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Postseismic Transient after the 2002 Denali Fault Earthquake from VLBI Measurements at Fairbanks

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Abstract

The VLBI antenna (GILCREEK) at Fairbanks, Alaska observes in networks routinely twice a week with operational networks and on additional days with other networks on a more uneven basis. The Fairbanks antenna position is about 150 km north of the Denali fault and from the earthquake epicenter. We examine the transient behavior of the estimated VLBI position during the year following the earthquake to determine how the rate of change of postseismic deformation has changed. This is compared with what is seen in the GPS site position series.

1. Solution Description and Observed Motion at Fairbanks

To investigate the behavior of the position of GILCREEK after the Denali earthquake in November 2002, we modified our standard solution to estimate the GILCREEK position for each epoch (VLBI 24-hour experiment). In a standard terrestrial reference frame solution, we estimate site positions and velocities as global parameters. Ma et al. [1990] gives a description of the VLBI SOLVE analysis program and most of the theoretical models that are generally applied. To remove degeneracies corresponding to invariances of the VLBI group delay observable, no net translation and no net rotation conditions are imposed on station positions and velocities in order to align the terrestrial reference frame with ITRF2000. The standard solution models site episodic motion as a simple offset with the same velocity before and after the episodic event.

After several months of observing after the Denali earthquake, it became apparent that the rate of change of the position of Fairbanks in the horizontal directions after the earthquake was significantly different from the rate before the earthquake. We now have a little more than a year of data since Denali and find that the rates have still not returned to their pre-earthquake values.

In Figures 1, 2, and 3 are shown a recent solution for the local site coordinate series at GILCREEK. The last VLBI data point before the Denali fault earthquake (Nov. 3, 2002) was measured on Oct. 31, 2002 and the first point afterwards was on Nov. 4, 2002. For each series, the offset, rate, and annual terms were estimated using only data prior to the earthquake and then removed from the entire series.

In the plots of horizontal motion in Figures 2-3, we show a fit to the postseismic data using a transient decay model,

$$X(t) = X_0 + X_1[1 - exp(-(t - t_0)/\tau_c)]$$

where t_0 is the epoch of the earthquake. The fits gave characteristic decay times, τ_c, of 1.18 years for the North and 0.32 years for the East. The postseismic amplitudes, X_1, assuming this model were -29 mm in the North and 10 mm in the East. Coseismic offsets, X_0, were -56 mm and 23

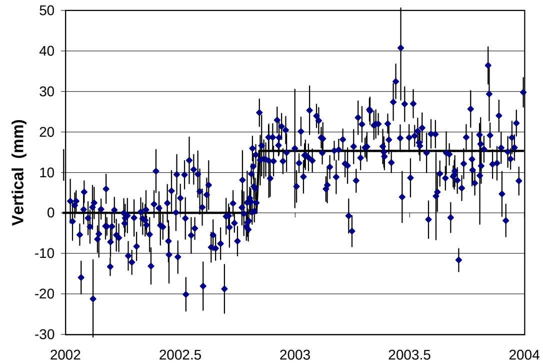

Figure 1. VLBI Fairbanks vertical position time series. Offsets, linear rates, and annual terms were estimated from data before the earthquake and then removed from the series. The episodic site adjustment is shown with a solid line.

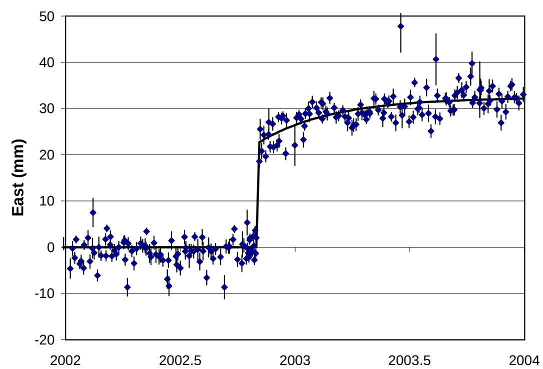

Figure 2. VLBI Fairbanks east position time series. Offsets, linear rates, and annual terms were estimated from data before the earthquake and then removed from the series. The transient decay model fit to the data after the earthquake is indicated by the solid line.

