GLOBAL POSITIONING SYSTEM
GPS STATION COORDINATES FROM THE GIG'91 EXPERIMENT:

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The following solutions were derived from 21 globally distributed Rogue receivers operating from
January 22 - February 12 1991 in the GIG'91 experiment.

Summary description of the terrestrial system attached to the set of station
coordinates SSC(JPL) 91 P 01:

1- Technique : GPS
2- Analysis Center : JPL
3- Solution identifier : SSC(JPL) 91 P 01
4- Software used : GIPSY
5- Relativity scale : Local Earth
6- Permanent tide correction on Station : No
7- Tectonic plate model : None (single epoch solution)
8- Velocity of light : 299792458 m/sec
9- GM : 3.98600440*10**14 m**3 s**-2
10- Reference epoch : 1991.1
11- Adjusted parameters : Station X, Y, Z at 1991.1

PMX, PMY every 24 hours;
GPS epoch state and 3 solar radiation biases every
24 hours;
Random walk zenith tropospheres;
White noise clocks (Goldstone H-maser is the reference
clock);
Carrier phase ambiguities as real valued (not bias-fixed)

12- Definition of origin : GEM T2 (truncated to 12 x 12)
with C10 = C11 = S11 = 0

13- Definition of orientation : Loose a priori constraints on all GPS epoch states,
station coordinates and polar motion from Bulletin-B
forces crude alignment with ITRF to within
several meters.

14- Constraint for time-evolution : No time evolution.

Summary description of the terrestrial system attached to the set of station coordinates SSC(JPL) 91 P 02:

1- Technique: GPS
2- Analysis Center: JPL
3- Solution identifier: SSC(JPL) 91 P 02
4- Software used: GIPSY
5- Relativity scale: Local Earth;
   Scale JPL91G01 solution to ITRF90 (mapped to 1991.1 using site velocities from GLB718, except for KOSG for which we used SSC(IERS)90L02)
6- Permanent tide correction on Station: No
7- Tectonic plate model: None (single epoch solution)
8- Velocity of light: 299792458 m/sec
9- GM: 3.98600440*10**14 m**3 s**-2
10- Reference epoch: 1991.1
11- Adjusted parameters: Station X, Y, Z at 1991.1;
    PMX, PMY every 24 hours;
    GPS epoch state and 3 solar radiation biases every 24 hours;
    Random walk zenith tropospheres;
    White noise clocks (Goldstone H-maser is the reference clock);
    Carrier phase ambiguities as real valued (not bias-fixed)
12- Definition of origin: Apply translation of JPL 91 P 01 into ITRF90 (mapped to 1991.1)
13- Definition of orientation: Apply rotation of JPL 91 P 01 into ITRF90 (mapped to 1991.1)
14- Constraint for time-evolution: No time evolution.
Table 1. TRANSFORMATION BETWEEN SSC(JPL) 91 P 01 AND ITRF90 (MAPPED TO 1991.1)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>ESTIMATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Translation in X</td>
<td>-0.100 ± 0.013 (m)</td>
</tr>
<tr>
<td>Translation in Y</td>
<td>0.134 ± 0.016 (m)</td>
</tr>
<tr>
<td>Translation in Z</td>
<td>-0.134 ± 0.012 (m)</td>
</tr>
<tr>
<td>Scale</td>
<td>-3.459 ± 1.402 (10**-9)</td>
</tr>
<tr>
<td>Rotation about X</td>
<td>3.592 ± 3.445 (10**-9 radians)</td>
</tr>
<tr>
<td>Rotation about Y</td>
<td>-2.672 ± 3.445 (10**-9 radians)</td>
</tr>
<tr>
<td>Rotation about Z</td>
<td>-302.006 ± 1.794 (10**-9 radians)</td>
</tr>
</tbody>
</table>

Normalized Chi-square 0.967

Notes:
(1) Only sites with available ties could be used.
(2) YELL was not used due to a relatively large formal error in ITRF90.
(3) Transformation is a least-squares weighted fit using only diagonal covariance elements. Error in propagating ITRF90 from 1988.0 to 1991 was assumed to be negligible. Input GPS error bars have been defined such that normalized chi-square of this fit is close to 1.
(4) Transformation parameters are as defined by IERS, with the following sign convention:
(GPS-ITRF) = TRANFORMATION * ITRF

Table 2. COORDINATE RESIDUALS: SSC(JPL) 91 P 02 - ITRF90 (MAPPED TO 1991.1)

