A performance analysis of the IGS predictions of the GPS satellite clocks

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INTRODUCTION

This poster presents the results of an in-depth performance analysis study of the IGS prediction scheme for the GPS satellite clocks. The output of this prediction scheme is delivered to users in the IGS ultra-rapid SP3 product. Specifically, the study focuses on two quantities: satellite clock time offset (SCTO) prediction errors and satellite clock difference prediction errors, which are errors in the prediction of the difference between satellite clock pairs. Both of these quantities are defined here. As far as the positioning, navigation and timing (PNT) applications of GNSS are concerned, it is not the absolute value of the SCTO estimation (or prediction) error (w.r.t. a realisation of GPS Time, in this case) but rather the nature and the extent of the mis-synchronization amongst the satellite clocks that directly influences the end-user's PNT solution. In this study, it is the satellite clock difference prediction error quantity that represents this mis-synchronization. Thus, it is the accuracy of the IGS prediction scheme in predicting satellite clock differences that should be used to evaluate its performance in a PNT context.

DEFINITIONS

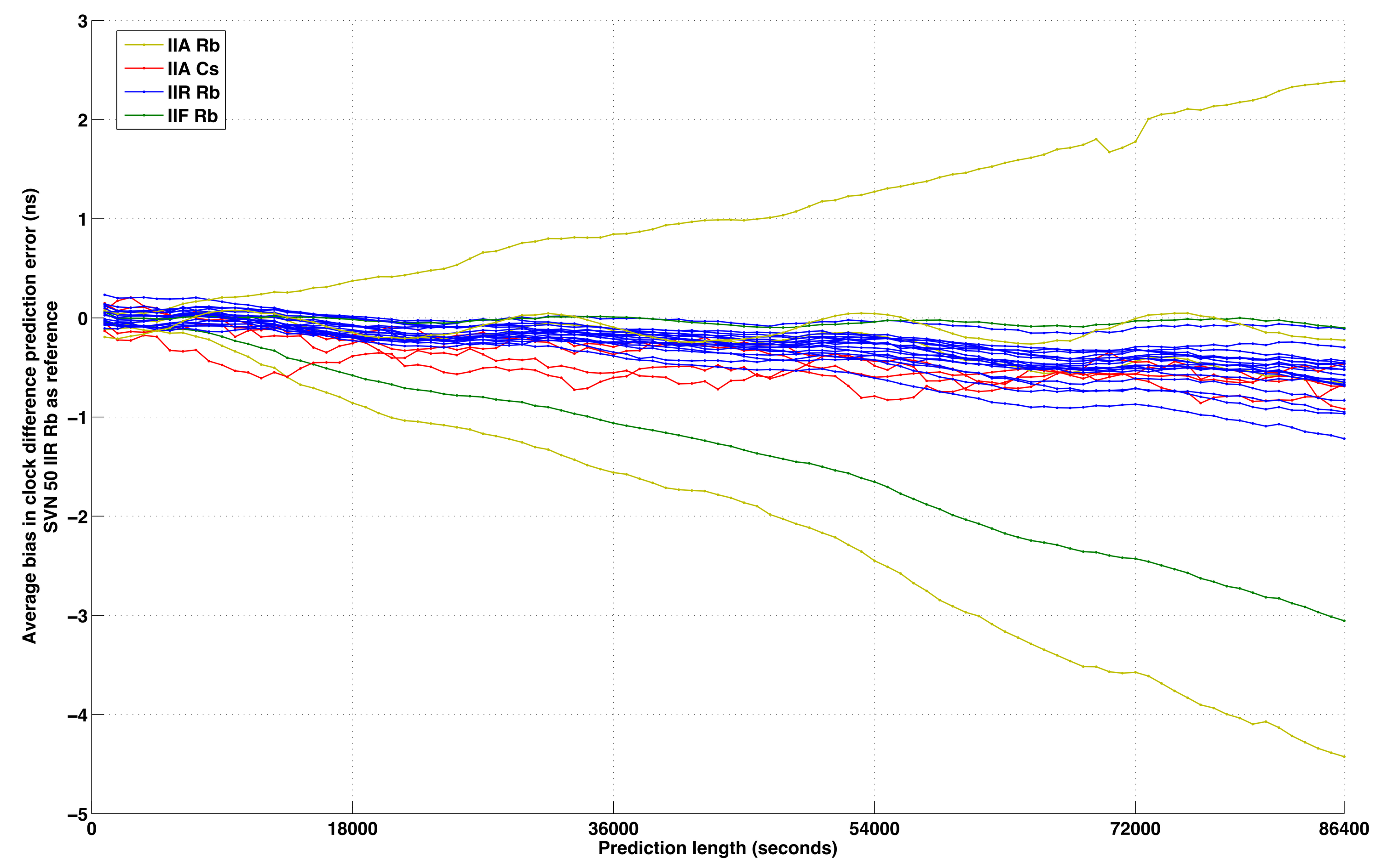
The approach developed for measuring the performance of the IGS prediction strategy for the GPS satellite clocks is based upon the statistical analysis of clock prediction error, which is precisely defined here. The first requirement is a timescale (or a individual clock) to represent "true" time – this is the reference timescale. Then, a set of satellite clock time offset (SCTO) estimates (w.r.t. the reference timescale), of sufficient quality, in terms of precision and accuracy is required to represent true clock behaviour. With these in place, it is possible to define clock prediction error (CPE) at epoch n as

