



FormaTerre

Data and services for the Solid Earth



Les chaînes de traitement en corrélation d'image du pôle FormaTerre pour le suivi des déformations du sol

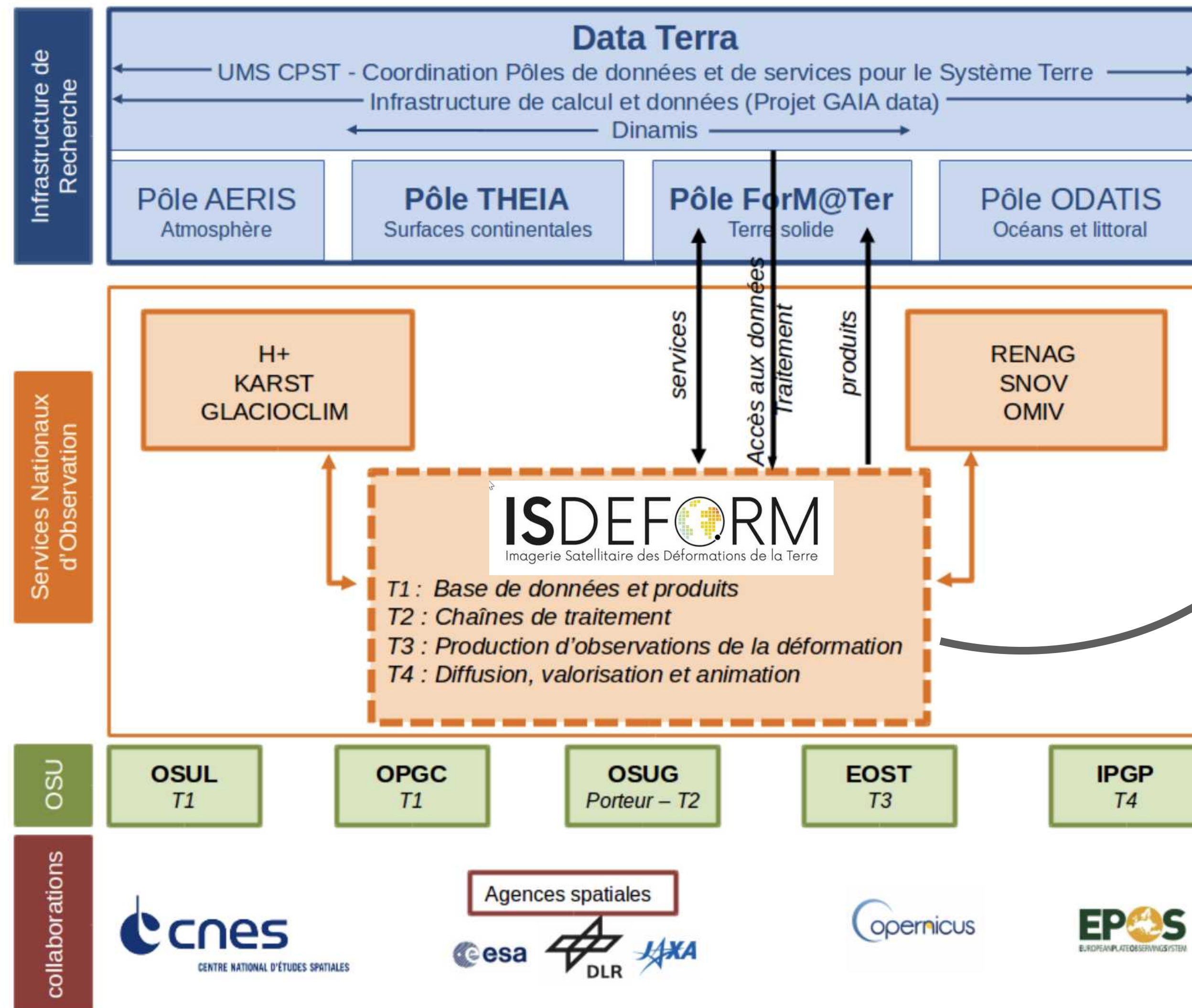
Floriane Provost

David Michéa, Jean-Philippe Malet, Elisabeth Pointal, Antoine Lamielle,
Pascal Lacroix, Marie-Pierre Doin
Nicolas d'Oreye, Dominique Derauw

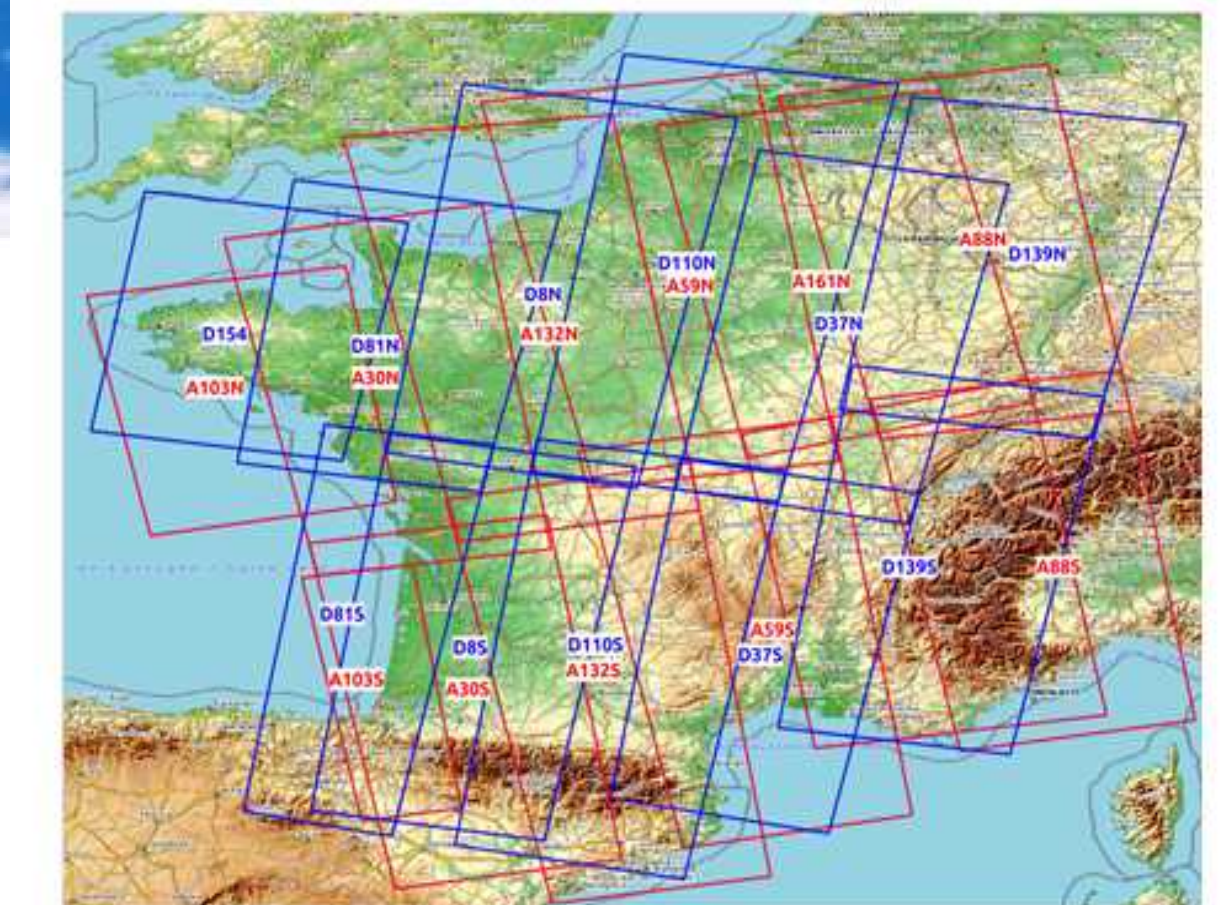
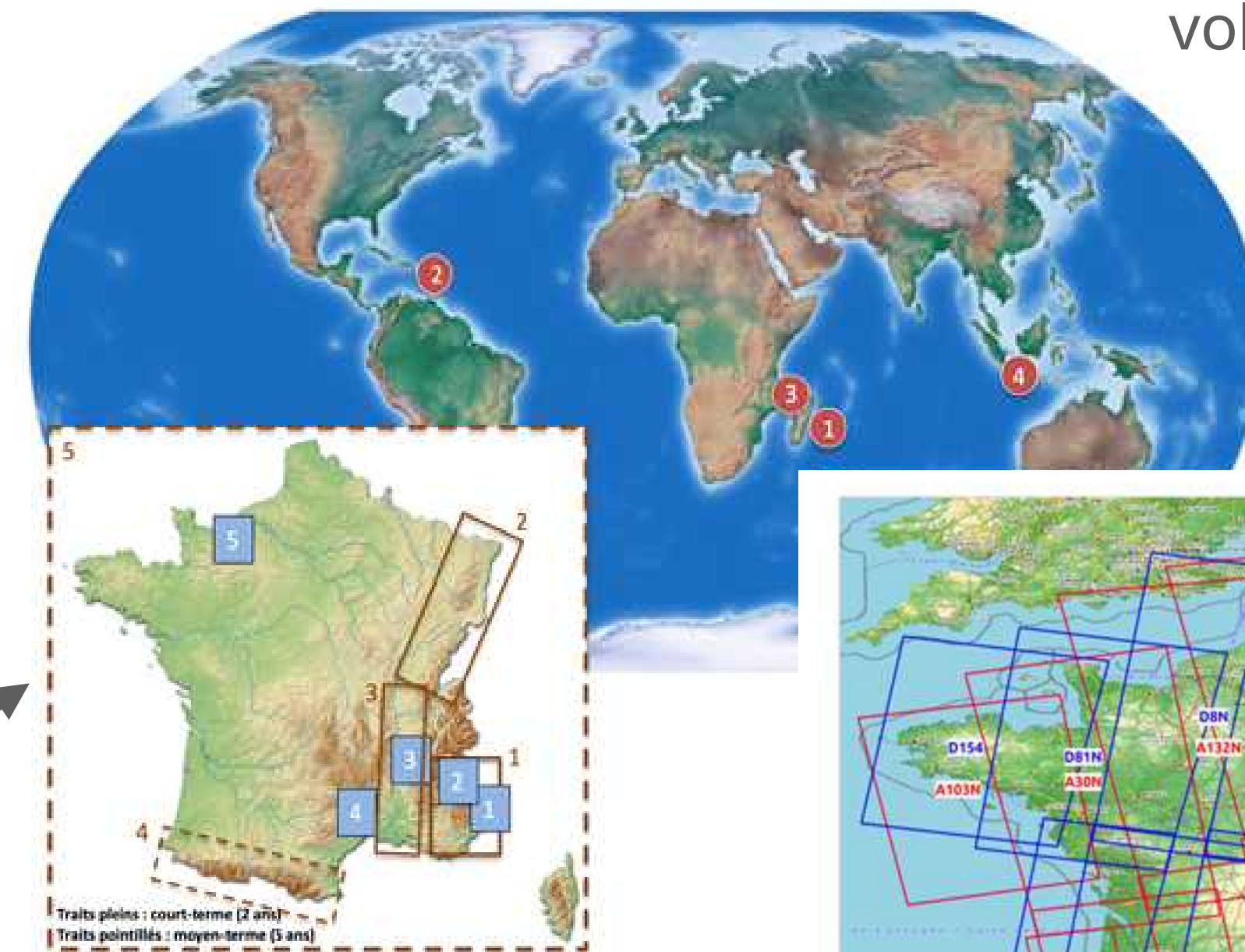


PNTS | May 20, 2025 | Bordeaux

Formaterre & ISDeform | A national observatory for ground motion

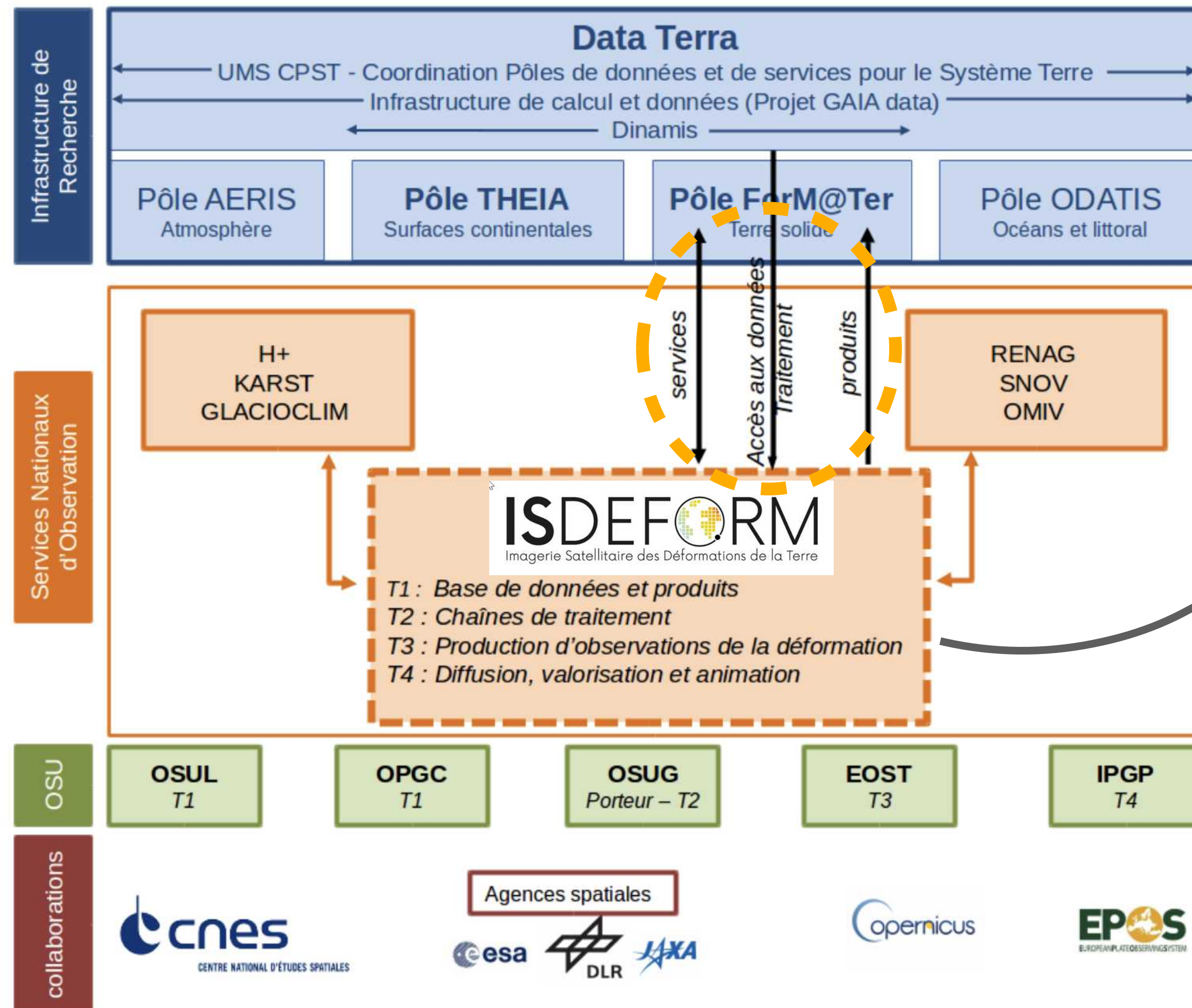


ISDeform Targets
National territory ,
landslides (OMIV) and
volcanoes (SNOV)

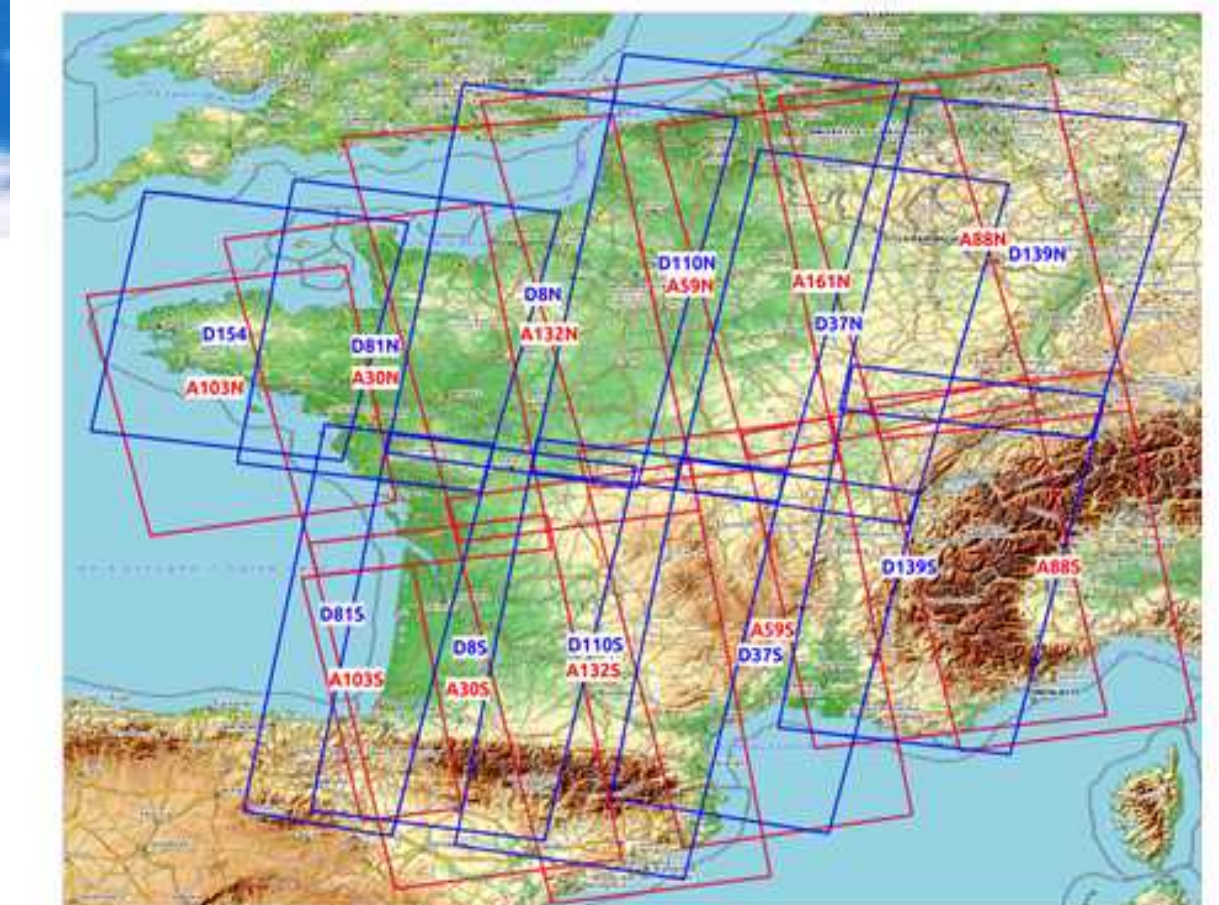
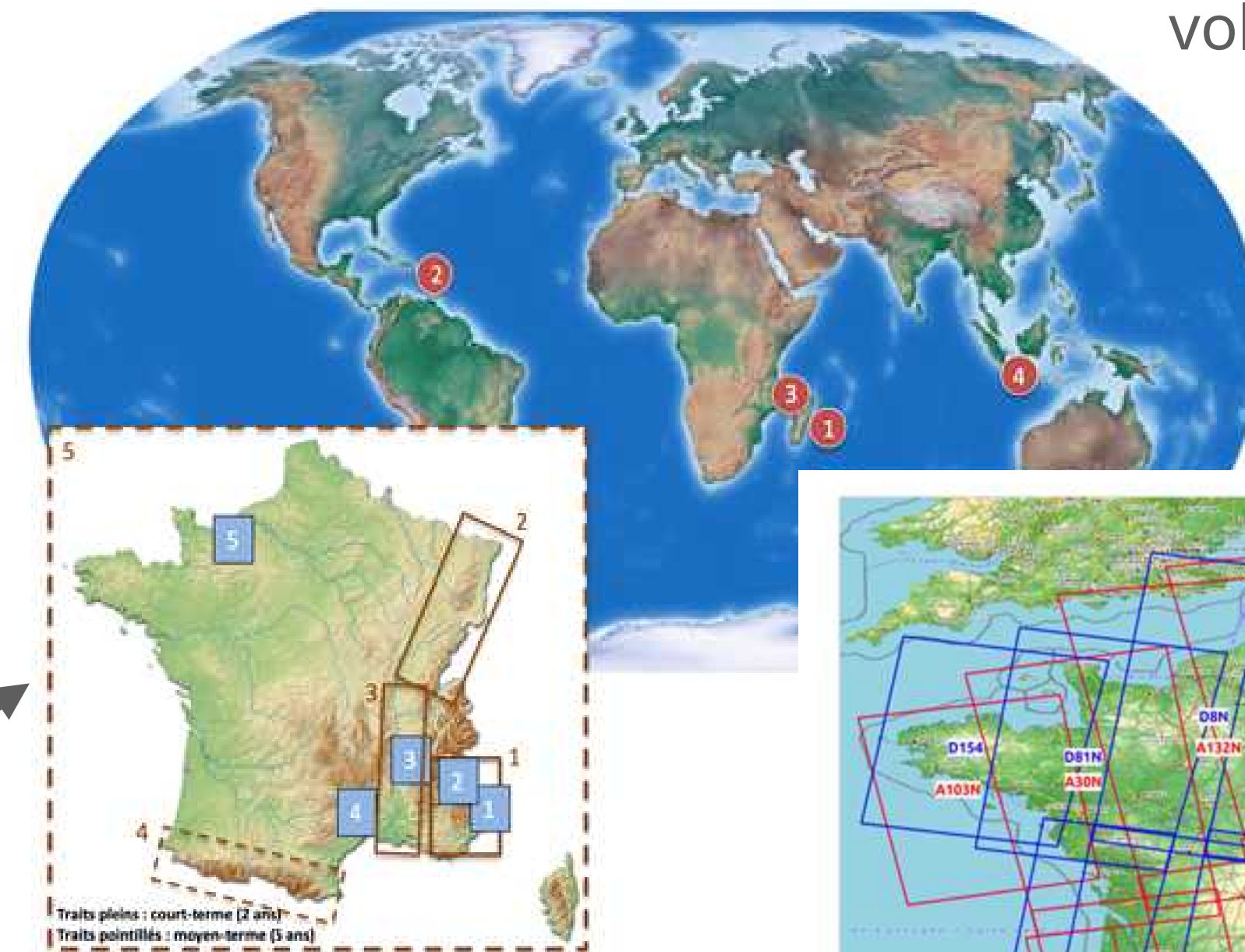


Sentinel-1: 2015-Avril 2021: 31000 scènes, 220 To de données brutes,
70000 interférogrammes
Prétraitement sur le HPC du CNES: service "FLATSIM"
Retraitement à ISTerre (UGA)

Formaterre & ISDeform | A national observatory for ground motion

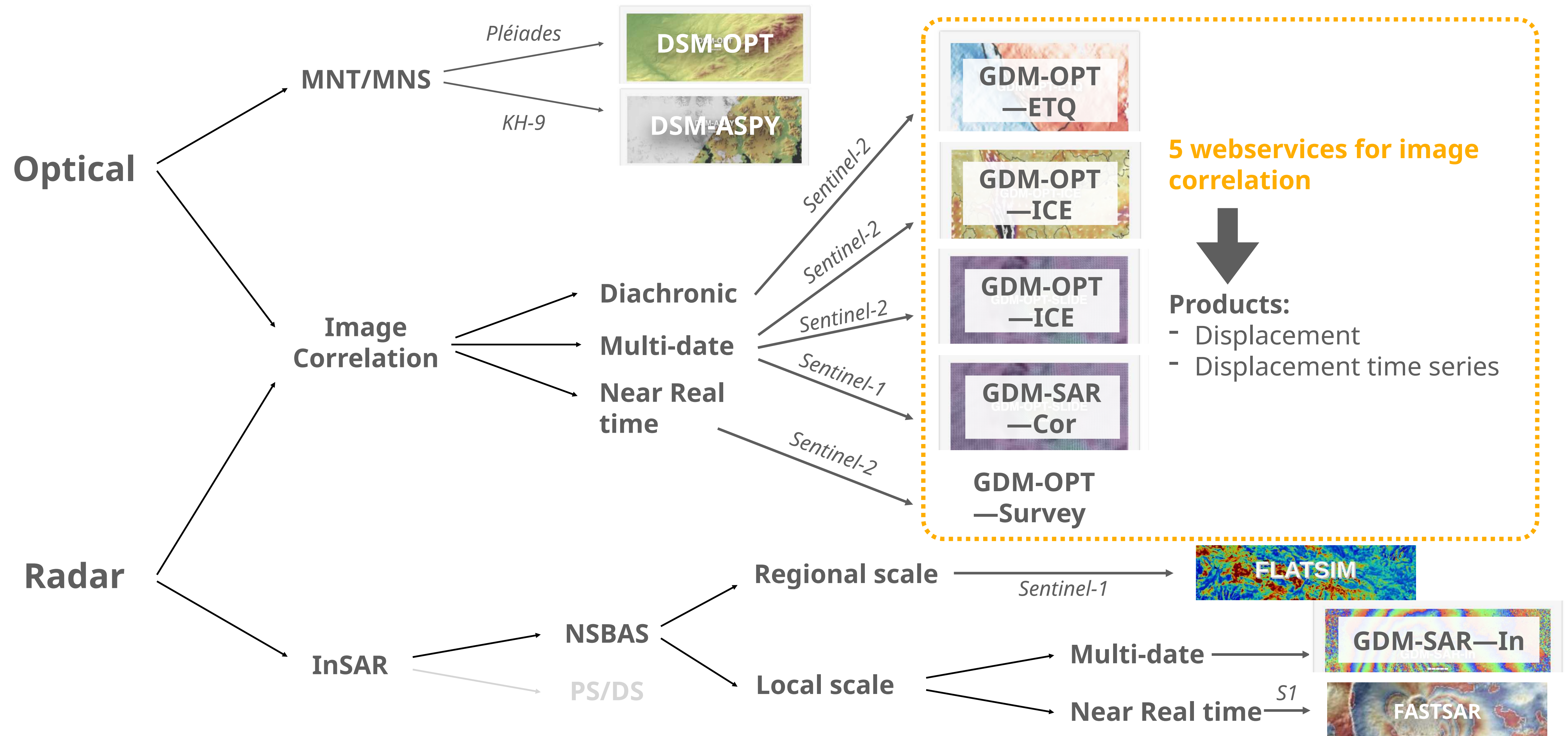


ISDeform Targets
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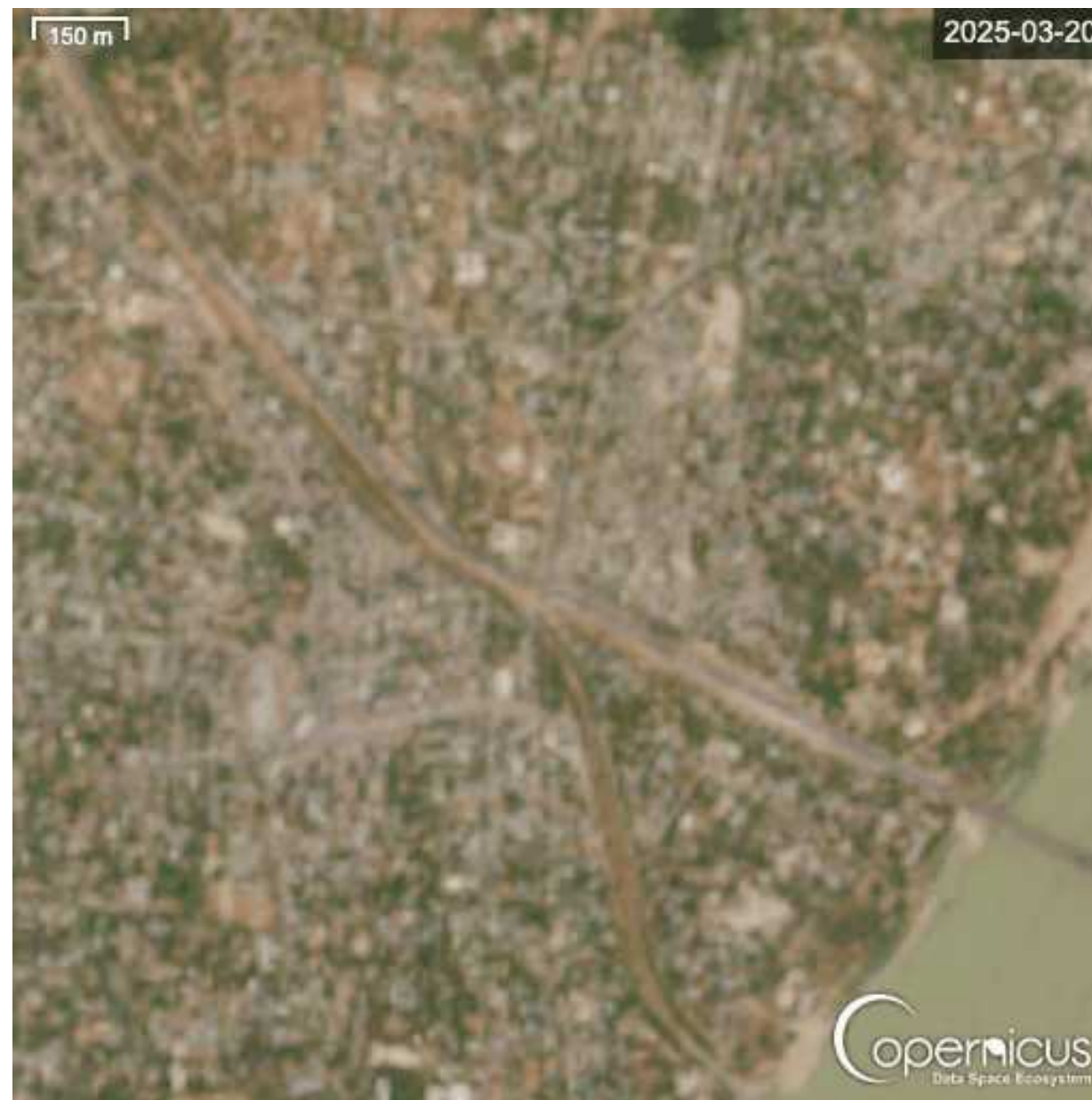
Sentinel-1: 2015-Avril 2021: 31000 scènes, 220 To de données brutes,
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Formaterre & ISDeform | Processing workflow & webservices

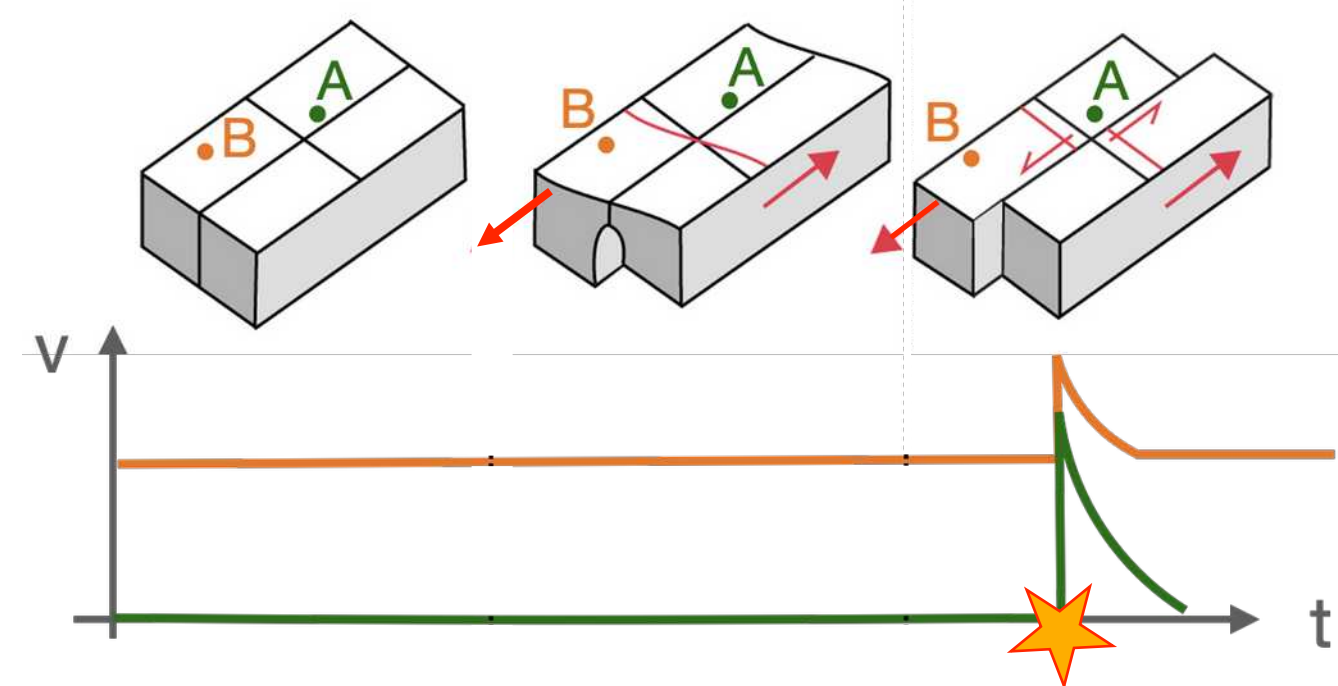


GDM-OPT | What is the interest of Image Correlation ?

