Persistent Scatterer Interferometry

Millimetric Deformation and Stability Monitoring from Space

The Persistent Scatterer Interferometry (PSI) technique is a non-invasive wide-area surveying method that has the remarkable capability to measure minute relative elevation changes of the earth's surface and structures down to millimetric levels. Satellite radar (SAR) images have been recorded over much of the world on a near-monthly basis for more than a decade. This archive can be exploited to provide a unique and important historical record of gradual and subtle surface or structure movement dating back to 1992.

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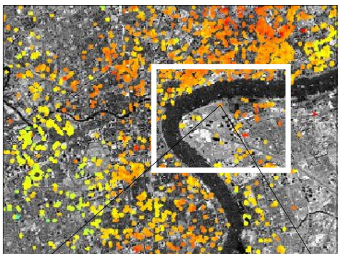
Such knowledge is valuable for engineering and construction projects. The extent and scale of historical subsidence and upheaval can be mapped for entire cities and conurbations, indicating their stability since 1992. Vulnerable ground or infrastructure can be readily identified for ongoing monitoring. PSI is the ideal tool for identifying general motion trends with millimetric precision, which can help to prioritise expensive local ground surveys and cut costs.

The high precision of this technique allows us to measure up to sub-millimetre levels of motion by exploiting the SAR data archive as a stack of image scenes. Each scene is processed to identify networks of persistent radar-reflecting features on the ground, such as buildings, bridges and rocky outcrops. Precise millimetric motion measurements are then calculated against these individual ground and structure points. The result (in tabular format) comprises measurements of yearly average motion and a time series of displacement for every measurement point. The measurement point density is high for urban areas (hundreds of points per km^2) but low for rural environments (tens of points per km^2).

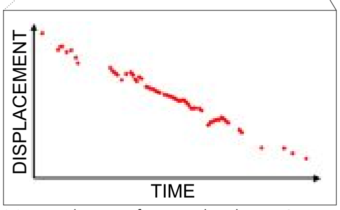
Case study 1: Urban subsidence, Shanghai, P.R. China

NPA's PSI result for Shanghai spans 1992-2004. The result yields over 11,000 individual measurement points for central Shanghai. In this area subsidence measurements of up to -55mm/year were recorded.

In the Pudong region (top and middle image) rates of -30mm/year have been recorded. The motion history of a single measurement point can be visualised as A graph (bottom image). Shanghai is a low-lying city, sitting 3-5m above sea level. The ground is mainly composed of coarse silts and sandy mud. Its geological setting, as well as man-made influences such as water pumping and intensive construction, has led to high subsidence rates in the city.



PSI data for Pudong, Shanghai



Motion history for a subsiding PS point

NPA Group,
Crockham Park,
Edenbridge,
Kent,
TN8 6SR, UK

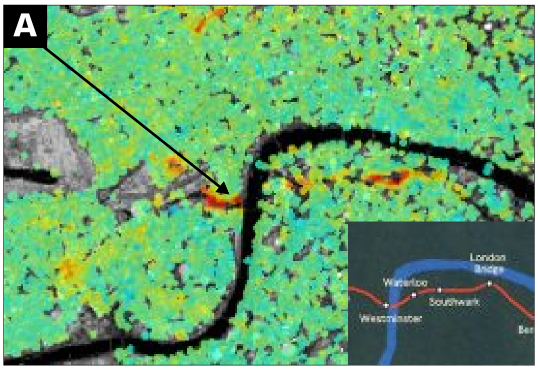
www.npagroup.com/insar
Telephone: +44 (0)1732 865023
Fax: +44 (0)1732 866521

NPA SATELLITE MAPPING

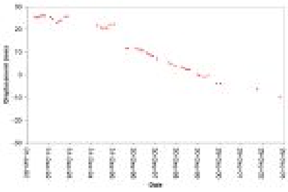
Case study 1: Underground Tunnel, London, UK

Mapping the extent and magnitude of ground displacement caused by tunneling works for the validation of engineering subsidence models.

The main image shows the PSI 'ground velocity' map for part of London, UK. Colours represent interpolated average annual ground displacement over 11 years (1992-2003), e.g. dark red indicates >5mm per year for 11 years (55mm minimum total). Areas coloured in green exhibit minimal displacement. Our data show a red linear feature corresponding with underground tunneling activity for London Underground's Jubilee Line extension work (this magnitude of subsidence was anticipated and taken into consideration before engineering work began). Precise monitoring was undertaken and corresponds well with the PSI data. The start of tunneling work in December 1993 can be seen from the displacement history of the highlighted point (A), see graph opposite.



PSI 'ground velocity' map for part of London, UK.



Motion history chart for a subsiding point over the Jubilee Line extension tunnel (see A).

Case study 2: Flood susceptibility mapping, London, UK

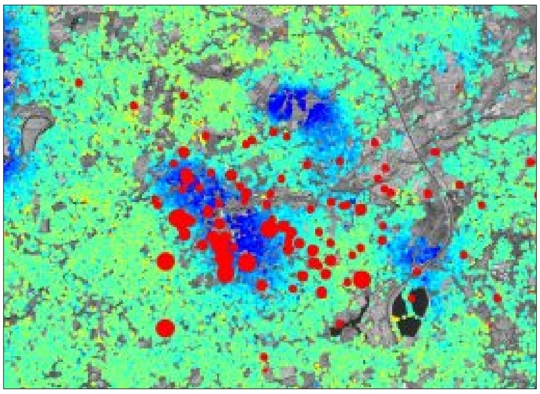
Correlating ground motion data with LiDAR height imagery to assess flood risk.

The image opposite is a LiDAR image coloured to highlight land that is the same level as the River Thames (blue) and therefore susceptible to flooding. Subsidence data from PSI processing has been overlaid to indicate areas of increased risk due to historical ground motion trends.

Case study 3: Pre-seismic ground motion, Manchester, UK

Assessing stress accumulation prior to seismic activity.

The image shows PSI data with earthquake epicentre data overlain (red points). The concentrated areas of blue show high levels of uplift (>5mm/yr). The epicentre data was recorded during the Manchester earthquake swarm of 2002. The result shows the relationship between the data and demonstrates the distinct benefit of using this retrospective technique. In this case it allows users to assess stress accumulation prior to the earthquake swarm of 2002.



Interpolated PSI 'ground velocity' map for part of Manchester, UK. Ground uplift is shown as blue. Earthquake epicentres are shown as red points.

Technical specifications for PSI:

Potential area and time coverage	Worldwide. 1992 to present day
Typical point coverage	100-200/km^2 over urban areas and 10s/km^2 over rural areas
Data sources	SAR (Synthetic Aperture Radar) data acquired by ERS-1, ERS-2, and Envisat (operated by ESA))
Measurement direction	Sensor line-of-sight (23° from vertical for ERS/Envisat)
Measurement precision	Sub-millimetre to millimetre, depending on parameters such as number of data scenes, atmospheric conditions, local topography, distance from the reference location
Relative spatial accuracy	+/- 5m in E-W, +/- 3.5m N-S
Absolute spatial accuracy	>15m

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