IERS TECHNICAL NOTE 5

Earth orientation and reference frame determinations, atmospheric excitation functions, up to 1989, (Annex to the IERS Annual Report for 1989)

IERS Analysis Centres for VLBI, LLR, SLR, AAM

113348

June 1990

Central Bureau of IERS - Observatoire de Paris
61, avenue de l'Observatoire
F-75014 PARIS - France

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ALL RESULTS DESCRIBED IN THIS ISSUE ARE AVAILABLE ON REQUEST FROM THE CENTRAL BUREAU OF IERS.

IERS Technical Notes

This series of publications gives technical information related to the IERS activities, e.g. reference frames, excitation of the Earth rotation, computational or analysis aspects, models, etc. It also contains the description and results of the analyses performed by the IERS Analysis Centres for the Annual Report global analysis.

Issues available

No 1 : C. Boucher and Z.Altamimi. The initial IERS Terrestrial Reference Frame.

No 2 : Earth orientation and reference frame determinations, atmospheric excitation functions, up to 1988, (Annex to the IERS Annual Report for 1988).

No 3 : IERS Standards (1989)

No 4 : C. Boucher and Z. Altamimi. Evaluation of the realizations of the Terrestrial Reference System done by the BIH and IERS (1984-1988).

No 5 : Earth orientation and reference frame determinations, atmospheric excitation functions, up to 1989, (Annex to the IERS Annual Report for 1989).

Future issues

No 6 : C. Boucher and Z. Altamimi. ITRF89 and other realizations of the IERS Terrestrial Reference System for 1989.

No 7 : E.F. Arias and J.-F. Lestrade. Connection of the IERS and HIPPARCOS celestial reference frames.

VERY LONG BASELINE INTERFEROMETRY

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

GSFC 90 R 01

C. Ma, Code 626.9, Goddard Space Flight Center, Greenbelt, Md., 20771, USA
J. W. Ryan, Code 601.9, Goddard Space Flight Center, Greenbelt, Md. 20771, USA
D. S. Caprette, STX, 4400 Forbes Blvd., Lanham, Md., 20706, USA

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

C. Ma, Code 626.9, Goddard Space Flight Center, Greenbelt, Md., 20771, USA
J. W. Ryan, Code 601.9, Goddard Space Flight Center, Greenbelt, Md. 20771, USA
D. S. Caprette, STX, 4400 Forbes Blvd., Lanham, Md., 20706, USA

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

J.A. Steppe, S.H. Oliveau, O.J. Sovers - Jet Propulsion Laboratory,
California Institute of Technology Pasadena, California 91109, USA

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

W.E. Carter and D.S. Robertson, National Geodetic Survey, N/CG114, Charting and Geodetic Services, NOAA Rockville, Maryland 20852, USA

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

Luo Shifang, Zhou Ruexian
Shanghai Observatory, Academia Sinica - Shanghai, P.R. China

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

T.M. Eubanks, M.S. Carter, F.J. Josties, D.N. Matsakis, and D. D. McCarthy
U.S. Naval Observatory, Washington, D.C., 20392-5100
J. Russell, Naval Research Laboratory, Washington, D.C., 20375-5000

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

LUNAR LASER RANGING

EARTH ROTATION (UT0-UTC) FROM LUNAR LASER RANGING

JPL 90 M 01
JPL 90 M 02

X X Newhall, J. G. Williams, and J. O. Dickey - Jet Propulsion Laboratory
California Institute of Technology - Pasadena, California 91109-8099

Lunar Laser Ranging (LLR) data have been acquired and analyzed between August, 1969 and January, 1990. These data are used to estimate station locations, reflector locations, and lunar gravity and orbit parameters. Beginning in 1970, data acquisition was sufficiently dense to permit determinations of Earth rotation UT0. Values of UT0-UTC through 1988 have been submitted previously; 66 such values were derived from data acquired in 1989.

The full range data set comprises 6600 normal points taken from five sites: the McDonald Observatory 2.7-meter telescope; the McDonald Laser Ranging Station (MLRS, situated in separate locations before and after a move in early 1988); the Haleakala Observatory on Maui, Hawaii; and the CERGA system in Grasse, France. These normal points are used to estimate the set of lunar and Earth-related parameters. The post-fit residuals are analyzed by the daily-decomposition method (Dickey *et al.*, 1985) to obtain estimates of UT0-UTC for each station-reflector pair on every day for which sufficient data are available.

Two processes were employed to estimate UT0-UTC, both employing a decomposition of post-fit range residuals. Following the process used in previous years, UT0-UTC and a constant were fit to the range residuals from each station-reflector pair over a pass. That set of values is designated EOP(JPL) 90 M 01. The other method used the fitting of variation of latitude to a pass in lieu of the constant; the set of results is designated EOP(JPL) 90 M 02 and contains values of UT0-UTC, variation of latitude, and the correlations between them. Values derived from both methods have a median uncertainty of 0.13 msec.

The IAU expression has been used for Greenwich mean sidereal time (Aoki *et al.*, 1982).The planetary and lunar ephemeris used in the fit was DE303/LE303; this ephemeris uses the equator and equinox of J2000. It is on the dynamical equinox and has a zero point consistent with that of the FK5 star catalog. The lunar librations were integrated simultaneously with the ephemeris.

Plate motion has been applied to the station coordinates using the AM0-2 model of Minster and Jordan (1978). The base epoch for plate motion is January 1, 1988 (JD 2447161.5).

A correction to the luni-solar precession constant (Lieske *et al.*, 1977 ; Lieske, 1979) has been estimated, giving a correction of -2.5 mas/yr. The correction has been made so as not to cause a rate change in UT (Williams and Melbourne, 1982 ; Zhu and Mueller, 1983).

The IAU nutation (Seidelmann, 1982) has had an annual correction of 1.8 mas (taken from Herring *et al.*, 1986) applied ($\Delta\varepsilon$ = 0.0018" cos l', and sin $\varepsilon\Omega$, $\Delta\psi$ = 0.0018" sin l'). Corrections to the 9-year terms were applied from Kinoshita and Souchay (1990): $\Delta\varepsilon$ =-0..0002" cos 2Ω, and sinε, $\Delta\psi$ =0.00045" sin 2Ω ; corrections to the 18.6 yr nutation coefficients were estimated, yielding

$$\Delta\varepsilon = +3.1\cos\Omega + 1.1\sin\Omega \text{ mas}$$
$$\sin\varepsilon,\ \Delta\psi = -3.5\sin\Omega + 0.8\cos\Omega \text{ mas}$$

The two out-of-phase terms (the second terms on the right side) were constrained to the expected ratio; the constraint of the two in-phase terms also includes a correction for the precession change and the solid-body correction of Kinoshita and Souchay (1990). Subject to the two constraints, the uncertainty in the four nutation coefficients is about 2 mas, and the precession uncertainty is 0.5 mas/yr. Without the two constraints these uncertainties would be larger.

With the production of the 1989 values of UT0-UTC a set of station locations has been established. The IERS designation is SSC(JPL) 90 M 01, and the components are given in the following table:

Cylindrical station coordinates SSC(JPL) 90 M 01

Station	Spin Radius (meters)	East Longitude (arc seconds)	Z-height (meters)
McDonald 2.7 m	5492414.362	921520.8097	3235697.605
MLRS (old site)	5492037.635	921542.8347	3236146.599
MLRS (new site)	5491888.370	921545.2911	3236481.626
Haleakala Tmtr	5971474.381	733478.7369	2242188.500
CERGA	4615328.560	24917.6470	4389354.795
Haleakala Rcvr-Tmtr	-7.446	0.0000	18.151

Cartesian station coordinates (meters)

	X	*Y*	*Z*
McDonald 2.7 m	- 1330781.238	- 5328755.654	3235697.605
MLRS (old site)	- 1330120.982	- 5328532.214	3236146.599
MLRS (new site)	- 1330021.377	- 5328403.232	3236481.626
Haleakala Tmtr	- 5466006.941	- 2404428.082	2242188.500
CERGA	4581692.262	556195.770	4389354.795

The separation between the Haleakala transmitter and receiver conforms to a survey.

The approximate uncertaintities in each of the cylindrical coordinates for all stations are: spin radius, 4 cm; longitude, 1.5 mas (4 cm); and *z*, 10 cm. Each of the three cylindrical coordinates of the five sites has significant correlation with the corresponding coordinate of the remaining four sites ; these correlations are positive, implying that the coordinates shift together in the estimation process.

It should be noted that the McDonald 2.7 m telescope ceased LLR activity in June, 1985.

The above station locations were derived using the formulation of the relativistic solar-system barycentric frame of reference. The transformation to the relativistic geocentric formulation requires the application of a scale factor.

The Jet Propulsion Laboratory provides current values of UT0-UTC on the General Electric Mark 3 system for the benefit of interested users.

ACKNOWLEDGMENTS.

We wish to acknowledge and thank the staffs of CERGA, Haleakala, the University of Texas McDonald Observatory, and the Lunar Laser Ranging associates. Normal points were constructed from individual photon returns by R. Ricklefs, P. Shelus, A. Whipple, and J. Ries at the University of Texas for the MLRS and for Haleakala data. D. O'Gara produced Haleakala normal points independently. C. Veillet provided normal points for the CERGA data. The planetary ephemeris was produced by E. M. Standish. This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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EOP(JPL) 90 M 01 Available from 1970 to 1989

Number of measurements and RMS uncertainty per year
Units : 0.0001s.

YEAR	UT0	
	Nb	Sigma
1970	16	12.83
1971	38	12.04
1972	75	6.67
1973	110	13.65
1974	72	7.51
1975	87	9.54
1976	75	7.40
1977	71	5.73
1978	61	7.28
1979	69	5.57
1980	72	5.24
1981	47	6.30
1982	6	6.23
1983	10	6.50
1984	78	7.77
1985	167	9.80
1986	45	12.57
1987	45	2.30
1988	80	3.11
1989	66	2.85

EOP(JPL) 90 M 02 Available from 1970 to 1989

Number of measurements and RMS uncertainty per year
Units : 0.001" for UT.

YEAR	FI		UTO	
	Nb	Sigma	Nb	Sigma
1970	16	53.56	16	13.48
1971	38	61.54	38	12.72
1972	74	40.38	74	6.82
1973	110	140.17	110	14.45
1974	72	39.32	72	7.94
1975	87	23.84	87	9.32
1976	75	19.94	75	7.54
1977	71	13.88	71	5.87
1978	61	17.06	61	7.58
1979	69	13.75	69	5.65
1980	72	14.69	72	5.31
1981	47	22.40	47	6.93
1982	6	22.59	6	5.36
1983				
1984	42	18.27	42	6.50
1985	164	13.95	164	5.36
1986	45	52.58	45	11.84
1987	45	25.64	45	3.71
1988	80	5.82	80	1.56
1989	66	12.40	66	3.17

DETERMINATION OF UNIVERSAL TIME BY LUNAR LASER RANGING SHA 89 M 01

Jin Wenjing, Xu Huaguan - Shanghai Observatory, China

Universal time has been determined from global data of Lunar Laser Ranging during JD 2446796.5 - JD 2447891.5. The data set McDonald (71111, 71112) Grasse (1910) and Haleakala contains 1317 normal points reflected from four reflectors and were usable for determination of universal time. Due to the need of solving the normal equation the observing interval between first and last normal points should be greater than 0.8 hour and more than two points per day are need. The theoretical distances from station to the retro-reflector on the Moon are calculated using the IERS Standards. The influence of plate motion is not taken into account. The planetary ephemeris DE200/LE200 is used for calculating the positions of the Moon and the Earth. Eckhardt 500 is adopted for calculating the lunar physical libration.

The station coordinates are adopted as follows

Station code	Radius (km)	Longitude (°)	Latitude (°)
71111	6374.568224	255.98412053	30.50843366
71112	6374.609734	255.98480229	30.51170897
1910	6369.277323	6.92156500	43.56245573
56610	6378.550976	203.74409422	20.58040141

The reflector coordinates are adopted from IERS Standards.

