method as the combination of SSC to produce the ITRF91 and consistent with it. NUVEL-1 NNR has been selected as a reference motion model and it was included in the global adjustment of the ITRF91 velocity field. The original formal errors given by the analysis centers in their individual solutions have been modified in order to obtain a realistic combined velocity field, while an error of 3 mm has been used for NUVEL-1 NNR velocities. Some NUVEL-1 NNR velocities have been deweighted in the combination (with 10 cm as apriori sigma). This concerns sites whose motion may differ from that given by NUVEL-1 NNR, such as sites in California, Japan and in the Mediterranean area. The same weighting formula (1) as for SSC has been used for velocity fields. The values of A and B attributed to the velocity fields are given in Table 5.

3) RESULTS

3.1) Values

We have adjusted combined coordinates in the ITRF91 solution for epoch 1988.0. They are given in Table T6 under the label SSC(IERS) 92 C 01. They are also published in Table T-3 of the IERS Annual Report for 1991.

The adjusted transformation parameters were published in Table T-2 of the IERS Annual Report for 1991. They are also available in Table T7 of the appendix.

Table T8 gives the rate of change of the translation and rotation parameters. The scale factor is assumed to be invariant with time. These values have to be considered as annual variations to the transformation parameters given in Table T7. So for a given transformation parameter T at an epoch t in years, we have:

$$T(t) = T(1988.0) + \dot{T} . (t - 1988.0) \qquad (2)$$

T and $\dot{T}$ are given in Tables T7 and T8 respectively. When $\dot{T}$ is not given one can assume $\dot{T} = 0$.

Table T9 lists the ITRF91 combined velocity field. These velocities should be used to refer the ITRF91 coordinates from the 1988.0 epoch to another desired epoch. This Table gives for each site its DOMES number, name, the individual solutions in which its velocities are available, the cartesian velocities and their standard deviations, the plate and a code : CN for Combined Velocities with NUVEL-1 NNR, C for Combined velocities with NUVEL-1 NNR velocities deweighted, and N for NUVEL-1 NNR velocities.

3.2) <u>Analysis of results</u>

The factor of unit variance is 1.5 for both the ITRF91 station coordinates and velocity field combined solutions. Although it is close to 1, the proper weighting in the combined adjustment is a rather critical and delicate problem.

For a sample of 6 stations covering the Earth, Figures 17 to 22 show the evolution of their position in the local frame, from ITRF0 to ITRF91.

