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Ground deformation monitoring in Shenyang city and Fushun pit mine (Northeastern China) by Advanced InSAR analysis

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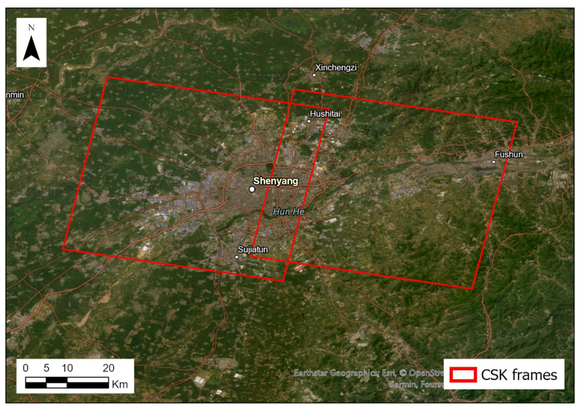
Abstract

The heavy industrial district in the Shenyang municipality in Northeast China plays a relevant role in the economic and social development. The hard mining activities have a strong impact on local environment due to continuous ground excavations related to coal and iron extraction. Therefore, Shenyang is subject to a multi-hazard exposure including subsidence, landslides, ground fissure and building inclination. In particular, starting from the ESA DRAGON-4 project we begun to study the Shenyang city and the Fushun open pit mine by means of multi-source remote sensed data. One of the most important adopted methodology consisted on the use of the Advanced InSAR (A-InSAR) technique able to provide ground velocity and displacement time series with millimetric accuracy per year. Then, in the framework of the Dragon-5 project, we went on to monitor such areas, and to achieve this goal, a new COSMO-SkyMed (CSK) images dataset, operated by the Italian Space Agency (ASI), was required to extend the investigated period using the Persistent Scatterers Interferometry (PSI) technique. In fact, results from the previous Dragon-4 project indicated landslides around open-pit mines, building instability and structural damages. Furthermore, the tunnel construction of underground lines in Shenyang has caused surface fissuring, subsidence and sinkholes. The city of Shenyang is covered is covered by two distinct descending CSK frames along the descending orbit (Figure below).

InSAR data processing and results



Where we are: Map overview of the area of BASF region analysed by InSAR techniques. The purple rectangles refer to the CSK image footprints.

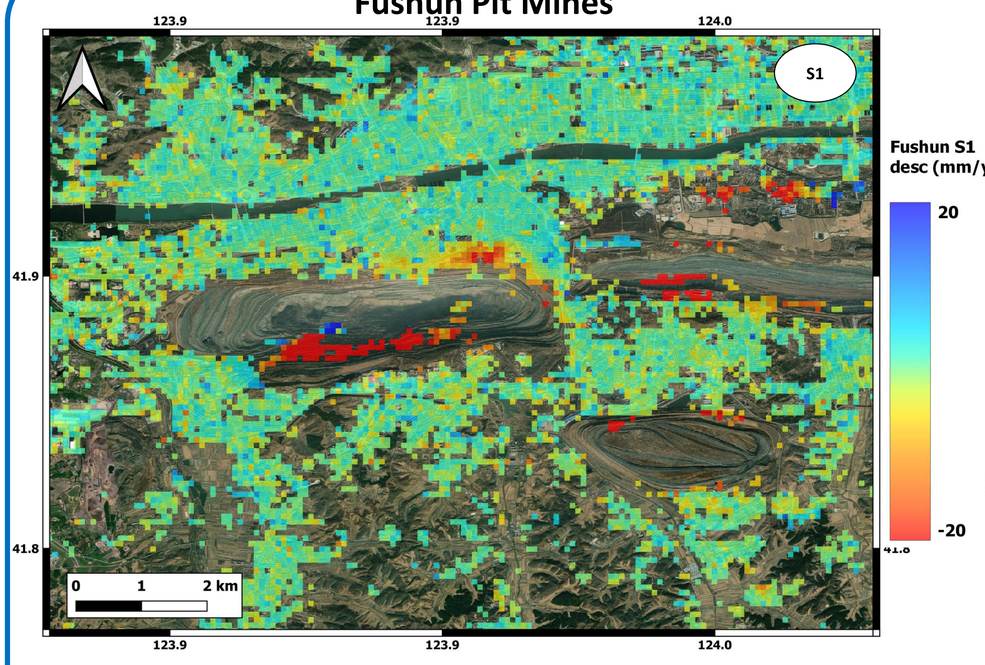
We applied the Enhanced PSI methodologies to SAR image datasets, acquired from the Italian Space Agency (ASI) COSMO-SkyMed satellites, and tha SBAS approach to the Sentinel-1 acquisiitons operated by the European Space Agency (ESA, (see in Table 1 for details). We obtained mean ground velocity maps and the relative displacement time series for each retrieved coherent pixel.