The mathematical model is described in reference 2 (Jin *et al.* 1985). UT0 is calculated in one day intervals. The precision of the normal point is taken for the weight of observational equation.

Acknowledgments

The planetary ephemeris DE200/LE200 is supplied by Jet Propulsion Laboratory, California Institute of Technology. The global data of Lunar Laser Ranging are obtained from Dr. Veillet, CERGA.

References

1. D.D. McCarthy et al. 1989 : *IERS Standards (1989)* - IERS Technical Note 3.
2. Jin Wenjing, Wang Qiangguo. 1985 : Determination of ERP with Lunar Laser Ranging and discussion of the influence of the adopted parameters. *Proceedings of the International Conference on Earth rotation and the terrestrial reference frame* , p. 287-295.

EOP(SHA) 89 M 01 Available from 1987 to 1989

Number of measurements and RMS uncertainty per year
Units : 0.0001s for UT.

YEAR	UT0	
	Nb	Sigma
1987	37	2.39
1988	65	1.90
1989	64	3.14

UT0 DETERMINATION FROM LUNAR LASER RANGING OBSERVATIONS FOR 1969 - 1989
UTXMO 90 M 01

A.L. Whipple, J. Gyorgyey Ries, R.L. Ricklefs, P.J. Shelus, J.R. Wiant - McDonald Observatory Department of Astronomy. The University of Texas at Austin - Austin, Texas 78712 (USA)
R. W. King - Department of Earth and Planetary Sciences Massachusetts Institute of Technology Cambridge, MA 02139 (USA)

We have analyzed the total set of lunar laser ranging data available to us to determine UT0-UTC. These data were acquired between September, 1969 and March, 1990. A total of 6726 normal points, from the McDonald Observatory 2.7m telescope (which ceased operation in 1985), the McDonald Laser Ranging Station (saddle site and Mt. Fowlkes site) near Fort Davis, Texas, the Haleakala Observatory on Maui, Hawaii and the CERGA station in Grasse, were used in this solution. The data were edited and reweighted using an automated and objective scheme which identifies suspected outliers and adjusts station assigned weights to yield consistent distributions of the weighted residuals for all stations. There were sufficient data for 764 station/reflector pair estimations of UT0-UTC including 54 UT0 estimates, on 40 nights, in 1989. Our method of analysis was similar to that described by Langley et al. (1981). We first used the MIT Planetary Ephemeris Program (PEP) to estimate corrections to the global parameters. The IERS Standards (1989) were used with corrections made to the mass of the Earth-Moon system, the constant of precession, obliquity of the ecliptic, and the 18.6 year, annual, semi- annual, and fortnightly nutation terms. Adjustments to the MIT ITR-78 solution were made for the Earth-Moon barycenter orbit, lunar orbit, and lunar libration. The node of the Earth-Moon barycenter orbit was fixed to tie the longitude of the celestial frame. The AM0-2 plate motion model was used without adjustment. Our a priori Earth orientation series was the MIT UT1COM42/WOBCOM29 until 2 April 1988 (MJD 47253.0) followed by the University of Texas Center for Space Research (CSR) LGN7692 (adjusted to the MIT series). There is a bias of -0.99 ms in UT1, -0.15 mas in X and -1.00 mas in Y between the MIT and CSR EOP series (in the sense of CSR-MIT). These biases introduce a bias in our LLR UT0 series this year, relative to last year, of 0.96 ms (in the sense of 1989-1988). We estimated a piecewise linear spline for the polar motion components and UT1 to model long period deficiencies in the series. The orientation of the terrestrial frame was tied by fixing the zero point of the a priori EOP adjustments at 11 January 1985 (MJD 46076.0). The station coordinates which resulted from the fit are given in the table below. We also estimated a third degree and order lunar potential, lunar Love number, and lunar dissipation parameter along with the selenocentric retroreflector coordinates. Lastly, we estimated time delay biases, relative to MLRS, for the 2.7m, Maui and CERGA.

SSC(UTXMO) 90 M 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
2S001	FORT DAVIS	40442S002	-1330781.134	-5328755.424	3235697.904	NOAM
2S002	FORT DAVIS	40442S001	-1330120.873	-5328531.978	3236146.949	NOAM
2S003	FORT DAVIS	40442S014	-1330021.347	-5328403.033	3236481.988	NOAM
8S002	MAUI	40445S005	-5466006.724	-2404428.151	2242188.600	PCFC
10S001	GRASSE	10002S002	4581692.247	556195.711	4389355.046	EURA

Following the global solution, we analyzed the post-fit residuals in the usual fashion (e.g., Stolz et al., 1976) to determine nightly corrections to UT0 and variation of latitude. The nightly corrections were then added to the EOP corrections contained in the splines, and the a priori ERP series to obtain the final values of UT0-UTC. A minimum of three normal points for each station/reflector pair and at least a 1.5 hour span of coverage were the criteria we adopted for the nightly UT0 estimations. The root mean square of the final postfit range residuals, for the entire span of data, was 15.2 cm. The rms of the postfit residuals for the 451 normal points obtained by the three active stations during 1989 was 3.0 cm.

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SUMMARY SHEET

1 - Technique: LLR

2 - Analysis Center: UT/McD

3 - Solution identifier: UTXMO 90 M 01

4 - Software used: PEP

5 - Relativity scale: SSB

6 - Permanent tidal correction on station: No

7 - Tectonic plate model: AM0-2

8 - Velocity of light (C) = 299792458

9 - Geogravitational constant (GM) = 3.986004459e14

10 - Reference epoch = 1984.0

11 - Adjusted parameters: lambda, phi, h

12 - Definition of the origin: Geocenter

13 - Definition of the orientation: Fixed to MIT UT1COM42 & WOBCOM29 ERP series at 11 Jan 1985

14 - Constraint for time evolution: Constrained to AM0-2

EOP(UTXMO)90 M 01 Available from 1970 to 1990

Number of measurements and RMS uncertainty per year
Units : 0.0001s.

YEAR	UT0	
	Nb	Sigma
1970	5	6.17
1971	12	5.77
1972	49	5.58
1973	56	5.72
1974	28	4.59
1975	41	5.77
1976	41	5.39
1977	30	4.47
1978	22	4.86
1979	27	4.61
1980	36	4.29
1981	3	4.28
1982	2	4.15
1983	9	4.33
1984	53	6.41
1985	129	5.52
1986	31	4.43
1987	35	11.17
1988	60	3.30
1989	55	9.02
1990	45	2.48

SATELLITE LASER RANGING

EARTH ORIENTATION RESULTS FROM THE CENTER FOR SPACE RESEARCH ANALYSIS CENTER CSR 89 L 02

R. J. Eanes, B. E. Schutz, B. D. Tapley, M. M. Watkins
Center for Space Research, University of Texas at Austin, Austin TX 78712

Earth orientation parameters were derived from the 1989 Lageos quick-look data using the models and terrestrial reference from the previously reported series labelled EOP (CSR) 89 L 02. The results for 1989 are a continuation of the 89 L 02 series with the exception that the relative weights for some of the stations were changed and, overall, the formal uncertainties were scaled downward to better match the internal consistency of the series.

Three day intervals were used for the solutions whenever the quantity and distribution of the data were sufficient. The last two intervals of 1989 had to be combined and used as a 6-day arc. The three day intervals used are centered on dates for which the Modified Julian Date is divisible by 3. In each interval 8 parameters were adjusted, 6 orbital elements of Lageos plus the x and y component of polar motion, using the range residuals from a long arc beginning 15 Nov 1988 and ending 28 Mar 1990. The UT1R estimates are obtained from the Lageos node residuals of this long arc along with the constraint that they follow IRIS VLBI results at periods greater than about 60 days. Hence regardless of the terrestrial system's longitude origin, the origin of the UT1 series is that of IRIS VLBI.

Station positions were held fixed to the SSC (CSR) 89 L 02 values (see IERS Technical Note No 2; p. 54). This station position solution was obtained from all of the Lageos data through February 1989. The Minster-Jordan plate motion model AM1-2 was held fixed in the adjustment. To correct the EOP series to the AM0-2 plate motion model subtract linear terms with slopes of 0.50 and 0.23 milliarcsec/yr from x and y respectively. No correction to UT1 is required.

Table 1 shows the statistics for the 18 stations contributing the most observations to the solutions. The last column shows the standard deviation of the range observations that was used to derive the formal uncertainties a for the EOP values.

Table 1- STATIONS WITH MORE THAN 1000 2-MINUTE NORMAL POINTS IN THE LONG ARC USED FOR THE 1989 REPORT

STATION	#PASSES	#OBS	RMS (cm)	PREC (cm)	SIGMA
7080 MCDON4	403	4697	3.9	1.2	15
7090 YARAG	376	6256	3.6	.6	15
7097 EASTR2	102	1047	6.4	1.3	30
7105 GRF105	204	2767	3.6	.6	15
7109 QUINC2	327	5036	4.2	.5	15
7110 MNPEAK	481	7166	3.9	.7	15
7122 MAZTLN	211	2744	4.5	.6	15
7210 HOLLAS	151	1889	7.6	1.8	15
7288 MOJAV2	94	1427	3.5	.9	30
7810 ZIMMER	284	3820	7.9	3.7	30
7834 WETZEL	152	1702	7.2	2.8	30
7835 GRASSE	844	12827	6.0	1.5	15
7838 SHO	124	1745	7.7	2.8	20
7839 GRAZ	206	2728	5.2	1.1	15
7840 RGO	635	6913	5.8	2.5	15
7843 ORRLLR	299	3141	5.3	1.2	20
7907 ARELAS	245	2957	12.8	9.1	30
7939 MATERA	280	4180	10.9	7.8	30

EOP(CSR) 89 L 02 Available from 1976 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	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1976	16	7.53	16	7.24	16	4.16
1977	24	4.31	24	3.40	24	2.55
1978	18	4.04	18	3.27	18	2.39
1979	38	2.64	38	2.28	38	1.66
1980	61	2.04	61	1.49	61	1.21
1981	62	2.55	62	1.74	62	1.24
1982	60	2.14	60	1.44	60	1.30
1983	81	1.64	81	1.84	81	1.10
1984	122	1.36	122	1.43	122	1.13
1985	121	1.37	121	1.40	121	0.98
1986	122	1.30	122	1.22	122	1.00
1987	122	1.28	122	1.25	122	1.02
1988	122	1.68	122	1.82	122	1.35
1989	120	0.95	120	0.90	120	0.75

EARTH ORIENTATION PARAMETERS AND STATION COORDINATES OF THE SOLUTION DGFII 89 L 03

Christoph Reigber and Wilfried Ellmer

The Solution (DGFII)89L03 is a five-year LAGEOS solution as part of DGFI's reprocessing program of all LAGEOS data since 1980. It is using a carefully rescreened Full-rate ranging data set of 19708 LAGEOS passes in the period 1983 to 1987. A new model MMD2 is used, and a new set of solve-for parameters is chosen including horizontal station motions.

1.) The model

The model underlying the (DGFII)89L03 solution is the DGFI LAGEOS Model MMD2 [Reigber *et al.*, 1989] used for parameter estimation within the DGFI Orbit and Geodetic Parameter Estimation Program (DOGS). The Model MMD2 is described hereafter.

