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Global Positioning System Reobservations over the Eastern United States Strain Monitoring Network

Prepared by
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National Geodetic Survey
National Oceanic and Atmospheric Administration

Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

In the period March-May, 1990, a 45 station geodetic network, originally established in November-December, 1987, was reobserved using global positioning system (GPS) technology. This network, known as the Eastern U. S. Strain Network, was established for the purpose of determining strain and deformation in the central and eastern United States. This 1990 reobservation was the first of a series of reobservations scheduled to take place over a decade in order to place meaningful constraints on the small differential movements involved.

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INTRODUCTION

During the period 9 March to 21 May, 1990, the National Geodetic Survey (NGS) performed reobservations of a Global Position System (GPS) network originally established in 1987. This network, designated the Eastern U. S. Strain Network, spans the United States east of 105° west longitude (Figure 1). The network was established in support of the Nuclear Regulatory Commission (NRC) for the purpose of monitoring crustal strain deformation. The 1990 reobservations are the first of a series of reobservations planned to span a period of a decade or more. Such long term monitoring is required because likely strain rates are very small and strain determinations accurate to about $1:10^8$ are desired.

Results of the initial 1987 survey were reported by Strange (1981). This report provides the results of the 1990 reobservations. Although some comparisons are made between the 1987 and 1990 surveys to evaluate the accuracies being achieved, no attempt is made to estimate strain rates. The time period between the two sets of observations of no more than 2.5 years is too short to allow meaningful strain estimates using only these two sets of determinations. Following a third set of observations in the late 1992 to late 1993 time frame there will be a separation of 5 to 6 years between observations and meaningful initial estimates of upper bounds can be placed on strain rates. However, it is still believed that a full decade of monitoring will be required to achieve the $1:10^8$ level.

DESCRIPTION OF THE REOBSERVATION SURVEY

The Eastern U. S. Strain Network reobservation survey was planned and performed as an eleven (11) week effort by an observing team using five (5) Trimble SST receivers. During each weekly period, the team occupied five stations for a 5.5 hour session on three days. Each weekly period extended from Wednesday of one week through Tuesday of the following week. On Wednesday the observers traveled to the site. On Thursday arrangements were made and the site identified. Actual observations were performed on Friday, Monday, and Tuesday. The observations were planned to extend across the weekend in order to have additional time between observations. This was desirable to achieve maximum variability in weather conditions. The eleven sets of observations were tied together by having at least one station in every weekly station set included in another station set. Table 1 lists the stations observed and gives a set of abbreviated ID-codes which are used in the remainder of this report. The location of the stations is shown in Figure 1.

Table 2 gives the observation schedule undertaken by the National Geodetic Survey field team. During week 5, the Texas Department of Transportation co-observed at four stations. During week 6,

EASTERN US STRAIN NETWORK

1990 OBSERVATIONS

NATIONAL GEODETIC SURVEY
PROJECT DEVELOPMENT BRANCH
MAY 1996

the New Mexico Highway Department co-observed at three stations. These co-observations are summarized in Table 3. The purpose of scheduling three days of observations was to assure that even if something went wrong on one day, there would be at least two successful sets of observations at each station to achieve redundancy. This was achieved. Of the 165 station occupations planned, the field team achieved a 95% success rate. Of the eight station occupations that were unsuccessful, five involved stations that were observed in more than one weekly period so that only three of the stations occupied by the NGS field teams had less than three successful occupations. These stations were Hyde, Ays 2, and Westford (OCP3). In the case of Westford (OCP3), the observations from the Westford CIGNET station were used to support orbit adjustment. Since Westford CIGNET station and OCP3 are strongly connected, the Westford site was represented by numerous observations.

During the 1990 reobservation campaign, all but four of the stations observed during the original 1987 survey were re-occupied. In two of these four cases, another point which has been closely tied to the original station was observed at the site. Thus, there should be negligible loss of accuracy at these sites from changing stations. At Richmond, Florida, data was used from the Richmond CIGNET antenna rather than a receiver placed over the ground monument, TIMER. These have been accurately connected with local GPS surveys. At Ft. Davis, Texas, the monument Harvard RM 3 was occupied, rather than the monument Harvard RM 4 which was occupied in 1987. This was done because Harvard RM 4 was not available for occupation. However, these two monuments have been interconnected at the few millimeter level using ground survey.

