EXECUTIVE OVERVIEW

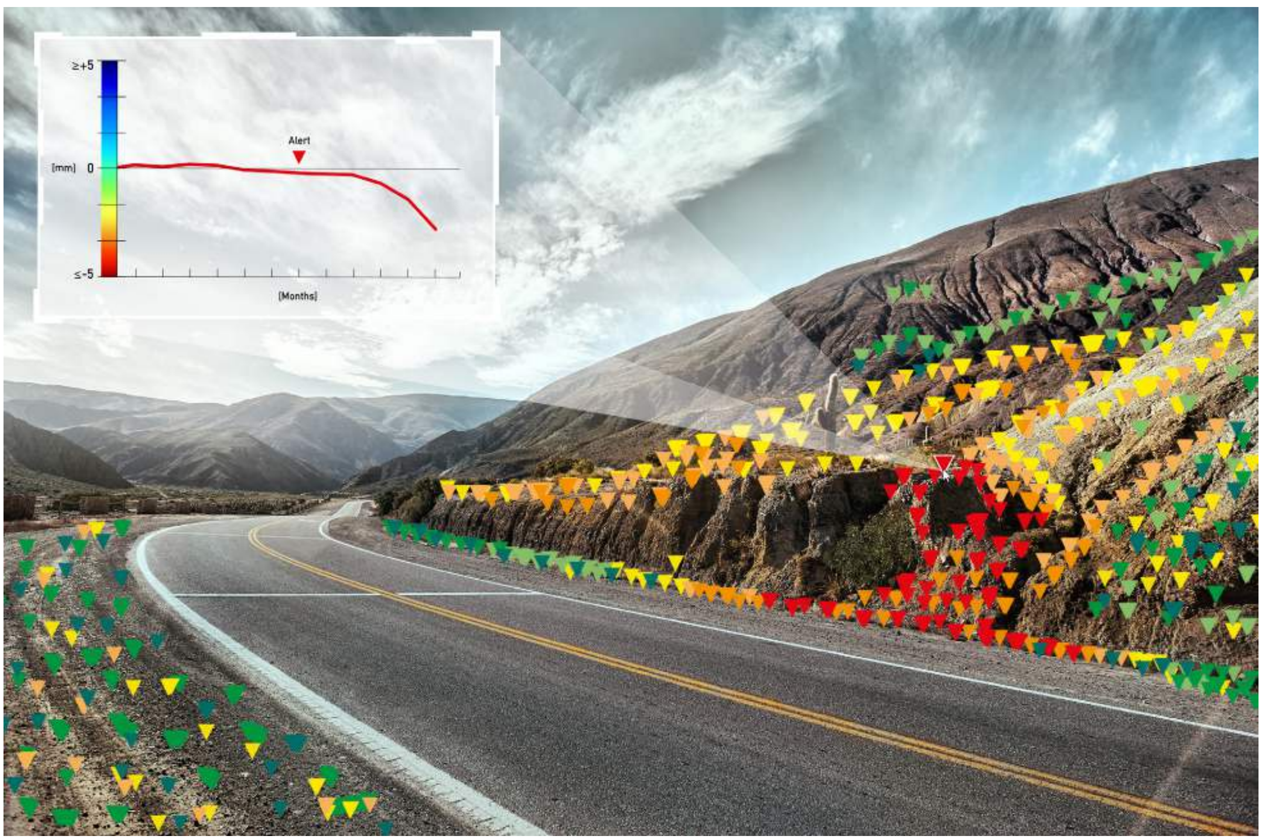
How state-of-the-art space-borne radar (InSAR) is transforming risk management and loss prevention for valueable infrastructure and assets.

CATALYST
EARTH DATA, SIMPLIFIED.

Introduction

Uplift and subsidence are ground displacements that can put dangerous strain on critical infrastructure, such as pipelines, buildings, dams, and roadways. To facilitate affordable, repetitive monitoring of millimeter-level ground movement, we have unveiled a new InSAR workflow called Small-baseline Subset Persistent Scatterer Interferometry (SBAS-PSI) in our CATALYST solutions.

