Characterising Iran's rapidly subsiding regions using Earth Observation data

Jessica Payne[1], Andrew Watson[2], Scott Watson[2], Mark Thomas[2], Kate Donovan[3], Yasser Maghsoudi[2], Milan Lazecky[2], Richard Rigby[2], and John Elliott[2]

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Abstract

In Iran, both local and regional scale land-surface deformation has resulted from the decline in groundwater levels (Motagh et al., 2008). Moreover, the gap between groundwater extraction and renewal is so large that the resulting short-term impacts are likely to be irreversible (Olen, 2021).

Here we use Earth Observation (EO) data to calculate vertical subsidence rates due to groundwater extraction in Tehran, Iran's capital city. This data includes Sentinel-1 Interferometric Synthetic Aperture Radar (InSAR); very high-resolution (VHR) Pléiades optical stereo imagery; and ICESAT-2 laser altimetry data.

The Centre for Observing and Monitoring Earthquakes and Tectonics (COMET) Looking into Continents from Space (LiCSAR) automated processing system is used to process six years (2015-2021) of Sentinel-1 SAR acquisitions (Lazecký et al., 2020) for interferometric (InSAR) analysis. The system generates short baseline networks of interferograms. We also correct for atmospheric noise using the GACOS system (Yu et al., 2018; Yu et al., 2018) and perform time-series analysis using open-source LiCSBAS software (Morishita et al., 2020). Vertical and horizontal (east-west) velocities are calculated and mapped to produce nationwide and regional velocity fields (Watson et al., 2022). Preliminary results indicate maximum subsidence rates in Tehran exceed 100 mm/year.

VHR Digital Elevation Models (DEMs) and laser altimetry ground returns are also used to calculate land subsidence rates in Tehran. By comparing rates calculated using all three EO techniques we aim to validate InSAR velocities whilst investigating and constraining the benefits, drawbacks, and biases associated with each technique. Phase bias (Zan et al., 2015), for example, may be introduced to calculated InSAR velocities when using the LiCSBAS short baseline network strategy as subsiding regions in Iran are often vegetated cropland.

Publishing the open-source COMET-LiCS Subsidence Portal was the focus of previous work (https://comet-subsidencedb.org/). The portal presents automatically processed LiCSAR Sentinel-1 interferograms and LiCSBAS velocity timeseries for 99 subsiding regions across Iran. Interactive tools allow stakeholders to make quick, critical assessments related to extents and rates of subsidence. Validating portal data using DEMs and laser altimetry is essential before expanding the portal to have a global focus.

References

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2 – Edinburgh Climate Change Institute

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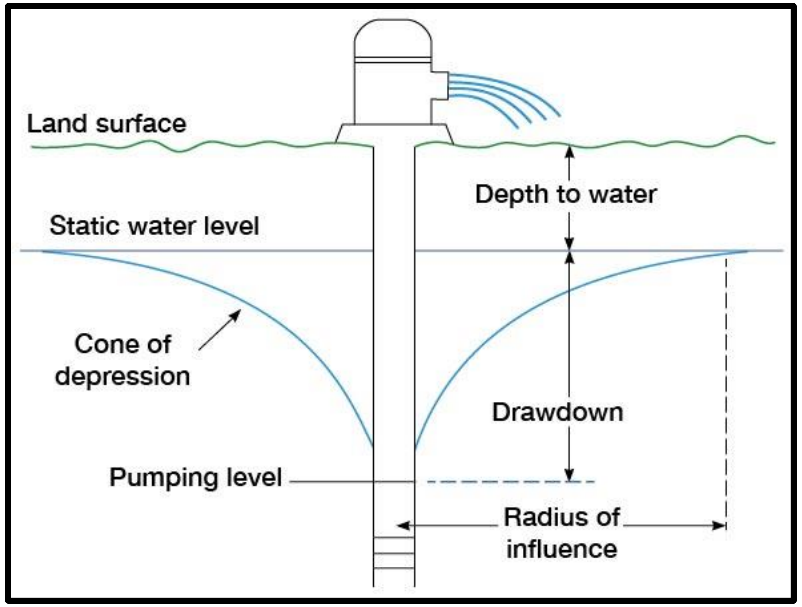
OSPA QR Code

1. Groundwater extraction and subsidence



EFFECTIVE STRESS CONCEPT

$$\sigma = \sigma' + u$$

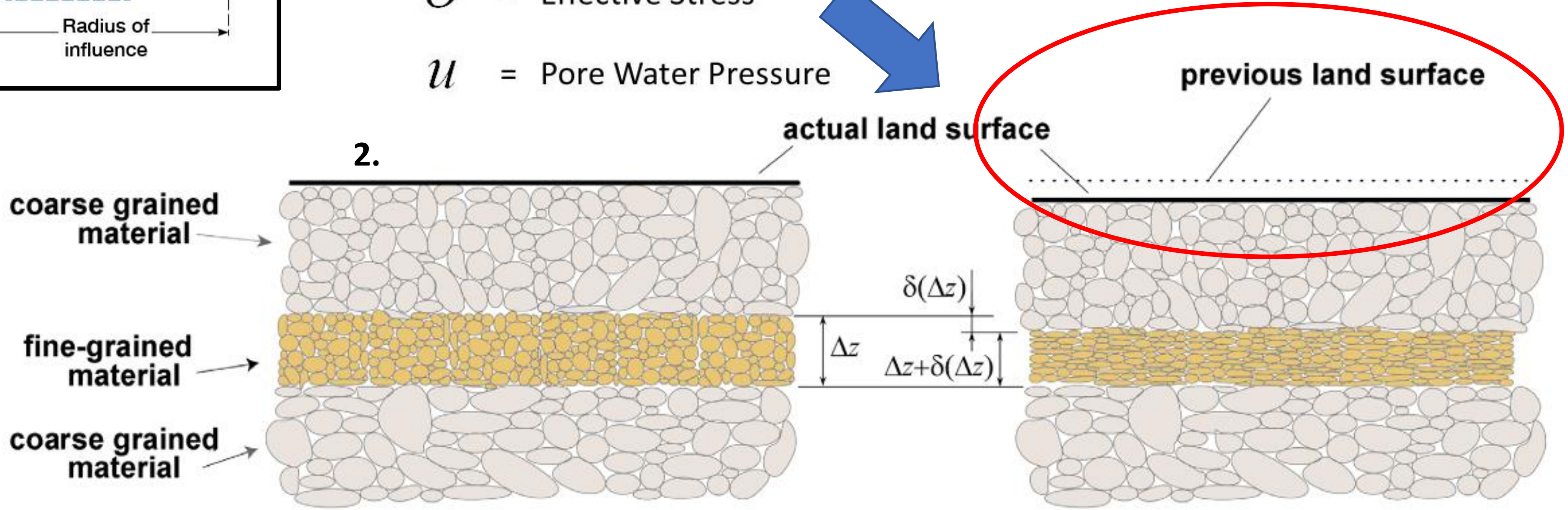
where...

σ = Total Vertical Stress

σ' = Effective Stress

u = Pore Water Pressure

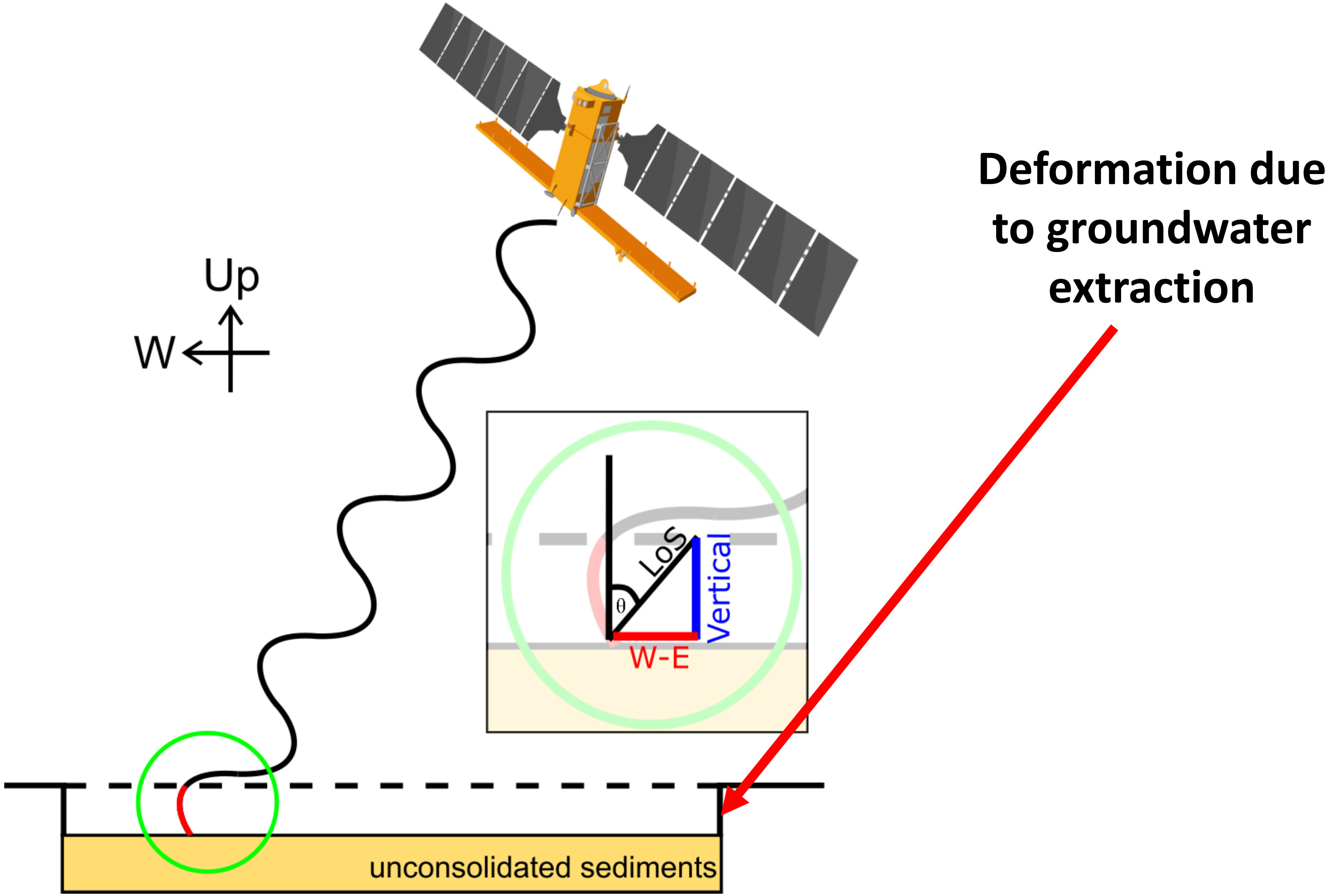
Deformation due to groundwater extraction



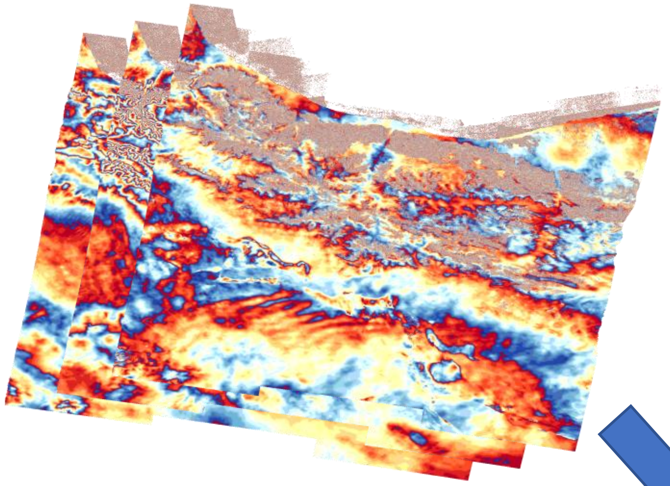
Gambolati & Teatini (2015)

1. Groundwater extraction and subsidence

Sentinel-1:
- **Oct 2014-present**
- **6 or 12** day repeat time
- **100 m pixel** width
- **Global** coverage

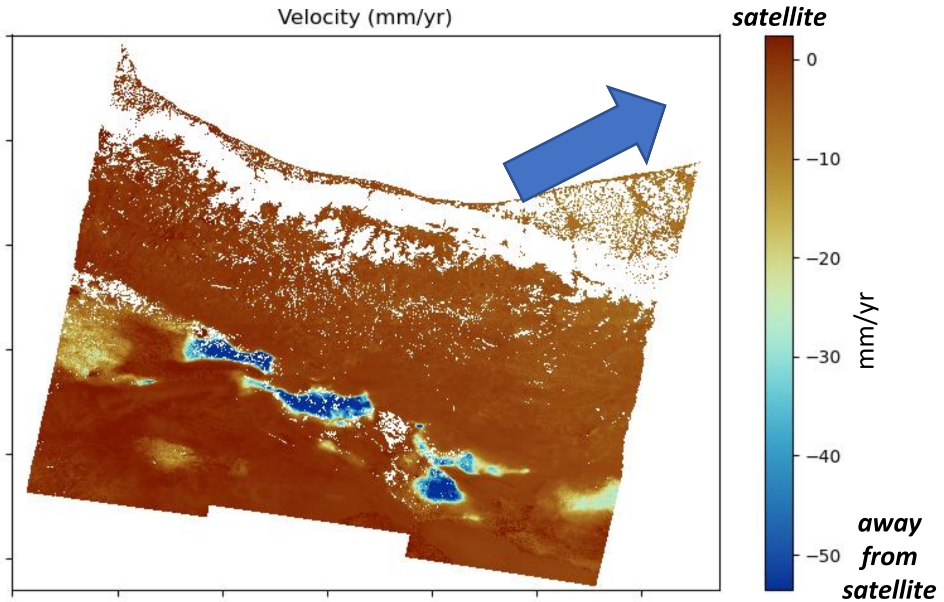


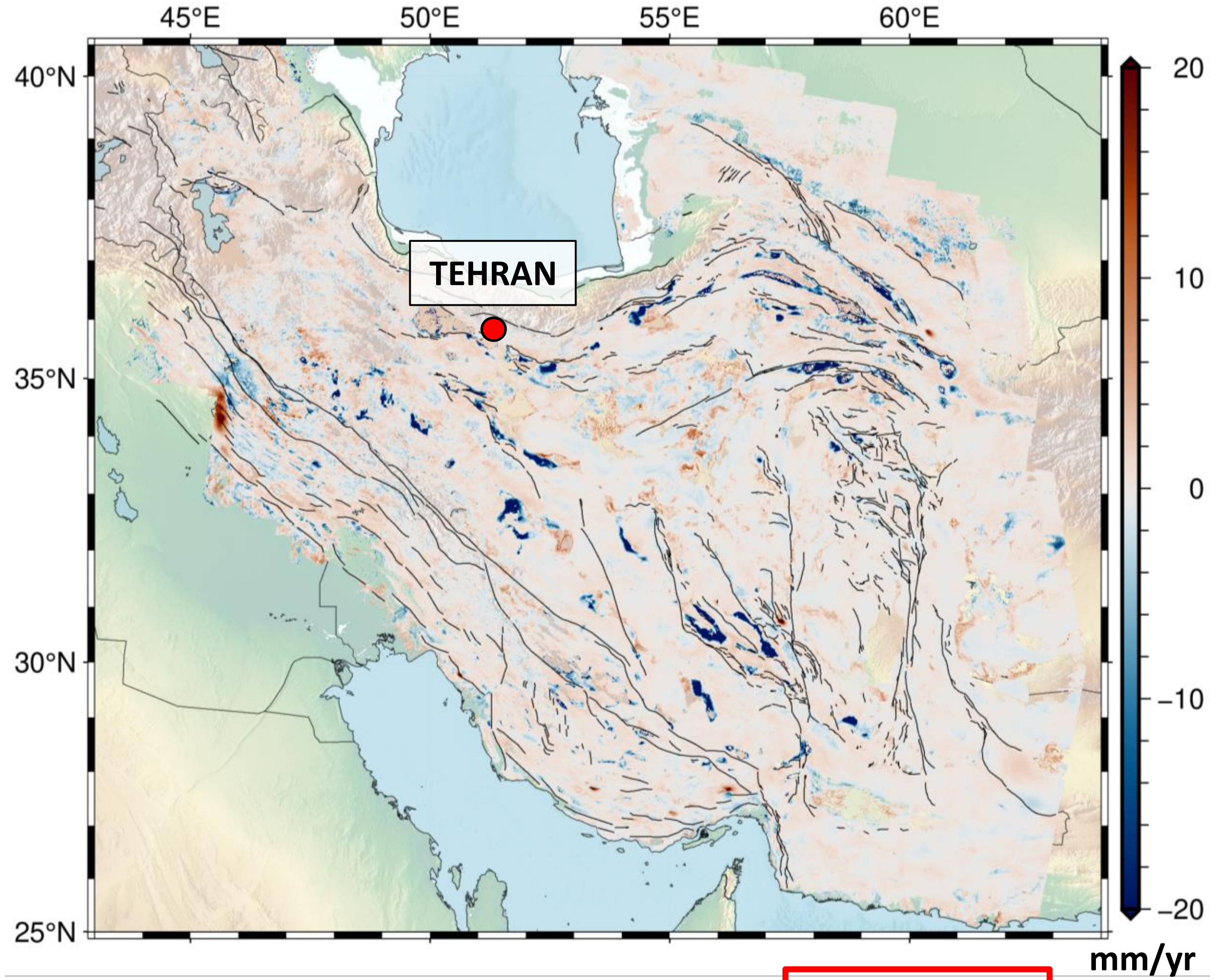
2. Calculate vertical InSAR velocities



Sentinel-1 interferograms
LiCSAR
Lazecky *et al*. (2020)

LoS time-series analysis
LiCSBAS
Morishita *et al*., (2020)

