SnowBall

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SnowBall Project: Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective (2014 – 2016)

CHANGE-DETECTION BASED MAPPING OF AVALANCHES IN SENTINEL-1 IMAGES

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Detection of avalanches in remote sensing images

Satellites has a great potential for mapping of avalanches since it makes it possible to monitor large areas **fast** and **efficient**. We may:

- Monitor size and the frequency of avalanches in areas without settlements
- Provide an independent assessment of the risk of avalanches in areas of special interest
- Create statistics on where avalanches most likely occur, how large they are, and under which weather conditions they are triggered
    - Important in future planning of infrastructure

The Snowball project aims to develop algorithms for (semi)-automated detection of avalanches in high resolution Sentinel-1 images

Objectives

Main objective

Develop methodology supporting a future service providing hind-cast and real-time snow and avalanche information retrieved from earth observation data.

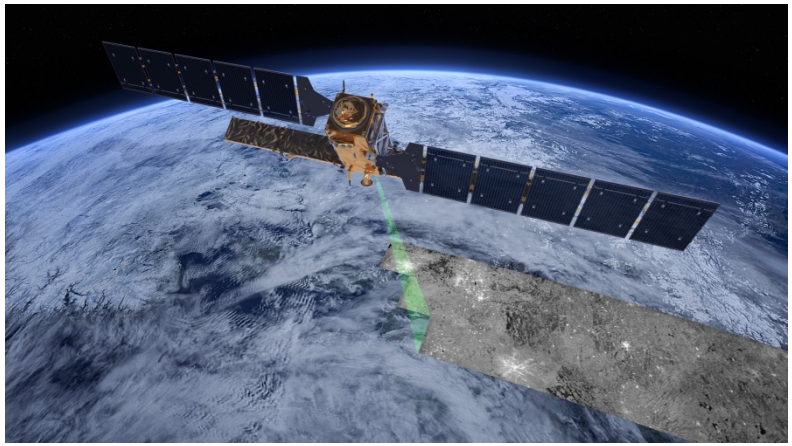
Sub-objectives

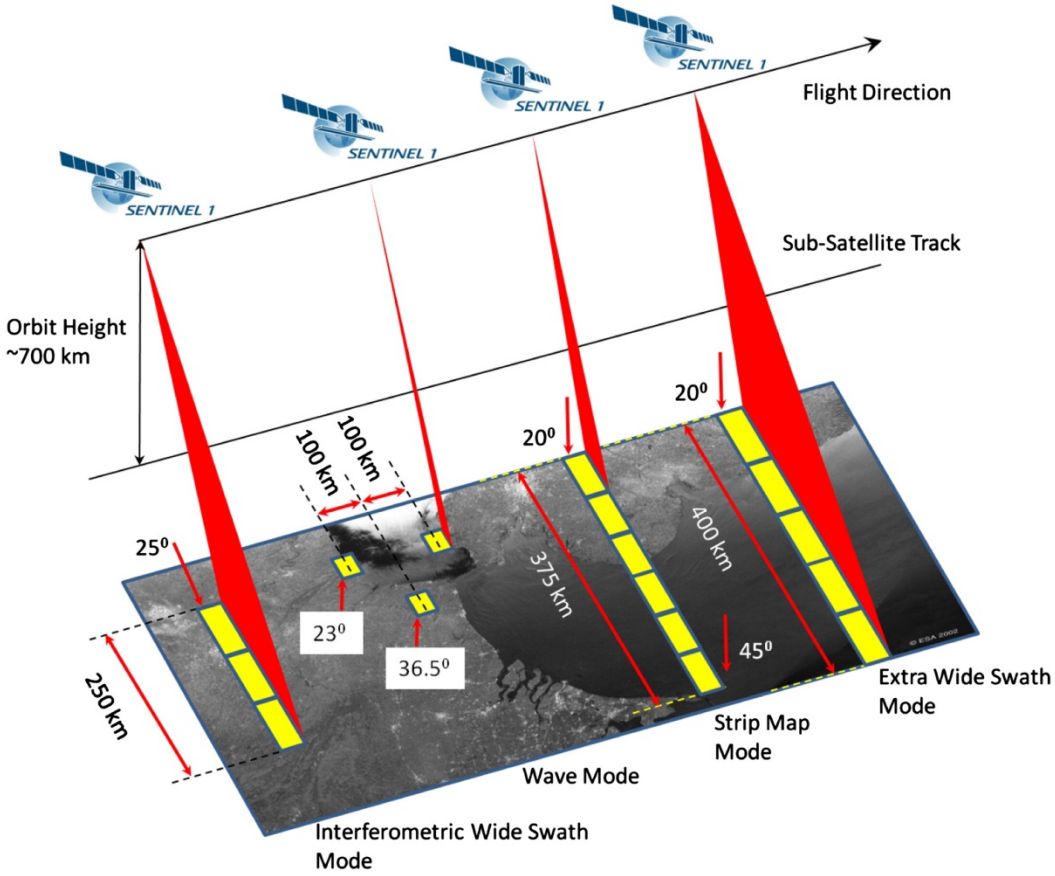
- Develop robust pattern recognition techniques to detect and map the outline of avalanches in VHR optical satellite data.
- Develop robust change-detection algorithms to detect changes in land and snow cover caused by avalanches in High Resolution (HR) satellite data.
- Create the avalanche inventory and the associated geodatabase regarding morphometric parameters and snow characteristics.
- Perform simulation of avalanche trajectories based on DEM's, release areas and friction parameters.
- Develop improved avalanche hazard assessment.

Synthetic aperture radar (SAR) imaging

SAR
Active sensor
Side looking

Sentinel-1
IW GRD mode: 10 m resolution
Repeat cycle: 6 days
Dual polarization (VV – VH)



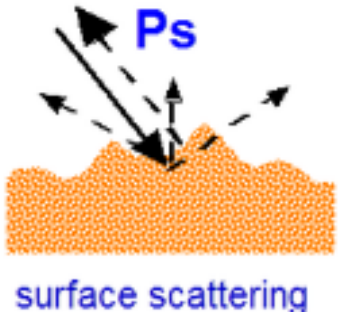


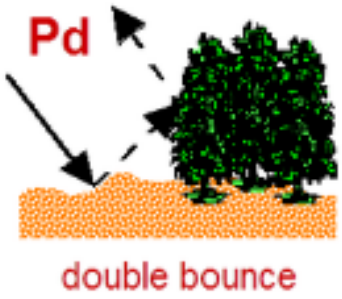
Synthetic aperture radar (SAR) imaging

Interaction between microwaves and Earth's surface

When microwaves strike a surface, the proportion of energy scattered back to the sensor depends on many factors:

- Physical factors such as the dielectric constant of the surface materials which also depends strongly on the moisture content
- Geometric factors such as surface roughness, slopes, orientation of the objects relative to the radar beam direction
- The types of land cover (soil, vegetation or man-made objects)
- Microwave frequency, polarization and incident angle

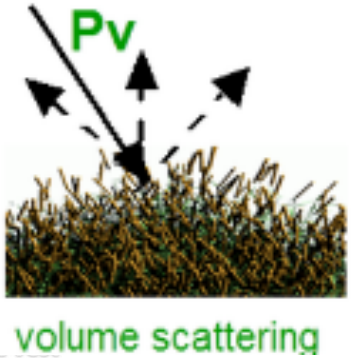




All-weather imaging

Due to the cloud penetrating property of microwave, SAR is able to acquire "cloud-free" images in all weather.

Being an active remote sensing device, it is also capable of night-time operation.



Hypothesis and approach

- Compacted rough snow of an avalanche has very high backscatter values (σ^0) compared to homogeneous snow cover and bare ground, even if the snow is wet (Wiesmann et al., 2001).

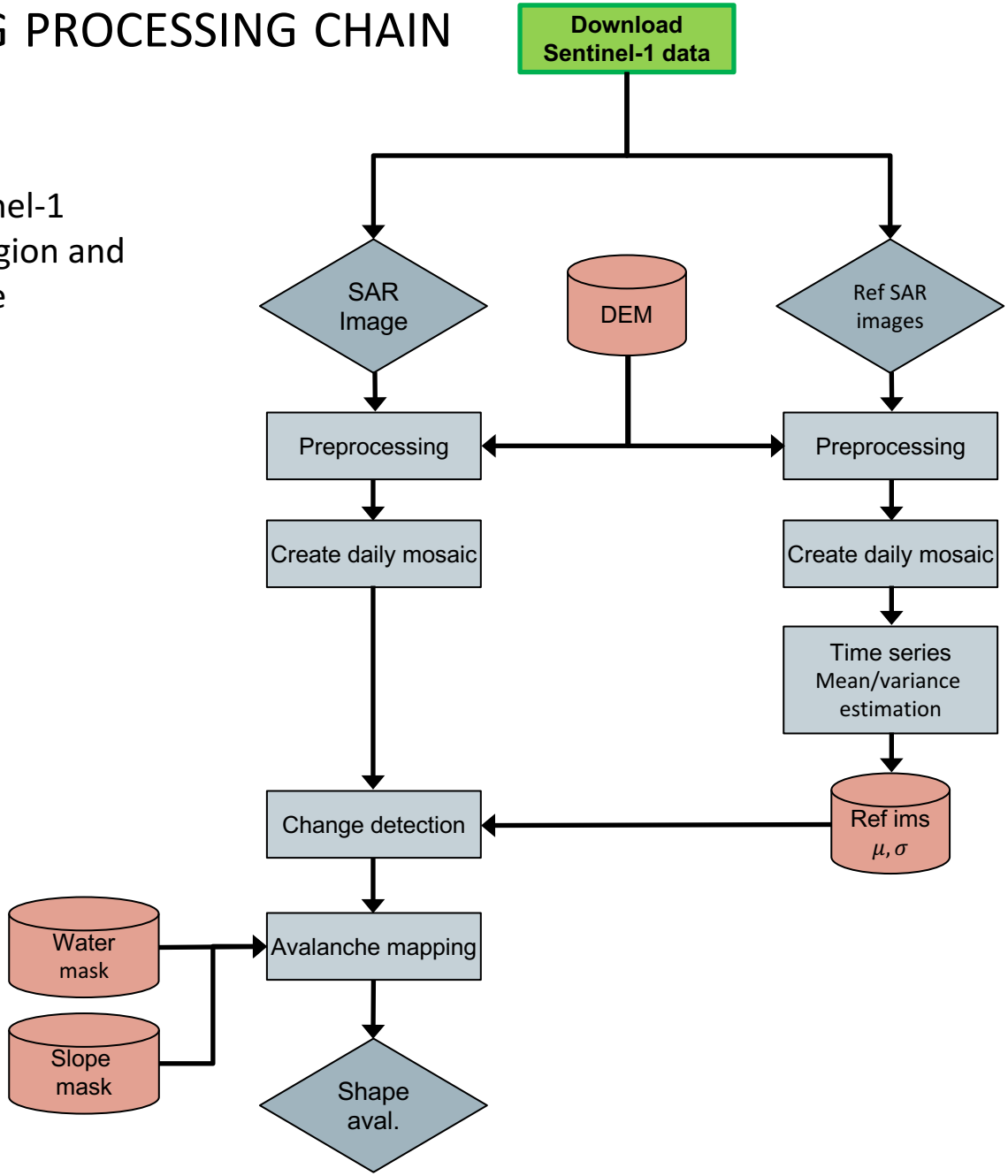
- As suggested by Wiesmann et al. (2001), the proposed algorithm is also based on multi-date SAR images.