The original station occupied at Lubbock had been destroyed, and a new station established by the Texas Department of Transportation at the site was occupied. At the time of the 1990 survey, it had not been possible to reduce the data from station Bravo near Minneapolis, Minnesota. It was feared that the cause of the problem was interference from active radar units at the site, which was on a military base. Therefore, it was decided to move to a nearby site at Riverside, Wisconsin, which was a part of the Wisconsin High Accuracy Reference Network. Subsequent to the 1990 survey, a way was found to process the 1987 data from station Bravo, and it is no longer believed that the problem was active radars. During future surveys, it is anticipated that both Bravo and Riverside will be occupied.

In addition to the data observed by the field teams, data taken by stations of the Cooperative International GPS Network (CIGNET) located at Westford, Massachusetts; Richmond, Florida; and Mojave, California were used to support satellite orbit adjustment during the reduction phase. The stations were occupied by Minimax receivers.

TABLE 1
STATIONS OBSERVED

STATION NAME	ID-CODE	STATE OF LOCATION
ALBERG	ALBU	VERMONT
AMARILLO	AMAR	TEXAS
ARP2	ARP2	NEW YORK
ASHCOPORT	ASHC	OHIO
ASTRO	ASTW	VIRGINIA
AUSTIN	AUST	TEXAS
BEARTOWN	BEAR	PENNSYLVANIA
BEAUMONT	BEAU	TEXAS
BLOOMINGTON	BLOO	INDIANA
BLUFFPORT	BLUF	MISSOURI
BOLTON	BOLT	OHIO
BRINKLEY	BRIN	ARKANSAS
BRONSON	BRON	MISSISSIPPI
CHEYENNE	1169	WYOMING
EL PASO	ELPA	TEXAS
FARM	FARM	LOUISIANA
FLNR	FLNR	FLORIDA
FREEMAN	FREE	MICHIGAN
FT DAVIS 2	HAR3	TEXAS
FUTRELL	FUTZ	NORTH CAROLINA
GPS37	GP37	TENNESSEE
GPS47	GP47	TENNESSEE
GPS57	GP57	TENNESSEE
GREENBANK	T007	WEST VIRGINIA
HAPGOOD	HAGO	SOUTH CAROLINA
K169	K169	MAINE
LAS CRUCES	LACR	NEW MEXICO
LEONARD	LEON	OKLAHOMA

STATION NAME	ID-CODE	STATE OF LOCATION
LIME	LIME	MAINE
LINCOLN	LINC	NEBRASKA
LUBBOCK 2	LUB2	TEXAS
MARYLAND POINT	MDPT	MARYLAND
MCDAVID	MCDA	FLORIDA
MILES CITY	MILE	MONTANA
NEW CARROLLTON	CARR	GEORGIA
NMB1	NMB1	NEW MEXICO
NORTH LIBERTY	NOLI	IOWA
ODESSA	ODES	TEXAS
PIERRE	HYDE	SOUTH DAKOTA
PLATTVILLE	PLAT	COLORADO
PRINCETON	PRIN	NEW JERSEY
RICHMOND CIGNET	RICH	FLORIDA
RIVERSIDE	RIVR	WISCONSIN
ROCK	ROCK	WISCONSIN
ROSWELL	ROSW	NEW MEXICO
STANPORT	STAN	KENTUCKY
STATESPORT	STAT	NORTH CAROLINA
TAOS	TAOS	NEW MEXICO
WALTPORT	WALT	SOUTH CAROLINA
WESTFORD	OCP3	MASSACHUSETTS
WILLIAMSON	WILL	ILLINOIS

