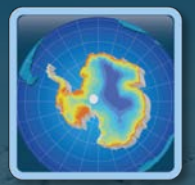
sea ice cci

greenland ice sheet cci



antarctic ice sheet cci

glaciers cci

snow cci

permafrost cci

CRYOSPHERE ECVS

Thomas Nagler, Annett Bartsch, Rene Forsberg, Thomas Lavergne, Frank Paul and Andrew Shepherd

26 November 2020

Mid-Term Review

SCIENCE QUESTIONS IN CRYOSPHERE (1/2)

Earth's cryosphere is the most responsive element of the climate system, but it remains the most poorly represented in climate models.

Major science questions include

- **How can we optimize cryosphere ECV products for spurring the diagnostic and predictive skills of climate models?**
- **How can cryosphere ECV's support the tracking of obstacles and progress towards the Paris Agreement?**

ECV Specific Questions

Sea Ice

- Can we better understand and predict pathways towards an ice-free Arctic ocean in future emission scenarios?
- When and where will a climate change signal emerge from the large natural variability of Antarctic sea ice?

Antarctic Ice Sheet

- How can EO data contribute to reducing the uncertainty in sea level projections?
- How quickly will the West Antarctic ice sheet collapse?

SCIENCE QUESTIONS IN CRYOSPHERE (2/2)

Greenland Ice Sheet

- How can EO data from multiple sensors be utilized to give a most precise estimate of mass loss?
- What is the role of melt water, ocean melt, and englacial hydrology for rapidly changing outlet glaciers ?

Glaciers

- How much water is stored in glaciers, and how do they respond to climate change?
- How will the decline of glaciers impact hydrology and geo-hazards?
- Why and where do glaciers surge and collapse?

Snow

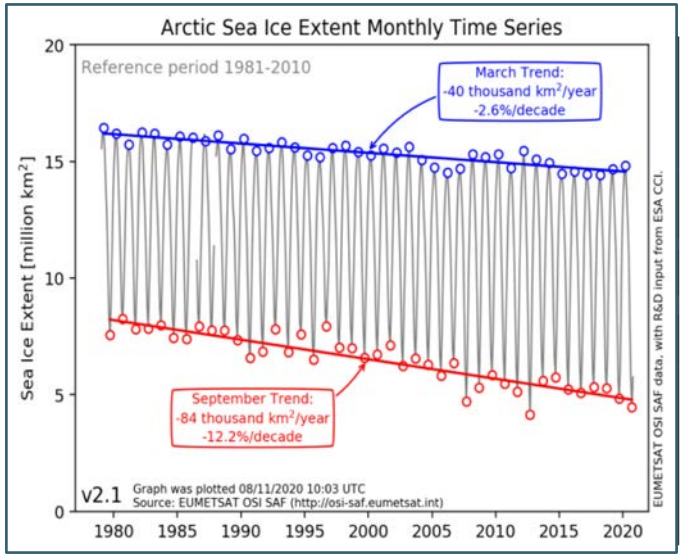
- Which regions are affected by changes in snow extent, how do snow onset/depletion dates change?
- How much water is stored in the snowpack and how is the snow mass affected by changes in atmospheric forcing?
- What is the role of snow in Arctic and mountainous regions in changes of ecosystems & landscape?

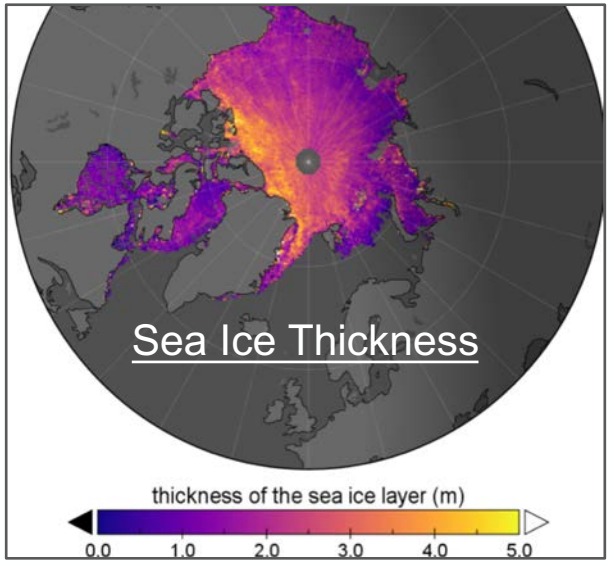
Permafrost

- Which regions have been most affected by permafrost thaw and what is the magnitude of ground temperature change?
- What is the impact of permafrost thaw on the carbon and water cycle?