$$E_{R,i,p,n}=(T_R-C_i)_n-(T_P-C_{i,p})_n$$

where T_R is the reference timescale, C_i is time according clock i at epoch n, and $(T_P-C_{i,p})_n$ is the predicted SCTO value for clock i at epoch n. The difference between the true SCTO as represented by $(T_R-C_i)_n$ and the predicted SCTO value, $(T_P-C_{i,p})_n$, is the prediction error for clock i (with respect to T_R) at epoch n, denoted $E_{R,i,p,n}$. Here, it also necessary to define the error in the prediction of the difference between satellite clock pairs (or clock difference prediction error (CDPE)). Here, the clock difference prediction error at epoch n is defined as

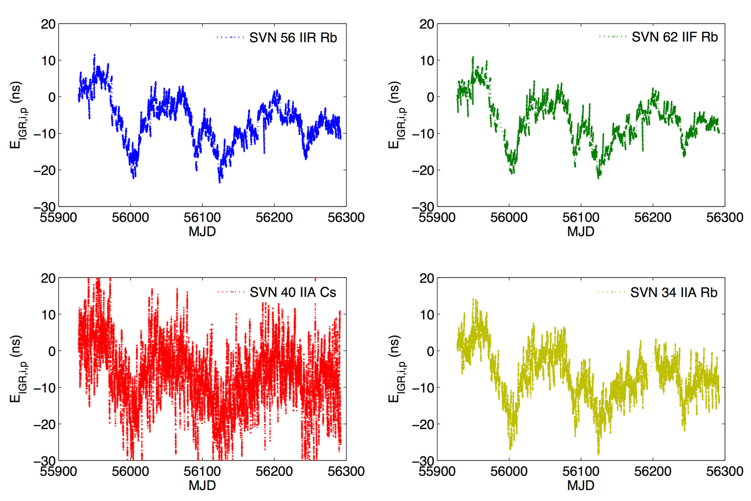
$$E_{ij,p,n}=(C_i-C_j)_{R,n}-(C_i-C_j)_{p,n}$$

where $E_{ij,p,n}$ is the error in the prediction of the difference between clock j and clock i (the reference clock) at epoch n, $(C_i-C_j)_{R,n}$ is the computed value for the clock difference derived from SCTO estimates (i.e. from observations), and $(C_i-C_j)_{p,n}$ is the predicted clock difference.

