Detection And Monitoring of Large Landslides from Optical Satellite Image Time-Series: The Prototype MPIC Service Tailored for the Alpine Massif

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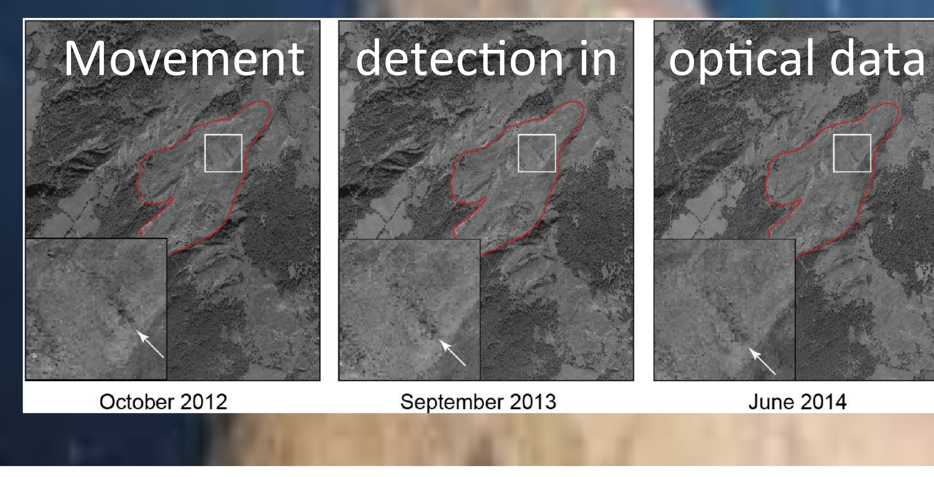


Summary

Large and permanently moving landslides are widespread in many landscapes of the Alpine Space, with significant impacts on erosion, sediment transfer and human settlements. While in situ geophysical methods and terrestrial remote sensing are indispensable for a detailed monitoring and understanding of individual landslides, their area-wide mapping and monitoring is still challenging. SAR interferometry has proven useful for the detection and monitoring of very slow movements (< 1 m.yr-1) but limitations are encountered for the investigation of slow-moving landslides (1 m.yr-1 – 30 m.month-1). Such limitations can be addressed through the analysis of time series of optical remote sensing images, such as Sentinel 2 and Landsat 8.

