L’interférométrie radar par approche SBAS (Small Baseline Subset) et les services d’analyse du SNO ISDeform et du pôle FormaTerre (GDM-SAR-in, FAST-SAR, FLATSIM-FRANCE)

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1 Univ. Grenoble-Alpes ISTerre, 2 CNES, 3 IPGP

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CENTRE NATIONAL D'ÉTUDES SPATIALES

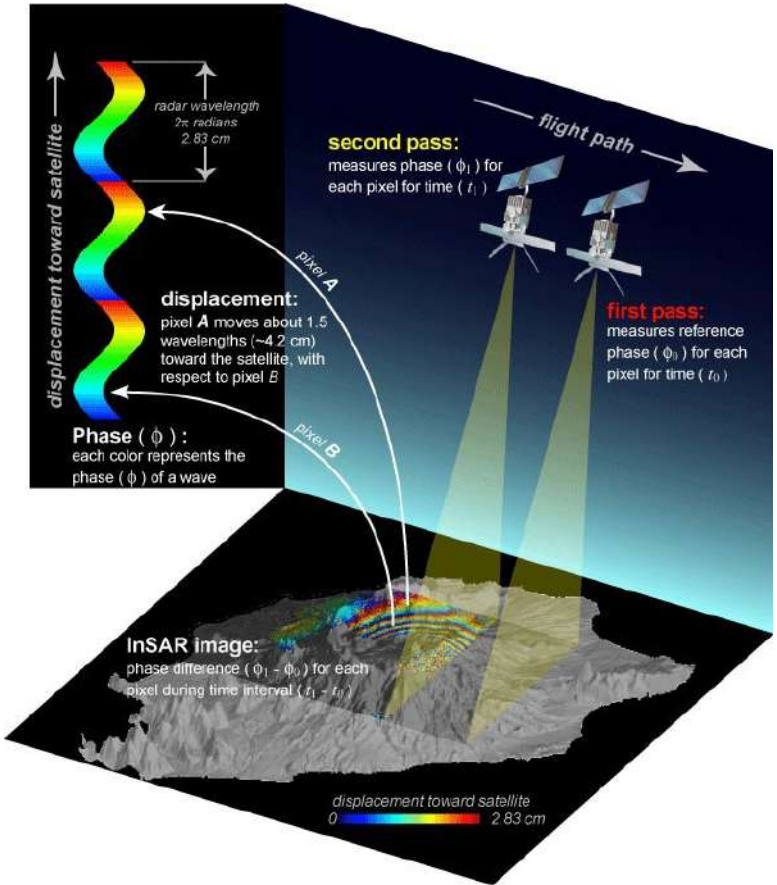
ForM@Ter

ISDEFORM
Imagerie Satellitaire des Déformations de la Terre

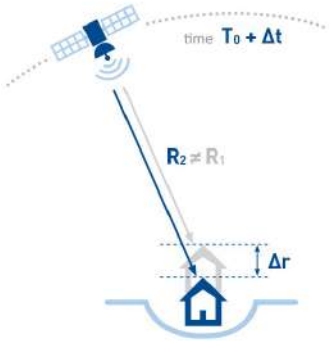
OSUG

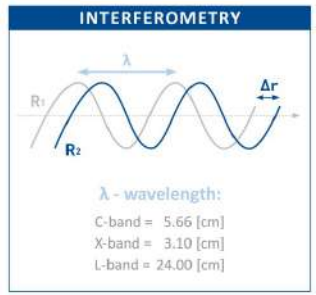
InSAR : Interferometric Synthetic Aperture Radar

Mesure différentielle : Mesure de la différence de temps de trajet entre deux passages du satellite et entre deux points

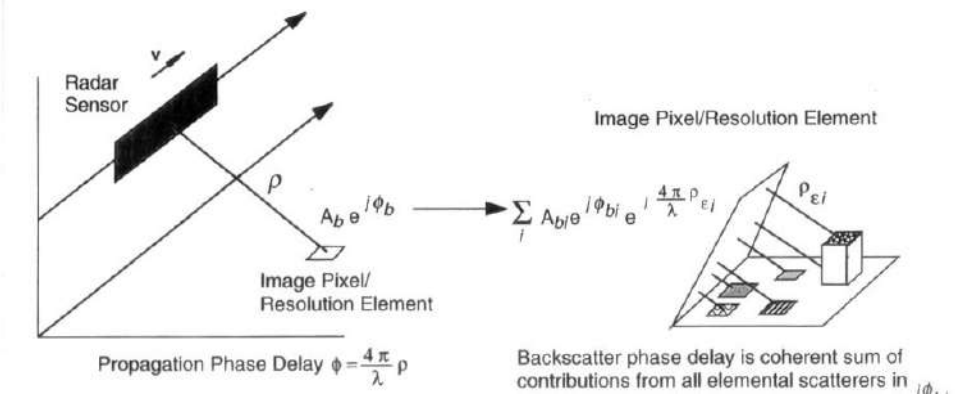


Mesure de phase, modulo 2π ⇒ déroulement de la phase

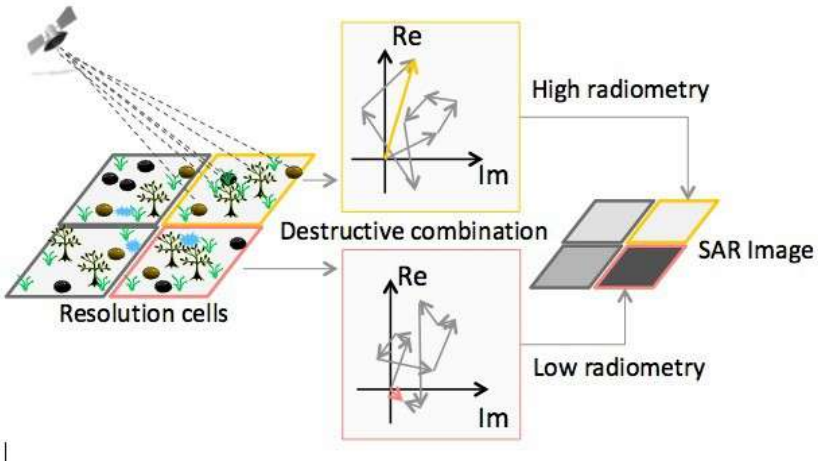


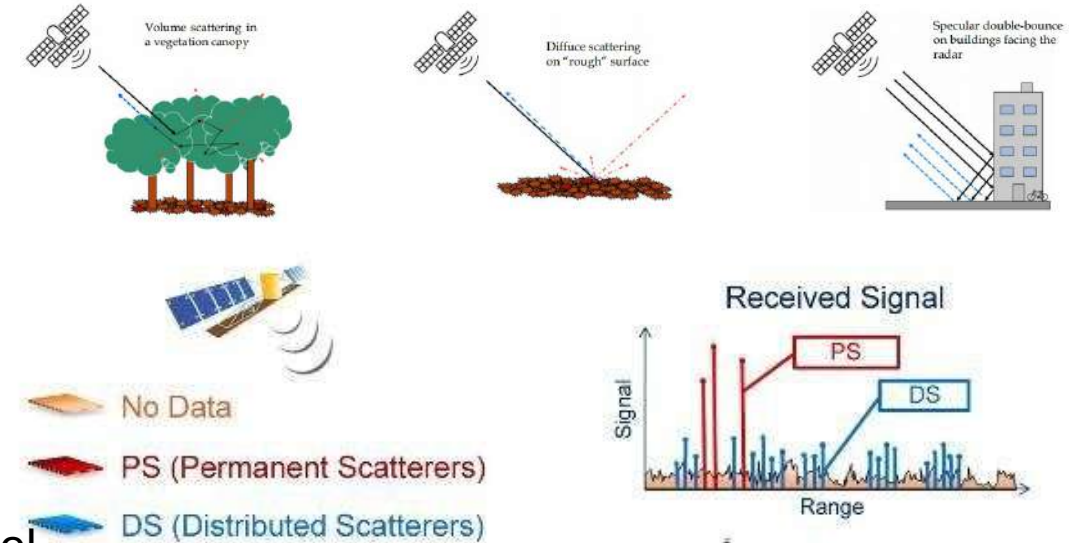


Propagation + interaction onde/sol



PS-DS versus SBAS et interaction onde-sol





PS : 1 seul rétrodiffuseur, très fort dans le pixel, très stable
DS: moyenne d'un ensemble de pixels, rétrodiffusion forte et stable

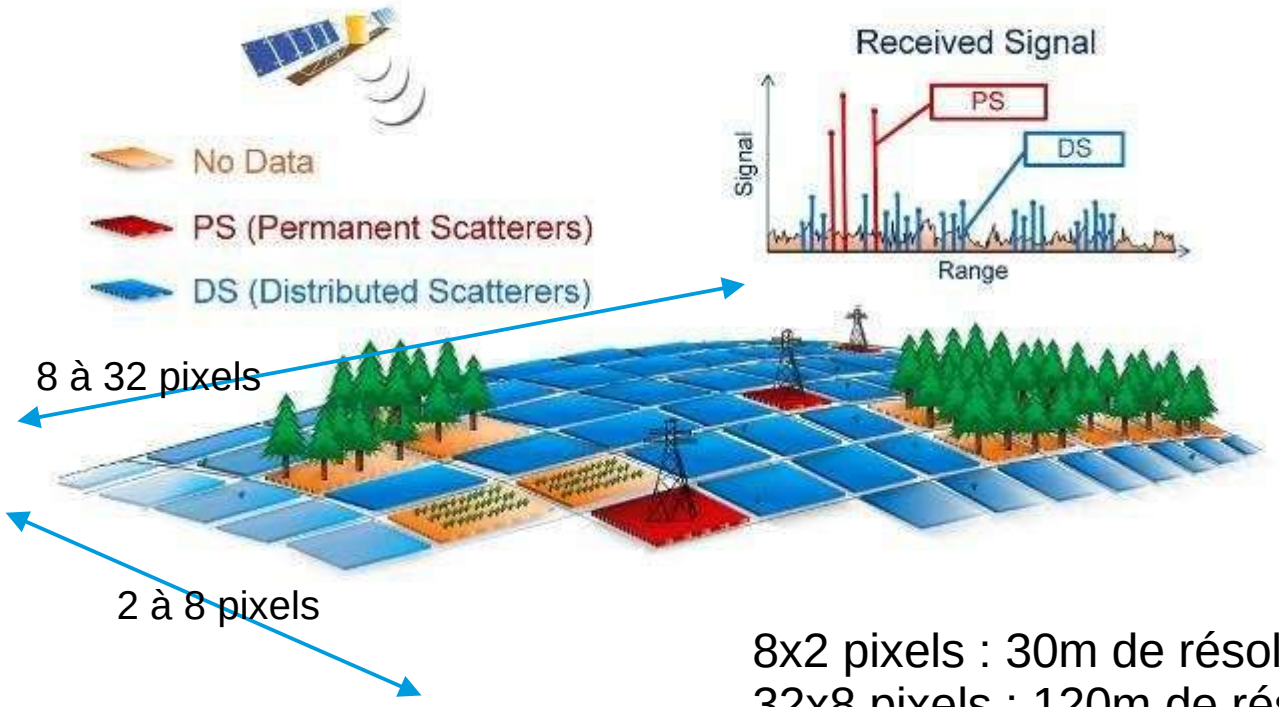
→ Continuité temporelle entre PS/DS voisins pour résoudre l'ambiguïté de 2π