TABLE 2
FINAL OBSERVING SCHEDULE
FIELD TEAM GPS RECEIVERS

OBSERVING WEEK	DAY	STATIONS OCCUPIED (FOUR CHARACTER ID-CODE)				
1	68	MCDA	CARR	FLNR	FARM	BRON
	71	MCDA	CARR	FLNR	FARM	BRON
	72	MCDA	CARR	FLNR	FARM	BRON
2	75	STAT	CARR	WALT	FUTZ	HAGO
	78	STAT	CARR	WALT	FUTZ	HAGO
	79	STAT	CARR	WALT	FUTZ	HAGO
3	82	GP57	CARR	GP37	(1)	GP47
	85	GP57	CARR	GP37	BRIN	GP47
	86	GP57	CARR	GP37	BRIN	GP47
4	89	WILL	LEON	BLUF	BRIN	GP47
	92	WILL	LEON	BLUF	BRIN	GP47
	93	WILL	LEON	BLUF	BRIN	GP47
5	96	(2)	LEON	AMAR	AUST	ODES
	99	FARM	LEON	AMAR	AUST	ODES
	100	FARM	LEON	AMAR	AUST	ODES
6	103	(3)	1169	AMAR	NMBI	ODES
	106	PLAT	1169	AMAR	NMBI	ODES
	107	PLAT	1169	AMAR	NMBI	ODES
7	110	PLAT	MILE	HYDE	LINC	RIVE
	113	PLAT	MILE	(2)	LINC	RIVE
	114	PLAT	MILE	HYDE	LINC	RIVE
8	117	WILL	BLOO	FREE	NOLI	ROCK
	119	WILL	BLOO	FREE	NOLI	ROCK
	120	WILL	BLOO	FREE	NOLI	ROCK
9	123	STAN	BLOO	BOLT	(1)	ASHC
	126	STAN	BLOO	BOLT	T007	ASHC
	127	STAN	BLOO	BOLT	T007	ASHC

OBSERVING WEEK	DAY	STATIONS OCCUPIED (FOUR CHARACTER ID-CODE)				
10	130	PRIN	ASTW	MDPT	TOO7	BEAR
	133	PRIN	ASTW	MDPT	TOO7	BEAR
	134	PRIN	ASTW	MDPT	(4)	BEAR
11	137	ARP2	K169	LIME	ALBU	OCP3
	140	ARP2	K169	LIME	ALBU	OCP3
	141	(1)	K169	LIME	ALBU	(5)

- (1) Instrument problems
- (2) Session aborted due to lightning danger
- (3) Unexpected locked gate prevented access
- (4) Operator illness prevented observations
- (5) Station already occupied by other group

TABLE 3
CO-OBSERVATIONS BY OTHER ORGANIZATIONS

OBSERVING WEEK	DAY	STATIONS OCCUPIED (FOUR CHARACTER ID-CODE)			
5	99	ELPA	LUB2	BEAU	HRM3
	100	ELPA	LUB2	BEAU	HRM3
6	103	TAOS	LACR	ROSW	
	106	TAOS	LACR	ROSW	
	107	TAOS	LACR	ROSW	

DATA REDUCTION

As was the case with the original 1987 survey, data reduction was performed using the OMNI reduction program with simultaneous solution for differential station positions and improved satellite orbital elements. Using this procedure, the positions of at least two, and preferably three, stations, in addition to the reference station, must be held fixed to allow the orbital improvement to be performed. This was accomplished by including in the reductions data from the three CIGNET stations which are co-located with Very Long Baseline Interferometry (VLBI) stations that monitor time variation of positions.

The preferred solution mode was to use one of the stations occupied by the field team as the reference station for a solution and to hold fixed the positions of the CIGNET stations so that they could serve as fiducial stations. The parameters solved for were then: differential positions between the reference station and the other field stations, corrections to the satellite orbital elements, a tropospheric refraction parameter for each station, and initial satellite integer constants. The station chosen for the reference station for a session was, wherever possible, a station that had previously been occupied by GPS.

Because of failures of equipment at the CIGNET stations, it was not always possible to process the results as originally planned. There were a total of 33 observing sessions. Of these, 17 sessions could be processed using data from all three CIGNET stations. An additional seven sessions could be processed using data from two of the three CIGNET stations. Of the remaining nine sessions, five sessions were processed using one CIGNET station and using one of the stations occupied by a field receiver to act as a fiducial station. Four sessions could not be processed because none of the CIGNET stations had usable data. Table 4 gives the reference station and fiducial stations used in processing each session.

