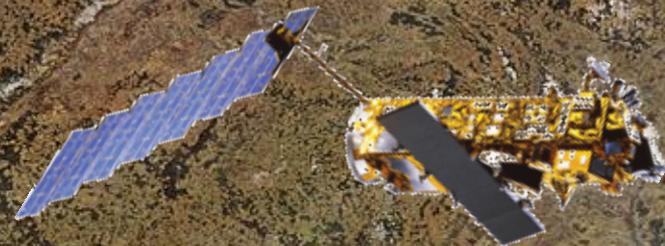


SENTINEL-1, 2,3 BASED SNOW AND GLACIER PRODUCTS BY ENVEO

presented by **Gabriele Bippus**

ENVEO IT GmbH
Innsbruck, Austria



- *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

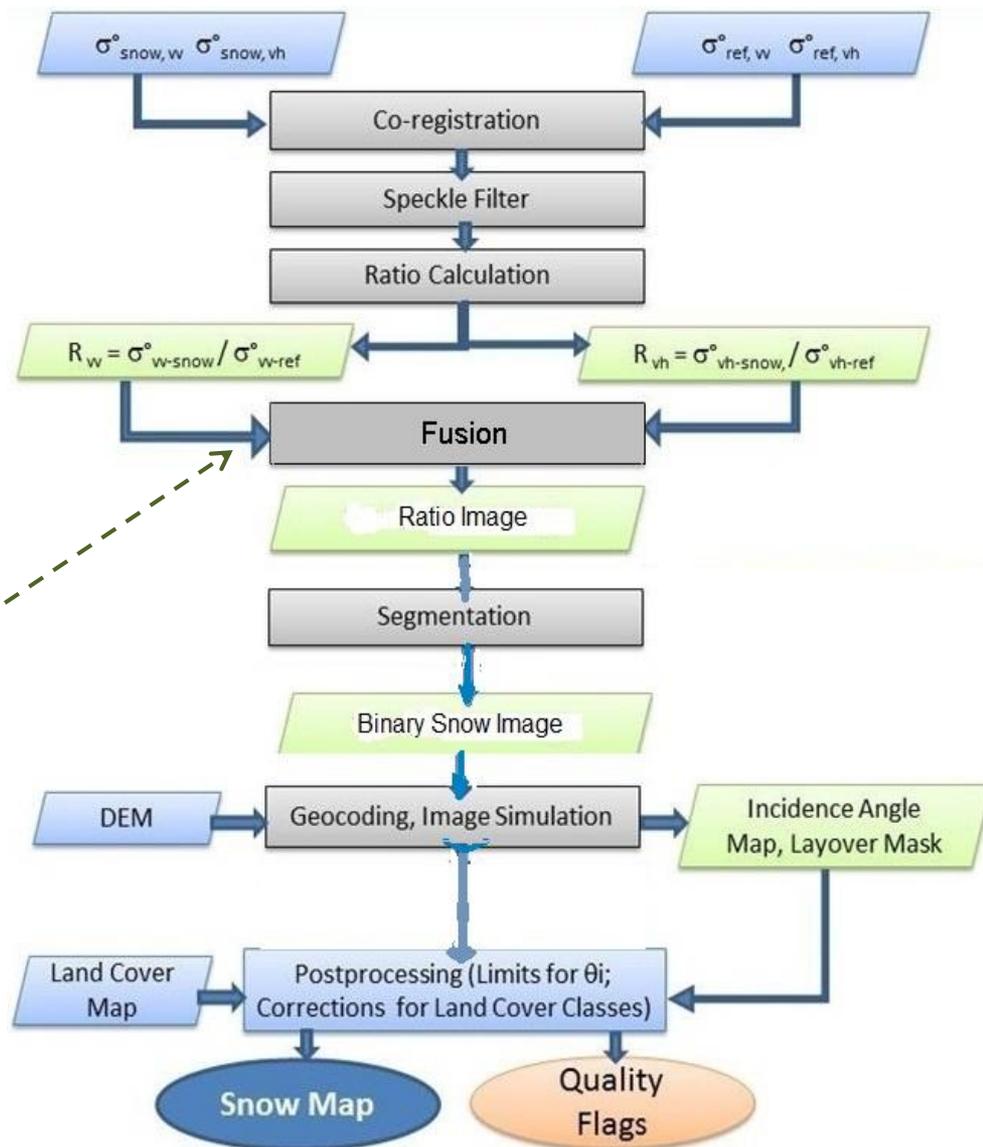
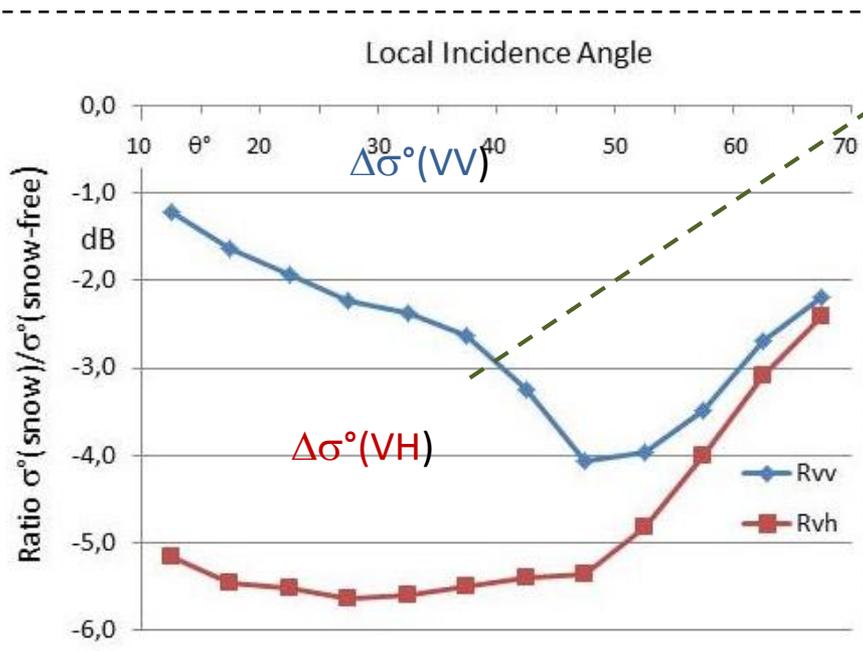
Products	Sensor	Projection / Datum	Spatial Coverage	Spatial Resolution	Temporal Resolution	Delivery period	Latency time	File Format
Wet (melting) Snow Area	<i>Sentinel-1</i>	Geographic / WGS84	Alps	100 m (50 m)	Weekly	Melting Season	< 1 day	Raster (GeoTIFF, netCDF)
Fractional Snow Cover	Sentinel-3 (MODIS, VIIRS)	Geographic / WGS84	72°N/11°W- 35°N/50°E	0.005 deg	Daily	Full Year	< 1 day	Raster (GeoTIFF, netCDF)
Fractional Snow Cover	Sentinel-3 (MODIS, VIIRS)	Geographic / WGS84, others (user defined)	Alpine region	0.003 deg	Daily	Full Year	< 1 day	Raster (GeoTIFF)

