

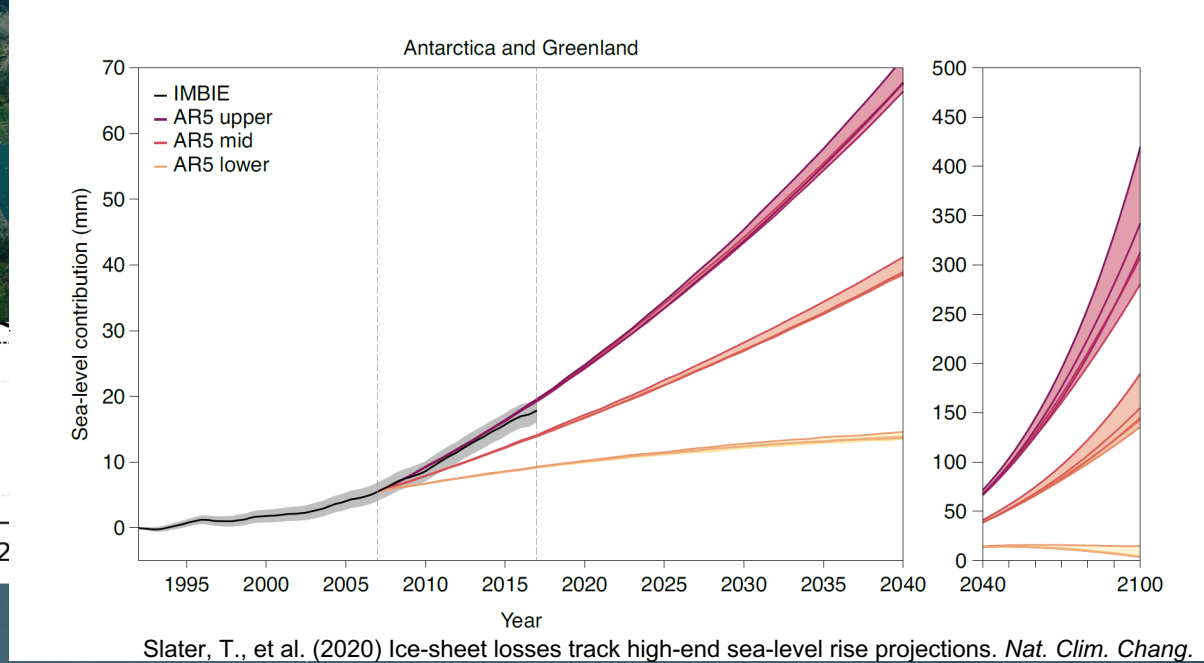
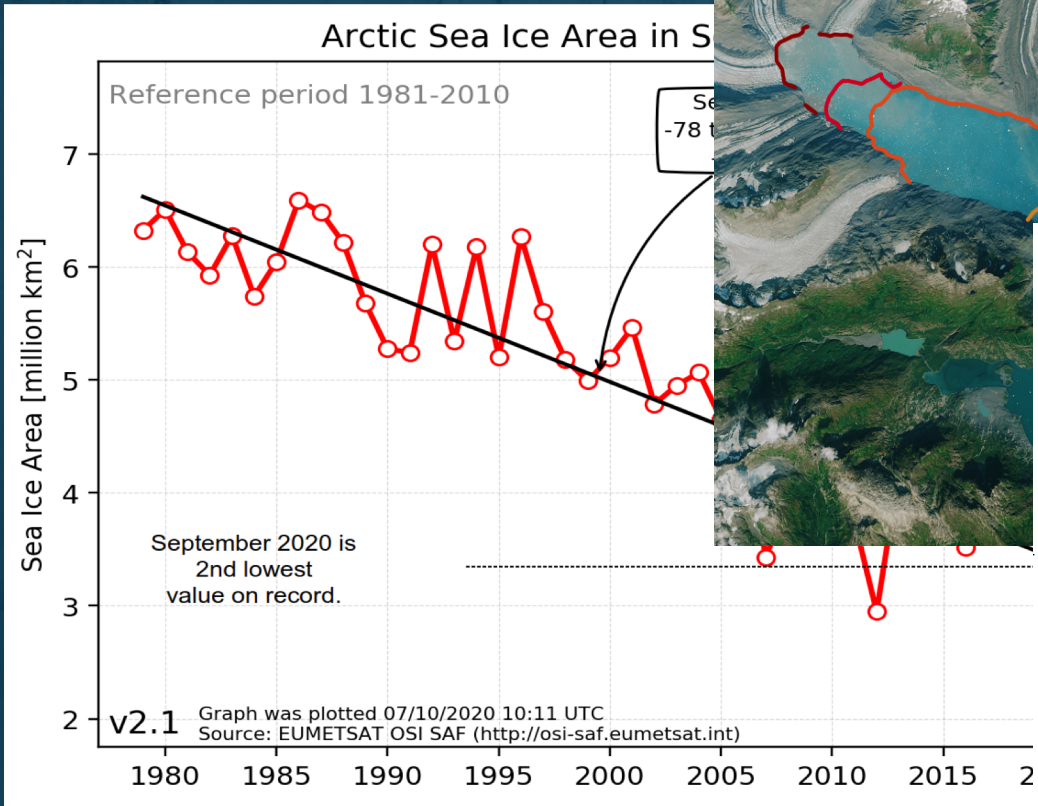
# ESA Climate Change Initiative – Observing Climate and the Cryosphere from Space

Anna Maria Trofaier (ESA Climate Office)

With contributions from Annett Bartsch (b.geos/CCI Permafrost), Rene Forsberg, (DTU/CCI Greenland), Thomas Lavergne (Met NO/CCI Sea Ice), Thomas Nagler (ENVEO/CCI Snow), Frank Paul (UZH/CCI Glaciers) and

Andrew Shepherd (UoLeeds/CCI Antarctica/IMBIE)

17 September 2021



EUMETSAT OSI SAF data with R&D contribution processed at the Norwegian Meteorological Institute.

Ice Sheets are tracking IPCC AR5's worst case scenario.

# The international community and climate



**1992 UNFCCC** at Rio Earth Summit  
Calls for research and systematic observations of the Earth (Article 5)

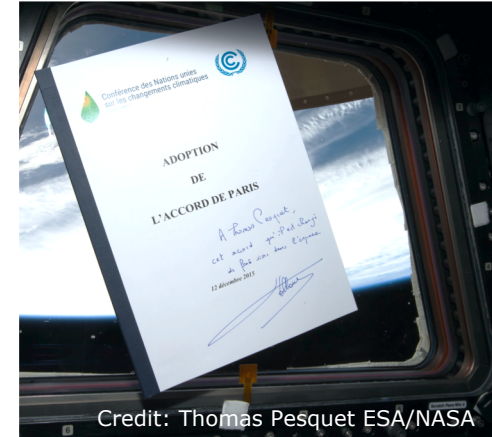
**Global Climate Observing System** founded to identify parameters needed to understand the climate system:  
Birth of the *Essential Climate Variables (ECVs)*



