VERY LONG BASELINE INTERFEROMETRY

EARTH ORIENTATION PARAMETERS WITH ESTIMATED SITE VELOCITIES FROM THE NASA CRUSTAL DYNAMICS PROJECT

GSFC 90 R 01

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Mark III VLBI data acquired since 1979 by the NASA Crustal Dynamics Project and the POLARIS/IRIS programs have been analyzed for Earth orientation parameters. The reference frame origin is defined by the a priori position of the 18-m Westford antenna on 1980 Oct. 17 and moving with AM0-2 velocity. The orientation of the frame is defined by values from BIH Circular D, modified by the IERS Standard UT1 tidal model, and the Standard J2000.0 precession and IAU 1980 nutation models for the reference date 1986 Nov. 6 and by the azimuth of the Westford-Richmond baseline, which evolves according to the AM0-2 model. Short period tidal terms in UT1 have not been removed from the tabulated values of UT1-UTC. All uncertainties are 1-sigma formal standard errors from the sequential least-squares solution described below.

The basic models used to calculate the VLBI delays are consistent with the IERS Standards and are contained in the Goddard CALC 7.0 program. These include IAU 1980 nutation with daily offsets in longitude and obliquity estimated, solid earth tides ($h_2 = 0.60697$, $l_2 = 0.085$) correcting the K_1 term but not the zero frequency displacement, pole tide, vertical ocean loading, CfA 2.2 troposphere mapping, tidal variation of smoothed a priori UT1, PEP solar system ephemeris rotated to J2000.0, and a modified Hellings (1986) VLBI time delay consistent with the alternative IERS standard model at 1 ps rms. For each session a single reweighting constant computed for the particular day was added in quadrature to the data uncertainties derived strictly from SNR to reflect the actual data scatter. The dry troposphere was modeled from local meteorological data and the residual wet troposphere was estimated using a continuous piecewise linear function. The behavior of the site clocks for each day was similarly estimated using a quadratic polynomial and a continuous piecewise linear function. For both estimates the variation in the continuous function was constrained to physically reasonable values except in the rare instances when the data dictated otherwise. The horizontal velocities of all sites with sufficient data were estimated as well as the vertical velocities of HRAS 085 (Texas), Gilcreek (Alaska), and Kashima (Japan). Richmond was constrained to move only in the a priori direction of Westford. The more complete treatment of relativity in the VLBI time delay model and the use of a single reweighting constant for each day are the major changes from our previous submission.

357 439 dual-frequency Mark III delays from 824 sessions using fixed stations as well as several mobile sites in >3000 km networks were combined to estimate site positions and velocities, source positions, Earth orientation parameters, and troposphere and clock behavior from a least-squares solution with 341 global parameters and 154 137 arc parameters. A weak input covariance on polar motion and UT1 (x, y - 45 mas, UT1 - 3 ms) was used so that all three components could be estimated for each session with more reliable indication of uncertainty and correlation. The weighted rms post-fit residual of the solution was 45.6 ps. The reduced chi-square was 0.974 including the constraints in the computation of the degrees of freedom (Theil, 1963).

The complete Earth orientation time series is designated EOP(GSFC)90 R 01. Other results are source positions designated RSC(GSFC)90 R 01 and site coordinates at 1979-92 Jan 1.5 designated SSC(GSFC)90 R 01.

Hellings, R. W., 1986, *Astron. J.*, **91**, 1446.
Theil, H., 1963, *Amer. Stat. Ass. J.*, **58**, 401.

IERS(1990) Technical Note no 5.

SITE POSITIONS FOR JANUARY 1.5, 1988 MJD 47161.5 SSC(GSFC) 90 R 01

NETWORK NUMBER		SITE	X m	Y m	Z m	MEAN MJD	DATA SPAN days	SX m	SY m	SZ m
7282	S	ALGOPARK	918036.586	-4346133.087	4561971.539	46159.8	377.0	.008	.009	.008
7215	S	CHLBOLTN	4008311.855	-100651.733	4943795.089	44532.0	7.0	.009	.004	.010
1642	S	DSS45	-4460933.432	2682764.921	-3674381.118	47433.3	272.0	.013	.010	.010
1665	S	DSS65	4849338.428	-360489.791	4114749.101	47517.0	277.0	.003	.002	.005
7203	S	EFLSBERG	4033949.273	486989.526	4900431.116	44584.0	1258.0	.011	.018	.011
7225	S	GILCREEK	-2281545.413	-1453645.916	5756993.687	47005.7	1922.0	.001	.002	.004
1513	S	GOLDVENU	-2351127.388	-4655477.959	3660957.372	45639.5	2424.0	.004	.007	.007
7120	M	HALEAKAL	-5465996.776	-2404409.435	2242228.926	47344.7	15.0	.014	.007	.008
7232	S	HARTRAO	5085444.377	2668262.563	-2768696.783	46984.4	1176.0	.012	.009	.008
7218	S	HATCREEK	-2523968.182	-4123507.231	4147753.051	46733.6	2150.0	.002	.003	.004
7205	S	HAYSTACK	1492406.565	-4457267.353	4296882.133	45198.8	3649.0	.001	.002	.002
7216	S	HRAS 085	-1324209.205	-5332023.991	3232118.815	46345.4	3354.0	.001	.002	.002
1856	S	KASHIMA	-3997890.601	3276580.392	3724118.844	46985.3	2087.0	.004	.002	.007
1311	S	KAUAI	-5543844.303	-2054565.049	2387814.294	46904.3	1828.0	.003	.003	.005
4968	S	KWAJAL26	-6143534.830	1363996.343	1034707.924	46490.6	1492.0	.008	.004	.007
7217	S	MARPOINT	1106631.194	-4882908.052	3938087.349	45279.0	438.0	.057	.057	.068
7230	S	MEDICINA	4461371.806	919595.829	4449559.505	47330.5	690.0	.003	.003	.005
7222	S	MOJAVE12	-2356169.237	-4646756.759	3668471.058	47031.2	2376.0	.001	.002	.003
7547	S	NOTO	4934564.914	1321200.274	3806484.755	47713.3	89.0	.006	.003	.006
7204	S	NRAO 140	882881.707	-4924483.159	3944131.072	45074.2	3379.0	.002	.004	.003
7213	S	ONSALA60	3370607.828	711916.513	5349831.064	46210.4	3413.0	.002	.001	.004
7207	S	OVRO 130	-2409599.002	-4478350.421	3838603.669	45474.2	3379.0	.001	.003	.004
7283	M	PENTICTN	-2058838.680	-3621287.185	4814421.171	46185.3	377.0	.020	.027	.029
7234	S	PIETOWN	-1640951.894	-5014816.852	3575412.354	47639.3	356.0	.001	.003	.004
7258	M	PLATTVIL	-1240706.380	-4720455.221	4094482.093	46652.3	2146.0	.002	.007	.006
7219	S	RICHMOND	961259.817	-5674090.871	2740534.156	46838.6	2200.0	.001	.002	.001
1561	S	ROBLED32	4849246.985	-360279.123	4114884.840	45460.0	1.0	.053	.013	.044
7227	S	SESHAN25	-2831684.991	4675732.941	3275328.326	47450.1	352.0	.006	.005	.010
7226	S	SHANGHAI	-2847696.522	4659872.049	3283959.400	46595.0	1.0	.124	.108	.097
7223	M	VNDNBERG	-2678092.995	-4525451.698	3597410.589	46820.9	1828.0	.002	.003	.004
7209	S	WESTFORD	1492208.423	-4458131.350	4296015.901	46501.1	3152.0	0.000	0.000	0.000
7224	S	WETTZELL	4075541.699	931734.279	4801629.697	46808.6	2235.0	.002	.001	.004
7285	M	YELLOWKN	-1224122.743	-2689531.483	5633555.733	46125.0	377.0	.015	.022	.027

RADIO SOURCE COORDINATES RSC(GSFC) 90 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0016+731	0	19	45.785944	73	27	30.01535	0.000083	0.00030
0048-097	0	50	41.317382	- 9	29	5.21075	0.000009	0.00019
0106+013	1	8	38.771037	1	35	0.31616	0.000002	0.00014
0119+041	1	21	56.861671	4	22	24.73208	0.000012	0.00035
0212+735	2	17	30.812731	73	49	32.62067	0.000027	0.00012
0224+671	2	28	50.051044	67	21	3.02831	0.000024	0.00017
0229+131	2	31	45.893981	13	22	54.71589	0.000003	0.00013
0234+285	2	37	52.405550	28	48	8.98937	0.000005	0.00012
0235+164	2	38	38.930013	16	36	59.27409	0.000008	0.00034
0300+470	3	3	35.242000	47	16	16.27502	0.000009	0.00013
0316+413	3	19	48.159904	41	30	42.10380	0.000013	0.00020
0336-019	3	39	30.937757	- 1	46	35.80328	0.000018	0.00054
0355+508	3	59	29.746999	50	57	50.16190	0.000011	0.00013
0420-014	4	23	15.800671	- 1	20	33.06380	0.000002	0.00014
0430+052	4	33	11.095437	5	21	15.62003	0.000029	0.00157
0454-234	4	57	3.179247	-23	24	52.01744	0.000012	0.00021
0528+134	5	30	56.416675	13	31	55.15142	0.000003	0.00013
0552+398	5	55	30.805437	39	48	49.16664	0.000007	0.00012
0727-115	7	30	19.112442	-11	41	12.59701	0.000004	0.00015
0742+103	7	45	33.059466	10	11	12.69588	0.000004	0.00019
0814+425	8	18	15.999538	42	22	45.41816	0.000019	0.00023
0820+560	8	24	47.236131	55	52	42.67259	0.000052	0.00037
0823+033	8	25	50.338312	3	9	24.52432	0.000010	0.00034
0851+202	8	54	48.874869	20	6	30.64407	0.000003	0.00012
0919-260	9	21	29.353982	-26	18	43.38376	0.000125	0.00316
0923+392	9	27	3.013828	39	2	20.85503	0.000007	0.00012
0953+254	9	56	49.875377	25	15	16.05194	0.000017	0.00057
1034-293	10	37	16.079683	-29	34	2.80910	0.000014	0.00024
1055+018	10	58	29.605173	1	33	58.82765	0.000002	0.00015
1144+402	11	46	58.297958	39	58	34.30726	0.000007	0.00013
1150+812	11	53	12.499748	80	58	29.15678	0.000090	0.00024
1156+295	11	59	31.833933	29	14	43.82961	0.000005	0.00013
1219+285	12	21	31.690583	28	13	58.50336	0.000017	0.00062
1226+023	12	29	6.699700	2	3	8.60147	********	0.00014
1253-055	12	56	11.166450	- 5	47	21.52225	0.000006	0.00022
1308+326	13	10	28.663931	32	20	43.78508	0.000005	0.00013
1334-127	13	37	39.782707	-12	57	24.69054	0.000007	0.00020
1354+195	13	57	4.436699	19	19	7.37399	0.000006	0.00016
1404+286	14	7	0.394476	28	27	14.69141	0.000004	0.00013
1418+546	14	19	46.597636	54	23	14.78850	0.000018	0.00018
1502+106	15	4	24.979812	10	29	39.20013	0.000003	0.00015
1548+056	15	50	35.269238	5	27	10.44933	0.000003	0.00014
1611+343	16	13	41.064362	34	12	47.90888	0.000012	0.00020
1622-253	16	25	46.891518	-25	27	38.32574	0.000051	0.00275
1633+382	16	35	15.493083	38	8	4.50035	0.000006	0.00012

RADIO SOURCE COORDINATES RSC(GSFC) 90 R 01

SOURCE	RIGHT ASCENSION H M S	DECLINATION o ' "	SIGMA R.A. S	SIGMA D. "
1637+574	16 38 13.456572	57 20 23.97867	0.000013	0.00013
1642+690	16 42 7.848952	68 56 39.75586	0.000024	0.00015
1641+399	16 42 58.810083	39 48 36.99363	0.000007	0.00012
1730-130	17 33 2.705703	-13 4 49.54799	0.000005	0.00016
1739+522	17 40 36.978046	52 11 43.40655	0.000012	0.00013
1741-038	17 43 58.856101	- 3 50 4.61685	0.000002	0.00015
1749+701	17 48 32.840641	70 5 50.76684	0.000168	0.00078
1749+096	17 51 32.818580	9 39 0.72791	0.000003	0.00014
1803+784	18 0 45.684655	78 28 4.01707	0.000038	0.00012
1921-293	19 24 51.055857	-29 14 30.12108	0.000007	0.00020
1923+210	19 25 59.605389	21 6 26.15931	0.000028	0.00109
1928+738	19 27 48.495291	73 58 1.56727	0.000093	0.00067
1954+513	19 55 42.738365	51 31 48.54382	0.000029	0.00030
1958-179	20 0 57.090359	-17 48 57.67309	0.000015	0.00024
2037+511	20 38 37.034825	51 19 12.66039	0.000012	0.00013
2113+293	21 15 29.413449	29 33 38.36444	0.000011	0.00029
2121+053	21 23 44.517356	5 35 22.09121	0.000003	0.00013
2128-123	21 31 35.261621	-12 7 4.79781	0.000022	0.00032
2134+004	21 36 38.586280	0 41 54.21207	0.000002	0.00014
2145+067	21 48 5.458639	6 57 38.60213	0.000003	0.00013
2200+420	22 2 43.291350	42 16 39.97733	0.000008	0.00012
2201+315	22 3 14.975785	31 45 38.26788	0.000026	0.00067
2216-038	22 18 52.037695	- 3 35 36.88125	0.000003	0.00015
2234+282	22 36 22.470818	28 28 57.41090	0.000006	0.00013
2251+158	22 53 57.747891	16 8 53.55864	0.000003	0.00012
2255-282	22 58 5.962854	-27 58 21.25893	0.000035	0.00227
2345-167	23 48 2.608491	-16 31 12.02291	0.000010	0.00018

EOP(GSFC) 90 R 01 Available from 1979 to 1989

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	X Nb	X Sigma	Y Nb	Y Sigma	UT1 Nb	UT1 Sigma	dPsi Nb	dPsi Sigma	dEps Nb	dEps Sigma
1979	2	1.44	2	2.81	2	1.05	2	1.93	2	0.67
1980	20	2.90	20	8.98	20	2.30	20	1.26	20	0.42
1981	32	11.45	32	36.03	32	9.24	32	2.79	32	1.41
1982	55	11.01	55	34.53	55	8.93	55	2.93	55	1.09
1983	66	15.75	66	31.20	66	8.04	66	2.67	66	1.28
1984	91	8.90	91	6.97	91	1.62	91	1.13	91	0.41
1985	94	5.42	94	3.62	94	0.71	94	0.83	94	0.37
1986	108	0.84	108	4.26	108	0.53	108	0.71	108	0.27
1987	129	0.68	129	0.53	129	0.28	129	0.69	129	0.25
1988	127	0.45	127	0.47	127	0.24	127	0.60	127	0.24
1989	100	0.34	100	0.35	100	0.17	100	0.52	100	0.21

FIXED STATION AND MOBILE SITE POSITION RESULTS WITH ESTIMATED SITE VELOCITIES FROM THE NASA CRUSTAL DYNAMICS PROJECT GSFC 90 R 02

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Mark III VLBI data acquired since 1979 by the NASA Crustal Dynamics Project and the POLARIS/IRIS programs have been analyzed for site positions. The reference frame origin is defined by the a priori position of the 18-m Westford antenna on 1980 Oct. 17 and moving with AM0-2 velocity. The orientation of the frame is defined by values from BIH Circular D, modified by the IERS Standard UT1 tidal model, and the standard J2000.0 precession and IAU 1980 nutation models for the reference date 1986 Nov. 6 and by the azimuth of the Westford-Richmond baseline, which evolves according to the AM0-2 model. All uncertainties are 1- sigma formal standard errors from the sequential least-squares solution described below.

