Introduction to Interferometric SAR (InSAR)

UNBC GEOG457 Advanced Remote Sensing
February 18, 2024

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)

- Energy is polarized
  - Can send Horizontal or Vertical, can Receive Horizontal or Vertical
    - HH or VV or HV or VH
    - Single pol: 1 combination
    - Dual pol: 2 combinations
    - Quad-pol: 4 combinations
- SAR distortions:
  - Foreshortening
  - Layover
  - Shadow

# 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, Di-electric properties)

- **Speckle**
  is a scattering phenomenon that arises because the spatial resolution of the sensor is not sufficient to resolve individual scatterers.
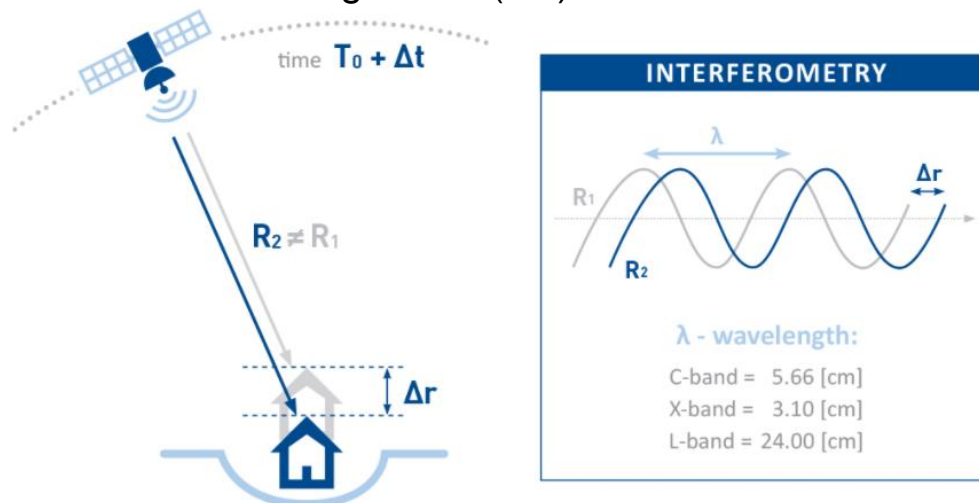
- **Coherence**
  is the backscatter cross-correlation coefficient of the SAR image pair estimated over a small window. InSAR only works for coherent pixels. Too much speckle is bad for InSAR.
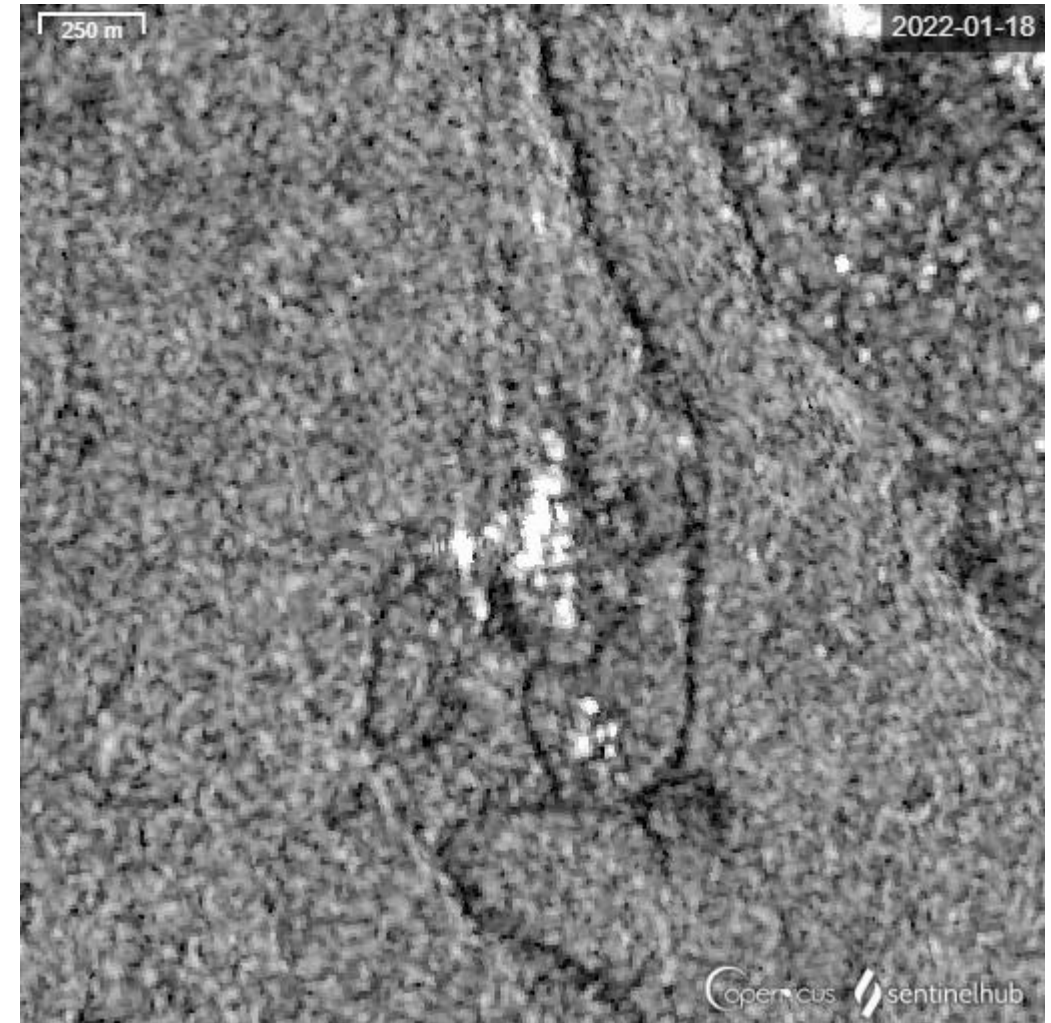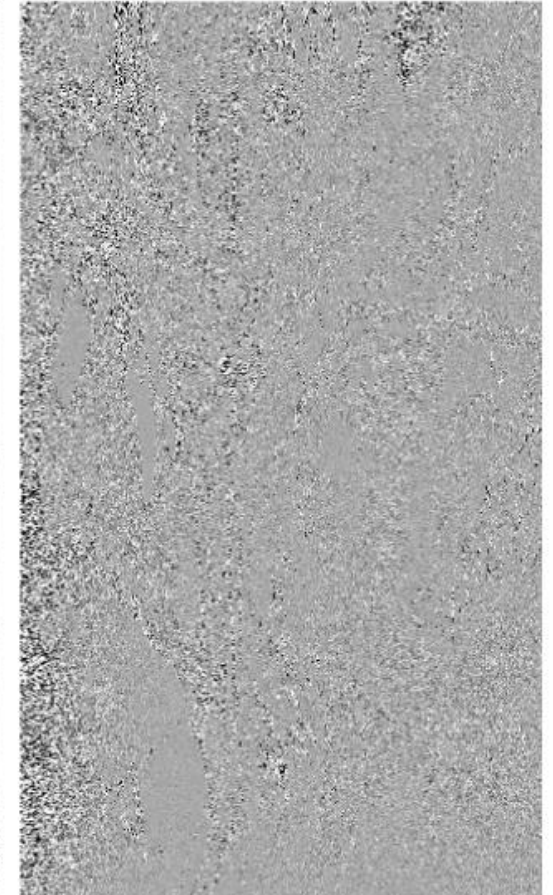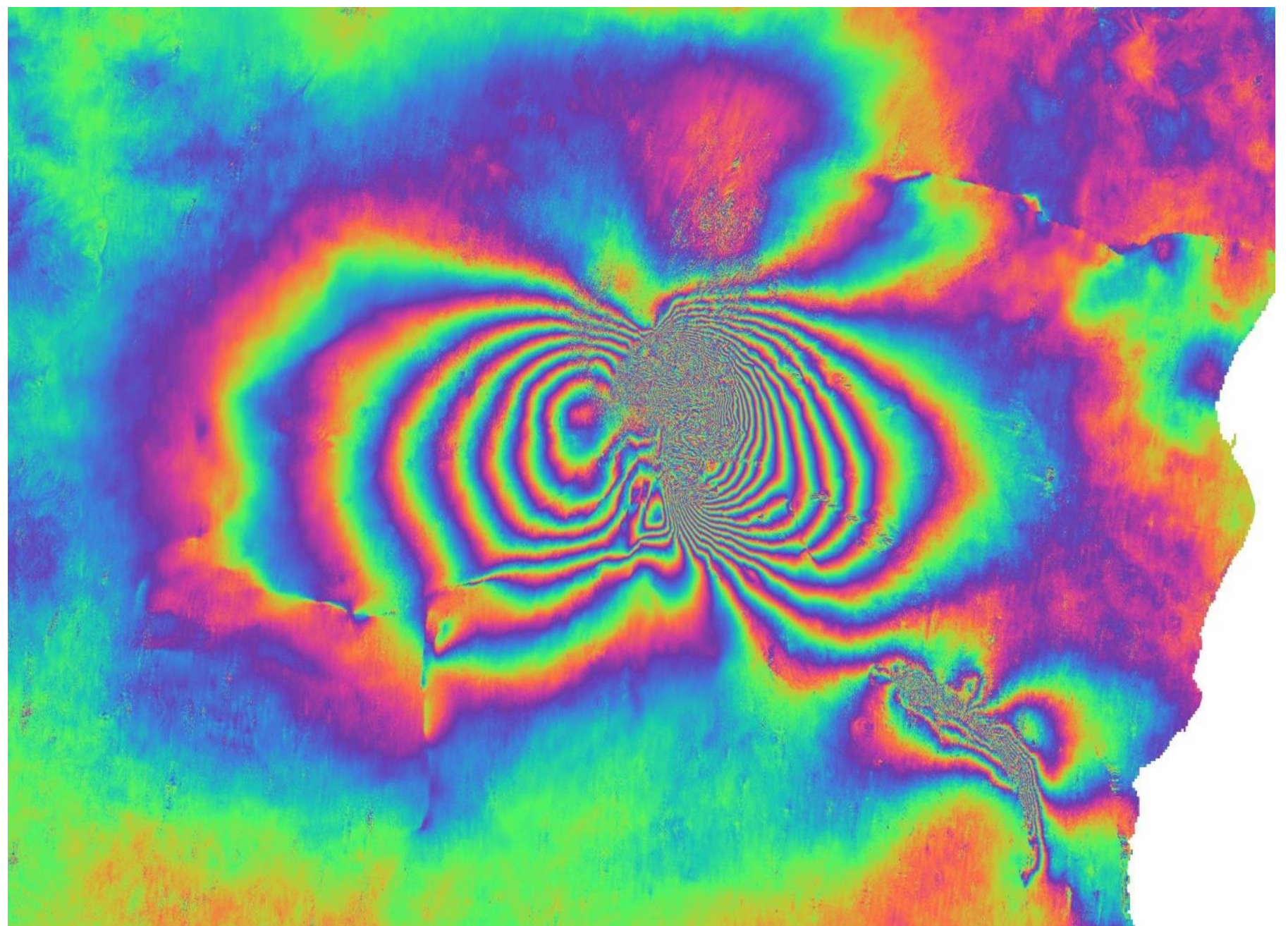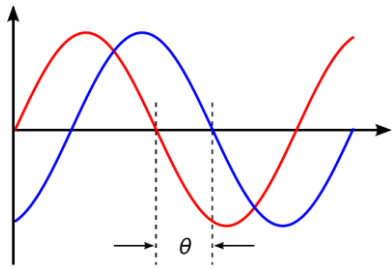
Interferometry