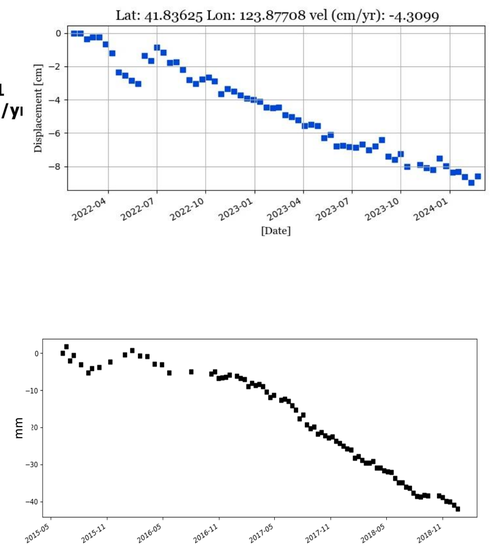
The CSK SAR datasets were processed using the processing chains implemented into the Sarscape© software (Sarmap), included in the ENVI (NV5©) package. The S1 dataset was processed by using the P-SBAS service implemented into the ESA GeoExploitation Platform (GEP).

Sensor	Frame	Sensor Mode	Orbit	# of images	Time period (YYYY-MM-DD)
SCS_B(L1A)	WEST	STR_HIMAGE	Descending	71	20190407 - 20231111
SCS_B(L1A)	EAST	STR_HIMAGE	Descending	94	20181013 – 20231230
S1	105	TOPSAR	Descending	63	20220127_20240222

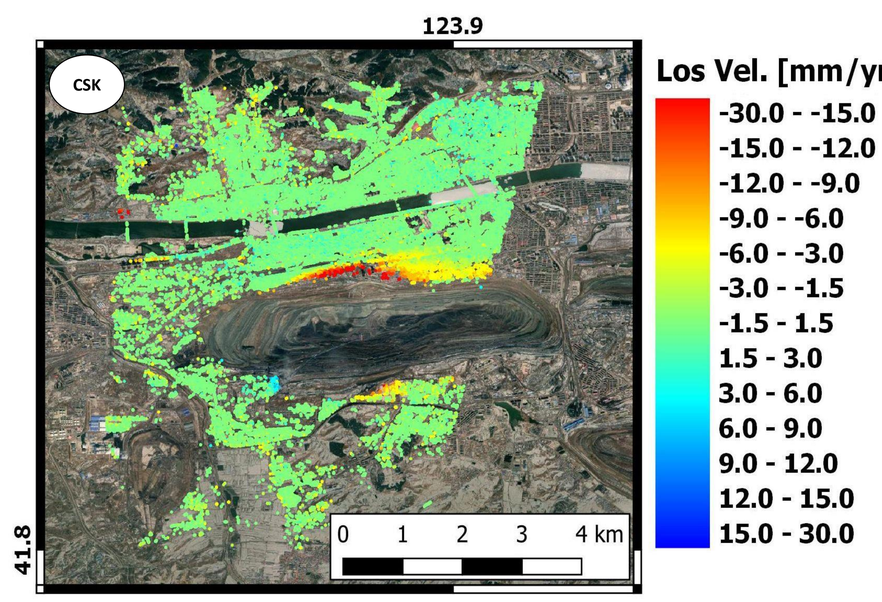
A total of 71 images were considered for the western part of Shenyang city, spanning from April 7, 2019 to November 11, 2023, , while 94 images were acquired for the eastern part, also interesting the Fushun open pit mine area, and covering the period from October 13, 2018 to December 30, 2023. Finally 63 S1 TOPSAR images were considered along the descending orbit to cover both the Fushun open mine and a large area of the Shenyang city.