Retrieval of Snowmelt Area by S1 IW Mode Data

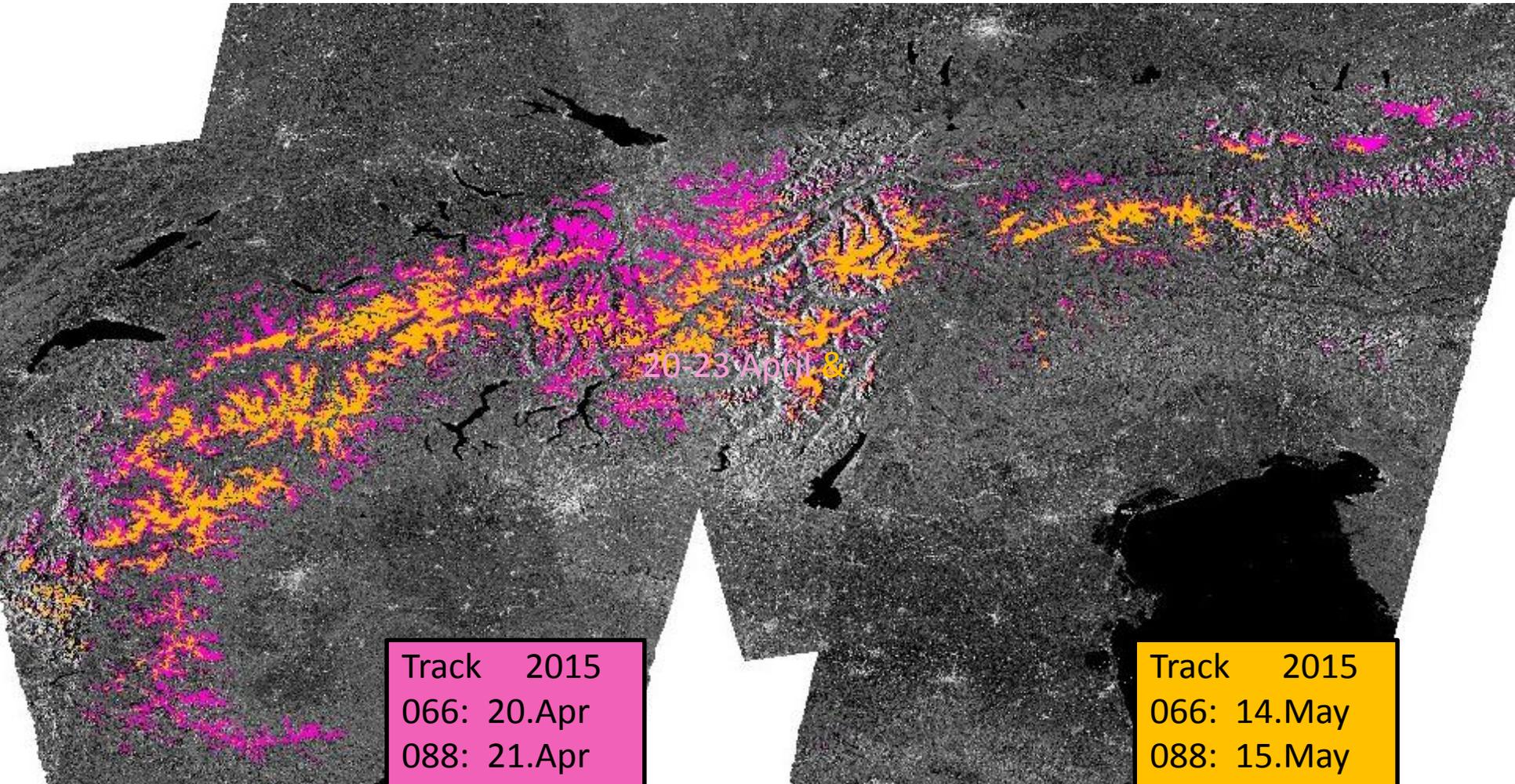
Flowline for Retrieval algorithm from Sentinel-1 **IW-mode data (SLC)**

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

σ° 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

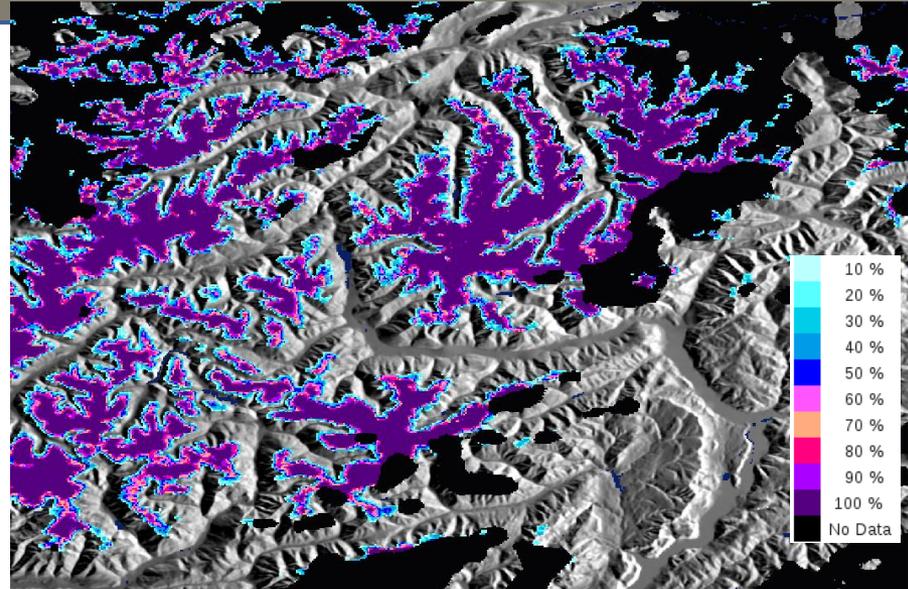
Track	2015
066	14.May
088	15.May
095	16 May
117	17 May