ISDeform : pas de sélection, mais application de poids et moyennage spatial

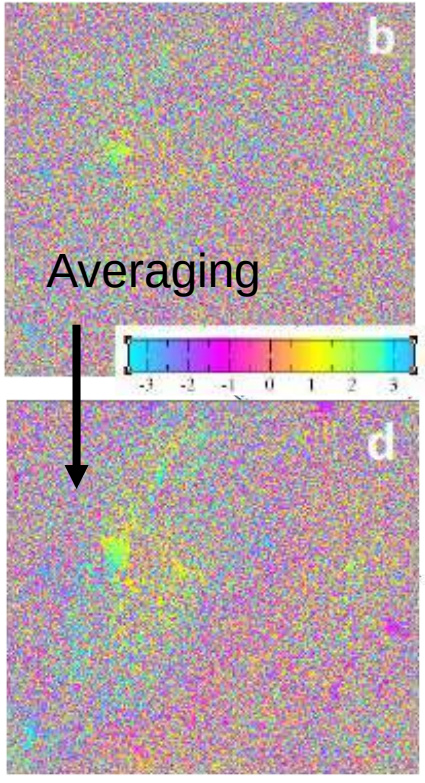
→ Continuité spatiale entre pixels voisins pour résoudre l'ambiguïté de 2π

SBAS : Réduction du bruit par moyennage spatial

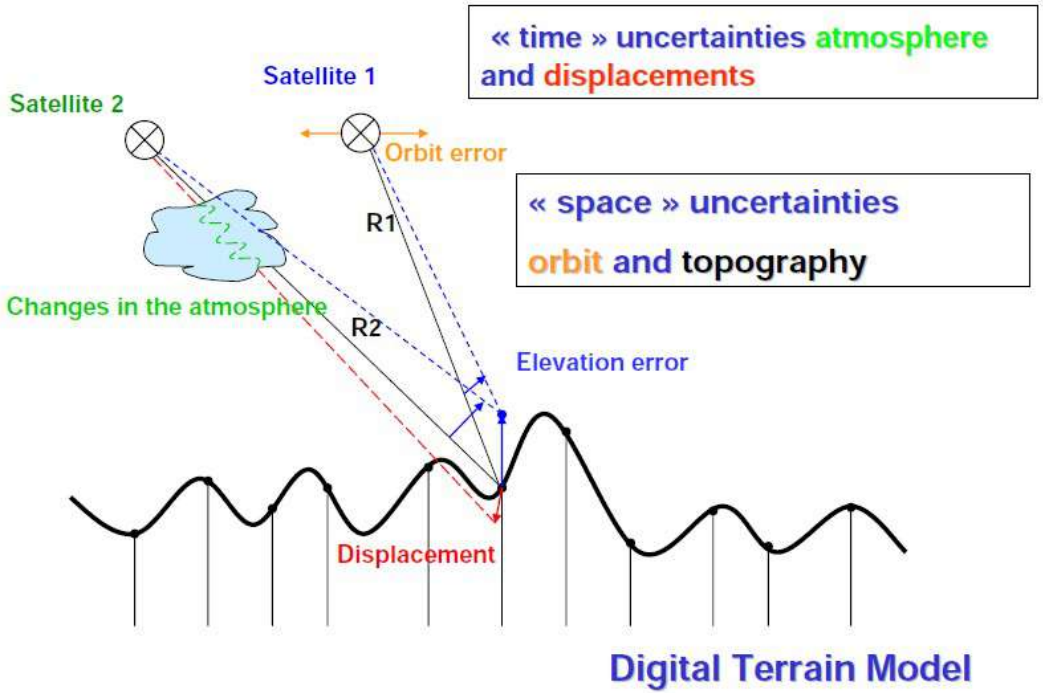
Moyennage aveugle ou pondéré, non linéaire car sur un nombre complexe
==> Mélange des types de pixel

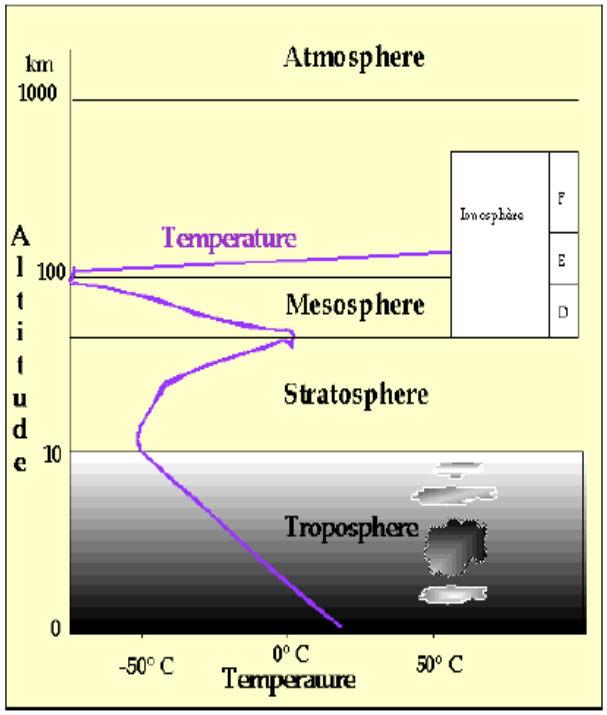


8x2 pixels : 30m de résolution
32x8 pixels : 120m de résolution



Propagation de l’onde et corrections

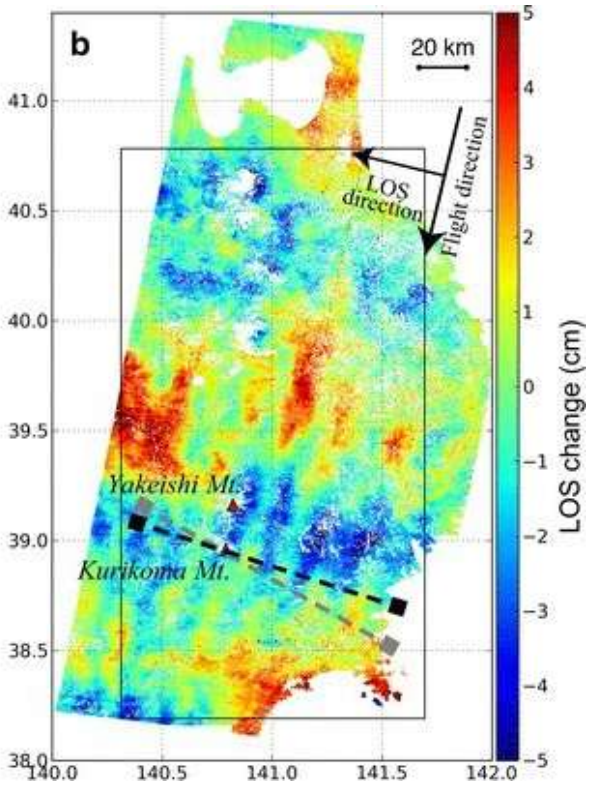




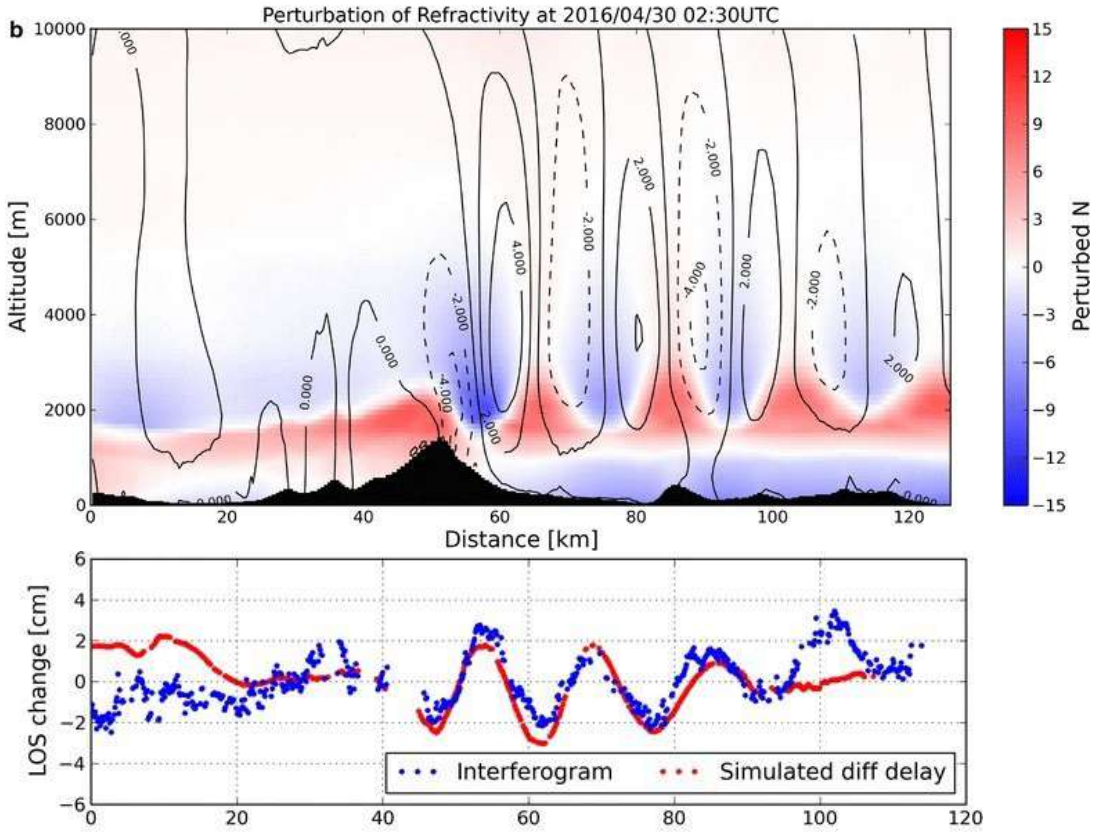
- Modèle numérique de terrain
- Orbites précises
- Modèles troposphériques globaux (ECMWF)

Propagation de l’onde et corrections

Exemple de délai atmosphérique “modéré”, non corrigé par les modèles atmosphériques globaux

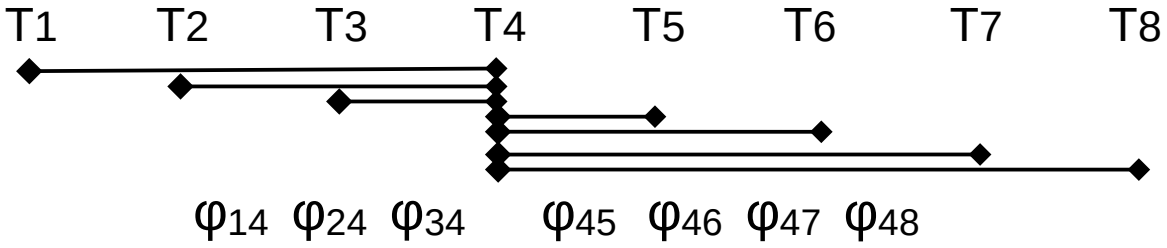


« Lee waves »



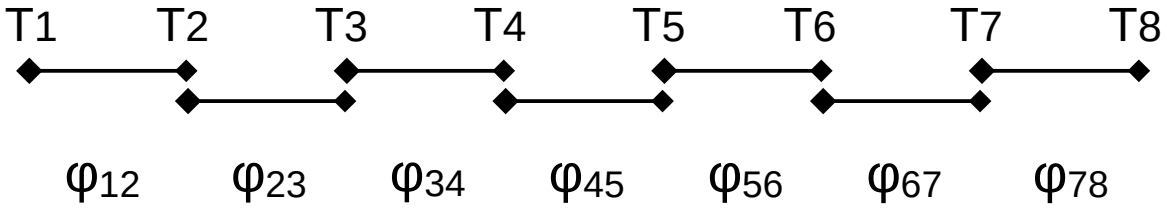
Kinoshita et al., 2017

Reconstitution de la série temporelle



Méthode PS

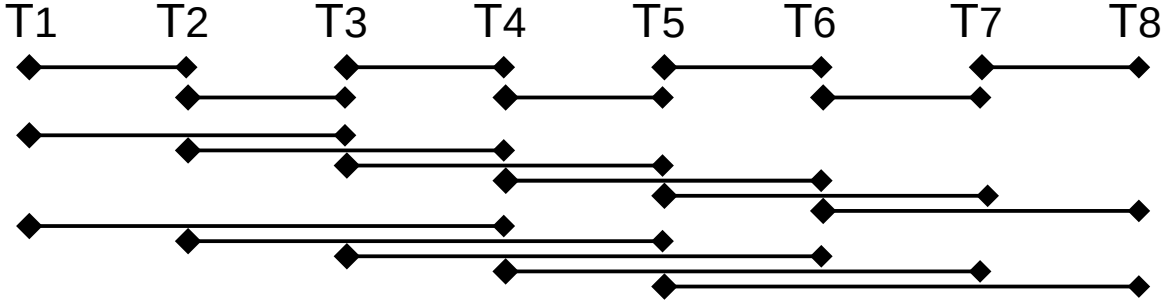
Une image de référence unique, ici T4



Small BASeline, SBAS

« Daisy chain », ifgs à 6 jours

$\varphi_{18} = \varphi_{12} + \ldots + \varphi_{78}$



Ifgs à 6, 12, 18 jours, etc...

