Committee on Earth Observation Satellites

Landslide Disaster Working Group Pilot:

September 8th, 2016

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

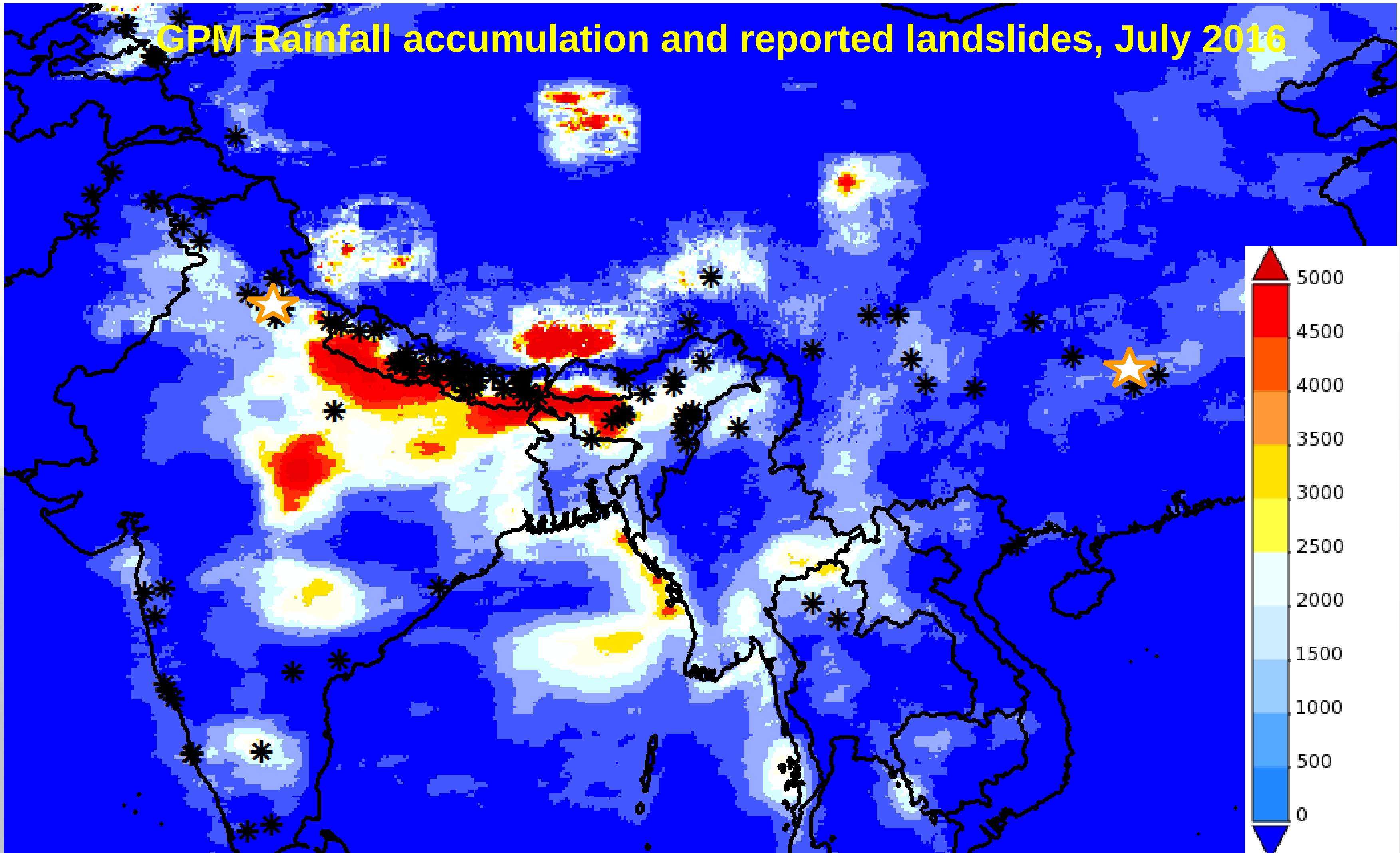
Dr. Sigrid Roessner, GFZ German Research Centre for Geosciences, Germany

Selected Landslides, July 2016 (around the world)

Rockslide on the highway to Gangotri, Uttarakhand in nort hern India, Published July 24, 2016
https://www.youtube.com/watch?v=FK6g4IlH7j0

Landslide affecting houses in a village of central China's Hunan Province. Published on Jul 19, 2016
https://www.youtube.com/watch?v=gXNdV9_8kCk

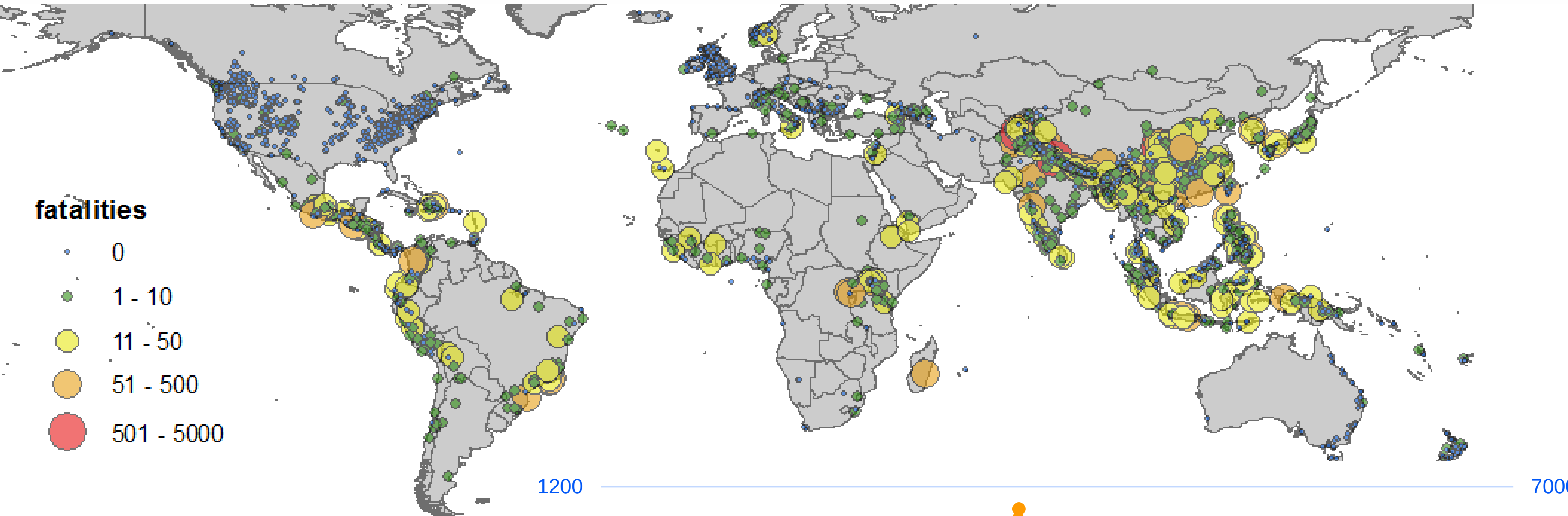
Landslides and rainfall, July 2016

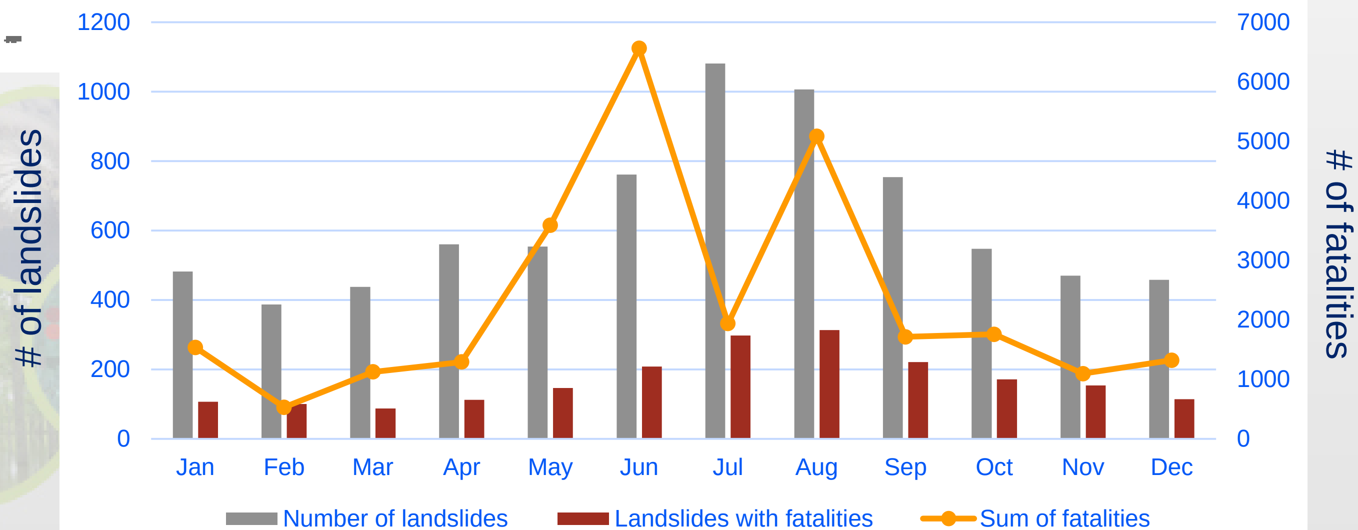


Rainfall-triggered landslides reported by the NASA's Global Landslide Catalog

Landslide impacts

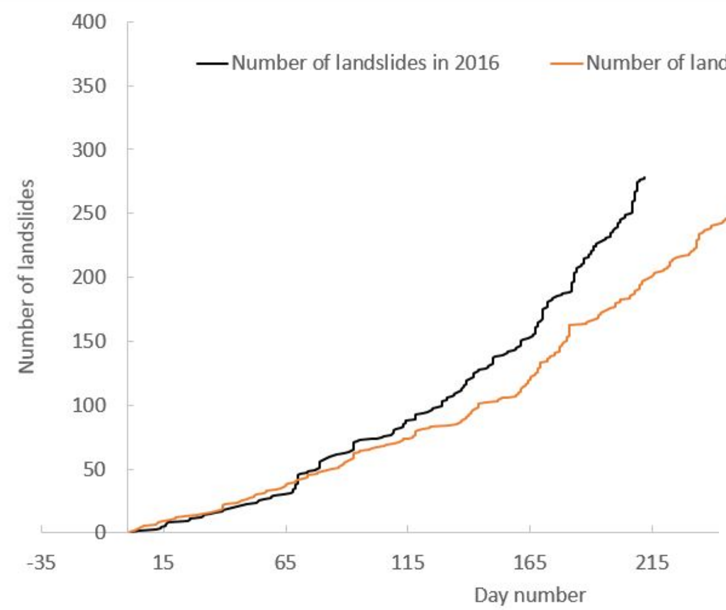
Global distribution of rainfall-triggered landslides



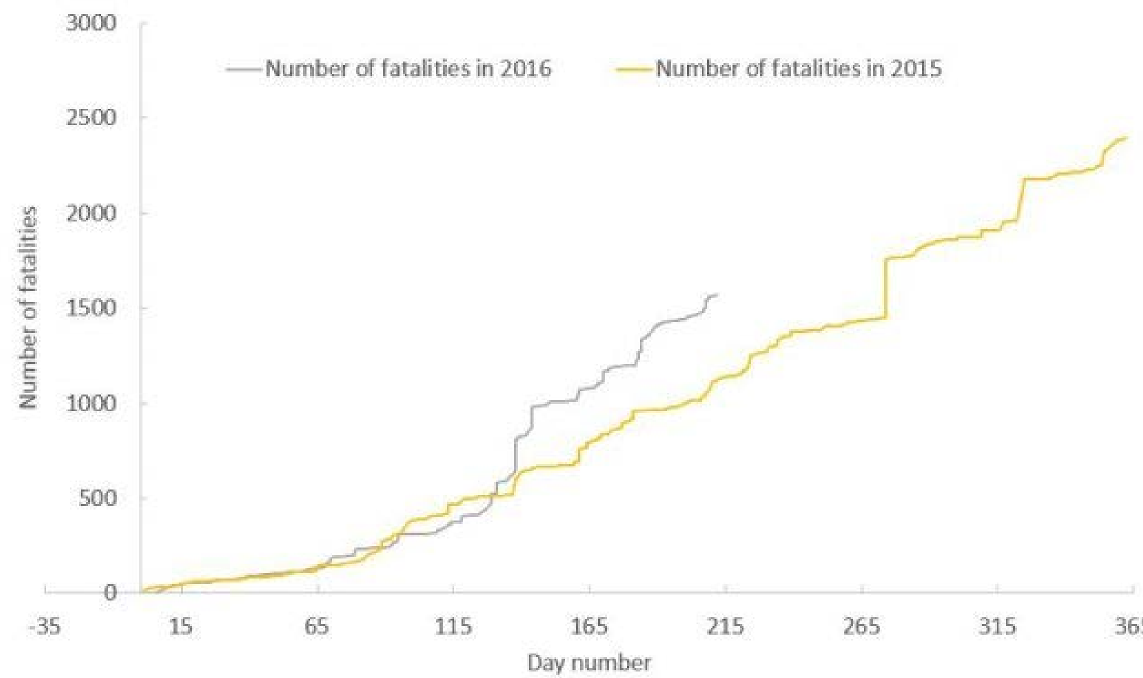


Source: GLC, 2007-2016

Landslide Fatalities (2015-16)



Fatality-inducing landslide events and losses
Comparing 2016 to 2015



http://blogs.agu.org/landslideblog/2016/08/01/2016-landslide-losses/

Landslides Pilot: Main Goals

To demonstrate the **effective exploitation** of Earth observations (EO) data and technologies to **detect, map and monitor landslides and landslide prone hillsides**, in different physiographic and climatic regions.