Comparison MODIS Snow Extent / S1 Snowmelt Area



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



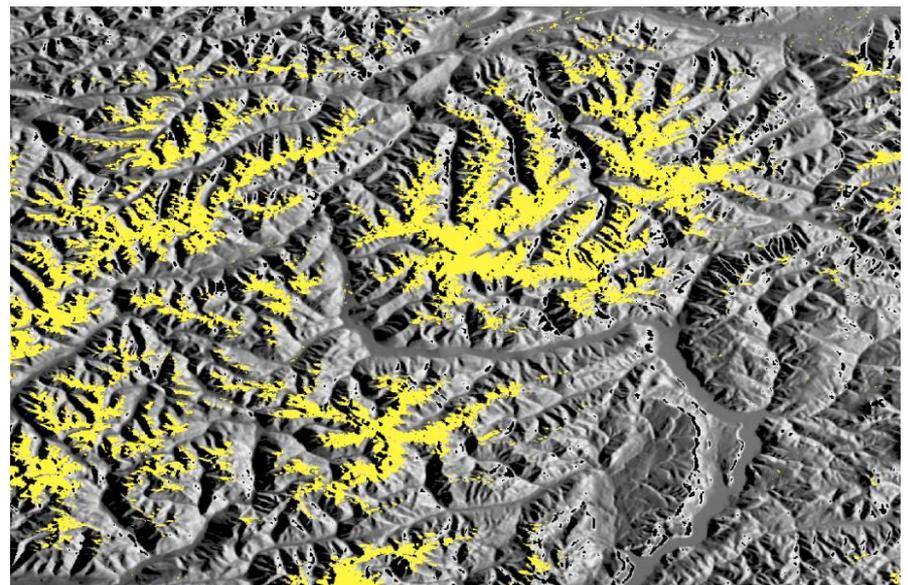
Confusion Matrix

S1

Overall=89.51

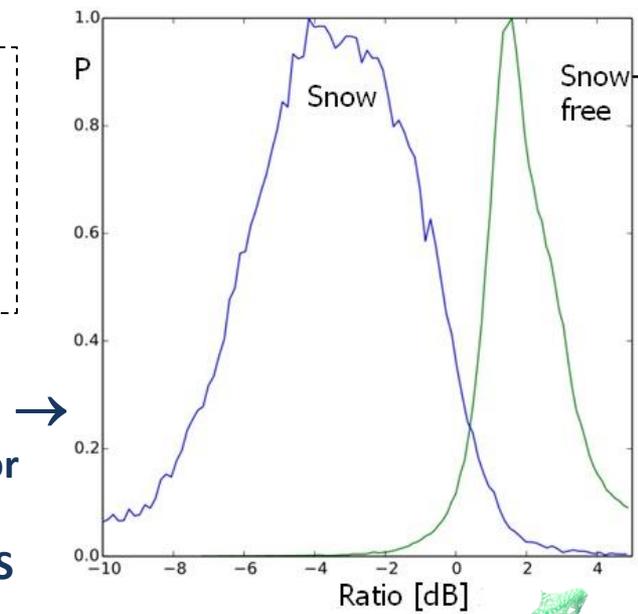
MODIS

	SC(S1)	SF(S1)
SC	83.96	16.04
SF	8.86	91.14



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

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



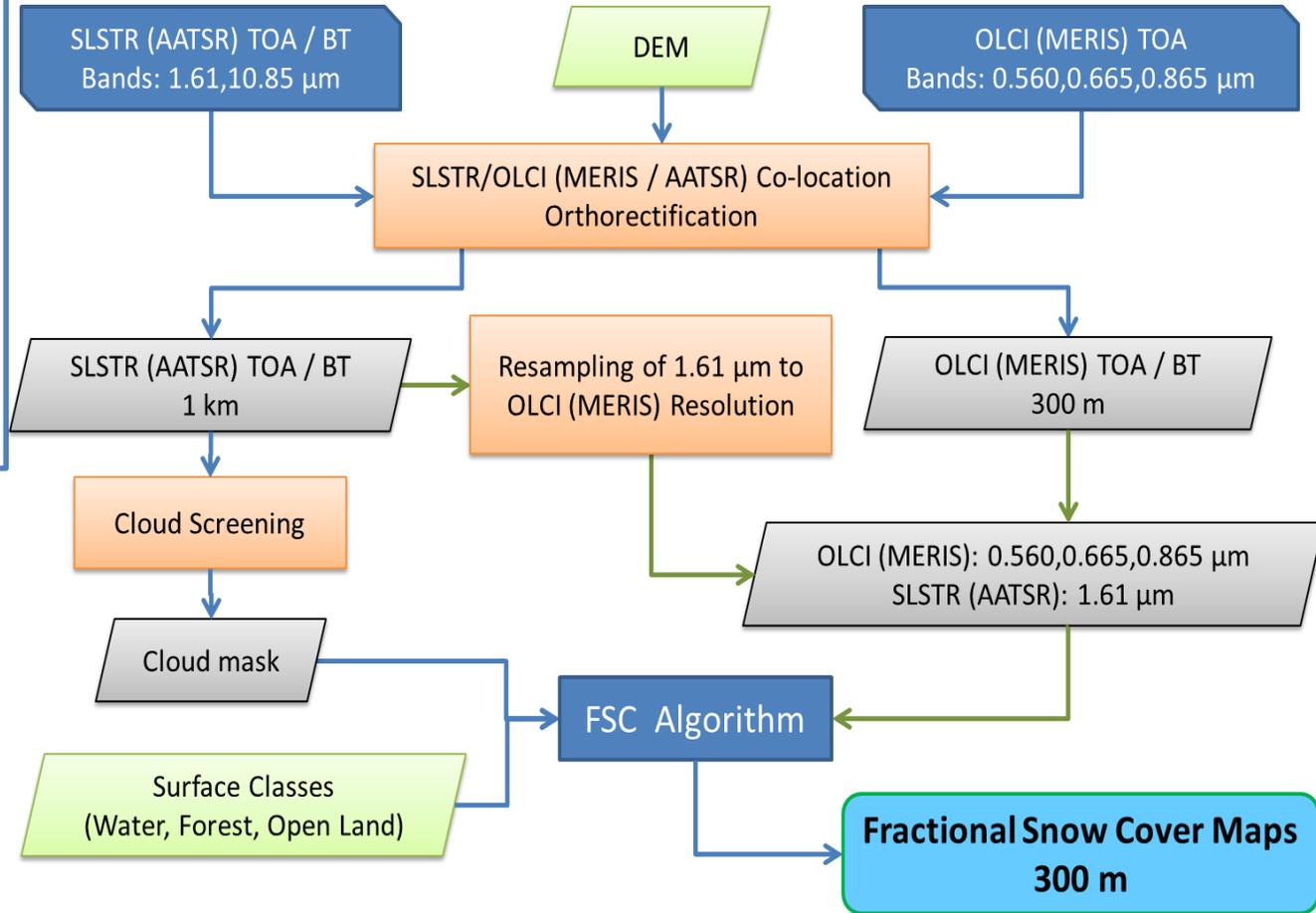
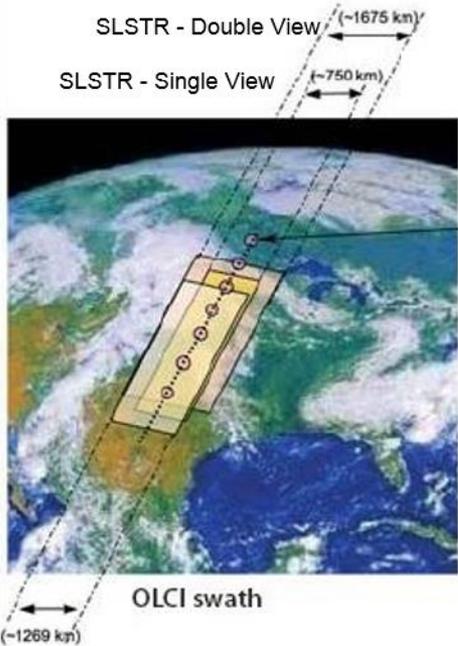
Concept for SENTINEL-3 Snow Mapping using SLSTR (AATSR) and OLCI (MERIS)

