Committee on Earth Observation Satellites

Landslide Demonstrator

EO-based Landslide services: Paving the Way for Landslide Risk Management Products

Working Group Presentation

September 22, 2021

Landslide Demonstrator Objectives

Demonstrator Leads

Jean-Philippe Malet (CNRS/University of Strasbourg)
Dalia Kirschbaum (NASA)
Corey Froese (BGC Engineering)
Clément Michoud (Terranum)

Landslide demonstrator focuses on three key areas in which landslide hazard/risk assessment may be advanced using a combination of EO data and models to support different end-user communities.

- **Application 1**: Use satellite data for landslide disaster assessment and mitigation along **transportation and pipeline corridors**, with goal of establishing local monitoring of areas of possible danger with consistency of observation, and of facilitating the assessment of the future evolution of these slopes
- **Application 2:** Use of satellite data for establishing **landslide risk financing products** (country or region risk profiles, hazard and risk maps) in full complementarity with the World Bank Disaster Risk Financing and Insurance Program (DRFIP).
- **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.

Demonstrator Timeline

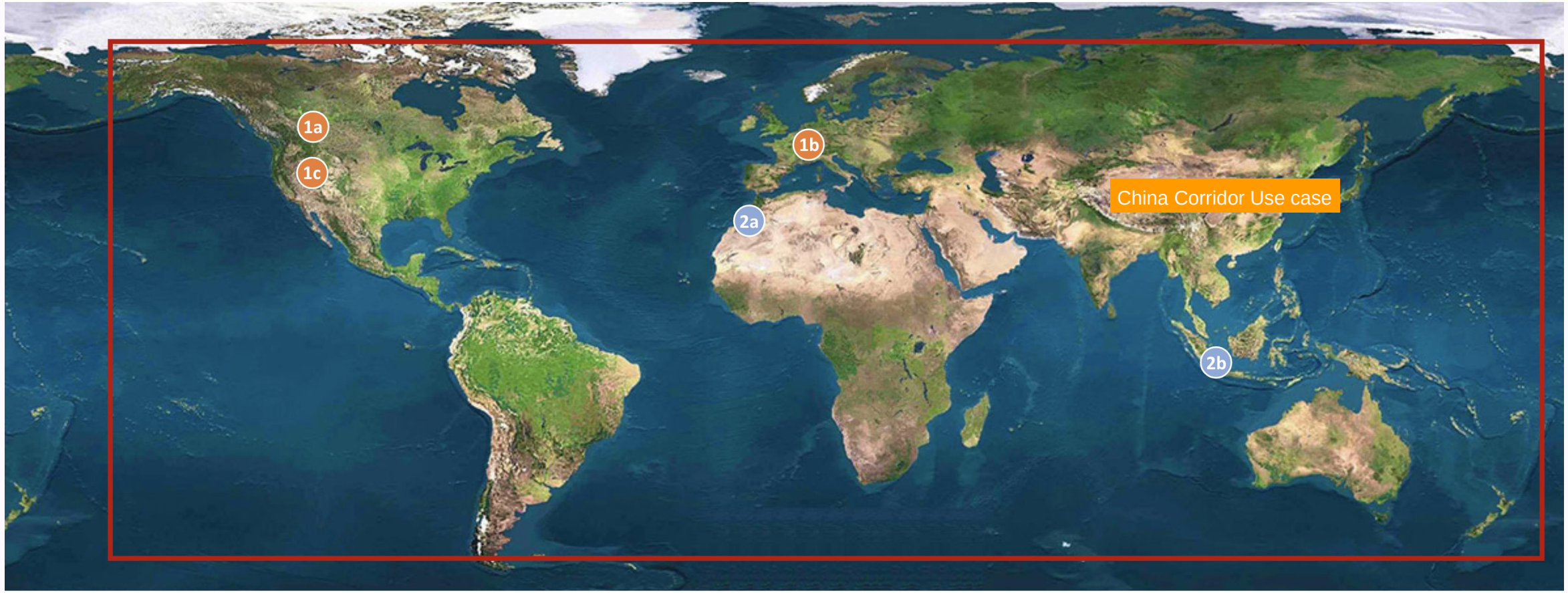
Demonstrator Implementation Plan – Start Date: June 2021

- **Year 1 (June 2021 – June 2022):**
  - Definition of landslide services and products requirements for the three applications.
  - EO-satellite database creation for the geographical use cases.
  - Consolidation of resources (persons, data, IT processing).

- **Year 2 (June 2022 – June 2022):**
  - Demonstration of the landslide services for some use cases and reporting;
  - Concept of the prototype demonstration App on GEP for the three applications.

- **Year 3 (June 2023 – June 2024):**
  - Implementation of the prototype demonstration App on GEP for the three applications;
  - Training and dissemination on-line user-oriented material for the three applications.
  - Final Demonstrator reporting

Use cases



CEOS Landslide Demonstrator

- Application 1 / Corridor (1a: Canada/Alberta – Swan Hills, 1b: France-Italy-Swiss - Aosta/Wallis/Arve , 1c: US – Midwest)
- Application 2 / DRF (2a: Morocco / Rif-Tetouan-Tanger, 2b: Indonesia)
- Application 3 / Inventories

Data procurements: status

- **CSA** (Canada): **RCM data** (5 m Strip Map) over Swan Hills

Collection started End July 2020 – on-going (acquisition each 4 days)

- **DLR** (Germany): **TSX SpotLight** tasking over 2 sites (1 Canada, 1 France) for 2 years time series (140 images per sites)

Data acquisition started over Drynoch (Canada), start in October for La Valette/Ubaye (France)

- **CNES** (France): **Stereo/Tri-stereo Pléiades** tasking over 3 sites for time series

Request send to CNES early September (6500 km^2 / year - for 2 years)

- **Conae / ASI**: **SAOCOM** for 2 years over 2 sites

For Canada, agreement pending with Conae ; For Swiss – request to ASI in preparation

- **ASI**: **CSK** tasking for 2 years for 1 site

1 Morocco – request to send to ASI

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, Pipeline 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

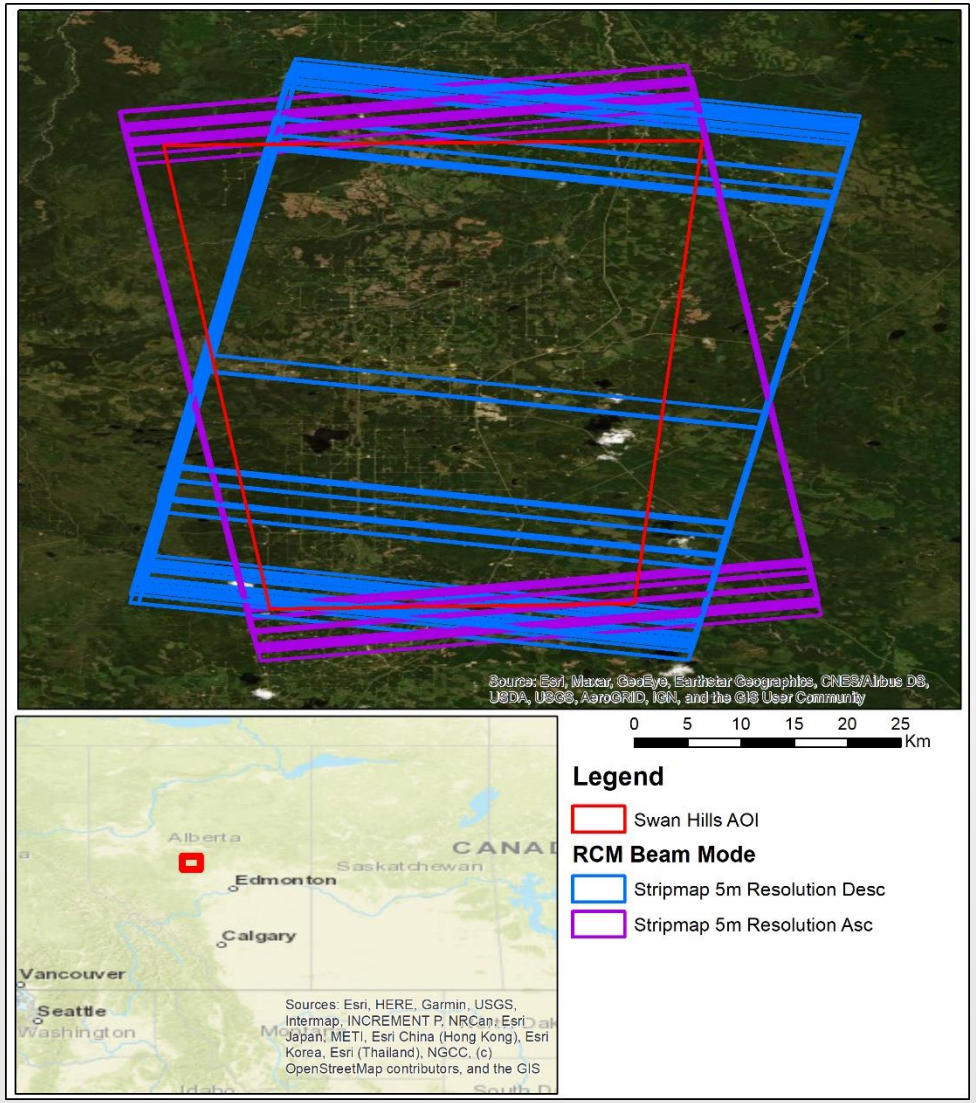
Transportation Corridors: Use case Swan Hills

Given the monitoring history, the Swan Hills site is considered ideal to develop and test the operational limitations of using space-based earth observation (SBEO) for landslide disaster risk management

Targeted collections of SAR data includes:

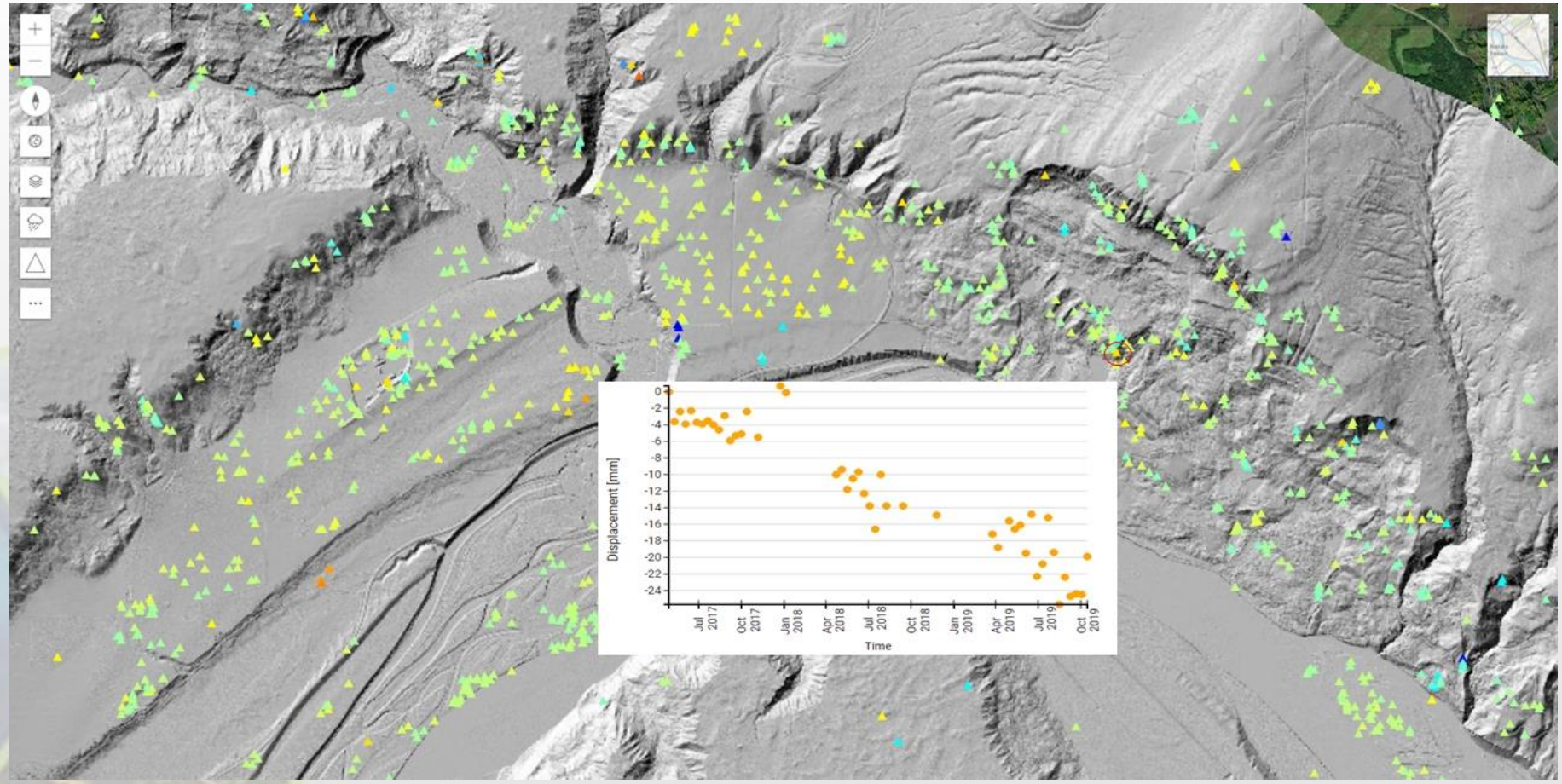
- Radarsat Constellation Mission (RCM) – 5 m Stripmap mode data in Ascending and Descending mode. Captured roughly every 4 days from 2020-07-24 and acquisitions are ongoing

