# Technical report on common satellite data interface description document to describe how satellite derived cryospheric measurement data can be accessed and utilized

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## WP 3: Integrating in-situ and satellite components

## Task 3.1 Streamlining satellite remote sensing data flows for new multi-sensor, multi-dimensional products, Deliverable D3.1.1

## Document version 1

## Introduction

This technical report provides a description of the infrastructure used to centralize the dissemination of satellite data products using OGC web services standards. It further elaborates on the application interface implemented that is the GeoServer with details about the installation setup. The document also describes how to access the data provided on GeoServer. It also gives further examples of sample products and web clients that have been designed to access the data. This document is part of iCUPE projects work package 3.1 Streamlining satellite remote sensing data flows for new multi-sensor, multi-dimensional products.

## Satellite data dissemination interface

The infrastructure behind the satellite data dissemination interface is hosted at the Sodankylä site by the Finnish Meteorological Institute's Arctic Space Centre. The Arctic Research Centre is located in Sodankylä (67°22 'N, 26°39 'E). It is one of two main principal observation infrastructure deployed by the Finnish Meteorological Institute (FMI). The location, Finnish Lapland, is ideal for the atmospheric and environmental research of boreal and sub-arctic zone. The Sodankylä facility hosts programs addressing upper air chemistry and physics, atmospheric column measurements, snow/soil hydrology, biosphere-atmosphere interaction and satellite calibration-validation studies. It also hosts the development of satellite systems for the monitoring of cryospheric processes and arctic atmosphere:

Reference systems and measurements e.g. for ESA SMOS, ESA CoReH2O, NASA AURA, NASA/Jaxa AMSR-E, NASA MODIS, ESA AATSR.

***Overview of the Satellite Data Interface***

There are four main elements in Satellite data interface; the data storage, indexing database, backend administration and frontend servers. This is illustrated in Figure 1.

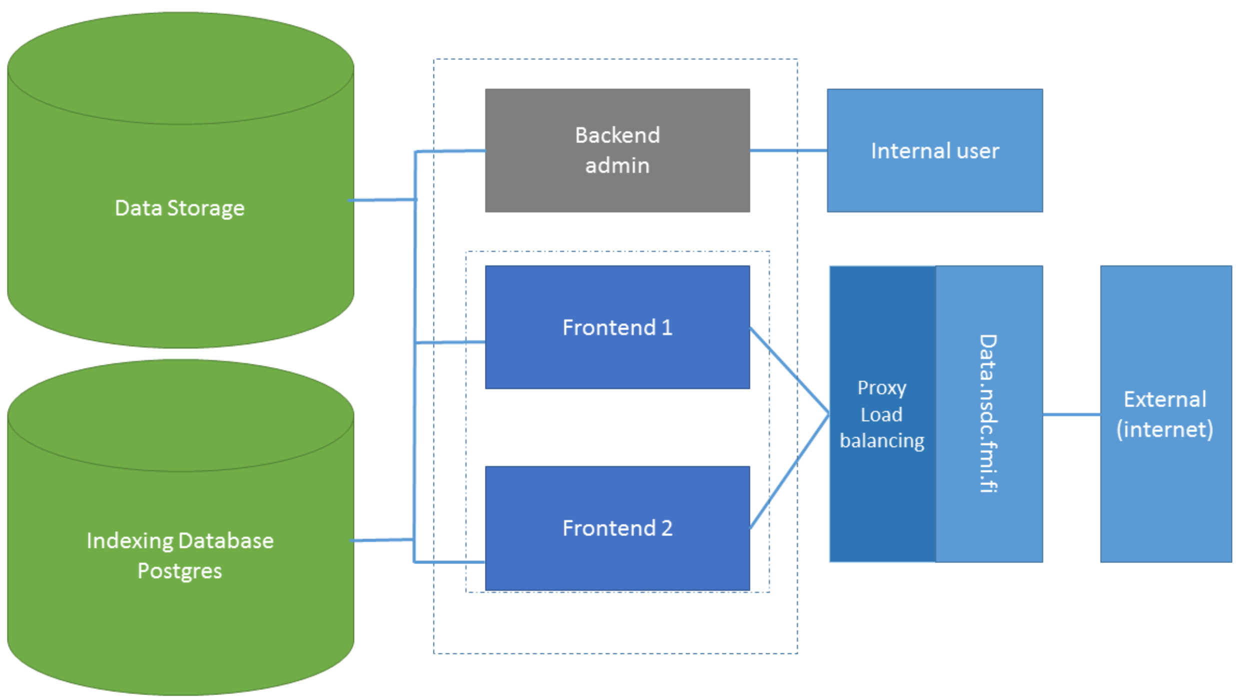



*Figure 1 Architecture of the Satellite Data Interface*

## Software and hardware description

Geoserver is an open source java software that is designed to support interoperability for distributing and sharing geospatial data among various users. The GeoServer installation includes a web interface that can be used to load, manage and publish data. To provide indexing and improve performance, postgres postgis database is being used as the data management system. This helps to track various dimensions of the data, for instance time, elevation and other constraints that define multidimensions.

The GeoServers implemented have been dockerized. Using docker makes it easier and simpler to port or multiply the GeoServer instances. Thus making the satellite data dissemination interface more scalable, easier to maintain and manage. The docker containers contain some health checks, for instance if the service checks fail the docker containers are restarted automatically. GeoServers, are running on linux virtual servers. Virtualization enables one to be able to upgrade and improve the server specifications easily, for instance in the case when system usage increases, with the Sodankylä infrastructure it is easy to just increase the RAM without physically changing the server hardware. Currently there are four virtual servers; one backend for administration purpose and two clustered frontend servers and one database server. The frontends are load balanced using HAProxy. HAProxy is an open source software that provides high performance and reliable load balancing service.

For version control, a FMI inhouse docker registry is used to keep track of the version of software running. This is coupled with the FMI private github repository that is used to keep track of configurations. The entire system, the virtual machines, server health is also monitored by the 24/7 operator using NAGIOS. This makes the satellite data interface more reliable and efficient.

