UAVSAR Pathfinder for DESDynI Potential for InSAR Monitoring of Gulf Coast Subsidence Through Integration with Geodesy and Geophysical Models

Ronald Blom[1], *Bruce Chapman*[1], *Roy Dokka*[2], *Eric Fielding*[1], *Scott Hensley*[1], *Erik Ivins*[1], *Rowena Lohman*[3]

[1.] Jet Propulsion Laboratory California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109

[2.] Louisiana Spatial Reference Center and Center for GeoInformatics
Louisiana State University
Baton Rouge, LA 70803

[3.] Department of Earth and Atmospheric Sciences
Cornell University, Snee Hall,
Ithaca, NY 14850

1.0 INTRODUCTION

Hurricanes Katrina and Rita focused attention on the vulnerability of the U.S. Gulf Coast. It is inevitable that future hurricanes will impact the area with disastrous potential. Several processes operate simultaneously to increase hurricane vulnerability, including wetland loss due to lack of present day sediment flux, land subsidence due to sediment compaction, sediment oxidation, fluid withdrawal, salt evacuation, tectonics, and also subsidence due to crustal loading. Key to protection of lives and property in future hurricanes are precise and accurate measurements of subsidence, and accurate predictions of future subsidence rates. This information is vital to a myriad or users, from planning and maintaining hurricane protection structures, to community planning, to the planning of evacuation routes. We are extending subsidence measurements from traditional geodetic techniques (including GPS), to geographically comprehensive measurements derived from synthetic aperture radar interferometry (InSAR). This technique uses sequential radar observations to construct interferograms which can be used to measure elevation changes. The Gulf Coast is a challenging environment for InSAR techniques and we are developing new persistent scatterer methods to be used with existing C- and L-band satellite radar data, and incorporating newly acquired observations with the JPL/NASA UAVSAR, a new airborne interferometer system (http://uavsar.jpl.nasa.gov/). A fundamental requirement to integrating these disparate data sets is a calibrated and validated reference system. NOAA Technical Report 50 (Shinkle and Dokka, 2004 http://www.ngs.noaa.gov/heightmod/Tech50.shtml) adjusts and validates old survey data with modern surveys. Most significantly, benchmarks were indexed to the North American Vertical Datum of 1988 (NAVD88). These calibrated measurements revealed the entire Gulf Coast is sinking and also shows many surveys are inaccurate due to lack of sufficient vertical control. The goal of our current work is to provide a geographically comprehensive way to monitor long term subsidence, predict expected subsidence with data constrained geophysical models, and enable users to incorporate these results into their responsibilities.

2.0 METHODS: GEOPHYSICAL MODELING, GEODESY, AND INSAR

In order to make accurate predictions of future subsidence we combine the geodetic data derived from InSAR, GPS, and other geodetic techniques, with geophysical modeling of the Gulf Coast. The least studied subsidence driving phenomena is the effect of crustal loading due to Mississippi River sediments, and the geologically recent ~130 m (427 ft.) rise in sea level. We model subsidence rates expected from these loads using methods developed for, and validated by, research on post-glacial rebound. Work to date has resulted in a model predicted, and geodetically observed, vertical subsidence rate which varies between 2 - 8 mm per year over areas of 30,000 to 750 square kilometers, respectively. This viscoelastic flexure is the background crustal deformation field, upon which larger amplitude, but smaller spatial scale, subsidence occurs due to other factors mentioned earlier. Figure 1 (Ivins, et al., 2007) shows the present model predicted subsidence and measured subsidence of benchmarks indicted.

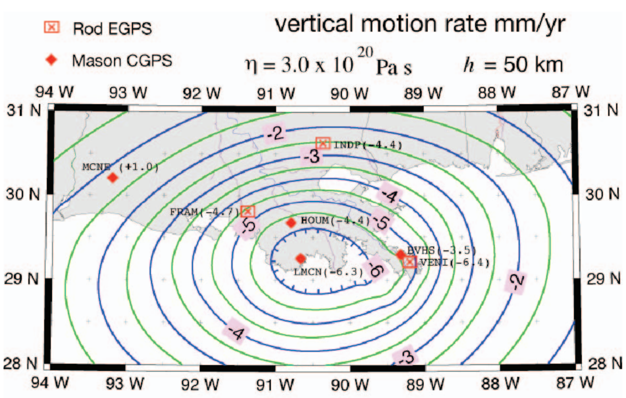


Figure 1. Present-day vertical motion model predictions compared with GPS data. Red diamonds are continuous Global Positioning System (CGPS) measurements. Episodic ('E') GPS measurements in crossed rectangles. Benchmarks are deep and so largely ignore surface processes. Modeled bedrock subsidence rates are comparable to measured rates.

