Introduction to Synthetic Aperture Radar

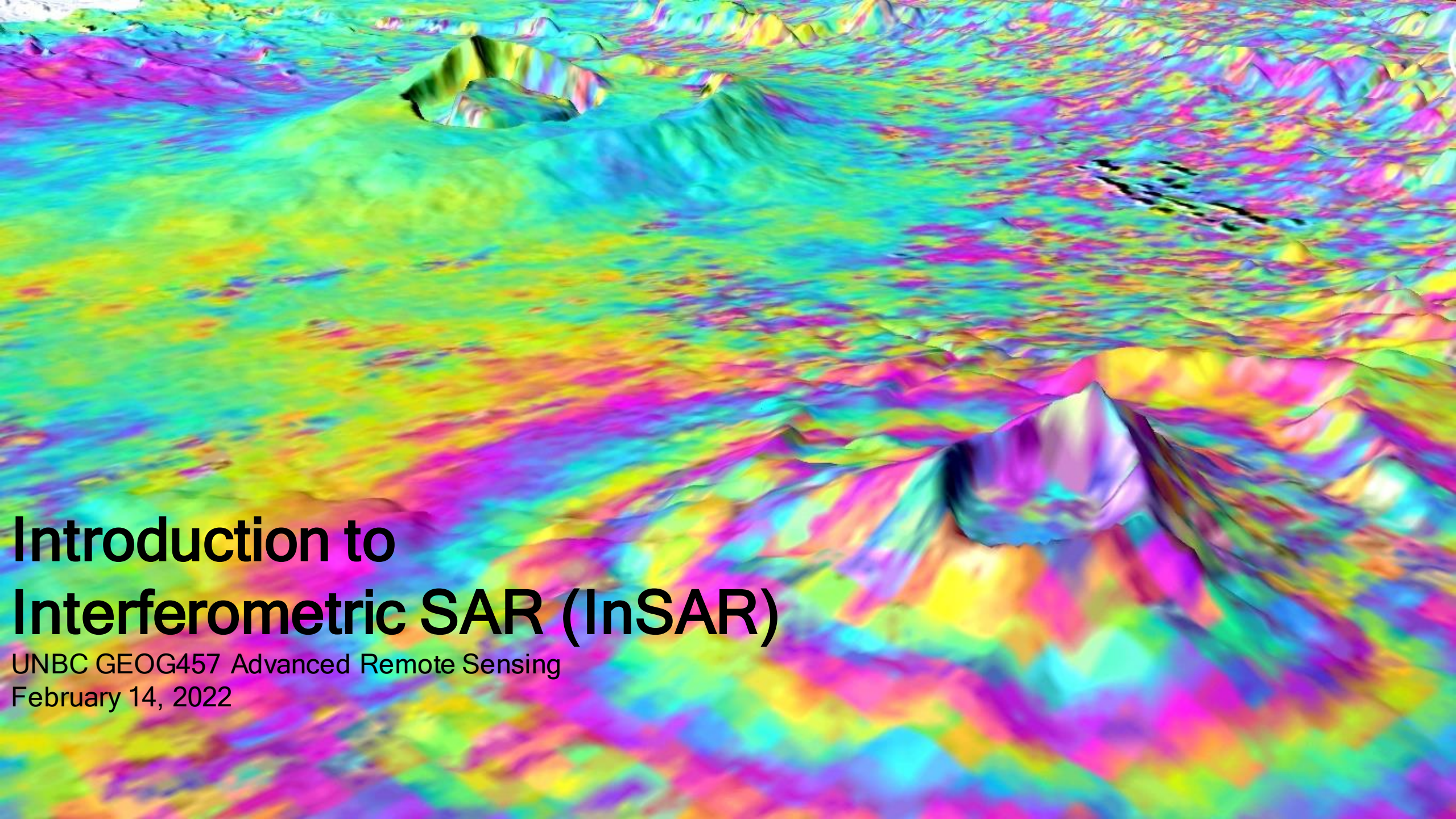
UNBC GEOG457 Advanced Remote Sensing

February 11, 2022

Sentinel-1, Fraser Delta, Floods

Review

- SAR platforms:
  - Satellite
  - Aircraft
  - Space shuttle
- SAR can acquire data at night and through clouds
- Orbits are ascending or descending, looks to one side only
- Resolution is controlled by:
  - Pulse duration (range/across-track/x direction)
  - Length of aperture (azimuth/along-track/y direction)
- Different wavelengths typically include:
  - X (10 GHz ~3 cm) TerraSAR-X, Capella
  - C (5.3 GHz ~ 5 cm) ERS, Sentinel-1, Radarsat, SRTM
  - L (1.2 GHz ~ 20 cm) J-ERS, ALOS, NISAR (soon)
- SAR data consists of:
  - Phase (where on sine wave)
  - Amplitude (strength of return)
- Polarization
  - HH or VV or HV or VH
  - Single, dual, or quad
- SAR distortions:
  - Foreshortening
  - Layover
  - Shadow



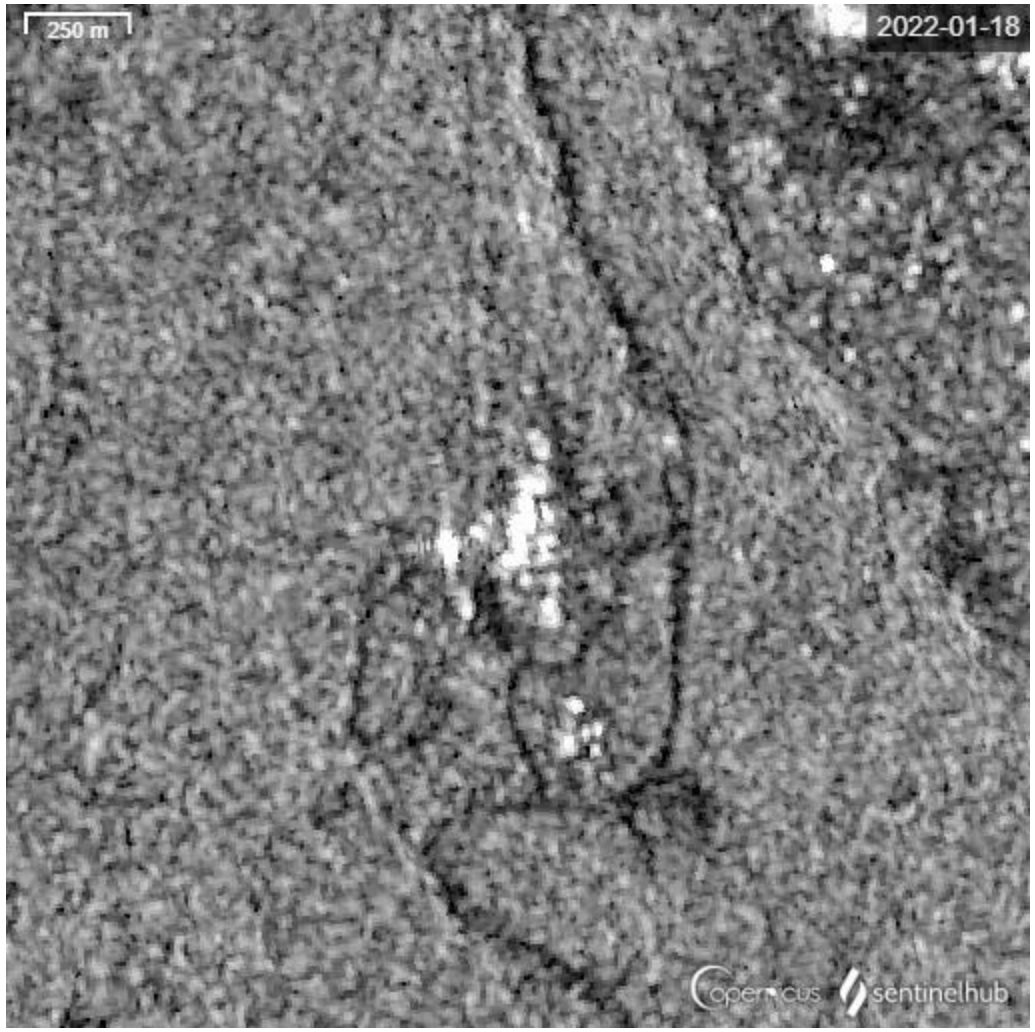
Introduction to Interferometric SAR (InSAR)

UNBC GEOG457 Advanced Remote Sensing

February 14, 2022

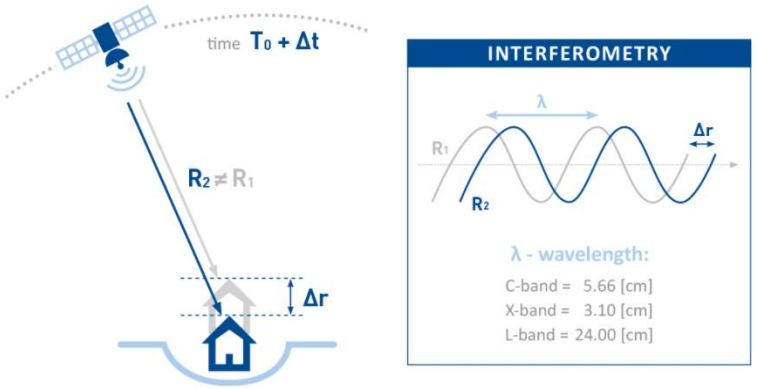
Backscatter, Speckle and Coherence

- **Backscatter**
  is the reflection of the radar pulse. Various properties of the target affect how much it backscatters the signal (e.g. Slope, Texture, Dielectric properties)
- **Speckle**
  is a scattering phenomenon that arises because the spatial resolution of the sensor is not sufficient to resolve individual scatterers.
- **Coherence**
  is the backscatter cross-correlation coefficient of the SAR image pair estimated over a small window. InSAR only works for coherent pixels. Too much speckle is bad for InSAR.



