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Guidelines for InSAR monitoring of landslides

Keynote: ICEO Taiwan, 2018

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- Why we need high resolution and rapid revisit InSAR for monitoring?
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- Conclusions

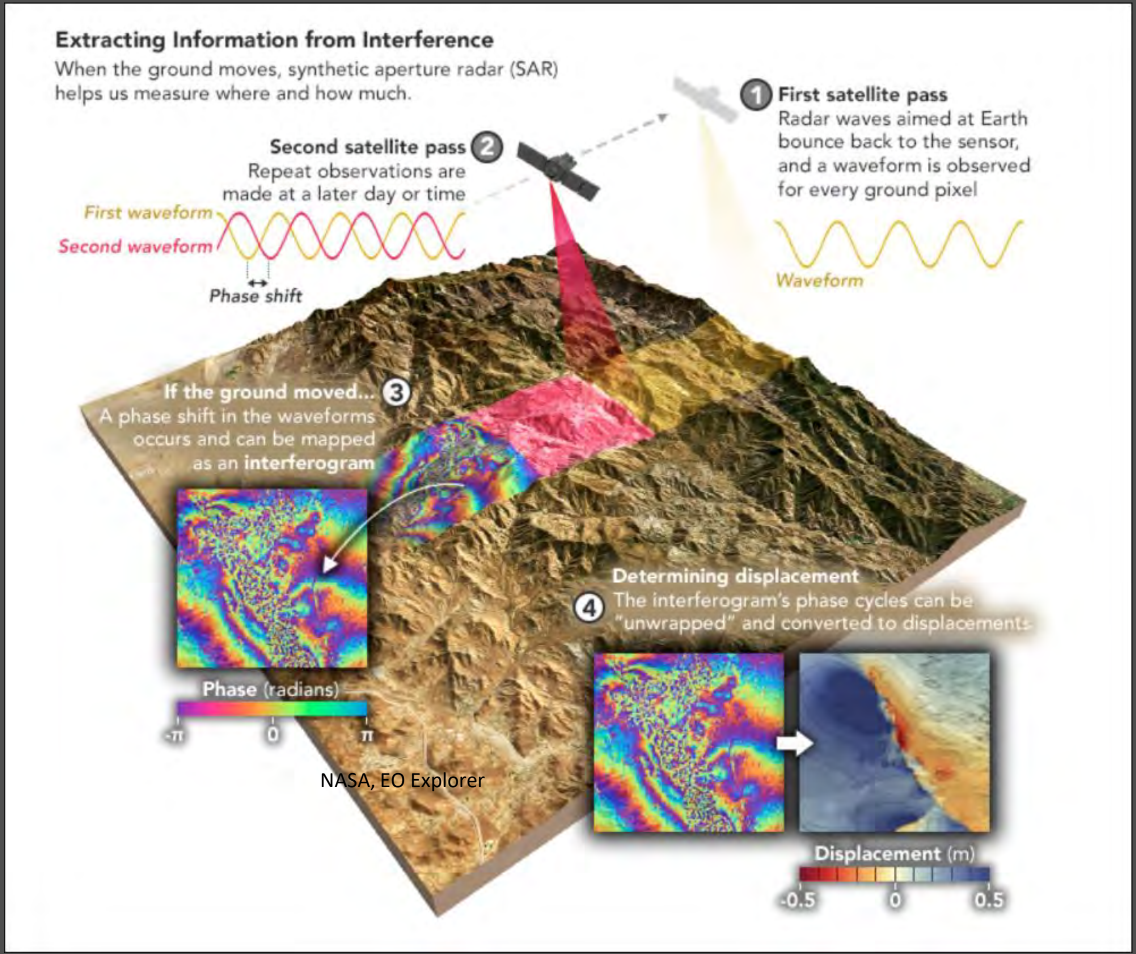
Highlights

- Simple guidelines on InSAR monitoring are needed to produce reliable measurements.
- These InSAR guidelines are essential in developing an early warning system for geohazards.
- The availability of more frequent satellite revisits from the RADARSAT Constellation Mission (RCM) and others require improved InSAR processing techniques taking advantage of several viewing geometries, distributed targets and corner reflectors.
- The InSAR deformation profiles using both point and distributed targets show the spatial and temporal terrain movements needed to understand the dynamics of low-velocity landslides.

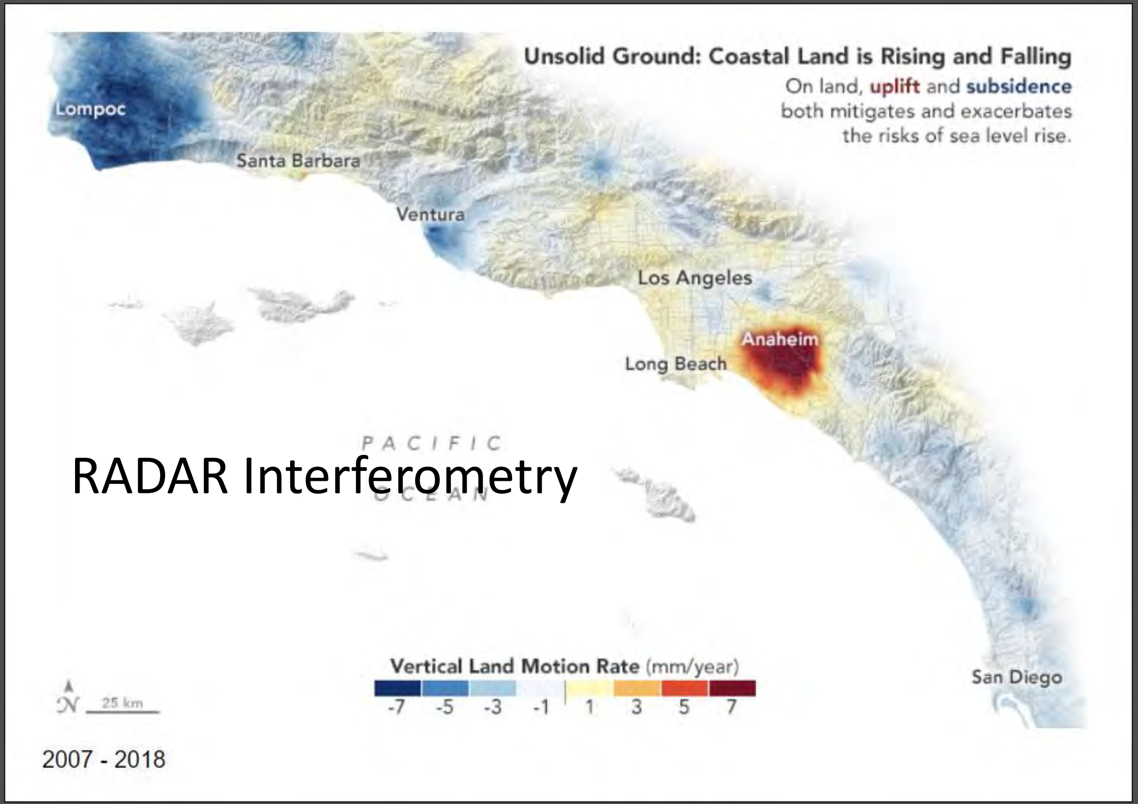
InSAR- Radar interferometry (101)

- InSAR uses two or more sequential radar images to detect surface changes over large areas. We can create a time series of land motion from these sequential radar acquisitions.
- InSAR produces a map of ground deformation with centimeter accuracy in a timely manner.
- Radar satellites represents a major leap forward in the way we are able to monitor geohazards such as land subsidence, earthquake volcanic and landslide motion.

This JPL example is used to explain the previous slide



NASA, EO Explorer



RADAR Interferometry

Erica Podest, NASA, JPL

Radar Missions for InSAR (2021)

European Space Agency (ESA)

Sentinel 1a and 1b (Launch April 2016). Two C-band radar satellites (5m resolution) with 6 days revisit for InSAR.

Japanese Space Agency (JAXA)

ALOS 2 PALSAR L band satellite 3 m resolution with 14 days revisit for InSAR (Launch May 2014).

German Space Agency (DLR)

Terra SAR X and Tandem –X, 11 days revisit for InSAR (DLR, InfoTerra) (Launch-June 2010).

Cosmo SKYMED (Italian Space Agency)

4 satellite Constellation: Variable revisit time (1,3, 4,8 days) for InSAR.

New InSAR Missions

RADARSAT Constellation, Canadian Space Agency (4 days revisit for InSAR Launch July 2019).

TerraSAR / PAZ constellation (DLR/INTA) 4 days InSAR revisit

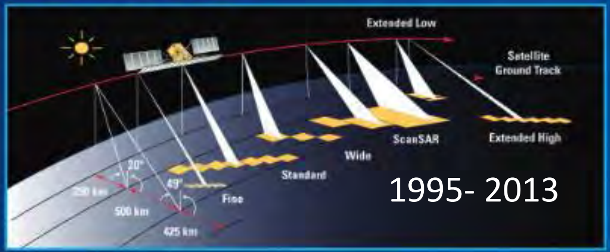
RISAT/ NISAR (ISRO/JPL) L band, 12 days repeat for InSAR (Launch 2021?)

