

living planet symposium | BONN

23–27 May
2022

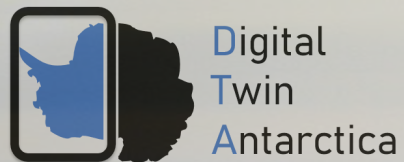
TAKING THE PULSE
OF OUR PLANET FROM SPACE



Digital Twin Earth – Antarctica

Noel Gourmelen, University of Edinburgh

25/05/2022



Digital Twin Earth - Antarctica



Noel Gourmelen¹, Dan Goldberg¹, Ghislain Picard², Malcolm McMillan³, Amber Leeson³, Xavier Fettweis⁴, Quentin Claude⁴, Martin Ewart⁵, Livia Jakob⁵, Alex Horton⁵, Carolyn Michael⁵, Martin Wearing^{1,5}, George Malczyk^{1,5}, Diarmuid Corr³, Andrew Twelves¹, Amos Storkey¹, Diego Fernandez⁶

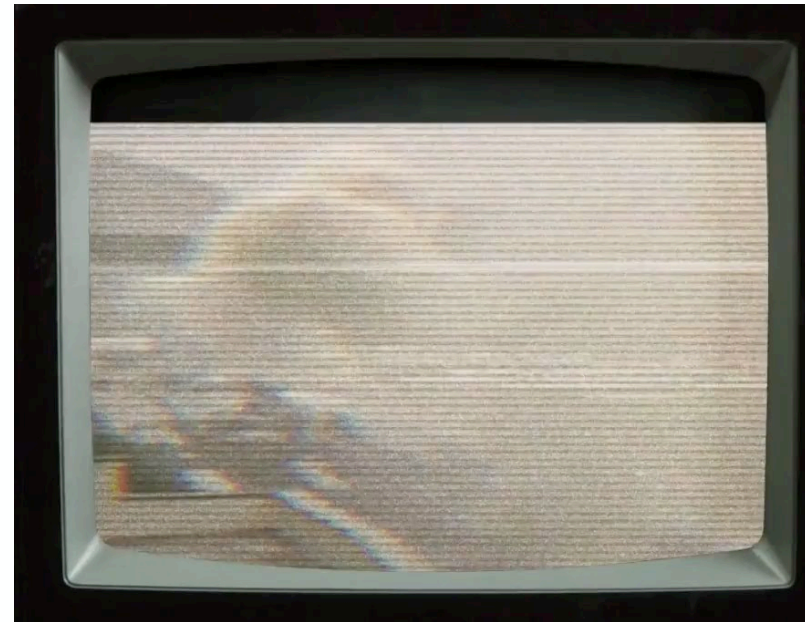
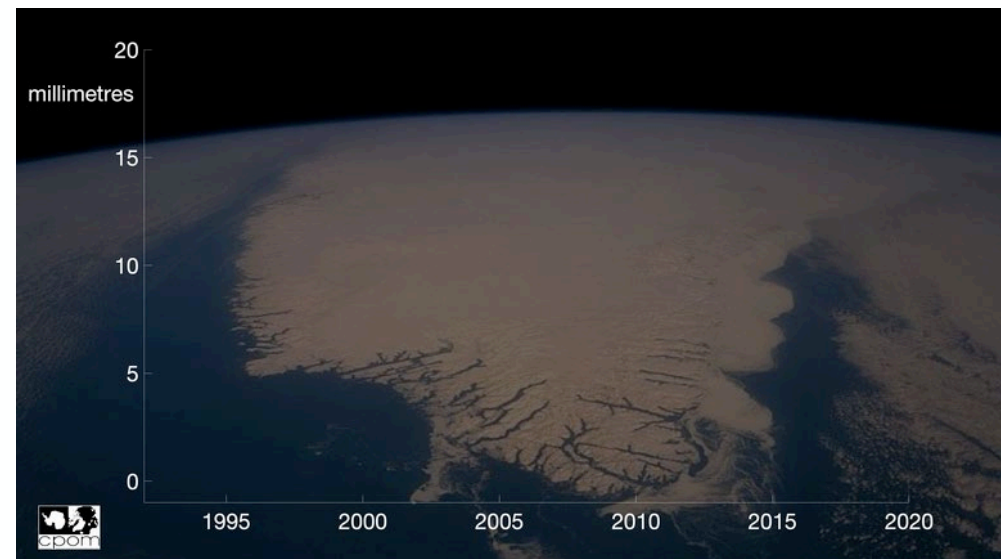
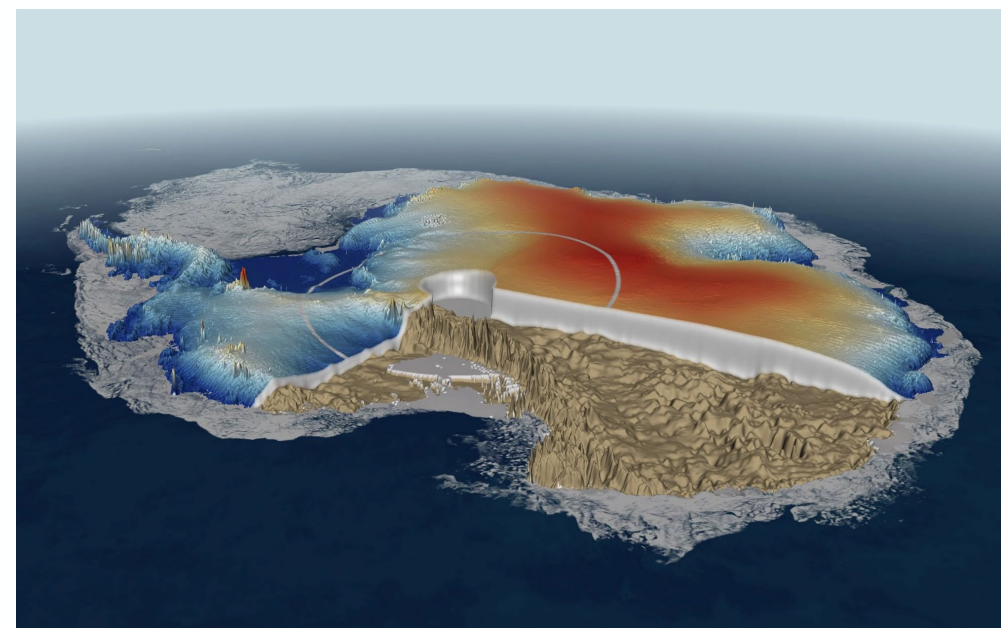
1 University of Edinburgh, UK
 2 IGE, FR
 3 U. of Lancaster, UK
 4 U. of Liege, BE
 5 Earthwave, UK
 6 ESA