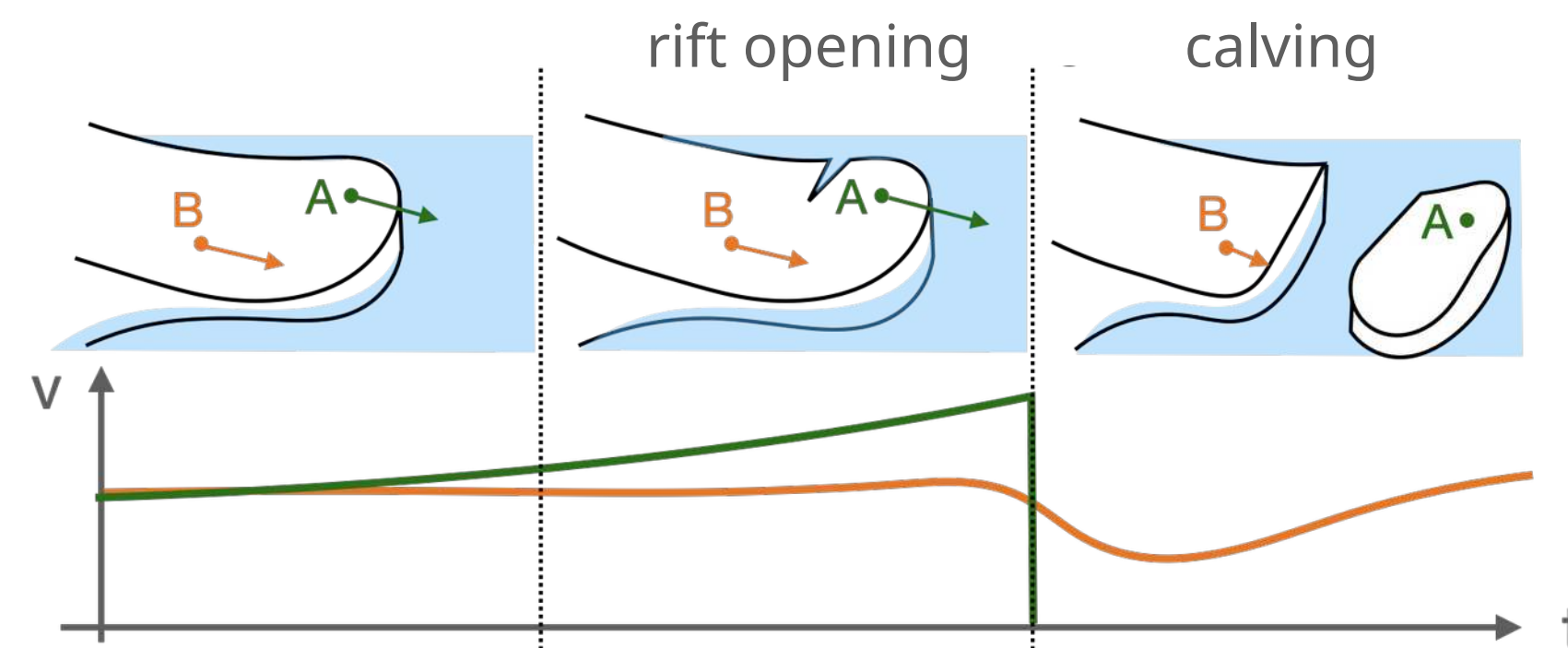
EARTHQUAKES



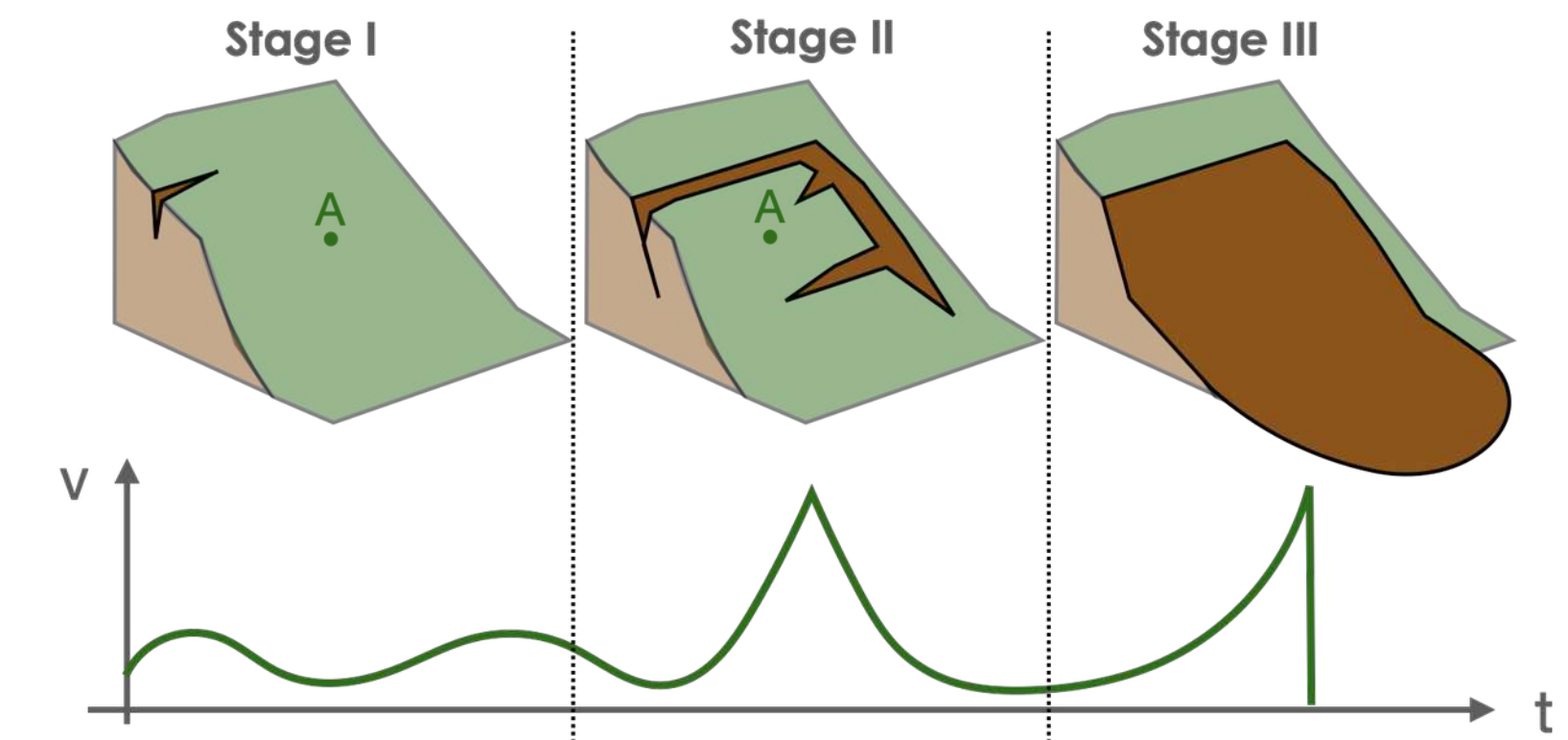
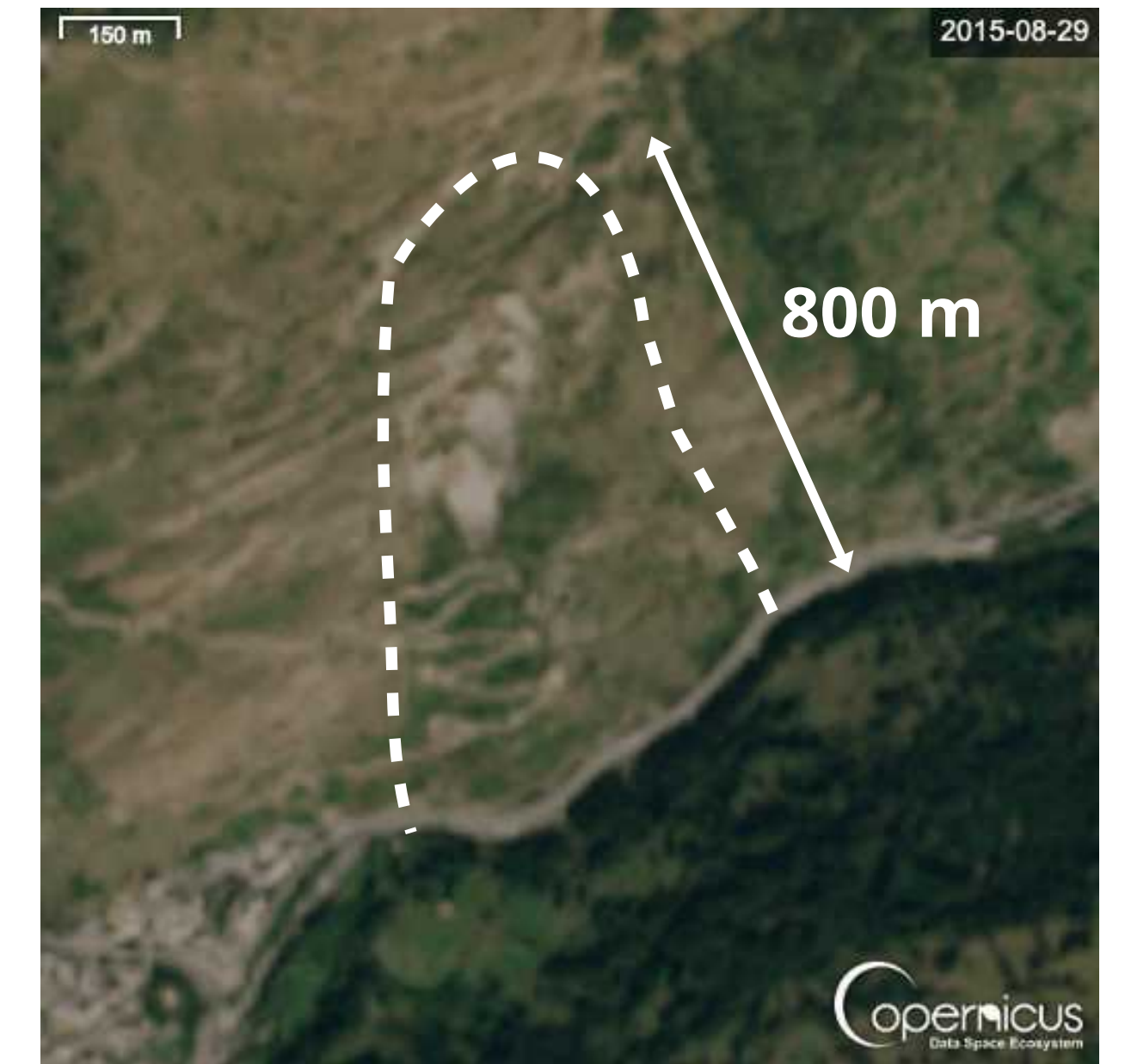
« Initial state » Loading Earthquake



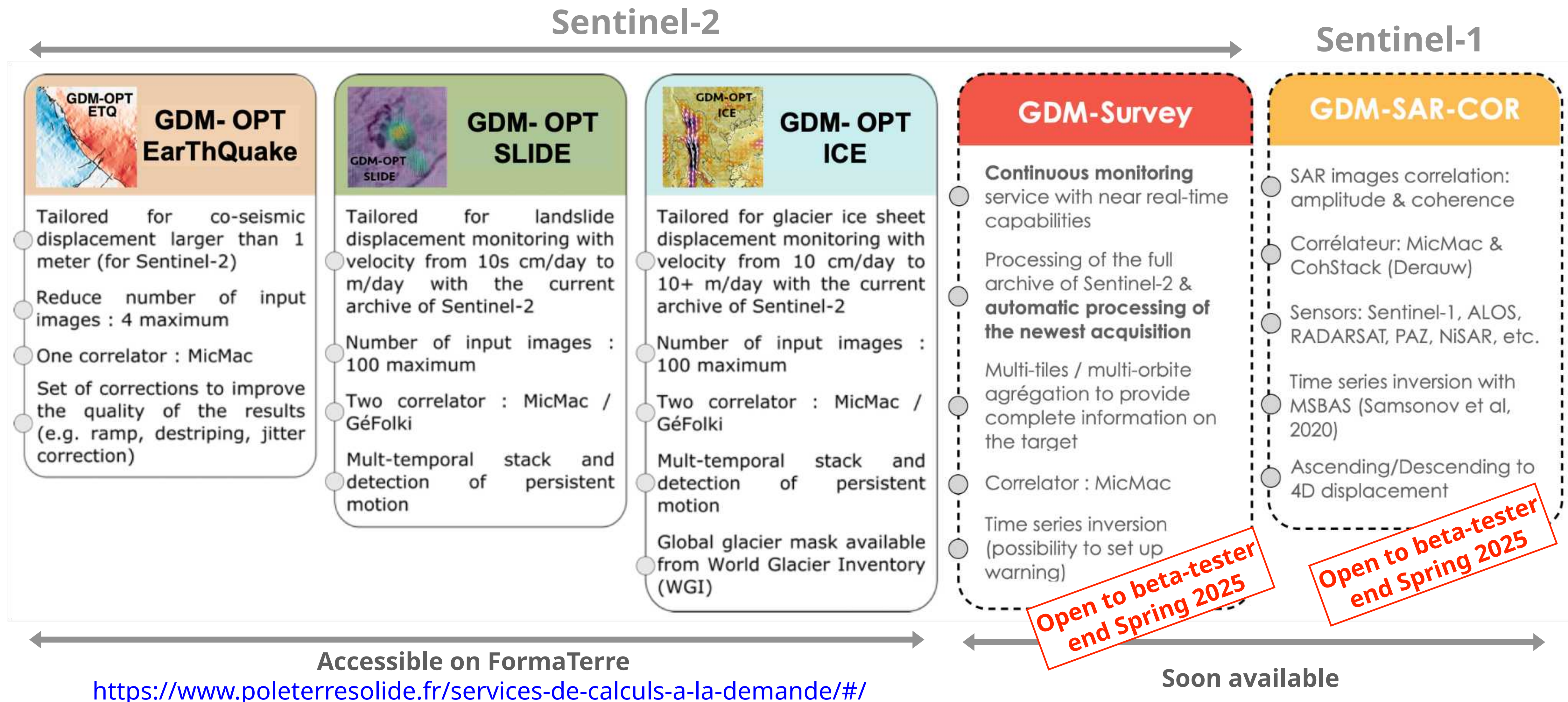
GLACIERS



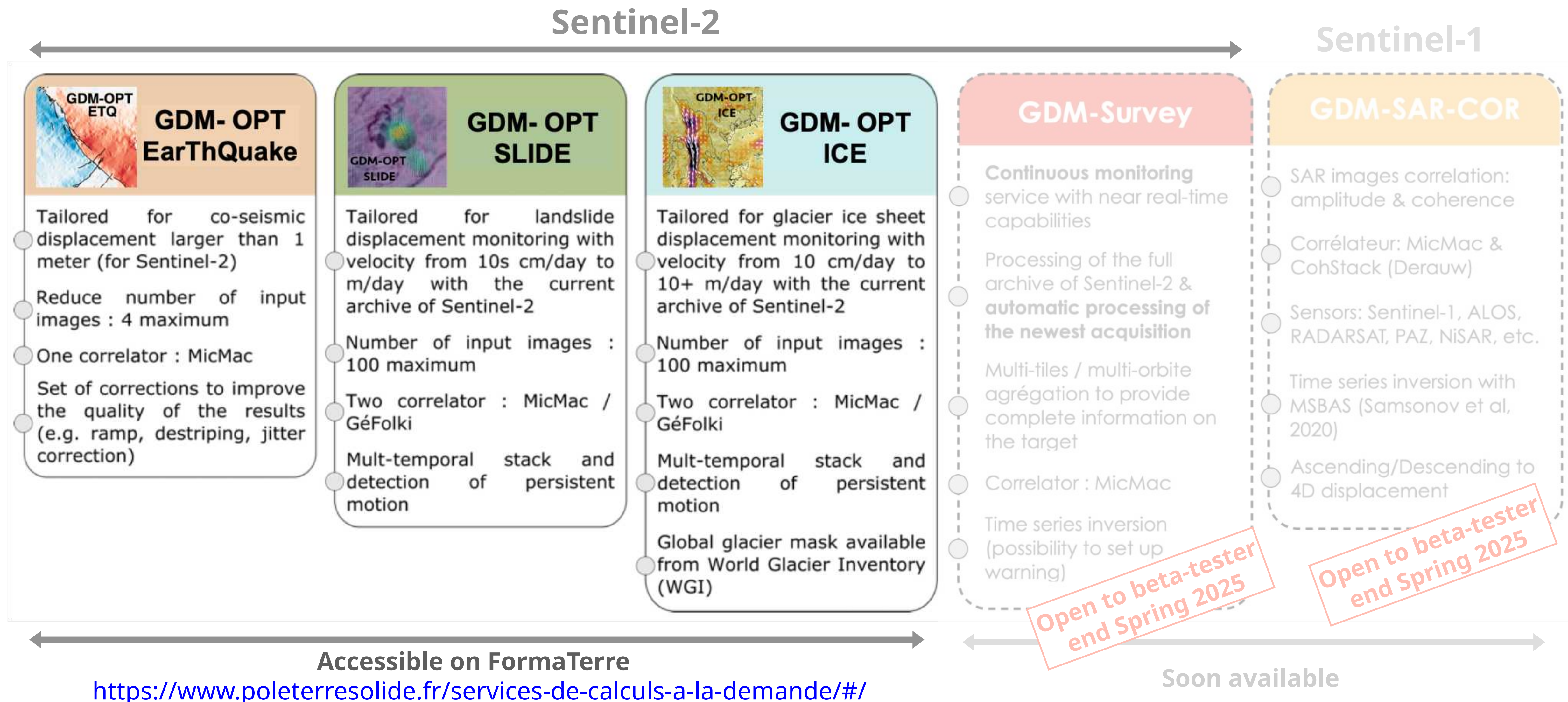
LANDSLIDES



Formaterre & ISDeform | Webservices : Image Correlation (IC)

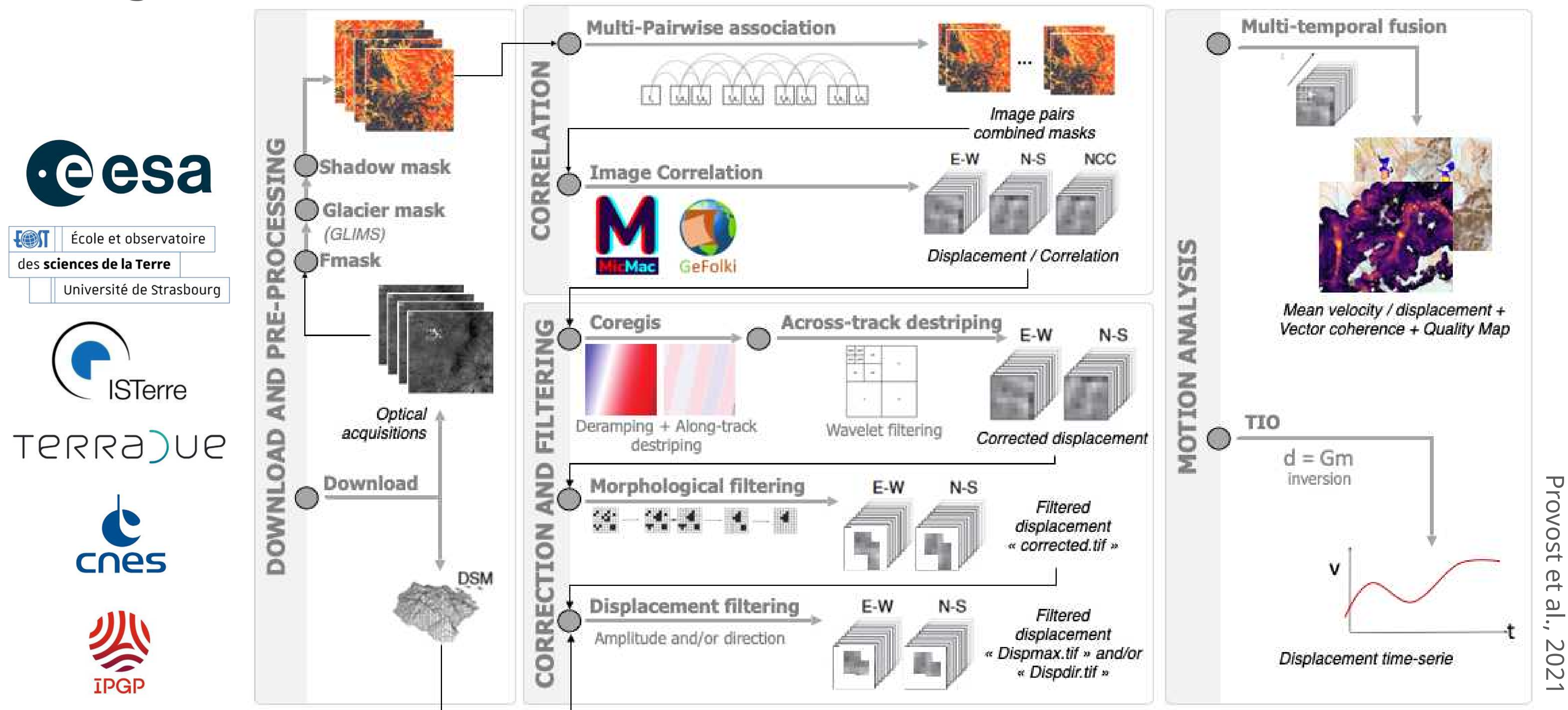


Formaterre & ISDeform | Webservices : Image Correlation (IC)



GDM-OPT | A generic workflow for Image Correlation

One generic workflow...



... deployed on the Strasbourg HPC ...

GDM-OPT | A generic workflow for Image Correlation

... available to the scientific community as 3 webservices

GDM-OPT EarThQuake

- Tailored for co-seismic displacement larger than 1 meter (for Sentinel-2)
- Reduce number of input images : 4 maximum
- One correlator : MicMac
- Set of corrections to improve the quality of the results (e.g. ramp, destriping, jitter correction)

GDM-OPT SLIDE

- Tailored for landslide displacement monitoring with velocity from 10s cm/day to m/day with the current archive of Sentinel-2
- Number of input images : 100 maximum
- Two correlator : MicMac / GéFolki
- Mult-temporal stack and detection of persistent motion

GDM-OPT ICE

- Tailored for glacier ice sheet displacement monitoring with velocity from 10 cm/day to 10+ m/day with the current archive of Sentinel-2
- Number of input images : 100 maximum
- Two correlator : MicMac / GéFolki
- Mult-temporal stack and detection of persistent motion
- Global glacier mask available from World Glacier Inventory (WGI)

... via two main platforms



GDM-OPT ICE

Réinitialiser

Collection

SENTINEL-2ST ▼

Etendue temporelle

Définir la période d'analyse sur la carte ou sélectionner l'identifiant d'une tulle S2

De 01/11/2015

A 08/12/2020

Zone d'intérêt

Dessinez une bounding box sur la carte ou sélectionnez l'identifiant d'une tulle S2

Tulle

Identifiant MGRS coord:

Filtres

Paramètres de calcul

Job name

Corrélation Module -

Images input (2 ≤ N ≤ 100)

Use Region of Interest

DEM Copernicus ▼

Image band B04 ▼

Matching mode Acquisitions ▼

Maximum matching range 2

Minimum matching range 2

Matching direction Forward ▼

A propos

GDM-OPT stands for Ground Deformation Monitoring using OPTical image time series. The service is developed and maintained by CNRS/EOST (Strasbourg) with contribution of IGN/Matis (Marne-la-Vallée), ONERA (Palaiseau) and CNRS/ISTerre (Grenoble). The service allows the processing of optical image pairs for the monitoring of Earth surface deformation.

The service version GDM-OPT-ICE is designed for monitoring glacier and ice sheet persistent motion. It enables the on-demand processing of Sentinel-2 image time series. It provides

1. a module for image matching of multiple image pairs using pixel and sub-pixel image correlation or optical flow,
2. a module for image pairs geometrical correction and filtering; and
3. a module for the spatio-temporal analysis of surface motion.

It builds on the MicMac (IGN/Matis; Rosu et al., 2015), GeFolki (ONERA; Brigot et al., 2016), CO-REGIS (CNRS/EOST; Stumpf et al., 2018), MPIC (Stumpf et al., 2014), TIO (CNRS/ISTerre; Bontemps et al., 2017) and FMask (Texas Tech University; Qiu et al., 2019) algorithms.