- SAOCOM data (L-band SAR) – currently being negotiated in collaboration with CONAE



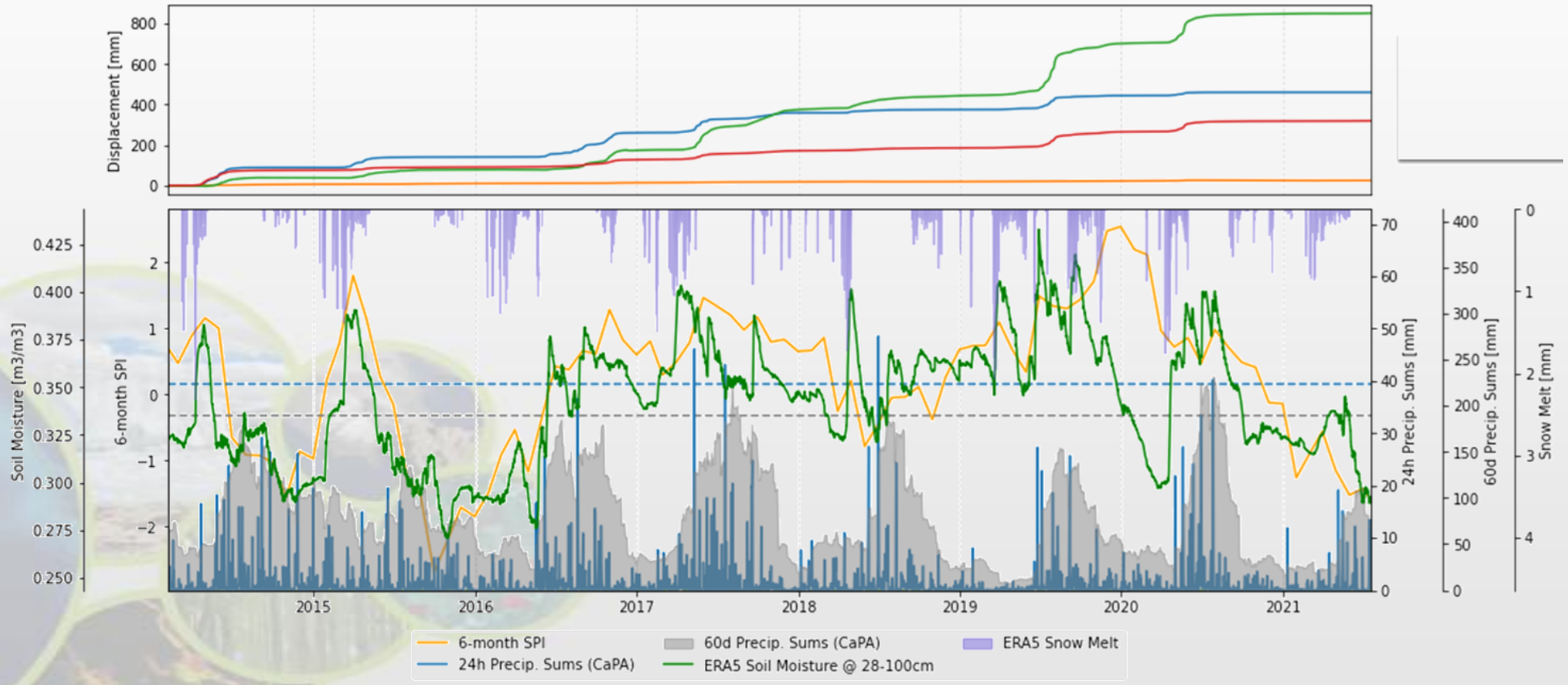
Transportation Corridors: Use case Swan Hills

Space based EO techniques used for risk-informed decision making in areas affected by slope instabilities in the presence of critical infrastructure and utilities



Transportation Corridors: Use case Swan Hills

The displacement rates are analysed with EO derived hydroclimatic parameters to assess spatial and temporal trends and their impacts on slope activity. The end results will aim to support regional landslide management programs



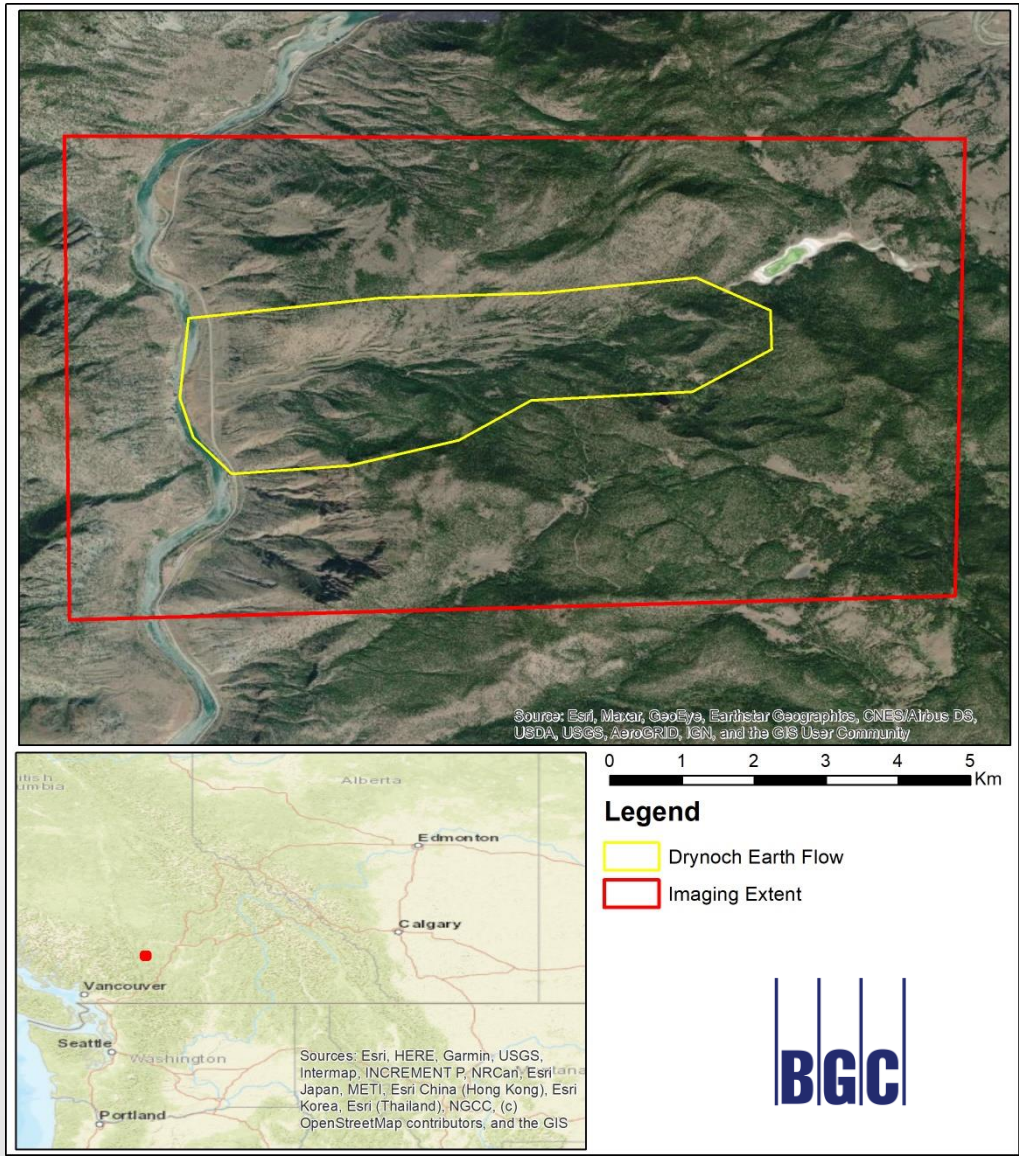
Transportation Corridors: Use case Drynoch

Given the monitoring history, the Drynoch earthflow will be used for developing tools for monitoring fast moving earthflows using a real-world rapidly moving earth flow as test case.

Targeted collections of space-based earth observation data include:

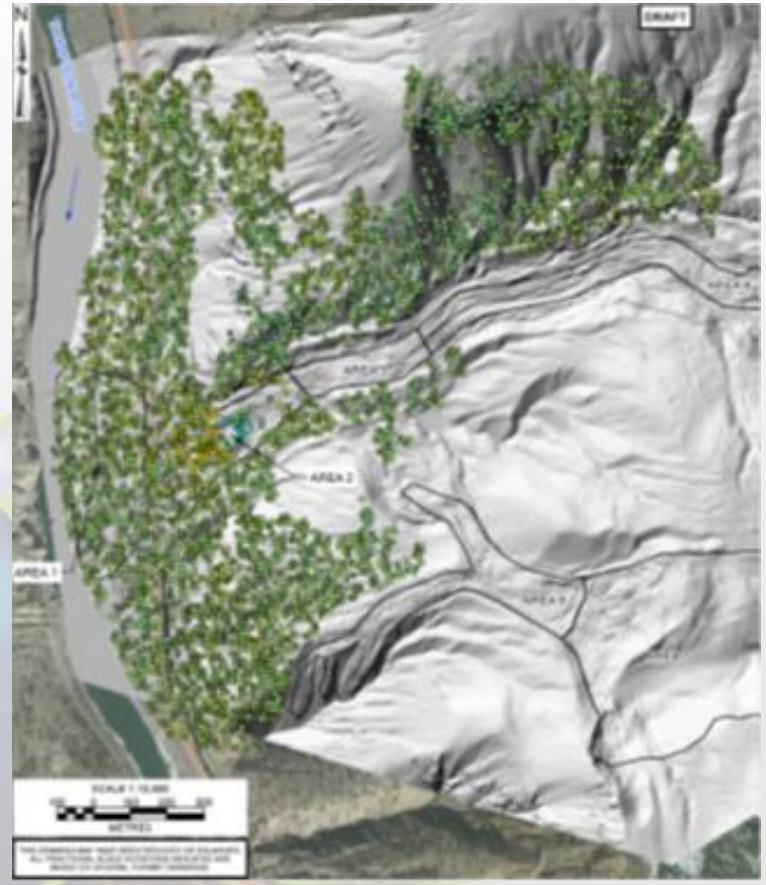
- TerraSAR-X – High resolution Spotlight Mode acquisitions have been approved for collection by DLR. Data to be captured between 22-to-33-day intervals between October 2021 and July 2023

- Pléiades 70 cm tri-stereo acquisitions are currently being negotiated. Time series data acquisitions anticipated between Q4 2021 and Q4 2023

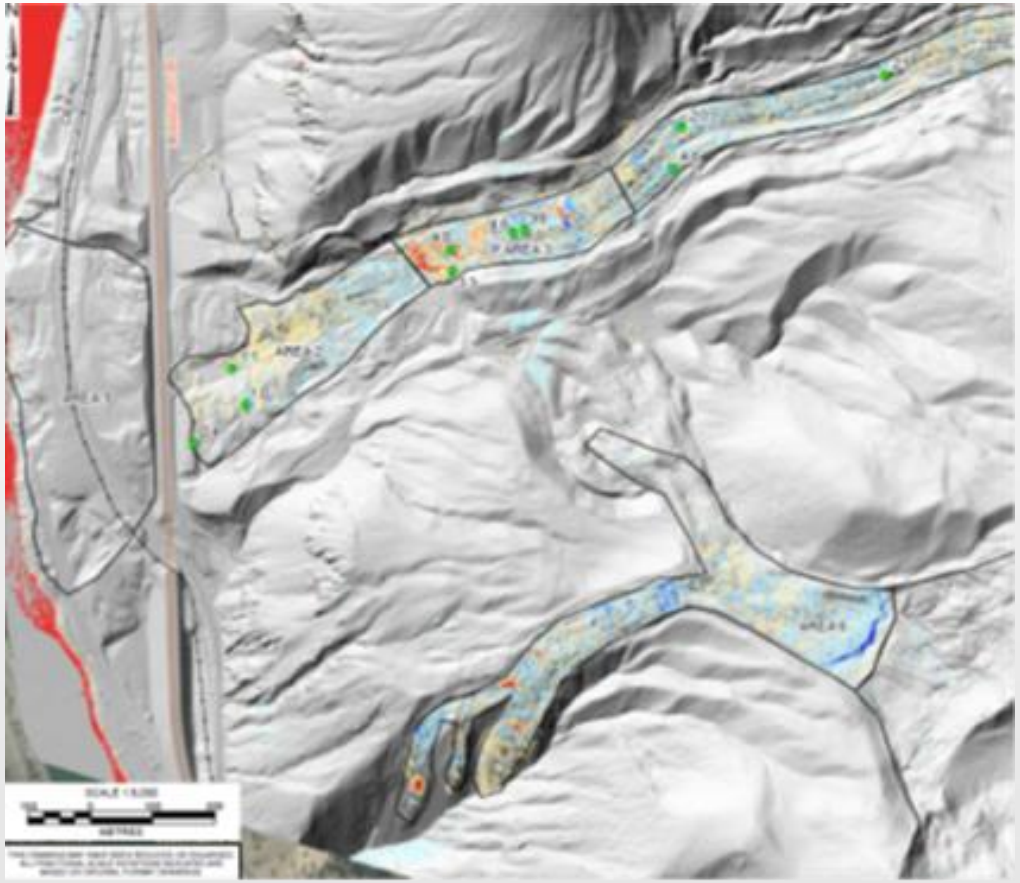


Transportation Corridors: Use case Drynoch

LiDAR and InSAR combined to assess different activity zones:
slower moving marginal zones vs. fast moving earth flow



