Monitoring groundwater depletion in Iran from space: results from gravity and InSAR observations

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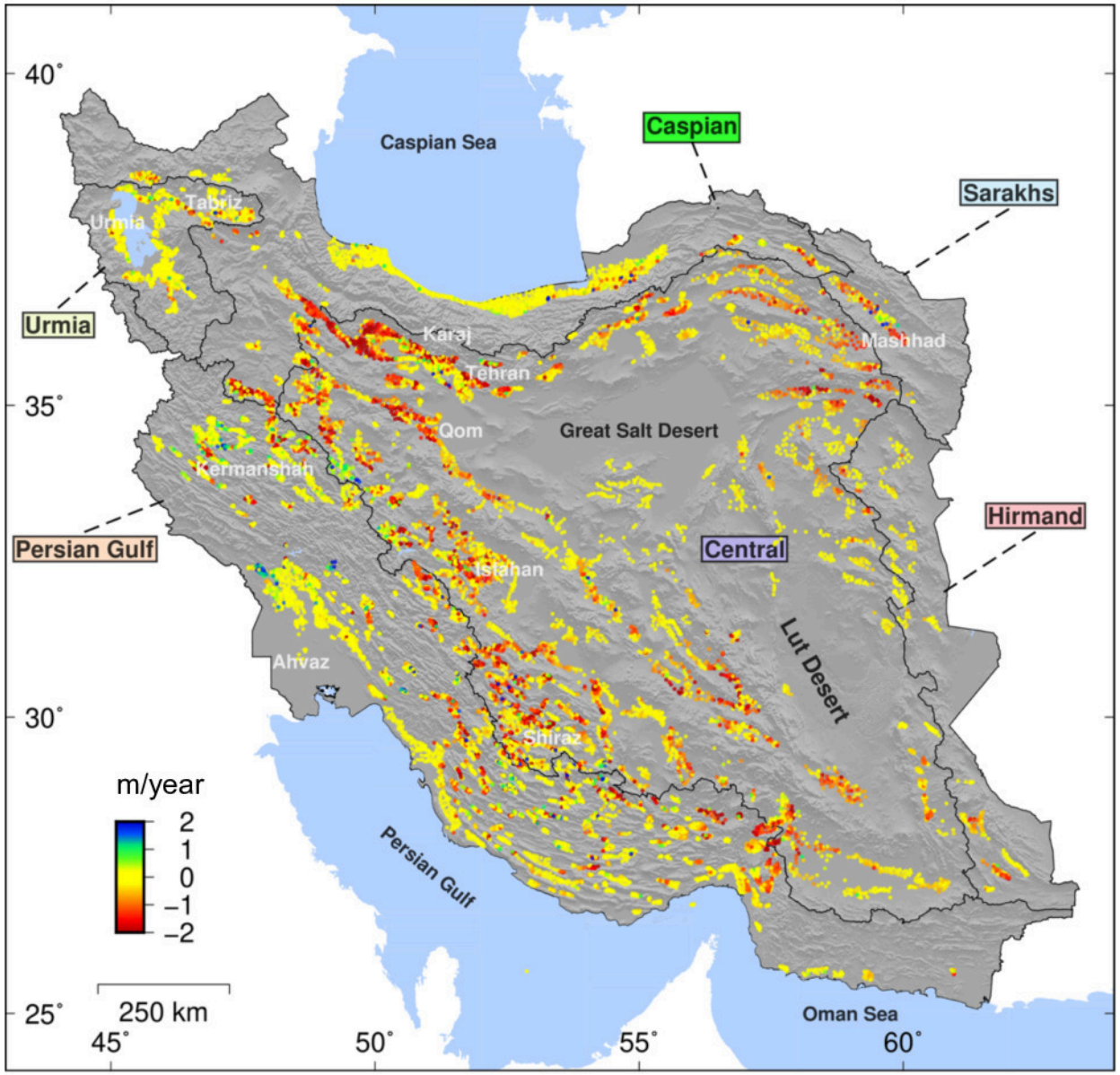
Introduction

- Groundwater is used for domestic needs of roughly half of the world's population
- 40% of the global irrigation depends on groundwater (Zektser et al., 2004)
- Over-exploitation contributes to decreasing trend of Terrestrial Water Storage (TWS) in a number of places (Rodel et al., 2018)

- **Objectives of this study**
- Country-scale measurement of groundwater across Iran
- What is the implication of stress on groundwater resources in terms of subsidence hazard across Iran?
- Can we evaluate the health and sustainability of this important (hidden) resource using modern satellite technology?

Groundwater variations in Iran from observation wells (2010 – 2018)



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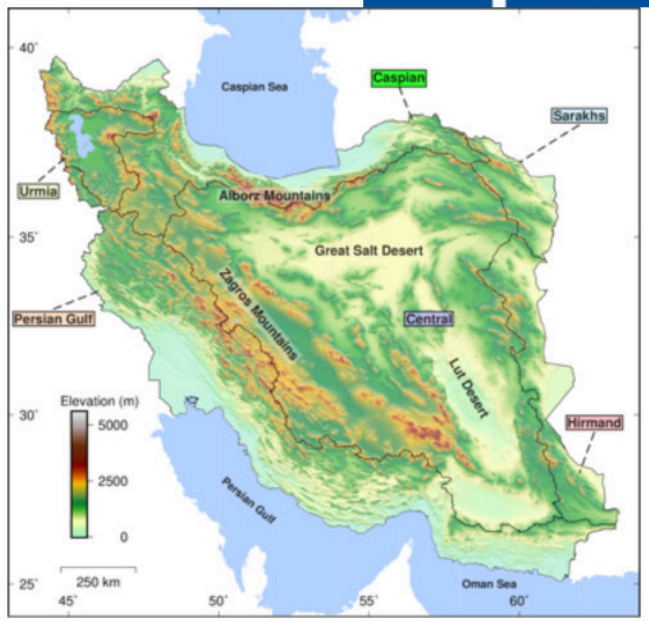
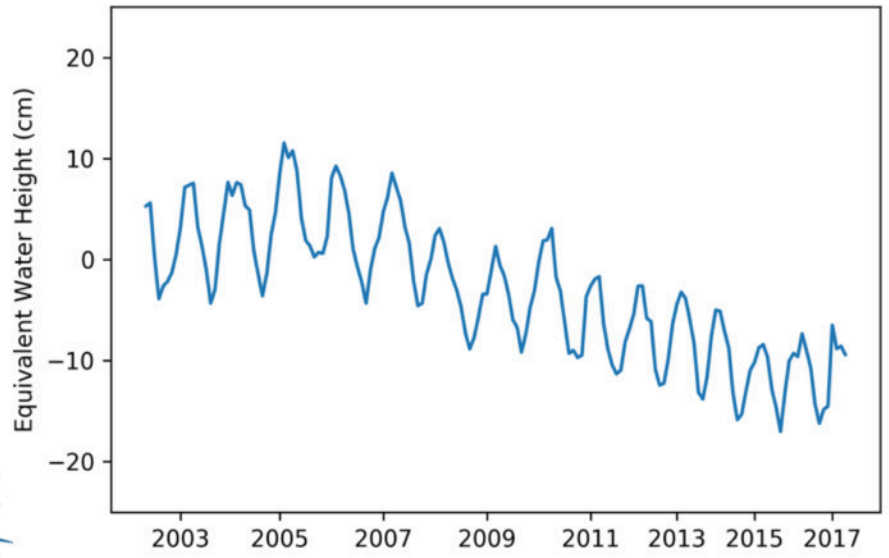
Variations of Water Resources from GRACE

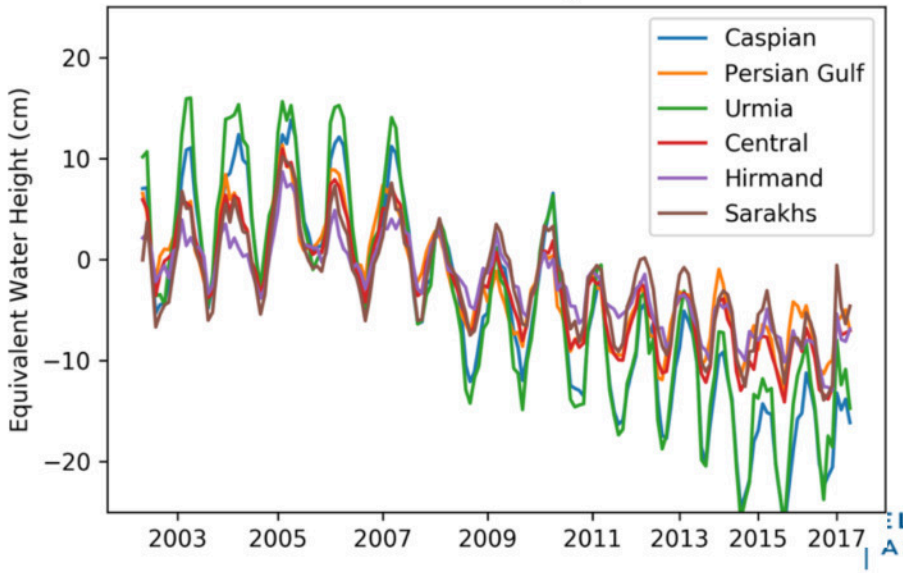
- **GRACE Equivalent Water Height (EWH) from GRACE**
  - Sum of soil moisture, surface water, snow, ice, and groundwater
  - **The decline is caused mainly by groundwater depletion**
  - Caspian and Urmia basins are also affected by surface water changes