SBAS-PSI is an InSAR technique that detects and measures ground displacement as small as five mm over large areas by analyzing Synthetic Aperture Radar (SAR) data captured by public and commercial satellites. The new SBAS-PSI workflow and algorithms are available now in CATALYST Professional, CATALYST Microservices, and is the workflow used in our CATALYST Insights Displacement Mapping web-service. The new capability gives end-users access to reliable measurements as a service and geospatial professionals access to the algorithms and tools needed to build their own workflows.



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Why Monitor Ground Movement?

Ground displacement is a subtle danger usually invisible to the naked eye. As the terrain sinks or rises by just a few centimeters per year, physical strain is put on nearby structures which may show no outward signs of damage until the breaking point is reached. Ground displacement can compromise the integrity of buildings, transportation networks, pipelines, dams, mines and slopes, which can result in costly downtime, property damage, and loss of life.

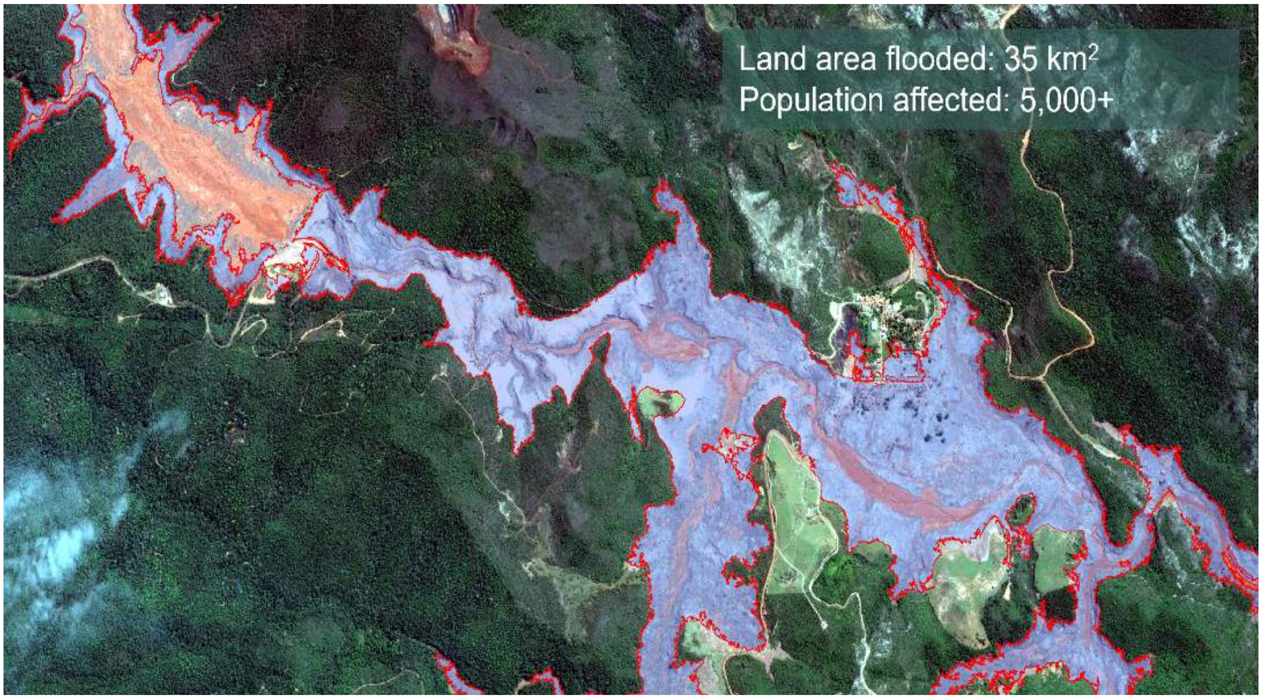

Figure 1: The extents of the Mariana (Samarco dam disaster as seem from space. A tailings dam failed in 2015 which resulted in 43.7 million tonnes of tailings to flood the valley, causing billions of dollars in economic and environmental damage.

Some land displacements are natural – like sinkholes in karst topography – but many relate to the extraction of either fluids or materials from underground. Production of hydrocarbons, pumping of ground water, and hard rock mining are among the most common examples. But the weight of enormous structures, including dams and buildings, can cause shifts in the surrounding terrain as well.

