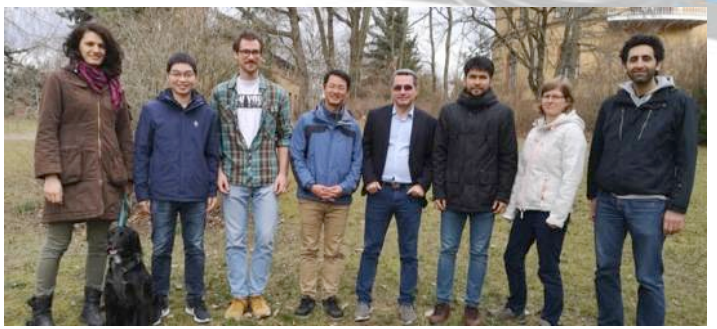
GFZ Helmholtz Centre Potsdam

Leibniz Universität Hannover

Towards InSAR everywhere, All the time: opportunities and challenges

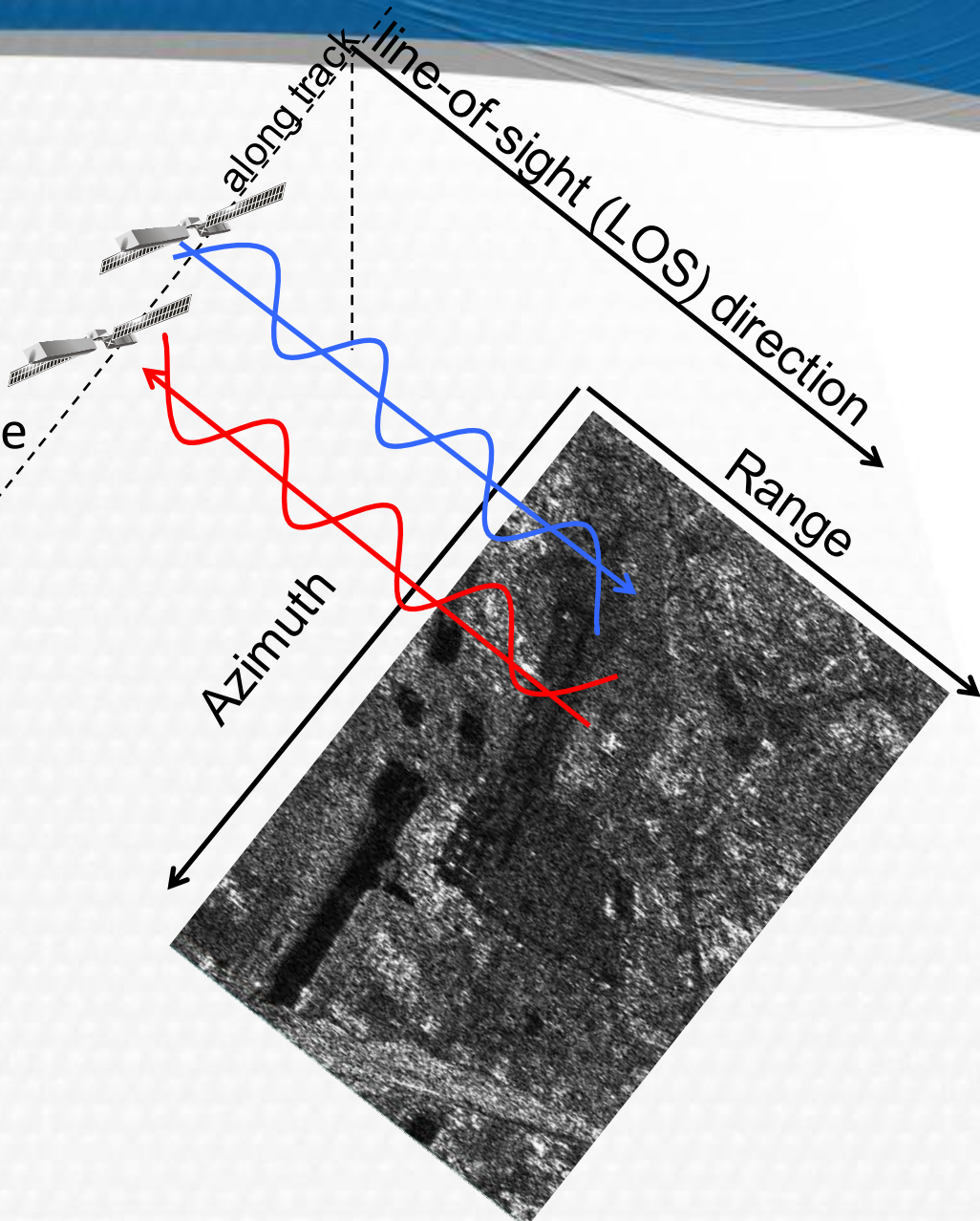
Mahdi Motagh

Acknowledgements:
M. Haghshenas Haghighi, M. Vassileva, J. Neelmeijer, Z. Wang, J. Hu, W. Tang, H. Sharifi, S. Vajedian (LUH)



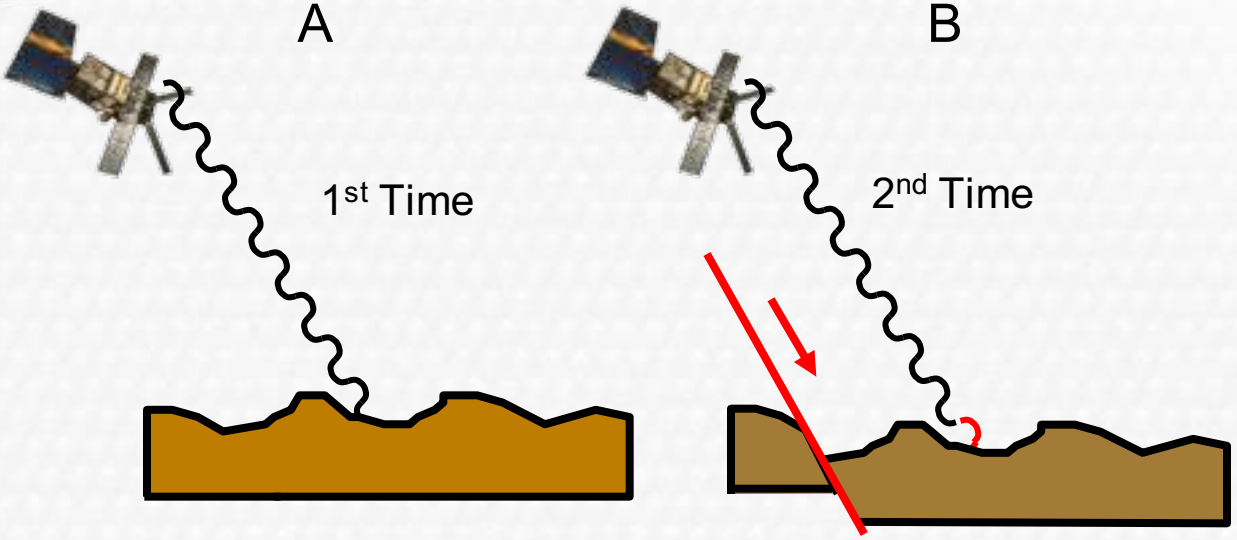
Synthetic Aperture Radar (SAR)

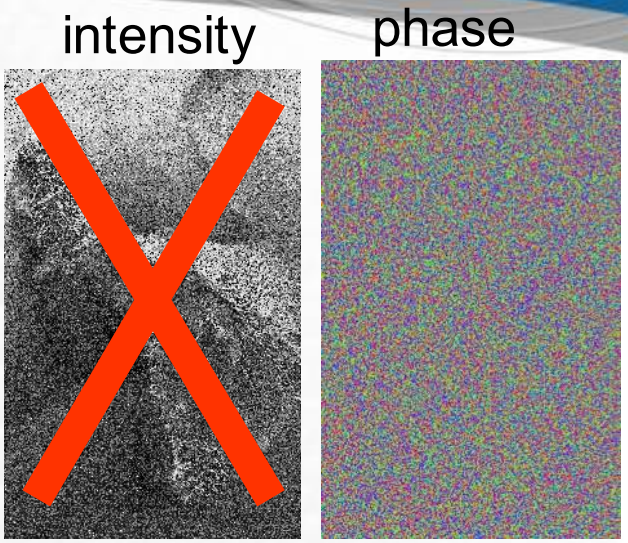
- Active remote sensing
- Transmit and receive microwave
  - Amplitude: reflectivity of the ground
  - Phase: sensor-to-target distance



- No matter day or night
- No matter clouds or rain

SAR Interferometry & Imaging Geodesy

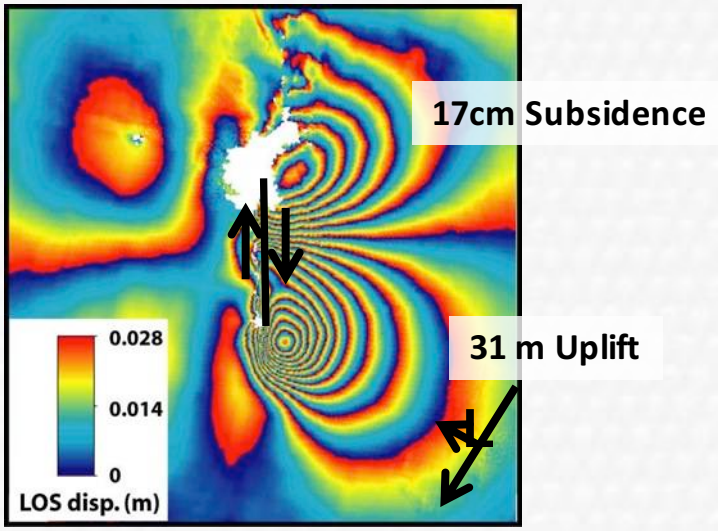


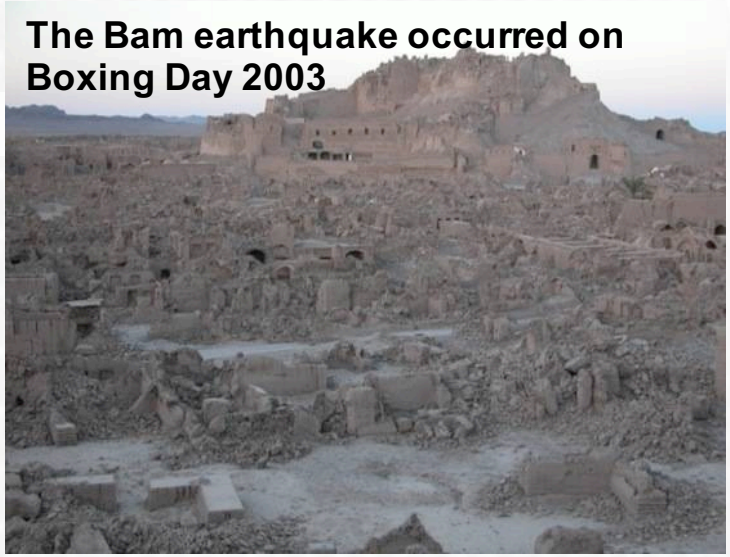


Interferogram =
Phase A – Phase B

$$\delta\phi = \frac{4\pi}{\lambda}\Delta R_{def}$$

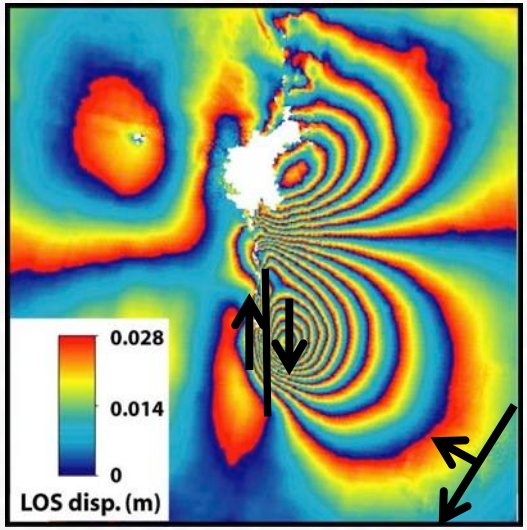
$$if\ \ \delta\phi = 2\pi \Rightarrow \Delta R_{def} = \frac{\lambda}{2}$$

