Optical image correlation: exploiting the Sentinel-2 archive for Earth Surface Deformation monitoring.

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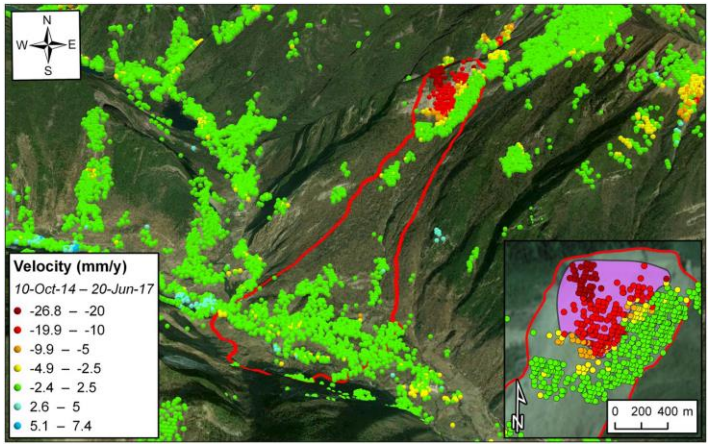
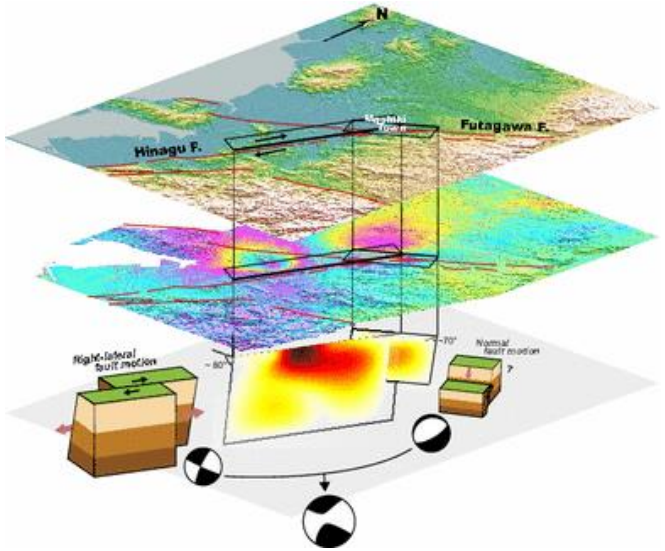
EO for monitoring surface deformation

Motivations

- EOs are key datasets for better understanding, modelling and forecasting geohazards such as volcanoes, landslides or glaciers.
- Open medium resolution constellation with short revisit time are now available.
- Processing this amount of data offers numerous perspectives for scientific communities…but also challenges.



Kang et al., 2019



Optical observations for monitoring surface deformation

Space borne InSAR

- **Sensitve to motion in the LOS** i.e. sensitive to EW and vertical motion. **Poorly sensitive to NS motion**.
- **Millimetric accuracy**.
- **Monitoring of very small (mm) to cm motion**. In cas of larger motion, decorelation usually prevents to monitor the deformation.
- **Non sensitive to cloud cover**.

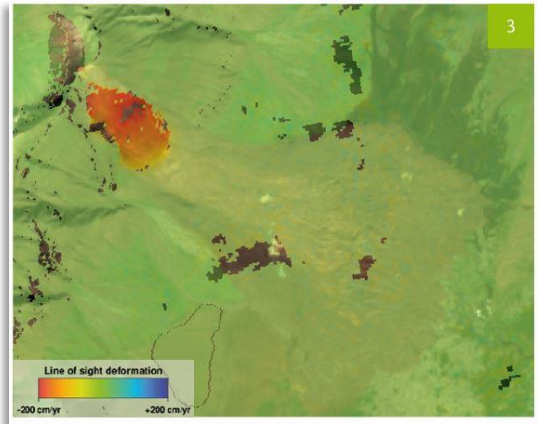
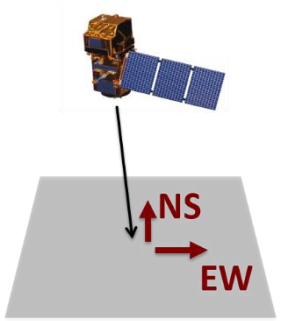


Figure 3. Yearly rate map of the Fagraskógarfjall landslide between July and November 2017. Green represents relatively stable areas while the red-yellow region highlights significant slip of the landslide. Up to 2 m per year of slip may have occurred in some parts of the landslide. © CGG 2018. Images contain modified Copernicus Sentinel data (2018).

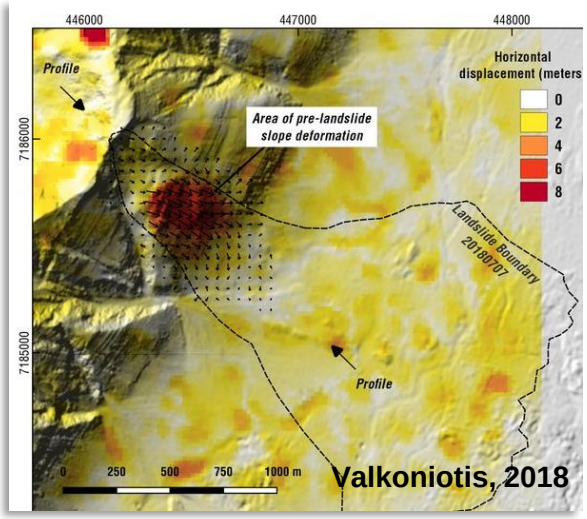


Space borne Optical Image Correlation

- **Sensitve to Horizontal movement**,

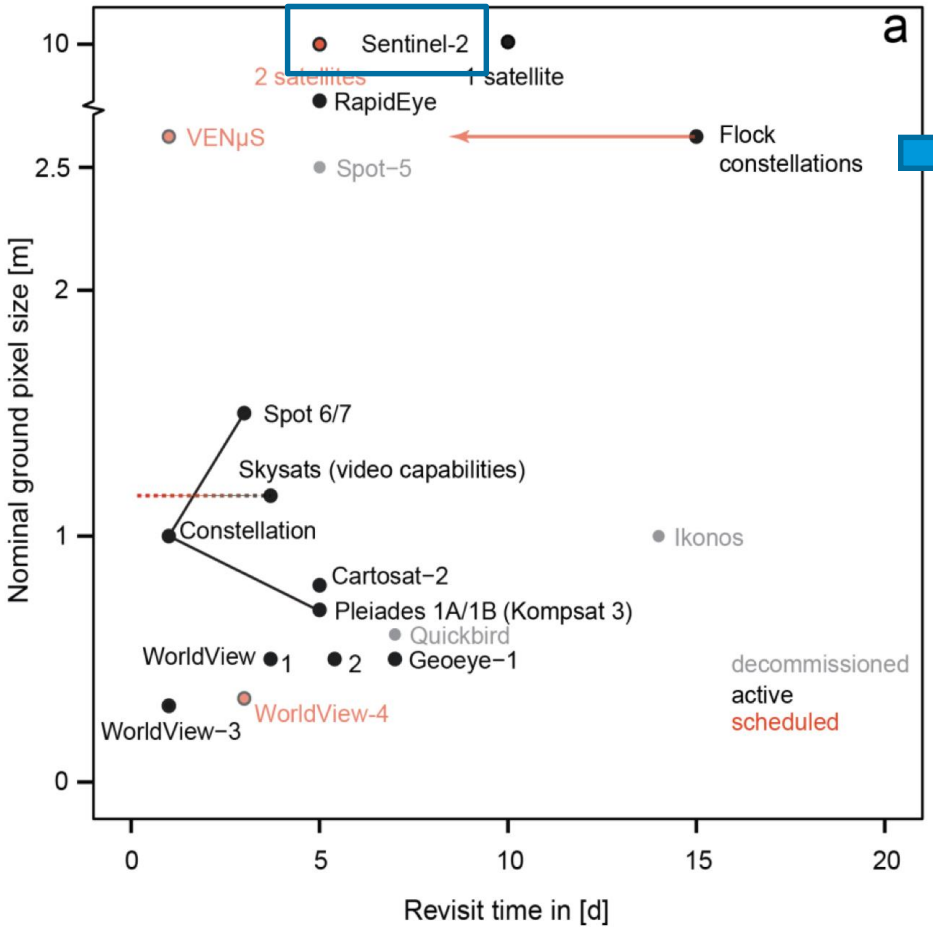
Non sensitive to vertical motion.