In three of the five instances where a field receiver was used as a fiducial station, the receiver was co-located at a station with repeat VLBI measurements which could provide a means of defining station motion. This was the case when using Harvard RM 3 located at Ft. Davis, Texas, as a fiducial station for days 99 and 100, and when using the Platville station on day 106. In the case of the use of station Farm on days 68 and 71, the position for Farm derived for reductions of days 96, 99, and 100 where a position for Farm was computed.

TABLE 4
REFERENCE AND FIDUCIAL STATIONS
USED IN DATA REDUCTION

DAY	REFERENCE STATION	FIDUCIAL STATIONS
68	CARROLLTON	MOJAVE, FARM
71	RICHMOND	MOJAVE, FARM
72	CARROLLTON	RICHMOND, MOJAVE
75	NOT PROCESSED	
78	CARROLLTON	RICHMOND, WESTFORD
79	CARROLLTON	RICHMOND, WESTFORD, MOJAVE
82	CARROLLTON	RICHMOND, WESTFORD, MOJAVE
85	CARROLLTON	RICHMOND, WESTFORD, MOJAVE
86	CARROLLTON	RICHMOND, WESTFORD, MOJAVE
89	NOT PROCESSED	
92	LEONARD	RICHMOND, WESTFORD, MOJAVE
93	LEONARD	RICHMOND, WESTFORD, MOJAVE
96	LEONARD	RICHMOND, WESTFORD
99	LEONARD	FT. DAVIS, MOJAVE
100	LEONARD	FT. DAVIS, MOJAVE
103	NMBI	RICHMOND, MOJAVE
106	NMBI	MOJAVE, PLATTVILLE
107	PLATTVILLE	RICHMOND, MOJAVE
110	PLATTVILLE	MOJAVE, RICHMOND, WESTFORD
113	PLATTVILLE	MOJAVE, RICHMOND, WESTFORD
114	PLATTVILLE	MOJAVE, RICHMOND, WESTFORD
117	BLOOMINGTON	MOJAVE, RICHMOND, WESTFORD
119	NOT PROCESSED	
120	BLOOMINGTON	MOJAVE, RICHMOND, WESTFORD
123	BLOOMINGTON	MOJAVE, RICHMOND, WESTFORD
126	BLOOMINGTON	MOJAVE, RICHMOND, WESTFORD
127	BLOOMINGTON GREEN BANK	MOJAVE, RICHMOND, WESTFORD
130	TO07	MOJAVE, RICHMOND, WESTFORD

DAY	REFERENCE STATION	FIDUCIAL STATIONS
133	MARYLAND POINT	MOJAVE, WESTFORD
134	MARYLAND POINT	MOJAVE, RICHMOND, WESTFORD
137	HAYSTACK OCP3	MOJAVE, RICHMOND
140	HAYSTACK OCP3	MOJAVE, RICHMOND, WESTFORD
141	NOT PROCESSED	

PRESENTATION AND DISCUSSION OF RESULTS

Table 5 presents the final results of the data reductions in the form of differential vectors between stations. The differential vectors are presented in the form of Δx , Δy , Δz . It is premature to try to determine strains from two sets of data (the 1987 and 1990 surveys) which are only about 2.5 years apart in time. However, it is worthwhile to perform some comparisons to evaluate the accuracy being achieved and the level of accuracy to be anticipated for strain determinations over a time period of 5 to 6 years (i.e. following the next set of observations) and from a full decade of observations.

The most meaningful parameter to use in evaluating deformation over the time periods 1987 to 1993 (and 1987 to 1997) will be changes in the length of interstation vectors. This is true for two reasons. First, the greatest interest in the monitoring of the eastern United States is strain as determined from changes in differential horizontal position between stations. The use of interstation vector length largely eliminates the effects of errors in the station height determination, the most weakly determined parameter. Second, the use of interstation vector length eliminates the impact of small coordinate system translations and rotations on the results. This is important because the maintaining of exact coordinate system agreement over a decade will be very difficult. This is particularly the case with the 1987 and 1990 surveys where orbit adjustments are necessary and different sets of fiducial stations are, of necessity, used in data reduction. Therefore, the comments which follow are based on comparisons of interstation vector lengths.