The major shortcoming of conventional survey methods, including continuously operating GPS stations, is lack of geographic continuity. That is, while GPS provides a continuous and accurate measurement at a point, it does not provide regional coverage. Conversely, the InSAR technique can potentially provide sequential snapshots of subsidence over an entire region, albeit at lower accuracy than the GPS data. Combined, these techniques can provide something otherwise not possible, a calibrated map of subsidence that is geographically complete. Since a levee, or evacuation route, is only as high as its lowest point, the importance of this is obvious. Accordingly, efforts to incorporate InSAR are underway. We use two approaches with InSAR. One is to further techniques to deal with decorrelation in shorter wavelength radar data available for longer observation intervals. The other approach is to capitalize on longer wavelength ALOS PALSAR and airborne NASA UAVSAR data becoming available. Recent advancements in the persistent scatterer technique (Hooper, 2004) by Lohman et al., (2007), are applied to existing C-Band radar data, primarily RADARSAT and Envisat. Progress has been made which increases the range of circumstances, and confidence, in these methods (Lohman, et al., 2007). Japanese L-Band PALSAR data are being analyzed. Unfortunately, operational constraints realistically limit PALSAR observations to a few times per year. We are now acquiring NASA UAVSAR data (Hensley, et al., 2007). A unique attribute of UAVSAR is the possibility of multiple interferometric observations within days, or even hours. Such temporal sampling is impossible with spaceborne radars at present. Our first UAVSAR observations were made on June 16th and September 9th 2009. Figure 2a-c show the location of two of our flight lines, a preliminary interferogram, and a close up of a segment of the interfergram. It is clear that there are detectable features in the interferogram that are not instrumental or atmospheric in origin, and are likely due to soil moisture or water level changes within flooded bayous (the "double-bounce " effect, e.g, Kim et al., 2005, Lu and Kwoun, 2008). UAVSAR data collections are continuing.

Figure 2a (left, below). Location map for two of our flight lines.

Figure 2b (above right). Preliminary interferogram. There are features which are clearly not related to instrument or atmosphere.

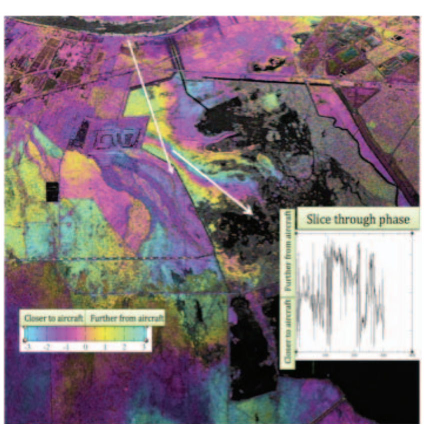
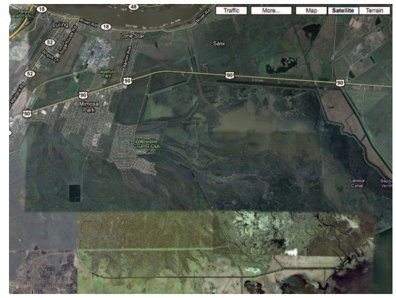


Figure 2c left. Enlargement of segment of the interferogram illustrating the strong coherence and correlation of apparent variations in the line-of-sight distance between the satellite and the ground with bayous and levee boundaries



Figue 2d right. Google Earth image of the area in figure 2c. Note that it is a wetland and therefore we speculate that the double bounce effect associated with water level changes is a likely explanation.

3.0 SUMMARY AND FUTURE WORK

It is clear that subsidence in New Orleans and along the Gulf Coast is incompletely understood and inadequately monitored, and that safety and economic impacts can be severe. Significant improvement in geophysical understanding of subsidence rates, temporal variability, and geographic distribution is not only an interesting scientific challenge, it is necessary for long term protection of lives and property. An integrated geophysical approach is the only way to unravel conflicting interpretations derived from very different measurement techniques and gain physical insight into the processes. Coastal inundation is a key natural hazard recognized by the Subcommittee on Disaster Reduction in "Grand Challenges for Disaster Reduction" (www.sdr.gov). Additionally, this integrated approach may have applicability to other critical low-lying areas as civilization deals with rising sea levels and disruption of sediment delivery at river deltas. A successful proof of concept here will prove valuable for future DESDynI InSAR applications.

4.0 REFERENCES

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