Optical processing for quantifying Earth surface deformation: the ALADIM, MPIC and DSM-OPT on-demand services

ForM@Ter-MDIS Workshop – Strasbourg and La Petite-Pierre,
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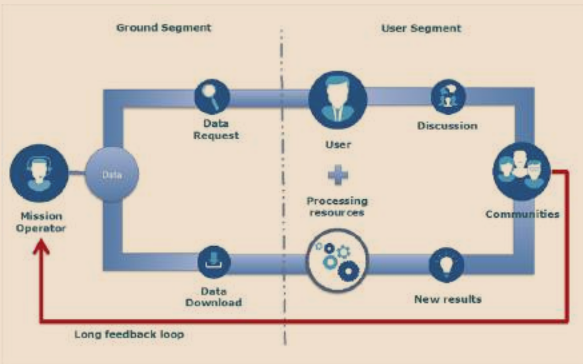
ESA Thematic Exploitation Plateforms

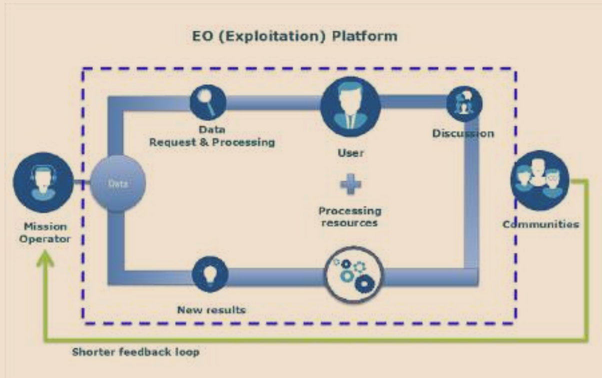
hydrology tep
geohazards tep
urban tep
tep thematic exploitation platform
coastal tep
forestry tep
polar tep
food security tep

Thematic Exploitation Platforms - TEPs

- TEPs are an ESA originated **R&D activity on the EO ground segment** to demonstrate the benefit of new technologies for large scale processing of EO data
- TEPs are technology R&D, but still fully user driven

- ***New concept:***





Data and tools are transferred to the user.
Transferred many times, replicated in many places, and with data exploitation taking place at users' premises.

Users access a platform work environment providing the data, tools, and resources.
The user is involved in its governance and invited (and enabled) to share and collaborate.

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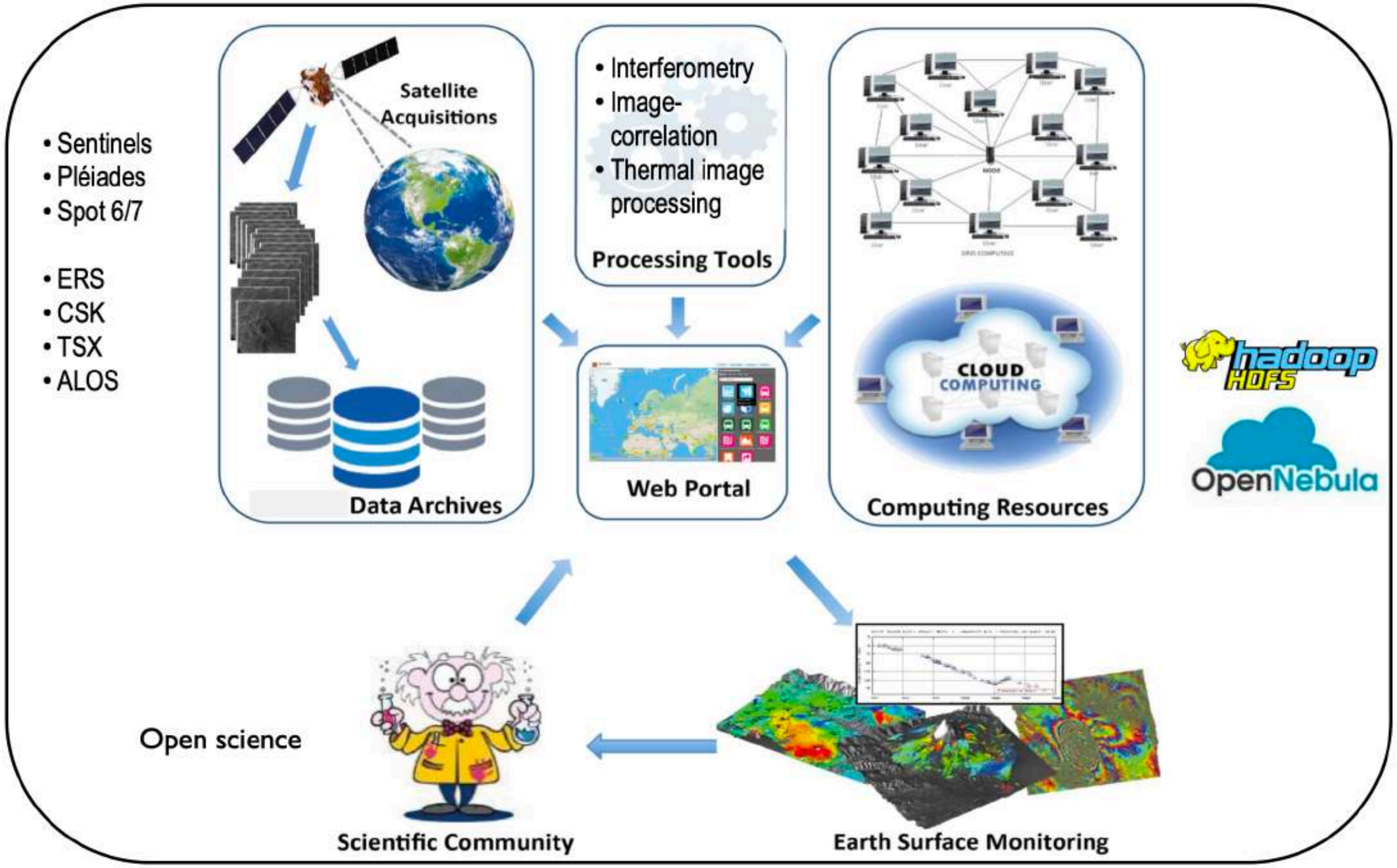
The GeoHazards Exploitation Platform

As part of the Thematic Exploitation Platform initiative, ESA is developing the GEP to bring the **user closer to the data** with a focus on new services and products

→ focus on large scale geohazard mapping and monitoring



Geohazards Exploitation Plateform

How to get access to the Geohazard Exploitation Platform – GEP ?

- **ESA Network of Ressources (NoR)**

Single access point for **Resource tier** providers (ICT Providers hosting collocated EO data) and **Platform service** providers (built on top of a resource tier provider) for

- **Self-funded user:** Any user world wide requiring for any reason Resource Tier or Platform Services (e.g. Science, Development, Pre-commercial and Commercial) who funds the consumption themselves;
- **User sponsored**: (Science, Development, Pre-commercial) by ESA and other entities via Announcement of Opportunity

- Available before end of 2019 for Resource Tier and at the **beginning of 2020 for platform services.**

- Application will be selected on the basis of **scientific excellence** and **the practicability to realize the project in due time**.

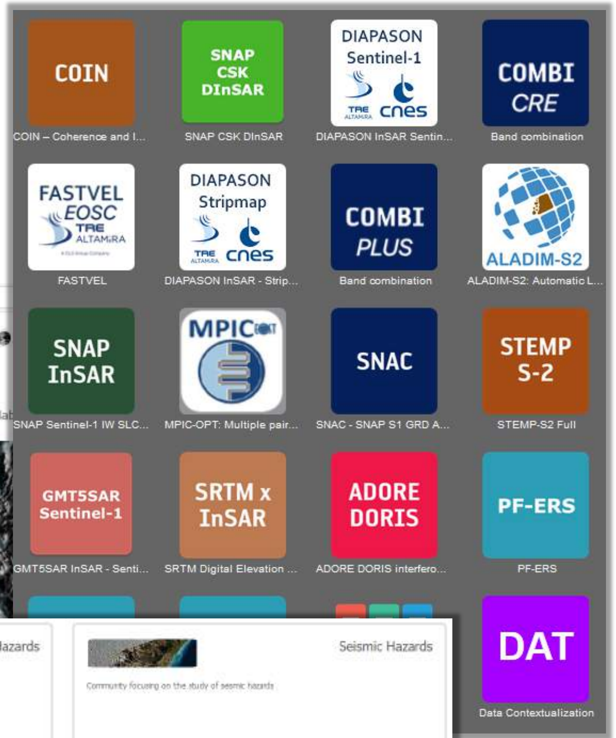
- As pre-requisites,
  - Users should **have a nationality or be appointed at universities from ESA Member States** contributing to EOEP5.
  Exceptions can be made for valuable international cooperation activities.
  - Users intent to **publish a paper / poster** acknowledging the 'sponsoring' that was provided by ESA or the external cost waiving entities, promoting both the 'Network of Resources' as well as the used resource/platform providers

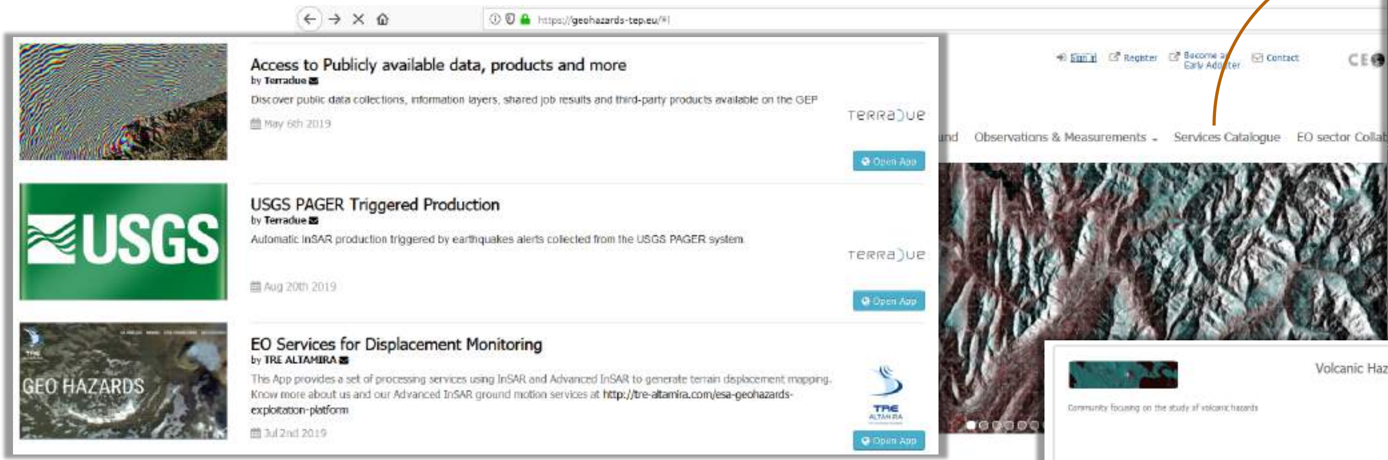
- **Sponsoring application form already available via Open Science Earth Observation (OSEO) call:**
https://eo4society.esa.int/2019/06/07/network-of-resources/

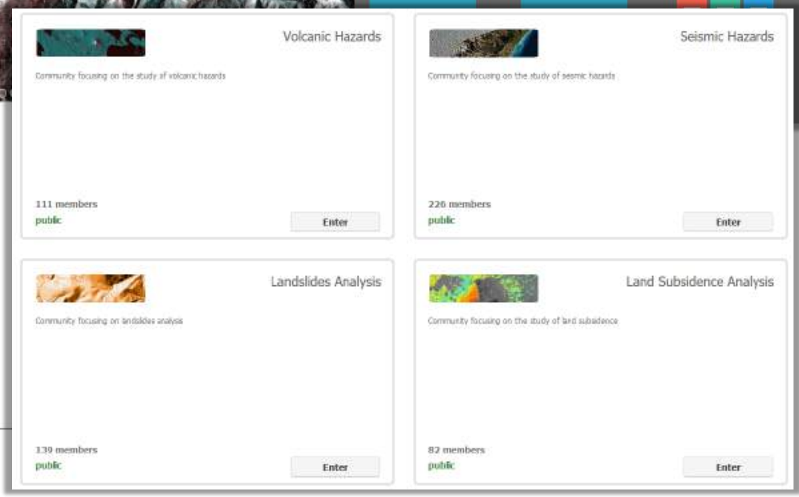
GEP – Main features

http://geohazard-tep.eu

Services Catalogue ①
Description of the available services







③ **Thematic Apps**
Working area with access to the services and jobs (personal and of the community)

Communities ②
Private or Public. Give access to specific apps and services

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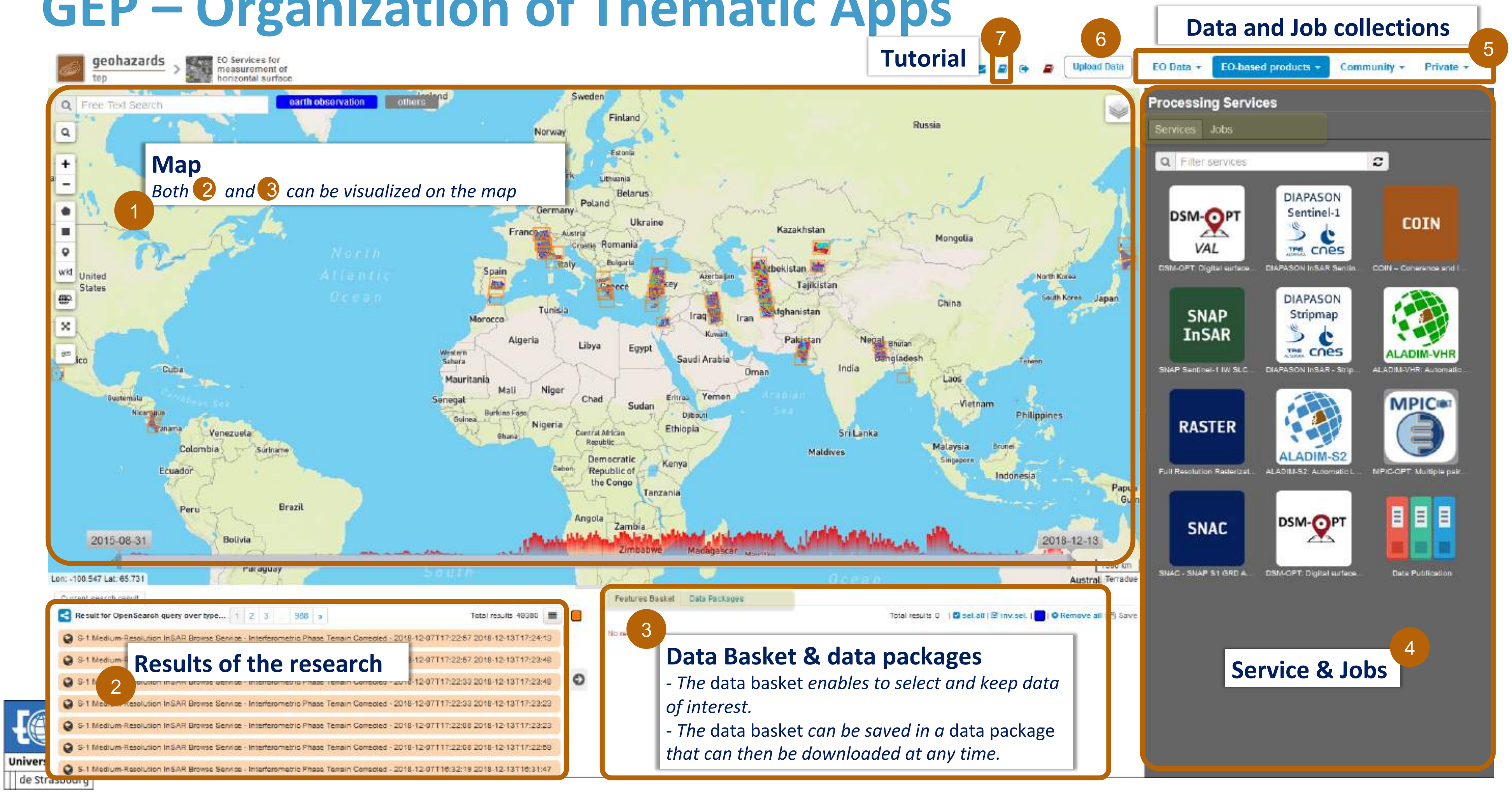
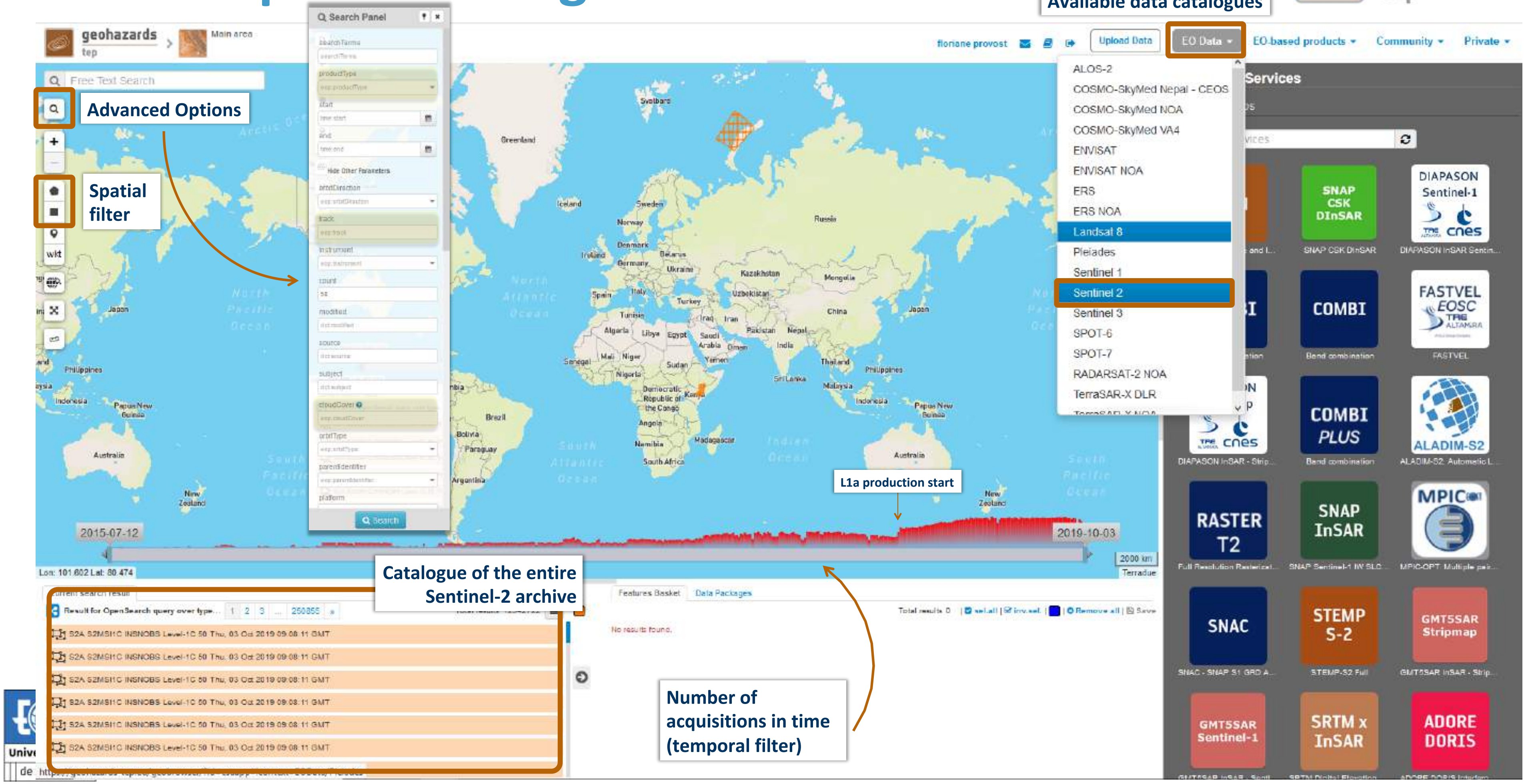
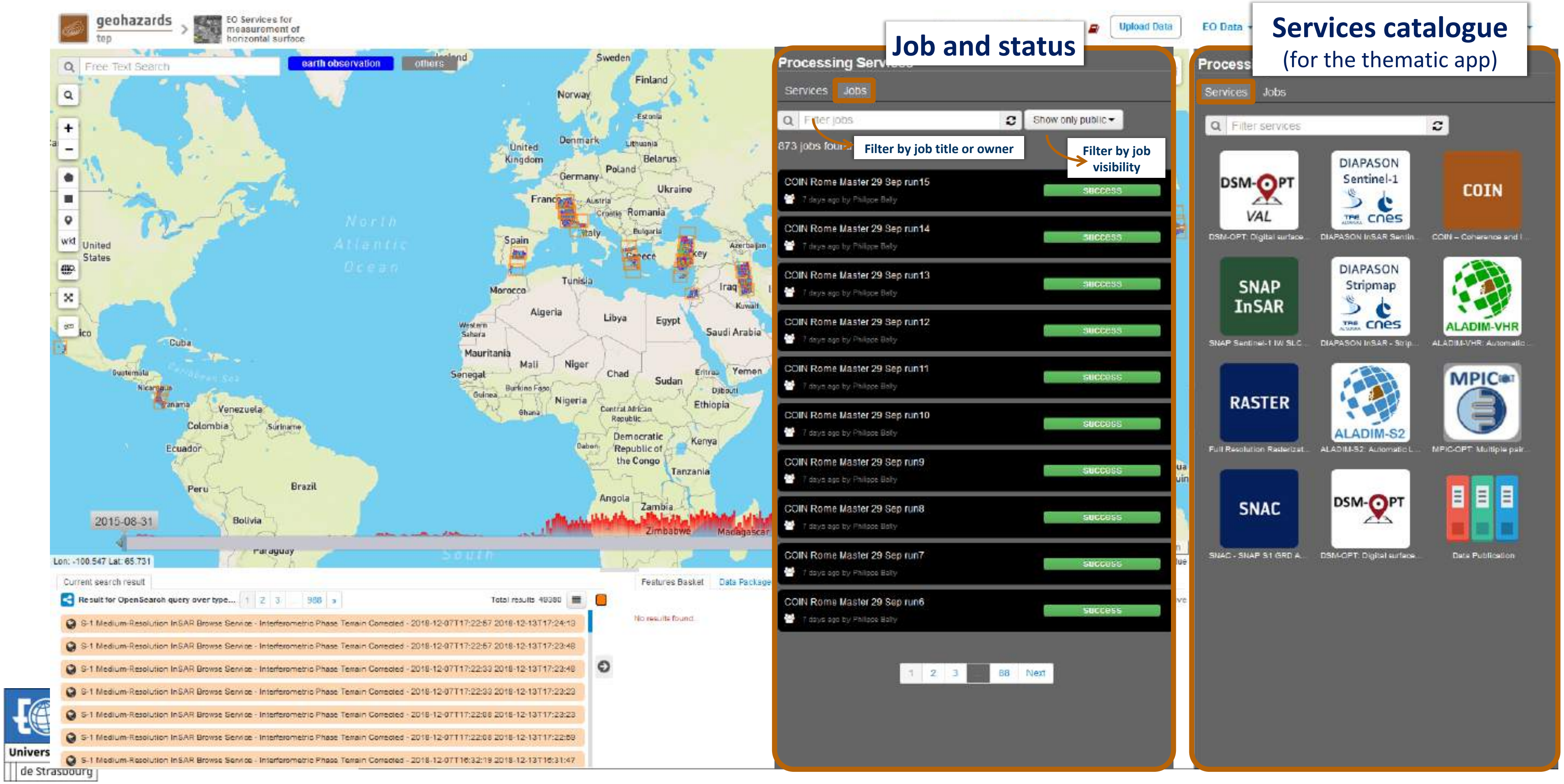
GEP – Organization of Thematic Apps