Sentinel-3:

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

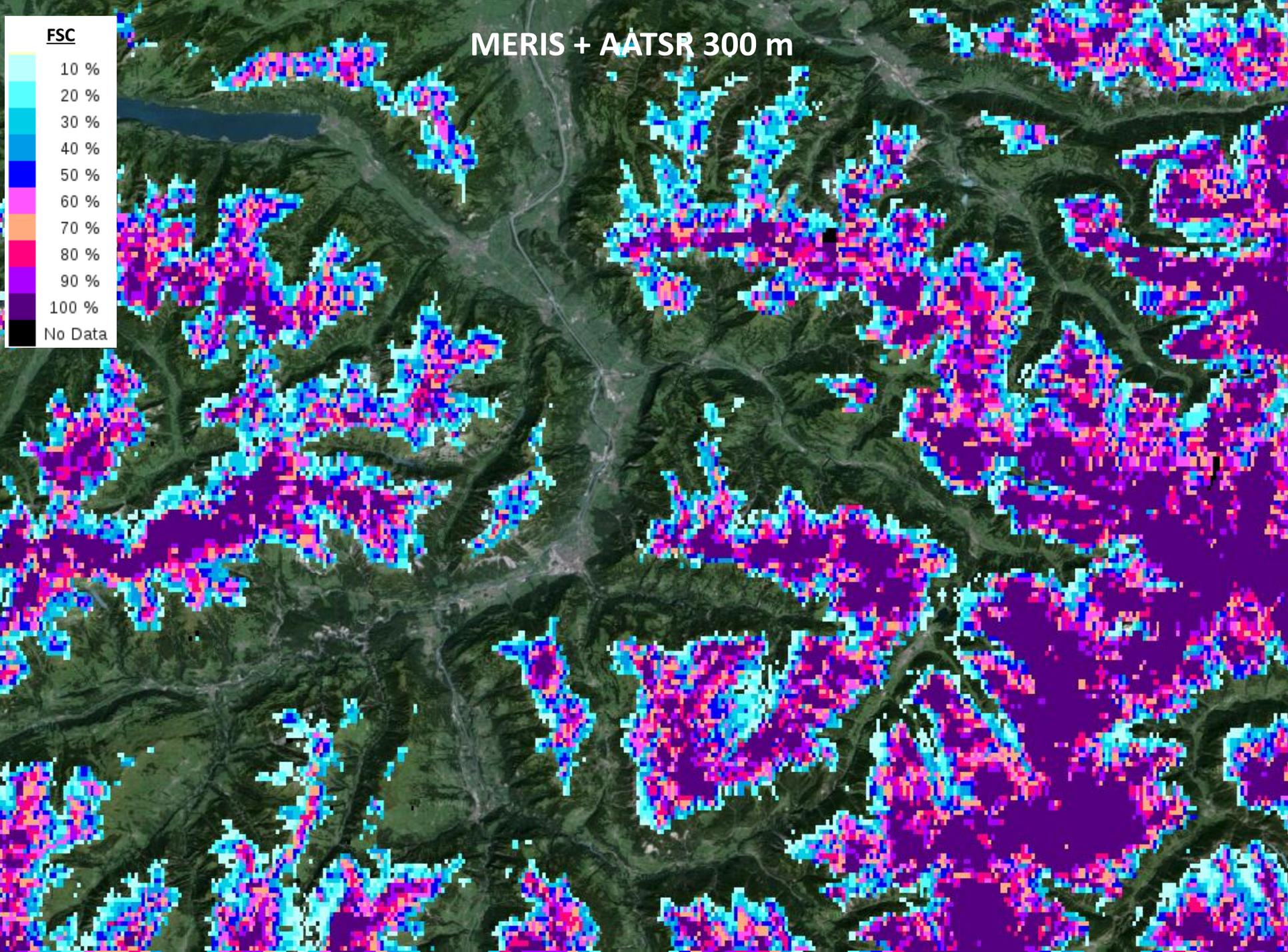
OLCI (follow on of MERIS):
0.4.-1.2 μm ; 300 m

Daily Global Coverage



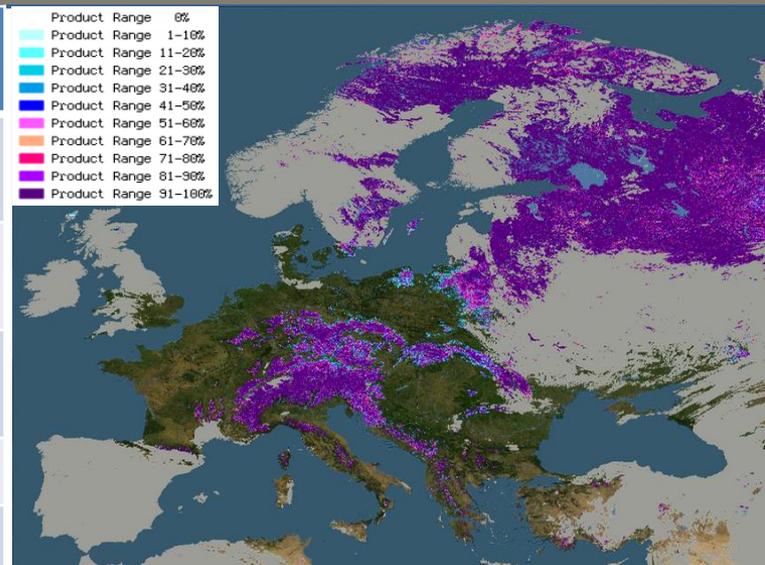
Fractional Snow Extent estimated using multi-spectral algorithm

MERIS + AATSR 300 m

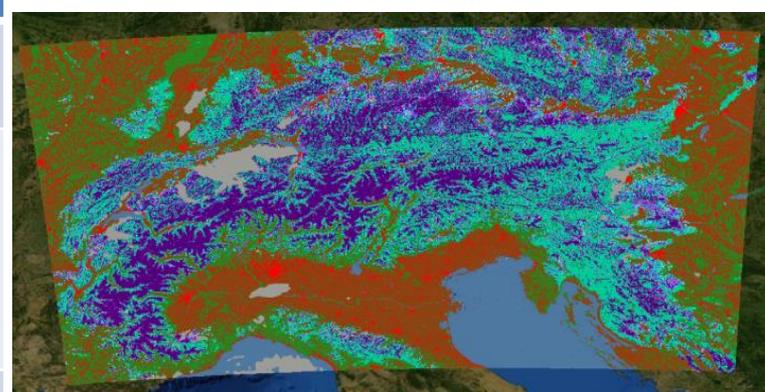


Current status of Pan-European & Alpine Fractional Snow Cover Products

Products Specifications	Pan-European	Alpine
Domain	72°N 11°W – 35°N 50°E	Full Alpine ridge and lowlands
Temporal resolution	1 day	1 day
Projection	LatLon/WGS84	LatLon / WGS84, or as requested by users
Pixel size	0.005° (ca 500 m)	0.0025° (ca 250 m)
Latency time	< 1 day	< 1 day
Status	Pan-European	Alpine
Sensor	MODIS (Backup: VIIRS, Future: <i>Sentinel-3</i>)	MODIS (Backup: VIIRS, Future: <i>Sentinel-3</i>)
Uncertainty information	Unbiased RMSE provided per pixel for each daily product, validation with snow maps from high and very high resolution optical satellite data	Periodic validation with snow maps from high resolution optical satellite data
Archive	Daily snow maps from 2000 – present	Daily snow maps from 01/10/2012 – present
Processing status	Fully operational in NRT	Fully operational in NRT



