4DGreenland
- towards a digital twin of Greenland

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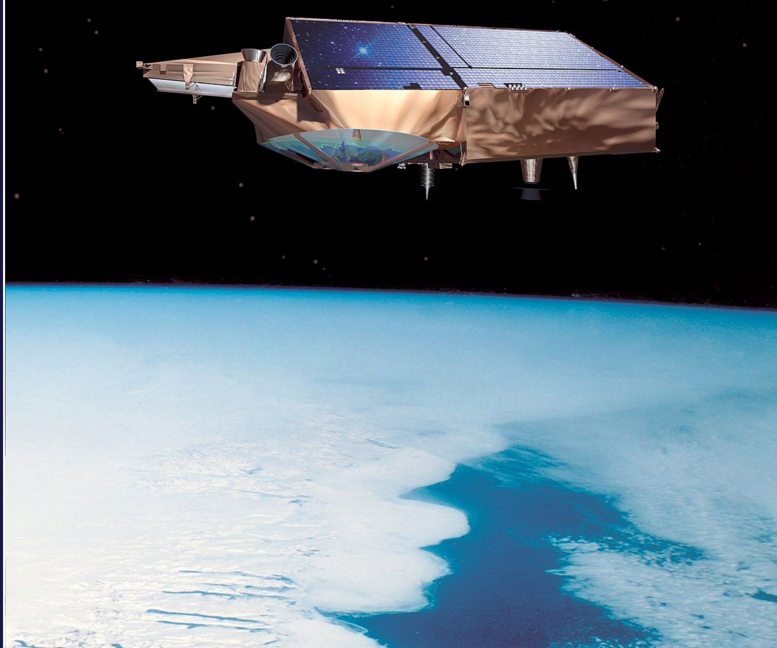
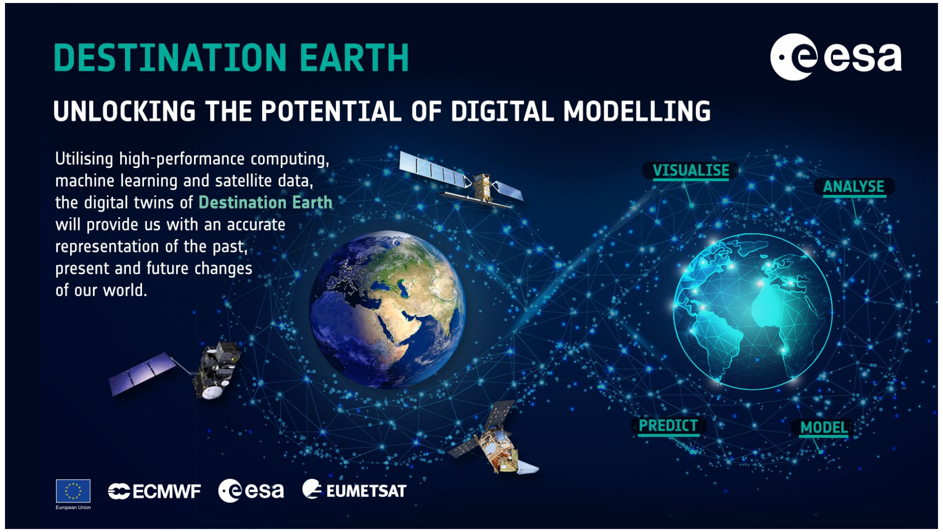