HIGHLIGHTS – SEA ICE

- Time series of **Sea Ice Concentration (SIC),** and **Sea Ice Thickness** for both Arctic and Antarctic, with quantification of uncertainty, since 1979. Data sources are altimeters from ESA (ERS, EV, CS2), radiometers from US and Japan, SAR from ESA/EU (EV, S1)
- Back-extension of SIC to the mid-1970s from precursor satellites (under development)
- Successful transformation of production to EUMETSAT OSI SAF and EU C3S
- Data are used in climate research (e.g. SIMIP) and re-analyses (e.g. C3S)
- Contribution to the on-going IPCC process

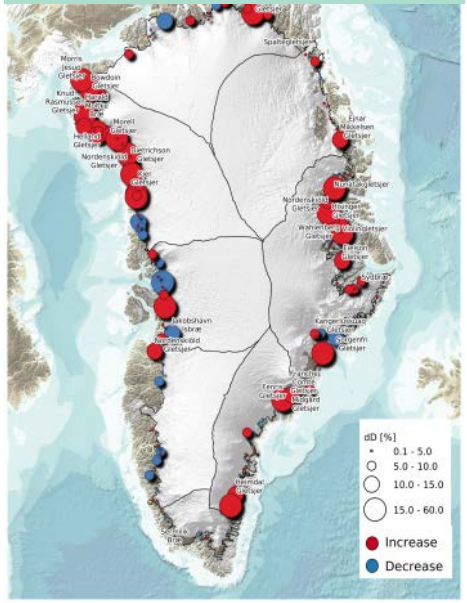




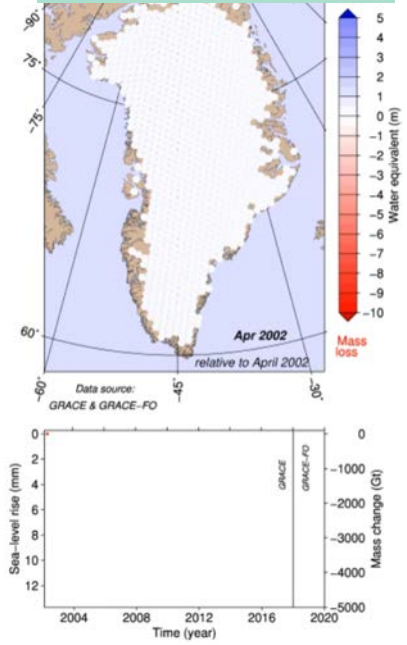
HIGHLIGHTS – GREENLAND ICE SHEET

- Unified processing for time series of **SEC and GMB**
- **Sentinel-1 ice sheet wide velocity** maps and continuous monitoring of ice flow of outlet glaciers
- **Mass flux and ice discharge** from Greenland outlet glaciers
- Production of baseline IV and SEC products adopted by EU-C3S
- Several high-level publications, contributing to the IPCC process

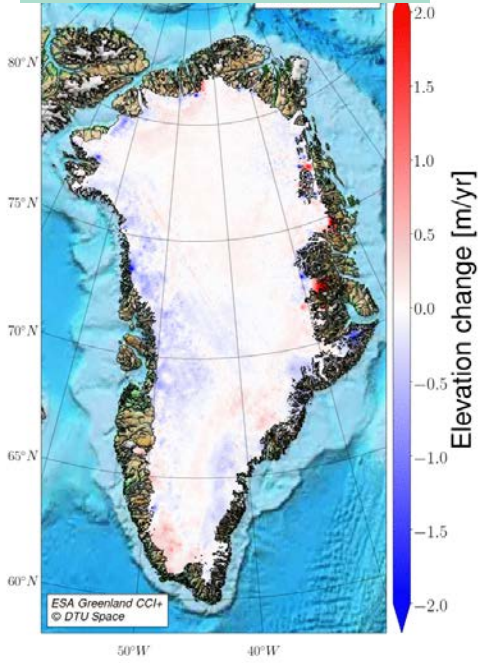
Change of Mass Discharge from Outlet Glaciers