Ground subsidence has typically been tracked quite accurately with traditional surveying around site-specific targets, such as oil wells and mines, but these measurements are localized and expensive to collect on regular schedules resulting in data gaps.

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InSAR satellite data offers an effective and efficient complement to field surveying by covering large regions – entire metropolitan areas, for example – in a single image. Even over such an expansive area, our SBAS-PSI workflow can reliably measure millimeter-level movements at densities as high as 25 centimeters on the ground surface. And depending on the severity of the situation or application, the measurements can be repeated as often as the satellite passes overhead, which is quickly approaching daily revisits.

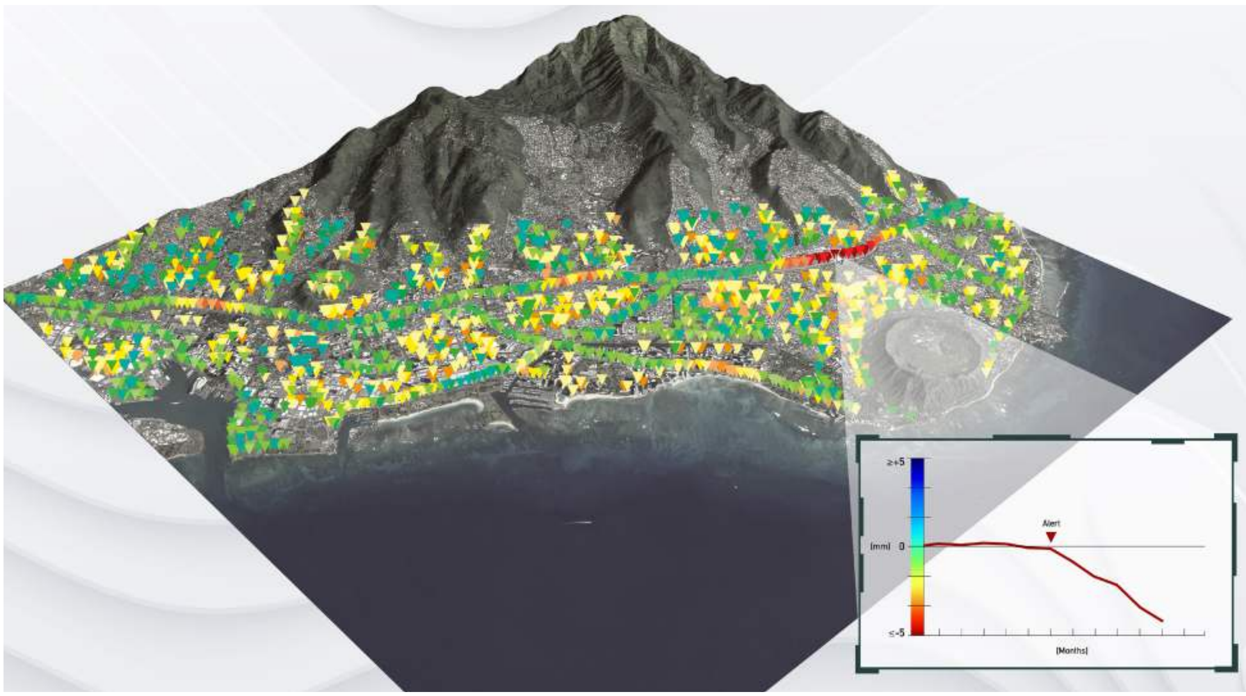


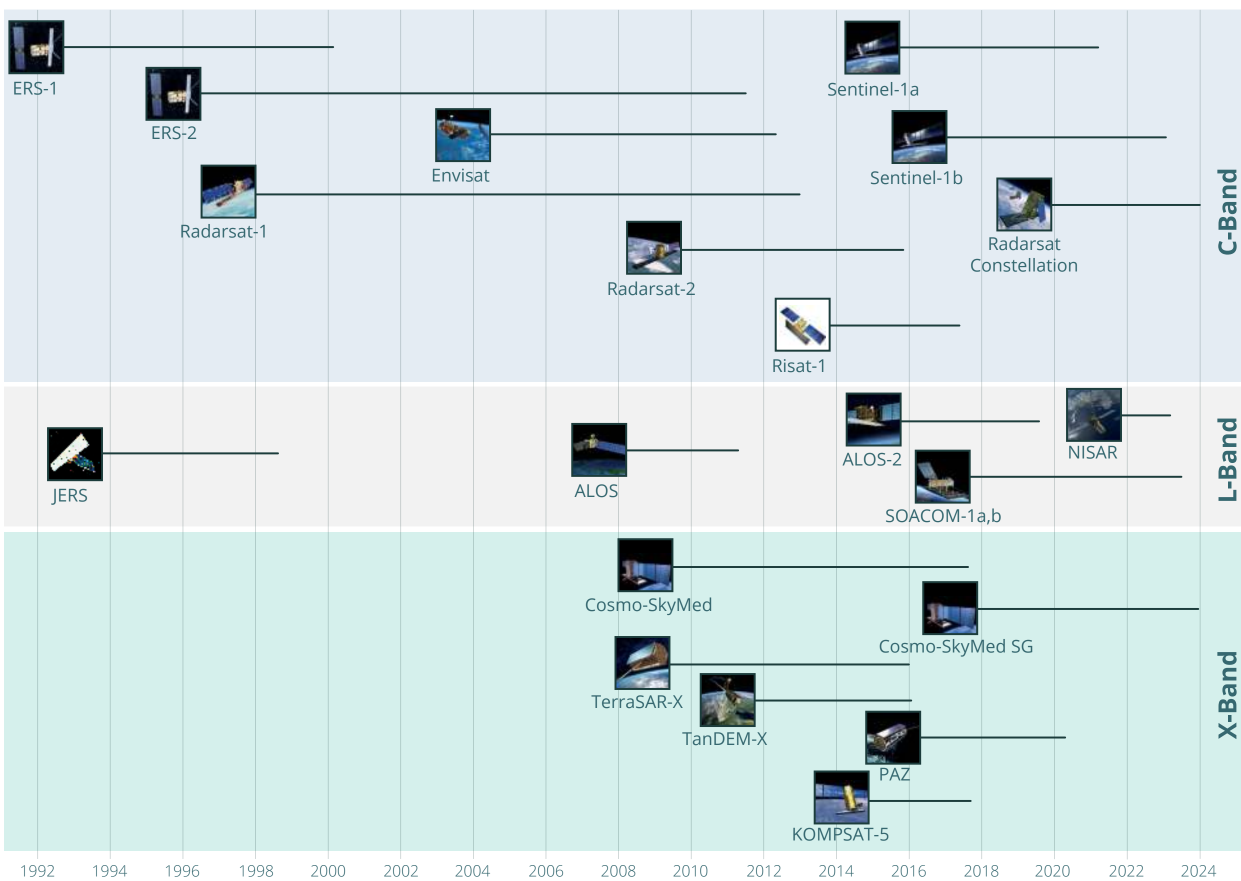
Figure 2: Monitor ground displacement for entire cities, counties or even countries.

Who Should Use PSI to Monitor Displacement?

Organizations that will benefit the most from incorporating the PSI workflow into their surveying and monitoring programs include owners and operators of mines, dams, development sites, and oil and gas fields. Agencies responsible for roadways, railways, and other transportation corridors can also mitigate risk of damage and downtime to their networks by regularly monitoring ground movement using InSAR. Another important user group will be city managers who need to ensure buildings in their municipalities are stable and that infrastructure passing through their jurisdictions face minimal risk from ground movement.

An additional advantage of satellite InSAR is that it can be applied to the many years of archived data sets compiled by programs like Radarsat, Sentinel-1A/B, and TerraSAR-X. By measuring ground displacement extracted from archived data, the workflow can identify historical trends dating back to the mid-90s that can support geotechnical engineering models and designs to improve the selection of new development sites and the integrity of new structures.

Figure 3: A list of commissioning dates for popular Synthetic Aperture RADAR (SAR) satellites and their radar bands. CATALYST's InSAR algorithms are sensor agnostic.



