Committee on Earth Observation Satellites

Landslide Demonstrator, highlights and successes

J.-P. Malet[1], D. Kirschbaum[2], C. Froese[3], C. Michoud[4], P. Amatya[2], J. Engelbrecht[3], A. Déprez[1], **F. Provost[1]**

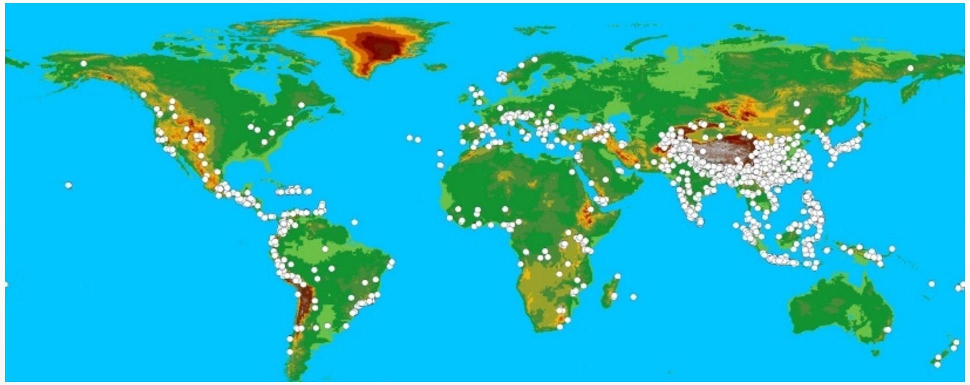
October 3, 2022
Nice

1. Ecole et Observatoire des Sciences de la Terre, CNRS/University of Strasbourg/EOST, CNRS, Strasbourg, France
2. Hydrological Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA
3. BGC Engineering, Vancouver, Canada
4. Terranum srl, Lausanne, Switzerland

Use of space-based technologies for Landslide Monitoring and Mapping

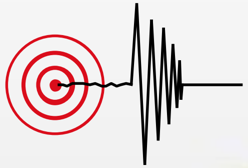
- **Landslide: a global phenomenon, observed in multi-hazard environments**

  Fatal landslides 2002-2012: ca. ***90,000*** *fatalities*



Credits: Petley The landslide blog

- **Major triggers**



EARTHQUAKES

New Zealand: 2016 (7.8Mw) ca. **6,000** landslides

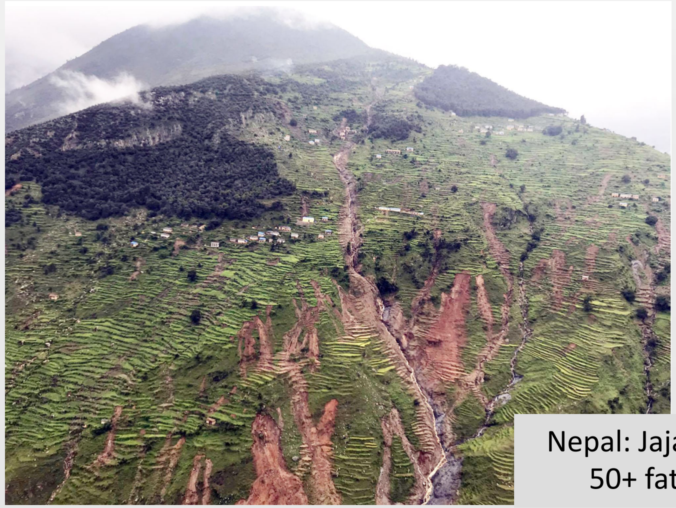
Nepal: 2015 (7.8Mw) ca. **20,000** landslides

Nepal: Bhote Koshi (drone image 1 month after EQ)

HYDROMETEOROLOGIC EXTREMES

(e.g. typhoon)

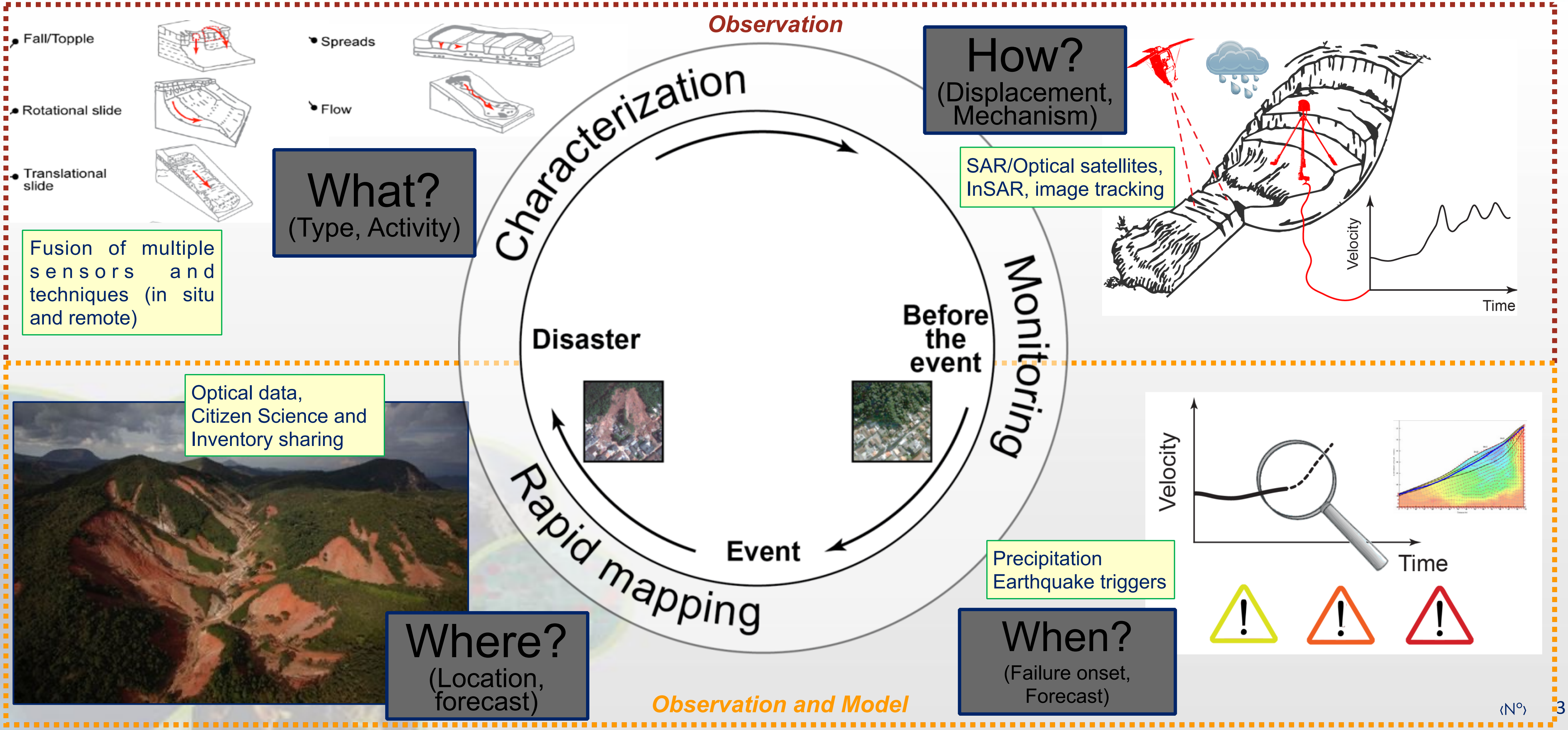
Taiwan: 2009 Typhoon Morakot: ca. **20,000** landslides



Nepal: Jajarkot, July 2020, 50+ fatalities in 5 days

Landslide Remote Sensing

Many data and many techniques for different purposes



Credits: André Stumpf (Univv. Strasbourg)

CEOS Disaster Working Group

Our Work

Working Groups

- WGCapD
- WGCV
- WGClimate
- WGDisasters
  - Landslide Pilot
  - Flood Pilot
  - Seismic Hazards Pilot
  - Volcano Pilot
  - Recovery Observatory
  - GEO-DARMA
  - Meetings
  - Documents
  - Contact Us
- WGISS

Virtual Constellations

CEOS / Our Work / Working Groups / WGDisasters

WGDisasters

The Working Group on Disasters

Damage from the Great East Japan Tsunami in Otsuchi, Iwate, Japan, 15 March 2011. Source: wikimedia commons.

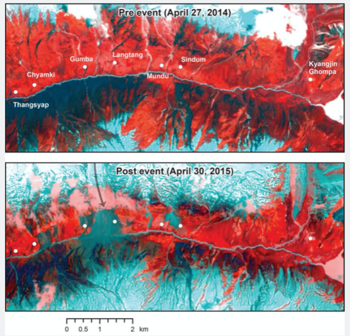
Disaster Risk Management (DRM) continues to gain political, economic, and geopolitical importance as disasters cause increasing human and economic losses, and these losses only expected to grow as a result of increasing global urbanization (expected to double by the year 2050) and an increasing number of extreme events (expected to triple by the year 2100). While 2014 was a relatively calm year for disasters (overall losses from natural disasters totaled $110 billion (92.5 billion euros), compared with $140 billion a year earlier according to Munich Re), every indication points toward increased damages in the future. In March 2015, UN Secretary-General Ban Ki-moon warned "growing global inequality, increasing exposure to natural hazards, rapid urbanization and the overconsumption of energy and natural resources threaten to drive risk to dangerous and unpredictable levels with systemic global impacts." According to the 2015 Global Assessment Report on Disaster Risk Reduction (GAR15), economic losses from disasters are now reaching an average of US$250 billion to US$300 billion annually.

CEOS / Our Groups / Working Groups / WGDisasters / Landslides

Landslides

Overview

Landslides occur around the world, on every continent, and play an important role in the evolution of landscapes. They also represent a serious hazard in many areas of the world. Despite their importance, it has been estimated that past landslide and landslide potential maps cover less than 1% of the slopes in the landmasses. Systematic information on the type, abundance, and distribution of existing landslides is lacking. Even in countries where landslide information is abundant (e.g. Italy), the vast majority of landslides caused by meteorological (intense or prolonged rainfall, rapid snowmelt) or geophysical (earthquake) triggers go undetected. This paucity of knowledge has consequences on the design of effective remedial and mitigation measures. Systematic use of Earth observation (EO) data and technologies can contribute effectively to detect, map, and monitor landslides, and landslide prone hillsides, in different physiographic and climatic regions.



Click to enlarge.

Landslide Pilot

The CEOS Landslide Pilot aims to demonstrate the effective exploitation of satellite EO across the full cycle of landslide disaster risk management, including preparedness, response, and recovery at global, regional, and local scales, with a distinct multi-hazard focus on cascading impacts and risks.