115 248 dual-frequency Mark III delays from 221 mobile sessions were added to the fixed station solution designated GSFC 90 R 01 to generate a densified global terrestrial reference frame. The values and correlations of polar motion and UT1 from ERP(GSFC)90 R 01 were applied as a priori covariance information for each mobile session. Otherwise the analysis configuration was identical to solution GSFC 90 R 01. Horizontal velocities were estimated for all sites with sufficient data and vertical velocities were estimated for HRAS 085 (Texas), Gilcreek (Alaska), and Kashima (Japan). The additional data increased the global parameters from 341 to 611 and the arc parameters from 154 137 to 205 413. The weighted rms post-fit residual of the mobile data was 43.6 ps. The reduced chi- square of the solution was 1.01 including the troposphere, clock and EOP constraints in the computation of the degrees of freedom.

The site coordinates at 1979-92 Jan 1.5 are designated SSC(GSFC)90 R 02. The Earth Orientation series generated from the combined fixed and mobile VLBI session using only a weak input covariance (x, y - 45 mas, UT1 - 3 ms) is designated EOP(GSFC) 90 R 02, and the source positions are designated RSC(GSFC) 90 R 02.

SITE POSITIONS FOR JANUARY 1.5, 1988 MJD 47161.5 SSC(GSFC) 90 R 02

NETWORK NUMBER	SITE	X m	Y m	Z m	MEAN MJD	DATA SPAN days	SX m	SY m	SZ m
7282 S	ALGOPARK	918036.586	-4346133.088	4561971.540	46159.8	377.0	.008	.009	.008
7890 M	AUSTINTX	-737792.056	-5459893.125	3202990.906	46988.0	1.0	.004	.016	.009
7294 M	BERMUDA	2307211.231	-4874216.665	3394318.269	47012.7	7.0	.005	.010	.007
7269 M	BLKBUTTE	-2306305.206	-4787915.302	3515736.874	46524.2	1815.0	.004	.008	.006
7291 M	BLOOMIND	302386.202	-4941699.890	4007908.890	47027.0	1.0	.010	.035	.029
7604 M	BREST	4228878.861	-333105.167	4747181.288	47771.5	6.0	.013	.003	.014
7603 M	CARNUSTY	3526418.159	-171422.097	5294099.195	47760.0	3.0	.012	.004	.016
7228 M	CARROLGA	453522.375	-5300507.615	3507207.839	46995.0	1.0	.009	.036	.022
7215 S	CHLBOLTN	4008311.853	-100651.732	4943795.090	44532.0	7.0	.008	.004	.010
7267 M	DEADMANL	-2336817.906	-4732587.832	3570330.434	46610.6	1435.0	.007	.012	.009
7231 S	DSS15	-2353537.008	-4641650.396	3676670.465	47101.0	1.0	.004	.009	.007
1642 S	DSS45	-4460933.448	2682764.920	-3674381.099	47433.3	272.0	.012	.009	.008
1665 S	DSS65	4849338.428	-360489.794	4114749.101	47517.0	277.0	.003	.002	.004
7203 S	EFLSBERG	4033949.273	486989.525	4900431.114	44584.0	1258.0	.011	.018	.010
7286 M	ELY	-2077234.556	-4486713.583	4018754.199	47023.3	1836.0	.003	.007	.006
7261 M	FLAGSTAF	-1923990.921	-4850855.385	3658589.748	46693.5	1643.0	.005	.011	.008
7266 M	FORT ORD	-2697025.016	-4354394.185	3788078.060	46683.0	1639.0	.005	.008	.007
7241 M	FORTORDS	-2699838.513	-4359127.973	3781051.412	47564.2	185.0	.006	.010	.008
7900 M	FTD 7900	-1324226.191	-5332063.890	3232023.477	47443.0	1.0	.004	.013	.008
7225 S	GILCREEK	-2281545.413	-1453645.919	5756993.691	47023.9	1922.0	.001	.001	.002
1513 S	GOLDVENU	-2351127.378	-4655477.950	3660957.363	45768.9	2424.0	.002	.004	.003
7102 M	GORF7102	1130688.334	-4831353.874	3994111.307	47744.5	136.0	.003	.010	.009
7605 M	GRASSE	4581699.438	556124.761	4389351.765	47785.0	3.0	.010	.004	.011
7120 M	HALEAKAL	-5465996.779	-2404409.438	2242228.936	47344.7	15.0	.014	.007	.007
7232 S	HARTRAO	5085444.377	2668262.559	-2768696.777	46984.4	1176.0	.011	.007	.006
7218 S	HATCREEK	-2523968.183	-4123507.230	4147753.053	46937.9	2172.0	.001	.002	.002
7205 S	HAYSTACK	1492406.565	-4457267.352	4296882.132	45243.0	3649.0	.001	.002	.002

NETWORK NUMBER	SITE	X m	Y m	Z m	MEAN MJD	DATA SPAN days	SX m	SY m	SZ m
7600 M	HOHENFRG	3778216.658	698643.785	5074053.939	47701.8	6.0	.005	.002	.007
7216 S	HRAS 085	-1324209.205	-5332023.991	3232118.816	46393.4	3374.0	.000	.001	.001
7263 M	JPL MV1	-2493304.239	-4655198.465	3565519.785	46246.4	2213.0	.004	.007	.005
1856 S	KASHIMA	-3997890.604	3276580.389	3724118.853	46993.6	2087.0	.003	.002	.004
1311 S	KAUAI	-5543844.306	-2054565.051	2387814.304	46917.5	1861.0	.002	.002	.003
7278 M	KODIAK	-3026938.426	-1575912.675	5370362.982	47050.8	1811.0	.005	.003	.009
4968 S	KWAJAL26	-6143534.835	1363996.341	1034707.938	46490.6	1492.0	.008	.004	.005
7292 M	LEONRDOK	-522229.830	-5145677.740	3720152.780	47032.0	1.0	.004	.019	.012
7259 M	MAMMOTHL	-2448245.020	-4426739.189	3875436.349	46009.2	1212.0	.008	.015	.013
7217 S	MARPOINT	1106631.123	-4882908.040	3938087.355	46390.2	2540.0	.002	.006	.005
7850 M	MCD 7850	-1330006.399	-5328392.413	3236503.159	47441.0	1.0	.003	.010	.006
7230 S	MEDICINA	4461371.806	919595.827	4449559.504	47330.5	690.0	.003	.002	.004
7601 M	METSHOVI	2890654.556	1310294.351	5513959.063	47715.0	5.0	.007	.004	.012
7038 M	MILESMON	-1204437.250	-4239211.969	4596266.511	47267.0	1.0	.009	.029	.029
7288 M	MOJ 7288	-2356492.356	-4646608.552	3668427.074	47101.0	1.0	.006	.011	.008
7222 S	MOJAVE12	-2356169.237	-4646756.759	3668471.061	46943.3	2377.0	.001	.001	.002
7274 M	MON PEAK	-2386287.661	-4802347.448	3444884.426	46613.6	2405.0	.002	.005	.003
7279 M	NOME	-2658148.669	-693822.769	5737237.091	46321.6	748.0	.009	.006	.015
7547 S	NOTO	4934564.920	1321200.270	3806484.758	47718.6	94.0	.004	.002	.004
7204 S	NRAO 140	882881.707	-4924483.159	3944131.072	45074.2	3379.0	.002	.004	.003
7214 S	NRAO85 3	882327.387	-4925138.811	3943398.038	47677.5	2.0	.003	.010	.008
7270 M	OCOTILLO	-2335599.334	-4832245.170	3434392.890	45991.0	367.0	.058	.053	.072
7213 S	ONSALA60	3370607.829	711916.512	5349831.063	46289.1	3413.0	.002	.001	.003
7853 M	OVR 7853	-2410419.478	-4477801.290	3838690.780	47101.0	1.0	.004	.007	.006
7207 S	OVRO 130	-2409598.997	-4478350.418	3838603.669	45908.2	3387.0	.001	.002	.002
7254 M	PBLOSSOM	-2464069.177	-4649426.515	3593906.161	46345.6	1814.0	.005	.010	.008
7283 M	PENTICTN	-2058838.678	-3621287.185	4814421.170	46185.3	377.0	.020	.027	.029

SITE POSITIONS FOR JANUARY 1.5, 1988 MJD 47161.5 SSC(GSFC) 90 R 02

NETWORK NUMBER	SITE	X m	Y m	Z m	MEAN MJD	DATA SPAN days	SX m	SY m	SZ m
7234 S	PIETOWN	-1640951.893	-5014816.848	3575412.351	47560.4	356.0	.001	.002	.002
7256 M	PINFLATS	-2369634.199	-4761325.789	3511116.596	46528.0	1652.0	.003	.006	.005
7258 M	PLATTVIL	-1240706.378	-4720455.219	4094482.092	46545.3	2146.0	.002	.005	.004
7252 M	PRESIDIO	-2707703.121	-4257610.479	3888374.641	46703.2	1999.0	.004	.005	.005
7251 M	PT REYES	-2732331.349	-4217635.769	3914491.509	46808.4	1992.0	.004	.006	.005
7268 M	PVERDES	-2525451.047	-4670036.545	3522887.212	46871.1	1902.0	.006	.012	.009
7221 M	QUINCY	-2517229.141	-4198596.099	4076531.738	46653.5	2390.0	.003	.005	.005
7219 S	RICHMOND	961259.817	-5674090.871	2740534.159	46865.1	2200.0	.001	.001	.001
1561 S	ROBLED32	4849246.984	-360279.123	4114884.842	45460.0	1.0	.053	.013	.044
7255 M	SANPAULA	-2554474.924	-4608628.259	3582138.753	46718.5	1979.0	.007	.012	.009
7229 M	SEATTLE1	-2295346.247	-3638030.368	4693409.188	46670.0	1.0	.016	.027	.032
7227 S	SESHAN25	-2831684.997	4675732.937	3275328.336	47450.1	352.0	.006	.005	.007
7226 S	SHANGHAI	-2847696.513	4659872.039	3283959.401	46595.0	1.0	.124	.108	.097
7280 M	SNDPOINT	-3425460.170	-1214670.019	5223858.774	47104.4	1828.0	.007	.003	.010
7281 M	SOURDOGH	-2419991.728	-1664229.628	5643538.735	46509.7	1117.0	.005	.004	.010
7602 M	TROMSONO	2102905.890	721601.559	5958201.707	47739.5	4.0	.005	.003	.012
7290 M	VERNAL	-1631471.544	-4589129.789	4106760.327	47243.2	1124.0	.003	.008	.006
7223 M	VNDNBERG	-2678092.993	-4525451.696	3597410.593	46746.6	2148.0	.001	.002	.002
7209 S	WESTFORD	1492208.423	-4458131.350	4296015.901	46557.8	3152.0	0.000	0.000	0.000
7224 S	WETTZELL	4075541.699	931734.277	4801629.695	46842.9	2235.0	.002	.001	.003
7284 M	WHTHORSE	-2215211.853	-2209262.477	5540292.985	47180.2	1830.0	.004	.004	.010
7277 M	YAKATAGA	-2529742.450	-1942092.174	5505028.411	46652.0	1110.0	.006	.005	.012
7285 M	YELLOWKN	-1224122.742	-2689531.485	5633555.734	46125.0	377.0	.015	.022	.027
7894 M	YUMA	-2196776.173	-4887337.920	3448425.682	46696.5	1815.0	.002	.005	.004