FIG. 17 CANBERRA SLR 7943

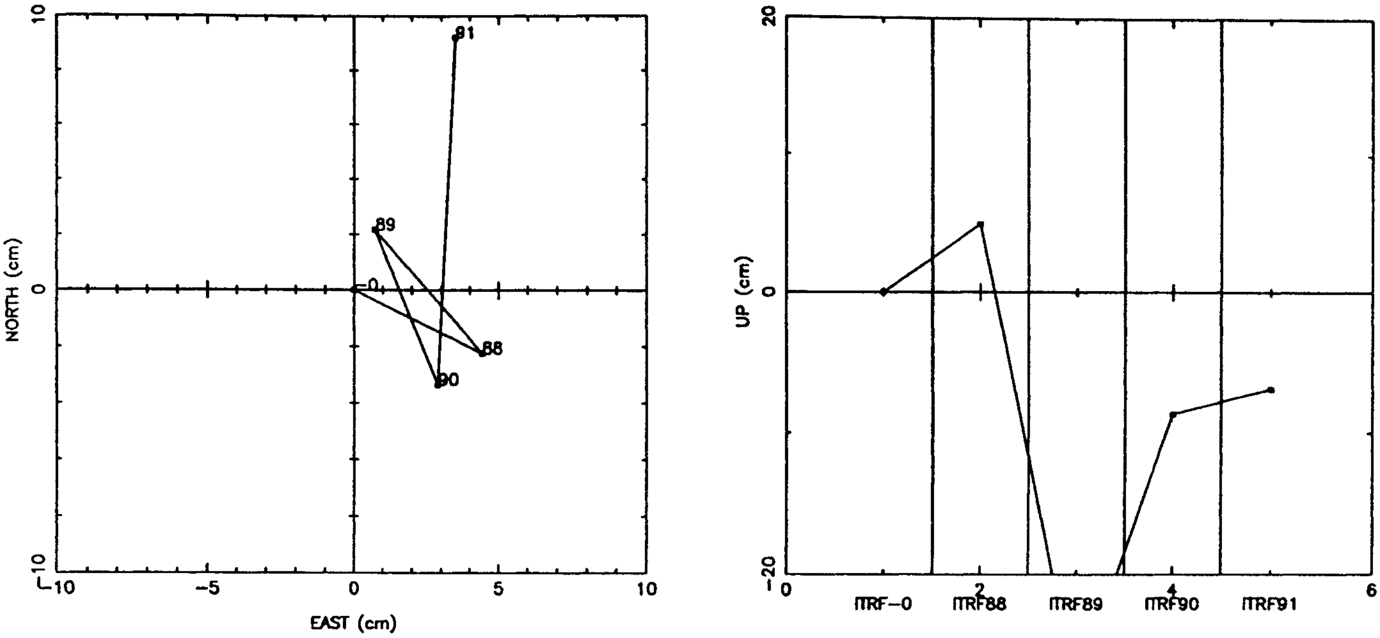


FIG. 18 SIMOSATO SLR 7838