Interferometry

- The measurement of relative distance to an object using the phase information from two or more SAR observations
- Conditions:
  - Observations must be separated in space or in time
  - Observations must be coherent with similar acquisition geometries
  - Interferometry only works on the order of the wavelength



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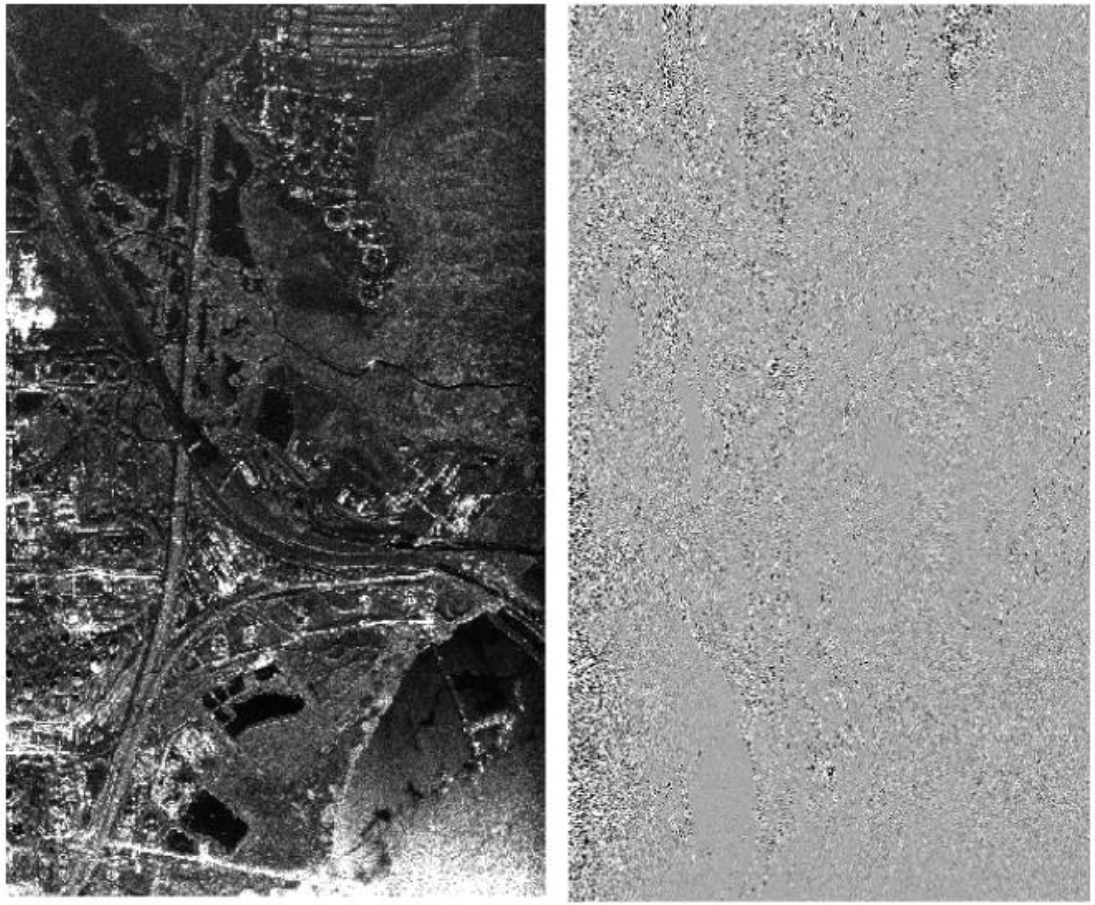
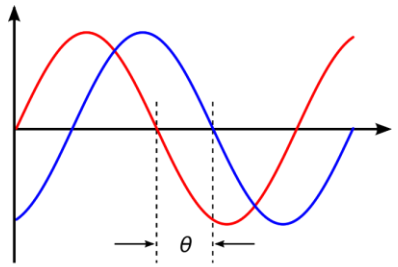
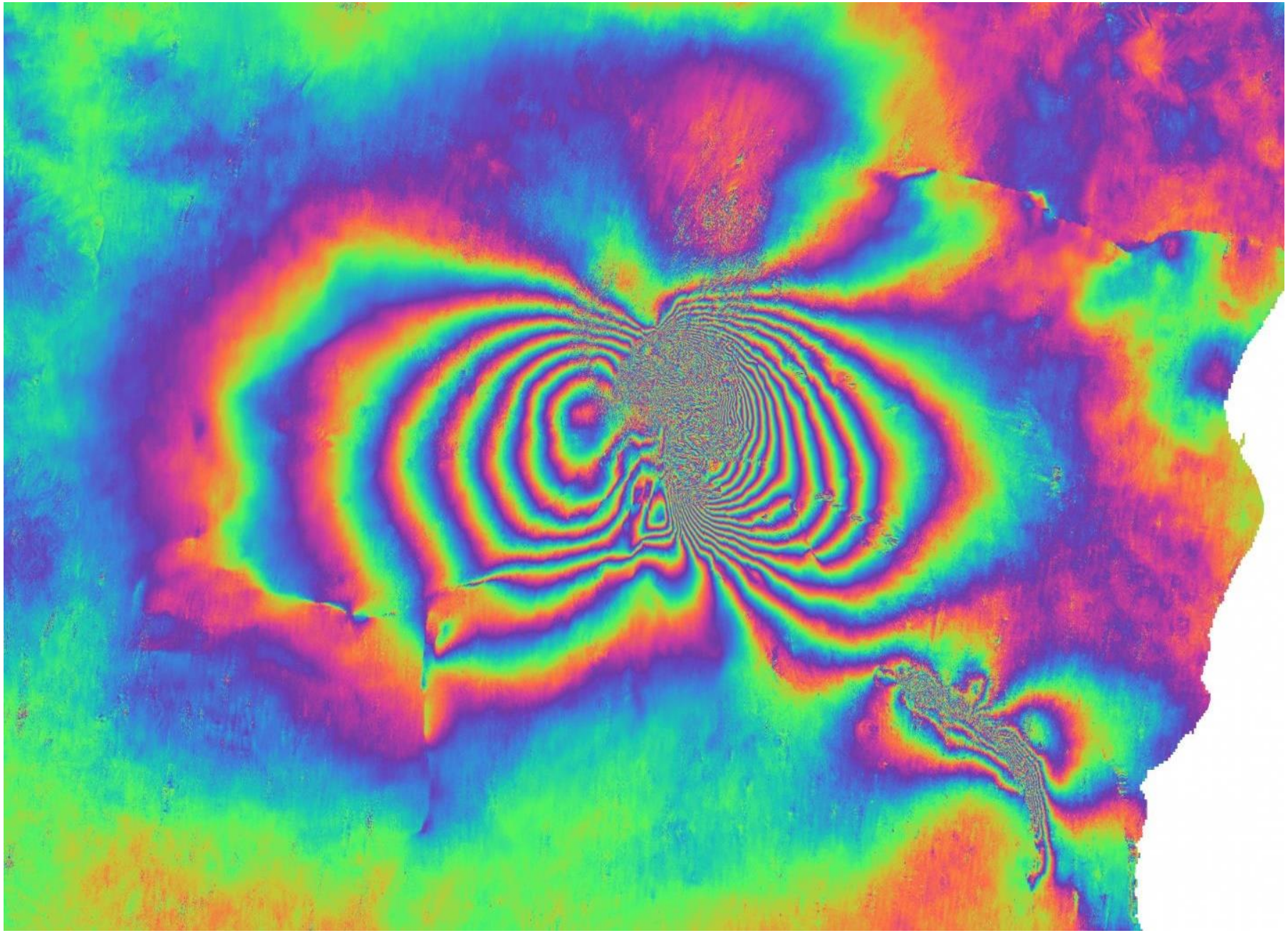


https://medium.com/the-downlinq/sar-201-an-introduction-to-synthetic-aperture-radar-part-2-895beb0b4c0a

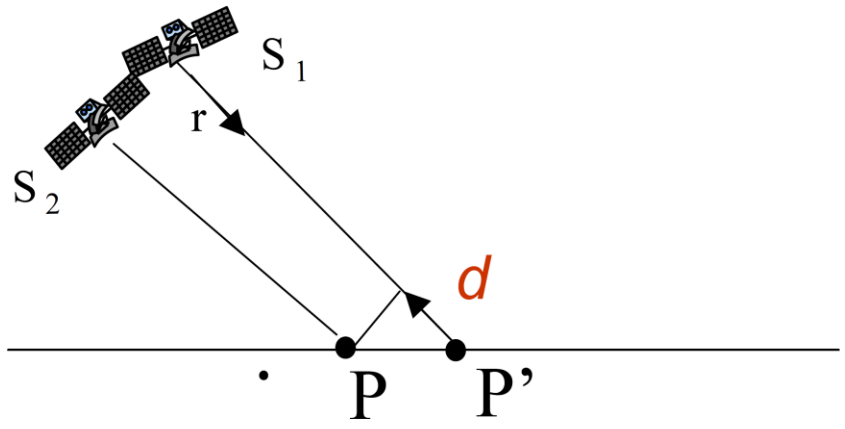




This is an interferogram of the December 2018 eruption of Etna in southern Italy, based on Sentinel-1 satellite images. Interferograms spatially map ground surface movements. The colors represent the fringes.
MOUNTS system, Data: ESA Sentinel, edited: Sébastien Valade, GFZ

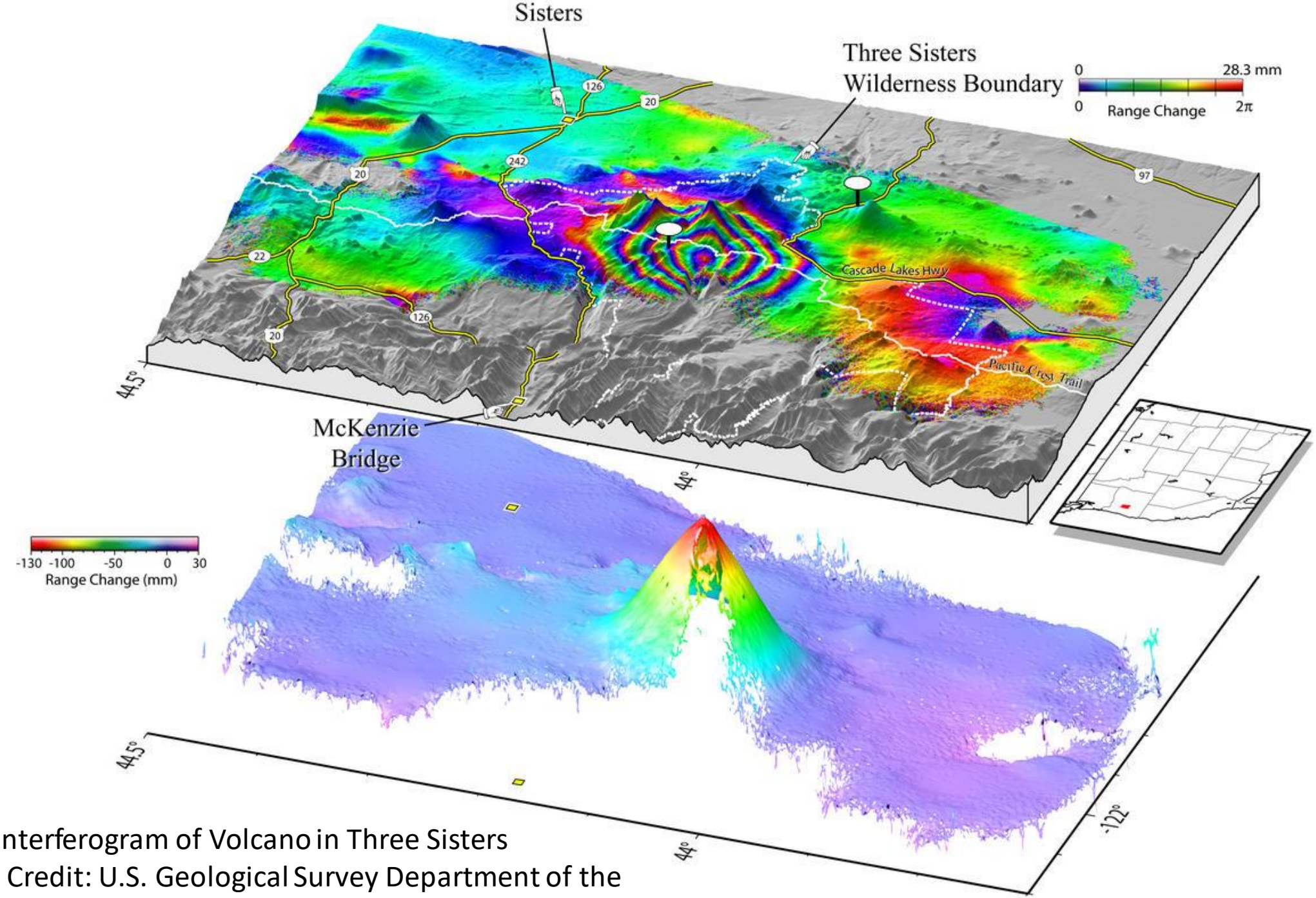
Line of Sight (LOS) Phase differencing

What kind of displacement is not visible to SAR?

