AGI Webinar Mapping Displacement and Subsidence with Time-series Radar
Additional Questions & Answers

Which interpolation method has been applied for the subsidence mapping?

Derrold Holcomb (Hexagon): The subsidence (displacement) maps are not interpolated. Each pixel that is identified as a persistent scatter is a point in a Shapefile and has its own displacement time-plot.

What is the annual budget for InSAR data Acquisitions for your AZ project?

Brian Conway (ADWR): Sentinel-1 data has an open data policy so it's free. ADWR has also been using Radarsat-2 data which is a commercial satellite and purchases on average $120,000 of data a year.

Would the State (AZ) consider migrating to a commercial service, where the InSAR data is processed and interpreted outside the agency?

Brian Conway (ADWR): At this time, ADWR is not considering migrating to a commercial service. ADWR has been successfully processing and analyzing InSAR data since 2002 and using it operationally and providing it to the public free of charge.

Does the flooding in the floodplain result from groundwater recharge mounding heterogeneities from the caliche soil in AZ?

Brian Conway (ADWR): The flooding in the floodplain is from land subsidence and the changing of natural drainage slope and subsidence bowls.

InSAR monitoring is not new, what has been the commercial limits of general use in North America all these years? And how is the Hexagon/Planetek product enabling a change in that opportunity? What is the per seat cost of the Rheticus Service or the Suite necessary for local processing and outputs?

Derrold Holcomb (Hexagon): The cost of the radar imagery and the required Analyst time caused this to be an expensive technology to use. The advent of free Sentinel-1 imagery and the development of largely automated data processing lowered both of these costs. The Hexagon/Rheticus service addresses the need for personalized and skilled Analyst time in ordering the data, controlling the analysis process and providing the software to interpret the results. The end-user of the information does not need to understand or work with the underlying technology that extracts the displacement data.

The Hexagon service will tailor the data acquisition, processing and final Products to the customer based on their application and needs. So this could be a small area, analyzed once with free S-1 imagery or a critical facility analyzed with high-resolution imagery and a report every couple months. The cost will be different for each project which is why the IMAGINE-based Service Request is for a project quote.

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How much is the high resolution data per scene? How do I know if I need high resolution data?

Derrold Holcomb (Hexagon): High spatial resolution imagery can cost $500 to $800 per scene. If the free data doesn't have the point density you need, higher resolution imagery will probably find more Permanent Scatterers in your area-of-interest. Or if the free Sentinel data shows activity of critical importance, such as a dam or power plant, it may be worthwhile to use more precise imagery to get better or confirmatory results. It is a cost-benefit decision for each project. The Hexagon-Planetek Analyst can help guide your decisions.

What is the typical temporal resolution for these satellite images?

Brian Conway (ADWR): The temporal resolution for the Sentinel 1 A and B satellites is 12-day repeats.

Derrold Holcomb (Hexagon): This, of course, varies with the satellites. The free Sentinel-1 data has a 11-day repeat cycle. Cosmo, with several satellites, can image an area every day or 2. Temporal resolution might be appropriate for events like earthquakes, where an after-event scene is needed immediately. In most cases, people are monitoring things that are moving centimeters per year so a close temporal spacing isn't really the issue.

Do you integrate gravity methods with InSAR in relation to aquifer monitoring?

Brian Conway (ADWR): ADWR collects ground-based micro-gravity data in the Phoenix and Pinal Active Management Areas for monitoring change in aquifer storage. InSAR data is also integrated with the gravity data.

Are you calibrating groundwater flow with InSAR observation?

Brian Conway (ADWR): InSAR data is used in conjunction with certain groundwater flow models at ADWR.

How small can the persistent reflectors be? Would a one-foot diameter boulder qualify to be a persistent reflector?

Derrold Holcomb (Hexagon): It could if it were oriented correctly and high spatial-resolution data was being used. But, as a general rule, and certainly with Sentinel-1 imagery, that would be pretty small.

Is the method taking into account the amplitude or the phase stability to identify the PS points?

Derrold Holcomb (Hexagon): The algorithm defining the persistent scatterer points uses both criteria for the initial search but ultimately it is the phase stability that is the critical parameter. That is why the analysis software interface allows the Coherence, which is phase stability, to be varied.

What about east coast? More humidity, more vegetation, less quality data, what's the solution for monitoring displacement and subsidence?

Derrold Holcomb (Hexagon): Vegetation decorrelation is always a problem for interferometry. Fortunately, the features most important to monitor with this technology are usually man-made and are in man-made areas. And these areas tend to have lots of features that are strong stable reflectors, power poles, cell phone towers, metal rails, buildings, bridges. All these things are, or have in them, metal. As shown in the McMullen test area, the agricultural areas were phase unstable but the surrounding area, roads and residential areas had scatterers.

There are atmospheric-correction metadata, available for some radar satellites, that incorporate water vapor correction. These model-based calculations use weather records to correct for water vapor at the time of the satellite overpass. This “Precise” or “Scientific” ephemeris data is available several weeks after the image acquisition, but that is fine for this temporal PS-InSAR application. In addition, the use of more images strengthens the atmosphere estimation algorithm.

