Regularization of nutation time series at GSFC

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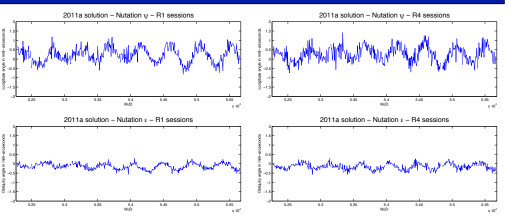
Abstract. VLBI is unique in its ability to measure all five Earth orientation parameters. In this poster we focus on the two nutation parameters which characterize the orientation of the Earth's rotation axis in space. We look at the spectral characteristics of these parameters and discuss their meaning. We also investigate different methods of regularizing the series, taking into account the spectral and stochastic properties of the signals, and discuss the pros and cons of different approaches including the Singular Spectrum Analysis, and the Kalman filter.

GSFC 2011a nutation time series – spectral characteristics

The time series we considered are (psi,epsilon) nutation time series obtained from the GSFC solution 2011a. These time series cover the period 1979 to 2011. Nevertheless, in this study, we do not take into account the early VLBI observations which are known to be more unstable and of poorer quality than the observations after 1993.

To study the spectral characteristics of these time series, we decided to focus on two sets of time series: one obtained from R1 sessions and the other from R4 sessions. These time series have a regular data span of one week between observations, making it easier to analyze with common statistical tools such as the Allan variance.



Periodicities

To analyze our time series of nutation parameters, we first determined the periodic signals for periods shorter than 600 days. Figure 1 shows two sets of periodograms for each time series. In the first plot, the four time series show agreement for a term at 450 days. In the second plot, periods of 510 days, 180 days, and 385 days are visible for each time series independently. Figure 2 gives spectrograms using a Short-Time Fourier Transform (STFT). The time series are divided in six segments and the STFT is performed on each of the segments ("Time" axis).

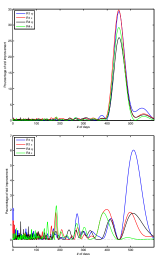


Figure 1: Periodograms. Top: initial time series. Bottom: time series with the major periodic signal removed.

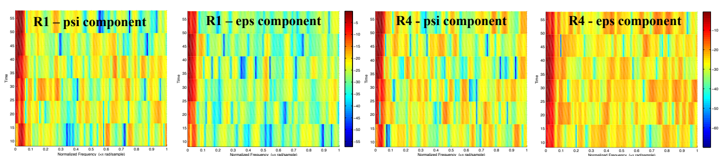


Figure 2: Spectrograms of nutation time series considering R1 and R4 sessions.

Type and level of noise

The Allan variance is used here to indicate the type and level of noise. Figure 3 gives the Allan variances of the initial time series on the left side. It indicates that there is some periodic signal which needs to be removed before giving conclusive results on noise. Once we remove six of the major periodic signals, the dominant noise in the time series is determined as white noise (slope of the curve equal to -1).

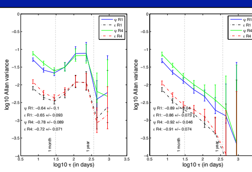


Figure 3: Allan variance plots.
Left: initial time series.
Right: time series with six major periodic signals removed.

Nutation time series - regularization

The histograms in figure 4 give the number of days between observations for two periods: the long period 1979-2011 containing the earliest VLBI observations with a mean of 2.45 days and a maximum value of 251 days between two observations, and the period 1991-2011 with a mean of 2.25 days and a maximum value of 10 days between two observations.

As the goal of this study is to develop a tool which can regularize non-regular nutation time series into daily time series, we investigated two methods: the Kalman filter which is used at Goddard and a method using the Singular Spectrum Analysis which interpolates where data is missing.

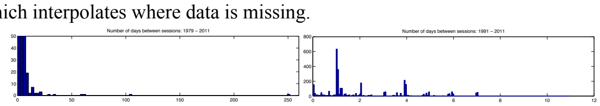
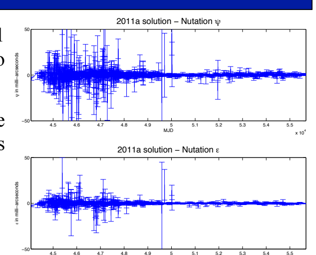


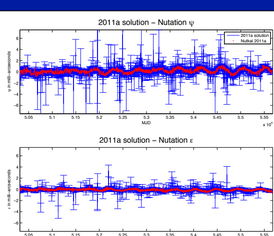
Figure 4: Histograms giving the number of days between two consecutive observations.
Left: period 1979-2011. Right: period 1991-2011.



Kalman filter

At GSFC, a FORTRAN routine, *nutkal.f*, was developed by John Gipson. This routine uses the Kalman filter to regularize nutation time series from the output of a *Solve* run.

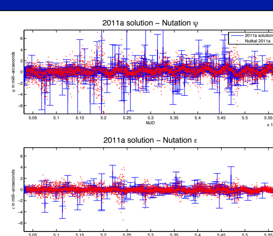
We applied this filter routine to our 2011a solution and obtain the red curves, a daily determination of the nutation time series.



Singular Spectrum Analysis

Another view on regularizing time series is to consider the time series as daily and to fill in missing data. To do so, we use an iterative method derived from the Singular Spectrum Analysis (SSA) developed by Zhang from Elsner/Tsonis.

As a covariance-lag, we used the most significant period determined in the previous section.



The SSA captures the tendency of the time series. The resulting time series using the SSA are noisier than the ones using the Kalman filter.

Conclusions

Regularizing time series properly means keeping the same characteristics of the initial time series: same signals and same type and level of noise. That is the reason why a simple interpolation does not work sufficiently for the nutation time series and why we investigated the Kalman filter as well as Singular Spectrum Analysis.

Nevertheless, we did not take into account phenomena seen in these time series such as the Free Core Nutation. This is the next step in this study.

References

Gipson J., "Implementation of the Goddard EOP Kalman Filter/Smoother", Internal report NASA/GSFC, 1997.

Elsner J.B. and Tsonis A.A., "Singular Spectrum Analysis: A New Tool in Time Series Analysis (Language of Science)", Plenum Press, 1996.

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