IERS TECHNICAL NOTE 1

The initial IERS Terrestrial Reference Frame

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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.

The Initial IERS Terrestrial Reference Frame

The IERS Standards has adopted a description of the Conventional Terrestrial Reference System (CTRS) to be used for all IERS activities, either by individual techniques or combinations.

Its main characteristics are described by:

"a) it should be geocentric. The geocenter is defined for the whole Earth, including oceans and atmosphere

b) its scale should be the one of a local Earth frame , in the meaning of a relativistic theory of gravitation

c) its orientation should be given by the BIH orientation at 1984.0

d) its time evolution should follow a no global net rotation or translation condition.

When one wants to realize such a CTRS through a reference frame (CTRF), i.e. a network of stations reference points or ground marks with coordinates - or set of station coordinates (SSC) - , it is furthermore recommended:

e) to include the permanent solid earth tidal deformation, so that the adopted coordinates will differ from the instantaneous coordinates by only periodic terms (see chapter 6)

f) to adopt cartesian equatorial coordinates X, Y, Z, by preference. If geographical coordinates are needed, the GRS 80 ellipsoid is recommended (a = 6378137 m 1/f = 298.257222 see IERS recommended values).

In order to facilitate the actual implementation of the IERS Terrestrial Reference System (ITRS) by the various analysis centers which participate to IERS, but also by potential users, in particular the GPS community, this study presents several informations which could be useful for these purposes:

1) a critical description of the latest TRF established by BIH, namely BTS 87.

2) a currently improved combination of BTS 87 input data,

following strictly the IERS standards, and to be used as Initial IERS Terrestrial Reference Frame (ITRF-0).

3) some suggestions for implementation of the ITRS, especially by the IERS Central Bureau in its future combined solution (ITRF 88...).

1) The BTS 87 terrestrial reference frame

The detailed description of the BTS 87 frame is given in a paper attached in appendix [4].

We want only to identify here the main characteristics of this frame, mainly in order to show the various little improvements which has been adopted for ITRF-0.

It is important to note that BIH has established each year from 1985 such frames, which were realizations of the BIH terrestrial system : BTS 84, BTS 85, BTS 86 and finally BTS 87. Details about the slight changes both in models and data can be found in the successive BIH Annual Reports, from 1984 to 1987.

The main characteristics of the BTS 87 are:

a) model

a.1) physical model

The physical model used for BTS 87 was described in [4]. It basically models equations which connect BTS frame to various sets of station coordinates (SSC) and Earth rotation parameter (ERP) series, belonging to various individual terrestrial reference systems.

As described below, input coordinate data were given at various epochs. The position in BTS 87 system at epoch t was modelled as:

$$X(t) = X_o + \dot{x}\ (t-t_o)$$

were $\dot{x}$ was computed from AM0-2 model and t_o was Jan. 1 1984.

As all considered input data were derived with a full solid earth tide correction, X_o is also corrected from the permanent

correction. The coordinates X_o^* which would differ from the instantaneous position by only periodic term would be :

$$X_o^* = X_o + \Delta X_{perm}$$

with

$$\Delta X_{perm} \sim \frac{X_o}{|X_o|} \Delta h_{perm}$$

and

$$\Delta h_{perm} = -0.121 \left(\frac{3}{2} \sin^2\varphi - \frac{1}{2}\right) m$$

See [1].

Table 2 gives ΔX_{perm} for primary sites, also plotted in Figure 1.

Finally as scale is derived from SLR, the relativistic model is the local earth frame.

a.2) adjusted parameters

In the BTS 87 adjustment, the following parameters were solved for:

- three coordinates per site X_o, Y_o, Z_o, representing the values at t_o of the position of a particular mark selected as reference mark for the whole site. Local excentricities between this mark and the various points (VLBI or SLR intersection of axis...) to which coordinates of SSCs are referred, were held fixed in the BTS adjustment.

The exact meaning of X_o was given in (a.1).

- ERP values, each 0.05 year

- 7 transformation parameters for each SSC, some of them being fixed (see Table 1 of [4]).

a.3) datum fixation

Origin : mean position of 5 SSCs (3 LLR and 2 SLR) - see Table 1 of paper [4]; obtained by constraining to zero the corresponding translation parameters (see Table 3 of [4]).

Scale : mean value of 2 SSC (SLR), obtained by constraining to zero the corresponding scale parameters (see Table 1 and 3 of [4])

Orientation : aligned on BIH orientation by putting an alignment constraint on ERP parameters, using BIH values for 1986.

Evolution with time : Follows a no global net rotation, by adopting as fixed AMO-2 displacements.

b) input data

The list of SSC and ERP used in the BTS 87 solution is given in Table 1 of [4]. These data were used with diagonal variances.

Moreover as local excentricities were used as fixed data, it was legitimate to consider the contribution of their uncertainties into the a priori standard deviations put for SSCs.

Finally, in order to take that into account, and to avoid optimistic values which would not reflect the actual accuracy but rather the inner precision of the computed solutions for SSCs, it was decided to use 3 cm and 1 cm as lower bounds for standard deviations of SLR and VLBI coordinates respectively.

c) output data

In the official publication of BTS 87, namely the BIH Annual Report for 1987, the following data are provided:

- list of X_o, Y_o, Z_o for reference marks and tracking instrument

of all sites participating to SSCs, distinguishing between colocation sites (i.e. the site occurs at least in two SSCs) and no-colocation sites (one occurence) (Table 2A of [4])

- list of $\dot{x}$, $\dot{y}$, $\dot{z}$ for each site, from AMO-2 (Table 2B of [4])

- list of transformation parameters (Table 3 of [4])

No standard deviation are published.

2) The Initial IERS Terrestrial Reference Frame

Considering what can be done on a short term basis, the following improvements has been adopted to compute a new frame (ITRF-0), to be accepted as initial frame:

1) the permanent solid earth tide correction should be applied, so that X_o^* will be published, in place of X_o .

2) the reference epoch will be 1988 Jan 1 (MJD = 47161).

3) all 7 parameters will be adjusted, except for an additional SSC which will be the BTS87 values for 1984 Jan 1, with a priori standard deviations of 0.1 m for each point (only one per site - see table 3), and for which all 7 parameters are held fixed to zero. By this way :

- the new frame is in the BTS87 system

- no overconstraint is coming from a priori fixation of some scale or translation

- the initial BTS87 coordinates will influence weakly (10 cm !) the inner consistency of used data.

4) The finally accepted input data are :

SSC(NGS) 88 R 01
SSC(GSFC) 88 R 01
SSC(CSR) 88 L 01
SSC(GSFC) 87 L 14
SSC(BIH) 88 C 01 (extract of BTS87)

The used standard deviation are given in Appendix 3.

5) No ERP are now used.

6) The local survey data used in ITRF-0, together with the same data used for BTS87 are given in Table 3.

7) The sites are now classified, following the criteria described below.

We call primary site any site where a threedimensional position can be estimated within a few centimeters in the IERS system, and for any epoch, within the present years.

The criterion to select such a site are:

a) to have a permanent instrument (SLR or VLBI) preferably. For a mobile unit, the relocation should be guaranteed by an accurate survey within a few mm.

b) to use the best technology: 3rd generation lasers, or S/X Mark III VLBI with H-masers

c) to get regular measurements in order to be able to estimate positions at regular epochs (typically monthly) at cm level, and for which the interpolation will keep this cm level for any epoch within the specific time span, which should include present days.

In order to have a better look to the characteristic of the stations, an inventory (given in appendix 2) has been done, giving for each potential IERS site the list of tracking points with :

- their description
- their CDP number (if available)
- their DOMES number
- a code T (temporary) or P (permanent) giving the status of the instrument
- a monthly code, from Jan 1976, giving the status of the mesurements :

  blanc : no measurement

  \- : potential measurement (i.e. the tracking instrument is installed but we do not know if it has produced significant data)

  * : actual measurement

  number : monthly position can be derived. Their accuracy, at one sigma level, labelled AMP (accuracy of monthly position) is classifed (see appendix 2).

We must specify the strict definition of a tracking point, in this analysis : it is a physical mark to which one tracking technique has been attached. Specifically it can be :

- a permanent VLBI instrument (IAR)

- a permanent SLR instrument (IAR or ground mark)

- a ground mark with successive mobile VLBI occupancies

- a ground mark with successive mobile SLR occupancies

So, if a same mark has been used by two types of systems (SLR or VLBI), two tracking points are defined.

From the analysis of this inventory, we have selected, at this stage, 34 primary sites (Figure 2 and Table 1).

The SSC(BIH) 88 C 01 is the set of BTS 87 coordinates (epoch 1984.0) with 0.1 m as standard deviation of each cartesian

component, for reference point of each primary site.

8) The output of the adjustment is given in Appendix 4 :

- transformation parameters with a posteriori standard deviations
- input standard deviations and residuals.

The final coordinates are given for primary sites in Table 1, with a posteriori standard deviations. In each site, both reference point and tracking points are given.

3)Proposal for ITRF

For analysis within IERS, we think that further improvements are necessary:

a) positions should be introduced in the model as time series X_k , for each point of the site. The basic epoch could be the month. The time series X_k should be expressed as

$$X_k = X_o + V_o (t_k - t_o) + L_k$$

where X_o will be the mean position at a reference epoch t_o (1988.0).

V_o would be the trend over several years (horizontal and vertical).

L_k would be the offset from the trend, including several variations (ground waters...), and eventually local discrepencies from the trend, if it is computed from a global model

b) input data should be enlarged :

- analysis centers should provide preferably monthly values, or by default, yearly values, or position and velocity at a reference epoch

- local surveys (terrestrial or GPS) should be included with their epoch and covariance matrix

- geophysical information for V_o should also be included as a priori information, with a proper stochastic model

c) transformation parameters between ITRS and individual systems will be determined for t_o , together with a rate of change (in particular for orientation)

d) the time evolution will be ensured by Tisserand conditions.

References

[1] BOUCHER C. Definition and realization of terrestrial reference systems for monitoring Earth rotation. IUGG General Assembly, Vancouver, 1987 - Symp. nº 4.

[2] BIH Annual Report for 1987. Paris (1988).

[3] MINSTER J.B., JORDAN T.H. Present-day plate motions, J. Geophys. Res., 83, 5331, 1978.

[4] BOUCHER C., ALTAMIMI Z., FEISSEL M. A Combined Terrestrial Reference Frame based on Space Geodesy.

Acronyms

AMP : Accuracy of Monthly Position
BTS : BIH Terrestrial System
CTRF : Conventional Terrestrial Reference Frame
CTRS : Conventional Terrestrial Reference System
GRS : Geodetic Reference System
IERS : International Earth Rotation Service
ITRF : IERS Terrestrial Reference Frame
ITRS : IERS Terrestrial Reference System

Table 1

The Initial IERS Terrestrial Reference Frame(ITRF-0)

Reference epoch 1988.0 AM0-2 model (see note below)

DOMES number	Name	X_o m	Y_o m	Z_o m	Vx mm/y	Vy mm/y	Vz mm/y
10002	Grasse						
M001		4581933.421	556384.131	4389077.242	-14.1	18.0	12.4
		.072	.074	.078			
S001		4581691.860	556159.358	4389359.368			
S002		4581692.438	556195.831	4389354.930			
10402	Onsala						
M003		3370764.112	711471.631	5349802.716	-17.2	14.4	9.0
		.071	.070	.076			
S001		3370966.310	711465.885	5349663.845			
S002		3370606.203	711917.374	5349830.597			
11001	Graz						
M001		4194424.238	1162702.390	4647245.221	-16.8	16.8	11.0
		.075	.073	.078			
S002		4194426.768	1162693.883	4647246.515			
12711	Bologna						
M001		4461385.692	919555.791	4449529.756	-15.5	17.7	11.9
		.076	.074	.084			
S001		4461370.205	919596.674	4449559.039			
12734	Matera						
S001		4641965.142	1393069.923	4133262.204	-16.2	18.1	12.1
		.075	.076	.081			
M001		4641965.142	1393069.923	4133262.204			
M004		4641990.399	1393042.299	4133231.840			
M005		4641984.666	1393057.722	4133233.439			
13212	Herstmonceux						
M002		4033586.048	24250.909	4924205.820	-13.7	16.4	11.2
		.069	.070	.074			
S001		4033463.882	23662.319	4924305.024			
13504	Kootwijk						
M001		3899217.468	396767.961	5015070.104	-15.2	16.0	10.6
		.083	.083	.078			
M002		3899237.735	396769.159	5015055.017			
S001		3899224.114	396742.872	5015073.722			
14001	Zimmerwald						
M001		4331274.006	567584.254	4633139.172	-14.8	17.3	11.7
		.074	.075	.078			
S001		4331283.612	567549.445	4633139.976			
14106	Potsdam						
M001		3800621.416	882005.377	5028859.642	-16.9	15.7	10.1
		.109	.109	.092			
S001		3800621.343	882005.356	5028859.592			

Note: the permanent solid earth tide correction is not applied. To obtain X_o^* add the values as given in Table 2.

14201	Wettzell						
M001		4075575.227	931832.059	4801568.895	-16.5	16.5	10.8
		.072	.072	.076			
M002		4075385.287	931600.590	4801792.340			
M003		4075551.441	931825.405	4801587.755			
M004		4075582.659	931837.192	4801559.850			
M005		4075602.106	931826.409	4801547.688			
M007		4075520.903	931749.526	4801626.959			
S004		4075540.103	931735.126	4801629.259			
S002		4075530.100	931781.275	4801618.187			
20702	Bar Giyyora						
M001		4443967.434	3121945.385	3334694.363	-24.3	15.3	18.0
		.085	.086	.092			
S001		4443968.510	3121946.848	3334695.427			
21605	Shanghai						
M001		-2831089.881	4676203.019	3275170.119	-25.1	-7.9	-10.3
		.203	.188	.177			
S001		-2831087.632	4676203.423	3275172.797			
21701	Kashima						
M001		-3997912.773	3276621.120	3724030.144	-21.5	-11.7	-12.8
		.086	.083	.114			
S001		-3997892.349	3276581.177	3724118.279			
21726	Simosato						
M001		-3822373.413	3699359.761	3507585.767	-22.4	-11.2	-12.6
		.082	.081	.098			
M002		-3822387.121	3699362.226	3507571.924			
S001		-3822388.379	3699363.442	3507573.085			
40405	Goldstone						
M001		-2353394.106	-4641529.704	3676899.234	-15.8	-1.5	-12.0
		.065	.065	.068			
M006		-2356475.665	-4646618.374	3668424.716			
M010		-2356494.046	-4646607.759	3668426.619			
M002		-2350861.551	-4655546.327	3660997.828			
S009		-2356170.919	-4646755.964	3668470.587			
S001		-2353621.112	-4641341.703	3677052.383			
S019		-2353538.678	-4641649.680	3676670.086			
S014		-2351129.053	-4655477.148	3660956.885			
40408	Fairbanks						
S001		-2282195.211	-1452934.546	5756900.319	-23.3	-2.7	-9.9
		.064	.069	.069			
S002		-2281547.095	-1453645.055	5756993.201			
40420	Vandenberg						
M001		-2668815.870	-4530761.551	3598687.233	-15.5	-1.4	-13.2
		.065	.067	.072			
M002		-2678094.568	-4525451.167	3597409.870			
M004		-2668868.017	-4530743.139	3598684.717			
40424	Kauai						
S001		-5543845.996	-2054564.221	2387813.773	-10.5	68.5	34.6
		.075	.081	.093			
40433	Quincy						
M001		-2516893.115	-4198845.082	4076411.498	-17.3	-1.7	-12.4
		.064	.065	.066			
M002		-2517234.689	-4198556.262	4076569.653			
M006		-2516983.795	-4198812.329	4076391.056			
M004		-2517230.799	-4198595.251	4076531.244			

M005		-2517242.300	-4198550.954	4076570.268			
40439	Owens Valley						
M001		-2410422.379	-4477802.748	3838686.657	-16.4	-1.6	-12.2
		.064	.065	.068			
M003		-2410590.264	-4477745.252	3838648.815			
M004		-2410421.156	-4477800.487	3838690.274			
S002		-2409600.673	-4478349.624	3838603.164			
40440	Haystack						
M001		1492453.766	-4457278.813	4296815.900	-18.2	-2.8	3.4
		.064	.061	.069			
S002		1492404.901	-4457266.549	4296881.706			
S003		1492206.765	-4458130.533	4296015.471			
40442	Fort Davis						
M004		-1330832.474	-5328746.584	3235663.718	-14.2	-1.5	-8.4
		.066	.064	.070			
M001		-1330125.296	-5328526.632	3236150.240			
M005		-1330125.296	-5328526.632	3236150.240			
S002		-1330781.273	-5328755.579	3235697.665			
S007		-1330120.944	-5328532.280	3236146.685			
S003		-1324210.882	-5332023.182	3232118.382			
40445	Maui						
M001		-5466006.470	-2404427.916	2242187.470	-15.3	67.3	34.9
		.072	.076	.082			
M002		-5465998.456	-2404408.507	2242228.397			
S005		-5466006.953	-2404428.128	2242188.473			
40451	Washington						
M110		1130731.489	-4831322.617	3994136.414	-17.1	-2.6	1.7
		.064	.062	.070			
M107		1130689.334	-4831341.933	3994123.414			
M108		1130691.385	-4831351.077	3994111.909			
M101		1131240.360	-4831179.753	3994148.415			
M102		1130686.680	-4831353.042	3994110.862			
M103		1130685.722	-4831348.722	3994116.303			
M104		1131095.899	-4831196.967	3994170.694			
M105		1130719.793	-4831350.586	3994106.463			
M106		1131355.599	-4831168.346	3994131.618			
M111		1131364.829	-4831168.807	3994128.874			
M112		1130714.846	-4831367.747	3994087.337			
M114		1130745.832	-4831367.989	3994077.066			
M116		1130735.374	-4831324.625	3994132.307			
40489	Hat Creek						
M001		-2523871.893	-4123580.006	4147719.091	-17.6	-1.8	-12.4
		.064	.066	.069			
S001		-2523969.869	-4123506.424	4147752.585			
40496	Platteville						
M002		-1240708.052	-4720454.373	4094481.606	-17.5	-2.0	-7.7
		.064	.063	.066			
M001		-1240678.155	-4720463.410	4094480.591			
40497	Monument Peak						
M001		-2386277.924	-4802354.329	3444881.451	-36.2	34.7	23.3
		.066	.065	.069			
M002		-2386292.193	-4802347.457	3444880.855			
M003		-2386289.301	-4802346.534	3444883.973			
40499	Richmond						
M001		961317.873	-5674054.858	2740563.633	-12.3	-1.8	0.6

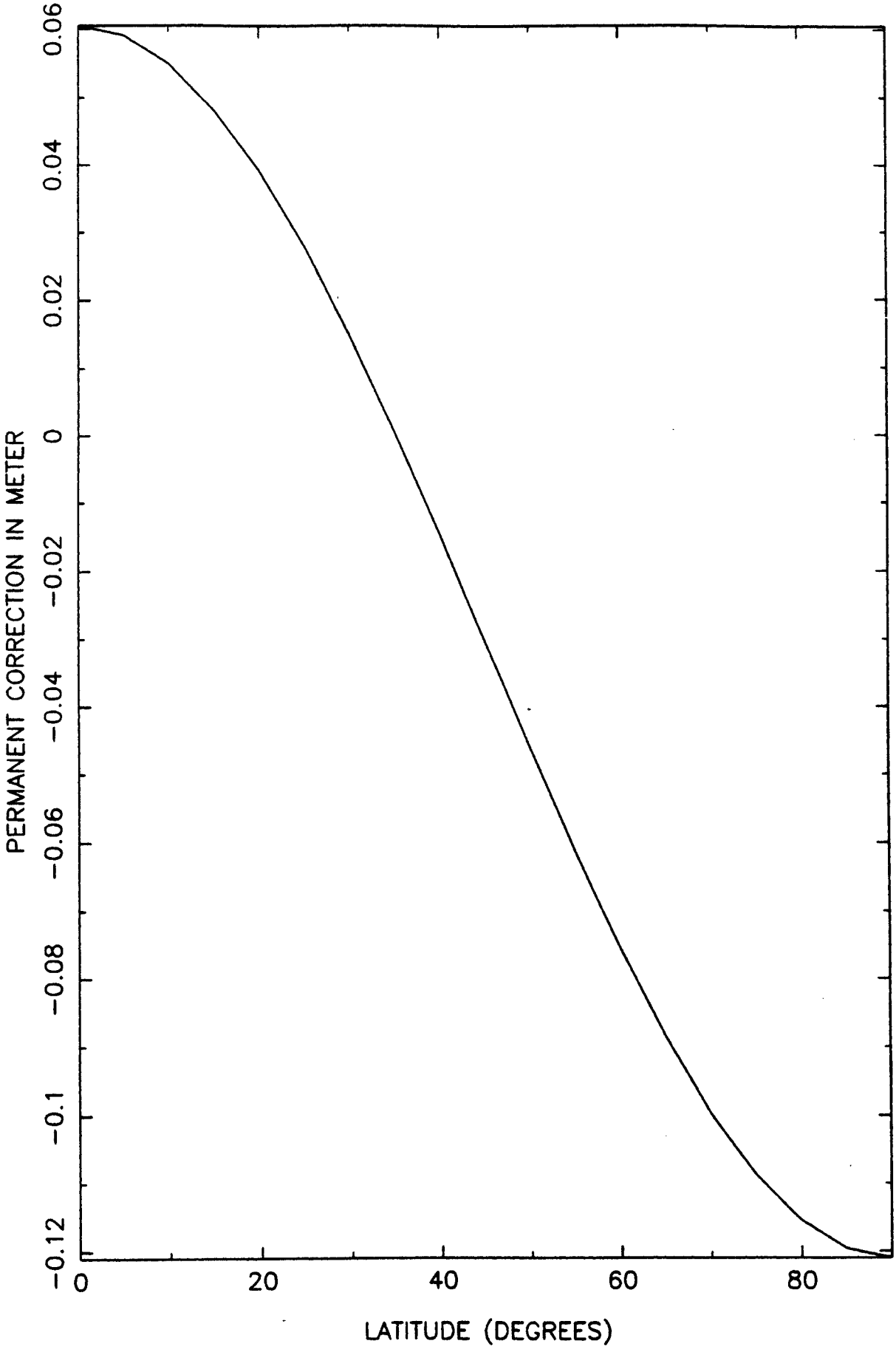
		.069	.066	.077			
S001		961258.151	-5674090.071	2740533.714			
40504	Mazatlan						
M001		-1660089.280	-5619100.405	2511637.834	-11.4	-1.0	-9.8
		.070	.066	.073			
41703	Easter Island						
M001		-1884983.905	-5357606.784	-2892852.671	85.9	-25.3	-9.0
		.229	.209	.207			
M002		-1884984.327	-5357607.984	-2892853.324			
42202	Arequipa						
M002		1942784.901	-5804081.721	-1796911.235	-5.4	-4.7	9.3
		.092	.094	.093			
S001		1942791.958	-5804077.741	-1796919.347			
50103	Orroral						
M103		-4466609.920	2683169.494	-3667428.544	-36.2	-2.7	42.2
		.114	.109	.113			
M106		-4446469.836	2678122.900	-3696248.829			
S006		-4451074.164	2676824.106	-3691347.785			
S003		-4447548.802	2677134.104	-3694996.661			
S005		-4460981.202	2682413.771	-3674582.659			
S001		-4460894.573	2682361.681	-3674748.961			
50107	Yarragadee						
M001		-2389006.512	5043329.292	-3078525.371	-51.4	8.0	53.0
		.116	.109	.117			
92202	Motu Hiumoo						
M001		-5345882.693	-2958272.283	-1824430.449	-43.8	57.2	35.4
		.094	.092	.093			
M002		-5345865.282	-2958246.621	-1824623.822			

Table 2

Permanent correction of the solid Earth tide.

