As some solutions have derived velocities or used an other model than AM0-2, we have repeated the adjustment at the epoch 1984.0 for these solutions. We fixed the LC rotation parameters for 1984 at their values of 1988 plus rotation correction from AM1-2/AM0-2 angular velocities. We then estimated annual rates of rotation for RG, LD and LU.

3) RESULTS

3.1) Values

We have adjusted combined coordinates in the ITRF89 solution for epoch 1988.0. They are given in Table T6 under the label SSC(IERS) 90 C 01.

As no global velocity field has been adjusted, the AM0-2 model is still valid to estimate positions at other epochs.

The adjusted transformation parameters and rates were published in Table T-2 of the IERS Annual Report for 1989. It is also available in Table T7 of the appendix.

We have also computed for a practical point of view positions for epochs 1984, 1986, 1988, 1990, for both the combined and some individual solutions. For the last solutions, the procedure used is:

a) to compute position at the epoch using values of the individual solution, namely positions at the reference epoch and corresponding velocity.

b) to compute transformation parameters at the epoch from table T7 values. For this case, only corrections exist for some rotation angles.

c) to convert positions to IERS values using this formula.

This is done for :

RG	SSC(IERS) 90 R 01 (84, 86, 88, 90)
RN	SSC(IERS) 90 R 02 (88)
LC	SSC(IERS) 90 L 01 (84, 86, 88, 90)
LG	SSC(IERS) 90 L 02 (84, 86, 88, 90)
LD	SSC(IERS) 90 L 03 (84, 86, 88, 90)
LU	SSC(IERS) 90 L 04 (84, 86, 88, 90)

For RN only 1988 values have been computed as velocities were not available at IFTS.

3.2) Analysis of results

The factor of unit variance is 1.3. Although it is close to 1, the proper weighting in the combined adjustment is a rather critical and delicate problem.

As presented in the IERS Technical Note 4 for past BIH/IERS solutions, a sample of 6 stations is given in Tables 3 and 4, where we have also repeated ITRF88 solutions. See also Figures 1 to 6.

Table 3

Solutions for a sample of stations

I : Raw data

Notes :

- for each station this table gives:
  * the coordinates in the combined solution,
  * the original coordinates in 3 individual solutions (RN : VLBI NGS, RG : VLBI GSFC and LC : SLR CSR)
  * the transformed coordinates (T) in the corresponding combined solution using the transformation parameters between the combined solution and the individual one,

- USX : unscaled standard deviation on X,

- SSX : scaled standard deviation on X, in the case of combined solutions and a priori value adopted in the combination, in the case of individual solution.

Canberra SLR 7943

Solution Date	point	X (m) USX(m)	SSX(m)	Y (m) USY(m)	SSY(m)	Z (m) USZ(m)	SSZ(m)
ITRF88	7943	-4447548.848		2677134.080		-3694996.708	
1988.0		±0.030	(0.165)	±0.029	(0.159)	±0.033	(0.182)
RG88	1545	-4460933.406		2682764.817		-3674381.113	
1988.0		±0.015	(0.015)	±0.011	(0.011)	±0.010	(0.010)
	exc.	13386.172		-5631.623		-20614.965	
		---		---		---	
	7943	-4447547.234		2677133.194		-3694996.078	
RG88(T)		-4447548.857		2677134.081		-3694996.747	
1988.0							
LC88	7943	-4447548.581		2677134.298		-3694996.587	
1988.0		±0.013	(0.013)	±0.015	(0.015)	±0.014	(0.014)
LC88(T)	7943	-4447548.748		2677134.003		-3694996.691	
1988.0							

ITRF89	7943	-4447548.620		2677133.986		-3694996.479		
1988.0		±0.018	(0.023)	±0.017	(0.022)	±0.018	(0.023)	
RN89	1545	-4460935.217		2682765.664		-3674381.460		
1988.0		±0.026	(0.026)	±0.019	(0.020)	±0.016	(0.020)	
	exc.	13386.516		-5631.785		-20614.724		
		---		---		---		
	7943	-4447548.890		2677133.879		-3694996.184		
RN89(T)		-4447548.721		2677134.001		-3694996.421		
1988.0								
RG89	1545	-4460933.448		2682764.920		-3674381.099		
1988.0		±0.012	(0.020)	±0.009	(0.020)	±0.008	(0.020)	
	exc.	13386.516		-5631.785		-20614.724		
		---		---		---		
	7943	-4447546.932		2677133.135		-3694995.823		
RG89(T)		-4447548.547		2677133.998		-3694996.432		
1988.0								
LC89	7943	-4447548.581		2677134.298		-3694996.587		
1988.0		±0.013	(0.040)	±0.015	(0.040)	±0.014	(0.040)	
LC89(T)	7943	-4447548.710		2677134.016		-3694996.636		
1988.0								

Simosato SLR 7838

Solution	point	X (m)	SSX(m)	Y (m)	SSY(m)	Z (m)	SSZ(m)
		USX(m)		USY(m)		USZ(m)	
ITRF88	7838	-3822388.405		3699363.434		3507573.079	
1988.0		±0.020	(0.110)	±0.019	(0.105)	±0.031	(0.171)
LC88	7838	-3822388.009		3699363.804		3507573.109	
1988.0		±0.013	(0.013)	±0.013	(0.013)	±0.013	(0.013)
LC88(T)	7838	-3822388.407		3699363.445		3507573.071	
1988.0							
ITRF89	7838	-3822388.355		3699363.504		3507573.098	
1988.0		±0.017	(0.022)	±0.017	(0.022)	±0.019	(0.025)
LC89	7838	-3822388.009		3699363.804		3507573.109	
1988.0		±0.013	(0.040)	±0.013	(0.040)	±0.013	(0.040)
LC89(T)	7838	-3822388.367		3699363.452		3507573.090	
1988.0							

Hartebeesthoek VLBI 7232

Solution	point	X (m)	SSX(m)	Y (m)	SSY(m)	Z (m)	SSZ(m)
		USX(m)		USY(m)		USZ(m)	
ITRF88	7232	5085442.883		2668263.355		-2768697.313	
1988.0		±0.032	(0.176)	±0.032	(0.176)	±0.028	(0.154)
RN88	7232	5085442.778		2668263.461		-2768697.652	
1984.0		±0.026	(0.026)	±0.013	(0.013)	±0.016	(0.016)
1988.0	7232	5085442.648		2668263.553		-2768697.623	
RN88(T)	7232	5085442.856		2668263.404		-2768697.263	
1988.0							
RG88	7232	5085444.366		2668262.522		-2768696.748	
1988.0		±0.018	(0.018)	±0.014	(0.014)	±0.010	(0.016)
RG88(T)	7232	5085442.878		2668263.352		-2768697.320	
1988.0							
ITRF89	7232	5085442.832		2668263.404		-2768697.266	
1988.0		±0.023	(0.030)	±0.024	(0.031)	±0.023	(0.030)
RN89	7232	5085442.677		2668263.264		-2768697.487	
1988.0		±0.015	(0.020)	±0.008	(0.020)	±0.009	(0.020)
RN89(T)	7232	5085442.827		2668263.387		-2768697.232	
1988.0							
RG89	7232	5085444.377		2668262.559		-2768696.777	
1988.0		±0.011	(0.020)	±0.007	(0.020)	±0.006	(0.020)
RG89(T)	7232	5085442.831		2668263.421		-2768697.300	
1988.0							

Wettzell SLR 7834

Solution	point	X (m)	SSX(m)	Y (m)	SSY(m)	Z (m)	SSZ(m)
		USX(m)		USY(m)		USZ(m)	
ITRF88	7834	4075530.090		931781.263		4801618.163	
1988.0		±0.017	(0.094)	±0.016	(0.088)	±0.019	(0.105)
RN88	7224	4075540.371		931735.319		4801629.057	
1984.0		±0.007	(0.007)	±0.004	(0.004)	±0.010	(0.010)
1988.0	7224	4075540.303		931735.387		4801629.101	
	exc.	-10.003		46.149		-11.072	
		4075530.300		931781.536		4801618.029	
RN88(T)	7834	4075530.102		931781.302		4801618.129	
1988.0							
RG88	7224	4075541.673		931734.246		4801629.685	
1988.0		±0.006	(0.006)	±0.004	(0.004)	±0.011	(0.011)
	exc.	-10.003		46.149		-11.072	
	7834	4075531.670		931780.395		4801618.613	
RG88(T)	7834	4075530.089		931781.268		4801618.160	
1988.0							
LC88	7834	4075530.300		931781.077		4801618.122	
1988.0		±0.015	(0.015)	±0.018	(0.018)	±0.012	(0.012)
LC88(T)	7834	4075530.132		931781.307		4801618.213	
1988.0							
ITRF89	7834	4075530.091		931781.322		4801618.178	
1988.0		±0.013	(0.017)	±0.013	(0.017)	±0.013	(0.017)
RN89	7224	4075540.325		931735.227		4801629.044	
1988.0		±0.004	(0.020)	±0.002	(0.020)	±0.005	(0.020)
	exc.	-10.003		46.149		-11.072	
	7834	4075530.322		931781.376		4801617.972	
RN89(T)	7834	4075530.084		931781.349		4801618.165	
1988.0							
RG89	7224	4075541.699		931734.277		4801629.695	
1988.0		±0.002	(0.020)	±0.001	(0.020)	±0.003	(0.020)
	exc.	-10.003		46.149		-11.072	
	7834	4075531.696		931780.426		4801618.623	
RG89(T)	7834	4075530.078		931781.341		4801618.168	
1988.0							
LC89	7834	4075530.300		931781.077		4801618.122	
1988.0		±0.015	(0.040)	±0.018	(0.040)	±0.012	(0.040)
LC89(T)	7834	4075530.128		931781.312		4801618.222	
1988.0							

Arequipa SLR 7907

Solution	point	X (m) USX(m)	SSX(m)	Y (m) USY(m)	SSY(m)	Z (m) USZ(m)	SSZ(m)
ITRF88	7907	1942792.009		-5804077.744		-1796919.359	
1988.0		±0.021	(0.116)	±0.023	(0.127)	±0.022	(0.121)
LC88	7907	1942791.451		-5804077.903		-1796919.266	
1988.0		±0.015	(0.015)	±0.007	(0.007)	±0.017	(0.017)
LC88(T)	7907	1942791.950		-5804077.767		-1796919.364	
1988.0							
ITRF89	7907	1942792.013		-5804077.661		-1796919.307	
1988.0		±0.017	(0.022)	±0.017	(0.022)	±0.017	(0.022)
LC89	7907	1942791.451		-5804077.903		-1796919.266	
1988.0		±0.015	(0.040)	±0.007	(0.040)	±0.017	(0.040)
LC89(T)	7907	1942791.940		-5804077.724		-1796919.321	
1988.0							