Canadian Space Agency / Agence spatiale canadienne

Deformation Monitoring using RADARSAT

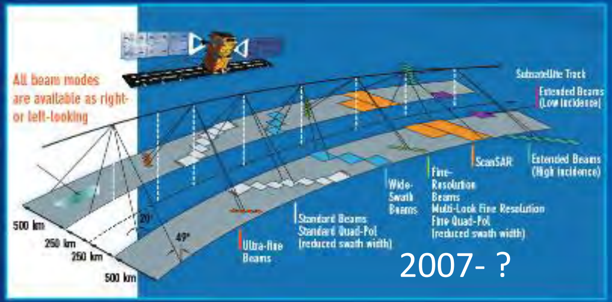
BEAM MODES

RADARSAT-1



Beam Modes	Nominal Swath Width (km)	Nominal Resolution (m)
Fine	45	8
Standard	100	30
Wide	150	30
Scansar narrow	300	50
Scansar wide	500	100
Extended high incidence	75	18-27
Extended low incidence	170	30

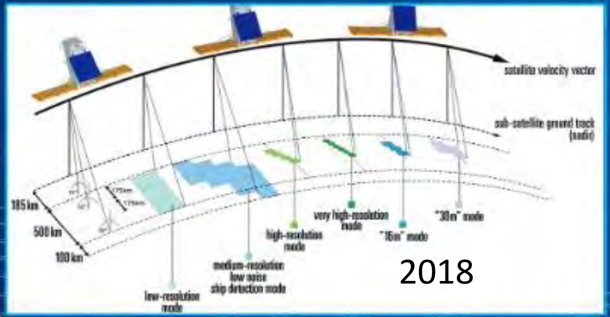
RADARSAT-2



Beam Modes		Nominal Swath Width (km)	Approximate Resolution (m) *1
Selective Polarization Transmit H or V receive H and/or V	Fine	50	10 x 9
	Standard	100	25 x 28
	Low incidence	170	40 x 28
	High incidence	75	20 x 28
	Wide	150	25 x 28
	ScanSAR narrow	300	50 x 50
	ScanSAR wide	500	100 x 100
Polarimetric Transmit H and V on alternate pulses / receive H and V on any pulse	Fine Quad-pol	25	11 x 9
	Standard Quad-pol	25	25 x 28
Selective Single Polarization Transmit H or V receive H or V	Ultra-Fine	20	3 x 3
	Spotlight	18	3 x 1
	Multi-Look Fine	50	11 x 9

*1. Ground range by azimuth

RADARSAT Constellation



Beam Modes	Nominal Swath Width (km)	Approximate Resolution (m)
Low Resolution	500	100 x 100
Medium Resolution (Maritime)	350	50 x 50
Medium Resolution (Land)	30	16 x 16
Medium Resolution (Land)	125	30 x 30
High Resolution	30	5 x 5
Very High Resolution	20	3 x 3
Ice/Oil Low Noise	350	100 x 100
25 m ship mode	350	Variable
Spotlight mode	5	1 x 3

3 satellites, Dual/Compact/Quad Polarization, Right looking
4 days repeat cycle, Lifetime: 7 years 300,000 scenes/yr

www.asc-csa.gc.ca

Canada

WHY InSAR GUIDELINES ?

- Current state-of-the-art in real-time monitoring of active slopes developed for early warning of landslides is expensive. InSAR is cheaper .
- InSAR complements real time monitoring such as GPS, TLS, and TInSAR and field measurements.
- Simple guidelines on InSAR monitoring are needed to produce reliable measurements.
- These guidelines are essential because the availability of more frequent satellite revisits from the RADARSAT Constellation Mission (RCM) and others require improved InSAR processing techniques to take advantage of high resolution, viewing geometries, distributed targets and corner reflectors.

The need for high resolution and rapid revisit InSAR monitoring provided by SAR Constellations

- The high-resolution InSAR images with a short temporal acquisitions are critical for active surface deformation monitoring.
- The high resolution allows high InSAR coherence on sparsely and non-vegetated areas
- High resolution images consistently produce excellent results
- Rapid revisit produces better stack images and reliable results with better signal to noise ratios .

Guidelines for reliable InSAR measurements

Reliable measurements of surface displacement can be achieved under specific conditions.

- Using radar image pairs or numerous scenes (more than 15),with similar viewing geometries, short perpendicular baselines (less than 100m), short time intervals between acquisitions.
- Correct for the effect of topography use high resolution DEM if possible.
- Select stable reference sites for phase unwrapping
- The InSAR deformation maps should be accompanied by profiles of linear motion along the line of sight. This will assist with time series interpretation
- 3D-motion using ascending and descending orbits will provide the vertical and horizontal motion for geotechnical interpretation and additional viewing

Some Processing Software (there are others)

- PS-InSAR TM(persistent scattering-PS) processes strong signals reflected from relatively small objects, which stay coherent over the time.
- Squeeze SARTM is a processing technique developed by TRE Inc. It takes advantage of both PS and distributed scatters (DS) of homogeneous areas where the backscatters are less strong as PS.
- GAMMA toolbox provides a wide functionality with different processing tasks which can run individually from scripts in a more automated way.
- SBAS (Small Baseline Subset) algorithm uses the “stacking” technique from a large number of InSAR scenes with short orbital baselines. This allows the estimation of average deformation over extended natural areas by assuming linear deformation and by reducing non-linear feature like atmospheric phase delay.
- Each technique has their respective strengths.

InSAR Methodology (101-fundamentals)

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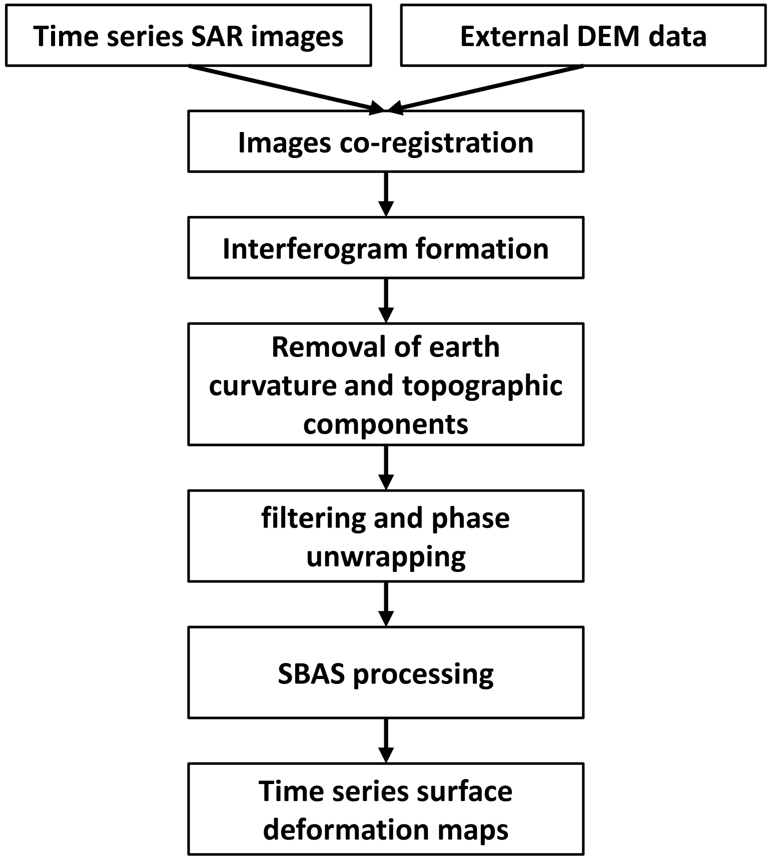


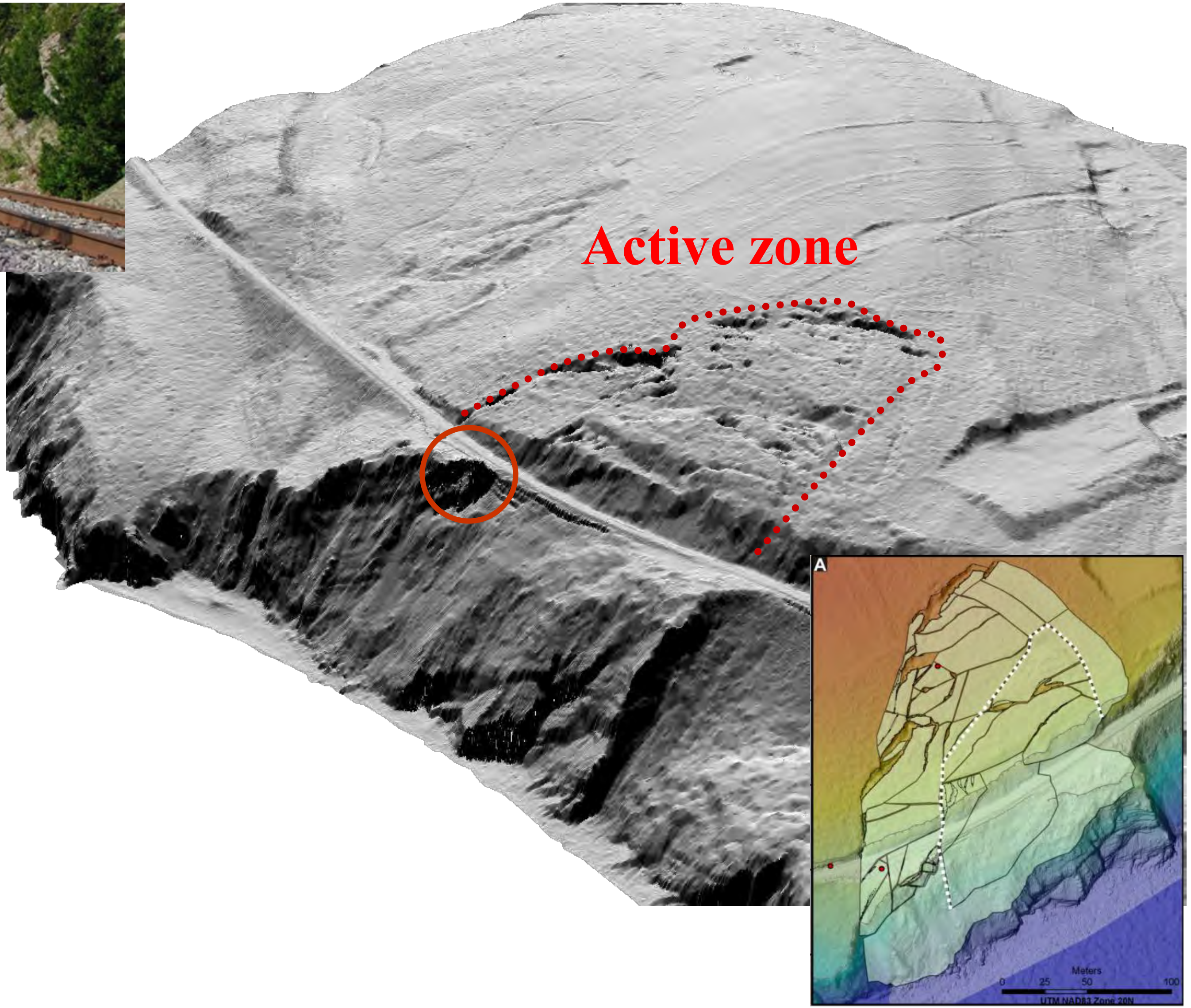
Corner Reflectors (101)

