GEOHAZARD MONITORING GROUP | irpi

SPOT4(Take5) USER WORKSHOP
Toulouse 18-19 November 2014

Snow Water Equivalent and Slope Movements from Satellite Data: potential of space-borne observations with high spatial and temporal sampling. Case study: Tena Valley (Central Pyrenees, Spain)

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irpi Consiglio Nazionale delle Ricerche
Istituto di Ricerca per la Protezione Idrogeologica

CNR - National Council of Research

IRPI - Research Institute for Geo-Hydrological Protection

Ordinary activities: Identification, analysis and monitoring of geo-hydrological hazards

Extra-ordinary: Technical and scientific support during and after emergencies (floods, earthquakes, landslides, etc.)

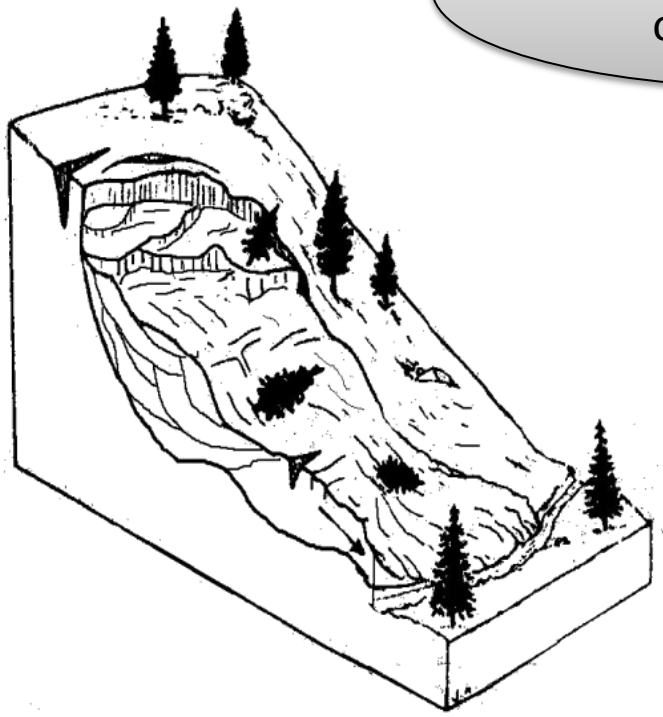
Competence center of the National Civil Protection Department (DPC) for landslide phenomena

Landslides are caused by several factors, including…

Earthquakes

Groundwater level change

Hydrogeological characteristics of the bedrock



Soil infiltration capacity

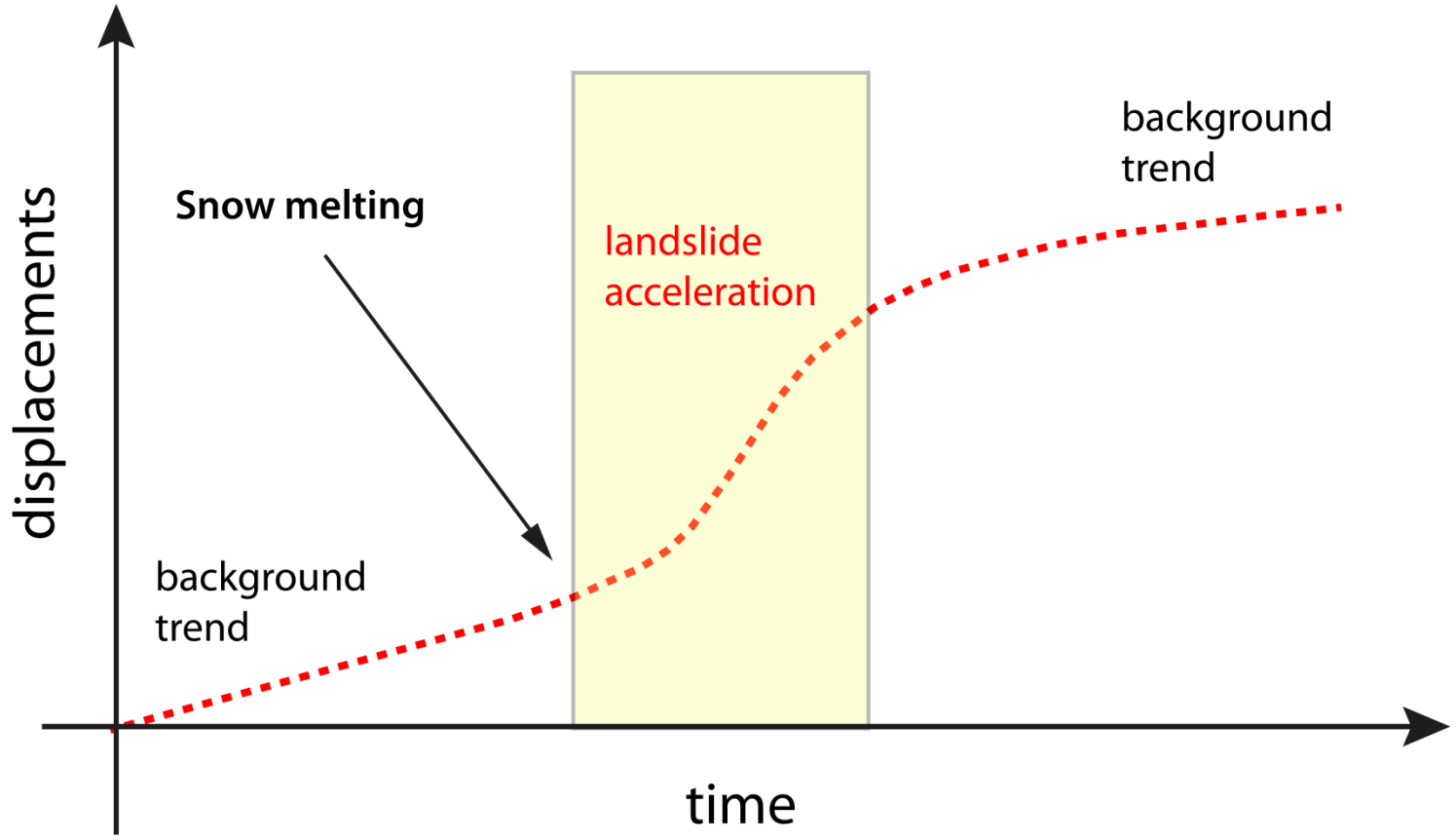
Stream erosion

Snow melting

Intense rainfall

Diagram by J. Appleby, R. Kilbourne, and T. Spittler after Varnes, 1978

Response of Landslides to Snow Melting



Reference: García-Davalillo et al. (2014) ; Crosta et al (2013)

Snow Water Equivalent – Snow Depth – Snow Density

(SWE) Snow Water Equivalent (mm) = h (cm) * d (Kg m^{-3})/100

Estimation of parameters

Ground measurements, snow-meteorological observatories (data collected fresh snowfall, depth snow, snow surface temperature).

Satellite data, MODIS Product MOD 10 - Snow Cover, Snow Depth derived from the passive microwave sensor SSM/I.

General circulation models (GCMs), parameterizing snow cover fraction, snow depth and snow water equivalent using various empirical formulae and satellite data.

Sometimes the ground data are not available or are not easy to collect

The GCMs models and the snow satellite data products are usually at GLOBAL SCALE

SPOT 4 (Take 5) Program

	Landsat	SPOT	Sentinel-2	
Number in series	7+1*	5**	starting with 2	
Launch	1972 to 1999*	1986 to 2002	S2-A launch end 2013	
Measurement principle	scanner	pushbroom	pushbroom	
Earth coverage	16	26	5	days
Swath	185	2 × 60	290	km
Multispectral bands	7(8*)	4+1 (panchromatic)	13	
Spatial sampling distance	30, 60	10, 20, (2.5)	10, 20, 60	m

* LCDM mission targeted early 2013

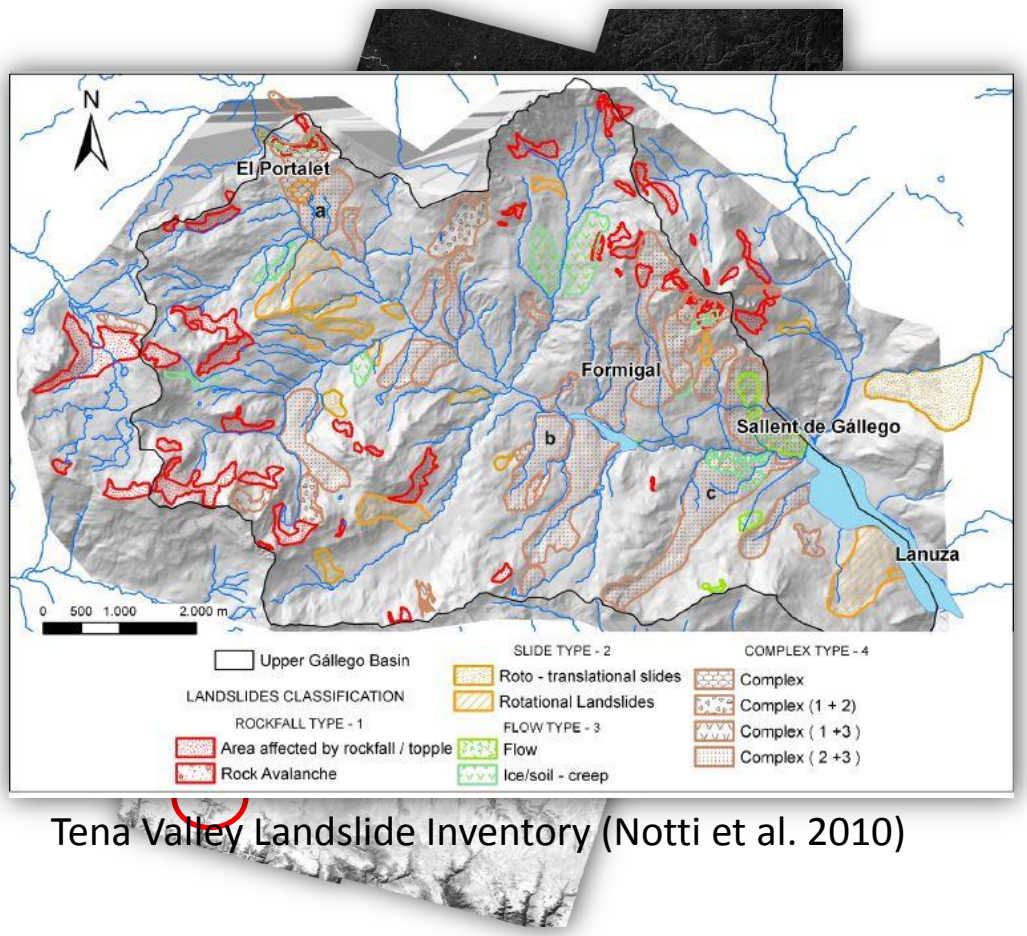
** SPOT-6 targeted end 2012

We exploited the chance given by the SPOT4 (Take5) initiative to evaluate the possibility of measuring snow depth from satellite data acquired at high spatial and temporal resolution (simulation of Sentinel – 2 acquisition mode).

Case Study: Tena Valley (Central Pyrenees, Spain)

The study area is the Tena Valley, a sector of the Spanish Pyrenees.

This area is also a test site for the FP7 project LAMPRE (LAndslide Modelling and tools for vulnerability assessment Preparedness and REcovery management).



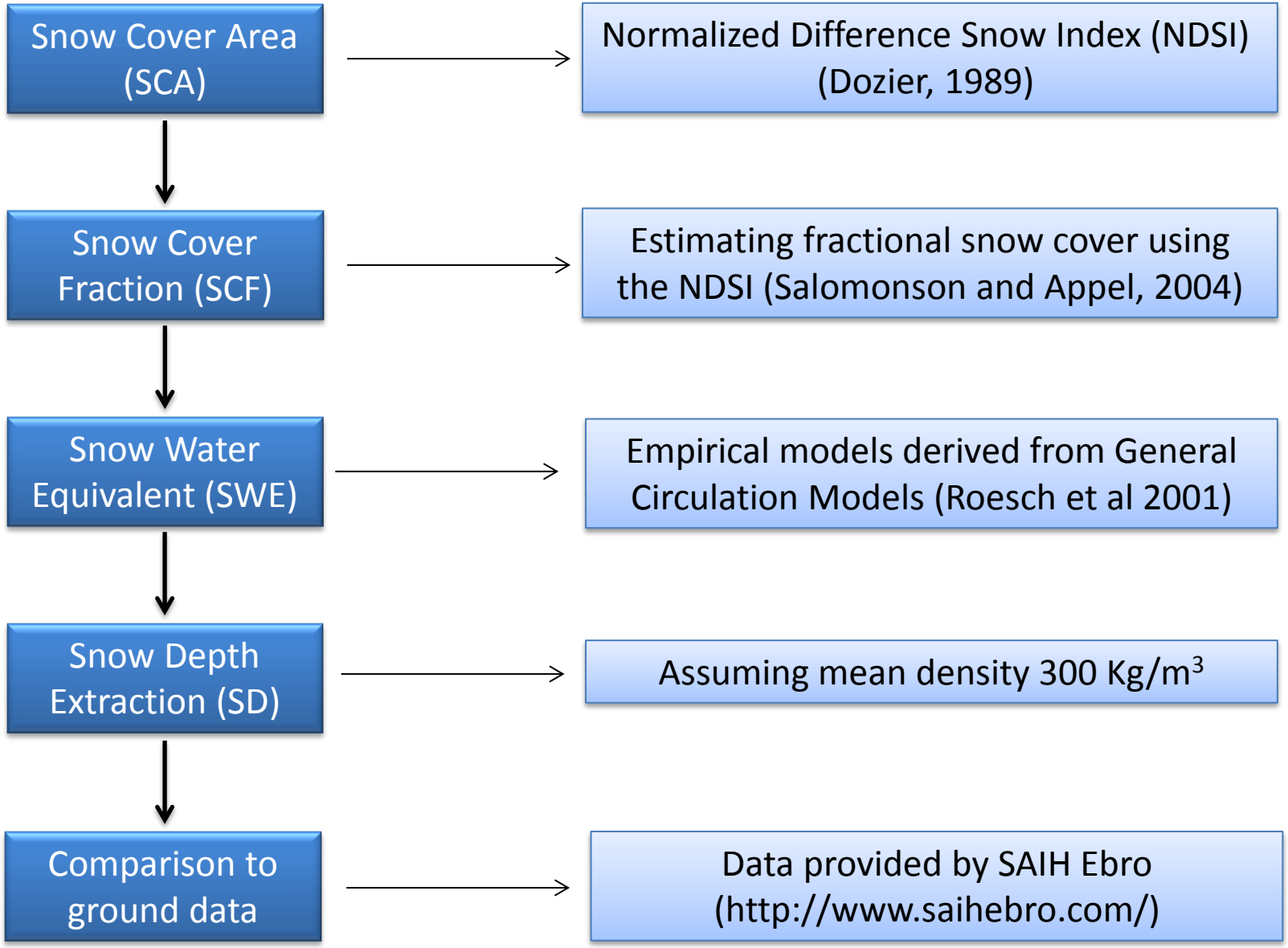
Tena Valley Landslide Inventory (Notti et al. 2010)

Data Set

SPOT4 Take5 images, site Midi-Pyrénées (South West), period from February 2013 to June 2013.

