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A Grey Model Based on First Differences in the Application of Satellite Clock Bias Prediction† ⋆

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Abstract In consideration of the characteristics of satellite clock bias (SCB), a grey GM(1,1) model based on the first difference method is proposed. The first differences between the SCB values of two adjacent epoches are firstly derived to obtain the corresponding first difference sequence. Then, a grey model is made based on the sequence to predict the first difference values for the time following. Finally, the predicted first difference sequence is recovered to be the corresponding predicted SCB. The clock bias data provided by the IGS (International GNSS Service) are used as the experimental data, and the cases with different lengths of modeling data and different prediction step lengths are compared and analyzed. The result shows that the prediction accuracy of this method is higher than that of traditional grey GM(1,1) model, especially for the PRN01 satellite clock, whose forecast effect is the best. With the first difference method, the model prediction accuracy and stability can be effectively improved and enhanced. This method is feasible and reliable for the relatively long term SCB prediction.

Key words astrometry: time, methods: data analysis

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1. INTRODUCTION

The prediction of satellite clock bias (SCB) is a kind of very important work. The navigation accuracy depends directly on the level of clock bias prediction. The study of clock bias prediction is beneficial to improving the reliability and accuracy of parameter prediction [1−3]. At present, many researchers around the world have put forward several prediction methods, such as the second-order polynomial model, grey model, neutral network and various combined models[4−11]. The grey model has the advantages of the less requirement on the data sample and the strong resistance to disturbance. A new and more regular data sequence can be made up by the progressive addition or progressive substraction on the original data, and hereby to set up a prediction model. Because that the satellite clock is very sensitive, very easy to be affected by external or internal factors, and its variation is too subtle to be known in detail, so its variation process may be regarded as a grey system. Therefore, many researchers have introduced the grey theory in the study of clock bias prediction, and have acquired rather good results: Cui Xian-qiang et al.[8] applied the grey GM(1,1) model to the satellite clock bias prediction, which was set up by using only the known satellite clock biases of a few epoches, so that the quantity of data to be used was reduced, the modeling speed, raised, and the accuracy of satellite clock bias prediction, significantly improved; Li Wei et al.[9] used the model of grey system in a short-term clock bias prediction, and got a rather high prediction accuracy; Lu Xiao-feng et al.[10] suggested an optimized method of grey theory, and used it in the satellite clock bias prediction, thereby improving further the prediction accuracy; Li Xiao-yu et al.[11] proposed a combined model of clock bias prediction, which combines an improved grey model with the Auto-Regressive and Moving Average (ARMA) model, thus to improve further the prediction accuracy. On the basis of above-mentioned studies, and considered the characteristics of clock bias data, in this paper, a grey GM(1,1) method of clock bias prediction based on the first differences is proposed by taking advantage of the excellent properties of the grey system. This method derives at first the first differences between the SCB values of two adjacent epoches, and sets up a prediction model with the first difference values to be the modeling data of grey model; then, the first difference values are predicted according to the time series; finally, by a restoration the predicted values of clock bias are given. In this paper, the precise clock bias data provided by IGS with the sampling interval of 5 min are adopted to give examples, and the feasibility and effectiveness are investigated for various types of atomic clocks, different modeling data and diverse prediction step lengths.

2. GREY PREDICTION MODEL BASED ON FIRST DIFFERENCES

It is known from the clock bias data of atomic clocks that the difference between the values of two adjacent epoches is small. To make the first differences between two adjacent epoches on the clock bias data, a data sequence with the reduced significant figures can be obtained.