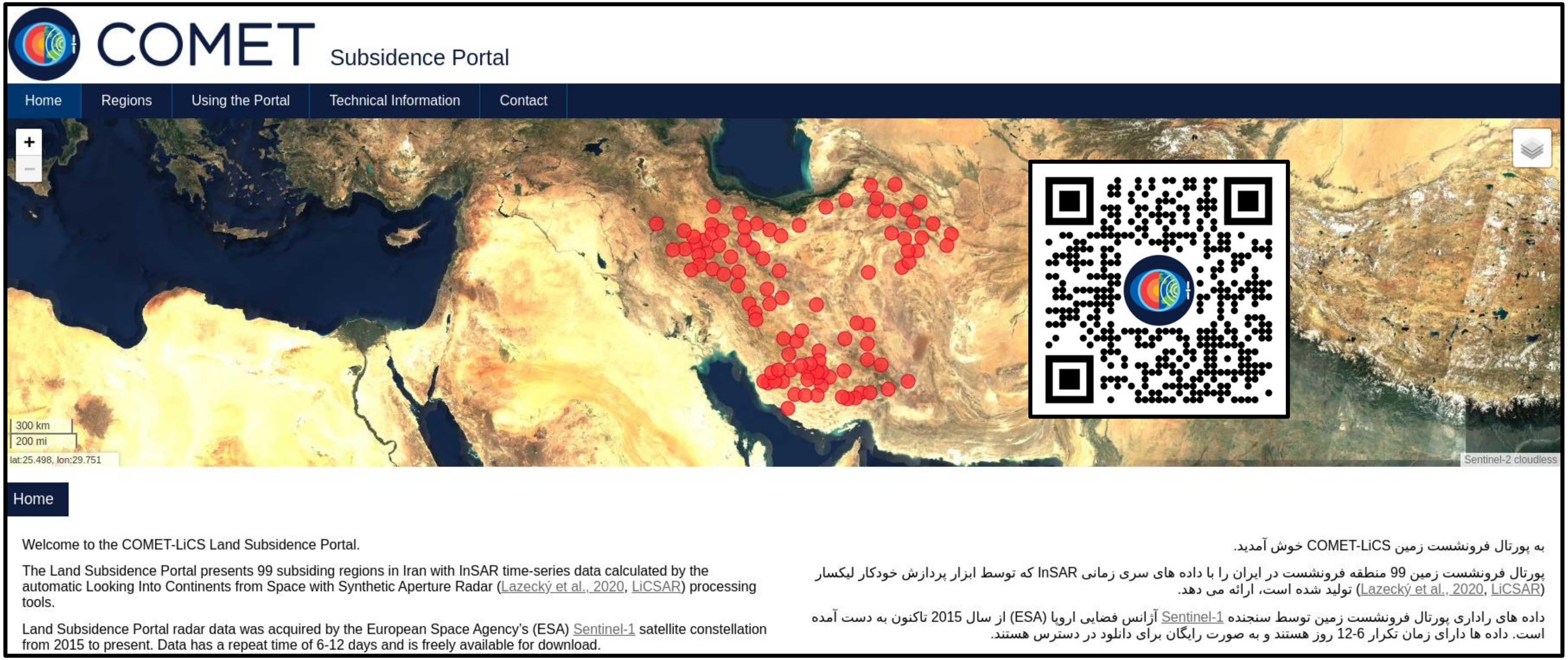




Velocity decomposition +
velocity field construction
Watson *et al*., (2022)

G34A-06
Wed 14th
Poster

2: Calculate InSAR velocities



https://comet-subsidencedb.org/

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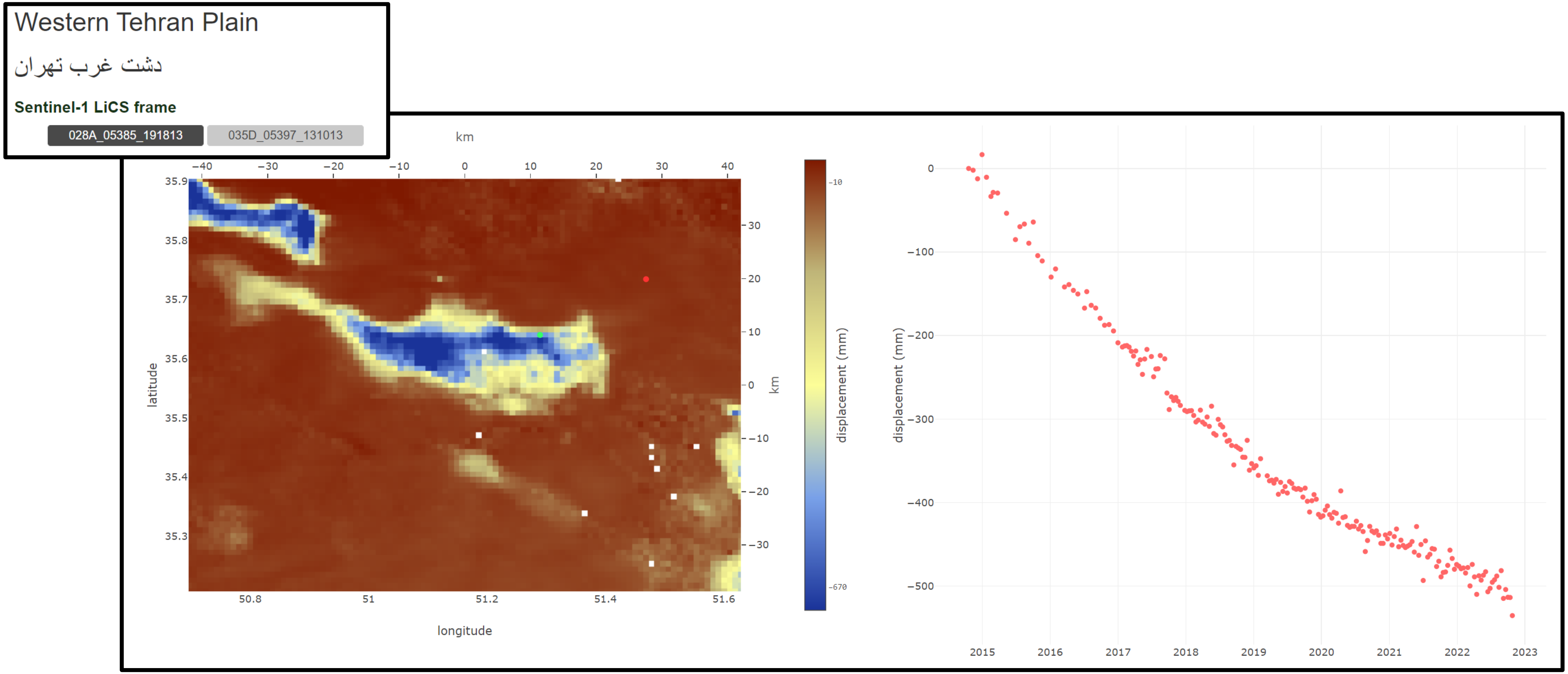

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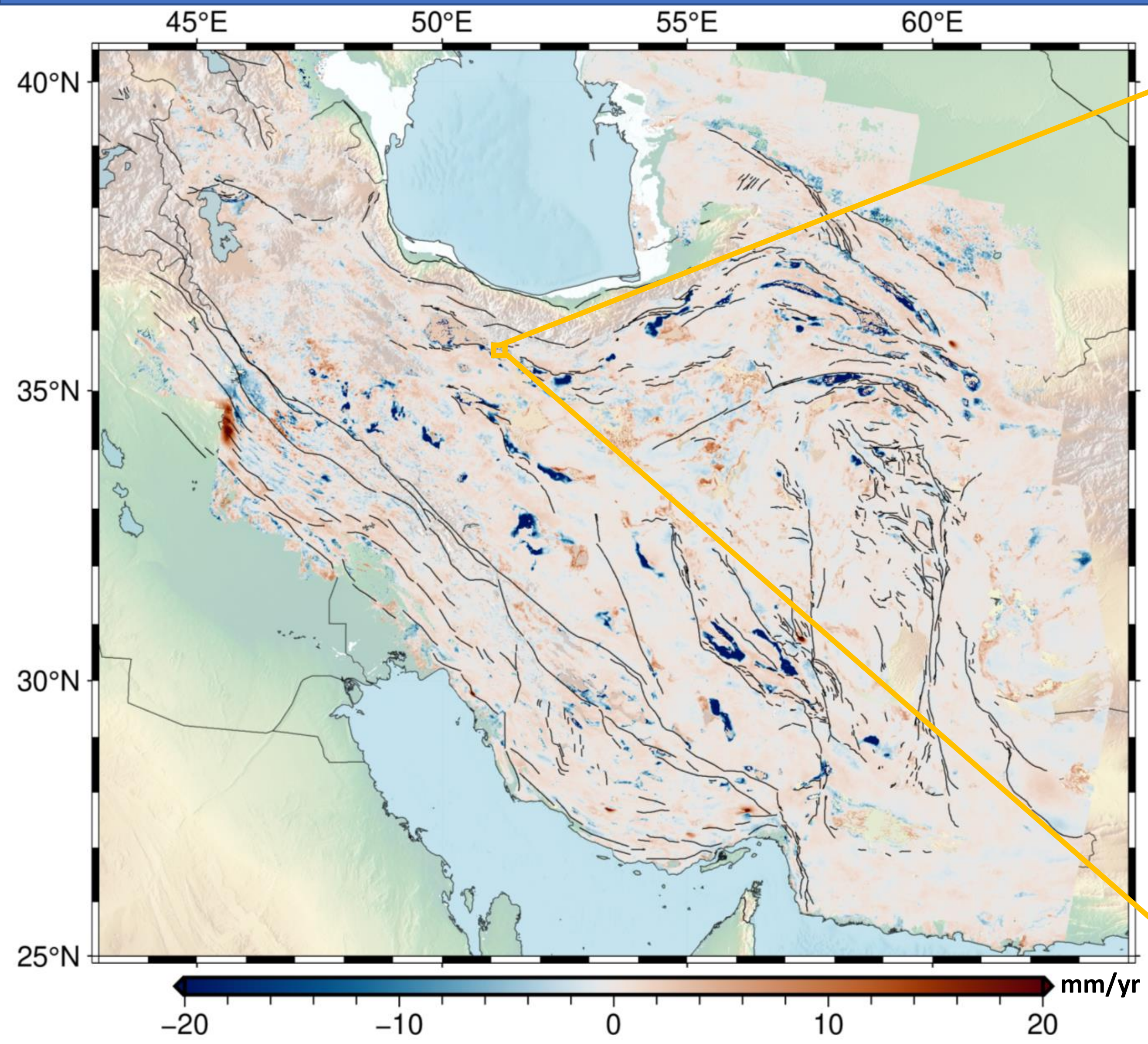