SPOT 4 Take 5 images
SPOT4_HRVIR_XS_20130216_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130303_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130308_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130407_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130412_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130417_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130512_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130606_N1_TUILE_CSudmipy-OD0000B0000
SPOT4_HRVIR_XS_20130616_N1_TUILE_CSudmipy-OD0000B0000

Methodology

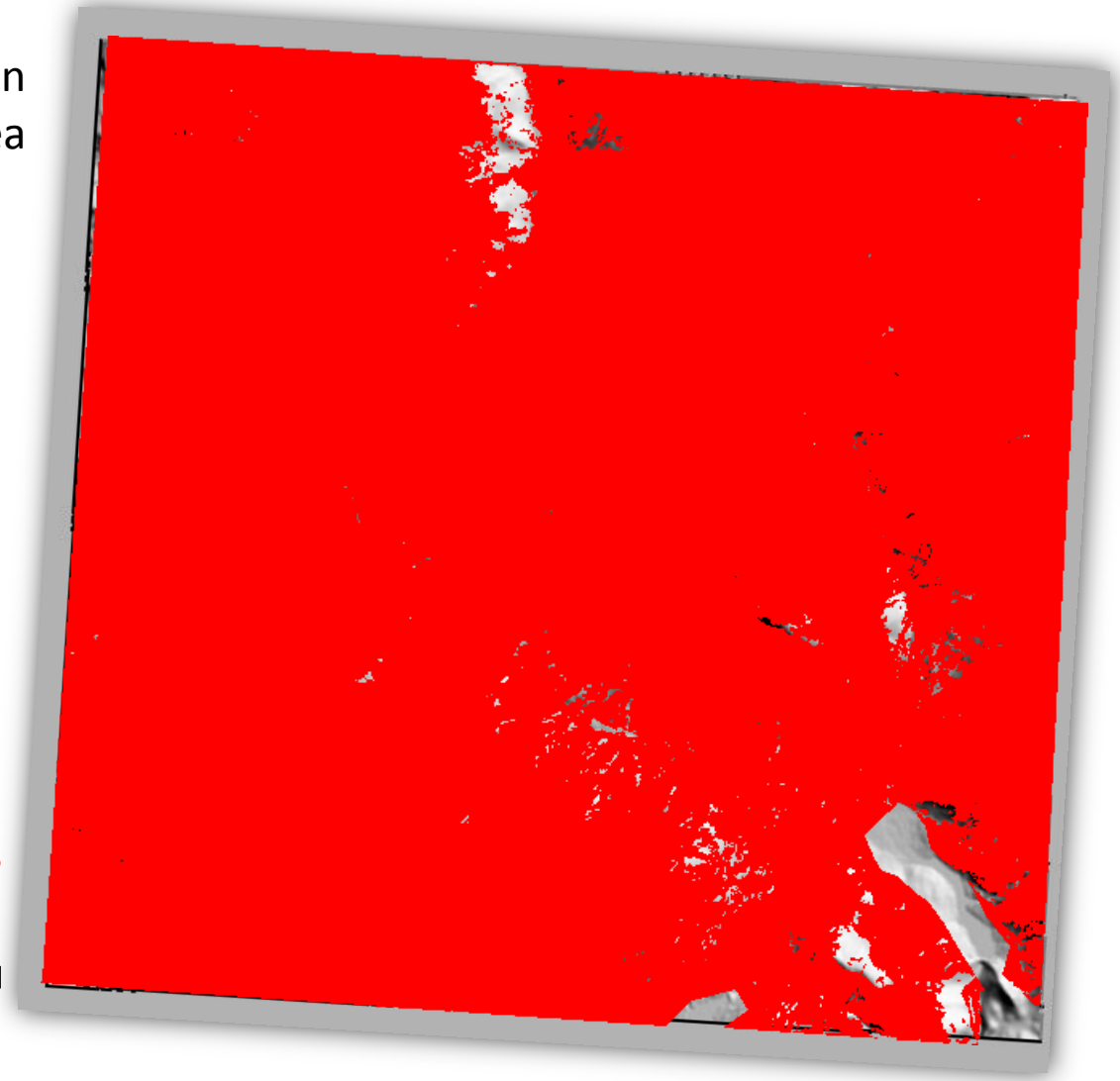


Snow Cover Area (SCA)

Monitoring of the evolution of the snow cover area during a winter season.

Normalized Difference Snow Index (NDSI).

NDSI > 0.4 →snow
(Dozier, 1989)
(red in the image)



SCA → SCF → SWE → SD → Comparison

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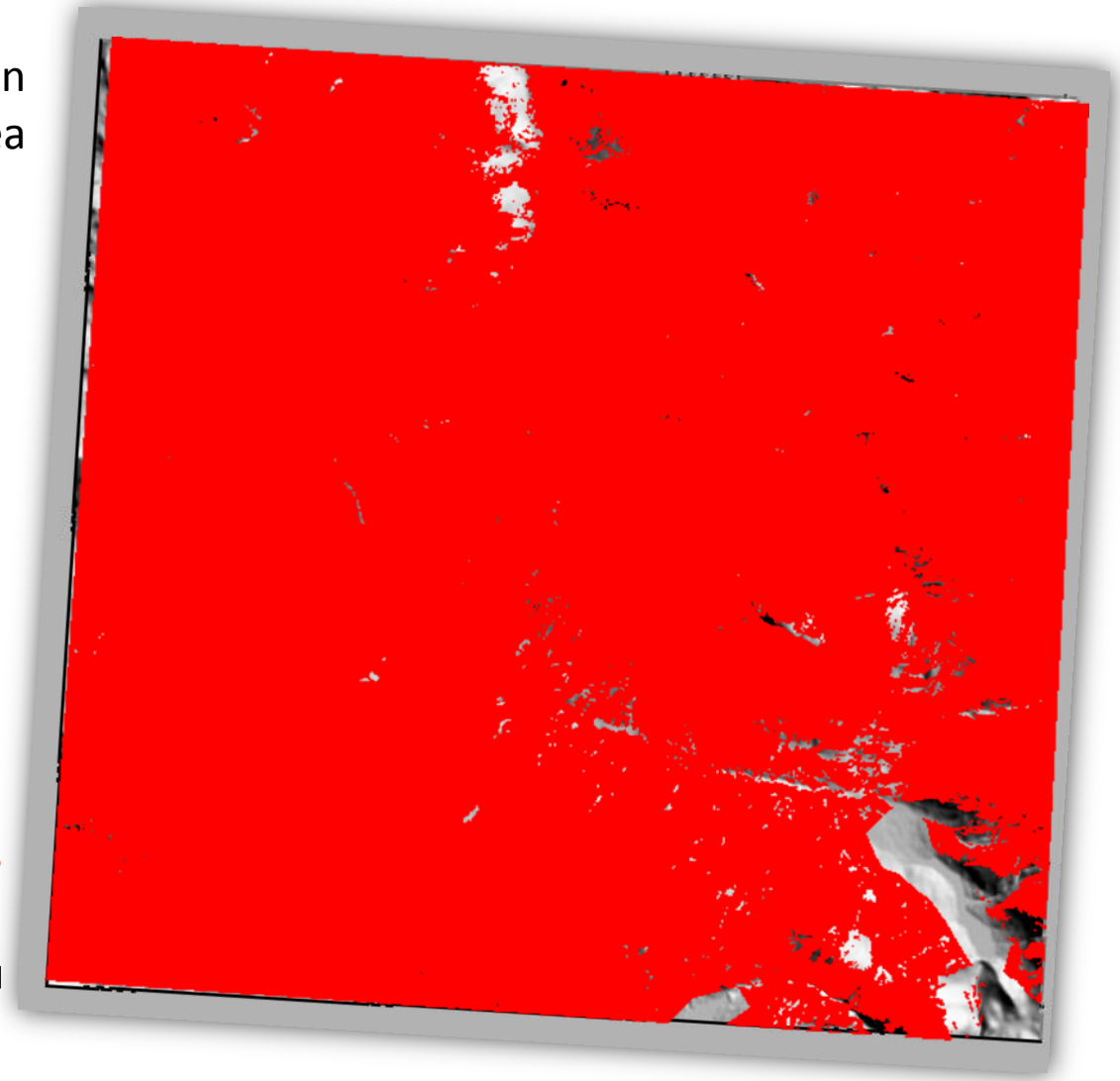

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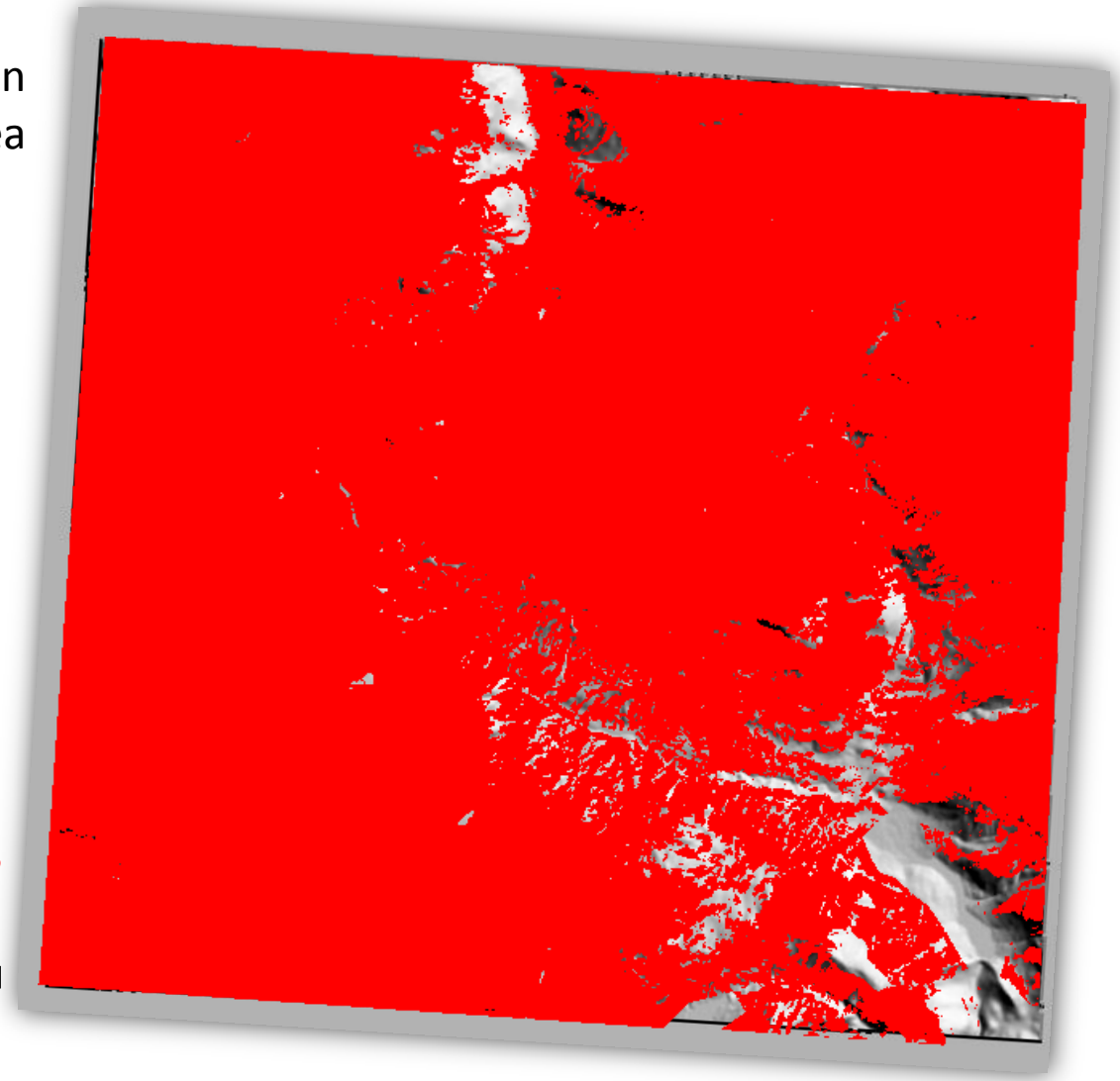