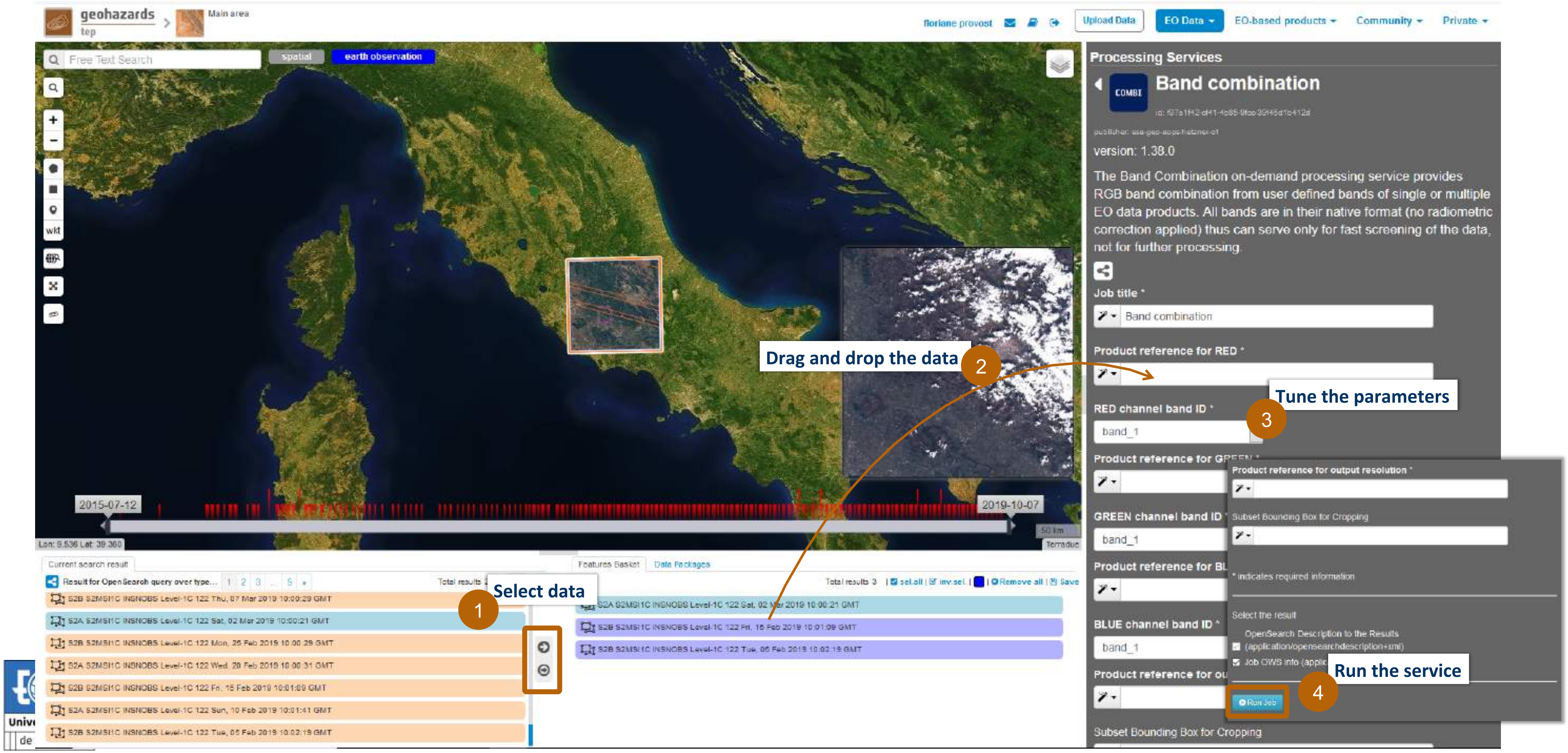
GEP – Explore catalogues



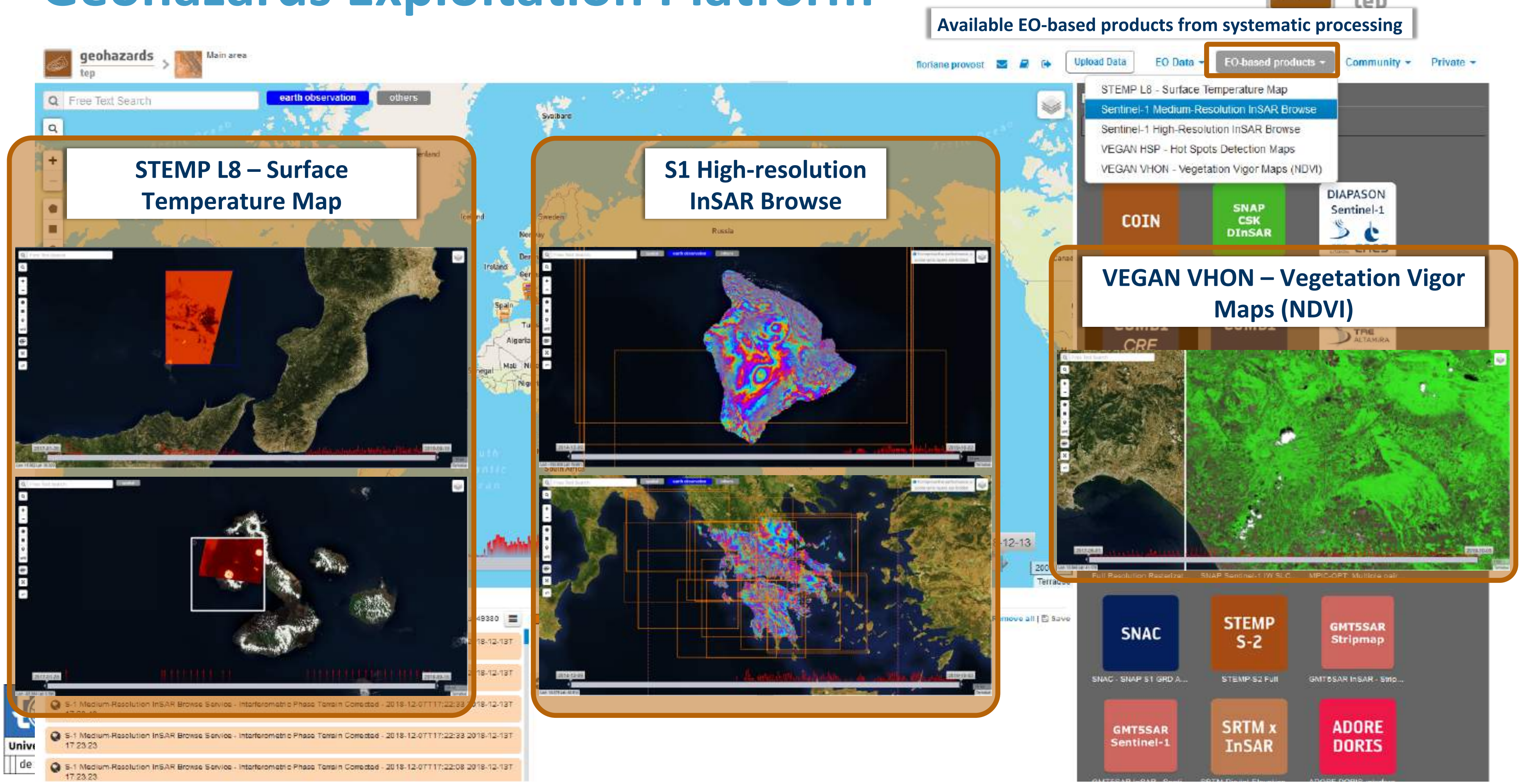
GEP – Processing services



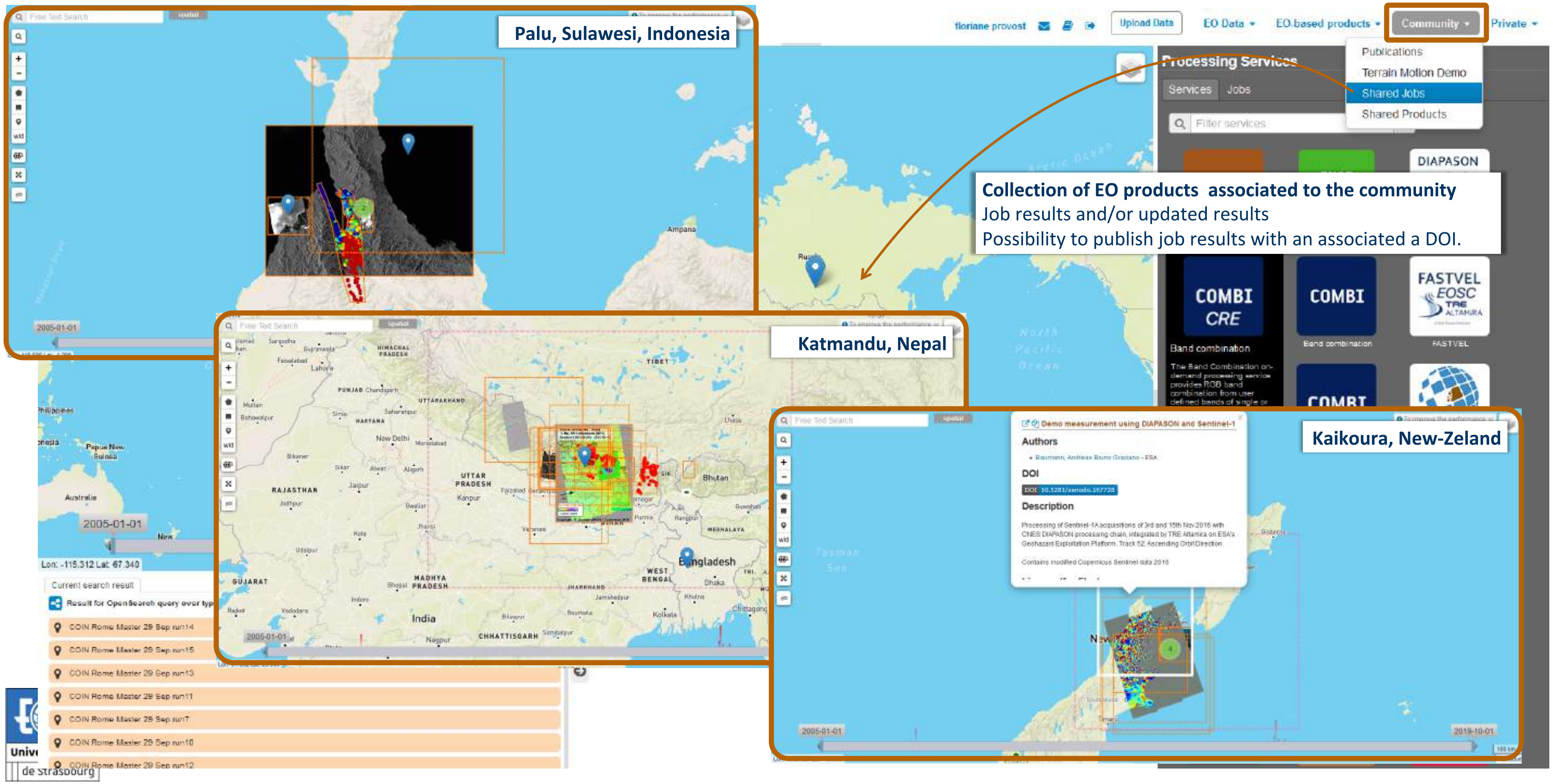
GEP – Run a service



Geohazards Exploitation Platform



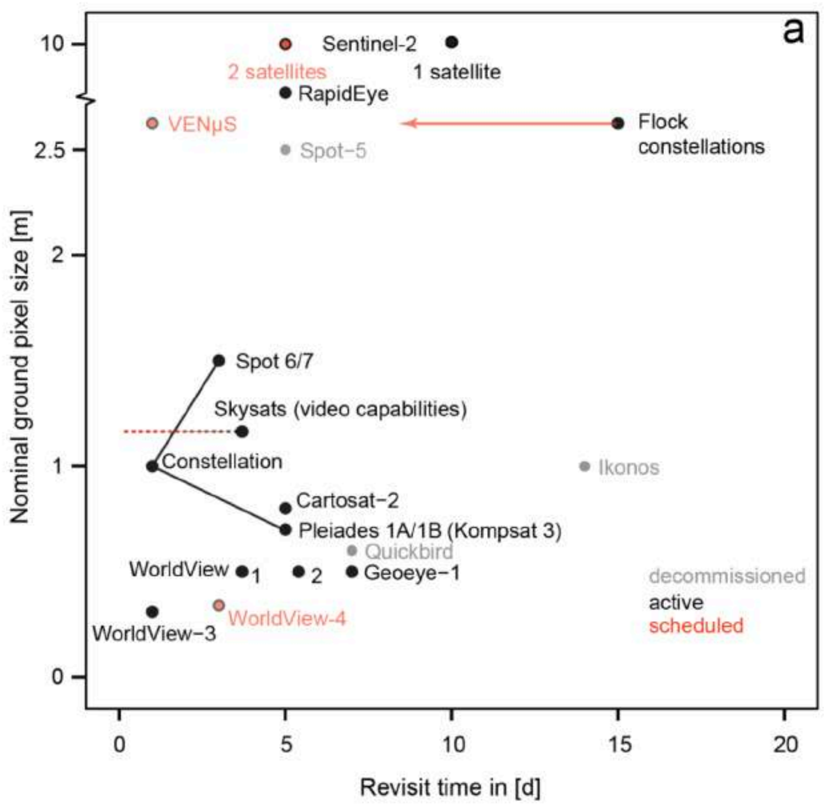
GeoHazards Exploitation Platform



Multispectral (MS)/Optical data for Earth surface deformation

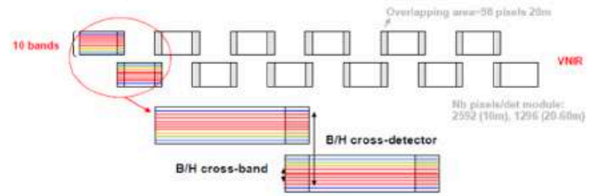
Increasing spatial and temporal resolution of MS/optical satellites

Becomes an opportunity for geohazard mapping, monitoring, and understanding

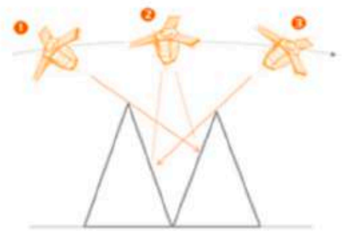


For instance …

- **Sentinel-2** MSI instrument alone acquires 800 GB/day (2 x 800 GB/day with S-2B)



- **Pléiades + SPOT6/7** constellation provide tri-stereo at 0.7 - 1.5 m resolution (< 24h response time)



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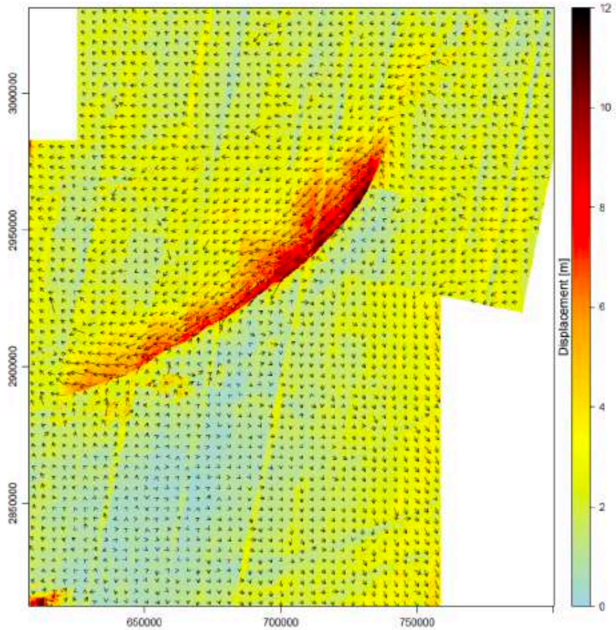
Multispectral/Optical data for Earth surface deformation

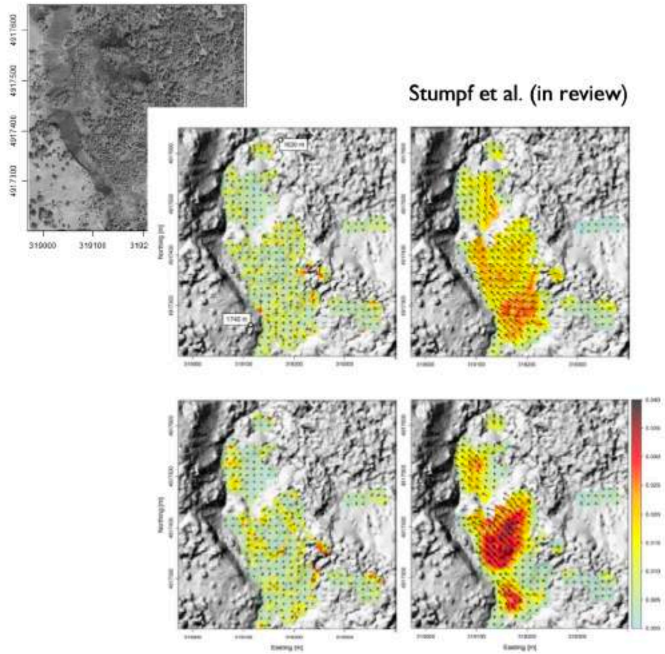
Build “generic” and “versatile” services based on optical image correlation for geohazards

Rapid response / mapping
e.g. quantification of surface displacement after major earthquakes (pre/post event images)



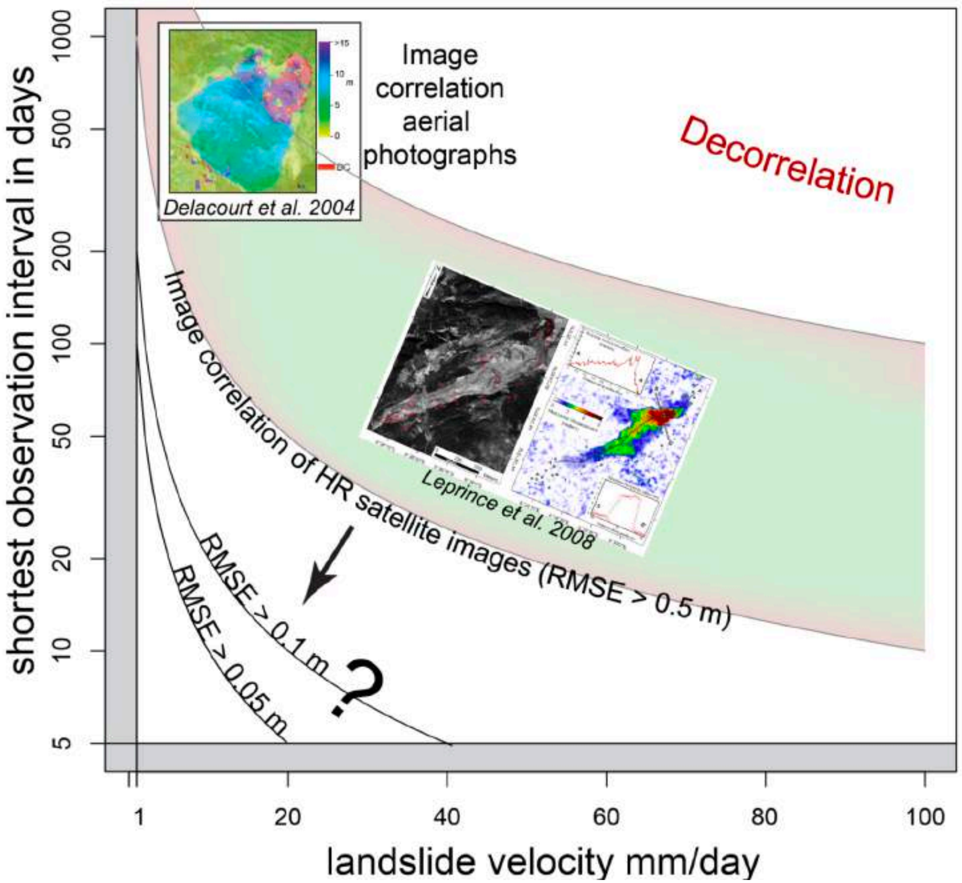
Surface slip from the Balochistan earthquake (2013) for Landsat 8 images

Process monitoring
Time-series processing (archives, on-going fluxes of images)

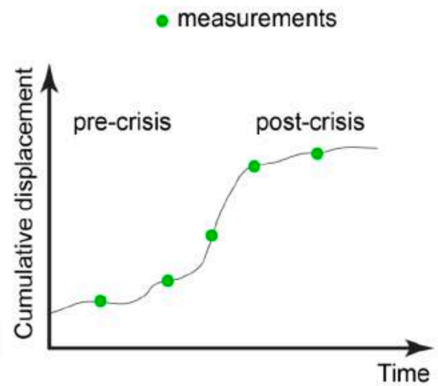


Surface motion of a landslide in the French Alps over two years

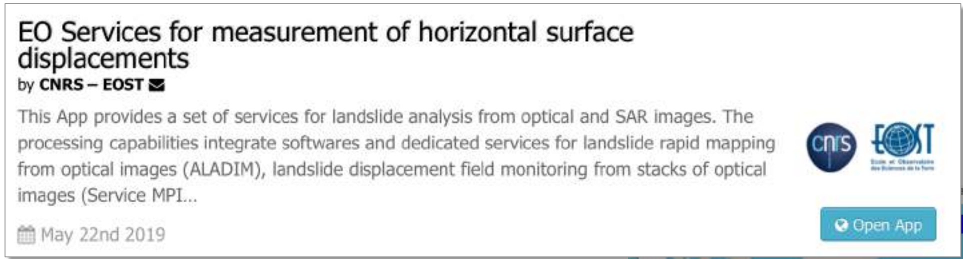
Measuring displacement with MS/optical data - limitations



- Which accuracy is possible with VHR satellite images?
- Can the processing be automated?
- How much ground control?



