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地球定向参数高精度预报方法研究

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地球自转表征了固体地球与大气、海洋、地幔和地核在各种时空尺度上的耦合过程, 地球的自转运动可以用地球定向参数(EOP)(主要包括极移两个分量和日长变化)来描述. EOP是地球参考系和天球参考系之间的转换参数, 在深空探测、卫星精密定轨和天文地球动力学研究等领域都有重要应用. 由于复杂的数据处理过程, 空间大地测量技术获取的EOP存在几天至两个星期的延迟. 现代空间导航等对EOP预报值的需求日益增长, 使得寻求高精度EOP预报方法成为一项需要深入研究的课题. 本文主要从以下几个方面展开, 探讨提高EOP预报精度的方法.

(1)分析基础预报序列的长度对EOP预报精度的影响, 并应用线性的自回归(AR)模型和非线性的人工神经网络(ANN)模型对EOP残差序列作预报, 结合最小二乘(LS)外推EOP周期项数据, 对比分析两种方法的预报精度. 结果表明, EOP预报精度与基础预报序列长度具有一定的联系, 预报工作中应合理地选取基础数据序列, 预报跨度比较小的时候, 基础预报序列可以短一些, 预报跨度大时, 则需要比较长的基础预报序列. 对于EOP序列的不同跨度预报, LS+AR模型在短期预报中精度较高, 而LS+ANN模型则在中长期预报中显出优势.

(2)研究一种AR模型与卡尔曼滤波(Kalman filter)的组合预报方法(AR+Kalman), 并将此联合方法首次运用到EOP的短期预报中. 该联合方法是以EOP序列建立观测方程, 以AR模型自回归系数建立状态方程, 形成卡尔曼滤波函数模型, 对AR模型自回归系数进行滤波改正. 计算结果表明, 与单纯的AR模型以及其他EOP预报结果相比较, AR+Kalman方法预报精度较高, 表现更稳定. 其中, 对PM_X和PM_Y, 预报呈现出明显的精度优势, 对UT1-UTC和ΔLOD, 预报也有较高的精度表现.

(3)为了检验我们的EOP预报工作, 自2010年起参加了国际地球定向参数联合预报(EOPC PP-P)活动, 也是我国首次参与此项活动. 我们的预报产品包括PM_X、PM_Y、UT1-UTC和ΔLOD的短期至中期(1~90 d)预报序列. 从目前的统计结果来看, 我们的EOP预报精度处于国际中等水平. 在EOP预报方面, 我们还处于起步阶段, 今后将进一步拓展, 开展更多的创新研究来提高EOP预报精度, 更好地为导航定位等应用需求服务.

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Researches on High Accuracy Prediction Methods of Earth Orientation Parameters

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The Earth rotation reflects the coupling process among the solid Earth, atmosphere, oceans, mantle, and core of the Earth on multiple spatial and temporal scales. The Earth rotation can be described by the Earth's orientation parameters, which are abbreviated as EOP (mainly including two polar motion components PM_X and PM_Y, and variation in the length of day ΔLOD). The EOP is crucial in the transformation between the terrestrial and celestial reference systems, and has important applications in many areas such as the deep space exploration, satellite precise orbit determination, and astrogeodynamics. However, the EOP products obtained by the space geodetic technologies generally delay by several days to two weeks. The growing demands for modern space navigation make high-accuracy EOP prediction be a worthy topic. This thesis is composed of the following three aspects, for the purpose of improving the EOP forecast accuracy.

(1) We analyze the relation between the length of the basic data series and the EOP forecast accuracy, and compare the EOP prediction accuracy for the linear autoregressive (AR) model and the nonlinear artificial neural network (ANN) method by performing the least squares (LS) extrapolations. The results show that the high precision forecast of EOP can be realized by appropriate selection of the basic data series length according to the required time span of EOP prediction: for short-term prediction, the basic data series should be shorter, while for the long-term prediction, the series should be longer. The analysis also showed that the LS+AR model is more suitable for the short-term forecasts, while the LS+ANN model shows the advantages in the medium- and long-term forecasts.

(2) We develop for the first time a new method which combines the autoregressive model and Kalman filter (AR+Kalman) in short-term EOP prediction. The equations of observation and state are established using the EOP series and the autoregressive coefficients respectively, which are used to improve/re-evaluate the AR model. Comparing to the single AR model, the AR+Kalman method performs better in the prediction of UT1-UTC and ΔLOD, and the improvement in the prediction of the polar motion is significant.

(3) Following the successful Earth Orientation Parameter Prediction Comparison Campaign (EOP PCC), the Earth Orientation Parameter Combination of Prediction Pilot Project (EOPC PPP) was sponsored in 2010. As one of the participants from China, we update and submit the short- and medium-term (1 to 90 days) EOP predictions every day. From the current comparative statistics, our prediction accuracy is on the medium international level. We will carry out more innovative researches to improve the EOP forecast accuracy and enhance our level in EOP forecast.