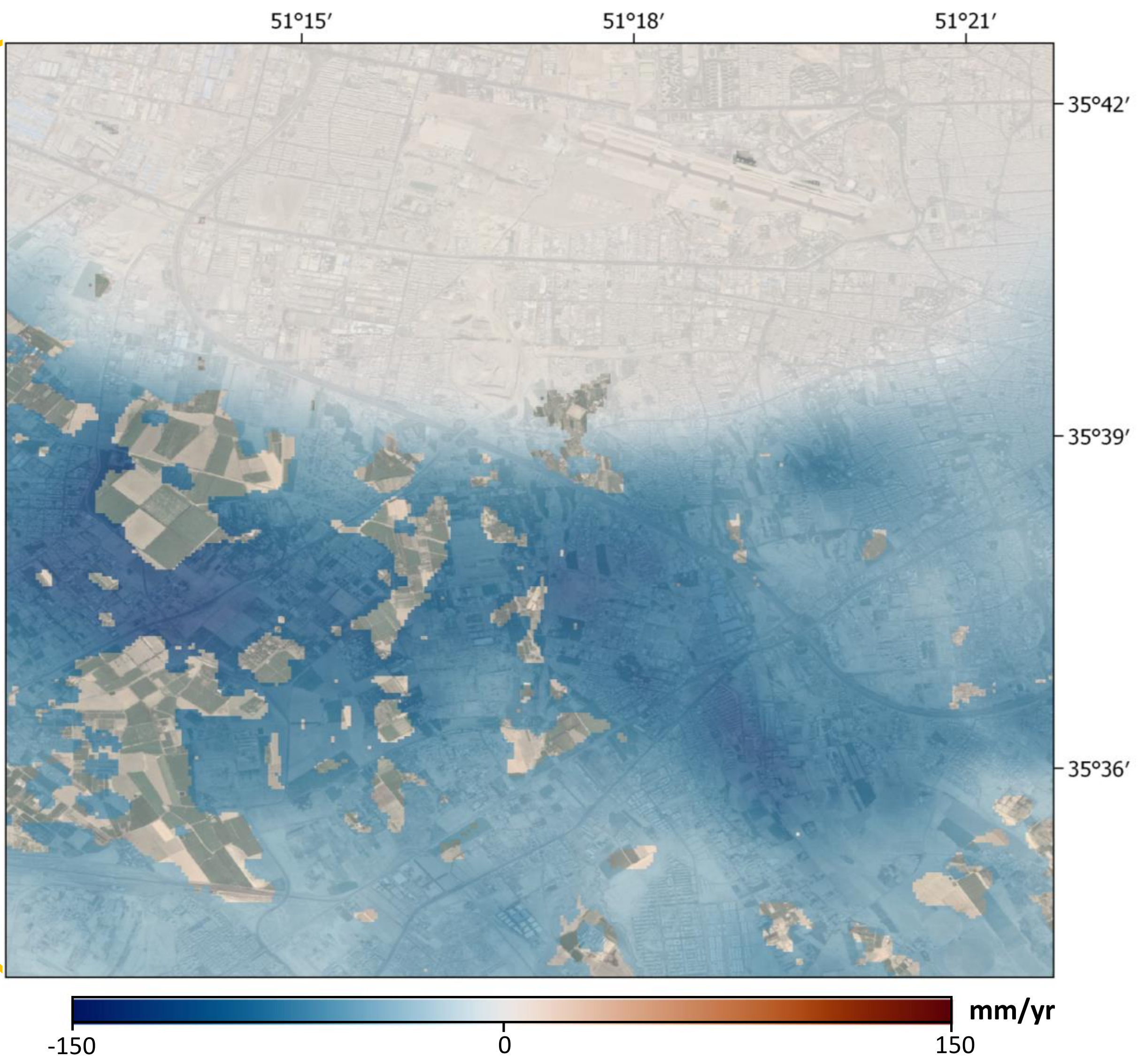

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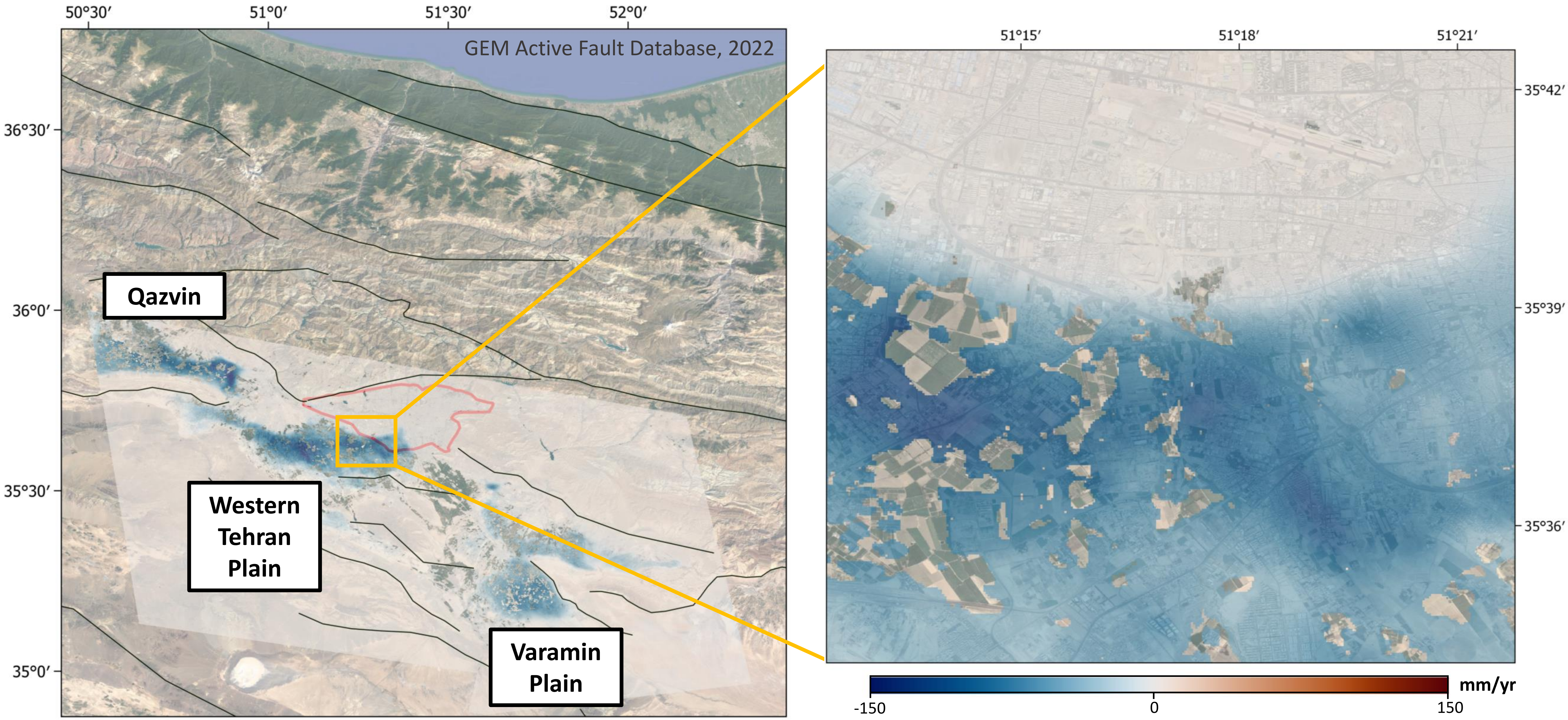
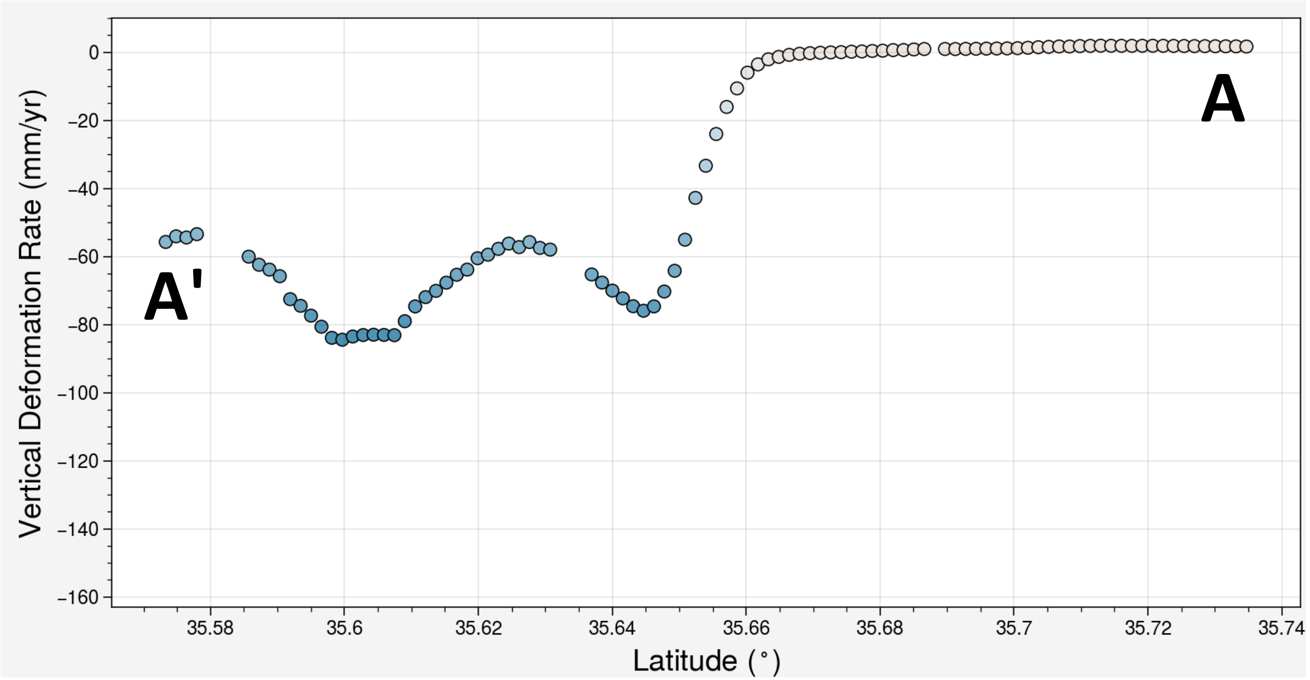
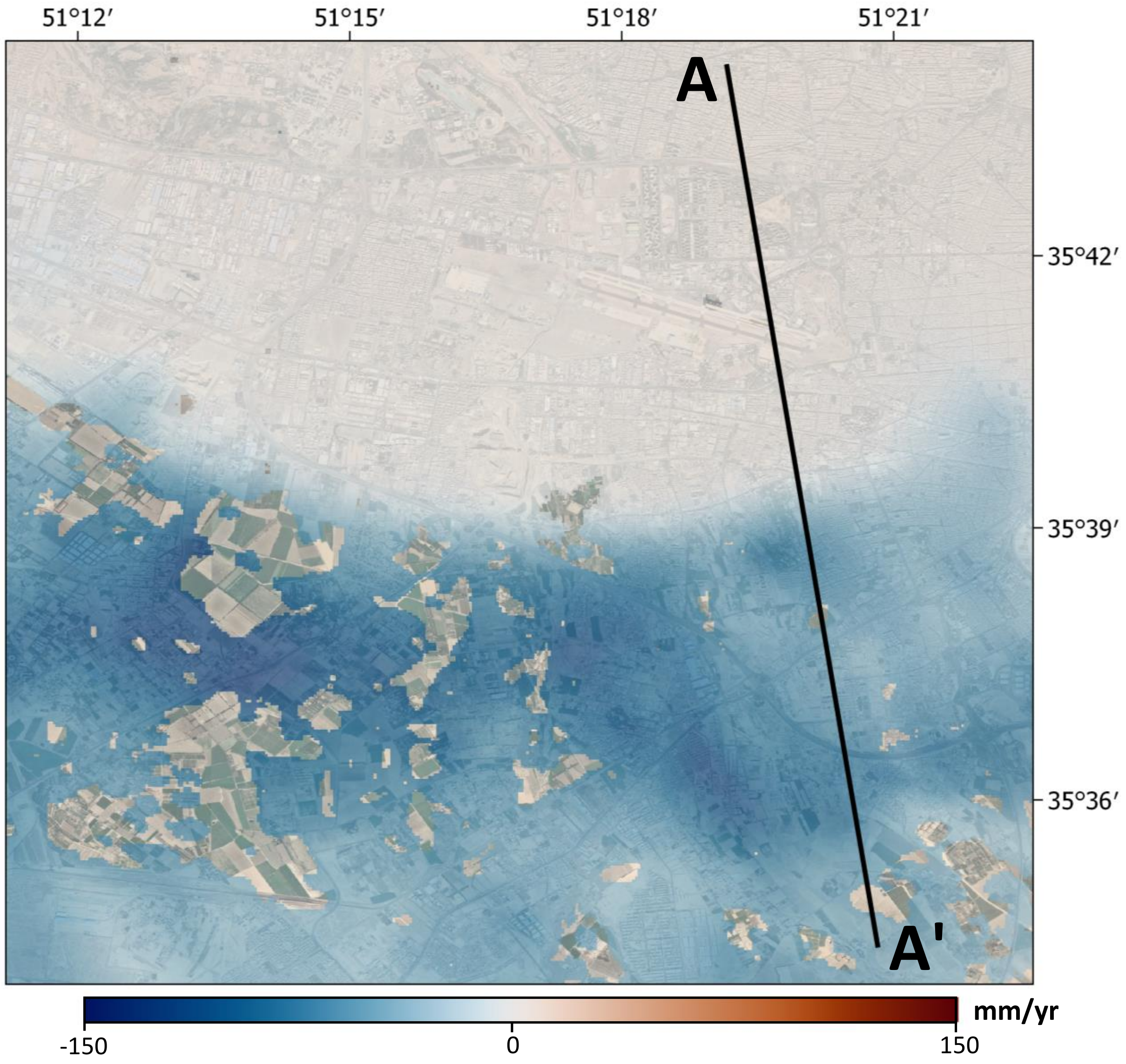


2: Calculate InSAR velocities

Western Tehran Plain





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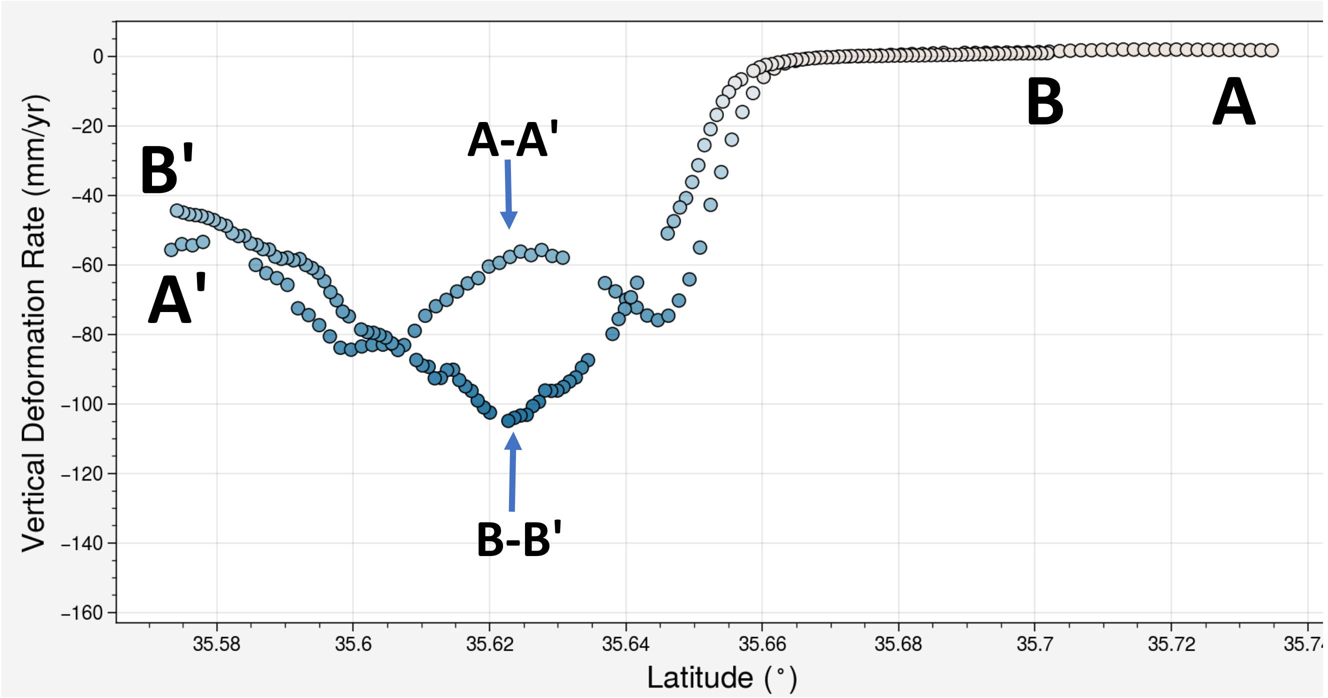
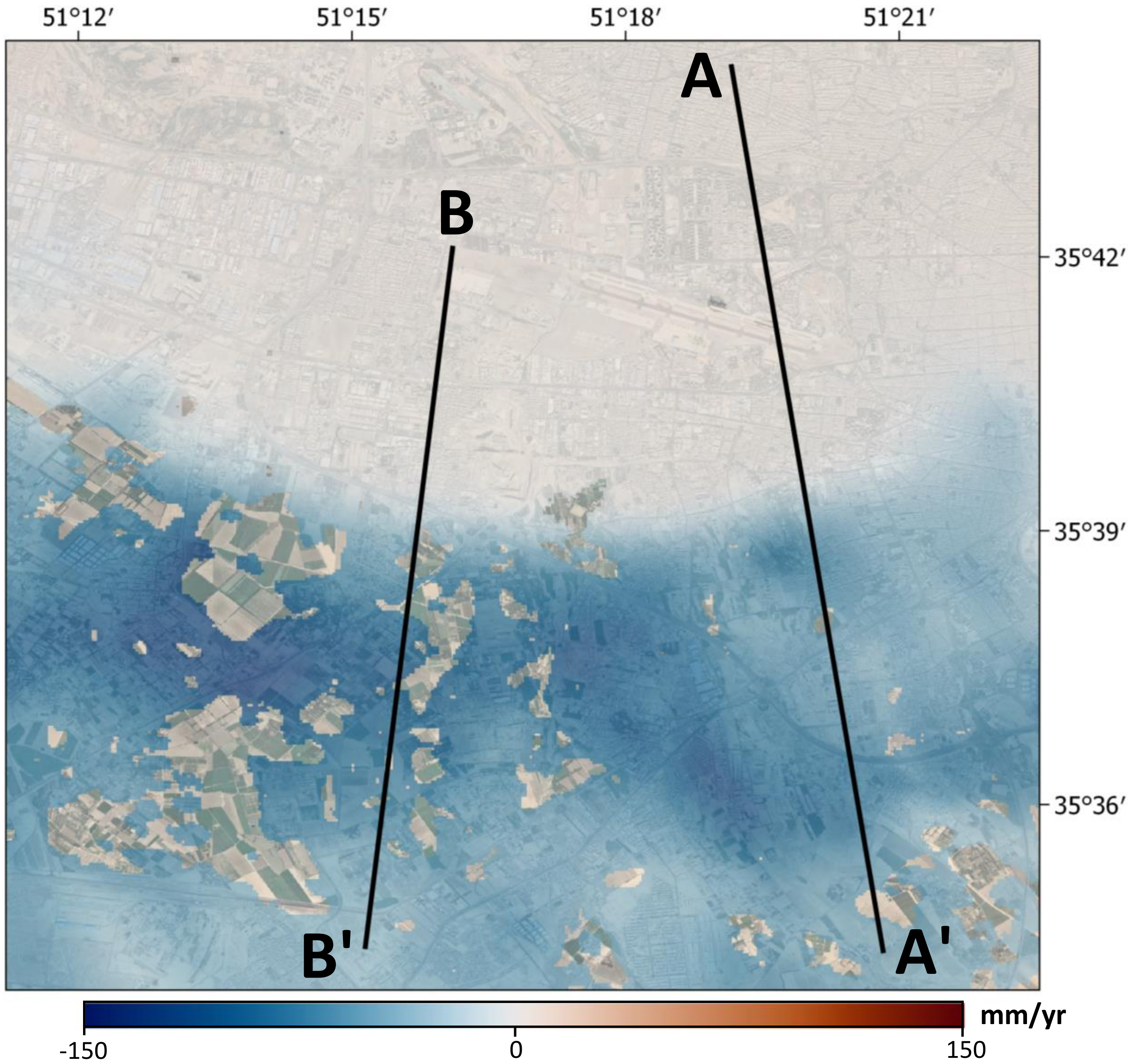
Western Tehran Plain



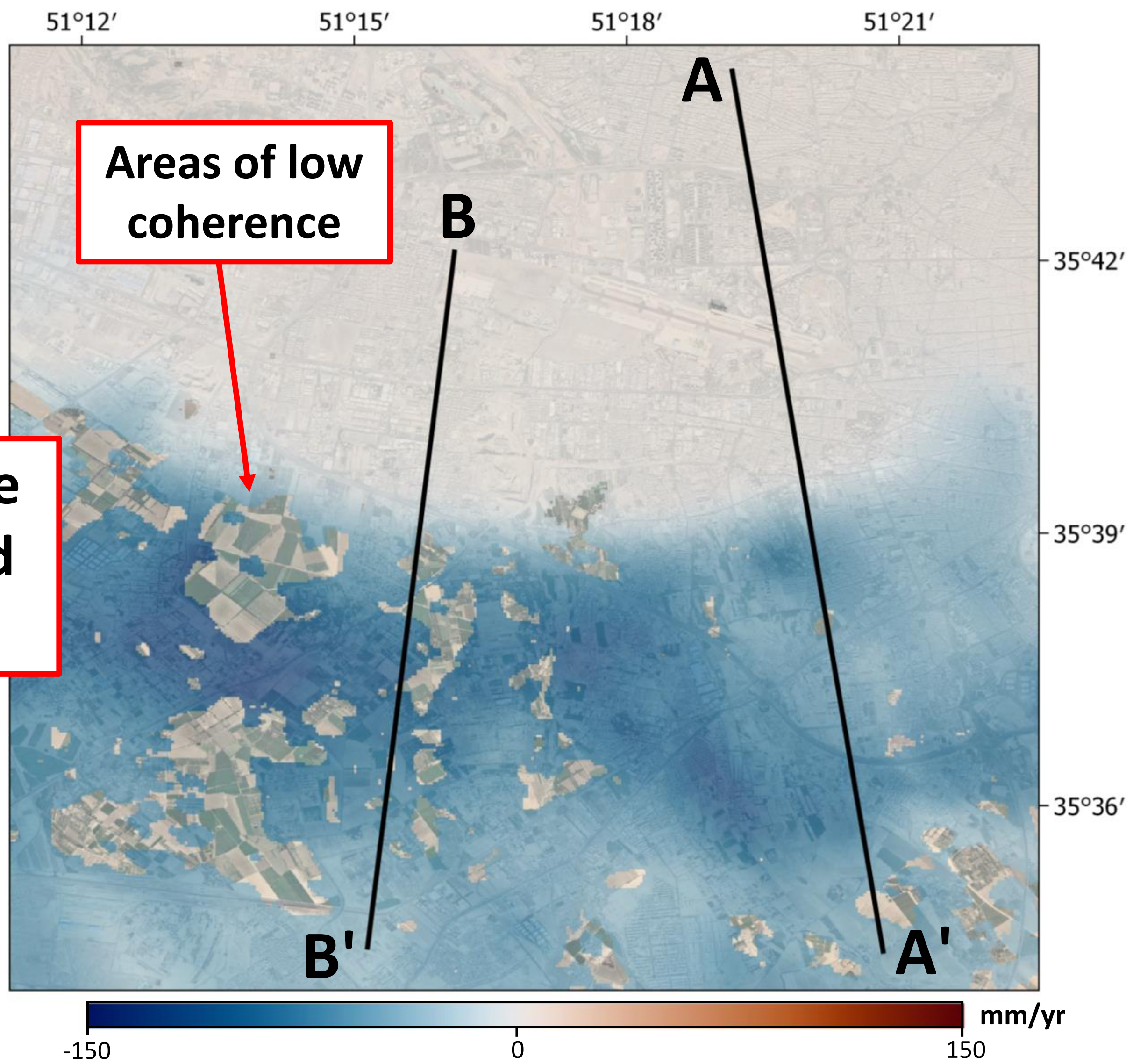


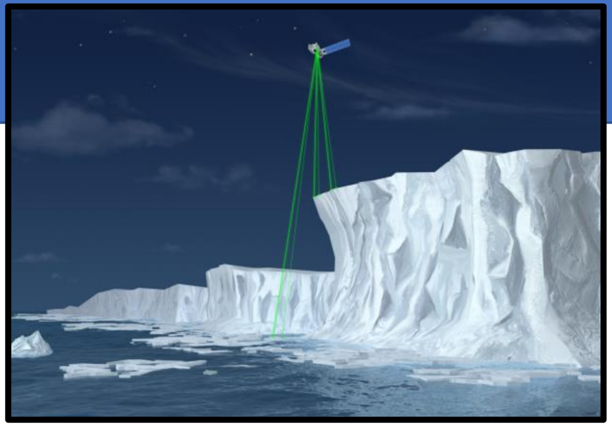
2: Calculate InSAR velocities

Western Tehran Plain

	Maxiumum subsidence rate (mm/yr)	Instrument	Acquisition period
Motagh *et al.* (2008)	30	Envisat	Jun-Oct 2004
Foroughnia *et al.* (2019)	~150	Envisat, Sentinel-	
Dehghani *et al.* (2013)	~200	Envisat	
Haghshenas Haghighi & Motagh (2019)	250	Envisat, ALOS, TerraSAR-X, Sentinel-1	2003-2017
This study	**150**	**Sentinel-1**	**2014-2022**

Can we validate these rates and magnitudes?

