Leveraging SAR for Nuclear Fuel Cycle Monitoring

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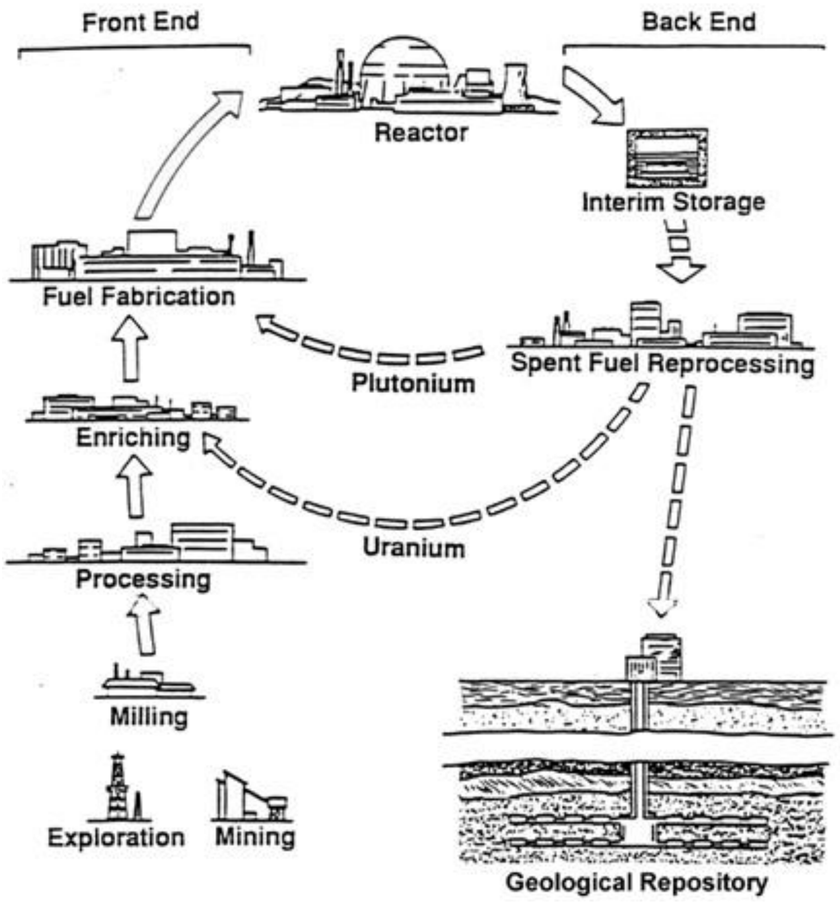
Why SAR for Nuclear Fuel Cycle Monitoring?

Nuclear safety

(infrastructural health, risk management)

Nuclear safeguards and non-proliferation

(monitoring declared/known and undeclared/unknown facilities)



Source: Manson Benedict, Thomas Pigford, and Hans Levi, Nuclear Chemical Engineering (New York: McGraw-Hill Book Co., 1981