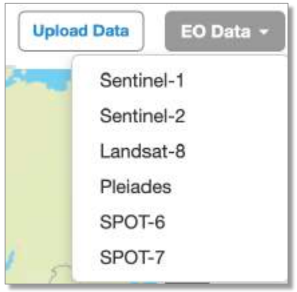
MS/Optical services on the Geohazards Exploitation Platform

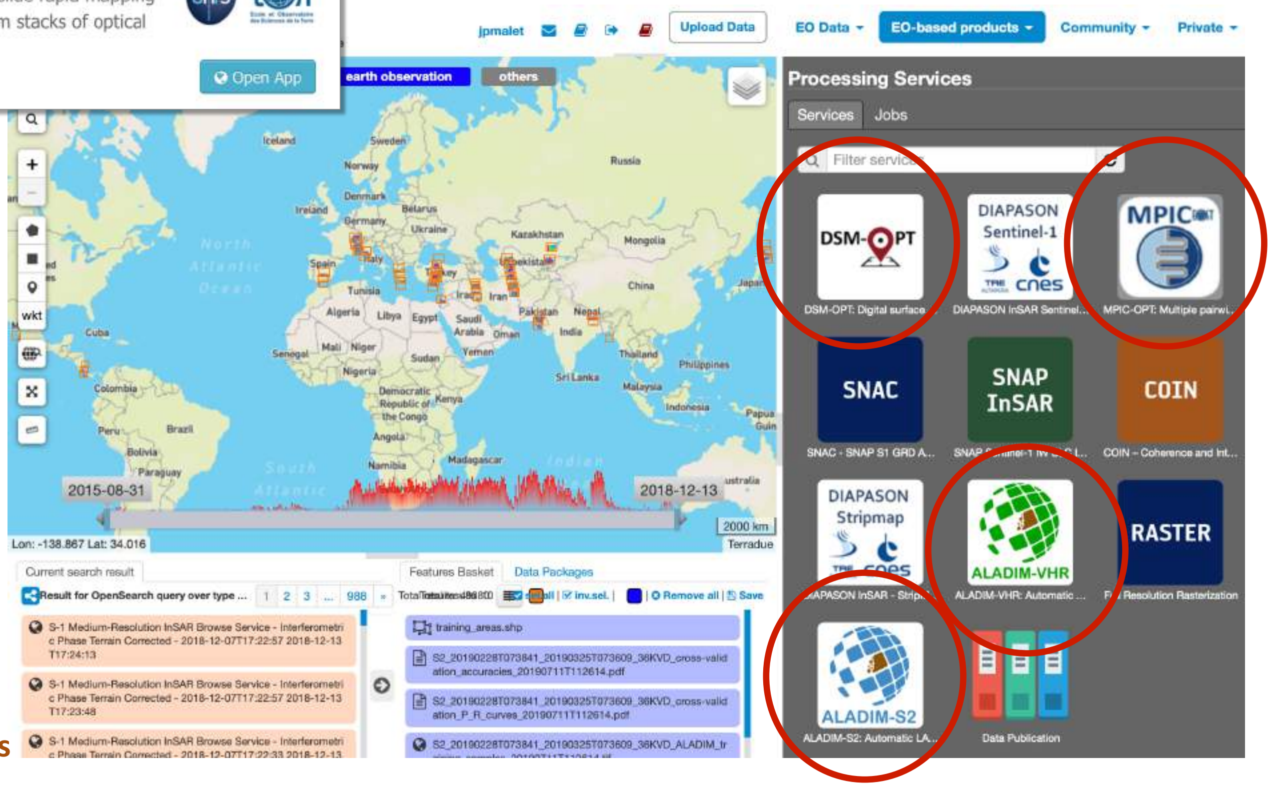


Thematic App / Optical services

Services

Data

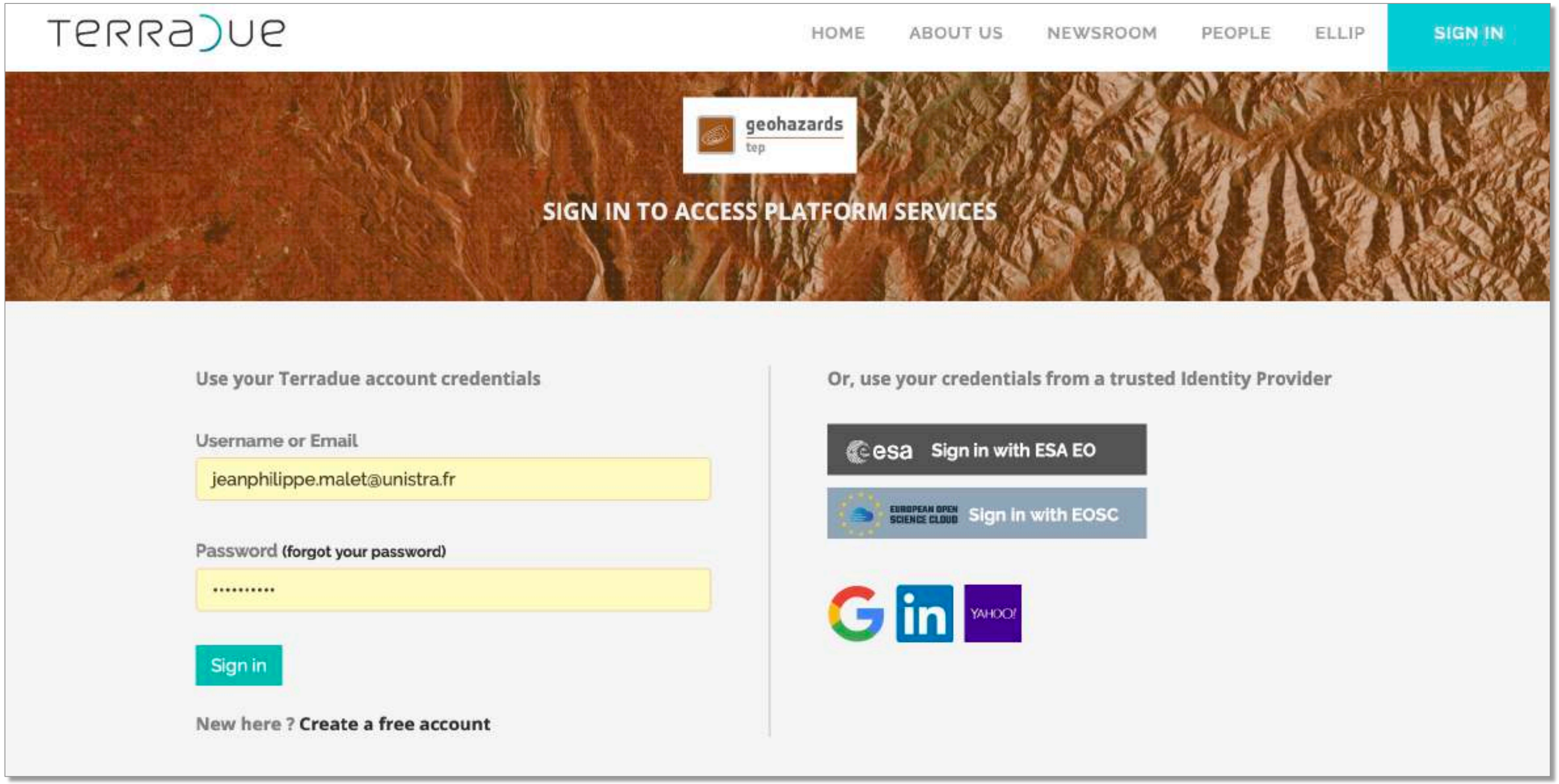




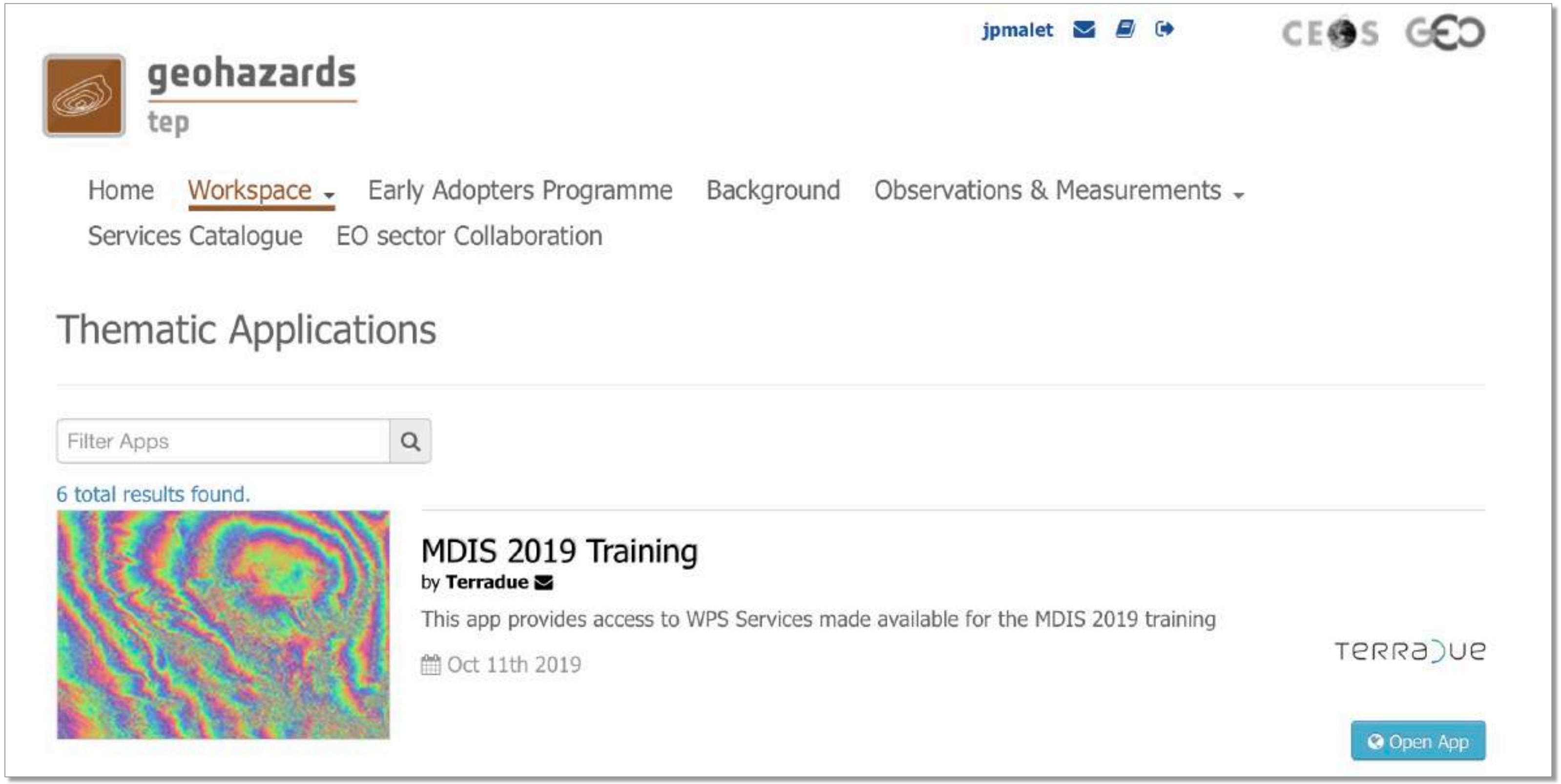
Products

Practical: MDIS Thematic App

Connect on: https://geohazards-tep.eu



Practical: MDIS Thematic App



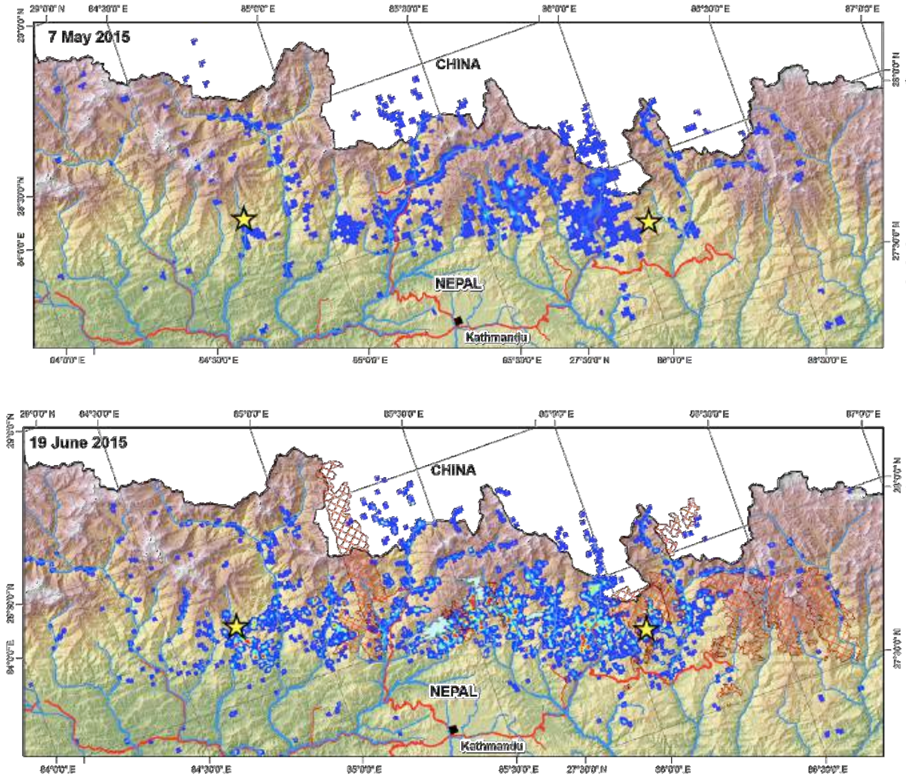
Detecting and mapping landslides

Motivation: building landslide inventories from space

Earthquakes and extreme rainfall (typhoons) can cause >1000s to 100,000s landslides.

Landslide inventories are key elements for all phases of DRM cycle

EO data is a useful source of information … but there is a lack of fast and standard procedures to produce accurate and operational inventories



Williams et al. (2017):
Landslide inventory map post-Gorkha earthquake

Detecting and mapping landslides

Motivation: building landslide inventories from space

Many landslides triggered on 15 March 2019 in Mozambique by Tropical Cyclone Idai

Sentinel 2 imagery gives the opportunity to rapiddly and efficiently detect and map landslides
in very short time

ALADIM: an automated and generic IA-based change detection algorithm tailored for multispectral images

ALADIM

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Detecting and mapping landslides

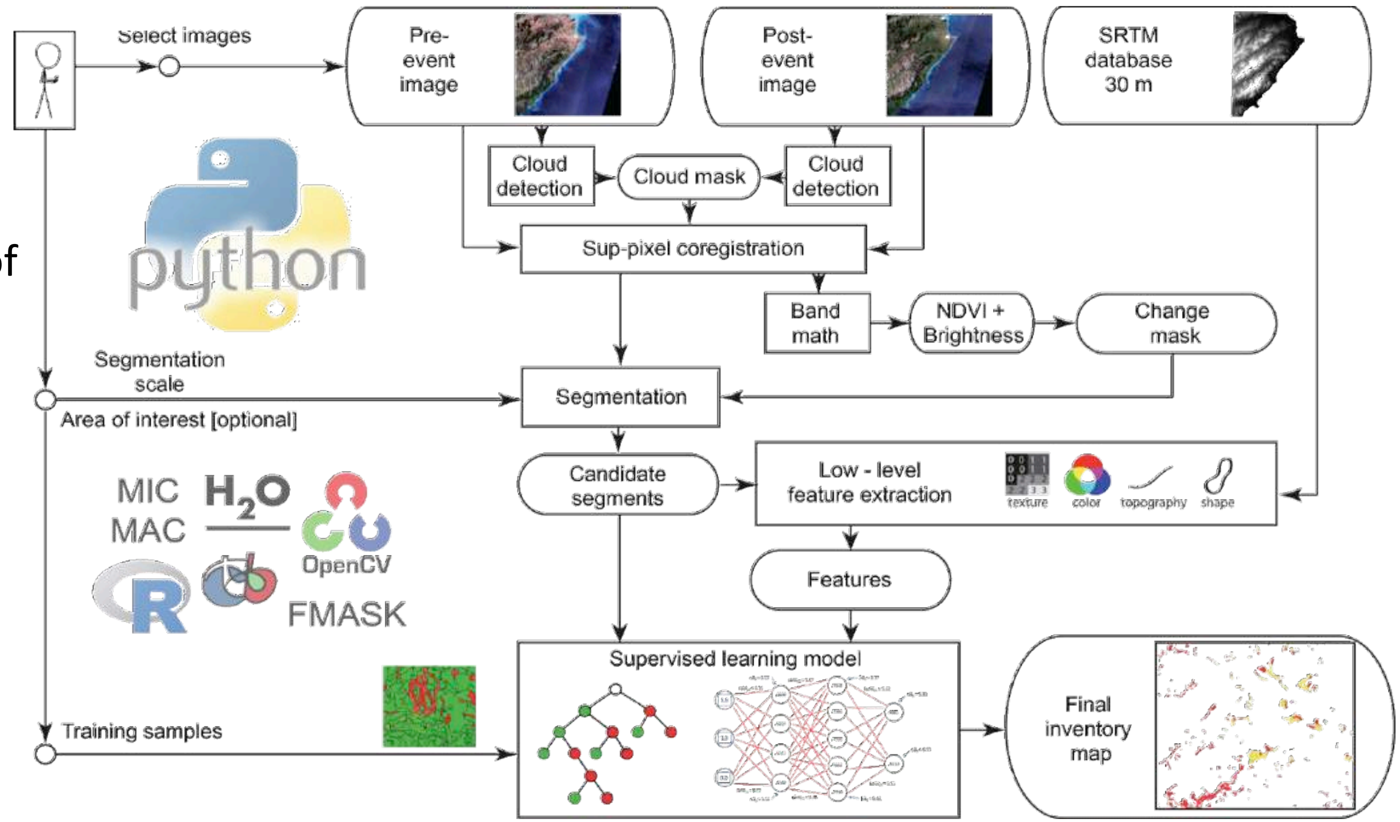
ALADIM service: Automatic landslide detection and inventory mapping

ALADIM

Image sources: MRO (S2) + VHRO (ortho-images)

Approach: Supervised change detection method - Selection of image features – Machine Learning

Computation: HPC + cloud-based implementation (dockerisation)



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Detecting and mapping landslides

ALADIM service: Automatic landslide detection and inventory mapping

Region of Interest and digitalization of a few training sample

See note: https://terradue.github.io/doc-tep-geohazards/tutorials/aladim_input_dataset_preparation.html

geohazards tep | Site | Page | « ADORE DORIS | ALADIM-S2: Au... » | Source | TERRADUE

ALADIM-S2 and ALADIM-VHR: Preparation of input datasets

- Creation of the landslide initial training samples: training_samples.shp
- Creation of the training areas: training_areas.shp
- Creation of the AOI – Area of Interest: aoi.shp

ALADIM-S2 and ALADIM-VHR: Preparation of input datasets

Creation of the landslide initial training samples: training_samples.shp

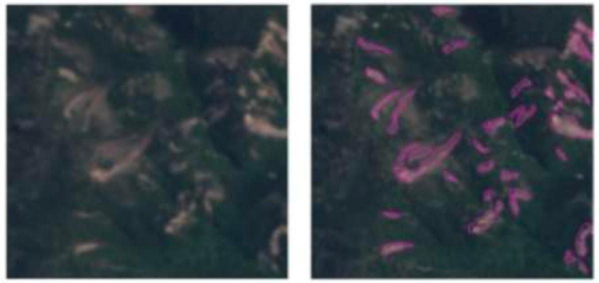
The first mandatory shape file is composed of the **training samples**. The landslide training samples should be :

- Digitized (image interpretation) on the post-event imagery;
- Representative of the distribution of landslide sizes (with the digitalization of small, medium and large landslide sizes);
- Digitized over the complete range of landscape properties (e.g. low, medium and high slope gradients; low, medium and high image reflectance values).

The training samples should comprise a minimum number of landslide events (e.g. typically 5%) of the expected total number of landslide events over the study areas.

The training samples should be recorded in *.shp file format, and created out of the GEP Platform. The training samples should be presented as a polygon shapefile with one single layer. It is typically a good starting point to divide the study area with a grid and select about 10 grid cells in which all landslides are mapped to construct the training sample. Please assure that the training samples shapefile does not contain NULL geometries or other geometry problems.

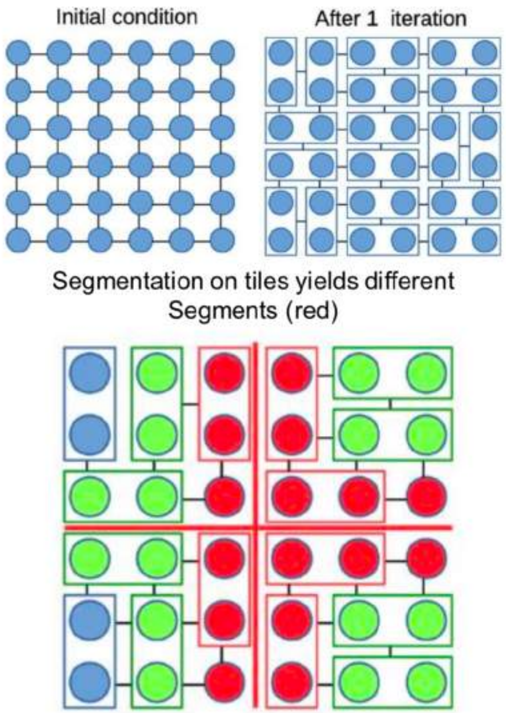
Name the shapefile like this: **training_samples.shp**

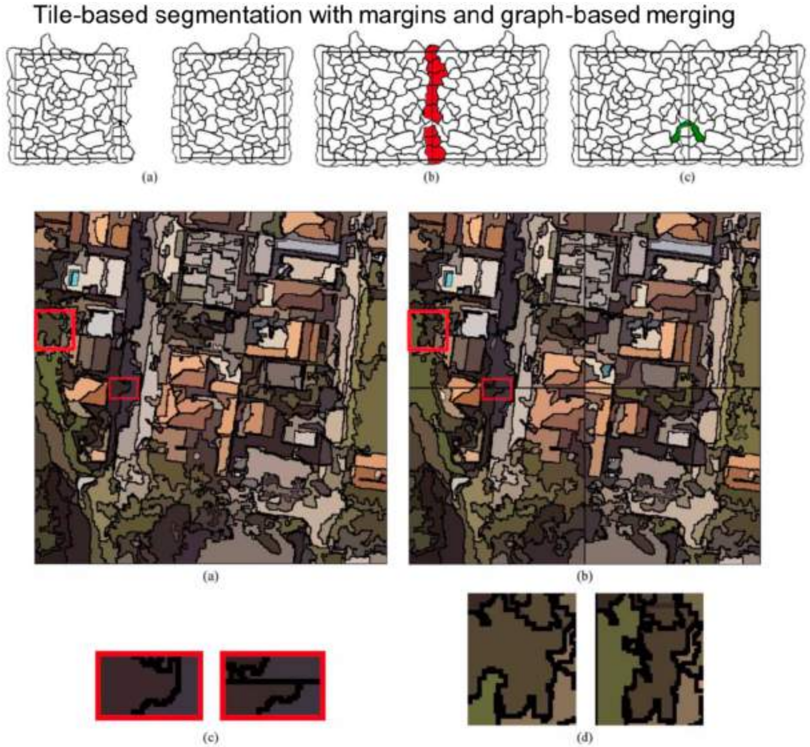


Detecting and mapping landslides

ALADIM service: Automatic landslide detection and inventory mapping

Segmentation: parallell implementation of a region-merging algorithm





Detecting and mapping landslides

ALADIM service: Automatic landslide detection and inventory mapping

ALADIM

Feature extraction

Name	Derived from	Number
Area	Polygons	1
Flow accumulation (mean, variance)	DEM	2
Distance to drainage (mean, variance)	DEM	2
Distance to crest (mean, variance)	DEM	2
Flow direction (mean, variance)	DEM	1
Slope (mean, variance)	DEM	2
Topographic wetness index (mean, variance)	DEM	2
Fraction of stream pixels (mean, variance)	DEM	2
NDVI (mean, variance, change)	NDVI, pre-and post-images	6
Band values (mean, variance)	10 bands, pre-and post-images	40
Reflectance (mean, variance, change)	Average reflectance visible bands, pre-and post-images	6
Circularity	Polygons	1
Circularity (Haralick)	Polygons	1
Convexity	Polygons	1
Eccentricity (bounding box)	Polygons	1
Eccentricity (eigen vectors)	Polygons	1
Elongation	Polygons	1
Rectangularity	Polygons	1
Solidity	Polygons	1
GLCM contrast (topo-guided)	DEM, panchromatic	2
GLCM correlation (topo-guided)	DEM, panchromatic	2
GLCM entropy (topo-guided)	DEM, panchromatic	2
GLCM mean	panchromatic	1
TOTAL		**83**

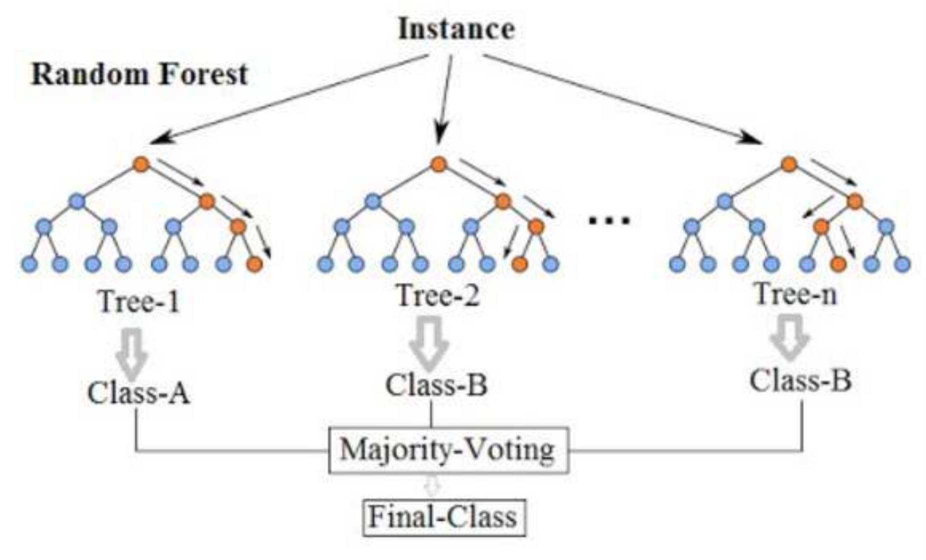
Detecting and mapping landslides

ALADIM service: Automatic landslide detection and inventory mapping

Classification: machine learning using a Random Forest classifier

Principle

- Build a large amount of decision trees (>500) from a training set.
- Each tree is built from a sub-sample of the training set (2/3 of the training set).
- Each node is built by testing radomly < √n attributes (n=total number of attributes).
- Different thresholds are tested for the attributes.
- A node is built for the attributes that maximizes a gain function (e.g. Gini coeff.) between two classes.
- When a node is pure (contain only one classe) the tree stops.



