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User Requirements Document

snow cci

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ESA STUDY CONTRACT REPORT

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Abstract:

The European Space Agency (ESA) Climate Change Initiative aims to generate high quality Essential Climate Variables (ECVs) derived from long-term satellite data records to meet the needs of climate research and monitoring activities. This document outlines the requirements for *snow_cci* ECVs (snow cover fraction – SCF; snow water equivalent – SWE) obtained through engagement with users from across climate applications, including aspects of hydrology and meteorology. This document provides details on the *snow_cci* user community, snow user requirements which pre-exist the *snow_cci* project, and requirements derived specifically for the *snow_cci* project based on input from the CRG, other CCI projects, the *snow_cci* user requirements workshop, and an online survey to the targeted user community. The consolidated user requirements for *snow_cci* products are provided, and mapped against the baseline specifications of the *snow_cci* products.

The work described in this report was done under ESA Contract. Responsibility for the contents resides in the author or organisation that prepared it.

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1. INTRODUCTION

The European Space Agency (ESA) Climate Change Initiative aims to generate high quality Essential Climate Variables (ECVs) derived from long-term satellite data records to meet the needs of climate research and monitoring activities. This document outlines the requirements for *snow_cci* ECVs (snow cover fraction – SCF; snow water equivalent – SWE) obtained through engagement with users from across climate applications, including the detection of variability and trends, climate modelling, and aspects of hydrology and meteorology. The primary parameters to be evaluated are requirements for the GCOS parameters snow extent and snow water equivalent, from which snow depth can be inferred using different approaches to estimate snow density.

1.1. Purpose and Scope

This document provides the user requirements for satellite-derived ECVs for fractional snow cover (SCF) and snow water equivalent (SWE). The user community for these products is composed of three primary groups:

- The Climate Research Group (CRG) of the *snow_cci* project team, which conducts case studies on *snow_cci* data usage and act as the interface with the CCI Climate Modelling User Group (CMUG).
- Other CCI projects for which (1) snow is a required input variable in their processing chains such as land surface temperature; permafrost; soil moisture, or (2) snow may feed directly into or support the *snow_cci* processing chain such as *cloud_cci*.
- The broader snow-climate research community, including climate modelling, large-scale hydrology, meteorology, and operational environmental prediction. Note that other segments of the snow science community were not engaged such as local-scale hydrology, transportation and infrastructure, avalanches, etc. in order to retain focus on the global climate aspect of CCI ECVs.

1.2. Document Structure

This document first provides details on the *snow_cci* user community and associated initiatives (Section 2). Snow user requirements from other initiative which pre-exist *snow_cci* were surveyed (Section 3.1). Requirements derived specifically for the *snow_cci* project were based on input from the CRG, other CCI projects, the *snow_cci* user requirements workshop, and an online survey to the targeted user community (Section 3.2). An overall summary is provided in Section 4. The online survey and results are provided in Appendices A and B.

1.3. Applicable and Reference Documents

[AD-1] IGOS Cryosphere Theme Report: http://cryos.ssec.wisc.edu/docs/cryos_theme_report.pdf

[AD-2] The GCOS Essential Climate Variable (ECV) Data Access Matrix: https://www.ncdc.noaa.gov/gosic/gcos-essential-climate-variable-ecv-data-access-matrix

[AD-3] WMO Observing Systems Capability Analysis and Review Tool: https://www.wmo-sat.info/oscar/

[AD-4] Global Cryosphere Watch: https://globalcryospherewatch.org/projects/snowwatch.html

1.4. Acronyms

CCI	Climate Change Initiative
CMIP	Coupled Model Inter-comparison Project
CMUG	Climate Modelling User Group
CNRS	Centre National de la Recherche Scientifique
CRG	Climate Research Group
ECCC	Environment and Climate Change Canada
ECMWF	European Centre for Medium Weather Forecast
ECV	Essential Climate Variable
ERA5	5th major global ECMWF Reanalysis
ESM-SnowMIP	Earth System Model-Snow Model Inter-comparison Project
GCOS	Global Climate Observing System
IGOS	Integrated Global Observing Strategy
OSCAR	Observing Systems Capability Analysis and Review tool
SCA	Snow Covered Area, synonym for SCE
SCE	Snow Cover Extent
SCF	Snow Cover Fraction
SMHI	Swedish Meteorological and Hydrological Institute
SWE	Snow Water Equivalent
TOPC	Terrestrial Observation Panel for Climate
UED	University of Edinburgh
WMO	World Meteorological Organization

2. USERS OF ECV SNOW PRODUCTS

This section provides an overview of the various elements of the *snow_cci* user community (Section 2.1). *snow_cci* primarily aims to generate products for climate applications across various domains, including climate observations, climate modelling, hydrology, and meteorology. Based on user responses from these communities, requirements for *snow_cci* products were derived (as presented in Section 3). Terrestrial snow user requirements from other international initiatives are also provided as context to *snow_cci* (Section 2.2).

2.1. Users of ECV Snow Products

2.1.1. Climate Research Group

The Climate Research Group (CRG) is an expert advisory group embedded within the *snow_cci* project to provide assessments of the value and significance of products emerging from the project by carrying out climate-relevant use cases. Collectively, the CRG have wide and internationally recognised expertise in observational and modelling studies of seasonal snow dynamics in response to climate variability and change and are ideally placed to assess the value and contribution of the *snow_cci* project for their specific applications. The five case studies are:

1. Regional and global snow cover trend analysis in support of climate assessments (lead C. Derksen / ECCC). Analysis of *snow_cci* products are used to estimate both global and regional SCF and SWE trends. Trends from the *snow_cci* products are also compared with observationally constrained land surface models.
2. Evaluation of CMIP6 simulations (lead G. Krinner / CNRS). *snow_cci* products are used to evaluate coupled climate model simulations over the historical period (including CMIP6 simulations covering the 1979-2014 period with prescribed sea-surface conditions) and a set of land-only simulations using meteorological forcing over the historical period.
3. Evaluation of ESM-SnowMIP simulations using *snow_cci* products (lead R. Essery / UED). The aim of this case study is to evaluate the use of *snow_cci* products to extend the evaluation of snow model simulations over larger regions and longer times than those for which detailed in situ measurements are available.
4. Use of CCI+ snow products to explain impacts of climate change on the hydrological regime in the pan-arctic drainage basin of the Arctic Ocean (lead D. Gustafsson / SMHI). The aim of this use case is to apply the *snow_cci* products to investigate the role of snow cover changes relative to the observed changes in the hydrological regime over large pan-arctic drainage basins of the Arctic Ocean.

5. Multi-decadal comparison between the ECMWF ERA5 climate reanalysis and the *snow_cci* snow cover data records (lead P. de Rosnay / EMCWF). *snow_cci* products are assessed for their potential contribution to ERA5 ECMWF reanalysis, including potential engagement with other operational centres.