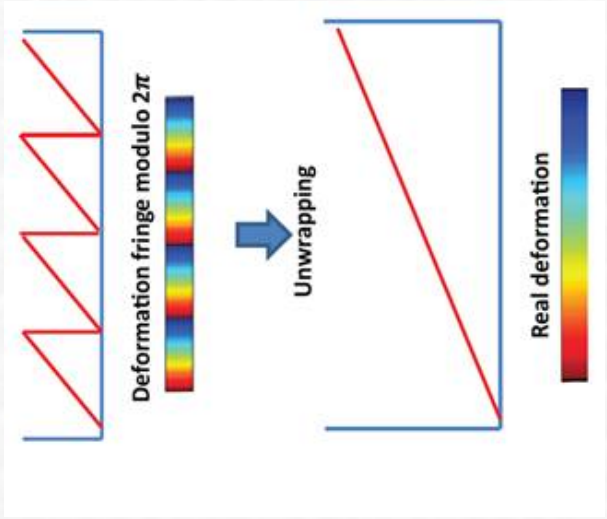




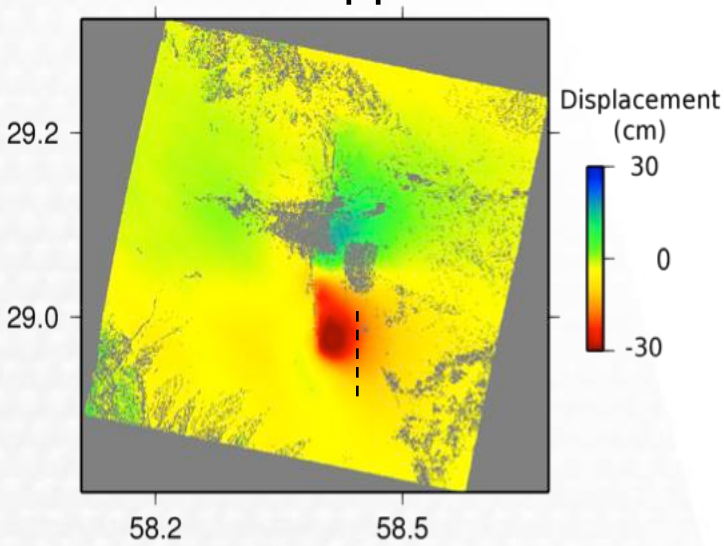
Phase unwrapping

wrapped





unwrapped



$$e^p = \sum_{i,j} (\hat{\phi}_{i+1,j} - \hat{\phi}_{i,j} - \Delta^x_{i,j})^p + \sum_{i,j} (\hat{\phi}_{i,j+1} - \hat{\phi}_{i,j} - \Delta^y_{i,j})^p$$

$$\Delta^x_{i,j} = \psi_{i+1,j} - \psi_{i,j}$$

$$\Delta^y_{i,j} = \psi_{i,j+1} - \psi_{i,j}$$

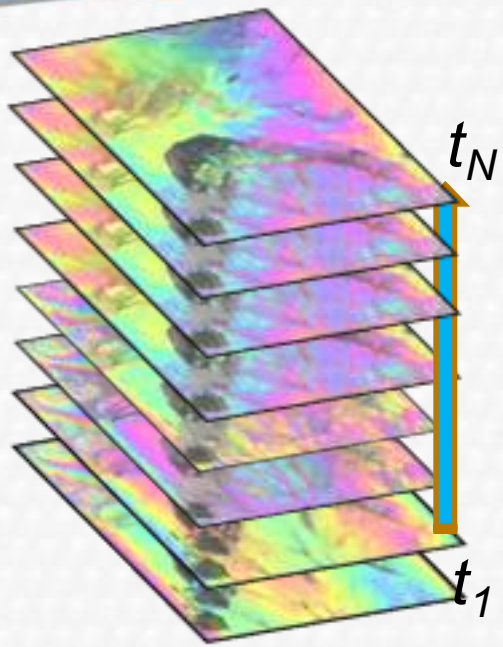
$\hat{\phi}$ = unwrraped (unknown, to be estimated)

ψ= wrapped phase

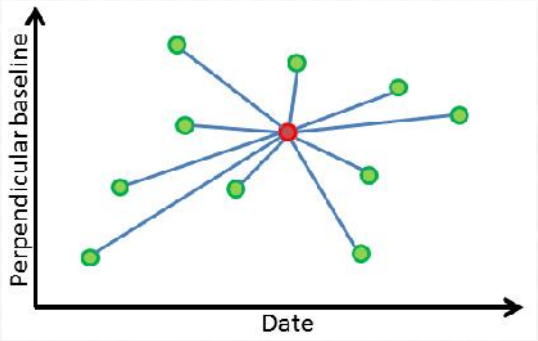
Δ = derivatives of the observed phase

p= exponent (1,2,..)