- The underlying principle is a pixel-wise comparison of the backscatter intensities of two SAR images, an event image (the one with avalanches) and a reference image.

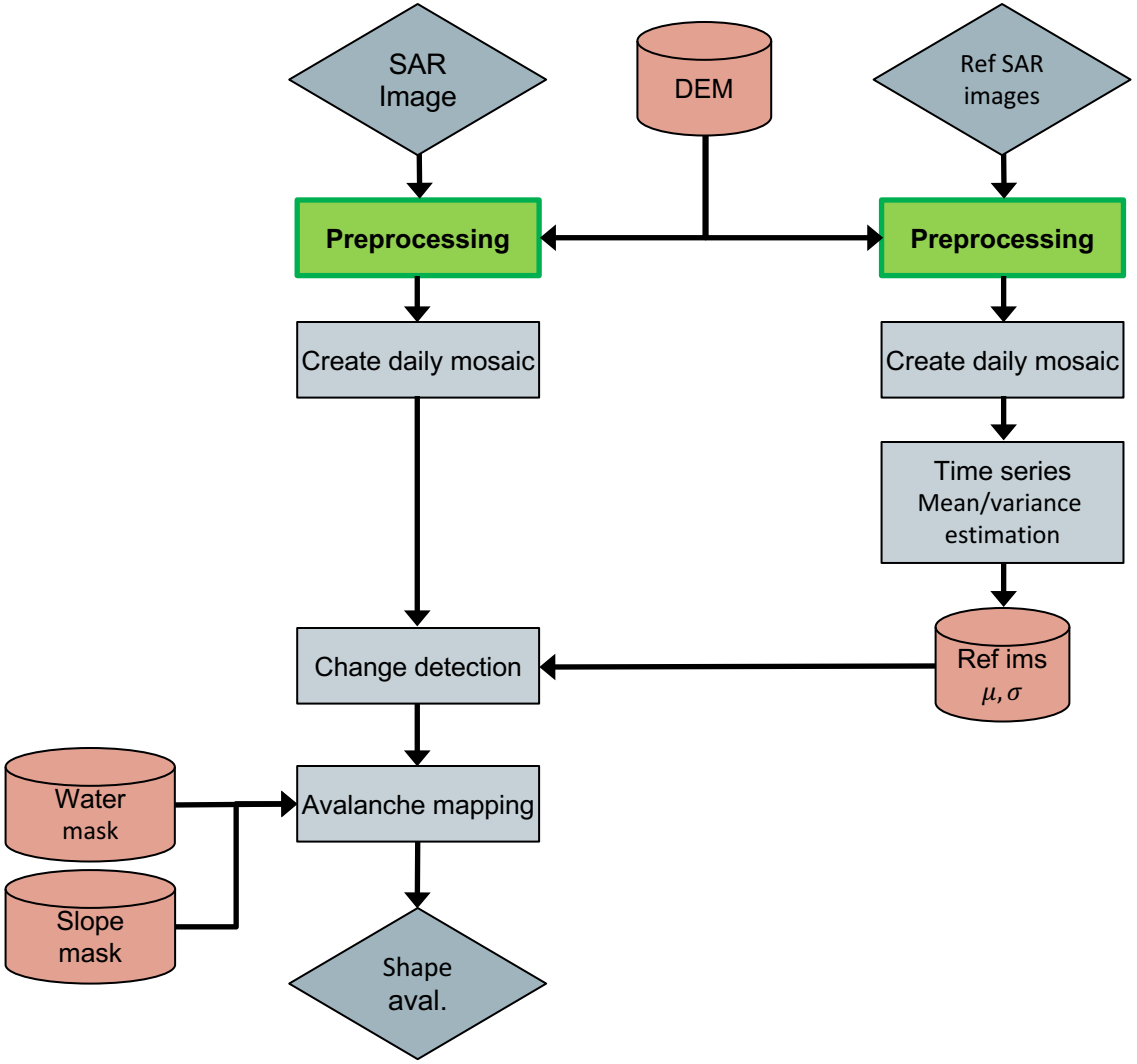
- The algorithm assumes that both the event image and the reference image need to have the same beam mode, pass direction and preferably, be in the same repeat cycle.

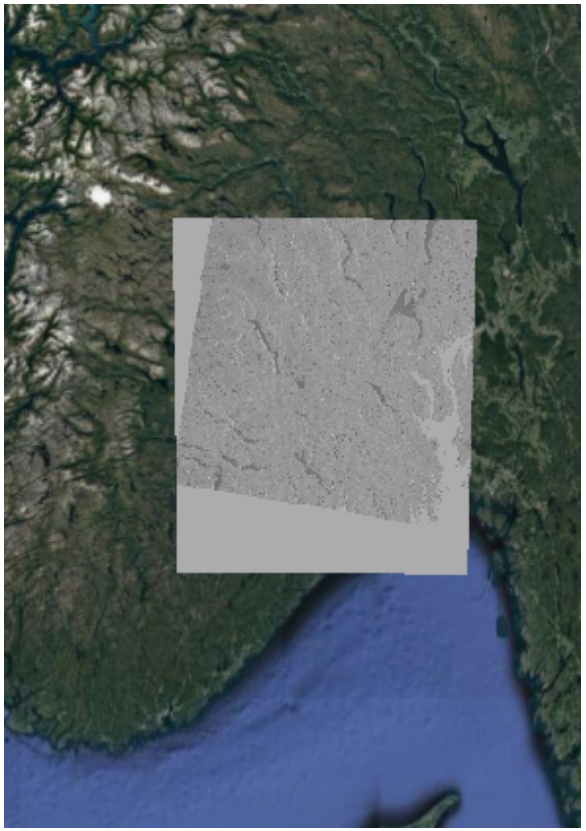
AVALANCHE MAPPING PROCESSING CHAIN

Module for downloading Sentinel-1 data. SAR images for a given region and dates are downloaded from the Copernicus Open Access Hub