The CRG is also the *snow_cci* interface to the CCI CMUG team, in order to coordinate information exchange on requirements, product specifications, and data sets to support international climate modelling activities. Further details on the CRG case studies are provided annually in the Climate Applications Report (CAR; Deliverable 5.1).

2.1.2. Other CCI Projects

Other CCI projects represent an important user group for *snow_cci* products. Snow is a required input variable in their processing chains. The following CCI projects provided their requirements for snow products:

- permafrost CCI
- land surface temperature CCI
- soil moisture CCI

2.1.3. Snow-Climate Research Community

There is an extensive user community for satellite-derived ECVs of SCF and SWE spanning diverse disciplines across climatology, hydrology, ecology, and numerical modelling. There is a range of maturity across this community with respect to the use of satellite data, ranging from exploratory research to operational applications. The objective of the user community engagement was to solicit requirements for *snow_cci* from users with a climate focus, and hence the need for consistent, objective, long time series of SCF and/or SWE data covering extensive spatial domains. This includes the evaluation of climate models, land surface modelling (including data assimilation), hydro-climatology, and ecological applications. A *snow_cci* user group email list is maintained for the distribution of product updates.

2.2. Related Initiatives

A number of initiatives have compiled requirements for in situ and satellite-derived snow observations. These will be presented in Section 3.1 in order to provide context for the *snow_cci* user requirements. The following initiatives are included:

1. The Global Climate Observing System (GCOS) is a United Nations *Framework* Convention on Climate Change (UNFCCC) sponsored initiative to ensure that adequate global observations are available to support climate related monitoring and research. Three expert panels provide an ongoing focus on the atmosphere, ocean, and land, with terrestrial snow requirements defined and collated by the Terrestrial Observation Panel for Climate (TOPC).

2. The Integrated Global Observing Strategy (IGOS) seeks to strengthen and coordinate satellite and in situ data acquisition in support of global environmental observations. A summary of current and planned capabilities and requirements for terrestrial snow *parameters* was produced as part of an IGOS-Cryosphere theme report (2007).
3. The Observing Systems Capability Analysis and Review Tool (OSCAR) was developed by the World Meteorological Organization (WMO). It links user-defined requirements for earth observation of physical variables (required across weather, water, and *climate* applications) to satellite and surface-based capabilities.

3. USER REQUIREMENTS

This section summarizes snow user requirements from other initiatives as context, before presenting the *snow_cci* user requirements determined from the First User Workshop (held in November 2018) and an accompanying online user survey. The requirements from GCOS, IGOS, and OSCAR (Section 3.1) are necessarily broad, covering a range of applications (of which climate is just one) and techniques (satellite and surface measurements). Conversely, the *snow_cci* requirements (Section 3.2) are more narrowly defined to deliver essential climate variables derived from satellite data. As such, the *snow_cci* requirements occupy part of the broader distribution of snow user requirements.

3.1. Snow Requirements from Other Initiatives

3.1.1. Global Climate Observing System (GCOS)

A summary of GCOS requirements for terrestrial snow ECVs is summarized in Table 3.1. The characteristics for snow covered area (SCA) and SWE are similar: daily data at 1 km resolution, with a more stringent spatial resolution requirement in complex terrain are required. The accuracy requirements are expressed as a percentage for SCA and in absolute terms (mm) for SWE, but the values are similar because 10 mm SWE uncertainty corresponds to 5% to 10% for snow packs with 100 to 200 mm SWE. Unlike the IGOS requirements (Section 3.1.2), there is no consideration within GCOS for how these requirements align with current spaceborne capabilities. For instance, while 1 km is achievable for SCA from existing and heritage optical sensors, there is no appropriate spaceborne measurement at this resolution from which SWE can be derived.

Table 3.1: GCOS Requirements for ECV snow, regarding the parameters snow covered area, snow water equivalent (SWE) and snow depth, according to GCOS Report Nr. 200 (2016).

Product	*Frequency*	*Resolution*	*Measurement Uncertainty*	*Stability*
Snow Covered Area	Daily	1 km 100 m complex terrain	5% (maximum error of omission and commission in snow area) location accuracy better than 1/3 IFOV with target IFOV 100 m in areas of complex terrain, 1 km elsewhere	4% (maximum error of omission and commission in snow area); location accuracy better than 1/3 IFOV with target IFOV 100 m in areas of complex terrain,1 km elsewhere
SWE	Daily	1 km	10 mm	10 mm
Snow Depth	Daily	1 km 100 m in complex terrain	10 mm	10 mm

3.1.2. IGOS

A summary of capabilities and requirements for terrestrial snow parameters (both surface and satellite-derived) from the IGOS-Cryosphere theme report is shown in Table 3.2. Requirements are differentiated between threshold (the minimum necessary) and objective (desired future target) values. As this report was issued in 2007, the progress in satellite snow cover product development is clearly evident relative to the IGOS current/threshold/objective requirements. The 'target' of 0.5 km snow cover information is now 'current' via measurements from MODIS and VIIRS; the objective requirement of 0.1 km is now possible using, for instance, Sentinel-2 measurements. Capabilities for satellite-derived SWE, however, do not approach the threshold requirements as defined by IGOS (e.g. 0.5 km resolution).

Table 3.2: IGOS Summary of current/planned capabilities and requirements for terrestrial snow parameters. C = Current Capability, T = Threshold Requirement (Minimum necessary), O= Objective Requirement (Target), L = Low end of measurement range, U = Unit, H = High end of measurement range, V = Value (http://cryos.ssec.wisc.edu/docs/cryos_theme_report.pdf).

Parameter	CTO	Measurement Range			Measurement Accuracy		Resolution				Comment or Principal Driver
							Spatial		Temporal		
		L	H	U	V	U	V	U	V	U	
Snow Cover	C	20	100	%	15-20	%	1	km		day	e.g. MODIS
	T	0	100	%	10	%	0.5	km	1	day	Hydromet
	O	0	100	%	5	%	0.1	km	12	hr	
Snow Water Equivalent, satellite (Shallow)	C	0	0.2	m	2-10	cm	25	km	1	day	e.g. AMSR-E
	T	0	0.3	m	3	cm	0.5	km	6	day	Hydromet
	O	0	0.3	m	2	cm	0.1	km	12	hr	
Snow Water Equivalent, satellite (Deep)	C	none	---	---	---	---	---	---	---	---	Need HF SAR
	T	0.3	3	m	10	%	0.5	km	6	day	Hydromet
	O	0.3	3	m	7	%	0.1	km	12	hr	
Snow Water Equivalent, in situ (Shallow)	C	0	3	m	1	cm	1	m	30	day	Hydromet
	T	0	3	m	1	cm	1	m	7	day	Hydromet
	O	0	3	m	1	cm	1	m	1	day	
Snow Depth, satellite (Shallow)	C	0	~0.7	m	6-35	cm	25	km	1	day	e.g. AMSR-E
	T	0	1	m	10	cm	0.5	km	6	day	Hydromet
	O	0	1	m	6	cm	0.1	km	1	hr	Transportation
Snow Depth, satellite (Deep)	C	none	---	---	---	---	---	---	---	---	Need HF SAR
	T	1	10	m	10	%	0.5	km	6	day	Hydromet
	O	1	10	m	6	%	0.1	km	1	hr	Transportation
Snow Depth, in situ	C	0	10	m	1	cm	1	m	1	day	Hydromet
	T	0	10	m	1	cm	1	m	6	hr	Hydromet
	O	0	10	m	1	cm	1	m	1	hr	