- 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 size (cm)

time $T_0 + \Delta t$

$R_2 \neq R_1$

Δr

INTERFEROMETRY

λ

R_1

R_2

Δr

λ - wavelength:

C-band = 5.66 [cm]
X-band = 3.10 [cm]
L-band = 24.00 [cm]

https://site.tre-altamira.com/insar/

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.
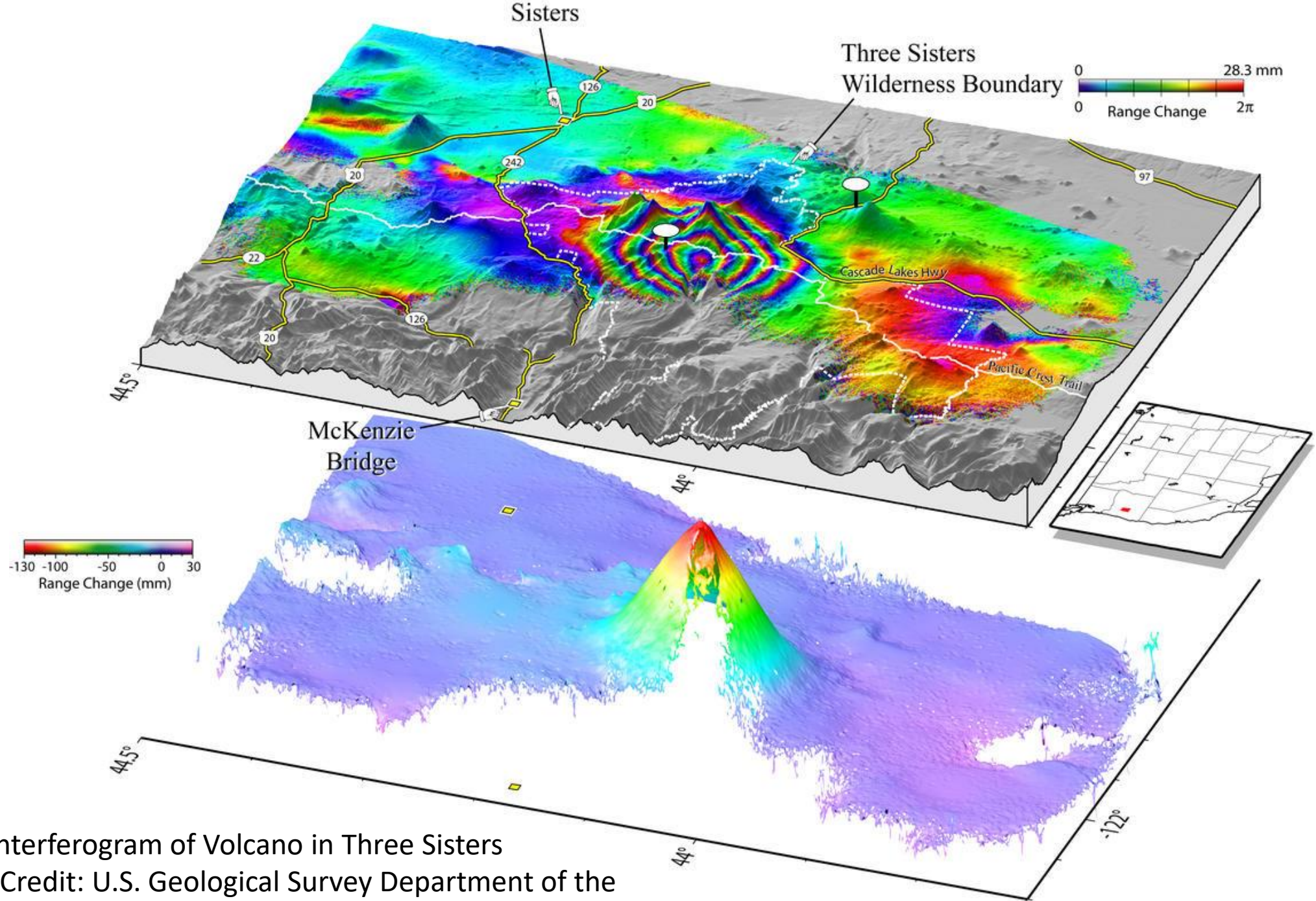MOUNTS system, Data: ESA Sentinel, edited: Sébastien Valade, GFZ

Line of Sight (LOS) Phase differencing

What kind of displacement is not visible to SAR?
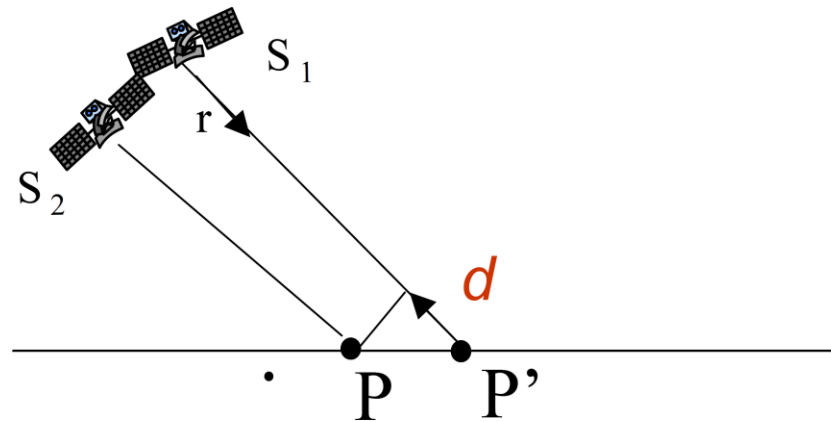
$$\Delta\varphi_{displacement} = \frac{4\pi}{\lambda}d$$

