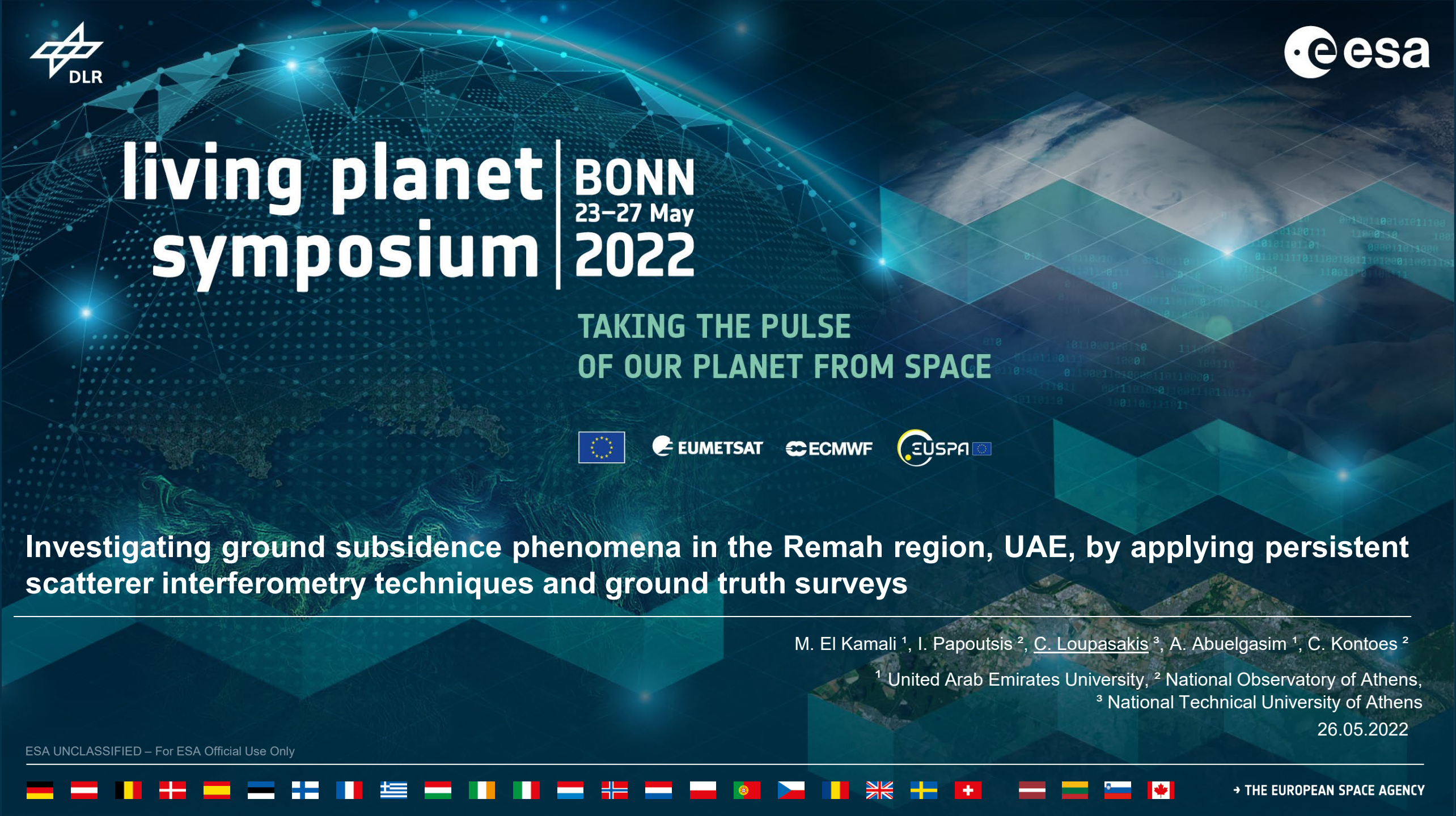

Investigating ground subsidence phenomena in the Remah region, UAE, by applying persistent scatterer interferometry techniques and ground truth surveys

