→ FRINGE 2015 WORKSHOP

Advances in the Science and Applications of SAR Interferometry and Sentinel-1 InSAR Workshop

Improved PSI Performance for Landslide Monitoring Applications

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ALTAMIRA INFORMATION

23–27 March 2015 | ESA–ESRIN | Frascati (Rome), Italy

European Space Agency

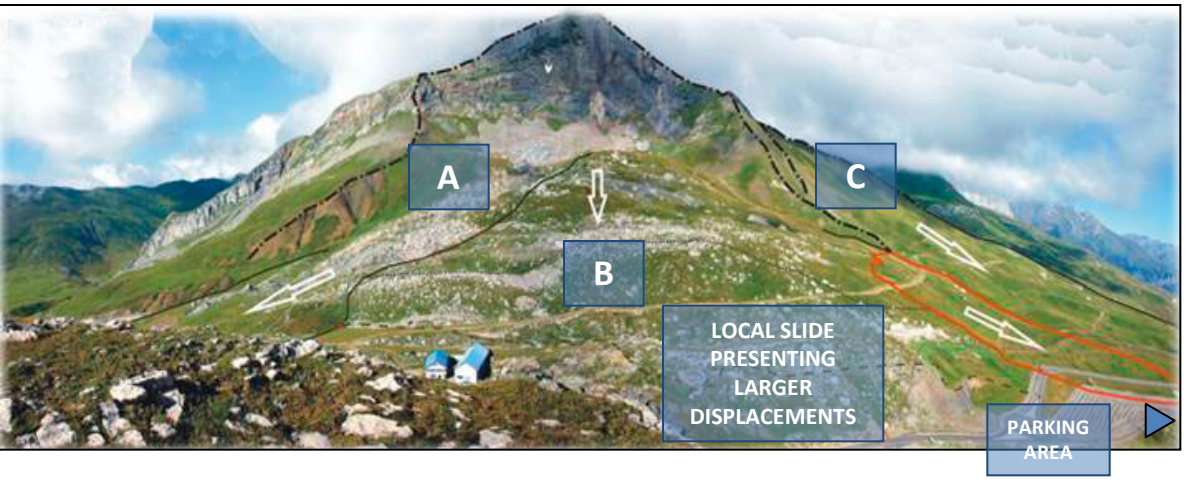
Outline

- Area of Study
- Previous PSI (and others) studies
  - Main conclusions → Motivation!
- Non-Linear InSAR filtering
- Down-slope hypothese
- PSI Results
- Conclusions and future work

Area of study

El Portalet study case

- Located in the upper part of *Gallego River* basin, in the *Central Spanish Pyrenees* (Huesca).
- The area is characterized by a high density of landslides.
- They have been reactivated due to the constant erosion of the Gallego River and human activity:
  - The area of interest is affected by three main roto-translational landslides (A-B-C).
  - A local slide located over the parking area presenting larger displacements has been identified.
  - Reactivated by the excavation works carried out to build a parking area during summer 2004.

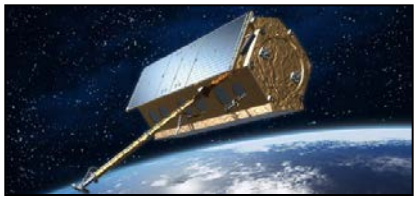


Previous studies

- Summary of previous works and performance evaluation

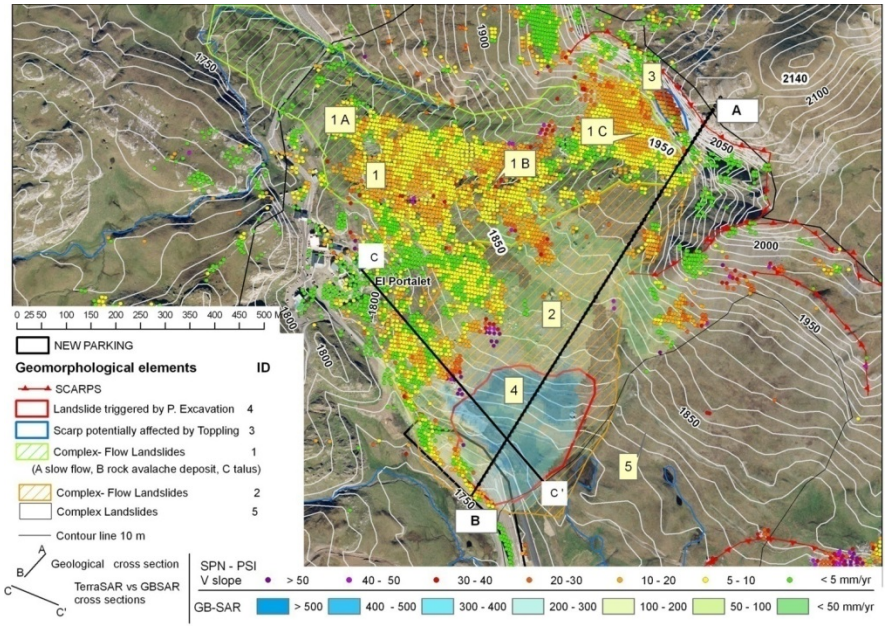
88 ERS/ENVISAT (2001-2007)