CEOS Disaster Working Group:
an initiative of > 60 space agencies to support Disaster Risk Management applications with EO data

http://ceos.org/ourwork/workinggroups/disasters/

- → **Landslide Pilot – 2016/2020**
- → **Landslide Demonstrator – 2021/2024**

Objectives of the Landslide WG

Landslide Pilot (2016-2020)

A. **Establish effective practices** for merging different Earth Observation data (e.g. optical and radar) to better monitor and map landslide activity

B. **Demonstrate** how landslide products, models, and services can **support disaster risk management** for multi-hazard and cascading landslide events

C. **Engage and partner with data brokers and end users** to understand requirements and user expectations and get feedback

KEY USER COMMUNITY

Users: national, regional and local governments, civil protection agencies, meteorological and geological services, land use planning decision makers, disaster risk reduction specialists (NGOs, international organisations), industry (including e.g., insurance, transport, forestry sectors).

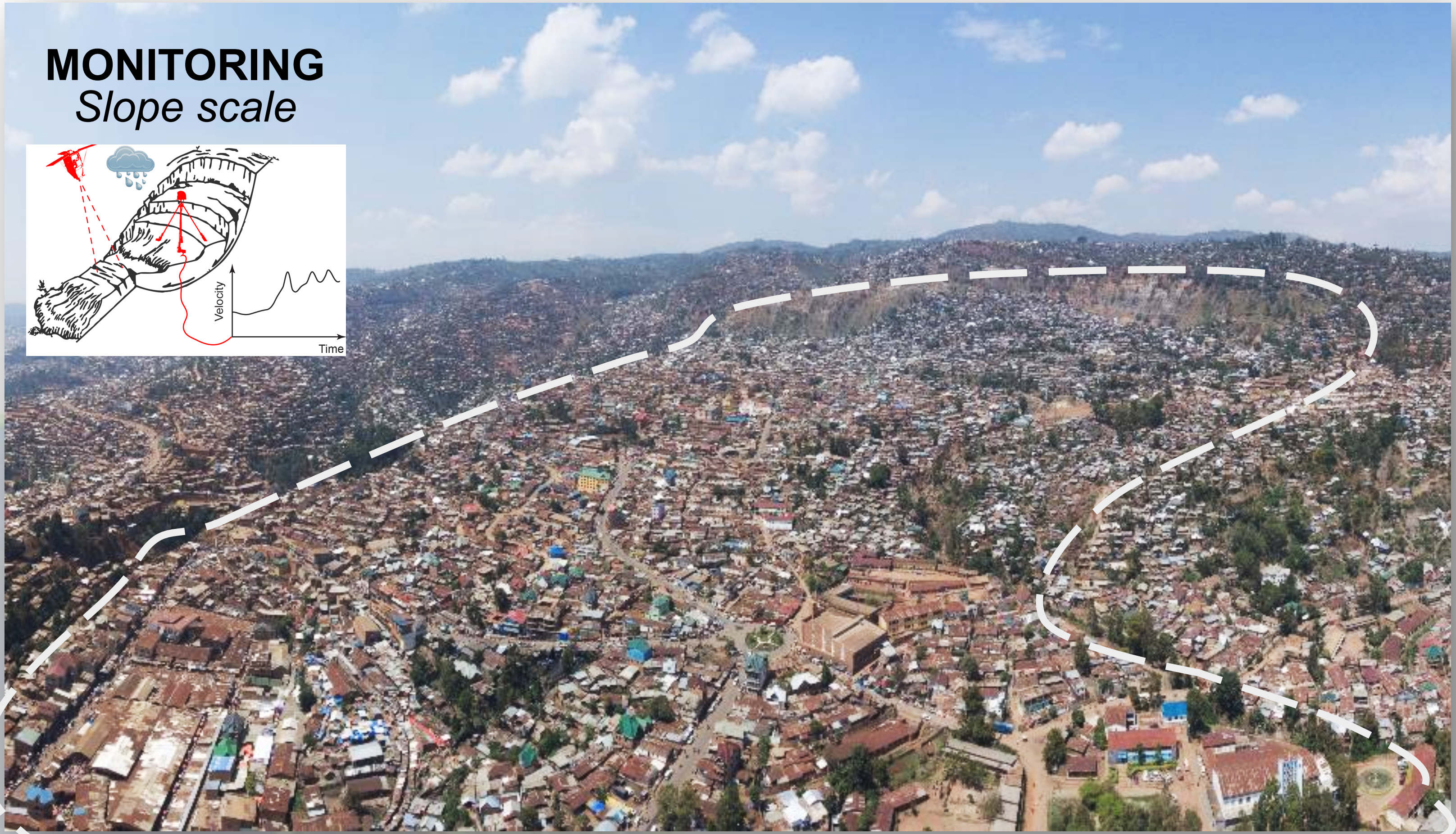
Practitioners: landslide scientists and engineers, meteorological and geological services, satellite data providers, volcano observatories, and value added service companies.

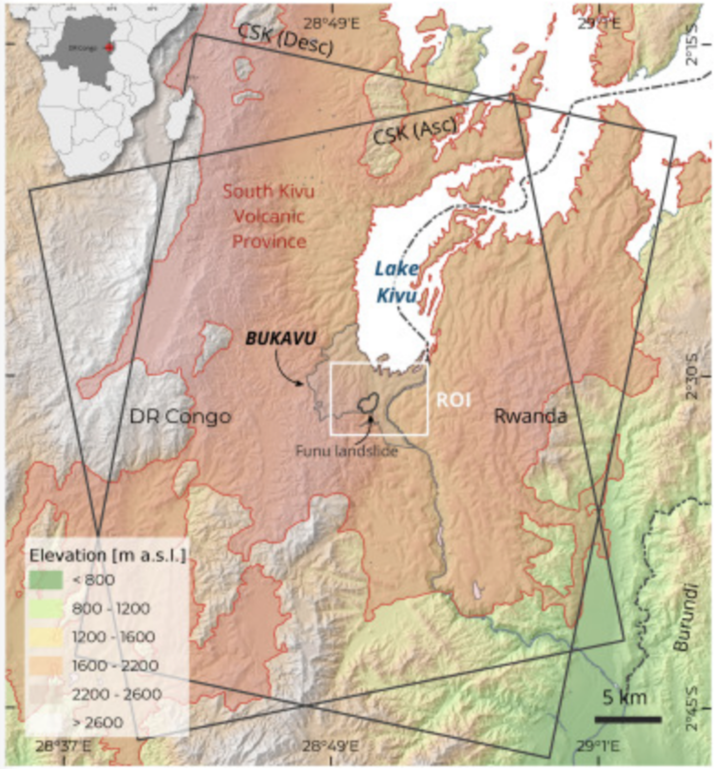
Institutional bodies responsible for risk communication : research institutions with operational responsibilities.

General public: landslide event information for some of the case studies will be made available to the general public for increased awareness