To apply satellite EO across the **cycle of landslide disaster risk management**, including preparedness, situational awareness, response and recovery with a distinct multi-hazard focus on cascading impacts and risks.

Status for Landslide WG

- **December 2015**: Convened first Disaster Landslide Pilot meeting (virtual)
- **January-Feb 2016**: Conducted survey of participants to define expertise, interests, and areas of focus
- **March 2016:** Introduction of potential Landslide Pilot at CEOS #5 meeting in Bonn, Germany
- **April 2016**: In person meeting of pilot participants in Vienna, Austria
- **July 2016**: Drafted CEOS DRM Landslide Pilot Plan and further defined study areas and co-leads
- **August 2016**: Co-lead meeting to discuss further development of study areas and Landslide Pilot Plan
- **September 2016**: Propose plan to CEOS Disaster WG for approval as 4th disaster pilot
- **September 2016**: Establish the Landslide Pilot web presence on CEOS.ORG with a summary of goals, objectives and participants

Proposed Objectives

- **Objective A** – Establish effective practices for merging different Earth Observation data (e.g. optical and radar) to better monitor and map landslide activity over time and space.
- **Objective B** – Demonstrate how landslide products, models or services can support disaster risk management for multi-hazard and cascading landslide events.
- **Objective C** – Exploit the experience, data, and lessons learned from ongoing pilots (i.e., seismic hazards, floods, volcanoes).
- **Objective D** – Engage and partner with data brokers and end users to understand user and service requirements, user expectations, and to get feedback through the activities described in objectives A-C.

Proposed CEOS Objectives

- Leverage and exploit existing imagery, technology for processing data, and expertise provided for the other three pilots, where applicable, for rapid development and application within landslide/multi-hazard pilot activities;
- Improve coordination and sharing of satellite acquisitions and data products in support of landslide management across the existing flood, seismic, and volcano pilots to maximize utility of CEOS contributions;
- Demonstrate the value of satellite EO in the context of integrated landslide management practices.
- Capture and maximize use of lessons learned from other pilots (volcanoes, earthquakes, floods), including the participation of key contributors and end users of the pilots.

Key Pilot Outputs & Deliverables

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

- 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)**

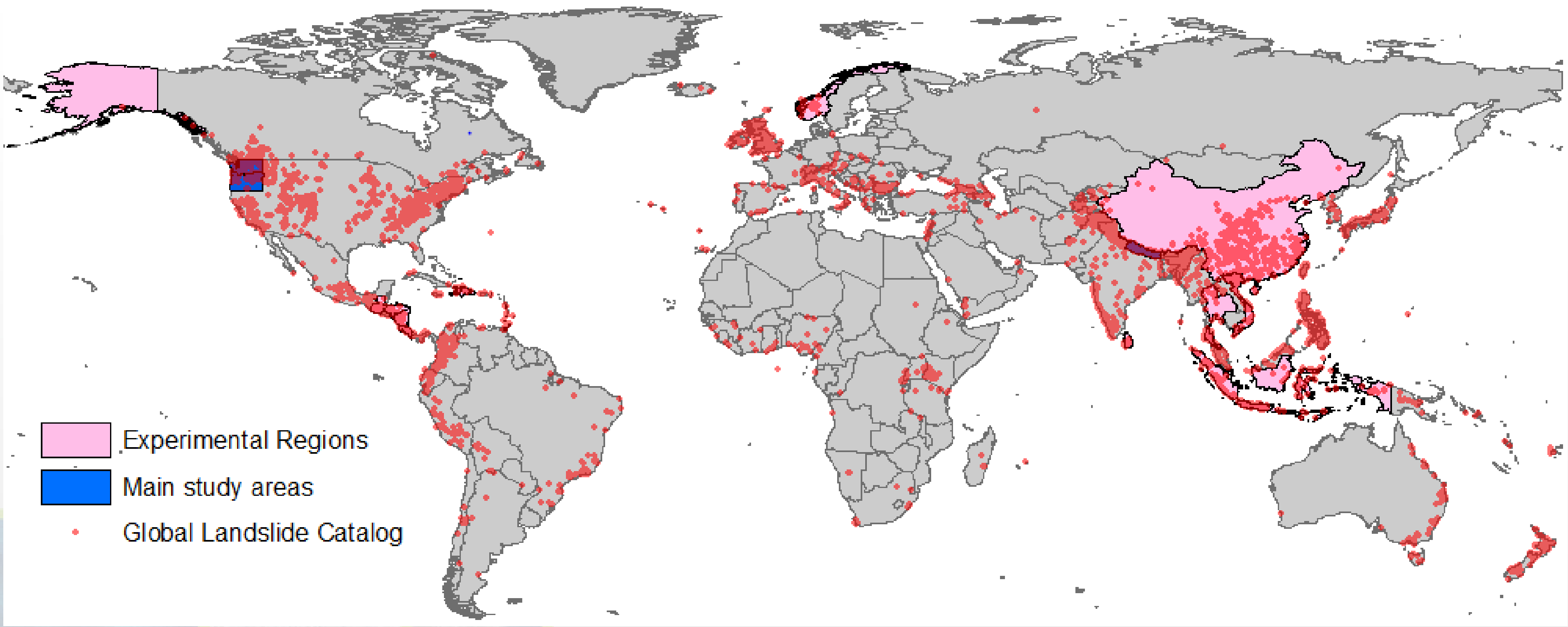
- Landslide event inventory and activity (monitoring) maps produced using optical and SAR imagery and technologies, and their combination, for selected case studies / geographical areas. **(Objectives B-C)**

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

Proposed key user communities

- **Users**: national, regional and local governments, civil protection agencies, meteorological and geological services, land use planning decision makers, disaster risk reduction specialists with NGOs and international organisations, industry (including e.g., insurance, transport, forestry sectors).
- **Practitioners**: landslide modelers, scientists and engineers in hydrology, water and environment ministries, meteorological and geological services, satellite data providers, volcano observatories, and value added service companies.
- **Institutional bodies responsible for communication of risk** (gap between technical level and shared information with communities): 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 of these hazards and remote sensing capabilities, although the main focus of the pilot is on specialized users.

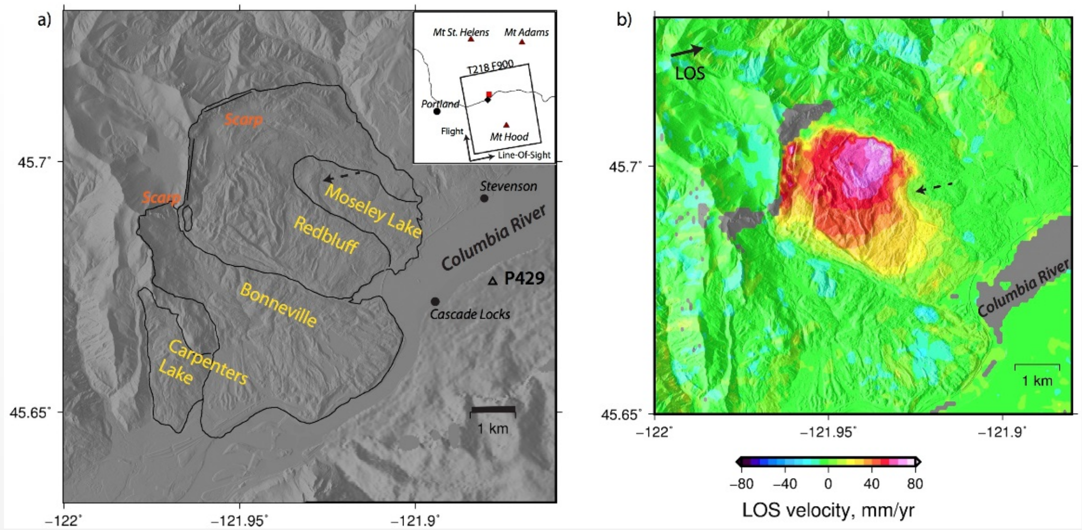
Proposed Regional Foci



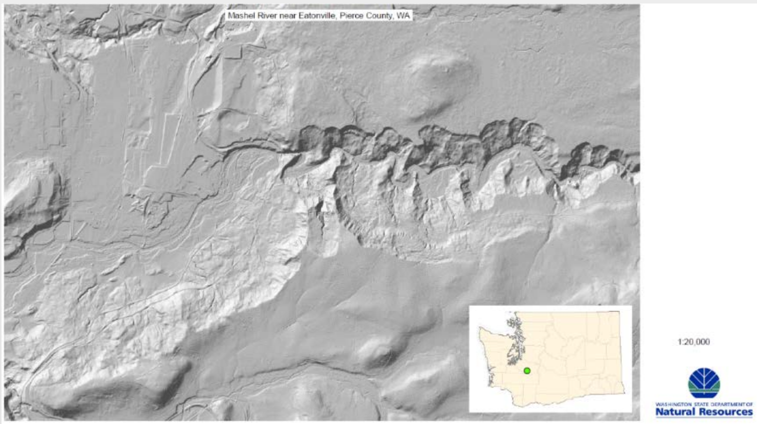
- **Main Focus areas:**
  - **Nepal**
  - **Pacific Northwest, US**
- **Experimental areas:**
  - **SE Alaska**
  - **China**
  - **The Caribbean (Cuba, Haiti, Antillas)**
  - **Sri Lanka/India**

Pacific Northwest, USA

- **Why**: Active geomorphologic and tectonic settings with extensive landsliding throughout the landscape
- **Who:** There is a breadth of experience from USGS, state geological surveys, research groups, NASA, and others with experience apply remote sensing techniques to both monitor active landslides and conduct multi-temporal landslide mapping within the region
- **What**: several existing activities already underway in this region, including engagement from end users (DOTs, NPS, NFS, etc.)
- **Meeting planned for late September, Denver**



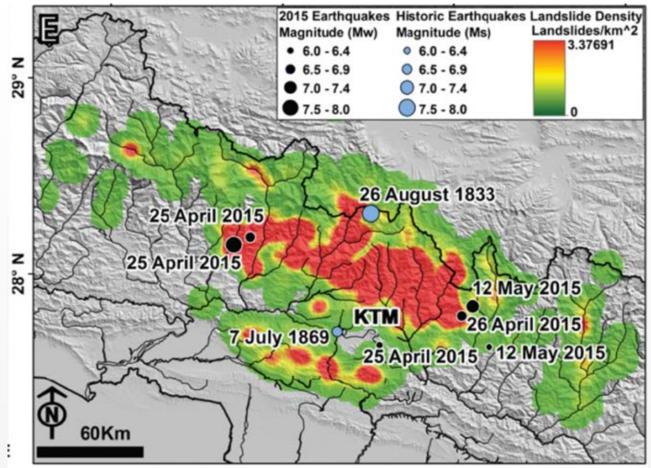
(left) Shaded relief map of the Cascade Landslide Complex located along the Columbia River Gorge from a LiDAR DEM. (right) Average line-of-sight velocity measured by InSAR (ALOS-1) indicating active movement of the Redbluff landslide. Warm colors indicate motion away from the satellite in the look direction (black solid arrow). The background shading is based on the 2m-resolution DEM from LiDAR. Figure prepared by Xiaopeng Tong.



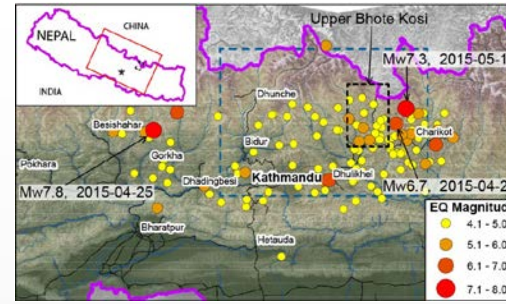
Example of multiple slope movements from the Mashel River near Eatonville, WA. Shaded relief from LiDAR, provided by Washington DNR.

Nepal

- **Why**: highly active tectonic setting with strong monsoon season that triggers hundreds-thousands of landslides each year. Gorka Earthquake, 2015 caused thousands of landslides that were mapped by many different groups.
- **Who**: Wide range of groups working in this area (Durham University, ITC, USGS, NASA, and other academics, and many more) with a breadth of experience and expertise in this region
- **What**: Engagement with stakeholders and regional experts within the region, leverage data from supersite



Kargel, J. S., et al. 2015, *Science*



Durham, NSET Nepal, BGS, site monitoring and mapping in Sindhupalchowk, Upper Bhote Kosi, Arniko Highway

Figure 15. Aerial image of the Pisang 2 earth slide along the Marsyangdi River upstream from Pisang village. As of May 30, 2015, this landslide constricted the river with a 350-m-long slackwater lake upstream of the landslide deposit. Maximum width of impoundment in image is approximately 50 m.