C-band InSAR (2015 - 2019)

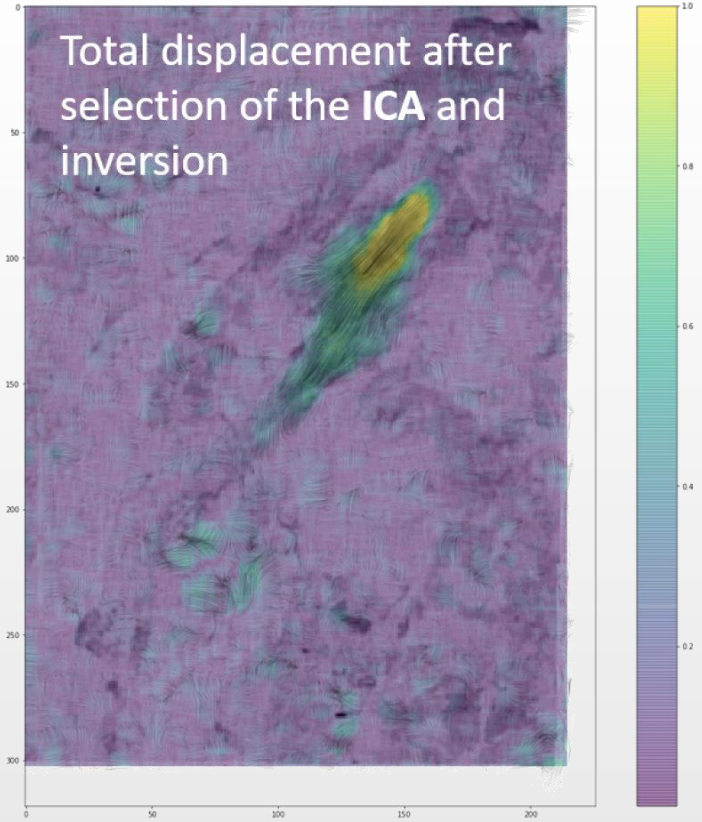


ALS Change detection (2016 - 2017)

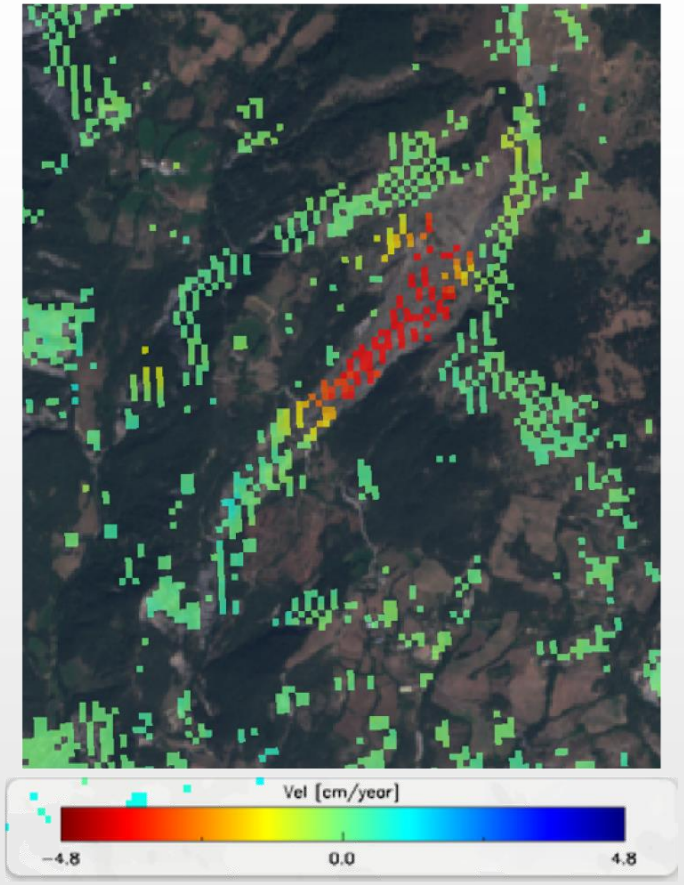
Transportation Corridors: Use case La Valette

- Large slow-moving landslide (2 to 5 m.yr^{-1}) affecting a railway and a national road
- Use case to develop methods combining InSAR / optical image correlation motion products
- LiDAR and automated total station (50 benchmarks) for accuracy assessment of the SBEO products
- Part of the GIRN/Alps Local Landslide Early-Warning System (LEWS)

MPIC-OPT-SLIDE ground motion (S2)



P-SBAS ground motion (S1)



Goals:

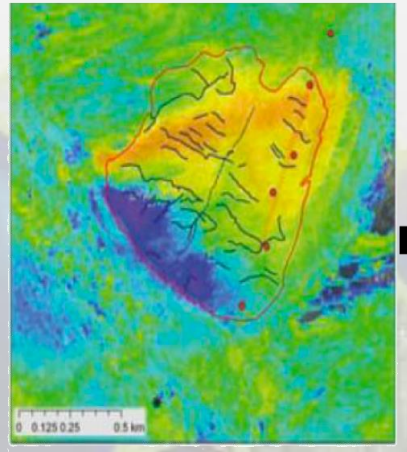
- Fusion of motion products
- From medium resolution (Sentinel) to high resolution (TSX + Pléiades)

In Q3 2022: an operational system for landslide monitoring/hazard modelling in the Alps

“eo4alps-landslide” products delivered to end-users

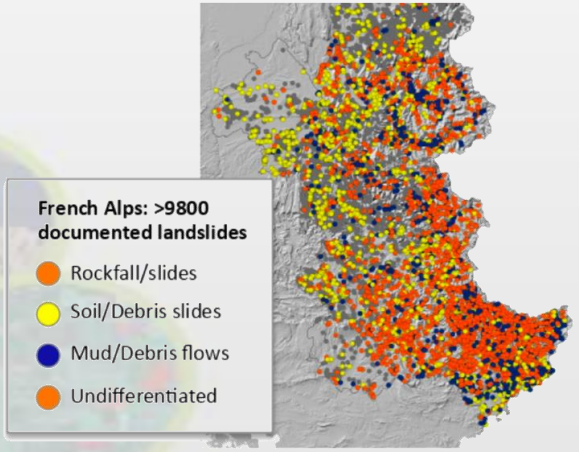
- automatic landslide detection/ground motion using satellite optical/InSAR services
- harmonised and advanced landslide catalogues
- susceptibility/hazard maps consisting of possible landslide source areas and landslide runout modelling

Product 1



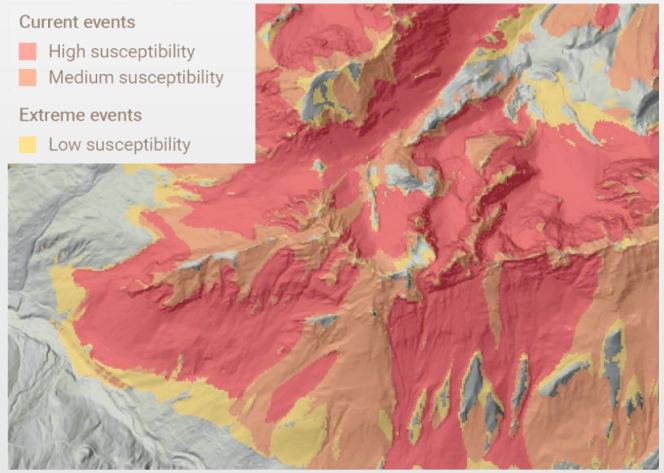
ground motion maps

Product 2



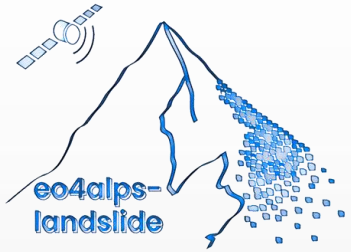
inventory maps

Product 3



hazard maps

In Q3 2022: an operational system for landslide monitoring/hazard modelling in the Alps



"is user-tailored and focuses on categories of services

Landslide-Motion

This service is dedicated to the survey of unstable slopes in near-real time and in a systematic mode, and generates landslide ground motion products.

Landslide-Inventory

This service is dedicated to the creation and update of detailed catalogues of landslide events.

Landslide-Hazard

This service is dedicated to the forecast of spatial landslide hazard and landslide evolution scenarios.

User-driven

The services are user-driven with the engagement of many authorities and stakeholders responsible for landslide Disaster Risk Management.

Scales of analysis

The services are tailored for three analysis scales using specific data and models (Tier 1: regional/basin authority level; Tier 2: municipality level; Tier 3: slope specific level).

Interoperability

The services are accessible online and optimized for high performance computing. They are designed as generic as possible for application in other settings and interoperability with other information systems.

Application 2: Landslide Risk Financing

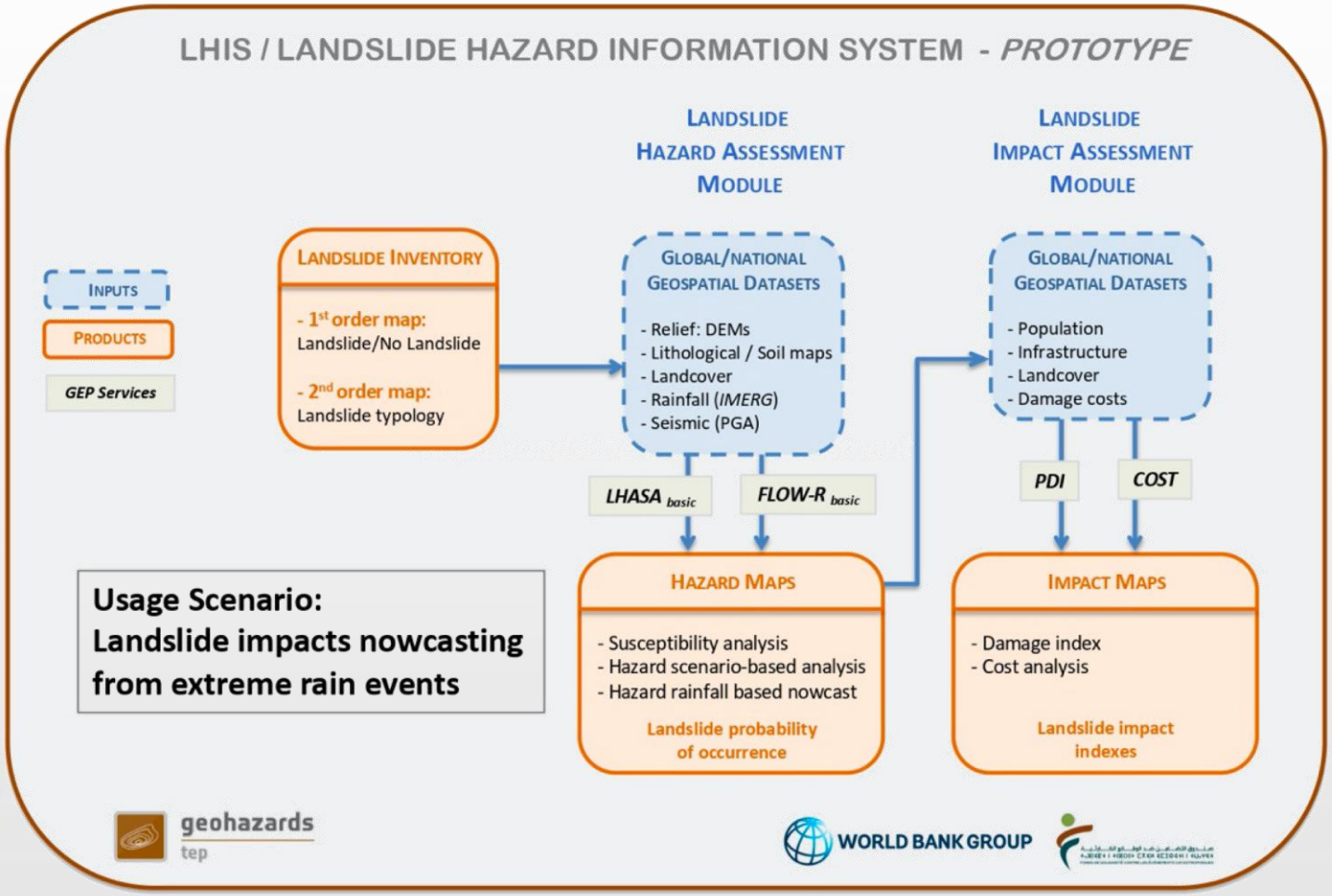
Application 2: Operational Landslide EO Products for Disaster Risk Financing and Insurance Program (World Bank)

