Visualizing the Quality of Reprocessed GPS Orbit Solutions

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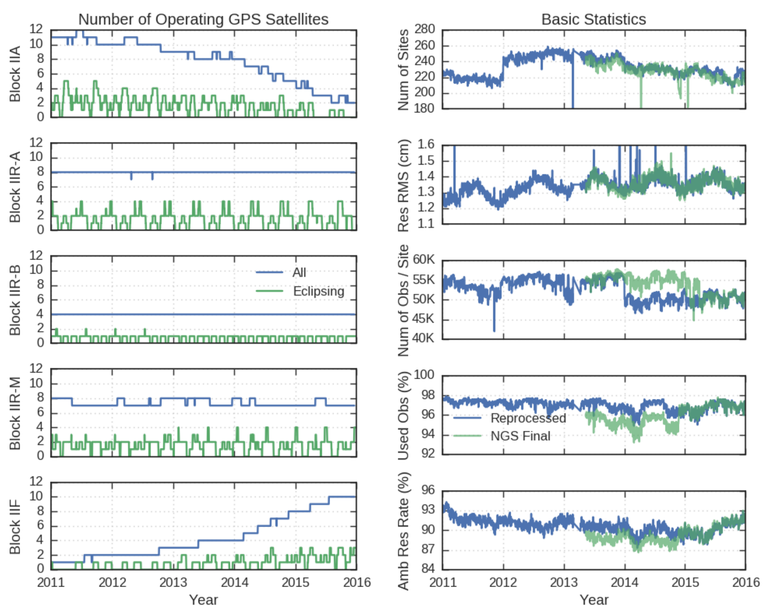
Abstract

The quality of GPS orbit solutions can be measured and then compared by various quality metrics. Examples of such quantities are double difference residual RMS, orbit discontinuity RMS, ambiguity resolution rate, orbit difference RMS and orbit frame difference represented by Helmert transformation parameters.

When these quantities are plotted, they can be presented in different perspectives to reveal different characteristics of those numbers. A quality metric can be plotted with time on the x-axis to investigate patterns in time domain. The power density of the same quality metric at different frequencies can be plotted with frequency on the x-axis to investigate patterns in frequency domain. When these values are plotted as a function of sun (beta) angles, such plots provide researchers with new insight hidden in any other plots.

When analysis centers reprocess historical data with new software and new processing strategies, the differences of the previous solutions and the new set of solutions from reprocessing must be investigated in various perspectives. In this poster, strength of various plots will be discussed using data from the current on-going reprocessing effort at NGS.

Introduction



- NGS is planning to reprocess GPS data from 1994 up to the end of 2015. The orbit solutions used for this study is from a preliminary reprocessing of 5 year data from 2011 to 2015.
- Blue data points in this poster represent solutions from the preliminary reprocessing and green data points represent the operational NGS final solutions.
- The first step to asses the quality of solutions is to review the basic statistics shown in the plots above right hand side.
- Log files from the operational NGS final orbit processing for days before mid 2013 were misplaced and not available for this study.

- At the GPS satellite's altitude, solar radiation pressure modeling plays the major role to determine the performance of the orbit determination.
- Different blocks of GPS satellites go through different yaw maneuver during eclipse. Therefore, the effect from the solar radiation pressure mismodeling is different on satellites from different blocks. Knowing blocks of the operating GPS satellites at a particular day (plots shown above left hand side) can help understand the orbit determination performance.
- In the following sections, plots for Block IIR-B satellites are not shown because of the limited poster space.