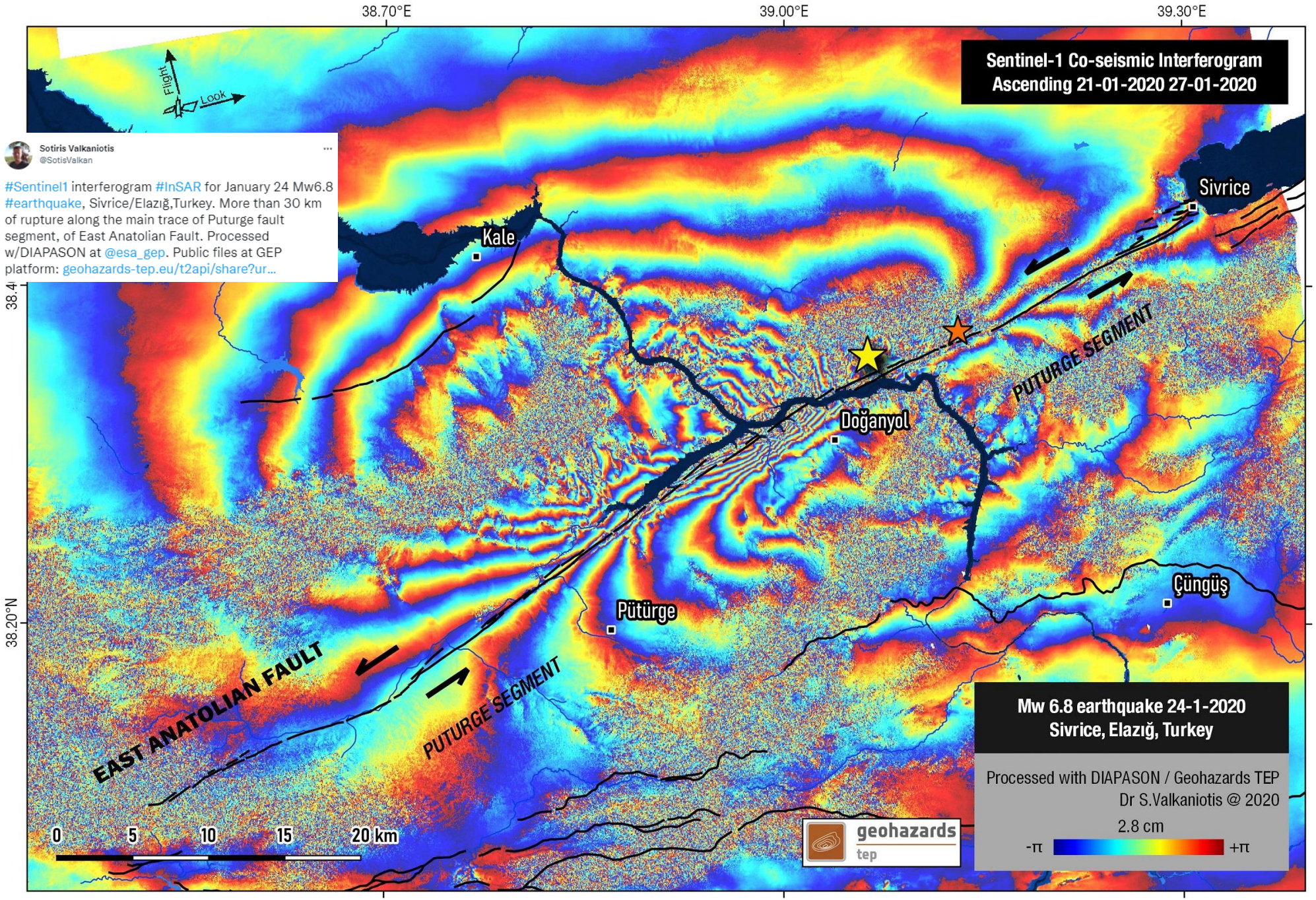


$$\Delta\varphi_{displacement} = \frac{4\pi}{\lambda} d$$

Here, d is the relative scatterer displacement projected on the slant-range direction



1995-2001 Interferogram of Volcano in Three Sisters Wilderness. Credit: U.S. Geological Survey Department of the Interior/USGS


38.70°E
39.00°E
39.30°E
38.4
38.20°N
Flight
Look
Sentinel-1 Co-seismic Interferogram
Ascending 21-01-2020 27-01-2020
Sotiris Valkaniotis
@SotisValkan
#Sentinel1 interferogram #InSAR for January 24 Mw6.8 #earthquake, Sivrice/Elazığ,Turkey. More than 30 km of rupture along the main trace of Puturge fault segment, of East Anatolian Fault. Processed w/DIAPASON at @esa_gep. Public files at GEP platform: geohazards-tep.eu/t2api/share?ur...
Kale
Sivrice
Doğanyol
Pütürge
Çüngüş
PUTURGE SEGMENT
EAST ANATOLIAN FAULT
PUTURGE SEGMENT
0 5 10 15 20 km
geohazards tep
Mw 6.8 earthquake 24-1-2020
Sivrice, Elazığ, Turkey
Processed with DIAPASON / Geohazards TEP
Dr S.Valkaniotis @ 2020
2.8 cm
-π
+π

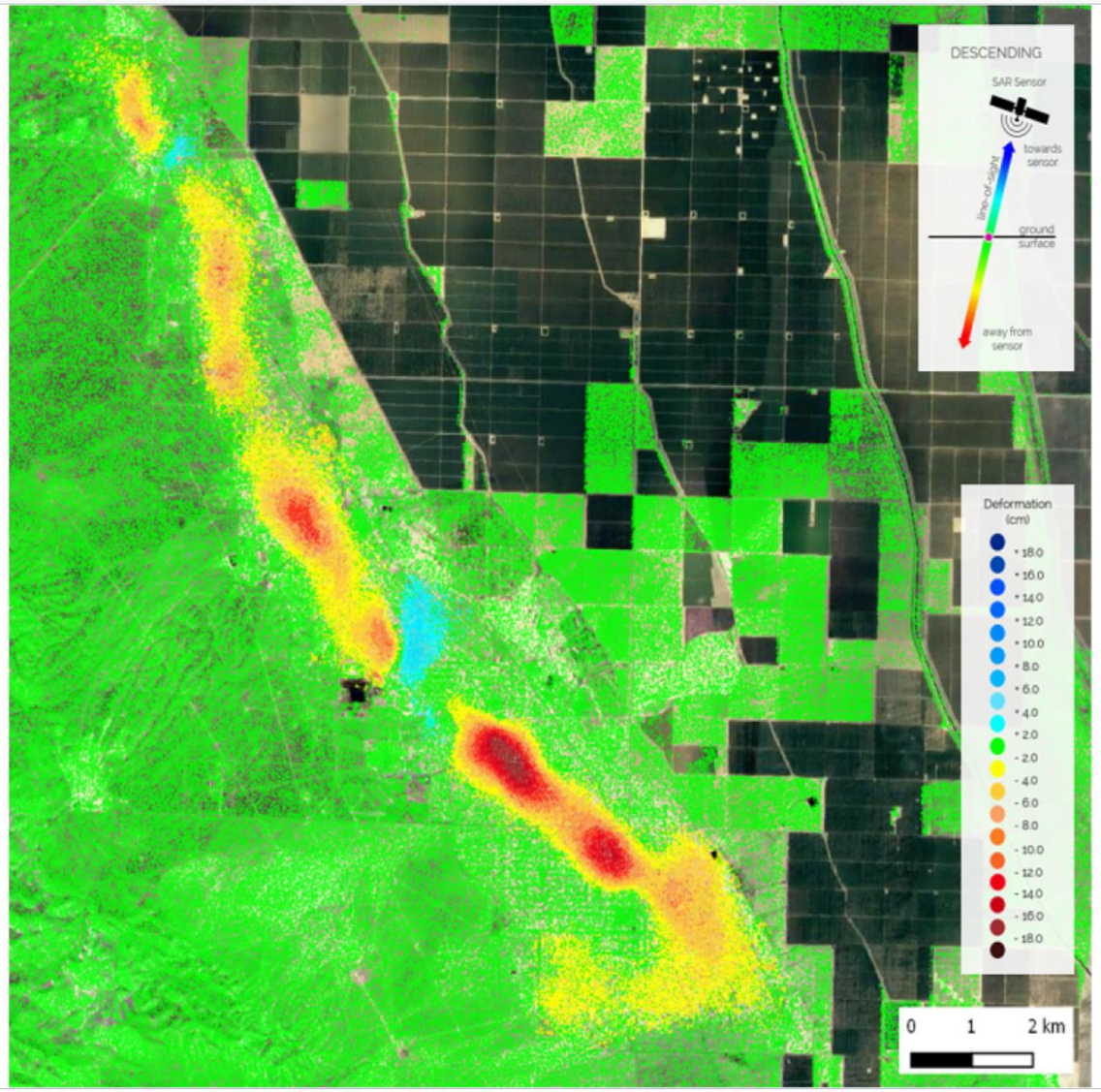
SOUTH-BELRIDGE OIL FIELD,
CALIFORNIA, USA

