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The SISPEC netCDF encoding specification

This document defines the technical specifications required for describing hyperspectral measurements of snow surface compliant to guidelines listed by field spectroscopy and snow research communities. This document is not a reviewed standard and may not be referred to as a recognized standard. It is subject to change without notice. However, this document is a draft in preparation for official reviews by international organizations on this particular technology topic. Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

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i. Abstract

The SISPEC netCDF encoding specification is a summary of conventions that supports efficient exchange of hyperspectral measurements performed on snow surfaces. Compared to the ASCII encoding, this netCDF encoding offers more compact storage and better performance at the cost of additional restrictions on the kinds of features that can be stored.

ii. Keywords

The following are keywords to be used by search engines and document catalogues: snow, ice, hyperspectral measurements, spectral signature, netCDF, CF convention.

iii. Preface

This document provides a method to encode discrete hyperspectral measurement and snow observations as netCDF files. This specification combines two existing OGC specifications and guidelines provided by the International classification of seasonal snow on the ground:

- The Network Common Data Form (netCDF) standard [OGC 10-092r3], which provides the binary encoding of array-oriented scientific data; and
- A subset of the Climate and Forecast (CF) conventions [OGC 11-165r2], which provides standard names and layout for the arrays to encode in a netCDF file.
- The international classification for seasonal snow on the ground (UNESCO, IHP (International Hydrological Programme)–VII, Technical Documents in Hydrology, No 83; IACS (International Association of Cryospheric Sciences) contribution No 1)

iv. Author organizations

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1. Scope

These technical specifications give guidelines for encoding in netCDF files the hyperspectral measurements performed on snow surfaces. The aim of this document is to integrate available standards (such as the ISO 19115 guidelines, the INSPIRE directive, the ACDD and the CF conventions) with an extension specific for snow observations, defined considering guidelines provided by the different involved communities. The proposed scheme includes different metadata components that can be summarized as: General attributes, Field spectroscopy metadata and the Point data body. While the general metadata group the base and acquisition attributes standardized by the ISO and INSPIRE normatives, the field spectroscopy component includes information about the spectral measurements considered in the described dataset. This last group of metadata is composed of information about the experimental setup and the meteoclimatogical conditions of the target site, which were identified considering the different communities interested in field spectral measurements. The data body of the proposed schema is designed as a list of point features, that must be described by the same general and field spectroscopy attributes, which are coupled to spectral measurements, to the description of the snow surface and to ancillary information about the position, time and meteorological conditions of the single measurement. Particular attention was focused on the description of the snow surface in order to align the required information to the International Classification for Seasonal Snow on the Ground (Fierz et al., 2009). This document describes relevant attributes from the Climate and Forecast (CF) conventions in sufficient detail that client applications do not need to deal with the entire scope of CF conventions. Applications only need to understand a restricted subset of CF conventions in order to be able to interpret moving features in netCDF files.

2. Conformance

The conformance with this specification shall be checked using the examples specified in Annex A, we are scheduled to prepare specific tests in the next future.

3. References

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

- INSPIRE: Technical Guidance for the implementation of INSPIRE dataset and service metadata based on ISO/TS 19139:2007, 2017

- ISO: ISO 19115-1:2014: Geographic information – Metadata – Part 1: Fundamentals, 2014
- ISO: ISO 19115-2:2019: Geographic information – Metadata – Part 2: Extensions for acquisition and processing, 2019
- OGC: OGC 10-090r3:OGC Network Common Data Form (netCDF): Core Encoding Standard, 2011
- OGC: OGC 10-092r3:NetCDF Binary Encoding Extension Standard: netCDF Classic and 64-bit Offset Format, 2011
- OGC: OGC 11-165r2:CF-netCDF3 Data Model Extension standard, 2012
- Lawrence Livermore National Laboratory: NetCDF CF Metadata Conventions –http://cfconventions.org/
- ESIP: Attribute Convention for Data Discovery (ACDD) – http://wiki.esipfed.org/index.php/Attribute_Convention_for_Data_Discovery
- IACS: The international classification for seasonal snow on the ground (UNESCO, IHP (International Hydrological Programme)–VII, Technical Documents in Hydrology, No 83; IACS (International Association of Cryospheric Sciences) contribution No 1.

4. Conventions

This section provides details and examples for conventions used in the document.

4.1 Abbreviated terms

The following symbols and abbreviated terms are used in this Best Practice:
SISPEC Snow and Ice Spectral Library
ACDD: Attribute Convention for Data Discovery
CF conventions: Climate and Forecast conventions
CRS: Coordinate Reference System
EPSG: IOGP’s EPSG geodetic dataset
IACS: International Association of Cryospheric Sciences
ISO: International Organization for Standardization
NetCDF: Network Common Data Form
OGC: Open Geospatial Consortium
1D: One Dimensional
2D: Two Dimensional

5. Data model

The data model used by the binary encoding is equivalent to that used by the CSV encoding.

6. Data structure and file format

The binary encoding of arrays and attributes is defined by OGC 10-092r3–NetCDF Binary Encoding Extension Standard: netCDF Classic and 64-bit Offset Format. That netCDF standard defines only a “container” format – it does not define the meaning of attributes stored in the file (the “schema” in XML terminology). Meanings of attributes in a netCDF file are defined by a separate standard, OGC 11-165r2–CF-netCDF3 Data Model Extension. All remaining requirements and recommendations in this document apply to a subset of those CF conventions.

6.1 NetCDF global attributes

Global attributes apply to the netCDF file as a whole. They specify a succinct description of what is in the dataset, the kind of sampling geometry, the geographic bounding box, the vertical extent, the time period, the coordinate reference systems used and many other metadata (see CF convention). Some global attributes are merely a convenience for information that may otherwise be tedious to compute.

6.1.1 Non-redundant global attributes

This sub-section presents some global attributes that do not duplicate information provided by other attributes.

6.1.1.1 Identification of conventions

To identify that the file uses the CF convention, OGC 11-162r2 §7.3.2.1 requires that the Conventions global attribute is set to the “CF-1.7” string value. This Best Practice also uses some attribute convention for data discovery, which is notified by the “ACDD-1.3” string value.

6.1.1.2 Feature type

The CF conventions allow different kinds of sampling geometry such as point, time series, profile, or trajectory. This binary encoding specification focuses on points. This choice constrains the data layout to a series of data points with the same global (Table 1 and 2) and field spectroscopy (Table 3) attributes.

Table 1 - Global attributes

Field name	Description	Example	Source	Obligation
metadata_naming_authority	Person or party responsible for maintenance of the namespace	National Research Council of Italy	ISO19115-1	Optional
metadata_id	Value uniquely identifying an object within a namespace	https://niveos.cnr.it/SISpec/metadata/332b.xml	ISO19115-1	Optional
metadata_scope	Class of information to which the referencing entity applies	dataset	INSPIRE	Mandatory
metadata_creator_individual	INSPIRE requires the metadata point of contact: maybe we should rename this metadata_point_of_contact_name	Roberto Salzano	ISO19115-1	Optional
metadata_creator_institution	INSPIRE requires the metadata point of contact: maybe we should rename this metadata_point_of_contact_institution	National Research Council of Italy	INSPIRE	Mandatory
metadata_creator_email	INSPIRE requires the metadata point of contact: maybe we should rename this metadata_point_of_contact_email	info@niveos.cnr.it	INSPIRE	Mandatory
date_metadata_modified	The date on which the metadata was last modified. The ISO 8601:2004 extended date format is recommended, as described in the Attributes Content Guidance section.	2021-05-03	INSPIRE	Mandatory
metadata_link	A URL that gives the location of more complete metadata. A persistent URL is recommended for this attribute.	https://niveos.cnr.it/SISpec/metadata/332b.xml	ACDD	Optional
geospatial_bounds	Describes the data's 2D or 3D geospatial extent in OGC's Well-Known Text (WKT) Geometry format (reference the OGC Simple Feature Access (SFA) specification). The meaning and order of values for each point's coordinates depends on the coordinate reference system (CRS). The ACDD default is 2D geometry in the EPSG:4326 coordinate reference system. The default may be overridden with geospatial_bounds_crs and geospatial_bounds_vertical_crs (see those attributes). EPSG:4326	POINT (79.00, 164.00)	ACDD	Optional

