Network of Resources (NoR) Initiative

Final Reporting – NoR project id. 190791

Monitoring land subsidence and its induced risk using advanced InSAR methods

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Use-case and societal challenge

To address increasing water demands in expanding metropolises, many aquifers worldwide are overexploited

This process is further exacerbated by climate change and its impacts on the availability of groundwater resources

Land subsidence due to aquifer depletion often combines with ground fracturing and damage to private and public urban infrastructure

NoR project objectives

- Retrieve land subsidence patterns and rates from space by exploiting long time series of satellite SAR data and multi-temporal InSAR
- Estimate the risk to infrastructure (housing, service and transport networks) induced by land deformation and the impacted population
- Validate satellite observations with ground truth and other monitoring data

Platform & Services exploited

<u>Platform</u>

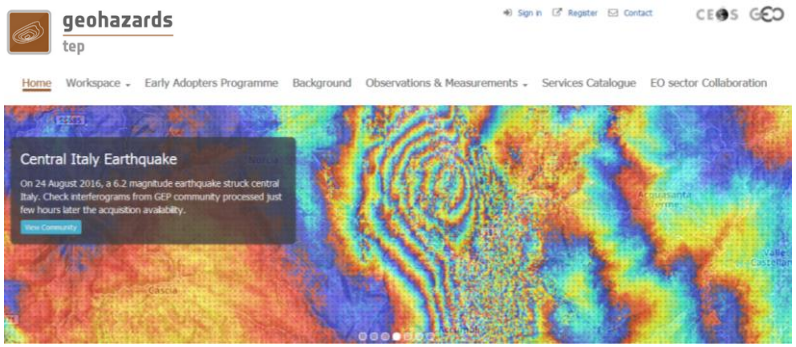
- Geohazards Exploitation Platform (GEP): https://geohazards-tep.eu/

<u>EO data</u>

- Sentinel-1 IW dual-pol. SAR scenes (in SLC and/or GRD format)

<u>On-demand services</u>

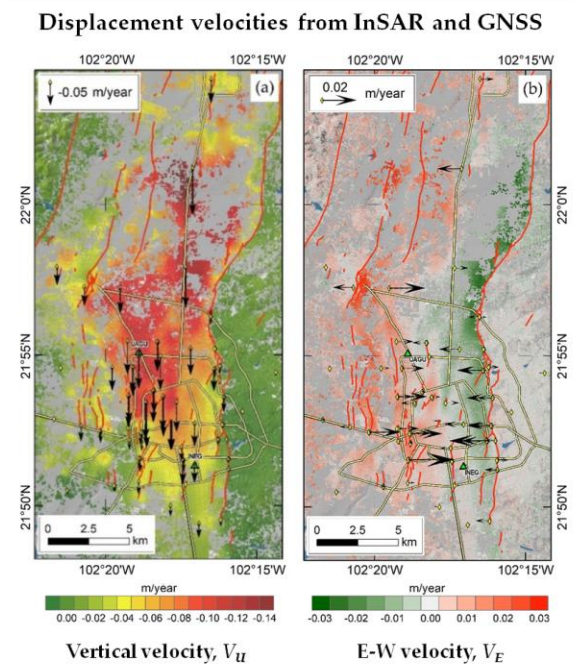
- P-SBAS Sentinel-1 processing on-demand by CNR-IREA
- ONDA DIAS product order (Europe + North and South America)
- SNAP Sentinel-1 IW SLC Interferogram and Displacements
- SNAC - SNAP S-1 GRD Amplitude Change
- COIN - Coherence and Intensity change for Sentinel-1