3.1.3. OSCAR

A summary of requirements collated within OSCAR for snow cover and SWE are shown in Table 3.3 and Table 3.4, respectively. Similar to IGOS, the OSCAR requirements differentiate between threshold (minimum requirement), breakthrough (requirements which represents a notable improvement from the threshold), and goal (the ultimate target) requirements. Because OSCAR is a resource which aggregates requirements from various sources and communities, a wide range is evident: for example, the needs of numerical weather prediction are quite different from climate and hydrology. Even within application areas there can be a broad range of requirements. For instance, the requirements defined by CliC and GEWEX, two different climate-oriented projects within the World Climate Research Program, capture different requirements for snow cover and SWE.

Table 3.3: Summary of OSCAR requirements defined for snow cover. (https://www.wmo-sat.info/oscar/variables/view/143). Goal is marked blue, breakthrough green, and threshold orange.

App Area	Uncertainty	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness
Climate-AOPC (deprecated)	10 % 13 % 20 %		100 km 200 km 500 km		24 h 2 d 7 d	6 h 12 h 24 h
CLIC (deprecated)	10 % 13 % 20 %		1 km 2.9 km 25 km		24 h 41 h 5 d	7 d 11 d 30 d
GEWEX (deprecated)	10 % 20 % 50 %		15 km 50 km 250 km		24 h 2 d 7 d	30 d 45 d 90 d
Global NWP	10 % 20 % 50 %		5 km 15 km 100 km		3 h 24 h 5 d	3 h 24 h 5 d
High Res NWP	5 % 15 % 20 %		1 km 5 km 20 km		60 min 3 h 12 h	60 min 3 h 12 h
Hydrology	5 % 8 % 20 %		0.1 km 1 km 100 km		24 h 46 h 7 d	24 h 44 h 6 d
Nowcasting / VSRF	10 % 13 % 20 %		5 km 10 km 50 km		60 min 6 h 24 h	60 min 2 h 6 h
Agricultural Meteorology	2 % 4 % 10 %		1 km 2.2 km 10 km		5 d 6 d 7 d	24 h 44 h 6 d
Climate-TOPC (deprecated)	5 % 7 % 10 %		0.1 km 0.45 km 10 km		24 h 3 d 30 d	30 h 3 d 15 d

Table 3.4: Summary of OSCAR requirements defined for snow water equivalent. (https://www.wmo-sat.info/oscar/variables/view/145). Goal is marked blue, breakthrough green, and threshold orange.

App Area	Uncertainty	Stability / decade	Hor Res	Ver Res	Obs Cyc	Timeliness
Climate-AOPC (deprecated)	5 mm 6.5 mm 10 mm		100 km 200 km 500 km		24 h 2 d 7 d	6 h 12 h 24 h
CLIC (deprecated)	5 mm 8 mm 20 mm		10 km 13.6 km 25 km		24 h 41 h 5 d	7 d 11 d 30 d
GEWEX (deprecated)	5 mm 10 mm 20 mm		15 km 50 km 250 km		12 h 24 h 7 d	30 d 45 d 90 d
Global NWP	2 mm 10 mm 20 mm		5 km 15 km 100 km		3 h 24 h 5 d	3 h 24 h 5 d
High Res NWP	5 mm 8 mm 20 mm		0.5 km 2 km 20 km		60 min 3 h 6 h	60 min 3 h 24 h
Hydrology	5 mm 8 mm 20 mm		0.1 km 0.464 km 10 km		24 h 46 h 7 d	24 h 44 h 6 d
Agricultural Meteorology	5 mm 23.2 mm 500 mm		30 km 2.2 km 10 km		7 d 11 d 30 d	24 h 46 h 7 d
SIAF (deprecated)	5 mm 10 mm 20 mm		50 km 100 km 500 km		24 h 2 d 7 d	24 h 2 d 7 d
SSLP	5 mm 10 mm 20 mm		50 km 100 km 500 km		24 h 2 d 7 d	24 h 2 d 7 d

3.1.4. Summary of Requirements for Snow Parameters

A synthesis of input from GCOS, IGOS, and OSCAR illustrates the full range of user needs, within which *snow_cci* requirements and product specification will occupy a specific niche. For both snow cover extent (SCE) and SWE, there are three general categories of users each with unique requirements: (1) climate, (2) terrestrial applications such as hydrology and agriculture, and (3) numerical weather prediction (NWP). In a general sense, the requirements for climate are relaxed with respect to characteristics such as spatial resolution and latency; NWP needs are most demanding, particularly for regional and/or nowcasting applications. Common requirements across applications are the need for daily data across extensive spatial domains.

The general baseline requirements for ***snow cover*** are daily data at spatial resolutions of at least 1 km with uncertainty of 5 to 10%. Because of the different variables related to snow cover (snow extent; snow covered area; snow cover fraction) it's not always clear from the requirements tables exactly what the uncertainty values correspond to, or how they can be derived. A distinction in spatial resolution requirements is made between alpine and non-alpine regions due increased heterogeneity in complex terrain. The update frequency, latency, and repeat interval vary between applications.

Requirements for attributes specific to the derivation of snow cover parameters from optical remote sensing are not provided. For example, there are no user requirements for cloud screening and clearing.

The general baseline requirements for ***snow water equivalent*** are similar to snow extent: daily data with spatial resolution of 1 km with uncertainty of approximately 10%. In some cases, the heritage of SWE retrieval from satellite passive microwave measurements is reflected in a more realistically achievable spatial resolution (5 to 25 km), and a distinction between shallow and deep snow. This is similar to the simple versus complex terrain requirements for SCE, and reflects the tendency for passive microwave measurements to saturate under deep snow conditions.

In summary, the GCOS requirements represent a reasonable consensus for satellite snow products: daily data at 1 km spatial resolution with 5-10% uncertainty. For snow cover parameters, these align closely with the capabilities of the spaceborne optical measurements used to derive these products. For SWE, the spatial resolution requirements cannot be achieved using satellite data alone. Product-specific requirements are lacking from the existing user requirements summarized here. This includes user needs related to metadata, data format (file format, projection, etc.), and access. It is also important to note that requirements are available for other snow variables not discussed here, such as snow depth, albedo, and snow wet/dry state (https://www.wmo-at.info/oscar/variables/view/144).