RADIO SOURCE COORDINATES RSC(GSFC) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0016+731	0	19	45.785951	73	27	30.01529	0.000083	0.00030
0048-097	0	50	41.317381	- 9	29	5.21107	0.000009	0.00019
0106+013	1	8	38.771038	1	35	0.31589	0.000002	0.00013
0119+041	1	21	56.861671	4	22	24.73181	0.000012	0.00035
0212+735	2	17	30.812737	73	49	32.62060	0.000027	0.00012
0224+671	2	28	50.051043	67	21	3.02818	0.000024	0.00017
0229+131	2	31	45.893982	13	22	54.71567	0.000003	0.00013
0234+285	2	37	52.405551	28	48	8.98922	0.000005	0.00012
0235+164	2	38	38.930016	16	36	59.27380	0.000008	0.00034
0300+470	3	3	35.242001	47	16	16.27492	0.000009	0.00012
0316+413	3	19	48.159894	41	30	42.10211	0.000011	0.00015
0336-019	3	39	30.937757	- 1	46	35.80361	0.000018	0.00054
0355+508	3	59	29.746996	50	57	50.16173	0.000011	0.00012
0420-014	4	23	15.800671	- 1	20	33.06413	0.000002	0.00014
0430+052	4	33	11.095443	5	21	15.61908	0.000023	0.00079
0454-234	4	57	3.179239	-23	24	52.01784	0.000011	0.00020
0528+134	5	30	56.416676	13	31	55.15118	0.000003	0.00013
0552+398	5	55	30.805435	39	48	49.16653	0.000007	0.00012
0727-115	7	30	19.112439	-11	41	12.59729	0.000004	0.00015
0742+103	7	45	33.059465	10	11	12.69563	0.000004	0.00018
0814+425	8	18	15.999531	42	22	45.41812	0.000018	0.00022
0820+560	8	24	47.236128	55	52	42.67253	0.000052	0.00037
0823+033	8	25	50.338311	3	9	24.52409	0.000010	0.00034
0851+202	8	54	48.874868	20	6	30.64394	0.000003	0.00012
0919-260	9	21	29.353960	-26	18	43.38326	0.000125	0.00317
0923+392	9	27	3.013825	39	2	20.85496	0.000006	0.00012
0953+254	9	56	49.875379	25	15	16.05182	0.000017	0.00057
1034-293	10	37	16.079677	-29	34	2.80947	0.000014	0.00024
1055+018	10	58	29.605173	1	33	58.82745	0.000002	0.00015
1144+402	11	46	58.297955	39	58	34.30723	0.000007	0.00013
1150+812	11	53	12.499728	80	58	29.15680	0.000090	0.00024
1156+295	11	59	31.833929	29	14	43.82957	0.000005	0.00013
1219+285	12	21	31.690580	28	13	58.50331	0.000017	0.00062
1226+023	12	29	6.699700	2	3	8.60135	********	0.00013
1253-055	12	56	11.166450	- 5	47	21.52248	0.000005	0.00020
1308+326	13	10	28.663929	32	20	43.78506	0.000005	0.00012
1334-127	13	37	39.782695	-12	57	24.69062	0.000006	0.00019
1354+195	13	57	4.436697	19	19	7.37387	0.000006	0.00015
1404+286	14	7	0.394474	28	27	14.69137	0.000004	0.00012
1418+546	14	19	46.597631	54	23	14.78851	0.000018	0.00018

RADIO SOURCE COORDINATES RSC(GSFC) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
1502+106	15	4	24.979811	10	29	39.20006	0.000003	0.00015
1548+056	15	50	35.269237	5	27	10.44921	0.000003	0.00014
1611+343	16	13	41.064362	34	12	47.90887	0.000012	0.00019
1622-253	16	25	46.891535	-25	27	38.32623	0.000029	0.00132
1633+382	16	35	15.493083	38	8	4.50034	0.000006	0.00012
1637+574	16	38	13.456572	57	20	23.97870	0.000013	0.00013
1642+690	16	42	7.848952	68	56	39.75592	0.000024	0.00015
1641+399	16	42	58.810082	39	48	36.99364	0.000007	0.00012
1730-130	17	33	2.705705	-13	4	49.54822	0.000004	0.00015
1739+522	17	40	36.978047	52	11	43.40656	0.000012	0.00013
1741-038	17	43	58.856100	- 3	50	4.61704	0.000002	0.00014
1749+701	17	48	32.840652	70	5	50.76686	0.000169	0.00079
1749+096	17	51	32.818582	9	39	0.72783	0.000003	0.00014
1803+784	18	0	45.684666	78	28	4.01711	0.000038	0.00012
1921-293	19	24	51.055847	-29	14	30.12146	0.000007	0.00019
1923+210	19	25	59.605391	21	6	26.15918	0.000028	0.00110
1928+738	19	27	48.495299	73	58	1.56731	0.000093	0.00067
1954+513	19	55	42.738370	51	31	48.54381	0.000029	0.00030
1958-179	20	0	57.090355	-17	48	57.67340	0.000015	0.00023
2037+511	20	38	37.034830	51	19	12.66039	0.000012	0.00013
2113+293	21	15	29.413452	29	33	38.36436	0.000011	0.00029
2121+053	21	23	44.517356	5	35	22.09103	0.000002	0.00013
2128-123	21	31	35.261620	-12	7	4.79808	0.000022	0.00032
2134+004	21	36	38.586287	0	41	54.21154	0.000002	0.00014
2145+067	21	48	5.458640	6	57	38.60195	0.000003	0.00013
2200+420	22	2	43.291353	42	16	39.97728	0.000008	0.00012
2201+315	22	3	14.975793	31	45	38.26772	0.000026	0.00068
2216-038	22	18	52.037696	- 3	35	36.88152	0.000003	0.00015
2234+282	22	36	22.470819	28	28	57.41077	0.000005	0.00012
2251+158	22	53	57.747893	16	8	53.55850	0.000003	0.00012
2255-282	22	58	5.962842	-27	58	21.25847	0.000035	0.00227
2345-167	23	48	2.608490	-16	31	12.02323	0.000010	0.00018

EOP(GSFC) 90 R 02 Available from 1979 to 1989

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	X		Y		UT1		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1979	2	1.44	2	2.81	2	1.05	2	1.91	2	0.67
1980	20	2.91	20	9.02	20	2.31	20	1.26	20	0.42
1981	32	11.49	32	36.18	32	9.28	32	2.80	32	1.42
1982	59	11.57	59	33.89	59	9.21	59	5.65	59	1.93
1983	81	16.66	81	30.29	81	9.84	81	11.59	81	3.91
1984	111	11.98	111	11.88	111	6.46	111	26.92	111	10.78
1985	118	6.91	118	8.28	118	3.38	118	3.04	118	1.13
1986	136	3.14	136	6.01	136	1.83	136	1.45	136	0.54
1987	168	4.68	168	6.73	168	2.95	168	2.66	168	1.01
1988	164	2.64	164	4.63	164	1.63	164	2.16	164	0.78
1989	154	3.95	154	3.56	154	2.10	154	1.23	154	0.50

EARTH ROTATION PARAMETERS FROM DSN VLBI

JPL 90 R 01
JPL 90 R 02

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Earth Rotation Parameter (ERP) estimates have been obtained from an analysis of Deep Space Network (DSN) VLBI data that directly aligns its celestial and terrestrial reference frames with those of the International Earth Rotation Service (IERS). NASA's Deep Space Network operates radio telescopes for the primary purpose of communicating with interplanetary spacecraft. The DSN has three complexes: in California (stations DSS 12,13,14,15), in Spain (DSS 61,63,65), and in Australia (DSS 42,43,45). Two projects at JPL (called TEMPO and CAT M&E below) use these telescopes to make VLBI observations from which we have estimated earth rotation parameters. TEMPO uses the 70 meter DSN antennas (DSS 14, 43, 63) whenever possible and the 34 meter DSN antennas when the larger antennas are not available; before 1989 CAT M&E did likewise. Each observing session uses antennas in two complexes, and usually exactly one antenna in each complex. This report describes a homogeneous reduction of currently available dual frequency (S and X band) VLBI data from both projects.

The Time and Earth Motion Precision Observations (TEMPO) project makes rapid turnaround VLBI measurements of station clock synchronization and earth orientation in support of spacecraft navigation, which needs extremely timely, moderate accuracy earth rotation information. In TEMPO observations the raw bit streams recorded at the telescopes are telemetered to JPL for correlation, so that no physical transportation of magnetic tapes is involved. TEMPO uses the JPL-developed Block I VLBI system, which has a 500 000 bits/second sampling rate, with time-division multiplexing of channels. This sampling rate permits the telemetry, and thus makes rapid turnaround possible. The reduced sensitivity caused by the relatively low sampling rate in comparison to other present-day VLBI systems is largely compensated by the very large antennas and very low system noise levels of the DSN telescopes. Currently, TEMPO records 3 channels in S band (2285 MHz) and 3 channels in X band (8420 MHz) with a spanned bandwidth of 40 MHz in each band. At present the DSN nominally schedules two TEMPO observing sessions per week, one on the Spain-California (SC) baseline, and the other on the Australia-California (AC) baseline. Each session is generally 3 hours in duration (occasionally less), and records a maximum of 20 sources. TEMPO observes most sources for 3 minutes and 18 seconds, a few for 6 minutes and 36 seconds. We plan to produce an operational series of ERP estimates from TEMPO sessions during 1990 that will be a continuation of the ERP series reported here.

The Catalog Maintenance and Enhancement (CAT M&E) project determines celestial coordinates of radio sources, and baseline vectors between DSN stations, for use in spacecraft navigation. In CAT M&E observations the raw bit streams are recorded on magnetic tapes for transportation to the correlator. CAT M&E used the Mark II VLBI system from late 1978 through 1988; some more recent CAT M&E observing sessions have used the Mark III VLBI system. The DSN schedules CAT M&E observing sessions at irregular intervals, typically several times per year. Separate observing sessions on the SC and AC baselines are generally scheduled within a few days of each other. Each session is nominally 24 hours in duration and typically includes 100 to 250 observations of 50 to 80 radio sources.

Data from both the TEMPO and CAT M&E projects were used in the solution process for the ERP series reported here. In order that the TEMPO operational series of ERP estimates during 1990 can be an exact continuation of the ERP series reported here, the solution process consisted of two major steps. First, a "catalog solution" designated JPL 1990-2 (see below) determined radio source coordinates, station coordinates, and a parametric model for the motion of the Celestial Ephemeris Pole. Then the second step, called the "ERP solution", used
these results from the catalog solution to determine the earth rotation parameters in a manner that can be exactly continued in the operational series. In the ERP solution the data from each observing session were processed independently to provide an estimate of the UT0 and variation of latitude (DPHI) of the baseline vector for that session. Except for the UT0 and variation of latitude, the relation between the earth-fixed reference frame and the radio-quasar reference frame was specified entirely by a priori data (which includes the results from the catalog solution). In addition to UT0 and DPHI, the other parameters estimated in the ERP solution were:

1. A first degree polynomial clock model, including a term allowing for a bias in the delay rate data, with breaks as needed. Such clock breaks are rare in TEMPO sessions but common in the longer duration CAT M&E sessions.

2. Adjustments to the troposphere zenith delay at each station. In the CAT M&E sessions, new troposphere zenith parameters were introduced approximately every three hours. A priori estimates of the troposphere zenith delays, derived from tables of monthly average zenith delays for each station, were included in the solution with a 6 cm standard deviation.

Other properties of the ERP solution were:

1. Stations move with plate tectonic motion as specified by the Minster-Jordan AM0-2 model.

2. Ocean loading effects were calculated from the model of Pagiatakis (1982; personal communication, 1988).

3. Pole tidal effects were included (Sovers and Fanselow, 1987).

4. The Lanyi (1984) function was used for mapping zenith tropospheric delays to observed elevations.

5. The effects of charged particles in the ionosphere and solar plasma on the single-band delay and delay rate observables were removed by using the appropriate linear combination of the single-band data to form "dual frequency" delay and delay rate observables.

6. Only sessions with 5 or more acceptable delay observations were included in the solution reported here.

7. The effect on path lengths caused by moving ("slewing") the antenna subreflector, so as to maximize the antenna gain when its focal length changes as the elevation angle changes, has been modeled for the TEMPO data. No such model is needed for the CAT M&E data since CAT M&E does not slew the subreflector. (Apparent station coordinates estimated from VLBI data will be corrupted if the subreflector is slewed but the effect on path length is not modeled in the delay calculations. The station coordinates estimated by the JPL 1990-2 catalog solution and used in the ERP solution are appropriate both for the case where the subreflector is not slewed and no path length effect is modeled and also for the case where the subreflector is slewed and the resulting effect on path length is explicitly modeled in the calculations.)

We derived formal errors by adding an "additive noise" constant to the square of each raw observable error to make the Chi Square of the postfit residuals equal to the number of degrees of freedom in the solution. The delay and delay rate additive noise constants were adjusted separately for each CAT M&E observing session. For the TEMPO data, the additive noises were adjusted for each of several blocks of observing sessions.

Each Earth Rotation measurement here is a UT0-DPHI pair, and has an associated error ellipse in the UT0-DPHI plane. Each such error ellipse is completely specified by the reported standard errors and correlation coefficient between UT0 and DPHI. For single baseline VLBI measurements of ERP, such as those reported here, this error ellipse is typically quite elongated, with a ratio of major axis to minor axis of about 4:1. Therefore, for a proper interpretation of these data, it is crucial to make full use of the reported correlation coefficient.

For a single-baseline VLBI estimate of earth rotation, the orientation of the error ellipse in the UT0-DPHI plane is mostly determined by the global station geometry. The direction of the minor axis of the error ellipse in the UT0-DPHI plane as predicted by the station geometry is called the transverse rotation direction, and corresponds to the motion of the baseline in the local horizontal. In addition to being relatively insensitive to random measurement errors, the transverse rotation component is also relatively free of errors introduced by tropospheric modeling errors, antenna deformations, and other sources of systematic local-vertical errors. The transverse rotation components for the DSN baselines are:

Baseline	Transverse Component
Australia-California	-1.000 DPHI + 0.00 (UT0-TAI)
Spain-California	+0.582 DPHI + 12.21 (UT0-TAI)
Spain-Australia	-0.972 DPHI + 2.77 (UT0-TAI)

These coefficients assume that UT0 and DPHI are expressed in seconds of time and in arcseconds, respectively; the units of the transverse components are arcseconds. We recommend that these linear combinations be used to take full advantage of the inherent accuracy of these data.

The ERP solution produced earth orientation results for a total of 601 observing sessions between October 28, 1978, and March 25, 1990.