A Digital Twin of Greenland

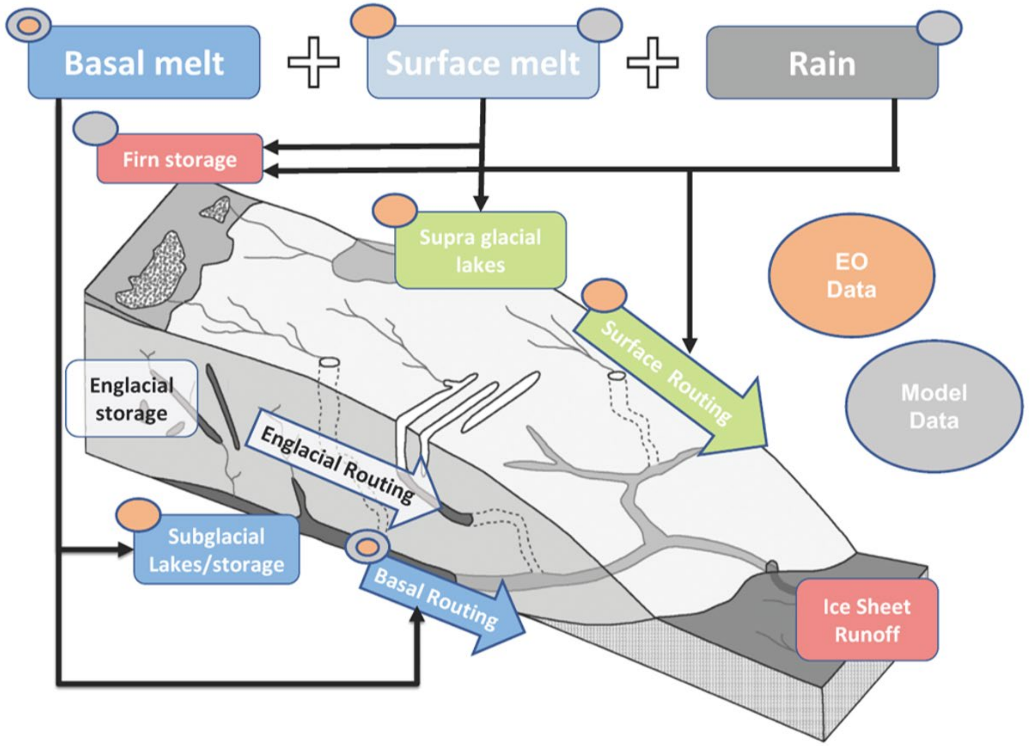
Requirements (could be..):

- Should help visualise, monitor and/or forecast ice sheet processes and dynamics.
- Should be built around models that are useful for monitoring the health of the ice sheet.
- Not just data visualization – the data should inform models for predictions.
- Capitalize on the extensive EO data portfolio.
- Near real-time component.
- Machine learning component would be obvious.



About 4DGreenland

- Activity 1 : **Surface melt processes**
- Activity 2 : **Supraglacial storage and drainage**
- Activity 3 : **Subglacial melt, drainage and lakes**
- Activity 4 : **Integrated Greenland hydrology assessment**



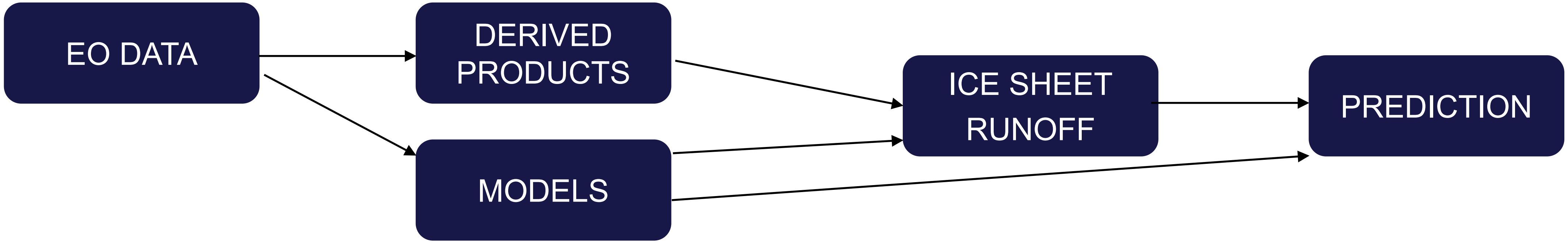
Background image adapted from Cuffey and Paterson (2010)

Goal: integrated assessment of Greenland's hydrology through maximizing the use of Earth observation (EO) data.

