Committee on Earth Observation Satellites

Landslide Pilot Working Group Presentation

September 5 - 7, 2018
Naples, Italy

Co-leads of landslide pilot

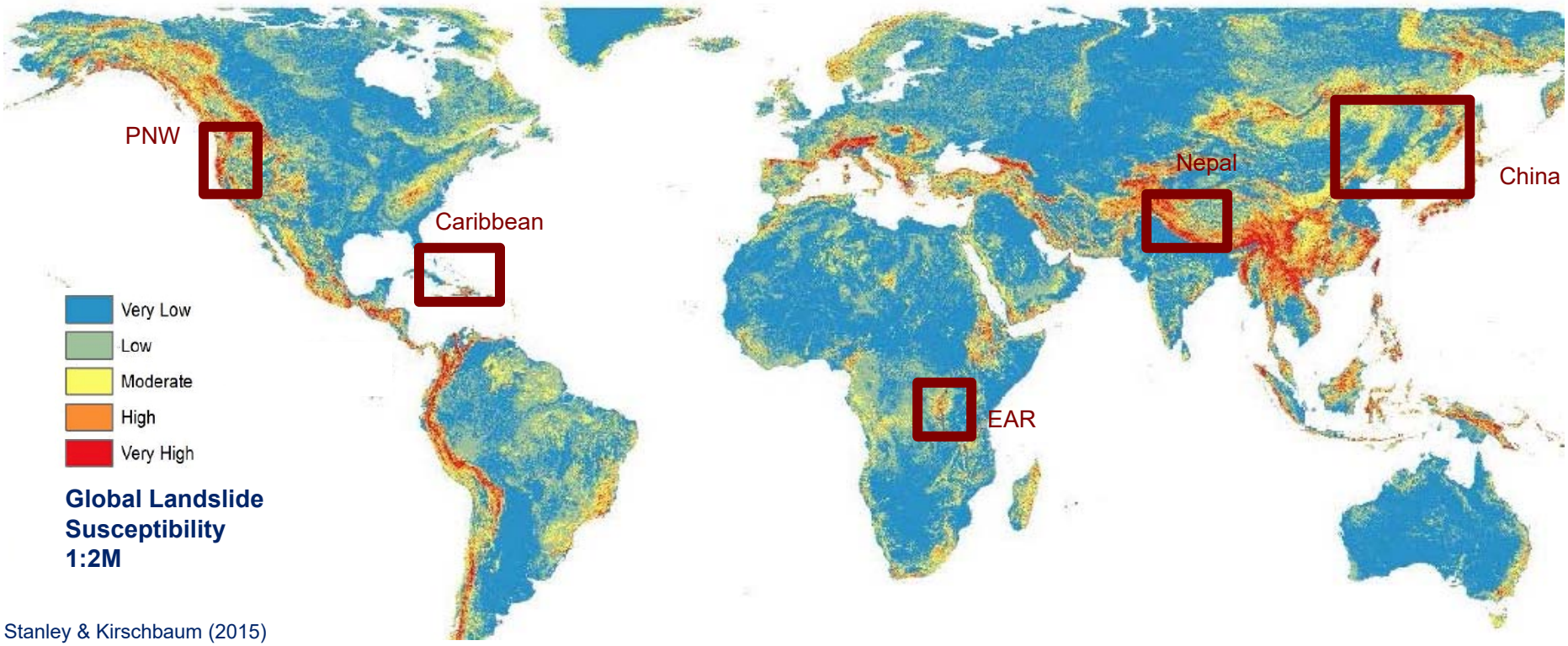
Dr. Dalia Kirschbaum, NASA Goddard Space Flight Center, Maryland, USA

Dr. Jonathan Godt, Landslide Hazards Coordinator, U.S. Geological Survey, Colorado, USA

Dr. Jean-Philippe Malet, School and Observatory of Earth Sciences, University of Strasbourg, France

Dr. Sigrid Roessner, GFZ German Research Centre for Geosciences, Germany

Regional study areas

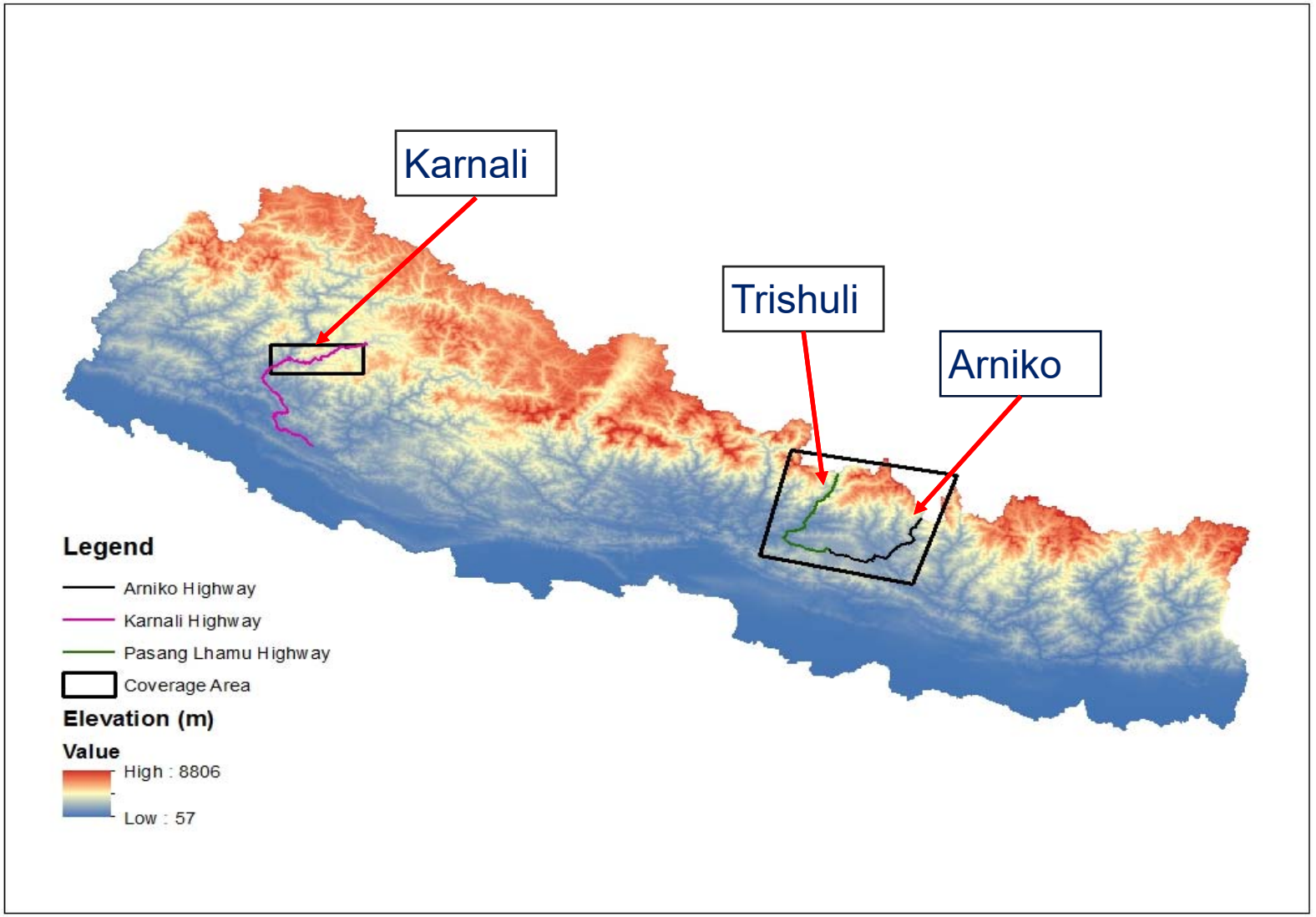


Stanley & Kirschbaum (2015)

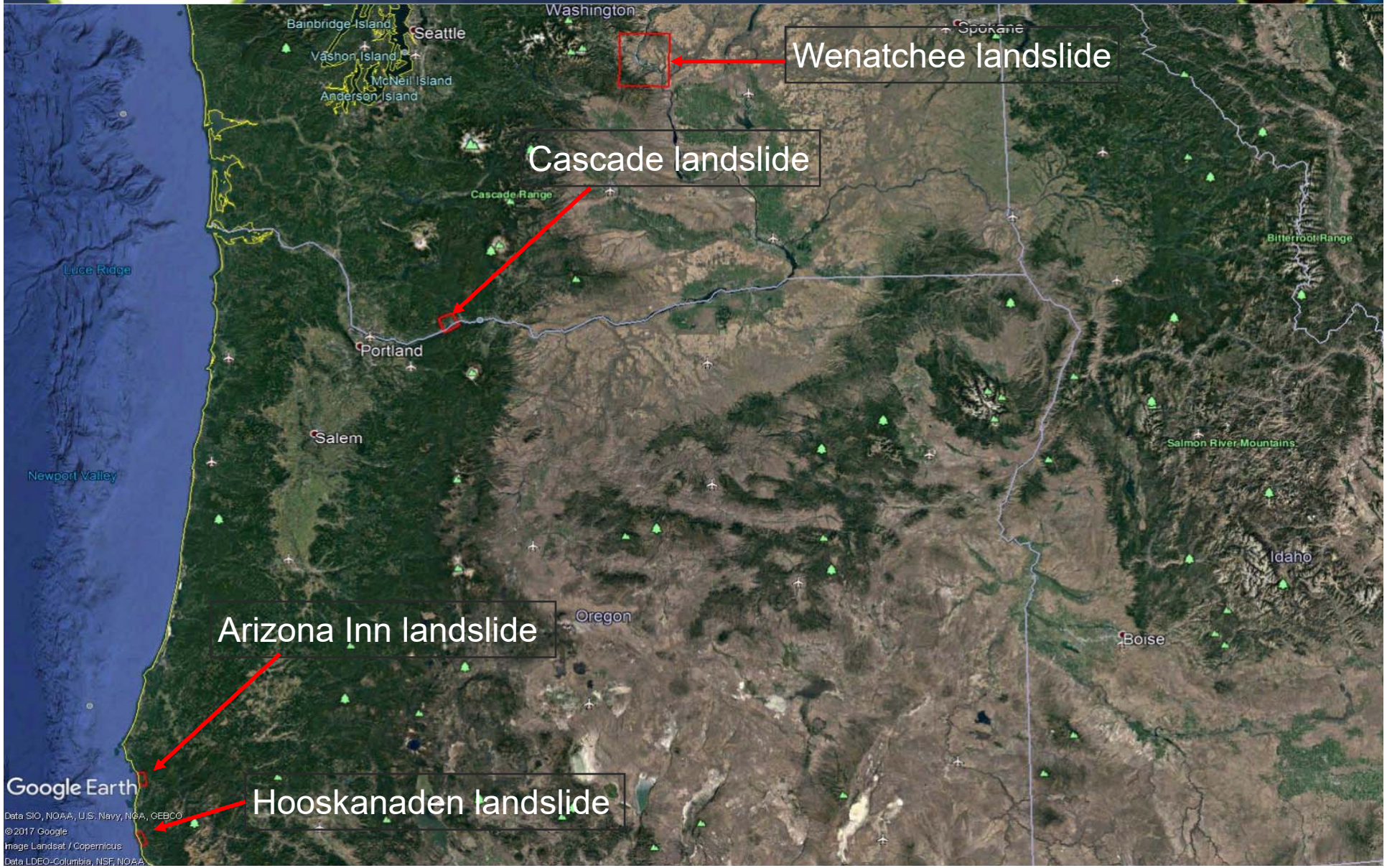
Regional study areas and leads

Region	*Regional Point of Contact*
Nepal	**Nick Rosser, Sigrid Roessner, Dalia Kirschbaum**
Pacific Northwest, US	**Jonathan Godt, Dalia Kirschbaum**
Eastern Africa	**Olivier Dewitte**
Caribbean (Haiti/Lesser Antilles)	**Georgina Bennett, Jean-Philippe Malet**
China	**Zeng-Guang Zhou**

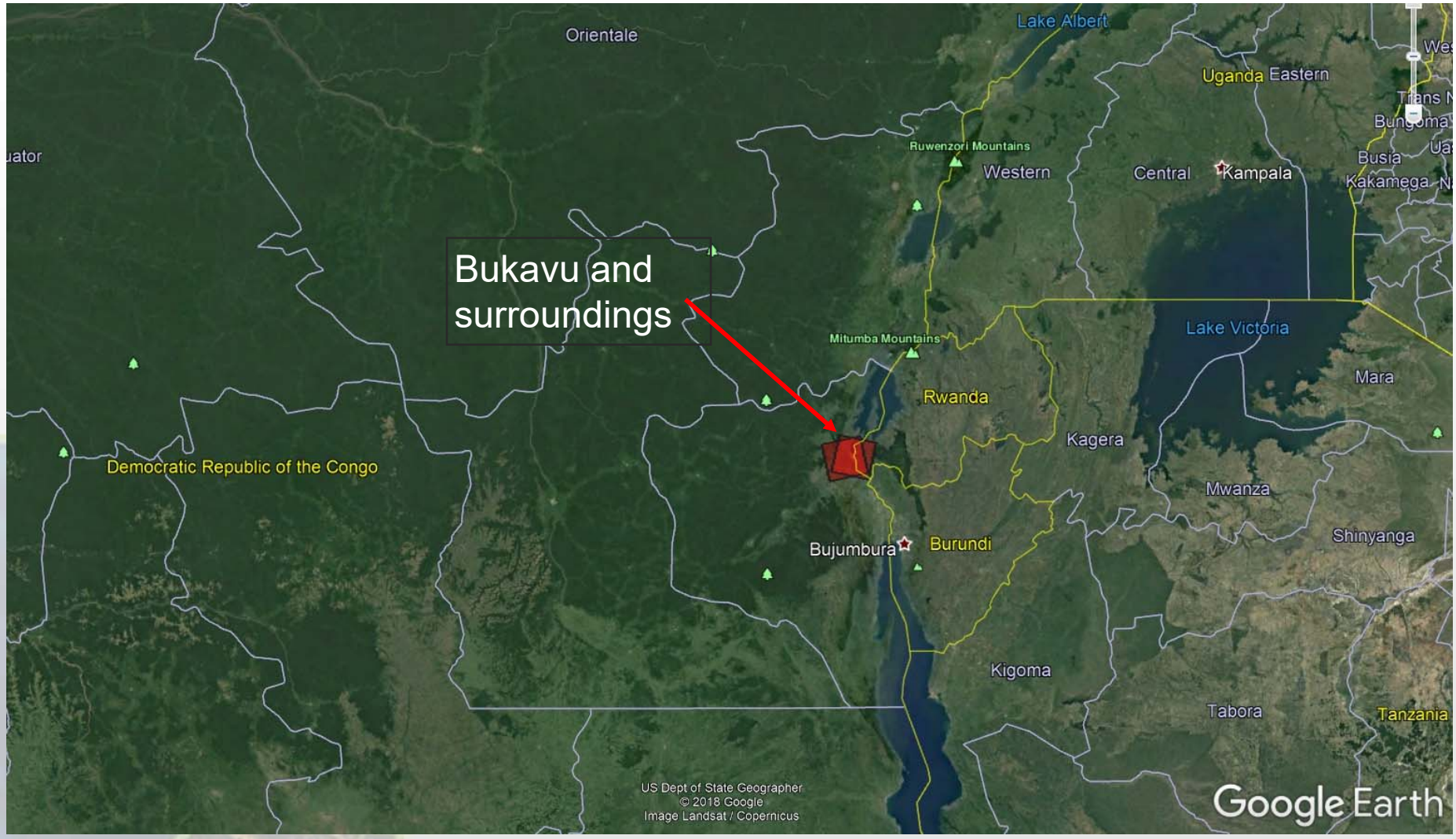
Nepal data request areas



PNW data request areas



East Africa data request area



Caribbean data request areas

DLR/TerraSAR-X

Total quota: Decided by DLR upon review of the proposal

Ordered:

1. Nepal: Acquisition in Arniko study area of Nepal. Trishuli not feasible.
2. PNW: Not possible
3. East Africa: Not possible

Status: Acquisition ongoing for Arniko and data hosted on DLR ftp

CSA/Radarsat-2

Quota available:

1. Nepal: 30 tasking, 30 archived

2. PNW: 30 archived

Status: so far, no request received – but the possibility of using quad pol data acquisition over Nepal for polarimetric landslide detection is explored

ASI/COSMO-SkyMed

Total quota: 300 images/year

Ordered:

Nepal: Trishuli (72 asc/72 des), 2015 earthquake data also available with permission from ASI

PNW: Wenatchee (10 asc/10 des), Cascade (10 asc/10 des). Extended till Dec 2018.