$\varphi_{13} \neq \varphi_{12} + \varphi_{23}$

φ_{18} reconstruite par inversion du réseau d'ifg

Service National d’Observation ISDeform

Missions et objectifs

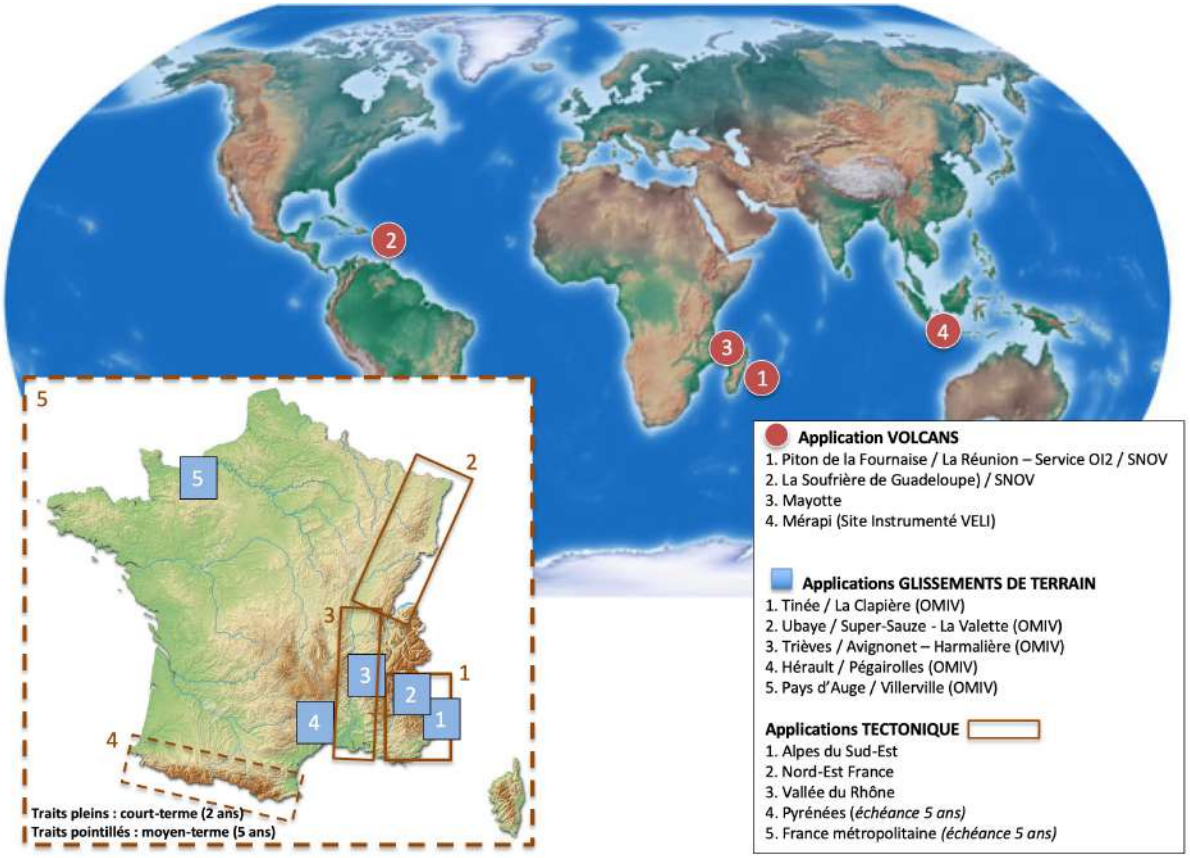
- Suivre le déplacement du sol associé aux risques naturels (e.g.
- earthquakes, landslides, volcanic activity) par imagerie satellite **optique et radar satellite.**
- Développement des softwares et des chaînes de traitement
- Animer la communauté scientifique
- Formation

Focus sur les services et produits basés sur l’interférométrie SAR Sentinel-1 :

- FAST-SAR : Interférogrammes Sentinel-1 6, 12, 18, … jours, systématiques, sites cibles, 30m
- GDM-SAR-In : Interférogrammes Sentinel-1, courtes séries temporelles
- FLATSIM-France : Interferogrammes Sentinel-1 30m enroulés, 120m déroulés, séries temporelles longues (2015-2021, puis mise à jour)

Service National d'Observation ISDeform

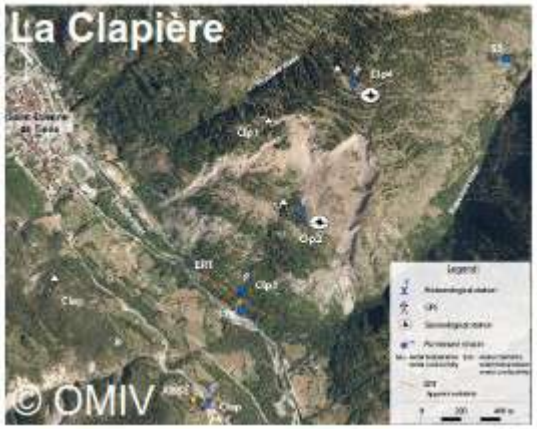
Sites cibles



Application VOLCANS
1. Piton de la Fournaise / La Réunion – Service OI2 / SNOV
2. La Soufrière de Guadeloupe) / SNOV
3. Mayotte
4. Mérapi (Site Instrumenté VELI)

Applications GLISSEMENTS DE TERRAIN
1. Tinée / La Clapière (OMIV)
2. Ubaye / Super-Sauze - La Valette (OMIV)
3. Trièves / Avignonet – Harmalière (OMIV)
4. Hérault / Pégairolles (OMIV)
5. Pays d'Auge / Villerville (OMIV)

Applications TECTONIQUE
1. Alpes du Sud-Est
2. Nord-Est France
3. Vallée du Rhône
4. Pyrénées *(échéance 5 ans)*
5. France métropolitaine *(échéance 5 ans)*



GDM-SAR-In : page d'accès au service

FormaTerre
DATA TERRA

News Diary Franç

FORMATERRE POLE DATA AND SERVICES RESOURC

GDM-SAR-IN SERVICE

The GDM-SAR-In (Ground Deformation Monitoring using SAR Interferometry) **on-demand processing** service is a Data Terra service developed and operated by its solid Earth hub, FormaTerre, in collaboration with ISTerre (OSUG), IPGP, CNES and the ISDeform NOS. The service is deployed on the CNES computing center. It was set up with the support of CNES and CNRS/INSU.

It is linked to the **Thematic Core Service « Satellite Data »** of the European research infrastructure **EPOS**, as GDM-SAR-In provides products that can be **exposed on the EPOS data portal**.

GDM-SAR-In uses the **NSBAS processing chain** (Doin et al., 2011, Grandin, 2015) to process radar images acquired by the **Sentinel-1** satellites (in IW mode) of the Copernicus program. It enables the user to calculate **interferograms** or **InSAR time series**, as well as other associated products (see examples of applications and products). Detailed product descriptions are available in a dedicated document. This service is complementary to FormaTerre's FLATSIM service, providing an **easy-to-use** InSAR data exploration tool and **delivers results quickly**, but on limited data volumes. Quantitative exploitation of the results requires a degree of expertise and potentially re-analysis by the user.

ACCESS | USE | INTEROPERABILITY | APPLICATIONS | TEAMS | REFERENCES

In its initial phase, GDM-SAR-In is accessible to national users, in particular within the RI Data Terra framework, via the FormaTerre portal. The service is accessible to anyone with a **FormaTerre account**, subject to acceptance of their profile: to access the service, you need to **authenticate yourself** by following the instructions.

Conditions of use are detailed in the service charter available on the service access page.

Qualified and validated products from the GDM-SAR-In service are **made available in the FormaTerre's metacatalog under a CC-BY-NC license**, excluding any commercial use.

GDM-SAR-IN PRESENTATION

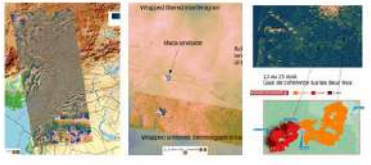
START YOUR CALCULATIONS

Tutorial

GDM-SAR-In

gdm-sar at poleterresolide.fr

EXAMPLES OF APPLICATIONS AND PRODUCTS



GDM-SAR-In : Portfolio

EXAMPLES OF GDM-SAR-IN APPLICATIONS AND PRODUCTS

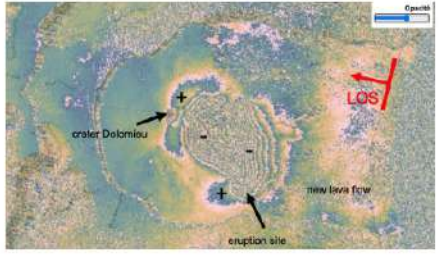
Some typical examples of gdm-sar runs can be found and visualised in the "public results" tab of the GDM-SAR-In interface.

They have been validated and the products are freely available. The aim of the portfolio is to show how the service can be used as a function of the scientific goal. It is also here to show the potential limits of an automatic InSAR processing: the products may or may not be used "as is" in a scientific publication. The user in particular must be aware that of potential filtering effects, unwrapping errors and remaining atmospheric delays. In "easy" cases (good coherence AND weak relief AND weak displacements gradients) the results should be nearly optimal. *GDM-SAR-In is therefore an easy-to-use exploration tool of InSAR data, but the quantitative exploitation of the results must rely on an expert eye and potentially a reanalysis by the user.* Displayed examples include cases at high resolution without time series (e.g., Maca landslides) and small time series examples (e.g., Ridgecrest and Mexico City). We can be interested in coherence changes (Landes forest fires or Ridgecrest EQ), in high resolution wrapped interferograms (e.g., Maca landslide), in medium-resolution wrapped interferograms (Ridgecrest or Turkey Earthquakes, or volcano deformation, La Réunion), or in small time series (e.g., Mexico City, or co- and post-seismic time series, Ecuador or Ridgecrest EQ). Note that the default parameters for the filter may destroys fringes where they are too narrow. Please then include: filterstyle=SWg (see tutorial).

CO-SISMIQUE – TURQUIE/SYRIE – 2023

Interferogrammes cosismiques sur la séquence sismique du 6 Février 2023 en Turquie, Mw 7.8 et 7.5. Interférogrammes couvrant les deux séismes décrochants de forte magnitu...

21.02.2023 Read more →



DÉFORMATION VOLCANIQUE – LA RÉUNION – 2023

Produits interférométriques couvrant l'éruption de Juillet 2023 du volcan Piton de la Fournaise [orbite descendante, résolution enroulée : 2 looks, résolution déroulée : 2 loo...