DOMES Number	Site	ΔX mm	ΔY mm	ΔZ mm	Δh mm
10002	Grasse	-18.9	-2.3	-18.2	-26.3
10402	Onsala	-36.0	-7.6	-57.5	-68.3
11001	Graz	-24.1	-6.7	-26.9	-36.8
12711	Bologna	-20.1	-4.1	-20.1	-28.7
12734	Matera	-12.0	-3.6	-10.8	-16.5
13212	Herstmonceux	-30.7	-.2	-37.8	-48.7
13504	Kootwijk	-32.2	-3.3	-41.7	-52.8
14001	Zimmerwald	-24.5	-3.2	-26.4	-36.2
14106	Potsdam	-31.7	-7.4	-42.3	-53.4
14201	Wettzell	-27.6	-6.3	-32.8	-43.3
20702	Bar Giyyora	7.2	5.0	5.4	10.3
21605	Shanghai	-5.4	8.8	6.2	12.1
21701	Kashima	1.3	-1.1	-1.2	-2.1
21726	Simosato	-3.0	2.9	2.8	5.0
40405	Goldstone	.2	.3	-.3	-.5
40408	Fairbanks	31.6	20.1	-80.2	-88.5
40420	Vandenberg	-.9	-1.5	1.2	2.1
40424	Kauai	-30.2	-11.2	13.1	34.8
40433	Quincy	5.7	9.5	-9.3	-14.4
40439	Owens Valley	2.2	4.2	-3.6	-5.9
40440	Haystack	-5.3	15.9	-15.4	-22.7
40442	Fort Davis	-2.8	-11.1	6.8	13.3
40445	Maui	-32.4	-14.2	13.4	37.8
40451	Washington	-2.0	8.7	-7.2	-11.4
40489	Hat Creek	6.7	11.0	-11.1	-17.0
40496	Platteville	2.9	11.1	-9.7	-15.1
40497	Monument Peak	-2.6	-5.2	3.8	7.0
40499	Richmond	4.0	-23.6	11.5	26.6
40504	Mazatlan	-8.3	-28.2	12.7	32.0
41703	Easter Island	-6.7	-19.1	-10.4	22.7
42202	Arequipa	14.0	-41.8	-13.0	45.9
50103	Orroral	.1	-.1	.1	-.2
50107	Yarragadee	-6.6	14.0	-8.6	17.7
92202	Motu Hiumoo	-38.1	-21.1	-13.1	45.5

FIG. 1. PERMANENT CORRECTION OF THE SOLID EARTH TIDE



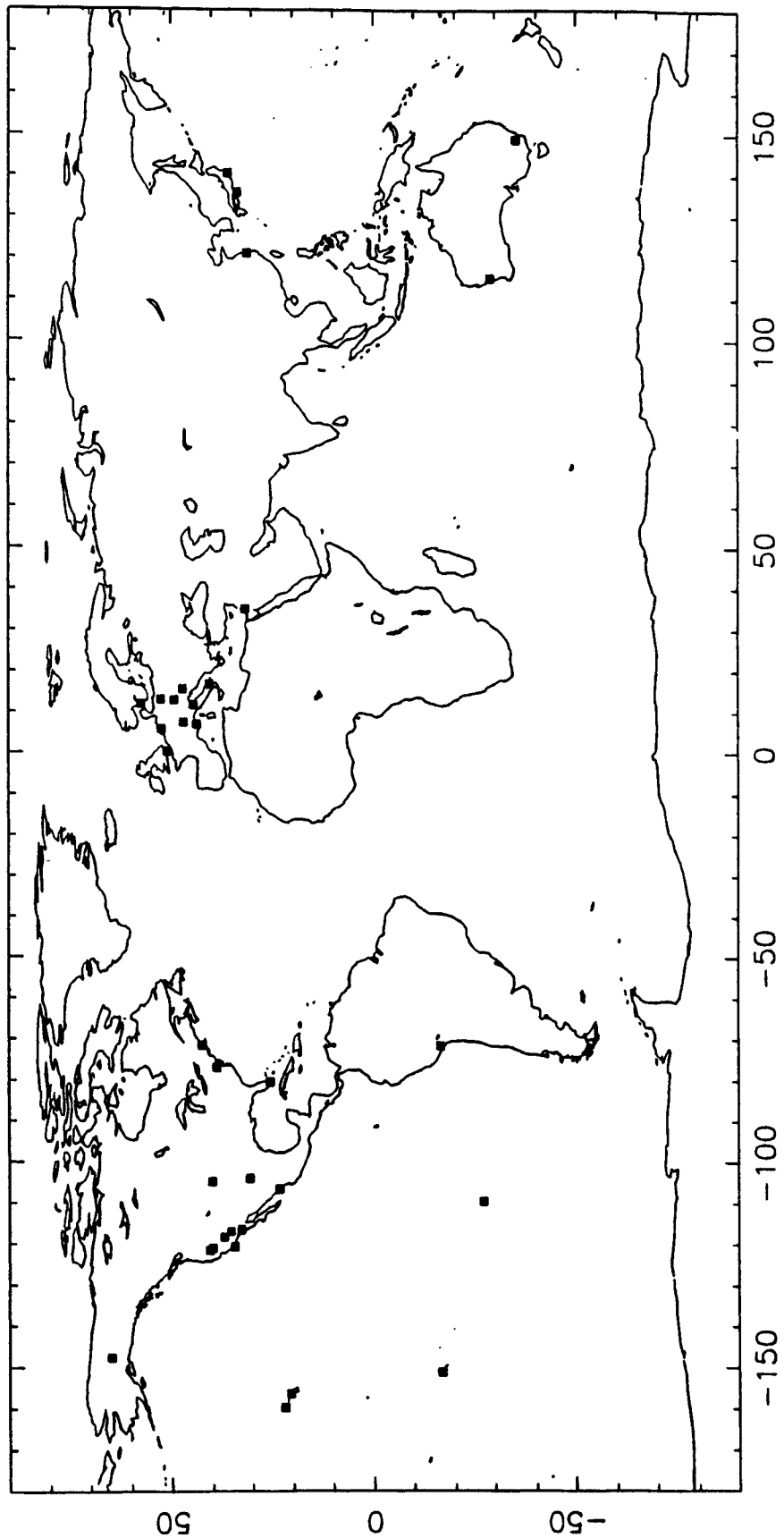


FIG. 2. PRIMARY SITES OF THE ITRF (ITRF-0)

Table 3

Local Surveys for ITRF-0

DIRECTORY OF STATIONS

DOMES Number	Site	CDP Number	Designation
10002	Grasse		
M001			Mark Caussols 3 (F 2)
S001		7835	SLR IAR
S002		7845	LLR IAR
10402	Onsala		
M003			NLS Mark 761331 (S7331)
S001		7212	VLBI ref. pt. ONSALA85
S002		7213	VLBI ref. pt. ONSALA60
11001	Graz		
M001			Mark (A171)
S002		7839	SLR IAR
12711	Bologna		
M001			Pillar
S001		7230	Radiotelescope ref. pt.
12734	Matera		
M001			Mark (I 201130)
M004		7541	Mark SLR 7541 "C"
M005		7540	Mark SLR 7540 "B"
S001		7939	SLR IAR
13212	Herstmonceux		
M002			Primary pillar (GB 481)
S001		7840	SLR IAR
13504	Kootwijk		
M001			Perm. mark 1980
M002		8833	Monument MTLRS 1984
S001		7833	SLR IAR (NL 233)
14001	Zimmerwald		
M001			Mark (CH 99)
S001		7810	SLR IAR
14106	Potsdam		
M001			Pillar tour Helmert
S001		1181	SLR IAR

14201	Wettzell		
M001			Astro. Pillar
M002			Trig. Point (D6843)
M003		7595	SLR and GPS mark
M004		7596	SLR TLRS-1,2 mark
M005		7597	SLR TLRS-1 mark
M007		7599	SLR TLRS-1 mark
S004		7224	VLBI Ref. Point
S002		7834	SLR IAR
20702	Bar Giyyora		
M001		7530	SLR mark 7530
S001		7530	MOBLAS-2 (ML0214)
21605	Shanghai		
M001			Mark connect with bedrock
S001		7837	SLR IAR
S008		7226	VLBI 6m radiotelescope
S009		7227	VLBI 25m antenna
21701	Kashima		
M001			Metal station mark (Denken 1)
S001		1856	VLBI 26m antenna
21726	Simosato		
M001			Stone marker
M002		7838	SLR mark (center of the ring of the base pier)
S001		7838	SLR IAR fixed
40405	Goldstone		
M001		7085	MOBLAS 7085 Goldstone val
M002		7115	MOBLAS 7115-1979 standard NASA disk
M006		7265	Mojave NCMN 1983 NGS station disk
M010		7287	Mojave TLRS 1984 standard NASA disk
S009		7222	Mojave fixed 12m VLBI ref. point
S001		1514	Mars 64m fixed VLBI ref. point (DSS14)
S014		1513	Venus 26m fixed VLBI ref. point (DSS13)
S019			Mars 34m fixed VLBI ref. ponit (DSS15)
40408	Fairbanks		
S001			26m antenna
S002		7225	26m VLBI ref. point (GILMORE CREEK)
40420	Vandenberg		
M001		7111	DMA disk MOBLAS 7111 (1981)
M002		7223	DMA disk VLBI 7223 (1983)
M004		7887	DMA disk TLRS 7887 (1983)
40424	Kauai		
S001		1311	9m VLBI ref. point

40433	Quincy		
M001		7051	Steel plate MOBLAS 7051
M002		7109	MOBLAS 7109 (1981) Standard NASA disk
M006		7260	Quincy ARIES 1979
M005		7886	TLRS 7886 (1982) standard NASA disk
M004		7221	TLRS and VLBI standard NASA disk
40439	Owens Valley		
M001		7114	MOBLAS 7114 (1979) standard NASA disk
M003		7084	MOBLAS, TLRS 7084 standard NASA disk
M004		7853	Mobile VLBI Jul 87 standard NASA disk
S002		7207	40m VLBI ref. point
40440	Haystack		
M001		7091	MOBLAS HAYSTACK INTER COMP 1977
S002		7205	37m VLBI ref. point of radio telescope
S003		7209	18m VLBI ref. point of radio telescope
40442	Fort Davis		
M004			McDonald RM4 1977
M001		7086	MLRS, MOBLAS, TLRS-1 standard NASA disk
M005		7885	MLRS, MOBLAS, TLRS-1 standard NASA disk
S002		7206	LLR McDONALD 2
S007			LLR MLRS
S003		7216	85-foot VLBI ref. point (HRAS 085)
40445	Maui		
M001		7210	HOLLAS fixed carriage bolt
M002		7120	MOBLAS 7120 (1980)
S005			LLR HALEAKALA transmitter
40451	Washington		
M110			Greenbelt north GEOS(GSFC) GORF
M107		7064	Mobile SLR 7064 standard NASA disk
M108		7065	Mobile SLR 7065 standard NASA disk
M101		7101	MOBLAS 7101-1977 standard NASA disk
M102		7102	Mobile SLR 7102-1978 standard NASA disk
M103		7103	Mobile SLR 7103-1978 standard NASA disk
M104		7104	Mobile SLR 7104-1978 standard NASA disk
M105		7105	MOBLAS -7 7105-1981 standard NASA disk
M106		7100	Mobile SLR 7100-1977 standard NASA disk
M111		7899	TLRS 7899-1980 standars NASA disk
M112		7063	STALAS fixed Laser standard NASA disk
M114		7125	MTLRS 7125-1985 standard NASA disk
M116		7130	TLRS-2 7130-1985 standard NASA disk
M117		7920	TLRS-1 7125-B standard NASA disk
M118		7889	TLRS 7889-1981 standard NASA disk
M119		7917	Steel plate SAO-3 (previously 7807)
M120		7918	TLRS-3 standard NASA disk
M121		7919	TLRS-4 standard NASA disk
40489	Hat Creek		
M001			Mark NCMN B
S001		7218	26m VLBI ref. point of radio telescope

40496	Platteville		
M002		7258	NCMN 1981 mobile VLBI NGS station disk
M001		7112	Moblas 7112-1980 standard NASA disk
40497	Monument Peak		
M001		7110	ORT station 7110-1981 standard NASA disk
M002		7220	ARIES ORION STA 7220-1981
M003		7274	NCMN 1983 mobile VLBI NGS disk
40499	Richmond		
M001			Timer 1962
S001		7219	65 foot VLBI antenna
40504	Mazatlan		
M001		7122	MOBLAS 7122-1983 standard NASA disk
41703	Easter Island		
M001		7061	TLRS-2 7061-1983 NASA-GSFC station disk
M002		7097	TLRS-2 7097-1986 NASA brass disk
42202	Arequipa		
M002			Satellite mark 1961
S001		7907	SAO-2 fixed laser
50103	Orroral		
M103			Stromlo PZT4
M106		7843	Orroral center ground mark 7843
S003		7943	SAO-3 fixed laser
S001			DSS43 Antenna
S005			DSS42 Antenna
S006			DSS44 Antenna
50107	Yarragadee		
M001		7090	MOBLAS 7090 brass disk
92202	Motu Hiumoo		
M001			Tube Huahine no. 5
M002		7121	MOBLAS-1 7121-1982 standard NASA disk
M003		7123	TLRS-2 7123 standard NASA disk

LOCAL ECCENTRICITIES

DOMES Number	Site	From	To	dX(m)	dY(m)	dZ(m)
10002	Grasse	M001	S001	-241.561	-224.773	282.126
			S002	-240.983	-188.300	277.688
10402	Onsala	M003	S001	202.198	-5.746	-138.871
			S002	-157.909	445.743	27.881
11001	Graz	M001	S002	2.530	-8.507	1.294
12711	Bologna	M001	S001	-15.487	40.883	29.283
12734	Matera	S001	M001	0.0	0.0	0.0
			M004	25.257	-27.624	-30.364
			M005	19.524	-12.201	-28.765
13212	Herstmonceux	M002	S001	-122.166	-588.590	99.204
13504	Kootwijk	M001	M002	20.267	1.198	-15.087
			S001	6.646	-25.089	3.618
14001	Zimmerwald	M001	S001	9.606	-34.809	.804
14006	Potsdam	M001	S001	-.073	-.021	-.050
14201	Wettzell	M001	M002	-189.940	-231.469	223.445
			M003	-23.786	-6.654	18.860
			M004	7.432	5.133	-9.045
			M005	26.879	-5.650	-21.207
			M007	-54.324	-82.533	58.064
			S004	-35.124	-96.933	60.364
			S002	-45.127	-50.784	49.292
20702	Bar Giyyora	M001	S001	1.076	1.463	1.064
21605	Shanghai	M001	S001	2.249	.404	2.678
			S008			
			S009			
21701	Kashima	M001	S001	20.424	-39.943	88.135
21726	Simosato	M001	M002	-13.708	2.465	-13.843
			S001	-14.966	3.681	-12.682
		M002	S001	-1.258	1.216	1.161
40405	Goldstone	M001	M002	2532.555	-14016.623	-15901.406
			M006	-3081.559	-5088.670	-8474.518
			M010	-3099.940	-5078.055	-8472.615
			S009	-2776.813	-5226.260	-8428.647
			S001	-227.006	188.001	153.149
			S014	2265.053	-13947.444	-15942.349
			S019	-144.572	-119.976	-229.148

40408	Fairbanks	S001	S002	648.116	-710.509	92.882
40420	Vandenberg	M001	M002	-9278.698	5310.384	-1277.363
			M004	-52.147	18.412	-2.516
40424	Kauai	S001				
40433	Quincy	M001	M002	-341.574	288.820	158.155
			M004	-337.684	249.831	119.746
			M005	-349.185	294.128	158.770
			M006	-90.680	32.753	-20.442
40439	Owens Valley	M001	M003	-167.885	57.496	-37.842
			M004	1.223	2.261	3.617
			S002	821.706	-546.876	-83.493
40440	Haystack	M001	S002	-48.865	12.264	65.806
			S003	-247.001	-851.720	-800.429
40442	Fort Davis	M004	M001	707.178	219.952	486.522
			M005	707.178	219.952	486.522
			S002	51.201	-8.995	33.947
			S007	711.530	214.304	482.967
			S003	6621.592	-3276.598	-3545.336
40445	Maui	M001	M002	8.014	19.409	40.927
			S005	-.483	-.212	1.003
40451	Washington	M110	M107	-42.155	-19.316	-13.000
			M108	-40.104	-28.460	-24.505
			M101	508.871	142.864	12.001
			M102	-44.809	-30.425	-25.552
			M103	-45.767	-26.105	-20.111
			M104	364.410	125.650	34.280
			M105	-11.696	-27.969	-29.951
			M106	624.110	154.271	-4.796
			M111	633.340	153.810	-7.540
			M112	-16.643	-45.130	-49.077
			M114	14.343	-45.372	-59.348
			M116	3.885	-2.008	-4.107
40489	Hat Creek	M001	S001	-97.976	73.582	33.494
40496	Platteville	M002	M001	29.897	-9.037	-1.015
40497	Monum. Peak	M001	M002	-14.269	6.872	-.596
			M003	-11.377	7.795	2.522
40499	Richmond	M001	S001	-59.722	-35.213	-29.919
40504	Mazatlan	M001				
41703	Easter Is.	M001	M002	-.422	-1.200	-.653

42202	Arequipa	M002	S001	7.057	3.980	-8.112
50103	Orroral	M103	M106	20140.084	-5046.594	-28820.285
			S003	19061.118	-6035.390	-27568.117
			S001	5715.347	-807.813	-7320.417
			S005	5628.718	-755.723	-7154.115
			S006	15535.756	-6345.388	-23919.241
50107	Yarragadee	M001				
92202	Motu Hiumoo	M001	M002	17.411	25.662	-193.373
			M003			

Appendix

1 - A combined terrestrial reference frame based on space geodesy

2 - List of potential IERS sites

3 - Input systems (from BIH Annual Report for 1987)

4 - Results of ITRF-0 (transformation parameters and residuals)

APPENDIX 1

Appendix 1

A COMBINED TERRESTRIAL REFERENCE FRAME BASED ON SPACE GEODESY

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INTRODUCTION

A terrestrial reference frame of 64 sites has been compiled on the basis of several space geodesy analyses, leading to the last realisation of the Terrestrial System of the Bureau International de l'Heure (BIH), BTS 1987 (BIH 1988), before the BIH activities on Earth rotation be transfered to the new International Earth Rotation Service (IERS). This realisation provides the initial definition of the IERS Terrestrial System.

The method described herenfter is based on a proposal of Guinot (1981). Its implementation has been studied by Boucher and Feissel (1984), following models described by Zhu and Mueller (1983).

The definition is as follows. A direct geocentric system of tri-rectangular axes is selected. The axis Gz is in the direction of the BIH pole origin in its previous realization ; the axis Gx is in the direction of the origin of longitudes, as previously realized by the BIH ; the length unit is the metre (SI).

DATA ANALYSIS

The analysis takes into account homogeneous Sets of Stations Coordinates (SSC) derived from programs of observations using space techniques in several networks, from which series of Earth Rotation Parameters (ERP : coordinates of the pole and universal time) are derived. The networks and series of ERP participating to the adjustment are listed in Table 1.

The fiducial points selected for the realization of the terrestrial system are one point per colocation site, i.e., sites for which station coordinates are available in at least two of the networks of Table 1. A site is defined as an area of dimension up to 50 km for which precise geodetic ties between space geodesy stations and geodetic marks are available. The selected sites are listed in Table 2. Some of the ground stations on these sites do not belong to the permanent tracking networks used in the determination of the Earth's rotation. Nevertheless their coordinates are assumed to be consistent with those of the permanent stations of the same network. This is the case for the VLBI networks, and the Doppler network for which a number of points obtained with portable receivers are included. Some other sites could not be included due to lack of information either on the local geodetic ties or on the station coordinates in one of the networks.

The epoch of the BTS (1987) is 1984.0. The plate motion model AM0-2 (no net rotation) of J.B. Minster and T.H. Jordan (1978) is adopted. This model is the one recommended in the MERIT Standards (Melbourne et al., 1985).

The terrestrial system is realized through the cartesian coordinates adopted for the selected sites. For linking the system to the geocentre, the adopted origin is derived from the determinations of the dynamical solutions SSC(JPL) 88 M 01, SSC(CERGA) 88 M 01, SSC(SHA) 86 M 01, SSC(CSR) 88 L 01, and SSC(GSFC)87 L 14. The adopted scale is based on SSC(CSR) 88 L 01 and SSC(GSFC)87 L 14. The orientation is obtained by insuring the continuity of the derived series of ERP with the preceding BIH series.

A least square estimation is performed among the observed coordinates of the colocation sites in the different networks, and the determinations of the ERP of the different series. The station coordinates are brought to the fiducial point of their site by means of the known geodetic ties ; the series of ERP are under the form of normal values at 0.05 year interval. In the case of VLBI, the rotation angles of the associated frames of Radio Source Coordinates around the polar axis (A3) are constrained to values obtained from the comparison of coordinates of common radio sources (Arias et al., 1988). The following unknowns are adjusted:

- a set of cartesian coordinates for each site in the BTS (Table 2),
- a set of 7 transformation parameters which relate the individual SSC to the BTS (Table 3), for 1984.0,
- a series of ERP at 0.05 year interval, referred to the BTS, from 1987.00 to 1987.95.

RESULTS

Table 1 lists the Sets of Stations Coordinates (SSC) and the corresponding series of Earth Rotation Parameters (ERP) contributing to the realisation of the BTS, with the following information.

SSC : label of the SSC, plate motion model used, number of colocated sites, status of the transformation parameters in the global adjustment.

ERP : name and label of the series, time span and a priori standard deviations used in the constraints for the orientation of the axes of the BTS. The later are proportional to the formal uncertainties of normal values of the coordinates of the pole (x, y) and universal time (UT) at 0.05 year interval. The multiplying factors are derived from the analysis of the stability of each time series. The original series which were originally referred to the AM1-2 plate motion model are brought to the AM0-2 model by linear drifts derived from the relative rotation of the two models.

Table 2 lists the cartesian coordinates for 1984.0 (MJD=45700) of the reference points of the colocated sites. Each site is designated by its name, the DOMES number of the reference point, the mention of the networks to which it is related, and the plate to which it belongs. DOMES is the Directory of MERIT sites, a part of the space geodesy coordinates data base of the Institut Géographique National.

The complete description of the points of each site and the local ties used in the adjustment is given in Note Interne du BIH nr 5, available on request. In addition to the site reference marks, the table contains for each site the coordinates of the VLBI, LLR and SLR reference points, using local excentricities published in the Note Interne. Because doubts can exist on some local surveys, the coordinates of these reference points are in some cases more reliable that those of the reference marks. For colocation sites between two different observing techniques, this reliability is tested by the combined adjustment.

The site coordinates can be brought to date by use of the velocity vectors given in Table 2A (AM0-2 model).

Table 3 lists the numerical values of the parameters which transform the coordinates in the SSC's of Table 1 into the BTS at epoch 1984.0. In the case of VLBI, the associated values of A3 are listed. The transformation parameters for the terrestrial systems are in the sense combined towards individual system.

The transformation parameters for the World Geodetic System 1984 (WGS 84) of the U.S. Defense Mapping Agency are also listed. They are obtained as explained by Boucher et al. (1988).

ACCESS TO THE TERRESTRIAL SYSTEM, LINK TO CELESTIAL SYSTEM

The access to the terrestrial system can be obtained through comparison of an individual series of ERP with the series ERP(BIH) 87 C 02 (Feissel and Guinot, 1988). This series is identical to the BIH combined solution for the years 1984-1987. Starting with 1988, the IERS series can be used. Prior to this date, it is based on a calibration of the earlier BIH series of ERP. The part of the uncertainty which is due to the instability of this series in this type of access is given hereafter for averaging times of one day and one year, in units of 0.001".

Period:	1962-1966		1967-1971		1972-1977		1978-1983		1984-1987	
averaging time	1d	1y	1d	1y	1d	1y	1d	1y	1d	1y
direction										
pole	24	10	17	6	11	5	6	4	3	2
longitudes	30	15	23	10	20	8	17	4	10	2

When using the transformation parameters of the terrestrial systems, the uncertainty due to the realization of the BTS is estimated to a few cm in the origin, 0.002 ppm in the scale and up to 0.004" in the orientation.