During calendar year 1989, the TEMPO project produced earth rotation measurements from 84 dual frequency observing sessions, with a median standard error along the minor axis of the error ellipse of 0.5 milliarcseconds (mas), and along the major axis of 2.7 mas.

JPL 1990-2 CATALOG

The JPL 1990-2 catalog was developed specifically for use in TEMPO operational ERP solutions during 1990. Since short duration VLBI determinations of the ERP are sensitive to errors in the position of the Celestial Ephemeris Pole (CEP), and since the current IAU standards for the CEP are known to be in error by amounts significant to TEMPO, it is important that TEMPO use a CEP series that is corrected from the IAU standards and is consistent with the radio source coordinates (RSC) used. Current practicalities of TEMPO operations favor the use of a parametric model for the CEP that includes the long period motions. Therefore we have estimated such a model along with the RSC and set of station coordinates (SSC) in the JPL 1990-2 catalog solution. Although this CEP model has the form of adjustments to the coefficients of the IAU precession-nutation model, it is intended only to permit processing of TEMPO data for the ERP during the period reported here and during 1990, and will presumably need revision in 1991. In particular, it may not include all significant components and all its parameters may not be well separated, but we believe it is adequate for our purposes.

The JPL 1990-2 catalog solution had the following properties:

1. Except where otherwise noted, the catalog solution was essentially identical to the ERP solution described above.

2. All the CAT M&E data and most of the TEMPO data through the end of 1989 were included.

3. Information from intra-complex radio interferometry and ground surveys was used to constrain the coordinate differences between stations within each complex (with a standard deviation of 1cm).

4. For each pair of observing sessions that occurred within 12 hours of each other and used different pairs of DSN complexes (that is, California-to-Spain and California-to-Australia), the adjustment (dx,dy,dUT1) to the initial values of earth orientation is the same for both members of the pair. (The initial-value ERP series was provided by Richard Gross of JPL; it is a Kalman-smoothed, combination-of-techniques ERP series obtained by Kalman filtering in a manner similar to the SPACE87 system of Eubanks (1988).) This treatment of close-in-time pairs serves to determine the angle between the California-to-Spain and California-to-Australia baseline vectors. There were 46 such pairs of TEMPO sessions; there were no CAT M&E observing sessions in any such pairs.

5. The terrestrial frame of the JPL 1990-2 system was tied to the International Earth Rotation Service Terrestrial Reference Frame ITRF-88 (IERS, 1989, Table T-4) in the following way. The coordinates of all the DSN stations, including all those in California, were estimated in the catalog solution subject to six constraints applied to the nine coordinates of DSS 14, DSS 43, and DSS 63. These constraints are such that if a seven parameter transformation (3 translations, 3 rotations, 1 scale) between the JPL 1990-2 and ITRF-88 systems were estimated by unweighted least squares applied to the coordinates of DSS 14, 43, and 63, then the resulting 3 translation and 3 rotation parts of the transformation would be zero while the scale could be nonzero and unknown in advance of computing the catalog. (When expressed as the dot product of a nine dimensional unit vector with the nine station coordinates, each constraint is assigned an a priori standard deviation of 1 cm; this does not affect the resulting coordinates but does affect the calculated formal errors, giving them a more spherical distribution than would result if either very large or very small a priori standard deviations were used.) These constraints serve to determine both the translation and the rotation of the terrestrial coordinate system. The station coordinates resulting from the solution apply at a reference time of 1988.0, in agreement with that of ITRF-88.

6. The Right Ascension and Declination of OJ 287 (0851+202) and the Declination of CTD 20 (0234+285), which are among the best observed sources in the DSN catalog and are primary sources in the IERS Celestial Reference Frame ICRF-88, were held fixed at their values in that frame as specified in the set of radio source coordinates RSC(IERS)89 C 01 (IERS, 1989, Table C-3). By this means the coordinate system of the JPL 1990-2 RSC is tied to the IERS celestial frame ICRF-88. (The Right Ascension of 3C 273 was NOT held fixed.) The formal errors of these three source coordinates are properly zero, but in order to convey the quality of determination of these two sources we have replaced these three zeros in our source list RSC(JPL)90 R 02 by the formal errors for these three coordinates from a similar solution that had three coordinates of two different well-observed sources held fixed; we have similarly replaced the two correlation coefficients between Right Ascension and Declination for these two sources.

7. The reference epoch of the JPL 1990-2 celestial system was J2000, and the definition of sidereal time was a function of the estimated precession constant.

The resulting CEP model is presented below as adjustments to the IAU precession and nutation coefficients along with two offset parameters which represent the estimated position of the (mean) CEP at epoch J2000 as expressed in the coordinate system of the radio sources. A positive X-offset represents a displacement of the CEP toward 18 hours Right Ascension, and a positive Y-offset represents a displacement of the CEP toward 0 hours Right Ascension. Only those nutation terms listed below were adjusted in the catalog solution. Two sets of standard errors are presented; the "formal" errors are just the formal errors from the catalog solution, and the "generalized" errors are the formal errors from a similar solution which also estimated additional components with periods of 121.75, 27.55, and 13.63 days as well as both out-of-phase nutations for all eight periods. (None of these other components appeared to be genuinely significant from our data set.)

Celestial Ephemeris Pole Motion Model

Index	Period days	Phase	Component	Adjustment mas	Formal Error mas	Generalized Error mas
precession			Longitude	-2.29/yr	0.11/yr	1.76/yr
Y-offset			L sin eps	-13.29	0.63	10.94
X-offset			Obliquity	+ 0.65	0.49	0.57
1	6798.38	In	Longitude	- 6.51	0.75	3.60
			Obliquity	+ 1.61	0.13	0.25
		Out	Obliquity	+ 2.72	0.23	0.55
2	3399.19	In	Longitude	+ 3.27	0.52	1.63
			Obliquity	+ 0.06	0.17	0.21
10	365.26	In	Longitude	+ 4.39	0.29	0.33
			Obliquity	+ 1.62	0.11	0.15
		Out	Longitude	+ 1.50	0.29	0.40
			Obliquity	- 0.36	0.10	0.12
9	182.62	In	Longitude	+ 1.46	0.26	0.32
			Obliquity	- 0.61	0.10	0.12
		Out	Longitude	- 0.69	0.26	0.32
			Obliquity	- 0.73	0.10	0.13
31	13.66	In	Longitude	- 0.42	0.24	0.38
			Obliquity	+ 0.23	0.10	0.16

For accurate interpretation of the UT0 and DPHI values reported here, one should use accurate values of the latitude and longitude of the baseline vector; these can be calculated for each station pair from the SSC estimated in the JPL 1990-2 catalog solution and reported here. Approximate values are:

Baseline	Latitude (degrees)	Longitude (degrees)
Australia-California	- 43.97	+106.05
Spain-California	+ 2.99	+ 30.73
Spain-Australia	+38.50	- 18.10

ACKNOWLEDGEMENTS. We would like to thank each and every one of the many people who contributed to the acquisition and analysis of the DSN VLBI data. The work described in this paper was carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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SUMMARY DESCRIPTION OF TERRESTRIAL SYSTEM FOR JPL 1990-2 STATION COORDINATES

1 - Technique	VLBI
2 - Analysis Center	JPL
3 - Solution identifier	1990-2
4 - Software used	Masterfit
5 - Relativity scale	SSB
6 - Permanent tidal correction	No
7 - Tectonic plate model	AM0-2
8 - Velocity of light	299 792 458 m/s
9 - Geogravitational constant	3.9860 0448 *10**14 m**3*s**-2
10 - Reference epoch	1 Jan 1988
11 - Adjusted parameters	X0, Y0, Z0
12 - Definition of the origin, and	
13 - Definition of the orientation	

Six constraints were applied (with 1cm uncertainty) to the nine coordinates of DSS 14, DSS 43, and DSS 63, such that if a seven parameter transformation (3 translations, 3 rotations, 1 scale) between the JPL 1990-2 and ITRF-88 systems were estimated by unweighted least squares applied to the coordinates of DSS 14, 43, and 63, then the resulting 3 translation and 3 rotation parts of the transformation would be zero while the scale could be nonzero and unknown in advance of computing the catalog. See text for details.

14 - Constraint for time evolution AM0-2 model

Domes Number	Number	X m	Y m	Z m	MEAN MJD	SX m	SY m	SZ m
40405S003	DSS 12	-2350443.597	-4651980.781	3665630.847	45759.0 0.0	0.012	0.015	0.016
40405S014	DSS 13	-2351128.967	-4655477.020	3660956.797	45587.0 0.0	0.013	0.016	0.016
40405S001	DSS 14	-2353621.038	-4641341.479	3677052.204	46343.0 0.0	0.009	0.013	0.013
40405S019	DSS 15	-2353538.600	-4641649.455	3676669.909	47220.0 0.0	0.012	0.016	0.016
50103S005	DSS 42	-4460980.791	2682413.526	-3674582.159	46784.0 0.0	0.026	0.015	0.018
50103S001	DSS 43	-4460894.363	2682361.556	-3674748.670	46227.0 0.0	0.024	0.011	0.015
50103S010	DSS 45	-4460935.021	2682765.708	-3674381.485	0.0 0.0	0.026	0.015	0.018
13407S003	DSS 61	4849245.184	-360278.271	4114884.222	46440.0 0.0	0.019	0.019	0.026
13407S001	DSS 63	4849092.612	-360180.675	4115108.884	46219.0 0.0	0.016	0.016	0.024
13407S010	DSS 65	4849336.712	-360488.968	4114748.555	47487.0 0.0	0.019	0.019	0.026

EOP(JPL) 90 R 01 - Available from 1978 to 1990

Number of measurements and RMS uncertainty per year
Units : 0.001" FI; 0.0001s for UT.

YEAR	FI Nb	FI Sigma	UT0 Nb	UT0 Sigma
1978	3	0.56	3	1.73
1979	6	2.66	6	2.89
1980	21	7.54	21	10.46
1981	18	9.99	18	12.10
1982	43	10.16	43	9.53
1983	74	5.71	74	7.20
1984	71	6.51	71	6.89
1985	19	4.87	19	4.66
1986	72	4.10	72	3.89
1987	76	3.55	76	4.15
1988	89	3.20	89	3.46
1989	89	2.37	89	2.20
1990	20	2.17	20	2.38

RADIO SOURCE COORDINATES RSC(JPL) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0008-264	0	11	1.246989	-26	12	33.37967	0.000103	0.00147
0019+058	0	22	32.441228	6	8	4.26995	0.000034	0.00119
0048-097	0	50	41.317342	- 9	29	5.20745	0.000052	0.00132
0104-408	1	6	45.108126	-40	34	19.95965	0.000094	0.00101
0106+013	1	8	38.771080	1	35	0.31850	0.000027	0.00053
0111+021	1	13	43.145077	2	22	17.31602	0.000099	0.00167
0112-017	1	15	17.099904	- 1	27	4.57594	0.000027	0.00058
0113-118	1	16	12.522004	-11	36	15.43352	0.000035	0.00070
0119+115	1	21	41.595045	11	49	50.41412	0.000027	0.00050
0119+041	1	21	56.861601	4	22	24.73821	0.000050	0.00128
0133+476	1	36	58.594845	47	51	29.09994	0.000046	0.00043
0146+056	1	49	22.370842	5	55	53.57065	0.000028	0.00058
0149+218	1	52	18.059036	22	7	7.70108	0.000059	0.00592
0201+113	2	3	46.657041	11	34	45.41068	0.000026	0.00057
0202+149	2	4	50.413951	15	14	11.04337	0.000031	0.00045
0212+735	2	17	30.813518	73	49	32.62197	0.000107	0.00037
0221+067	2	24	28.428151	6	59	23.34308	0.000028	0.00057
0224+671	2	28	50.051684	67	21	3.02935	0.000086	0.00050
0229+131	2	31	45.894053	13	22	54.71666	0.000028	0.00095
0234+285	2	37	52.405706	28	48	8.99050	0.000027	0.00038
0235+164	2	38	38.930154	16	36	59.27455	0.000029	0.00038
0237-233	2	40	8.174749	-23	9	15.74096	0.000856	0.01179
0239+108	2	42	29.170911	11	1	0.72784	0.000037	0.00068
0256+075	2	59	27.076668	7	47	39.64106	0.000041	0.00186
0259+121	3	2	30.546885	12	18	56.76612	0.000613	0.06485
0300+470	3	3	35.242264	47	16	16.27572	0.000039	0.00039
0306+102	3	9	3.623496	10	29	16.34122	0.000028	0.00254
0309+411	3	13	1.962171	41	20	1.18370	0.000037	0.00075
0316+413	3	19	48.160177	41	30	42.10347	0.000075	0.00103
0326+277	3	29	57.669385	27	56	15.49831	0.000034	0.00112
0332-403	3	34	13.654544	-40	8	25.39707	0.000120	0.00106
0333+321	3	36	30.107675	32	18	29.34197	0.000038	0.00054
0336-019	3	39	30.937744	- 1	46	35.80140	0.000027	0.00066
0342+147	3	45	6.416521	14	53	49.55890	0.000028	0.00088
0400+258	4	3	5.586619	26	0	1.49678	0.000736	0.00967
0402-362	4	3	53.749868	-36	5	1.91229	0.000066	0.00077
0406+121	4	9	22.008723	12	17	39.84743	0.000033	0.00087
0420-014	4	23	15.800722	- 1	20	33.06534	0.000022	0.00043
0420+417	4	23	56.009856	41	50	2.71542	0.000207	0.00297
0425+048	4	27	47.570328	4	57	8.32896	0.000124	0.00211