Fort Davis SLR 7086

Solution	point	X (m) USX(m)	SSX(m)	Y (m) USY(m)	SSY(m)	Z (m) USZ(m)	SSZ(m)
ITRF88	7086	-1330125.273		-5328526.693		3236150.236	
1988.0		±0.011	(0.061)	±0.011	(0.061)	±0.013	(0.072)
RN88	7216	-1324210.748		-5332023.121		3232118.544	
1984.0		±0.005	(0.005)	±0.017	(0.017)	±0.015	(0.015)
1988.0	7216	-1324210.804		-5332023.129		3232118.512	
	exc.	-5914.397		3496.510		4031.862	
		---		---		---	
	7086	-1330125.201		-5328526.619		3236150.374	
RN88(T)	7086	-1330125.272		-5328526.679		3236150.200	
1988.0							
RG88	7216	-1324209.184		-5332023.991		3232118.820	
1988.0		±0.001	(0.001)	±0.002	(0.002)	±0.003	(0.003)
	exc.	-5914.397		3496.510		4031.862	
		---		---		---	
	7086	-1330123.581		-5328527.481		3236150.682	
RG88(T)	7086	-1330125.272		-5328526.678		3236150.210	
1988.0							
LC88	7086	-1330125.610		-5328526.465		3236150.379	
1988.0		±0.015	(0.015)	±0.009	(0.009)	±0.013	(0.013)
LC88(T)	7086	-1330125.277		-5328526.668		3236150.244	
1988.0							
ITRF89	7086	-1330125.262		-5328526.629		3236150.242	
1988.0		±0.010	(0.013)	±0.010	(0.013)	±0.010	(0.013)
RN89	7216	-1324210.697		-5332023.106		3232118.569	
1988.0		±0.001	(0.020)	±0.003	(0.020)	±0.003	(0.020)
	exc.	-5914.397		3496.510		4031.862	
		---		---		---	
	7086	-1330125.094		-5328526.596		3236150.431	
RN89(T)	7086	-1330125.256		-5328526.623		3236150.224	
1988.0							
RG89	7216	-1324209.205		-5332023.991		3232118.816	
1988.0		±0.001	(0.020)	±0.001	(0.020)	±0.001	(0.020)
	exc.	-5914.397		3496.510		4031.862	
		---		---		---	
	7086	-1330123.599		-5328527.481		3236150.678	
RG89(T)	7086	-1330125.253		-5328526.624		3236150.220	
1988.0							
LC89	7086	-1330125.610		-5328526.465		3236150.379	
1988.0		±0.015	(0.040)	±0.009	(0.040)	±0.013	(0.040)
LC89(T)	7086	-1330125.267		-5328526.621		3236150.263	
1988.0							

Table 4

Solutions for a sample of stations

II : Comparisons / ITRF-0

Note : this table is schematized in figures 1 to 6 following it

CANBERRA SLR 7943

Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	-4.6	-2.4	-4.7
RG88(T)	-5.5	-2.3	-8.6
LC88(T)	5.4	-10.1	-3.0
ITRF89	18.2	-11.8	18.2
RN89(T)	8.1	-10.3	24.0
RG89(T)	25.5	-10.6	22.9
LC89(T)	9.2	-8.8	2.5

SIMOSATO SLR 7838

Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	-2.6	-0.8	-0.6
LC88(T)	-2.8	0.3	-1.4
ITRF89	2.4	6.2	1.3
LC89(T)	1.2	1.0	0.5

HARTEBEESTHOEK VLBI 7232

Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	4.7	-11.0	-1.6
RN88(T)	2.0	-6.1	3.4
RG88(T)	4.2	-11.3	-2.3
ITRF89	-0.4	-6.1	3.1
RN89(T)	-0.9	-7.8	6.5
RG89(T)	-0.5	-4.4	-0.3

WETTZELL SLR 7834

Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	-1.0	-1.2	-2.4
RN88(T)	0.2	2.7	-5.8
RG88(T)	-1.1	-0.7	-2.7
LC88(T)	3.2	3.2	2.6
ITRF89	-0.9	4.7	-0.9
RN89(T)	-1.6	7.4	-2.2
RG89(T)	-2.2	6.6	-1.9
LC89(T)	2.4	3.7	3.5

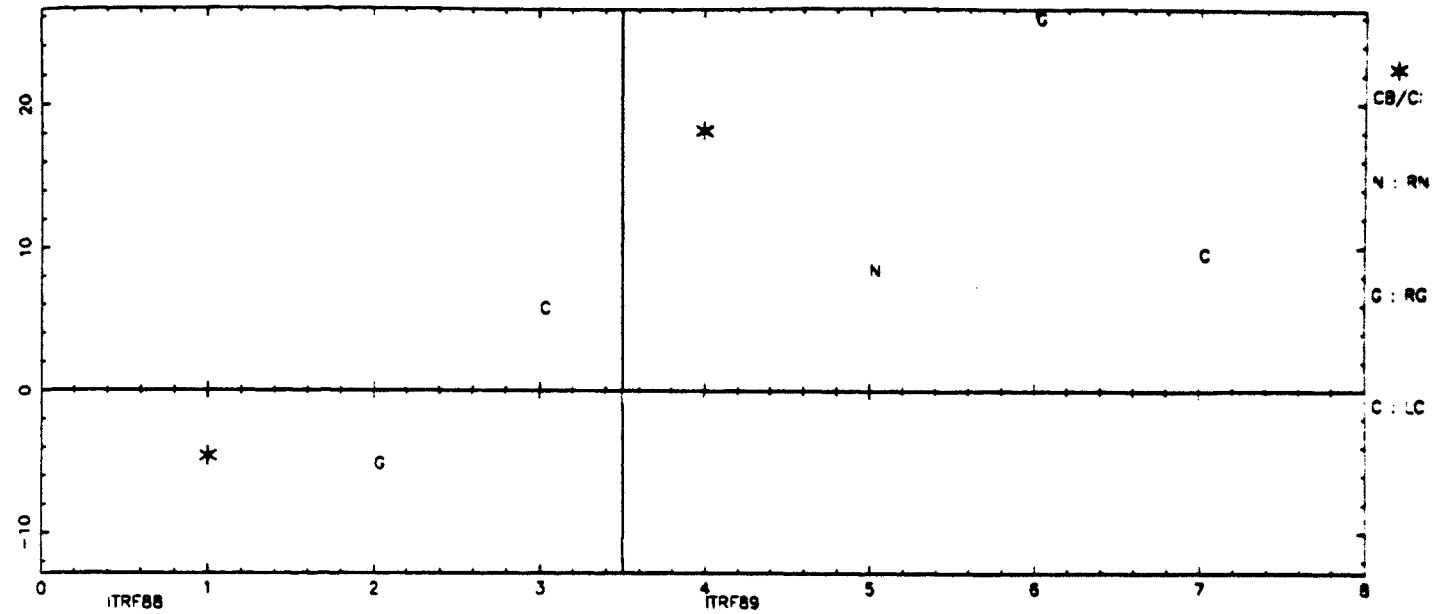
AREQUIPA SLR 7907

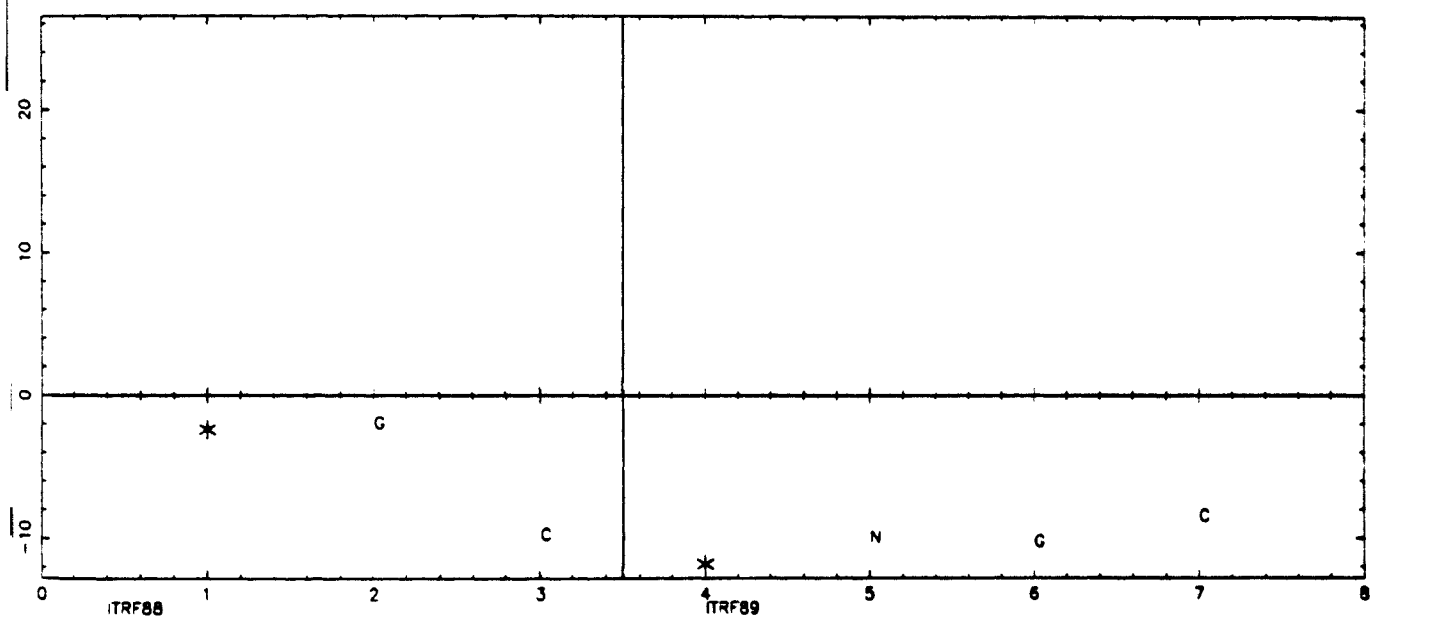
Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	5.1	-0.3	-1.2
LC88(T)	-0.8	-2.6	-1.7
ITRF89	5.5	8.0	4.0
LC89(T)	-1.8	1.7	2.6

FORT DAVIS SLR 7086

Solution	X - X0 cm	Y - Y0 cm	Z - Z0 cm
ITRF88	2.3	-6.1	-0.4
RN88(T)	2.4	-4.7	-4.0
RG88(T)	2.4	-4.6	-3.0
LC88(T)	1.9	-3.6	0.4
ITRF89	3.4	0.3	0.2
RN89(T)	4.0	0.9	-1.6
RG89(T)	4.3	0.8	-2.0
LC89(T)	2.9	1.1	2.3