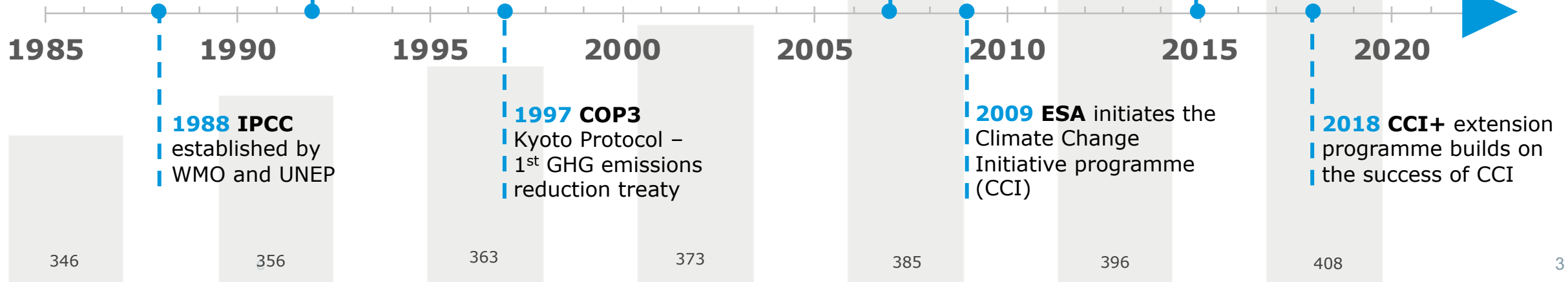
**2007 COP13** at UN Climate Change Conference in Bali  
No adequate long-term monitoring from space to address climate change  
Space agencies work together to establish a common strategy for climate monitoring from space

**2015 COP21** led to the Paris Agreement – 1<sup>st</sup> legally binding and universal agreement on climate is established.

*Inter alia*, it calls to strengthen scientific knowledge on climate, including research, [and] systematic observation of the climate system (Article 7.7)



Atmospheric CO<sub>2</sub> [ppm]

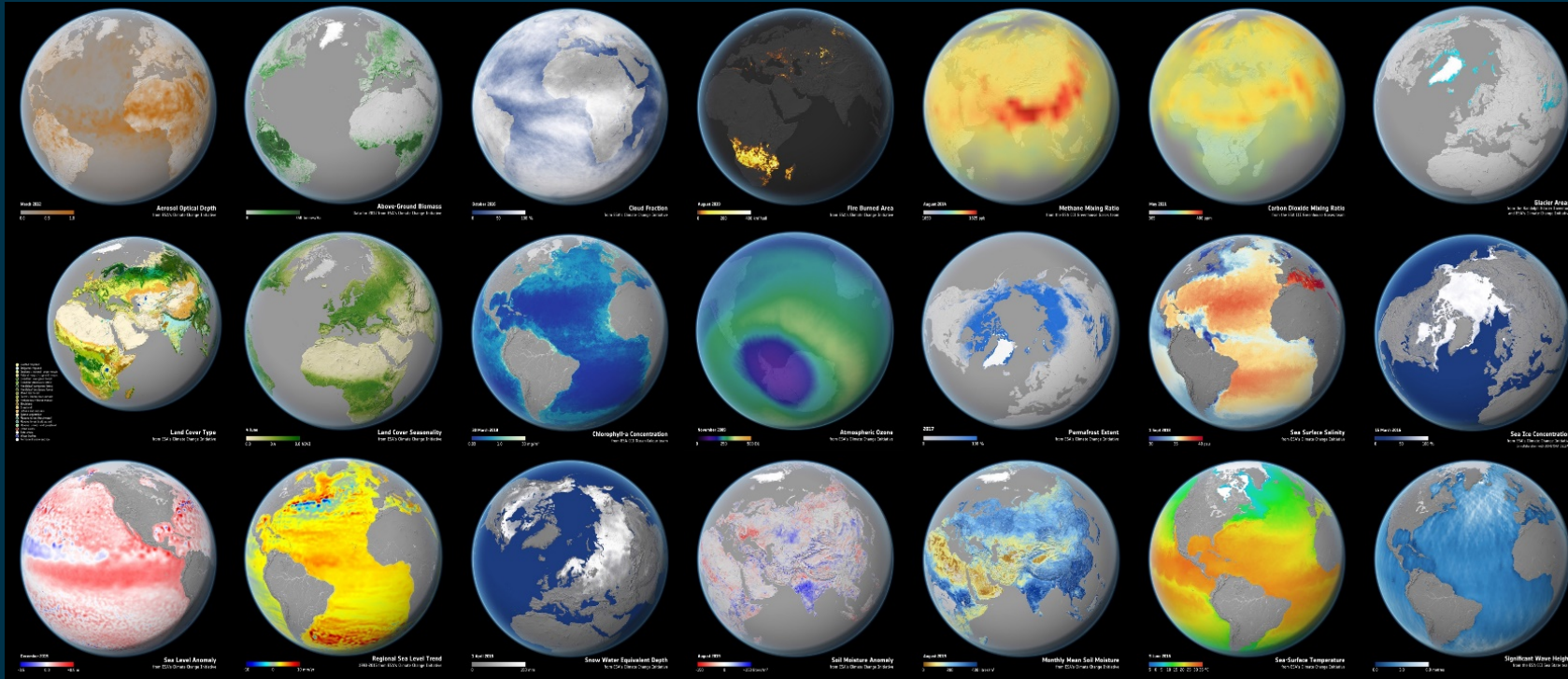


# Climate Change Initiative: Climate Data Records

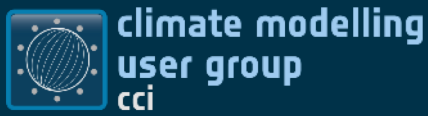
WMO defined **54** Essential Climate Variables

**36** benefit from space observations

**21** generated by ESA Climate Change Initiative



Based on user consultation |  
Transparent and traceable  
**calibration** | **Validation** using  
independent datasets | Fully  
characterized and validated  
**uncertainties** | **Consistency**  
between CCI\_ECV datasets | Data  
**standards** for harmonization  
developed | Working with  
**operational services**