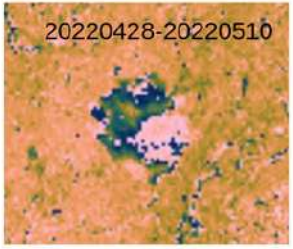
27.01.2023 Read more →

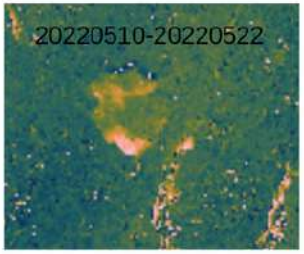
GLISSEMENT DE TERRAIN – PÉROU – 2022

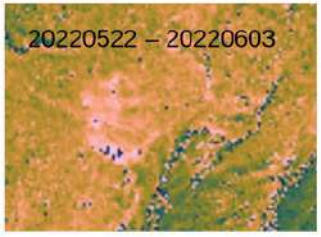
Série sur les glissements de terrain de la vallée de Colca au Pérou entre Avril et Août 2022. Interférogrammes couvrant les glissements de terrain de la vallée de la Colca. [...]

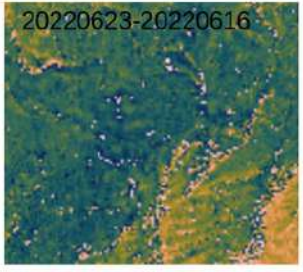
30.08.2022 Read more →

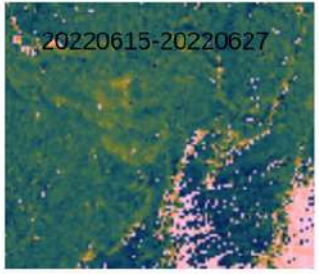
GDM-SAR-In : Exemple de Maca

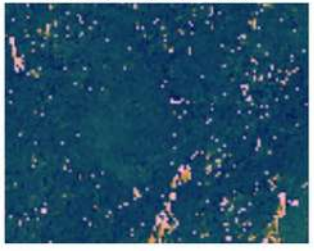








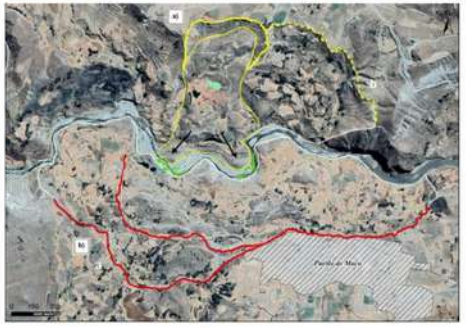




Maca landslide : Successive wrapped interferograms in radar geometry (without E-W flip), showing the progressive decrease in landslide velocity from April to July

Interferogrammes successifs montrant le mouvement de déstabilisation lent du glissement de terrain de Maca, et son arrêt progressif.

Lien avec le séisme Mw5.5 du 16 Mars 2022.
Lien avec les pluies



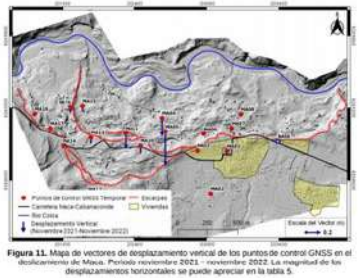
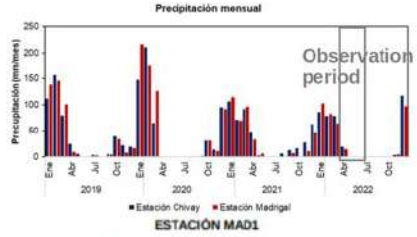
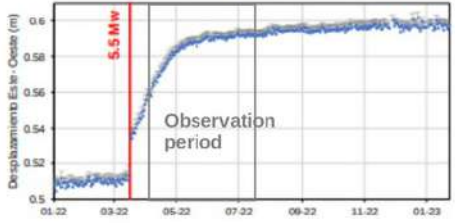
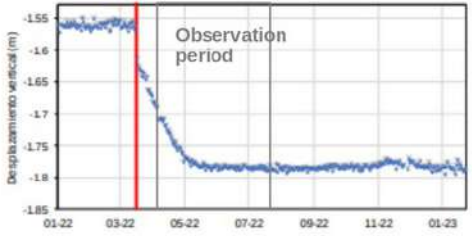


Figura 11. Mapa de vectores de desplazamiento vertical de los puntos de control GNSS en el deslizamiento de Maca. Periodo noviembre 2021 - noviembre 2022. La magnitud de los desplazamientos horizontales se puede apreciar en la tabla 5.



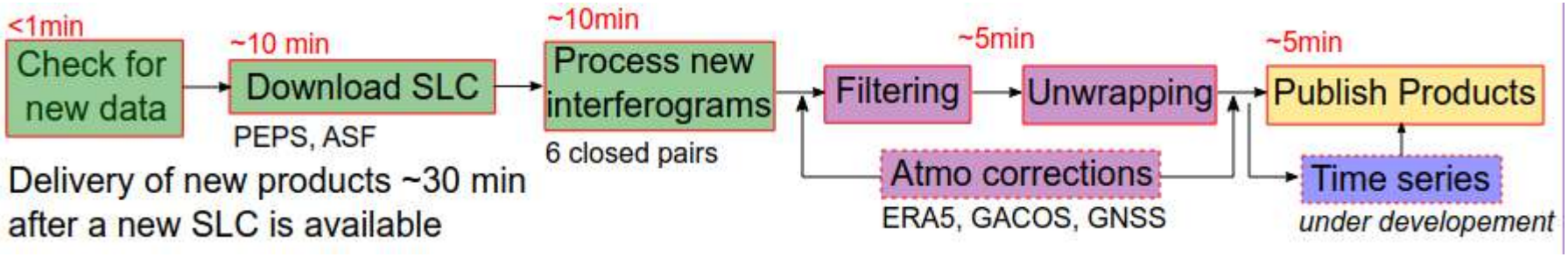


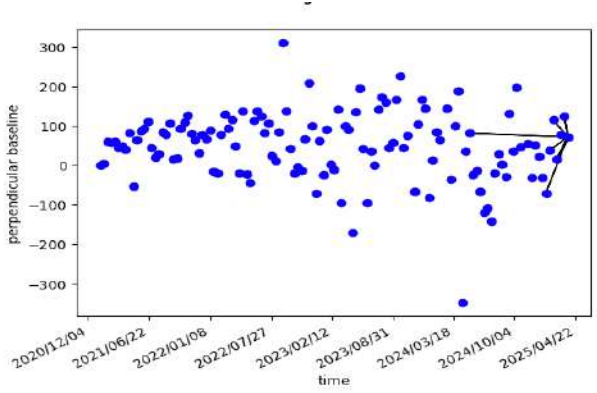


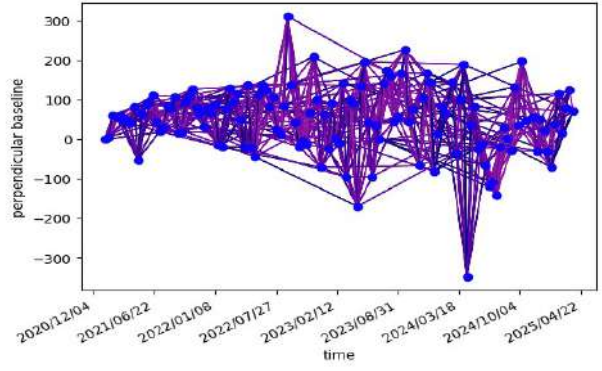
Figures montrant le lien entre la déstabilisation du glissement de Maca en 2022 et le séisme ainsi que la saison des pluie. Source : https://sigrid.cenepred.gob.pe/sigridv3/storage/biblioteca//16648_informe-tecnico-a7441-monitoreo-del-deslizamiento-de-maca-periodo-2022-distrito-maca-provincia-caylloma-departamento-arequipa.pdf

FAST-SAR: Fully Automated processing on Small Targets using SAR data

- Traitement InSAR en routine des cibles priortiares ISDeform
- Modifications de **NSBAS** pour ne calculer que les nouveau produits

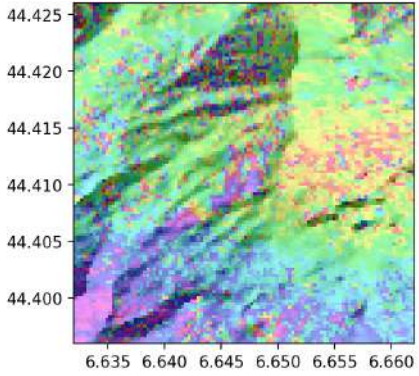


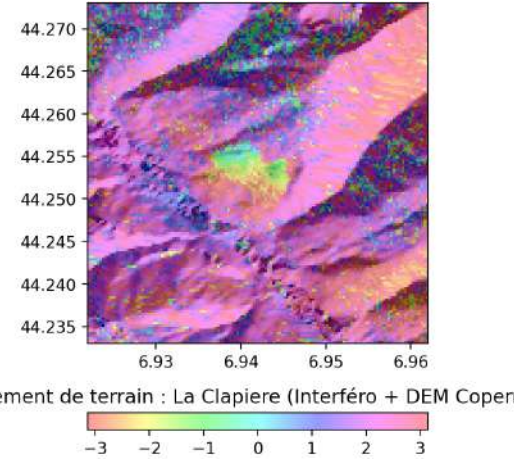




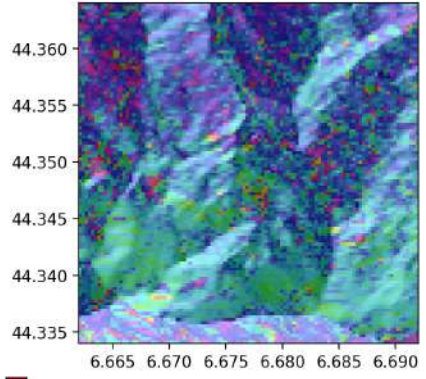
FAST-SAR: Fully Automated processing on Small Targets using SAR data

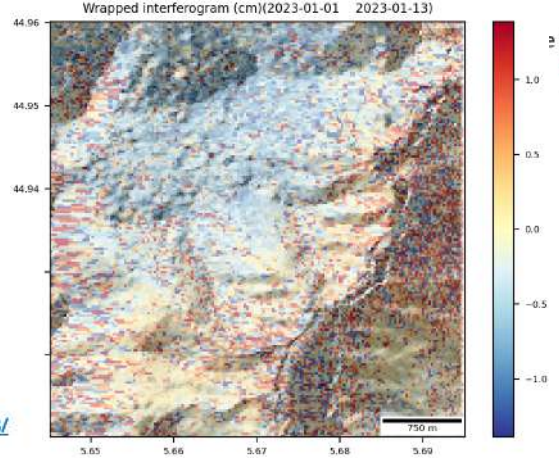
- La Valette
- La Clapière
- Super Sauze
- Avignonet Harmalière