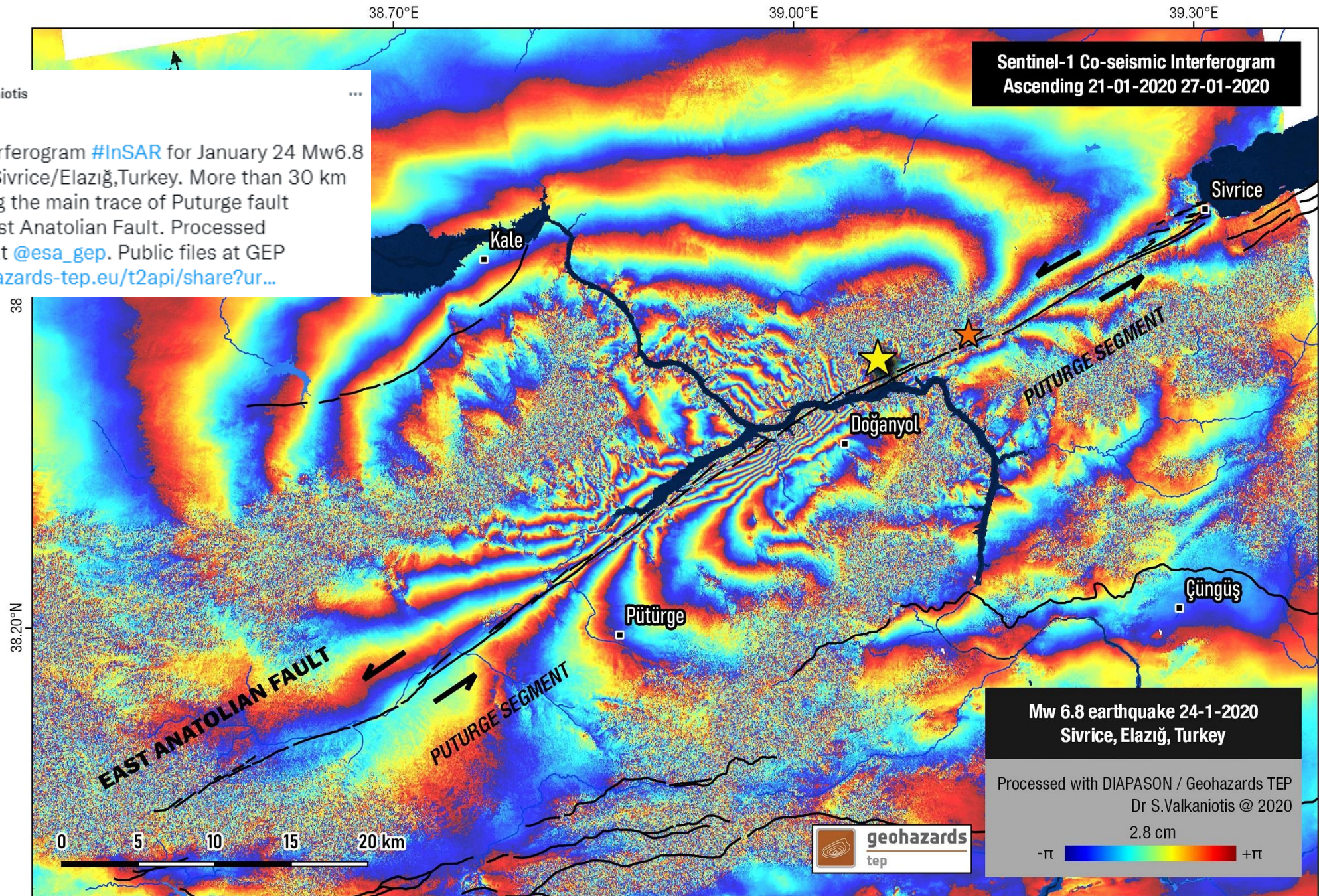Here, d is the relative scatterer displacement projected on the slant-range direction

