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Real-time GNSS Positioning – High-Precision Kinematic Testing

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Abstract

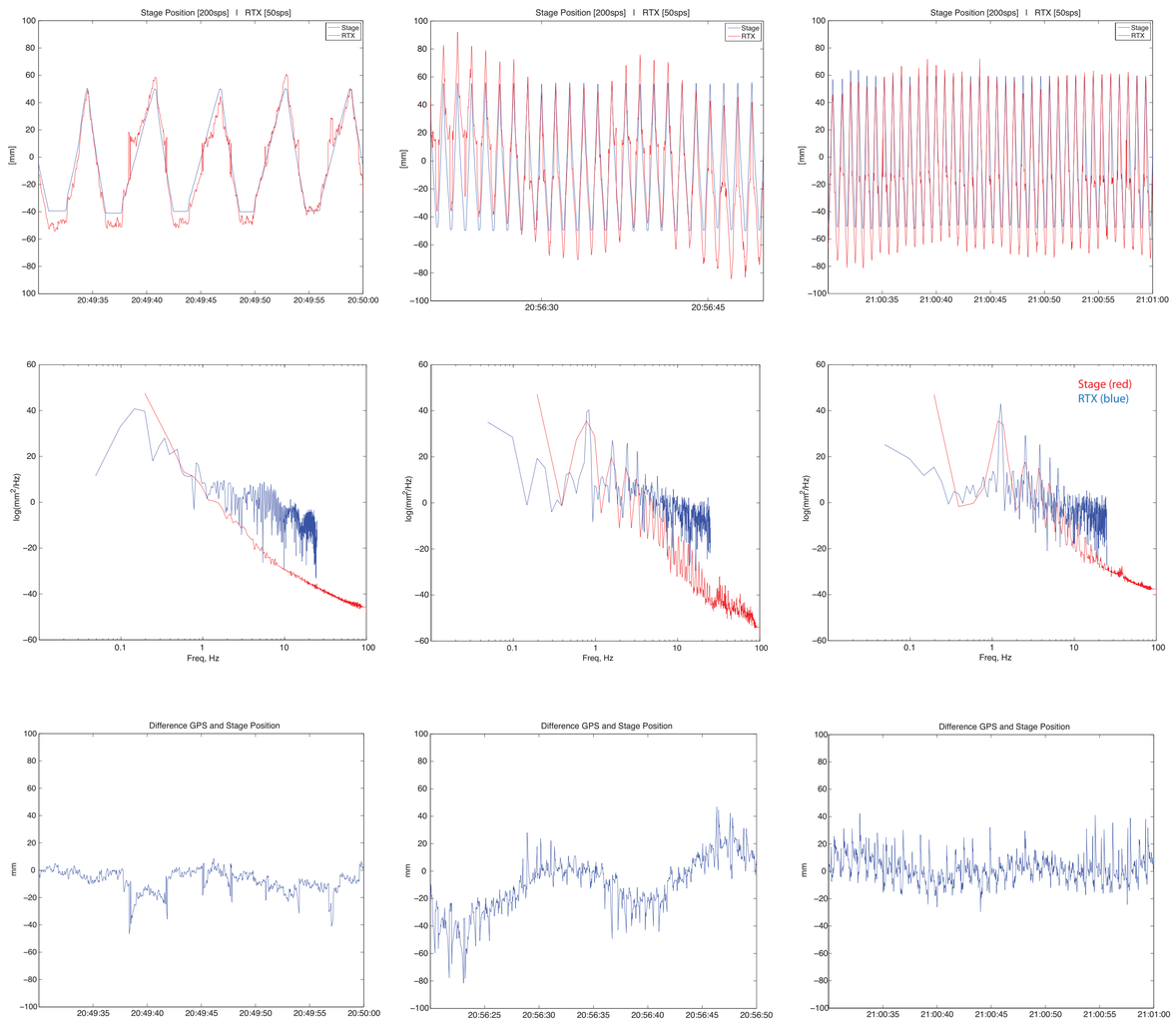
The use of high-rate and real-time GNSS measurements for hazards monitoring and scientific applications is still in its infancy and there is great potential for its integration with strain, gravity and seismic measurements. Many commercial vendors and public agencies now offer real-time positioning services that provide sub-decimeter accuracy, with some approaching the sub-centimeter level. As GNSS network operators begin transitioning into offering real-time products, they will need to consider a number of factors including but not limited to: cost, position accuracy, solution latency, network topology and bandwidth. Periodic evaluation of real-time positioning systems will need to be conducted in order to optimize their integration into hazard-monitoring and multi-disciplinary networks. Controlled outdoor kinematic and static experiments provide a useful method for evaluating real-time systems, helping to identify system limitations, and characterize performance and reliability.