The tie of the BTS polar origin with the Conventional International Origin as realized by the International Latitude Service (ILS) is estimated from the differences between the ILS and BIH series of the coordinates of the pole over 1964-1966. The coordinates of the ILS CIO with respect to the BTS pole are $x = -0.034" \pm 0.018"$, $y = \pm 0.010" \pm 0.014"$.

This terrestrial frame, the combined celestial frame of Arias et al. (1988), the series ERP(BIH)87 C 02, and the corresponding time series of celestial pole offsets with respect to the IAU 1976 precession and IAU 1980 Nutation models (available on request) form a consistent ensemble, with uncertainties given in the present report and by Arias et al. (1988).

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Table 1 - CONTRIBUTIONS TO THE COMBINED TERRESTRIAL FRAME

SETS OF STATION COORDINATES

Set	Station Coordinates	Plate motion model	Nb of coloc. sites	Status of the transformation parameters: centre	scale	orient.
1	SSC(NGS) 88 R 01	AM0-2	13	free	free	free
2	SSC(GSFC) 88 R 01	AM0-2	18	free	free	free
3	SSC(JPL) 83 R 05	(1)	3	free	free	free
4	SSC(SHA) 88 R 01	(1)	5	free	free	free
5	SSC(JPL) 88 M 01	(1)	3	Fixed	free	free
6	SSC(CERGA)88 M 01	(1)	3	Fixed	free	free
7	SSC(SHA) 86 M 01	(1)	2	Fixed	free	free
8	SSC(CSR) 88 L 01	AM1-2	53	Fixed	Fixed	free
9	SSC(GSFC) 87 L 14	AM0-2	51	Fixed	Fixed	free
10	SSC(DGFI)87 L 03	(2)	46	free	free	free
11	SSC(SHA) 87 L 01	AM1-2	22	free	free	free
12	SSC(DUT) 87 L 04	(1)	25	free	free	free
13	SSC(DMA) 77 D 01(3)	(1)	39	free	free	free

SERIES OF EARTH ROTATION PARAMETERS

Label	Time span	A priori standard deviation (averaging time : 0.05 y) x 0.001"	y 0.001"	UT1 0.0001s
ERP(NGS) 88 R 01	1986.0-1988.0	1.0	1.0	0.5
ERP(GSFC) 88 R 01	1986.0-1988.0	1.0	1.0	0.5
ERP(JPL) 83 R 01	1986.0-1988.0			4.7(4)
ERP(SHA) 88 R 01	1986.0-1987.2	2.1	2.4	3.0
ERP(JPL) 88 M 01	1986.0-1988.0			5.0(4)
ERP(CERGA)88 M 01	1986.0-1988.0			5.0(4)
ERP(SHA) 86 M 01	1986.0-1987.9			9.0
ERP(CSR) 88 L 01(5)	1986.0-1988.0	1.0	1.0	
ERP(GSFC) 87 L 14	1986.0-1987.5	1.0	1.0	
ERP(DGFI)87 L 02	1986.0-1986.9	3.3	3.0	
ERP(SHA) 87 L 01(5)	1986.0-1988.0	2.2	2.1	
ERP(DUT) 87 L 04	1986.0-1987.0	2.3	2.0	

Notes
(1) No plate motion assumed.
(2) Motion of the sites adjusted.
(3) NSWC 9Z-2.
(4) UT0 - UTC
(5) Series referred to AM0-2 by the following linear corrections.

$$\dot{x} = -0.00052"/y,$$
$$\dot{y} = -0.00024"/y,$$
$$\dot{UT1} = -0.000047s/y.$$

Complete reference to the data listed can be found in the BIH Annual Report for 1987, p. D-2 to D-8.

TABLE 2 - SITE COORDINATES FOR EPOCH 1984.0

SITE, SITE REFERENCE MARKS	DOMES NUMBER	NETWORKS (1) 0000000001111 1234567890123	X m	Y m	Z m	PLATE
ALGONQUIN	40104M001	* *	918127.795	-4346061.976	4561984.210	NOAM
VLBI 7282	40104S001		918035.035	-4346132.256	4561971.144	
AMERICAN SAMOA	50503M001	*** *	-6100045.746	-996203.486	-1568976.542	PCFC
SLR 7096M001	50503M001		-6100045.746	-996203.486	-1568976.542	
AREQUIPA	42202M002	******	1942784.899	-5804081.705	-1796911.286	SOAM
SLR 7907S001	42202S001		1942791.969	-5804077.735	-1796919.376	
ASKITES	12612M001	* * *	4353445.043	2082666.212	4156506.621	EURA
SLR 7510M001	12612M001		4353445.043	2082666.212	4156506.621	
BAR GIYYORA	20702M001	*** *	4443967.518	3121945.281	3334694.354	AFRC
SLR 7530M001	20702M001		4443967.518	3121945.281	3334694.354	
BEAR LAKE	40438M001	*** *	-1735997.063	-4425048.200	4241430.462	NOAM
SLR 7082M001	40438M001		-1735997.063	-4425048.200	4241430.462	
BERMUDA	42501M001	** *	2308538.609	-4874079.933	3393628.512	NOAM
SLR 7067M001	42501M001		2308538.609	-4874079.933	3393628.512	
BOLOGNE	12711M001	** *	4461385.752	919555.797	4449529.710	EURA
VLBI 7230	12711S001		4461370.265	919596.680	4449558.993	
CABO SAN LUCAS	40505M001	**	-1997241.481	-5528041.166	2468355.083	PCFC
SLR 7882M001	40505M001		-1997241.481	-5528041.166	2468355.083	
CAGLIARI	12725M202	*** *	4885453.227	783999.779	4011509.915	EURA
SLR 7545M001	12725M002		4893398.179	772673.204	4004140.913	
CERRO TOLOLO	41706M001	***	1815517.137	-5213464.857	-3187999.424	SOAM
SLR 7401M001	41706M001		1815517.137	-5213464.857	-3187999.424	
CHILBOLTON	13201M001	** *	4008269.778	-100699.680	4943807.047	EURA
VLBI 7215	13201S002		4008310.294	-100650.914	4943794.600	
DIONYSOS	12602M001	* *	4595211.886	2039440.665	3912635.283	EURA
SLR 7940S001	12602S001		4595217.739	2039464.564	3912613.341	
EFFELSBERG	14209S001	** *	4033947.687	486990.358	4900430.577	EURA
VLBI 7203	14209S001		4033947.687	486990.358	4900430.577	
FLAGSTAFF	40491M003	***	-1923998.797	-4850850.819	3658590.927	NOAM
SLR 7891M001	40491M002		-1923976.564	-4850871.640	3658574.751	
FORT DAVIS	40442M004	** **********	-1330832.406	-5328746.596	3235663.743	NOAM
VLBI 7216	40442S003		-1324210.814	-5332023.194	3232118.407	
LLR MCD 2.7	40442S002		-1330781.205	-5328755.591	3235697.690	
LLR MLRS	40442S007		-1330120.876	-5328532.292	3236146.710	
SLR 7086M001	40442M001		-1330125.228	-5328526.644	3236150.265	
SLR 7885M001	40442M005		-1330125.228	-5328526.644	3236150.265	
GOLDSTONE	40405M001	*** *** *	-2353394.040	-4641529.700	3676899.298	NOAM
VLBI 7222	40405S009		-2356170.853	-4646755.960	3668470.651	
VLBI DSS14	40405S001		-2353621.046	-4641341.699	3677052.447	
VLBI DSS15	40405S019		-2353538.612	-4641649.676	3676670.150	
VLBI DSS13	40405S014		-2351128.987	-4655477.144	3660956.949	
SLR 7085M001	40405M001		-2353394.040	-4641529.700	3676899.298	
SLR 7115M001	40405M002		-2350861.485	-4655546.323	3660997.892	
SLR 7265M001	40405M006		-2356475.599	-4646618.370	3668424.780	
GRAND TURK	43602M001	** *	1919494.539	-5620965.118	2316112.861	NOAM
SLR 7068M001	43602M002		1920482.719	-5619478.288	2318914.351	

TABLE 2 - (CONT.) SITE COORDINATES FOR EPOCH 1984.0

SITE, SITE REFERENCE MARKS	DOMES NUMBER	NETWORKS (1) 0000000001111 1234567890123	X m	Y m	Z m	PLATE
GRASSE	10002M001	*********	4581933.461	556384.065	4389077.201	EURA
LLR CERGA	10002S002		4581692.478	556195.765	4389354.889	
SLR 7835S001	10002S001		4581691.900	556159.292	4389359.327	
GRAZ	11001M001	******	4194424.308	1162702.297	4647245.175	EURA
SLR 7839S001	11001S002		4194426.838	1162693.790	4647246.469	
GREENBANK	40441M001	** *	883223.826	-4924442.820	3944067.031	NOAM
VLBI 7204	40441S001		882880.146	-4924482.320	3944130.611	
HAYSTACK	40440M001	** * *** *	1492453.875	-4457278.775	4296815.869	NOAM
VLBI 7205	40440S002		1492405.010	-4457266.511	4296881.675	
VLBI 7209	40440S003		1492206.874	-4458130.495	4296015.440	
SLR 7091M001	40440M001		1492453.875	-4457278.775	4296815.869	
HELWAN	30101S001	****	4728283.419	2879669.884	3156894.162	AFRC
SLR 7831S001	30101S001		4728283.419	2879669.884	3156894.162	
HERSTMONCEUX	13212M002	******	4033586.098	24250.831	4924205.776	EURA
SLR 7840S001	13212S001		4033463.932	23662.241	4924304.980	
JOHANNESBURG	30302M001	**	5084867.344	2670346.577	-2768064.652	AFRC
VLBI 7231	30302S001		5085442.840	2668263.384	-2768697.439	
KARITSA	12614M001	*** *	4596042.734	1733476.733	4055720.797	EURA
SLR 7520M001	12614M001		4596042.734	1733476.733	4055720.797	
KATAVIA	12615M001	* * *	4573400.112	2409322.220	3723881.784	EURA
SLR 7512M001	12615M001		4573400.112	2409322.220	3723881.784	
KOOTWIJK	13504M001	**** *	3899217.579	396767.860	5015070.066	EURA
SLR 7833S001	13504S001		3899224.225	396742.771	5015073.684	
KWAJALEIN ATOLL	50505M001	* *** *	-6143447.463	1364699.748	1034162.876	PCFC
VLBI 4968	50505S003		-6143536.697	1363996.771	1034707.116	
SLR 7092M001	50505M001		-6143447.463	1364699.748	1034162.876	
MADRID	13407S003	** *	4849245.503	-360278.377	4114884.354	EURA
VLBI DSS61	13407S003		4849245.503	-360278.377	4114884.354	
VLBI DSS63	13407S001		4849092.956	-360180.764	4115109.040	
VLBI DSS62	13407S005		4846700.403	-370196.097	4116905.644	
MARYLAND POINT	40490M001	** *	1106560.128	-4882972.913	3938004.944	NOAM
VLBI 7217	40490S001		1106629.567	-4882907.175	3938086.890	
MATERA	12734S001	*****	4641965.199	1393069.834	4133262.152	EURA
SLR 7540M001	12734M005		4641984.723	1393057.633	4133233.387	
SLR 7541M001	12734M004		4641990.456	1393042.210	4133231.788	
SLR 7939S001	12734S001		4641965.199	1393069.834	4133262.152	
MAUI	40445M001	** ******	-5466006.395	-2404428.159	2242187.329	PCFC
LLR HAL.TMTR	40445S005		-5466006.878	-2404428.371	2242188.332	
SLR 7120M001	40445M002		-5465998.381	-2404408.750	2242228.256	
SLR 7210M001	40445M001		-5466006.395	-2404428.159	2242187.329	
MAZATLAN	40504M001	*****	-1660089.260	-5619100.387	2511637.853	NOAM
SLR 7122M001	40504M001		-1660089.260	-5619100.387	2511637.853	
METSAHOVI	10503M001	**** *	2892580.841	1311797.673	5512614.168	EURA
SLR 7805S001	10503S001		2892595.545	1311808.220	5512610.017	

TABLE 2 - (CONT.) SITE COORDINATES FOR EPOCH 1984.0

SITE, SITE REFERENCE MARKS	DOMES NUMBER	NETWORKS (1) 0000000001111 1234567890123	X m	Y m	Z m	PLATE
MONTE GENEROSO	14005M002	**	4390309.978	696751.949	4560835.845	EURA
SLR 7590M001	14005M002		4390309.978	696751.949	4560835.845	
MONUMENT PEAK	40497M001	*****	-2386277.797	-4802354.450	3444881.362	PCFC
SLR 7110M001	40497M001		-2386277.797	-4802354.450	3444881.362	
SLR 7220M001	40497M002		-2386292.066	-4802347.578	3444880.766	
SLR 7274M001	40497M003		-2386289.174	-4802346.655	3444883.884	
MOTU HIUMOO	92202M001	*****	-5345882.518	-2958272.496	-1824430.598	PCFC
SLR 7121M001	92202M002		-5345865.107	-2958246.834	-1824623.971	
MOUNT HOPKINS	40434M001	** *	-1936760.353	-5077703.320	3331925.385	NOAM
SLR 7921S001	40434S001		-1936760.073	-5077707.130	3331922.515	
NATAL	41604M002	*** *	5186779.180	-3653499.313	-653908.448	SOAM
SLR 7929S001	41604S001		5186467.956	-3653856.205	-654322.072	
ONSALA	10402M003	** * *	3370764.171	711471.646	5349802.684	EURA
VLBI 7213	10402S001		3370966.369	711465.900	5349663.813	
ORRORAL	50103M103	* *** **	-4466609.699	2683169.494	-3667428.677	INDI
VLBI DSS44	50103S006		-4451073.943	2676824.106	-3691347.918	
VLBI DSS42	50103S005		-4460980.981	2682413.771	-3674582.792	
VLBI DSS43	50103S001		-4460894.352	2682361.681	-3674749.094	
SLR 7843M001	50103M106		-4446469.615	2678122.900	-3696248.962	
SLR 7943S001	50103S003		-4447548.581	2677134.104	-3694996.794	
OWENS VALLEY	40439M001	** *** *	-2410422.293	-4477802.758	3838686.719	NOAM
VLBI 7207	40439S002		-2409600.587	-4478349.634	3838603.226	
SLR 7084M001	40439M003		-2410590.178	-4477745.262	3838648.877	
SLR 7114M001	40439M001		-2410422.293	-4477802.758	3838686.719	
PASADENA	40400M001	*** *	-2493211.773	-4655229.681	3565574.482	PCFC
SLR 7896M001	40400M001		-2493211.773	-4655229.681	3565574.482	
PATRICK AFB	40417M001	** *	917901.094	-5548374.189	2998777.166	NOAM
SLR 7069M001	40417M002		917959.154	-5548370.269	2998776.606	
PLATTEVILLE	40496M002	* ****	-1240707.975	-4720454.350	4094481.666	NOAM
VLBI 7258	40496M002		-1240707.975	-4720454.350	4094481.666	
SLR 7112M001	40496M001		-1240678.078	-4720463.387	4094480.651	
POTSDAM	14106M001	*****	3800621.523	882005.307	5028859.509	EURA
SLR 1181S001	14106S001		3800621.450	882005.286	5028859.459	
QUINCY	40433M001	******	-2516893.058	-4198845.075	4076411.496	NOAM
SLR 7051M001	40433M001		-2516893.058	-4198845.075	4076411.496	
SLR 7109M001	40433M002		-2517234.632	-4198556.255	4076569.651	
SLR 7886M001	40433M005		-2517242.243	-4198550.947	4076570.266	
RICHMOND	40499M001	** * *	961317.965	-5674054.862	2740563.635	NOAM
VLBI 7219	40499S001		961258.243	-5674090.075	2740533.716	
ROUMELLI	12613M001	*** *	4728694.813	2174373.268	3674572.941	EURA
SLR 7517M001	12613M001		4728694.813	2174373.268	3674572.941	
SAN DIEGO	40436M001	**** *	-2428809.139	-4799757.042	3417274.825	PCFC
SLR 7062M001	40436M002		-2428825.688	-4799750.642	3417272.632	
SANTIAGO	41705M001	***	1769699.753	-5044612.882	-3468260.046	SOAM
SLR 7400M001	41705M001		1769699.753	-5044612.882	-3468260.046	

TABLE 2 - (CONT.) SITE COORDINATES FOR EPOCH 1984.0

SITE, SITE REFERENCE MARKS	DOMES NUMBER	NETWORKS (1) 0000000001111 1234567890123	X m	Y m	Z m	PLATE
SHANGHAI	21605M001	**** *	-2831089.696	4676203.044	3275170.120	EURA
SLR 7837S001	21605S001		-2831087.447	4676203.448	3275172.798	
SIMOSATO	21726M001	*****	-3822373.283	3699359.794	3507585.808	EURA
SLR 7838M001	21726M002		-3822386.991	3699362.259	3507571.965	
TRIESTE	12718M002	*** *	4336738.715	1071271.377	4537910.975	EURA
SLR 7550M001	12718M002		4336738.715	1071271.377	4537910.975	
VANDENBERG AFB	40420M001	* **	-2668815.814	-4530761.553	3598687.322	NOAM
VLBI 7223	40420M002		-2678094.512	-4525451.169	3597409.959	
SLR 7887M001	40420M004		-2668867.961	-4530743.141	3598684.806	
VERNAL	40492M001	***	-1631484.576	-4589133.818	4106749.549	NOAM
SLR 7892M001	40492M001		-1631484.576	-4589133.818	4106749.549	
WASHINGTON	40451M110	******	1130731.532	-4831322.625	3994136.411	NOAM
SLR 7063M001	40451M112		1130714.889	-4831367.755	3994087.334	
SLR 7064M001	40451M107		1130689.377	-4831341.941	3994123.411	
SLR 7065M001	40451M108		1130691.428	-4831351.085	3994111.906	
SLR 7100M001	40451M106		1131355.642	-4831168.354	3994131.615	
SLR 7101M001	40451M101		1131240.403	-4831179.761	3994148.412	
SLR 7102M001	40451M102		1130686.723	-4831353.050	3994110.859	
SLR 7103M001	40451M103		1130685.765	-4831348.730	3994116.300	
SLR 7104M001	40451M104		1131095.942	-4831196.975	3994170.691	
SLR 7105M001	40451M105		1130719.836	-4831350.594	3994106.460	
SLR 7899M001	40451M111		1131364.872	-4831168.815	3994128.871	
WETTZELL	14201M001	** * ******	4075575.172	931832.026	4801568.796	EURA
VLBI 7224	14201S004		4075540.172	931735.126	4801629.196	
SLR 7834S001	14201S002		4075530.045	931781.242	4801618.088	
XRISOKALARIA	12616M001	*** *	4745949.696	1905705.836	3799169.046	EURA
SLR 7525M001	12616M001		4745949.696	1905705.836	3799169.046	
YARRAGADEE	50107M001	******	-2389006.268	5043329.273	-3078525.568	INDI
SLR 7090M001	50107M001		-2389006.268	5043329.273	-3078525.568	
YIGILCA	20804M001	**	4117362.146	2517076.743	4157678.983	EURA
SLR 7587M001	20804M001		4117362.146	2517076.743	4157678.983	
YUMA	40493M001	***	-2196777.736	-4887337.107	3448425.286	NOAM
VLBI 7894	40493M001		-2196777.736	-4887337.107	3448425.286	
SLR 7894M001	40493M001		-2196777.736	-4887337.107	3448425.286	
ZIMMERWALD	14001M001	*** **	4331274.089	567584.205	4633139.107	EURA
SLR 7810S001	14001S001		4331283.695	567549.396	4633139.911	

Note.

(1) Reference of the networks: a site has positions in the networks marked with *.

01 : SSC(NGS) 88 R 01	02 : SSC(GSFC) 88 R 01	03 : SSC(JPL) 83 R 05
04 : SSC(SHA) 88 R 01	05 : SSC(JPL) 88 M 01	06 : SSC(CERGA)88 M 01
07 : SSC(SHA) 88 M 01	08 : SSC(CSR) 88 L 01	09 : SSC(GSFC) 87 L 14
10 : SSC(DGFI) 87 L 03	11 : SSC(SHA) 87 L 01	12 : SSC(DUT) 87 L 04
13 : SSC(DMA) 77 D 01		

TABLE 2A - VELOCITIES OF SITES (AMO-2 MODEL)

SITE	DOMES NUMBER	VX m	VY m	VZ m	PLATE
ALGONQUIN	40104M001	-.0193	-.0029	.0012	NOAM
AMERICAN SAMOA	50503M001	-.0199	.0664	.0353	PCFC
AREQUIPA	42202M002	-.0054	-.0047	.0093	SOAM
ASKITES	12612M001	-.0186	.0171	.0109	EURA
BAR GIYYORA	20702M001	-.0243	.0153	.0180	AFRC
BEAR LAKE	40438M001	-.0180	-.0020	-.0095	NOAM
BERMUDA	42501M001	-.0147	-.0025	.0064	NOAM
BOLOGNE	12711M001	-.0155	.0177	.0119	EURA
CABO SAN LUCAS	40505M001	-.0498	.0281	.0227	PCFC
CAGLIARI	12725M202	-.0138	.0189	.0131	EURA
CERRO TOLOLO	41706M001	-.0019	-.0059	.0085	SOAM
CHILBOLTON	13201M001	-.0133	.0164	.0112	EURA
DIONYSOS	12602M001	-.0178	.0178	.0116	EURA
EFFELSBERG	14209S001	-.0152	.0164	.0109	EURA
FLAGSTAFF	40491M003	-.0158	-.0016	-.0105	NOAM
FORT DAVIS	40442M004	-.0142	-.0015	-.0084	NOAM
GOLDSTONE	40405M001	-.0158	-.0015	-.0120	NOAM
GRAND TURK	43602M001	-.0106	-.0018	.0044	NOAM
GRASSE	10002M001	-.0141	.0180	.0124	EURA
GRAZ	11001M001	-.0168	.0168	.0110	EURA
GREENBANK	40441M001	-.0169	-.0025	.0007	NOAM
HAYSTACK	40440M001	-.0182	-.0028	.0034	NOAM
HELWAN	30101S001	-.0227	.0167	.0187	AFRC
HERSTMONCEUX	13212M002	-.0137	.0164	.0112	EURA
JOHANNESBURG	30302M001	-.0019	.0240	.0197	AFRC
KARITSA	12614M001	-.0172	.0179	.0118	EURA
KATAVIA	12615M001	-.0186	.0176	.0114	EURA
KOOTWIJK	13504M001	-.0152	.0160	.0106	EURA
KWAJALEIN ATOLL	50505M001	.0212	.0725	.0305	PCFC
MADRID	13407S003	-.0102	.0188	.0136	EURA
MARYLAND POINT	40490M001	-.0169	-.0025	.0016	NOAM
MATERA	12734S001	-.0162	.0181	.0121	EURA
MAUI	40445M001	-.0153	.0673	.0349	PCFC
MAZATLAN	40504M001	-.0114	-.0010	-.0098	NOAM
METSAHOVI	10503M001	-.0198	.0129	.0073	EURA
MONTE GENEROSO	14005M002	-.0150	.0175	.0118	EURA
MONUMENT PEAK	40497M001	-.0362	.0347	.0233	PCFC
MOTU HIUMOO	92202M001	-.0438	.0572	.0354	PCFC
MOUNT HOPKINS	40434M001	-.0145	-.0014	-.0106	NOAM
NATAL	41604M002	-.0043	-.0085	.0132	SOAM
ONSALA	10402M003	-.0172	.0144	.0090	EURA
ORRORAL	50103M103	-.0362	-.0027	.0422	INDI
OWENS VALLEY	40439M001	-.0164	-.0016	-.0122	NOAM
PASADENA	40400M001	-.0339	.0362	.0235	PCFC
PATRICK AFB	40417M001	-.0133	-.0020	.0005	NOAM
PLATTEVILLE	40496M002	-.0175	-.0020	-.0077	NOAM
POTSDAM	14106M001	-.0169	.0157	.0101	EURA
QUINCY	40433M001	-.0173	-.0017	-.0124	NOAM
RICHMOND	40499M001	-.0123	-.0018	.0006	NOAM

TABLE 2A - (CONT.) VELOCITIES OF SITES (AMO-2 MODEL)

SITE	DOMES NUMBER	VX m	VY m	VZ m	PLATE
ROUMELLI	12613M001	-.0176	.0181	.0119	EURA
SAN DIEGO	40436M001	-.0363	.0351	.0235	PCFC
SANTIAGO	41705M001	-.0011	-.0061	.0082	SOAM
SHANGHAI	21605M001	-.0251	-.0079	-.0103	EURA
SIMOSATO	21726M001	-.0224	-.0112	-.0126	EURA
TRIESTE	12718M002	-.0162	.0173	.0114	EURA
VANDENBERG AFB	40420M001	-.0155	-.0014	-.0132	NOAM
VERNAL	40492M001	-.0175	-.0020	-.0091	NOAM
WASHINGTON	40451M110	-.0171	-.0026	.0017	NOAM
WETTZELL	14201M001	-.0165	.0165	.0108	EURA
XRISOKALARIA	12616M001	-.0170	.0183	.0121	EURA
YARRAGADEE	50107M001	-.0514	.0080	.0530	INDI
YIGILCA	20804M001	-.0201	.0163	.0101	EURA
YUMA	40493M001	-.0150	-.0014	-.0116	NOAM
ZIMMERWALD	14001M001	-.0148	.0173	.0117	EURA

TABLE 3 - TRANSFORMATION BETWEEN THE INDIVIDUAL AND THE COMBINED TERRESTRIAL SYSTEMS

NETWORK	SSC	T1	T2	T3	D	R1	R2	R3	A3
					10^{-8}				
		cm	cm	cm		0.001"	0.001"	0.001"	0.001"
SSC(NGS)	88 R 01	-8.9	14.3	-1.6	0.9	-4.3	9.3	-3.3	-0.5
SSC(GSFC)	88 R 01	167.1	-105.4	40.0	-2.3	-7.2	5.0	-3.6	-0.2
SSC(JPL)	83 R 05	24.2	-12.1	-18.3	-3.9	-1.4	-4.8	-5.7	-0.3
SSC(SHA)	88 R 01	163.8	-97.5	41.7	-0.9	-4.7	5.8	-3.4	-8.0
SSC(JPL)	88 M 01	0.0	0.0	0.0	-1.7	4.0	-0.4	-8.6	
SSC(CERGA)	88 M 01	0.0	0.0	0.0	-2.4	-5.6	-0.8	-3.8	
SSC(SHA)	86 M 01	0.0	0.0	0.0	-3.8	1.4	7.5	-15.5	
SSC(CSR)	88 L 01	0.0	0.0	0.0	0.0	-4.7	2.3	-10.5	
SSC(GSFC)	87 L 14	0.0	0.0	0.0	0.0	-1.8	6.2	-7.5	
SSC(DGFI)	87 L 03	-4.0	0.9	11.9	1.3	-284.2	-44.9	6.8	
SSC(SHA)	87 L 01	-4.3	-4.5	7.2	0.5	-4.3	-2.7	-1.9	
SSC(DUT)	87 L 04	-7.5	4.7	11.9	1.0	0.2	-1.0	-0.0	
SSC(DMA)	77 D 01 (1)	7.1	-50.9	-466.6	58.3	17.9	-0.5	-807.3	
WGS84		7.1	-50.9	-16.6	-1.7	17.9	-0.5	6.7	

Notes

1 - NSWC 9Z-2

Remark.