East Africa: Bukavu (42 asc/42 des)

Status: Acquired data hosted on ASI ftp

CNES - Pleiades/SPOT

Pléiades

Total quota: 40.000 km^2 for the life of the project.

Ordered:

1. Nepal: Karnali (22242 km^2), Arniko (300 km^2)
2. PNW: Eel river (6605 km^2), Southern Oregon Coast (1535 km^2)
3. Caribbean: Montserrat (56 km^2)

Status: data delivered directly to requestor.

SPOT

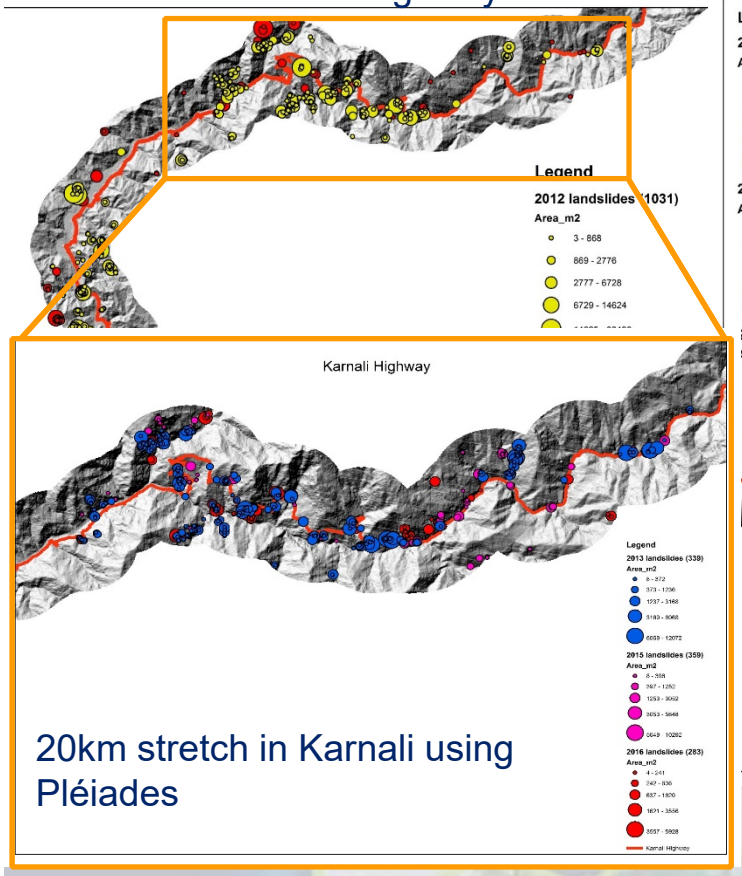
Most of the image request came for SPOT 6/7 which is not available from CEOS.

Status: Resubmitted proposal with smaller area. Data available on GeoSud/THEIA repository since End August – Licensing to be carried out.

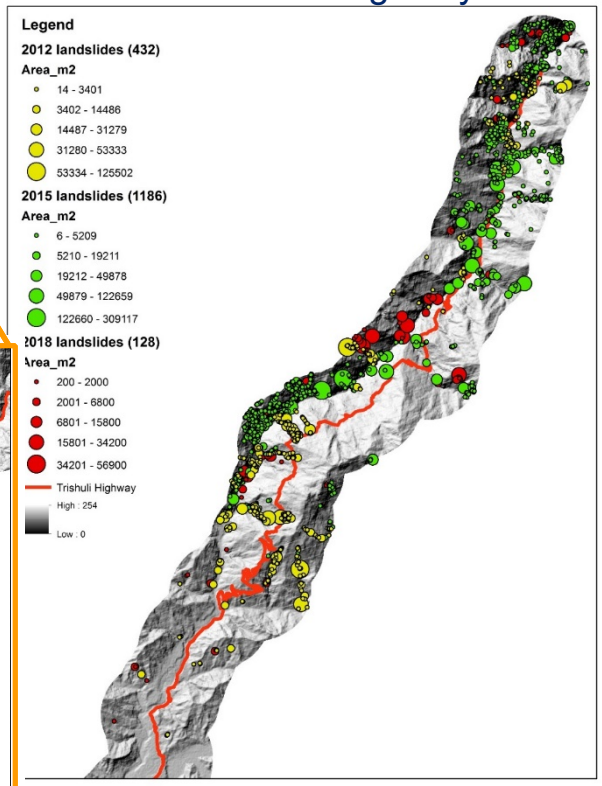
Nepal Study Sites: Preliminary Results

Landslide mapping using Optical Data

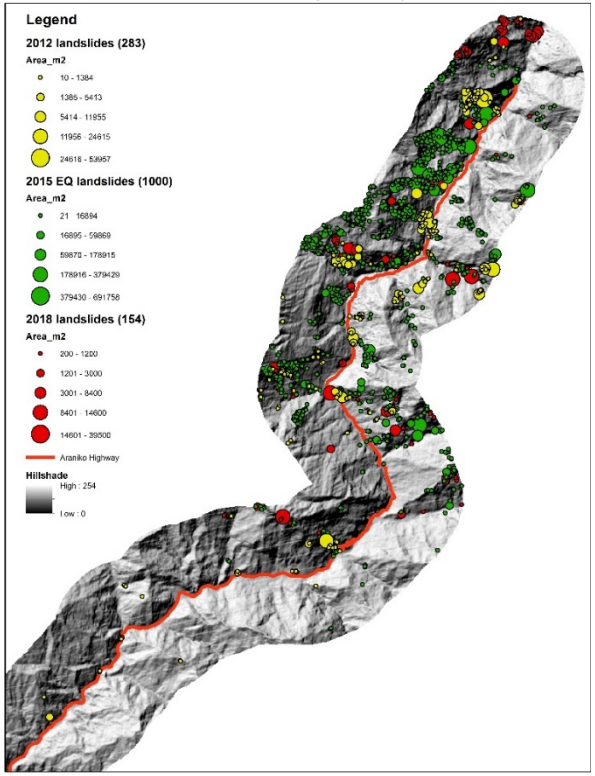
Karnali Highway



Trishuli Highway



Arniko Highway



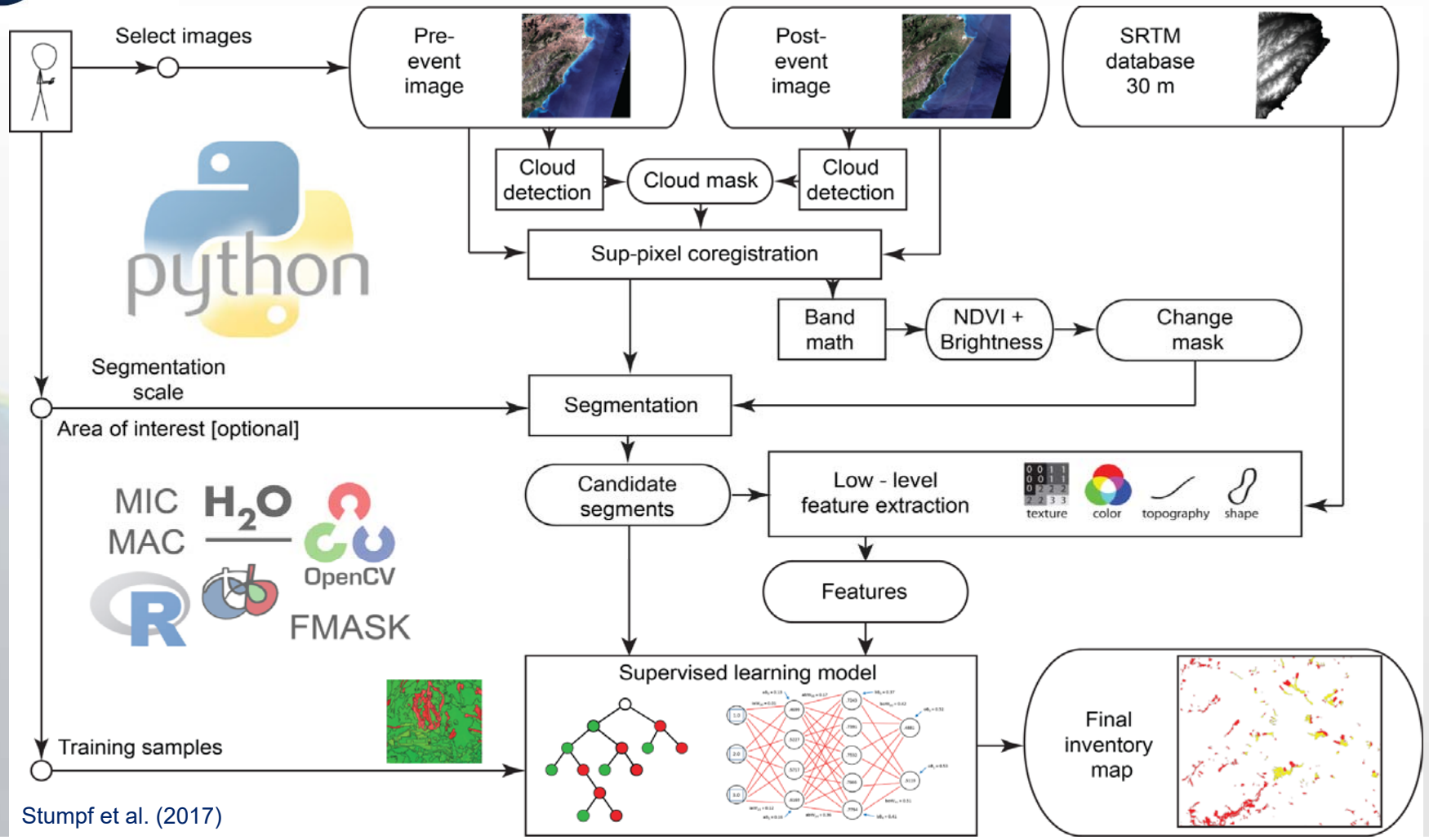
Landslides were mapped using DigitalGlobe, Pleiades and Sentinel-2A for three highways in Nepal, characterizing landslide size.

Pukar Amatya (NASA/USRA), Dalia Kirschbaum (NASA)

Landslide mapping using medium-resolution Sentinel-2 Optical Data

ALADIM: Automated Landslide Detection and Inventory Mapping

Image sources: S2 + VHRO ortho-images
Supervised method - Selection of image features – Random Forest classifier
HPC + cloud-based implementation (through dockerisation)



Stumpf et al. (2017)

Landslide mapping using medium-resolution Sentinel-2 Optical Data

- Test of ALADIM algorithm for automated landslide mapping for Nepal – Creation of pre-, post-monsoon landslide inventories

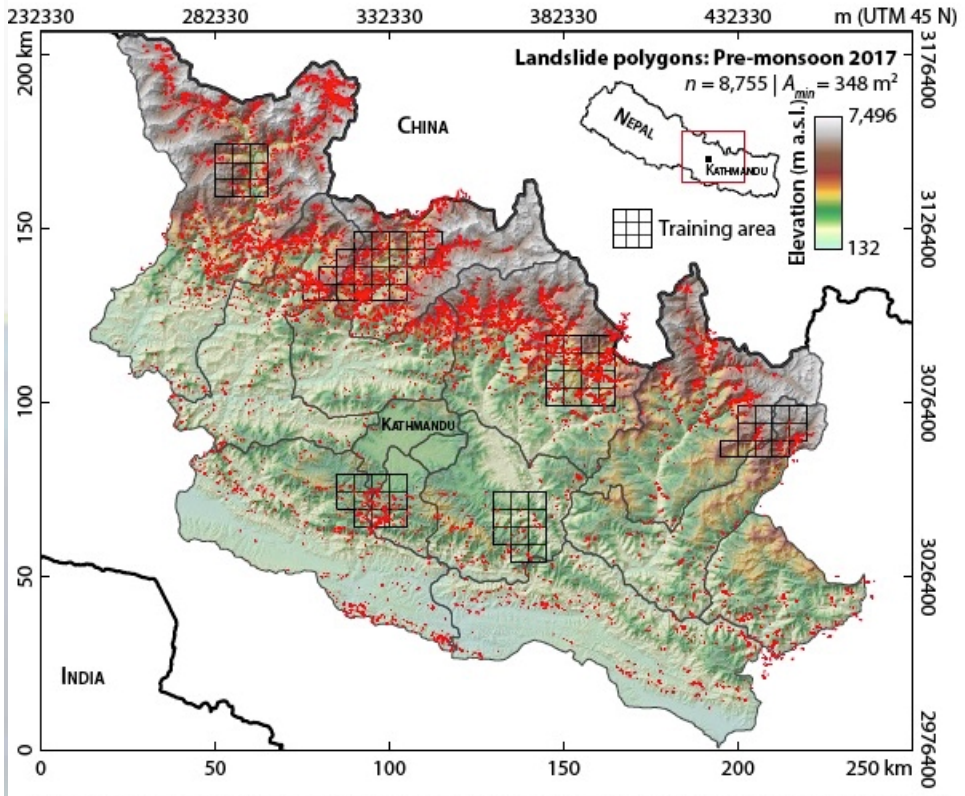


Figure 1: Landslide polygons mapped from Sentinel-2 imagery across the 14 districts (delineated in grey) prior to the 2017 monsoon. Six training areas are visible that cover a range of topography, including two in the Sivalik Hills

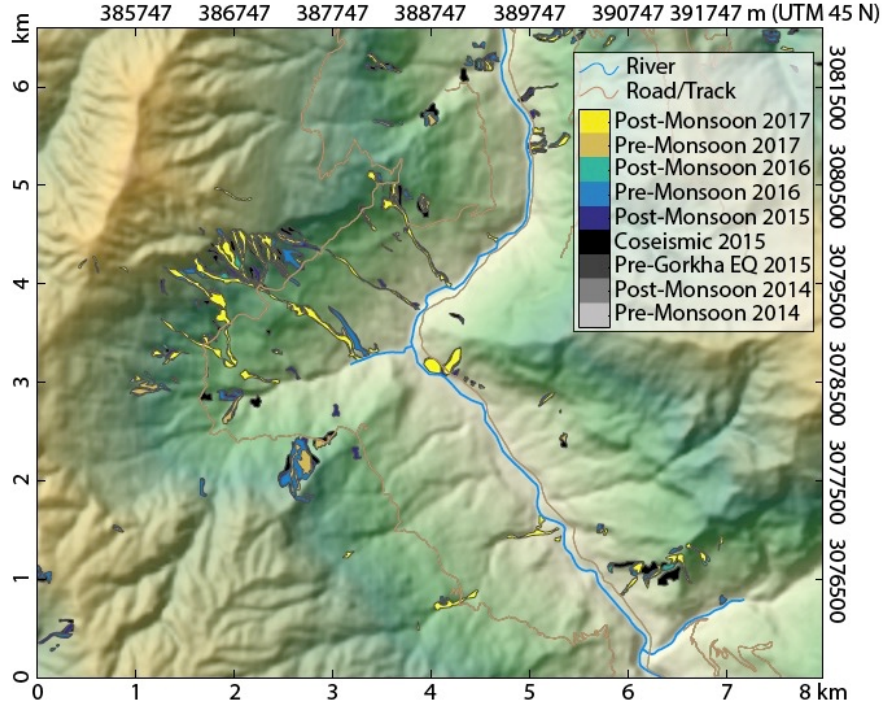
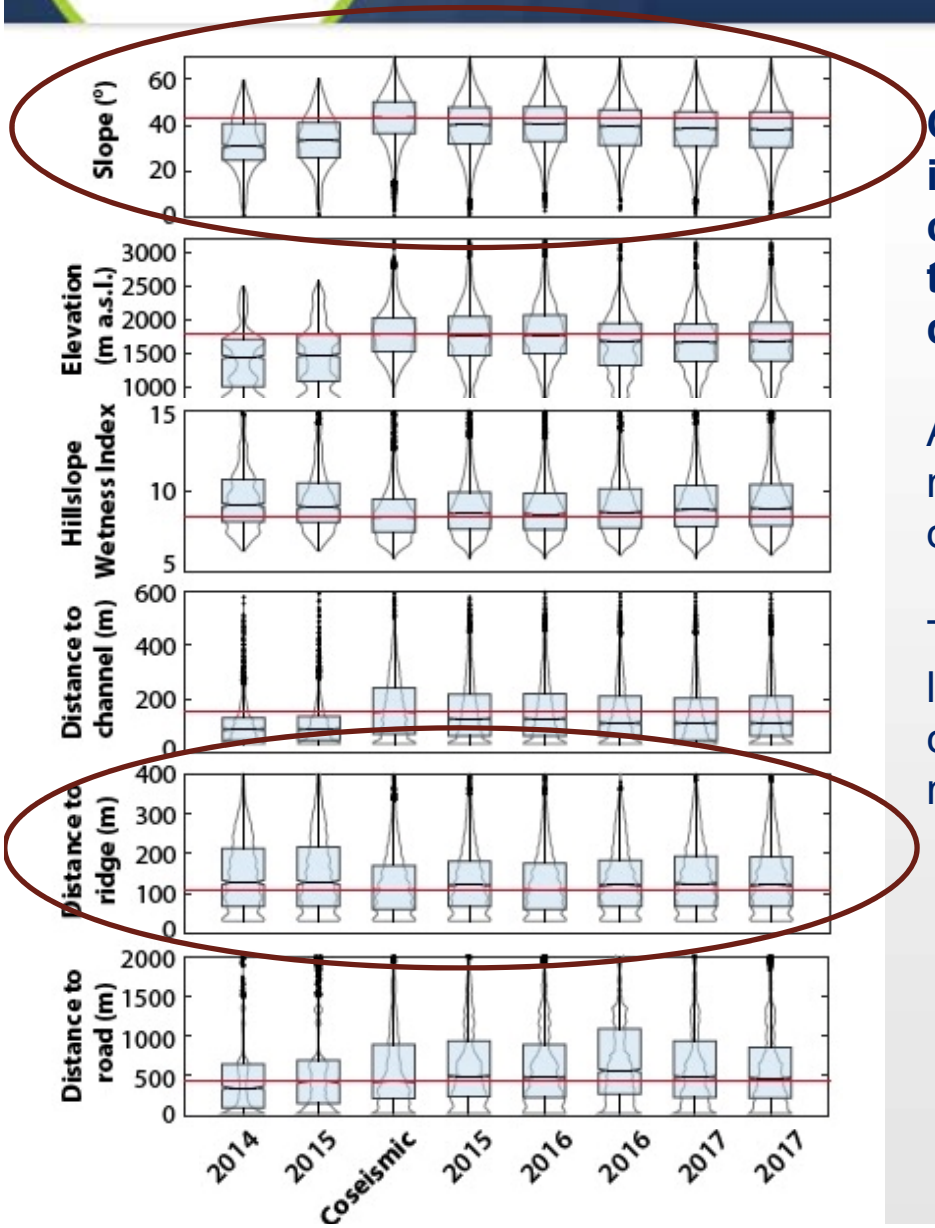