Fushun Pit Mines



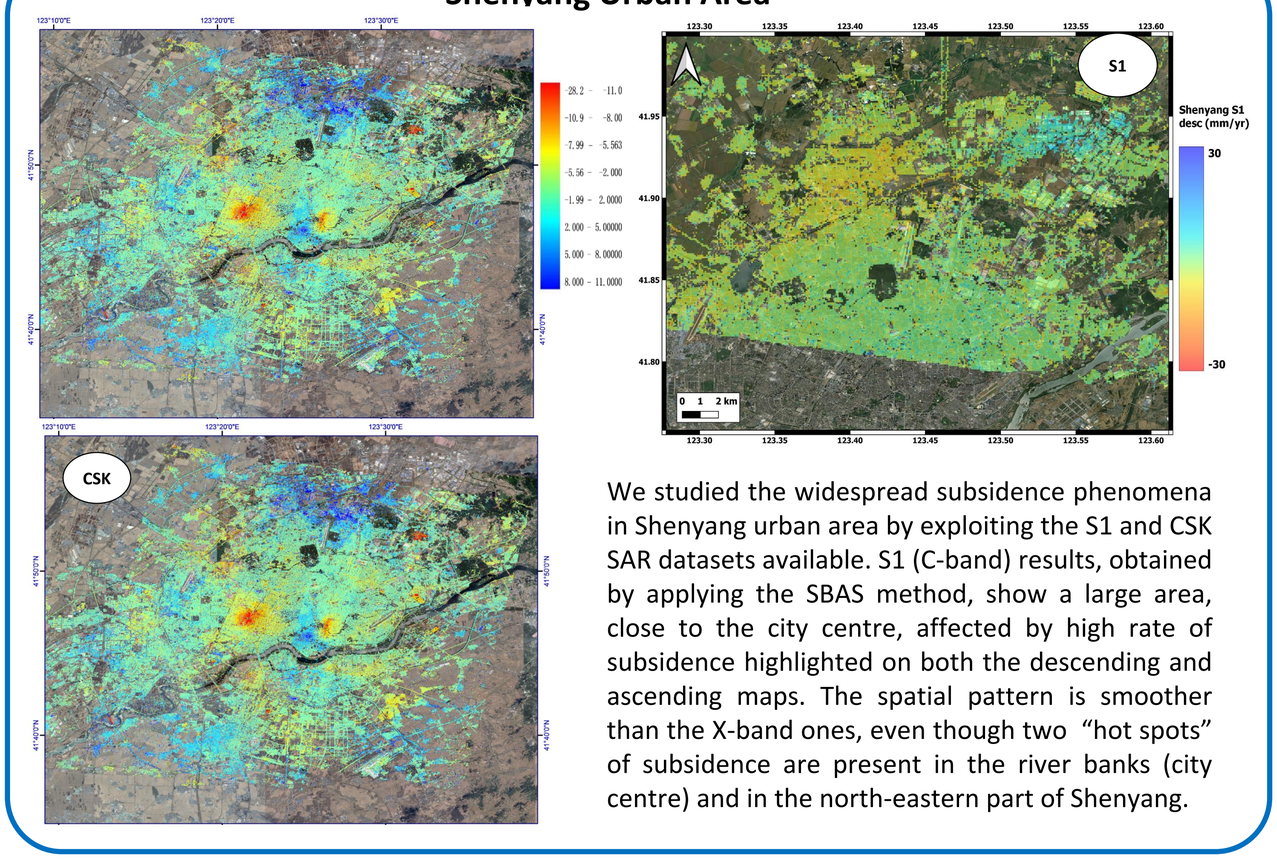


Some small areas (localized pixels) show positive values (uplift) probably due to stockpile of excavation debris or processing waste material. S1 time series show an almost linear decreasing trend for the whole investigated temporal interval.



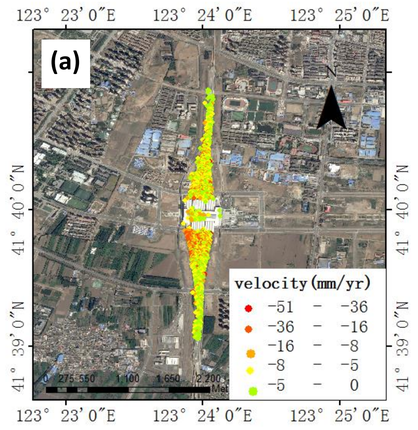
S1 & CSK results show very similar pattern for the ground deformation. Subsidence phenomena are still ongoing reaching values higher than -50 mm/yr at the edges of the pit.