[www.climate.esa.int](http://www.climate.esa.int)





sea ice  
cci



greenland  
ice sheet  
cci



antarctic  
ice sheet  
cci



glaciers  
cci

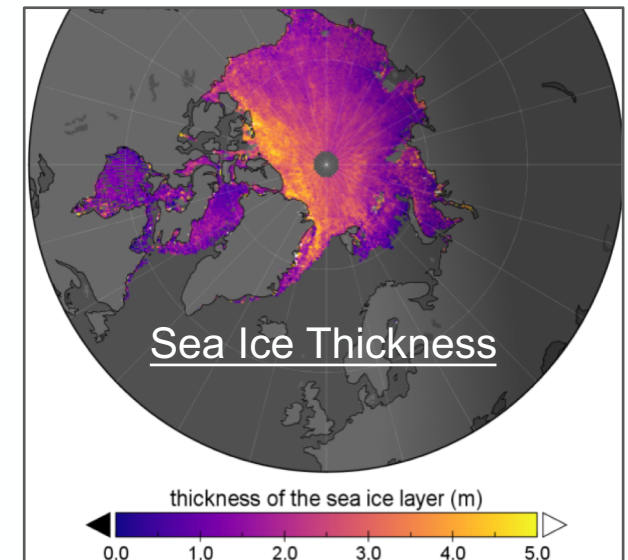
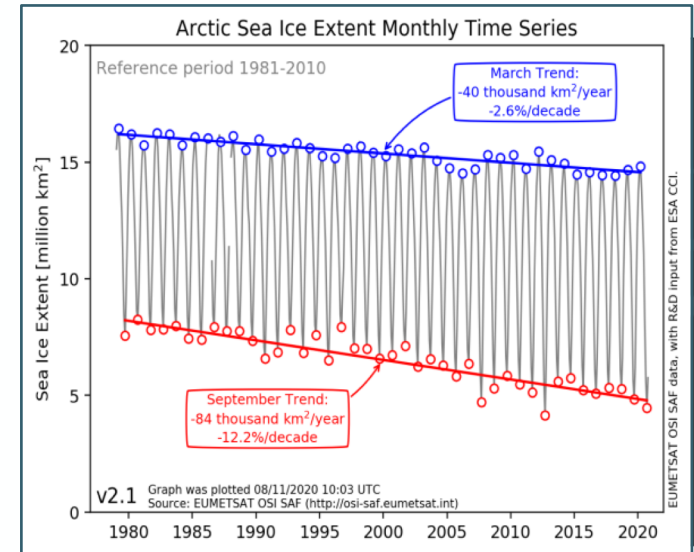


snow  
cci



permafrost  
cci

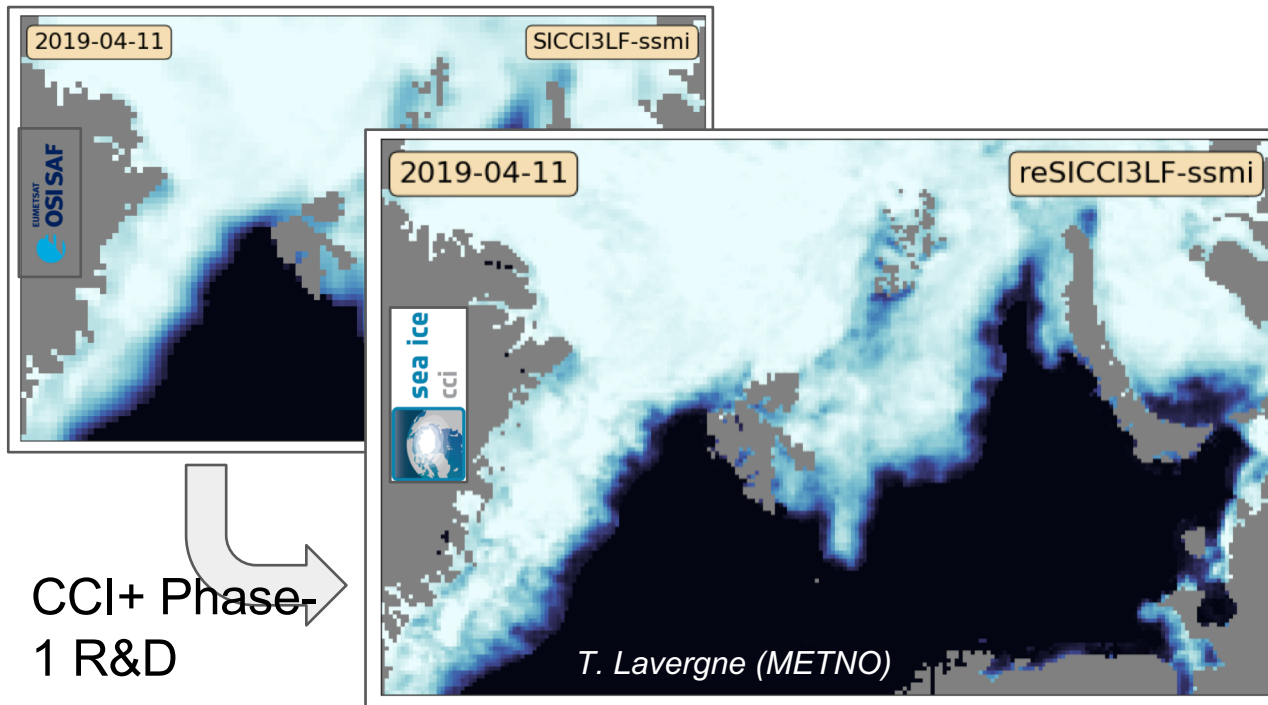
- Time series of **Sea Ice Concentration (SIC)**, and **Sea Ice Thickness** for both Arctic and Antarctic, with quantification of uncertainty, since 1979. Data sources are altimeters from ESA (ERS, ENVISAT, Cryosat-2), radiometers from US and Japan, SAR from ESA/EU (ENVISAT, Sentinel-1)
- Back-extension of SIC to the mid-1970s from precursor satellites (under development) – Nimbus-5 ESMR
- Successful transformation of production to EUMETSAT OSI SAF and EU C3S
- Cited/plotted in IPCC AR6 August 2021 report.



# Sea Ice ECV in CCI+ Phase 1

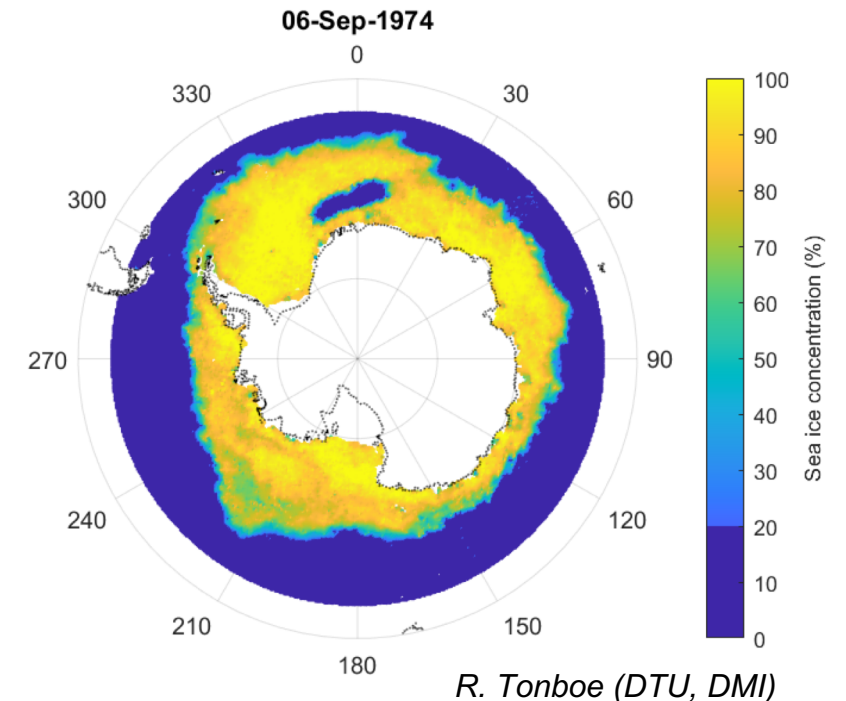
## Higher spatial resolution in the last 30 years

Using the high-frequency imagery (near-90GHz) of the SSM/Is and AMSRs. The challenge is to keep retrieval uncertainties as low as possible.