Variations of EWH in Iran



Variations of EWH for major basins in Iran



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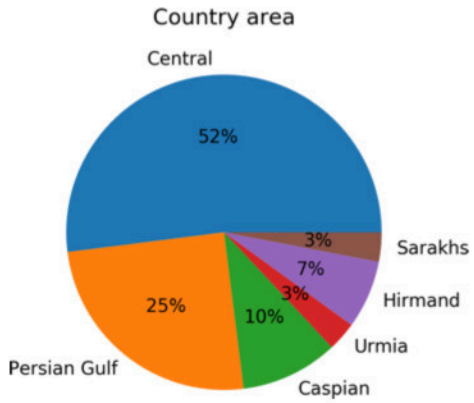
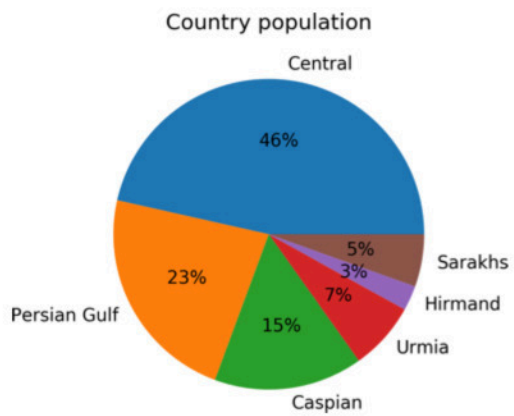
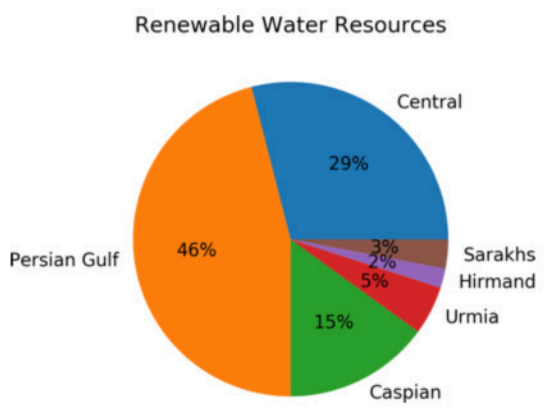
Water Resources in Iran

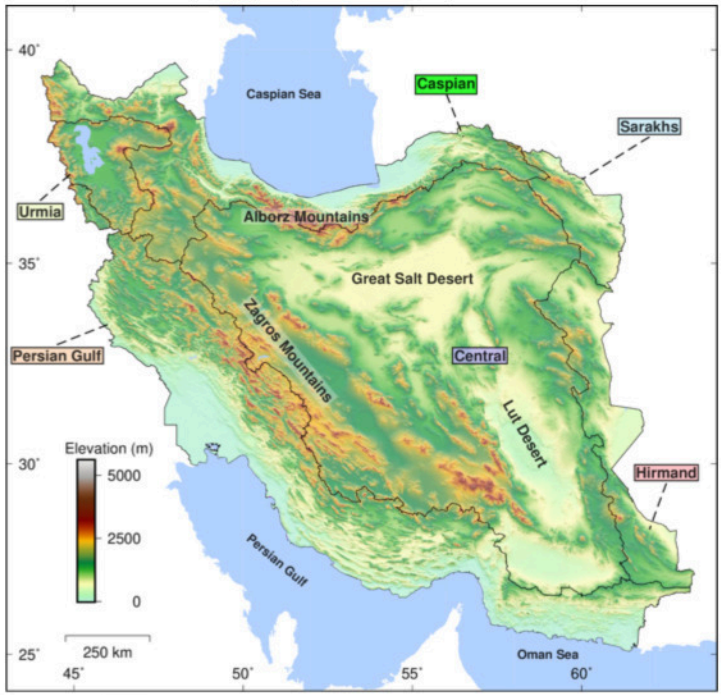
- **Six major basins**
  - Water resources: not distributed equally
  - Central Plateau basin host + 40% of population, but has only 29% of water