### *Operational processing chains feeding data to the dissemination interface*

There are several data sources that upload data to the satellite dissemination interface. These data sources are part of operational processing chains. The products are processed on separate dedicated servers which then push the data to ceph object storage. The advantage of using the ceph cloud storage is that the data is readily available to be accessed by the instances of the GeoServer. Figure 2 shows the operational products that are uploaded to the GeoServers and how they can be visualized and accessed.

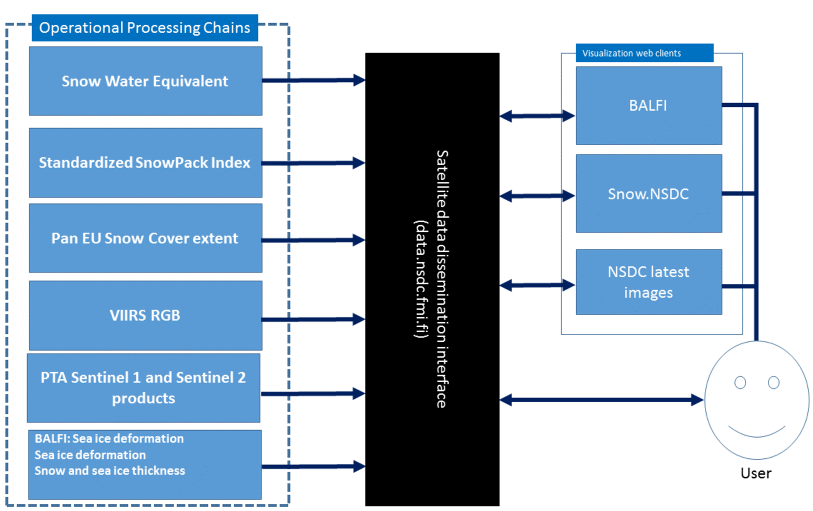



*Figure 2 Dataflow in the Satellite dissemination Interface*

## Visualization web clients

### *The FMI NSDC Snow Service*

This service uses the WMS services from the Satellite data interface, to show snow products that are derived from satellite data. Figure 3 shows an example of the SuperSwe product, with a plot of the historical values from a certain coordinate.

