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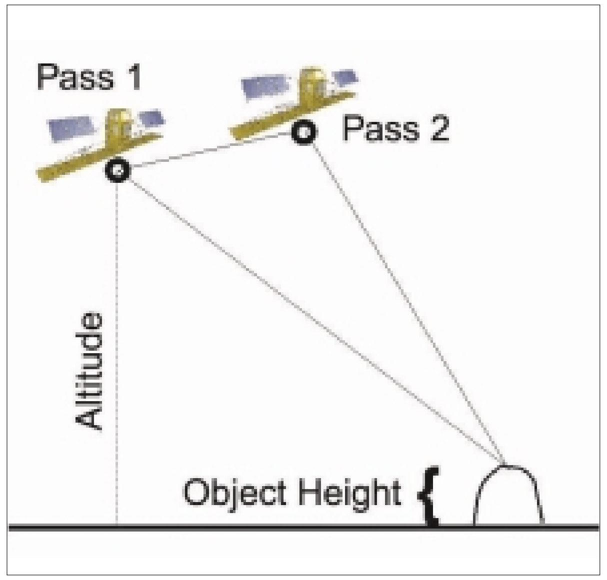
Bringing the Small Picture to the Surface

The InSAR Insight

Natural disasters are most often measured on a quantitatively large scale: ‘the big picture’. But it is just as important to keep track of small shifts, since these may have major consequences. Professionals responsible for ensuring a stable environment keep track of those ground movements that don’t make the headlines; those shifts that go undetected by sight or feel. Numerous studies world-wide have revealed that these undetected movements are frequent and that they can be as fine as a shift of a few millimetres.

By Mary Jo Wagner, Vancouver, Canada

How can such small movements be detected? A variety of surveying instruments may be used, such as GPS, photogrammetry and extensometers, which have been the traditional tools of choice for many industries that face a risk of ground-movement. However, within the past three years a long-studied technique has begun to surface as a less-expensive and more precise alternative for measuring land subsidence: InSAR.



INSAR Data Collection (Provided courtesy of RADARSAT International)

This radar satellite-data processing technique, Interferometric Synthetic Aperture Radar (InSAR), is a relatively new tool that allows users to map and to monitor very subtle – 1 centimetre and smaller - changes in surface movement, whether it be vertical movement of the surface, structural movement through subsidence or lateral movement of a glacial floe.
It may seem implausible that a satellite orbiting eight hundred kilometres above the Earth and carrying a single SAR sensor can detect such a centimetre or millimetre creep. But that is exactly where C-band SAR satellites, such as Canada’s RADARSAT-1 and the European Space Agency’s ERS-1 and ERS-2 satellites excel. They map the ‘small picture’: the millimetre movements of the ground that taken cumulatively may lead to the big picture of land displacement over a large area.
What InSAR is revealing, perhaps disconcertingly, is that many areas around the globe once thought to be stable environments aren’t so stable after all.