## Extend the Climate Data Record in the past

Using the ESMR precursor mission (1972-1976). Challenge is that ESMR only had one imagery channel.



# Sea Ice ECV in CCI+ Phase 1

## Improve the accuracy of SIT data products

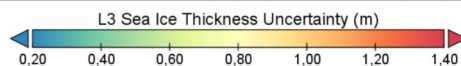
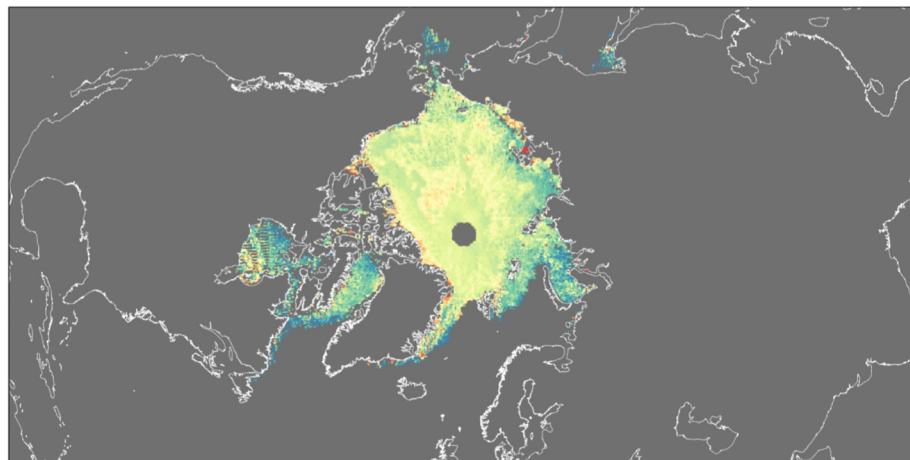
Progress on the snow-depths used in the radar-altimeter retrieval (incl. using reanalyses).

Improve the characterization of uncertainties.

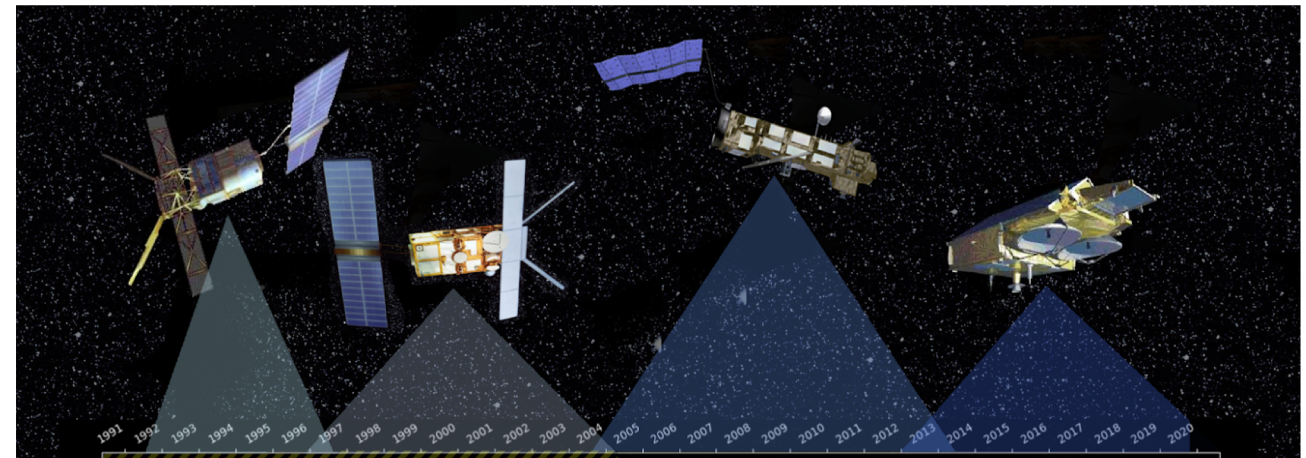
## Extend the Climate Data Record in the past

Using the ERS-1 and ERS-2 missions (>1992). Challenges include pulse deblurring and snow load.