	coordinate values are latitude (decimal degrees_north) and longitude (decimal degrees_east), in that order. Longitude values in the default case are limited to the [-180, 180) range. Example: 'POLYGON ((40.26 -111.29, 41.26 -111.29, 41.26 -110.29, 40.26 -110.29, 40.26 -111.29))'.			
geospatial_bounds_crs	The coordinate reference system (CRS) of the point coordinates in the geospatial_bounds attribute. This CRS may be 2-dimensional or 3-dimensional, but together with geospatial_bounds_vertical_crs, if that attribute is supplied, must match the dimensionality, order, and meaning of point coordinate values in the geospatial_bounds attribute. If geospatial_bounds_vertical_crs is also present then this attribute must only specify a 2D CRS. EPSG CRSs are strongly recommended. If this attribute is not specified, the CRS is assumed to be EPSG:4326. Examples: 'EPSG:4979' (the 3D WGS84 CRS), 'EPSG:4047'.	http://www.opengis.net/def/crs/EPSG/8.5/4979	INSPIRE	Mandatory
Title	A short phrase or sentence describing the dataset. In many discovery systems, the title will be displayed in the results list from a search, and therefore should be human readable and reasonable to display in a list of such names. This attribute is also recommended by the NetCDF Users Guide and the CF conventions.	Spectral reflectance obtained in-situ at Mt Abbot (Antarctica) in November 1998	INSPIRE	Mandatory
date_created	The date on which this version of the data was created. (Modification of values implies a new version, hence this would be assigned the date of the most recent values modification.) Metadata changes are not considered when assigning the date_created. The ISO 8601:2004 extended date format is recommended, as described in the Attribute Content Guidance section.	2021-05-03	INSPIRE	Mandatory

naming_authority	The organization that provides the initial id (see above) for the dataset. The naming authority should be uniquely specified by this attribute. We recommend using reverse-DNS naming for the naming authority; URIs are also acceptable. Example: 'edu.ucar.unidata'.	International DOI Foundation	ISO19115-1	Optional
Id	An identifier for the data set, provided by and unique within its naming authority. The combination of the "naming authority" and the "id" should be globally unique, but the id can be globally unique by itself also. IDs can be URLs, URNs, DOIs, meaningful text strings, a local key, or any other unique string of characters. The id should not include white space characters.	https://doi.org/10.1109/5.77107343	INSPIRE	Mandatory
summary	A paragraph describing the dataset, analogous to an abstract for a paper.	SISpec is a database containing spectroradiometric, snow and ancillary (environmental and meteorological) data acquired in polar environments. The project is the result of the co-operation of different expertise, and its main objective is to contribute to the knowledge of the interaction between microphysics characteristic of the snow cover and its reflection properties of the solar incident radiation and to study glacial environment and	INSPIRE	Mandatory

		particularly to monitor the snow/ice covers by multispectral remote sensing data. Field surveys were performed in Antarctica, in the region where the Italian research station of Terra Nova Bay is located, the climatic characteristics and the low human impact allow to study snow/ice surfaces without impurities and with different characteristics with respect to those of the Arctic and the Alpine regions, where seasonal melting of the snow cover occur		
creator_name	The name of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	National Research Council of Italy	ISO19115-1	Mandatory
contributor_institution	The name of any individuals, projects, or institutions that contributed to the creation of this data. May be presented as free text, or in a structured format compatible with conversion to ncML (e.g., insensitive to changes in whitespace, including end-of-line characters).	Rosamaria Salvatori	ISO19115-1	Conditional
contributor_role	The role of any individuals, projects, or institutions that contributed to the creation of this data. May be presented as free text, or in a structured format compatible with conversion to ncML (e.g., insensitive to changes in whitespace, including end-of-line characters). Multiple roles	principalInvestigator	ISO19115-1	Conditional

	should be presented in the same order and number as the names in contributor_names.			
contributor_name	The name of any individuals, projects, or institutions that contributed to the creation of this data. May be presented as free text, or in a structured format compatible with conversion to ncML (e.g., insensitive to changes in whitespace, including end-of-line characters).	Rosamaria Salvatori	ISO19115-1	Optional
contributor_email	The email address of the person that contributed to the preparation of this dataset.	info@niveos.cnr.it	ISO19115-1	Optional
creator_url	The URL of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	www.niveos.cnr.it	ACDD	Optional
creator_individual	The name of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	Roberto Salzano	ISO19115-1	Optional
creator_type	Specifies the type of creator with one of the following: 'person', 'group', 'institution', or 'position'. If this attribute is not specified, the creator is assumed to be a person.	institution	ISO19115-1	Mandatory
Institution	The name of the institution principally responsible for originating this data. This attribute is recommended by the CF convention.	National Research Council of Italy	INSPIRE	Mandatory
creator_institution	The institution of the creator; should uniquely identify the creator's institution. This attribute's value should be specified even if it matches the value of publisher_institution, or if creator_type is institution.	National Research Council of Italy	ACDD	Optional
creator_email	The email address of the person (or other creator type specified by the creator_type attribute) principally responsible for creating this data.	info@niveos.cnr.it	INSPIRE	Mandatory
publisher_name	The name of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data	National Research Council of Italy	ACDD	Optional

	file or product to users, with its current metadata and format.			
publisher_institution	The institution that presented the data file or equivalent product to users; should uniquely identify the institution. If publisher_type is institution, this should have the same value as publisher_name.	National Research Council of Italy	ACDD	Optional
publisher_url	The URL of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	www.niveos.cnr.it	ACDD	Optional
publisher_email	The email address of the person (or other entity specified by the publisher_type attribute) responsible for publishing the data file or product to users, with its current metadata and format.	info@niveos.cnr.it	ACDD	Optional
publisher_type	Specifies type of publisher with one of the following: 'person', 'group', 'institution', or 'position'. If this attribute is not specified, the publisher is assumed to be a person.	institution	ACDD	Optional
featureType	Subset of feature types from cited feature catalogue occurring in dataset	point	INSPIRE	Mandatory
dataFormatType	Data formats that support the creation, access, and sharing of array-oriented scientific data.	netCDF	INSPIRE	Mandatory
Conventions	A comma-separated list of the conventions that are followed by the dataset. For files that follow this version of ACDD, include the string 'ACDD-1.3'. (This attribute is described in the NetCDF Users Guide.)	CF-1.7, ACDD-1.3, SISPEC-1.0	CF	Mandatory
geospatial_lat_resolution	Information about the targeted spacing of points in latitude. Recommend describing resolution as a number value followed by the units. Examples: '100 meters', '0.1 degree'	3 meters	INSPIRE	Conditional

geospatial_lon_resolution	Information about the targeted spacing of points in longitude. Recommend describing resolution as a number value followed by units. Examples: '100 meters', '0.1 degree'	3 meters	INSPIRE	Mandatory
geospatial_vertical_resolution	Information about the targeted vertical spacing of points.	10 meters	ISO19115-1	Optional
geospatial_lat_units	Units for the latitude axis described in "geospatial_lat_min" and "geospatial_lat_max" attributes. These are presumed to be "degree_north"; other options from udunits may be specified instead.	degree_north	ISO19115-1	Optional
geospatial_lon_units	Units for the longitude axis described in "geospatial_lon_min" and "geospatial_lon_max" attributes. These are presumed to be "degree_east"; other options from udunits may be specified instead.	degree_east	ISO19115-1	Optional
topic_category	The topic category is a high-level classification scheme to assist in the grouping and topic-based search of available spatial data resources	environment	INSPIRE	Mandatory
time_coverage_start	Describes the time of the first data point in the data set. Use the ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.	1998-11-15T12:00:00+00:00	INSPIRE	Mandatory
time_coverage_end	Describes the time of the last data point in the data set. Use ISO 8601:2004 date format, preferably the extended format as recommended in the Attribute Content Guidance section.	1998-11-15T12:00:00+00:00	INSPIRE	Mandatory
time_coverage_resolution	Describes the targeted time period between each value in the data set. Use ISO 8601:2004 duration format, preferably the extended format as recommended in the Attribute Content Guidance section.	P1S	INSPIRE	Mandatory
time_coverage_duration	Describes the duration of the data set. Use ISO 8601:2004 duration format, preferably the extended format as recommended in the	P	ACDD	Optional