FIG. 1 CANBERRA SLR 7943





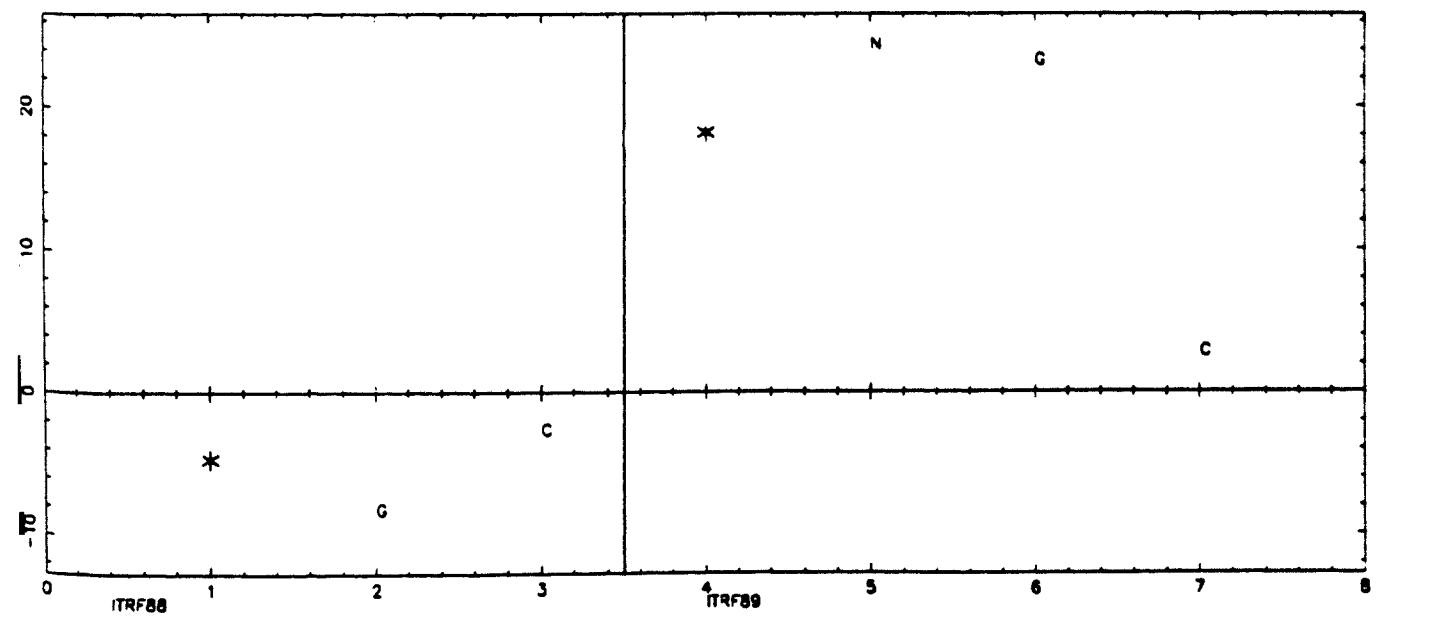
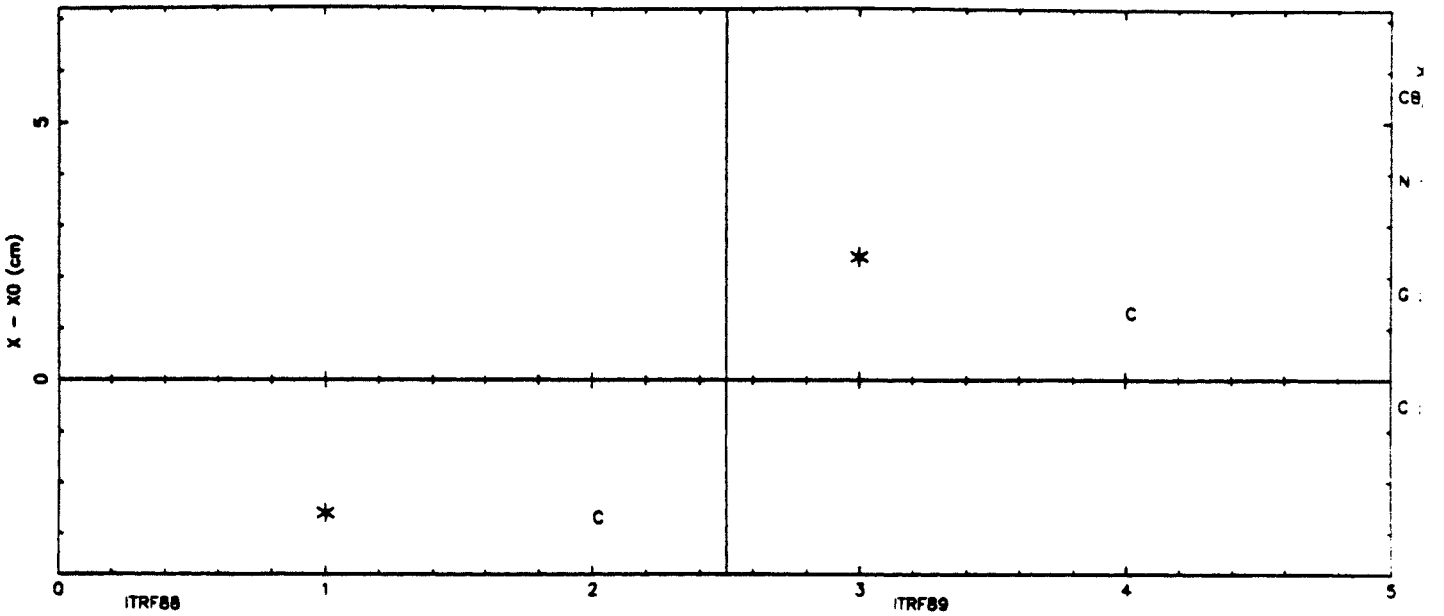
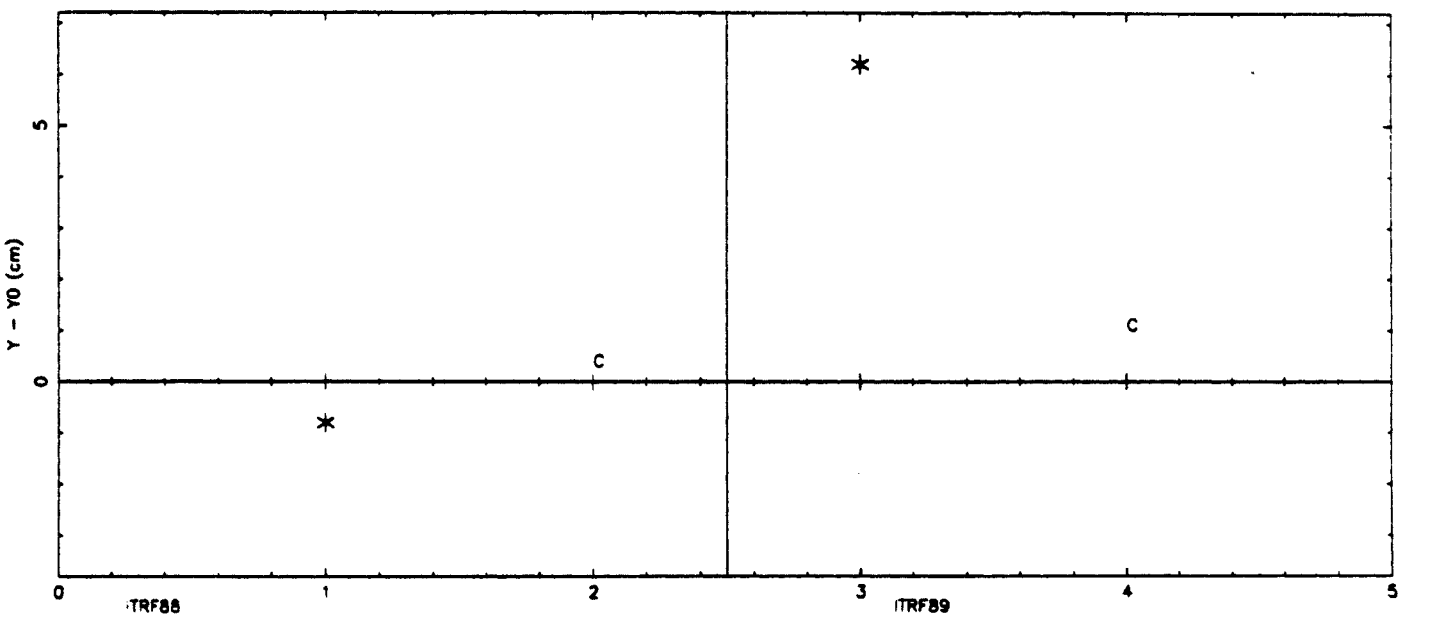