Achievements of Landslide Pilot
Landslide displacement monitoring

- Demonstration of InSAR for slow moving events



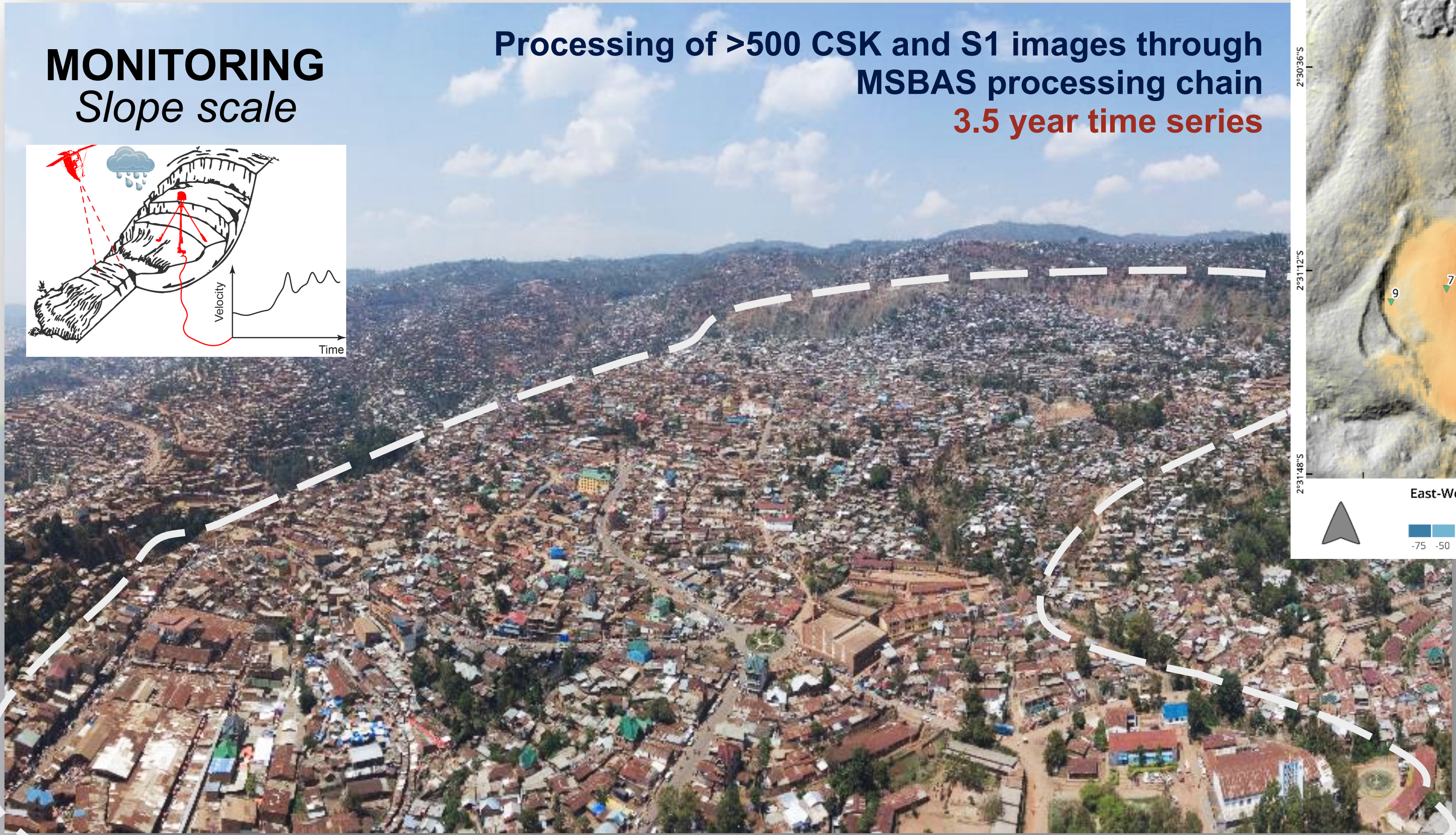


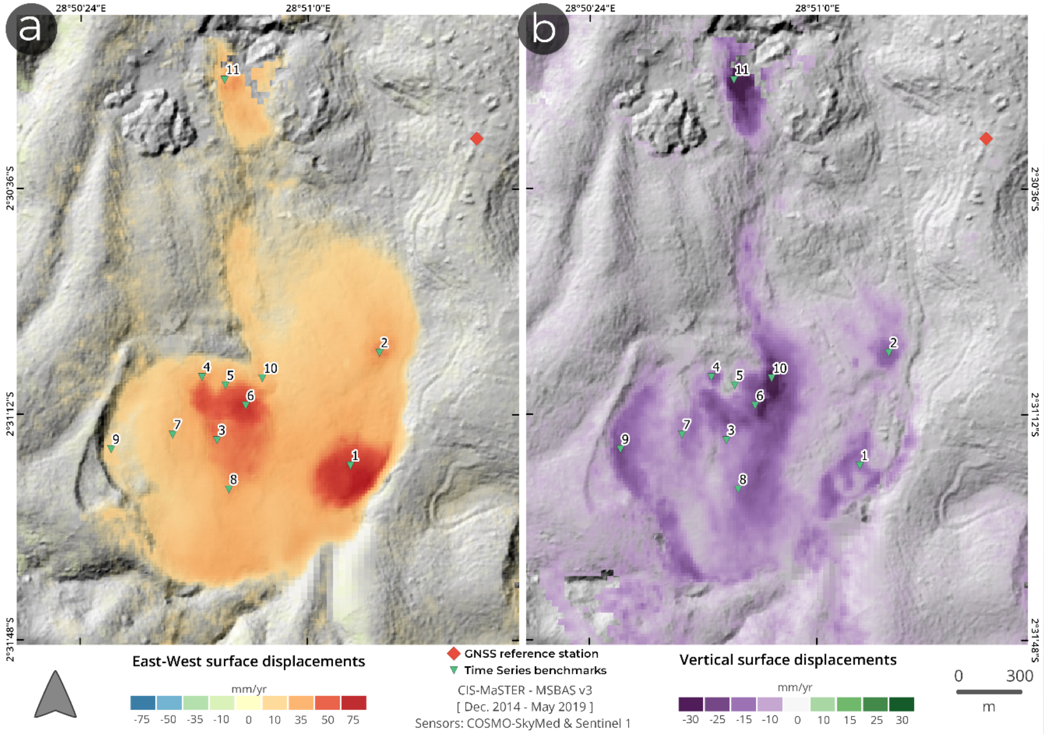
Samsonov, S., Dille, A., Dewitte, O., Kervyn, F., & d'Oreye, N. (2020). Satellite interferometry for mapping surface deformation time series in one, two and three dimensions: A new method illustrated on a slow-moving landslide. *Engineering Geology*, *266*, 105471.

Achievements of Landslide Pilot

Landslide displacement monitoring

- Demonstration of InSAR for slow moving events





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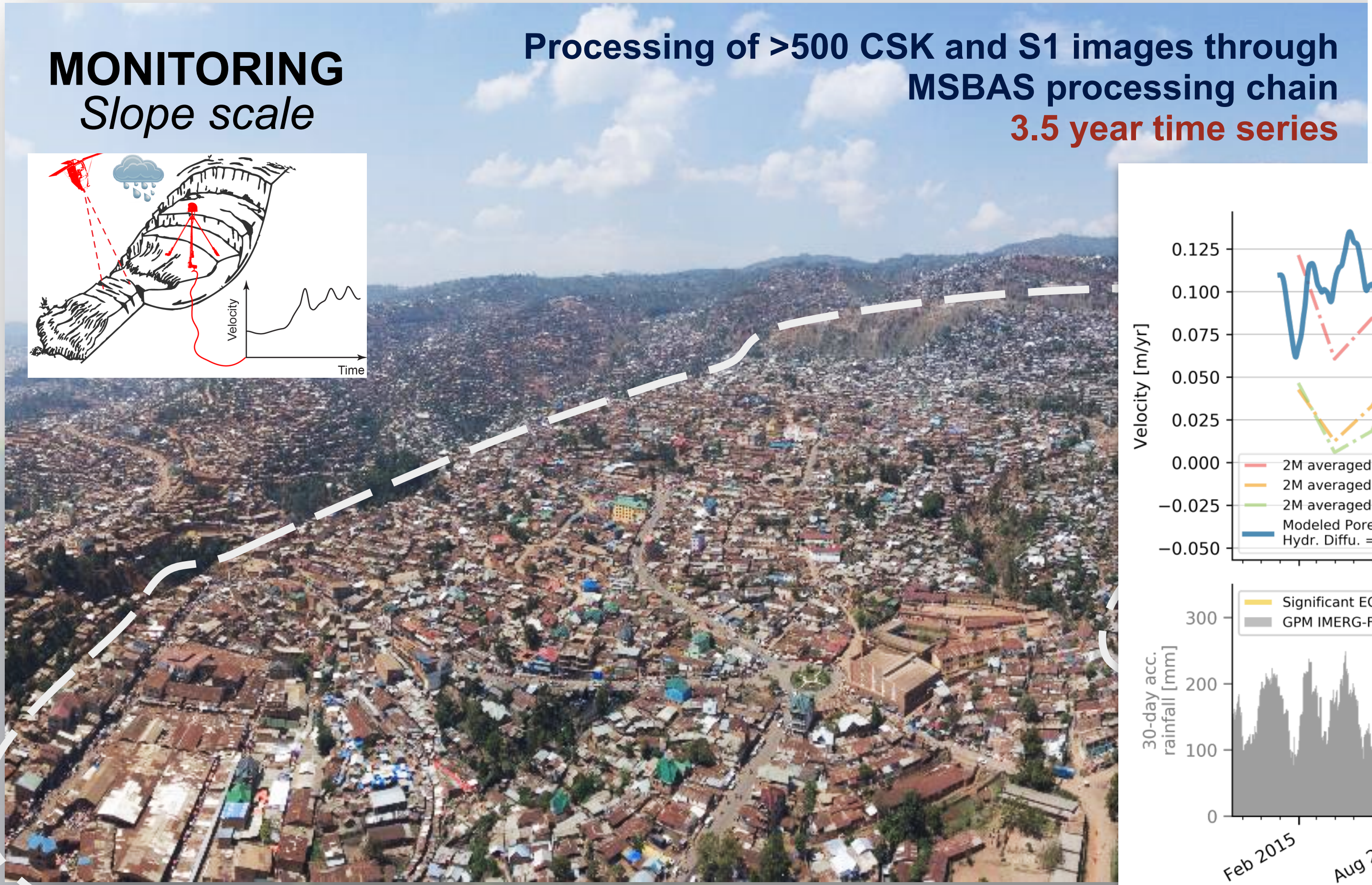
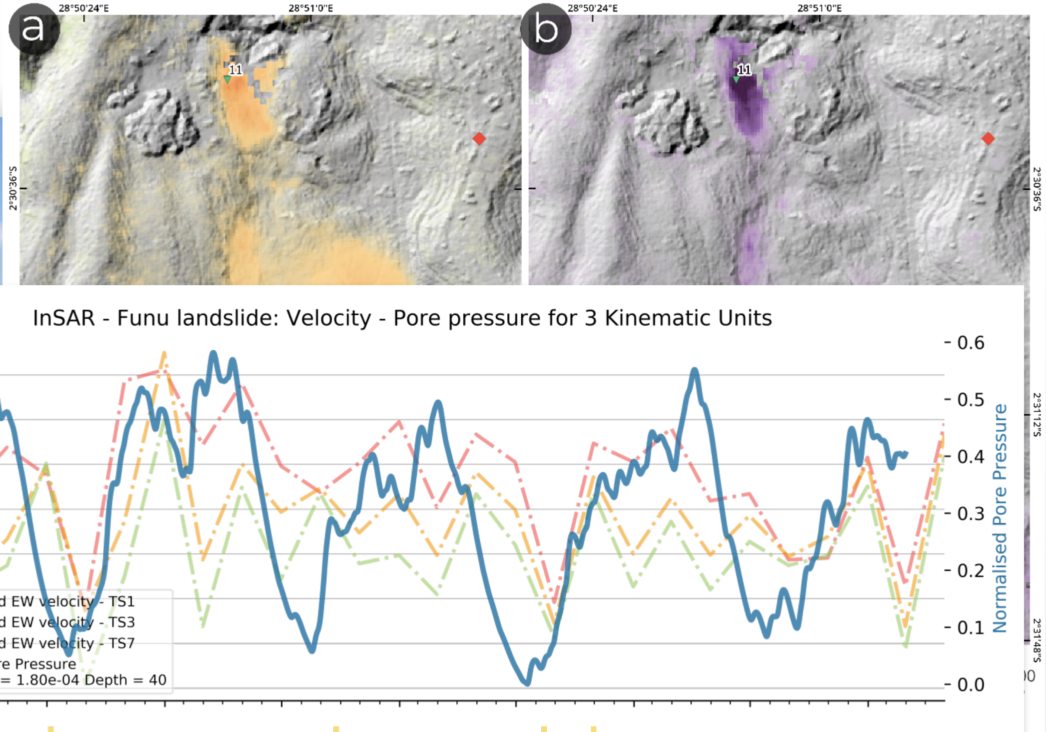
Achievements of Landslide Pilot
Landslide displacement monitoring

- Demonstration of InSAR for slow moving event

MONITORING
Slope scale

Processing of >500 CSK and S1 images through MSBAS processing chain
3.5 year time series