SAR Applications for Nuclear Monitoring

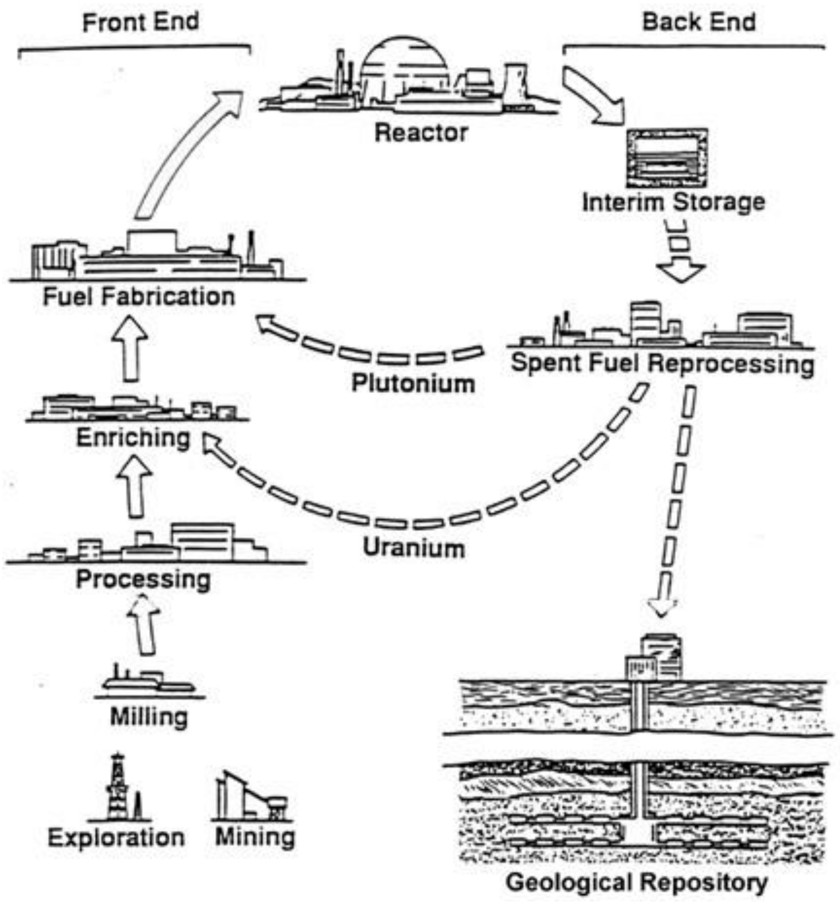
- Reliable constant monitoring & time series analysis
- Monitoring of potential deformations

→ Improved capabilities to…

(a) verify **non-diversion of declared/known…**

(b) provide assurances as to the **absence of undeclared/unknown…**

… nuclear material and activities for nuclear-weapons purposes.



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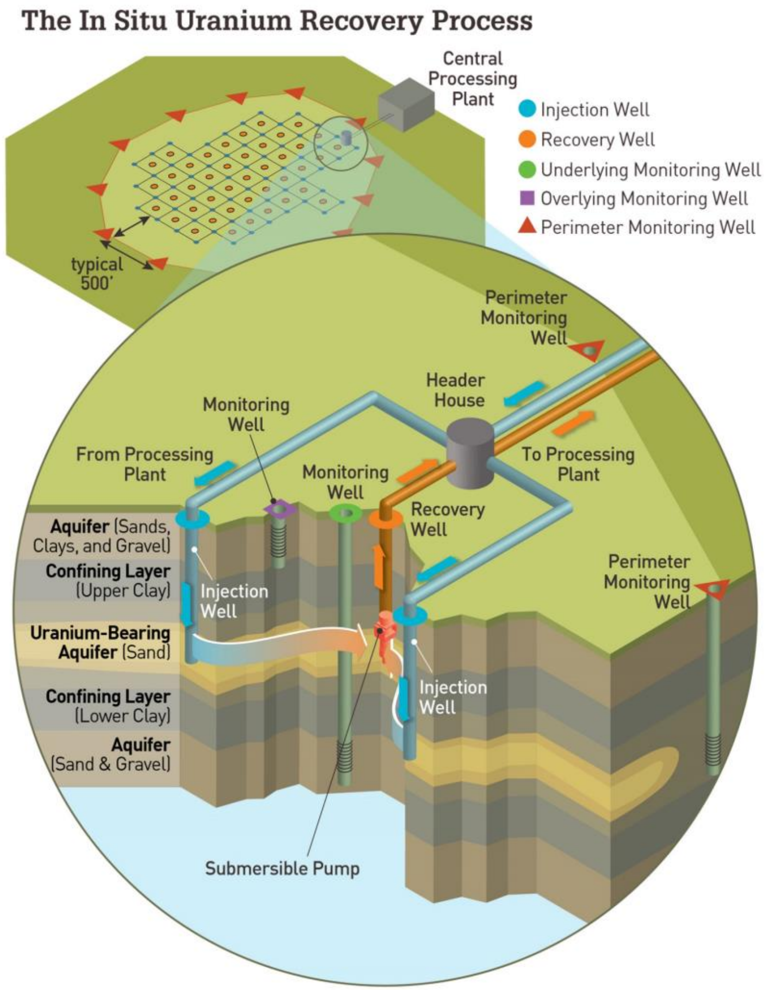
Case 1: Monitoring of underground in-situ uranium mining