4DGreenland talk tomorrow in A9.04.03

Towards a 4DGreenland Digital Twin

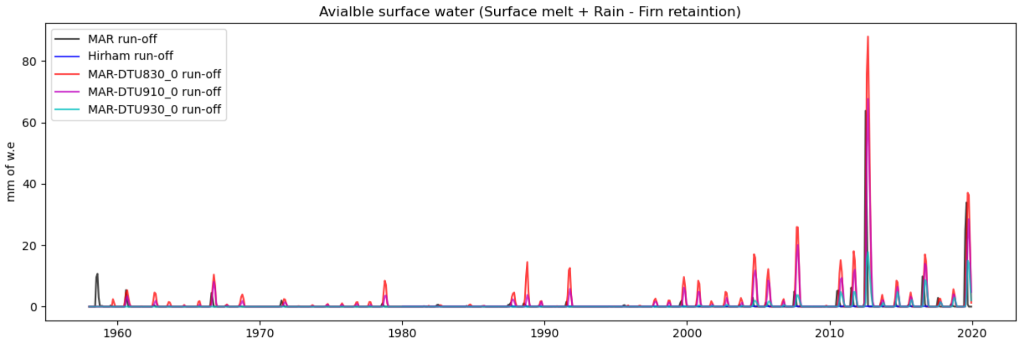
- Not all aspects of Greenland hydrology are observable from EO
- Models are still required and used to close the integrated assessment.
- A Digital Twin can build on the vast observational datasets generated within 4DGreenland and progress towards bridging the gap between models and EO data.
- The diversity of the derived EO dataset provides an ideal playground for investigating hidden features within the data using AI/ML.