	Attribute Content Guidance section.			
geospatial_lon_min	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_min specifies the westernmost longitude covered by the dataset. See also geospatial_lon_max.	163.00	INSPIRE	Mandatory
geospatial_lon_max	Describes a simple longitude limit; may be part of a 2- or 3-dimensional bounding region. geospatial_lon_max specifies the easternmost longitude covered by the dataset. Cases where geospatial_lon_min is greater than geospatial_lon_max indicate the bounding box extends from geospatial_lon_max, through the longitude range discontinuity meridian (either the antimeridian for -180:180 values, or Prime Meridian for 0:360 values), to geospatial_lon_min; for example, geospatial_lon_min=170 and geospatial_lon_max=-175 incorporates 15 degrees of longitude (ranges 170 to 180 and -180 to -175).	164.00	INSPIRE	Mandatory
geospatial_lat_min	Describes a simple lower latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_min specifies the southernmost latitude covered by the dataset.	-75.00	INSPIRE	Mandatory
geospatial_lat_max	Describes a simple upper latitude limit; may be part of a 2- or 3-dimensional bounding region. Geospatial_lat_max specifies the northernmost latitude covered by the dataset.	-74.00	INSPIRE	Mandatory
geospatial_vertical_min	Describes the numerically smaller vertical limit; may be part of a 2- or 3-dimensional bounding region. See geospatial_vertical_positive and geospatial_vertical_units.	640.00	ISO19115-1	Optional
geospatial_vertical_max	Describes the numerically larger vertical limit; may be part of a 2- or 3-dimensional bounding region. See geospatial_vertical_positive	660.00	ISO19115-1	Optional

	and geospatial_vertical_units.			
geospatial_vertical_units	Units for the vertical axis described in "geospatial_vertical_min" and "geospatial_vertical_max" attributes. The default is EPSG:4979 (height above the ellipsoid, in meters); other vertical coordinate reference systems may be specified. Note that the common oceanographic practice of using pressure for a vertical coordinate, while not strictly a depth, can be specified using the unit bar. Examples: 'EPSG:5829' (instantaneous height above sea level), 'EPSG:5831' (instantaneous depth below sea level).	meters	ISO19115-1	Optional
geospatial_vertical_positive	One of 'up' or 'down'. If up, vertical values are interpreted as 'altitude', with negative values corresponding to below the reference datum (e.g., under water). If down, vertical values are interpreted as 'depth', positive values correspond to below the reference datum. Note that if geospatial_vertical_positive is down ('depth' orientation), the geospatial_vertical_min attribute specifies the data's vertical location furthest from the earth's center, and the geospatial_vertical_max attribute specifies the location closest to the earth's center.	up	ACDD	Optional
geospatial_bounds_vertical_crs	The vertical coordinate reference system (CRS) for the Z axis of the point coordinates in the geospatial_bounds attribute. This attribute cannot be used if the CRS in geospatial_bounds_crs is 3-dimensional; to use this attribute, geospatial_bounds_crs must exist and specify a 2D CRS. EPSG CRSs are strongly recommended. There is no default for this attribute when not specified. Examples: 'EPSG:5829' (instantaneous height above sea level), "EPSG:5831" (instantaneous	EPSG:4979	ISO19115-1	Optional

	depth below sea level), or 'EPSG:5703' (NAVD88 height).			
maintenance_and_update_frequency	Frequency with which changes and additions are made to the resource after the initial resource is completed	Complete	ISO19115-1	Optional
keywords	A comma-separated list of key words and/or phrases. Keywords may be common words or phrases, terms from a controlled vocabulary (GCMD is often used), or URIs for terms from a controlled vocabulary (see also "keywords_vocabulary" attribute).	GEMET:snow, GEMET:solar radiation, INSPIRE:land cover, SNOWTERM:spectral reflectance, SNOWTERM:grain shape	INSPIRE	Mandatory
keywords_vocabulary	If you are using a controlled vocabulary for the words/phrases in your "keywords" attribute, this is the unique name or identifier of the vocabulary from which keywords are taken. If more than one keyword vocabulary is used, each may be presented with a prefix and a following comma, so that keywords may optionally be prefixed with the controlled vocabulary key. Example: 'GCMD:GCMD Keywords, CF:NetCDF COARDS Climate and Forecast Standard Names'.	GEMET:GEneral Multilingual Environmental Thesaurus,INSPIRE:GEMET - INSPIRE themes; version 1.0, SNOWTERM:Thesaurus on Snow and Ice	INSPIRE	Mandatory
keywords_vocabulary_publication_date	Effective publication date of each keyboard originating controlled vocabulary.	GEMET:2021-01-21,INSPIRE:2008-06-01, SNOWTERM:2020-06-07	INSPIRE	Mandatory
standard_name_vocabulary	The name and version of the controlled vocabulary from which variable standard names are taken. (Values for any standard_name attribute must come from the CF Standard Names vocabulary for the data file or product to comply with CF.) Example: 'CF Standard Name Table v27'.	CF Standard Name Table v27	ACDD	Optional
limitations_on_public_access	Access constraints applied to assure the protection of privacy or intellectual property, and any special restrictions or limitations on obtaining the resource.	http://inspire.ec.europa.eu/metadata-codelist/LimitationsOnPublicAccess/noLimitations	INSPIRE	Mandatory

license	Provide the URL to a standard or specific license, enter "Freely Distributed" or "None", or describe any restrictions to data access and distribution in free text.	otherRestrictions	INSPIRE	Mandatory
language	This is the language in which the data elements are expressed.	eng	INSPIRE	Mandatory
language_name	The name of the language(s) of the described resource in the language of the metadata should be used as the text content of the gmd:LanguageCode element.	English	INSPIRE	Mandatory
character_encoding	The character encoding describes the way the characters of the textual information are encoded in the described data set.	utf8	ISO19115-1	Mandatory
distribution_link	Link where the dataset is distributed	https://niveos.cnr.it/SISpec/data/332b.nc	ISO19115-1	Optional
distribution_protocol	Specifies how Web Coverage Service (WCS) clients and servers can communicate over the Internet using HTTP GET with key/value pair (KVP) encoding	HTTP	ISO19115-1	Optional
distribution_name	Name of the distribution	332b	ISO19115-1	Optional
distribution_description	Description of the distribution	Spectral reflectance NetCDF-SISPEC encoded data	ISO19115-1	Optional
distribution_function	What function the distribution provides	download	ISO19115-1	Optional
date_issued	Date identifies when the resource was issued (In ISO code list CI_DateTypeCode "publication")	2021-05-03	ISO19115-1	Optional
date_modified	The date on which the data was last modified. Note that this applies just to the data, not the metadata. The ISO 8601:2004 extended date format is recommended, as described in the Attributes Content Guidance section.	2021-05-03	ACDD	Optional
product_version	Version of the product	1.0	ISO19115-1	Optional
processing_level	A textual description of the processing (or quality control) level of the data.	data are averaged reflectance values	ACDD	Optional
conformance_scope	Conformance with the Implementing Rule for	dataset	ISO19115-1	Optional

	interoperability of spatial data sets and services			
conformance_specification_link	Link to data quality conformance specification	http://inspire.ec.europa.eu/id/citation/ir/reg-1089-2010	INSPIRE	Mandatory
conformance_specification_title	Regulation on conformance rules title	COMMISSION REGULATION (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services	INSPIRE	Mandatory
conformance_specification_publication_date	Publication date of regulation on conformance rules	2010-12-08	INSPIRE	Mandatory
conformance_specification_explanation	Declaration of conformity	This data set is conformant with the INSPIRE Implementing Rules for the interoperability of spatial data sets and services	INSPIRE	Mandatory
conformance_specification_pass	Indication of the conformance result where 0 = fail and 1 = pass	true	INSPIRE	Mandatory
history	Provides an audit trail for modifications to the original data. This attribute is also in the NetCDF Users Guide: 'This is a character array with a line for each invocation of a program that has modified the dataset. Well-behaved generic netCDF applications should append a line containing: date, time of day, user name, program name and command arguments.' To include a more complete description you can append a reference to an ISO Lineage entity; see NOAA EDM ISO Lineage guidance.	averaged measurements	INSPIRE	Mandatory

6.1.2 Convenience global attributes for data discovery

This sub-section presents global attributes that duplicate information available in other attributes, but in a more convenient manner. For example, the geographic bounding box attributes duplicate information provided by the geospatial bounds attributes, but may avoid the need to apply an inverse map projection. The geospatial bounds attribute themselves to duplicate attributes associated with coordinate variables. But the attributes described in this subsection make it easier to discover the data. Indeed, all attributes in this subsection come from the Attribute Convention for Data Discovery (ACDD). By contrast, most attributes in other sections come from the Climate and Forecast (CF) convention.

6.1.2.1 Geographic bounding box

The geographic bounding box is given in longitude and latitude regardless of the Coordinate Reference System (CRS) used by the points. Coordinate precision may be of only two decimal places of a degree.

6.1.2.2 Temporal bounds

The times of the first and last data points in the file are specified as a range of dates. Dates are formatted as specified by ISO 8601:2004, preferably the extended date-time format (YYYY-MM-DDThh:mm:ss optionally followed by the time zone).