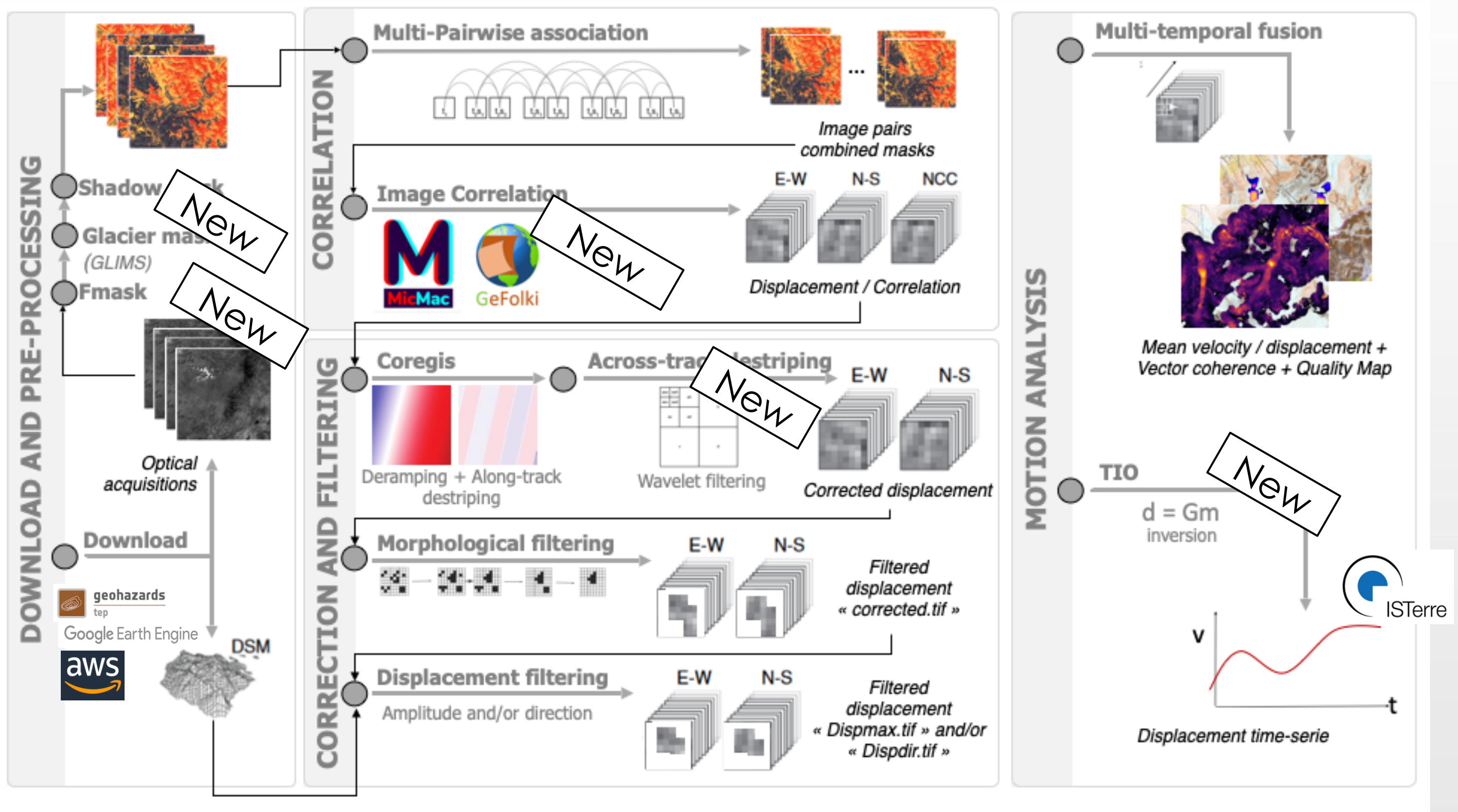




Achievements of Landslide Pilot

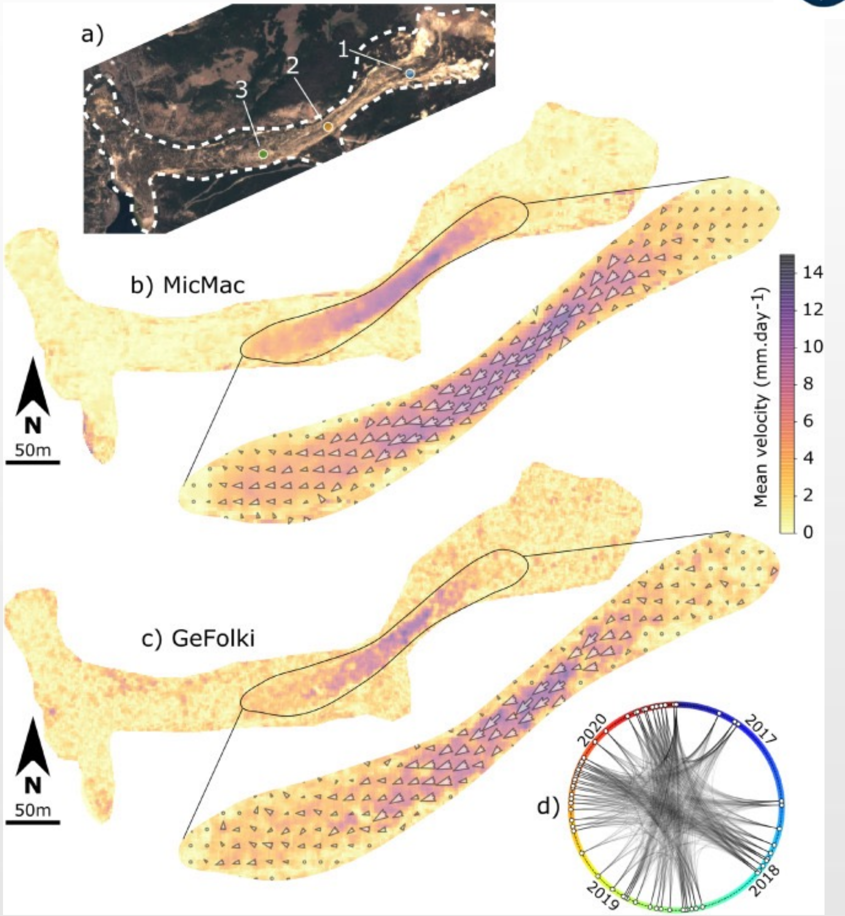
Landslide displacement monitoring

- Demonstration of Optic Image Correlation : GDM-OPT service



Provost et al., 2022

Slumgullion landslide, USA
Sentinel-2 , 2015-2020 / 90+ images



Achievements of Landslide Pilot

Landslide displacement monitoring

- Online access to the service for the French community :

https://www.poleterresolide.fr/services-de-calculs-a-la-demande/#/optic

ForM@Ter

Intranet English

LE PÔLE FORM@TER DONNÉES ET SERVICES RESSOURCES

CALCULS À LA DEMANDE | GDM-OPT

Demande d'accès Se déconnecter

CHOISIR UN SERVICE RESULTATS DES CALCULS RÉSULTATS PUBLICS TUTORIEL CONTACT

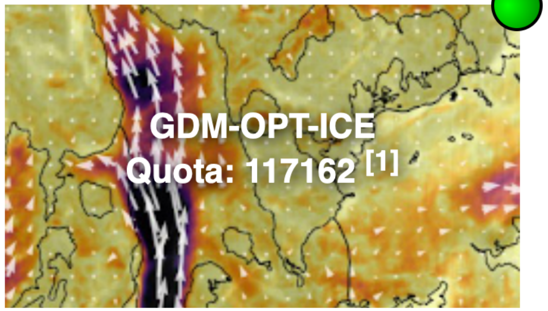
Consultez la charte d'utilisation des services.

GDM-OPT-SLIDE

GDM-OPT signifie Ground Deformation Monitoring with OPTical image time series (Suivi de la déformation du sol à partir de séries temporelles d'images optiques).

GDM-OPT-ETQ

GDM-OPT signifie Ground Deformation Monitoring with OPTical image time series (Suivi des déformations du sol à partir de séries temporelles d'images optiques).



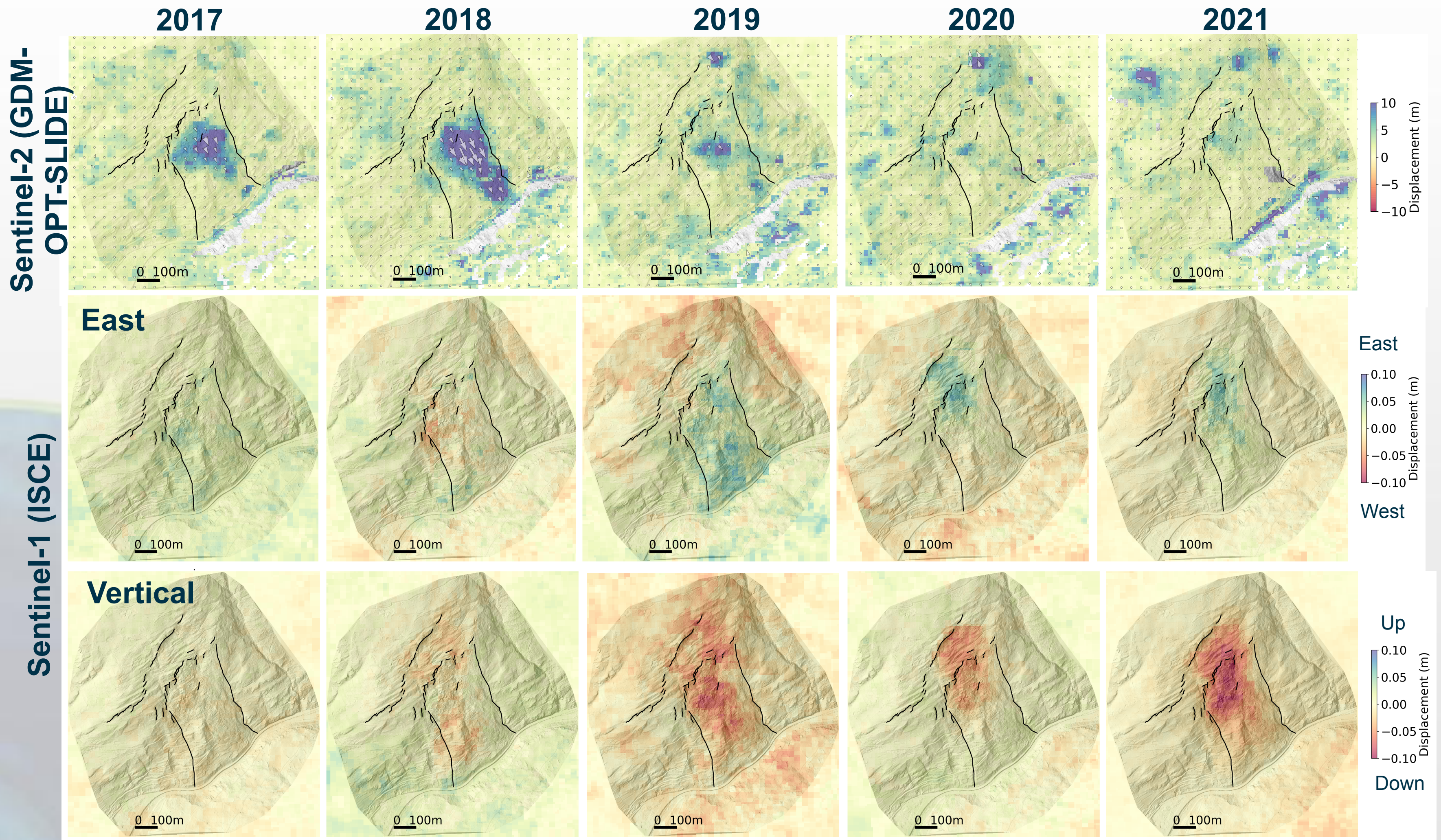
GDM-OPT-ICE

GDM-OPT signifie Ground Deformation Monitoring with OPTical image time series (Suivi de la déformation du sol à partir de séries temporelles d'images optiques).

