IERS TECHNICAL NOTE 2

Earth orientation and reference frame determinations, atmospheric excitation functions, up to 1988, (Annex to the IERS Annual Report for 1988)

IERS Analysis Centres for VLBI, LLR, SLR, AAM

June 1989

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

Table of contents

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).

Future issues

IERS Standards.

VERY LONG BASELINE INTERFEROMETRY

EARTH AND SKY ORIENTATION RESULTS FROM THE NASA CRUSTAL DYNAMICS PROJECT

GSFC 89 R 01

C.Ma,Code 621.9. Goddard Space Flight Center, Greenbelt, MD 20771, USA
W.Himwich,Interferometrics. 8150 Leesburg Pike Vienna, VA 22180, USA .
D.Caprette,STX, 4400 Forbes Blvd., Lanham, MD 20706, USA

Mark III VLBI data acquired since 1979 by the NASA Crustal Dynamics Project and the NGS POLARIS/IRIS programs have been analyzed for Earth orientation parameters. The reference frame is defined by the position of the Westford 18-m antenna defined 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 Yoder UT1 tidal model. and the standard J2000.0 precession and IAU 1980 nutation models for the reference date 1986 Nov. 6. Short period tidal terms in UT1 have not been removed from the tabulated values of UT1-UTC. All uncertainties are 1-sigma formal statistical errors from the sequential least-squares estimation described below. It should be noted that the scaling for earth orientation and nutation parameters is by the normalized residual of each session rather than by the reduced chi-square of the whole solution.

The basic models used in calculating the VLBI theoreticals are described in Ma (1978), and the data analysis procedures are described in Ma et al. (1989). The astronomical and geophysical models are contained in the GSFC program CALC 6.0 and are consistent with the MERIT standards with the addition of the pole tide. In the analysis which generated these results, however, adjustments in longitude and obliquity were estimated for each session except the reference day. All stations move with their AM0-2 velocities. It should be noted that Kashima has been placed on the North American plate. The use of constrained troposphere and clock rates and the elimination of delay rate data are major changes from previous submissions. 298 056 Mark III observations from 709 sessions were used to estimate station positions, source positions, Earth orientation parameters, nutation parameters and clock and troposphere behavior from a least-squares solution with 220 global parameters and 112 681 arc, i.e., session-dependent, parameters. A weak input covariance on the Earth orientation parameters (X, Y - 45 mas, UT1 - 3 ms) was used so that all three components could be estimated for each session with a more reliable indication of uncertainty and correlation. This affected only single baselines and nearly degenerate triangles. The overall rms fit of the solution was 44.4 ps; the reduced chi-square of the solution was .83.

The complete Earth orientation time series is designated ERP(GSFC)89 R 01. It should be noted that values from IRIS normally have X-UT correlations of 0.7 and that single baseline correlations approach unity. These correlations should taken into account when applying the parameter uncertainties since the size of the error ellipsoid will otherwise be excessively large. Other results are source positions designated RSC(GSFC)89 R 01 and station coordinates at epoch 1989 Jan 1.5 designated SSC(GSFC)89 R 01.

References

C. Ma, NASA TM-79582, 1978. - C. Ma et al., NASA TM-100723, 1989.

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
401S010	ALGONQUIN	40104S001	918036.559	-4346133.067	4561971.523	.002	.008	.008	NOAM	47527
106S010	CHILBOLTON	13201S002	4008311.818	-100651.763	4943795.111	.008	.003	.010	EURA	47527
501S040	ORRORAL	50103S010	-4460933.584	2682764.872	-3674381.036	.013	.009	.009	INDI	47527
108S050	MADRID	13407S010	4849338.430	-360489.793	4114749.144	.008	.004	.009	EURA	47527
101S010	EFFELSBERG	14209S001	4033949.252	486989.510	4900431.156	.007	.003	.009	EURA	47527
429S010	FAIRBANKS	40408S002	-2281545.417	-1453645.946	5756993.667	.001	.002	.004	NOAM	47527
410S030	GOLDSTONE	40405S014	-2351127.376	-4655477.965	3660957.350	.002	.005	.005	NOAM	47527
451M001	MAUI	40445M002	-5465996.758	-2404409.394	2242228.981	.011	.006	.007	PCFC	47527
301S010	JOHANNESBURG	30302S001	5085444.386	2668262.550	-2768696.710	.018	.011	.009	AFRC	47527
407S010	HAT CREEK	40489S001	-2523968.177	-4123507.256	4147753.039	.002	.003	.004	NOAM	47527
403S010	HAYSTACK	40440S002	1492406.546	-4457267.354	4296882.134	.001	.002	.002	NOAM	47527
406S010	FORT DAVIS	40442S003	-1324209.200	-5332023.986	3232118.806	.001	.002	.003	NOAM	47527
203S010	KASHIMA	21701S001	-3997890.622	3276580.323	3724118.838	.004	.003	.006	EURA	47527
430S010	KAUAI	40424S001	-5543844.286	-2054565.016	2387814.350	.003	.003	.005	PCFC	47527
507S010	KWAJALEIN ATOLL	50505S003	-6143534.801	1363996.357	1034707.994	.009	.004	.007	PCFC	47527
415S010	MARYLAND POINT	40490S001	1106631.114	-4882908.039	3938087.366	.004	.015	.013	NOAM	47527
112S010	BOLOGNE	12711S001	4461371.770	919595.809	4449559.522	.004	.002	.005	EURA	47527
427S010	GOLDSTONE	40405S009	-2356169.223	-4646756.767	3668471.039	.001	.002	.003	NOAM	47527
404S010	GREENBANK	40441S001	882881.694	-4924483.139	3944131.056	.001	.004	.003	NOAM	47527
103S020	ONSALA	10402S002	3370607.799	711916.495	5349831.073	.002	.001	.004	EURA	47527
405S010	OWENS VALLEY	40439S002	-2409598.977	-4478350.421	3838603.635	.001	.003	.004	NOAM	47527
402M001	PENTICTON	40105M001	-2058838.649	-3621287.265	4814421.160	.016	.028	.035	NOAM	47527
432M001	PLATTEVILLE	40496M002	-1240706.377	-4720455.221	4094482.081	.002	.008	.007	NOAM	47527
412S010	RICHMOND	40499S001	961259.809	-5674090.861	2740534.161	.001	.002	.001	NOAM	47527
108S020	MADRID	13407S003	4849247.019	-360279.141	4114884.936	.067	.015	.056	EURA	47527
201S020	SHANGHAI	21605S009	-2831685.068	4675732.889	3275328.323	.006	.006	.008	EURA	47527
201S010	SHANGHAI	21605S008	-2847696.473	4659871.926	3283959.342	.178	.154	.136	EURA	47527
428M001	VANDENBERG AFB	40420M002	-2678093.002	-4525451.661	3597410.623	.002	.003	.004	NOAM	47527
409S010	HAYSTACK	40440S003	1492208.404	-4458131.352	4296015.905	.010	.010	.010	NOAM	47527
115S010	WETTZELL	14201S004	4075541.666	931734.260	4801629.710	.003	.002	.005	EURA	47527
431M001	YELLOWKNIFE	40127M001	-1224122.768	-2689531.508	5633555.733	.006	.012	.026	NOAM	47527

RADIO SOURCE COORDINATES RSC(GSFC) 89 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
0016+731	0	19	45.785849	73	27	30.01586	0.000098	0.00031
0048-097	0	50	41.317350	- 9	29	5.21138	0.000031	0.00031
0106+013	1	8	38.771066	1	35	0.31595	0.000003	0.00015
0212+735	2	17	30.812736	73	49	32.62053	0.000028	0.00012
0224+671	2	28	50.051127	67	21	3.02804	0.000026	0.00018
0229+131	2	31	45.894008	13	22	54.71560	0.000003	0.00014
0234+285	2	37	52.405576	28	48	8.98917	0.000005	0.00013
0235+164	2	38	38.930023	16	36	59.27439	0.000008	0.00035
0300+470	3	3	35.242011	47	16	16.27481	0.000010	0.00013
0316+413	3	19	48.159924	41	30	42.10354	0.000016	0.00022
0355+508	3	59	29.747033	50	57	50.16157	0.000012	0.00014
0420-014	4	23	15.800700	- 1	20	33.06429	0.000003	0.00015
0430+052	4	33	11.095429	5	21	15.62227	0.000030	0.00152
0454-234	4	57	3.179255	-23	24	52.01782	0.000018	0.00026
0528+134	5	30	56.416701	13	31	55.15111	0.000003	0.00014
0552+398	5	55	30.805452	39	48	49.16640	0.000007	0.00013
0727-115	7	30	19.112454	-11	41	12.59729	0.000004	0.00017
0742+103	7	45	33.059505	10	11	12.69477	0.000007	0.00033
0814+425	8	18	15.999553	42	22	45.41744	0.000034	0.00033
0823+033	8	25	50.338302	3	9	24.52496	0.000014	0.00044
0851+202	8	54	48.874880	20	6	30.64391	0.000003	0.00013
0923+392	9	27	3.013838	39	2	20.85495	0.000007	0.00012
0953+254	9	56	49.875351	25	15	16.05211	0.000019	0.00062
1034-293	10	37	16.079679	-29	34	2.80918	0.000018	0.00027
1055+018	10	58	29.605190	1	33	58.82761	0.000004	0.00019
1144+402	11	46	58.297977	39	58	34.30741	0.000008	0.00014
1150+812	11	53	12.499371	80	58	29.15648	0.000172	0.00053
1156+295	11	59	31.833936	29	14	43.82980	0.000007	0.00014
1219+285	12	21	31.690602	28	13	58.50295	0.000020	0.00066
1226+023	12	29	6.699700	2	3	8.60152	1.000000	0.00014
1253-055	12	56	11.166470	- 5	47	21.52199	0.000005	0.00021
1308+326	13	10	28.663945	32	20	43.78523	0.000006	0.00013
1334-127	13	37	39.782708	-12	57	24.69069	0.000007	0.00021
1354+195	13	57	4.436705	19	19	7.37394	0.000007	0.00017
1404+286	14	7	0.394490	28	27	14.69144	0.000004	0.00013
1418+546	14	19	46.597633	54	23	14.78850	0.000020	0.00020
1502+106	15	4	24.979821	10	29	39.20013	0.000004	0.00016
1548+056	15	50	35.269245	5	27	10.44962	0.000003	0.00015
1633+382	16	35	15.493092	38	8	4.50040	0.000007	0.00013
1637+574	16	38	13.456617	57	20	23.97881	0.000014	0.00014

RADIO SOURCE COORDINATES RSC(GSFC) 89 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
1642+690	16	42	7.849054	68	56	39.75568	0.000025	0.00016
1641+399	16	42	58.810100	39	48	36.99367	0.000007	0.00013
1730-130	17	33	2.705720	-13	4	49.54805	0.000005	0.00018
1739+522	17	40	36.978046	52	11	43.40658	0.000017	0.00018
1741-038	17	43	58.856116	- 3	50	4.61666	0.000003	0.00016
1749+701	17	48	32.840820	70	5	50.76700	0.000207	0.00095
1749+096	17	51	32.818601	9	39	0.72791	0.000004	0.00015
1803+784	18	0	45.684719	78	28	4.01707	0.000039	0.00012
1921-293	19	24	51.055874	-29	14	30.12139	0.000008	0.00024
1923+210	19	25	59.605391	21	6	26.15973	0.000030	0.00115
1928+738	19	27	48.495276	73	58	1.56744	0.000143	0.00088
1958-179	20	0	57.090358	-17	48	57.67340	0.000021	0.00027
2037+511	20	38	37.034852	51	19	12.66025	0.000012	0.00013
2113+293	21	15	29.413464	29	33	38.36486	0.000013	0.00035
2121+053	21	23	44.517386	5	35	22.09119	0.000003	0.00014
2128-123	21	31	35.261605	-12	7	4.79779	0.000034	0.00043
2134+004	21	36	38.586302	0	41	54.21177	0.000003	0.00015
2145+067	21	48	5.458665	6	57	38.60194	0.000004	0.00014
2200+420	22	2	43.291374	42	16	39.97729	0.000008	0.00012
2201+315	22	3	14.975854	31	45	38.26812	0.000025	0.00055
2216-038	22	18	52.037725	- 3	35	36.88125	0.000003	0.00016
2234+282	22	36	22.470843	28	28	57.41080	0.000007	0.00013
2251+158	22	53	57.747916	16	8	53.55843	0.000004	0.00013
2345-167	23	48	2.608501	-16	31	12.02329	0.000014	0.00021

EOP(GSFC) 89 R 01 **Available from 1979 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		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1979	2	1.20	2	2.52	2	0.87	2	1.58	2	0.56
1980	20	2.28	20	7.02	20	1.81	20	1.13	20	0.39
1981	32	8.60	32	26.80	32	6.94	32	2.56	32	1.29
1982	55	8.62	55	26.79	55	6.99	55	2.68	55	0.99
1983	66	9.73	66	21.38	66	5.53	66	2.24	66	0.95
1984	92	6.45	92	4.58	92	1.18	92	0.99	92	0.36
1985	94	2.84	94	1.84	94	0.41	94	0.67	94	0.27
1986	107	0.70	107	2.80	107	0.39	107	0.59	107	0.23
1987	127	0.56	127	0.44	127	0.23	127	0.56	127	0.21
1988	113	0.36	113	0.36	113	0.19	113	0.51	113	0.20

EARTH AND SKY ORIENTATION RESULTS FROM THE NASA CRUSTAL DYNAMICS PROJECT WITH SITE VELOCITIES ADJUSTED

GSFC 89 R 02

C.Ma,Code 621.9 Goddard Space Flight Center, Greenbelt, MD 20771, USA
W.Himwich,Interferometrics, 8150 Leesburg Pike, Vienna, VA 22180, USA
D.Caprette,STX. 4400 Forbes Blvd., Lanham MD 20706, USA

Mark III VLBI data acquired since 1979 by the NASA Crustal Dynamics Project and the NGS POLARIS/IRIS programs have been analyzed for Earth orientation parameters. The reference frame is defined by the position of the Westford 18-m antenna defined 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 Yoder UT1 tidal model. 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 changes 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 statistical errors from the sequential least-squares estimation described below. It should be noted that the scaling for earth orientation and nutation parameters is by the normalized residual of each session rather than by the reduced chi-square of the whole solution.

The basic models used in calculating the VLBI theoreticals are described in Ma (1978), and the data analysis procedures are described in Ma et al.(1989). The astronomical and geophysical models are contained in the GSFC program CALC 6.0 and are consistent with the MERIT standards with the addition of the pole tide. In the analysis which generated these results, however, adjustments in longitude and obliquity were estimated for each session except the reference day. The velocities of all stations with sufficient data were adjusted. With the exceptions of HRAS and Kashima, all sites were constrained to move horizontally. Richmond was constrained to move only in the a priori direction of Westford. The adjustment of site velocities, the use of constrained troposphere and clock rates and the elimination of delay rate data are major changes from previous submissions.

298 056 Mark III observations from 709 sessions were used to estimate station positions and velocities, source positions, Earth orientation parameters, nutation parameters and clock and troposphere behavior from a least-squares solution with 313 global parameters and 112 681 arc, i.e., session-dependent, parameters. A weak input covariance on the Earth orientation parameters (X, Y - 45 mas, UT1-3 ms) was used so that all three components could be estimated for each session with a more reliable indication of uncertainty and correlation. This affected only single baselines and nearly degenerate triangles. The overall rms fit of the solution was 44.0 ps; the reduced chi-square of the solution was .82.

The complete Earth orientation time series is designated ERP(GSFC)89 R 02. It should be noted that values from IRIS normally have X-UT correlations of 0.7 and that single baseline correlations approach unity. These correlations should taken into account when applying the parameter uncertainties since the size of the error ellipsoid will otherwise be excessively large. Other results are source positions designated RSC(GSFC)89 R 02 and station coordinates at epochs 1979-89 Jan 1.5 designated SSC(GSFC)89 R 02.

References : C. Ma, NASA TM-79582, 1978. - C.Ma et al., NASA TM-100723, 1989.

IERS(1989) · Technical Note no 2.

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
401S010	ALGONQUIN	40104S001	918036.597	-4346133.082	4561971.520	.012	.013	.012	NOAM	47161
106S010	CHILBOLTON	13201S002	4008311.817	-100651.749	4943795.069	.009	.005	.010	EURA	47161
501S040	ORRORAL	50103S010	-4460933.407	2682764.821	-3674381.122	.015	.011	.011	INDI	47161
108S050	MADRID	13407S010	4849338.432	-360489.807	4114749.115	.009	.004	.010	EURA	47161
101S010	EFFELSBERG	14209S001	4033949.252	486989.513	4900431.089	.017	.032	.016	EURA	47161
429S010	FAIRBANKS	40408S002	-2281545.392	-1453645.941	5756993.678	.002	.002	.004	NOAM	47161
410S030	GOLDSTONE	40405S014	-2351127.365	-4655477.971	3660957.379	.002	.005	.005	NOAM	47161
451M001	MAUI	40445M002	-5465996.730	-2404409.465	2242228.933	.011	.006	.008	PCFC	47161
301S010	JOHANNESBURG	30302S001	5085444.364	2668262.524	-2768696.752	.019	.014	.010	AFRC	47161
407S010	HAT CREEK	40489S001	-2523968.161	-4123507.251	4147753.058	.002	.003	.004	NOAM	47161
403S010	HAYSTACK	40440S002	1492406.565	-4457267.350	4296882.123	.001	.002	.002	NOAM	47161
406S010	FORT DAVIS	40442S003	-1324209.185	-5332023.990	3232118.820	.001	.002	.003	NOAM	47161
203S010	KASHIMA	21701S001	-3997890.568	3276580.329	3724118.825	.005	.003	.007	EURA	47161
430S010	KAUAI	40424S001	-5543844.261	-2054565.083	2387814.301	.003	.003	.006	PCFC	47161
507S010	KWAJALEIN ATOLL	50505S003	-6143534.798	1363996.284	1034707.930	.009	.004	.008	PCFC	47161
415S010	MARYLAND POINT	40490S001	1106631.177	-4882908.039	3938087.353	.061	.062	.072	NOAM	47161
112S010	BOLOGNE	12711S001	4461371.777	919595.797	4449559.495	.004	.003	.006	EURA	47161
427S010	GOLDSTONE	40405S009	-2356169.209	-4646756.766	3668471.061	.001	.002	.003	NOAM	47161
404S010	GREENBANK	40441S001	882881.708	-4924483.144	3944131.061	.001	.004	.003	NOAM	47161
103S020	ONSALA	10402S002	3370607.806	711916.482	5349831.048	.003	.002	.005	EURA	47161
405S010	OWENS VALLEY	40439S002	-2409598.973	-4478350.427	3838603.671	.001	.003	.004	NOAM	47161
402M001	PENTICTON	40105M001	-2058838.660	-3621287.231	4814421.170	.026	.036	.038	NOAM	47161
432M001	PLATTEVILLE	40496M002	-1240706.362	-4720455.220	4094482.092	.002	.008	.007	NOAM	47161
412S010	RICHMOND	40499S001	961259.821	-5674090.864	2740534.163	.001	.002	.002	NOAM	47161
108S020	MADRID	13407S003	4849247.008	-360279.135	4114884.874	.067	.018	.056	EURA	47161
201S020	SHANGHAI	21605S009	-2831684.965	4675732.885	3275328.297	.008	.006	.010	EURA	47161
201S010	SHANGHAI	21605S008	-2847696.446	4659871.939	3283959.342	.177	.152	.135	EURA	47161
428M001	VANDENBERG AFB	40420M002	-2678092.969	-4525451.705	3597410.593	.002	.003	.004	NOAM	47161
409S010	HAYSTACK	40440S003	1492208.423	-4458131.350	4296015.901	.010	.010	.010	NOAM	47161
115S010	WETTZELL	14201S004	4075541.674	931734.246	4801629.687	.003	.002	.005	EURA	47161
431M001	YELLOWKNIFE	40127M001	-1224122.733	-2689531.517	5633555.738	.016	.023	.027	NOAM	47161

RADIO SOURCE COORDINATES RSC(GSFC) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
0016+731	0	19	45.785826	73	27	30.01565	0.000097	0.00031
0048-097	0	50	41.317346	- 9	29	5.21116	0.000031	0.00031
0106+013	1	8	38.771066	1	35	0.31596	0.000003	0.00015
0212+735	2	17	30.812719	73	49	32.62054	0.000028	0.00012
0224+671	2	28	50.051063	67	21	3.02813	0.000025	0.00018
0229+131	2	31	45.894005	13	22	54.71563	0.000003	0.00014
0234+285	2	37	52.405572	28	48	8.98919	0.000005	0.00013
0235+164	2	38	38.930031	16	36	59.27385	0.000008	0.00035
0300+470	3	3	35.242008	47	16	16.27483	0.000010	0.00013
0316+413	3	19	48.159914	41	30	42.10339	0.000015	0.00022
0355+508	3	59	29.747009	50	57	50.16168	0.000011	0.00014
0420-014	4	23	15.800696	- 1	20	33.06421	0.000003	0.00015
0430+052	4	33	11.095462	5	21	15.62112	0.000029	0.00151
0454-234	4	57	3.179245	-23	24	52.01770	0.000018	0.00026
0528+134	5	30	56.416698	13	31	55.15115	0.000003	0.00014
0552+398	5	55	30.805446	39	48	49.16645	0.000007	0.00012
0727-115	7	30	19.112447	-11	41	12.59717	0.000004	0.00016
0742+103	7	45	33.059492	10	11	12.69533	0.000007	0.00033
0814+425	8	18	15.999572	42	22	45.41748	0.000033	0.00033
0823+033	8	25	50.338299	3	9	24.52498	0.000014	0.00044
0851+202	8	54	48.874878	20	6	30.64396	0.000003	0.00013
0923+392	9	27	3.013835	39	2	20.85500	0.000007	0.00012
0953+254	9	56	49.875364	25	15	16.05195	0.000019	0.00061
1034-293	10	37	16.079680	-29	34	2.80902	0.000018	0.00027
1055+018	10	58	29.605188	1	33	58.82768	0.000004	0.00019
1144+402	11	46	58.297974	39	58	34.30740	0.000008	0.00013
1150+812	11	53	12.499413	80	58	29.15638	0.000170	0.00053
1156+295	11	59	31.833934	29	14	43.82984	0.000006	0.00014
1219+285	12	21	31.690593	28	13	58.50303	0.000019	0.00065
1226+023	12	29	6.699700	2	3	8.60154	1.000000	0.00014
1253-055	12	56	11.166464	- 5	47	21.52197	0.000005	0.00021
1308+326	13	10	28.663944	32	20	43.78525	0.000006	0.00013
1334-127	13	37	39.782696	-12	57	24.69049	0.000007	0.00021
1354+195	13	57	4.436703	19	19	7.37402	0.000007	0.00017
1404+286	14	7	0.394488	28	27	14.69147	0.000004	0.00013
1418+546	14	19	46.597621	54	23	14.78853	0.000020	0.00020
1502+106	15	4	24.979821	10	29	39.20015	0.000004	0.00016
1548+056	15	50	35.269245	5	27	10.44962	0.000003	0.00015
1633+382	16	35	15.493092	38	8	4.50035	0.000007	0.00013
1637+574	16	38	13.456611	57	20	23.97880	0.000014	0.00014