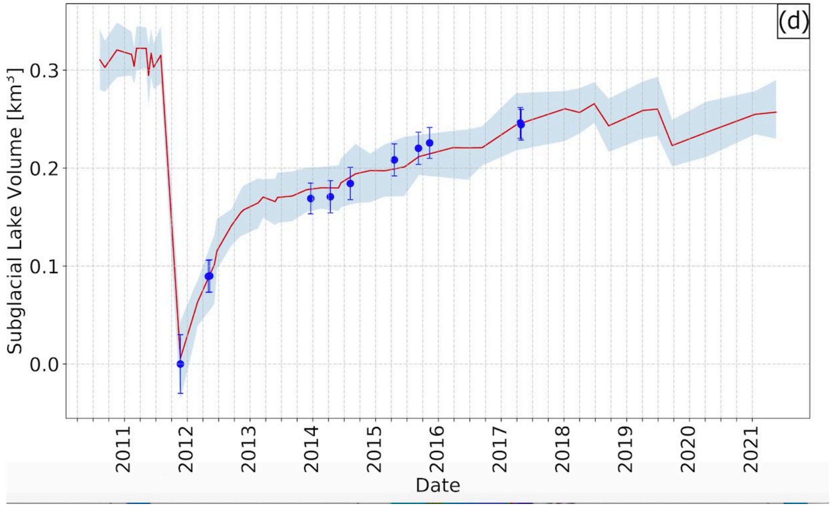
Towards a 4DGreenland Digital Twin

Products derived in 4DGreenland

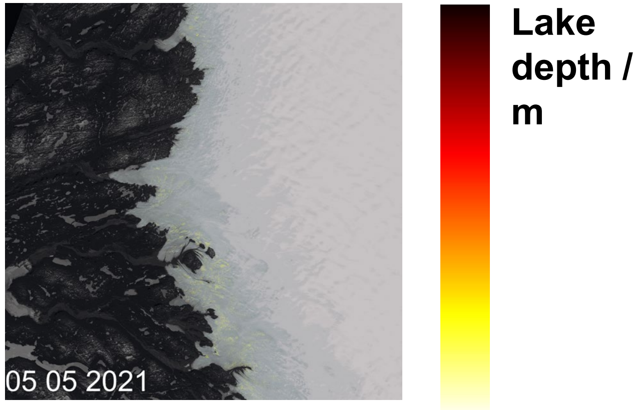
Surface melt



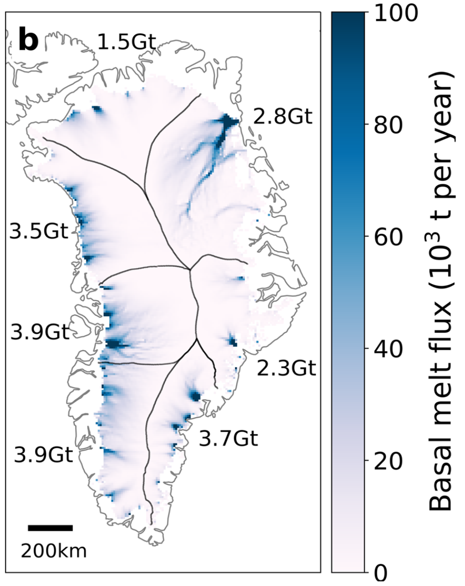
Firn retention



Subglacial lake volumes



Supraglacial lake volumes



Basal melt

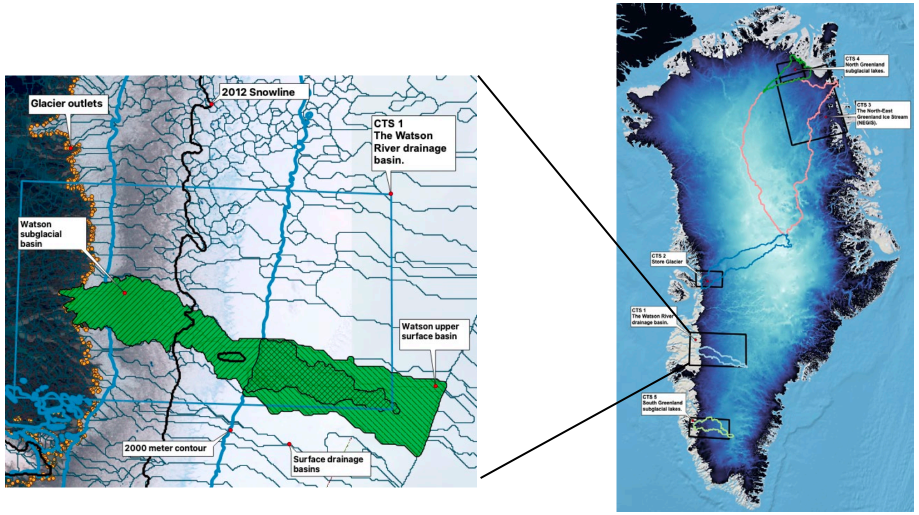
Towards a 4DGreenland Digital Twin

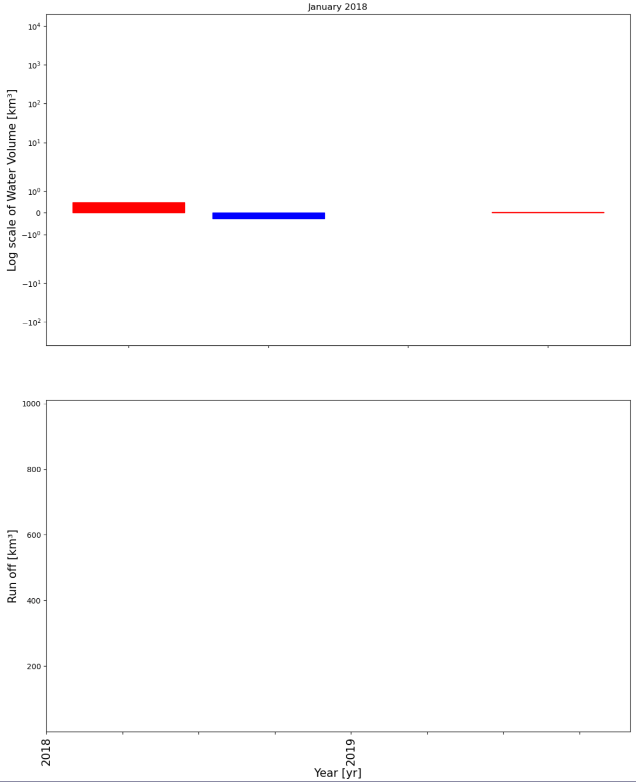
Integrated assessment

- DT to provide near real-time estimates of basin scale monthly runoff – This requires an effort to operationalize the different components.