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

Industry Participant: World Bank

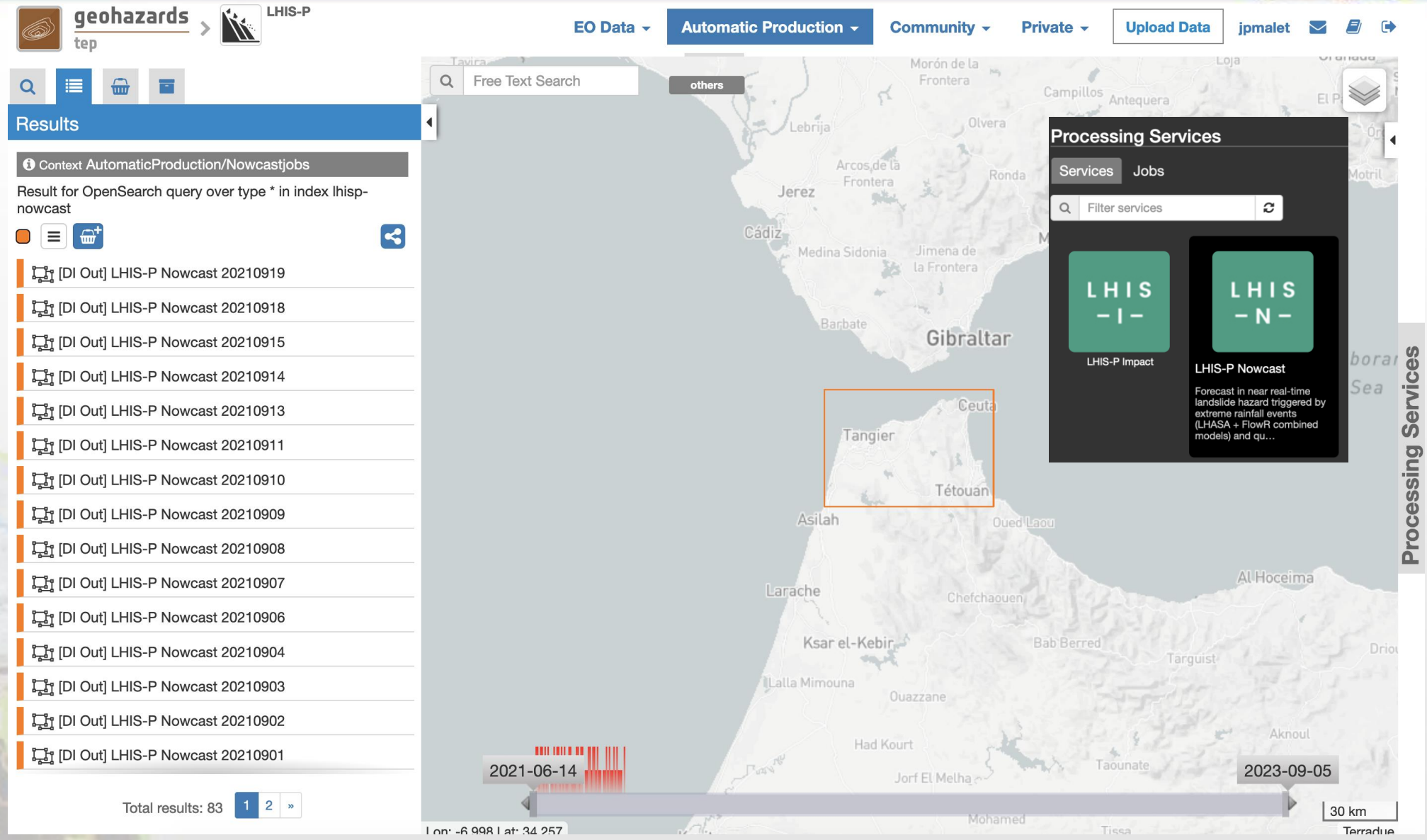
Goal: implement a platform prototype to respond to likely landslide events (in Near-Real Time, NRT) in order to provide estimates of parameters suitable to inform parametric insurance calculations.

→ Prototype for North Morocco (with state stakeholders)
→ All the developments are generic to be easily transferred to other countries and risk situations (especially in SE Asia).



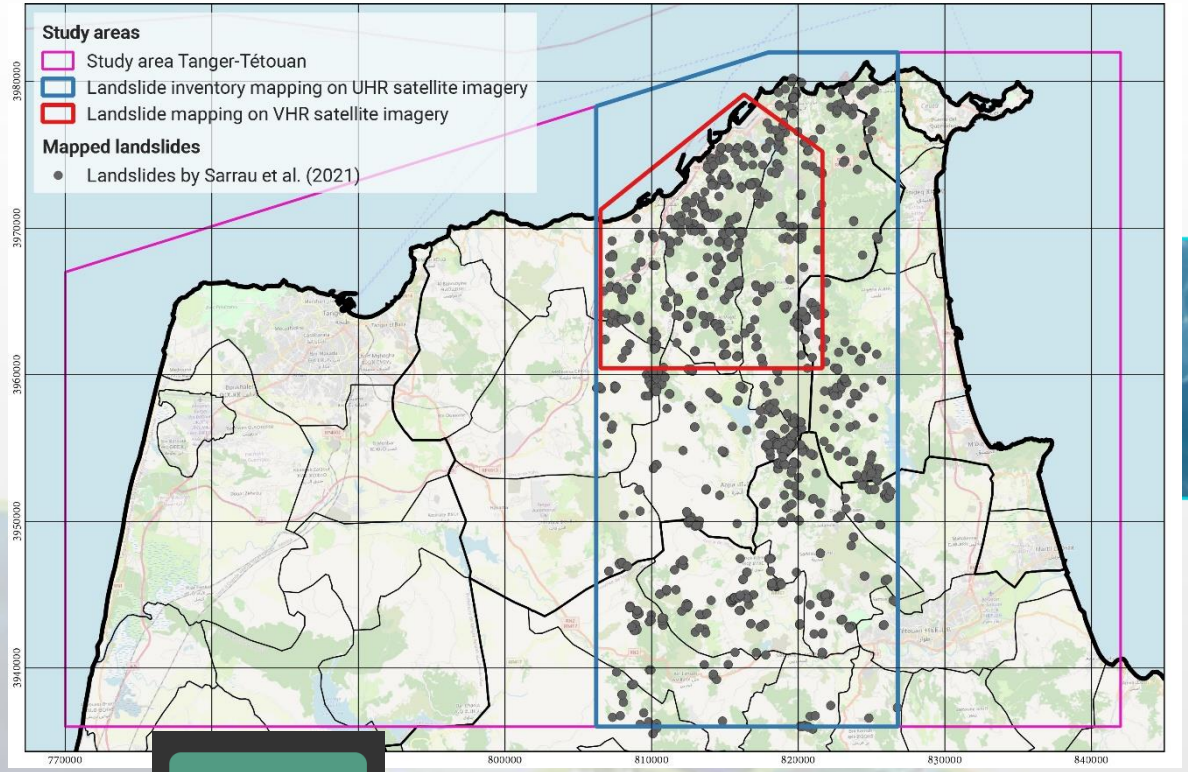
Application 2: Landslide Risk Financing

LHIS prototype implemented on GEP



Application 2: Landslide Risk Financing

Morocco/Rif Area: multi-date landslide inventory



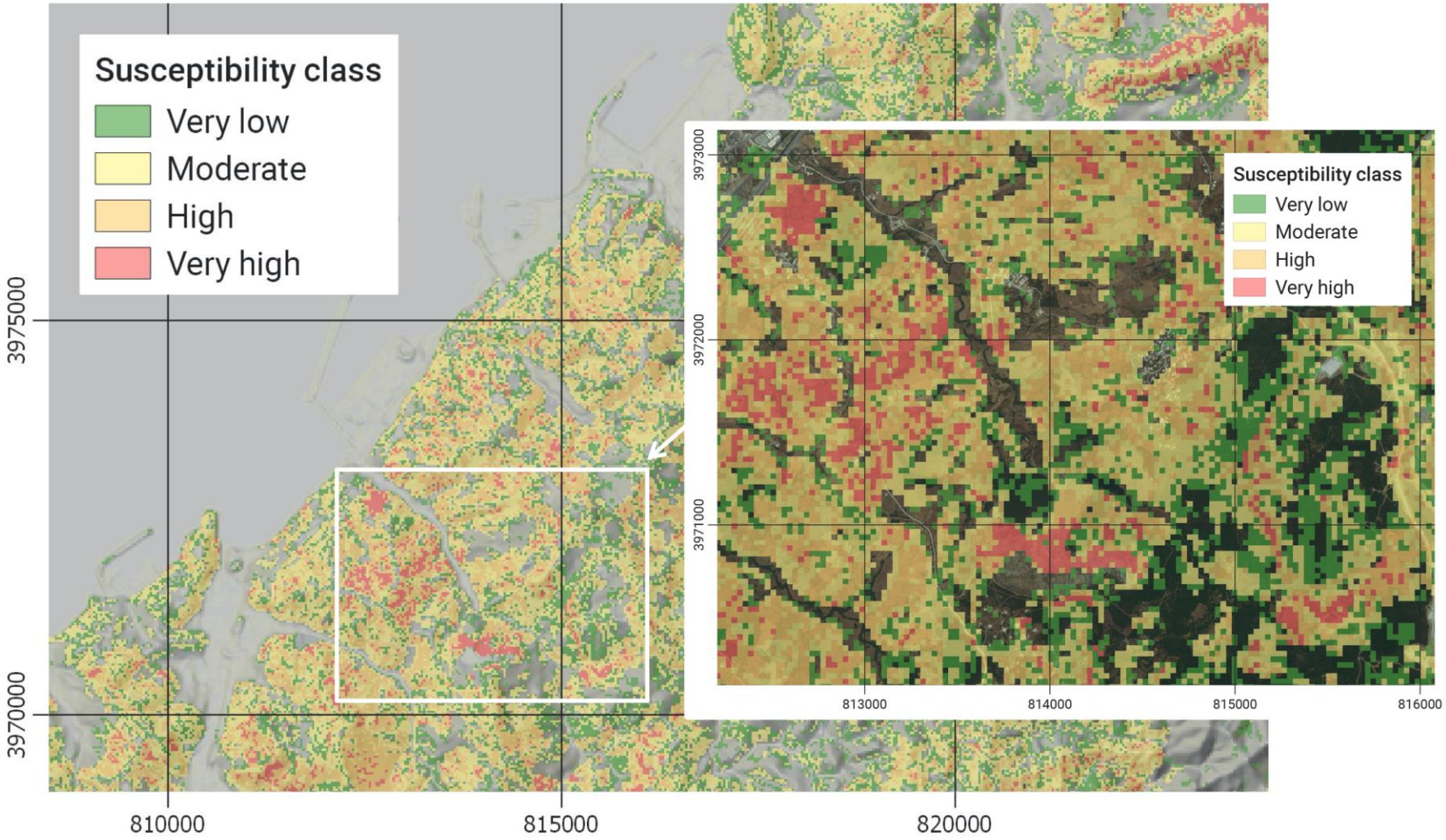
LHIS-P Impact

Module LHIS-Impact

Use of a combination of visual/expert interpretation and ALADIM service (period 2013-2020)

Application 2: Landslide Risk Financing

Module LHIS-Nowcast



Extrait de la carte de susceptibilité aux glissements de terrain pour la région du port Tanger-Med (échelles 1:100'000 et 1:20'000)

Application 2: Landslide Risk Financing

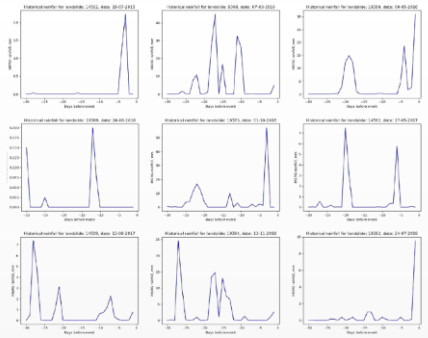
Module LHIS-Nowcast

LHIS -N-

LHIS-P Nowcast

Forecast in near real-time landslide hazard triggered by extreme rainfall events (LHASA + FlowR combined models) and qu…

IMERG nowcast



LHASA

Step 1

7-day Antecedent Rainfall Index (ARI)