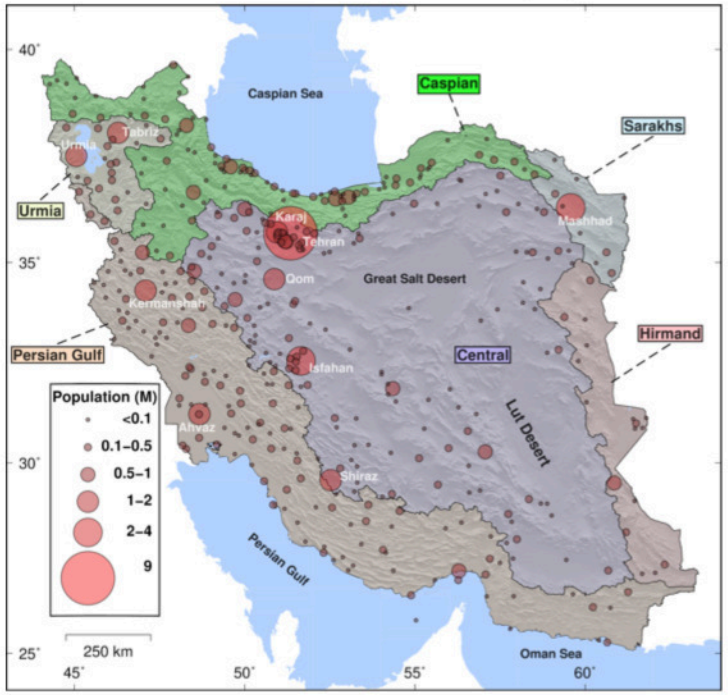




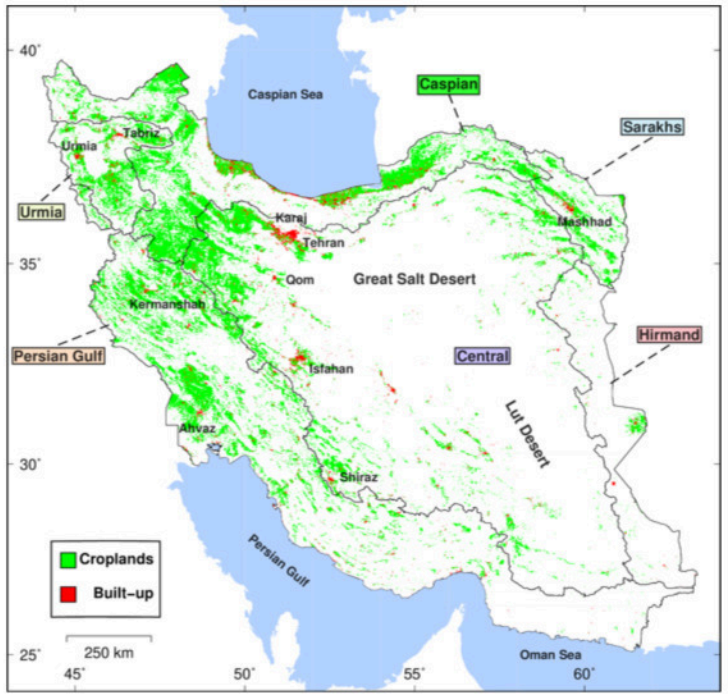
Topographic map of Iran



Non-uniform distribution of population



Non-uniform agriculture development



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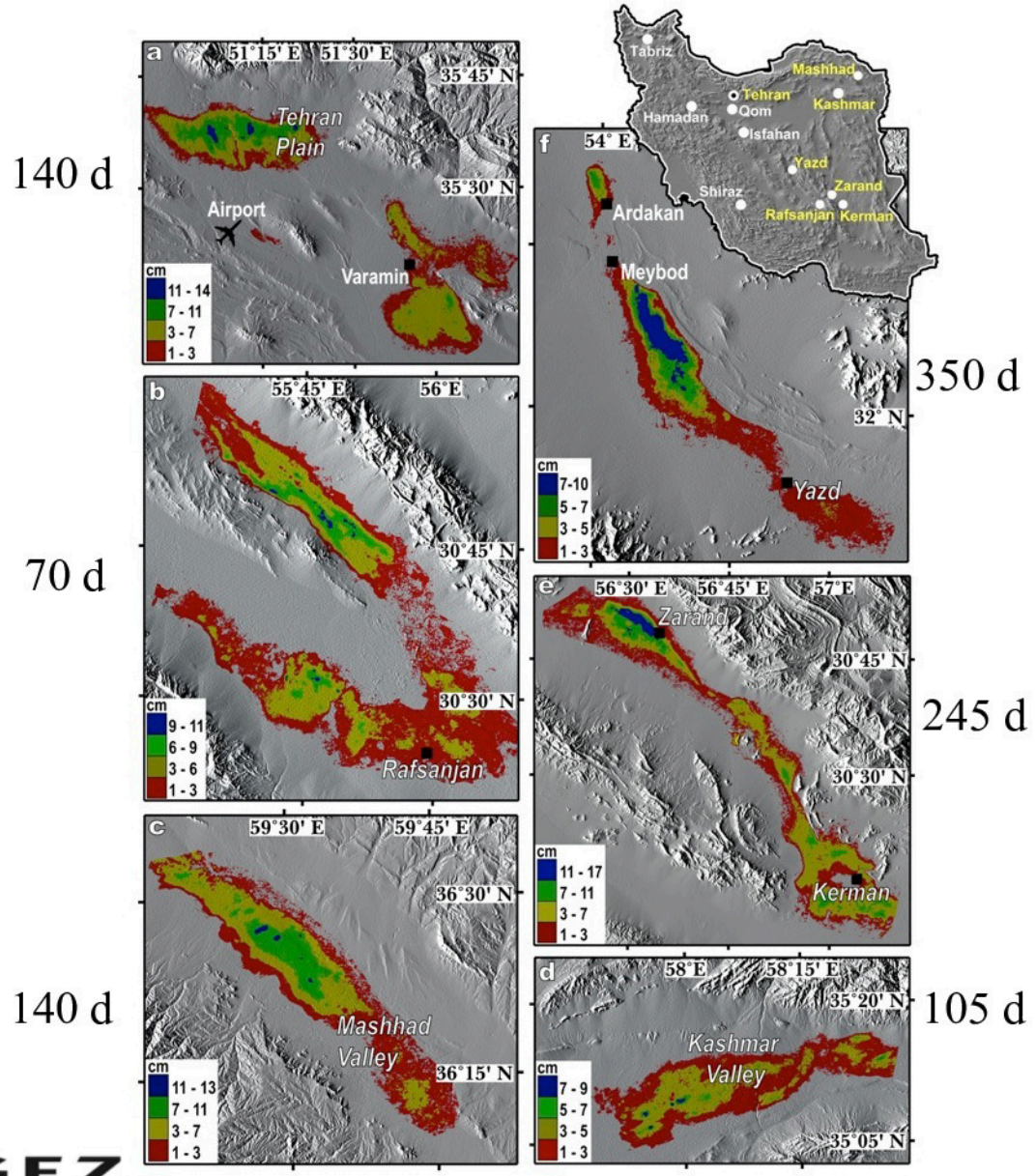
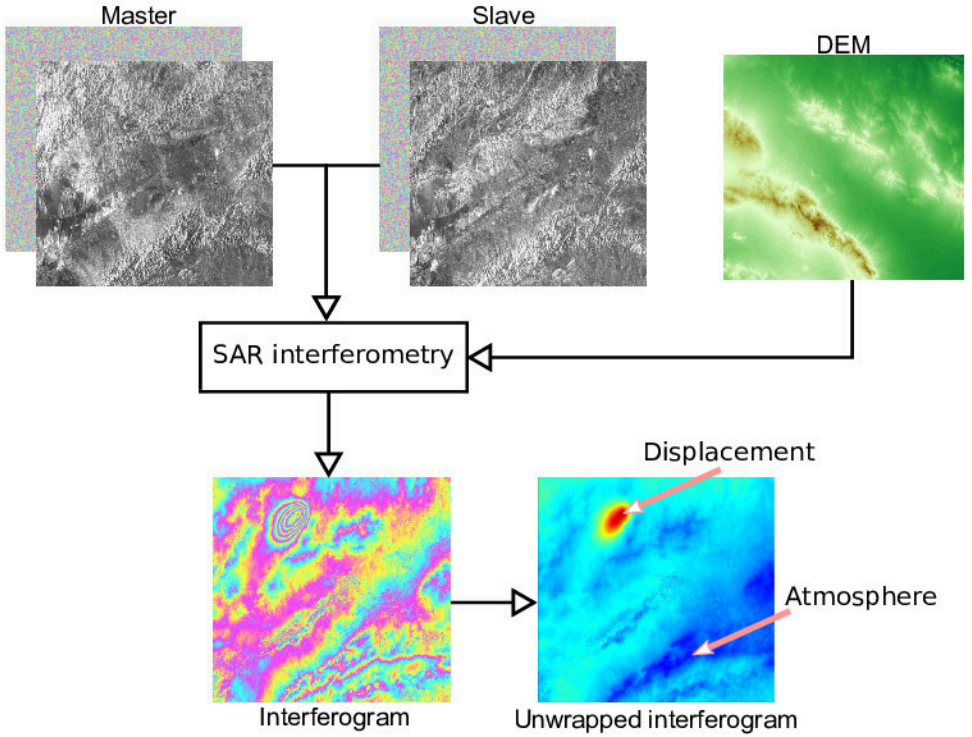
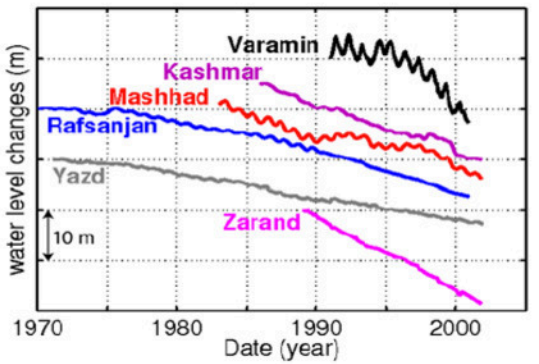
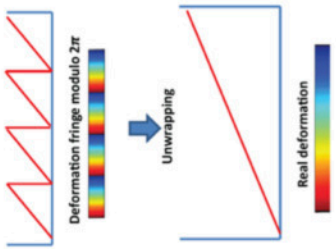
InSAR Observation of Land subsidence in Iran







Motagh, et al., GRL, 2008



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

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

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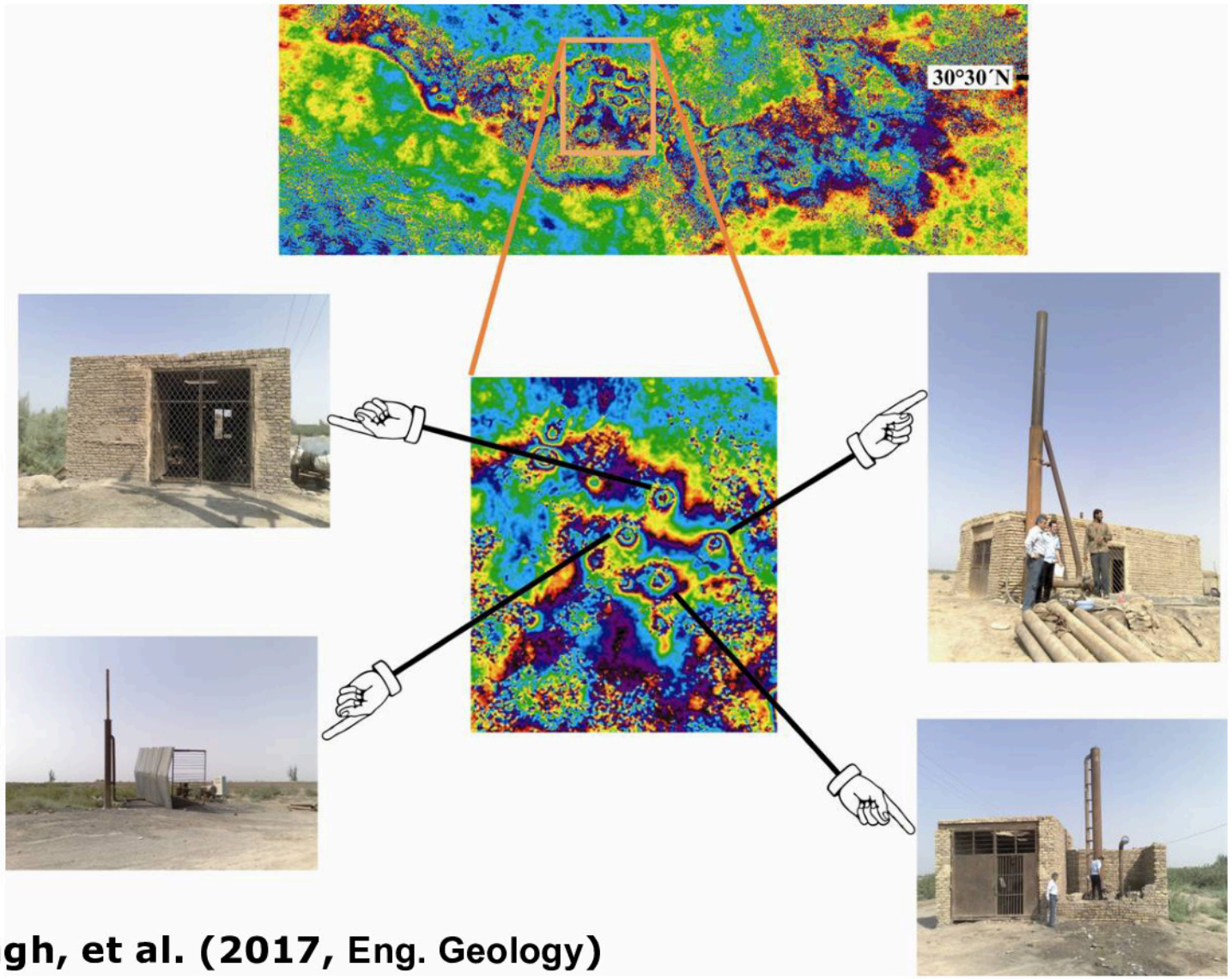
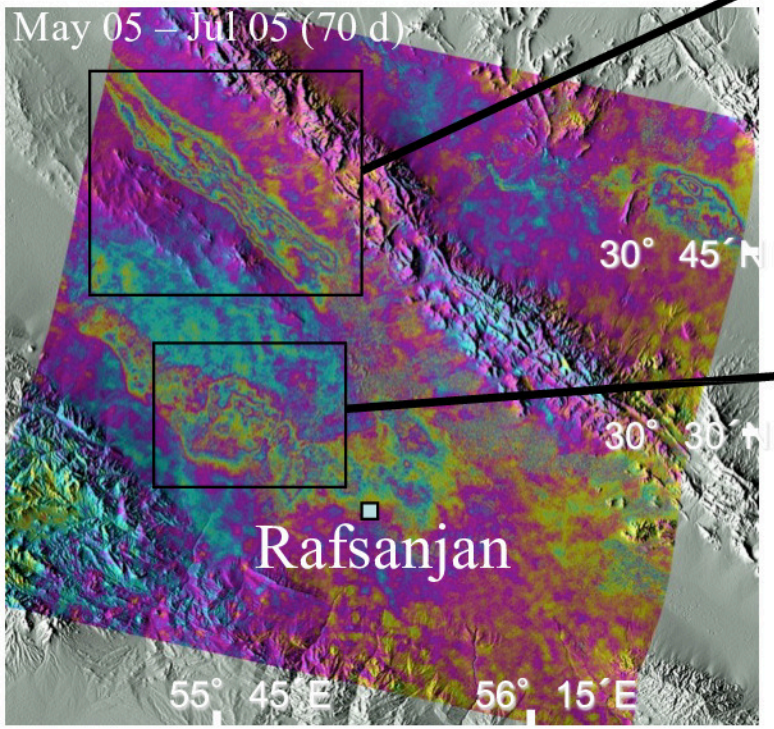
Field check-up