Recently released real-time precise point positioning (PPP) services such as Trimble's RTX promise ~4 cm accuracy with 95% confidence. The RTX positioning client can run onboard a GNSS receiver where it obtains orbit and clock corrections via cellular network or satellite. Trimble's corrections are generated using its proprietary global tracking network. Trimble also offers a RTX server client that collects and processes data streams from multiple receivers, and commercial server-based packages such as RT-Net are also in use. GNSS network operators are currently evaluating both receiver- and server-based types of clients for hazard monitoring applications.

To characterize the kinematic performance of real-time positioning algorithms, UNAVCO has developed a portable low-cost antenna actuator. We have performed tests using controlled 1-d antenna motions and will present comparisons between these and other post-processed kinematic algorithms including GIPSY-OASIS and TRACK. In addition to kinematic testing, long-term static testing of Trimble's RTX service is ongoing at UNAVCO and will be used to characterize the stability of the position time-series produced by RTX. A receiver-based RTX client was enabled at the Plate Boundary Observatory site P041 in June, 2013. Position estimate analysis for this and other PBO stations using the server-based RTX client will be presented for comparison.

Left: A low-cost antenna actuator utilizing a pneumatic cylinder for controlled 1-d antenna motion. The maximum displacement of the staged is limited to ~300mm. Antenna displacement is measured independently from GPS using a Turck linear position sensor. The system is controlled by a Raspberry Pi and a simple micro controller. The precise displacement measurements are logged using a Kinemetrics Basalt Rock data logger.

Kinematic Test Results



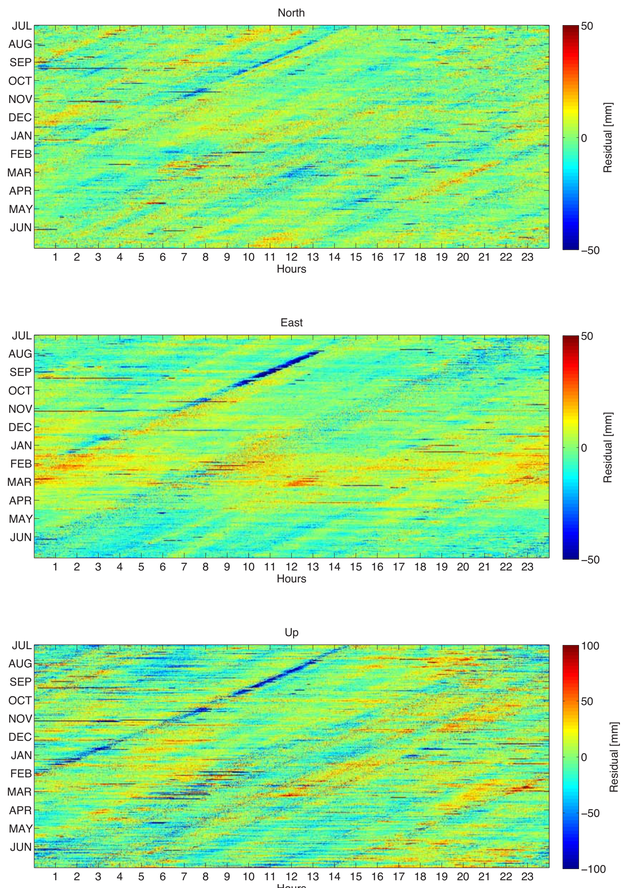
Top: Time series showing horizontal displacement of the test antenna as measured by a receiver with Trimble's receiver based RTX client (red) at 50 sps. The stage position was independently measured at 200 sps (blue). We conducted tests using three different shaking frequencies.

Middle: We used the displacement spectrum to identify the approximate frequency of the shaking. The spectral peaks from left to right are: 0.14, 0.83 and 1.25Hz. Due to the compressibility of air, the testing apparatus does not have tight control over the movement and cannot accurately reproduce a true sinusoidal motion.