RADIO SOURCE COORDINATES RSC(JPL) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0430+052	4	33	11.095543	5	21	15.62109	0.000059	0.00116
0434-188	4	37	1.482724	-18	44	48.61346	0.000054	0.00081
0438-436	4	40	17.179930	-43	33	8.60208	0.000126	0.00102
0440-003	4	42	38.661037	- 0	17	43.42470	0.000511	0.00786
0440+345	4	43	31.635249	34	41	6.66301	0.000029	0.00058
0446+112	4	49	7.671089	11	21	28.59746	0.000024	0.00169
0451-282	4	53	14.646273	-28	7	37.32072	0.000295	0.00373
0458+138	5	1	45.270894	13	56	7.21796	0.000159	0.00890
0459+060	5	2	15.445613	6	9	7.54419	0.000414	0.09569
0500+019	5	3	21.197128	2	3	4.67797	0.000025	0.00161
0502+049	5	5	23.184634	4	59	42.76299	0.000226	0.03867
0454+844	5	8	42.364176	84	32	4.54341	0.000316	0.00052
0506+101	5	9	27.457088	10	11	44.60112	0.000022	0.00102
0507+179	5	10	2.369170	18	0	41.58165	0.000023	0.00050
0511-220	5	13	49.113505	-21	59	16.08135	0.001264	0.01788
0528+134	5	30	56.416807	13	31	55.14935	0.000024	0.00042
0537-441	5	38	50.361361	-44	5	8.93702	0.000097	0.00090
0537-158	5	39	32.005716	-15	50	30.25138	0.009465	0.15222
0536+145	5	39	42.366022	14	33	45.56125	0.000021	0.00046
0544+273	5	47	34.148988	27	21	56.84369	0.000050	0.00159
0552+398	5	55	30.805620	39	48	49.16505	0.000020	0.00034
0556+238	5	59	32.033172	23	53	53.92648	0.000020	0.00043
0600+177	6	3	9.130289	17	42	16.81057	0.000023	0.00044
0605-085	6	7	59.699138	- 8	34	49.97733	0.000117	0.00218
0607-157	6	9	40.949718	-15	42	40.67509	0.000270	0.00396
0642+214	6	45	24.099541	21	21	51.20168	0.000020	0.00048
0657+172	7	0	1.525598	17	9	21.70057	0.000045	0.00097
0722+145	7	25	16.807787	14	25	13.74618	0.000019	0.00051
0723-008	7	25	50.639969	- 0	54	56.54491	0.000045	0.00078
0727-115	7	30	19.112514	-11	41	12.60117	0.000028	0.00052
0735+178	7	38	7.393763	17	42	18.99900	0.000025	0.00050
0736+017	7	39	18.033926	1	37	4.61837	0.000100	0.00374
0738+313	7	41	10.703374	31	12	0.22944	0.000086	0.00120
0742+103	7	45	33.059532	10	11	12.69199	0.000020	0.00039
0743+259	7	46	25.874143	25	49	2.13501	0.000021	0.00048
0745+241	7	48	36.109282	24	0	24.11047	0.000032	0.00068
0748+126	7	50	52.045778	12	31	4.82750	0.000031	0.00060
0754+100	7	57	6.642960	9	56	34.85045	0.000020	0.00061
0805-077	8	8	15.537151	- 7	51	9.90079	0.000805	0.01111
0814+425	8	18	15.999658	42	22	45.41406	0.000028	0.00040

RADIO SOURCE COORDINATES RSC(JPL) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0823+033	8	25	50.338392	3	9	24.51976	0.000019	0.00038
0827+243	8	30	52.086164	24	10	59.82116	0.000026	0.00037
0836+710	8	41	24.365606	70	53	42.17125	0.000297	0.00176
0851+202	8	54	48.874933	20	6	30.64118	0.000020	0.00037
0859-140	9	2	16.830898	-14	15	30.87343	0.000178	0.00282
0859+470	9	3	3.990059	46	51	4.13648	0.000080	0.00193
0912+029	9	14	37.913496	2	45	59.24570	0.000047	0.00076
0920-397	9	22	46.418165	-39	59	35.06764	0.000656	0.00567
0923+392	9	27	3.013866	39	2	20.85143	0.000020	0.00026
0925-203	9	27	51.824556	-20	34	51.23403	0.000492	0.00600
0952+179	9	54	56.823415	17	43	31.23187	0.000770	0.01254
1004+141	10	7	41.498391	13	56	29.59815	0.000540	0.00733
1012+232	10	14	47.065480	23	1	16.57067	0.000035	0.00048
1022+194	10	24	44.809633	19	12	20.41117	0.000027	0.00296
1034-293	10	37	16.079869	-29	34	2.81396	0.000068	0.00078
1038+064	10	41	17.162527	6	10	16.92294	0.000030	0.00078
1040+123	10	42	44.605930	12	3	31.26013	0.000354	0.00477
1042+071	10	44	55.911237	6	55	38.26818	0.000052	0.00720
1044+719	10	48	27.619889	71	43	35.93791	0.000117	0.00042
1055+018	10	58	29.605266	1	33	58.82363	0.000020	0.00044
1104-445	11	7	8.694370	-44	49	7.61921	0.000112	0.00095
1111+149	11	13	58.695115	14	42	26.95263	0.000031	0.00054
1116+128	11	18	57.301505	12	34	41.71677	0.000050	0.00417
1123+264	11	25	53.711910	26	10	19.97854	0.000018	0.00038
1127-145	11	30	7.052749	-14	49	27.38949	0.000071	0.00115
1128+385	11	30	53.282598	38	15	18.54658	0.000030	0.00057
1144-379	11	47	1.370821	-38	12	11.02339	0.000079	0.00085
1145-071	11	47	51.553537	-	7	24 41.03728	0.000228	0.03571
1148-001	11	50	43.870899	-	0	23 54.20567	0.000078	0.00209
1156-094	11	59	12.712431	-	9	40 52.06034	0.002305	0.03412
1222+037	12	24	52.421929	3	30	50.29342	0.000035	0.00091
1226+023	12	29	6.699738	2	3	8.59959	0.000022	0.00056
1228+126	12	30	49.423465	12	23	28.04350	0.000302	0.00404
1243-072	12	46	4.231126	-	7	30 46.55611	0.002765	0.04353
1244-255	12	46	46.802256	-25	47	49.29016	0.000057	0.00086
1253-055	12	56	11.166641	-	5	47 21.52534	0.000028	0.00072
1302-102	13	5	33.015097	-10	33	19.45139	0.000071	0.01464
1308+326	13	10	28.663836	32	20	43.78264	0.000019	0.00049
1313-333	13	16	7.986073	-33	38	59.17235	0.000131	0.00142
1334-127	13	37	39.782870	-12	57	24.69337	0.000032	0.00077

RADIO SOURCE COORDINATES RSC(JPL) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
1342+662	13	43	45.959348	66	2	25.74470	0.000087	0.00055
1342+663	13	44	8.679483	66	6	11.64316	0.000072	0.00044
1349-439	13	52	56.535299	-44	12	40.38875	0.000159	0.00132
1354+195	13	57	4.436640	19	19	7.37259	0.000018	0.00059
1354-152	13	57	11.245080	-15	27	28.78684	0.000038	0.00085
1404+286	14	7	0.394384	28	27	14.69068	0.000022	0.00067
1406-076	14	8	56.481301	- 7	52	26.68687	0.000075	0.02468
1418+546	14	19	46.597326	54	23	14.78664	0.000041	0.00056
1430-178	14	32	57.690679	-18	1	35.24921	0.000275	0.00382
1443-162	14	45	53.376263	-16	29	1.59539	0.000176	0.01735
1445-161	14	48	15.054221	-16	20	24.54872	0.000040	0.00093
1502+106	15	4	24.979803	10	29	39.19895	0.000019	0.00070
1504-166	15	7	4.787028	-16	52	30.26657	0.000039	0.00108
1510-089	15	12	50.532968	- 9	5	59.82898	0.000029	0.00085
1511-100	15	13	44.893463	-10	12	0.26036	0.000043	0.00435
1514-241	15	17	41.813324	-24	22	19.47673	0.000083	0.00127
1519-273	15	22	37.676124	-27	30	10.78562	0.000069	0.00111
1532+016	15	34	52.453644	1	31	4.20802	0.000031	0.00085
1548+056	15	50	35.269221	5	27	10.44897	0.000025	0.00081
1555+001	15	57	51.433968	- 0	1	50.41196	0.000033	0.00099
1611+343	16	13	41.064208	34	12	47.90897	0.000025	0.00076
1614+051	16	16	37.556822	4	59	32.73738	0.000025	0.00082
1622-297	16	26	6.020282	-29	51	26.96137	0.001217	0.01738
1633+382	16	35	15.492942	38	8	4.50031	0.000025	0.00069
1638+398	16	40	29.632710	39	46	46.02920	0.000031	0.00073
1641+399	16	42	58.809903	39	48	36.99423	0.000025	0.00066
1655+077	16	58	9.011444	7	41	27.54261	0.000031	0.00105
1656+053	16	58	33.447245	5	15	16.44638	0.000115	0.00187
1657-261	17	0	53.154221	-26	10	51.72512	0.000058	0.00121
1706-174	17	9	34.345430	-17	28	53.36348	0.000058	0.00133
1717+178	17	19	13.048463	17	45	6.43830	0.000033	0.00174
1730-130	17	33	2.705811	-13	4	49.54535	0.000031	0.00096
1738+476	17	39	57.128940	47	37	58.36152	0.000035	0.00077
1741-038	17	43	58.856144	- 3	50	4.61544	0.000026	0.00088
1749+701	17	48	32.840218	70	5	50.76915	0.000096	0.00064
1749+096	17	51	32.818560	9	39	0.72976	0.000024	0.00093
1803+784	18	0	45.683332	78	28	4.01836	0.000292	0.00073
1807+698	18	6	50.680456	69	49	28.10933	0.000069	0.00055
1821+107	18	24	2.855264	10	44	23.77468	0.000039	0.00158
1908-201	19	11	9.652968	-20	6	55.10849	0.000047	0.00108

RADIO SOURCE COORDINATES RSC(JPL) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
1920-211	19	23	32.189857	-21	4	33.33130	0.000038	0.00106
1921-293	19	24	51.056175	-29	14	30.12106	0.000056	0.00108
1923+210	19	25	59.605326	21	6	26.16258	0.000027	0.00072
1933-400	19	37	16.217230	-39	58	1.55010	0.000449	0.00415
1936-155	19	39	26.657816	-15	25	43.05777	0.000034	0.00099
1958-179	20	0	57.090519	-17	48	57.67162	0.000035	0.00098
2008-159	20	11	15.710991	-15	46	40.25240	0.000033	0.00095
2021+614	20	22	6.681524	61	36	58.80585	0.000074	0.00070
2030+547	20	31	47.958504	54	55	3.14857	0.000206	0.00305
2029+121	20	31	54.994260	12	19	41.34005	0.000066	0.00143
2113+293	21	15	29.413427	29	33	38.36786	0.000033	0.00070
2121+053	21	23	44.517398	5	35	22.09392	0.000026	0.00071
2128-123	21	31	35.261730	-12	7	4.79486	0.000031	0.00085
2131-021	21	34	10.309614	- 1	53	17.23787	0.000027	0.00076
2134+004	21	36	38.586417	0	41	54.21329	0.000026	0.00072
2145+067	21	48	5.458675	6	57	38.60468	0.000026	0.00068
2149+056	21	51	37.875395	5	52	12.95565	0.000046	0.00108
2155-152	21	58	6.281997	-15	1	9.32824	0.000097	0.00153
2200+420	22	2	43.291366	42	16	39.98082	0.000042	0.00049
2216-038	22	18	52.037748	- 3	35	36.87966	0.000030	0.00084
2223-052	22	25	47.259286	- 4	57	1.39006	0.000031	0.00079
2227-088	22	29	40.084333	- 8	32	54.43390	0.000030	0.00078
2229+695	22	30	36.469816	69	46	28.07869	0.000110	0.00044
2230+114	22	32	36.408934	11	43	50.90467	0.000026	0.00058
2234+282	22	36	22.470852	28	28	57.41430	0.000033	0.00049
2243-123	22	46	18.231970	-12	6	51.27616	0.000032	0.00080
2245-328	22	48	38.685786	-32	35	52.18626	0.000054	0.00094
2251+158	22	53	57.747951	16	8	53.56145	0.000029	0.00060
2253+417	22	55	36.707804	42	2	52.53367	0.000060	0.00104
2254+074	22	57	17.303424	7	43	12.22148	0.000211	0.03796
2254+024	22	57	17.563147	2	43	17.51187	0.000052	0.00090
2318+049	23	20	44.856625	5	13	49.95330	0.000028	0.00062
2320-035	23	23	31.953739	- 3	17	5.02237	0.000032	0.00072
2335-027	23	37	57.338703	- 2	30	57.52750	0.000256	0.06645
2345-167	23	48	2.608503	-16	31	12.02125	0.000048	0.00096
2351-154	23	54	30.195264	-15	13	11.20595	0.000160	0.02355
2355-106	23	58	10.882437	-10	20	8.61137	0.000041	0.00093

POLAR MOTION AND UT1 TIME SERIES DERIVED FROM VLBI OBSERVATIONS

NGS 90 R 01
NGS 90 R 02

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Estimates of x, y, and UT1-UTC have been derived from a composite set of Mark III Very Long Baseline Interferometry (VLBI) observations collected under the aegis of projects MERIT [Wilkins, 1984], POLARIS and IRIS [Carter et al., 1985], and the NASA Crustal Dynamics Project. 286 241 observations amassed during 628 observing sessions conducted between September, 1980, and March, 1990, were combined in a single least squares adjustment to obtain self consistent Earth orientation time series (Table NGS-1), source coordinates (Table NGS-2) [see Robertson et al., 1986] and the coordinates of the VLBI reference points of each of the radio telescopes (Table NGS-3). Table NGS-4 contains a daily series of UT1 values for the period April through June, 1984, and April 1985 through March, 1990. These UT1 values were produced from a series of special observing sessions using only the Westford-Wettzell baseline for 45 minutes each day. These restricted observing sessions are sufficient to determine only UT1.

