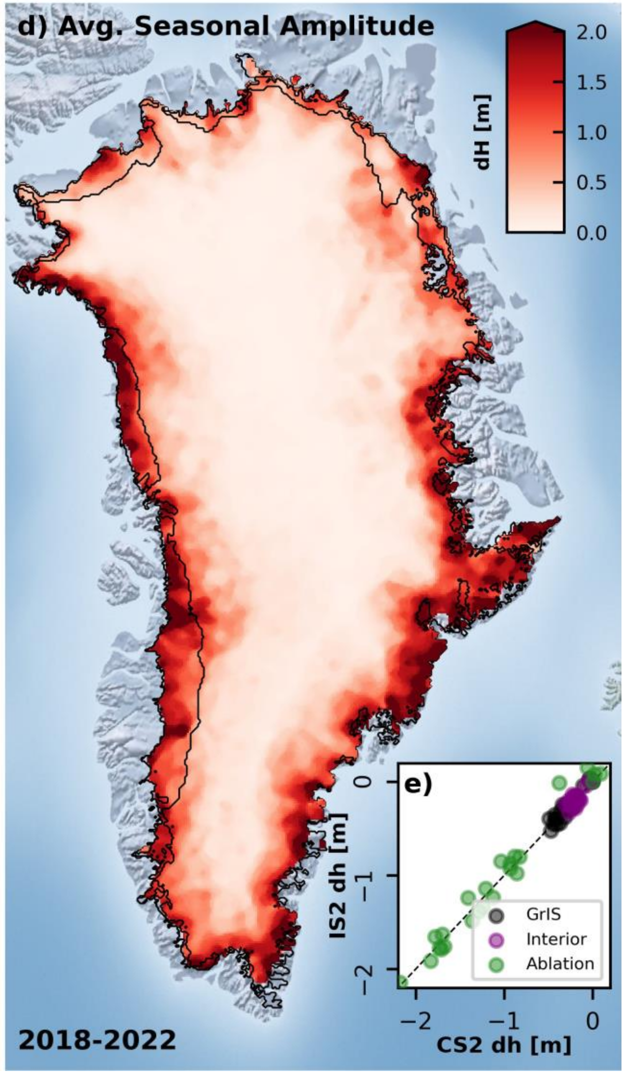
# Elevation and Volume changes from combined radar and laser altimetry

- Between 2018 & 2022, GrIS thinned at 11.6 ± 1.6 cm/yr
- Mean seasonal amplitude in the ablation zone is 61.1 ± 26.8 cm
- Between 2010 & 2022, volume loss rate is 196 ± 37 km$^3$/yr
  - Large interannual variability in the interior (96 km$^3$/yr) - SMB driven