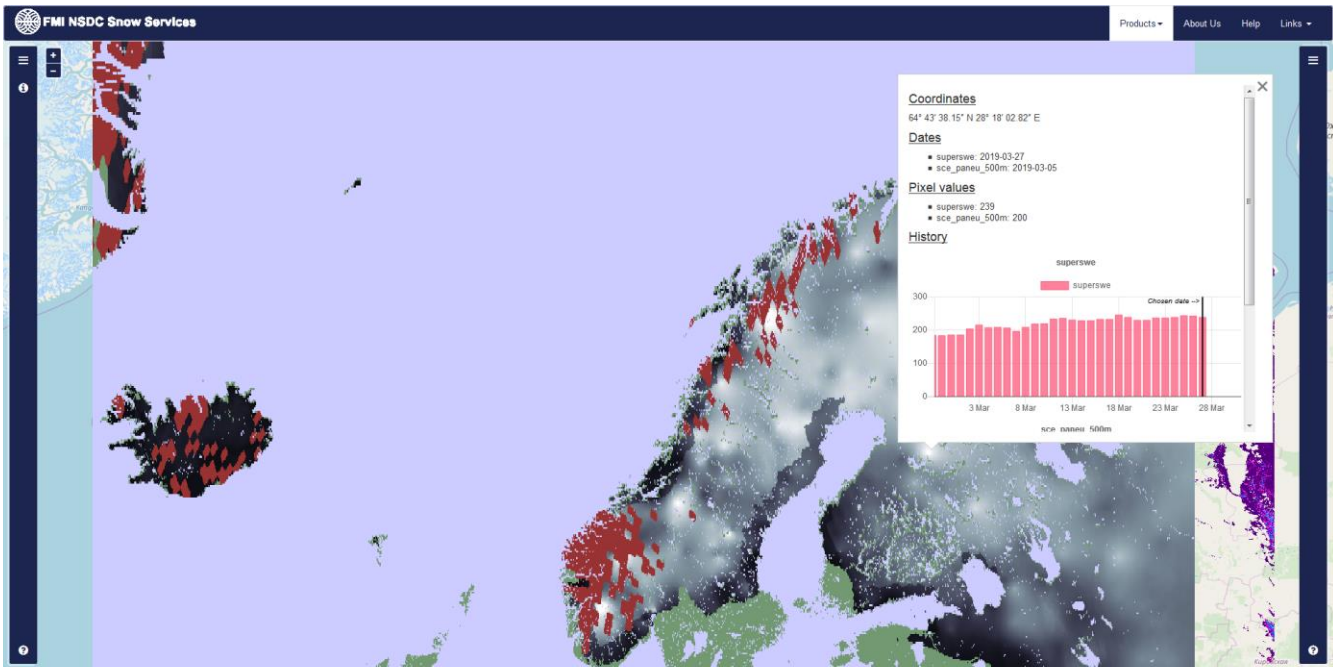



*Figure 3 FMI NSDC Snow Service web client SuperSwe 20190327*

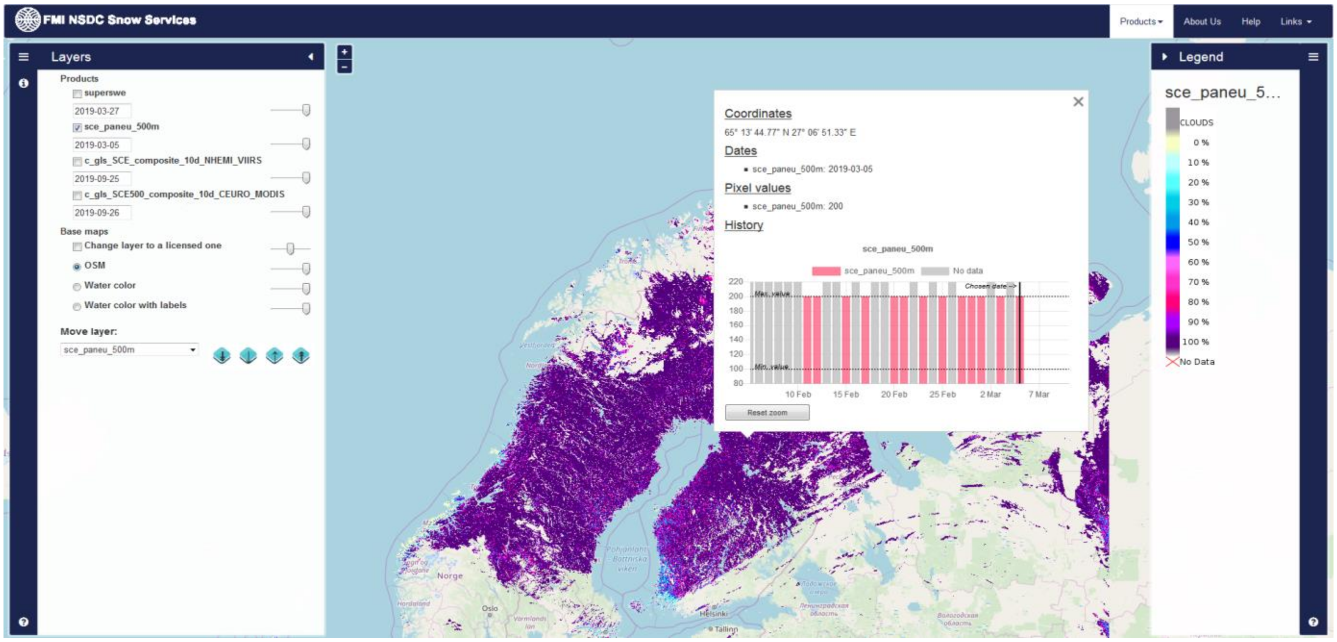



*Figure 4 FMI NSDC Snow Services: Pan EU Snow Cover Extent 20190305*

*BALFI (http://balfi.nsdc.fmi.fi/)*

The Baltic Sea: Baltic Sea landfast ice extent and thickness (BALFI) service uses web map services hosted on the satellite dissemination interface. The service incudes maps of snow and ice thickness and ice deformation map on the landfast ice. The ice thickness map also shows the full extent of the landfast ice. The maps are based on three Baltic Sea products of the Copernicus Marine Environment Monitoring Service (CMEMS), SENTINEL-1 SAR imagery, and a sea ice thermodynamic model (called HIGHTSI) run at FMI.