CryoLand pan-European FSC product, 4/3/2013



Operational version of the Alpine fractional snow cover map from Terra MODIS data, 4/3/2013

Products are accessible through the CryoLand GeoPortal: <http://www.cryoland.eu>

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

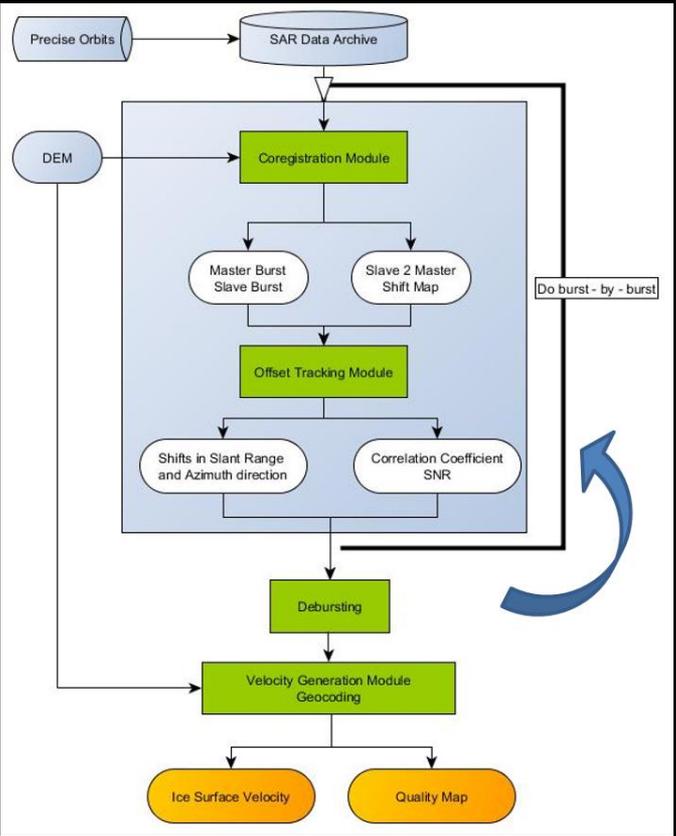
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 - **Glacier ice surface velocity** from *Sentinel-1 IWS* data (from crossing orbits (asc/desc)) using Interferometry or Offset Tracking
 - **Glacier outlines** from *Sentinel-2 MSI* data
 - **Snow and ice areas on glaciers** from *Sentinel-2 MSI*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

Glacier Products Specifications

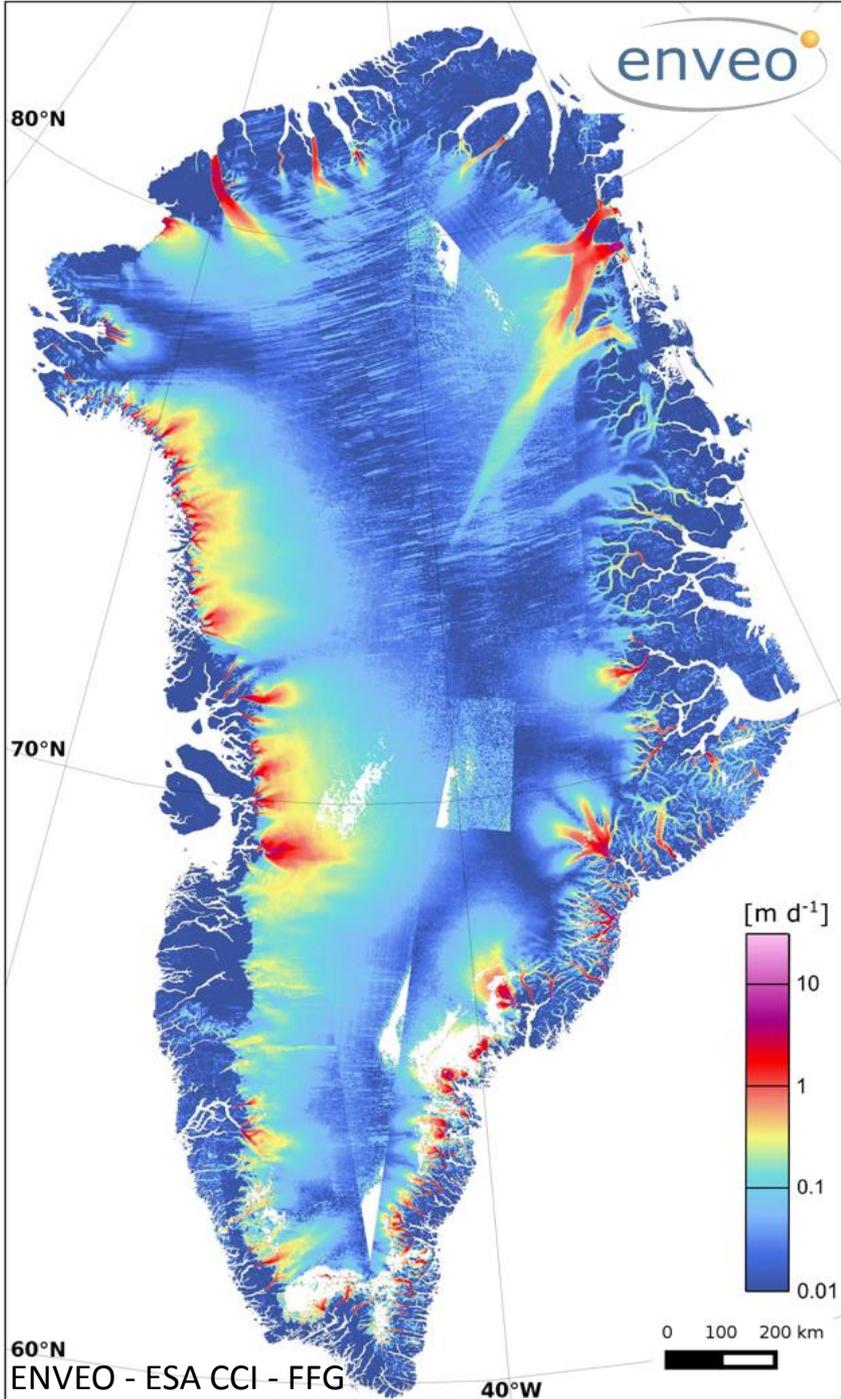
Products	Sensor	Projection / Datum	Spatial Coverage	Spatial Resolution	Temporal Resolution	Delivery period	Latency time	File Format
Ice Surface Velocity	<i>Sentinel-1</i>	Geographic / WGS84	Selected glaciers	5 m - 20 m	Seasonally / Annually	TBD	< 3 months	Raster (GeoTIFF, netCDF)
Glacier Outlines / Area	<i>Sentinel-2 (Landsat)</i>	Geographic / WGS84	Selected regions	10 m	Annually	TBD	< 3 months	Vector (Shapefile, GLIMS Standards)
Snow / Ice Areas on Glaciers	<i>Sentinel-2 (Landsat)</i>	Geographic / WGS84	Selected glaciers	10 m	Seasonally / Annually	TBD	< 3 months	Raster (GeoTIFF), Vector (Shapefile, GLIMS Standards)