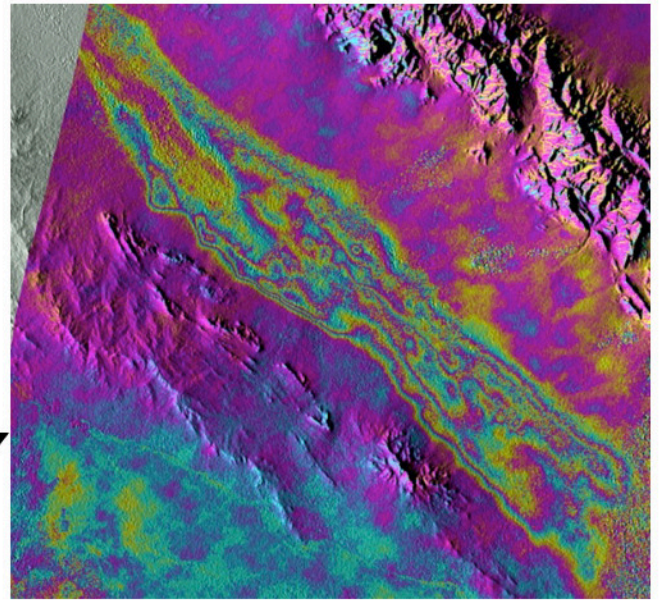


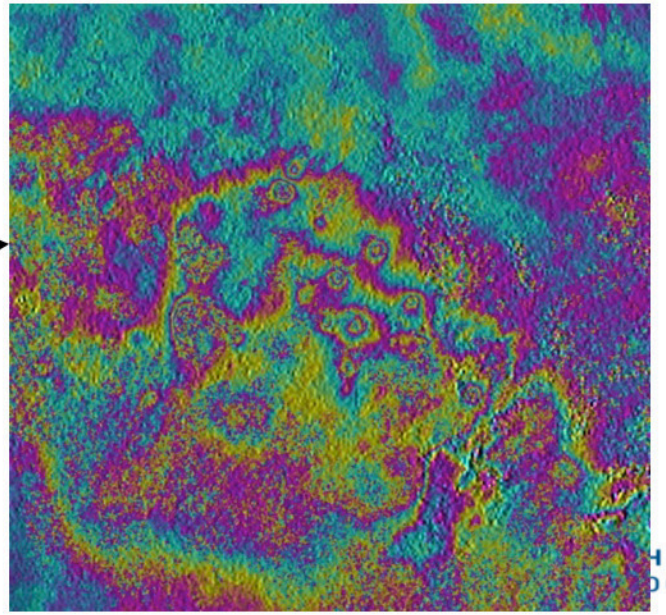
Motagh, et al. (2017, Eng. Geology)

Land Subsidence in Rafsanjan Observed by InSAR

- **Iran's center of Pistachio plantation**







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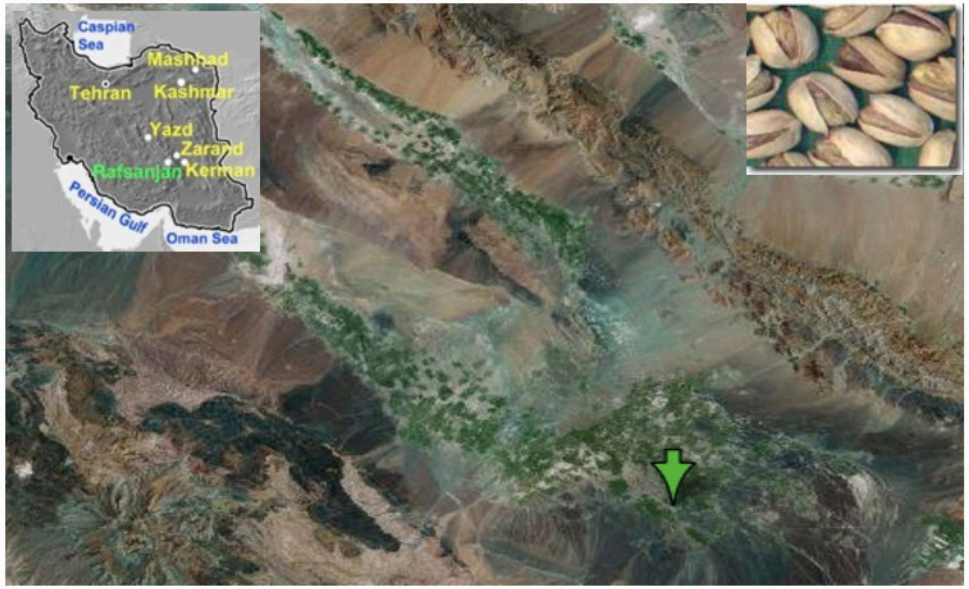
Stress on groundwater resources



Local innovation to extract water from 350 m!!!

Sentienl-1 InSAR Observation of Subsidence in Iran

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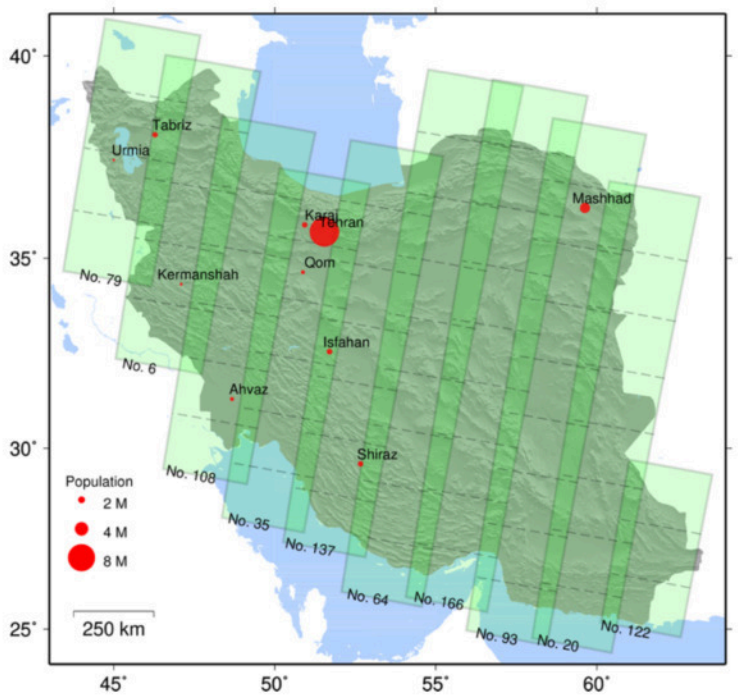
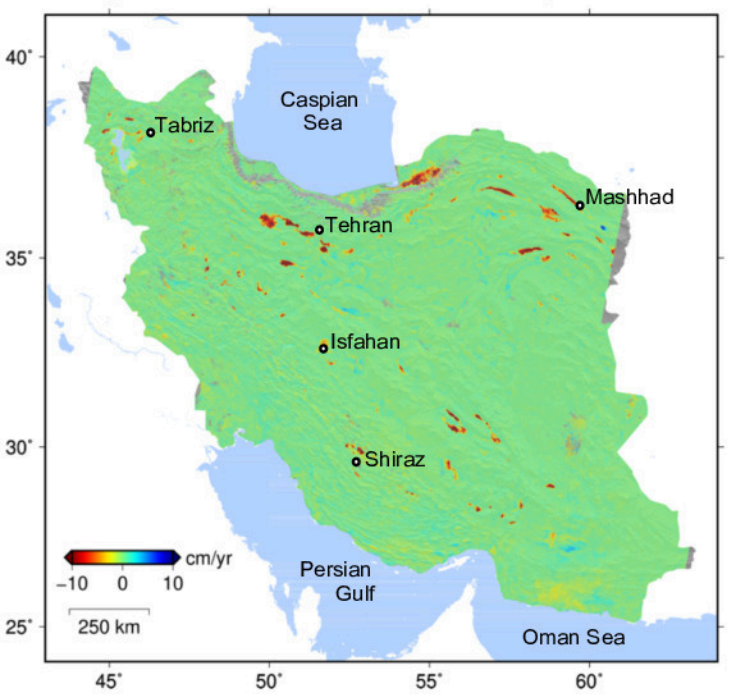
Coverage of Sentienl-1 in Iran



- Systematic acquisitions every 6/12/24 days
- 250 km x 1000+ km: Continental-scale mapping
- 20 year operational program, free and open data policy

- Dataset used here (2014-2017)
  - 10 descending orbit
  - 66 frames

Country-scale subsidence map across Iran



- InSAR observations using 3500 Sentinel-1 images
- approx. 300 subsidence areas
- Subsidence is widespread across the country