- More than half of the world's uranium resources are now mined through in situ leaching (ISL)

- Wide area extraction & little to no observable signatures on optical imagery

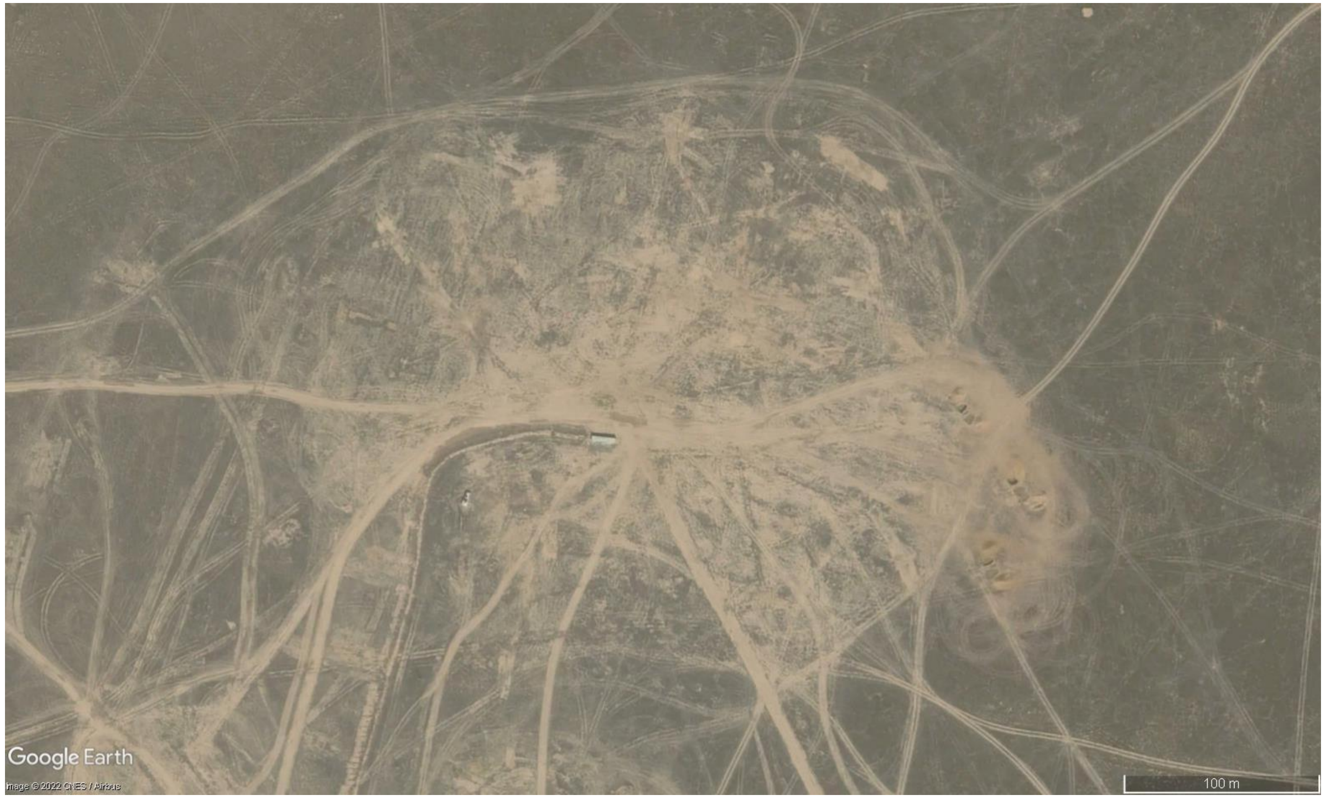