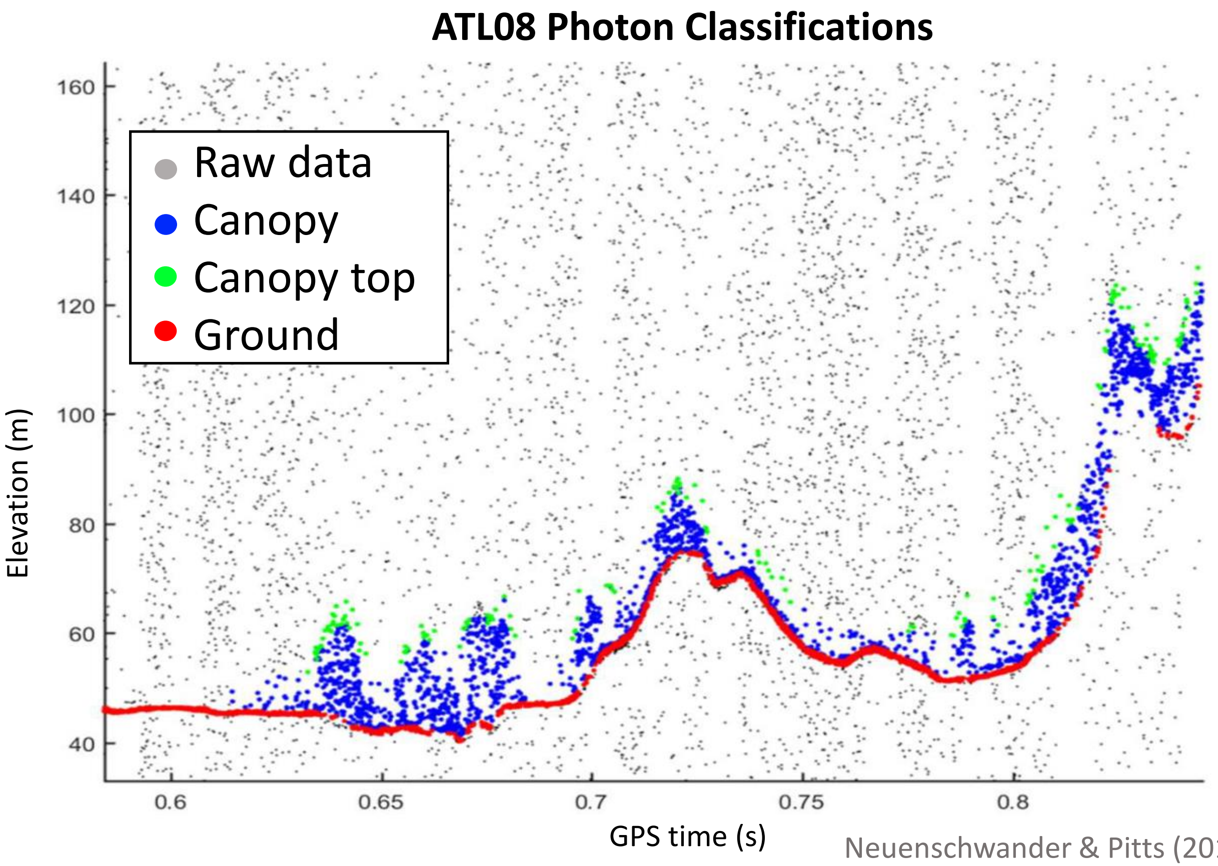




1. ICESat-2 laser altimetry
data (repeat time ~3 months)

- ATL03 product = Geolocated Photon Data
- ATL08 product = Land and Vegetation Height
- Difference the ground returns

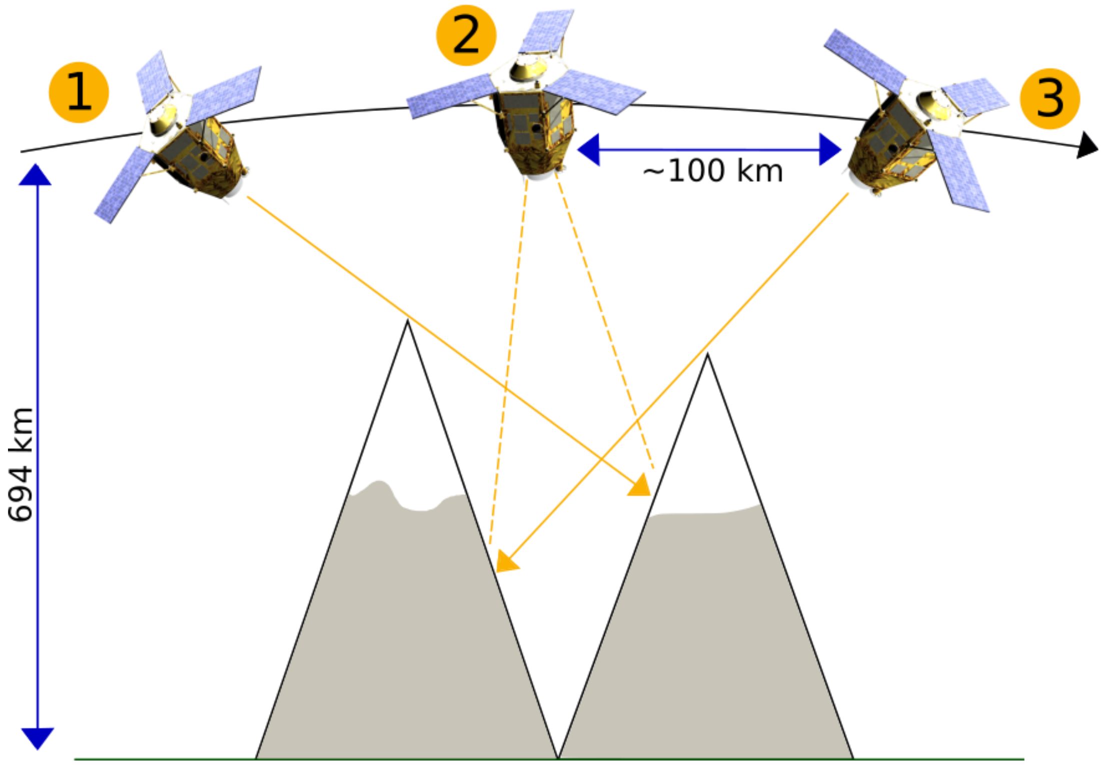
  -> subsidence rate



Neuenschwander & Pitts (2019)

3. Validating InSAR: VHR DEMs

1. **Pléiades 50 cm/Pléiades Neo 30 cm stereoscopic** imagery
2. Construct dense point cloud and **1.5m DEM** from each stereoscopic set
3. **Reproject** secondary DEM to reference DEM grid
4. **Remove static offset** between DEM pairs
5. **Difference DEMs** to calculate vertical change



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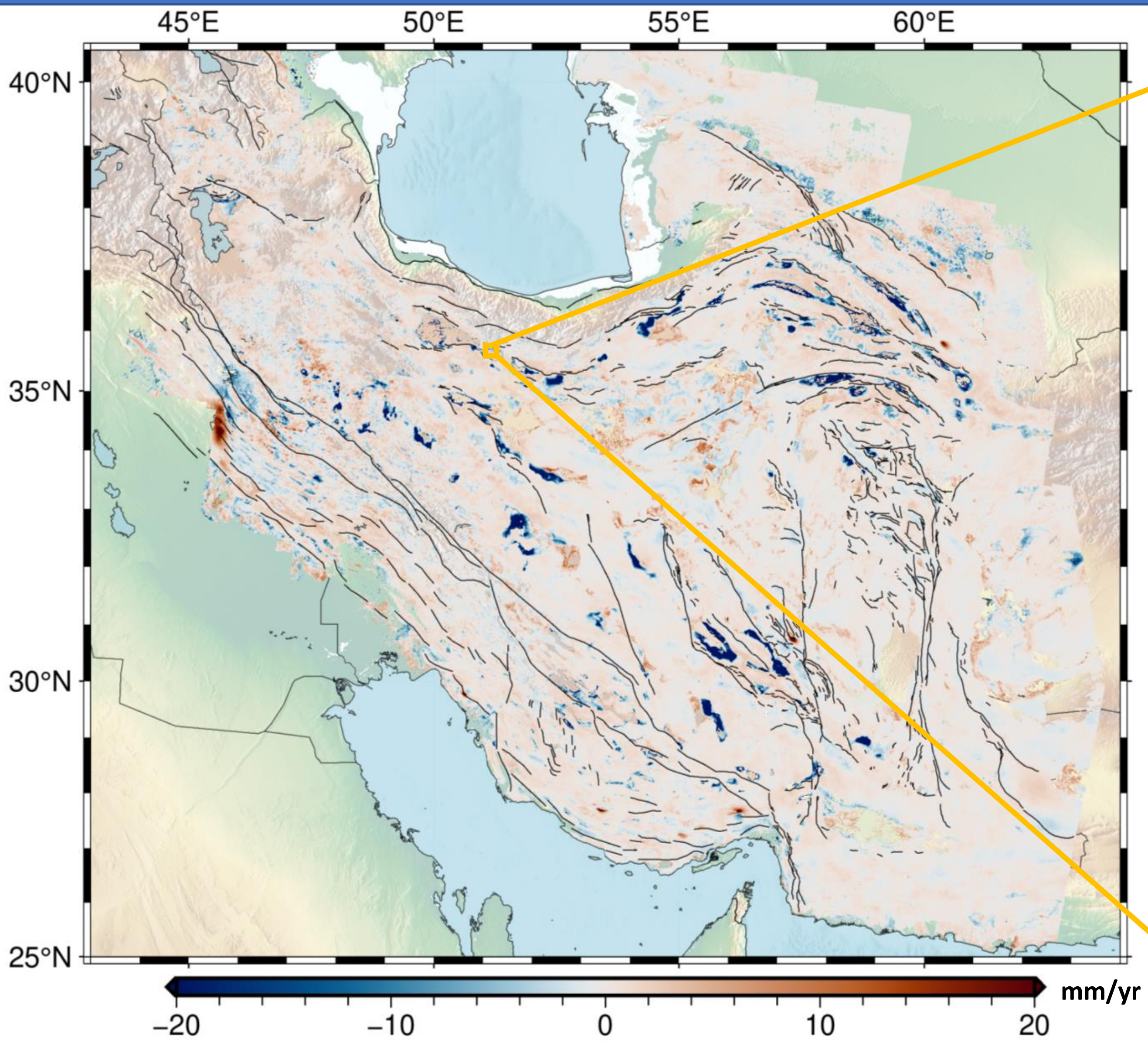
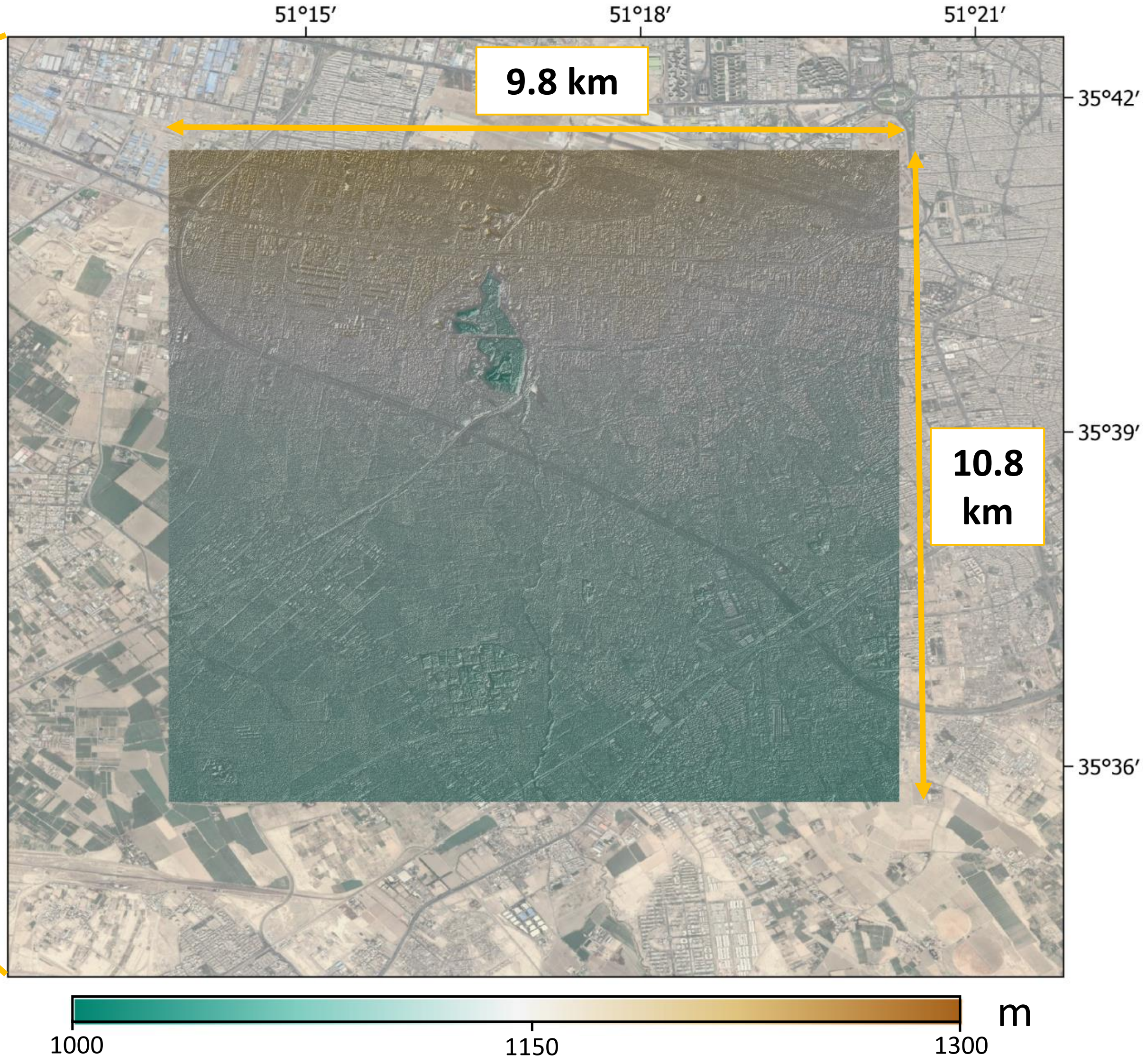
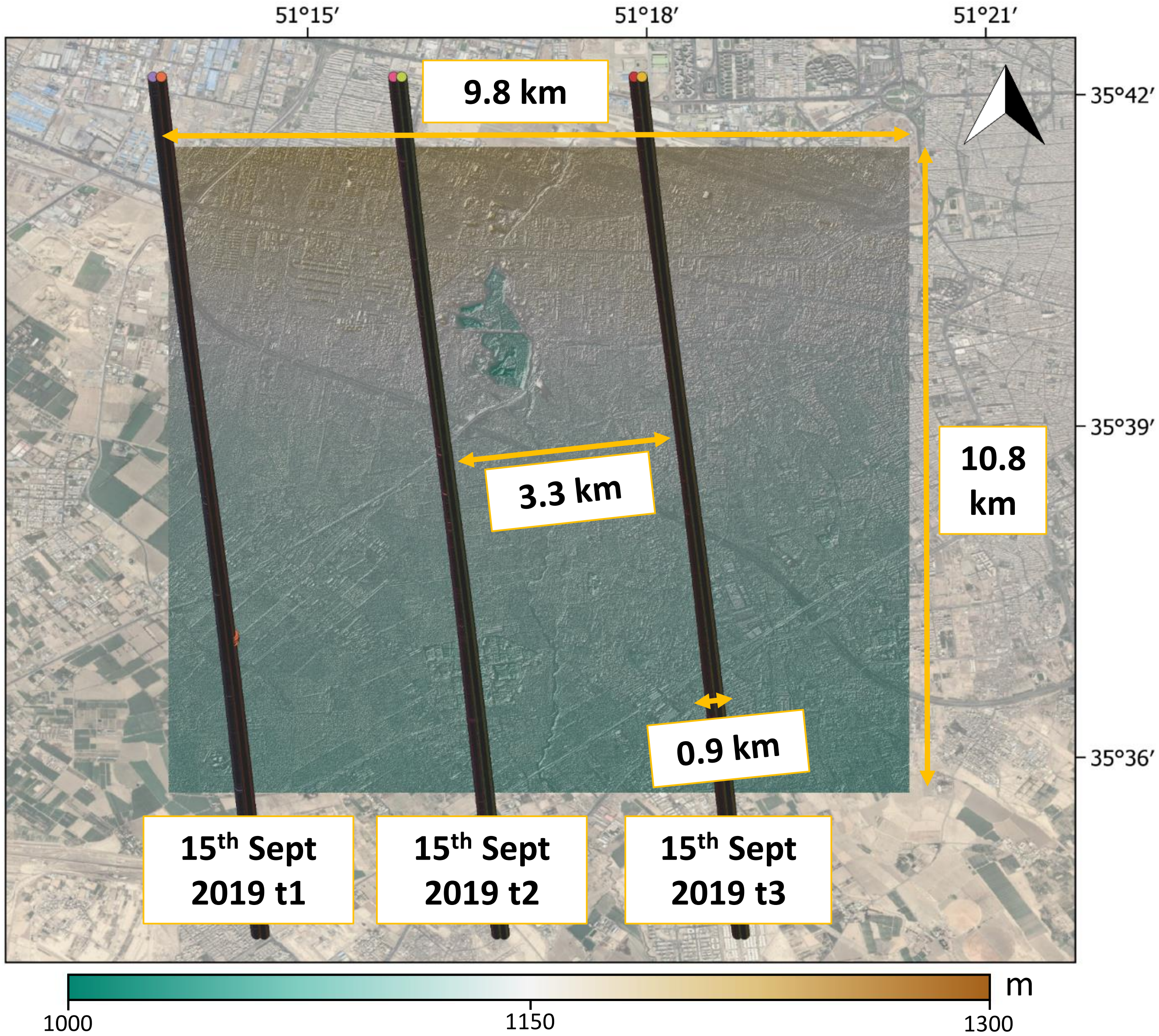