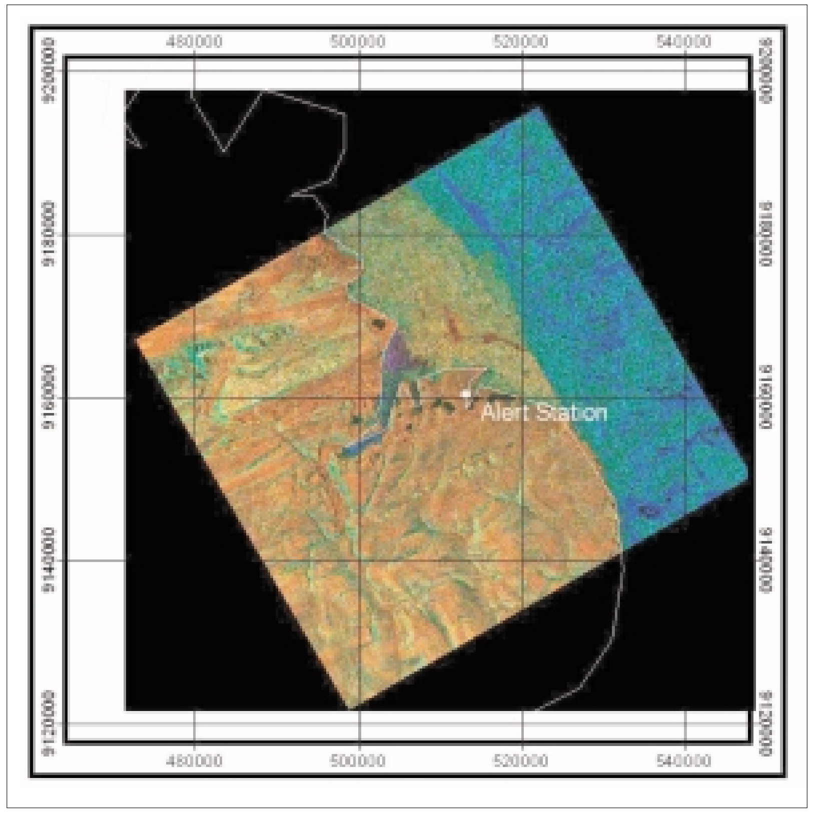
Inside InSAR

The practice of space-borne SAR interferometry dates back about ten years to when the ESA ERS-1 satellite came on the scene and offered scientists the ability to exploit the technique. Traditionally, the process involves examining SAR backscatter signal phases over the same geographic area at different intervals. The differences in the signal phases are a direct result of changes in the distance between the target and satellite due to the slightly different position of the spacecraft at each pass. By combining two SAR images taken from the same vantage point in space, an interferogram is produced which illustrates any phase differences between the images through a pattern of fringes, each of which represents elevation levels. By then removing the topographic component with a digital elevation model (DEM), a ‘differential’ interferogram is generated, leaving just the topographic changes that occurred between the two SAR acquisitions. With this information users can detect land or building movements.
Although early successes with InSAR in mapping surface movements after natural disasters such as earthquakes helped put the technique on the radar-application map, it has been difficult for the geospatial industry to develop a commercial business out of this conventional technique because it has several limitations. It demands appropriate revisits of the satellite, a strict orbit configuration and a high degree of ground-feature similarity between the two satellite passes; any changes in the ground cover from vegetation or moisture will cause temporal decorrelation. Both the ERS-1 and ERS-2 satellites have followed varying repeat cycles, ranging from 35 to 168 days, the latter of which is too long. The orbit constraint of the RADARSAT-1 satellite was not originally designed

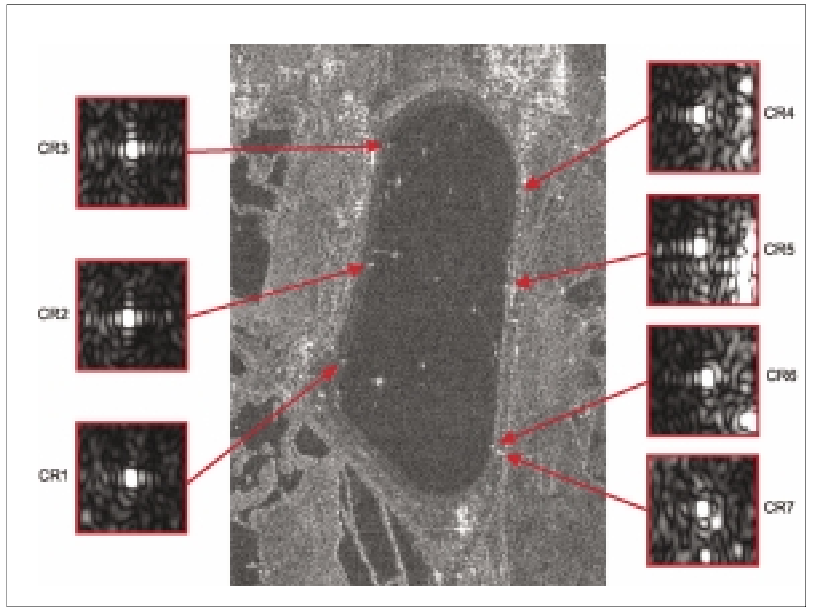
and acquired four RADARSAT scenes between April and September. Using conventional InSAR processing for each of the reflector points, Via+ personnel measured displacements ranging from 1mm to 35mm over the five-month period.