Figure 2: Extract of landslide polygons pre- and post-earthquake. All landslides (new and existing) are mapped independently for each epoch, enabling changes in individual landslide geometry and style to be identified through time. A frequent observation is the conversion of coseismic landslides to debris flows.

EGU2018: J. Williams / N. Rosser (U. Durham)
J.-P. Malet (EOST)

Landslide mapping using medium-resolution Sentinel-2 Optical Data



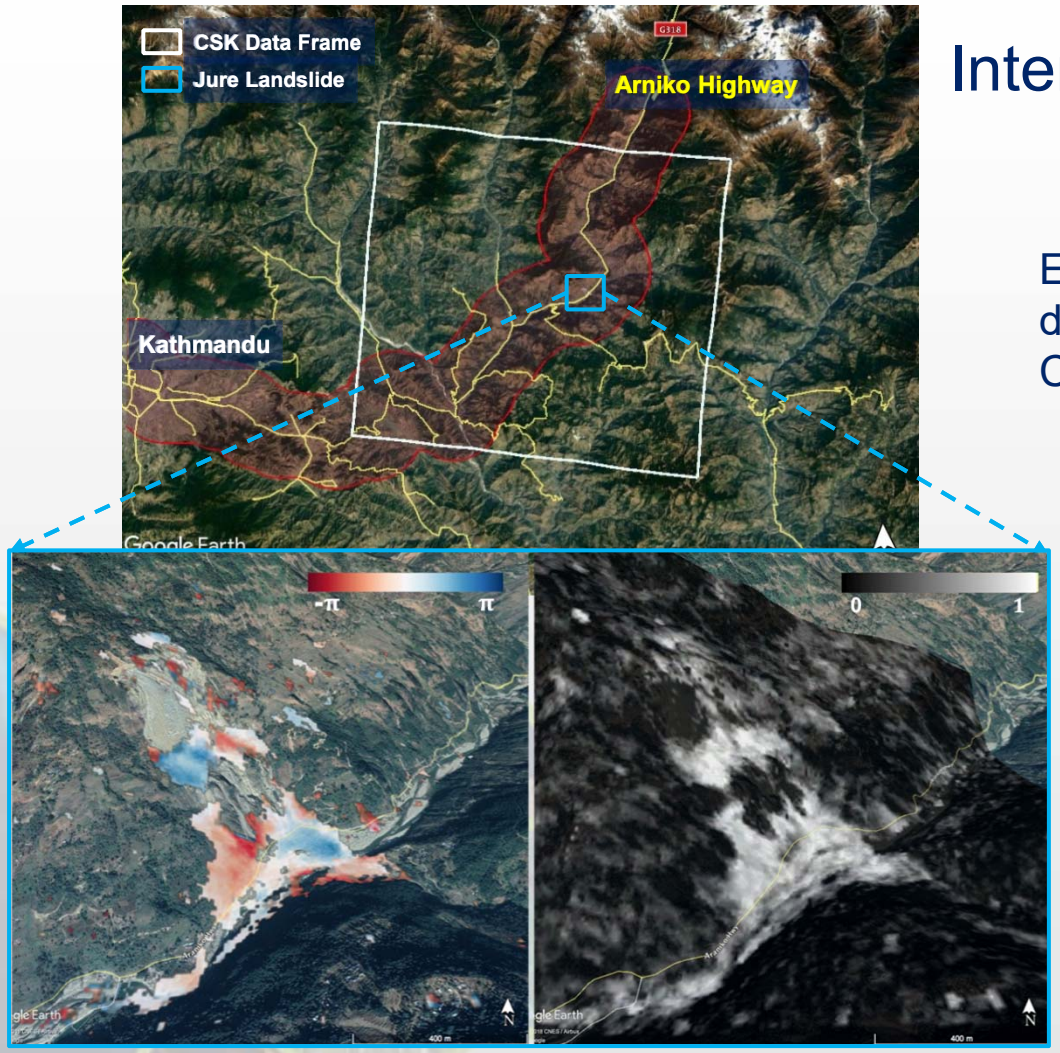
Changes in landslide topographic distribution in time for the period 2014/2017 (pre-seismic, co-seismic, post-seismic) represented in terms of box and whisker plots (+ kernel density estimates).

A coseismic shift in slope and distance to the ridgeline is siginficatively observed as well as a a decay towards pre-EQ distributions.

This appears to be ongoing and suggests that landslides are undergoing shape change and elongation from the ridgeline towards roads and the channel network.

EGU2018: J. Williams / N. Rosser (U. Durham)
J.-P. Malet (EOST)

Landslide mapping by Radar Data (Jure Landslide)



Interferometric SAR (InSAR)

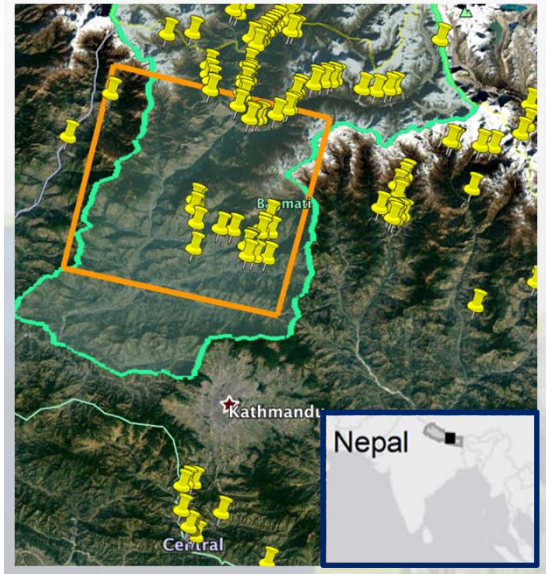
Earthquake triggered landslide deformation measured from COSMO-SkyMed SAR Data.

Landslide deformation (left) and interferometric coherence (right). Surface deformation of about 1-2 cm was measured by using 4-day InSAR pair in coherent area.

Credit: MinJeong Jo (NASA/USRA)

Landslide mapping using SAR Sentinel-1 data

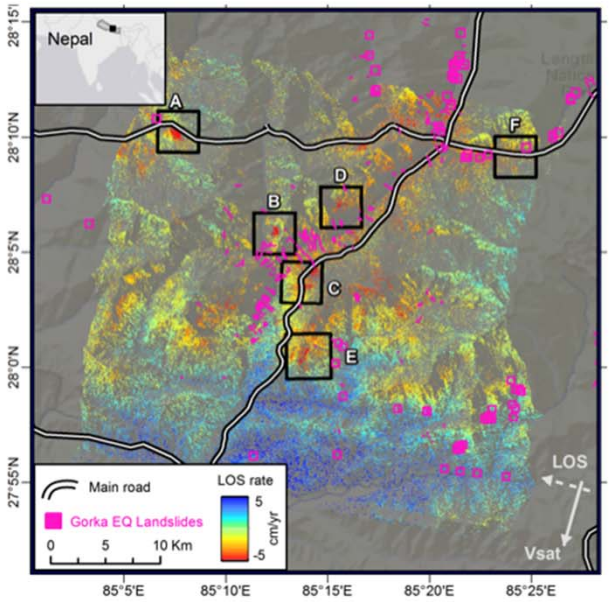
- Using multi-temporal SAR overpasses this work seeks to determine the feasibility of using Sentinel-1 data for identifying landslide movement within the Trishuli basin
- Field surveys provided by the Univ. of Durham helped to corroborate or explain our observations with the SAR data

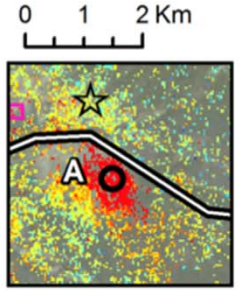


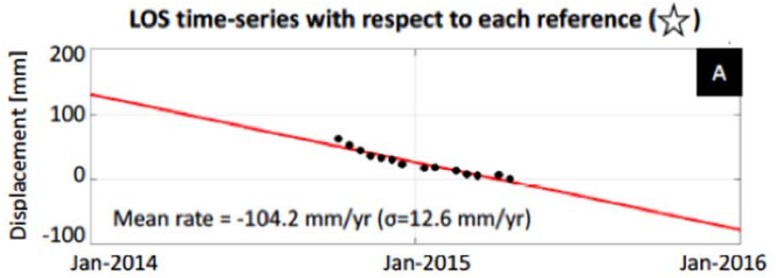
Improved understanding on causes & correlation with physical processes requires dense spatio-temporal landslide catalogues

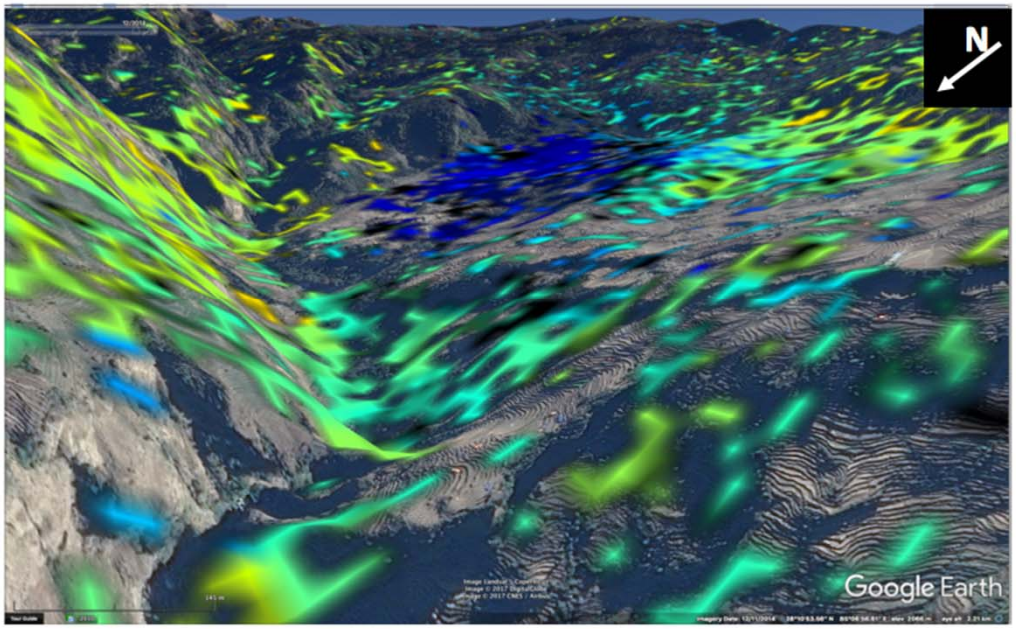
D. Bekaert et al., NASA/JPL

Line of Site time series change using Sentinel-1 data









D. Bekaert et al., NASA/JPL

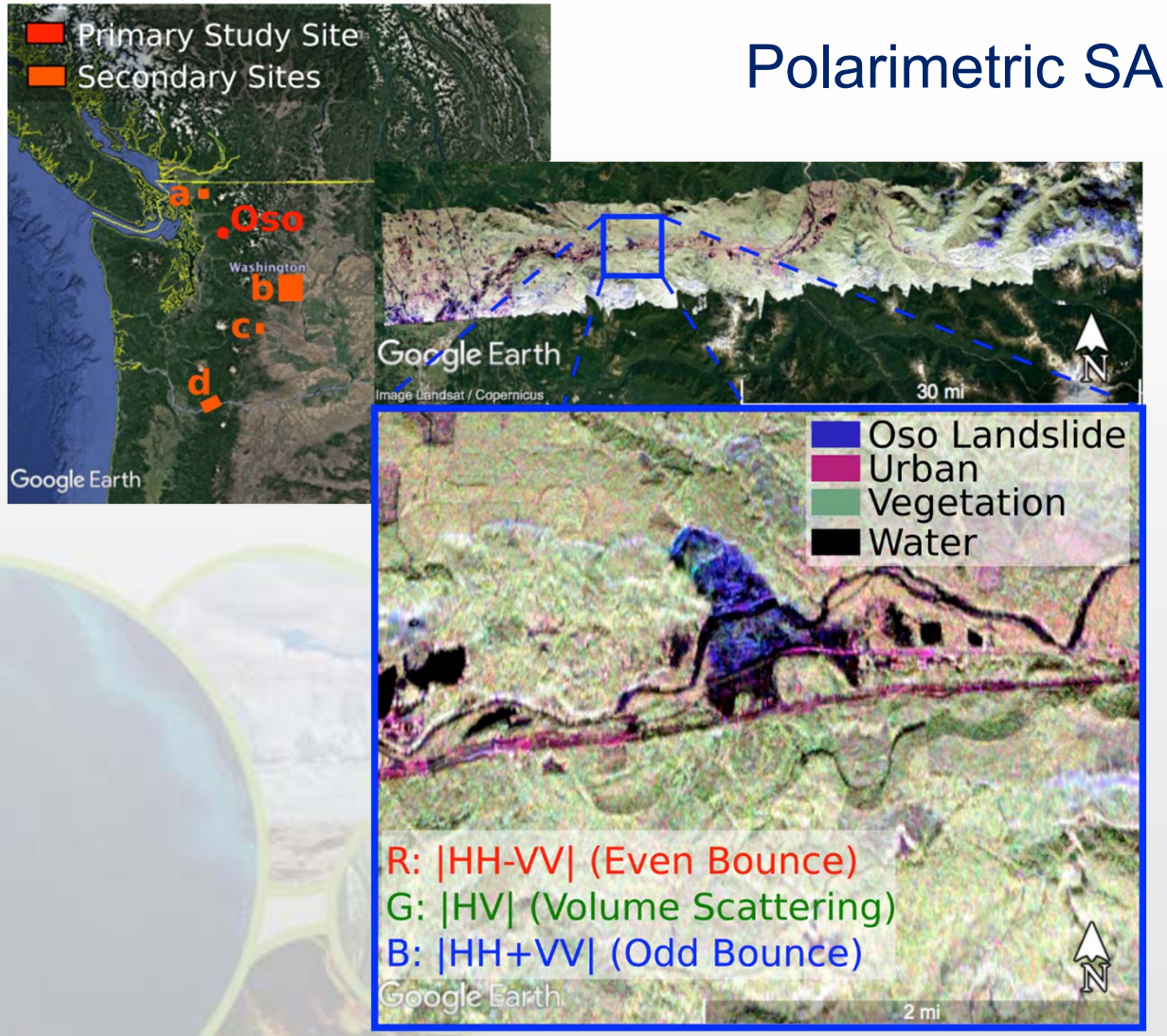
Summary

- SAR data can be used in a variety of ways to map landslides
- Detection success rate for SAR strongly related to:
  - Sensor resolution
  - Landslide orientation vs satellite acquisition geometry
  - Scattering changed from snow, precip, vegetation
- There is not a one-fit all SAR technique towards landslide mapping
  - Fast moving landslides
  - Slow moving landslides
  - Critical failure landslides
- Time-series InSAR capable of mapping slowly moving slides
  - Local detector successfully applied on regional processing to identity slowly moving landslide area's from superimposed noise sources

Pacific Northwest Study Site: Preliminary Results

Landslide mapping by Radar Data

Polarimetric SAR (PolSAR) Approach



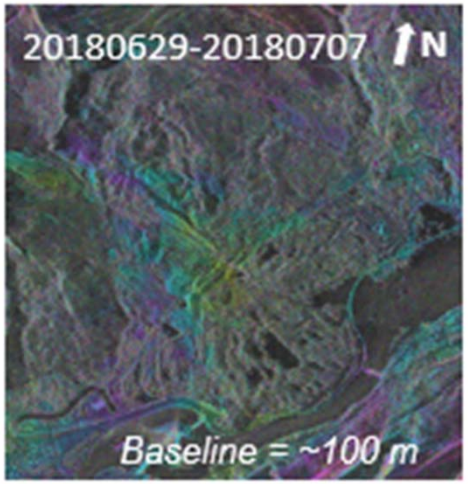
Landslide scar was detected for ***Oso Landslide*** in WA using AirMOSS airborne SAR data.

