

Modelling of GPS Satellite Clocks and Comparisons of IGU Clock Products

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Introduction

Official IGS (International GPS Service) products, e.g. the IGS Ultra Rapid orbits and clock corrections to GPS Time (IGU's), are the result of a weighted combination process, based on individual submissions of up to 8 IGS Analysis Centers (AC's). The quality of clock corrections submitted by the AC's to the Ultra Rapid combination is evaluated on a regular basis at the TU Vienna (TUW) covering both, the observed and the predicted clock corrections. The results are posted regularly at <http://www.hg.tuwien.ac.at>. In this presentation we focus on the predicted values only. Ultra Rapid clock predictions are currently delivered by 5 AC's, namely CODE, ESA, GFZ, NRC (EMR), and USNO. We calculate the RMS of deviations between the clock information given in the AC's sp3-product files and the IGS Rapid clock solutions (IGR) and investigate the long term quality of predictions in specific time intervals up to 12 hours. Based on this experience a new clock prediction model has been developed at TUW.

In order to judge the quality of the clock predictions we calculate the RMS of drift and offset reduced AC-IGR differences. The RMS is evaluated for time frames of variable length, namely 3, 6, 9, and 12 hours (see figures 2a-c). Our diagrams clearly make evident that for a certain number of satellite clocks the RMS is growing nearly quadratic with the length of the prediction interval. Short term predictions perform quite well, e.g. 3-h predictions are usually at the 1 ns level while predictions over 12 h are only slightly better than broadcast clocks. Moving towards a more frequent update of Ultra Rapid orbits and clock corrections as anticipated by IGS AC's is therefore severely recommended.

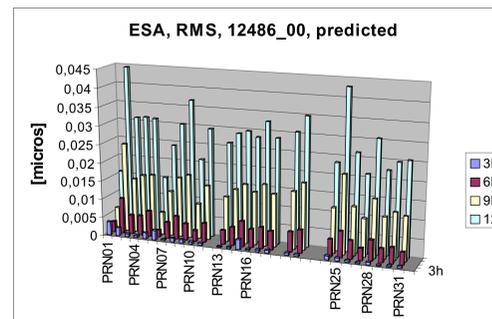


Figure 2b

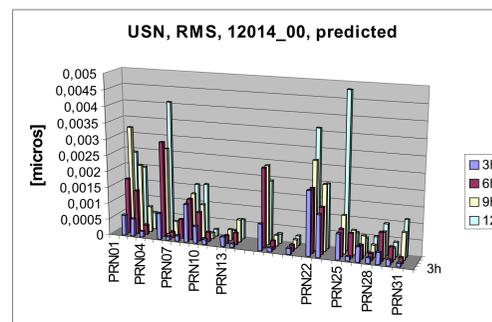


Figure 2c

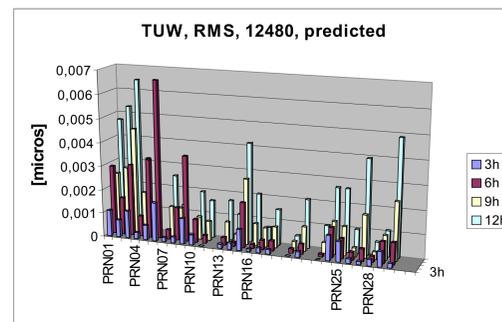


Figure 2a

GPS satellites are equipped with two types of clocks (Rubidium and Cesium) which show a different behaviour in terms of time instability. While Rubidium clocks show a long term frequency drift best described by a second degree polynomial, the Cesium clocks show a periodic modulation with a main period of about 12 hours (see figures 4a,b). Studying this behaviour is important for setting up a reliable prediction model. We also have to keep in mind that variations in the satellite clock corrections are closely linked to radial orbit variations. We computed the Allan Variance for all satellites with data sets covering one day. Figure 4c shows the results for block IIA satellite PRN30 and the new block IIR satellite PRN28, both representing Rubidium clocks but of different quality. Moreover it displays the Allan Variance for block IIA satellite PRN06 (Cesium clock). We may summarize that Cesium clocks deliver a very good long term stability while Rubidium clocks are more stable within the first 12 hours.