Interferogrammes à 30m, enroulés





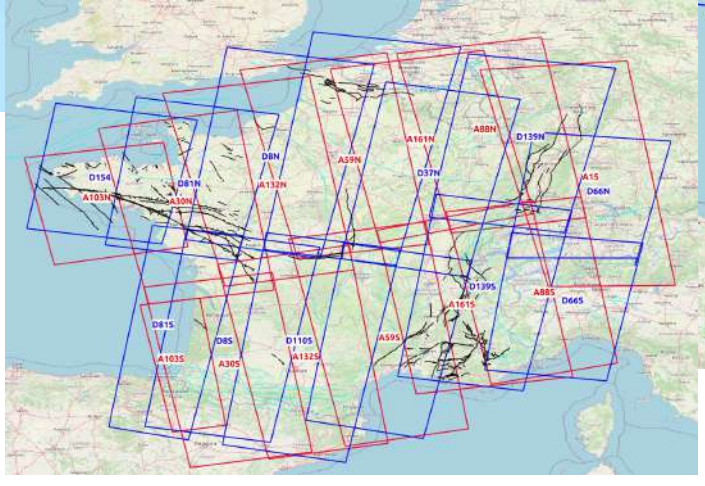
ACCÈS AUX COLLECTIONS

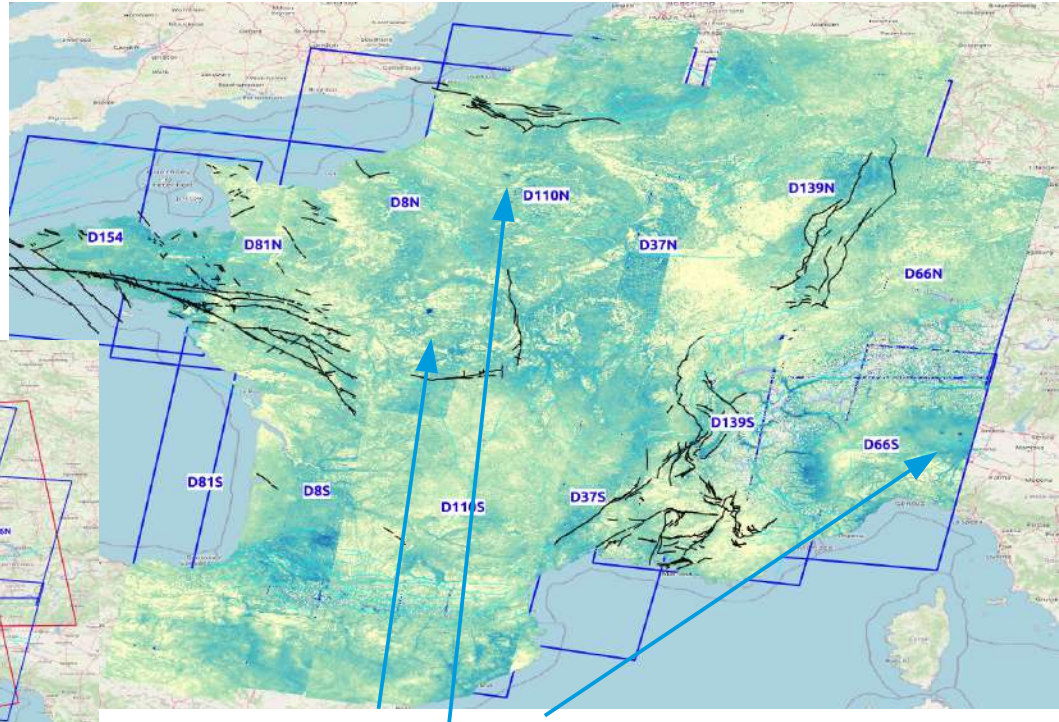
HARMALIÈRE

https://formater.osug.fr/permanent-products-repository/public/isdeform/small_targets//Harmaliere/D139_FR4B/

FLATSIM and ISDeform solution over France

FLATSIM: ForM@Ter LArge-scale multi-Temporal Sentinel-1 InterferoMetry processing chain





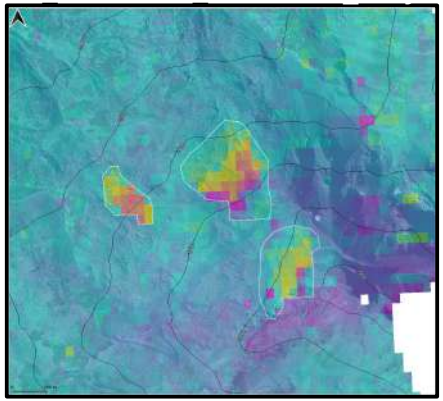
Composante de déplacement printemps-automne: stockage de gaz souterrain, humidité des sols (RGA)

FLATSIM and ISDeform solution over France

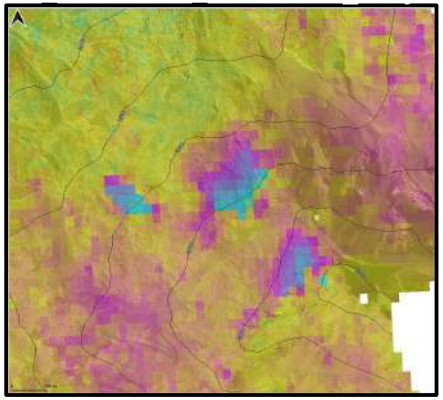
- Interferogrammes enroulés avec une résolution de 30m : ⇒ glissements très rapides

Glaciers rocheux

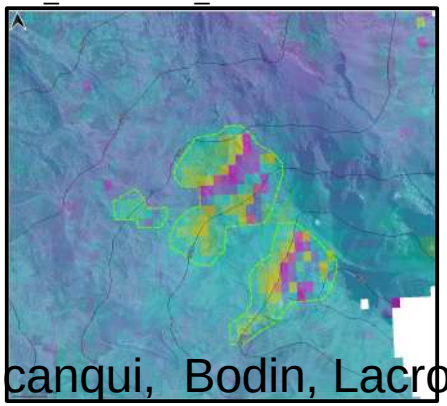
S1_2018-07-02_2018-07-08



S1_2018-09-12_2018-09-18



S1_2018-08-07_2018-08-19



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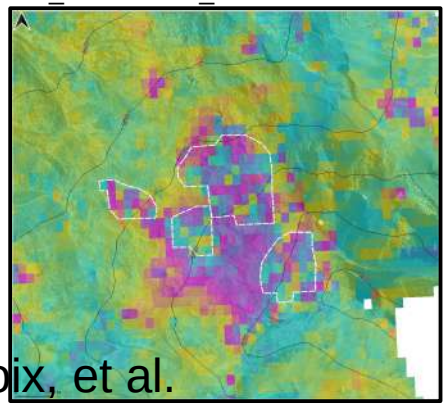
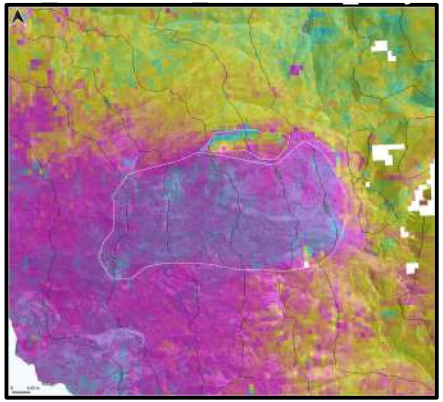


Glissements de terrain

S1_2018-07-02_2018-07-08



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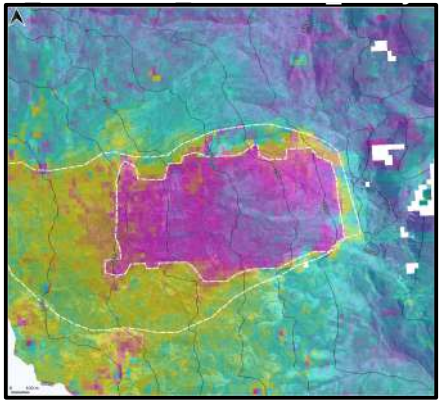

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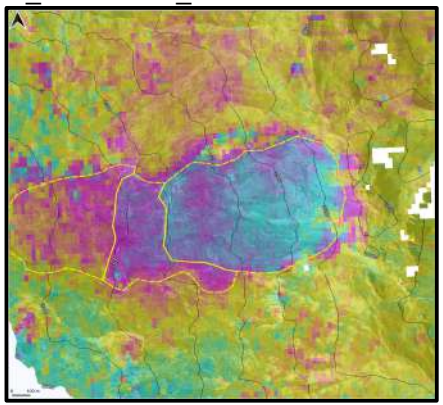

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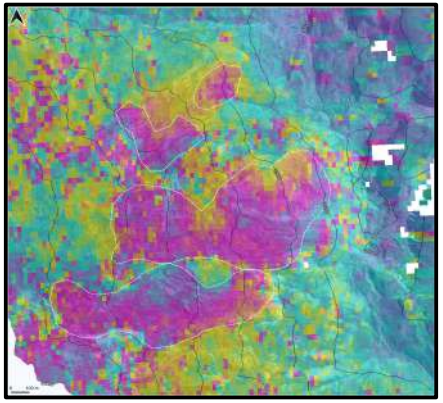
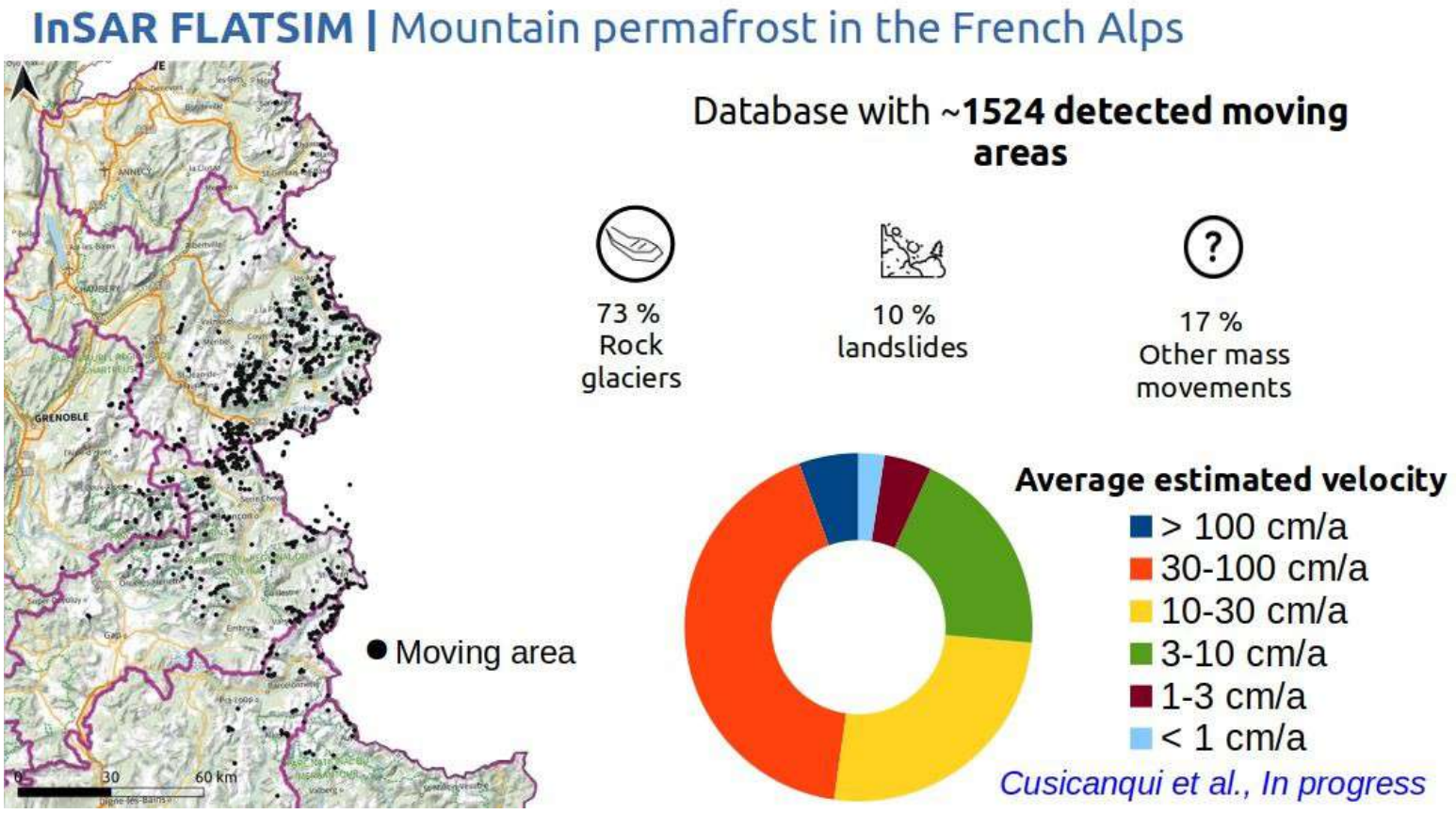


Cusicanqui, Bodin, Lacroix, et al.

