Terrestrial photography applications on snow cover in Svalbard (PASSES)

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1. Introduction

Mapping the evolution of the snow cover in Arctic regions is a critical task that must be addressed in order to estimate how the environment is affected and adapts to climate change. The snow cover characterization and its spatiotemporal evolution represent important factors to be considered in the framework of climate modelling at a global scale. Furthermore, snow cover is an Essential Climate Variable (ECV) of the Global Climate Observing System (GCOS), and high priority is assigned to enhancing and maintaining snow observations (World Meteorological Organization 2016). From this perspective, the continuous monitoring of snow cover is a major contemporary scientific challenge, and the advances in remote sensing explain why optical data are so commonly used for this purpose (Dietz et al. 2012; Petäjä et al. 2020). The description of snow cover comprises different parameters, and two variables – its extent and albedo – can be investigated using optical remote sensing (Gascoin et al. 2020; Vermote et al. 2016; Riggs et al. 2017). However, two different aspects must be considered for the enhancement of the final output: time and spatial resolution. Both components are connected using remotely sensed data (Dietz et al. 201), since the higher the spatial resolution (below hundreds of meters), the lower the revisit frequency will be (more than 1 week). The major advantage of monitoring the snow with remotely sensed data is the possibility of deriving area-wide and spatially comprehensive surface information with a regular and repeatable set of measurements, even in remote areas. In mountain areas, where the surface heterogeneity is greater, additional problems could affect the results. The state-of-the-art snow products concerning the snow extent are derived using remotely sensed data, and they are based mainly on the relation between the radiative behaviour of the surface and the Fractional Snow Cover (FSC), also defined as the Fractional Snow-Covered Area (f_{SCA}). This parameter describes the fraction of surface covered by snow in the picture element (pixel) of a remotely sensed image. The relation between the FSC and the optical behaviour of the surface represents the most common inference required by remote sensing studies (Gascoin et al. 2020; Riggs et al. 2017; Vermote et al. 2016). There are many options for estimating this relation: combining satellite products with a different spatial resolution (Salomonson and Appel 2006, Yin et al. 2013), using spectral unmixing (Painter et al., 2009), and using ground-truth information (Aalstad et al 2020; Gascoin et al. 2020; Salzano et al. 2019). From this perspective, terrestrial photography provides an opportunity to have accurate ground truth when satellite overpass occurs, this ground truth could represent robust information useful for estimating site-specific relations between retrievals from different satellite platforms and FSC. The available time-lapse and webcam networks are important data sources for calibrating and validating satellite products, but a survey about available image datasets and the homogenization of the different data chains is needed to create a regional infrastructure. The availability of a time series concerning the snow cover is an important gap that can be filled by using terrestrial time-lapse photography. The use of terrestrial photography is not limited only to the estimation of the snow-covered area, but it has also shown potential in assessing other snow parameters. The optical calibration of the camera system can be useful for albedo-oriented applications, where the use of reference targets supports the description of the optical behaviour of snow (Corripio 2004; Garvelmann et al. 2013). Furthermore, modifications of the spectral sensitivity of the camera can be used for the retrieval of relationships between the reflectance in the near-infrared wavelength domain and the snow microphysics (Matzl and Schneebeli 2006). Additional snow features can be extracted from terrestrial images focussed on reference targets that can geometrically evidence the snow height (Bongio et al. 2019; Garvelmann et al. 2013; Parajka et al. 2012). Finally, terrestrial photography applications can also be adapted to other disciplines in order to study glacier dynamics (How et al. 2019; Vallot et al 2019), coastal processes (Nicu et al. 2020), and vegetation phenology at Arctic sites (Anderson et al. 2016; Beamish et al. 2020; Kępski et al. 2017). From this perspective, terrestrial photography provides a large variety of snow cover applications with different maturity levels. Hardware limitations can nowadays be easily bypassed, since the technological developments and the limited costs support the availability of reliable devices that can operate under severe environmental conditions. Image processing represents the challenging component of this approach, since different algorithms are proposed, but the definition of a standardized procedure could be an important requirement. This summary is aimed at defining the background where a snow camera network could be implemented in the framework of Svalbard Integrated Arctic Earth Observing System. The proposed contribution will be composed of the following sections: an overview of available webcams in the Svalbard archipelago; a first survey about available camera systems; the definition of a metadata profile useful for characterizing every camera node; and the description of processed datasets.

2. Overview of existing data

There is a large number of network cameras in Svalbard that can potentially be used for assessing the evolution of the snow cover. The knowledge about available datasets, their metadata descriptions, their processing chains, and their product specifications are all important factors for obtaining a complete overview of terrestrial photography applications in such a remote area. The overview of cameras operating in the Svalbard archipelago has been approached by searching for specific applications on the snow cover and by collecting information about images that can be found on the web – that are not solely focussed on research purposes in the cryospheric domain (Figure