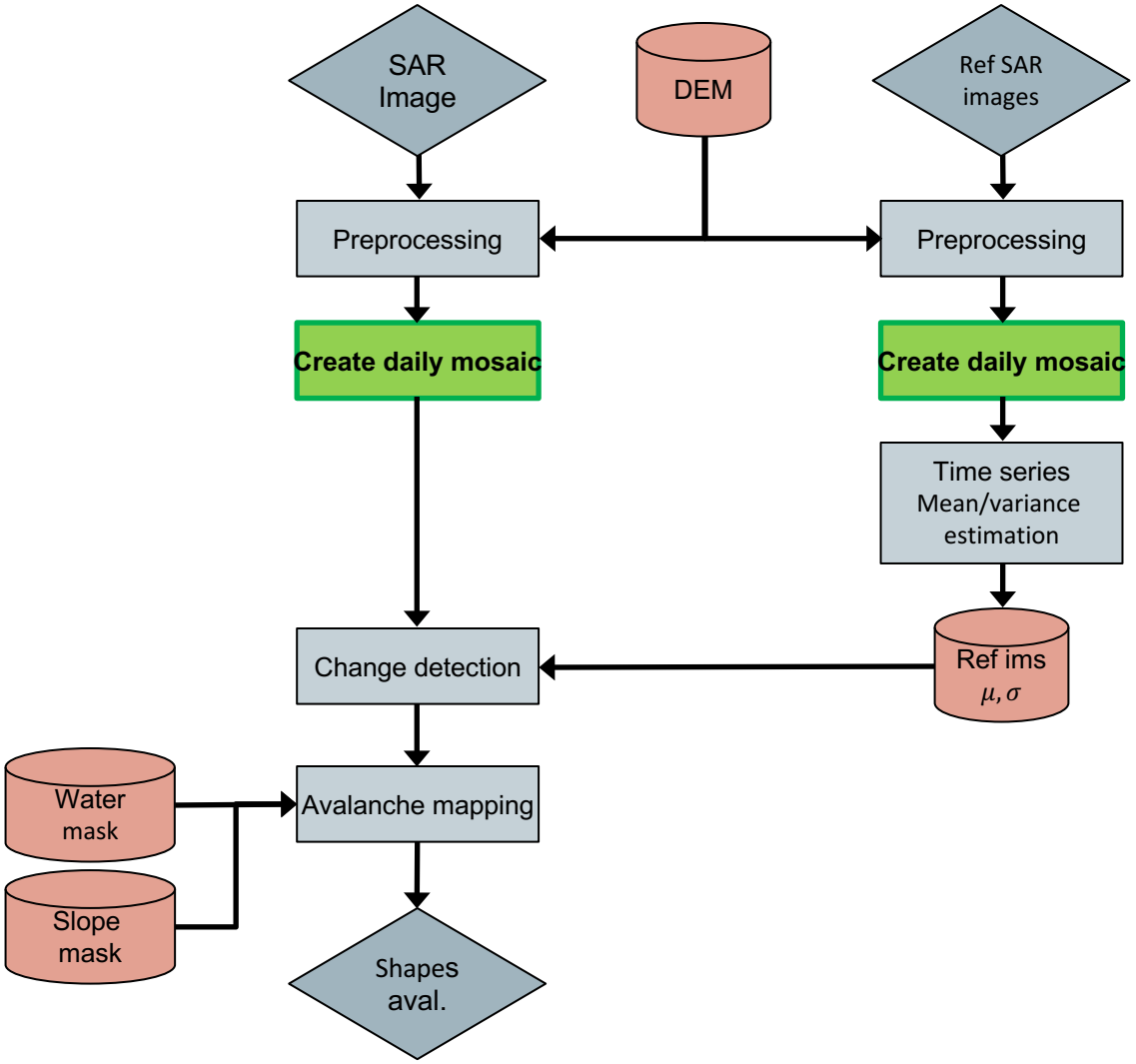
AVALANCHE MAPPING PROCESSING CHAIN

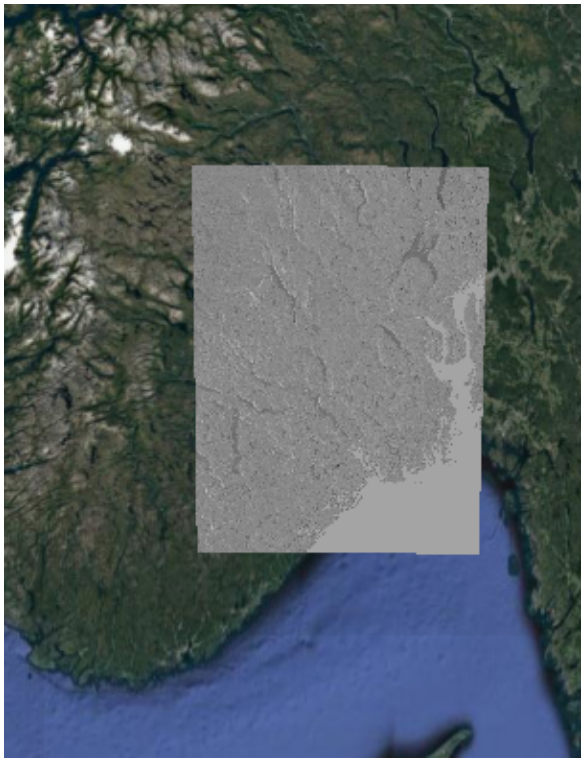




Module for calibration and geocoding of SAR images

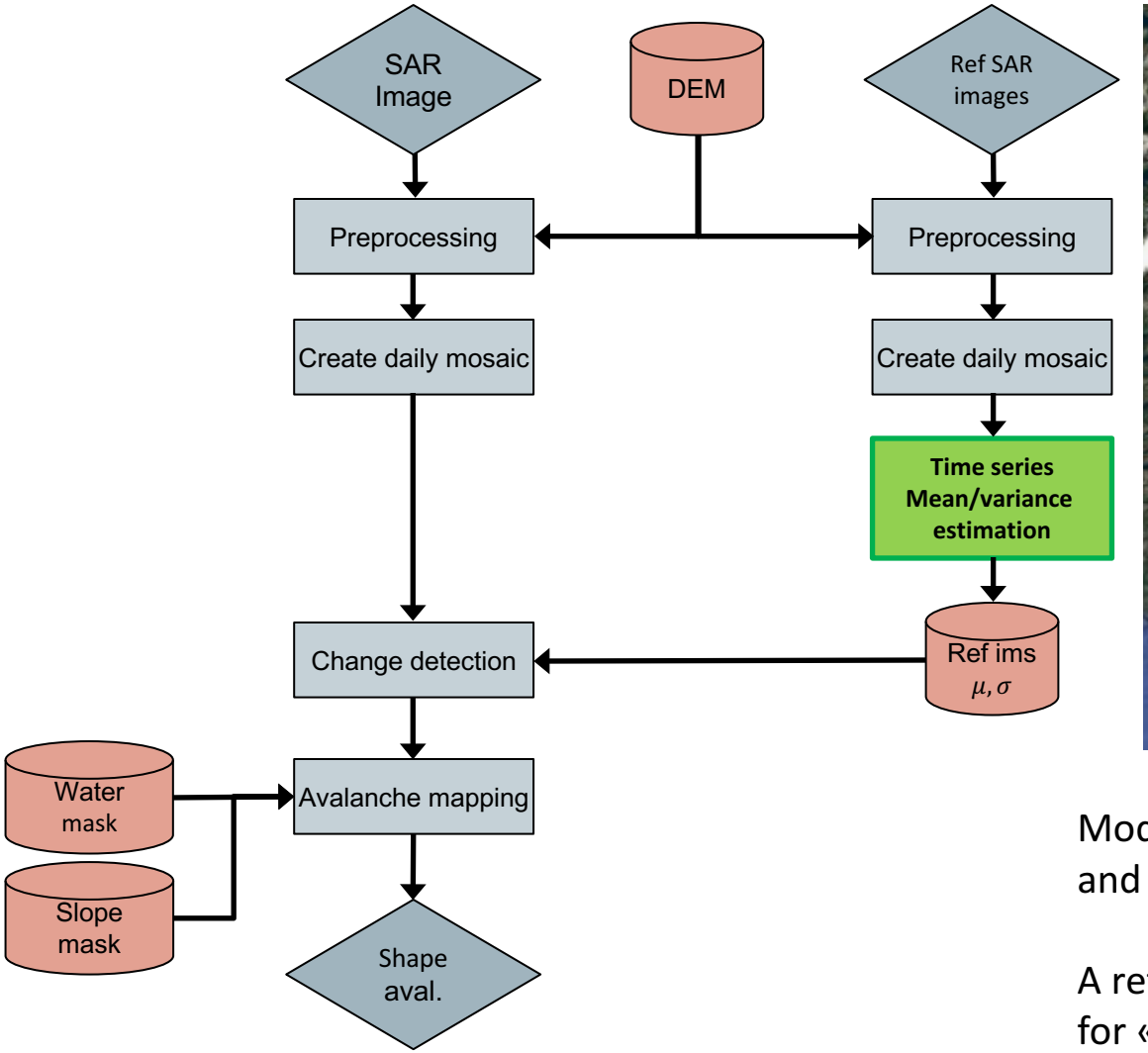
AVALANCHE MAPPING PROCESSING CHAIN

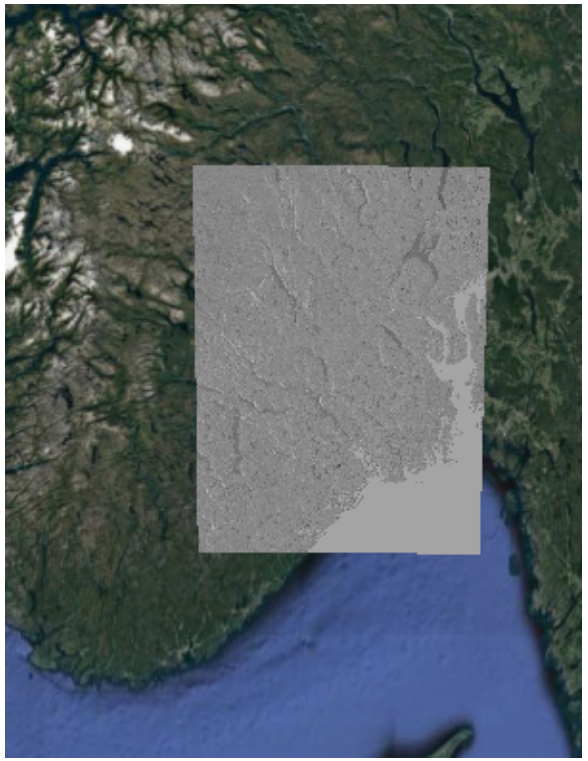




Module for mosaicking of SAR images corresponding to the region of interest.

AVALANCHE MAPPING PROCESSING CHAIN

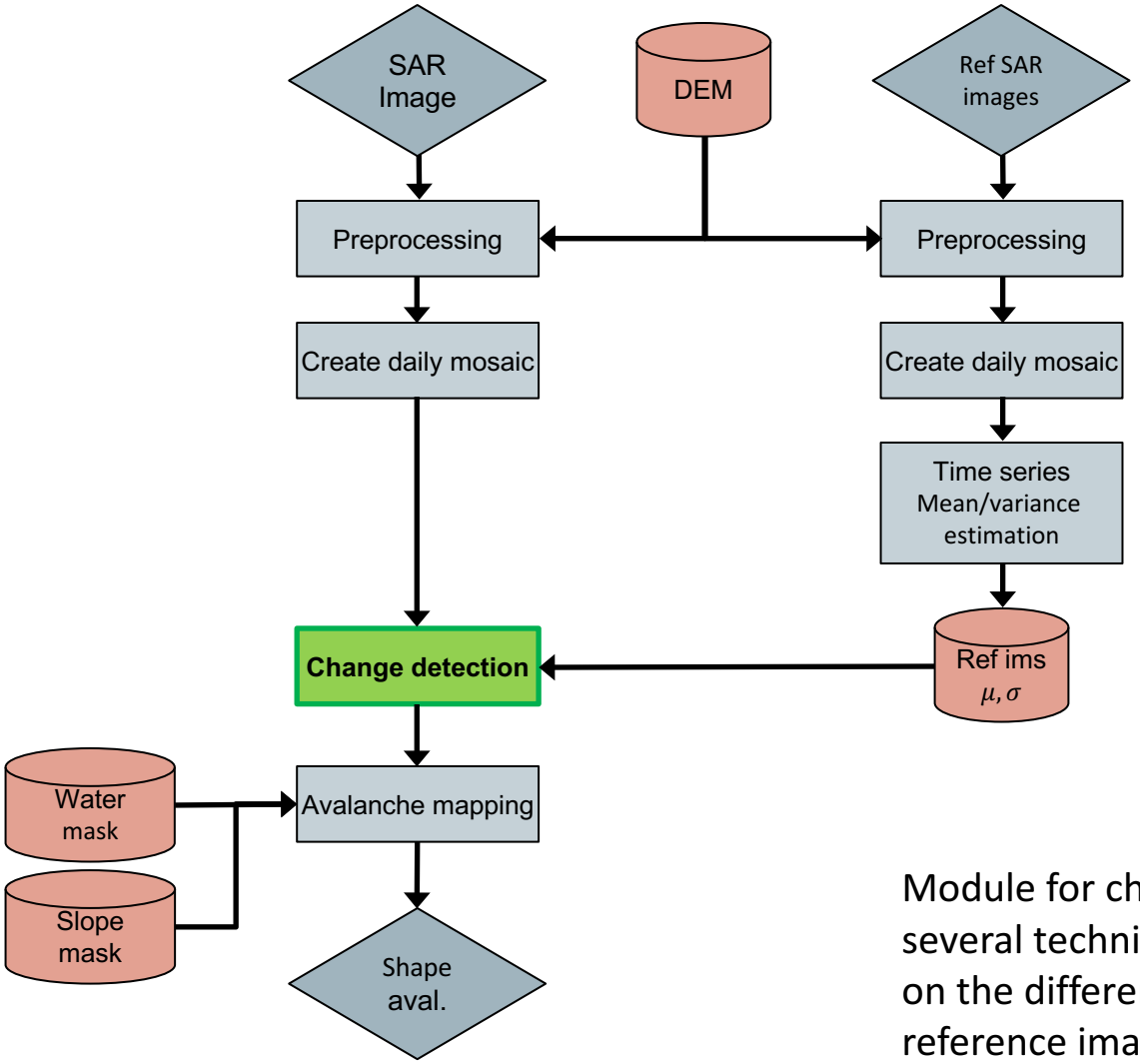




Module for generation of reference image and corresponding variance image.

