VECTOR TIME-SERIES FROM MULTIPLE INSAR GEOMETRIES APPLIED TO POST-RIFTING DEFORMATION AT KILAUEA

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1. INTRODUCTION

We present a modified Small Baseline Subset (SBAS) algorithm designed to estimate time-dependent vector deformation from multiple InSAR time-series, acquired on different dates, and with varying incidence and heading angles. We use our method to examine crustal deformation following the 2007 "Father's Day" event at Hawaii's Kilauea volcano. We use InSAR observations from ALOS PALSAR, which operates at L-band rather than C-band, in order to reduce the effects of spatial and temporal decorrelation. The L-band data produce interferograms with higher coherence than C-band, however, due to the relatively long repeat-pass times and the frequently changing modes of operation, the ALOS time-series have low temporal resolution. We address inadequate temporal sampling by using both single and dual polarization images, and obtain vector solutions by combining phase information from ascending and descending passes of varying incidence angles. Thus we realize higher temporal resolution and also can characterize the time-varying vector deformation field more accurately than using data from only passes of identical acquisition geometry.

2. METHODOLOGY

In our algorithm, we first produce a geocoded InSAR stack for each observation geometry. Following coherent pixel selection, we unwrap [1] and compute an initial SBAS inversion [2] that involves all InSAR pairs, both pre and post-event. This produces a set of independent line of sight (LOS) time-series measurements. The time-series are then aligned temporally and limited to the post-event period in an interpolation step. Since the post-event deformation is nearly quadratic in time, we interpolate the time series by a polynomial fit to each data set. Finally, with multiple LOS observations at each time, we form a linear system of equations, and invert for the three-dimensional time-series.

3. RESULTS

Figs. 1 and 2 show the least squares (LS) and regularized least squares (RLS) solutions for the vector time-series at two GPS stations located near the caldera. In both position estimates, we see subsidence, indicating post-event deflation of Kilauea. The LS estimate provides a reasonable approximation in the east and vertical directions,

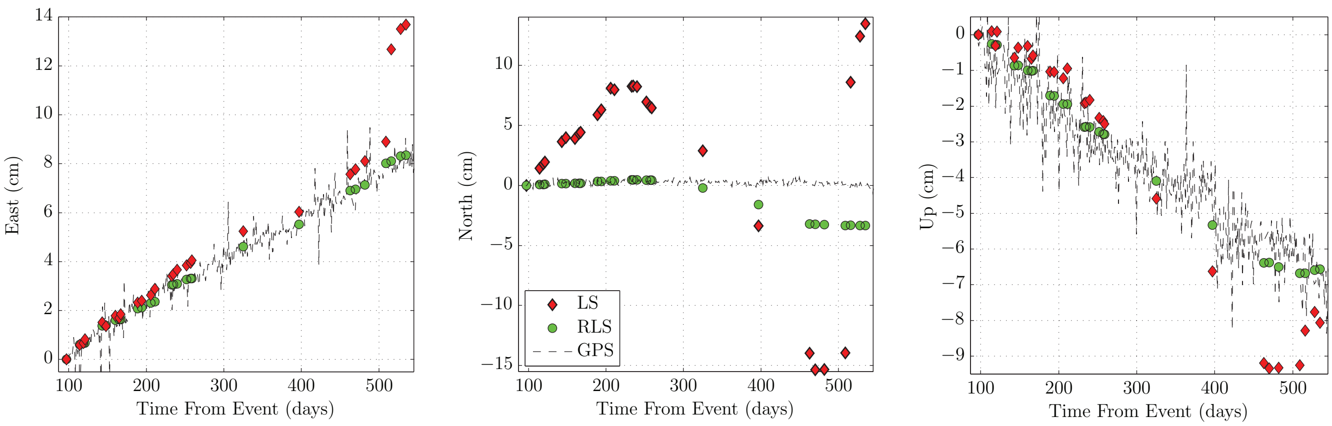


Fig. 1. Comparison of SBAS and GPS time-series at the KOSM GPS station. SBAS results are given for both least squares (LS) and regularized least squares (RLS) inversions.