Method

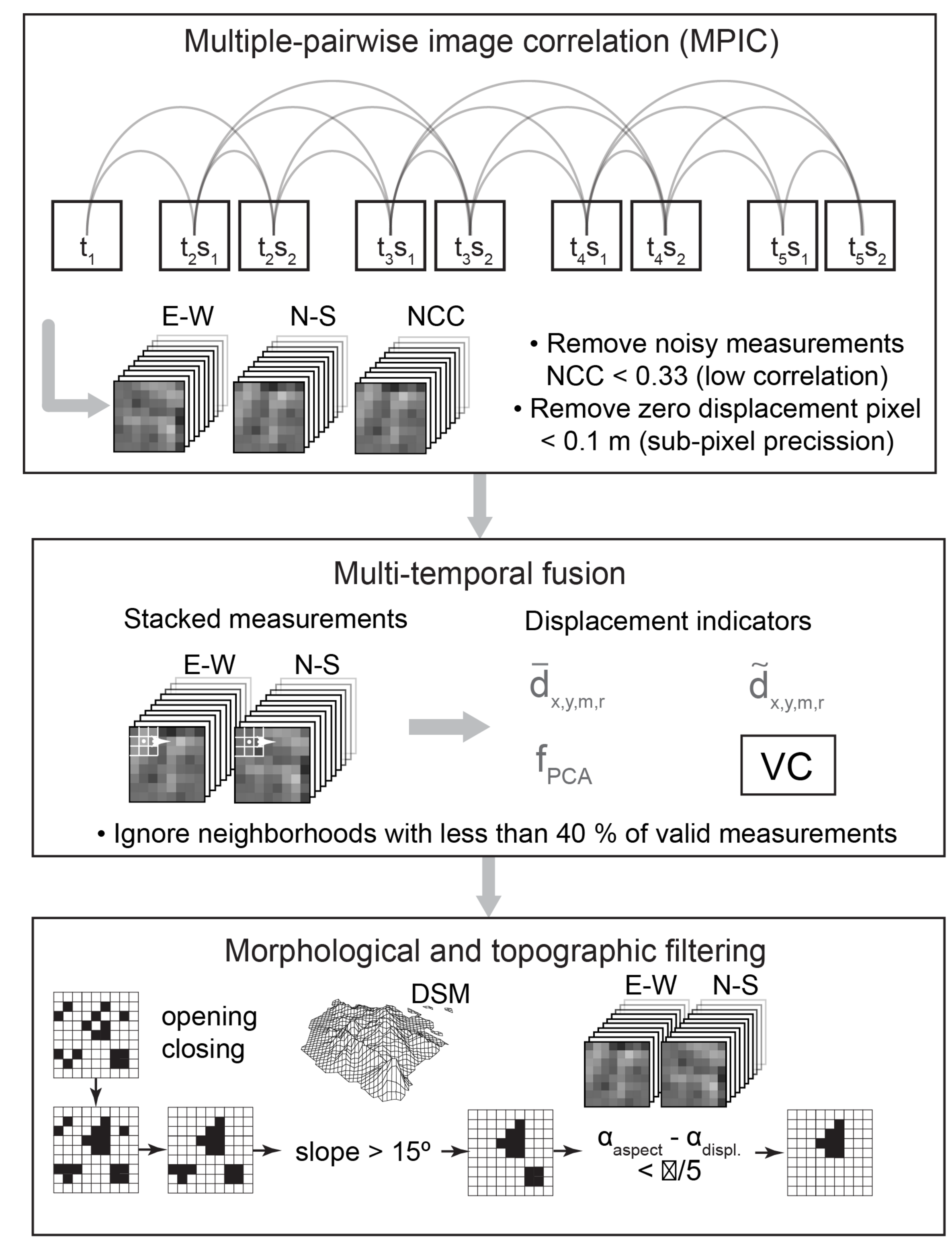
MPIC has been initally developed for the analysis if time series of monoscopic and stereoscopic VHRO (Pléiades) images (Stumpf et al., é017), and furthert extended to the analysis of time series of Sentinel 2 and Landsat 8 images (Stumpf et al., 2018).

The processing workflow is described in Figure 1. It consists in three steps, comprising :

