TIME STABILITY OF DORIS AND GPS TERRESTRIAL REFERENCE FRAMES

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Introduction

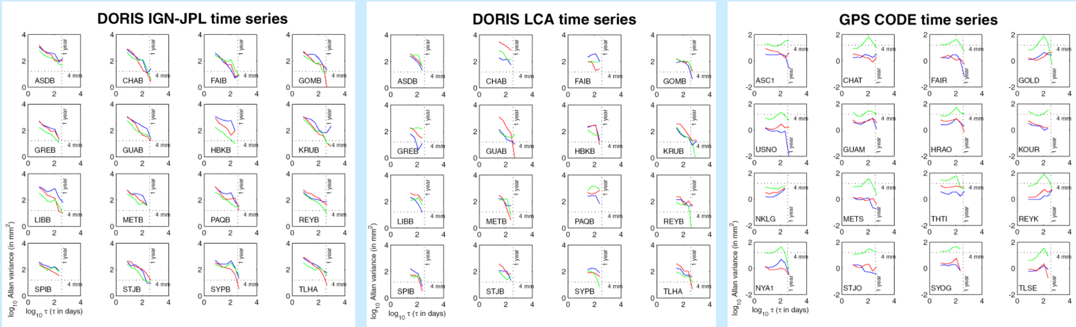
The goal of this study is to characterize the error spectrum of station coordinates time series by means of the Allan variance and its application in the three-cornered hat method. We use time series derived from DORIS or GPS observations in collocated sites.

Two different approaches are shown :

-Study of each individual time series. These series are residuals with respect to a linear drift (model of the velocity of the station). It gives information about the non linear signal;

-Study of series differences of the same station (DORIS-DORIS) or of the collocated station (DORIS-GPS) by the three-cornered hat method. It permits to eliminate the common geophysical signal.

Figure 1 : Allan variance for North(blue), East(red) and Up(green) components for collocated stations of the DORIS (IGN-JPL and LCA) and GPS (CODE) series. Data: time series of residuals with respect to a linear drift. Data span: at least 4 years between 1993 and 2004.



The data

Among the 35 DORIS-GPS collocated stations, only 16 are studied because of lack of data, not processed time series or not corresponding span between GPS and DORIS series.

The three time series sets of the study are the following :

- For DORIS :

• IGN-JPL series : SINEX files from IGN-JPL solution are processed with the CATREF software to refer the series to ITRF2000 positions and velocities. Outliers due to known geophysical and physical perturbations are cleaned. The time series are at weekly intervals. Series provided by Zuheir Altamimi (IERS).

• LCA series : SINEX files from LCA solution are processed in the same way as IGN-JPL series. The resulting time series are at monthly intervals. Series provided by Jean-Jacques Valette (IDS).

- For GPS :

• CODE series : SINEX files from CODE solution are processed. The cumulated IGS realization of a terrestrial frame gives the a priori positions and velocities. The time series are at weekly intervals. Series provided by Rémi Ferland (IGS).

The Allan Variance and the three-cornered hat method

The Allan Variance is a statistical tool which characterizes the type of noise of a time series with regular step.

If $x_i, i=1,n$ are the measurements and T the sampling time, the mathematical expression of the Allan variance is :

$$\sigma^2(n,T)=\frac{1}{2}<(x_{i+1}-x_i)^2>$$, where <.> is the average.

Let a temporal process which has a spectral density D proportional to f

$D(f)=h_\alpha f^\alpha$, where the α parameter characterizes the type of noise :

• α=0 for white noise,

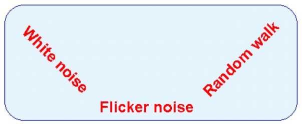
• α=-1 for flicker noise,

•α=-2 for random walk.

The Allan variance allows to specify a noise in a time series through the relationship :

$$\log\sigma^2(2,T)=\mu\log T$$

- μ=-1 corresponds to white noise,
- μ=0 to flicker noise,
- μ=1 to random walk.



Given a set of three independent time series of measurements x, y and z at the same dates. Let's assume that each time series is composed of two terms :

$$x_i = S + \varepsilon_x^i$$

where S is the geophysical signal, and ε_x^i the noise.

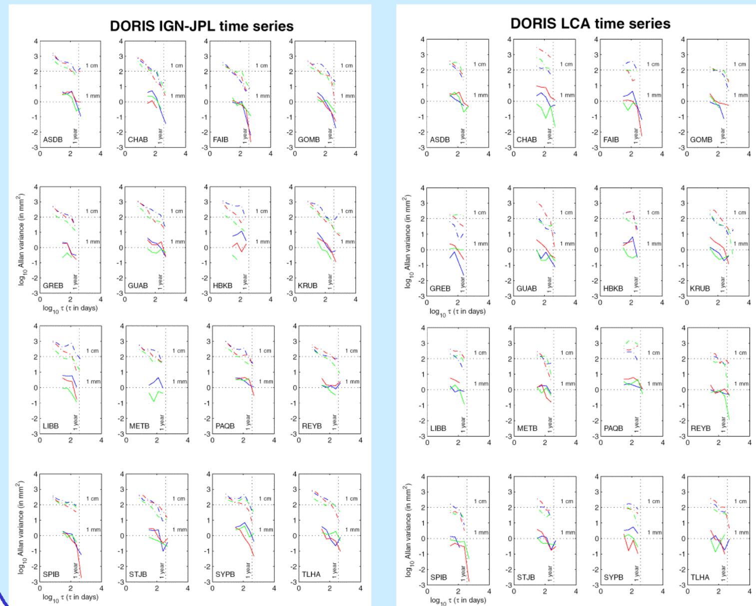
S is common in the three time series (same station or collocated station). So the three-cornered hat method allows to determine the variance of each series noise by mean of their differences :

$$\begin{cases}\sigma^2(x-y)=\sigma^2(\varepsilon_x)+\sigma^2(\varepsilon_y)\\ \sigma^2(x-z)=\sigma^2(\varepsilon_x)+\sigma^2(\varepsilon_z)\\ \sigma^2(z-y)=\sigma^2(\varepsilon_z)+\sigma^2(\varepsilon_y)\end{cases}$$

Figure 2 : Allan variance for North(blue), East(red) and Up(green) components for each station of the DORIS (IGN-JPL and LCA) and GPS (CODE) series

Solid lines:three-cornered hat method

Dashed lines:direct method reproducing fig. 1



Results

Direct analysis : Figure 1 shows the Allan variance graphs for each studied time series.

• DORIS time series have white noise with a starting level of several cm, while GPS time series have flicker noise with a level of few mm.

• Long term stability of DORIS at one year gets closer to GPS one.

Three-cornered hat : Figure 2 shows the Allan variance graphs for each time series, after the three-cornered hat processing of the three studied sets of series together. The Allan variance graphs of figure 1 are plotted for comparison.

• The series still have white noise with nearly one-order magnitude improvement. This may be due to residual modelling error in DORIS data analysis.

Reference

Allan, D. W. 1966, Proc IEEE, 54, 221