CryoSat-2 AWI v2.1 algorithm test (April 2017)  
new (I3) SIT uncertainty



S. Hendricks, AWI

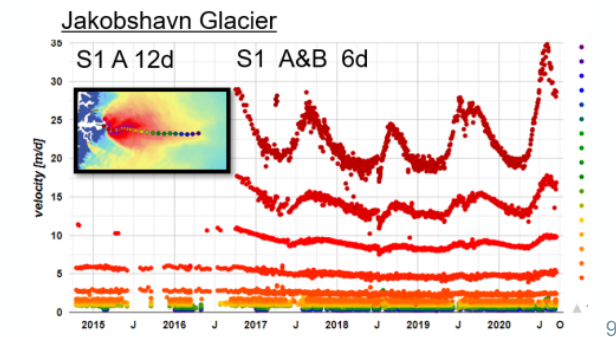
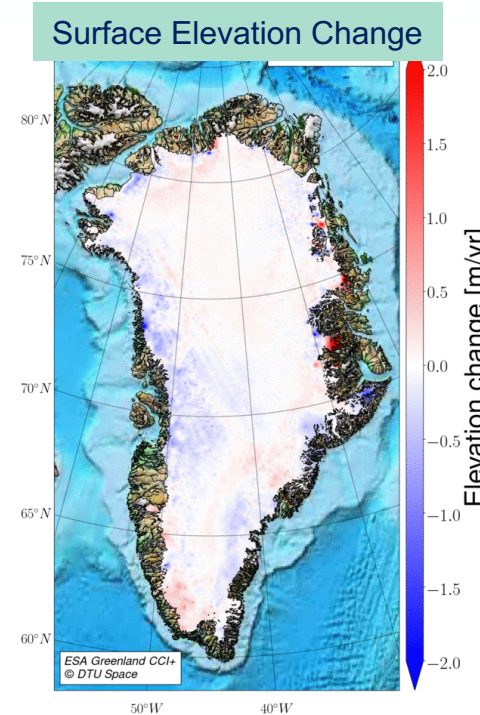
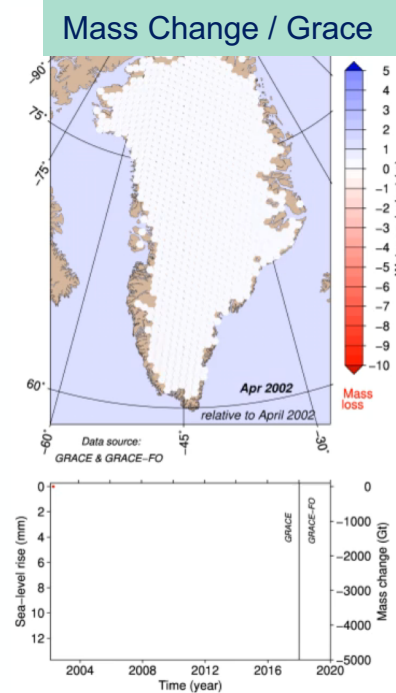
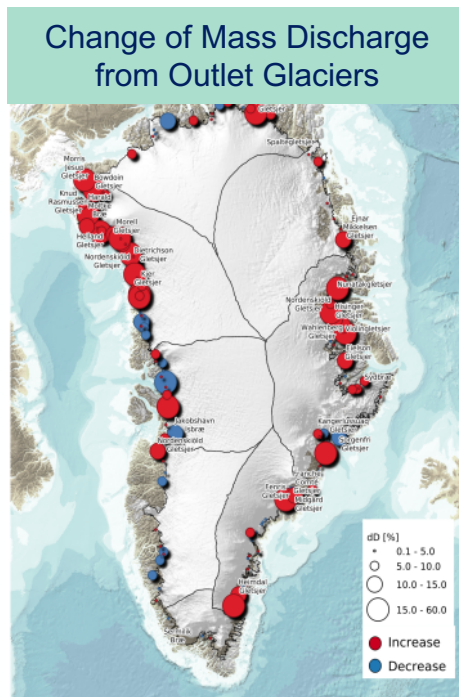
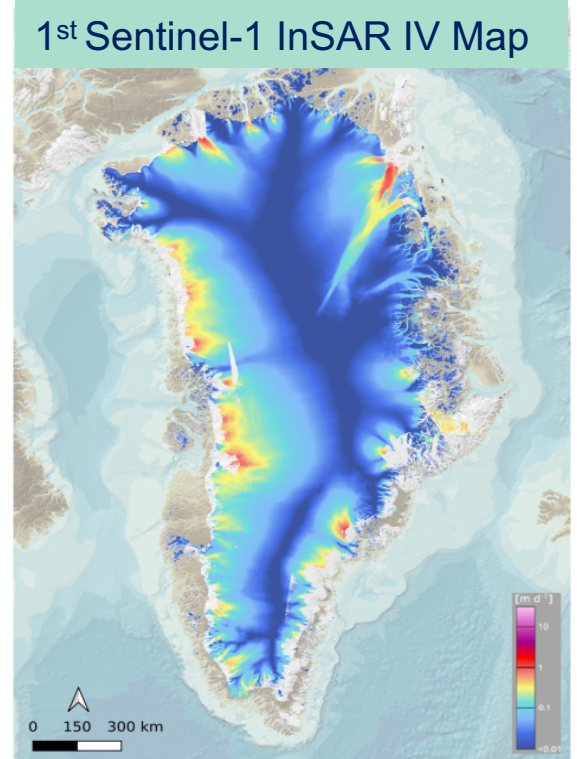


ERS-1 & 2  
(work in progress in CCI+)

Envisat + CryoSAT2  
(already in CCI, improved in CCI+)



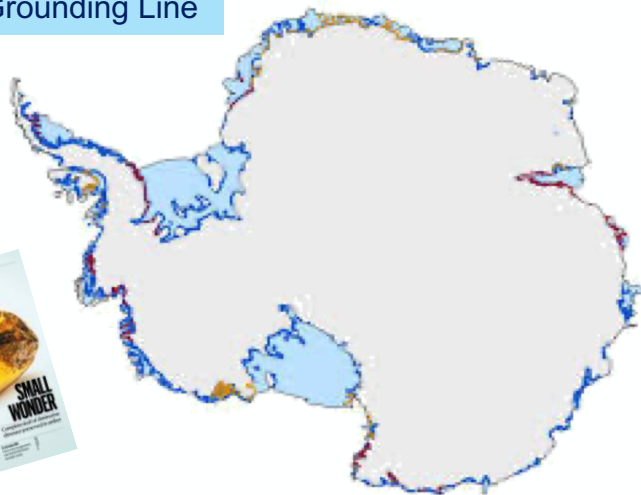
- Unified processing for time series of **SEC** and **GMB**
- **Sentinel-1 ice sheet wide velocity** maps and continuous monitoring of ice flow of outlet glaciers
- **Mass flux and ice discharge** from Greenland outlet glaciers
- Production of baseline IV and SEC products adopted by EU-C3S
- Several high-level publications, cited in IPCC AR6 August 2021 report



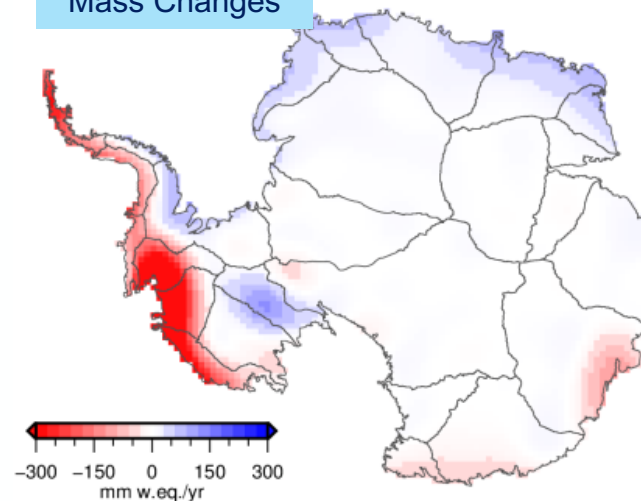
- R&D and generation of time series for **surface elevation change**, **ice velocity**, **grounding line location**, and **gravimetry mass balance**, including consistency and error characterisation.
- Lead and contribution to the Ice Sheet Mass Balance Inter-comparison Exercise (**IMBIE**), with major international contribution
- Transferred core satellite altimetry **SEC production** to EU-C3S
- High level publications, cited in IPCC AR6 August 2021 report