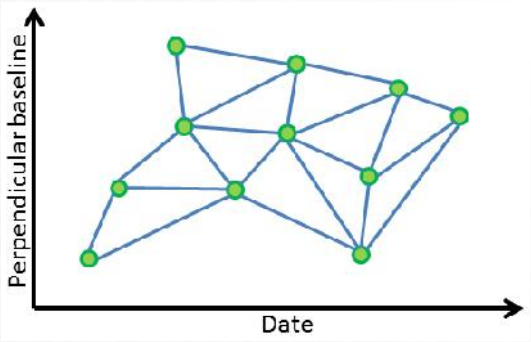
InSAR time-series analysis

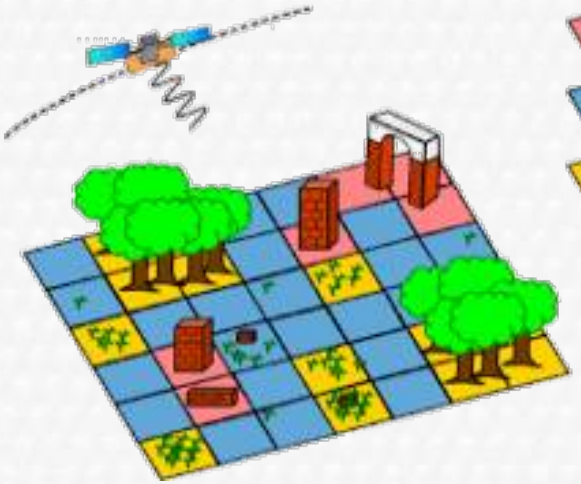


Single-master interferograms



Multi-master interferograms



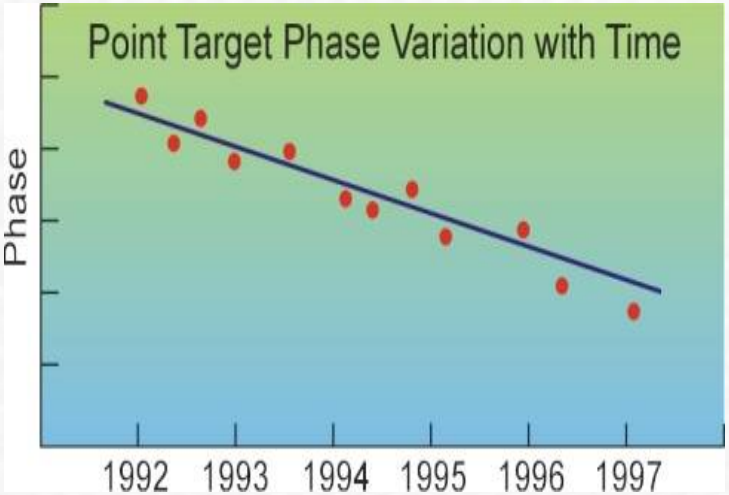


PS

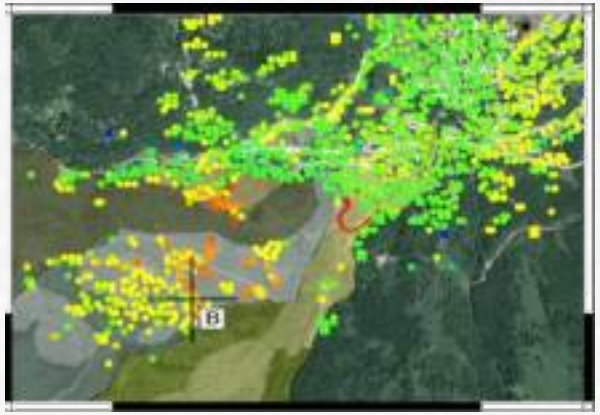
DS

No Data

Time-series Analysis

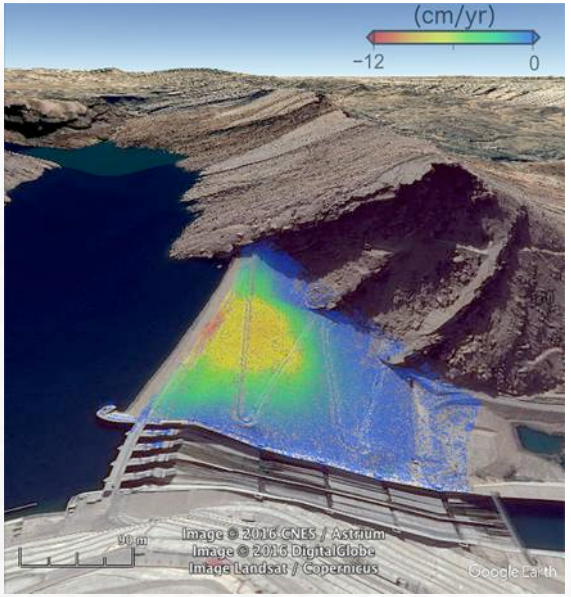


Landslide

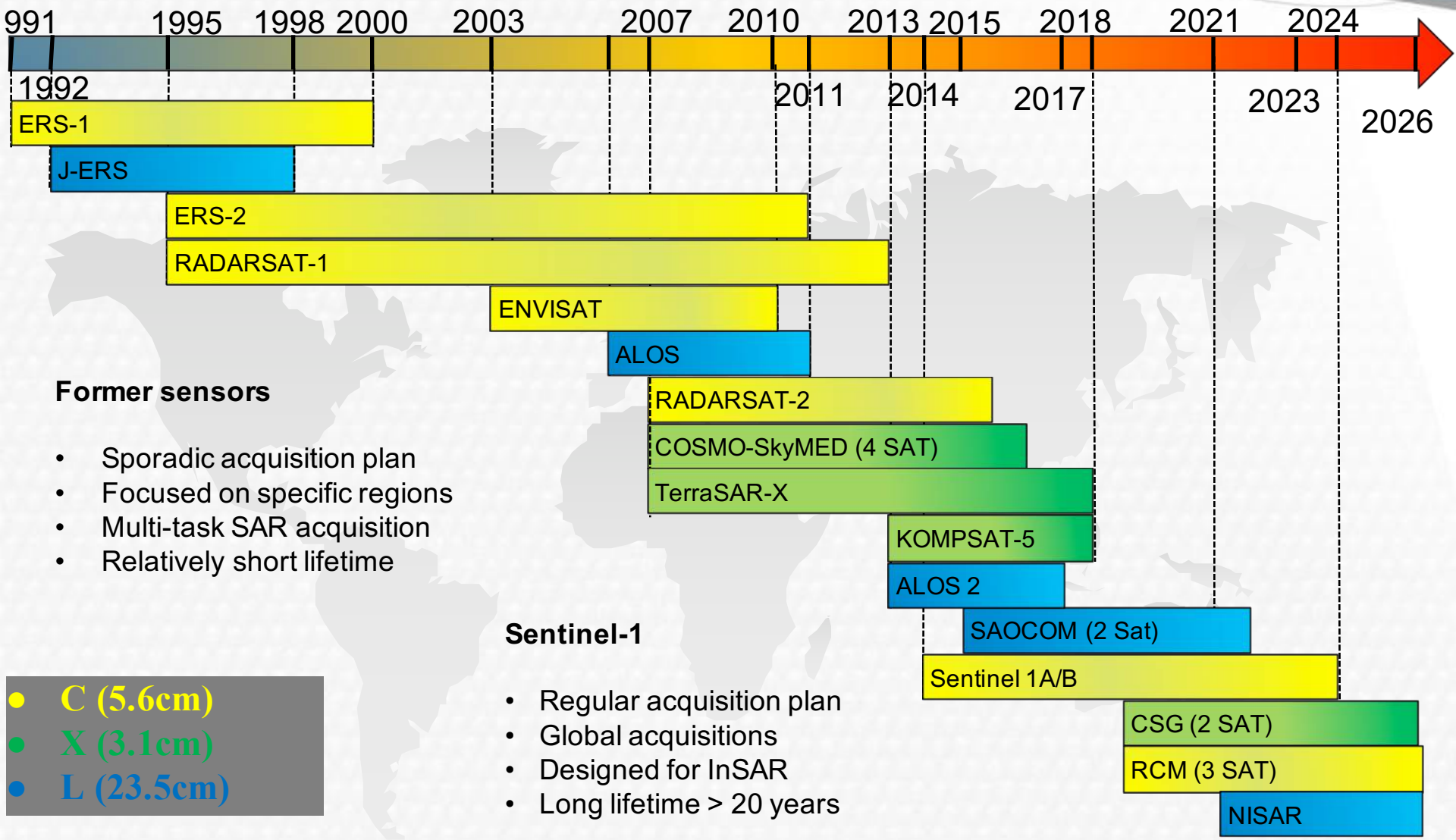


Volcano hazard

Dam monitoring



SAR Missions



Former sensors

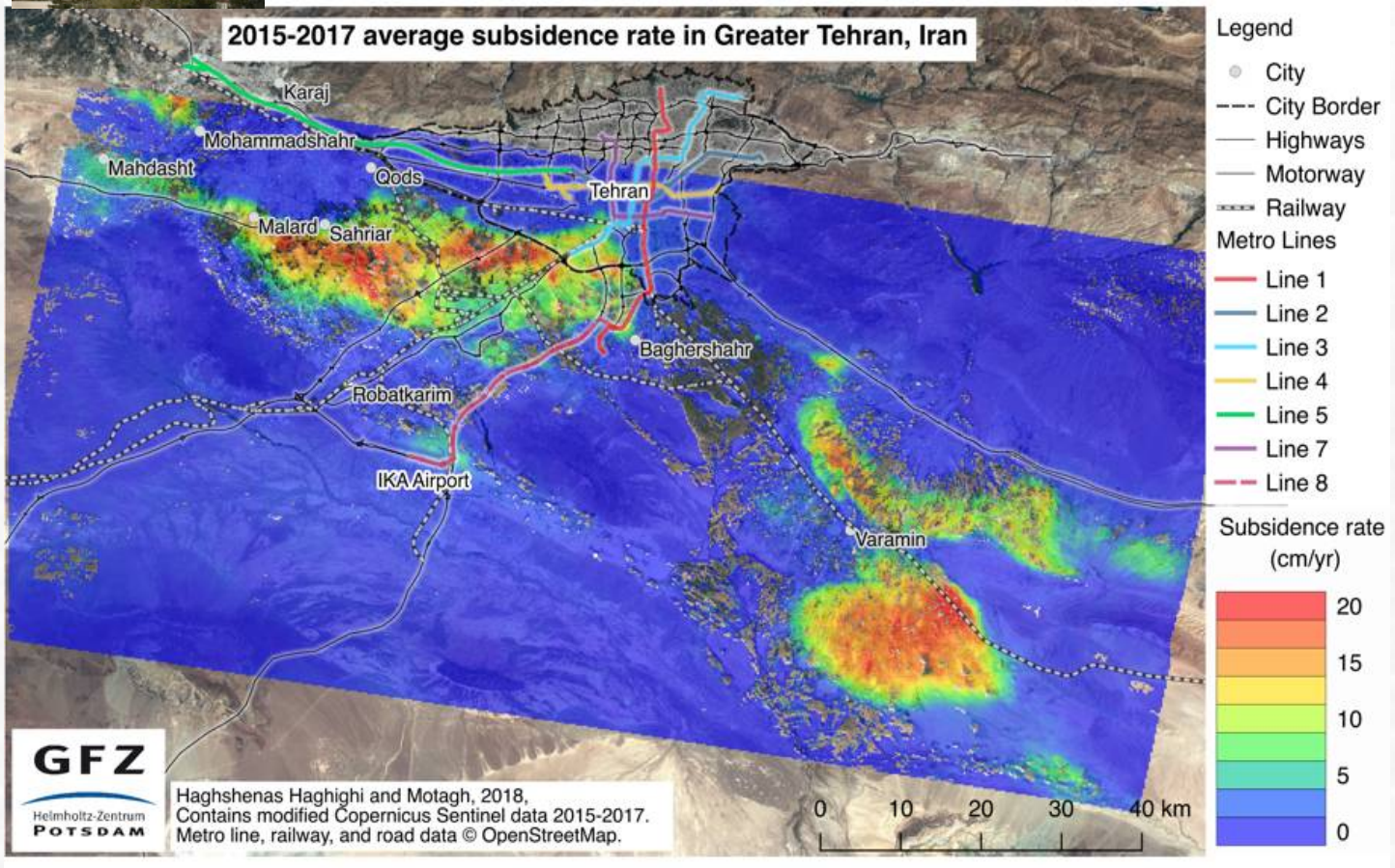
- Sporadic acquisition plan
- Focused on specific regions
- Multi-task SAR acquisition
- Relatively short lifetime

- C (5.6cm)
- X (3.1cm)
- L (23.5cm)

Sentinel-1

- Regular acquisition plan
- Global acquisitions
- Designed for InSAR
- Long lifetime > 20 years

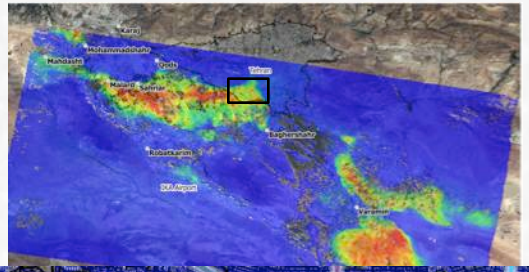
Checking transient in aquifer systems: Example from Tehran, Iran

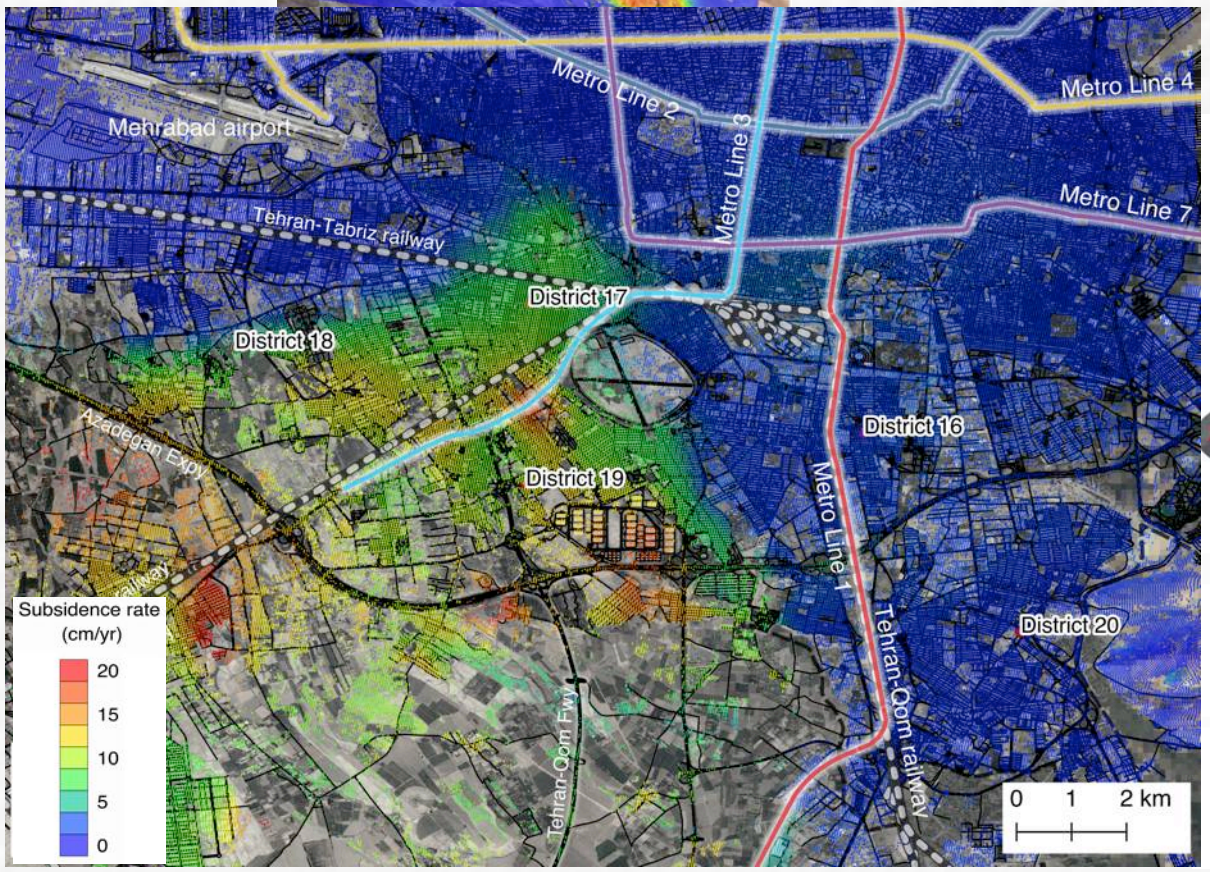


- The largest city in southwest Asia Population: 6.8 M (1995), 13 M (2018)
- 3000 identified illegal wells; > 10 m reduction in water level in 25 years