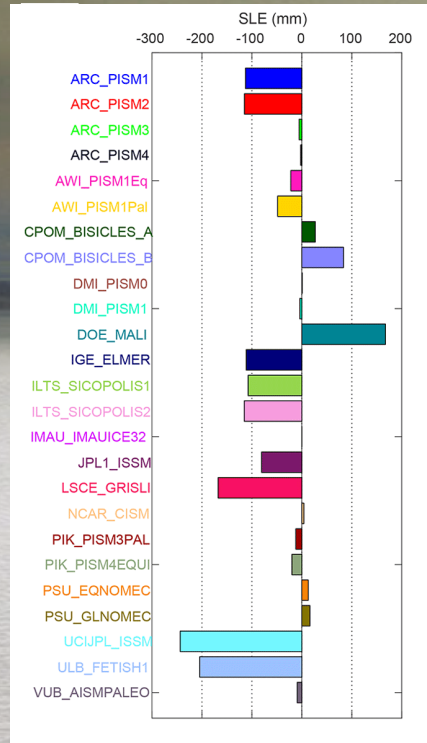
THE UNIVERSITY of EDINBURGH



- ❖ Largest Earth's fresh-water reservoir
- ❖ Largest uncertainty in future sea-level change
- ❖ Key role in Earth's energy balance through impacts on atmosphere, ocean, primary productivity



Simulating the Antarctic Ice Sheet

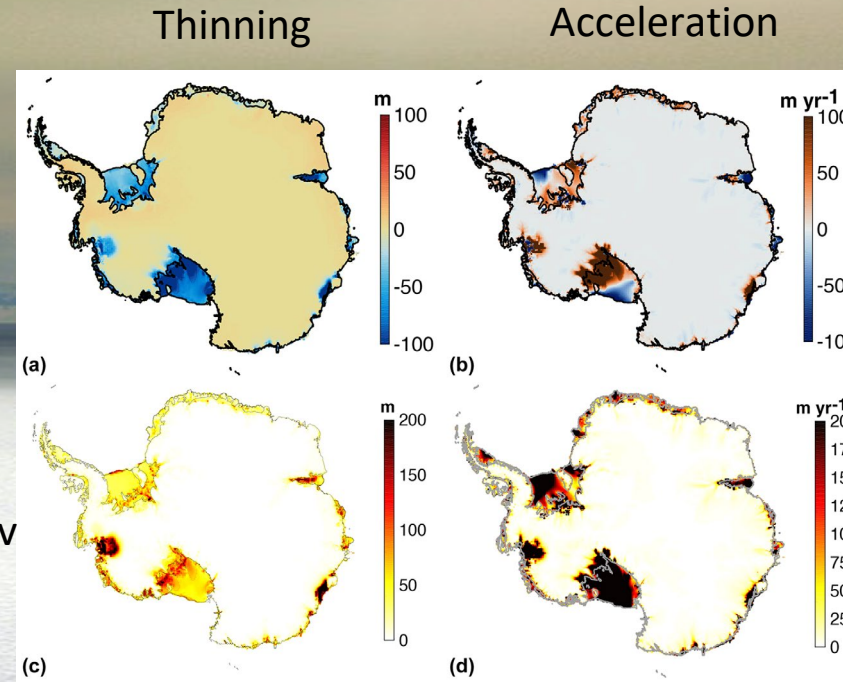


Seroussi, 2019

Mass change trend among ice-sheet models which are tuned to the **current state** of Antarctica (thickness and surface velocity)