Shenyang Urban Area

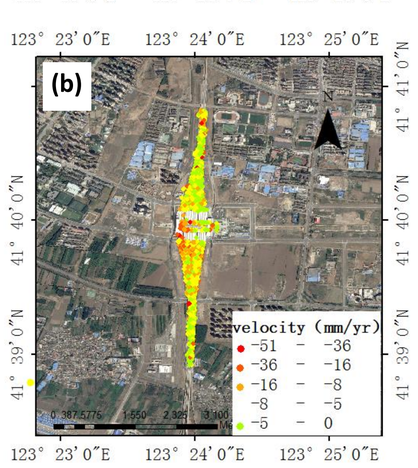


We studied the widespread subsidence phenomena in Shenyang urban area by exploiting the S1 and CSK SAR datasets available. S1 (C-band) results, obtained by applying the SBAS method, show a large area, close to the city centre, affected by high rate of subsidence highlighted on both the descending and ascending maps. The spatial pattern is smoother than the X-band ones, even though two "hot spots" of subsidence are present in the river banks (city centre) and in the north-eastern part of Shenyang.

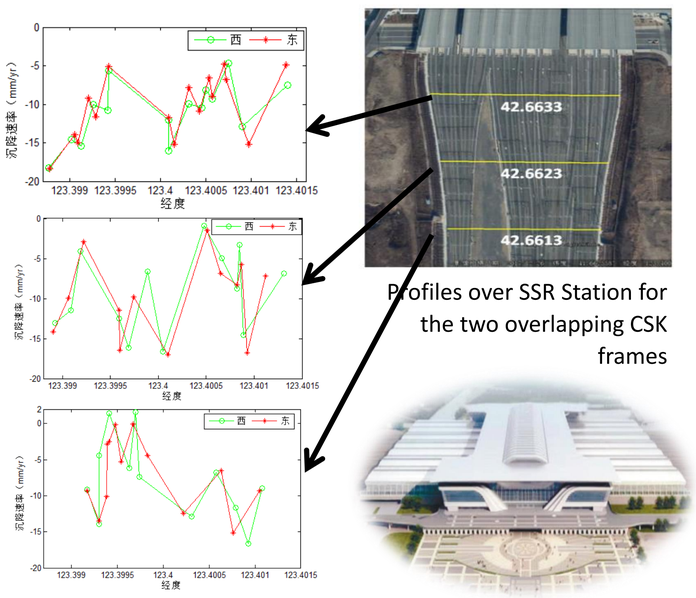
Shenyang Railway investigation



We used CSK data even to monitor the ground movements occurred close to the newly-built Shenyang South Railway Station and the nearby high-speed railway tracks). The largest deformation happens on the rail tracks near the southern part of the platform, with velocities varying from -50 mm/yr to -15 mm/yr. Instead, the deformation of other parts of the stations is smaller, with deformation rate varying from -15 mm/yr to 0mm/yr.



CSK mean ground velocities over Shenyang South Railway Station: (a) eastern frame, (b) western frame



Profiles over SSR Station for the two overlapping CSK frames

Conclusions

Our results confirm that the heavy industrial exploitation of Fushun pit mine and water pumping in the BASF region of Northeast China cause clear and strong ground deformation effects of high potential impact on the local infrastructures and population. The use of multiple stacks, from different sensors, of InSAR data allows to monitor these phenomena with an accuracy and a temporal sampling not possible otherwise.

The use of EO products plays a fundamental role to monitor natural and man-induced hazards and to support Disaster Risk Management providing an important tool for local and national organizations; to this aim, a continuous monitoring is strongly recommended.

Acknowledgments

"The COSMO-SkyMed data are provided by ASI through the project card ID 896.*Project carried out using CSK® Products, © ASI (Italian Space Agency), delivered under an ASI licence to use*". **"COSMO-SkyMed Product - ©ASI - Agenzia Spaziale Italiana - 2015). All Rights Reserved".**