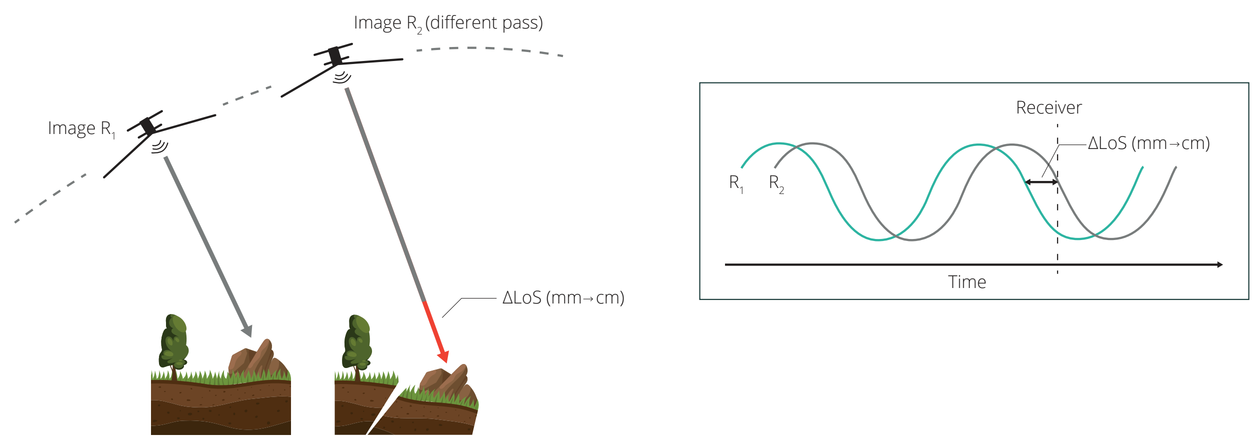
What's the Differential?

CATALYST users may already be familiar with Differential Interferometry, an InSAR technique that has been available for several years. Both SBAS-PSI and Differential InSAR detect and measure ground surface changes from multi-temporal stacks of satellite synthetic aperture radar (SAR) data. But the similarity between the two ends there.

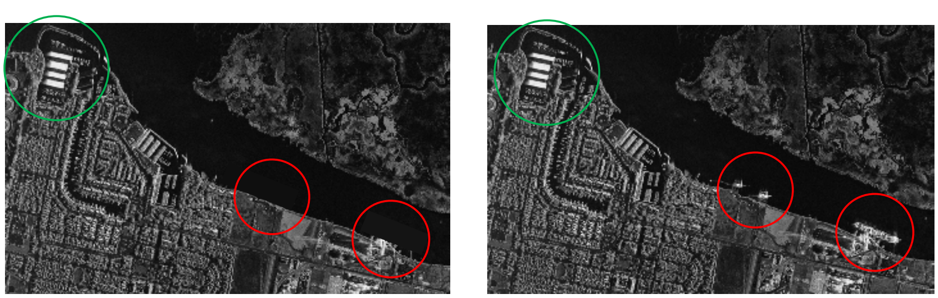
Overall, SBAS-PSI produces elevation measurements more reliable than Differential. And in terms of applications, SBAS-PSI performs much better in areas with sparse vegetation cover, anthropogenic environments, like built-up urban areas, industrial sites, and along physical infrastructure, which are all known as stable points.

In general, InSAR calculates ground displacement by measuring the changes in phase between returned radar signals in two SAR images captured at different times over the same area on the Earth's surface. The signals compared in the two data sets are referred to as the 'reference' and 'dependent' signals. Thanks to advanced algorithms and computing power, today's InSAR can make these phase comparisons between dozens or even hundreds of images, instead of just two.

Figure 4: Basics of InSAR. The phase along the returning beam can be compared between multiple images of a pixel to measure subtle (millimeter-level) movements.