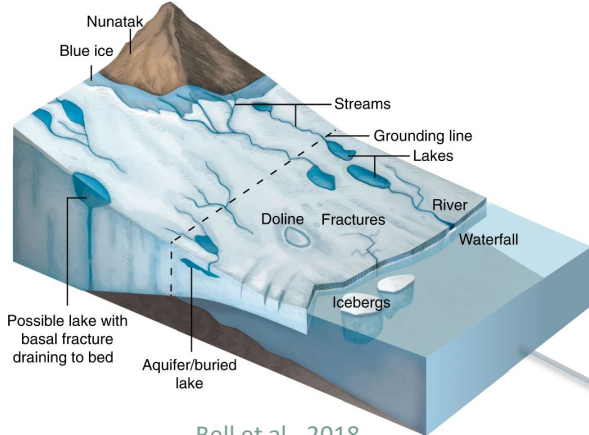
Mean

Std dev

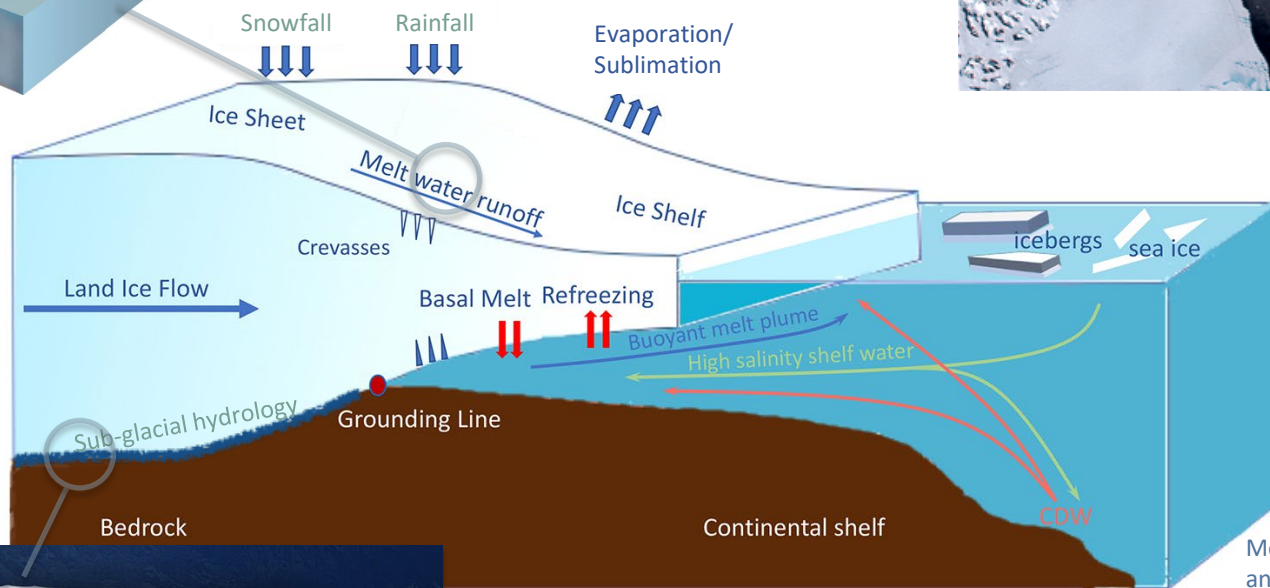
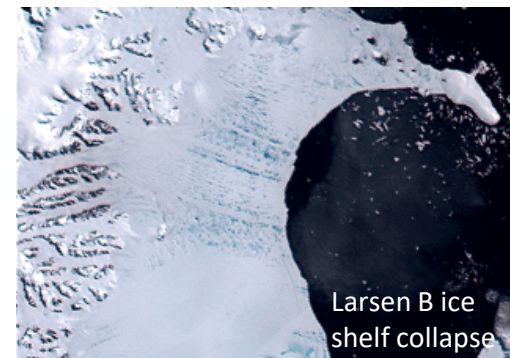


Seroussi, 2020

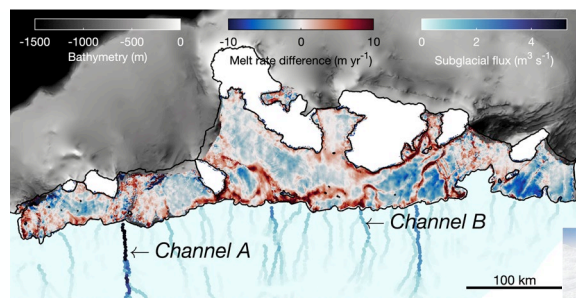
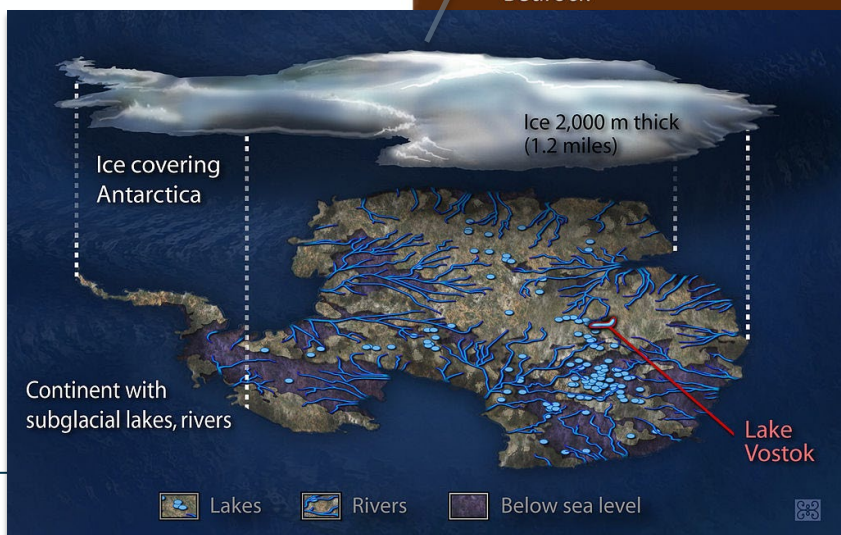
Thinning and acceleration (mean and standard deviation) in the ISMIP6 coordinated experiments