Table 6 presents comparisons of interstation vector lengths for the repeat differential positions presented in Table 5. Results are presented for 42 baselines. For the 1990 results given in Table 6, the maximum spread in repeat baseline length determinations is less than 6 cm for 80 percent of the baselines. In no case does the maximum spread exceed 9.5 cm. In four of the eight instances where the maximum spread exceeds 6 cm, there are three determinations with two of the three agreeing rather closely and the other being the outlier. The degree of baseline repeatability in the raw results suggests that, with careful examination of a few outliers so that they can be either rejected or improved, the lengths of 90 percent of the baselines can be determined to the 2 or 3 cm accuracy level.

Another way to evaluate accuracy is to compare 1987 and 1990 results. While the time interval is not adequate to give definitive strain rate estimates, comparisons of determinations at the two epochs can give another measure of accuracy for baselines. Geophysical considerations and measurements using VLBI lead to the expectation that strain deformation in the

eastern United States is not in excess of a few parts in 10^8 per year at most. Thus differences of no more than a few centimeters between the 1987 and 1990 determinations for baselines in the 200 to 500 km length range would be expected.

Table 7 gives a comparison of mean baseline lengths for the 1987 and 1990 determinations. The ten baselines used in this table are baselines which were directly measured in both 1987 and 1990, as contrasted to baselines derived indirectly from differencing the positions measured for two stations. The differences between 1987 and 1990 mean values shown in Table 7 are compatible with strain rate determinations at the few parts in 10^8 per year level over an 8- to 10-year period, the approximate planned duration of this experiment. The only excessively large difference between means is the 8.3 cm value for the CARR to GPS57 baseline. As may be seen from Table 7, this is the result of a single bad baseline estimate made in 1987. Thus 50 of the 51 baseline determinations shown in Table 7 are accurate enough to support satisfactory strain rate determinations.

With four epochs of measurement planned for this experiment, there should be no problem in identifying and eliminating a small percentage of outliers to provide satisfactory strain rate estimates. This is particularly true because extremely accurate orbit data will be available for the remaining two observation epochs of the experiment. Therefore, it will not be necessary to depend upon the availability of local reference station data to perform orbit adjustments simultaneously with the station position estimates. The availability of the accurate orbits will substantially increase the accuracy of baseline computations for the final two epochs of baseline determination.

TABLE 5
REDUCTION RESULTS

WEEK	DAY	REF STATION	TO STATIONS	$\Delta x(m)$	$\Delta y(m)$	$\Delta z(m)$
1	68	CARR	BRON	-435970.351	-154538.705	-213230.574
			FLNR	-286920.801	-201553.264	-377739.176
			MCDA	-199338.446	-173021.971	-253637.899
1	71	RICH	FLNR	-220868.022	172015.616	388929.287
			MCDA	-707127.252	200546.941	513030.578
1	72	CARR	BRON	-435970.381	-154538.705	-213230.574
			FLNR	286920.736	-201553.326	-377739.117
			MCDA	-199338.492	-173022.003	-253637.836
2	78	CARR	FUTZ	688822.530	291811.543	260141.028
			HAGO	413003.579	82268.953	44541.547
			STAT	361347.455	183436.195	199934.128
			WALT	418229.401	12661.306	-60577.349
3	82	CARR	GP37	-20567.118	125311.746	183532.780
			GP47	-415958.350	107988.379	184110.356
			GP57	-316900.387	84874.637	149432.615
	85	CARR	GP37	-20567.151	125311.826	183532.797
			GP47	-415958.398	107988.464	184110.333
			GP57	-316900.439	84874.730	149432.590
			BRIN	-560903.993	63771.881	120106.265
3	86	CARR	GP37	-20567.057	125311.797	183532.748
			GP47	-415958.348	107988.389	184110.320
			GP57	-316900.391	84874.714	149432.562
			BRIN	-560903.975	63771.859	120106.234
4	92	LEON	WILL	609095.185	96759.752	163309.382
			BLUF	493309.487	30169.587	76571.151
			BRIN	414848.247	-91058.052	-92838.653

