# Introduction to JPL's GPS Time Series

***Orbits***
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# GPS Time Series - Four Basic Steps

**Step 1 - Orbits**
Get data from roughly 80 global GPS receivers
Compute precise GPS orbits and clocks in a free-network reference frame
Compute transformation parameters from the free-network reference frame to IGS08

**Step 2 - Point Positions**
Compute point positions for thousands of global GPS receivers in a free-network reference frame
Resolve phase ambiguities
Apply transformation parameters to obtain positions in IGS08

**Step 3 - Post-processing**
Remove outliers
Search for breaks
Fit time series by estimating positions, velocities, breaks and seasonal parameters

**Step 4 - Results**
Create tables and plots which are available on the web site
Create edited time series and residuals which are available on the FTP site

# Step 1 - Orbits

**Input Data**
Daily rinex files from roughly 80 global GPS receivers

**Fit Parameters**
Satellite initial conditions
Satellite non-gravitational forces
Satellite clocks
Receiver tropospheric zenith delay and gradients
Receiver positions
Receiver clocks
Polar motion and rate
UT rate
Resolved phase ambiguities
Transformation parameters from free-network GPS frame to IGS08

**Models**
Gravity from Earth, Sun, Moon, and other planets
DE421 planetary ephemeris
GSPM10 satellite solar pressure model
IAU06 model for precession and nutation
IERS2010 tides
FES2004 ocean loading
IGS satellite and receiver antenna phase center models

# Step 2 - Point Positioning

**Input Data**
Daily rinex files for thousands of global GPS receivers
Satellite orbits from step 1
Satellite clocks from step 1
Phase ambiguities from step 1
Transformation parameters from step 1

**Fit Parameters**
Receiver tropospheric zenith delay and gradients
Receiver position
Receiver clocks
Resolved phase ambiguities

**Reference Frame**
Free-network orbits and clocks are used for point positioning
Transformation parameters from step 1 are applied to obtain position estimates in IGS08

# Step 3 - Post-processing

**Input data**
Daily GPS position estimates

**Fit Parameters**
Receiver Positions
Receiver Velocities
Receiver Breaks
Receiver Seasonals

**Outliers**
Large formal errors often indicate loss of receiver data and/or incomplete ambiguity resolution
The minimum vertical formal error is computed for each site
Points with formal errors > 3 * minimum vertical formal error are rejected

**Breaks**
An F-test is used to accept or reject position break candidates
CHI^2 is computed with and without each break
Breaks with F > 200 are accepted
F = [(Chi^2(without) – Chi^2(with))/Chi^(with)] * [(ndata – pwith)/(pwith-pwithout)]
ndata is the number of position observations being fit
pwith is the number of parameters with the break included
pwithout is the number of parameters without the break included

# Step 4 - Results

**Web Launch date**
November 29, 1994

**Implementation**
HTML5
Javascript

**Interface**
Google map
List of sites

**Tables**
Positions
Velocities
Breaks
Seasonals
Methods

**FTP**
Time series
Residuals

## GPS Time Series

The Global Positioning System (GPS) is a constellation of 30 satellites which is used for navigation and precise geodetic position measurements. Data from over 2000 receivers have been analyzed at the Jet Propulsion Laboratory, California Institute of Technology under contract with the National Aeronautics and Space Administration. JPL's GIPSY software is used to produce these time series and other useful data products. Horizontal velocities, mostly due to motion of the Earth's tectonic plates, are represented on the map by lines extending from each site. Click on a dot or name to see detailed time series for a particular site. Additional information may be obtained from mbh@jpl.nasa.gov.