The table lists the values of the parameters which transform the coordinates in the SSC's into the combined system at epoch 1984.0, according to the relationship

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} XS \\ YS \\ ZS \end{pmatrix} - \begin{pmatrix} T1 \\ T2 \\ T3 \end{pmatrix} - \begin{pmatrix} D & -R3 & R2 \\ R3 & D & -R1 \\ -R2 & R1 & D \end{pmatrix} \begin{pmatrix} XS \\ YS \\ ZS \end{pmatrix}$$

where X, Y, Z are the coordinates in the combined system, and XS, YS, ZS are the cartesian coordinates in the individual system. T1, T2, T3 are the components of the translation vector, R1, R2, R3 are the rotation angles and D is the excess to 1 of the scale factor.

APPENDIX 2

Appendix 2

LIST OF POTENTIAL IERS SITES

A - List by DOMES numbers

B - Catalogue by alphabetic order

Codes for monthly information :

- potential measurements

* actual measurements

1 AMP = 1-3 cm (3rd generation SLR or LLR, VLBI SX Mark 3)

2 AMP = 3-6 cm (idem, mobile equipments or poor data)

3 AMP = 6-10 cm (2nd generation SLR or LLR; VLBI SX Mark 2; DORIS)

4 AMP = 10-50 cm (poor SLR or VLBI; best Transit Doppler with PE)

5 AMP = 50-100 cm (typical Transit Doppler with PE)

6 AMP = 100-300 cm (Transit Doppler with BE)

AMP : Accuracy of Monthly Position (at one sigma)

BE : Broadcast Ephemerides

PE : DMA Precise Ephemerides

A - List by DOMES numbers

Site	DOMES number	IGN/BDG number
GRASSE	10002	100002
TROMSO	10302	103002
ONSALA	10402	104002
METSAHOVI	10503	105003
GRAZ	11001	110001
DIONYSOS	12602	126002
ASKITES	12612	126012
ROUMELLI	12613	126013
KARITSA	12614	126014
KATAVIA	12615	126015
XRISOKALARIA	12616	126016
LAMPEDUSA	12706	127006
BOLOGNA	12711	127011
TRIESTE	12718	127018
CAGLIARI	12725	127025
MATERA	12734	127034
CHILBOLTON	13201	132001
HERSTMONCEUX	13212	132012
MADRID	13407	134007
KOOTWIJK	13504	135004
ZIMMERWALD	14001	140001
MONTE GENEROSO	14005	140005
POTSDAM	14106	141006
WETTZELL	14201	142001
EFFELSBERG	14209	142009
BAR GIYYORA	20702	207002
DIYARBAKIR	20801	208001
YOZGAT	20802	208002
MELENGICLICK	20803	208003
YIGILCA	20804	208004
SHANGHAI	21605	216005
KASHIMA	21701	217001
SIMOSATO	21726	217026
HELWAN	30101	301001
JOHANNESBURG	30302	303001
ALGONQUIN	40104	401004
PENTICTON	40105	401005
WHITEHORSE	40118	401018
YELLOWKNIFE	40127	401027
PASADENA	40400	404100
PALOS VERDES	40403	404107
PEARBLOSSOM	40404	404108
GOLDSTONE	40405	404005
SAN FRANCISCO (PRESIDIO)	40406	404110
PINON FLATS	40407	404116
FAIRBANKS	40408	404008
POINT REYES	40410	404118
AUSTIN	40412	404012
YAKATAGA	40416	404120

PATRICK AFB	40417	404017
KODIAK	40419	404121
VANDENBERG	40420	404015
NOME	40421	404122
SAND POINT	40423	404123
KAUAI	40424	404024
SOURDOUGH	40425	404124
FORT ORD	40427	404125
SANTA PAOLA	40428	404126
BLACK BUTTE	40430	404127
DEADMAN LAKE	40431	404128
ELY	40432	404032
QUINCY	40433	404033
MOUNT HOPKINS	40434	404034
SAN DIEGO	40436	404036
MAMMOTH LAKES	40437	404129
BEAR LAKE	40438	404038
OWENS VALLEY	40439	404039
HAYSTACK	40440	404040
GREENBANK	40441	404041
FORT DAVIS	40442	404042
MAUI	40445	404045
OCTILLO	40449	404130
WASHINGTON	40451	404051
HAT CREEK	40489	40489
MARYLAND POINT	40490	404101
FLAGSTAFF	40491	404114
VERNAL	40492	404115
YUMA	40493	404113
PLATTEVILLE	40496	404112
MONUMENT PEAK	40497	404111
RICHMOND	40499	404103
MAZATLAN	40504	405004
CABO SAN LUCAS	40505	405005
SANTIAGO DE CUBA	40701	407001
NATAL	41604	416004
EASTER ISLAND	41703	417003
SANTIAGO	41705	417005
CERRO TOLOLO	41706	417006
AREQUIPA	42202	422002
BERMUDA	42501	425001
GRAND TURK	43602	436002
ORRORAL	50103	501003
YARRAGADEE	50107	501007
AMERICAN SAMOA	50503	505003
KWAJALEIN ATOLL	50505	505005
MOTU HIUMOO	92202	922002

B - Catalogue by alphabetic order

Site	CDP num.	DOMES number	T/P	76 0000000001111000000000111 1234567890121234567890121	77 000000000111 234567890121	78 000000000111 234567890121
ALGONQUIN		40104M001				
VLBI	7282	40104S001	P			
AMERICAN SAMOA		50503M001				
SLR	7096	50503M001	T			
AREQUIPA		42202M002				
SLR	7907	42202S001	P	**********	*********	*********
ASKITES		12612M001				
SLR	7510	12612M001	T			
AUSTIN		40412M001				
SLR	7890	40412M001	T			
BAR GIYYORA		20702M001				
SLR	7530	20702M001	P			
BEAR LAKE		40438M001				
SLR	7082	40438M001	T	***		
BERMUDA		42501M001				
SLR	7067	42501M001	T	*		****
BLACK BUTTE		40430M001				
VLBI	7269	40430M001	T			
BOLOGNA		12711M001				
VLBI	7230	12711S001	P			
CABO SAN LUCAS		40505M001				
SLR	7882	40505M001	T			
CAGLIARI		12725M202				
SLR	7545	12725M002	T			
CERRO TOLOLO		41706M001				
SLR	7401	41706M001	T			
CHILBOLTON		13201M001				
VLBI	7215	13201S002	P			
DEADMAN LAKE		40431M001				
VLBI	7267	40431M001	T			

```
                79          80          81          82          83
 DOMES      000000000111000000000111000000000111000000000111000000000111
 number     123456789012123456789012123456789012123456789012123456789012
---------   ------------------------------------------------------------
40104M001
40104S001

50503M001
50503M001         ***** **********

42202M002
42202S001   ************************* ***********************************

40412M001
40412M001                          *

12612M001
12612M001

20702M001
20702M001

40438M001
40438M001     *** **                 **                              **

42501M001
42501M001

40430M001
40430M001                                                            *

12711M001
12711S001

40505M001
40505M001

12725M202
12725M002

41706M001
41706M001

13201M001
13201S002                    *

40431M001
40431M001                                                         **
```

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                84          85          86          87          88
 DOMES      000000000111000000000111000000000111000000000111000000000111
 number     123456789012123456789012123456789012123456789012123456789012
---------   ------------------------------------------------------------
40104M001
40104S001         *           **

50503M001
50503M001

42202M002
42202S001  ********************************************** -----------

12612M001
12612M001                              **

40412M001
40412M001

20702M001
20702M001                               ************* *    -----------

40438M001
40438M001  *

42501M001
42501M001

40430M001
40430M001    *          *               *    *   *  *    *

12711M001
12711S001

40505M001
40505M001   **                                              ------

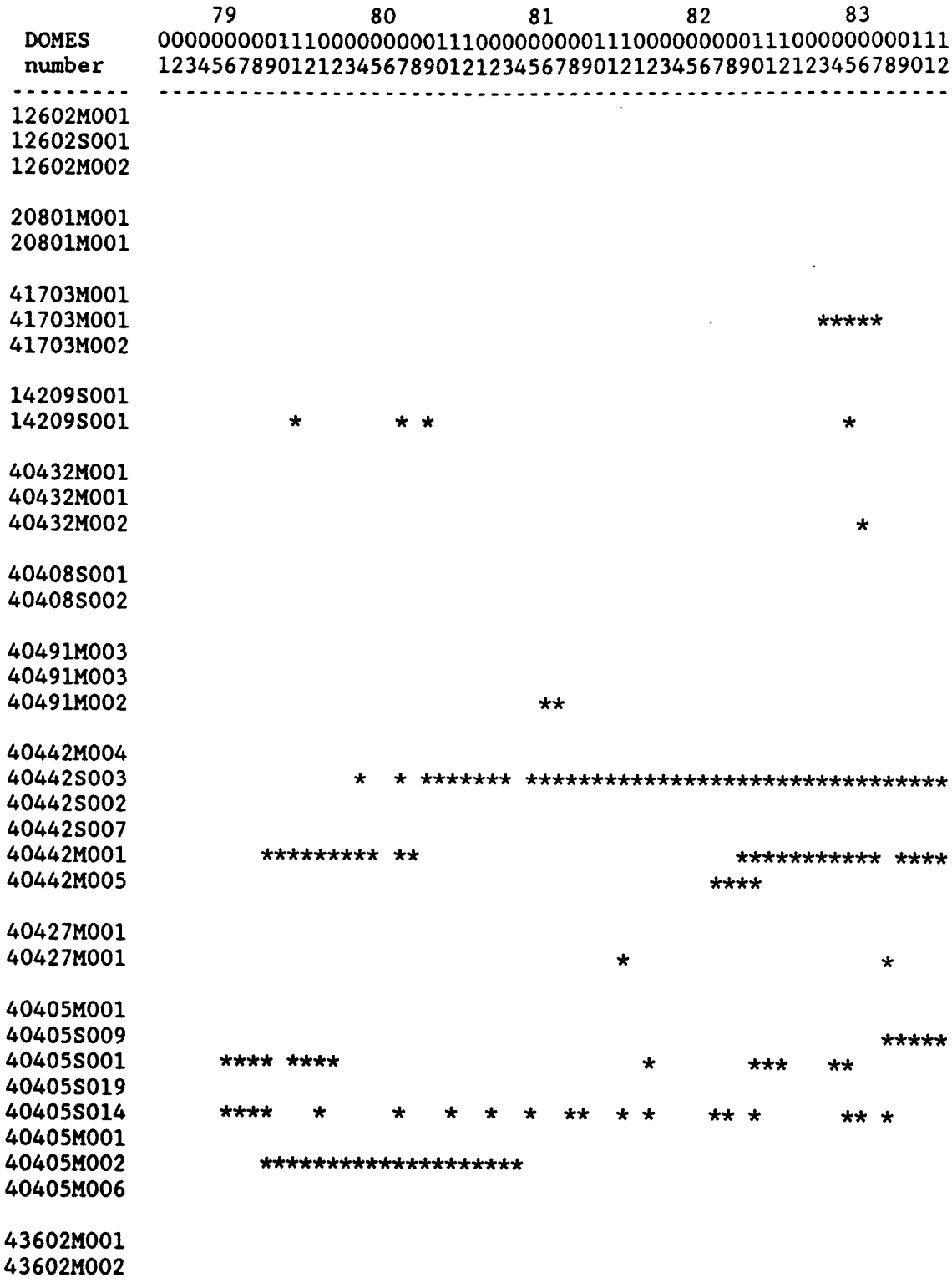
12725M202
12725M002                         **                    ---