RADIO SOURCE COORDINATES RSC(GSFC) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
1642+690	16	42	7.849001	68	56	39.75584	0.000025	0.00016
1641+399	16	42	58.810096	39	48	36.99366	0.000007	0.00013
1730-130	17	33	2.705714	-13	4	49.54799	0.000005	0.00018
1739+522	17	40	36.978061	52	11	43.40654	0.000017	0.00018
1741-038	17	43	58.856114	- 3	50	4.61663	0.000003	0.00016
1749+701	17	48	32.840835	70	5	50.76679	0.000204	0.00094
1749+096	17	51	32.818597	9	39	0.72794	0.000004	0.00015
1803+784	18	0	45.684720	78	28	4.01703	0.000038	0.00012
1921-293	19	24	51.055873	-29	14	30.12126	0.000008	0.00024
1923+210	19	25	59.605387	21	6	26.15986	0.000030	0.00114
1928+738	19	27	48.495272	73	58	1.56742	0.000141	0.00087
1958-179	20	0	57.090353	-17	48	57.67333	0.000021	0.00027
2037+511	20	38	37.034846	51	19	12.66023	0.000012	0.00013
2113+293	21	15	29.413460	29	33	38.36483	0.000012	0.00035
2121+053	21	23	44.517382	5	35	22.09119	0.000003	0.00014
2128-123	21	31	35.261601	-12	7	4.79774	0.000033	0.00043
2134+004	21	36	38.586302	0	41	54.21173	0.000003	0.00015
2145+067	21	48	5.458664	6	57	38.60195	0.000004	0.00014
2200+420	22	2	43.291369	42	16	39.97726	0.000008	0.00012
2201+315	22	3	14.975819	31	45	38.26801	0.000025	0.00055
2216-038	22	18	52.037724	- 3	35	36.88125	0.000003	0.00016
2234+282	22	36	22.470841	28	28	57.41080	0.000007	0.00013
2251+158	22	53	57.747914	16	8	53.55844	0.000004	0.00013
2345-167	23	48	2.608498	-16	31	12.02322	0.000013	0.00021

EOP(GSFC) 89 R 02 Available from 1979 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		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1979	2	1.22	2	2.58	2	0.88	2	1.57	2	0.56
1980	20	2.30	20	7.06	20	1.82	20	1.11	20	0.38
1981	32	8.55	32	26.65	32	6.90	32	2.54	32	1.27
1982	55	8.57	55	26.65	55	6.96	55	2.67	55	0.98
1983	66	9.65	66	21.31	66	5.52	66	2.23	66	0.94
1984	92	6.46	92	4.57	92	1.18	92	0.99	92	0.36
1985	94	2.88	94	1.87	94	0.42	94	0.67	94	0.27
1986	107	0.70	107	2.82	107	0.39	107	0.60	107	0.23
1987	127	0.56	127	0.44	127	0.23	127	0.56	127	0.21
1988	113	0.37	113	0.37	113	0.20	113	0.51	113	0.20

FIXED AND MOBILE POSITION RESULTS FROM THE NASA CRUSTAL DYNAMICS PROJECT WITH SITE VELOCITIES ADJUSTED

GSFC 89 R 03

C.Ma,Code 621.9, Goddard Space Flight Center, Greenbelt, MD 20771, USA
W.Himwich,Interferometrics, 8150 Leesburg Pike, Vienna, VA 22180, USA
D.Caprette,STX 4400 Forbes Blvd., Lanham, MD 20706, USA

Mark III VLBI data acquired since 1979 by the NASA Crustal Dynamics Project and the NGS POLARIS/IRIS programs have been analyzed for site positions. The reference frame is defined by the position of the Westford 18-m antenna defined 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 Yoder UT1 tidal model, 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 changes according to the AM0-2 model. All uncertainties are 1-sigma formal statistical errors from the sequential least-squares estimation described below.

The basic models used in calculating the VLBI theoreticals are described in Ma (1978), and the data analysis procedures are described in Ma et al. (1989). The astronomical and geophysical models are contained in the GSFC program CALC 6.0 and are consistent with the MERIT standards with the addition of the pole tide. In the analysis which generated these results, however, adjustments in longitude and obliquity were estimated for each session except the reference day. The velocities of all sites with sufficient data were adjusted. With the exceptions of HRAS and Kashima, all sites were constrained to move only horizontally. Richmond was constrained to move only in the a priori direction of Westford. The inclusion of mobile data, the adjustment of site velocities, the use of constrained troposphere and clock rates and the elimination of delay rate data are major changes from previous submissions.

379 437 Mark III observations from 869 sessions were used to estimate site positions and velocities, source positions, Earth orientation parameters, nutation parameters and clock and troposphere behavior from a least-squares solution with 521 global parameters and 145 782 arc, i.e., session-dependent, parameters. A weak input covariance on the Earth orientation parameters (X, Y - 45 mas, UT1 - 3 ms) was used so that all three components could be estimated for each session. The overall rms fit of the solution was 42.2 ps; the reduced chi-square of the solution was .87.

The site coordinates at epochs 1979-89 Jan 1.5 are designated SSC(GSFC)89 R 03.

References

C.Ma, NASA TM-79582, 1978. - C.Ma et al., NASA TM-100723, 1989.

IERS(1989) : Technical Note no 2.

IGNF NUMBER	STATION	X m	Y m	Z m	EPOCH MJD	DURATION	SX m	SY m	SZ m
7282 S	ALGOPARK	918036.597	-4346133.082	4561971.520	46159.8	377.0	.012	.013	.012
9997 M	AUSTINTX	-737792.039	-5459893.124	3202990.909	46988.0	1.0	.003	.014	.009
9995 M	BERMUDA	2307211.160	-4874216.432	3394318.113	47011.7	4.0	.018	.070	.049
7269 M	BLKBUTTE	-2306305.181	-4787915.315	3515736.880	46524.2	1815.0	.004	.009	.007
9994 M	BLOOMIND	302386.214	-4941699.905	4007908.894	47027.0	1.0	.019	.043	.033
9996 M	CARROLGA	453522.376	-5300507.581	3507207.826	46995.0	1.0	.008	.033	.020
7215 S	CHLBOLTN	4008311.816	-100651.750	4943795.067	44532.0	7.0	.009	.005	.010
7267 M	DEADMANL	-2336817.875	-4732587.837	3570330.432	46610.6	1435.0	.009	.016	.012
7231 S	DSS15	-2353536.985	-4641650.416	3676670.478	47101.0	1.0	.003	.006	.006
1642 S	DSS45	-4460933.406	2682764.817	-3674381.113	47383.4	202.0	.015	.011	.010
1665 S	DSS65	4849338.432	-360489.807	4114749.116	47453.0	1.0	.008	.004	.010
7203 S	EFLSBERG	4033949.250	486989.513	4900431.087	44584.0	1258.0	.017	.032	.016
7286 M	ELY	-2077234.530	-4486713.592	4018754.202	46867.3	1649.0	.003	.008	.007
7261 M	FLAGSTAF	-1923990.904	-4850855.403	3658589.761	46693.5	1643.0	.005	.011	.008
7266 M	FORT ORD	-2697024.985	-4354394.193	3788078.057	46683.0	1639.0	.005	.008	.008
7225 S	GILCREEK	-2281545.393	-1453645.941	5756993.676	46858.8	1618.0	.002	.002	.004
1513 S	GOLDVENU	-2351127.356	-4655477.963	3660957.369	45785.6	2424.0	.002	.004	.004
7120 M	HALEAKAL	-5465996.731	-2404409.466	2242228.934	47344.7	15.0	.011	.006	.008
7232 S	HARTRAO	5085444.366	2668262.522	-2768696.748	46818.7	744.0	.018	.014	.010
7218 S	HATCREEK	-2523968.155	-4123507.243	4147753.049	46703.2	1973.0	.001	.003	.004
7205 S	HAYSTACK	1492406.565	-4457267.350	4296882.122	45106.1	2603.0	.001	.002	.002
7216 S	HRAS 085	-1324209.184	-5332023.991	3232118.820	46259.3	3184.0	.001	.002	.003
7263 M	JPL MV1	-2493304.206	-4655198.472	3565519.785	46135.1	1936.0	.005	.008	.007
1856 S	KASHIMA	-3997890.568	3276580.327	3724118.823	46790.2	1783.0	.005	.003	.007
1311 S	KAUAI	-5543844.260	-2054565.084	2387814.301	46807.3	1618.0	.003	.003	.006
7278 M	KODIAK	-3026938.396	-1575912.697	5370362.959	46829.7	1444.0	.006	.004	.011
4968 S	KWAJAL26	-6143534.797	1363996.282	1034707.931	46490.5	1492.0	.009	.004	.008
9993 M	LEONRDOK	-522229.813	-5145677.727	3720152.779	47032.0	1.0	.003	.017	.011
7259 M	MAMMOTHL	-2448245.004	-4426739.220	3875436.364	46009.2	1212.0	.011	.021	.018
7217 S	MARPOINT	1106631.149	-4882908.026	3938087.337	45856.8	1875.0	.009	.015	.010
7230 S	MEDICINA	4461371.776	919595.796	4449559.494	47244.3	606.0	.004	.003	.006
7038 M	MILESMON	-1204437.234	-4239211.990	4596266.525	47267.0	1.0	.009	.029	.029
7288 M	MOJ 7288	-2356492.332	-4646608.567	3668427.082	47101.0	1.0	.004	.009	.007

IGNF NUMBER	STATION	X m	Y m	Z m	EPOCH MJD	DURATION	SX m	SY m	SZ m
7222 S	MOJAVE12	-2356169.209	-4646756.766	3668471.062	46625.4	1955.0	.001	.002	.003
7274 M	MON PEAK	-2386287.629	-4802347.455	3444884.434	46411.2	2029.0	.003	.006	.005
7279 M	NOME	-2658148.668	-693822.803	5737237.095	46321.6	748.0	.013	.008	.022
7204 S	NRAO 140	882881.708	-4924483.144	3944131.061	45074.2	3379.0	.001	.004	.003
7270 M	OCOTILLO	-2335599.347	-4832245.165	3434392.807	45991.0	367.0	.059	.057	.069
7213 S	ONSALA60	3370607.804	711916.482	5349831.045	46064.7	3028.0	.003	.002	.005
7853 M	OVR 7853	-2410419.451	-4477801.295	3838690.780	47101.0	1.0	.004	.007	.006
7207 S	OVRO 130	-2409598.970	-4478350.425	3838603.668	45819.7	3379.0	.001	.003	.004
7254 M	PBLOSSOM	-2464069.144	-4649426.520	3593906.159	46345.6	1814.0	.006	.011	.009
7283 M	PENTICTN	-2058838.659	-3621287.230	4814421.168	46185.3	377.0	.026	.036	.038
7256 M	PINFLATS	-2369634.172	-4761325.801	3511116.601	46528.0	1652.0	.004	.008	.007
7258 M	PLATTVIL	-1240706.361	-4720455.222	4094482.093	46430.4	1959.0	.002	.006	.005
7252 M	PRESIDIO	-2707703.085	-4257610.487	3888374.638	46430.9	1639.0	.005	.007	.007
7251 M	PT REYES	-2732331.320	-4217635.782	3914491.504	46566.4	1633.0	.005	.008	.008
7268 M	PVERDES	-2525451.018	-4670036.565	3522887.220	46599.0	1547.0	.009	.016	.012
7221 M	QUINCY	-2517229.112	-4198596.101	4076531.736	46324.3	2024.0	.005	.009	.009
7219 S	RICHMOND	961259.822	-5674090.865	2740534.166	46651.4	1835.0	.001	.002	.001
1561 S	ROBLED32	4849247.007	-360279.136	4114884.875	45460.0	1.0	.067	.018	.056
7255 M	SANPAULA	-2554474.892	-4608628.257	3582138.748	46439.5	1623.0	.009	.017	.013
7229 M	SEATTLE1	-2295346.220	-3638030.374	4693409.173	46670.0	1.0	.025	.198	.197
7227 S	SESHAN25	-2831684.967	4675732.884	3275328.295	47374.6	246.0	.008	.006	.010
7226 S	SHANGHAI	-2847696.438	4659871.930	3283959.336	46595.0	1.0	.177	.152	.135
7280 M	SNDPOINT	-3425460.148	-1214670.046	5223858.760	46839.7	1461.0	.009	.005	.014
7281 M	SOURDOGH	-2419991.702	-1664229.658	5643538.744	46708.5	1460.0	.004	.003	.009
7290 M	VERNAL	-1631471.530	-4589129.804	4106760.336	47043.5	936.0	.005	.012	.010
7223 M	VNDNBERG	-2678092.966	-4525451.706	3597410.594	46562.0	1896.0	.001	.003	.004
7209 S	WESTFORD	1492208.423	-4458131.350	4296015.901	46345.2	2787.0	0.000	0.000	0.000
7224 S	WETTZELL	4075541.673	931734.246	4801629.685	46635.5	1870.0	.003	.002	.005
7284 M	WHTHORSE	-2215211.849	-2209262.509	5540292.997	46896.3	1460.0	.006	.005	.012
7277 M	YAKATAGA	-2529742.428	-1942092.204	5505028.416	46652.0	1110.0	.007	.006	.013
7285 M	YELLOWKN	-1224122.734	-2689531.517	5633555.737	46125.0	377.0	.016	.023	.027
7894 M	YUMA	-2196776.147	-4887337.932	3448425.689	46696.5	1815.0	.003	.006	.005

SITE POSITIONS FOR JANUARY 1.5, 1988 MJD 47161.5

EARTH ROTATION PARAMETERS FROM DSN VLBI

JPL 89 R 01

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 that directly account for tectonic plate motions and for corrections to precession and nutation have been obtained from analysis of Deep Space Network (DSN) VLBI data. 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. Both these projects use the 70 meter DSN antennas (DSS 14, 43, 63) whenever possible and the 34 meter DSN antennas when the larger antennas are not available. Each observing session uses antennas in two complexes, and usually exactly one antenna in each complex. This reportdescribes 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 1989 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 and 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. 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 ge-

nerally 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 and E projects were used in the solution process for the ERP series reported here. In this 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. The reference frame tie was provided by the JPL 1989-2 solution (see below) for source positions, baseline vectors, and a parametric model for the motion of the Celestial Ephemeris Pole. 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 and E sessions.

2. Adjusts to the troposphere zenith delay at each station. In the CAT M and 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.

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 and 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.

During calendar year 1988, the TEMPO project produced earth rotation measurements from 78 observing sessions, with a median standard error along the minor axis of the error ellipse of 0.8 milliarcseconds (mas), and along the major axis of 3.5 mas.

JPL 1989-2 CATALOG

The JPL 1989-2 catalog was developed specifically for use in TEMPO operational ERP solutions during 1989. 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 1989-2 catalog solution. Although this CEP model has the form of adjusts 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 1989, and will presumably need revision in 1990. 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 1989-2 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 described above were included.

3. Information from intra-complex radio interferometry and ground surveys was used to constrain the coordinate differences between stations within each complex.

4. The coordinates of DSS-14 were held fixed at conventional values; this fixes the translation of the terrestrial coordinate system. The station coordinates resulting from the solution apply at a reference time of 1985.0.

5. Values of UT1-UTC and polar motion were taken from Eubanks (1988), Kalman smoothing 87S, for the time period 1978-1987.0. This combination-of-techniques ERP series utilized neither CAT M and E nor TEMPO VLBI results. The Kalman-filter estimates of uncertainties were adopted as the standard errors of these a priori ERP values. By this means the origin of coordinates of the ERP series in the 1989-2 system is tied to the SPACE87 system of Eubanks, which is in turn tied to the BIH system for the year 1986.

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 RSC(IERS) 88 C 01 (Arias et al.,1988), were held fixed at their values in that frame. By this means the coordinate system of the 1989-2 RSC is tied to the IERS celestial frame. (The Right Ascension of 3C 273 was NOT held fixed.)

7. The reference epoch of the 1989-2 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 adjusts 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. No out-of-phase nutations were estimated 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 solutions which also estimated the out-of-phase nutations and additional components with periods of 121.75, 27.55, and 13.63 days. (None of these other components appeared to be genuinely significant from our data set.)

Celestial Ephemeris Pole Motion Model

Index	Period	Component	Adjust	Formal Error	Generalized Error
	days		mas	mas	mas
precession		Longitude	-2.05/yr	0.15/yr	0.16/yr.
Y-offset		L sin eps	-11.81	0.84	0.85
X-offset		Obliquity	- 0.60	0.33	0.34
1	6798.38	Longitude	- 4.29	0.85	1.40
		Obliquity	+ 1.08	0.14	0.18
2	3399.19	Longitude	+ 0.49	0.54	0.59
		Obliquity	- 0.80	0.10	0.12
10	365.26	Longitude	+ 4.02	0.29	0.41
		Obliquity	+ 1.47	0.11	0.42
9	182.62	Longitude	+ 1.31	0.24	0.27
		Obliquity	- 0.73	0.11	0.12
31	13.66	Longitude	+ 0.70	0.27	0.37
		Obliquity	- 0.39	0.11	0.14

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 1989-2 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.

REFERENCES:

Arias,E.F., M.Feissel, and J.-F.Lestrade, An extragalactic celestial reference frame consistent with the BIH terrestrial system (1987), in BIH Annual Report for 1987, pp. D-113-D-121, 1988.

Eubanks,T.M., Combined earth orientation series smoothed by a Kalman filter, in BIH Annual Report for 1987, pp. D-85-D-86, 1988.

Lanyi,G.E., Tropospheric delay effects in radio interferometry, Telecommunications and Data Acquisition Prog. Rept. 42-78, pp.152-159, Jet Propulsion Laboratory, Pasadena, California, April-June, 1984.

Pagiatakis,S.D., Ocean Tide Loading, Body Tide and Polar Motion Effects on Very Long Baseline Interferometry, Technical Report No.92, Dept. of Surveying Engineering, University of New Brunswick, Fredericton, N.B., Canada, Dec.1982.

Sovers,O.J., and J.L.Fanselow, Observation Model and Parameter Partials for the JPL VLBI Parameter Estimation Software "MASTERFIT"-1987, Publication 83-39, Rev. 3, Jet Propulsion Laboratory, Pasadena, California, December 15, 1987.

SSC(JPL) 89 R 02

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
12S001	GOLDSTONE	40405S003	-2350443.458	-4651980.814	3665630.650	.010	.010	.010	NOAM	46066
13S001	GOLDSTONE	40405S014	-2351128.815	-4655477.049	3660956.586	.010	.010	.010	NOAM	46066
14S001	GOLDSTONE	40405S001	-2353620.898	-4641341.510	3677052.000	.010	.010	.010	NOAM	46066
15S001	GOLDSTONE	40405S019	-2353538.465	-4641649.487	3676669.704	.010	.010	.010	NOAM	46066
42S001	ORRORAL	50103S005	-4460980.745	2682413.341	-3674582.283	.075	.049	.054	INDI	46066
43S001	ORRORAL	50103S001	-4460894.317	2682361.371	-3674748.794	.016	.011	.034	INDI	46066
45S001	ORRORAL	50103S010	-4460935.007	2682765.461	-3674382.046	.010	.010	.010	INDI	46066
61S001	MADRID	13407S003	4849245.144	-360278.110	4114883.964	.018	.035	.050	EURA	46066
63S001	MADRID	13407S001	4849092.597	-360180.497	4115108.651	.007	.016	.029	EURA	46066
65S001	MADRID	13407S010	4849336.697	-360488.790	4114748.322	.010	.010	.010	EURA	46066

EOP(JPL) 89 R 01 Available from 1978 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	FI		UTO	
	Nb	Sigma	Nb	Sigma
1978	3	0.56	3	1.73
1979	6	2.66	6	2.89
1980	21	7.54	21	10.47
1981	18	9.99	18	12.11
1982	43	10.17	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	4.24
1988	87	3.24	87	3.48

RADIO SOURCE COORDINATES RSC(JPL) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
0008-264	0	11	1.246693	-26	12	33.37619	0.000101	0.00148
0019+058	0	22	32.441199	6	8	4.27021	0.000031	0.00132
0048-097	0	50	41.317292	- 9	29	5.20653	0.000057	0.00172
0104-408	1	6	45.108025	-40	34	19.95829	0.000105	0.00111
0106+013	1	8	38.771034	1	35	0.31908	0.000025	0.00062
0111+021	1	13	43.145054	2	22	17.31617	0.000099	0.00171
0112-017	1	15	17.099941	- 1	27	4.59599	0.000270	0.07418
0113-118	1	16	12.521920	-11	36	15.43190	0.000066	0.00126
0119+115	1	21	41.595045	11	49	50.41205	0.000050	0.00819
0119+041	1	21	56.861589	4	22	24.73881	0.000047	0.00140
0133+476	1	36	58.594863	47	51	29.10061	0.000043	0.00049
0146+056	1	49	22.370958	5	55	53.55465	0.000134	0.02702
0149+218	1	52	18.059037	22	7	7.69967	0.000058	0.00580
0201+113	2	3	46.657112	11	34	45.39357	0.000065	0.01167
0202+149	2	4	50.413933	15	14	11.04430	0.000030	0.00053
0212+735	2	17	30.813536	73	49	32.62173	0.000097	0.00036
0221+067	2	24	28.427640	6	59	23.47167	0.000328	0.05414
0224+671	2	28	50.051699	67	21	3.02932	0.000084	0.00049
0229+131	2	31	45.894129	13	22	54.70478	0.000068	0.01144
0234+285	2	37	52.405735	28	48	8.99042	0.000025	0.00000
0235+164	2	38	38.930135	16	36	59.27494	0.000026	0.00041
0237-233	2	40	8.174495	-23	9	15.73700	0.000874	0.01197
0239+108	2	42	29.170908	11	1	0.72778	0.000036	0.00074
0256+075	2	59	27.076667	7	47	39.64096	0.000040	0.00186
0259+121	3	2	30.546855	12	18	56.76435	0.000615	0.06221
0300+470	3	3	35.242281	47	16	16.27540	0.000038	0.00038
0306+102	3	9	3.623583	10	29	16.33418	0.000140	0.02606
0309+411	3	13	1.962231	41	20	1.18170	0.000107	0.00151
0316+413	3	19	48.160182	41	30	42.10377	0.000081	0.00107
0326+277	3	29	57.669255	27	56	15.49931	0.000200	0.00254
0332-403	3	34	13.654626	-40	8	25.39661	0.000128	0.00119
0333+321	3	36	30.107677	32	18	29.34288	0.000037	0.00057
0336-019	3	39	30.937755	- 1	46	35.80151	0.000043	0.00093
0342+147	3	45	6.416450	14	53	49.55951	0.000110	0.00173
0400+258	4	3	5.586665	26	0	1.49681	0.000723	0.00955
0402-362	4	3	53.749915	-36	5	1.91154	0.000083	0.00104
0406+121	4	9	22.008726	12	17	39.84787	0.000032	0.00092
0420-014	4	23	15.800741	- 1	20	33.06527	0.000023	0.00055
0420+417	4	23	56.009865	41	50	2.71553	0.000205	0.00298
0425+048	4	27	47.570378	4	57	8.32831	0.000123	0.00215