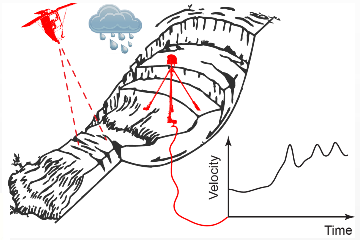
Achievements of Landslide Pilot

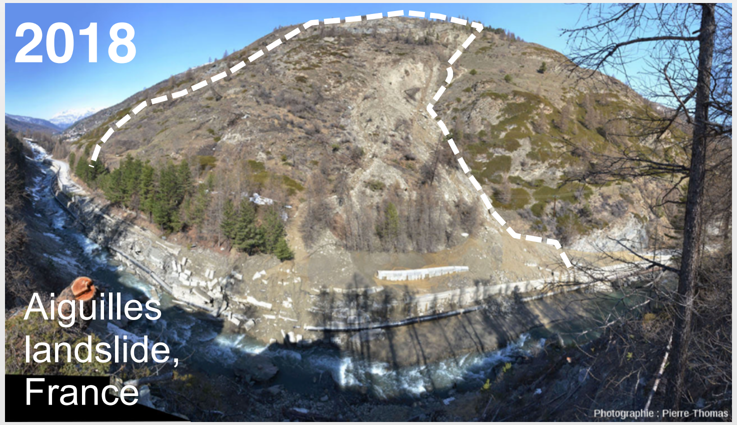
Landslides displacement monitoring at regional scale

- Demonstration of Optic Image Correlation



MONITORING
slope scale

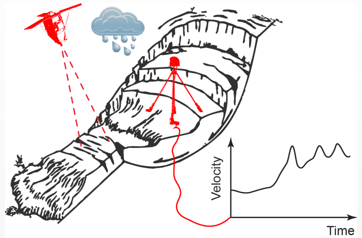


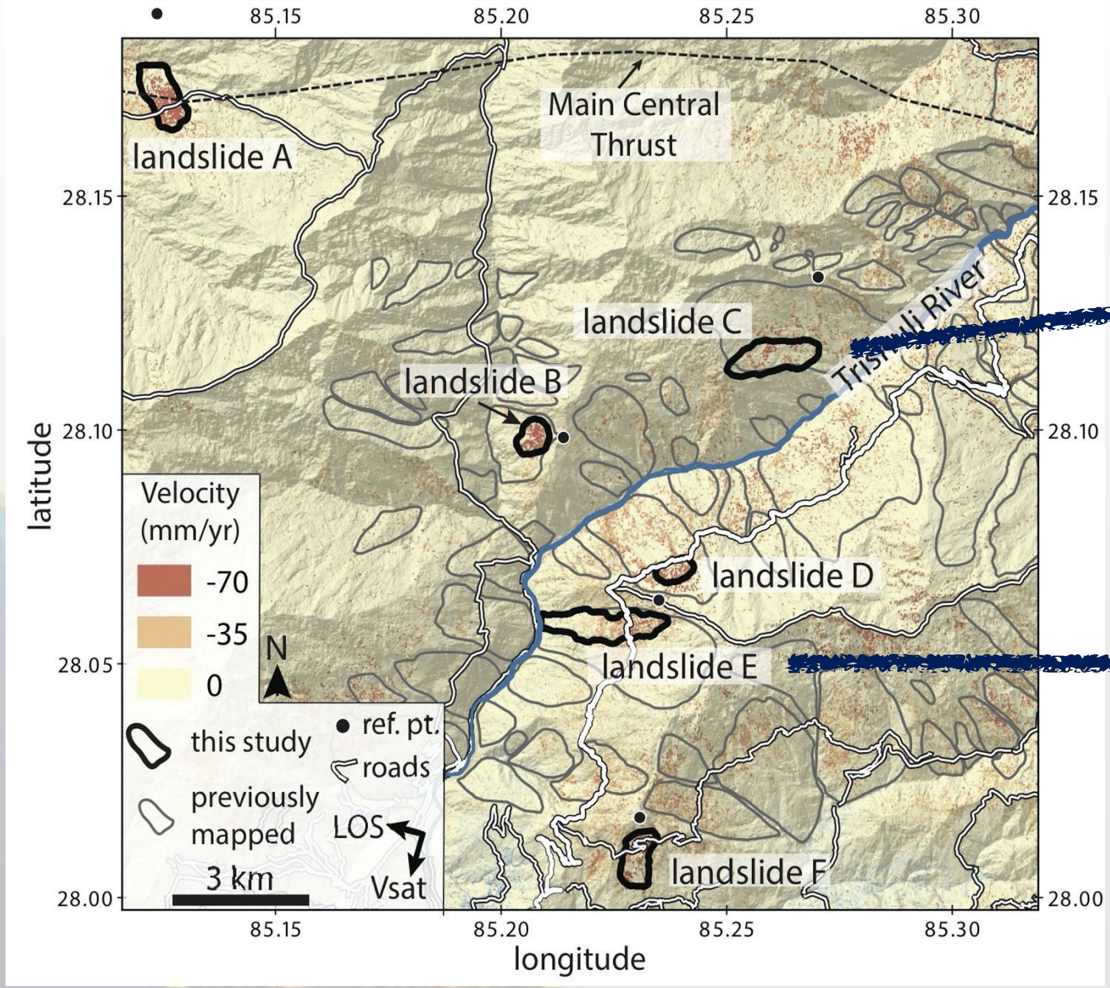


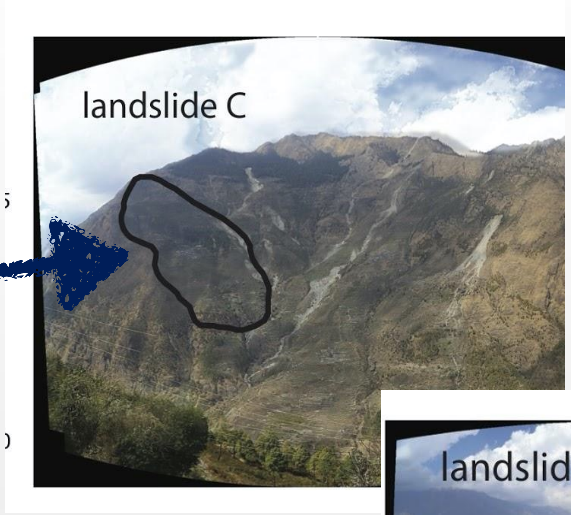
Achievements of Landslide Pilot
Landslides displacement monitoring at regional scale

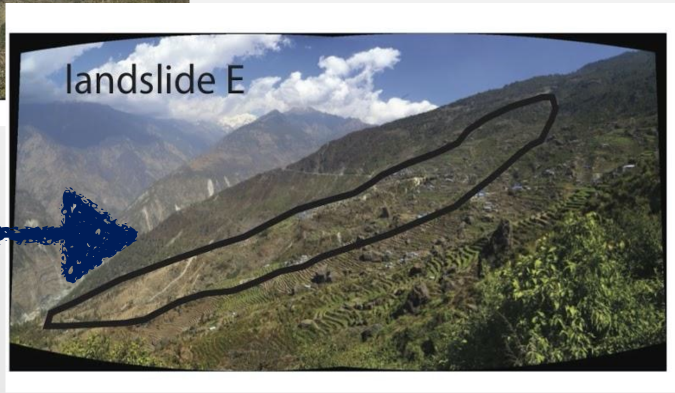
- Demonstration of InSAR for slow moving events

MONITORING
Regional scale









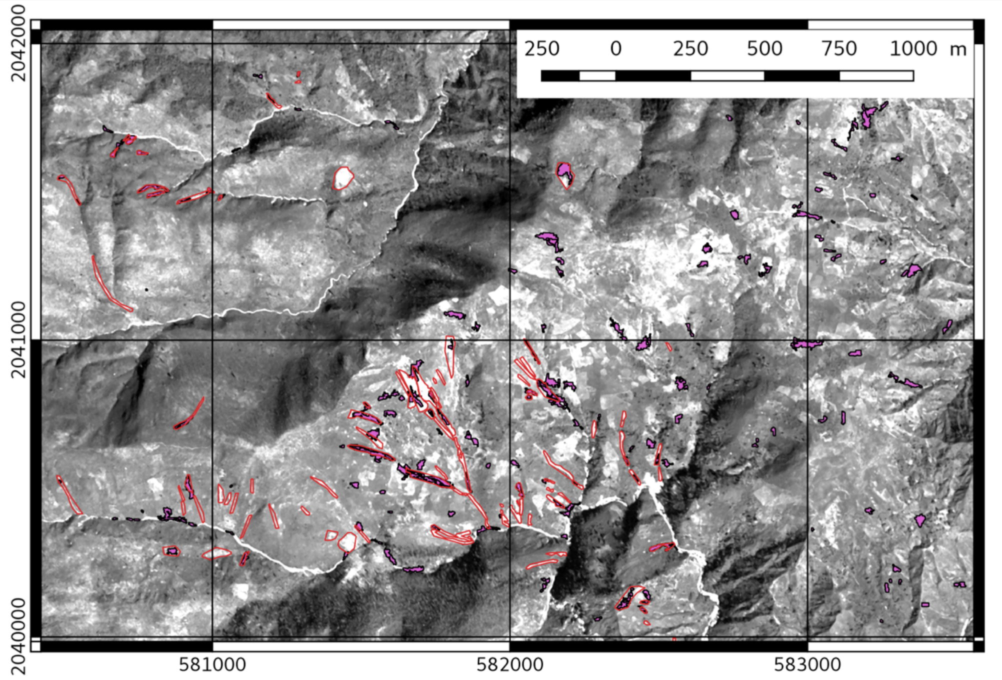
Bekaert et al. 2020, Nepal-based slow moving landslides using InSAR time series from Sentinel-1B. Field validated by other Pilot participants (N. Rosser)

Achievements of Landslide Pilot

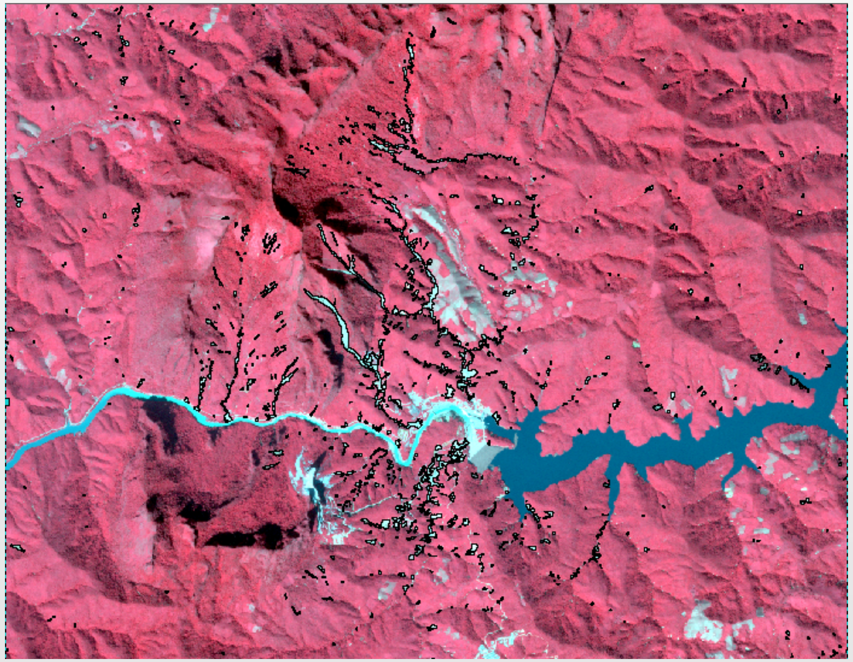
Landslide Rapid mapping

- Advancements in Landslide Mapping:
  - **ALADIM** (Strabourg) and **SALaD** (NASA) algorithms were developed for VHR optical (Pleiades and Planet) to advance modeling capabilities. Methodologies and results were compared and used during disasters to inform local populations about landslide hazard