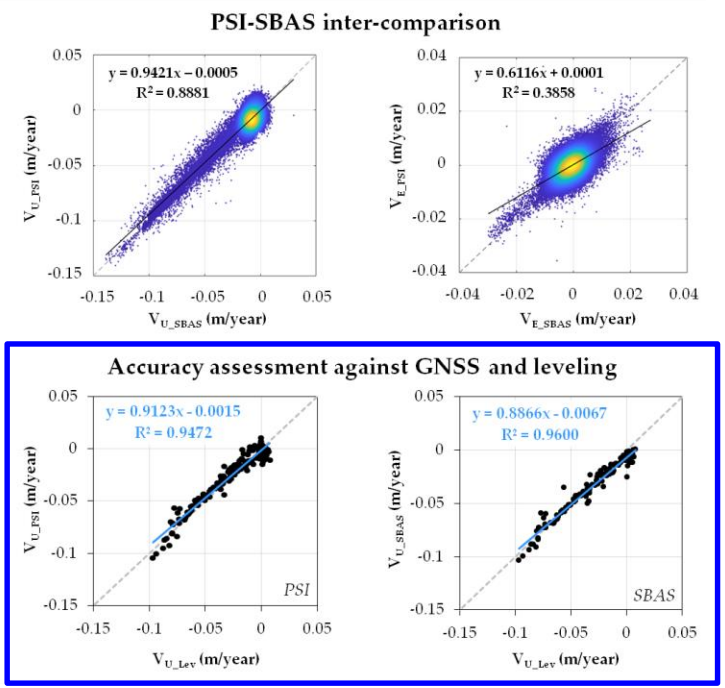


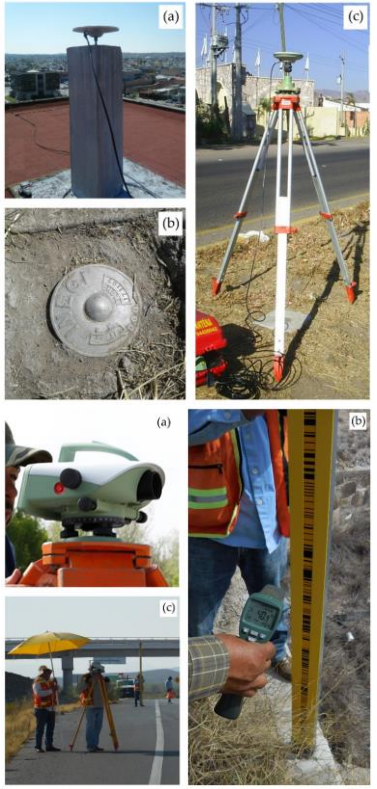
Sentinel-1 P-SBAS | DIAS product order Europe | DIAS product order North and South America | SNAP InSAR | SNAC | COIN

Key results #1: Accuracy of InSAR-derived displacement velocity vs. geodetic data

- The accuracy of P-SBAS InSAR ground displacement velocities was estimated against permanent GNSS, static GNSS benchmark repositioning and geodetic leveling monitoring data by the Mexican INEGI
- ***V_U* relative errors < 20%** at locations subsiding faster than −15 mm/year







Geodetic data by INEGI: *National Institute of Statistics, Geography and Informatics*

Full paper: **CIGNA *et al.* 2021,** https://doi.org/10.3390/rs13234800

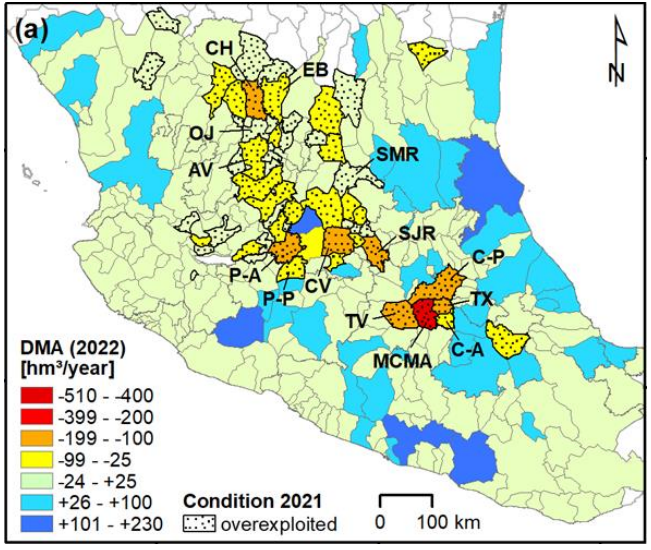
Key results #2: Quasi-continental Sentinel-1 InSAR survey in Central Mexico

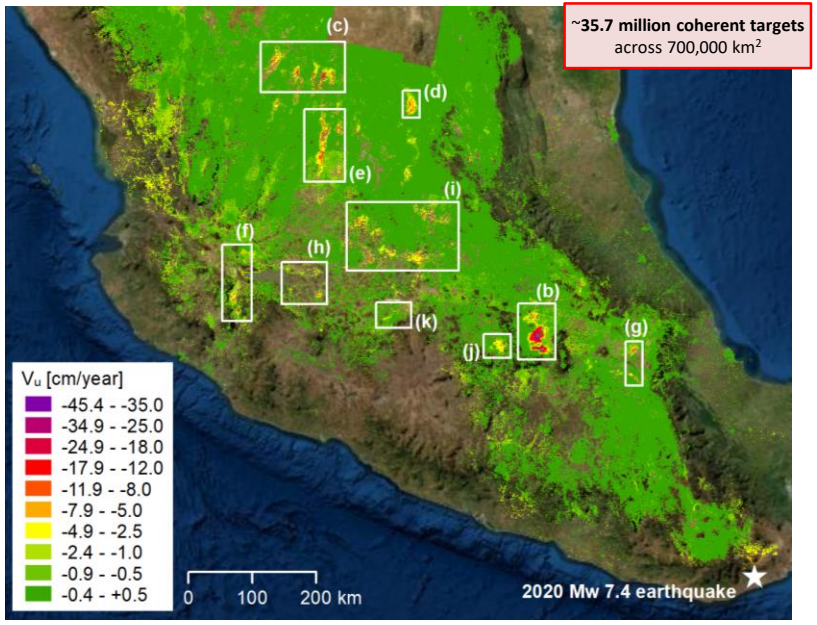
Mexican aquifers provide 40% (i.e. ~35,300 hm^3/year) of the total consumed water of the country