41706M001
41706M001      **

13201M001
13201S002

40431M001
40431M001   **          *                       *         *
```

Site	CDP num.	DOMES number	T/P	76 77 78 0000000001110000000001110000000001111 1234567890121234567890121234567890121
DIONYSOS		12602M001		
SLR	7940	12602S001	T	
SLR	7515	12602M002	T	
DIYARBAKIR		20801M001		
SLR	7575	20801M001	T	
EASTER ISLAND		41703M001		
SLR	7061	41703M001	T	
SLR	7097	41703M002	T	
EFFELSBERG		14209S001		
VLBI	7203	14209S001	P	
ELY		40432M001		
VLBI	7286	40432M001	T	
VLBI	7257	40432M002	T	
FAIRBANKS		40408S001		
VLBI	7225	40408S002	P	
FLAGSTAFF		40491M003		
VLBI	7261	40491M003	T	
SLR	7891	40491M002	T	
FORT DAVIS		40442M004		
VLBI	7216	40442S003	P	
LLR MCD 2.	7206	40442S002	P	
LLR MLRS	7086	40442S007	P	
SLR	7086	40442M001	P	
SLR	7885	40442M005	T	
FORT ORD		40427M001		
VLBI	7266	40427M001	T	
GOLDSTONE		40405M001		
VLBI	7222	40405S009	P	
VLBI DSS14	1514	40405S001	P	***
VLBI DSS15		40405S019	P	
VLBI DSS13	1513	40405S014	P	
SLR	7085	40405M001	T	**
SLR	7115	40405M002	T	
SLR	7265	40405M006	T	
GRAND TURK		43602M001		
SLR	7068	43602M002	T	*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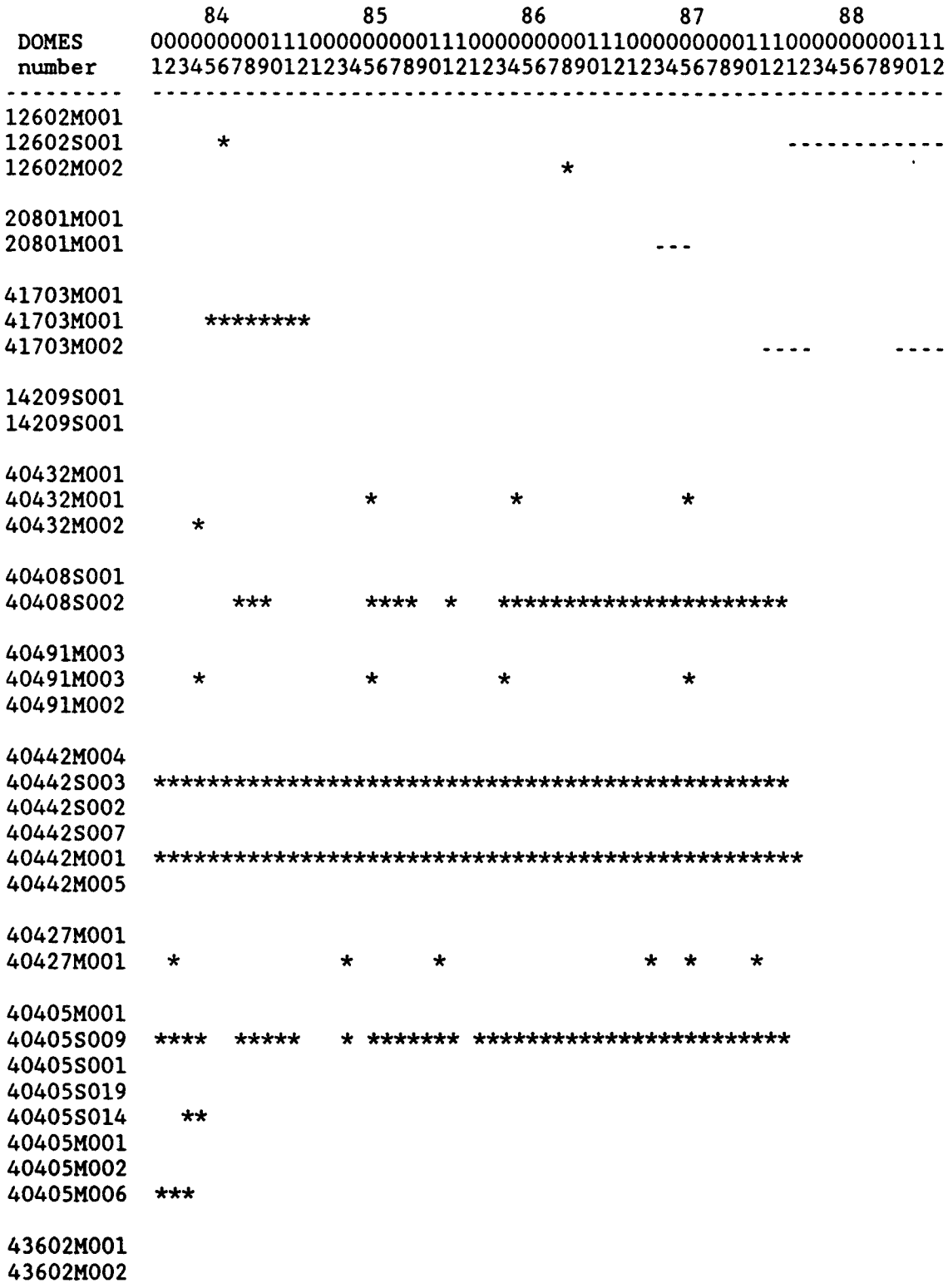
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40405M006
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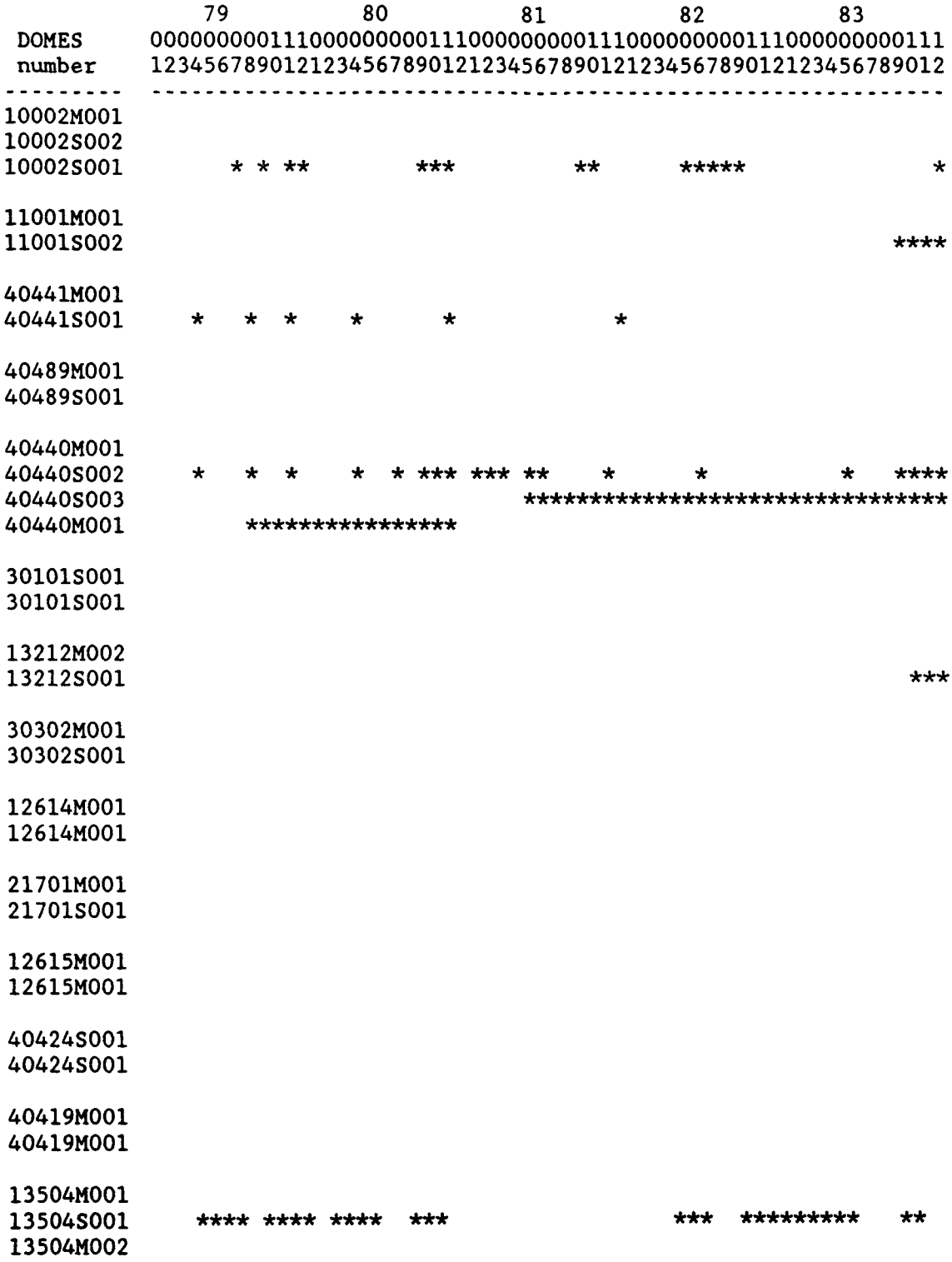
43602M002

Site	CDP num.	DOMES number	T/P	76 0000000001111000000000111000000000111 1234567890121234567890121234567890121
GRASSE		10002M001		
LLR CERGA		10002S002	P	
SLR	7835	10002S001	P	
GRAZ		11001M001		
SLR	7839	11001S002	P	
GREENBANK		40441M001		
VLBI	7204	40441S001	P	* * * * * *** *
HAT CREEK		40489M001		
VLBI	7218	40489S001	P	
HAYSTACK		40440M001		
VLBI	7205	40440S002	P	** * * * * *** *
VLBI	7209	40440S003	P	
SLR	7091	40440M001	T	***
HELWAN		30101S001		
SLR	7831	30101S001	P	
HERSTMONCEUX		13212M002		
SLR	7840	13212S001	P	
JOHANNESBURG		30302M001		
VLBI	7231	30302S001	P	
KARITSA		12614M001		
SLR	7520	12614M001	T	
KASHIMA		21701M001		
VLBI	1856	21701S001	P	
KATAVIA		12615M001		
SLR	7512	12615M001	T	
KAUAI		40424S001	P	
VLBI	1311	40424S001	P	
KODIAK		40419M001		
VLBI	7278	40419M001	T	
KOOTWIJK		13504M001		
SLR	7833	13504S001	P	
SLR	8833	13504M002	T	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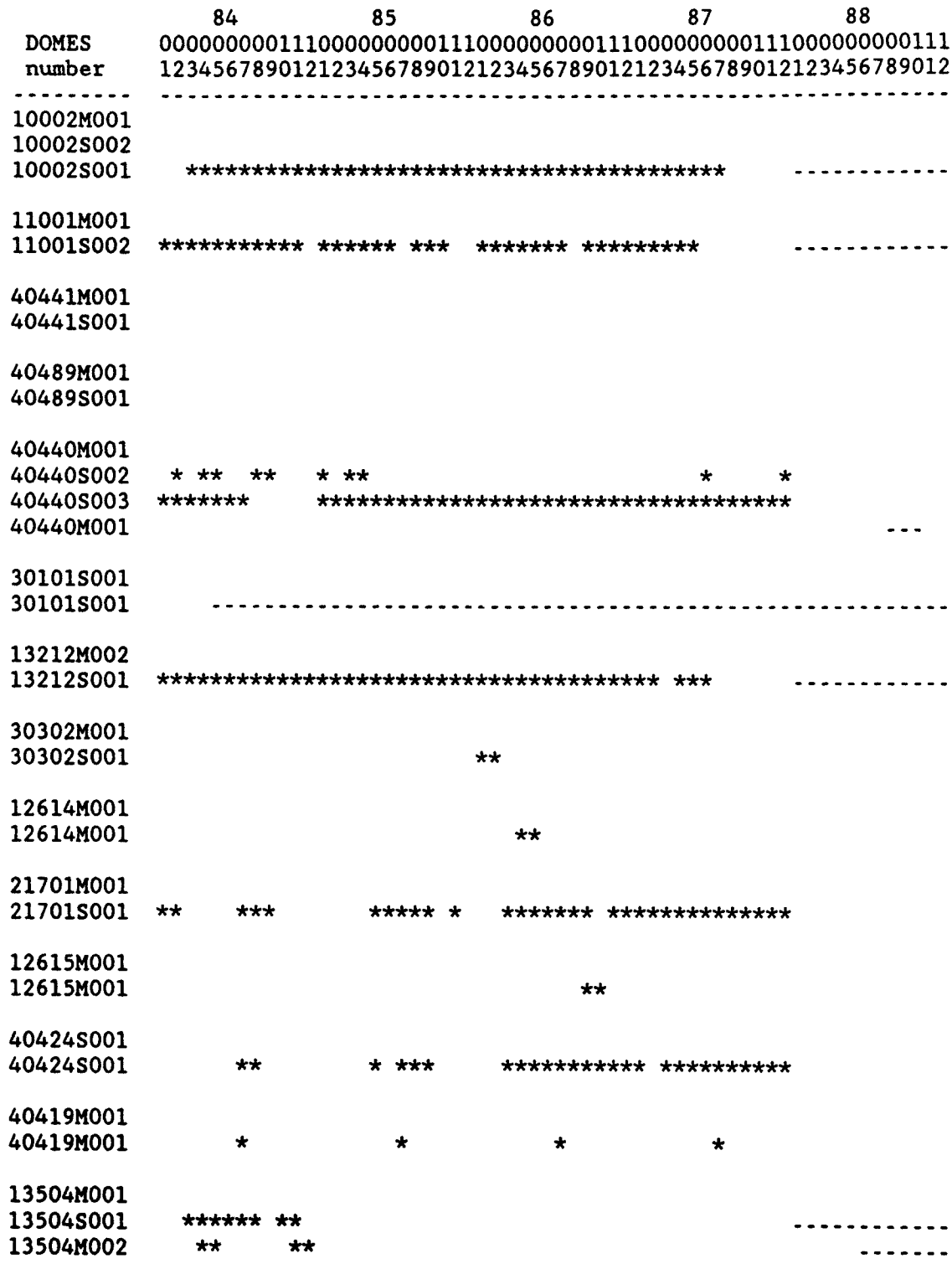
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40419M001
40419M001
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13504S001
13504M002

Site	CDP num.	DOMES number	T/P	76 0000000001111000000000111000000000111 1234567890121234567890121234567890121
KWAJALEIN ATOLL		50505M001		
VLBI	4968	50505S003	P	
SLR	7092	50505M001	T	
LAMPEDUSA		12706M001		
SLR	7544	12706M001		
MADRID		13407S003		
VLBI DSS61		13407S003	P	
VLBI DSS63		13407S001	P	
VLBI DSS62		13407S005	P	
MAMMOTH LAKES		40437M001		
VLBI	7259	40437M001	T	
MARYLAND POINT		40490M001		
VLBI	7217	40490S001	P	
MATERA		12734S001		
SLR	7540	12734M005	T	
SLR	7541	12734M004	T	
SLR	7939	12734S001	P	
MAUI		40445M001		
VLBI	7120	40445M002	T	
LLR HAL. T		40445S005	P	
SLR	7120	40445M002	T	
SLR	7210	40445M001	P	
MAZATLAN		40504M001		
SLR	7122	40504M001	P	
MELENGICLICK		20803M001		
SLR	7580	20803M001	T	
METSAHOVI		10503M001		
SLR	7805	10503S001	P	
MONTE GENEROSO		14005M002		
SLR	7590	14005M002	T	
MONUMENT PEAK		40497M001		
VLBI	7220	40497M002		
VLBI	7274	40497M003		
SLR	7110	40497M001	P	
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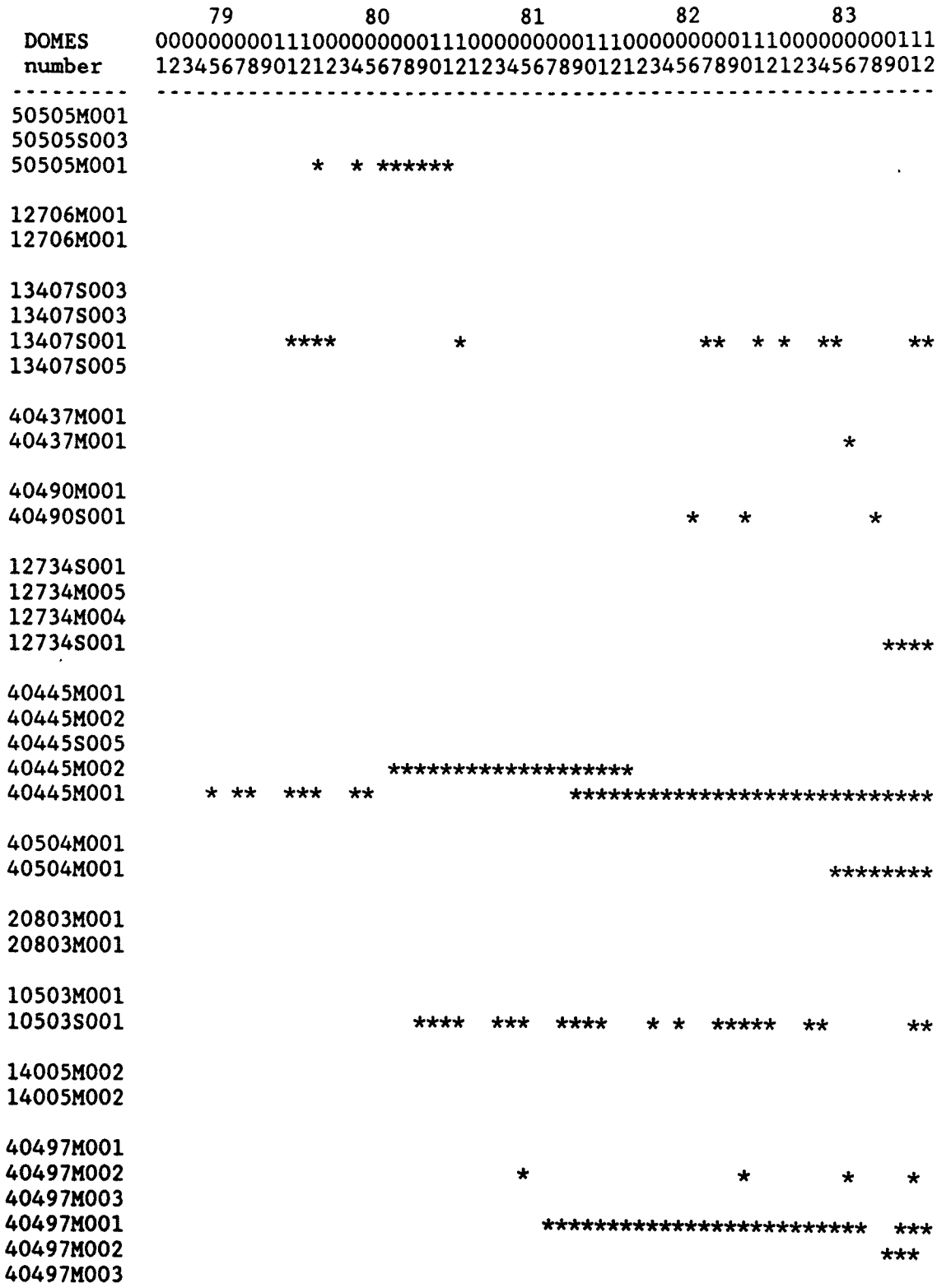
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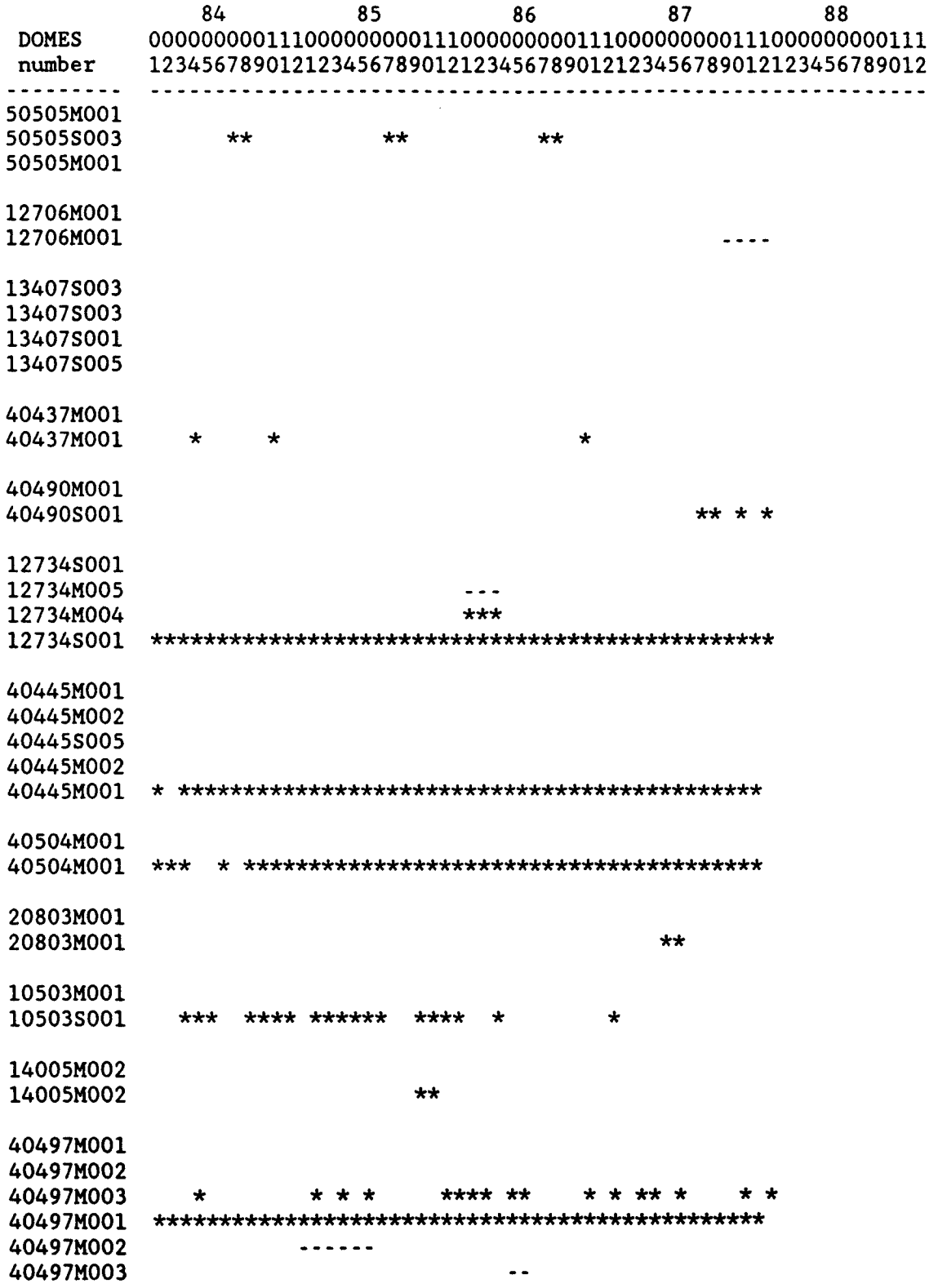
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40497M001
40497M002
40497M003

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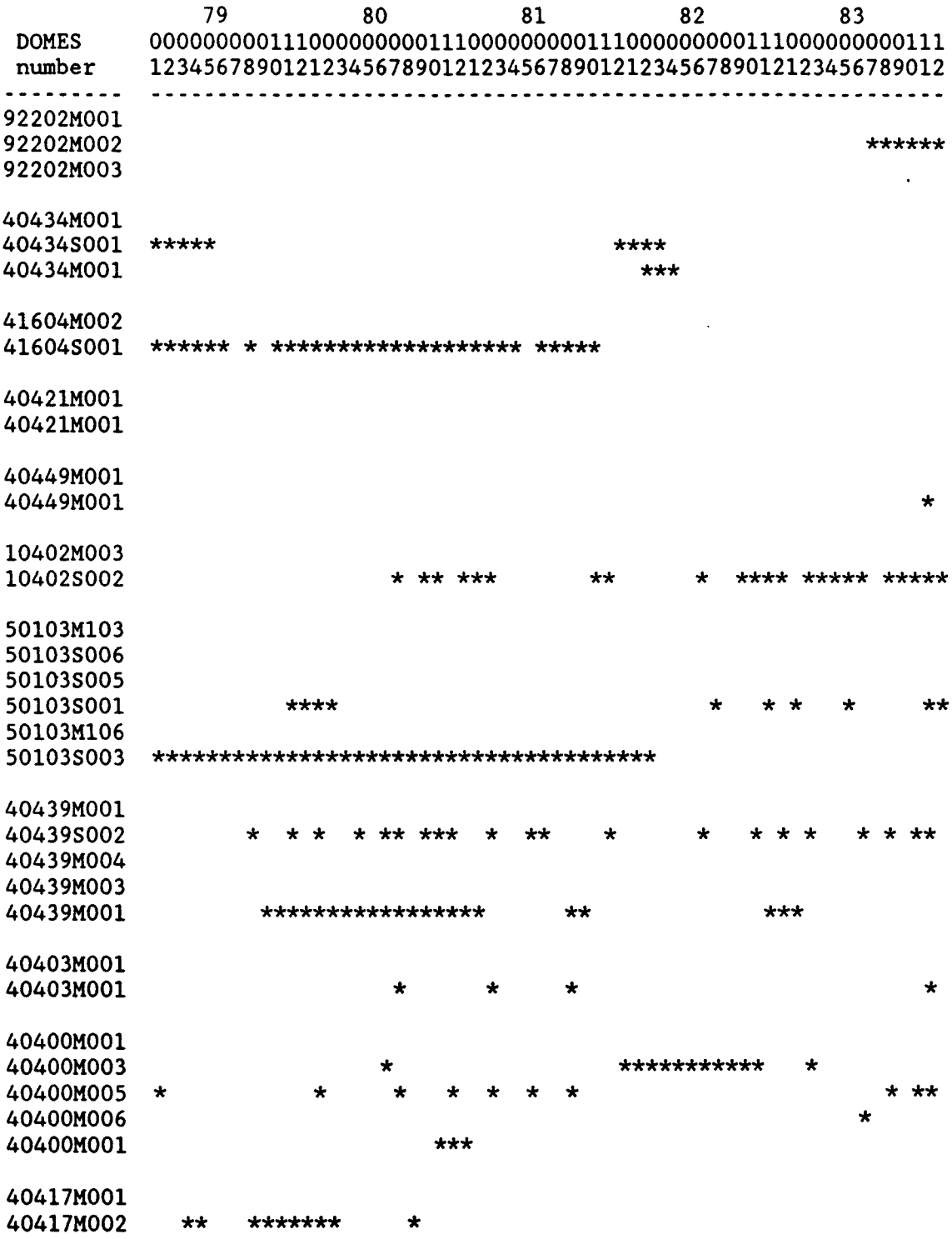
MOTU HIUMOO		92202M001		
SLR	7121	92202M002	T	
SLR	7123	92202M003	T	
MOUNT HOPKINS		40434M001		
SLR	7921	40434S001	P	********************** *********
SLR	7888	40434M001	T	
NATAL		41604M002		
SLR	7929	41604S001	P	****************** ** *****
NOME		40421M001		
VLBI	7279	40421M001	T	
OCTILLO		40449M001		
VLBI	7270	40449M001	T	
ONSALA		10402M003		
VLBI	7213	10402S002	P	* * *
ORRORAL		50103M103		
VLBI DSS44		50103S006	P	
VLBI DSS42		50103S005	P	
VLBI DSS43		50103S001	P	***
SLR	7843	50103M106	P	
SLR	7943	50103S003	P	****************** *** ****
OWENS VALLEY		40439M001		
VLBI	7207	40439S002	P	** * * * * * ** *
VLBI	7853	40439M004	T	
SLR	7084	40439M003	T	**
SLR	7114	40439M001	T	
PALOS VERDES		40403M001		
VLBI	7268	40403M001	T	* *
PASADENA		40400M001		
VLBI	7263	40400M003	T	* * *** *
VLBI	7264	40400M005	T	
VLBI	7272	40400M006	T	
SLR	7896	40400M001	T	
PATRICK AFB		40417M001		
SLR	7069	40417M002	P	------------------------------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40417M002

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40434M001

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41604S001

40421M001
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40449M001
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10402M003
10402S002   *****  **    ****** ****** **** ***** ***** *****

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50103S006
50103S005
50103S001
50103M106                  *** *************** ----------------------
50103S003

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40439M001

40403M001
40403M001                  *                          *         *

40400M001
40400M003      *      *  * *       *      *      ****         * *
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40400M006
40400M001

40417M001
40417M002
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VLBI	7253	40404M002	T	* *
PENTICTON		40105M001		
VLBI	7283	40105M001	T	
PINON FLATS		40407M001		
VLBI	7256	40407M001	T	
PLATTEVILLE		40496M002		
VLBI	7258	40496M002	T	
SLR	7112	40496M001	T	
POINT REYES		40410M001		
VLBI	7251	40410M001	T	
POTSDAM		14106M001		
SLR	1181	14106S001	P	----------
QUINCY		40433M001		
VLBI	7221	40433M004	T	
VLBI	7260	40433M006	T	
SLR	7051	40433M001	T	****
SLR	7109	40433M002	P	
SLR	7886	40433M005	T	
RICHMOND		40499M001		
VLBI	7219	40499S001	P	
ROUMELLI		12613M001		
SLR	7517	12613M001	T	
SAN DIEGO		40436M001		
SLR	7062	40436M002	T	* *** *** ***
SAND POINT		40423M001		
VLBI	7280	40423M001	T	
SAN FRANCISCO (PRESIDIO)		40406M001		
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SANTA PAOLA		40428M001		
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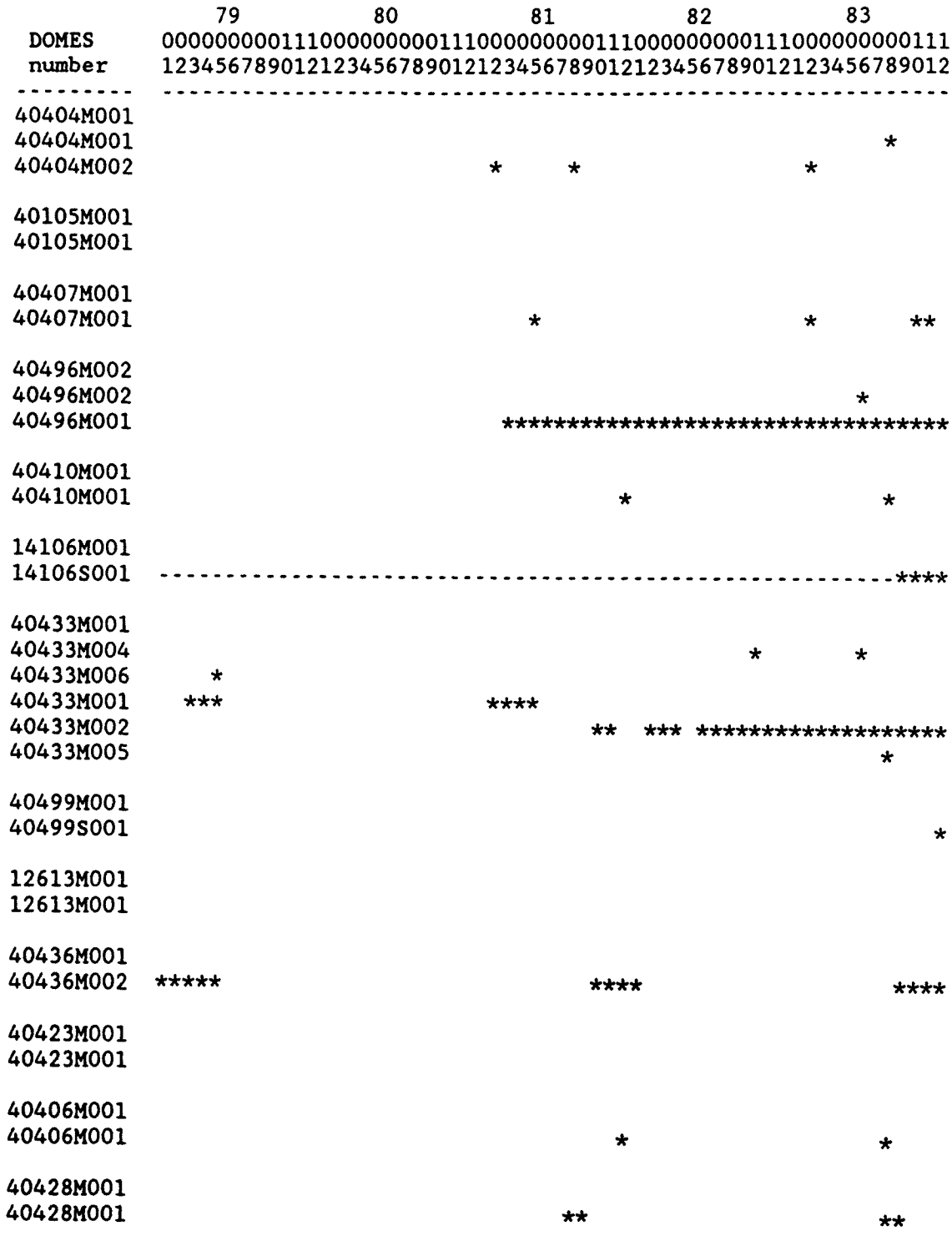
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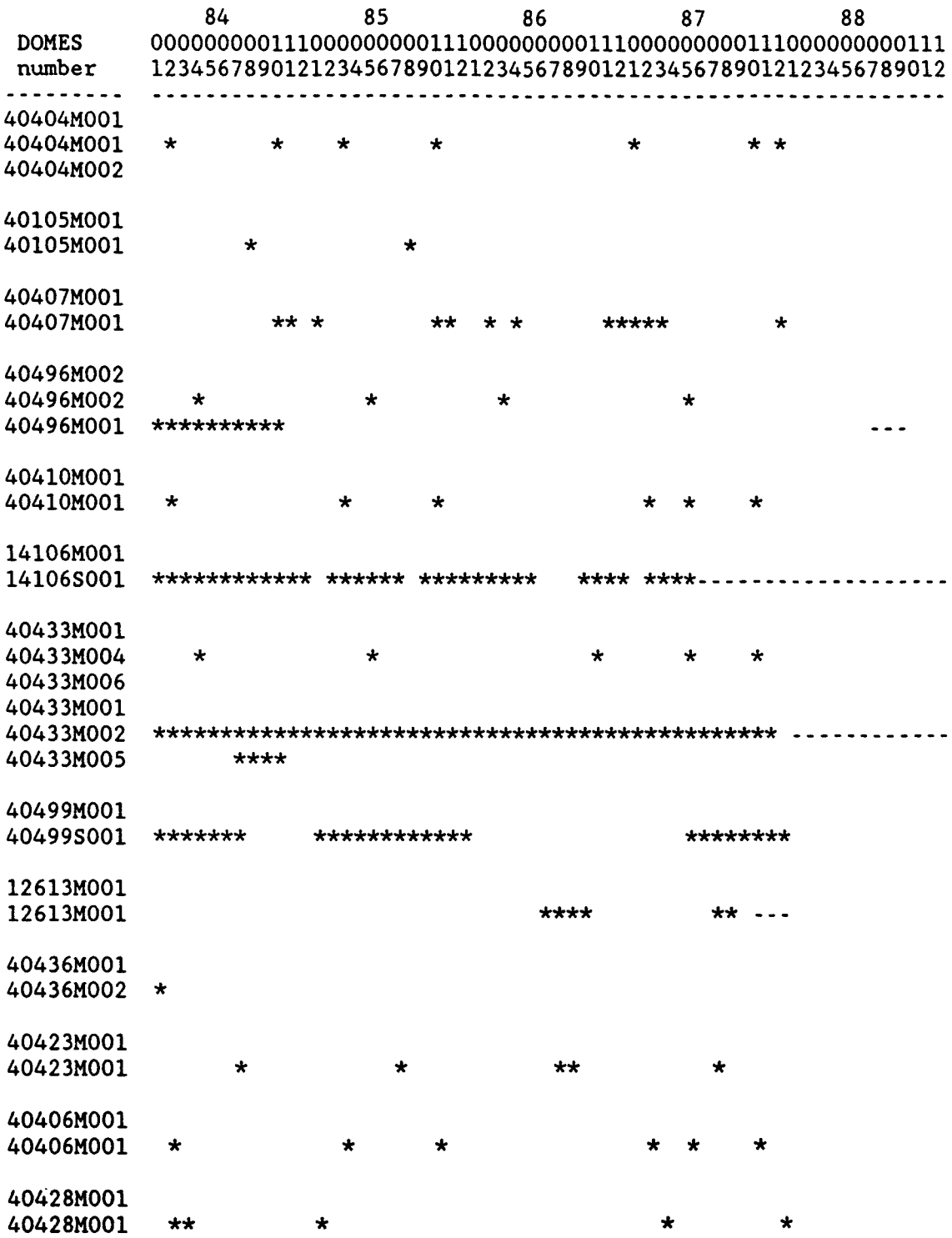
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40428M001

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SANTIAGO		41705M001		
SLR	7400	41705M001	T	
SANTIAGO DE CUBA		40701S001		
	1953	40701S001	P	----------
SHANGHAI		21605M001		
VLBI	7226	21605S008	P	
VLBI	7227	21605S009	P	
SLR	7837	21605S001	P	
SIMOSATO		21726M001		
SLR	7838	21726M002	P	
SOURDOUGH		40425M001		
VLBI	7281	40425M001	T	
TRIESTE		12718M002		
SLR	7550	12718M002	T	
VANDENBERG		40420M001		
VLBI	7223	40420M002	T	
VLBI	7111	40420M001	T	
SLR	7111	40420M001	T	
SLR	7887	40420M004	T	
VERNAL		40492M001		
VLBI	7290	40492M002	T	
SLR	7892	40492M001	T	
WASHINGTON		40451M110		
SLR	7063	40451M112	P	** ** ********** *** *
SLR	7064	40451M107	T	*
SLR	7065	40451M108	T	--
SLR	7100	40451M106	T	** --------
SLR	7101	40451M101	T	-----
SLR	7102	40451M102	T	
SLR	7103	40451M103	T	
SLR	7104	40451M104	T	
SLR	7105	40451M105	P	
SLR	7899	40451M111	T	
SLR	7125	40451M114	T	
SLR	7130	40451M116	T	
SLR	7920	40451M117	T	
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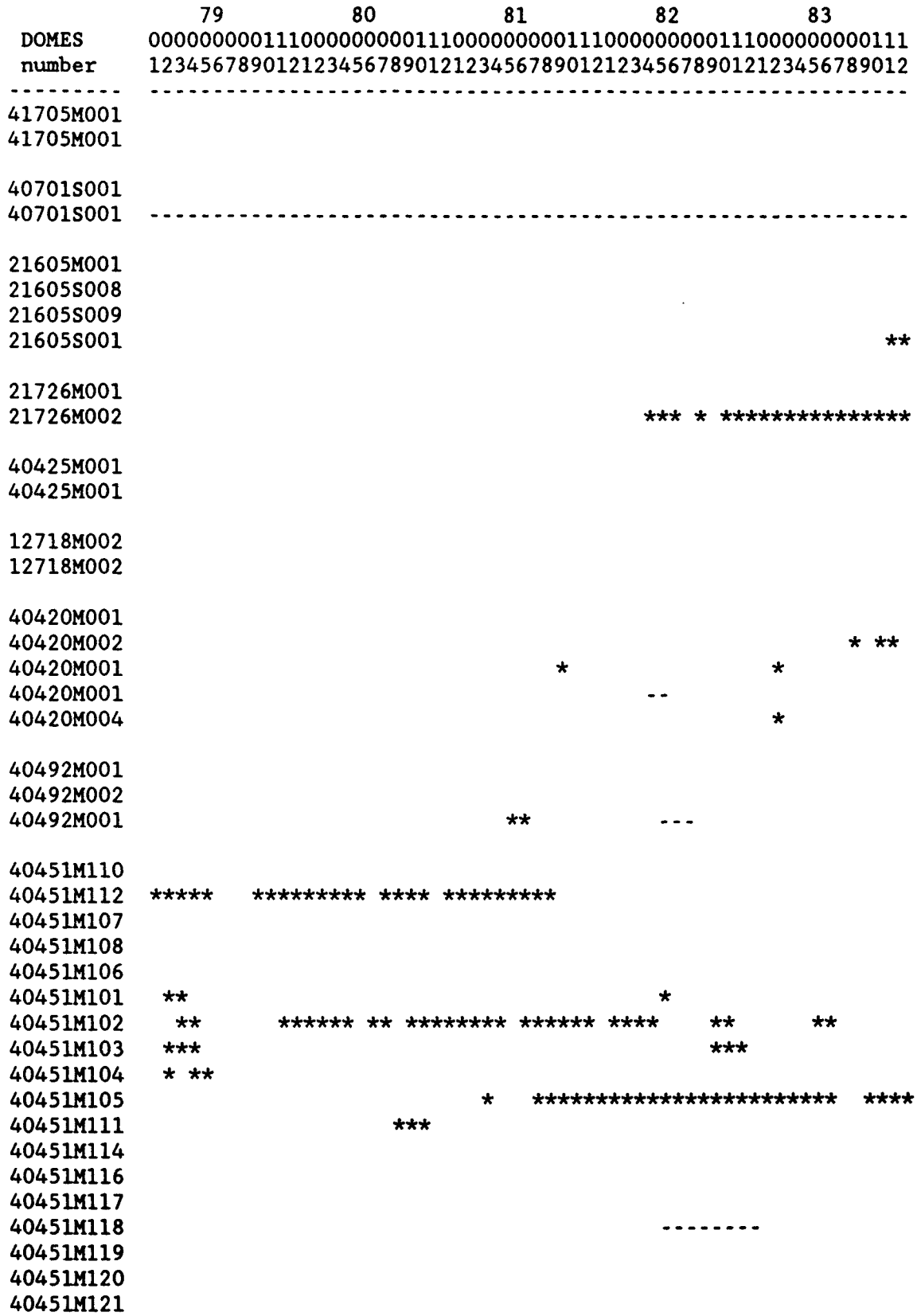
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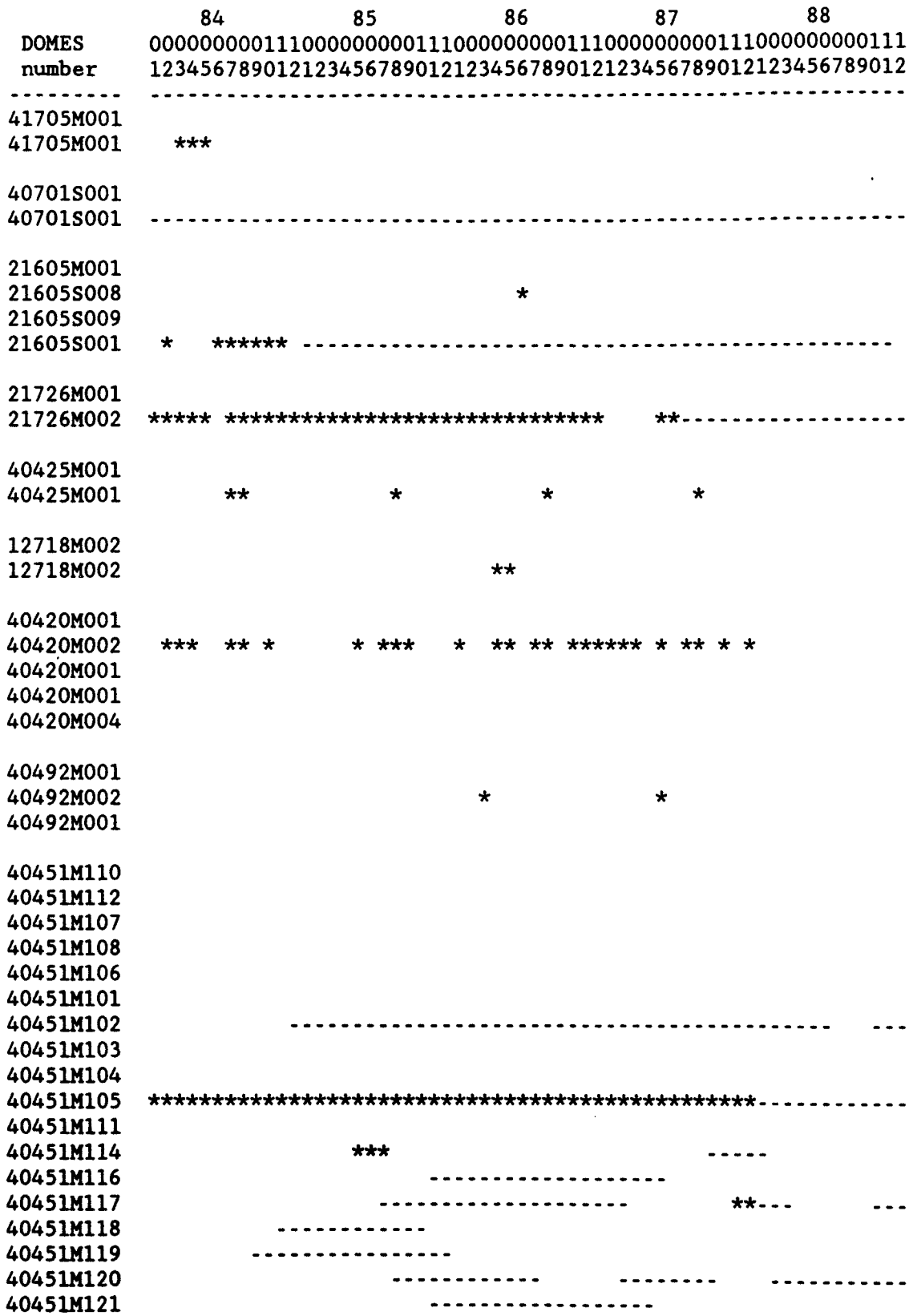
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WETTZELL		14201M001		
VLBI	7224	14201S004	P	
SLR	7834	14201S002	P	****
SLR	7596	14201M004	T	
SLR	7597	14201M005	T	
SLR	7599	14201M007	T	
WHITEHORSE		40118M001		
VLBI	7284	40118M001	T	
XRISOKALARIA		12616M001		
SLR	7525	12616M001	T	
YAKATAGA		40416M001		
VLBI	7277	40416M001	T	
YARRAGADEE		50107M001		
SLR	7090	50107M001	P	
YELLOWKNIFE		40127M001		
VLBI	7285	40127M001	T	
YIGILCA		20804M001		
SLR	7587	20804M001	T	
YOZGAT		20802M001		
SLR	7585	20802M001	T	
YUMA		40493M001		
VLBI	7273	40493M002	T	
VLBI	7894	40493M001	T	
SLR	7894	40493M001	T	
ZIMMERWALD		14001M001		
SLR	7810	14001S001	P	

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                79          80          81          82          83
 DOMES     000000000111000000000111000000000111000000000111000000000111
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14201S004                                                           **
14201S002   ******      ***       *     ** ** *     *********  ****  *****
14201M004
14201M005
14201M007

40118M001
40118M001

12616M001
12616M001

40416M001
40416M001

50107M001
50107M001           * ****************************************        **

40127M001
40127M001

20804M001
20804M001

20802M001
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40493M001                                                          *
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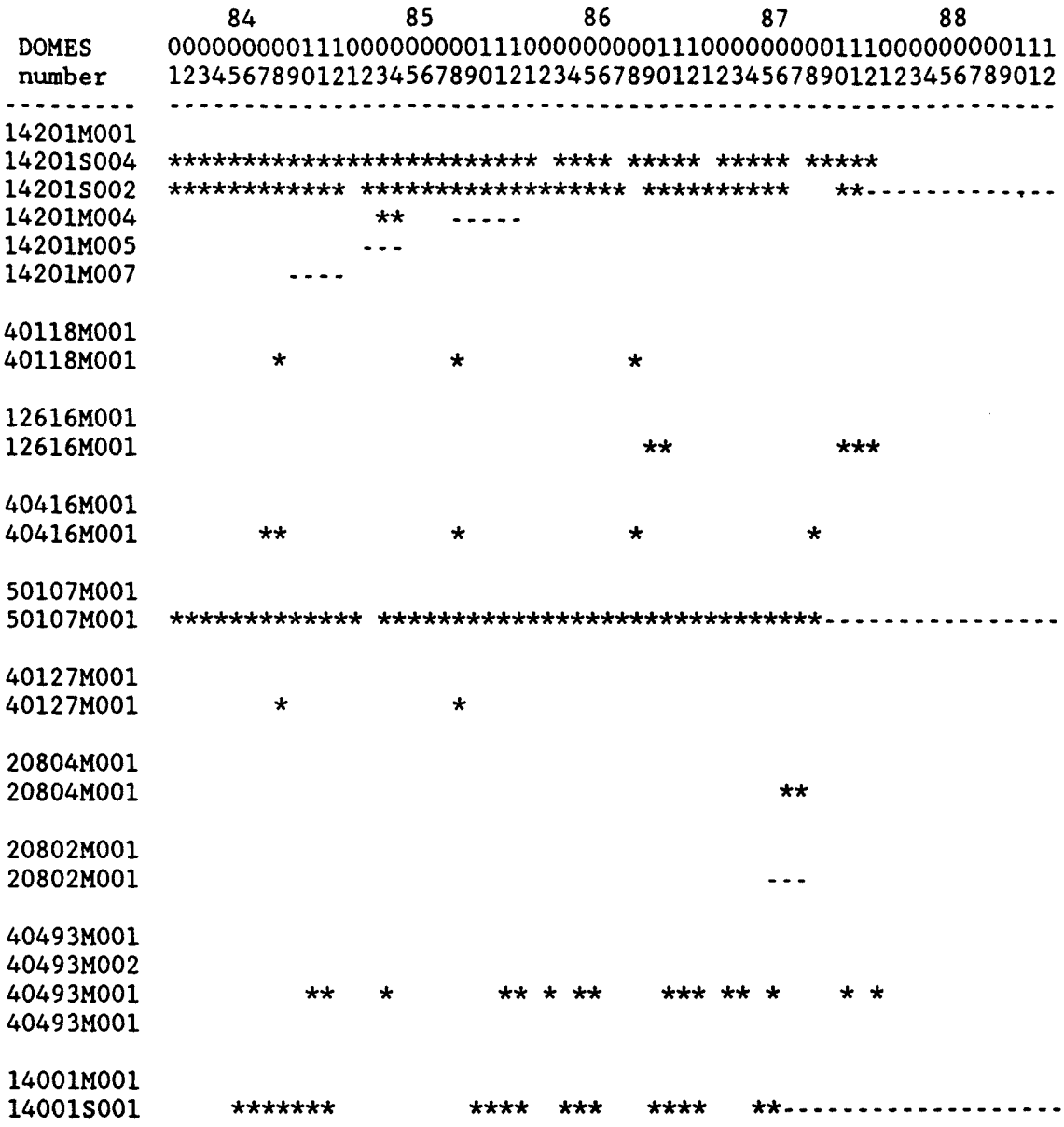
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14001S001

APPENDIX 3

Appendix 3

INPUT SYSTEMS (from BIH Annual Report for 1987)

EARTH ORIENTATION RESULTS FROM THE NASA CRUSTAL DYNAMICS PROJECT

ERP(GSFC)88 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
A. Mallama - SAR, 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 Haystack 37-m antenna moving with AM0-2 velocity and its position defined on 1980 Oct. 17. The orientation of the frame is defined by values from BIH Circular D and the standard J2000.0 precession and IAU 1980 nutation models for the same date. 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.

The basic models used in calculating the VLBI theoreticals are described in Ma (1978), and the data analysis procedures are described in Ryan et al. (1986) and Ma et al. (1986). These 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, the ocean loading model was not used and adjustments in longitude and obliquity were estimated for each session except the reference day. All stations move with their AM0-2 velocities on the listed tectonic plates. It should be noted that Kashima has been placed on the North American plate.

222 183 Mark III observations from 566 sessions were used to estimate station positions, source positions, Earth orientation parameters, nutation parameters and local clock and troposphere behavior from a least-squares solution with 192 global parameters and 14 246 arc, i.e., session-dependent, parameters. A weak input covariance on the Earth orientation parameters (X, Y-15 mas, UT1-1 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 83.1 ps for delay and 73.0 fs/s for rate. The reduced chi-square of the solution was .98.

The Earth orientation time series spanning nine years is given in ERP(GSFC)88 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 be 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 given in RSC(GSFC)88 R 01, station coordinates at epoch 1980 Oct. 17 given in SSC(GSFC)88 R 01, and nutation adjustments relative to 1980 Oct. 17 in NUT(GSFC)88 R 01.

References

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J. Ryan et al., J. Geophys. Res. 91, 1935, 1986.
C. Ma et al., Astron. J. 92, 1020, 1986.

BIH(1988) : Annual Report for 1987.

STATION COORDINATES SSC(GSFC) 88 R 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX	SY	SZ	PLATE	EPOCH MJD
401S010	ALGONQUIN	40104S001	918036.723	-4346133.066	4561971.561	.002	.006	.007	NOAM	44529