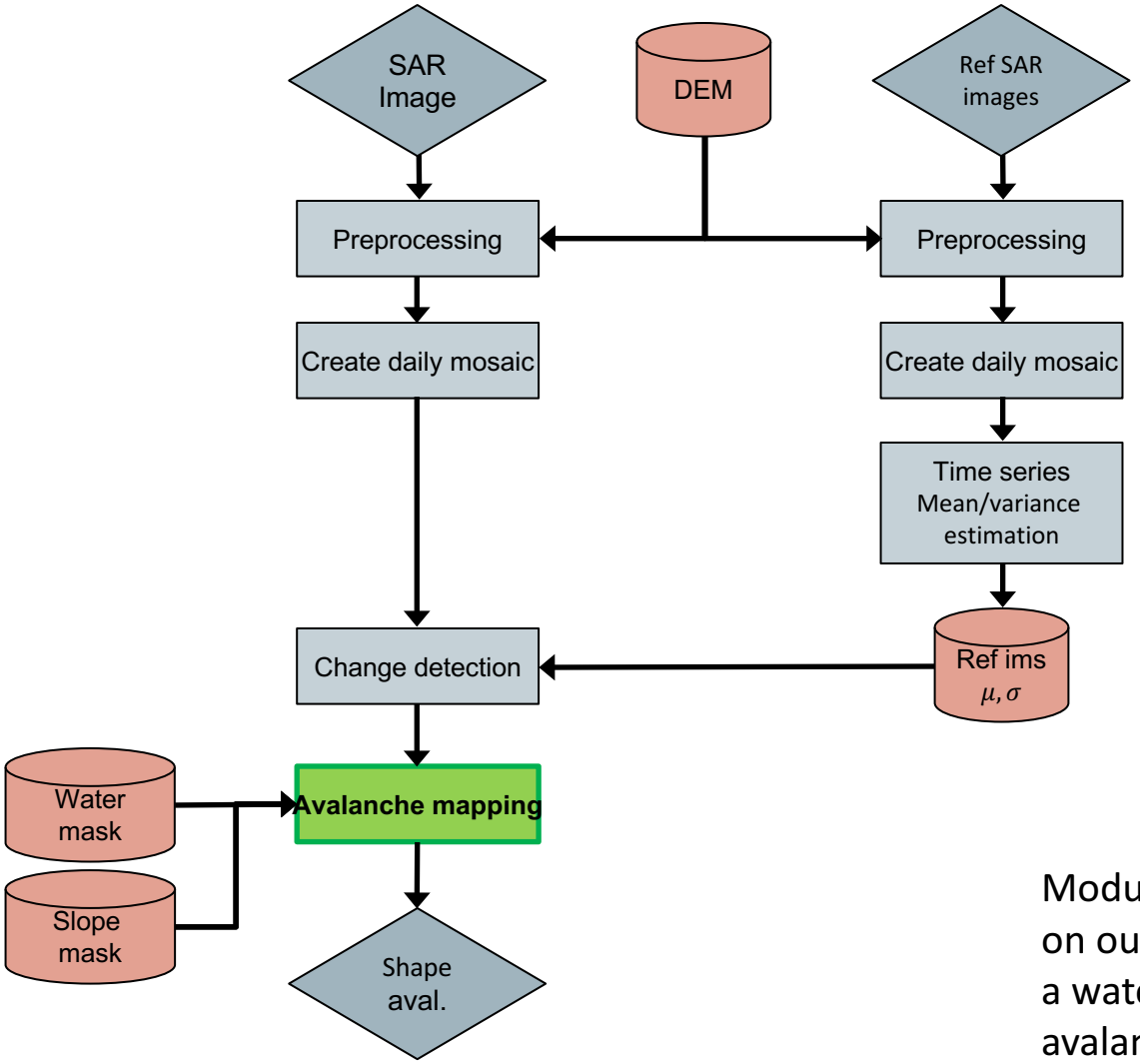
A reference image for «ascending» and one for «descending» orbit directions are constructed.

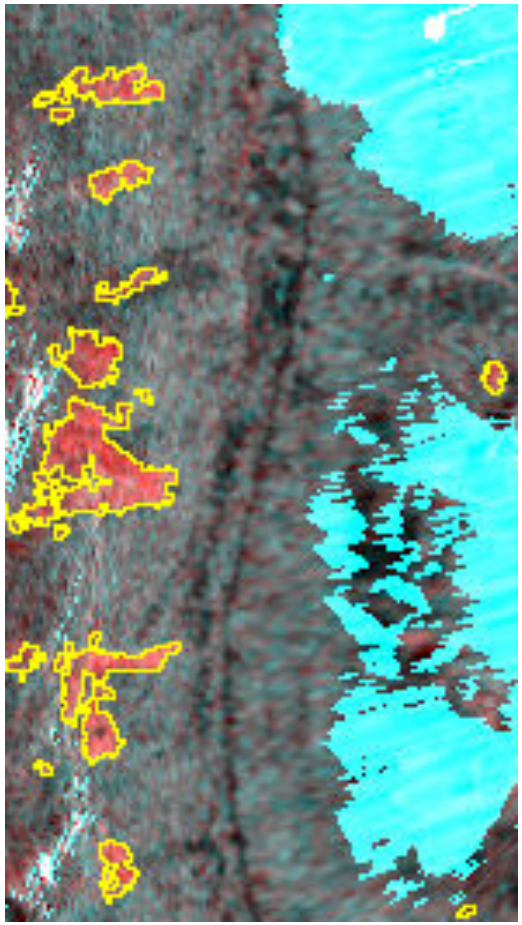
AVALANCHE MAPPING PROCESSING CHAIN



Module for change detection . This supports several techniques for change detection based on the difference between the event image and reference image, with and without correction for pixel-based variance

AVALANCHE MAPPING PROCESSING CHAIN





Module for avalanche mapping. Based on output from the change detection, a water mask and slope mask, potential avalanches are identified and written to a shape file.

Experiment with Radarsat-2 ultrafine dataset

Location	Date	Product
Kvaløya	Mars 4, 2014	U19
Lavangsdalen	Mars 23, 2014	U78
Storfjord	Mars 16, 2014	U74
Lakselvbugt	Mars 7, 2014	U22
Tromsdalstinden	April 1, 2014	U9
Vikøyri	Mars 9, 2014	U12

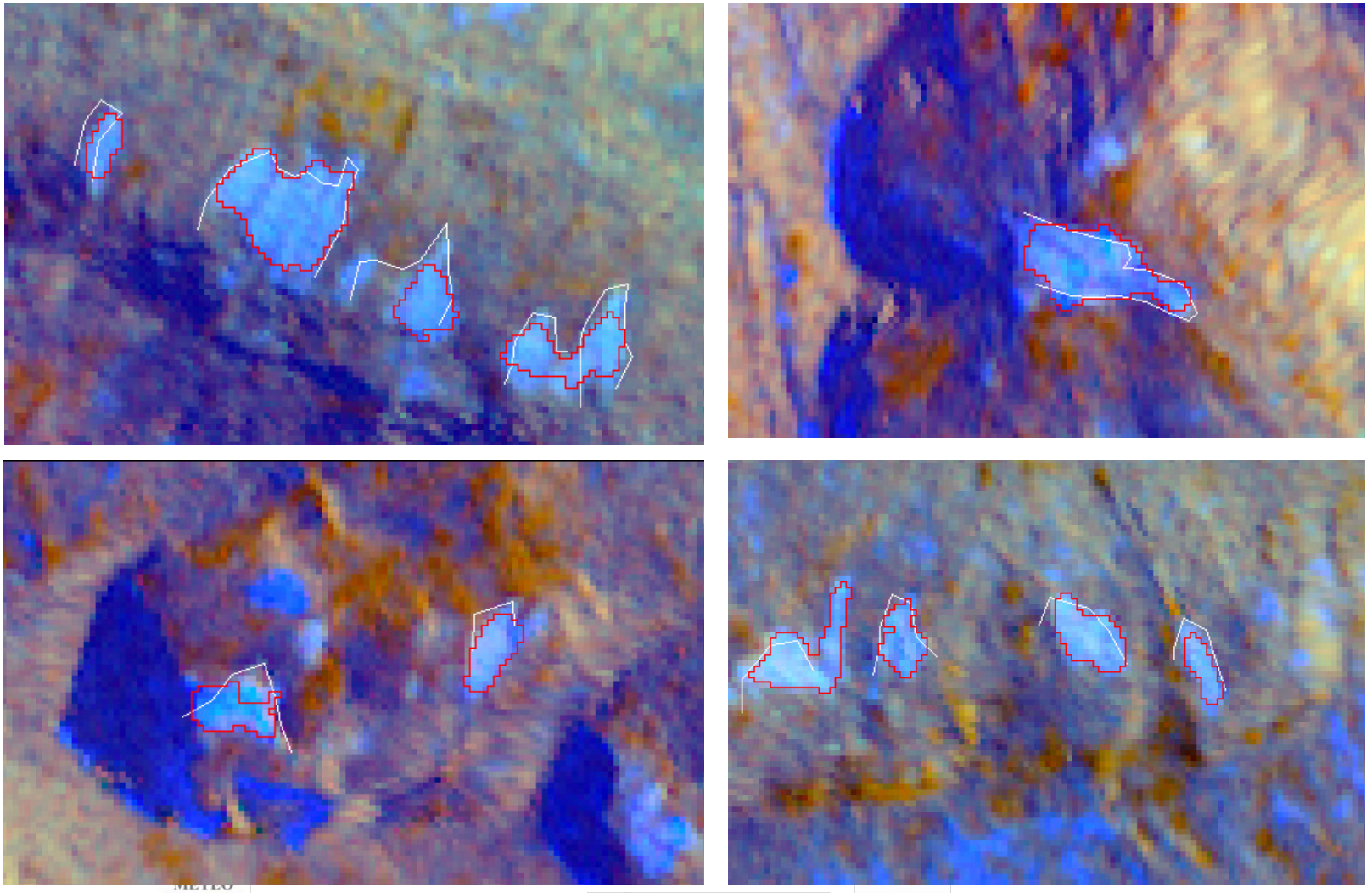
The out-of-bag confusion matrix indicates that most false objects are rejected