3. Validating InSAR: ICESat-2 laser altimetry



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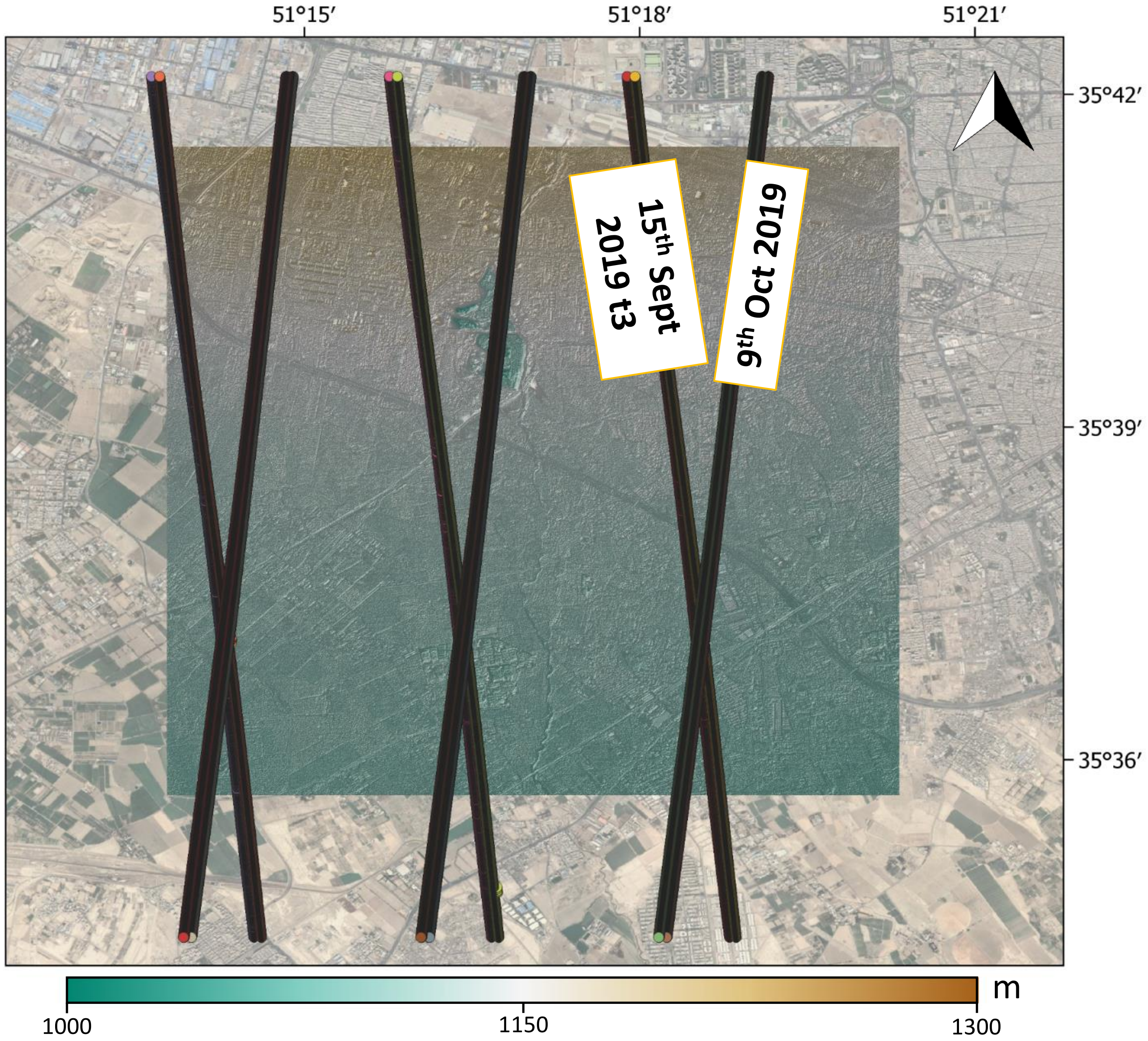

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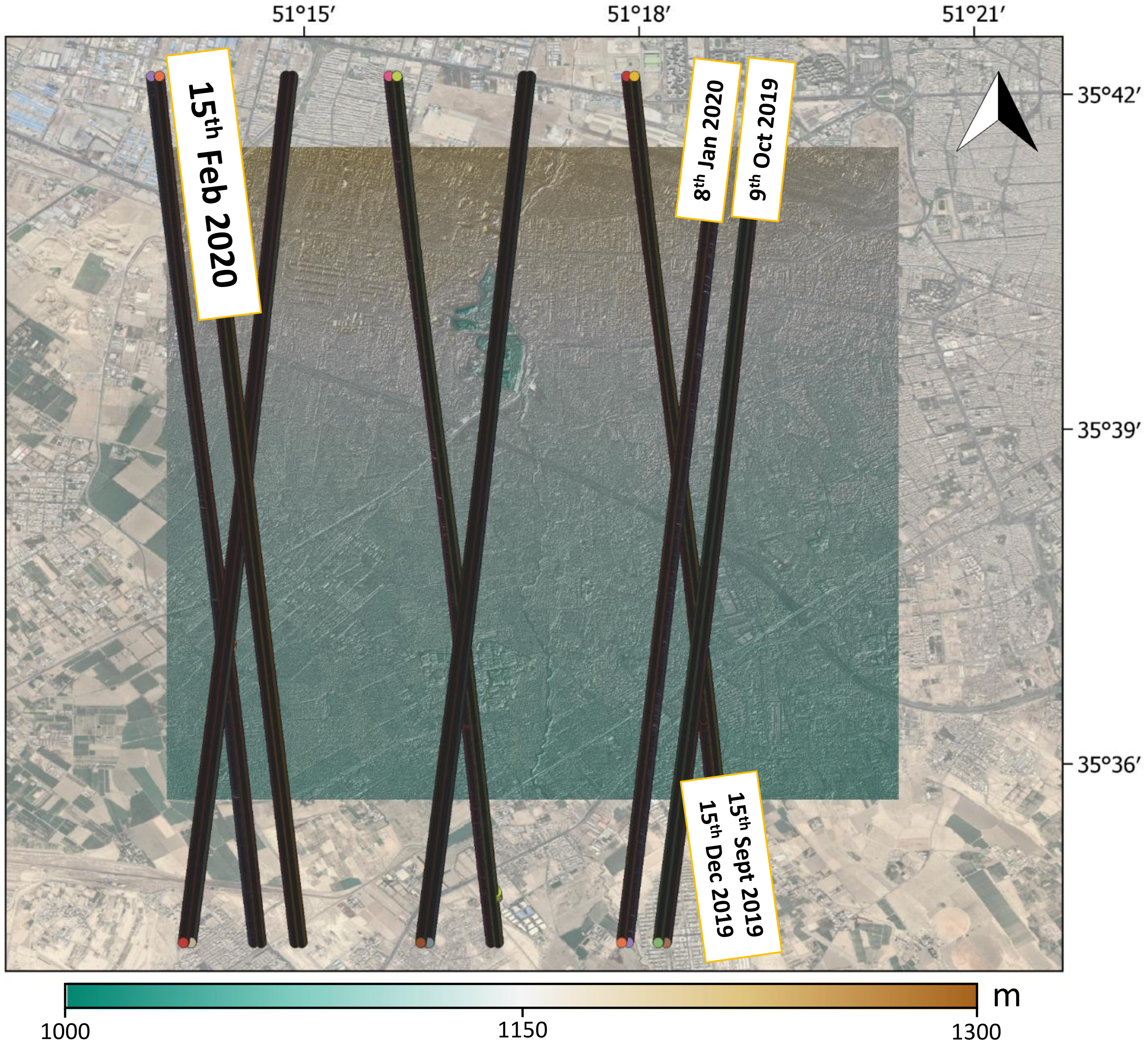
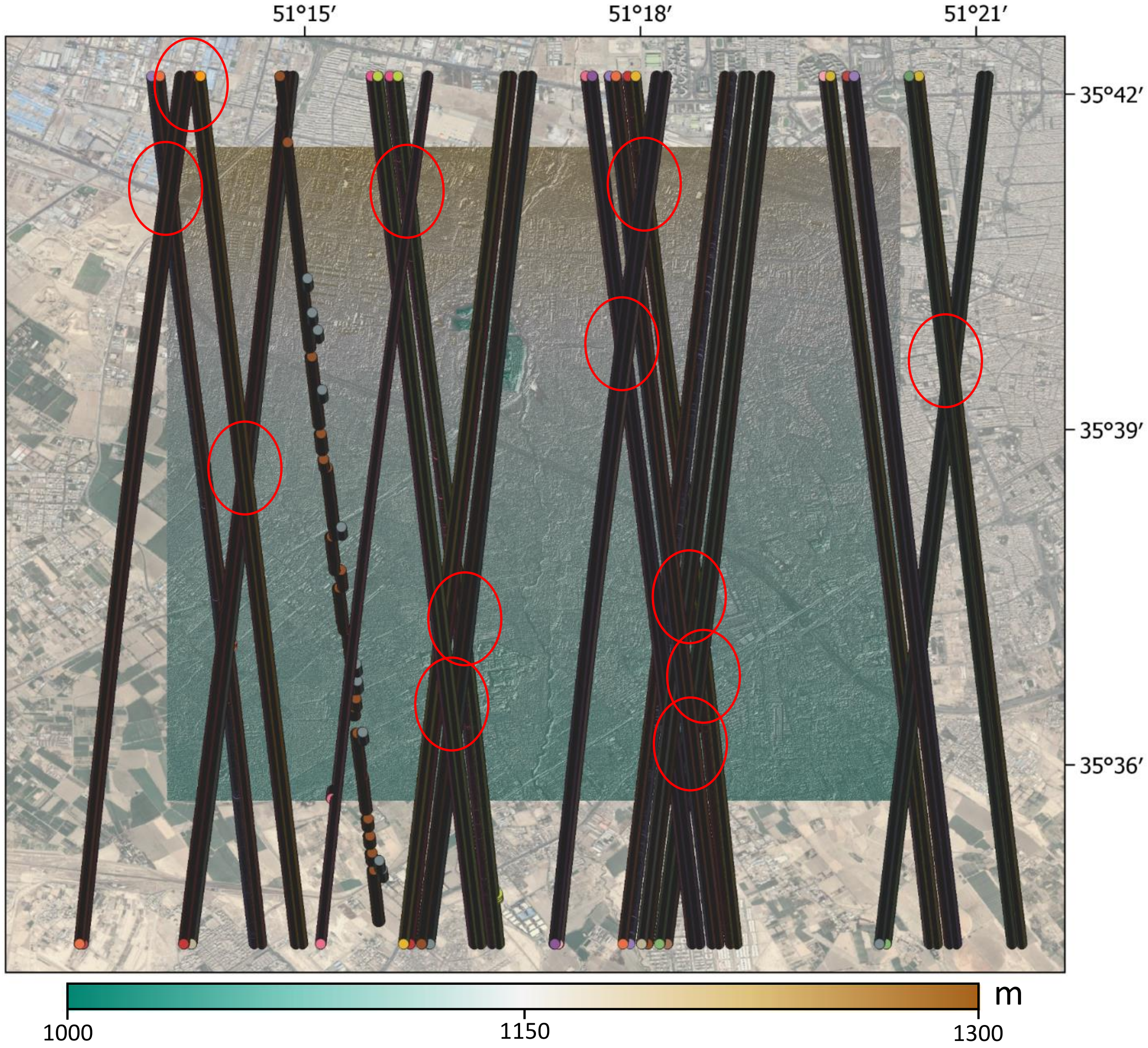