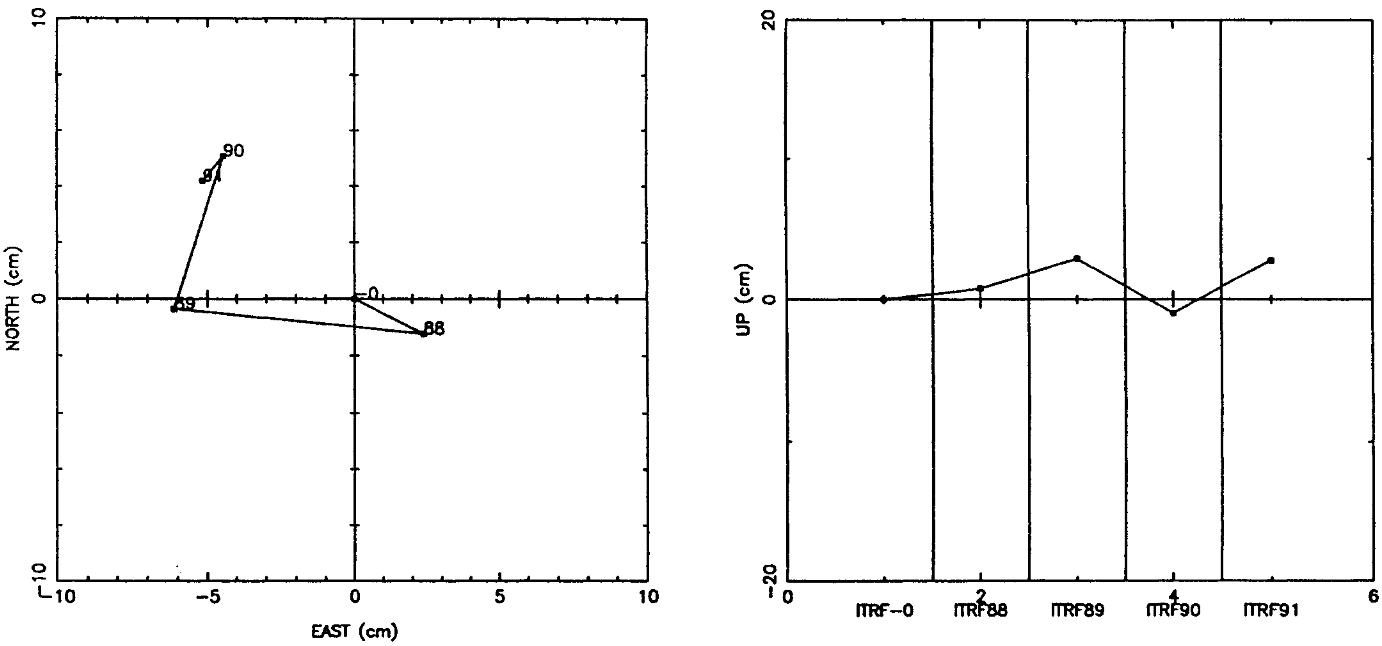


FIG. 19 HARTEBEESTHOEK VLBI 7232

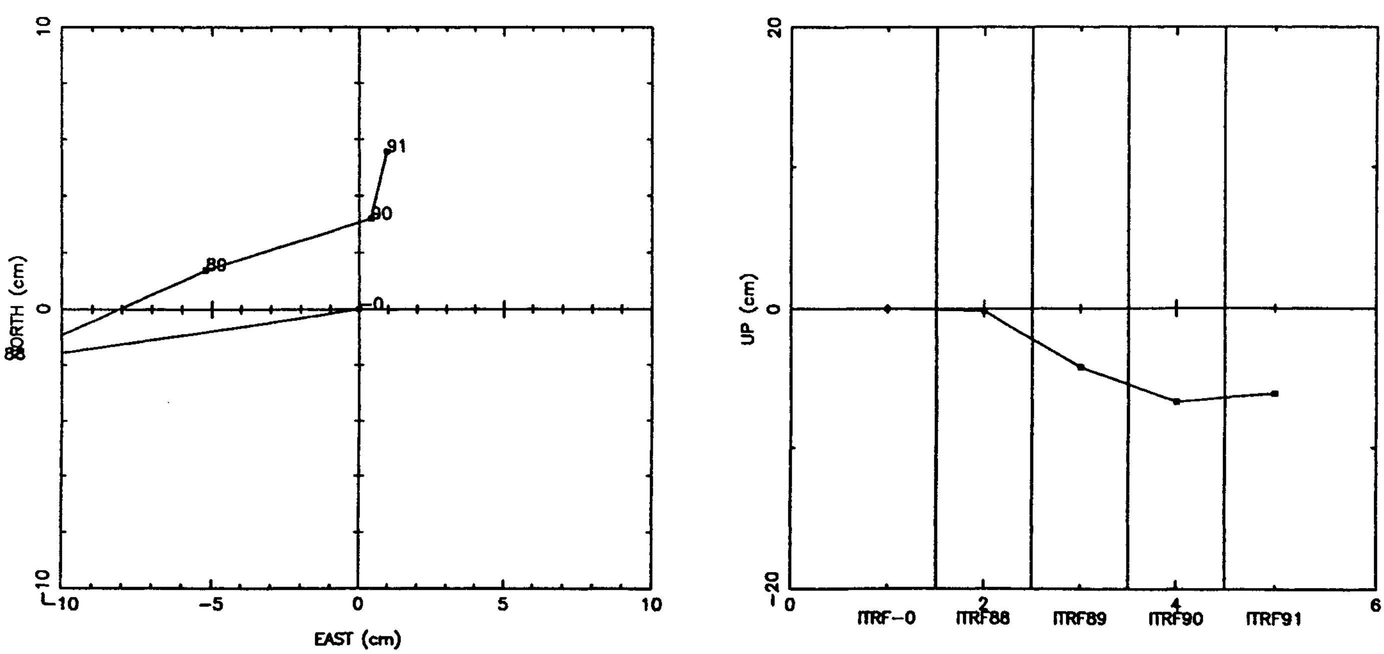