RADIO SOURCE COORDINATES RSC(JPL) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
0430+052	4	33	11.095516	5	21	15.62194	0.000059	0.00128
0434-188	4	37	1.482655	-18	44	48.61207	0.000057	0.00105
0438-436	4	40	17.179884	-43	33	8.60059	0.000131	0.00117
0440-003	4	42	38.660993	- 0	17	43.42351	0.000514	0.00795
0440+345	4	43	31.635406	34	41	6.66093	0.000128	0.00333
0446+112	4	49	7.671036	11	21	28.61796	0.000110	0.01526
0451-282	4	53	14.646288	-28	7	37.32033	0.000304	0.00387
0458+138	5	1	45.270964	13	56	7.20920	0.000211	0.00984
0459+060	5	2	15.445543	6	9	7.59165	0.000554	0.13134
0500+019	5	3	21.197046	2	3	4.70271	0.000331	0.08689
0502+049	5	5	23.184679	4	59	42.76955	0.000252	0.04839
0454+844	5	8	42.364037	84	32	4.54330	0.000347	0.00058
0506+101	5	9	27.457138	10	11	44.59969	0.000065	0.00165
0507+179	5	10	2.369205	18	0	41.57994	0.000070	0.00172
0511-220	5	13	49.113425	-21	59	16.07914	0.001349	0.01913
0528+134	5	30	56.416791	13	31	55.15051	0.000026	0.00057
0537-441	5	38	50.361269	-44	5	8.93526	0.000105	0.00106
0537-158	5	39	32.005827	-15	50	30.25216	0.009513	0.15297
0536+145	5	39	42.366101	14	33	45.56222	0.000056	0.00157
0544+273	5	47	34.149129	27	21	56.84251	0.000081	0.00183
0552+398	5	55	30.805630	39	48	49.16554	0.000025	0.00033
0556+238	5	59	32.033203	23	53	53.92523	0.000063	0.00129
0600+177	6	3	9.130326	17	42	16.81043	0.000077	0.00194
0605-085	6	7	59.699136	- 8	34	49.97858	0.000107	0.00247
0607-157	6	9	40.949991	-15	42	40.67936	0.000334	0.00506
0611+131	6	13	57.688773	13	6	45.25894	0.000359	0.02613
0642+214	6	45	24.099498	21	21	51.20434	0.000072	0.00241
0657+172	7	0	1.525590	17	9	21.70085	0.000054	0.00113
0722+145	7	25	16.808501	14	25	13.65470	0.000322	0.03442
0723-008	7	25	50.639949	- 0	54	56.54431	0.000045	0.00085
0727-115	7	30	19.112482	-11	41	12.60046	0.000029	0.00066
0735+178	7	38	7.393749	17	42	18.99934	0.000027	0.00057
0738+313	7	41	10.703363	31	12	0.22844	0.000098	0.00133
0742+103	7	45	33.059519	10	11	12.69218	0.000022	0.00047
0743+259	7	46	25.874222	25	49	2.13750	0.000121	0.00751
0745+241	7	48	36.109278	24	0	24.11133	0.000034	0.00073
0748+126	7	50	52.045759	12	31	4.82801	0.000031	0.00066
0754+100	7	57	6.643660	9	56	34.77247	0.000274	0.03682
0805-077	8	8	15.537149	- 7	51	9.90071	0.000905	0.01250
0814+425	8	18	15.999649	42	22	45.41472	0.000028	0.00041

RADIO SOURCE COORDINATES RSC(JPL) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
0823+033	8	25	50.338364	3	9	24.52048	0.000025	0.00060
0827+243	8	30	52.086350	24	10	59.81641	0.000279	0.00382
0836+710	8	41	24.365734	70	53	42.17202	0.000275	0.00172
0851+202	8	54	48.874929	20	6	30.64119	0.000000	0.00000
0859-140	9	2	16.830808	-14	15	30.87273	0.000149	0.00250
0859+470	9	3	3.990121	46	51	4.13879	0.000113	0.00208
0912+029	9	14	37.913984	2	45	59.12838	0.000673	0.18311
0920-397	9	22	46.418211	-39	59	35.06769	0.000704	0.00614
0923+392	9	27	3.013862	39	2	20.85188	0.000022	0.00035
0925-203	9	27	51.824557	-20	34	51.23401	0.000541	0.00659
0952+179	9	54	56.823552	17	43	31.22848	0.000768	0.01252
1004+141	10	7	41.498566	13	56	29.59422	0.000479	0.00653
1012+232	10	14	47.065405	23	1	16.57043	0.000178	0.01079
1022+194	10	24	44.809701	19	12	20.40305	0.000267	0.02591
1034-293	10	37	16.079665	-29	34	2.81156	0.000075	0.00099
1038+064	10	41	17.162464	6	10	16.92368	0.000033	0.00088
1040+123	10	42	44.605857	12	3	31.26049	0.000355	0.00482
1042+071	10	44	55.911239	6	55	38.27346	0.000237	0.04020
1044+719	10	48	27.619953	71	43	35.93694	0.000186	0.00098
1055+018	10	58	29.605207	1	33	58.82433	0.000021	0.00048
1104-445	11	7	8.694061	-44	49	7.61701	0.000136	0.00117
1111+149	11	13	58.695355	14	42	26.95037	0.000467	0.00592
1116+128	11	18	57.301520	12	34	41.71677	0.000302	0.00633
1123+264	11	25	53.711893	26	10	19.97880	0.000024	0.00052
1127-145	11	30	7.052656	-14	49	27.38879	0.000083	0.00135
1128+385	11	30	53.282582	38	15	18.54686	0.000034	0.00069
1144-379	11	47	1.370660	-38	12	11.02199	0.000072	0.00091
1145-071	11	47	51.553603	-	7	24 41.01927	0.000310	0.05889
1148-001	11	50	43.870830	-	0	23 54.20655	0.000077	0.00236
1156-094	11	59	12.712596	-	9	40 52.06339	0.002420	0.03578
1222+037	12	24	52.421851	3	30	50.29398	0.000036	0.00093
1226+023	12	29	6.699655	2	3	8.59960	0.000021	0.00052
1228+126	12	30	49.423337	12	23	28.04470	0.000305	0.00411
1244-255	12	46	46.802063	-25	47	49.28770	0.000060	0.00097
1253-055	12	56	11.166536	-	5	47 21.52471	0.000026	0.00070
1302-102	13	5	33.014817	-10	33	19.43333	0.000212	0.03356
1308+326	13	10	28.663798	32	20	43.78253	0.000022	0.00047
1313-333	13	16	7.985930	-33	38	59.17155	0.000131	0.00143
1334-127	13	37	39.782716	-12	57	24.69223	0.000031	0.00074
1342+662	13	43	45.959436	66	2	25.74447	0.000105	0.00074

RADIO SOURCE COORDINATES RSC(JPL) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
1342+663	13	44	8.679546	66	6	11.64286	0.000072	0.00045
1349-439	13	52	56.535177	-44	12	40.38794	0.000159	0.00127
1354+195	13	57	4.436618	19	19	7.37204	0.000025	0.00058
1354-152	13	57	11.244848	-15	27	28.74912	0.000157	0.02540
1406-076	14	8	56.481217	- 7	52	26.66014	0.000586	0.10226
1418+546	14	19	46.597332	54	23	14.78657	0.000042	0.00051
1430-178	14	32	57.690423	-18	1	35.24691	0.000288	0.00400
1445-161	14	48	15.054475	-16	20	24.59917	0.000378	0.05193
1502+106	15	4	24.979720	10	29	39.19956	0.000021	0.00063
1504-166	15	7	4.786923	-16	52	30.26645	0.000037	0.00101
1510-089	15	12	50.532849	- 9	5	59.82860	0.000030	0.00075
1511-100	15	13	44.893550	-10	12	0.29143	0.000359	0.05776
1514-241	15	17	41.813628	-24	22	19.55408	0.000528	0.04495
1519-273	15	22	37.675922	-27	30	10.78396	0.000069	0.00104
1532+016	15	34	52.453123	1	31	4.30832	0.000374	0.09677
1548+056	15	50	35.269018	5	27	10.48359	0.000100	0.02007
1555+001	15	57	51.433904	- 0	1	50.41249	0.000032	0.00087
1611+343	16	13	41.064180	34	12	47.90897	0.000028	0.00065
1614+051	16	16	37.556874	4	59	32.73614	0.000082	0.00242
1633+382	16	35	15.492904	38	8	4.50091	0.000028	0.00055
1638+398	16	40	29.632685	39	46	46.02968	0.000033	0.00060
1641+399	16	42	58.809874	39	48	36.99467	0.000027	0.00052
1656+053	16	58	33.447178	5	15	16.44518	0.000113	0.00252
1657-261	17	0	53.154162	-26	10	51.72557	0.000059	0.00111
1706-174	17	9	34.345338	-17	28	53.36365	0.000058	0.00123
1717+178	17	19	13.048597	17	45	6.43613	0.000182	0.00311
1730-130	17	33	2.705747	-13	4	49.54672	0.000030	0.00080
1738+476	17	39	57.128967	47	37	58.36262	0.000043	0.00077
1741-038	17	43	58.856078	- 3	50	4.61556	0.000025	0.00071
1749+701	17	48	32.840245	70	5	50.76904	0.000099	0.00054
1749+096	17	51	32.818498	9	39	0.72894	0.000032	0.00095
1803+784	18	0	45.683936	78	28	4.01924	0.000340	0.00082
1807+698	18	6	50.680478	69	49	28.10936	0.000078	0.00046
1821+107	18	24	2.855258	10	44	23.77075	0.000041	0.00186
1908-201	19	11	9.652893	-20	6	55.10780	0.000059	0.00118
1920-211	19	23	32.189715	-21	4	33.33072	0.000059	0.00118
1921-293	19	24	51.055992	-29	14	30.11998	0.000069	0.00103
1923+210	19	25	59.605317	21	6	26.16484	0.000046	0.00132
1933-400	19	37	16.216882	-39	58	1.54866	0.000460	0.00414
1936-155	19	39	26.657692	-15	25	43.04437	0.000086	0.01336

RADIO SOURCE COORDINATES RSC(JPL) 89 R 02

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
1958-179	20	0	57.090415	-17	48	57.67161	0.000044	0.00096
2008-159	20	11	15.711023	-15	46	40.25405	0.000076	0.01223
2021+614	20	22	6.681781	61	36	58.80700	0.000098	0.00117
2030+547	20	31	47.958597	54	55	3.14645	0.000192	0.00267
2029+121	20	31	54.994244	12	19	41.33972	0.000063	0.00147
2113+293	21	15	29.413402	29	33	38.36787	0.000031	0.00069
2128-123	21	31	35.261773	-12	7	4.79442	0.000083	0.01430
2131-021	21	34	10.309512	- 1	53	17.21224	0.000210	0.05740
2134+004	21	36	38.586333	0	41	54.21400	0.000030	0.00079
2145+067	21	48	5.458649	6	57	38.60436	0.000021	0.00062
2149+056	21	51	37.875361	5	52	12.95537	0.000043	0.00105
2155-152	21	58	6.281871	-15	1	9.32704	0.000097	0.00151
2200+420	22	2	43.291384	42	16	39.98088	0.000035	0.00055
2216-038	22	18	52.037696	- 3	35	36.87942	0.000028	0.00084
2223-052	22	25	47.259232	- 4	57	1.38994	0.000030	0.00080
2227-088	22	29	40.084352	- 8	32	54.44684	0.000083	0.01821
2230+114	22	32	36.408862	11	43	50.90531	0.000025	0.00064
2234+282	22	36	22.470837	28	28	57.41439	0.000027	0.00054
2243-123	22	46	18.231899	-12	6	51.27554	0.000034	0.00087
2245-328	22	48	38.685774	-32	35	52.18607	0.000117	0.00141
2251+158	22	53	57.747932	16	8	53.56079	0.000024	0.00059
2253+417	22	55	36.707815	42	2	52.53418	0.000053	0.00106
2254+074	22	57	17.303408	7	43	12.22517	0.000203	0.03663
2254+024	22	57	17.563397	2	43	17.42171	0.000195	0.05268
2318+049	23	20	44.856448	5	13	49.98212	0.000086	0.02194
2320-035	23	23	31.953678	- 3	17	5.02251	0.000031	0.00096
2335-027	23	37	57.338726	- 2	30	57.55702	0.000425	0.11383
2345-167	23	48	2.608504	-16	31	12.02143	0.000057	0.00108
2355-106	23	58	10.882381	-10	20	8.61098	0.000048	0.00108

THE JPL 1989-3 EXTRAGALACTIC RADIO SOURCE CATALOG JPL 89 R 03

O.J.Sovers, C.D.Edwards, C.S.Jacobs, G.E.Lanyi and R.N.Treuhaft
Jet Propulsion Laboratory - California Institute of Technology,
Pasadena CA 91109, U.S.A

Radio source position catalog JPL 1989-3 results from a fit to 8230 delay + delay rate pairs of dual-frequency VLBI observations involving the DSN stations in California Australia and Spain. The origin of right ascension is fixed by adopting the usual fixed value of RA (3c 273) the Earth-fixed frame is fixed by fixing the position of the Goldstone 70-m antenna DSS 14. A new set of station coordinates is estimated for each of the 64 observing sessions spanning the period October 1978 to November 1988. Nutations in longitude and obliquity are fixed to the present standard IAU model values on 1983 May 21 : two celestial pole angles are estimated for all other sessions. Precession is fixed at the IAU value.

Results of phase-delay interferometric measurements, or of ground surveys are used for intra-complex ties, e.g. DSS 13 and DSS 15 to DSS 14. Motion of Spain and Australia relative to California is found to be in general agreement with the AMO-2 model.

EOP(JPL) 89 R 03 **Available from 1978 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	dPsi		dEps	
	Nb	Sigma	Nb	Sigma
1978	3	9.32	3	6.05
1979	6	8.19	6	6.12
1980	7	5.32	7	2.93
1981	2	8.04	2	1.76
1982	6	3.90	6	1.29
1983	8	1.88	8	0.73
1984	8	6.44	8	2.14
1985	2	2.65	2	1.00
1986	6	4.97	6	2.20
1987	7	5.14	7	1.86
1988	8	2 90	8	1.65

RADIO SOURCE COORDINATES RSC(JPL) 89 R 03

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
0008-264	0	11	1.246824	-26	12	33.37528	0.000108	0.00177
0013-005	0	16	11.088983	- 0	15	12.55512	0.010554	3.04109
0019+058	0	22	32.441256	6	8	4.27165	0.000039	0.00146
0048-097	0	50	41.317406	- 9	29	5.20621	0.000065	0.00191
0104-408	1	6	45.108054	-40	34	19.95649	0.000157	0.00167
0106+013	1	8	38.771083	1	35	0.32017	0.000037	0.00096
0111+021	1	13	43.145112	2	22	17.31712	0.000102	0.00185
0112-017	1	15	17.099956	- 1	27	4.57743	0.000275	0.07488
0113-118	1	16	12.521836	-11	36	15.42818	0.000127	0.00221
0119+115	1	21	41.595084	11	49	50.41279	0.000057	0.00844
0119+041	1	21	56.861652	4	22	24.73972	0.000053	0.00157
0133+476	1	36	58.594827	47	51	29.10317	0.000063	0.00066
0146+056	1	49	22.371023	5	55	53.55476	0.000137	0.02717
0149+218	1	52	18.059069	22	7	7.70021	0.000065	0.00591
0201+113	2	3	46.657157	11	34	45.39377	0.000070	0.01175
0202+149	2	4	50.413969	15	14	11.04564	0.000040	0.00084
0212+735	2	17	30.813558	73	49	32.62438	0.000133	0.00049
0221+067	2	24	28.427680	6	59	23.47833	0.000330	0.05426
0224+671	2	28	50.051892	67	21	3.03304	0.000154	0.00094
0229+131	2	31	45.894169	13	22	54.70586	0.000073	0.01159
0234+285	2	37	52.405777	28	48	8.99202	0.000041	0.00064
0235+164	2	38	38.930168	16	36	59.27611	0.000039	0.00077
0237-233	2	40	8.174670	-23	9	15.73755	0.000879	0.01204
0239+108	2	42	29.170936	11	1	0.72940	0.000044	0.00097
0256+075	2	59	27.076709	7	47	39.64192	0.000047	0.00202
0259+121	3	2	30.546835	12	18	56.77482	0.000616	0.06229
0300+470	3	3	35.242307	47	16	16.27785	0.000060	0.00061
0306+102	3	9	3.623629	10	29	16.33718	0.000143	0.02616
0309+411	3	13	1.962276	41	20	1.18371	0.000114	0.00158
0316+413	3	19	48.160200	41	30	42.10648	0.000096	0.00135
0326+277	3	29	57.669323	27	56	15.49973	0.000203	0.00259
0332-403	3	34	13.654564	-40	8	25.39597	0.000157	0.00169
0333+321	3	36	30.107744	32	18	29.34358	0.000050	0.00078
0336-019	3	39	30.937773	- 1	46	35.80033	0.000060	0.00132
0342+147	3	45	6.416490	14	53	49.56080	0.000113	0.00184
0400+258	4	3	5.586627	26	0	1.49885	0.000725	0.00959
0402-362	4	3	53.749756	-36	5	1.90912	0.000115	0.00151
0406-127	4	9	5.772604	-12	38	48.18310	0.003109	0.04762
0406+121	4	9	22.008770	12	17	39.84896	0.000041	0.00112
0420-014	4	23	15.800762	- 1	20	33.06395	0.000036	0.00102

RADIO SOURCE COORDINATES RSC(JPL) 89 R 03

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
0420+417	4	23	56.009872	41	50	2.71817	0.000223	0.00331
0425+048	4	27	47.570381	4	57	8.32990	0.000125	0.00227
0430+052	4	33	11.095544	5	21	15.62328	0.000064	0.00149
0434-188	4	37	1.482635	-18	44	48.61099	0.000070	0.00150
0438-436	4	40	17.179782	-43	33	8.59937	0.000150	0.00161
0440-003	4	42	38.660967	- 0	17	43.42248	0.000519	0.00805
0440+345	4	43	31.635508	34	41	6.66228	0.000136	0.00340
0446+112	4	49	7.671087	11	21	28.61771	0.000114	0.01537
0451-282	4	53	14.646119	-28	7	37.31783	0.000361	0.00443
0458+138	5	1	45.270935	13	56	7.21209	0.000213	0.00987
0459+060	5	2	15.445576	6	9	7.58368	0.000557	0.13161
0500+019	5	3	21.197099	2	3	4.69693	0.000338	0.08830
0502+049	5	5	23.184715	4	59	42.76920	0.000254	0.04866
0454+844	5	8	42.365450	84	32	4.54509	0.000419	0.00066
0506+101	5	9	27.457168	10	11	44.60087	0.000071	0.00179
0507+179	5	10	2.369230	18	0	41.58138	0.000075	0.00182
0511-220	5	13	49.113208	-21	59	16.07245	0.001359	0.01919
0528+134	5	30	56.416822	13	31	55.15144	0.000036	0.00086
0537-441	5	38	50.361127	-44	5	8.93383	0.000172	0.00172
0537-158	5	39	32.006194	-15	50	30.25564	0.009722	0.15640
0536+145	5	39	42.366136	14	33	45.56251	0.000062	0.00169
0544+273	5	47	34.149181	27	21	56.84366	0.000087	0.00192
0552+398	5	55	30.805713	39	48	49.16626	0.000048	0.00059
0556+238	5	59	32.033236	23	53	53.92652	0.000069	0.00142
0600+177	6	3	9.130349	17	42	16.81100	0.000081	0.00203
0605-085	6	7	59.698855	- 8	34	49.97274	0.000420	0.00622
0607-157	6	9	40.950078	-15	42	40.67981	0.000341	0.00521
0611+131	6	13	57.688785	13	6	45.25991	0.000361	0.02618
0642+214	6	45	24.099515	21	21	51.20482	0.000077	0.00249
0657+172	7	0	1.525558	17	9	21.70179	0.000060	0.00129
0722+145	7	25	16.808482	14	25	13.65507	0.000323	0.03457
0723-008	7	25	50.639939	- 0	54	56.54377	0.000049	0.00119
0727-115	7	30	19.112451	-11	41	12.60012	0.000040	0.00123
0735+178	7	38	7.393785	17	42	18.99886	0.000037	0.00082
0738+313	7	41	10.703449	31	12	0.22724	0.000105	0.00146
0742+103	7	45	33.059536	10	11	12.69166	0.000032	0.00085
0743+259	7	46	25.874255	25	49	2.13758	0.000125	0.00756
0745+241	7	48	36.109327	24	0	24.11065	0.000044	0.00092
0748+126	7	50	52.045786	12	31	4.82735	0.000039	0.00092
0754+100	7	57	6.643659	9	56	34.76750	0.000276	0.03702