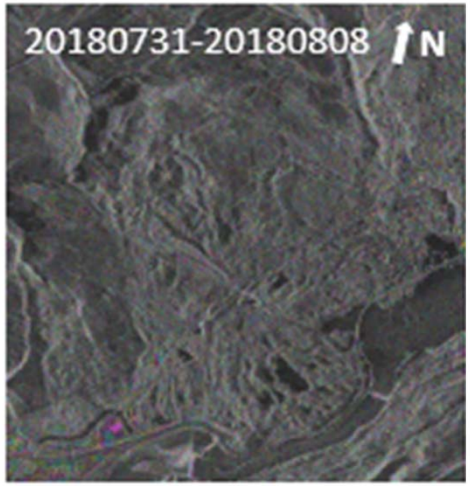
The area in blue show single bounce dominant scattering mechanisms, highlighting the Oso Landslide area.

Credit: MingJeong Jo (NASA/USRA)

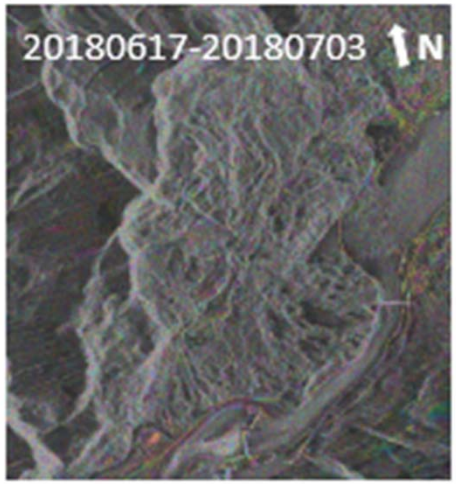
Preliminary results over Cascade Landslide, PNW

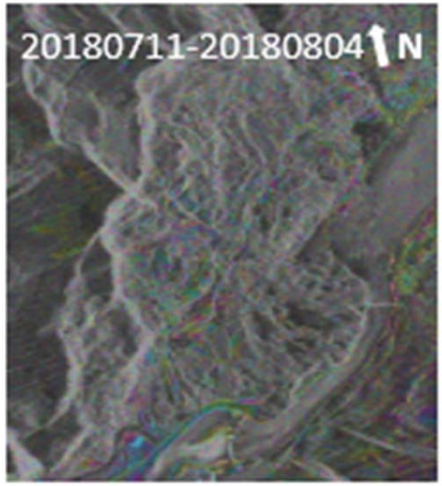
Preliminary results





Ascending track





Descending track

Credit: Zhong Lu (Southern Methodist University)

Preliminary results over Cascade Landslide, PNW

❑ Problems

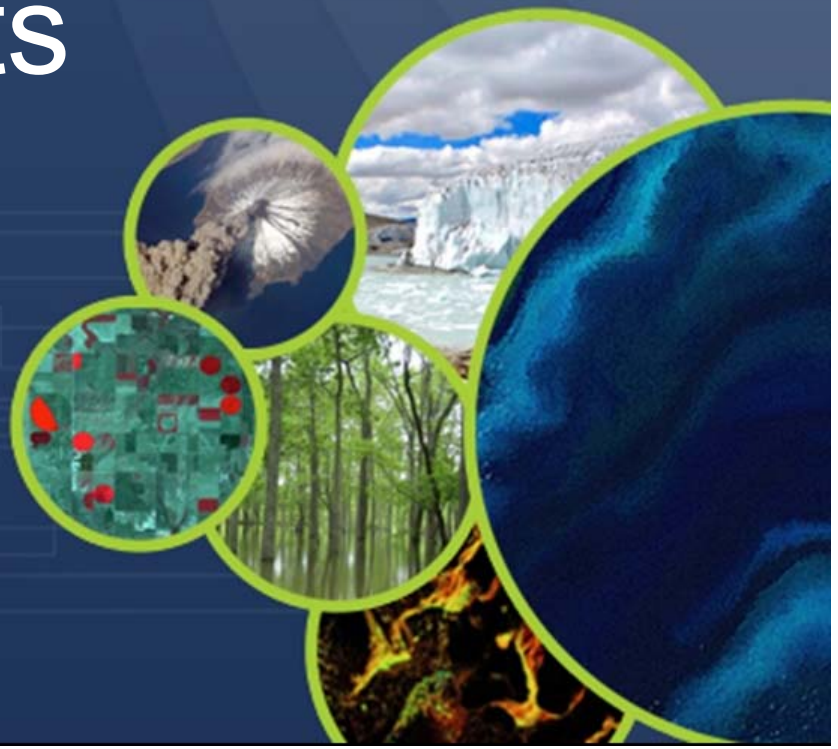
(1) Large spatial baselines and vegetation in the target region cause severe decorrelation of X-band COSMO-SkyMed InSAR images.
(2) Limited SAR acquisitions prevent us from conducting PSInSAR anlaysis on stable scatters

❑ What's next?

(1) We need more COSMO-SkyMed data covering Cascade Landslide Complex to run PSInSAR analysis: about 30 images per track.
(2) Particularly, we would like more images during Nov 2018 and March 2019, the season of peak landslide movement/activity.

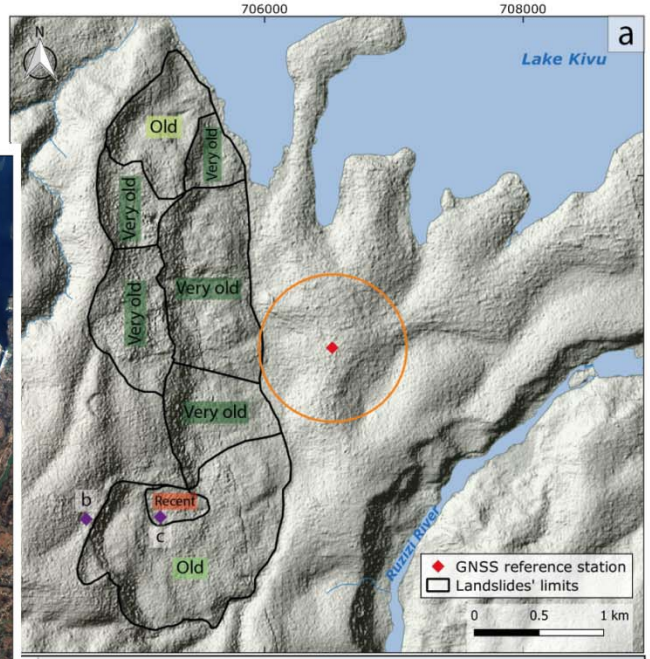
Credit: Zhong Lu, Southern Methodist University

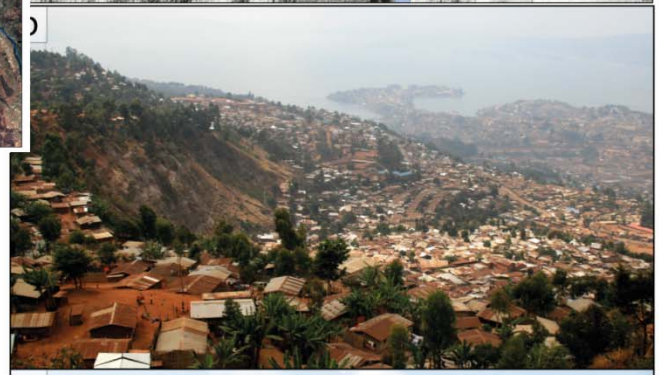
Africa Study Site: Preliminary Results



Ground deformation

- Focus on the city of Bukavu and its surroundings
- **InSAR (MSBAS) by Univ. Liège**
- **Image Correlation by CNRS EOST**
- Ground-based validation (UAV, DGPS + LIDAR)
- Field investigation

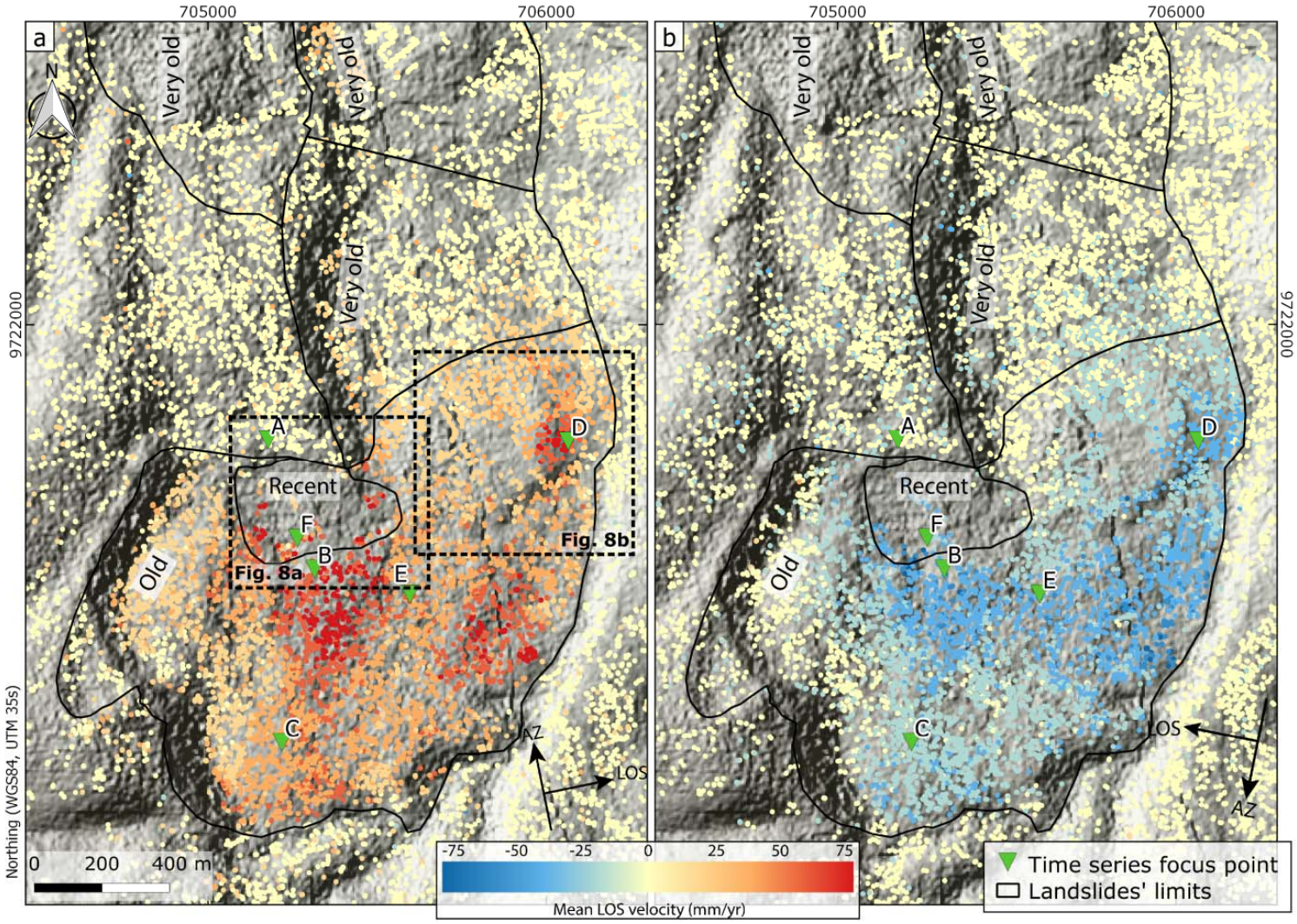




Nobile et al., 2018. Remote sensing.

Ground deformations

CSK images are now acquired via CEOS



Next steps:

- **300 CSK images**
- **Combination with Sentinel images**
- **Use of MSBAS**
- **Image correlation with Pléiades**

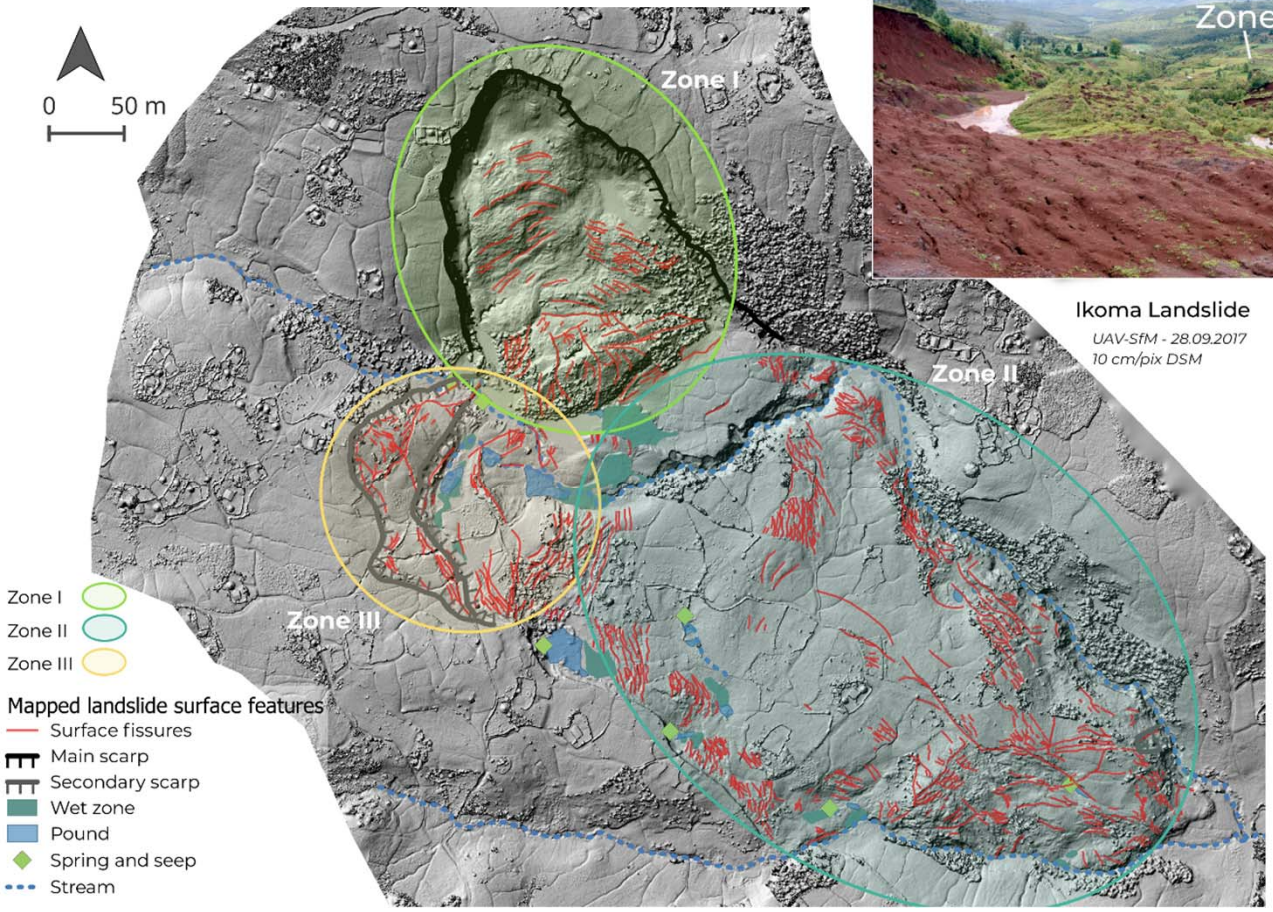
Nobile et al., 2018. Remote sensing.