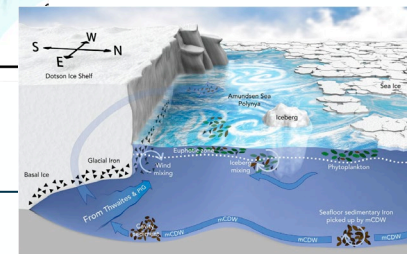
Bell et al., 2018



Modified from Nowicki and Seroussi, 2018

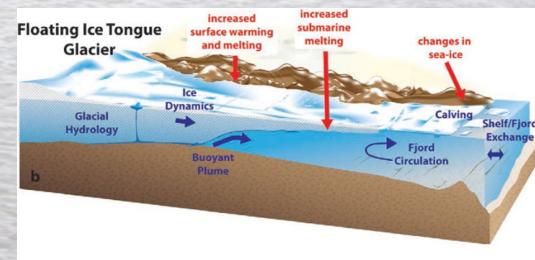
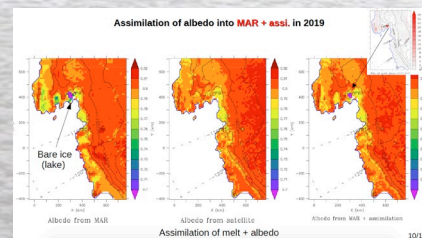
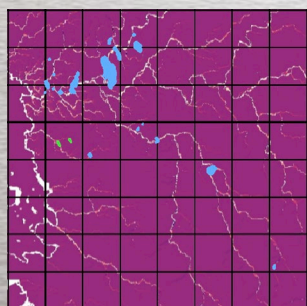
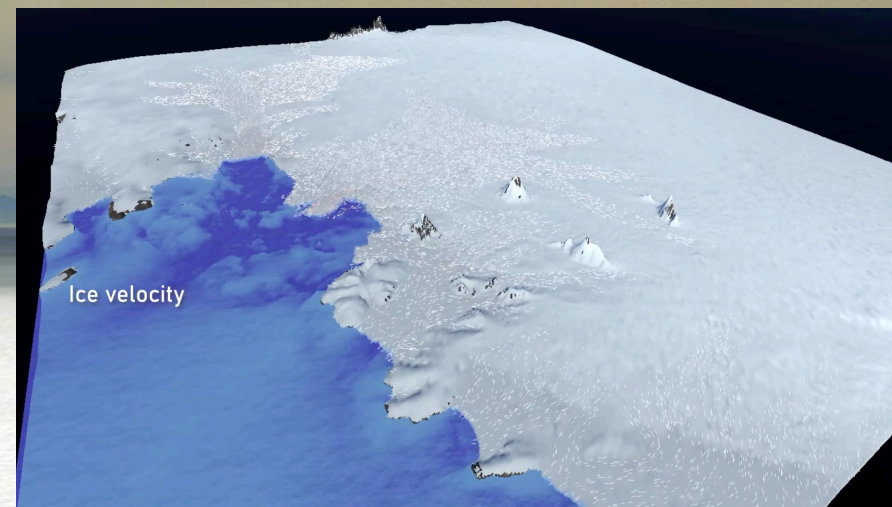


Wei et al., 2020



Demonstration activities towards a full reconstruction of the Antarctic system

- Focus on Amundsen Sea Sector
- Dedicated data lake
- Automatic detection of supra- and sub- glacial lakes
- Data assimilation into a regional climate model
- EO and simulation of the Antarctic system
- Dynamic and interactive 4D environment

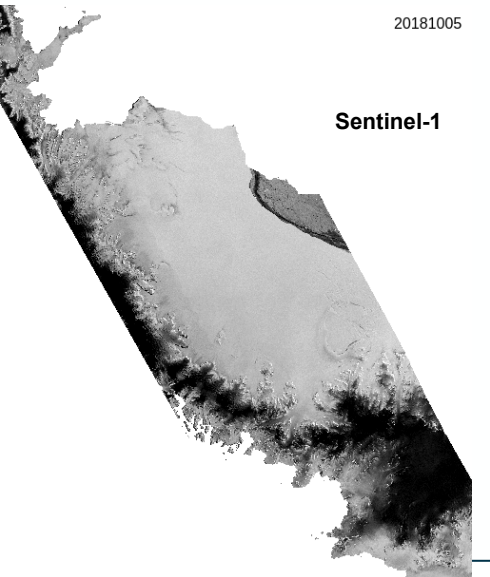
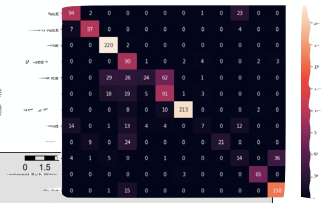


Demonstrator: Surface melt - Data assimilation

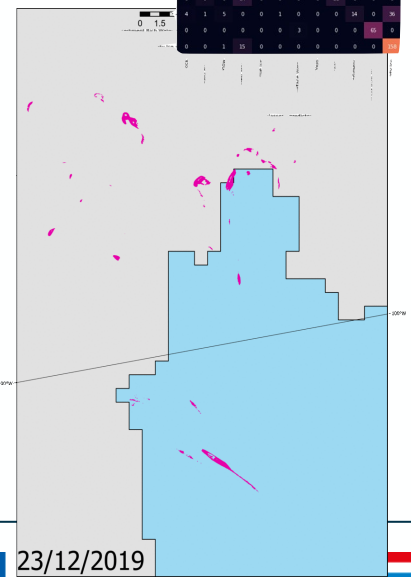
- ❖ Space-based automatic and NRT detection of liquid water at the surface of the Antarctic Ice Sheet, and space-based mapping of surface albedo
- ❖ Data assimilation in regional climate model MAR



