geoconvention
Calgary • Canada • May 15-17 2023

Interferometric monitoring of the Bayou Corne sinkhole

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Summary

The Napoleonville salt dome in Assumption Parish Louisiana, was the site of an infamous sinkhole that swallowed large tracts of land in 2012. In early 2013, 11 seismic stations were deployed around the Bayou Corne sinkhole to monitor the area for potential precursor seismic activity to sinkhole expansion. The network was operational for the last of the major collapses in 2014, after no significant expansion of the sinkhole occurred. Using two years of data, of ambient seismic data to monitor daily relative seismic velocity changes. The results show significant velocity decreases in early 2013 associated with the collapse phases of the sinkhole. Two seismically active periods generate smaller velocity drops. While we have demonstrated the technique on a sinkhole dataset, interferometric monitoring has a wide array of applications including mine site monitoring, CO2 plume migration, and potentially any other field when subsurface changes with time require characterization.

Background

The Bayou Corne sinkhole is a lake-forming land subsidence covering an area of several acres in a marshland area in Louisiana, USA. The sinkhole was caused by the erosion of the walls of a well dug to extract brine by the Texas Brine Company: the failure of one of the salt dome mining caverns abruptly formed the sinkhole when the side wall collapsed.

This collapse displaced 350 community members living near Bayou Corne in the community of the same name. As the disaster area has expanded, multiple problems have arisen: contamination of aquifers, the fracturing of the soil to underground gas and crude oil reserves, proximity of the sinkhole to butane storage well, etc.

Following the initial collapse and formation of the sinkhole, a seismic network was installed to monitor seismic activity that could help determine potential future collapses. This data was collected from early 2013 to 2017. During this time period, further collapse of the sinkhole of the sinkhole and numerous seismic events were detected.

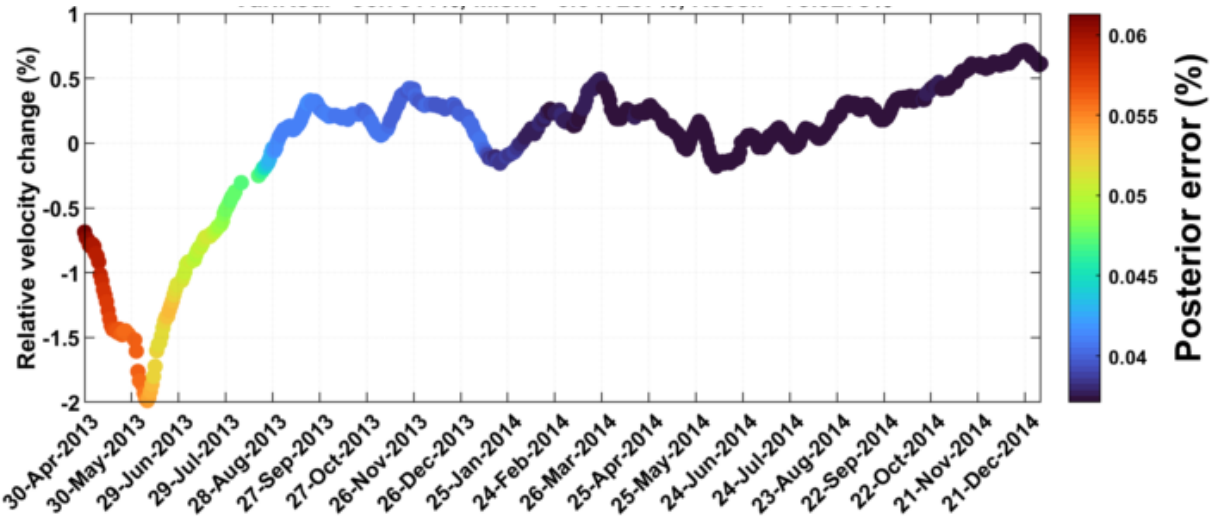
Interferometric monitoring

Interferometric monitoring uses ambient noise to construct Green's functions between pairs of geophones. Using a reference Green's function, we can compare travel time differences between a given time period to estimate the change in velocity relative to the reference.

We use the stretching method (Sens-Schönfelder & Brenguier, 2019) to measure the relative velocity changes in the coda of the correlations. This method consists in stretching or compressing a reference correlation up to the point where it becomes similar to a current correlation. The stretching factor for which to maximize the correlation coefficient between the current and the stretched reference correlation is the measure of the relative velocity change (dv/v) at the calendar time of the current correlation.

We analyzed data from early 2013 through 2014 to investigate whether the sinkhole formation could or any precursor features be identified through interferometric monitoring. Changes in velocity were computed every day for each station pair where data was available. The figure below shows the relative velocity change for one station pair that crosses the sinkhole.

The large dip in velocity in May, 2013 corresponds to the expansion of the sinkhole that occurred in March 2013. The decreases in October and December 2013 correlate with increased seismic activity around the sinkhole.



Conclusions

The velocity change results show evident temporal variations of the subsurface seismic velocities, which can be correlated with known events seen from the surface or recorded by seismometers. Our analysis shows that the sinkhole has been active for most of 2013 but

stabilized in 2014. We also find a clear spatial trend, with large velocity decreases located south of the sinkhole. Each time there is seismic or surficial evidence of activity of the sinkhole, the southern section is the most affected. This is in good agreement with the southward extension of the sinkhole during its formation and evolution.