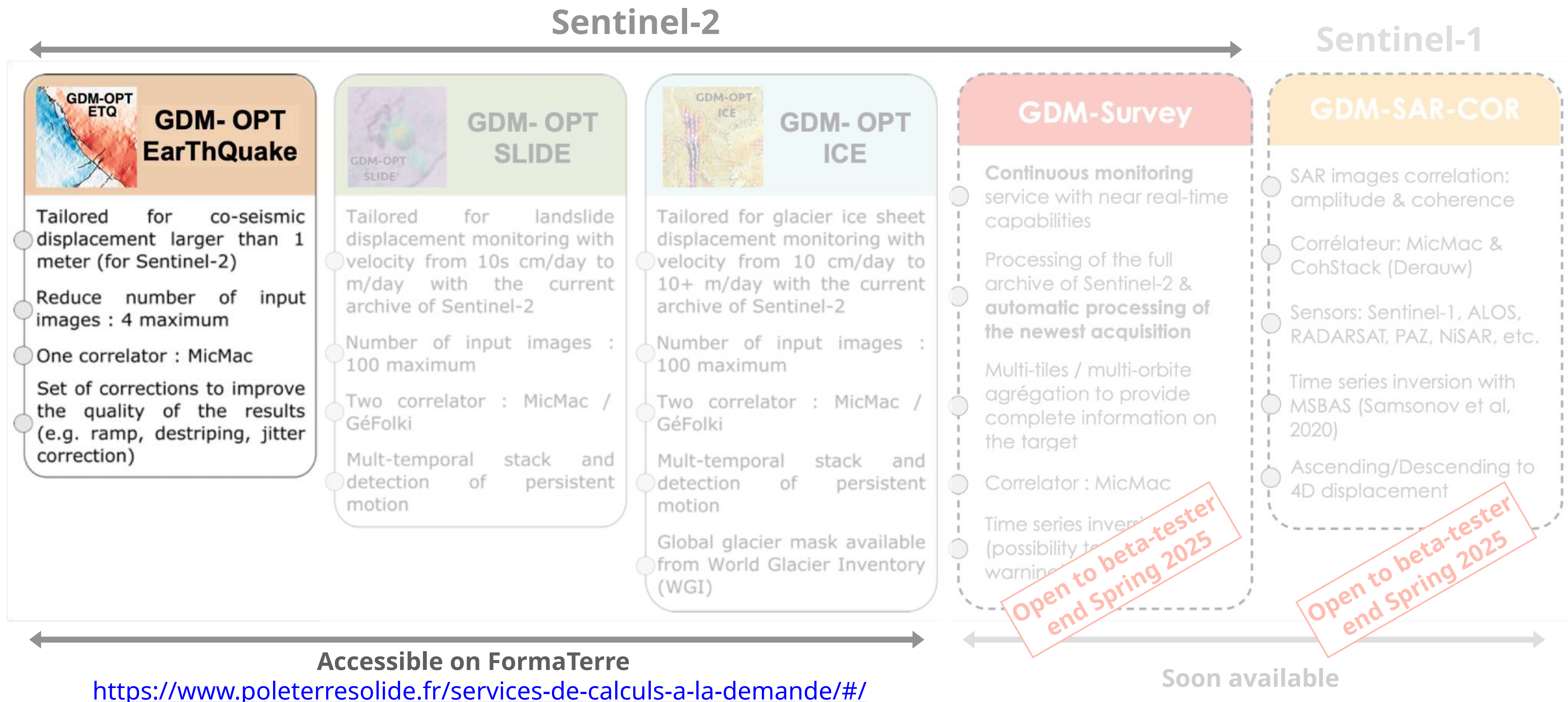
The service is designed for the processing of a maximum of 100 images. Specific tools and parameterizations for ice monitoring are available such as the possibility to focus the analysis on the extent of the glaciers based on the GLIMS database.



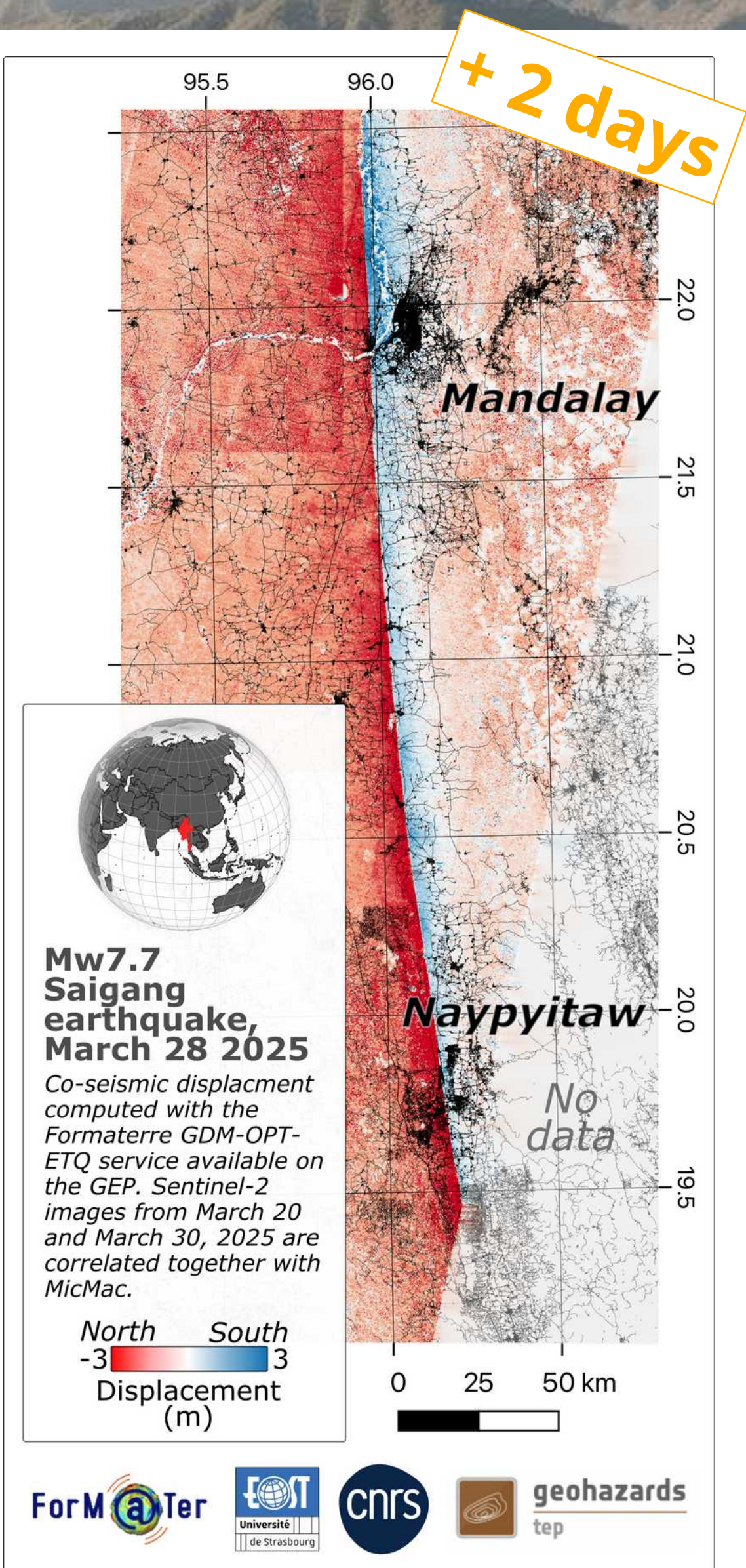
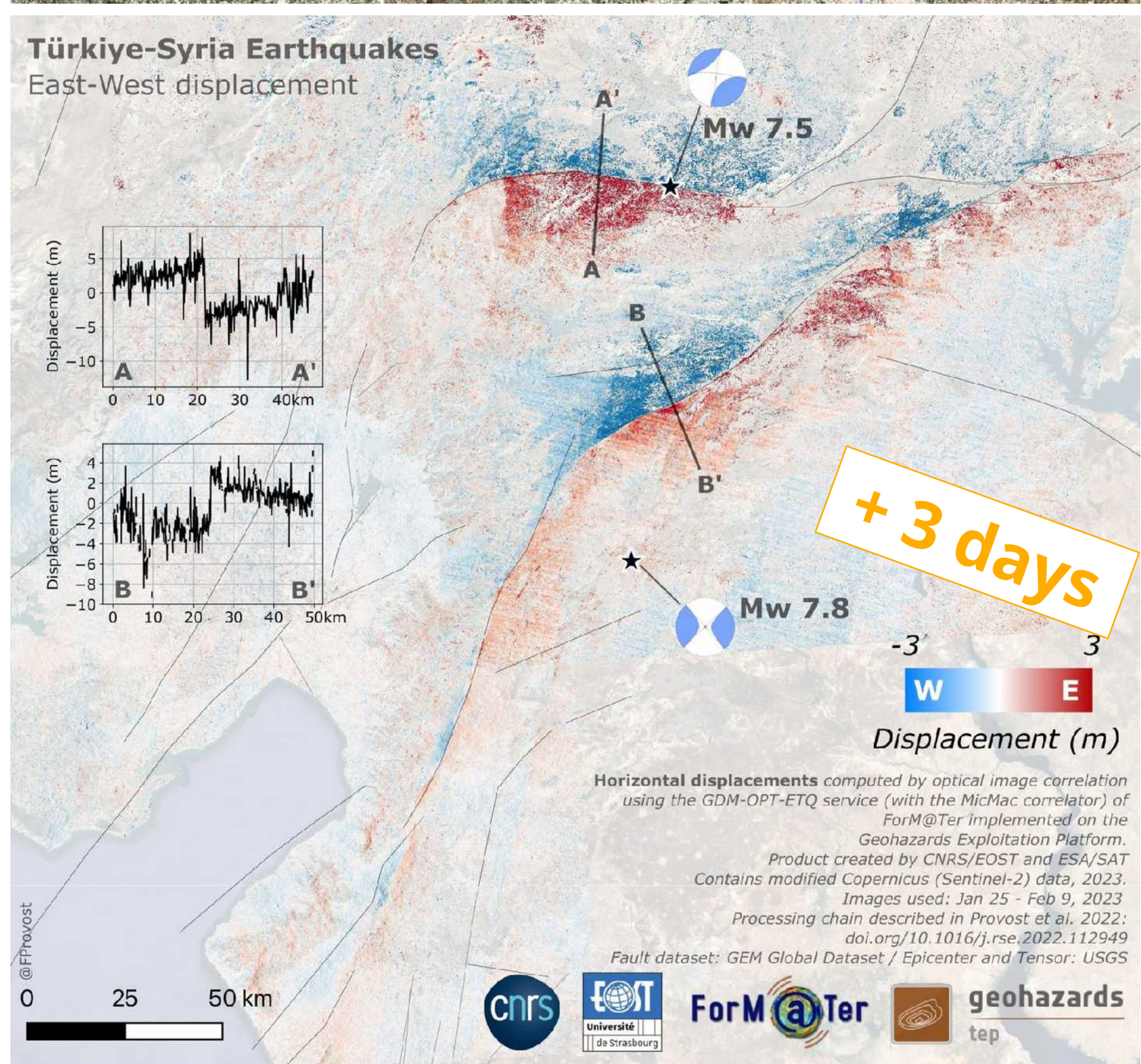
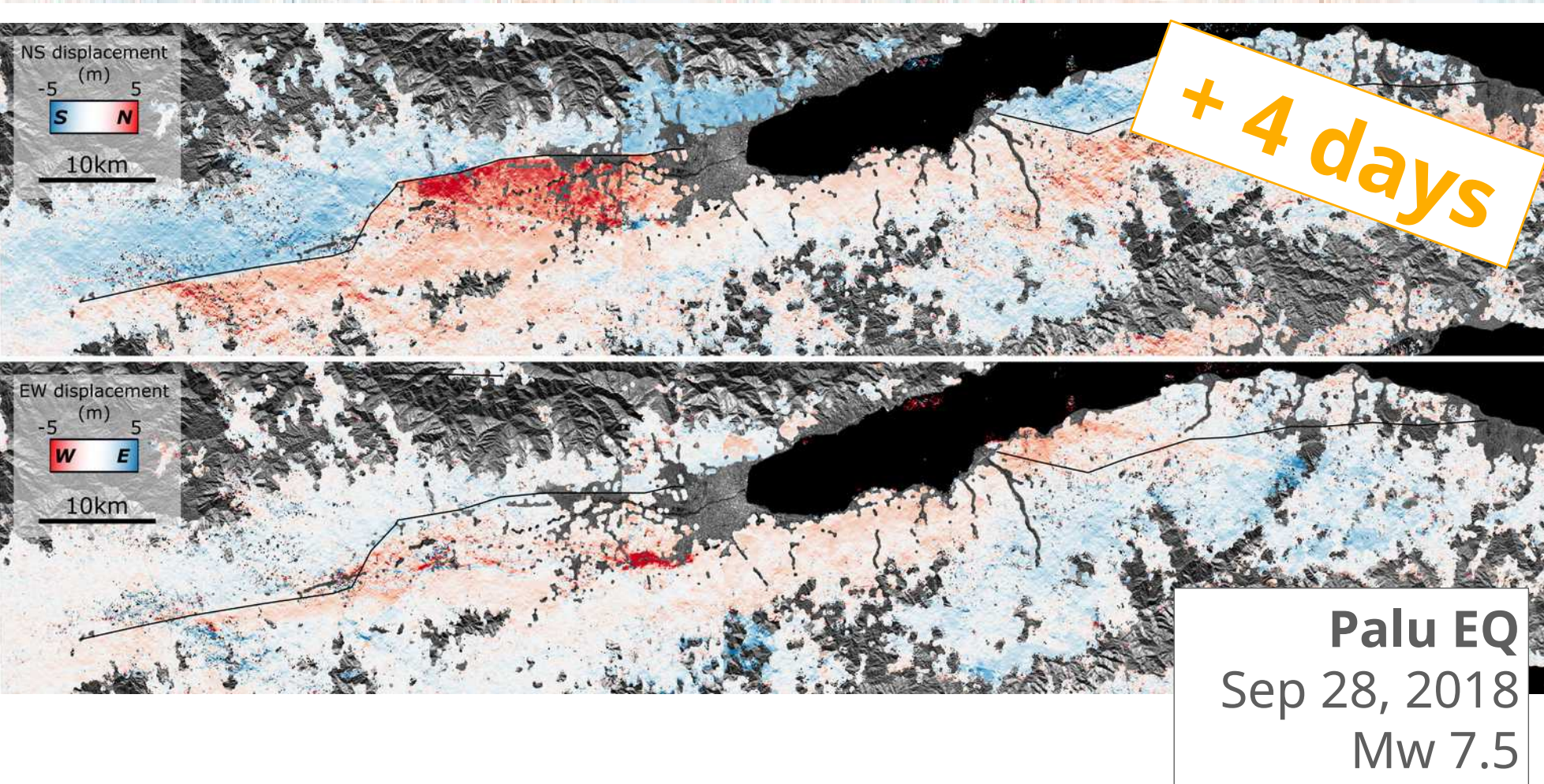
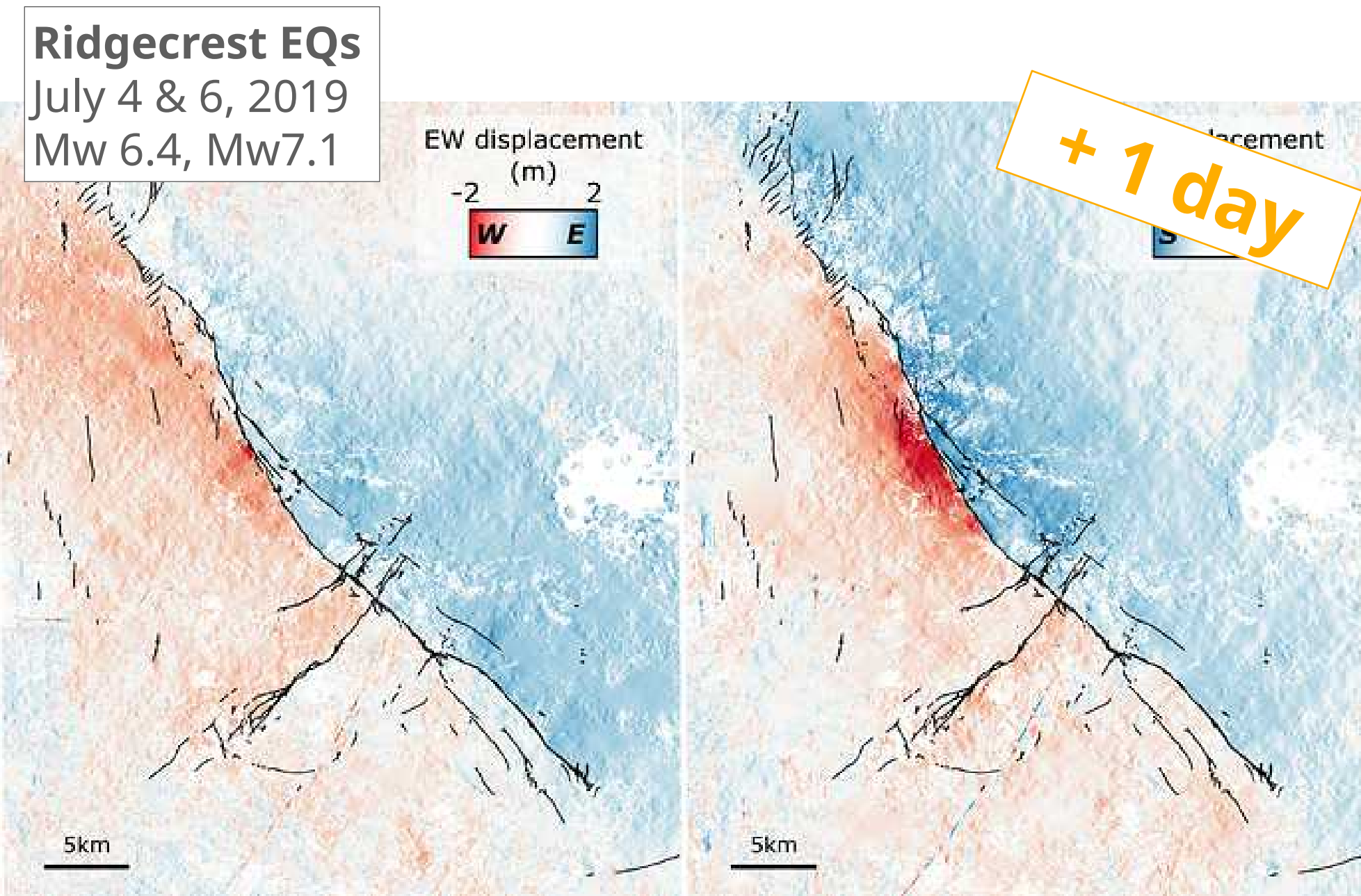
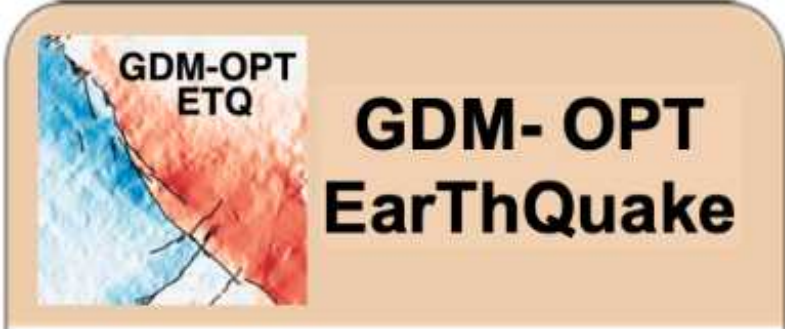
geohazards
tep
by Terradue

The screenshot displays the Copernicus Emergency Management Center (CEMC) interface. The main map shows Europe with a red area indicating a disaster zone. The sidebar on the left lists search results for 'SDA SUMM2A Level-2A 48 Wld, 05 May 2021 05:46:41 GMT'. The right panel, titled 'Processing Services', offers various options including ALA, DSH-OPT, and MPIC-OPT. The top navigation bar includes links for 'EO Data', 'EO-based products', 'Community', and 'Private'.

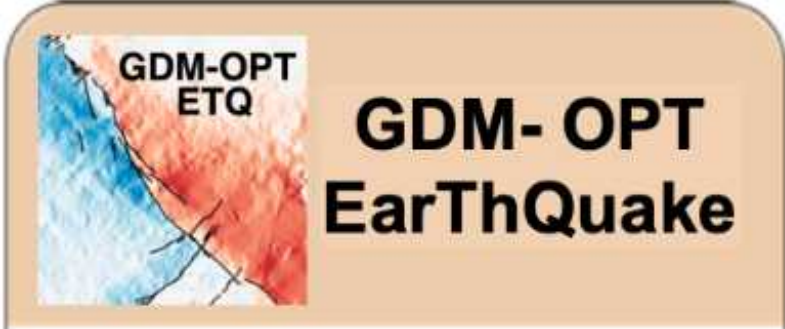
Formaterre & ISDeform | Webservices : Image Correlation (IC)



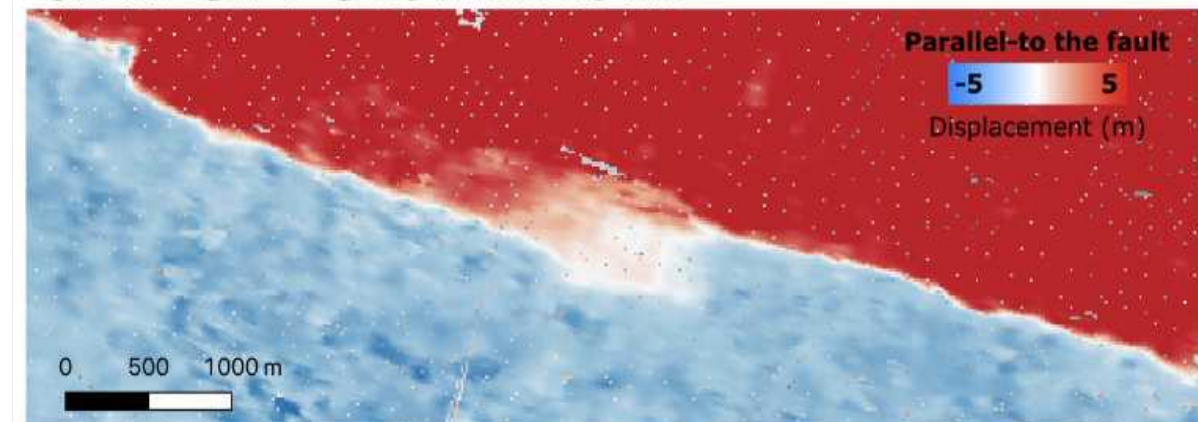
GDM-OPT-ETQ | Measuring co-seismic displacement



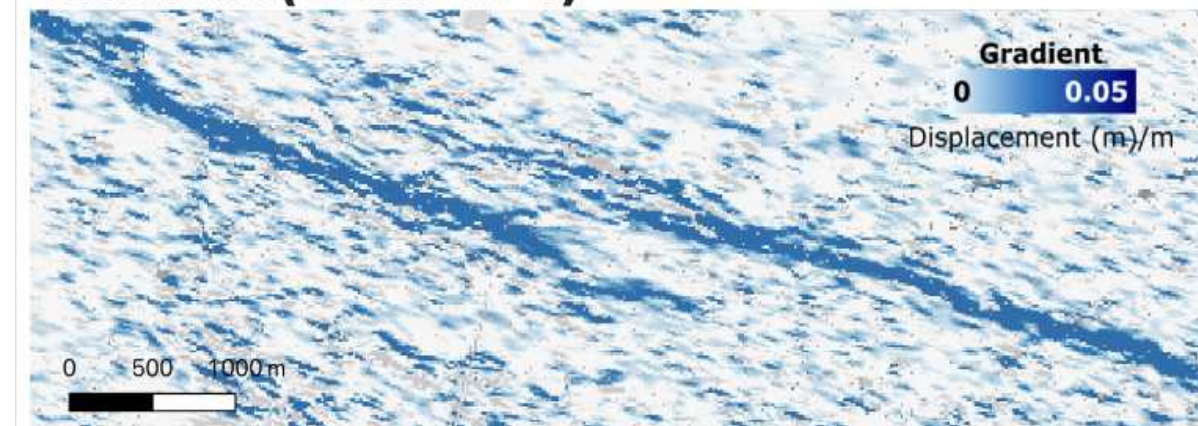
GDM-OPT-ETQ | Measuring co-seismic displacement



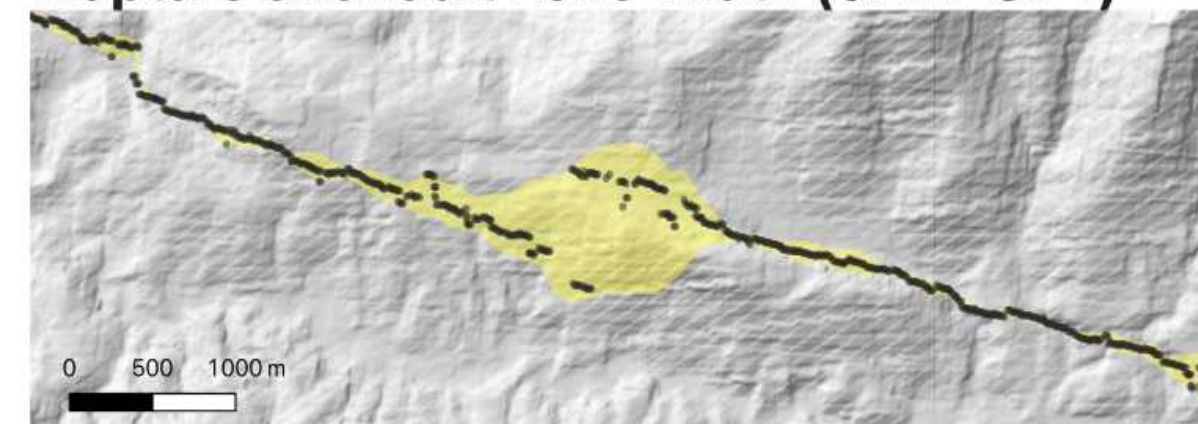
GDM-OPT @10 m x 10 m



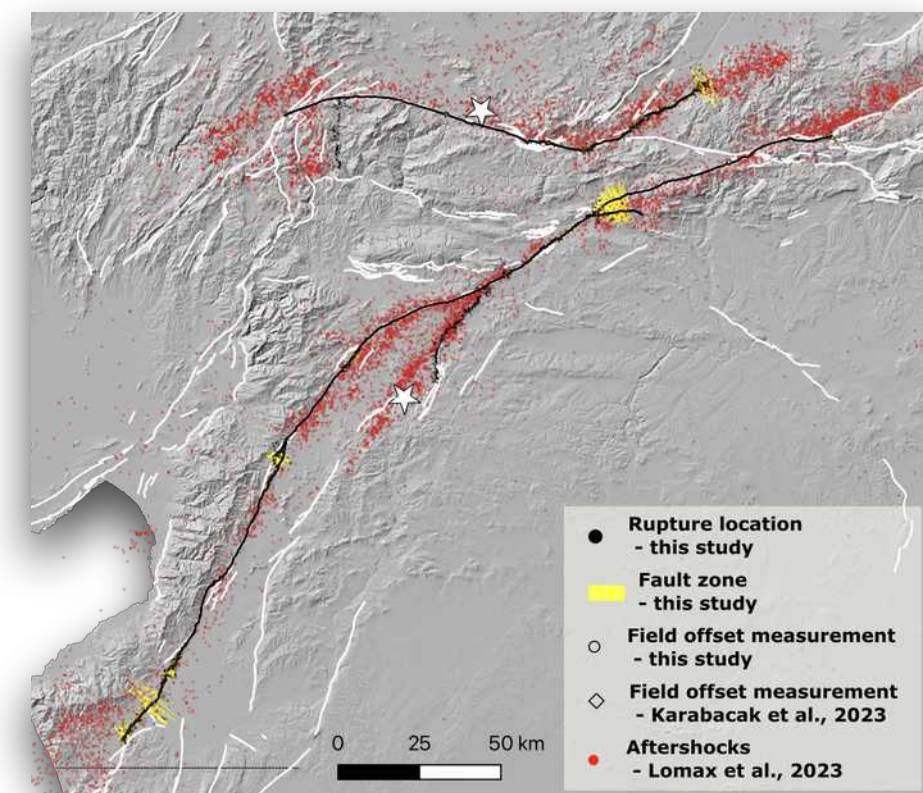
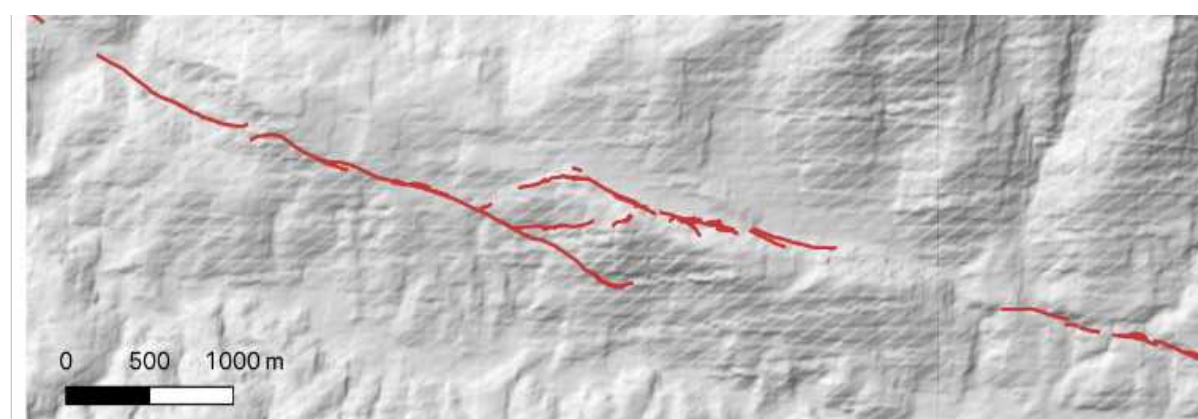
Gradient (GDM-OPT)



Rupture and fault zone width (GDM-OPT)