Collins and Jibson, Open-File Report 2015-1142

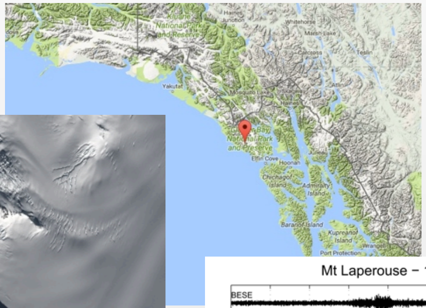
GFZ Potsdam: Field based monitoring and remote sensing analysis after Gorkha earth-quake for understanding long- term landsliding and erosion (slides below)

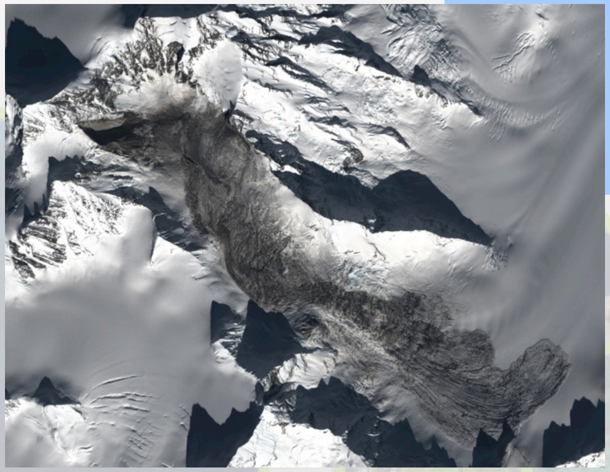
Experimental Regions

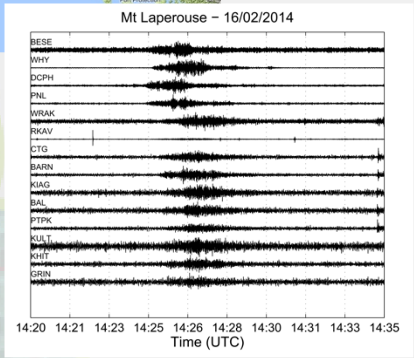
Southeast Alaska

- Slow-moving landslides
- Heterogeneous landslide triggers
- Active projects
- End users: National Forest Service, USGS

Sitka, Alaska landslide, August, 2015, James Poulson/The Daily Sitka Sentinel via AP







Mont La Pérouse rockslide, 2014/0216(Glacier Bay National Park). Optical imagery (Pléiades) and seismic signals (Starck, Ekström & Hibert; Univ. Columbia and Univ. Strasbourg)

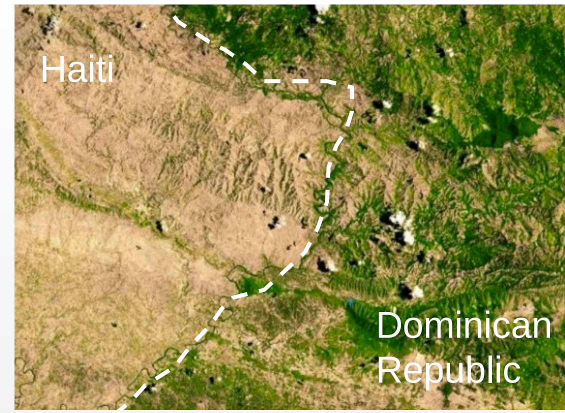
- Very large rockslides
- Detection and characterization by coupling Earth Observation and seismology
- Active projects (LDO/Columbia NY, EOST/Univ. Strasbourg)

Experimental Regions

The Caribbean: Cuba, Haiti and French Antillas

- Tropical climate, active tectonic region and diverse geomorphologic settings
- Rainfall, Earthquake and Anthropogenic induced failures
- Active engagement from Ministry of Energy and Mines (Cuba), CNIGS (Haiti) and CNRS (French Antillas)
- Active projects (Univ. of Strasbourg, CNES KAL-HAITI)
- Also an experimental region of other Disaster Pilots (floods, volcanoes)

Effects of deforestation on landslide susceptibility



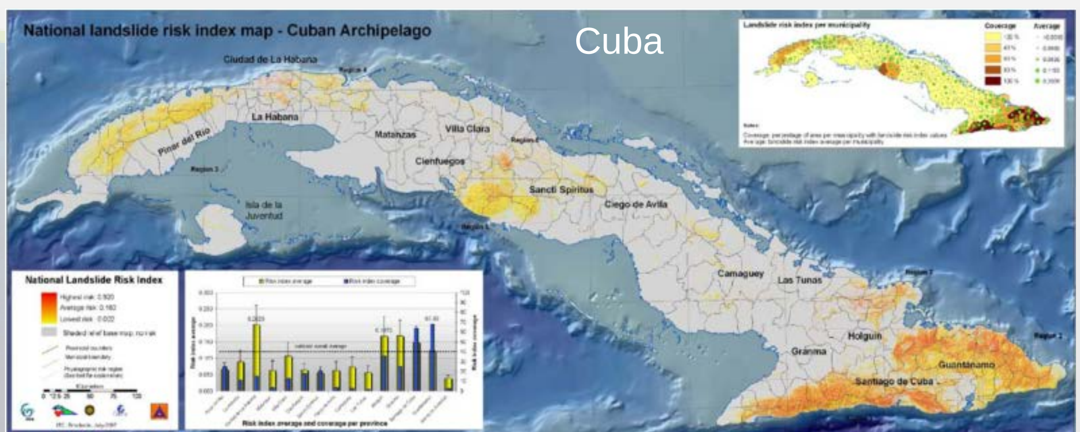
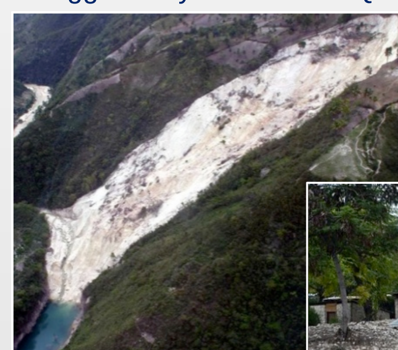


Fig. 8 Final landslide risk index map, as presented to the National Civil Defence authorities. *Inset map* in the *upper right corner* indicates the landslide risk index per municipality, both as the percentage of area with landslide risk index larger than 0 (coverage) as well as the average landslide risk index. The *barchart* shows the landslide risk index values per province

Castellanos & Van Westen (2008)

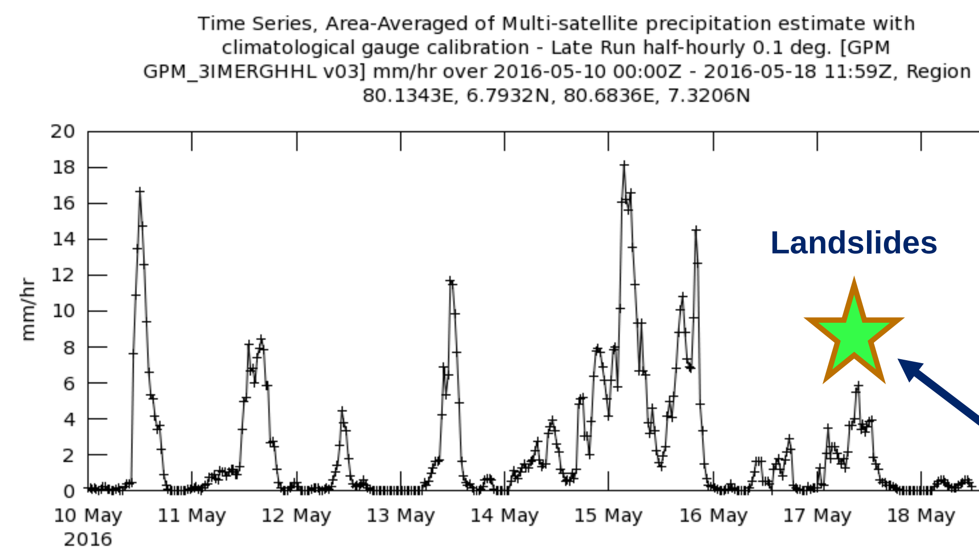
Landslide dam (Jacmel, Haiti) triggered by the 2010 ETQ

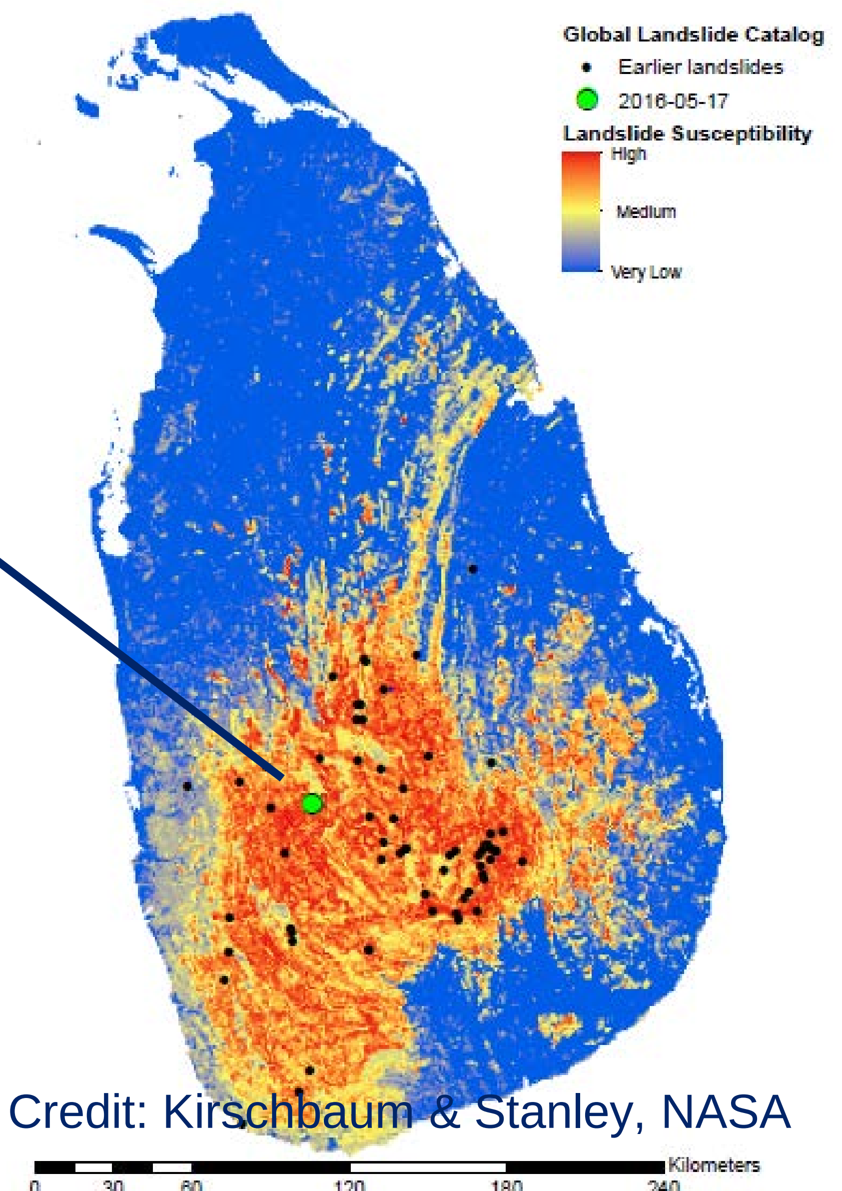


Mudslide (Haiti) triggered by storm Erika (2015)

Experimental Regions

Sri Lanka / India





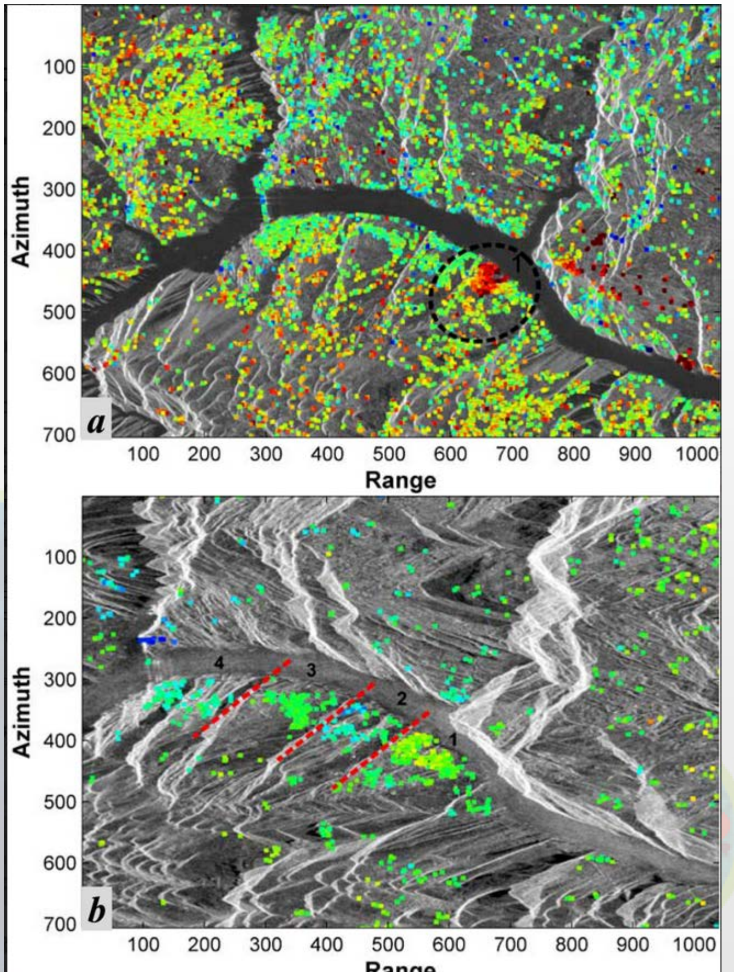
Credit: Kirschbaum & Stanley, NASA

On the afternoon of May 17th, 2016, a major landslide event caused at least 92 deaths, with 109 still missing*. The site was rated highly susceptible to landslides in a new global landslide susceptibility map. IMERG data suggest that both antecedent and current rainfall as well as complex topography played a role in the slope failures.