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26.05.2022

LS mechanism due to ground water overexploitation

Ground water drawdown

↓

decrease of the ground water pressure

↓

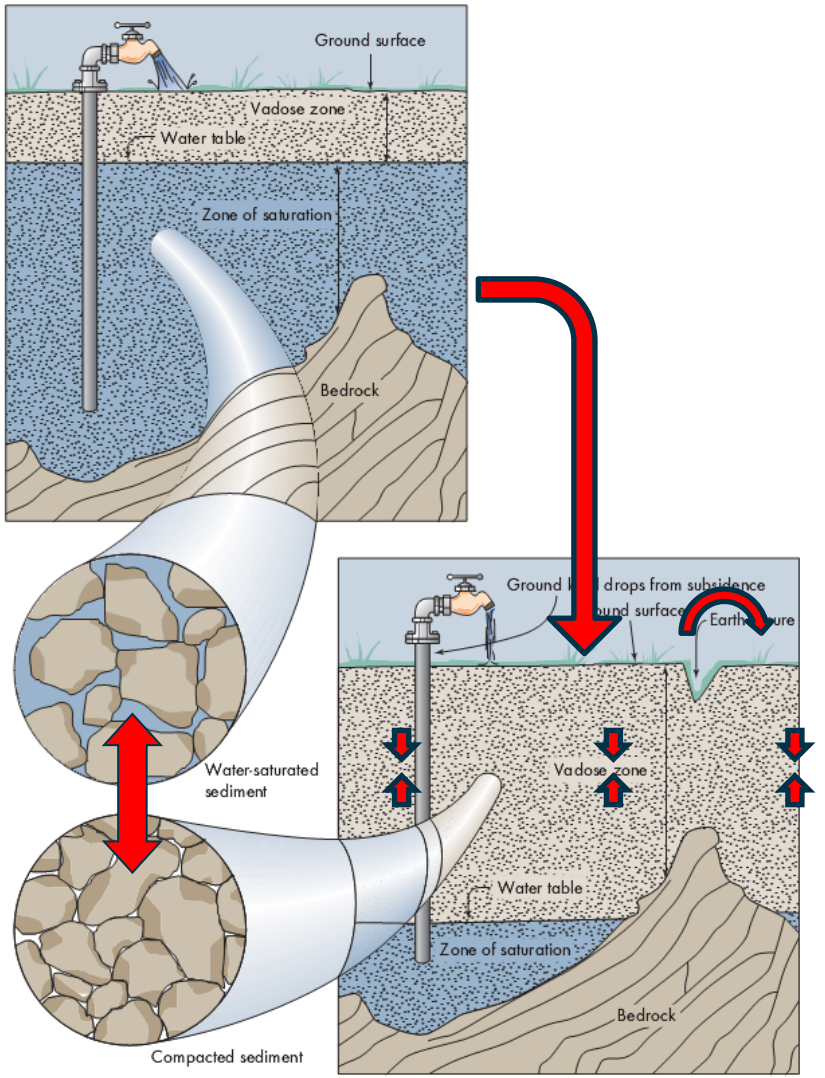
Increase of the active earth pressures

↓

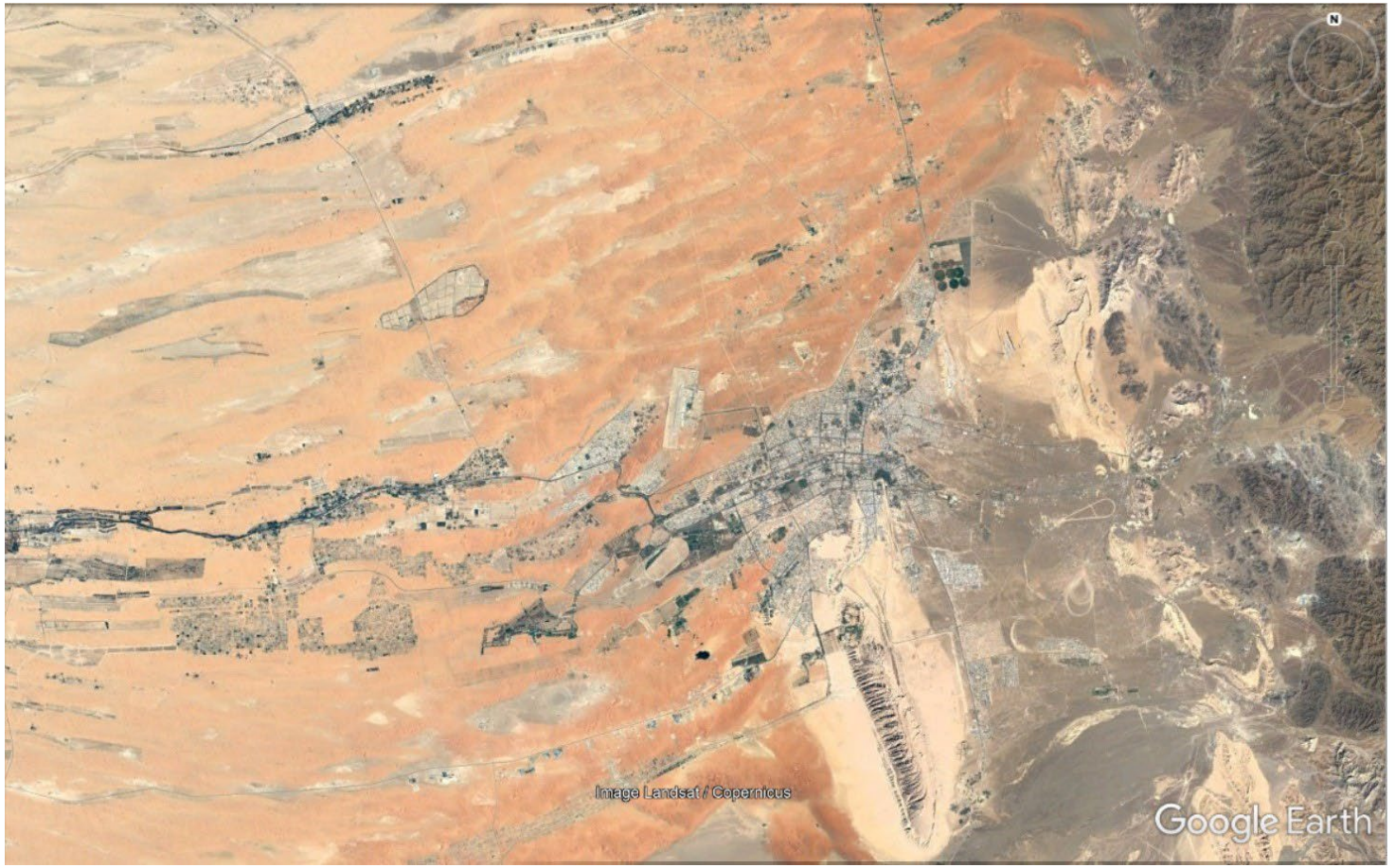
Activation of the consolidation

↓

Generation of ground fractures



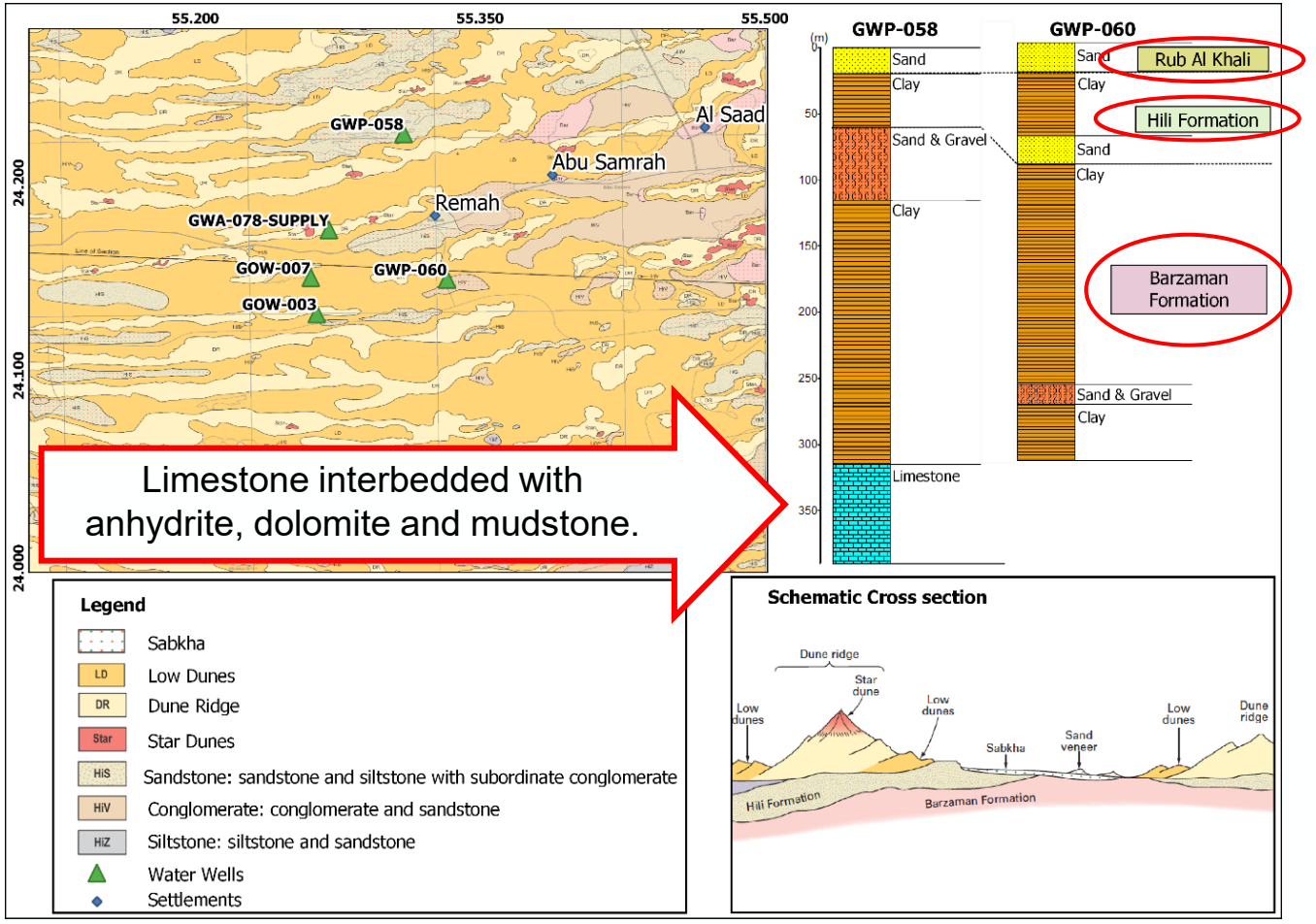
The Remah region, UAE



- Remah is located 43km east of Al Ain city.
- Desert, cover with sand dunes disconnected by flat areas (interdunes)
- Elevation ranges from 80 m a.s.l., in the west, up to 200 m a.s.l., in the east.
- In the east the Jabal Hafit and Al Hajar Mountains can be identified.

Geological Setting

The Remah area is occupied by three geological formations:



Barzaman formation (≈ 200m): fluvial sedimentary rocks mainly with conglomerates

Hili formation: three units (conglomerate and sandstone, siltstone and mudstone, sandstone and siltstone with conglomerate)