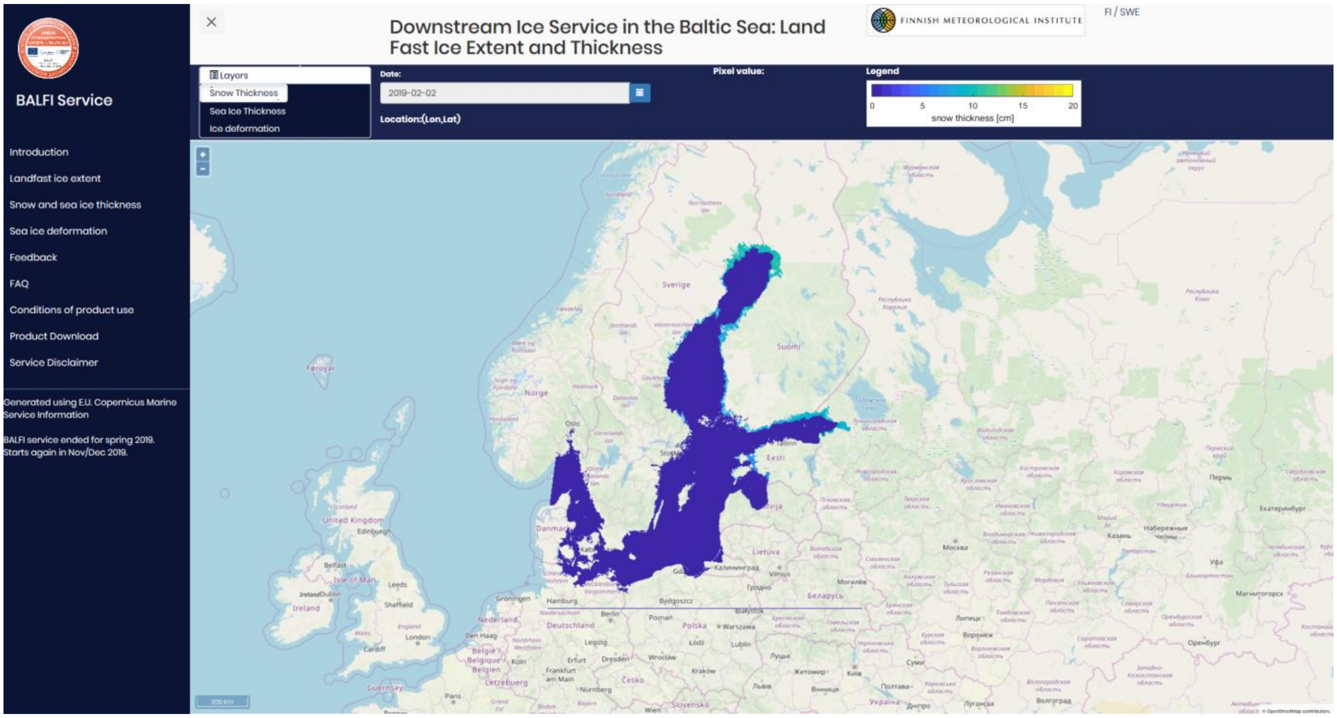



*Figure 5 BALFI Snow Thickness Product*

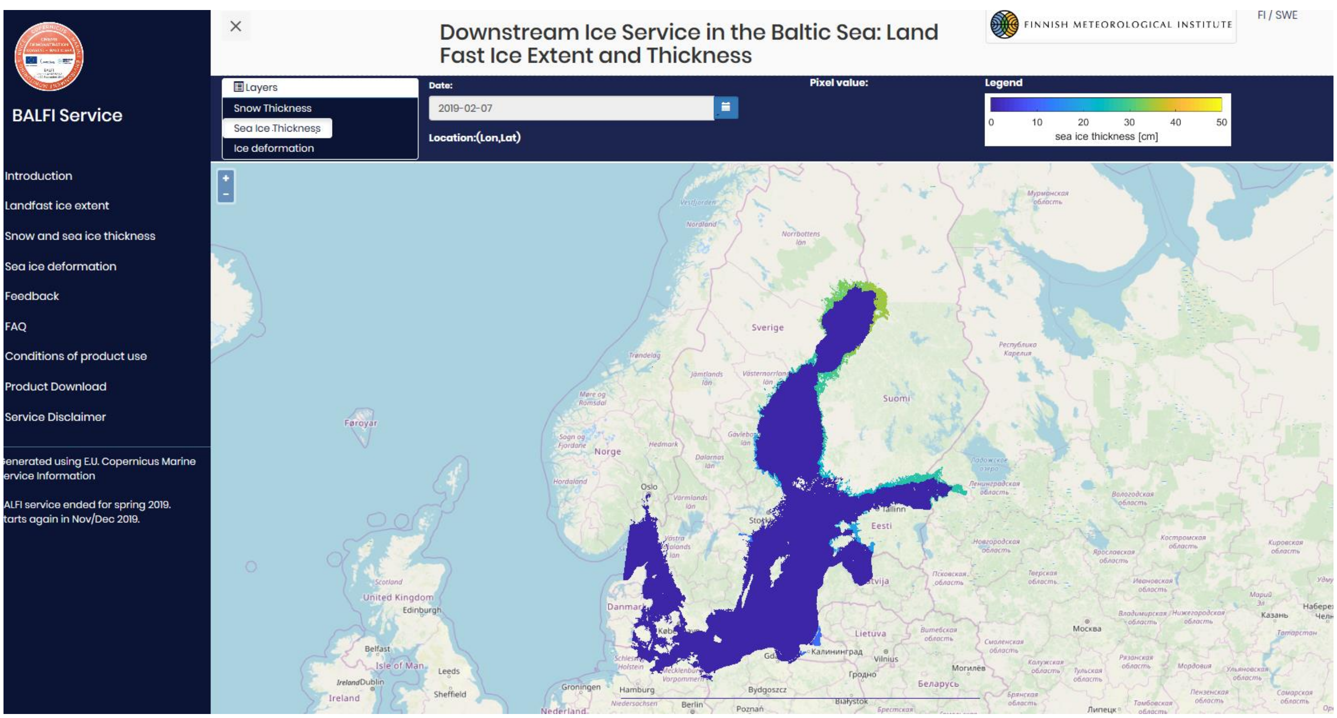



*Figure 6 BALFI Sea ice Thickness Product*

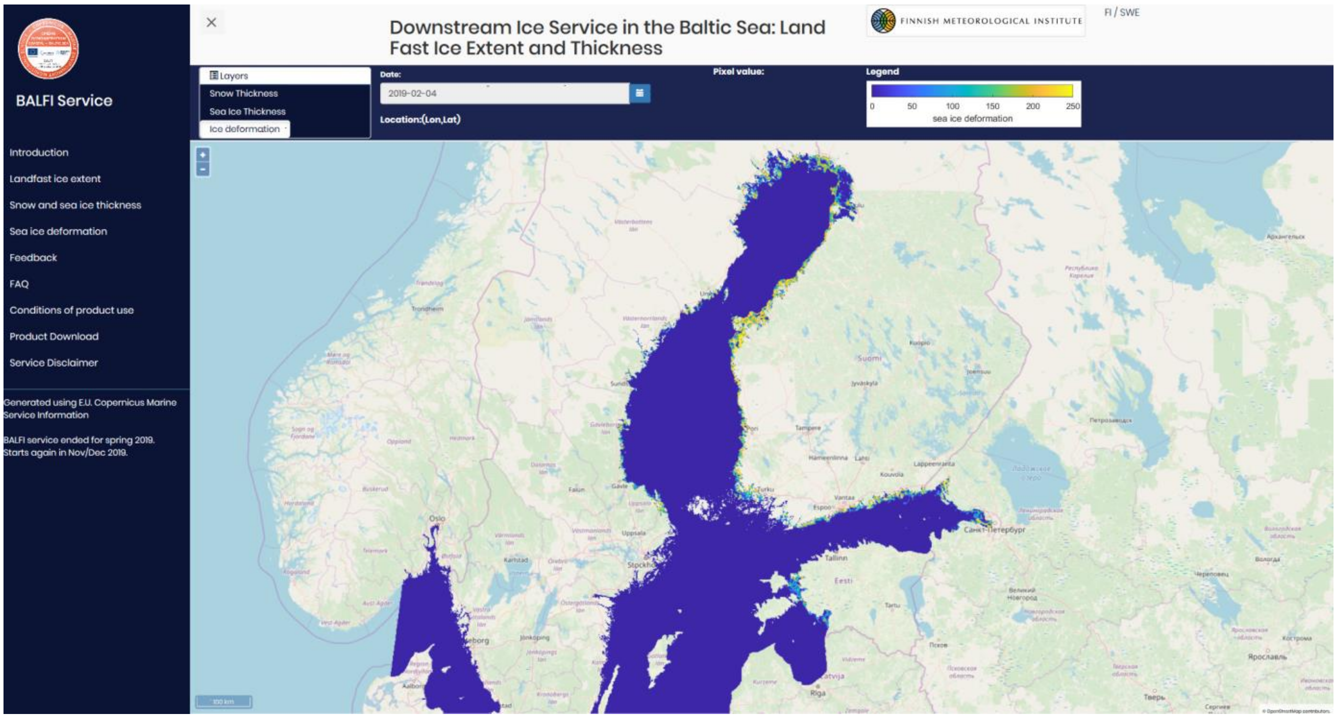



*Figure 7 Ice Deformation Product*

## How to access the data

Users can connect and request geospatial data from the satellite data interface using OGC Web Map Service (WMS), version 1.1.1 or version 1.3.0 and OGC Web Coverage Service (WCS) version 1.1.1 or version 1.1.0 .