Geodetic Positions and Velocities II Cartesian Positions and Velocities
Break Estimates II Seasonal Estimates
FTP Time Series II FTP Residuals
Methods

# GPS Time Series Plots

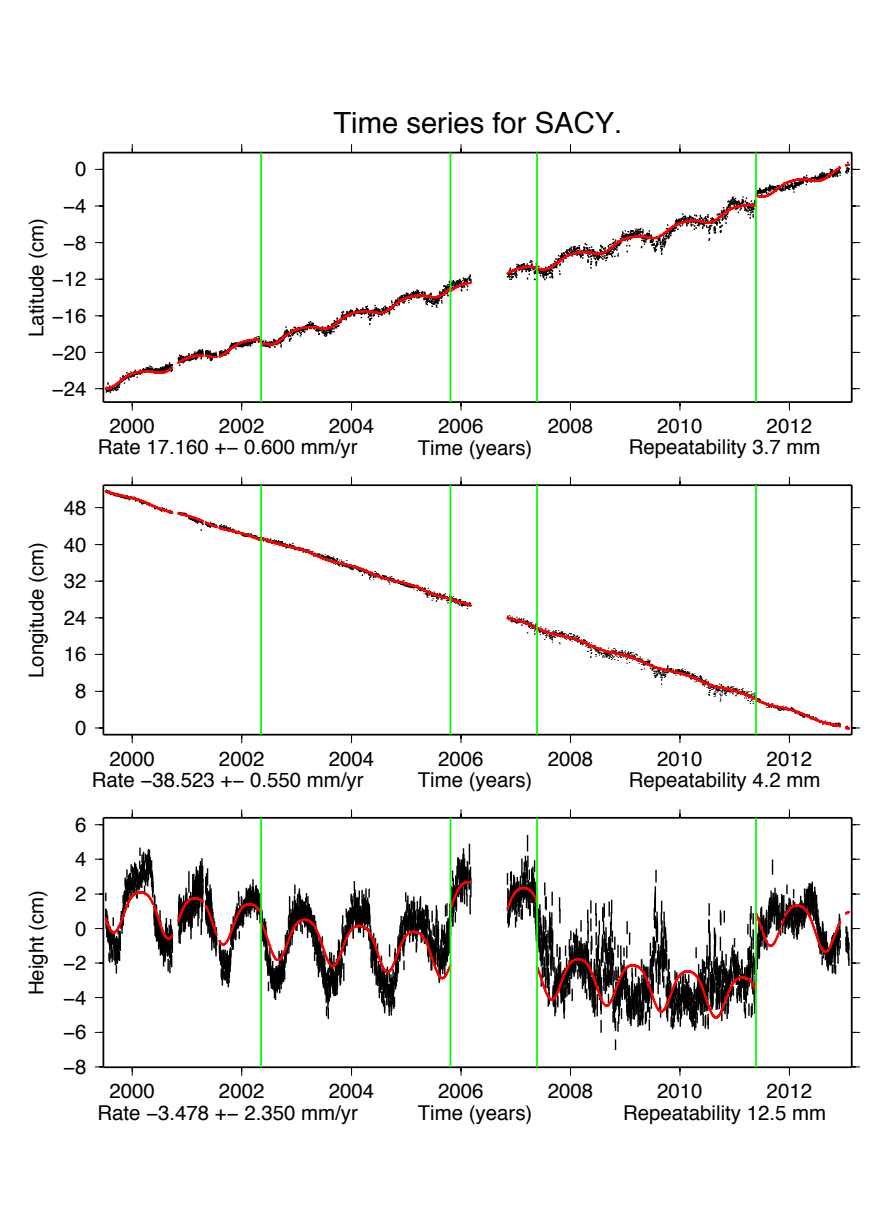
**Observations**
Black points with error bars