*BBC News (http://www.bbc.com/news/world-asia-36355980)

Experimental Areas

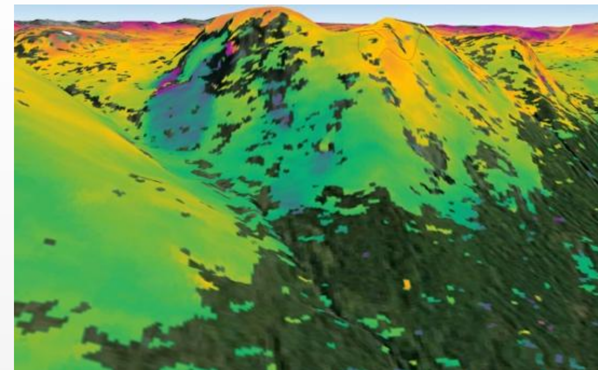
China

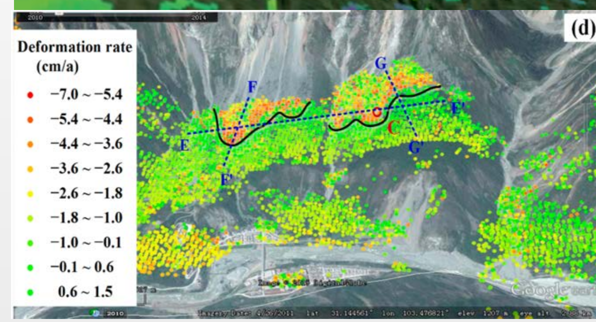


Deformation velocities at PS points in Badong identified by PS-InSAR: (a) from Advanced Land Observing Satellite (ALOS) Phased Array L-band Synthetic Aperture Radar (PALSAR) data; (b) from Environmental Satellite (ENVISAT) Advanced Synthetic Aperture Radar (ASAR) ascending data; and (c) from ENVISAT ASAR descending data. The numbered circles outline the two active landslides. The number 1 in (a) refers to the Huangtupo landslide. The red lines in (b) divided the southern riverbank into several significant deformation zones. The red star in (c) indicates the location of the reference point.

Tantianuparp, P., X. Shi, L. Zhang, T. Balz, and M. Liao, 2013: Characterization of Landslide Deformations in Three Gorges Area Using Multiple InSAR Data Stacks. *Remote Sens.*, **5**, doi:10.3390/rs5062704.

Norway





(Top) A 24-day Sentinel-1 (C-band) interferogram demonstrating landslide mapping in Kåfjord, Norway, where the ground moved ~1 cm. Copyright to ESA. Copernicus data (2014)/ESA/Norut–SEOM Insarap study. (Right) Linear velocity estimated after sophisticated time-series processing of 11 ALOS (L-band) SAR images [*Tang et al.*, 2016] overlaid on optical imagery.

Proposed regional study leads

Region	*Regional Point of Contact*
Nepal	**Nick Rosser, Sigrid Roessner, Dalia Kirschbaum**
Pacific Northwest, US	**Jonathan Godt, Dalia Kirschbaum**
Southeast Alaska	***Marten Geertsema***
Norway	***John Dehls***
Caribbean	***Enrique Castellanos, Jean-Philippe Malet***
China	***Zeng-Guang Zhou (TBD)***
India / Sri Lanka	***TBD***

Methodology

I. Mapping

- Creating inventories
- Documentation

II. Monitoring

- Routine processing over sample sites

III. EO-based Analysis

- Automatic
- Standardized methods to establish thresholds

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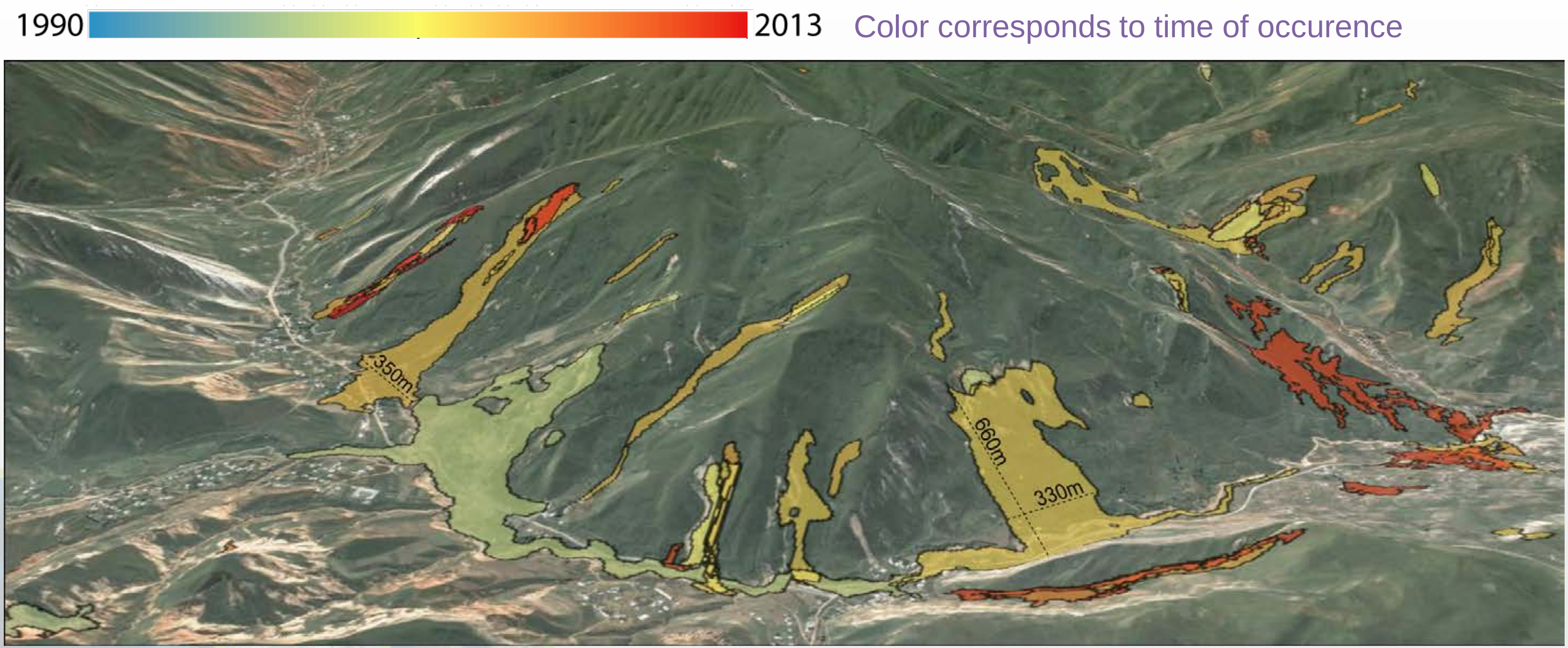
Long-term Landslide Mapping
object-based multi-temporal detection



Automated Approach identifies landslides:

- of different shapes, sizes, lithology, activity stage (fresh, reactivation)
- of multiple activations (enlargements, secondary movements)

Behling, R., Roessner, S., et al., 2016. Derivation of long-term spatiotemporal landslide activity - A multi-sensor time series approach. *Remote Sensing of Environment,* 186, 88–104.

Multi-temporal Landslide Mapping 2015 Gorkha earthquake, Nepal

Need for understanding of relationship between short-term earthquake induced landslide activity and long-term inter-seismic landscape response

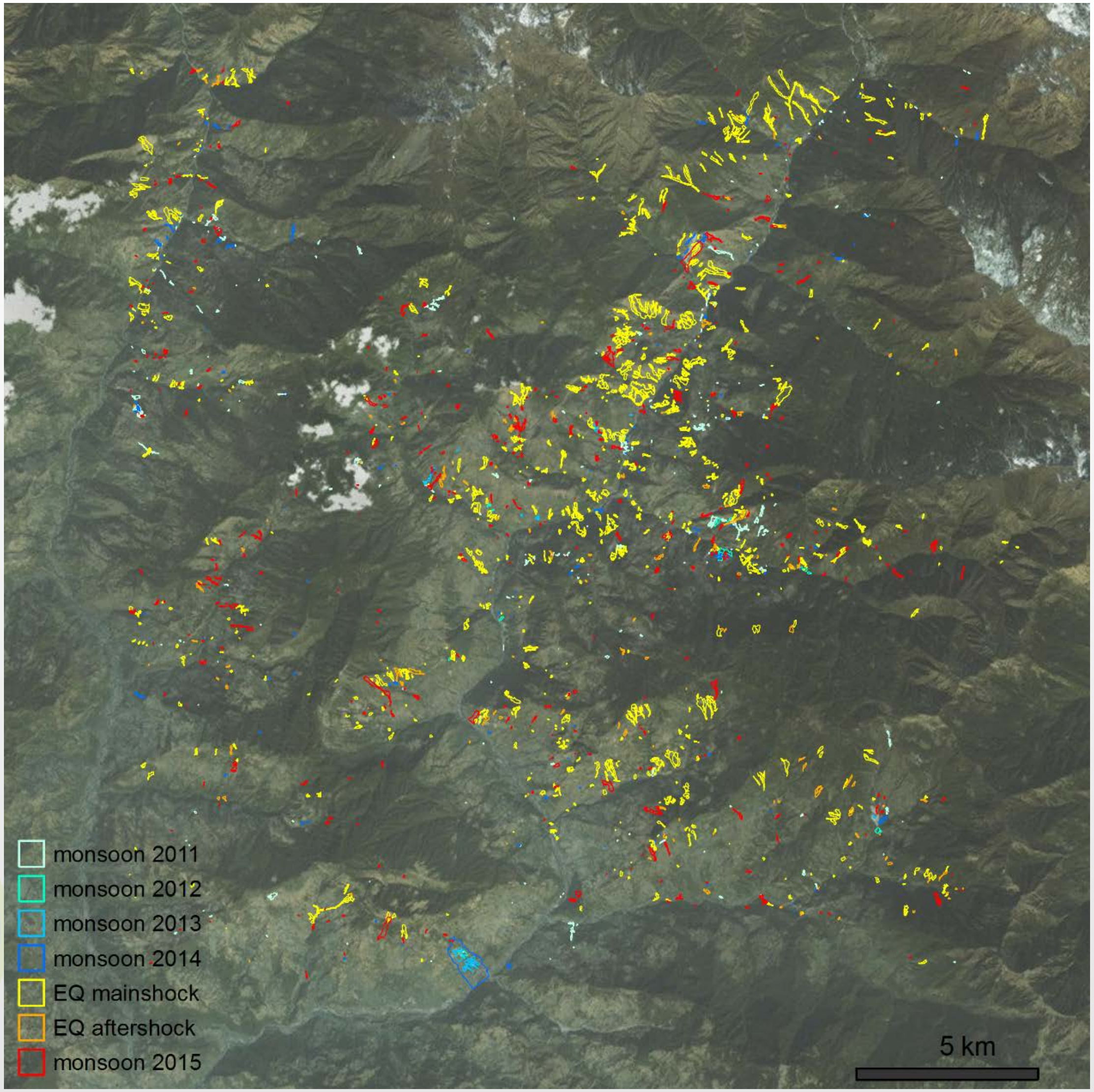
Automated analysis of pilot area (25*25 km) using RapidEye and Landsat data (2011 – 2015)

~2000 total landslides

~1000 co-seismic landslides

~500 landslides during monsoon 2015

few 100's of landslides before

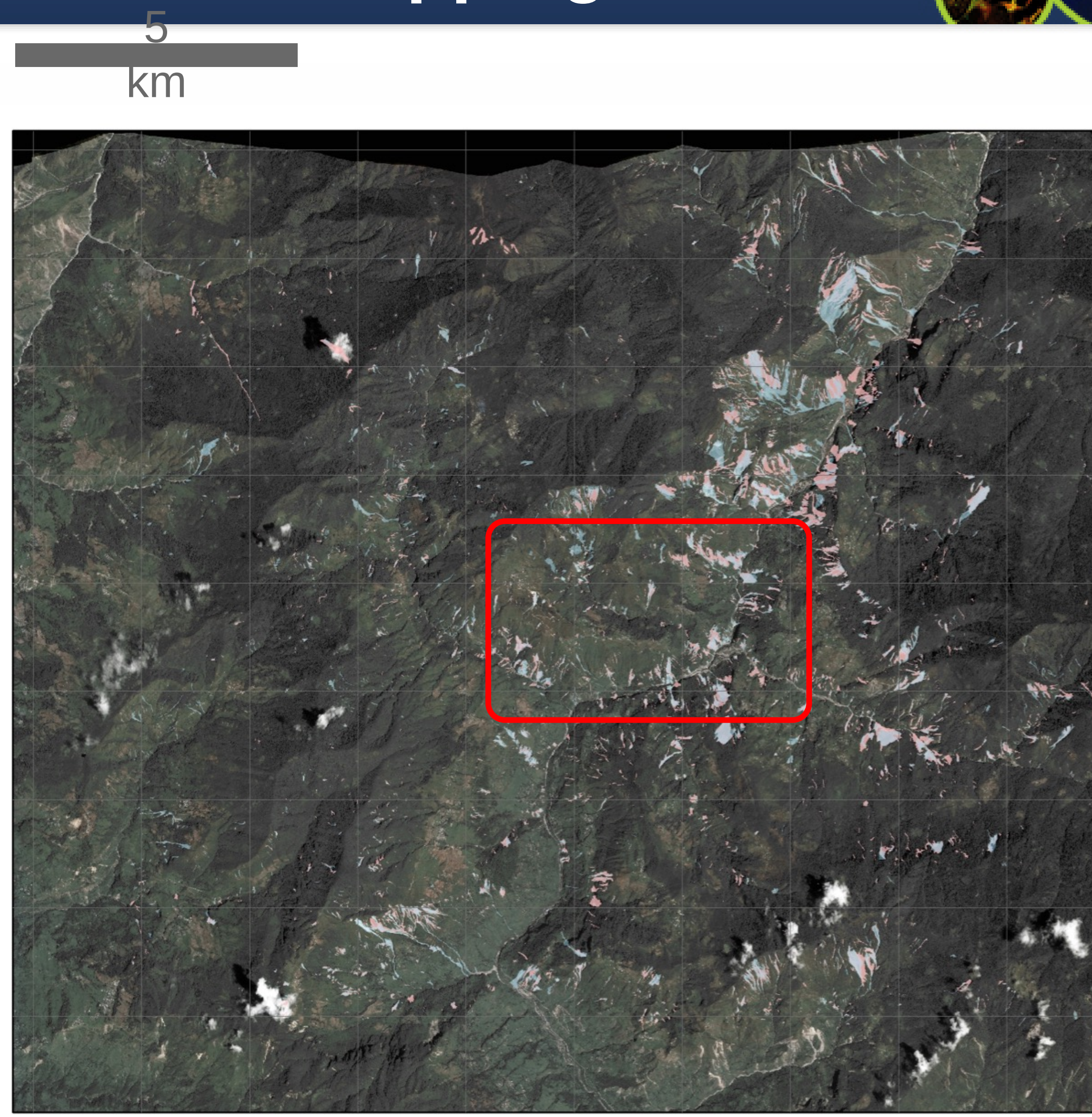


Robert Behling and Odin Marc, GFZ Potsdam

Pre- & post-monsoon landslide mapping, 2015

Pre- & post- monsoon

- WorldView & Quickbird
  - May 2014 & 24th May 2015
- Pléiades image
  - 9th September 2015
- Significant registration errors in steep topography