Low

High

Susceptibility

Step 2

Low-Very Low

Moderate-High

Very High

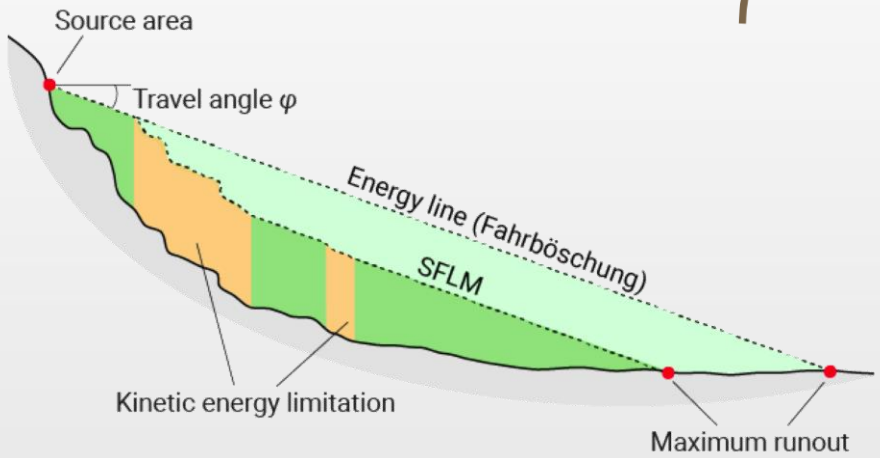
No Nowcast

Moderate-Hazard Nowcast

High-Hazard Nowcast

+

FLOW-R

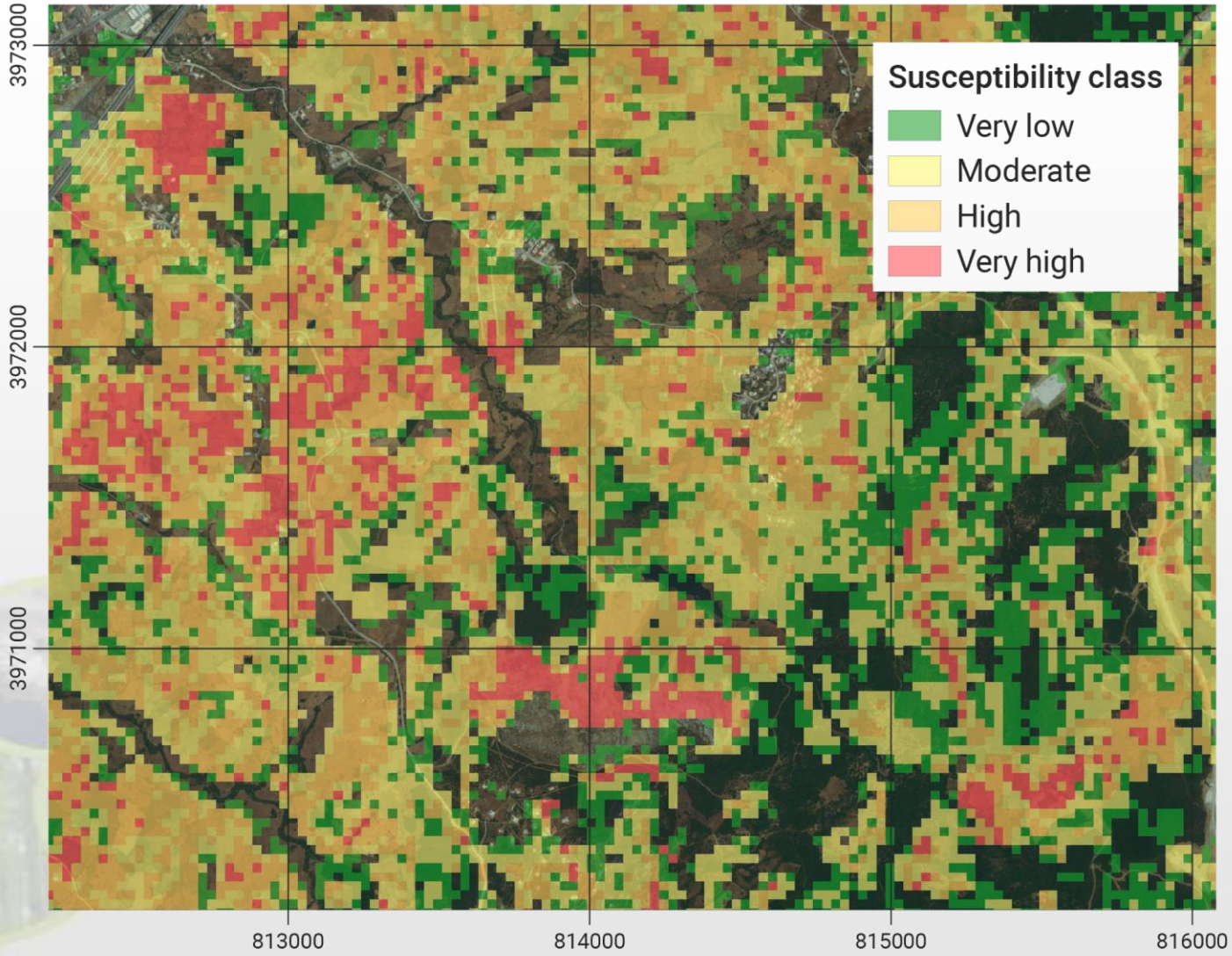


Dynamic Landslide Hazard – source and propagation areas

Application 2: Landslide Risk Financing

Module LHIS-Nowcast

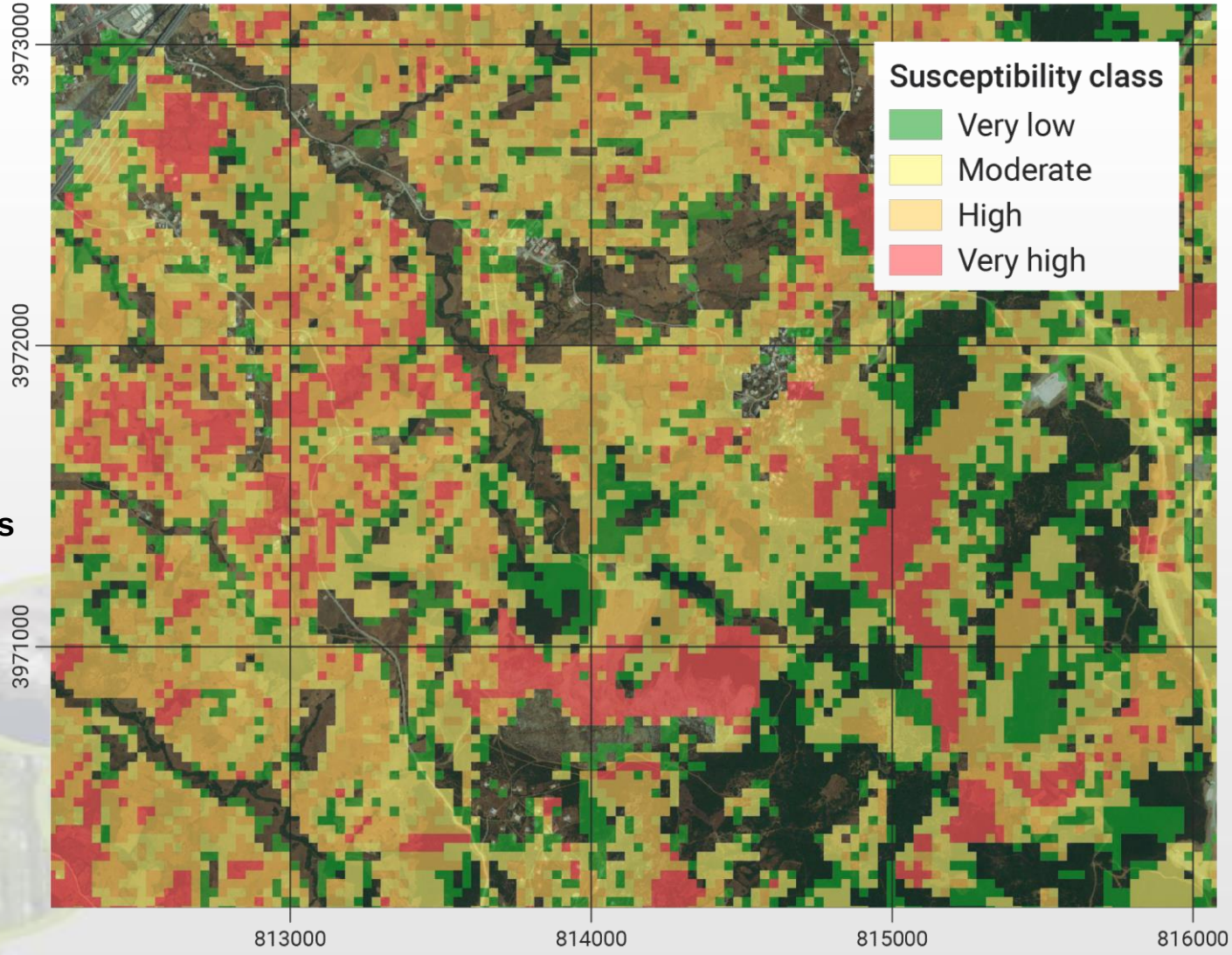
Modelling landslide **source areas**



Application 2: Landslide Risk Financing

Module LHIS-Nowcast

Modelling landslide **propagation areas**



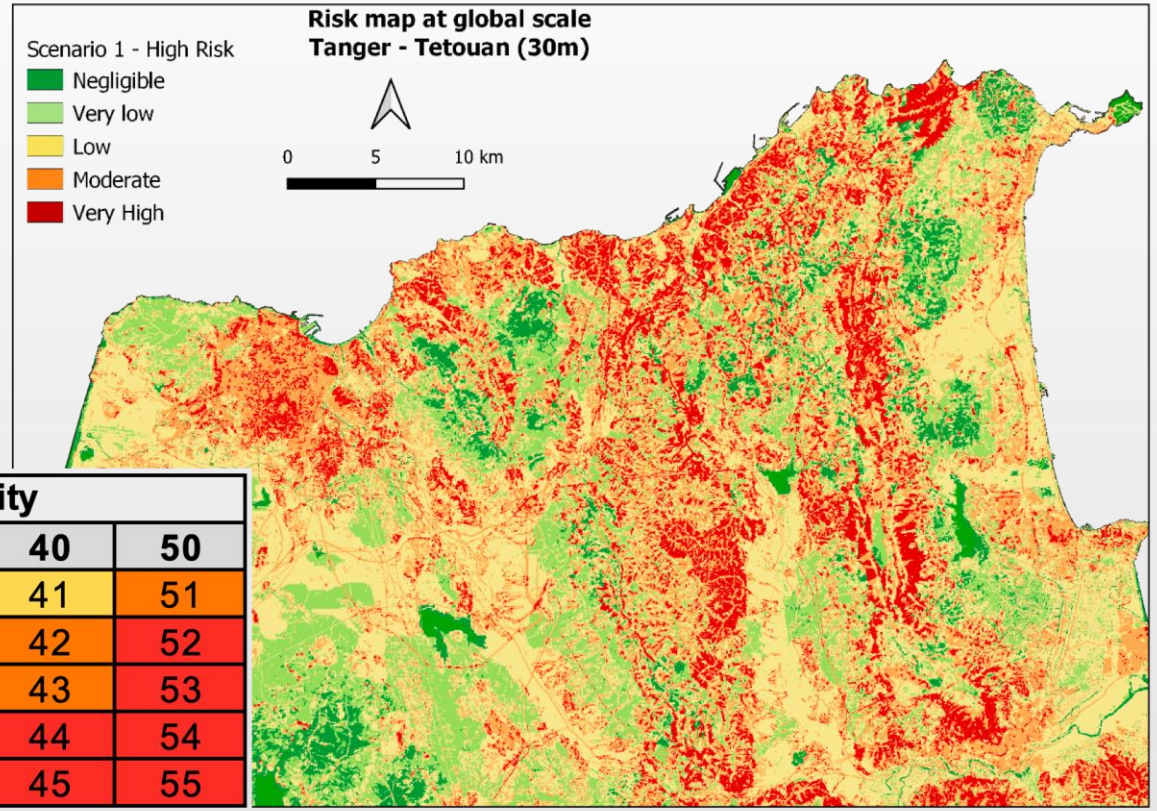
Application 2: Landslide Risk Financing

Module LHIS-Nowcast

Modelling landslide **damage**

Potential Damage Index

- Croisement de la carte de susceptibilité avec les dommages potentiels
- Selon la matrice de risque
  → ajustable aux besoins



	Susceptibility				
PDI	10	20	30	40	50
1	11	21	31	41	51
2	12	22	32	42	52
3	13	23	33	43	53
4	14	24	34	44	54
5	15	25	35	45	55

Application 2: Landslide Risk Financing

Next steps

Morocco: from a region prototype to a national scale system

- Increase the quality of the landslide inventory (for increasing the quality of the hazard/risk assessment) – use of InSAR services and new optical VHR data
- From nowcast to forecast
- Training with other operational stakeholders
- Engage with CRTS (Moroccan Space Agency) with support of CNES and World Bank for service take up

Global:

- Test the system over tropical countries subjected to extreme rainfall events

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.

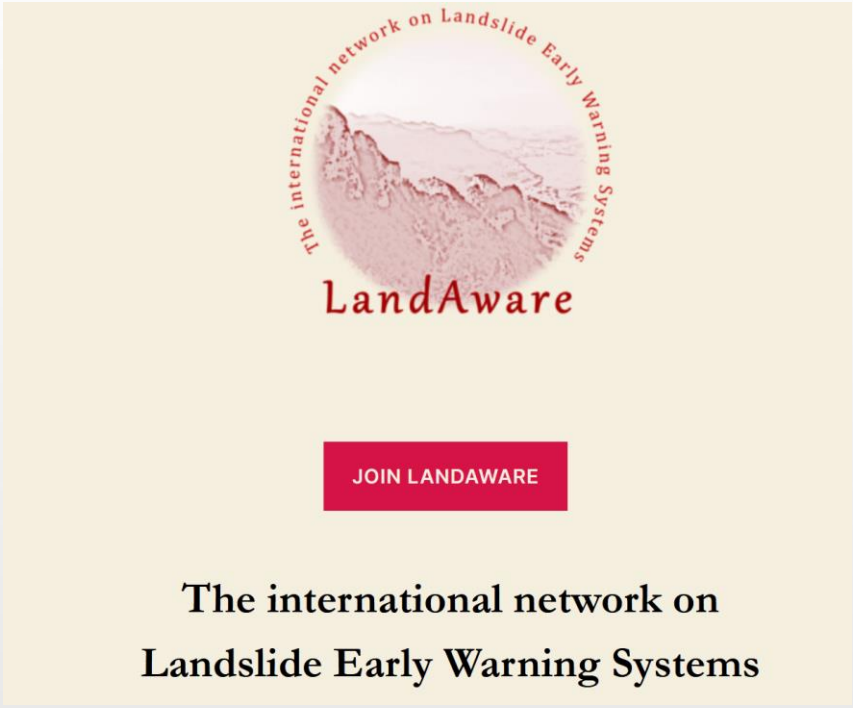
Demonstrator Leads: Dalia Kirschbaum, Jean-Philippe Malet (CNRS/EOST) and Olivier Dewitte (RMCA).