Advantages

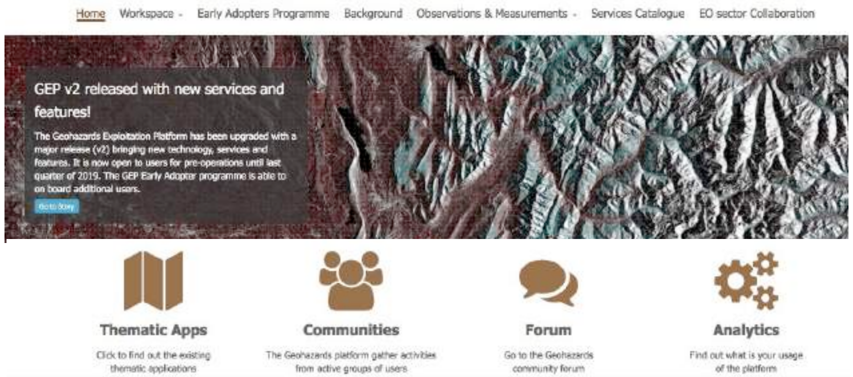
- Fast.
- Proven to be the most accurate method for a wide range of applications.
- Allow the use of a large number of attributes.
- Minimize over-fiting.
- Handle non-linear data.
- Unbiased estimation of the accuracy: Out Of Bag uses 1/3 of the training set to test the model.
- Estimate the attribute importance.
- Allow unsupervised classification and outlier detection.

Detecting and mapping landslides

ALADIM service: Automatic landslide detection and inventory mapping

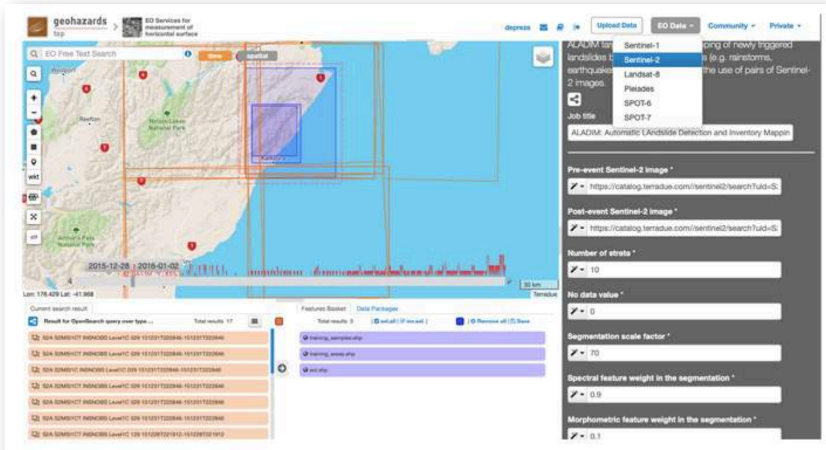
ALADIM

Available on geohazards tep **→ ALADIM-S2** ALADIM-S2 **and ALADIM-VHR** ALADIM-VHR



Service selection

Service use



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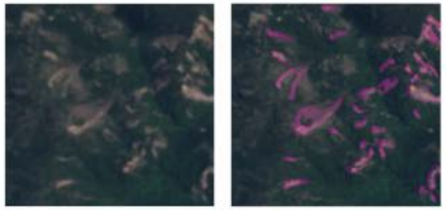
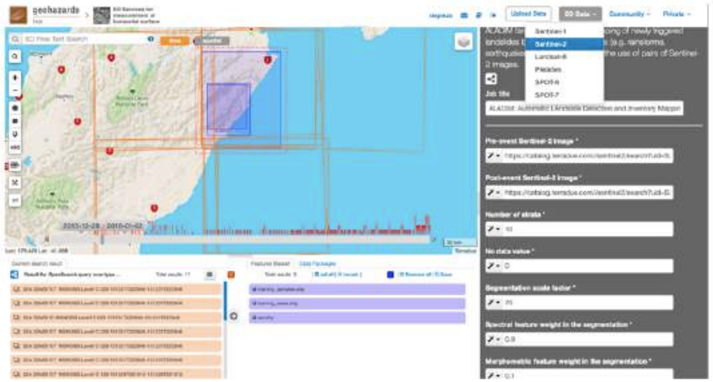
Detecting and mapping landslides

ALADIM service: Step by Step

1. Creation of a landslide initial training sample



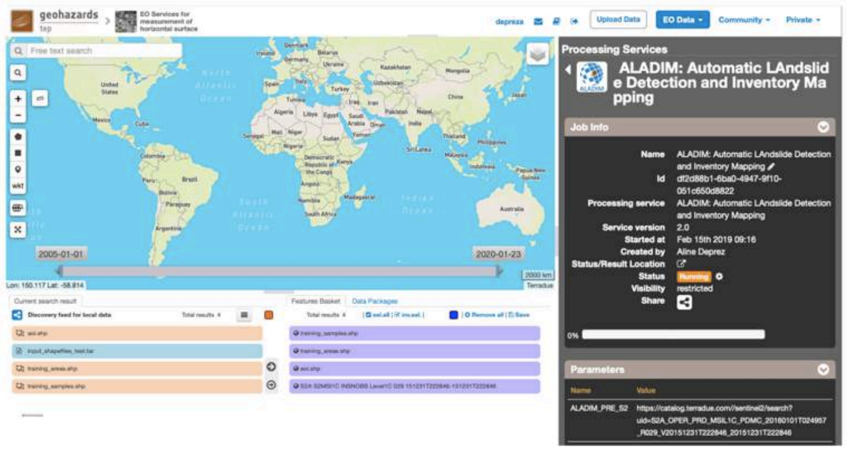
2. Selection of input data



3. Setting of the parameters

- Segmentation scale factor,
- Usage of cloud mask,
- Grid code,
- Sun elevation & azimuth …

4. Launching the job



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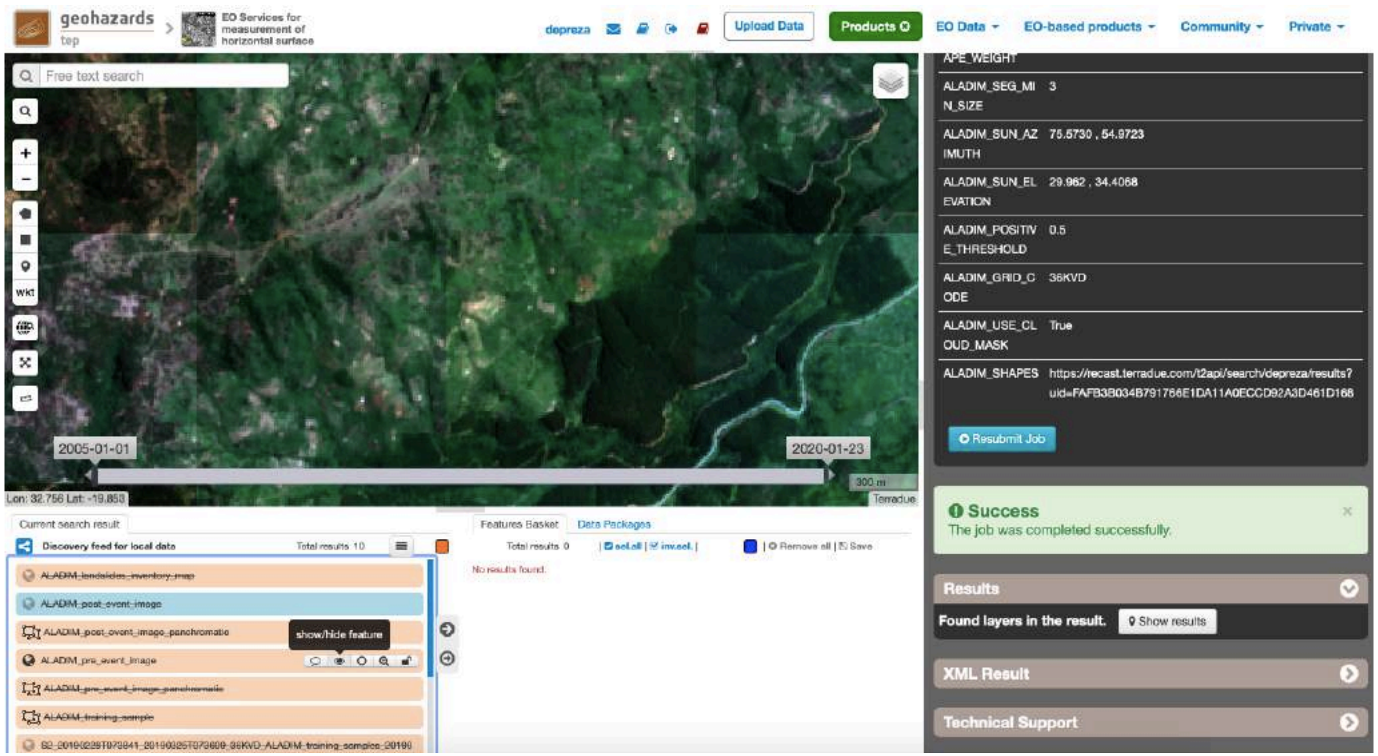
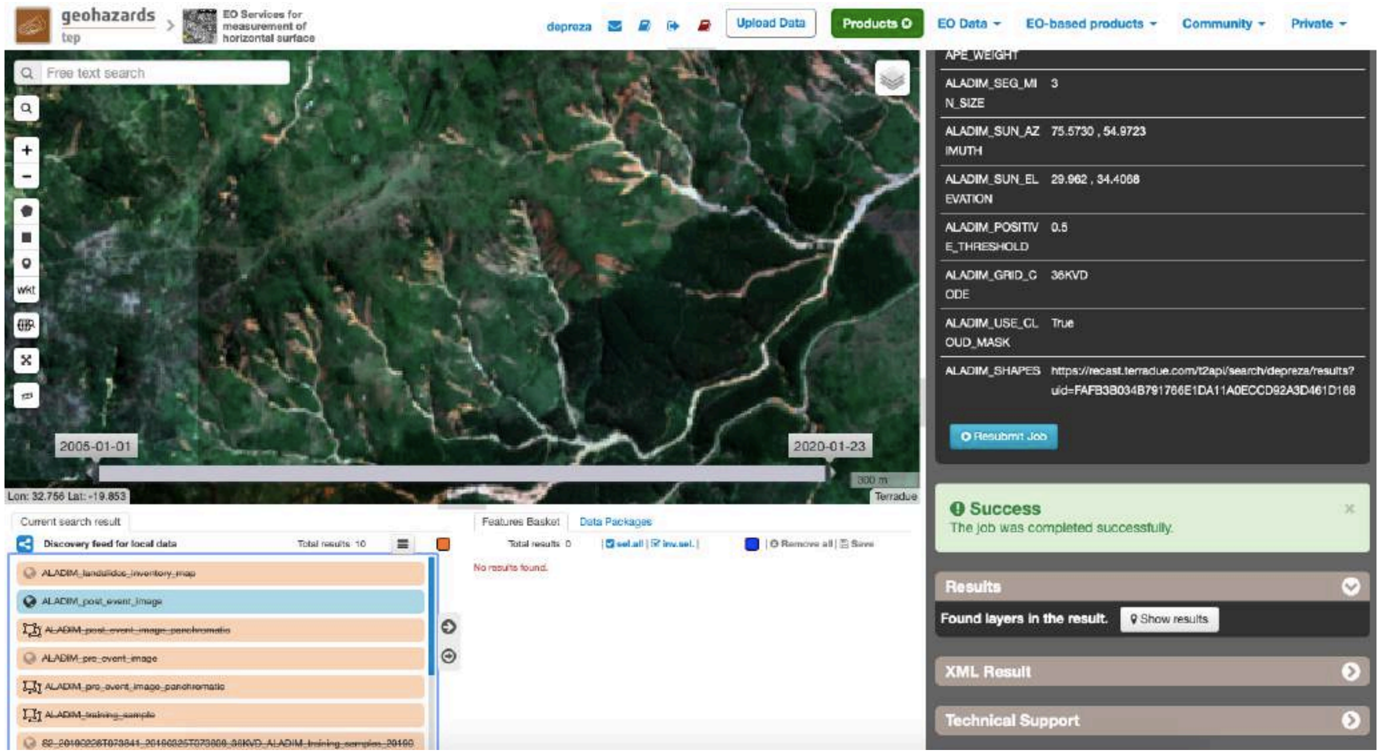
Detecting and mapping landslides

Application for Mozambique Cyclone Idai - March 2019 - S2 data



Detecting and mapping landslides

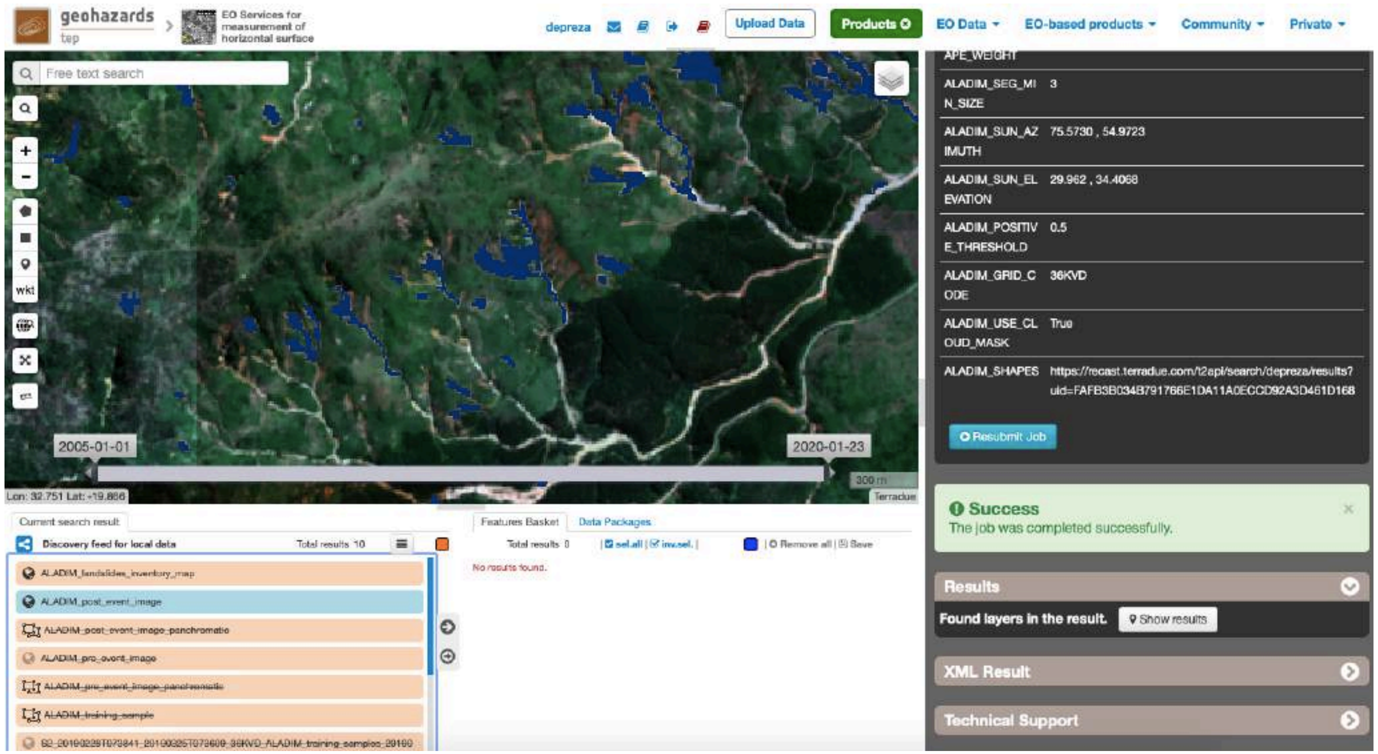
Application for Mozambique Cyclone Idai - March 2019 - S2 data



Detecting and mapping landslides

Application for Mozambique Cyclone Idai - March 2019 - S2 data

ALADIM



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Detecting and mapping landslides

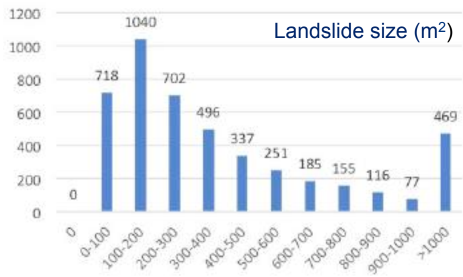
Use of landslide inventory maps

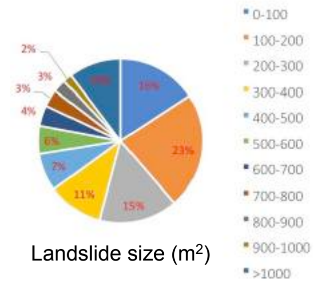
Computation of indicators / statistics

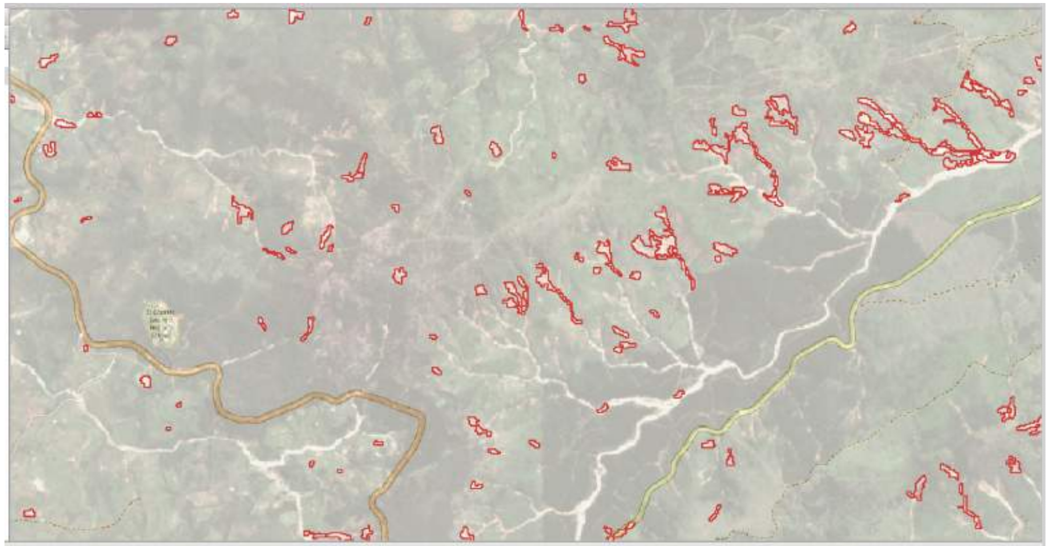
- *Landslide number,*
- *Landslide surface,*
- *Landslide density maps,…*

Overlay of the landslide inventory maps with:

- *Exposure maps,*
- *Population density maps, …*
- *Correlation with triggers (rainfall, ETQ M_W)*

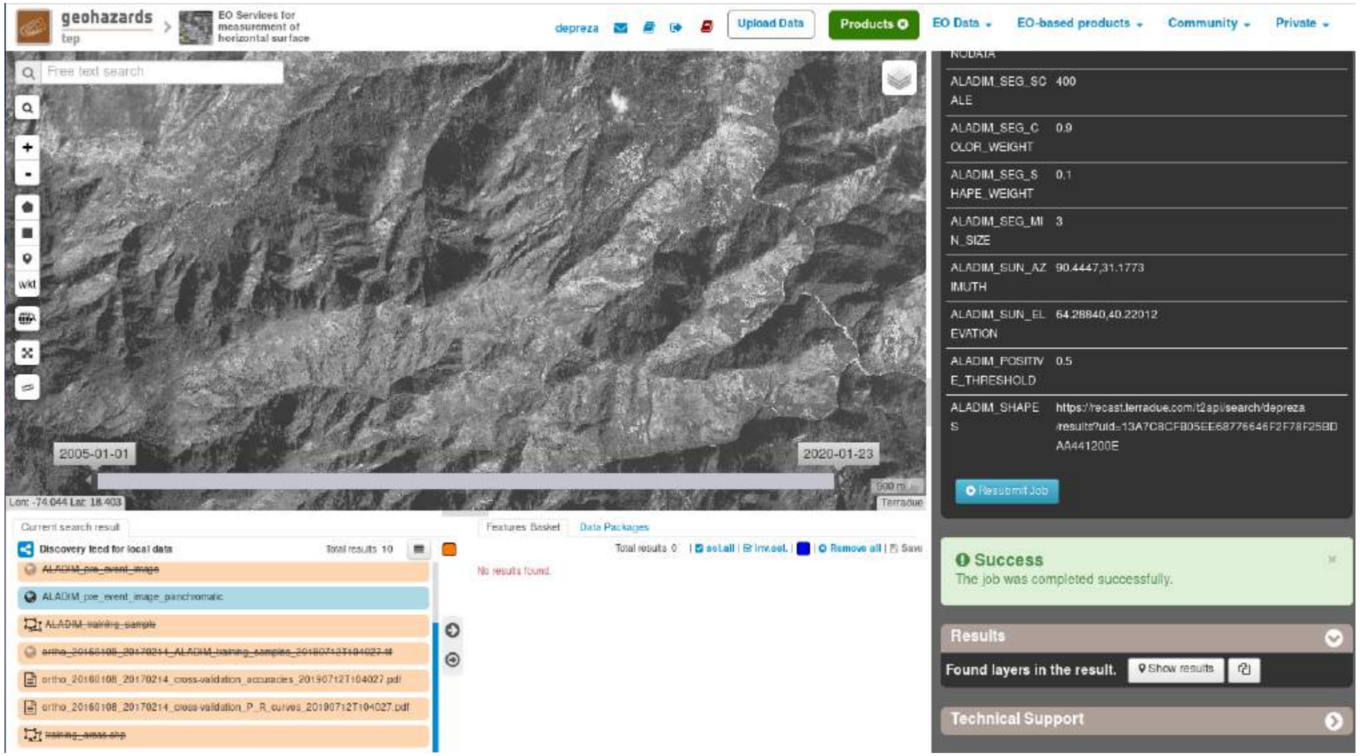






Detecting and mapping landslides

Other application – ALADIM-VHR: Haiti landslide inventory



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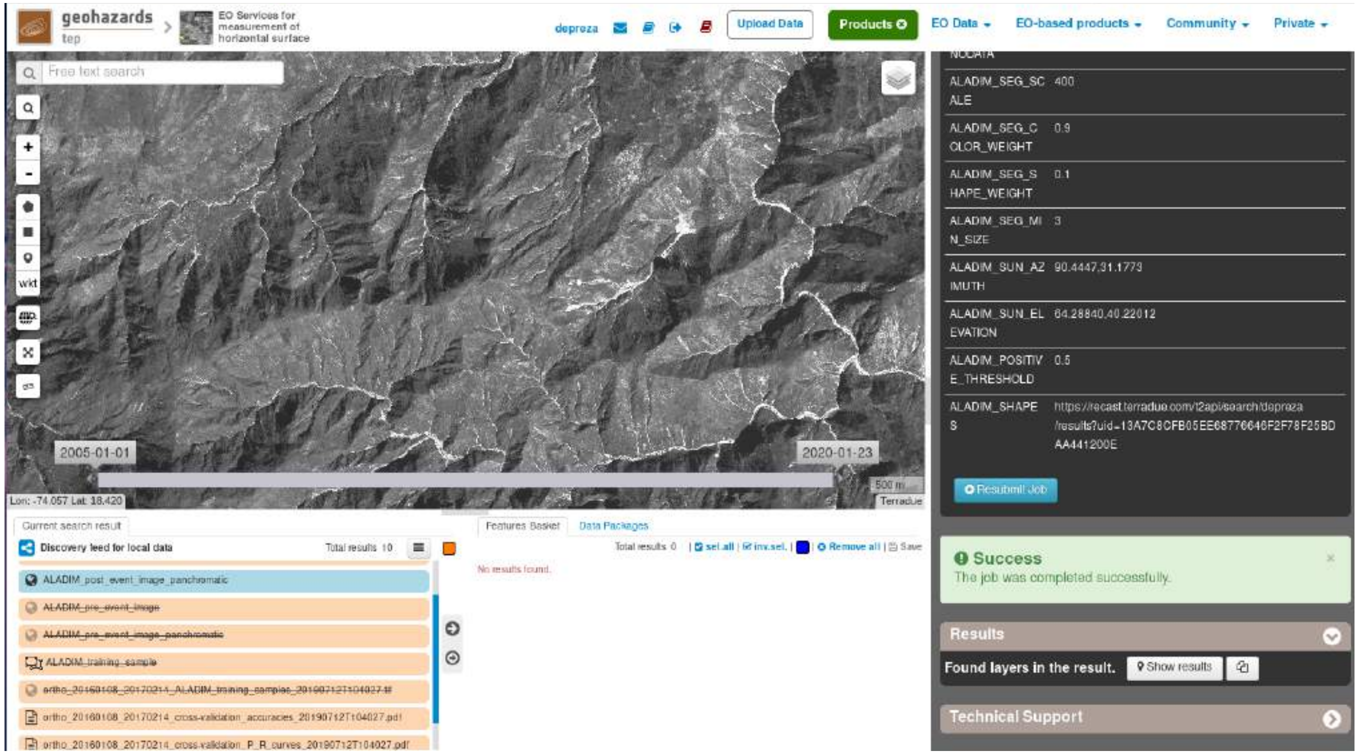