FIG. 2 SIMOSATO SLR 7838





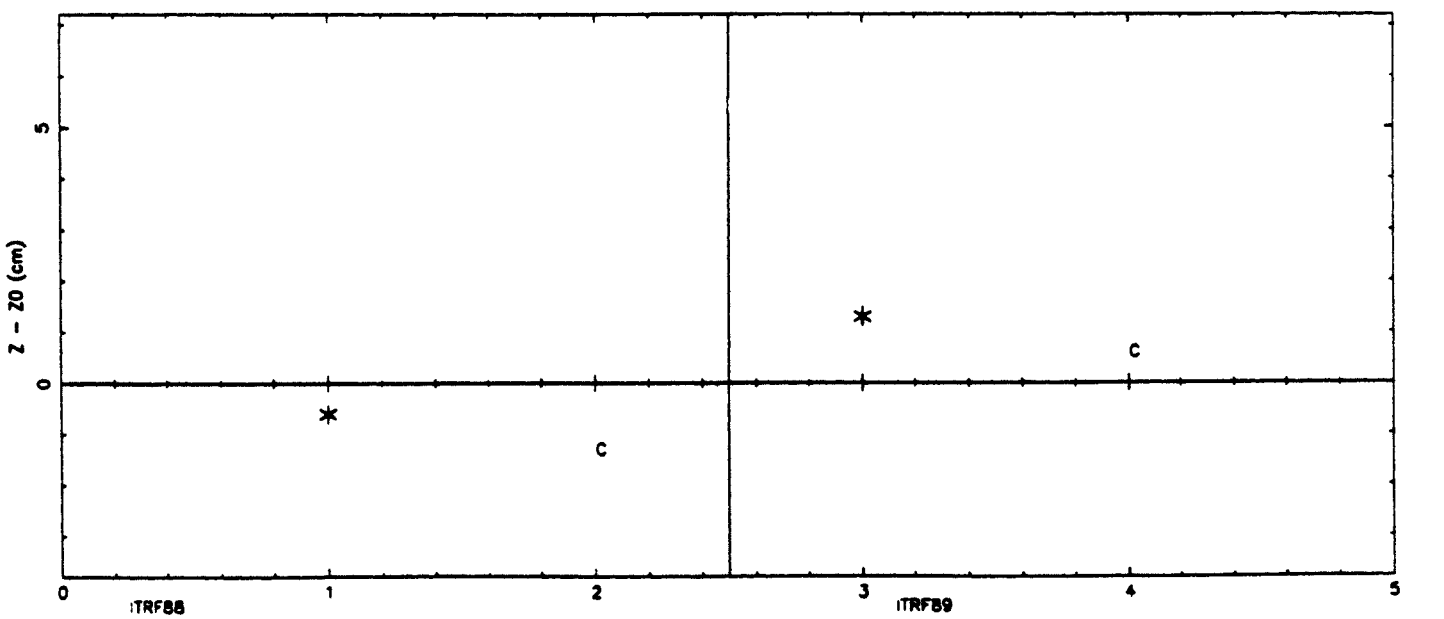
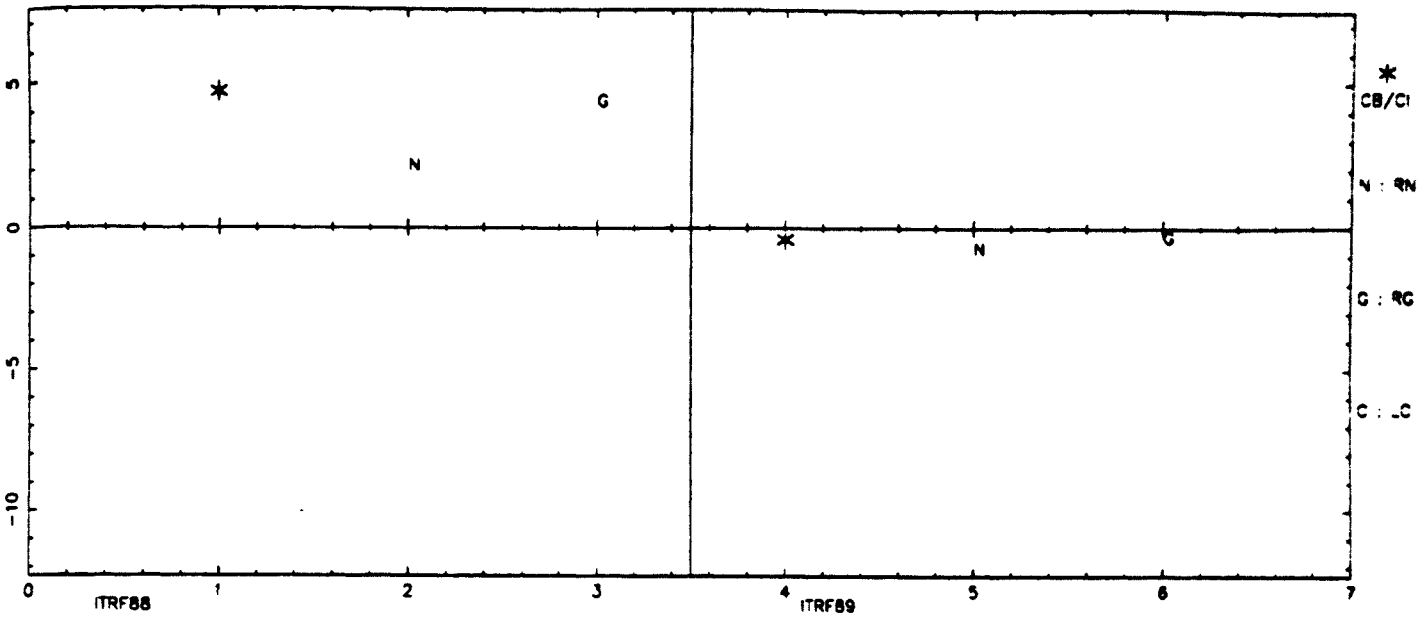
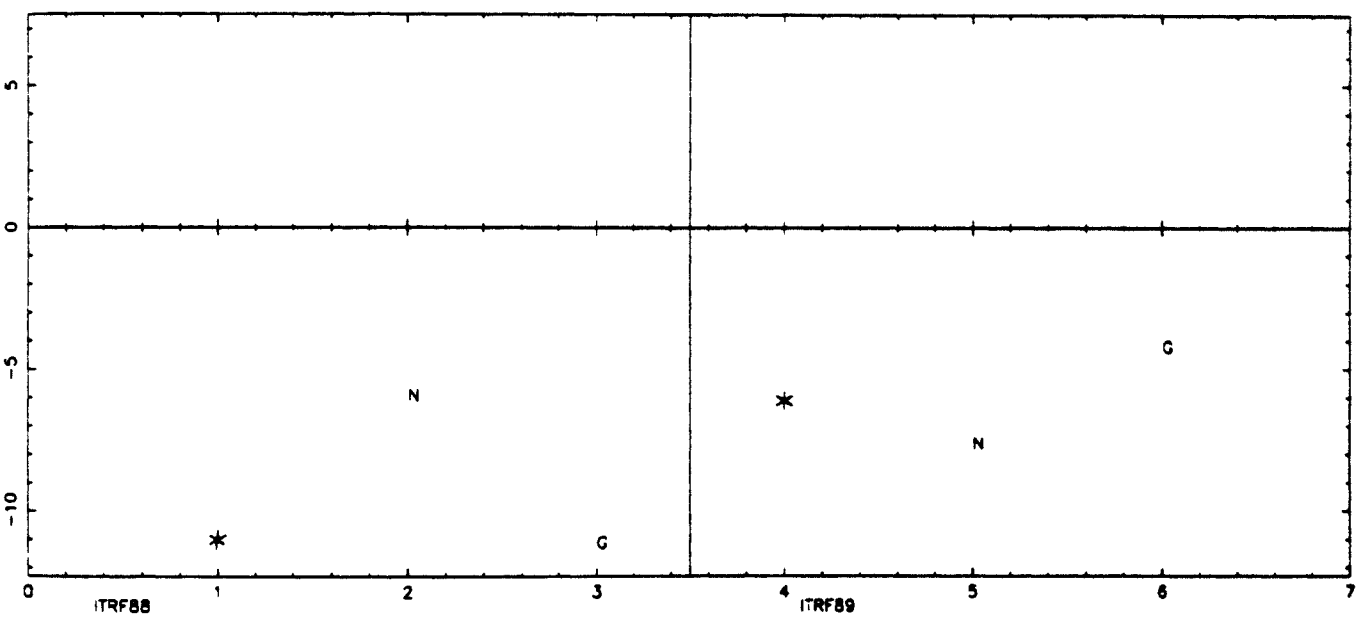


FIG. 3 HARTEBEESTHOEK VLBI 7232





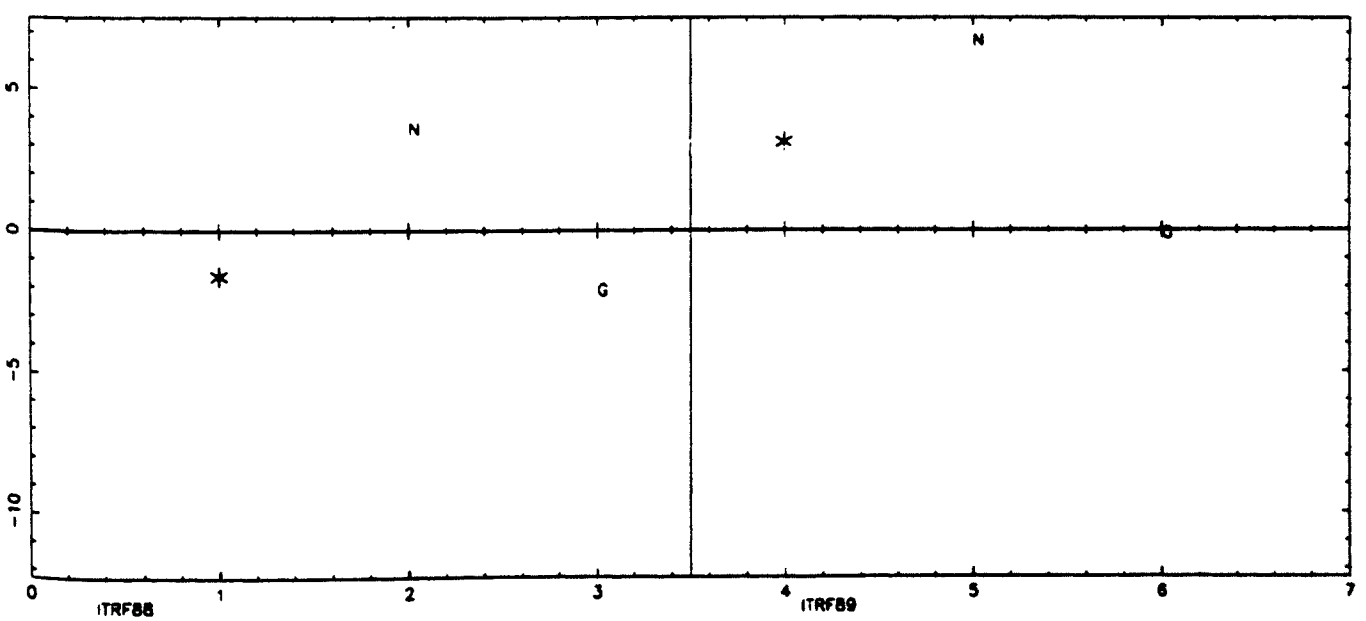
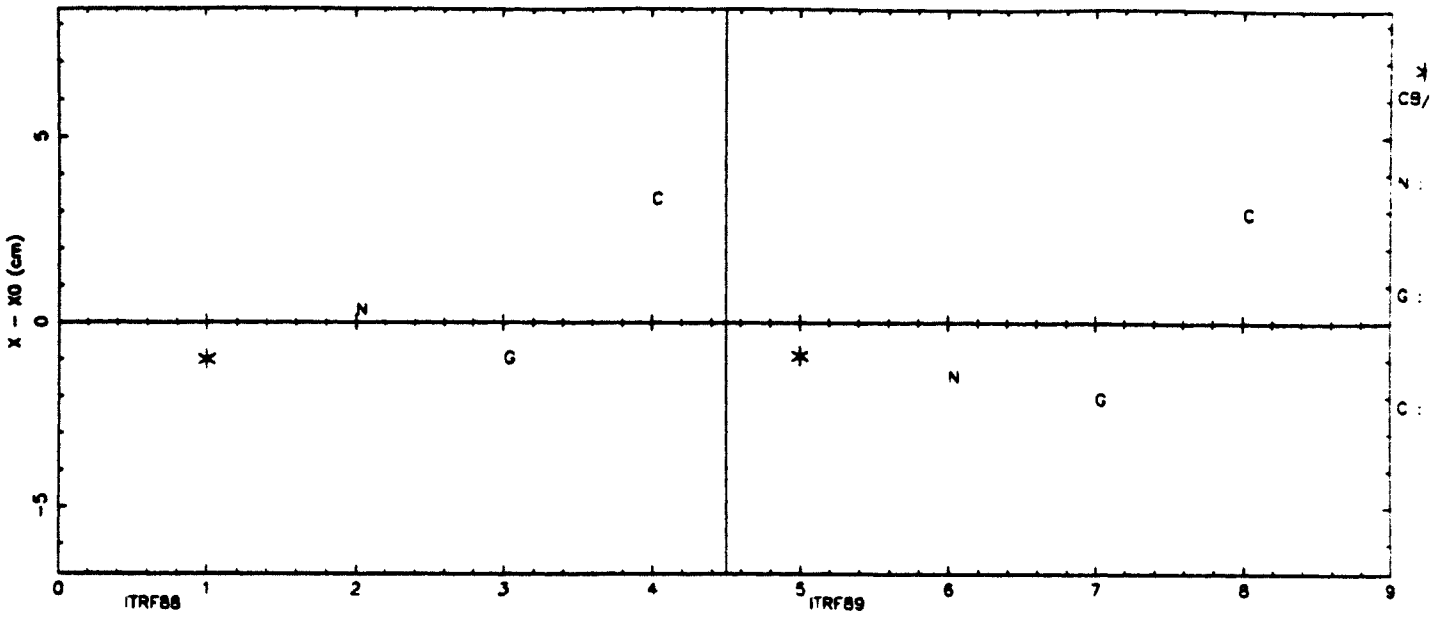
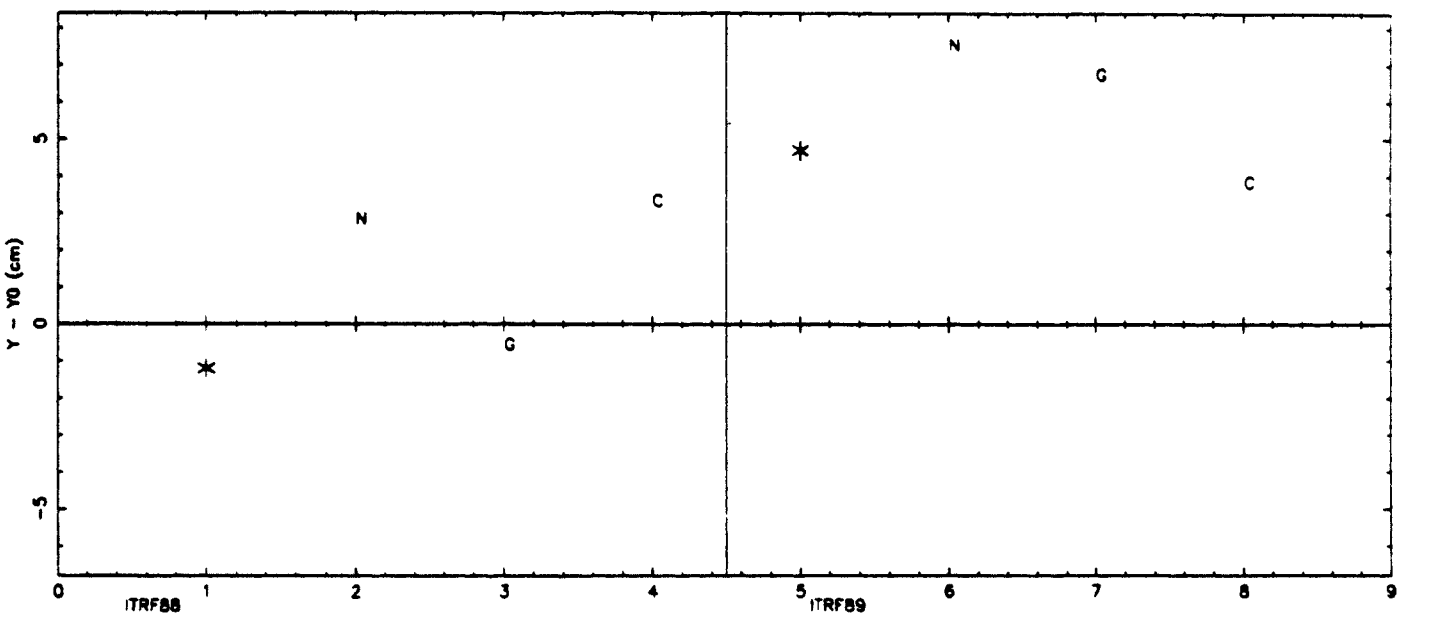