Reference Frame

CIS	: mean equator and equinox of J2000.0
Precession	: IAU 1976 (MERIT standards)
Nutation	: IAU 1980 + Herring 1987 correction
Planetary Ephemerides	: DE200/LE200 ephemerides
Initial Pole Series	: BIH87C02S homog. series (corr. to mean pole)
UT1 Parameter	: BIH87C02S homog. series
Initial Station Coordinates	: DGFI 87L03
Initial Station Velocities	: Zero
Rotation of Coordinate System	: stations 7086, 7090, 7105, 7109, 7110, 7122, 7210, 7810, 7834, 7835, 7838, 7839, 7840, 7907, 7939 [c.f. Bender/Goad, 1979]

Dynamical Model

GM	: 3.98600440 E+14 m**3 s**-2, to be solved for
Semi Major Axis of Earth	: 6378136 m
Eccentricity 1/f	: 298.257810
Rotation of Earth	: 0.7292115 E-4 rad/s
Gravity Model of Earth	: GEM-T1
C(2,1), S(2,1)	: applied, computed with respect to zero mean pole
Gravity Model of Moon	: Ferrari 77 (4*4)
Third Body	: Sun, Moon, Jupiter, Venus, Saturn, Mars, Mercury
Air Drag	: not applied
Albedo	: Heurtel analytical model
Ocean Tides	: GEM-T1 (32 waves)
Solid Earth Tides	: MERIT standards (Wahr model), with permanent tide (H-term) not removed
Relativistic Motion Equation	: harmonic isotropic

Measurement Model

Marini-Murray Refraction Model : MERIT standards
Solid Earth Tides Displacement : MERIT standards (Wahr model)
Ocean Loading Site Displacement: Schwiderski model
Pole Tide : applied
Normal point elimin. criterion : eliminated when 3 or less single shots per normal point

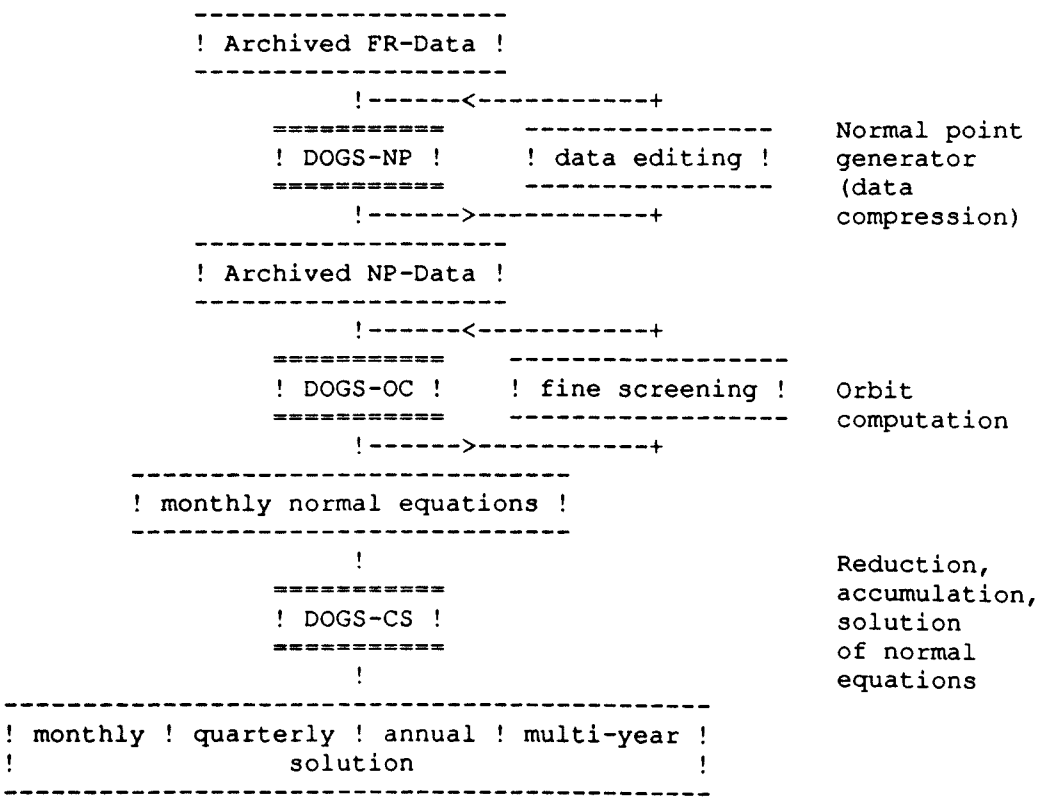
2.) The data

For the solution (DGFII)89L03 two minute normal points were generated using the module DOGS-NP. For the five years period considered here a set of 255596 normal points was generated. It has been created out of a total of 37 million LAGEOS release C full-rate data points gathered from 80 fixed and mobile sites around the world.

3.) The analysis process

The analysis was performed with the DOGS program. DOGS consists of several macro modules, those which were used for the described analysis are: the normal point generator (DOGS-NP) (see above), the orbit computation module (DOGS-OC), and the reduction, accumulation and solution module (DOGS-CS). The processing sequence is shown in table 1.

Table 1. DOGS ANALYSIS SEQUENCE



DOGS-OC is used for orbit computation, fine screening of data, and for the creation of monthly arc normal equations. DOGS-CS is firstly providing the reduced normal equations, secondly accumulating several reduced normal equations including datum contraints and eccentricity conditions, and thirdly solving the combined normal equation system.

4.) The Geodetic Datum

The solution has to be minimum constrained. Since the three translations are fixed by setting the first degree and order terms in the gravity model to zero and the scale by the velocity of light, the three rotations remain to be fixed. This is done by forcing the three rotation angles between the initial and the adjusted coordinates of a selected set of stations to become zero in the average [Bender, Goad, 1979]. In the same way the rotational drift rates around the three coordinate axes are forced to be zero with respect to a given set of horizontal station position drift rates of a geophysical plate motion model, which is in the present case the AM0-2 model [Minster, Jordan, 1978].

5.) Eccentricity conditions

In order to achieve reasonable drift rates on stations successively occupied by different systems some conditions have to be applied. First all station coordinate rates of the same site are set equal. Then eccentricity vectors between two occupations have been applied as observations only where the constraint on the solution remains reasonable small. In contrary, some occupations had to be divided into two occupations without an eccentricity vector, because a discontinuity appeared somewhere in the data.

6.) Solve-for Parameters

The solve-for parameters can be taken from table 2. Some of these parameters have been reduced in the monthly normal equations before combining the equations to a multi-year system in order to reduce the size of the system. The solution has 80 sets of X-, Y-, Z- station coordinate parameters. Only horizontal station velocities were solved for. Some of the station velocity parameters are set to the same value, so there are only 50 independent sets of N-, E- velocity parameters. All 100 velocity parameters are solved for regardless of their significance. Nevertheless, good coordinate results can only be achieved for stations having observed for a longer period of time.

Table 2. SOLVE-FOR PARAMETERS

Gravity Model Parameters	: C(0,0)
Direct Solar Radiation Param.	: CR (per 15 days)
Along Track Acceleration	: CA (per 15 days)
Orbital State Vector	: 6 parameters per monthly arc
Polar Motion	: one x and y parameter per 5 days
dLOD	: one parameter per 5 days
Station Coordinates	: geocentric coordinates X, Y, Z
Velocity of Stations	: North and East

7.) The Results

The description of the terrestrial system implementation is in appendix 1.

Station coordinates are given in appendix 2. Since horizontal station movements are also solved for, a reference epoch for the coordinates is given. The format is following the IERS rules, so column 2 to 10 contains the DOMES numbers, column 10 to 20 the CDP station number and site occupation designator, followed by x, y, z coordinates in m, the MJD of the reference epoch of the coordinates, the time span and the uncertainties of x, y, z in m. Stations with an observation period of two years or less are not included in the list since the velocity parameters are not reliably determined. The only exeption are the 5 Aegean MEDLAS sites having been occupied in 1986 as well as in 1987. All coordinates are referred to the optical axes of the ranging systems.

In appendix 3 the velocity parameters are given as follows: DOMES number, CDP station number, station motion in latitude in m/year, station motion in longitude*cosφ in m/year, uncertainties in latitude and longitude in the same dimensions. The station motions of different occupations of the same site are forced to be the same, so only one line is to be found for each site.

Earth orientation parameters for a five-year interval are given in appendix 4.

References

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Appendix 1:

SUMMARY SHEET FOR THE DESCRIPTION OF THE TERRESTRIAL SYSTEM ATTACHED TO A SET OF STATION COORDINATES

-=-=-=-=-=-

1 - Technique : SLR

2 - Analysis Center : DGFI

3 - Solution identifier : SSC(DGFII)89 L 03

4 - Software used : DOGS

5 - Relativity scale : LE

6 - Permanent tidal correction on station : NO

Date sent:

7 - Tectonic plate model : AM0-2 (only for velocity datum)

8 - Velocity of light (C) = 299792458 m/sec

9 - Geogravitaional constant (GM) = parameter solved for

10 - Reference epoch = depending on the epoch of the initial values,
c.f. column 61 to 67 in the coordinate table

11 - Adjusted Parameters : GM X Y Z $\dot{\lambda}$*COS φ $\dot{\varphi}$ (for five years)
6 Keplerian elements (for each month)
CR CA (for 15 days)
PX PY LODR (for 5 days)

12 - Definition of the origin : C10=C11=S11=0.

13 - Definition of the orientation : Forcing of rotation angles between initial and adjusted coordinates of 15 stations to becomes zero in the average [Bender/Goad, 1979]

14 - Constraint for time evolution : Linear horizontal motion of each site to be solved for. Rotational drift rates around the three coordinate axes are forced to become zero with respect to a given set of AM0-2 horizontal station position drift rates.

Appendix 2: SSC (DGFII) 89 L 03

Domes Number	Network Number	X m	Y m	Z m	Epoch MJD	Data Span Days
X14106S001	1181 3901	3800620.344	882012.335	5028859.124	45704.5	1581.0
X40442S	7086ML2403	-1330121.478	-5328527.799	3236153.892	45704.5	790.5
X40442S	7086ML2404	-1330121.508	-5328527.820	3236153.853	45704.5	1030.5
X50107S	7090ML0501	-2389006.965	5043327.432	-3078534.588	45704.5	1701.0
X50107S	7090ML0506	-2389006.960	5043327.437	-3078534.608	45704.5	120.0
X40451S	7105ML0207	1130719.580	-4831347.372	3994115.452	45704.5	150.0
X40451S	7105ML0702	1130719.585	-4831347.378	3994115.448	45704.5	240.0
X40451S	7105ML0704	1130719.591	-4831347.382	3994115.460	45704.5	730.5
X40451S	7105ML0709	1130719.582	-4831347.400	3994115.442	45704.5	880.5
X40433S	7109ML0802	-2517236.655	-4198552.740	4076576.990	45704.5	1365.8
X40433S	7109ML0805	-2517236.627	-4198552.737	4076576.983	45704.5	455.3
X40497S	7110ML0301	-2386279.768	-4802352.369	3444889.449	45704.5	210.0
X40479S	7110ML0402	-2386279.661	-4802352.138	3444889.246	45704.5	1611.0
X40504S001	7122ML0601	-1660090.508	-5619099.754	2511646.600	45704.5	1826.3
X40445S001	7210 2301	-5466007.334	-2404425.420	2242190.505	45704.5	1826.3
X12612S	7510MT1501	4353446.385	2082673.276	4156503.699	46617.0	90.0
X12612S	7510MT1601	4353446.494	2082673.218	4156503.665	46617.0	90.0
X12615S	7512MT1501	4573401.414	2409328.729	3723878.234	46617.0	60.0
X12615S	7512MT1602	4573401.432	2409328.733	3723878.224	46617.0	60.0
X12602S	7515MT1501	4595217.914	2039441.848	3912626.591	46617.0	30.0
X12602S	7515MT1502	4595217.927	2039441.873	3912626.551	46617.0	90.0
X12613S	7517TL1102	4728697.099	2174379.985	3674571.715	46617.0	30.0
X12613S	7517MT1503	4728696.185	2174379.571	3674569.732	46617.0	60.0
X12613S	7517MT1601	4728696.183	2174379.646	3674569.737	46617.0	90.0
X12616S	7525TL1104	4745951.919	1905712.667	3799168.200	46617.0	90.0
X12616S	7525MT1601	4745951.155	1905712.165	3799166.279	46617.0	60.0
X14001S001	7810 4801	4331282.634	567555.964	4633140.115	45704.5	1305.8
X30101S001	7831 4601	4728284.499	2879672.547	3156890.956	45522.0	1461.0
X14201S001	7834 3001	4075529.046	931787.953	4801617.815	45704.5	1731.0
X10002S001	7835 3101	4581690.850	556165.479	4389359.630	45704.5	1185.8
X21726S001	7838 3601	-3822389.204	3699368.233	3507567.194	45704.5	1701.0
X11001S002	7839 3401	4194425.721	1162700.332	4647245.845	45704.5	1581.0
X13212S001	7840 3501	4033462.793	23669.157	4924305.890	45704.5	1551.0
X42202S001	7907 4001	1942792.500	-5804080.136	-1796910.832	45704.5	1826.3
X12734S001	7939 4101	4641964.199	1393075.683	4133261.301	45704.5	1581.0