Detecting and mapping landslides

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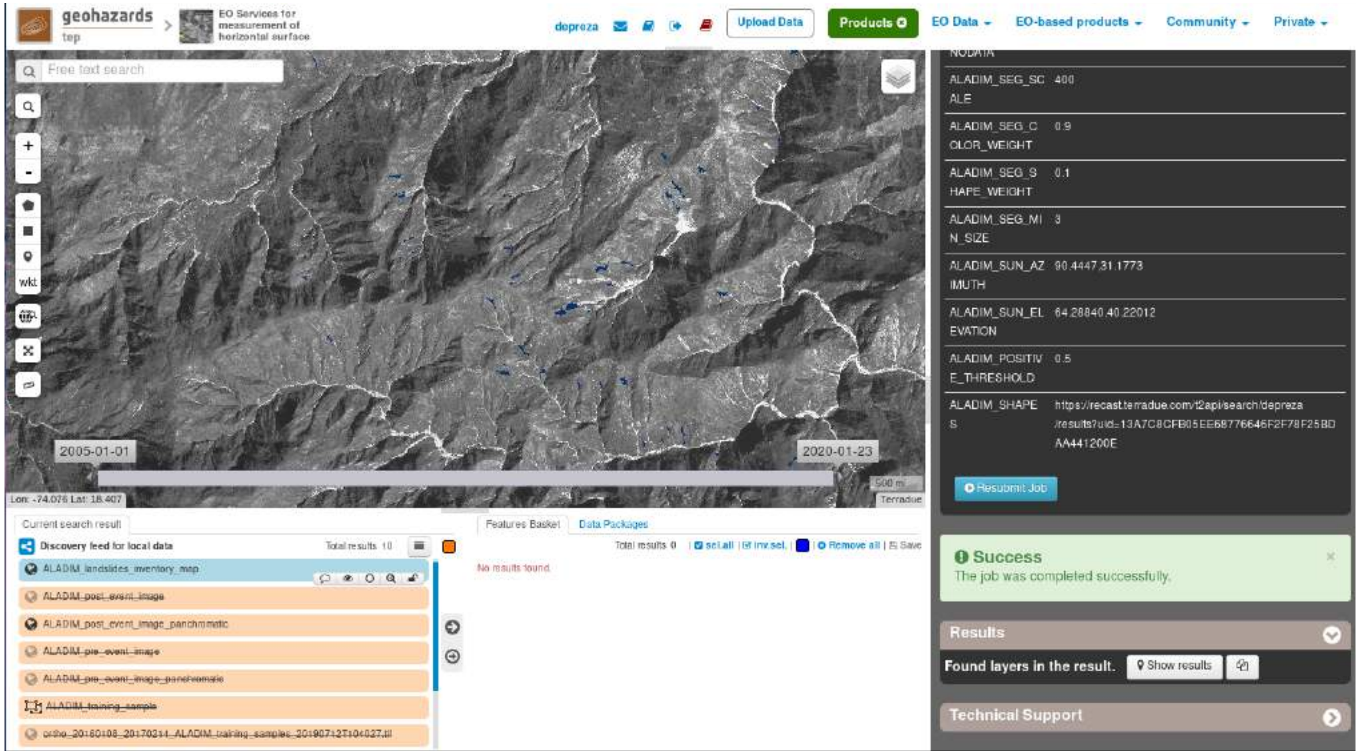
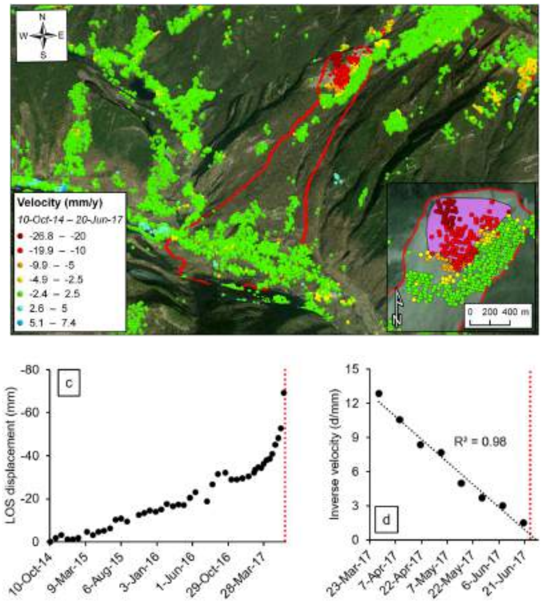


Quantifying tectonic deformation and monitoring landslide motion

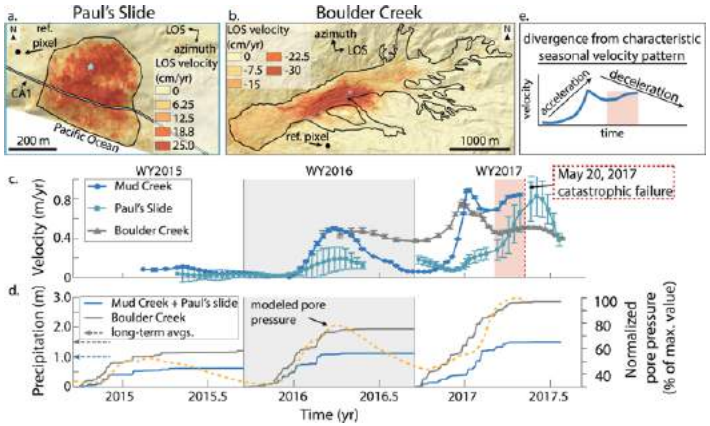
Surface motion monitoring for geohazards

Risk management and risk



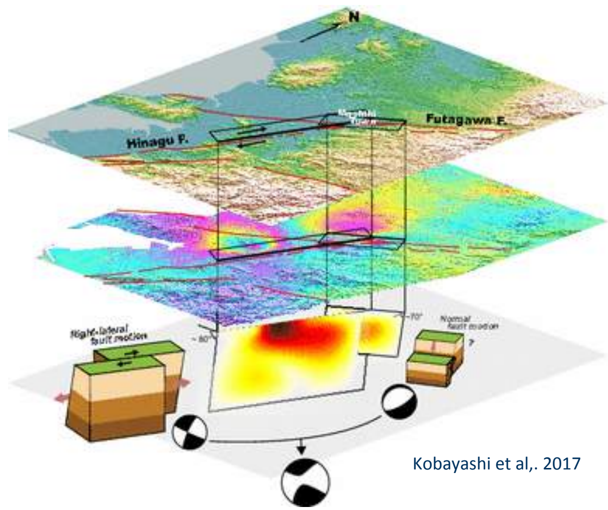
Kang et al., 2019

Better understanding of the mechanisms controlling the phenomena



Handwerger et al., 2019

Modelling of the phenomena

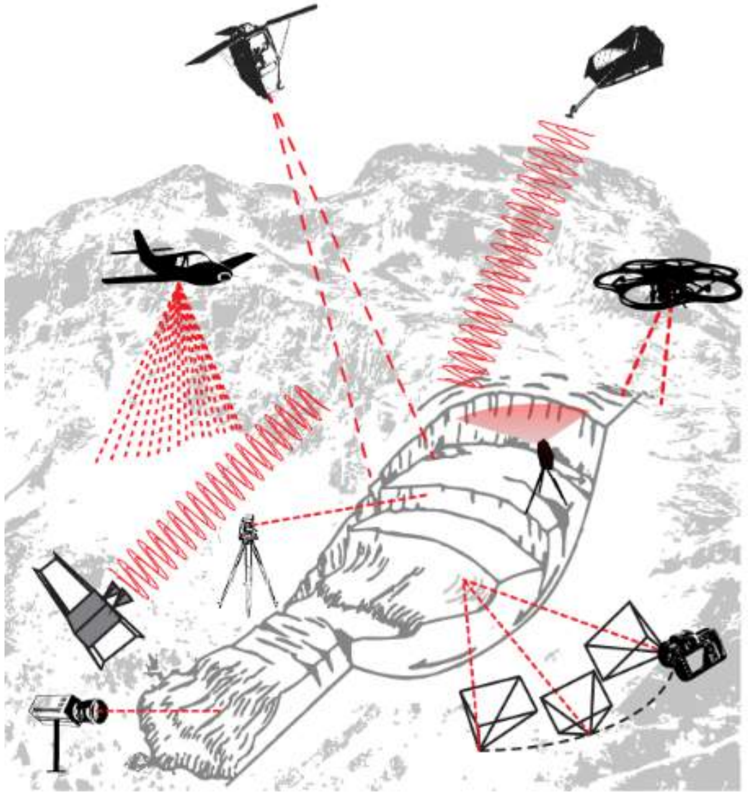


Kobayashi et al,. 2017

Quantifying tectonic deformation and monitoring landslide motion

Surface motion monitoring instruments and techniques

Methods	Measure	Instrument
GNSS	3D displacement at 1 point	Ground-based
Tacheometer	LOS motion at 1 point	Ground-based
Levelling	Z motion at 1 point	Ground-based
LiDAR	3D reconstruction	Ground-based, airborne
Photogrametry	3D reconstruction	Ground-based, airborne, space borne
InSAR	LOS motion over a large area	Ground-based, airborne, space borne
Image Correlation	2D motion in the plane perpendicular to LOS	Ground-based, airborne, space borne



→ The 3 last methods are ground-based or space-borne allowing a large range of spatial resolution and revisit frequency

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Quantifying tectonic deformation and monitoring landslide motion

Image correlation – sub-pixel offset or feature tracking

- Measure internal misalignment using a moving template window, while measuring displacements that occurred in the time span between two acquisitions.

- Measure the displacement in the plan perpendicular to the camera LOS (ie. in case of nadir looking space borne, measure of horizontal motion).

- Different approaches have been implemented:
  - Normalized Cross-Correlation
  - Correlation in the frequency domain, etc.

- Different algorithms are available: CosiCorr (Caltech), MicMac (IGN), AMES (NASA), GeoFolki (ONERA), MathWorks-normxcorr2, DPIV, , etc.

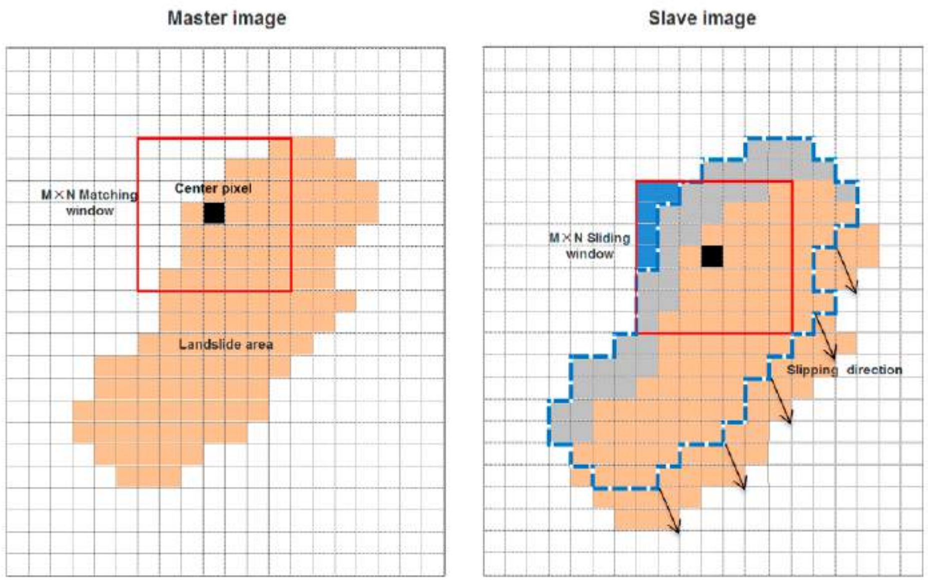

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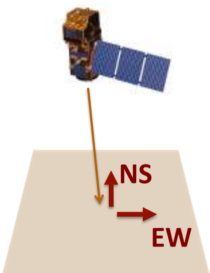
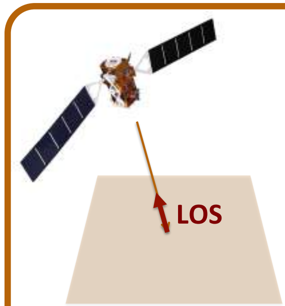
Image correlation – sub-pixel offset or feature tracking – advantages/limitations



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**.



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**.

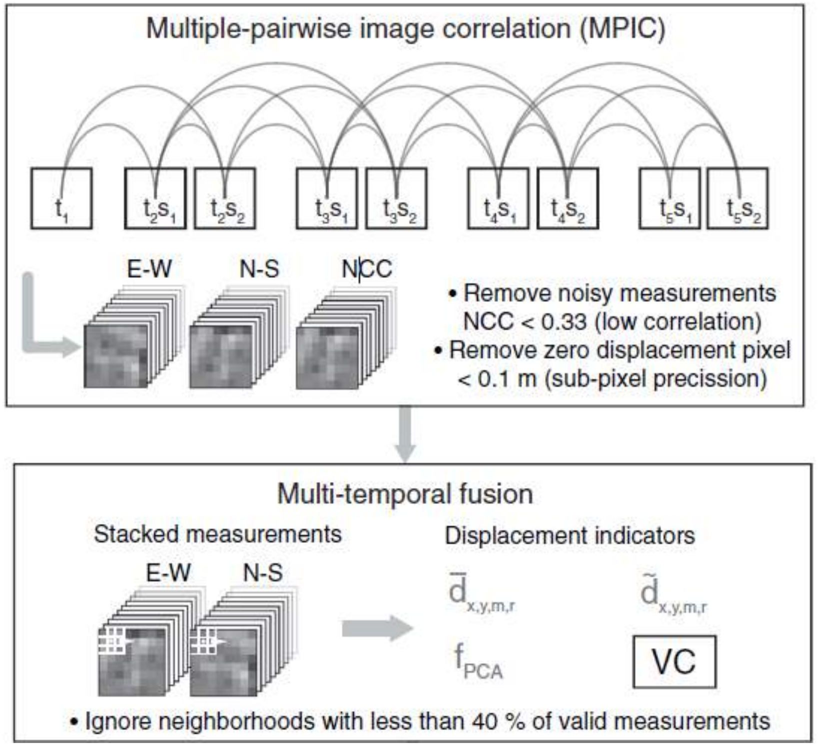
This two techniques are complementary to retrieve the complete 3D displacement for different magnitude of deformation

Quantifying tectonic deformation and monitoring landslide motion

Description of the MPIC processing chain

- MPIC stands for **Multiple-Pairwise Image Correlation**.
- The MPIC service comprises two main steps:
  1. The MPIC itself,
  2. A multi-temporal fusion that compute different features of the displacement time series in order to detect **persistent motion pattern**.

Inputs: Several optical acquisitions – Sentinel 2
Outputs: Correlation coefficient for each pair of images
Cloud masks
EW and NS displacement for each pair of images
Mean absolute velocity EW and NS
Mean displacement magnitude in meters
Vector coherence

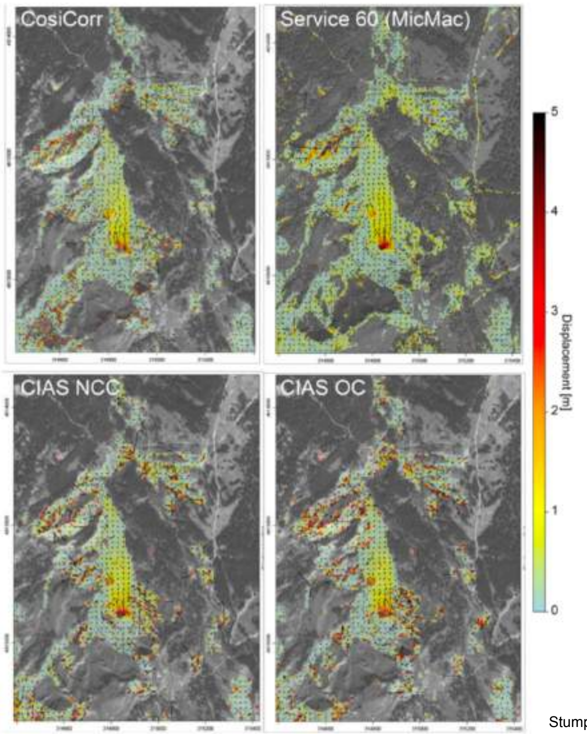


Stumpf et al. (2016)

Quantifying tectonic deformation and monitoring landslide motion

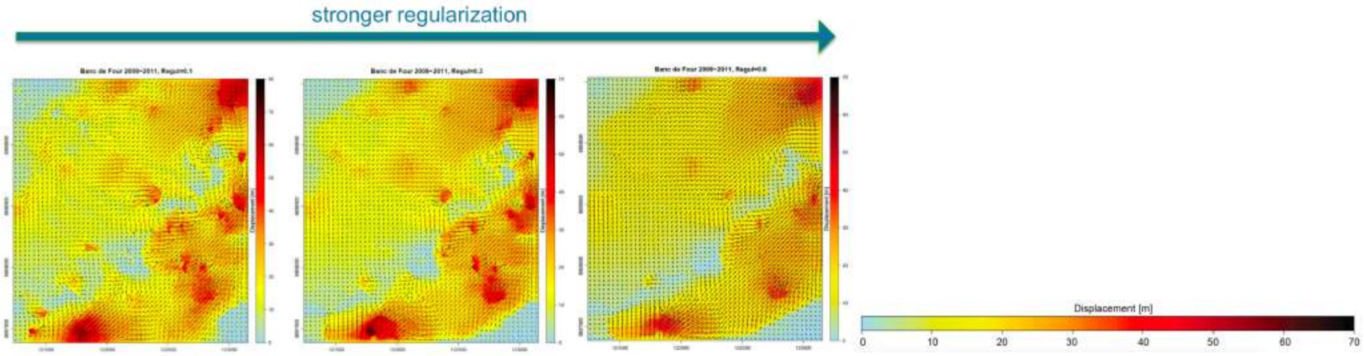
Parameterization

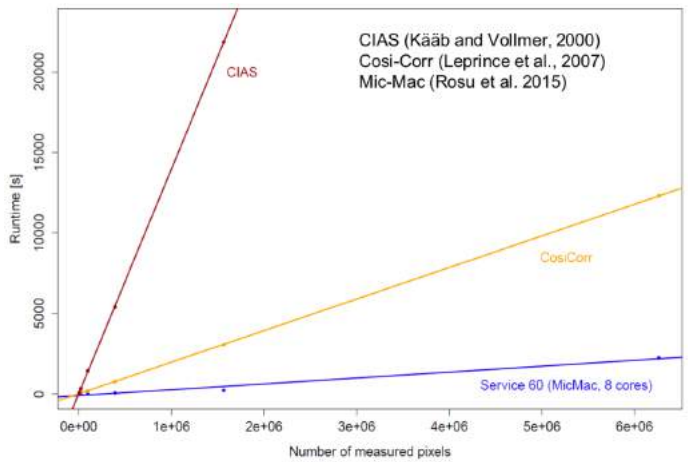
- **Effect of image correlation algorithms and parameterization**



Stumpf et al. (2016)

- **Effect of increasing spatial regularization strength**





- **Effect of runtime scaling**

Quantifying tectonic deformation and monitoring landslide motion

Description of the MPIC processing chain

➢ **MPIC**

MicMac, developed by IGN, is used to compute the NCC and the sub-pixel displacement.
MicMac was chosen among other algorithm because of its regularization method, it produces smoother results with less noise and smaller windows size.

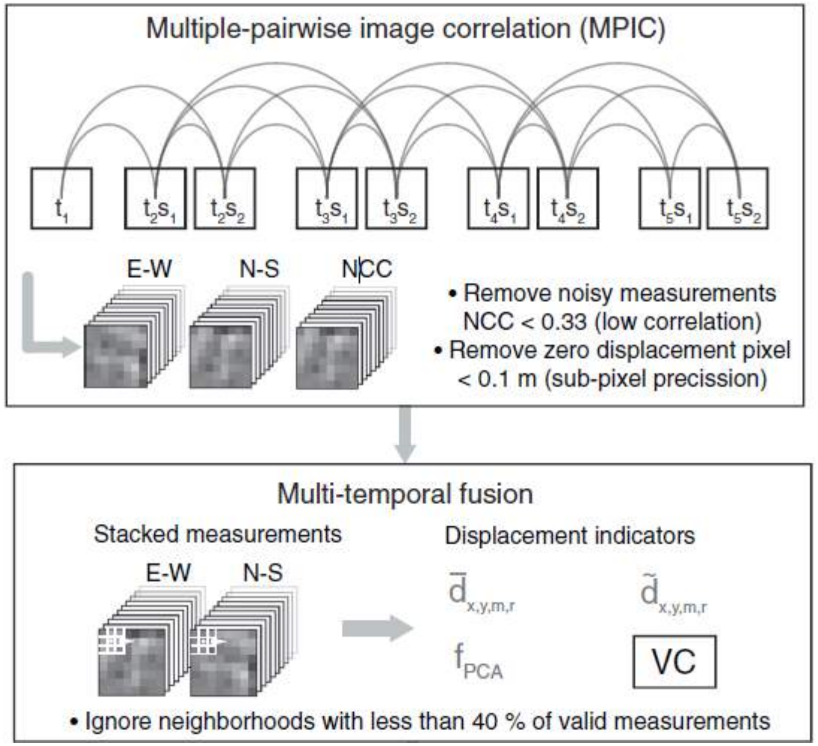
➢ **Multi-temporal fusion**

$$\bar{d}_{x,y,m,r} = \left\| \left(\frac{1}{|\Delta X|}\sum_{i=1}^{|\Delta X|}\Delta X_i \right), \left(\frac{1}{|\Delta Y|}\sum_{i=1}^{|\Delta Y|}\Delta Y_i \right) \right\|$$

Mean displacement
Account for persistent of the movement in space and time.

$$VC = \frac{\left\| \left(\sum_{i=1}^{|\Delta X|}\Delta X_i \right), \left(\sum_{i=1}^{|\Delta Y|}\Delta Y_i \right) \right\|}{\sum_{i=1}^{|\Delta X|} \| \Delta X_i, \Delta Y_i \|}$$

Vector Coherence
Account for coherence of the direction and magnitude of the motion in space and time.



Stumpf et al. (2016)

Quantifying tectonic deformation and monitoring landslide motion

MPIC

MPIC – algorithm details

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.

