# Polar+ Surface Mass Balance







# Aims & Objectives

- 2-year feasibility study; 2020-2022.
- Aim: To demonstrate the feasibility of measuring Surface Mass Balance (SMB) from space.





# Ambitions of EO4SMB

- > To lay the foundations for a new era of **operational monitoring of SMB** from space.
- > To demonstrate the feasibility of a **future SMB thematic product**.
- > To systematically evaluate and optimise processing algorithms for SMB product generation.
- > To explore the feasibility of several higher risk exploratory methods.
- > To develop a **future roadmap** setting out the path from feasibility study to operational product.



# **Background & Motivation**





### Ice Sheet Surface Mass Balance

- > The net mass exchange of all processes that operate at an ice sheet's upper surface.
- SMB encompasses total precipitation (snowfall and rainfall), sublimation (from the surface and from drifting snow), drifting snow erosion and melt water run-off.
- Responsible for >50% of Greenland's ice imbalance.



> The Polar regions are warming, ice melt is increasing.



- Extreme events are increasing in magnitude and frequency:
  - Record Greenland ice loss in 2019.
  - ➢ First rainfall at summit in 2021.







Projections of future cumulative sea level rise from Greenland SMB, under a range of forcing scenarios (Fettweis *et al.*, 2013).

# The Impact of SMB

Resolving SMB is critical for a wide range of applications:



Perner et al., 2019

### The Impact of SMB

Resolving SMB is critical for a wide range of applications:



# The Impact of SMB

Resolving SMB is critical for a wide range of applications:



Field site

# **EO4SMB** Concept



- Proof of concept focused on Greenland.
- Period 2010-2020.

# **EO4SMB** Concept



### Altimetry Concept





# First Estimates of Ice Sheet wide run-off from Space





Slater et al., in press

#### **Pushing Spatial & Temporal Resolution**

> Optimising methodology to achieve local estimates of run-off.



#### **Pushing Spatial & Temporal Resolution**

Integrate EO velocity measurements into the processing chain.



#### **Pushing Spatial & Temporal Resolution**

- Optimising temporal sampling:
  - ➢ 60-day to monthly.
  - Sliding window.
  - Singular Spectrum Analysis to identify dominant frequencies and remove noise.



# **EO4SMB** Concept



#### Joint Inversion Concept

- Gravimetry is coarse resolution, but can nonetheless provide an additional constraint on the regional SMB solution.
- Utilise GRACE + GRACE FO, altimetry, GPS-derived elastic uplift and ice discharge to invert for SMB.

![](_page_20_Picture_3.jpeg)

![](_page_20_Figure_4.jpeg)

Credit: R. Forsberg

### EO4SMB Concept

![](_page_21_Figure_1.jpeg)

#### **Deep Learning**

> Test whether near-surface melt information can be retrieved from low level radar altimetry data.

![](_page_22_Figure_2.jpeg)

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> Test whether near-surface melt information can be retrieved from low level radar altimetry data.

Block 2

Conv 1D + relu

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Flatten

- 1-d CNN trained on MODIS surface temperature data.
- Training and tuning performed on 9 years of CryoSat-2 LRM data.
- Testing based on remaining 1 year of CryoSat-2 LRM data.

![](_page_23_Figure_5.jpeg)

#### **Deep Learning**

- > Test whether near-surface melt information can be retrieved from low level radar altimetry data.
  - 1-d CNN trained on MODIS surface temperature data.
  - Training and tuning performed on 9 years of CryoSat-2 LRM data.
  - Testing based on remaining 1 year of CryoSat-2 LRM data.
  - Preliminary analysis is encouraging suggests ~ 70% of unseen waveforms correctly classified.

![](_page_24_Figure_6.jpeg)

Feasibility study – outlook and future potential is key.

![](_page_25_Picture_2.jpeg)

![](_page_26_Picture_1.jpeg)

![](_page_27_Figure_1.jpeg)

![](_page_28_Figure_1.jpeg)

ICE SHEET VELOCITY MAP FROM SENT

![](_page_29_Figure_1.jpeg)

![](_page_29_Picture_2.jpeg)

![](_page_30_Figure_1.jpeg)

![](_page_30_Figure_2.jpeg)

![](_page_30_Figure_3.jpeg)

![](_page_31_Figure_1.jpeg)

![](_page_32_Figure_1.jpeg)

![](_page_32_Figure_2.jpeg)

#### **Broader Perspective**

![](_page_33_Figure_1.jpeg)

- Synergy of multiple ESA projects.
- Broader links to oceanography, global climate & impacts.

#### **Broader Perspective**

![](_page_34_Figure_1.jpeg)

Credit: Masashi Niwano https://www.youtube.com/watch?v=t2ALaJ28feU