- **Sup-pixel accuracy** (in general metric to cm).
- Monitoring of **large movement** (metric). Smaller movement can also be measured depending on satellite pixel size.
- **Sensitive to cloud cover**.

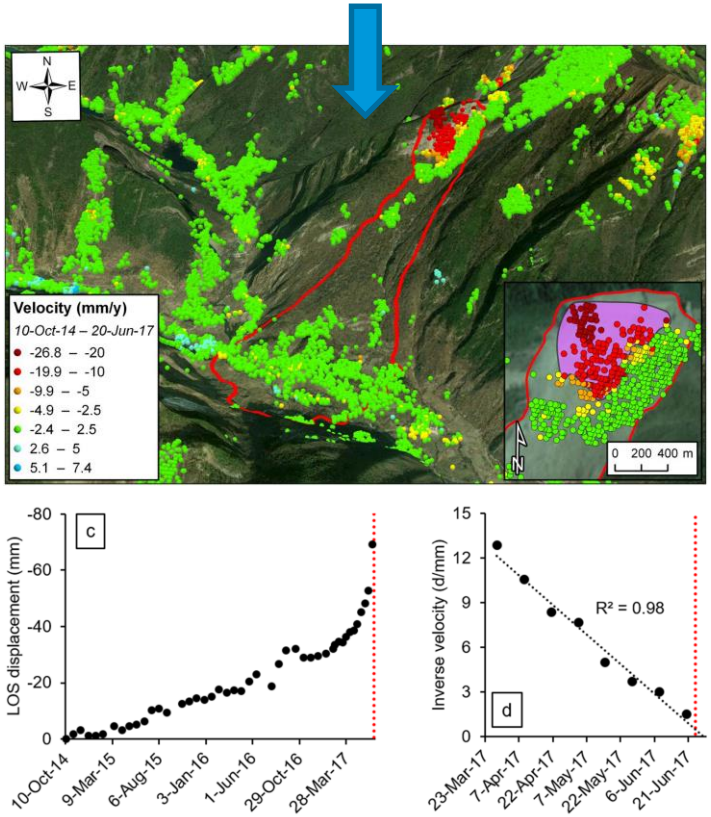


Sentinel-2 observations for monitoring surface deformation

Open, free data access



Sentinel-2 revisit frequency should allow to compute time series



Kang et al., 2019

Method – Optical offset tracking

MPIC – Multi-Pairwise Image Correlation

1. Cloud mask

Computed with python function ***Fmask*** (Zhu, Z. and Woodcock, C.E., 2015) for each Sentinel-2 acquisition, then combined.

2. Correlation

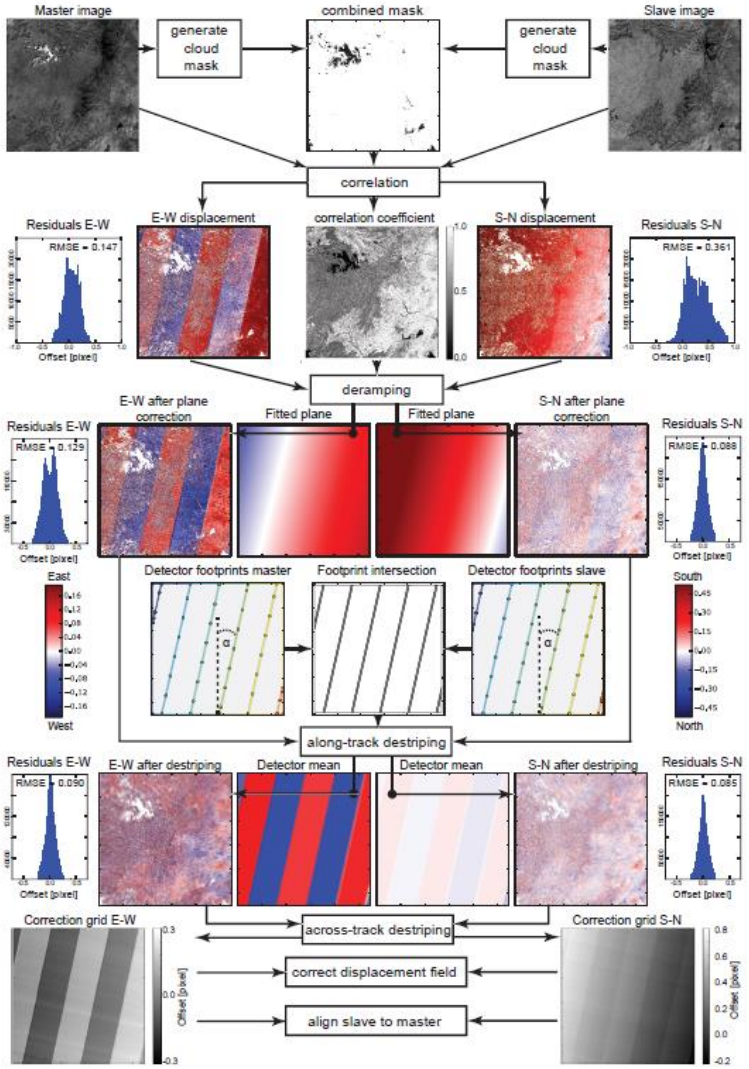
Computed with **MicMac** for all pairs.

3. Deramping

Correct systematic offset resulting mainly from translation and rotation.

4. De-striping

Correct small systematic image offsets which manifest as along-track striping artefacts which are particularly visible in the EW component but can also be observed in the NS component (for Sentinel-2). This is due to staggered sensor arrays of push broom satellite such as Sentinel-2.