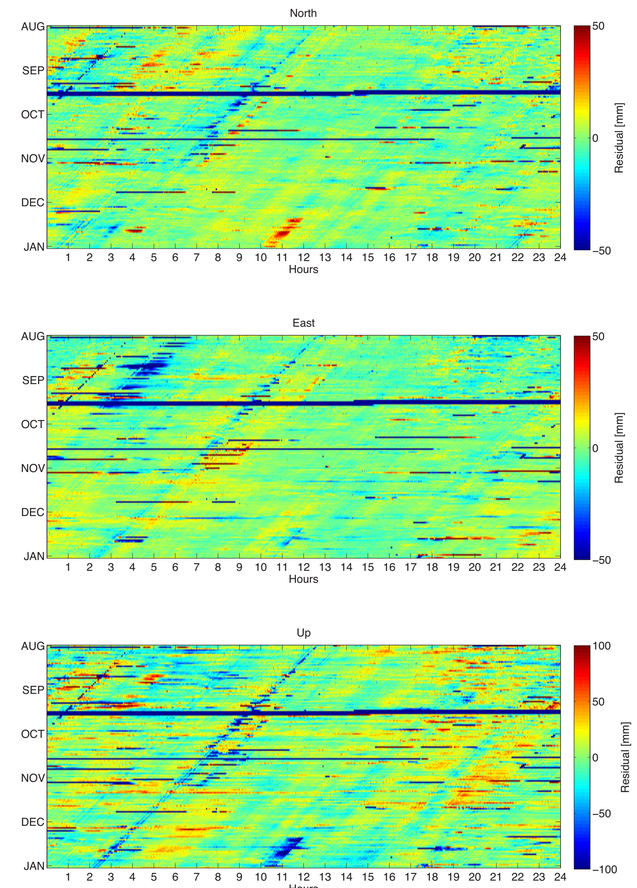
Bottom: The difference between the receiver based RTX client and the independently measured stage position. At 0.83 Hz we observe a low frequency oscillation.

Static Test Results

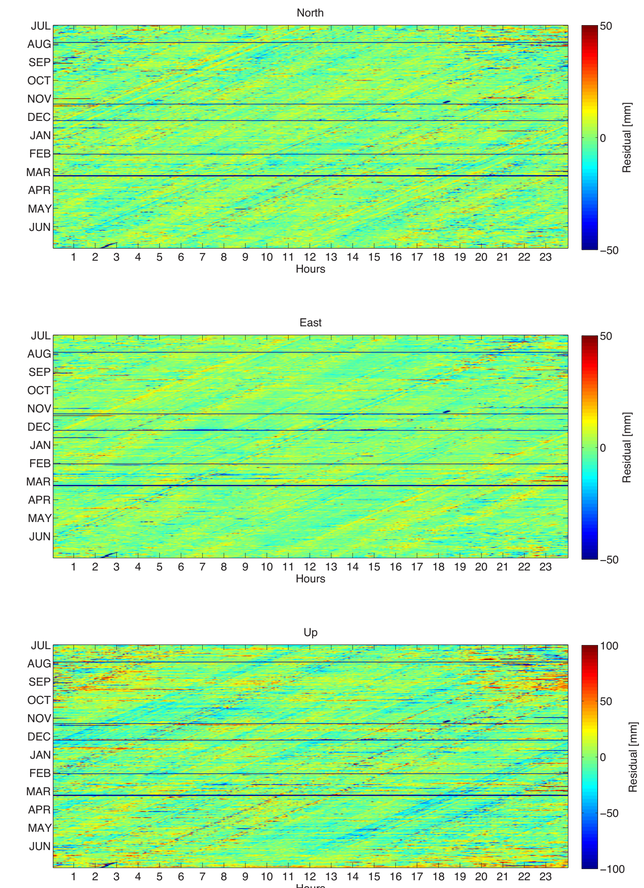
P041 - RTX (RECEIVER)



P041 - RTX (PIVOT)