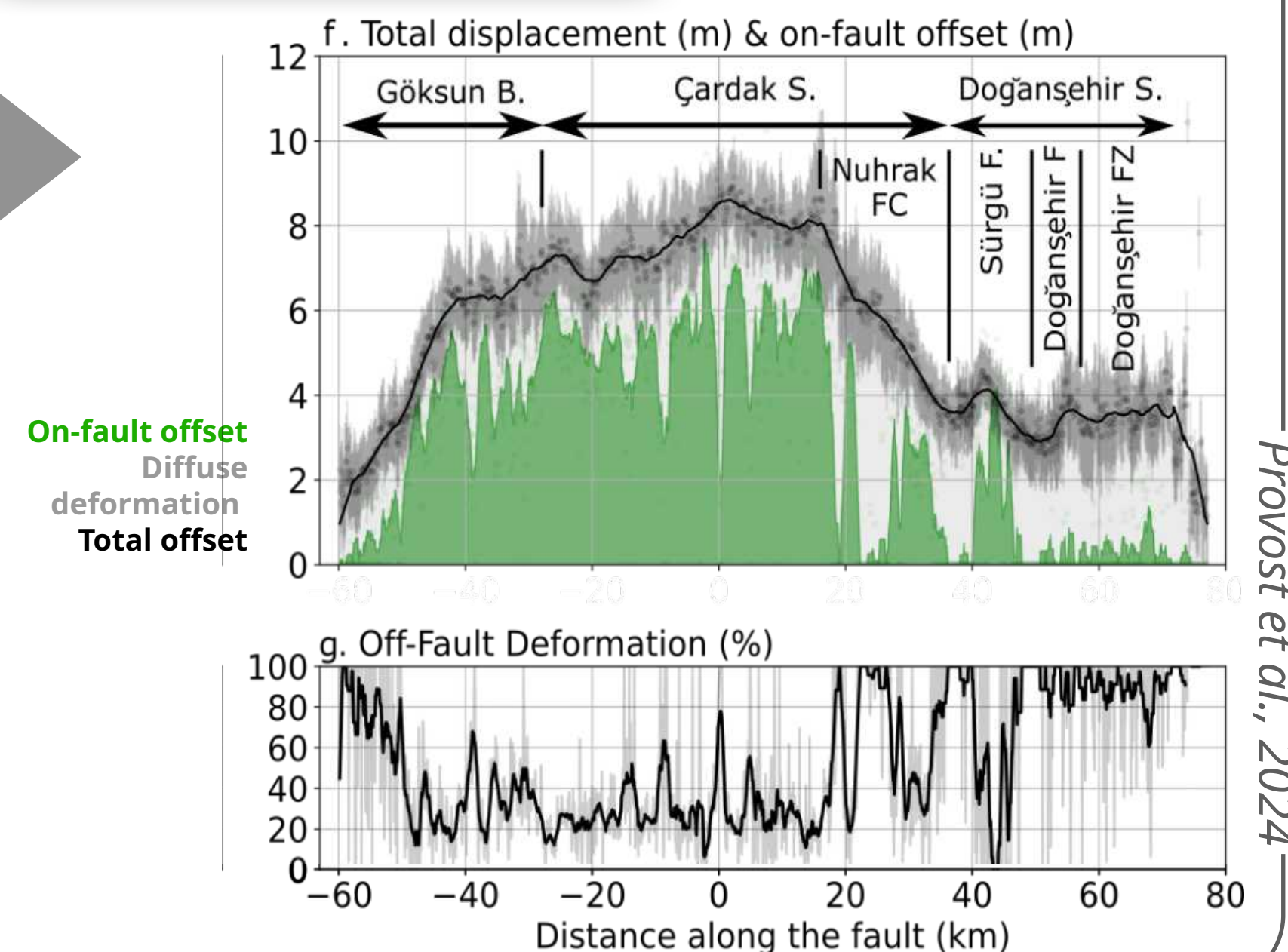


Reitman et al., 2023

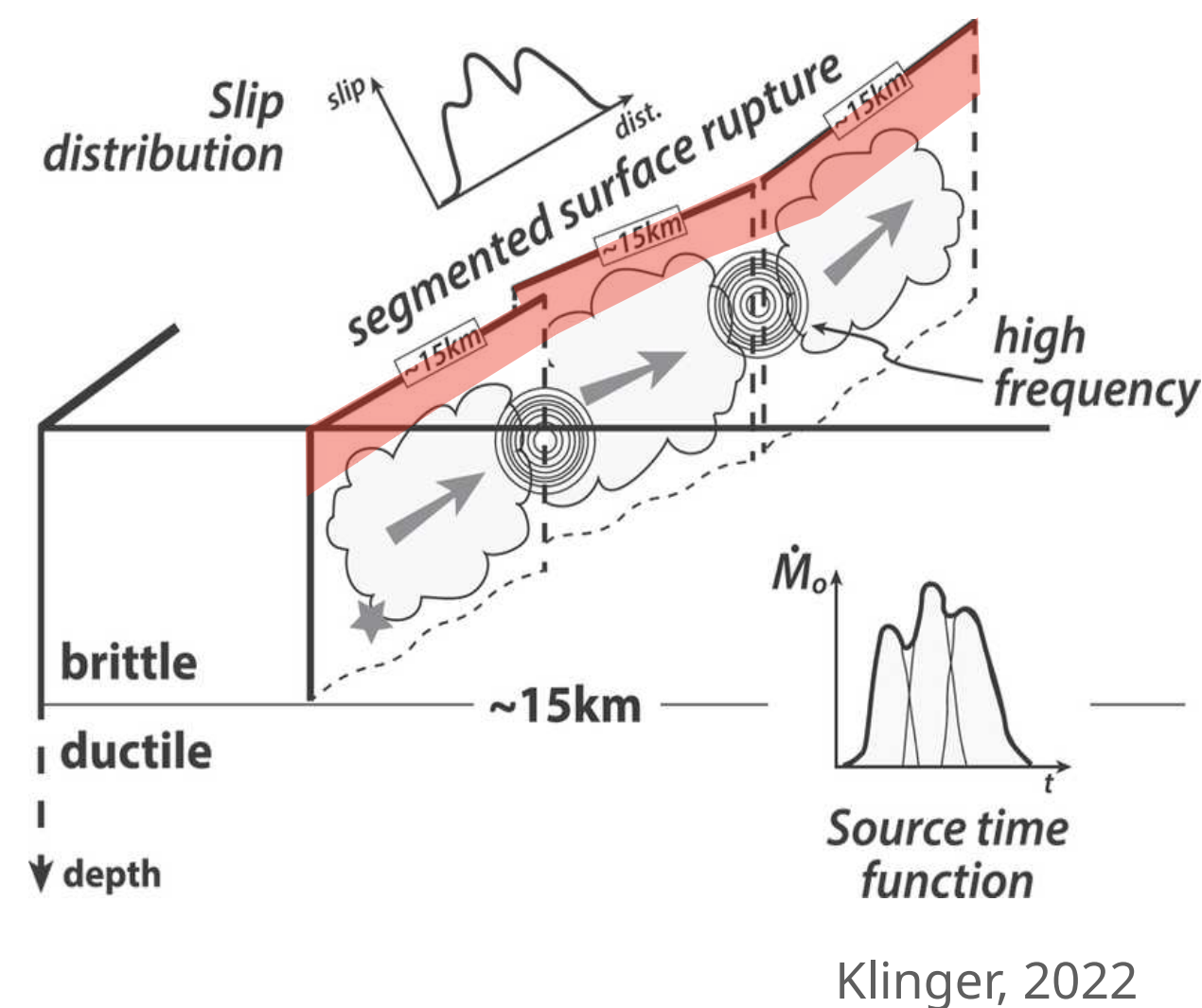


Mapping of
rupture location ,
extension and
deformation

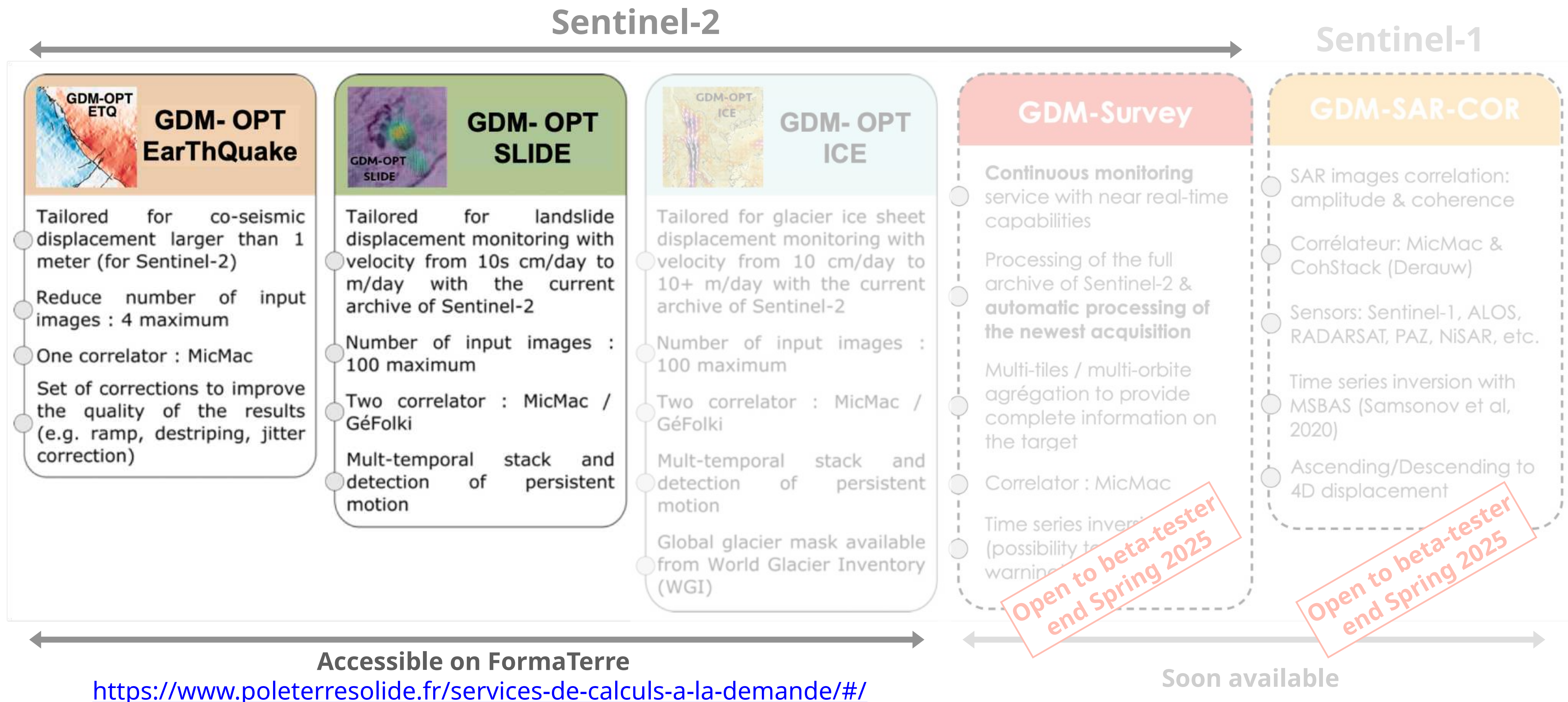
~400 km de rupture
10m de résolution le
long de la rupture



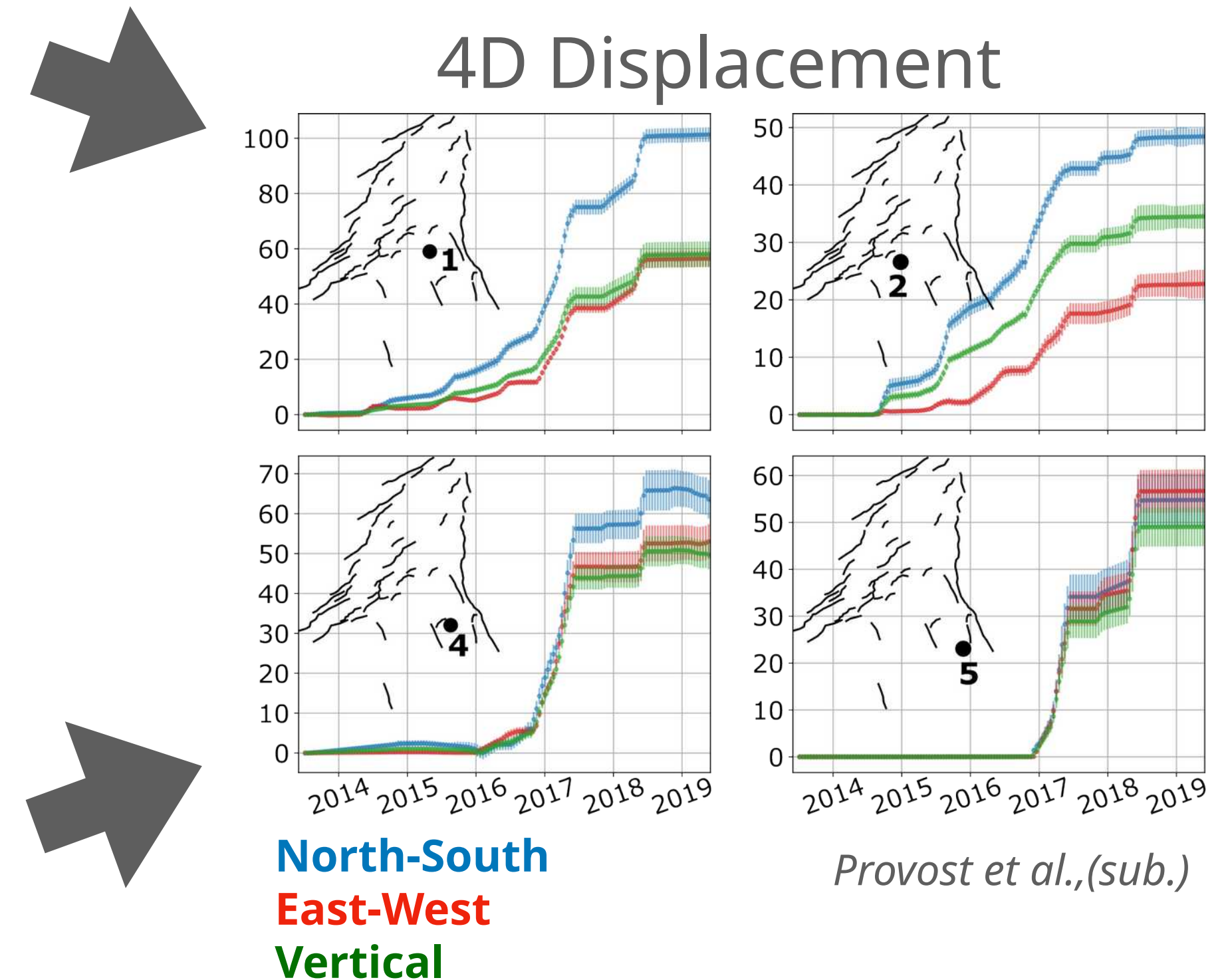
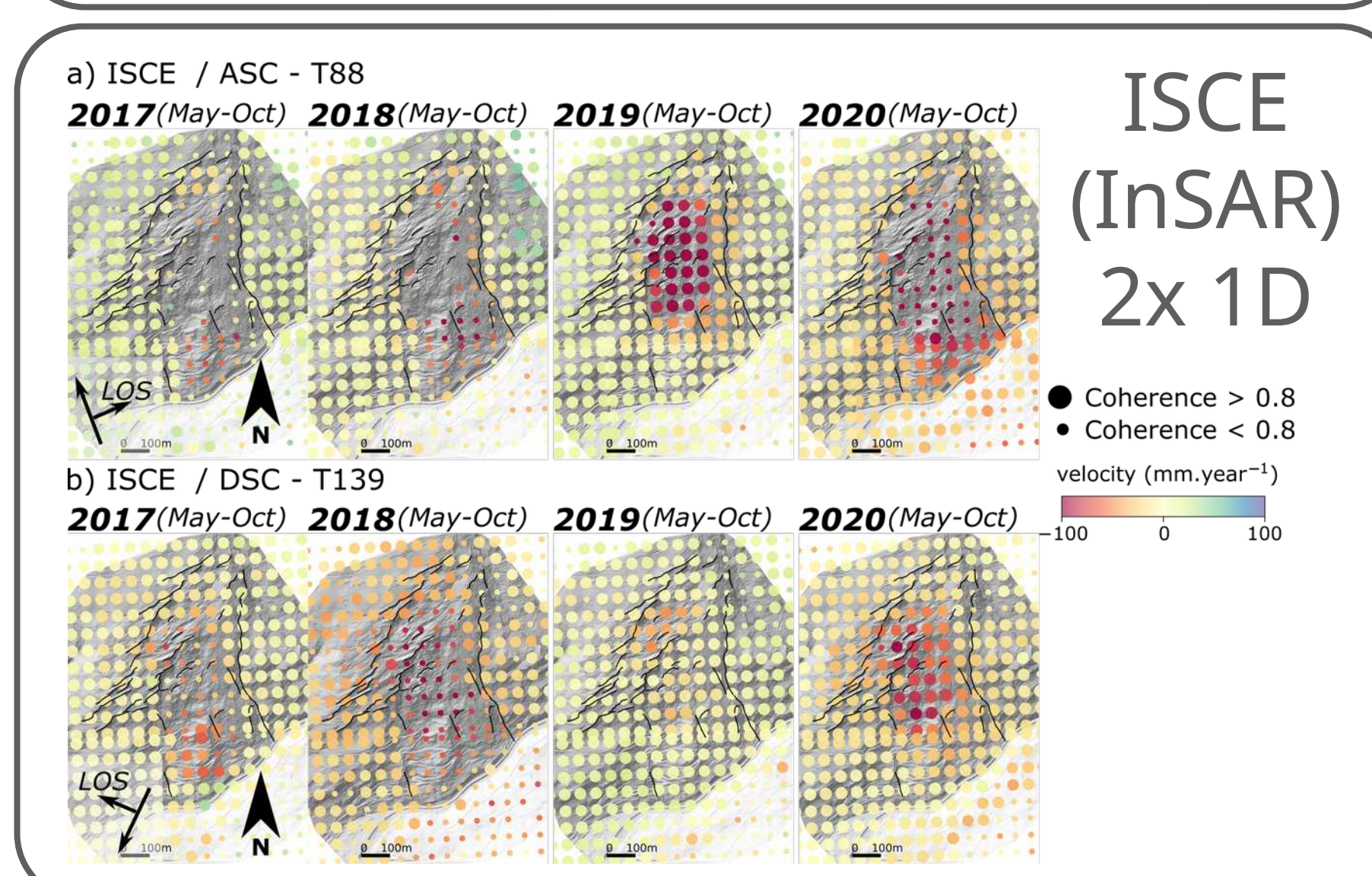
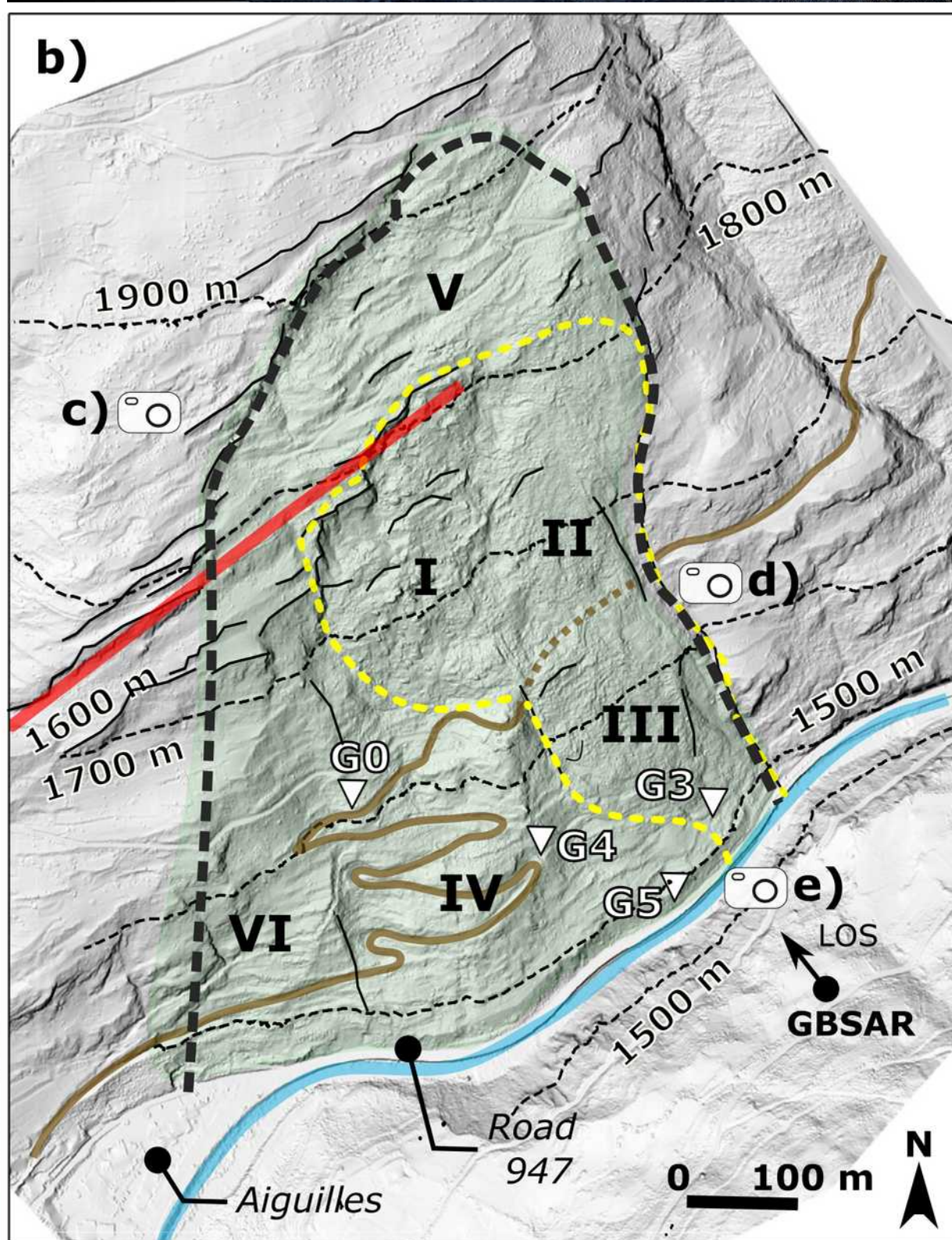
Modelling sub-
surface rupture and
crust properties



Formaterre & ISDeform | Webservices : Image Correlation (IC)

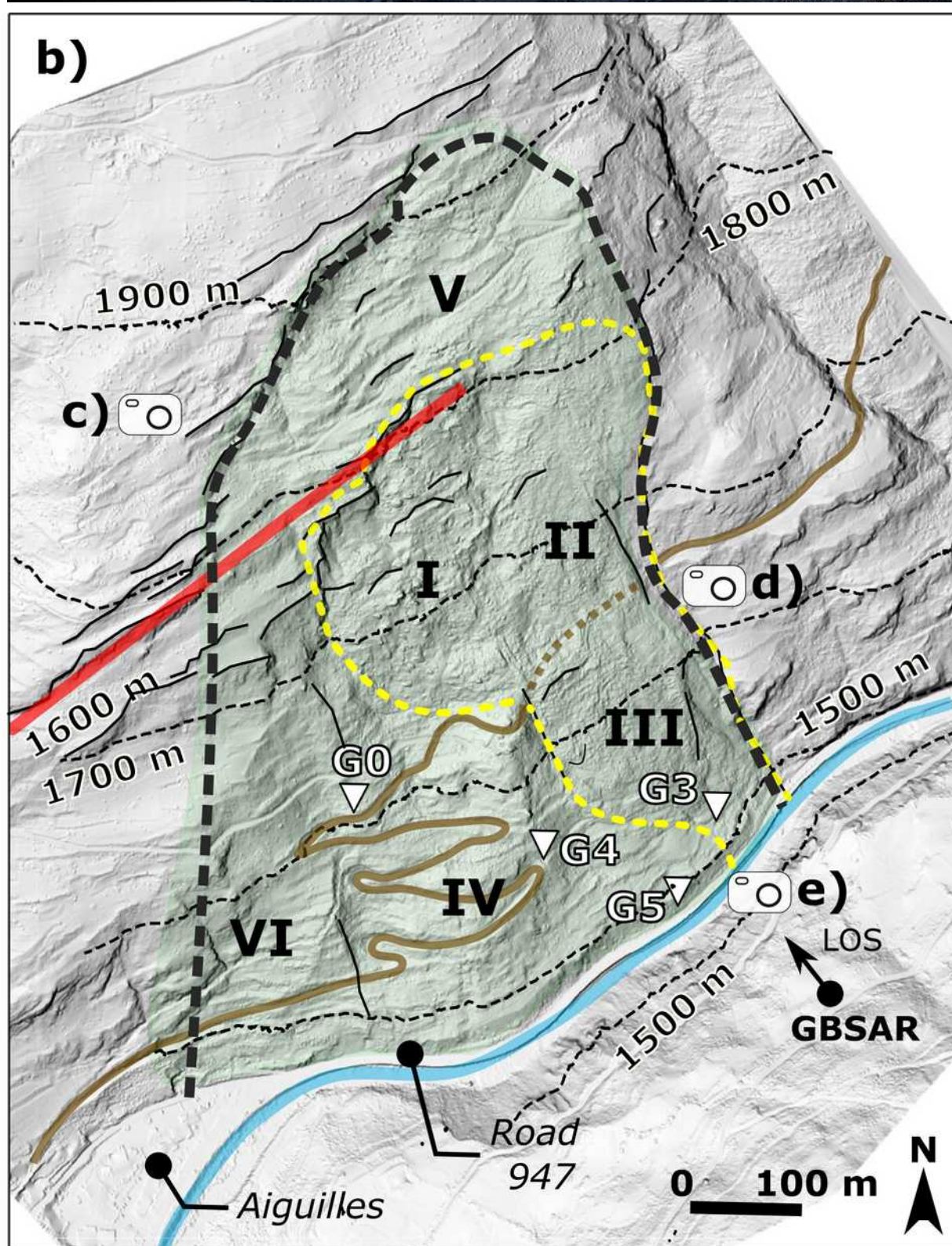


**GDM- OPT
SLIDE**



Provost et al.,(sub.)

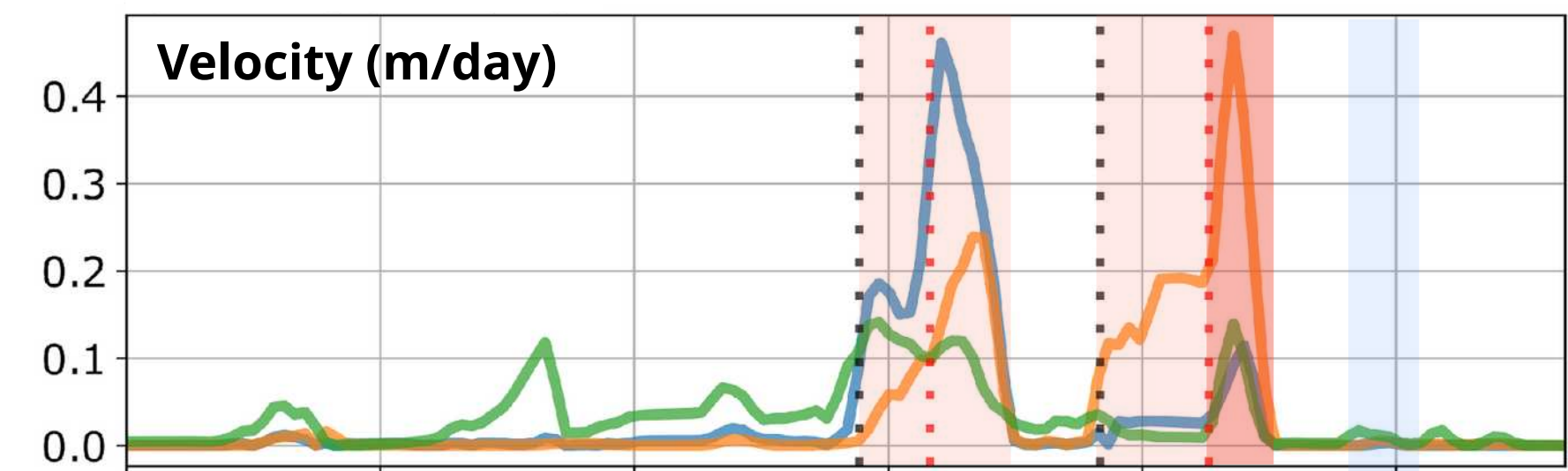
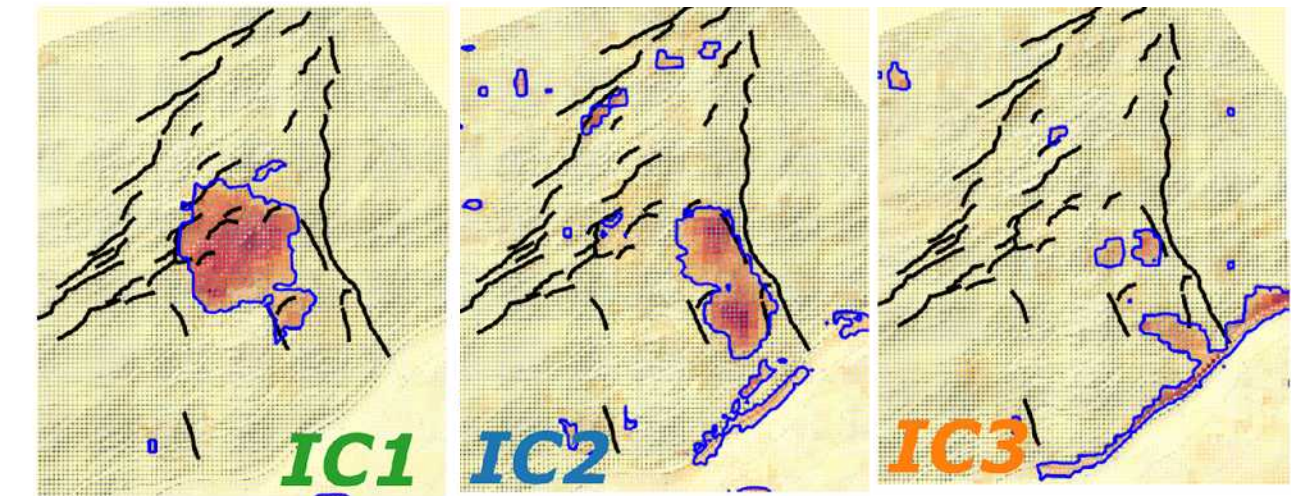
**GDM- OPT
SLIDE**