12 ALOS (2007-2011)

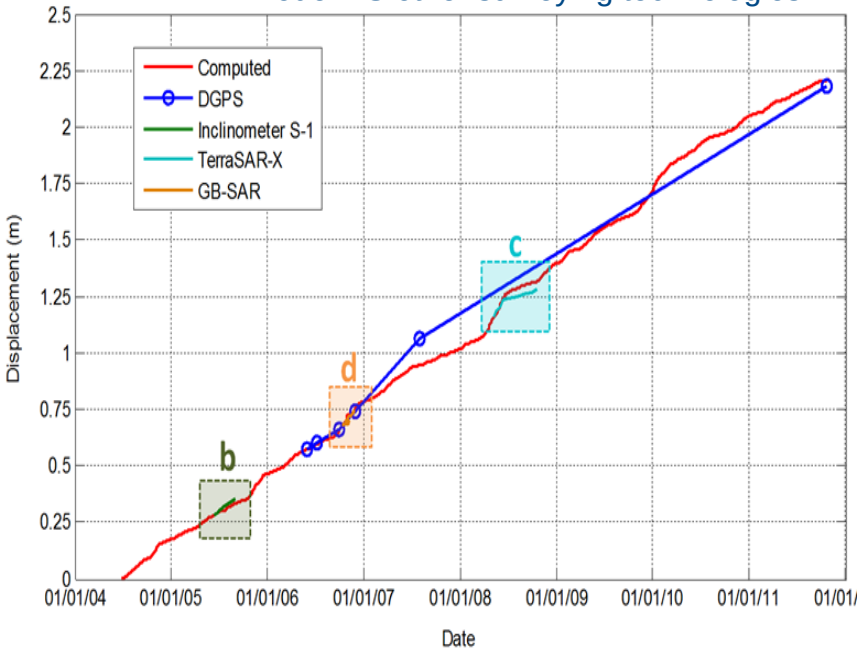


14 TerraSAR-X (2008)

GB-SAR (2007) Vs TSX 2009 INSAR motions results



2D FEM model VS other surveying technologies



Departing point

- Main conclusions:
  - Not all areas are sampled → Need for high PS density → both distributed and point like targets (new filtering approach?).
  - Temporal decorrelation, no use of winter acquisitions… less number of images (distributed approach).
  - LOS maps hard to interpret → downslope approach.
  - Previous slope analysis (layover, foreshortening,…) for data acquisition to maximize motion information.

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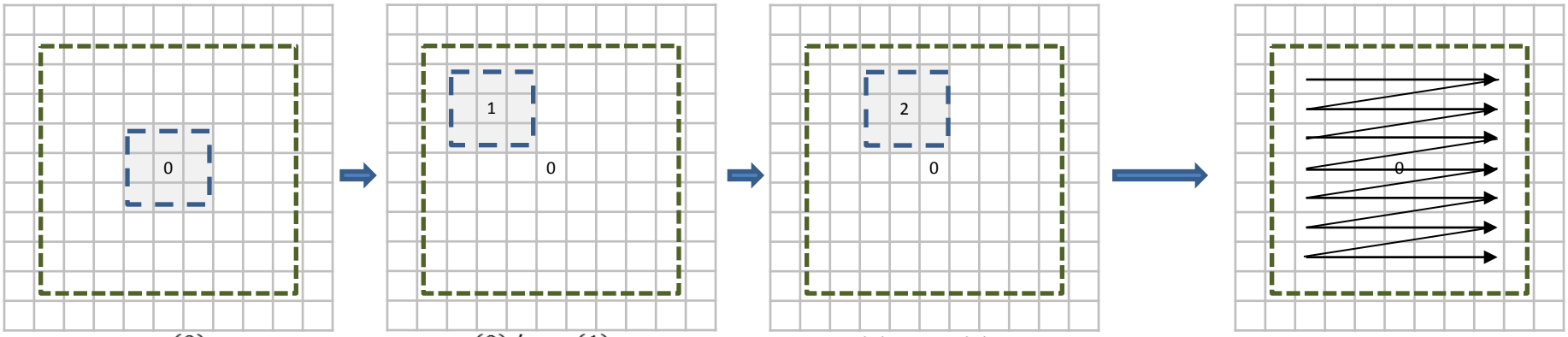
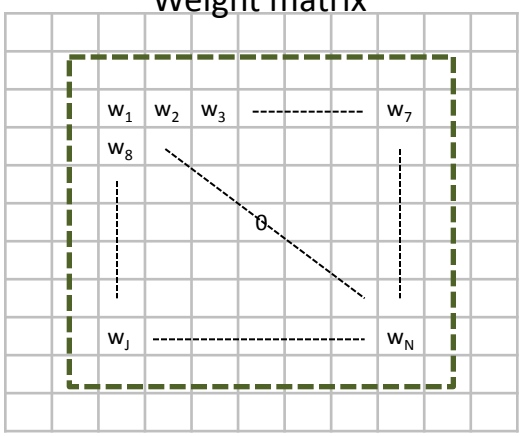
NL-InSAR filtering

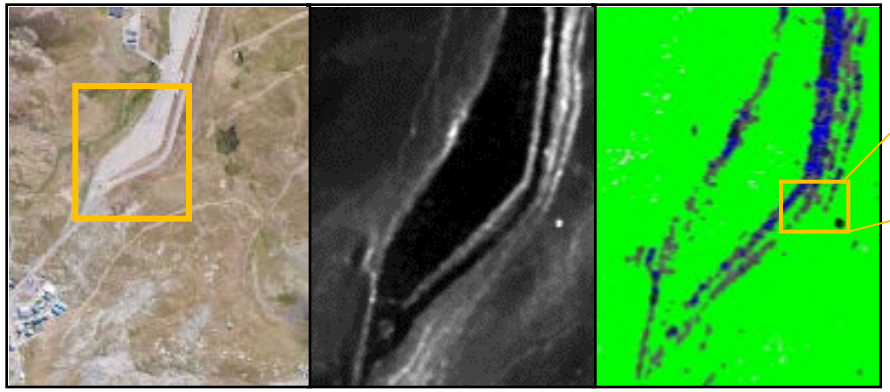
- NL-InSAR filtering consists on a probabilistic criterion based on the intensities and the interferometric phases surrounding two given patches.



$stat(0)$ $\quad$ $stat(0)/stat(1) \rightarrow w_1$ $\quad$ $stat(0)/stat(2) \rightarrow w_2$ $\quad$ $stat(0)/stat(i) \rightarrow w_i, \forall i$

Weight matrix





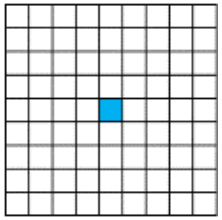
- 1 look
- 70 – 100 looks
- 200 – 300 looks

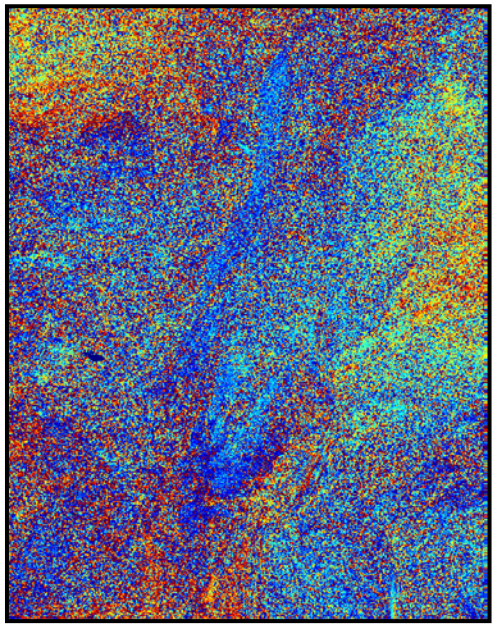
$$\hat{L}_s = \frac{(\sum_t w(s,t))^2}{\sum_t w(s,t)^2}$$

Deledalle, C.-A. et al., "NL-InSAR: Nonlocal Interferogram Estimation", IEEE Transactions on Geoscience and Remote Sensing 49, 1441-1452 (Apr. 2011).