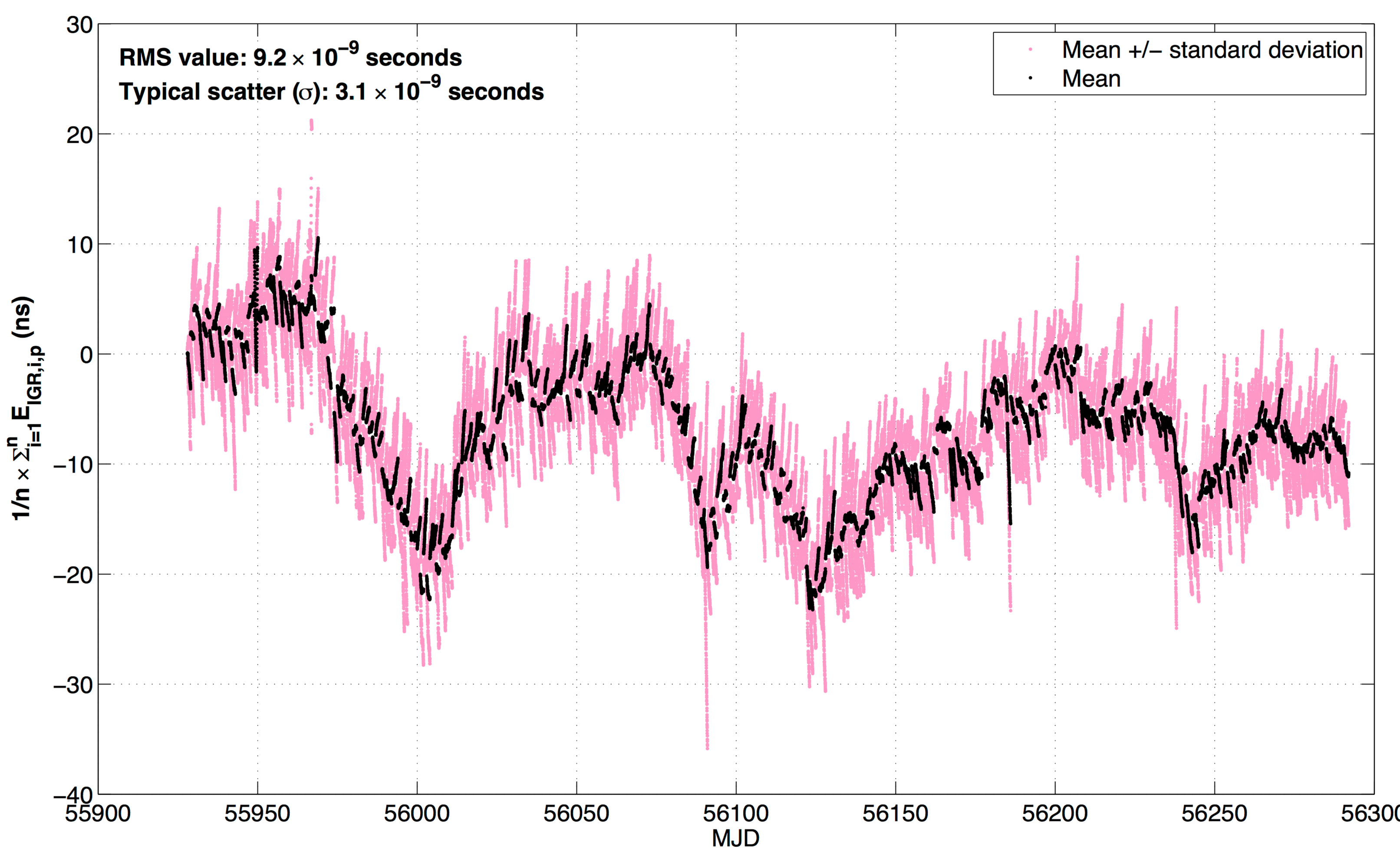


The average bias in the IGS predictions of the GPS satellite clock differences with SVN 50 IIR-M Rb as reference clock, for a range of prediction lengths from fifteen minutes to twenty-four hours. Here, the IGS rapid clock difference represents "truth". The average calculation uses data across the whole of 2012.