- Vegetation decorrelates the radar signals. Therefore, stable coherent targets such as installed corner reflectors (point targets) or buildings, roads and bridges (distributed targets) are used to calculate the landslide motion.
- The uses of installed field corner reflectors are increasing on remote vegetated sites.
- Most reflectors are generally trihedral shaped and made of perforated aluminum.
- Large reflectors produce the more precise measurements.
- Depending on the vegetation density, L band may require less corner reflectors.
- The orientation of the corner reflectors is perpendicular to the radar line of sight.

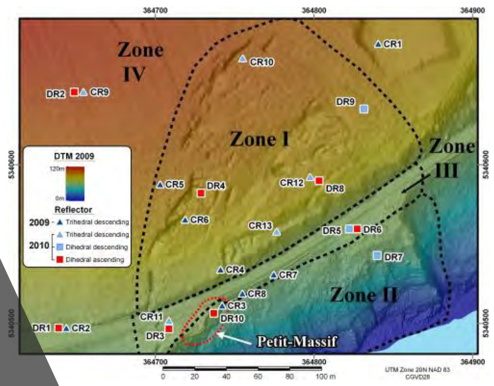
InSAR Examples in Canada, Taiwan, Nepal, India, Haiti using these simple guidelines

Lidar DEM of Landslide at Gaspe, Canada

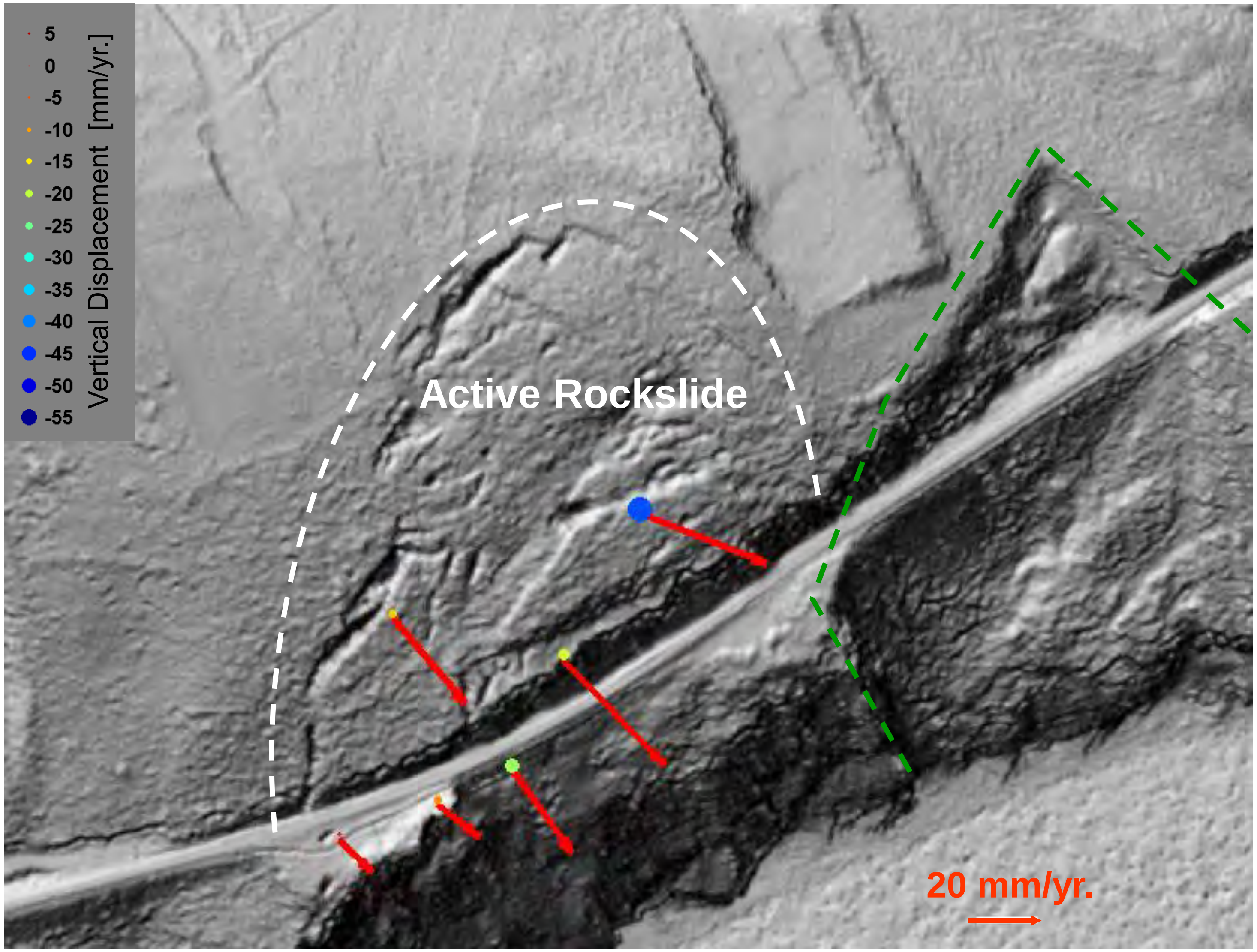
Charbonneau- CCRS



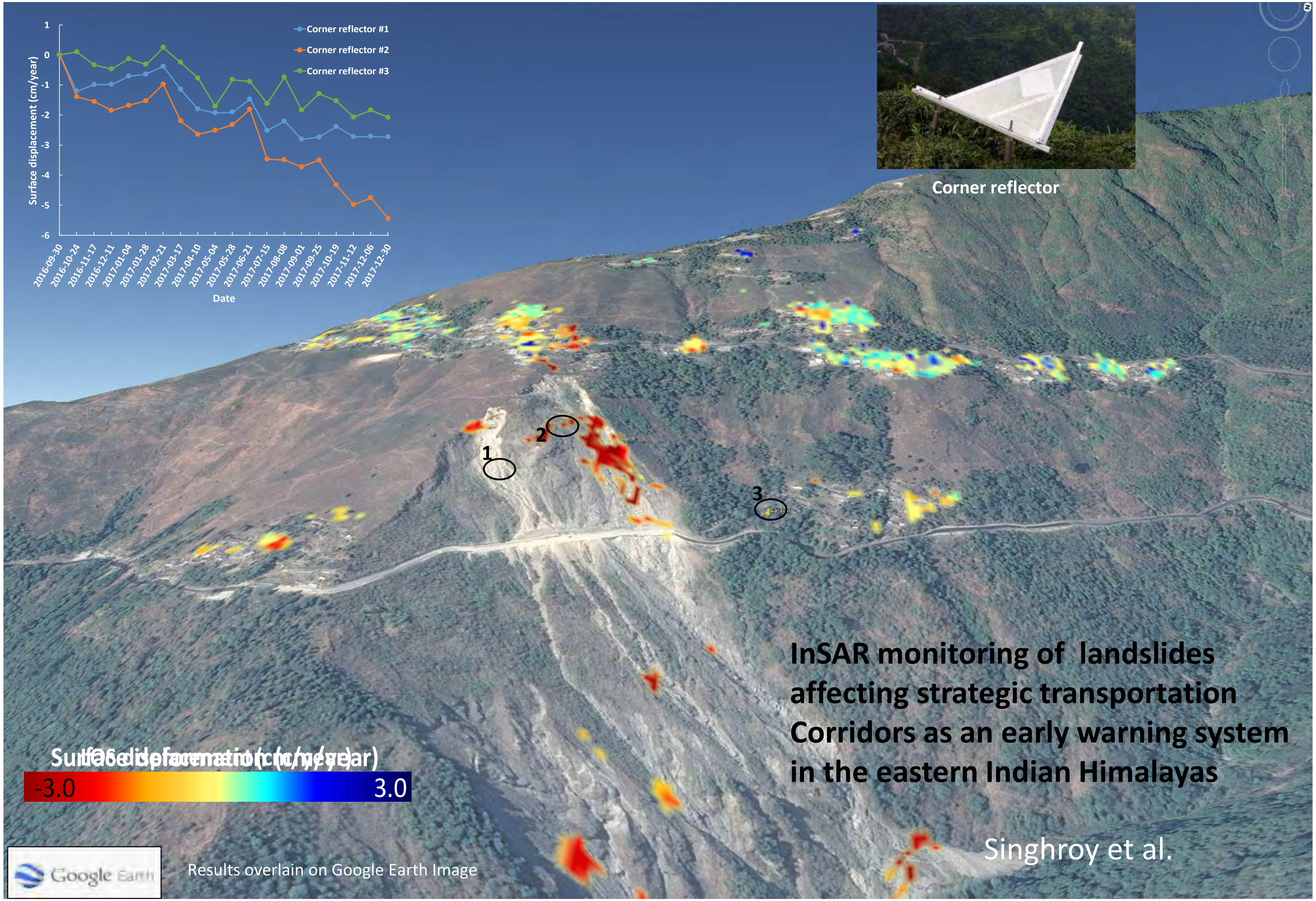
Deployment of corner reflectors Descending & Ascending (Charbonneau-CCRS)