RADIO SOURCE COORDINATES RSC(JPL) 89 R 03

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
0805-077	8	8	15.537389	- 7	51	9.90223	0.001002	0.01347
0814+425	8	18	15.999762	42	22	45.41376	0.000051	0.00065
0823+033	8	25	50.338370	3	9	24.51964	0.000033	0.00101
0827+243	8	30	52.086378	24	10	59.81559	0.000285	0.00395
0836+710	8	41	24.366309	70	53	42.17072	0.000376	0.00206
0851+202	8	54	48.874978	20	6	30.64031	0.000030	0.00067
0859-140	9	2	16.830633	-14	15	30.87059	0.000275	0.00437
0859+470	9	3	3.991876	46	51	4.12624	0.000280	0.00447
0912+029	9	14	37.913968	2	45	59.11773	0.000676	0.18364
0923+392	9	27	3.013940	39	2	20.85045	0.000046	0.00059
0920-397	9	22	46.417988	-39	59	35.06343	0.000733	0.00626
0925-203	9	27	51.824406	-20	34	51.23163	0.000524	0.00634
0952+179	9	54	56.823558	17	43	31.22670	0.000770	0.01255
1004+141	10	7	41.498623	13	56	29.59181	0.000483	0.00659
1012+232	10	14	47.065397	23	1	16.57284	0.000182	0.01099
1022+194	10	24	44.809650	19	12	20.40857	0.000269	0.02598
1034-293	10	37	16.079601	-29	34	2.81237	0.000105	0.00150
1038+064	10	41	17.162491	6	10	16.92184	0.000034	0.00111
1040+123	10	42	44.605950	12	3	31.25784	0.000356	0.00486
1042+071	10	44	55.911225	6	55	38.27955	0.000239	0.04055
1044+719	10	48	27.620408	71	43	35.93592	0.000211	0.00105
1055+018	10	58	29.605222	1	33	58.82279	0.000025	0.00093
1104-445	11	7	8.694026	-44	49	7.61799	0.000202	0.00187
1111+149	11	13	58.695438	14	42	26.94716	0.000470	0.00597
1116+128	11	18	57.301564	12	34	41.71394	0.000303	0.00637
1123+264	11	25	53.711941	26	10	19.97663	0.000036	0.00067
1127-145	11	30	7.052666	-14	49	27.39027	0.000088	0.00170
1128+385	11	30	53.282642	38	15	18.54451	0.000050	0.00078
1144-379	11	47	1.370621	-38	12	11.02300	0.000090	0.00140
1145-071	11	47	51.553712	- 7	24	41.04024	0.000311	0.05982
1148-001	11	50	43.870850	- 0	23	54.20657	0.000077	0.00279
1156-094	11	59	12.713119	- 9	40	52.06901	0.001803	0.02611
1222+037	12	24	52.421897	3	30	50.29191	0.000035	0.00114
1226+023	12	29	6.699700	2	3	8.59756	0.000000	0.00087
1228+126	12	30	49.423353	12	23	28.04266	0.000308	0.00417
1244-255	12	46	46.802075	-25	47	49.28883	0.000064	0.00145
1253-055	12	56	11.166616	- 5	47	21.52784	0.000025	0.00113
1302-102	13	5	33.014866	-10	33	19.42962	0.000214	0.03408
1308+326	13	10	28.663829	32	20	43.78078	0.000037	0.00058
1313-333	13	16	7.985912	-33	38	59.17197	0.000151	0.00185

RADIO SOURCE COORDINATES RSC(JPL) 89 R 03

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
1334-127	13	37	39.782821	-12	57	24.69441	0.000032	0.00117
1342+662	13	43	45.959410	66	2	25.74212	0.000127	0.00079
1342+663	13	44	8.679521	66	6	11.64059	0.000104	0.00054
1349-439	13	52	56.535289	-44	12	40.38954	0.000197	0.00179
1354+195	13	57	4.436656	19	19	7.37018	0.000032	0.00070
1354-152	13	57	11.244936	-15	27	28.74253	0.000159	0.02606
1404+286	14	7	0.394430	28	27	14.68842	0.000071	0.00420
1406-076	14	8	56.481236	- 7	52	26.64511	0.000586	0.10233
1418+546	14	19	46.597293	54	23	14.78414	0.000069	0.00059
1430-178	14	32	57.690485	-18	1	35.24808	0.000292	0.00412
1445-161	14	48	15.054601	-16	20	24.60170	0.000378	0.05199
1502+106	15	4	24.979778	10	29	39.19791	0.000025	0.00079
1504-166	15	7	4.787072	-16	52	30.26832	0.000039	0.00134
1510-089	15	12	50.532972	- 9	5	59.83072	0.000033	0.00110
1511-100	15	13	44.893603	-10	12	0.28276	0.000361	0.05811
1514-241	15	17	41.813488	-24	22	19.50695	0.000563	0.05303
1519-273	15	22	37.675961	-27	30	10.78449	0.000097	0.00153
1532+016	15	34	52.453018	1	31	4.35661	0.000378	0.09764
1548+056	15	50	35.269083	5	27	10.48592	0.000102	0.02046
1555+001	15	57	51.434007	- 0	1	50.41407	0.000034	0.00106
1611+343	16	13	41.064151	34	12	47.90767	0.000042	0.00068
1614+051	16	16	37.556945	4	59	32.73528	0.000084	0.00266
1633+382	16	35	15.492851	38	8	4.49911	0.000044	0.00060
1638+398	16	40	29.632610	39	46	46.02820	0.000048	0.00062
1641+399	16	42	58.809790	39	48	36.99320	0.000044	0.00055
1655+077	16	58	9.011410	7	41	27.54166	0.000049	0.00121
1656+053	16	58	33.447269	5	15	16.44356	0.000116	0.00269
1657-261	17	0	53.154358	-26	10	51.72687	0.000063	0.00148
1706-174	17	9	34.345517	-17	28	53.36509	0.000062	0.00150
1717+178	17	19	13.048538	17	45	6.43493	0.000188	0.00336
1730-130	17	33	2.705912	-13	4	49.54784	0.000036	0.00115
1738+476	17	39	57.128812	47	37	58.36172	0.000059	0.00081
1741-038	17	43	58.856196	- 3	50	4.61610	0.000030	0.00097
1749+701	17	48	32.839768	70	5	50.76765	0.000124	0.00063
1749+096	17	51	32.818563	9	39	0.72889	0.000038	0.00108
1803+784	18	0	45.683289	78	28	4.01857	0.000362	0.00097
1807+698	18	6	50.680063	69	49	28.10834	0.000106	0.00057
1821+107	18	24	2.855310	10	44	23.77072	0.000046	0.00196
1908-201	19	11	9.653085	-20	6	55.10846	0.000066	0.00148
1920-211	19	23	32.189934	-21	4	33.33166	0.000067	0.00150

RADIO SOURCE COORDINATES RSC(JPL) 89 R 03

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″	S	″
1921-293	19	24	51.056139	-29	14	30.11942	0.000093	0.00144
1923+210	19	25	59.605324	21	6	26.16469	0.000052	0.00135
1933-400	19	37	16.217308	-39	58	1.55002	0.000567	0.00558
1936-155	19	39	26.657871	-15	25	43.04780	0.000091	0.01354
1958-179	20	0	57.090609	-17	48	57.67192	0.000054	0.00130
2008-159	20	11	15.711208	-15	46	40.25891	0.000084	0.01256
2021+614	20	22	6.681619	61	36	58.80737	0.000208	0.00249
2030+547	20	31	47.958622	54	55	3.14577	0.000294	0.00301
2029+121	20	31	54.994283	12	19	41.34018	0.000069	0.00154
2113+293	21	15	29.413360	29	33	38.36853	0.000041	0.00074
2121+053	21	23	44.517463	5	35	22.09811	0.000080	0.01630
2128-123	21	31	35.261959	-12	7	4.80079	0.000091	0.01465
2131-021	21	34	10.309684	- 1	53	17.22981	0.000218	0.05896
2134+004	21	36	38.586446	0	41	54.21407	0.000039	0.00099
2145+067	21	48	5.458719	6	57	38.60455	0.000032	0.00080
2149+056	21	51	37.875443	5	52	12.95564	0.000049	0.00117
2155-152	21	58	6.281859	-15	1	9.32491	0.000151	0.00230
2200+420	22	2	43.291277	42	16	39.98262	0.000048	0.00063
2216-038	22	18	52.037815	- 3	35	36.87925	0.000038	0.00107
2223-052	22	25	47.259358	- 4	57	1.38970	0.000039	0.00105
2227-088	22	29	40.084487	- 8	32	54.44752	0.000090	0.01841
2229+695	22	30	36.469412	69	46	28.08123	0.000235	0.00104
2230+114	22	32	36.408911	11	43	50.90599	0.000035	0.00079
2234+282	22	36	22.470814	28	28	57.41535	0.000038	0.00064
2243-123	22	46	18.232054	-12	6	51.27527	0.000045	0.00118
2245-328	22	48	38.685893	-32	35	52.18487	0.000129	0.00168
2251+158	22	53	57.747947	16	8	53.56201	0.000037	0.00082
2253+417	22	55	36.707733	42	2	52.53531	0.000062	0.00111
2254+074	22	57	17.303466	7	43	12.22731	0.000205	0.03685
2254+024	22	57	17.563482	2	43	17.41893	0.000199	0.05312
2318+049	23	20	44.856525	5	13	49.97807	0.000091	0.02237
2320-035	23	23	31.953781	- 3	17	5.02186	0.000040	0.00117
2335-027	23	37	57.338766	- 2	30	57.54613	0.000428	0.11418
2345-167	23	48	2.608671	-16	31	12.02123	0.000068	0.00142
2355-106	23	58	10.882503	-10	20	8.61052	0.000056	0.00135

EARTH ORIENTATION PARAMETERS BY VLBI IRIS-P NETWORK NAOMZ 89 R 01

K.Yokoyama, S.Manabe, National Astronomical Observatory, Division of Earth Rotation, Mizusawa-shi, Iwate-ken. 023 Japan
T.Yoshino, Communications Research Laboratory. Koganei-shi. Tokyo-to. Japan

Monthly estimates of x and y components of polar motion, UT1-TAI, and longitude and obliquity components of precession-nutation offsets have been determined from the VLBI IRIS-P network (Yokoyama et al., 1988: Yoshino et al., 1988), for the period from April, 1987 through October 1988.

24-hour session observations have been conducted on once-per-month basis since April, 1987. The constituent stations and their coordinates adopted in the data analysis are given in Table 1, in which the coordinates of Kashima and Fairbanks were determined with reference to the IRIS coordinates system, using consecutive IRIS-P and IRIS-A observations. The adopted plate motion model is AM0-2.

The radio sources and their adopted coordinates are given in Table 2. During April, 1987 and March, 1988. the objective of the IRIS-P operation was two-fold. namely, EOP determination and time comparison between Kashima and Richmond. Thereafter, we have used a revised observing schedule aiming at more precise EOP determination.

The method of analysis is given in the report of the IERS VLBI analysis center at the National Astronomical Observatory, Japan (Manabe and Yokoyama, 1989) in this annual report.

References

Manabe,S., and Yokoyama,K., 1989: The Data Analysis and the Earth Orientation Results of the IERS VLBI Analysis Center at the National Astronomical Observatory, Japan, IERS Annual Report for the year 1988 (this volume).

Yokoyama,K., Manabe,S., Hara,T., Yoshino,T., Takahashi,Y., and Kawaguchi,N., 1988: The Earth rotation parameters determined with the new IRIS-P VLBI network, Vistas in Astronomy, Vol. 31.

Yoshino.T., Kawaguchi.N., Takahashi,Y.. Heki,K., Yokoyama,K., and Manabe,S., The IRIS-P VLBI experiment for the Earth rotation measurement and time comparison, ibid.

THE DATA ANALYSIS METHOD AND THE EARTH ORIENTATION RESULTS OF THE IERS VLBI ANALYSIS CENTER AT THE NATIONAL ASTRONOMICAL OBSERVATORY JAPAN

S.Manabe and K.Yokoyama. National Astronomical Observatory, Division of Earth Rotation. Mizusawa-shi. Iwate-ken, 023 Japan.

We derived 148 sets of the Earth orientation parameters (EOP's) from both the IRIS-A(129) and IRIS-P VLBI (19) observations from January, 1987 to October, 1988. The derived EOP's are the x and y components of polar motion, UT1-TAI and longitude and obliquity component of the precession-nutation offsets from the IAU1976 precessionand the IAU 1980 nutation table. The other parameters simultaneously with the EOP's are the clock polynomials and the zenith atmospheric delay.

The basic physical models adopted are the same as the ones described in Manabe et al.(1984) except for the atmospheric delay and the plate motion model. We use CfA-2.2 (Davis et al. 1985) as the atmospheric delay model and AMO-2 as the plate motion model. The robust M-estimation method, namely Tukey's biweight method, is used in the parameter fitting.

Table 1 shows the coordinates of the stations at 1984.0 (MJD45700). The IRIS system (Carter, Robertson and Fallon 1988) is adopted as the coordinates of the IRIS-A stations, which are Westford, Ft. Davis, Richmond, Wettzell, Onsala and Bologne. On the other hand the coordinates of Kashima and Fairbanks, which are the member of the IRIS-P but not of IRIS-A, are determined on the basis of the following idea.

Although only the two stations, which are Ft. Davis and Richmond, are in common between IRIS-A and IRIS-P and the observation periods of the two networks do not overlap, it is possible to estimate the EOP's and the coordinates of Kashima and Fairbanks in reference to the other stations, making use of the fact that the two networks observe in consecutive two days. We divide 48 hours into consecutive three intervals spanning 12, 24 and 12 hours, respectively, and assume that x, y and UT1 are constant in each interval. Since in the second interval all the stations contribute to the determination of the EOP and the coordinates of three or more stations are fixed, the EOP and the coordinates of the remaining two stations are safely estimated.

The positions of the radio sources are shown in Yokoyama and Manabe (1989) in this annual report.

The number of observation sessions and the internal precisions of the derived EOP's are summarized in Table 3.

References

Carter,E.W., Robertson,D.S., and Fallon,F.:1988, Polar Motion and UT1 Series Derived from VLBI Observations, Anuual Report of BIH for the Year 1987.

Davis,J.L., Herring,T., Shapiro,I.I., Rogers,A.E.E., and Elgard,G.: 1985, Geodesy by radio interferometry: Effects of atmospheric modeling errors on estimates of baseline length, Radio Science, Vol.20, pp.1593-1607.

Manabe,S., Takahashi,Y., Hanada,H., Ishikawa,T., Fujishita,M., Sato,T., Koike, K., and Yoshino,T.:1984. Physical Models Adopted in KAPRI, Publ. Intern. Latit. Obs. Mizusawa, Vol.XVIII, pp93-104.

Yokoyama,K., Manabe,S., and Yoshino,T.:1989, Earth Orientation Parameters by VLBI IRIS-P Network, IERS Annual Report for the Year 1988(this volume).

TABLE 1.

SSC(NAOMZ)89 R 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
429S010	FAIRBANKS	40408S002	-2281546.882	-1453644.799	5756993.301	NOAM
406S010	FORT DAVIS	40442S003	-1324210.830	-5332023.024	3232118.568	NOAM
409S010	HAYSTACK	40440S003	1492206.923	-4458130.340	4296015.490	NOAM
115S010	WETTZELL	14201S004	4075540.310	931735.336	4801629.022	EURA
203S010	KASHIMA	21701S001	-3997892.158	3276581.596	3724118.464	EURA
103S020	ONSALA	10402S002	3370606.449	711917.595	5349830.451	EURA

SX, SY, SZ = 0.100m. EPOCH-MJD = 45700

TABLE 2.

RADIO SOURCE COORDINATES

RSC(NAOMZ)89 R 01

SOURCE	RIGHT ASCENSION H	M	S	DECLINATION °	'	"	SIGMA R.A. S	SIGMA D. "
0106+013	1	8	38.771080	1	35	0.31790	9.000000	9.00000
0212+735	2	17	30.813140	73	49	32.62150	9.000000	9.00000
0229+131	2	31	45.894050	13	22	54.71670	9.000000	9.00000
0234+285	2	37	52.405670	28	48	8.98950	9.000000	9.00000
0420-014	4	23	15.800710	- 1	20	33.06430	9.000000	9.00000
0528+134	5	30	56.416740	13	31	55.15010	9.000000	9.00000
0552+398	5	55	30.805550	39	48	49.16560	9.000000	9.00000
0851+202	8	54	48.874890	20	6	30.64150	9.000000	9.00000
0923+392	9	27	3.013830	39	2	20.85290	9.000000	9.00000
1144+402	11	46	58.297840	39	58	34.30400	9.000000	9.00000
1226+023	12	29	6.699700	2	3	8.59870	9.000000	9.00000
1404+286	14	7	0.394380	28	27	14.69030	9.000000	9.00000
1637+574	16	38	13.456390	57	20	23.97970	9.000000	9.00000
1641+399	16	42	58.809870	39	48	36.99500	9.000000	9.00000
1741-038	17	43	58.856140	- 3	50	4.61210	9.000000	9.00000
1803+784	18	0	45.684080	78	28	4.01810	9.000000	9.00000
2121+053	21	23	44.517400	5	35	22.09590	9.000000	9.00000
2134+004	21	36	38.586310	0	41	54.21690	9.000000	9.00000
2200+420	22	2	43.291400	42	16	39.98200	9.000000	9.00000
2251+158	22	53	57.747960	16	8	53.56310	9.000000	9.00000

TABLE 3.

EOP(NAOMZ) 89 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		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	82	0.70	82	0.67	82	0.34	82	0.70	82	0.27
1988	66	0.97	66	0.82	66	0.43	66	0.89	66	0.38

POLAR MOTION AND UT1 TIME SERIES DERIVED FROM VLBI OBSERVATIONS

NGS 89 R 01
NGS 89 R 02

W.E. Carter, D.S. Robertson, and F.W. Fallon, 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). More than 170 000 observations amassed during 543 observing sessions conducted between September, 1980, and January, 1989, plus 58 000 observations from 51 NASA CDP observing sessions (added to increase the station coverage to define the terrestrial reference system), were combined in a single least squares adjustment to obtain self consistent Earth orientation time series (Table NGS-3), 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-1). Table NGS-4 contains a daily series of UT1 values for the period April through June, 1984, and April 1985 through January, 1988. 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 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 K1 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). 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). Plate motions are modeled using the no-net-rotation model of Minster and Jordan (Minster and Jordan, 1978), with the reference epoch for the motion defined to be Jan 1, 1984. The most 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, 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 three hours.

X and Y coordinates of the pole derived from satellite laser ranging (SLR) (Eanes et al., 1987), modified to remove a constant offset between the VLBI and SLR time series, were used in processing the single-baseline 24-hour observing sessions, to determine the Y component of the pole prior to January, 1984. After that time values interpolated from the IRIS series were used.

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 Informatik.V 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.

References:

Carter,W.E., D.S.Robertson, and J.R.MacKay, Geodetic Radio Interferometric Surveying: Applications and Results, J.Geophys.Res., 90, 4577-4587, 1985.

Davis,J.L., T.A.Herring, I.I.Shapiro, A.E.E.Rogers, and G.Elgered,Geodesy by Radio Interferometry: Effects of Atmospheric Modeling Errors on Estimates of Baseline Length, Radio Science, 20, 1593-1607, 1985.

Eanes,R.J., B.E.Schutz, and B.D.Tapley, Earth Rotation from Laser Ranging to Lageos, this volume, 1988.

Hellings,R.W., Relativistic Effects in Astronomical Timing Measurements, Astronomical Journal, 91, 650-659, 1986.

Herring,T.A., C.R.Gwinn, and I.I.Shapiro, Geodesy by Radio Interferometry: Studies of the Forced Nutations of the Earth, Part I: Data Analysis, J.Geophys. Res., 91, 4745-4754, 1986a.

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

Robertson,D.S., W.E.Carter, B.D.Tapley, B.E.Schutz, R.J.Eanes, Polar Motion Measurements: Sub-Decimeter Accuracy Verified by Intercomparison, Science, 229, 1259-1261, 1985a.

Robertson,D.S., W.E.Carter, J.A.Campbell, and H.Schuh, Daily UT1 Determinations from IRIS Very Long Baseline Interferometry, Nature, 316, 424-427, 1985b.

Robertson,D.S., F.W.Fallon and W.E.Carter, Celestial Reference Coordinate Systems: Sub-millisecond of Arc Repeatability Demonstrated with VLBI Observations, Astron.J., 91, 1456-1462, 1986.

Wahr,J.M., Deformation Induced by Polar Motion, J.Geophys.Res., 90, 9363-9368, 1985.

Wilkins,G.A., (ed.), Project MERIT: Report on the second MERIT Workshop held at the Royal Greenwich Observatory on 1983 May 15-19, Herstmonceux, 74 pp., 1984.

Table NGS-1. SSC(NGS) 89 R 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
430S010	KAUAI	40424S001	-5543845.981	-2054564.139	2387814.101	.008	.013	.016	PCFC	45700
429S010	FAIRBANKS	40408S002	-2281546.859	-1453644.888	5756993.376	.004	.005	.010	NOAM	45700
407S010	HAT CREEK	40489S001	-2523969.705	-4123506.325	4147752.809	.003	.007	.009	NOAM	45700
428S010	VANDENBERG AFB	40420S003	-2678097.242	-4525455.466	3597414.085	.003	.007	.009	NOAM	45700
405S010	OWENS VALLEY	40439S002	-2409600.523	-4478349.527	3838603.405	.002	.007	.008	NOAM	45700
427S010	GOLDSTONE	40405S009	-2356170.776	-4646755.874	3668470.805	.002	.006	.008	NOAM	45700
432S010	PLATTEVILLE	40496S003	-1240708.690	-4720457.402	4094484.501	.005	.017	.015	NOAM	45700
406S010	FORT DAVIS	40442S003	-1324210.748	-5332023.121	3232118.544	.001	.005	.005	NOAM	45700
412S010	RICHMOND	40499S001	961258.300	-5674090.031	2740533.791	.002	.003	.003	NOAM	45700
404S010	GREENBANK	40441S001	882880.246	-4924482.259	3944130.710	.002	.007	.006	NOAM	45700
415S010	MARYLAND POINT	40490S001	1106629.672	-4882907.123	3938086.969	.005	.020	.016	NOAM	45700
403S010	HAYSTACK	40440S002	1492405.134	-4457266.469	4296881.768	.001	.003	.003	NOAM	45700
409S010	HAYSTACK	40440S003	1492206.990	-4458130.442	4296015.513	.010	.010	.010	NOAM	45700
106S010	CHILBOLTON	13201S002	4008310.523	-100650.727	4943794.492	.011	.006	.016	EURA	45700
101S010	EFFELSBERG	14209S001	4033947.898	486990.539	4900430.437	.014	.007	.020	EURA	45700
112S010	BOLOGNE	12711S001	4461370.484	919596.858	4449558.852	.009	.005	.012	EURA	45700
103S020	ONSALA	10402S002	3370606.507	711917.568	5349830.477	.006	.004	.010	EURA	45700
115S010	WETTZELL	14201S004	4075540.371	931735.319	4801629.057	.007	.004	.010	EURA	45700
301S010	JOHANNESBURG	30302S001	5085442.778	2668263.461	-2768697.652	.026	.013	.016	AFRC	45700
203S010	KASHIMA	21701S001	-3997892.233	3276581.442	3724118.438	.013	.009	.020	EURA	45700
507S010	KWAJALEIN ATOLL	50505S003	-6143536.543	1363997.274	1034707.606	.019	.015	.022	PCFC	45700

Table NGS-2.