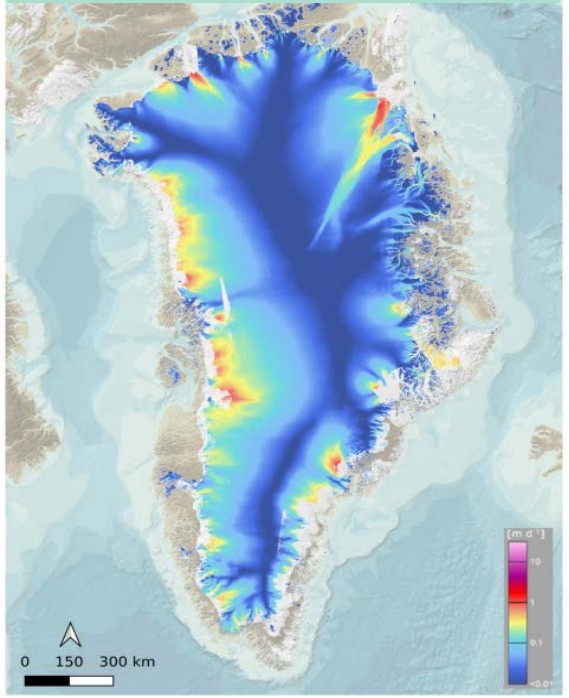
Mass Change / Grace



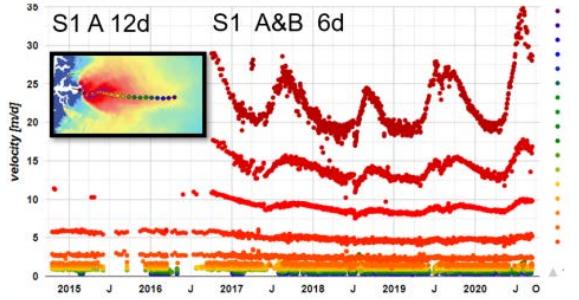
Surface Elevation Change



1st Sentinel-1 InSAR IV Map



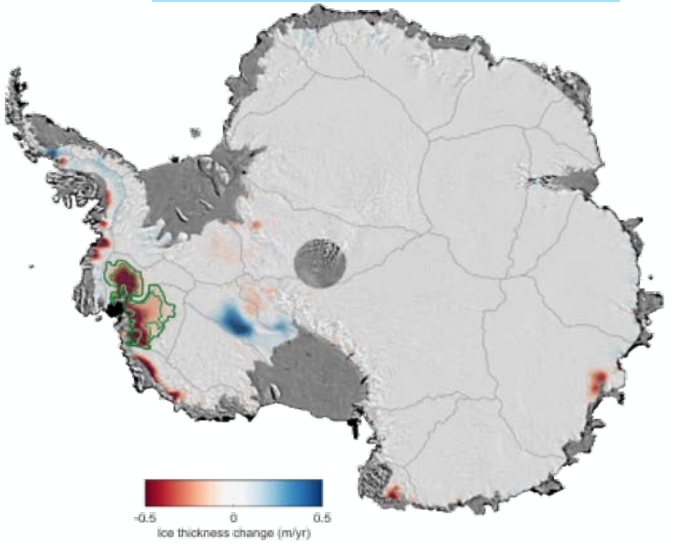
Jakobshavn Glacier



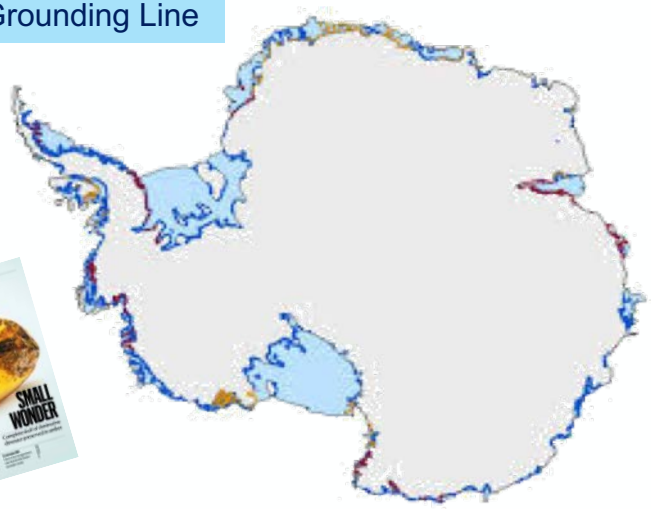
HIGHLIGHTS – ANTARCTIC ICE SHEET

- R&D and generation of time series for **surface elevation change, ice velocity**, **grounding line location**, and **gravimetry mass balance**, including consistency and error characterisation.
- Lead and contribution to the Ice Sheet Mass Balance Inter-comparison Exercise (**IMBIE**), with major international contribution
- Transferred core satellite altimetry **SEC production** to EU-C3S
- High level publications, contributing to the ongoing IPCC process