Source: U.S. Nuclear Regulatory Commission

Case 1: Monitoring of underground uranium mining

West Mynkuduk, Kazakhstan

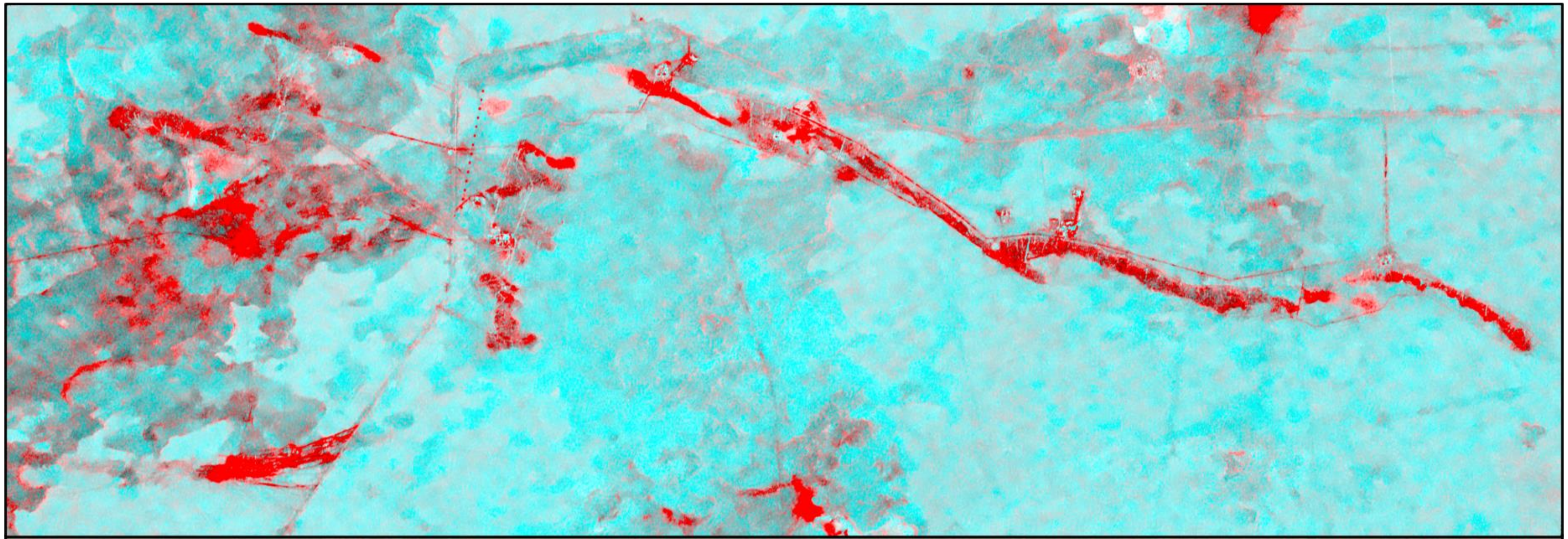
One of the largest in-situ leaching mining sites of the country (~10.000 sq km)