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

Application 3: Global Landslide Data

- Kirschbaum (NASA) and Mirus (USGS) co-leading a Landslide Early Warning System (LEWS) Data Working Group
- LandAware Kickoff Meeting, December 2020
- LEWS Data WG KO (Jan. 2021) + WG meetings (March 2021, Sept. 2021)

- **Topics:**
  - LEWS Data Review – White Paper and Journal Article
  - Collection of Benchmark Datasets
  - Repository and Metadata for inventories and other products
  - What is an ideal landslide benchmark dataset?



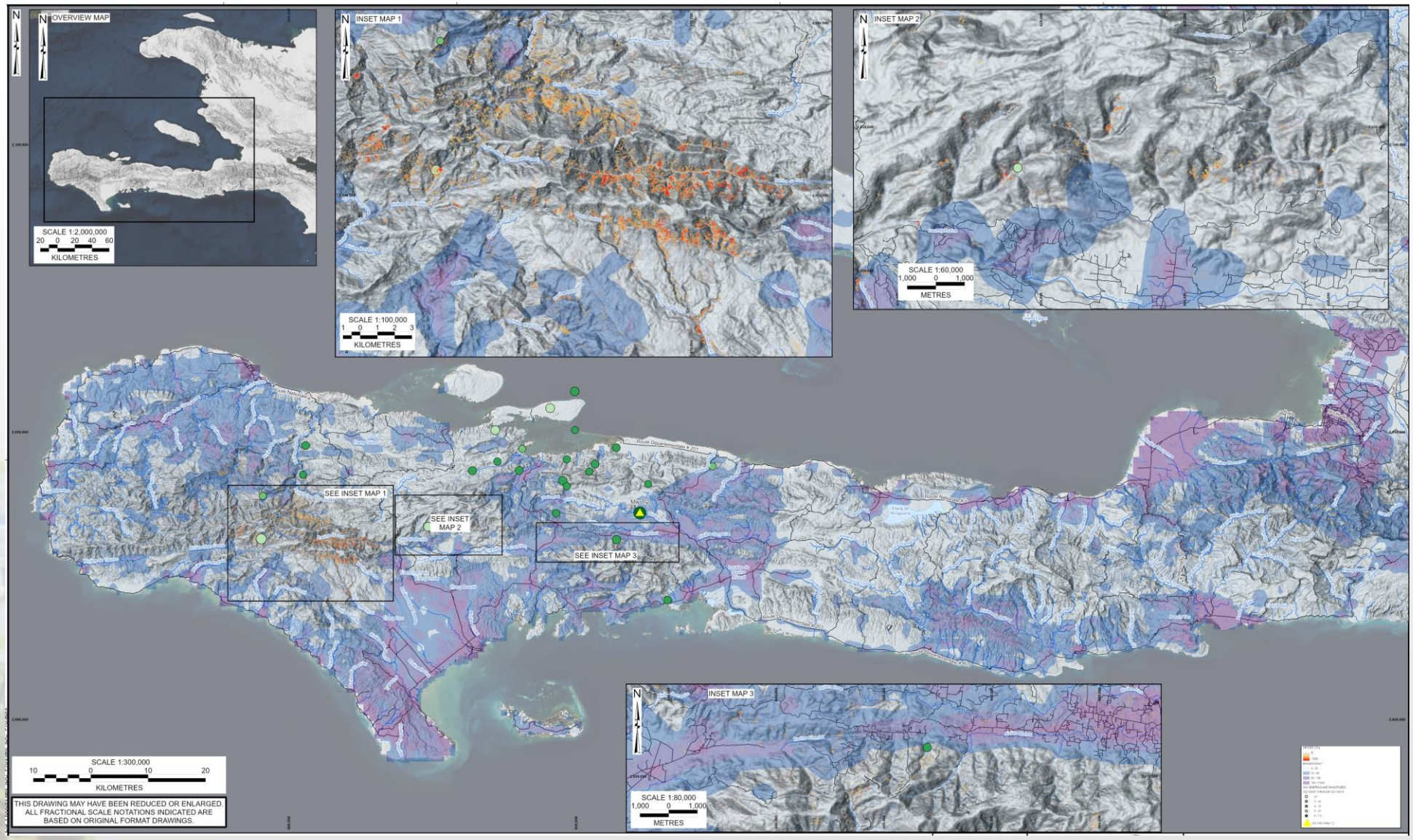
Landslide inventory mapping / Haïti

NDVI-based landslide detection

Thresholding

Source: Sentinel-2

Credit: BCG Engineering



Landslide inventory mapping / Haïti

SAR backscatter change → landslide proxy density map for Haiti earthquake

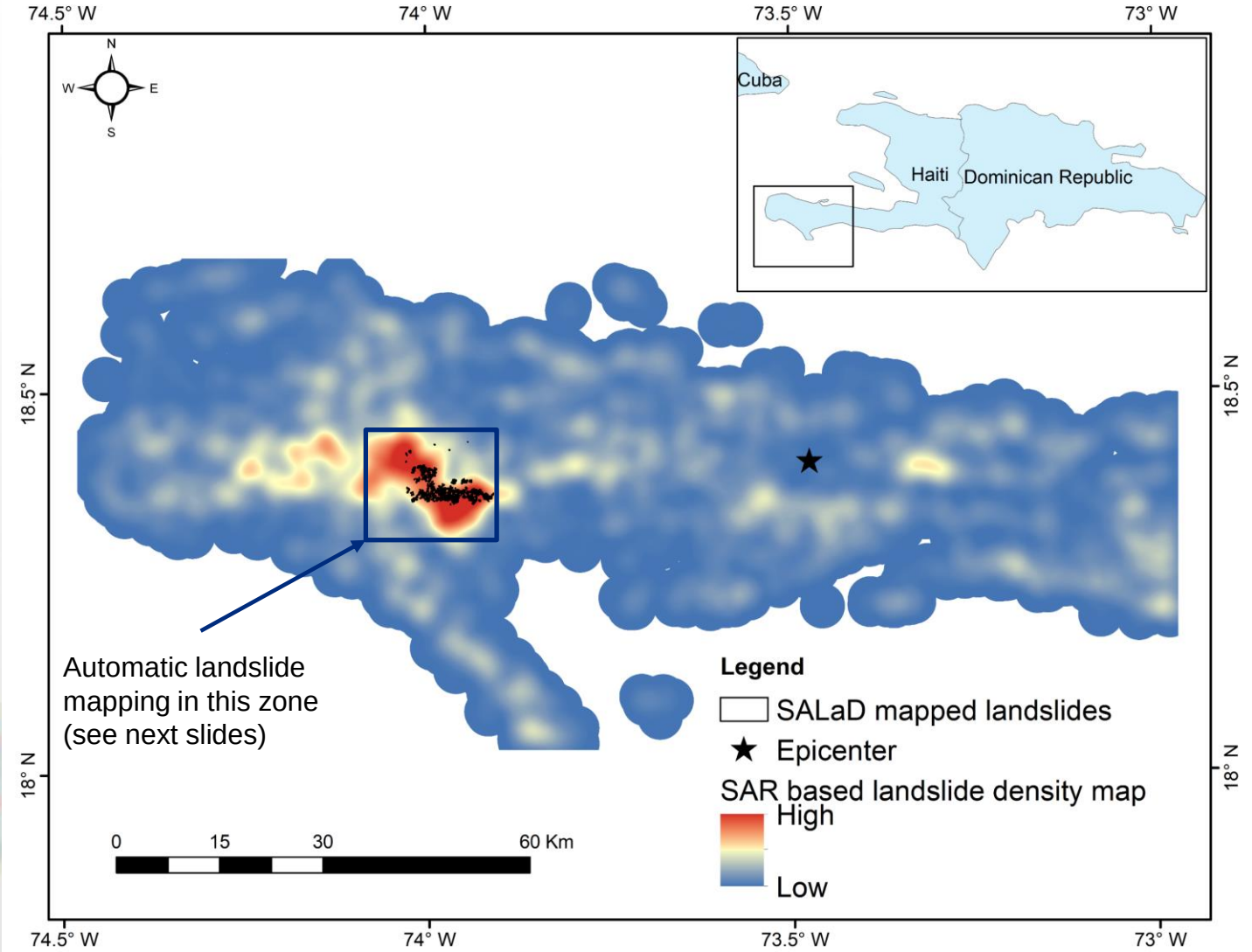
Use of 1 post-event imagery

Source: Sentinel-1

Pre-event stack: 01/01/2020 – 08/13/2021

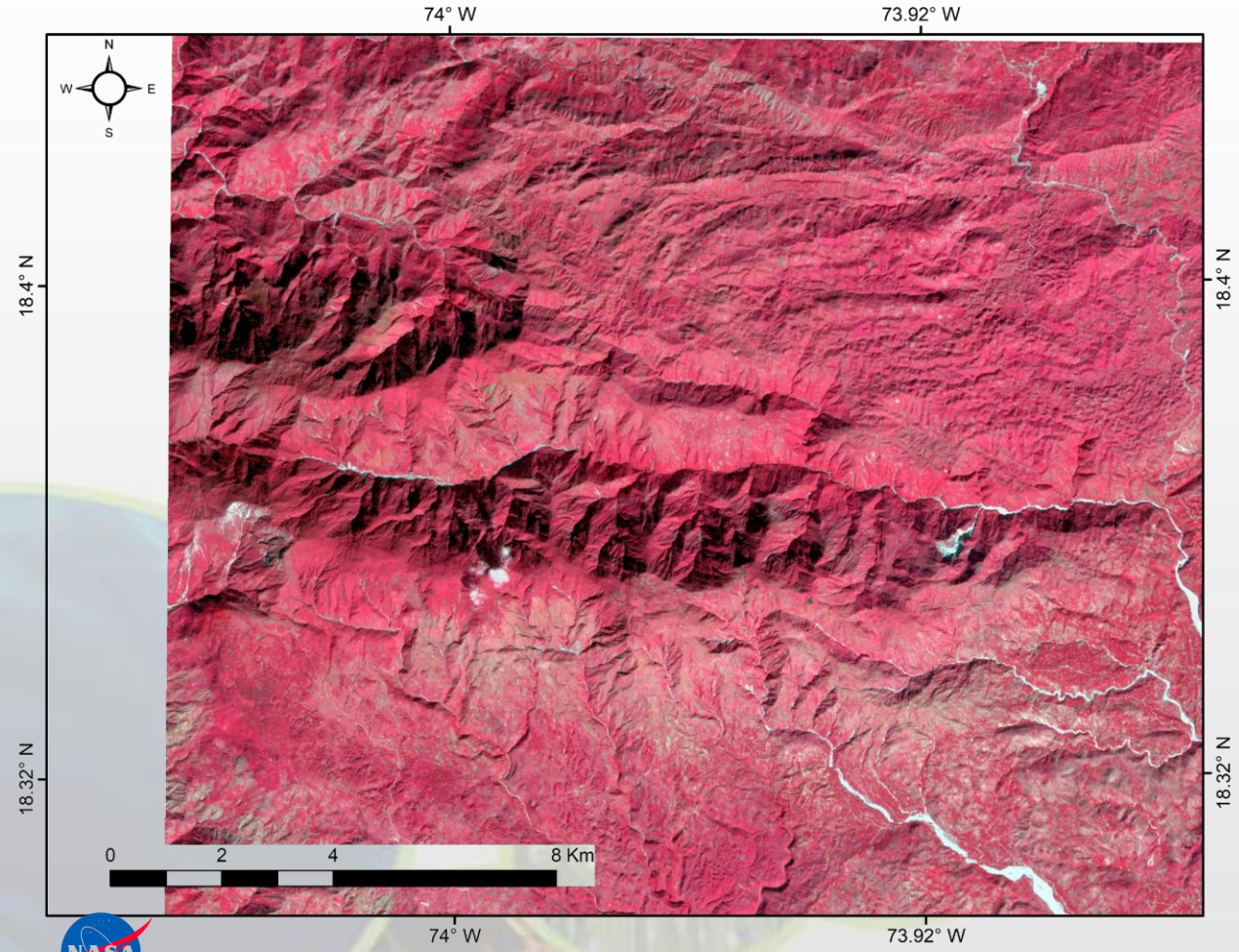
Post-event stack: 08/14/2021 – 08/16/2021

Credit: A. Handwerger (JPL) and M.-H. Huang (UMD)