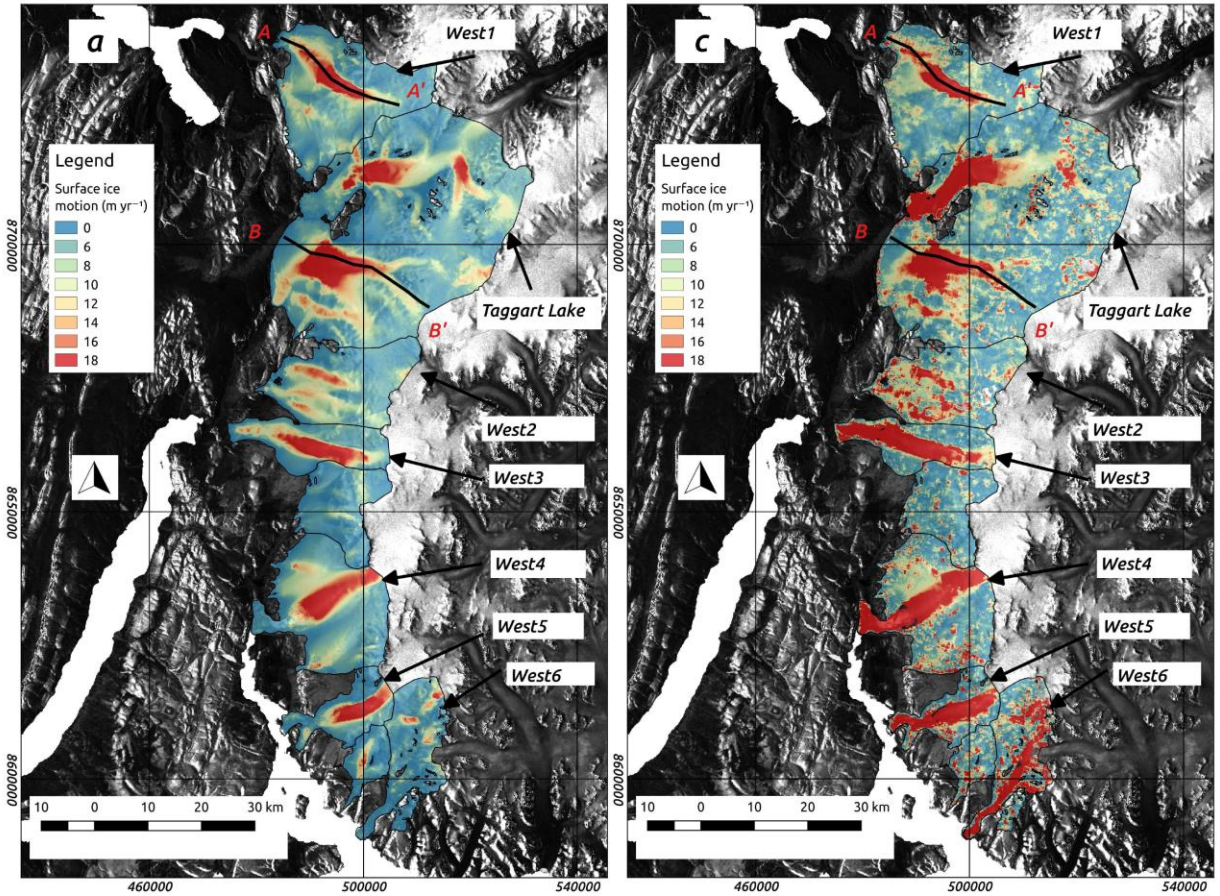
Heave monitoring for oil extraction

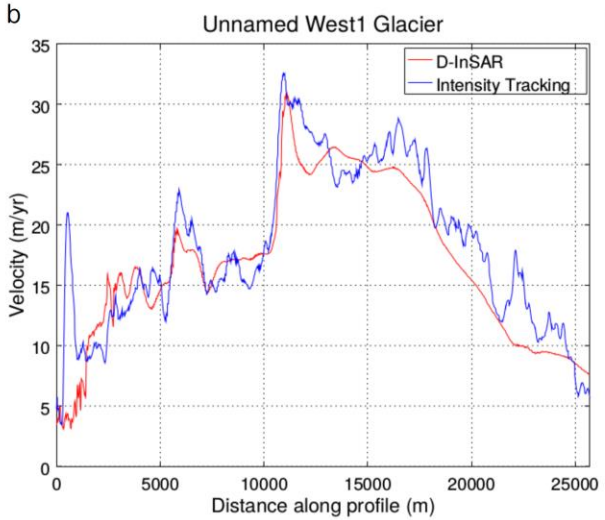
Clear spots of surface deformation have been detected over production areas

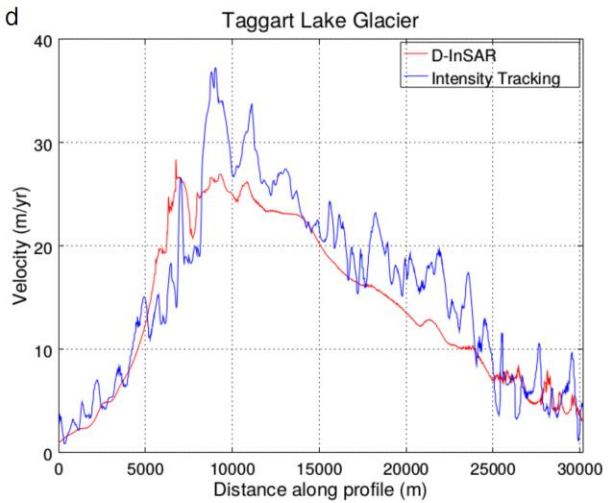
South-Belridge is considered one of the most productive oil reservoirs in the US. This figure shows an accumulated displacement of up to 20 cm corresponding to a 12-month period between 2018 and 2019 using a total of 33 Sentinel-1 images in DSC mode. Subsidence spots correspond to the areas with higher number of wells.

NEXT CASE









remote sensing

MDPI

Article

Glacier Surface Velocity Retrieval Using D-InSAR and Offset Tracking Techniques Applied to Ascending and Descending Passes of Sentinel-1 Data for Southern Ellesmere Ice Caps, Canadian Arctic

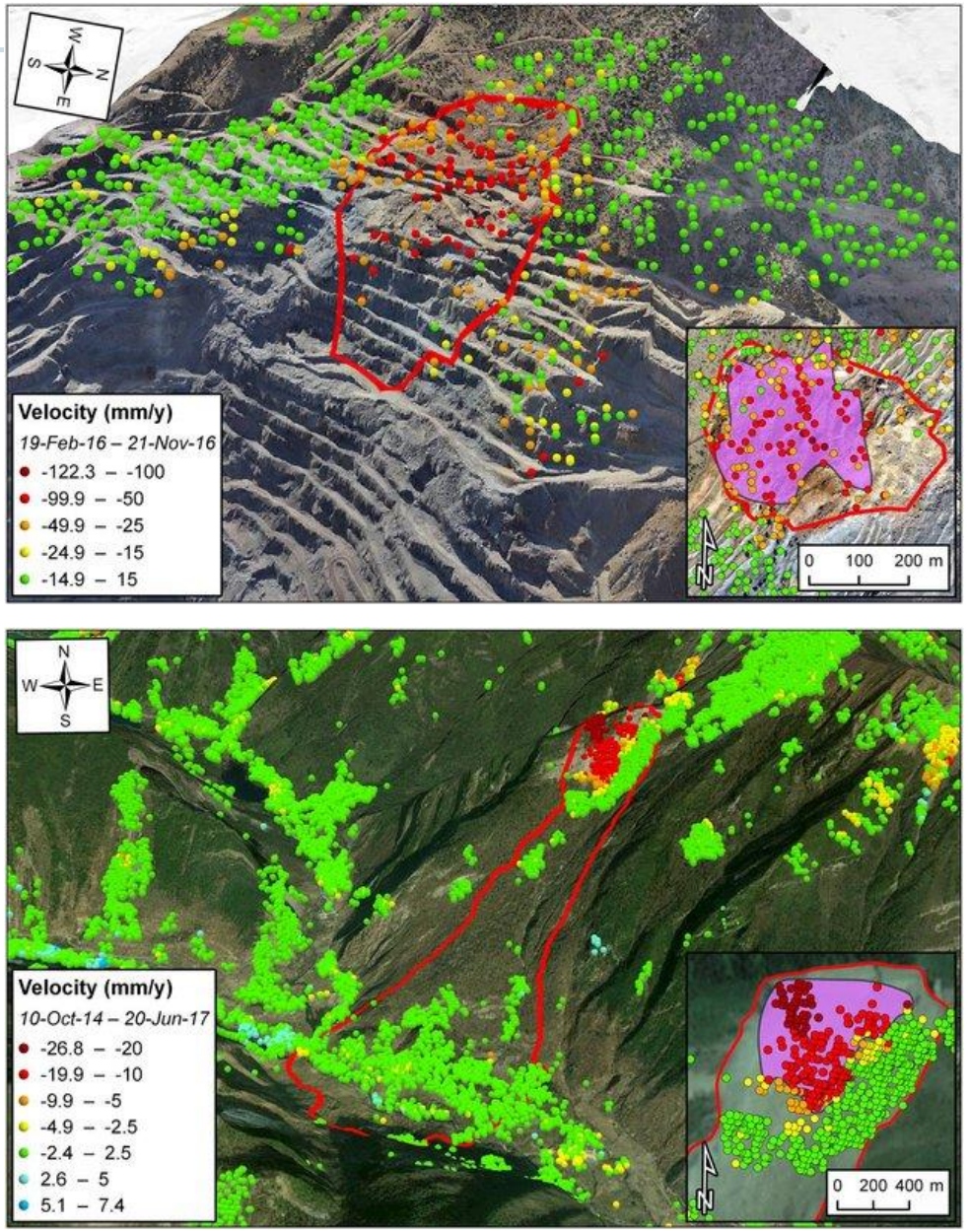
Pablo Sánchez-Gámez * and Francisco J. Navarro