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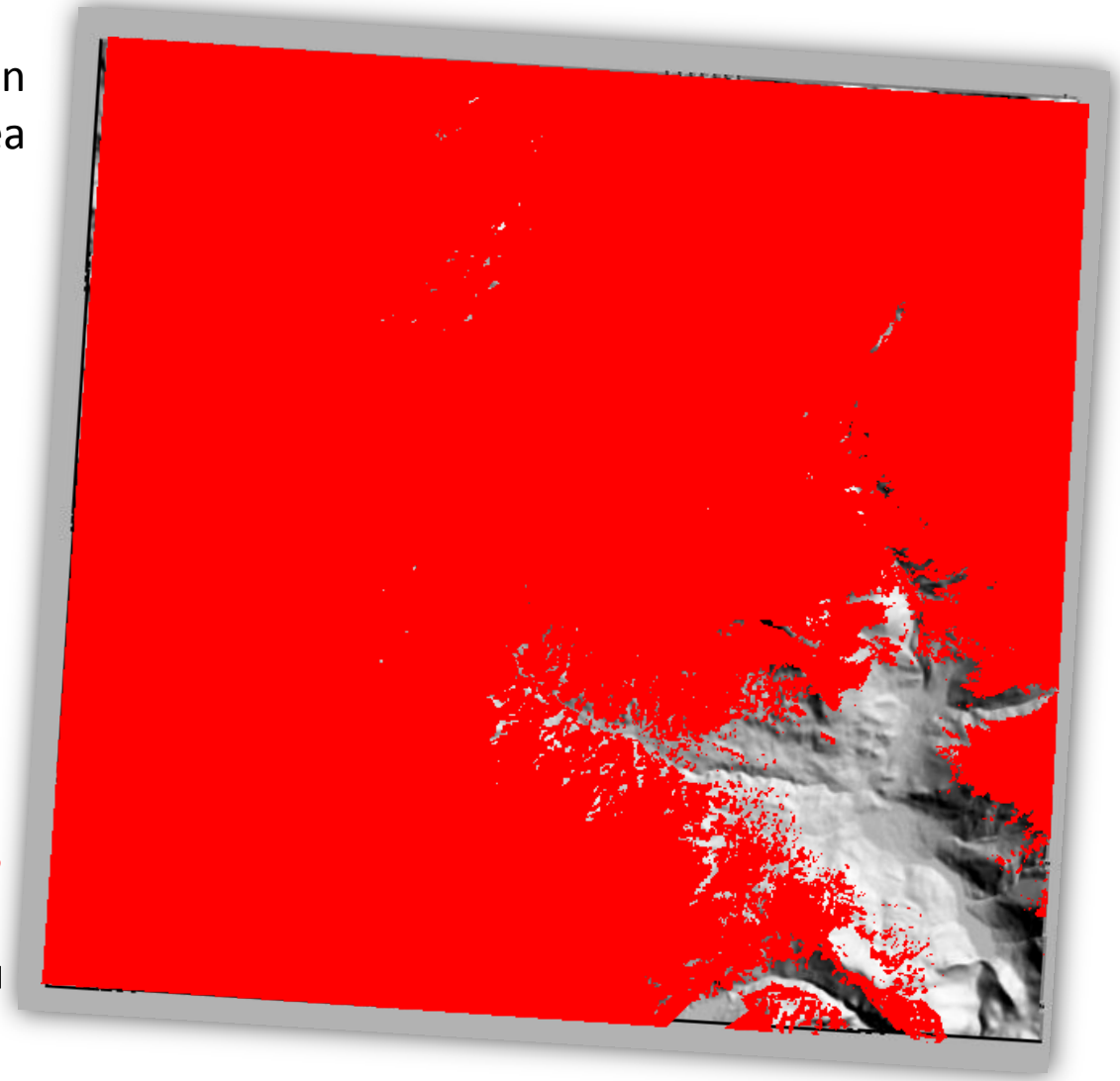

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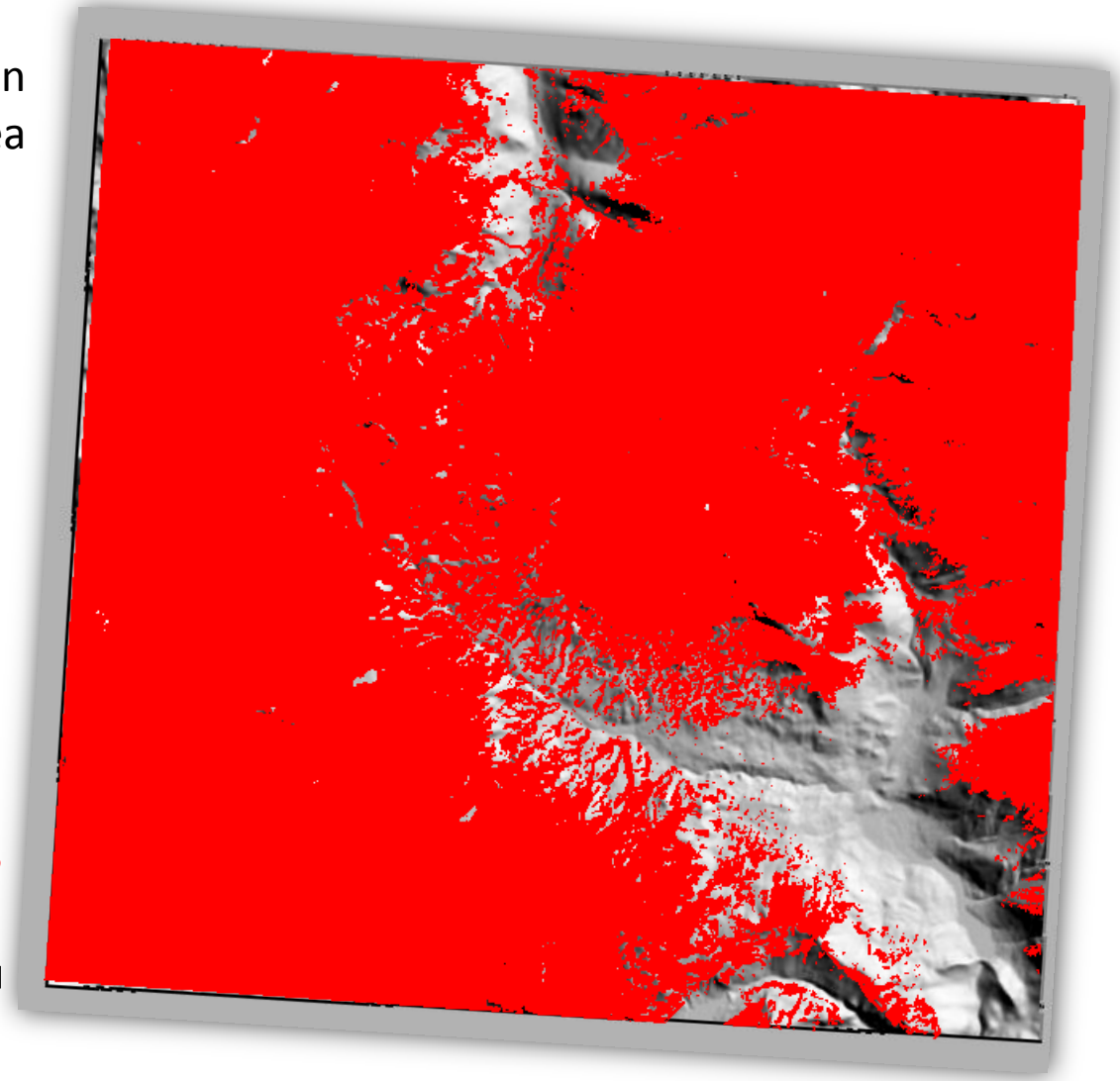

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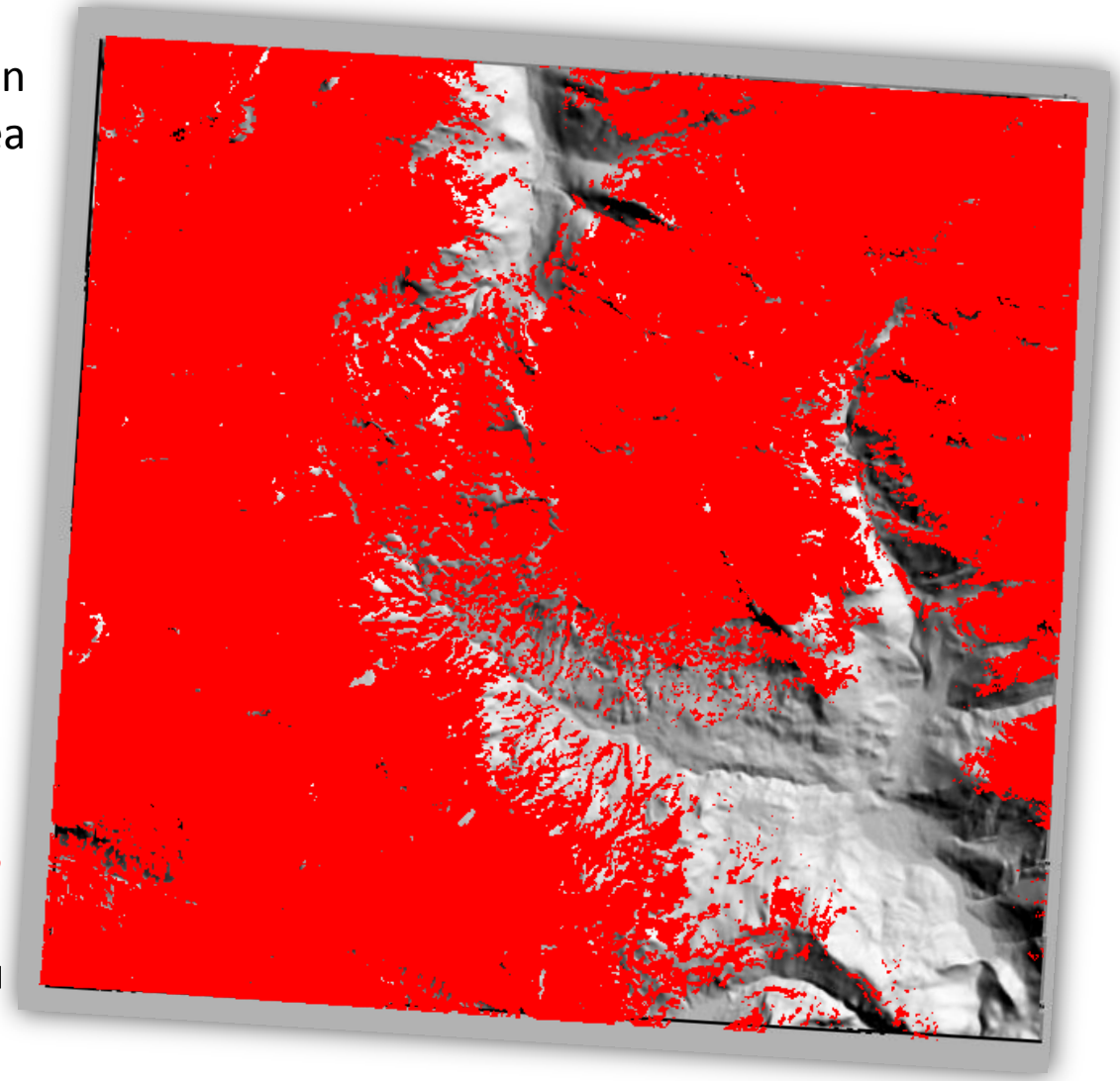

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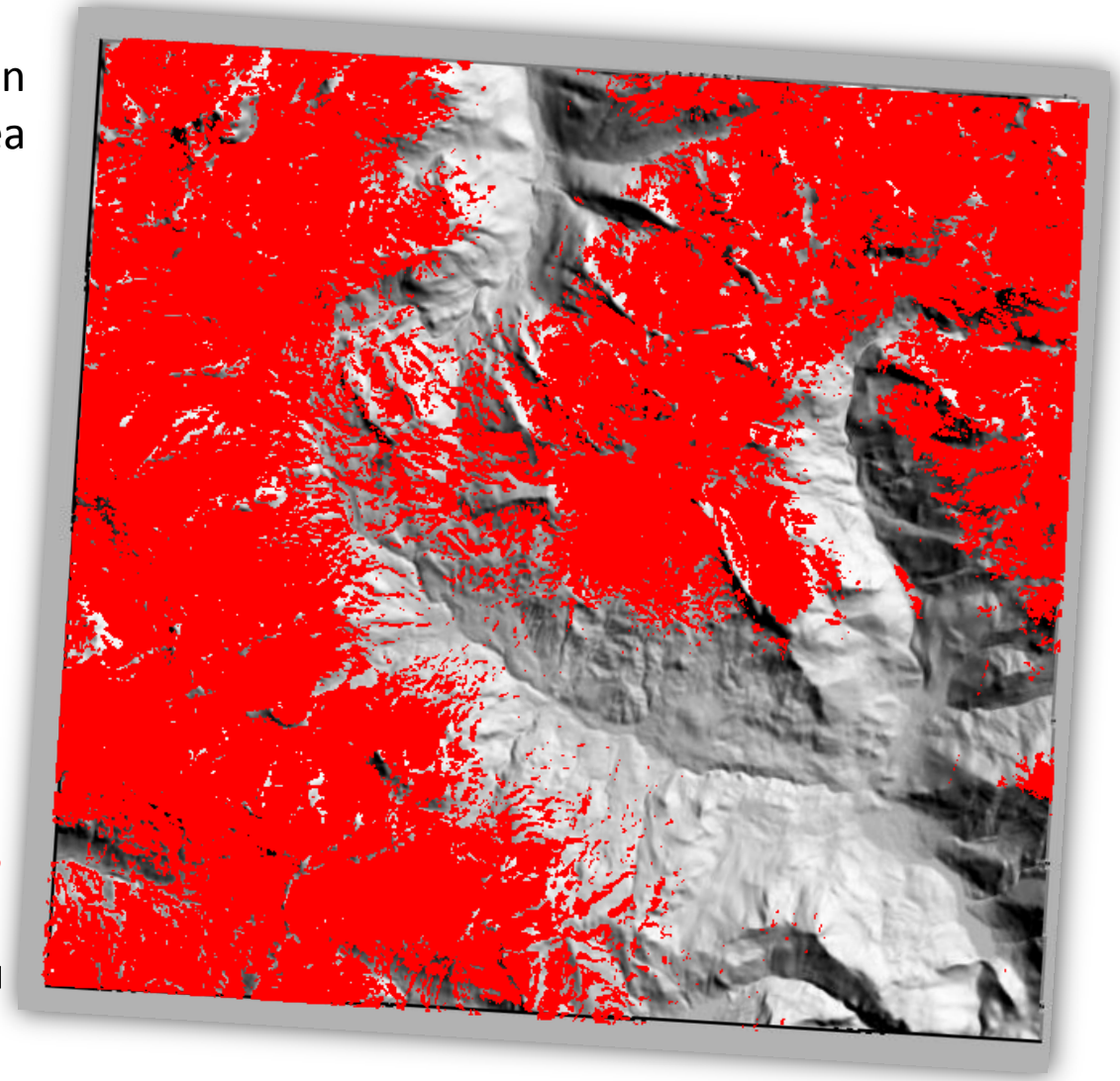