FIG. 4 WETTZELL SLR 7834





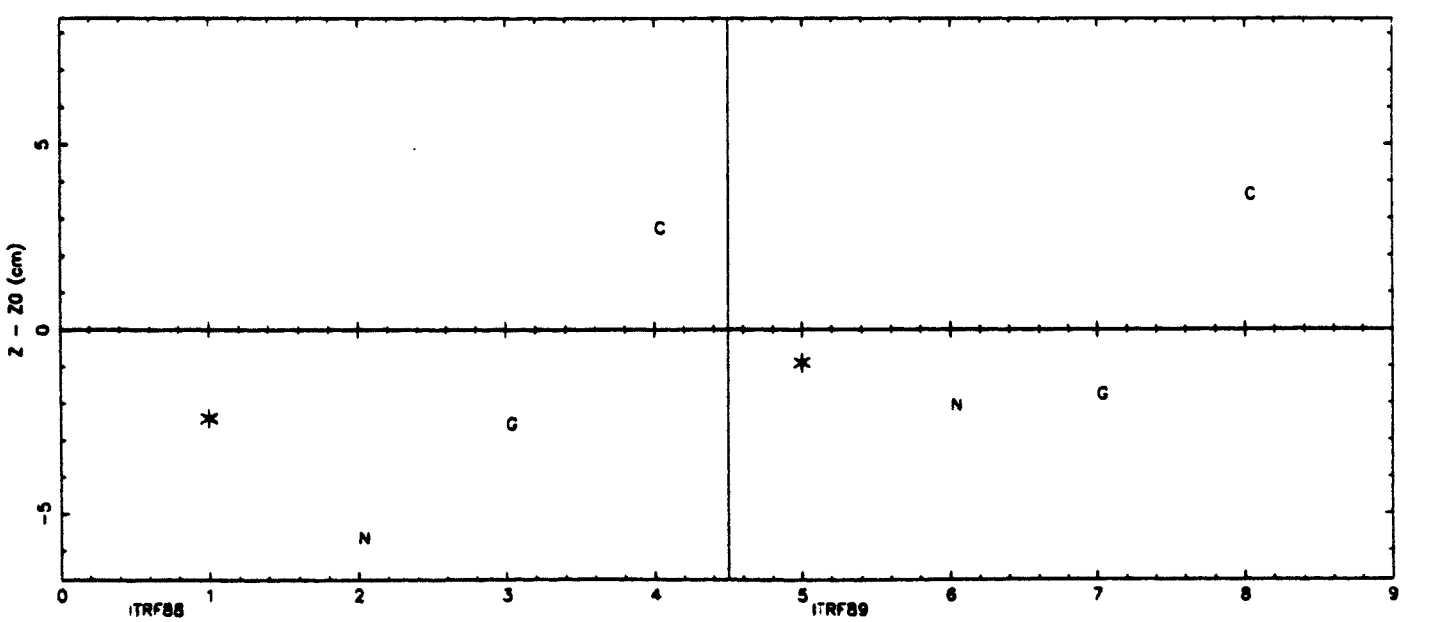
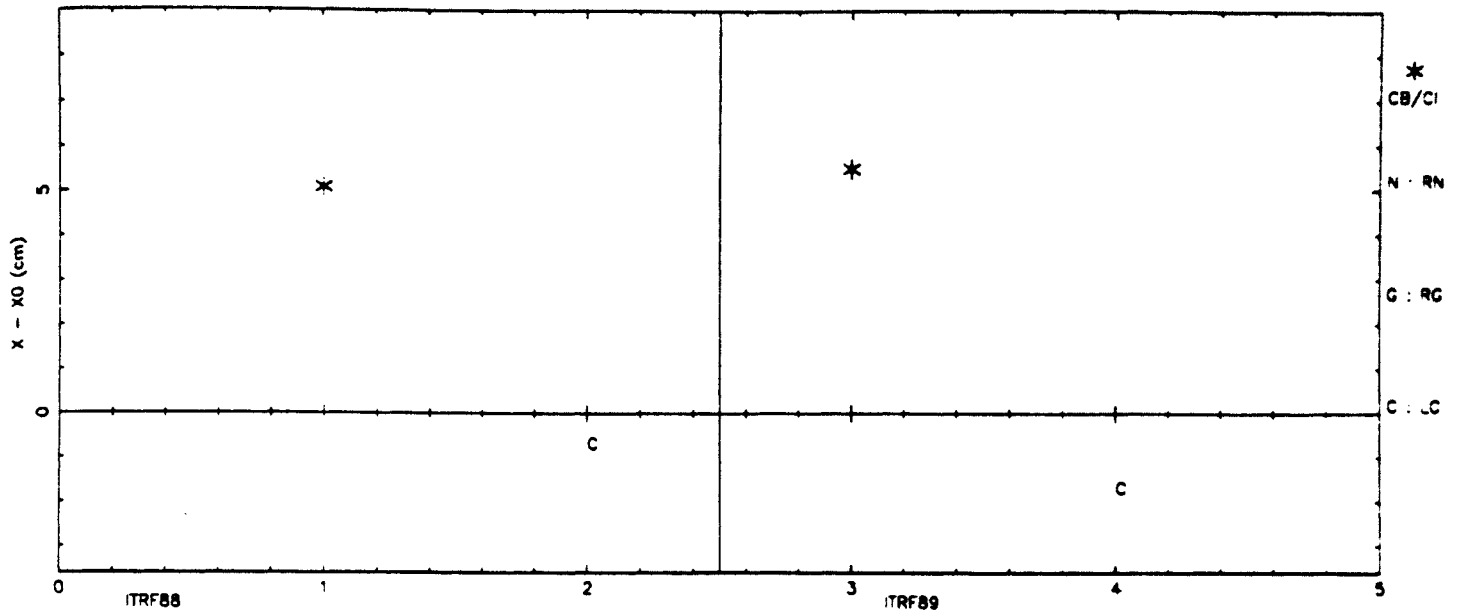
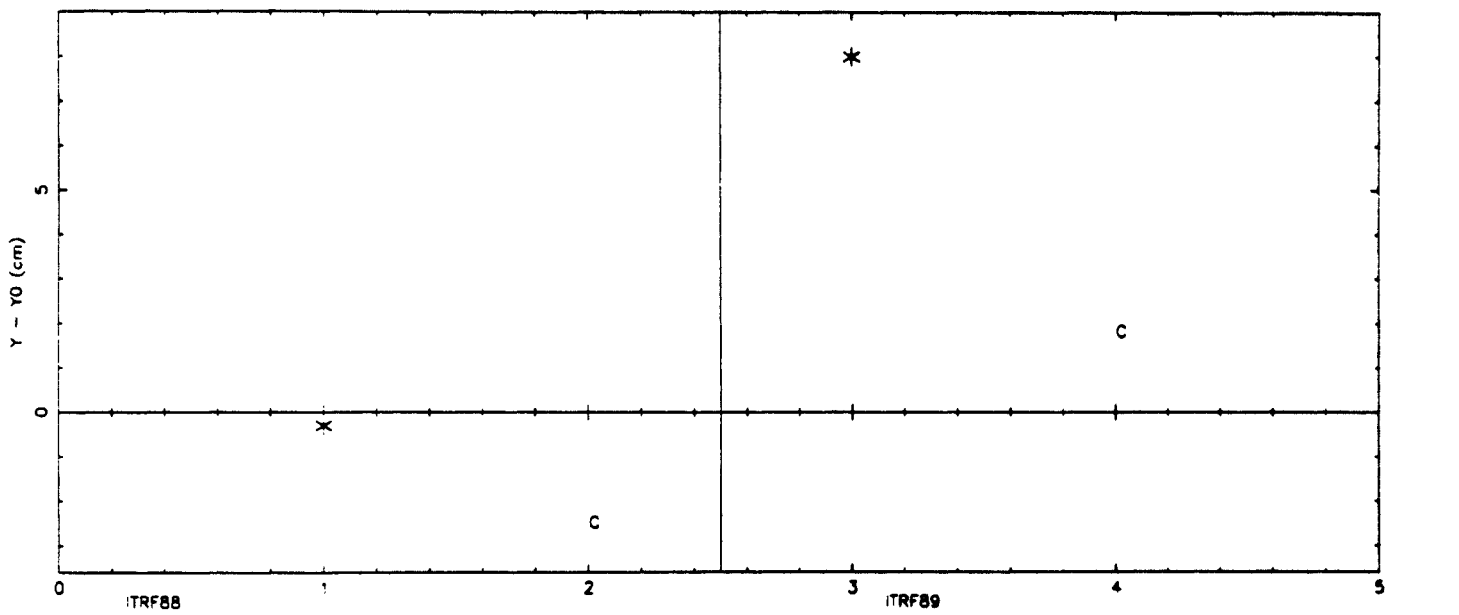