106S010	CHILBOLTON	13201S002	4008312.009	-100651.879	4943794.796	.009	.005	.012	EURA	44529
101S010	EFFELSBERG	14209S001	4033949.409	486989.385	4900430.754	.008	.005	.013	EURA	44529
429S010	FAIRBANKS	40408S002	-2281545.170	-1453645.805	5756993.684	.003	.005	.010	NOAM	44529
410S030	GOLDSTONE	40405S014	-2351127.274	-4655477.930	3660957.507	.008	.015	.013	NOAM	44529
301S010	JOHANNESBURG	30302S001	5085444.328	2668262.049	-2768697.257	.026	.017	.017	AFRC	44529
407S010	HAT CREEK	40489S001	-2523968.042	-4123507.192	4147753.186	.002	.006	.008	NOAM	44529
403S010	HAYSTACK	40440S002	1492406.691	-4457267.330	4296882.102	.001	.001	.001	NOAM	44529
406S010	FORT DAVIS	40442S003	-1324209.126	-5332023.968	3232118.942	.002	.005	.005	NOAM	44529
203S010	KASHIMA	21701S001	-3997890.433	3276580.390	3724118.715	.011	.007	.020	NOAM	44529
430S010	KAUAI	40424S001	-5543844.213	-2054565.546	2387814.078	.007	.010	.015	PCFC	44529
507S010	KWAJALEIN ATOLL	50505S003	-6143534.953	1363995.752	1034707.618	.015	.013	.020	PCFC	44529
415S010	MARYLAND POINT	40490S001	1106631.226	-4882907.983	3938087.339	.004	.011	.009	NOAM	44529
112S010	BOLOGNE	12711S001	4461371.968	919595.660	4449559.136	.009	.005	.013	EURA	44529
427S010	GOLDSTONE	40405S009	-2356169.122	-4646756.731	3668471.197	.001	.005	.007	NOAM	44529
404S010	GREENBANK	40441S001	882881.815	-4924483.116	3944131.063	.001	.005	.005	NOAM	44529
103S020	ONSALA	10402S002	3370608.017	711916.419	5349830.741	.005	.004	.010	EURA	44529
405S010	OWENS VALLEY	40439S002	-2409598.868	-4478350.390	3838603.796	.001	.005	.007	NOAM	44529
402M001	PENTICTON	40105M001	-2058838.556	-3621287.265	4814421.387	.005	.010	.013	NOAM	44529
432M001	PLATTEVILLE	40496M002	-1240706.242	-4720455.146	4094482.175	.002	.008	.008	NOAM	44529
412S010	RICHMOND	40499S001	961259.855	-5674090.884	2740534.192	.002	.004	.003	NOAM	44529
108S020	MADRID	13407S003	4849247.098	-360279.338	4114884.533	.045	.014	.040	EURA	44529
201S020	SHANGHAI	21605S009	-2831684.418	4675732.822	3275327.682	.086	.083	.096	EURA	44529
201S010	SHANGHAI	21605S008	-2847695.758	4659871.645	3283958.812	.128	.110	.102	EURA	44529
428M001	SOUTH VANDENBERG	40420M002	-2678092.771	-4525451.947	3597410.498	.002	.006	.008	NOAM	44529
409S010	HAYSTACK	40440S003	1492208.546	-4458131.313	4296015.858	.001	.002	.002	NOAM	44529
115S010	WETTZELL	14201S004	4075541.876	931734.136	4801629.343	.006	.004	.011	EURA	44529
431M001	YELLOWKNIFE	40127M001	-1224122.542	-2689531.382	5633555.746	.006	.012	.025	NOAM	44529

Epoch of station positions is 1980 October 17.

POLAR MOTION AND UT1 TIME SERIES DERIVED FROM VLBI OBSERVATIONS

ERP(NGS) 88 R 01
ERP(NGS) 88 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 138 000 observations amassed during 460 observing sessions conducted between September 9, 1980, and January, 1988, were combined in a single least squares adjustment to obtain self consistent Earth orientation time series (Table NGS-1), source coordinates (Table NGS-2) (see Robertson et al., 1986) and the coordinates of the VLBI reference points of each of the radio telescopes (Table NGS-3).
Table NGS-4 contains corrections to the IAU 1980 nutation series from the IRIS 5-day observing sessions.
Table NGS-5 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 daily values track smoothly between the regular 5-day IRIS values, and we estimate their accuracy to be 0.1 millisec (Robertson et al., 1985b).

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. Hellings' model for the relativistic corrections for signal propagation was used (Hellings, 1986). Atmospheric refraction 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. 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). 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). X and Y coordinates of the pole derived from satellite laser ranging (SLR) (Eanes et al., 1988), 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.

BIH(1988) : Annual Report for 1987.

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), and intercomparisons between these values and the daily UT1 values (see below) indicates that the UT1 values are accurate to at least ± 0.1 milliseconds of time (Robertson et al., 1985b).

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

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TABLE NGS-3. Station Coordinates SSC(NGS) 88 R 01

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX m	SY m	SZ m	PLATE	MJD
405S010	OWENS VALLEY	40439S002	-2409600.583	-4478349.451	3838603.446	.003	.008	.009	NOAM	45700
427S010	GOLDSTONE	40405S009	-2356170.843	-4646755.780	3668470.833	.003	.014	.016	NOAM	45700
406S010	FORT DAVIS	40442S003	-1324210.830	-5332023.025	3232118.569	.002	.005	.006	NOAM	45700
404S010	GREENBANK	40441S001	882880.174	-4924482.166	3944130.697	.002	.007	.006	NOAM	45700
412S010	RICHMOND	40499S001	961258.209	-5674089.934	2740533.783	.002	.004	.003	NOAM	45700
415S010	MARYLAND POINT	40490S001	1106629.600	-4882907.034	3938086.959	.005	.020	.016	NOAM	45700
409S010	HAYSTACK	40440S003	1492206.923	-4458130.340	4296015.490	.010	.010	.010	NOAM	45700
403S010	HAYSTACK	40440S002	1492405.068	-4457266.374	4296881.746	.001	.003	.003	NOAM	45700
103S020	ONSALA	10402S002	3370606.448	711917.597	5349830.449	.006	.004	.010	EURA	45700
106S010	CHILBOLTON	13201S002	4008310.439	-100650.707	4943794.438	.012	.006	.016	EURA	45700
101S010	EFFELSBERG	14209S001	4033947.824	486990.561	4900430.388	.014	.008	.021	EURA	45700
115S010	WETTZELL	14201S004	4075540.310	931735.337	4801629.022	.007	.004	.011	EURA	45700
112S010	BOLOGNE	12711S001	4461370.423	919596.875	4449558.816	.011	.006	.015	EURA	45700
301S010	JOHANNESBURG	30302S001	5085442.656	2668263.457	-2768697.703	.026	.014	.017	AFRC	45700

The station coordinate epoch is January 1, 1984.

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Telex 704265 CSRUTX UD
BITNET: SCHUTZ at UTADNX
SPAN: UTSPAN::UTADNX::SCHUTZ
GE Mark 3 AUTA

A single continuous Lageos ephemeris was fit to Lageos laser range data for the interval from May 1976 to January 1988. The data base contained about 316 000 three-minute normal points formed from over 32 000 passes collected from more than 90 sites.

The force model referred to as the CSR 8801 system. contains some departures from the MERIT Standards GM=398600.440 km**3/s**2 and the order one GEM-L2 coefficients were adjusted for consistency with the MERIT C(2,1) and S(2,1). Furthermore. some ocean tide parameters depart from the Standards.

The station coordinates were obtained simultaneously with the ephemeris and selected force model parameters. The stations were assumed to be attached to the tectonic plates noted in the following table with rates defined by the AM1-2 model of Minster and Jordan (1978). The epoch of the derived station coordinates is 1983 January 1 00:00 UTC.

The earth rotation parameters estimated simultaneously with the other parameters were three day values of pole position (x,y) and UT1. The estimated UT1 values contain Lageos node model errors which were filtered to remove periods greater than about 80 days. The reference UT1 series was the combined series of T.M. Eubanks (this volume p.D-85) from 1976 to 1986. After 1986, the reference was the monthly IRIS values reported on G.E.Mark 3.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. During periods from 1976 to 1980, some three-day intervals did not have adequate tracking coverage, as reflected by larger standard errors when compared to the period from 1980 to 1988.

Note - Plate motion model : AM1-2 from Minster, J.B., and Jordan, T.H., 1978, Present-Day Plate Motions. J.Geophys.Res., 83, 5331-5354.

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NETWORK NUMBER	SITE	DOMES NUMBER	X	Y	Z	SX	SY	SZ	PLATE	MJD
1181S001	POTSDAM	14106S001	3800621.502	882005.190	5028859.501	.034	.034	.022	EURA	45335
1953S001	SANTIAGO DE CUBA	40701S001	1474548.542	-5811242.444	2168945.108	.155	.117	.179	NOAM	45335
7051M001	QUINCY	40433M001	-2516893.229	-4198844.933	4076411.540	.018	.016	.013	NOAM	45335
7062M001	SAN DIEGO	40436M002	-2428825.918	-4799750.460	3417272.808	.016	.014	.014	PCFC	45335
7063M001	WASHINGTON	40451M112	1130714.656	-4831367.715	3994087.426	.012	.009	.009	NOAM	45335
7064M001	WASHINGTON	40451M107	1130689.505	-4831341.933	3994123.795	1.000	1.000	1.000	NOAM	45335
7065M001	WASHINGTON	40451M108	1130692.329	-4831351.962	3994111.385	1.000	1.000	1.000	NOAM	45335
7067M001	BERMUDA	42501M001	2308538.384	-4874079.996	3393628.615	.072	.048	.073	NOAM	45335
7068M001	GRAND TURK	43602M002	1920482.507	-5619478.398	2318914.376	1.000	1.000	1.000	NOAM	45335
7069M001	PATRICK AFB	40417M002	917958.723	-5548370.183	2998776.759	1.000	1.000	1.000	NOAM	45335
7082M001	BEAR LAKE	40438M001	-1735997.267	-4425047.933	4241430.546	.026	.024	.017	NOAM	45335
7084M001	OWENS VALLEY	40439M003	-2410590.137	-4477745.038	3838648.579	.108	.096	.063	NOAM	45335
7085M001	GOLDSTONE	40405M001	-2353393.953	-4641529.064	3676899.086	.092	.100	.067	NOAM	45335
7086M001	FORT DAVIS	40442M001	-1330125.465	-5328526.469	3236150.434	.007	.004	.006	NOAM	45335
7090M001	YARRAGADEE	50107M001	-2389006.010	5043329.294	-3078525.709	.006	.004	.005	INDI	45335
7091M001	HAYSTACK	40440M001	1492453.575	-4457278.669	4296815.896	.013	.011	.010	NOAM	45335
7092M001	KWAJALEIN ATOLL	50505M001	-6143447.273	1364700.159	1034162.907	.017	.024	.024	PCFC	45335
7096M001	AMERICAN SAMOA	50503M001	-6100045.820	-996203.193	-1568976.425	.013	.020	.019	PCFC	45335
7100M001	WASHINGTON	40451M106	1131355.671	-4831168.899	3994132.165	1.000	1.000	1.000	NOAM	45335
7101M001	WASHINGTON	40451M101	1131240.446	-4831179.848	3994148.474	1.000	1.000	1.000	NOAM	45335
7102M001	WASHINGTON	40451M102	1130686.536	-4831353.013	3994110.947	.013	.011	.009	NOAM	45335
7103M001	WASHINGTON	40451M103	1130685.537	-4831348.684	3994116.392	.021	.020	.014	NOAM	45335
7104M001	WASHINGTON	40451M104	1131095.752	-4831196.858	3994170.811	.062	.052	.054	NOAM	45335
7105M001	WASHINGTON	40451M105	1130719.655	-4831350.539	3994106.549	.007	.004	.005	NOAM	45335
8213S001	WASHINGTON	40451S131	1130705.584	-4831348.397	3994117.858	.032	.026	.026	NOAM	45335

SSC(CSR) 88 L 01 (CONT.)

NETWORK NUMBER	SITE	DOMES NUMBER	X	Y	Z	SX	SY	SZ	PLATE	MJD
7106S001	WASHINGTON	40451S132	1130659.662	-4831292.885	3994173.166	1.000	1.000	1.000	NOAM	45335
7109M001	QUINCY	40433M002	-2517234.789	-4198556.005	4076569.837	.006	.005	.005	NOAM	45335
7110M001	MONUMENT PEAK	40497M001	-2386277.959	-4802354.291	3444881.457	.006	.004	.005	PCFC	45335
7112M001	PLATTEVILLE	40496M001	-1240678.317	-4720463.231	4094480.743	.009	.007	.006	NOAM	45335
7114M001	OWENS VALLEY	40439M001	-2410422.484	-4477802.514	3838686.824	.011	.010	.009	NOAM	45335
7115M001	GOLDSTONE	40405M002	-2350861.738	-4655546.142	3660998.028	.011	.010	.009	NOAM	45335
7120M001	MAUI	40445M002	-5465998.458	-2404408.509	2242228.372	.008	.011	.010	PCFC	45335
7121M001	MOTU HIUMOO	92202M002	-5345865.243	-2958246.680	-1824623.841	.011	.015	.014	PCFC	45335
7122M001	MAZATLAN	40504M001	-1660089.509	-5619100.244	2511638.033	.007	.004	.006	NOAM	45335
7123M001	MOTU HIUMOO	92202M003	-5345865.285	-2958246.677	-1824623.917	.019	.021	.022	PCFC	45335
7125M001	WASHINGTON	40451M114	1130745.769	-4831368.075	3994077.122	.021	.017	.014	NOAM	45335
7130M001	WASHINGTON	40451M116	1130735.232	-4831324.617	3994132.372	.125	.107	.084	NOAM	45335
7210M001	MAUI	40445M001	-5466006.508	-2404427.887	2242187.423	.004	.007	.006	PCFC	45335
7220M001	MONUMENT PEAK	40497M002	-2386292.284	-4802347.456	3444880.936	.015	.015	.013	PCFC	45335
7265M001	GOLDSTONE	40405M006	-2356475.780	-4646618.095	3668424.904	.019	.020	.014	NOAM	45335
7274M001	MONUMENT PEAK	40497M003	-2386289.363	-4802346.465	3444884.007	.016	.016	.014	PCFC	45335