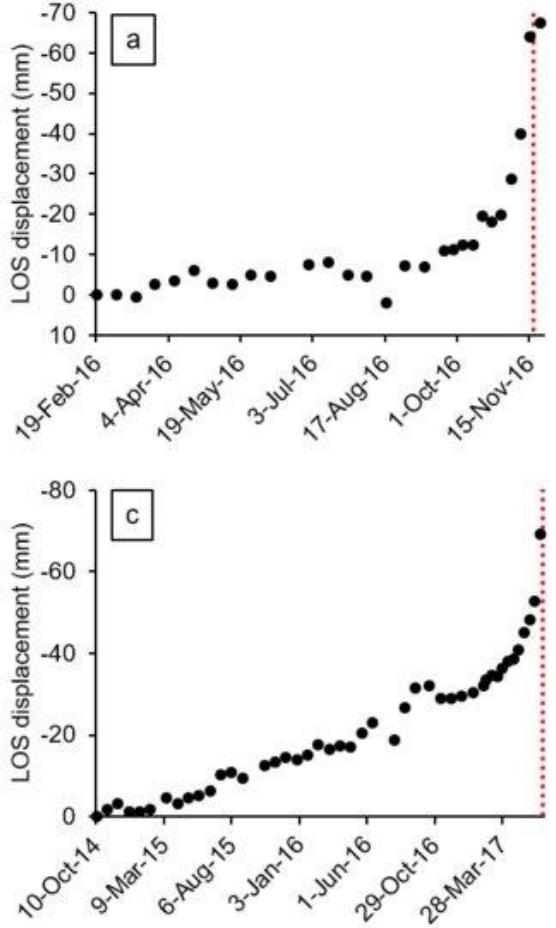
scientific reports

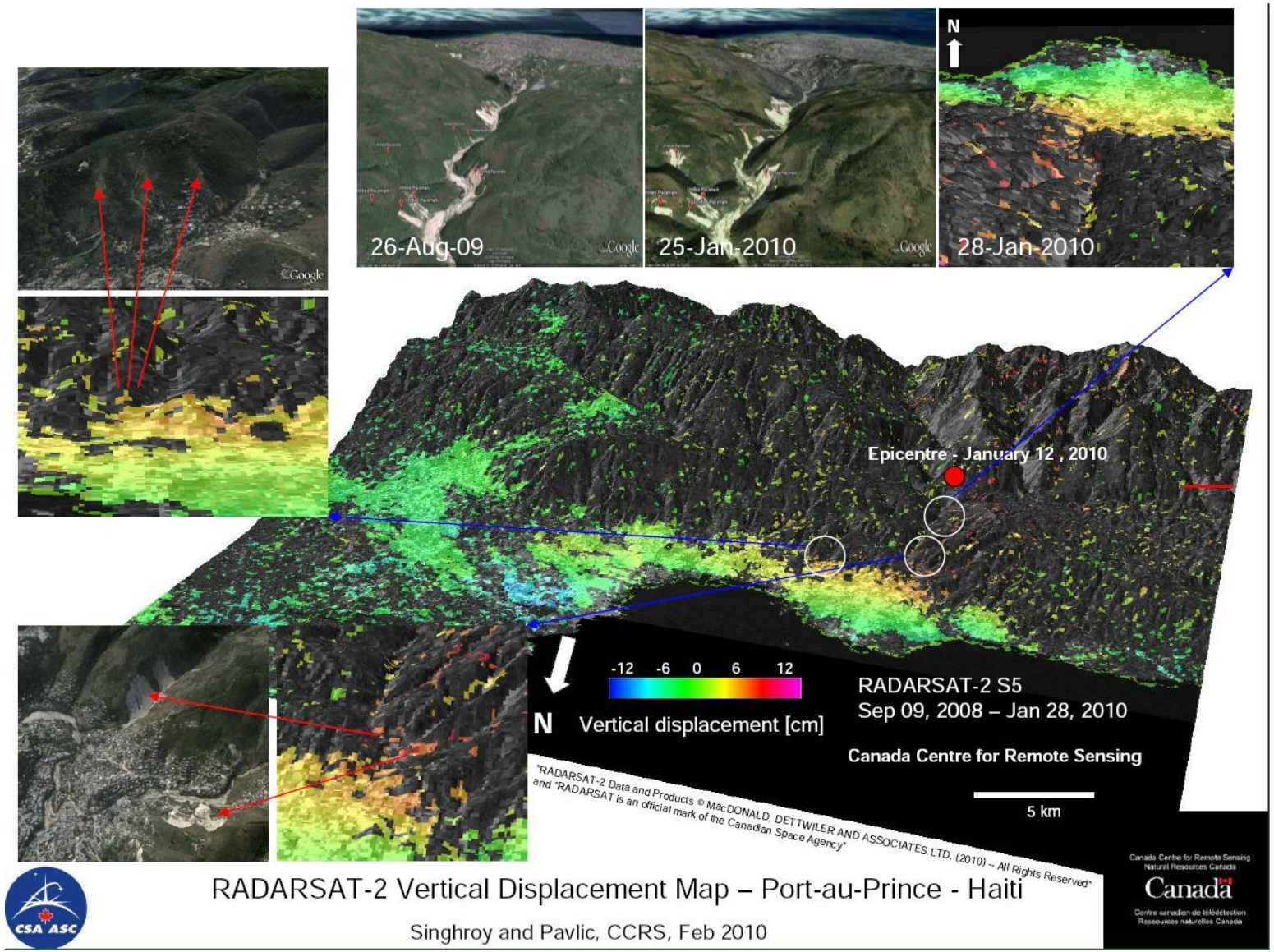
Article | Open Access | Published: 01 October 2019

Perspectives on the prediction of catastrophic slope failures from satellite InSAR

Tommaso Carlà, Emanuele Intrieri, Federico Raspini, Federica Bardi, Paolo Farina, Alessandro Ferretti, Davide Colombo, Fabrizio Novali & Nicola Casagli