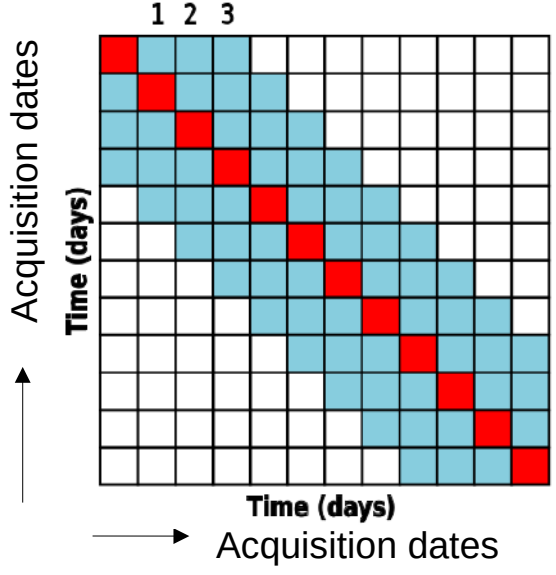
FLATSIM and ISDeform solution over France

- Interferogrammes enroulés avec une résolution de 30m : ⇒ glissements très rapides



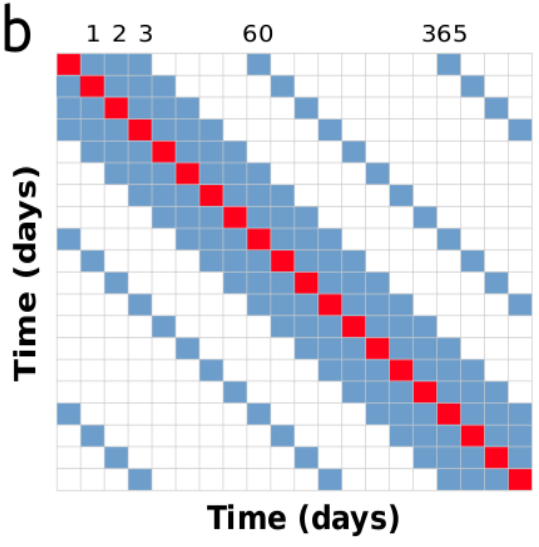
FLATSIM and ISDeform solution over France

- Séries temporelles 2015 à 2021/2022 avec une resolution de 120m
- France : retraitement à l'UGA pour des produits de qualité



n/n+1, n/n+2, n/n+3

Précision (~cm/a) pour les glissements de terrain rapides (> 2 cm/a)

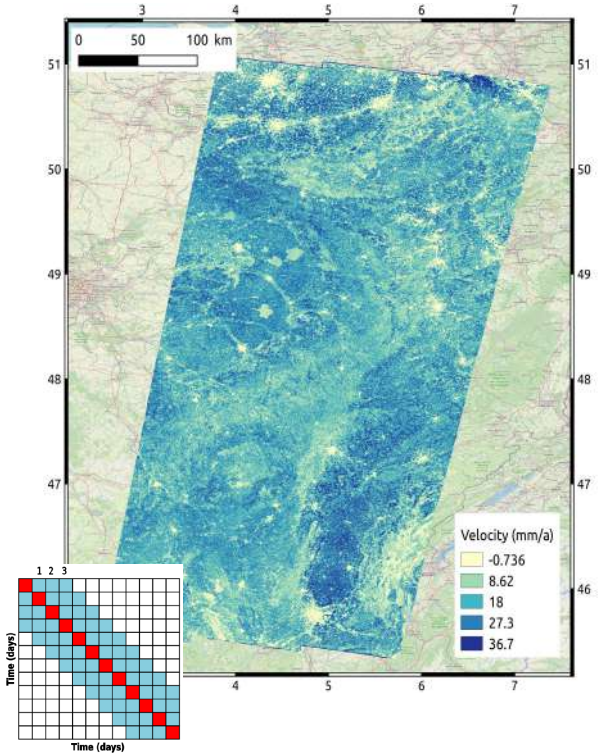


+2 mois, + 1 an

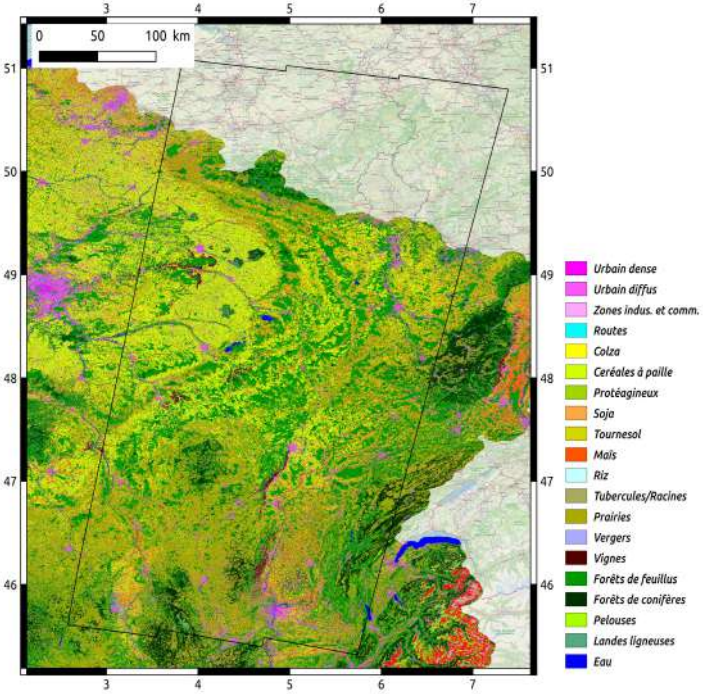
Très bonne précision (<mm/a) pour les glissements de terrain/ instabilités gravitaires lentes (< 1-2 cm/a)

Carte de vitesse : effet de la végétation

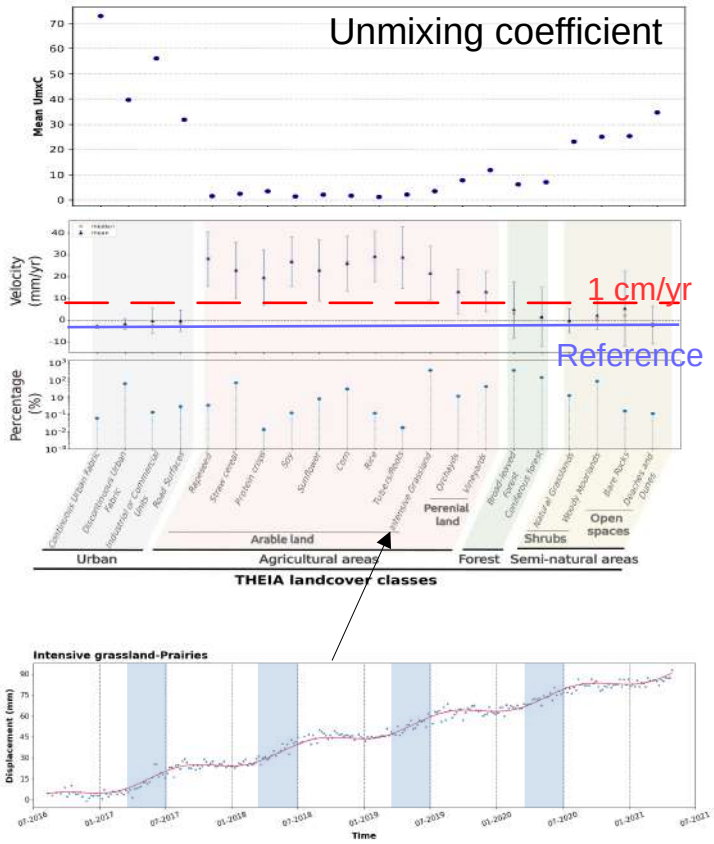
- Séries temporelles avec ifgs 6, 12, 18 jours



Velocity map
6-12-18 days ifgs



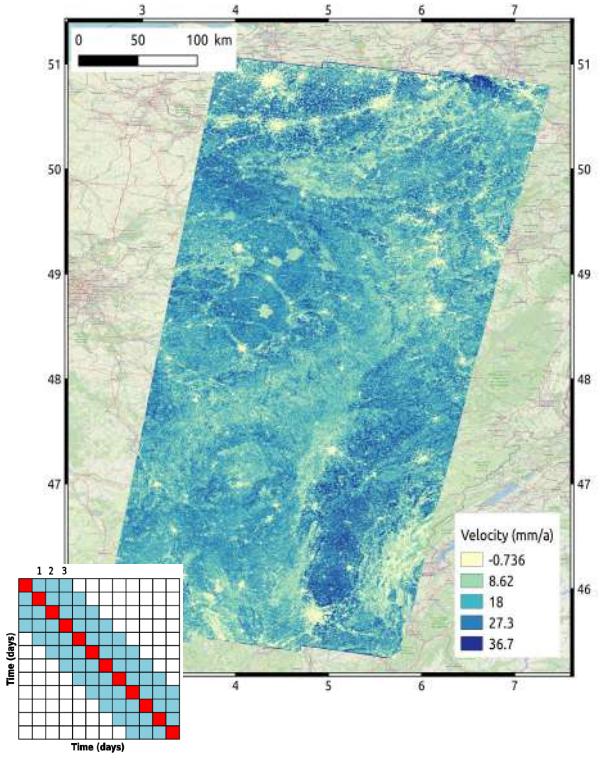
Landcover



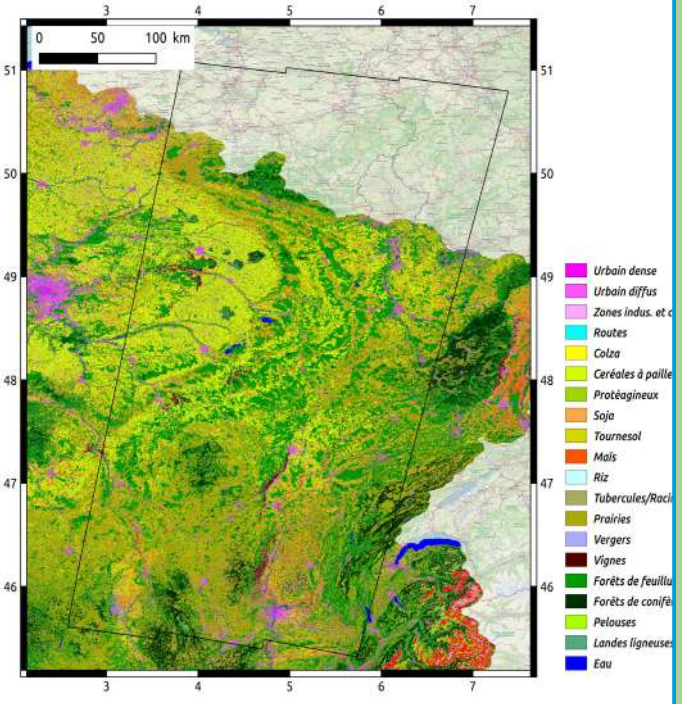
Main contribution : soil + vegetation processes !!!