- The multiple datasets of 4DGreenland can form the basis for establising correlation / statistics / dependencies / empirical relationships between individual components

→ predictions (near future)





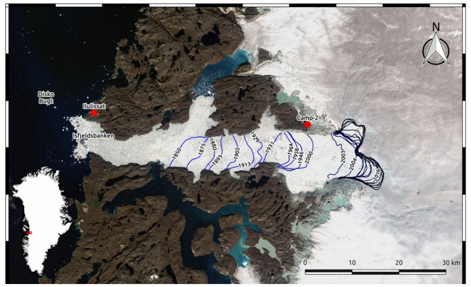
Towards a 4DGreenland Digital Twin

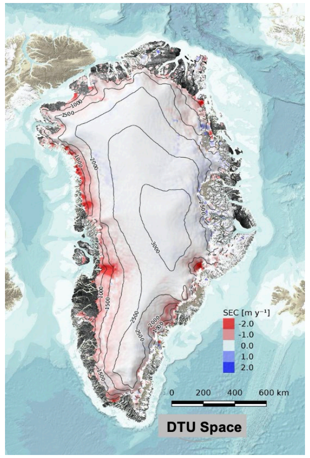
Visualization of EO data records and their inter-connections

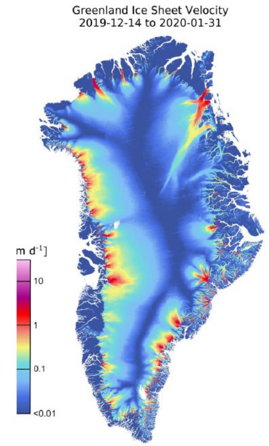
- Temporal evolution of hydrological components, and basin scale time series.

- Building also on EO data products from CCI+ Greenland ice sheet R&D, and operationalized within Copernicus Climate Change Service →
  Ice velocity, ice topography, grounding line location and calving fronts →
  Investigate how are these linked?

- Long time series of satellite derived datasets
  - Clear evidence for climate change
  - Good cases for policy makers etc