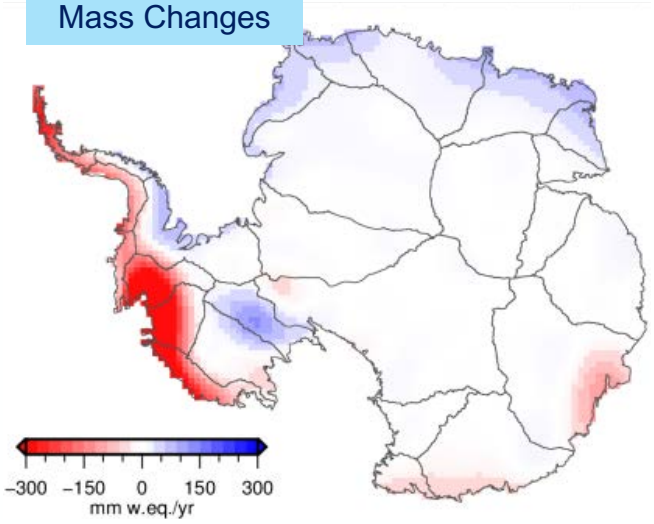
Surface Elevation Change



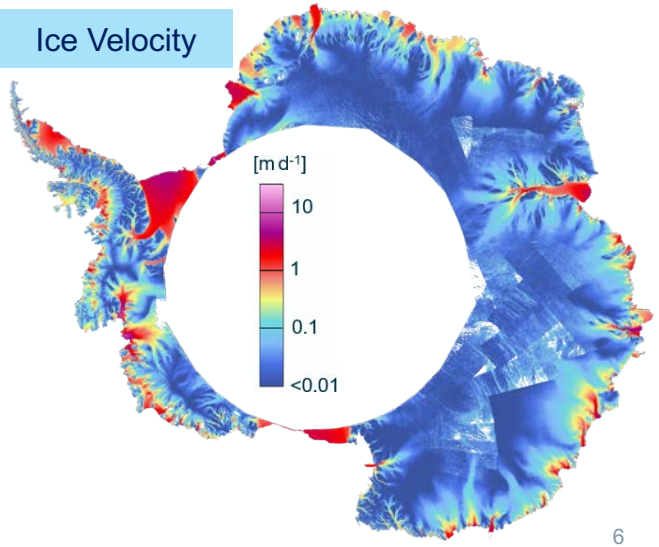
Grounding Line



Mass Changes

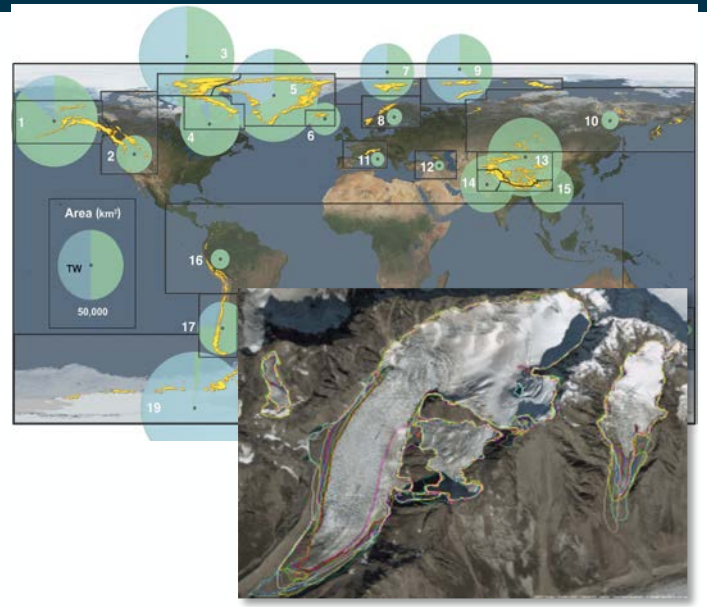


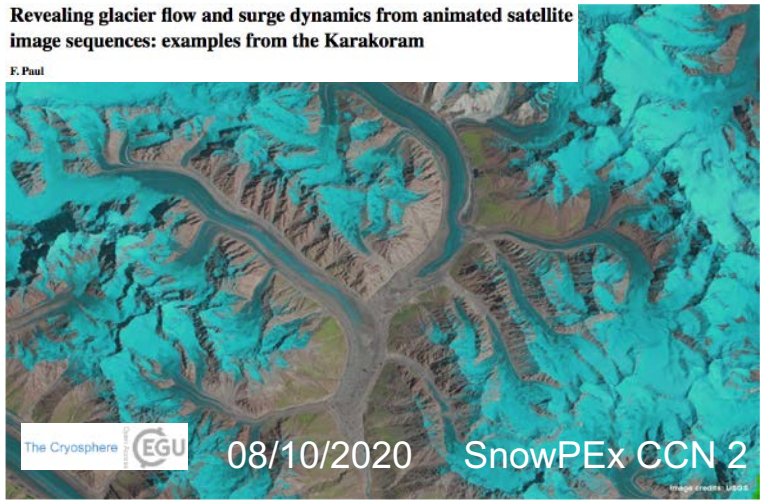
Ice Velocity



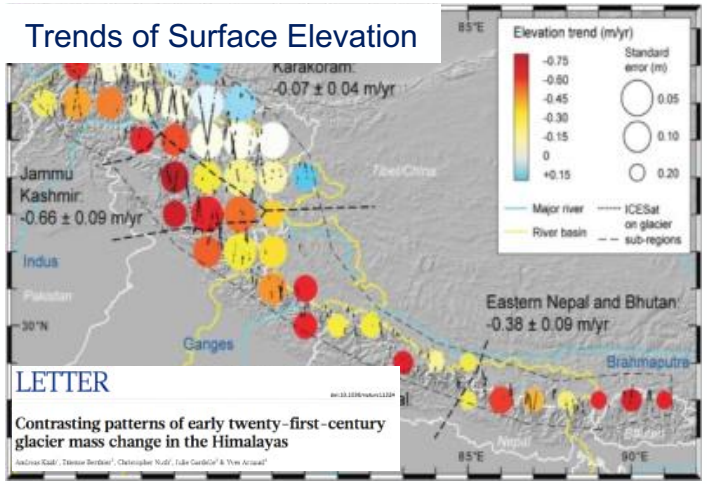
HIGHLIGHTS - GLACIERS

- Major contribution to the **Randolph Glacier Inventory (RGI)**, uncertainty assessment of glacier extents
- Time series of **glacier snow lines** for several mountain ranges
- Assessment of **glacier mass changes in High Mountain Asia** and their contribution to regional hydrology and sea-level rise
- Time series **for ice dynamics of large glaciers** from SAR and optical sensors, visualization of glacier flow and surges
- Several high-level publications, cited in IPCC AR5 and SROCC