NL-InSAR filtering

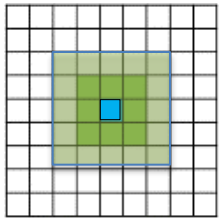
Full resolution pixel

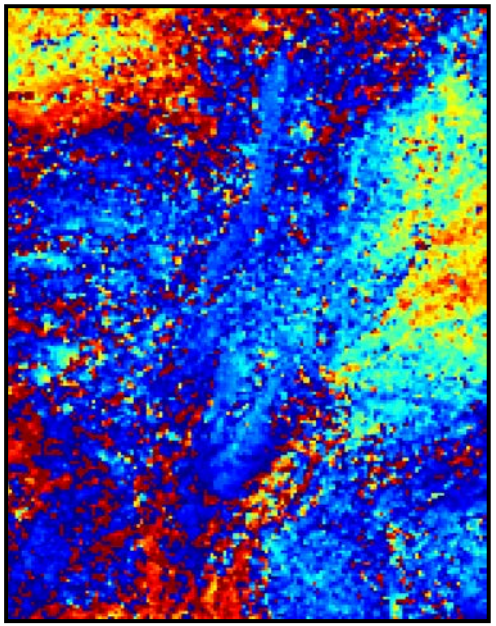




$-\pi$ π

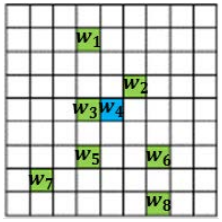
Boxcar 5X5

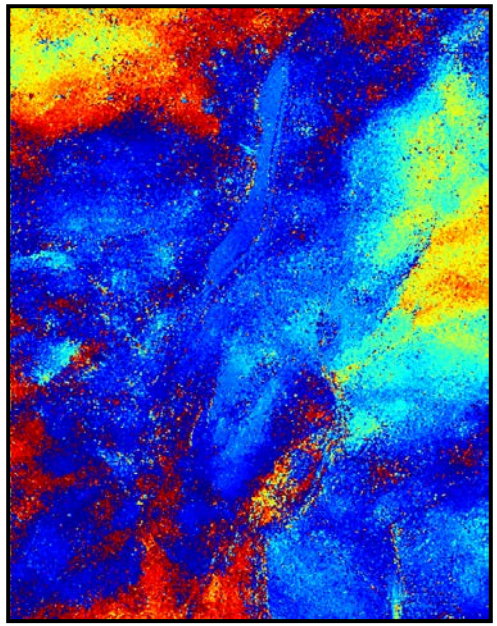




$-\pi$ π

NL-InSAR filtering

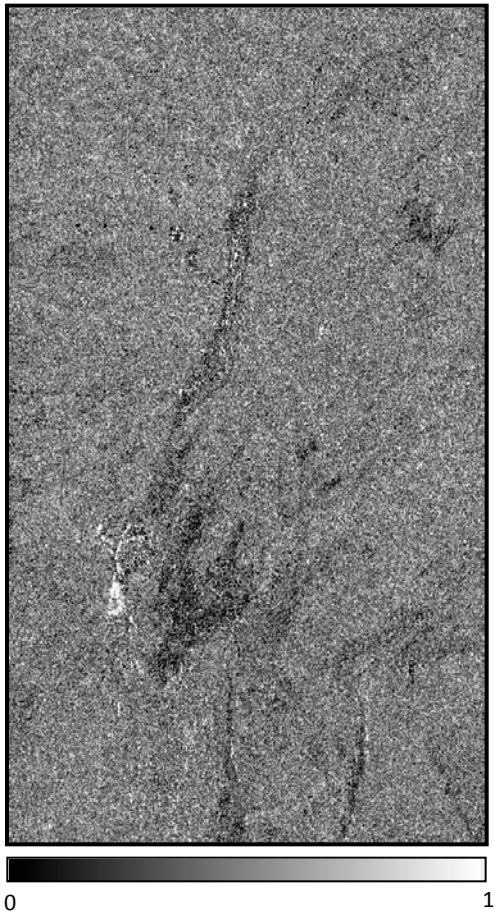




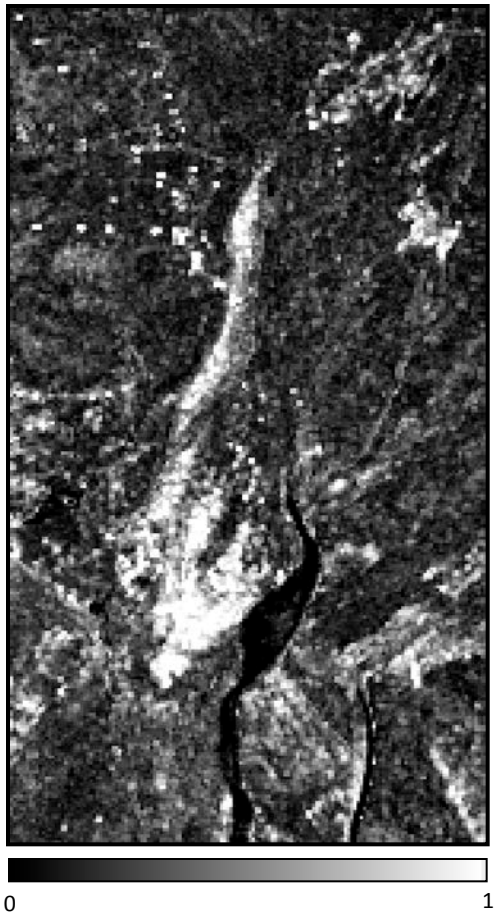
$-\pi$ π

NL-InSAR filtering

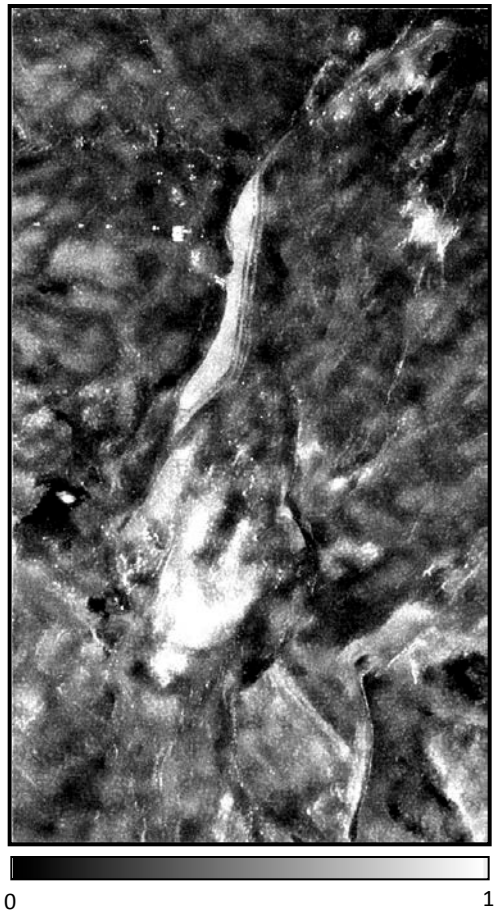
Amplitude Dispersion



Mean Coherence (5x5 boxcar)



NL-InSAR Filtering



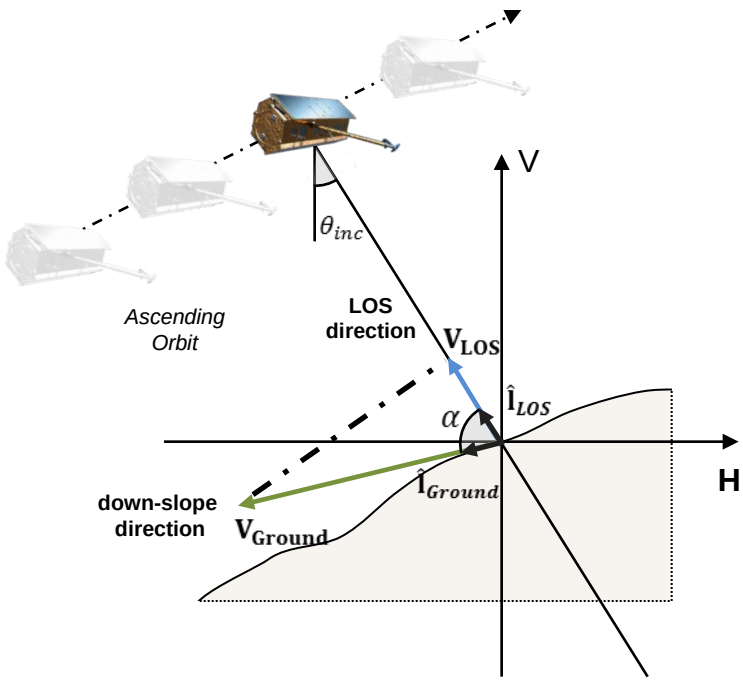
Down-Slope hypothesis

- SAR systems only have sensitivity in the LOS direction.
- Measured displacements in the LOS direction are rarely the real ones, but a projection of them:

$$\boldsymbol{v}_{LOS} = |\boldsymbol{v}_{LOS}| \cdot \hat{\boldsymbol{I}}_{LOS} \qquad \boldsymbol{v}_{LOS} = |\boldsymbol{v}_{LOS}| \cdot \hat{\boldsymbol{I}}_{LOS}$$

$$\boldsymbol{v}_{Ground} = |\boldsymbol{v}_{Ground}| \cdot \hat{\boldsymbol{I}}_{Ground} \qquad \cos\alpha = \hat{\boldsymbol{I}}_{LOS} \cdot \hat{\boldsymbol{I}}_{Ground}$$