FIG. 5 AREQUIPA SLR 7907





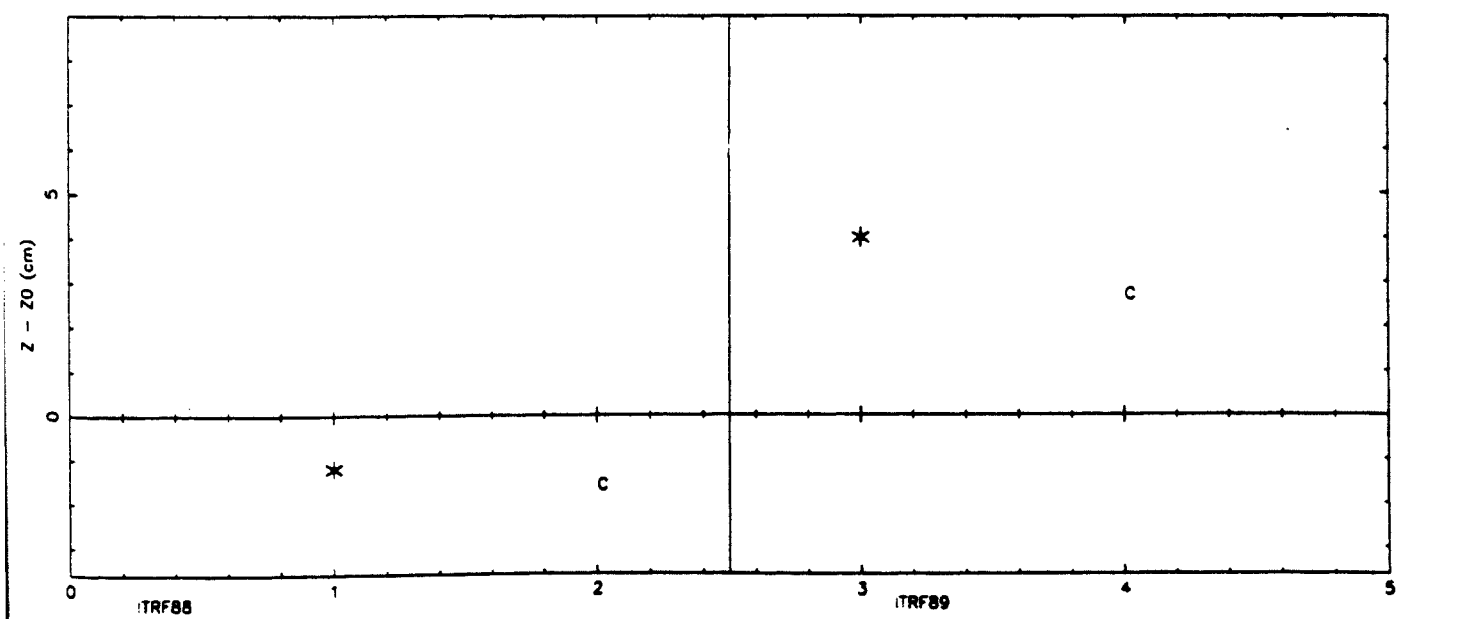
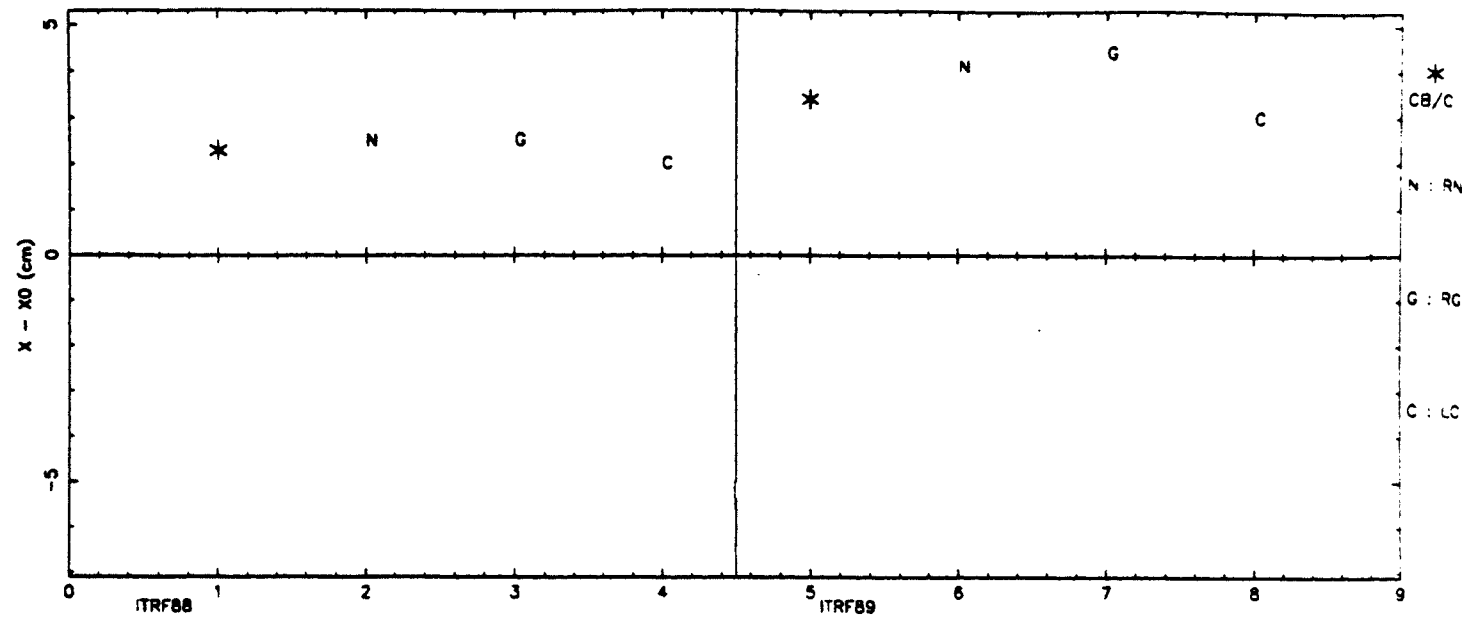
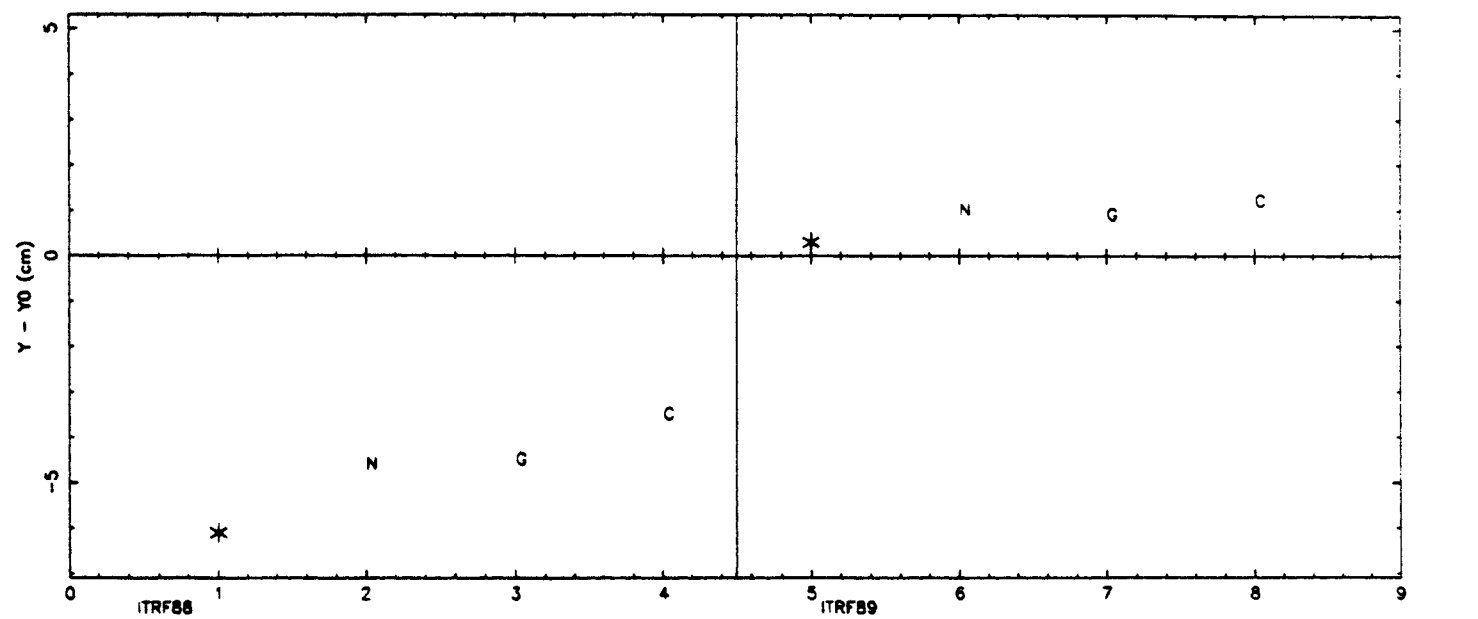