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

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

PUTURGE SEGMENT

Doğanyol

Çüngüş

Pütürge

EAST ANATOLIAN FAULT

PUTURGE SEGMENT

Mw 6.8 earthquake 24-1-2020
Sivrice, Elazığ, Turkey

Processed with DIAPASON / Geohazards TEP
Dr S.Valkaniotis @ 2020

2.8 cm

-π   +π

0   5   10   15   20 km

geohazards
tep

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.
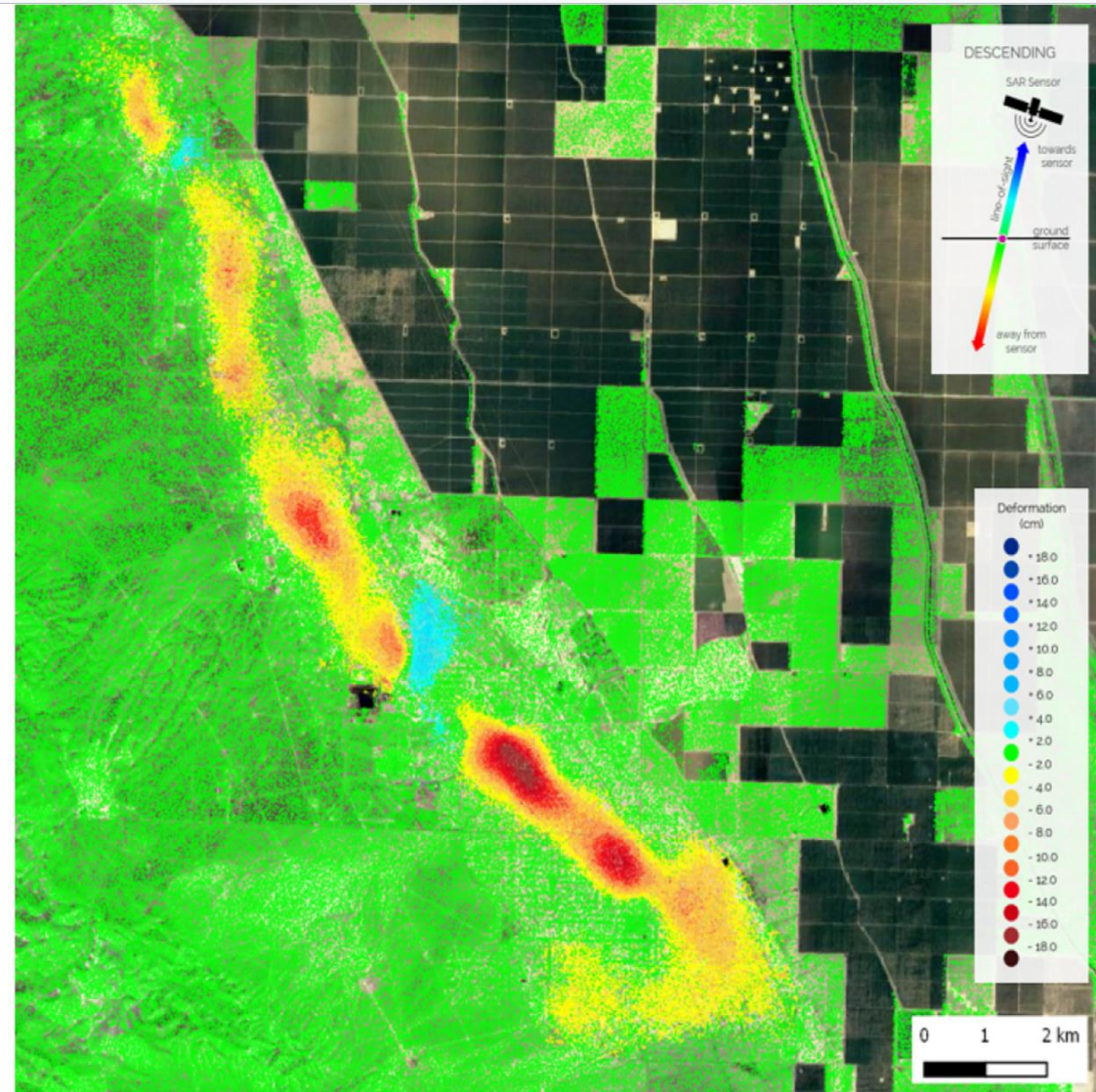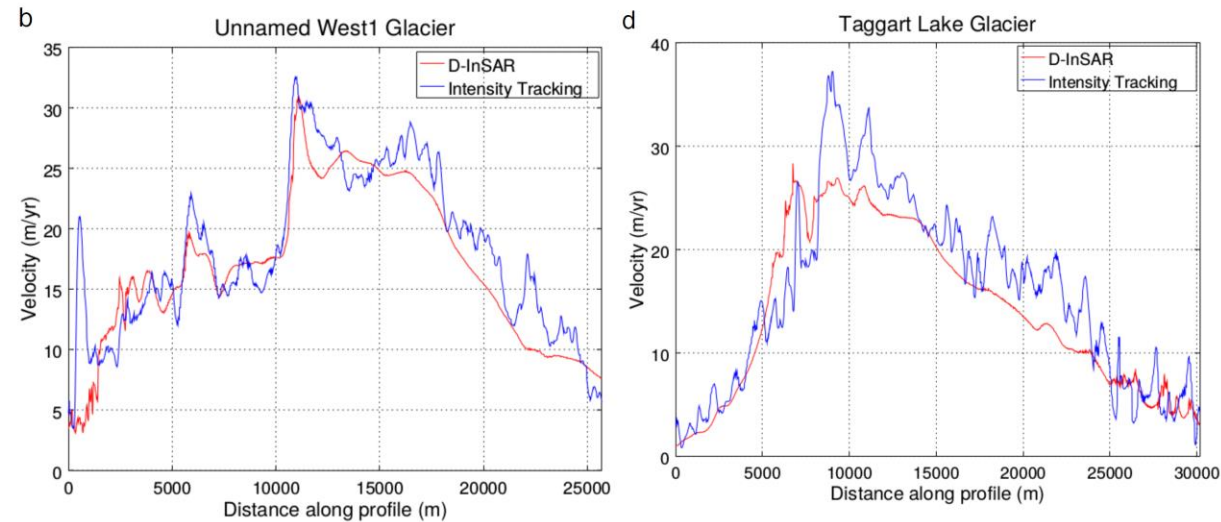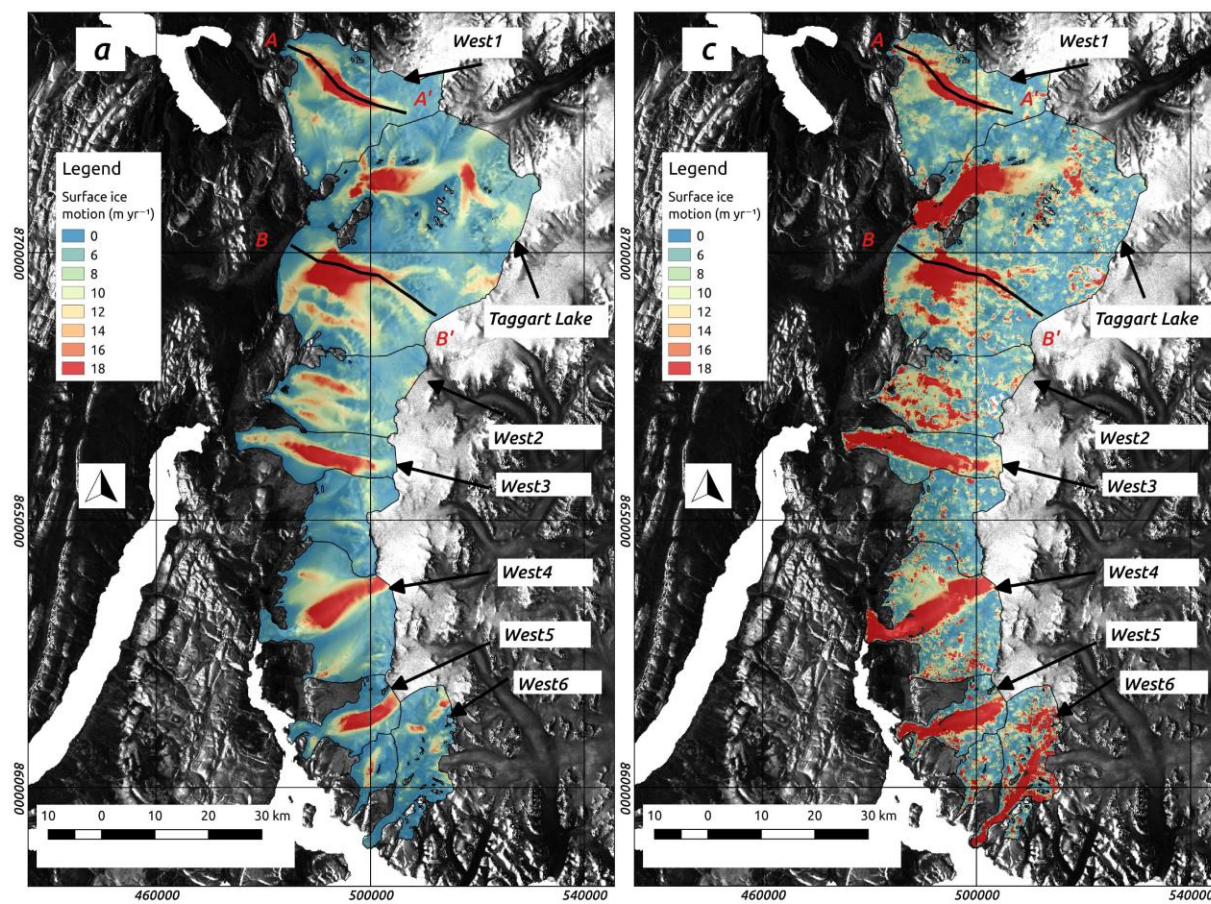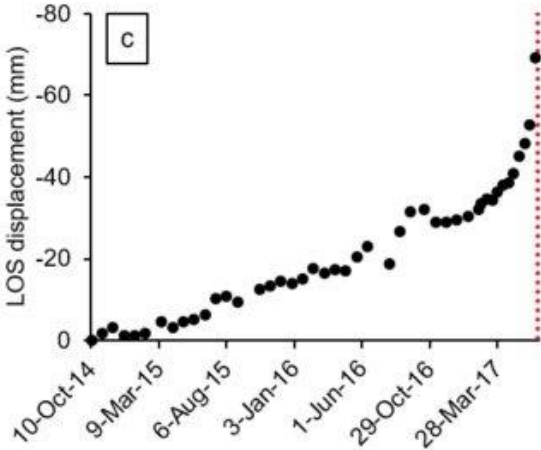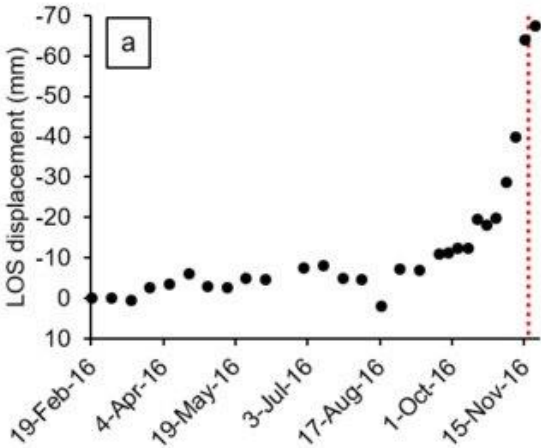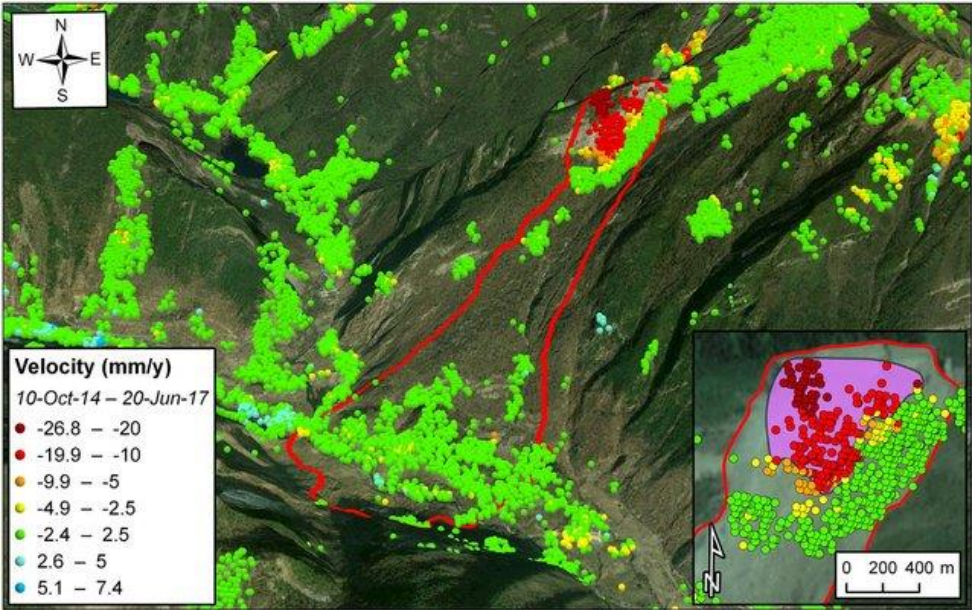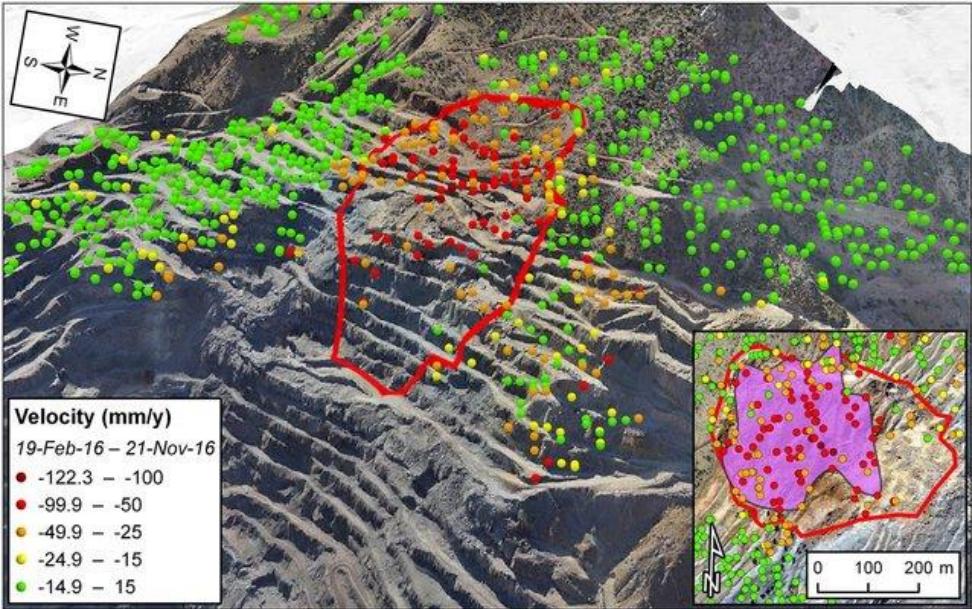
NEXT CASE

