• **Snow products:**
  – Weekly Regional **Wet Snow Cover Maps** using multi-temporal **Sentinel-1 IWS** data
  – Daily Regional & Pan-European **Fractional Snow Cover Maps** using synergistic **Sentinel-3 SLSTR/OLCI** data

• **Glacier products:**
  – **Glacier ice surface velocity** from **Sentinel-1 IWS** data (from crossing orbits (asc/desc)) using Interferometry or Offset Tracking
  – **Glacier outlines** from **Sentinel-2 MSI** data
  – **Snow and ice areas on glaciers** from **Sentinel-2 MSI** (glacier facies) and **Sentinel-1 IWS** data (wet snow cover on glaciers)

→ **Sentinel data from ESA Scientific Data Hub**
## Snow Products Specifications

<table>
<thead>
<tr>
<th>Products</th>
<th>Sensor</th>
<th>Projection / Datum</th>
<th>Spatial Coverage</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Delivery period</th>
<th>Latency time</th>
<th>File Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet (melting) Snow Area</td>
<td>Sentinel-1</td>
<td>Geographic / WGS84</td>
<td>Alps</td>
<td>100 m (50 m)</td>
<td>Weekly</td>
<td>Melting Season</td>
<td>&lt; 1 day</td>
<td>Raster (GeoTIFF, netCDF)</td>
</tr>
<tr>
<td>Fractional Snow Cover</td>
<td>Sentinel-3</td>
<td>Geographic / WGS84</td>
<td>72°N/11°W-35°N/50°E</td>
<td>0.005 deg</td>
<td>Daily</td>
<td>Full Year</td>
<td>&lt; 1 day</td>
<td>Raster (GeoTIFF, netCDF)</td>
</tr>
<tr>
<td>Fractional Snow Cover</td>
<td>Sentinel-3</td>
<td>Geographic / WGS84, others (user defined)</td>
<td>Alpine region</td>
<td>0.003 deg</td>
<td>Daily</td>
<td>Full Year</td>
<td>&lt; 1 day</td>
<td>Raster (GeoTIFF)</td>
</tr>
</tbody>
</table>
Retrieval of Snowmelt Area by S1 IW Mode Data

Flowline for Retrieval algorithm from Sentinel-1 **IW-mode data (SLC)**

**SLC** data enable optimal speckle filtering, data fusion, segmentation and geocoding

$\Delta \sigma^\circ (VV)$

$\Delta \sigma^\circ (VH)$

$\sigma^\circ$ ratio in IW mode data, for area in Eastern Alps, 2 June 2015
Sentinel-1 maps of melting snow areas, Alps April and May 2015

Track 2015
066: 20.Apr
088: 21.Apr
095: 22.Apr
117: 23.Apr

Track 2015
066: 14.May
088: 15.May
095: 16 May
117: 17 May

Copernicus Sentinel Data 2015
Gabriele Bippus
Comparison MODIS Snow Extent / S1 Snowmelt Area

MODIS, 17+18 May 2015, Map of Fractional Snow Extent (grid size 250 m)

Confusion Matrix

<table>
<thead>
<tr>
<th>MODIS</th>
<th>SC(S1)</th>
<th>SF(S1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>83.96</td>
<td>16.04</td>
</tr>
<tr>
<td>SF</td>
<td>8.86</td>
<td>91.14</td>
</tr>
</tbody>
</table>

Overall = 89.51

S1 Snow Melt Area
2015/05/17
100 m grid

Probability $\Delta \sigma^o$ for snow/snow free areas from MODIS

Gabriele Bippus
Concept for SENTINEL-3 Snow Mapping using SLSTR (AATSR) and OLCI (MERIS)

**Sentinel-3:**

SLSTR (follow on of AATSR):
0.5 – 1.6, -3.7 μm + TIR
500 m / 1 km

OLCI (follow on of MERIS):
0.4.-1.2 μm; 300 m

Daily Global Coverage

Fractional Snow Extent estimated using multi-spectral algorithm
## Current status of Pan-European & Alpine Fractional Snow Cover Products

<table>
<thead>
<tr>
<th>Products Specifications</th>
<th>Pan-European</th>
<th>Alpine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Domain</strong></td>
<td>72°N 11°W – 35°N 50°E</td>
<td>Full Alpine ridge and lowlands</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>1 day</td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Projection</strong></td>
<td>LatLon/WGS84</td>
<td>LatLon / WGS84, or as requested by users</td>
</tr>
<tr>
<td><strong>Pixel size</strong></td>
<td>0.005° (ca 500 m)</td>
<td>0.0025° (ca 250 m)</td>
</tr>
<tr>
<td><strong>Latency time</strong></td>
<td>&lt; 1 day</td>
<td>&lt; 1 day</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Status</strong></th>
<th>Pan-European</th>
<th>Alpine</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensor</strong></td>
<td>MODIS (Backup: VIISR, Future: Sentinel-3)</td>
<td>MODIS (Backup: VIISR, Future: Sentinel-3)</td>
</tr>
<tr>
<td><strong>Uncertainty information</strong></td>
<td>Unbiased RMSE provided per pixel for each daily product, validation with snow maps from high and very high resolution optical satellite data</td>
<td>Periodic validation with snow maps from high resolution optical satellite data</td>
</tr>
<tr>
<td><strong>Archive</strong></td>
<td>Daily snow maps from 2000 – present</td>
<td>Daily snow maps from 01/10/2012 – present</td>
</tr>
<tr>
<td><strong>Processing status</strong></td>
<td>Fully operational in NRT</td>
<td>Fully operational in NRT</td>
</tr>
</tbody>
</table>

*Products are accessible through the CryoLand GeoPortal: [http://www.cryoland.eu](http://www.cryoland.eu)*