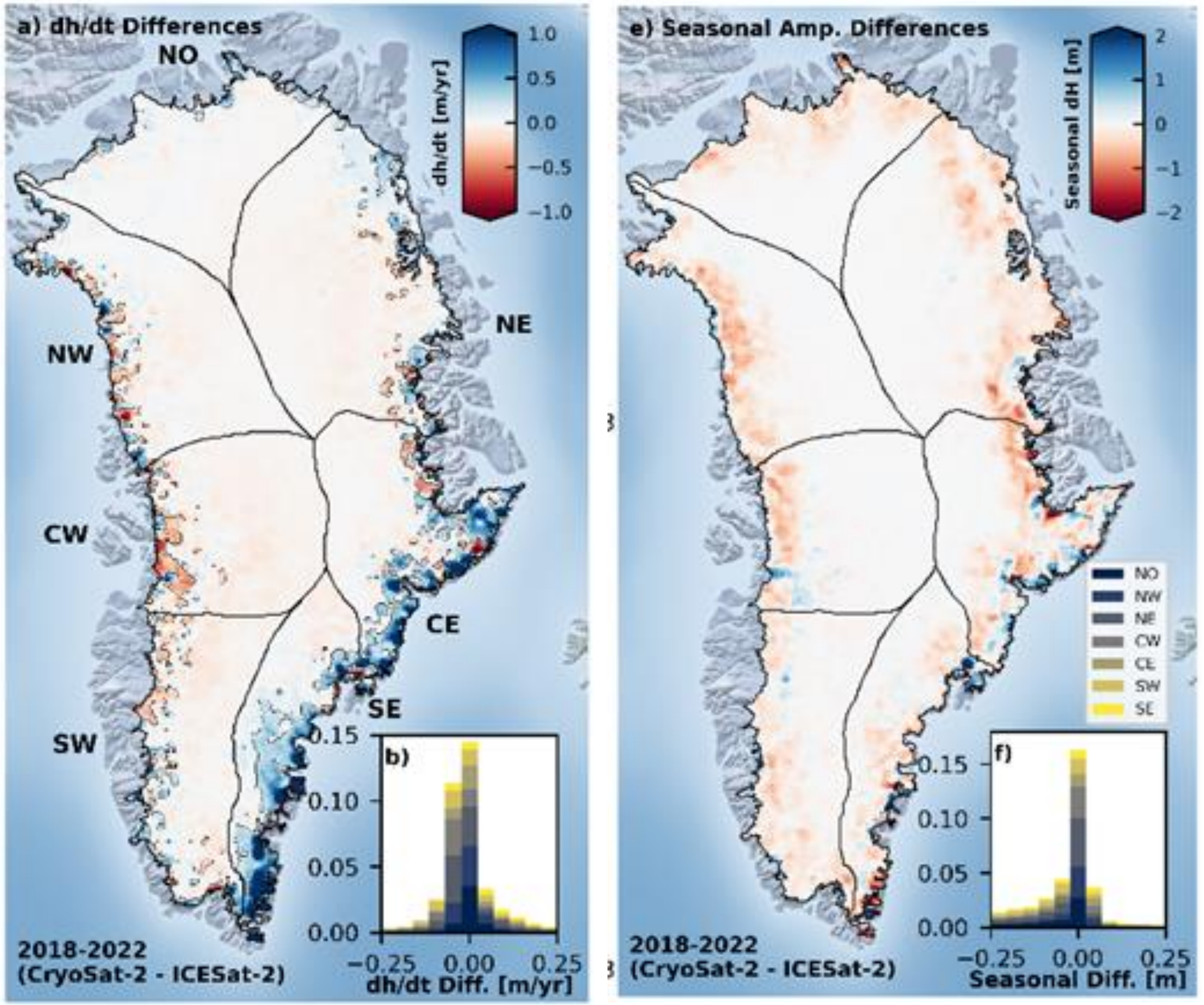



# Spatial Variability of Differences

At basin scale,

- **NO**, **NE** and **NW** have best agreement
  - Interannual trends agree within -1.2 ± 1.8
  - Seasonal amplitudes agree within 12.5 ± 23.5

- SE has the largest differences
  - Complex topography affects elevation measurements