6.1.2.3 Spatial Reference System

The Coordinate Reference System (CRS) of the geospatial and vertical bounds is specified by an authority code, preferably from the EPSG geodetic dataset. While ACDD uses simple strings of the form “EPSG:4979”, this document recommends URNs of the form “urn:ogc:def:crs:EPSG::4979” instead. However, software should be prepared to read both forms. Note that axis order is the same with both forms, namely (latitude, longitude, ellipsoidal height) in EPSG:4979 case.

Table 2 - Acquisition attributes (from ISO 19115-2)

Field name	Description	Example	Obligation
Instrument	Name of the contributing instrument(s) or sensor(s) used to create this data set or product. Indicate controlled vocabulary used in instrument_vocabulary.	Fieldspec FSP350-2500P (Analytical Spectral Device inc.)	Mandatory
instrument_vocabulary	Controlled vocabulary for the names used in the "instrument" attribute.	https://gcmd.earthdata.nasa.gov/KeywordViewer	Optional
instrument_link	Link to the instrument producer	https://www.malvernpanalytical.com/en/products/product-range/asd-range/fieldspec-range	Optional
instrument_id	Unique identification of the	serial number 634	Optional

	instrument		
instrument_type	Name of the type of instrument	Spectroradiometer	Optional
platform	Name of the platform(s) that supported the sensor data used to create this data set or product. Platforms can be of any type, including satellite, ship, station, aircraft or other. Indicate controlled vocabulary used in platform_vocabulary.	tripod	Mandatory
platform_vocabulary	Controlled vocabulary for the names used in the "platform" attribute.	https://gcmd.earthdata.nasa.gov/KeywordViewer	Optional
operation_name	Name of the activity which provided the data	Field campaign	Optional
project	The name of the project(s) principally responsible for originating this data. Multiple projects can be separated by commas, as described under Attribute Content Guidelines. Examples: 'PATMOS-X', 'Extended Continental Shelf Project'.	Field campaign	Optional
program	The overarching program(s) of which the dataset is a part. A program consists of a set (or portfolio) of related and possibly interdependent projects that meet an overarching objective. Examples: 'GHRSST', 'NOAA CDR', 'NASA EOS', 'JPSS', 'GOES-R'.	Field campaign	Optional
operation_description	General information about an identifiable activity which provided the data	Field survey close to Terra Nova Bay, Italian Antarctic Station	Optional
operation_status	Status of the data acquisition	completed	Optional
operation_type	Collection technique for the operation	real	Optional
acquisition_objective	Object or area of interest to be sensed	https://data.aad.gov.au/aadc/gaz/scar/display_name.cfm?gaz_id=114527	Optional
acquisition_objective_title	Name of the object or area of interest to be sensed	Terra Nova Bay	Optional
acquisition_meteorological_conditions	Meteorological conditions in the area, in particular clouds, snow and wind	calm wind condition	Optional
acquisition_objective_type	Type of activity of acquisition	survey	Optional

Table 3 - Field spectroscopy attributes

Field name	Description	Example	Obligation
graphic_file_type	tag vector, comma separated, describing the purpose of the selected files (for example: spectrum, environment, target, sampling, sky)	spectrum, environment, target, sampling, sky	Optional
graphic_file_name	name vector, comma separated, of the selected files	332b dataset	Optional
graphic_file_description	vector of indications, comma separated, on the content of the selected files	the file shows the spectral reflectance between 350 and 2500 nm, Gently waved surface on the higher part of the relief, Decomposing and fragmented precipitation particles, view of the experimental setup, sky condition during the field measurement	Optional
graphic_file_link	link vector, comma separated, where the files can be downloaded	https://niveos.cnr.it/SISpec/spectrum/332b.jpg, https://niveos.cnr.it/SISpec/environ/332b.jpg, https://niveos.cnr.it/SISpec/target/332b.jpg, https://niveos.cnr.it/SISpec/sampling/332b.jpg, https://niveos.cnr.it/SISpec/sky/332b.jpg	Optional
illumination_source	Type of the illumination source	Sun	Mandatory
solar_azimuth	The sun azimuth angle at the moment of measure acquisitions. The solar azimuth angle is the azimuth angle of the Sun's position in degrees_east.	35	Optional
solar_elevation	The sun elevation angle at the moment of measure acquisitions. The elevation angle is the angle between the Sun and the horizontal plane in degrees.	180	Optional
illumination_elevation	The elevation angle from the horizontal plane at the moment of measure acquisitions. The elevation angle is the angle between the illumination source and the horizontal plane in	0.5	Optional

	degrees.		
illumination_azimuth	The azimuth angle at the moment of measure acquisitions.The azimuth angle of the illumination source is the azimuth angle of the source position in degrees_east.	45	Optional
illumination_distance	Distance in centimeters between the illumination source and target (for artificial illumination)	90	Optional
instrument_foreoptics	designator given to the optics used	fiber	Mandatory
instrument_field_of_view	field of view of the instrument used for the measurements in degrees	25	Mandatory
instrument_calibration_reference	name of the surface material used as white reference	Spectralon	Mandatory
instrument_distance	distance between the instrument and target surface in meters	0.5	Mandatory
instrument_zenith_angle	instrument zenith angle measured from nadir in degrees	0	Mandatory
instrument_goniometer	name of the sensor or goniometric facility used to measure angles	FIGIFIGO	Optional
goniometer_azimuth_sensor	name of the sensors that measure the azimuth angle on the goniometer apparatus	LSM303	Optional
instrument_internal_scans	Number of Spectra recorded internally and averaged over by the Instrument	100	Optional
instrument_averaged_readings	number of Spectra averaged for each target	10	Optional
instrument_azimuth_angle	Sensor azimuth angle relative to the illumination angle in degrees_east	180	Mandatory
instrument_calibration_date	date of the last instrument calibration	1998-01-10	Optional
instrument_calibration_data	spectrum derived from calibration procedures	https://niveos.cnr.it/SISpec/data/calibration/cal_19980110.txt	Optional
instrument_calibration_radiance	radiance spectra, as provided by the instrument (usually acquired with a reference panel)	https://niveos.cnr.it/SISpec/data/calibration/rad_19980110.txt	Optional
instrument_calibration_irradiance	irradiance spectrum, as provided by instrument (usually acquired with a cosine receptor)	https://niveos.cnr.it/SISpec/data/calibration/irr_19980110.txt	Optional
instrument_dark_current_correction	information on last dark current measurement	yes	Optional

instrument_gain_array	instrument(fieldspec) specif gain	1, 52, 27	Optional
instrument_offset_array	instrument(fieldspec) specif offset	0, 2073, 2086	Optional
instrument_scan_duration	time of spectrum acquisition in milliseconds	100	Optional
instrument_signal_to_noise	computation of the signal to noice value	400	Optional
instrument_spectral_resolution	defintion of the spectral resolutio of the instrument in nanometers	2	Mandatory
instrument_fwhm	value of the Full-Width Half-Maximum, of the instrument	1.2	Optional
instrument_time_white_reference	time (second) since last white reference measurement	600	Optional
instrument_time_dark_current	time (second) since last dark current measurement	600	Optional
instrument_software_name	name of the operational software used for acquisition	FR	Optional
instrument_software_version	version of the software used for acquisitin	1.0	Optional
instrument_raw_data_format	indication of the format of the row data as produced by the instrument	raw data format asd	Optional
surface_description	description of the surface where the target was selected	smooth surface with rounded grains of 0.4 mm average radius	Optional
instrument_spectral_bandwith	bandwidth of the instrument in nanometers	2	Optional
instrument_wavelength_range	instrument acquisition wavelenght range (lowest:highest) in nanometers	350, 2500	Mandatory
processing_description	description of processing algorithm applied to spectrum	average	Optional
processing_rationale	description of processing algorithm applied to spectrum	average between different measurements	Optional

6.2 Points (data body)

The CF convention proposes four different ways to organize the feature coordinates and attributes in a netCDF file. This specification chooses the “Point feature” representation (section H.1 CF convention), which is the simplest strategy and where the collection has identical coordinates along the element axis.
The file is organized by first defining netCDF dimensions (not to be confused with spatio-temporal dimensions), then variables.The dimension and variable names shall comply with the restrictions documented in OGC 11-162r2 §7.3.2.2.

6.2.1 NetCDF dimensions

The Point feature representation needs three netCDF dimensions, described in Table 4.