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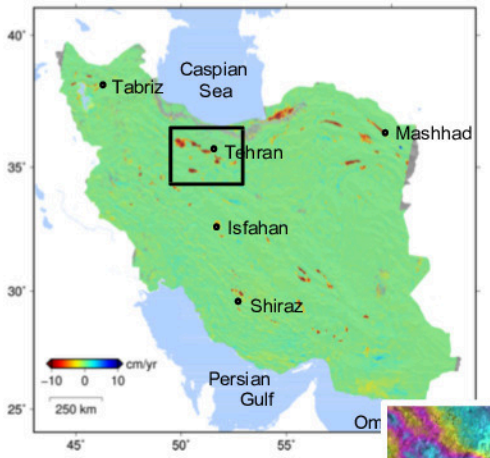
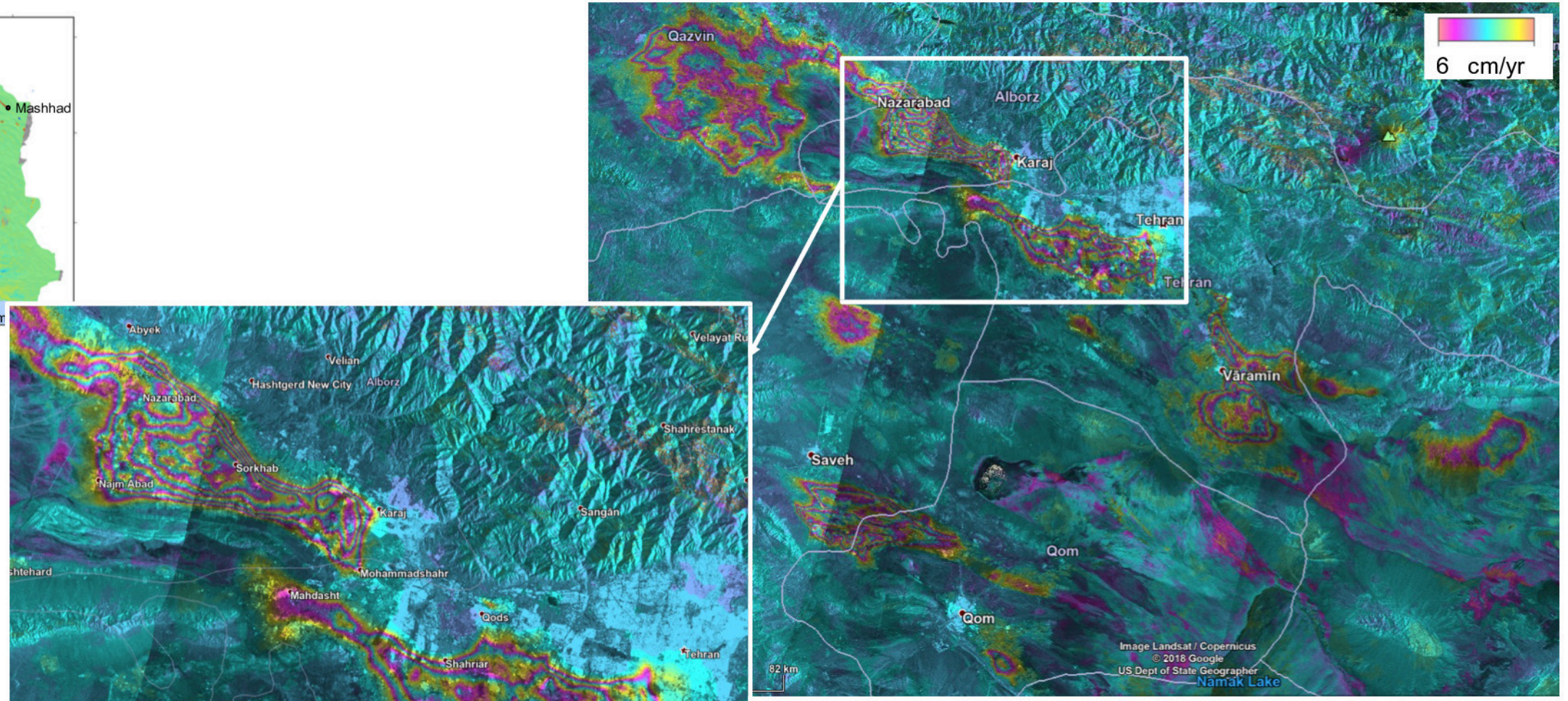
Regional-scale Subsidence Across Iran





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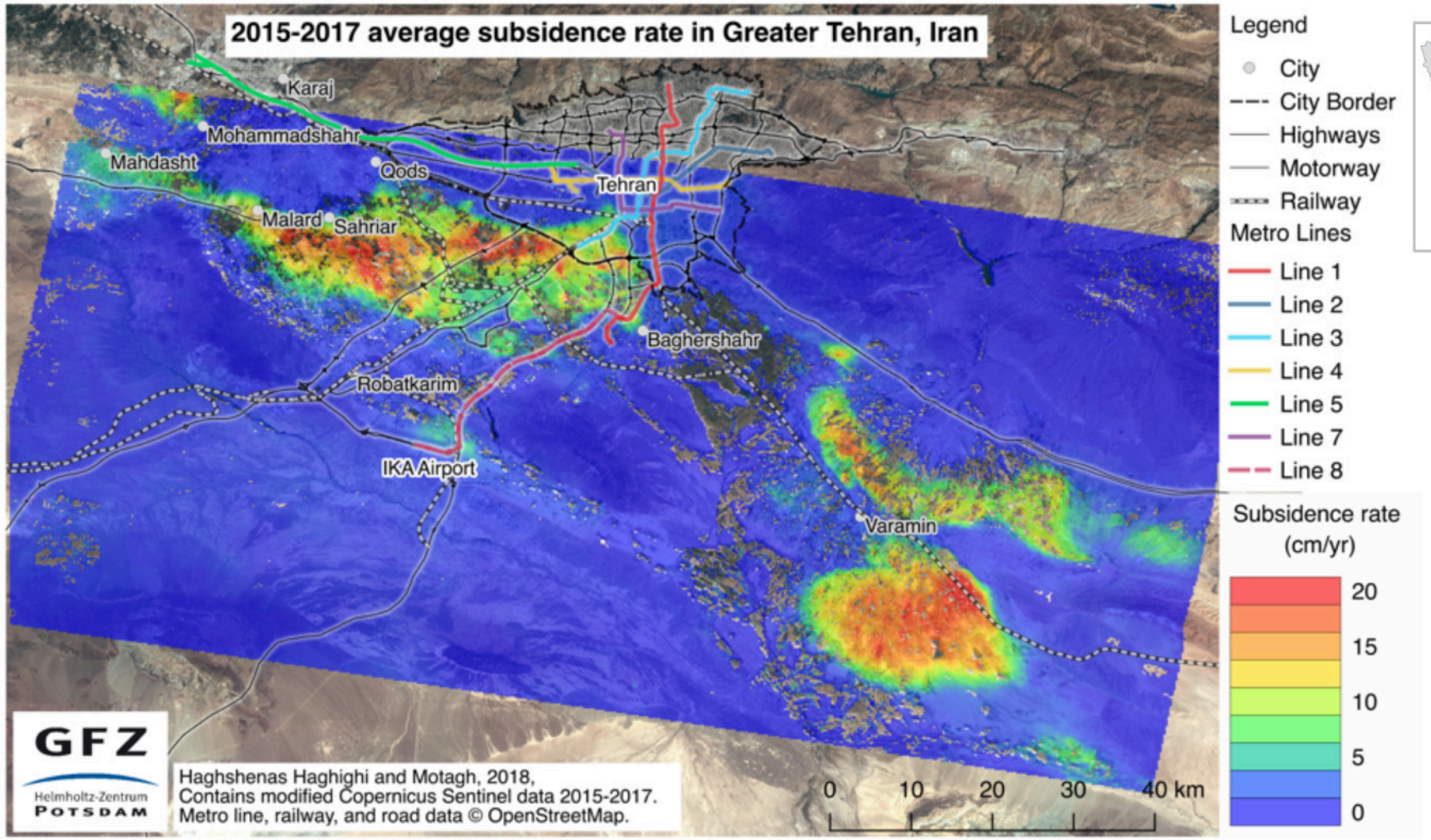
Example of Land Subsidence in Tehran



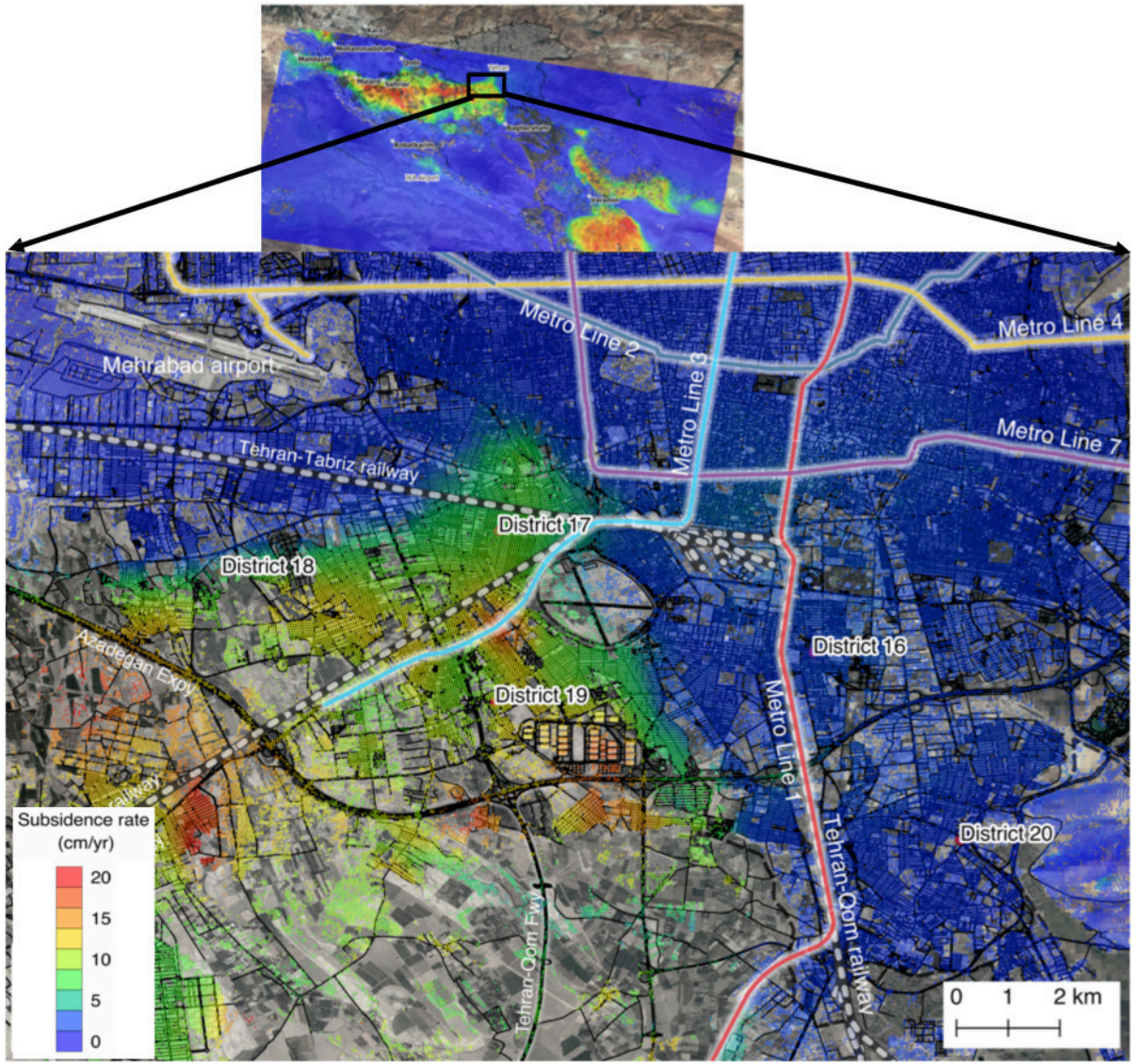
Subsidence affects:

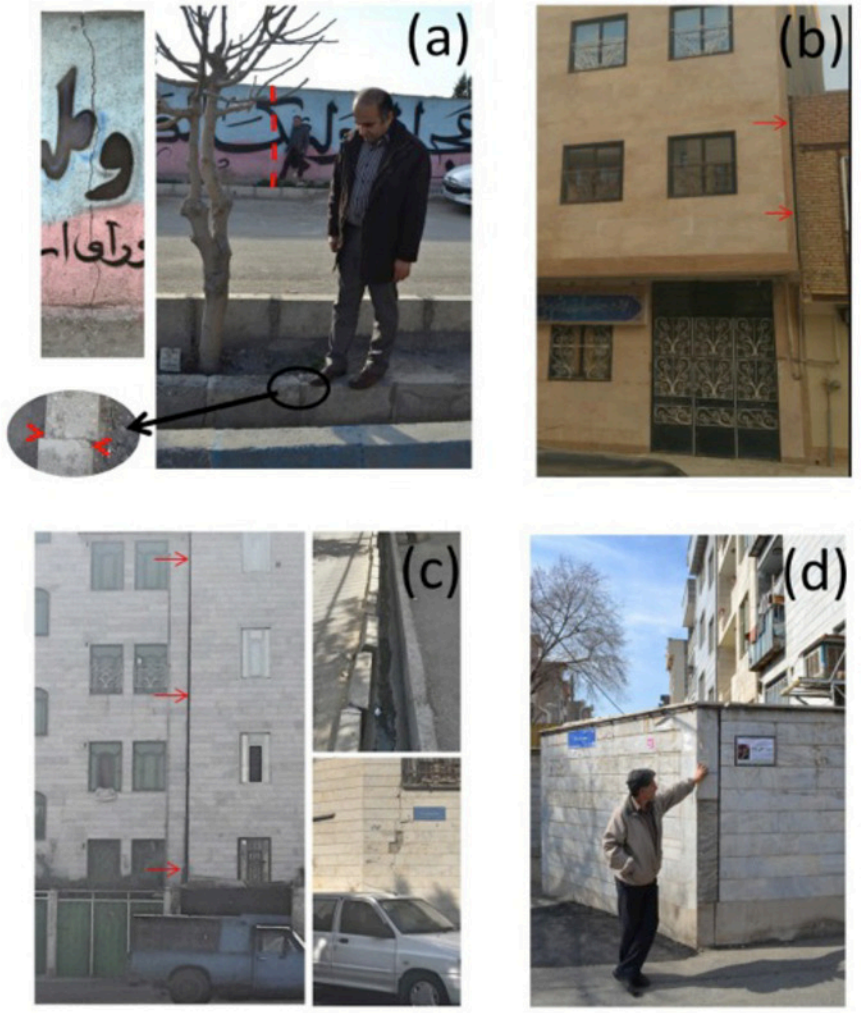
- 120 km of railway
- 2,300 km of road
- 21 bridges
- 30 km of oil pipeline
- 200 km of gas pipeline,
- 70 km of high-voltage electricity lines
- 250,000+ buildings
- and the International Airport

- The largest city in southwest Asia Population: 6.8 M (1995), 13 M (2018)
- 30000 wells are operating, > 10 m reduction in water level in 25 years

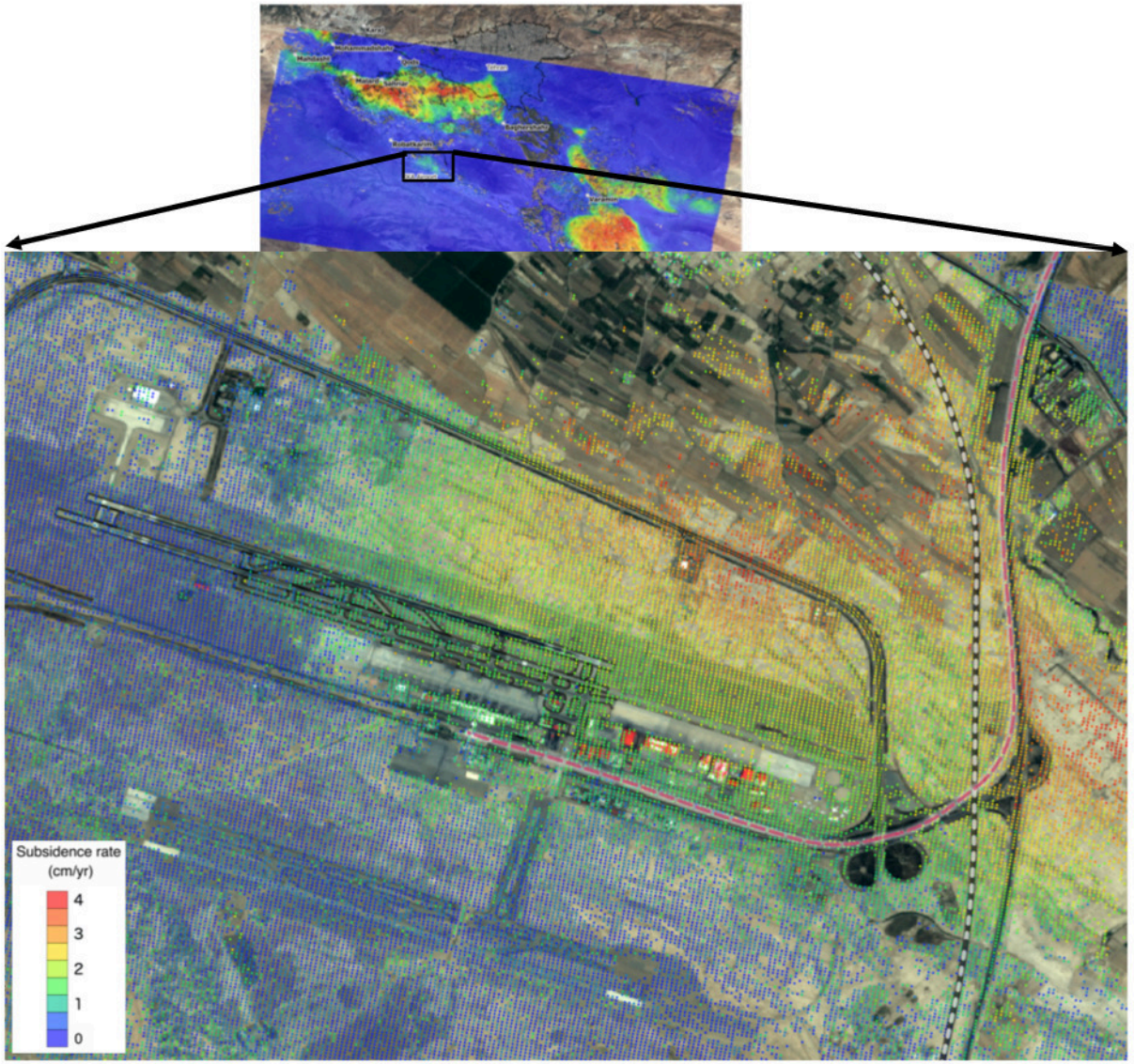
Haghshenas Haghighi & Motagh (2019, RS of Environment)