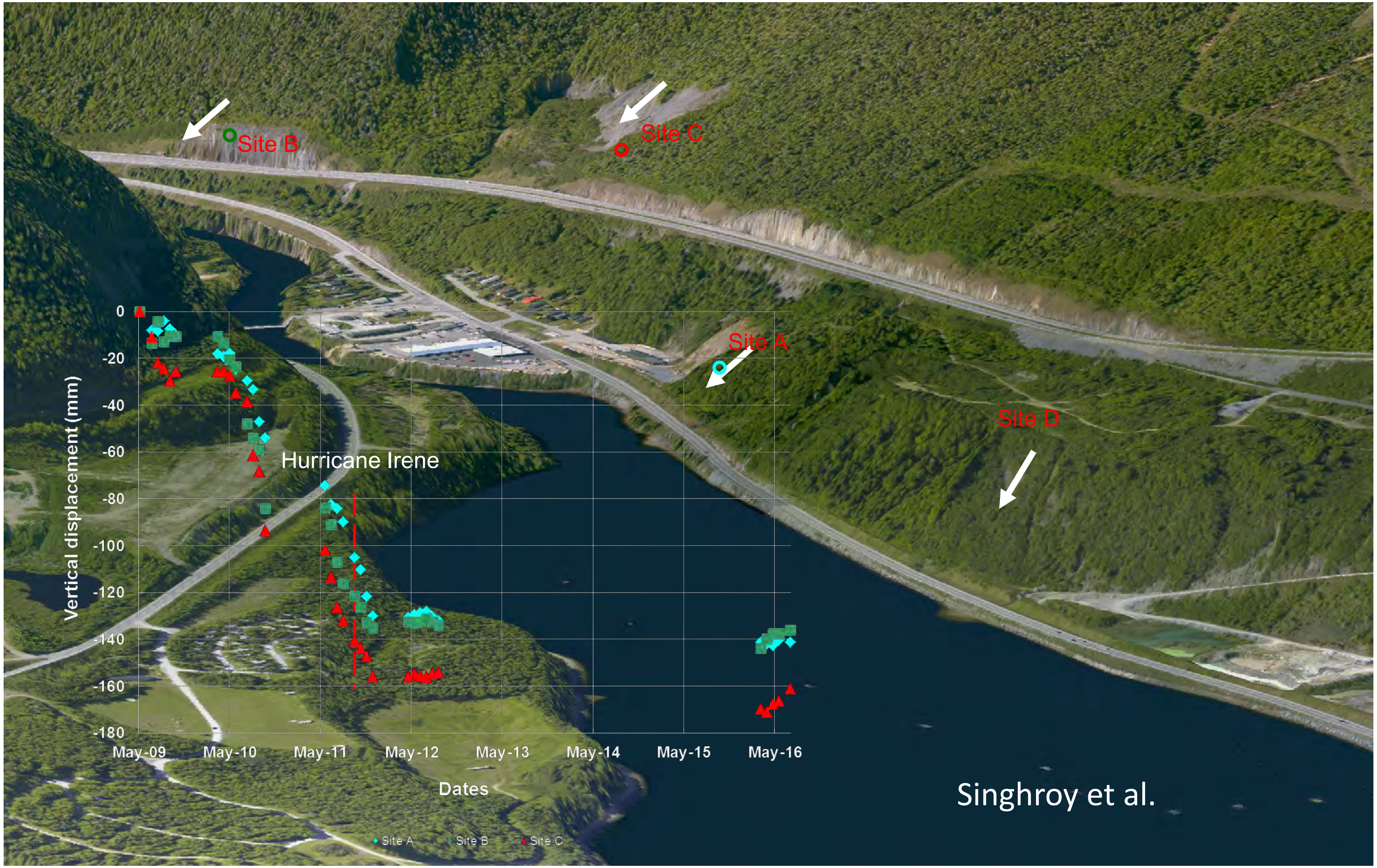


Radarsat 2 InSAR results Charbonneau (CCRS)



InSAR results have been integrated with geomechanical models


Corner reflector #1
Corner reflector #2
Corner reflector #3
Surface displacement (cm/year)
1
0
-1
-2
-3
-4
-5
-6
2016-09-30
2016-10-24
2016-11-17
2016-12-11
2017-01-04
2017-01-28
2017-02-21
2017-03-17
2017-04-10
2017-05-04
2017-05-28
2017-06-21
2017-07-15
2017-08-08
2017-09-01
2017-09-25
2017-10-19
2017-11-12
2017-12-06
2017-12-30
Date
Corner reflector
1
2
3
InSAR monitoring of landslides affecting strategic transportation Corridors as an early warning system in the eastern Indian Himalayas
Surface deformation (cm/year)
-3.0
3.0
Singhroy et al.
Google Earth
Results overlain on Google Earth Image



RADARSAT 2 InSAR monitoring the effects of Hurricane Irene on Landslides near highway routes- Corner Brook, Newfoundland, Canada