Back to the Beginning

PSInSAR and CRInSAR together with conventional InSAR applications - InSAR DEMs for topographic mapping or measuring subsidence - is still one of the main strengths of InSAR technology and is still a strong source of business for many geospatial companies.
Sarmap of Purasca, Switzerland is a case in point. One of its most recent assignments came from Switzerland’s telephone operator, Swisscom, which requested a DEM of the entire 45,000 square-km country. Using ERS tandem data (ERS-1 and ERS-2 data combined), Sarmap staff produced within six months an InSAR DEM with a vertical accuracy of better than 15m.
In May 2001, Sarmap obtained a pair of RADARSAT-1 fine beam mode images over Alert Bay in the North West Territories of Canada and created a DEM to map ground movements and ice motion. Using SARscape, its commercial data processing and analysis package, personnel produced a DEM of the area with a height accuracy of 5m and a horizontal precision of 10m.
The technical barriers to commercialisation of InSAR technology are now down. Perhaps what is needed to secure viable InSAR business are more headlines. Not the screaming titles that spell out large-scale disaster but those that describe the small picture, the creeping events that, if left undetected, may eventually lead to the catastrophe headline.◆



RADARSAT-1 Digital Elevation Model (DEM) of Alert Bay, NWT Canada displayed in grey scale. Ice velocity displayed in colour scale (+/- 60 cm per month). The estimated height accuracy is 5m, while the horizontal spacing is 10m. (Provided courtesy of Sarmap)



Satellite Image showing Wraysbury Reservoir with corner reflectors (Provided courtesy of Nigel Press Associates)

Biography of the Author

Mary Jo Wagner

Mary Jo Wagner is a Vancouver-based freelance writer, specialising in geospatial technology and IT issues and trends. Mrs. Wagner graduated from the University of Wisconsin-Madison in 1991 with degrees in journalism and sociology. After working in television for two years she moved to Italy to join the staff of Eurimage, a satellite data provider, as an in-house editor and writer. A former editor of GEOEurope magazine, Ms Wagner has more than nine years experience in covering the geospatial technologies, including remote sensing, GIS, GPS, photogrammetry, cartography and aerial photography. In addition to a further two years experience in covering the IT industry, she has written about sectors including agriculture, telecommunication, utilities, local government, retail, archeology, urban planning, navigation and transport and the environment.

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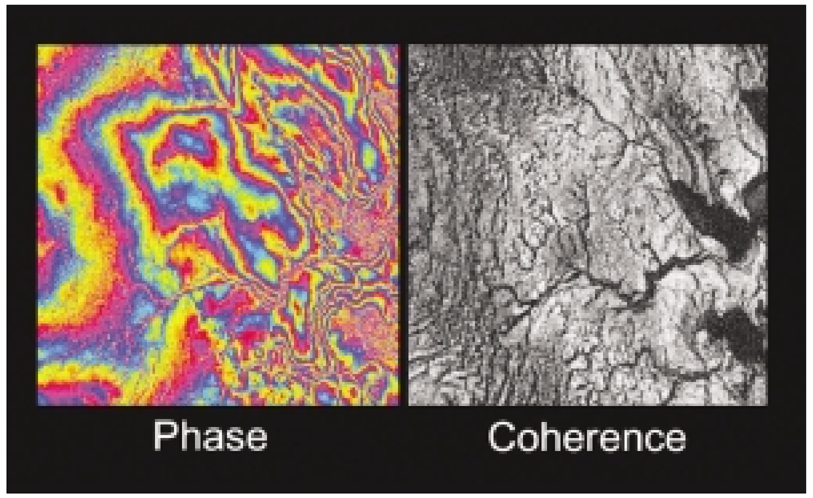
with InSAR in mind. In addition, in January 2001 an on-board anomaly caused detrimental damage to the attitude and orbit control system of ERS-2, weakening its reliability for InSAR applications.
However, in March 2001 the Canadian Space Agency agreed to maintain RADARSAT-1 in a ⁄ 2km orbit constraint, a minimum requirement for detection of subtle changes on the Earth's surface.