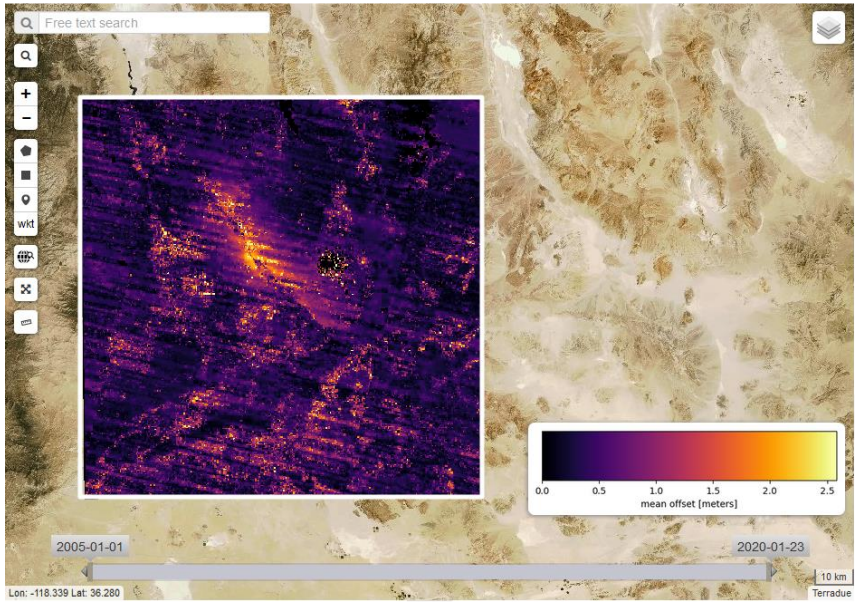
Stumpf et al., 2018

Results for Earthquakes monitoring

MPIC – Multi-Pairwise Image Correlation

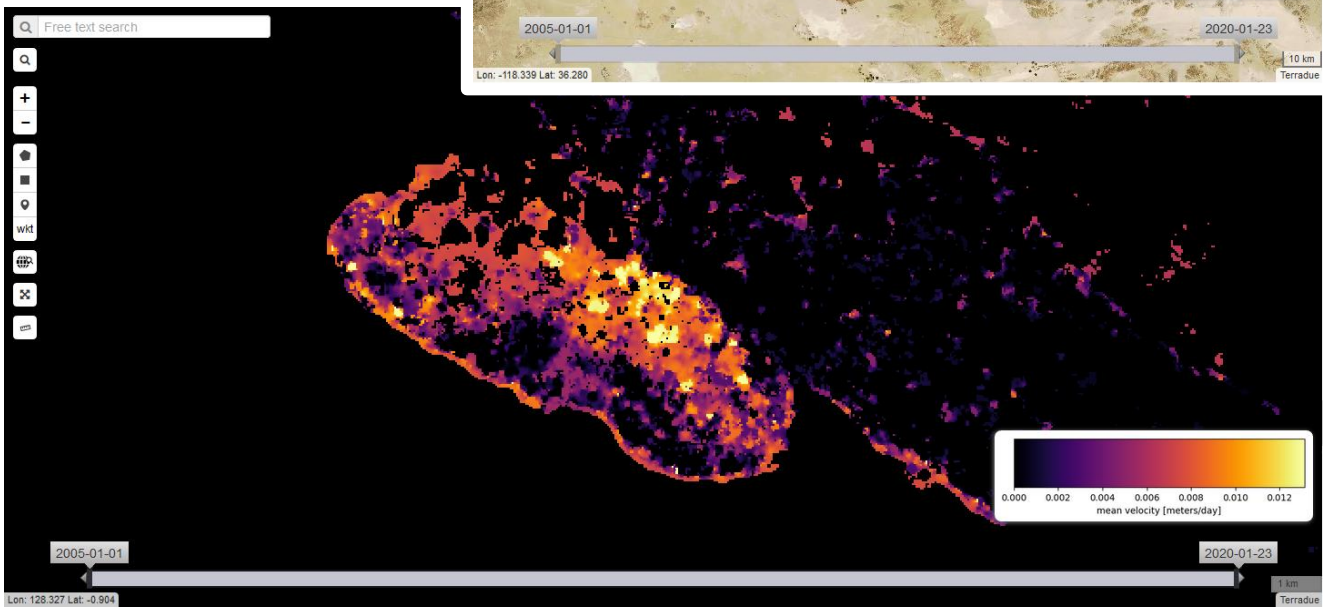
- **Diachronic processings**

Ridgecrest earthquake sequence - July, 2019
2019/06/28 – 2019/07/13



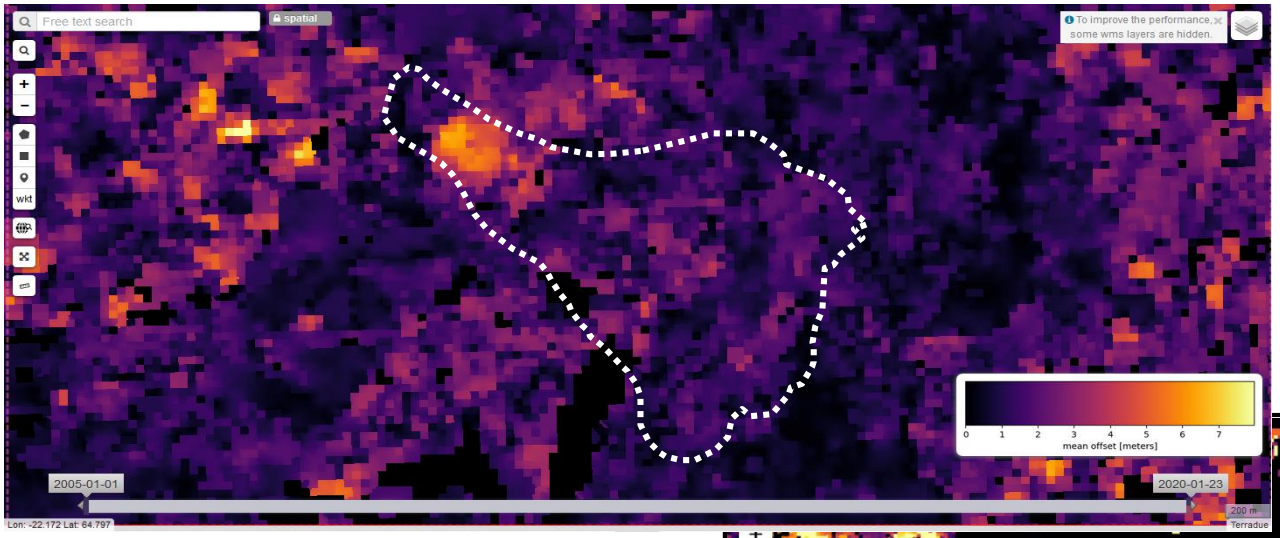
geohazards tep

Mw 7.2 Halmahera Earthquake, July 14, 2019
2018/11/12 - 2019/08/09



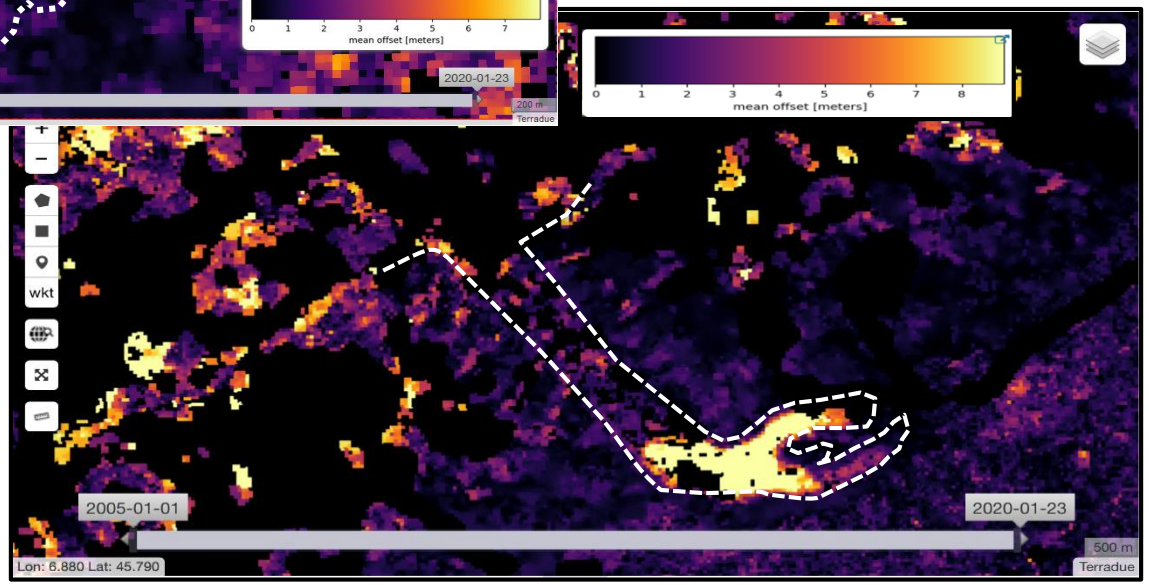
Results for landslide and glacier monitoring

MPIC – Multi-Pairwise Image Correlation



Fagraskógarfjall landslide , Iceland
2017/05/21 – 2018/06/20

geohazards tep



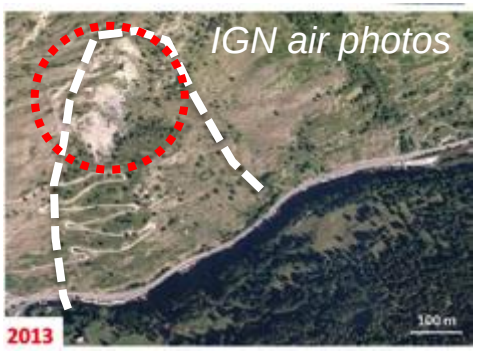
Miage glacier , French Alps, France
2016/08/13, 2017/10/07, 2018/08/28