		Predicted class		
		Non-avalanche	Avalanche	Classification error
Actual class	Non-avalanche	4420	159	0.035
	Avalanche	160	233	0.41

The performance metric indicates that the algorithm does not agree completely with the manual identifications

Scene	Number of manually identified avalanches	Number of automatic detected avalanches	Error of omission (manually vs. automatic)	Error of commission (manually vs. automatic)
Lavangsdalen 2014	104	65	37%	32%
Kvaløya 2014	45	25	44%	39%
Storfjord 2014	41	20	51%	60%
Lakselvbugt	22	9	59%	53%

The algorithm identifies avalanches if they appear as bright «blobs» and favorable DEM



SnowBall

Remote sensing, model and in-situ data fusion for snowpack parameters and related hazards in a climate change perspective (SnowBall)

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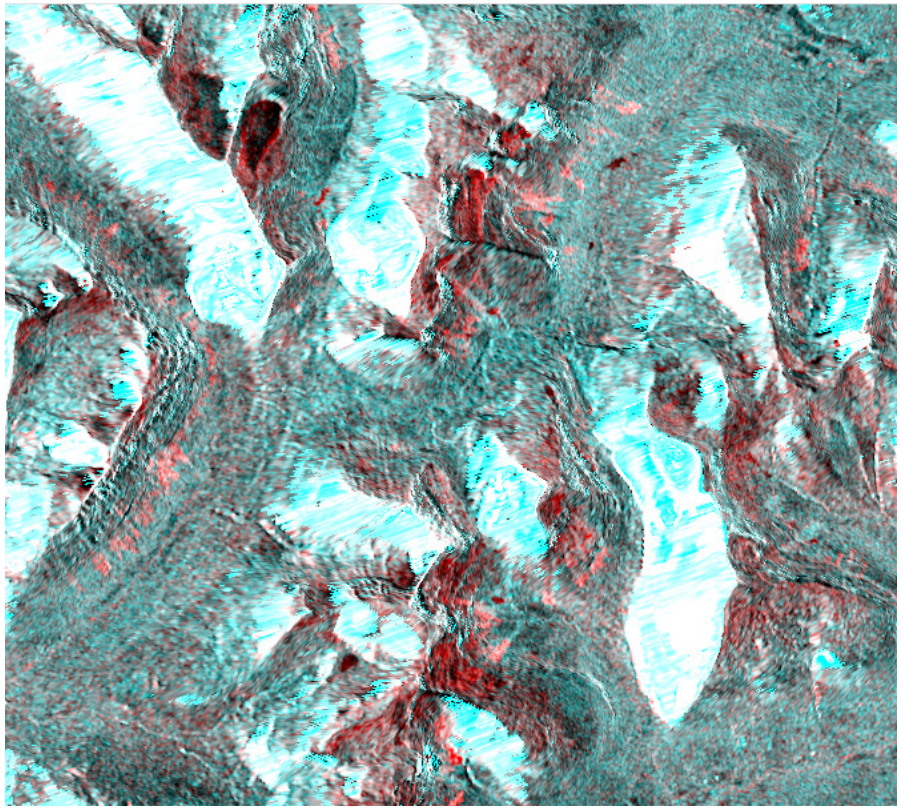
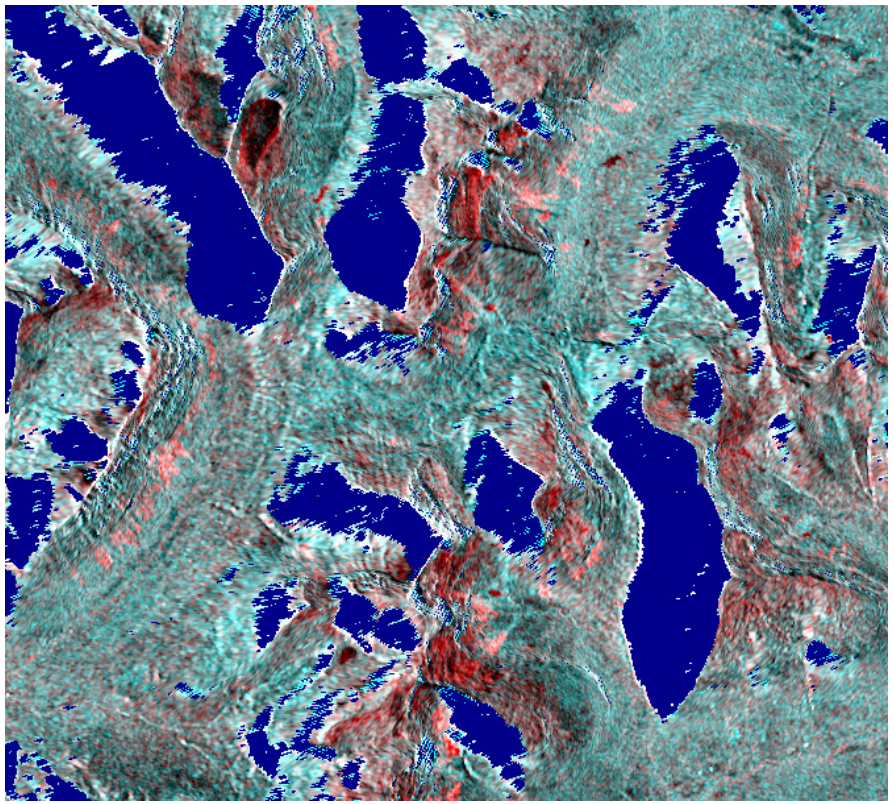
Avalanches in the Troms region, Norway, 8 January 2015





VV polarization
Dark blue: Layover / shadow areas

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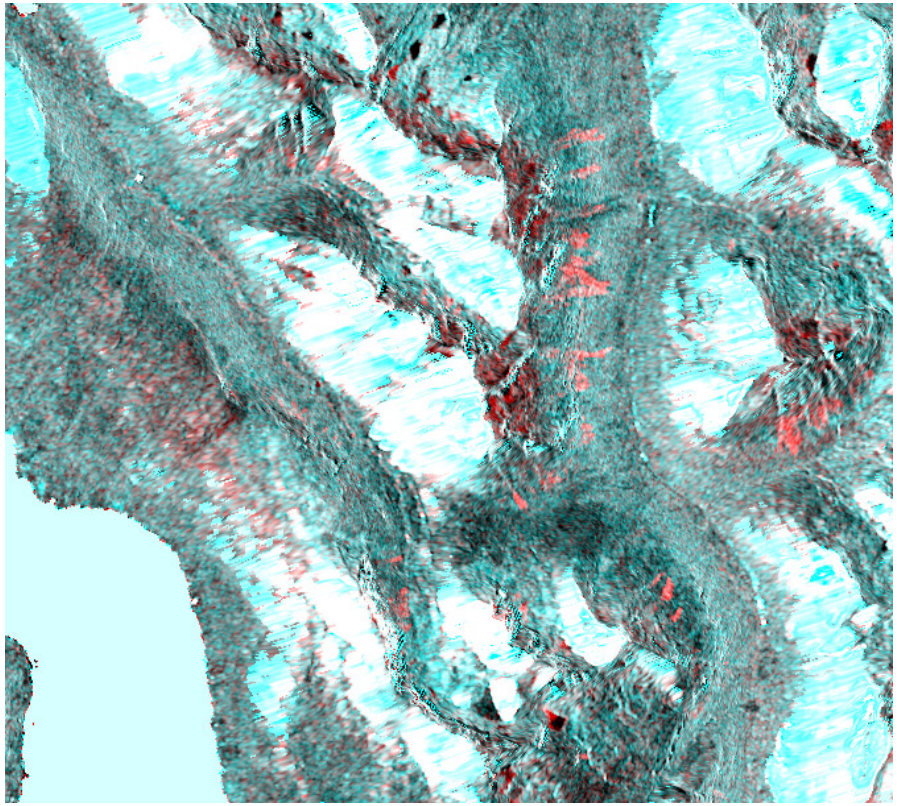