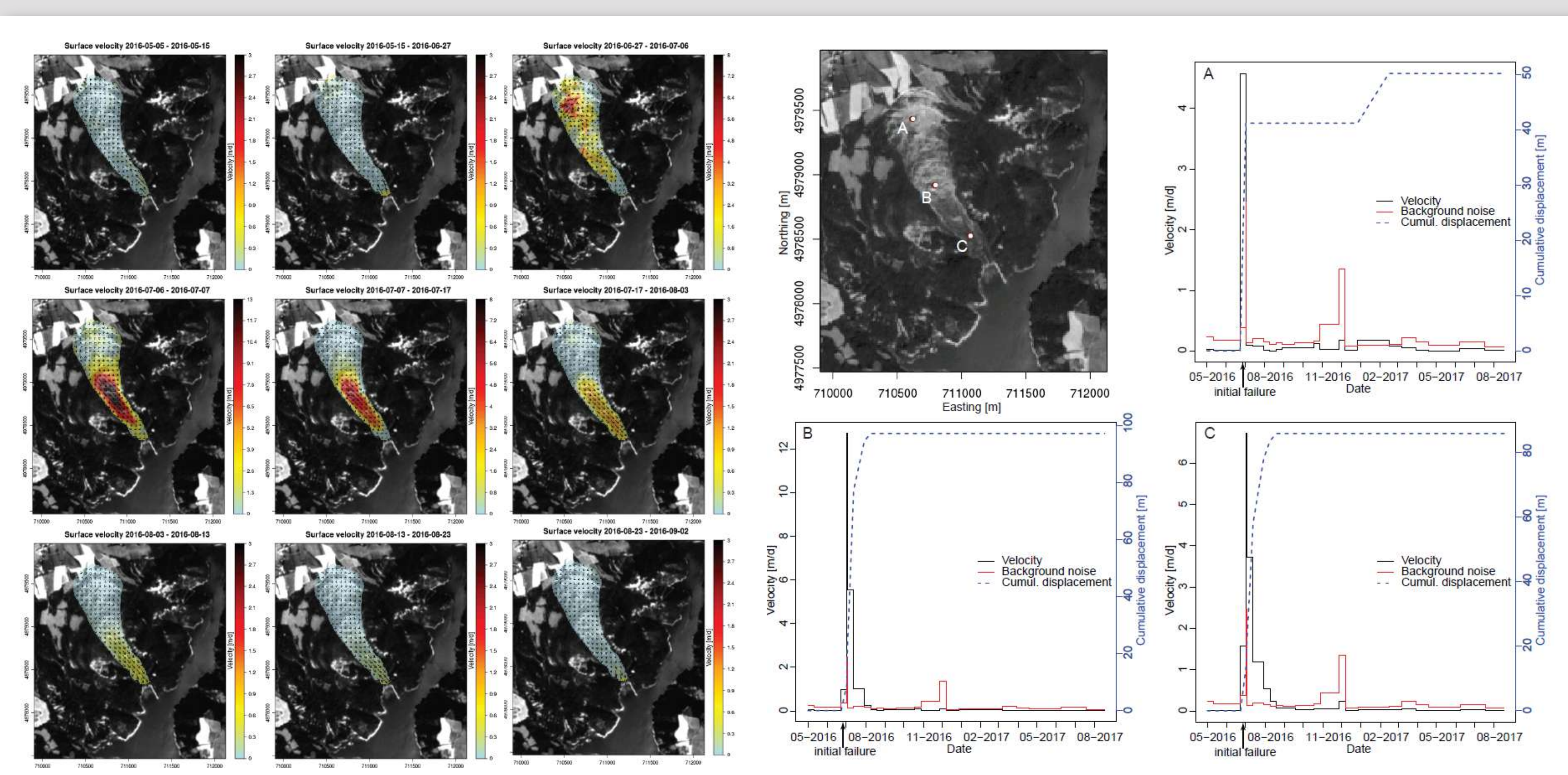
a) Pairwise image correlation among images from multiple time steps using the MicMac open source library,
b) The use of four different multi-temporal indicators with the vector coherence V being the most effective, and,
c) further morphological and topographic filtering.

The MPIC code has been optimized in C++ and is currently implemented as an-online service on the Geohazards Exploitation Platform (GEP) of the European Space Agency and on the A²S processing cluster of University of Strasbourg.

Figure 1 - Principle of Multiple Pairwise Image Correlation – MPIC – for Earth Surface morion analysis (Stumpf et al., 2017, 2018)



Application 1: Landslide



The Harmalière landslide, located 30 km South of Grenoble, underwent another abrupt acceleration starting June 27 2016. To document this period of acceleration, a time-series of 31 Sentinel-2 images and 1 Landsat-8 image spanning the period 2016-05-05 to 2017-08-21 have been processed. The evolution of the surface motion pattern shows an acceleration that initiated with retrogressive failures at the head scarp (Fig. 2) , whereas the toe remained initially stable. After the initial failure, the largest measured displacements are observed at a secondary scarp at the center of the landslide. The measured surface velocities range from 0.32 m.d^{-1} to up to 13.3 m in a single day.