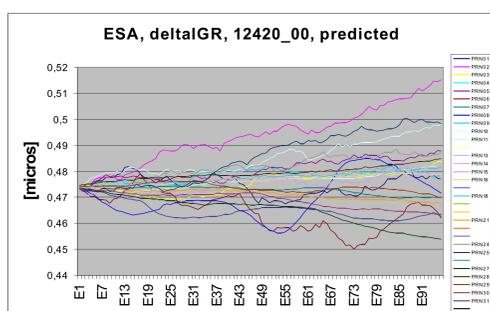


Figure 1a

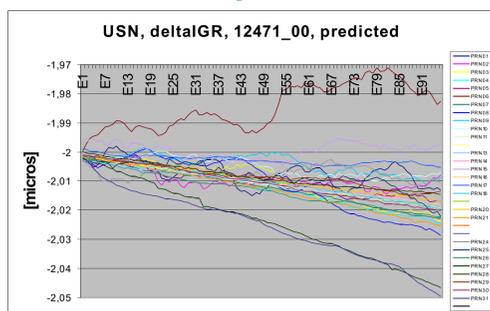


Figure 1b

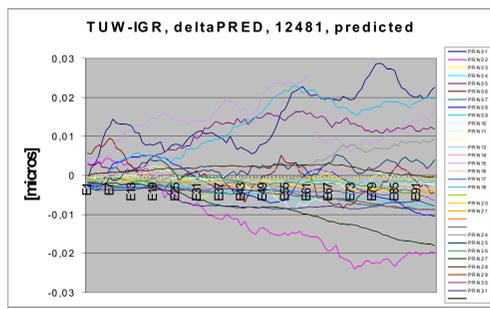


Figure 1c

Typical clock correction differences between the predicted parts of the individual AC Ultra Rapid clock solutions and the IGR solution are shown in figures 1a (ESA-IGR) and 1b (USNO-IGR). Differences are usually in the order of a few nanoseconds [ns] over the first 12 hours but may grow up to some tenths of nanoseconds for 'badly behaving' satellite clocks. To establish reliable satellite clock correction predictions at TUW we use data of the past two consecutive days of observed IGU clock corrections as well as the history of our own model. This model consists of a second degree polynomial extended by periodical terms. TUW-IGR clock correction differences are presented in figure 1c.

Figures 3a-d show for two test satellites how the RMS of the clock predictions of the various IGS AC's develops over almost half a year (GPS weeks 1225-1248). The yellow curve represents the TUW predictions. In general, the curves of the individual AC's solutions match quite well for most of the satellites. Nevertheless, for individual satellites and intervals some prediction models seem to fit slightly worse, like e.g. for PRN27 and a prediction interval of 12 hours (see figure 3d). Right to each figure the average value of the referring RMS is listed.

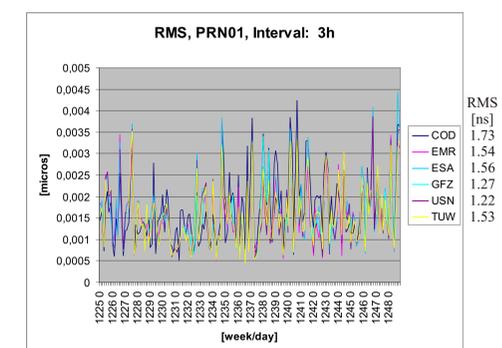


Figure 3a

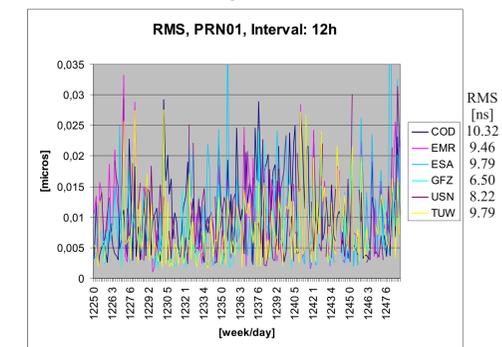


Figure 3b

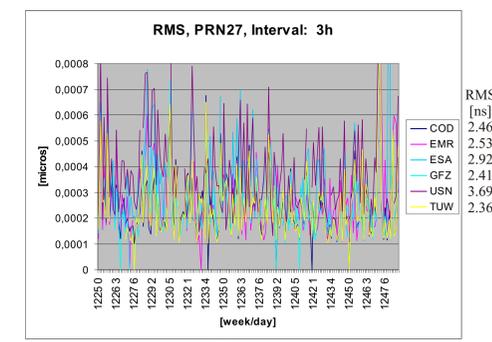


Figure 3c

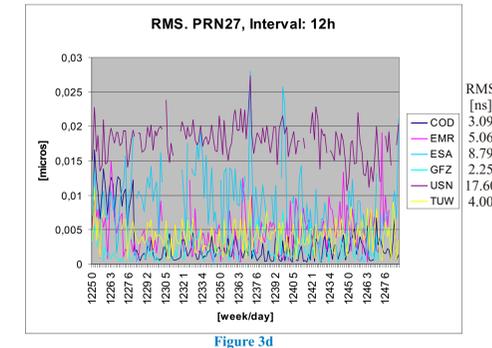


Figure 3d

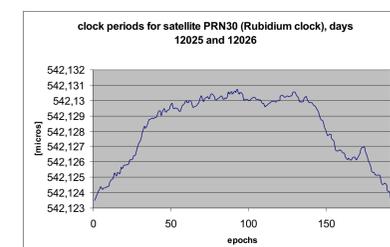


Figure 4a

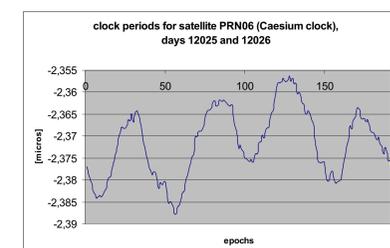


Figure 4b

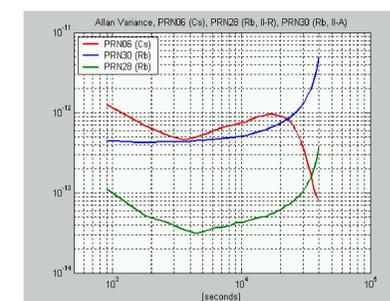


Figure 4c

Future work. Further work will deal with the following topics:
 *) improving the TUW prediction model
 *) analysing the stability of satellite and station clocks by means of the Allan Variance
 *) prediction of GLONASS satellite clocks

References:
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