WEEK	DAY	REF STATION	TO STATIONS	$\Delta x(m)$	$\Delta y(m)$	$\Delta z(m)$
			GP47	559793.842	-46841.487	-28834.579
4	93	LEON	WILL	609095.282	96759.858	163309.326
			BLUF	493309.558	30169.669	76571.107
			BRIN	414848.266	-91057.993	92838.696
			GP47	559793.876	-46841.411	-28834.617
5	96	LEON	FARM	235938.318	-215932.745	-288898.924
			AMAR	-549575.584	39130.404	-62462.612
			AUST	-215562.207	-314215.333	-517161.865
			ODES	-634211.095	-151658.218	-371002.674
5	99	LEON	FARM	235938.363	-215932.883	-288898.875
			AMAR	-549575.595	39130.463	-62462.599
			AUST	-215562.219	-314215.371	-517161.873
			ODES	-634211.109	-151658.192	-371002.713
			ELPA	-1026233.150	-49841.209	-369310.607
			LUB2	-566732.012	-65111.858	-217047.646
			BEAU	119995.755	-358948.042	-534359.378
5	100	LEON	FARM	235938.390	-215932.836	-288898.904
			AMAR	-549575.584	39130.563	-62462.701
			AUST	-215562.162	-314215.439	-517161.849
			ODES	-634211.090	-151658.107	-371002.773
			ELPA	-1026233.140	-49841.159	-369310.625
			LUB2	-566731.996	-65111.815	-217047.670
			BEAU	119995.804	-358947.989	-534359.443
6	103	NMBI	1169	260439.597	359657.453	532315.560
			AMAR	423350.886	-95770.610	15129.116
			ODES	338715.408	-286559.261	-293411.033
			TAOS	107614.291	64169.020	128104.905
			LACR	-76273.045	-154005.010	-254957.548

WEEK	DAY	REF STATION	TO STATIONS	$\Delta x(m)$	$\Delta y(m)$	$\Delta z(m)$
			ROSW	156081.928	-154592.635	-158515.178
			PLAT	254449.950	290321.409	451921.029
6	106	NMBI	1169	260439.671	359657.322	532315.549
			AMAR	423350.876	-95770.760	15129.176
			ODES	338715.358	-286559.379	-293410.915
			TAOS	107614.304	64168.942	128104.936
			LACR	-76273.115	-154005.044	-254957.471
			ROSW	156081.898	-154592.734	-158515.089
6	107	PLAT	1169	5989.728	69335.918	80394.515
			AMAR	168900.966	-386092.024	-436791.943
			LACR	-330723.028	-444326.386	-706878.562
			NMBI	-254449.941	-290321.366	-451921.064
			ODES	84265.405	-576880.673	-745332.019
			ROSW	-98368.045	-444914.056	-610436.181
			TAOS	-146835.629	-226152.425	-323816.132
7	110	PLAT	MILE	36266.759	481231.239	501773.271
			HYDE	423401.235	228184.733	344677.185
			LINC	675642.872	-84658.180	48084.051
			RIVR	1062987.820	289824.434	475136.510
	113	PLAT	MILE	36266.751	481231.279	501773.235
			LINC	675642.848	-84658.245	48084.112
			RIVR	1062987.830	289824.423	475136.500
	114	PLAT	MILE	36266.759	481231.265	501773.229
			HYDE	423401.214	228184.740	344677.169
			LINC	675642.840	-84658.220	48084.094
			RIVR	1062987.820	289824.411	475136.509
8	117	BLOO	ROCK	-261867.087	284935.532	336057.573
			NOLI	-433296.753	179440.398	218980.223