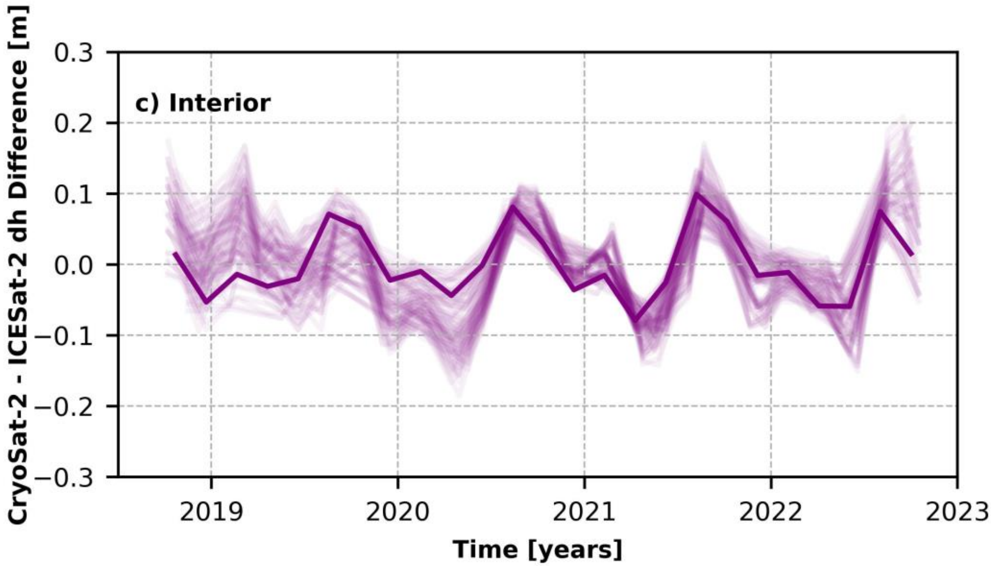
# Temporal Variability of Differences

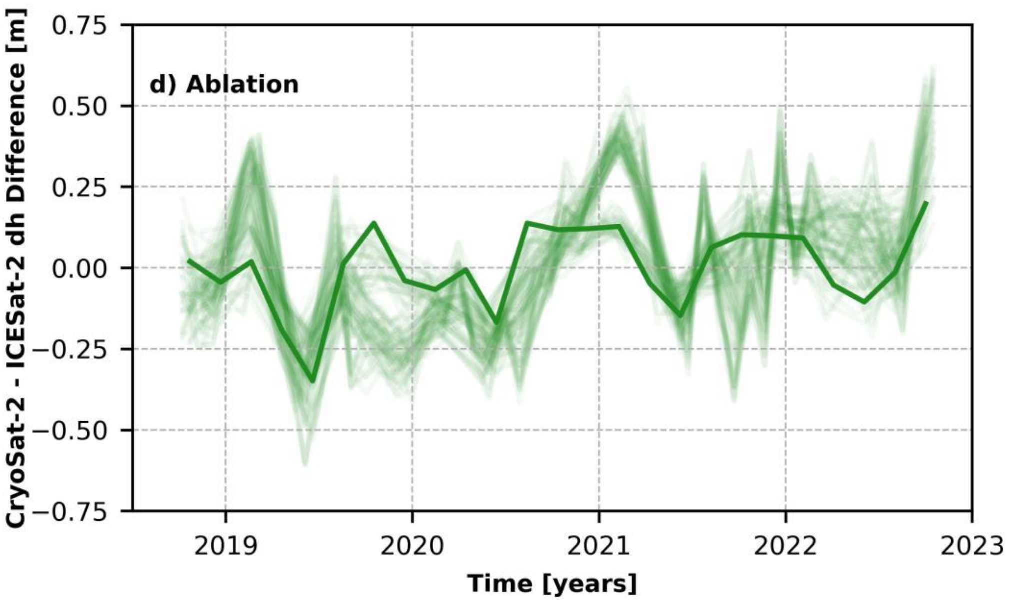
Height change differences exhibit a seasonal pattern

In the interior, this could be due to

- Sampling differences
- Impact of snow/firn properties on penetration

- In the ablation zone
  - Onset of seasons are not same
  - Heavy snowfall events can be differently resolved



# Conclusions

Interannual trends and seasonal changes are sensitive to spatial and temporal sampling, respectively

| | CryoSat-2 | | | ICESat-2 | | |
|---|---|---|---|---|---|---|
| | Outlier Exclusion | Epoch Window | Interpolation Distance | Outlier Exclusion | Epoch Window | Interpolation Distance |
| **Interannual Trends** | 2*SD | 60-Day | 25 km | 3*SD | 60-Day | 25 km |
| **Seasonal Changes** | 3*SD | 30-Day | 50 km | 3*SD | 30-Day | 50 km |

- Our parameter choices lead to strong agreement
  - Interannual trends agree within -0.3 ± 1.8 cm/yr
  - Seasonal amplitudes agree within 3.5 ± 38.0 cm

Volume change rate between 2010 to 2022 is 196 ± 37 $km^3$/yr

- Large interannual variability likely due to SMB-related processes such as strong summer melts

Residual differences may arise due to-

- Spatio-temporal sampling
- Short-term SMB-driven fluctuations in snow/firnpack properties

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