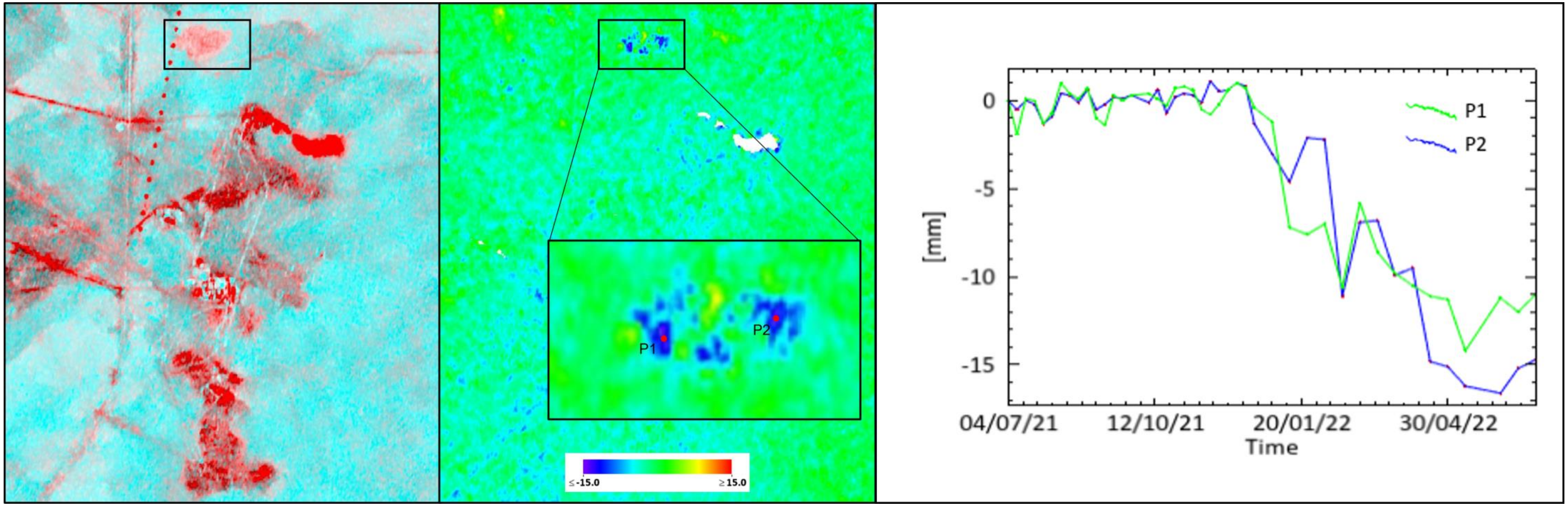
Source: World Nuclear Association

Sentinel-1, July 2021–July 2022 (43 acquisitions)

Multitemporal coherence
coefficient of variation
mean



Google Earth/Image Landsat/Copernicus, December 2020



Multitemporal coherence
coefficient of variation
mean

Multitemporal interferometry
Small Baseline Subset (SBAS)

Displacement time series at two possible extraction points

Clear acceleration starting in early 2022

Sentinel-1, July 2021–July 2022 (43 acquisitions)

Case 2: Monitoring undeclared/unknown nuclear facilities

The New York Times

Fears Grow Over Iran's Nuclear Program as Tehran Digs a New Tunnel Network

June 16, 2022

WASHINGTON — Israeli and American intelligence officials have been watching each day as Iran digs a vast tunnel network just south of the Natanz nuclear production site, in what they believe is Tehran's biggest effort yet to construct new nuclear facilities so deep in the mountains that they can withstand bunker-busting bombs and cyberattacks.

A satellite image of Iran's Natanz nuclear site. The new tunnel complex is being built into the mountain on the bottom left of the image. Planet Labs Pbc/Planet Labs PBC, via Associated Press