Rub al Khali formation: sand dunes (unconsolidated fine to medium grain sand)

Hydrogeological Setting

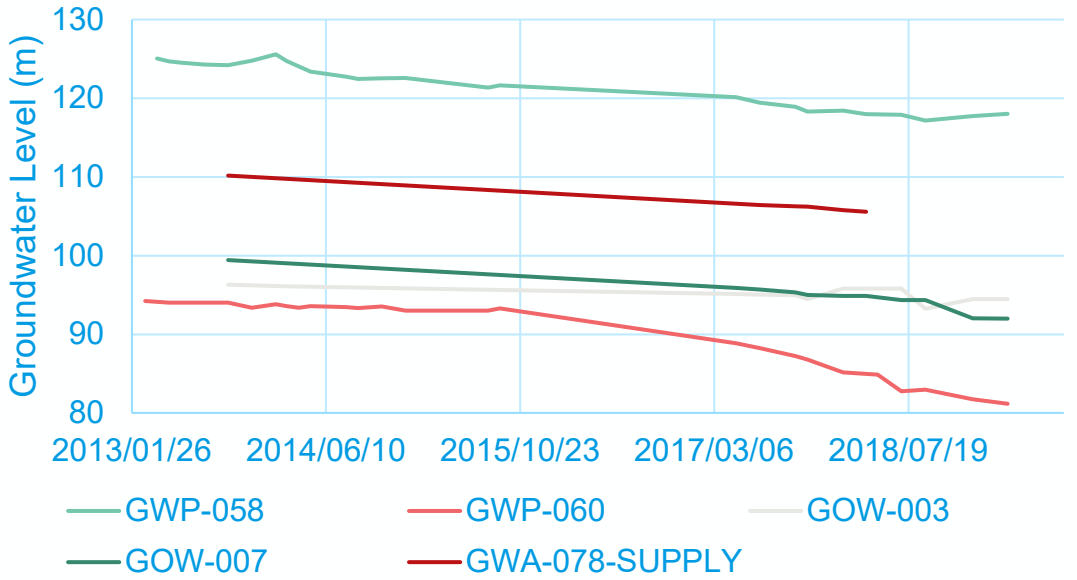
The geological formations of the wider Abu Dhabi Emirate bear four hydrological units:
(1) the carbonate aquifers occupying the macro permeable carbonate formations along the borders with Oman,
(2) the western gravel aquifer, along the foothill of the Al Hajar Mountains
(3) the sand dune aquifer covering most of the Emirate, and
(4) the coastal aquifer at the coastal Sabkhas

- The narrow study area is located at the sand dune aquifers unit.
- The unconfined aquifers of the area occupy the coarse grain layers of the formations
- The groundwater of the deep carbonate aquifer recharges the sand dune aquifers either directly or through the western gravel aquifer. The unconfined aquifers are fed laterally by the carbonate aquifers.