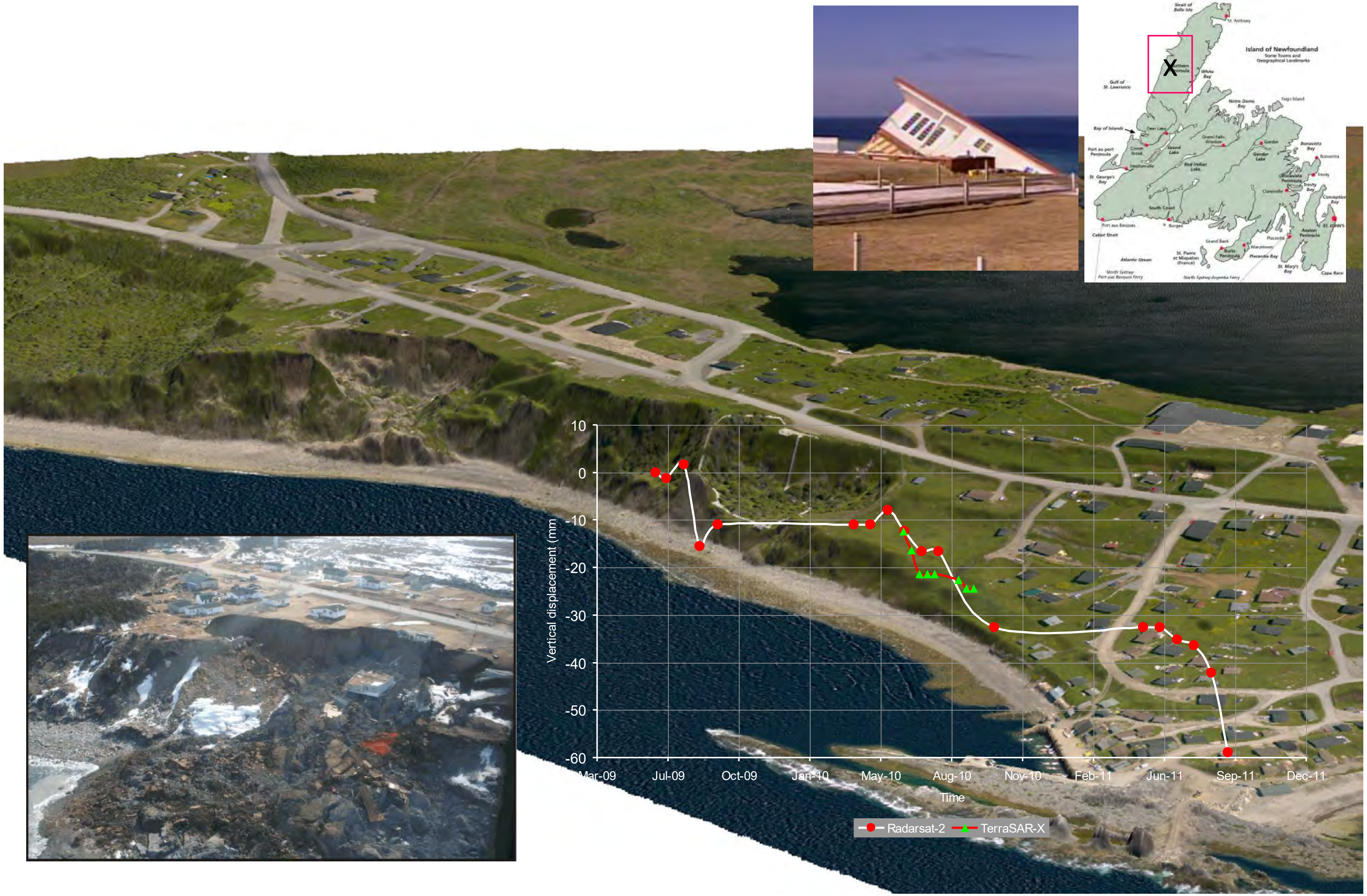
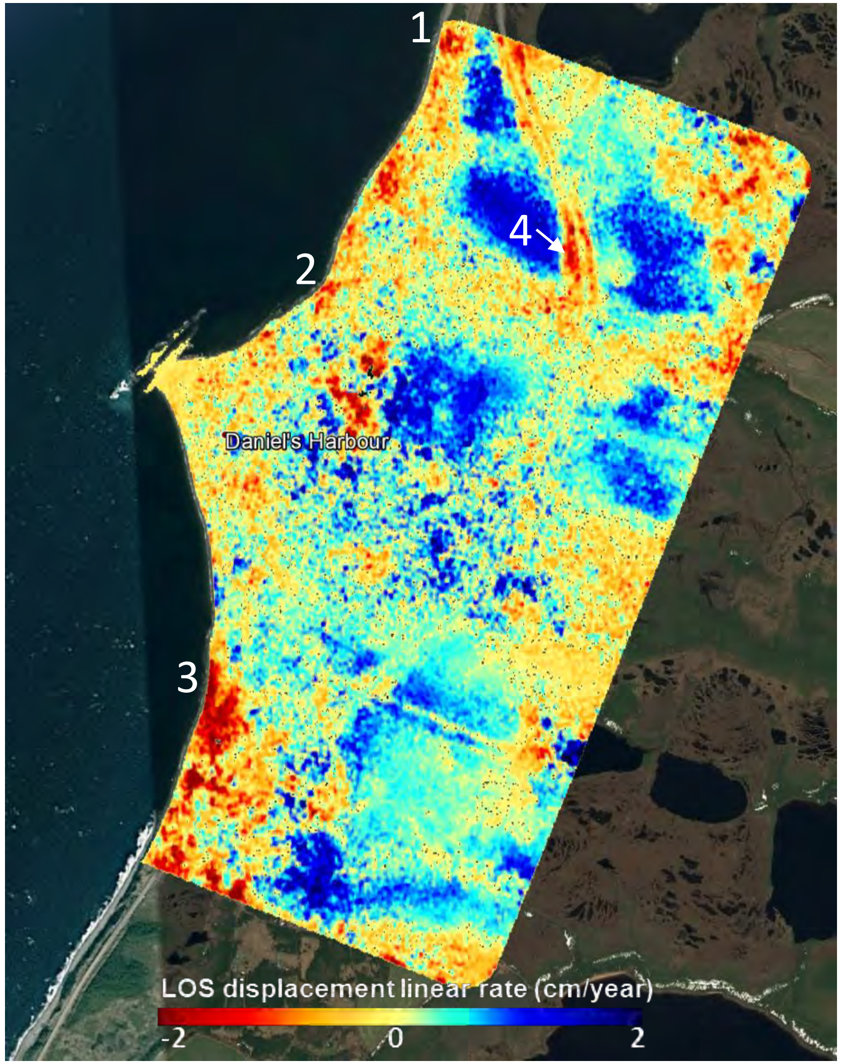
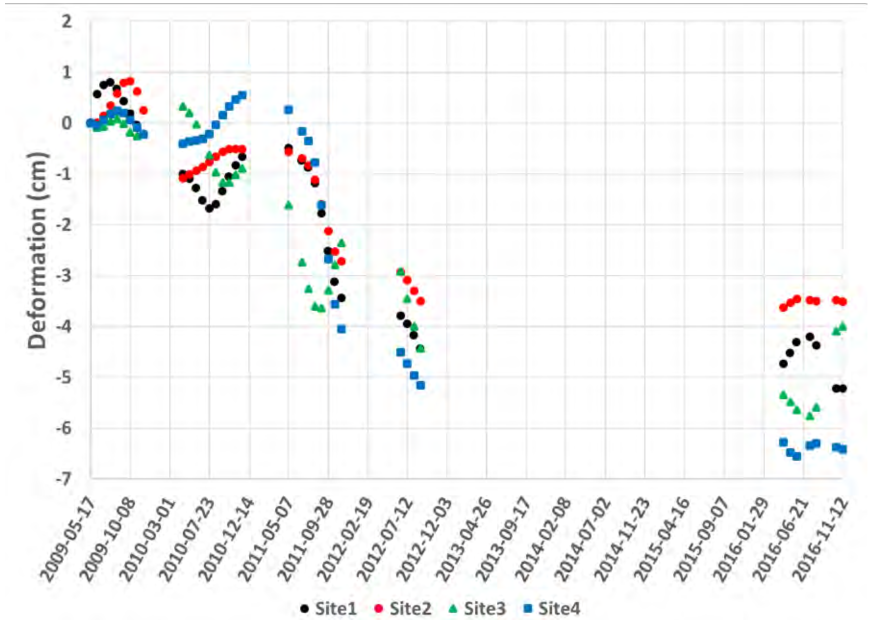


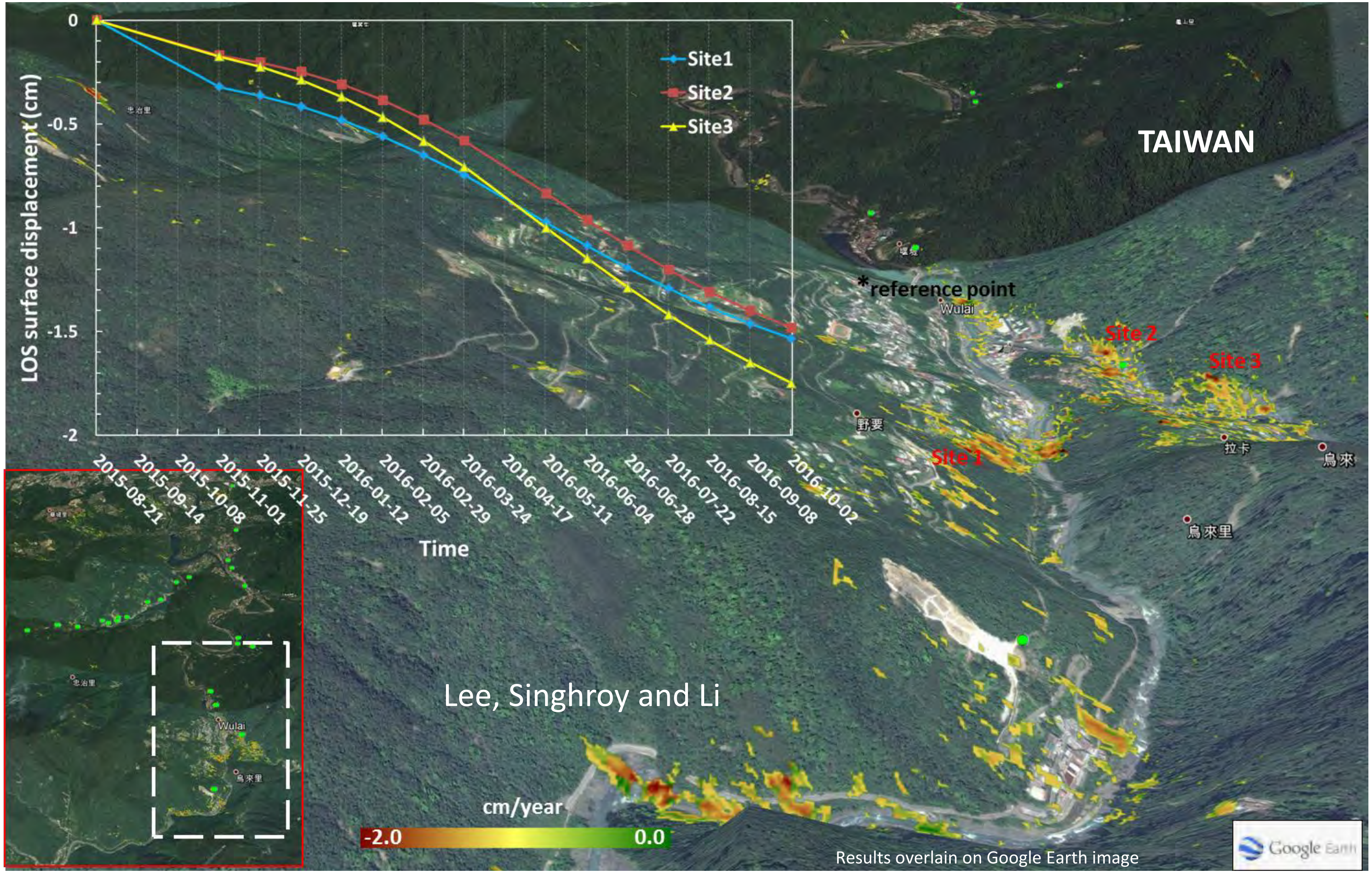
Fig.2 InSAR monitoring of Landslides at Daniels Harbour, Newfoundland (Singhroy et al.)