RADIO SOURCE COORDINATES RSC(NGS) 89 R 01

SOURCE	RIGHT ASCENSION				DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	′	″		S	″
0106+013	1	8	38.771070	1	35	0.31890		0.000002	0.00020
0212+735	2	17	30.813210	73	49	32.62230		0.000036	0.00020
0224+671	2	28	50.051450	67	21	3.02980		0.000040	0.00030
0229+131	2	31	45.894050	13	22	54.71760		0.000004	0.00020
0234+285	2	37	52.405660	28	48	8.99070		0.000007	0.00020
0235+164	2	38	38.930110	16	36	59.27670		0.000011	0.00040
0300+470	3	3	35.242150	47	16	16.27580		0.000031	0.00040
0316+413	3	19	48.160040	41	30	42.10390		0.000030	0.00040
0355+508	3	59	29.747230	50	57	50.16240		0.000017	0.00020
0420-014	4	23	15.800700	- 1	20	33.06360		0.000003	0.00020
0454-234	4	57	3.179220	-23	24	52.01830		0.000016	0.00030
0528+134	5	30	56.416750	13	31	55.15060		0.000004	0.00020
0552+398	5	55	30.805600	39	48	49.16590		0.000011	0.00010
0727-115	7	30	19.112450	-11	41	12.59940		0.000008	0.00020
0742+103	7	45	33.059590	10	11	12.68770		0.000091	0.00250
0851+202	8	54	48.874910	20	6	30.64140		0.000004	0.00020
0923+392	9	27	3.013880	39	2	20.85250		0.000009	0.00020
1034-293	10	37	16.079720	-29	34	2.81160		0.000023	0.00040
1055+018	10	58	29.605190	1	33	58.82400		0.000005	0.00030
1144+402	11	46	58.297900	39	58	34.30560		0.000011	0.00020
1226+023	12	29	6.699690	2	3	8.59880		0.000002	0.00020
1253-055	12	56	11.166470	- 5	47	21.52170		0.000069	0.00230
1308+326	13	10	28.663870	32	20	43.78300		0.000007	0.00020
1354+195	13	57	4.436630	19	19	7.37200		0.000014	0.00030
1404+286	14	7	0.394390	28	27	14.68970		0.000005	0.00020
1418+546	14	19	46.597370	54	23	14.78690		0.000025	0.00020
1502+106	15	4	24.979770	10	29	39.19870		0.000006	0.00020
1548+056	15	50	35.269190	5	27	10.44890		0.000005	0.00020
1633+382	16	35	15.492900	38	8	4.50080		0.000010	0.00020
1637+574	16	38	13.456340	57	20	23.97910		0.000021	0.00020
1642+690	16	42	7.848660	68	56	39.75630		0.000039	0.00020
1641+399	16	42	58.809930	39	48	36.99380		0.000009	0.00010
1730-130	17	33	2.705720	-13	4	49.54740		0.000009	0.00020
1741-038	17	43	58.856090	- 3	50	4.61560		0.000004	0.00020
1749+096	17	51	32.818560	9	39	0.72900		0.000008	0.00030
1803+784	18	0	45.683850	78	28	4.01790		0.000059	0.00010
1921-293	19	24	51.055890	-29	14	30.11920		0.000021	0.00030
1923+210	19	25	59.605380	21	6	26.16050		0.000027	0.00100
1928+738	19	27	48.494730	73	58	1.57010		0.000156	0.00100
1958-179	20	0	57.090370	-17	48	57.67150		0.000064	0.00040

Table NGS-2. (Cont.)

RADIO SOURCE COORDINATES RSC(NGS) 89 R 01

SOURCE	RIGHT ASCENSION			DECLINATION			SIGMA R.A.	SIGMA D.
	H	M	S	°	'	"	S	"
2121+053	21	23	44.517360	5	35	22.09390	0.000003	0.00020
2128-123	21	31	35.261630	-12	7	4.79420	0.000028	0.00040
2134+004	21	36	38.586300	0	41	54.21520	0.000002	0.00020
2145+067	21	48	5.458650	6	57	38.60490	0.000005	0.00020
2155-152	21	58	6.281850	-15	1	9.32540	0.000038	0.00070
2200+420	22	2	43.291330	42	16	39.98030	0.000009	0.00020
2216-038	22	18	52.037710	- 3	35	36.87820	0.000004	0.00030
2234+282	22	36	22.470820	28	28	57.41400	0.000011	0.00030
2251+158	22	53	57.747910	16	8	53.56160	0.000003	0.00020
2345-167	23	48	2.608490	-16	31	12.02060	0.000011	0.00030

Table NGS-3.

EOP(NGS) 89 R 01 Available from 1980 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		dPsi		dEps	
	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma	Nb	Sigma
1980	17	1.17	16	1.33	17	0.58	17	1.55	17	0.53
1981	31	2.86	6	1.76	31	2.13	31	2.59	31	1.26
1982	51	2.63	10	2.54	51	2.19	51	2.32	51	0.87
1983	57	2.14	17	2.19	57	1.57	57	2.35	57	0.77
1984	72	1.06	70	1.30	72	0.63	72	1.04	72	0.37
1985	72	1.17	70	0.68	72	0.40	72	0.92	72	0.41
1986	79	0.77	79	0.76	79	0.40	79	0.88	79	0.32
1987	81	0.82	81	0.84	81	0.43	81	0.90	81	0.32
1988	77	0.72	77	0.66	77	0.37	77	0.85	77	0.31

Table NGS-4.

EOP(NGS) 89 R 02 Available from 1986 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	UT1	
	Nb	Sigma
1986	237	0.58
1987	246	0.58
1988	255	0.58

POLAR MOTION AND UT1 FROM IRIS-A

SHA 89 R 01

Luo Shifang. Zhou Ruesian. Xue Zhule. Yi Jian.
Shanghai Observatory. Academia Sinica, Shanghai. China.

The series of Polar Motion and UT1 from April to November of 1987 have been derived from the observations of IRIS-A (International Radio Interferometric Surveying-Atlantic network), which were provided by NAO of Japan and NGS, NOAA of USA with VLBI data base format.

The models used to calculate the motions and deformations of Earth were consistent with MERIT Standards (Melbourne et al.,1983). The model for ocean loading has been used, but no model for plate motion. AIC (Akaike Information Criteria) in Time Series Analysis has been used to determine the number and the time of the broken points and the models in each section for the clock behaviour (Zheng Dawei et al.1986). The priori source positions, the coordinates and the zenith path lengths for stations are listed in tables 1 and 2, respectively.

References

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

2. Zheng Dawei, Shifang Luo and J.R. McKay. An Optical Identification of Clock Behaviour Model for VLBI, Annuals of Shanghai Observatory, No 8, pp. 25-31, 1986.

Table 1. SSC(SHA) 89 R 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE	Lz (ns)
409S010	HAYSTACK	40440S003	1492208.554	-4458131.329	4296015.877	NOAM	7.5037
406S010	FORT DAVIS	40442S003	-1324209.147	-5332024.062	3232118.978	NOAM	6.7918
115S010	WETTZELL	14201S004	4075541.906	931734.189	4801629.393	EURA	7.4981
103S020	ONSALA	10402S002	3370608.089	711916.448	5349830.842	EURA	7.9120
412S010	RICHMOND	40499S001	961259.862	-5674090.979	2740534.258	NOAM	8.5626
112S010	BOLOGNE	12711S001	4461370.900	919590.900	4449563.800	EURA	7.0000

SX, SY, SZ = 0.100m. EPOCH-MJD = 46993.

Table 2.

RADIO SOURCE COORDINATES RSC(SHA) 89 R 01

SOURCE	RIGHT ASCENSION H M S	DECLINATION ° ' "	SIGMA R.A. S	SIGMA D. "
0106+013	1 8 38.771040	1 35 0.32320	9.000000	9.00000
0212+735	2 17 30.813390	73 49 32.62330	9.000000	9.00000
0229+131	2 31 45.893920	13 22 54.72060	9.000000	9.00000
0528+134	5 30 56.416650	13 31 55.14840	9.000000	9.00000
0552+398	5 55 30.805640	39 48 49.16540	9.000000	9.00000
0851+202	8 54 48.874860	20 6 30.63900	9.000000	9.00000
0923+392	9 27 3.013750	39 2 20.85050	9.000000	9.00000
1226+023	12 29 6.699700	2 3 8.59580	9.000000	9.00000
1404+286	14 7 0.394190	28 27 14.68840	9.000000	9.00000
1641+399	16 42 58.809670	39 48 36.99570	9.000000	9.00000
1803+784	18 0 45.683640	78 28 4.02060	9.000000	9.00000
2134+004	21 36 38.586150	0 41 54.21950	9.000000	9.00000
2200+420	22 2 43.291210	42 16 39.98370	9.000000	9.00000
2251+158	22 53 57.747860	16 8 53.56550	9.000000	9.00000

Table 3.

EOP(SHA) 89 R 01 Available from 1987 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		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1987	41	0.72	47	0.50	48	0.24

LUNAR LASER RANGING

EARTH ROTATION (UT0) FROM LUNAR LASER RANGING CERGA 89 M 01

A determination of UT0 has been made at CERGA from the Lunar Laser Ranging data obtained from October 1987 till March 1989.

C. Veillet. J. Pham-Van OCA/CERGA - Avenue Copernic - F-06130 Grasse

Normal points have been used from three stations : the McDonald Laser Ranging Station (MLRS). the Haleakala station on Maui (Hawai), and the CERGA station in Grasse.

The same method as JPL has been used (Dickey et al..1985) for deriving UT0-UTC values from residuals on the measured ranges. Precession (Lieske et al., 1977: Lieske, 1979), nutation (Seidelmann. 1982) and Greenwich mean sidereal time (Aoki et al., 1982). No plate motion has been considered for this series covering 18 months.

The lunar position from the JPL ephemeris DE121/LE65 has been modified by fitting the lunar ephemeris to the observations (using the JPL partials). The lunar libration (LLB13) hasn't been changed.

A set of station coordinates has been determined with this UT series. The following table gives the values determined from the data set (the formal errors are given in the unit of the last digit). TLRS position is poorly determined as the data set from this station is small.

SSC(CERGA)89 M 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
10S001	GRASSE	10002S002	4581692.174	556195.580	4389354.610	EURA
2S002	FORT DAVIS	40442S007	-1330121.190	-5328531.937	3236146.778	NOAM
8S002	MAUI	40445S005	-5466006.939	-2404427.766	2242188.408	PCFC
2S003	FORT DAVIS	40442S014	-1330021.660	-5328402.784	3236481.167	NOAM

SX SY, SZ = 0.030m. EPOCH-MJD = 47328.

Separation between Haleakala transmitter and receiver has been taken as given in BIH Annual Report for 1986 page D-29, and conforms to a survey.

ACKNOWLEDGEMENTS.
We wish to acknowledge station staff at Mc Donald, Haleakala and CERGA for getting data, as well as R. Ricklefs and P. Shelus at UTex for MLRS and Maui normal points, and JPL for the ephemeris provided.

REFERENCES

Aoki S., Guinot B., Kaplan G.H., Kinoshita.H., McCarthy,D.D., and Seidelmann,P. K., 1982. The new definition of Universal Time, Astron. Astrophys. 105,1.

Dickey,J.O., Newhall.XX, and Williams,J.G., 1985. Earth orientation from Lunar Laser Ranging and an error analysis of Polar Motion Services. J. Geophys. Res. 90. B11, 9353.

Lieske,J.H., Lederle,T., Fricke,W., and Morando,B., 1977. Expressions for the Precession quantities based upon the IAU (1976) System of astronomical constants. Astron. Astrophys. 58, 1.

Lieske,J.H., 1979. Precession matrix based on IAU (1976) System of Astronomical constants. Astron. Astrophys. 73, 282.

Seidelmann,P.K., 1982. 1980 IAU theory of nutation : the final report of the IAU Working Group on nutation. Celest. Mech. 27, 79.

EOP(CERGA)89 M 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	Nb	UTO Sigma
1987	22	2.78
1988	79	3.19

EARTH ROTATION (UT0) FROM LUNAR LASER RANGING JPL 89 M 01

XX 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. 1989. 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 1987 have been submitted previous-ly : 81 such values were derived from data acquired in 1988.

The full range data set comprises 6000 normal points taken from six 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: the Orroral Valley observatory in Australia: 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. Uncertainties in the submitted values have a median value of 0.20ms, with a minimum value of 0.04ms.

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 DE121/LE65; this ephemeris uses the equator and equinox of B1950.0. It is on the dynamical equinox and has a zero point consistent with that of the FK5 star catalog. The numerically integrated lunar physical librations used are designated LLB13. Small corrections to the nominal ephemerides and librations result during the fitting process.

This year, plate motion has been applied to the station coordinates using the AM0-2 model of Minster and Jordan (1978). The LLR UT0 system has been adjusted so that it approximates that of the IERS.

A correction to the luni-solar precession constant (Lieske et al.,1977; Lieske, 1979) has been estimated, giving a correction of -0.0031"/y. 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 0.0021" (taken from Herring's solution given in Carter, 1988) applied ($\Delta\varepsilon$ = 0.0021" cos 1', and sin $\varepsilon\,\Delta\psi$ = 0.0021 sin 1').

Corrections to the 18.6y nutation coefficients were estimated, yielding

$$\Delta\varepsilon = +0.0045''\cos\Omega + 0.0034''\sin\Omega$$
$$\sin\varepsilon\,\Delta\psi = -0.0055''\sin\Omega + 0.0025''\cos\Omega$$

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 preliminary solid-body correction of Kinoshita (1988). Subject to the two constraints, the uncertainty in the four nutation coefficients is about 0.002", and the precession uncertainty is 0.0006"/y. Without the two constraints these uncertainties would be larger.

With the production of the 1988 values of UT0-UTC a set of station locations has been established. The base epoch for plate motion is January 1, 1988 (MJD 2447161.5). The IERS designation is EOP SSC (JPL) 89 M 01, and the components are given in the following table:

SSC(JPL) 89 M 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
2S001	FORT DAVIS	40442S002	-1330781.573	-5328755.568	3235697.347	NOAM
2S002	FORT DAVIS	40442S007	-1330121.335	-5328532.089	3236146.516	NOAM
2S003	FORT DAVIS	40442S014	-1330021.586	-5328403.177	3236481.500	NOAM
8S002	MAUI	40445S005	-5466007.069	-2404427.759	2242188.444	PCFC
10S001	GRASSE	10002S002	4581692.249	556195.508	4389354.856	EURA

SX SY SZ = 0.030m. EPOCH-MJD = 47161.

Cylindrical station coordinates

Station	Spin Radius (meters)	East Longitude (arc seconds)	Z-Height (meters)
McDonald 2.7 m	5492414.360	921520.7967	3235697.347
MLRS (old site)	5492037.599	921542.8208	3236146.516
MLRS (new site)	5491888.367	921545.2830	3236481.500
Haleakala Tmtr	5971474.368	733478.7249	2242188.444
CERGA	4615328.516	24917.6355	4389354.856

Haleakala Rcvr-Tmtr	Spin Radius	-7.446m
	East Longitude	0.000"
	Z-height	18.151m

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

It should be noted that the McDonald 2.7m 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 Mark3 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, J.Storm, and J.Ries at the University of Texas for the MLRS and for Haleakala data. M.White and 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.

References.

Aoki,S., Guinot,B., Kaplan,G.H., Kinoshita,H., McCarthy,D.D., and Seidelmann,P. K., "The New Definition of Universal Time," Astron.Astrophys. 105,1 (1982).

Carter,W.E., "Corrections to the IAU 1980 Nutation Series", Annual Report for 1987, D-105, Bureau International de l'Heure, Paris (1988).

Dickey,J.O., Newhall,XX, and Williams,J.G., "Earth Orientation from Lunar Laser Ranging and an Error Analysis of Polar Motion Services", J.Geophys.Res. 90, B11, 9353 (1985).

Kinoshita,H.,"Preliminary Corrections to the Nutation with Argument N and 2N", Annual Report for 1987 , D-103, Bureau International de l'Heure, Paris (1988).

Lieske,J.H., Lederle,T., Fricke,W., and Morando,W.,"Expressions for the Precession Quantities Based upon the IAU (1976) System of Astronomical Constants", Astron.Astrophys. 58, 1 (1977).

Lieske,J.H.,"Precession Matrix Based on IAU (1976) System of Astronomical Constants", Astron. Astrophys. 73, 282 (1979).

Minster,J.B. and Jordan,T.H.,"Present-Day Plate Motions", J.Geophys.Res. 83, B11 (1978).

Seidelmann,P.K.,"1980 IAU Theory of Nutation: The Final Report of the IAU Working Group on Nutation," Celest.Mech. 27,79 (1982).

Williams,J.G. and Melbourne,W.G.,"Comments on the Effects of Adopting New Precession and Equinox Corrections", Proceedings, High-Precision Earth Rotation and Earth-Moon Dynamics: Lunar Distances and Related Observations, O.Calame, ed., 293-304, D.Reidel, Hingham, MA (1982).

Zhu,S.Y. and Mueller,I.I.,"Effects of Adopting New Precession, Nutation, and Equinox Corrections on the Terrestrial Reference Frame", Bull. Geod., 57, 29-42 (1983).

EOP(JPL) 89 M 01 Available from 1970 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	UTO	
	Nb	Sigma
1970	14	17.24
1971	33	14.73
1972	73	9.61
1973	104	14.10
1974	72	12.38
1975	81	13.73
1976	75	12.20
1977	71	9.44
1978	61	12.00
1979	72	9.80
1980	77	9.62
1981	46	7.60
1982	6	10.26
1983	10	10.71
1984	78	11.35
1985	163	10.60
1986	42	6.79
1987	45	2.86
1988	80	4.16

UT0 DETERMINATION FROM LUNAR LASER RANGING OBSERVATIONS UTXM0 89 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 all short pulse Neodymium-YAG lunar laser ranging data to determine UT0-UTC. The data were acquired between November 1984 and December 1988. A total of 1206 normal points, from the Haleakala Observatory on Maui, Hawaii, the McDonald Laser Ranging Station (saddle site and Mt. Fowlkes site) near Fort Davis, Texas, 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 135 station/reflector pair estimations of UT0-UTC on 114 nights, including 56 UT0 estimates in 1988. A significant development of 1988 was the acquisition, by the CERGA station, of data on several nights which permitted the determination of UT0 from more than one, and sometimes all four, retroreflectors.

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 MERIT standards were used with constrained corrections made to 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 University of Texas Center for Space Research (CSR) LGN7689. We estimated slopes for the polar motion components of this series and a piecewise linear spline to model long period deficiencies in the UT1 series. The longitude of the terrestrial frame was tied by fixing the zero point of the CSR Earth orientation adjustments at the last CSR IRIS tie of 13 January 1989. The station coordinates which resulted from the fit are given 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 Maui and CERGA.

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 a bias. The nightly corrections were then added to the corrections contained in the UT1 spline, and the a priori UT1-UTC 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 weighted rms of the final postfit range residuals was 2.9 cm.

References

Langley,R.B., R.W.King, I.I.Shapiro, "Earth Rotation from Lunar Laser Ranging", J. Geophys. Res., 86, 11913-11918. 1981.

Stolz,A., P.L.Bender, J.E.Faller, E.C.Silverberg, J.D.Mulholland, P.J.Shelus, J.G.Williams, W.E.Carter, D.G.Gurnie, W.M.Kaula. "Earth Rotation Measured by Lunar Laser Ranging". Science, 193, 997-999, 1976.

SSC(UTXMO)89 M 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
2M001	FORT DAVIS	40442M001	-1330185.538	-5328511.363	3236150.176	NOAM
2M002	FORT DAVIS	40442M006	-1330081.173	-5328386.640	3236480.617	NOAM
8M001	MAUI	40445M001	-5466033.416	-2404366.189	2242187.274	PCFC
10S001	GRASSE	10002S002	4581698.654	556143.910	4389354.433	EURA

SX SY. SZ = 0.100m. EPOCH-MJD = 45700.

EOP(UTXMO) 89 M 01 **Available from 1984 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	UTO Nb	UTO Sigma
1984	1	1.41
1985	25	0.63
1986	20	0.41
1987	32	0.38
1988	57	0.23

DETERMINATION OF UNIVERSAL TIME BY LUNAR LASER RANGING SHA 86 M 01

Jin Wenjing Qian Changxi
Shanghai Observatory Academia Sinica. Shanghai. China

Universal time has been determined from global data of Lunar Laser Ranging during Jan.1-Sept.7 1988. The data set obtained from McDonald. Grasse and Haleakala contains 358 normal points reflected from four retroreflectors and were usable for determination of universal time. Due to the needs of solving the normal equation, the data with observing interval of less than one hour, one normal point and bad points in a day rejected. Only 192 normal points have been used for the present results. The theoretical distances from the stations to the retro-reflectors of the Moon are calculated using the IAU 1976 system of astronomical constants (Melbourne et al.,1983). The new IAU expressions have been used for precession, nutation and Greenwith mean sidereal time. The influence of ocean load, lunar tide and Earth tide are taken into account. The planetary and lunar ephemeris DE200/LE200 are used for calculating the positions of the Moon, the Earth and major planets. LLB200 is adopted for calculating the lunar physical libration.

The station coordinates are adopted as follows.

SSC(SHA) 86 M 01

IGNF NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
2S002	FORT DAVIS	40442S007	-1330120.991	-5328532.157	3236146.357	NOAM
10S001	GRASSE	10002S002	4581692.359	556195.489	4389354.773	EURA
8S001	MAUI	40445S002	-5466003.619	-2404426.691	2242197.421	PCFC
2S003	FORT DAVIS	40442S014	-1330021.443	-5328403.185	3236481.380	NOAM

SX SY, SZ = 0.100m. EPOCH-MJD = 45700.

The reflector coordinates are adopted from MERIT standards.

The mathematical model is described in Reference (Jin et al.,1985).UTOR-UTC is calculated in one-day interval. The precision of the normal point is taken for the weight of observational equation.