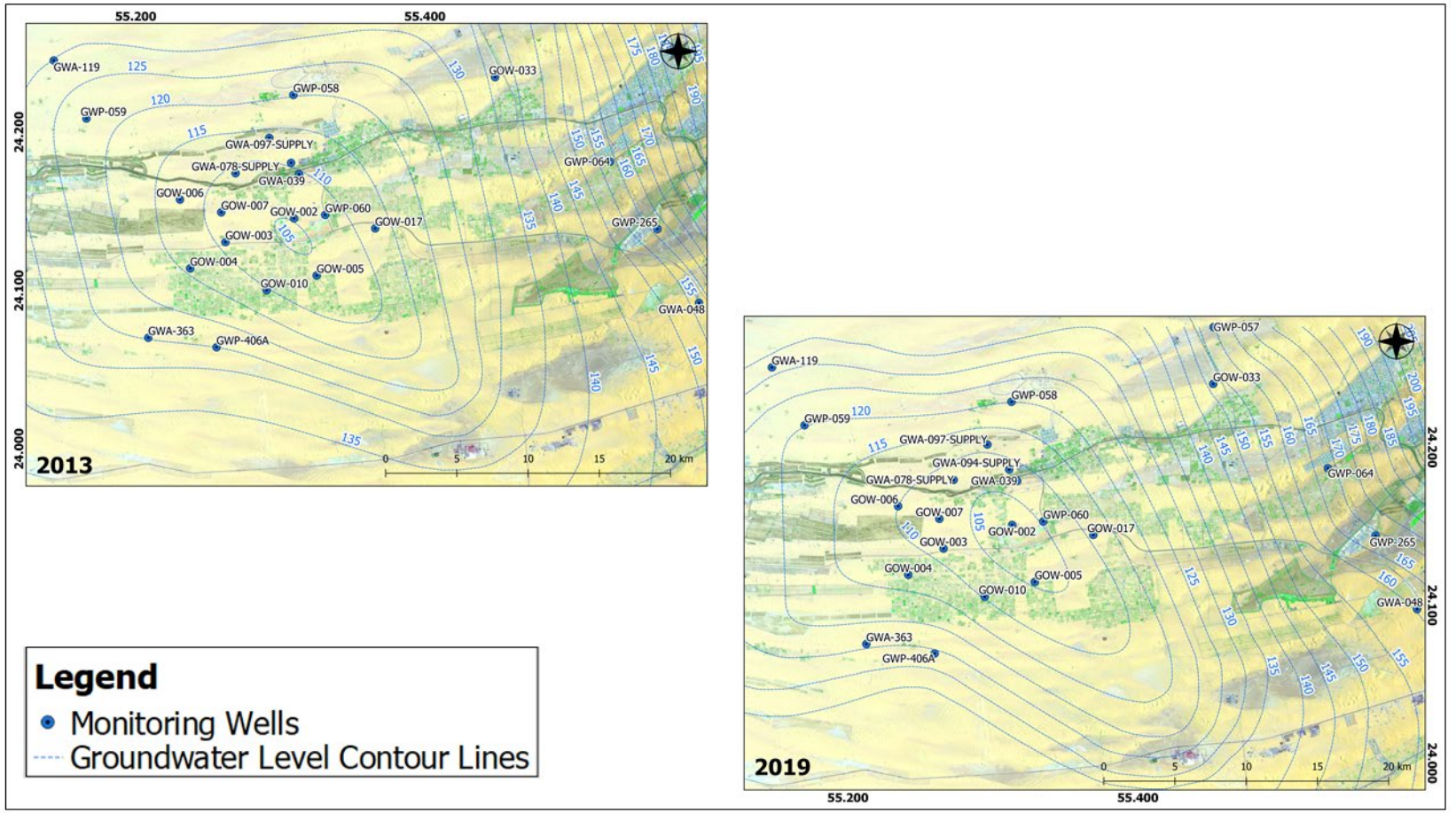
Hydrogeological Setting

- 50% of the agricultural activities of the emirate are located in the Al-Ain region.
- The area under investigation holds 524 active farms.
- The agricultural activities are supported by a network of water wells exploiting the underground water, with annual water discharge of 244 million m^3.
- The groundwater, although unsuitable for irrigation due to its high salinity, is the only source of water in the area.
- The average depth of the water table in the shallow aquifer ranges between 52 and 67 m.
- At the narrow study area, due to overexploitation, the aquifers form a depression cone reaching further down to the depth of 120 m.

Groundwater level drawdown at the monitoring wells.



Hydrogeological Setting



Groundwater level contours shown over the study area in 2013 and 2019
The blue circles are representing the monitoring water wells.

Proof of the continuous expansion of the depression cone and the groundwater level drawdown.

Evidence for the possibility of Land Subsidence to occure due to over pumping!!!

Field Observation Survey

The field observation survey can be considered crucial when studying land subsidence as the low deformation rates of the phenomenon can only be identified through the deformations and the failures of rigid constructions founded over the site.

Numerous land surface subsidence effects have been captured in the study are:

- Leaning and fractured walls caused by the deferential settlements of the foundations.
- Buildings appear cracked by the deferential settlements of the foundations.
- Well casings appear protrusion signs due to the surface subsidence.
- Electrical pillars appear dislocated with the wires tensioned due to the differential surface movements.