6.2.1.1 Feature instance dimension

The netCDF file shall declare a dimension for information about each feature as a whole (information that does not depend on the time). The length of this dimension is the maximal number of features that can be stored in the file. It is acceptable to declare a length larger than needed in order to reserve room for future feature additions, provided that values in the count variable (§7.2.2.2) are set to zero for all missing features.

6.2.1.2 Sample dimension

The netCDF file shall declare a dimension for the actual data (time, geospatial coordinates and feature attributes). This dimension could have a fixed length, but it is more convenient to declare this dimension length as unlimited if new data needs to be appended. Note that a netCDF file can have only one dimension of unlimited length.

6.2.1.3 Wavelength dimension

The netCDF file shall declare a dimension for the wavelength range. This range is specific for the considered experimental setup, depending on the used instrument.

7.2.1.4 Snow grain types dimension

The netCDF file shall declare a dimension for the number of snow grain types identified in each feature following the procedure described in the IACS document.

Table 4 - Dimensions

Standard name	Long name	Attribute description	Coverage content type	valid_max	valid_min	units	Dimension name
number_of_observations	Number of observation	A variable with the standard name of number_of_observations contain the number of discrete observations or measurements from which the values of another data variable have been derived. The linkage between the data variable and the variable with a standard_name of number_of_observations is achieved using the ancillary_variables attribute.	auxiliaryInformation	unlimited	1	1	obs
radiation_wavelength	Radiation wavelength	The radiation wavelength can refer to any electromagnetic wave, such as light, heat radiation and radio waves.	physicalMeasurement	2500	350	m	wavelength
number_of_snow_grain_shapes	number of identified snow grain shape	snow can be considered as an aggregate of single particles for recording both grain shape and grain size .In this context, ‘particle’ and ‘grain’ are used interchangeably. While the former may consist of several single crystals, the latter, strictly speaking, would stand for one single crystal of ice only. Grain shape is most easily determined in the field by using a crystal card and a magnifying glass (8x magnification at least)	thematicClassification	3	1		shape

6.2.2 NetCDF variables

In the point feature representation, the netCDF file shall contain the following variables (Table 5): • One feature identification variable; • One wavelength variable; • One grain shape type counting variable; • four auxiliary coordinate variables (not to be confused with “simple” coordinate variables): examples: lat, lon, altitude (ellipsoidal height) and time; and • an arbitrary number of variables for feature attributes (not to be confused with global attributes or variable attributes): examples: snow conditions, weather conditions.

6.2.2.1 Auxiliary coordinate variables

Points coordinates are specified in one variable for each spatio temporal dimension. Those “auxiliary coordinate variables” are not subject to the usual restrictions of netCDF “coordinate variables”. In particular: • The variable name does not match the dimension name; • The values do not need to be ordered monotonically; • The variable does not have axis attribute; and • The variable may have missing values represented by filling values.

6.2.2.2 Physical Measurements

The Physical measurements are listed in Table 5 and in particular: • The variable name does not match the dimension name; • The values do not need to be ordered monotonically; • The variable does not have axis attribute; and • The variable may have missing values represented by filling values.

6.2.2.3 Thematic Classifications

The Thematic classifications are listed in Table 5 and in particular: • The variable name does not match the dimension name; • The values do not need to be ordered monotonically; • The variable does not have axis attribute; • The variable may have missing values represented by filling values; The variable is coupled to a flag meaning value where the flag value identifies the selected value..

Table 5 - Variables

Standard name	Long name	Attribute description	Coverage content type	valid_max	valid_min	units
surface_bidirectional_reflectance	Surface bidirectional reflectance	The surface called "surface" means the lower boundary of the atmosphere. "Bidirectional_reflectance" depends on the angles of the incident and measures radiation. Reflectance is the ratio of the energy of the incident radiation. A coordinate variable of radiation_wavelength or radiation_frequency can be used to specify the wavelength or frequency, respectively, of the radiation.	physicalMeasurement	1	0	1
snow_grain_size	Snow grain size	The size of a grain or particle is its greatest extension measured in millimetres.A simple method suitable for field measurements is to place a sample of the grains on a plate that has a millimetre grid (crystal card). Both average size and average maximum size are then estimated by comparing the size of the grains with the spacing of the grid lines on the plate.	physicalMeasurement	0.1	5	m
snow_grain_fraction	Percentage of each snow grain shape	The estimate amount of snow grain with specific shape and size	physicalMeasurement	0	100	percent
snow_shape_main_type	The main class of the snow grain shape	The main snow grain shape class describes the morphological characteristics of the snow gain.	thematicClassification	9	1	1:9
snow_shape_sub_type	The sub class of the identified main snow grain shape class	The snow grain sub-classes decribe a formation process oriented on characterising the grain shape	thematicClassification	37	1	1:37

snow_hardness_quality_flag	Snow hardness	Hardness is the resistance to penetration of an object into snow. Hardness measurements produce a relative index value that depends on both the operator and the instrument; therefore, the device has to be specified.	thematicClassification	6	1	
temperature_in_surface_snow	Temperature in surface snow	"Temperature in surface snow" is the bulk temperature of the snow, not the surface (skin) temperature. Surface snow refers to the snow on the solid ground or on surface ice cover, but excludes, for example, falling snowflakes and snow on plants.	physicalMeasurement	10	-20	degree_Celsius
wetness_quality_flag_of_surface_snow	Wetness index of surface snow	Measurements of liquid water content or wetness are expressed as either a volume or mass fraction. Both can be reported as a percent, which usually requires a separate measurement of density. A general classification of liquid water content in terms of volume fraction is given inTable 1.5 of Fierz et al 2009.	thematicClassification	5	1	
density_of_surface_snow	Surface snow density	Snow density is the density of the snow cover. Surface snow refers to the snow on the solid ground or on surface ice cover, but excludes, for example, falling snowflakes and snow on plants. The density of a substance is its mass per unit volume.	physicalMeasurement	500	30	kg.m-3
snow_surface_roughness_quality_flag	Snow surface roughness code	the general appearance of the surface snow.These surface features are due to the following main processes: deposition, redistribution and erosion by wind, melting and refreezing, sublimation and evaporation, and rain.	thematicClassification	5	1	
thickness_of_snow_layer	Snow layer thickness	The snow layer thickness (measured in centimetres or fractions thereof) is an essential parameter when characterising the current state of a snowpack. Layer thickness is usually measured vertically. If the measurement is taken perpendicular, i.e., slope normal, layer thickness should be denoted by Lp.	physicalMeasurement	1000	1	m

snow_surface_roughness_lateral_extent	Snow surface lateral extent of roughness	The average lateral extent of any of the roughness elements, measured in cm	physicalMeasurement	100	1	m
snow_surface_roughness_vertical_extent	Snow surface vertical extent of roughness	The average vertical extent of any of the roughness elements, measured in cm	physicalMeasurement	500	0	m
latitude	Latitude	Latitude is positive northward; its units of degree_north (or equivalent) indicate this explicitly. In a latitude-longitude system defined with respect to a rotated North Pole, the standard name of grid_latitude should be used instead of latitude. Grid latitude is positive in the grid-northward direction, but its units should be plain degree.	Coordinate	90	-90	degree_north
longitude	Longitude	Longitude is positive eastward; its units of degree_east (or equivalent) indicate this explicitly. In a latitude-longitude system defined with respect to a rotated North Pole, the standard name of grid_longitude should be used instead of longitude. Grid longitude is positive in the grid-eastward direction, but its units should be plain degree.	Coordinate	360	0	degree_east
altitude	Altitude	Altitude is the (geometric) height above the geoid, which is the reference geopotential surface. The geoid is similar to mean sea level.	Coordinate	8000	0	m
time	Time	time of the observation	Coordinate	1998-12-31	1998-01-01	s since 1990-01-01 00:00:00 UTC

wind_speed	Wind speed	Speed is the magnitude of velocity. Wind is defined as a two-dimensional (horizontal) air velocity vector, with no vertical component. (Vertical motion in the atmosphere has the standard name upward_air_velocity.) The wind speed is the magnitude of the wind velocity.	physicalMeasurement	30	0	m.s-1
cloud_area_fraction	Cloud cover	"X_area_fraction" means a fraction of the horizontal area occupied by X. "X_area" means the horizontal area occupied by X within the grid cell. Cloud area fraction is also called "cloud amount" and "cloud cover". The cloud area fraction is for the whole atmosphere column, as seen from the surface or the top of the atmosphere. The cloud area fraction in a layer of the atmosphere has the standard name cloud_area_fraction_in_atmosphere_layer.	thematicClassification	100	0	percent
air_temperature	Air temperature	Air temperature is the bulk temperature of the air, not the surface (skin) temperature.	physicalMeasurement	50	-50	degree_Celsius