- In landslides applications the more realistic assumption of the displacement direction with no *a priori* knowledge consists on considering that the displacement is produced along the steepest gradient of the terrain slope.
- This information may be directly derived employing an accurate DEM of the illuminated area.



Outline

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- Non-Linear InSAR filtering
- Down-slope hypothese
- PSI Results
  - DataSet
  - PSc Density
  - Velocity maps
- Conclusions and future work

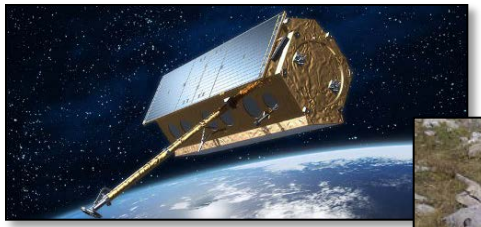
Results: Data Set

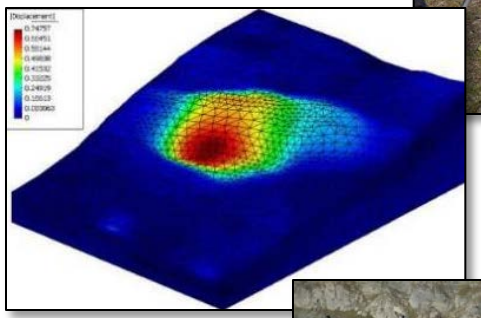
- INSAR: Two TerraSAR-X data sets acquired in ascending mode:
  - 13 TerraSAR-X from April 2011 to November 2011.
  - 8 TerraSAR-X from August to November 2013.
  - Network of 11 CRs used as super benchmarks.

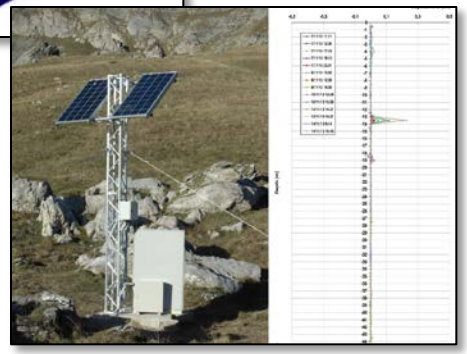
- DGPS measuraments are employed to cross-check with PSI displacement results.

- 3D FEM model which is currently in development.

- An AIS was installed in a new borehole in August 2013 measurements of movements for underneath layers.