North-South
East-West
Vertical

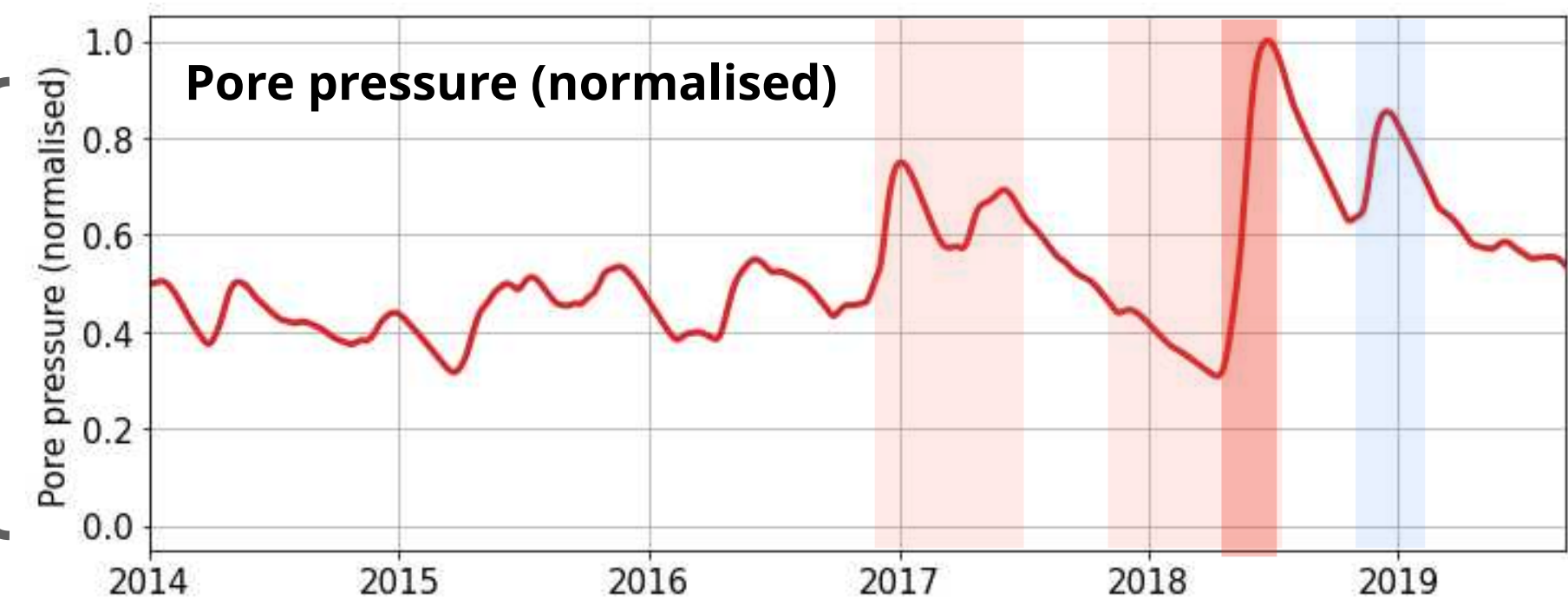
DEFORMATION 3D | Analyse ICA

PLUIE + NEIGE ($T < 0^{\circ}\text{C}$)



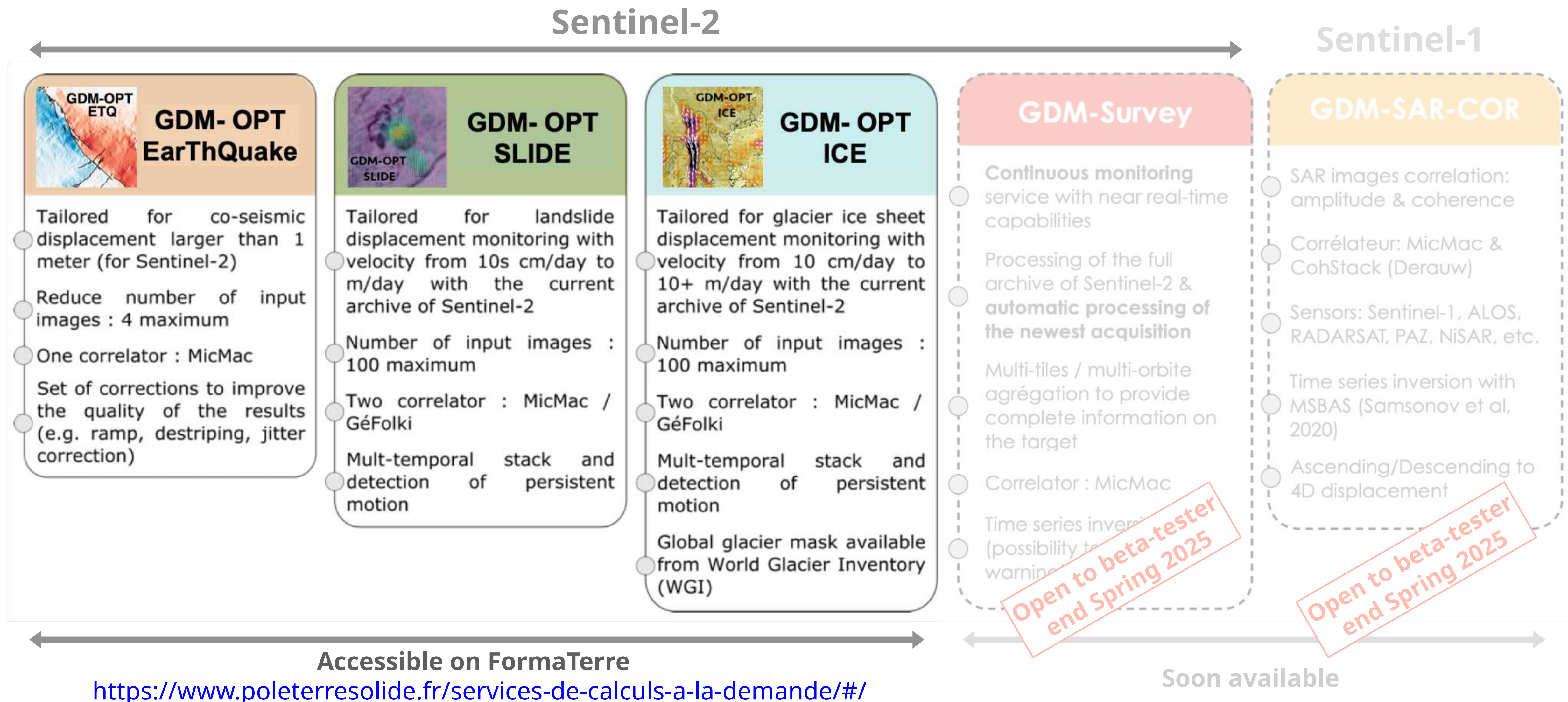
SNOW COVERAGE (%)

THEIA (satellite)
Gascoin et al, 2019



Provost et al.,(sub.)

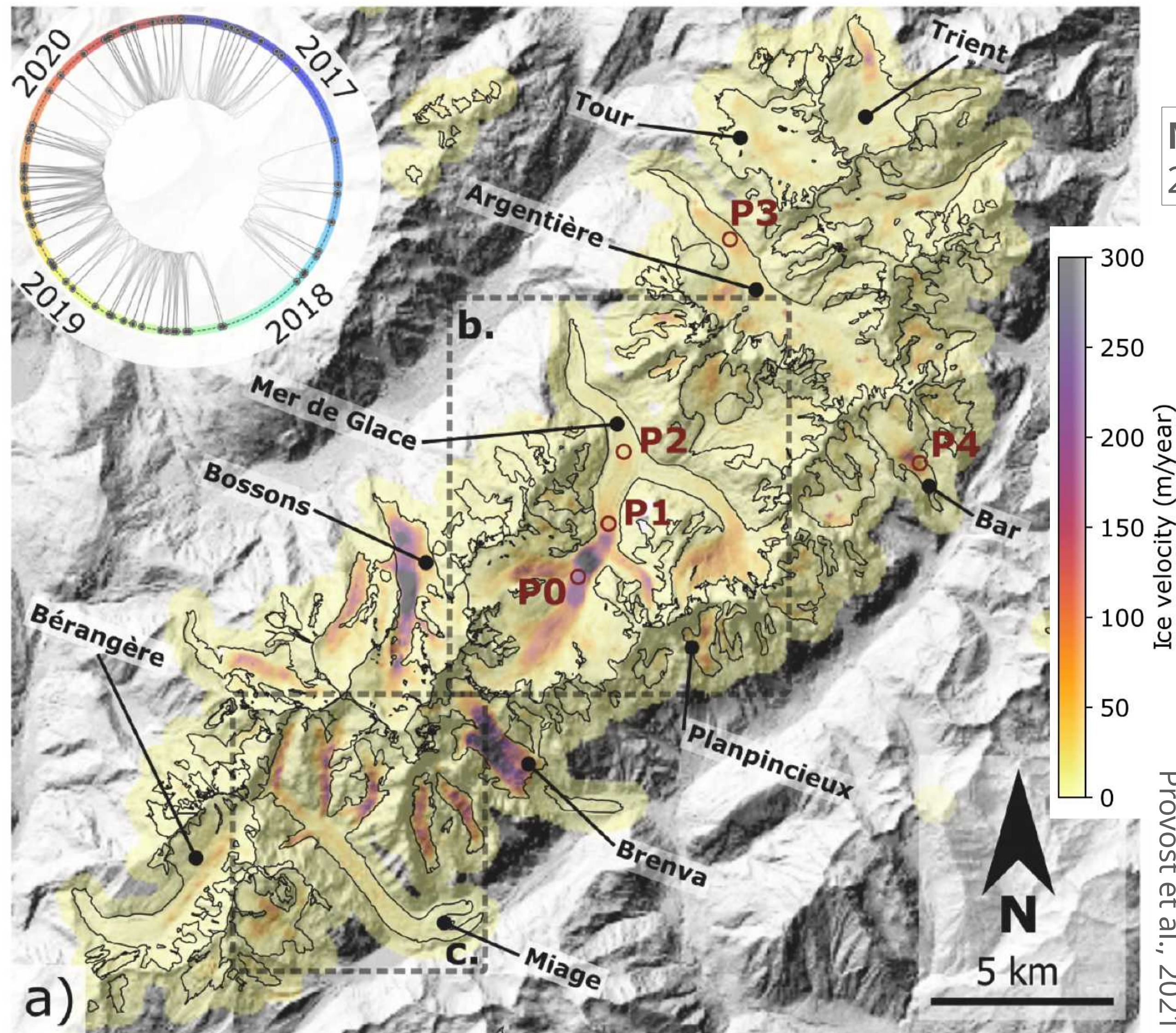
Formaterre & ISDeform | Webservices : Image Correlation (IC)



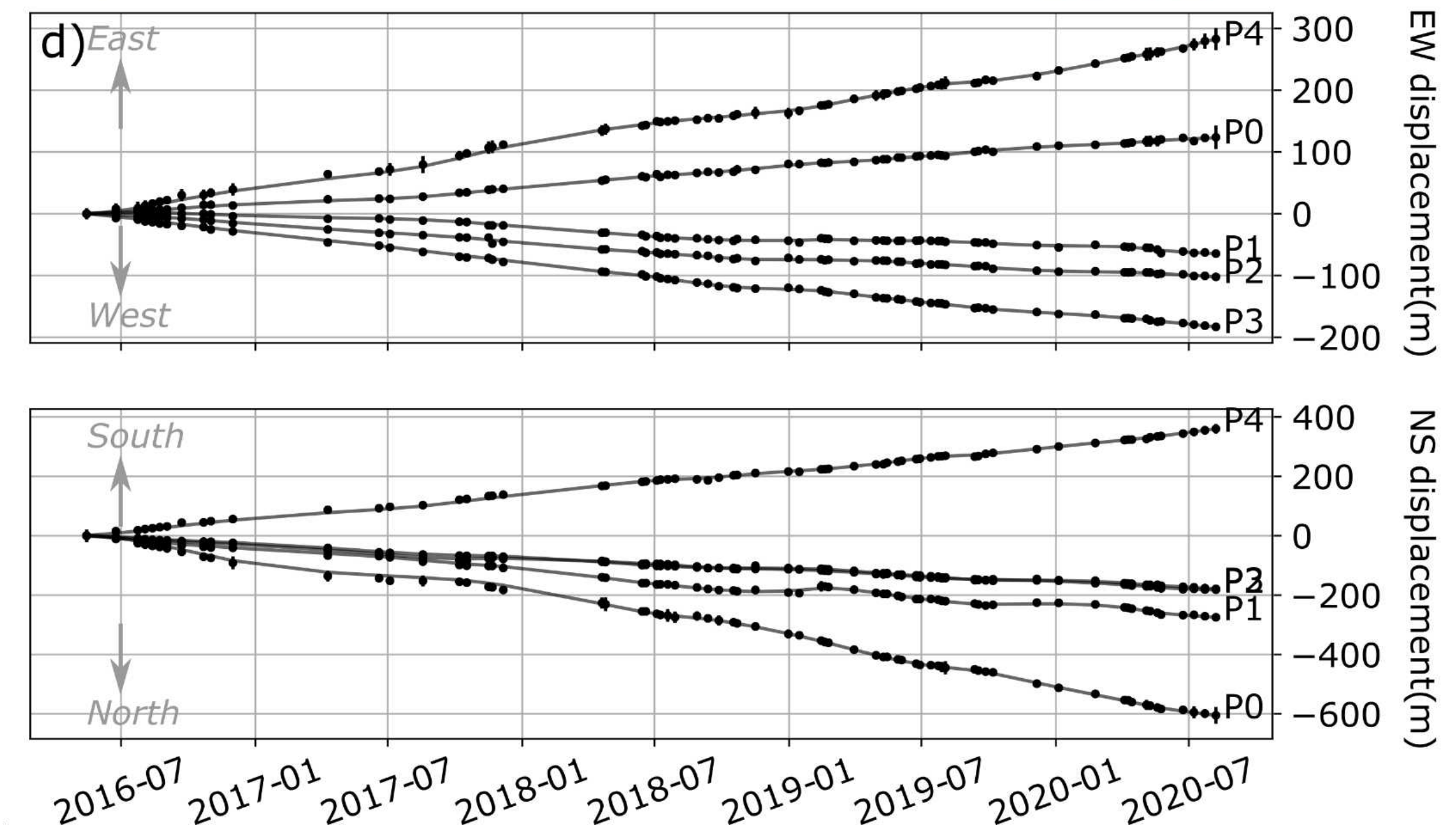
GDM-OPT-ICE | Measuring Ice surface velocity



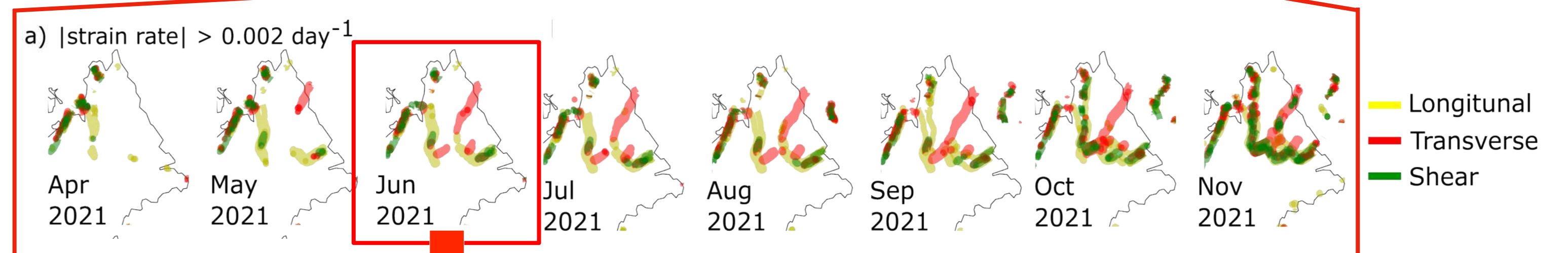
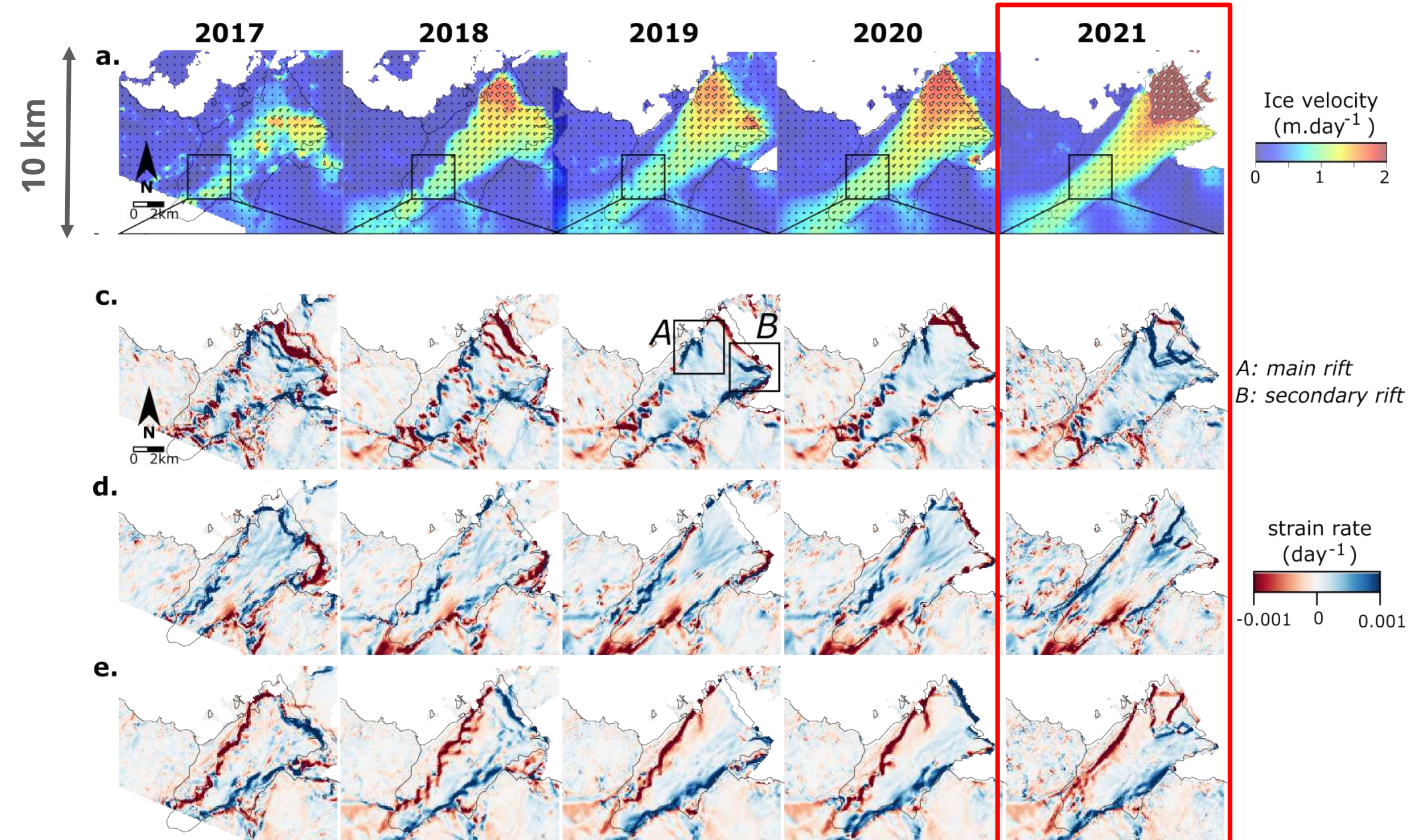
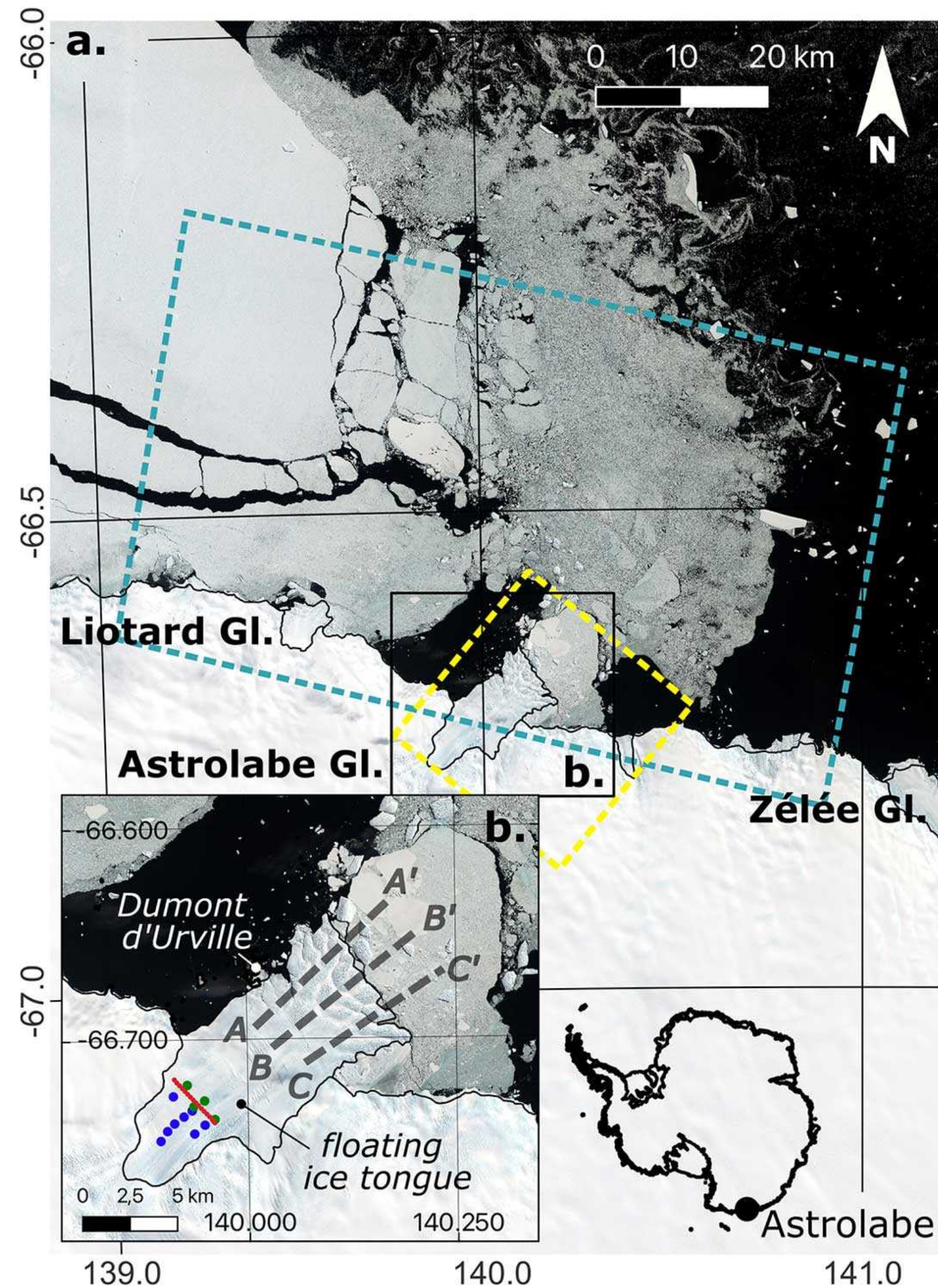
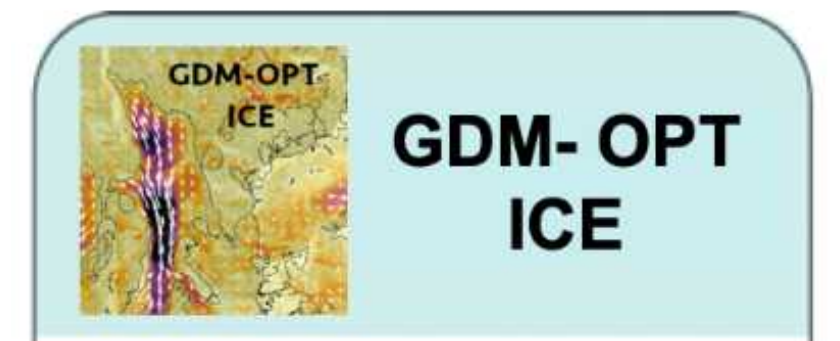
GDM- OPT
ICE



Mer de Glace glaciers (Fr, S, It)
2016-2020



GDM-OPT-ICE | Measuring Ice surface velocity



Rupture during the **Austral winter** (confirmed by Sentinel-1 images)