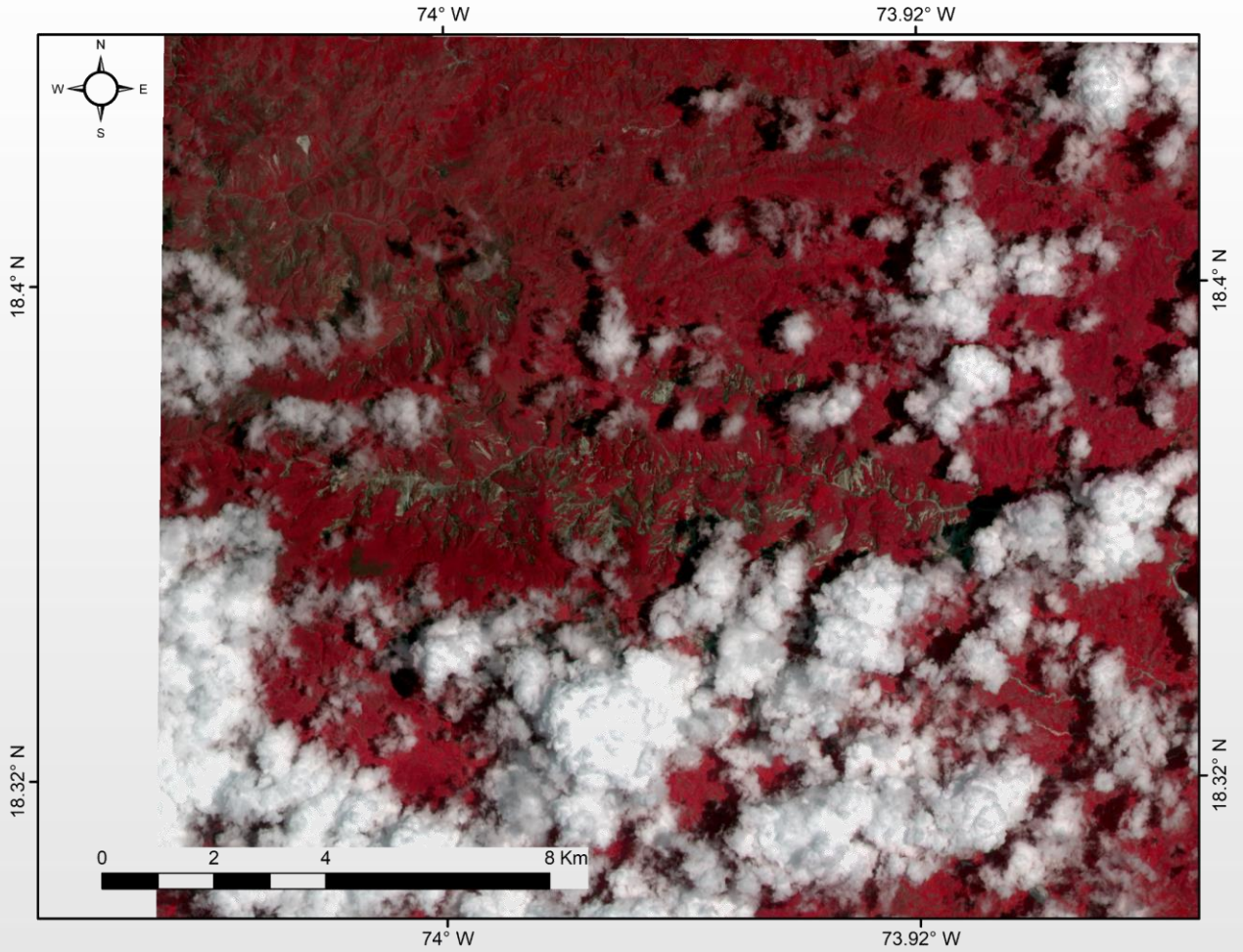


Landslide inventory mapping / Haïti

Sentinel-2 imagery pre- and post- Haiti earthquake



Pre (01/06/2021)



Post (08/14/2021)

Landslide inventory mapping / Haïti

SALaD mapped landslides post Haiti Earthquake

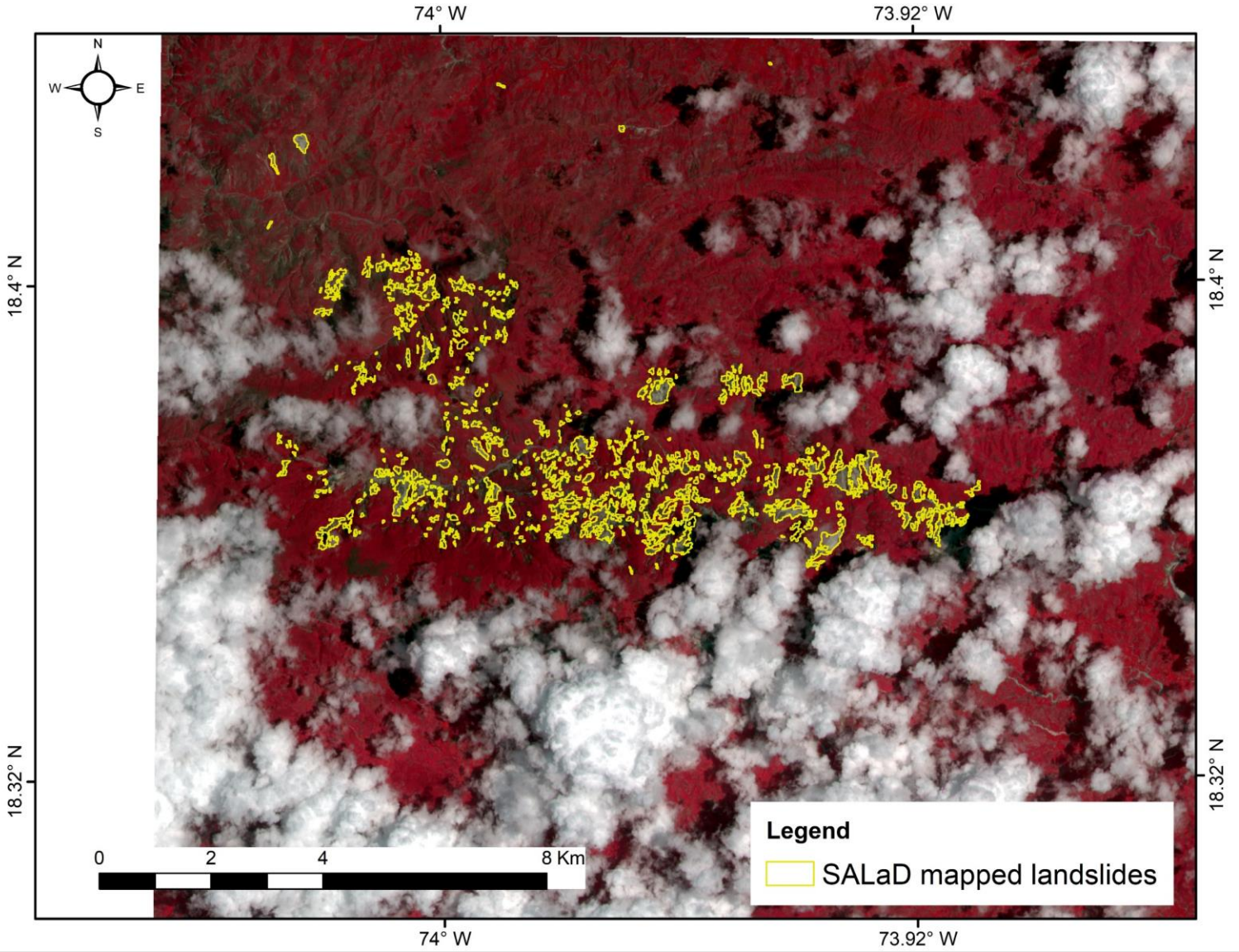
Source: Sentinel-2

Pre-event : 01/06/2021

Post-event : 08/14/2021

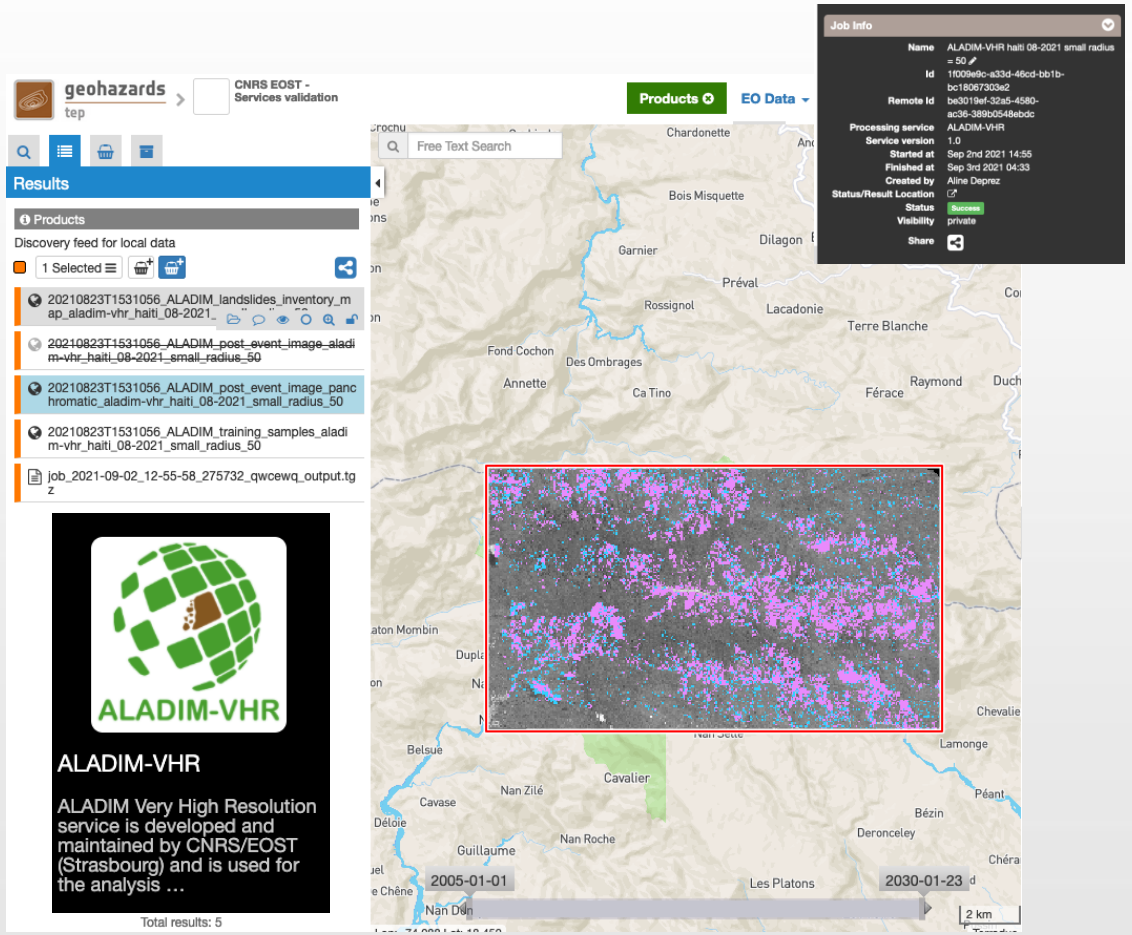
Credit: P. Amatya (USRA)

https://maps.disasters.nasa.gov/arcgis/home/item.html?id=e34b9f8f6f774d6ca2f6ae6ad3d8b21b



Landslide inventory mapping / Haïti

ALADIM VHR-Pléiades
mapped landslides post Haiti Earthquake using GEP



Landslide inventory mapping / Haïti

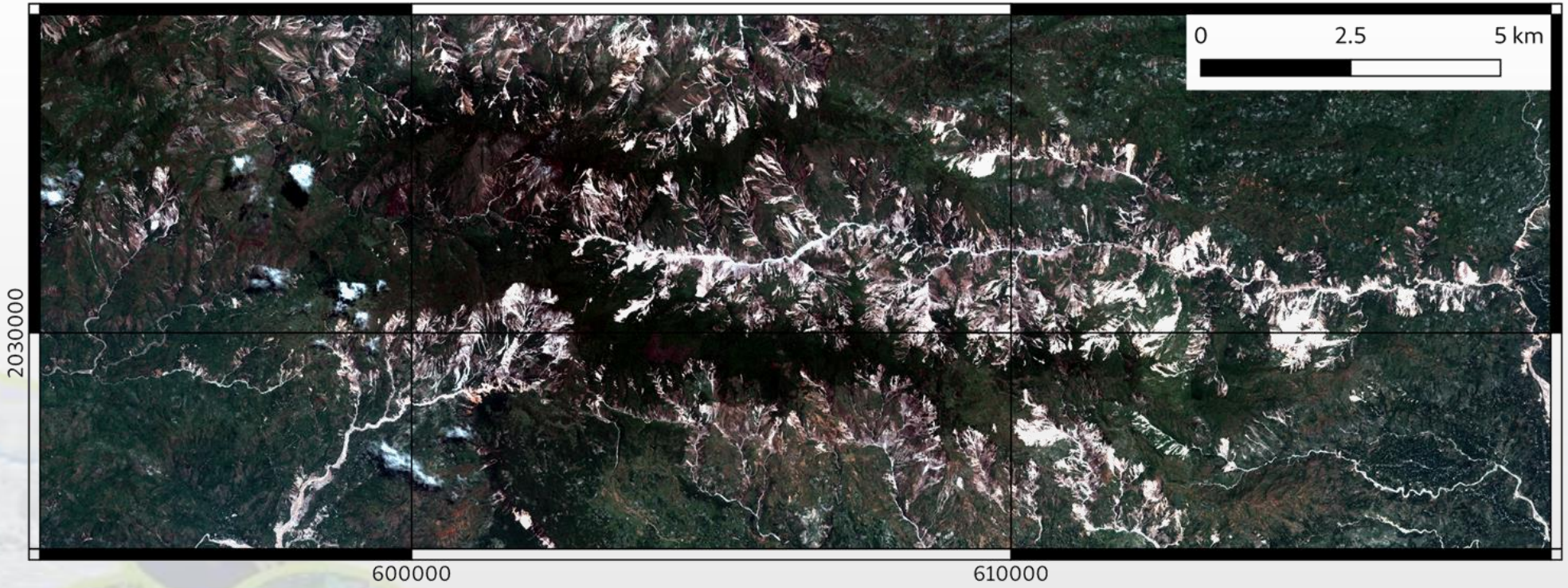
ALADIM VHR-Pléiades
mapped landslides post Haiti Earthquake using GEP