FIG. 20 WETTZELL SLR 7834

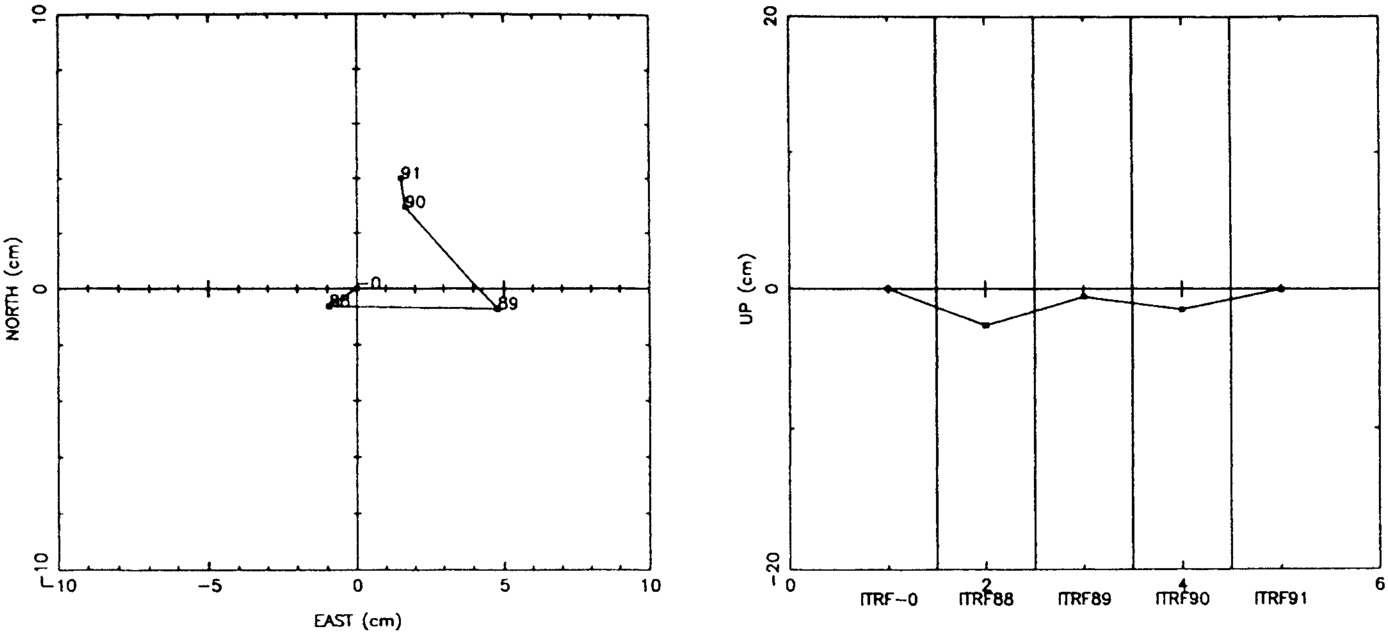