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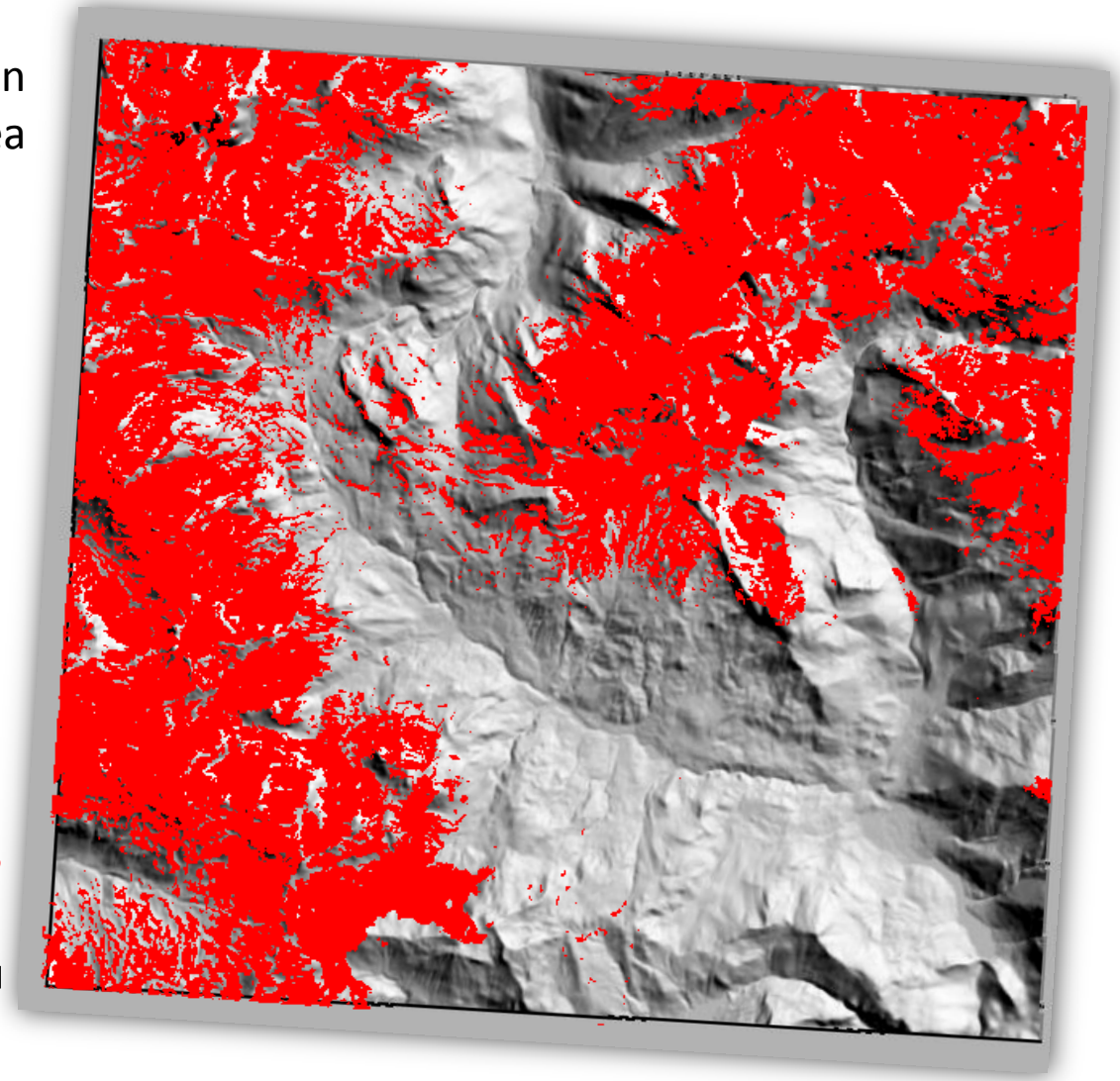

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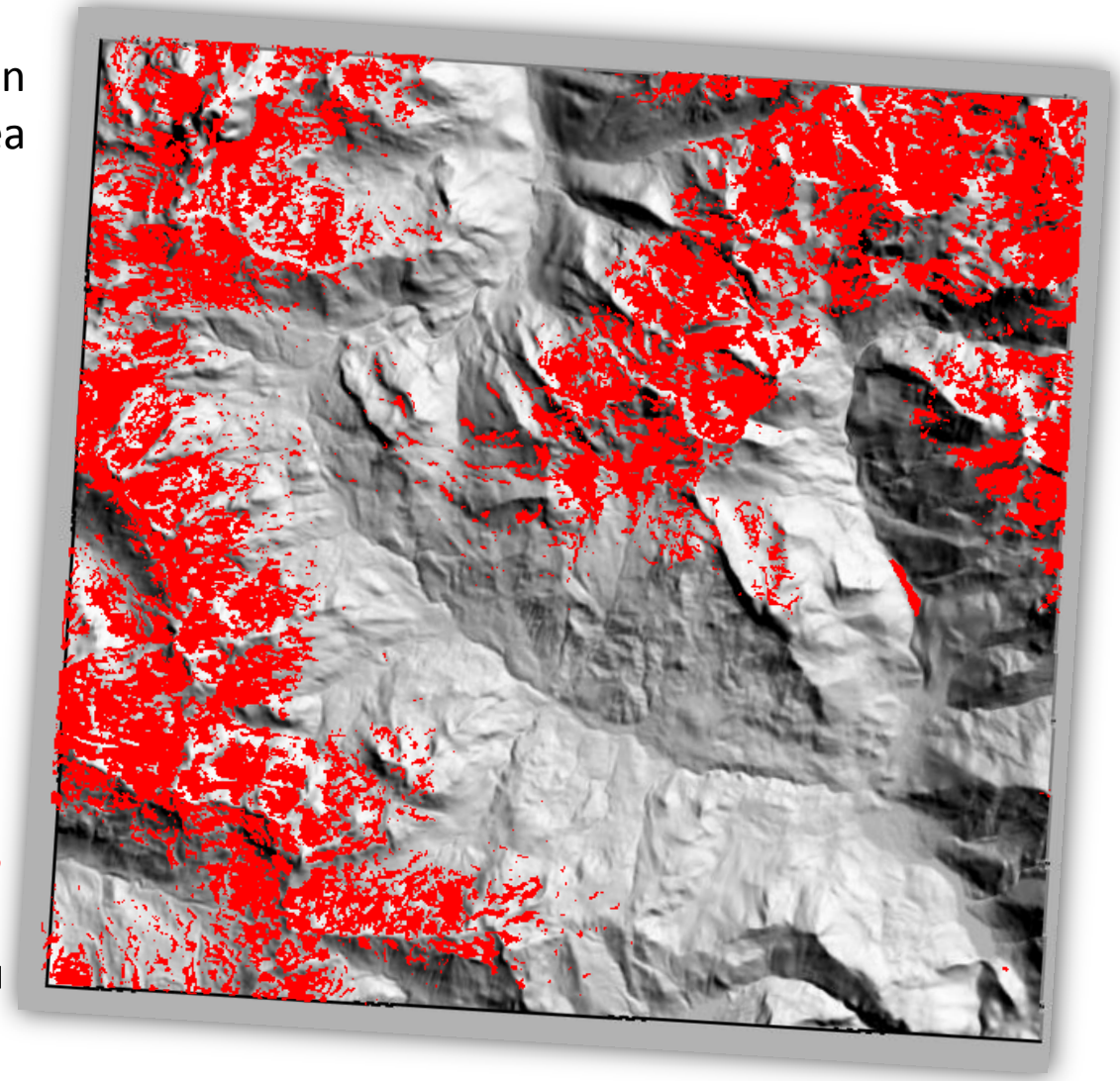
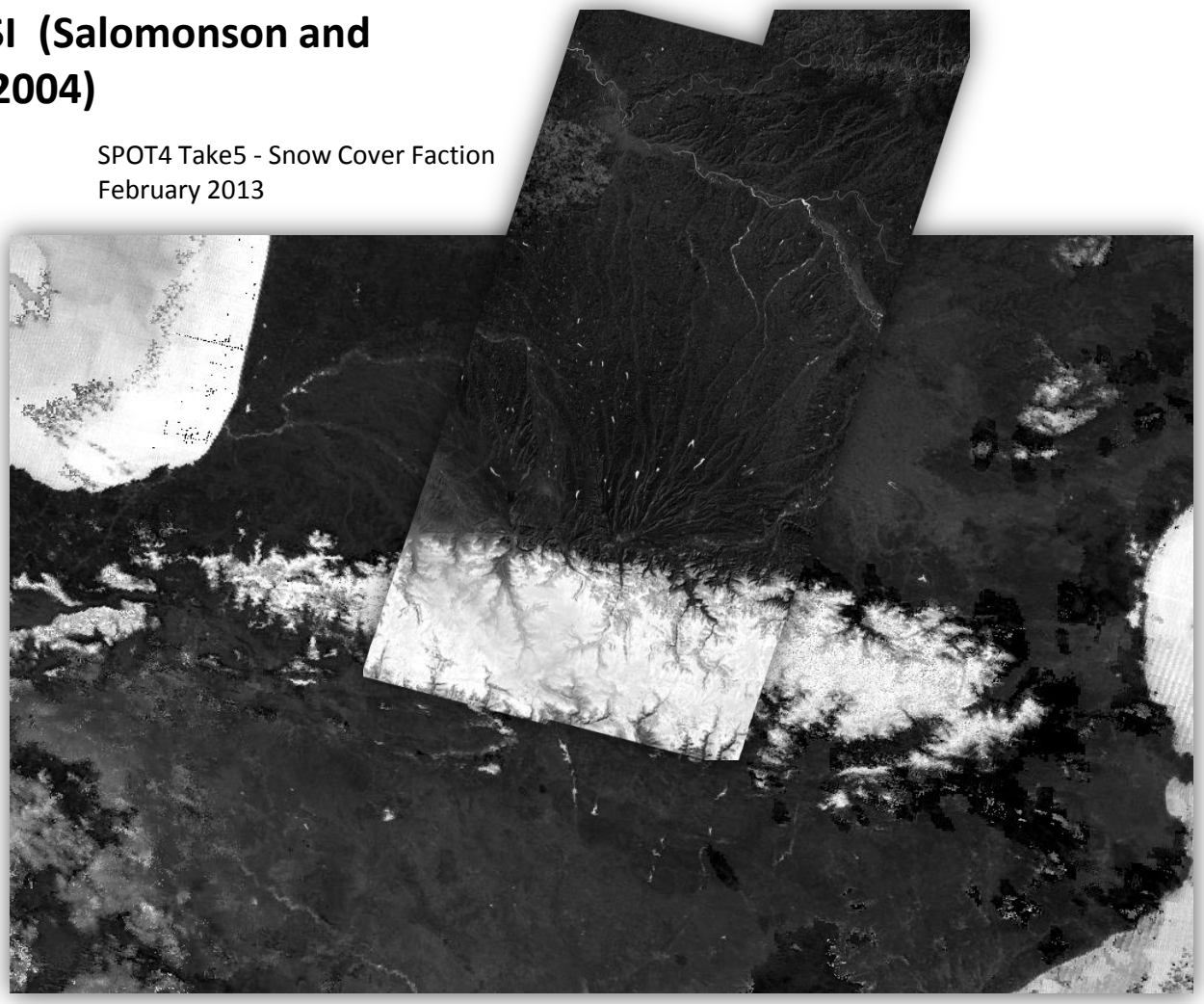


SCA → SCF → SWE → SD → Comparison

Snow Cover Fraction (SCF)

SCF = 0,06 + 1,21*NDSI (Salomonson and Appel, 2004)