R. Fletcher

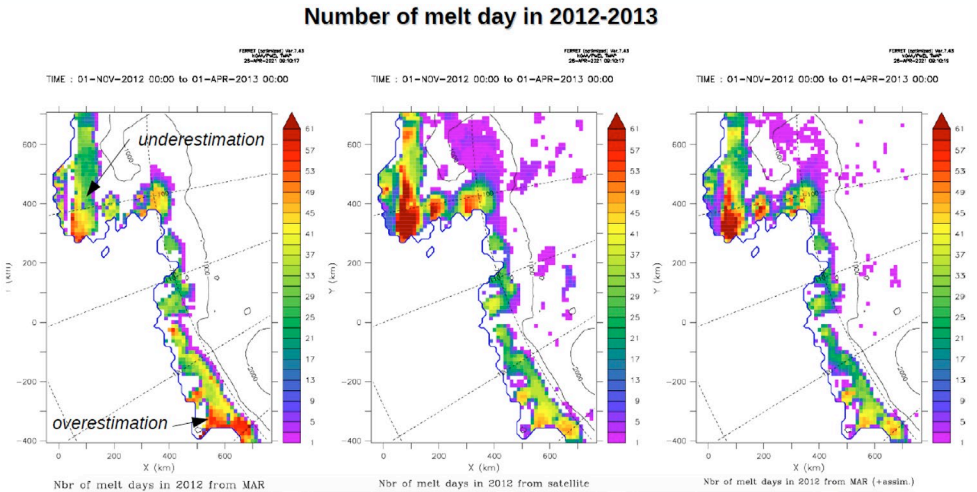


Sentinel-1



ML classification (RF) of supra-glacial Lakes

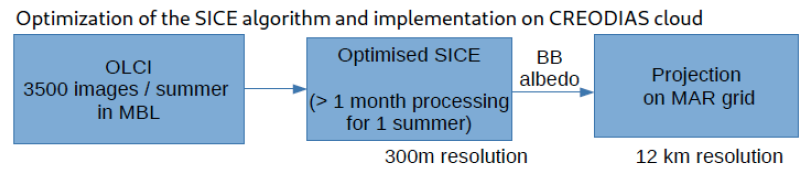
23/12/2019



Assimilation of PMW-derived melt and broadband albedo in MAR

Assimilation of albedo can be beneficial during the core of the season.
 ESA S3Snow project has developed an algorithm to retrieve broadband albedo for Sentinel 3 OCLI → SICE algorithm is in production at 1 km over Greenland (J. Box)

IGE Digital Twin Antarctica activity:



Cloud cover is omnipresent. Very conservative cloud mask applied to avoid cloud contamination → remain 25% of valid data on average per day (on the ice sheet)

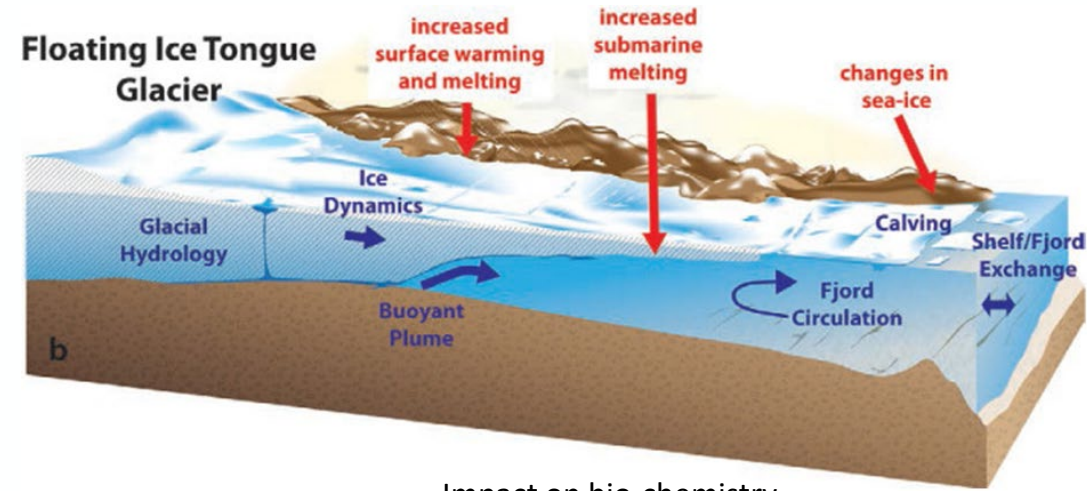
Ice sheet, sub-glacial, ocean, sea-ice, bio-chemistry interactions - joined Observation and Numerical simulations across all 5 systems

From analogues in Greenland we can expect that the buoyancy added by runoff causes

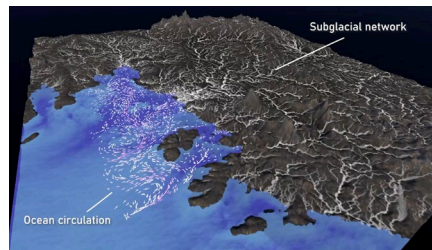
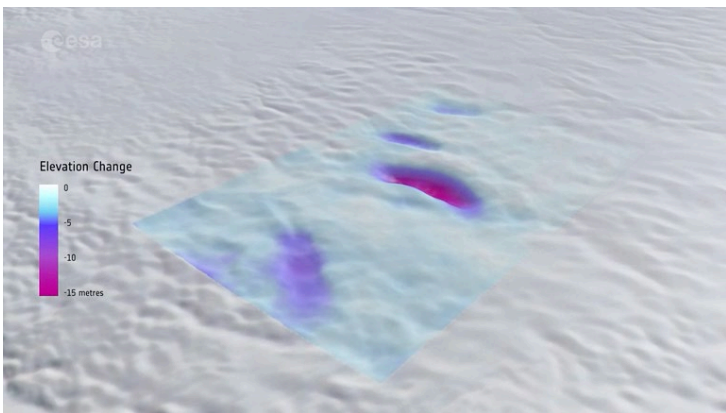
- Mixing near the grounding line
- Increased melting, and modified circulation along coast
- Transport of nutrients from subglacial environment (iron)