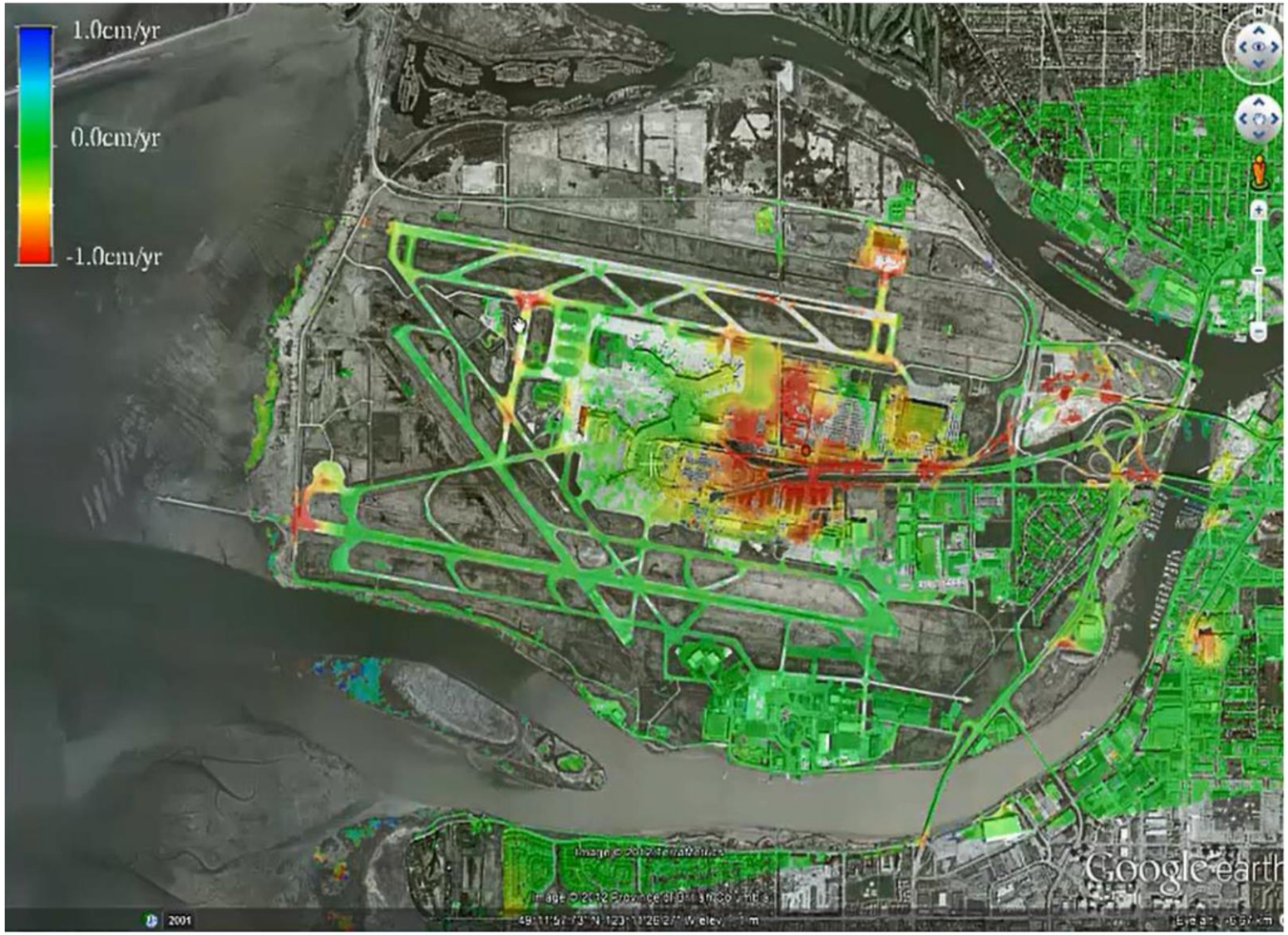


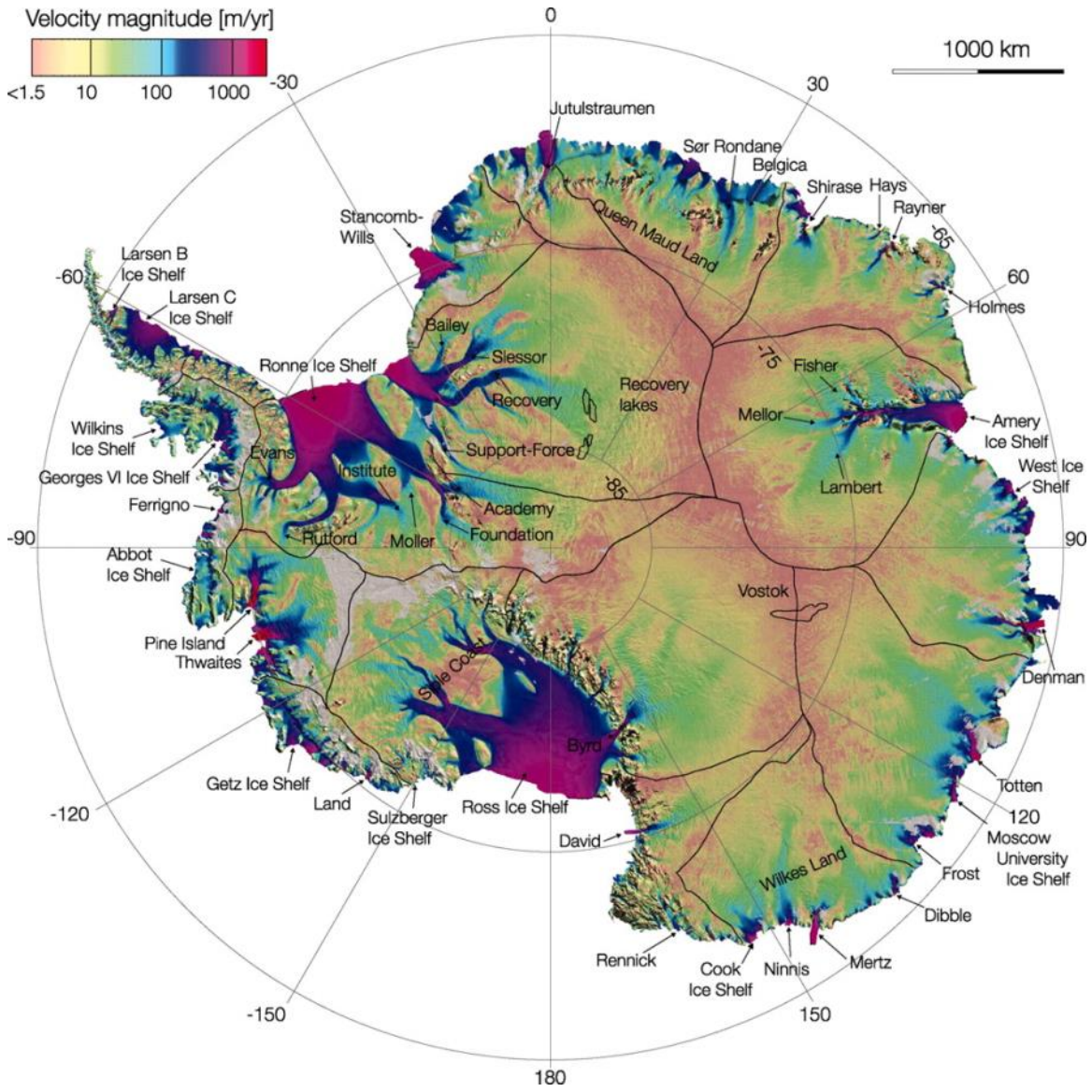




RADARSAT-2 Vertical Displacement Map – Port-au-Prince - Haiti

Singhroy and Pavlic, CCRS, Feb 2010


1.0cm/yr
0.0cm/yr
-1.0cm/yr
Google earth



Rignot et al. 2011 **Science**

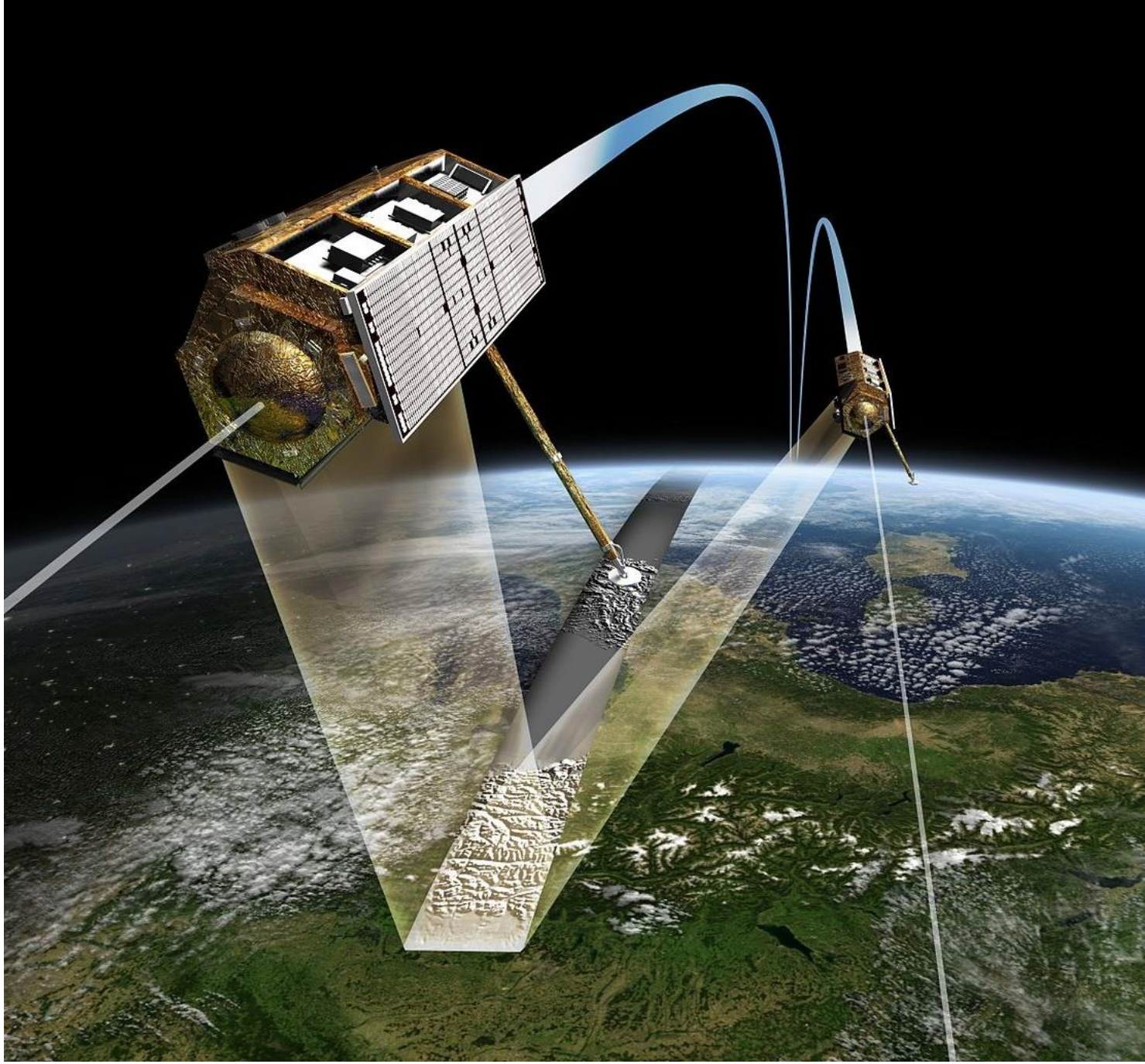
Antarctic ice velocity derived from ALOS PALSAR, Envisat ASAR, RADARSAT-2, and ERS-1/2 satellite radar interferometry.

Methods

- **Interferometric SAR (InSAR)**
  Used for DEM generation. InSAR converts the phase differences between two images to relative heights. To get absolute heights a reference DEM is required.
- **Differential InSAR (DInSAR)**
  Used to observe phase changes between two images in a given time. It is used to monitor subsidence/uplift or lateral deformation. To be independent from topograpy, the topographic phase is simulated using a reference DEM and then removed from the interferogram. Time series analysis of the pixels that are coherent in a stack can be done using:
  - **Persistent Scatterer InSAR (PSInSAR or PSI)** or
  - **Small Baseline Subset (SBAS)**

InSAR for DEM

- SRTM
  - Single Pass
  - C-band
  - <60 Lat
  - 90 m and 30 m
  - Vertical accuracy (5-10m)
  - Mapped the globe in 11 days (Feb 2000)
- TanDEM-X
  - Repeat pass
  - X-band
  - Global
  - 12 m
  - Vertical precision (2m)
  - Failed in Dec. 2021



Evaluation of TanDEM-X DEMs on selected Brazilian sites: Comparison with SRTM, ASTER GDEM and ALOS AW3D30

Carlos H. Grohmann

Institute of Energy and Environment, University of São Paulo, São Paulo 05508-010, Brazil

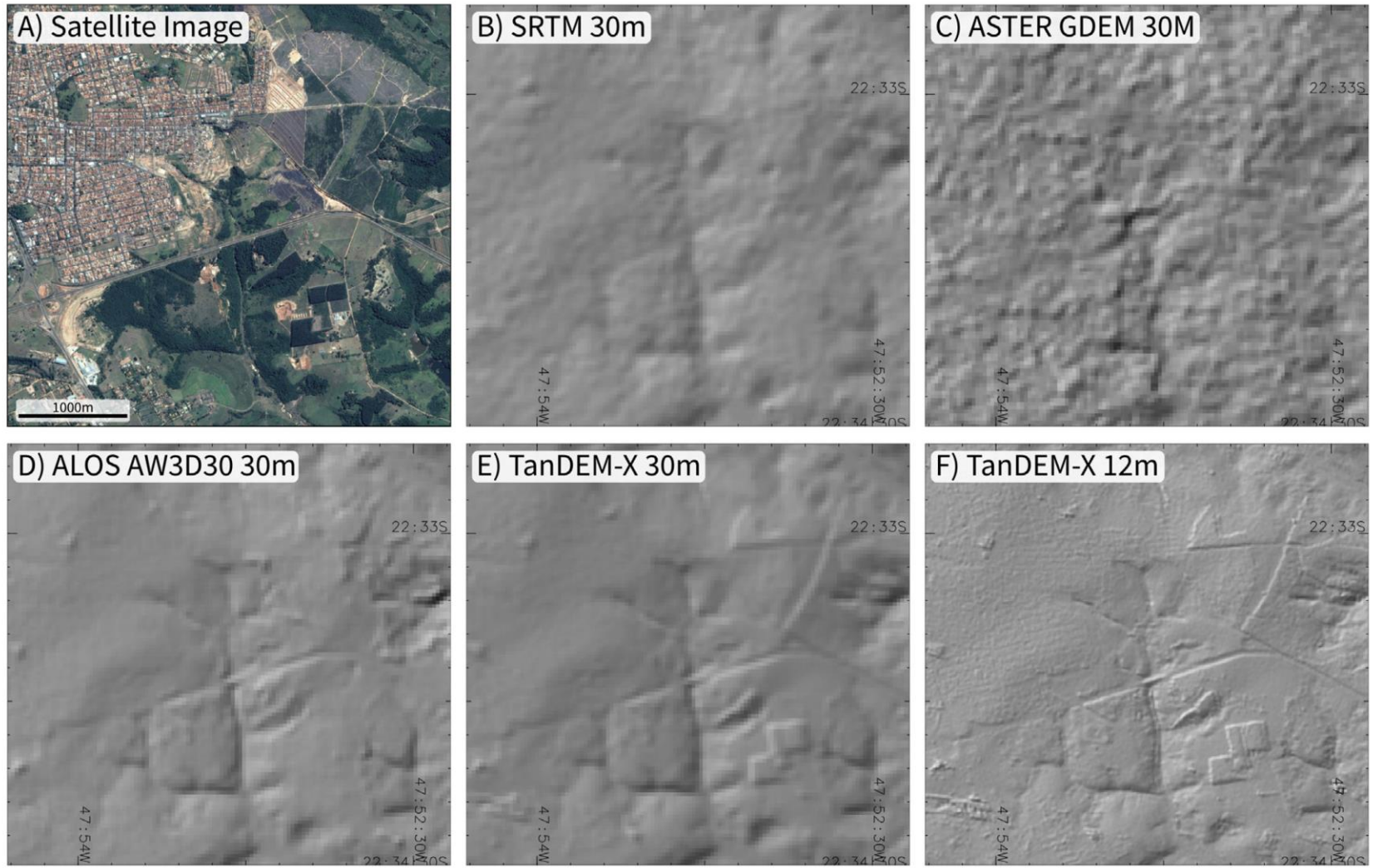
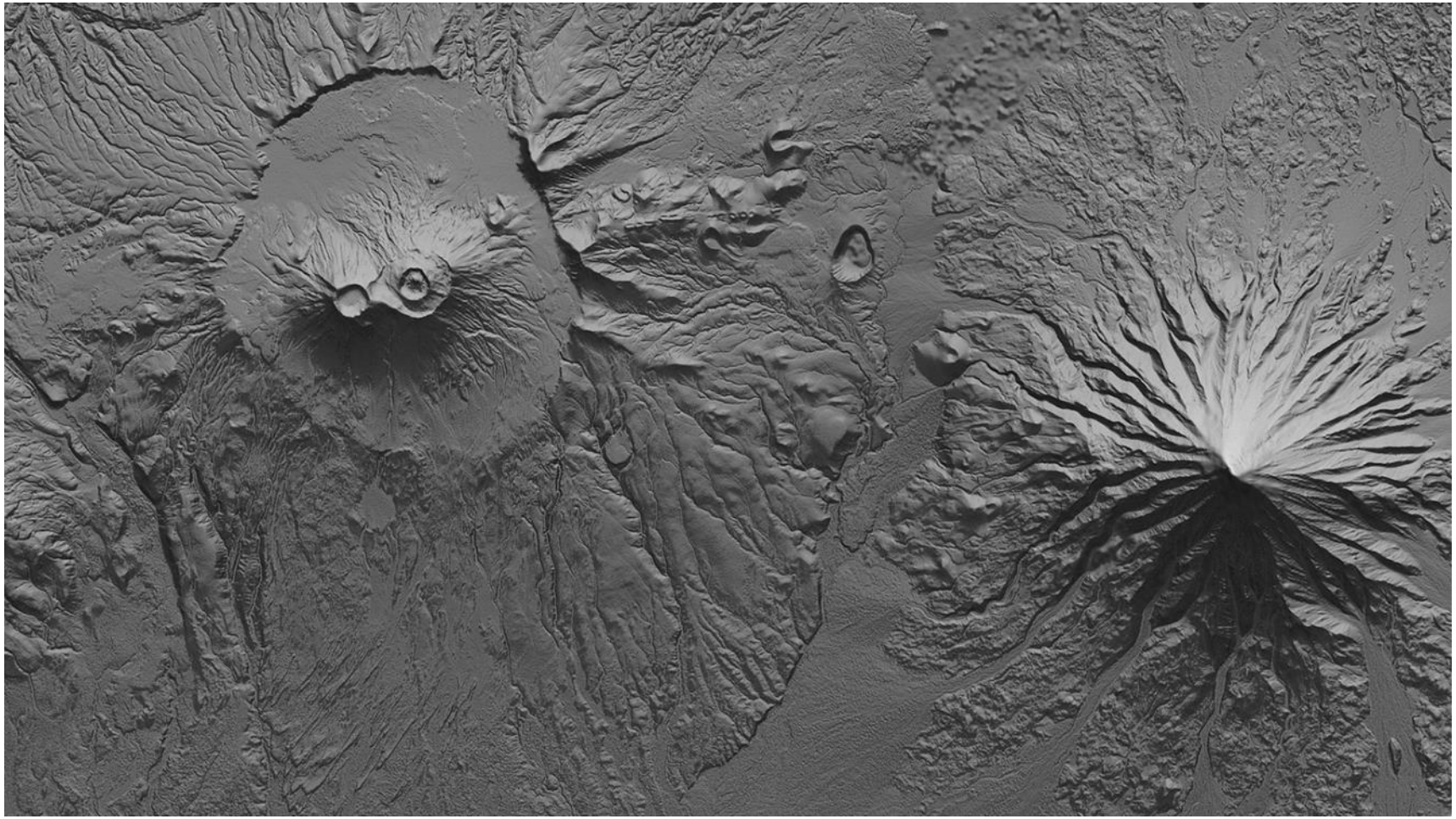