Processing of **70 COSMO-SkyMed images**

(StripMap HIMAGE: scene size of 40x40 km ; Az & R resolution : 3 m)

Ground deformation

UAV-SfM – Tool for characterization and validation

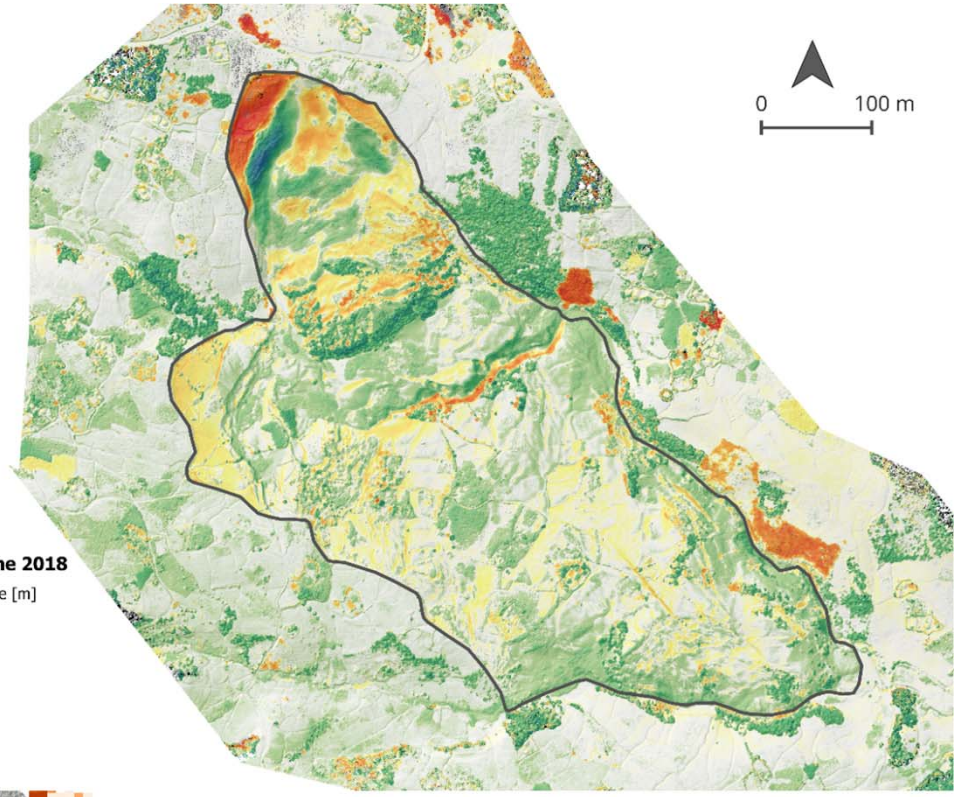


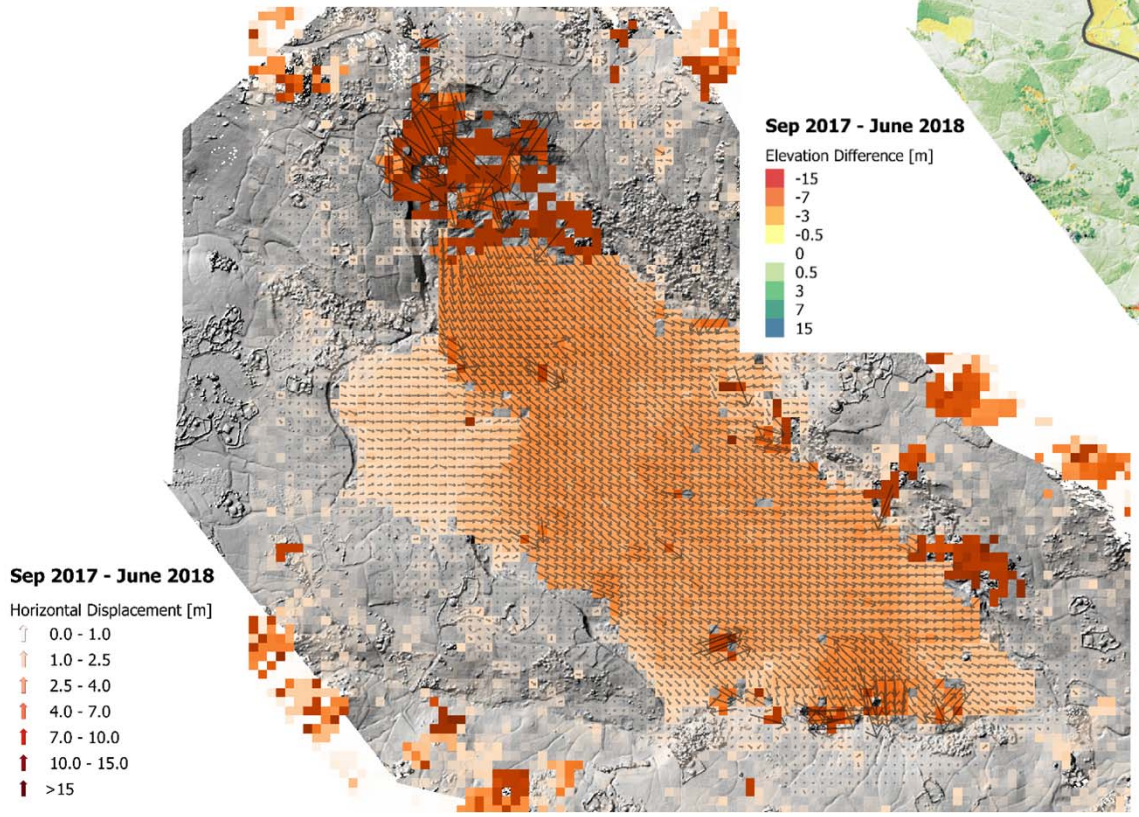
Ikoma landslides – DRC (Bukavu)

History of landslide movement

Recent evolution

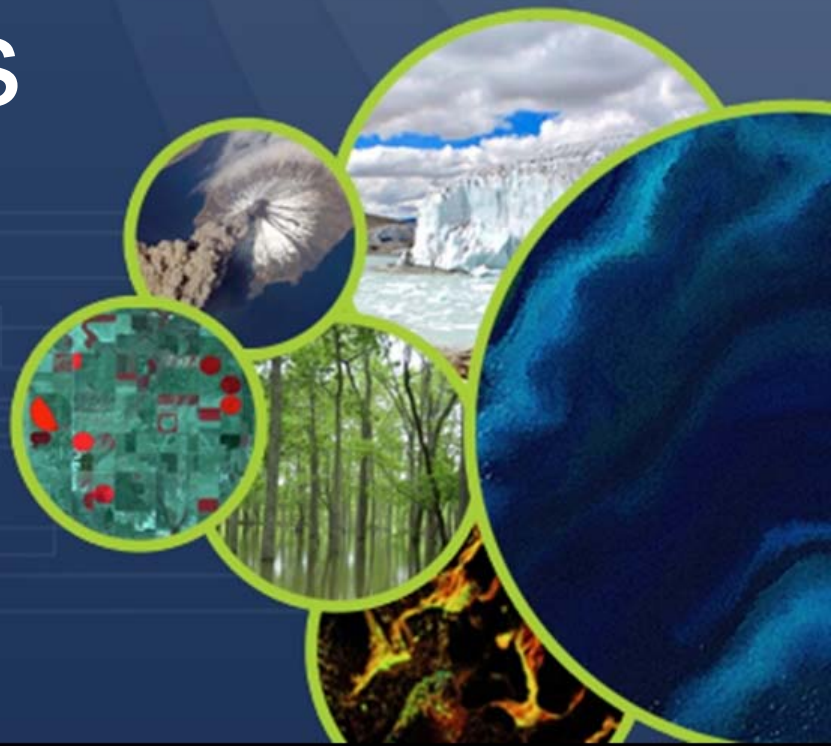
UAV-SfM Point Cloud comparison





Next step: image correlation Pléiades, Sentinel, Spot, PlanetScope

Caribbean Study Site: Preliminary Results



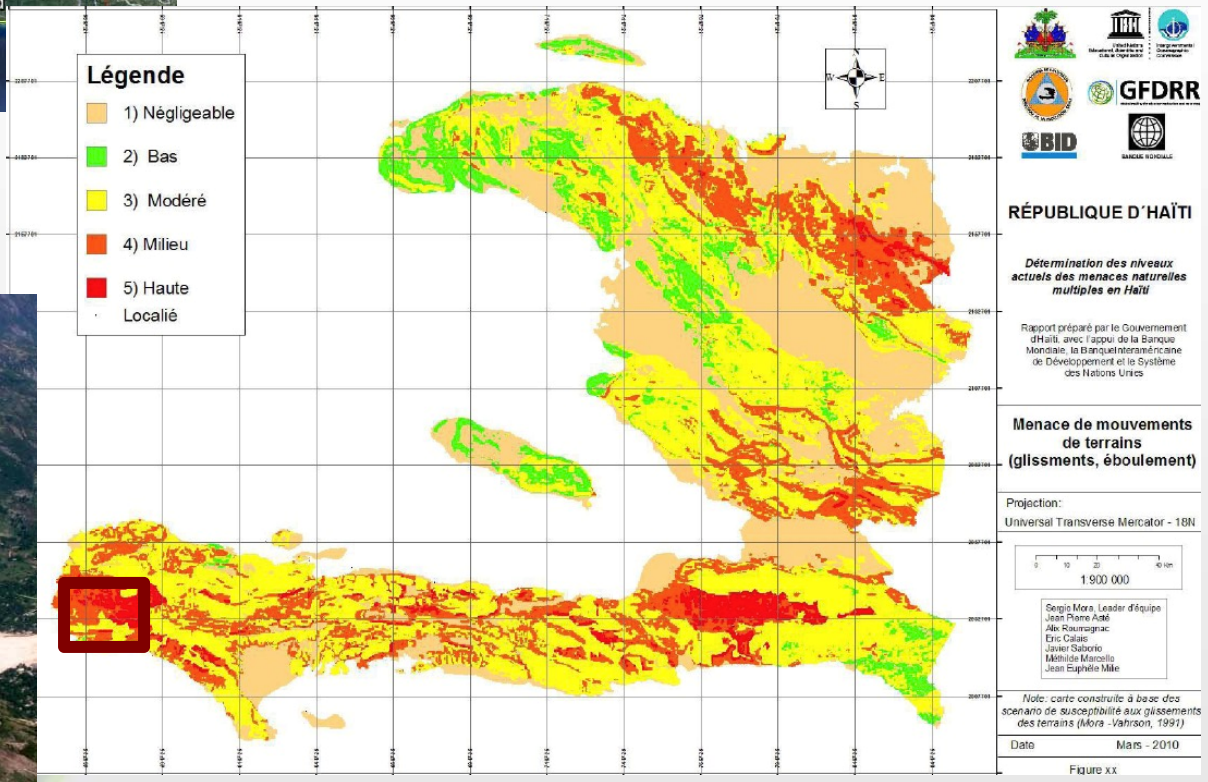
Post-hurricane landslide detection and mapping: Haiti

First landslide susceptibility map for the country

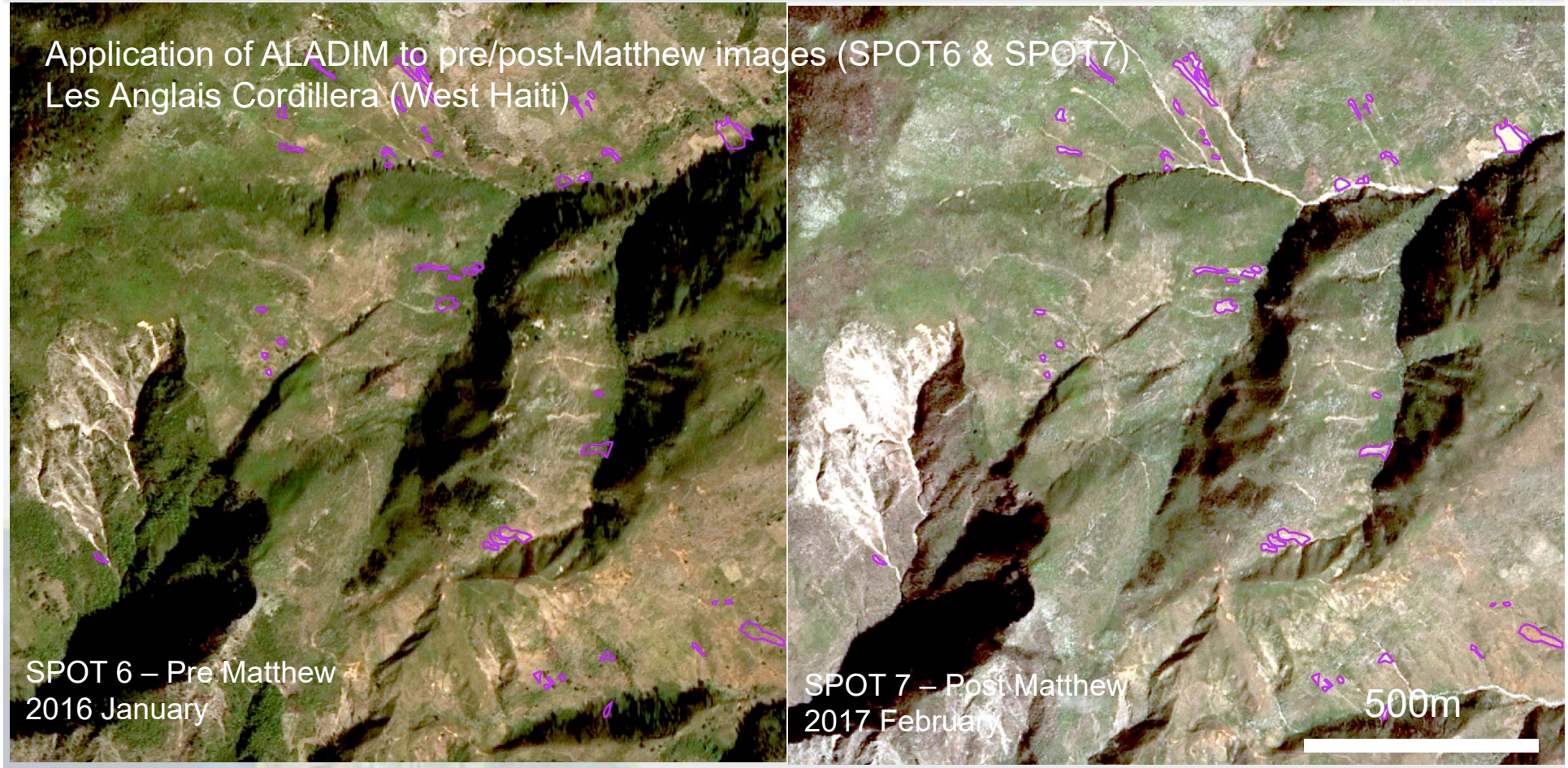
Map created without landslide information (!)