SPOT4 Take5 - Snow Cover Faction
February 2013

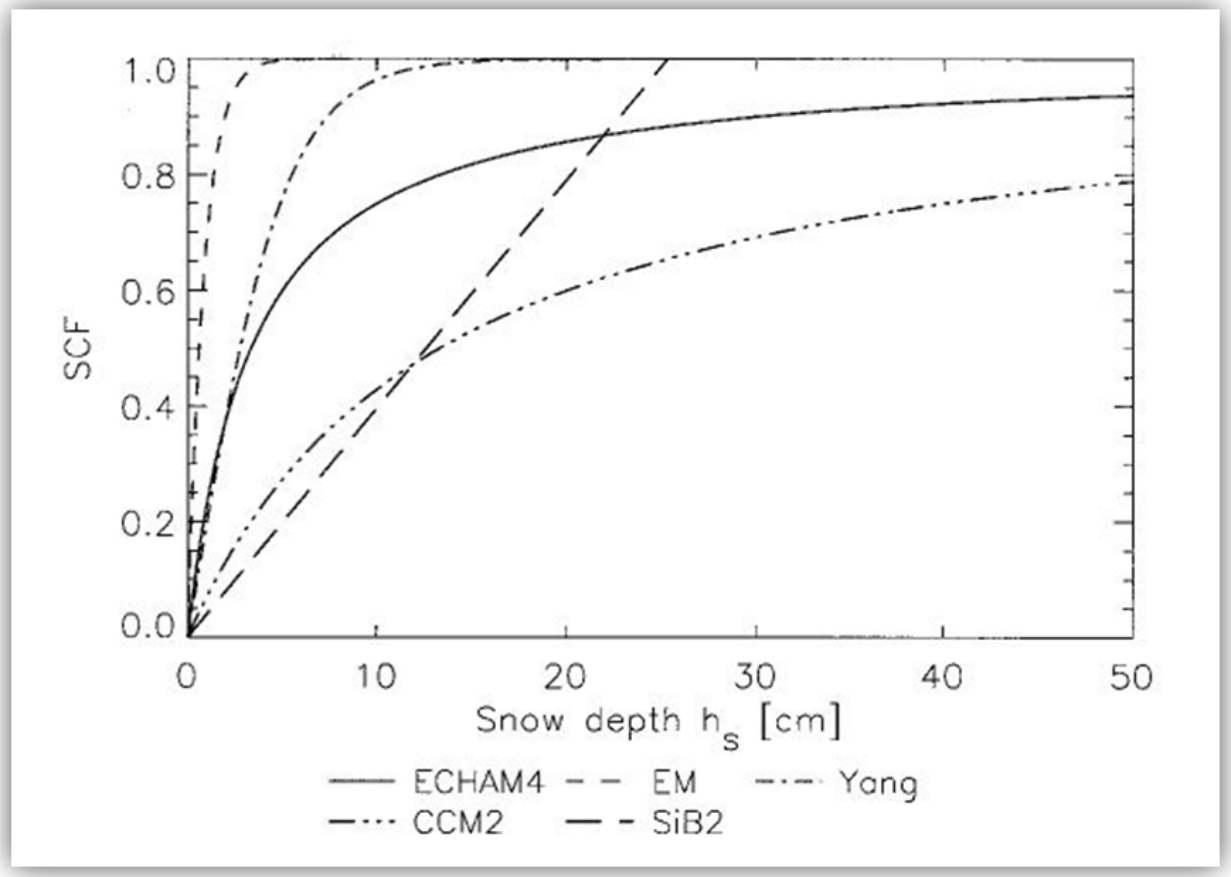


Relationship estimating fractional snow cover from MODIS by using the normalized difference snow index, tested with Landsat.

MODIS (MOD09A1) Snow Cover Faction
February 2013

SCA → SCF → SWE → SD → Comparison

Snow Water Equivalent (SWE)



Source: Roesch et al 2001

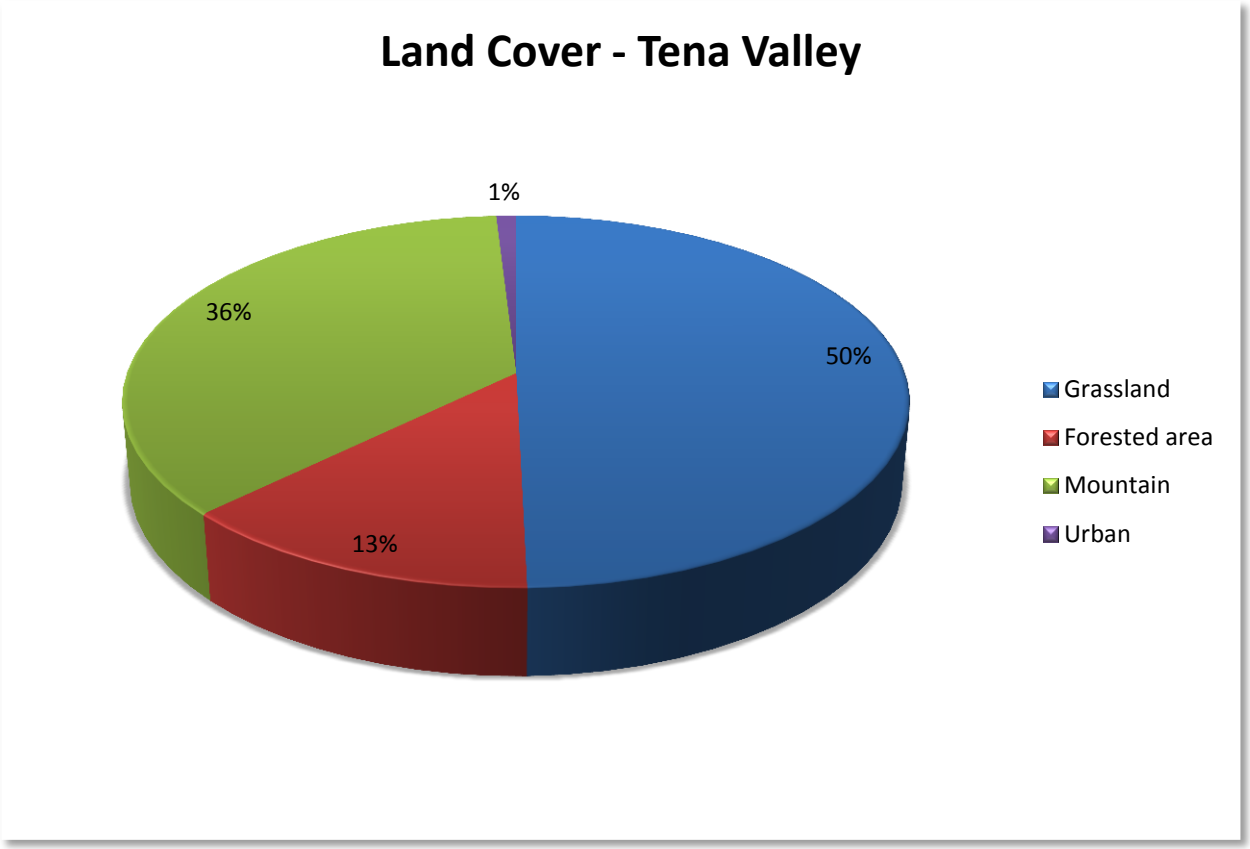
There are several general circulation models (GCMs) parameterizing snow cover fraction, snow depth and snow water equivalent by using a number of empirical formulae and satellite data.

Relationship between snow depth and snow cover fraction assuming a snow density = 300Kg/m^3

SCA → SCF → SWE → SD → Comparison

Snow Water Equivalent (SWE)

We use the ECHAM 4 GCM. Roesch et al. (2001) considers new parametrization for the calculation of SCF over (1) flat non-forested areas (2) mountainous non-forested areas (3) forested areas.



Source Corine 2006

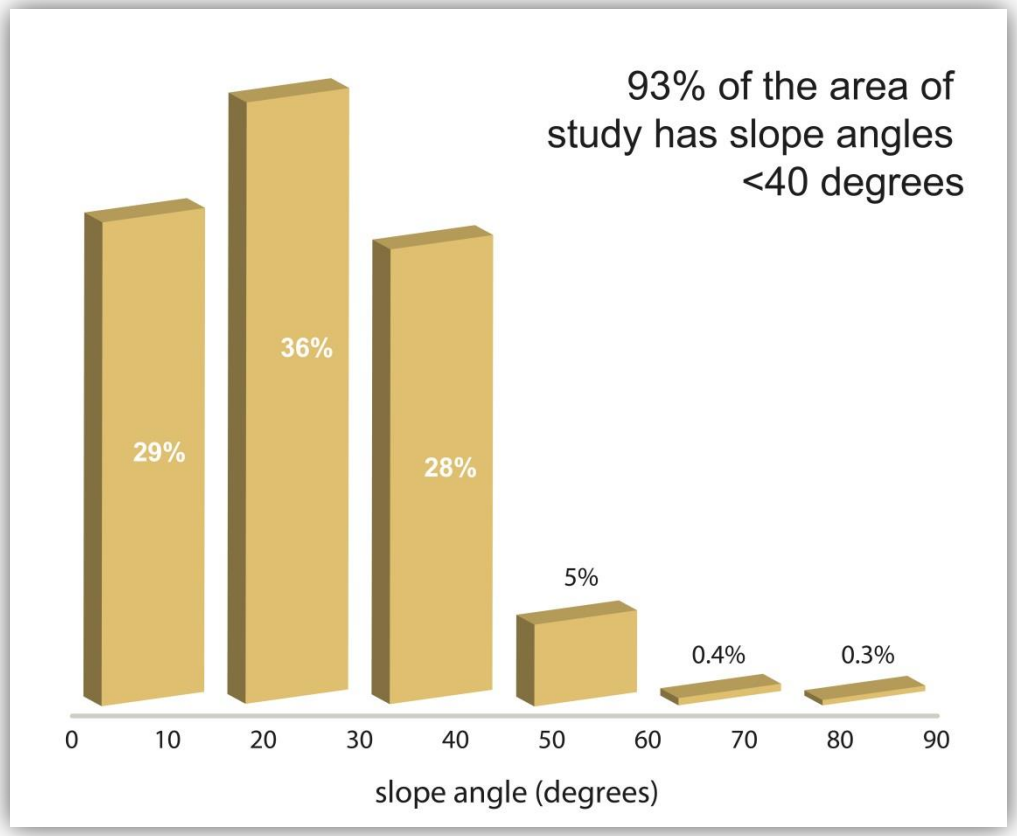
SCA → SCF → SWE → SD → Comparison

Snow Water Equivalent (SWE)

$$F_s = b * \tanh(100 * S_n) * (1000 * S_n / 1000 * S_n + \varepsilon + 0.15\,\sigma_Z)^{1/2}$$

ε = small number to avoid division by zero and

σ_Z= standard deviation of the sub-grid orography



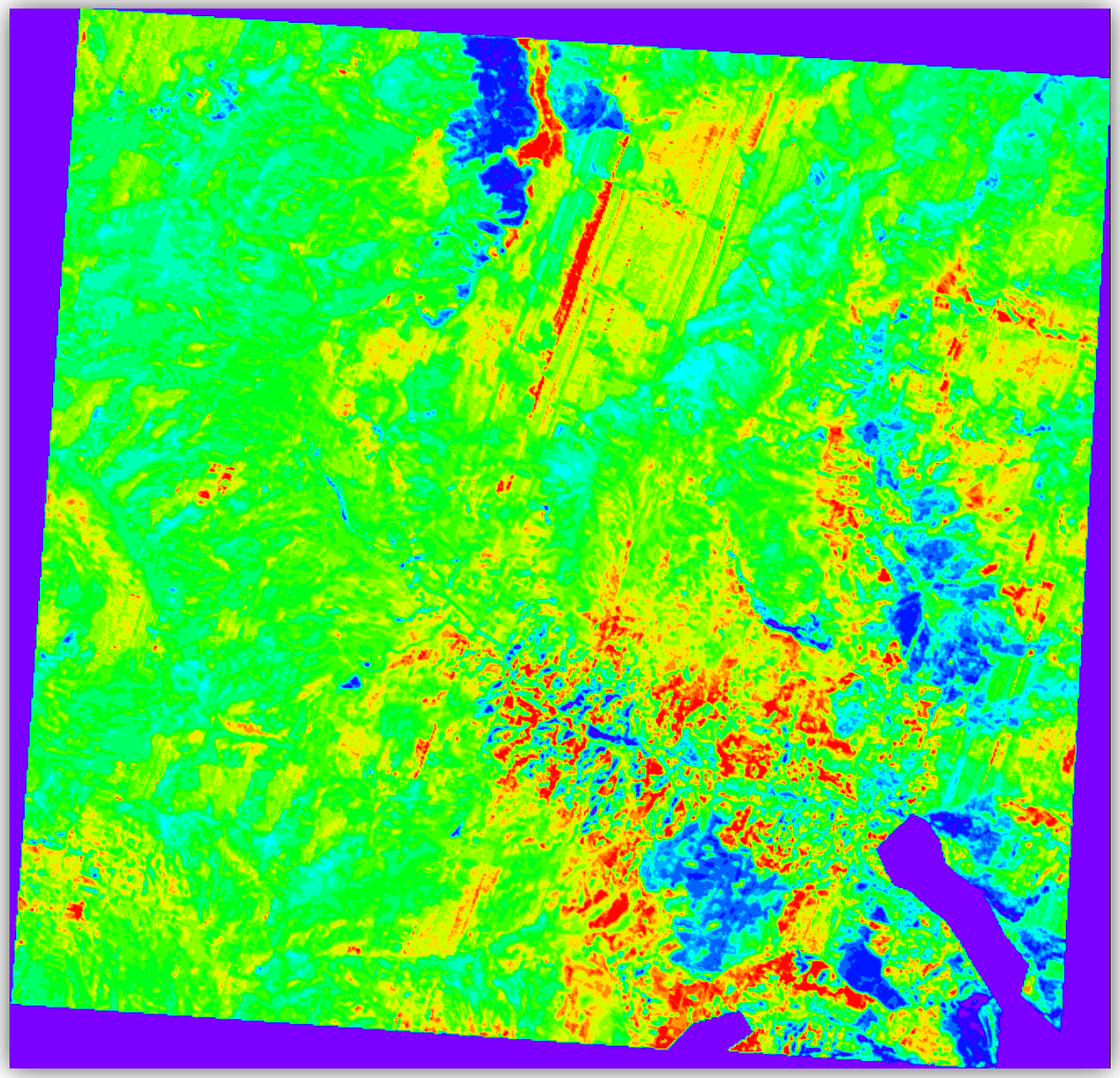
$F_s = b * \tanh(a * S_n)$
with *a*= 100 and *b*= 0.95