7400M001	SANTIAGO	41705M001	1769699.470	-5044613.079	-3468260.030	.024	.017	.021	SOAM	45335
7401M001	CERRO TOLOLO	41706M001	1815516.827	-5213465.024	-3187999.357	.016	.012	.015	SOAM	45335
7510M001	ASKITES	12612M001	4353445.220	2082666.089	4156506.496	.011	.013	.010	EURA	45335
7512M001	KATAVIA	12615M001	4573400.372	2409321.969	3723881.605	.012	.015	.012	EURA	45335
7515M001	DIONYSOS	12602M002	4595216.723	2039435.100	3912629.354	.010	.012	.010	EURA	45335
7517M001	ROUMELLI	12613M001	4728694.991	2174373.131	3674572.801	.009	.012	.010	EURA	45335
7520M001	KARITSA	12614M001	4596042.880	1733476.594	4055720.703	.018	.018	.013	EURA	45335
7525M001	XRISOKALARIA	12616M001	4745949.832	1905705.702	3799168.889	.014	.015	.013	EURA	45335
7530S001	BAR GIYYORA	20702S001	4443968.823	3121946.640	3334695.252	.017	.019	.017	AFRC	45335

SSC(CSR) 88 L 01 (CONT.)

NETWORK NUMBER	SITE	DOMES NUMBER	X	Y	Z	SX	SY	SZ	PLATE	MJD
7540M001	MATERA	12734M005	4641984.804	1393057.512	4133233.313	.025	.023	.016	EURA	45335
7541M001	MATERA	12734M004	4641990.544	1393042.066	4133231.699	.015	.017	.012	EURA	45335
7544M001	LAMPEDUSA	12706M001	5072832.228	1130885.990	3684836.789	.017	.022	.015	EURA	45335
7545S001	CAGLIARI	12725S010	4893400.912	772673.560	4004139.670	.017	.023	.016	EURA	45335
7550M001	TRIESTE	12718M002	4336738.804	1071271.271	4537910.910	.027	.034	.022	EURA	45335
7575M001	DIYARBAKIR	20801M001	3848636.442	3251760.707	3898909.061	.030	.030	.023	EURA	45335
7580M001	MELENGICLICK	20803M001	4247620.925	2778638.789	3851607.309	.021	.025	.014	EURA	45335
7585M001	YOZGAT	20802M001	4029731.058	2802093.132	4062067.857	.034	.044	.019	EURA	45335
7587M001	YIGILCA	20804M001	4117362.322	2517076.651	4157678.883	.024	.019	.014	EURA	45335
7596S001	WETTZELL	14201S010	4075585.514	931837.601	4801559.120	.021	.027	.016	EURA	45335
7597S001	WETTZELL	14201S011	4075605.116	931826.877	4801546.858	1.000	1.000	1.000	EURA	45335
7599S001	WETTZELL	14201S007	4075517.644	931753.917	4801630.174	1.000	1.000	1.000	EURA	45335
7805S001	METSAHOVI	10503S001	2892596.253	1311808.420	5512610.217	.088	.080	.056	EURA	45335
7810S001	ZIMMERWALD	14001S001	4331283.806	567549.295	4633139.842	.017	.018	.011	EURA	45335
7831S001	HELWAN	30101S001	4728283.921	2879670.171	3156894.061	.092	.099	.080	AFRC	45335
7833S001	KOOTWIJK	13504S001	3899224.214	396742.740	5015073.744	.030	.031	.019	EURA	45335
8833S001	KOOTWIJK	13504S007	3899238.142	396769.020	5015055.104	.029	.030	.019	EURA	45335
7834S001	WETTZELL	14201S002	4075530.306	931781.132	4801618.123	.009	.010	.007	EURA	45335
7835S001	GRASSE	10002S001	4581692.009	556159.170	4389359.259	.008	.010	.007	EURA	45335
7837S001	SHANGHAI	21605S001	-2831087.300	4676203.670	3275172.799	.103	.088	.075	EURA	45335
7838S001	SIMOSATO	21726S001	-3822388.035	3699363.759	3507573.109	.006	.006	.006	EURA	45335
7839S001	GRAZ	11001S002	4194426.945	1162693.702	4647246.399	.007	.008	.006	EURA	45335
7840S001	HERSTMONCEUX	13212S001	4033463.991	23662.159	4924304.933	.005	.007	.005	EURA	45335
7843S001	ORRORAL	50103S008	-4446476.429	2678127.203	-3696251.875	.008	.009	.007	INDI	45335
7882M001	CABO SAN LUCAS	40505M001	-1997241.720	-5528040.936	2468355.246	1.000	1.000	1.000	PCFC	45335

SSC(CSR) 88 L 01 (CONT.)

NETWORK NUMBER	SITE	DOMES NUMBER	X	Y	Z	SX	SY	SZ	PLATE	MJD
7885M001	FORT DAVIS	40442M005	-1330125.510	-5328526.416	3236150.395	.029	.031	.023	NOAM	45335
7886M001	QUINCY	40433M005	-2517242.397	-4198550.750	4076570.482	.015	.011	.008	NOAM	45335
7887M001	VANDENBERG	40420M004	-2668868.288	-4530743.159	3598684.956	1.000	1.000	1.000	NOAM	45335
7888M001	MOUNT HOPKINS	40434M002	-1936744.432	-5077638.897	3331994.034	.032	.025	.029	NOAM	45335
7891M001	FLAGSTAFF	40491M002	-1923976.799	-4850871.546	3658574.841	.032	.031	.024	NOAM	45335
7892M001	VERNAL	40492M001	-1631484.792	-4589133.647	4106749.651	.023	.025	.016	NOAM	45335
7894M001	YUMA	40493M001	-2196777.940	-4887336.898	3448425.436	.025	.024	.024	NOAM	45335
7896M001	PASADENA	40400M001	-2493211.982	-4655229.417	3565574.651	.024	.024	.019	PCFC	45335
7899M001	WASHINGTON	40451M111	1131364.615	-4831168.764	3994129.059	.036	.036	.030	NOAM	45335
7907S001	AREQUIPA	42202S001	1942791.630	-5804077.857	-1796919.262	.007	.003	.006	SOAM	45335
7918S001	WASHINGTON	40451S142	1130741.956	-4831371.376	3994079.333	1.000	1.000	1.000	NOAM	45335
7919S001	WASHINGTON	40451S145	1130705.676	-4831347.429	3994117.615	1.000	1.000	1.000	NOAM	45335
7921S001	MOUNT HOPKINS	40434S001	-1936760.322	-5077706.954	3331922.611	.016	.014	.014	NOAM	45335
7929S001	NATAL	41604S001	5186467.773	-3653856.349	-654321.819	.034	.044	.046	SOAM	45335
7939S001	MATERA	12734S001	4641965.336	1393069.698	4133262.086	.005	.006	.005	EURA	45335
7940S001	DIONYSOS	12602S001	4595217.574	2039464.233	3912612.946	1.000	1.000	1.000	EURA	45335
7943S001	ORRORAL	50103S003	-4447548.402	2677134.195	-3694996.869	.007	.008	.007	INDI	45335

AN 11.2 YEAR SLR EOP SERIES FROM LAGEOS SATELLITE LASER RANGING

SL7.1 (G14) ERP(GSFC)87 L 14

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P.J. Dunn. S.M. Klosko, E.C. Pavlis, J.R. Robbins, M.H.Torrence and
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Washington Analytical Services Center, Inc., Lanham, Maryland 20706
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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 1987. There were 362 810 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, 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 = 398600.4400 km3/sec2
- Tidal perturbations: Solid earth from Wahr, ocean tidal coeficients from GEM-T1
- Direct effect of solar radiation pressure adjusted twice in each monthly arc
- Along track acceleration adjusted twice in each monthly arc

MEASUREMENT MODEL

- Marini-Muray wavelength dependent refraction model with site meteorological measurements
- Velocity of light = 299792.458 km/sec
- Vertical and horizontal tide displacements: h2=0.6090, l2=0.0852
- 2 minute normal points following the Herstmonceux recommendations

BIH (1988) Annual Report for 1987.

REFERENCE FRAME

- Wahr nutation series
- J2000 precession (JPL DE200 ephemeris)
- Ae = 6378137. m
- Flattening = 1/298.257
- Apriori earth orientation (Xp Yp and A1-UT1) obtained from a weakly Vondrak smoothed earth orientation from SL7. These input values are adjusted at 5-day intervals (Xp, Yp, and A1-UT1): except that the first 5 day value of A1-UT1 in each monthly arc is fixed at the input value.
- The station positions were constrained to move according to the Minster/Jordan (1978) tectonic motion model AM0-2. The positions have an epoch of January 1983.

The Xp and Yp positions for the pole and the LOD values are in
ERP(GSFC) 87 L 14

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

The station positions are presented in cartesian coordinates in
SSC(GSFC) 87 L 14.

The positions are for an epoch of January 1983, and, as for the EOP, the sigmas 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, 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.

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX	SY	SZ	PLATE	EPOCH MJD
1181S001	POTSDAM	14106S001	3800621.602	882005.144	5028859.364	.110	.108	.074	EURA	45335
7051M001	QUINCY	40433M001	-2516893.067	-4198845.021	4076411.563	.017	.016	.012	NOAM	45335
7061M001	EASTER ISLAND	41703M001	-1884984.569	-5357606.615	-2892852.514	.128	.100	.099	NAZC	45335
7062M001	SAN DIEGO	40436M002	-2428825.759	-4799750.528	3417272.733	.015	.013	.014	PCFC	45335
7063M001	WASHINGTON	40451M112	1130714.845	-4831367.722	3994087.347	.001	.006	.005	NOAM	45335
7067M001	BERMUDA	42501M001	2308538.595	-4874079.899	3393628.478	.139	.089	.129	NOAM	45335
7068M001	GRAND TURK	43602M002	1920482.742	-5619478.322	2318914.296	.450	.248	.380	NOAM	45335
7069M001	PATRICK AFB	40417M002	917959.103	-5548370.284	2998776.608	.142	.083	.110	NOAM	45335
7082M001	BEAR LAKE	40438M001	-1735997.066	-4425048.120	4241430.592	.021	.021	.015	NOAM	45335
7084M001	OWENS VALLEY	40439M003	-2410590.154	-4477745.773	3838648.330	.218	.553	.620	NOAM	45335
7085M001	GOLDSTONE	40405M001	-2353394.103	-4641529.856	3676898.746	.195	.528	.609	NOAM	45335
7086M001	FORT DAVIS	40442M001	-1330125.326	-5328526.542	3236150.388	.004	.004	.003	NOAM	45335
7090M001	YARRAGADEE	50107M001	-2389006.169	5043329.303	-3078525.572	.003	.003	.005	INDI	45335
7091M001	HAYSTACK	40440M001	1492453.734	-4457278.710	4296815.799	.013	.011	.010	NOAM	45335
7092M001	KWAJALEIN ATOLL	50505M001	-6143447.292	1364700.020	1034163.076	.017	.024	.024	PCFC	45335
7096M001	AMERICAN SAMOA	50503M001	-6100045.859	-996203.244	-1568976.317	.014	.020	.019	PCFC	45335
7100M001	WASHINGTON	40451M106	1131355.720	-4831168.684	3994132.087	.226	.180	.195	NOAM	45335
7101M001	WASHINGTON	40451M101	1131240.510	-4831179.809	3994148.458	.084	.052	.075	NOAM	45335
7102M001	WASHINGTON	40451M102	1130686.655	-4831353.070	3994110.874	.012	.010	.008	NOAM	45335
7103M001	WASHINGTON	40451M103	1130685.716	-4831348.720	3994116.296	.018	.019	.012	NOAM	45335
7104M001	WASHINGTON	40451M104	1131095.963	-4831196.830	3994170.798	.064	.054	.053	NOAM	45335
7105M001	WASHINGTON	40451M105	1130719.791	-4831350.556	3994106.469	.001	.002	.002	NOAM	45335
7109M001	QUINCY	40433M002	-2517234.651	-4198556.103	4076569.835	.003	.004	.002	NOAM	45335
7110M001	MONUMENT PEAK	40497M001	-2386277.830	-4802354.367	3444881.451	.003	.004	.003	PCFC	45335
7112M001	PLATTEVILLE	40496M001	-1240678.167	-4720463.302	4094480.711	.006	.006	.004	NOAM	45335

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX	SY	SZ	PLATE	EPOCH MJD
7114M001	OWENS VALLEY	40439M001	-2410422.346	-4477802.637	3838686.825	.010	.010	.008	NOAM	45335
7115M001	GOLDSTONE	40405M002	-2350861.583	-4655546.248	3660998.016	.010	.010	.009	NOAM	45335
7120M001	MAUI	40445M002	-5465998.367	-2404408.648	2242228.437	.007	.010	.010	PCFC	45335
7121M001	MOTU HIUMOO	92202M002	-5345865.225	-2958246.707	-1824623.797	.005	.007	.006	PCFC	45335
7122M001	MAZATLAN	40504M001	-1660089.369	-5619100.296	2511637.990	.004	.004	.003	NOAM	45335
7125M001	WASHINGTON	40451M114	1130745.851	-4831368.061	3994077.088	.013	.011	.009	NOAM	45335
7210M001	MAUI	40445M001	-5466006.420	-2404428.020	2242187.486	.003	.005	.001	PCFC	45335
7220M001	MONUMENT PEAK	40497M002	-2386292.141	-4802347.466	3444880.901	.015	.013	.011	PCFC	45335
7265M001	GOLDSTONE	40405M006	-2356475.639	-4646618.163	3668424.890	.013	.014	.010	NOAM	45335
7400S001	SANTIAGO	41705S003	1769700.127	-5044614.829	-3468263.227	.018	.012	.015	SOAM	45335
7401S001	CERRO TOLOLO	41706S001	1815517.654	-5213466.857	-3188002.492	.012	.009	.010	SOAM	45335
7517M001	ROUMELLI	12613M001	4728694.983	2174373.086	3674572.753	.013	.016	.015	EURA	45335
7520M001	KARITSA	12614M001	4596042.901	1733476.580	4055720.619	.018	.017	.013	EURA	45335
7525M001	XRISOKALARIA	12616M001	4745949.861	1905705.653	3799168.881	.021	.026	.023	EURA	45335
7530M001	BAR GIYYORA	20702M001	4443967.730	3121945.143	3334694.117	.012	.013	.013	AFRC	45335
7541M001	MATERA	12734M004	4641990.591	1393042.047	4133231.626	.017	.019	.013	EURA	45335
7545M001	CAGLIARI	12725M002	4893398.335	772673.017	4004140.721	.011	.015	.011	EURA	45335
7550M001	TRIESTE	12718M002	4336738.868	1071271.219	4537910.819	.022	.029	.019	EURA	45335
7580S001	MELENGICLICK	20803S001	4247617.879	2778638.401	3851605.518	.017	.019	.012	EURA	45335
7587S001	YIGILCA	20804S001	4117365.393	2517078.417	4157679.809	.017	.015	.012	EURA	45335
7590M001	MONTE GENEROSO	14005M002	4390310.144	696751.792	4560835.721	.009	.011	.008	EURA	45335
7596S001	WETTZELL	14201S010	4075580.206	931836.253	4801560.288	.138	.194	.130	EURA	45335
7805S001	METSAHOVI	10503S001	2892595.668	1311808.074	5512609.766	.153	.143	.096	EURA	45335