3.2. Requirements from the 1st *snow_cci* User Workshop and *snow_cci* Online User Survey

snow_cci user requirements outlined below were defined using input from two primary sources: the Online User Requirement Survey and the First User Workshop:

1. Twenty responses were submitted to an online user requirements survey, sent to a targeted group of respondents covering the three *snow_cci* user categories outlined in Section 2.1. In addition to multiple choice questions, there was the opportunity to provide free-form input, which was submitted by nearly all respondents. The online survey is provided in Appendix A; a summary of responses is provided in Appendix B. For some product characteristics, a clear consensus was evident in the survey responses; in some cases, the requirements are application-specific and therefore quite broad.

2. To clarify these (and other) issues, a user requirements workshop was held on 29 November 2018 at the Zentralanstalt für Meteorologie und Geodynamik (ZAMG), in Vienna, Austria (agenda provided in Appendix C). The workshop presentations covered product development, processing plans, and baseline specifications for the *snow_cci* SCF and SWE products. Use cases (with associated requirements) were presented by CRG members, representatives of other CCI projects, and the snow-climate user community. There was group discussion to establish consensus on baseline product specifications for year 1 processing of *snow_cci*

products, approaches to deriving and delivering the uncertainty characterization, priorities for algorithm improvement, and potential approaches for temporal and spatial aggregation of *snow_cci* products which will be explored in year 2 and beyond.

Input from the online survey and the user workshop were used to derive the year 1 requirements for SCF and SWE ECVs. Outlined in Section 3.2.2, the consensus decision is provided for all product characteristics along with additional considerations which factored into the discussion. These are revisited as the *snow_cci* products evolve through updated product versions. For example, the *snow_cci* user community was re-engaged in the fall of 2020 in order to gather any changes to user requirements. No major changes in requirements were reported as part of this process. It is anticipated that the second user requirements workshop will be held virtually in the spring of 2021.

3.2.1. *snow_cci Parameters*

A summary of the *snow_cci* baseline product specifications identified before engagement with the user community is provided in Table 3.5. These specifications consider only the basic product parameters and are driven largely by the capability and availability of existing satellite measurements and retrievals. The snow extent related *snow_cci* product is per-pixel fractional snow extent retrieved from optical imagery and expressed as a percentage, which represents a notable improvement over a simple binary snow/no-snow classification. SWE is derived from a snow depth retrieval from passive microwave measurements converted to SWE via an estimate of snow density.

Table 3.5: Proposed *snow_cci* baseline ECV product specifications used as starting point for discussion with users.

	Snow Extent	***Snow Water Equivalent***
Parameter	Fractional snow extent [%]	Snow mass
Description	Viewable Snow (VS) Snow on Ground (SoG) - forested areas only as VS and SoG are the same in open areas	Snow depth converted to SWE via density
Spatial Coverage	Global (without Antarctica and Greenland ice sheet)	NH non-mountain areas (without Antarctica and all of Greenland)
EO Data	Optical imagery	Passive microwave brightness temperatures
Spatial Resolution	Ca. 4 km Ca. 1 km	Ca. 25 km
Period	1982 – onwards (4 km) 2000 – onwards (1 km)	1979 - onwards
Frequency	Daily	Daily
Update Frequency	Annual	Annual
Map Projection	Geographic Grid (Lat/Lon)	Geographic Grid (Lat/Lon)

3.2.2. Requirements for ECV SCF and SWE Products

Requirements for the *snow_cci* products reflect input from the online survey, first user workshop, and engagement with the user community during the fall of 2020, considered alongside the capabilities of satellite measurements and associated retrieval algorithms. The requirements are summarized in a series of tables, organized by general product characteristics. In each case, requirements met by the *snow_cci* version 1 products are highlighted in green rows. Changes to product specifications for version 2 will address some user requirements not met by version 1; these are summarized in yellow rows. Requirements not met by version 1 or 2 are flagged through user comments in red rows. These tables are updated annually, in the subsequent versions of the User Requirement Document. First, temporal and spatial considerations for the SCF and SWE products are summarized in Table 3.6.

Table 3.6: Summary of spatial and temporal requirements for the *snow_cci* products. Green rows indicate decisions made for version 1 processing; orange rows indicate considerations for future product versions.

snow_cci Product Characteristics		*Spatial Domain*	*Spatial Resolution*	*Temporal Coverage*	*Temporal Resolution*	*Update Frequency*	*Other Considerations*
SCF	**Version 1**	Global land areas without ice sheets (Antarctica / Greenland)	0.05 deg 0.01 deg	Single-sensor: 1982 onwards 2000 onwards	Daily	Annual	Land / water / surface class map derived from Land Cover CCI to be provided as additional information (at 0.01 - 0.05 deg)
	Version 2	No change	No change	Multi-sensor homogenized dataset	No change	Annual	No change
	User Comments	Antarctic dry valleys Islands in Southern Ocean	SCE resolution needs are broad, but 0.01 deg meets the majority of needs	Clear requirement for multi-sensor homogenized dataset		Snow CCI will not address NWP user requirement for near real time processing (6 hours latency)	
SWE	**Version 1**	Northern Hemisphere	0.25 deg Downscaling can be performed by users	1979 onwards	Daily	Annual	Land / water / surface class map derived from Land Cover CCI to be provided as additional information
	Version 2	No change	0.125 deg	No change	No change	No change	No change

snow_cci Product Characteristics		Spatial Domain	Spatial Resolution	Temporal Coverage	Temporal Resolution	Update Frequency	Other Considerations
	User Comments	Snow CCI will not meet user needs for southern hemisphere retrievals	Resolution enhancement addresses a clear user requirement			Snow CCI will not address NWP user requirement for near real time processing (6 hours latency)	

Version 1 processing for SWE focused on the northern hemisphere, while the SCF version 1 processing focused on global land areas excluding permanent snow and ice areas and ice sheets (Greenland, Antarctica). This initial focus for SWE on the northern hemisphere addresses all the user needs captured by the online survey and the user workshop. For SCF, decisions remain to be made regarding the potential inclusion of the Antarctic dry valleys and islands in the Southern Ocean (e.g. South Georgia) for future product versions. SWE retrievals will not be extended to the southern hemisphere because most snow occurs in high elevation or coastal areas which will be alpine and land/sea masked. The spatial resolution for SCF is limited by the characteristics of historical optical satellite data. The time series from 1982 onward will be at 0.05 degrees resolution, improving to 0.01 degrees starting in 2000. Separate time series at each resolution were processed for version 1, which will be followed by a homogenized multi-sensor dataset for version 2. SCE resolution requirements span 100 m to 10 km, but the 0.01 to 0.05 resolution range meets the majority of user needs. The SWE resolution of 0.25 degrees meets the majority of climate user requirements. While there is a need for higher resolution products to meet some user needs, this cannot be achieved directly using historical passive microwave measurements. As pointed out in the online survey, some users plan to perform their own downscaling of the 0.25 degree SWE data using various modelling approaches. Version 2 of the SWE product will utilize higher resolution resampled brightness temperatures at 12.5 km resolution; validation experiments are required to quantify changes in algorithm performance. The annual CCI product update schedule meets all user requirements, with the exception of operational environmental prediction (e.g. NWP) which requires a latency of <6 hours. This near real time service is not considered to be part of the CCI mandate.