Appendix A: NCDUMP of example

netcdf C:/Users/rober/ownCloud/Metadata/SISPEC_example_1.1.nc {
 dimensions:
 wavelength = 2151;
 shape = 3;
 obs = UNLIMITED; // (1 currently)
 variables:
 double wavelength(wavelength=2151);
 :standard_name = "radiation_wavelength";
 :long_name = "Radiation wavelength";
 :attribute_description = "The radiation wavelength can refer to any electromagnetic wave, such as light, heat radiation and radio waves.";
 :coverage_content_type = "physicalMeasurement";
 :valid_max = 2500.0; // double
 :valid_min = 350.0; // double
 :units = "m";
 :scale_factor = 1.0E-9; // double
 :_FillValue = 1.0E32; // double
 int shape(shape=3);
 :standard_name = "number_of_snow_grain_shapes";
 :long_name = "number of identified snow grain shape";
 :attribute_description = "snow can be considered as an aggregate of single particles for recording both grain shape and grain size .In this context, ‘particle’ and ‘grain’ are used interchangeably. While the former may consist of several single crystals, the latter, strictly speaking, would stand for one single crystal of ice only. Grain shape is most easily determined in the field by using a crystal card and a magnifying glass (8x magnification at least)";
 :coverage_content_type = "thematicClassification";
 :valid_max = 3; // int
 :valid_min = 1; // int
 :units = "1";
 :_FillValue = 999; // int

 int obs(obs=1);
 :standard_name = "number_of_observations";
 :long_name = "Number of observation";
 :attribute_description = "A variable with the standard name of number_of_observations contains the number of discrete observations or measurements from which the values of another data variable have been derived. The linkage between the data variable and the variable with a standard_name of number_of_observations is achieved using the ancillary_variables attribute.";
 :coverage_content_type = "auxiliaryInformation";
 :units = "1";
 :_FillValue = 999; // int
 :_ChunkSizes = 1024U; // uint

 float reflectance(obs=1, wavelength=2151);
 :graphic_file_type = "spectrum, environment, target, sampling, sky";
 :graphic_file_name = "spectrum of the 332b field measurement, landscape view around the 332b site, surface condition close to the 332b site, setup at the 332b site, sky condition during the 332b measurements";

:graphic_file_description = "the file shows the spectral reflectance between 350 and 2500 nm, Gently waved surface on the higher part of the plateau, Decomposing and fragmented precipitation particles (DFdc, 2.0 mm, 60% and DFbk, 1.0 mm, 20%) and precipitation particles (PPsd, 3.0-2.0 mm, 20%), view of the experimental setup, sky condition during the field measurement";

:graphic_file_link = "https://niveos.cnr.it/SISpec/spectrum/332b.jpg, https://niveos.cnr.it/SISpec/environment/332b.jpg, https://niveos.cnr.it/SISpec/target/332b.jpg, https://niveos.cnr.it/SISpec/sampling/332b.jpg, https://niveos.cnr.it/SISpec/sky/332b.jpg";

:illumination_source = "sun";

:solar_azimuth = "35";

:solar_elevation = "180";

:illumination_elevation = "0.5";

:illumination_azimuth = "45";

:illumination_distance = "90";

:instrument_foreoptics = "fiber";

:instrument_field_of_view = "25";

:instrument_calibration_reference = "Spectralon";

:instrument_distance = "50";

:instrument_zenith_angle = "0";

:instrument_goniometer = "FIGIFIGO";

:goniometer_azimuth_sensor = "LSM303";

:instrument_internal_scans = "100";

:instrument_averaged_readings = "10";

:instrument_azimuth_angle = "180";

:instrument_calibration_date = "1998-01-10";

:instrument_calibration_data = "https://niveos.cnr.it/SISpec/data/calibration/cal_19980110.txt";

:instrument_calibration_radiance = "https://niveos.cnr.it/SISpec/data/calibration/rad_19980110.txt";

:instrument_calibration_irradiance = "https://niveos.cnr.it/SISpec/data/calibration/irr_19980110.txt";

:instrument_dark_current_correction = "yes";

:instrument_gain_array = "1, 52, 27";

:instrument_offset_array = "0, 2073, 2086";

:instrument_scan_duration = "100";

:instrument_signal_to_noise = "400";

:instrument_spectral_resolution = "2";

:instrument_fwhm = "1.2";

:instrument_time_white_reference = "600";

:instrument_time_dark_current = "600";

:instrument_software_name = "FR";

:instrument_software_version = "1.0";

:instrument_raw_data_format = "raw data format asd";

:surface_description = "smooth surface with rounded grains of 0.4 mm average radius";

:instrument_spectral_bandwith = "2";

:instrument_wavelength_range = "350, 2500";

:processing_description = "average";

:processing_rationale = "average between different measurements";

:standard_name = "surface_bidirectional_reflectance";

:long_name = "Surface bidirectional reflectance";

:attribute_description = "The surface called \"surface\" means the lower boundary of the atmosphere. \"Bidirectional_reflectance\" depends on the angles of incident and measured radiation. Reflectance is the ratio of the energy of the reflected to the incident radiation. A coordinate variable of

radiation_wavelength or radiation_frequency can be used to specify the wavelength or frequency, respectively, of the radiation.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 1.0f; // float
:valid_min = 0.0f; // float
:units = "1";
:coordinates = "time lat lon alt";
:accuracy = "0.02";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1U, 2151U; // uint

float lat(obs=1);
:standard_name = "latitude";
:long_name = "Latitude";
:attribute_description = "Latitude is positive northward; its units of degree_north (or equivalent) indicate this explicitly. In a latitude-longitude system defined with respect to a rotated North Pole, the standard name of grid_latitude should be used instead of latitude. Grid latitude is positive in the grid-northward direction, but its units should be plain degree.";
:coverage_content_type = "coordinate";
:valid_max = 90.0f; // float
:valid_min = -90.0f; // float
:units = "degree_north";
:accuracy = "0.01";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

float lon(obs=1);
:standard_name = "longitude";
:long_name = "Longitude";
:attribute_description = "Longitude is positive eastward; its units of degree_east (or equivalent) indicate this explicitly. In a latitude-longitude system defined with respect to a rotated North Pole, the standard name of grid_longitude should be used instead of longitude. Grid longitude is positive in the grid-eastward direction, but its units should be plain degree.";
:coverage_content_type = "coordinate";
:valid_max = 360.0f; // float
:valid_min = 0.0f; // float
:units = "degree_east";
:accuracy = "0.01";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

float alt(obs=1);
:standard_name = "altitude";
:long_name = "Altitude";
:attribute_description = "Altitude is the (geometric) height above the geoid, which is the reference geopotential surface. The geoid is similar to mean sea level.";
:coverage_content_type = "coordinate";
:valid_max = 8000.0f; // float
:valid_min = 0.0f; // float
:units = "m";
:positive = "up";
:accuracy = "10";

:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

double time(obs=1);
:standard_name = "time";
:long_name = "Time";
:attribute_description = "Time of the measurement";
:coverage_content_type = "coordinate";
:valid_max = 9.150588E8; // double
:valid_min = 8.836092E8; // double
:units = "s since 1970-01-01 00:00:00 UTC";
:_FillValue = 1.0E32; // double
:_ChunkSizes = 512U; // uint

int main_type(obs=1, shape=3);
:standard_name = "snow_shape_main_code";
:long_name = "The main class of the snow grain shape";
:attribute_description = "The main snow grain shape class describing the morphological characteristics of the snow gain.";
:coverage_content_type = "thematicClassification";
:valid_max = 9; // int
:valid_min = 1; // int
:flag_values = 1, 2, 3, 4, 5, 6, 7, 8, 9; // int
:flag_meanings = "PP MM DF RG FC DH SH MF IF";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int
:_ChunkSizes = 1U, 3U; // uint

int sub_type(obs=1, shape=3);
:standard_name = "snow_shape_sub_code";
:long_name = "The sub class of the identified main snow grain shape class";
:attribute_description = "The snow grain sub-classes decribe a formation process oriented on characterising the grain shape";
:coverage_content_type = "thematicClassification";
:valid_max = 37; // int
:valid_min = 1; // int
:flag_values = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37; // int
:flag_meanings = "PPco PPnd PPpl PPsd PPir PPgp PPhl PPip PPrm MMrp MMci DFdc DFbk RGsr RGlr RGwp RGxf FCso FCsf FCxr DHcp DHpr DHch DHla DHxr SHsu SHcv SHxr MFcl MFpc MFsl MFcr IFii IFic IFbi IFrc IFsc";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int
:_ChunkSizes = 1U, 3U; // uint

float fraction(obs=1, shape=3);
:standard_name = "snow_grain_shape_percentage";
:long_name = "Percentage of each snow grain shape";
:attribute_description = "The estimate amount of snow grain with specific shape and size";
:coverage_content_type = "physicalMeasurement";
:valid_max = 0.0f; // float
:valid_min = 100.0f; // float