Interferogram (Provided courtesy of RADARSAT International)

A New Phase

Despite the recent setbacks to ERS-2 and the late arrival of RADARSAT-1 as a reliable source for InSAR applications, InSAR work has continued. Recent advancements in InSAR technology have spawned new techniques that both overcome the obstacles of conventional InSAR and offer even better precision. These techniques are corner reflector InSAR (CRInSAR) and permanent scatterer InSAR (PSInSAR).
Unlike conventional InSAR, which relies on the natural surface topography for measurements, CRInSAR allows users to remotely and directly measure and monitor with millimetre accuracy displacements of specific structures such as dams, bridges, reservoirs or pipelines. Using aluminium corner reflectors strategically anchored to or near the structure, any structural movements between successive radar acquisitions are registered through the difference in the radar signal phase between the satellite and the reflector. Conventional InSAR processing then calculates the exact line of sight movement.
PSInSAR, regarded as the most powerful InSAR technique, was invented two years ago by Milan-based TeleRilevamento Europa (TRE) of the Politecnico di Milano. A new method for measuring subsidence with better accuracy and over periods unachievable with conventional InSAR, PSInSAR uses a minimum of thirty radar scenes over the same area to identify a dense network of pre-existing ‘permanent scatterers’: manmade buildings, radio masts or prominent natural features that provide strong reflection back to the satellite. With this array of points, users can measure the present and historical movement of individual structures and ground features with millimetre accuracy.
Together, CRInSAR and PSInSAR are heightening the commercial attractiveness of InSAR to a broad breadth of organisations such as utilities, insurance companies, local government and extractive companies.


Corner Reflector used in CRInSAR (Provided courtesy of Nigel Press Associates)

Applying InSAR

A three-year ESA-supported InSAR project is underway to use PSInSAR technology to monitor active faults and assess earthquake risk in five areas of southern Japan, including Tokyo, Hamamatsu, Shizuoka and the Izu Peninsula. A total of eight partners are involved in the project of which one, Willis Reinsurance, is the principal end user. ERS satellite data, as it offers a sufficient archive, is the primary source of data for evaluating earthquake risk. However, more than thirty RADARSAT-1 scenes are being acquired, initially over Tokyo, both to adapt the PSInSAR processing chain for RADARSAT imagery and to validate its use with this technique. When completed, an accurate model will emerge of current and historical seismic strain, enabling an improvement in analysis of earthquake risk and any subsequent liability.
The use of InSAR in Japan is not limited, however, to PSInSAR. One of the country’s largest civil engineering consulting companies, which has historically used GPS to measure land deformation, has contracted the ImageOne company (one of the eight partners mentioned above) to measure and monitor land displacement in specific areas using CRInSAR and RADARSAT-1 imagery.