3. Validating InSAR: ICESat-2 laser altimetry

ICESat-2 tracks: Oct 2019 – Oct 2022

Intersections >2 years



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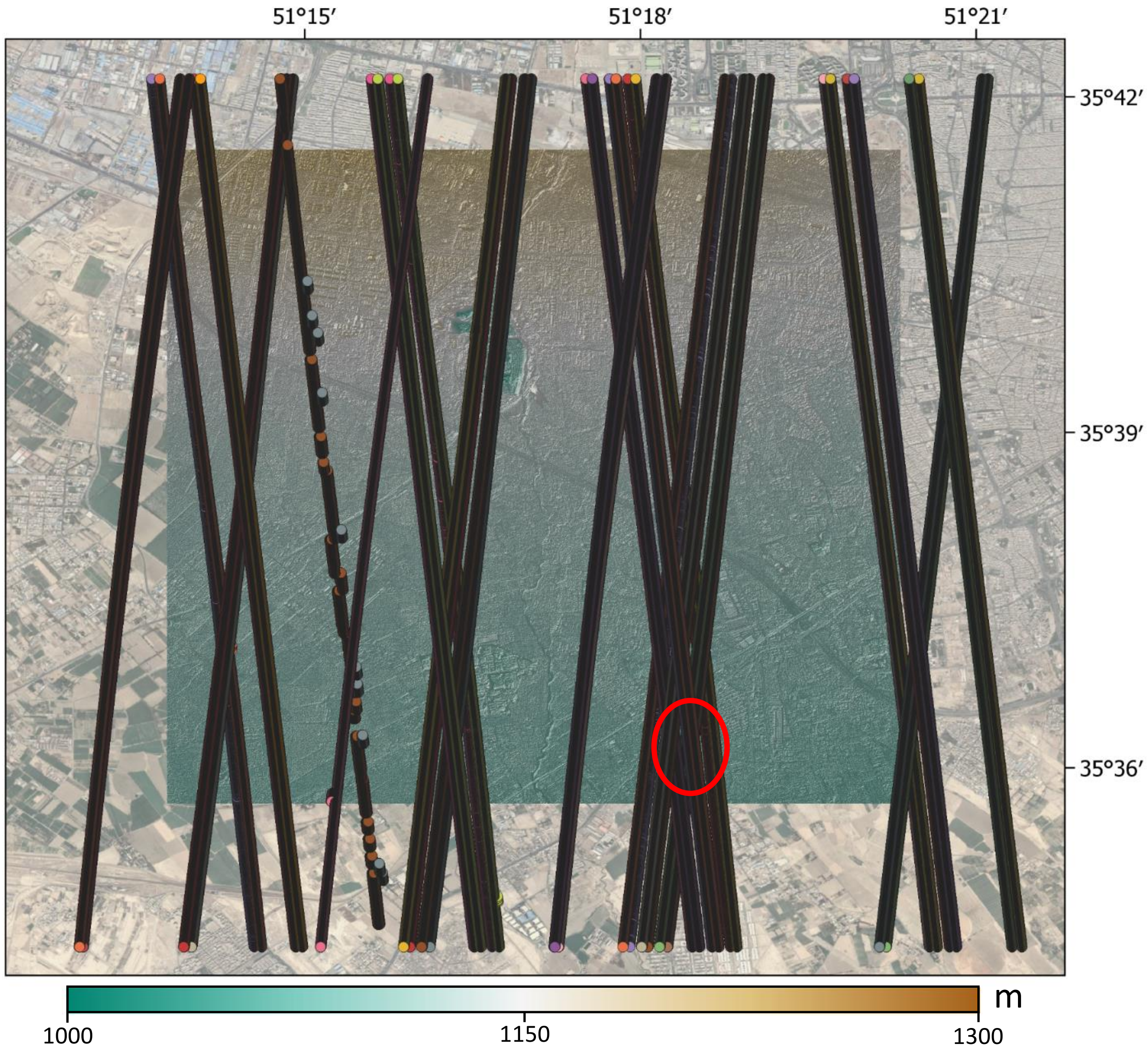
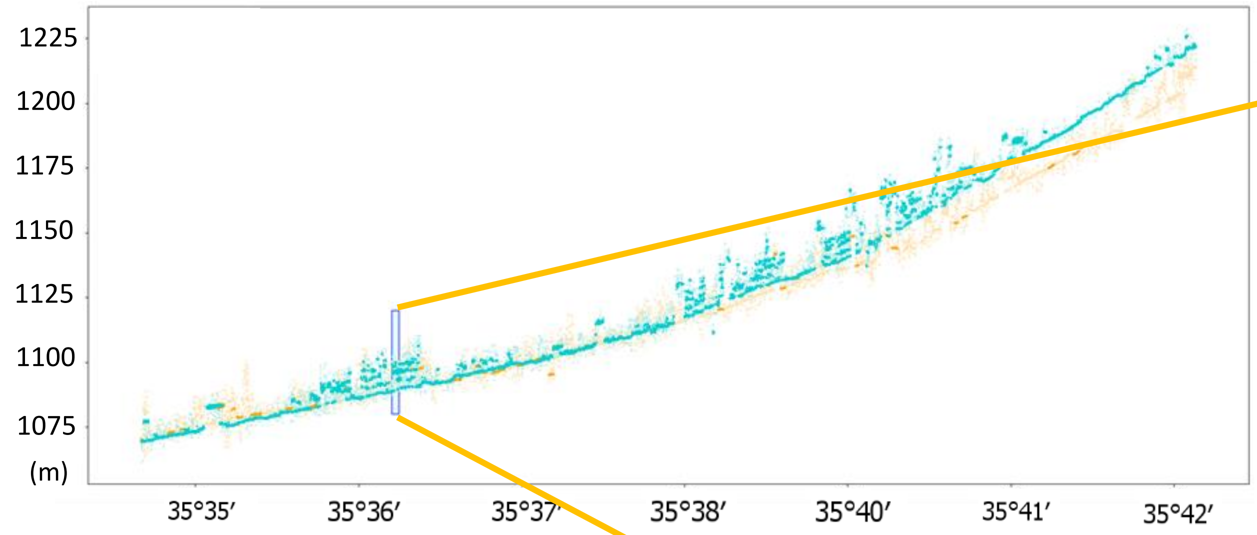
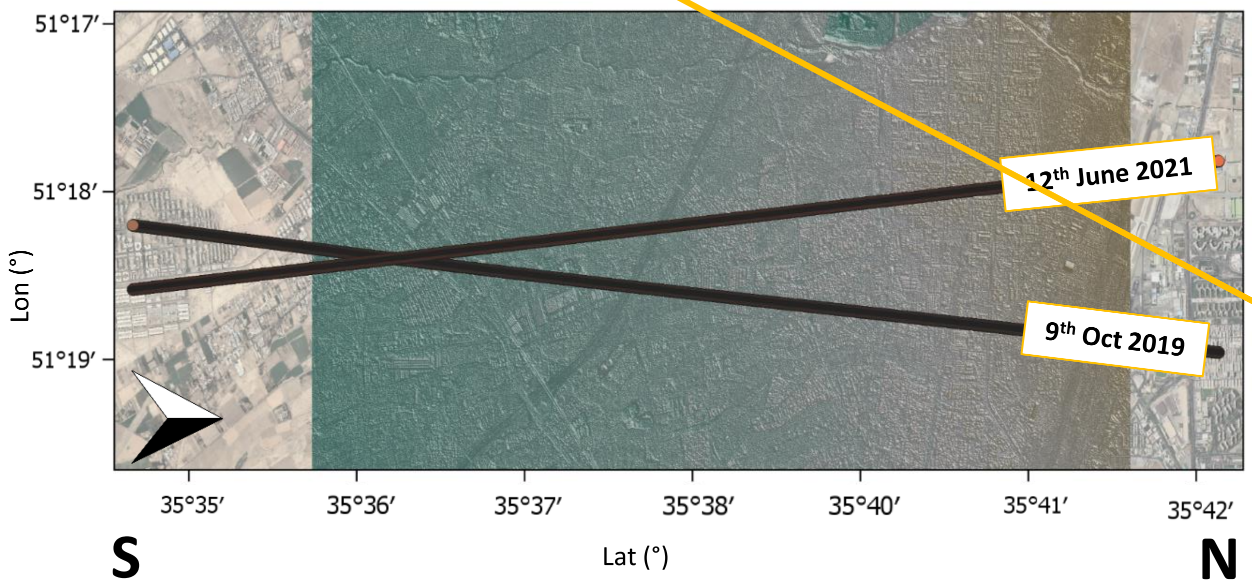
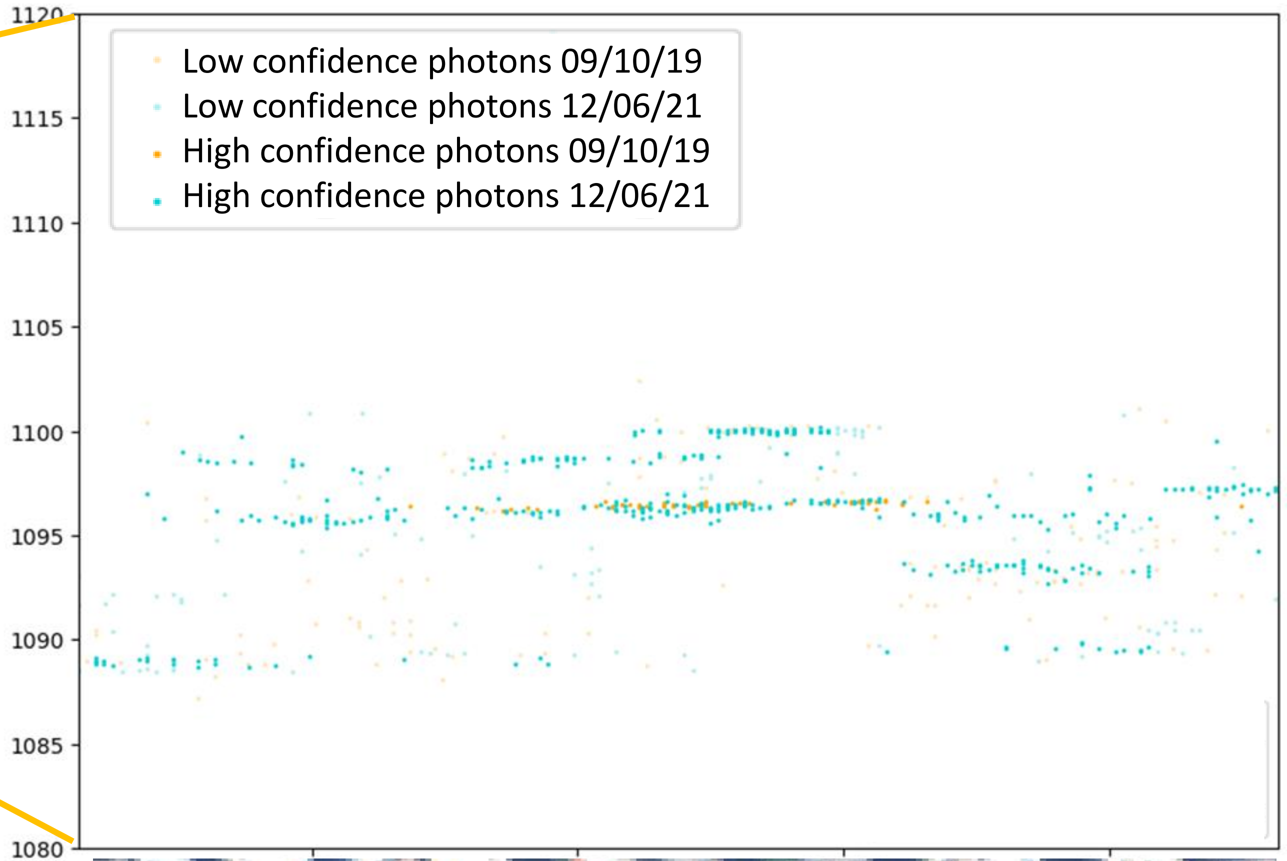


Intersections >2 years

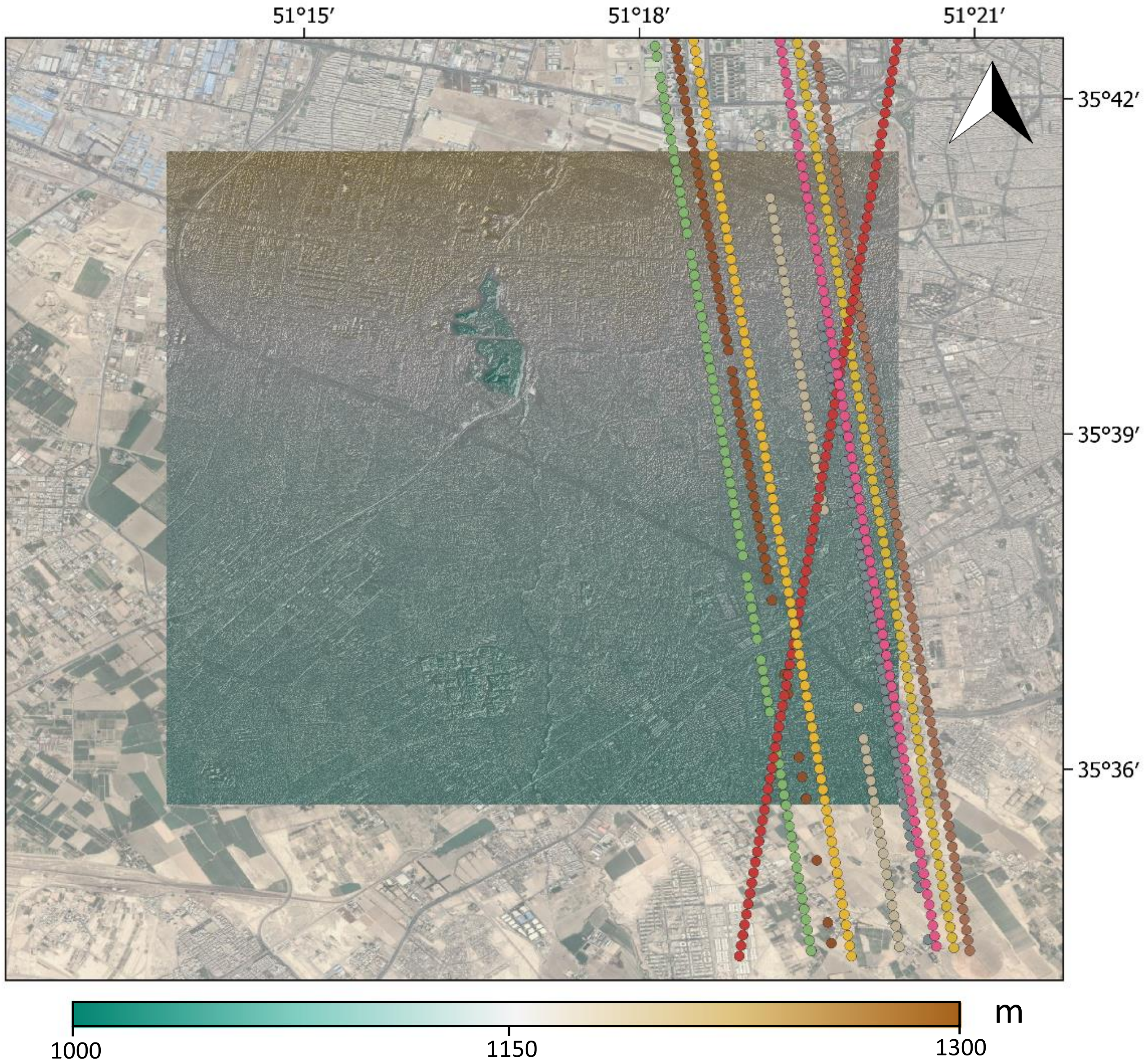
3. Validating InSAR: ICESat-2 laser altimetry





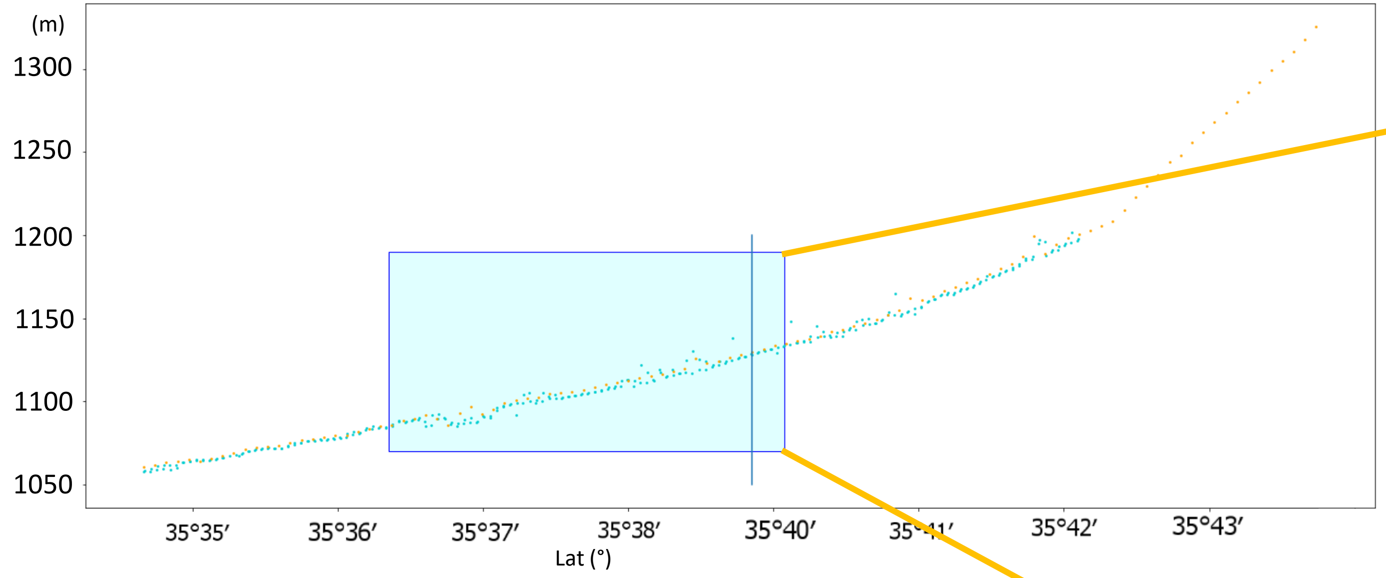


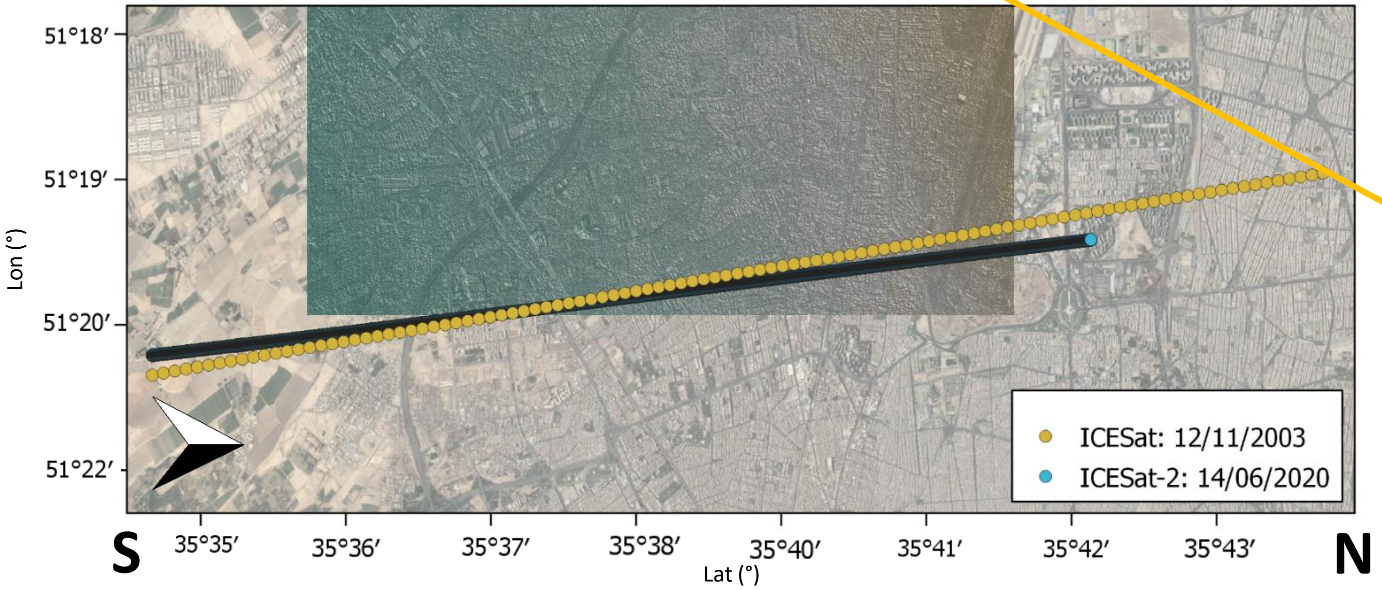
3. Validating InSAR: **ICESat** Laser altimetry

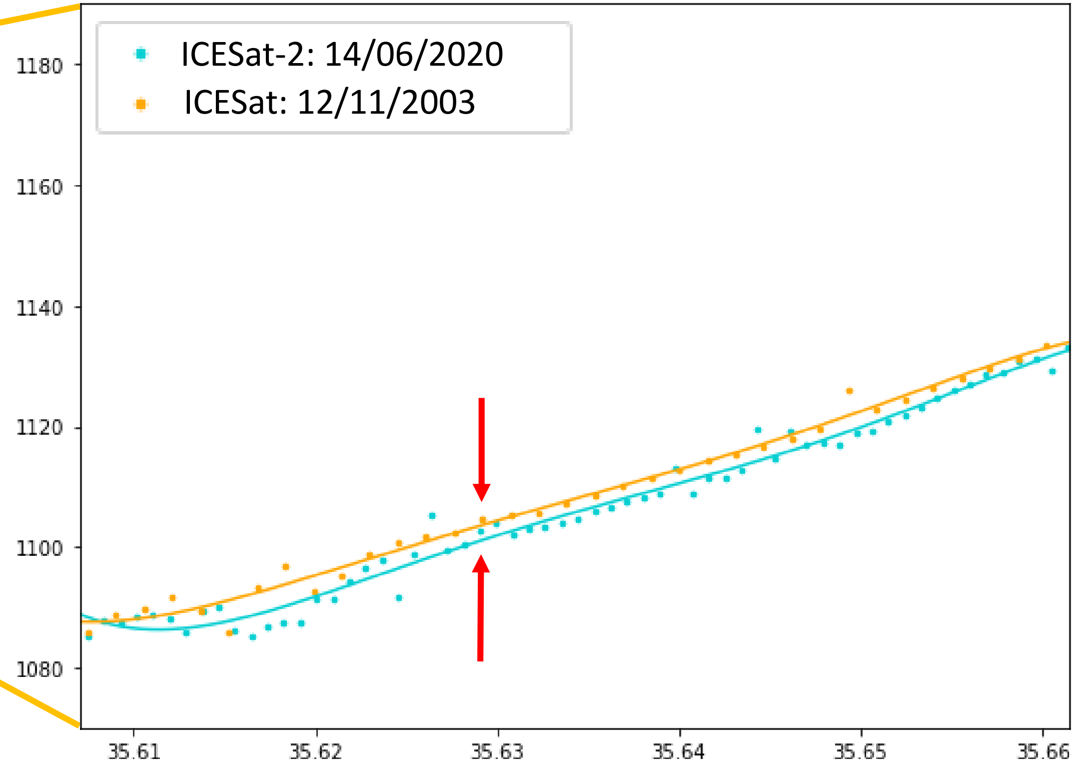


Track	Laser	Date
1241	Laser 2A	14/10/2003
326	Laser 2A	12/11/2003
326	Laser 2C	14/06/2004
326	Laser 3A	31/10/2004
326	Laser 3B	17/03/2005
326	Laser 3C	16/06/2005
326	Laser 3D	17/11/2005
326	Laser 3E	21/03/2006
326	Laser 3F	20/06/2006
326	Laser 3G	21/11/2006
326	Laser 3I	29/10/2007
326	Laser 2D	12/11/2008