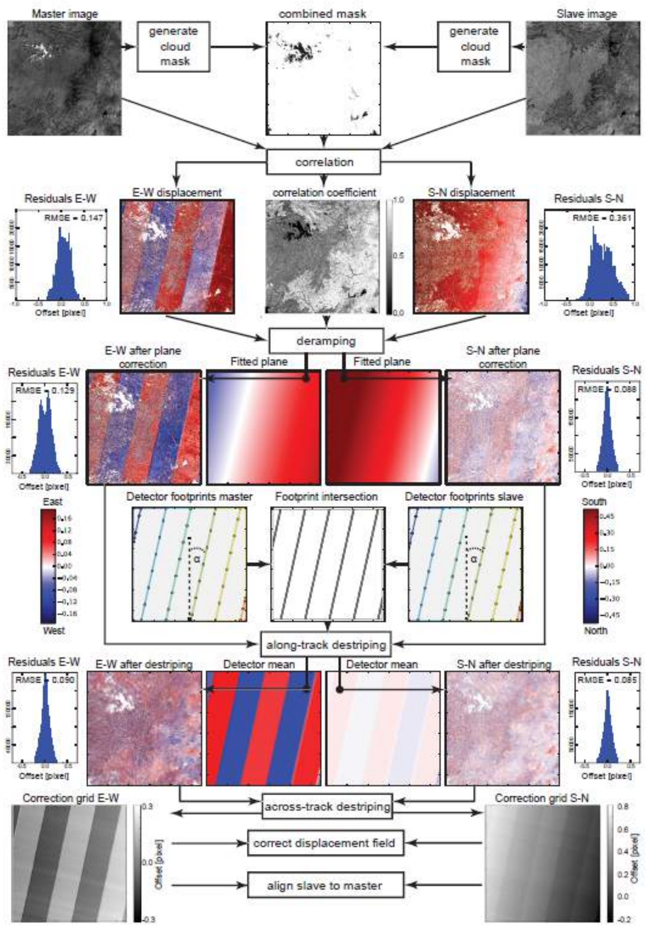
$$\Delta x_{a,i} = a_x + b_x x_{r,i} + c_x y_{r,i}$$

$$\Delta y_{a,i} = a_y + b_y x_{r,i} + c_y y_{r,i}$$

Modelling of the ramp

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

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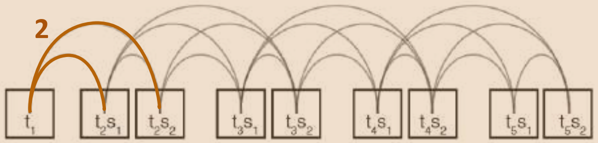
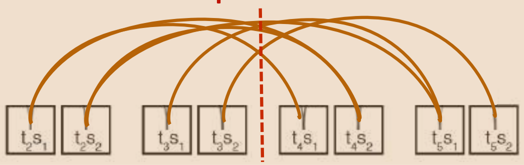
Description of the MPIC parameters on GEP

Defines how many pairs will be created considering the temporal order of the selected images.

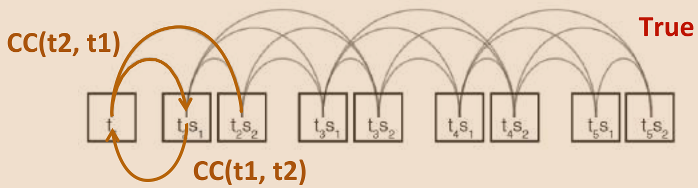


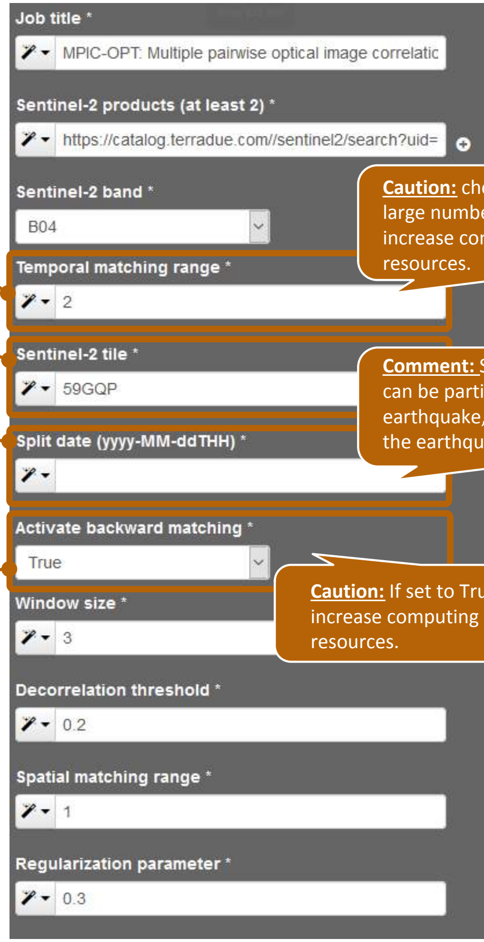
Sentinel-2 tile > can be found in the product name after the "T"
Ex: S2A_MSIL1C_20170223T222531_N0204_R029_T**59GQP**_20170223T222726

Split the time series into two subsets and pairs will only be formed among members of different subsets. Default: **NONE**.



If set to **True** backward matching will be performed for each pair.





Caution: choosing to compute a large number of pairs rapidly increase computing time and resources.

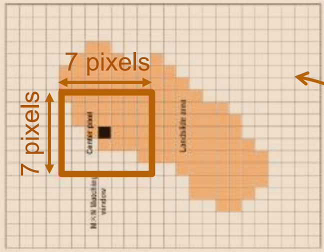
Comment: Setting this parameter can be particularly interesting for an earthquake, the splitting date being the earthquake date.

Caution: If set to True, it will increase computing time and resources.

Quantifying tectonic deformation and monitoring landslide motion

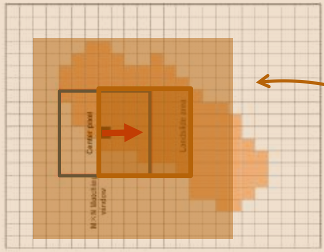
Description of the MPIC parameters on GEP

Size of the template used for matching among the input images.
Default value: ***3*** (i.e. 7x7pixel window size).

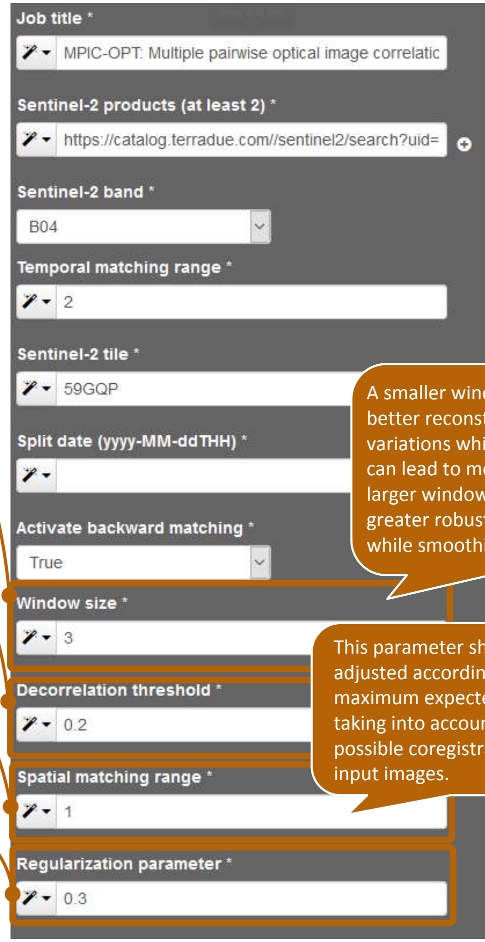


Matches with a correlation coefficient below this threshold will be discarded.

Defines the search range in pixel for finding matches. The actual search range is computed from this parameter as round(Spatial matching range/0.8)+2.



Controls the smoothness of the expected motion field. Increasing the regularization parameter is putting greater emphasis on a smooth motion field where neighbouring pixels will have similar displacement values.



A smaller window will allow to better reconstruct small scale variations while at the same time can lead to more noise. Vice versa larger window sizes will lead to greater robustness against noise while smoothing small scale details.

This parameter should be adjusted according to the maximum expected displacement taking into account also the possible coregistration bias of the input images.

Quantifying tectonic deformation and monitoring landslide motion

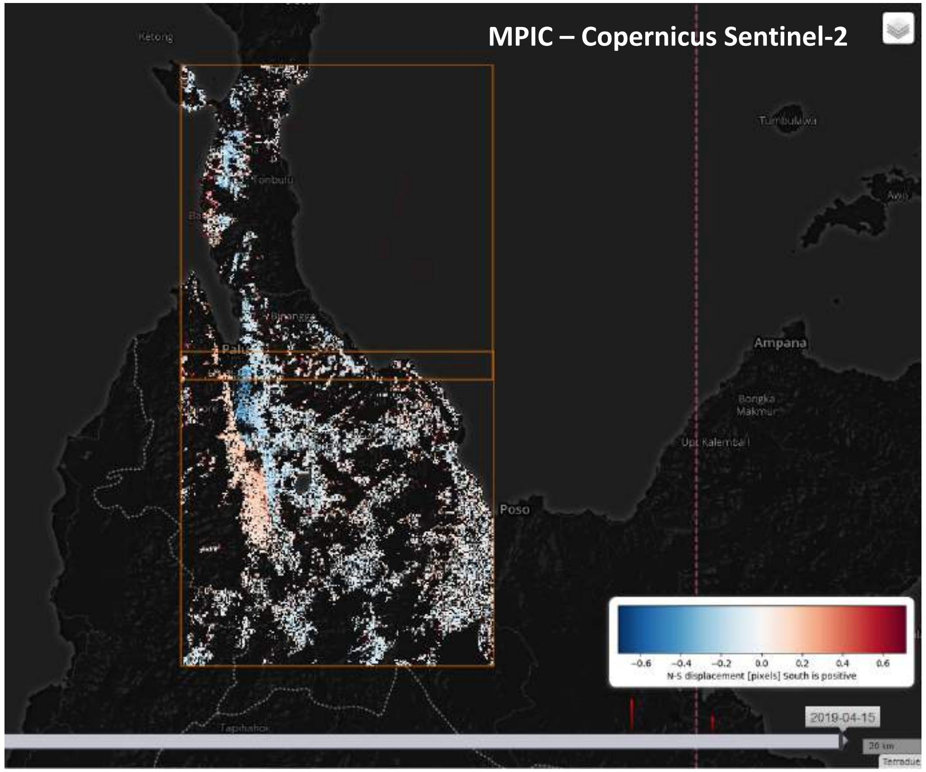
MPIC for tectonic deformation – Comparison to other results

➢ **Mw 7.5 Sulawesi Earthquake - Sep 29, 2018**

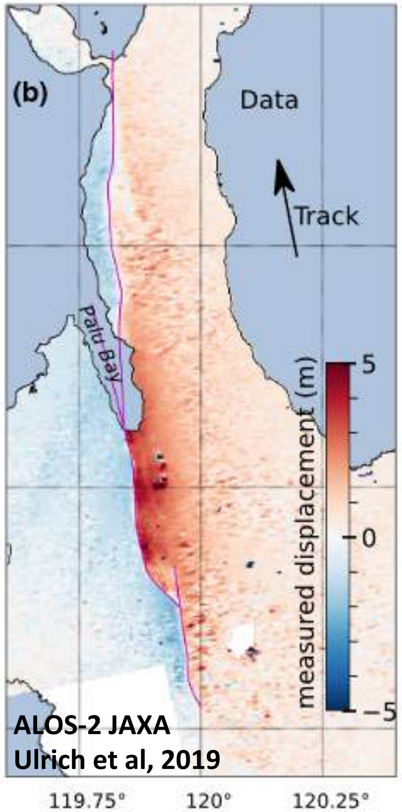
JOBS: MPIC-OPT-Palu2018 - 50MRD
MPIC-OPT-Palu2018 - 50MRE

Inputs: 2 images,
2018/09/17 – 2018/10/02

NS displacement (pixel)



Along track displacement (m)



ALOS-2 JAXA
Ulrich et al, 2019

Quantifying tectonic deformation and monitoring landslide motion

MPIC for tectonic deformation – Influence of Regularization and windows size parameters

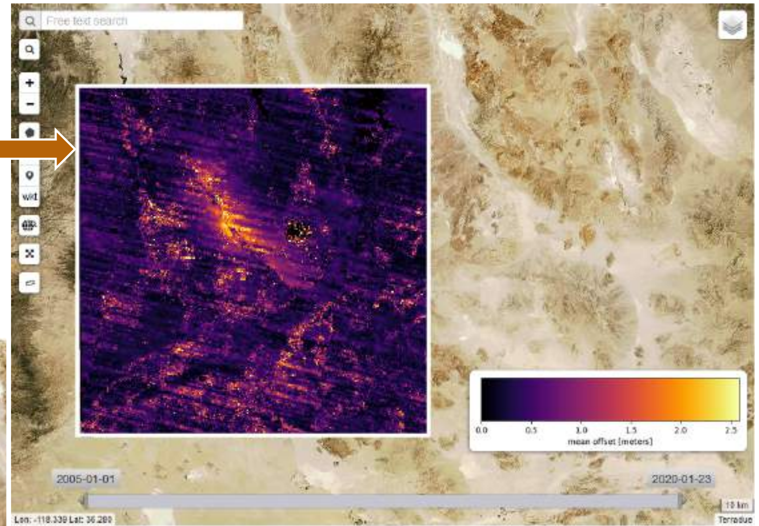
- **Ridgecrest earthquake sequence - July, 2019**

JOBS: MPIC-OPT S2B Ridgecrest EQ 20190628-20190708
MPIC-OPT - Ridgecrest EQ 2019 – reg0.8
MPIC-OPT - Ridgecrest EQ 2019 - win7

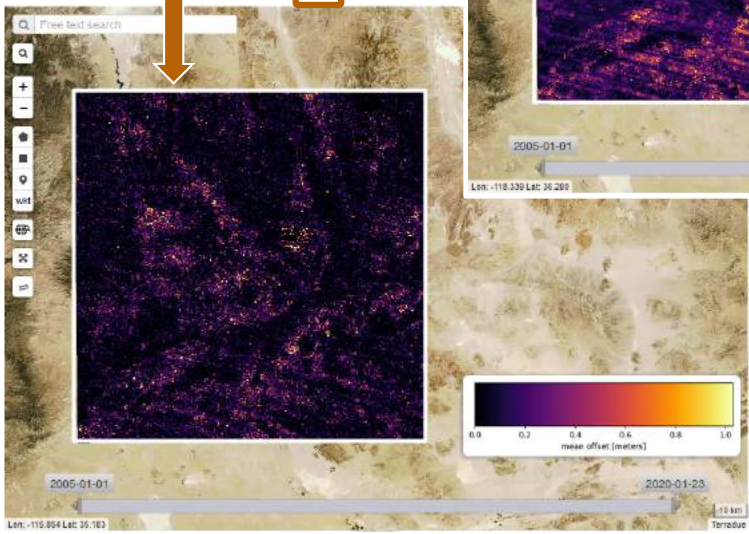
Inputs: 2 images,
2019/06/28 – 2019/07/08

Mean displacement magnitude (m)

Window size = 3
Regularization parameter = 0.8



Window size = 3
Regularization parameter = 0.4



Quantifying tectonic deformation and monitoring landslide motion

MPIC for tectonic deformation – Influence of Regularization and windows size parameters

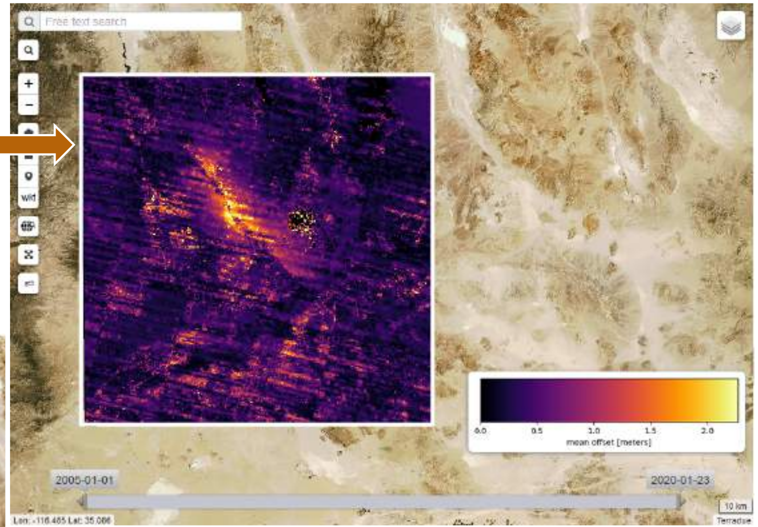
- ➢ **Ridgecrest earthquake sequence - July, 2019**

JOBS: MPIC-OPT S2B Ridgecrest EQ 20190628-20190708
MPIC-OPT - Ridgecrest EQ 2019 – reg0.8
MPIC-OPT - Ridgecrest EQ 2019 - win7

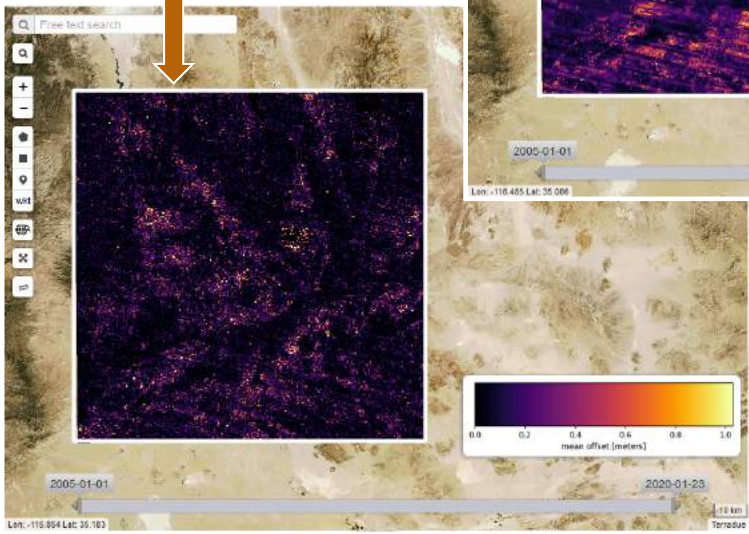
Inputs: 2 images,
2019/06/28 – 2019/07/08

Mean displacement magnitude (m)

Window size = 7
Regularization parameter = 0.3



Window size = 3
Regularization parameter = 0.4



Quantifying tectonic deformation and monitoring landslide motion

MPIC for tectonic deformation – Influence of Regularization and windows size parameters

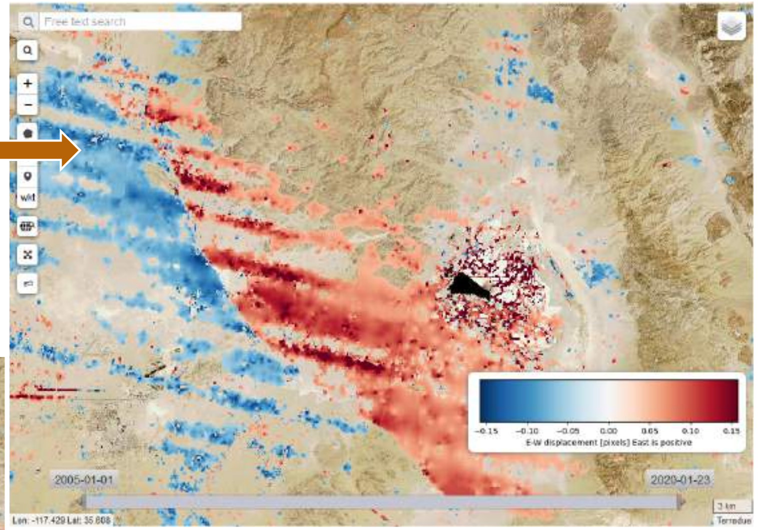
- ➢ **Ridgecrest earthquake sequence - July, 2019**

JOBS: MPIC-OPT S2B Ridgecrest EQ 20190628-20190708
MPIC-OPT - Ridgecrest EQ 2019 – reg0.8
MPIC-OPT - Ridgecrest EQ 2019 - win7

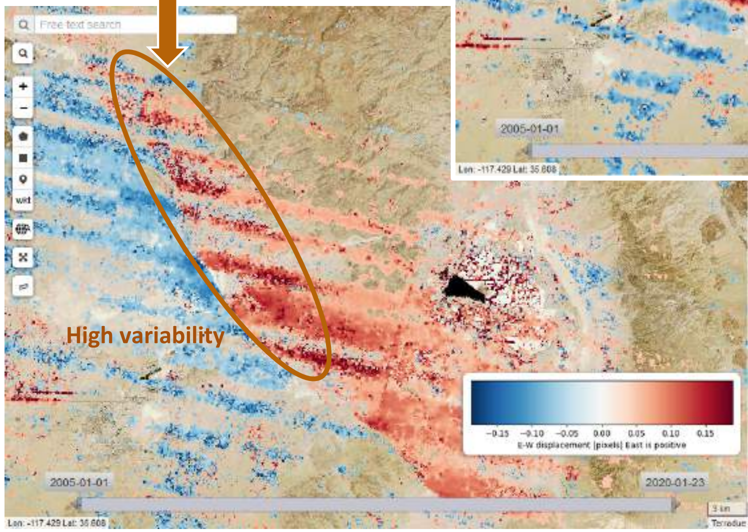
Inputs: 2 images,
2019/06/28 – 2019/07/08

EW displacement (pixel)

Window size = 3
Regularization parameter = 0.8



Window size = 3
Regularization parameter = 0.4



$$\bar{d}_{x,y,m,r} = \left\| \left(\frac{1}{|\Delta X|}\sum_{i=1}^{|\Delta X|}\Delta X_i\right),\left(\frac{1}{|\Delta X|}\sum_{i=1}^{|\Delta Y|}\Delta Y_i\right)\right\|$$

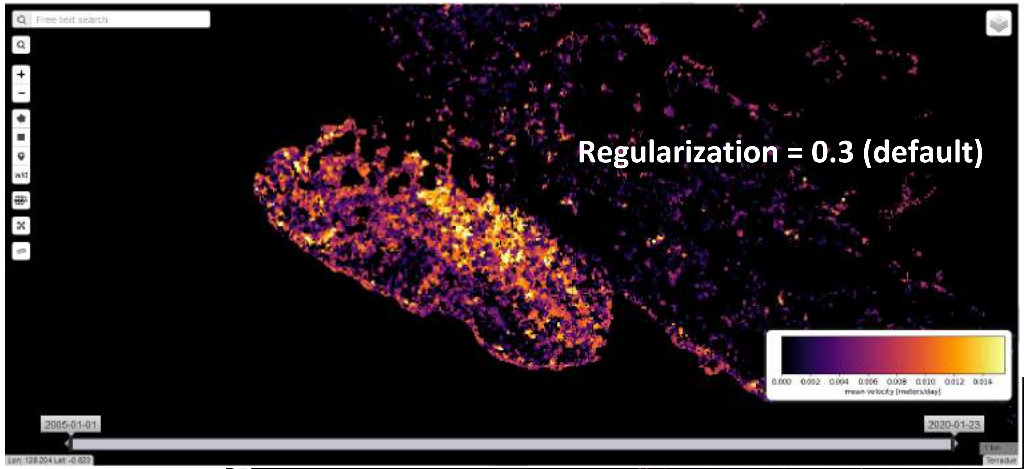
Mean displacement
Account for persistent of the movement in **space** and time.