As part of the demonstrator:

- Coupled ice sheet - ocean model - Subglacial hydrology model
- Subglacial run-off implementation in ocean model
- Coupling of bio-chemical model (BLING) with MITgcm

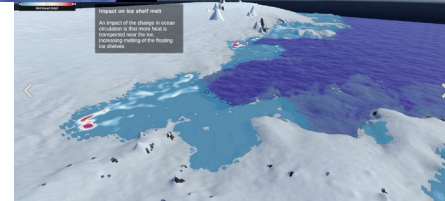


Subglacial water flux

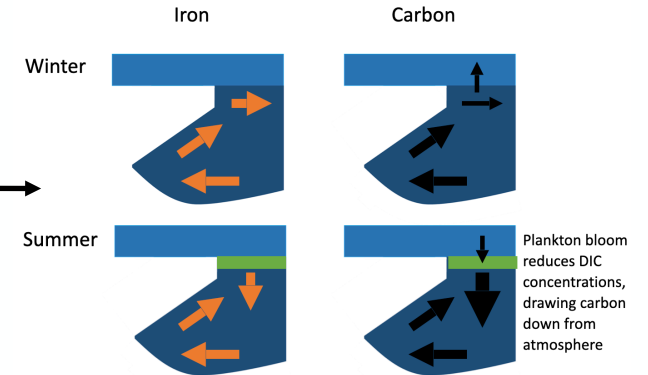


Ocean dynamics

Impact on ocean circulation and ice shelves melt rate



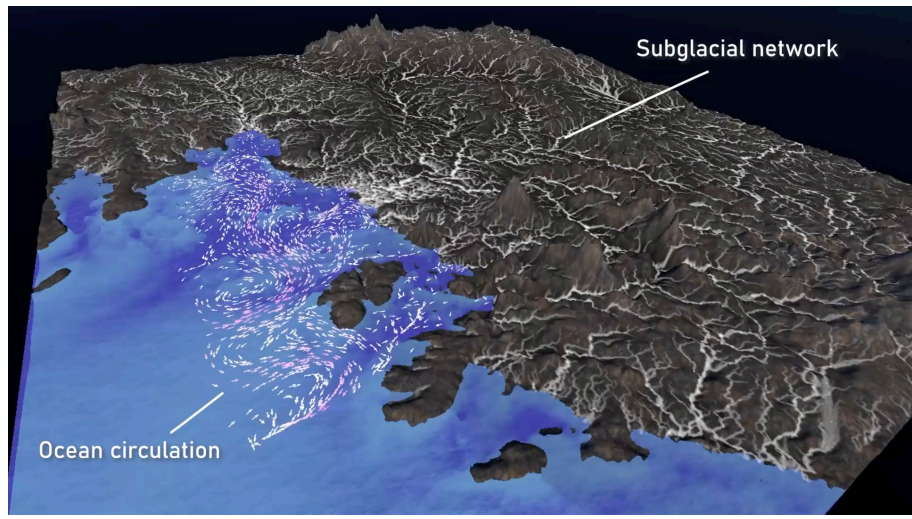
Impact on bio-chemistry



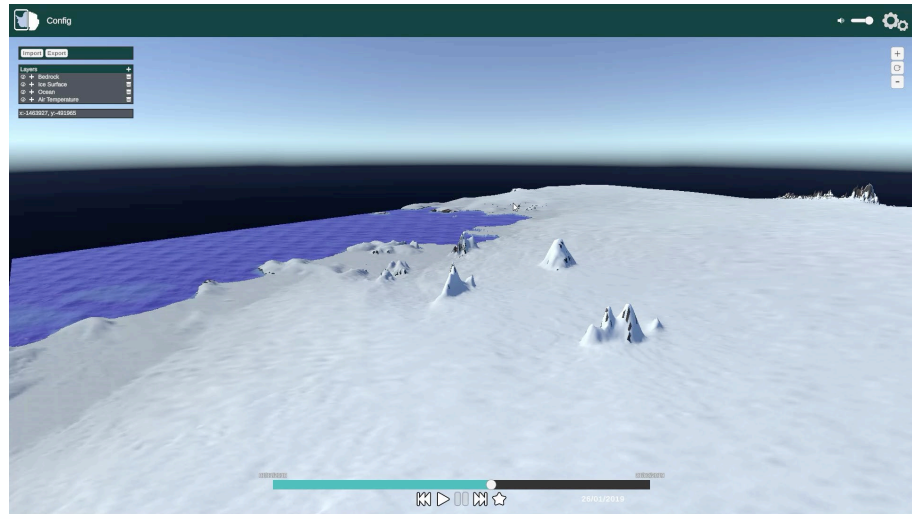
Demonstrator: Virtual 4D Environment



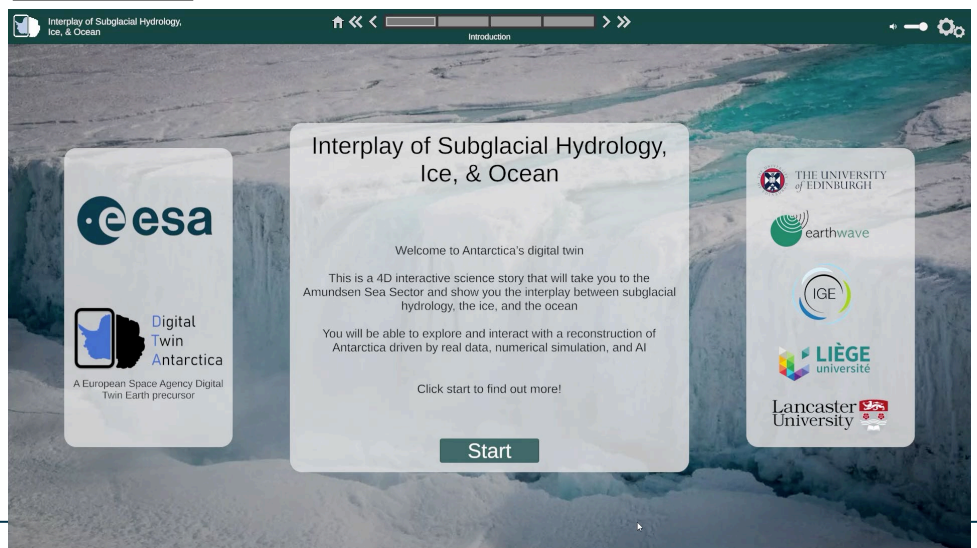
Overview of ice sheet, sub-glacial, ocean dataset