Appendix 3: SSV (DGFII) 89 L03

Domes Number	Network Number	$\dot{\varphi}$ m/y	$\dot{\lambda}*\cos\varphi$ m/y	$\sigma_{\dot{\varphi}}$ m	$\sigma_{\dot{\lambda}}$ m
14106S001	1181 3901	.030	.026	.006	.006
40442S	7086	-.002	-.005	.001	.002
50107S	7090	.063	.031	.001	.001
40451S	7105	.006	-.010	.001	.002
40433S	7109	-.014	-.033	.001	.001
40479S	7110	.011	-.041	.001	.001
40504S001	7122ML0601	-.008	-.014	.001	.001
40445S001	7210 2301	.030	-.071	.001	.001
12612S	7510	.026	.003	.010	.010
12615S	7512	-.063	-.096	.021	.022
12602S	7515	-.055	.006	.010	.010
12613S	7517	-.037	-.002	.008	.009
12616S	7525	-.013	-.004	.013	.013
14001S001	7810 4801	.012	.027	.004	.005
30101S001	7831 4601	.103	.703	.012	.008
14201S001	7834	.013	.013	.001	.002
10002S001	7835 3101	.003	.015	.002	.002
21726S001	7838	-.009	-.008	.002	.002
11001S002	7839 3401	.015	.019	.001	.001
13212S001	7840 3501	.020	.018	.001	.001
42202S001	7907 4001	.011	.010	.001	.001
12734S001	7939	.019	.014	.001	.001

EOP(DGFII)89 L 03 Available from 1983 to 1987

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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1983	73	0.80	73	0.59	73	0.011
1984	73	0.33	73	0.29	73	0.007
1985	73	0.36	73	0.27	73	0.005
1986	73	0.31	73	0.27	73	0.006
1987	73	0.29	73	0.26	73	0.006

EARTH ROTATION AND STATION COORDINATES COMPUTED FROM 4 YEARS OF LAGEOS OBSERVATIONS.

DUT 90 L 01

R. Noomen, B.A.C. Ambrosius, K.F. Wakker.
Delft University of Technology Faculty of Aerospace Engineering

A continuous series of 5-day solutions for polar motion and the A1-UT1 time difference has been computed from global laser ranging observations on the geodetic satellite LAGEOS. The time span covers a period of 4 years: 1986 through 1989. The analysis was based on full-rate data for 1986, 1987 and 1988, whereas the results for 1989 were derived from quick-look observations, i.e. sampled full-rate data.

In the analyses the observations were processed in batches of multiple contiguous 1-week data arcs, in which the orbit parameters and the earth rotation parameters are estimated simultaneously. This approach was used since the analyses were also aimed at the determination of crustal deformations, showing up in successive solutions for the positions of laser stations. Therefore, all station coordinates were adjusted simultaneously with the other parameters. The individual solutions cover data periods ranging from 8 to 19 weeks. This resulted in a total of 17 different global station coordinates solutions, together with solutions for polar motion and the A1-UT1 time difference.

The reference frame was defined with the following constraints. The longitude of Greenbelt (station id. 7105) was kept fixed at the value according to the University of Texas UT/CSR 84.02 coordinates solution. During the time-span covered by each individual solution, the stations were supposed to exhibit no motion. In addition, the average shift of the polar motion and A1-UT1 time difference with respect to the *a priori* value was defined to be zero, for each of the 17 parameter solutions. The a priori values for the earth rotation parameters were taken from the monthly IERS Bulletin B.

A summary of the computation model that was used is given in Table 1. Main elements are the NASA/GSFC GEM-T1 gravity field, the Wahr harmonic expansion model for the solid earth tides and a subset of the NASA/GSFC GEM-T1 solution for ocean tides. Here, only the constituents that are also included in the Schwiderski model were used. Table 2 provides information on the individual laser stations. The table includes the station coordinates at the reference epoch (January 1, 1986), the corresponding standard deviations, the apparent yearly motion of these stations and the corresponding standard deviations.

Both station coordinates and yearly motions were derived from a weighted least squares fit through the successive multi-week parameter solutions. The values are in m (coordinates) and in m/yr (motions). The coordinates refer to the monuments. The solution presented here may be designated as the SSC(DUT) 90 L 01 global coordinates solution. Table 3, finally, gives the raw, unsmoothed solutions for polar motion and UT1-UTC. The solution is designated EOP(DUT) 90 L 01.

Table 1- Models and constants

Dynamic model:	
Gravity field	NASA/GSFC GEM-T1 model, truncated at 20 x 20
GM	398600.4359 km3/s2
c	299792.458 km/s
ae	6378.1370 km
1/f	298.257
Solar and lunar attraction	JPL DE-118 ephemeris
Solid earth tides	Wahr model
Ocean tides	NASA/GSFC GEM-T1 model (constituents of 55 elements also in Schwiderski model only)
Solar radiation	CR adjusted occultation by earth and moon umbra and penumbra
Along-track acceleration	AT adjusted
Reference frame:	
Station coordinates	adjusted, except for longitude of Greenbelt (7105)
Earth rotation	adjusted, a priori values from IERS Bulletin B
CIS	mean equator and equinox of J1950.0
Precession	J1950 precession (JPL DE-118 ephemeris)
Nutation	Wahr series
Measurement model:	
Observations	DGFI normal points (1986, 1987) Bendix normal points (1988) Quick-look data (1989)
Tropospheric refraction	Marini-Murray model
Tidal uplift	$h_2 = 0.6090$, $l_2 = 0.0852$

Table 2: Global coordinates solution. SSC(DUT) 90 L 01

Network Number	X m	Y m	Z m	
7080	-1330021.0181	-5328401.7930	3236480.8898	
	0.0178	0.0331	0.0506	<= SX,SY,SZ (m)
	-0.0035	-0.0034	-0.0442	<= Vx,Vy,Vz (m/y)
	0.0157	0.0167	0.0202	<= SVx,SVy,SVz (m/y)
7086	-1330125.3085	-5328526.5952	3236150.1878	
	0.0076	0.0140	0.0212	
	-0.0298	-0.0128	-0.0058	
	0.0159	0.0173	0.0214	
7090	-2389006.3242	5043329.2404	-3078525.4802	
	0.0068	0.0107	0.0181	
	-0.0506	0.0219	0.0505	
	0.0217	0.0196	0.0232	
7097	-1884984.6434	-5357607.9583	-2892853.4118	
	0.0641	0.0313	0.0517	
	0.0552	-0.0447	-0.0075	
	0.0271	0.0214	0.0245	
7105	1130719.7554	-4831350.5644	3994106.3506	
	0.0161	0.0130	0.0160	
	-0.0204	0.0045	0.0008	
	0.0151	0.0134	0.0157	
7109	-2517234.7164	-4198556.1881	4076569.5619	
	0.0057	0.0154	0.0155	
	-0.0135	0.0140	0.0065	
	0.0149	0.0160	0.0160	
7110	-2386277.9083	-4802354.3574	3444881.2844	
	0.0053	0.0132	0.0165	
	-0.0326	0.0425	0.0243	
	0.0152	0.0155	0.016450	
7122	-1660089.3318	-5619100.3457	2511637.7643	
	0.0083	0.0098	0.0182	
	-0.0214	-0.0030	0.0033	
	0.0157	0.0151	0.0173	
7210	-5466006.4270	-2404427.9479	2242187.3127	
	0.0037	0.0179	0.0202	
	-0.0292	0.0584	0.0344	
	0.0163	0.0184	0.0200	
7510	4353444.9877	2082666.1575	4156506.5308	
	0.0322	0.0272	0.0273	
	-0.0173	0.0119	-0.0161	
	0.0148	0.0137	0.0139	
7512	4573400.1044	2409322.0800	3723881.6348	
	0.0384	0.0325	0.0360	
	0.0024	0.0106	-0.0194	
	0.0172	0.0156	0.0167	
7515	4595216.4742	2039435.1927	3912629.4093	
	0.0294	0.0259	0.0271	
	0.0114	0.0067	-0.0343	
	0.0158	0.0149	0.0153	
7517	4728694.7143	2174373.2173	3674572.8551	
	0.0297	0.0264	0.0291	
	0.0058	0.0170	-0.0234	
	0.0161	0.0152	0.0161	

Table 2 (cont.) : Global coordinates solution. SSC(DUT) 90 L 01

Network Number	X m	Y m	Z m	
7520	4596042.6457	1733476.6630	4055720.7169	
	0.0382	0.0347	0.0351	<= SX, SY, SZ (m)
	0.0129	-0.0171	-0.0086	<= Vx,Vy,Vz (m/y)
	0.0165	0.0157	0.0159	<= SVx,SVy,SVz (m/y)
7525	4745949.5472	1905705.8393	3799168.9351	
	0.0375	0.0347	0.0370	
	0.0294	-0.0158	-0.0226	
	0.0168	0.0162	0.0168	
7530	4443966.0578	3121945.0110	3334693.4016	
	0.0286	0.0240	0.0272	
	0.0222	0.0197	0.0469	
	0.0170	0.0173	0.0169	
7544	5072832.0075	1130886.0650	3684836.7932	
	0.0499	0.0554	0.0579	
	0.0036	0.0214	0.0097	
	0.0197	0.0214	0.0222	
7545	4893398.0739	772673.1807	4004140.8118	
	0.0559	0.0684	0.0614	
	0.0128	0.0156	-0.0055	
	0.0196	0.0256	0.0213	
7550	4336738.6126	1071271.3408	4537910.8953	
	0.0383	0.0368	0.0324	
	-0.0060	0.0190	0.0051	
	0.0164	0.0162	0.0151	
7575	3848636.1222	3251760.8491	3898909.0723	
	0.0609	0.0442	0.0491	
	-0.0249	-0.0222	0.0076	
	0.0219	0.0176	0.0191	
7580	4247620.6307	2778638.9299	3851607.3880	
	0.0568	0.0449	0.0490	
	-0.0325	-0.0355	-0.0235	
	0.0208	0.0178	0.0189	
7585	4029730.8262	2802093.2992	4062067.8480	
	0.0562	0.0451	0.0449	
	-0.0218	-0.0537	0.0008	
	0.0214	0.0182	0.0184	
7587	4117362.0770	2517076.7411	4157678.9144	
	0.0547	0.0437	0.0439	
	0.0066	-0.0168	-0.0171	
	0.0209	0.0180	0.0181	
7810	4331283.6367	567549.4329	4633139.7548	
	0.0212	0.0219	0.0183	
	0.0034	0.0141	0.0029	
	0.0125	0.0126	0.0121	
7834	4075530.0977	931781.1451	4801618.0459	
	0.0194	0.0184	0.0150	
	-0.0031	0.0146	-0.0032	
	0.0123	0.0121	0.0115	
7835	4581691.8475	556159.2622	4389359.2058	
	0.0226	0.0239	0.0219	
	-0.0195	0.0063	-0.0044	
	0.0126	0.0129	0.0128	