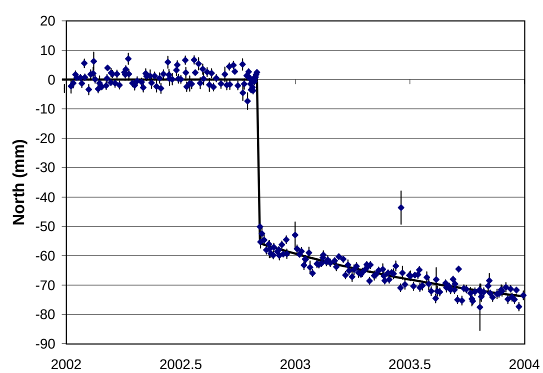

Figure 3. VLBI Fairbanks north position time series and the corresponding transient decay model (solid line)

mm for North and East respectively. The average rates of change over the year following the earthquake are about -16 mm/yr in the North and about 8 mm/yr in the East. It is possible that some of the deviations from the model are systematic and indicate that a more complicated model is needed but this will require further investigation.

2. GPS Comparisons

We have compared the postseismic trends from VLBI and GPS measurements. Here we show the operational JPL series from the web site maintained by Mike Heflin [Heflin, 2004]. To compare the GPS and VLBI series, offsets, rates, and annual terms were estimated from data before the earthquake and removed from each entire series. The observed precision (wrms residual motion) of the GPS series (4.9 mm for East and 4.1 mm for North) is not as good as for VLBI (3.0 mm for East and 3.1 mm for North). Looking at Figure 4 there is reasonably good agreement between the trends of the two series after the earthquake although there appear to be some possible systematic differences in the first several months of the East motion series.

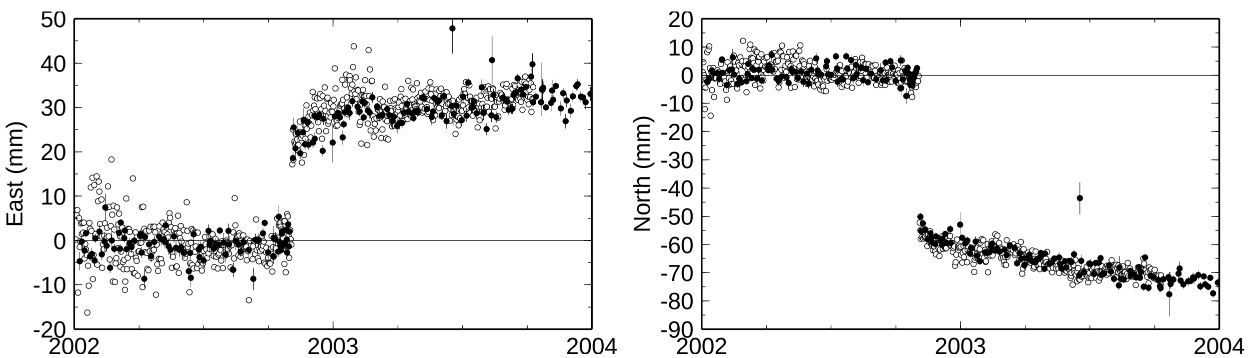

Figure 4. Comparison of VLBI (black circles with error bars) and GPS (open black circles) motion at Fairbanks. Error bars for GPS (not shown) are 3-4 mm. The GPS series is from JPL [Heflin, 2004].

3. EOP Errors from Fairbanks Motion

If the postseismic behavior of Fairbanks is not modeled in a VLBI terrestrial reference frame solution, EOP estimates will exhibit systematic errors. We show the effect in Figures 5- 7 of not modeling the post-seismic behavior at Fairbanks for the R1 sessions. The figures show the difference between a solution where there was no Fairbanks model and one where the above transient model was applied. For polar motion, we can make comparisons with GPS IGS series to evaluate the model. For the period of time after the earthquake, modeling reduced the WRMS X-pole difference from 130 μas to 115 μas and the WRMS Y-pole difference from 127 μas to 113 μas.