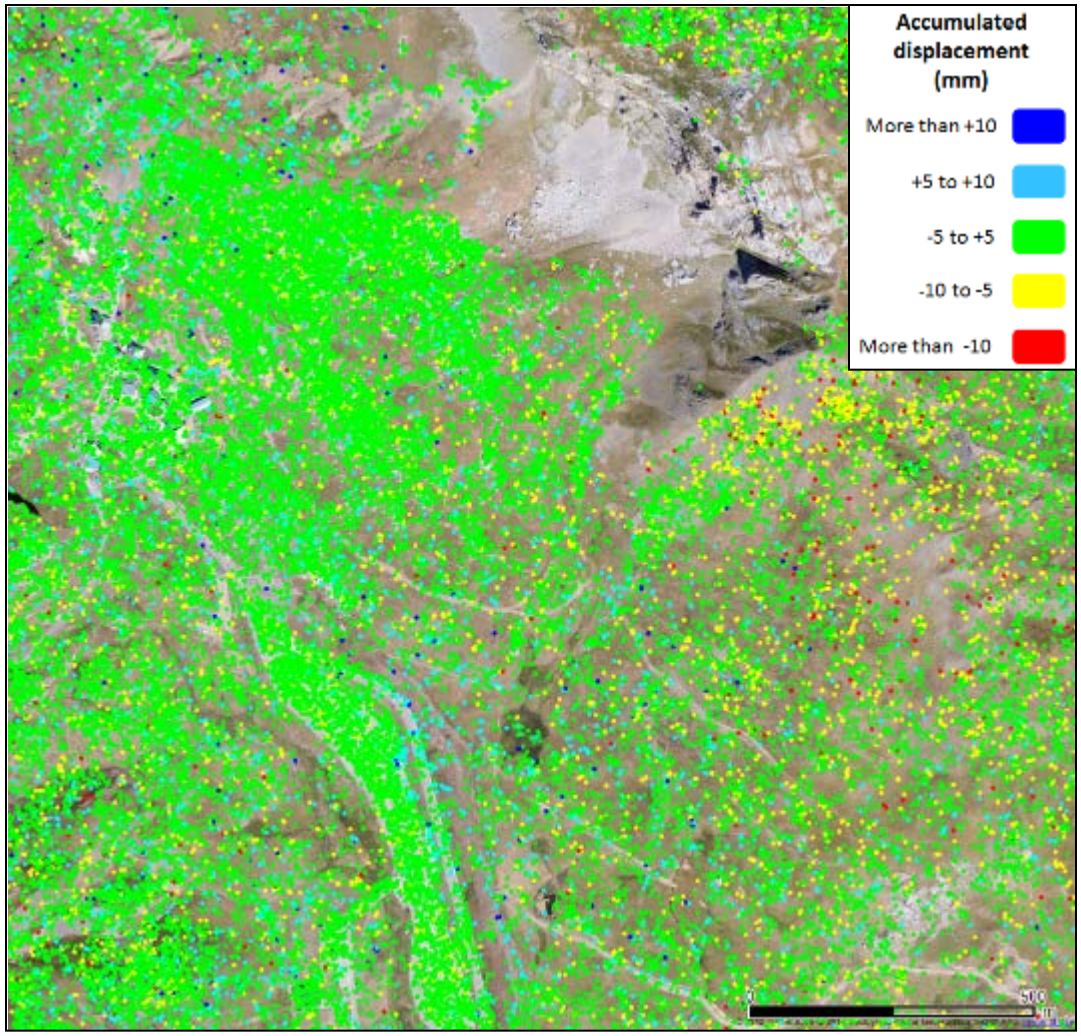




Results: PSc Density

- **Full Resolution**
- Point density of 27.106 PS/km^2

→ Noisy result due to the low number of images (8 acquisitions in 3 months).

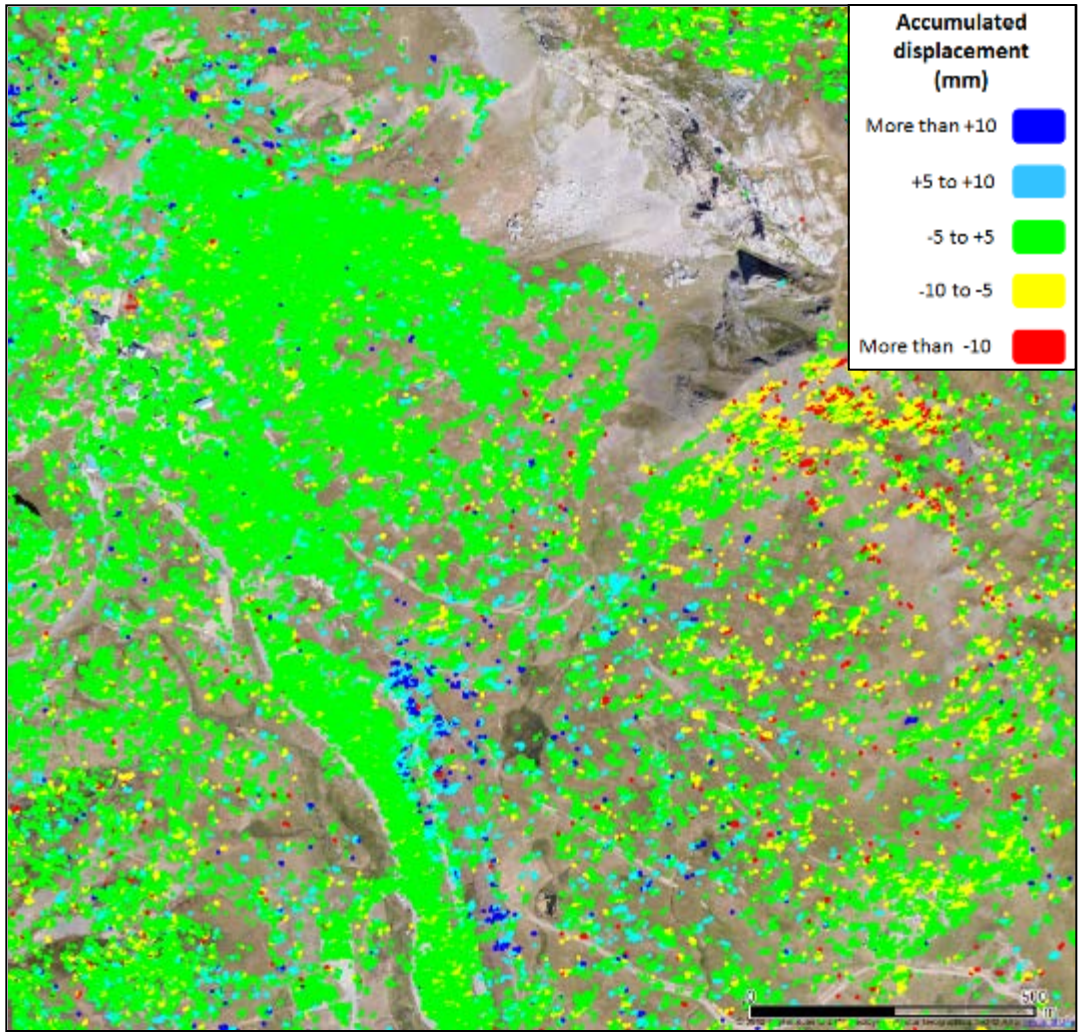


Results: PSc Density

- **Boxcar 5x5**
- Point density of 51.384 PS/km^2

→ The number of points increases improving the identification of motion areas.