P041 - GIPSY

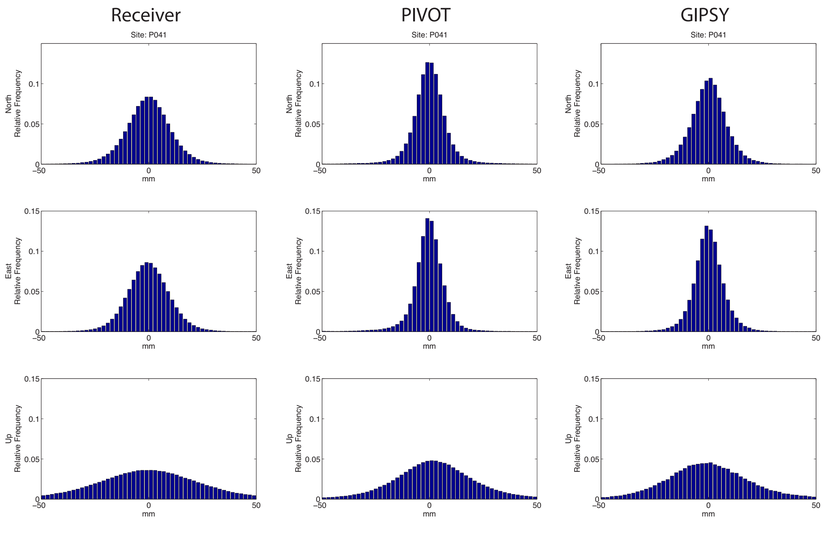


Far Left: Stacked daily time series from Plate Boundary Observatory (PBO) station P041 located in Boulder, CO. A receiver based RTX client was enabled at P041 starting in June of 2013. A linear trend was removed from each component and the residuals are shown in color. Dark blue lines indicates days with missing or incomplete data. The receiver based RTX client receives orbit, clock and wide-lane bias corrections via Trimble's L-band satellite service allowing the receiver to continue position estimation during telemetry outages.

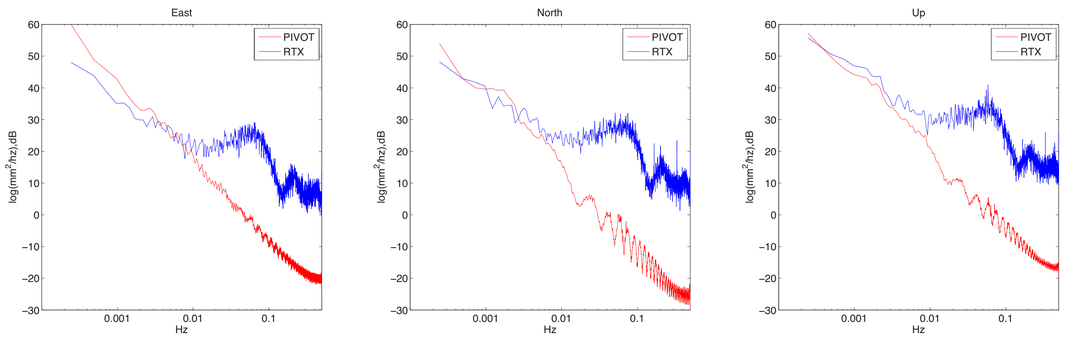
Middle: In August of 2013, UNAVCO began processing telemetered data streams from P041 using Trimble's server based RTX client (PIVOT). Data for P041 were not available after January of 2014. The PIVOT time series exhibits more frequent re-initialization of the PPP solution than the receiver based solution.

Right: Five minute GIPSY solutions for P041 from the University of Nevada Reno for comparison. The diagonal artifacts present in all of the time series are likely related to the sidereal orbits of the GPS constellation. The GPS orbits repeat approximately 4mins earlier each day.

P041 - Histograms



P041 - Periodograms



Above: Power spectral densities were computed at station P041 from four days of data using a 1 hour window overlapping window. The blue line shows the PSD from the receiver based RTX client. The red line shows the PSD from the server based RTX client (PIVOT). The PSD from the PIVOT time series (red) clearly shows the effect of a weighted mean filter. UNAVCO will be testing PIVOT configurations over the next few months and make the necessary adjustments to output unfiltered real-time GPS position products.

Left: Histograms showing the relative frequency of each component after a linear trend has been removed from Each component. The increased peaky-ness of the PIVOT histogram can likely be attributed smoothing from the weighted mean filter.

Discussion

Testing of Trimble's RTX service is ongoing at UNAVCO. These results along with future testing will help to identify the optimal configuration for UNAVCO's real-time service which consists of a subset of sites within the Plate Boundary Observatory GPS network of 1100 stations.

Testing to independently characterize RTX at frequencies and displacements that occur during large earthquakes will continue. Our results suggest that RTX's response, is not frequency independent over seismic frequencies.

In long-term testing at the station P041 the receiver based RTX service has proven to be less prone to re-initialization than it's server based sibling.