Differential InSAR measures these phase differences between every pixel in the SAR data sets, whereas the PSI process compares only those pixels that are 'persistent scatterers' of the radar signals. Persistent scatterers are identified when emitted SAR signals reflect off stable ground surface features, resulting in coherent pixel values. In other words, an unmoving surface object such as a building, oil rig, dam, or roadway will return coherent pixels. Features that are often moving, like ocean waves, tree branches, and corn stalks, result in noisy, non-coherent pixels.



Amplitude dispersion: Stable ('persistent') points have very similar amplitudes across all scenes in a stack for a co-registered pixel.

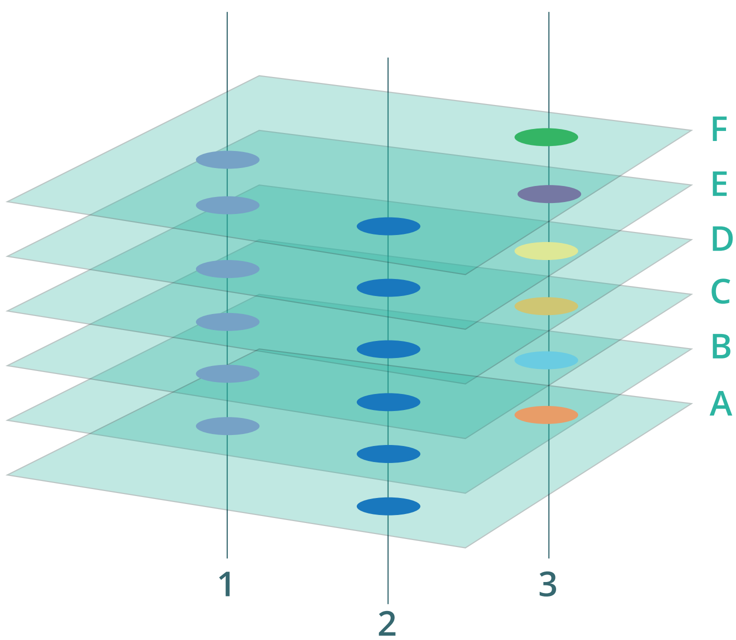
Why PSI is Better for Infrastructure

Since SBAS-PSI InSAR searches for and measures phase differences only for pixels representing stable features, this technology works best in the relatively fixed built and sparsely vegetated environments. Differential InSAR, on the other hand, doesn't verify that pixels are coherent first before processing all pixels, which is why it can produce unreliable measurements.

It would seem the Differential workflow should yield more accurate results since it calculates phase differences for every pixel. But it doesn't because the non-coherent pixels processed by Differential are inherently noisy, which can introduce errors in the displacement measurements.

Conversely, SBAS-PSI deals only with stable targets whose values have very small margins of error. As a result, there is a high level of confidence in the accuracy of the SBAS-PSI phase calculations and displacement measurements.

Figure 5: To select stable points, pixels in an InSAR stack are compared. Images with low variances in amplitude are selected as stable and processed, other pixels are thrown away.



Colors represent amplitude values

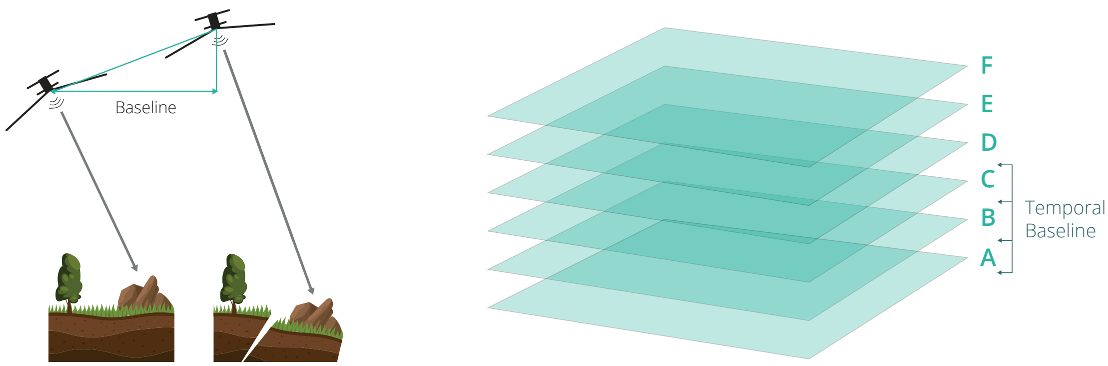
Another important factor that makes SBAS-PSI favorable in the eyes of many end users is the speed of the processing workflow. Since Differential InSAR 'unwraps' a far greater number of noisy pixels needed for the processing algorithms, this technique can literally take hours or days longer to complete, compared to SBAS-PSI.