Table 2 (cont.) : Global coordinates solution. SSC(DUT) 90 L 01

Network Number	X m	Y m	Z m	
7838	-3822387.0181	3699362.2859	3507571.8725	
	0.0214	0.0168	0.0182	<= SX, SY, SZ (m)
	0.0251	0.0138	-0.0045	<= Vx,Vy,Vz (m/y)
	0.0168	0.0168	0.0213	<= SVx,SVy,SVz (m/y)
7839	4194426.7528	1162693.7539	4647246.3834	
	0.0190	0.0175	0.0152	
	-0.0036	0.0108	-0.0043	
	0.0123	0.0120	0.0116	
7840	4033463.8519	23662.2252	4924304.9122	
	0.0161	0.0169	0.0134	
	-0.0041	0.0079	-0.0159	
	0.0118	0.0119	0.0114	
7843	-4446476.4741	2678126.9517	-3696251.6975	
	0.0122	0.0259	0.0297	
	-0.0785	0.0606	0.0336	
	0.0223	0.0214	0.0241	
7907	1942791.8895	-5804077.6880	-1796919.3938	
	0.0212	0.0093	0.0198	
	-0.0079	0.0179	0.0071	
	0.0187	0.0180	0.0198	
7939	4641965.1080	1393069.7857	4133262.0646	
	0.0170	0.0162	0.0160	
	0.0056	0.0125	0.0064	
	0.0122	0.0122	0.0123	

EOP(DUT) 90 L 01 Available from 1986 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	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1986	72	1.80	72	1.80	72	13.56
1987	72	0.82	72	0.82	72	6.14
1988	73	1.14	73	1.15	73	1.62
1989	73	1.10	73	1.10	73	1.46

EARTH ROTATION PARAMETERS AND STATION COORDINATES FOR 1988 AND 1989
LAGEOS DATA GAOUA 90 L 01

V.K.TARADY, K.Kh.NURUTDINOV, V.N.SALYAMOV, M.L.TSESIS

Computer program: Kiev - Geodynamics - 3.

The force and measurement models were those of the IERS Standards with following exceptions:

- cylindrical model for the Earth shadow;
- occultation by the Moon;
- reflectance coefficient CR= 1.14 and the empirical along-track acceleration coefficient CT =-3.4 were taken fixed.

Adjusted parameters:

cartesian coordinates X,Y,Z of 41 stations, 6 orbital elements, 2 pole coordinates and excess of length of day.

Data:

106119 normal points for LAGEOS obtained by 41 stations at interval January 1988 - August 1989.

Data processing:

At the first stage station coordinates and arc- dependent LAGEOS orbital elements (5-day arcs) were solved for parameters from the normal equation system for time interval. A priori values of the Earth rotation parameters (ERP) from IERS Bulletin B and fixed longitude of Grasse station (7835) were used. At the second stage the ERP and the LAGEOS orbital elements were determined on the basis of the 5-day arcs.

Mean value of post-fit orbital residuals is 0.069 m.

The positions of station are for the reference points of the laser ranging system and include the permanent tidal deformation. Reference epoch is MJD 47161.

The ERP and station positions are presented in EOP(GAOUA) 90 L 01
and SSC(GAOUA) 90 L 01.

1 - Technique : SLR
2 - Analysis Center : GAOUA
3 - Solution identifier : SSC(GAOUA) 90 L 01
4 - Software used : KIEV-GEODYNAMICS - 3
5 - Relativity scale : LE
6 - Permanent tidal correction on station : NO
7 - Tectonic plate model : AM0-2
8 - Velocity of light (C) = 299 792 458
9 - Geogravitational constant (GM) = 3.9860 0440*10**14
10 - Reference epoch = MJD 47161
11 - Adjusted parameters : X,Y,Z
12 - Definition of the origin : C10=0, C11=0, S11=0
13 - Definition of the orientation : ERP values from IERS Bulletin B
14 - Constraint for time evolution : fixed plate motion model

EOP(GAOUA)90 L 01 Available from 1988 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1988	73	0.21	73	0.22	73	0.011
1989	49	0.29	49	0.26	49	0.014

Domes Number	Network Number	X m	Y m	Z m	Mean MJD	Data Span Days	SX m	SY m	SZ m
X14106S001	1181S001	3800621.293	882005.259	5028859.348	47484.5	559.2	0.009	0.008	0.007
X12302S002	1884S001	3183895.941	1421496.505	5322802.929	47499.1	433.1	0.013	0.011	0.008
X	1893S001	3785945.015	2550780.471	4439461.153	47599.9	131.5	0.032	0.030	0.017
X40701S001	1953S001	1474548.313	-5811242.494	2168944.869	47486.3	471.6	0.011	0.008	0.011
X40436S	7035S001	-2428827.534	-4799756.260	3417268.415	47404.6	38.9	0.011	0.011	0.009
X40442S	7080S001	-1330021.305	-5328403.346	3236481.663	47459.3	565.4	0.004	0.003	0.005
X40442S	7086S001	-1330120.847	-5328532.251	3236146.666	47176.9	24.6	0.016	0.011	0.012
X50107S	7090S001	2389007.729	5043331.802	-3078526.845	47470.4	598.8	0.004	0.004	0.005
X40440S	7091S001	1492454.403	-4457280.159	4296819.348	47425.5	44.8	0.013	0.012	0.009
X41703S	7097S001	-1884984.878	-5357609.359	-2892854.029	47405.5	449.3	0.009	0.009	0.009
X40451S	7105S001	1130720.336	-4831352.952	3994108.400	47457.7	572.0	0.005	0.004	0.005
X40433S	7109S001	-2517235.889	-4198558.264	4076571.584	47456.5	598.2	0.004	0.003	0.005
X40497S	7110S001	-2386279.115	-4802356.760	3444883.073	47447.6	601.3	0.004	0.003	0.005
X40496S	7112S001	-1240678.817	-4720466.058	4094479.357	47414.5	49.5	0.009	0.007	0.008
X40504S	7122S001	-1660090.080	-5619103.084	2511639.024	47373.0	601.0	0.006	0.005	0.007
X92202S	7123S001	-5345868.028	-2958248.067	-1824624.657	47424.7	428.8	0.011	0.013	0.013
X40445S	7210S001	-5466006.942	-2404428.055	2242188.456	47333.1	348.6	0.004	0.005	0.007
X40405S	7288S001	-2356494.958	-4646609.537	3668428.108	47382.5	409.8	0.009	0.007	0.008
X40499S	7295S001	961319.628	-5674093.225	2740487.675	47308.3	104.9	0.014	0.009	0.012
X12613S	7517S001	4728697.975	2174374.777	3674573.436	47662.5	26.0	0.015	0.015	0.013
X12614S	7520S001	4596045.191	1733477.771	4055719.465	47728.1	34.0	0.012	0.016	0.012
X12706S	7544S001	5072834.885	1130886.605	3684835.303	47614.9	3.0	0.433	0.378	0.142
X12725S	7545S001	4893400.872	772673.714	4004139.671	47211.1	68.3	0.011	0.016	0.011
X12711S	7546S001	4461402.494	919567.274	4449509.454	47306.7	33.0	0.027	0.045	0.026
X20802S	7585S001	4029732.981	2802094.683	4062066.726	47764.8	11.6	0.016	0.016	0.013
X20804S	7587S001	4117365.093	2517078.513	4157679.881	47760.1	12.3	0.020	0.024	0.021
X14001S001	7810S001	4331283.614	567549.539	4633139.776	47495.3	538.7	0.004	0.005	0.005
X	7811S001	3738333.063	1148245.884	5021815.563	47480.6	394.9	0.013	0.014	0.012
X30101S001	7831S001	4728283.566	2879670.367	3156894.132	47723.8	75.9	0.013	0.023	0.020

SSC(GAOUA) 90 L 01

Domes Number	Network Number	X m	Y m	Z m	Mean MJD	Data Span Days	SX m	SY m	SZ m
X14201S002	7834S001	4075530.080	931781.263	4801618.061	47492.0	572.0	0.007	0.008	0.006
X10002S001	7835S001	4581691.836	556159.355	4389359.328	47445.8	513.2	0.003	0.001	0.001
X21605S001	7837S001	-2831087.691	4676203.437	3275172.937	47438.1	194.1	0.025	0.020	0.018
X21726S001	7838S001	-3822388.232	3699363.438	3507573.058	47403.1	558.1	0.006	0.007	0.007
X11001S002	7839S001	4194426.710	1162693.852	4647246.397	47469.1	562.0	0.005	0.005	0.005
X13212S001	7840S001	4033463.779	23662.311	4924304.848	47478.5	606.9	0.003	0.004	0.005
X40439S	7853S001	-2410422.387	-4477802.745	3838688.934	47459.9	30.1	0.009	0.008	0.008
X40505S	7882S001	-1997241.337	-5528044.705	2468356.197	47321.5	44.0	0.011	0.009	0.011
X	7883	-2406127.820	-4898370.330	3290337.946	47697.1	91.0	0.025	0.018	0.019
X42202S001	7907S001	1942791.936	-5804077.453	-1796919.297	47449.3	565.0	0.005	0.004	0.006
X12734S001	7939S001	4641965.038	1393069.876	4133262.074	47425.7	563.1	0.004	0.004	0.005
X13504S	8833S001	3899238.099	396769.180	5015054.992	47394.6	99.8	0.011	0.014	0.010

Notes

We have no data on the DOMES site number of the stations 1893,7811,7883
and DOMES point number of stations 1893,7035,7080,7086,7090,7091,7097,7105,
7109,7110,7112,7122,7123,7210,7288,7295,7517,7520,7544,7545,7546,7585,7587,
7811,7853,7882,7883,8833.

THE 20-MONTH EARTH ORIENTATION PARAMETERS SERIES FROM LAGEOS LASER RANGING

LPAC 90 L 01

O.A. Abrikosov - Politecnical Institute, Lvov, USSR
S.K.Tatevian, D.V.Chapurin - Astronomical Council, USSR Academy of Sciences, Moscow, USSR

The solution LPAC 90 L 01 was made at the Astronomical Council (Moscow) with the use of the GEORAN-2 system of programs /1, 2/. The Lageos Laser Ranging normal point data generated at the CSR of the University of Texas at Austin were used to form this solution. There were 92 000 of normal points from January, 1988 through August, 1989.

The GEORAN-2 program consists of two main modules. The first one is for orbit computation, fine screening of data and accumulation of observation equations. The second one is the solution module. The sequence of processing is shown below (Fig. 1). A combination of normal equations can be made in "short" or "long" arcs depending on the solve-for parameters. The 5-day arc normal equations were used for estimation of EOPs. The coefficients of solar radiation reflection and along track acceleration C_R, C_T have been estimated in each of 15 and 30-day arcs. Station coordinates have been determined in the whole (20 months) arc.

The force model and constants used in the solution were taken according to the IERS Standards (1989).

Dynamical Model

- IERS constants
- Gravity Model - GEM T1 (20 x 20) with C (2,1) ans S (2,1) of IERS Standards.
- Third Body - Moon (central point mass), Sun, Jupiter, Venus, Saturn, Mars.
- Air Drag - not applied.
- Ocean Tides - Schwiderski Model, 11 Tidal waves.
- Solid Earth Tides - Wahr model.
- Relativistic correction to equations of motion.
- Solar Radiation (direct) with conical model of shadow /3/.