<table>
<thead>
<tr>
<th>SITE</th>
<th>RESIDUAL (CM)</th>
<th>FORMAL ERROR (CM)</th>
<th>RESIDUAL (LOCAL COORDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
<tr>
<td>ALGO</td>
<td>-1.9</td>
<td>2.4</td>
<td>-3</td>
</tr>
<tr>
<td>JPLM</td>
<td>2.1</td>
<td>1.1</td>
<td>-1.5</td>
</tr>
<tr>
<td>KOKB</td>
<td>-0.5</td>
<td>-8</td>
<td>-3</td>
</tr>
<tr>
<td>KOSG</td>
<td>1.5</td>
<td>-1.7</td>
<td>2.0</td>
</tr>
<tr>
<td>PINY</td>
<td>-5</td>
<td>-2.3</td>
<td>1.2</td>
</tr>
<tr>
<td>TROM</td>
<td>1.5</td>
<td>-6</td>
<td>1.6</td>
</tr>
<tr>
<td>WETB</td>
<td>0</td>
<td>-1</td>
<td>-1.2</td>
</tr>
</tbody>
</table>

Weighted RMS for X coordinate (4.67 DOF) = 1.4 cm
Weighted RMS for Y coordinate (4.67 DOF) = 1.6 cm
Weighted RMS for Z coordinate (4.67 DOF) = 1.2 cm
Weighted RMS for all (14.00 DOF) = 1.4 cm

Unweighted RMS for E coordinate (4.67 DOF) = 1.5 cm
Unweighted RMS for N coordinate (4.67 DOF) = 1.0 cm
Unweighted RMS for V coordinate (4.67 DOF) = 2.3 cm
Unweighted RMS for all (14.00 DOF) = 1.7 cm

Notes:
(1) Quoted RMS values correctly account for number of degrees of freedom (DOF).
(2) Formal error is computed in the weighted least-squares process, where input data were (GPS-ITRF) coordinates with GPS+ITRF error added in quadrature.
(2) Total weighted RMS is smaller than unweighted RMS, indicating that it is better to use weights rather than use none at all.
(3) Clearly, the vertical component is not as well determined; however, this information was not incorporated into weights (since we used diagonal weight matrix in cartesian system). This is why RMS for local coordinates are only quoted as "unweighted RMS".
Distribution of the 21 sites of the terrestrial frame SSC(JPL) 92 P 01.

Distribution of the uncertainties (quadratic mean of $\sigma_x$, $\sigma_y$, $\sigma_z$) for the 21 stations of the terrestrial frame SSC(JPL) 92 P 01.
POLAR MOTION AND UT1 TIME SERIES DERIVED FROM GPS OBSERVATIONS

JPL 91 P 03

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Daily estimates of UT1 and polar motion parameters x (PMX) and y (PMY) have been obtained with measurements from a worldwide network of Global Positioning System (GPS) receivers, obtained during the three week GIG'91 experiment in January-February, 1991 (Lichten et al., 1992; Herring et al., 1991; Lindqwister et al., 1992). The GIG'91 experiment was carried out between January 22 and February 13, 1991 by numerous international agencies and utilized over 120 GPS receivers (Melbourne et al., 1992). A subset of 21 globally distributed Rogue GPS receivers was chosen for this study. For a complete list of station names and locations see Heffin et al. (1991).

The data analysis was carried out at JPL using the GIPSY orbit determination and baseline estimation software package. Single day solutions were obtained using a factorized Kalman-type filter (Bierman, 1977). Station positions; initial satellite positions, velocities, and solar radiation pressure coefficients; and carrier phase ambiguities were all estimated daily as constant parameters, with the exception of the coordinates of the fiducial stations, which were not estimated at all. The wet zenith tropospheric delay was estimated as a random walk stochastic with a process noise constraint of 0.17 mm/sec**-0.5 corresponding to a 5 cm variation over a day of the tropospheric parameter at zenith. The Lanyi mapping function was used to obtain delays at all observed elevation angles down to the 15 degree elevation cutoff (Lanyi, 1984). All station and satellite clocks were solved for using a white noise stochastic model, with the exception of the clock at Goldstone, which was used as a reference. For more details on the parameter estimation strategies routinely used by GIPSY to reduce GPS data see Lichten and Border (1987).