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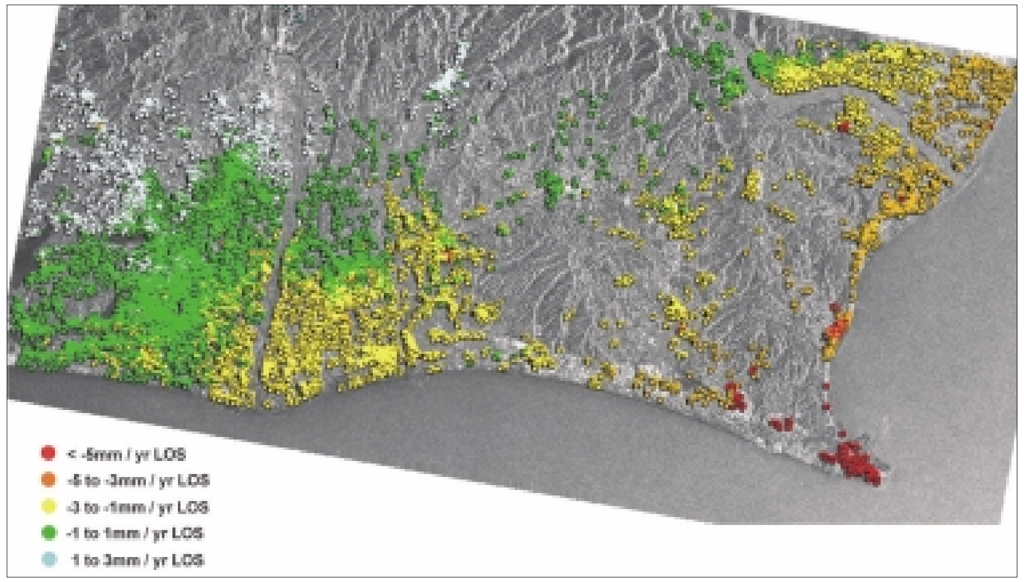
Feature



ESA project in Japan (zoomed image): Permanent Scatterer points colour-coded by displacement rate (Provided courtesy of Nigel Press Associates, ImageOne, TRE, GSI, and Willis Reinsurance)

InSAR for Utilities

The interest in achieving higher precision in subsidence monitoring than that which can presently be attained with GPS technology is motivating utility companies like London-based Thames Water (TW) to adopt InSAR techniques for their operations. Recently acquired by German power company RWE Energie AG, TW is the world’s third largest water utility and is responsible for water and sewerage services to the residents of London, as well as for maintaining the integrity of numerous water reservoirs west of the city. Traditionally, it used GPS instruments to measure the stability of reservoir retaining walls, but in November 2000 TW commissioned NPA to evaluate the feasibility of replacing GPS with CRInSAR technology and RADARSAT-1 imagery to monitor and measure subtle deviations of the walls due to water loading fluctuations.
The company chose the Wraysbury Reservoir, one of its major reservoirs, as the initial test site. NPA placed six 1-metre corner reflectors around the reservoir and anchored one unit on stable ground away from the reservoir as a reference point. Over a 24-day period, the set revisit time of RADARSAT, two sequential RADARSAT scenes were acquired and the specific reflector points were analysed for any deflections. NPA staff found the embankment walls had shifted a few millimetres between the two acquisitions and the calculations were put in an Excel spreadsheet and delivered to TW. RADARSAT acquisitions continued during 2001 to provide a time series monitoring any motion.
Impressed with the results, the company has contracted NPA not only to continue monitoring the Wraysbury Reservoir indefinitely but to begin monitoring a new reservoir in Turkey, which sits on an active fault line.

Digging for the Truth

In addition to utility companies, CRInSAR is also finding an audience among extractive companies such as those dealing in oil, gas and coal. InSAR data can provide these companies with environmental intelligence to monitor the impact of their operations and devise strategies for property damage avoidance. Most importantly, according to Moness Rizkalla, president and chief technology officer of Visitless Integrity Assessments (Via+), a Canadian research and satellite value-adding company for the pipeline and utility industries, InSAR can help companies reduce ‘windshield and seat time’.
With its Canadian technical partner C-CORE, an applied research and development company based in Newfoundland, Via+ offers clients a ground movement management service based on CRInSAR technology to help them monitor with sub-centimetre accuracy subsidence around their linear assets.
For example, in 1998 Via+ was commissioned to monitor a 1.5-kilometre section of a pipeline corridor in north western Alberta using CRInSAR and RADARSAT-1. The 30-metre wide corridor was chosen because it traverses an unstable slope vulnerable to ground motion. Staff placed five corner reflectors around the site

Wraysbury Reservoir with corner reflector sites (Provided courtesy of Nigel Press Associates)