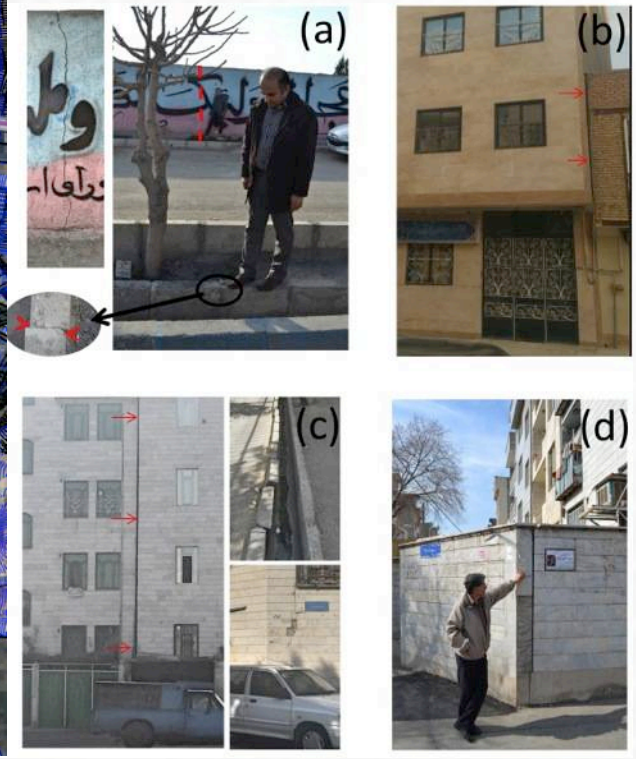
Haghshenas Haghighi & Motagh (2019, RS of Environment)

Land subsidence in Tehran, Iran

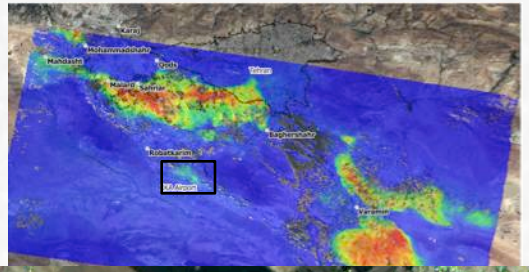


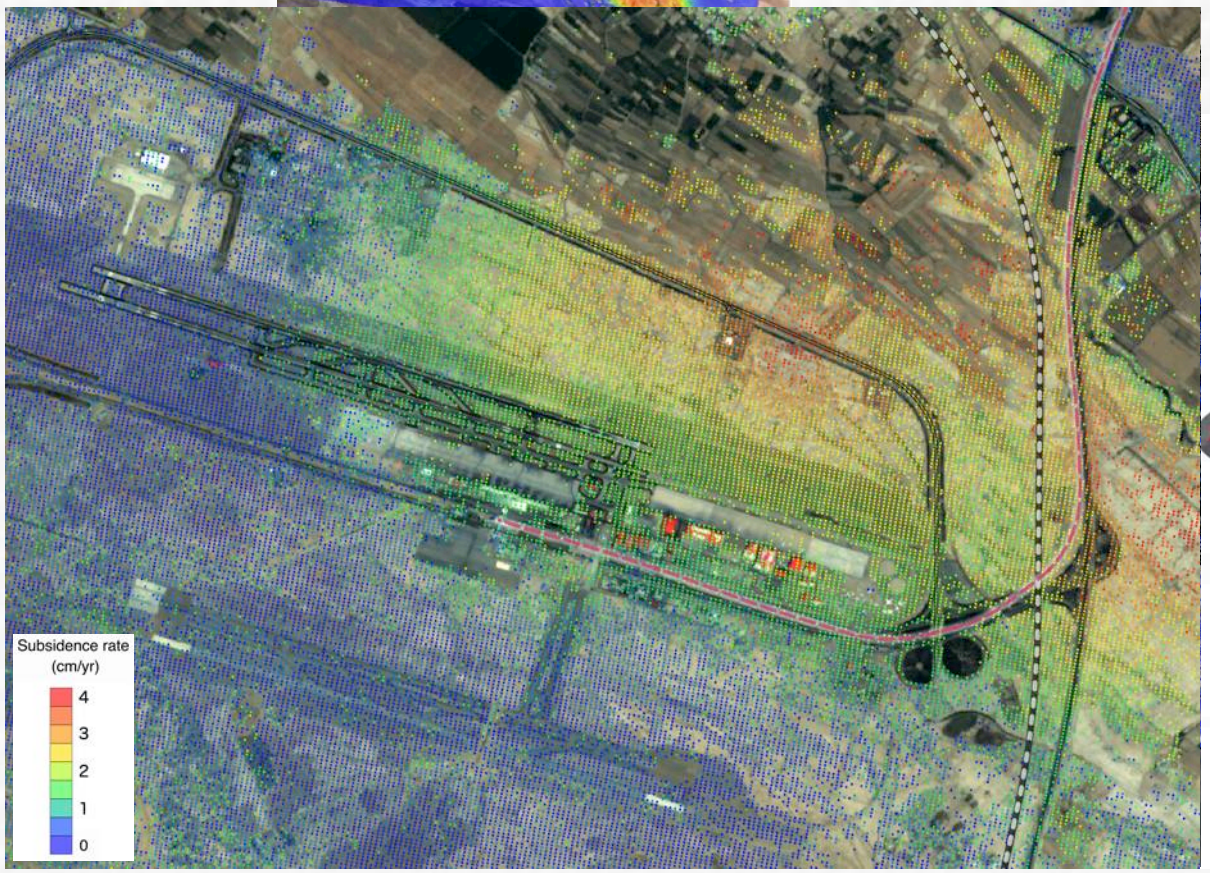


- 120 km of railway
- 2300 km of road
- 21 bridges
- 30 km of oil pipeline
- 200 km of gas pipeline
- 70 km of high-voltage electricity lines
- > 250.000 buildings



Land subsidence in Tehran, Iran





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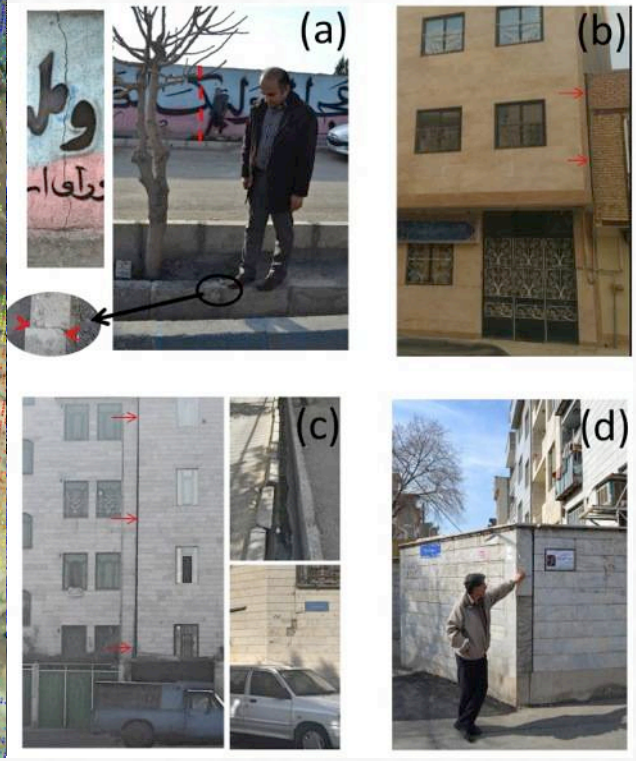

International exposure

Tehran's drastic sinking exposed by satellite data

Parts of Iran's capital city, home to 13 million people, are subsiding by 25 centimetres each year.

Kate Ravilious

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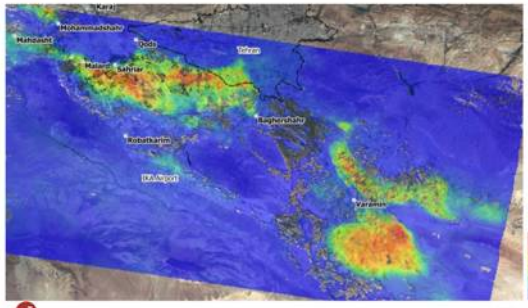
Hauptstadt auf dem Weg nach unten

Teils mehr als 25 Zentimeter pro Jahr sinkt die Region um die iranische Hauptstadt Teheran ab - weil Grundwasservorkommen rücksichtslos ausgebeutet werden. Forscher warnen, dass manche der Speicher irreparabel geschädigt sind.



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Irans Hauptstadt sackt gefährlich ab

Blick auf Teheran. (Foto: Simon Dawson/Bloomberg)

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The Current

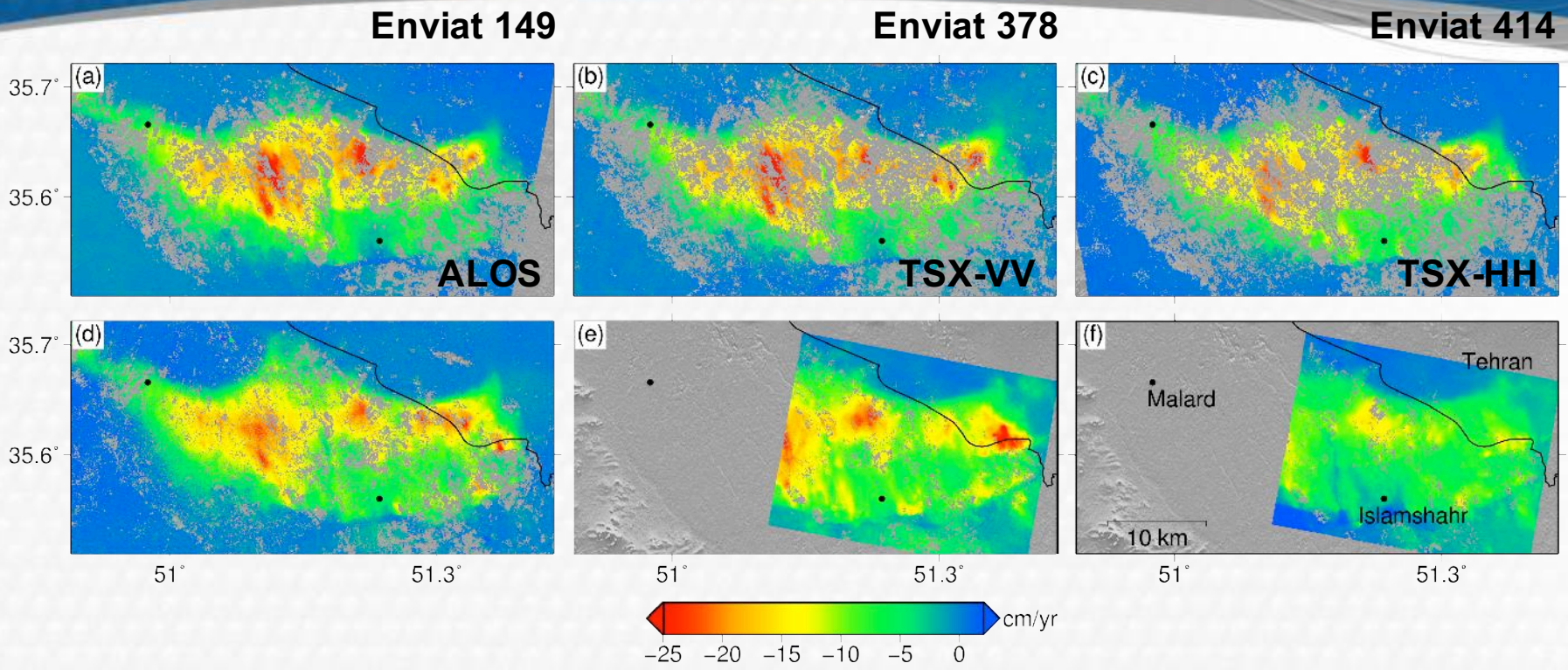
Parts of Tehran are sinking into the ground at 25cm a year, says scientist