Land subsidence in Tehran





Tehran International Airport



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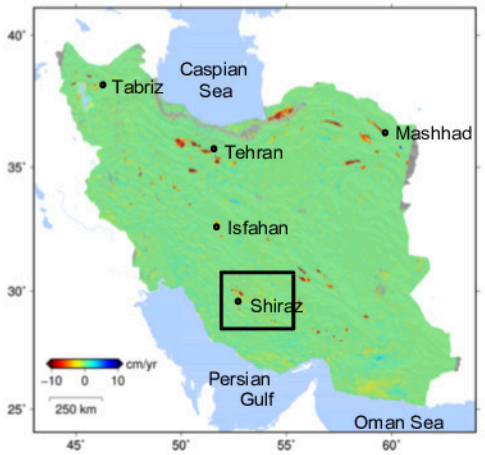
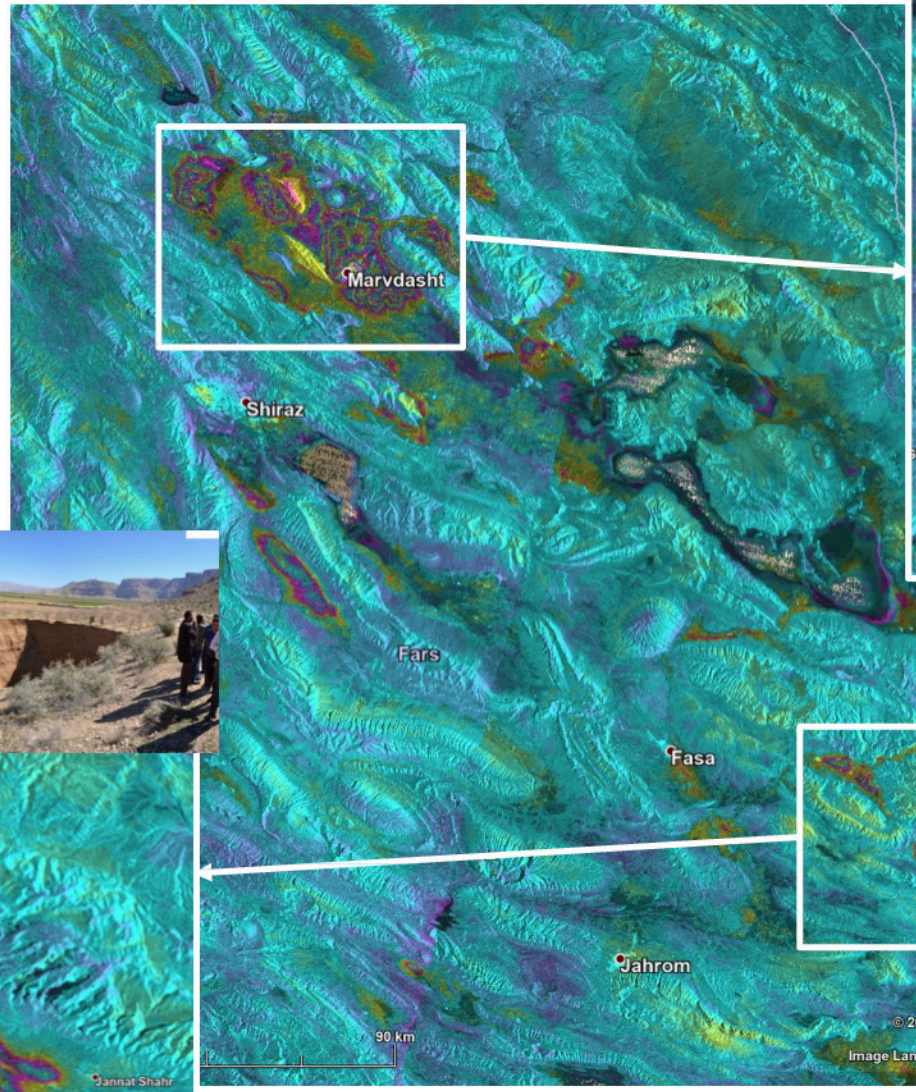
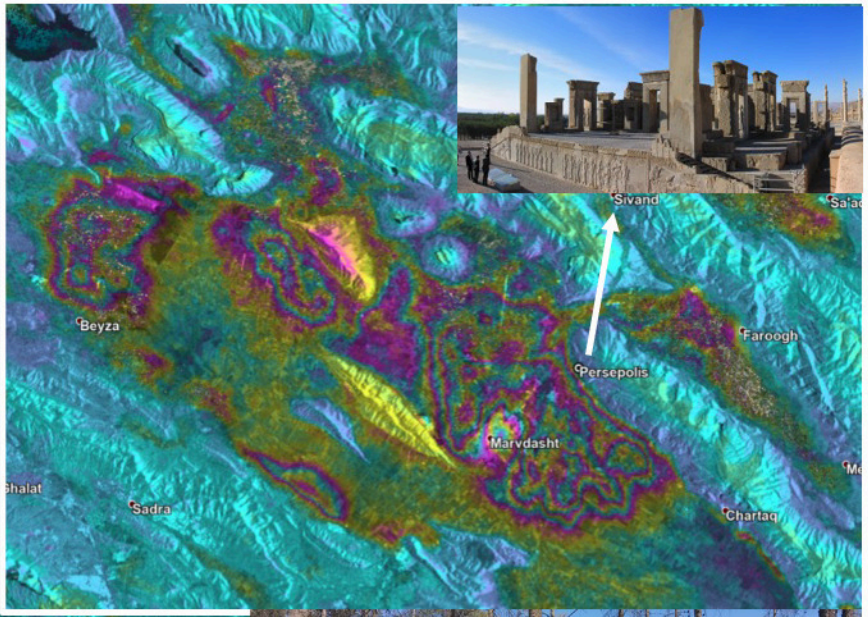
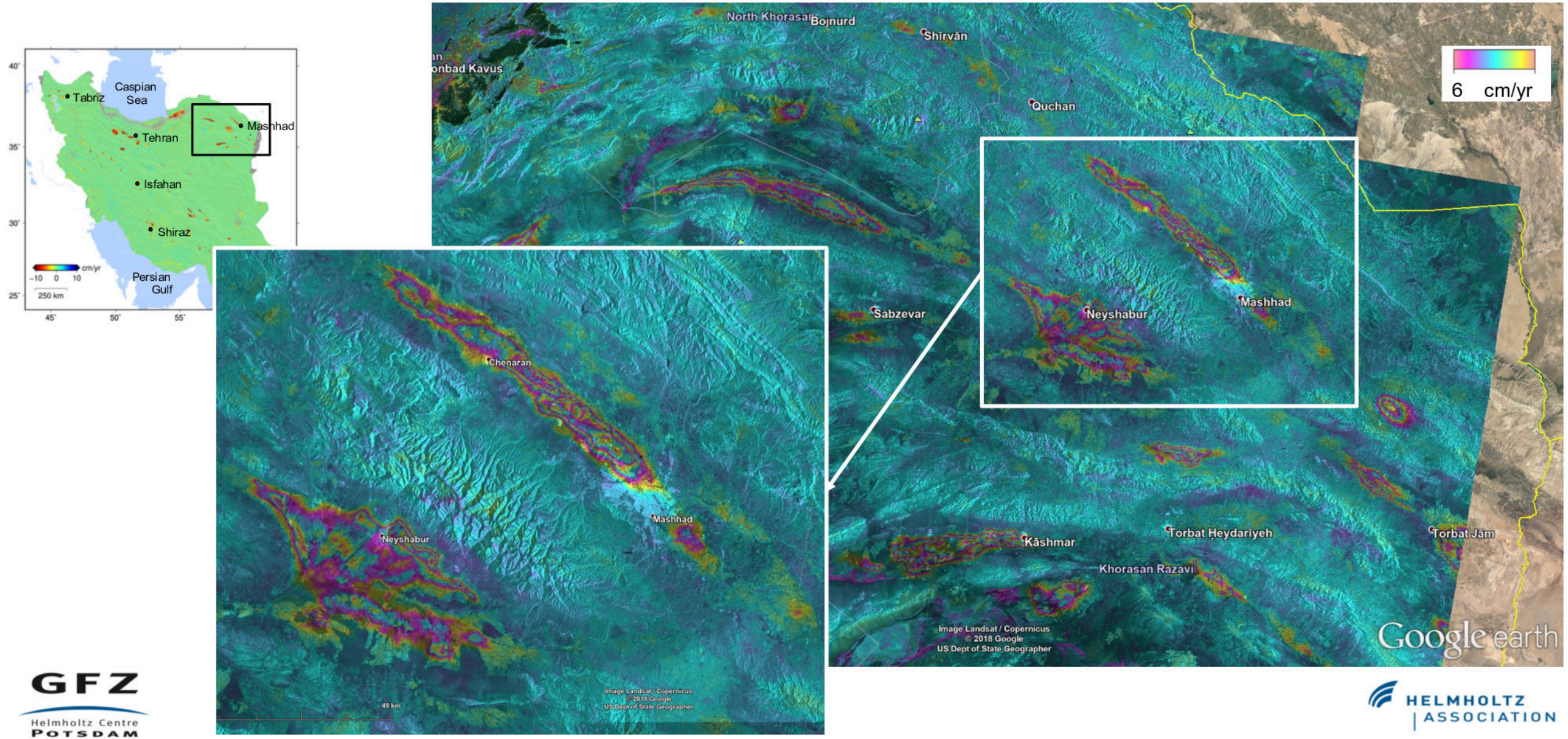
Regional-scale Subsidence Across Iran