ALADIM mapped landslides in La Reunion Island from Hurricane Matthew



Aline Déprez & Jean-Philippe Malet (CNRS/EOST)



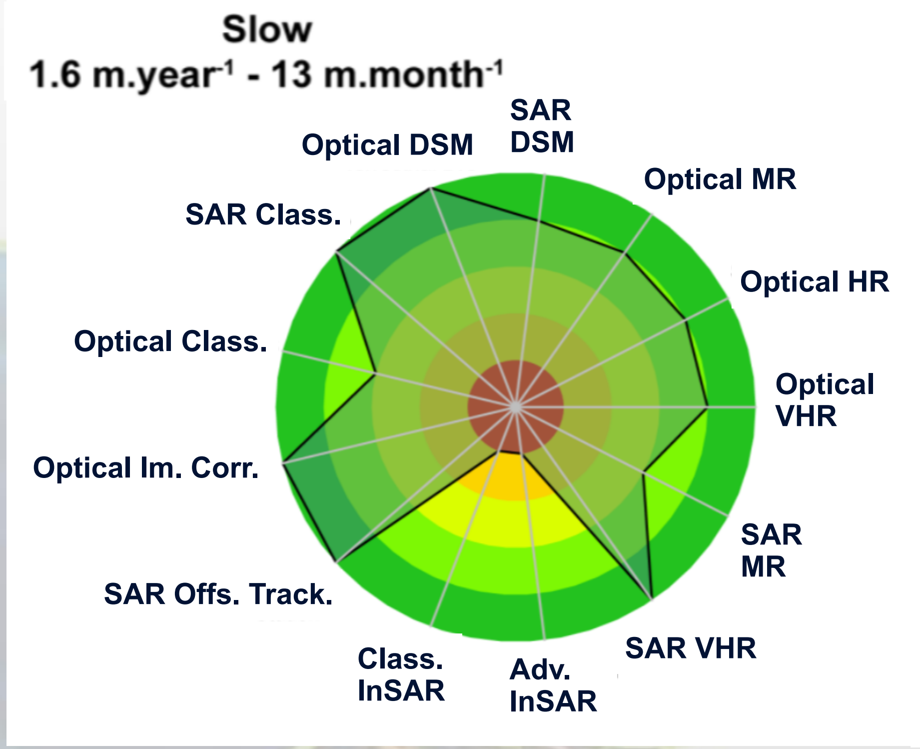
SALaD-based inventory using Planet in Vietnam

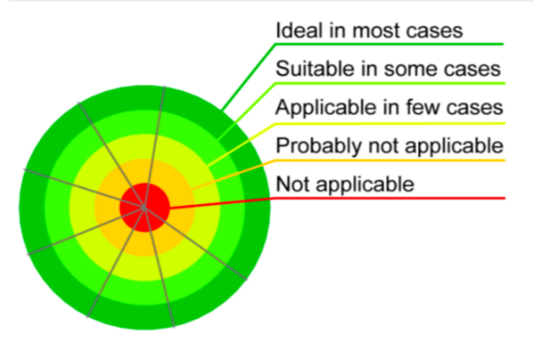
Pukar Amatya (NASA/USRA)

Achievements of Landslide Pilot

Guidelines for EO users

- Establishment of guidelines and relevant criteria for the operational use of EO (satellite) data for landslide detection, mapping and monitoring at several spatial scales



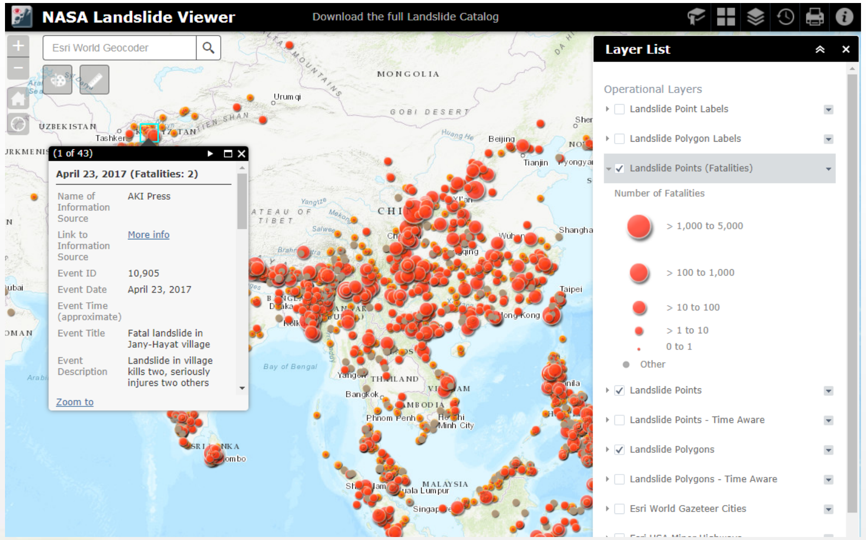


Technological criteria

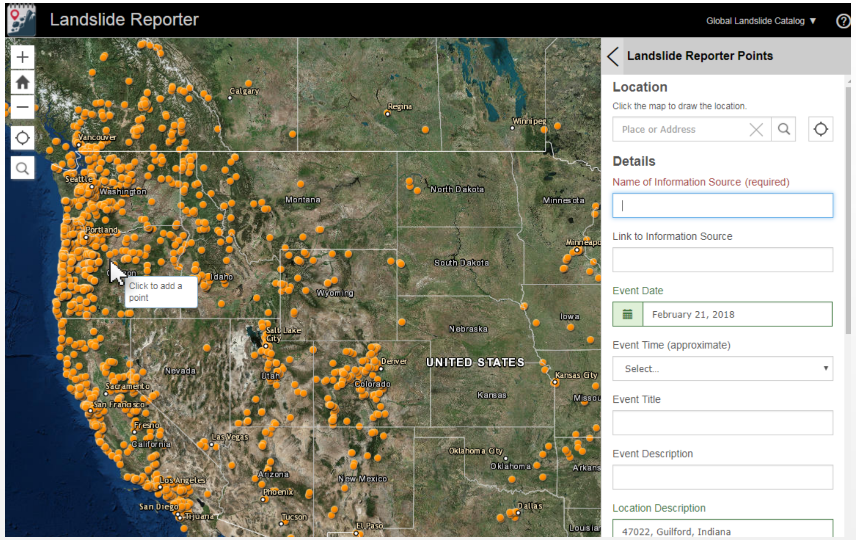
Criteria	Scale range	Explanation
Spatial coverage	Local (e.g. slope) Regional	Typical scales at which the measurements are carried out.
Information type	Landslide location	Geographical position of the landslide
	Landslide size	Geographical position and extent of the landslide
	Landslide volume	Volume of the landslide
	Landslide displacement fields	1D (one component of the displacement or change along a spatial axis or along the Line-Of-Sight -LoS- of the sensor), 2D (horizontal displacement field), 3D (3D displacement field)
	Landslide surface features	Time and space evolution of typical landslide surface features (cracks , boulders)
Spatial resolution	10^{-1} to 10^{2} m	Typical spacing of individual measurements
Temporal resolution	Days to months	Typical time lag between individual measurements
Measurement accuracy	10^{-1} to 10^{2} m for size 10^{1} to 10^{3} m^{3} for volumes 10^{-1} to 10^{2} $m.day^{-1}$ for displacement rates	Accuracy of the measured quantities such as displacement rates, volumes and the location of surface features
Operation mode	Continuous – data flow type processing	Automatic calculation can be carried out without human intervention for long time periods and for each new sensor images
	Campaigns – on-demand processing	Measurements require regular human intervention and are thus typically carried at intervals of several days, weeks or months.
Approximate elaboration time	minutes to days	Approximate time lag between the measurement of the system and the production of the output results.
Approximate costs	XXXX $	Typical costs including sensor data acquisition and processing
Technological maturity	Concept	Technical design and potential applications have been proposed.
	Prototype	Working prototypes have been tested in a limited number of experiments.
	Case-studies	Operating systems have been tested for landslide applications for short time periods.
	Commercial	Working systems and processing softwares are

Cooperative Open Online Landslide Repository (COOLR):
Landslide Viewer and Landslide Reporter

LANDSLIDE VIEWER



LANDSLIDE REPORTER



https://landslides.nasa.gov

Landslide occurs → Submit to Landslide Reporter → Validation by NASA → See event on Landslide Viewer → Download and Analyze

***COOLR** is a new platform to view and report landslide events around the world that contains two web apps: Landslide Viewer and Landslide Reporter. With Landslide Viewer, landslide reports from **NASA's Global Landslide Catalog (GLC), citizen science data**, and **other contributed inventories** can be visualized on top of environmental data or downloaded for research or response activities. Landslide Reporter allows citizen scientists and the public to add new landslide events to COOLR.*

Objectives of the Landslide WG

Landslide Demonstrator (2021-2024)

A. **Application 1:** Use satellite data for landslide **disaster assessment and mitigation along transportation and corridors**, with goal of establishing local monitoring of areas.

B. **Application 2:** Use of satellite data for establishing **landslide risk financing products**.

C. **Application 3**: Coordinate and expand the availability of landslide inventories and supporting data to advance **landslide science at global scale**, with the systematic documentation of large landslide disasters triggered by intense rainfall and/or high magnitude earthquakes in terms of standardized inventories of different complexity.

KEY USER COMMUNITY

Users: national, regional and local governments, civil protection agencies, meteorological and geological services, land use planning decision makers, disaster risk reduction specialists (NGOs, international organisations), industry (including e.g., insurance, transport, forestry sectors).

Practitioners: landslide scientists and engineers, meteorological and geological services, satellite data providers, volcano observatories, and value added service companies.

Institutional bodies responsible for risk communication : research institutions with operational responsibilities.