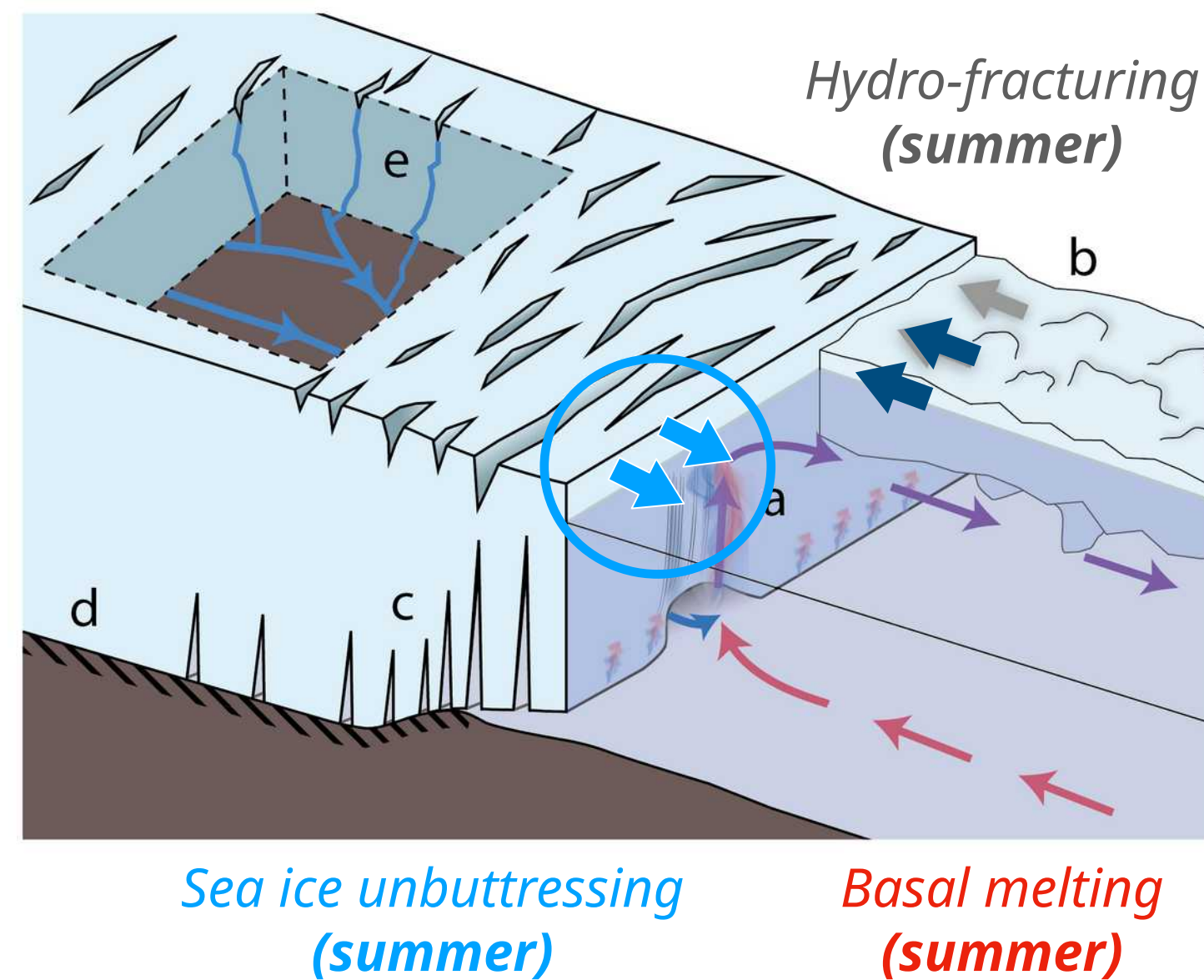
Provost et al., 2024

GDM-OPT-ICE | Measuring Ice surface velocity

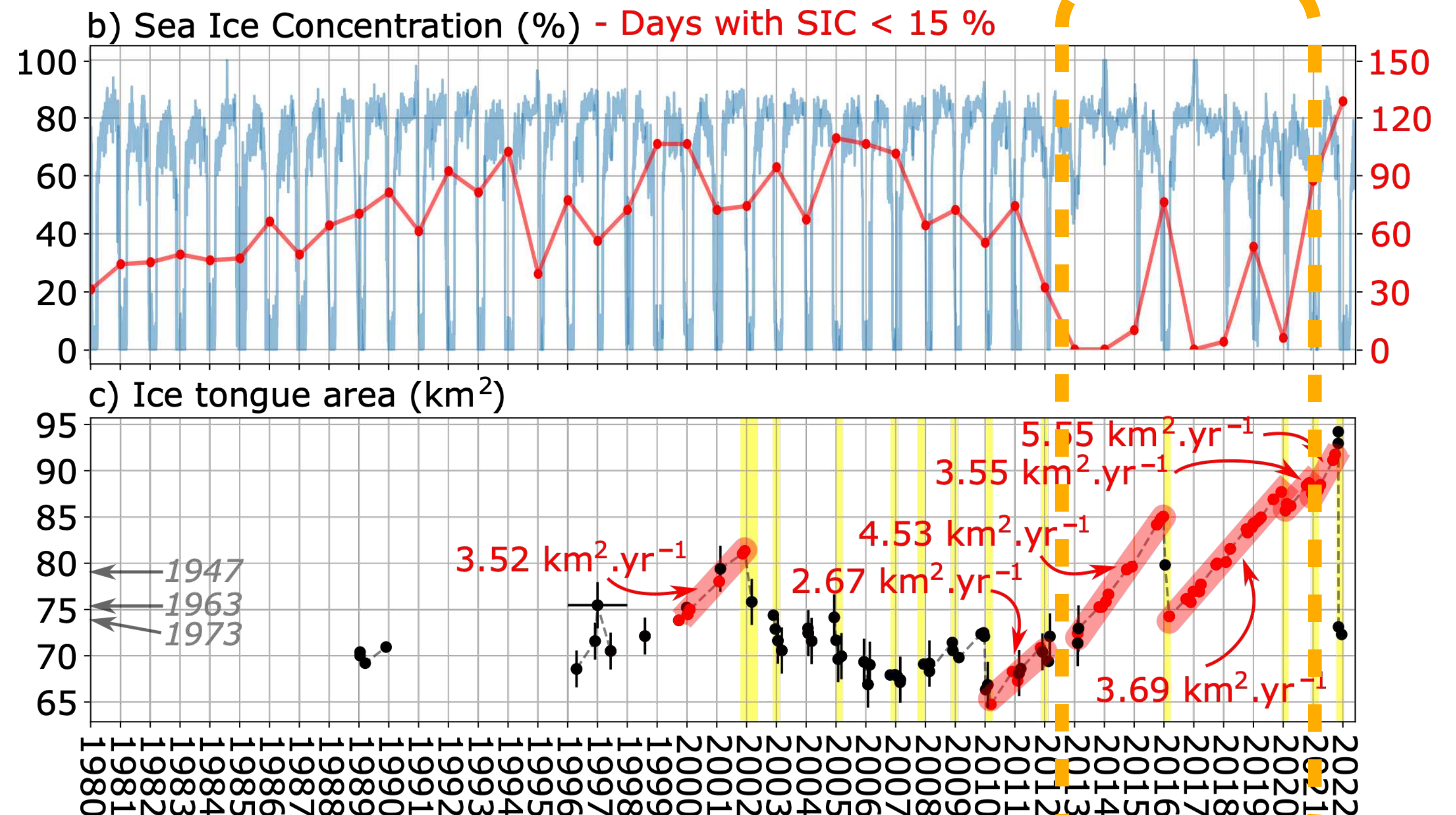


GDM- OPT
ICE

Mecanismos favoring fracturing and calving



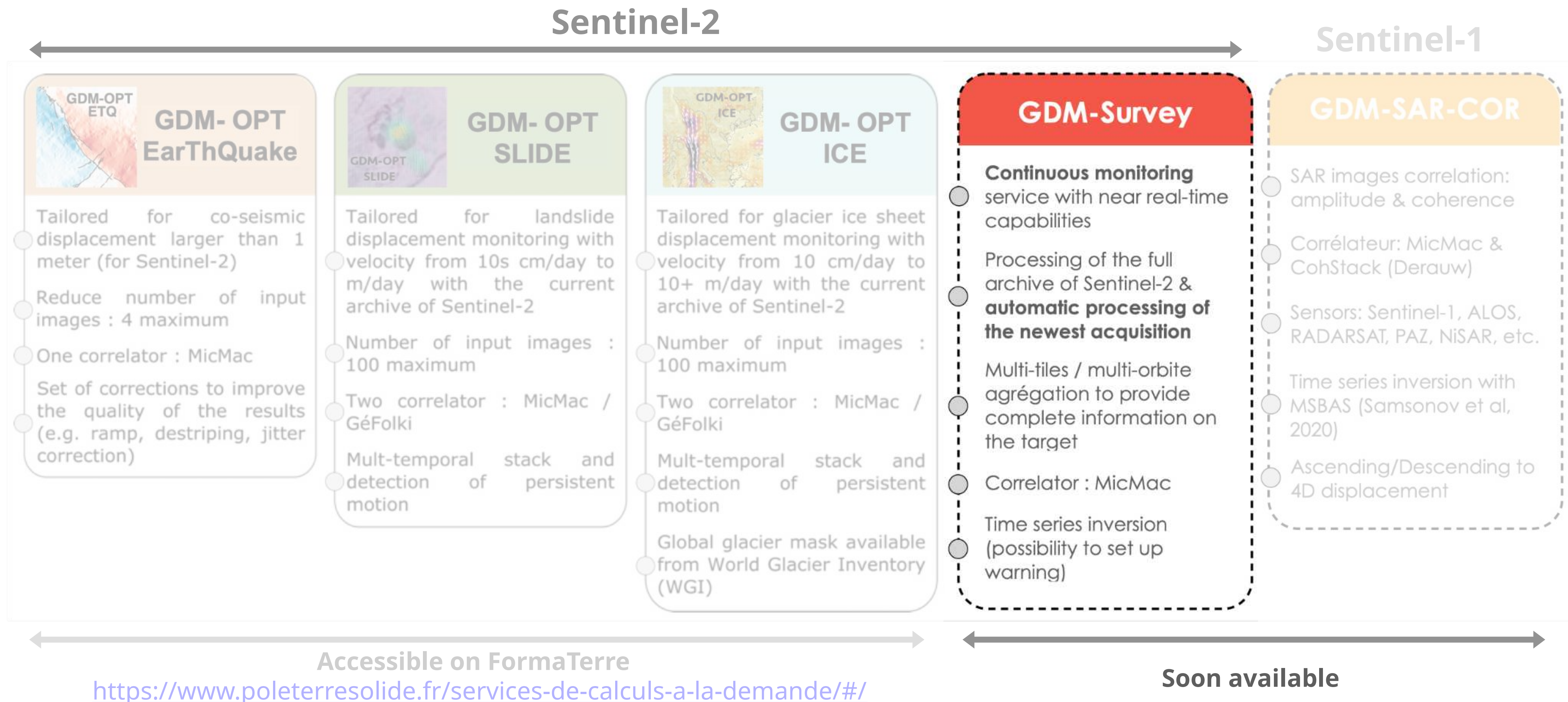
Period of persistent sea-ice

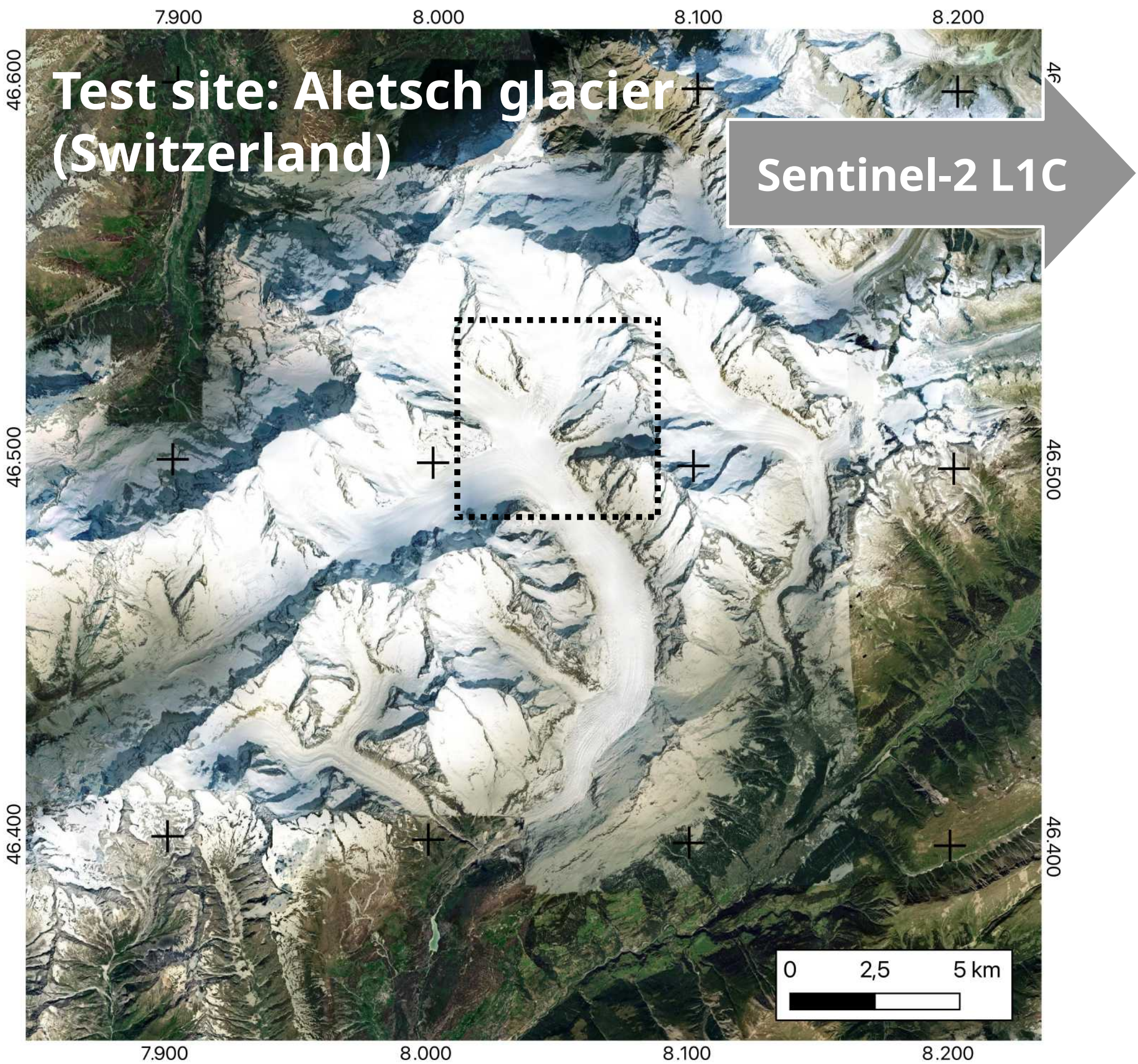


Provost et al., 2024

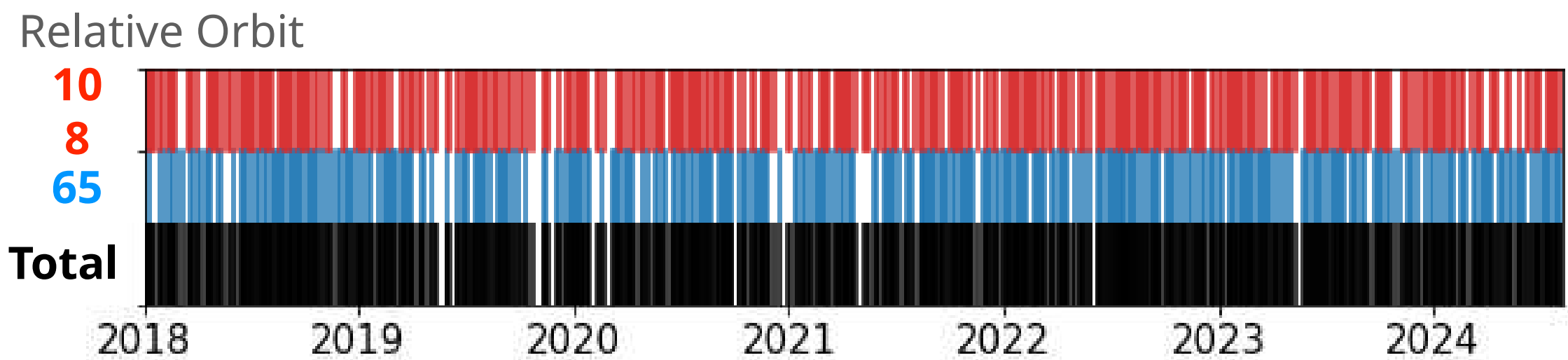
Period of persistent growth of
Astrolabe glacier

Formaterre & ISDeform | Webservices : Image Correlation (IC)



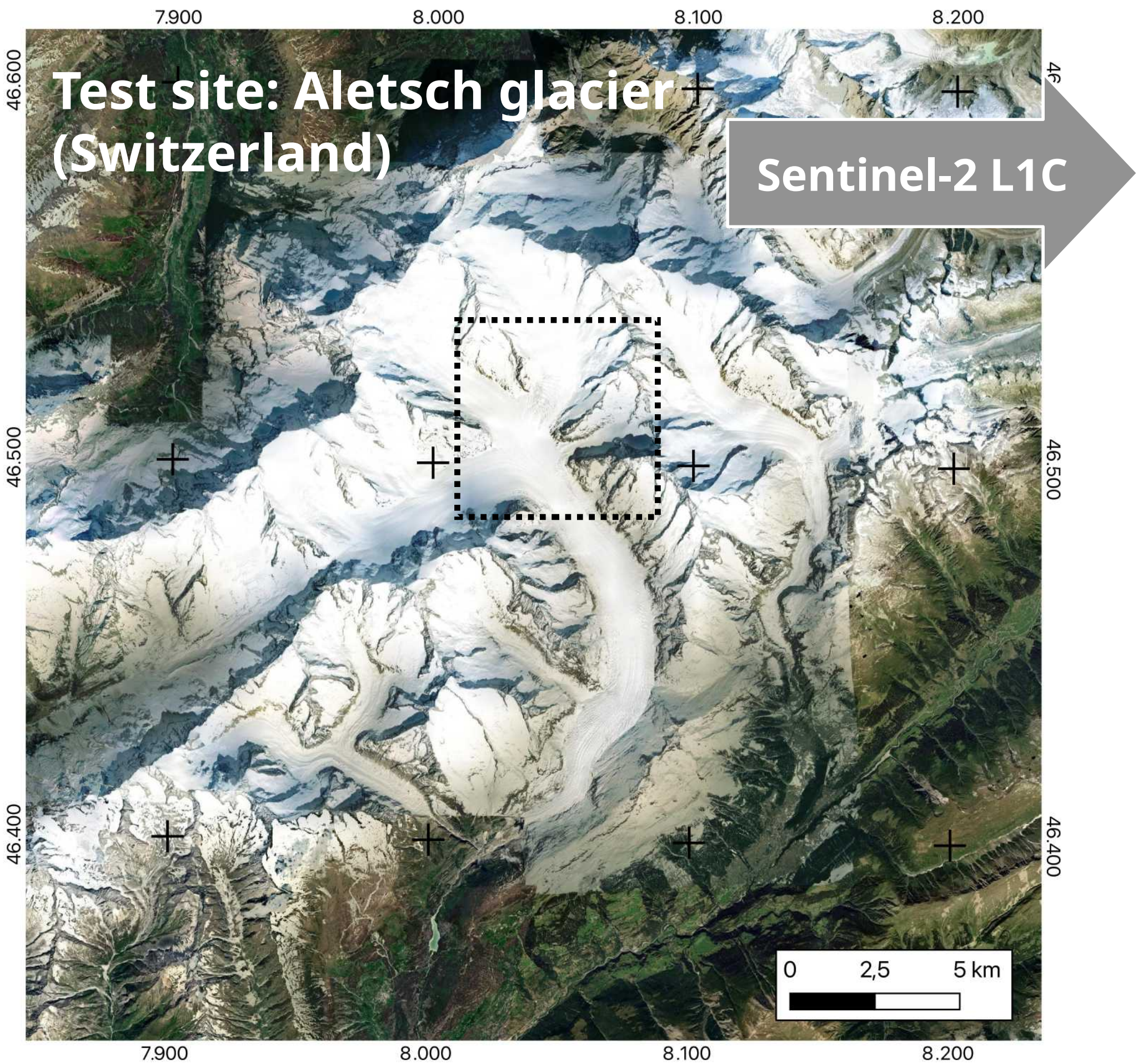


1. GDM-Survey is « multi-tile », « multi-orbit »

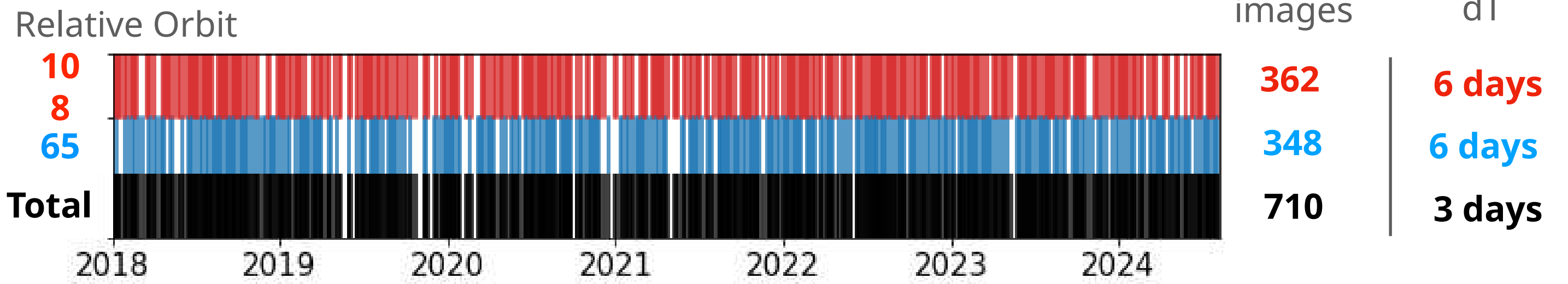


Nb of images	Mean dT
362	6 days
348	6 days
710	3 days

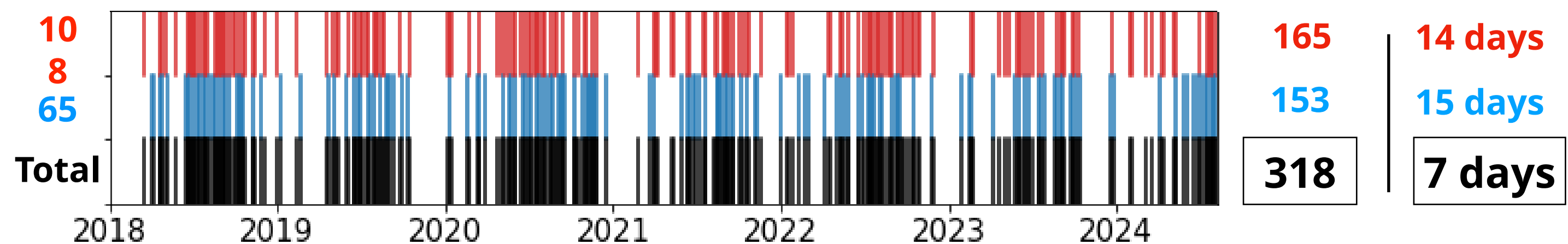
GDM-OPT-Survey | Continuous monitoring of GM



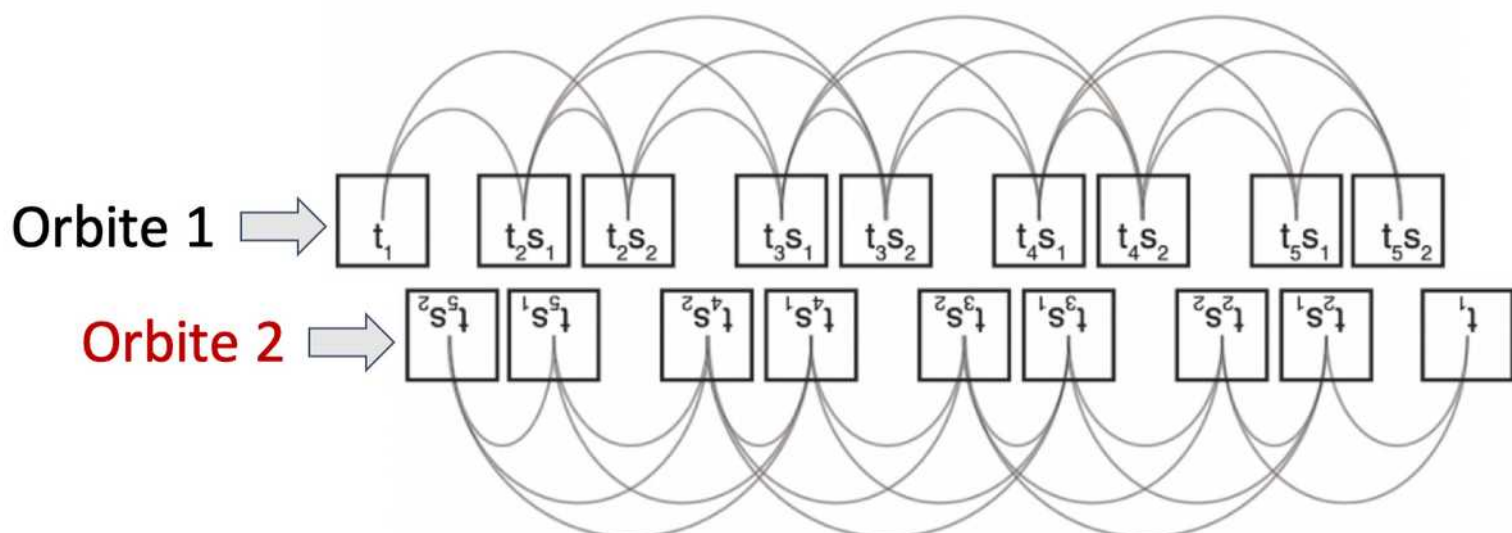
1. GDM-Survey is « multi-tile », « multi-orbit »



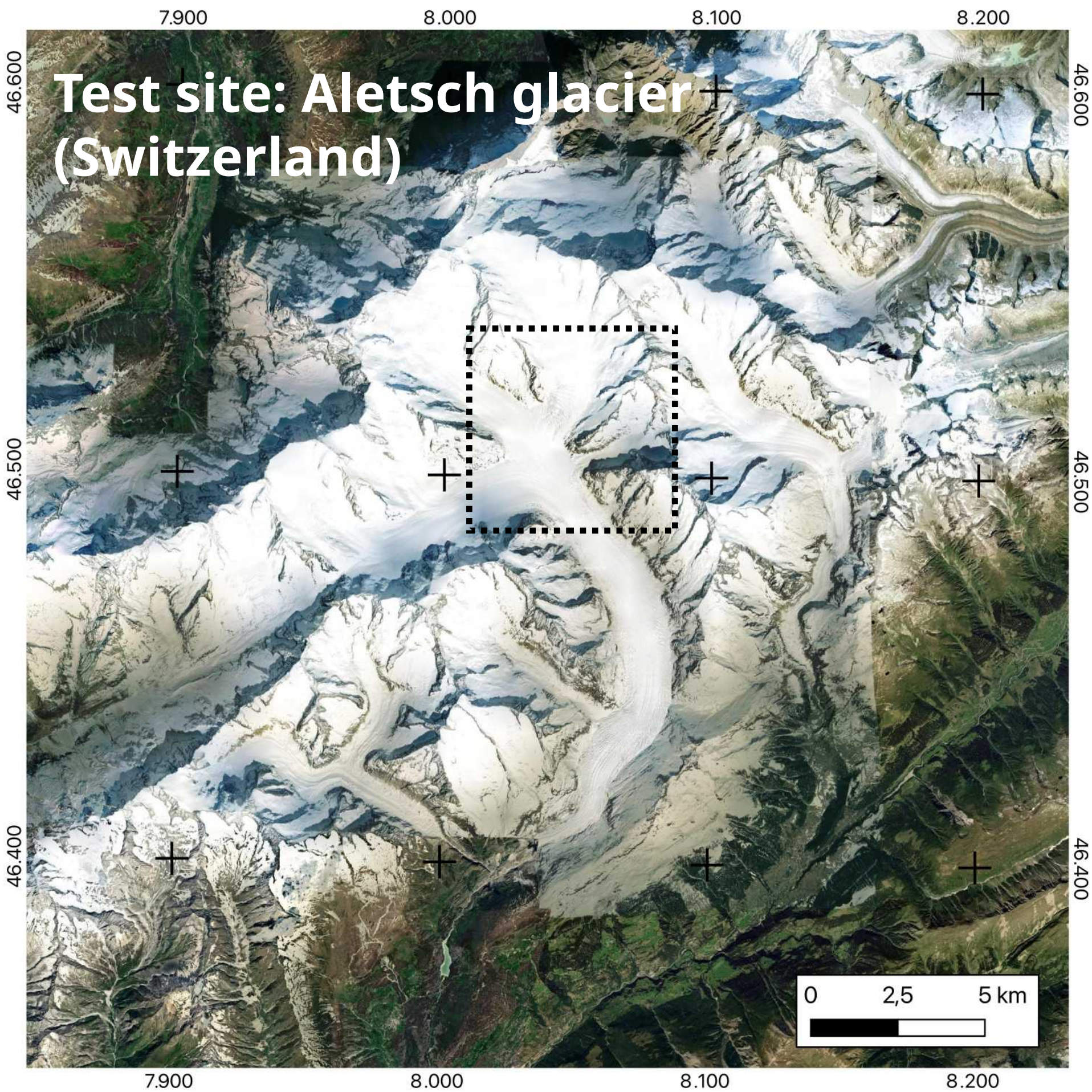
2. Cloud-coverage is computed on the AOI



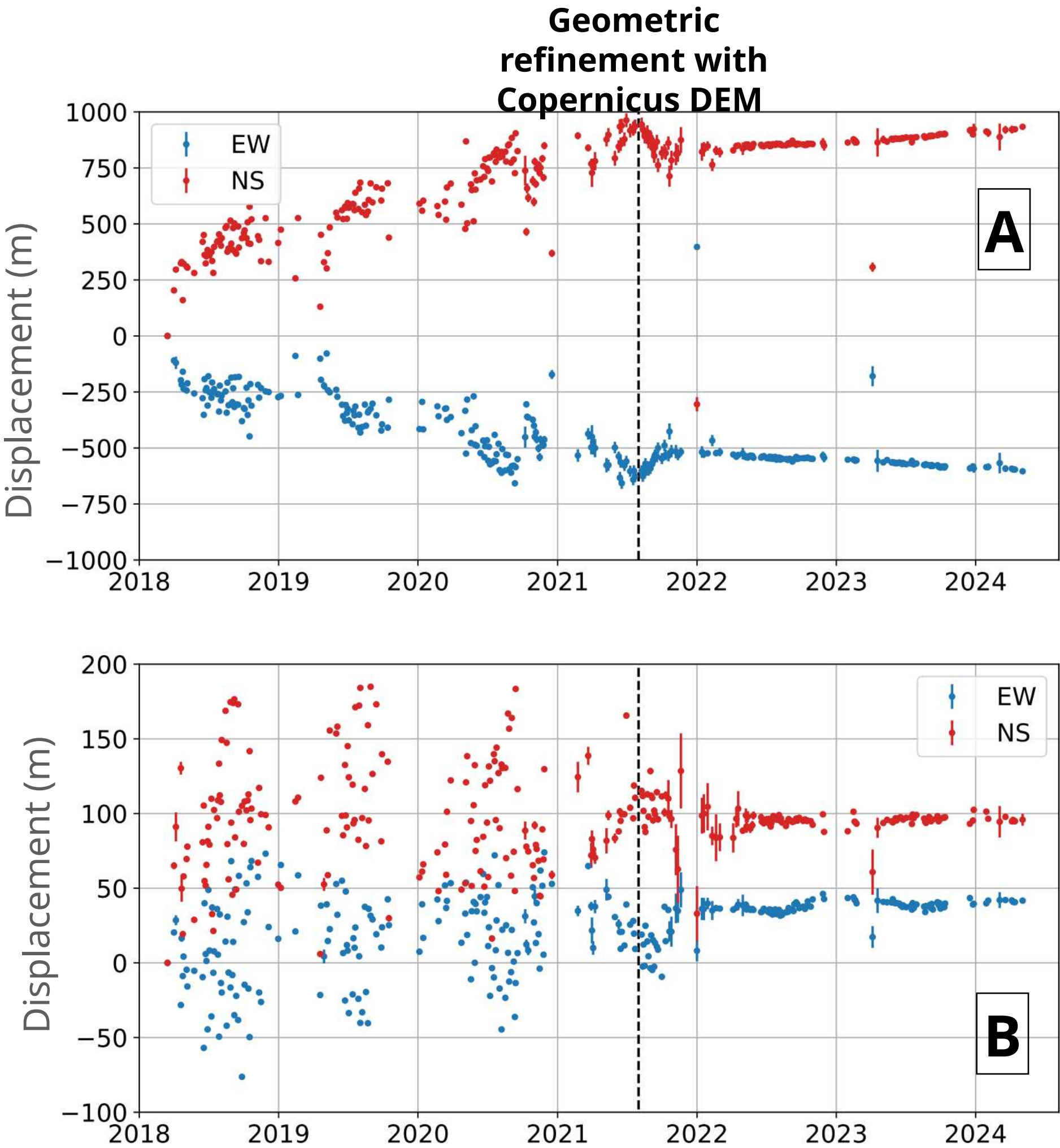
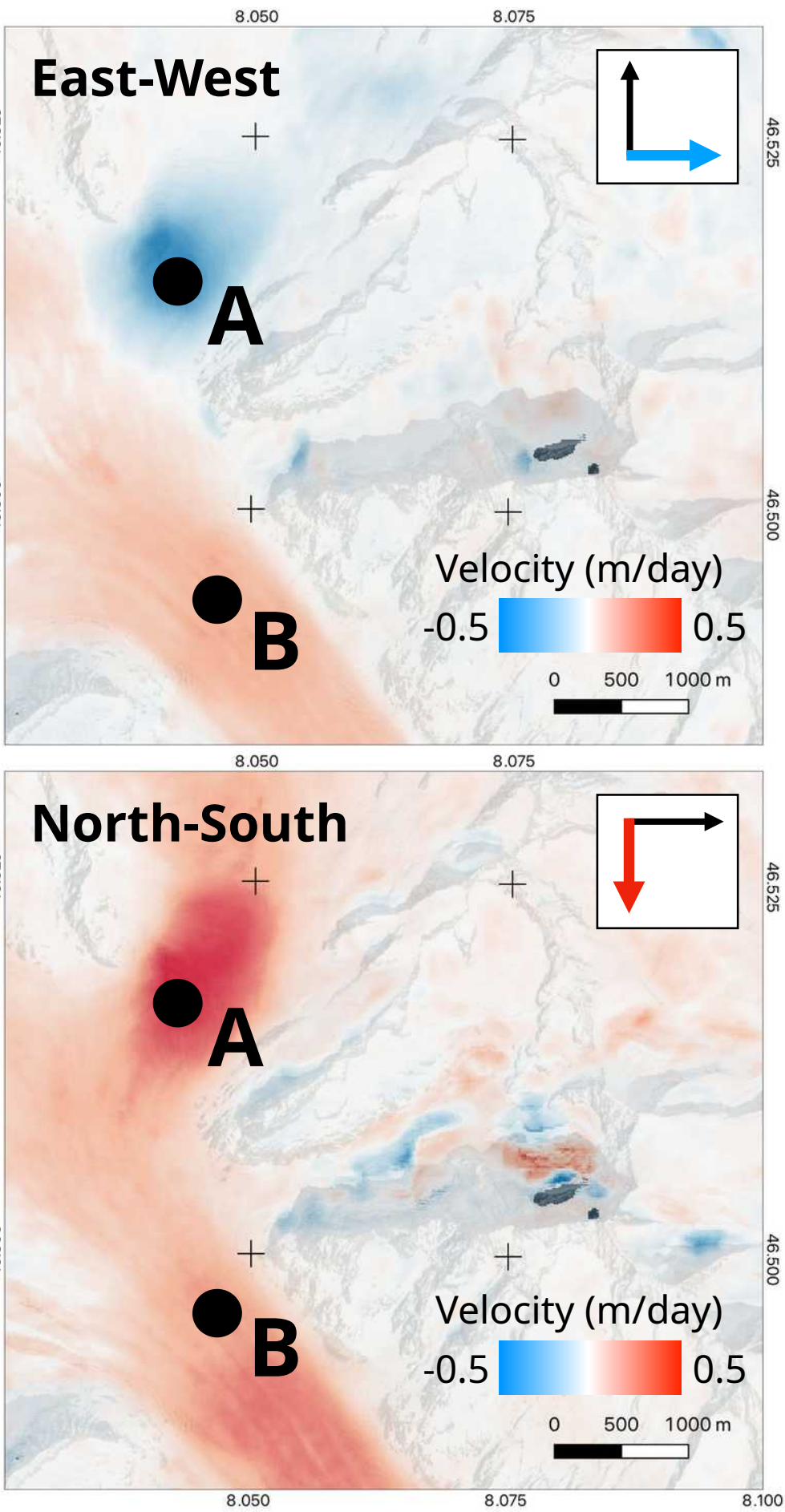
3. Paires are created per orbit