Fig. 2. Inset of the Rio Claro area (see location in Fig. 1E), where the level of detail depicted by each DEM is show by shaded relief maps. All shaded relief images have illumination from 315°N, 20° above horizon. A) Satellite image (image date: 04-18-2016); B) SRTM (30 m); C) ASTER GDEM (30 m); D) ALOS AW3D30 (30 m); E) TanDEM-X (30 m); F) TanDEM-X (12 m). Satellite imagery ©CNES/Airbus, powered by Google.



Elevation models of volcanoes on the Russian Kamchatka Peninsula [German Aerospace Center (DLR), 2015]

Field methods: Corner reflectors

CORNER REFLECTORS AS THE TIE BETWEEN INSAR AND GNSS MEASUREMENTS: CASE STUDY OF RESOURCE EXTRACTION IN AUSTRALIA

Matthew C. Garthwaite [1], Sarah Lawrie [1], John Dawson [1], Medhavy Thankappan [1]

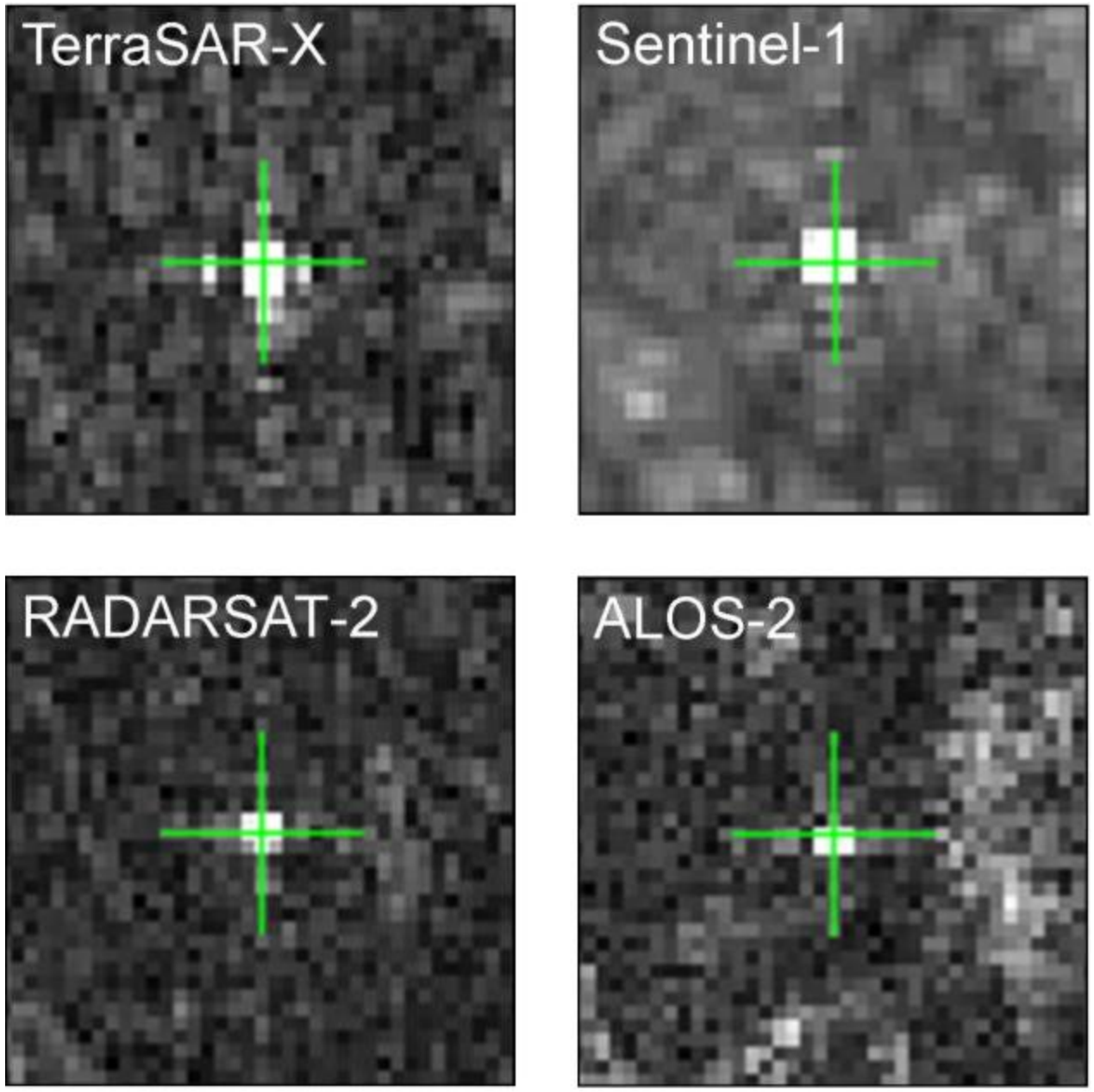


Figure 3. Impulse response for the 1.5 m corner

ESA Sentinel 1

- **Sentinel-1A** is a **C-Band** SAR satellite sensor (**~5.4 GHz**) that was launched aboard the **Soyuz** rocket on **April 3, 2014**
- "Anyone can access SENTINEL data. No distinction is made between public, commercial and scientific uses, or between European or non-European users."
- S1A operates day and night and in all weather conditions, has a **12 day repeat** cycle alone, and **6 day repeat** cycle with S1B is launched in 2016.
- Sentinel 1B failed in late December 2021 and will likely not been fixed
- Dual polarisation capability**:** VV+VH or HH or HV or HH or VV
  HH-HV or HH polarization for the monitoring of polar environments, sea-ice zones
  VV-VH or VV polarization for all other observation zones
- 4 imaging modes with different resolutions (up to 5m) and coverage (up to 400km)

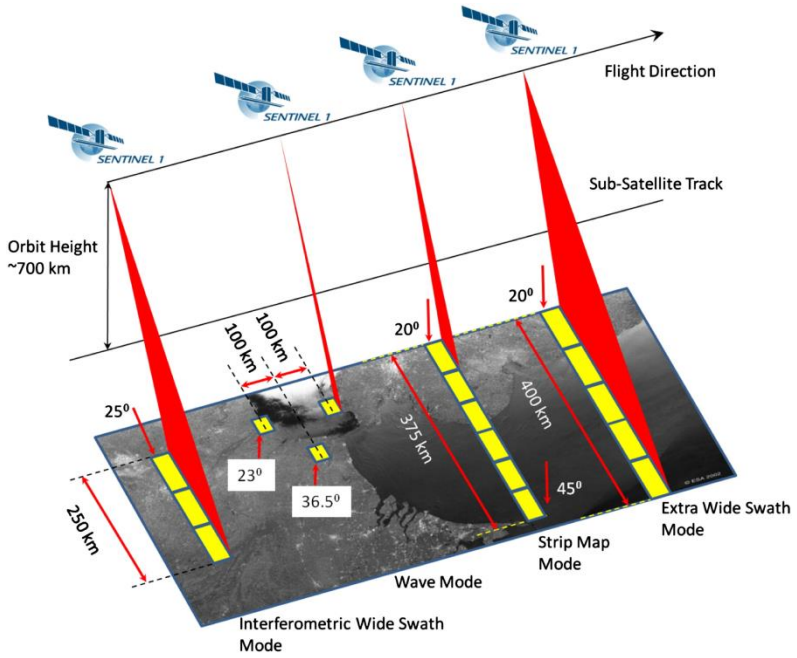
S1 Acquisition modes

- **Strip Map Mode** (SM):
  80 km swath, 5 x 5 m spatial
  Special acquisitions (e.g. priority or emergency)
  HH+HV, VH+VV, HH, VV