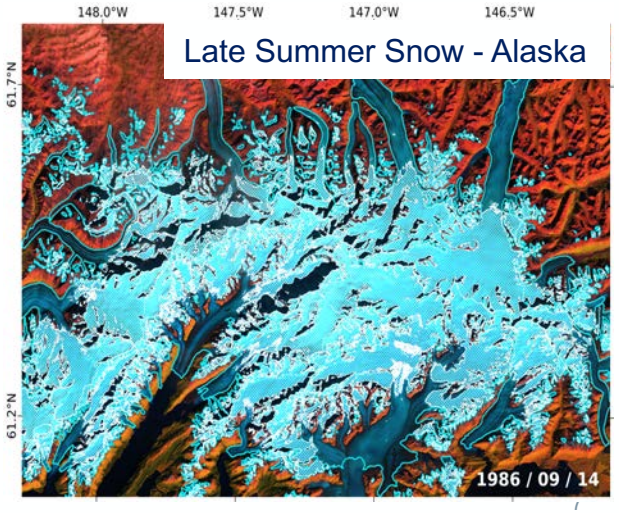




Trends of Surface Elevation



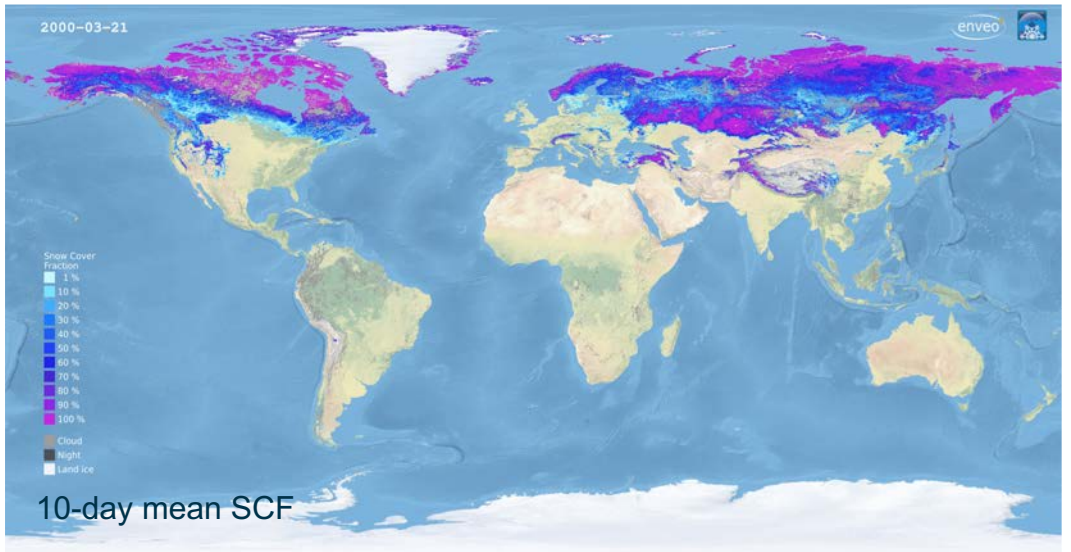
Late Summer Snow - Alaska

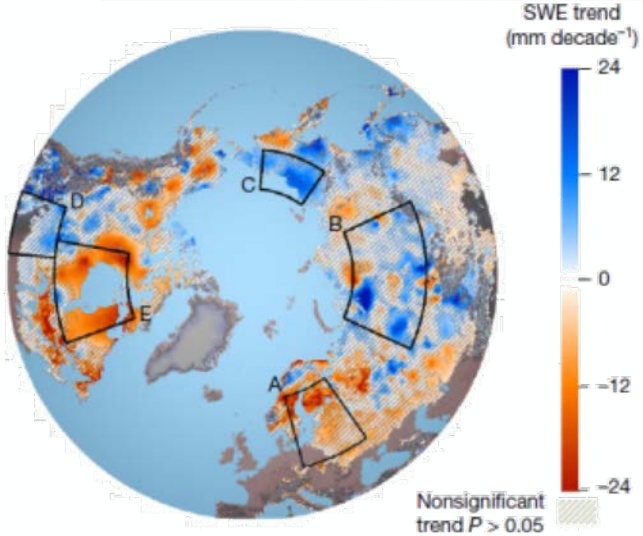


HIGHLIGHTS - SNOW

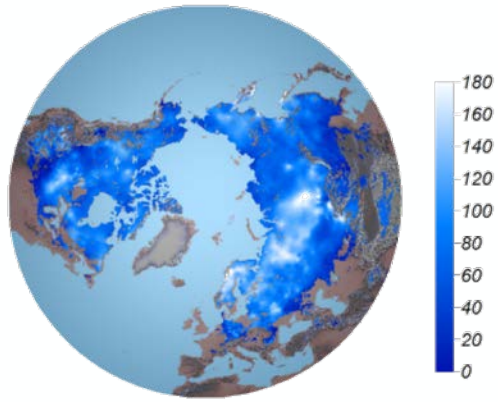
- **Daily, global homogenised snow extent and snow water equivalent products** with uncertainty (~1980→) using products from *landcover_cci* and *cloud _cci*