FIG. 6 FORT DAVIS SLR 7086





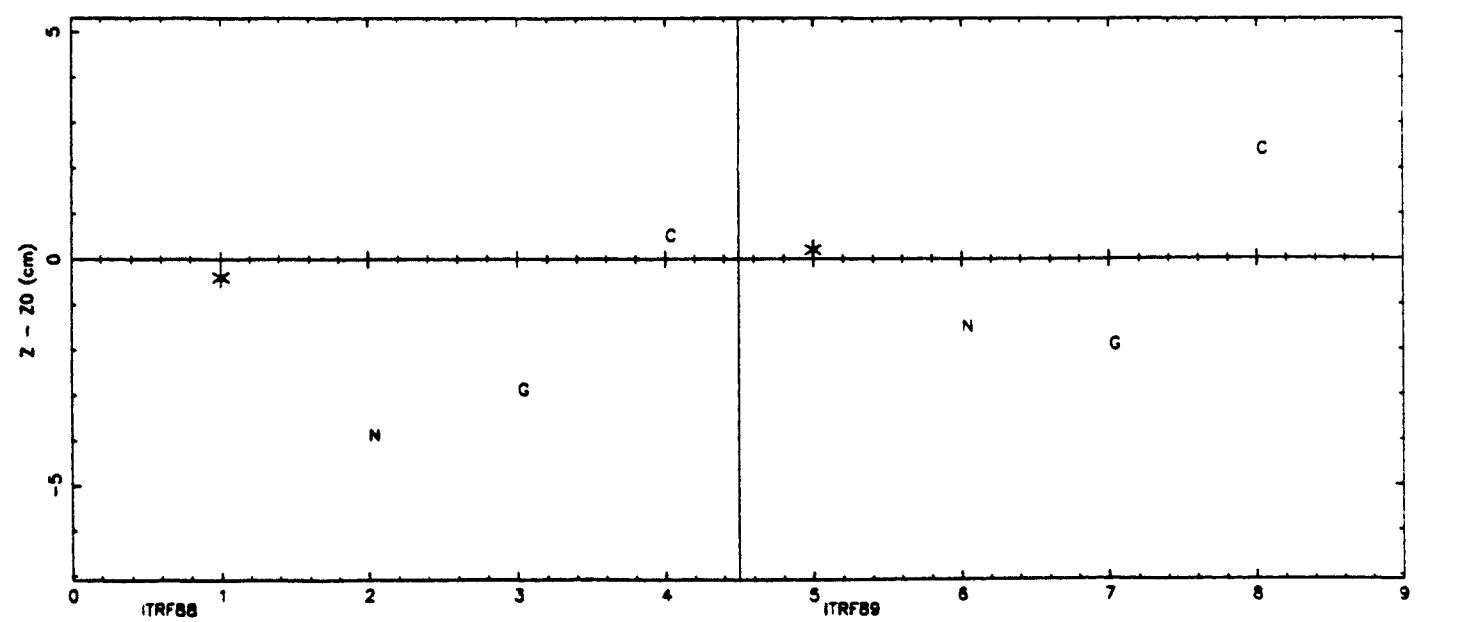


FIGURE 7

SSC(GSFC) 90 R 02/GLB628/CALC 7/

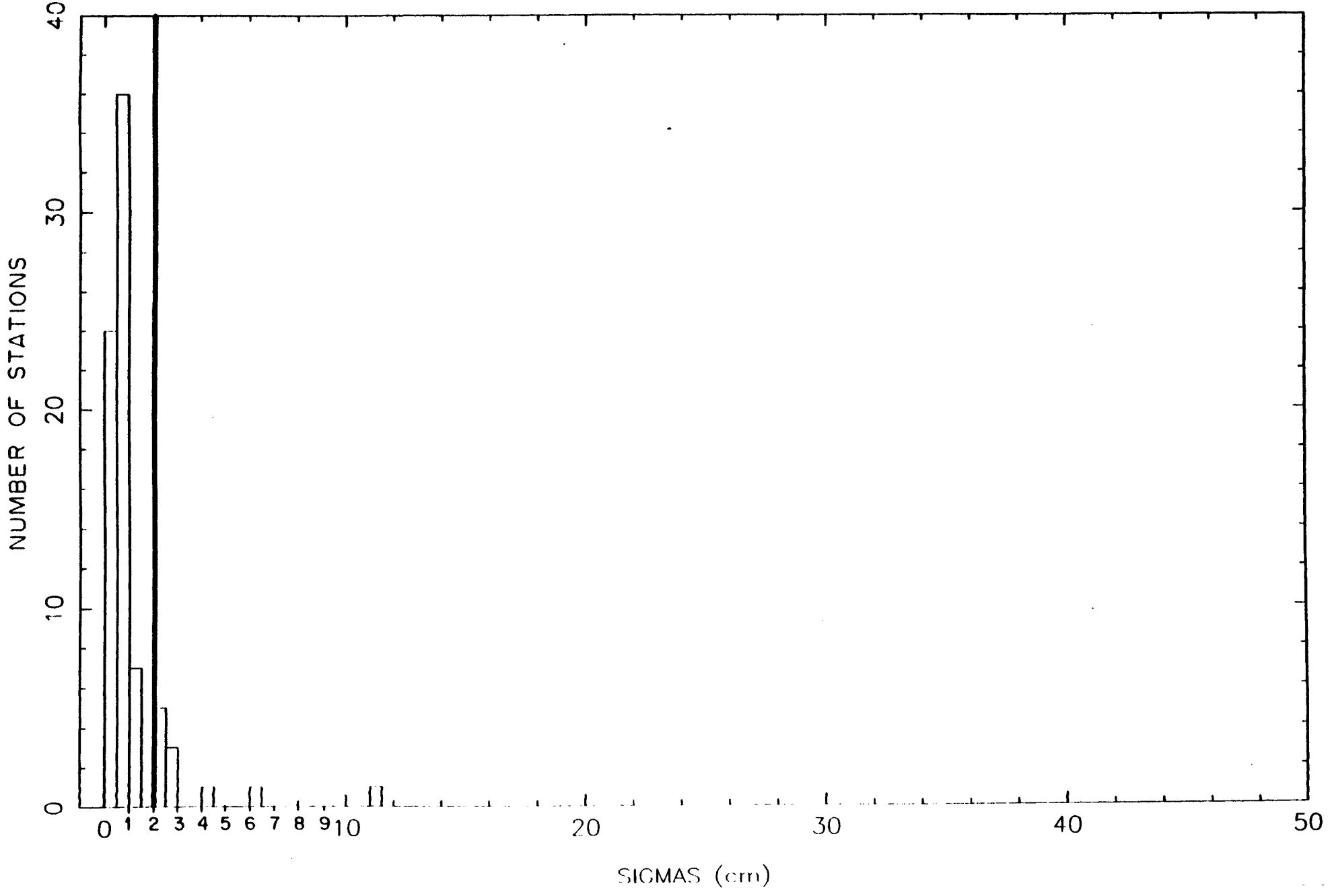


FIGURE 8

SSC(NGS) 90 R 01

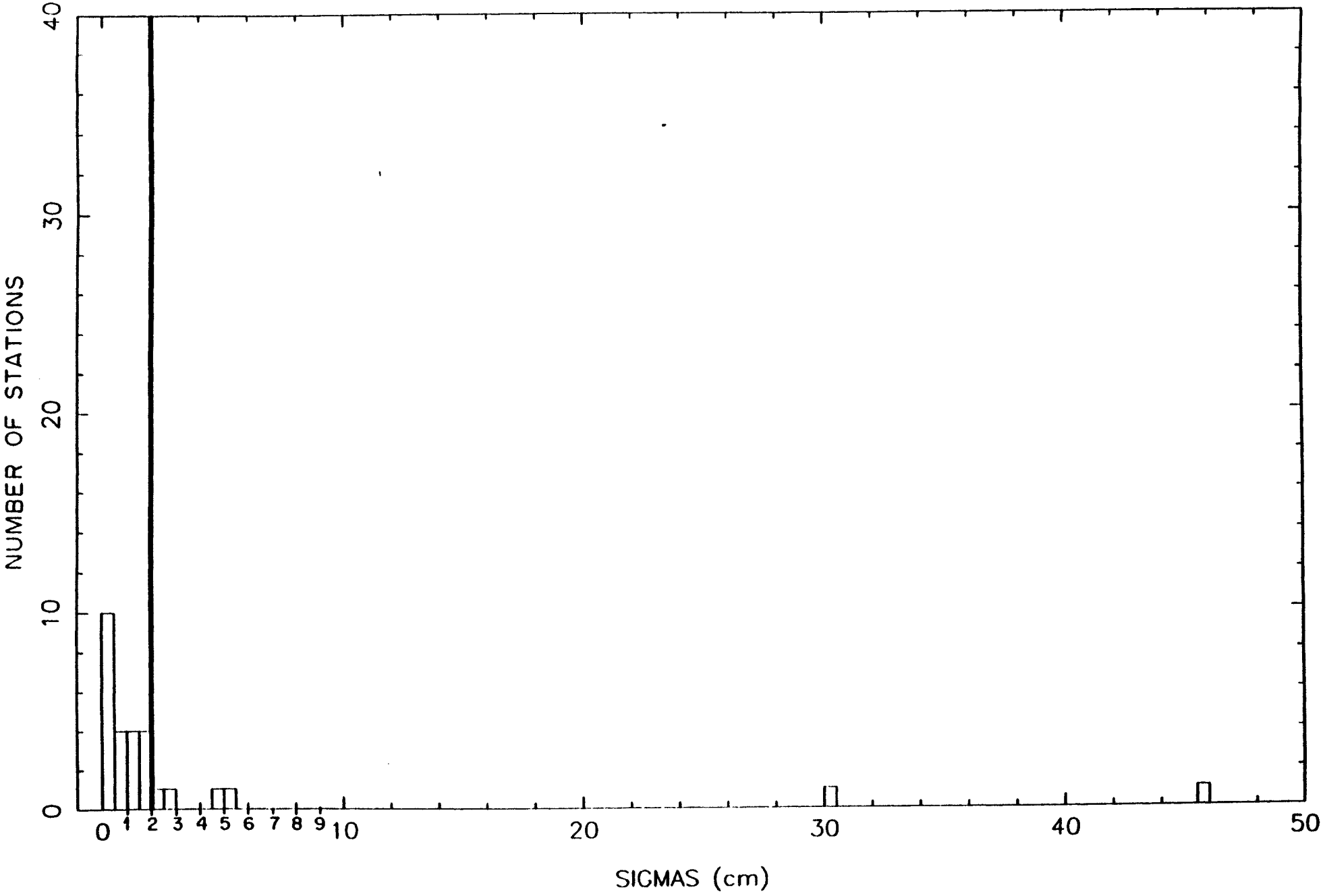


FIGURE 9

SSC(CSR) 89 L 02

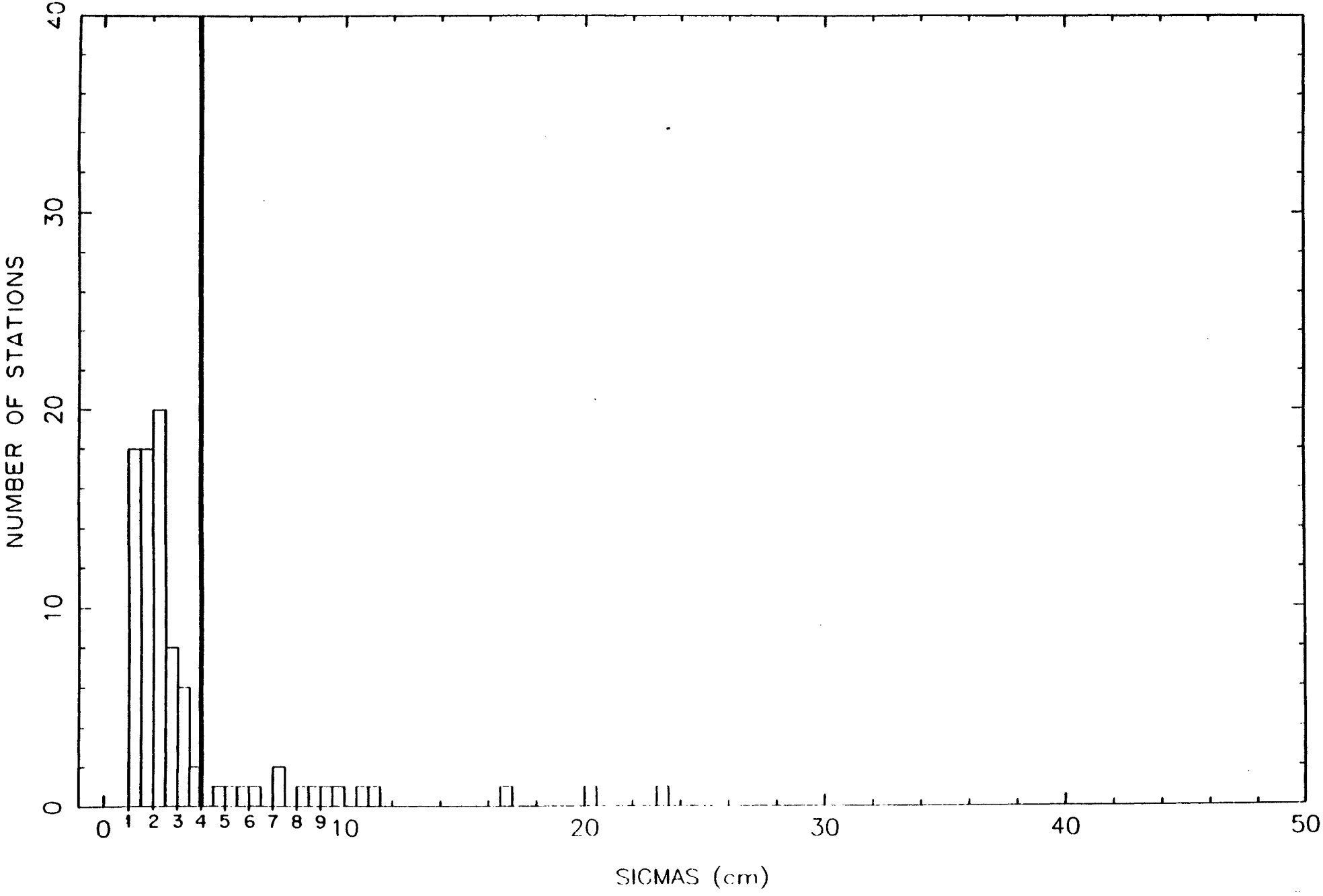
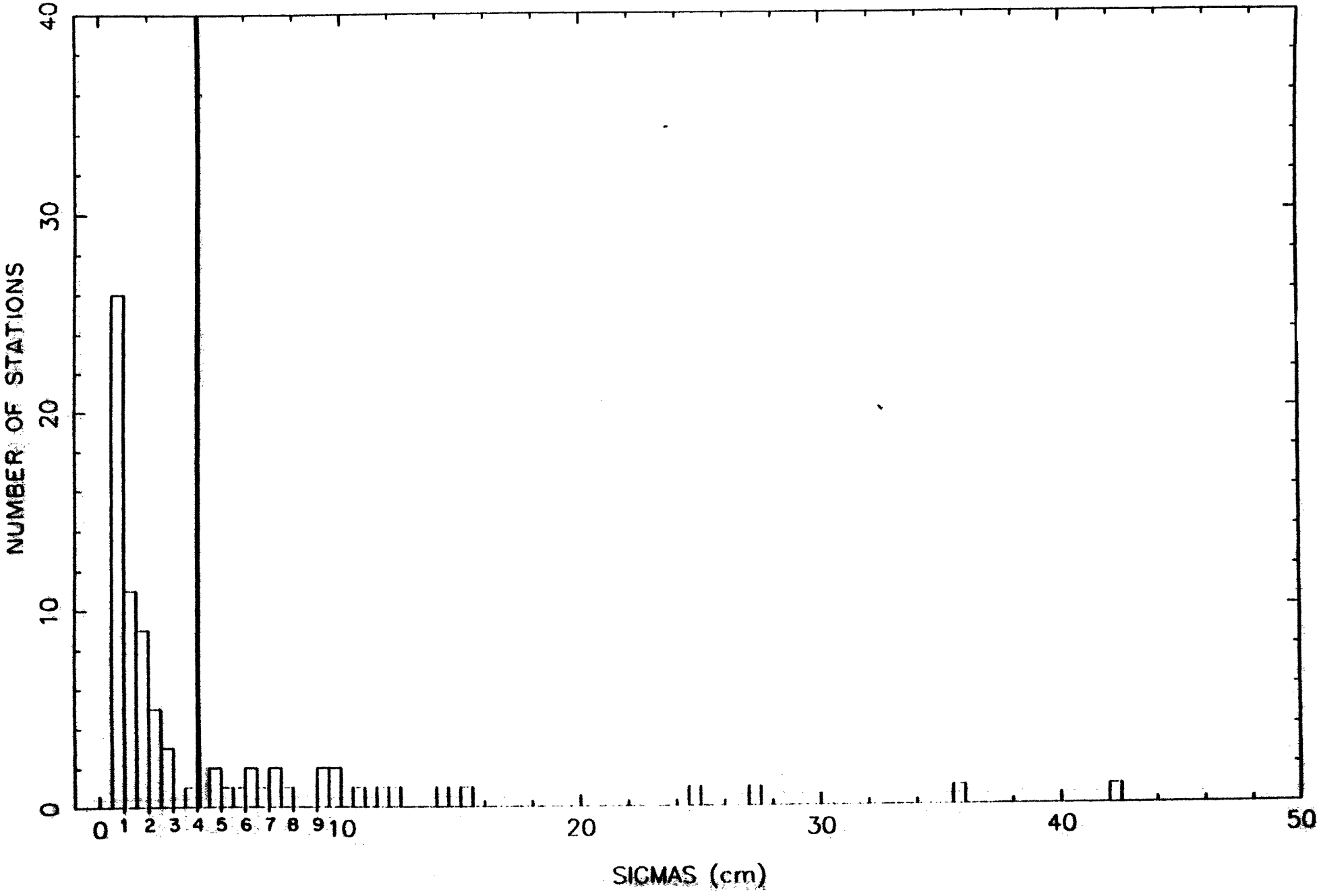