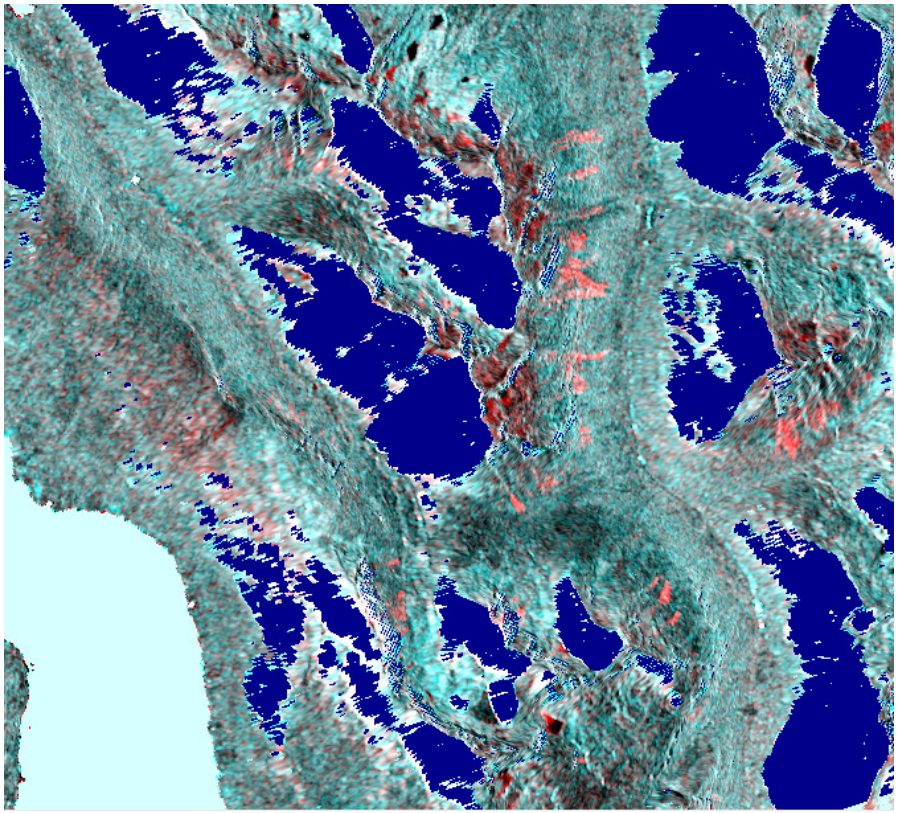

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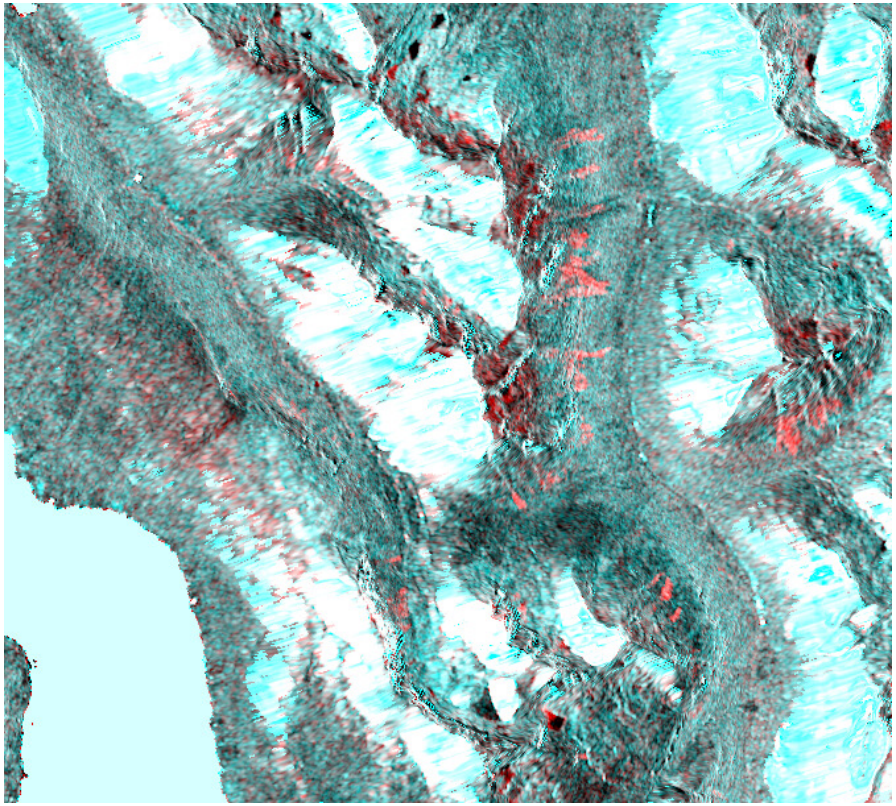

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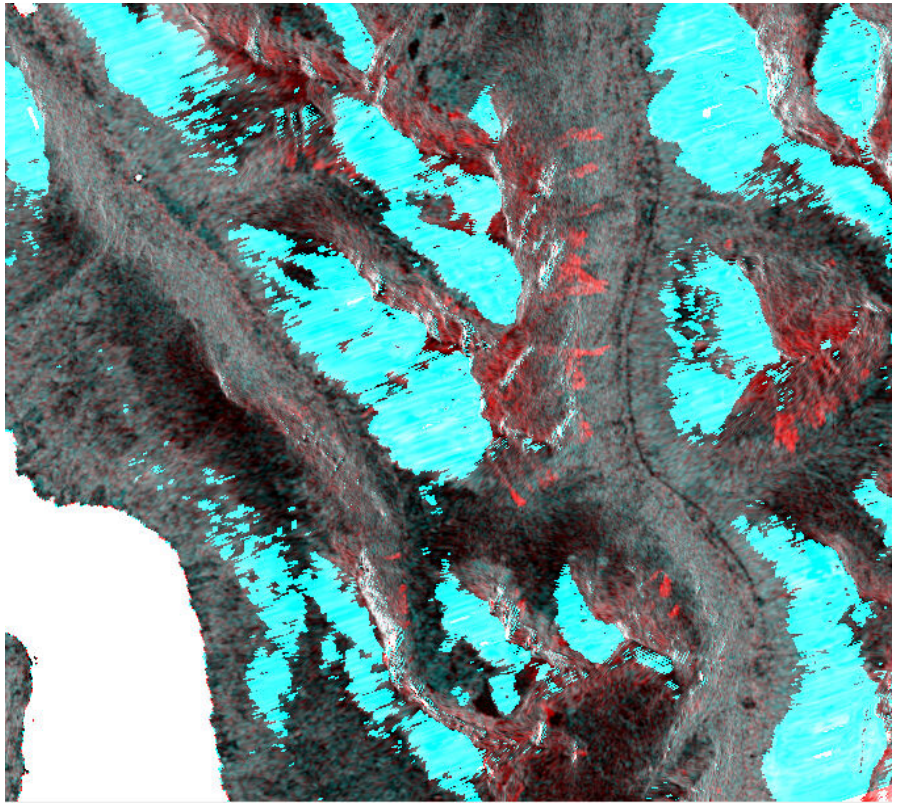

VH polarization

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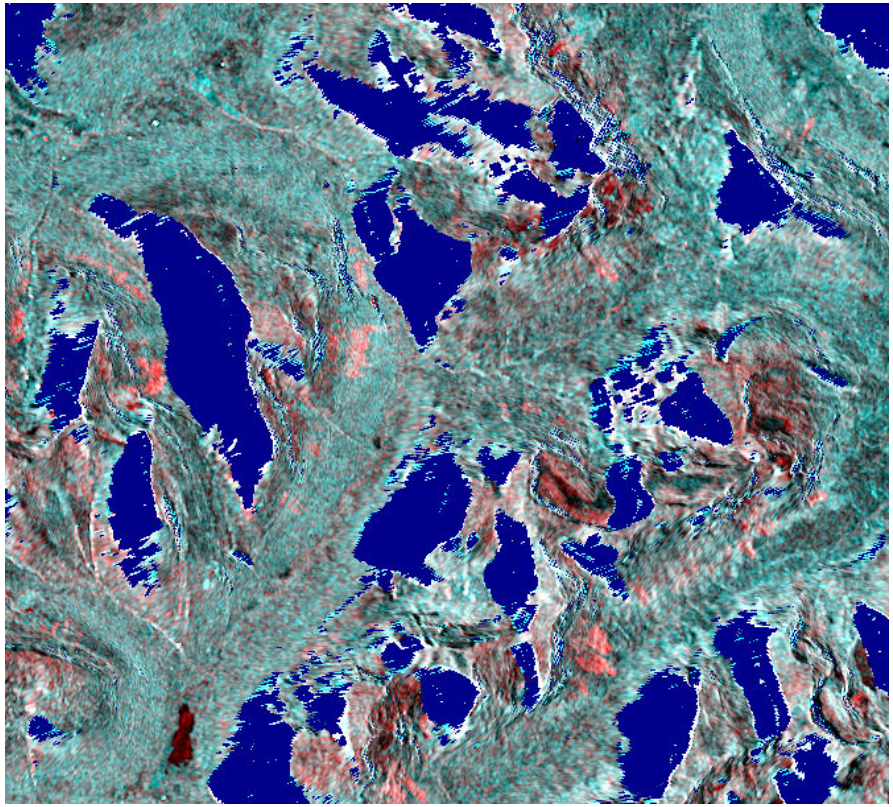
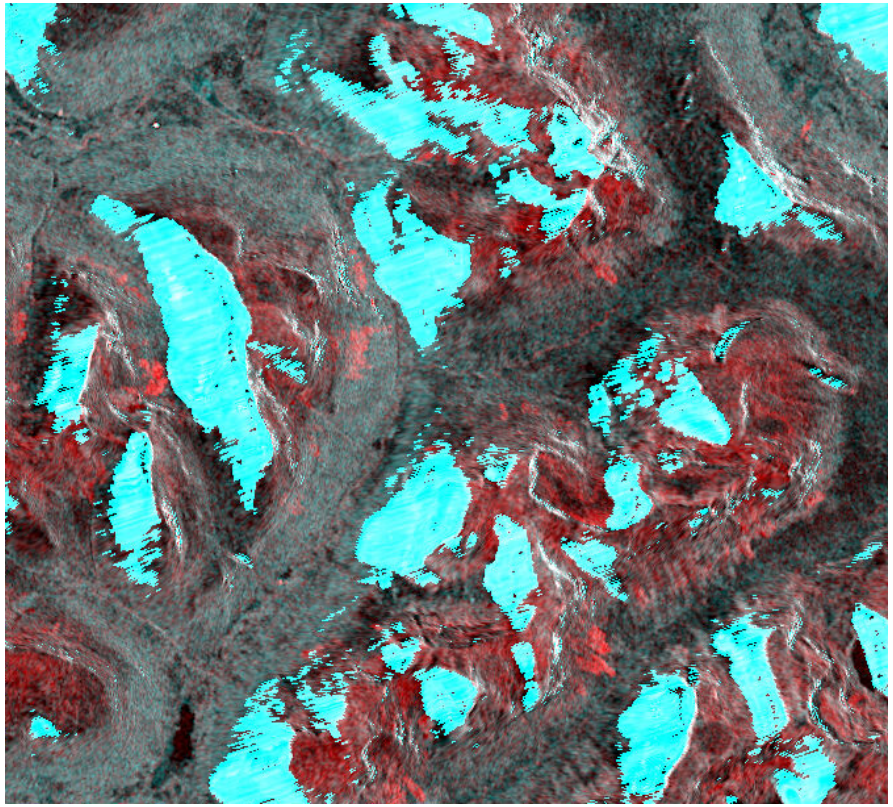


