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ESA CCI Permafrost time series maps as Essential Climate Variable (ECV) products primarily derived from satellite measurements and visualized within the AWI O2A (Observation to Analysis and Archive) framework

Antonie Haas[1], Birgit Heim[1], Annett Bartsch[2], Andreas Walter[1], Roland Koppe[1], Peter Konopatzky[1], Mareike Wieczorek[1], Guido Grosse[1,3], Tazio Strozzi[4], Sebastian Westermann[5], Frank Martin Seifert[6], and Sonja Hänzelmann[1]

[1]Alfred Wegener Institut Helmholtz Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany (antonie.haas@awi.de)

[2]b.geos, Austria

[3]Earth and Environmental Science Institute, University Potsdam, Germany

[4]Gamma Remote Sensing, Swiss

[5]University of Oslo, Norway

[6]ESA - ESRIN, Italy

We demonstrate the latest version of the visualization of permafrost-related map products in the context of ESA CCI+ Permafrost initiatives (Phase I and II, 2018-2021, 2023-2026). Already in ESA DUE GlobPermafrost project (2016-2018), a comprehensive range of remote sensing products was produced by the project committee and visualized as viewer in the AWI O2A (Observation to Analysis & Archive) infrastructure framework: North-south transects in the northern hemisphere with trends in Landsat multispectral indices (e.g. Tasseled Cap Brightness, Greenness and Wetness, and Normalized Difference Vegetation Index (NDVI)), Arctic land cover (e.g. shrub height and vegetation composition), lake ice grounding, InSAR-based land surface deformation and rock glacier velocities. The main products were the Global Permafrost Essential Climate Variables (ECVs), which were derived from a spatially distributed permafrost model driven by Land Surface Temperature and Snow Water Equivalent products. These Permafrost ECVs include mean annual ground temperature (MAGT) and active layer thickness (ALT) at pixel level, and additionally permafrost extent and probability (PFR).

In the context of the ESA CCI+ Permafrost project, time was incorporated as a significant climate-related variable into the products. This resulted in a time series spanning over twenty years. It comprises CCI+ Permafrost Circum-Arctic model output for MAGT, from the surface down to a depth of 10 meters, as well as PFR and ALT. All data products are available at yearly resolution, as well as the calculated averages of MAGT, PFR and ALT over the time series.

To make the products publicly visible, we created WebGIS projects using WebGIS technology within the O2A (Observation to Analyses and Archive) data workflow framework at AWI. This

modular, scalable and highly automated spatial data infrastructure (SDI) has been developed and operated at AWI for over a decade. It has undergone continuous improvement and provides map services for geographic information system (GIS) clients and portals. The FAIR principles were implemented to address the increasing demand for research data and metadata that is discoverable, accessible and reusable. The ESA Permafrost WebGIS products were designed using GIS software and published as Web Map Services (WMS), an internationally standardised Open Geospatial Consortium (OGC) format using GIS server technology. Additionally, visualisations of raster and vector data products have been developed that are specific to the projects and adapted to their spatial scales and resolutions.

In addition to data products derived from remote sensing, the locations of WMO GCOS ground-monitoring networks belonging to the permafrost community, which are managed by the International Permafrost Association (IPA) and form part of the Global Terrestrial Network for Permafrost (GTN-P), were incorporated as a feature layer and updated on an ongoing basis. All data products have previously undergone registration with the Digital Object Identifier (doi), and have been published in the data archives PANGAEA or ESA CEDA.