2019 SCEC Proposal

Bias introduced from soil moisture variability in InSAR time series along sedimentary-basement contacts in the Mojave

Summary from Proposal:
The SCEC Community Geodetic Model (CGM), has the goal of developing a consensus model characterizing deformation in Southern California. One of the inputs into the CGM is derived from synthetic aperture radar (SAR) data, which has become much more frequently acquired and easily available in the past few years.

Interferometric Synthetic Aperture Radar (InSAR) observations are being used by the tectonic geodesy group at SCEC to constrain characteristics of the ground displacement time history, including the secular rate, magnitude and timing of seasonal signals, etc. InSAR is sensitive to displacements of the ground surface towards or away from the satellite, but also has well-known sensitivity to variations in the troposphere and ionosphere. For the most part, the latter variations tend to be random in time, and their impact on the inferred ground displacement can be mitigated through temporal-spatial filtering and/or comparisons with weather models.

Another source of error in InSAR time series analysis comes from variations in surface reflective properties, including those due to variations in soil moisture in the uppermost few cm of the subsurface. In the past, this variability was small enough and the sampling in time was so sparse, that it was generally ignored or treated as a low-level noise source. The data now available from the Sentinel-1a/b constellation is being acquired over the Mojave at a frequency of one observation every 6-12 days – allowing observation of the evolution in interferometric phase and coherence after individual storms as well as longer-term studies of the variability.

The soil moisture term, while often small, is particularly problematic in studies of fault zones within Southern California because the impact of soil moisture is highly correlated with soil type – something that is also correlated with faults that displace one unit relative to another. We proposed to characterize the contribution of soil moisture variability to InSAR time series analysis and corrections based on other aspects of the SAR time series (amplitude, other polarizations, etc.).

Progress report:
Our work so far has focused on a region where the contrasts in surface type are even more pronounced than in the Mojave - the Imperial Valley and associated agricultural fields. This

project started as an effort to simply examine anthropogenic deformation, but we quickly identified interesting signals that are relevant to the problem of faulting in Mojave as well.

The key observation is that, in areas with disturbed ground (such as on the grounds of the Imperial airport), adjacent to pavement, we see differences in interferometric phase between those two surface types. This discrepancy is particularly apparent at GPS site P497, which is located in a bare field near one of the airstrips at Imperial airport. Note in Figure 1, that the InSAR-inferred velocity is quite high compared to the GPS velocity at that site (colored circle). This comparison includes all InSAR pixels within a few hundred meters of the GPS site. If we only include pixels that are located on impervious pavement (e.g., parking lots, airstrip), then the two data types are much more in agreement (black box in Figure 1).

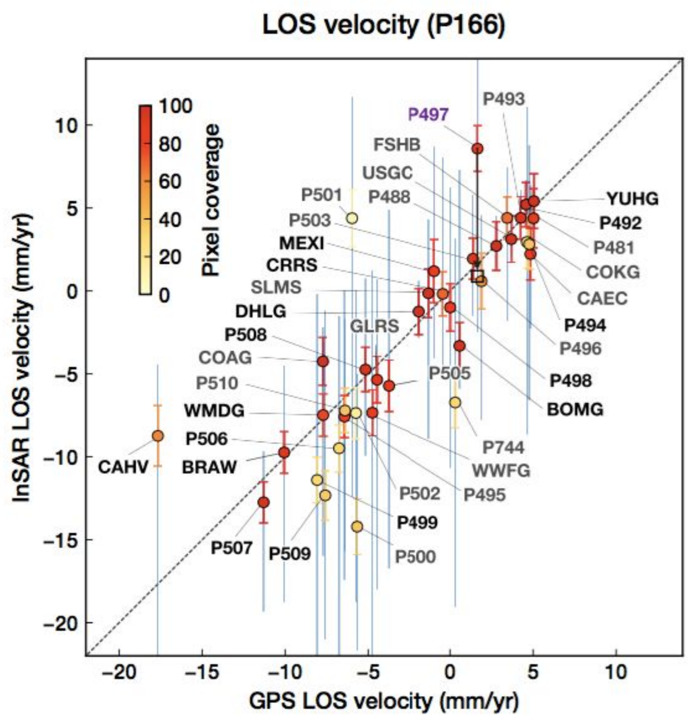

Figure 1: InSAR vs. GPS velocity when projected into the satellite radar line-of-sight (LOS). Average rate of the entire study area has been removed from both GPS and InSAR datasets, such that there is no sensitivity to deformation over spatial scales larger than approximately the width of the Imperial Valley. Date points are colored by the percent pixel coverage for the InSAR data, i.e., how many pixels are not masked out due to decorrelation in the vicinity of the GPS point. Vertical bars indicate measures of the spatial and temporal variability of the InSAR-inferred rates in the vicinity of each GPS site.

The higher rates observed at some of the InSAR sites are consistent with the observation that individual fields that lay fallow for much of the Sentinel observation period (late 2014-present) also tend to show positive apparent uplift rates more often than they show negative rates. We infer, based on the fact that the deep-braced GPS site P497, located within one of these bare fields, does not show the same motion, that the apparent uplift is a result of processes occurring in the shallow subsurface. Because the Imperial Valley is known for gypsic soils and even have large crystals of gypsum and other salts in some regions, this shallow uplift may be associated with the formation of such minerals in time periods between large rain events. We do not observe these discrepancies in undisturbed desert regions, which suggests that recently-plowed or disturbed soils that are no longer armoured by pebbles/desert pavement may be more susceptible to such motion.

Future work:
Similar large rates of uplift are observed in dry lake beds around southern California, including Laguna Salada, which has only been occasionally water-filled since around 2000, and within the Mojave. Uplift associated with salars, and with cm/yr rates or more, has been observed in South America. We plan on comparing the VV and VH observations at the Imperial Valley sites to determine whether the rates of motion are the same (which would imply that it is a true "uplift" signal) or if they differ (which would suggest that we are seeing a signal associated with soil moisture or vegetation). Since some of the major faults in the Mojave are also associated with dry lake beds, determining how reliable InSAR observations, and whether part of the observed motion is only due to processes occurring in the shallowest subsurface, is critical.

Deliverables so far:
Dr. Jiang and I have presented on this topic at the 2019 SCEC and AGU meetings, and have a publication currently in revision with SCEC contribution #10073.