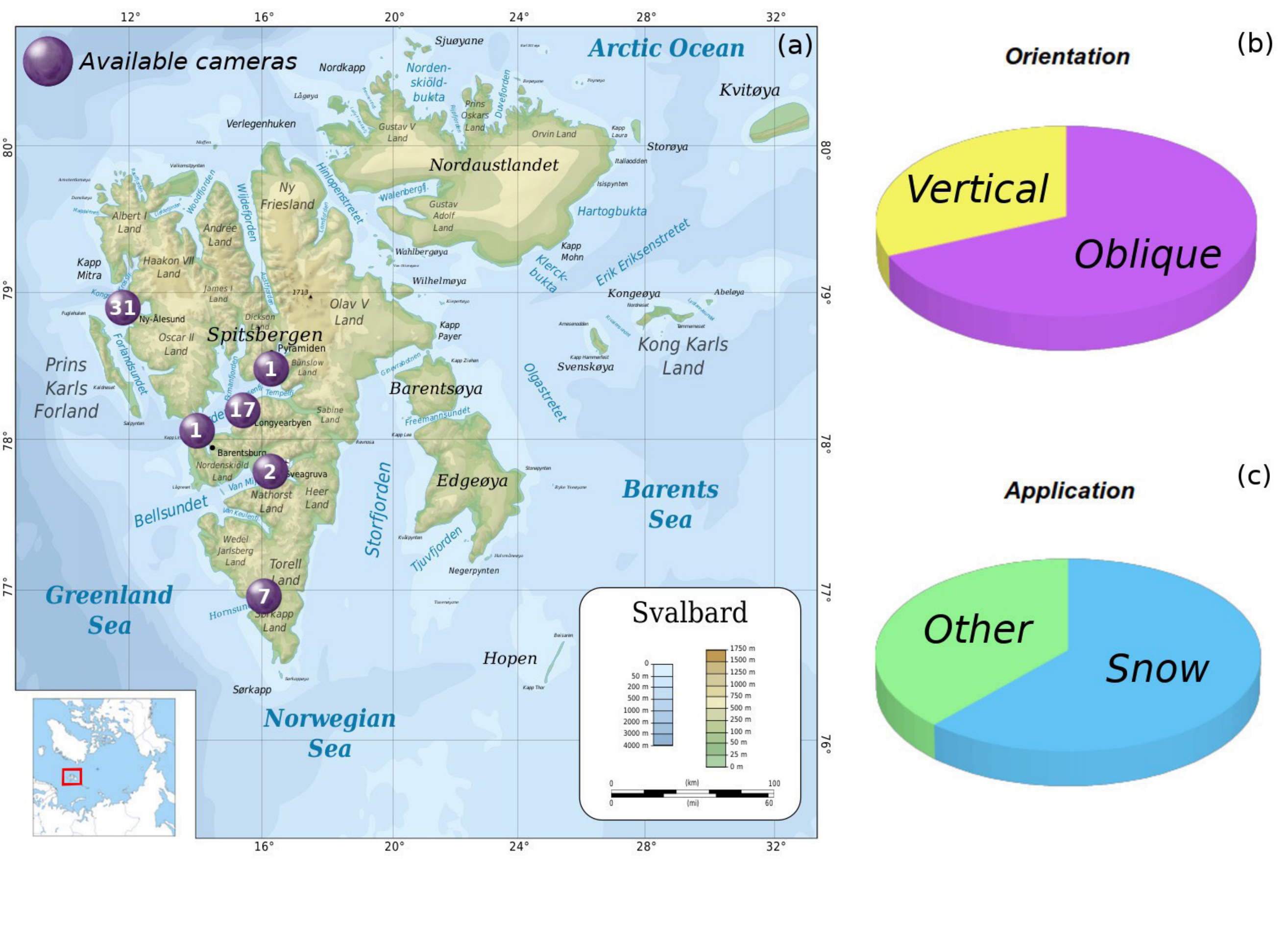

Figure 1: Distribution map of available cameras in Svalbard (a). Fraction of cameras with vertical versus oblique setups (b) and fraction that show snow cover (c).

1). The first step in defining a webcam network aimed at estimating the snow coverage with time-lapse cameras is to designate a metadata profile suitable for creating a registry of available devices.

2.1. Metadata profiling of terrestrial cameras

This primary task can be approached following the guidelines prepared by SIOS (Godøy and Holmen 2017), where the core of a metadata profile is based on mandatory information. This first component must be coupled with an expansion specific to instrumental devices and can possibly be enriched by additional data that are prepared for similar applications or to identify specific FSC estimations. The first component is described in the ISO 19115, where a general-purpose metadata is described. More detailed models for some aspects of resource description, including quality, data structure, or imagery, are defined in other ISO geographic information standards. The metadata model described herein enables the implementation of domain-specific user extensions based on a common pattern to facilitate the implementation of software using those extensions. Extensions have been prepared considering the experience of other communities on similar camera networks (Peltoniemi et al. 2018; Seyednasrollah et al. 2019; Wingate et al. 2015) for other purposes such as vegetation phenology or ski resort monitoring. The increasing interest in establishing snow-related camera networks in the European Alps (Flöry et al. 2020; Portenier et al. 2020) has supported the identification of specific expansion components (Figure 2) for collecting information on: (i) already tested camera setups; (ii) repositories where imageries are archived; (iii) ortho-rectification approaches; (iv) quality check procedures; and (v) snow classification algorithms. Once a network is established, additional expansions can be defined in order to characterize site-specific conditions and uncertainties about the monoplotting procedures and the snow cover retrievals.