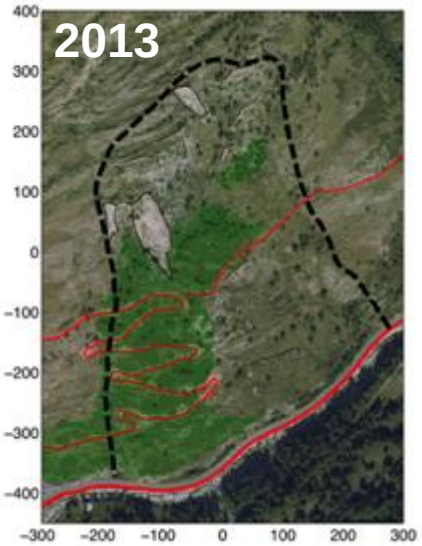
Test site

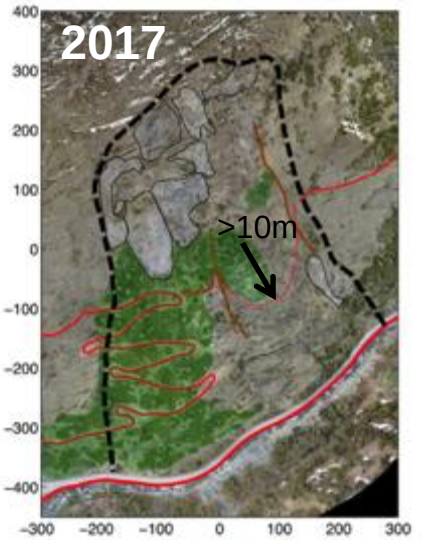
- Aiguilles landslide

Test site – evolution

- Aiguilles landslide



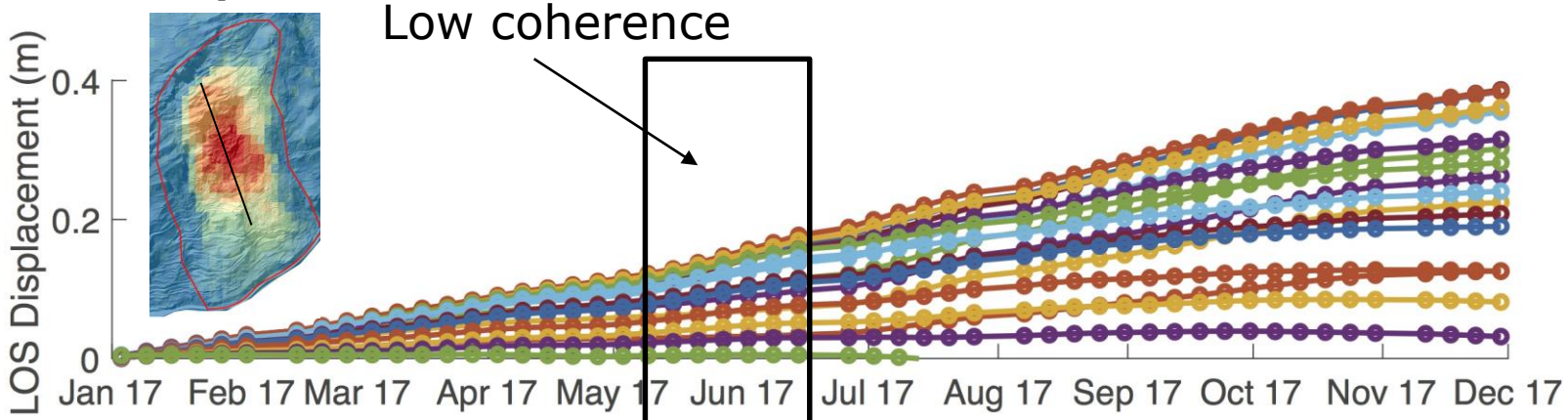




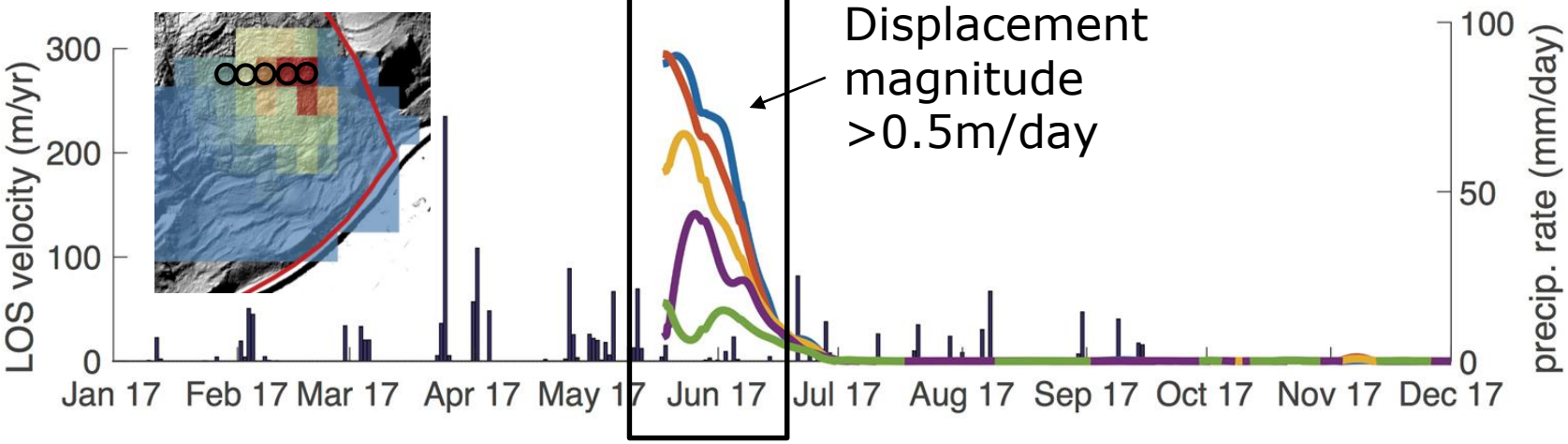
Test site – evolution

- Aiguilles landslide

Sentinel-1A/B



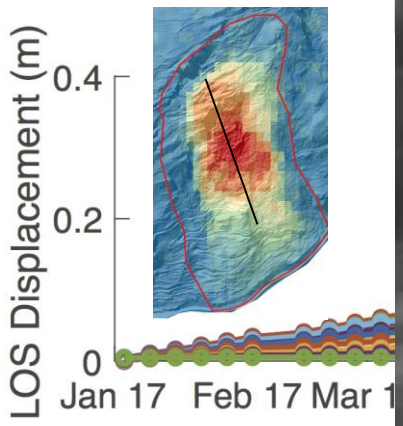
GBSAR



Test site – evolution

- Aiguilles landslide

Sentinel-1A/B



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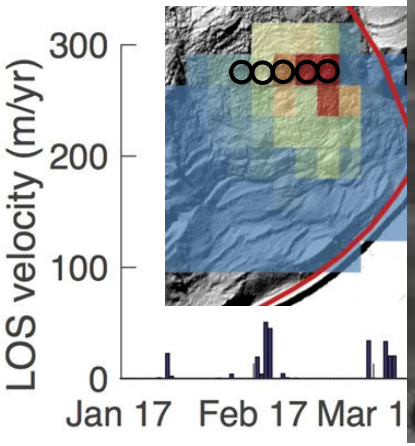
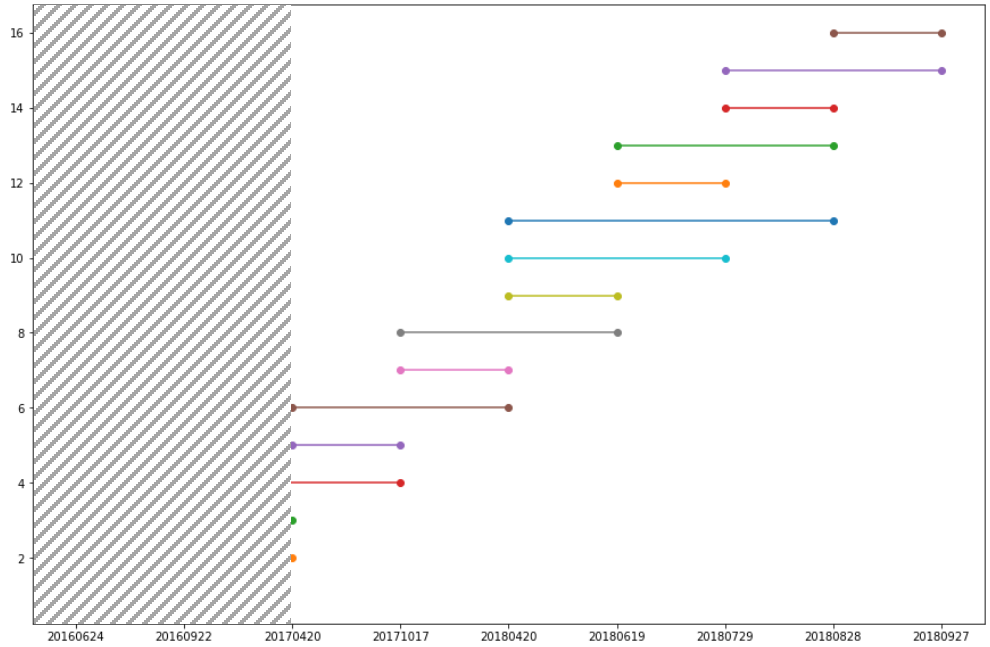
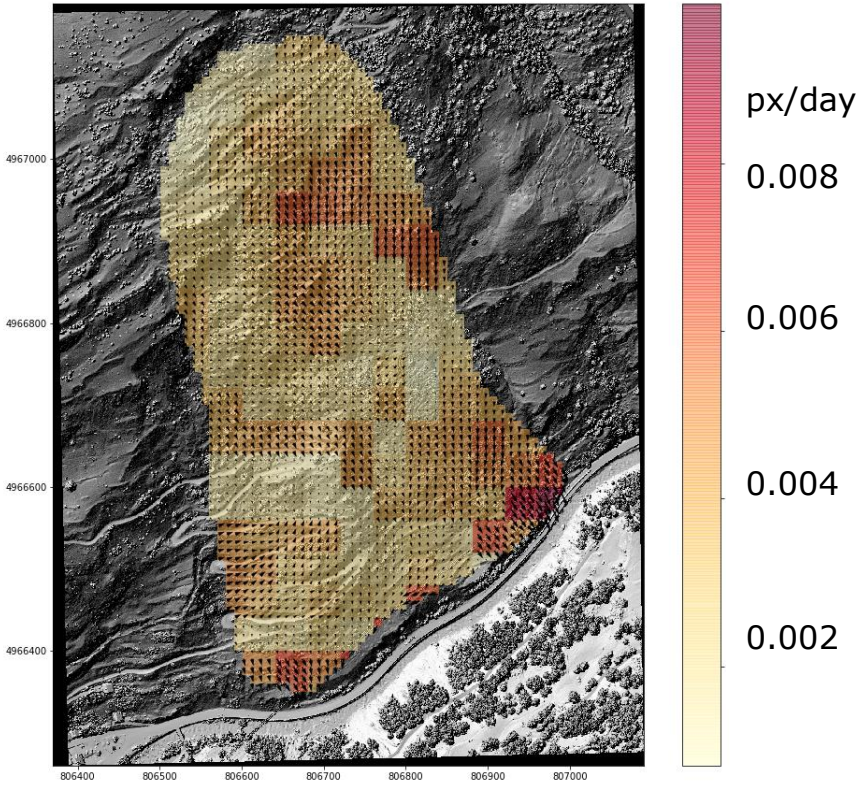