As of 2022, >**200 aquifers were in deficit and >100 overexploited** (57 in Central Mexico, where >85.2 M inhab., ~68% tot pop.)

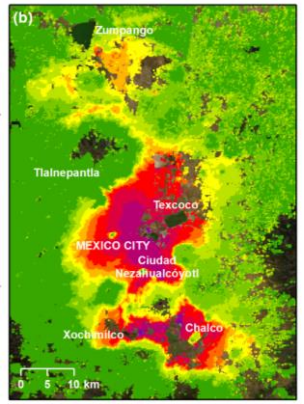
DMA (availability) = *recharge – natural discharge – licensed pumping*

Overexploited if *pumping/recharge* ≥ 1.1

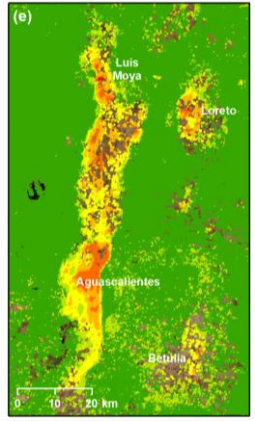




~35.7 million coherent targets across 700,000 km^2



Mexico City Metropolitan Area



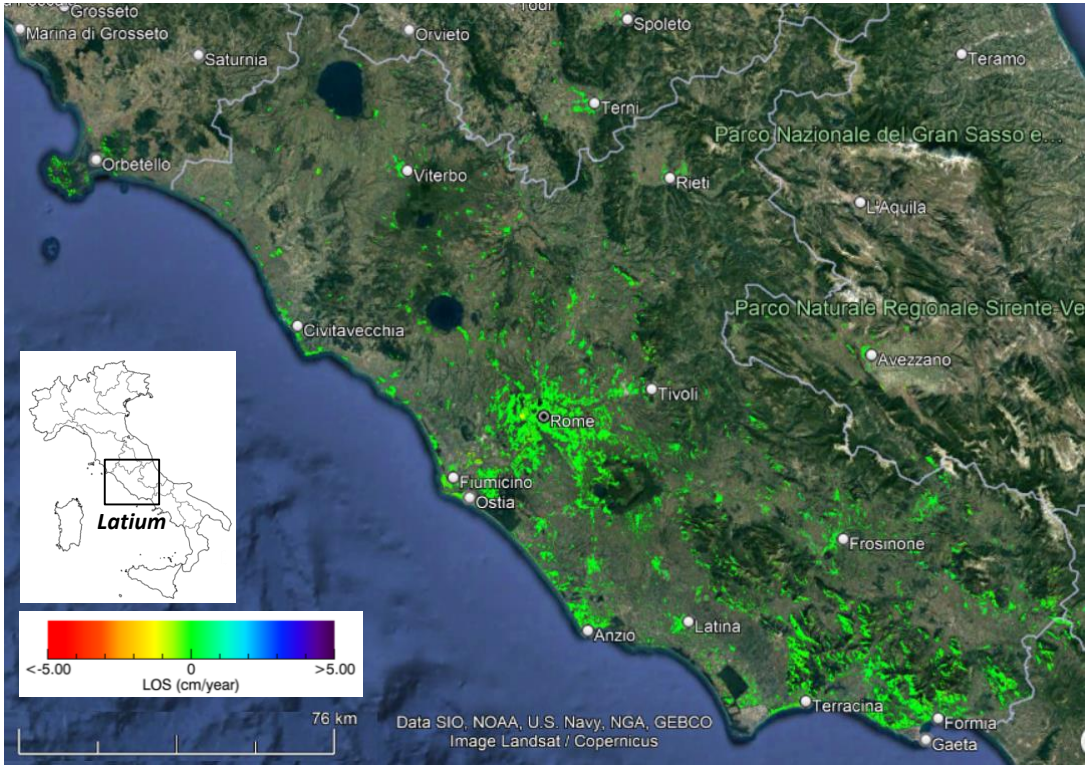
Aguascalientes Valley

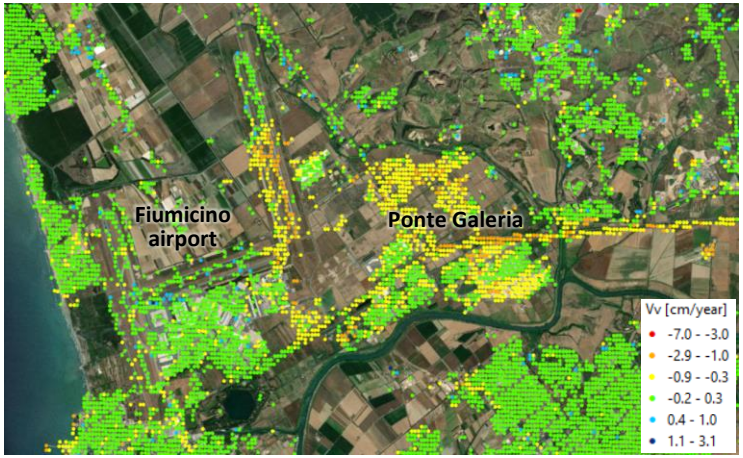
- **30+ land subsidence "hotspots"** were identified in 2019-2020
- Urban infrastructure is impacted when differential deformation is significant (i.e. in zones of high angular distortions)

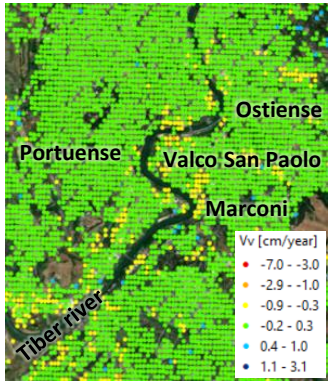
Full paper: **CIGNA & TAPETE 2022,** https://doi.org/10.1029/2022GL098923

Key results #3: Present-day ground instability across Latium region (Italy)

- P-SBAS enabled the estimation of 2018–2022 ground displacement histories and rates at >460,700 coherent targets across the whole region (17,242 km^2)





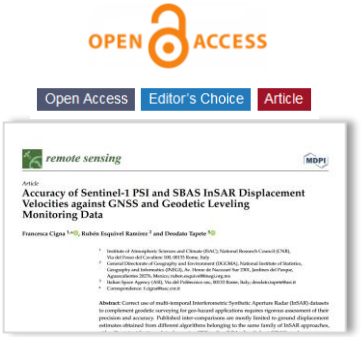


- Surface deformation was observed at Fiumicino airport, Ponte Galeria and along the Tiber river alluvium
- Processes that may represent a potential threat to archaeological sites and cultural heritage assets were identified

Full paper: **CIGNA *et al. 2023*** *(in press)*

Highlights of benefits to society

- Ground instability observations retrieved with advanced InSAR services running in GEP proved to be valuable and robust inputs for impact and risk assessment models in urban areas (for both buildings and transport networks, and heritage assets)