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
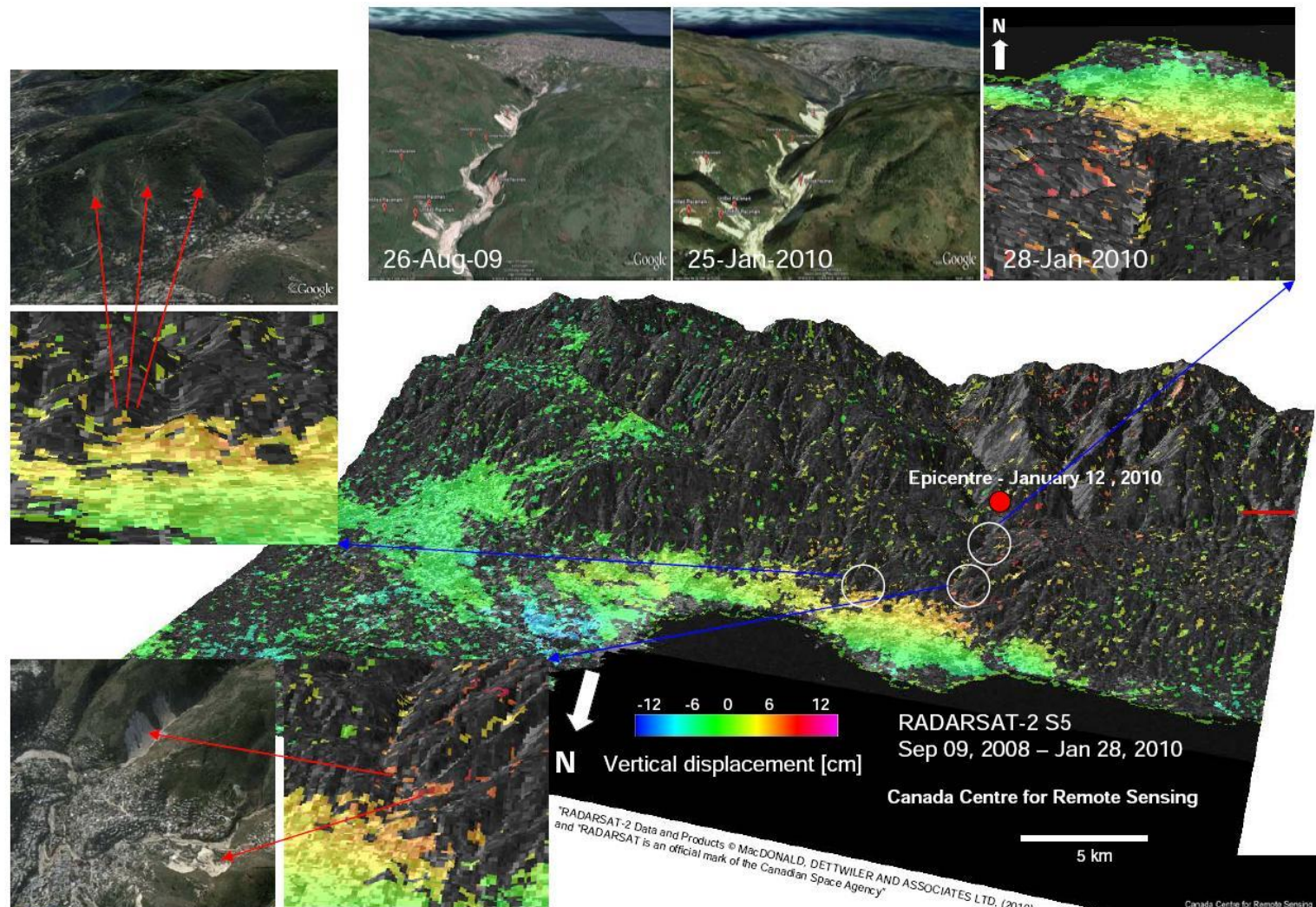
Pablo Sánchez-Gámez * and Francisco J. Navarro