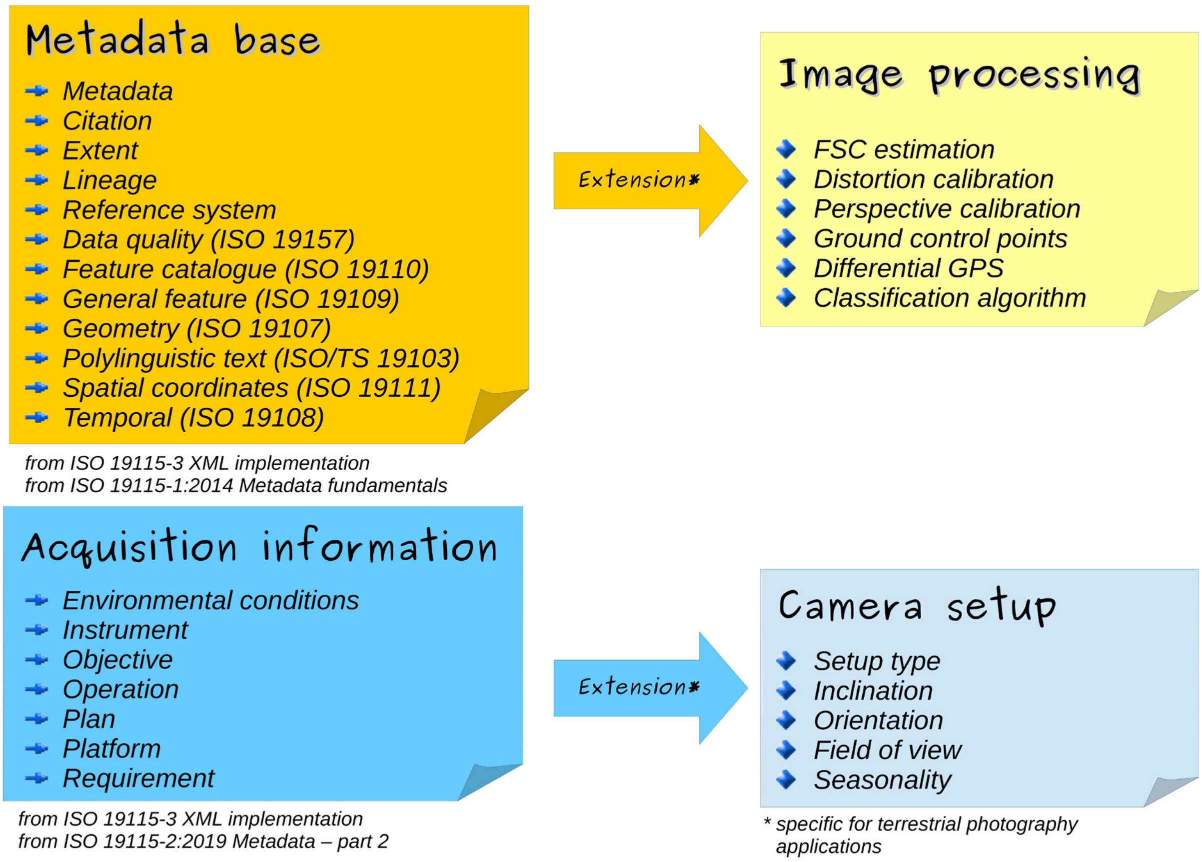

Figure 2: Identified components for describing the metadata profile required by a terrestrial camera network.

The collection of this information will be useful for: (i) an overview of the already tested camera setups; (ii) identification of the repositories where imageries are archived; (iii) survey of approaches focussed on ortho-rectification; (iv) censoring of quality check procedures; and (v) identification of snow classification algorithms.

2.2. Overview of cameras available in Svalbard

The overview of cameras operating in the Svalbard archipelago has been approached by searching for specific applications on the snow cover and by collecting information about images that can be found on the web – that are not solely focussed on research purposes in the cryospheric domain (Figure 1). The survey identified at least 60 cameras operating in the region that are managed by research institutions (87%) and local private companies (13%). The collected information includes facilities operated by 4 nationalities (Norway, Poland, Italy and France), by 8 SIOS members and by 8 non-SIOS member institutions. Further censusing activities are still necessary in order to involve parties in providing more detailed information, but this incomplete picture points us to the important constraints about the framework on terrestrial photography applications. Around 61% of the registered devices are involved in activities focussed on assessing the snow cover condition of the surface. About 70% of these cameras are actually operating, and about 30% are discontinued or under maintenance. Furthermore, while 32% of the imaging sensors are provided by systems with a vertical setup and a limited field of view, the rest are acquired by oblique-oriented systems, with a larger field of view. The number of motorized systems is increasing and pan/tilt/zoom cameras are available with large panoramic views. From this perspective, the identified systems can be categorized into four different classes defined by combining the orientation, site location and the resulting perspective (Table 1).

The installation of the registered cameras is affected by logistic issues (power supply, network connection, maintenance and other environmental problems), and the available locations are consequently limited to a few areas where settlements are present: Longyearbyen, Ny-Ålesund and Hornsund. Mature snow-cover estimations from camera systems are limited to a few locations that will be described in the next sections. The rest of the cameras are not processed in terms of snow cover, and they are usually not archived in order to be compliant with the national regulations on privacy. This summary is focussed on the description of the datasets that have been designed for snow-related studies, are maintained at the moment and accessible to the scientific community.

Table 1: Classification of different camera setups

Orientation	Camera setup	Camera type	Coverage
Vertical	Close range	Standard	1–10 m2
Oblique	Close range	Standard	< 1 km2
	Long range	Standard	1–5 km2
	Multiple views	Motorized	> 5 km2

2.3. Ny-Ålesund

2.3.1. The Zeppelin Observatory

The Zeppelin Observatory is a research infrastructure managed by the Norwegian Polar Institute where a combination of different time-lapse cameras have been operating since 2000. The facility is located close to the top of the Zeppelin mountain (at 475 m a.s.l.) facing the Kongsfjorden in front of the Ny-Ålesund village. This dataset represents the longest camera time series available in Svalbard (Pedersen 2013), and different devices have been involved in acquiring images. The longest component of this dataset is the view looking at Ny-Ålesund village, where different cameras have been used during the acquisition history. This imagery has been provided by a fixed and oblique setup with a projected covered area ranging from 3 to 5 km^2. The camera system, upgraded from a low resolution sensor to the latest AXIS P5635-E-MKII device, has increased the image size from a

480sd to a 1080p format. Furthermore, the final acquisition timing has been fixed at an hourly scale, and all of the images have been archived, streamed online and made publicly available. The second component of this dataset is constituted by the imagery acquired by a pan/tilt/zoom device that now provides 4 different views of the Kongsfjorden once per day. The perspective is assessed by having at least ten ground control points (buildings, infrastructures, etc.) but all of the images are controlled in terms of alignment using customized procedures based on recognized patterns or objects in each image (mainly identified from coastline and topography). Finally, projected pixels are grouped in satellite-derived grids (Sentinel, Landsat and MODIS are considered at the moment), and only grid elements with a consistent number of pixels included (100 pixels) are selected for the FSC retrieval. The analysis of this long time series provided a description of snow cover evolution over a decadal temporal range (Figure 3) and the obtained dataset was combined with different satellite platforms (Petäjä et al. 2020).