Regional-scale Subsidence Across Iran



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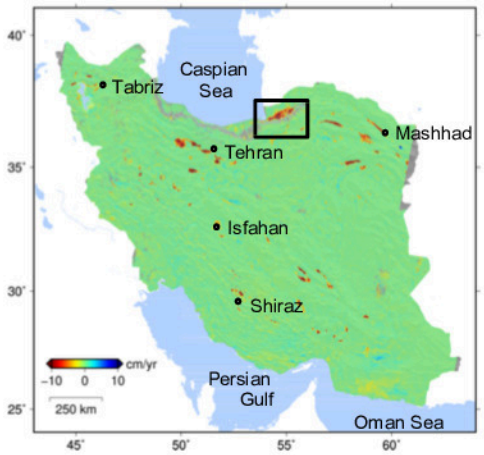
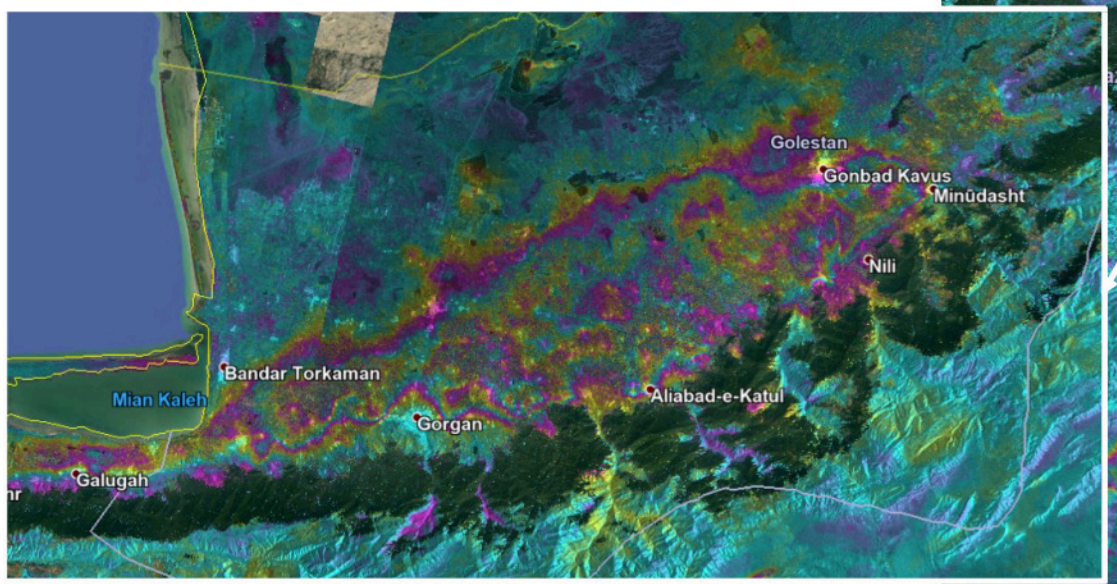
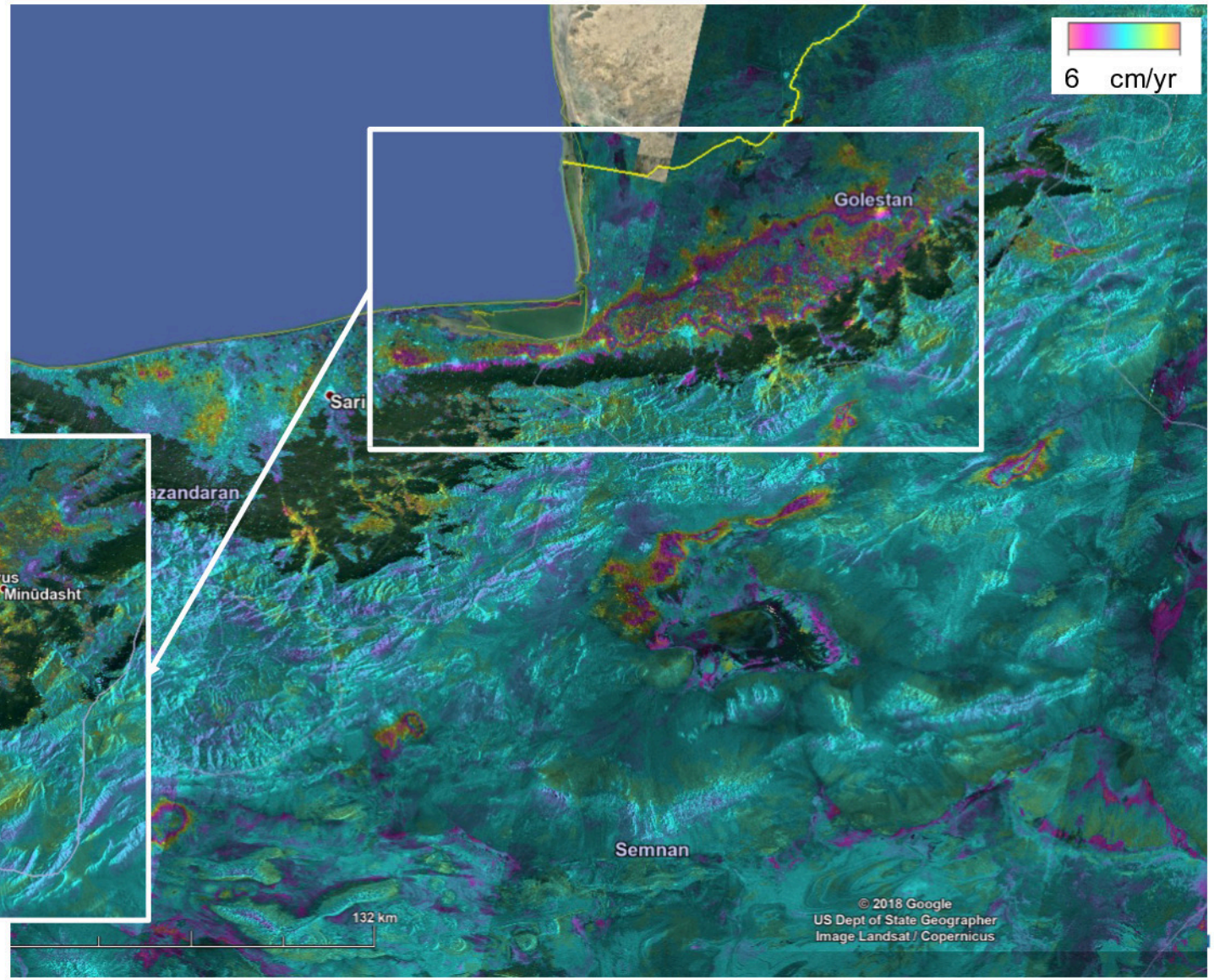
Regional-scale Subsidence Across Iran







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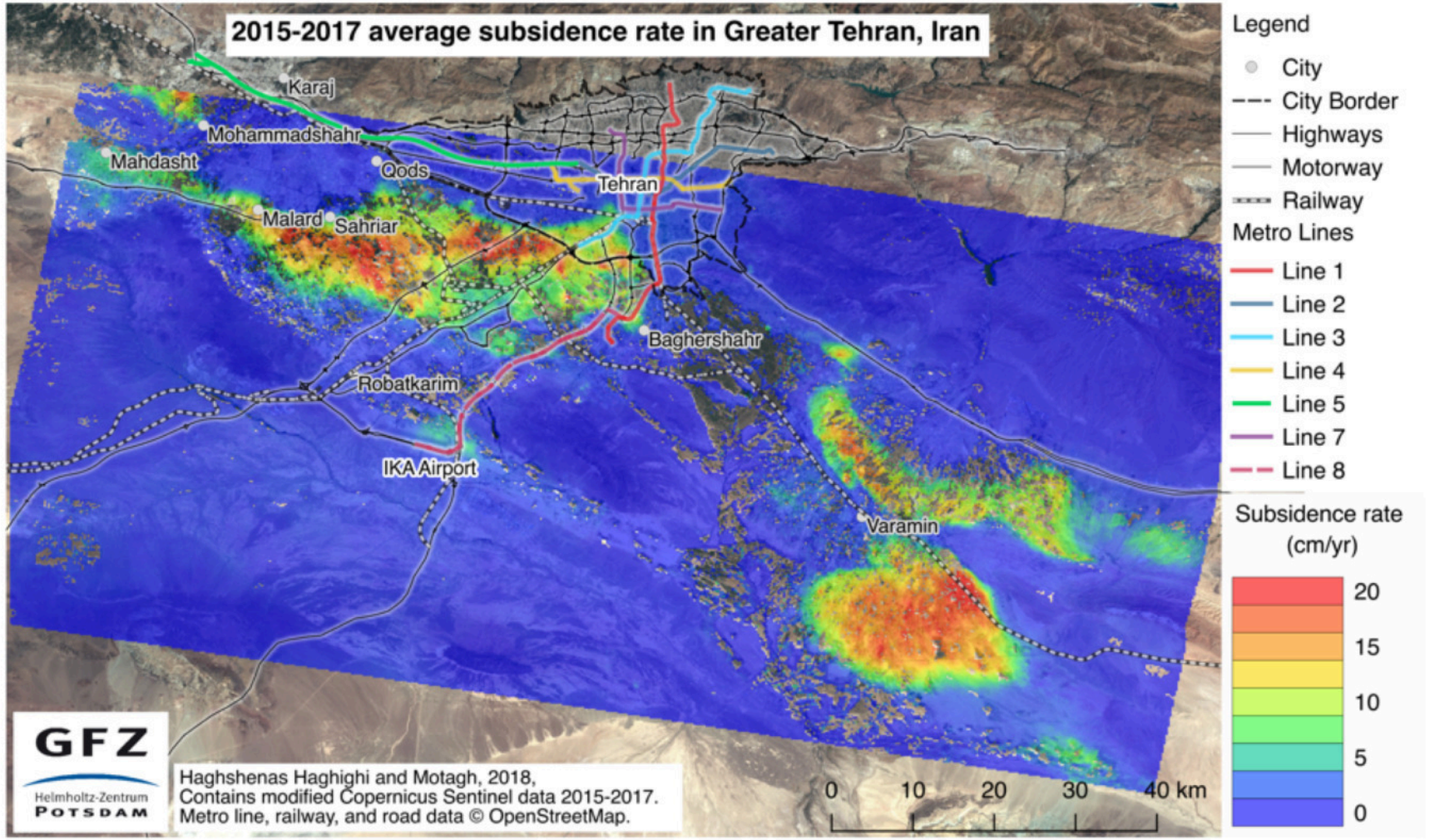
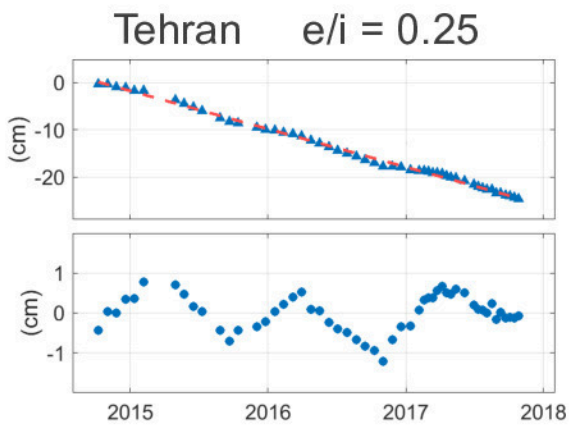
Aquifer Health and Sustainability





Conclusion

- Large-scale Sentinel-1 survey using a stack of 3500 Sentinel-1 images reveals approx. 300 subsidence areas in Iran

- The Central Iranian Plateau hosts some of the fastest sinking basins with rates exceeding 30 cm/yr

- Sentinel-1 survey suggests that the dominant component of deformation in many basins is irreversible