→ But the resolution decreases.

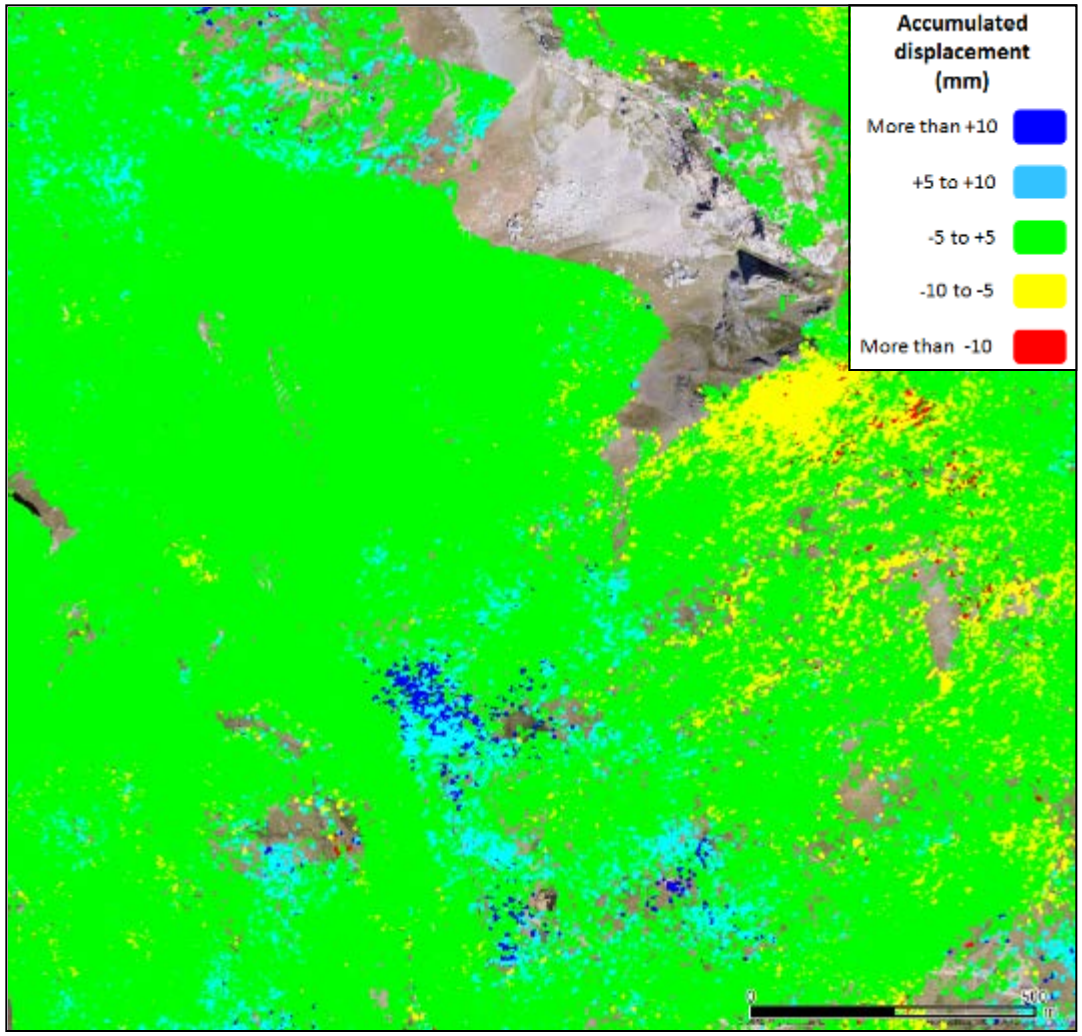


Results: PSc Density

- **Non-Local Mean filter**
- Point density of 162.625 PS/km^2

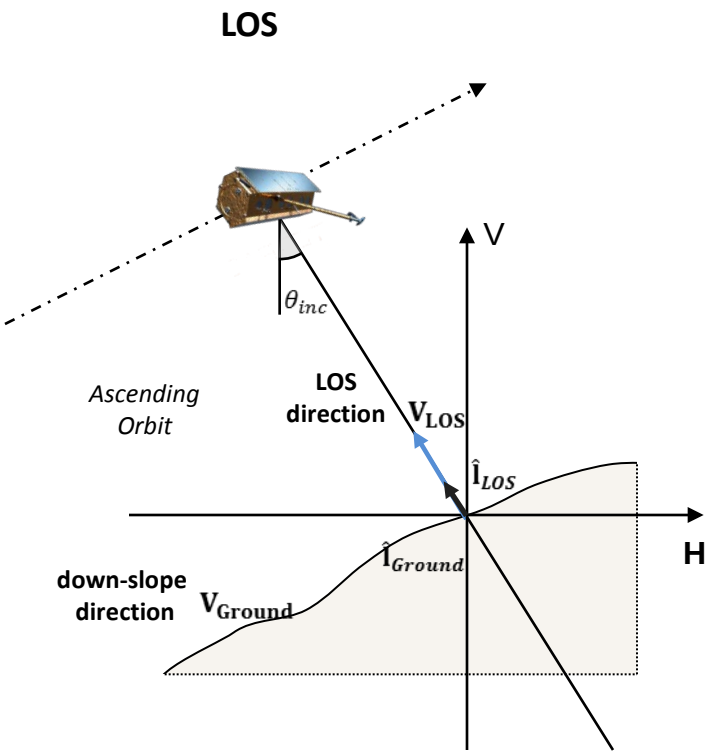
→ The number of points increases maintaining the full resolution.