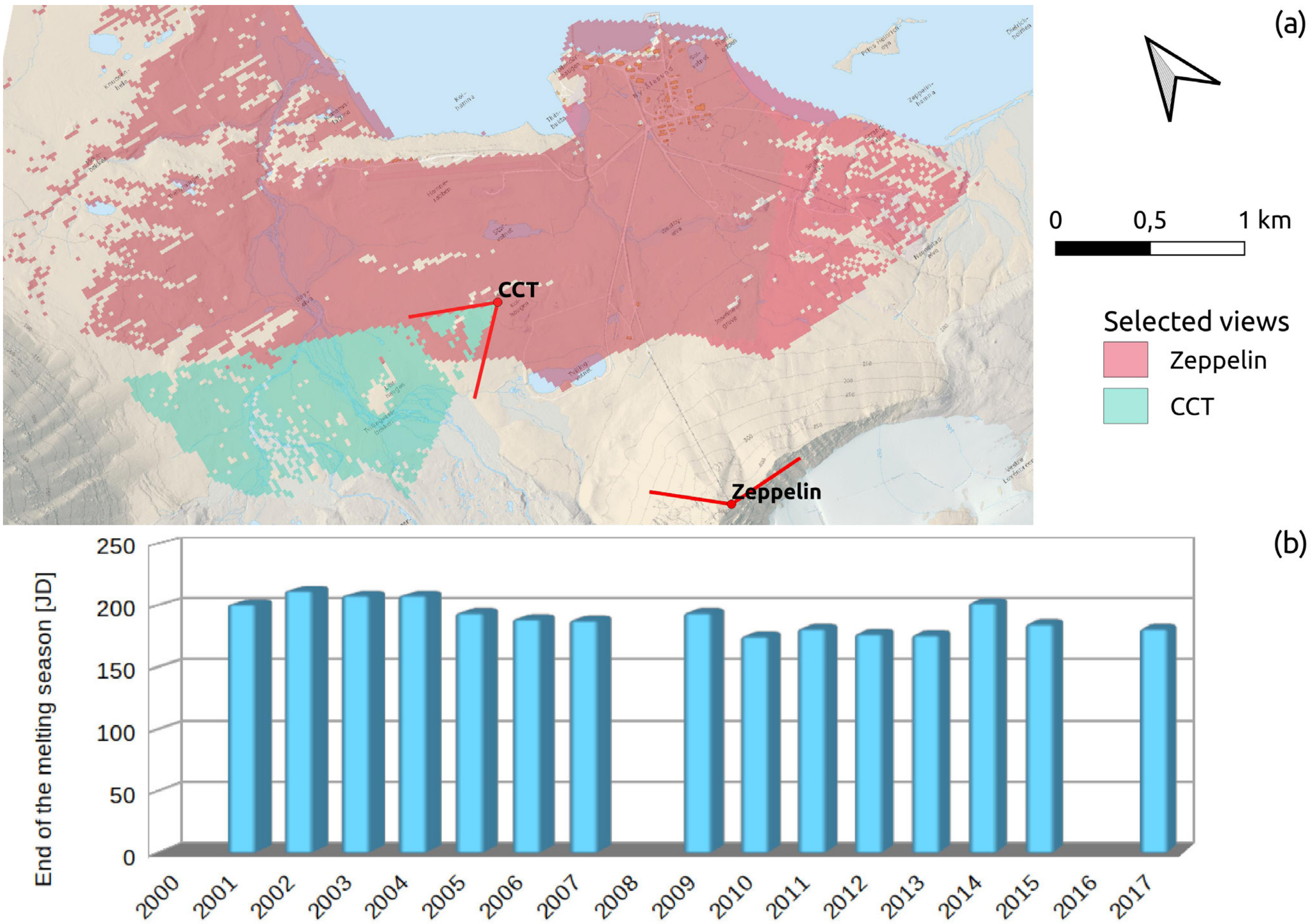

Figure 3: Representation of the projected areas covered by the different available cameras (a) on Zeppelinfjellet and close to the Amundsen-Nobile Climate-Change Tower (CCT). Estimation of the first snow-free day in the Brøggerdalen area (b).

2.3.2. The Climate Change Tower

Two cameras are located close to the Amundsen-Nobile Climate Change Tower at the Kolhaugen site: one with a vertical setup and one with an oblique orientation and a limited field of view. While the first device is positioned at 3 m above the ground, the second one is installed 15 m above the surface. Both are customized systems where the sensor is a Sony IMX219 with an 8 megapixel resolution. The projected area covered by each perspective view is controlled by each setup, and it can be estimated to be 5 m^2 and 1.2 km^2 respectively. Furthermore, both cameras acquire images hourly, and they have been operating since 2015 (vertical) and 2018 (oblique). Data are routinely downloaded to the CNR servers and are processed in terms of fractional snow cover using algorithms based on the blue-channel thresholding (Salvatori et al. 2011) and the spectral similarity approach (Salzano et al. 2019). The perspective, especially for the oblique setup, is assessed by having at least ten ground control points but all of the images are controlled in terms of alignment using customized procedures based on recognized patterns or objects in each image. Finally, projected pixels are grouped in satellite-derived grids (Sentinel, Landsat and MODIS are considered at the moment), and only grid elements with a consistent number of pixels included (100 pixels) are selected for the FSC retrieval (Figure 4). The aims of these devices are: (i) to approach the multi-scale issue through different perspectives with different spatial resolutions (Petäjä et al. 2020); and (ii) to integrate the FSC assessment with the retrieval of spectral reflectance obtained by other instruments (Salzano et al. 2016).

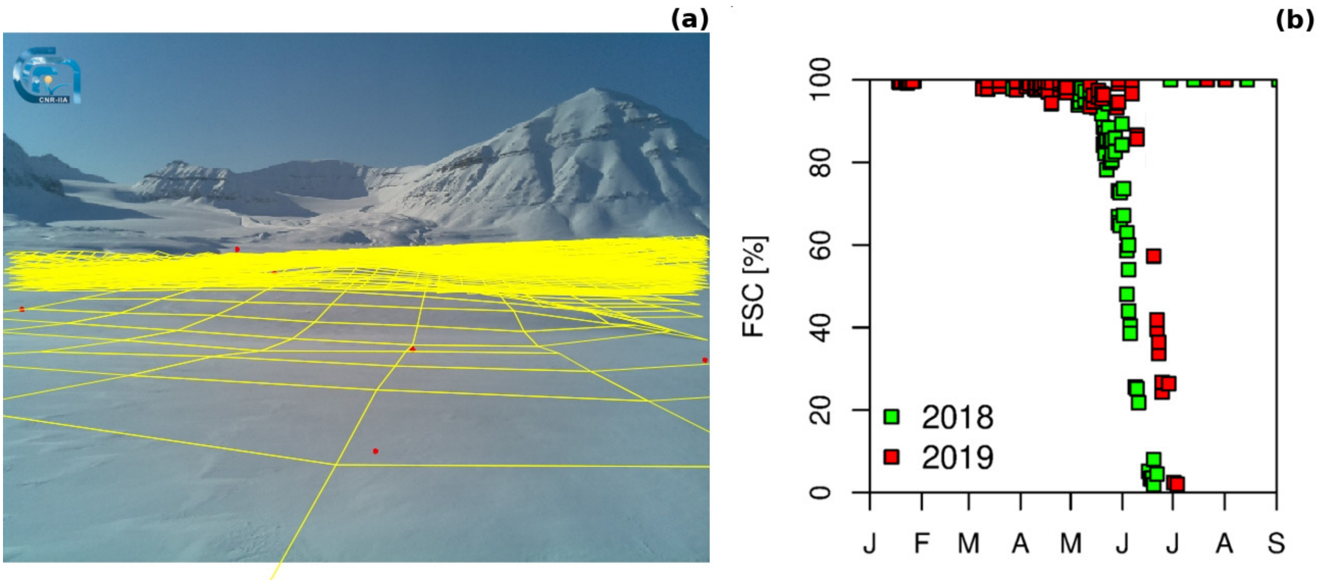

Figure 4: Example of a 20x20 m resampling grid projected on the image (a). Evolution of the melting season close to the Climate Change Tower (b).