Landscape after Matthews

Major rain events



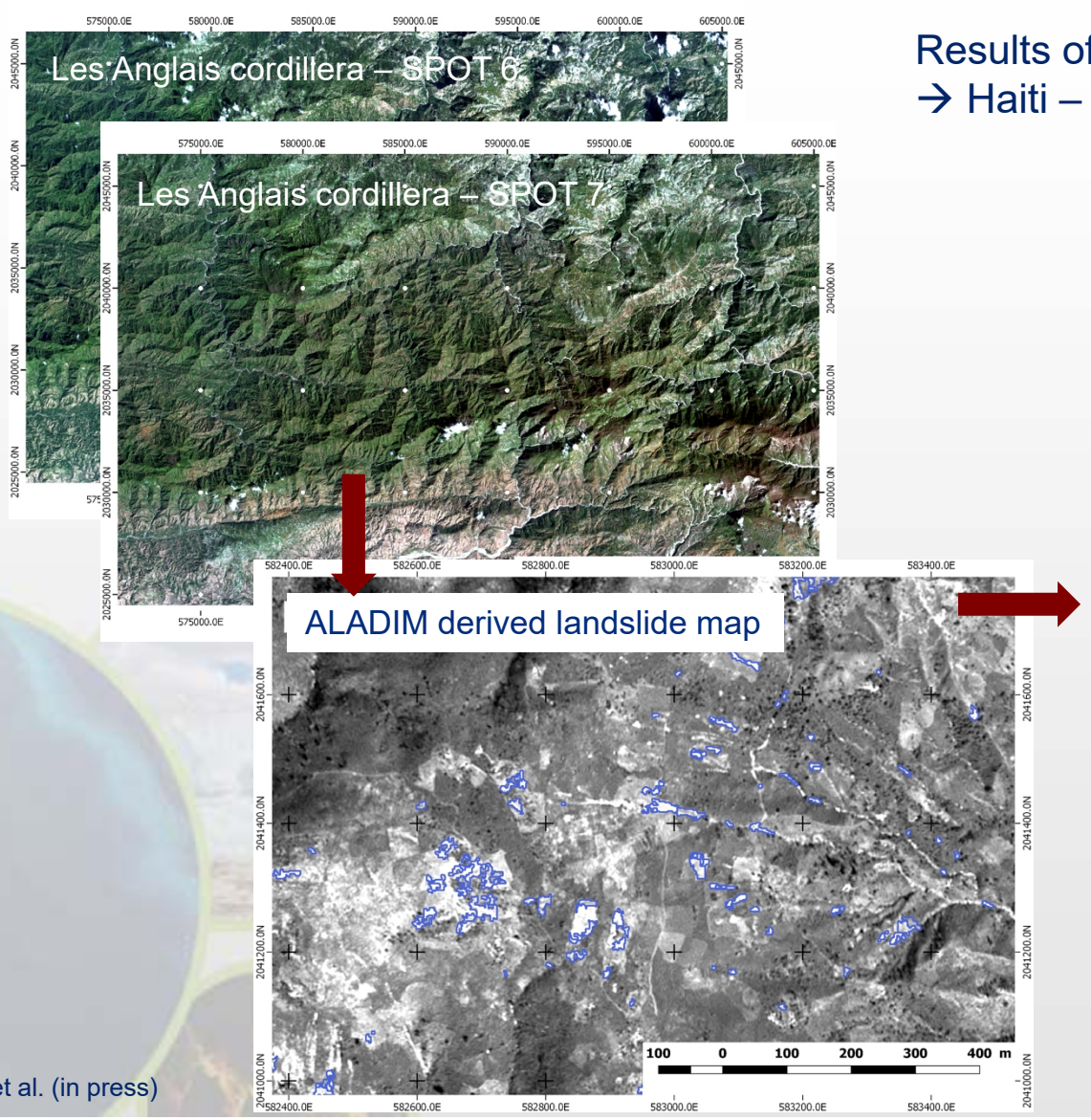
Post-hurricane landslide detection and mapping: Haiti



Channel deposits are difficult to map (they may add ~30% of affected areas)
Shadows on West and North slopes may cause underestimation of the total landsliding
Many bare soils …. Difficult for automated mapping

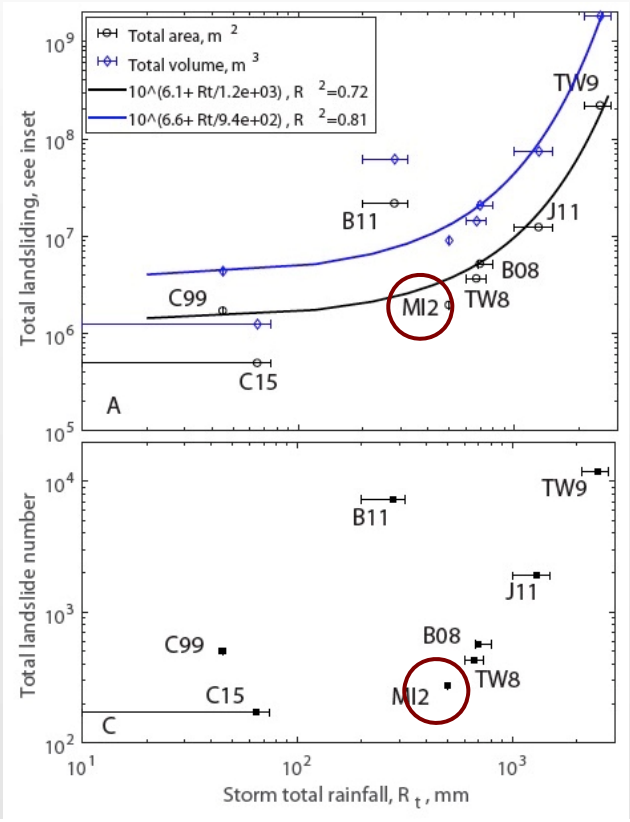
Marc et al. (2017)

Post-hurricane landslide detection and mapping: Haiti



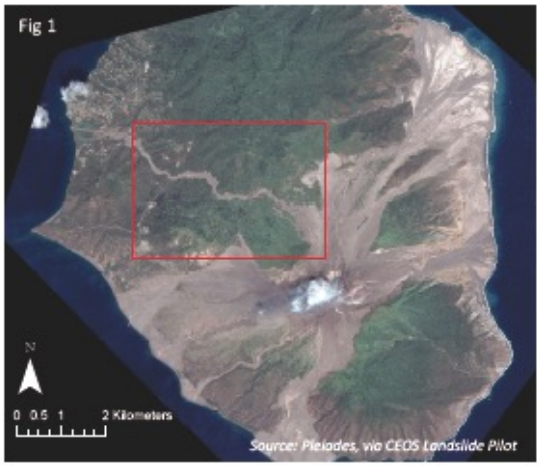
Results of ALADIM-Caribbean:
→ Haiti – post-Matthews landslides

Landslide statistics and relation to triggers for several recent Hurricanes/Cyclons



Marc et al. (in press)

Lahar hazards in Montserrat



Vegetation recovery in The Belham River Valley, Montserrat, West Indies, following eruption of Soufriere Hills Volcano.

Preliminary Normalised Difference Vegetation Index (NDVI) results acquired from Pleiades satellite imagery

James Christie[1], Dr Georgina Bennett[1], Prof Jenni Barclay[1], Dr Melanie Froude[2], Dr Adam Stinton[3]

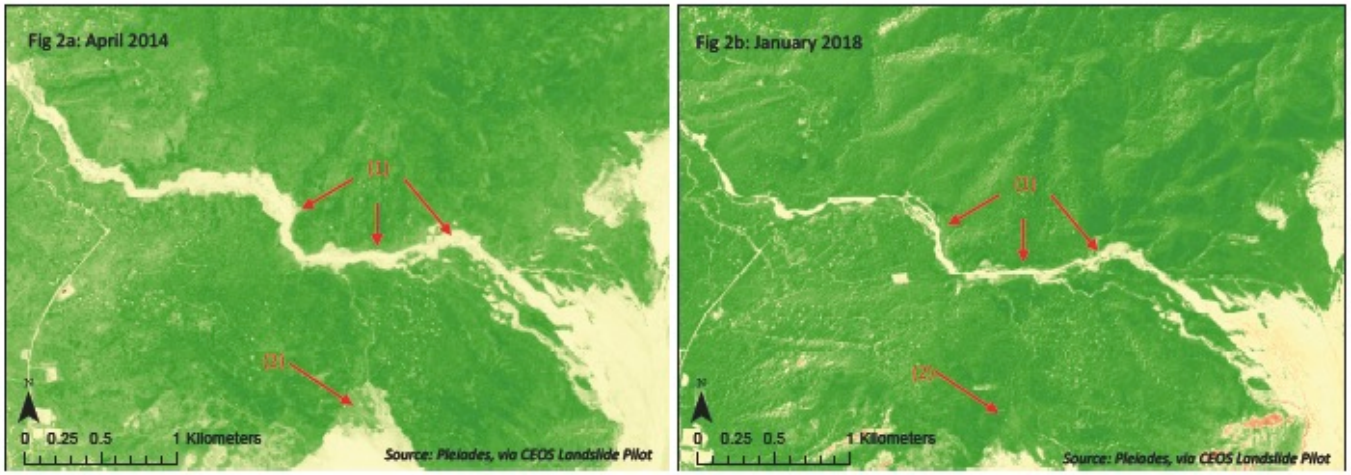
1. University of East Anglia; 2. University of Sheffield, 3. Montserrat Volcano Observatory

Key findings:

1) Clear in-channel re-establishment of vegetation shown by the narrowing of channel.
2) Recovery of vegetation in upstream areas of the catchment, particularly to the south.

Background and rationale:

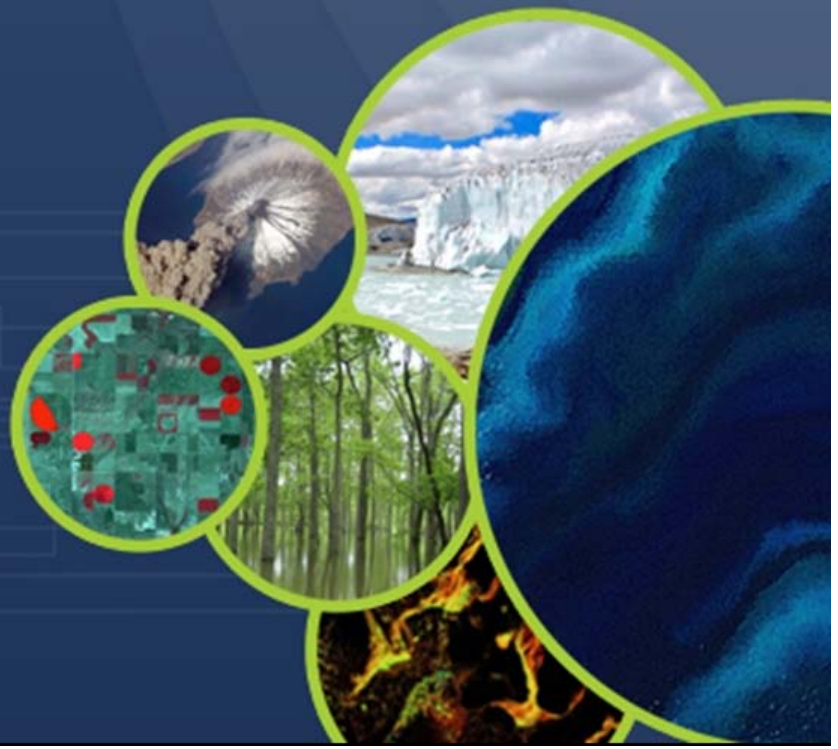
- Significant deposition of volcaniclastic material in The Belham River Valley between 1995– 2010 as a result of explosive eruption of Soufriere Hills Volcano.
- Channel prone to hazardous rain-triggered lahars.
- Vegetation damage was extensive during eruption. Vegetation coverage is an important control on runoff dynamics and influences the probability of lahar initiation and subsequent magnitude; understanding vegetation change aids the understanding and modelling of an **evolving hazard**.



Figures:
Figure 1 (upper left): Satellite image of Soufriere Hills Volcano, April 2014 with the Area of Interest (upper and middle sections of the Belham River valley) shown in red box;
Figures 2a and 2b (lower right): NDVI images of Area of Interest in a) April 2014, and b) January 2018.

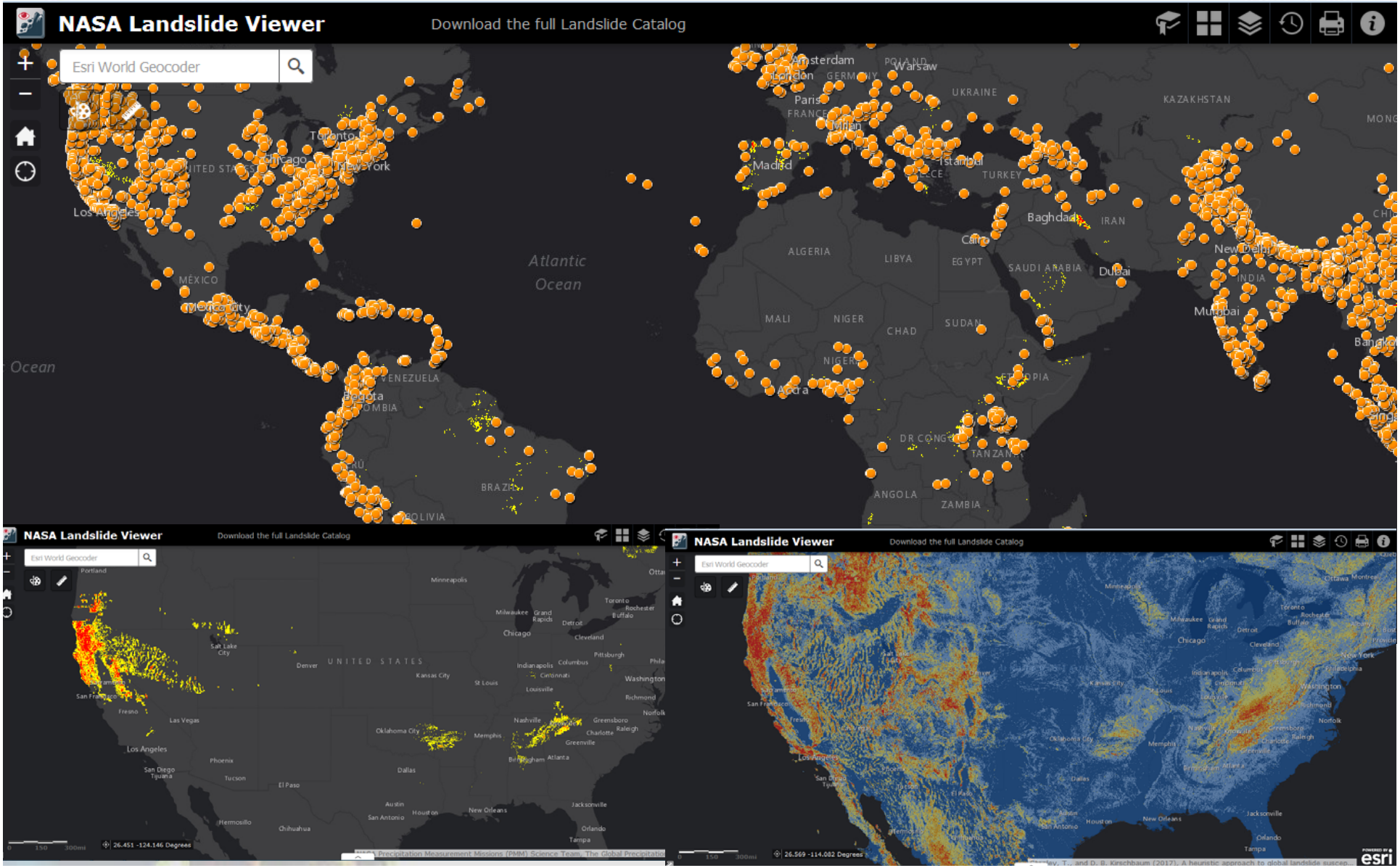
China Study Site

Global work



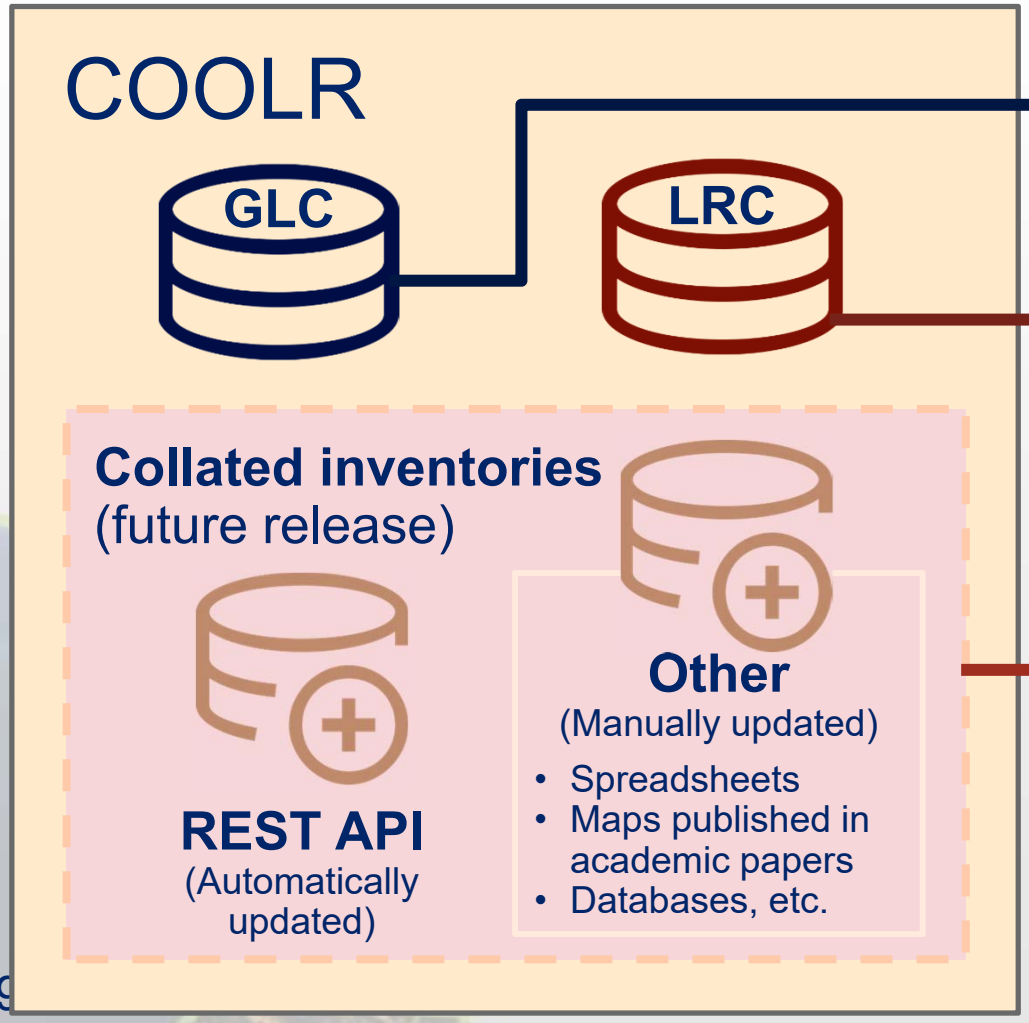
Landslide Viewer

https://landslides.nasa.gov/viewer



The Cooperative Open Online Landslide Repository (COOLR)

https://landslides.nasa.gov



Global Landslide Catalog (GLC): NASA GSFC's catalog of rainfall triggered landslide events, collected since 2007