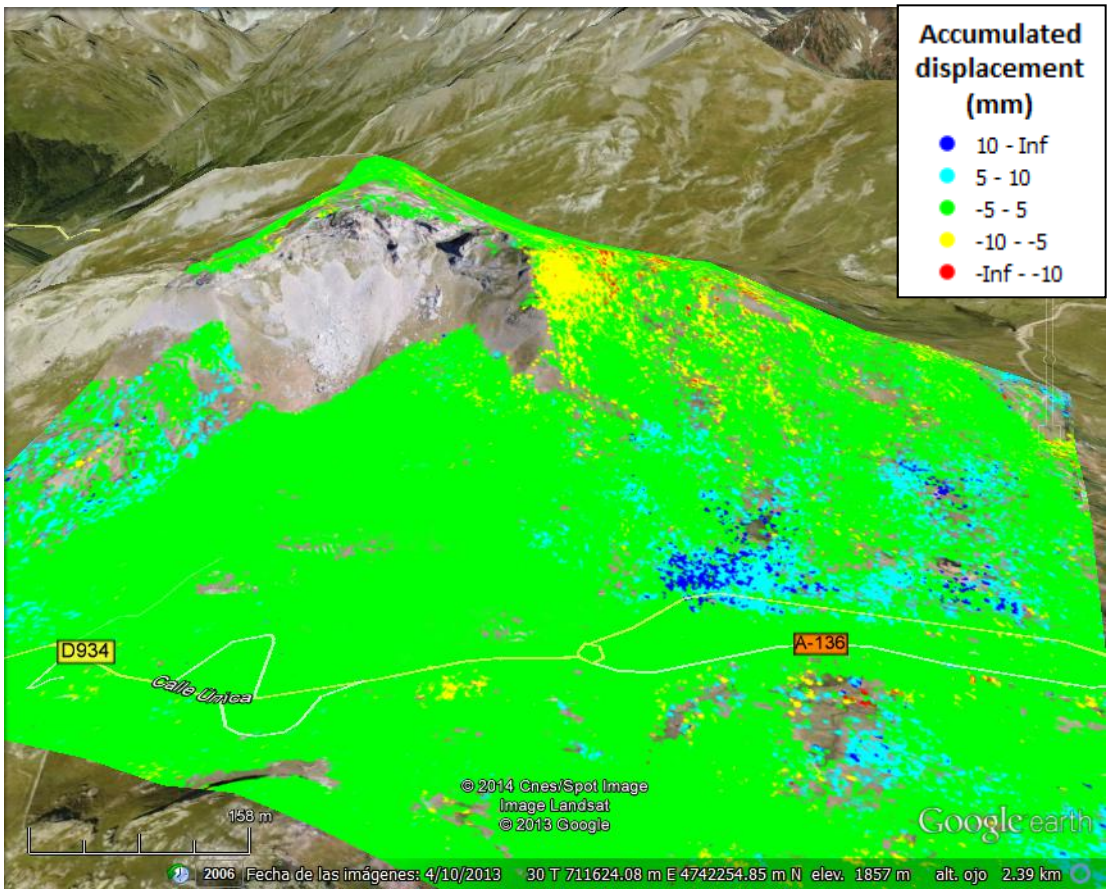
→ Ground deformation can be perfectly identified and characterized (perimeters, gradients, magnitudes).