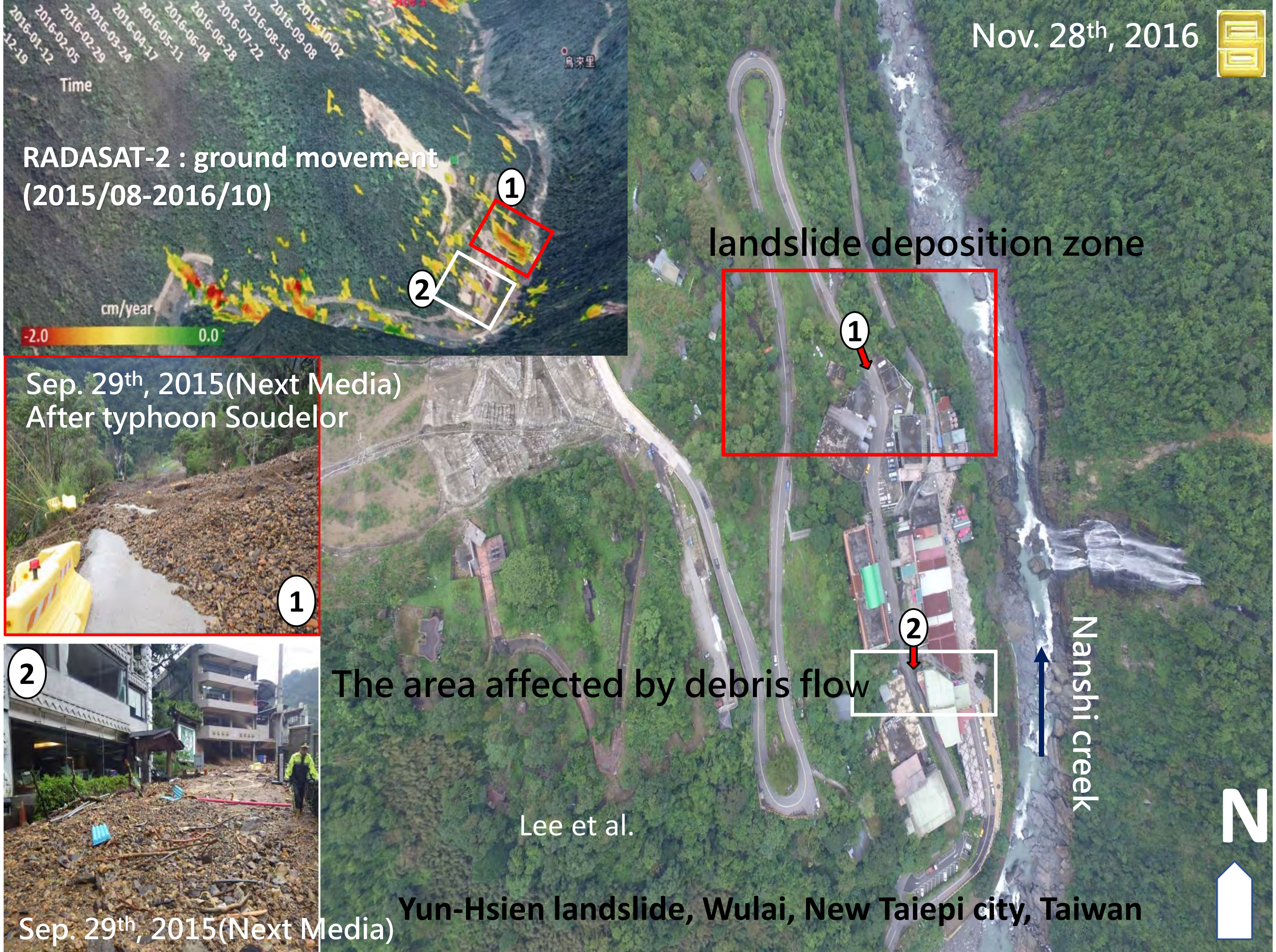


Daniels Harbour, NF R2 U7

Singhroy et al

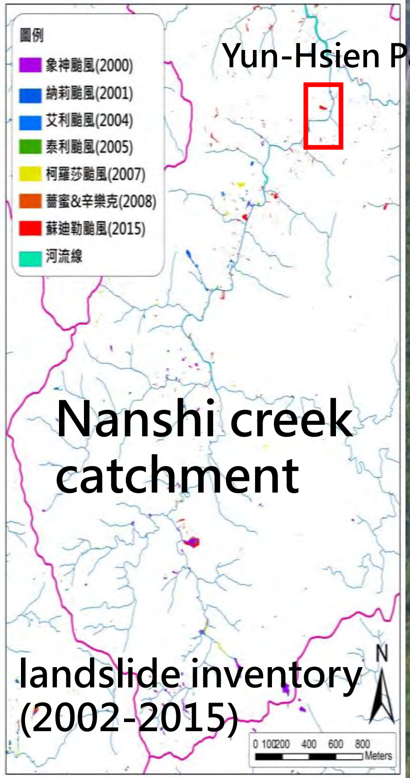


RADARSAT 2-(Extra-Fine Descending) 3m resolution for **Wulai, TAIWAN**



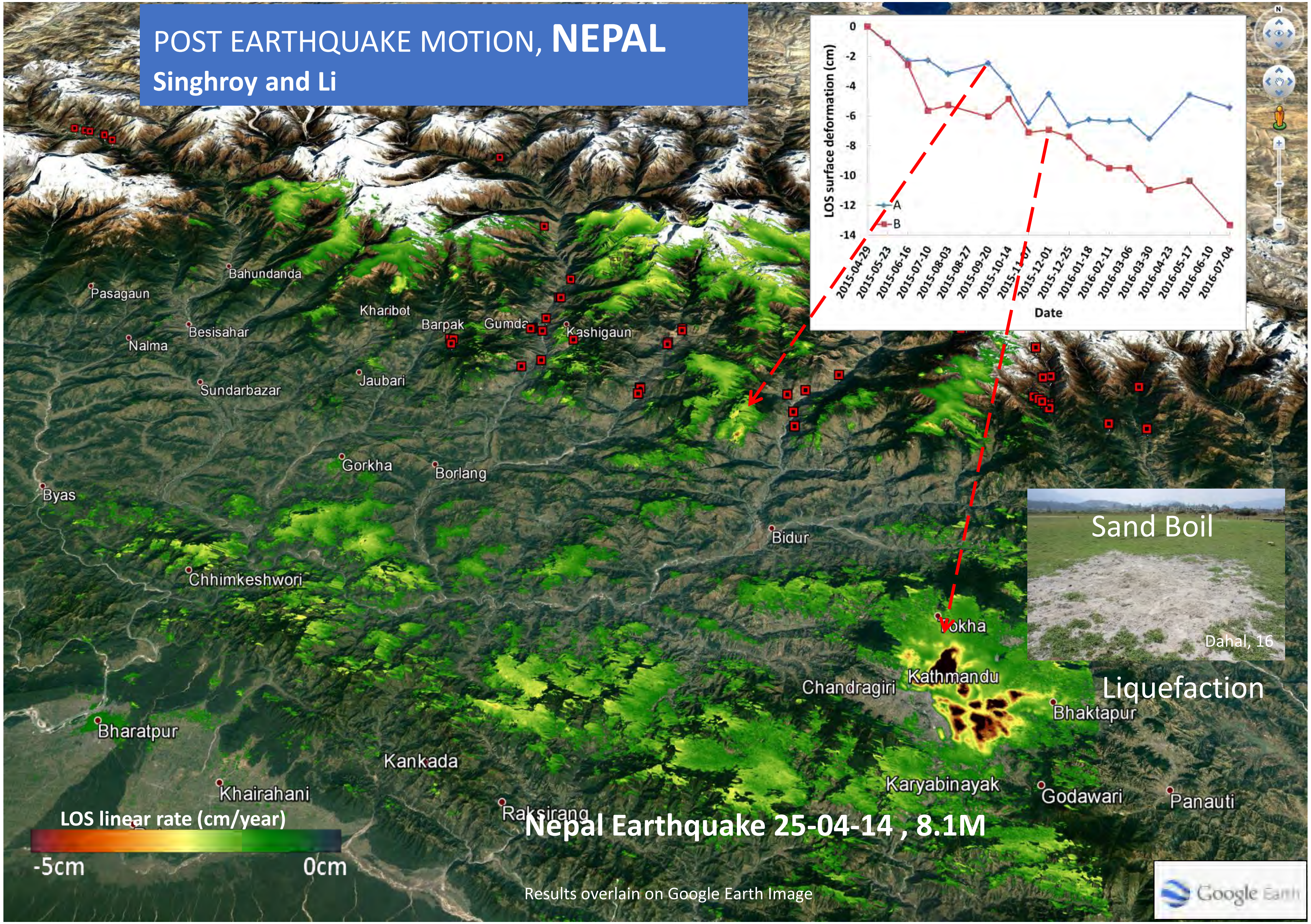
Nov. 28th, 2016
2016-01-12
2016-02-05
2016-02-29
2016-03-24
2016-04-17
2016-05-11
2016-06-04
2016-06-28
2016-07-22
2016-08-15
2016-09-08
2016-10-02
Time
烏來里
RADASAT-2 : ground movement
(2015/08-2016/10)
cm/year
-2.0
0.0
1
2
landslide deposition zone
Sep. 29th, 2015(Next Media)
After typhoon Soudelor
The area affected by debris flow
Nanshi creek
Lee et al.
N
Sep. 29th, 2015(Next Media)
Yun-Hsien landslide, Wulai, New Taiepi city, Taiwan