Perspectives on the prediction of catastrophic slope failures from satellite InSAR
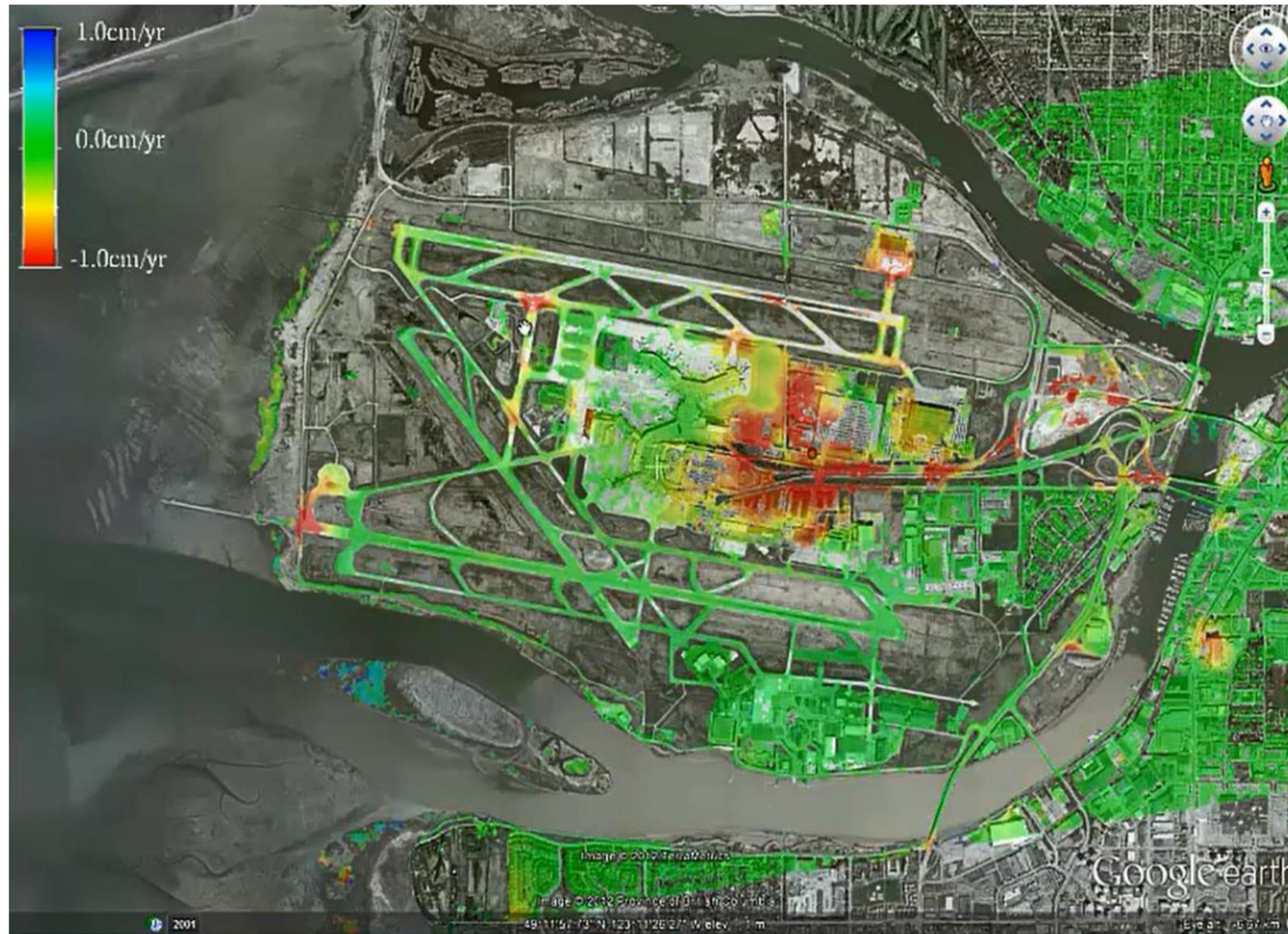
Tommaso Carlà ✉, Emanuele Intrieri, Federico Raspini, Federica Bardi, Paolo Farina, Alessandro Ferretti, Davide Colombo, Fabrizio Novali & Nicola Casagli
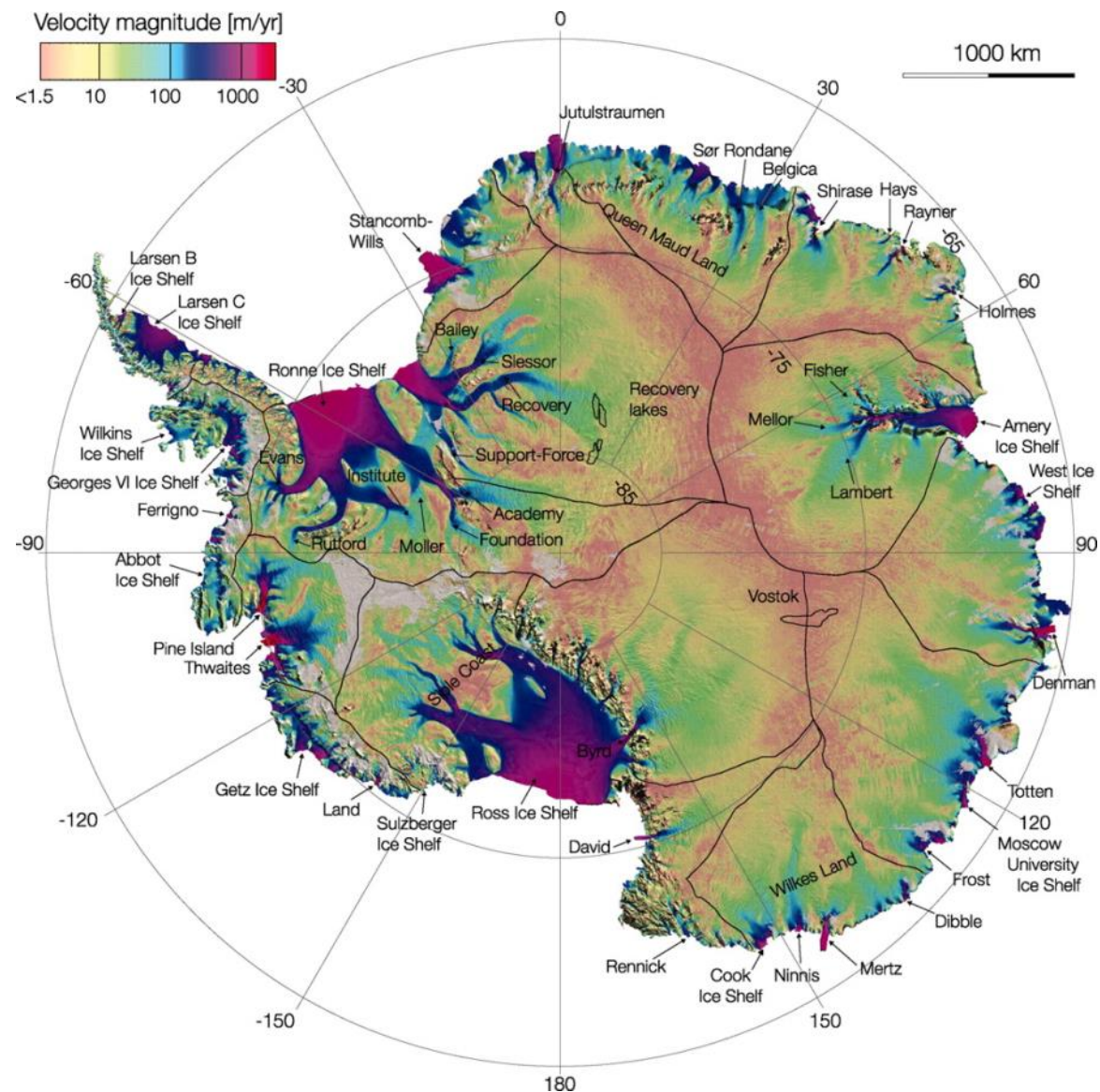
26-Aug-09   25-Jan-2010   28-Jan-2010

Epicentre - January 12 , 2010

-12   -6   0   6   12

N   Vertical displacement [cm]

RADARSAT-2 S5
Sep 09, 2008 – Jan 28, 2010

Canada Centre for Remote Sensing

5 km

"RADARSAT-2 Data and Products © MacDONALD, DETTWILER AND ASSOCIATES LTD. (2010) – All Rights Reserved" and "RADARSAT is an official mark of the Canadian Space Agency"