Carte de vitesse : effet de la végétation

- Séries temporelles avec ifgs 6, 12, 18 jours

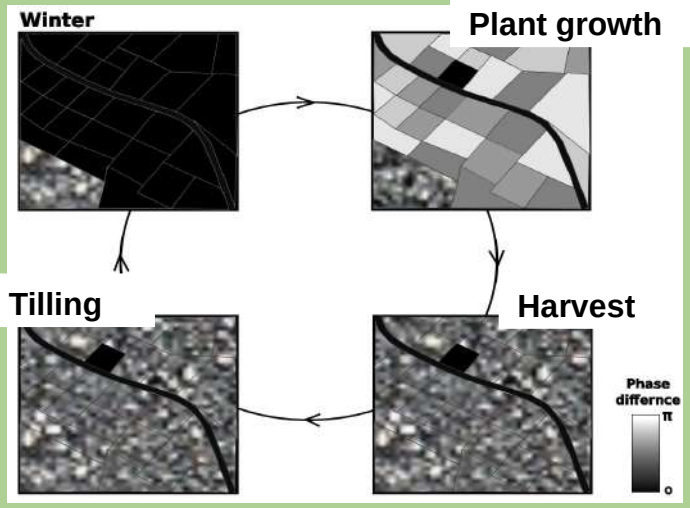


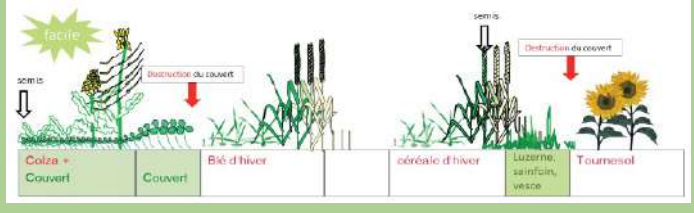
Velocity map
6-12-18 days ifgs



Landcover

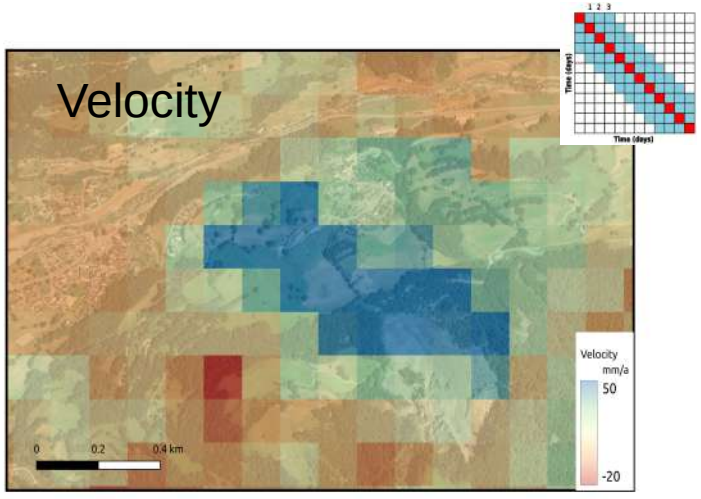
Assymetric vegetation cycle





Main contribution : soil + vegetation processes !!!

Exemple du glissement de Viella, Pyrénées



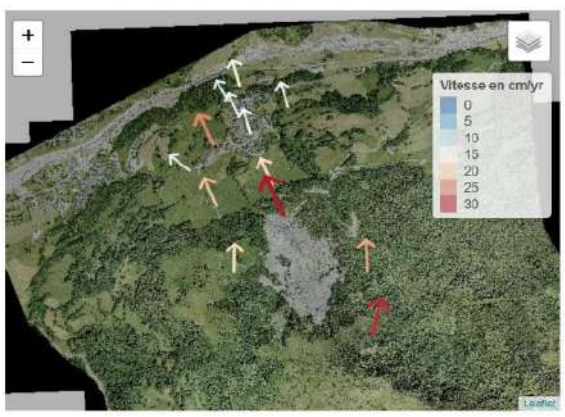
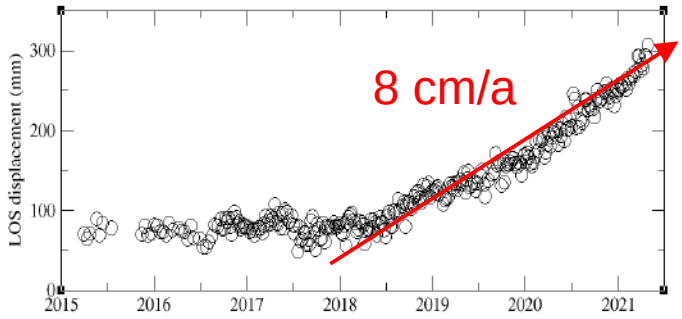
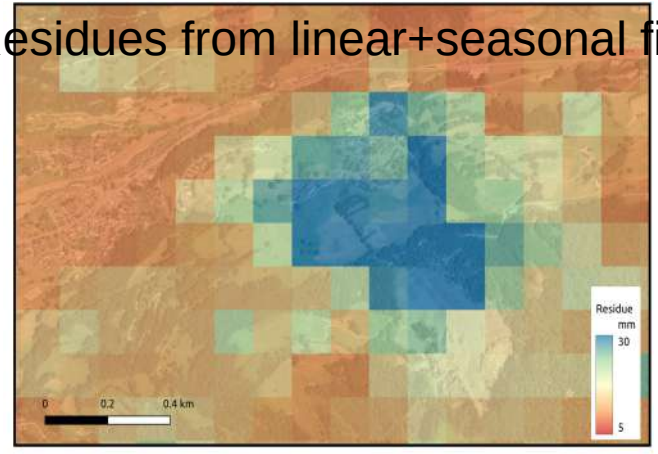


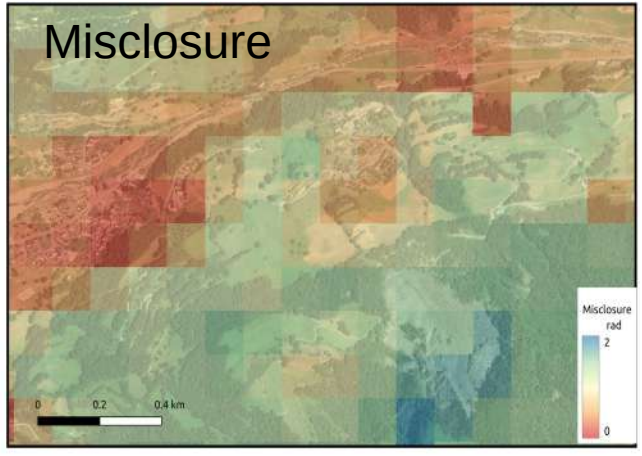
Figure 16. Velocity vectors in m/year for reflectors in the Viella landslide (France) September 2023 to August 2024