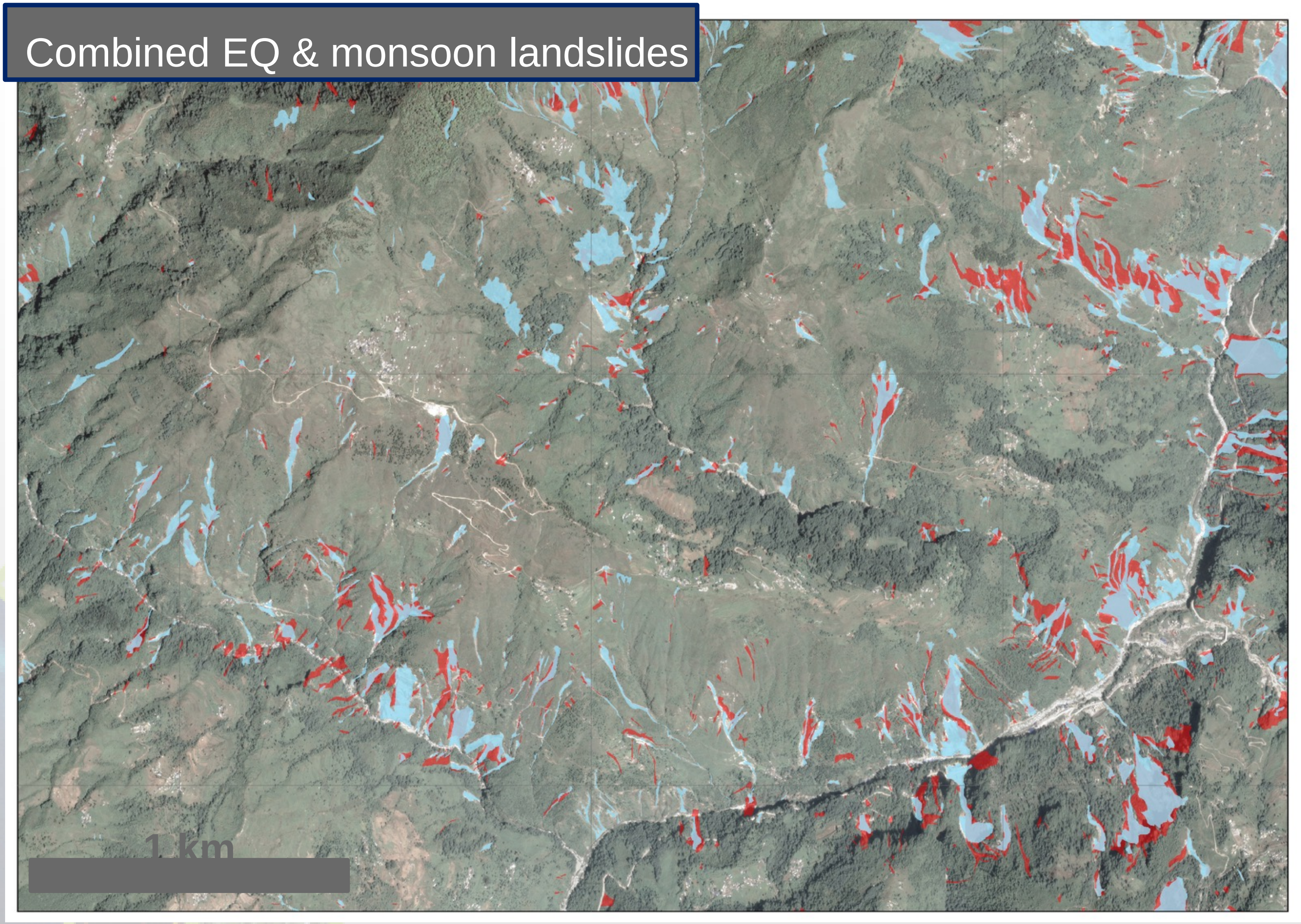


Results:

- 389 pre-EQ landslides (*c*. 1.3 / km^2)
- 2,626 post-EQ landslides (*c*. 9 / km^2)
- 2,550 post-monsoon landslides

Slides from N. Rosser/Durham

Pre- & post-monsoon landslide mapping, 2015

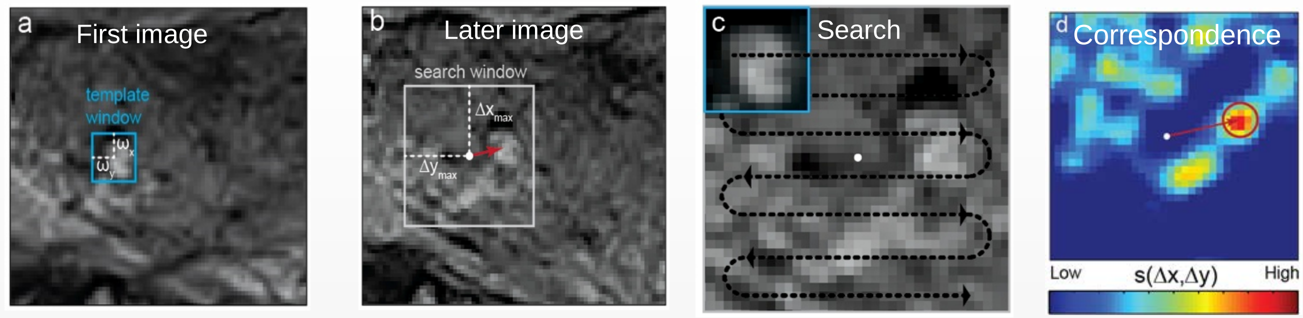


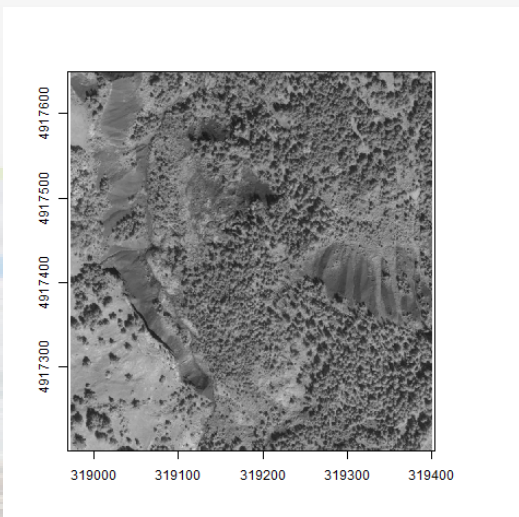
Slides from N. Rosser/Durham

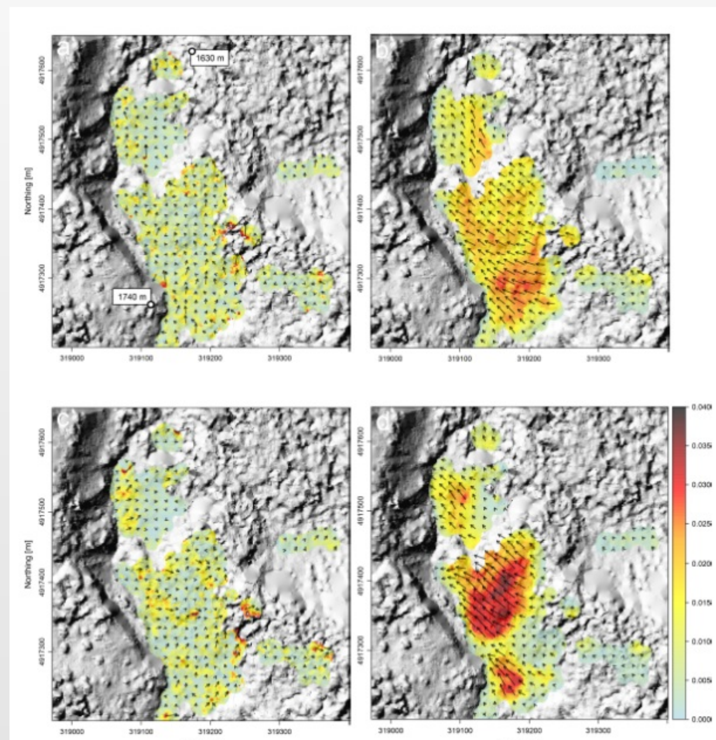
Deformation of Large Landslides From Time Series of Optical Sensors

Satellite image matching / correlation for time series processing

Principle of image correlation





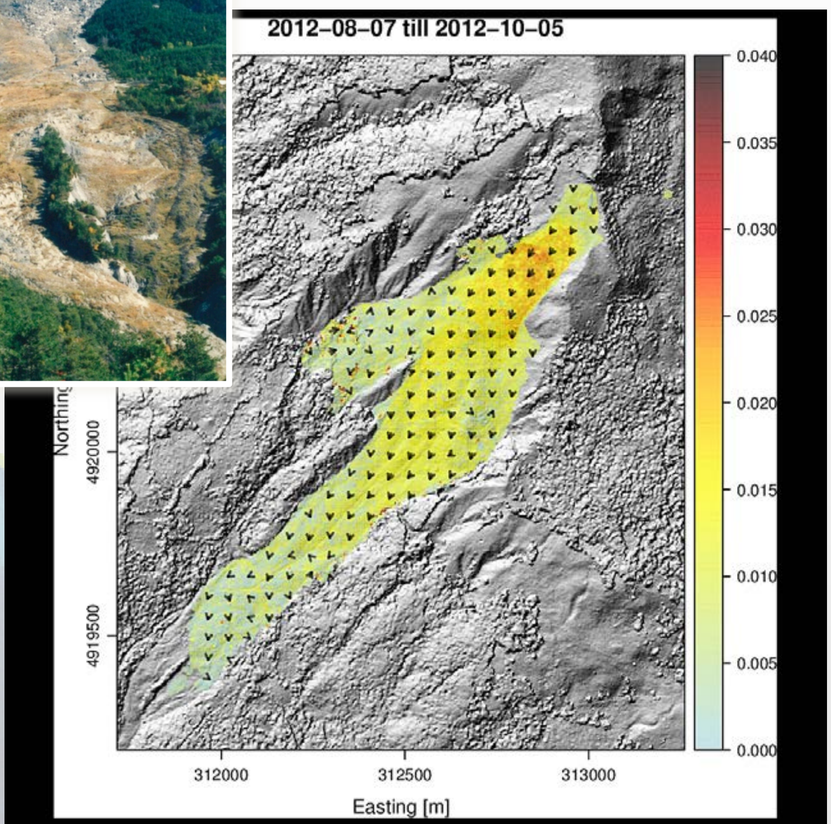


Surface motion of a landslide in the French Alps over two years (from Pleiades imagery)

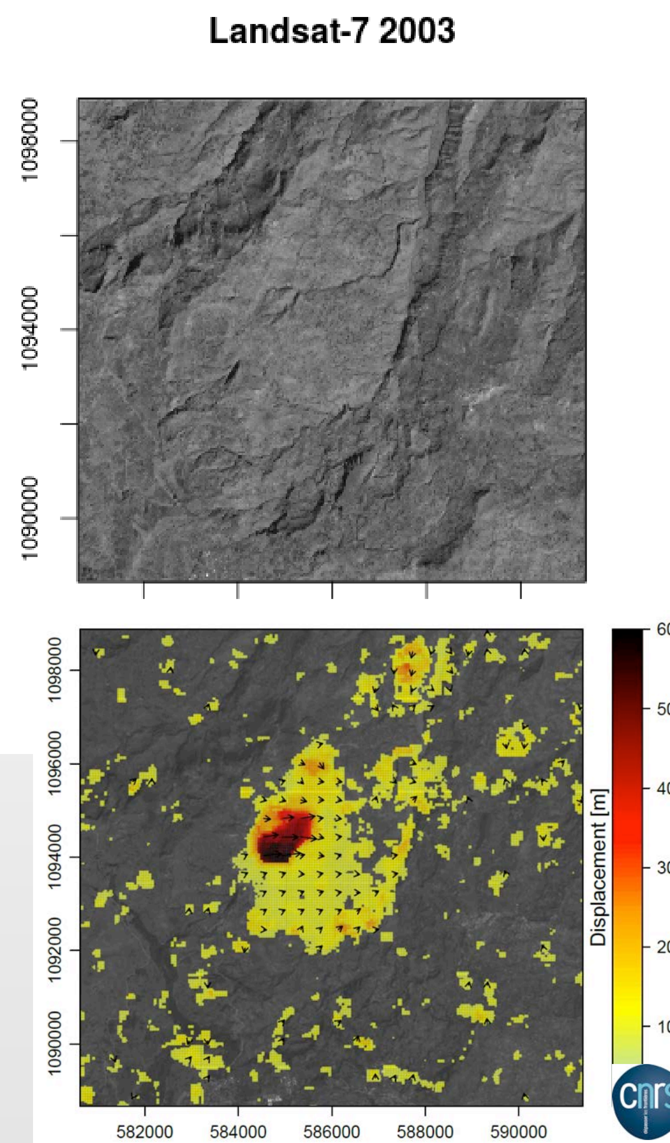
(Stumpf & Malet, RSE, 2016 – in press)