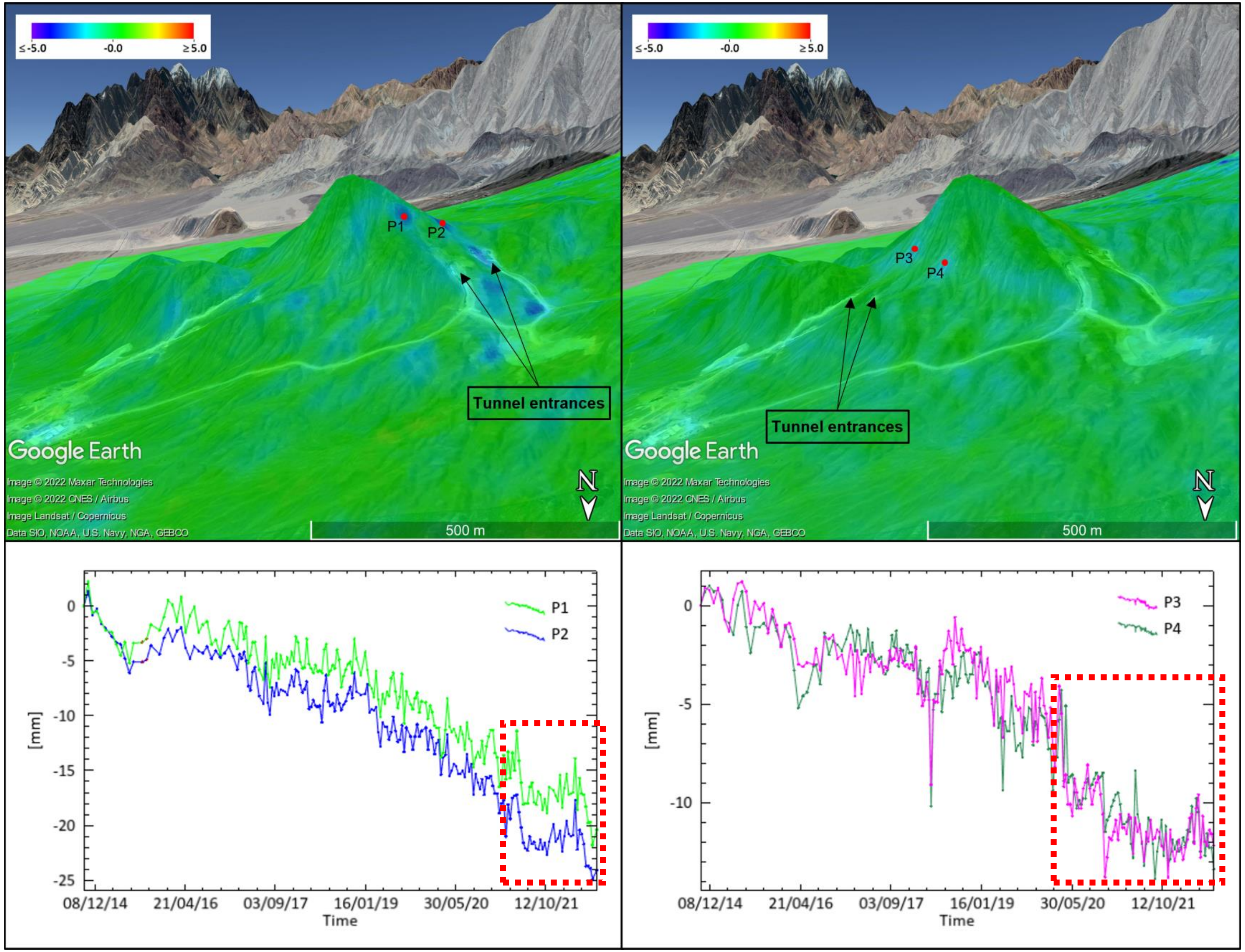
Descending (left) and ascending (right) SBAS

Sentinel-1, 2014-2022

201 acquisitions for descending track

192 acquisitions for ascending track

overlaid on Planet Labs image from 19 August 2022



Displacement rates over point areas right above the tunnel entrances suggest that the strongest deformations accelerated in late 2020 to early 2021, which is indeed when the excavations likely started.