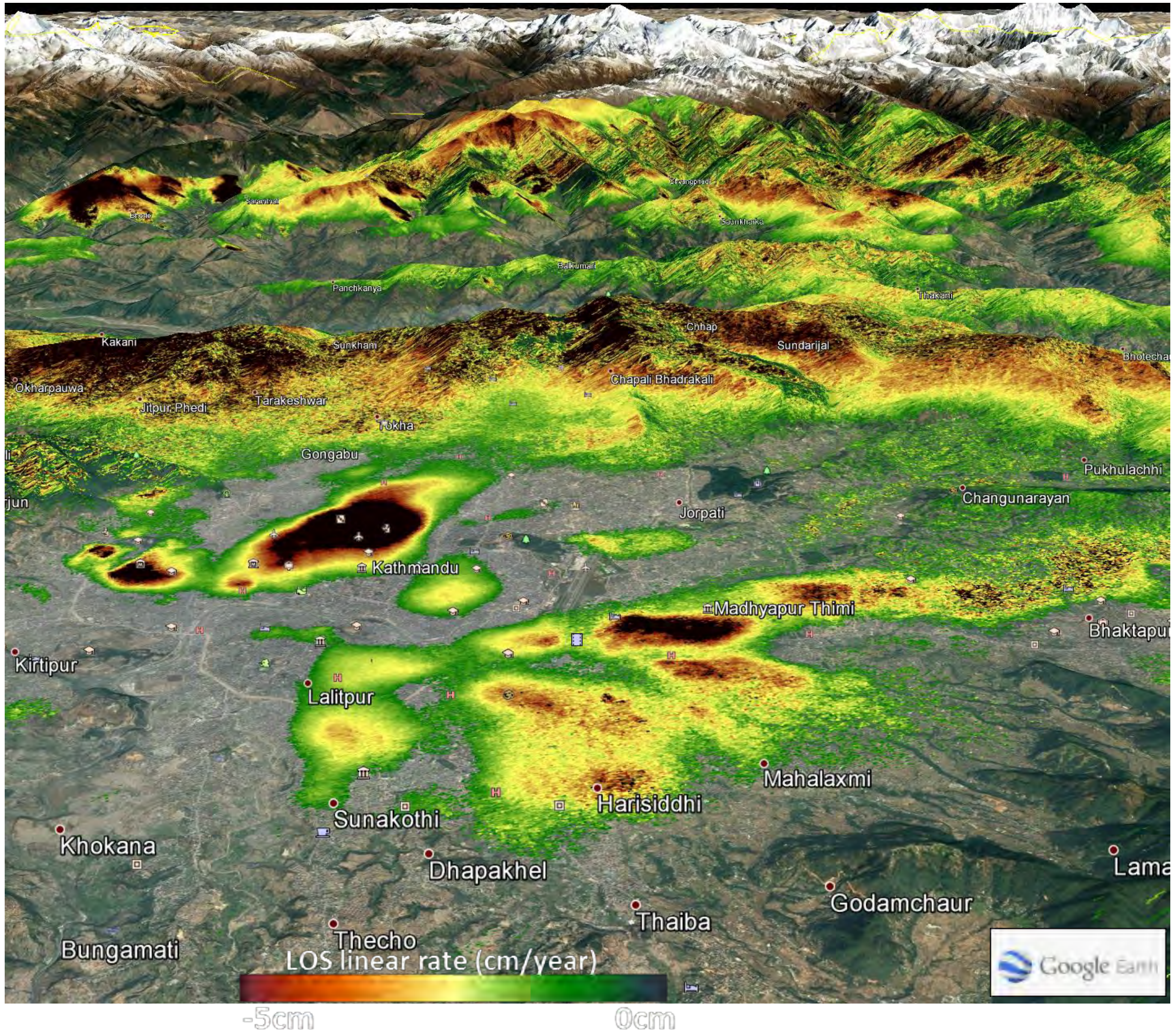
Yun-Hsien landslide, Wulai, New Taiepi city, Taiwan



POST EARTHQUAKE MOTION, **NEPAL**

Singhroy and Li



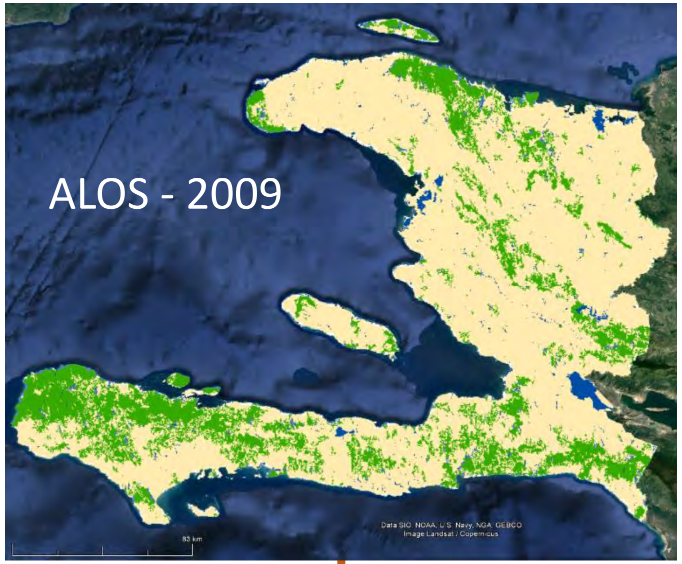


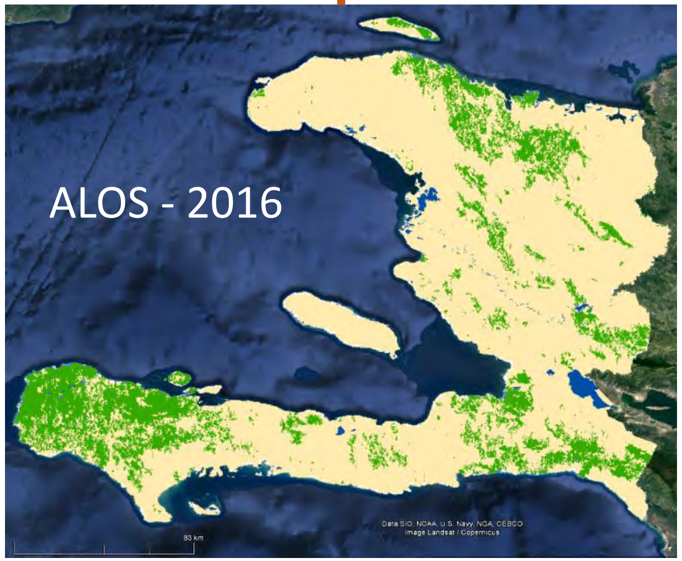
ALOS-2 20150502 20150725 20150822 20151003 20160220 stacking (Singhroy and Li)

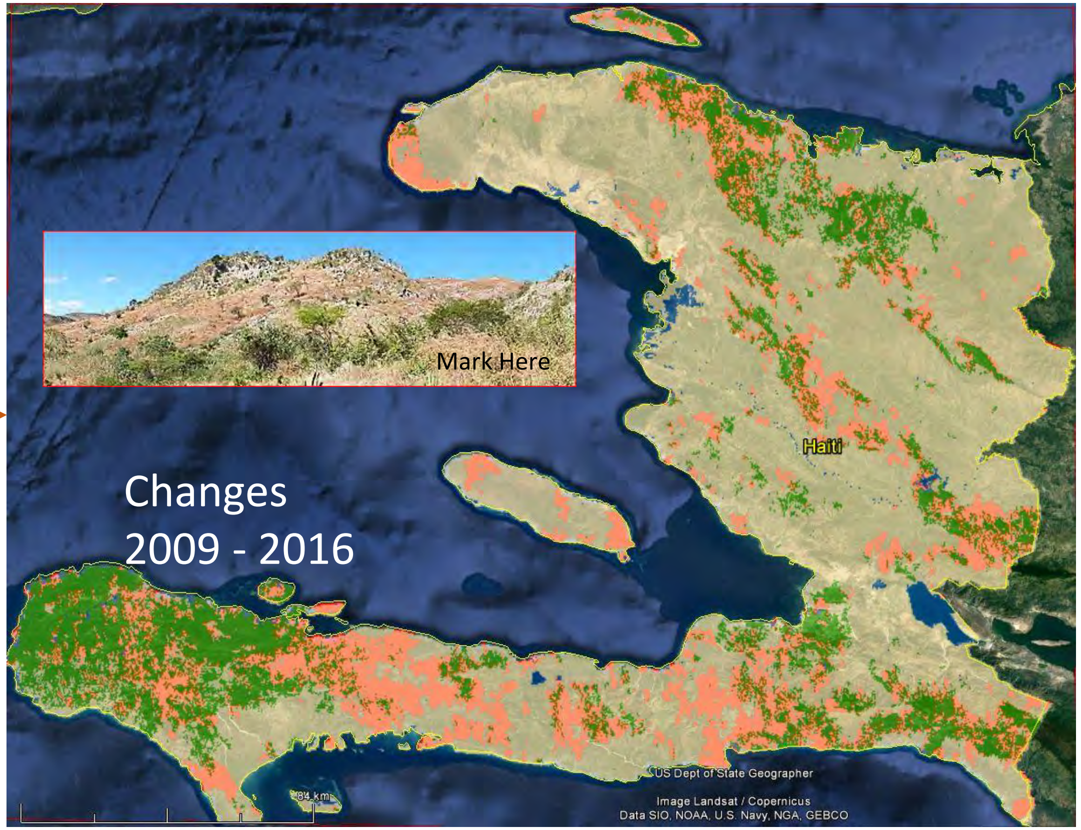
Change detection map before InSAR :Haiti