3. Validating InSAR: Laser altimetry

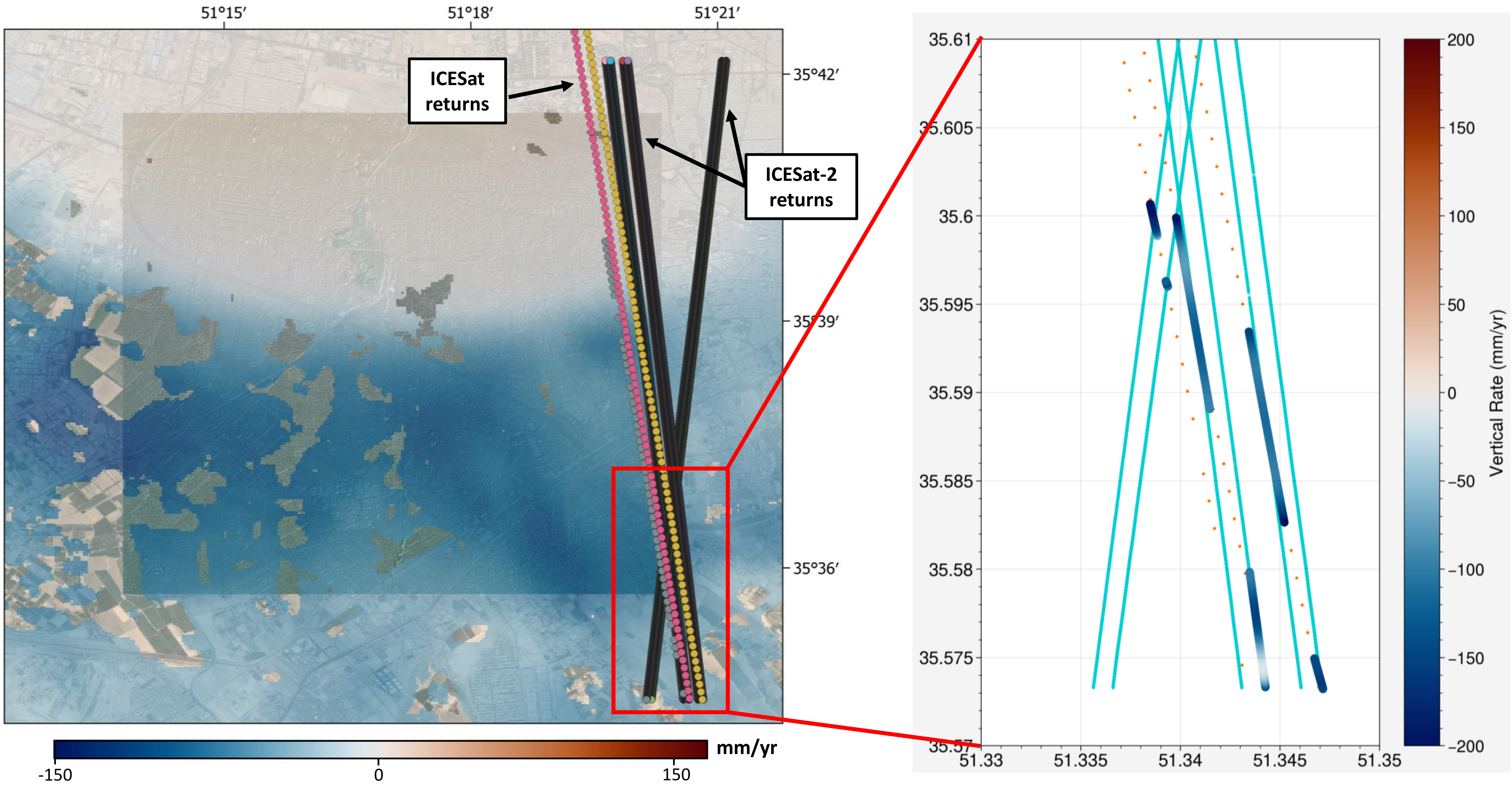






1.5-2.5 m subsidence in 16.5 years

3. Validating InSAR: Laser altimetry



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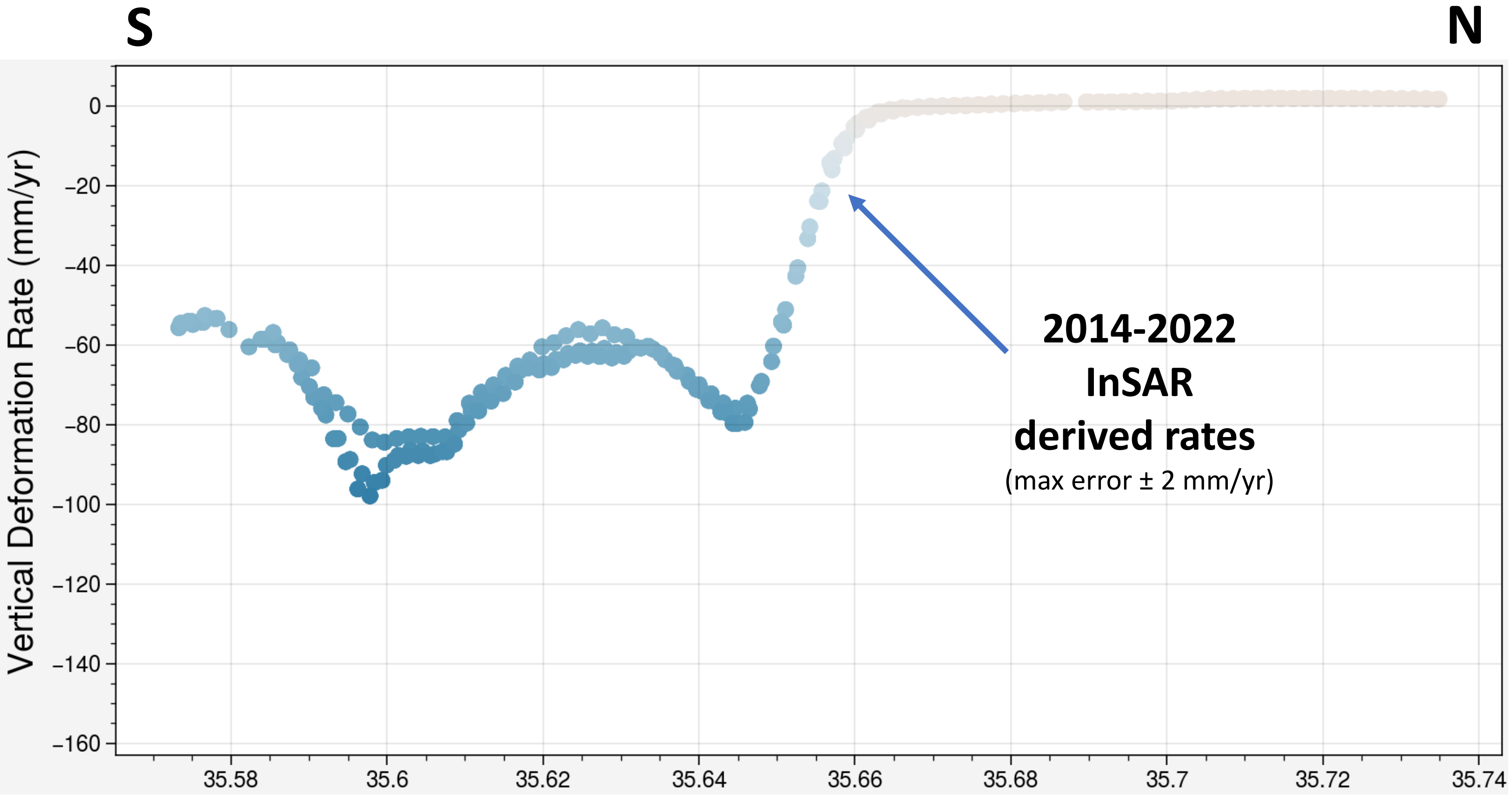

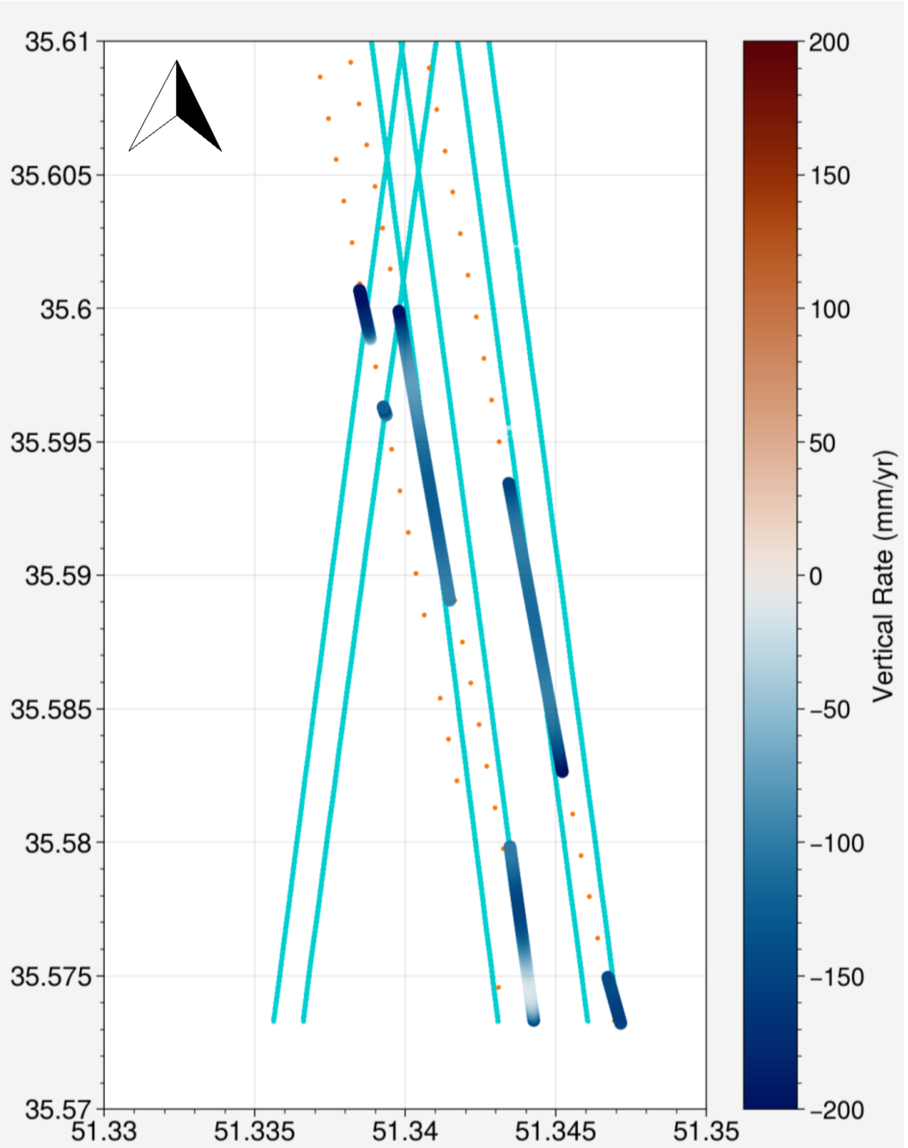

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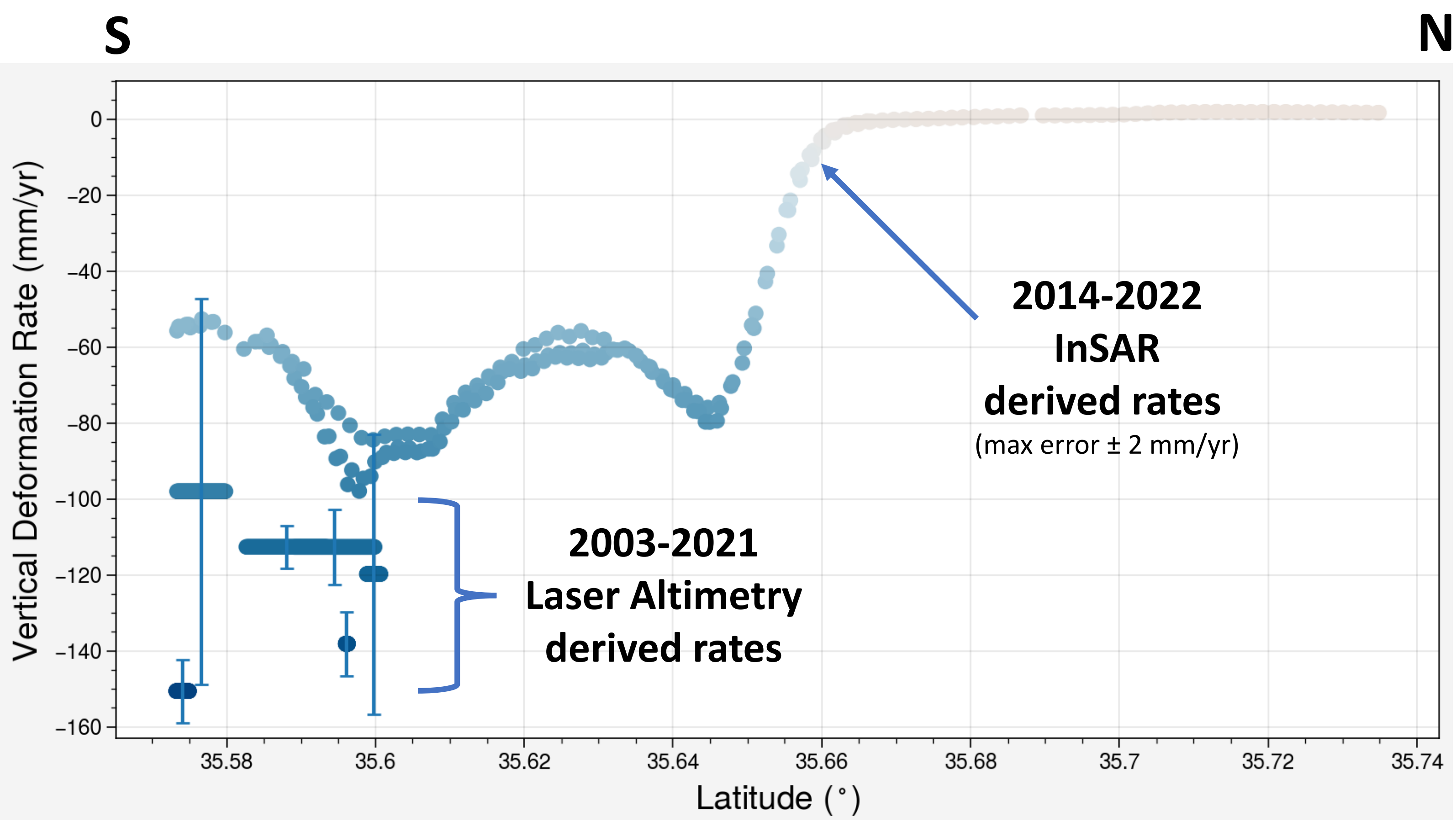