FIG. 21 AREQUIPA SLR 7907

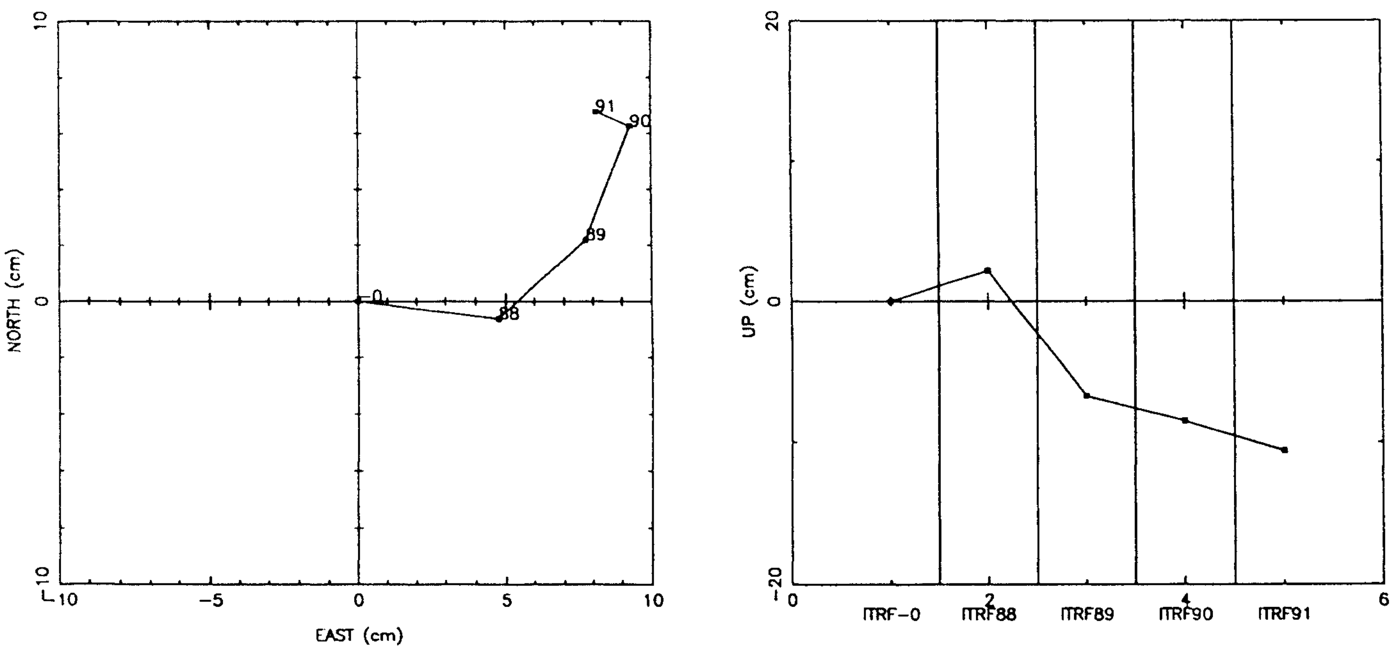
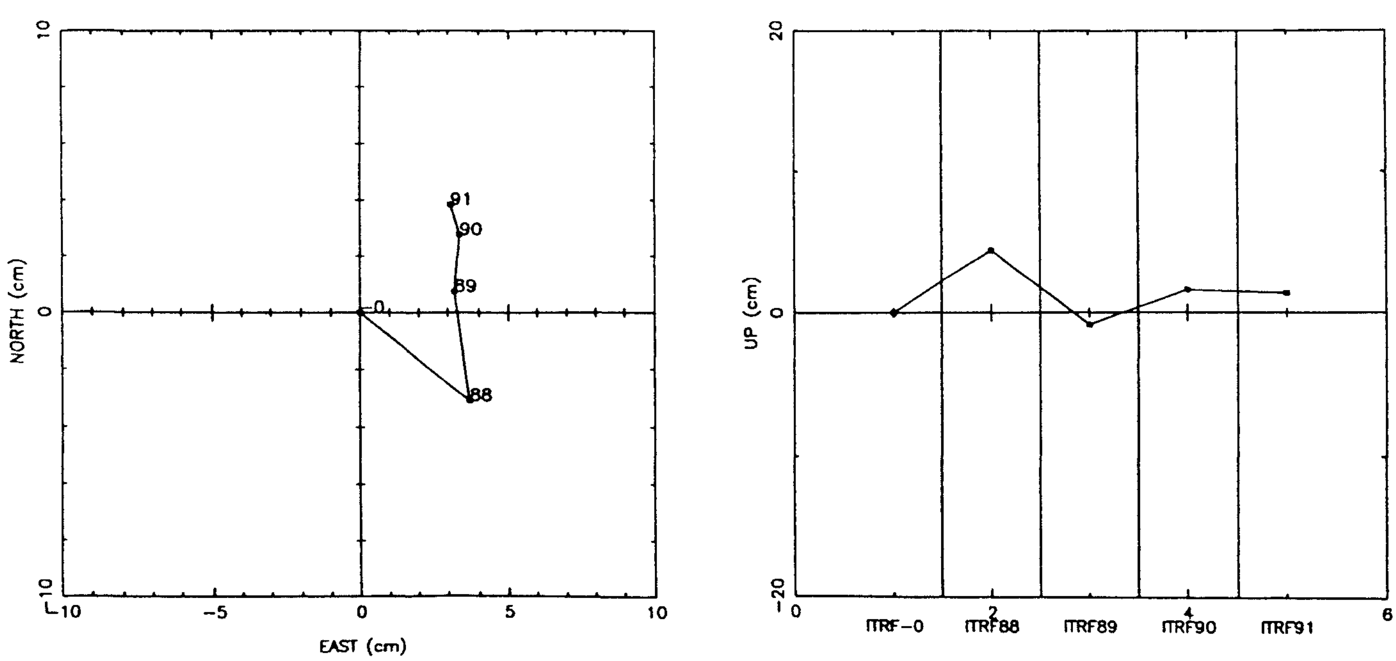