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

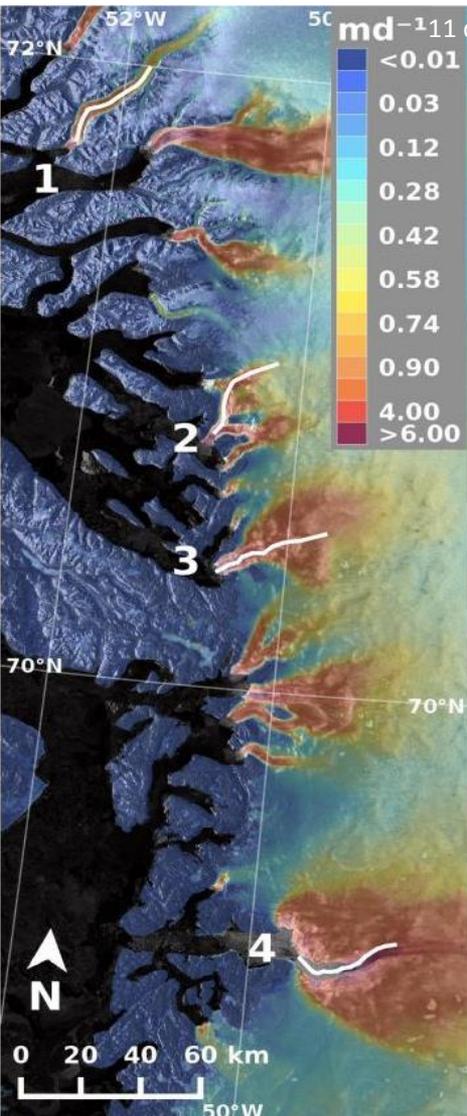


Nagler, et al.,
 Rem. Sens. 2015

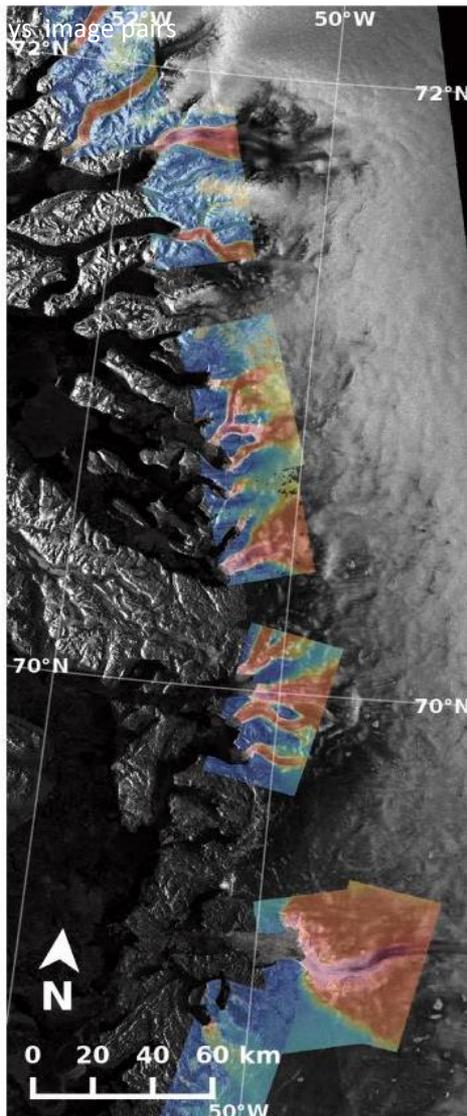


Sentinel-1 Ice Surface Velocity & Comparison to TSX and PALSAR

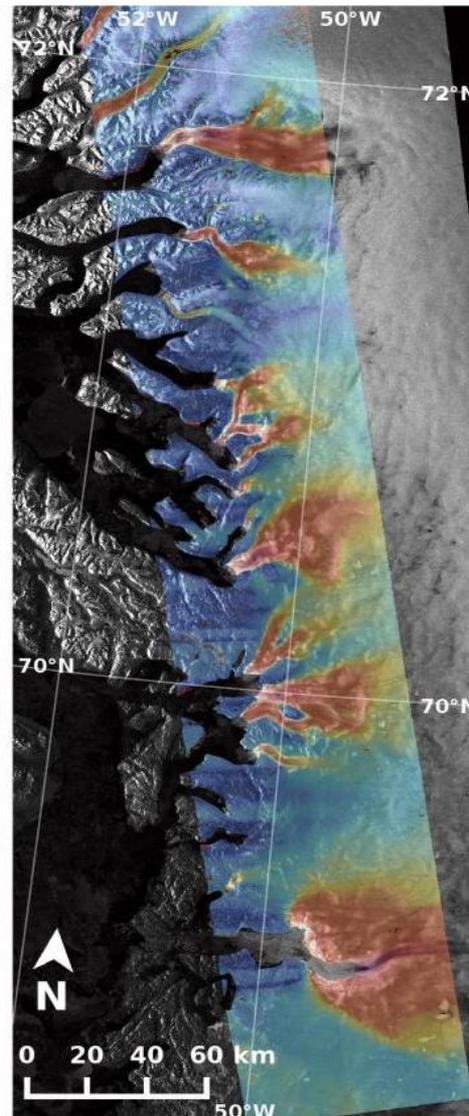
S1 3-15 Jan 2015
12 days



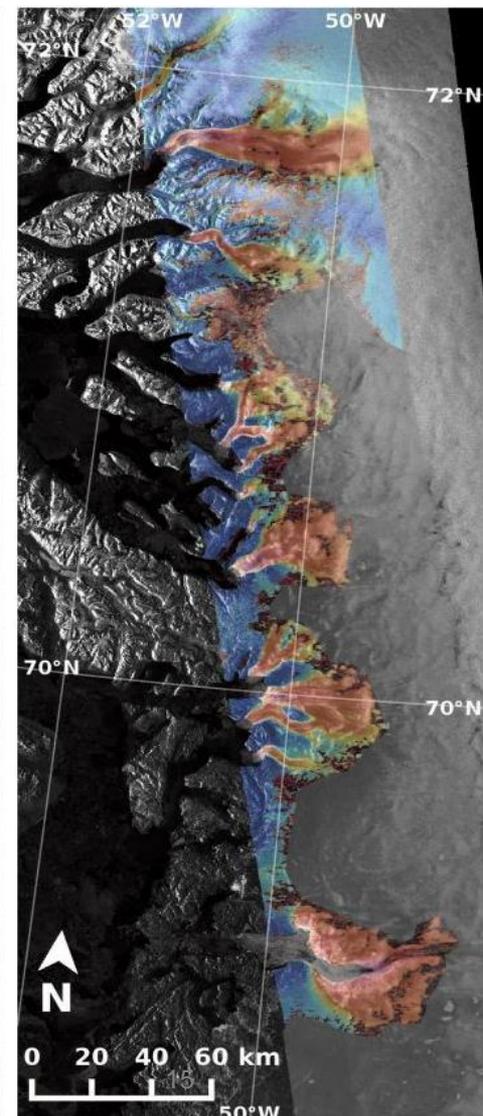