F_s = Snow Cover Fraction

S_n = Snow Water Equivalent

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



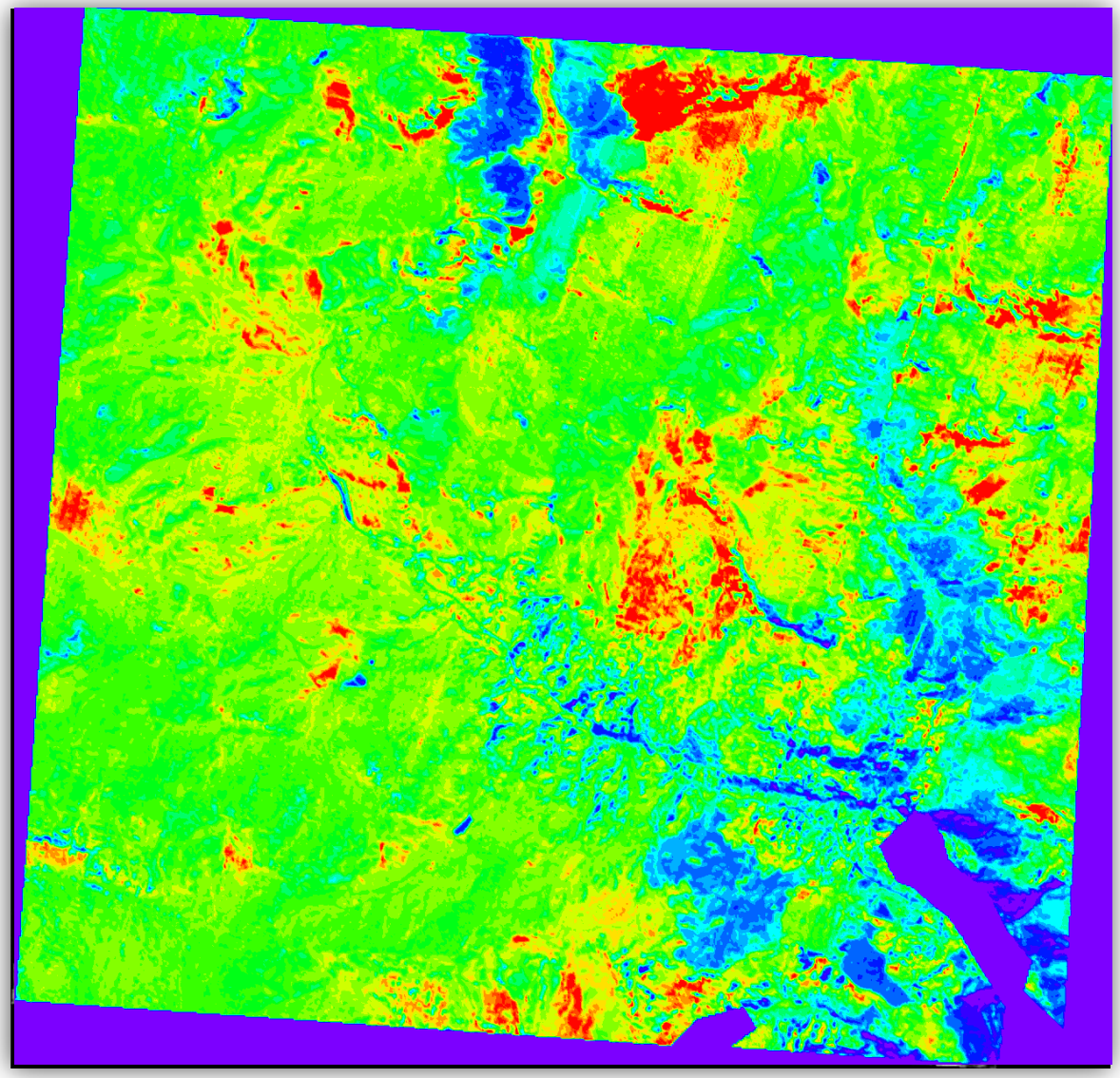
Legenda SD (cm)

- 0 to 40
- 41 to 82
- 83 to 124
- 125 to 166
- 167 to 207
- 208 to 249
- 250 to 291
- 292 to 333
- 334 to 374
- 375 to 416
- 417 to 458
- 459 to 500
- 501 to 541
- 542 to 583
- 584 to 625
- 626 to 667