Acknowleedgments

The Planetary ephemeris DE200/LE200 and numerically integrated lunar physical libration LLB200 are supplied by Jet Propulsion Laboratory, California Institute of Technology. The global data of lunat laser ranging are obtained from Dr. Veillet, CERGA.

References

W.Melbourne et al. Project MERIT Standards USNO Circular No 167.

Jin Wenjing, Wang Qiangguo. Determination of ERP with Lunar Laser Ranging and Discussion of the Influence of the Adopted Parameters presented to the Third MERIT Workshop. Ohio University, July, 1985.

ERP(SHA) 86 M 01 **Available from 1983 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	UT1	
	Nb	Sigma
1983	14	18.78
1984	66	11.49
1985	103	17.71
1986	46	14.00
1987	49	1.91
1988	61	2.16

SATELLITE LASER RANGING

EARTH ROTATION FROM LAGEOS LASER RANGING

CSR 89 L 02

B. E. Schutz B. D. Tapley R. J. Eanes and M. M. Watkins
Center for Space Research - The University of Texas at Austin
Austin TX 78712-1085

A single, continuous Lageos ephemeris was fit to Lageos laser range data for the interval from May 1976 to February 1989. The data base contained about 360 000 three-minute normal points formed from over 37 000 passes collected from more than 100 sites.

The force and measurement models were the MERIT Standards with some exceptions. A preliminary Topex gravity field. PTGF-3 (Tapley, et al., 1987). was used with an adopted value of GM equal to 398600.4404 km**3/s**2. Some ocean tide parameters were adjusted in the solution. The laser range residual weighted RMS was 28 cm for the 12.8 year span; however, the postprocessing weighted RMS was 8.5 cm. The postprocessing allowed further adjustment of the orbit elements and Earth orientation within time-dependent intervals. For 1976-1979. 15-day intervals were used, whereas 6-day and 3-day intervals were used in the periods 1980-1983 and 1983-1989, respectively. In the later time intervals, the weighted RMS was 4 to 5 cm. A further adjustment for time-dependent station coordinates was accomplished using 60-day intervals, however. only the mean coordinates are reported here.

The stations were assumed to be attached to the tectonic plates noted in the following table with rates defined by the AM1-2 model. The epoch of the derived station coordinates is 1988 January 1 00:00 UTC.

The estimated UT1 values contain Lageos node model errors which were filtered to remove periods greater than about 80 days. As a consequence, the long period (greater than 80 days) represents the reference UT1 series, but for periods below about 40 days, the Lageos UT1 estimates are independent of the reference series.

References

Tapley,B.D., B.E.Schutz, C.K.Shum J.C.Ries and D.N.Yuan, An improved model for the Earth's gravity field, Proc. IUGG 19th General Assembly, Vancouver, August 1987.

SSC(CSR) 89 L 02

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
1181S001	POTSDAM	14106S001	3800621.487	882005.127	5028859.474	.036	.035	.023	EURA	47161
1884S001	RIGA	12302S002	3183895.971	1421496.199	5322803.882	.237	.270	.186	EURA	47161
1953S001	SANTIAGO DE CUBA	40701S001	1474548.287	-5811242.476	2168945.067	.100	.071	.100	NOAM	47161
7035M001	SAN DIEGO	40436M003	-2428826.870	-4799754.092	3417267.173	.021	.019	.017	PCFC	47161
7051M001	QUINCY	40433M001	-2516893.342	-4198844.913	4076411.485	.022	.020	.017	NOAM	47161
7061S001	EASTER ISLAND	41703S002	-1884985.186	-5357609.287	-2892853.992	.045	.035	.033	NAZC	47161
7062M001	SAN DIEGO	40436M002	-2428826.170	-4799750.277	3417272.876	.020	.017	.019	PCFC	47161
7063M001	WASHINGTON	40451M112	1130714.500	-4831367.773	3994087.399	.018	.013	.014	NOAM	47161
7067M001	BERMUDA	42501M001	2308538.269	-4874080.101	3393628.585	.070	.047	.073	NOAM	47161
7069M001	PATRICK AFB	40417M002	917958.601	-5548370.248	2998776.658	.118	.066	.094	NOAM	47161
7080M001	FORT DAVIS	40442M006	-1330021.272	-5328401.732	3236480.936	.016	.010	.014	NOAM	47161
7082M001	BEAR LAKE	40438M001	-1735997.376	-4425047.955	4241430.476	.030	.026	.021	NOAM	47161
7084M001	OWENS VALLEY	40439M003	-2410590.303	-4477745.094	3838648.485	.100	.093	.058	NOAM	47161
7085M001	GOLDSTONE	40405M001	-2353394.104	-4641529.082	3676898.986	.088	.100	.065	NOAM	47161
7086M001	FORT DAVIS	40442M001	-1330125.610	-5328526.465	3236150.379	.015	.009	.013	NOAM	47161
7090M001	YARRAGADEE	50107M001	-2389006.200	5043329.408	-3078525.391	.014	.009	.013	INDI	47161
7091M001	HAYSTACK	40440M001	1492453.556	-4457278.790	4296815.914	.026	.023	.017	NOAM	47161
7092M001	KWAJALEIN ATOLL	50505M001	-6143447.139	1364700.628	1034163.170	.017	.028	.028	PCFC	47161
7096M001	AMERICAN SAMOA	50503M001	-6100045.972	-996202.697	-1568976.180	.014	.024	.023	PCFC	47161
7097M001	EASTER ISLAND	41703M002	-1884984.827	-5357608.038	-2892853.296	.023	.018	.020	NAZC	47161
7100M001	WASHINGTON	40451M106	1131355.465	-4831169.112	3994131.978	.162	.132	.145	NOAM	47161
7101M001	WASHINGTON	40451M101	1131240.195	-4831179.869	3994148.466	.079	.053	.078	NOAM	47161
7102M001	WASHINGTON	40451M102	1130686.378	-4831353.065	3994110.933	.019	.014	.015	NOAM	47161
7103M001	WASHINGTON	40451M103	1130685.374	-4831348.750	3994116.371	.025	.023	.018	NOAM	47161
7104M001	WASHINGTON	40451M104	1131095.589	-4831196.954	3994170.733	.061	.051	.051	NOAM	47161
7105M001	WASHINGTON	40451M105	1130719.505	-4831350.588	3994106.528	.015	.010	.012	NOAM	47161
7109M001	QUINCY	40433M002	-2517234.916	-4198555.981	4076569.782	.014	.011	.012	NOAM	47161
7110M001	MONUMENT PEAK	40497M001	-2386278.203	-4802354.091	3444881.569	.014	.010	.013	PCFC	47161
7112M001	PLATTEVILLE	40496M001	-1240678.439	-4720463.245	4094480.700	.016	.011	.012	NOAM	47161
7114M001	OWENS VALLEY	40439M001	-2410422.629	-4477802.494	3838686.769	.017	.014	.014	NOAM	47161

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7115M001	GOLDSTONE	40405M002	-2350861.871	-4655546.116	3660997.971	.017	.014	.015	NOAM	47161
7120M001	MAUI	40445M002	-5465998.548	-2404408.075	2242228.603	.010	.017	.017	PCFC	47161
7121M001	MOTU HIUMOO	92202M002	-5345865.530	-2958246.263	-1824623.628	.011	.016	.017	PCFC	47161
7122M001	MAZATLAN	40504M001	-1660089.656	-5619100.229	2511637.978	.015	.008	.014	NOAM	47161
7123M001	MOTU HIUMOO	92202M003	-5345865.500	-2958246.241	-1824623.680	.018	.023	.023	PCFC	47161
7125M001	WASHINGTON	40451M114	1130745.563	-4831368.074	3994077.101	.132	.109	.086	NOAM	47161
7130M001	WASHINGTON	40451M116	1130735.056	-4831324.653	3994132.359	.128	.109	.087	NOAM	47161
7210M001	MAUI	40445M001	-5466006.615	-2404427.458	2242187.634	.008	.014	.015	PCFC	47161
7220M001	MONUMENT PEAK	40497M002	-2386292.537	-4802347.259	3444881.046	.021	.019	.019	PCFC	47161
7265M001	GOLDSTONE	40405M006	-2356475.920	-4646618.088	3668424.857	.024	.024	.020	NOAM	47161
7274M001	MONUMENT PEAK	40497M003	-2386289.602	-4802346.258	3444884.119	.023	.021	.019	PCFC	47161
7288M001	GOLDSTONE	40405M013	-2356494.289	-4646607.440	3668426.760	.022	.017	.019	NOAM	47161
7295M001	RICHMOND	40499M002	961318.671	-5674090.990	2740489.606	.029	.018	.026	NOAM	47161
7400M001	SANTIAGO	41705M001	1769699.322	-5044613.130	-3468260.020	.031	.021	.028	SOAM	47161
7401M001	CERRO TOLOLO	41706M001	1815516.674	-5213465.076	-3187999.363	.023	.016	.021	SOAM	47161
7510M001	ASKITES	12612M001	4353445.203	2082666.049	4156506.518	.016	.020	.016	EURA	47161
7512M001	KATAVIA	12615M001	4573400.331	2409321.949	3723881.634	.017	.022	.018	EURA	47161
7515M001	DIONYSOS	12602M002	4595216.711	2039435.067	3912629.377	.015	.019	.016	EURA	47161
7517M001	ROUMELLI	12613M001	4728694.960	2174373.104	3674572.828	.014	.018	.016	EURA	47161
7520M001	KARITSA	12614M001	4596042.867	1733476.563	4055720.710	.023	.025	.019	EURA	47161
7525M001	XRISOKALARIA	12616M001	4745949.798	1905705.678	3799168.918	.019	.022	.019	EURA	47161
7530S001	BAR GIYYORA	20702S001	4443968.770	3121946.609	3334695.318	.023	.025	.023	AFRC	47161
7540M001	MATERA	12734M005	4641984.815	1393057.458	4133233.320	.030	.030	.023	EURA	47161
7541M001	MATERA	12734M004	4641990.532	1393042.024	4133231.711	.020	.023	.017	EURA	47161
7544M001	LAMPEDUSA	12706M001	5072832.196	1130885.945	3684836.831	.022	.028	.021	EURA	47161
7545M001	CAGLIARI	12725M002	4893398.243	772673.039	4004140.851	.018	.025	.019	EURA	47161
7546M001	BOLOGNE	12711M002	4461399.890	919566.627	4449510.393	.064	.090	.052	EURA	47161
7550M001	TRIESTE	12718M002	4336738.800	1071271.253	4537910.910	.033	.043	.028	EURA	47161
7575M001	DIYARBAKIR	20801M001	3848636.370	3251760.706	3898909.088	.037	.037	.029	EURA	47161
7580M001	MELENGICLICK	20803M001	4247620.849	2778638.741	3851607.372	.026	.032	.020	EURA	47161

SSC(CSR) 89 L 02

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7585M001	YOZGAT	20802M001	4029731.026	2802093.086	4062067.868	.042	.053	.026	EURA	47161
7587M001	YIGILCA	20804M001	4117362.328	2517076.601	4157678.902	.030	.026	.020	EURA	47161
7596S001	WETTZELL	14201S010	4075585.489	931837.518	4801559.135	.027	.034	.021	EURA	47161
7599S001	WETTZELL	14201S007	4075517.624	931753.856	4801630.192	.060	.064	.040	EURA	47161
7805S001	METSAHOVI	10503S001	2892595.358	1311808.207	5512609.884	.138	.118	.078	EURA	47161
7810S001	ZIMMERWALD	14001S001	4331283.783	567549.298	4633139.826	.016	.019	.013	EURA	47161
7831S001	HELWAN	30101S001	4728283.844	2879670.408	3156894.110	.203	.162	.130	AFRC	47161
7833S001	KOOTWIJK	13504S001	3899224.257	396742.657	5015073.770	.035	.036	.023	EURA	47161
8833M001	KOOTWIJK	13504M002	3899238.047	396768.985	5015055.124	.022	.026	.017	EURA	47161
7834S001	WETTZELL	14201S002	4075530.300	931781.077	4801618.122	.015	.018	.012	EURA	47161
7835S001	GRASSE	10002S001	4581691.978	556159.125	4389359.262	.012	.016	.012	EURA	47161
7837S001	SHANGHAI	21605S001	-2831087.321	4676203.715	3275172.835	.094	.081	.070	EURA	47161
7838S001	SIMOSATO	21726S001	-3822388.009	3699363.804	3507573.109	.013	.013	.013	EURA	47161
7839S001	GRAZ	11001S002	4194426.927	1162693.666	4647246.415	.012	.015	.011	EURA	47161
7840S001	HERSTMONCEUX	13212S001	4033463.987	23662.125	4924304.934	.012	.015	.010	EURA	47161
7843S001	ORRORAL	50103S008	-4446476.618	2678127.296	-3696251.606	.013	.015	.014	INDI	47161
7853M001	OWENS VALLEY	40439M004	-2410421.373	-4477800.120	3838690.462	.022	.018	.018	NOAM	47161
7882M001	CABO SAN LUCAS	40505M001	-1997242.102	-5528041.060	2468355.372	.022	.017	.021	PCFC	47161
7885M001	FORT DAVIS	40442M005	-1330125.655	-5328526.418	3236150.337	.033	.033	.027	NOAM	47161
7886M001	QUINCY	40433M005	-2517242.527	-4198550.726	4076570.416	.021	.017	.014	NOAM	47161
7888M001	MOUNT HOPKINS	40434M002	-1936744.587	-5077638.883	3331993.985	.035	.026	.032	NOAM	47161
7891M001	FLAGSTAFF	40491M002	-1923976.911	-4850871.510	3658574.816	.034	.033	.027	NOAM	47161
7892M001	VERNAL	40492M001	-1631484.916	-4589133.656	4106749.611	.027	.027	.019	NOAM	47161
7894M001	YUMA	40493M001	-2196778.096	-4887336.858	3448425.358	.030	.027	.028	NOAM	47161
7896M001	PASADENA	40400M001	-2493212.210	-4655229.217	3565574.763	.027	.026	.023	PCFC	47161
7899M001	WASHINGTON	40451M111	1131364.469	-4831168.794	3994129.010	.039	.037	.033	NOAM	47161
7907S001	AREQUIPA	42202S001	1942791.455	-5804077.903	-1796919.266	.015	.007	.015	SOAM	47161
7921S001	MOUNT HOPKINS	40434S001	-1936760.473	-5077706.972	3331922.545	.022	.017	.021	NOAM	47161
7929S001	NATAL	41604S001	5186467.551	-3653856.422	-654321.812	.039	.053	.056	SOAM	47161
7939S001	MATERA	12734S001	4641965.325	1393069.672	4133262.106	.012	.015	.012	EURA	47161
7943S001	ORRORAL	50103S003	-4447548.581	2677134.298	-3694996.587	.013	.015	.014	INDI	47161

EOP(CSR) 89 L 02 Available from 1976 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
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

EARTH ROTATION AND STATION COORDINATES FROM 1986 AND 1987 LAGEOS DATA.

DUT 89 L 01

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

A continuous series of 5-day solutions for polar motion and the Al-UTl time difference has been computed for 1986 and 1987 from global full-rate laser ranging measurements on the LAGEOS satellite.

In the analysis 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. Therefore, for each of these batches which covered data periods ranging from 8 to 16 weeks, also all the station coordinates were adjusted, simultaneously with the other parameters. This resulted in a total of 9 different global station coordinates solutions, together with solutions for polar motion and the Al-UTl time difference.

The reference frame was defined using the following constraints. The longitude of Greenbelt (station 7105) was held fixed at the value according to the University of Texas UT/CSR 84.02 coordinates solution. During the time-span covered by each batch of 1-week data arcs, the stations were supposed to exhibit no motion. Further constraints imposed upon each of the 9 parameter solutions were equivalent to a zero mean shift with respect to the a priori values for the X and Y position of the pole and for the Al-UTl time difference. A priori values for the earth rotation parameters were taken from the IERS Bulletin B.

A summary of the computation model that was used is given in Table 1. Main elements are the NASA/GSFC GEM-Tl gravity field, the Wahr harmonic expansion model for the solid earth tides and a subset of the NASA/GSFC GEM-Tl solution for ocean tides (only the constituents that are also included in the Schwiderski model were used). Table 2 lists an averaged solution for the monument coordinates of the laser stations from which measurements were processed. These results represent the best estimate for the epoch January 1, 1987, and were obtained from the 9 individual global network solutions after corrections for tectonic motions and for systematic differences between these solutions. For the averaging, the effects of tectonics were either modeled using the Minster & Jordan AM1-2 geologic model or estimated, for stations with uncertain tectonic characteristics (sites in the Mediterranean area, Monument Peak and Simosato). The solution presented here may be designated as the SSC(DUT) 89 L 01 global coordinates solution. Table 3, finally, gives the raw, unsmoothed solutions for polar motion and UTl-UTC. The solution is designated ERP(DUT) 89 L 01.

Table 1 Models and constants.

Dynamic model.		
Gravity field	-	NASA/GSFC GEM-T1. truncated at 20 x 20
GM	-	398600.4359 km**3/s**2
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.		
Tropospheric refraction	-	Marini-Murray model
Tidal uplift	-	h2 = 0.6000, l2 = 0.0750

EOP(DUT) 89 L 01 **Available from 1986 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		UT1	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1986	71	0.90	71	0.90	71	6.76
1987	72	0.82	72	0.82	72	6.14

Table 2.

SSC(DUT) 89 L 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7086M001	FORT DAVIS	40442M001	-1330125.341	-5328526.590	3236150.191	.005	.008	.012	NOAM	46796
7090M001	YARRAGADEE	50107M001	-2389006.359	5043329.278	-3078525.396	.005	.008	.014	INDI	46796
7105M001	WASHINGTON	40451M105	1130719.727	-4831350.550	3994106.352	.010	.009	.011	NOAM	46796
7109M001	QUINCY	40433M002	-2517234.727	-4198556.160	4076569.578	.004	.011	.011	NOAM	46796
7110M001	MONUMENT PEAK	40497M001	-2386277.938	-4802354.300	3444881.308	.004	.010	.012	PCFC	46796
7121M001	MOTU HIUMOO	92202M002	-5345865.317	-2958246.515	-1824623.915	.016	.017	.024	PCFC	46796
7122M001	MAZATLAN	40504M001	-1660089.358	-5619100.329	2511637.774	.006	.007	.013	NOAM	46796
7123M001	MOTU HIUMOO	92202M003	-5345865.312	-2958246.482	-1824623.940	.016	.017	.024	PCFC	47796
7210M001	MAUI	40445M001	-5466006.438	-2404427.878	2242187.374	.003	.013	.015	PCFC	46796
7510M001	ASKITES	12612M001	4353444.980	2082666.147	4156506.527	.021	.018	.018	EURA	46796
7512M001	KATAVIA	12615M001	4573400.081	2409322.091	3723881.670	.025	.021	.023	EURA	46796
7515M001	DIONYSOS	12602M002	4595216.486	2039435.183	3912629.396	.019	.017	.018	EURA	46796
7517M001	ROUMELLI	12613M001	4728694.726	2174373.212	3674572.851	.019	.016	.018	EURA	46796
7525M001	XRISOKALARIA	12616M001	4745949.571	1905705.821	3799168.986	.027	.024	.026	EURA	46796
7530M001	BAR GIYYORA	20702M001	4443966.060	3121945.007	3334693.513	.019	.015	.018	AFRC	46796
7810S001	ZIMMERWALD	14001S001	4331283.659	567549.451	4633139.809	.014	.014	.012	EURA	46796
7834S001	WETTZELL	14201S002	4075530.088	931781.148	4801618.061	.014	.013	.011	EURA	46796
7835S001	GRASSE	10002S001	4581691.773	556159.253	4389359.204	.015	.016	.015	EURA	46796
7838M001	SIMOSATO	21726M002	-3822386.990	3699362.311	3507571.918	.020	.016	.018	EURA	46796
7839S001	GRAZ	11001S002	4194426.740	1162693.763	4647246.407	.014	.013	.011	EURA	46796
7840S001	HERSTMONCEUX	13212S001	4033463.846	23662.221	4924304.909	.012	.012	.010	EURA	46796
7843S001	ORRORAL	50103S008	-4446476.534	2678127.021	-3696251.587	.009	.019	.022	INDI	46796
7907S001	AREQUIPA	42202S001	1942791.877	-5804077.594	-1796919.374	.018	.008	.017	SOAM	46796
7939S001	MATERA	12734S001	4641965.105	1393069.786	4133262.085	.012	.011	.012	EURA	46796

EARTH ORIENTATION FROM LASER RANGING TO LAGEOS
STATION COORDINATES FROM LASER RANGING TO LAGEOS GAOUA 89 L 01

Ya.S. Yatskiv, K.KH. Nurutdinovv, V.N. Salyamov, V.K. Tarady, M.L. Tsesis
Main Astronomical Observatory of Ukrainian Academy of Sciences, Kiev, USSR

Computer program · Kiev - Geodynamics - 3

Models · MERIT Standards with following exceptions :
Dynamical model :
- cylindrical model for the Earth's shadow,
- occultation by Moon,
- Earth's rotational deformation,
- relativistic perigee advance.

Reference frame :
- relativistic effects in Earth's rotation.

Measurement model :
- body pole tide,
- tectonic plate motion (AM0-2).

Reflectance coefficient CR = 1.14 and the empirical along-track acceleration coefficient CT = -2.9 are not adjusted parameters.

Data : normal points for LAGEOS at interval January 1986 - December 1987.

Estimated parameters · 6 orbital elements (5-day intervals), 2 pole coordinates and excess of length of the day DR = (5-day interval), station coordinates X, Y, Z.

Orbital fit : standard deviation +/- 6-10cm.

Station positions : station coordinates have been solved together with arc-dependent orbital elements (5-day arcs) from two-year normal equation system.

At this stage BIH combined solution for Earth rotation parameters (Circular D) and fixing of longitude and latitude of Arequipa station (7907) have been used. The positions for stations are for the reference points of the laser ranging system and include the permanent tidal deformation.

Note added by the editor : the results arrived late and they cannot be printed in this document. The series of EOP and the SSC will be available in the same conditions as the other ones.

A 12.2 YEAR SLR EOP SERIES FROM LAGEOS SATELLITE LASER RANGING

SL7.1 (G44) GSFC 89 L 01

D.E.Smith, R Kolenkiewicz and B.H.Putney - the Geodynamics Branch, GSFC. Greenbelt. Maryland
P.J.Dunn, S.M.Klosko. E.C.Pavlis. J.R.Robbins, M.H.Torrence and R.G.Williamson Washington Analytical Services Center, Inc., Lanham, Maryland 20706
S.M.Fricke - Republic Management System, Inc.. Lanham. Maryland 20706.