Figure 2 – Application of MPIC at the Harmalière landslide (French Alps). Left: Horizontal surface displacement of the Harmalière landslide from 05-05-2016 to 2016-09-02; Right: Surface motion time-series for the Harmalière landslide from 05-05-2016 to 2017-08-21 at 3 selected points at the head scarp, transport zone and the toe.

Application 2: Earthquake

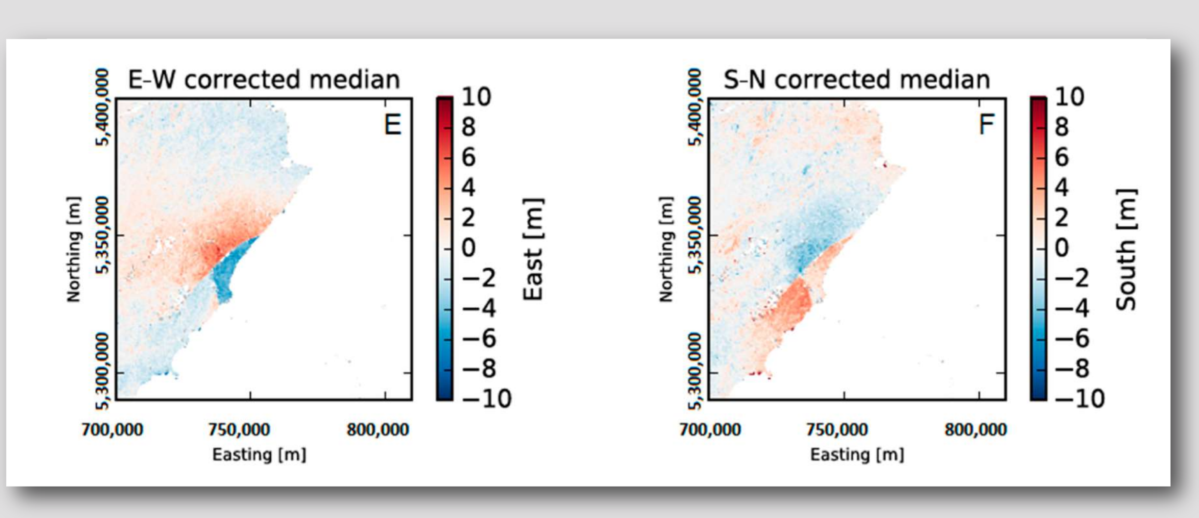
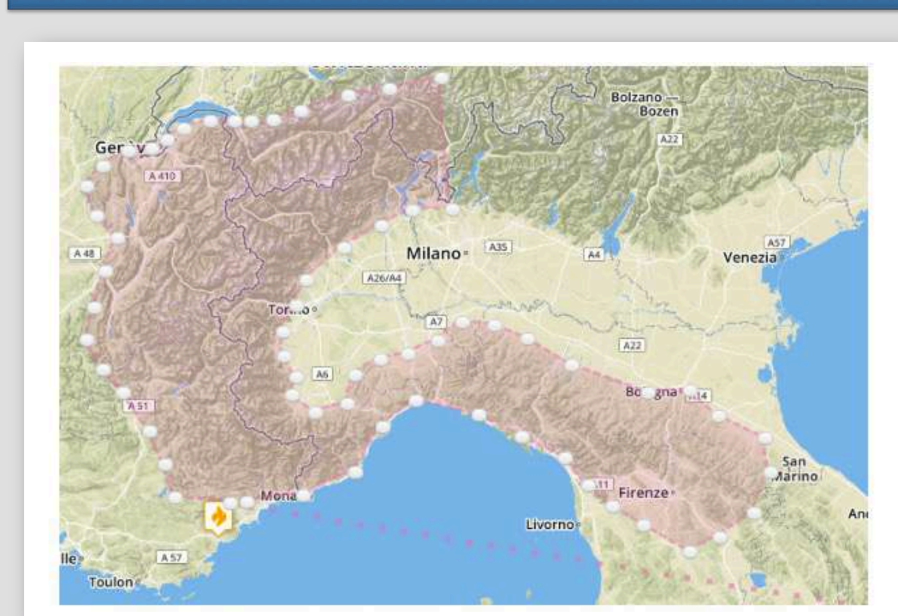


Figure 3 – Application of MPIC for quantifying co-seismic slip from S2 data.