**Fit**
Red points

**Breaks**
Green bars

**Rate**
Value and formal error in mm/yr

**Repeatability**
Value in mm



# Lat, Lon, Rad File Format

**Fields**

Time in years
Value in cm
Formal error in cm
Site name
Component
Date

**Example**

```
1994.0014  -4.715238240429318e+00   7.453062599186759e-02  ALGO  LAT  94JAN01
1994.0041  -4.890997156680867e+00   7.092009642598809e-02  ALGO  LAT  94JAN02
1994.0068  -4.420055773683383e+00   7.475541353702948e-02  ALGO  LAT  94JAN03
1994.0096  -4.431090906451742e+00   7.378606176810082e-02  ALGO  LAT  94JAN04
1994.0123  -4.401386862639640e+00   7.202632463808149e-02  ALGO  LAT  94JAN05
1994.0151  -4.474379746551663e+00   8.979867875505296e-02  ALGO  LAT  94JAN06
1994.0178  -4.698582773779657e+00   7.905038141622234e-02  ALGO  LAT  94JAN07
1994.0205  -4.711169277707698e+00   8.080369748003380e-02  ALGO  LAT  94JAN08
1994.0233  -4.622185395745391e+00   7.369648866521711e-02  ALGO  LAT  94JAN09
1994.0260  -4.121520594588868e+00   7.221249302376066e-02  ALGO  LAT  94JAN10
1994.0287  -4.196773542687666e+00   7.399094939468943e-02  ALGO  LAT  94JAN11
1994.0315  -4.000956237788889e+00   8.080533048114016e-02  ALGO  LAT  94JAN12
1994.0342  -3.936341397844107e+00   7.413607923789212e-02  ALGO  LAT  94JAN13
1994.0370  -4.257049244874136e+00   8.275471268320550e-02  ALGO  LAT  94JAN14
1994.0397  -4.094763714034487e+00   7.501178949880111e-02  ALGO  LAT  94JAN15
1994.0424  -4.538966918324131e+00   7.353020289932045e-02  ALGO  LAT  94JAN16
1994.0452  -3.948801206455010e+00   7.202892058743045e-02  ALGO  LAT  94JAN17
1994.0479  -3.945534106083658e+00   7.116442767811204e-02  ALGO  LAT  94JAN18
1994.0507  -4.113484441142655e+00   7.099784664513113e-02  ALGO  LAT  94JAN19
1994.0534  -4.046565673187480e+00   7.504325354737477e-02  ALGO  LAT  94JAN20
...
```

# Cartesian Coordinate File Format

**Example**

The reference frame is IGS08. The epoch is January 1, 2013.
Positions given in mm. Velocities given in mm/yr.

```
                        X               Y               Z
AB01 POS -3896563022.287  -395471585.479  5017141747.008   0.068   0.029   0.084
AB01 VEL         -17.828           6.713         -10.835   1.950   0.850   2.500
AB02 POS -3776808234.140  -744083819.119  5068728032.568   0.057   0.025   0.069
AB02 VEL         -19.789           1.818         -11.762   1.950   0.850   2.400
AB04 POS -2799600599.869  -465105417.258  5692966324.946   0.077   0.043   0.163
AB04 VEL         -20.537          -2.102         -10.734   1.050   0.600   2.250
AB06 POS -3524499626.257 -1049128153.714  5194459959.323   0.051   0.028   0.072
AB06 VEL         -20.268           1.449         -11.668   0.700   0.400   1.000
AB07 POS -3425750154.051 -1214685869.021  5223662753.918   0.045   0.025   0.066
AB07 VEL         -16.784           7.416          -8.308   0.550   0.300   0.800
AB08 POS -3068712181.327  -753699324.317  5521813418.688   0.070   0.039   0.127
AB08 VEL         -21.241           1.956         -10.480   2.400   1.300   4.400
AB09 POS -2583614734.572  -546236976.665  5786501744.792   0.036   0.022   0.085
AB09 VEL         -21.180          -3.320         -10.095   0.650   0.400   1.500
AB11 POS -2658010391.499  -693674822.417  5737338515.816   0.032   0.019   0.071
AB11 VEL         -21.191          -3.931         -11.165   0.450   0.250   1.000
AB13 POS -3299991590.790 -1299648762.374  5283906992.448   0.041   0.024   0.066
AB13 VEL         -15.966           9.105          -7.448   0.550   0.300   0.900
AB14 POS -3066909560.979 -1171658274.659  5450696605.310   0.185   0.118   0.313
AB14 VEL         -20.021          -1.024         -11.044   0.750   0.500   1.300
...
```

