ANALYSIS OF POSITIONS TIME SERIES OF GPS-DORIS COLLOCATED STATIONS

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Abstract

We study the signal of weekly solution time series of coordinate residuals for 10 GPS-DORIS collocation sites, using the wavelet transform to extract their trends and periodic signals, and the Allan variance to characterizes their noise.

The obtained results show that the wavelet analysis has useful revealed the trends and periodic signals of the three position components (north, east and vertical). However, after a periodic signals have been removed, the Allan variance analysis shows that the GPS noise type of all three components is a combination of flicker and white noise, while the DORIS time series have a white noise. The GPS positioning is more stable in the horizontal components (1mm) than in the vertical one. The noise level of the studied time series shows that the GPS stations are more stable than the DORIS stations.

1. Wavelet Transform Analysis

❖ The **Wavelet Transform (WT)** can be defined as the projection of the signal X(t) on the basis of wavelet function $\psi_{u,s}$:

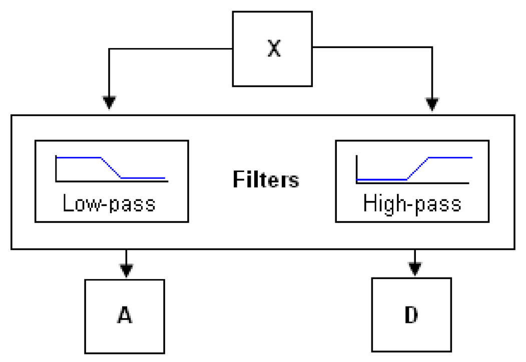
$$WT(u,s) = \langle X, \Psi_{u,s} \rangle = \int_{-\infty}^{+\infty} X(t)\,\overline{\psi}_{u,s}(t)\,dt \qquad \psi_{u,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-u}{s}\right) \qquad u,s \in R;\ s \neq 0$$

Where: u, s translation and scale factor, respectively, and $\overline{\psi}_{u,s}$ the complex conjugate of $\psi_{u,s}$.

❖ The **original signal can be reconstructed** from its wavelet coefficients WT(u,s)

$$X(t) = \frac{1}{C_\psi} \int_{u\in\Re}\int_{s>0} WT(u,s)\ \psi_{u,s}(t)\,du\,\frac{ds}{s^2} \qquad C_\psi = \int_0^{+\infty} \frac{|FT(\psi(t))|^2}{t}\,dt < +\infty$$

Where: C_ψ is the standardization coefficient and FT is the Fourier transform.



The filtering process: the original signal X passes through two complementary filters and emerges as two signals (A and D)

❖ Taken $s = 2^m$ and $u = n\,2^m$ ($n, m \in Z$), The **Discrete Wavelet Transform (DWT)** is formalized as :

$$DWT_{m,n} = \langle X, \Psi_{m,n} \rangle = 2^{-\frac{m}{2}} \int_{-\infty}^{+\infty} X(t)\,\overline{\psi}(2^{-m}t - n)\,dt \qquad \Psi_{m,n}(t) = 2^{-\frac{m}{2}}\Psi(2^{-j}t - n)$$

❖ The DWT allows the computation of the wavelet coefficients in the context of **multi-resolution analysis** which allows, by successive filtering, to produce a series of signals corresponding to an increasingly fine resolution of the signal. The signal is separated in two components : one representing the **approximation** of the signal (represented by its low-frequency) and the other representing its **details** (represented by its high-frequency). To separate both, we thus need a pair of filters: a low-pass filter to obtain the approximation A, and a high-pass filter to estimate its details D. The **trends** contained in the signal are identified by the approximation coefficients (A). The **periodic signals** are identified by the details coefficients (D).

2. Allan Variance Analysis

❖ The **Allan variance** of coordinate residuals, for a given time interval, is computed by averaging coordinate the residuals over that interval and computing the variance of differences between adjacent averaged values. The Allan variance of a time series X_i with k items and sampling time τ is defined by:

$$\hat{\sigma}_X^2(\tau) = \frac{1}{2} < (\overline{X}_{k+1} - \overline{X}_k)^2 >$$

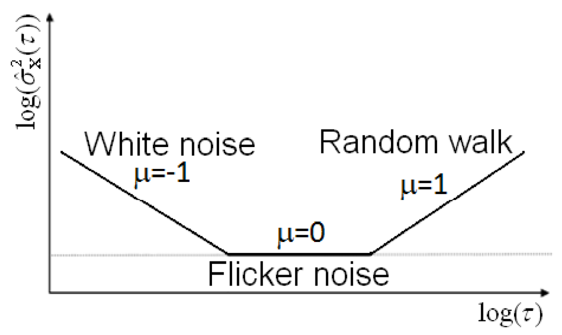
❖ The **noise type** of the time series can be determined from the slope μ of the Allan variance graph according to the time of sampling τ :

$$\log(\hat{\sigma}_X^2(\tau)) = \mu \log(\tau) \quad \text{for} \quad \tau = \tau_0, 2\tau_0, 4\tau_0, \ldots \qquad \tau_0 \text{ is a constant time interval of measurement}$$

White noise: random errors affecting the measurements (independent of time).