The new VLBI observatory at Hobart, Tasmania, in concert with the station at Hartebeesthoek which is now operational on a year- round basis, has enabled us to significantly expand our coverage of the southern hemisphere. Nine new radio sources have been added in the declination range of -42° to -80°. The formal errors on the coordinates of these sources are generally around 1 milliarcsecond or less. Further observations with these and other new southern hemisphere stations in the coming years should enable us to finish the celestial coordinate system in the southern hemisphere to a quality comparable to the northern hemisphere.

The observations were processed at NGS using algorithms generally consistent with the MERIT standards [Melbourne et al., 1983], which include use of the IAU 1980 nutation model, an Earth tide model based on ephemeris positions for the Sun and Moon with the K_1 term removed, and a model for ocean loading displacements. Shapiro's model for the relativistic corrections for signal propagation was used. This model is consistent with the corrections derived by Hellings [Hellings, 1986], with the corrections noted in Ryan's report to the IERS. Refraction in the neutral atmosphere was modeled with the CFA-2.2 model [Davis et al., 1985], using meteorological data (pressure, temperature, humidity) taken at each VLBI station during each observing session. The dispersive portion of the atmospheric refraction (ionosphere) was eliminated by the use of dual frequency (X and S band) observations. Wahr's model was used for the solid Earth deformations resulting from the motion of the pole [Wahr, 1985]. Three vector components of the velocity of each station were estimated, for those stations whose data spanned more than a few months. These additional parameters introduce six new singularities into the definition of the terrestrial reference coordinate system, three for the velocity of the center of the system, and three rotation rate singularities. The velocity of the center of the system was constrained to by fixing the Westford velocity to the Minster-Jordan AM0-2 value, and the rotational singularities were removed by fixing the values of pole position and UT1 on two reference dates, rather than one as in the past. The two reference dates, 1985 Mar 24 and 1989 May 12, were selected to minimize differences with the past polar motion and UT1 series. The nutation reference date remains 1985 Oct 25. The quoted station coordinates are calculated for January 1, 1988.

Another significant deviation from the MERIT standards was that the IAU 1980 nutation model was corrected by estimating daily adjustments in longitude and obliquity. This deviation is necessary

because the accuracy of the VLBI observations is sufficient to detect the errors in the annual, semi-annual, and fortnightly terms in the model [Herring, 1986].

The data were processed in a single least-squares solution in which the station and source coordinates, station velocities, polar motion and UT1 corrections, and the nutation corrections are estimated. The clock errors were treated by estimating coefficients of polynomials, usually one or two second-order polynomials per day. Atmospheric refraction modeling errors were treated by estimating the break-points of a piece-wise continuous function with break- points set every hour.

The standard errors quoted in tables 1-4 are strictly the formal values obtained from the adjustment, and should be understood as a limit on the accuracy of the determinations, the limit that would be attained in the absence of unmodeled systematic errors. Based on intercomparisons with satellite laser ranging series we estimate that since the Wettzell observatory became operational in January 1984 the IRIS x and y components of polar motion have accuracies no worse than 2 milliseconds of arc [Robertson et al., 1985a]. Intercomparisons between the 5-day and the daily UT1 values (see below) indicates that both series are accurate to at least ± 0.1 milliseconds of time [Robertson et al., 1985b].

On behalf of the joint International Association of Geodesy (IAG), Committee on Space Research (COSPAR) Subcommission International Radio Interferometric Surveying (IRIS) the NGS distributes the monthly IRIS Bulletin A, Earth Orientation Information, and maintains a file containing the same data on the NGS computers which can be accessed via telephone by users who would like to have the data in machine-readable form. Additional information or assistance concerning the data presented here, or the data available through the MARK 3, IRIS Bulletin A, or NGS computer system may be obtained by contacting the authors.

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Table NGS-1.

EOP(NGS) 90 R 01 Available from 1984 to 1990

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	X		Y		UT1		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1984	70	1.11	70	1.48	70	0.75	70	1.52	70	0.53
1985	70	0.60	70	0.63	70	0.32	70	0.94	70	0.36
1986	79	0.53	79	0.53	79	0.28	79	0.87	79	0.32
1987	81	0.57	81	0.59	81	0.49	81	0.89	81	0.32
1988	77	0.48	77	0.51	77	0.28	77	0.88	77	0.31
1989	78	0.52	77	0.41	78	0.26	79	0.91	79	0.35
1990	12	0.36	12	0.37	12	0.20	12	0.67	12	0.25

Table NGS - 2.

RADIO SOURCE COORDINATES RSC(NGS) 90 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0048-097	0	50	41.317360	- 9	29	5.20930	0.000010	0.00030
0106+013	1	8	38.771030	1	35	0.31750	0.000002	0.00020
0119+041	1	21	56.861610	4	22	24.73540	0.000007	0.00030
0208-512	2	10	46.200250	-51	1	1.89330	0.000100	0.00310
0212+735	2	17	30.813030	73	49	32.62160	0.000052	0.00020
0224+671	2	28	50.051340	67	21	3.02940	0.000043	0.00030
0229+131	2	31	45.893990	13	22	54.71740	0.000005	0.00020
0234+285	2	37	52.405580	28	48	8.99070	0.000010	0.00020
0235+164	2	38	38.930030	16	36	59.27610	0.000010	0.00040
0300+470	3	3	35.242090	47	16	16.27600	0.000018	0.00020
0316+413	3	19	48.159960	41	30	42.10420	0.000028	0.00030
0355+508	3	59	29.747150	50	57	50.16220	0.000021	0.00020
0420-014	4	23	15.800670	- 1	20	33.06260	0.000002	0.00020
0454-234	4	57	3.179190	-23	24	52.01670	0.000009	0.00030
0530-727	5	29	30.041450	-72	45	28.50780	0.000669	0.00170
0528+134	5	30	56.416700	13	31	55.15220	0.000005	0.00020
0537-441	5	38	50.376240	-44	5	8.94950	0.008880	0.02750
0552+398	5	55	30.805530	39	48	49.16670	0.000013	0.00020
0637-752	6	35	46.507050	-75	16	16.81340	0.000431	0.00120
0727-115	7	30	19.112490	-11	41	12.59720	0.000004	0.00020
0742+103	7	45	33.059530	10	11	12.69570	0.000007	0.00040
0823+033	8	25	50.338340	3	9	24.52450	0.000016	0.00050
0851+202	8	54	48.874920	20	6	30.64330	0.000005	0.00020
0923+392	9	27	3.013880	39	2	20.85380	0.000010	0.00020
1034-293	10	37	16.079750	-29	34	2.81120	0.000012	0.00030
1055+018	10	58	29.605220	1	33	58.82610	0.000003	0.00030
1057-797	10	58	43.307500	-80	3	54.16180	0.000545	0.00120
1104-445	11	7	8.693740	-44	49	7.62250	0.000103	0.00180
1144+402	11	46	58.297960	39	58	34.30570	0.000011	0.00020
1156+295	11	59	31.833940	29	14	43.82770	0.000008	0.00020
1226+023	12	29	6.699750	2	3	8.59970	0.000002	0.00020
1253-055	12	56	11.166510	- 5	47	21.52340	0.000010	0.00040
1308+326	13	10	28.663900	32	20	43.78350	0.000008	0.00020
1334-127	13	37	39.782760	-12	57	24.69250	0.000007	0.00030
1354+195	13	57	4.436710	19	19	7.37220	0.000009	0.00020
1404+286	14	7	0.394450	28	27	14.68980	0.000007	0.00020
1418+546	14	19	46.597470	54	23	14.78750	0.000026	0.00030
1424-418	14	27	56.297210	-42	6	19.44130	0.000096	0.00170
1502+106	15	4	24.979830	10	29	39.19820	0.000004	0.00020
1548+056	15	50	35.269250	5	27	10.44770	0.000003	0.00020

Table NGS - 2. (Cont.)

RADIO SOURCE COORDINATES RSC(NGS) 90 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
1611+343	16	13	41.064290	34	12	47.90840	0.000010	0.00020
1610-771	16	17	49.276630	-77	17	18.47170	0.000321	0.00120
1622-253	16	25	46.891560	-25	27	38.32770	0.000013	0.00040
1633+382	16	35	15.493000	38	8	4.49980	0.000011	0.00020
1637+574	16	38	13.456400	57	20	23.97840	0.000023	0.00020
1642+690	16	42	7.848740	68	56	39.75590	0.000042	0.00020
1641+399	16	42	58.810000	39	48	36.99320	0.000012	0.00020
1730-130	17	33	2.705740	-13	4	49.54940	0.000007	0.00020
1739+522	17	40	36.977910	52	11	43.40670	0.000019	0.00020
1741-038	17	43	58.856130	- 3	50	4.61810	0.000003	0.00020
1749+096	17	51	32.818560	9	39	0.72690	0.000004	0.00020
1803+784	18	0	45.684120	78	28	4.01770	0.000072	0.00020
1815-553	18	19	45.399510	-55	21	20.74800	0.000114	0.00140
1921-293	19	24	51.055900	-29	14	30.12190	0.000011	0.00030
1923+210	19	25	59.605260	21	6	26.16190	0.000029	0.00110
1928+738	19	27	48.495110	73	58	1.56950	0.000112	0.00080
1958-179	20	0	57.090420	-17	48	57.67370	0.000020	0.00030
2113+293	21	15	29.413410	29	33	38.36660	0.000015	0.00040
2121+053	21	23	44.517360	5	35	22.09170	0.000003	0.00020
2128-123	21	31	35.261590	-12	7	4.79730	0.000028	0.00040
2134+004	21	36	38.586290	0	41	54.21270	0.000002	0.00020
2145+067	21	48	5.458630	6	57	38.60290	0.000003	0.00020
2155-152	21	58	6.281710	-15	1	9.32960	0.000041	0.00070
2200+420	22	2	43.291340	42	16	39.97880	0.000012	0.00020
2216-038	22	18	52.037700	- 3	35	36.88060	0.000003	0.00030
2234+282	22	36	22.470820	28	28	57.41220	0.000008	0.00020
2251+158	22	53	57.747900	16	8	53.55980	0.000004	0.00020
2255-282	22	58	5.962860	-27	58	21.25640	0.000015	0.00040
2326-477	23	29	17.704370	-47	30	19.11640	0.000067	0.00210
2345-167	23	48	2.608420	-16	31	12.02220	0.000012	0.00030

Table NGS-3. Coordinates of the VLBI Antenna Reference Points. SSC(NGS) 89 R 01

Site Name	X m	SX m	Y m	SY m	Z m	SZ m
KWAJALEIN	-6143536.4373	.0164	1363997.1914	.0092	1034707.7006	.0115
KAUAI	-5543845.8512	.0049	-2054564.1776	.0070	2387814.1448	.0079
TIDBINBILLA	-4460935.2172	.0255	2682765.6639	.0188	-3674381.4602	.0159
KASHIMA	-3997892.0723	.0080	3276581.3260	.0051	3724118.4581	.0106
HOBART	-3950237.6546	.6254	2522347.9591	.3848	-4311562.9710	.2955
NOBEYAMA	-3871168.0703	.0201	3428274.0633	.0158	3723697.7838	.0234
SESHAN	-2831686.5067	.0140	4675733.9172	.0154	3275327.8794	.0160
VANDENBERG	-2678094.4790	.0020	-4525450.7952	.0046	3597410.3777	.0046
HATCREEK	-2523969.6463	.0021	-4123506.3212	.0045	4147752.8262	.0048
OVRO	-2409600.4777	.0021	-4478349.5232	.0050	3838603.4530	.0048
MOJAVE	-2356170.7174	.0009	-4646755.8584	.0035	3668470.8387	.0036
GILCREEK	-2281546.8072	.0023	-1453644.9500	.0032	5756993.3824	.0052
HRAS	-1324210.6974	.0008	-5332023.1062	.0028	3232118.5693	.0026
PLATTVILLE	-1240707.8348	.0027	-4720454.3026	.0087	4094481.8227	.0075
NRAO	882880.2229	.0155	-4924481.9552	.0650	3944130.4775	.0523
ALGOPARK	918035.1444	.0085	-4346132.1182	.0319	4561971.1380	.0301
RICHMOND	961258.3120	.0010	-5674090.0150	.0019	2740533.8313	.0015
MARPOINT	1106629.6718	.0923	-4882906.8058	.4158	3938086.8470	.3035
WESTFORD	1492206.9904	---	-4458130.4420	---	4296015.5132	---
HAYSTACK	1492405.1443	.0058	-4457266.4514	.0134	4296881.7293	.0146
ONSALA	3370606.4789	.0034	711917.4808	.0021	5349830.4576	.0050
CHLBOLTN	4008310.5218	.0126	-100650.8310	.0084	4943794.4973	.0183
EFLSBERG	4033947.9370	.0144	486990.4420	.0086	4900430.4847	.0207
WETTZELL	4075540.3247	.0038	931735.2272	.0023	4801629.0437	.0052
MEDICINA	4461370.4264	.0068	919596.7695	.0033	4449558.8430	.0079
MADRID	4849336.9615	.0184	-360488.8589	.0067	4114748.3861	.0200
NOTO	4934563.5538	.0665	1321201.2499	.0288	3806484.0600	.0591
HARTRAO	5085442.6771	.0147	2668263.2637	.0078	-2768697.4869	.0089

Table NGS - 4.

EOP(NGS) 90 R 02 Available from 1984 to 1990

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	UT1 Nb	UT1 Sigma
1984	64	0.74
1985	161	0.36
1986	237	0.38
1987	246	0.44
1988	255	0.52
1989	234	0.62
1990	58	0.68

POLAR MOTION AND UT1 FROM VLBI

SHA 90 R 01

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The series of Polar Motion and UT1 from January 1987 to November 1988 have been derived from the observations of IRIS (International Radio Interferometric Surveying), which were provided by NGS, NOAA of USA with NGS format.

The models used to calculate the motions and deformations of the Earth were consistent with the MERIT Standards (Melbourne et al., 1983), but no models for plate motions and ocean loading were used. AIC (Akaike Information Criteria) in Time Series Analysis was used to determine simultaneously the number and the time of the broken points and the models in each section for the clock behaviour in order to eliminate the analyst errors (Zheng Dawei et al., 1986). The coordinates of IRIS stations used in the processing are listed in Table 1.The coordinates of radio sources are shown in Table 2. Finally, the series of polar motion and UT1 are listed in Table 3.