# Geodetic Coordinate File Format

**Example**

The reference frame is IGS08. The epoch is January 1, 2013.
The reference ellipsoid for latitude, longitude, and height is GRS80.
Latitude and longitude are given in degrees. Height is given in mm.
Latitude, longitude, and height errors are given in mm.
Velocities and their errors are given in mm/yr.

| | LAT | LON | HEIGHT | | | |
|---|---|---|---|---|---|---|
| AB01 POS | 52.209503691 | -174.204757061 | 25467.132 | 0.036 | 0.028 | 0.102 |
| AB01 VEL | -20.121 | -8.479 | 1.891 | 1.050 | 0.800 | 3.000 |
| AB02 POS | 52.970604642 | -168.854670653 | 192793.085 | 0.030 | 0.023 | 0.085 |
| AB02 VEL | -22.303 | -5.609 | 2.091 | 1.050 | 0.800 | 2.950 |
| AB04 POS | 63.656863593 | -170.567443342 | 136561.685 | 0.055 | 0.042 | 0.173 |
| AB04 VEL | -23.227 | -1.292 | -0.476 | 0.750 | 0.600 | 2.400 |
| AB06 POS | 54.885321484 | -163.423454577 | 500418.365 | 0.029 | 0.023 | 0.085 |
| AB06 VEL | -22.264 | -7.171 | 1.392 | 0.400 | 0.300 | 1.200 |
| AB07 POS | 55.349275434 | -160.476758390 | 89568.188 | 0.027 | 0.020 | 0.076 |
| AB07 VEL | -15.698 | -12.598 | 0.751 | 0.350 | 0.250 | 0.950 |
| AB08 POS | 60.384831318 | -166.200857218 | 26513.553 | 0.047 | 0.035 | 0.138 |
| AB08 VEL | -22.707 | -6.966 | 0.852 | 1.600 | 1.200 | 4.750 |
| AB09 POS | 65.614980449 | -168.062125376 | 162086.696 | 0.027 | 0.021 | 0.088 |
| AB09 VEL | -23.667 | -1.133 | -0.356 | 0.500 | 0.350 | 1.600 |
| AB11 POS | 64.564495215 | -165.373458789 | 349450.621 | 0.023 | 0.018 | 0.075 |
| AB11 VEL | -24.209 | -1.547 | -0.850 | 0.300 | 0.250 | 1.050 |
| AB13 POS | 56.307325650 | -158.503795152 | 487819.354 | 0.026 | 0.019 | 0.075 |
| AB13 VEL | -13.716 | -14.322 | 0.193 | 0.350 | 0.250 | 1.000 |
| AB14 POS | 59.108165466 | -159.091532030 | 657648.917 | 0.121 | 0.091 | 0.351 |
| AB14 VEL | -22.033 | -6.188 | 0.313 | 0.500 | 0.350 | 1.450 |

...

# Break File Format

**Example**

| Site | Time | N | E | V | 3D |
|---|---|---|---|---|---|
| | years | cm | cm | cm | cm |
| AB01 | 2011.70 | -0.14 | 0.53 | -0.51 | 0.74 |
| AB02 | 2010.54 | 1.30 | 1.51 | -0.10 | 1.99 |
| AB02 | 2011.47 | 0.17 | -0.49 | -0.40 | 0.65 |
| AB07 | 2011.48 | -0.67 | 0.02 | -0.66 | 0.94 |
| AB08 | 2009.92 | 0.21 | 0.81 | -0.65 | 1.06 |
| AB14 | 2013.00 | 0.75 | -0.11 | 0.71 | 1.04 |
| AB18 | 2007.66 | 0.24 | -0.68 | 0.33 | 0.79 |
| AB18 | 2007.93 | 0.94 | 1.10 | -0.33 | 1.49 |
| AB18 | 2008.35 | -0.64 | -0.97 | -0.36 | 1.22 |
| AB18 | 2008.48 | -0.39 | -0.63 | 0.45 | 0.86 |
| AB18 | 2011.93 | 0.69 | 1.12 | -0.11 | 1.32 |
| AB18 | 2012.41 | -0.39 | -1.50 | -0.32 | 1.58 |
| AB28 | 2009.53 | -0.18 | -0.18 | 0.93 | 0.96 |
| AB35 | 2009.63 | -0.89 | -0.10 | 1.04 | 1.37 |
| AB36 | 2007.76 | -1.12 | -0.42 | 0.37 | 1.25 |
| AB36 | 2008.40 | 0.45 | 0.32 | 0.06 | 0.55 |
| AB37 | 2005.20 | 0.59 | -0.66 | -0.19 | 0.90 |
| AB37 | 2005.65 | 0.16 | -0.72 | 0.27 | 0.79 |
| AB37 | 2006.81 | 0.24 | -0.61 | -0.01 | 0.66 |
| AB37 | 2011.30 | -0.38 | 0.46 | -0.20 | 0.63 |
| AB42 | 2012.02 | 0.02 | 0.24 | -1.10 | 1.12 |
| AB42 | 2012.48 | 0.08 | -0.04 | -0.43 | 0.43 |