Web Map Service supports the following operations:

*Table 1 Web Map Service supported operations*

| Operation | Description |
| --- | --- |
| Exceptions | If an exception occur |
| GetCapabilities | This operation provides metadata about the services, operations and data available. |

| | |
|---|---|
| GetMap | Fetches a map image for a specified area and content |
| GetFeatureInfo (optional) | Retrieves the underlying data, including geometry and attribute values, for a pixel location on a map |
| DescribeLayer (optional) | Indicates the WFS or WCS to retrieve additional information about the layer. |
| GetLegendGraphic (optional) | Retrieves a generated legend for a map |

Example wms GetCapabilities request parameters

| |
|---|
| https://data.nsdc.fmi.fi/geoserver/wms?request=GetCapabilities |

Example wms GetMap request parameters

| |
|---|
| https://data.nsdc.fmi.fi/geoserver/Satellite/wms? |
| service=WMS&<br>version=1.1.0&<br>request=GetMap&<br>layers=superswe&<br>styles=&<br>time=2019-03-05&<br>bbox=53670.0,6610937.780158112,891130.0,7817840.0&<br>width=532&<br>height=768&<br>srs=EPSG:3067&<br>format=application/openlayers |

*Table 2 OGC Web Coverage Service supported operations:*

| Operation | Description |
|---|---|
| GetCapabilities | Retrieves an xml proving a list of available data, and all valid and supported WCS operations and parameters |
| DescribeCoverage | Gets an XML document that describes the request coverages. |
| GetCoverage | Allows retrieval of coverage data subsets. It returns a coverage in a well known format for example GeoTiff |

## Products Available

### *Visible Infrared Imaging Radiometer Suite (VIIRS) RGB*

VIIRS, a scanning radiometer, collects visible and infrared imagery and radiometric measurements of the land, atmosphere, cryosphere, and oceans. VIIRS data is used to measure cloud and aerosol properties, ocean color, sea and land surface temperature, ice motion and temperature, fires, and Earth's albedo. Climatologists use VIIRS data to improve our understanding of global climate change.

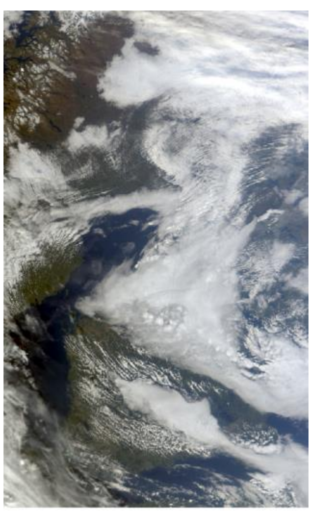


*Figure 8 VIIRS 20190929*

### *PTA Sentinel 1 mosaic ground range detected VH polarization*

Sentinel 1 mosaics for the GRD products, which is the horizontal polarization ground back scatter of vertical polarization radar pulse.

- *Maximum back scatter* - As several measurements have been summed up over 11 days, this is the maximum of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Minimum back scatter*- As several measurements have been summed up over 11 days, this is the minimum of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Mean back scatter* - As several measurements have been summed up over 11 days, this is the average of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Standard deviation* - As several measurements have been summed up over 11 days, this is the standard deviation of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.

*PTA Sentinel 1 mosaic ground range detected VV polarization*

Sentinel 1 mosaics for the GRD product, which is the vertical polarization ground back scatter of vertical polarization radar pulse

- *Maximum back scatter* - As several measurements have been summed up over 11 days, this is the maximum of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Minimum back scatter*- As several measurements have been summed up over 11 days, this is the minimum of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Mean back scatter* - As several measurements have been summed up over 11 days, this is the average of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.
- *Standard deviation* - As several measurements have been summed up over 11 days, this is the standard deviation of these measurements. Usually a single pixel is surveyed every 2-3 days over Finland.

*Sentinel 2 mosaics processed by SYKE*

- *Sentinel 2 normalized difference vegetation index mosaic*

  Mosaic of Sentinel 2 image indexes made for highlighting vegetation covered areas and to monitor the condition of vegetation or vegetation health. Chlorophyll content of vegetation absorb strongly the red wavelength of sunlight and reflect in near-infrared wavelengths. Unhealthy or dry vegetation has much lower chlorophyll content.

  Equation NDVI= (SWIR-NIR) / (SWIR+NIR), gives values between -1 and 1 with healthy heavy vegetation getting values >0.6, shurbs, grasslands and drying crops getting low positive values from 0.2 to 0.5, snow and barren soil getting values close to zero and deep water getting high negative values down to -1.

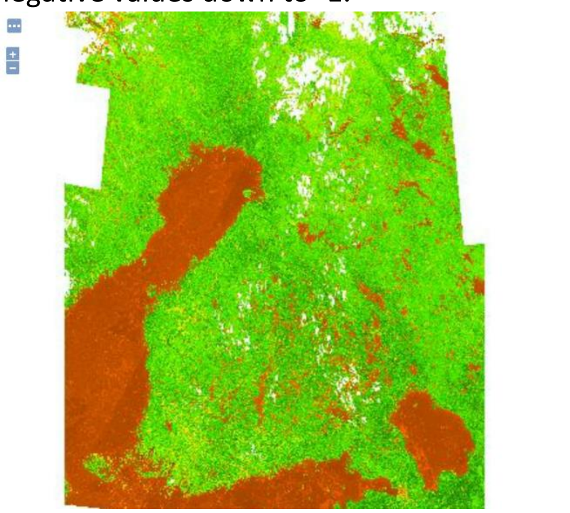


*Figure 9 NDVI 2019-08-31*

- *Sentinel 2 normalized difference build-up index mosaic*

  Mosaic of Sentinel 2 image indexes made for highlighting build-up areas. Build-up areas heavily modified human activity tend to have lot features such as asphalt and concrete that are highly reflective on shortwave infrared (SWIR) and less so on near infrared (NIR) part of electromagnetic spectrum. Equation (SWIR-NIR) / (SWIR+NIR) will give build-up areas positive values and other features values close to zero or negative.