Small Baseline Makes the Difference

Our SBAS-PSI methodology differs from others in two key ways. First, the CATALYST SBAS-PSI workflow is intuitive, and sensor agnostic. Our workflow can be easily applied to a variety of InSAR compatible commercial and open-source sensors to provide reliable and timely ground movement measurements.

The second important advantage of our approach to SBAS-PSI is our workflow leverages small baseline interferometry (SBAS), which yields a denser network of measurements. In a standard PSI workflow, measurements are computed only for stable targets between individual pairs in the stack (A-B, B-C, C-D). SBAS utilizes a better selection of scenes drawing from a network of highly reliable measurement points capable of millimeter-level precision (A-B, A-C, A-D, B-C, B-D, B-E...).

Figure 6: One of the challenges with Persistent Scatterer Interferometry (PSI) is lack of stable points. Using the Short baseline subset (SBAS) method improves our chances to find more stable measurements.



As a result, the CATALYST SBAS-PSI technique generates a much larger number of measurements, which delivers greater density, coverage and confidence in the accuracy of the ground displacement measurements.

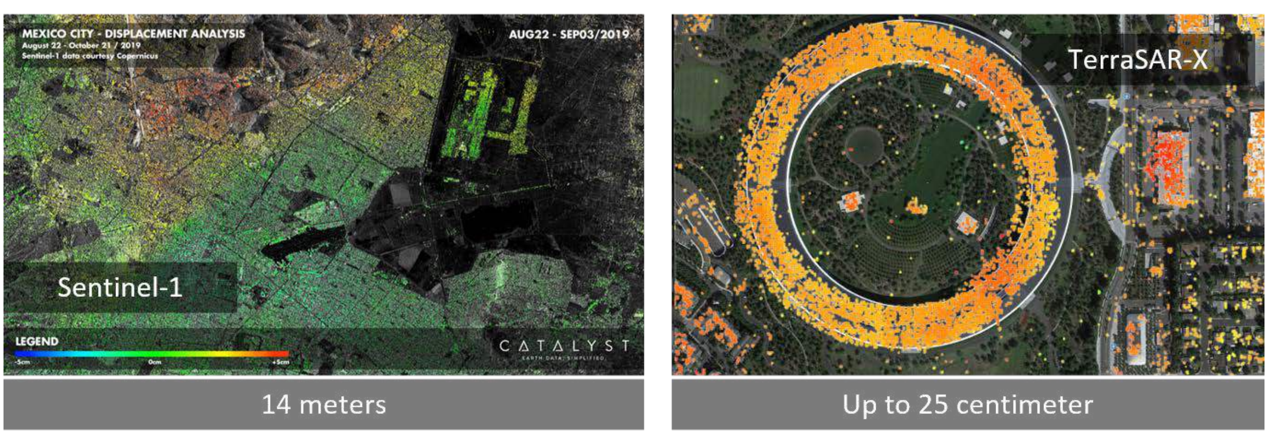


Figure 7: Our SBAS-PSI algorithm is sensor agnostic. This provides the advantage of computing measurements from the most appropriate data source available for your application.

PSI Accuracy Validation

CATALYST senior scientist Gabriel Gosselin conducted a validation study of our SBAS-PSI technology by comparing it to third-party GPS points. For the study, he used 3D location points collected continuously at permanent GPS stations established by UNAVCO, a consortium of geoscientists. The data captured at these stations is readily downloadable from the web.

Gabriel selected a study area around San Jose, California, for several reasons. Most importantly, there are several GPS stations located there. In addition, the San Jose region is known for seasonal variations in ground displacement, both subsidence and uplift, as water is extracted from the ground for human use and then recharged with spring rains.