- Exploitation of **AI to generate snow reference data** from Sentinel-2 and Landsat
- **Temporal trends and snow mass anomalies** derived from snow products
- First results published in high level journals
- *Snow_cci* products used in CMIP6 and ESM-SnowMIP evaluations, in Pan-Arctic hydrological models, and for comparison with ECMWF-ERA5.

Snow Cover Fraction (SCF) and uncertainty maps (1 km)





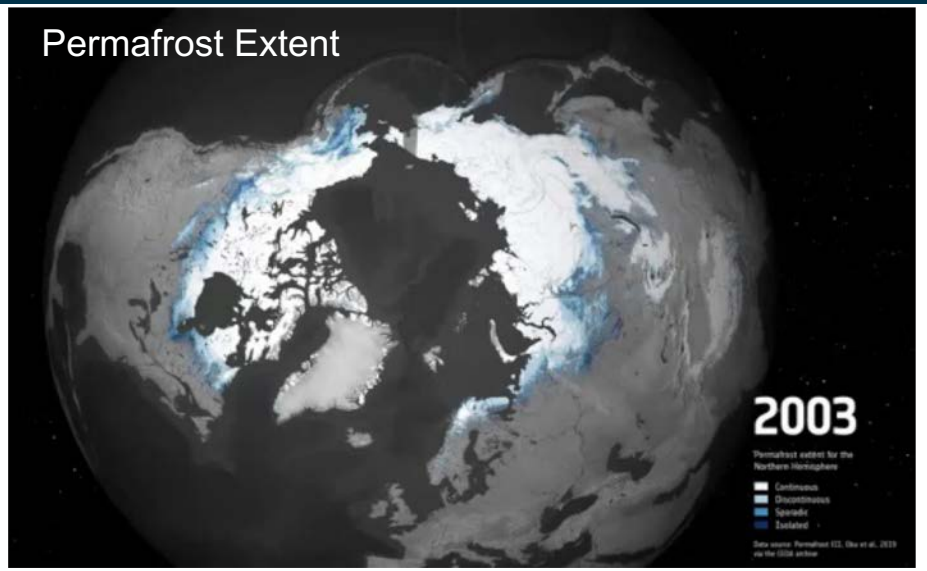
Snow Water Equivalent (without mountains)