16.02.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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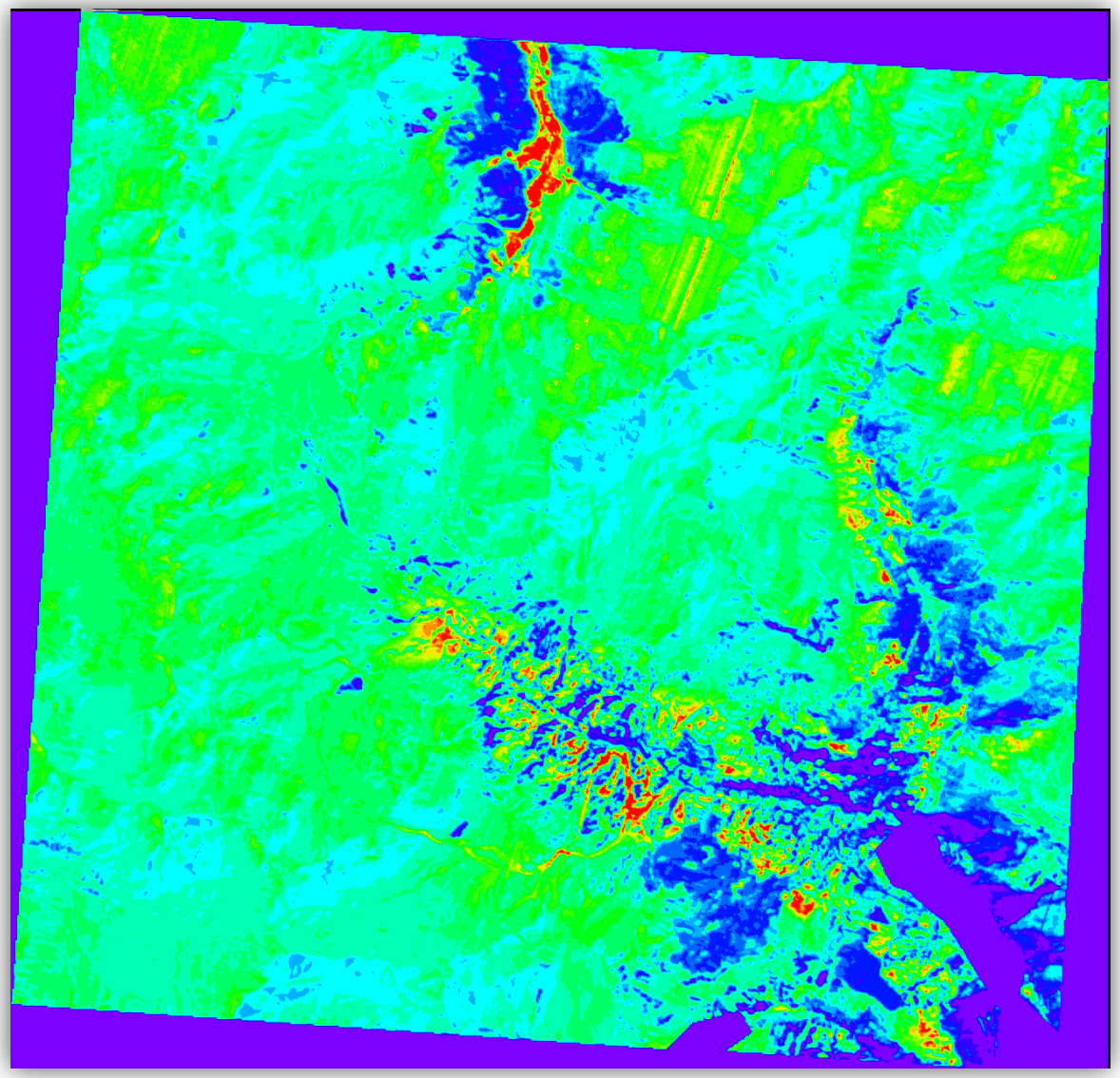
03.03.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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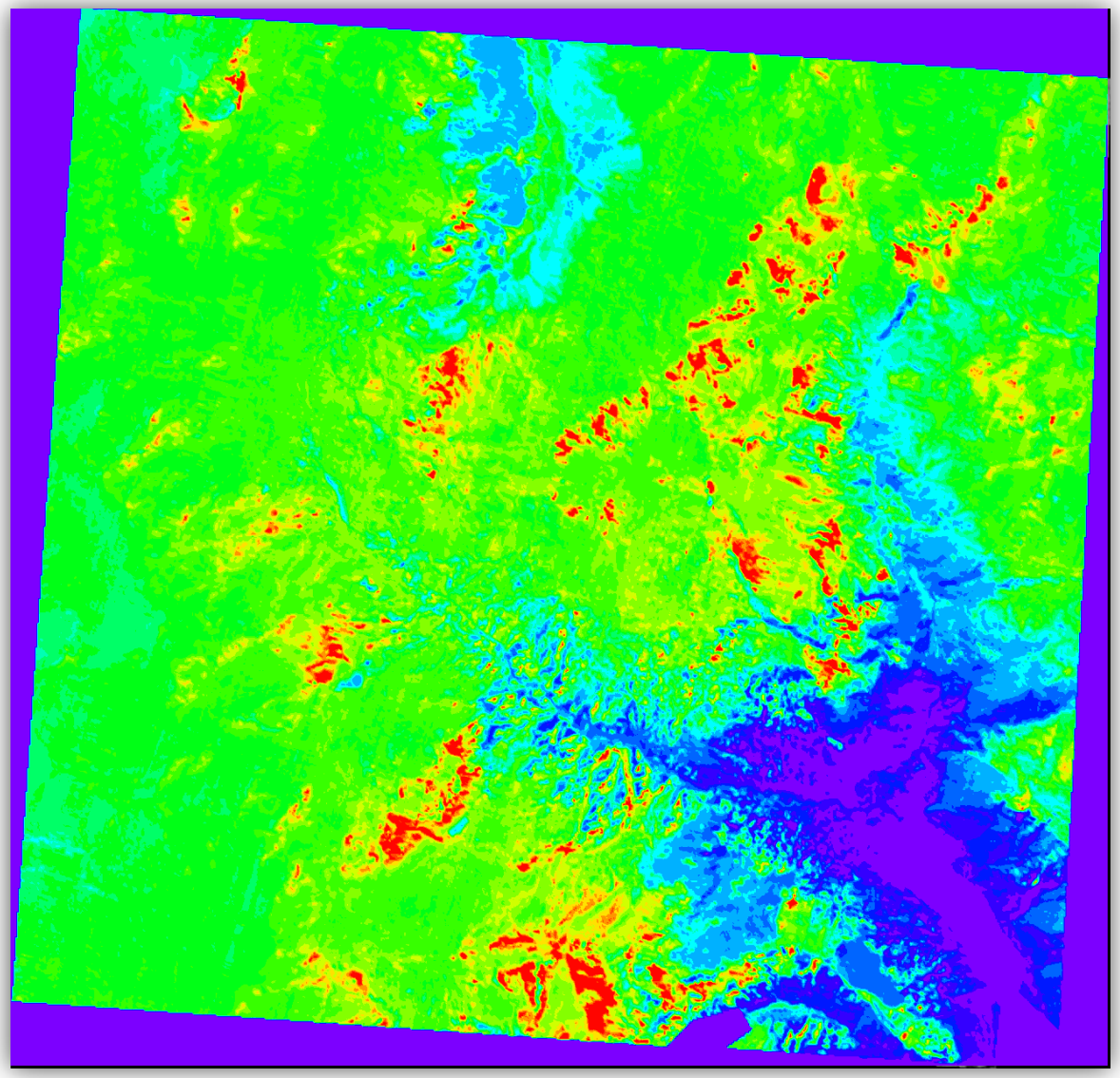
08.03.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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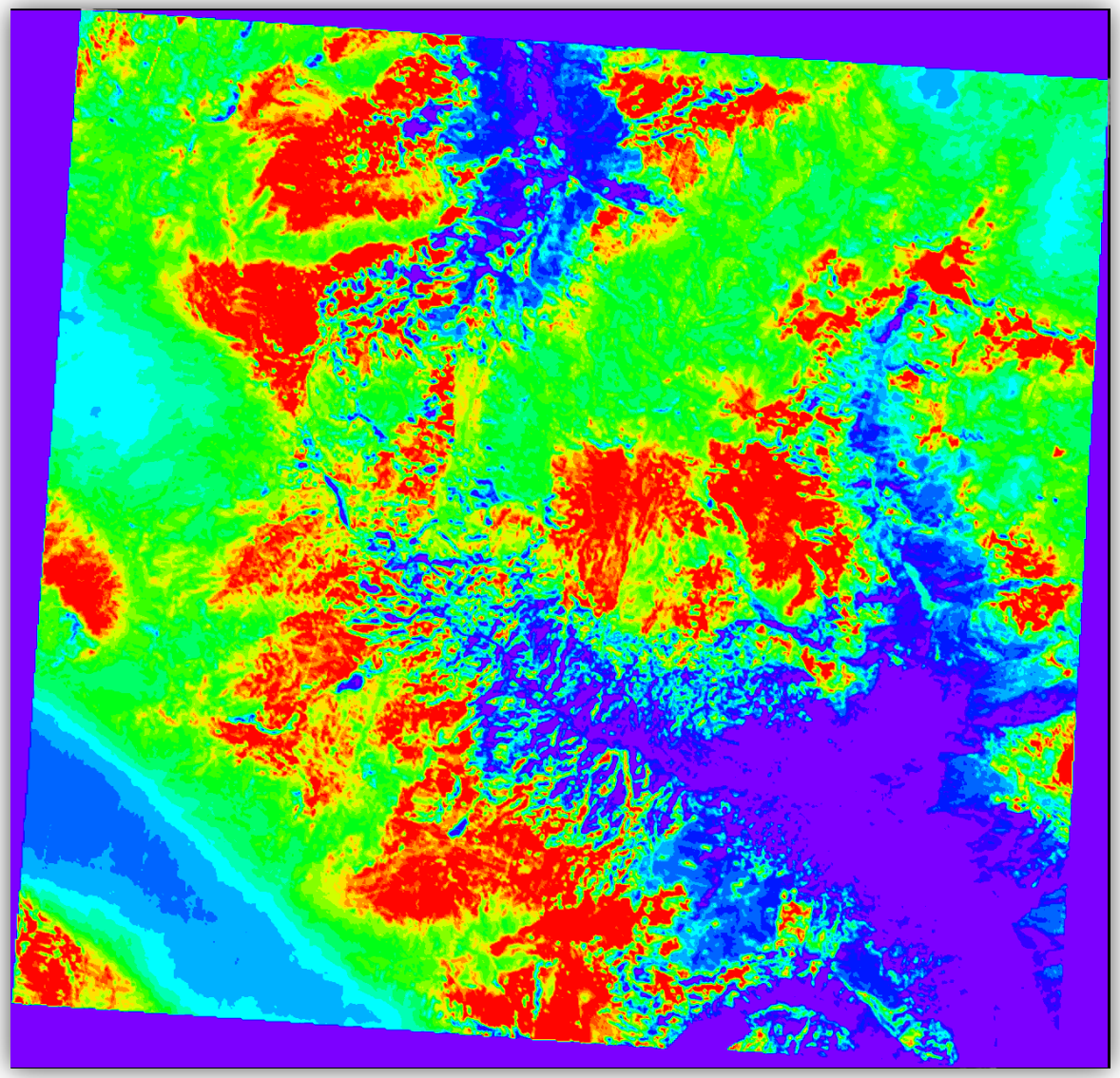
07.04.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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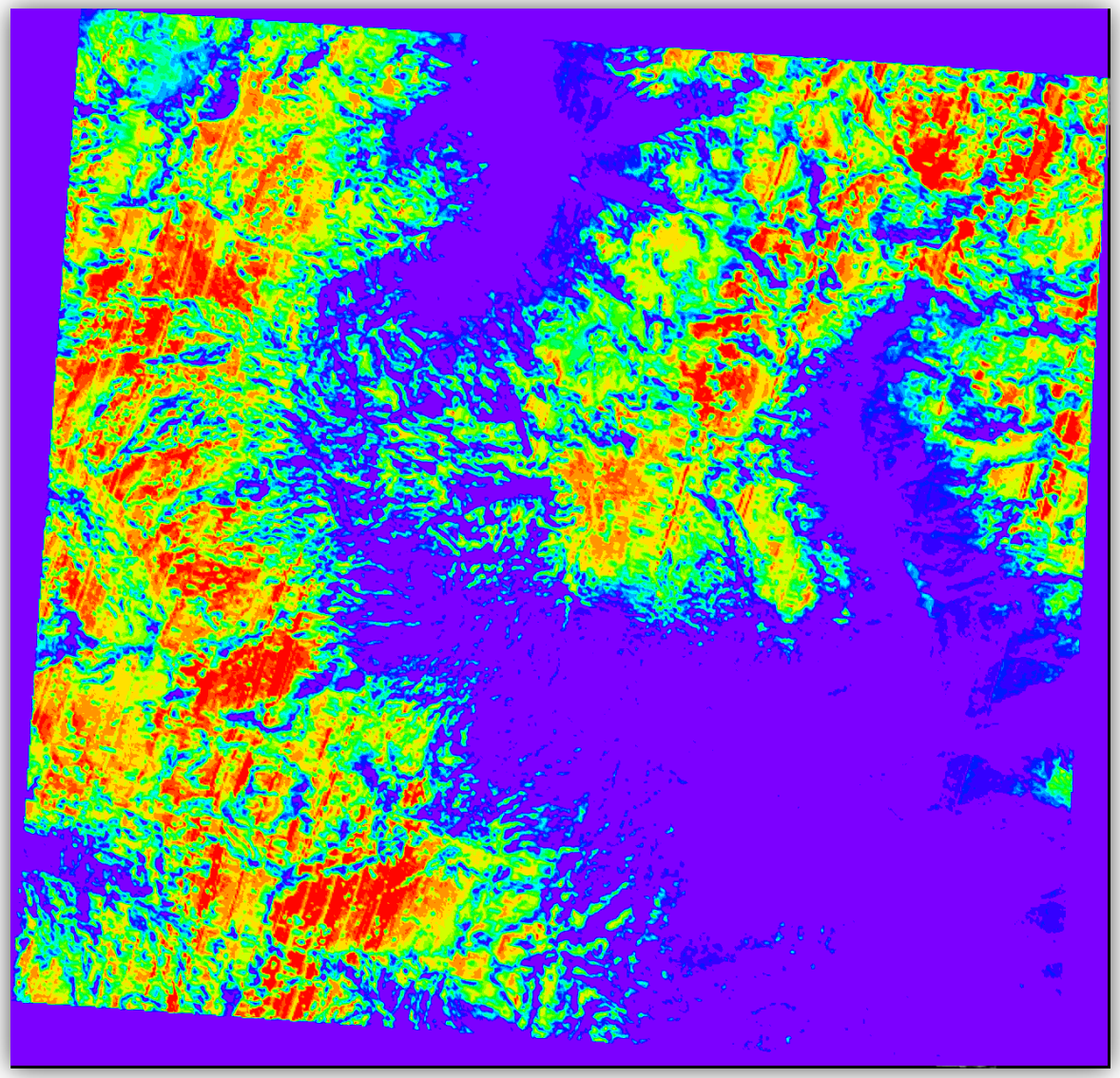
12.04.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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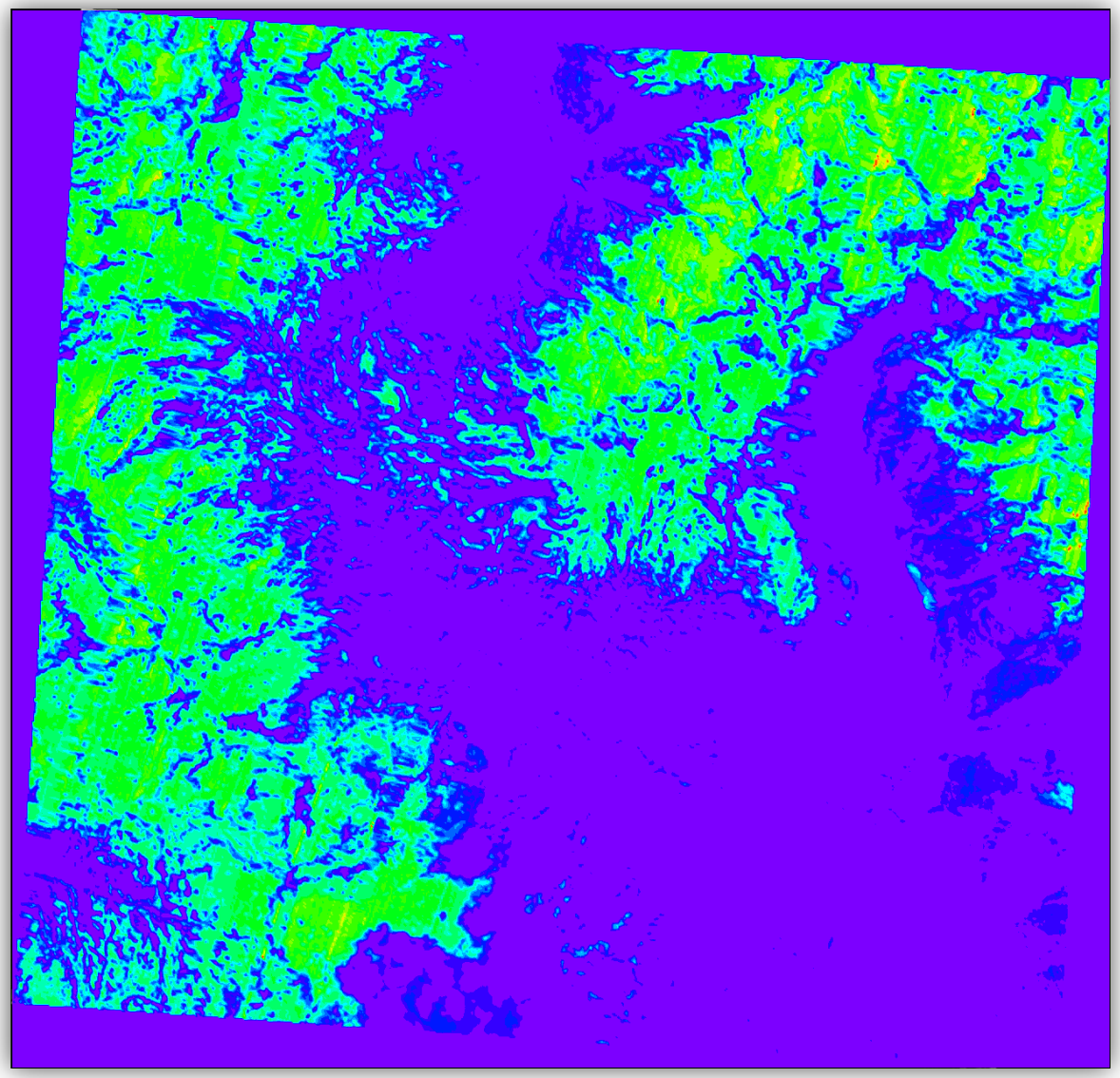
12.05.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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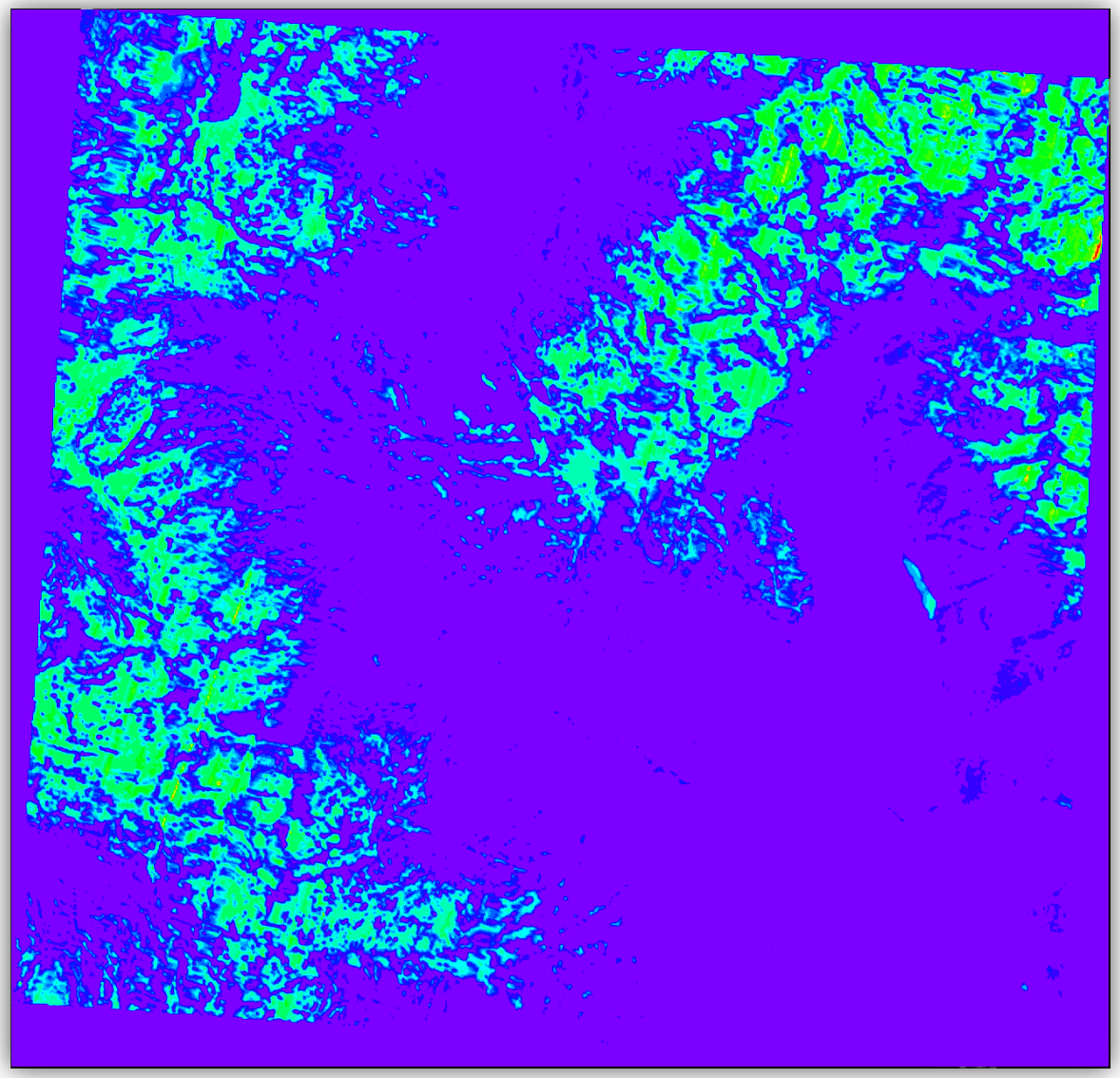
06.06.2013