References

Melbourne, W., R. Anderle, M., Feissel, R. King, D. McCarthy, D. Smith, B. Tapley and R. Vincent. *U.S. Naval Observatory, Circular No 167*, Washington D.C. 1983.

Zheng Dawei, Shifang Luo and J.R. MacKay. An Optimal Idenfification of Clock Behaviour Model of VLBI, *Annals of Shanghai Observatory, No 8* p. 25-31 (1986).

TABLE 1. STATION COORDINATES

SSC(SHA) 90 R 01

SITE	X m	Y m	Z m
Westford	1492208.55400	-4458131.32899	4296015.87700
Hras 085	-1324209.14740	-5332024.06190	3232118.97780
Wettzell	4075541.90600	931734.18900	4801629.39301
Richmond	961259.86200	-5674090.97900	2740534.25800
Onsala 60	3370608.02400	711916.50600	5349830.78700

TABLE 2 .

RADIO SOURCE COORDINATES RSC(SHA) 90 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0106+013	1	8	38.770360	1	35	0.30290	0.000140	0.00230
0212+735	2	17	30.811850	73	49	32.62260	0.000190	0.00080
0229+131	2	31	45.893920	13	22	54.72060	********	*******
0420-014	4	23	15.800590	- 1	20	33.06270	********	*******
0528+134	5	30	56.416120	13	31	55.13980	0.000140	0.00190
0552+398	5	55	30.804980	39	48	49.17000	0.000150	0.00130
0851+202	8	54	48.874360	20	6	30.64100	0.000160	0.00160
0923+392	9	27	3.013460	39	2	20.85590	0.000130	0.00100
1055+018	10	58	29.604960	1	33	58.82770	********	*******
1226+023	12	29	6.699700	2	3	8.59870	********	*******
1404+286	14	7	0.394180	28	27	14.68940	0.000070	0.00080
1633+382	16	35	15.492730	38	8	4.50210	********	*******
1641+399	16	42	58.809740	39	48	36.99210	0.000080	0.00080
1741-038	17	43	58.855850	- 3	50	4.61000	********	*******
1803+784	18	0	45.683950	78	28	4.01510	0.000230	0.00040
2121+053	21	23	44.517270	5	35	22.09710	********	*******
2134+004	21	36	38.585680	0	41	54.19970	0.000130	0.00260
2200+420	22	2	43.290650	42	16	39.97550	0.000100	0.00060
2251+158	22	53	57.747220	16	8	53.55260	0.000110	0.00170

TABLE 3.

EOP(SHA) 90 R 01 Available from 1987 to 1988

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	X		Y		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	66	0.87	66	0.56	66	0.27
1988	53	0.83	53	0.59	53	0.30

EARTH ORIENTATION RESULTS FROM THE U.S. NAVAL OBSERVATORY VLBI PROGRAM

USNO 90 R 02

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As part of its participation in the National Earth Orientation Service (NEOS) the U.S. Naval Observatory (USNO) has developed a program in Very Long Baseline Interferometry (VLBI) to monitor changes in the orientation of the Earth on a regular basis. NEOS is a joint cooperative effort of the USNO and the National Geodetic Survey (NGS), and this VLBI program is designed to complement the observations coordinated by the NGS as part of the International Radio Interferometric Surveying (IRIS) subcommission. The Naval Research Laboratory (NRL) and the Crustal Dynamics Project VLBI group at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) also assisted in the development of the program. The Navy VLBI Network (Navnet) measures the orientation of the Earth in space from Mark III VLBI observations acquired with telescopes at Gilmore Creek, (Alaska), Kokee Park, (Hawaii), Richmond (Florida), Green Bank (West Virginia) and, in the past, Maryland Point (Maryland). Radio telescopes at Mojave (California), and Medicina and Noto, (Italy), have also participated in these experiments on an occasional basis. Current Navnet operations consist of one 24 hour duration observing session per week together with three hour duration observing sessions on two other days of the week. The Navnet data are used to estimate UT1, polar motion and nutation for inclusion in the International Earth Rotation Service (IERS) combined solutions.

The USNO VLBI program began observations in June, 1987, with a series of 8 hour duration GNUT (Goddard Navy UT) experiments. These observing sessions mostly used the Maryland Point to Gilmore Creek, baseline, although Kokee Park, participated occasionally and Richmond, participated starting in the beginning of 1988. The GNUT experiments were under the operational control of the NRL, with assistance from the NASA-GSFC VLBI group. After a period of experimentation, routine Navnet observations began on January 5, 1989, on a weekly basis using the Maryland, Alaska, Hawaii and Florida antennas. The Green Bank antenna provided its first VLBI data on January 25, 1989, and has participated in Navnet observations since that time. The USNO assumed full operational control of the Navnet experiments in April, 1989, and the use of the Maryland Point antenna was phased out in August, 1989. One 24 hour duration GNUT was observed in September, 1988; monthly 24 hour duration Navnets commenced in April, 1989, and all of the weekly Navnets have been 24 hours in duration since June 27, 1989. At present, one 24 hour duration Navnet experiment is scheduled every week using at least three of the Florida, Alaska, Hawaii and West Virginia antennas. These data are reduced and released to NEOS and the IERS on a regular basis; typical processing times are now on the order of 13 to 20 days from the acquisition of data to release of the final results.

The Navnet VLBI data are acquired using Mark III VLBI data acquisition terminals with a nominal 8 X band and 6 S band channels, each with a 2 MHz bandwidth. The technique of band width synthesis is used to improve the accuracy of the group delay estimates, and these channels are spread across 85 MHz at S band and 350 MHz at X band, using the channel frequencies in Table 1. The Navnet VLBI data have all been correlated at the Washington Correlator, which is located on the Naval Observatory grounds and is run by a consortium among the USNO, the NGS, the NRL, and NASA. The correlator provides estimates of the band width synthesis group delay and the phase

delay rate from the radio noise recorded at the stations, together with estimates of the random (thermal) noise associated with each measurement and a Quality Factor describing the reliability of the measurement. Only observations with Quality Factors of 5 or higher are used in the USNO reduction of the Navnet data. Observations with letter Quality Factors of A through F, which indicate serious problems with the correlated data, are also not used in the USNO reduction.

After correlation, fringe fitting, and the removal of any remaining bandwidth synthesis delay ambiguities, the Navnet and GNUT data are used in a series of weighted least squares solutions to define a USNO VLBI reference frame and to estimate the Earth orientation within that reference frame. The data are processed with IERS standard models to the maximum extent possible. The Minster and Jordan AM0-2 plate motion model is used without adjustment to describe the tectonic motions of the stations. The CFA 2.2 tropospheric mapping function is used to relate line of sight tropospheric propagation delays to the tropospheric zenith delay. Although the vertical deformations due to ocean tidal loading are modeled in the reduction process, the horizontal deformations are not, and ground deformations due to atmospheric loading are currently ignored.

Table 1 : Navnet Channel Frequencies

Channel Number	Band	Frequency MHz
1	S	2217.99
2	S	2222.99
3	S	2237.99
4	S	2267.99
5	S	2292.99
6	S	2302.99
1	X	8210.99
2	X	8220.99
3	X	8250.99
4	X	8310.99
5	X	8420.99
6	X	8500.99
7	X	8550.99
8	X	8570.99

Unmodeled variations in the tropospheric propagation delays and the relative time offset between the station clocks are a significant source of error in geodetic VLBI. The surface pressure, temperature and relative humidity are recorded at each station and used to estimate the variations in the hydrostatic zenith tropospheric propagation delay. Further variations in these quantities are treated by the estimation of piecewise linear models directly in the least squares solutions. A new piecewise linear function is introduced every 60 minutes for the zenith tropospheric propagation and every 90 minutes for the relative station clocks.

An attempt is made to align the Navnet reference frame as closely as is possible with both the terrestrial and celestial reference frames maintained by the IERS, and to minimize bias offsets between the Navnet Earth orientation parameter estimates and those of the IERS combined solutions. Due to software limitations, the Navnet reference frame is obtained from the USNO VLBI data in a two solution process. In the first solution, the IERS Rapid Service (Bulletin A) estimates of the UT1 and polar motion are treated as a priori measurements and the nutation in longitude and obliquity is fixed at the IERS Rapid Service values, while the right ascension of the source 2216-038 is fixed at the value given in the IERS combined celestial reference frame for 1989 (RSC (IERS) 89 C 01). All

source coordinates, and all of the station coordinates except for the Richmond station, are adjusted in this solution. The purpose of this solution is to align the celestial reference frame with the celestial pole implied by the IERS Rapid Service nutation values. The coordinates of two sources, 0202+149 (in right ascension and declination) and 0742+103 (in declination only) are then fixed in a second solution to the values obtained in the first solution. This second solution globally adjusts the coordinates of all of the other sources and all of the station coordinates except for the Richmond station, together with an adjustment for UT1, Polar Motion, both components of nutation plus the piecewise linear clock and troposphere models separately for each experiment. The IERS Rapid Service estimates of the UT1 and polar motion are treated as a priori measurements in this solution. The polar motion y component is fixed at the IERS Rapid Service value for those experiments with data from a single baseline only. The position of the Richmond station at the epoch 1988.0 is fixed at the value given by the ITRF-88 for that epoch, and the station is allowed to move at the AM0-2 rate. Five radio sources (3C84, 3C273B, 3C345 and 3C454.3) were judged to have too much source structure to be usable for geodetic work and are no longer observed; these sources were treated as "arc" parameters in the solution, with a separate position being estimated for each experiment in which they were observed. The USNO reference frame 1990-2 was obtained from such a solution using all of the USNO VLBI data from 1987 through February 1990; this solution used a total of 21430 observation pairs (delay and delay rate) with a weighted rms residual scatter of 47.4 picoseconds for the delay observations and 72.2 femtoseconds per second for the delay rate data. The station coordinates for all of the Navnet stations from this solution are given in Table 2, for the epoch 1980 October 17, while Table 4 provides the corresponding source positions.

The Navnet Earth orientation results (Table 3) are obtained from the 24 hour duration experiments in a multi-parameter least squares adjustment for UT1, polar motion and both components of nutation, together with the piecewise linear clock and troposphere models. Additional baseline dependent clock offsets are added whenever the non- closure of the clock estimates around station triangles is judged to be significant. This solution used a total of 15622 observation pairs (delay and delay rate) and produced weighted rms residual scatters of 47.5 picoseconds for the delay observations and 97.9 femtoseconds per second for the delay rate data. The station coordinates and source positions are fixed at the a priori values given by the Navy 1990-2 reference frame; source positions whose formal errors are larger than one milli second of arc in either right ascension or declination in the 1990-2 reference frame are treated as arc parameters, with a separate position being estimated for each experiment in which they were observed. The tie to the 1990-2 reference frame is thus obtained by the fixed station coordinates and source positions; this method avoids week to week variations in the reference frame used in the reduction of the Navnet data. Although the Earth orientation parameter formal errors thus do not fully reflect errors introduced by uncertainties in the station coordinates and source positions, solutions performed without these constraints indicate that inclusion of these errors would not significantly increase the resulting Earth orientation parameter formal errors.

The errors presented in this report are formal errors obtained from the covariance matrix of the least squares adjustment. The post fit residual scatter is always larger than would be expected given the formal error estimates for the delay and delay rate observables provided by the correlator. The total residual scatter is made to agree with that expected given the observable error estimates through addition of empirically determined "noise" additive variances to the square of the correlator formal error estimates. These additive variances are determined separately for each experiment; different constants are used for the delay and delay rate data from each baseline used in an experiment. Table 5 presents the full covariance matrix for each 24 hour duration experiment in the form of parameter sigmas and all 10 correlation coefficients between the five Earth orientation parameters. Note that in Table 4 the nutation in longitude and its formal error are expressed in milli seconds of arc in longitude, while in Table 5 the longitude formal error has been scaled by the sine of the mean obliquity of J2000.0 to provide true milli seconds of arc on the sky.

TABLE 2 : NAVNET Station Locations in the 1990-2 Reference Frame SSC(USNO) 90 R 02

Domes ID	Station Name	CIO X m	CIO Y m	CIO Z m	Mean MJD	Data Span Days	X Err	Y Err	Z Err
							----- Meters -------		
40499S001	RICHMOND	961258.217	-5674090.080	2740533.707	47577.0	732.0	0.0	0.0	0.0
40408S002	GILCREEK	-2281546.912	-1453645.131	5756993.257	47450.5	985.0	0.004	0.006	0.007
40424S001	KAUAI	-5543845.864	-2054564.789	2387813.569	47469.5	947.0	0.005	0.008	0.007
40441S002	NRAO85 3	882325.821	-4925138.031	3943397.582	47747.5	391.0	0.001	0.003	0.003
40490S001	MARPOINT	1106629.551	-4882907.223	3938086.879	47360.5	805.0	0.002	0.005	0.004
40405S001	MOJAVE12	-2356170.797	-4646755.962	3668470.691	47756.5	81.0	0.004	0.008	0.007
12711S001	MEDICINA	4461370.185	919596.459	4449558.866	47451.5	131.0	0.018	0.015	0.027
---------	NOTO	4934563.288	1321200.861	3806484.170	47748.0	64.0	0.012	0.008	0.014

TABLE 3 :

EOP(USNO) 90 R 02 Available from 1988 to 1990

Number of measurements and RMS uncertainty per year
Units : 0.001" for X,Y,dPsi,dEps; 0.0001s for UT; ms for D

YEAR	X		Y		UT1		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1988	1	1.75	1	2.39	1	0.83	1	1.27	1	0.47
1989	29	0.65	29	0.79	29	0.36	29	0.56	29	0.24
1990	16	0.39	16	0.47	16	0.22	16	0.41	16	0.17

TABLE 4.