FIG. 22 FORT DAVIS SLR 7086



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

All residuals by site are given in Table T10 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,

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

$$NSX = f \sqrt{\frac{\sum_i (NX_i^2 + NY_i^2 + NZ_i^2)}{3N}} \qquad (4)$$

$$SP = \sqrt{\frac{\sum_i (RE_i^2 + RN_i^2)}{2N}} \qquad (5)$$

$$SU = \sqrt{\frac{\sum_i (RU_i^2)}{N}} \qquad (6)$$

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

$$f = \frac{1}{\sigma_0} \sqrt{\frac{\text{Number of degree of freedom}}{\text{Number of observation}}} \qquad (7)$$

A summary of the quality of the various sites is given in Table 3, where can be found N, NSX, SP and SU in cm, the maximum standard deviation of ITRF91 coordinates for this site, also in cm.

A similar analysis has been done by solution. Table 4 gives the results for the sets of station coordinates and Table 5 for the velocity fileds. Statistics presented in these two tables involve the following parameters:

N	: number of points common to other solutions
SP, SU and NSX	: as defined in page 31
WSX	: weighted 3-D RMS
A and B:	: the two weighting parameters of the formula (1), page 2

In addition, one can analyze transformation parameters as given in Table T7, and also compare ITRF91 to previous solutions, such as ITRF90. This global transformation is obtained taking into account one point per site only. The values are (from ITRF90 to ITRF91) :

T1(cm)	= -0.1	(±0.3)
T2(cm)	= 0.4	(±0.3)
T3(cm)	= 1.6	(±0.2)
D (10^{-8})	= -0.03	(±0.03)
R1(0.001")	= 0.0	(±0.1)
R2(0.001")	= 0.0	(±0.1)
R3(0.001")	= 0.0	(±0.1)

Finally, in order to analyse the ITRF91 combined velocity field, we illustrated in figures given in the appendix, site velocities in the local frame given by the combined solution, NUVEL1-NNR as well as the individual solutions.