7810S001	ZIMMERWALD	14001S001	4331283.787	567549.214	4633139.808	.010	.010	.008	EURA	45335
7831S001	HELWAN	30101S001	4728284.495	2879668.706	3156893.476	.961	.586	.569	AFRC	45335

NETWORK NUMBER	SITE	DOMES NUMBER	X m	Y m	Z m	SX	SY	SZ	PLATE	EPOCH MJD
7833S001	KOOTWIJK	13504S001	3899224.448	396742.640	5015073.765	.112	.100	.060	EURA	45335
7834S001	WETTZELL	14201S002	4075530.330	931781.054	4801618.012	.005	.005	.006	EURA	45335
7835S001	GRASSE	10002S001	4581692.038	556159.120	4389359.173	.004	.005	.006	EURA	45335
7837S001	SHANGHAI	21605S001	-2831087.340	4676203.655	3275172.911	.259	.222	.185	EURA	45335
7838M001	SIMOSATO	21726M002	-3822386.775	3699362.450	3507572.076	.005	.005	.005	EURA	45335
7839S001	GRAZ	11001S002	4194426.989	1162693.663	4647246.336	.062	.006	.006	EURA	45335
7840S001	HERSTMONCEUX	13212S001	4033464.057	23662.119	4924304.856	.004	.004	.005	EURA	45335
7843S001	ORRORAL	50103S008	-4446476.623	2678127.231	-3696251.826	.008	.007	.009	INDI	45335
7882M001	CABO SAN LUCAS	40505M001	-1997241.608	-5528041.072	2468355.192	.025	.025	.022	PCFC	45335
7885M001	FORT DAVIS	40442M005	-1330125.353	-5328526.400	3236150.360	.026	.027	.021	NOAM	45335
7886S001	QUINCY	40433S010	-2517242.383	-4198554.007	4076572.330	.046	.040	.025	NOAM	45335
7887M001	SOUTH VANDENBERG	40420M004	-2668868.171	-4530743.777	3598685.125	.152	.641	.152	NOAM	45335
7888S001	MOUNT HOPKINS	40434S003	-1936744.321	-5077638.990	3331994.003	.027	.020	.024	NOAM	45335
7890M001	AUSTIN	40412M001	-754162.126	-5459061.176	3200744.117	.273	.242	.118	NOAM	45335
7891M001	FLAGSTAFF	40491M002	-1923976.590	-4850871.519	3658574.912	.030	.029	.023	NOAM	45335
7892M001	VERNAL	40492M001	-1631484.646	-4589133.808	4106749.711	.021	.023	.014	NOAM	45335
7894S001	YUMA	40493S001	-2196777.875	-4887339.166	3448428.343	.024	.023	.022	NOAM	45335
7896M001	PASADENA	40400M001	-2493211.835	-4655229.593	3565574.617	.023	.025	.019	PCFC	45335
7899M001	WASHINGTON	40451M111	1131364.780	-4831168.801	3994128.931	.036	.037	.031	NOAM	45335
7907S001	AREQUIPA	42202S001	1942791.702	-5804077.774	-1796919.376	.005	.003	.003	SOAM	45335
7921S001	MOUNT HOPKINS	40434S001	-1936760.118	-5077707.051	3331922.681	.021	.018	.020	NOAM	45335
7929S001	NATAL	41604S001	5186467.860	-3653856.360	-654322.101	.014	.019	.021	SOAM	45335
7939S001	MATERA	12734S001	4641965.355	1393069.678	4133261.996	.004	.004	.006	EURA	45335
7943S001	ORRORAL	50103S003	-4447548.622	2677134.259	-3694996.847	.008	.008	.008	INDI	45335
8833S001	KOOTWIJK	13504S007	3899238.088	396768.950	5015055.087	.032	.030	.018	EURA	45335

APPENDIX 4

Appendix 4

RESULTS OF ITRF-0

TRANSFORMATION PARAMETERS BETWEEN THE INDIVIDUAL TERRESTRIAL SYSTEMS

SSC	T1	T2	T3	D	R1	R2	R3
	cm	cm	cm	10^{-8}	0.001"	0.001"	0.001"
RN SSC(NGS) 88 R 01	-13.7	17.0	-2.7	1.5	-3.6	9.8	.1
	6.9	6.8	6.5	.9	2.8	2.7	2.2
RG SSC(GSFC) 88 R 01	159.5	-96.4	38.2	-1.2	-5.8	5.2	-1.5
	6.7	6.8	6.3	.9	2.7	2.6	2.2
LC SSC(CSR) 88 L 01	-.3	-.0	1.6	-.2	-4.6	1.9	-11.0
	6.5	6.5	6.0	.9	2.6	2.5	2.2
LG SSC(GSFC) 88 L 01	-1.9	.1	2.1	-.3	-1.7	6.0	-7.7
	6.5	6.5	6.0	.9	2.6	2.5	2.2
SSC(BIH) 88 C 01	.0	.0	.0	.0	.0	.0	.0
(EXTRACT OF BTS87)	.0	.0	.0	.0	.0	.0	.0

SITE DOMES NUMBER		SOLUTION	SIGMAS (cm) XO	YO	ZO	RESIDUALS (cm) X	Y	Z
GRASSE 10002	S001	LG	.4	.5	.6	.5	1.2	.2
	S001	LC	.8	1.0	.7	-2.2	-4.8	-.3
	M001	BTS87	10.0	10.0	10.0	1.6	-.6	-.9
ONSALA 10402	S002	RN	.6	.4	1.0	-.7	-.4	-.5
	S002	RG	.5	.4	1.0	.5	.4	.5
	M003	BTS87	10.0	10.0	10.0	1.0	-7.3	-.4
METSAHOVI 10503	S001	LG	15.3	14.3	9.6	49.1	23.8	30.8
	S001	LC	8.8	8.0	5.6	-16.2	-7.4	-10.5
GRAZ 11001	S002	LG	6.2	.6	.6	.8	1.4	-.1
	S002	LC	.7	.8	.6	-.0	-2.5	.1
	M001	BTS87	10.0	10.0	10.0	-.2	2.5	.2
ROUMELLI 12613	M001	LG	1.3	1.6	1.5	1.6	4.2	-.8
	M001	LC	.9	1.2	1.0	-.8	-2.4	.4
KARITSA 12614	M001	LG	1.8	1.7	1.3	.5	1.3	1.0
	M001	LC	1.8	1.8	1.3	-.5	-1.5	-1.0
XRISOKALARIA 12616	M001	LG	2.1	2.6	2.3	-.4	5.2	-4.3
	M001	LC	1.4	1.5	1.3	.2	-1.7	1.4
BOLOGNE 12711	S001	RN	1.1	.6	1.5	-1.3	-.7	-1.1
	S001	RG	.9	.5	1.3	.9	.5	.8
	M001	BTS87	10.0	10.0	10.0	.2	-7.6	-.2
TRIESTE 12718	M002	LG	2.2	2.9	1.9	-.5	2.3	.9
	M002	LC	2.7	3.4	2.2	.8	-3.2	-1.2
CAGLIARI 12725	M002	LG	1.1	1.5	1.1	-.6	1.6	1.2
	S010	LC	1.7	2.3	1.6	1.5	-3.9	-2.5
MATERA 12734	M004	LG	1.7	1.9	1.3	2.5	1.8	1.5
	S001	LG	.4	.4	.6	.4	1.1	.9

	M005	LC	2.5	2.3	1.6	4.1	-3.8	-.3
	M004	LC	1.5	1.7	1.2	3.4	-1.5	1.2
	S001	LC	.5	.6	.5	-1.5	-2.3	-1.1
	S001	BTS87	10.0	10.0	10.0	.7	1.7	.4
CHILBOLTON 13201	S002	RN	1.2	.6	1.6	1.0	-.6	1.9
	S002	RG	.9	.5	1.2	-.6	.4	-1.1
HERSTMONCEUX 13202	S001	LG	.4	.4	.5	.4	.8	-.1
	S001	LC	.5	.7	.5	-.6	-2.6	.1
	M002	BTS87	10.0	10.0	10.0	.4	1.3	-.1
KOOTWIJK 13504	S001	LG	11.2	10.0	6.0	-13.0	4.7	-20.8
	S007	LG	3.2	3.0	1.8	6.0	4.7	4.0
	S001	LC	3.0	3.1	1.9	3.2	-4.4	-11.6
	S007	LC	2.9	3.0	1.9	-6.6	-1.4	9.4
	M001	BTS87	10.0	10.0	10.0	-5.0	3.7	-.5
ZIMMERWALD 14001	S001	LG	1.0	1.0	.8	2.1	2.0	-1.5
	S001	LC	1.7	1.8	1.1	-5.9	-6.4	2.8
	M001	BTS87	10.0	10.0	10.0	-2.3	-2.0	1.9
POTSDAM 14106	S001	LG	11.0	10.8	7.4	-2.8	3.0	6.5
	S001	LC	3.4	3.4	2.2	.7	-.4	-1.0
	M001	BTS87	10.0	10.0	10.0	-3.9	.7	9.3
WETTZELL 14201	S004	RN	.7	.4	1.1	1.3	-.7	3.2
	S004	RG	.6	.4	1.1	2.0	.1	3.4
	S002	LG	.5	.5	.6	-.6	2.3	.1
	S010	LC	2.1	2.7	1.6	-3.5	-2.7	8.4
	S011	LC	100.0	100.0	100.0	-13.7	-3.4	7.9
	S007	LC	100.0	100.0	100.0	598.2	-394.4	-379.6
	S002	LC	.9	1.0	.7	-4.2	-5.1	-4.4
	M001	BTS87	10.0	10.0	10.0	12.1	-3.3	5.6

EFFELSBERG 14209	S001	RN	1.4	.8	2.1	1.5	.2	3.0
	S001	RG	.8	.5	1.3	-.5	-.1	-1.2
BAR GIYYORA 20702	S001	LG	1.2	1.3	1.3	.4	1.7	1.2
	S001	LC	1.7	1.9	1.7	-.8	-3.7	-1.9
	M001	BTS87	10.0	10.0	10.0	1.3	4.2	-6.3
YIGILCA 20804	S001	LG	1.7	1.5	1.2	-.6	1.9	.3
	M001	LC	2.4	1.9	1.4	1.3	-3.0	-.4
SHANGHAI 21605	S001	LG	25.9	22.2	18.5	9.3	-7.5	-.8
	S001	LC	10.3	8.8	7.5	7.5	.6	-2.1
	M001	BTS87	10.0	10.0	10.0	-8.5	.7	4.0
KASHIMA 21701	S001	RG	1.1	.7	2.0	-.1	.0	.3
	M001	BTS87	10.0	10.0	10.0	8.1	-9.6	-8.6
SIMOSATO 21726	S001	LG	.5	.5	.5	-.1	-.9	.1
	S001	LC	.6	.6	.6	.2	1.3	-.2
	M001	BTS87	10.0	10.0	10.0	-4.1	1.2	.9
HELWAN 30101	S001	LG	96.1	58.6	56.9	-57.4	145.1	52.5
	S001	LC	9.2	9.9	8.0	.5	-4.1	-1.0
JOHANNESBURG 30302	S001	RN	2.6	1.4	1.7	-.4	-2.2	-3.0
	S001	RG	2.6	1.7	1.7	.4	3.3	3.0
GOLDSTONE 40405	S009	RN	.3	1.4	1.6	-.8	-1.7	2.5
	S014	RG	.8	1.5	1.3	1.8	.4	-.8
	S009	RG	.1	.5	.7	.0	-1.1	.4
	M001	LG	19.5	52.8	60.9	-.1	29.4	66.2
	M002	LG	1.0	1.0	.9	3.3	6.3	-1.4
	M006	LG	1.3	1.4	1.0	-2.5	-6.9	.0
	M001	LC	9.2	10.0	6.7	-28.4	-41.4	34.2
	M002	LC	1.1	1.0	.9	5.5	4.1	-.6

	M006	LC	1.9	2.0	1.4	-1.7	-5.3	.6
	M001	BTS87	10.0	10.0	10.0	-.2	.2	-1.6
FAIRBANKS 40408	S002	RG	.3	.5	1.0	-.0	.0	.1
	S001	BTS87	10.0	10.0	10.0	.6	-1.9	-6.9
VANDENBERG 40420	M002	RG	.2	.6	.8	-.0	-.0	.1
	M004	LG	15.2	64.1	15.2	15.6	79.0	-21.9
	M004	LC	100.0	100.0	100.0	14.3	26.0	-3.9
	M001	BTS87	10.0	10.0	10.0	.6	.8	-3.6
PATRICK AFB 40417	M002	LG	14.2	8.3	11.0	-.5	.1	.1
	M002	LC	100.0	100.0	100.0	24.5	-7.9	-5.4
KAUAI 40424	S001	RG	.7	1.0	1.5	-.0	-.2	-.2
	S001	BTS87	10.0	10.0	10.0	8.0	22.5	10.9
QUINCY 40433	M001	LG	1.7	1.6	1.2	-1.1	9.0	11.1
	M002	LG	.3	.4	.2	-.1	-.8	-.6
	S010	LG	4.6	4.0	2.5	3.0	2.1	5.0
	M001	LC	1.8	1.6	1.3	1.7	9.5	14.5
	M002	LC	.6	.5	.5	.3	-1.3	.3
	M005	LC	1.5	1.1	.8	-.0	4.0	-2.7
	M001	BTS87	10.0	10.0	10.0	1.2	.0	5.2
MOUNT HOPKINS 40434	S001	LG	2.1	1.8	2.0	-4.5	1.5	-6.9
	S001	LC	1.6	1.4	1.4	2.6	-.9	3.4
SAN DIEGO 40436	M002	LG	1.5	1.3	1.4	-1.3	-.6	2.8
	M002	LC	1.6	1.4	1.4	1.5	.7	-2.8
BEAR LAKE 40438	M001	LG	2.1	2.1	1.5	-2.4	4.5	-3.3
	M001	LC	2.6	2.4	1.7	3.7	-5.9	4.2
OWENS VALLEY 40439	S002	RN	.3	.8	.9	-1.3	-.0	-.8
	S002	RG	.1	.5	.7	.2	-.8	-2.1
	M003	LG	21.8	55.3	62.0	-9.5	66.6	66.0

	M001	LG	1.0	1.0	.8	-1.8	3.4	.7
	M003	LC	10.8	9.6	6.3	-24.6	1.9	42.7
	M001	LC	1.1	1.0	.9	-1.4	-.1	2.4
	M001	BTS87	10.0	10.0	10.0	-2.1	1.7	-1.3
WESTFORD HAYSTAK 40440	S003	RN	1.0	1.0	1.0	.8	-.5	1.4
	S002	RN	.1	.3	.3	-.1	1.3	-.7
	S002	RG	.1	.1	.1	-.5	.0	-.3
	S003	RG	.1	.2	.2	.4	-.1	.6
	M001	LG	1.3	1.1	1.0	5.7	-9.4	8.3
	M001	LC	1.3	1.1	1.0	7.8	-10.3	7.9
	M001	BTS87	10.0	10.0	10.0	-3.6	-2.7	1.7
GREENBANK 40441	S001	RN	.2	.7	.6	.4	.4	-.3
	S001	RG	.1	.5	.5	-.1	-.2	.2
FORT DAVIS 40442	S003	RN	.2	.5	.6	.5	-.8	2.6
	S003	RG	.2	.5	.5	.1	-.4	2.7
	M001	LG	.4	.4	.3	-1.9	1.2	-1.4
	M005	LG	2.6	2.7	2.1	.8	-13.0	1.4
	M001	LC	.7	.4	.6	-1.4	-.0	-1.1
	M005	LC	2.9	3.1	2.3	3.1	-5.3	2.8
	M004	BTS87	10.0	10.0	10.0	-1.1	1.8	.9
MAUI 40445	M002	LG	.7	1.0	1.0	-3.8	3.5	-2.3
	M001	LG	.3	.5	.1	.1	-.2	.1
	M002	LC	.8	1.1	1.0	-2.0	1.2	-3.4
	M001	LC	.4	.7	.6	1.6	-1.9	-1.2
	M001	BTS87	10.0	10.0	10.0	-1.4	-2.6	.1
WASHINGTON 40451	M112	LG	.1	.6	.5	-.1	-.5	-.5
	M106	LG	22.6	18.0	19.5	-12.3	35.8	-46.4

	M101	LG	8.4	5.2	7.5	-15.2	7.6	-3.8
	M102	LG	1.2	1.0	.8	2.3	4.8	-.7
	M103	LG	1.8	1.9	1.2	.4	1.8	1.2
	M104	LG	6.4	5.4	5.3	-6.6	-11.7	-9.9
	M105	LG	.1	.2	.2	.0	-1.0	-.1
	M114	LG	1.3	1.1	.9	-2.1	9.2	-1.7
	M111	LG	3.6	3.7	3.1	4.7	1.4	-5.2
	M112	LC	1.2	.9	.9	5.0	2.1	.7
	M107	LC	100.0	100.0	100.0	-31.1	5.3	-28.5
	M108	LC	100.0	100.0	100.0	-108.4	93.8	62.0
	M106	LC	100.0	100.0	100.0	-21.2	60.6	-45.1
	M101	LC	100.0	100.0	100.0	-22.6	14.8	3.7
	M102	LC	1.3	1.1	.9	.4	2.4	1.1
	M103	LC	2.1	2.0	1.4	4.5	1.5	.7
	M104	LC	6.2	5.2	5.4	.7	-5.6	-2.1
	M105	LC	.7	.4	.5	-.2	.6	1.0
	M114	LC	2.1	1.7	1.4	-7.7	13.9	4.0
	M116	LC	12.5	10.7	8.4	.2	4.5	3.1
	M111	LC	3.6	3.6	3.0	7.4	1.0	-8.9
	M110	BTS87	10.0	10.0	10.0	2.6	1.8	-.4
HAT CREEK 40489	S001	RG	.2	.6	.8	-.0	-.0	.0
	M001	BTS87	10.0	10.0	10.0	.1	.4	-4.2
PASADENA 40400	M001	LG	2.3	2.5	1.9	-.8	4.7	.9
	M001	LC	2.4	2.4	1.9	.8	-4.4	-.9
MRYLAND POINT 40490	S001	RN	.5	2.0	1.6	-.2	.8	.6
	S001	RG	.4	1.1	.9	.2	-.2	-.2
RICHMOND 40499	S001	RN	.2	.4	.3	.3	.1	-.2
	S001	RG	.2	.4	.3	-.3	-.1	.2

	M001	BTS87	10.0	10.0	10.0	-4.3	1.1	-.4
MONUMENT PEAK 40497	M001	LG	.3	.4	.3	-.3	-.2	.1
	M002	LG	1.5	1.3	1.1	3.9	-3.1	-4.5
	M001	LC	.6	.4	.5	-.5	.4	1.6
	M002	LC	1.5	1.5	1.3	5.1	4.1	-5.9
	M003	LC	1.6	1.6	1.4	2.2	-2.7	-1.2
	M001	BTS87	10.0	10.0	10.0	1.8	-1.8	-.4
PLATTEVILLE 40496	M002	RG	.2	.8	.8	-.5	.3	-1.7
	M001	LG	.6	.6	.4	2.7	-.2	-.0
	M001	LC	.9	.7	.6	3.5	-.0	1.0
	M002	BTS87	10.0	10.0	10.0	-.8	-1.5	-2.9
YUMA 40493	S001	LG	2.4	2.3	2.2	-.7	-1.0	-.7
	M001	LC	2.5	2.4	2.4	.7	1.1	.9
FLAGSTAFF 40491	M001	LG	3.0	2.9	2.3	-3.4	-4.9	-4.9
	M001	LC	3.2	3.1	2.4	3.9	5.5	5.3
VERNAL 40492	M001	LG	2.1	2.3	1.4	-.3	3.8	-4.0
	M001	LC	2.3	2.5	1.6	.3	-4.4	5.3
MAZATLAN 40504	M001	LG	.4	.4	.3	-.4	-.2	-.1
	M001	LC	.7	.4	.6	1.1	.2	.2
	M001	BTS87	10.0	10.0	10.0	2.6	-1.4	2.1
CABO SAN LUCAS 40505	M001	LG	2.5	2.5	2.2	.0	.0	.0
	M001	LC	100.0	100.0	100.0	-1.1	-7.6	-1.6
NATAL 41604	S001	LG	1.4	1.9	2.1	-.9	1.7	2.3
	S001	LC	3.4	4.4	4.6	5.4	-9.1	-11.0
SANTIAGO 41705	S001	LG	1.8	1.2	1.5	-1.0	.0	-1.4
	M001	LC	2.4	1.7	2.1	1.8	-.1	2.7
EASTER ISLAND	M001	LG	12.8	10.0	9.9	-6.2	2.4	1.7

41703	M001	BTS87	10.0	10.0	10.0	3.8	-2.4	-1.7
CERRO TOLOLO	S001	LG	1.2	.9	1.0	-1.2	.1	.1
41706	M001	LC	1.6	1.2	1.5	2.1	-.2	-.3
AREQUIPA	S001	LG	.5	.3	.3	-1.1	-.9	-.0
42202	S001	LC	.7	.3	.6	2.2	.9	.1
	M002	BTS87	10.0	10.0	10.0	2.4	.3	1.4
BERMUDA	M001	LG	13.9	8.9	12.9	-6.7	-7.9	1.7
42501	M001	LC	7.2	4.8	7.3	1.8	2.3	-.6
GRAND TURK	M002	LG	45.0	24.8	38.0	-2.0	-.4	-.5
43602	M002	LC	100.0	100.0	100.0	9.8	6.7	3.2
ORRORAL	S008	LG	.8	.7	.9	10.7	-4.4	-.4
50103	S003	LG	.8	.8	.8	-1.0	-1.5	11.8
	S008	LC	.8	.9	.7	3.9	.4	-9.1
	S003	LC	.7	.8	.7	-10.4	6.9	.4
	M103	BTS87	10.0	10.0	10.0	-7.7	1.0	-3.5
YARRAGADEE	M001	LG	.3	.3	.5	.1	-.2	-.4
50107	M001	LC	.6	.4	.5	-.4	.4	.4
	M001	BTS87	10.0	10.0	10.0	-3.9	-1.3	-1.5
AMERICAN	M001	LG	1.4	2.0	1.9	.8	-1.1	.3
SAMOA 50503	M001	LC	1.3	2.0	1.9	-.7	1.1	-.3
KWAJALEIN	S003	RN	1.5	1.3	2.0	.4	.1	-4.6
ATOLL 50505	M001	LG	1.7	2.4	2.4	.2	1.1	2.1
	M001	LC	1.7	2.4	2.4	-.7	-1.4	4.5
MOTU HIUMOO	M002	LG	.5	.7	.6	-.3	-.5	.4
92202	M002	LC	1.1	1.5	1.4	1.4	2.2	-2.2
	M001	BTS87	10.0	10.0	10.0	-.0	-1.6	.7

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