Case 3: Infrastructural health of nuclear reactor sites

Source: Reuters

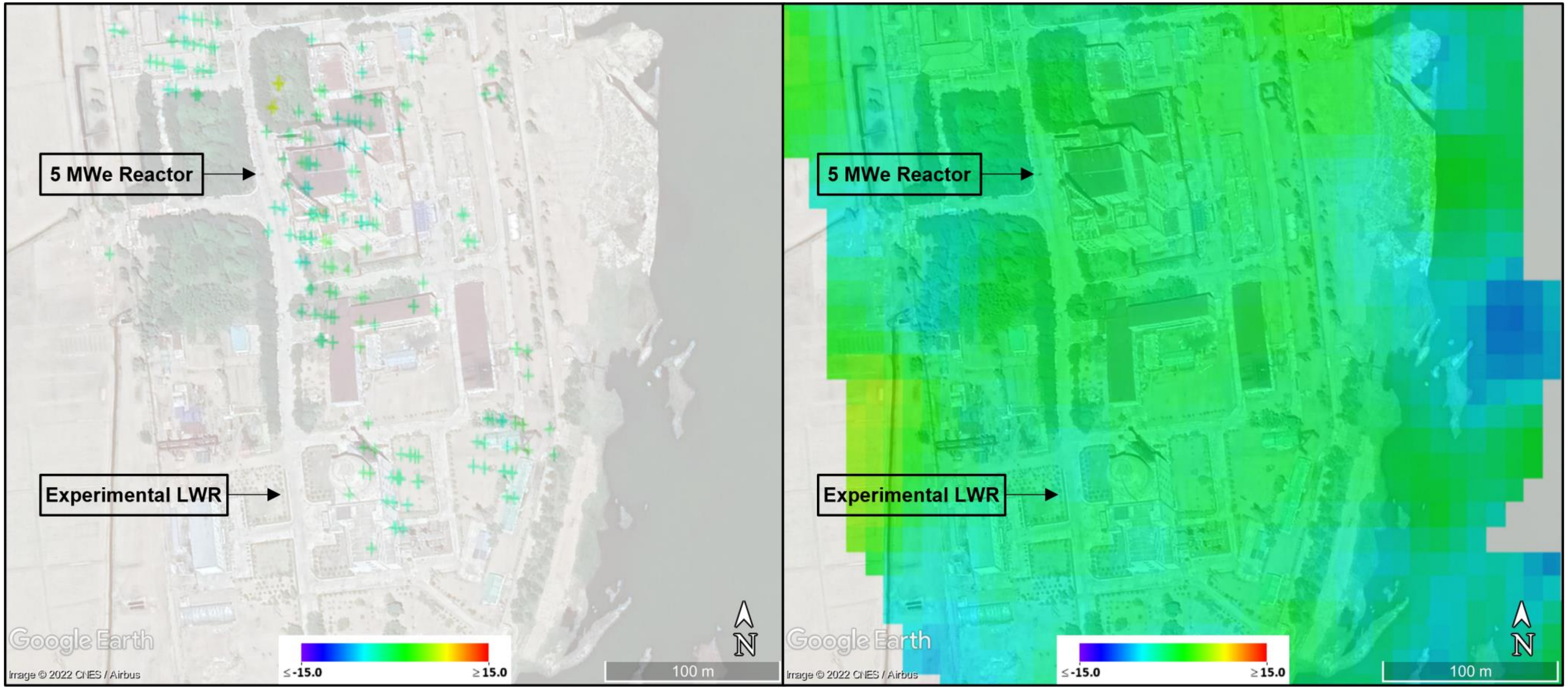
Possible applications

- Operative perimeter monitoring at nuclear power plant sites, especially where access is difficult or impossible
- InSAR techniques for infrastructural health diagnosis
    - Progressive deformation (age/insufficient maintenance)
    - Sudden deformation due to external shocks (earthquakes, floods)

Yongbyon Nuclear Reactor Site, North Korea

Persistent Scatterer (left) and Small Baseline Subset (SBAS) (right)

Sentinel-1, 2015–2022



→ While no substantial deformation can be identified in this case, the millimeter-precision level data can nonetheless provide important information and confidence about the structural stability of a site that is frequently at risk of being flooded

Conclusion

Wide-ranging applications for improved monitoring of nuclear facilities are possible

- **In particular:** monitoring of uranium mining sites and detecting undeclared/unknown facilities.

Will become an integral part for nuclear safeguards and non-proliferation monitoring

- **In particular:** multitemporal analysis, interferometric techniques, and high-resolution tasking.

Thank you for your attention!

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