- *Sentinel 2 normalized difference moisture index mosaic*

  Mosaic of Sentinel 2 image indexes made for monitoring changes in water content of leaves. This index is derived from the Near-Infrared (NIR) and Short Wave Infrared (SWIR) channels of the satellite instrument. SWIR reflectance is affected by changes in both the vegetation water content and the spongy mesophyll structure in vegetation canopies. NIR reflectance is affected by leaf internal structure and leaf dry matter content but not by water content. Equation NDBI=(NIR-SWIR)/(NIR+SWIR) gives values between -1 and 1 with open water getting close to 1, healthy well-watered vegetation getting values from 0.3 to 0.7, dry vegetation getting low positive values and bare soil getting negative values.

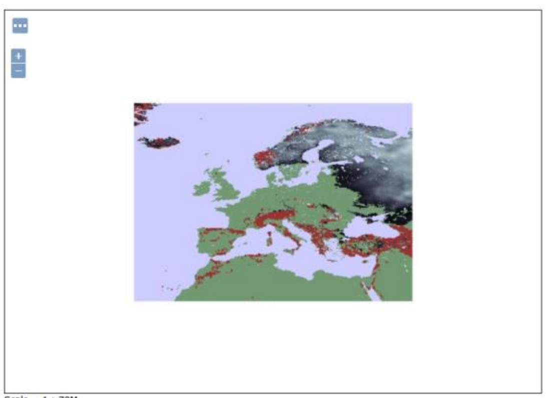
- *Sentinel 2 normalized difference snow index mosaic*
  Mosaic of Sentinel 2 image indexes made for highlighting snow covered areas and to differentiate snow from clouds. Snow is highly reflective on all visible bands of electromagnetic spectrum, but can easily be mixed with clouds that have similar properties (both look white). Snow however has far lower reflectance on shortwave infrared part of the spectrum and this can be used to differentiate snow and clouds. Equation NDSI=(VIS-SWIR)/(VIS+SWIR) gives values between -1 and 1 with snow getting values between 0.5 and 1 and clouds usually getting positive values close to zero.

- *Sentinel 2 normalized difference tillage index mosaic*
  Mosaic of Sentinel 2 image indexes made for detecting crop residue cover and tillage intensity. Based on cellulose absorption feature of dead vegetation and can be used to differentiate between dry bare soil, tilled fields and fields left fallow. Equation NDTI=(SWIR1-SWIR2)/(SWIR1-SWIR2)

Landsat mosaics from 1985 onward in 5 year intervals. Cloudless mosaics use imagery from +/- 2 years of the target year, with target year free pixels being prioritized. Pixel value is reflectance computed using Dark-object-subtraction method. Pixel size is 30x30 m. Mosaics Processed by Blom Kartta.

- *Landsat mosaic surface reflectance band 1*: Reflectance band nr is 1 - Blue 0.45-0.52 nm.
- *Landsat mosaic surface reflectance band 2*: Reflectance band nr is 2 - Green 0.52-0.60 nm.
- *Landsat mosaic surface reflectance band 3*: Reflectance band nr is 3 - Red 0.63-0.69 nm.
- *Landsat mosaic surface reflectance band 4*: Reflectance band nr is 4 - Near Infrared (NIR) 0.76-0.90 nm.
- *Landsat mosaic surface reflectance band 5*: Reflectance band nr is 5 - Shortwave infrared 1 (SWIR1) 1.55-1.75 nm.
- *Landsat mosaic surface reflectance band 7*: Reflectance band nr is 7 - Shortwave infrared 2 (SWIR2) 2.08-2.35 nm.

