Geophysical Research Abstracts
Vol. 18, EGU2016-17867, 2016
EGU General Assembly 2016

Operational GPS Imaging System at Multiple Scales for Earth Science and Monitoring of Geohazards

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Toward scientific targets that range from slow deep Earth processes to geohazard rapid response, our operational GPS data analysis system produces smooth, yet detailed maps of 3-dimensional land motion with respect to our Earth's center of mass at multiple spatio-temporal scales with various latencies. "GPS Imaging" is implemented operationally as a back-end processor to our GPS data processing facility, which uses JPL's GIPSY OASIS II software to produce positions from 14,000 GPS stations in ITRF every 5 minutes, with coordinate precision that gradually improves as latency increases upward from 1 hour to 2 weeks. Our GPS Imaging system then applies sophisticated signal processing and image filtering techniques to generate images of land motion covering our Earth's continents with high levels of robustness, accuracy, spatial resolution, and temporal resolution.

Techniques employed by our GPS Imaging system include: (1) similarity transformation of polyhedron coordinates to ITRF with optional common-mode filtering to enhance local transient signal to noise ratio, (2) a comprehensive database of ~100,000 potential step events based on earthquake catalogs and equipment logs, (3) an automatic, robust, and accurate non-parametric estimator of station velocity that is insensitive to prevalent step discontinuities, outliers, seasonality, and heteroscedasticity; (4) a realistic estimator of velocity error bars based on subsampling statistics; (5) image processing to create a map of land motion that is based on median spatial filtering on the Delauney triangulation, which is effective at despeckling the data while faithfully preserving edge features; (6) a velocity time series estimator to assist identification of transient behavior, such as unloading caused by drought, and (7) a method of integrating InSAR and GPS for fine-scale seamless imaging in ITRF.

Our system is being used to address three main scientific focus areas, including (1) deep Earth processes, (2) anthropogenic lithospheric processes, and (3) dynamic solid Earth events. Our prototype images show that the striking, first-order signal in North America and Europe is large scale uplift and subsidence from mantle flow driven by Glacial Isostatic Adjustment. At regional scales, the images reveal that anthropogenic lithospheric processes can dominate vertical land motion in extended regions, such as the rapid subsidence of California's Central Valley (CV) exacerbated by drought. The Earth's crust is observed to rebound elastically as evidenced by uplift of surrounding mountain ranges. Images also reveal natural uplift of mountains, mantle relaxation associated with earthquakes over the last century, and uplift at plate boundaries driven by interseismic locking. Using the high-rate positions at low latency, earthquake events can be rapidly imaged, modeled, and monitored for afterslip, potential aftershocks, and subsequent deeper relaxation. Thus we are imaging deep Earth processes with unprecedented scope, resolution and accuracy. In addition to supporting these scientific focus areas, the data products are also being used to support the global reference frame (ITRF), and show potential to enhance missions such as GRACE and NISAR by providing complementary information on Earth processes.