Deformation of Large Landslides from Time Series of Optical Sensors

Motion field of the Debre-Sina landslide (Ethiopia) 2003–2016 from a combination of Landsat-7 and Sentinel-2 images

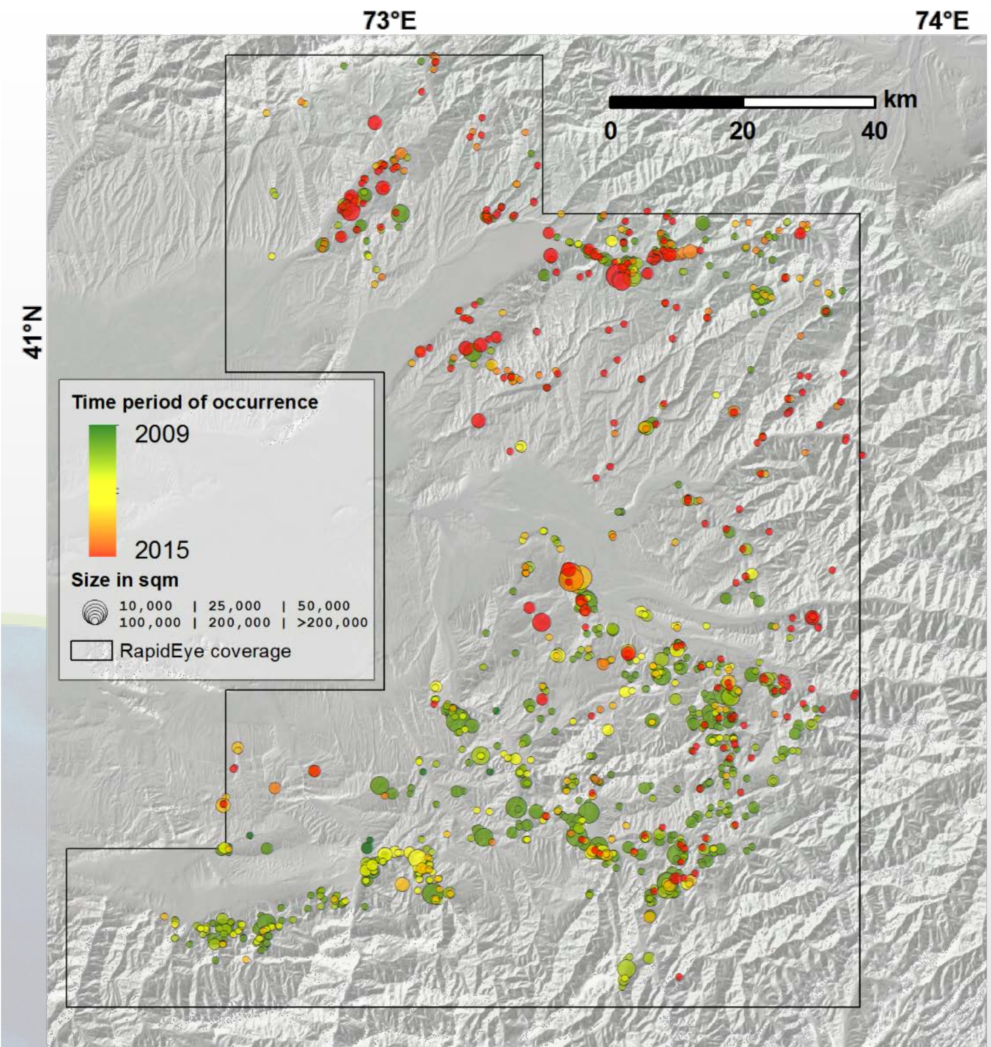


Motion field at La Valette landslide (SE Franch Alps) from a stack of 8 Pléiades images



(Stumpf & Malet, RSE, 2016 – in press)

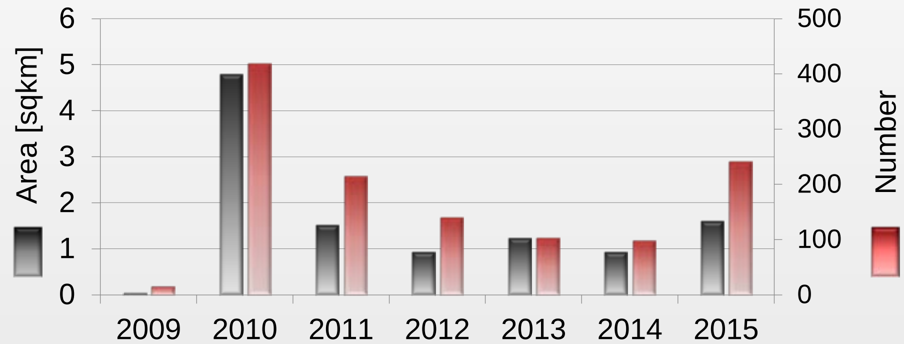
Automated Regular Monitoring of Landslides over Large Areas



Kyrgyzstan: 12,000 km² area

Time period: 2009 - 2015

- 1022 RapidEye datasets (RESA program)
  - intervals up to several days
- 1239 landslides (~90 reported by authorities)
- 100 sqm – 0.75 sqkm, 11 km² total
- Clear short-term spatiotemporal variations



- continuous landslide activity without any major trigger - need for regular monitoring

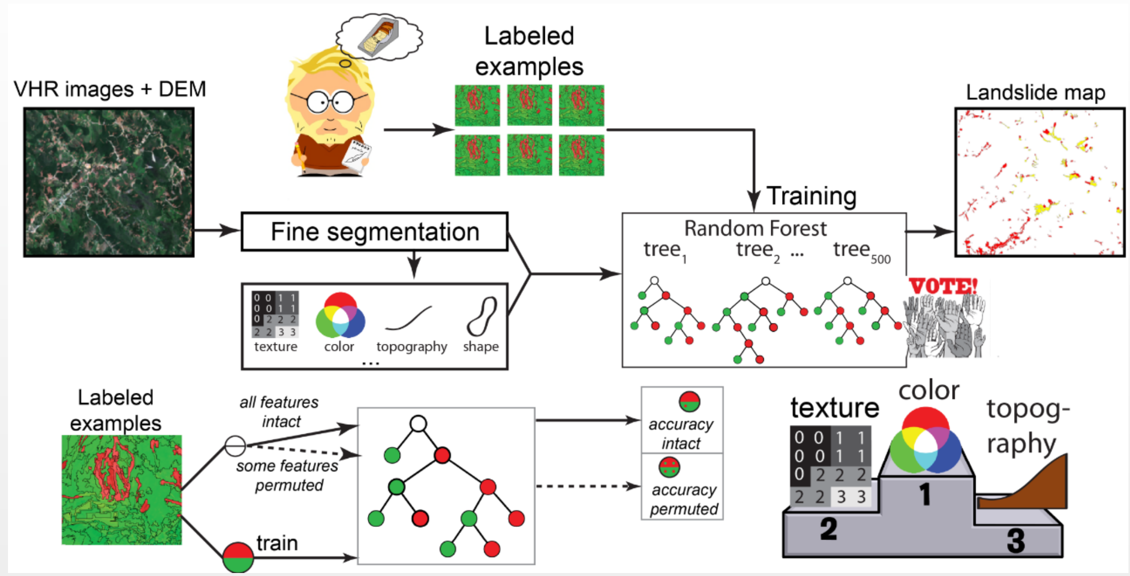
Behling, R., Roessner, S., et al., 2014. Automated Spatiotemporal Landslide Mapping over Large Areas Using RapidEye Time Series Data. *Remote Sensing*, 9, 8026-8055.

Behling, R., Roessner, S., et al., 2014. Robust Automated Image Co-Registration of Optical Multi-Sensor Time Series Data: Database Generation for Multi-Temporal Landslide Detection. *Remote Sensing*, 6, 2572-2600.

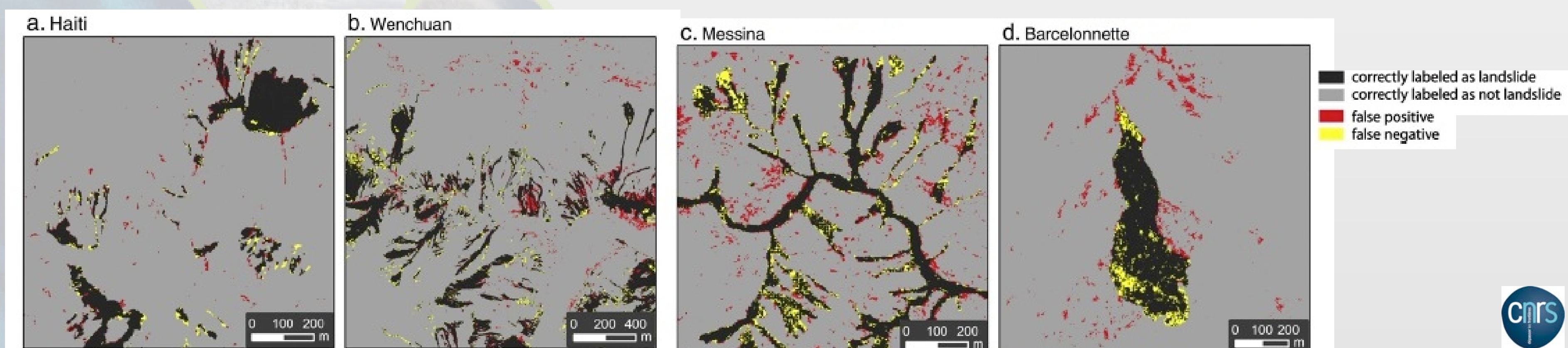
Setup a Reference for Benchmarking Landslide Detection Algorithms

Several groups are developing detection algorithms for mapping landslide after major triggering events using pre/post event imagery → a benchmark (images + a reference landslide inventory) is needed to improve the quality of the detections

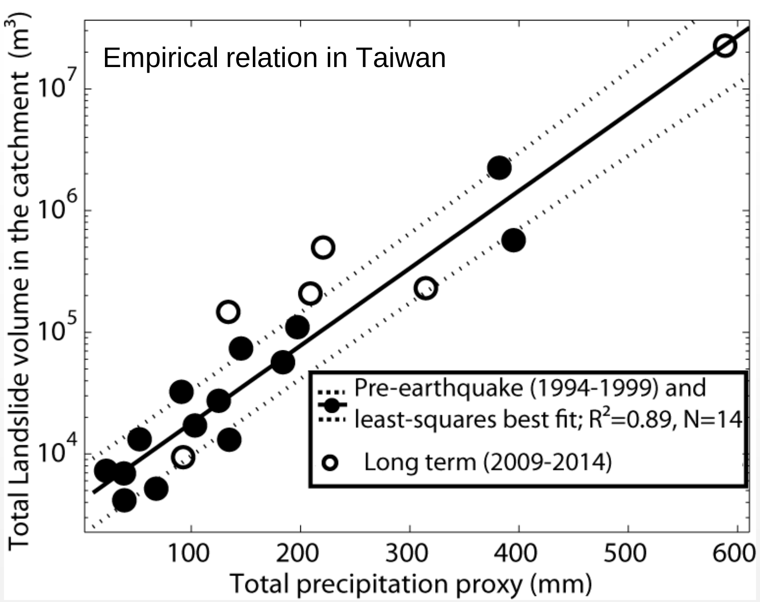
Flowchart of supervised landslide detection algorithms (pre/post event imagery)



(Stumpf et al., 2013)



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

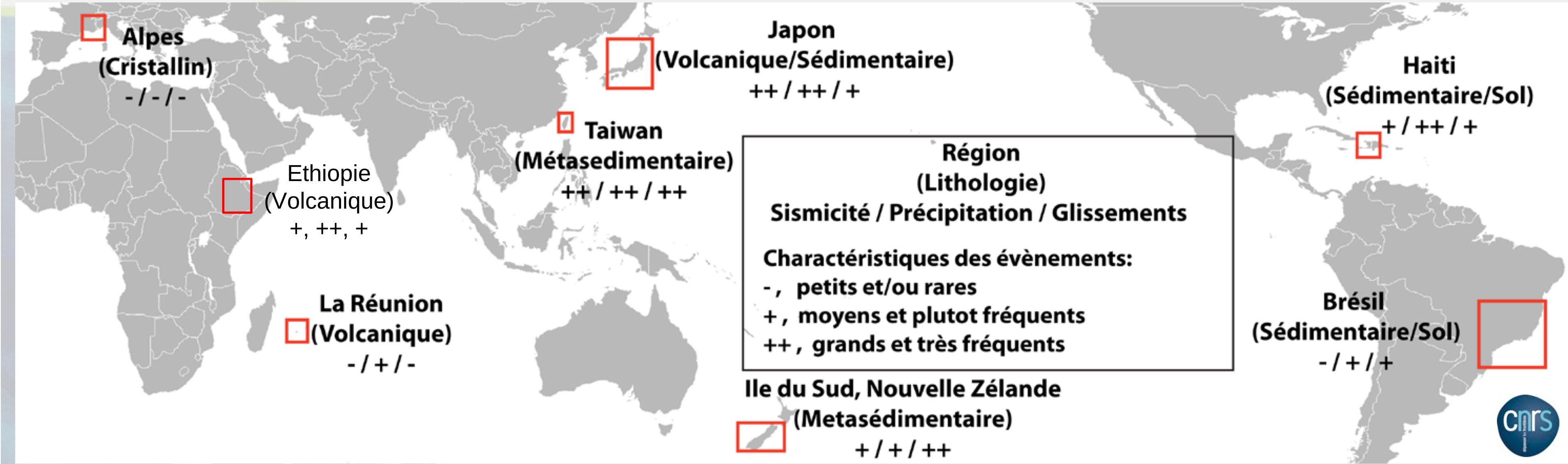


Systematizing the creation of EO-based landslide inventory after major triggering events (ETQ > threshold M_L; rainfall event > XX mm) at the global scale