General public: landslide event information for some of the case studies will be made available to the general public for increased awareness

Application #1: Transportation corridors

Application 1: A demonstrator for the operational landslide monitoring of traffic and pipeline corridors (China, European Alps, US, Canada)

Demonstrator Leads: Jean-Philippe Malet (CNRS/EOST) and Corey Froese (BGC)

Industry Participants: Highway/Train companies, Pipelines companies, Engineering Geology Bureaux, State offices

Pipelines to be protected

Methodologies

- Use of InSAR-PSI techniques to monitor slow-moving deformation patterns
- Use of optical derived techniques to monitor fast-moving deformation patterns
- Definition of procedures to propose permanent monitoring services over the uses cases as demonstrator

East France – March 2020 – landslide on high speed train TGV

Elkhorn city (Kentucky, US) – February 2020 – shallow landslide / mudflow

Application #2: Landslide Disaster Risk Products

Developed and tested in **Morocco** with the **FSEC** (Solidarity Fund Against Catastrophic Events) and the **World Bank**

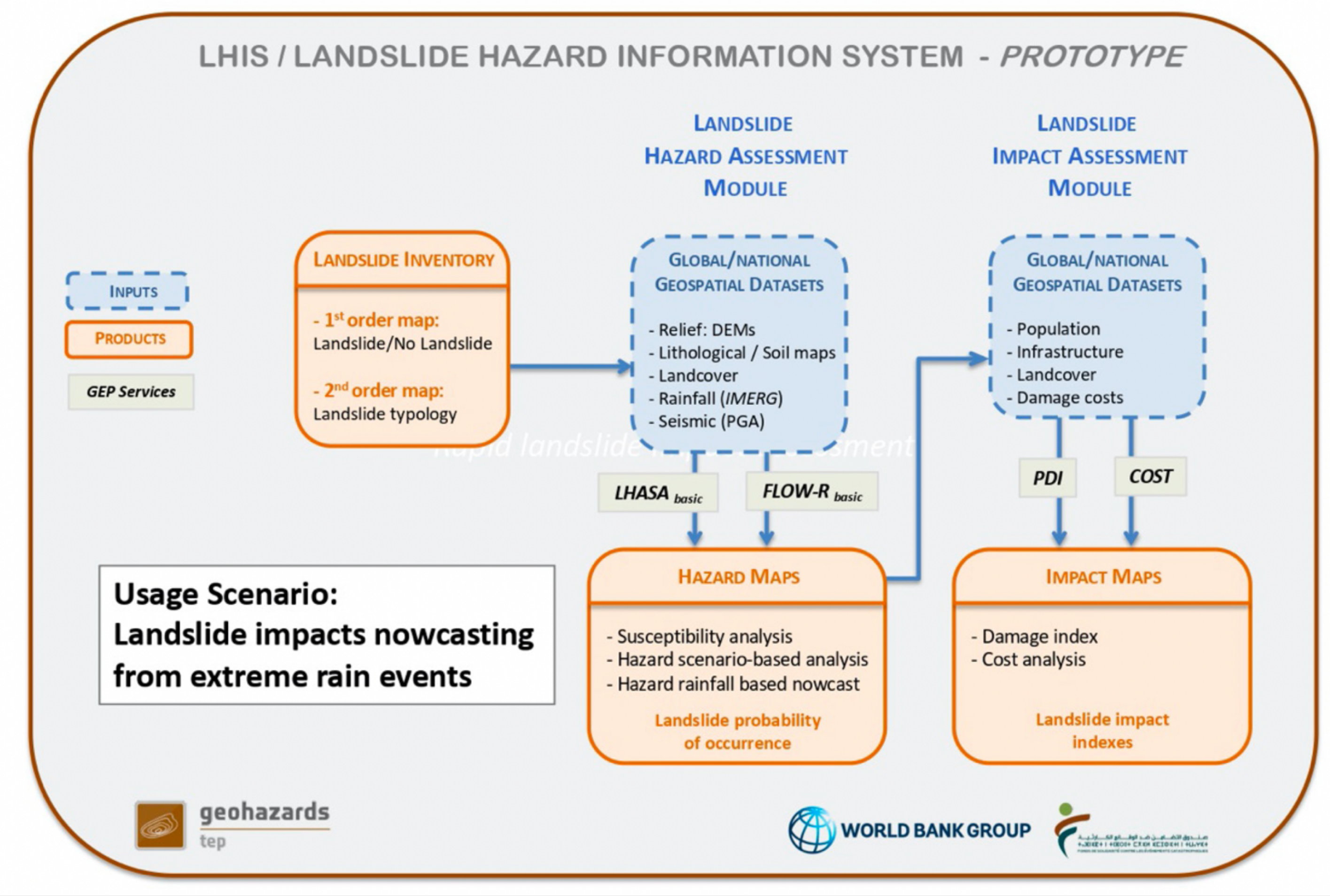
Application 2: Operational Landslide EO Products for Disaster Risk Financing and Insurance Program (World Bank)

Demonstrator Leads: Clément Michoud (Teranum) and Jean-Philippe Malet

Industry Participant: World Bank

Goal: implement a processing platform prototype to respond to likely landslide events (in Near-Real Time, NRT) in order to provide estimates of parameters suitable to inform parametric insurance calculations.

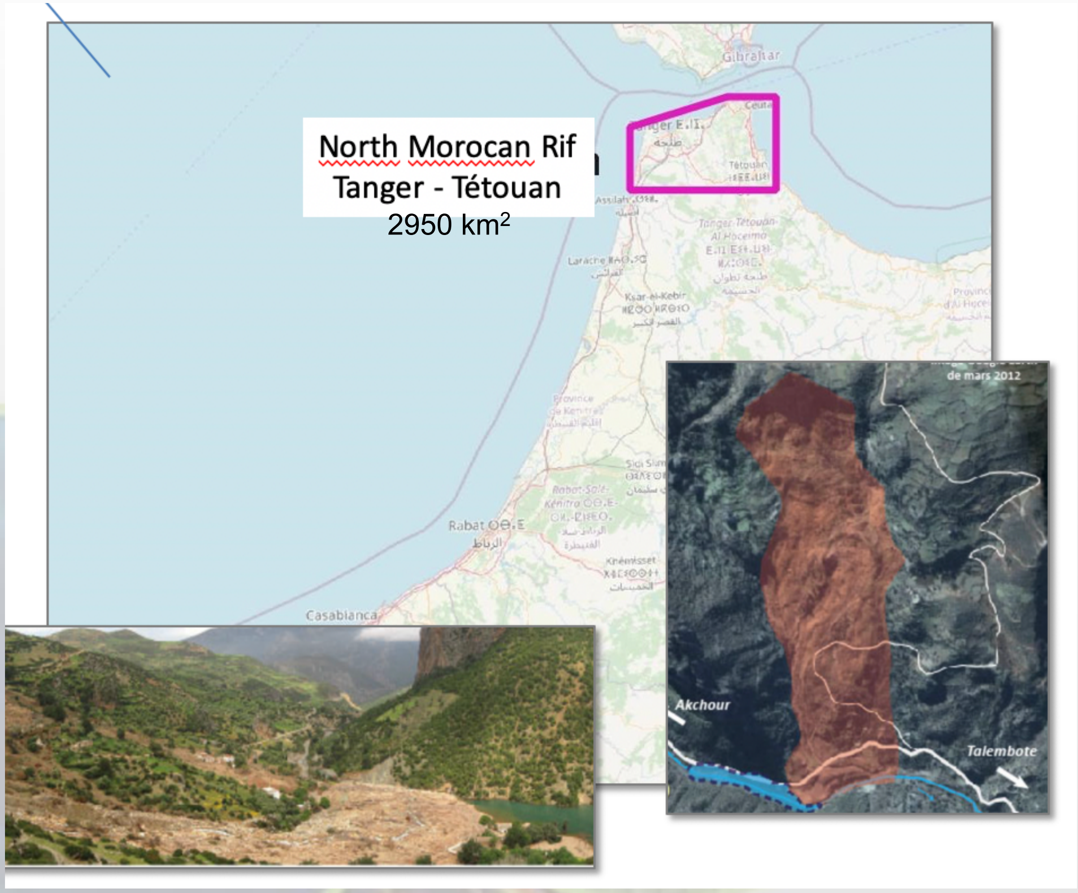
Development and stress-tests of services and products over Morocco, but all the development will be generic to be easily transferred to other countries and risk situations (especially in SE Asia).

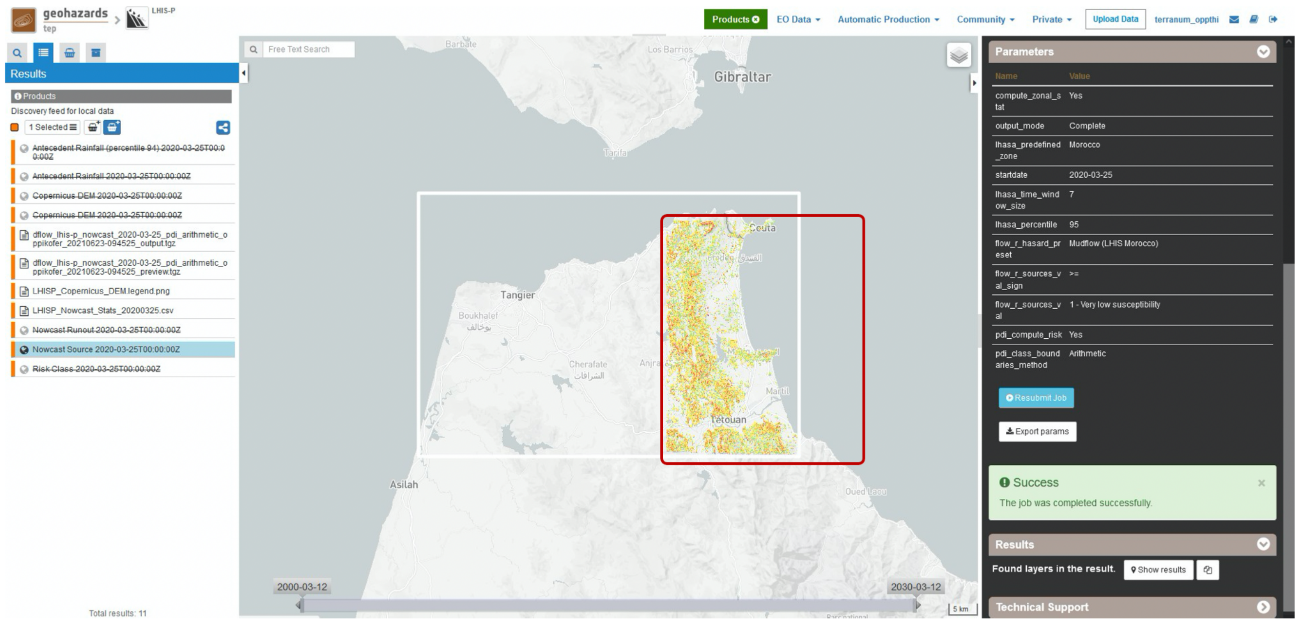


Application #2: Landslide Disaster Risk Products

Application 2: Operational Landslide EO Products for Disaster Risk Financing and Insurance Program (World Bank)