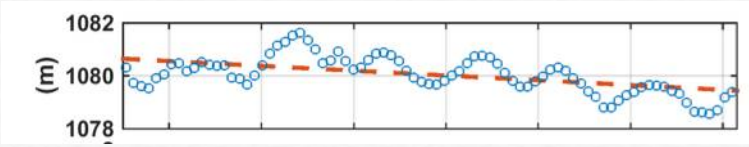
Professor says we need to pay attention to human factors leading to subsidence

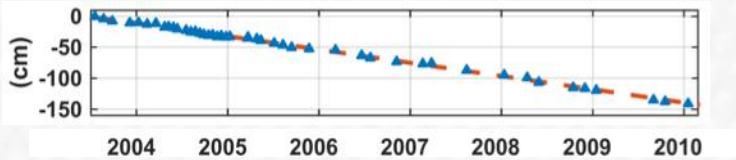
CBC Radio · December 5, 2018

This a view of an airport in Tehran, Iran, where subsidence is being recorded via satellite. (AP Photo/Vahid

Vertical displacement







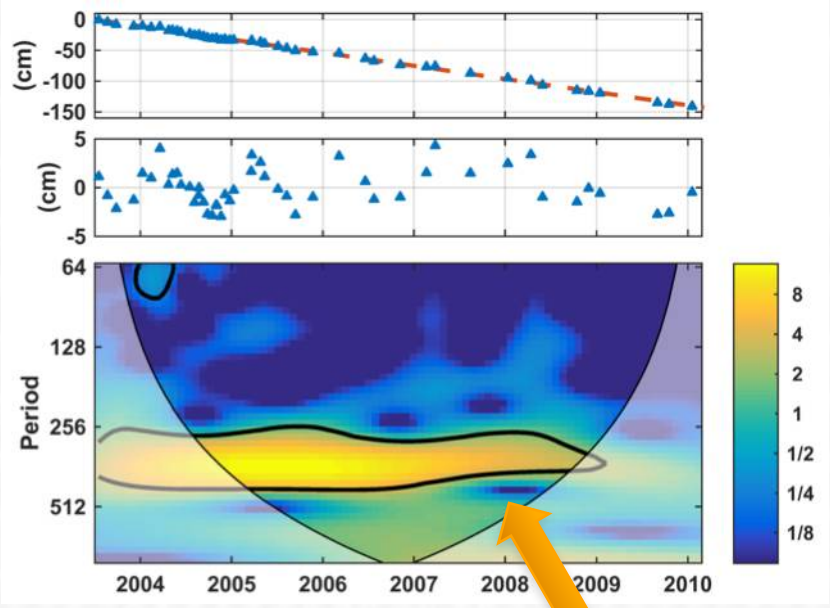
Groundwater level

InSAR time-series

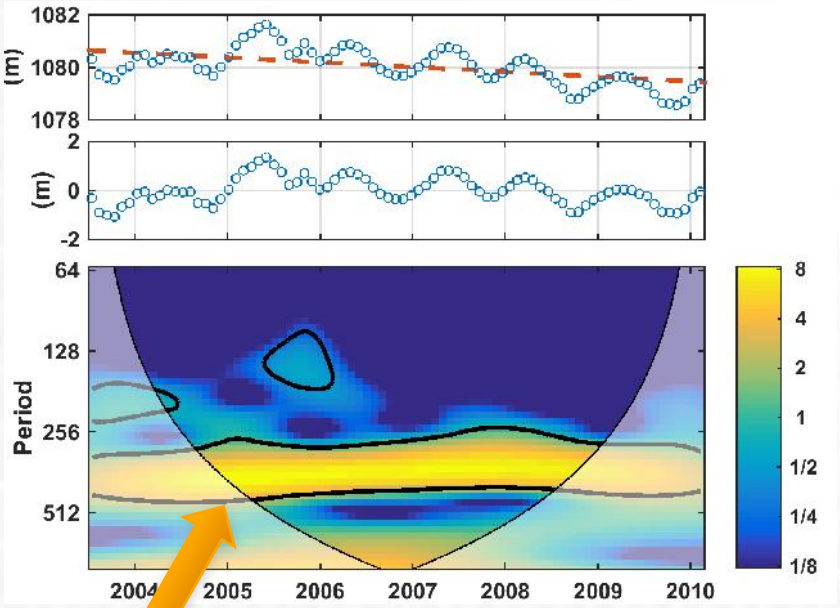
Tracking transient in the data: Wavelet analysis

- Tracking transient

InSAR time-series



Groundwater level



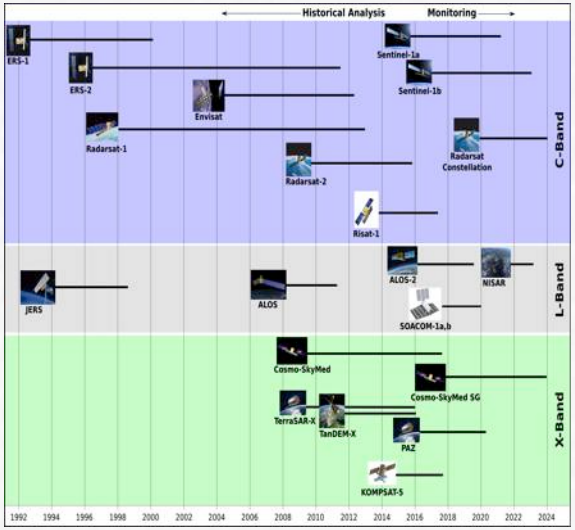
The same 1-year period in both time-series

Haghshenas Haghighi & Motagh (2019, RS of Environment)

Sentinel-1: A game changer in space

- Systematic acquisitions every 6/12/24 days: “InSAR everywhere all the time”
- TOPS: 250 km x 1000+ km: Continental scale InSAR
- 20 year operational program, designed for InSAR
- Free, full and open data policy

SAR data is growing faster than what we expected!



Source: unavco.org

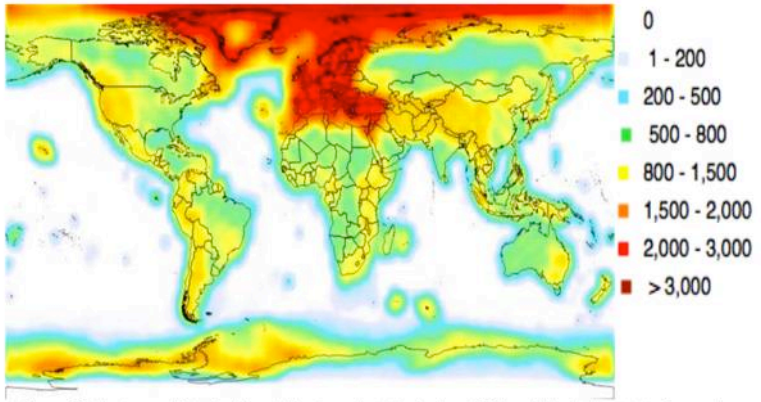
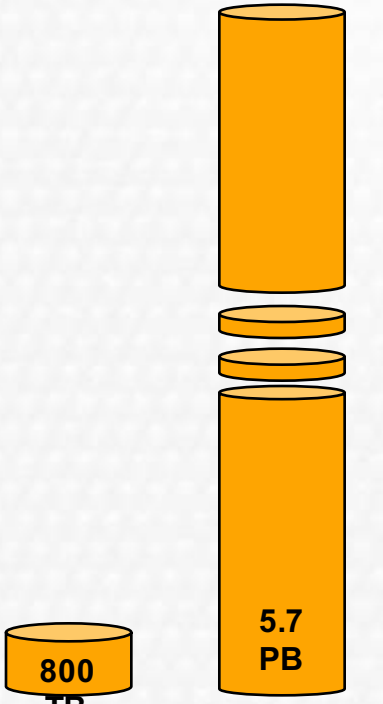


Figure 28: Heatmap of Sentinel-1 published products (excluding OCN) published since start of operations

Source: Sentinel data access 2017 annual report



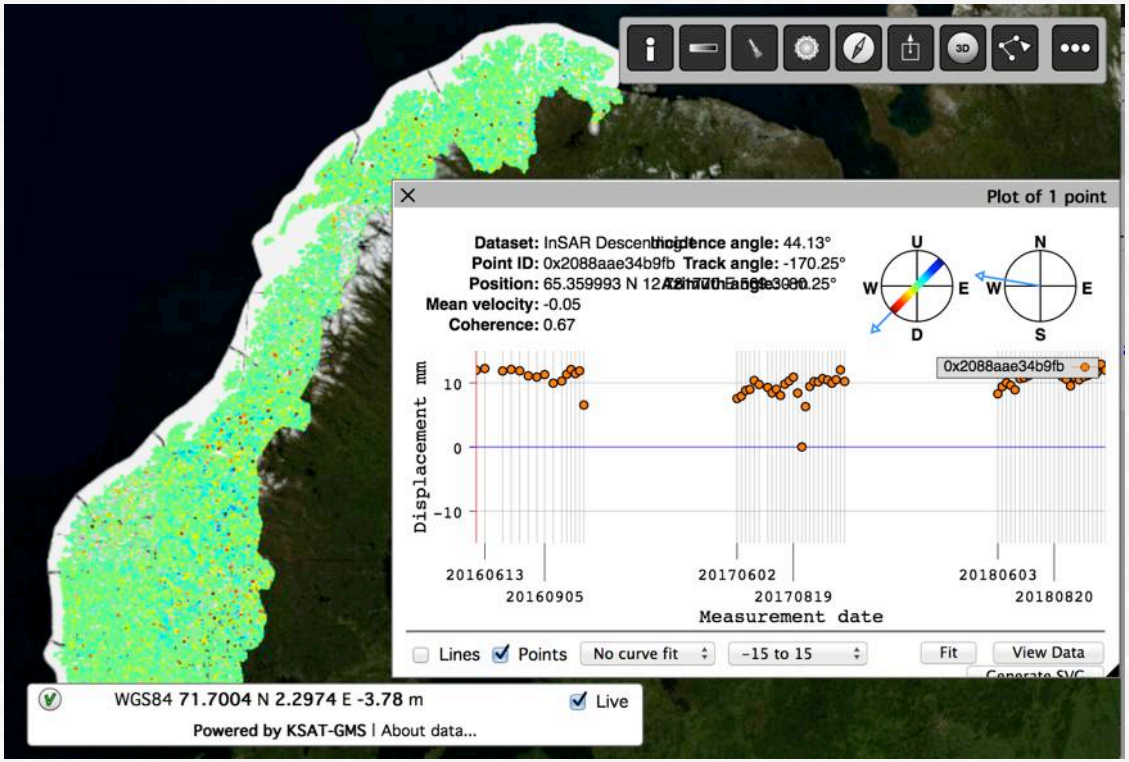
ERS 1/2 and Envisat (1991-2012)

Sentinel-1 (until Feb 2019)