VV polarization



VH polarization

Avalanches on the Svalbard island in November 2016

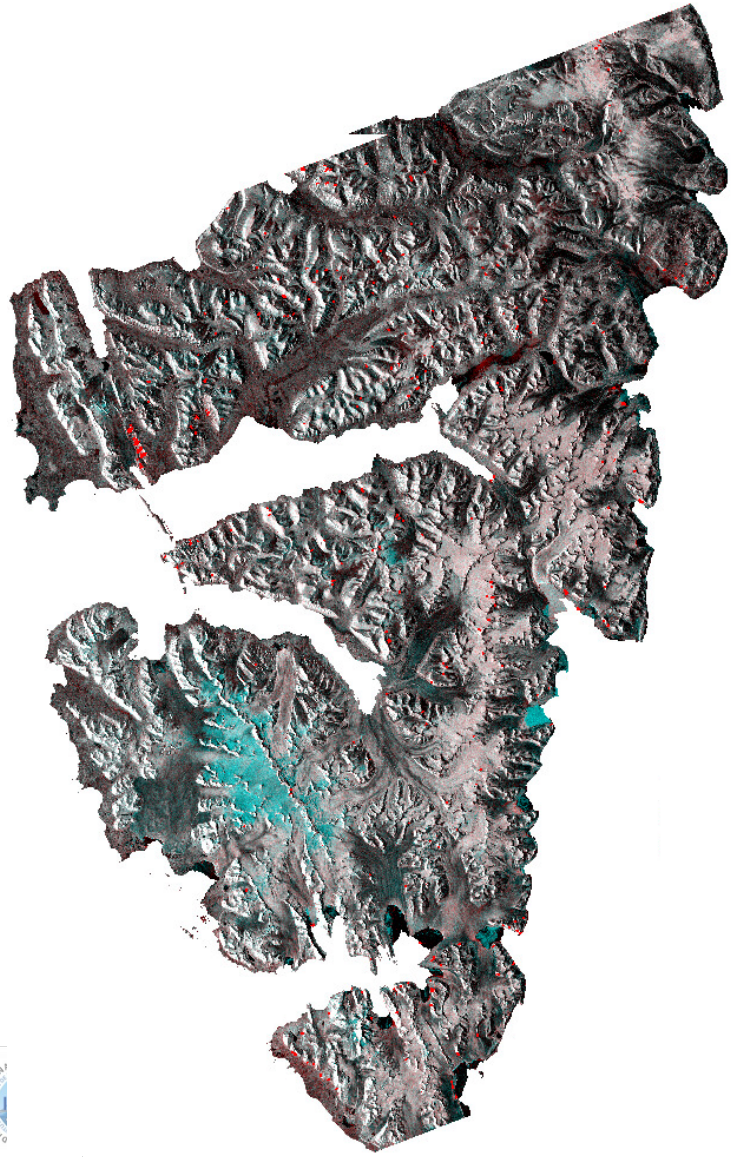
Due to bad weather conditions a number of avalanches was reported around November 11, 2016.

Event image: November 11, 2016

Reference image: October 31, 2016

RGB false color image

Red: Event image
Blue: Reference image
Green: Reference image



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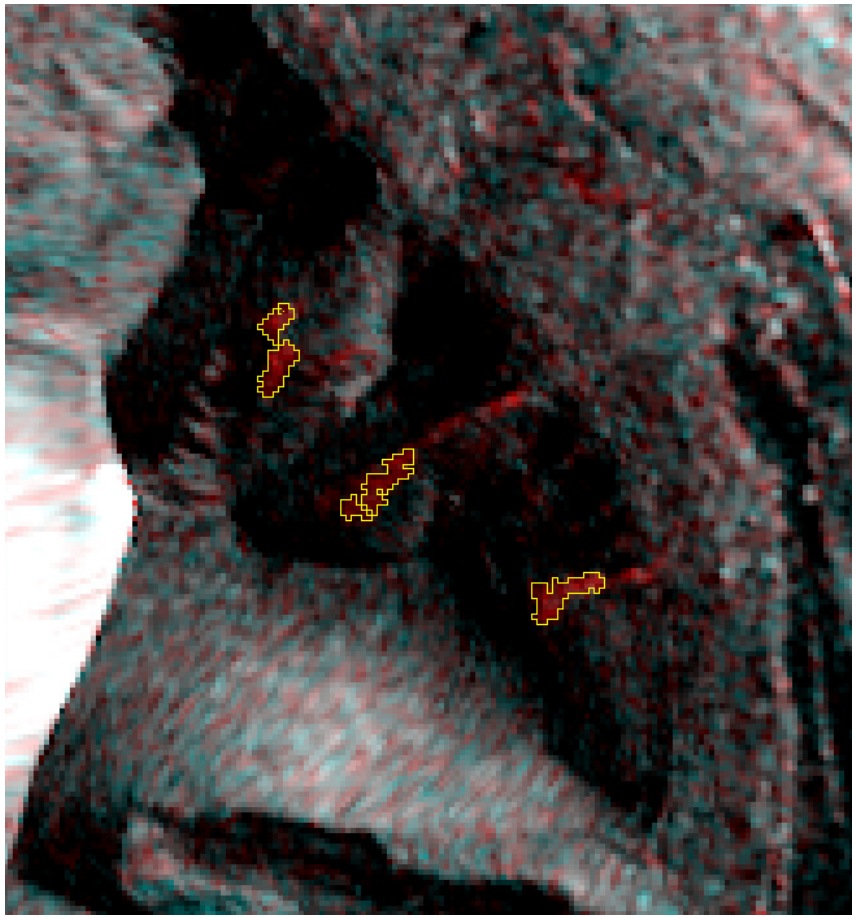