Table 3

Summary of the quality of the ITRF91 sites

SITE	N	NSX	SP cm	SU cm	Max(*) cm
GRASSE	14	0.7	1.4	1.6	1.1
TROMSO	8	0.4	2.6	1.2	1.4
TRYSIL	2	0.5	0.7	0.5	2.5
ONSALA	3	0.7	0.2	0.9	1.0
METSAHOVI	5	1.5	32.0	39.3	3.0
GRAZ	6	0.6	0.8	3.4	1.2
BOROWIEC	6	1.7	13.6	7.9	3.0
RIGA	6	1.6	12.9	14.8	16.9
KATZIVELY	10	0.6	5.1	7.1	5.7
DIONYSOS	9	1.6	22.4	45.0	13.0
ASKITES	6	0.3	1.0	0.7	1.4
ROUMELLI	6	0.4	0.9	1.5	1.3
KARITSA	6	1.0	3.7	1.5	1.6
KATAVIA	6	0.5	1.7	1.1	1.4
XRISOKALARIA	6	0.6	1.7	1.2	1.5
LAMPEDUSA	6	0.5	1.2	1.6	1.5
BOLOGNA	12	1.0	6.1	1.1	1.3
NOTO	8	0.9	2.9	1.7	2.1
TRIESTE	6	0.6	3.0	1.6	2.1
CAGLIARI	6	0.3	0.9	0.7	1.5
MATERA	24	0.8	2.4	1.5	2.2
MONTE VENDA	3	0.6	5.2	1.8	4.2
CHILBOLTON	2	0.7	1.2	2.9	2.4
HERSTMONCEUX	7	0.4	0.9	1.2	1.1
MADRID-ROBLEDO	8	0.6	0.9	2.6	3.9
KOOTWIJK	14	0.6	2.5	3.0	3.0
ZIMMERWALD	7	0.5	1.0	1.6	1.2
MONTE GENEROSO	4	0.8	2.7	1.4	2.3
POTSDAM	6	0.9	3.3	4.0	2.2
WETTZELL	25	0.8	2.3	2.2	3.7
EFFELSBERG	2	0.2	0.8	0.2	4.6
BAR GIYYORA	6	0.6	2.8	5.1	2.1
DIYARBAKIR	6	0.6	2.2	1.1	1.6
YOZGAT	6	0.4	1.4	1.6	1.8
MELENGICLICK	6	0.8	2.8	1.8	1.5
YIGILCA	6	0.5	1.6	1.4	1.6
SHANGHAI	11	1.3	2.6	5.5	27.4
KASHIMA	7	1.3	1.1	1.7	1.6
NOBEYAMA	3	0.7	1.8	12.6	2.0
SIMOSATO	7	1.3	2.7	3.9	1.3
CHICHIJIMA	5	1.7	18.9	7.0	7.3
HELWAN	7	2.8	9.0	4.4	1.5
JOHANNESBURG	7	0.9	9.8	1.3	3.3
ALGONQUIN	7	0.5	0.6	0.4	0.9
YELLOWKNIFE	4	0.9	1.2	5.9	2.0
PASADENA	9	1.9	7.2	4.8	1.4
GOLDSTONE	37	1.3	2.9	4.7	3.1
PINYON FLATS	4	0.9	1.4	0.8	1.6
FAIRBANKS	7	0.5	0.5	0.6	1.0
PATRICK AFB	2	0.3	7.7	6.0	29.3

VANDENBERG AFB	6	0.7	4.7	24.0	1.9
KAUAI	7	1.5	0.7	1.7	1.1
QUINCY	21	0.9	5.5	2.4	0.9
MOUNT HOPKINS	6	0.5	5.5	7.7	9.2
SAN DIEGO	12	0.5	2.8	2.3	1.3
BEAR LAKE	9	0.7	3.4	4.7	3.5
OWENS VALLEY	17	0.8	2.1	2.0	1.0
WESTFORD	16	1.6	3.4	4.3	0.8
GREENBANK	6	0.8	0.5	1.0	1.1
FORT DAVIS	39	1.1	3.2	3.0	1.2
MAUI	19	0.9	2.8	1.8	1.1
WASHINGTON	49	0.7	3.9	3.8	1.9
PIETOWN	2	1.3	0.2	1.8	1.0
LOS ALAMOS	2	0.7	0.5	0.7	1.0
HAT CREEK	3	0.4	0.4	0.5	0.9
MARYLAND POINT	4	0.5	0.6	0.6	1.0
FLAGSTAFF	7	1.8	4.8	14.2	2.0
VERNAL	4	0.4	6.2	1.7	3.6
YUMA	5	1.2	7.9	2.5	1.5
PLATTEVILLE	10	0.7	1.1	2.3	1.0
MONUMENT PEAK	17	0.7	1.8	1.5	1.0
RICHMOND	12	0.8	2.8	1.0	0.9
MAZATLAN	7	0.4	1.1	0.8	1.2
CABO SAN LUCAS	6	1.1	1.6	5.5	1.7
ENSENADA	5	1.0	7.2	2.9	2.8
SANTIAGO DE CUBA	5	1.6	14.8	11.5	2.8
NATAL	4	0.6	43.5	8.1	6.4
EASTER ISLAND	6	0.9	3.0	3.0	3.3
SANTIAGO	8	0.7	2.4	4.8	3.6
CERRO TOLOLO	6	1.2	8.8	3.1	1.7
SEST	2	0.6	0.5	2.5	3.0
AREQUIPA	11	0.9	1.7	2.8	1.8
CANBERRA	22	1.3	6.4	5.3	3.2
YARRAGADEE	10	0.8	1.3	2.3	1.4
HOBART	3	1.3	3.5	0.8	2.0
AMERICAN SAMOA	4	3.2	15.0	4.0	2.7
KWAJALEIN ATOLL	8	1.2	4.8	3.6	1.6
HUAHINE	13	1.9	5.5	3.8	1.5