Big amount of data, but not much information

Nation-wide deformation map

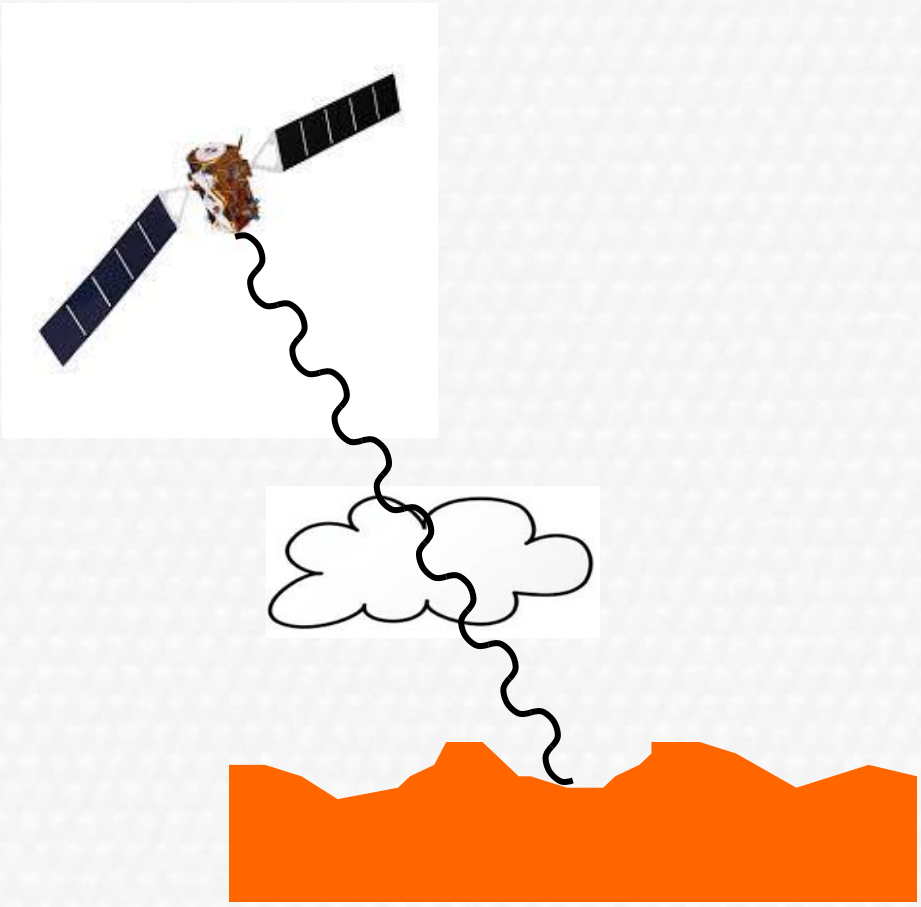
- Q: Challenges in large-scale?

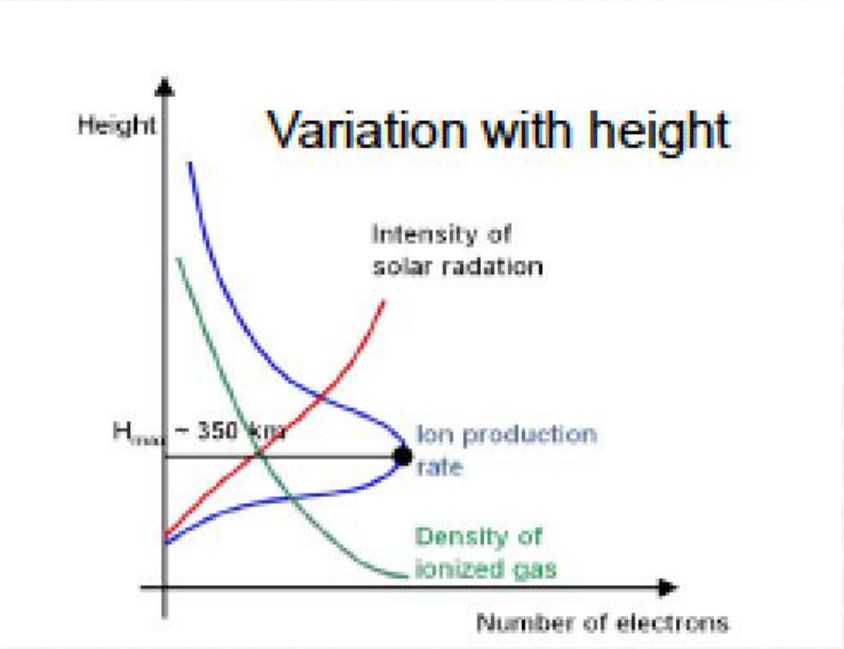


https://insar.ngu.no/

Atmospheric artifacts

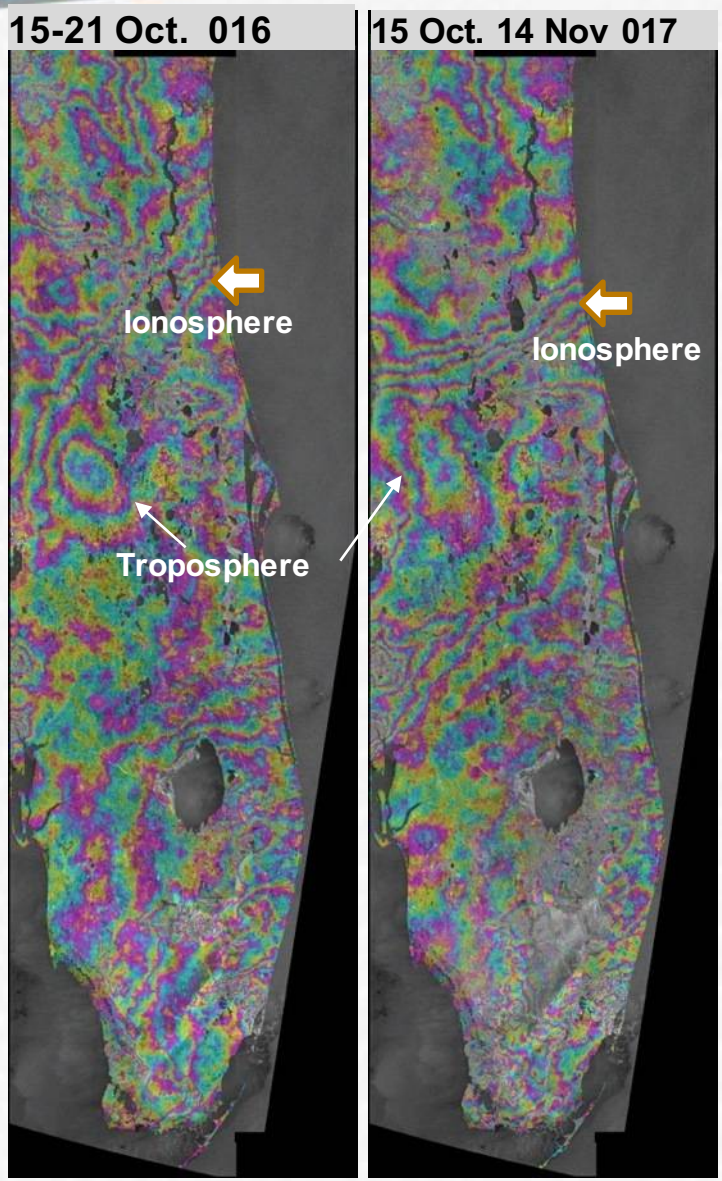
- Spatiotemporal variations in Atmosphere represent one of the major limitations of repeat-pass InSAR