The GPS points showed a distinct profile of ground displacement in the Z values. Using the CATALYST SBAS-PSI methodology, he generated displacment measurements from a stack of 33 archived TerraSAR images over the same area and same time period. The results were remarkably similar. The average difference in PSI measurements was only 3.64 mm compared to the GPS points with the displacement trend lines closely matching one another.

Put another way, the San Jose validation project confirmed the PSI InSAR technique provided reliable and accurate measurements consistent with that of the UNAVCO GPS stations.

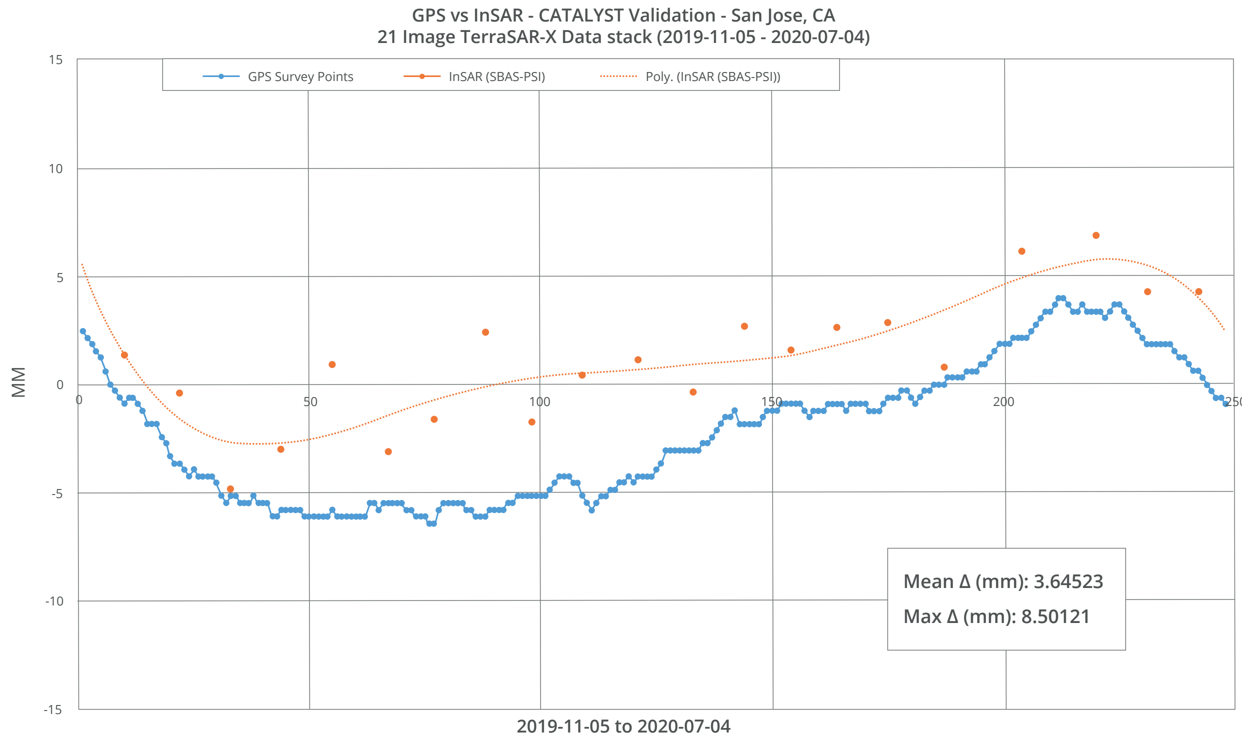


Figure 7: InSAR measurements using our new SBAS-PSI workflow were compared to the daily average from GPS survey points. The result was an incredible 3.64mm average difference between the two over 8 months.

About Catalyst

CATALYST is a PCI Geomatics brand, which has been introduced to put our leading edge technology into the hands of decision makers. CATALYST provides proven algorithms rooted in photogrammetry and remote sensing to offer engineers, environmental management, and other professionals accessible earth data measurements on a reliable basis derived with leading edge, scalable software solutions and platforms. We're a startup – with hundreds of algorithms, scalable solutions, and decades of experience.

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