RADIO SOURCE COORDINATES RSC(USNO) 90 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	o	'	"	S	"
0016+731	0	19	45.785947	73	27	30.01611	0.000097	0.00032
0048-097	0	50	41.317400	- 9	29	5.21131	0.000025	0.00081
0104-408	1	6	45.108301	-40	34	19.97079	0.000141	0.00543
0106+013	1	8	38.771088	1	35	0.31559	0.000013	0.00035
0119+041	1	21	56.861669	4	22	24.73282	0.000007	0.00019
0133+476	1	36	58.594615	47	51	29.09835	0.000018	0.00016
0201+113	2	3	46.656995	11	34	45.40794	0.000024	0.00035
0202+149	2	4	50.413856	15	14	11.04215	0.000000	0.00000
0212+735	2	17	30.812674	73	49	32.62102	0.000053	0.00023
0229+131	2	31	45.894015	13	22	54.71555	0.000013	0.00025
0234+285	2	37	52.405557	28	48	8.98937	0.000012	0.00021
0235+164	2	38	38.930041	16	36	59.27404	0.000010	0.00019
0256+075	2	59	27.076650	7	47	39.64391	0.000057	0.00181
0300+470	3	3	35.241993	47	16	16.27485	0.000013	0.00019
0333+321	3	36	30.107581	32	18	29.34264	0.000033	0.00041
0336-019	3	39	30.937801	- 1	46	35.80439	0.000029	0.00090
0402-362	4	3	53.750021	-36	5	1.91398	0.000037	0.00279
0420-014	4	23	15.800709	- 1	20	33.06478	0.000009	0.00016
0434-188	4	37	1.482790	-18	44	48.61263	0.000023	0.00094
0454-234	4	57	3.179276	-23	24	52.01943	0.000013	0.00059
0458-020	5	1	12.809894	- 1	59	14.25518	0.000020	0.00052
0528+134	5	30	56.416693	13	31	55.15034	0.000009	0.00015
0552+398	5	55	30.805461	39	48	49.16641	0.000012	0.00020
0657+172	7	0	1.525505	17	9	21.70359	0.000014	0.00025
0716+714	7	21	53.448125	71	20	36.36597	0.000045	0.00024
0727-115	7	30	19.112480	-11	41	12.59837	0.000011	0.00038
0742+103	7	45	33.059479	10	11	12.69471	0.000010	0.00000
0745+241	7	48	36.109235	24	0	24.11291	0.000017	0.00022
0814+425	8	18	15.999530	42	22	45.41744	0.000019	0.00017
0851+202	8	54	48.874907	20	6	30.64345	0.000012	0.00011
0859+470	9	3	3.990075	46	51	4.13998	0.000027	0.00027
0923+392	9	27	3.013869	39	2	20.85468	0.000019	0.00012
1034-293	10	37	16.079680	-29	34	2.80769	0.000023	0.00096
1055+018	10	58	29.605221	1	33	58.82655	0.000015	0.00041
1123+264	11	25	53.711922	26	10	19.98123	0.000020	0.00027
1124-186	11	27	4.392330	-18	57	17.43655	0.000027	0.00140
1144+402	11	46	58.298007	39	58	34.30693	0.000022	0.00019
1144-379	11	47	1.370632	-38	12	11.01988	0.000103	0.00399
1222+037	12	24	52.421884	3	30	50.29525	0.000026	0.00075
1244-255	12	46	46.801907	-25	47	49.26931	0.000085	0.00812

RADIO SOURCE COORDINATES RSC(USNO) 90 R 02

SOURCE	RIGHT ASCENSION	DECLINATION	SIGMA R.A.	SIGMA D.
	H M S	o ' "	S	"
1253-055	12 56 11.166476	- 5 47 21.52164	0.000011	0.00043
1308+326	13 10 28.663967	32 20 43.78457	0.000016	0.00024
1313-333	13 16 7.985985	-33 38 59.18043	0.000112	0.00534
1334-127	13 37 39.782687	-12 57 24.68948	0.000033	0.00135
1354-152	13 57 11.244914	-15 27 28.78333	0.000020	0.00098
1404+286	14 7 0.394470	28 27 14.69112	0.000019	0.00033
1418+546	14 19 46.597676	54 23 14.78792	0.000025	0.00025
1502+106	15 4 24.979833	10 29 39.19871	0.000017	0.00047
1510-089	15 12 50.532909	- 9 5 59.82881	0.000013	0.00056
1519-273	15 22 37.675887	-27 30 10.77942	0.000032	0.00246
1548+056	15 50 35.269269	5 27 10.44777	0.000011	0.00046
1611+343	16 13 41.064392	34 12 47.90826	0.000013	0.00034
1622-253	16 25 46.891492	-25 27 38.32800	0.000124	0.00313
1633+382	16 35 15.493104	38 8 4.49961	0.000013	0.00033
1637+574	16 38 13.456578	57 20 23.97820	0.000035	0.00045
1642+690	16 42 7.849057	68 56 39.75532	0.000037	0.00030
1730-130	17 33 2.705771	-13 4 49.54852	0.000024	0.00111
1739+522	17 40 36.978033	52 11 43.40648	0.000043	0.00045
1741-038	17 43 58.856121	- 3 50 4.61799	0.000011	0.00052
1749+096	17 51 32.818605	9 39 0.72684	0.000012	0.00048
1803+784	18 0 45.684673	78 28 4.01650	0.000051	0.00028
1823+568	18 24 7.068579	56 51 1.48866	0.000022	0.00031
1921-293	19 24 51.055910	-29 14 30.12226	0.000017	0.00073
1928+738	19 27 48.495453	73 58 1.56689	0.000049	0.00026
2037+511	20 38 37.034790	51 19 12.65907	0.000020	0.00024
2121+053	21 23 44.517371	5 35 22.09060	0.000013	0.00043
2128-123	21 31 35.261599	-12 7 4.79470	0.000047	0.00255
2145+067	21 48 5.458659	6 57 38.60110	0.000009	0.00033
2200+420	22 2 43.291307	42 16 39.97683	0.000014	0.00019
2216-038	22 18 52.037714	- 3 35 36.88252	0.000010	0.00038
2230+114	22 32 36.408872	11 43 50.90132	0.000009	0.00027
2234+282	22 36 22.470828	28 28 57.41047	0.000010	0.00019
2243-123	22 46 18.231888	-12 6 51.27079	0.000159	0.00759
2253+417	22 55 36.707789	42 2 52.52965	0.000026	0.00040
2255-282	22 58 5.962932	-27 58 21.25875	0.000029	0.00113
2345-167	23 48 2.608551	-16 31 12.02307	0.000015	0.00058
2355-106	23 58 10.882410	-10 20 8.61269	0.000015	0.00068

TABLE 5 : USNO VLBI EARTH ORIENTATION COVARIANCE MATRIX USING THE NAVY 90-2 REFERENCE FRAME

MJD	PM-X ERR	PM-Y ERR	UT1 ERR	PSI ERR	EPS ERR	CORR X-Y	CORR X-U	CORR Y-U	CORR X-P	CORR X-E	CORR Y-P	CORR Y-E	CORR U-P	CORR U-E	CORR P-E
	MILLI SECONDS OF ARC														
47415.000	1.75	2.39	1.25	0.50	0.47	-.8441	-.6340	0.1939	-.1612	-.0503	0.0841	0.0187	0.1643	0.0557	0.0460
47620.000	1.53	1.96	0.89	0.29	0.35	-.6318	-.9624	0.4506	-.0535	-.0206	-.0852	-.1314	0.0515	0.0384	0.1512
47655.000	0.56	0.76	0.42	0.16	0.16	-.3248	-.9381	0.0574	-.0246	-.0085	-.0327	-.0889	0.0733	0.0641	0.0869
47682.000	0.33	0.34	0.27	0.17	0.18	-.2881	-.7370	-.2564	0.2322	-.0751	-.0852	-.0444	-.1863	0.0351	0.0714
47705.000	0.60	0.85	0.43	0.18	0.19	-.4377	-.9389	0.1991	-.0482	-.0185	-.0082	0.1206	0.0691	0.0436	0.0806
47710.000	0.62	0.85	0.47	0.20	0.22	-.3795	-.9313	0.1279	-.0389	-.0577	-.0032	0.1347	0.0838	0.0934	0.1453
47717.000	0.14	0.12	0.09	0.10	0.12	-.0881	-.6860	0.0911	0.0538	0.0567	-.0275	0.0208	-.0011	0.0385	0.0145
47726.000	0.22	0.27	0.13	0.16	0.20	-.0894	-.6253	0.5301	0.0070	0.0377	0.0294	-.1271	0.0210	-.0204	0.0830
47731.000	0.65	0.80	0.45	0.17	0.19	-.4823	-.9556	0.2970	0.0283	0.0892	0.1270	0.0575	0.0072	-.0674	0.1355
47743.000	0.25	0.26	0.21	0.13	0.13	-.0975	-.8317	-.3039	0.1915	0.1494	0.0740	-.1248	-.1913	-.0368	0.1750
47746.000	0.52	0.68	0.37	0.15	0.17	-.4543	-.9374	0.2136	-.0560	0.0126	-.0235	0.0923	0.0966	0.0002	-.0114
47756.000	0.62	0.88	0.47	0.21	0.23	-.3864	-.9262	0.1268	-.0281	-.0042	0.0328	0.1374	0.0400	0.0415	0.0975
47763.000	0.77	0.92	0.53	0.18	0.20	-.6034	-.9578	0.4260	-.0030	0.0322	-.0505	0.0930	0.0603	0.0245	0.1155
47770.000	0.59	0.86	0.45	0.20	0.22	-.3116	-.9217	0.0373	-.0531	0.0018	-.0526	0.1188	0.0998	0.0514	0.0012
47777.000	0.51	0.73	0.35	0.15	0.16	-.4504	-.9397	0.2247	-.0548	0.0211	-.0579	0.1728	0.0836	0.0370	0.0297
47780.000	0.21	0.20	0.11	0.18	0.18	-.1009	-.6391	0.1728	-.0423	0.1288	-.1106	0.0929	-.0322	0.0271	-.0567
47787.000	0.33	0.36	0.27	0.17	0.20	-.1315	-.7956	-.3184	0.1237	0.1749	0.0379	-.1705	-.1423	-.0672	0.0987
47797.000	1.12	0.82	0.72	0.35	0.33	-.2061	-.9125	-.1177	-.0054	0.0889	0.1211	0.0520	0.0775	-.0572	0.0928
47805.000	0.81	0.94	0.51	0.18	0.23	-.6223	-.9522	0.4356	0.1231	0.3169	-.1279	-.1394	-.0592	-.2039	0.1875
47811.000	0.39	0.37	0.29	0.22	0.23	-.1395	-.6765	-.4537	0.0628	0.1053	-.1666	-.1318	-.0775	-.0362	0.2234
47816.000	0.99	0.86	1.69	0.38	0.34	0.1153	-.9199	-.4017	0.0947	0.3325	0.2115	0.1253	-.1795	-.3039	-.0924
47823.000	0.73	1.23	0.56	0.19	0.19	-.8801	-.1599	-.2804	-.1871	0.0910	0.0519	-.0622	0.3300	-.1136	-.0240
47830.000	0.86	1.35	0.71	0.27	0.23	-.8577	-.3040	-.1688	-.2400	0.0809	0.0351	-.0299	0.3440	-.1669	-.1644
47840.000	0.37	0.39	0.35	0.22	0.22	-.0113	-.7574	-.4600	0.1801	0.1288	-.0593	0.0238	-.3146	-.0822	0.0691
47852.000	0.32	0.31	0.23	0.18	0.21	-.1514	-.6634	-.4531	-.1741	0.0707	-.1772	-.4226	0.1986	0.2463	0.1709
47857.000	0.34	0.39	0.29	0.21	0.31	-.2898	-.5665	-.2120	0.1284	0.1879	-.1299	0.1626	-.3539	0.3001	-.3293
47865.000	0.35	0.38	0.29	0.23	0.19	-.1613	-.6025	-.5140	0.0444	-.0428	-.2455	-.1820	-.0268	-.0221	0.1872
47874.000	1.08	1.11	0.77	0.46	0.59	-.3421	-.7951	-.1283	0.0224	-.1710	0.0009	-.0495	-.1037	0.2730	-.0568
47878.000	0.27	0.26	0.23	0.18	0.16	-.0184	-.7327	-.3586	-.2771	0.1238	-.1557	-.0675	-.0589	0.1715	-.2446
47888.000	0.41	0.40	0.32	0.21	0.20	-.1586	-.8100	-.2990	0.3885	-.0346	-.2791	-.4643	-.2044	0.1495	-.0238
47895.000	0.46	0.41	0.35	0.24	0.25	-.1235	-.6457	-.5116	0.1040	0.1800	0.0828	0.0301	-.0629	-.0130	0.1560
47902.000	0.27	0.35	0.24	0.15	0.16	-.3668	-.7517	-.1464	-.0388	-.0623	-.0488	-.2653	-.0375	0.2576	0.0238
47909.000	0.42	0.33	0.28	0.17	0.17	-.2469	-.8788	-.1024	0.0909	-.0626	-.1971	-.2147	-.0722	0.1553	0.0637
47916.000	0.83	1.23	0.74	0.21	0.20	-.8556	-.4633	-.0074	-.1181	-.0187	0.1363	-.0035	0.0494	-.0045	-.0264
47923.000	0.69	0.99	0.69	0.21	0.24	-.8056	-.5150	-.0078	-.1154	0.0146	0.1155	0.0018	0.1047	0.0347	0.0837
47929.000	0.42	0.28	0.30	0.18	0.20	0.0270	-.8706	-.2986	0.0881	-.0303	-.1309	0.2000	-.1136	0.1925	-.0505
47937.000	0.27	0.29	0.22	0.16	0.18	-.1682	-.6947	-.3734	0.1083	0.1560	0.0111	0.0041	-.1558	-.0144	-.0606
47943.000	0.23	0.24	0.21	0.13	0.13	0.0467	-.7629	-.5328	0.1886	0.0189	-.0656	-.1976	-.1401	0.0624	0.0728