Max : Maximum standard deviation of ITRF91 coordinates

Table 4

Statistics of the ITRF91 combined solution

Solution	N	SP cm	SU cm	WSX cm	NSX	A cm	B
SSC(GSFC) 92 R 03	56	1.9	2.7	0.9	1.00	0.5	1.5
SSC(NOAA) 92 R 01	37	0.9	4.0	0.7	0.70	0.5	1.5
SSC(USNO) 92 R 03	14	1.9	3.6	0.9	1.01	0.5	1.5
SSC(NAOMZ)92 R 01	25	0.8	1.5	0.9	1.17	0.5	1.5
SSC(JPL) 92 R 01	7	0.8	1.5	1.0	0.50	1.0	1.0
SSC(CSR) 92 L 01	99	9.4	10.7	3.0	0.96	1.5	1.0
SSC(GSFC) 92 L 01	88	6.2	8.6	3.4	1.18	1.5	3.0
SSC(DGFII)92 L 01	80	11.8	4.3	4.4	1.35	2.0	3.0
SSC(DUT) 92 L 01	52	4.2	2.4	2.1	1.03	1.5	1.0
SSC(GFZ) 92 L 01	93	6.7	7.5	2.4	0.82	1.5	2.0
SSC(GAOUA)92 L 01	67	4.4	14.5	3.9	1.18	2.5	2.0
SSC(NAL) 92 L 01	28	8.2	7.2	3.3	0.95	1.5	2.0
SSC(UTXMO)92 M 01	5	3.8	2.7	3.1	1.30	1.5	0.2
SSC(JPL) 92 M 01	5	3.6	2.4	3.1	0.82	3.0	0.0
SSC(SHA) 92 M 01	4	7.5	5.7	6.6	1.05	5.0	0.0
SSC(JPL) 91 P 01	14	1.1	1.8	1.4	0.87	0.0	1.0

(*) : A is the additive variance in cm and B is the factor of the formula (1).

Table 5

Statistics of the ITRF91 combined velocity field

Network	N	SP mm /year	SU mm /year	WSX mm /year	NSX	A mm /year	B
Nuvel1-NNR	90	9.5	11.7	4.0	0.92	3 horizontal 10 vertical	0.0
SSC(GSFC) 92 R 03	57	1.4	2.6	1.0	0.60	0.5	1.5
SSC(NOAA) 92 R 01	28	2.5	20.2	1.5	0.85	0.5	1.5
SSC(NAOMZ)92 R 01	9	0.9	2.1	0.9	1.02	0.5	1.5
SSC(CSR) 92 L 01	43	5.3	---	2.7	1.09	1.5	1.0
SSC(GSFC) 92 L 01	22	4.6	---	4.6	1.56	3.0	0.0
SSC(DGFII)92 L 01	45	25.9	---	4.9	1.50	2.0	3.0
SSC(DUT) 92 L 01	40	16.1	10.8	5.9	0.97	1.5	2.0
SSC(GFZ) 92 L 01	40	12.8	10.3	4.6	0.88	1.5	2.0

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