Future Work

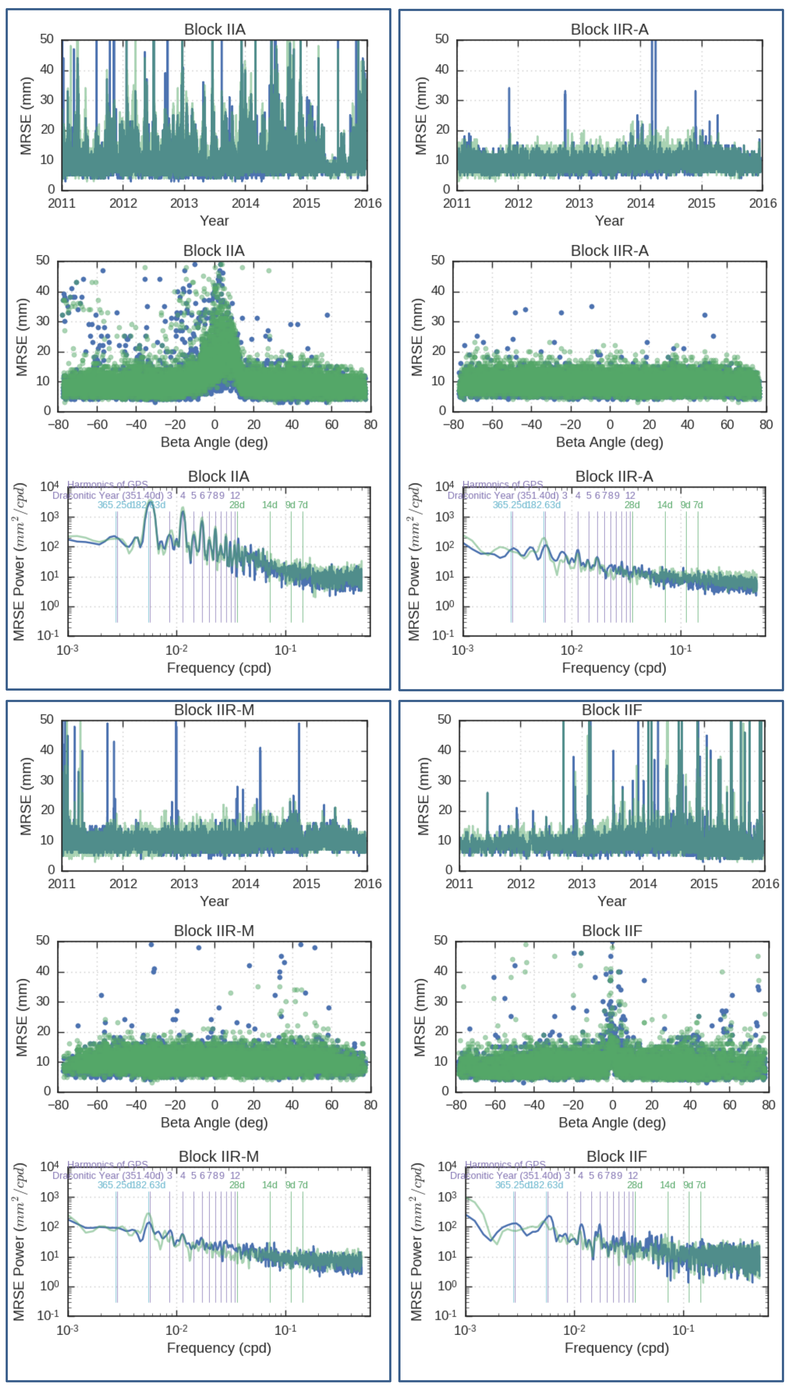
- To fully understand the orbit determination performance, the station coordinates which are estimated simultaneously must be investigated.
- Satellite Laser Ranging (SLR) residual analysis is the only way to measure the quality of orbit solutions in absolute sense. NGS is planning to build this capability.

References

[1] GPS Position Accuracy Measures, http://www.novatel.com/assets/Documents/Bulletins/apn029.pdf

[2] J. Griffiths, et al., (2009) On the Precision and Accuracy of IGS Orbits, Journal of Geodesy (2009) 83:277-287

Mean Radial Spherical Error (MRSE)