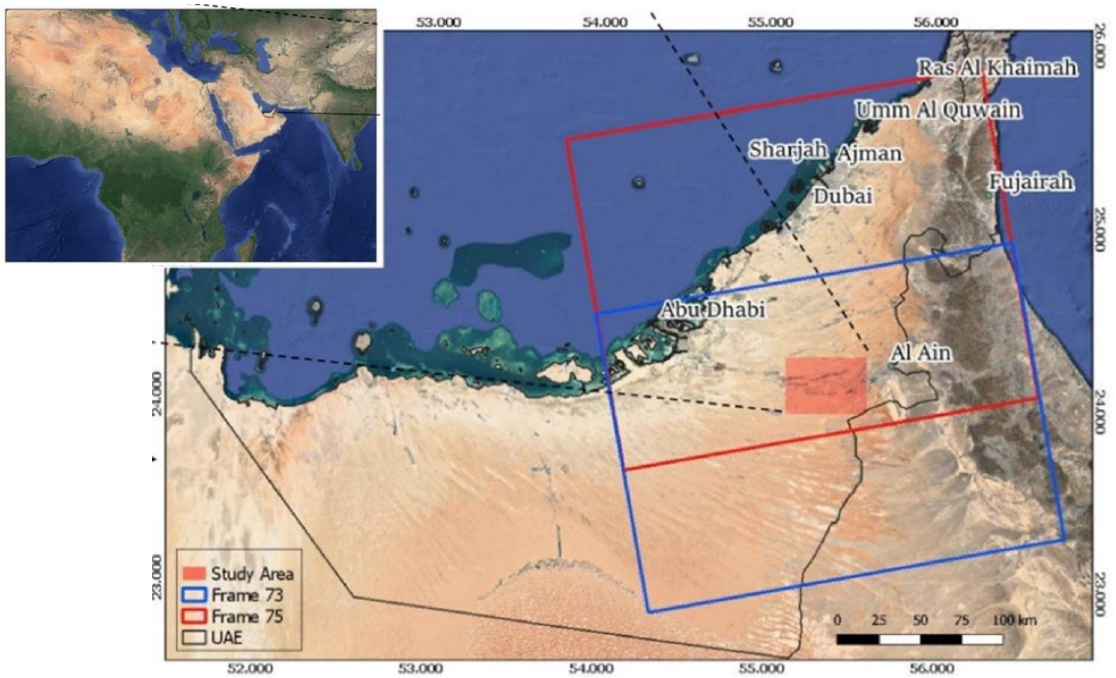
Interferometric Analysis

SAR dataset: Sentinel-1 dataset provided by the European Space Agency (ESA).

- Sentinel-1 operats in C-band (5.6 cm) and has a 12-day revisit period.
- The dataset consists of 37 Sentinel-1 Single Look Complex (SLC) images acquired along the ascending orbit from path 130 and frames 73 and 75, for a time span between February 2015 and May 2019.

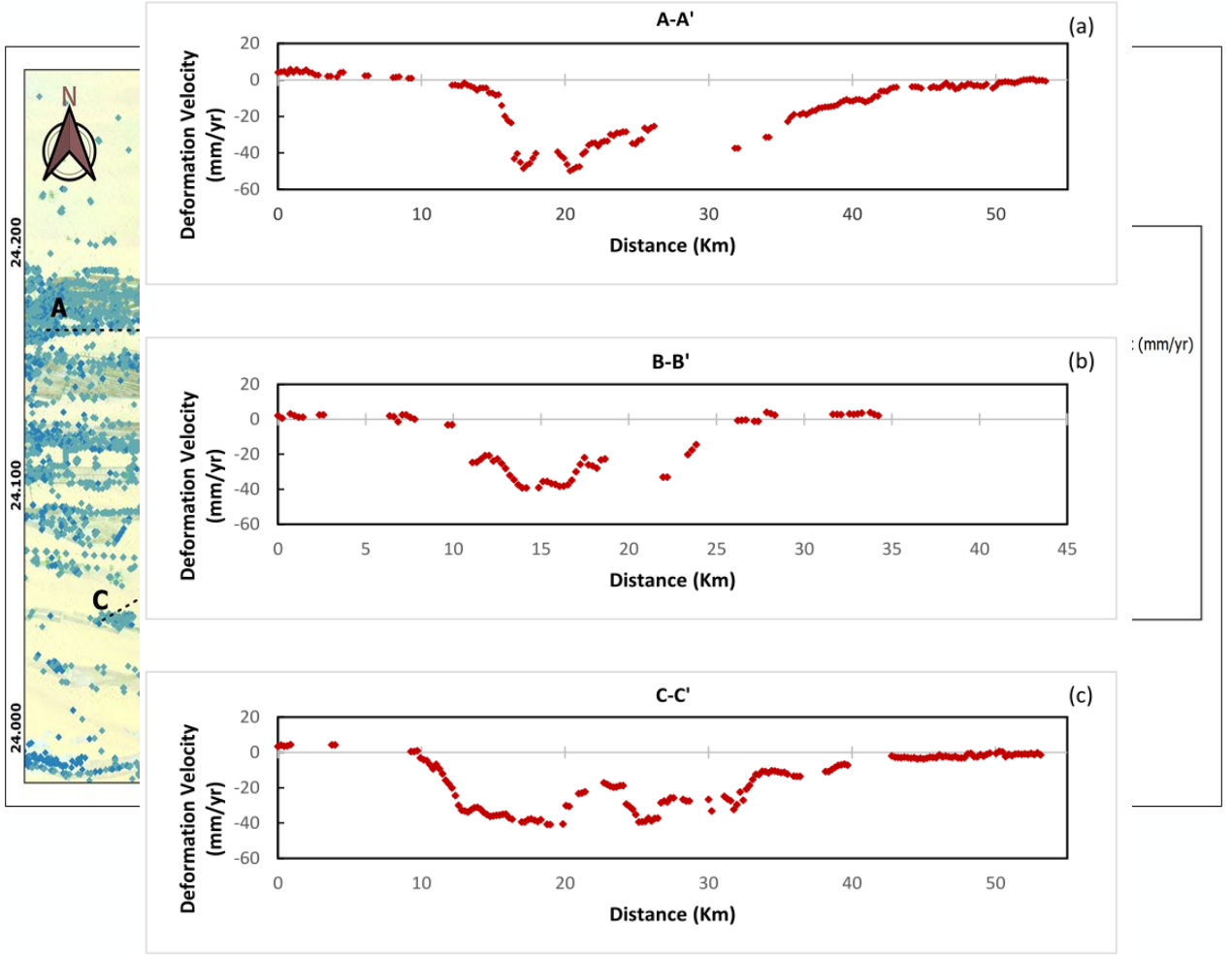
Applied techniques: Multitemporal Interferometric Synthetic Aperture Radar (InSAR) techniques.

The footprints for the Sentinel-1 path 130 are shown in blue frame for 73 and red frame for 75.