4D slicing

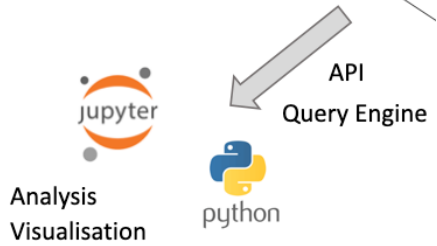


User stories



Dashboards

Exploration, analysis



DTA PM4 – Example dashboards for Decision Makers

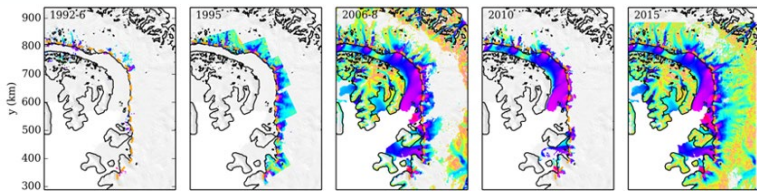
Dashboards - Global impacts



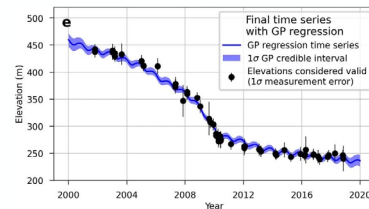
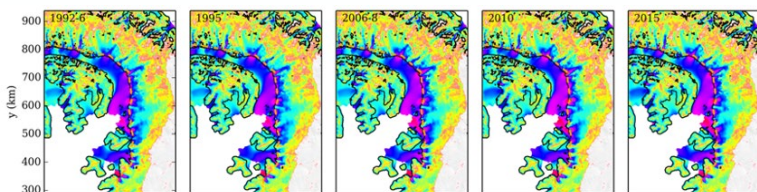
Analysis-ready data-cube of the “Antarctic system”

- Across ice sheet, subglacial, ocean, atmosphere and biological systems
- Collection of observations, re-analysis products, simulation
- AI-based feature extraction
- Need for constant stream of new products