4. Discussion

The frequent measurement of geodetic site positions allows one to investigate geophysical effects on time scales of weeks to months to years. At GPS sites that are closer to the Denali fault the postseismic change is similar but much larger than for Fairbanks and the exponential decay trend is more clear. At Fairbanks, it will probably take a year or two to discern the true postseismic trend.

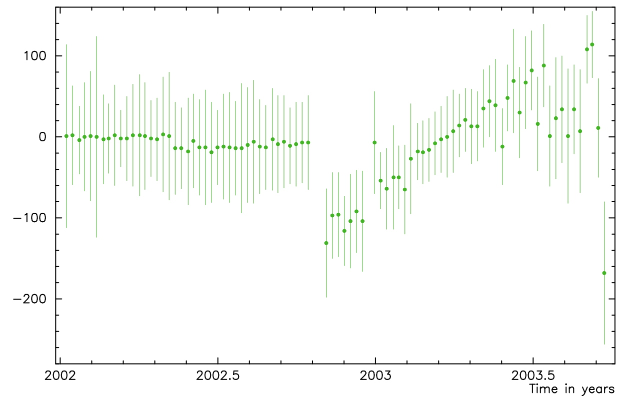

Figure 5. Effect on x-pole estimates (μas) from the R1 series of experiments when the transient behavior at Fairbanks is not modeled. The model used is the one shown in Figures 2-3.

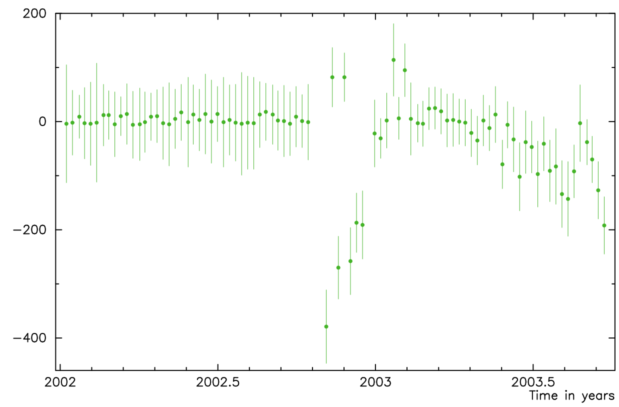

Figure 6. Same as Figure 5 except here the effect on y-pole (μas) is shown.

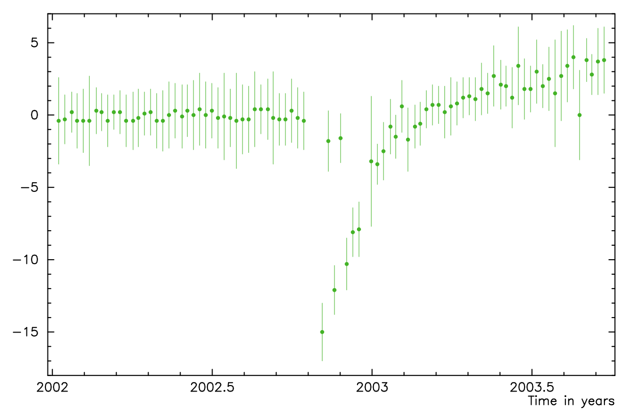

Figure 7. Same as for Figure 5 except here the effect on UT1 (μs) is shown.

At this point, eastward motion at Fairbanks appears to have nearly returned to the long-term pre-earthquake rate. Immediately after the earthquake, it was 31.2 mm/yr relative to the long-term rate (-9.1 mm/yr). Relative to the long-term rate (-22.4 mm/yr) before the earthquake, the current northward motion is about -9 mm/yr compared to the initial relative rate of -24.5 mm/yr. The rate of change at Fairbanks appears to begin immediately after the earthquake suggesting that the postseismic deformation is controlled by the coseismic stress change. We have no evidence to suggest a diffusing signal that first arrives at the observing site with a time offset delay from the earthquake occurrence.

References

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