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

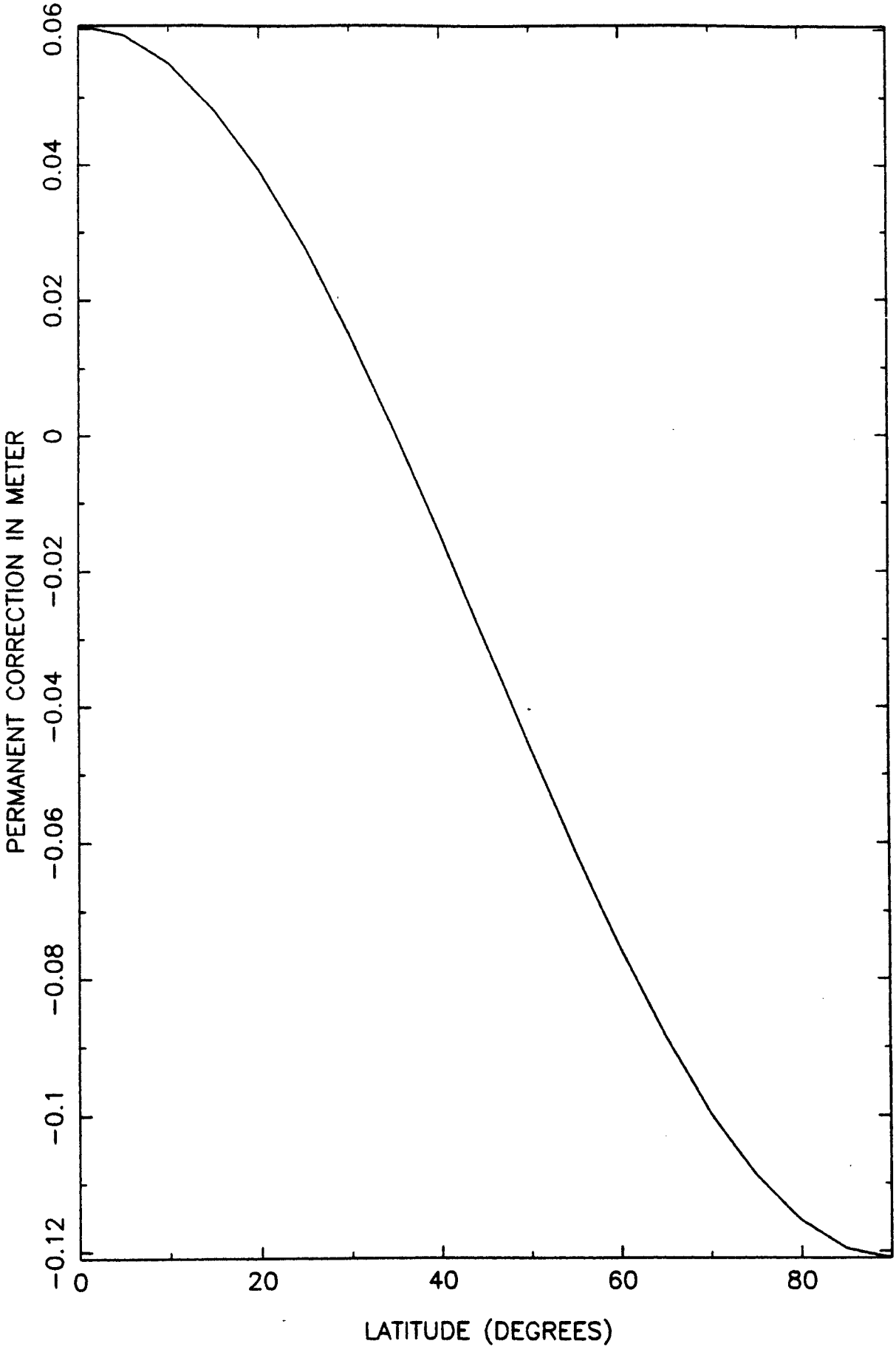
		.069	.066	.077			
S001		961258.151	-5674090.071	2740533.714			
40504	Mazatlan						
M001		-1660089.280	-5619100.405	2511637.834	-11.4	-1.0	-9.8
		.070	.066	.073			
41703	Easter Island						
M001		-1884983.905	-5357606.784	-2892852.671	85.9	-25.3	-9.0
		.229	.209	.207			
M002		-1884984.327	-5357607.984	-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