*Images: CryoLand pan-European FSC product, 4/3/2013*
Summary of status and ongoing work for SNOW products provided by ENVEO

- Existing processing lines adapted/improved for using Sentinel data as input (*ongoing*)
- Testing processing lines for snow product generation using archived satellite data with similar characteristics (*ongoing*)
- Implementation of tools for processing of Sentinel-1 data at ENVEO (*completed*)
- Improving algorithm for wet snow cover mapping using Sentinel-1 data (*ongoing*)
- Implementation of processing line for fractional snow cover mapping using VIIRS data as input (backup solution in case Terra MODIS fails, *ongoing*)
- Existing NRT services for daily Pan-European and Regional Fractional Snow Cover products based on MODIS data (future: Sentinel-3) are continuously running
• **Snow products:**
  – Weekly Regional **Wet Snow Cover Maps** using multi-temporal **Sentinel-1 IWS data**
  – Daily Regional & Pan-European **Fractional Snow Cover Maps** using synergistic **Sentinel-3 SLSTR/OLCI data**

• **Glacier products:**
  – **Glacier ice surface velocity** from **Sentinel-1 IWS data** (from crossing orbits (asc/desc)) using Interferometry or Offset Tracking
  – **Glacier outlines** from **Sentinel-2 MSI data**
  – **Snow and ice areas on glaciers** from **Sentinel-2 MSI** (glacier facies) and **Sentinel-1 IWS data** (wet snow cover on glaciers)
### Glacier Products Specifications

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</tr>
</thead>
<tbody>
<tr>
<td>Ice Surface Velocity</td>
<td><em>Sentinel-1</em></td>
<td>Geographic / WGS84</td>
<td>Selected glaciers</td>
<td>5 m - 20 m</td>
<td>Seasonally / Annually</td>
<td>TBD</td>
<td>&lt; 3 months</td>
<td>Raster (GeoTIFF, netCDF)</td>
</tr>
<tr>
<td>Glacier Outlines / Area</td>
<td><em>Sentinel-2</em></td>
<td>Geographic / WGS84</td>
<td>Selected regions</td>
<td>10 m</td>
<td>Annually</td>
<td>TBD</td>
<td>&lt; 3 months</td>
<td>Vector (Shapefile, GLIMS Standards)</td>
</tr>
<tr>
<td>Snow / Ice Areas on Glaciers</td>
<td><em>Sentinel-2</em></td>
<td>Geographic / WGS84</td>
<td>Selected glaciers</td>
<td>10 m</td>
<td>Seasonally / Annually</td>
<td>TBD</td>
<td>&lt; 3 months</td>
<td>Raster (GeoTIFF), Vector (Shapefile, GLIMS Standards)</td>
</tr>
</tbody>
</table>
Greenland Ice Sheet
Sentinel-1 Ice Velocity Map 2015

$v_E$, $v_N$, $v_dz$, 250 m pixel spacing
Main Period: Jan-March 2015
> 800 slices  > 30000 bursts
Method: Offset tracking

Nagler, et al.,
Rem. Sens. 2015
Sentinel-1 Ice Surface Velocity & Comparison to TSX and PALSAR

S1 3-15 Jan 2015
12 days

TSX, Dec-Feb 2015
11 / 22 days

PALSAR, Dec 2009,
46 days

PALSAR, Aug 2008
46 days
Preliminary tests for generation of glacier products from Sentinel-2 data

A scene acquired on 13 August 2015 (during commissioning phase) over the Hohe Tauern, Austria, was used for preliminary testing the processing lines for generating glacier outlines and snow and ice areas on glaciers.

**ENVEO was invited as expert at the Sentinel-2 Expert Meeting at ESA in Sept 2015.**

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**Glacier outlines**

Thresholds applied on NDSI, Band 2, Band 8 & Ratio B2/B4

**Snow/ice areas on glaciers**

Threshold applied on Band 8 within glacier outlines (AGI99)
Test sites for mapping glacier parameters from Sentinel-2 scene of 13 August 2015

RGB 432 composites of S2A scene:
2 test sites selected

Venedigergruppe, Austria

Glocknergruppe, Austria
Preliminary results of glacier area mapping test, overlaid with glacier outlines from Austrian Glacier Inventory of 1999 (red) (thresholds applied on NDSI, Band 2, Band 8 & Ratio B2/B4)

Venedigergruppe, Austria

Glocknergruppe, Austria
Mapping snow/ice areas on glaciers from Sentinel-2 scene of 13 August 2015

B8 ≥ 0.42

Venedigergruppe, Austria
Summary of status and ongoing work for GLACIER products provided by ENVEO

- Existing processing lines adapted/improved for using Sentinel data as input (ongoing)
- Implementation of tools for processing of Sentinel-1 data at ENVEO (completed)
- Generation of ice velocity maps from Sentinel-1 data (ongoing)
- Implementation of tools for processing Sentinel-2 data at ENVEO (ongoing)
- Testing and improving of processing lines for generation of glacier products from Sentinel-2 images acquired over the Alps during the commissioning phase (in completion)
ENVEO’s planning for winter/spring 2015/16

Snow products:
• Pre-operational generation of wet snow cover maps for Alpine region (planned for melting season 2016)
• Testing processing lines for high resolution snow maps from Sentinel-2 MSI data
• Testing of processing line for FSC maps from Sentinel-3 data (access to S3 data during spring 2016 needed)

Glacier products:
• Further adaptations/improvements of processing lines for glacier products from Sentinel-1/-2 data
• Generation of demonstration glacier products from Sentinel-1/-2 data for selected areas of interest identified by users
• Further investigating of synergy of Sentinel-1 and Sentinel-2 for retrieving glacier parameters planned