SCA → SCF → SWE → SD → Comparison

Results - Snow Depht (SD)



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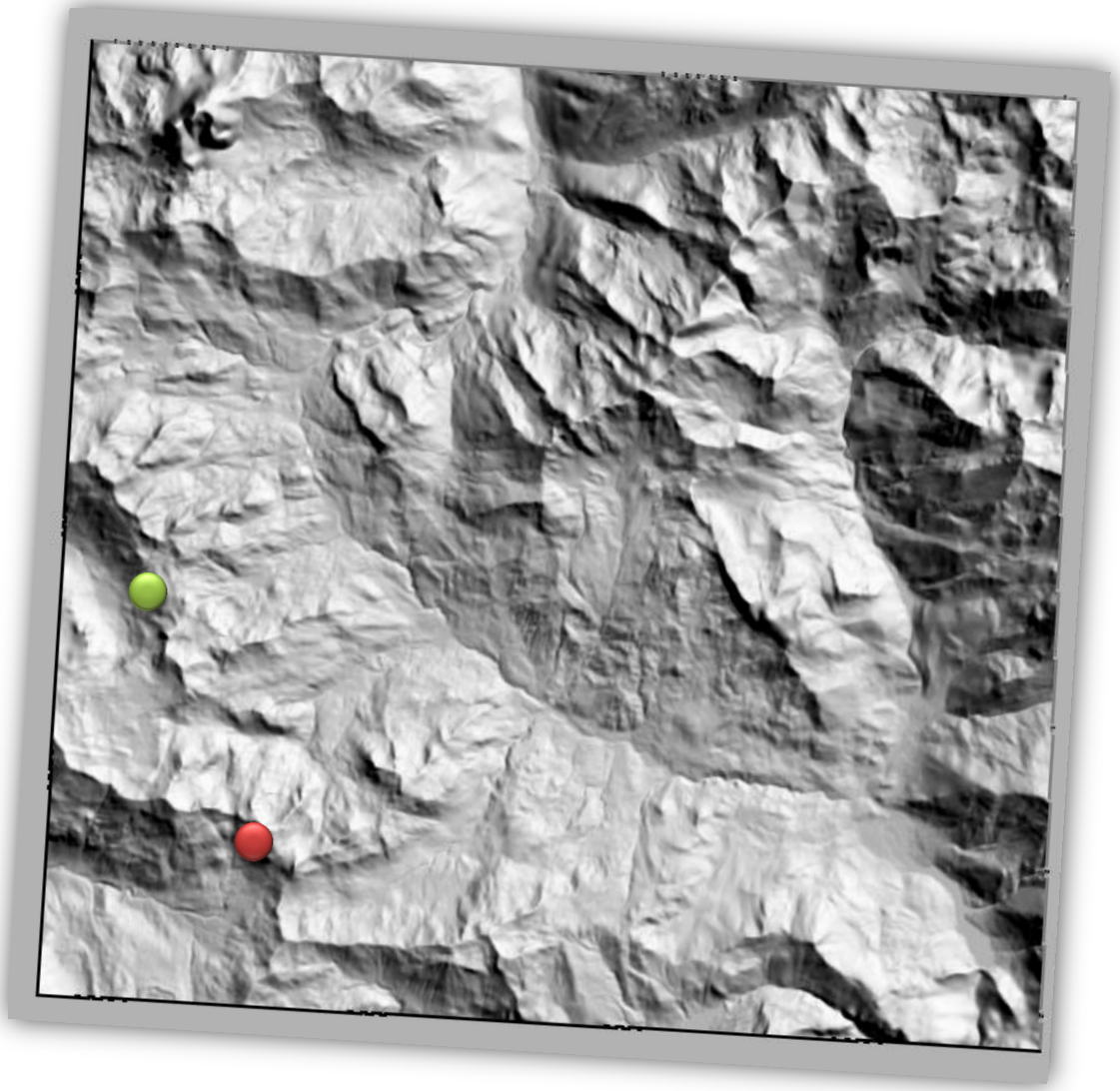
16.06.2013

SCA → SCF → SWE → SD → Comparison

Comparison to ground data



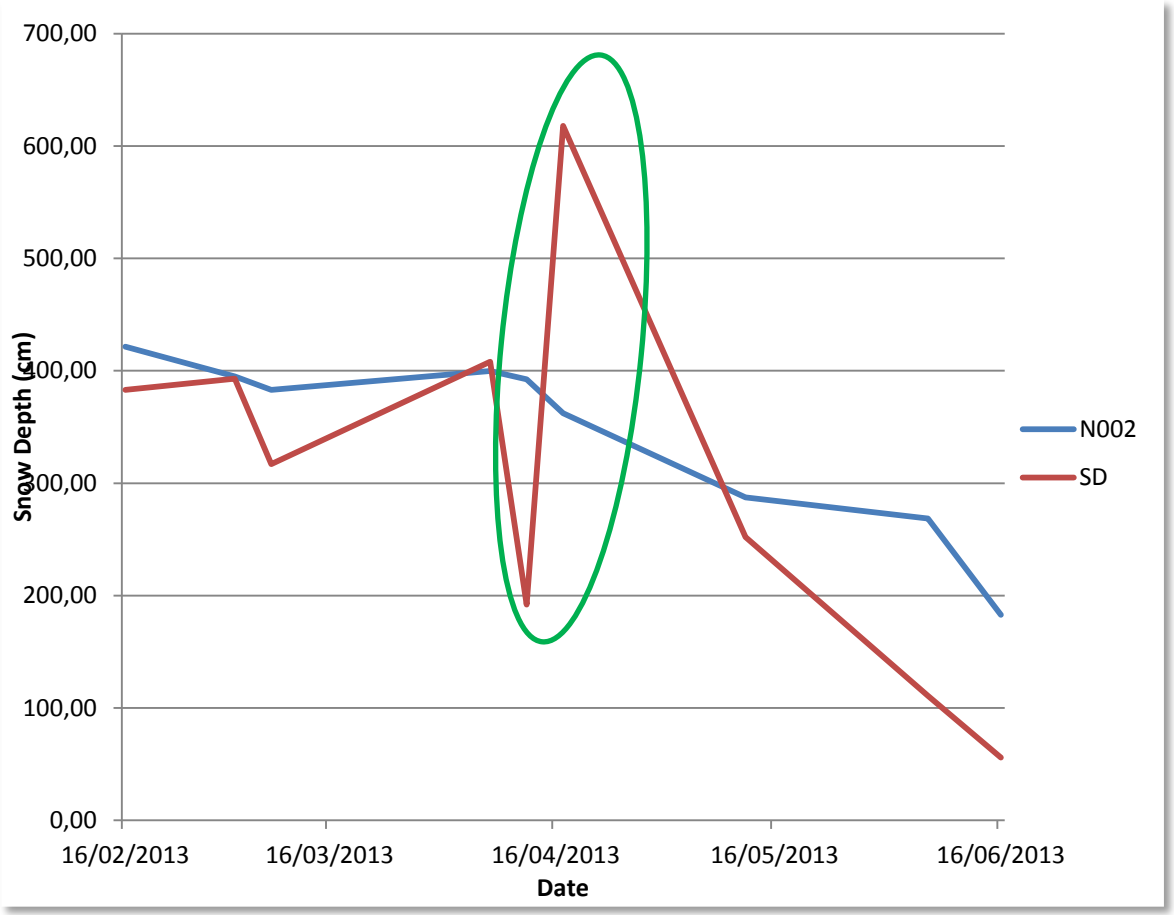
N002 Snow station en Izas
qt. 2080 m (red point)
x 710350 y 4736147

N003 Snow station Canal Roya qt. 1917 m (green point)
x 708767 y 4740751

Data provided by SAIH Ebro (Sistema Automático de Información Hidrológica de la Cuenca Hidrográfica del Ebro).

SCA → SCF → SWE → SD → Comparison

Comparison to ground data



	N002	SD
16/02/2013	421,48	383
03/03/2013	394,97	393
08/03/2013	383,17	317
07/04/2013	399,70	408
12/04/2013	392,43	192
17/04/2013	362,34	618
12/05/2013	287,36	252
06/06/2013	268,71	111
16/06/2013	182,97	56

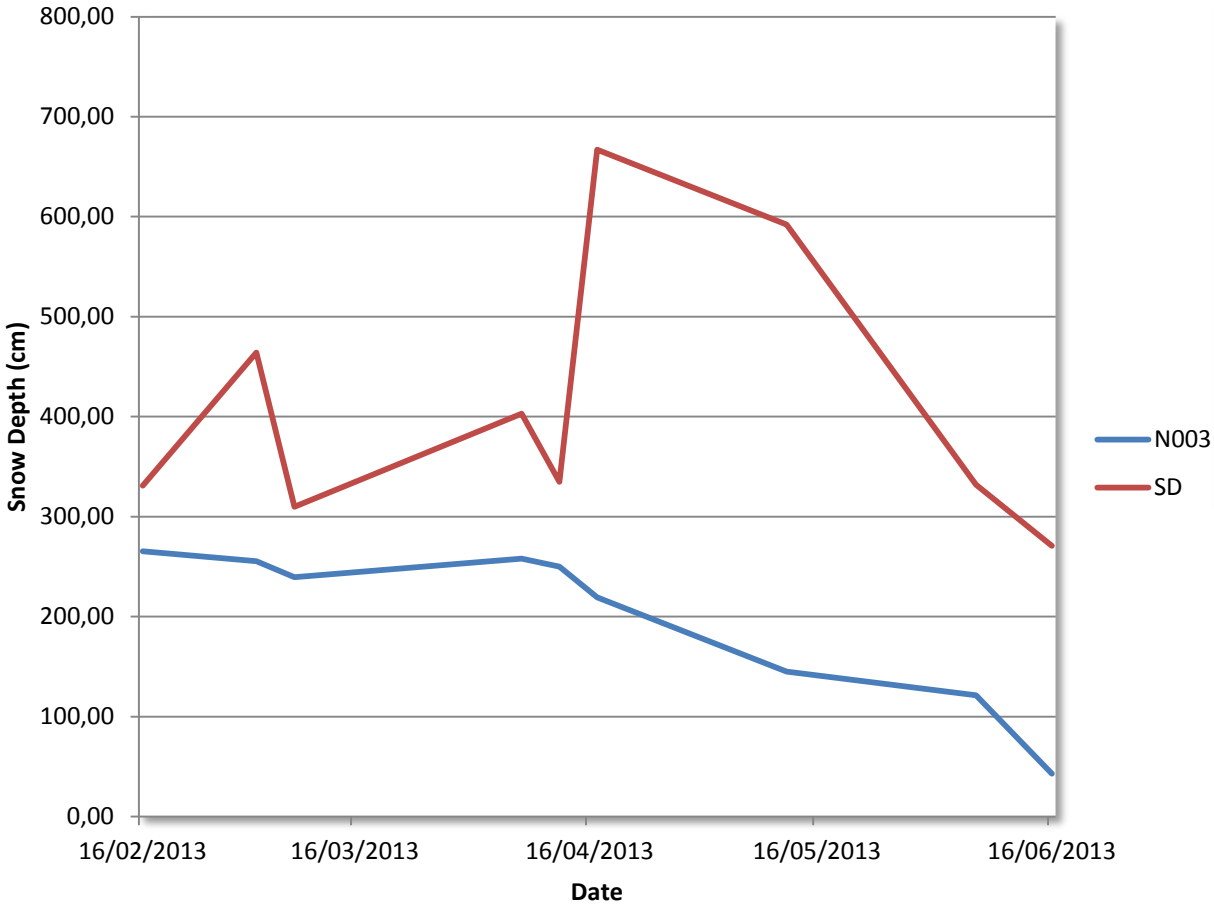
Mean	40,35
Dev. St	131,842158

Mean	59,77
Dev. St	62,15

SPOT4 (take5) images – N002 Snow station Izas qt. 2080 m

SCA → SCF → SWE → SD → Comparison

Comparison to ground data



	N003	SD
16/02/2013	265,39	331
03/03/2013	255,44	464
08/03/2013	239,58	310
07/04/2013	258,18	403
12/04/2013	249,90	335
17/04/2013	219,23	667
12/05/2013	145,24	592
06/06/2013	121,55	332
16/06/2013	43,15	271

Mean	-211,93
Dev. St	147,078572

Mean	-114,902
Dev. St	61,1625222

SPOT4 (take5) images - N003 Snow station Canal Roya qt. 1917 m

SCA → SCF → SWE → SD → Comparison

Considerations and Final Remarks

- Landslide is one of the major natural hazards, for this reason it is important to monitor and survey it.

- It is important to observe the spatial and temporal variations of snow melt in order to evaluate potential landslide activity and eventually estimate the occurrence of slope deformation.

- Recently, the use of remote sensing has become a standard practice to monitor and analyse the evolution of the territory in continuous mode, mainly due to the wide development and availability of several sensors at high spatial and spectral resolution.

- In our research we evaluated the possibility of measuring snow depth from satellite data acquired at high spatial and temporal resolution.

Considerations and Final Remarks

- Generally, preliminary results are good and we found positive corrispondence during winter season (january – april)
- Good correspondence between Snow Depth (SD) from satellite data and ground data of N002 Telenivometro en Izas qt. 2080 m.
- Overestimation between Snow Depth (SD) from satellite data and ground data of N003 Telenivometro en Canal Roya qt. 1917 m.

- Strongly check the procedure in test site with solid ground data and snow-meteorological observatories.
- Taking into account also other parameters that can affect the model at local/regional scale

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