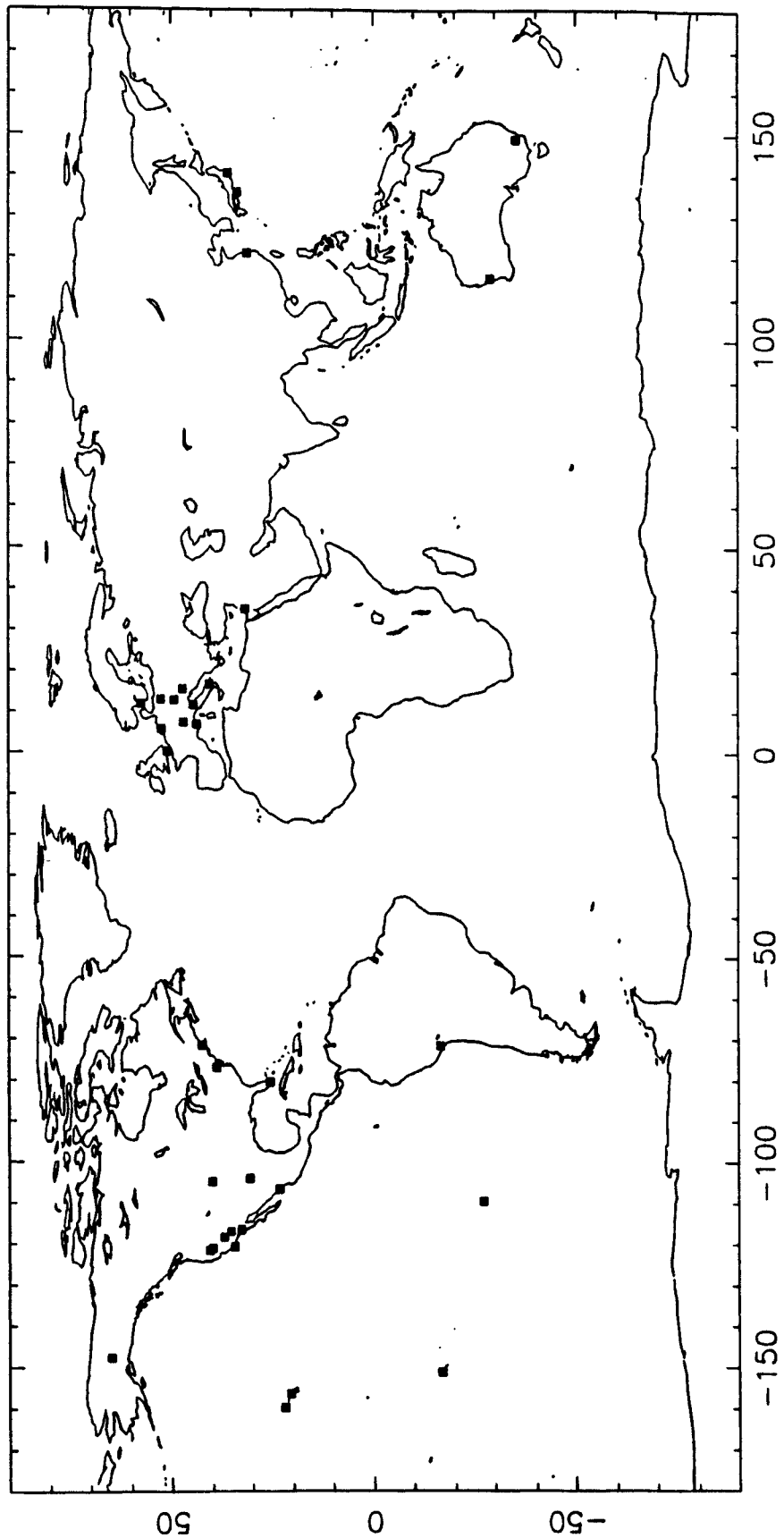


FIG. 2. PRIMARY SITES OF THE ITRF (ITRF-0)

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			