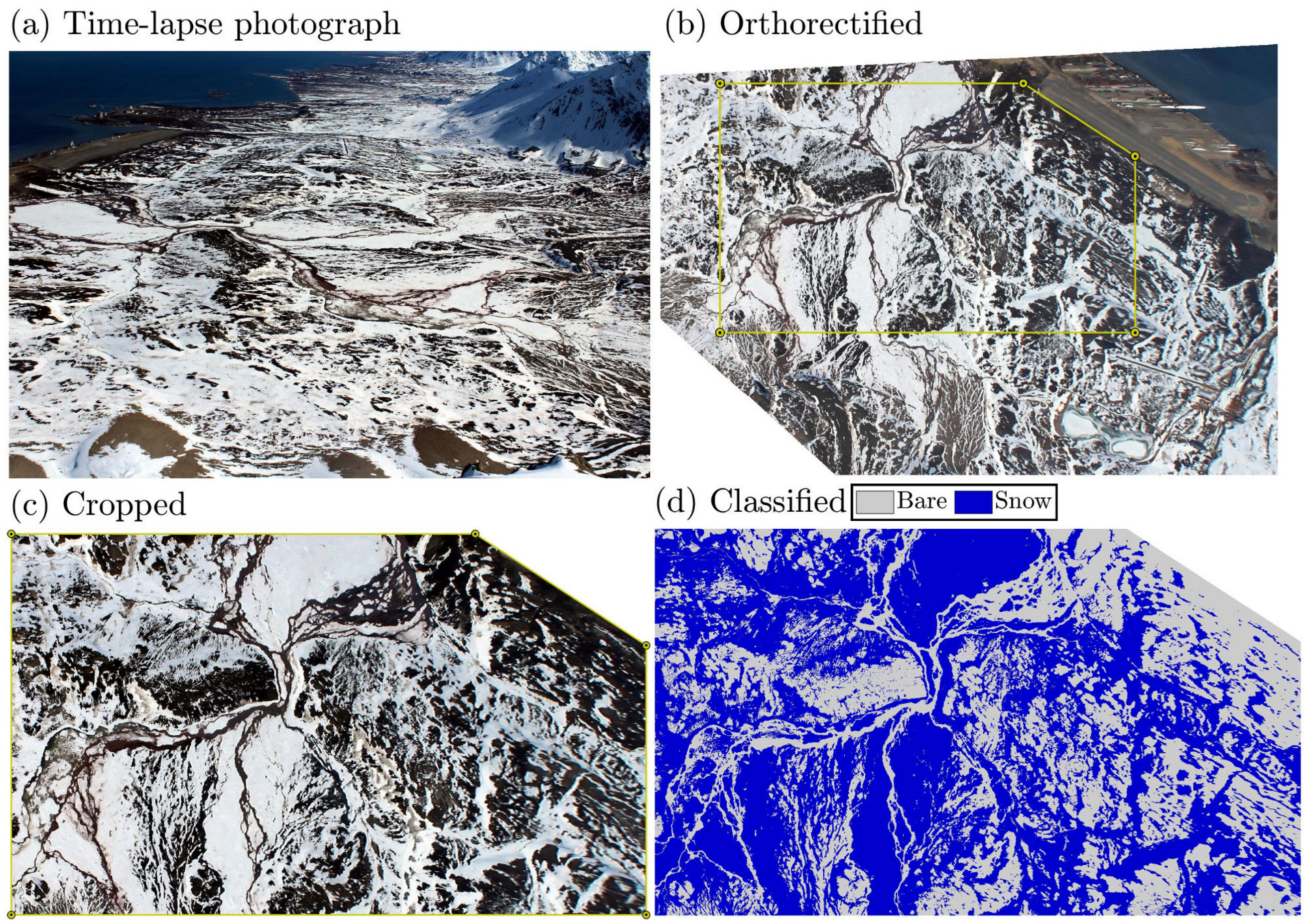

Figure 5: An example of the processing chain for the Scheteligfjellet camera: (a) a raw time-lapse photograph (10:31Z 03.06.2016); (b) the orthorectified version of this photo (the area of interest [AOI] is in the yellow polygon); (c) the same orthoimage cropped to the AOI; and (d) the final classified orthoimage with bare ground pixels in grey and snow-covered pixels in blue. Adapted from Aalstad et al. (2020).

2.3.3. The Scheteligfjellet site

An automatic camera system was deployed at 562 m a.s.l. near the summit of Scheteligfjellet (719 m a.s.l.) to monitor snowmelt patterns in the Bayelva catchment. The system consisted of a Canon EOS 1100D digital single-lens reflex camera triggered by a Harbortronics time-lapse package. It was maintained and installed for each ablation season (May–August) in the years 2012–2017 by scientists from the Department of Geosciences at the University of Oslo. The camera delivered hundreds of high-quality oblique daily images except in rare periods with low cloud cover, artifacts, or system malfunction that were later filtered out. These images were orthorectified with a camera calibration toolbox using a high-quality reference DEM and orthophoto. An independent validation indicated an average georeferencing error of under 2 m with no systematic shifts. These 0.5 m resolution orthoimages were then cropped to a 1.77 km^2 AOI to avoid edge distortions and significant anthropogenic disturbances. Subsequently, each of these images was individually and manually classified into binary snow-covered and snow-free pixels using an image-specific threshold on the blue band histogram. These high-resolution orthorectified binary snow cover images can be spatially aggregated and applied to validate satellite retrievals of FSC (Figure 5).