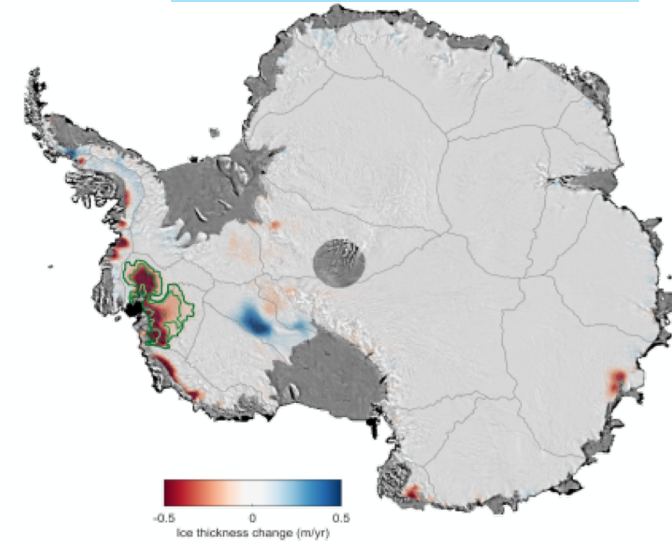
Grounding Line



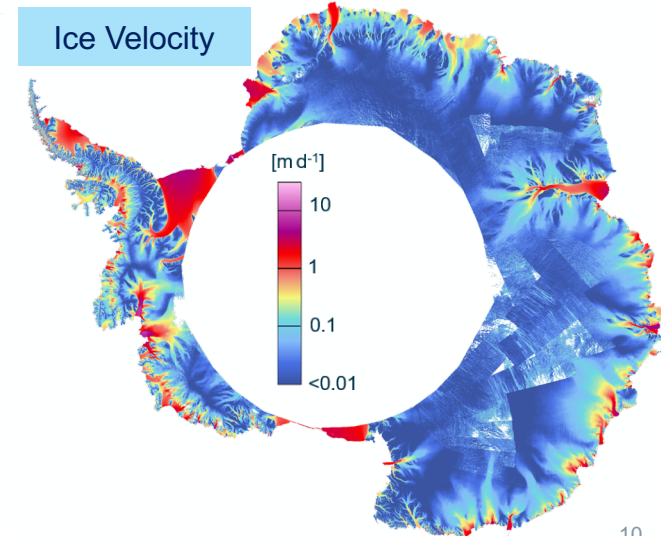
Mass Changes



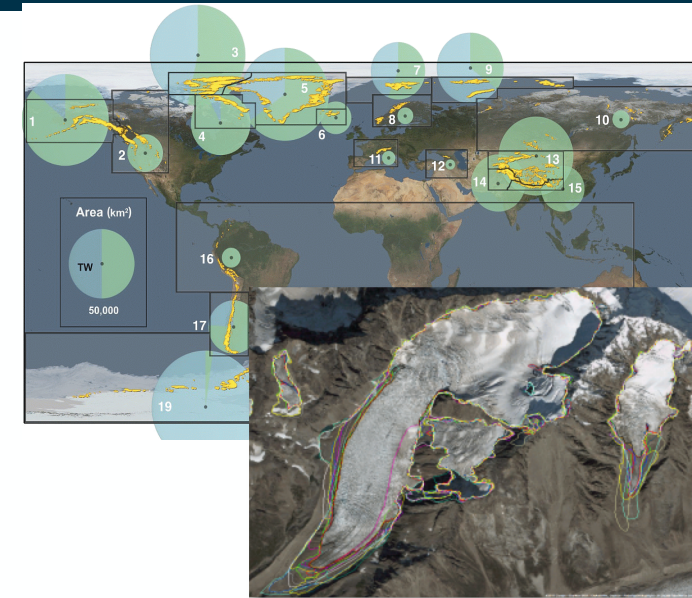
Surface Elevation Change



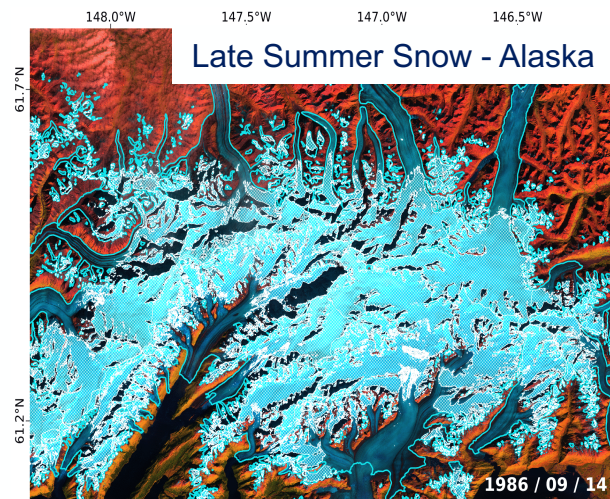
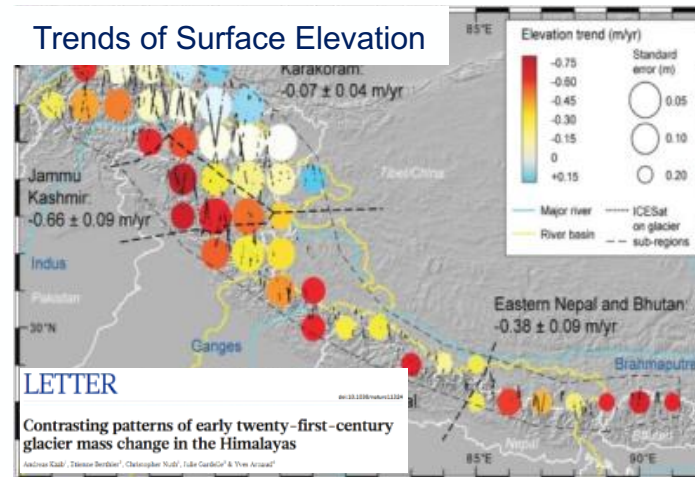
Ice Velocity



- 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 AR6 August 2021 report

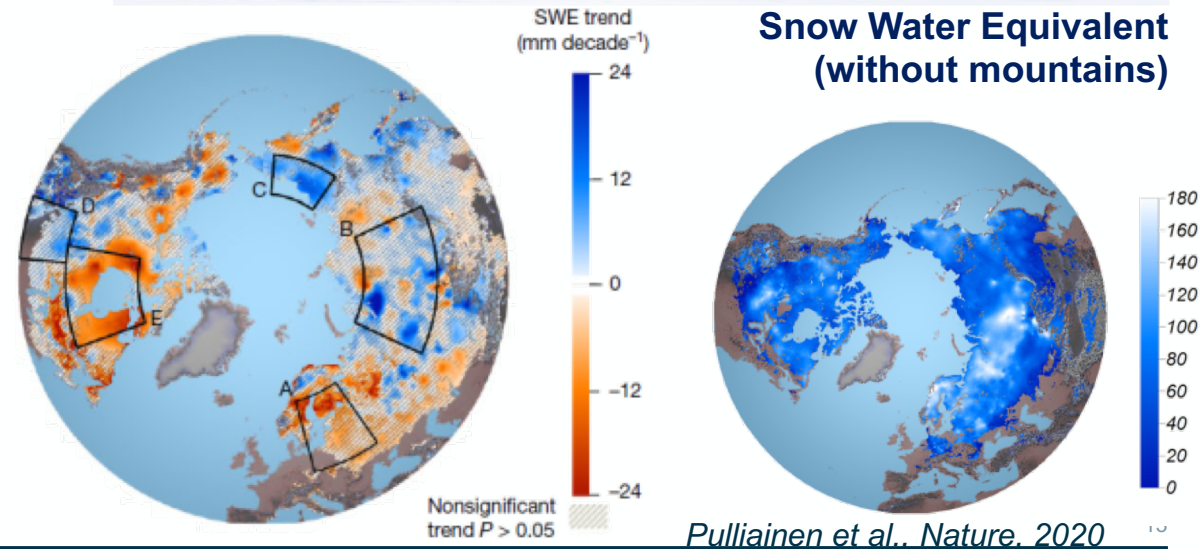
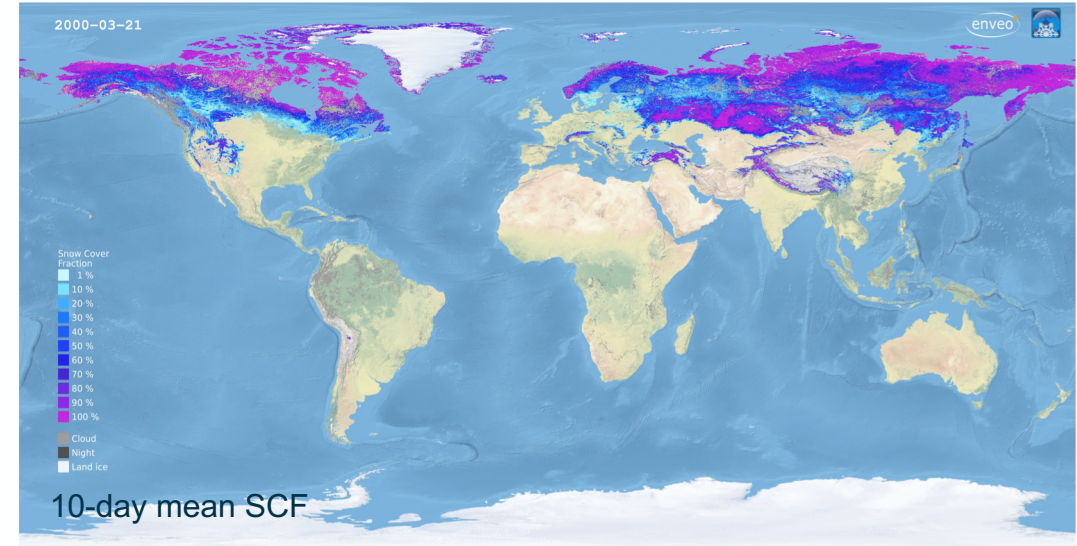