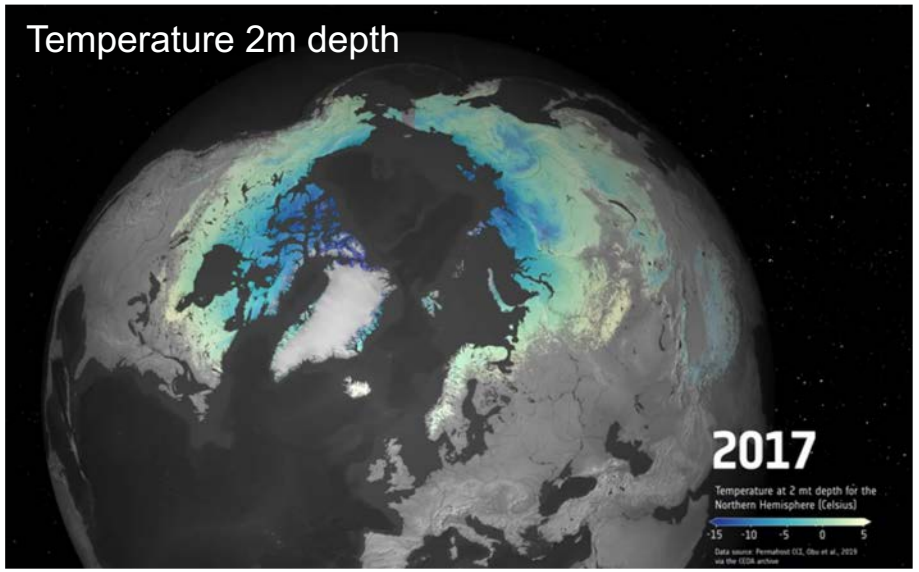


Pulliainen et al., Nature, 2020

HIGHLIGHTS - PERMAFROST

- **Permafrost ground temperature, active layer thickness and extent V1** generated using landcover_cci products for 1997 to 2018
- Development of benchmark dataset in collaboration with GTN-P initiated and almost completed
- Standard guidelines developed with IPA to produce EO based regional rock glacier inventories and kinematic time series
- Use cases: AI applied to address impact of permafrost thaw, climate modelling studies started, uptake specifically in HORIZON-2020 projects
- Link to NASA/ESA initiative AMPAC established





POTENTIAL CROSS-ECVS RELATED TO CRYOSPHERE (1 OF 2)

Interaction between different cryosphere components (ice sheets, sea ice, snow, glaciers, permafrost) with ocean (temperature, currents) & atmosphere (warming)

- **Successful Cross-ECV project - Sea level budget closure** (Greenland and Antarctic ice sheets, glaciers, sea level, lakes; new ECVs to be included: e.g. snow)