TSX, Dec-Feb 2015
11 / 22 days



PALSAR, Dec 2009,
46 days



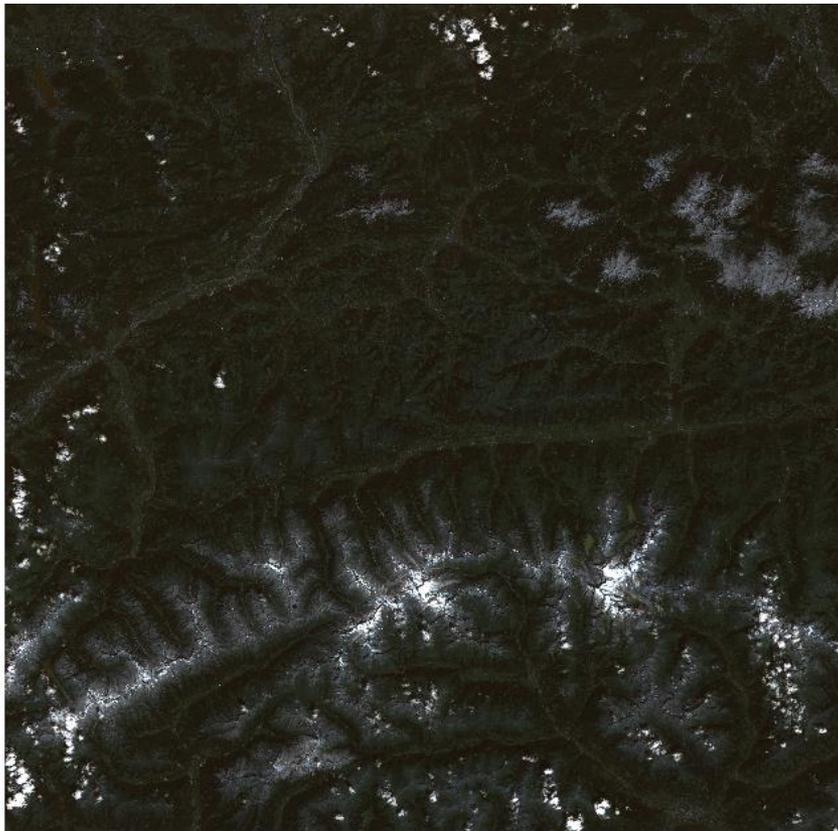
PALSAR, Aug 2008
46 days



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.

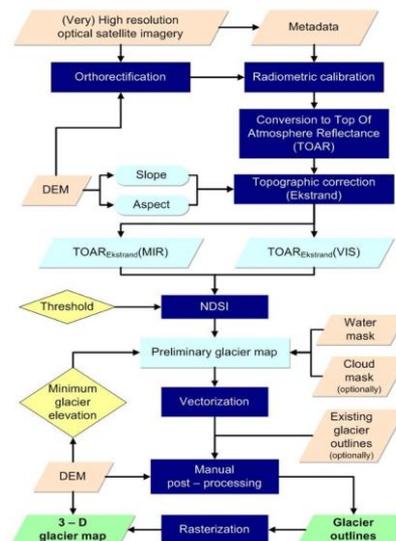
ENVEO was invited as expert at the Sentinel-2 Expert Meeting at ESA in Sept 2015.