Source: Pléiades

Mono-date detection
using machine learning

Post-event : 23/08/2021
Input: MS image

Credit: A. Déprez
(EOST/A2S)



Landslide inventory mapping / Haïti

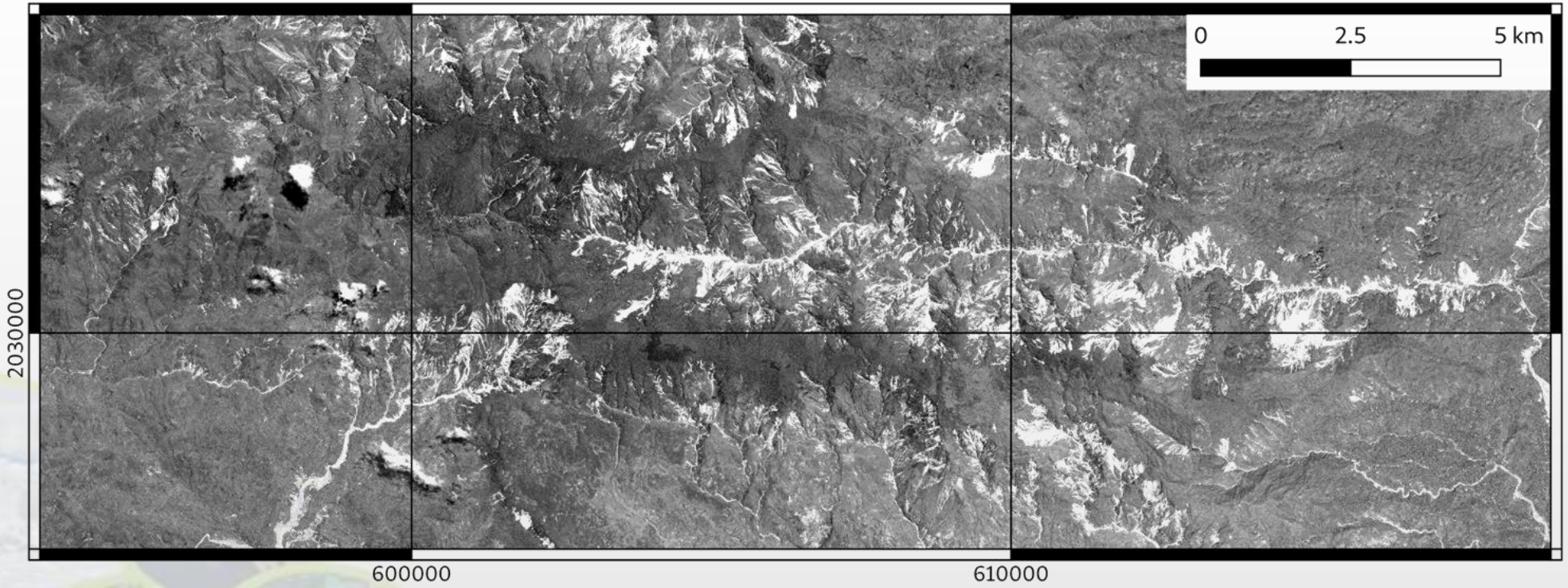
ALADIM VHR-Pléiades
mapped landslides post Haiti Earthquake using GEP

Source: Pléiades

Mono-date detection
using machine learning

Post-event : 23/08/2021
Input: P-band image

Credit: A. Déprez
(EOST/A2S)



Landslide inventory mapping / Haïti

ALADIM VHR-Pléiades
mapped landslides post Haiti Earthquake using GEP

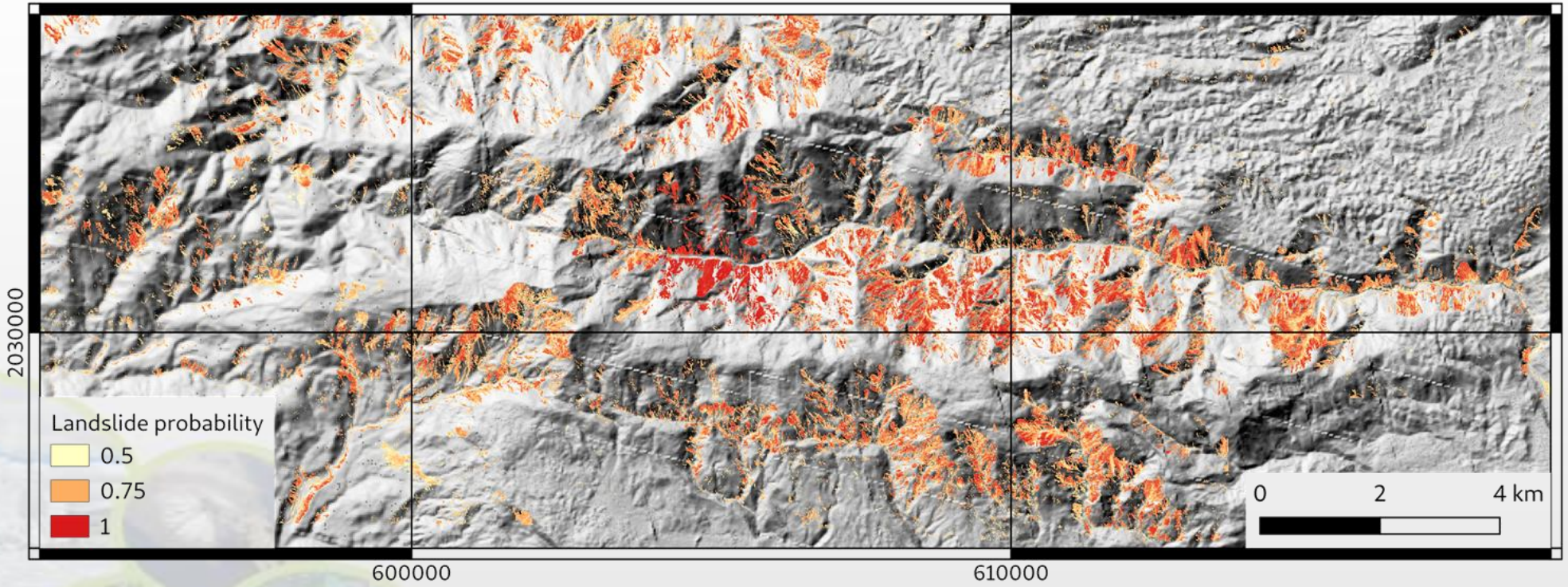
Source: Pléiades

Mono-date detection
using machine learning

Post-event : 23/08/2021

Results: landslide
detection probability

Credit: A. Déprez
(EOST/A2S)



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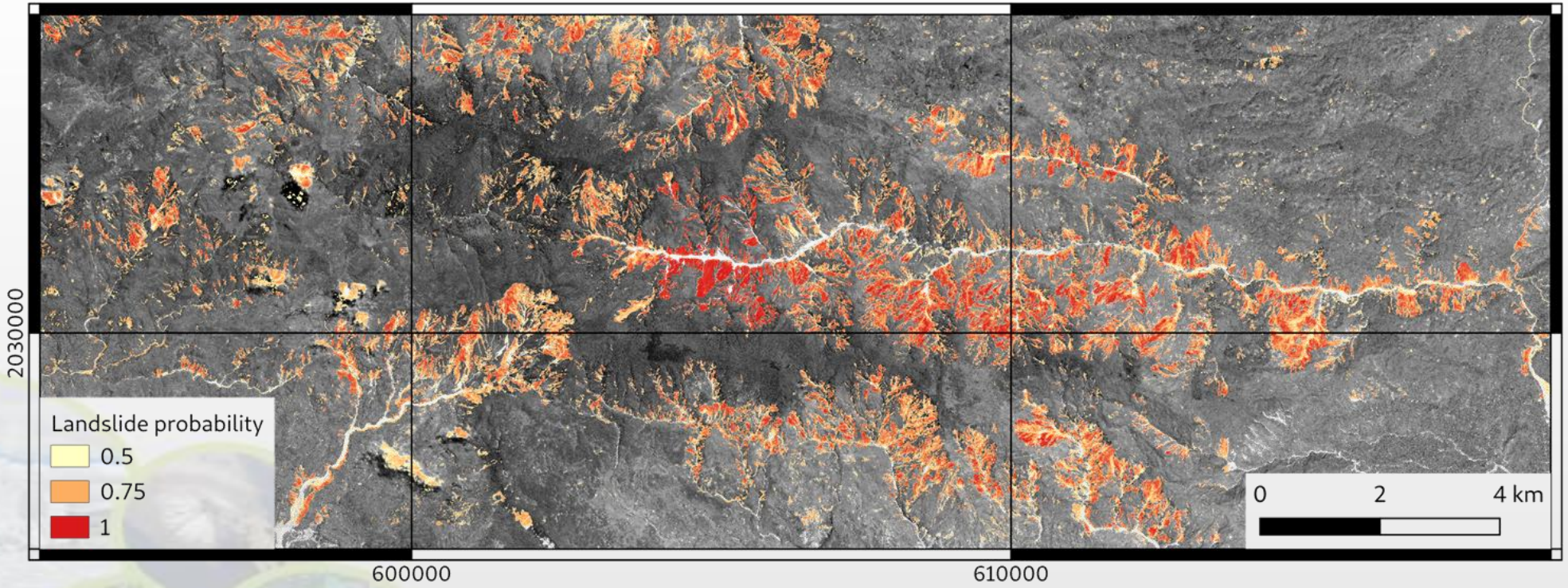
Credit: A. Déprez
(EOST/A2S)



Landslide inventory mapping / Haïti

ALADIM VHR-Pléiades
mapped landslides post Haiti Earthquake using GEP

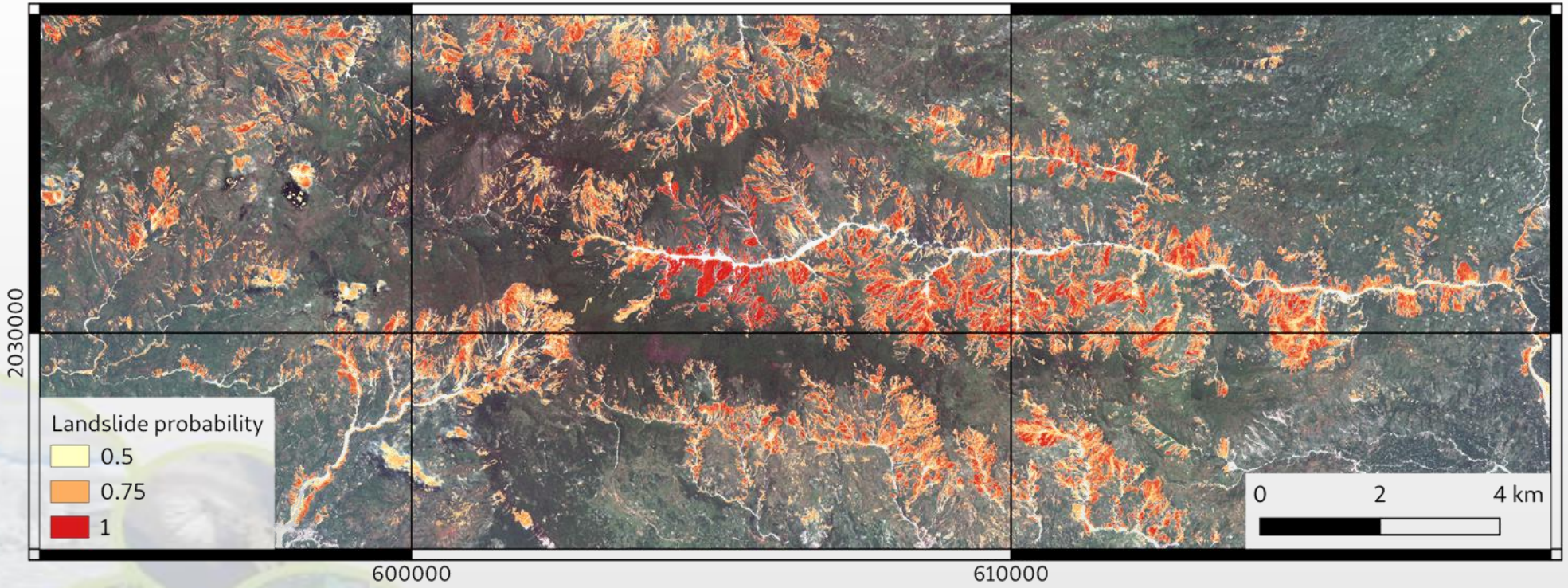
Source: Pléiades

Mono-date detection
using machine learning

Post-event : 23/08/2021

Results: landslide
detection probability

Credit: A. Déprez
(EOST/A2S)



Landslide statistics in relation with topography, ETQ magnitude and rainfall amounts in progress

Wrap-up

- We have made significant progress since June 2021!
- Satellite Acquisitions are continuing and still need some negotiations, particularly for Application 1
- A summary report from Application 2 (Morroco WB Project) will be developed and ultimately circulated
- Wrap up report for the Landslide Pilot will be completed by the end of the calendar year