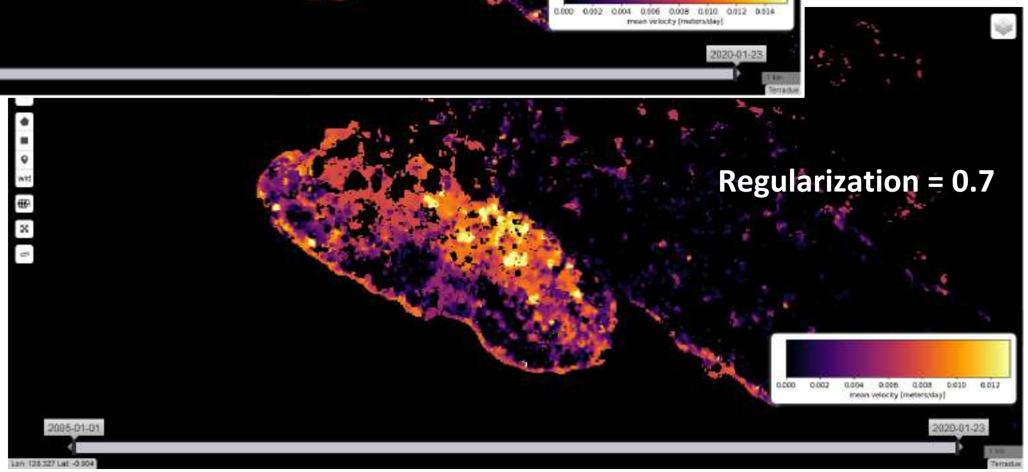
Quantifying tectonic deformation and monitoring landslide motion

Effect of the regularization parameter

- **Mw 7.2 Halmahera Earthquake, July 14, 2019**

Mean EW velocity (m/days)





JOBS:
MPIC-OPT - Halmahera earthquake 2019
MPIC-OPT - Halmahera earthquake 2019 – reg0.7

Inputs: 2 images, 2018/11/12 - 2019/08/09

MPIC

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Quantifying tectonic deformation and monitoring landslide motion

Monitoring landslide motion – pre-rupture signal

- **Fagraskógarfjall landslide , Iceland**

Rupture : 7th July 2018, 05:17am
Volume ~ 10 millions m^3 of debris

Quantifying tectonic deformation and monitoring landslide motion

Monitoring landslide motion – pre-rupture signal

- **Fagraskógarfjall landslide , Iceland**

Rupture: 7th July 2018, 05:17am
Volume ~ 10 millions m^3 of debris

Quantifying tectonic deformation and monitoring landslide motion

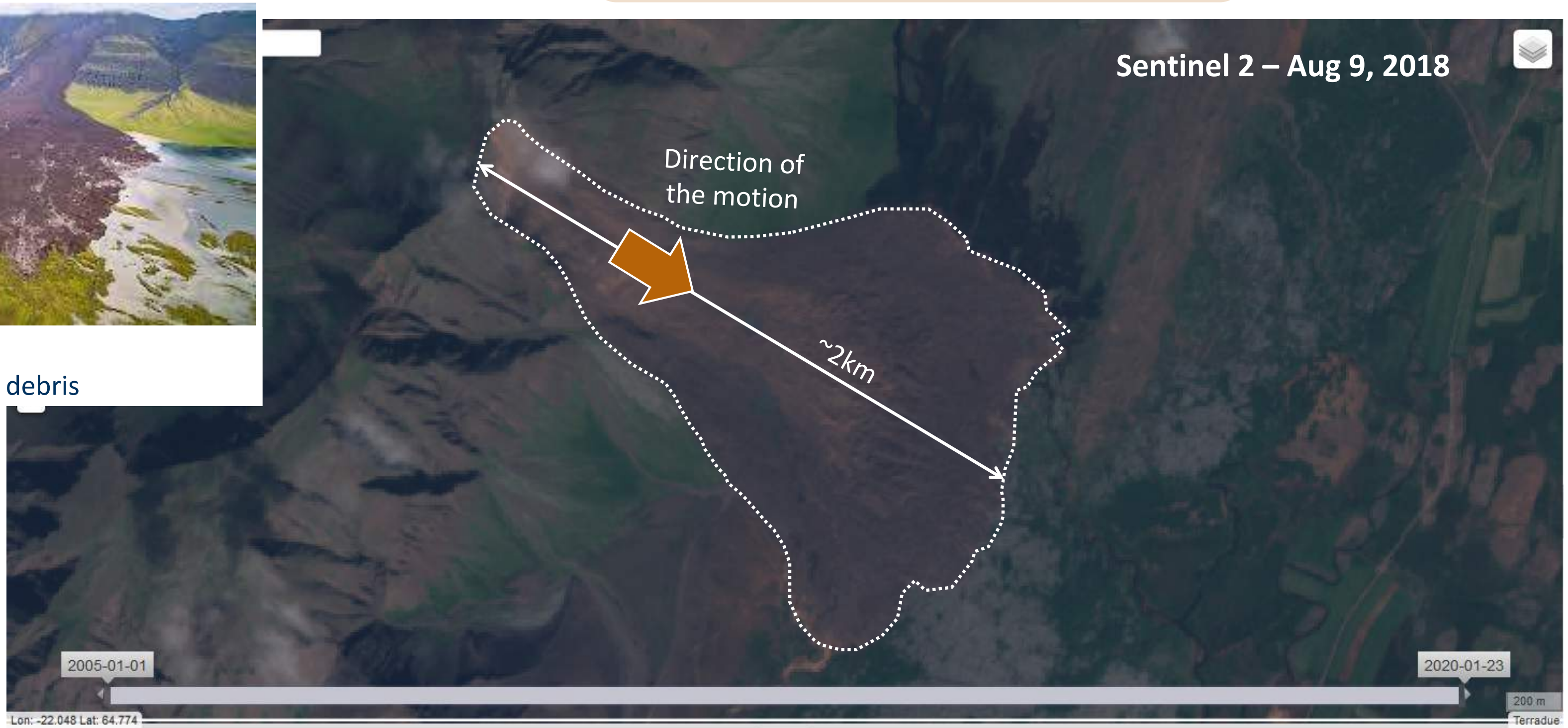
Monitoring landslide motion – pre-rupture signal

➢ **Fagraskógarfjall landslide , Iceland**

JOB:
Full Resolution Rasterization - Fagraskógarfjall 2018 landslide

Inputs: 2 images, 2018/06/20 – 2018/08/09

7th July 2018, 05:17am
Volume ~ 10 millions m^3 of debris



Quantifying tectonic deformation and monitoring landslide motion

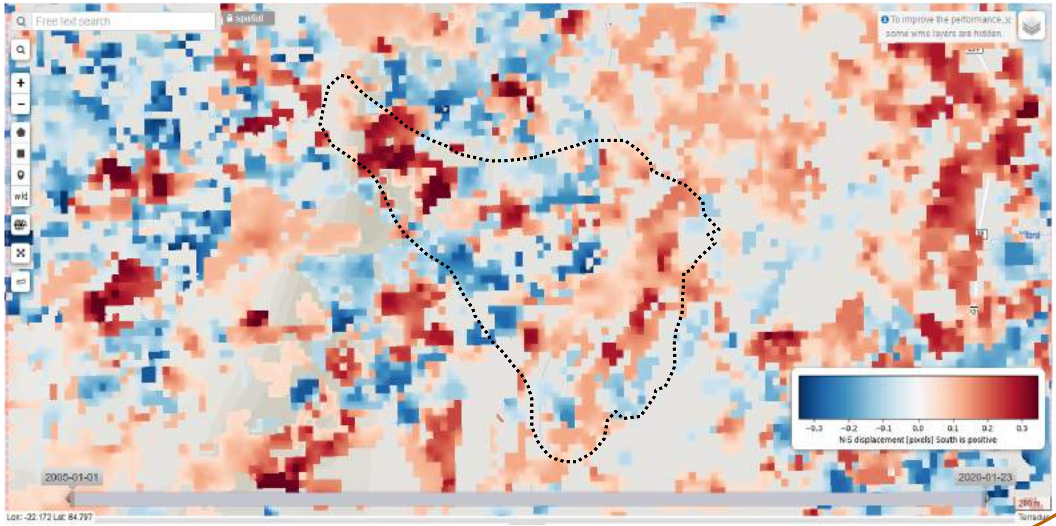
Monitoring landslide motion – pre-rupture signal

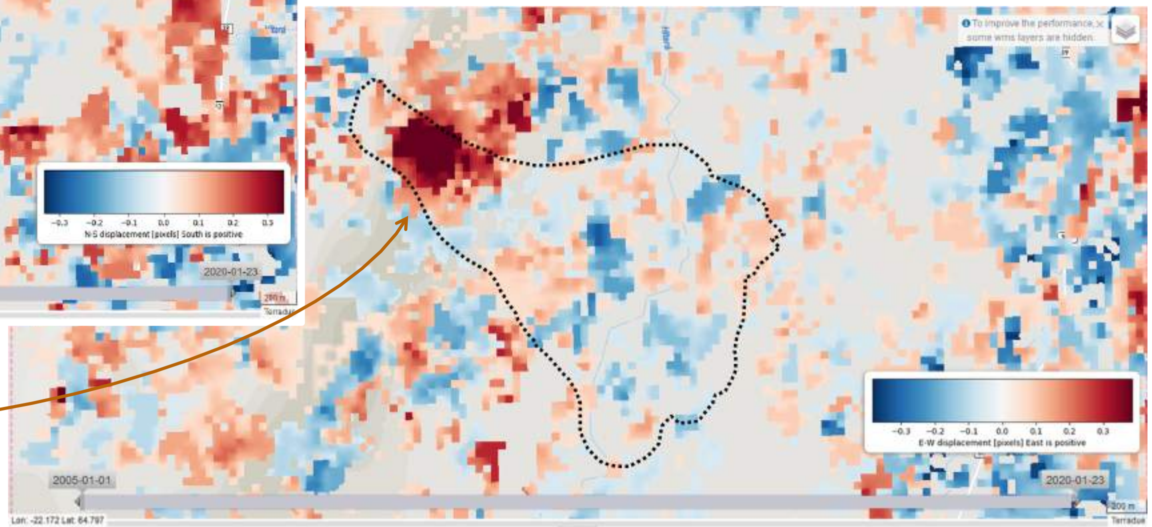
➢ **Fagraskógarfjall landslide , Iceland**

JOB:
MPIC-OPT - Fagraskógarfjall 2018 landslide

Inputs: 2 images, 2017/05/21 – 2018/06/20

EW (left) and NS (right) displacement (pixel)





Metric displacement are recorded in the year preceding the rupture….

Quantifying tectonic deformation and monitoring landslide motion

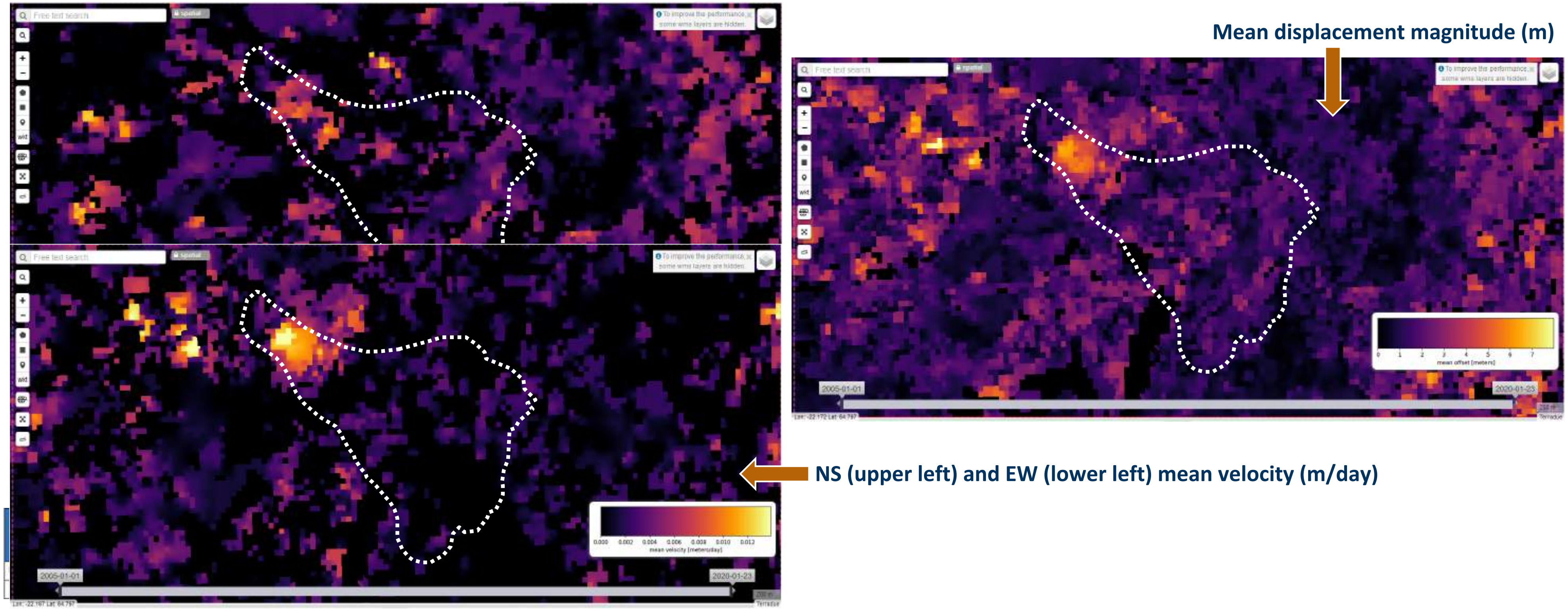
Monitoring landslide motion – pre-rupture signal

➢ **Fagraskógarfjall landslide , Iceland**

JOB:
MPIC-OPT - Fagraskógarfjall 2018 landslide

Inputs: 2 images, 2017/05/21 – 2018/06/20

Mean displacement magnitude (m)



NS (upper left) and EW (lower left) mean velocity (m/day)

Quantifying tectonic deformation and monitoring landslide motion

Monitoring glacier motion –

- Mer de glace, French Alps, France

Quantifying tectonic deformation and monitoring landslide motion

Monitoring glacier motion –

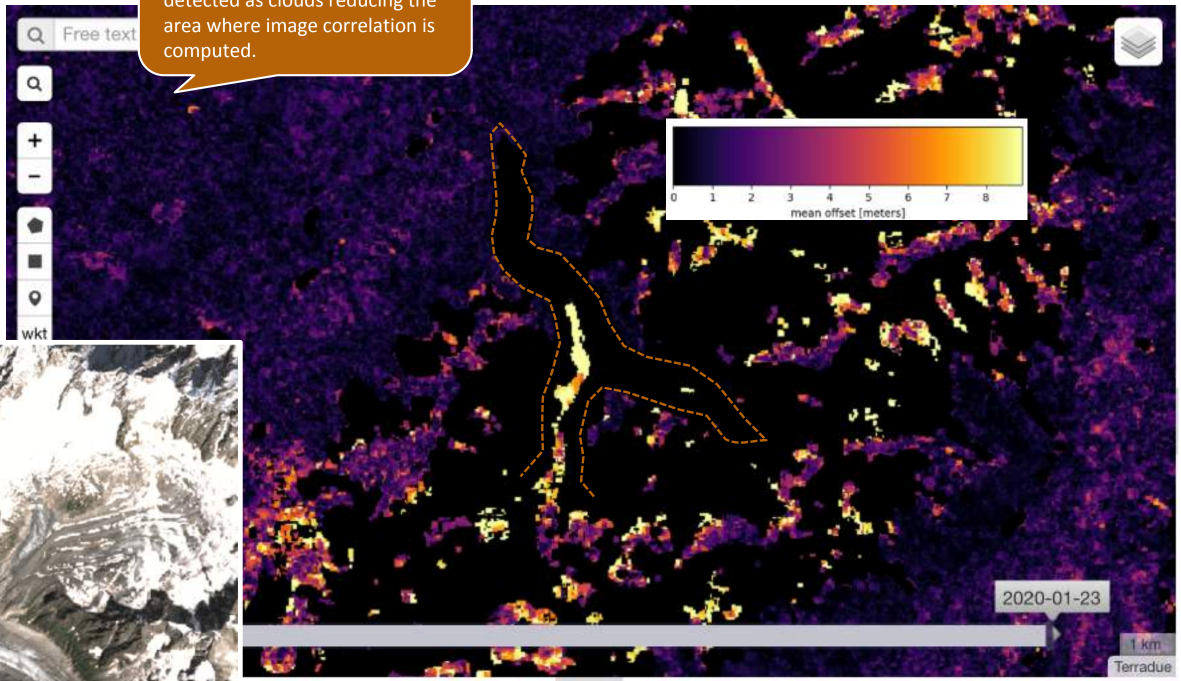
➢ **Mer de glace, French Alps, France**

JOBS:
MPIC-OPT – Chamonix2016-2018
Full Resolution Rasterization - Chamonix2016-2018

Inputs: 3 images,
2016/08/13, 2017/10/07, 2018/08/28

See the cloud masks quality. Most of the glacier areas are detected as clouds reducing the area where image correlation is computed.

Mean displacement magnitude (m)



Quantifying tectonic deformation and monitoring landslide motion

Monitoring glacier motion –

➢ **Miage glacier , French Alps, France**

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Quantifying tectonic deformation and monitoring landslide motion

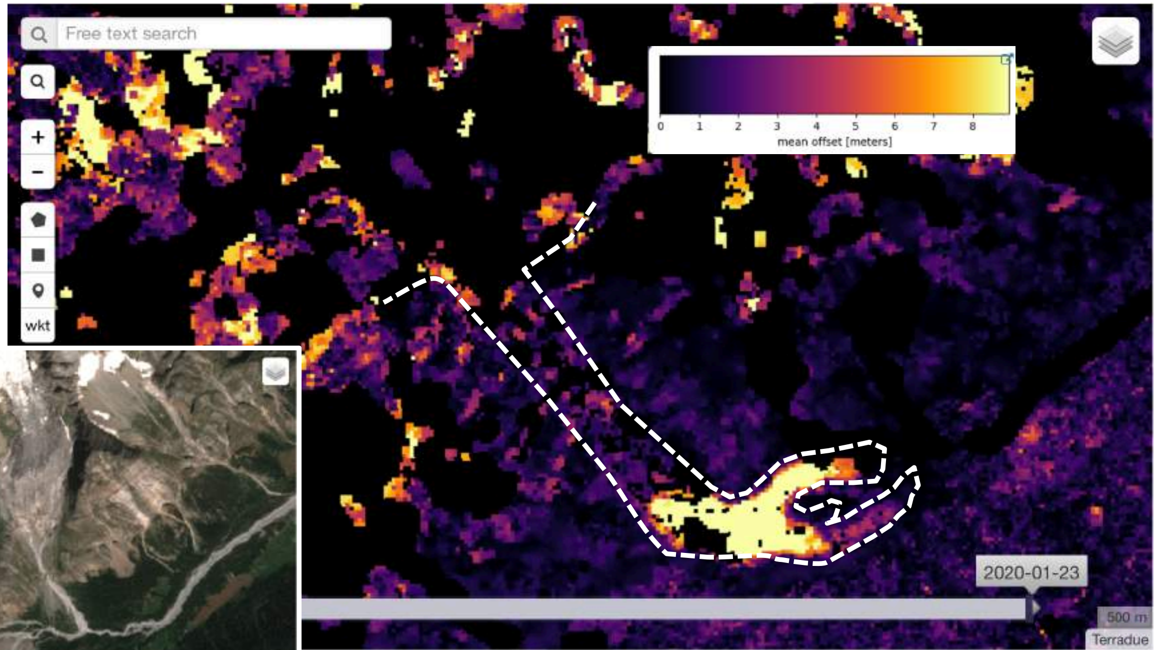
Monitoring glacier motion –

- **Miage glacier , French Alps, France**

JOBS:
MPIC-OPT – Chamonix2016-2018
Full Resolution Rasterization - Chamonix2016-2018

Inputs: 3 images,
2016/08/13, 2017/10/07, 2018/08/28

Mean displacement magnitude (m)



Creating high-resolution surface models

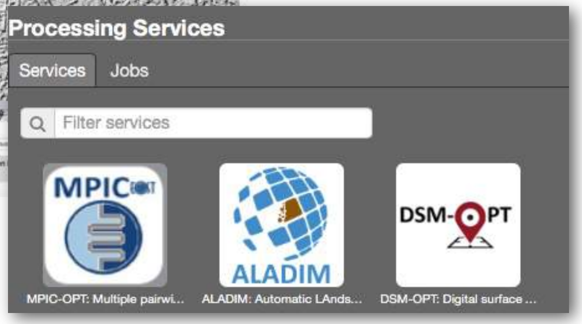
DSM-OPT service on-line on GEP: creation of High-Resolution Digital Surface Models (HR-DSMs) and orthophotos from Pléiades stereo-images

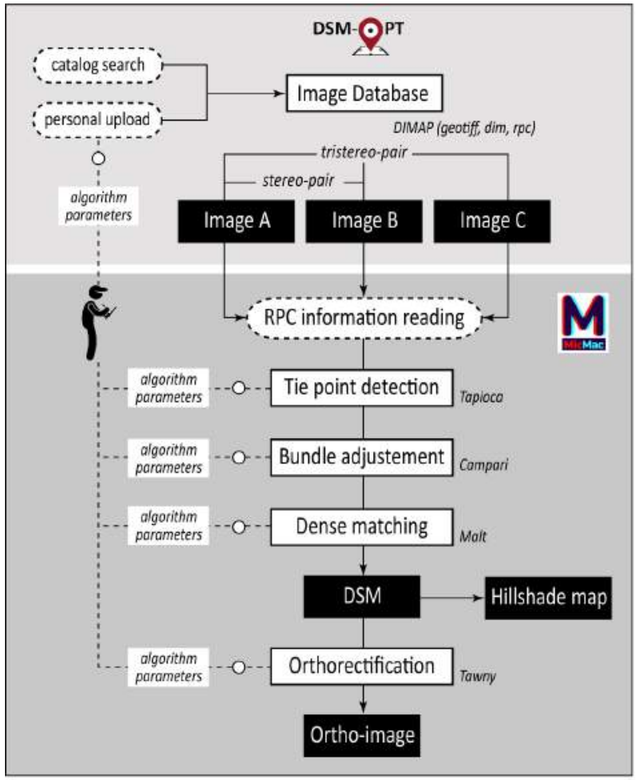

New GEP service from CNRS EOST - DSM-OPT for the generation of surface models from Pléiades satellite data

gep-blog

jeanphilippe.malet — 1 Mar 5

You need a high resolution surface model to analyse the traces of a fault rupture, to calculate the elevation differences (depletion, accumulation) following a large landslide, to estimate the volume of lava flows on volcanoes and estimate effusive rates, or integrate an accurate topography in InSAR processing? The new GEP service DSM-OPT from CNRS-EOST is for you! This service allows the generation of digital surface models (DSMs) and the respective ortho-images from stereo- and tri-stereo Pléiades images using the MicMac open source library.
An example of the service results using stereo-images over the complex urban landscape of Strasbourg is presented below, and is also posted here.