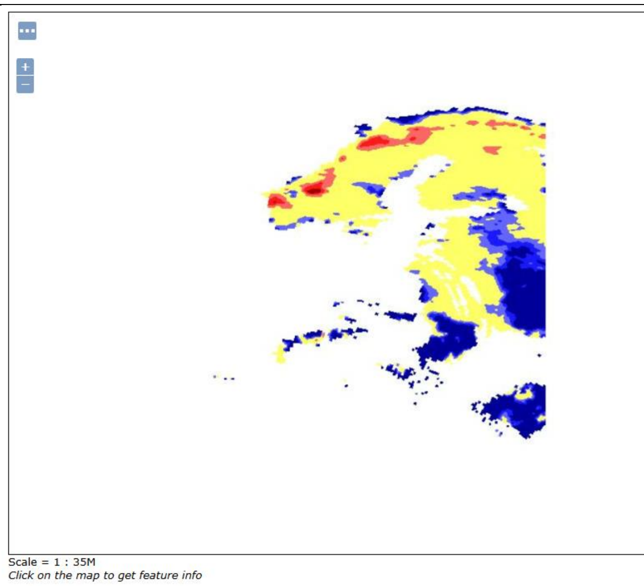
*Pan European Snow Water Equivalent*

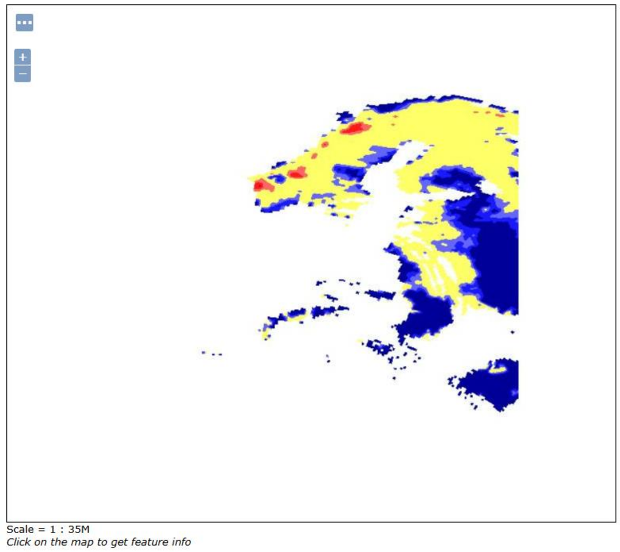
| | |
|---|---|
| **Overview** | The product estimates Snow Water Equivalent (SWE) in millimeters for Pan European grid in 0.05 degrees spatial resolution. The snow water equivalent estimate is obtained by data assimilation. This is done using various datasets, snow depth observations and radiometric data. The synoptic snow depth observations are kriging interpolated. The forward model is then used at the station locations to obtain estimate of snow grain size and variance. The grain size and variance are interpolated to the grid and then together with radiometer data and forward model. Some post processing done includes masking out ground without snow, mountains and water bodies. The snow line is masked using combination of IMS and VIIRS data. |
| **Example** | <br>*Figure 10 SuperSWE 20190301* |
| **Contact** | Matias Takala, Finnish Meteorological Institute<br><br>Email: Matias.Takala@fmi.fi |
| **Validation Status** | Validation is performed one season. Details are in manuscript:<br><br>Takala, M., Ikonen, J., Luojus, K., Lemmetyinen, J., Metsämäki, S., Cohen, J., Arslan, A. N. and Pulliainen, J., “New Snow Water Equivalent processing system with improved resolution over Europe and its applications in hydrology”. to be submitted |

| | |
|---|---|
| **Algorithm Theoretical Basis Document** | Algorithm is described in manuscript:<br><br>Takala, M., Ikonen, J., Luojus, K., Lemmetyinen, J., Metsämäki, S., Cohen, J., Arslan, A. N. and Pulliainen, J., "New Snow Water Equivalent processing system with improved resolution over Europe and its applications in hydrology". to be submitted |
| **Spatial Coverage & Resolution** | Pan European grid, 0.05 degrees pixel |
| **Temporal Coverage & Resolution** | Daily product |
| **Platform(s)** | DMSP F-series |
| **Sensor(s)** | SSMI/S |
| **Data Format (s)** | GeoTIFF |
| **Version** | V1.0 |
| **Producers** | FMI |
| **Data Policy** | Data are provided free of charge during the project period for non-commercial usage. |
| **Access** | Products will be provided through the FMIARC GeoPortal. (http://data.nsdc.fmi.fi)<br><br>Available via http, wms and wcs. |

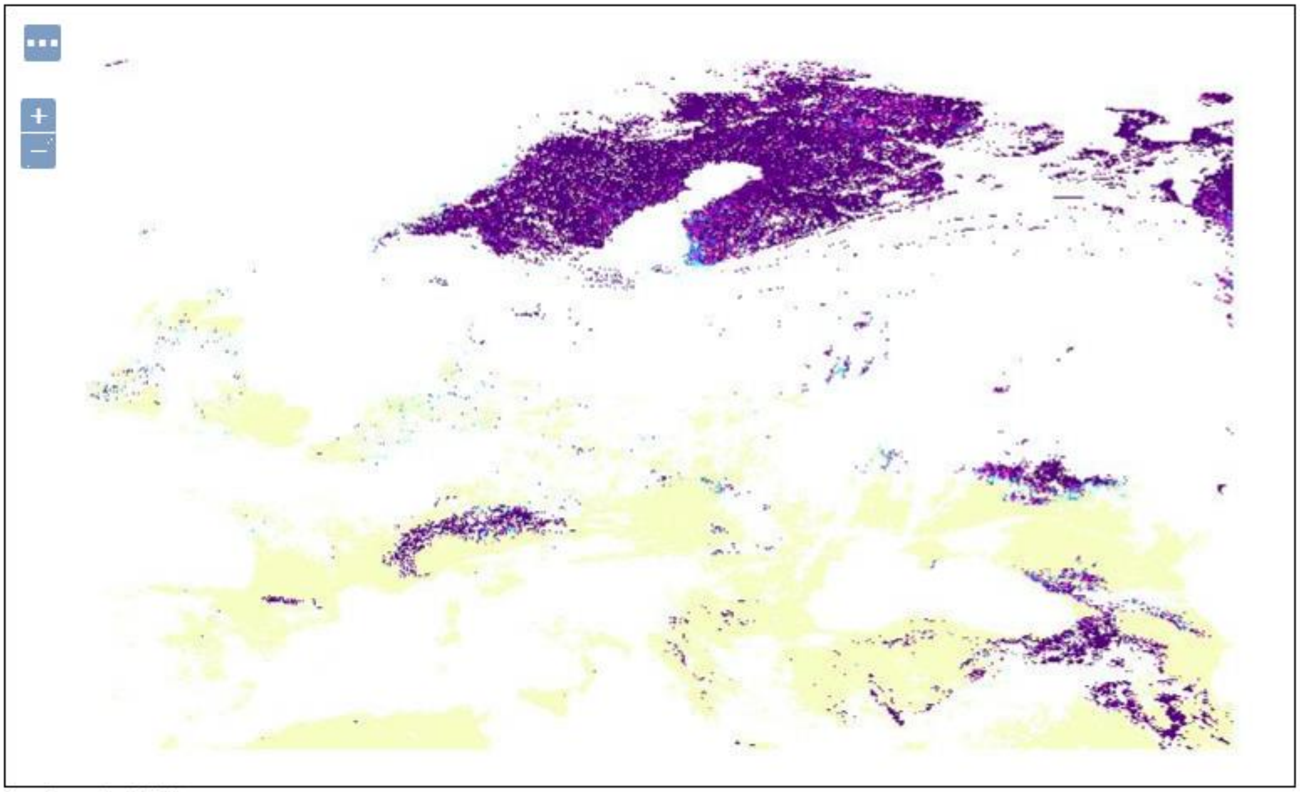
*SSPI: Standardized SnowPack Index*

| | |
|---|---|
| **Overview** | The availability of water in rivers, lakes and ground is mainly related to precipitation. However, in the cold climate when precipitation falls in the form of snow, water is stored in the snowpack and this will decrease runoff and ground water recharge during the winter months and, on the other hand, contribute to the increased runoff during the spring and early |

