CRYOSPHERE ECVS

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Mid-Term Review
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?
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
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.
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
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.
- **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
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