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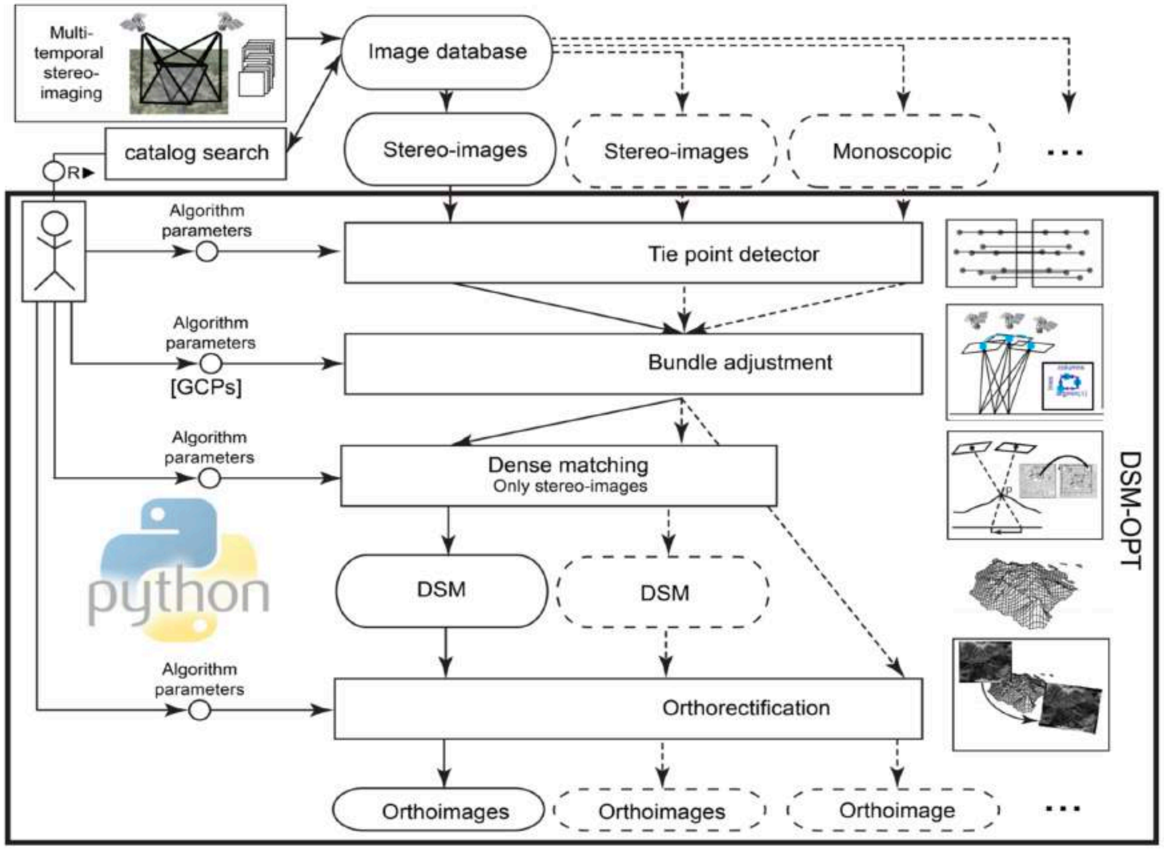
Creating high-resolution surface models

Tutorial: https://terradue.github.io/doc-tep-geohazards/tutorials/dsm-opt.html

- **DSM-OPT pipeline**



Stumpf et al. (2019)

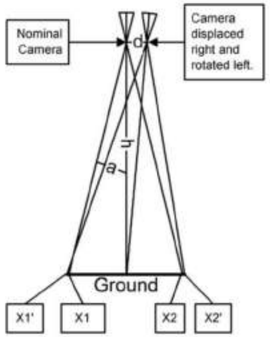
Creating high-resolution surface models

- **Bundle adjustment with Rational Polynomial Functions (RPC)**

  - Modern VHR stereo satellite images are provide with RPCs

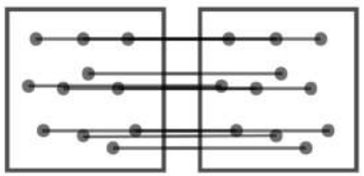
$$l = \frac{F_1(U,V,W)}{F_2(U,V,W)}$$
$$s = \frac{F_3(U,V,W)}{F_4(U,V,W)}$$

  - Those models are typically biased and induce due to imprecise knowledge of the satellite orbit

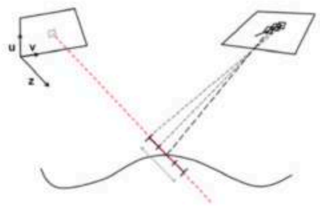


  - Bias terms are added to the model and estimated based on tie points and ground control points

$$l + A_0 + A_1 l + A_2 s = \frac{F_1(U,V,W)}{F_2(U,V,W)}$$
$$s + B_0 + B_1 l + B_2 s = \frac{F_3(U,V,W)}{F_4(U,V,W)}.$$



- **Dense matching**

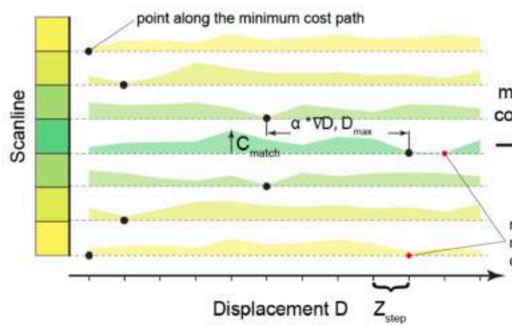


$$C_{glob} = \sum_{k=1}^{N} C_{match} + C_{trans}$$

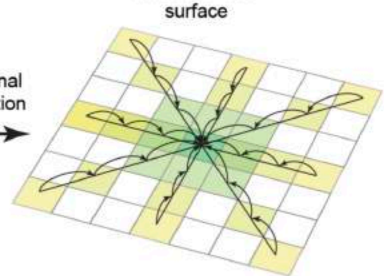
$$C_{trans} = \alpha * \nabla D$$

$$\nabla D > \nabla D_{max} \Rightarrow C_{trans} \rightarrow +\infty$$

dynamic programming to determine aproximate minimum-cost surface



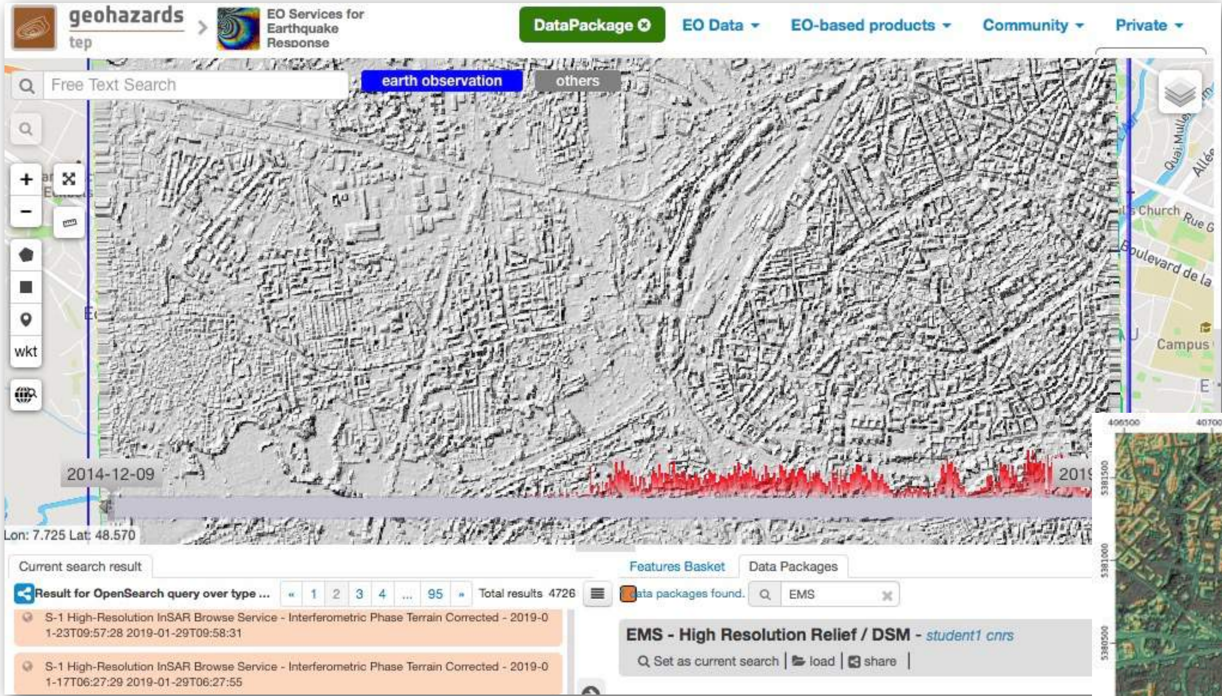
multi-directional cost aggregation



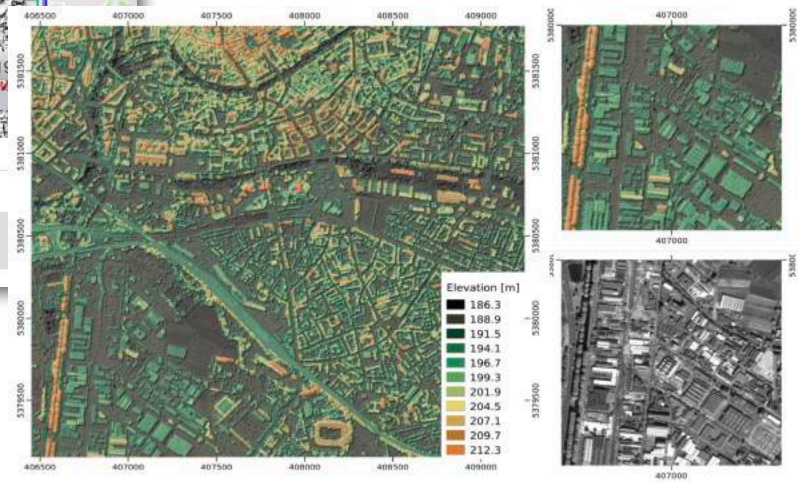
▶ aka semi-global matching

Deseiligny et al. (2014)
Rupnik et al. (2016)

Creating high-resolution surface models



Hillshade of a HR-DSM (0.5m) over the city of Strasbourg / Pléiades stereo of Sept. 2016

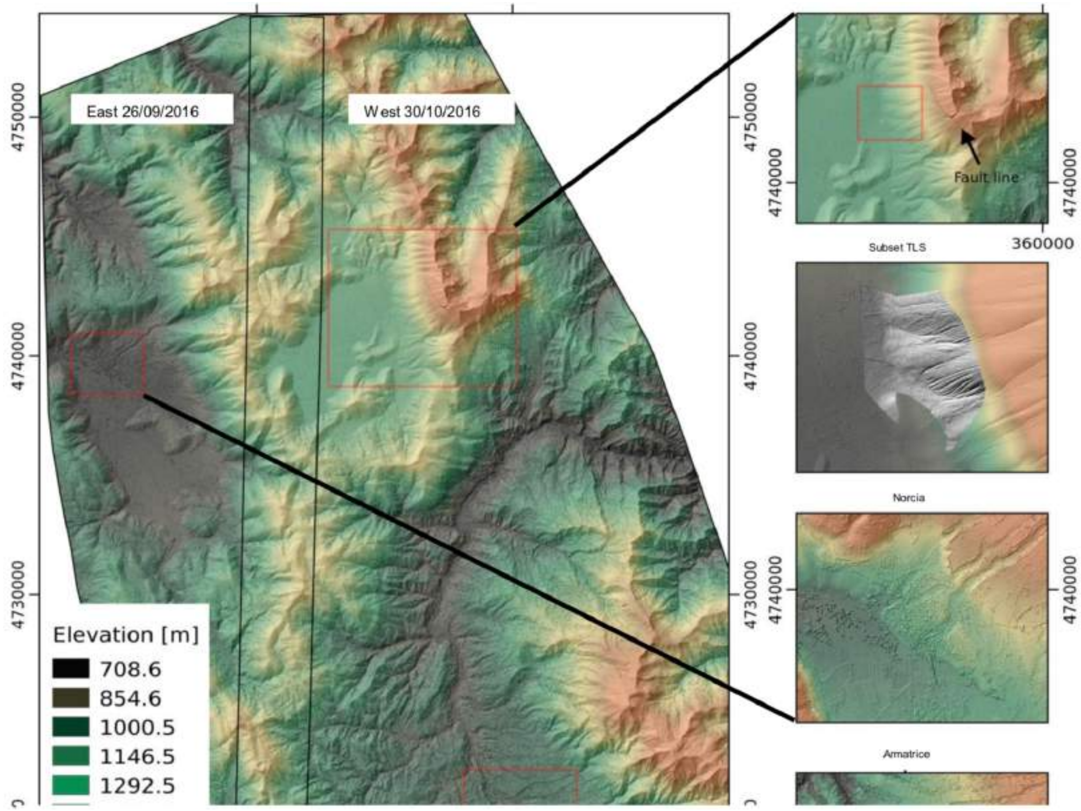


Creating high-resolution surface models

Ortho-image of a HR-DSM (0.5m) over the city of Strasbourg / Pléiades stereo of Sept. 2016

Creating high-resolution surface models

Application:
morpho-structures mapping

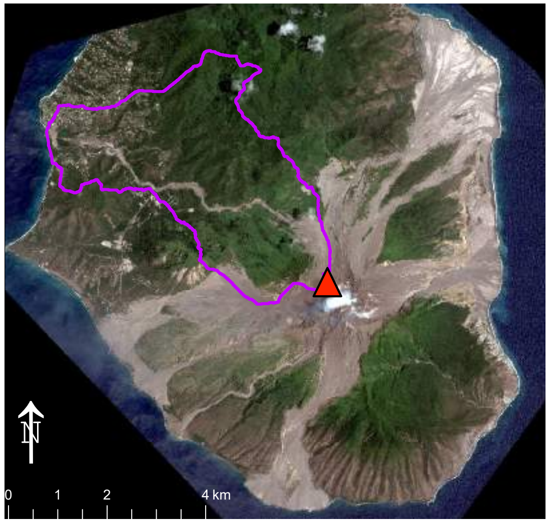


Hillshade of a HR-DSM (0.5m) over Norcia / N. Apennines ETQ. -2016 / Pléiades stereo of Sept. 2016

Creating high-resolution surface models

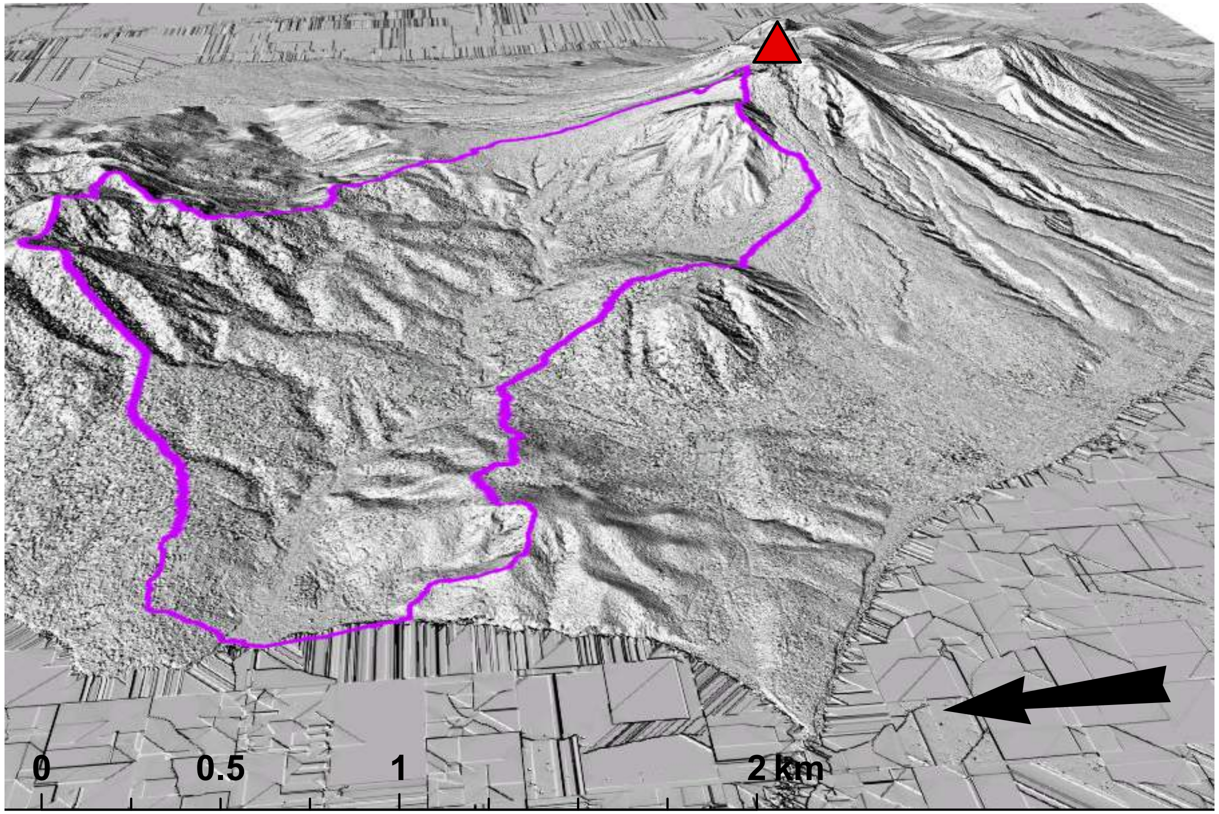
Application:
sediment budget analysis

Hillshade of a HR-DSM (0.5m) over Soufriere Hills / Montserrat



Pléiades image of Soufriere Hills Volcano, 2017.
(purple shows Belham Valley catchment)

Significant deposition of volcaniclastic material in the Belham River Valley between 1995– 2010
Channel prone to hazardous rain-triggered lahars and associated geomorphic changes
Our new 2019 DSM will be compared with a LIDAR DSM made in 2010 to quantify erosion and deposition in different parts of the valley.

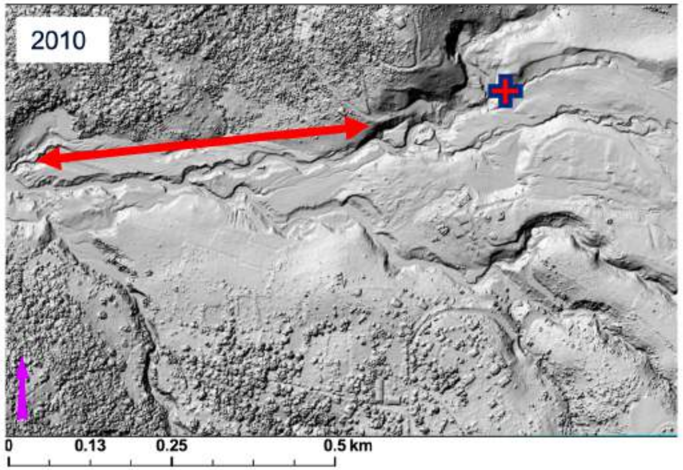


James Christie & Georgina Bennett (Univ. East Anglia)

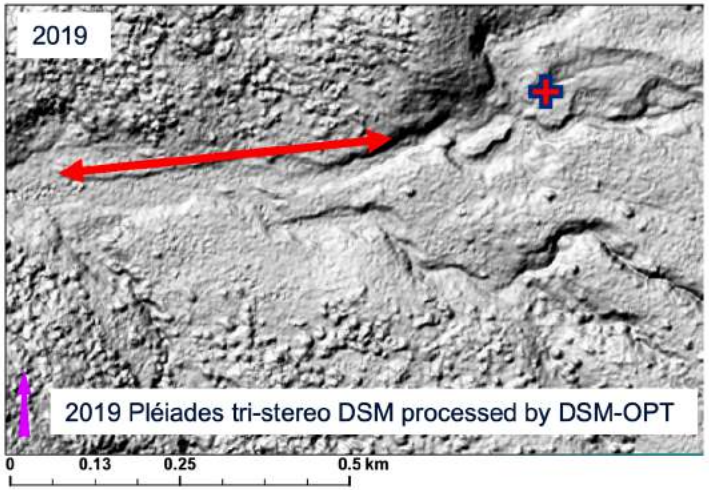
Creating high-resolution surface models

Application:
sediment budget analysis

2010 1m LiDAR DSM (*Montserrat Volcano Observatory)*



Area shown in the example target areas below (green box)



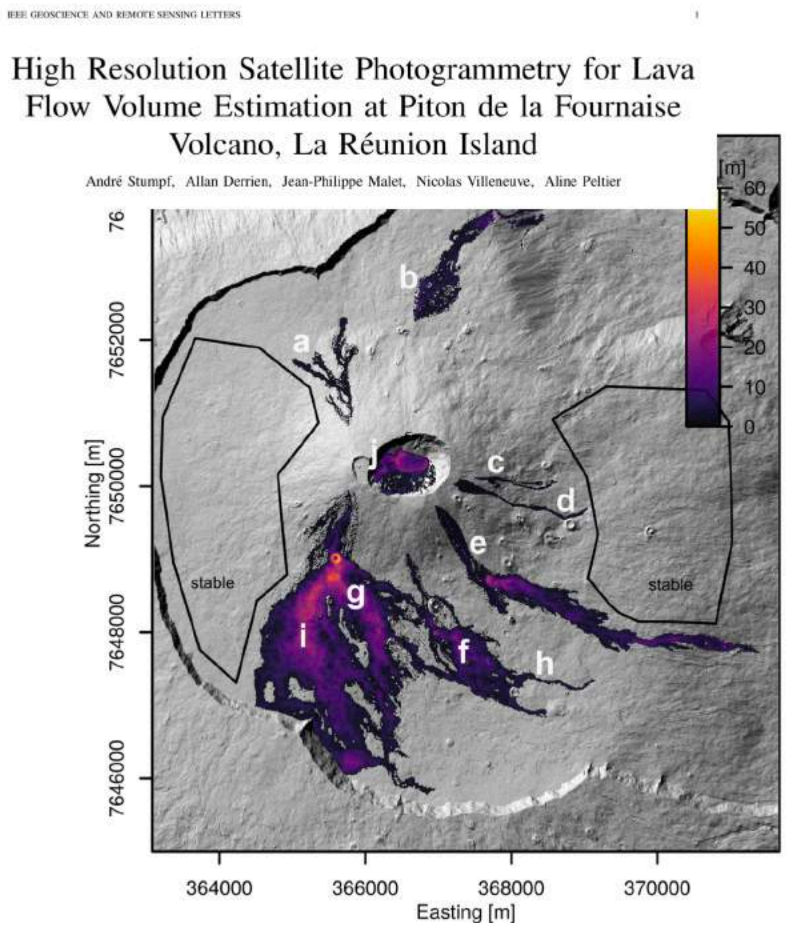
Hillshade of a HR-DSM (0.5m) over Soufriere Hills / Montserrat

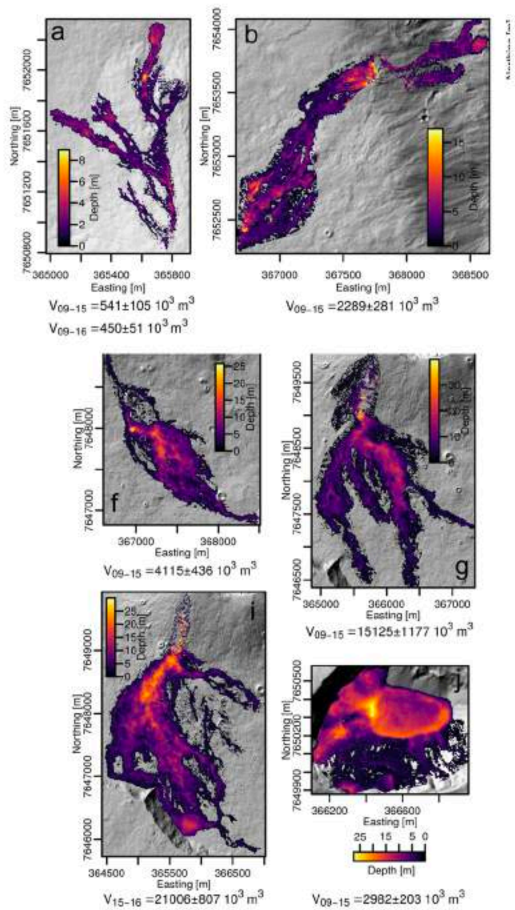
Qualitative observations:

- ↔ Channel widening and straightening (removal of pyroclastic terraces)
- ✚ Deep channel incision and increased sinuosity.

Creating high-resolution surface models

Application:
lava flow volume quantification





Hillshade of a HR-DSM (0.5m) over Piton de la Fournaise / La Réunion

Creating high-resolution surface models

DSM-OPT

A key issue: managing sensor Licence and distribution of products

Airbus Defense & Space May 2017

LICENCE TO USE PLEIADES PRODUCTS GRANTED AT A PREFERENTIAL PRICE BY CNES TO CATEGORY 1 INSTITUTIONAL USERS AND ASSIMILATED CATEGORY 1 INSTITUTIONAL USERS UNDER THE ISIS - PLEIADES PROGRAMME

Please read the terms and conditions of this User Licence Agreement carefully before placing any orders for Protected Products.

INTRODUCTION

In the framework of the public service delegation agreement concerning the operations of the Pleiades satellites concluded between CNES and Airbus DS (subsequently referred to as the "DSP"), Airbus DS has committed itself to distribute Pleiades products and services for the benefit of AUTHORISED INSTITUTIONAL USERS in order to fulfill their responsibilities in the frame of their institutional mission for NON-COMMERCIAL SERVICES.

CNES and Airbus DS have opened the ISIS programme to Pleiades products allowing eligible users (European scientific community) to obtain Pleiades images under special ISIS programme preferential pricing conditions, based on DSP Category 1 pricing.

Accomplishing any of the following acts implies acceptance by the USER of the terms of the present Licence Agreement (hereinafter "Licence":

Management of the Pléiades licence via GEP (for CEOS-related images)

On-going works and next steps ...

ALADIM

- As a GEP service: integrate the possibility of digitizing training samples on-line
- In terms of methods: integrate other VHRO sensors (Planets, Worldview, Deimos, etc) for further applicability
  develop a SAR (amplitude-based, coherence-based) change detection method
  integrate active learning sampling

MPIC

- As a GEP service: propose an earthquake-related service (4 images) and a landslide/glacier related service (times series)
- In terms of methods: integrate other VHRO sensors (Planets, Worldview, Deimos, etc) for further applicability
  integrate optical flow derived matching techniques to take into account more complex motion patterns
  increase the size of the time series (ESA/Unistra-A2S federation of resources)
  I integrate refined Sentinel-2 geometric correction for mountainous areas and detection of seasonal motion

DSM-OPT

- In terms of methods: integrate other VHRO sensors with stereo-photogrammetric acquisitions
  integrate DSM-related scenarios / parameterization and topography fusion

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