CSA ASC

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

Singhroy and Pavlic, CCRS, Feb 2010

Canada Centre for Remote Sensing
Natural Resources Canada

Canada

Centre canadien de télédétection
Ressources naturelles Canada

© MDA Corporation Radarsat 2 Imaging Modes and Applications Webinar

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)**
  - InSAR involves the use of two or more radar images acquired at different times over the same area.
  - The radar waves interact with the Earth's surface and create interference patterns (interferograms) based on the phase difference between the radar signals.
  - By analyzing these interferograms, it is possible to measure ground deformation, such as subsidence or uplift, with high precision.
- **Differential InSAR (DInSAR)**
  - DInSAR is a more specific application of InSAR that focuses on detecting and measuring subtle changes in ground deformation over time.
  - It involves the comparison of multiple interferograms acquired at different time intervals.
  - By differencing the interferograms, DInSAR can isolate and quantify the ground deformation that occurred between the different acquisition periods.
    - **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
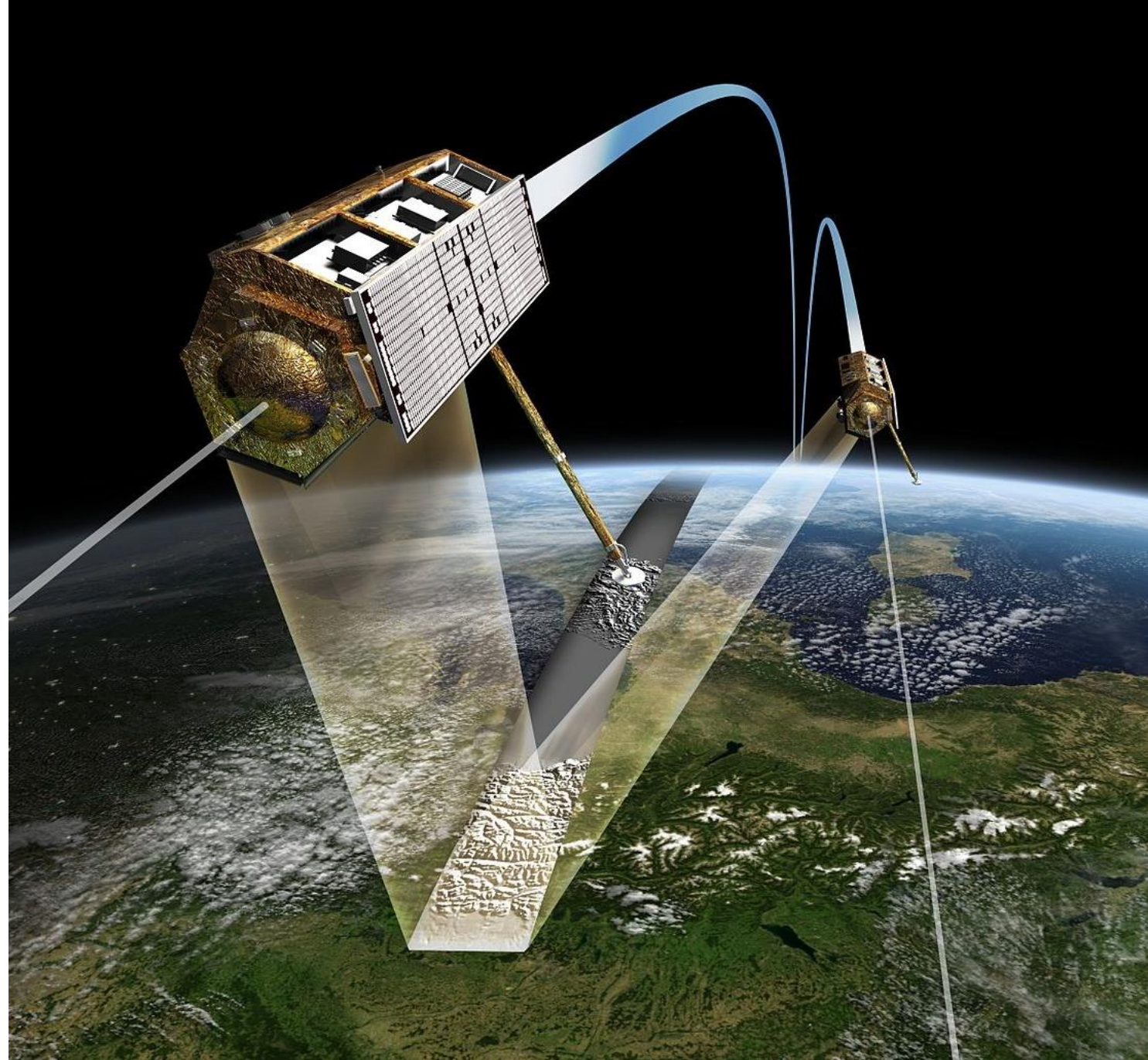
Evaluation of TanDEM-X DEMs on selected Brazilian sites: Comparison with SRTM, ASTER GDEM and ALOS AW3D30

Carlos H. Grohmann

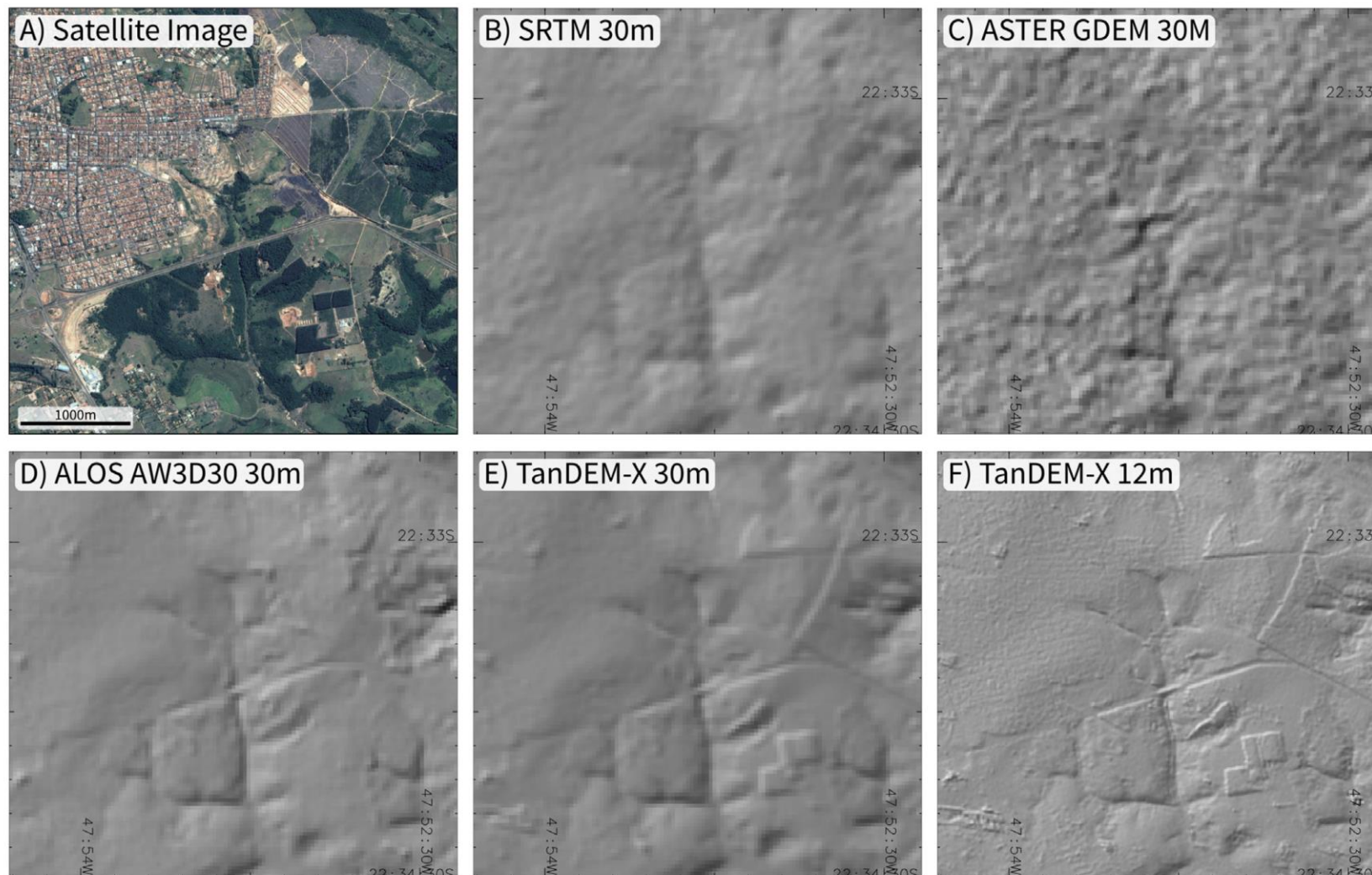*Institute of Energy and Environment, University of São Paulo, São Paulo 05508-010, Brazil*