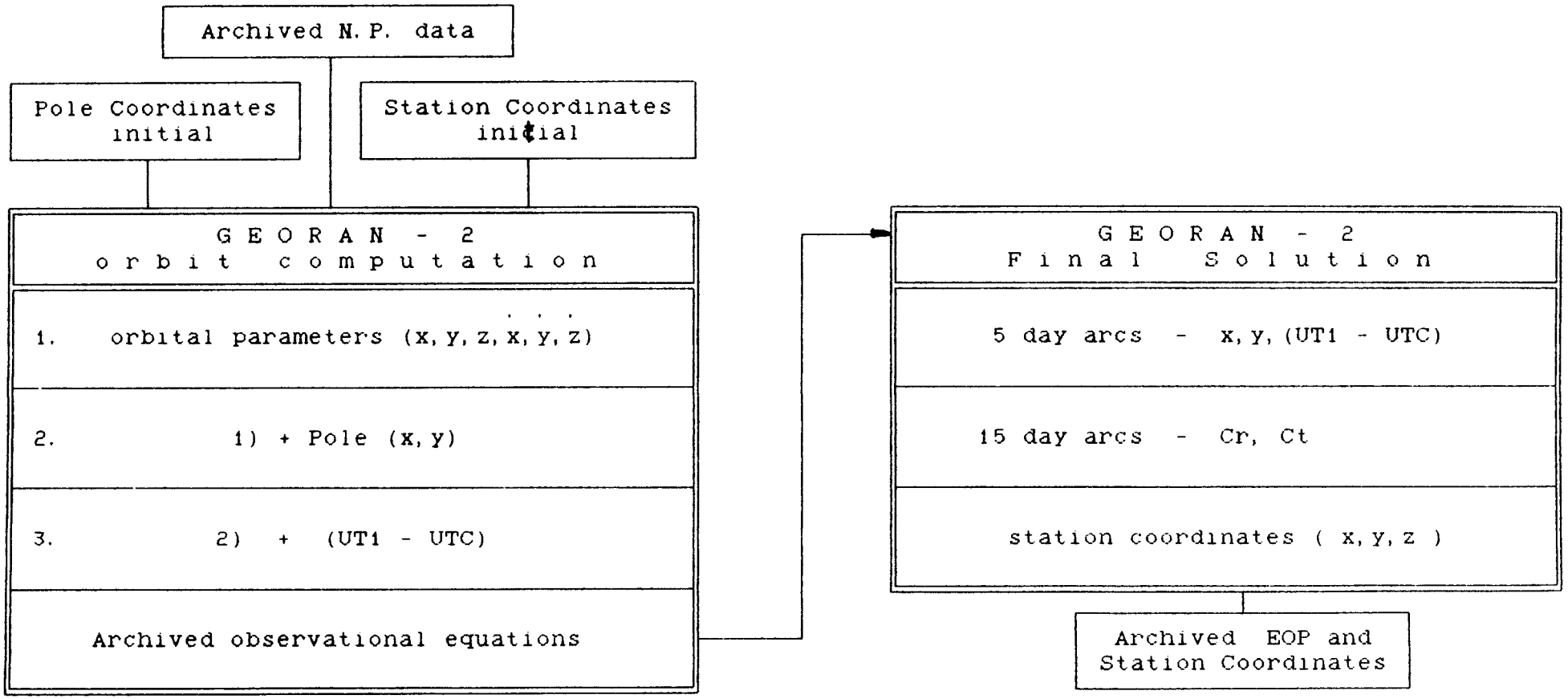
Archived N. P. data
Pole Coordinates initial
Station Coordinates initial
G E O R A N - 2
o r b i t c o m p u t a t i o n
1. orbital parameters (x, y, z, x, y, z)
2. 1) + Pole (x, y)
3. 2) + (UT1 - UTC)
Archived observational equations
G E O R A N - 2
F i n a l S o l u t i o n
5 day arcs - x, y, (UT1 - UTC)
15 day arcs - Cr, Ct
station coordinates (x, y, z)
Archived EOP and Station Coordinates

FIG. 1

Measurement Model

- Refraction - Marini-Murray Model.
- Relativistic propagation correction
- Normal points of CSR, Texas University.
- Solid Earth Tides and ocean loading site displacements.
- Pole tide.

Reference Frames

- CIS - mean equator and equinox of J 2000.0.

- Precession (IAU, 1976), Nutation (IAU, 1980). Trigonometrical series are transformed in Chebyshev polynomial series /4/.

- Planetary Ephemerides DE 200/LE2000, modified by compressing over 4-day intervals.
- Initial Pole Series - Bulletin B of IERS.

- Initial Station Coordinates - SSC (ZIPE) 89 L 01 + SSC (CSR) 89 L 02.

- The positions have an epoch of MJD=45700 and move according to the AM0-2 plate tectonic model.

- Fixed stations : 7105 (φ, λ), 7210 (φ).

EOP(LPAC) 90 L 01 Available from 1988 to 1989

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

Year	X		Y		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1988	71	0.18	71	0.20	71	0.18
1989	46	0.27	46	0.25	46	0.24

References

1. Marchenko, A.N. *et al.* 1988: Proceedings of the 2nd Orlov's Conference on the investigation of the Earth by means of Geophysics, Geodesy and Astronomy (in press).

2. Abrikosov, O.A. 1986: Cinematics and Physics of Celestial Bodies, Vol. 2, No 2, Kiev.

3. Abrikosov, O.A. 1989: Observations of the Artificial Earth's Satellites, No 26, (in Russ.) Cracow.

4. Marchenko, A.N. 1988: Cinematics and Physics of Celestial Bodies, Vol. 4, No 3-4. Kiev.

SSC(LPAC) 90 L 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE
1181S001	POTSDAM	14106S001	3800621.521	882005.206	5028859.630	0.005	0.005	0.003	EURA
1893S001	SIMEIS II	12337S006	3785945.379	2550779.969	4439461.343	0.045	0.053	0.027	EURA
1953S001	SANT. DE CUBA	40701S001	1474548.616	-5811242.586	2168945.179	0.012	0.009	0.008	NOAM
7080S001	FORT DAVIS	40442S014	-1330021.454	-5328403.303	3236481.719	0.002	0.002	0.002	NOAM
7086S004	FORT DAVIS	40442S016	-1330120.977	-5328532.255	3236146.680	0.008	0.012	0.008	NOAM
7090S002	YARRAGADEE	50107S004	-2389007.494	5043331.774	-3078527.130	0.002	0.002	0.002	INDI
7097S001	EASTER ISLAND	41703S004	-1884985.256	-5357609.275	-2892854.032	0.006	0.005	0.005	NAZC
7105S006	WASHINGTON	40451S148	1130720.343	-4831352.919	3994108.475	0.000	0.002	0.001	NOAM
7109S003	QUINCY	40433S014	-2517235.868	-4198558.242	4076571.677	0.002	0.002	0.002	NOAM
7110S003	MONUMENT PEAK	40497S006	-2386279.035	-4802356.880	3444883.105	0.002	0.002	0.002	PCFC
7112S002	PLATTEVILLE	40496S004	-1240678.351	-4720465.756	4094479.429	0.006	0.007	0.004	NOAM
7122S001	MAZATLAN	40504S001	-1660090.144	-5619103.166	2511639.151	0.003	0.003	0.003	NOAM
7210S001	MAUI I	40445S001	-5466006.786	-2404428.292	2242188.340	0.002	0.002	0.001	PCFC
7295S001	RICHMOND	40499S010	961319.304	-5674093.297	2740487.812	0.008	0.005	0.006	NOAM
7810S001	ZIMMERWALD	14001S001	4331283.628	567549.066	4633140.143	0.003	0.003	0.002	EURA
7831S001	HELWAN	30101S001	4728283.751	2879670.576	3156894.396	0.049	0.020	0.038	AFRC
7834S001	WETTZELL	14201S002	4075530.137	931781.192	4801618.143	0.004	0.004	0.003	EURA
7835S001	CERGA GRASSE	10002S001	4581691.827	556159.270	4389359.340	0.001	0.001	0.002	EURA
7837S001	SHANGHAI I	21605S001	-2831087.625	4676203.508	3275172.983	0.010	0.012	0.010	EURA
7838S001	SIMOSATO	21726S001	-3822388.244	3699363.776	3507573.391	0.003	0.004	0.004	EURA
7839S001	LUSTBUEHEL-GRAZ	11001S002	4194426.850	1162693.406	4647246.786	0.003	0.003	0.002	EURA
7840S001	HERSTMONCEUX	13212S001	4033463.860	23662.236	4924304.992	0.002	0.002	0.002	EURA
7882S001	CABO SAN LUCAS	40505S001	-1997243.133	-5528045.481	2468356.466	0.031	0.042	0.023	PCFC
7907S001	AREQUIPA	42202S001	1942791.910	-5804077.606	-1796919.343	0.002	0.002	0.003	SOAM
7939S001	MATERA	12734S001	4641965.176	1393069.825	4133262.215	0.002	0.002	0.002	EURA
8833S001	KOOTWIJK	13504S007	3899237.802	396768.664	5015055.171	0.010	0.006	0.005	EURA

Epoch MJD : 45700.

EARTH ORIENTATION FROM LAGEOS LASER RANGING SHA 90 L 01

Zhu Wenyao, Fong Chugang, Zhang Hua, Teng Zhanming and Zhou Ming
Shanghai Observatory, Academia Sinica - Shanghai, China

To determine a series of the Earth Orientation Parameters EOP(SHA) 90 L 01 and the station coordinates SSC(SHA) 90 L 01 system, the two year SLR data of LAGEOS from Jan. 1988 to Jan. 1990 have been processed with the SHORDE I program system. A "multistage-multiarc" procedure was used to estimate simultaneously satellite states, EOPs and the station coordinates in each of 60 day arcs. The station coordinates, as the global parameters, are adjusted in the whole of the 60 day arcs ; the satellite states, as the first-stage local parameters, are independently adjusted in the different subarc (10 days) ; the EOPs, as the second-stage local parameters, are independently adjusted from one sub-subarcs (5 days) to the next.

Each set of EOP solution includes three Earth Rotation Parameters Xp, Yp, DR as well as the rate of the polar motion Xp, Yp. The ability to detect the rate of polar motion with 5 day arc solution has been investigated and found to be better than 0.7 mas/day. In our solution the overall RMS fit of the laser observations to the orbits in 60-day arcs is generally about 10 cm.

The station coordinates of SSC(SHA) 90 L 01 were constrained to move according to the Minster/Jordan (1978) tectonic motion model AM0-2. The epoch of the derived SSC(SHA) 90 L 01 is MJD 47527.0. The positions of all stations are for the optical axis of the laser ranging system.

The force model and constants used in the solution adhere closely to the IERS Standards. The following is a summary of the kinematic and dynamical models used in our solutions :

Reference frame

- Mean equinox and equator of J 2000.0
- Station coordinates SSC(SHA) 90 L 01
- IAU 1976 precession
- IAU 1980 nutation
- DE200/LE200 planetary ephemerides
- TAI as the coordinate time scale of the earth-centered frame

Force model

- GEM T1 earth gravity field GM = 398600.436 km3/sec2
- Luni-Solar and planetary gravity perturbation
- Wahr solid earth tides
- Schwiderski ocean tides
- Solar radiation pressure (Cr adjusted)
- Drag-like perturbation (Cd adjusted)
- Atmospheric tide
- General relativistic perturbation (earth-centered frame)

Measurement Model

- Marini-Murray refraction model
- Solid earth tides displacement
- Ocean loading site displacement
- Relativistic correction.