Sentinel-2 time series

Test 1 - datasets of 8 Sentinel-2 images from 2017 to 2018

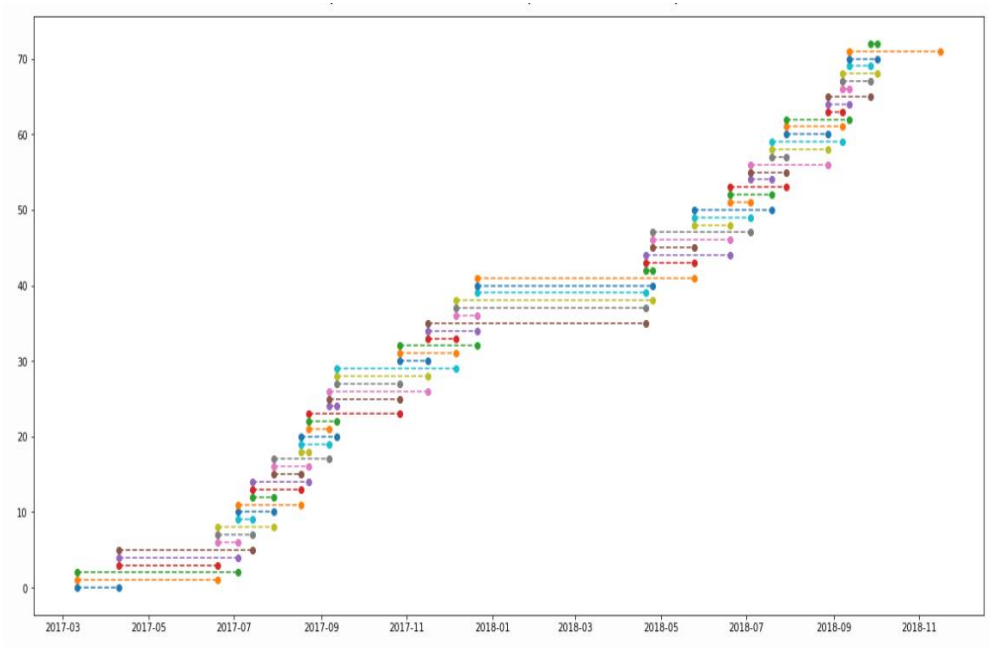


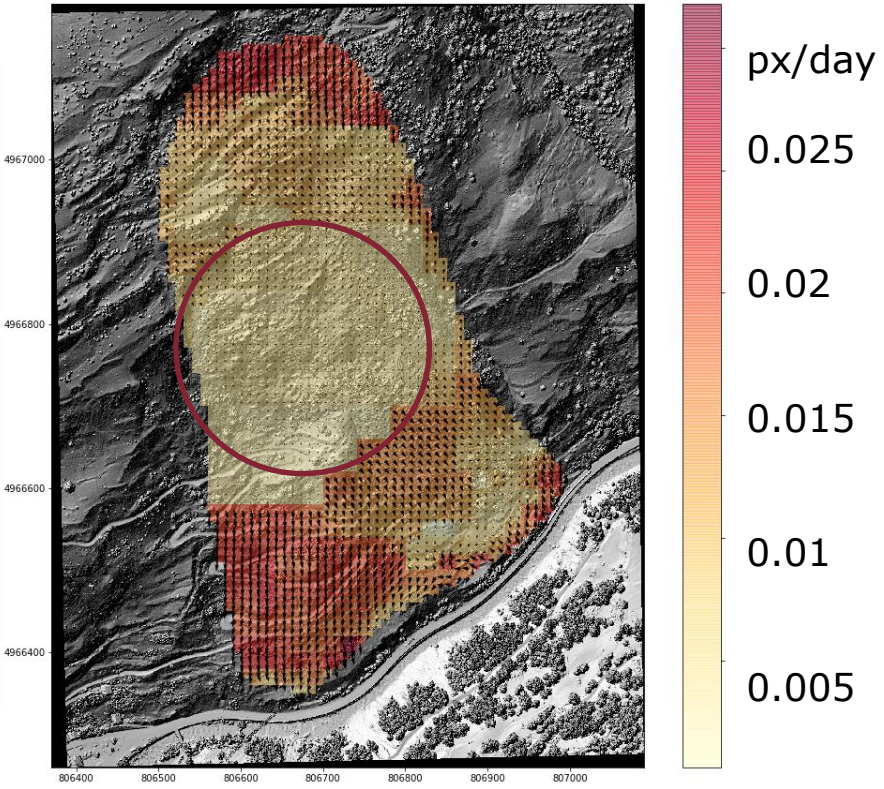


Sentinel-2 time series

Test 2 - datasets of 25 Sentinel-2 images from 2017 to 2018

Tiles with cloud cover < 20%

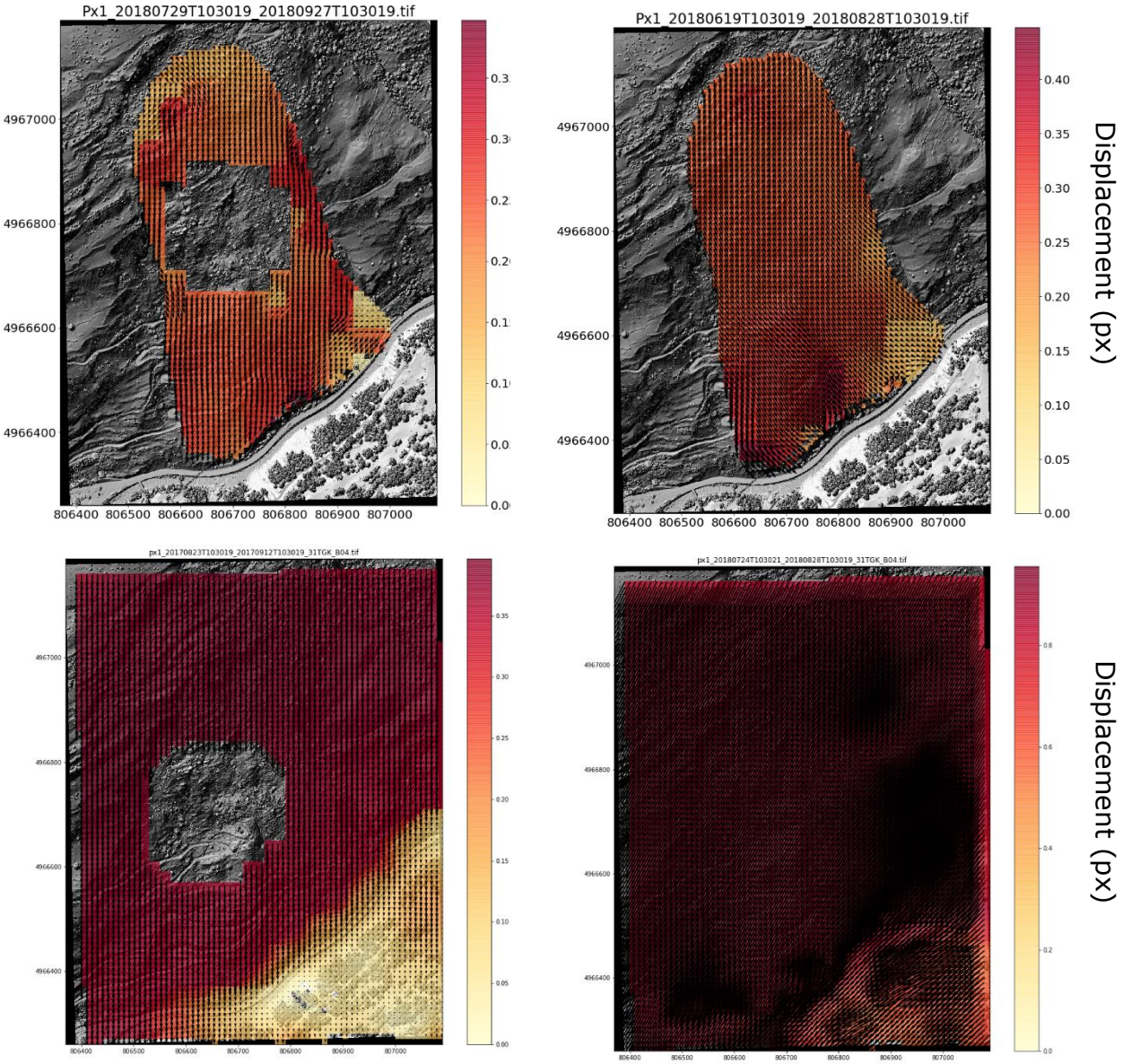