- **Main input data :** DEM (Copernicus GLO30, 30), ESA Land Cover map, ‘Global Forest Changes’ map, Landslide susceptibility map;
- **Nowcaster:**
  > Rainfall threshold is the TRIGGER, **NASA GPM/IMERG rainfall data,**
- Five outputs are automatically computed once a day:
  - Antecedent rainfall index**, nowcasted landslide sources and related runout extents,** objects at risks and statistics per municipality





24 March 2020 back-analysis: computed runout extents of alarmed potential source areas

Application #3: Global Landslide Data

Application 3: Advancing EO-based landslide inventories for extreme forcing events (heavy rains, high-magnitude earthquakes)

The goal of this application is to coordinate and share methodologies for the establishment of landslide inventories accross different geologic and morphologic zones. In this activity we will proose standard for creating and publishing EO-based landslides inventories, with the goal of develoing an online open system to share algorithms and inventories using SAR and optical methodologies. This work will be done in coordination with the newly formed LandAware consortium's Data Working Group, with EGS (EuroGeoSurveys) and with JRC

Methodologies

Inventories

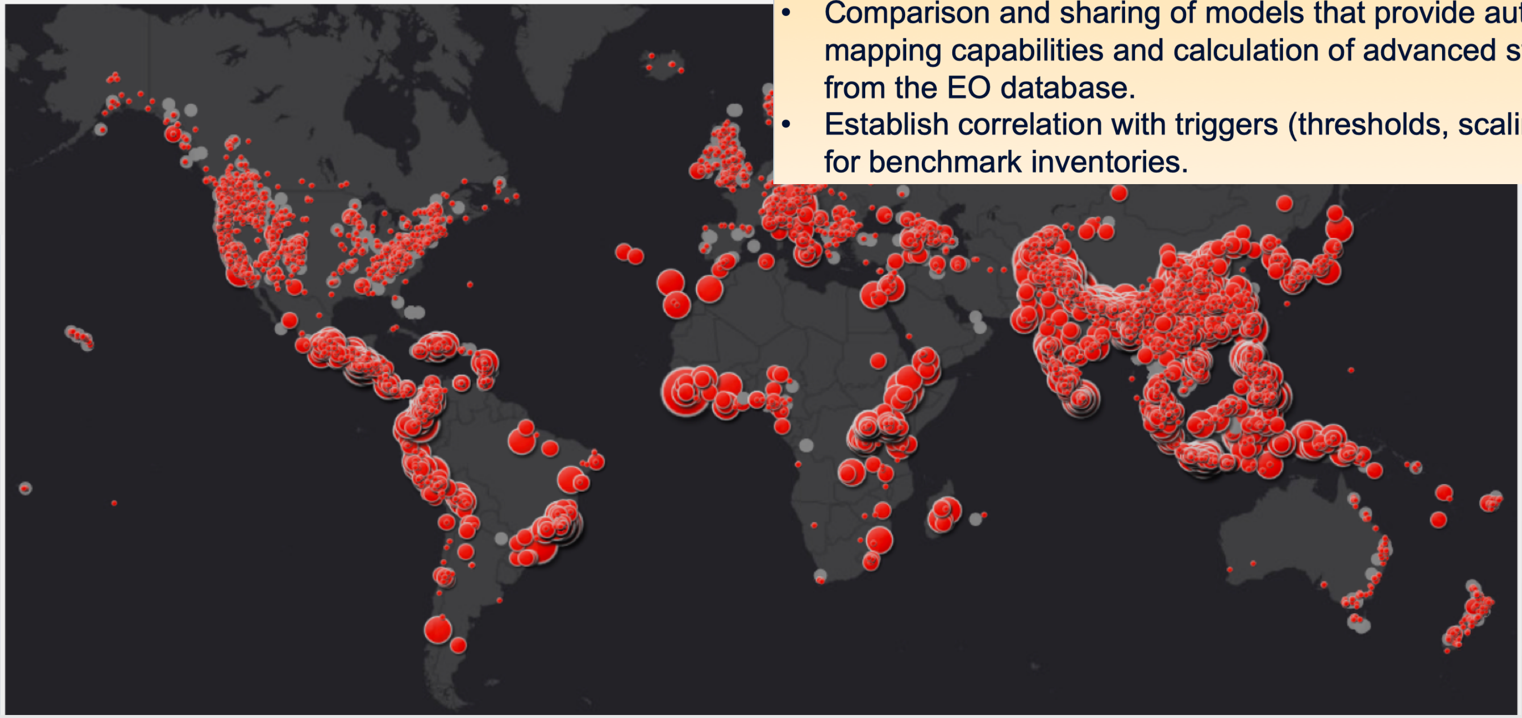
- New, open methods for SAR and optically-derived inventories. Definition of quality criteria for validating EO-based inventory and store the information, data standards
- System to store and disseminate inventories on-line

Models

- Comparison and sharing of models that provide automatic mapping capabilities and calculation of advanced statistics from the EO database.
- Establish correlation with triggers (thresholds, scaling laws) for benchmark inventories.

Demonstrator Leads: Dalia Kirschbaum, Jean-Philippe Malet (CNRS/EOST) and Olivier Dewitte (RMCA).

Industry Participants: LandAware Consortium, World Landslide Forum, USGS, EuroGeoSurveys, JRC and other geological mapping agencies

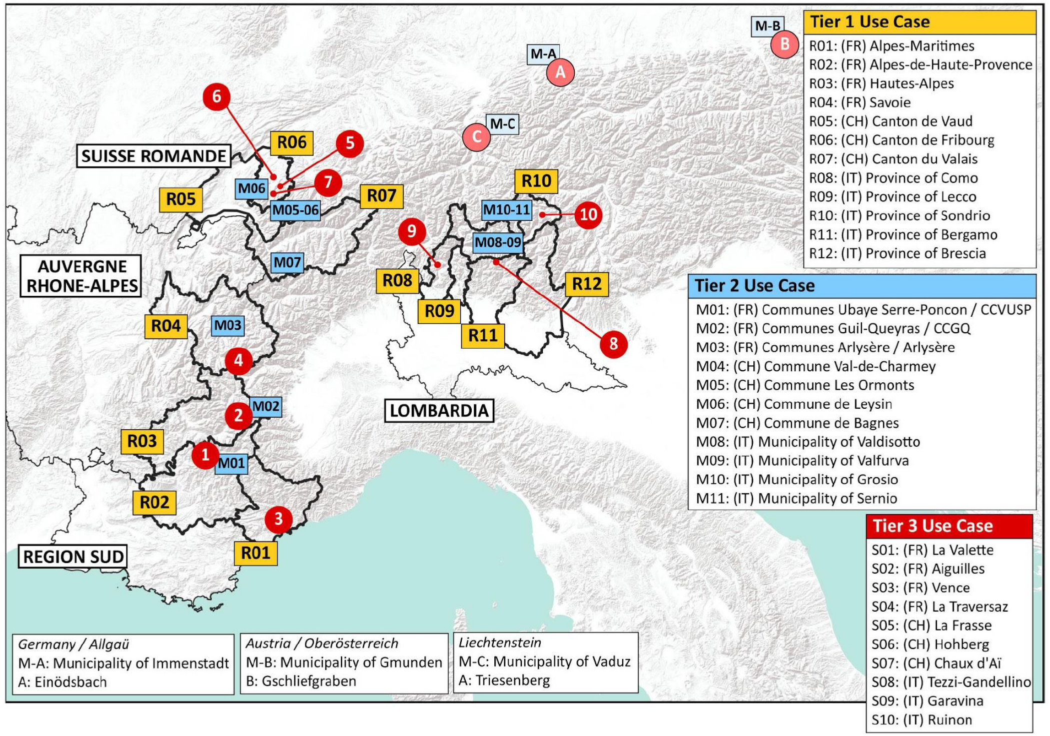


Application #3: Global Landslide Data

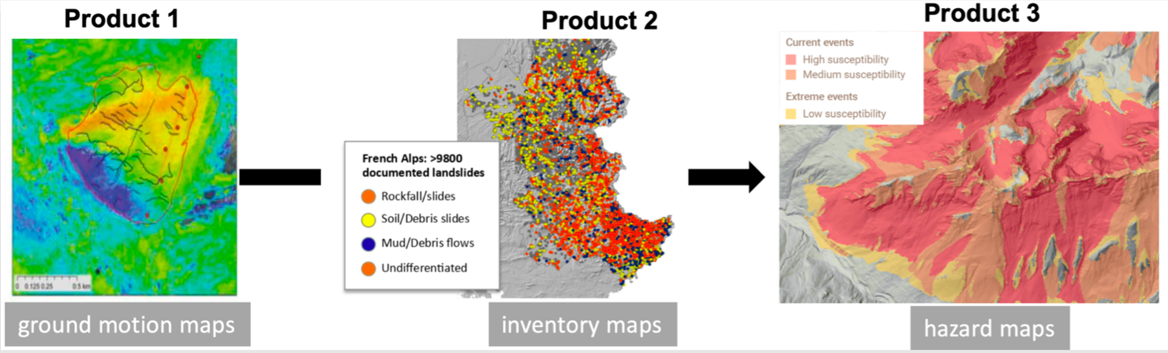
eo4alps-landslides focuses on selected use cases in the French, Swiss and Italian Alps

More than 20 landslide practitioners involved in the design, testing and update of the services

State agencies, Regional and local risk managers, Private bureaux in engineering geology, Private bureaux in hazard/risk assessment.



Monitoring services and landslide products available on the GEP



Wrap-up

- **Achievements in the Landslide Pilot**
  - **Case studies that demonstrate the following:**
    - **EO satellite data can effectively support** the estimation of relevant landslide parameters (location, size, velocity, triggers) over large spatial domains;
    - **the combination of Synthetic Aperture Radar (SAR) and multispectral satellite data can improve** classical landslide modeling approaches;
    - **EO satellite data can provide first order estimates of landslide hazard** where local ground-based observation capacity is limited, making it highly suitable for applications in developing countries.
- Goals for the Landslide Demonstrator
  - Demonstrate the **usefulness of satellite data for *operational applications of landslide disaster risk management (DRM)*** with the ultimate goal to increase resilience against landslide disasters.
    - Use EO data to engage the railway, transportation and pipeline sector on monitoring of hazards that may affect their operations and planning
    - Develop an operational platform to conduct and evaluate landslide risk financing products
    - Coordinate and expand the use of EO data for landslide inventory generation, particularly after major triggering events, create a repository for data and code sharing on this topic.

Thank you for your attention

Contact: jeanphilippe.malet@unistra.fr