WEEK	DAY	REF STATION	TO STATIONS	$\Delta x(m)$	$\Delta y(m)$	$\Delta z(m)$
			WILL	-215520.797	-107218.039	-124446.720
			FREE	174536.657	334051.090	362012.295
8	120	BLOM	ROCK	-261867.095	284935.538	336057.534
			NOLI	-433296.778	179440.378	218980.206
			WILL	-215520.838	-107218.109	-124446.680
			FREE	174536.646	334051.029	362012.318
9	123	BLOM	ASHC	467367.129	240807.852	219663.688
			BOLT	281755.427	76017.056	60999.398
			STAN	238231.602	-72094.038	-115579.095
	126	BLOM	ASHC	467367.129	240807.850	219663.711
			BOLT	281755.413	76017.081	60999.445
			STAN	238231.604	-72094.035	-115579.074
			TOO7	580839.192	17256.075	-63841.308
	127	BLOM	ASHC	467367.152	240807.792	219663.753
			BOLT	281755.432	76017.056	60999.449
			STAN	238231.607	-72094.089	-115579.050
			TOO7	580839.213	17256.113	-63841.349
10	130	TOO7	MDPT	227234.678	41469.951	-6062.185
			PRIN	403312.204	233522.102	167720.849
			ASTW	213824.375	27198.711	-20952.397
			BEAR	297893.633	182318.816	141178.767
	133	MDPT	TOO7	-223336.189	-41470.015	6062.177
			PRIN	179975.903	192052.186	173783.006
			ASTW	-9511.893	-14271.272	-14890.171
10	134	MDPT	PRIN	179975.957	192052.137	173783.055
			ASTW	-9511.906	-14271.216	-14890.217
			BEAR	74557.374	140848.915	147240.941
11	137	OCP3	ALBU	-191490.945	123505.462	183331.008

WEEK	DAY	REF STATION	TO STATIONS	$\Delta x(m)$	$\Delta y(m)$	$\Delta z(m)$
			ARP2	-382200.493	-2785.685	110635.234
			K169	216449.208	225142.633	143477.931
			LIME	160382.480	349567.312	278862.401
	140	OCP3	ALBU	-191490.905	123505.459	183330.918
			ARP2	-382200.470	-2785.713	110635.156
			K169	216449.181	225142.750	143477.773
			LIME	160382.470	349567.264	278862.376

TABLE 6
COMPARISON OF INTERSTATION VECTORS
(VECTOR LENGTH IN METERS)

FROM	TO	DAY	VECTOR LENGTH
CARR	BRONSON	68	509332.540
		72	.565
CARR	FLNR	68	515397.079
		71	.074
		72	.024
CARR	MCDAVID	68	366066.391
		71	.408
		72	.387
CARR	FUTRELL	78	792025.132
		79	.132
CARR	HAGOOD	78	423466.748
		79	.724
CARR	STATESPORT	78	451878.829
		79	.811
CARR	WALTPORT	78	422783.344
		79	.287
CARR	GPS37	82	223182.260
		85	.322
		86	.257
CARR	GPS47	82	467524.825
		85	.878
		86	.812
CARR	GPS57	82	360499.190
		85	.247
		86	.189
CARR	BRINKLEY	85	577153.062
		86	.036

FROM	TO	DAY	VECTOR LENGTH
LEONARD	WILLIAMSON	92	637988.517
		93	.612
LEONARD	BLUFFPORT	92	500127.579
		93	.647
LEONARD	BRINLEY	92	434752.404
		93	.419
LEONARD	GP47	92	562489.736
		93	.766
LEONARD	FARM	96	430994.697
		99	.758
		100	.782
LEONARD	AMARILLO	96	554496.248
		99	.262
		100	.269
LEONARD	AUSTIN	96	642382.079
		99	.108
		100	.103
LEONARD	ODESSA	96	750244.568
		99	.594
		100	.591
NMBI	1169 CHEYENNE	103	693211.456
		106	.482
		107	.410
NMBI	AMARILLO	103	434311.953
		106	.978
		107	.984
NMBI	ODESSA	103	531915.756
		106	.723

FROM	TO	DAY	VECTOR LENGTH
		107	.699
PLATTVILLE	MILES CITY	110	696186.181
		113	.182
		114	.169
PLATTVILLE	HYDE	110	591725.646
		114	.624
PLATTVILLE	LINCOLN	110	682621.692
		113	.680
		114	.668
PLATTVILLE	RIVERSIDE	110	1199873.331
		113	.334
		114	.325
BLOOMINGTON	ROCK	117	512540.068
		120	.050
BLOOMINGTON	NORTH LIBERTY	117	517587.935
		120	.942
BLOOMINGTON	WILLIAMSPORT	117	270983.225
		120	.266
BLOOMINGTON	FREELAND	117	522595.520
		120	.493
BLOOMINGTON	ASHCOPORT	123	569800.483
		126	.491
		127	.502
BLOOMINGTON	BOLTON	123	298136.947
		126	.951
		127	.964
BLOOMINGTON	STANPORT	123	274427.356
		126	.348