FIGURE 10
SSC(GSFC) 89 L 01 SL7.1(G4)



The quality of the results is also given by examining residuals by groups.

All residuals by site are given in Table T8 of the appendix. This Table gives residuals in meters both in equatorial and local frame, as well as equatorial residuals divided by the a priori standard errors.

At the end of each site, the following RMS means are given:

SX, 3-D RMS mean
NSX, 3-D RMS normalized mean
SP, 2-D RMS mean
SU, vertical RMS mean

with,

$$SX = \sqrt{\frac{\sum_i (RX_i^2 + RY_i^2 + RZ_i^2)}{3N}}$$

$$NSX = f \cdot \sqrt{\frac{\sum_i (NX_i^2 + NY_i^2 + NZ_i^2)}{3N}}$$

$$SP = \sqrt{\frac{\sum_i (RE_i^2 + RN_i^2)}{2N}}$$

$$SU = \sqrt{\frac{\sum_i RE_i^2}{N}}$$

with N as the number of points in the site, f a scaling facteur,

$$f = \frac{1}{\sigma_0} \sqrt{\frac{\text{Number of degree of freedom}}{\text{Number of observations}}}$$

A summary of the quality of the various sites is given in Table 5, where can be found N, NSX, SP and SU in cm, the maximum standard deviation of ITRF89 coordinates for this site, also in cm.

A similar analysis has been done by solution. Table 6 gives the results.

In addition, one can analyze transformation parameters as given in Table T7, and also compare ITRF89 to previous solutions, such as ITRF88. This global transformation is obtained with hypotheses (6) of Table 2. The values are (from ITRF88 to ITRF89) :

T1(cm) = 0.5 (±0.4)

T2(cm) = 3.6 (±0.4)

T3(cm) = 2.4 (±0.3)

D (10-8) = -0.3 (±0.1)

R1(0.001") = -0.1 (±0.2)

R2(0.001") = 0.0 (±0.2)

R3(0.001") = 0.0 (±0.1)

Table 5

Site	N	NSX	SP cm	SU cm	Max(*) cm
Grasse	16	0.7	2.8	3.5	1.5
Onsala	4	0.2	0.6	0.7	1.8
Metsahovi	5	1.7	28.6	34.2	2.4
Graz	8	1.4	7.6	4.3	1.6
Borowiec	2	4.3	22.8	9.1	3.4
Riga	4	2.1	30.3	28.9	3.2
Simeis	3	2.3	13.9	1.2	3.2
Dionysos	5	0.4	2.1	1.2	4.4
Askites	5	0.4	1.8	1.8	4.4
Roumelli	7	0.9	2.1	5.7	4.4
Karitza	4	0.5	2.2	1.2	2.2
Katavia	5	0.9	4.9	0.5	5.0
Xrisokalaria	5	0.5	2.2	2.0	4.5
Lampedusa	6	0.4	11.1	5.8	2.5

Bologna	9	0.6	4.4	2.7	1.7
Noto	3	0.8	2.5	2.9	2.2
Trieste	4	0.5	4.0	3.0	2.8
Cagliari	6	1.0	2.5	5.7	1.9
Matera	10	0.7	3.0	3.4	4.0
Chilbolton	2	1.0	1.7	2.6	1.9
Herstmonceux	8	0.8	3.0	4.5	1.6
Madrid	5	1.0	0.9	5.0	6.3
Kootwijk	7	1.5	7.7	6.9	3.7
Zimmerwald	8	1.4	8.0	2.5	1.6
Potsdam	7	1.3	4.9	7.3	1.9
Wettzell	16	0.8	3.1	3.9	6.4
Effelsberg	2	0.8	1.5	1.6	1.9
Bar Giyyora	2	0.4	1.2	2.1	2.9
Diyarbakir	4	0.7	6.0	2.8	2.7
Yozgat	5	0.7	3.8	2.7	2.4
Melengiclick	4	0.8	2.9	6.3	2.8
Yigilca	4	0.6	3.2	1.0	2.6
Shanghai	10	1.1	4.2	5.4	2.0
Kashima	3	0.4	1.8	1.1	2.2
Simosato	8	1.2	3.2	8.7	1.9
Helwan	5	1.7	15.2	9.9	3.2
Johannesburg	2	1.1	2.3	2.1	2.4
Algonquin	2	0.7	0.7	3.2	1.9
Pasadena	5	1.6	5.7	4.7	1.8
Goldstone	27	1.2	2.6	10.4	6.0
Fairbanks	4	0.3	1.7	3.6	1.5
Patrick AFB	2	0.5	4.6	11.7	10.7
Kauai	4	0.6	1.2	0.7	1.3
Quincy	18	1.0	4.5	2.9	3.0
Mount Hopkins	4	0.7	3.6	0.4	2.9
San Diego	8	0.6	2.2	2.8	1.4
Bear Lake	2	1.0	2.6	5.5	2.9
Owens Valley	12	0.9	3.5	3.2	1.2
Westford	14	0.7	1.7	3.8	1.2
Greenbank	4	1.9	1.3	17.5	2.1
Fort Davis	42	1.1	4.6	6.2	1.2
Maui	21	0.9	3.8	4.1	3.3
Washington	29	0.7	4.1	2.9	4.3
Hat Creek	2	0.2	0.3	0.4	1.6
Maryland Point	3	0.4	4.5	19.6	1.8
Flagstaff	5	1.7	4.4	8.0	1.8
Vernal	2	0.7	0.8	4.4	2.9
Yuma	3	0.8	3.3	0.6	1.8
Platteville	9	0.4	1.7	1.0	1.3
Monument Peak	16	0.8	2.9	2.8	4.3
Richmond	11	1.0	5.7	1.7	1.3
Mazatlan	8	0.6	1.2	3.6	1.6
Cabo San Lucas	5	1.6	3.0	10.0	1.9
Santiago de Cuba	5	2.2	13.6	9.1	2.6
Natal	2	1.8	4.8	12.5	3.4
Easter Island	6	0.5	2.5	1.9	2.0
Santiago	2	0.3	1.2	1.0	2.9
Cerro Tololo	2	0.3	1.3	0.2	2.9
Arequipa	8	1.4	4.7	6.7	1.7

Bermuda	2	0.6	5.3	6.2	6.3
Canberra	17	1.9	3.3	12.1	2.1
Yarragadee	8	1.0	5.1	3.9	4.9
American Samoa	2	0.2	0.8	0.3	2.9
Kwajalein atoll	6	0.8	3.3	1.6	1.9
Huahine	5	1.6	1.9	10.8	2.9

Max : Maximum standard deviation of ITRF89 coordinates

Table 6

Solution	N	SP	SU	WSX	NSX	(*)
RG	43	1.4	2.2	1.7	0.78	2
RN	26	2.2	9.9	2.1	0.92	2
RO	8	0.9	1.2	0.9	0.42	2
RS	5	0.9	2.2	1.4	0.43	3
RM	6	2.4	3.8	2.8	0.25	10
RJ	7	1.9	10.8	6.1	1.11	5
LC	85	9.3	12.2	4.9	1.07	4
LG	74	6.7	7.1	5.2	1.10	4
LD	23	3.5	1.9	3.0	0.68	4
LU	31	2.3	3.6	2.7	0.59	4
LZ	36	6.1	5.1	5.2	1.18	4
LS	41	6.0	6.9	4.2	0.90	4
LK	39	6.3	6.2	5.2	1.21	4
LL	24	11.6	9.6	10.8	2.02	5
MX	5	6.0	3.9	4.2	0.61	5
MJ	5	2.9	1.8	2.5	0.45	5
ME	4	12.8	19.3	14.4	2.58	5
MS	4	3.1	3.3	3.0	0.27	10

(*) : lower bound of the a priori standard deviation
for coordinates of the solution, in centimeters