For the Polar Motion analysis three stations at Goldstone (USA), Tromso (Norway), and Wettzell (Germany) were held fixed in the SV5 reference frame (Murray et al., 1990), which is a combined VLBI and SLR solution from 1990 computed at epoch 1991.1. The coordinates used for the three fiducial sites are available on request from the Central Bureau of IERS. The offset of the Earth's center of mass from the origin of the SV5 reference frame (the geocenter offset) was assumed to be zero. All the Earth orientation parameters (EOP) are hence computed in the SV5 reference frame. The origin and scale are defined within SV5 by the CSR8902 SLR adjustment (Schutz et al., 1989) and the orientation is consistent with the IERS ITRF89 reference frame (to a few ppb), and the fiducial station coordinates are derived from the GLB659 VLBI solution (Caprette et al., 1990). For more details on the SV5 solution, contact Mark Murray, MIT. The Polar Motion parameters were estimated as daily constants and the tabulated values represent 24-hour averages computed at noon UTC every day, spanning 3 weeks starting on January 22, 1991 (with the exception of January 31). The UT1 parameter was held fixed at nominal values published in IERS Bulletins B37 and B38 (1991).

The UT1 estimates were determined in separate filter solutions with Goldstone and Kootwijk held fixed as fiducials to coordinates from SV5. In addition, the Polar Motion parameters were held fixed at nominal values from Bulletins B37 and B38 (1991). The UT1 solutions were obtained simultaneously with estimates for the geocenter. UT1 was estimated from GPS data in three segments spanning the 3-week experiment: every 24 hrs (at midnight each day), new GPS orbit parameters were introduced and initially, every 12 hrs, UT1 estimates were output with a white noise reset being applied to UT1 each day at 12:00 noon. Because of the 24-hr smoothing applied to the GPS data, the original 12-hr estimates were averaged to produce new UT1 estimates once per day (at noon). These

are listed along with formal errors, which are at the level of 0.01-0.02 msec. Since data from several
days are not included in the table, the UT1 time series is restarted on Feb. 1 and Feb. 6.

Each of the three continuous segments of UT1 estimates are self-consistent, but between them there is
an arbitrary bias which cannot be determined from GPS data alone. We have calibrated this bias
simply by aligning the GPS estimates for each segment with the KEOF (VLBI/SLR) estimates for the
corresponding time interval in a mean sense. See Morabito et al. (1988) and Gross and Steppe (1992)
for a discussion on the KEOF combined VLBI- and SLR-network solutions for Earth orientation.
Thus the GPS estimates provide a precise record of change in UT1 from time point to time point
(where the data are continuous), but they may contain an arbitrary bias in UT common to all points in
each segment.

Note that the use of slightly different fiducials when deriving Polar Motion and UT1 still
fix each solution to the SV5 frame with at most a small bias (cm-level) between solutions. At the time
of the analysis the ground tie at Goldstone was not known. Instead coordinates from a previous
solution was used and then rotated into the SV5 frame using a seven parameter transformation.
Moreover the estimation of the geocenter in the UT1 solutions should be of little consequence relative
to the Polar Motion solutions (except for the possibility of introducing a bias to one or the other of the
series).

The errors quoted are the 1-sigma formal errors obtained directly from the filter and hence
should be considered a lower limit for the true errors in the series. Comparisons with similar polar
motion series from VLBI and SLR have shown rms agreement at the level of 0.3-0.5 mas for the
three week period covered by the experiment (Lindqwister et al., 1992). Note that the error bars
ranges from 0.2-0.4 mas, hence even though the error bars are minimal they are not likely to be far
from the true errors. The UT1 formal errors are at the level of 0.01-0.02 msec. Comparisons with
VLBI solutions for UT1 for this time period show rms agreement at the level of 0.04 ms (Lichten et

References


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Summary Description of the terrestrial system for solution EOP(JPL) 91 P 03:

1- Technique : GPS
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                           White noise clocks (Goldstone H-maser is the reference
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                           Carrier phase ambiguities as real valued (not bias-fixed)
12- Definition of origin : Defined through SV5.
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EOP(JPL) 91 P 03  From Jan 1991 to Feb 1991

Number of measurements per year and median uncertainties
Units: 0.001" for X,Y; 0.0001s for UT1

<table>
<thead>
<tr>
<th>YEAR</th>
<th>X Nb</th>
<th>X Sigma</th>
<th>Y Nb</th>
<th>Y Sigma</th>
<th>UT1 Nb</th>
<th>UT1 Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>22</td>
<td>0.25</td>
<td>22</td>
<td>0.30</td>
<td>20</td>
<td>0.10</td>
</tr>
</tbody>
</table>