:units = "percent";
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1U, 3U; // uint

float size(obs=1, shape=3);
:standard_name = "snow_grain_size";
:long_name = "Snow grain size";
:attribute_description = "The size of a grain or particle is its greatest extension measured in millimetres.A simple method suitable for field measurements is to place a sample of the grains on a plate that has a millimetre grid (crystal card). Both average size and average maximum size are then estimated by comparing the size of the grains with the spacing of the grid lines on the plate.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 0.1f; // float
:valid_min = 5.0f; // float
:units = "m";
:scale_factor = 0.001f; // float
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1U, 3U; // uint

float thickness(obs=1);
:acquisition_snow_depth = "1";
:standard_name = "thickness_of_snow_layer";
:long_name = "Snow layer thickness";
:attribute_description = "The snow layer thickness (measured in centimetres or fractions thereof) is an essential parameter when characterising the current state of a snowpack. Layer thickness is usually measured vertically. If the measurement is taken perpendicular, i.e., slope normal, layer thickness should be denoted by Lp.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 1000.0f; // float
:valid_min = 1.0f; // float
:units = "m";
:scale_factor = 0.001f; // float
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

int hardness(obs=1);
:standard_name = "snow_hardness_code";
:long_name = "Snow hardness";
:attribute_description = "Hardness is the resistance to penetration of an object into snow. Hardness measurements produce a relative index value that depends on both the operator and the instrument; therefore, the device has to be specified.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 6; // int
:valid_min = 1; // int
:flag_values = 1, 2, 3, 4, 5, 6; // int
:flag_meanings = "very_soft soft medium hard very_hard ice";
:instrument = "hand test";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int

:_ChunkSizes = 1024U; // uint

int wetness(obs=1);
:standard_name = "wetness_index_of_surface_snow";
:long_name = "Wetness index of surface snow";
:attribute_description = "Measurements of liquid water content or wetness are expressed as either a volume or mass fraction. Both can be reported as a percent, which usually requires a separate measurement of density. A general classification of liquid water content in terms of volume fraction is given inTable 1.5 of Fierz et al 2009.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 5; // int
:valid_min = 1; // int
:flag_values = 1, 2, 3, 4, 5; // int
:flag_meanings = "dry moist wet very_wet soaked";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int
:_ChunkSizes = 1024U; // uint

int density(obs=1);
:standard_name = "density_of_surface_snow";
:long_name = "Surface snow density";
:attribute_description = "Snow density is the density of the snow cover. Surface snow refers to the snow on the solid ground or on surface ice cover, but excludes, for example, falling snowflakes and snow on plants. The density of a substance is its mass per unit volume.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 500; // int
:valid_min = 30; // int
:units = "kg.m-3";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int
:_ChunkSizes = 1024U; // uint

int rough_code(obs=1);
:standard_name = "snow_surface_roughness_code";
:long_name = "Snow surface roughness code";
:attribute_description = "the general appearance of the surface snow.These surface features are due to the following main processes: deposition, redistribution and erosion by wind, melting and refreezing, sublimation and evaporation, and rain.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 5; // int
:valid_min = 1; // int
:flag_values = 1, 2, 3, 4, 5; // int
:flag_meanings = "smooth wavy concave_furrows convex_furrows random_furrows";
:coordinates = "time lat lon alt";
:_FillValue = 999; // int
:_ChunkSizes = 1024U; // uint

float rough_vert(obs=1);
:standard_name = "snow_surface_roughness_vertical_extent";
:long_name = "Snow surface vertical extent of roughness";
:attribute_description = "The average vertical extent of any of the roughness elements, measured in cm ";

:coverage_content_type = "physicalMeasurement";
:valid_max = 500.0f; // float
:valid_min = 0.0f; // float
:units = "m";
:scale_factor = 0.01f; // float
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

float snow_temp(obs=1);
:standard_name = "temperature_in_surface_snow";
:long_name = "Temperature in surface snow";
:attribute_description = "\"Temperature in surface snow\" is the bulk temperature of the snow, not the surface (skin) temperature. Surface snow refers to the snow on the solid ground or on surface ice cover, but excludes, for example, falling snowflakes and snow on plants.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 10.0f; // float
:valid_min = -20.0f; // float
:units = "degree_Celsius";
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

float air_temp(obs=1);
:standard_name = "air_temperature";
:long_name = "Air temperature";
:attribute_description = "Air temperature is the bulk temperature of the air, not the surface (skin) temperature.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 50.0f; // float
:valid_min = -50.0f; // float
:units = "degree_Celsius";
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

float cloud(obs=1);
:standard_name = "cloud_area_fraction";
:long_name = "Cloud cover";
:attribute_description = "\"X_area_fraction\" means the fraction of horizontal area occupied by X. \"X_area\" means the horizontal area occupied by X within the grid cell. Cloud area fraction is also called \"cloud amount\" and \"cloud cover\". The cloud area fraction is for the whole atmosphere column, as seen from the surface or the top of the atmosphere. The cloud area fraction in a layer of the atmosphere has the standard name cloud_area_fraction_in_atmosphere_layer.";
:coverage_content_type = "thematicClassification";
:valid_max = 1.0f; // float
:valid_min = 0.0f; // float
:units = "1";
:coordinates = "time lat lon alt";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

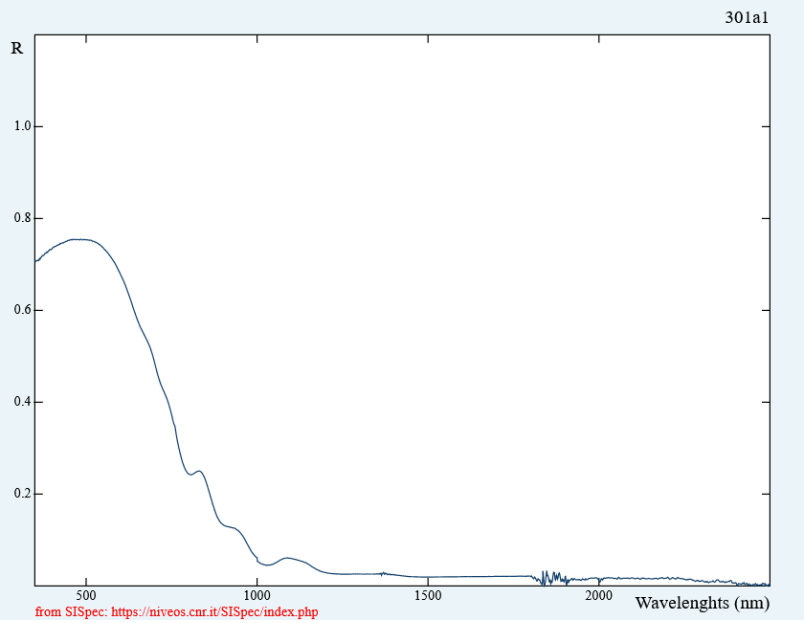
float wind(obs=1);
:standard_name = "wind_speed";
:long_name = "Wind speed";
:attribute_description = "Speed is the magnitude of velocity. Wind is defined as a two-dimensional (horizontal) air velocity vector, with no vertical component. (Vertical motion in the atmosphere has the standard name upward_air_velocity.) The wind speed is the magnitude of the wind velocity.";
:coverage_content_type = "physicalMeasurement";
:valid_max = 30.0f; // float
:valid_min = 0.0f; // float
:units = "m.s-1";
:coordinates = "time lat lon alt";
:accuracy = "1.5";
:_FillValue = 33333.0f; // float
:_ChunkSizes = 1024U; // uint