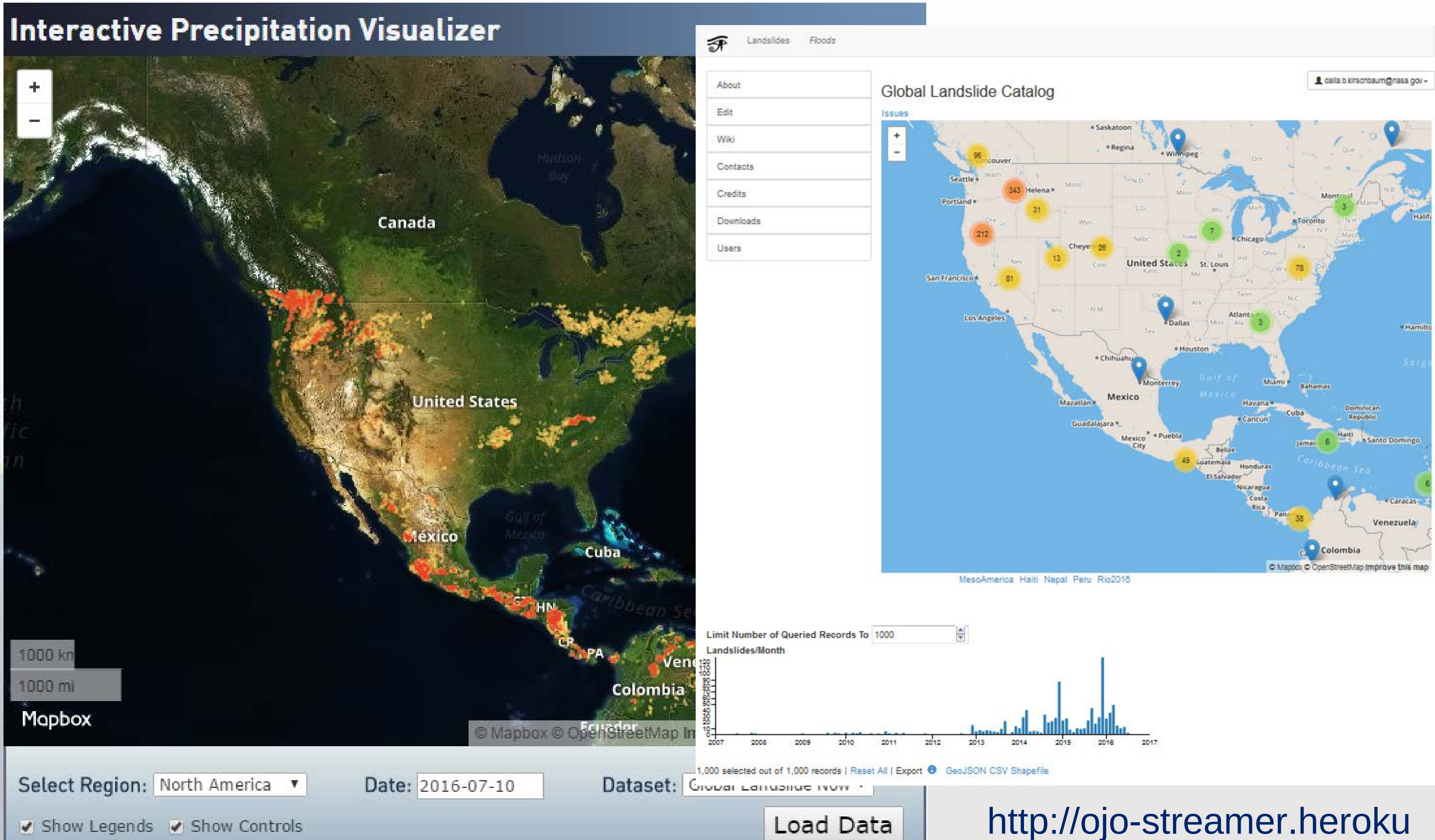
Document the triggering event (seismology, EO-based rainfall estimate using GPM)

→ Create scaling laws relating landslide intensity to the triggering events

→ CNES: 3 years post-doc project of Odin Marc



Global efforts

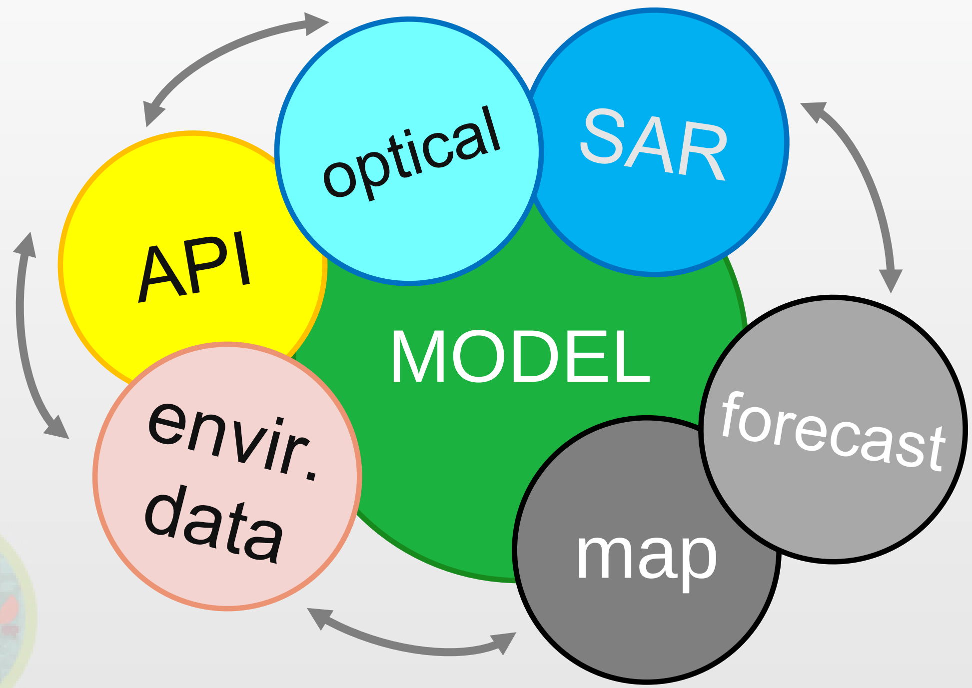


IN DEVELOPMENT at pmm.nasa.gov

http://ojo-streamer.herokuapp.com/

Future: Landslide Modelling

Advanced landslide modelling tools capable of assimilating remote sensing data and products for model initialization and validation.



Slide courtesy of Fausto Guzzetti

Take-Aways

- **Clear community need:** Landslide hazards are pervasive and research activities related to application of EO data are often not well-coordinated between regions
- **Proposed study regions** intersect many of existing pilots and have established projects
- **Methodology** – test methodologies in study regions to compare and establish best practices for community
- **Establish a benchmark dataset:** work across pilot regions to create a dataset that can be used for future algorithm development and calibration
- **Landslide Pilot in development:** seeking new participants and regional SMEs
- **Open to suggestions and guidance:** particularly from other pilots and end users

Next steps & Data needs

- **Data Needs**: Working with other pilots to determine data availability within other pilot regions to inform the new data request list
- **Officially approve** Landslide Pilot
- **Work across pilots** to determine previously acquired dates/locations
- **Confirm study sites** for landslide pilot
    - Confirm leads for each focus area
- **Define pilot objectives** to address in each study site
- **Determine data/sensor needs** based on Pilot objectives and current/planned activities

Data Requests: to be populated

Mission / Instrument	Agency	Image Counts		
		Existing Data from other pilots	New Data Requests	Cumulative Total
Optical - Moderate Resolution (10 to 100 m)				
Sentinel-2A / MSI	ESA			
EO-1 / ALI	NASA			
Landsat-8 / OLI	USGS			
Optical - High Resolution (<10 m)				
SPOT (archive only)	CNES			
Pleiades	CNES			
L-Band SAR				
ALOS-2 / PALSAR-2	JAXA			
C-Band SAR				
Sentinel-1A / SAR	ESA			
Sentinel-1B / SAR	ESA			
Radarsat-2 / SAR-C	CSA			
X-Band SAR				
Cosmo Sky-Med / SAR-2000	ASI			
TerraSAR-X	DLR			

Thank you!

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- Extra Slides

CEOS Landslide Pilot Survey

1. What is your area(s) of expertise or operational authority or responsibility (e.g. research focus or disaster response and recovery)?
2. In what geographic region(s) do you primarily work or have responsibility (e.g. Global, national, regional)?
3. Please rate your interest the proposed Pilot Objectives from Very important to not relevant
4. Please provide feedback on current objectives in terms of your proposed contribution and suggest ways to modify the objectives to better accommodate your expertise or the group's collective expertise.
5. What Earth Observation data are you most interested in acquiring as part of this pilot?
6. What specific aspects of this activity do you expect to participate in for the duration of the pilot?
7. The CEOS Landslide Pilot is in the scoping state. Who should be added to this discussion?
8. Please recommend others who you currently work with or who may be interested in this activity and include organization, point-of-contact name, affiliation, and email contact information.

28 Responses

Current Landslide Pilot Members (50)

Country	Number of participants	Organizations
USA	18	NASA, USGS, FEMA, GFDRR (World Bank), Southern Methodist University, U. of Oregon, U. of Washington, U. of Colorado
China	10	Academy of Opto-Electronics, CAS, China Earthquake Administration, Institute of Water Resources and Hydropower Research, Institute of Crustal Dynamics, CEA
Italy	7	CNR IRPI, ESA, EURAC, INGV, Università degli Studi di Firenze
France	6	CEA AIM, CNRS, UJF Grenoble, UNESCO, University of Strasbourg
Germany	2	GFZ German Research Centre for Geosciences
UK	4	University of Leeds, NERC COMET, University of Durham
Norway	2	Norut, Geological Survey of Norway
Kenya	1	RCMRD
EU	1	European Commission
Nepal	1	ICIMOD
India	1	ISRO
Barbados	2	CIMH
Sri Lanka	1	IWMI
Canada	1	NRCan
Taiwan	1	National Central University of Taiwan

Summary of Expertise

Roles	Research	Disaster Response	Imagery Type
Researcher	Landslide hazard mapping	National Landslide Hazard Program	InSAR for landslide mapping and monitoring
Disaster Response Coordinator	gradual landslide motion in mountain	Disaster Preparedness, Post disaster impact assessments	optical and radar satellite remote sensing for improved landslide process understanding
Manager for disaster preparedness and impact assessment	Initiation processes and early warning	Support to the Government for emergency management as centre of competence for civil protection	Satellite radar interferometry (InSAR) for landslides.
Regional Science Coordination Office	image analysis for automatic event landslide detection	Operational monitoring of landslides	satellite radar for measuring ground deformation
Scientific Advisor for National Civil Protection	optical and radar satellite remote sensing for improved landslide process understanding	Earthquake disaster emergency response and relief	Optical remote sensing with a particular focus on landslide mapping and monitoring
	forecasting, monitoring and assessment of hydrometeorological related hazards		airborne lidar analysis, landslide mechanics
	debris flow inundation hazard modeling		

Regional Foci of participants

Global

Regional

- Caribbean
- South Asia
- Asia
- Mediterranean
- Tibetan Plateau
- Central America

National

- US
- Western US, Appalachian States, California, Colorado
- France
- Norway
- Nepal
- Italy
- China
- Kyrgyzstan
- Iran

Local/sub-national efforts (catchment scale)

- Taiwan, Korea, Japan
- Southwest China

Interest in Objectives

	Objective A	Objective B	Objective C	Objective D
1 - Very Important	85%	60%	15%	21%
2- Moderately	10%	35%	60%	52%
3 - Neutral	5%	5%	25%	21%
4 - Not Important	0%	0%	0%	5%

Objective A:

Establish effective practices for merging different Earth Observation data (e.g. optical and radar) to better manage landslide detection, mapping, and monitoring.

- Developing / testing / benchmarking / sharing tools for high-frequency monitoring and rap id mapping of landslides with satellite EO data
- Leverage revisit time of multiple sensors (e.g. the Sentinel constellation (S1, S2) to use EO satellite images as a real source of information for the monitoring of landslide displac ement/deformation at high frequency.
- Processing stacks of Optical and SAR images to create horizontal displacement maps ov er time
- Improve the efficiency in processing remote sensing data for emergency response
- Establishment of benchmark datasets to test available semi-automatic techniques

Comments on Objectives

Objective B:

Create integrated products & services for practices or activities, such as landslide inventories, to support disaster risk management for multi-hazard and cascading landslide events.