A summary of technical characteristics for the SCF and SWE products is provided in Table 3.7.

Table 3.7: Summary of product requirements for the *snow_cci* products. Green rows indicate decisions made for version 1 processing; orange rows indicate considerations for future product versions.

snow_cci Product Characteristics		*Map Projection*	*File Format*	*Product Access*	*Metadata*
SCF	**Version 1**	Geographic Grid (Lat/Lon)	Daily netCDF	CCI portal	
	Version 2	No change	No change	No change	Observation time per pixel potentially added to snow products as layer of the netcdf file
	User Comments		Monthly multi-layer netCDF	Explore other means of delivery	User request for observation time per pixel to be added to snow products
SWE	**Version 1**	Geographic Grid (Lat/Lon)	Daily netCDF	CCI portal	
	Version 2	No change	No change	No change	
	User Comments		Monthly multi-layer netCDF	Explore other means of delivery	

A geographic (lat / lon) grid, netCDF file format, and ftp data acquisition via the CCI data portal meet the vast majority of user requirements. Only limited metadata requirements were provided by users, but for NWP applications the per-pixel observation time is required. This will potentially be added as a data layer in the version 2 products. Other static ancillary data layers such as the land/water mask and land cover class will be provided (see Table 3.6). As the products evolve, data flags related to potential cloud-gap filling procedures and the blending of alpine SWE information will be developed. Further efforts to acquire additional metadata requirements from the user community are needed.

A summary of accuracy/uncertainty requirements for the SCF and SWE products is provided in Table 3.8.

Table 3.8: Summary of product uncertainty requirements for the *snow_cci* products. Green rows indicate decisions made for year 1 processing; orange rows indicate considerations for future product versions.

snow_cci Product Uncertainty		*Accuracy Requirement*	*Accuracy Determination*	*Per-pixel Uncertainty*	*Delivery of Uncertainty*
SCF	**Version 1**	10-20% Unbiased RMSE	Validation conducted via comparisons with in situ data and high resolution optical imagery	Essential for applications such as data assimilation; derived as part of SCF retrieval	Accuracy determination provided via the Product Validation and Intercomparison Report Uncertainty maps provided as layer in daily netCDF files
	Version 2	Reduced RMSE through algorithm enhancements	Development of data flags (clouds, illumination, etc.)	No change	No change
	User Comments			Potential to develop confidence intervals?	
SWE	**Version 1**	20-30% unbiased RMSE	Systematic bias estimated via comparison with independent snow course data	Essential for applications such as data assimilation; derived as part of SCF retrieval	Accuracy determination provided via the Product Validation and Intercomparison Report Uncertainty maps provided as layer in daily netCDF files
	Version 2	Reduced RMSE through algorithm enhancements	Comparison with other gridded SWE products to determine agreement (climatology; anomalies; etc.)	No change	No change
	User Comments				

The extent to which the products meet the accuracy requirements (expressed as unbiased RMSE) is determined through the use of independent reference datasets: snow course data for SWE; in situ snow depth data and high resolution optical imagery for SCF. These validation statistics, along with

inter-comparisons with other snow products are reported in the Product Validation and Inter-comparison Report (PVIR; Deliverable 4.1). Additional metrics such as bias will be combined with RMSE to provide measures of the systematic error. Per-grid cell uncertainty is produced from the algorithm processing for both SCF and SWE (delivered via the daily netCDF files) and quantifies the random error component. This is described in the End-to-end Uncertainty Budget (E2EUB; Deliverable 2.3). Collectively, the derivation of systematic and random error meets user requirements. Understanding the systematic bias is required for applications such as climate model evaluation, model initialization, and trend determination. Daily, per-grid cell uncertainty is essential for applications such as data assimilation.

A summary of product development requirements for the SCF product is provided in Table 3.9. A primary limitation is the influence of clouds, which obscure the surface and must be masked. There was no clear user requirement with respect to the filling of cloud-covered areas using measurements from previous days when the surface was viewable (as is done, for instance, with the MODIS Cloud Gap Filled product; Hall et al., 2010). For some users, cloud-gap filling based on a physically based approach is desired, with flags to indicate where and from when cloud-gap filled data were used. These users typically screen for snow (e.g. the CCI soil moisture and LST projects). Other users noted that cloud-gap filling could be done following data acquisition, using in-house tools. Finally, some users noted it is important to not cloud fill for operational applications where a lack of information is preferred over SCF retrievals from some time lag. There will be no cloud-gap filling of the SCF product in the Phase 1, given the significant challenges in implementing a physically-based scheme. This option will be investigated further in Phase 2.

Table 3.9: Summary of SCF product development requirements. Green rows indicate decisions made for year 1 processing; orange rows indicate considerations for future product versions.

SCF Product	*Cloud Gap Filling*	*Temporal Aggregation*	*Spatial Aggregation*
Version 1	No gap filling	No temporal aggregation (daily data)	None (0.01 and 0.05 deg only)
Version 2	No change	Temporal aggregation to weekly products (will mitigate cloud issues)	TBD
User Comments	Physically-based approach with clear QC flagging and uncertainty Some applications require no gap filling	Temporal aggregation addresses some user requirements Document tools/methodology for temporal SCF aggregation Flagging required (e.g. number of surface looks within weekly aggregation period)	Aggregation to 0.25 deg for consistency with SWE product Document tools/methodology for spatial SCF aggregation require development Flagging required

There is a user requirement to provide a spatially aggregated 0.25 degree SCF product for consistent analysis of trends and model simulations with the SWE product. The temporal and spatial aggregation of daily SCF products is non-trivial because of the influence of clouds and the computation of 'SCF' from a variable number of clear-sky observations within the averaging window. For version 1, the SCF and SWE products are provided on a daily basis with aggregation left to the users. Tool development for aggregation will be considered in later project years. Spatially, the methodological approach will need to consider that clouds may obscure all or part of the 0.25 degree grid cells. Temporal aggregation to a weekly product will mitigate the influence of clouds, but a gap-filling scheme remains to be developed. Regardless, clear flagging and metadata will be required to indicate the temporal and spatial provenance of the raw data before aggregation. There was no clear user demand for monthly averaged SCF, given that snow is a dynamic variable, and can evolve from complete snow cover to complete snow-free conditions within a single month.