EOP(SHA) 90 L 01 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1988	73	0.79	73	0.87	73	0.038
1989	73	0.86	73	0.86	73	0.042
1990	4	0.70	4	0.79	4	0.040

Domes Number	Network Number	X m	Y m	Z m	SX m	SY m	SZ m	Epoch MJD
14106S001	1181S001	3800621.459	882005.092	5028859.473	0.066	0.056	0.034	47527.0
12302S002	1884S001	3183896.075	1421496.336	5322803.453	0.387	0.320	0.243	47527.0
40701S001	1953S001	1474548.138	-5811242.442	2168945.055	0.154	0.132	0.142	47527.0
40436S003	7035S001	-2428827.804	-4799755.994	3417268.574	0.032	0.024	0.028	47527.0
40442S006	7080S001	-1330021.544	-5328403.077	3236481.787	0.021	0.018	0.020	47527.0
40442S001	7086S001	-1330121.226	-5328532.137	3236146.821	0.024	0.021	0.028	47527.0
50107S001	7090S001	-2389007.499	5043331.918	-3078526.885	0.020	0.014	0.018	47527.0
40440S001	7091S001	1492454.186	-4457280.111	4296819.414	0.052	0.034	0.038	47527.0
40451S105	7105S001	1130720.051	-4831352.958	3994108.530	0.018	0.016	0.014	47527.0
40433S002	7109S001	-2517236.130	-4198558.076	4076571.757	0.019	0.016	0.017	47527.0
40497S002	7110S001	-2386279.421	-4802356.512	3444883.310	0.019	0.015	0.017	47527.0
40496S001	7112S001	-1240679.096	-4720465.850	4094479.526	0.023	0.019	0.021	47527.0
40504S001	7122S001	-1660090.454	-5619103.051	2511639.238	0.020	0.015	0.018	47527.0
92202S003	7123S001	-5345868.171	-2958247.730	-1824624.438	0.041	0.036	0.031	47527.0
40445S001	7210S001	-5466007.102	-2404427.654	2242188.674	0.023	0.021	0.024	47527.0
40405S013	7288S001	-2356495.242	-4646609.235	3668428.191	0.036	0.028	0.031	47527.0
40499S002	7295S001	961319.314	-5674093.183	2740487.791	0.039	0.027	0.036	47527.0
12612S001	7510S001	4353447.586	2082667.218	4156505.383	0.031	0.033	0.026	47527.0
12615S001	7512S001	4573402.589	2409323.281	3723880.234	0.042	0.031	0.031	47527.0
12602S002	7515S001	4595219.060	2039436.237	3912628.068	0.038	0.040	0.041	47527.0
12613S001	7517S001	4728698.058	2174374.470	3674573.295	0.027	0.029	0.024	47527.0
12616S001	7525S001	4745953.072	1905707.016	3799169.558	0.030	0.026	0.034	47527.0
12706S001	7544S001	5072834.726	1130886.578	3684835.442	0.024	0.034	0.026	47527.0
12725S002	7545S001	4893400.836	772673.504	4004139.557	0.026	0.036	0.031	47527.0
12711S002	7546S001	4461402.566	919567.244	4449509.356	0.124	0.086	0.110	47527.0
12718S002	7550S001	4336741.476	1071272.005	4537909.934	0.113	0.126	0.093	47527.0
20801S001	7575S001	3848638.377	3251762.297	3898907.822	0.042	0.036	0.028	47527.0
20803S001	7580S001	4247623.699	2778640.423	3851608.058	0.053	0.061	0.043	47527.0
20802S001	7585S001	4029733.158	2802094.459	4062066.758	0.051	0.038	0.036	47527.0
14001S001	7810S001	4331283.767	567549.354	4633139.848	0.023	0.016	0.017	47527.0
30301S001	7831S001	4728283.808	2879670.478	3156894.142	0.243	0.168	0.180	47527.0
14201S002	7834S001	4075530.280	931781.131	4801618.143	0.028	0.031	0.020	47527.0
10002S001	7835S001	4581691.943	556159.159	4389359.249	0.023	0.016	0.018	47527.0
21605S001	7837S001	-2831087.393	4676203.686	3275172.833	0.132	0.104	0.096	47527.0
21726S001	7838S001	-3822388.017	3699363.783	3507573.085	0.020	0.024	0.019	47527.0

SSC(SHA) 90 L 01

Domes Number	Network Number	X m	Y m	Z m	SX m	SY m	SZ m	Epoch MJD
11001S002	7839S001	4194426.907	1162693.723	4647246.432	0.026	0.020	0.023	47527.0
13212S001	7840S001	4033463.980	23662.173	4924304.952	0.024	0.018	0.017	47527.0
50103S008	7843S001	-4446476.684	2678127.259	-3696251.570	0.021	0.024	0.020	47527.0
40439S004	7853S001	-2410422.575	-4477802.436	3838689.092	0.036	0.042	0.034	47527.0
40505S001	7882S001	-1997241.667	-5528044.442	2468356.293	0.043	0.032	0.040	47527.0
42202S001	7907S001	1942791.502	-5804077.899	-1796919.262	0.021	0.015	0.024	47527.0
12734S001	7939S001	4641965.306	1393069.730	4133262.123	0.020	0.023	0.018	47527.0

EARTH ROTATION PARAMETERS AND
STATION COORDINATES
FROM LAGEOS LASER RANGING

ZIPE 90 L 01
ZIPE 90 L 02
ZIPE 90 L 03

H. Montag, G. Gendt, Th. Nischan, H. Pauscher, W. Sommerfeld
Central Institute for Physics of the Earth - Potsdam.

The Set of Station Coordinates (SSC) and three sets of Earth Orientation Parameters (EOP) were determined by the program package POTSDAM-5. They are based on Satellite Laser Ranging (SLR) normal points of the IERS stations for 1988 and partly 1989 (up to May). Generally, all constants and model parameters were taken from the IERS Standards (1989). As exceptions from this IERS publication the following effects were not considered :

- penumbra for the radiations pressure,
- relativistic corrections,
- tidal variations in UT1 caused by zonal tides with periods longer than 35 days and
- variations of station coordinates generated by the pole tide.

The station coordinates SSC(ZIPE) 90 L 01 were referred to the epoch 1988.0 applying the AM0-2 model for the tectonic plate motions. The origin of the reference system was defined by $C_{10} = C_{11} = S_{11} = 0$. The orientation was constrained by fixation of λ,and φ for the station 7210 and of φ for the station 7105. Additionally, no common net rotations were permitted in relation to the reference coordinate set ITRF88. Corrections due to the permanent tidal deformation of the Earth were applied. The standard deviations of the station coordinates are in the order of several millimeters for the third generation laser stations and of about two centimeters for the second generation stations. The accuracy obtained by comparison with other solutions via a seven-parameter Helmert transformation was estimated to be about or better than ± 3 cm.

For the EOP (pole coordinates and length of day-LOD) three sets with different time resolutions were determinated. The 5-days resolution set EOP(ZIPE) 90 L 01 was simultaneously estimated with the station coordinates (for the whole data interval), the 6 orbital elements and an empirical acceleration (both every 5-day interval). The average orbital fit amounts to between ±4 cm and ±5 cm.

The time resolution for the other two sets is higher, namely three days for the set EOP(ZIPE) 90 L 02 and two days for the set EOP(ZIPE) 90 L 03. In the solutions of these two sets the station coordinates were fixed to the values obtained from the processing of the mentioned 5-day values. Further, for the solutions L 02 and L 03 the seven orbit dependent parameters were estimated for 6-days intervals covering the 3- and 2-day intervals, respectively. This way a better stability could be obtained for intervals with a sparse data distribution.

While in the 5-days solutions the LOD values were directly estimated, in the L 02 and L 03 solutions UT1 values were solved for instead of LOD. These UT1 results were converted into LOD. That means that the time scales (col.1) for the ERP(ZIPE) 90 L 02 and L 03 have to be transferred for the LOD values by -1.5d and -1.0d, respectively.

Generally, the SLR data were weighted according to their estimated accuracy. In addition, several non permanent stations were provided with a smaller weight in order to reduce the influence of the change of the station distribution.

In the data processing no post-adjustment smoothing or filtering procedure was applied to the EOP series. The standard deviations of the EOP(ZIPE) 90 L 01 solution are about ±0.1 to ±0.3 mas for the pole coordinates and ±0.001 to ±0.009 ms for LOD ; the y-component of the pole is somewhat more precise than the x-component. The accuracy was estimated to be about ±0.001" (3cm) for the pole and ±0.1ms for LOD. The 3-days solutions L 02 show nearly the same precision as the 5-days solution if there are submitted at least data from 10 stations. For solutions with data from 0 to 9 stations the precision is between ±0.1 and ±0.4 mas and up to 0.4 ms, respectively. There are also several solutions on the basis of data from less than 6 stations. Here the uncertainty can rise several times. Naturally, the number of results being based on data of less than 6 stations is still higher for the EOP(ZIPE) 90 L 03 series with a time resolution of 2 days. These individual results can be at least partly worse depending on the relevance of the stations positions for the single EOP components. Therefore these individual results (7 for the L 02 and 34 for the L 03 series) were omitted. If there are measurements from at least 10 stations the precision for the L 03 series is about ±0.3 mas and ±0.02 ms, respectively. In the case of using data from 6 to 10 stations the precision of the L 03 results can be smaller by a factor up to about 2.

Domes Number	Network Number	X m	Y m	Z m	Mean MJD	Data Span Days	SX m	SY m	SZ m
X14106S001	1181S001	3800621.309	882005.330	5028859.288	47402.5	533.0	0.016	0.025	0.028
X12302S002	1884S001	3183896.121	1421496.717	5322803.158	47388.5	429.0	0.024	0.040	0.050
X	1893S001	3785945.030	2550780.532	4439461.183	47602.5	113.0	0.080	0.103	0.110
X40701S001	1953S001	1474548.281	-5811242.415	2168944.907	47407.5	353.0	0.024	0.035	0.036
X40436M003	7035M001	-2428826.567	-4799754.334	3417266.941	47404.5	39.0	0.003	0.004	0.003
X40442M006	7080M001	-1330020.927	-5328401.905	3236480.728	47439.5	473.0	0.001	0.002	0.001
X40442M001	7086M001	-1330125.280	-5328526.663	3236150.140	47162.5	53.0	0.004	0.006	0.004
X50107M001	7090M001	-2389006.546	5043329.275	-3078525.411	47403.0	534.0	0.001	0.002	0.002
X40440M001	7091M001	1492453.823	-4457278.754	4296815.770	47426.5	45.0	0.003	0.004	0.004
X41703M002	7097M001	-1884984.372	-5357608.172	-2892853.477	47376.5	477.0	0.003	0.004	0.004
X40451M105	7105M001	1130719.816	-4831350.566	3994106.386	47393.0	514.0	0.001	0.002	0.0
X40433M002	7109M001	-2517234.684	-4198556.230	4076569.579	47404.0	536.0	0.001	0.001	0.001
X40497M001	7110M001	-2386277.910	-4802354.362	3444881.316	47404.0	536.0	0.001	0.002	0.001
X40496M001	7112M001	-1240678.110	-4720463.411	4094480.509	47419.0	28.0	0.002	0.004	0.003
X40504M001	7122M001	-1660089.301	-5619100.424	2511637.746	47410.5	521.0	0.001	0.002	0.002
X92202M003	7123M001	-5345866.724	-2958247.476	-1824624.375	47337.5	131.0	0.003	0.005	0.005
X40445M001	7210M001	-5466006.555	-2404427.916	2242187.326	47324.0	372.0	0.001	0.0	0.0
X40405M013	7288M001	-2356494.020	-4646607.695	3668426.533	47429.0	410.0	0.002	0.004	0.004
X40499M002	7295M001	961319.059	-5674090.964	2740489.460	47299.0	86.0	0.003	0.006	0.005
X12613S004	7517S004	4728697.971	2174374.804	3674573.426	47403.5	533.0	0.003	0.006	0.006
X12706S002	7544S002	5072834.694	1130886.811	3684835.392	47614.5	3.0	0.623	1.432	0.962
X12725M002	7545M001	4893398.137	772673.317	4004140.826	47209.0	68.0	0.003	0.006	0.006
X12711M002	7546M001	4461399.727	919566.928	4449510.398	47300.0	30.0	0.006	0.017	0.013
X14001S001	7810S001	4331283.632	567549.568	4633139.803	47450.0	440.0	0.001	0.002	0.003
X	7811S002	3738332.756	1148246.456	5021815.906	47482.5	377.0	0.030	0.051	0.054
X14201S002	7834S001	4075530.080	931781.286	4801618.089	47405.0	536.0	0.001	0.003	0.003
X10002S001	7835S002	4581691.812	556159.389	4389359.270	47405.5	539.0	0.001	0.002	0.003
X21605S001	7837S004	-2831087.800	4676203.455	3275172.900	47389.5	241.0	0.010	0.014	0.014
X21726M001	7838M001	-3822387.085	3699362.277	3507571.862	47385.0	434.0	0.003	0.004	0.004
X11001S002	7839S001	4194426.724	1162693.894	4647246.431	47406.0	536.0	0.001	0.002	0.003
X13212S001	7840S001	4033463.854	23662.343	4924304.926	47405.5	539.0	0.001	0.002	0.002
X	7844S001	-4491072.536	3481527.827	2887391.598	47206.0	28.0	0.011	0.013	0.018
X40439M004	7853M001	-2410421.116	-4477800.438	3838690.233	47462.0	30.0	0.002	0.003	0.003
X40505M001	7882M001	-1997241.739	-5528041.299	2468355.157	47322.0	44.0	0.003	0.004	0.003
X42202S001	7907S001	1942792.047	-5804077.651	-1796919.335	47232.0	188.0	0.002	0.004	0.001
X42202S002	7907S002	1942792.019	-5804077.593	-1796919.349	47499.0	346.0	0.001	0.002	0.002
X12734S001	7939S001	4641965.116	1393069.948	4133262.148	47407.5	535.0	0.001	0.002	0.002
X13504M002	8833M001	3899237.899	396769.183	5015055.059	47412.0	14.0	0.003	0.007	0.008