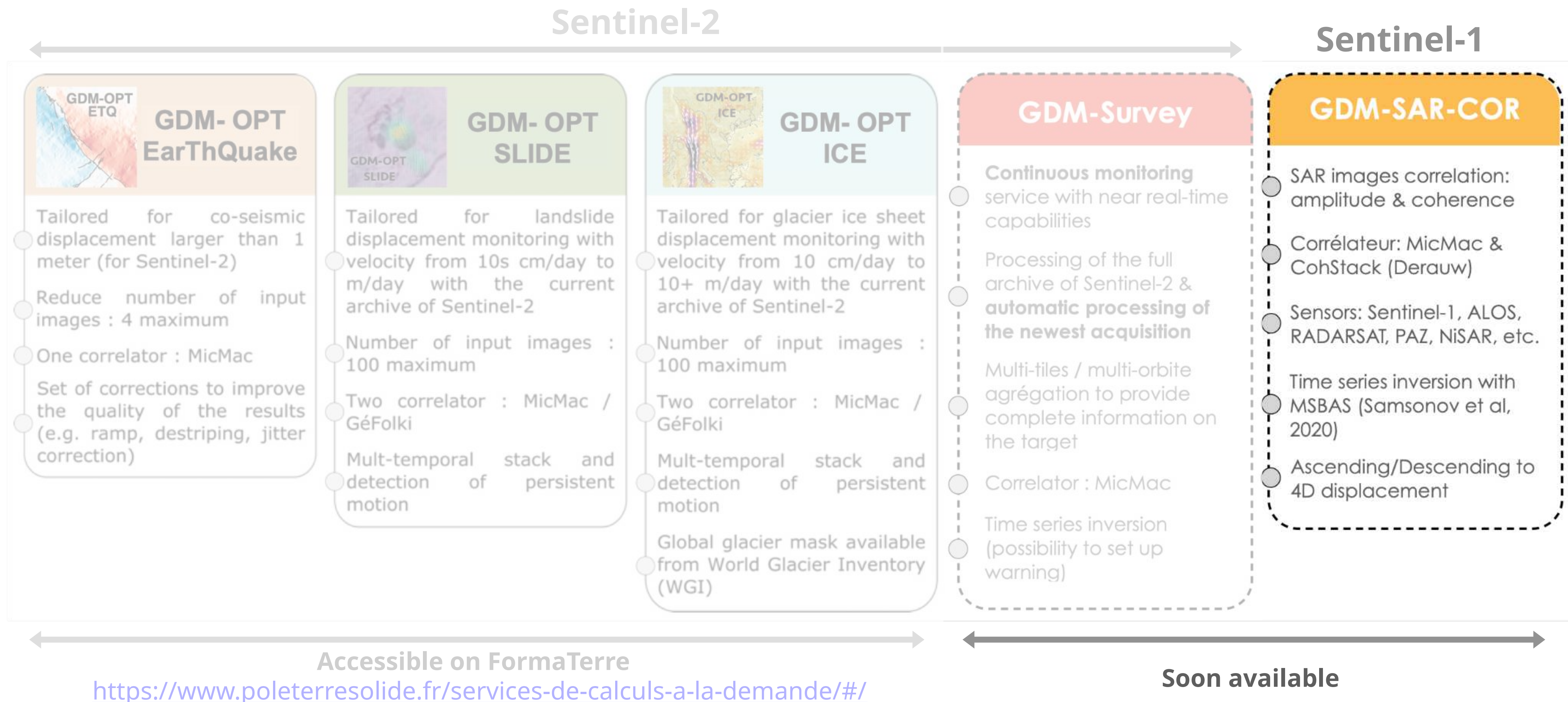
GDM-OPT-Survey | Continuous monitoring of GM



GDM-Survey (2018-2024)



Formaterre & ISDeform | Webservices : Image Correlation (IC)

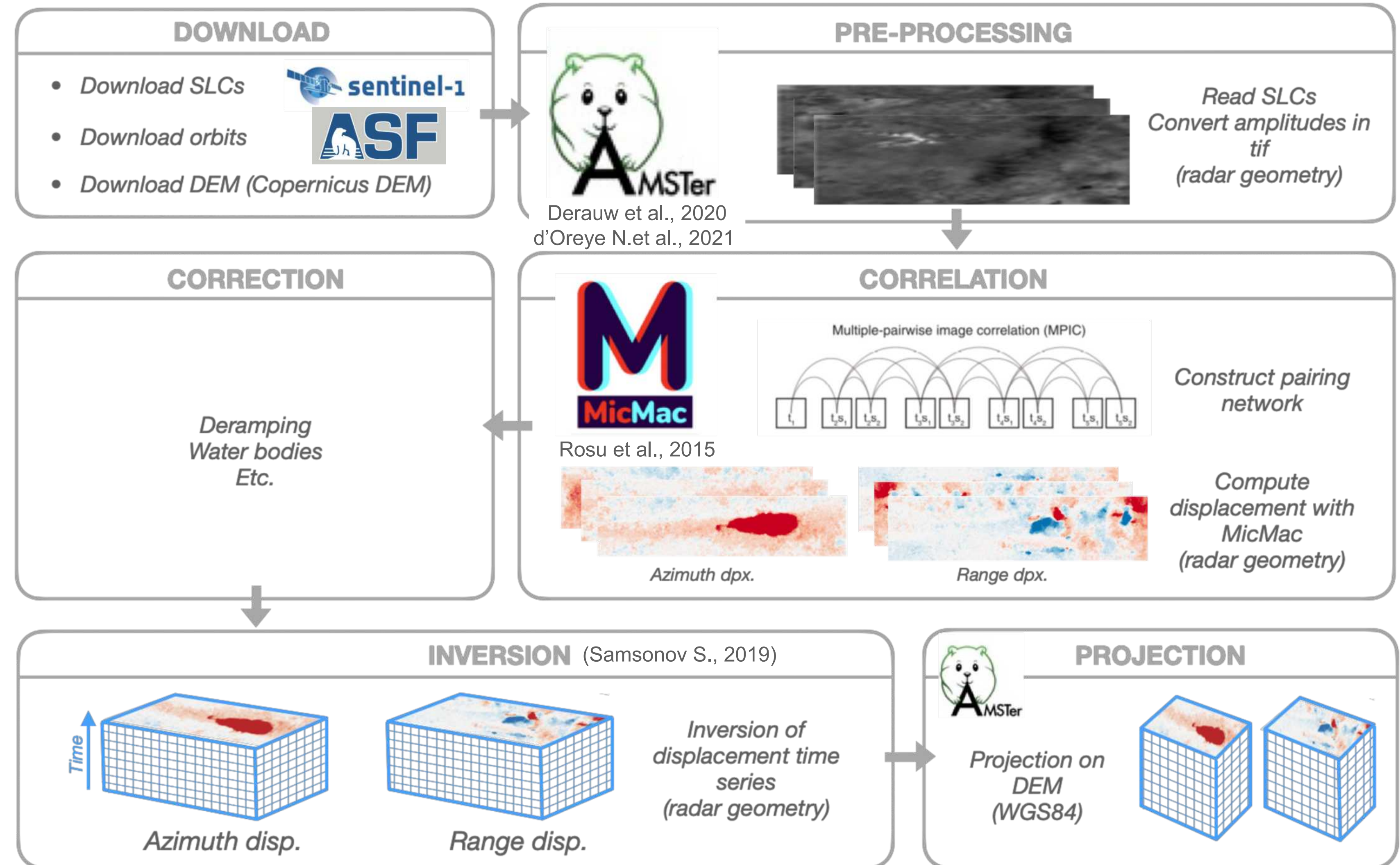


GDM-SAR-cor | Correlation of S1 images

GDM-SAR-COR

GDM-SAR-COR

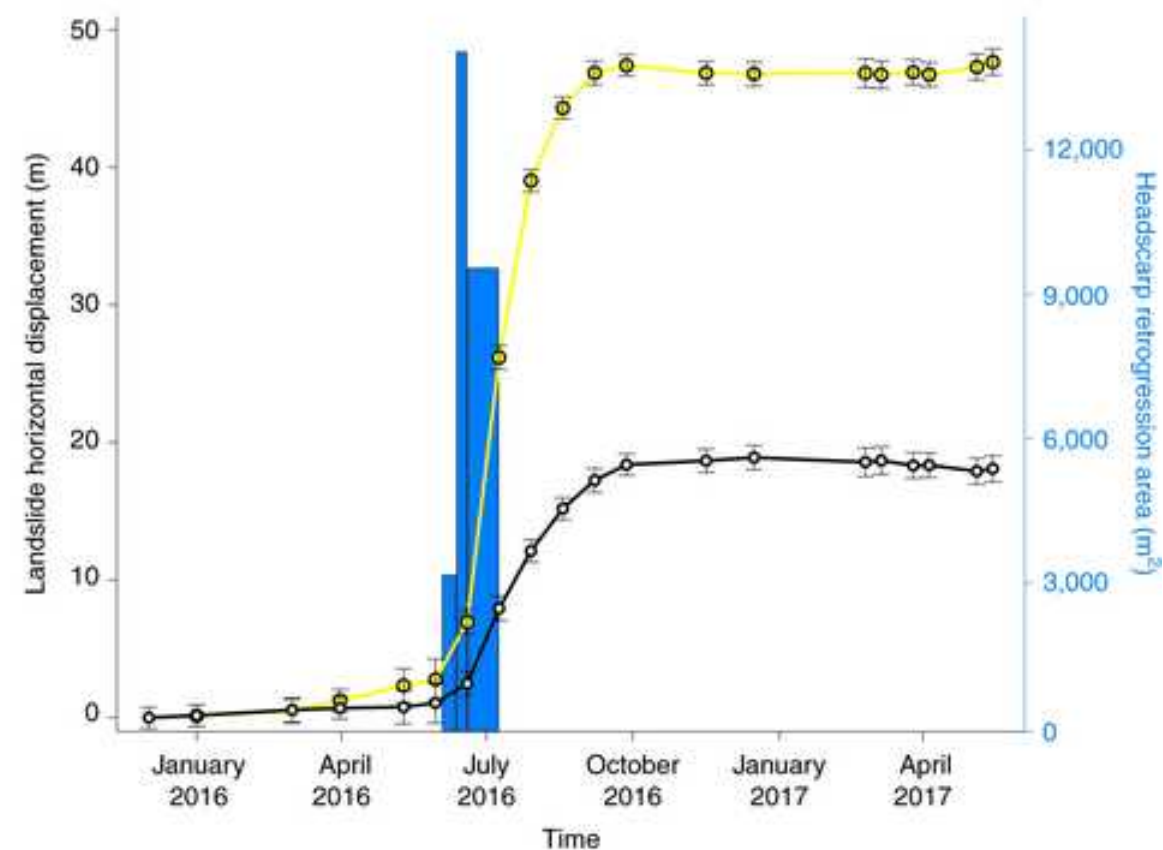
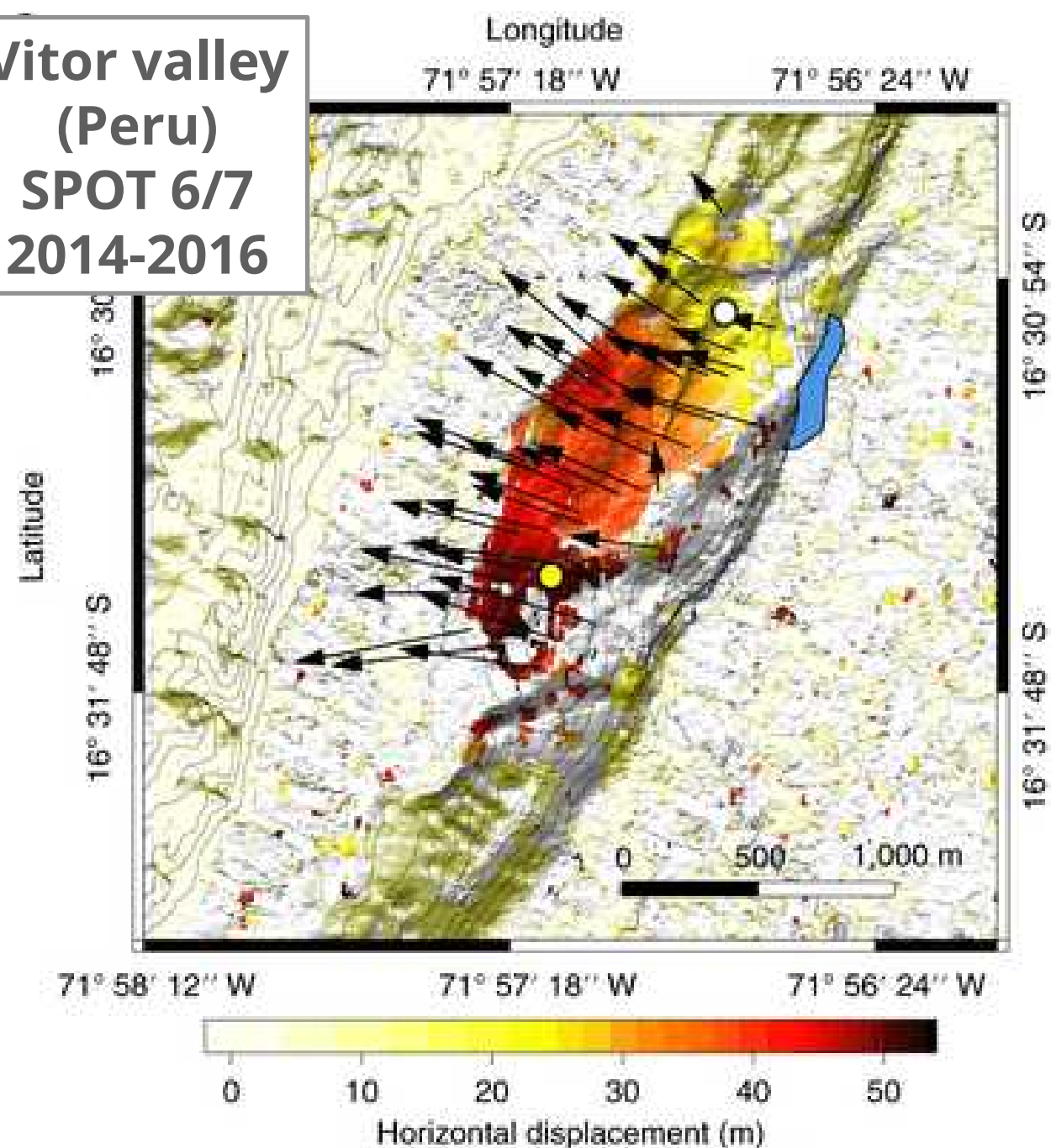
- SAR images correlation: amplitude & coherence
- Corrélateur: MicMac & CohStack (Derauw)
- Sensors: Sentinel-1, ALOS, RADARSAT, PAZ, NiSAR, etc.
- Time series inversion with MSBAS (Samsonov et al, 2020)
- Ascending/Descending to 4D displacement



GDM-SAR-cor | Correlation of S1 images

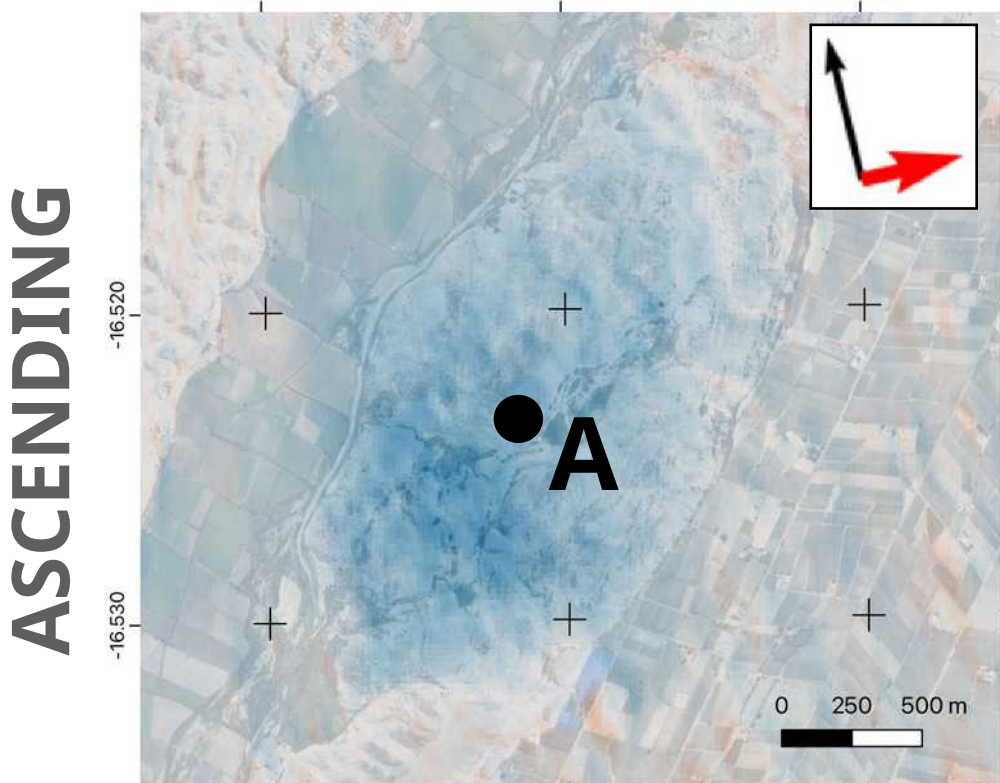


Vitor valley
(Peru)
SPOT 6/7
2014-2016

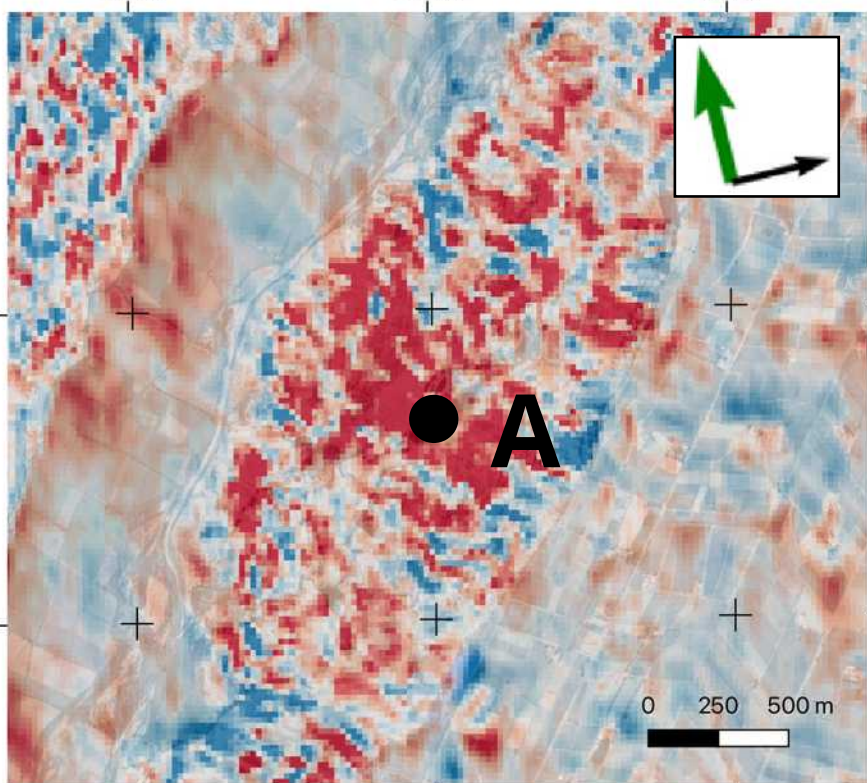


Lacroix et al., 2020

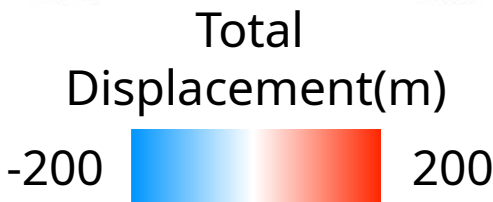
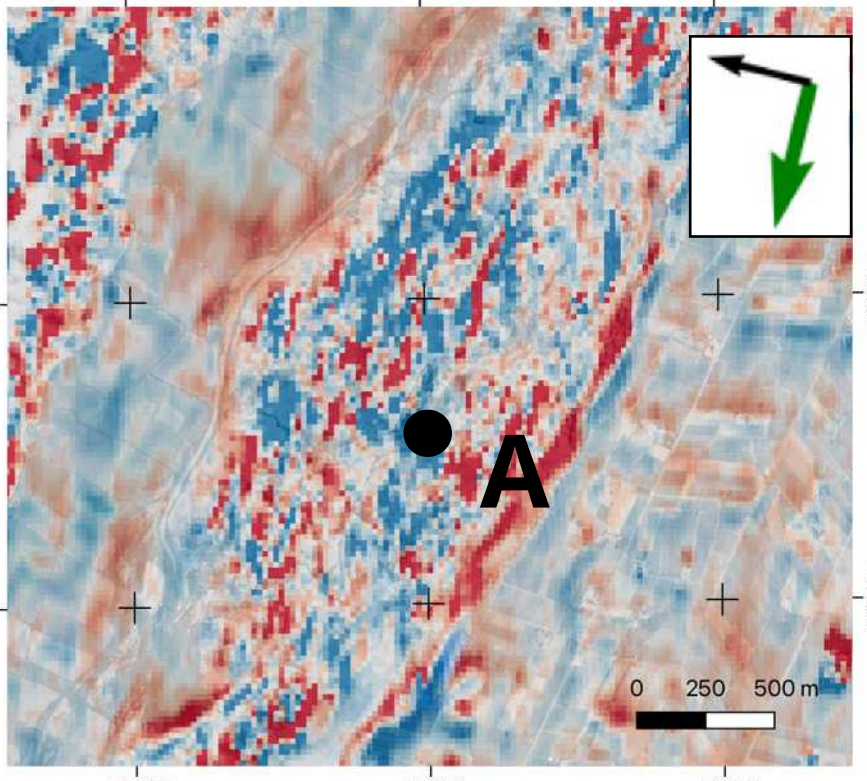
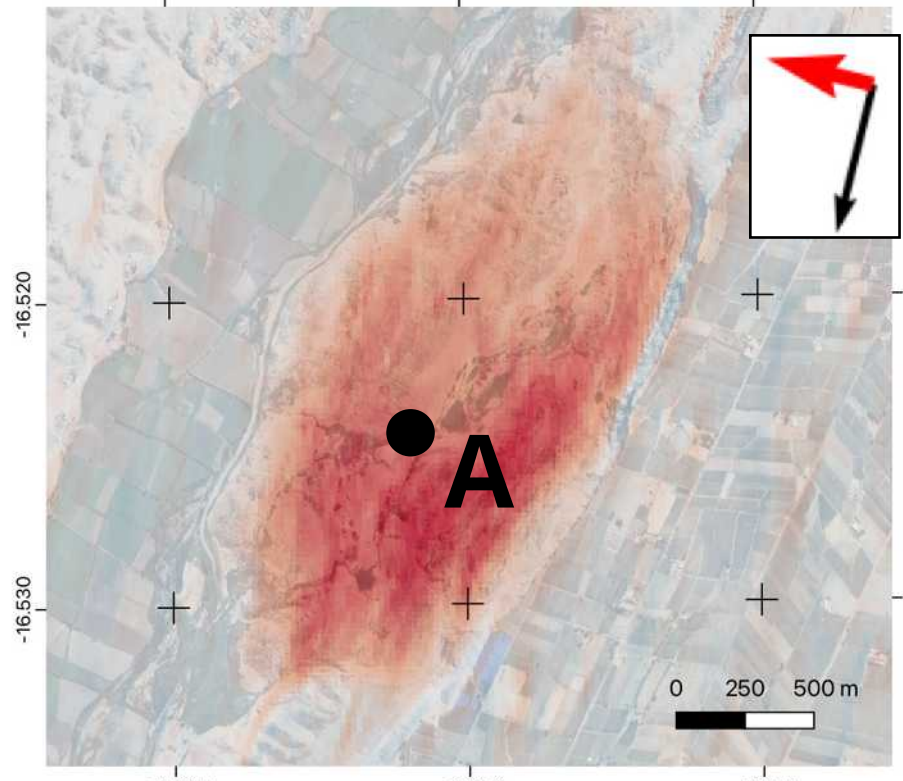
Range direction



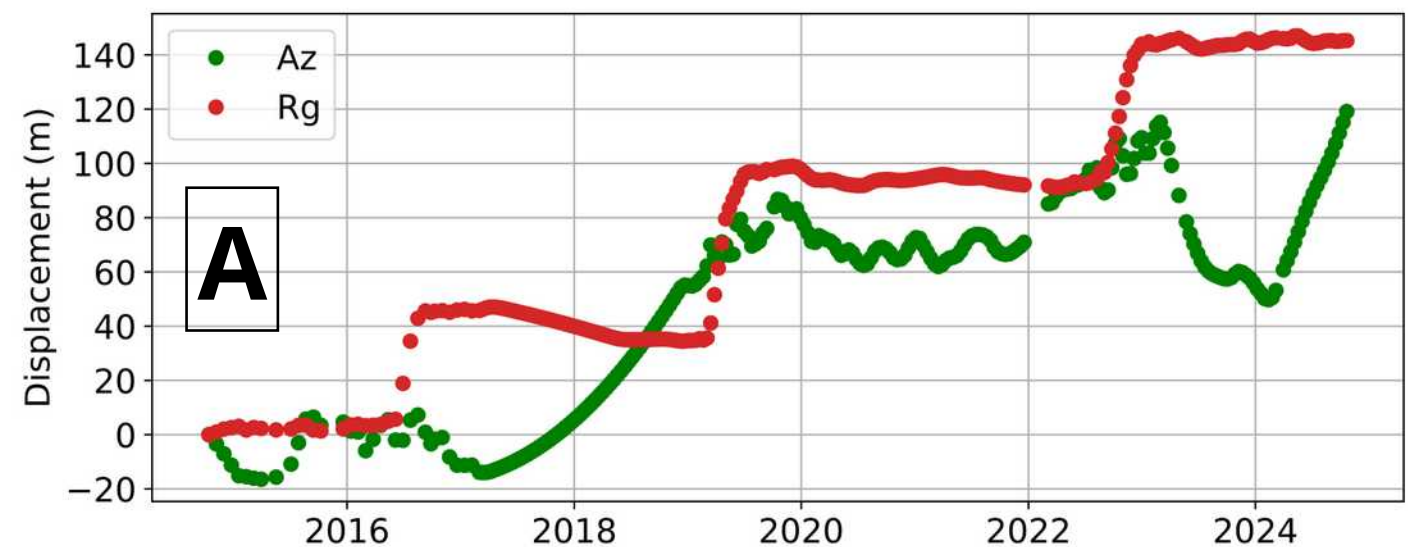
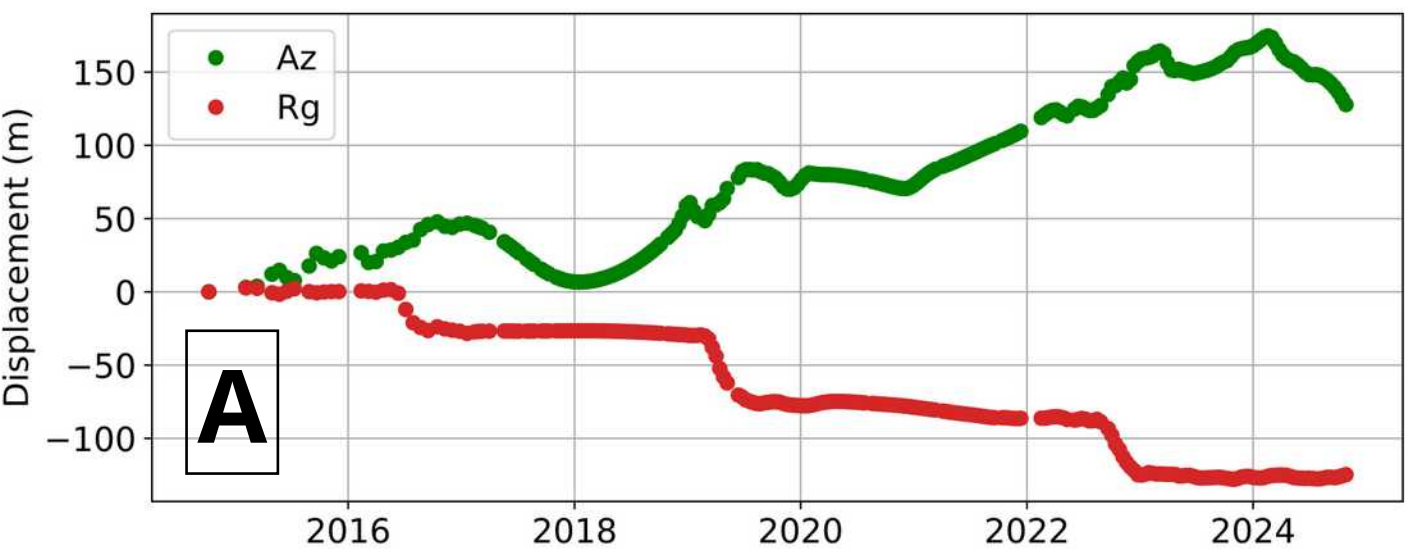
Azimuth direction