A summary of product development requirements for the SWE product is provided in Table 3.10.

Table 3.10: Summary of SWE product development requirements. Green rows indicate decisions made for year 1 processing; orange rows indicate considerations for future product versions.

SWE Product	*Alpine Regions*	*Weather Stations*	*Temporal Aggregation*	*Spatial Aggregation*	*Algorithm Enhancements*
Version 1 Consensus	Masked Mountain mask needs revision: generated from TanDEM-X DEM; criteria to define mountains (currently >2deg) may be revised	Weather stations screened for basic consistency criteria. Impact of weather station homogeneity determined via comparison with developmental dataset derived using time series of consistent weather station input	Daily	None (0.25 deg only)	Improved emission models: forest cover; sub-grid lakes
Version 2	No change	Weather stations screened for basic consistency criteria	No change	Determine CMUG needs	Dynamic snow density; enhanced spatial resolution
User Comments	Additional product version with alpine-filled SWE information (flagged, and derived from other sources)	Determine impact of weather station homogeneity: time series with temporally variable weather station input compared to time series with consistent weather station input	Monthly	Development of a fully synergistic SCF+SWE product?	

The baseline version 1 daily SWE product masks alpine areas; weather stations used as part of the SWE retrievals must pass quality check standards but are not fully consistent. Different user requirements will influence the importance of product improvements in these two areas. With respect to alpine areas, one standard non-filled product will continue to be provided to avoid model filling for some users. An additional version with alpine-filled information will be developed for later versions using a blending approach with SWE from land surface model datasets, following Mudryk et al (2017). Flags noting grid cells with blended input will be provided. Coarse resolution SWE products tend to underestimate SWE in alpine areas (Wrzesien et al., 2018) so further bias correction techniques will be explored. It is a user requirement to determine the impact of weather station homogeneity on the consistency of the SWE time series. This was addressed by comparing temporally variable weather station input (*snow_cci* v1) with a developmental time series derived using a smaller set of consistent weather station input. This assessment identified very little impact on product performance via the validation statistics, but some differences in high latitude trends were apparent (report in CAR; Deliverable 5.1). Some users requested a SWE product that does not use any in situ data. This cannot be met because (as shown in SnowPEx) in situ data are mandatory to produce realistic SWE retrievals.

Aggregation for SWE is straightforward compared to SCF because the data are cloud-free and already at coarse resolution. Daily and monthly averaged data will be produced at 0.25 degree resolution. Any further temporal and spatial aggregation will be performed to meet the CMUG requirements. As noted in Table 3.6, SWE version 2 will be derived at an enhanced resolution of 12.5 km, which will address some user needs for higher resolution data.

At present, the SCF and SWE products are fully independent. This means there will be differences in, for example, the snowline location between the two products. These differences will be reflected in climatologies, anomalies, and trends that will not be consistent. For instance, snow extent trends derived from the SCF product will not be the same as snow extent trends derived from the SWE product. A prototype fully synergistic SCF and SWE product is under investigation, but requires further evaluation, including whether there is user demand for such a product.

4. SUMMARY OF USER REQUIREMENTS

Consolidated user requirements for *snow_cci* products are provided in Table 4.1 (SCF) and Table 4.2 (SWE), mapped against the baseline specifications of the version 1 products. The majority of climate user requirements are met by the baseline specification for version 1; product development in later years will address the outstanding requirements. Note that user requirements for NWP cannot be met within the scope of *snow_cci*.

Table 4.1: Consolidated user requirements for SCF (right column) compared to the proposed *snow_cci* baseline specifications used as starting point for discussion with the users. Green highlighted text indicates agreement between requirement and specification. Yellow highlighted text indicates further development required to meet requirement. Red highlighted text indicates requirements not planned to be met by *snow_cci*.

	Snow Cover Fraction Baseline Specifications	***Snow Cover Fraction User Requirements***
Description	Viewable Snow (snow on top of forest canopy) Snow on Ground (canopy correction applied)	Correction for canopy effects to yield snow on ground information in forested areas.
Spatial Coverage	Global (without Antarctica and Greenland ice sheet)	Global (without ice sheets of Antarctica and Greenland), but include ice free areas in Greenland
Spatial Resolution	Ca. 4 km (1982 – present) Ca. 1 km (2000 – present)	500 m to 1 km
Map Projection	Geographic Grid (Lat/Lon)	Geographic Grid (Lat/Lon)
Period	1982 – onwards (4 km) 2000 – onwards (1 km)	As long as possible Ensure inter-sensor consistency
Frequency	Daily	Daily Weekly
Spatial Aggregation	None	0.25 deg CMUG requirement
Update frequency	Annual	Annual for climate Sub-daily for NRT (Note: NRT services are not the aim of *snow_cci*)
Coding	8-bit (0-255)	8-bit (0-255)
Format	netCDF	netCDF
Accuracy	10-20% RMSE	10-20% RMSE
Uncertainty Metric	Unbiased RMSE	Unbiased RMSE
Cloud-Gap Filling	None	Separate product with physically-based cloud-filling scheme and associated flagging
Data Access	CCI data portal (includes ftp)	Delivery via ftp
Metadata	Land/sea mask	Land/sea mask (common for all products) Measurement time

Table 4.2: Consolidated user requirements for SWE (right column) compared to the year 1 *snow_cci* baseline specifications. Green highlighted text indicates agreement between requirement and specification. Yellow highlighted text indicates further development required to meet requirement. Red highlighted text indicates requirement cannot be met by *snow_cci*.

	Snow Water Equivalent Baseline Specifications	***Snow Water Equivalent User Requirements***
Description	SWE in mm	SWE in mm
Spatial Coverage	Northern hemisphere non-mountain areas (without Antarctica and all of Greenland)	Northern Hemisphere
Spatial Resolution	25 km	25 km Some higher resolution requirements
Map Projection	Geographic Grid (Lat/Lon)	Geographic Grid (Lat/Lon)
Period	1979 – onwards	1979 – onwards
Frequency	Daily monthly	Daily Monthly
Spatial Aggregation	None	CMUG requirement
Update frequency	Annual	Annual for climate Sub-daily for NRT (Note: NRT services are not the aim of *snow_cci*)
Coding	8-bit (0-255)	8-bit (0-255)
Format	netCDF	netCDF
Accuracy	20-30% RMSE	10-25%
Uncertainty Metric	Unbiased RMSE	Unbiased RMSE
Alpine Filling	None	Separate product with alpine filling and associated flagging
Weather Station Consistency	Basic filtering and consistency criteria	Two product streams: (1) use of all available weather stations; (2) use of only consistent weather stations
Data Access	CCI data portal (includes ftp)	Delivery via ftp
Metadata	Land/sea mask	Land/sea mask Measurement time

The year to year evolution of *snow_cci* algorithms, processing, products, and associated user needs feeds into annual updates of the URD. This process captures progress in the *snow_cci* product specifications, and how they align with evolving user requirements. The user community is continually engaged via the CRG, through other CCI projects, and through the *snow_cci* user group. It is anticipated that the second user requirements workshop will be held virtually in spring 2021.