Copernicus Sentinel Data 2015

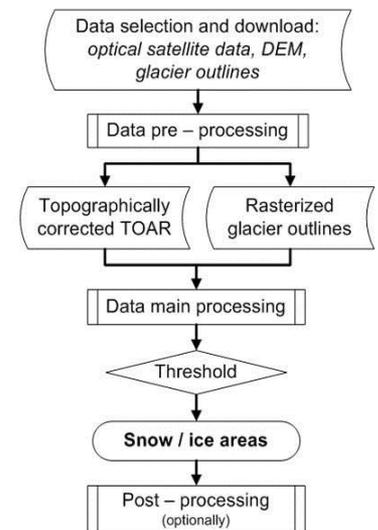
Glacier outlines

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



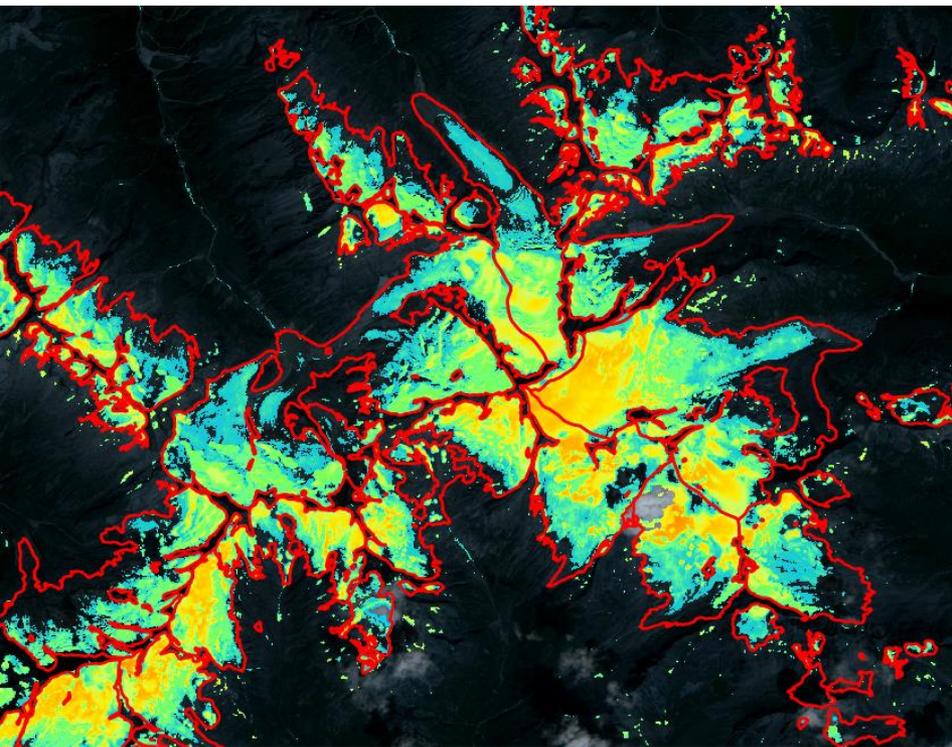
Venedigergruppe, Austria



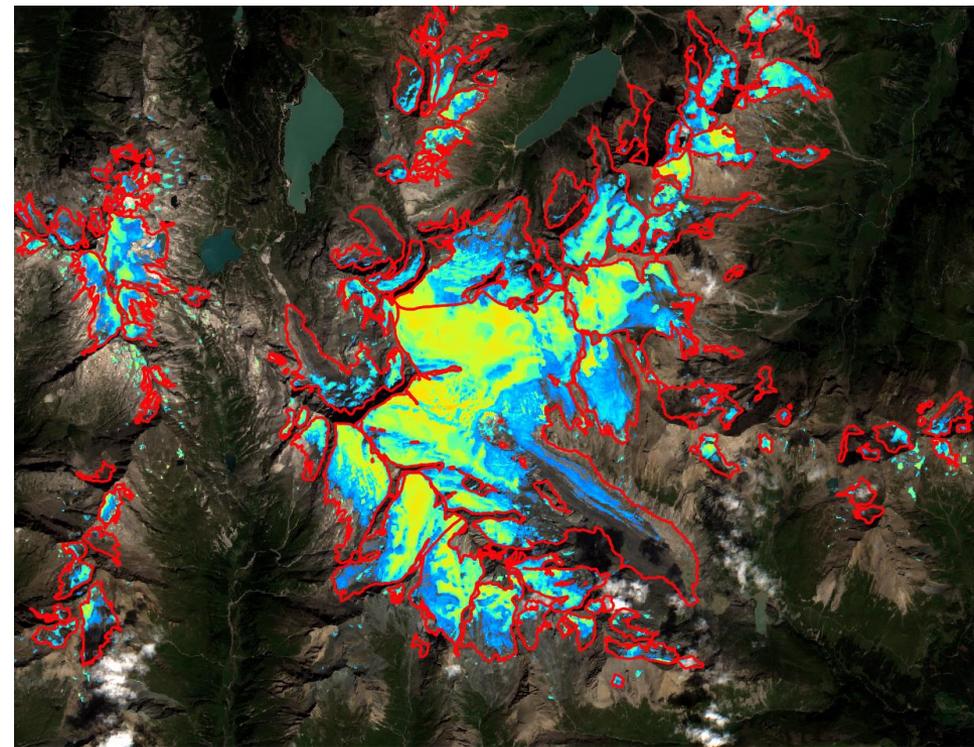
Glocknergruppe, Austria

Glacier outline mapping from Sentinel-2 scene of 13 August 2015

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)

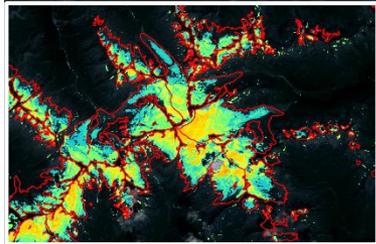


Venedigergruppe, Austria

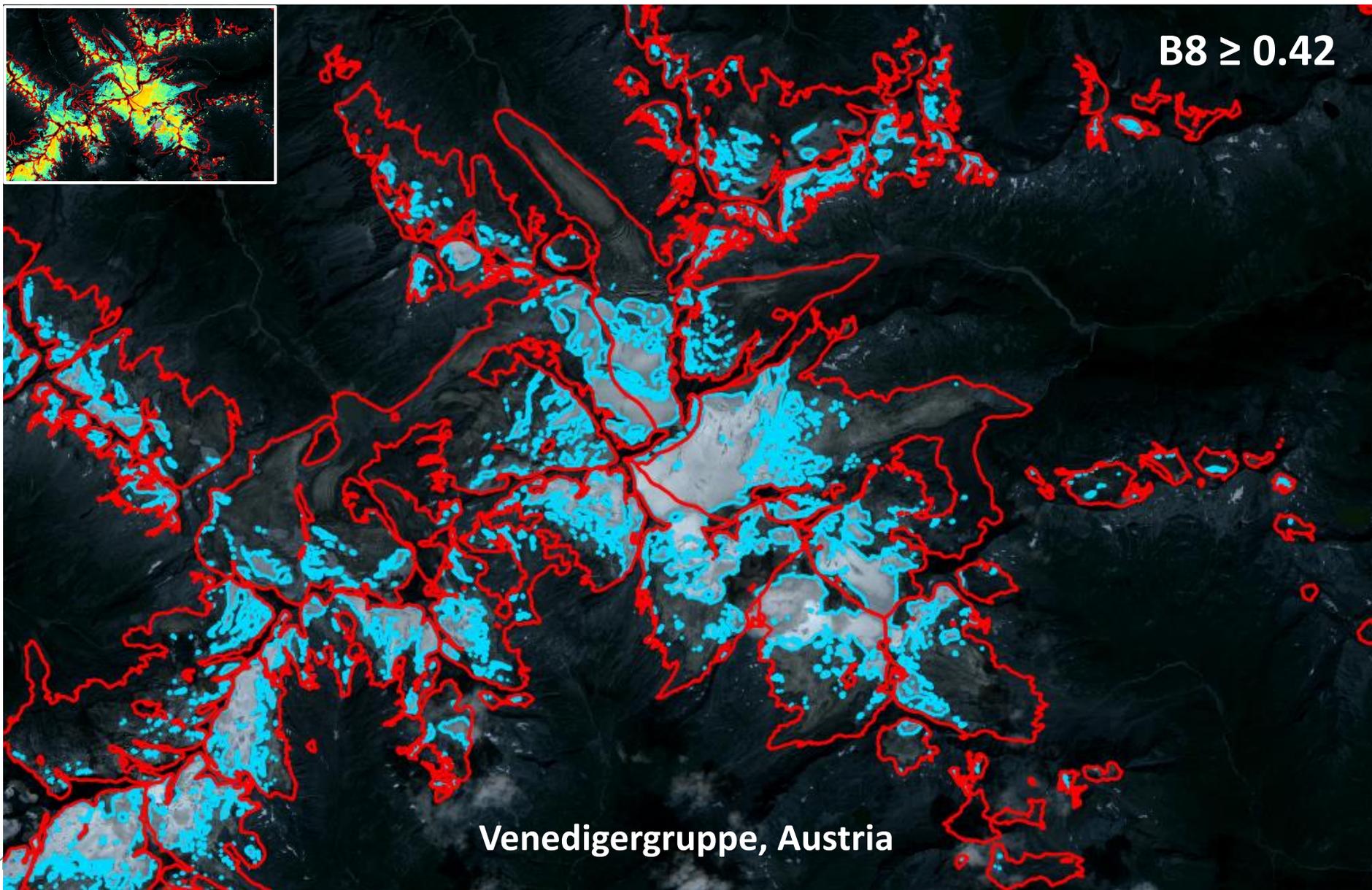


Glocknergruppe, Austria

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



B8 \geq 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*)



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