This solution was done by fitting 30 day (and occasionaly 35 day) day arcs of LAGEOS laser ranging normal point data from May 1976 through June 1988. There were 414.025 normal points used to form the solution, which were constructed from approximately 50 million full rate laser range observations. In each of the monthly arcs the initial state vector and two coefficients of solar radiation pressure and two coefficients of along track acceleration were estimated. The monthly arcs were combined to form a solution for earth orientation parameters and station positions. The following is a summary of the kinematic and dynamic models used for these solutions:

FORCE MODEL

- GEM-T1 Gravity model complete to degree and order 20.
- Third body perturbations: Sun, Moon, Venus, Mars, Jupiter, and Saturn (positioned with the JPL DE200 ephemeris)
- GM = 398600.4408 km3/sec2
- Tidal perturbations: Solid earth from Wahr, ocean tidal coeficients from with the 18.6 year coefficients adjusted to 2.3 cm, 278 deg.
- Direct effect of solar radiation pressure adjusted twice in each monthly
- Along track acceleration adjusted twice in each monthly arc

MEASUREMENT MODEL

- Marini-Muray wavelength dependent refraction model with site meteorologic
- Velocity of light = 299792.458 km/sec
- Vertical and horizontal tide displacements: h2=0.6272, l2=0.0986
- 2 minute normal points following the Herstmonceux recommendations

REFERENCE FRAME

- Wahr nutation series
- J2000 precession (JPL DE200 ephemeris)
- Ae = 6378137. m
- Flattening = 1/298.257
- A priori Earth orientation (Xp, Yp. and Al-UTl) obtained from a weakly Vo Earth orientation from SL7. These input values are adjusted at 5-day in (Xp, Yp, and Al-UTl) except that the first 5 day value of Al-UTl in each arc is fixed at the input value.
- The station positions were constrained to move according to the Minster/tectonic motion model AMO-2. The positions have an epoch of January 15. 1983.

The Xp and Yp positions for the pole and the LOD values are in ERP(GSFC)SL7.1(G44).

The sigmas given are scaled formal errors from the least squares adjustment.

The station positions are presented in cartesian coordinates in SCC(GSFC)SL7.1(G44).

The positions are for an epoch of January 15, 1983, and, as for the EOP, the sigma given are scaled formal errors from the least squares adjustment.

The positions for stations 7051,7061,7062,7063,7069,7082,7086,7090,7091, 7092,7096,7100,7101,7102,7103,7104,7105,7109,7110,7112,7114,7115, 7120,7121,7122,7210,7220,7265.7517,7520,7525,7530,7541,7545,7550, 7590,7838,7882,7885,7887,7888,7890,7891,7892,7896, and 7899 are for the pad marker at the site.

The positions for stations 1181,7400,7401,7805,7810,7831,7833,7834,7835, 7837,7839,7840,7843,7886,7894,7907,7921,7929,7939, and 7943 are for the optical axis of the laser ranging system.

Notes ·
The latitude and longitude of 7105 and the latitude of 7210 were the fixed coordinates in the solution.
The gravity model is GEM-Tl with the GEM-Tl tides the MERIT Standards have been followed.

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
1181S001	POTSDAM	14106S001	3800621.581	882005.142	5028859.433	.075	.072	.070	EURA	45349
7051M001	QUINCY	40433M001	-2516893.065	-4198845.049	4076411.554	.016	.015	.020	NOAM	45349
7061M001	EASTER ISLAND	41703M001	-1884984.534	-5357606.613	-2892852.522	.108	.083	.100	NAZC	45349
7062M001	SAN DIEGO	40436M002	-2428825.743	-4799750.541	3417272.720	.014	.012	.010	PCFC	45349
7063M001	WASHINGTON	40451M112	1130714.847	-4831367.732	3994087.356	.001	.005	.010	NOAM	45349
7064M001	WASHINGTON	40451M107	1130689.803	-4831342.691	3994123.447	2.819	1.652	1.000	NOAM	45349
7067M001	BERMUDA	42501M001	2308538.602	-4874079.890	3393628.491	.146	.092	.100	NOAM	45349
7068M001	GRAND TURK	43602M002	1920482.763	-5619478.311	2318914.303	.472	.260	.300	NOAM	45349
7069M001	PATRICK AFB	40417M002	917958.943	-5548370.459	2998776.607	.256	.168	.300	NOAM	45349
7080M001	FORT DAVIS	40442M006	-1330022.617	-5328401.924	3236480.057	.076	.059	.070	NOAM	45349
7082M001	BEAR LAKE	40438M001	-1735997.059	-4425048.160	4241430.596	.019	.019	.020	NOAM	45349
7084M001	OWENS VALLEY	40439M003	-2410590.154	-4477745.802	3838648.314	.228	.579	.500	NOAM	45349
7085M001	GOLDSTONE	40405M001	-2353394.103	-4641529.886	3676898.730	.204	.553	.500	NOAM	45349
7086M001	FORT DAVIS	40442M001	-1330125.320	-5328526.571	3236150.399	.003	.002	.010	NOAM	45349
7090M001	YARRAGADEE	50107M001	-2389006.174	5043329.309	-3078525.544	.002	.002	.010	INDI	45349
7091M001	HAYSTACK	40440M001	1492453.733	-4457278.721	4296815.811	.013	.011	.010	NOAM	45349
7092M001	KWAJALEIN ATOLL	50505M001	-6143447.309	1364699.984	1034163.069	.017	.023	.020	PCFC	45349
7096M001	AMERICAN SAMOA	50503M001	-6100045.851	-996203.268	-1568976.335	.014	.019	.020	PCFC	45349
7097M001	EASTER ISLAND	41703M002	-1884985.096	-5357607.971	-2892853.294	.010	.009	.010	NAZC	45349
7100M001	WASHINGTON	40451M106	1131355.725	-4831168.689	3994132.099	.228	.181	.200	NOAM	45349
7101M001	WASHINGTON	40451M101	1131240.525	-4831179.808	3994148.465	.085	.051	.070	NOAM	45349
7102M001	WASHINGTON	40451M102	1130686.662	-4831353.085	3994110.883	.011	.009	.010	NOAM	45349
7103M001	WASHINGTON	40451M103	1130685.722	-4831348.731	3994116.302	.018	.018	.020	NOAM	45349
7104M001	WASHINGTON	40451M104	1131095.967	-4831196.839	3994170.806	.065	.055	.060	NOAM	45349
7105M001	WASHINGTON	40451M105	1130719.794	-4831350.569	3994106.480	.001	.001	.010	NOAM	45349
7109M001	QUINCY	40433M002	-2517234.646	-4198556.122	4076569.837	.002	.002	.010	NOAM	45349
7110M001	MONUMENT PEAK	40497M001	-2386277.817	-4802354.394	3444881.433	.002	.002	.010	PCFC	45349
7112M001	PLATTEVILLE	40496M001	-1240678.159	-4720463.314	4094480.706	.005	.005	.010	NOAM	45349

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7114M001	OWENS VALLEY	40439M001	-2410422.342	-4477802.663	3838686.814	.010	.009	.010	NOAM	45349
7115M001	GOLDSTONE	40405M002	-2350861.580	-4655546.275	3660998.006	.010	.010	.010	NOAM	45349
7120M001	MAUI	40445M002	-5465998.367	-2404408.684	2242228.421	.007	.009	.010	PCFC	45349
7121M001	MOTU HIUMOO	92202M002	-5345865.217	-2958246.722	-1824623.804	.004	.005	.010	PCFC	45349
7122M001	MAZATLAN	40504M001	-1660089.359	-5619100.325	2511637.995	.003	.002	.010	NOAM	45349
7123M001	MOTU HIUMOO	92202M003	-5345866.657	-2958247.515	-1824624.371	.012	.013	.010	PCFC	45349
7125M001	WASHINGTON	40451M114	1130745.856	-4831368.072	3994077.096	.016	.012	.010	NOAM	45349
7210M001	MAUI	40445M001	-5466006.421	-2404428.051	2242187.491	.002	.002	.010	PCFC	45349
7220M001	MONUMENT PEAK	40497M002	-2386292.132	-4802347.487	3444880.898	.012	.010	.010	PCFC	45349
7265M001	GOLDSTONE	40405M006	-2356475.634	-4646618.187	3668424.884	.011	.011	.010	NOAM	45349
7288M001	GOLDSTONE	40405M013	-2356494.018	-4646607.566	3668426.816	.009	.006	.010	NOAM	45349
7400S001	SANTIAGO	41705S003	1769700.165	-5044614.808	-3468263.229	.015	.010	.010	SOAM	45349
7401S001	CERRO TOLOLO	41706S001	1815517.690	-5213466.839	-3188002.490	.009	.007	.010	SOAM	45349
7510M001	ASKITES	12612M001	4353445.190	2082666.029	4156506.499	.052	.058	.050	EURA	45349
7512M001	KATAVIA	12615M001	4573400.353	2409321.948	3723881.595	.056	.068	.060	EURA	45349
7515M001	DIONYSOS	12602M002	4595216.695	2039435.084	3912629.347	.045	.052	.050	EURA	45349
7517M001	ROUMELLI	12613M001	4728694.943	2174373.100	3674572.779	.040	.047	.050	EURA	45349
7520M001	KARITSA	12614M001	4596042.893	1733476.585	4055720.667	.018	.015	.020	EURA	45349
7525M001	XRISOKALARIA	12616M001	4745949.795	1905705.658	3799168.867	.055	.059	.060	EURA	45349
7530M001	BAR GIYYORA	20702M001	4443967.678	3121945.149	3334694.197	.006	.006	.010	AFRC	45349
7541M001	MATERA	12734M004	4641990.570	1393042.045	4133231.674	.013	.015	.010	EURA	45349
7544M001	LAMPEDUSA	12706M001	5072832.233	1130885.917	3684836.756	.069	.081	.080	EURA	45349
7545M001	CAGLIARI	12725M002	4893398.280	772673.061	4004140.805	.013	.018	.020	EURA	45349
7550M001	TRIESTE	12718M002	4336738.766	1071271.267	4537910.927	.055	.077	.070	EURA	45349
7575M001	DIYARBAKIR	20801M001	3848636.432	3251760.761	3898908.998	.117	.126	.120	EURA	45349
7580M001	MELENGICLICK	20803M001	4247620.855	2778638.740	3851607.359	.085	.097	.090	EURA	45349
7585M001	YOZGAT	20802M001	4029731.047	2802093.115	4062067.855	.122	.163	.140	EURA	45349
7587M001	YIGILCA	20804M001	4117362.322	2517076.619	4157678.905	.098	.075	.100	EURA	45349
7590M001	MONTE GENEROSO	14005M002	4390310.123	696751.790	4560835.765	.011	.012	.010	EURA	45349

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7596M001	WETTZELL	14201M004	4075580.179	931836.253	4801560.335	.168	.235	.200	EURA	45349
7805S001	METSAHOVI	10503S001	2892595.635	1311808.025	5512610.798	.154	.147	.150	EURA	45349
7810S001	ZIMMERWALD	14001S001	4331283.816	567549.263	4633139.813	.005	.005	.010	EURA	45349
7831S001	HELWAN	30101S001	4728283.993	2879669.959	3156893.986	.082	.134	.100	AFRC	45349
7833S001	KOOTWIJK	13504S001	3899224.428	396742.611	5015073.808	.107	.090	.100	EURA	45349
7834S001	WETTZELL	14201S002	4075530.303	931781.041	4801618.046	.004	.003	.010	EURA	45349
7835S001	GRASSE	10002S001	4581692.013	556159.120	4389359.236	.005	.005	.010	EURA	45349
7837S001	SHANGHAI	21605S001	-2831087.478	4676203.760	3275173.026	.487	.233	.500	EURA	45349
7838M001	SIMOSATO	21726M002	-3822386.774	3699362.431	3507572.109	.003	.003	.010	EURA	45349
7839S001	GRAZ	11001S002	4194426.968	1162693.641	4647246.381	.004	.003	.010	EURA	45349
7840S001	HERSTMONCEUX	13212S001	4033464.040	23662.115	4924304.892	.003	.003	.010	EURA	45349
7843S001	ORRORAL	50103S008	-4446476.605	2678127.229	-3696251.785	.007	.005	.010	INDI	45349
7882M001	CABO SAN LUCAS	40505M001	-1997241.598	-5528041.087	2468355.189	.021	.021	.020	PCFC	45349
7885M001	FORT DAVIS	40442M005	-1330125.339	-5328526.420	3236150.356	.024	.026	.030	NOAM	45349
7886S001	QUINCY	40433S010	-2517242.374	-4198554.028	4076572.330	.038	.033	.040	NOAM	45349
7887M001	VANDENBERG AFB	40420M004	-2668868.165	-4530743.797	3598685.126	.128	.540	.500	NOAM	45349
7888M001	MOUNT HOPKINS	40434M002	-1936744.310	-5077639.010	3331994.001	.025	.019	.020	NOAM	45349
7890M001	AUSTIN	40412M001	-754162.110	-5459061.190	3200744.117	.271	.240	.300	NOAM	45349
7891M001	FLAGSTAFF	40491M002	-1923976.587	-4850871.542	3658574.900	.030	.029	.030	NOAM	45349
7892M001	VERNAL	40492M001	-1631484.640	-4589133.829	4106749.704	.020	.022	.020	NOAM	45349
7894S001	YUMA	40493S001	-2196777.863	-4887339.190	3448428.341	.020	.018	.020	NOAM	45349
7896M001	PASADENA	40400M001	-2493211.830	-4655229.621	3565574.604	.023	.024	.020	PCFC	45349
7907S001	AREQUIPA	42202S001	1942791.743	-5804077.749	-1796919.370	.001	.002	.010	SOAM	45349
7921S001	MOUNT HOPKINS	40434S001	-1936760.101	-5077707.071	3331922.681	.021	.017	.020	NOAM	45349
7929S001	NATAL	41604S001	5186467.882	-3653856.333	-654322.066	.013	.018	.020	SOAM	45349
7939S001	MATERA	12734S001	4641965.326	1393069.669	4133262.052	.002	.002	.010	EURA	45349
7943S001	ORRORAL	50103S003	-4447548.620	2677134.262	-3694996.848	.008	.007	.010	INDI	45349
8833S001	KOOTWIJK	13504S007	3899238.066	396768.943	5015055.126	.027	.025	.030	EURA	45349

EOP(GSFC) 89 L 01 Available from 1976 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1976	47	96.70	47	47.15	35	0.412
1977	73	17.17	73	17.55	58	0.256
1978	72	23.78	72	12.95	55	0.332
1979	73	6.51	73	7.45	59	0.145
1980	74	1.79	74	1.21	61	0.043
1981	73	2.05	73	1.32	61	0.039
1982	73	1.51	73	0.95	61	0.034
1983	73	0.91	73	0.74	61	0.020
1984	73	0.37	73	0.33	61	0.013
1985	73	0.45	73	0.39	61	0.015
1986	73	0.53	73	0.44	61	0.018
1987	73	0.28	73	0.24	61	0.011
1988	36	0.48	36	0.38	30	0.014

EARTH ORIENTATION FROM LAGEOS LASER RANGING SHA 88 L 01

Zhu Wenyao, Fong Chugang, Teng Zhanming
Shanghai Observatory, Academia Sinica, Shanghai, China

To determine a series of the Earth Orientation Parameters EOP(SHA) 88 L 01, the 1988 Lageos quick-look normal points data obtained from 24 stations, kindly provided by CSR of Texas University at Austin, have been processed with a program system named SHORDE I. In the solution we have designed a software package embodying a "multistage-multiarc" procedure to estimate simultaneously satellite states, EOPs and some station coordinates. These adjustable parameters are devided into three groups. The first group, the global parameters, such as some station coordinates, are adjusted in the whole of the long arc (several months) in order to obtain stable and reliable results. The second group, the first-stage local parameters, such as satellite orbit states, are independently adjusted in the different subarcs (10 days) so as to reduce the effect of some unmodeled perturbations and obtain stable solutions. The third group, the second-stage local parameters, such as EOPs, are independently adjusted from one sub-subarcs (5 days) to the next so as to model properly their variation. The adjustment for whole long arc is to be accomplished step by step from one sub-subarc 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 0.001"/day. In our solution the overall RMS fit of the laser observations to the orbits in 10-day arcs is generally about 10cm.

The station coordinates used in our solution is from SSC(SHA) 88 L 01. In which most of station coordinates is derived from SSC(SHA) 87 L 01 to be attached to respective tectonic plates with motion defined by the AM1-2 model of Minster and Jordan 1978, the coordinates of a few stations are re-estimated simultaneously with the satellite orbit states and EOPs. The epoch of the derived SSC(SHA) 88 L 01 is January 1.0 1988 (MJD 47161.0). Modeling of AM1-2 tectonic plate motion is expected to enable improved maintenance of the system accuracy.

The force model and constants used in the solution adhere closely to the MERIT Standards. Some exceptions are following :

1. GM=398600.4404km^3/sec^2 . Re=6378145.0m
2. Earth radiation pressure and general relativistic perturbation have been considered.
3. The drag-like coefficient Cd and reflectivity of LAGEOS'surface Cr have been estimated in each 10-day arc along with the satellite states.

References

Minster,J.B. and T.H.Jordan, Present-day plate motions, JGR 83, No B11, 5331-5354, 1978.
He Miaofu et al., A series of ERP from LAGEOS during the MERIT Campaign, Proceedings of the International Conference on Earth Rotation and the Terrestrial Reference Frame, I.I.Mueller (convenor), 205-212.

SSC(SHA) 88 L 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	PLATE
1181S001	POTSDAM	14106S001	3800621.334	882005.320	5028859.745	EURA
7086M001	FORT DAVIS	40442M001	-1330125.462	-5328526.621	3236150.412	NOAM
7090M001	YARRAGADEE	50107M001	-2389006.464	5043329.442	-3078525.292	INDI
7091M001	HAYSTACK	40440M001	1492453.403	-4457278.786	4296815.818	NOAM
7105M001	WASHINGTON	40451M105	1130719.658	-4831350.680	3994106.618	NOAM
7109M001	QUINCY	40433M002	-2517234.855	-4198556.253	4076569.794	NOAM
7110M001	MONUMENT PEAK	40497M001	-2386278.116	-4802354.286	3444881.601	PCFC
7112M001	PLATTEVILLE	40496M001	-1240678.331	-4720463.336	4094480.682	NOAM
7122M001	MAZATLAN	40504M001	-1660089.494	-5619100.410	2511637.908	NOAM
7210M001	MAUI	40445M001	-5466006.622	-2404427.729	2242187.606	PCFC
7805S001	METSAHOVI	10503S001	2892595.172	1311808.161	5512609.943	EURA
7831S001	HELWAN	30101S001	4728282.998	2879669.620	3156894.238	AFRC
7834S001	WETTZELL	14201S002	4075530.183	931781.218	4801618.399	EURA
7835S001	GRASSE	10002S001	4581691.905	556159.287	4389359.452	EURA
7837S001	SHANGHAI	21605S001	-2831087.574	4676203.643	3275172.751	EURA
7838S001	SIMOSATO	21726S001	-3822388.302	3699363.521	3507573.153	EURA
7839S001	GRAZ	11001S002	4194426.787	1162693.817	4647246.663	EURA
7840S001	HERSTMONCEUX	13212S001	4033463.862	23662.227	4924305.145	EURA
7810S001	ZIMMERWALD	14001S001	4331283.520	567549.241	4633140.237	EURA
7843S001	ORRORAL	50103S008	-4446476.946	2678127.384	-3696252.111	INDI
7882M001	CABO SAN LUCAS	40505M001	-1997241.683	-5528041.124	2468355.203	PCFC
7907S001	AREQUIPA	42202S001	1942791.809	-5804077.858	-1796919.280	SOAM
7939S001	MATERA	12734S001	4641965.180	1393069.837	4133262.355	EURA
8833S001	KOOTWIJK	13504S007	3899237.883	396769.131	5015055.387	EURA

SX, SY, SZ = 0.100m. EPOCH-MJD = 47161.

EOP(SHA) 88 L 01 Available from 1988 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		D	
	Nb	Sigma	Nb	Sigma	Nb	Sigma
1988	72	1.02	72	1.12	72	0.548

EARTH ROTATION PARAMETERS IN 1987 AND STATION COORDINANTES FROM LASER RANGING TO LAGEOS

ZIPE 87 L 01
ZIPE 87 L 02
ZIPE 87 L 03

H.Montag. G.Gendt. Th.Nischan. H.Rehse - Zentralinstitut für Physik der Erde, Potsdam Akademie der Wissenschaften der DDR

Using the Satellite Laser Ranging (SLR) data to LAGEOS in 1987 a Set of Station Coordinates (SSC) and several series of Earth Orientation Parameters (EOP) were determined by the program package TOTSDAM-5. The SLR data were introduced as normal points delivered by Ch.Reigber, SLR Data Collection Center for Europe at the DGFI. All constants and model parameters were taken from the MERIT Standards and its updating - the International Earth Rotation Service Standards, Draft of December 1988. The only deviations from the latter document are :

- the GEM-T1 was used instead of GEM-L2 ; the coefficients C_{21} and S_{21} were reduced to the average pole position ;
- the effect of penumbra for the radiation pressure was not included ;
- no relativistic corrections ;
- the tidal variations in UT1 caused by zonal tide terms with periods greater than 35 days were not considered;
- the variation of station coordinates caused by polar tide was not taken into account.

The SSC results were referred to the epoch 1984.0 applying the AM0-2 tectonic plate model. The origin of the reference system was defined by $C_{10} = C_{11} = S_{11} = 0$, and the orientation was constrained by fixation of φ and λ for station 7210 and of φ for station 7105. The precision (formal error) of the station coordinates is in the order of +/- 5mm. The accuracy obtained by comparison with other solutions via a Helmert transformation with 7 free parameters was estimated to be about +/- 2cm.

For the EOP (pole coordinates and length of day (LOD)) several sets were determined : the set EOP(ZIPE) 87 L 01 with a time resolution of 5 days and the two sets EOP(ZIPE) 87 L 02 and L 03 with a resolution of 3 days. The 5-days resolutions (EOP(ZIPE) 87 L 01) were simultaneously computed with the station coordinates and the orbit dependent parameters (6 orbital elements, empirical acceleration). The average orbital fit amounts to about +/- 6cm. For both the other sets of EOP with a time resolution of 3 days the station coordinates were fixed to the values obtained from the 5-days solutions. The set EOP(ZIPE) 87 L 02 was obtained by simultaneous adjustment of the pole coordinates and the length of day together with the orbit dependent parameters for every 3-days interval. On the contrary, the set EOP(ZIPE) 87 L 03 differs from the latter in two points : the orbital improvement were performed for 6-days intervals, and instead of the pole coordinates and LOD the pole coordinates and LOD, the pole coordinates and UT1 values were estimated in a 3-days interval symmetrical situated inside of each converted into LOD. That means that the time scale has to be transferred by -1.5d for the LOD values of the set EOP(ZIPE) 87 L 03.