5. REFERENCES

Hall D., G. Riggs, J. Foster, and S. Kumar. 2010. Development and evaluation of a cloud-gap-filled MODIS daily snow-cover product. Remote Sensing of Environment. 114: 496–503.

Mudryk, L. R. and C. Derksen. 2017. CanSISE Observation-Based Ensemble of Northern Hemisphere Terrestrial Snow Water Equivalent, Version 2. Boulder, Colorado USA. NSIDC: National Snow and Ice Data Center. http://dx.doi.org/10.5067/96ltniikJ7vd.

Wrzesien, M., M. Durand, T. Pavelsky, S. Kapnick, Y. Zhang, J. Guo, and C. K. Shum. 2018. A new estimate of North American mountain snow accumulation from regional climate model simulations. Geophysical Research Letters. 45: 1423–1432. https://doi.org/10.1002/2017GL076664

A. THE *SNOW_CCI* ONLINE USER SURVEY

The goal of the *snow_cci* project is to establish fully validated processing lines for key global snow parameters from archived and current satellite observations to support climate applications. The key parameters are snow cover extent (SCE) and snow water equivalent (SWE).

The purpose of this survey is to determine user requirements for *snow_cci* products, in advance of the first User Workshop, to be held on 29 November 2018.

Contact person (name and email)

Organisation (name, country and type)

I agree that my contact information can be used within the ESA *snow_cci* project to inform me on the progress, any news and further events via newsletter or personal email according to the General Data Protection Regulation (EU) 2016/679 ("GDPR"). The personal data will be kept confidential within the project, and will not be distributed to any third party.

What are the primary applications of snow data in your organization?
(monitoring) (climate) (hydrology) (modelling/prediction) (process studies) (other)

What snow data sources does your organisation presently use?

- in-situ measurements at stations
- spatially interpolated in-situ measurements at stations
- modelled data (e.g. land surface models)
- raw satellite data
- products from satellite data

List the satellite or model-derived snow products currently in use at your organisation.

Are any of these products used operationally? If so, describe.

Is snow information used as input for generating value-added products or services? If so, describe.

Are snow products automatically ingested at your organisation?
Yes/No/Partially

Do the snow datasets used presently in your organisation meet your requirements?
Yes/No/Partially

What are your preferred data formats?

Do you wish to join the *snow_cci* User Group as a means to stay informed and provide feedback to the project?
Yes/No

How relevant are these snow variables to your needs?

	I do not need this product	It's nice to have	Important	Very important	Crucial
Snow cover area	❑	❑	❑	❑	❑
Snow Water Equivalent (low res)	❑	❑	❑	❑	❑
Snow Surface Temperature	❑	❑	❑	❑	❑
Map of melting snow	❑	❑	❑	❑	❑
Snow surface Wetness	❑	❑	❑	❑	❑
Surface Albedo Maps	❑	❑	❑	❑	❑

Rate the importance of these snow extent product characteristics:

	No importance	**Low importance**	**Medium importance**	**High importance**	**Essential**
Very high spatial resolution (<100 m)					
High spatial resolution (100 - 500 m)					
Moderate spatial resolution (1-4 km)					
Coarse spatial resolution (> 4km)					
High temporal resolution (daily)					
Moderate temporal resolution (weekly)					
Weekly max and min values					
Low temporal resolution (monthly)					
Monthly max and min values					
Cloud-gap Filling					
Spatial Domain: Global					
Spatial Domain: Continental					

	No importance	Low importance	Medium importance	High importance	Essential
Spatial Domain: Regional					
Latency: Seasonal updates					
Latency: Annual updates					
Per-pixel uncertainty values					
Forested areas: Estimates of 'viewable snow'1					
Forested areas: Estimates of 'snow on ground2'					

Provide any additional comments related to:

- Spatial resolution:
- Temporal resolution:
- Cloud gap filling:
- Spatial domain:
- Latency:
- Uncertainty:

Rate the importance of these snow water equivalent product characteristics:

	No importance	Low importance	Medium importance	High importance	Essential
Moderate spatial resolution (~5 km)					
Low spatial resolution (25 km)					
High temporal resolution (daily)					
Moderate temporal resolution (weekly)					
Low temporal resolution (monthly)					

1'viewable snow': snow observed at the top of the forest canopy
2'snow on ground': snow on the ground surface (correction for the forest canopy is applied)

	No importance	Low importance	Medium importance	High importance	Essential
Spatial Domain: Global					
Spatial Domain: Continental					
Spatial Domain: Regional					
Latency: Seasonal updates					
Latency: Annual updates					
Per-pixel uncertainty values					
Satellite-only SWE retrievals (alpine areas masked)					
Blended satellite SWE retrievals and land surface model estimates in alpine areas					

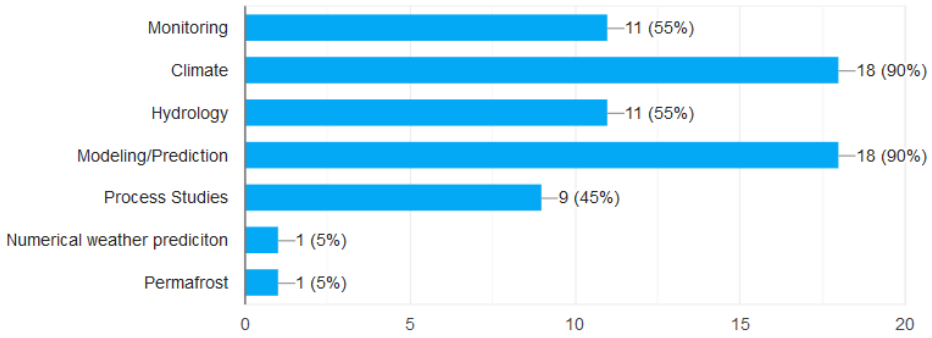
Provide any additional comments related to:

- Spatial resolution:
- Temporal resolution:
- Spatial domain:
- Latency:
- Uncertainty:
- Retrieval method:

B. ONLINE USER SURVEY – SUMMARY OF RESPONSES

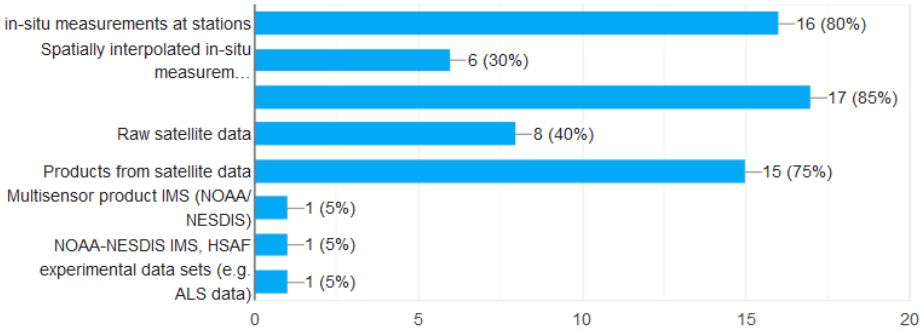
What are the primary applications of snow data in your organization?