Ideas for new cross-ECV activities

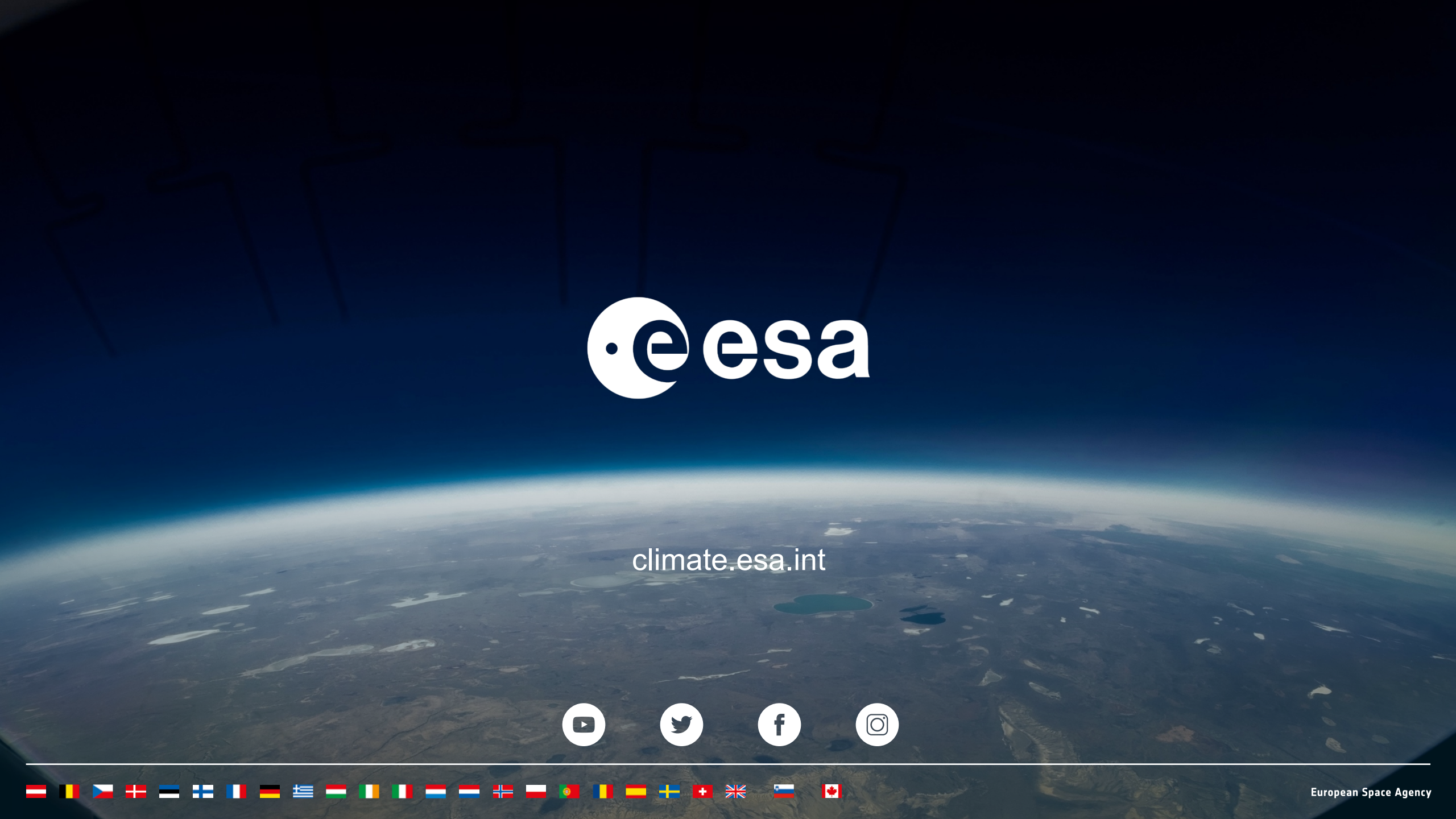
- **Arctic ocean fresh water fluxes and budget**: requires knowledge of sea-ice volume fluxes (concentration, thickness, drift), ice discharge and melt water from Greenland and Arctic ice caps, ocean currents, runoff of major rivers, precipitation, ground ice melt.

POTENTIAL CROSS-ECVS RELATED TO CRYOSPHERE (2 OF 2)

- **Oceanic forcing on flow dynamics and ice export of outlet glaciers** (ECVs ocean currents, sea ice, SST, ice sheets, glaciers)
- Stock take of **cryospheric energy budget** and associated heat transfer for global energy budget (Greenland and Antarctic ice sheets, glaciers, sea ice, snow, permafrost)
- Change of **water availability in mountain regions and high latitudes** in response to climate change (snow, glaciers, permafrost, land cover)
- Monitoring **Arctic coastal erosion** – combining permafrost, sea ice and sea level
- General **consistency of ECVs** for snow, glaciers, Greenland and Antarctic ice sheets, permafrost, land surface temperature, and interannual seasonality products from land cover

PRESSING TOPICS FOR CCI PHASE 2 AND/OR NEW CLIMATE PROGRAMME

- **R&D** for advanced retrievals of current and new ECVs and the use of new sensors including upcoming HPCM
- **Homogenisation of multi-sensor time series** of ECV parameters and **inter-ECV consistency**
- Recovering data from **historical missions and continuation** of ECV time series up to present (coordinated with C3S, EUMETSAT SAFs)
- Improving knowledge of **cryosphere interactions with climate forcing** (ocean and atmosphere)
- **Tracking climate model simulations and projections** to verify emissions pathways
- Specific **use cases for single and multiple ECVs** to intensify the link to cryospheric and climate modelling communities


esa
climate.esa.int
European Space Agency