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# Seasonal File Format

**Example**

Seasonal estimates for each site component.
Annual equation: AMP*cos(t*2.*3.14159 + PHA*2.*3.14159/360.)
Semi-annual equation: AMP*cos(t*4.*3.14159 + PHA*2.*3.14159/360.)
Amplitudes are given in mm.
Phases are given in degrees.

| | LAT | LON | HEIGHT |
|---|---|---|---|
| AB01 ANN AMP | 0.40 | 0.79 | 3.37 |
| AB01 ANN PHA | 155.92 | 49.83 | -40.33 |
| AB01 SEM AMP | 0.71 | 0.96 | 1.06 |
| AB01 SEM PHA | 75.85 | 99.98 | 116.03 |
| AB02 ANN AMP | 0.30 | 0.23 | 3.09 |
| AB02 ANN PHA | -144.44 | -143.88 | -37.94 |
| AB02 SEM AMP | 0.40 | 0.46 | 1.69 |
| AB02 SEM PHA | 33.01 | 43.69 | 108.25 |
| AB04 ANN AMP | 1.20 | 1.35 | 1.96 |
| AB04 ANN PHA | -42.58 | 81.43 | 9.85 |
| AB04 SEM AMP | 0.82 | 1.27 | 1.54 |
| AB04 SEM PHA | -12.54 | 86.13 | -37.69 |
| AB06 ANN AMP | 1.45 | 0.95 | 2.78 |
| AB06 ANN PHA | -145.39 | 89.94 | 25.55 |
| AB06 SEM AMP | 0.10 | 0.82 | 1.29 |
| AB06 SEM PHA | -69.86 | 150.95 | 12.30 |
| AB07 ANN AMP | 0.64 | 0.92 | 1.02 |
| AB07 ANN PHA | -69.60 | -38.90 | 24.33 |
| AB07 SEM AMP | 0.06 | 0.22 | 0.71 |
| AB07 SEM PHA | -19.06 | 45.00 | 125.01 |

...

# Performance

| Repeatablity | Best 20 | Best 200 | Best 400 |
|---|---|---|---|
| N Mean | 1.4 mm | 1.6 mm | 1.6 mm |
| E Mean | 1.5 mm | 1.7 mm | 1.7 mm |
| V Mean | 4.0 mm | 4.4 mm | 4.6 mm |

| GPS-ITRF08 | Best 20 | Best 200 | Best 400 |
|---|---|---|---|
| N Pos rms | 0.9 mm | 2.1 mm | 4.3 mm |
| E Pos rms | 0.8 mm | 2.4 mm | 4.4 mm |
| V Pos rms | 0.8 mm | 3.6 mm | 8.3 mm |

| GPS-ITRF08 | Best 20 | Best 200 | Best 400 |
|---|---|---|---|
| N Vel rms | 0.1 mm/yr | 0.2 mm/yr | 0.4 mm/yr |
| E Vel rms | 0.1 mm/yr | 0.2 mm/yr | 0.3 mm/yr |
| V Vel rms | 0.1 mm/yr | 0.3 mm/yr | 0.6 mm/yr |