DESCENDING



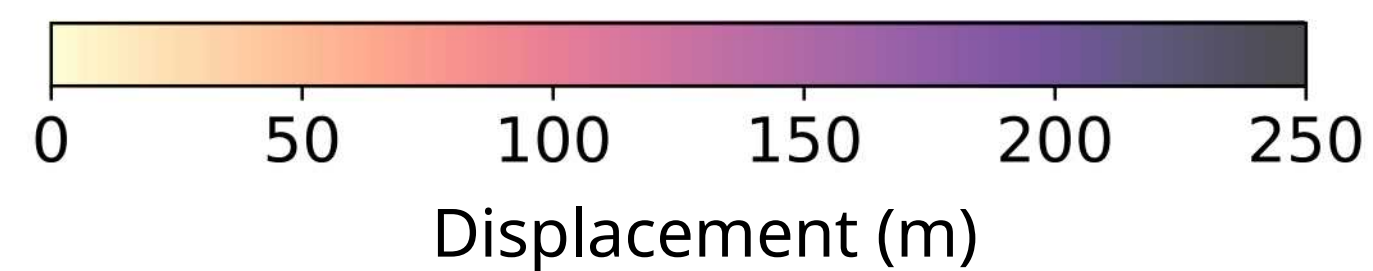
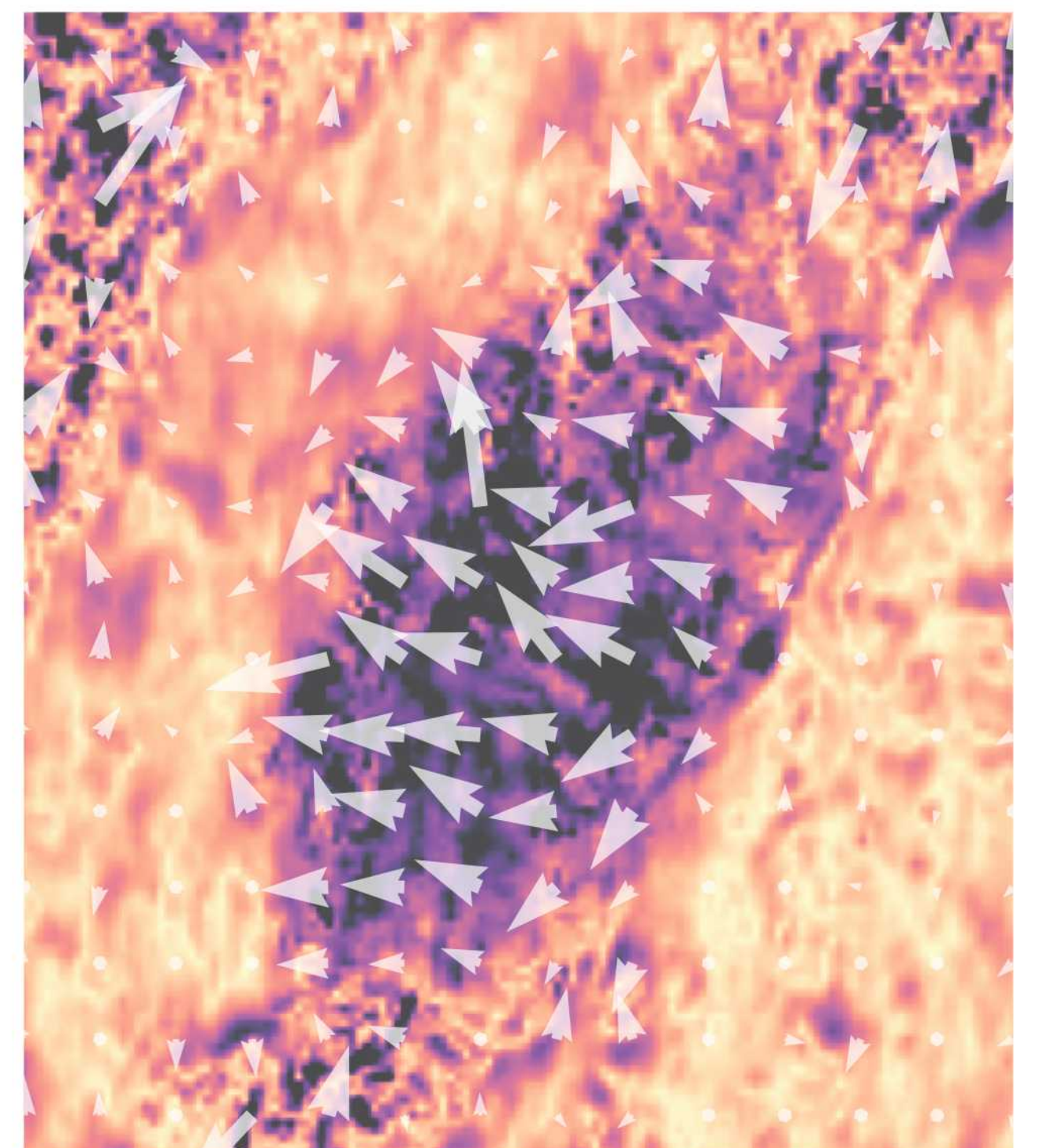
Vitor valley (Peru)
GDM-SAR-Cor | Sentinel-1
2014-2024
(12 days frequency ~250 images)



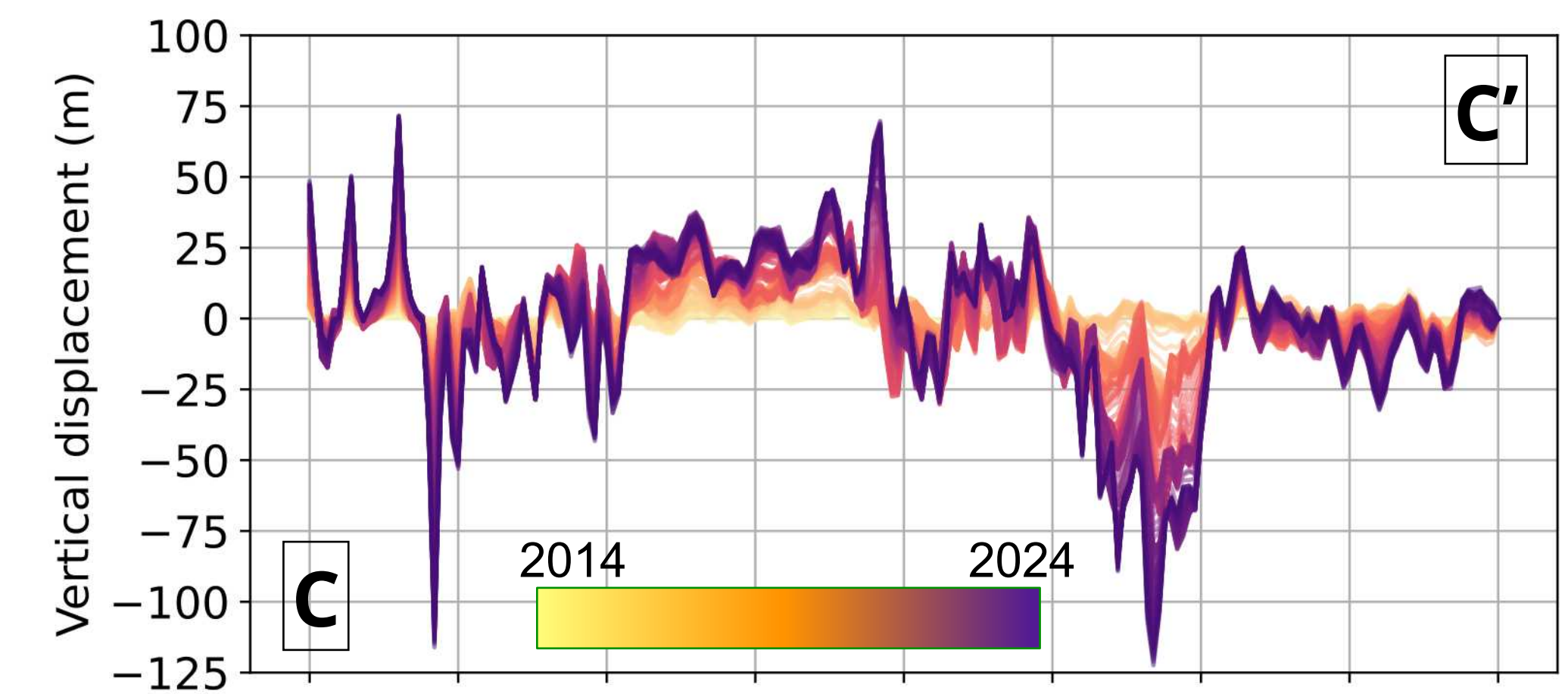
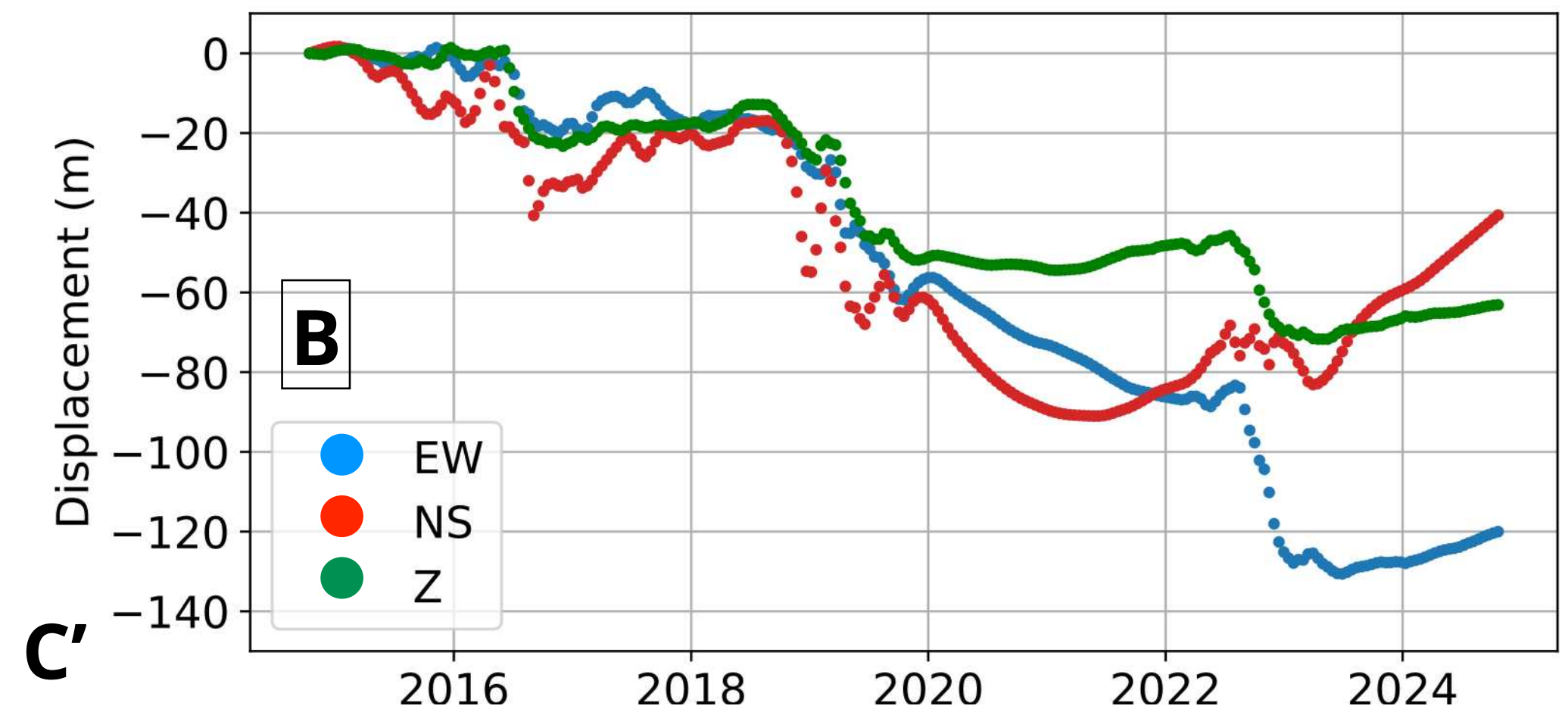
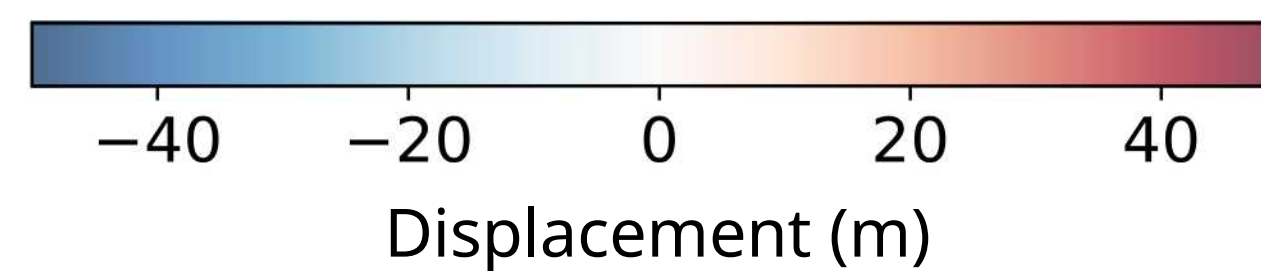
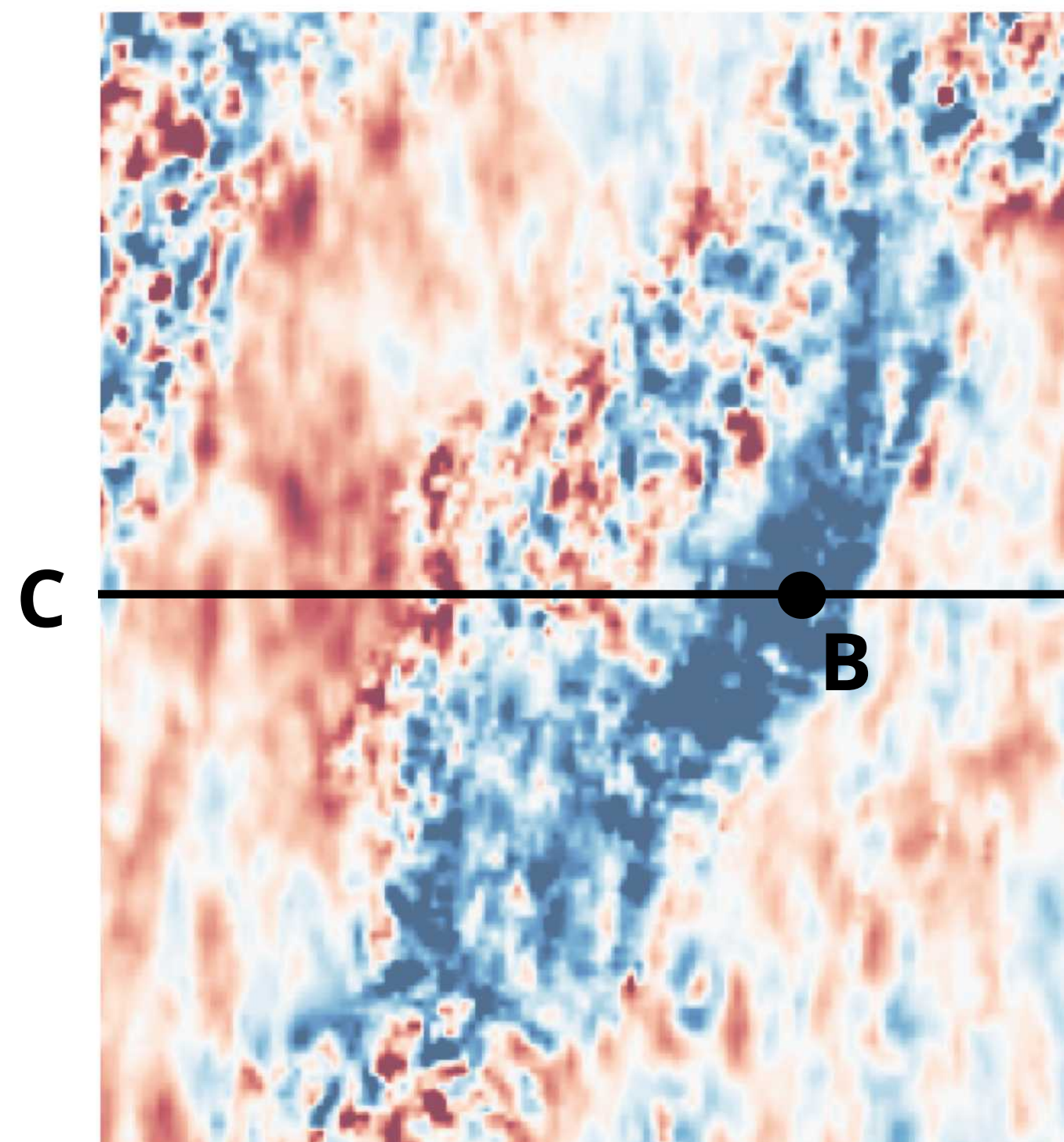
GDM-SAR-cor | Inversion of 3D displacement

GDM-SAR-COR

HORIZONTAL

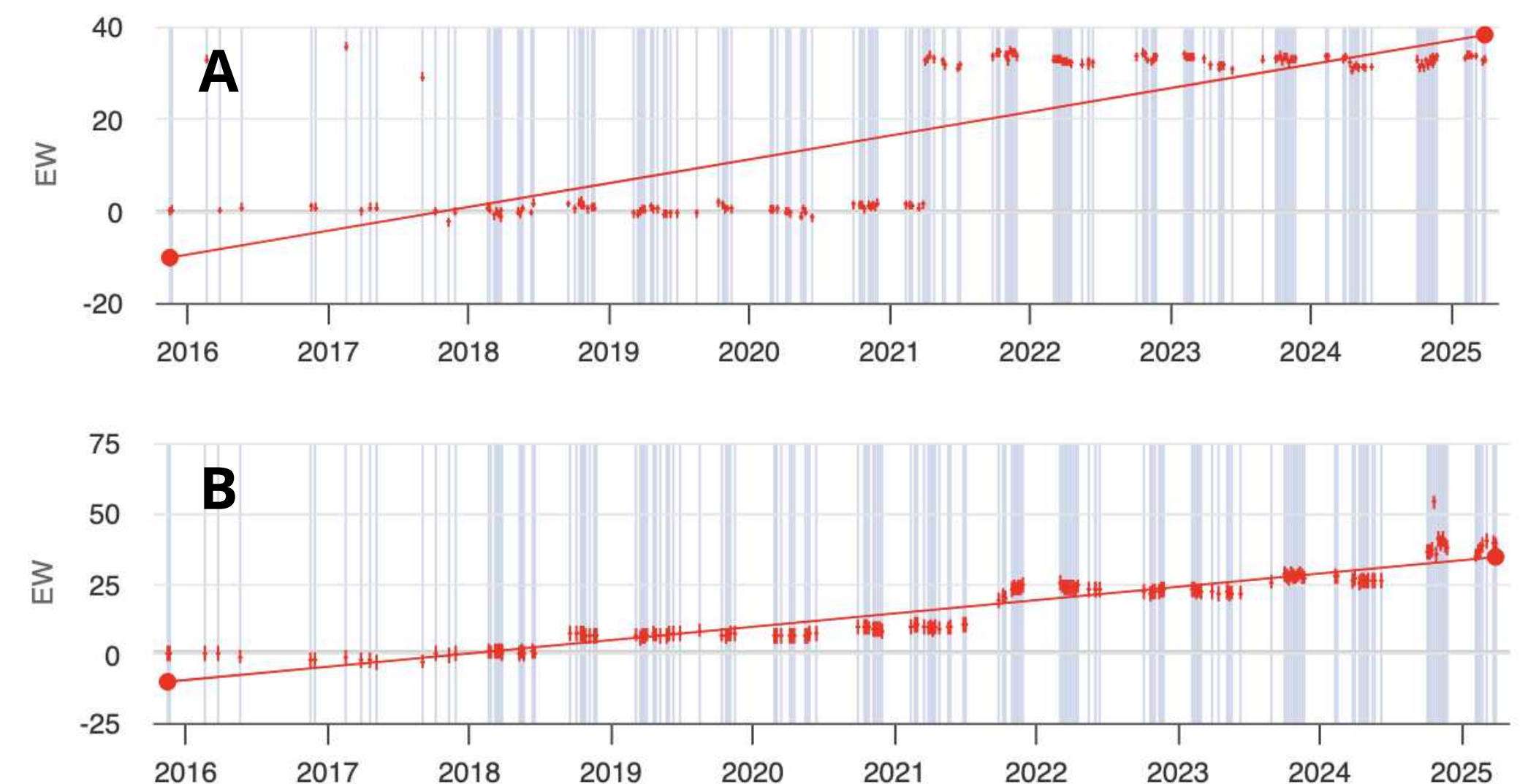
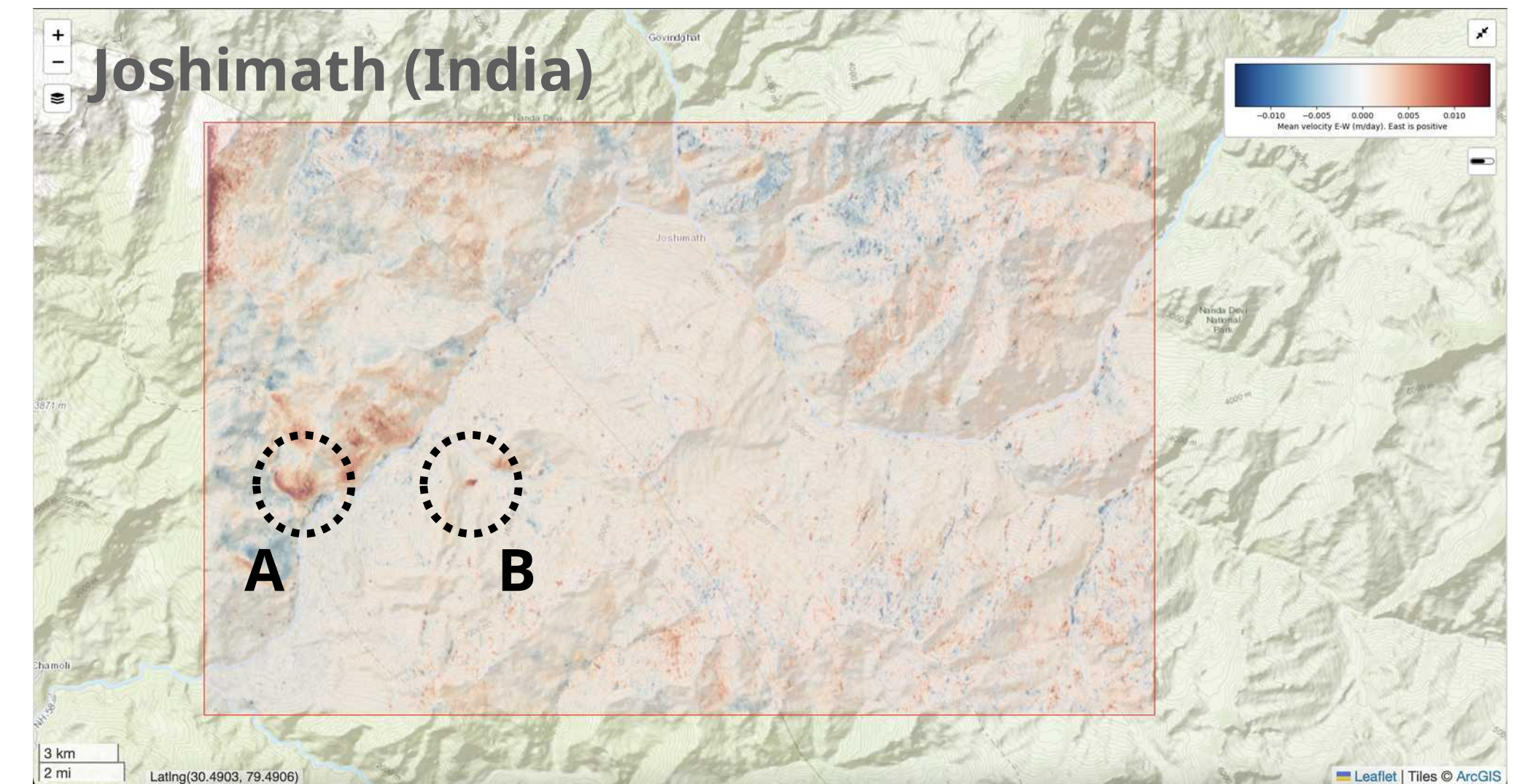


VERTICAL



GDM-OPT/SAR | Conclusions & Perspectives

- **5 webservices for image correlation**
 - 3 active since 4 years : 90+ users | 5000+ runs
 - 2 in Beta test : GDM-Survey | GDM-SAR-Cor
 - In perspective: integration of other catalogues | Landsat, Pléiades, Planet, + radar missions, ...
- **Sentinel-2 for ground motion monitoring**
 - 10 years time series : unique archive for studying the landslides/glaciers evolution at local, regional (?) global(?) scale...
 - Landside monitoring:
 - many examples of application to complement S1 InSAR processing;
 - Regional/global inventory: limitations due to **geometric accuracy of Sentinel-2 L1C** images;
 - Sentinel-2 NG:
 - increase of **spatial resolution** => more « objects » detected (smaller size / slower deformation);
 - Revisit time : 5 days => in reality ~15days average
 - Increase of spectral band => thermal bands?



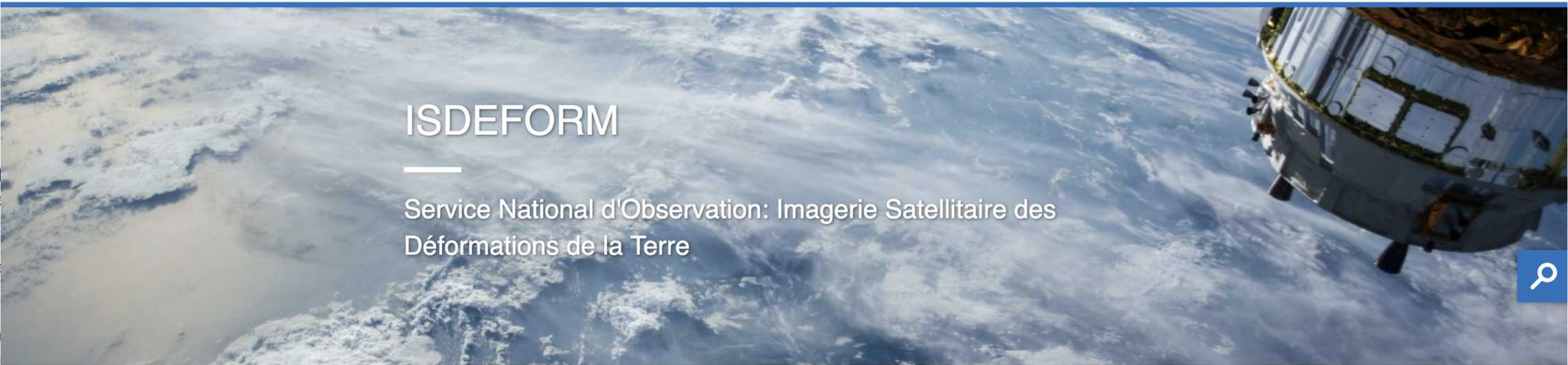
FormaTerre | For more information...

<https://www.poleterresolide.fr/>



Merci !

<https://www.isdeform.fr/>



ACTUALITÉS

Prochains Cafés ISDeform

Opportunités Stages et Thèses

Veillez trouver ci-dessous une offre de thèse de doctorat financée par une bourse de l'ANR MADALPS et du CNES, intitulée « Geodynamics of the Alps constrained by InSAR and GNSS uplift imaging ». La date limite de soumission est le 14 mars 2025 sur le portail du CNES :

<https://recrutement.cnes.fr/fr/annonce/3423593-25-136-geodynamics-of-the-alps-constrained-by-insar-and-gnss-uplift-imaging-38610-gieres>