ALOS PALSAR-2/PALSAR

- 25 m
- L - Band



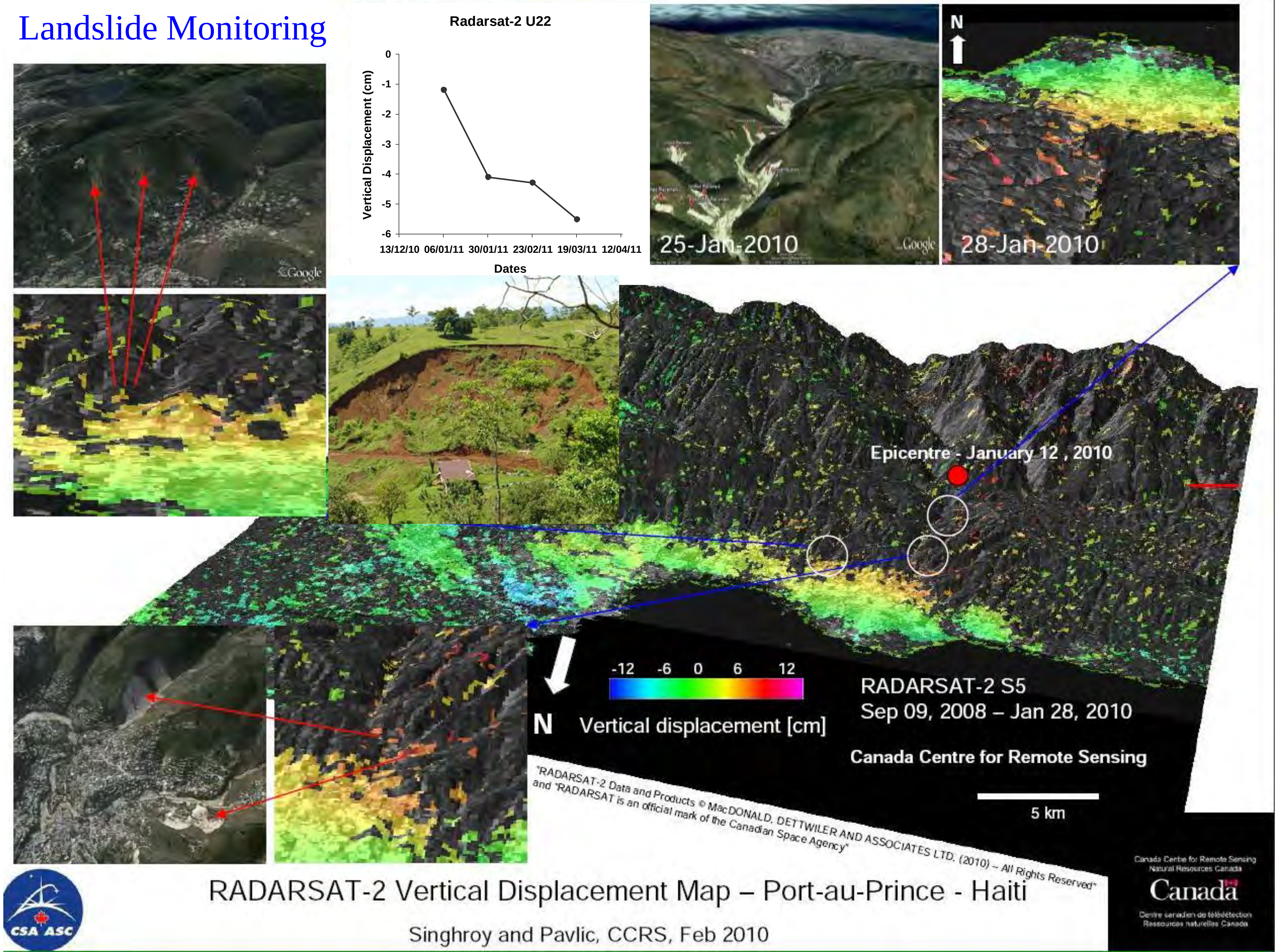




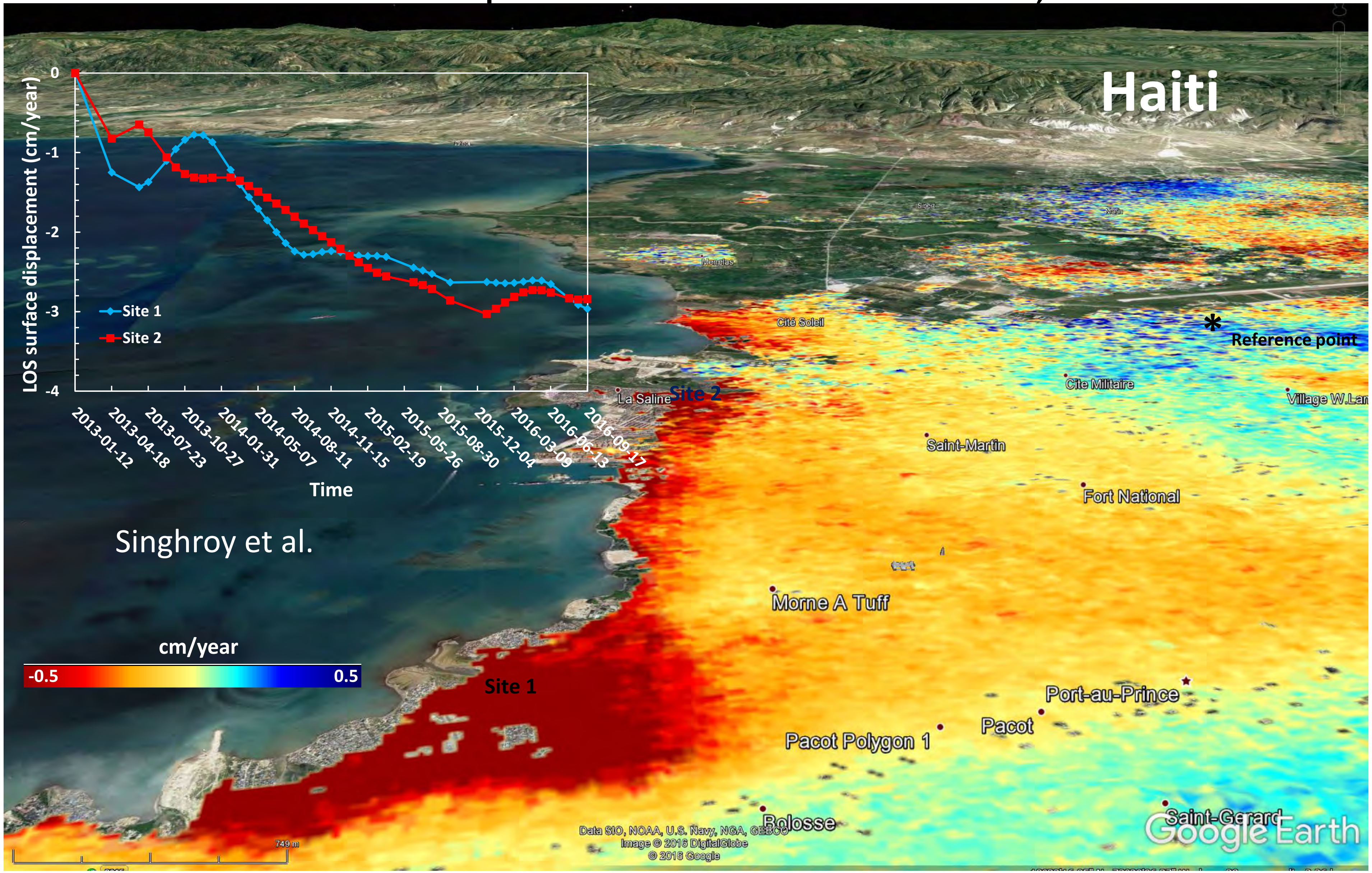
Changes 2009 – 2016
Forest
Non Forest

Singhroy, V. and Fobert, M. (CCRS)

Landslide Monitoring



Post earthquake subsidence on marine sediments, Haiti



Radarsat-2 Standard Beam Mode 5 (S5) Descending

Conclusions

- Reliable InSAR measurements of surface displacement can be achieved using simple guidelines.
- InSAR techniques are being used to monitor the spatial and temporal terrain movements in order to understand the dynamics of low velocity landslides affecting transportation and energy corridors.
- Our InSAR measurements show different rates of motion based on favourable geological and seasonal conditions. These factors explain triggering mechanisms and deformation behaviour.
- RADARSAT and other high resolution and rapid revisit constellations are useful to monitor deformation on a weekly basis for improved mitigation measures.
- The InSAR techniques are useful methodologies in developing a mitigation strategy and early warning system for areas affected by geohazards