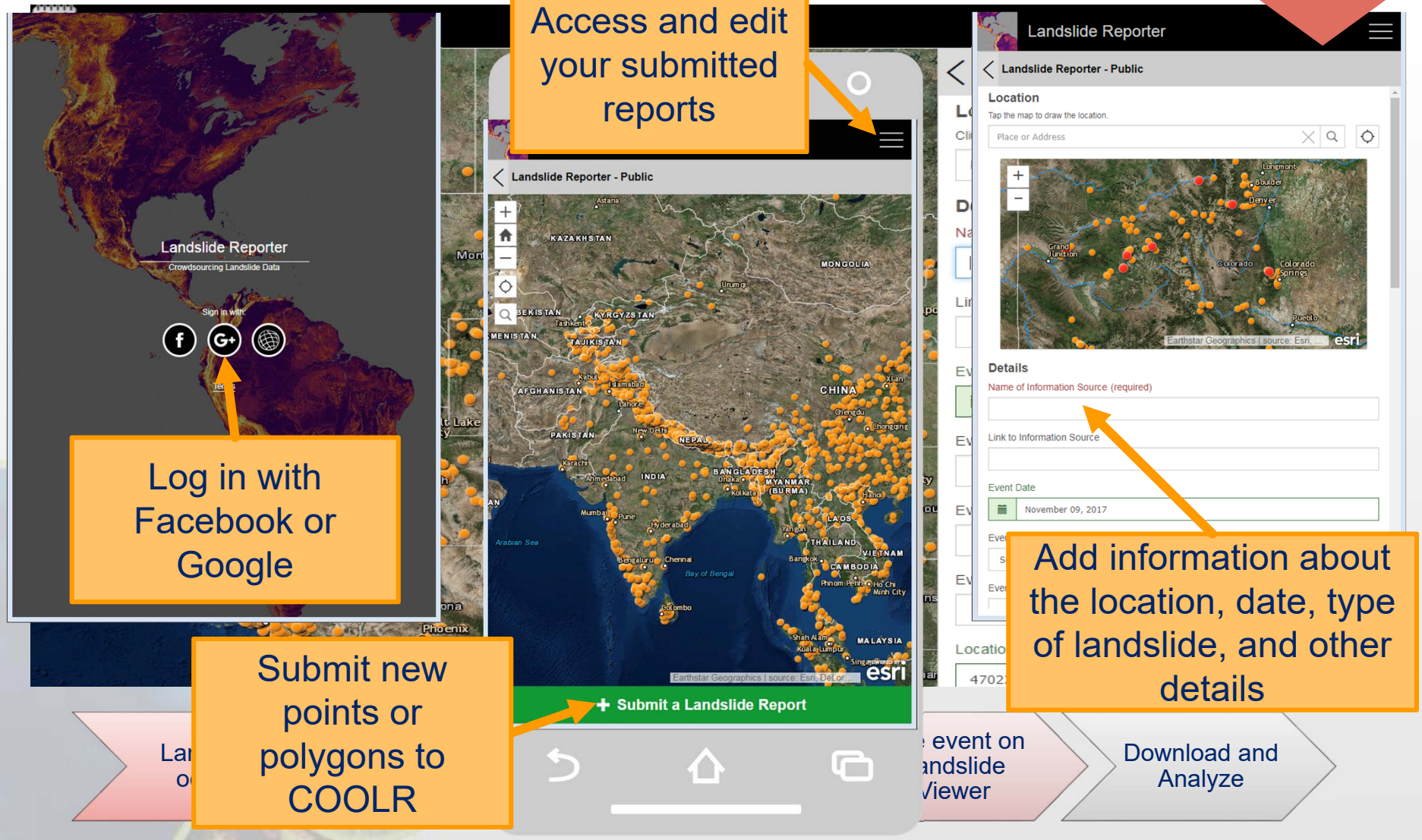
Landslide Reporter Catalog: landslide events contributed by citizen scientists

***For a future release*— Collated landslide inventories:** Landslide data from other sources will be added into COOLR

Landslide Reporter

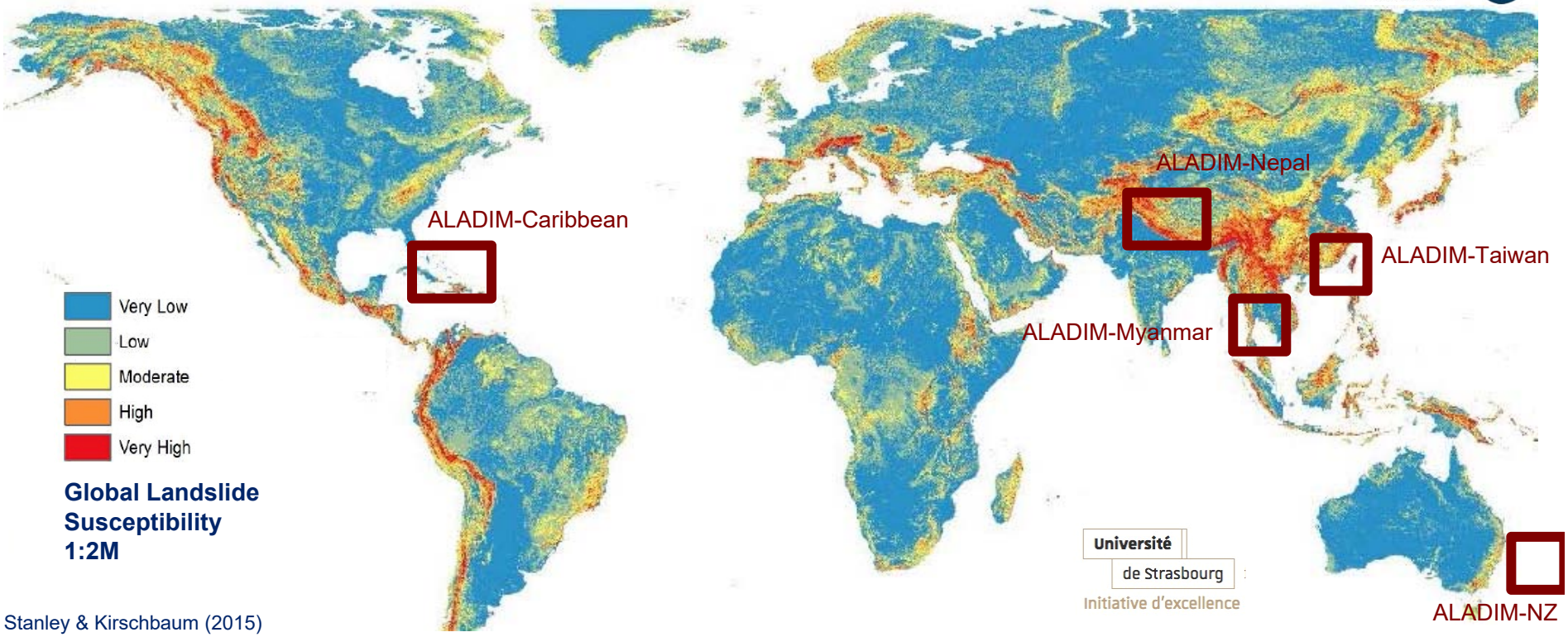
https://landslides.nasa.gov/reporter

Use on the computer or mobile device



landslides.nasa.gov

Generalizing the creation of EO-based inventories after major triggering events

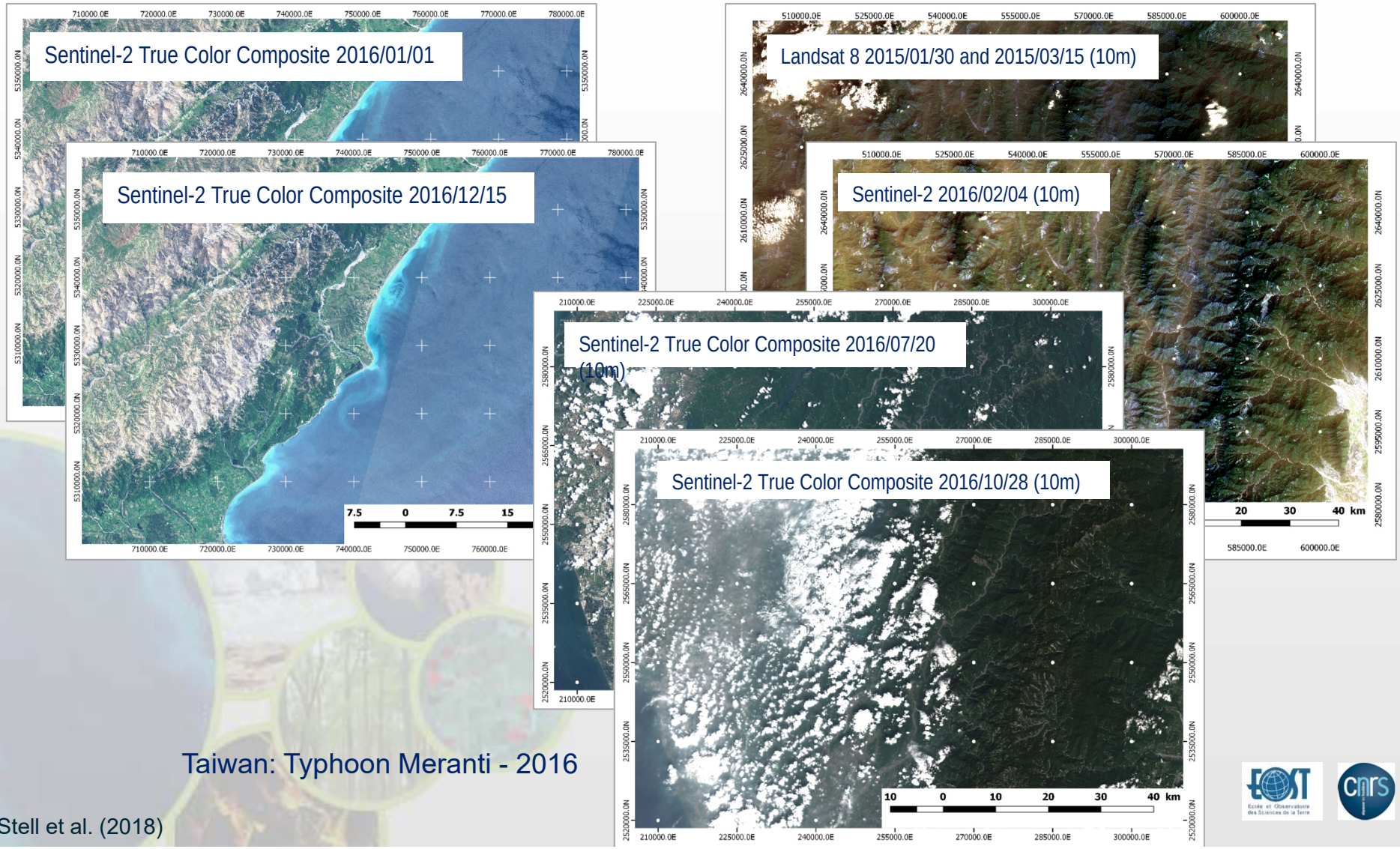


- → We are investigating the value of sharing the EO-based inventories created, even if imperfect ... Has a value for many applications ... Possibility: transfer the inventories to the COOLR NASA System?
- → Aim: rainfall thresholds, scaling laws relating landslide intensity to the triggering events
- → Possible links with GeoHazards Lab? With Charter? One aspect of a Landslide Demonstrator?