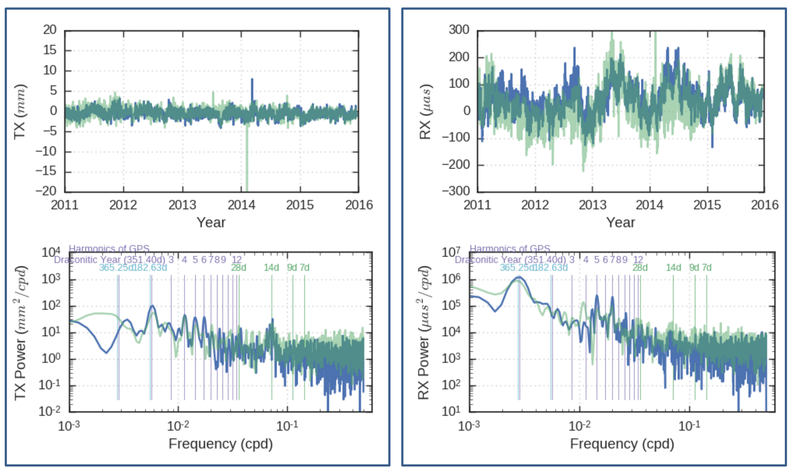


- Mean Radial Spherical Error (MRSE) is a measure of 3D positional error and is defined as [1]

$$\text{MRSE} = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2}$$

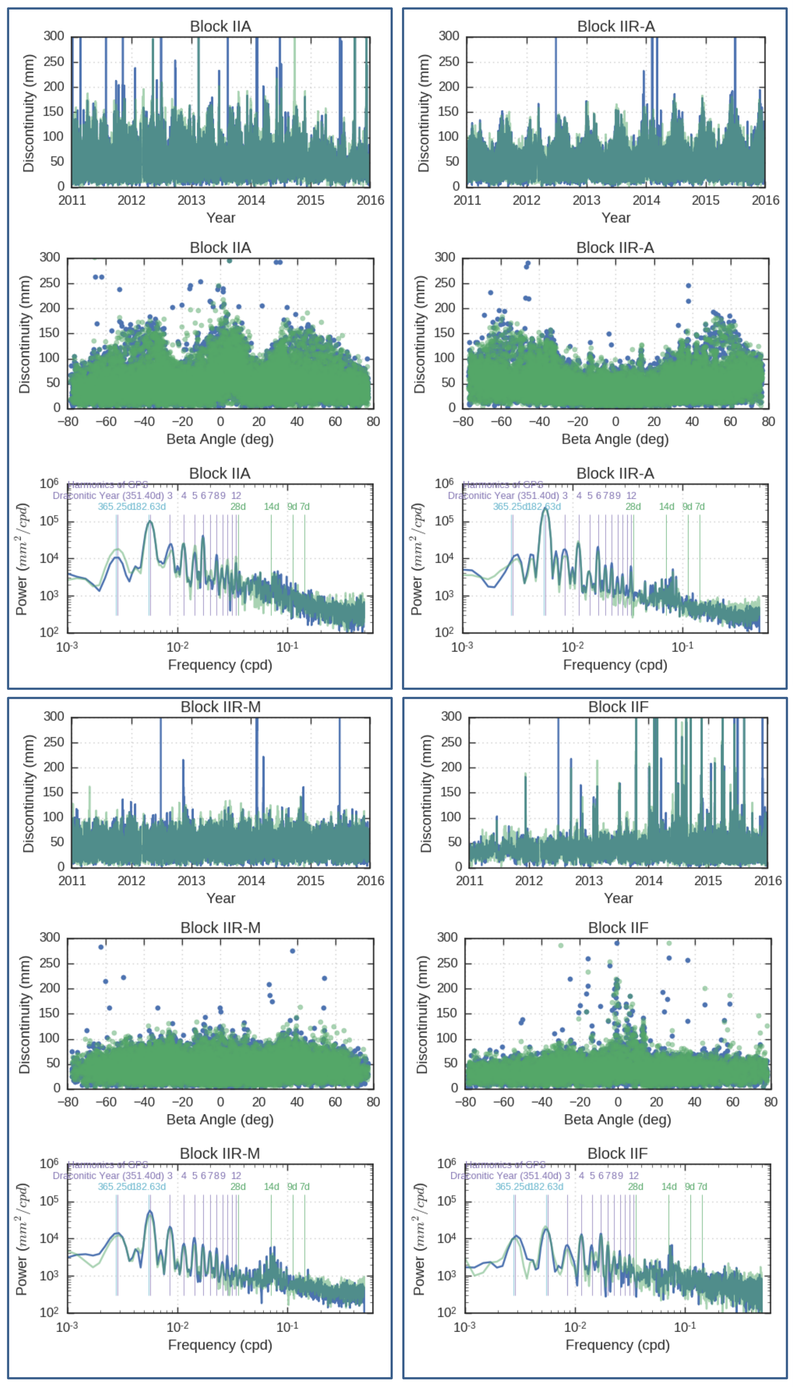
- MRSE shows the quality of orbit solutions compared to the **external** reference solutions, in this case IGS final ephemeris.
- Beta angle is the Sun elevation angle from the satellite orbital plane. Eclipse occurs when beta angle is near zero.
- High MRSE values near small beta angles for Block IIA satellites shows the possible problem in handling eclipsing Block IIA satellites in orbit processing.
- There are two eclipsing seasons in a year and that is why there is a strong peak at semi-annual frequency in PSD plots. Block IIA satellites exhibit the highest peak at semi-annual frequency.