Sentinel-2 time series

Comparison of the intermediary results

- 8 images
- 25 images



Sentinel-2 time series

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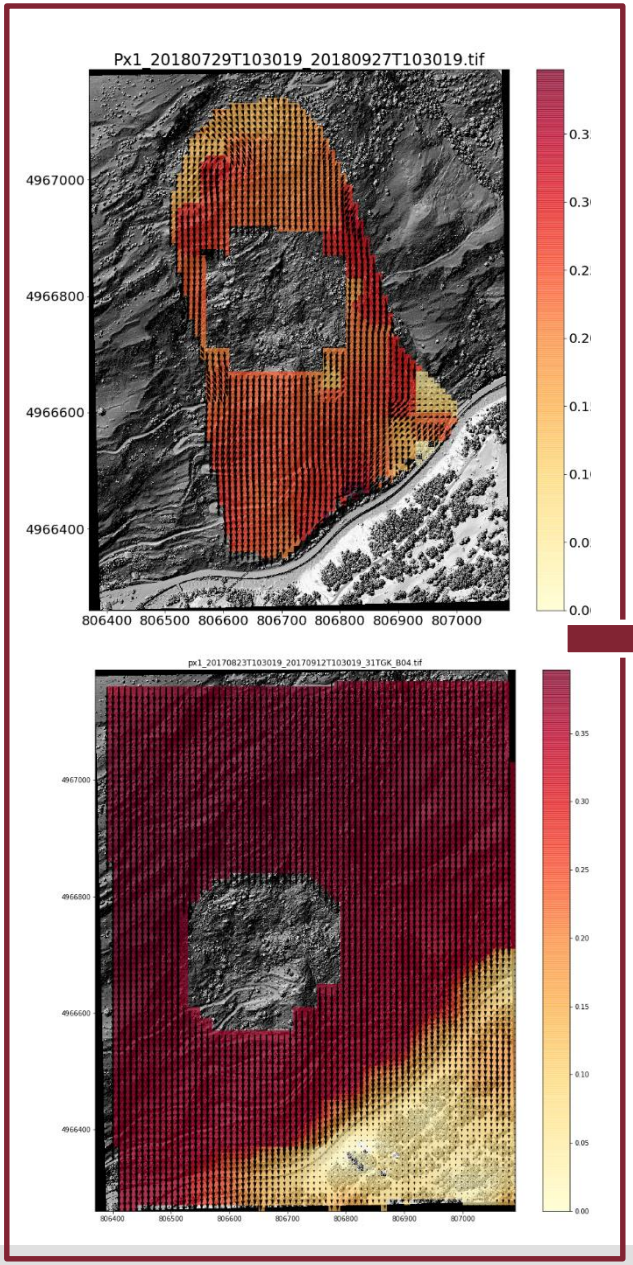
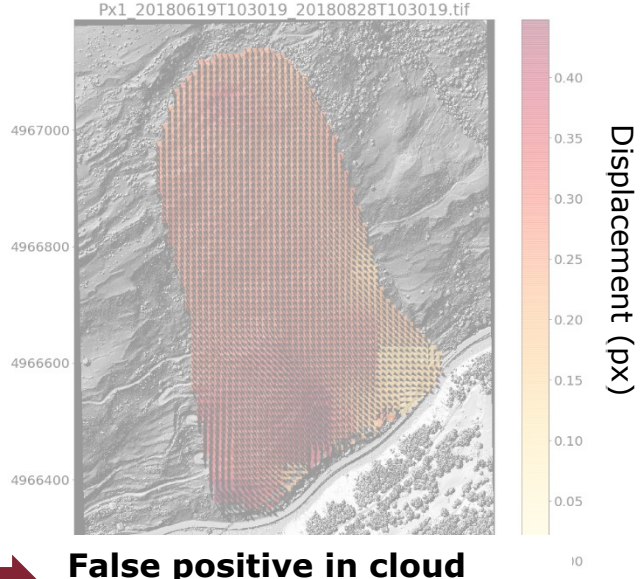
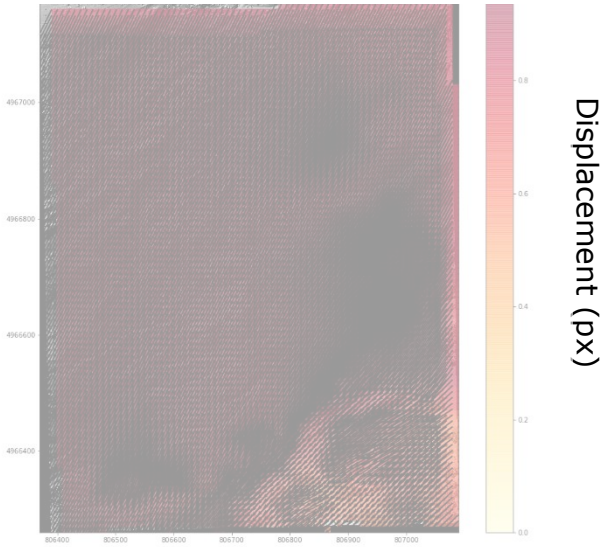