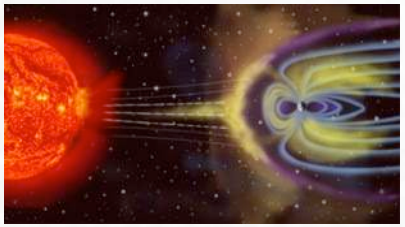




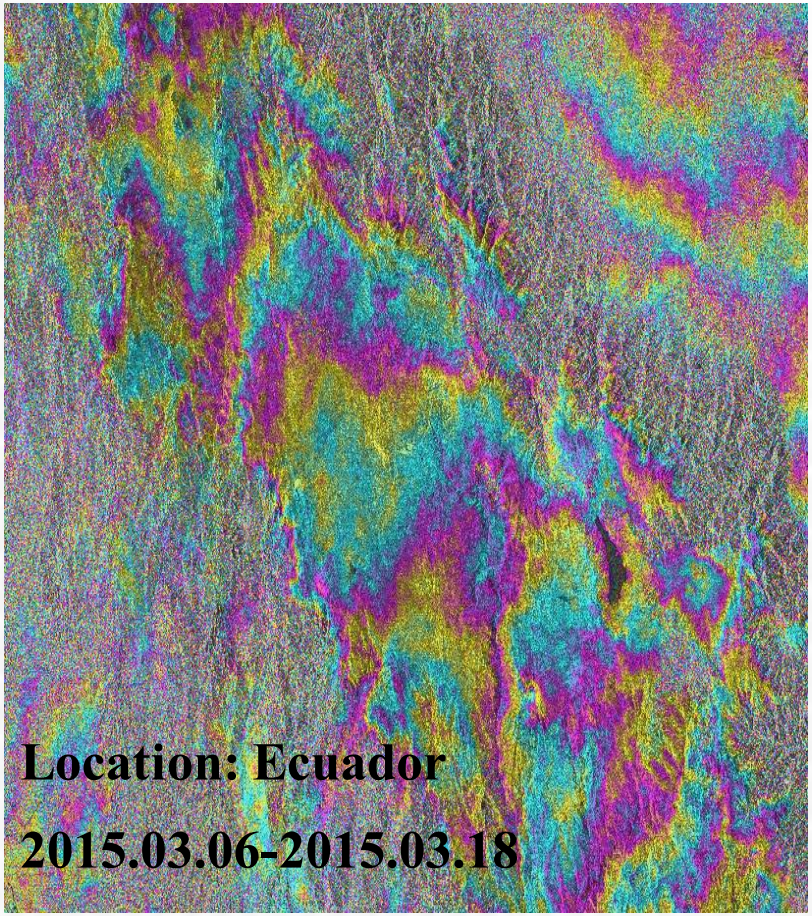
Examplary interferograms

Florida





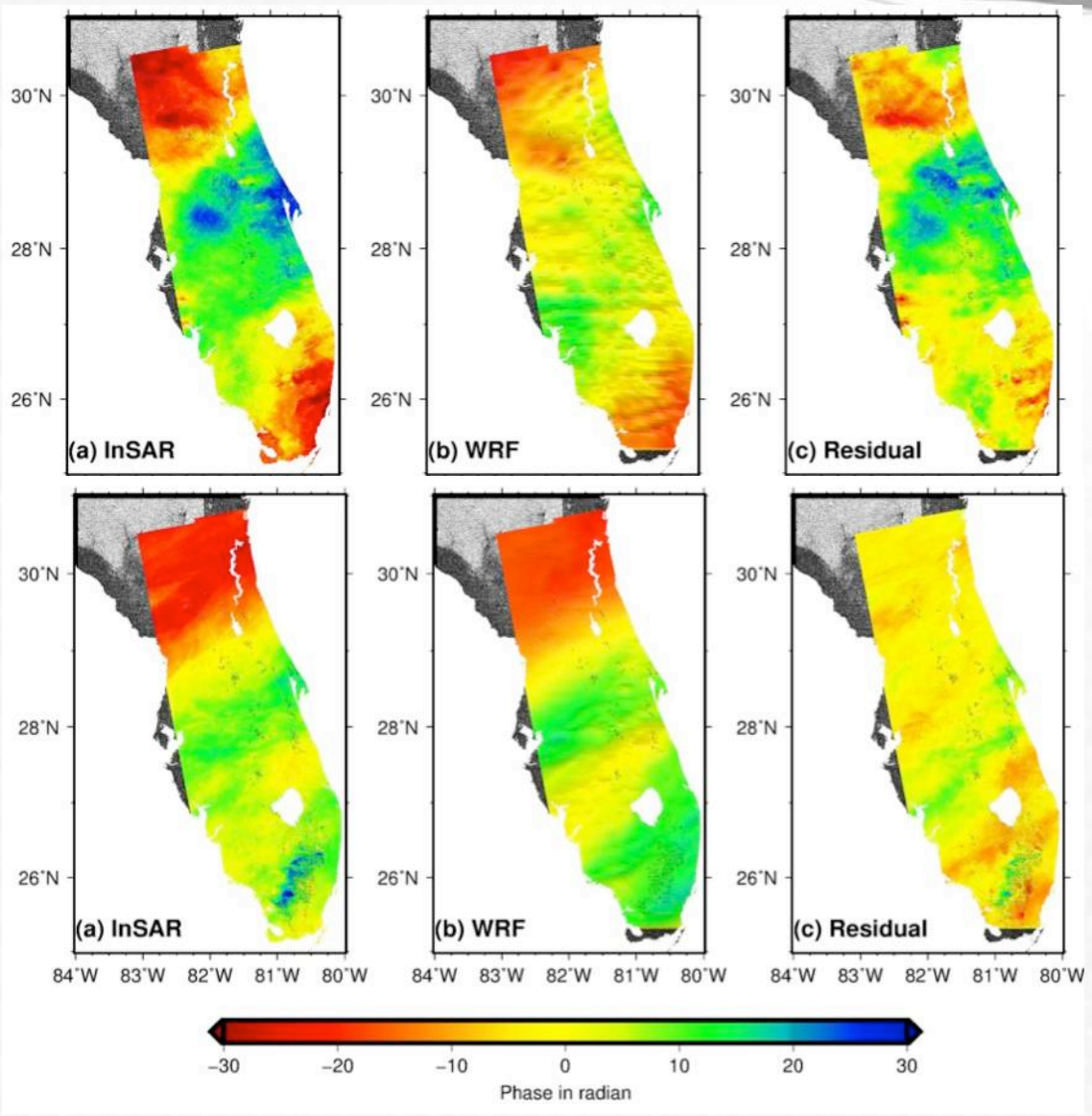
Geomagnetic Storm on 17.03.15



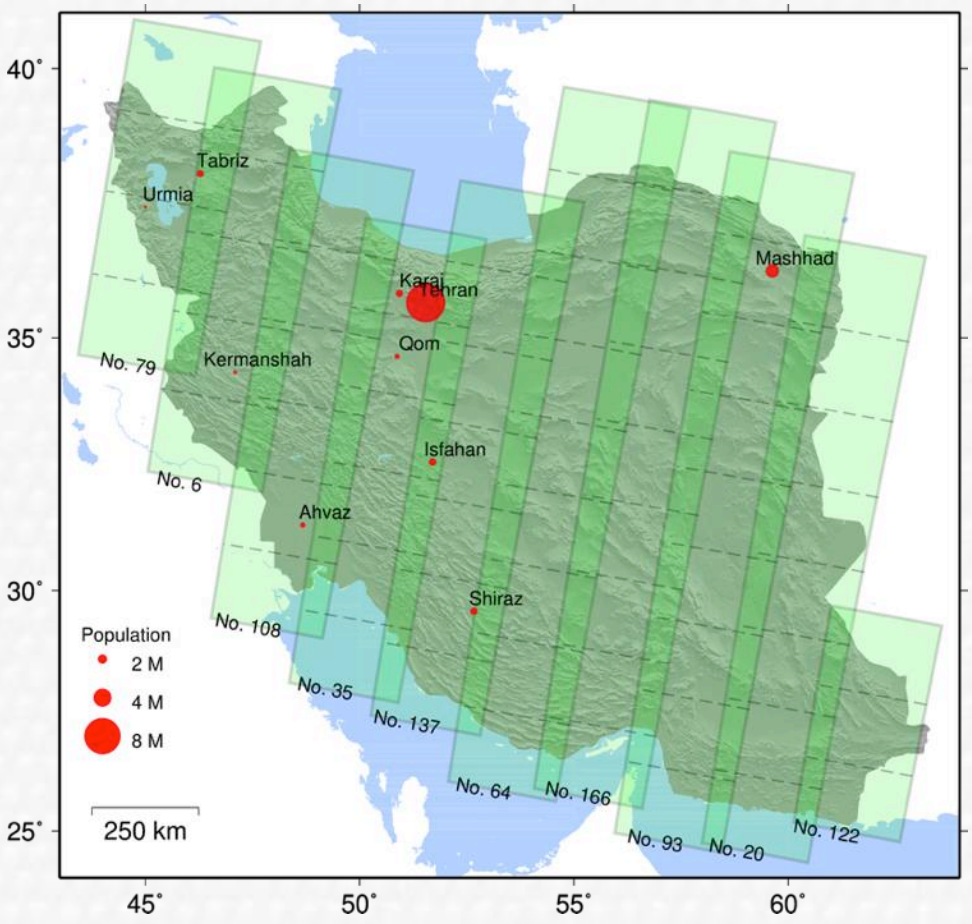
Tropospheric phase delay

20161015-20161021

20171215-20180120

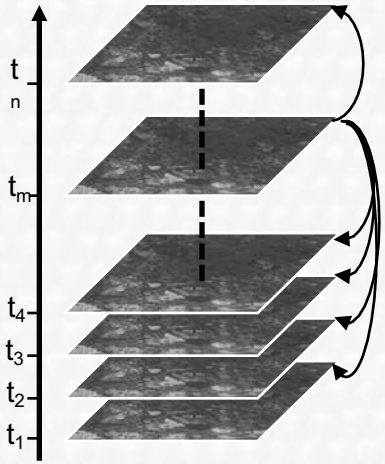


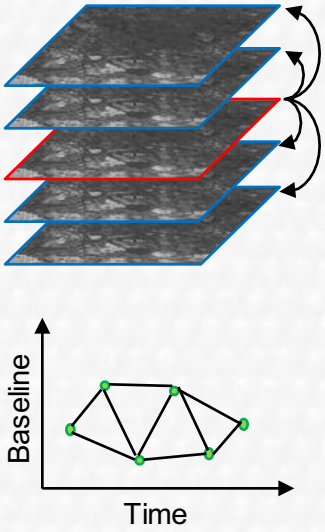
Sentinel-1 data over Iran



- Sentinel-1 observation in Iran
  - In both ascending and descending
  - 12 day repeat interval
- Dataset used here
  - 10 descending orbit
  - 66 frames
  - 2014 - 2018
  - ~3500 Sentinel-1 images
  - ~14 TB of SLC images