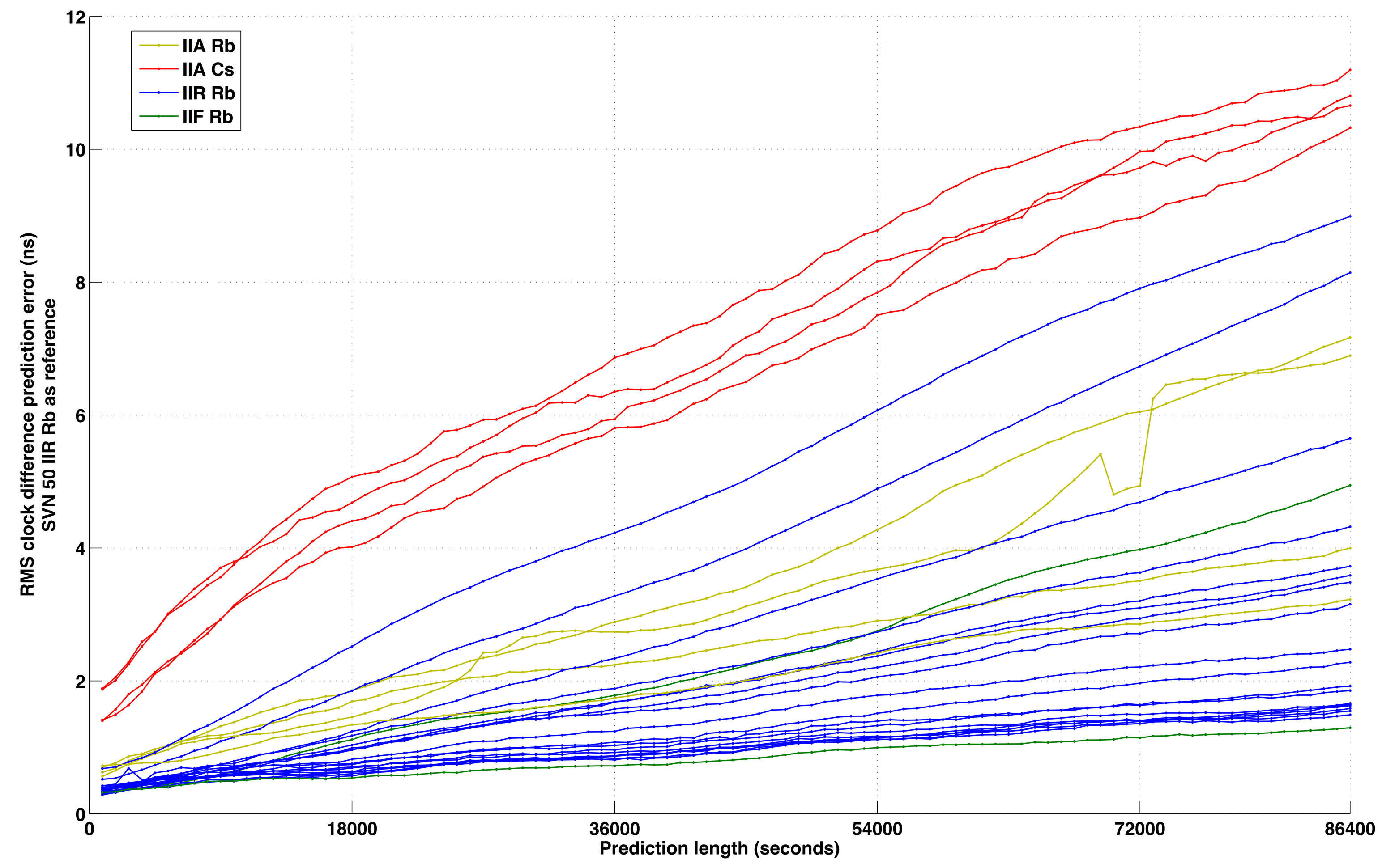
RESULTS



These are curves of $E_{igr,i,p}$, over the whole of 2012, for a chosen selection of GPS satellite clocks. All curves are clearly dominated by a common underlying signal. This is the influence of the timescale offset between IGS rapid time (which closely approximates IGS Time) and the IGS ultra-rapid timescale (which is as a real-time realisation of GPS Time).



The time-series represented by the black data points is the average GPS clock prediction error (with IGS Rapid Time as reference timescale) during 2012. Here, the average is an ensemble average taken across all of the GPS satellite clocks for which there is data available. The pink time-series represents +/- 1 standard deviation for each data point. This time-series is a representation of the T_{igr} – T_{igu} timescale offset quantity over the full year 2012.



The RMS prediction error of the IGS predictions of the GPS satellite clock differences, with SVN 50 IIR-M Rb as reference clock, for a range of prediction lengths from fifteen minutes to twenty-four hours. Here, the IGS rapid clock differences represent "truth". The RMS calculation uses data across the whole of 2012, i.e. an average RMS over 2012.

FINDINGS

The main findings of the study are described, briefly.

- There is a common signal, call this the offset between the IGS Rapid Timescale and the IGS Ultra-rapid timescale, which strongly influences the IGS predictions of the GPS SCTOs. In 2012, the typical (RMS) value for this quantity was 9.2 +/- 3.2 ns (1-sigma).
- The IGS prediction of the GPS satellite clock differences are biased. The nature of the bias indicates mis-modelling of linear frequency drift in the IGS prediction method.
- Periodic signals are observable in the IGS prediction errors of the GPS satellite clock differences. This is an indication that the periodic signals in the GPS satellite clocks are not fully accounted for in the IGS prediction method.

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