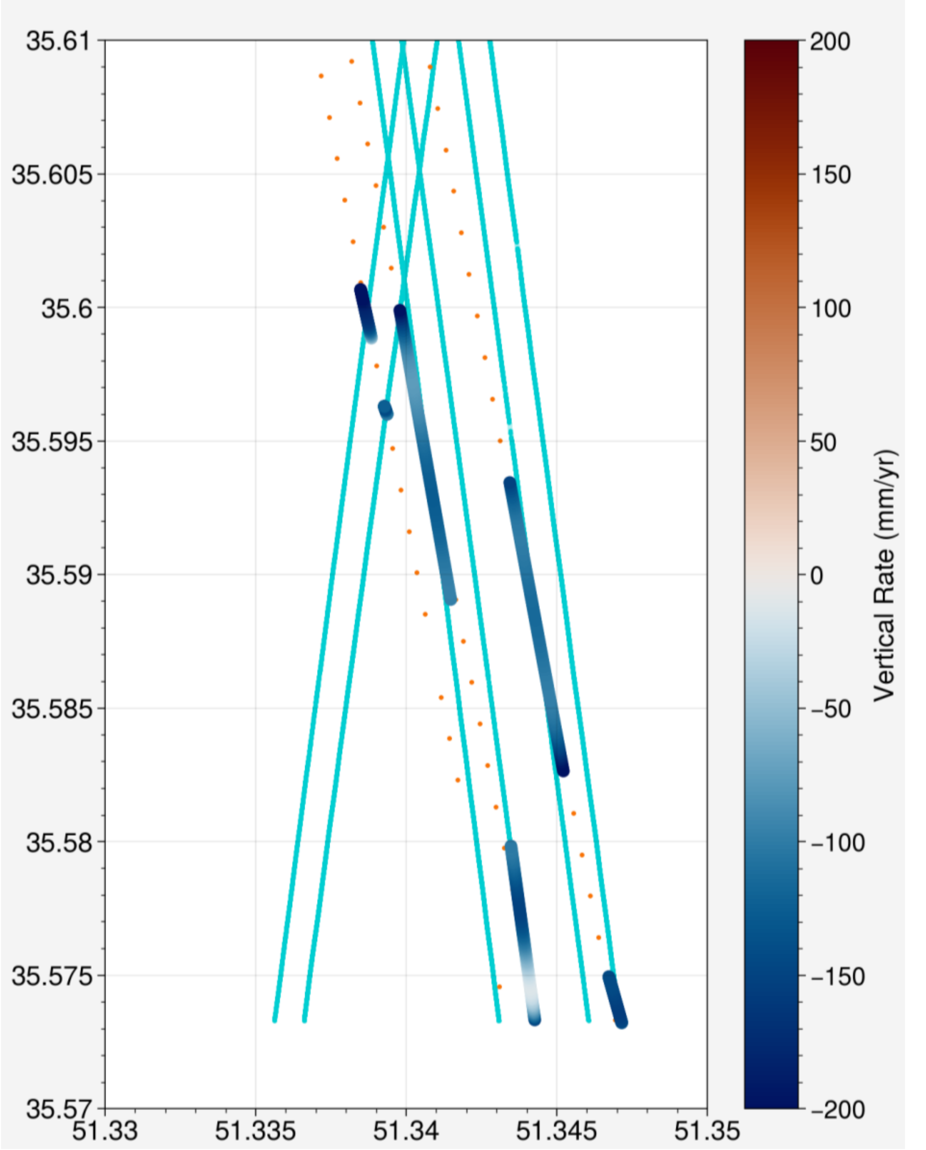

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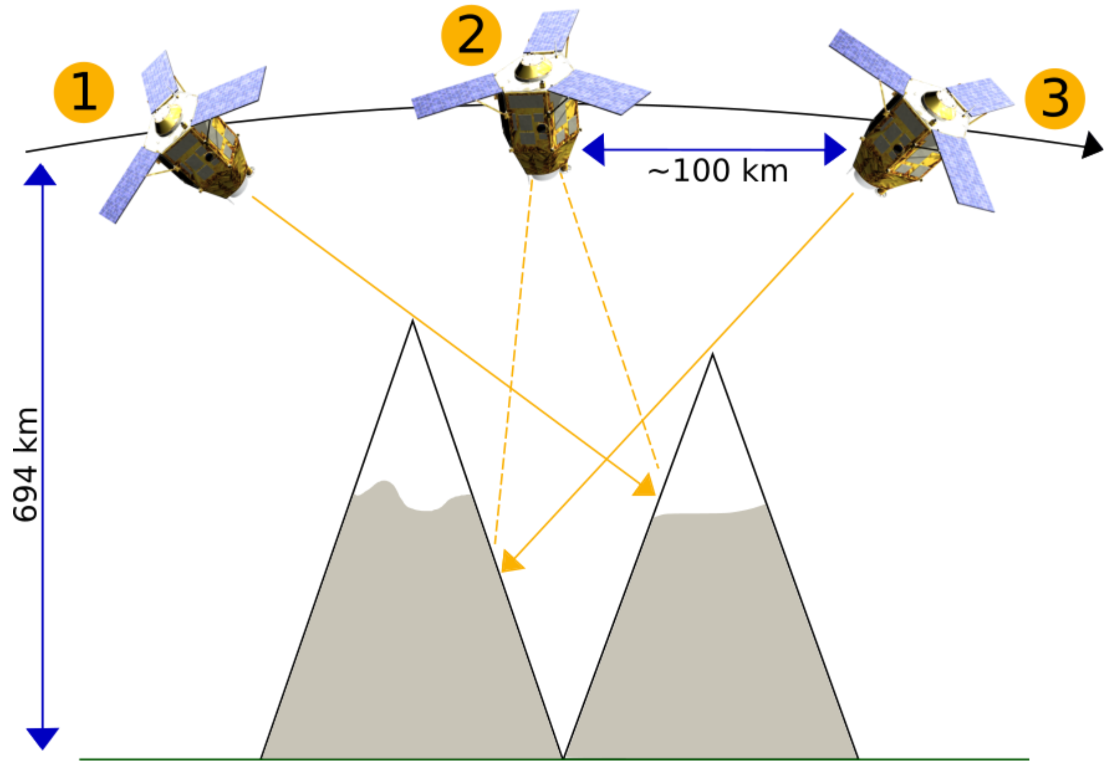

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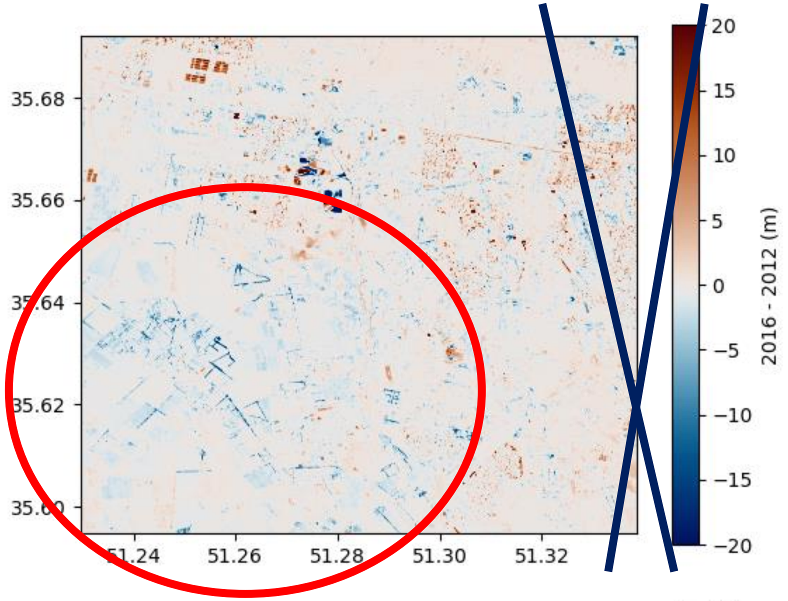

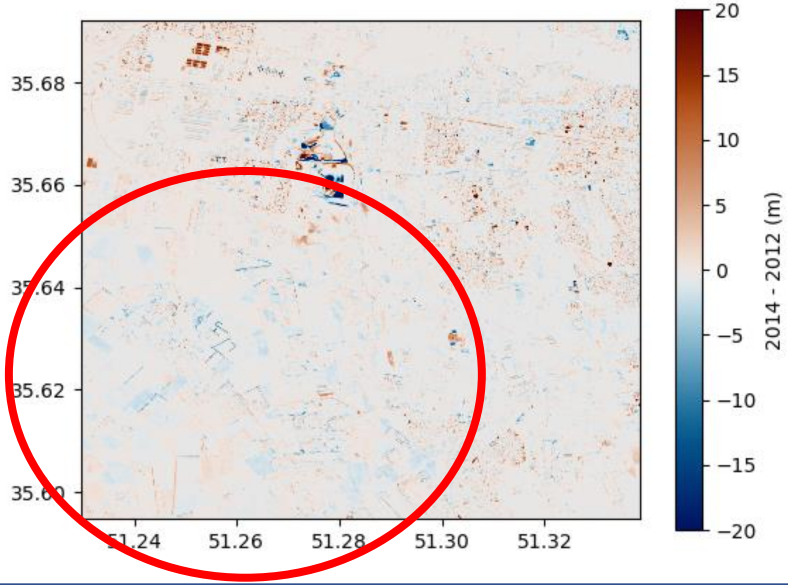

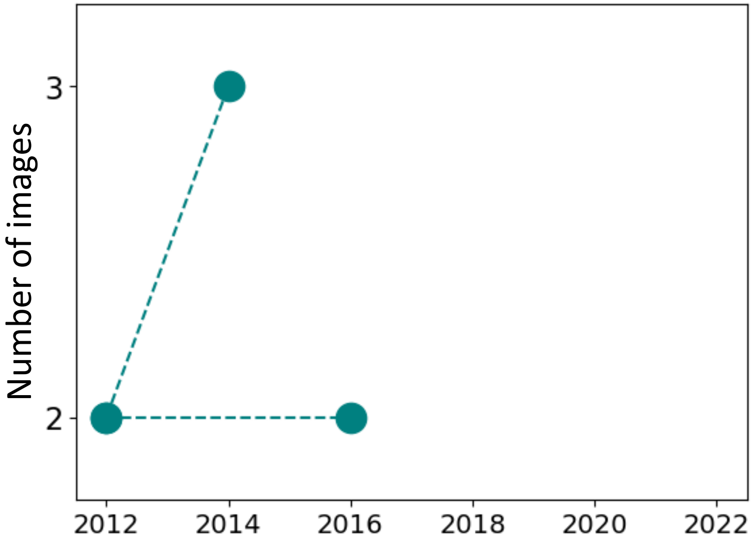

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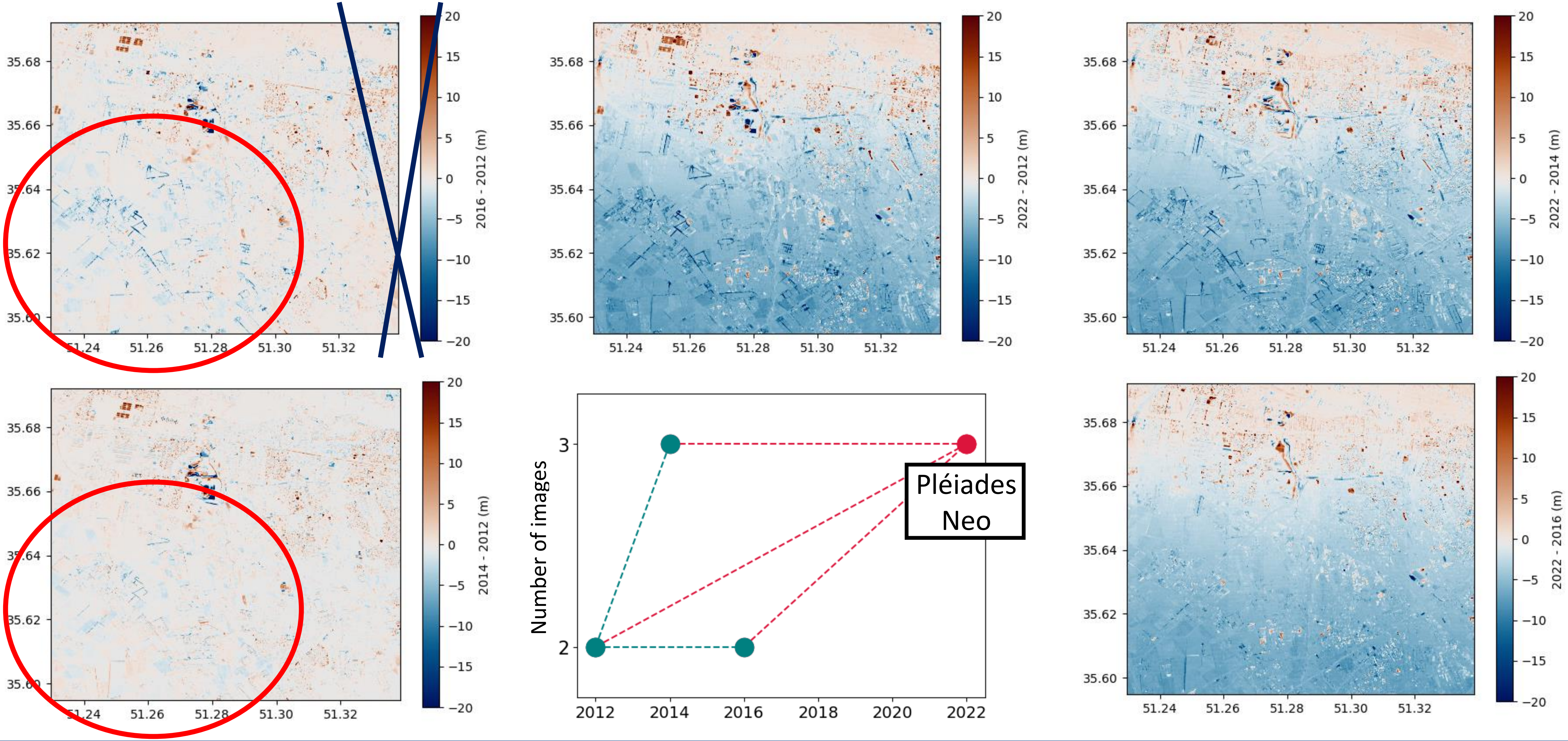
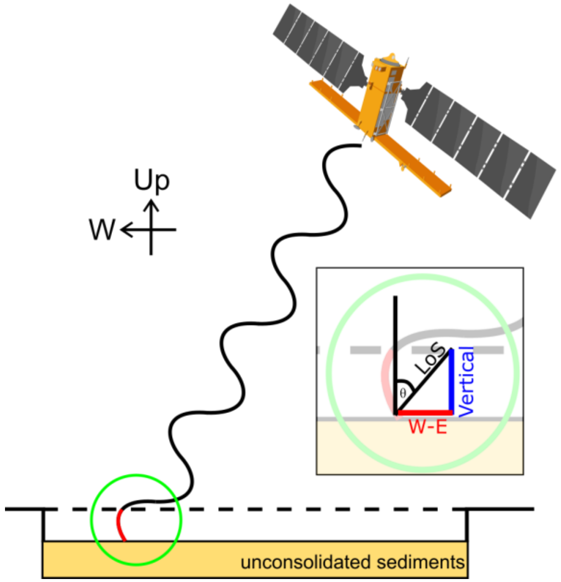


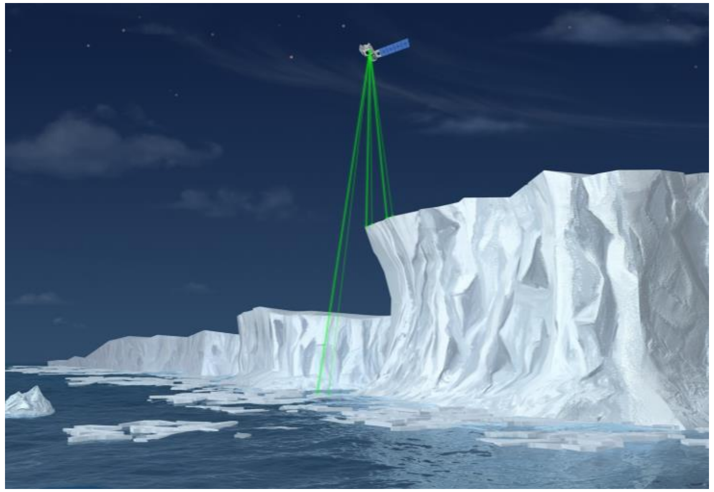
Conclusions

1. **Sentinel-1 InSAR** analysis **successfully maps subsidence** in medium resolution in low coherence areas

2. It is **challenging to systematically validate InSAR** results using laser altimetry and/or VHR DEMs

3. **Laser altimetry** only captures subsidence where **rates are fast and time-series long**

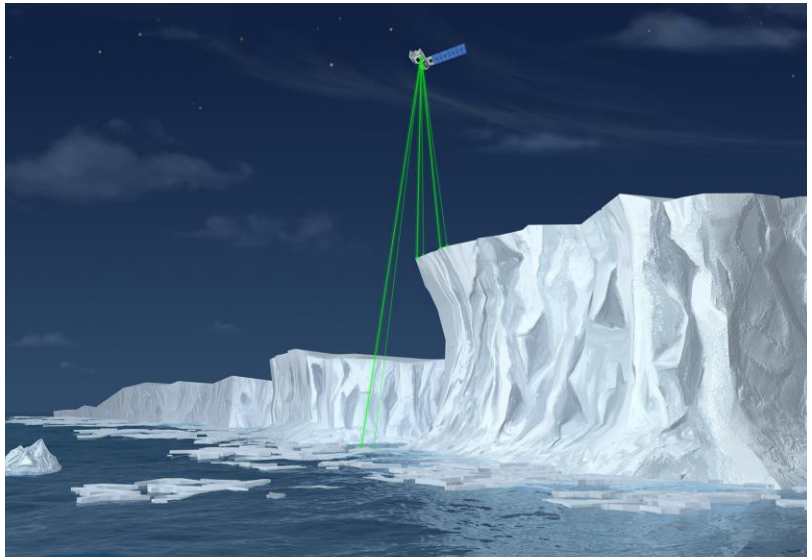


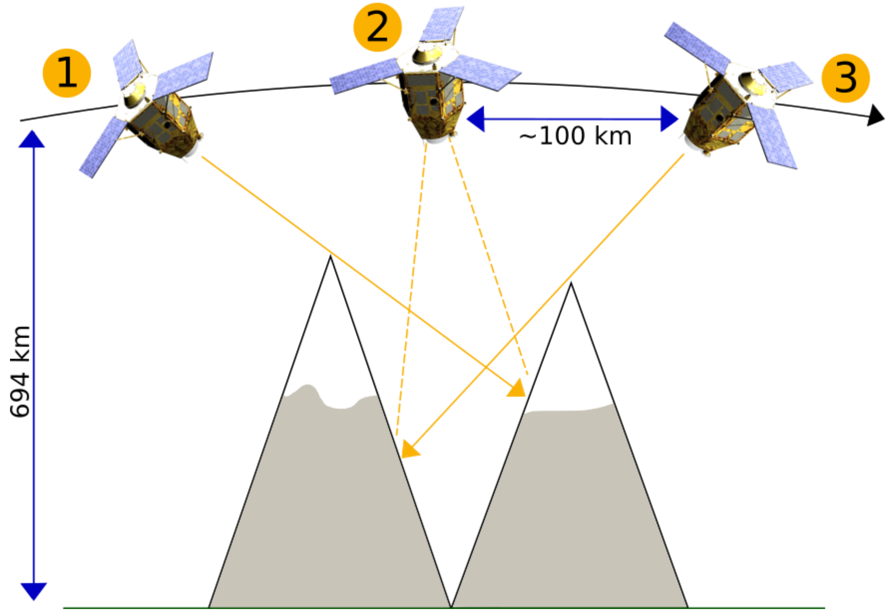


Future Work

1. Compare **DEM rates** with InSAR and laser altimetry rates

2. Check for **internal consistency of InSAR** data itself





Thank you for listening

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