Results: Velocity map

22/08/2013 – 18/11/2013, 8 TSX Stripmap images





Results: Velocity map

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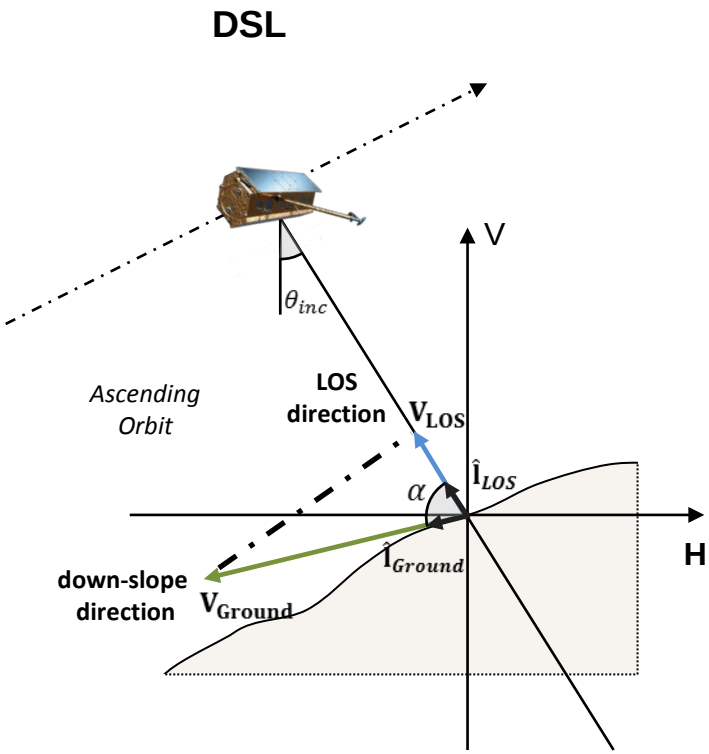
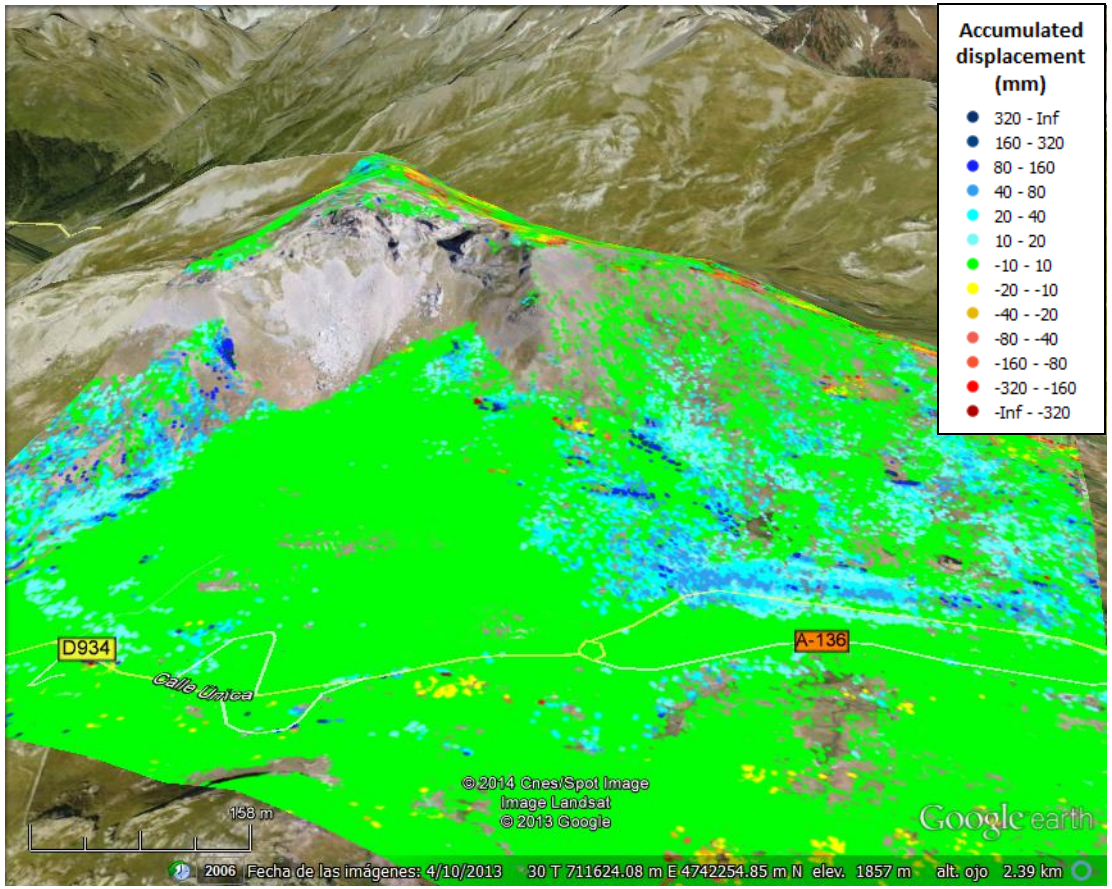
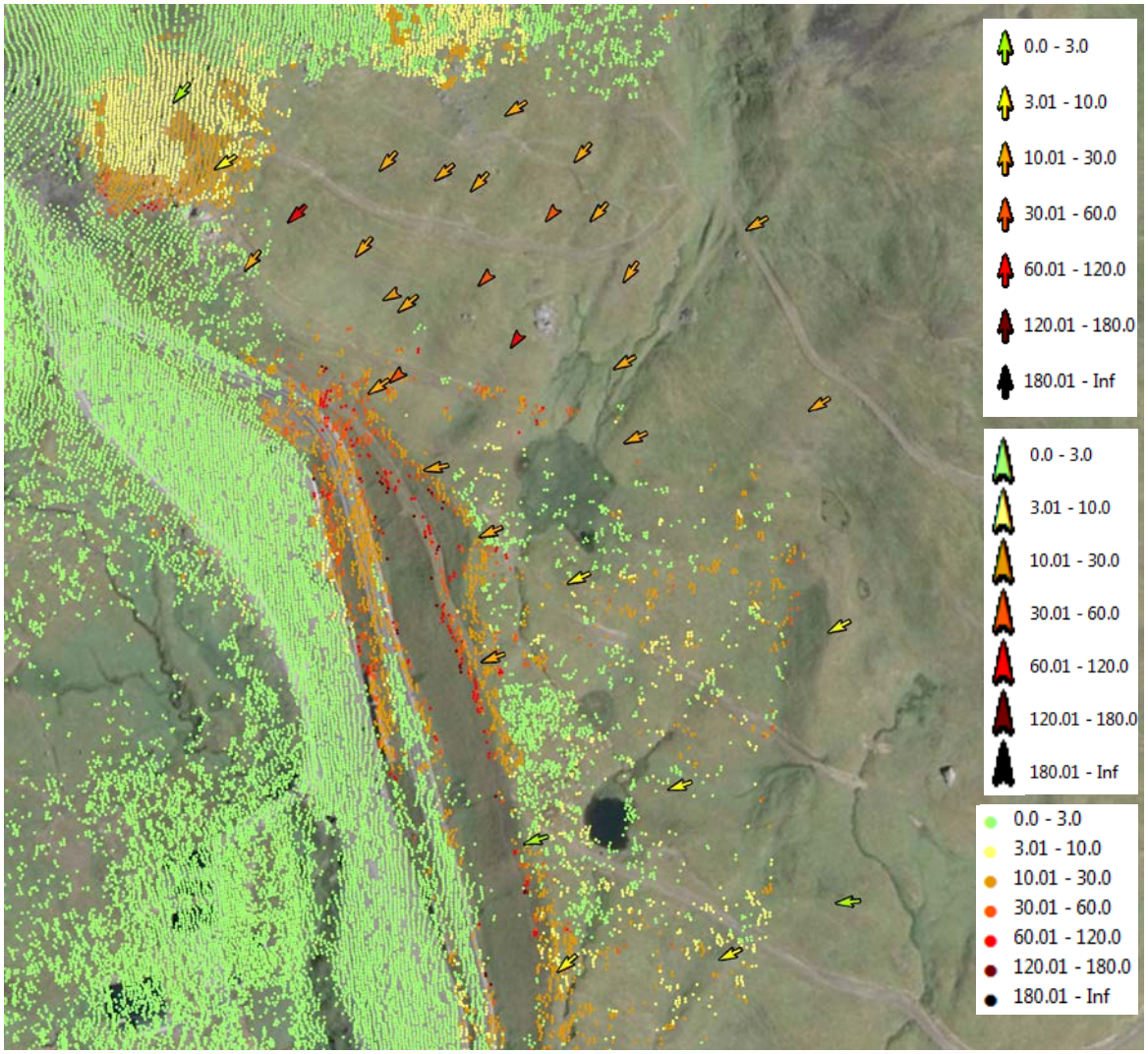




Results: Comparison



DGPS

CRS

PSI

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Conclusions and future work

- This presentation have showed advanced PSI improvements to enhance the characterization and detection of landslides in natural environments.

- NL-InSAR filtering improves the number of reliable high-quality during the PSI processing allowing the detection of both the point-like scatterers and the distributed scatterers preserving the full-resolution of SAR images.

- Prior to the PSI results interpretation, it has been proposed the application of a down-slope displacement model.

- Displacement results show a high agreement with the previous field and PSI results presented over the area of interest. DGPS measurements have been presented in order to validate the down-slope hypothesis.

- Some future work lines may include the validation of the data set corresponding to 2013 with the DGPS and the AIS measurements carried out during that year.

Thanks for your attention!