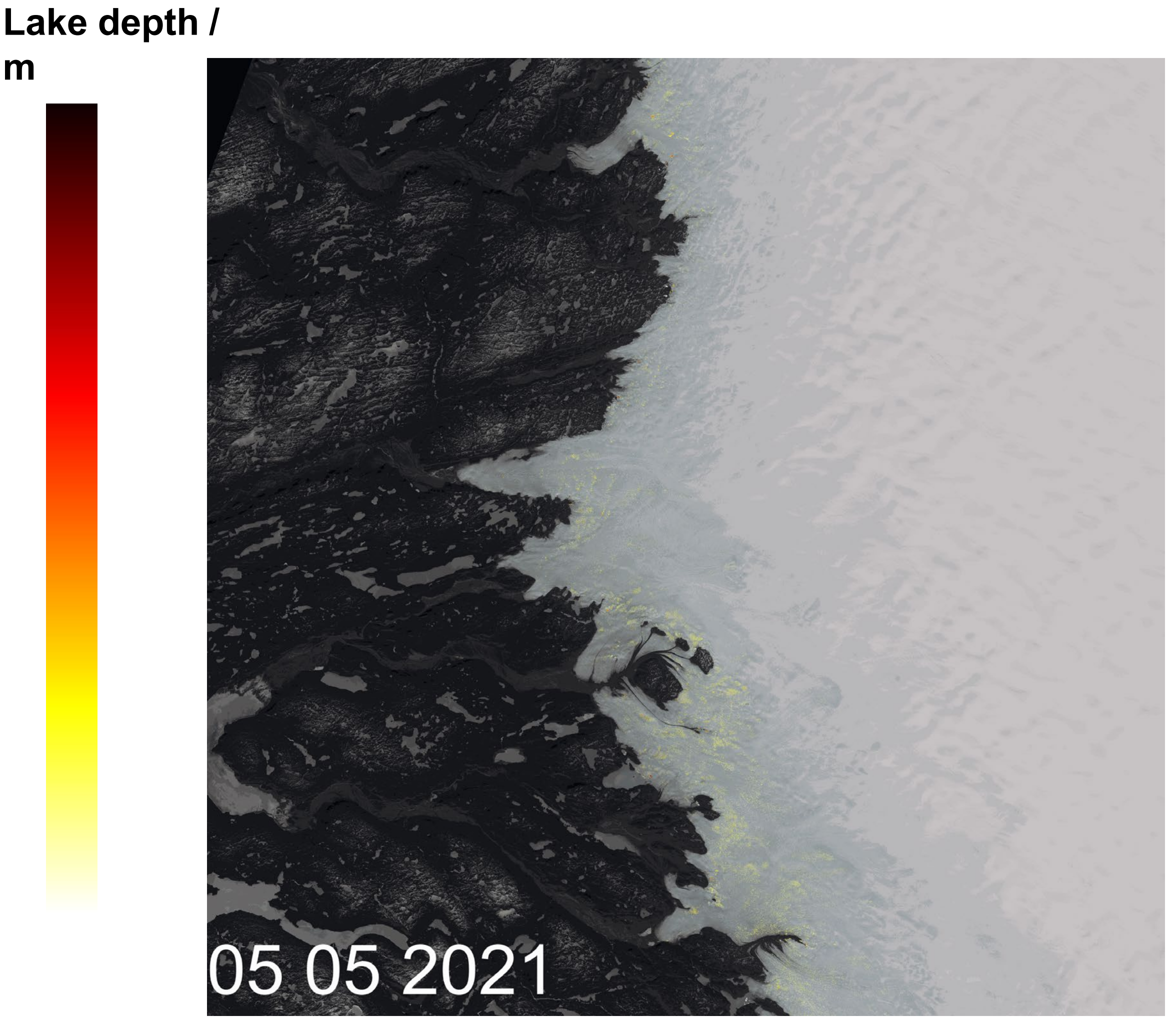






Supraglacial storage and drainage

- Main 4DG activity is to use a Random Forest (RF) approach (Supervised Learning algorithm) to map supraglacial hydrology ice sheet wide as detailed in the previous talk.
- Output of RF produces fortnightly estimates of the extent of supraglacial lakes, rivers and streams, from which depths are derived.
- Establishes the foundations of automated, large-scale monitoring of supraglacial hydrology within a Digital Twin, which until now has not been possible.



Supraglacial storage and drainage

- Future outlook for a Digital Twin:

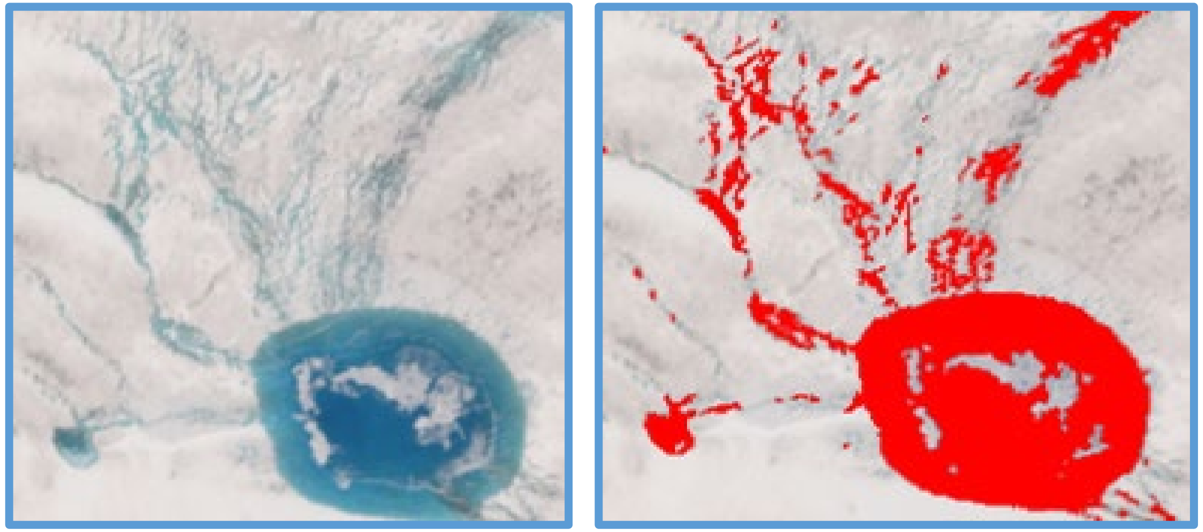
1. **Currently machine learning approach determines lake extent. Opportunty for R&D into Machine Learning approaches for determining lake depths.**
   - ➢ Current approaches baes upon physical (Radiative Transfer) models have limitations.
   - ➢ CNNs have recently shown to success at retrieving depths in other settings (e.g. coastal waters); opportunity for translation into glaciological setting.