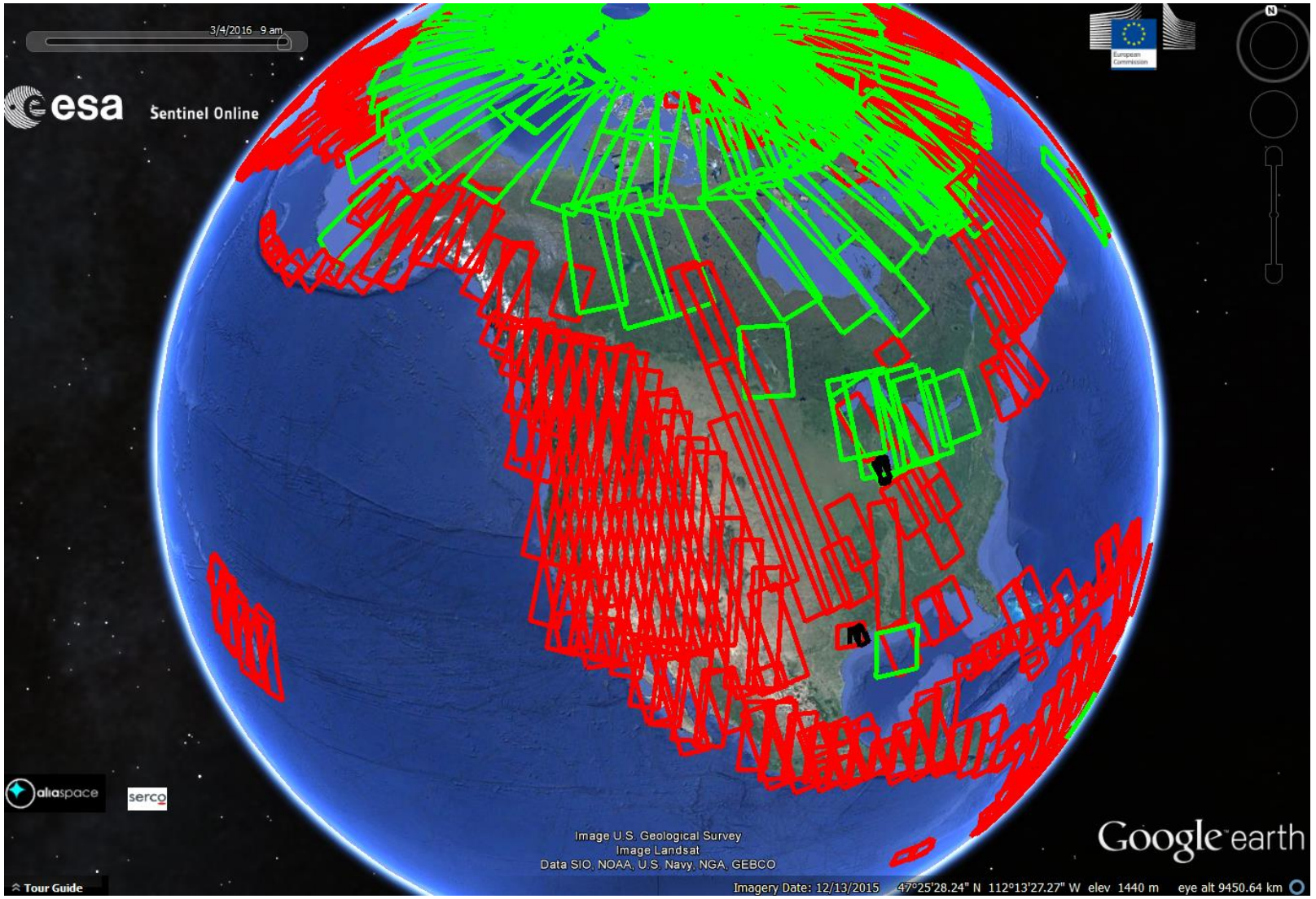
- **Interferometric Wide Swath** (IW):
  250 km swath, 5 x 20 m spatial
  Terrestrial
  HH+HV, VH+VV, HH, VV

- **Extra-Wide Swath Mode** (EW):
  400 km swath, 20 x 40 m
  Maritime, ice and polar
  HH+HV, VH+VV, HH, VV

- **Wave-Mode** (WV): 20 x 20 km, 5 x 5 m
  Ocean
  HH, VV



https://sentinel.esa.int/web/sentinel/missions/sentinel-1/instrument-payload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esa
Sentinel Online
aliaspace
serco
Image U.S. Geological Survey
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Tour Guide
Imagery Date: 12/13/2015 47°25'28.24" N 112°13'27.27" W elev 1440 m eye alt 9450.64 km

S1 Data products

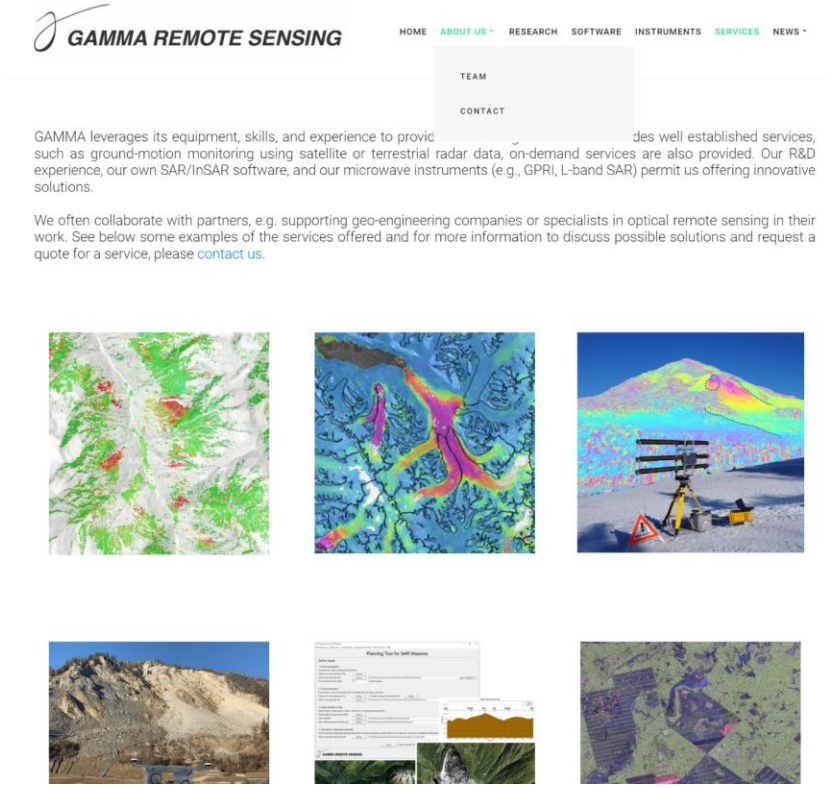
Each mode (SM, EW, IW, WV) can produce Level-0, -1 and -2 products

- **Level-0** Raw (RAW)
  Compressed unfocussed data, needs decompressing and focussing

- **Level-1** Single Look Complex (SLC)
  Focused SAR data geo-referenced using orbit and attitude data preserving the amplitude and phase information

- **Level-1** Ground Range Detected (GRD)
  Focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Phase information is lost.

- **Level-2** Ocean
  Combines SLC data with ocean current models for wind speed and direction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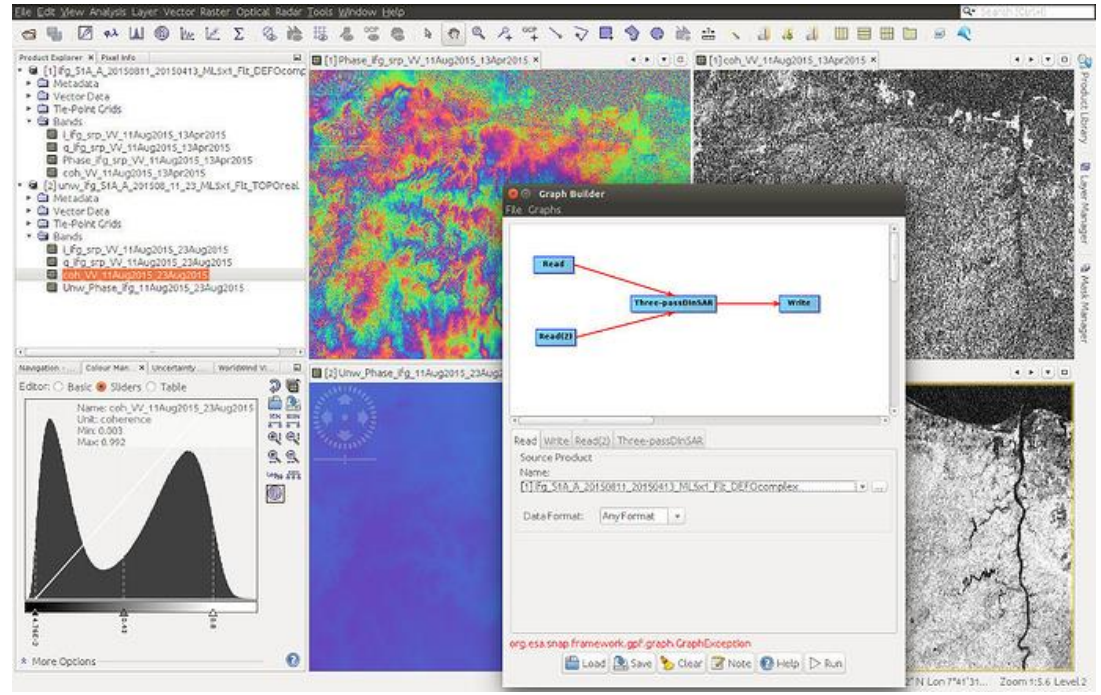
GAMMA leverages its equipment, skills, and experience to provi des well established services, such as ground-motion monitoring using satellite or terrestrial radar data, on-demand services are also provided. Our R&D experience, our own SAR/InSAR software, and our microwave instruments (e.g., GPRI, L-band SAR) permit us offering innovative solutions.
We often collaborate with partners, e.g. supporting geo-engineering companies or specialists in optical remote sensing in their work. See below some examples of the services offered and for more information to discuss possible solutions and request a quote for a service, please contact us.

SNAP


Graph Builder
Read
Three-passDInSAR
Write
Read(2)
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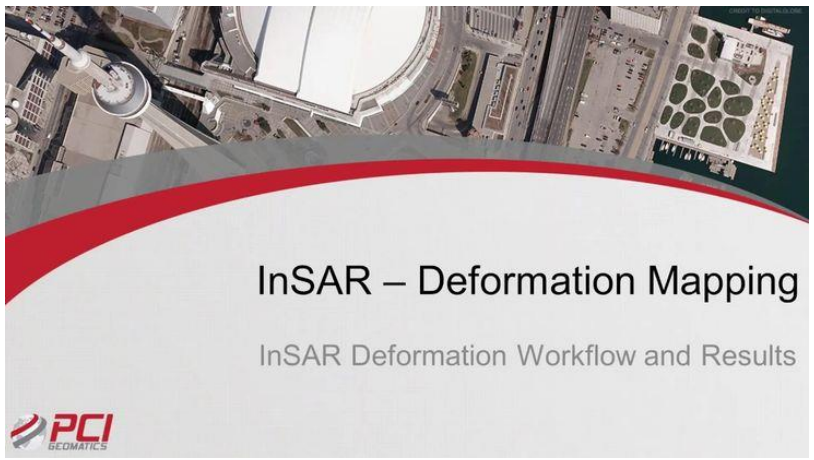
InSAR – Deformation Mapping
InSAR Deformation Workflow and Results
PCI GEOMATICS


GMTSAR
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Downloads
Generate DEM
SAF InSAR Time Series
Contact
Links
Get SAR data
GMTSAR_Wiki
GMT Hawaii
An InSAR processing system based on GMT
David Sandwell - Scripps Institution of Oceanography
Xiaohua (Eric) Xu - Scripps Institution of Oceanography
Rob Mellors - Lawrence Livermore Laboratory
Xiaopeng Tong - Chinese Academy of Sciences
Meng (Matt) Wei - University of Rhode Island
Paul Wessel - University of Hawaii
Anders Hogrelius - Earth Consultants International
Looking for volunteers for testing and development

Cloud processing – on the fly

- InSAR is not on Google Earth Engine or Microsoft Planetary Computer
- InSAR was added to ASF last year! https://search.asf.alaska.edu/