LIQUIDICE

Deliverable 2.1 Snow cover data set

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Executive summary

This report pertains to the Deliverable D2.1: Snow cover data set, as described in ANNEX 1, part A (p. 32) of the EC/REA Grant Agreement for project number 101184962, "LIQUIDICE". Work Package 2 of the LIQUIDICE project is led by NORCE with the support of CNR, IISC, IITB, GEUS, UNIVBRIS, SIOS-KC and IG PAS. Other beneficiaries were also asked to contribute to the deliverable by reaching out to key people and organisations in each of their own countries.

The enhancement of observations about the snow cover in remote areas requires novel strategies for limiting gaps associated with cloud cover, darkness, topography, and data availability. Two different approaches have been selected, and they both converge to the intermediate spatial resolution of Sentinel-2 imagery.

The first solution is based on imagery obtained by time-lapse cameras located in the Ny-Ålesund area (Svalbard). The projection of such oblique cameras into a 10m-grid provides the estimation of the Fractional snow-covered area that can be easily integrated with Sentinel-2 data.

The second approach is focused on two datasets produced for two study areas: Svalbard and Jotunheimen (Norway). While one dataset is at lower resolution with a long-term period based on Terra MODIS (2000-2025), the second one is shorter with higher resolution from Sentinel-2 data (2016-2025). The overarching idea is to find the connection between those satellite-derived datasets by training on a common time-period using state-of-the-art machine learning techniques.

1. Introduction

The integration between snow cover observations at different spatial and time scales is a primary issue required by a full description of the seasonality of snow melting. Different data sources fit with an integrated approach aimed at limiting gaps associated with polar darkness, topography, cloud cover, and availability of remotely sensed acquisitions. The overall strategy of the task focused on preparing datasets about the snow cover is based on converging on Sentinel-2 observations from observations obtained by terrestrial photography and downscaling coarse resolved data with higher time resolution (MODIS). Such approaches are concerned with generating detailed information on spatiotemporal variations in the snow cover, even using machine learning methods to reconstruct detailed high-resolution snow cover for periods when only low-res data (models/EO) are available. Such high-resolution data form the basis for assessing the evolution of snow cover at the intra and inter annual time scales.

2. Enhanced snow data sets

The improvement of snow cover observations through EO-based acquisitions is a primary task for matching the need of high resolution in modelling. Two convergent approaches have been selected for fulfilling such a requirement in absence of traditional satellite data. One is based on terrestrial photography, which integrate satellite acquisitions with imagery obtained by time-lapse cameras. One is based on integrating coarser data with finer ones using AI-solutions.

2.2. Fractional snow-covered area dataset (CNR)

The first year of the project CNR has concerned with high-resolution data produced in the Ny-Ålesund area (Svalbard). Such observations are based on time-lapse cameras located in different facilities dominating the Bayelva catchment from the Brøggerbreen glacier front up to the coastline. It is an area of about 10 km^2 that has been observed from 2015 to 2024 with daily acquisitions from the Zeppelin observatory and the Amundsen-Nobile Climate Change Tower. The first phase of this activity has been focused on harmonizing the available observations in a decadal dataset based on Sentinel-2 10m spatial grid. State-of-the-art algorithms have been performed on such imagery to obtain sub-10m information about the snow cover and to estimate consequently the fractional snow-covered area at 10m spatial resolution.

The dataset is available through the Italian Arctic Data Center (IADC) in the NetCDF data format compliant to the CF convention 1.8, under the CCBY license. Data are prepared as raster data (10 x 10 m spatial resolution) with EPSG:32632 and daily time resolution, in a collection of files separated on yearly basis within a time extent from 2015 to 2024.

This first product will be the basement for improving the coverage of datasets using foundation models based on harmonized satellite observations. The aim will be the gap filling of areas hidden by topography or partial cloud cover, and the generation on additional areas will be explored.

Dataset Link: https://doi.org/10.5281/zenodo.5705593

2.3. AI-enhanced Snow Cover datasets (NORCE)

The first year of the project NORCE has focused on two datasets (LR and HR) readily available from Svalbard and Jotunheimen (Norway). A low-resolution, long-term dataset from Terra MODIS (2000-2025) and a shorter high-resolution dataset from Sentinel-2 (2016-2025). The overarching idea is to find the connection between the LR and the HR dataset by training on a common time-period using state-of-the-art machine learning techniques. We will investigate techniques based on deep convolutional neural networks, and more advanced techniques like foundation models and diffusion models, at a later stage. When the connection between LR and HR is found, we should be able to use the LR-data to reproduce HR-snow maps for historical periods when only LR-data is available.

In sub-sequent phases of the project, we will also investigate other data sources to extend the dataset to even earlier periods (1986-2000) using AVHRR, and potentially before that using entirely other data sources like hydrological models based on in situ temperature and precipitation data (1900-1980).

3. Conclusions

The first year of Task 2.1 has provided two different datasets based on a decadal period. The fractional snow-covered area obtained by terrestrial photography is the premise of high spatial and time resolutions for the study area of Ny-Ålesund. Novel information about snow seasonality have been retrieved compared to in-situ automated stations and additional potentialities will be investigated to remove topographic or cloud cover limitations.

The super-resolution model performs well over the Svalbard AOI, where it was trained, showing that it can learn the relationship between MODIS SCF and Sentinel-2 NDSI under those conditions. However, performance drops when the model is applied to the Jotunheimen AOI. This indicates limited spatial generalization and suggests that the model has learned region-specific patterns rather than a more general representation of snow and surface properties. Similar issues are thus expected when applying a model trained only on Svalbard, to other new AOIs later in the project.