2. Links between observations, statistical and process-based hydrological models.

- ➢ For example change detection, extreme value analysis, data assimilation and emulation.

3. Extend machine learning methodology to other datasets.

- ➢ Opportunity to develop methods that leverage datasets to extract greater insight, e.g. optical, SAR, InSAR, Digital Elevation Models.



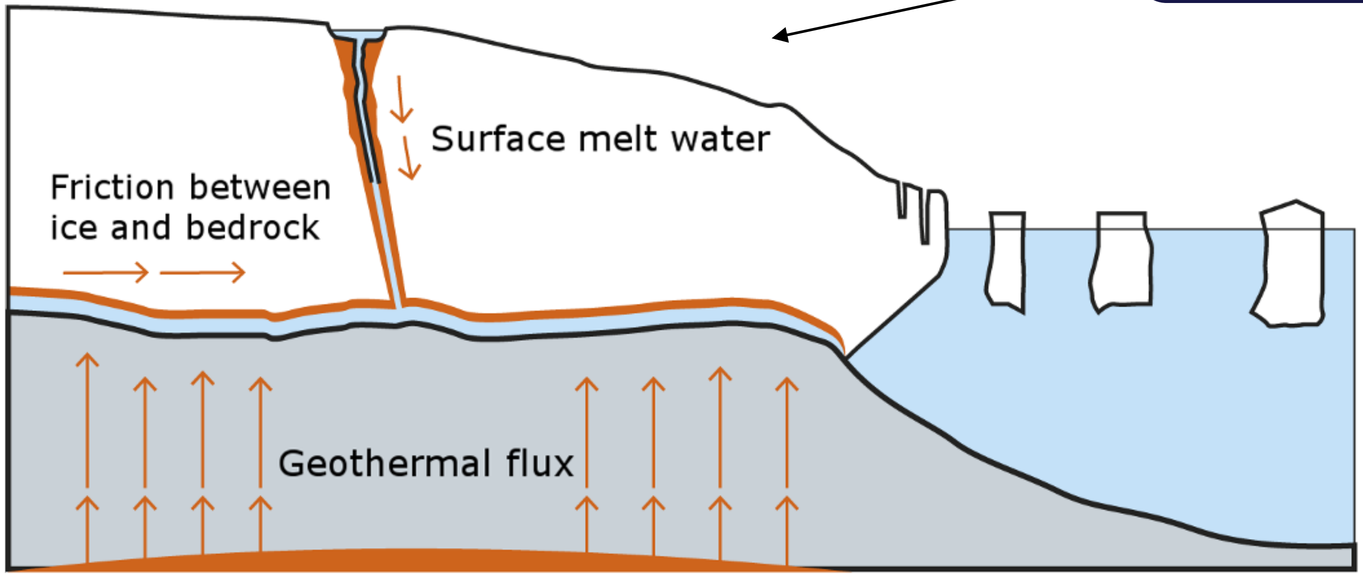
Random Forest Classification - Channel-Lake System

Random Forest Classification - Channel-Lake System

Subglacial melt

- Future outlook for a Digital Twin:

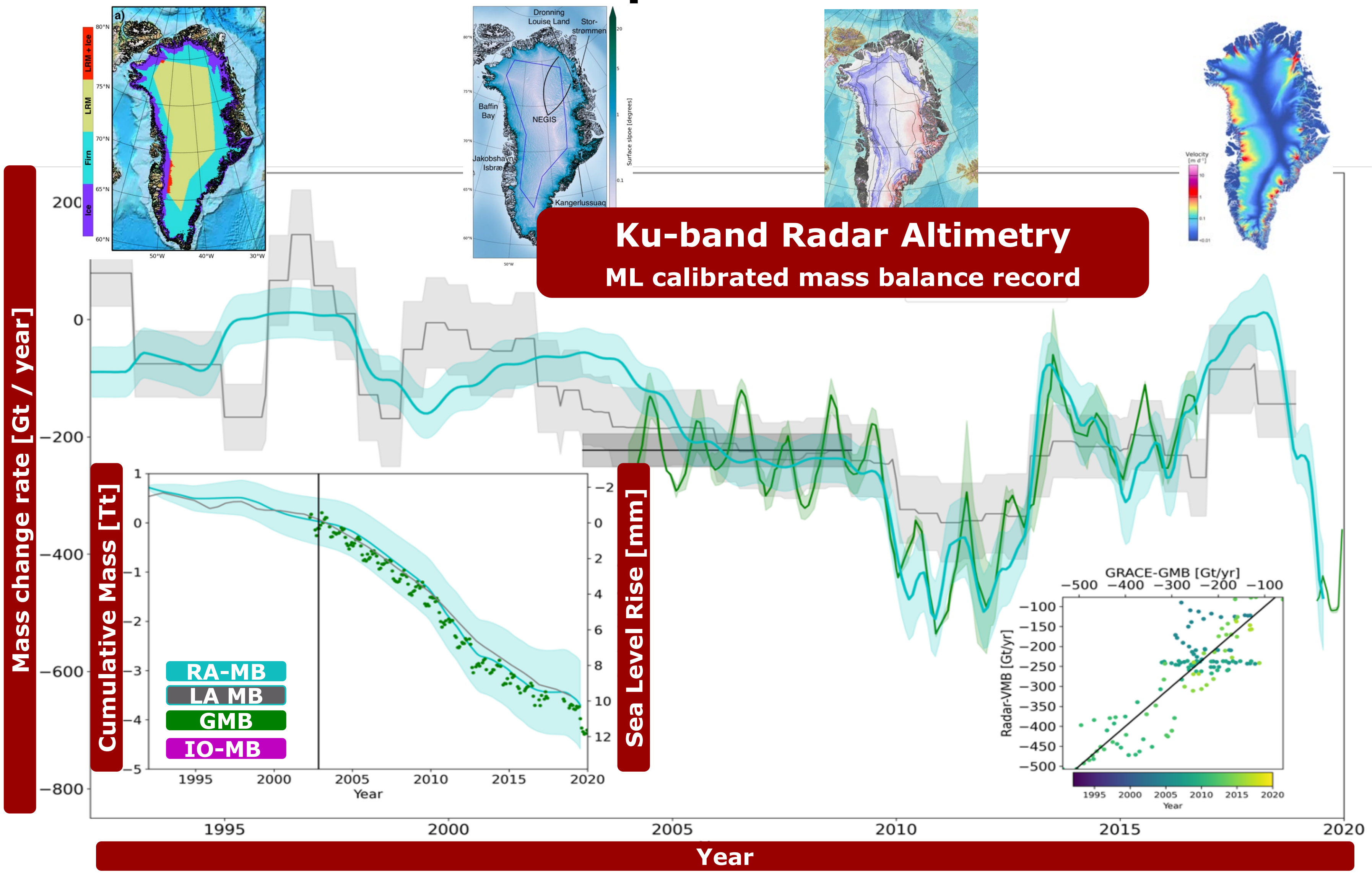
EO datasets & scenarios



How will the subglacial melt change in a warming climate?

Greenland ice sheet mass balance - AI for near future predictions

4DGreenland esa



- Longest record for Greenland mass balance from radar altimetry added by
  - Ice velocity
  - Firn air content
  - Surface type
  - Satellite sensing mode
- This predictor can be used to explore future scenarios

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

Towards a Digital Twin