Revealing glacier flow and surge dynamics from animated satellite image sequences: examples from the Karakoram



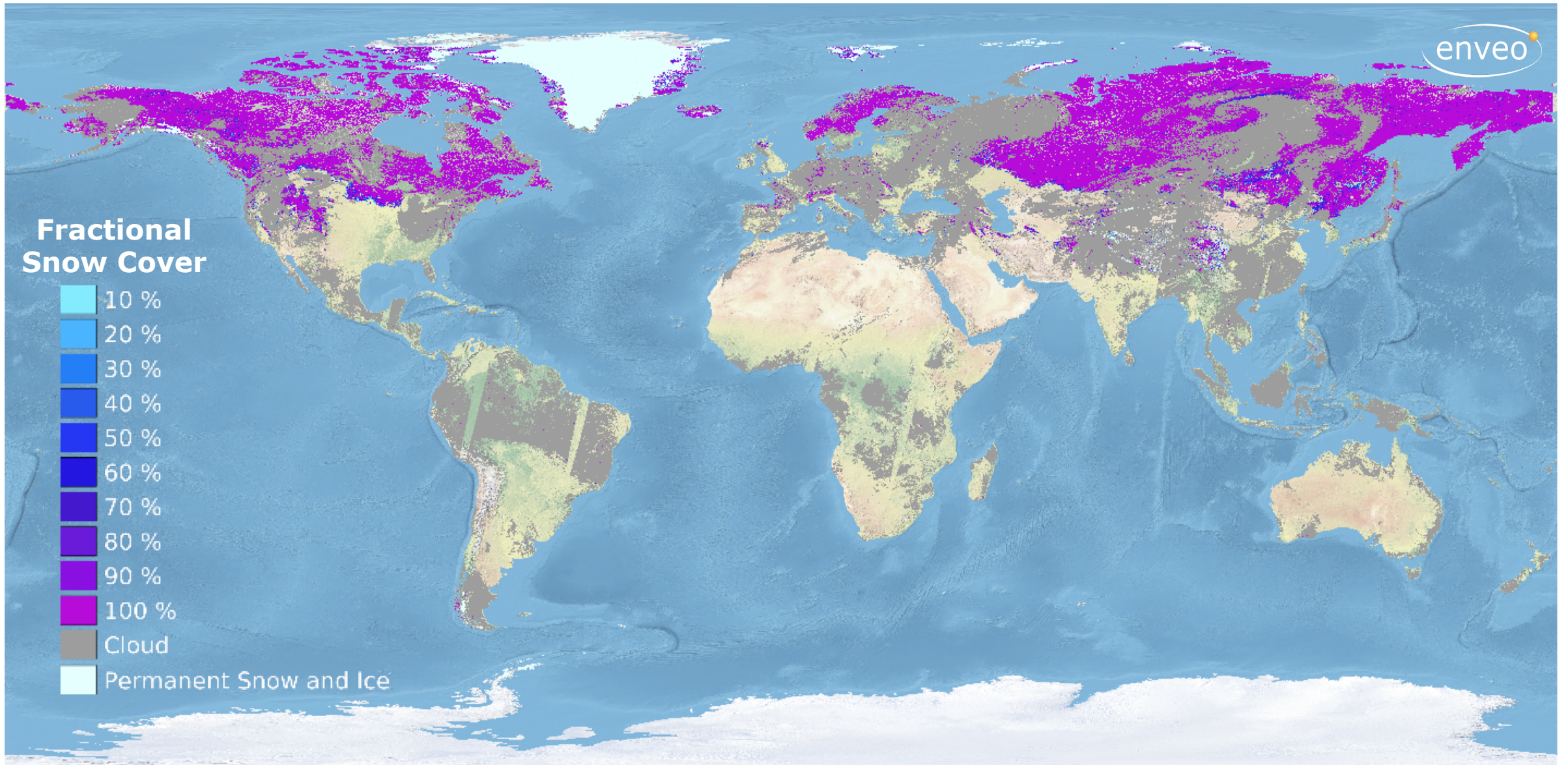
- **Daily, global homogenised snow extent and snow water equivalent products** with uncertainty (~1980→) using products from *landcover\_cci* and *cloud\_cci*
- Exploitation of **AI to generate snow reference data** from Sentinel-2 and Landsat
- **Temporal trends and snow mass anomalies** derived from 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)