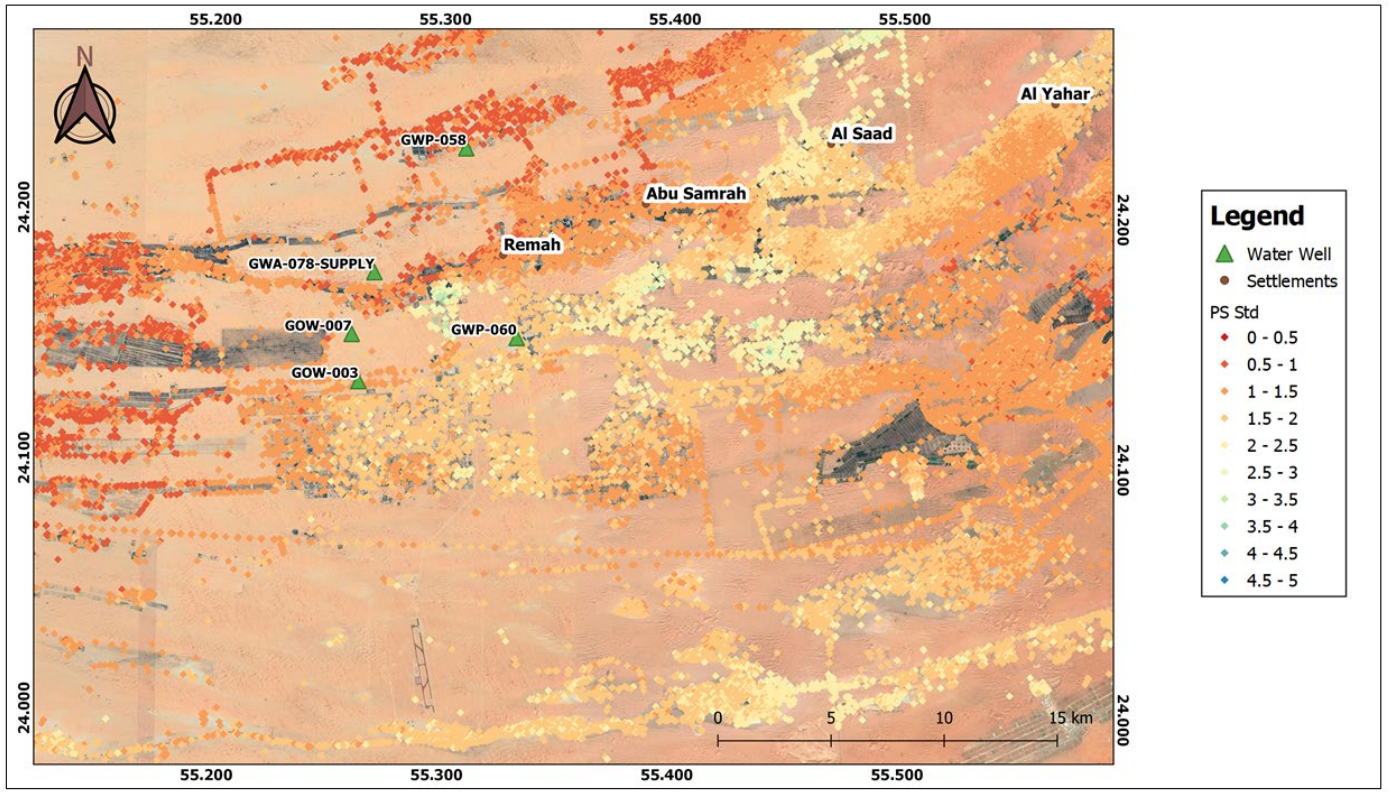
Interferometric Analysis

- The P-PSI technique for the Sentinel-1 stack managed to retrieve ground deformation with an excellent PS density reaching up to 3977 PSs/km^2
- Notably this was achieved over a rural and desert area like Remah, characterized by few human structures.
- The P-PSI procedure identified more than 3,400,000 PSs over the whole processed area of 860 km^2.
- **The processing results show a significant land surface subsidence at the Remah area with a subsidence rate of up to 40 mm/year.**
- **The center of the subsidence bowl is located in the southern part of Remah, south of Abu Dhabi – Al Ain highway.**
- **It extends northeast-southwest from Al Saad city in the east by 14 km to the southwest of Remah by 15 km.**
- **At the edge of the subsidence bowl, the measured subsidence rate was of the order of 10 mm/year and increased gradually towards the center.**
- Three cross-sections indicate that: Steep subsidence rate can be identified. **The detected subsidence extends for 25 to 30 km.**