Can this method be applied in karst studies in order to estimate the ongoing dissolution and triggered subsidence in the epikarst zone / soil zone above a cave?

Brian Conway (ADWR): InSAR can detect any ground motion at the surface. ADWR has used it for a karst area in eastern Arizona and has detected and monitors sinkholes with it.

Derrold Holcomb (Hexagon): Subsidence due to sub-surface dissolution would be revealed at the surface. So, yes, the slow initial subsidence due to a collapsing sinkhole would be detected. An area at risk could perhaps use Sentinel-1 imagery to monitor a specific region.

Can this be used to monitor submarine landslides? If so, how?

Derrold Holcomb (Hexagon): Probably not. Radar does not penetrate through water so there would be no signal at depth. And any surface effect, such as waves or turbulence, would dissipate fairly quickly.

Do you have any educational resources that can be used for teaching?

Brian Conway (ADWR): The Alaska Satellite Facility and UNAVCO are two great resources for obtaining educational resources that can be used for teaching.

Derrold Holcomb (Hexagon): There is not currently for this particular application. We are developing Training materials for various radar applications. But we certainly have materials like the PowerPoints slides you saw. If you have specific desires, contact Mike Lane at Hexagon.

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How does it compare to high resolution leveling or extensometer data?

Brian Conway (ADWR): InSAR compares quite well with extensometer data and GNSS data. Keep in mind that extensometer data is only measuring land subsidence where the extensometer is located in the sub-surface. InSAR data is measuring all the deformation at the land surface.

What is the highest frequency that measurements can be taken at any given point? Also, does vegetative cover/ tree canopy interfere with accurate readings?

Derrold Holcomb (Hexagon): The only limit is sensor repeat cycle, discussed above.

Vegetation decorrelation is discussed above. Anything in dense canopy would be in radar shadow. Longer wavelengths (say, L-band) will penetrate vegetation better, but the resolution is cm rather than mm.

Can this be used to monitor movement between monuments along a fault as a method for monitoring fault movement?

Brian Conway (ADWR): Yes, InSAR can be used to monitor vertical deformation in between two monuments along a fault.

Derrold Holcomb (Hexagon): PS-InSAR is definitely being used to monitor fault zones. But these zones can be huge (San Andreas is the length of California) and pass through areas of poor performance (crop land). Fixed scatterers, like monuments, could be used for critical areas if the monument was a good scatterer. Usually this is a large metal object or a self-powered “active” reflector, a standard geological monument would be too small.

Do you use only one type of radar images from a particular satellite? Or, do you use radar images from different satellites, such as Terrasar X, Sentinel, etc.?

Brian Conway (ADWR): ADWR has used and continues to use InSAR data from various satellite platforms. It currently uses data from the Sentinel-1, Radarsat-2, and ALOS-2 satellites. It has also used data from the ERS-1 and 2, Radarsat-1, Envisat, ALOS-1, and TSX satellites.

Derrold Holcomb (Hexagon): The Hexagon-Planetek Rheticus Service can use Sentinel-1, TerraSAR-X or Cosmo-SkyMed. But datasets have to be entirely from one sensor for the analysis to work; you cannot mix data types in one time-series stack. But you could, for example, use free Sentinel-1 for an initial study and , if the need required, do a follow-up study with a high-resolution satellite.

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Do you update your displacement map generated by INSAR using the measure GPS data?

Brian Conway (ADWR): We do not update the displacement maps generated InSAR data using measured GNSS data. We however publish both displacement maps with the GNSS monuments and results.

Derrold Holcomb (Hexagon): The Hexagon service does not apply any external data to the displacement map; it is exactly what the interferometry delivers.

It certainly is true that if you have very precise GPS data it could be used to modify or constrain the displacement file. For example, a very precise D-GPS position taken at a feature clearly identified as a persistent scatterer, could be used as a benchmark to slight shift the TS-InSAR map.

The problem you get into is having a sufficiently accurate and dense GPS dataset that allows you to confidently modify the dense interferometry dataset. The density of data points from TS-InSAR is high and the density of precise GPS point is likely very low, so merging these datasets is problematic. For example, if your GPS point is from several hundred yards away, is it really applicable?

Is anyone using LIDAR for subsidence measures in vegetated areas?

Derrold Holcomb (Hexagon): Yes, you could use lidar. But this is an air-borne system; expensive to deploy and not available world-wide. In addition, you would have to be sure you were using the lidar ground return. In moderate to dense vegetation, these points would be scarce, irregular and difficult to verify; you could have no ground return in a dense canopy.

What is the frequency of the satellite passing over a point of interest?

Brian Conway (ADWR): It is usually one-orbit which varies on the satellite. Sentinel-1 data has a 12-day repeat.

Derrold Holcomb (Hexagon): This is temporal resolution, discussed above.