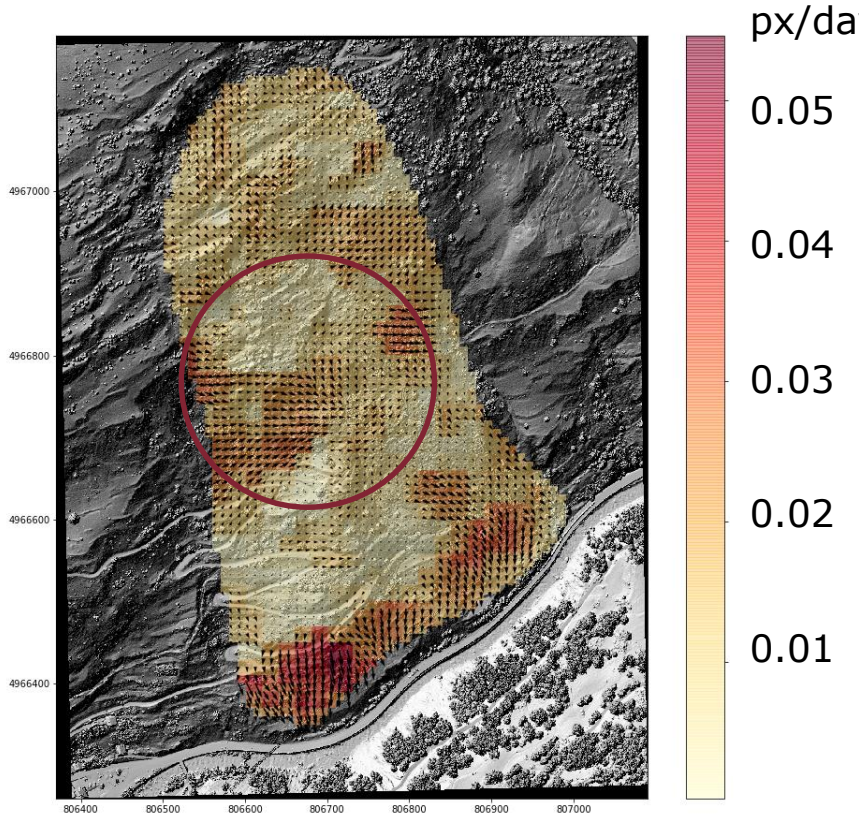
False positive in cloud identification



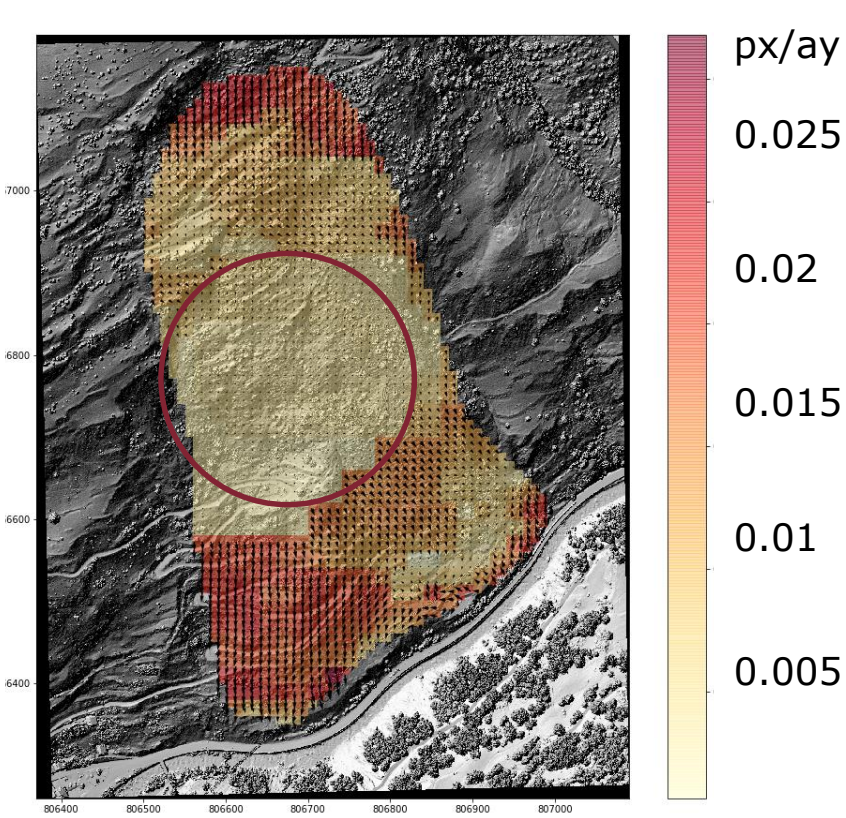
Sentinel-2 time series

Test 2 - datasets of 25 Sentinel-2 images from 2016 to 2018

No cloud filter



Cloud filter



Sentinel-2 time series

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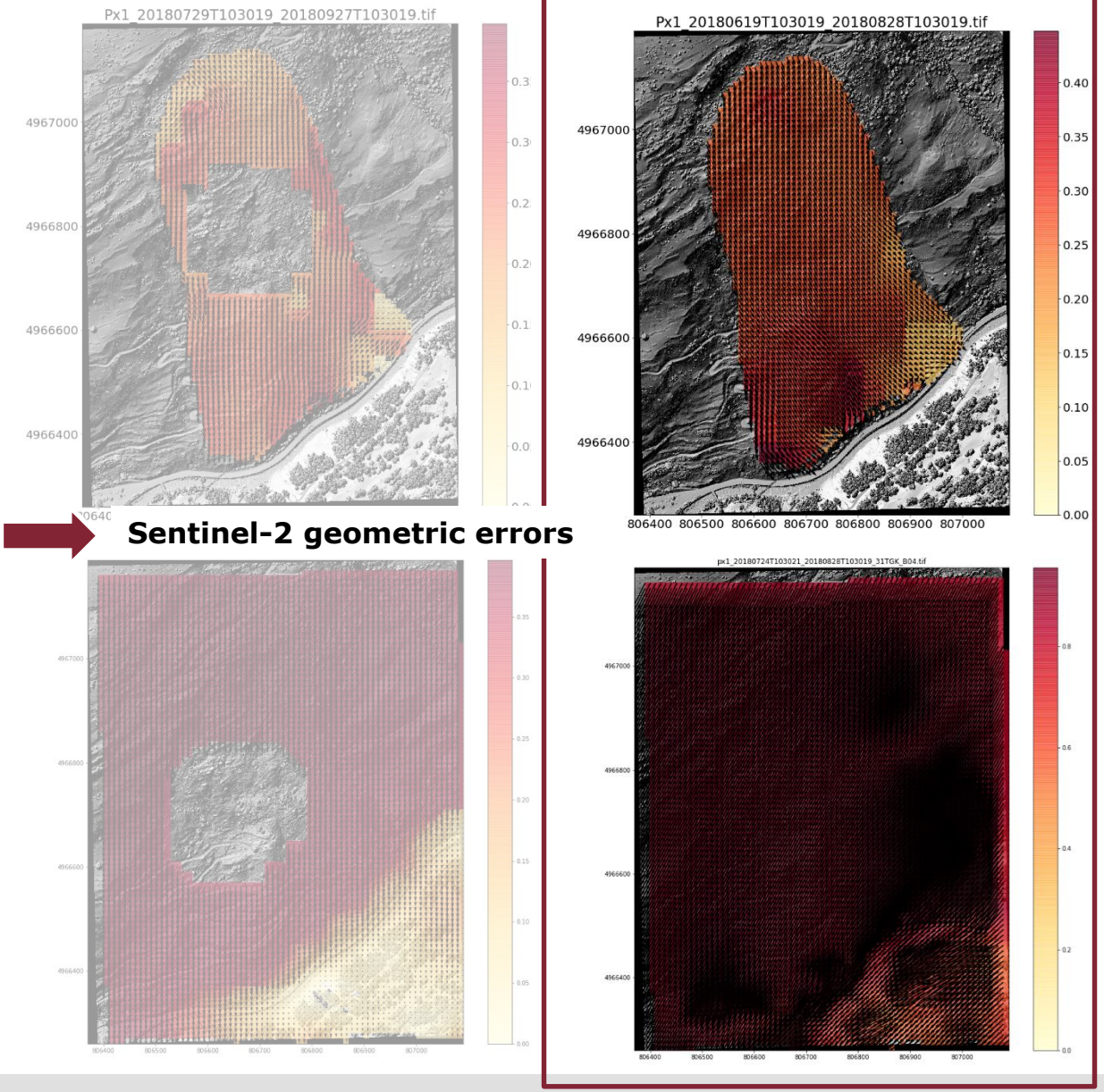
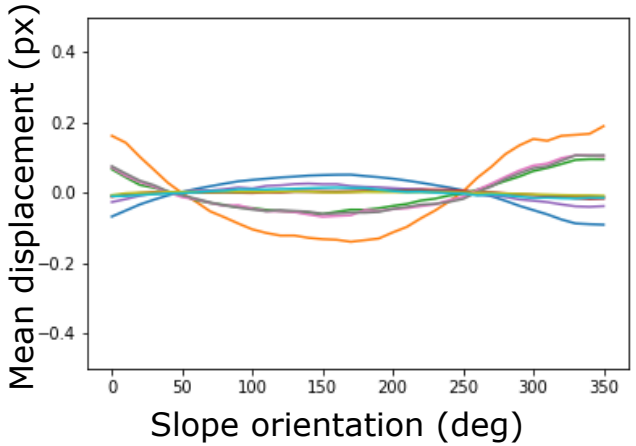
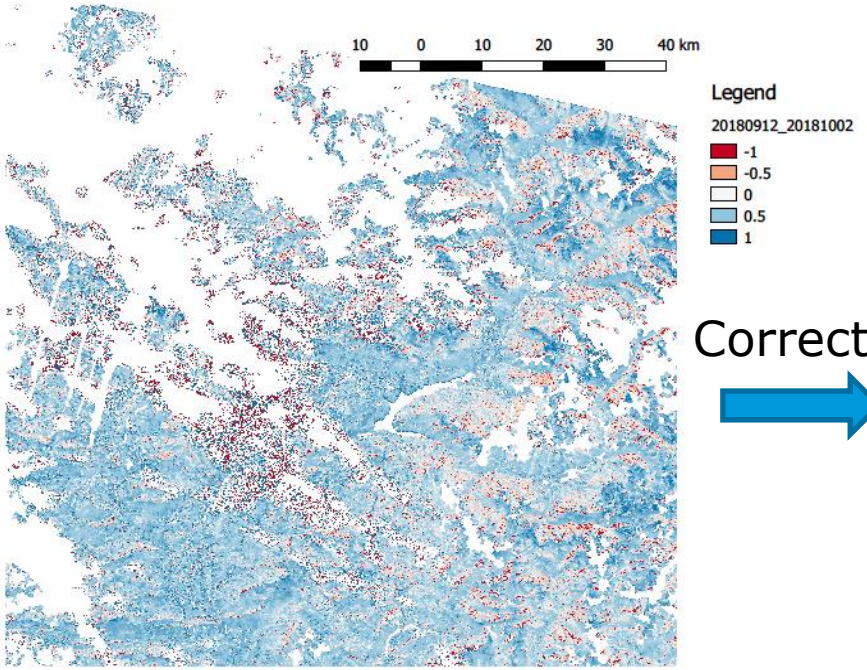