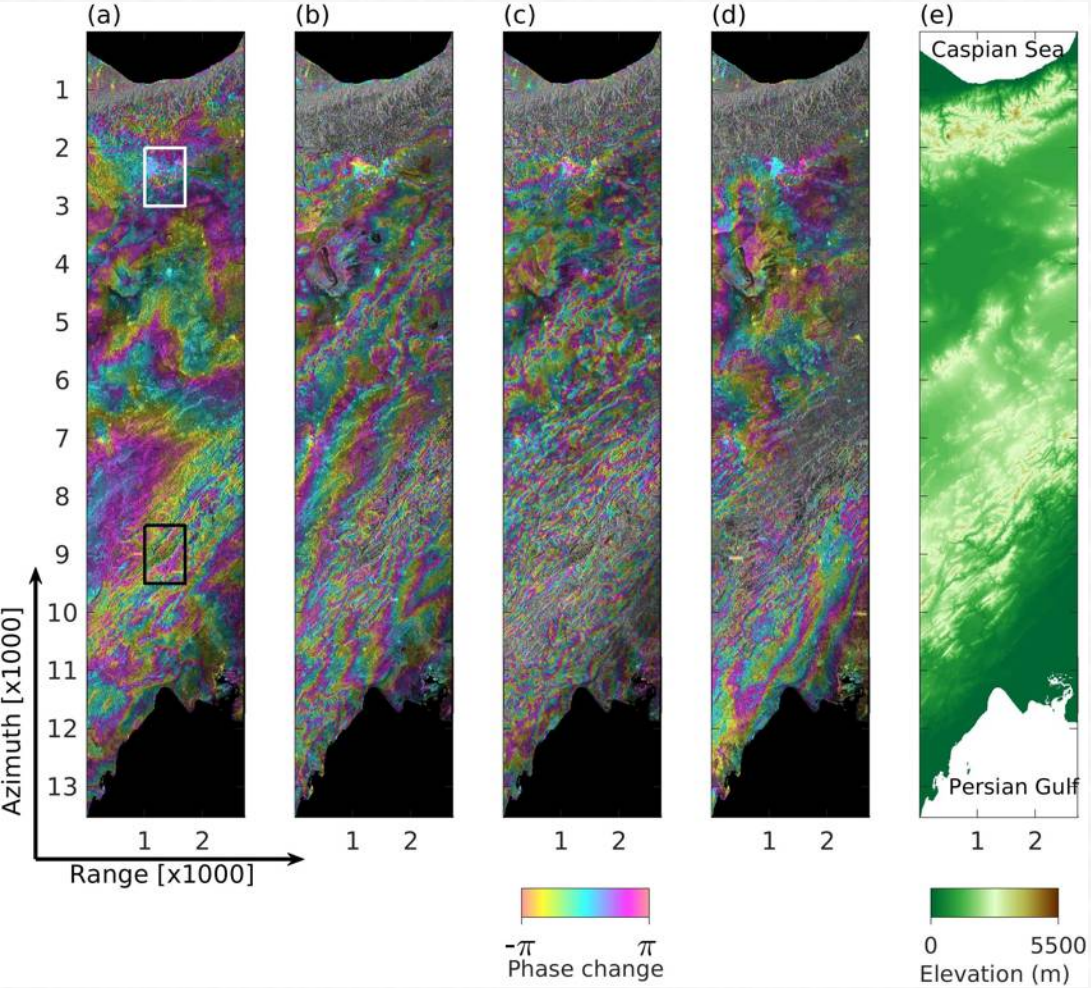
Land subsidence detection

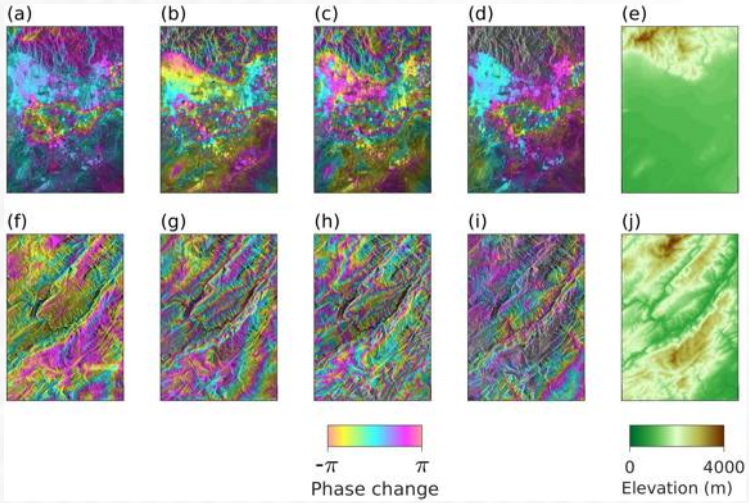




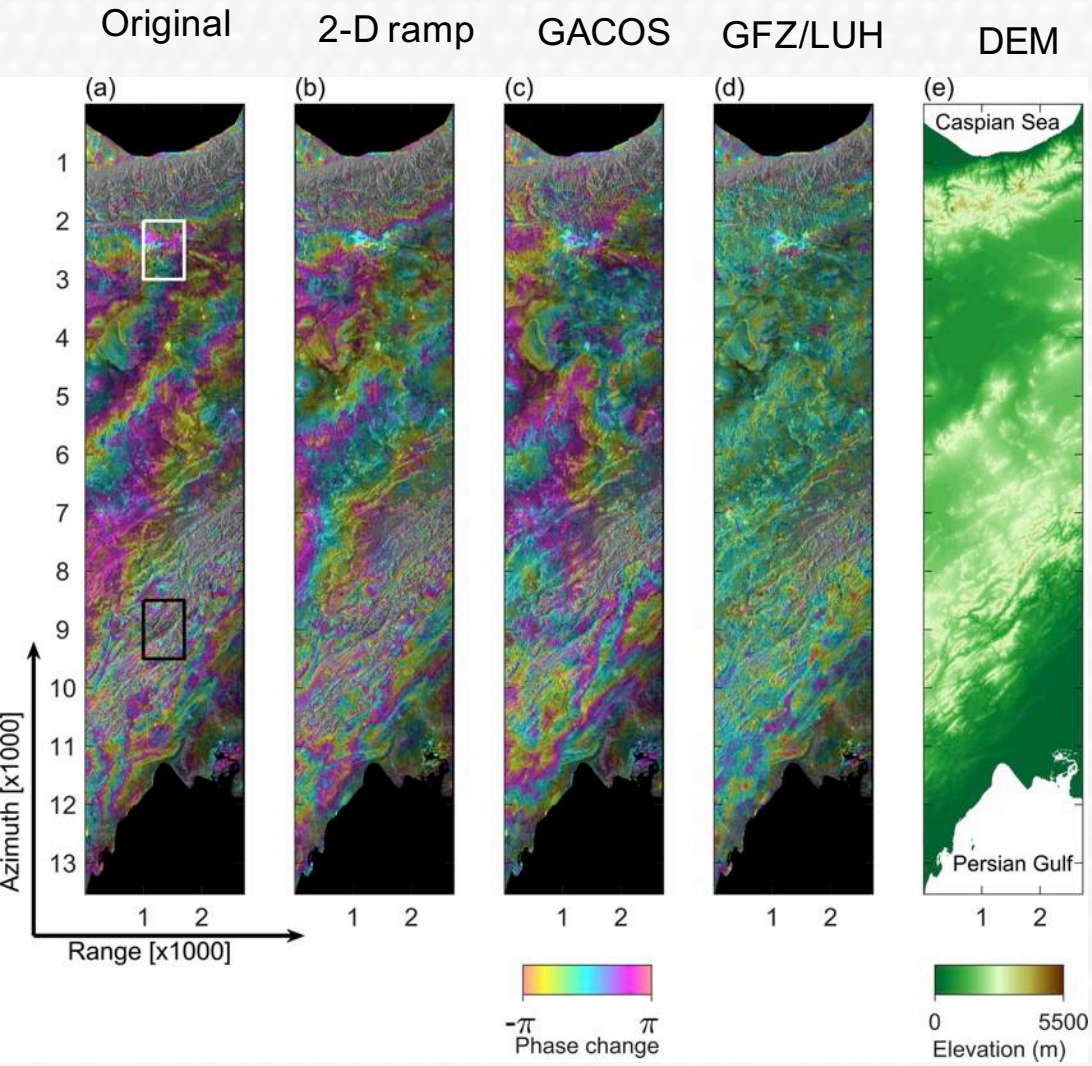
Examplary interferograms

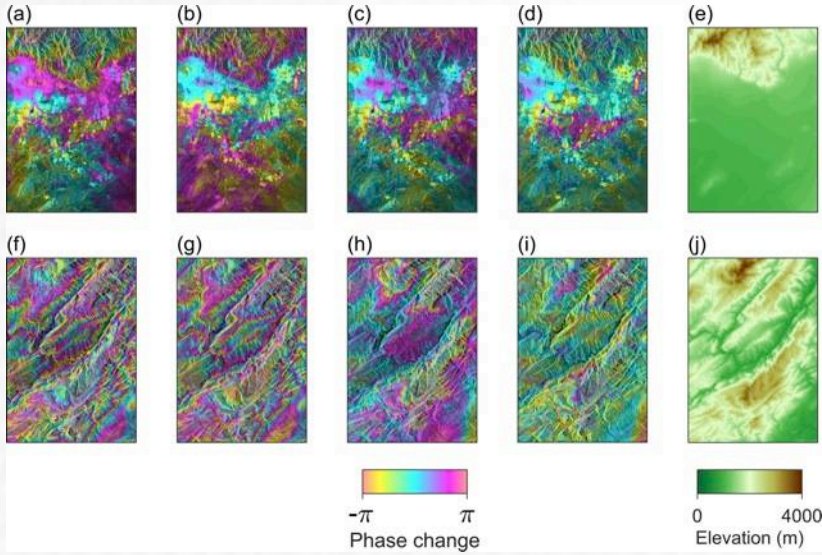
(a) 2017.08.05-2017.10.28
(b) 2017.04.07-2017.07.12
(c) 2016.07.29-2016.11.02
(d) 2017.02.18-2017.05.13



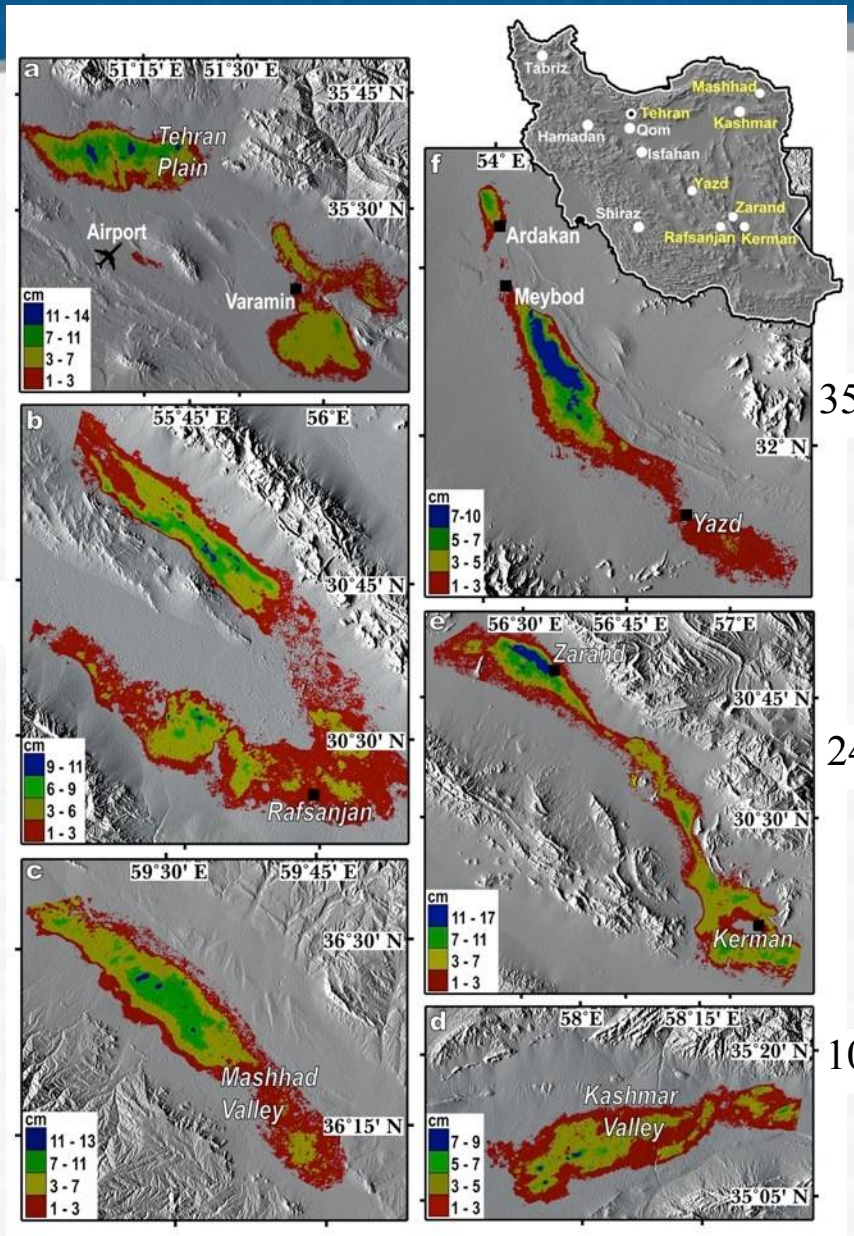


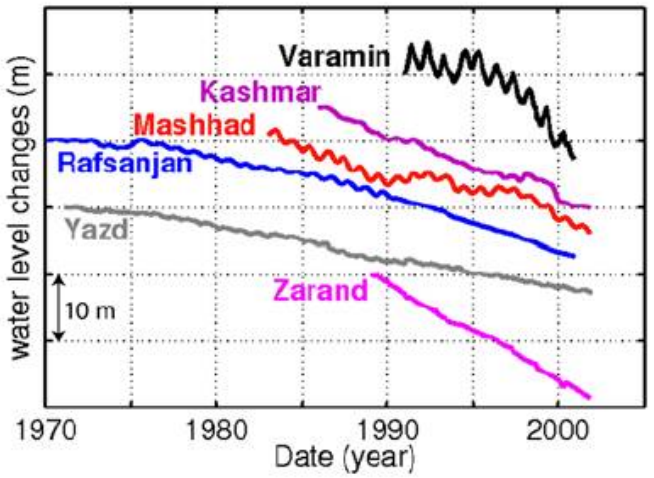
Large-scale analysis





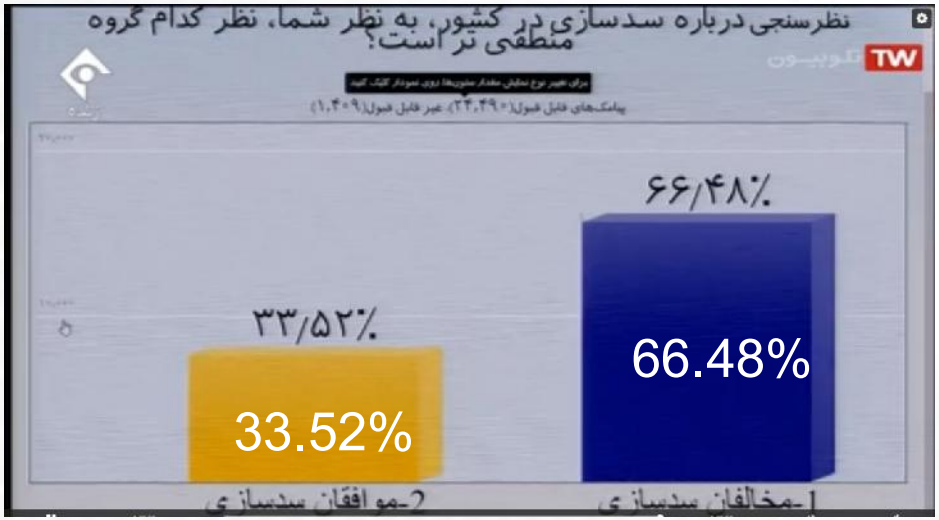
Land subsidence in Iran





Motagh, et al., GRL, 2008

National exposure



Summary & Conclusion

- Moderate-resolution C-band Sentinel-1 (S1) is a game changer in delivering low-latency products to both the science community and the public.
- Challenges in S1: Big data, near-real time processing and correction, data mining and deep learning approaches
- CR-InSARs are promising tools for developing the next generation of **Reference Points** for precise infrastructure stability analysis