A more detailed description of the processing chain for this camera system is provided in Aalstad et al. (2020). Therein, this imagery is used to validate FSC retrieved from several optical satellite sensors – namely Terra/Aqua MODIS, Landsat 8 OLI and Sentinel-2A/2B MSI – using algorithms varying in complexity from thresholding to spectral unmixing. A subset of the imagery was used in an earlier snow data assimilation experiment (Aalstad et al., 2018) for validation and to provide observation error variance estimates for the assimilated satellite retrievals. These error estimates were also used in a subsequent high resolution snow data assimilation framework that was implemented over the Swiss Alps (Fiddes et al., 2019).

2.4. The Adventdalen area

With support from the SIOS InfraNor project since 2018, the University of Tromsø established an automatic system for monitoring vegetation and environmental seasonal changes in Svalbard. Ten racks were distributed within the lower part of Adventdalen, south of Longyearbyen. All racks had basic equipment comprising one RGB camera, one non-imaging NDVI sensor and a sensor measuring both soil moisture and temperature. In addition, five racks were equipped with a thermal infrared sensor measuring surface temperature, and two racks had sensors recording the photochemical reflectance index (PRI). For calibration purposes, hemispheric NDVI and PRI sensors were mounted on three racks measuring incoming radiation. The cameras used were WingScapes TimeLapseCam cameras (WCT-00122; Ebsco Industries, China), with a resolution of 8 MP and were taking RGB images from a vertical position at a height of 2 m. The project has been operational with ten cameras since 2016.

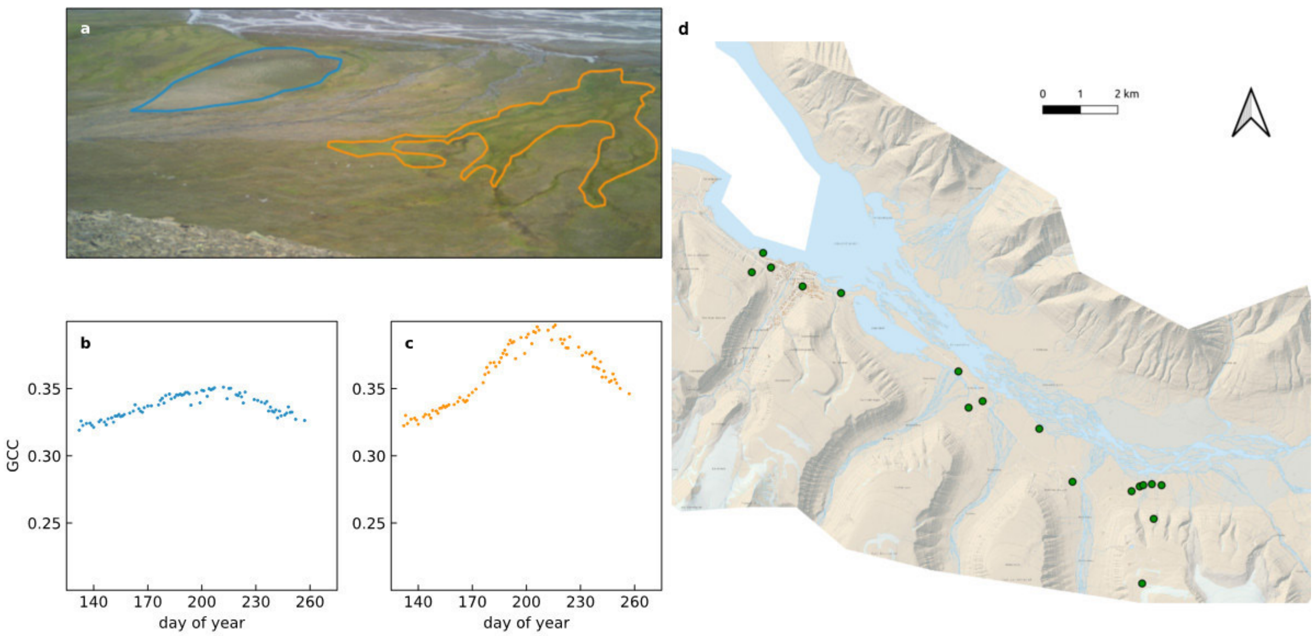

Figure 6: Examples of RGB indices derived from different regions of interest (ROI) during the growing season. The blue encircled area (a) has a low vegetation cover, which leads to lower values of the Green Chromatic Coordinate (GCC) index (b). The orange outline encircles dense vegetation which leads to a higher value of GCC (c). Distribution map of the available camera racks (d).

A landscape camera (CuddeBack H-1453, CuddeBack Digital, RGB, 20 Megapixel) is mounted up in the hillside of the Breinosa mountain, facing the Adventdalen river and surveilling 4 of the racks and their surroundings. The CuddeBack camera has been operative since 2018. Both the rack cameras and the landscape camera are set up in late April / early May and taken down again by the end of September. The main purposes of the rack cameras are to document, on a daily basis, the plant phenology at the plot and species level, as well as to generate vegetation indices (greenness indices). The landscape camera will monitor and document, on a daily basis, the appearance, growth and withering of plant communities surrounding the racks (Figure 6).

2.5. The Hornsund area

Seven time-lapse cameras are located in the neighbourhood of Polish Polar Station, Hornsund, which is managed by the Institute of Geophysics, the Polish Academy of Sciences. Two of them were installed in 2014, primarily for snow cover applications: one near the Fugleberget summit (550 m a.s.l.) overlooking the small Fuglebekken catchment and the second on a small container in the catchment (5 m a.s.l.) facing towards the slopes of the Fugleberget mountain. The devices used in those setups were Harbortronics Digisnap 2000 time-lapse camera systems, which originally provided 12.2 megapixel resolution. The one at the summit was replaced later by its modernized continuation rebranded as Cyclapse Pro. The one overlooking the slopes of Fugleberget was uninstalled in 2015. Both sets take photos every hour starting in the spring before the ablation season begins. The camera mounted near the summit was used for providing fractional snow cover estimates during the melting period for an area of about 0.7 km^2 (Figure 7). Snow classification was performed using blue-channel thresholding applied to the orthorectified imagery, originally to study the timing of snow disappearance from various tundra vegetation communities (Kępski et al. 2017). Other cameras installed in the Hornsund area are in-house developed systems based on DSLR cameras. They were designed for tracking the position of the glacier front, changes of the coastline and sea-ice dynamics. These cameras operate within the framework of oceanographic monitoring of the Polish Polar Station at Hornsund.