IERS(1989) : Technical Note no 2.

For The determination of EOP results the measurements were weighted according to their estimated accuracy. But, in addition, several non permanent stations (e.g. WEGENER project) were provided with a smaller weight in order to reduce the influence of the change of the station distribution. No post-adjustment smoothing or filtering procedure was applied to the EOP series. Generally, the accuracy of both the 5-days and 3-days solutions is very similar. Only in a few cases with only a small number of stations and passes the 3-days solutions are worse. The number of such worse solutions is of course smaller for the EOP(ZIPE) 87 L 03 set.

The average precision of all EOP sets is in the order of +/-0.0001" to 0.0002" (3 to 6mm) for the pole coordinates and +/- 0.003ms for LOD. The accuracy was estimated to be about +/- 3cm for the pole coordinates and less than +/- 0.1ms for LOD.

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	EPOCH MJD
7090S001	YARRAGADEE	50107S001	-2389007.470	5043331.776	-3078527.262	.001	.002	.003	INDI	45700
7105S002	WASHINGTON	40451S101	1130720.343	-4831352.970	3994108.249	.001	.002	.003	NOAM	45700
7109S002	QUINCY	40433S006	-2517235.902	-4198558.283	4076571.481	.002	.002	.001	NOAM	45700
7110S001	MONUMENT PEAK	40497S001	-2386279.043	-4802356.873	3444882.822	.001	.002	.001	PCFC	45700
7122S001	MAZATLAN	40504S001	-1660090.135	-5619103.205	2511638.940	.001	.002	.002	NOAM	45700
7210S001	MAUI	40445S001	-5466006.898	-2404428.355	2242188.123	.001	.002	.002	PCFC	45700
7838S001	SIMOSATO	21726S001	-3822388.212	3699363.578	3507572.913	.002	.003	.003	EURA	45700
7840S001	HERSTMONCEUX	13212S001	4033463.921	23662.205	4924304.766	.002	.002	.003	EURA	45700
7907S001	AREQUIPA	42202S001	1942791.969	-5804077.630	-1796919.555	.001	.002	.001	SOAM	45700
7939S001	MATERA	12734S001	4641965.167	1393069.803	4133261.958	.003	.002	.002	EURA	45700
7834S001	WETTZELL	14201S002	4075530.142	931781.150	4801617.913	.002	.003	.003	EURA	45700
7839S001	GRAZ	11001S002	4194426.830	1162693.755	4647246.258	.002	.002	.003	EURA	45700
7810S001	ZIMMERWALD	14001S001	4331283.712	567549.429	4633139.671	.002	.003	.003	EURA	45700
7835S001	GRASSE	10002S001	4581691.855	556159.264	4389359.050	.002	.002	.003	EURA	45700
7086S001	FORT DAVIS	40442S00	-1330120.924	-5328532.282	3236146.546	.001	.002	.001	NOAM	45700
7530S001	BAR GIYYORA	20702S001	4443968.585	3121946.739	3334695.138	.002	.004	.004	AFRC	45700
7512S001	KATAVIA	12615S001	4573402.475	2409323.345	3723880.192	.002	.004	.003	EURA	45700
7510S001	ASKITES	12612S001	4353447.548	2082667.266	4156505.303	.002	.003	.002	EURA	45700
7585S001	YOZGAT	20802S001	4029733.125	2802094.618	4062066.633	.005	.006	.006	EURA	45700
7515S001	DIONYSOS	12602S008	4595219.006	2039436.256	3912627.976	.001	.002	.002	EURA	45700
7517S002	ROUMELLI	12613S002	4728698.086	2174374.702	3674573.331	.002	.003	.003	EURA	45700
7517S003	ROUMELLI	12613S003	4728697.184	2174374.288	3674571.328	.002	.003	.003	EURA	45700
7544S001	LAMPEDUSA	12706S001	5072834.680	1130886.651	3684835.287	.002	.004	.003	EURA	45700
7525S004	XRISOKALARIA	12616S004	4745952.915	1905707.193	3799169.460	.002	.003	.003	EURA	45700
7575S001	DIYARBAKIR	20801S001	3848638.290	3251762.497	3898907.659	.003	.006	.006	EURA	45700
7580S001	MELENGICLICK	20803S001	4247623.732	2778640.762	3851608.016	.003	.004	.003	EURA	45700
7587S001	YIGILCA	20804S001	4117365.139	2517078.541	4157679.779	.003	.004	.004	EURA	45700
1884S001	RIGA	12302S002	3183895.028	1421495.804	5322800.743	.004	.009	.010	EURA	45700
7097S001	EASTER ISLAND	41703S004	-1884985.161	-5357609.245	-2892854.247	.004	.005	.005	NAZC	45700
1181S001	POTSDAM	14106S001	3800621.453	882005.240	5028859.299	.002	.003	.003	EURA	45700
7831S001	HELWAN	30101S001	4728283.735	2879670.382	3156893.992	.002	.003	.003	AFRC	45700

EOP(ZIPE) 89 L 01 Available from 1986 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
1986	4	0.16	4	0.16	4	0.032
1987	73	0.16	73	0.14	73	0.036

EOP(ZIPE) 89 L 02 Available from 1986 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
1986	6	0.18	6	0.19	6	0.039
1987	122	0.19	122	0.21	122	0.055

EOP(ZIPE) 89 L 03 Available from 1986 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
1986	6	0.21	6	0.22	6	0.176
1987	122	0.21	122	0.31	122	0.230

ATMOSPHERIC ANGULAR MOMENTUM

EFFECTIVE ANGULAR MOMENTUM FUNCTION FOR EARTH ROTATION AND POLAR MOTION FROM THE UNITED STATES NMC ANALYSIS

AAM(AER) 87 * 01

David A. Salstein - Atmospheric and Environmental Research. Inc.
840 Memorial Drive. Cambridge, MA 02139.

1. Introduction

Production of operational effective angular momentum functions (EAMF) has continued throughout 1988 from the global analysis of the United States National Meteorological Center (NMC). These functions, which relate the three components of Earth orientation to variations in winds (W) and atmospheric surface pressure (P), with and without the incorporation of the inverted barometer (IB) hypothesis, have been derived by Barnes et al. (1983). Their production from NMC analyses was described by Salstein (1987). Major changes of the NMC global analysis scheme during 1988 which may impact the EAMFs are highlighted in the next section : following that is a description of the data format.

2. NMC System Changes During 1988

The basic NMC global data assimilation system has been described by Dey and Morone (1985), although there have been a number of important modifications since. The changes in 1988 are summarized by the National Weather Service (1989). The major change in May represents an improvement in the surface evaporation which moistens the lowest layers of the atmosphere in the prediction model. A subsequent change implemented in November involves more realistic formulation of clouds. Because both these changes alter the atmosphere's heating and hence its circulation within the NMC model, they have the potential to impact the EAMF's though the magnitude of the impact is unknown.

Figure 1 is a plot of the angular momentum equivalent of the chi 3-wind term since 1981. One highlight in 1988 was a strong 30-50 day oscillation, especially during the early part of the year. Also during that year was a so-called "cold event" occurring in the tropical Pacific ocean (the opposite phase of the Southern Oscillation cycle to an El Niño event). The impact of the cold event on angular momentum in 1988 seems relatively small, unlike the markedly high values of momentum that occurred during the El Niño of 1982-83 and 1986-87.

3. Data Included

The EAMFs for the period January-December 1988 are given :

Date (MJD). chi 1-wind, chi 1 P 2/o IB, chi 1 P 2/ IB
Date (MJD), chi 2-wind, chi 2 P 2/o IB, chi 2 P 2/ IB
Date (MJD). chi 3-wind, chi 3 P 2/o IB, chi 3 P 2/ IB

Notes
1. Of the 732 twice-daily periods, 53 were missing, and are not on the file.
2. The chi 3 P w/o IB and chi 3 P w/ IB terms must be corrected by the addition of a relatively large constant, -13.980822, for precision.
3. All wind terms are integrated between 1 000 and 50mb.

References

Barnes,R.T., Hide,R., White,A.A., and Wilson,C.A. 1983: Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. Proc.R.Soc. London,Ser.A.387 , pp.31-73.

Dey.C.H., Morone,L.L. 1985: Evolution of the National Meteorological Center global data assimilation system: January 1982 - December 1983, Mon.Wea.Rev., 113. pp.304-318.

National Weather Service, 1988: Annual NWP Progress Report . January 1989. Available from United States Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Washington, DC 20233.

Salstein,D.A. 1987: Operational production of effective angular momentum function for Earth rotation and polar motion. Annual Report of the BIH for 1987, pp.D-49-54.

AAM(AER) 87 * 01 Available from 1976 to 1988

Year	Number of meas.	Year	Number of meas.
1976	182	1982	630
1977	356	1983	656
1978	352	1984	679
1979	333	1985	686
1980	326	1986	696
1981	630	1987	722
		1988	679

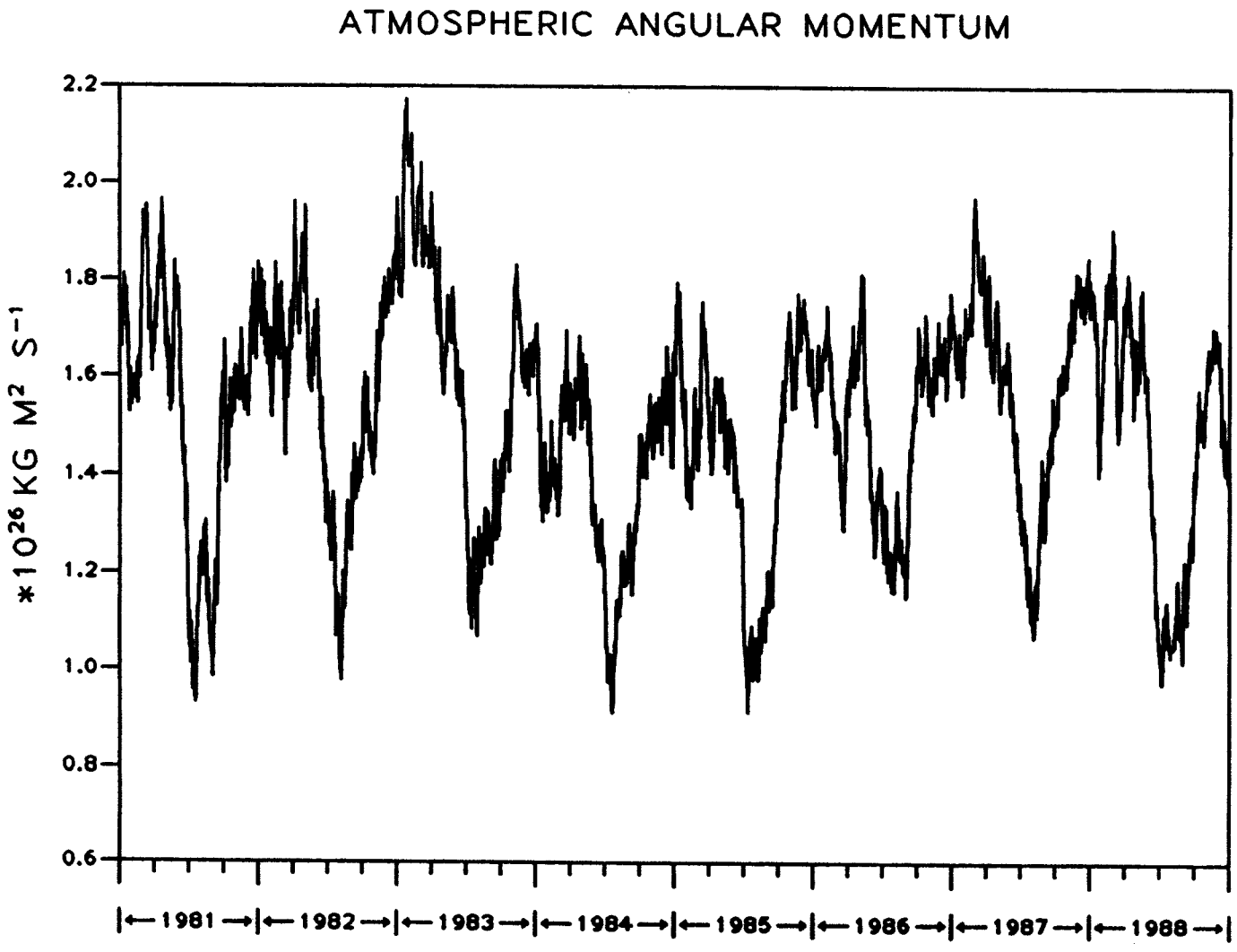

Fig. 1. Angular momentum of the atmosphere between 1000 and 50 mb during calendar years 1981-1988 based on the United States Meteorological Center (NMC) global analyses. Momentum units here can be derived from the chi 3-wind term on the data set through multiplication by the factor $-C\Omega$. C, the polar moment of intertia for the value 7.04×10^{37} kg m^2 and Ω, the earth's mean rotation frequency, is 7.29×10^{-5} s^{-1}.

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.

Since April 1987 the EAAM functions have been calculated operationally at ECMWF for all archived steps in the analysis-forecasting scheme, i.e. for analysis every 6 hours and for forecasts from 12 GMT each day up to 10 days ahead with an interval of 6 hours during the early forecasts after 5 days. The method used is described by Sakellarides (1989). Contributions to the three components of EAAM from wind (up to the 10 mb level) and from the surface pressure for both hemispheres are calculated and stored separately. These data have been extracted or re-calculated to make the time series for the following steps in the analysis-forecasting system easily available :

00 GMT analysis from 1 January 1988 onward,

12 GMT analysis from 1 January 1986 onward,

72, 120, and 240 hour forecasts from 1 January 1986 onward.

No calculations using the inverted barometer hypothesis have been done but these could be calculated from the available ECMWF archives.

References

G.Sakellarides, 1989 : Atmospheric effective angular momentum functions for 1986-1987. ECMWF Research Department Technical Report No.62.

AAM(ECMWF) 87 * 01 Available from 1986 to 1988

Year	Number of meas.
1986	365
1987	365
1988	732

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED FROM THE JMA DATA

AAM(JMA) 89 * 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(00GMT and 12GMT) 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 lelvel 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 hypothesis (IB). 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 stuffs of the Numerical Prediction Division, the Japan Meteorological Agency. for supporting this work.

References

Barnes,R.T.H., R.Hide, A.A.White & C.A.Wilson, 1983 : Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. Proc. R. Soc. Lond. A387, 31-73.

Kanamitsu,M., K.Tada, T.Kudo, N.Sato & S.Isa, 1983 : Description of the JMA operational spectral model, J. Meterol. Soc. Japan, 61, 812-828.

Kashiwagi,K..1987 : On the impact of space-based observing systems in the JMA global forecast/analysis system, J. Meteorol. Soc. Japan, 65, 189-220.

Kitade,T.,1988 : Numerical weather prediction in the Japan Meteorological Agency, JMA/NPD Technical Report. No.20.

Naito,I., N.Kikuchi & K. Yokoyama, 1987 : Results of estimating the effective atmospheric angular momentum functions based on the JMA global analysis data, Publ. Int. Latit. Obs. Mizusawa, 20, 1-11.

AAM(JMA) 87 * 01 Available from 1983 to 1988

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

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED BY THE U.K. METEOROLOGICAL OFFICE USING DATA PROCESSED AT THE EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTING

AAM(UKMOA)79 * 01

Geophysical Fluid Dynamics Laboratory (Met. O. 21) U.K. Meteorological Office Bracknell RG12 2SZ England U K. (Attention Dr. R.Hide Head of Met. O. 21).

Daily values of the effective atmospheric angular momentum (EAAM) functions defined by Barnes, Hide, White and Wilson (1983) have been calculated using meteorological fields produced by the European Centre for Medium-Range Weather Forecasting (ECMWF) since 01/12/1979. The wind integrals are approximated by the trapezoidal rule using initialised data interpolated onto 12 standard pressure levels between 1 000mb and 50mb. The matter terms are calculated using initiaalised surface pressure fields without applying the inverted barometer correction.

The present ECMWF operational model, which is documented by ECMWF Research Manuals 1-3 and also described by Simmons et al. (1989). Shaw et al. (1987) uses a 19 level hybrid (sigma/pressure) vertical grid and a spectral horizontal representation with triangular truncation at wavenumber 106. The model contains parametrisation schemes to represent sub-grid scale radiative and convetive processes. precipitation and boundary layer turbulence.

Data analyses are performed using a 3 dimensional multi-variate statistical interpolation scheme (for mass and wind fields). The first-guess field is a 6 hour forecast and the data cut-off time for the 12Z forecast is 20.45Z. A non-linear normal mode initialisation scheme is applied to the analysis fields to eliminate high frequency gravity waves.

Several improvements to the ECMWF operational model, which affect the matter terms particularly have been introduced since 1979. The representation of orography was changed on 01/04/1981 and 21/04/1983 and a schele for parametrising sub-grid scale gravity waves generated by topography included on 15/07/1986. Improvements in the initialisation of tropical diurnal variations were implemented on 04/03/86. The original gridpoint model was replaced by a T63 spectral model on 21/04/83 and the latter's resolution increased to T106 on 02/05/1985. The parametrisation of vertical diffusion was amended on 05/01/1988. Details of other changes are recorded in the quarterly ECMWF Forecast Reports.

Data is missing from the series on only two days - 31 Mar.1984 and 26 Aug.1987. The times of validity of the data are tabulated below.

Period	Hour of validity
01/12/79 - 30/11/80	12Z
01/12/80 - 15/03/82	00Z
16/03/82 - 29/02/84	12Z
01/03/84 - 15/03/84	00Z
15/03/84 - 31/05/87	12Z
01/06/87 - 31/12/88	mean of 00Z 06Z 12Z and 18Z

IERS(1989) Technical Note no 2.

References

Barnes R.T.H. Hide R. White.A.A. and Wilson.C.A. 1983 Atmospheric angular momentum fluctuations. length of day changes, and polar motion. Proceedings of the Royal Society A 397, pp.31-73.

ECMWF Research Manual 1 1986 ECMWF data assimilation scientific documentation. eds. Lonneberg,P. and Shaw,P.

ECMWF Research Manual 2 1986 ECMWF forecast model adiabatic part. ed.J.F.Louis.

ECMWF Research Manual 3 1986 ECMWF forecast model physical parametrisation. ed. J.F. Louis.

ECMWF Forecast Reports (issued quarterly by the ECMWF).

Shaw,D.B., Lonneberg,P., Hollingsworth,A., and Unden,P. 1987:Data assimilation: The 1984/85 revisions of the ECMWF mass and wind analysis. Quart.J.Roy.Meteor Soc. .113. pp.533-566

Simmons,A.J., Burridge,D.M., Jarraud,M., Girard,C. and Wergen,W. 1989: The

ECMWF medium range prediction models: Development of the numerical formulations and the impact of increased resolution. Met.and Atmos.Phys. (in the press).

AAM(UKMOA) 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

EFFECTIVE ATMOSPHERIC ANGULAR MOMENTUM FUNCTIONS COMPUTED BY THE U.K. METEOROLOGICAL OFFICE USING DATA PROCESSED AT THE U.K. METEOROLOGICAL OFFICE

AAM(UKMOB) 83 * 01

Geophysical Fluid Dynamics Laboratory (Met.0.21). U.K. Meteorological Office, Bracknell RG12. 2SZ, England, U.K. (Attention · Dr. R.Hide. Head of Met. 0.21).

Daily values of the effective atmospheric angular momentum (EAAM) functions defined by Barnes. Hide, White and Wilson (1983) have been calculated using meteorological fields produced by the United Kingdom Met.Office (UKMO) since 01/05/1983. The matter terms are evaluated without applying the inverted barometer correction.

From 01/05/1983 to 30/10/1986 the wind terms were determined from "analysis" data at 15 standard pressure levels between 1 000mb and 20mb and the matter terms from surface pressure fields reconstructed from the mean sea level pressure and a topographic data set. From 1/11/1986 to 26/11/1986 the wind integrals extended from 950mb to 50mb and the matter terms were calculated using surface pressure fields. As from 27/11/1987 the wind terms have been evaluated using data on all the model's 15 sigma levels §which extend up to about 25mb) and the matter terms have been found from the model's surface pressure field.

The present global UKMO operational model, which is described by Bell Dickinson (1987) uses a 15 level sigma coordinate vertical grid which extends up to about 25mb and a horizontal grid with 192 points around each latitude circle and 121 rows from north to south pole. The model contains parametrisation schemes to represent sub-grid scale radiative and convective processes, precipitation and boundary layer turbulence.

Data are assimilated into the numerical model by adding to the wind and the pressure fields a proportion of interpolated observational increments at each timestep during the 6 hour period preceding the analysis time. Gravity wave noise is reduced by damping horizontal divergence during this period.

The main change to the global UKMO model since 01/05/1983 has been the introduction of a scheme for parametrising the momentum transports due to sub grid scale mountain gravity waves on 12/12/1984. Details of recent changes are recorded in each "Quarterly report on numerical products from Bracknell".

Until 30/10/86 all the data is valid at 00Z. From 01/11/87 data is available for both 00Z and 12Z. Data is missing at the following time :

00Z on 27/05/83, 31/05/83, 11/06/83, 12/09/83, 03/12/86, 19/02/87, 23/03/87, 07/09/87, 22/09/87, 16/10/87, 26/03/88, 22/04/88, 05/05/88, 14/10/88 :

12Z on 02/12/86, 18/02/87, 19/02/87, 06/09/87, 21/09/87, 03/11/87, 01/12/87, 26/03/88. 01/07/88, 03/12/88.

References

Barnes.R.T.H.. Hide R.. White.A.A.. and Wilson.C.A. 1983: Atmospheric angular momentum fluctuations, length-of-day changes, and polar motion. Proceedings of the Royal Society A . 387. pp.31-73.

Bel,R.S., and Dickinson,A. 1987: London Meteotological Office Scientific Paper No.41 . The Meteorological Office operational numerical weather prediction system. U.K. Meteorological Office, London.

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

AAM(UKMOB) 83 * 01 Available from 1983 to 1988

Year	Number of meas.
1983	241
1984	366
1985	365
1986	306
1987	721
1988	725

Dépôt légal : 2ème trimestre 1989
Imprimeur : Observatoire de Paris

Le Gérant : P. Charvin