Kaikoura area (New-Zealand) was struck by a major Mw 7.8 earthquake on 14 November 2016 . We used 4 S2 pre-earthquake and 5 S2 post-earthquake images, and computed a total of 40 displacement maps considering all combinations. The final displacement maps are computed by stacking the two horizontal components. Figure 3 represents the median displacements which indicate a maximum horizontal along-fault slip of up to 10.6 m on the NE segment of the Kekerengu fault. Similarly the fault slip estimated on the Papatea fault agrees with more than 2 m slip observed in the field.

MPIC as a service for the Alps



MPIC has been optimized in order to be used as an online systematic service for ingesting and processing all S2 data available over the Alps (Fig. 4). The processing is currently in evaluation and prototyping using the A²S calculation resources of University of Strasbourg. The service is able to automatically download the relevant 20 S2 tiles covering the area, perform a precise co-registration of all images using the CO-REGIS algorithm, detect the cloud and water (Fmask), and calculate all possible combination of correlograms. Detection of stable vs. unstable zones are then performed.

Figure 4 – Area of interest for the systematic processing of S2 time series targetting the detection and monitoring of Earth surface processes, mainly slow moving landslides.

As an example of use case, the application of the MPIC surveillance prototype allowed the detection of the Aiguilles - Pas de l'Ours landslide and the transfer of relevant information to the risk managers and the identification of the size of the unstable area.

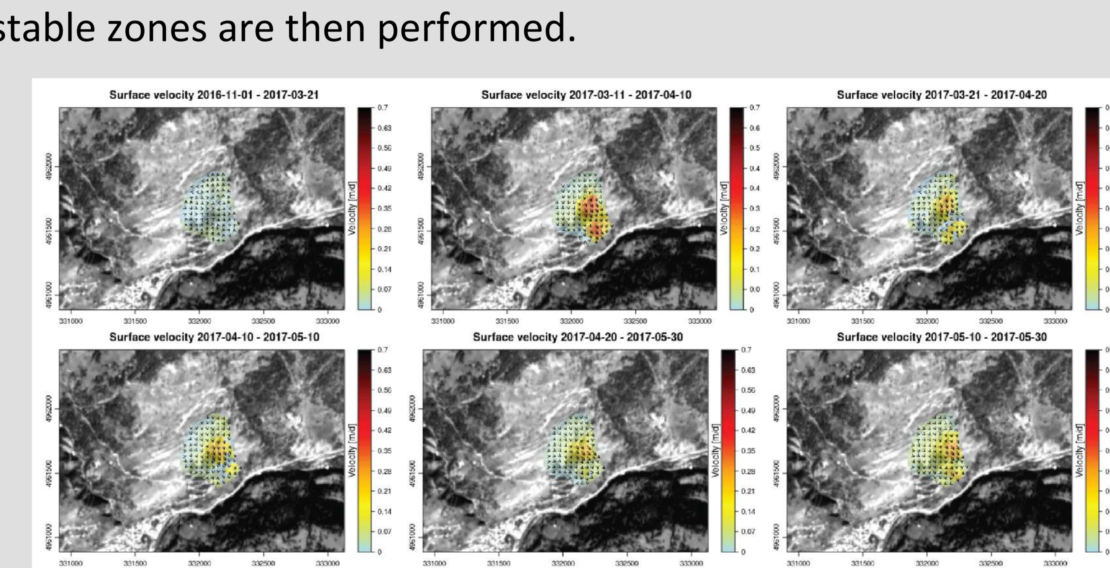


Figure 5 – Detection of displacement at the Aiguilles – Pas de l'Ours landslide in April 2017 from the application of MPIC.