Generalizing the creation of EO-based inventories after major triggering events

New Zealand: Kaikoura ETQ - 2016

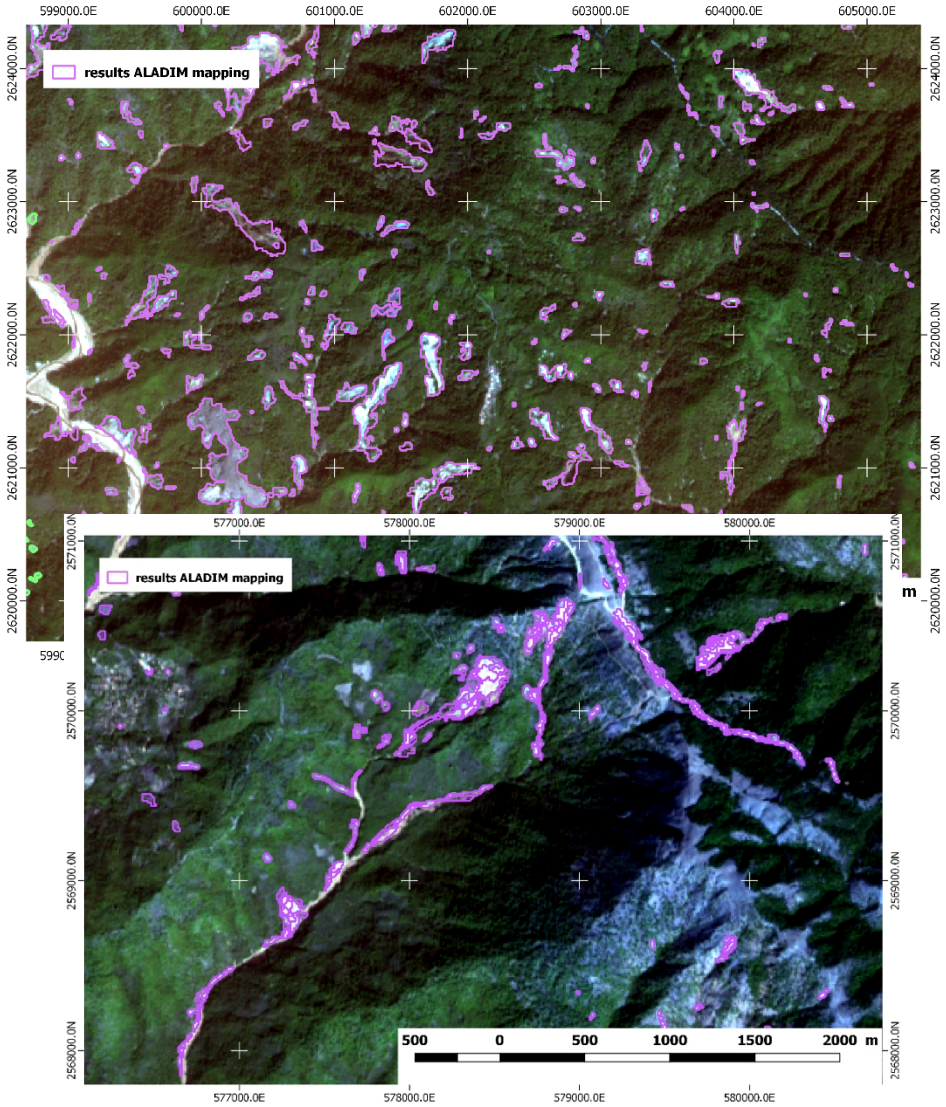
Myanmar: Cyclon Komen - 2015



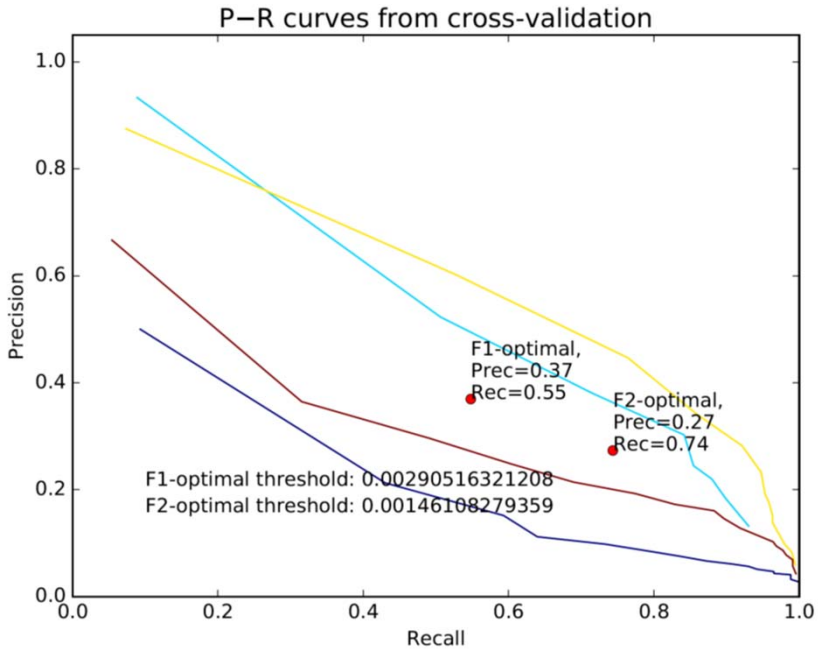
Taiwan: Typhoon Meranti - 2016

Stell et al. (2018)

Generalizing the creation of EO-based inventories after major triggering events



Myanmar: very good results
> 85% of mapped landslides detected by the algorithm



Stell et al. (2018)

Generalizing the creation of EO-based inventories after major triggering events

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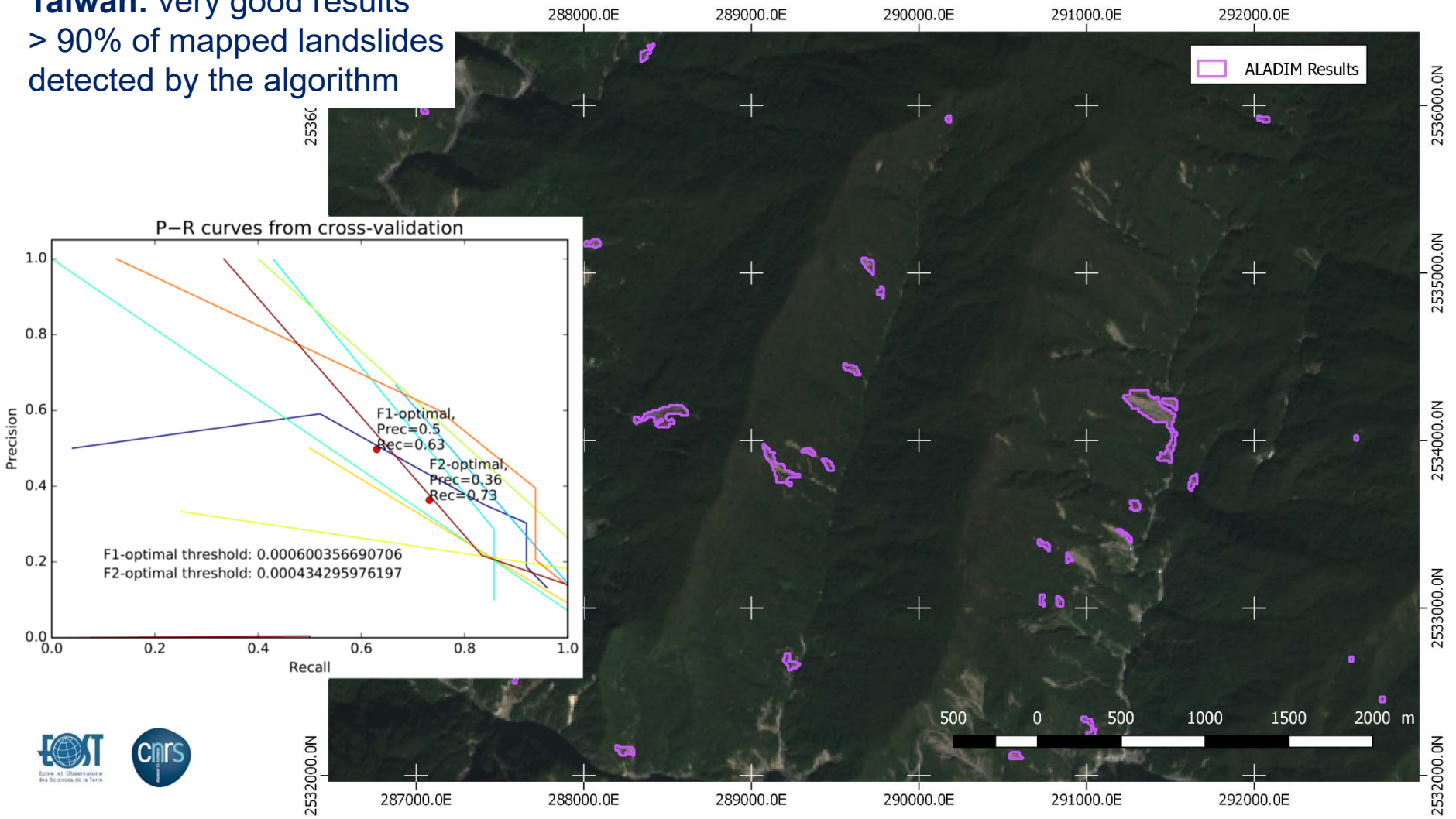

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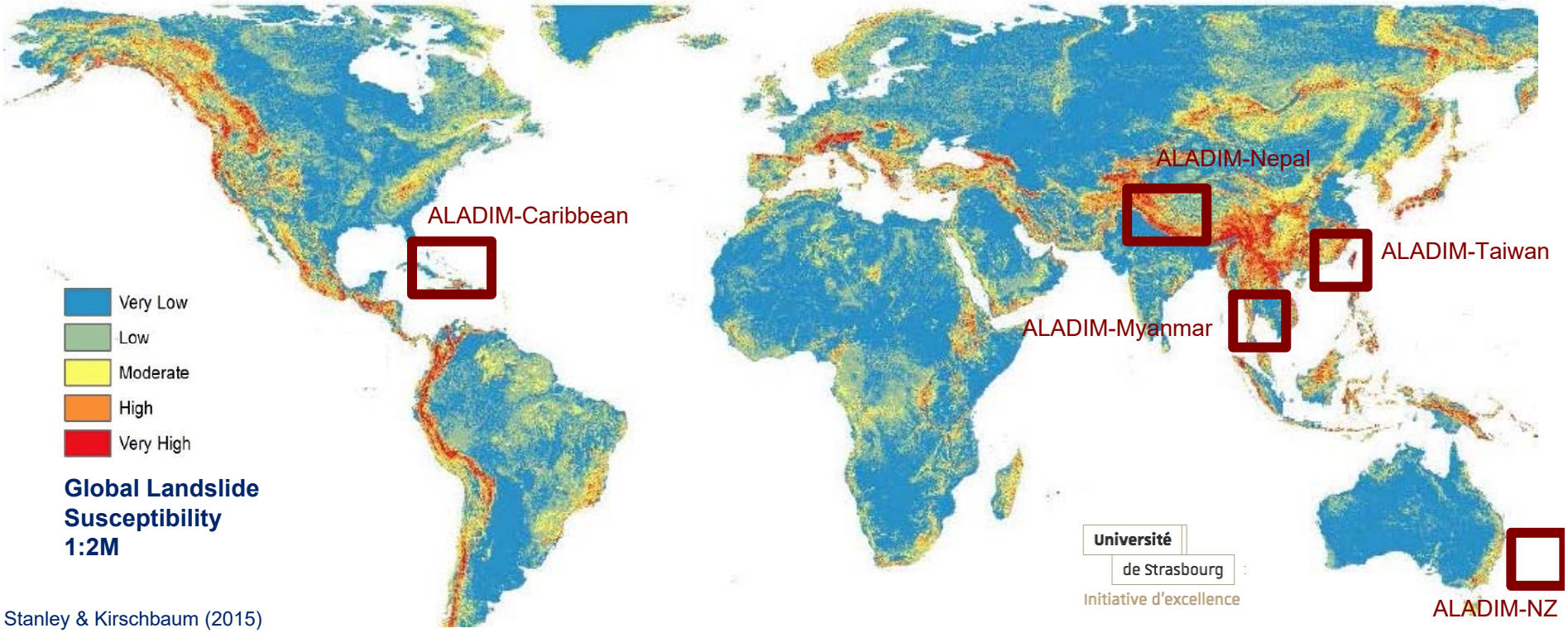
Generalizing the creation of EO-based inventories after major triggering events



Stanley & Kirschbaum (2015)

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Thematic App Landslide

jpmalet

geohazards tep

Home | Workspace | Background | Observations & Measurements | Services Catalogue | Community | EO sector Collaboration

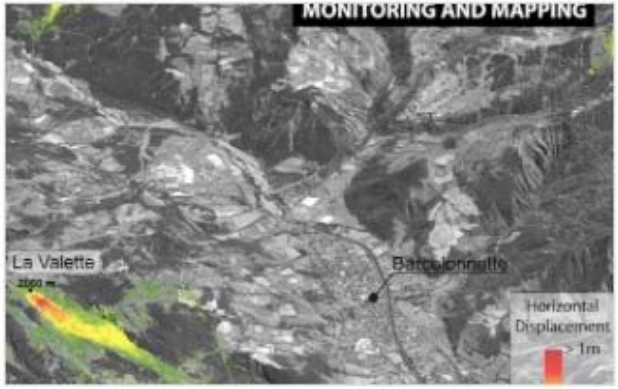
Thematic Applications

Satellite EO for landslide analysis: detection, monitoring and mapping

by **CNRS – EOST**

https://geohazards-tep-ref.terradue.com/#!thematic

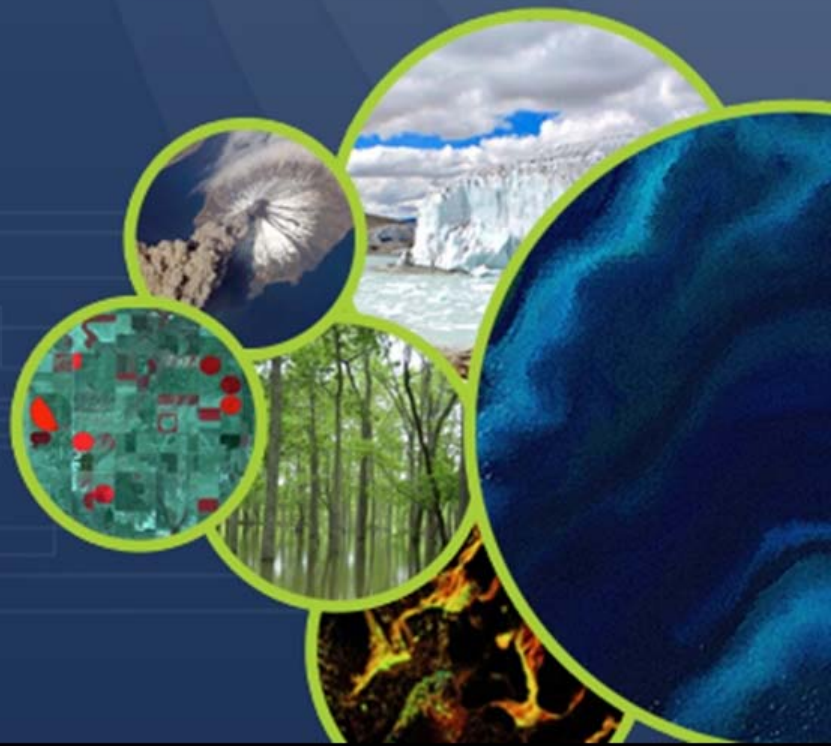
App | landslide | detection | monitoring



The App provides a set of services for landslide analysis from optical and SAR images. The processing capabilities integrate softwares and dedicated services for : - landslide rapid mapping from optical images (ALADIM), - landslide displacement field monitoring from stacks of optical images (Service MPIC-OPT), - Digital Surface Models creation from optial steropairs (Service DSM-OPT), - interferogram generation from multiple SAR sensors (Software DIAPASON), - landslide inventory analysis and susceptibility mapping (Services Land-SE and Land-STAT from CNR IRPI)

Close | Open App on the Geobrowser

Conclusions



Status on Key Pilot Outputs & Deliverables

1. Report on recommended practices for the combined exploitation of SAR and Optical imagery and technologies for landslide detection, mapping and monitoring". **(Objective A**)

Status: research is ongoing in the study sites to develop new methodologies for processing SAR and optical data. Some works already presented in Int. Conferences. Several papers in progress on this topic. On top of site/group papers, a collective paper highlighting the pro/con of each EO data and methods will be written.

2. Report on effective methodologies and strategies for considering multi-hazard and cascading aspect of landslides through multi-temporal landslide mapping from multiple triggers (leveraging information/interactions with the volcano, flood and earthquake pilots) **(Objective A-C)**

Status: research on this effort is still in the early stages. Landslide pilot has established links with RO initiative and GeoHazrd Lab to foster this. Work over Montserrat (Carribean volcanoes) could interest the Volcano Demonstrator.

Status on Key Pilot Outputs & Deliverables

3. Landslide event inventory and activity (monitoring) maps produced using optical and SAR imagery and technologies, and their combination, for selected case studies / geographical areas. **(Objectives B-C)**

Status: Launching of https://landslides.nasa.gov and work with the GEP have greatly expanded the potential for inventories being shared across geographic areas

4. Report on end user engagement strategies and characterize enablers, challenges, barriers to effective transfer of information, knowledge and technologies. **(Objective D)**

Status: While preliminary recommendations may be provided by the end of this pilot, we feel the deliverable will be best suited for a follow-on demonstrator phase given the current status of the research and (important) delays in obtaining data for this effort.

From a pilot to a demonstrator EO-landslide inventories

- Demonstrate the utility of an operational *« Landslide Detection and Mapping »* system for
  - rapid mapping (1st-order inventory) →*Users: first-aid response agencies, for instance USAID, others*
  - enhanced inventory mapping (2nd-order science-driven inventory) → *Users: scientists*
  - …. creating thresholds / scaling laws for Early-Warning

- Planned deployment of local applications of this system for hot spot regions with a capable and willing end user organization, these could be:
  - Caribbean (?)
  - SE Asia (ADPC?)
  - NZ (GNS?)

Technologies: GEP, DataCube, …

Algorithms: CNRS-ALADIM, NASA-SLIP for detection ; COOLR for database sharing

Data: mostly free - Sentinel, Landsat for detection ; GPM data for rain

From a pilot to a demonstrator
EO-based slope deformation monitoring

- Demonstrate the utility of an operational *« Landslide Deformation »* system for
  - slope instability now-casting / for-casting : time series of landslide deformation maps to complement in-situ sensors and detect precursors of « crisis »
  - Develop *case by case tailored products* for operational monitoring …

    → best method for a type of landslide for a type of data
  - Key issue: use the capability of 6 day revisit time of S1, high spatial resolution of TSX/CSK …, combination to VHRO images (Pléiades + US VHRO data)
  - Users: civil protection agencies, ….

- Selection of landslides
  - With in-situ sensors
  - Creating high exposure to the population…
  - In diverse lanscape contexts

Approach similar to the Volcano Demonstrator