Sentinel-2 time series

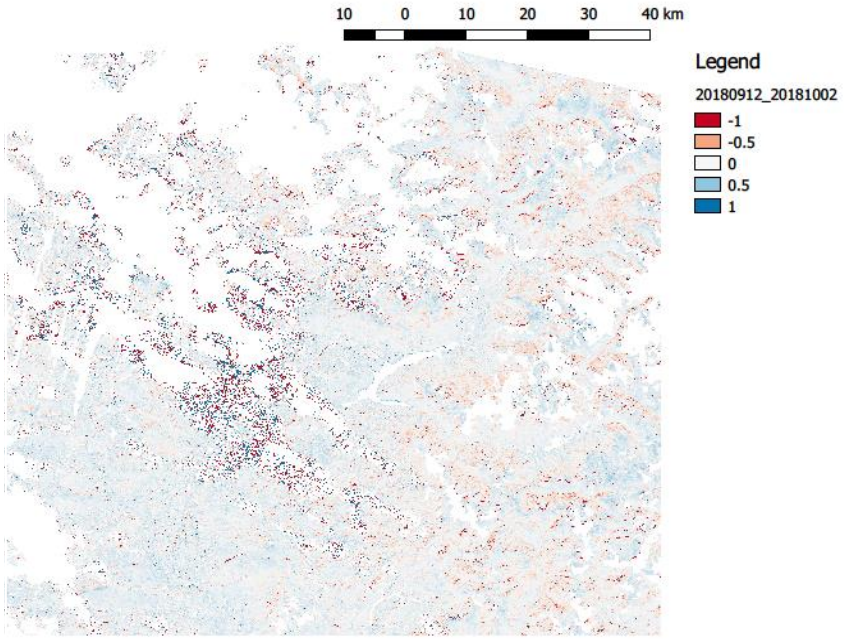
Possible correction

Statistical estimation of the
mean offset for slope orientation



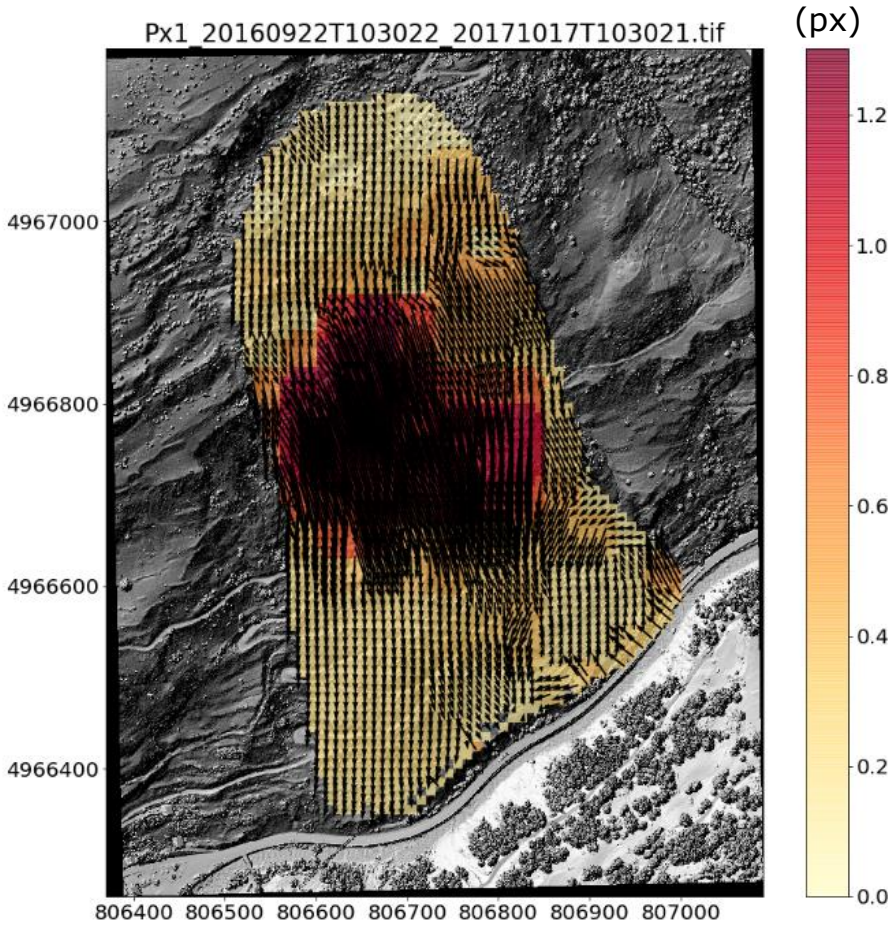


Correction



Sentinel-2 time series

Correlation of the longer temporal baseline



Conclusion and perspectives

Conclusion

- Sentinel-2 time series of the ground motion provides key information:

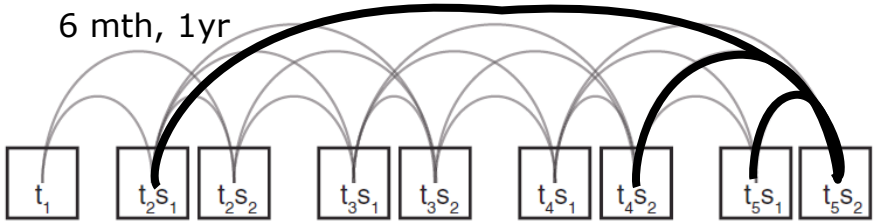
at the scale of one landslide to understand the acceleration phase.

at a regional scale, to detect these activations

- The current geometry of the L1C products contains distortions in the mountainous areas making difficult the processing of long time series when considering correlation between consecutive acquisitions

Perspectives

- Revise the scheme to compute the pairs by increasing the temporal baseline.



- Correction of the topographic offset is an option as well as the reprocessing of the Sentinel-2 archive with a better DEM (30m) and the GRI to improve the geolocation of the pixel through time.