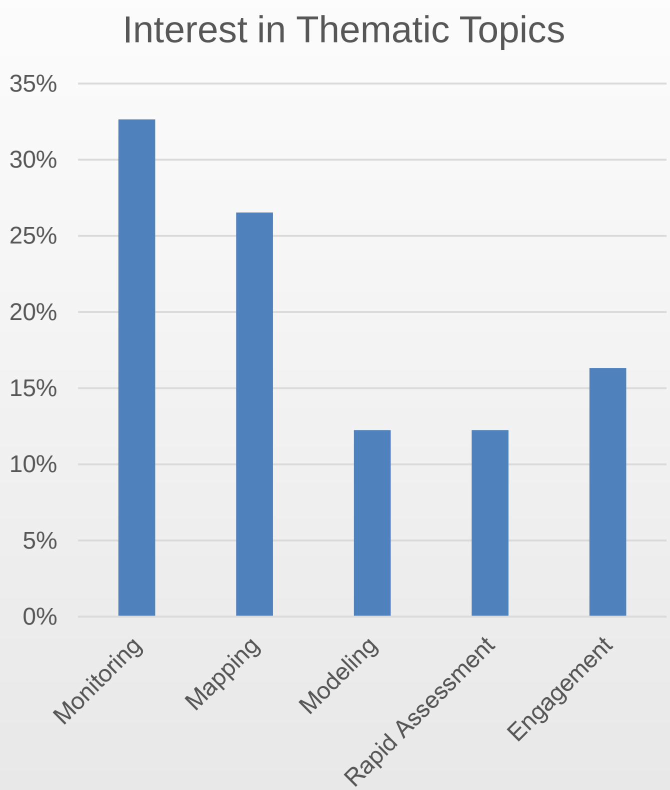
- Further develop operational services leveraging existing projects on landslide inventory mapping, landslide monitoring and early warning, landslide modeling and interpretation
- Demonstrate the rapid emergency response landslide mapping during major disasters in coordination with end users
- Create closer links between remote sensing analysis and the needs for hazard and risk analysis
- Use the longest available time series of remote sensing data to create systema tic spatiotemporal assessment of landslide activity

Interest in Data Access

	SAR	Optical	DEMS	Soil Moisture & rainfall	land use/soils	landslide inventories	LiDAR
Number interested	15	17	5	3	3	3	2
Percent	58%	65%	19%	12%	12%	12%	8%
Source	Sentinel-1 and 2,RADARSAT-2, COSMO-SkyMed, ALOS-1 and 2, TerraSAR-X, RISAT	Landsat, IRS, Worldview, Pleiades, SPOT5, SPOT-6/7, QuickBird, GF2, RapidEye, Sentinel-1, Sentinel-2, Venus	TanDEM-X	rainfall (weather data)		landslide catalogs	LiDAR
Resolution		1m-10m	<10m				
Notes	Polarimetric SAR (amplitude), better if HR/VHR; need the ability to target over specific sites of interest (supersites, Nepal), <u>time series important</u>	Multispectral (VHR better, GSD < 1 m); hyperspectral; <u>time series needed</u>			soil erosion, regolith depth, exposed bedrock for unconsolidated deposits	landslide maps (specifically after earthquakes) suceptibility maps	Time series would be best

Interest in Thematic Topics

1. **Monitoring:** Develop/advance/communicate monitoring capabilities leveraging and integr ating Optical and SAR data **(Obj A)**
2. **Mapping**: Develop methodologies for multi-t emporal image processing over select region to improve/expand landslide mapping/invent ories **(Obj A)**
3. **Hazard assessment/modeling:** Demonstrat ing how EO data (DEMs, hydrological inform ation, and imagery/SAR) can advance landsli de modeling/hazard assessment at a regiona l scale **(Obj B)**
4. **Rapid Assessment:** Demonstration of how EO data can be rapidly processed for inform ed decision making **(Obj A & D)**
5. **User/Pilot Engagement:** Need to leverage e xisting connections and those from other pilo ts to turn products into actionable information (Obj C & D)



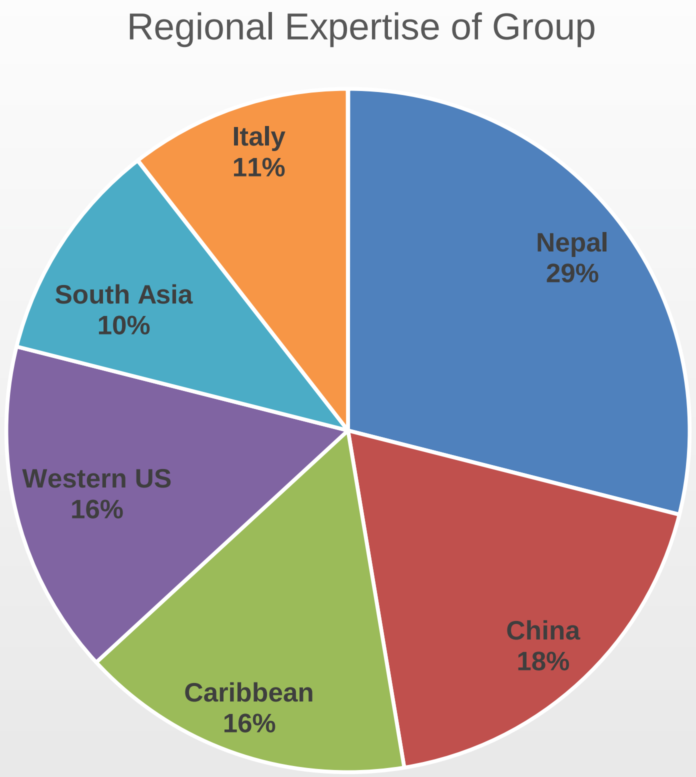
Suggested regional study areas

1. Nepal

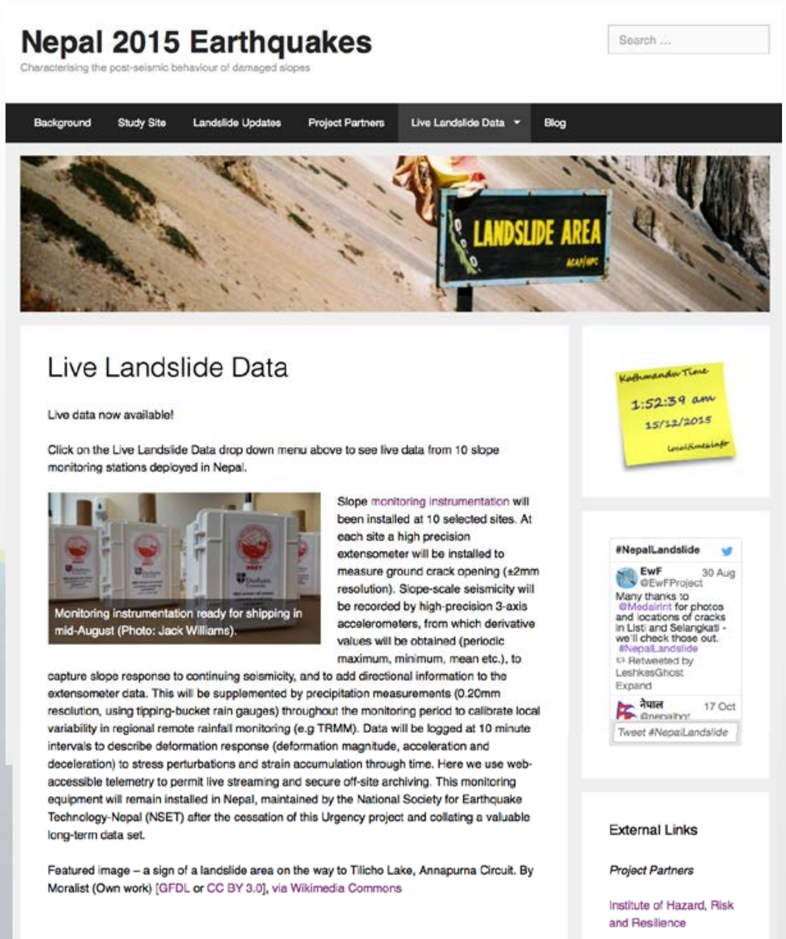
2. Pacific Northwest, U.S. (Oregon, Washington)

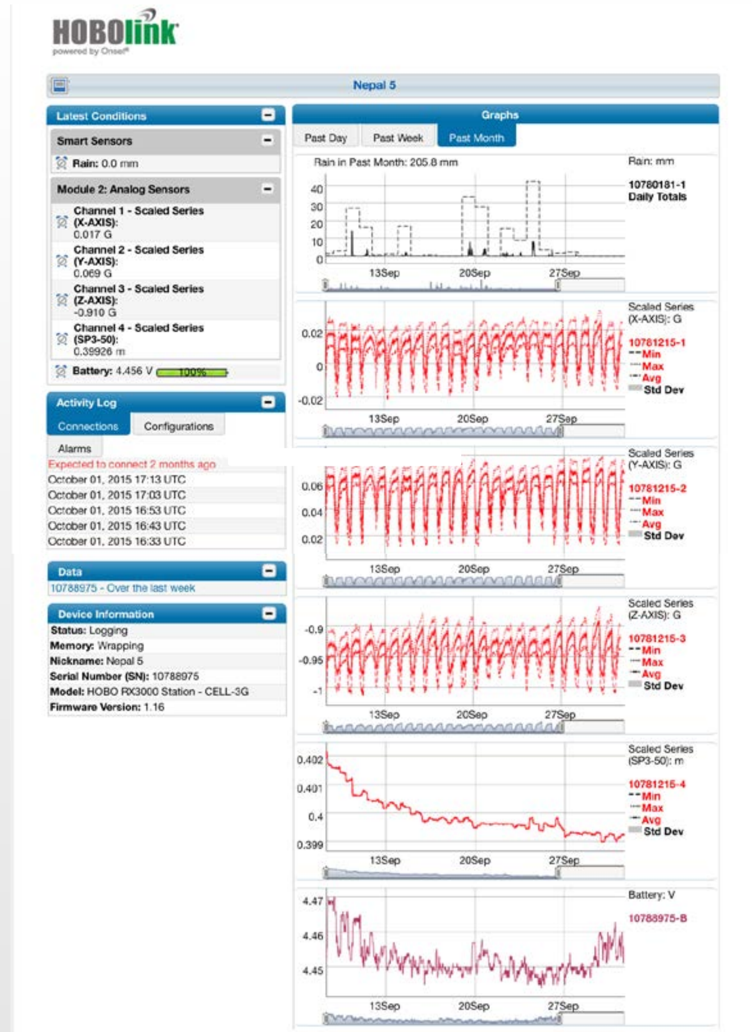
3. China (southwestern area)

4. Caribbean (focus area TBD)



Live data stream

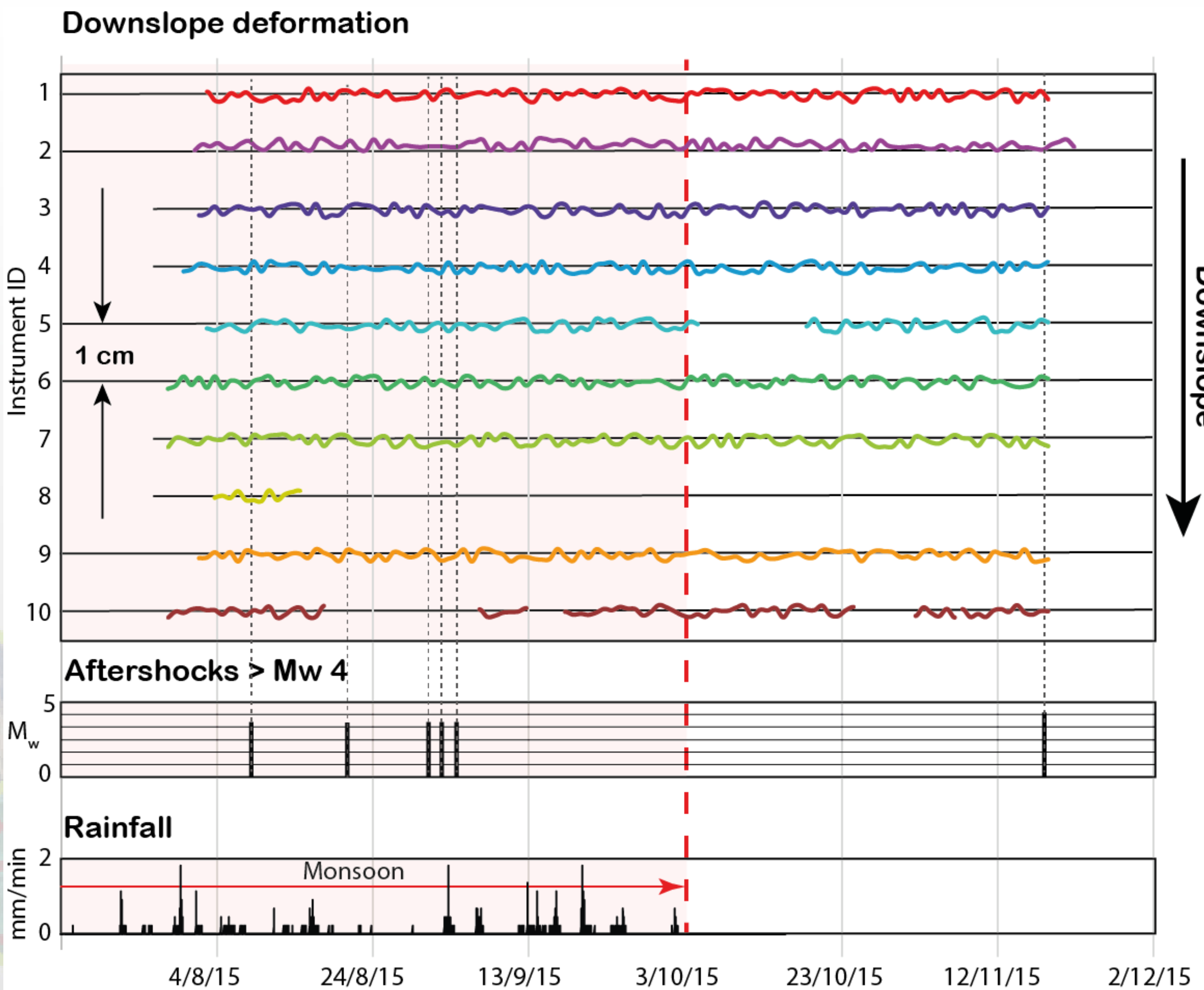




Slides from N. Rosser/Durham http://community.dur.ac.uk/nepal.2015eq

Monitoring data summary

- Tail end of monsoon captured from August onwards
- No response to rainfall or aftershocks to date
- Heavily damaged slopes remained static, but not necessarily stable
- Has anything changed during the monsoon?



Slides from N. Rosser/Durham