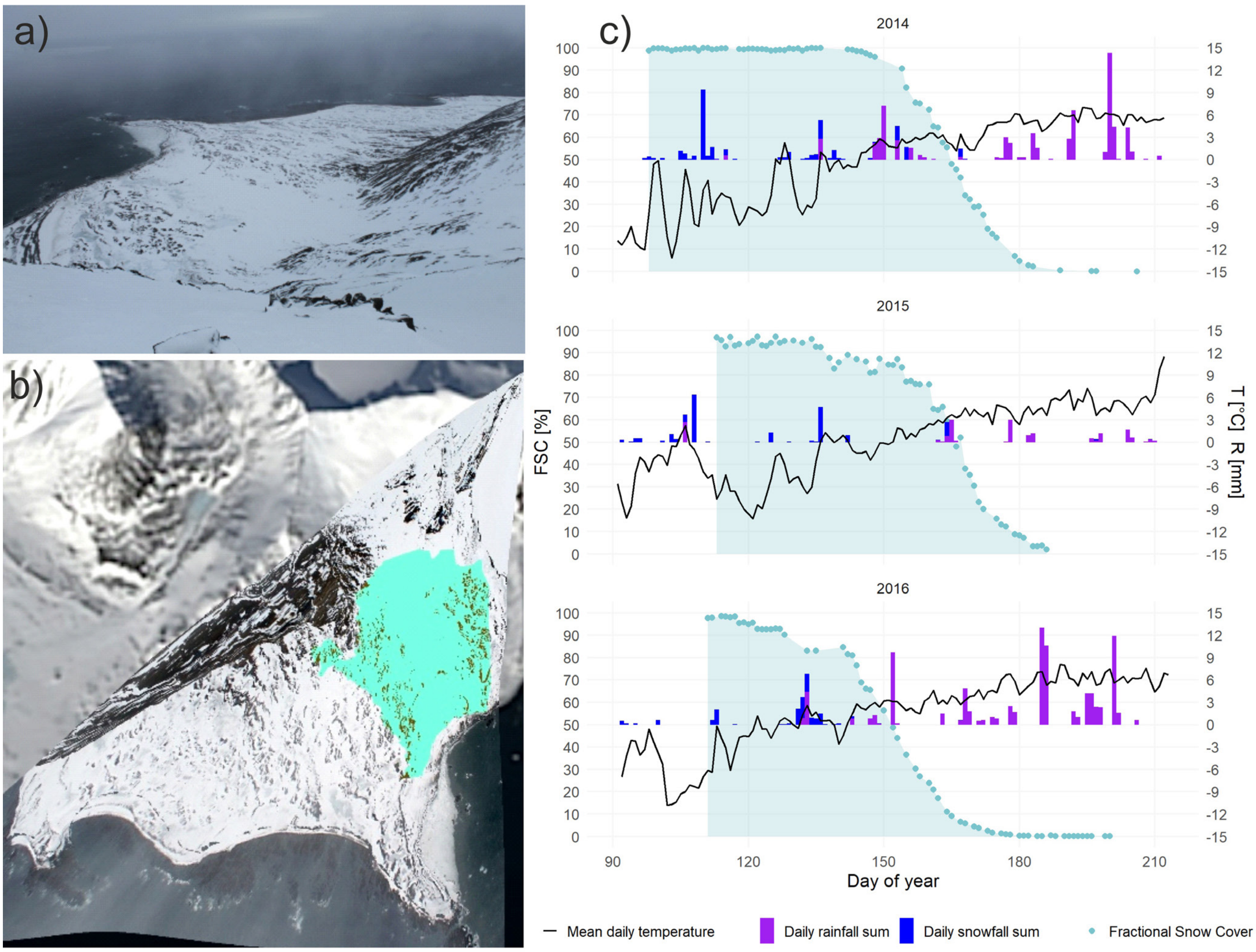

Figure 7: Time-lapse camera mounted near the Fugleberget summit in Hornsund: a) raw image; b) orthorectified image with binary classified snow surface clipped to mask with the smallest distortions of terrain (marked in cyan); and c) fractional snow cover in melting seasons 2014–2016.

3. Connections and synergies with other SESS report chapters

This data summary has different connections with previous SESS reports where the imagery provided by time-lapse cameras were mentioned as tools useful for studying snow-covered areas (Gallet et al. 2019) and as a ground-truth technique for vegetation-related studies based on remote sensing (Karlsen et al. 2020). Terrestrial photography is in fact an ideal approach for observing the evolution of the snow cover through a broader perspective than standard point measurements. Furthermore, the snow cover evolution affects the vegetation phenology, and, especially when the melting season is over, additional information about vegetation growth can be extracted from oblique or vertical time-lapse images. The contribution of terrestrial photography presented in this chapter also offers important synergies with other disciplines concerned with other chapters available in this report: (i) Svalbard long-term variabilities of terrestrial-snow and sea-ice cover extent (Killie et al. 2021); and (ii) satellite and modelling–based snow season time series for Svalbard: inter-comparisons and assessment of accuracy (Malnes et al. 2021). In both cases, terrestrial photography can offer an important source of ground truth, which is useful for combining different satellite observations obtained with different temporal and spatial resolutions. The seasonal description of the snow cover obtained by time-lapse cameras is certainly limited in terms of spatial coverage but it is almost continuously independent from the cloud cover.

4. Unanswered questions

The collected information showed a considerable availability of cameras located in the Svalbard archipelago that could be important data sources to be integrated between different disciplines. We defined a key background of the camera nodes useful for preparing the groundwork for establishing a snow-related camera network in Svalbard. The defined framework highlighted the need for key information from all of the identified systems. The survey is still ongoing since only 40% of the contacted camera operators have responded positively and are ready to provide details in line with the metadata profile, which would be useful for characterizing the data processing components.