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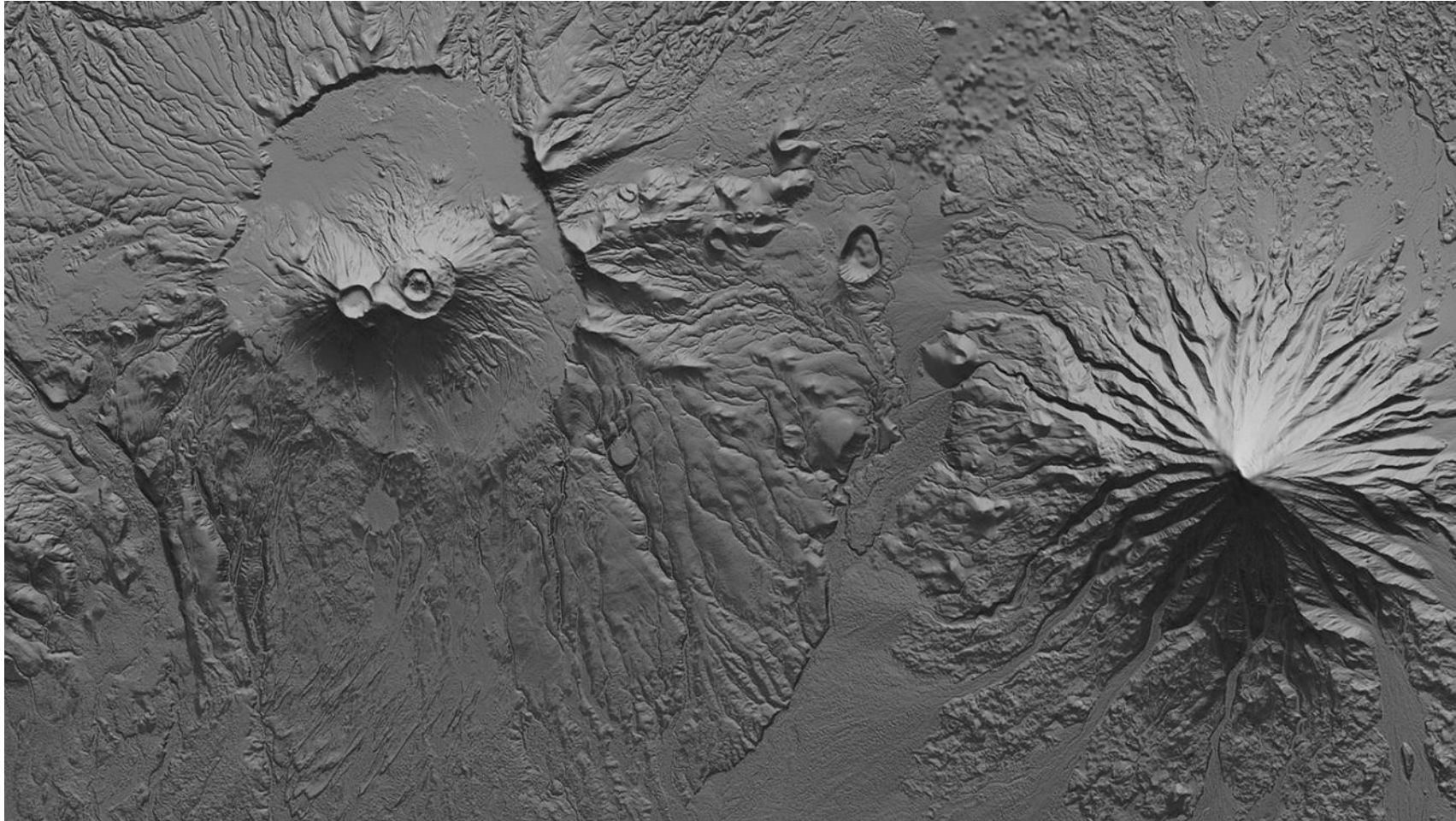
Elevation models of volcanoes on the Russian Kamchatka Peninsula [German Aerospace Center (DLR), 2015]

Field methods: Corner reflectors

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

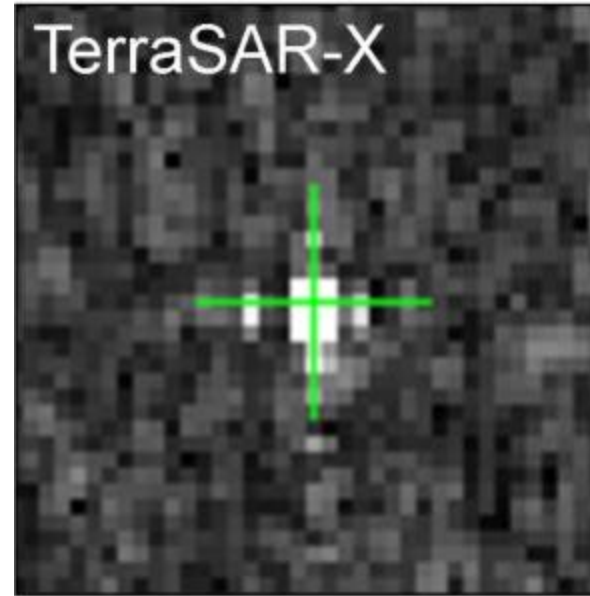Matthew C. Garthwaite [1], Sarah Lawrie [1], John Dawson [1], Medhavy Thankappan [1]

TerraSAR-X

Sentinel-1

RADARSAT-2

ALOS-2
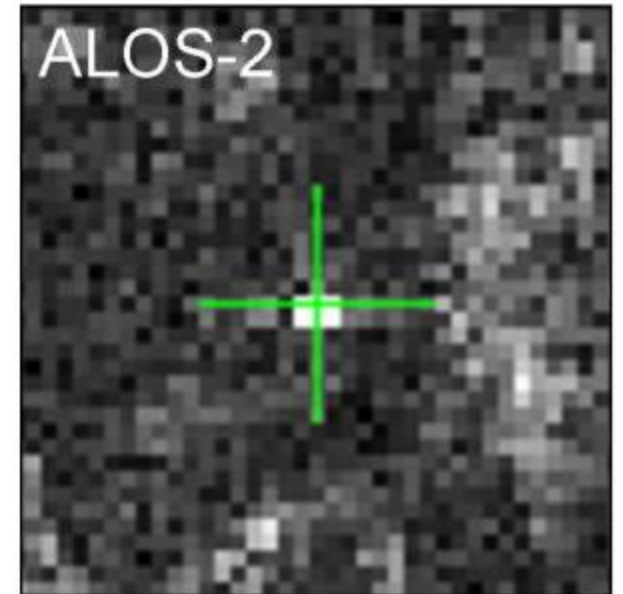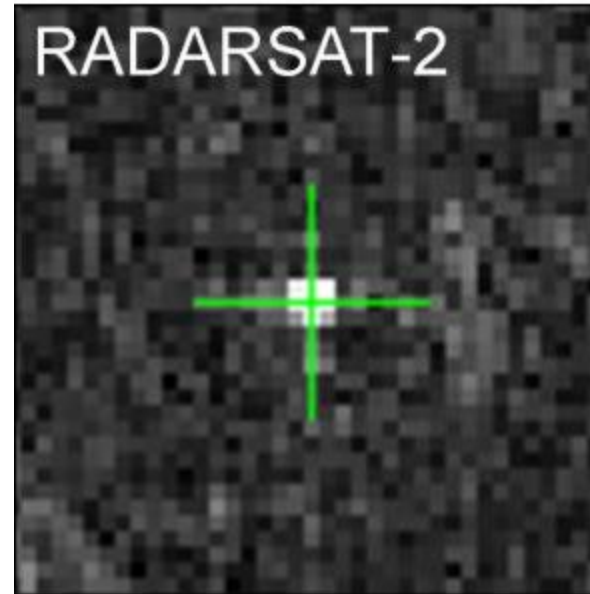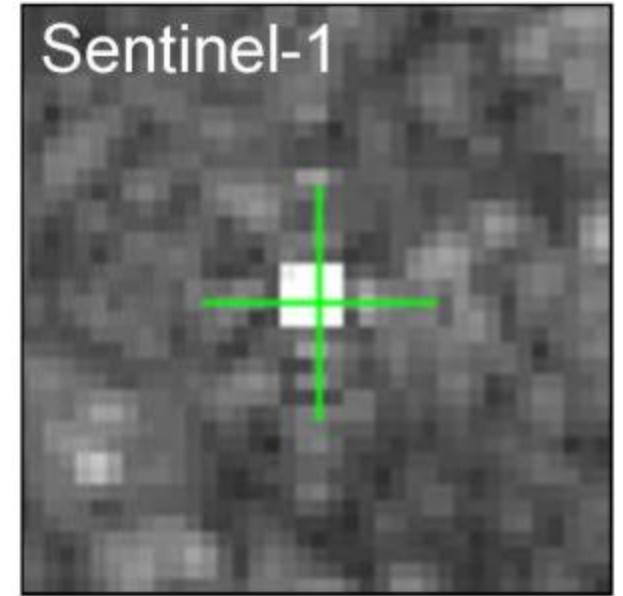
Figure 3. Impulse response for the 1.5 m corner

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

SNAP

GMTSAR

InSAR – Deformation Mapping

InSAR Deformation Workflow and Results

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/