Observations

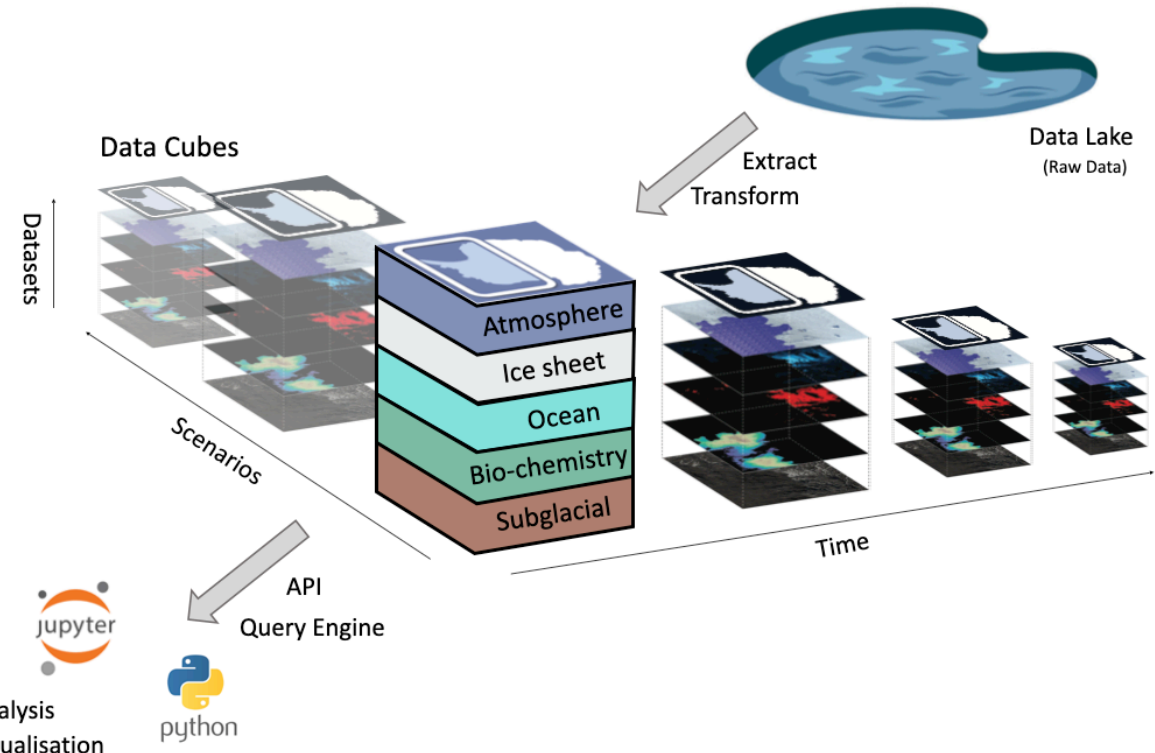


Observations with calibrated modelled data



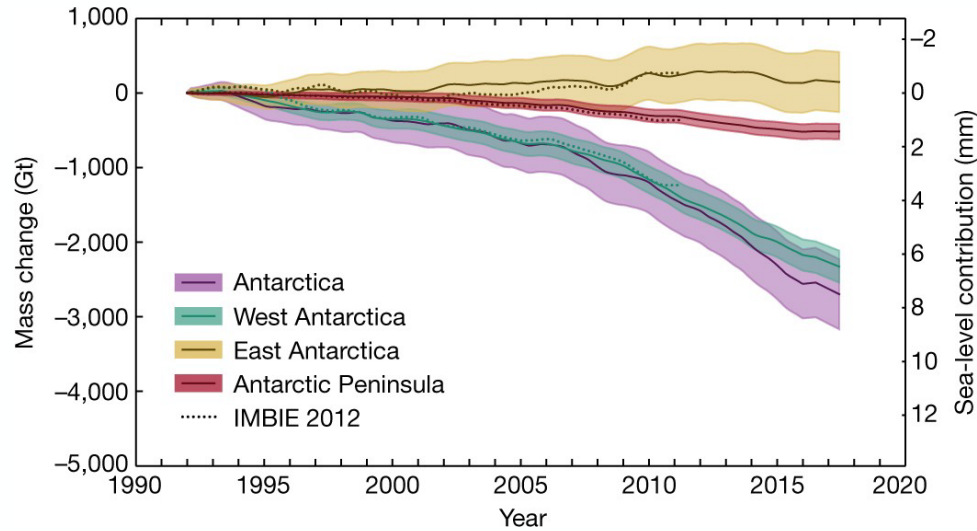
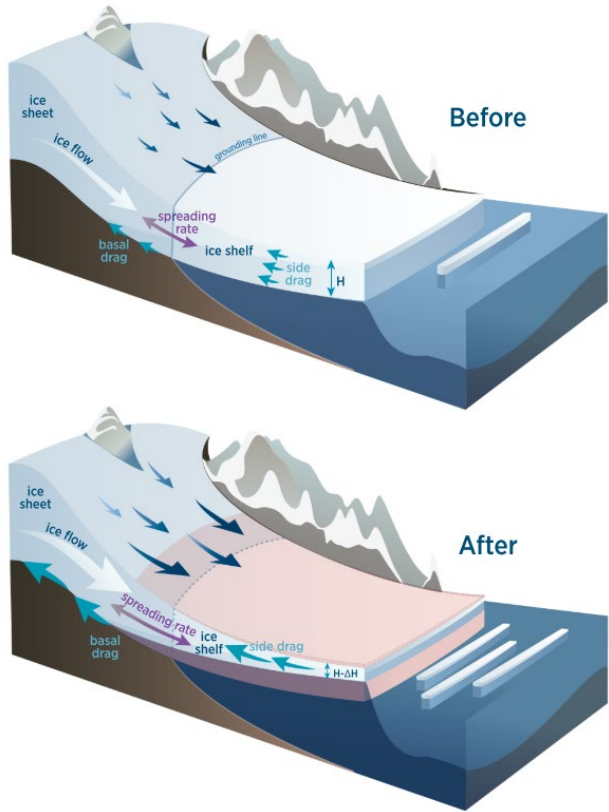
Hugonnet et al., *Nature*, 2021

Hogg et al., *GRL*, 2017



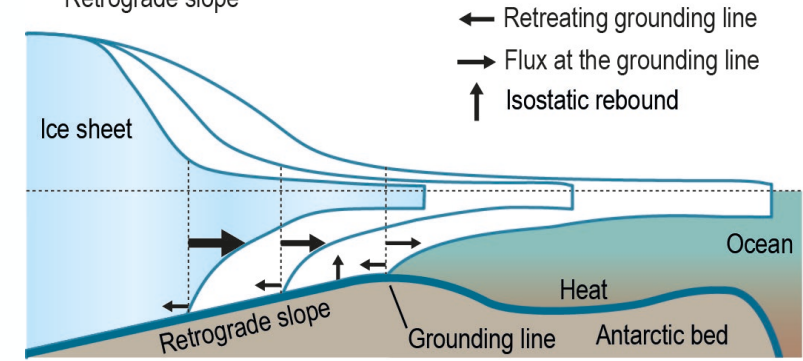
Key processes modulating ice sheet response to climate

Buttressing



Tipping points e.g. MISI, MICI

(a) Marine Ice Sheet Instability (MISI)
Retrograde slope



(b) Marine Ice Cliff Instability (MICI)
Pro/retrograde slopes