// global attributes:
:metadata_naming_authority = "National Research Council of Italy";
:metadata_id = "https://niveos.cnr.it/SISpec/metadata/332b.xml";
:metadata_scope = "dataset";
:metadata_creator_individual = "Roberto Salzano";
:metadata_creator_institution = "National Research Council of Italy";
:metadata_creator_email = "info@niveos.cnr.it";
:date_metadata_modified = "2021-05-03";
:metadata_link = "https://niveos.cnr.it/SISpec/metadata/332b.xml";
:geospatial_bounds = "POINT (79, 164)";
:geospatial_bounds_crs = "http://www.opengis.net/def/crs/EPSG/8.5/4979";
:title = "Spectral reflectance obtained in-situ at MT. Abbot (Antarctica) in November 1998";
:date_created = "2021-05-20";
:naming_authority = "International DOI Foundation";
:id = "https://doi.org/10.1109/5.77107343";
:summary = "SISpec is a database containing spectroradiometric, snow and ancillary (environmental and meteorological) data acquired in polar environments. The project is the result of the co-operation of different expertise, and its main objective is to contribute to the knowledge of the interaction between microphysics characteristic of the snow cover and its reflection properties of the solar incident radiation and to study glacial environment and particularly to monitor the snow/ice covers by multispectral remote sensing data. Field surveys were performed in Antarctica, in the region where the Italian research station of Terra Nova Bay is located, the climatic characteristics and the low human impact allow to study snow/ice surfaces without impurities and with different characteristics with respect to those of the Arctic and the Alpine regions, where seasonal melting of the snow cover occur";
:creator_name = "National Research Council of Italy";
:contributor_institution = "National Research Council of Italy";
:contributor_role = "principalInvestigator";
:contributor_name = "Rosamaria Salvatori";
:contributor_email = "info@niveos.cnr.it";
:creator_url = "www.niveos.cnr.it";
:creator_individual = "Roberto Salzano";
:creator_type = "institution";
:institution = "National Research Council of Italy";
:creator_institution = "National Research Council of Italy";
:creator_email = "info@niveos.cnr.it";
:publisher_name = "National Research Council of Italy";

:publisher_institution = "National Research Council of Italy";
:publisher_url = "www.niveos.cnr.it";
:publisher_email = "info@niveos.cnr.it";
:publisher_type = "institution";
:featureType = "point";
:dataFormatType = "netCDF";
:Conventions = "CF-1.7, ACDD-1.3, SISPEC-1.0";
:geospatial_lat_resolution = "3 meters";
:geospatial_lon_resolution = "3 meters";
:geospatial_vertical_resolution = "10 meters";
:geospatial_lat_units = "degree_north";
:geospatial_lon_units = "degree_east";
:topic_category = "environment";
:time_coverage_start = "1998-11-19T02:10:00Z";
:time_coverage_end = "1998-11-19T02:10:00Z";
:time_coverage_resolution = "P1S";
:time_coverage_duration = "P";
:geospatial_lon_min = "163.5303";
:geospatial_lon_max = "163.5303";
:geospatial_lat_min = "-74.7005";
:geospatial_lat_max = "-74.7005";
:geospatial_vertical_min = "650";
:geospatial_vertical_max = "650";
:geospatial_vertical_units = "meters";
:geospatial_vertical_positive = "up";
:geospatial_bounds_vertical_crs = "EPSG:4979";
:maintenance_and_update_frequency = "Complete ";
:keywords = "GEMET:snow, GEMET:solar radiation, INSPIRE:land cover, SNOWTERM:spectral reflectance, SNOWTERM:grain shape";
:keywords_vocabulary = "GEMET:GEneral Multilingual Environmental Thesaurus,INSPIRE:GEMET - INSPIRE themes; version 1.0, SNOWTERM:Thesaurus on Snow and Ice";
:keywords_vocabulary_publication_date = "GEMET:2021-01-21,INSPIRE:2008-06-01, SNOWTERM:2020-06-07";
:standard_name_vocabulary = "CF Standard Name Table v27";
:limitations_on_public_access = "http://inspire.ec.europa.eu/metadata-codelist/LimitationsOnPublicAccess/noLimitations";
:license = "http://inspire.ec.europa.eu/metadata-codelist/ConditionsApplyingToAccessAndUse/noConditionsApply";
:language = "eng";
:language_name = "English";
:character_encoding = "utf8";
:distribution_link = "https://niveos.cnr.it/SISpec/data/332b.nc";
:distribution_protocol = "HTTP";
:distribution_name = "332b";
:distribution_description = "Spectral reflectance NetCDF-SISPEC encoded data";
:distribution_function = "download";
:date_issued = "2021-05-03";
:date_modified = "2010-12-08";
:product_version = "1.0";
:processing_level = "data are averaged reflectance values";
:conformance_scope = "dataset";
:conformance_specification_link = "http://inspire.ec.europa.eu/id/citation/ir/reg-1089-2010";

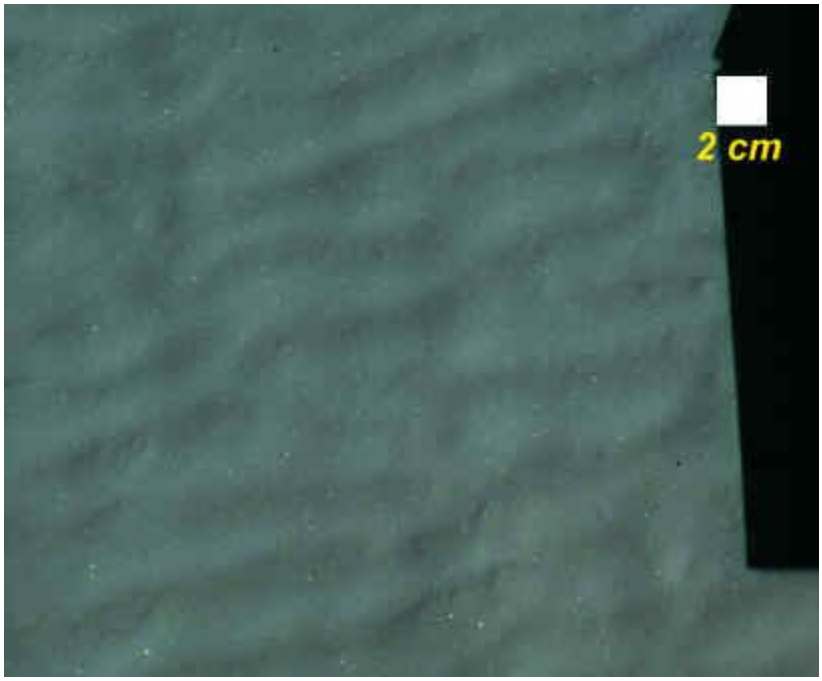
:conformance_specification_title = "COMMISSION REGULATION (EU) No 1089/2010 of 23 November 2010 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services";
:conformance_specification_publication_date = "2010-12-08";
:conformance_specification_explanation = "This data set is conformant with the INSPIRE Implementing Rules for the interoperability of spatial data sets and services";
:conformance_specification_pass = "TRUE";
:history = "averaged measurements";
:instrument = "Fieldspec FSP350-2500P (Analytical Spectral Device inc.)";
:instrument_vocabulary = "https://gcmd.earthdata.nasa.gov/KeywordViewer";
:instrument_link = "https://www.malvernpanalytical.com/en/products/product-range/asd-range/fieldspec-range";
:instrument_id = "serial number 634";
:instrument_type = "Spectroradiometer";
:platform = "tripod";
:platform_vocabulary = "https://gcmd.earthdata.nasa.gov/KeywordViewer";
:operation_name = "TLR_GIS";
:project = "TLR_GIS";
:program = "PNRA";
:operation_description = "Field survey close to the Terra Nova Bay, Italian Antarctic Station";
:operation_status = "completed";
:operation_type = "real";
:acquisition_objective = "https://data.aad.gov.au/aadc/gaz/scar/display_name.cfm?gaz_id=114527";
:acquisition_objective_title = "Field survey for the groud-thruth of satellite image classification (PNRA research program 3.1)";
:acquisition_meteorological_conditions = "calm wind condition";
:acquisition_objective_type = "survey";
:references = "Casacchia, R; Salvatori, R; Cagnati, A; Valt, M; Ghergo, S 2002. Field reflectance of snow/ice covers at Terra Nova Bay, Antarctica. Int. J. Remote Sensing vol.23, no.21, 4563-4667 DOI:10.1080/01431160110113863";
:comment = "The project has been funded by PNRA, has involved CNR and snow experts of ARPA Veneto";
:acknowledgement = "We would like to thank all the logistic staff involved in the field activity";
:source = "Reflectance measured with Fieldspec portable spectroradiometer in the range between 350-2500 nm";
}

Appendix B: Example of spectrum plot



Appendix C: Example of environmental graphic overview

Appendix D: Examples of the target surface graphic overview



Appendix E: Example of the graphic overview describing the experimental setup

Appendix F: Example of the graphic overview describing the sky condition