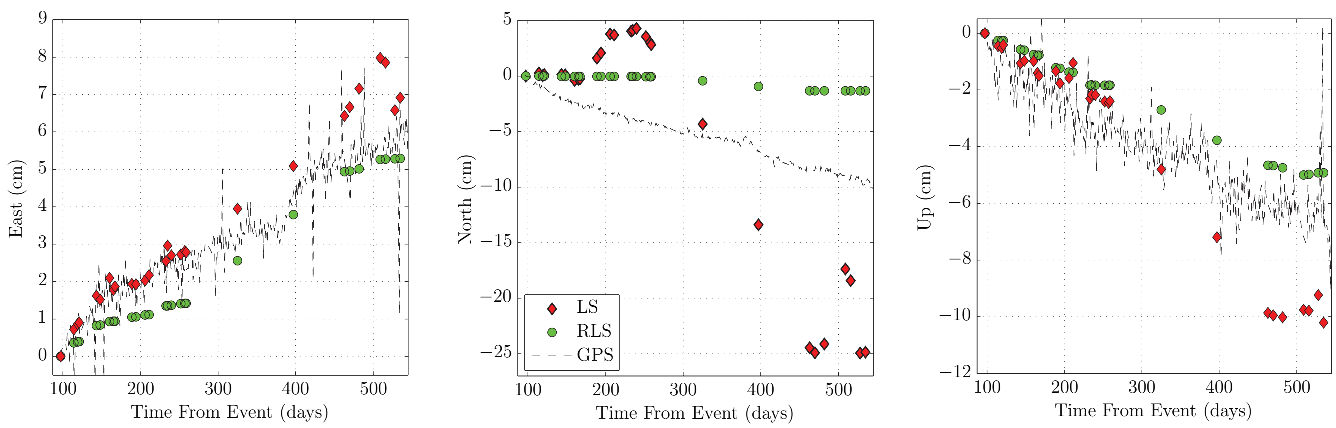
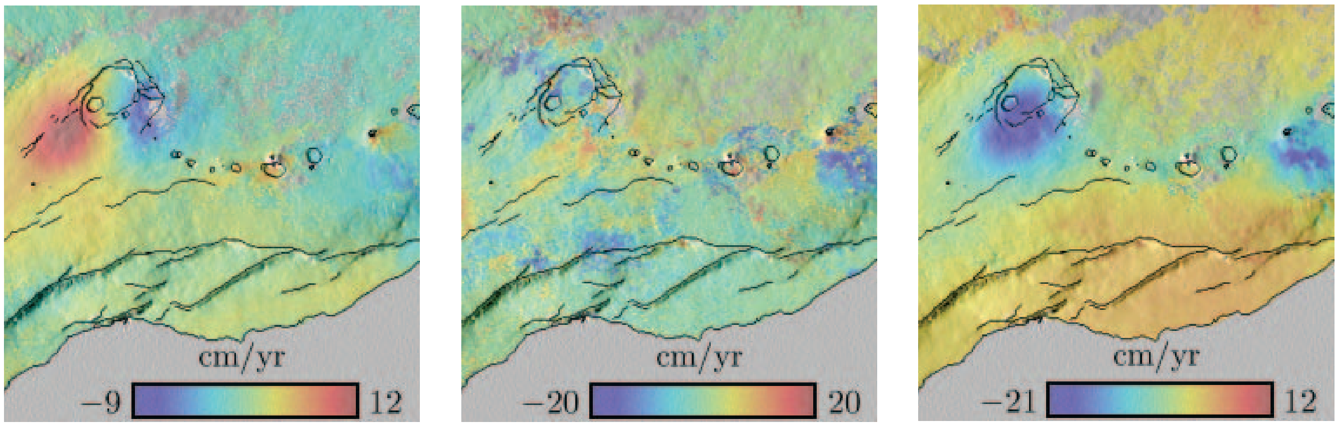


Fig. 2. Comparison of SBAS and GPS time-series at the UWEV GPS station. SBAS results are given for both least squares (LS) and regularized least squares (RLS) inversions.

however, we see a consistent degradation of its accuracy as a function of time. This behavior is a consequence of the number of observations decreasing with throughout the series (e.g., some LOS time-series are longer than others). As the number of observations decreases, the solution becomes more susceptible to noise. In addition, we see large errors in the northern component. Here the InSAR measurements are highly insensitive to the northern deformation, therefore, the solution in largely driven by noise. In general, observation noise is amplified in parts of the model corresponding to small singular values of the linear system. The RLS solution effectively damps these components by placing constraints on the phase norm and velocity. In both figures we see more accurate east and vertical fits to the GPS estimates with the RLS approach. On the other hand, the northern component does not accurately track GPS. We see similar solutions even when the underlying deformation signal is very different. This suggests that the RLS solution is discarding the measured north component in an effort to reduce noise in the other components. These results are further illustrated in Fig. 3, where the northern mean velocities are spurious, indicating little correlation to the expected deformation signal.



(a) East (b) North (c) Up

Fig. 3. Mean velocity estimates in cm/yr for the period spanning 97 to 535 days after the event.

4. CONCLUSIONS

Despite the fact that the system of equations is technically overdetermined, regularization is required to reduce the effects of noise in the initial LOS SBAS inversions because the noise level, especially in the north component, is very high. Thus we achieve high precision (~ 1 cm rms error with respect to GPS estimates) in the east and vertical directions, while the north deformation component is poorly constrained. The observed errors in the north component are systematic, and suggest that the residuals are artifacts of our regularization scheme. Here we analyze these errors, and suggest additional processing steps aimed at retrieving a noisy, but unbiased estimate of the northern deformation. Finally, we propose a vector inversion method that includes both the LOS and azimuth offset observations. This approach is an extension of [3], where we incorporate the azimuth offsets as an additional time-series to further constrain the solutions.

5. REFERENCES

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