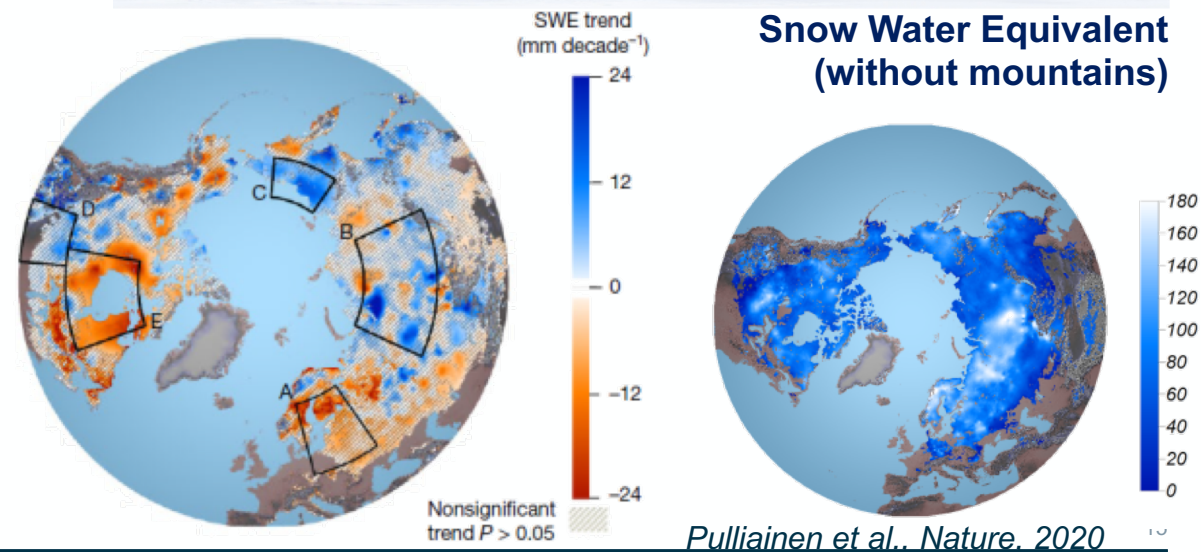
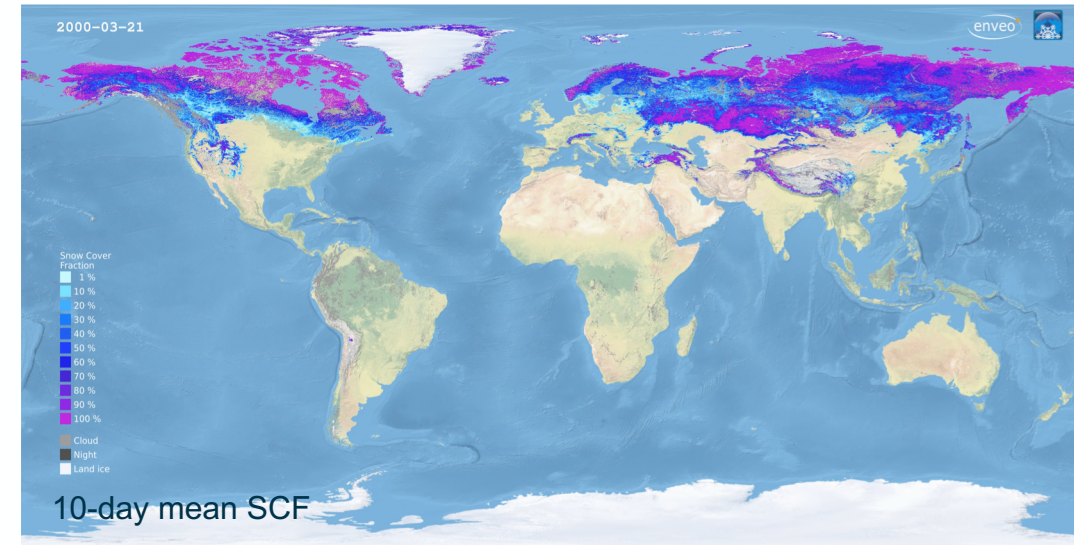
Pulliainen et al., Nature, 2020

# Snow Cover Fraction from Sentinel-3 SLSTR – 06 March 2020



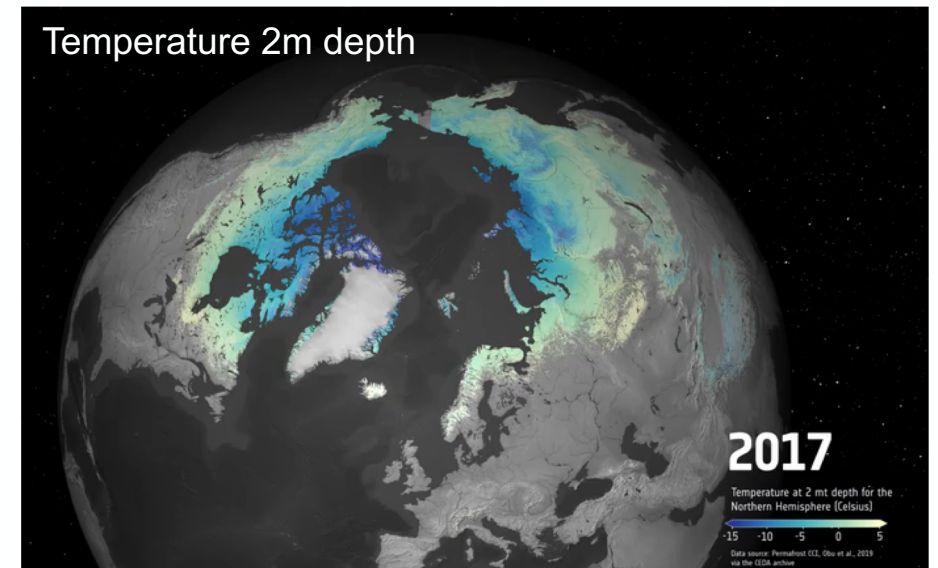
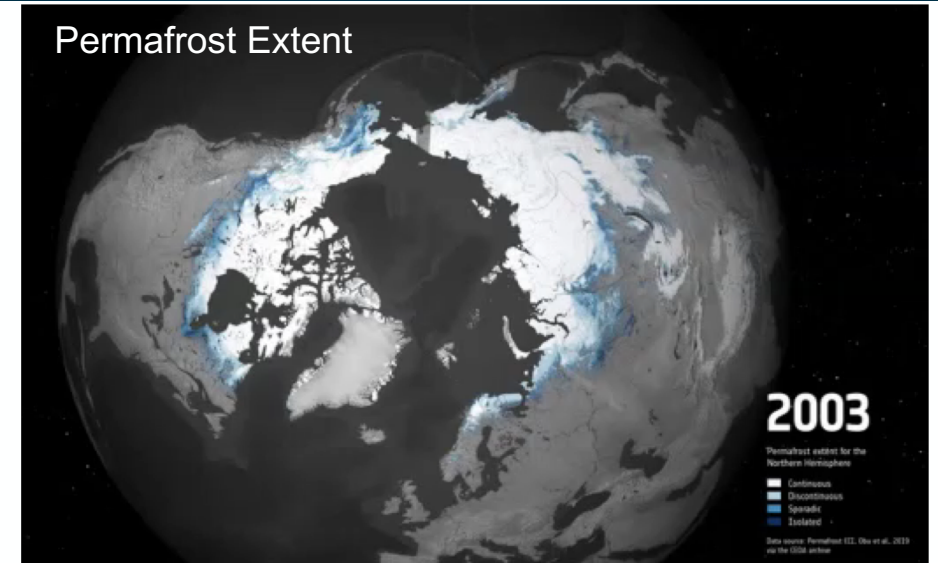
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Snow Cover Fraction (SCF) and uncertainty maps (1 km)



Pulliainen et al., Nature, 2020

- **Permafrost ground temperature, active layer thickness and extent V1** generated using landcover\_cci products.
- 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



# Contributions of the CCI in anticipation of COP26

How satellite climate data records contribute to e.g.

- Better understanding and predicting pathways towards an ice-free Arctic ocean in future emission scenarios
- Reducing the uncertainty in sea level projections
- Better understanding changes in seasonal snow extent

.... And many more