FROM	TO	DAY	VECTOR LENGTH
		127	.354
BLOOMINGTON	TO07	126	584591.868
		127	.894
MARYLAND POINT	TO07	130	227234.678
		133	.604
MARYLAND POINT	PRINCETON	130	315398.013
		133	.004
		134	.032
MARYLAND POINT	ASTROWEST	130	22712.616
		133	.607
		134	.635
MARYLAND POINT	BEARTOWN	130	216972.580
		134	.610
HAYSTACK OCP3	ALBURG	137	292459.638
		140	.554
HAYSTACK OCP3	ARP2	137	397900.907
		140	.864
HAYSTACK OCP3	K169	137	343693.732
		140	.726
HAYSTACK OCP3	LIME	137	475062.190
		140	.137

TABLE 7
COMPARISON OF 1987 AND 1990 INTERSTATION VECTORS

STATION PAIR	YEAR	DAY	INTERSTATION VECTOR LENGTH (METERS)	YEARLY MEAN OF LENGTH (METERS)	DIFFERENCE BETWEEN MEANS (CM)
CARR TO GP37	1987	322	223182.312		
		323	.270		
				223182.291	
	1990	82	223182.260		
		85	.322		1.1
		86	.257		
				223182.280	
CARR TO GP47	1987	321	467524.803		
		322	.824		
		323	.832		
				467524.820	
	1990	82	467524.825		
		85	.878		1.8
		86	.812		
				467524.838	
CARR TO GP57	1987	322	360499.052		
		323	.200		
				360499.126	
	1990	82	360499.190		
		85	.247		8.3
		86	.189		
				360499.209	
CARR TO HAGO	1987	321	423466.742		
		322	.741		
		323	.806		

STATION PAIR	YEAR	DAY	INTERSTATION VECTOR LENGTH (METERS)	YEARLY MEAN OF LENGTH (METERS)	DIFFERENCE BETWEEN MEANS (CM)
				423466.763	
	1990	78	423466.748		
		79	.724		2.7
				423466.736	
CARR TO WALT	1987	321	422783.341		
		323	.361		
				422783.351	
	1990	78	422783.344		3.6
		79	.287		
				422783.315	
CARR TO FLNR	1987	321	513397.142		
		322	.143		
		323	.085		
				513397.123	
	1990	68	513397.079		
		72	.024		8.9
				513397.034	
MDPT TO BEAR	1987	326	216972.608		
		327	.603		
		328	.617		
				216972.609	
	1990	130	216972.580		1.4
		134	.610		
				216972.595	
MDPT TO TO07	1987	326	227234.692		
		327	.665		

STATION PAIR	YEAR	DAY	INTERSTATION VECTOR LENGTH (METERS)	YEARLY MEAN OF LENGTH (METERS)	DIFFERENCE BETWEEN MEANS (CM)
		328	.696		
				227234.684	
	1990	130	227234.678		4.3
		133	.604		
				227234.641	
MDPT TO PRIN	1987	326	315398.046		
		327	.034		
		328	.027		
				315398.036	
	1990	130	315398.013		2.0
		133	.004		
		134	.032		
				315398.016	
BLOO TO BOLT	1987	336	298136.944		
		337	.933		
				298136.939	
	1990	123	298136.948		
		126	.951		1.5
		127	.964		
				298136.954	

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E. Zurflueh, NRC Project Manager

11. ABSTRACT (200 words or less)

In the period March-May, 1990, a 45 station geodetic network, originally established in November-December, 1987, was reobserved using global positioning system (GPS) technology. This network, known as the Eastern U.S. Strain Network, was established for the purpose of determining strain and deformation in the central and eastern United States. This 1990 reobservation was the first of a series of reobservations scheduled to take place over a decade in order to place meaningful constraints on the small differential movements involved.

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