EOP(ZIPE) 90 L 01 Available from 1987 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	5	0.21	5	0.19	5	0.005
1988	73	0.15	73	0.14	73	0.002
1989	30	0.16	30	0.17	30	0.002

EOP(ZIPE) 90 L 02 Available from 1987 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	7	0.29	7	0.24	7	0.020
1988	118	0.21	118	0.19	118	0.016
1989	49	0.22	49	0.21	49	0.017

EOP(ZIPE) 90 L 03 Available from 1987 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	8	0.32	8	0.30	8	0.025
1988	157	0.23	157	0.22	157	0.017
1989	68	0.26	68	0.28	68	0.023

ATMOSPHERIC ANGULAR MOMENTUM

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS AND RELATED PARAMETERS COMPUTED AT THE U.S. NATIONAL METEOROLOGICAL CENTER

AAM(AER) 87 * 01

Deirdre M. Kann
Climate Analysis Center, National Meteorological Center, Washington, DC 20233
David A. Salstein
Atmospheric and Environmental Research, Inc., 840 Memorial Dr., Cambridge, MA 02139

I. Introduction

As described in the IERS Technical Note 2, twice daily analysis values of effective atmospheric angular momentum (EAAM) functions (Barnes et al., 1983) have been calculated from NMC global analyses throughout 1989. These include variables which relate to Earth rotation and polar motion. Starting 1 October 1989, the operational start date of the SBAAM, a more complete set of analysis and forecast values of EAAM functions and related analysis parameters have been produced.

II. SBAAM Data

Following Sub-Bureau specifications, two files have been produced by NMC beginning 1 October 1989. The first, an analysis file, contains hemispheric values of the EAAM functions χ_1, χ_2, and χ_3, each of which is further partitioned into wind, pressure, and pressure + inverted barometer components. The Sub-Bureau also requested that wind terms be calculated to 100 mb, as well as to the top of the model; however, this is done only for the χ_3 term. As a result of an earlier formulation, all NMC χ_3 values calculated before October 1989 were multiplied by a minus sign. This was stopped on 1 October. This file also contains analyses of zonal mean zonal wind, zonal mean temperatures, mean surface pressure and low order spectral coefficients of surface pressure. With the exception of the surface pressure fields, all analysis parameters and EAAM functions are derived from an initialized global analysis. The complete analysis file is produced twice daily, at 00 and 12 UTC. The second file contains 21 sets of forecast values (00-h to 240-h) of the EAAM functions at 12-hour intervals starting at 00 UTC. These values are globally integrated. A more complete description of both files is found in Table 1. Days with missing values from both files are listed in Table 2.

These data are archived monthly, and are also available from a dial-up service at NMC. The analysis file and forecast file are transferred once daily are maintained on a 10-day rotating file. An additional file is produced for the dial-up service only and contains hemispheric values of the EAAM functions and forecast values of zonal mean zonal winds. Complete information on the NMC files and dial-up system is found in a NMC User's Guide, available from the Sub-Bureau.

III. NMC Global Analysis and Forecast System

The NMC global data assimilation and forecast system is described in detail by Kanamitsu (1989). The global analyses are produced every 6 hours with an intermittent assimilation of data that uses a 6-h forecast as an initial guess. A diabatic nonlinear normal mode initialization procedure is

performed on the analyses and is necessary for dynamic balance. The initialization procedure was changed on 14 December 1989 to a procedure which initializes only the analysis increments. This new procedure reduces the effect of the initialization on the analyses.

The NMC global forecast model has 18 vertical sigma layers and a horizontal resolution of 80 waves with triangular truncation. The EAAM functions are calculated after a vertical interpolation from the sigma coordinates to constant pressure levels (1000 mb to 50 mb) and a grid with horizontal resolution of 2.5 lat/lon. Therefore, wind integrals are calculated to 50 mb. Pressure terms are calculated on the model surface, where the orography is an enhancement of silhouette orography (Mesinger et al., 1988). On 14 December 1989 changes were implemented in the surface physics package which were designed to result in a more realistic cycle and pattern of evaportation. It is felt that this change will result in minor changes in the forecasted surface pressure.

Results of some of the NMC calculations are shown in the 1989 IERS Annual Report.

Table 1. CONTENT OF SBAAM FILES

Variable	Analysis File Specification	Array size
$\chi_2, \chi_2, \chi_2,$	hemispheric values of wind to 100mb, wind to top of model (50mb), pressure, pressure + inverted barometer	(8,3)
zonal mean zonal wind (m/s)	5 degree latitude bands, 12 mandatory pressure levels (1000 - 50mb)	(37,12)
zonal mean temperature (K)	5 degree latitude bands, 12 mandatory pressure levels (1000 - 50 mb)	(37,12)
mean global surface pressure (mb)		(1)
low-order spherical harmonics of surface pressure	4 wave, triangular truncation 20 wave, zonals only with and without inverted barometer	(30) (21) (30) (21)
	Forecast File	
$\chi_2, \chi_2, \chi_2,$	global values of wind to 100 mb, wind to top of model, pressure, pressure + inverted barometer; forecast lead times every 12 hours (00-h to 240-h)	21 arrays of (4,3)

Table 2. DAYS WITH MISSING DATA

	Analysis File (all parameters)	Analysis File (sfc coefficients only)	Forecast File
OCT 89	10/12 UTC 31/12 UTC	1/00 UTC 25/12 UTC - 26/00 UTC 27/12 UTC - 29/00 UTC	1, 2 (after 156-h), 28, and 29
NOV 89	-	-	-
DEC 89	-	-	14 and 21 (after 36-h)

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EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED AT THE EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS

AAM(ECMWF) 87 * 01

Klaus Arpe, European Centre for Medium-Range Weather Forecasts,
Shinfield Park, Reading, UK.

As reported in the IERS Technical Note 2, effective atmospheric angular momentum (EAAM) functions have continued to be calculated at ECMWF throughout 1989. The EAAM functions are calculated for the analyses every 6 hours and for forecasts from 12 UTC each day to 10 days (see Sakellarides, 1989). The inverted barometer terms are not calculated. The data are archived at ECMWF but are not supplied to the Sub-Bureau.

In May of 1989, ECMWF implemented changes in the cumulus convection and radiation schemes of its global model. The effect, if any, of these changes on the EAAM series is not known.

References

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AAM(ECMWF) 87 * 01
available from 1986 to 1989

Year	Number of Measurements
1986	365
1987	365
1988	732
1989	730

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED FROM THE JAPAN METEOROLOGICAL AGENCY DATA AAM(JMA)87*01

I.Naito, Y.Goto and N.Kikuchi, National Astronomical Observatory, Mizusawa, Iwate, 023 JAPAN

The effective atmospheric angular momentum (EAAM) functions proposed by Barnes, Hide, White & Wilson (1983) have been computed from the global analysis data provided by the Japan Meteorological Agency (JMA) since September 28, 1983. In general, the operational numerical weather prediction produces the three data sets called the analysis-phase analysis data, the initialized phase analysis data and the predicted values. The JMA global analysis data are the analysis-phase analysis data. For the use of this file, it should be noticed that the results during 1983/12/1 - 1986/6/30 are once-a-day values computed from daily mean global data of the JMA global analysis data averaged at each grid and each level, otherwise twice-a-day(00 UT and 12 UT) values computed without averaging.

The JMA global analysis data have been made on 1.875-degree (2.5-degree before 1988/3/1) latitude-longitude grid system at sixteen levels (fifteen levels before 1988/3/1) up to ten millibars by the following analysis and forecast models. The analysis model is based on a multi-variate optimum interpolation method in troposhere and on a sinusoidal fitting method in stratosphere, with the initial guess of six hour forecast and the cut-off time of six hours after map time. The forecast model is based on a 1.875-degree (2.5-degree before 1988/3/1) and sixteen-level (twelve-level before 1988/3/1) global spectral model after a non-linear normal mode initialization with physics. The model has a horizontal resolution of triangular truncation at wavenumber 63 (42 before 1988/3/1) and incorpolates full physical processes. The details for the analysis and forecast models after 1988/3/1 can be found in Kitade(1988), and in Kashiwagi (1987) and Kanamitsu, Tada, Kudo, Sato & Isa (1983) for those before 1988/3/1.

For computing the EAAM functions, the sea level pressure, the geopotential height and the wind velocities at each level are used. In addition, mountain heights of the same grid system are used for estimating surface pressures on land and for computing sea lelvel pressures on ocean with the Inverted Barometer (IB) hypothesis. The surface pressures on mountains are computed from the geopotential heights by using a cubic spline interpolation technique with estimating the thickness temperatures by the same techniques. Vertical integrations of the wind terms of the EAAM functions are done from surface pressure on land (or the sea level pressure on ocean) to ten millibars. The integral formula to evaluate the EAAM functions are basically due to the equations (5.1), (5.2) and (5.3) of Barnes *et al* (1983), but the axial component of the EAAM functions is due to the equation (5.3) multiplied by -1 for convenience. No smoothing have been done after evaluation. Details of the evaluation can be found in Naito, Kikuchi and Yokoyama (1987).

ACKNOWLEDGEMENTS

The authors thank the staff of the Numerical Prediction Division, the Japan Meteorological Agency, for supporting this work.

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available from 1983 to 1989

Year	Number of Measurements
1983	150
1984	357
1985	365
1986	549
1987	730
1988	732

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS CALCULATED AT THE U.K. METEOROLOGICAL OFFICE AAM(UKMO) 79 * 01

Throughout 1989, 00-hour and forecast values of effective atmospheric angular momentum (EAAM) functions as described by Barnes et al. (1983) have been calculated twice daily, from 00 and 12 UTC. The functions are archived at 24 hour intervals to 6 days, the limit of the UKMO global model. The matter terms are calculated without applying the inverted barometer correction. The UKMO global model and data assimilation have been described in the IERS Technical Note 2; no siginificant changes were implemented in 1989. Changes are routinely documented in each "Quarterly report on numerical products from Bracknell."

The UKMO forecast file is sent to the Sub-Bureau every three months. Starting in mid-1990, twice daily transmissions of these data will be completed using the GTS data link.

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Quarterly report on numerical products from Bracknell - U.K. Meteorological Office, London.

AAM(UKMO) 79 * 01 Available from 1979 to 1988

Year	Number of meas.	Year	Number of meas.
1979	31	1984	366
1980	366	1985	365
1981	365	1986	365
1982	365	1987	364
1983	365	1988	366

Dépôt légal : 3ème trimestre 1990
Imprimeur : Observatoire de Paris

Pour le Gérant :
Vice-Présidence : Y. Avignon