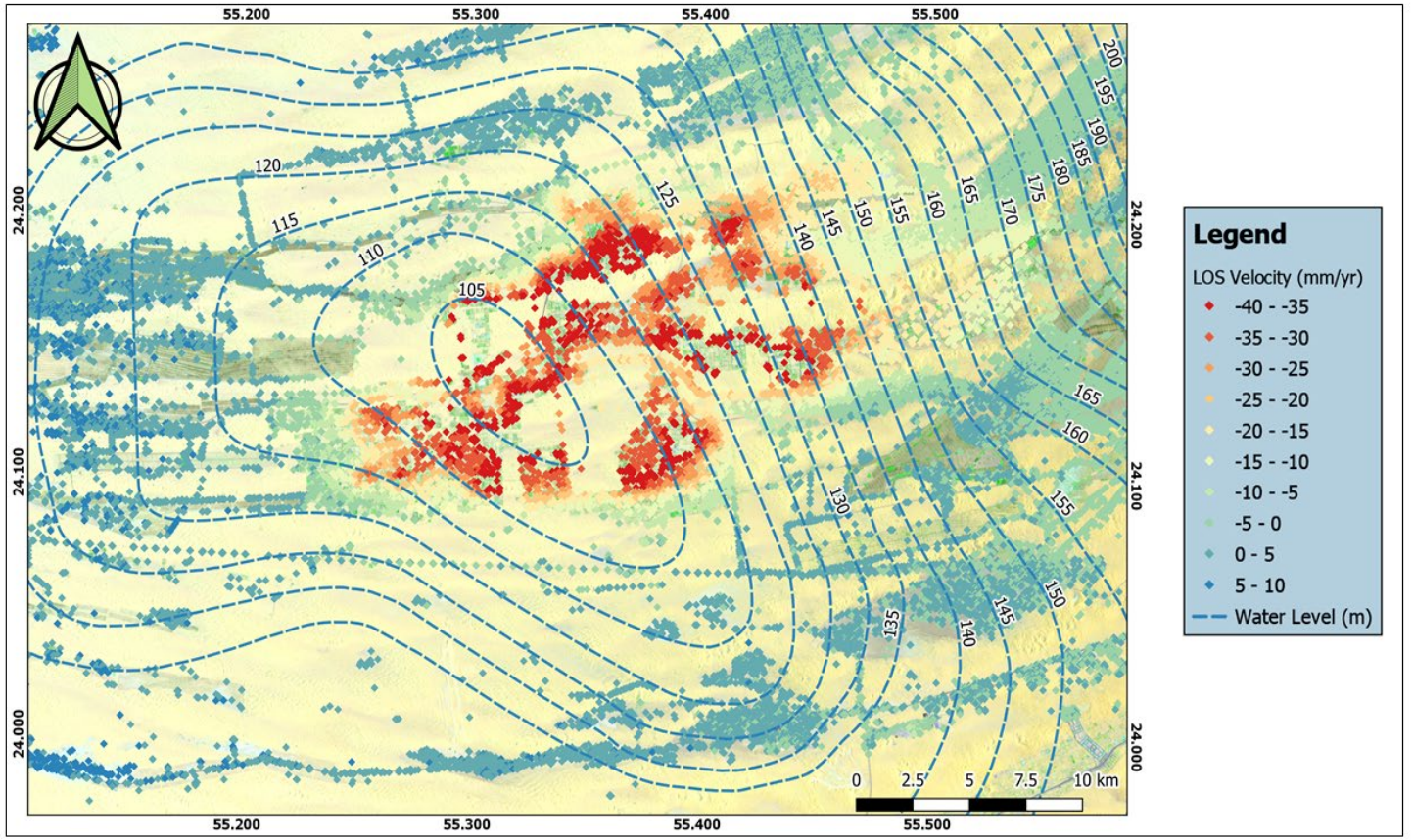


Interferometric Analysis

The standard deviation (Std) for the displacement rate was calculated for quality assessment purposes.
The std. at the subsidence bowl was only of the order of 2 mm/year, meaning that the derived subsidence rate is 40±2 mm/year.
So, the linear deformation model is an excellent fit and the velocity maps are robust and reliable!!!



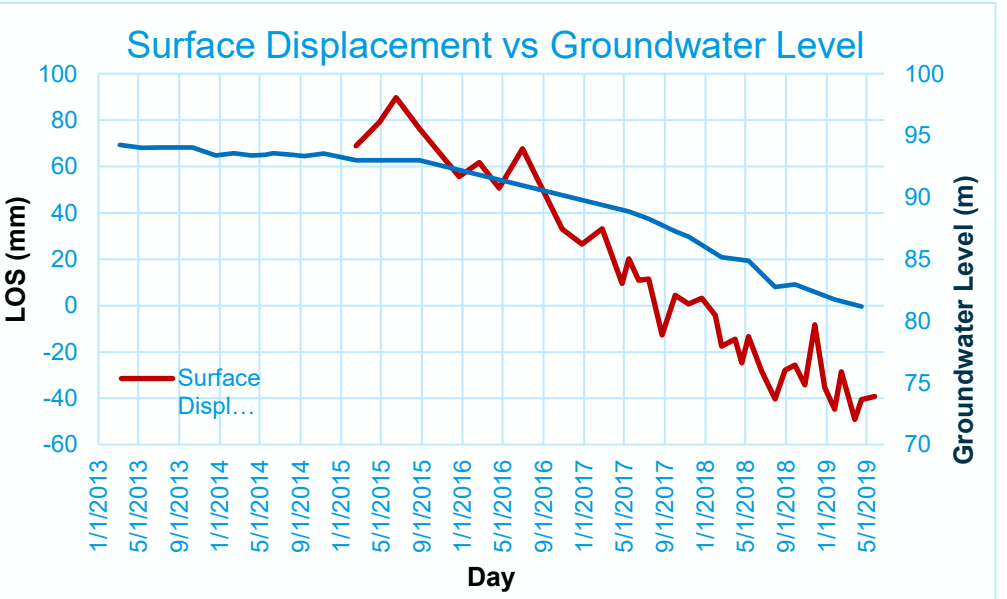
Correlation of GWL & InSAR Data



Correlating the piezometric contour lines of 2019 with the distribution of the deformations along the LOS it is clear that the spatial distribution of the land subsidence fits with the area affected by the overexploitation of the aquifers.

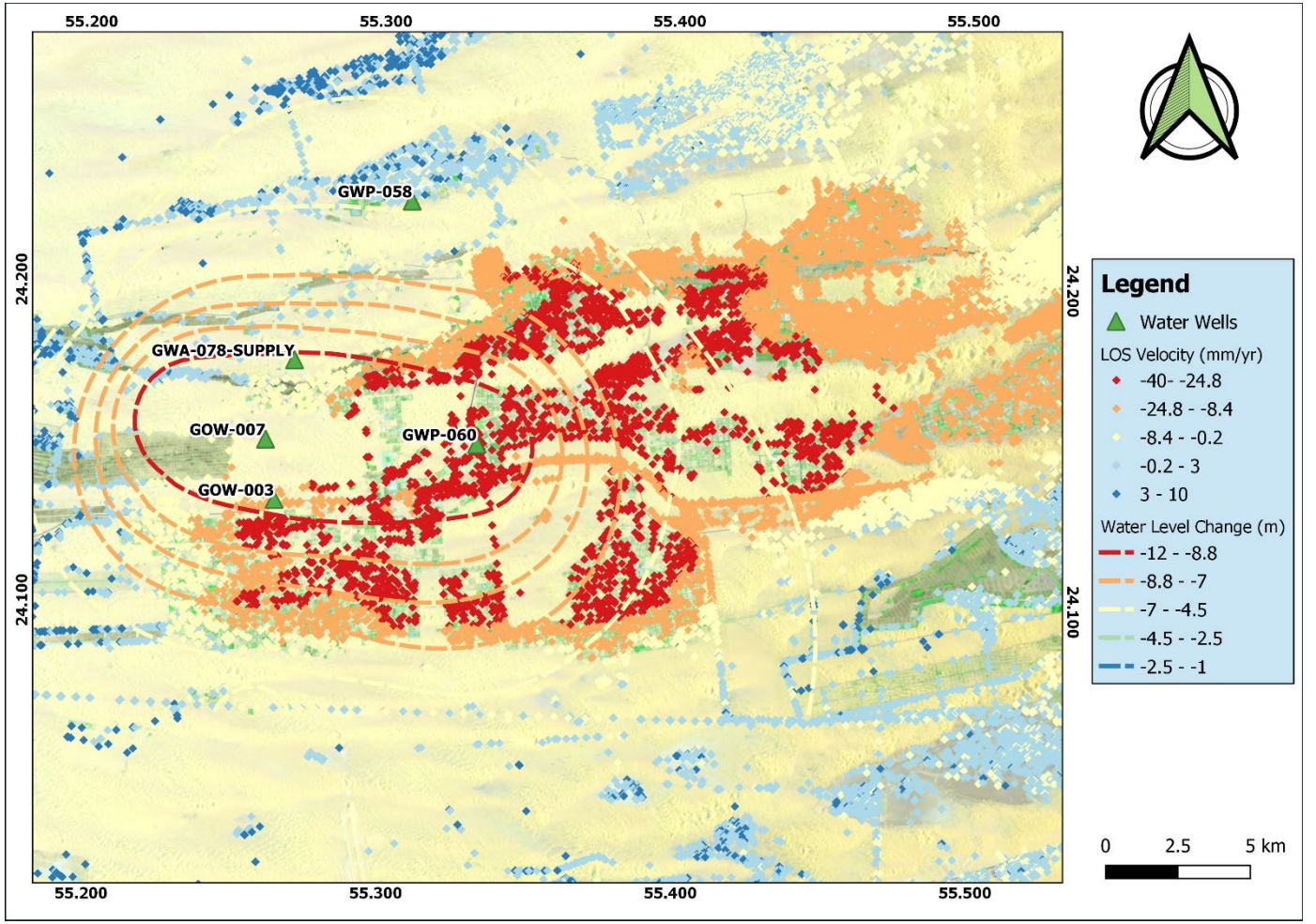
Correlation of the water level time series at the GWP-060 monitoring well with the land surface deformation at the surrounding PS pixels.