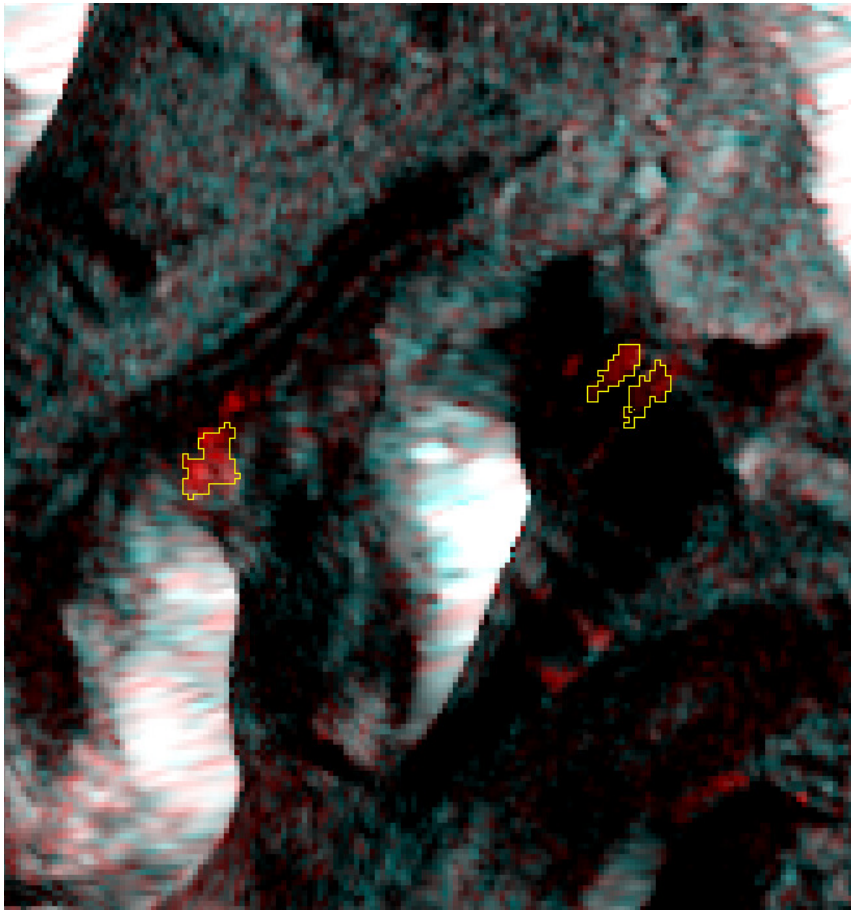

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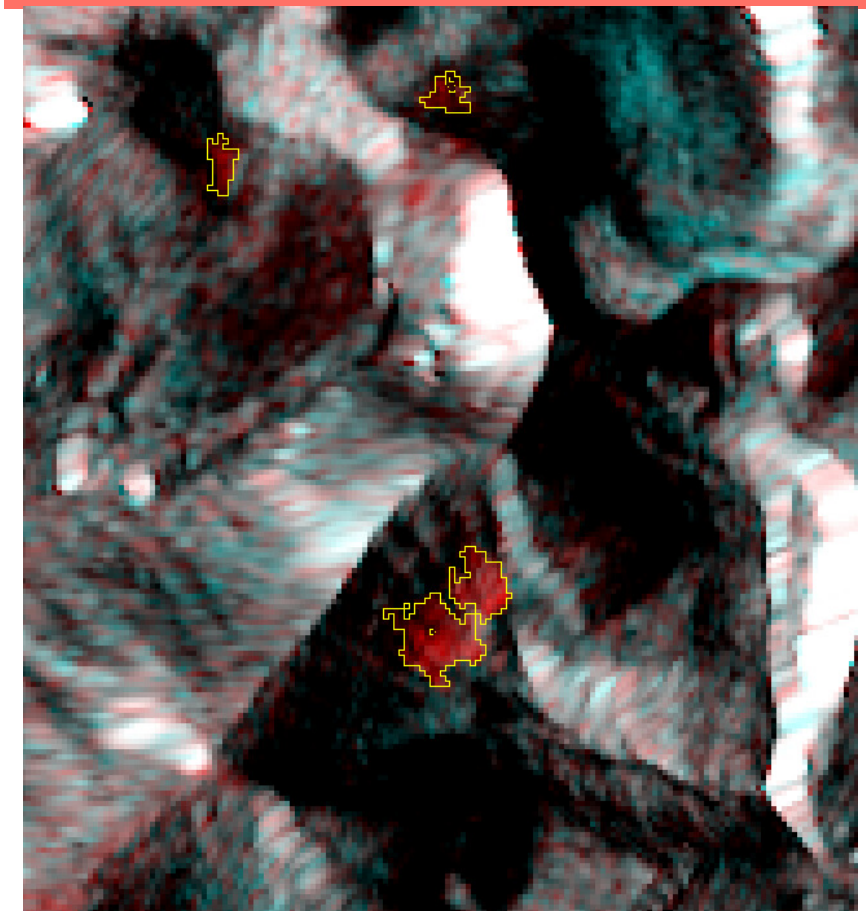
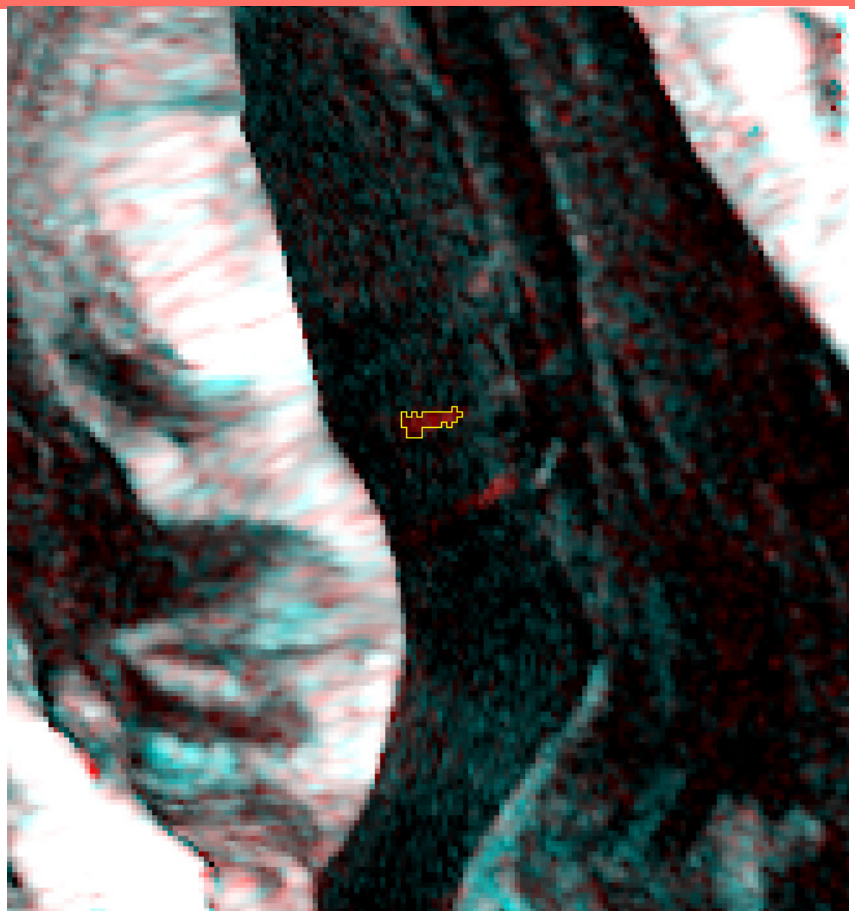


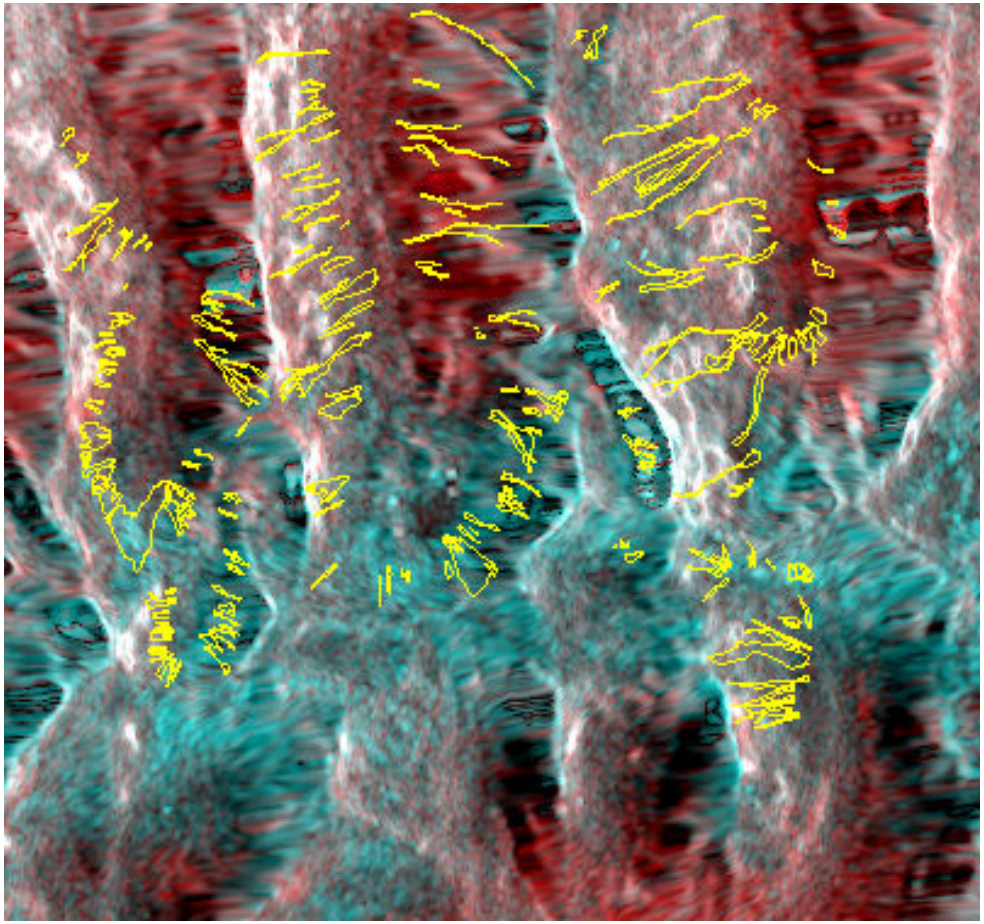


Avalanches in the Fagars region, 9 April 2016

Avalanches in Fagaras identified by drone (yellow polygons), not visible in the Sentinel-1 image.

Reasons:

- Too small avalanches
- Point release
- Severe terrain effects
- Snow conditions?



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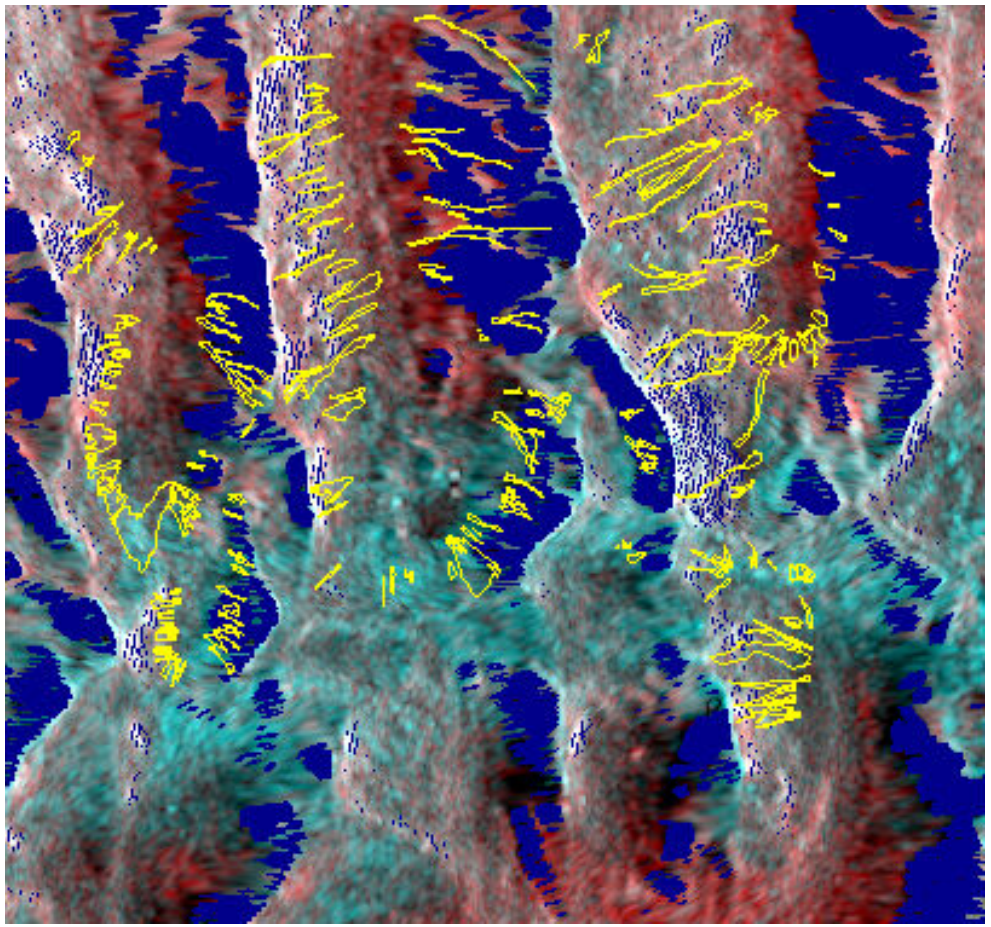

Conclusions

- When avalanches look like bright «blobs», the algorithm detect them in most cases.
- No cloud issues.
- Large avalanches are reliably detected

- The algorithm struggles to detect avalanches if the blob contrast is weak.
- The algorithm also detects some non-identified objects that appears as bright blobs and has favorable DEM conditions.
- Avalanches not visible in shadow and layover areas in the SAR images.
- Currently, only a semi-automatic approach is feasible.