| | |
|---|---|
| | summer. Changes in this pattern may cause serious shortfalls in the availability of water. The warming climate is predicted to decrease snowpack, cause snowmelt during winter and decrease the springtime snowmelt. Also the expected increased variation in the climate pattern will cause grater variations in the snowpack. Lack on snowmelt can increase possibilities for drought during the spring and early summer, which is an important growing period for plants and crops.<br><br>The SSPI is computed the same way as the SPI (Standardized Precipitation Index), except for being based on the daily snowpack water equivalent (=kg/m2 of snow) time series. The SSPI provides information of the relative volume of the snowpack in the catchment on a ten-daily and monthly basis compared to the period of reference.<br><br>The indicator can be used for awareness raising, evaluation of occurred droughts, forecasting future drought risks and management purposes. |
| **Example** | <br><br>*Figure 11 sspi 10 days 20190101 and* |

| | |
|---|---|
| | <br><br>*Figure 12 sspi 30 days 20190101* |
| **Contact** | Principal Investigator Jouni Pulliainen, firstname.lastname@fmi.fi<br><br>Project Manager Kari Luojus, firstname.lastname@fmi.fi |
| **Spatial Coverage & Resolution** | **Spatial scale:** Regional data; modelled for 25 km x 25 km grids in the catchment (soon 5 km X 5 km). The model uses remote sensing from the satellites. The SSPI can be calculated for any given area in Europe, e.g. river basin district, river basin or sub-basin. |
| **Temporal Coverage & Resolution** | **Temporal scale:** Daily values. Remote sensing gives real time observations once a day. |
| **Data Format (s)** | GeoTIFF |
| **Version** | V1.0 |
| **Producers** | FMI |
| **Data Policy** | Data are provided free of charge during the project period for non-commercial usage. |
| **Access** | Products are provided from NSDC wms data portal (http://data.nsdc.fmi.fi) |

### *Copernicus Global Land Service (GlobLand) Snow Cover Extent products*



Scale = 1 : 35M
*Click on the map to get feature info*

*Figure 13: GlobLand sce_paneu_500m&time=2019-03-05*

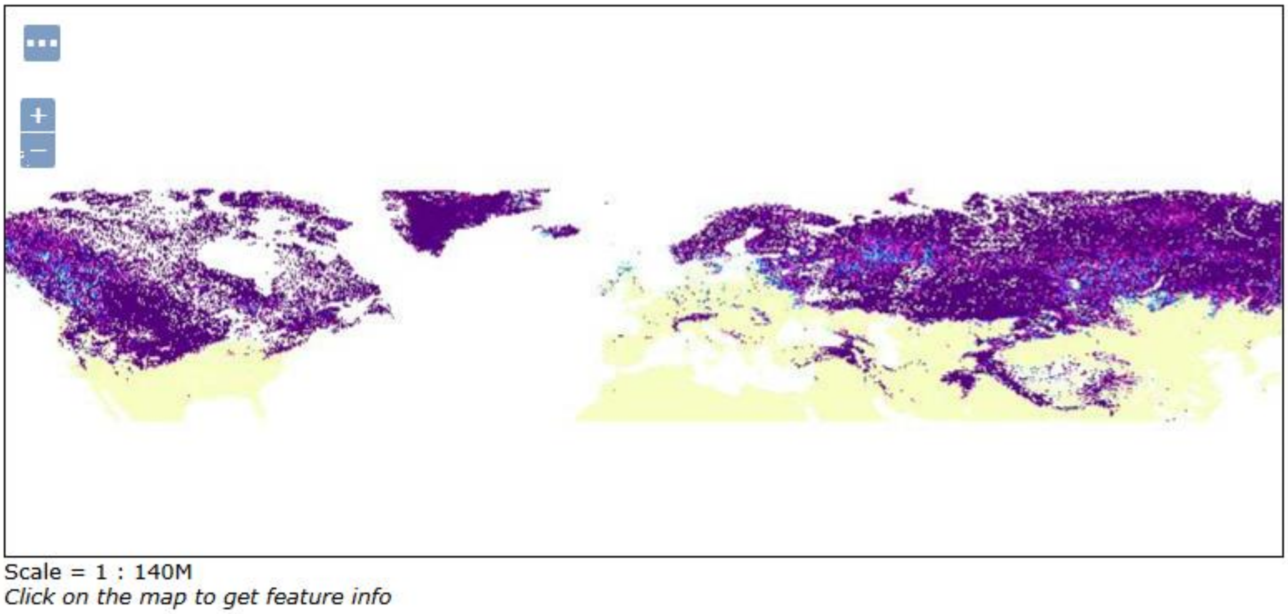



*Figure 14: GlobLand SCE_composite_10d_NHEMI_VIIRS 20190305*

## Summary

The satellite data dissemination interface consists of two clustered frontends, load balanced using HAProxy, a backend server for administration and a Postgres Postgis database. The backend and frontend are running dockerized version of GeoServer. The data is accessible from the GeoServer using WMS and WCS standard requests. Some of the requests include GetCapabilities, GetMap, GetCoverage, DescribeCoverage, GetFeatureInfo etc. The user can connect or make requests to the satellite dissemination interface from https://data.nsdc.fmi.fi/geoserver/wcs? Or https://data.nsdc.fmi.fi/geoserver/wms?. Some datasets available include VIIRS rgb, Sentinel 1, Sentinel 2, Landsat mosaics, Snow Water Equivalent, Standardized SnowPack Index and snow cover extent.