There is a strong positive relationship between rates of the water table drawdown and land-surface subsidence.



Correlation of GWL & InSAR Data

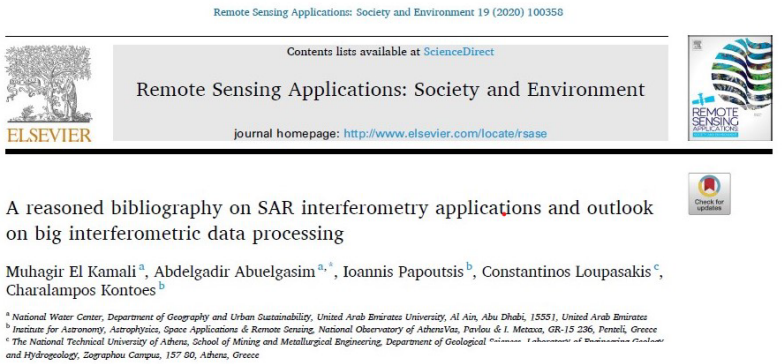
The groundwater discharge between 2013 and 2019 indicates that the depression extends towards the west in accordance with the extension of the newly cultivated areas. The depression cone is extending in areas with lower deformation rates.



Conclusions

- In the absence of other known tectonic and geological processes, and based at the above correlations, we believe that the land subsidence phenomenon is triggered by the overexploitation of the aquifers.
- The depression cone extends in areas with lower deformation rates. In areas expected to deform more rapidly in the future if the depression continues extending.
- Unlikely as there are not any other alternative sources of fresh water available at the wider area. So, the phenomenon is expected to continue extending and there are not any mitigation actions to be suggested.
- Considering that no any actions can be foreseen for the mitigation of the phenomenon the knowledge of its extend is crucial, as all major infrastructure can avoid the subsiding areas, or they can be designed in a way that they can bear the deformations.
- This study proved that the repeat-pass satellite SAR interferometry can provided substantial information about the actual extent of the land subsidence phenomenon.
- Space-based technologies are cost effective, providing high spatial coverage. So, they are able to fill the data and knowledge gaps and reduce the uncertainties by providing high spatial and temporal valuable information about the extend and the progress of the subsidence.
- The information provided by these studies can give rise to focused geotechnical and hydrogeological studies.

Publications



Remote Sensing Applications: Society and Environment 19 (2020) 100358

Contents lists available at ScienceDirect

Remote Sensing Applications: Society and Environment

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A reasoned bibliography on SAR interferometry applications and outlook on big interferometric data processing

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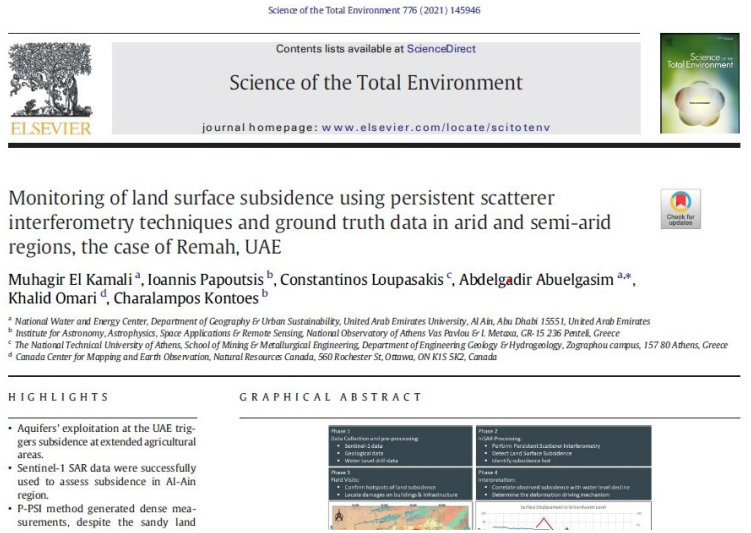
ARTICLE INFO

Keywords:
Land surface deformations
Synthetic aperture radar
Interferometry

ABSTRACT

In the past few decades, Synthetic Aperture Radar monitoring land surface deformations occurring n some anthropogenic activities, such as extraction with acceptable accuracy. The availability of SAR



Science of the Total Environment 776 (2021) 145946

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Monitoring of land surface subsidence using persistent scatterer interferometry techniques and ground truth data in arid and semi-arid regions, the case of Remah, UAE

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HIGHLIGHTS

- Aquifers' exploitation at the UAE triggers subsidence at extended agricultural areas.
- Sentinel-1 SAR data were successfully used to assess subsidence in Al-Ain region.
- P-PSI method generated dense measurements, despite the sandy land

GRAPHICAL ABSTRACT

THANK YOU FOR YOUR ATTENTION !!!