- Satellite-derived products provide quantitative evidence that can inform land and water resources management strategies



Publications & dissemination

Full papers in international journals

- CIGNA F., ESQUIVEL RAMÍREZ R., TAPETE D. 2021. Accuracy of Sentinel-1 PSI and SBAS InSAR displacement velocities against GNSS and geodetic leveling monitoring data. *Remote Sensing*, 13, 4800, https://doi.org/10.3390/rs13234800
- CIGNA F., TAPETE D. 2022. Land subsidence and aquifer-system storage loss in Central Mexico: A quasi-continental investigation with Sentinel-1 InSAR. *Geophysical Research Letters*, 49 (15), e2022GL098923, https://doi.org/10.1029/2022GL098923
- CIGNA F., BALZ T., TAPETE D., CASPARI G., FU B., ABBALLE M., JIANG H. 2023. Exploiting satellite SAR for archaeological prospection and heritage site protection: current achievements from the Dragon-5 SARchaeology project. *Geo-spatial Information Science*, Special Issue: ESA and NRSCC Dragon-5 cooperation mid-term results (2020-2022), in press

Scientific presentations at international conferences and workshops

- *ESA Living Planet Symposium 2022* (23-27 May 2022; Bonn, Germany)
- *EGU General Assembly 2022* (23-27 May 2022; Vienna, Austria & online)
- *ESA-MOST Dragon-5 Mid-Term Results Symposium* (17-21 Oct 2022; online)
- *ESA GEP webinar #1 on 'Wide-area subsidence monitoring from space'* (7 Dec 2022)

Other dissemination

- ESA GEP blog: https://discuss.terradue.com/t/sentinel-1-psi-sbas-insar-inter-comparison-and-accuracy-of-vertical-and-east-west-displacement-velocities-against-geodetic-data/1105