20 responses



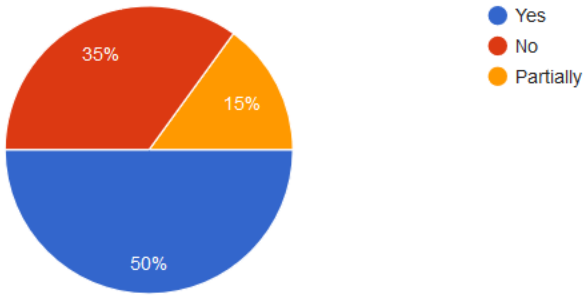
What snow data sources does your organisation presently use?

20 responses



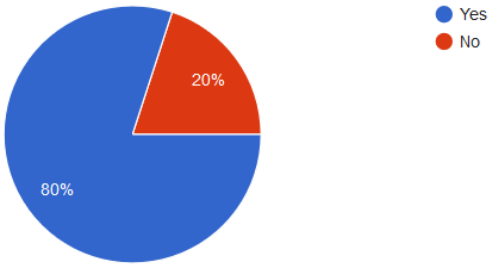
Are snow products automatically ingested at your organisation?

20 responses



Do you wish to join the snow_cci User Group as a means to stay informed and provide feedback to the project?

20 responses



	I do not need this product	It's nice to have	Important	Very important	Crucial
Snow cover area			1	8	10
Snow Water Equivalent (low res)	2		5	7	5
Snow Surface Temperature	4	4	3	6	1
Map of melting snow	2	9	4	2	
Snow surface Wetness	3	9	6		
Surface Albedo Maps	2	2	5	6	3

	No importance	Low importance	Medium importance	High Importance	Essential
Very high spatial resolution (<100 m)	5	7	2	5	
High spatial resolution (100 - 500 m)	2	3	5	3	6
Moderate spatial resolution (1-4 km)	1	5	2	9	2
Coarse spatial resolution (> 4km)	6		6	4	3
High temporal resolution (daily)		1	3	9	6
Moderate temporal resolution (weekly)	1	3	6	6	3
Weekly max and min values	5	6	7	1	
Low temporal resolution (monthly)	6	6	3	1	3
Monthly max and min values	5	7	6	1	
Cloud-gap Filling	2	4	4	2	3
Spatial Domain: Global	3	2	2	3	9
Spatial Domain: Continental	3	2	5	7	1
Spatial Domain: Regional	2	6	2	6	3
Latency: Seasonal updates	1	8	1	7	1
Latency: Annual updates	1	7	2	5	4
Per-pixel uncertainty values		2	6	8	3
Forested areas: Estimates of 'viewable snow'	1	5	7	5	1
Forested areas: Estimates of 'snow on ground'		2	3	10	4

	No importance	Low Importance	Medium importance	High Importance	Essential
Moderate spatial resolution (~5 km)		1	6	6	5
Low spatial resolution (25 km)	6	4		5	3
High temporal resolution (daily)		2	6	4	6
Moderate temporal resolution (weekly)	1	3	6	6	2
Low temporal resolution (monthly)	4	6	3	3	2
Spatial Domain: Global	4	2	3	4	5
Spatial Domain: Continental	1	5	4	7	1
Spatial Domain: Regional	1	4	4	5	4
Latency: Seasonal updates	1	9	3	5	
Latency: Annual updates	2	5	6	3	2
Per-pixel uncertainty values	1	1	4	9	3
Satellite-only SWE retrievals (alpine areas masked)	1	5	6	4	2
Blended satellite SWE retrievals and land surface model estimates in alpine areas	2	3	6	5	2

C. *SNOW_CCI* USER WORKSHOP AGENDA

Time	Topic	Presenter
09:00 – 09:20	Welcome and introductions	Thomas Nagler (ENVEO)+ Marc Olefs (ZAMG)
09:20 – 09:35	ESA CCI programme overview	Anna-Maria Trofaier (ESA)
09:35 – 9:50	*snow_cci* project overview	Thomas Nagler (ENVEO)
9:50 – 10:00	The GCOS perspective on Snow as an Essential Climate Variable	Valentin Aich (GCOS)
10:00 – 10:15	Snow extent and snow water equivalent baseline specifications	Gabriele Schwaizer (ENVEO), Juha Lemmetyinen (FMI)
10:15– 10:35	Regional and global snow cover trends Snow data assimilation at ECMWF Perspectives for the Snow CCI activities	Chris Derksen (CRG, ECCC) Patricia de Rosnay (CRG, ECMWF)
Break		
11:00 – 11:30	Impact of CCI+ snow products on the long-term simulations of large scale hydrological regimes in a variable climate Extending model evaluation around ESM-SnowMIP reference sites Evaluation of CMIP6 simulations	David Gustafsson (CRG, SMHI) Richard Essery (CRG, Univ. Edinburgh) Gerhard Krinner (CRG, IGE/CNRS)
11:30 – 12:10	Permafrost CCI – Requirements for Snow products Cloud or snow? The certainty of one is the uncertainty of the other ECV Towards consistency between long-term snow and soil moisture satellite data sets Exploring potential collaborations between Snow CCI and LST CCI	Christine Kroisleitner (b-geos, permafrost_cci) Rainer Hollmann (DWD, clouds_cci) Wouter Dorigo (TU-Wien, soil moisture_cci) Emma Dodd (Univ. Leicester, land_surface_temperatur_cci)
12:10 – 12:30	Impact of snow cover change on wild life in the frame of LifeWatch services Filling the gaps: merging snow observations and model estimates	Mathilde De Vroey (UCLouvain, LifeWatch) Gabrielle de Lannoy (KU Leuven)
Lunch		
13:30 – 14:15	Potential benefit of *snow_cci* for snow climate products at ZAMG Use of snow products at the Met Office Snow in the mountains: can satellites help for climate assessments? Evaluation of uncertainty in SWE products over North America Application of snow products for climate and regional water research	Marc Olefs (ZAMG) Eleanor Burke (UK MetOffice) Samuel Morin (Univ. Grenoble) Sujay Kumar/Carrie Vuyovich (NASA) Chad Thackeray, Alex Hall (UCLA, USA)
14:15 – 15:00	Discussion on product requirements	Moderated by Chris Derksen
Break		
15:30 – 16:30	Discussion continued and summary	
16:30 – 17:00	Snow CCI: the way forward & closing of WS	Thomas Nagler