Helmert Transformation Parameters



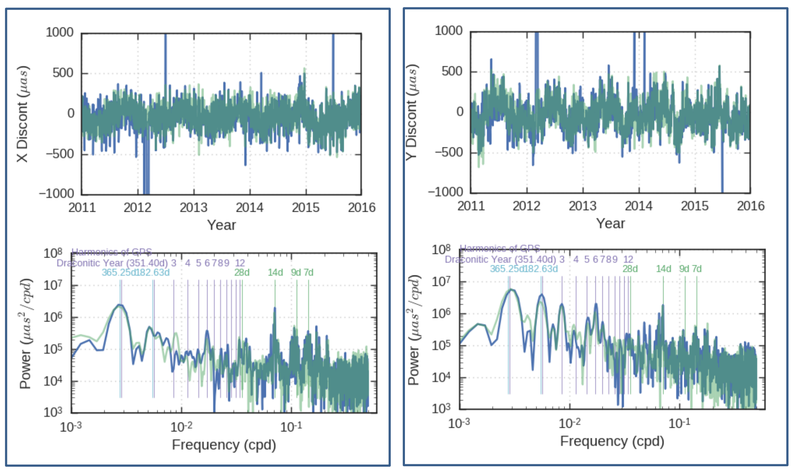
- Helmert transformation parameters represent the reference frame difference between the reference solutions (IGS final ephemeris) and obtained solutions.
- There are 7 parameters for Helmert transformation: 3 parameters for translation, 3 parameters for rotation and 1 parameter for scale. Plots only for translation in x direction (TX) and rotation about x axis (RX) are shown here because of the limited poster space.
- PSD plot for RX has strong peak at annual frequency.

Orbit Discontinuity



- Orbit discontinuity is computed by propagating the previous day solution forward and the next day solution backward to a common epoch and computing the difference between them. [2]
- Orbit discontinuity measures the **internal** consistency of solutions.
- Orbit discontinuity values near zero beta angle for Block IIA satellites have big numbers. This is consistent with the pattern shown in MRSE plots.
- Two peaks near ±40 deg for Block IIA and ±60 deg for Block IIR-A need further investigation.
- A set of peaks in PSD plots appear at the frequency of harmonics of draconitic year. Draconitic year (350.40 days) is a period that geometry of satellites to the Sun and the Earth repeats. Peaks at the semi-annual frequency is a member of this set.
- Another strong peak in PSD plots appear near 2 week period.

Earth Rotation Parameter Discontinuity



- NGS solves for the Earth rotation parameters as a part of the orbit processing. Earth rotation parameters consist of 5 parameters: x and y of rotation axis, rates of x and y and length of day (LOD) parameter.
- x and y values at the day boundary are computed using the previous day and the next day solutions. Their differences show internal solution consistency. Similar computation can be done for LOD even though plots for LOD discontinuity are not shown here.
- Like PSD plots of other quantities, strong peaks appear at the harmonics of draconitic year and near two week period.