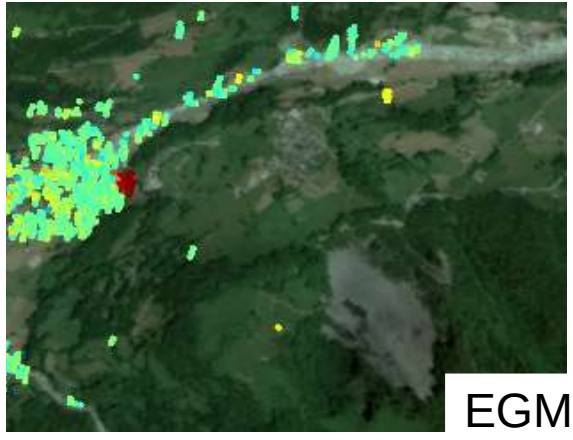


Viella landslide
Activated in February 2018

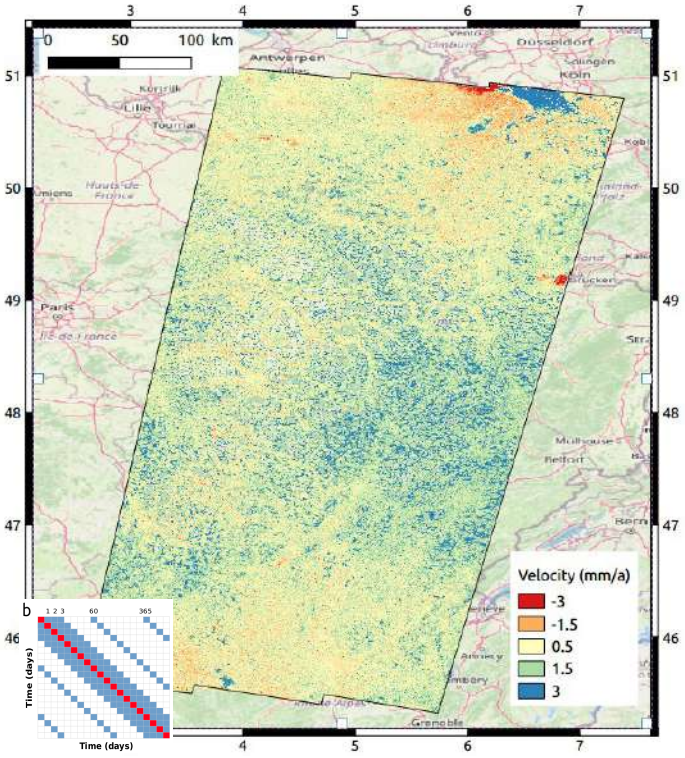
Residues from linear+seasonal fit



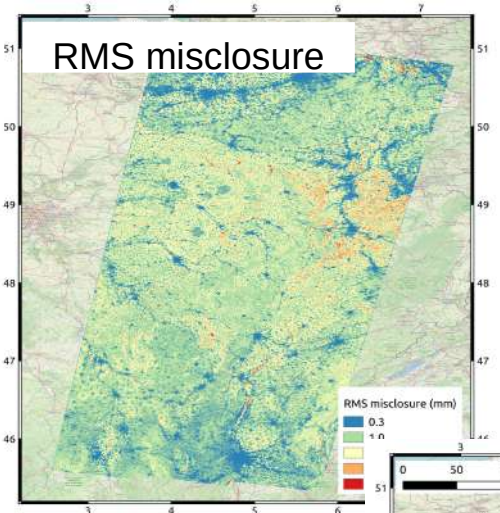


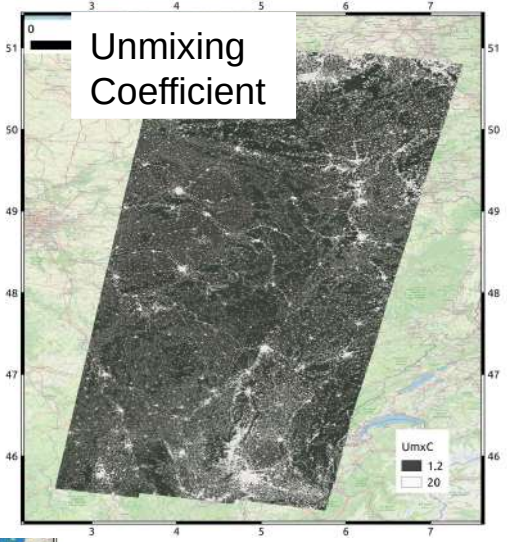


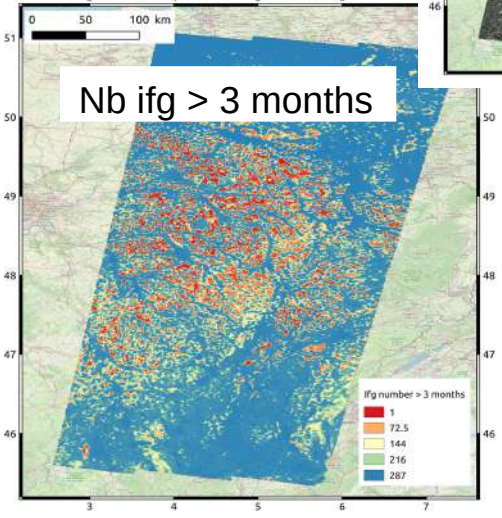
Carte de vitesse et facteurs de qualité



Velocity map
all ifgs



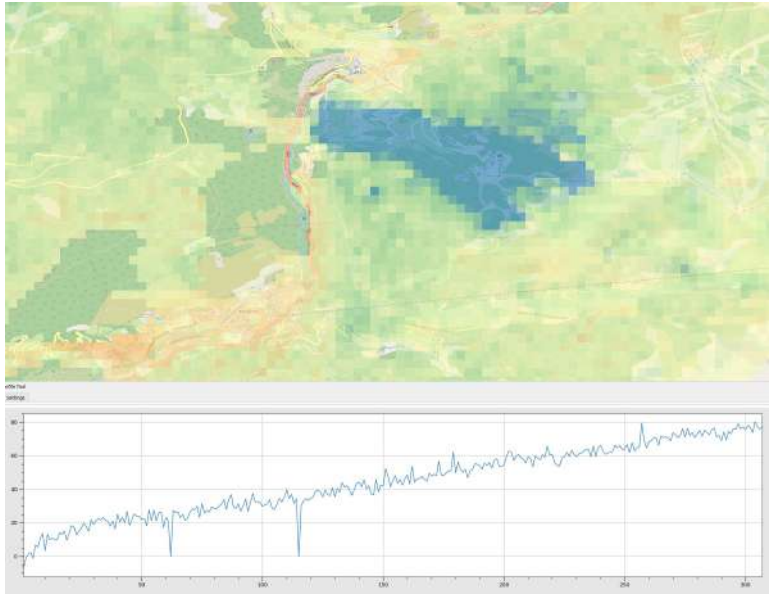


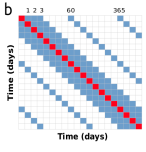


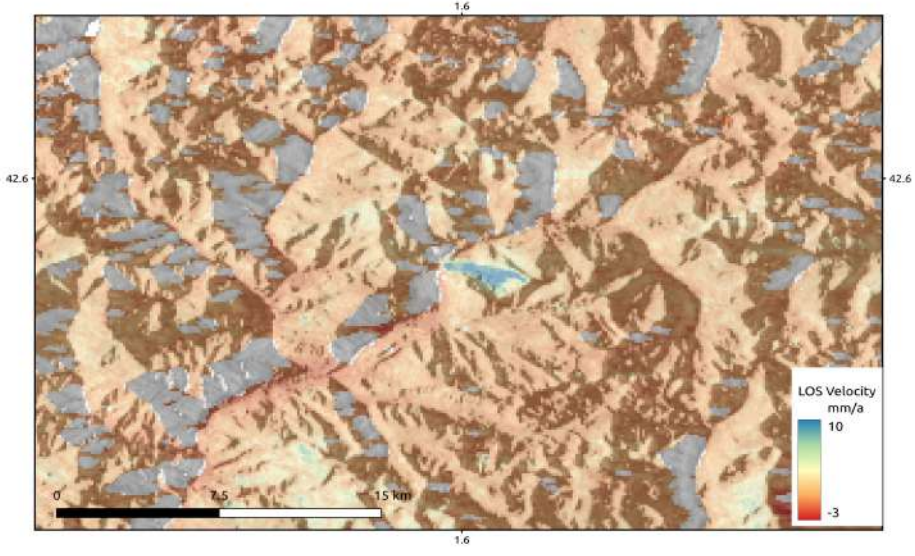
Exemple de glissement lent et massif

https://pyrmove.eu/fr/node/88.html

Glissement de terrain
Forn de Canillo, Andorre

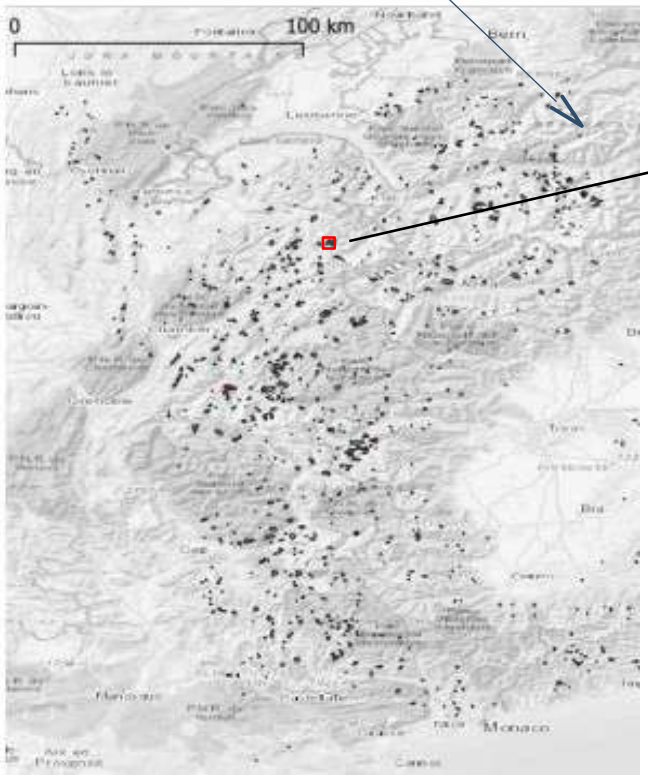




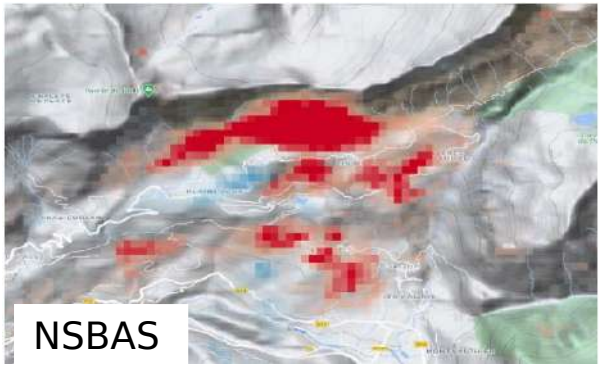


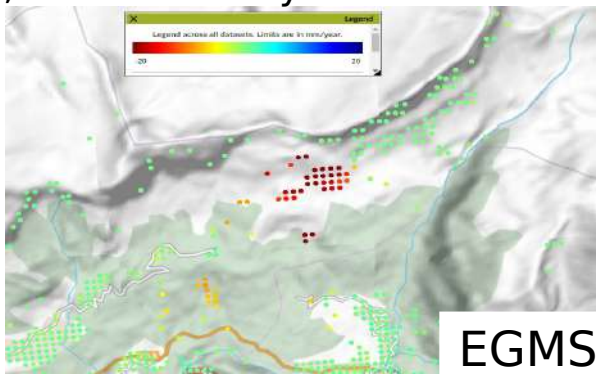
Inventaire de DSGSD

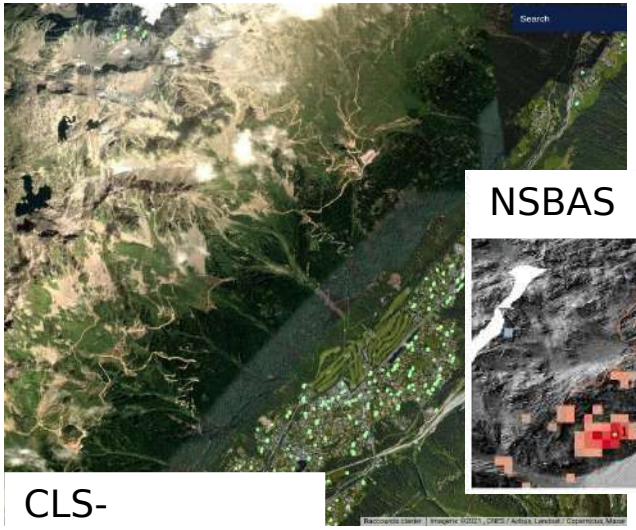
Inventaire des glissements lents et massifs
(<3 cm/an et > 3 mm/an)



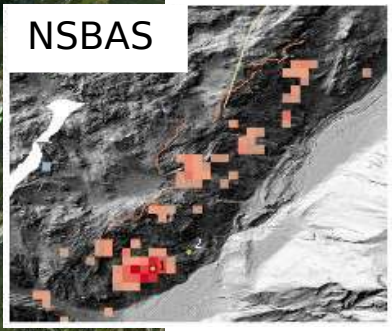
Dérochoir, Plateau d'Assy

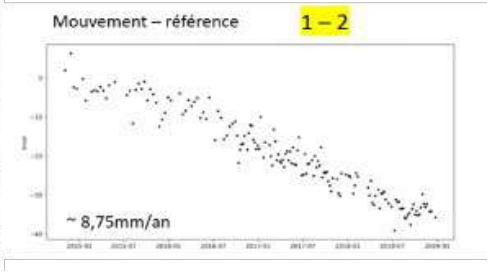






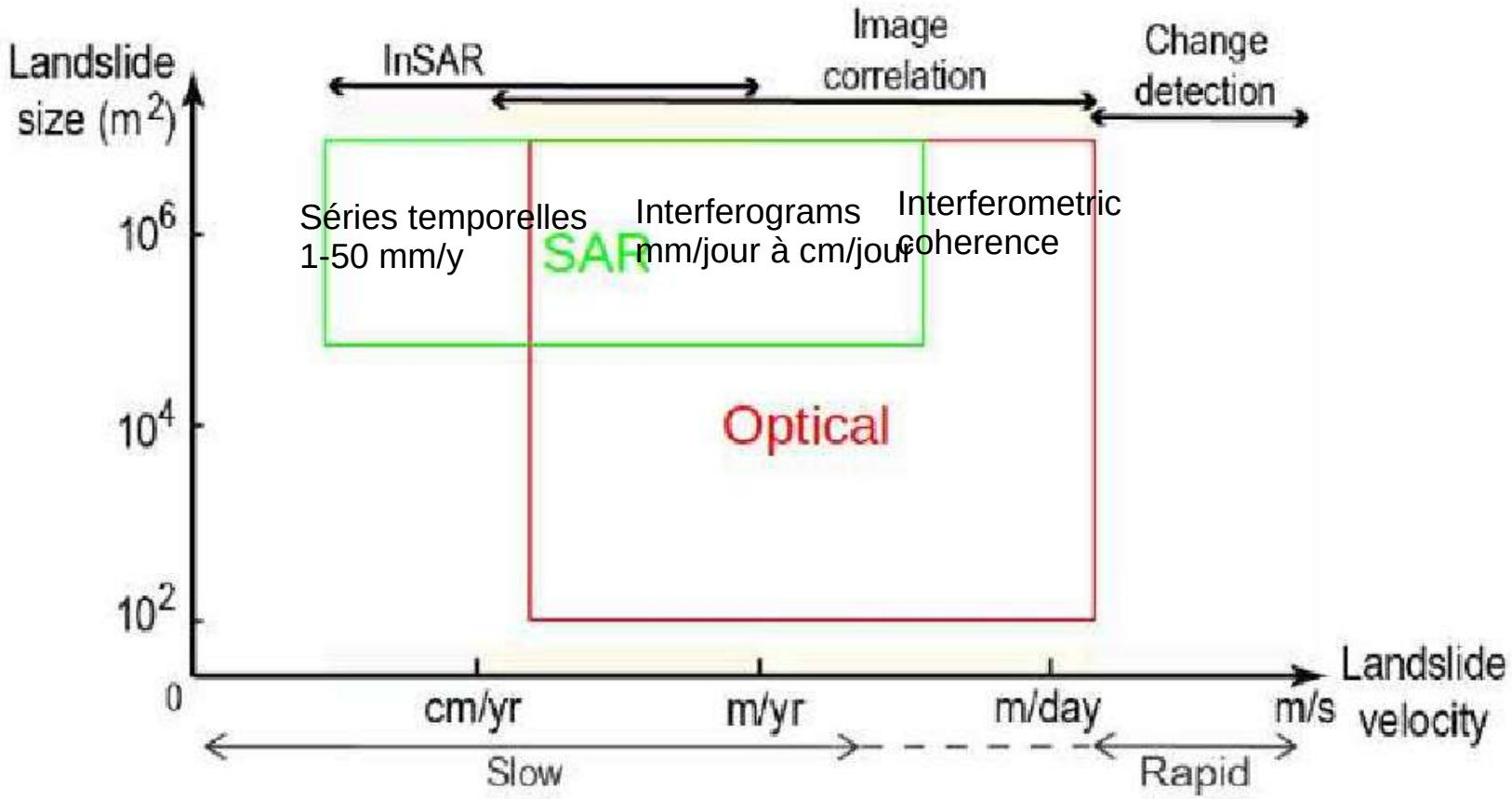
Instabilité gravitaire au dessus de la vallée d'Argentière





André et al., 2021

Conclusion



Lacroix et al., 2022