We defined a specific questionnaire that could represent a key tool for continuing the censusing activity developed in the PASSES website[1]. The dataset on available cameras is complete with respect to the most mature nodes (6) included in this contribution, and which were identified between the involved partners, but it still needs more effort for completing the harvesting of information from other research groups. Networking is a critical task and the aim of such an effort is to increase the number of locations investigated for snow cover purposes. Camera systems are, at the moment, available in a few selected sites where the logistical support can be easily provided: Longyearbyen, Ny-Ålesund and Hornsund. A few additional sites are present, but data chains from those have a lower maturity level, with images not being processed in terms of snow cover and/or not being archived due to privacy issues. More high-level nodes are necessary in order to obtain a good spatial distribution representing the different environmental conditions available in the archipelago.

Looking at the data processing, we identified the most important high-maturity datasets and analysed them in order to identify the key components that must be harmonized for having a standardized snow cover product. There are different setups that range from heterogeneous camera devices (different sensor resolutions, fore optics, sensor types), to installation features (site elevation, perspective coverage, acquisition seasoning), image data

1 https://niveos.cnr.it/passes/

processing (ortho-rectification and classification), and finally to the uncertainty estimation. There is a need for a shared strategy for the different components of these data processing chains, and the final solution will be a compromise between maintenance issues, logistic requirements, resource allocation and data/privacy constraints.

Once the strategy has been defined, such an infrastructure will be important for different disciplines (glaciology, hydrology, plant and animal ecology, coastal processes, sea-ice tracking, satellite cal/val) and it will be ready to be integrated with other SIOS and COPERNICUS infrastructures. This data summary could contribute to laying the groundwork for a regional service aimed at describing the FSC using terrestrial photography. Furthermore, the availability of different datasets can represent a training infrastructure for novel algorithms and innovative approaches focussed on integrating and assimilating different data sources. By defining the regional framework of available datasets – some of which are already connected to the SIOS data infrastructures – the Earth System Science community could increase the opportunity to fill the multi-scale gap present between different disciplines such as remote sensing and snow micro-physics.

5. Recommendations for the future

1. The aforementioned problems and knowledge gaps hinder the full use of the opportunities presented by terrestrial photography. To enhance its usefulness for snow cover and other related studies, we propose the following actions that can be taken by the SIOS community to support research in this field:

2. Promote actions and projects that assume usage of time-lapse cameras, especially in more remote areas of Svalbard. Most terrestrial photography setups focus on the Spitsbergen shores, close to human settlements. There are no cameras that cover the field of view of higher-elevation terrain.

3. Stimulate the creation of a Svalbard camera system network. Although all cameras provide valuable scientific data, it is currently difficult to use them collectively for one scientific purpose. There is a need to create a common and easy-to-apply algorithm for processing large quantities of images from different devices for snow cover applications.

4. Create a space on the SIOS website that gathers information about actively maintained camera systems on Svalbard. As a preliminary version, we propose the website created during the preparation of this report[2].

5. Promote the estimation of the fractional snow-covered area from images obtained by time-lapse cameras not specifically devoted to snow studies. This action will facilitate the involvement of local communities in the framework of citizen science, even if some privacy issues must be resolved first.

6. Stimulate the use of time-lapse cameras by different disciplines where high time–resolved information can be retrieved for different purposes (glaciology, hydrology, plant and animal ecology, coastal processes, sea-ice tracking, satellite cal/val).

2 https://niveos.cnr.it/passes/

6. Data availability

Dataset	Parameters	Period	Location	Metadata/Data Access	Data provider, reference
Svalbard cameras	Camera locations and ancillary information	2000–2020	Svalbard archipelago	http://iadc.cnr.it/cnr/metadata_view.php?id=113 SIOS data access portal: https://bit.ly/3fJugLZ	https://doi.org/10.5281/zenodo.4036510
Brøggerdalen	Raw imagery	2018–2020	Brøggerdalen	http://iadc.cnr.it/cnr/metadata_view.php?id=112	Data request (Roberto Salzano: roberto.salzano@cnr.it)
Brøggerdalen	Fractional snow cover	2018–2019	Brøggerdalen	http://iadc.cnr.it/cnr/metadata_view.php?id=80	Data request (Roberto Salzano: roberto.salzano@cnr.it)
CCTower	Raw imagery	2015–2020	Kolhaugen	http://iadc.cnr.it/cnr/metadata_view.php?id=110	Data request (Roberto Salzano: roberto.salzano@cnr.it)
Fuglebergsletta	Raw imagery	2016–2020	Hornsund	SIOS data access portal: https://bit.ly/37hfc5M	Data request (Mateusz Moskalik: mmosk@igf.edu.pl)
Fuglebekken catchment	Raw imagery	2014–2019	Hornsund	SIOS data access portal: https://bit.ly/2JcyqjK	Data request (Bartłomiej Luks: luks@igf.edu.pl)
Fuglebekken catchment	Fractional snow cover	2014–2016	Hornsund	https://doi.pangaea.de/10.1594/PANGAEA.874387 SIOS data access portal: https://bit.ly/39rYEt4	Kępski et al. (2017)
Zeppelin observatory	Raw imagery	2000–2020	Ny-Ålesund	https://doi.org/10.21334/npolar.2013.9fd6dae0 SIOS data access portal: https://bit.ly/39iFlgm	Pedersen (2013)
Zeppelin observatory	Fractional snow cover	2014–2019	Ny-Ålesund	http://iadc.cnr.it/cnr/metadata_view.php?id=111	Data request (Roberto Salzano: roberto.salzano@cnr.it)
Scheteligfjellet	Raw imagery	2012–2017	Ny-Ålesund	https://doi.pangaea.de/10.1594/PANGAEA.846617 SIOS data access portal: https://bit.ly/2J58IxL	Aalstad et al. (2020)
Scheteligfjellet	Fractional snow cover	2012–2017	Ny-Ålesund	SIOS data access portal: https://bit.ly/2K2vir8	Aalstad et al. (2020)
Adventdalen landscape	Raw imagery, vegetation index	2016–2020	Adventdalen	Available in the SIOS data access portal in Q1 2021	Data request (Lennart Nilsen: lennart.nilsen@uit.no)
Adventdalen racks	Raw imagery, NDVI, soil moisture, temperature (soil and surface)	2016–2020	Adventdalen	Available in the SIOS data access portal in Q1 2021	Data request (Lennart Nilsen: lennart.nilsen@uit.no)

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