Flicker noise: due to local tectonics, instruments defects, analysis strategy.

Random walk: caused by the gaps in a time series.



❖ The **noise level** is measured by the Allan deviation (square-root of the estimated Allan variance) for a one-year sampling time.

3. Data description

➢ Weekly solutions of coordinate residuals sets of GPS-DORIS collocation sites.

➢ The GPS series are provided by AIUB Analysis centre "CODE" o f th e IGS using the BERNES Software.

➢ The DORIS series are provided by IGN/JPL, using the GIPSY-OASIS II software package.

➢ The GPS-DORIS time series are referred to ITRF2000, and

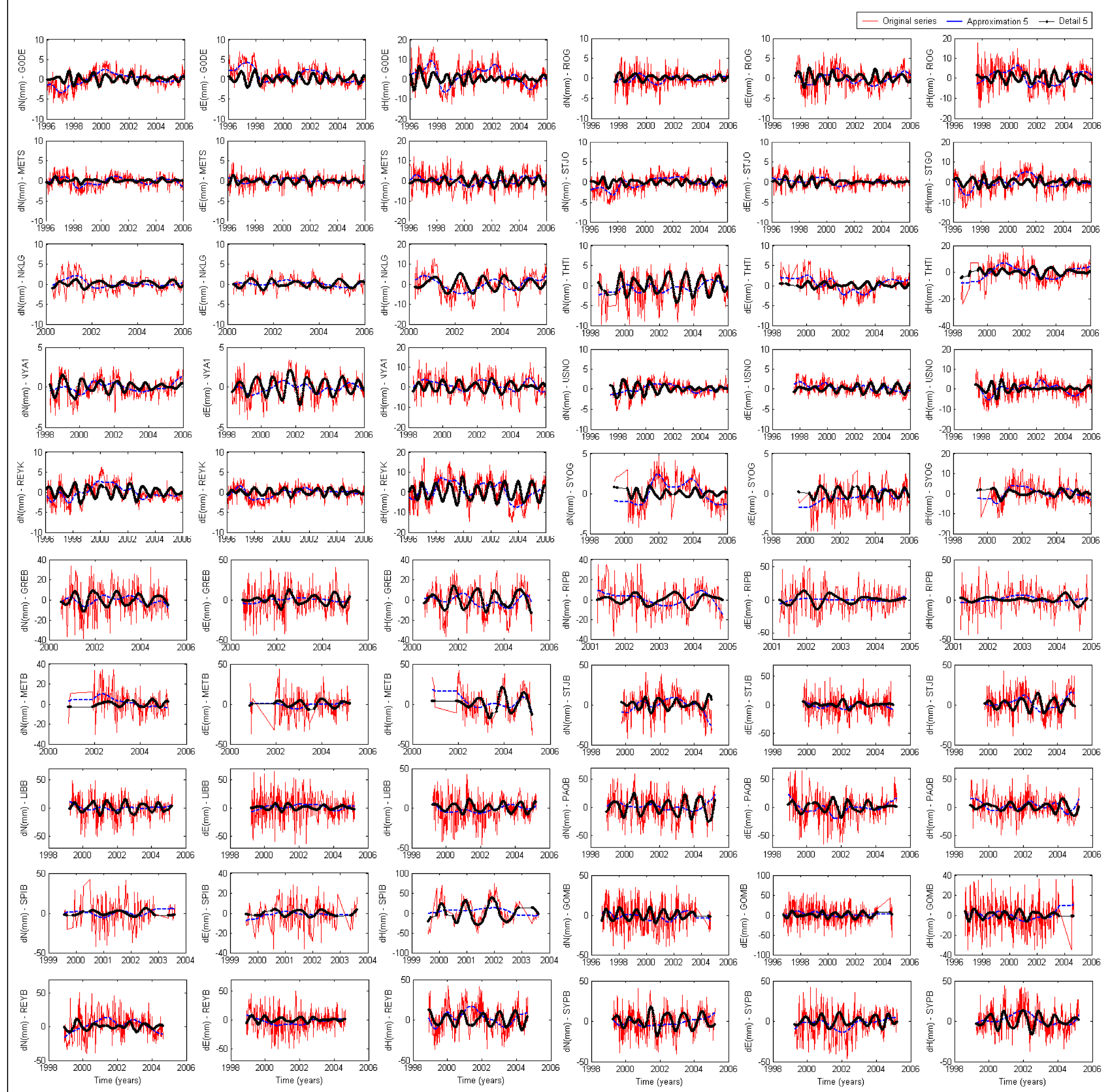
➢ expressed in the local geodetic reference frame (dN : North component, dE : East component and dH : Vertical component).

GPS-DORIS collocation sites selected in this study

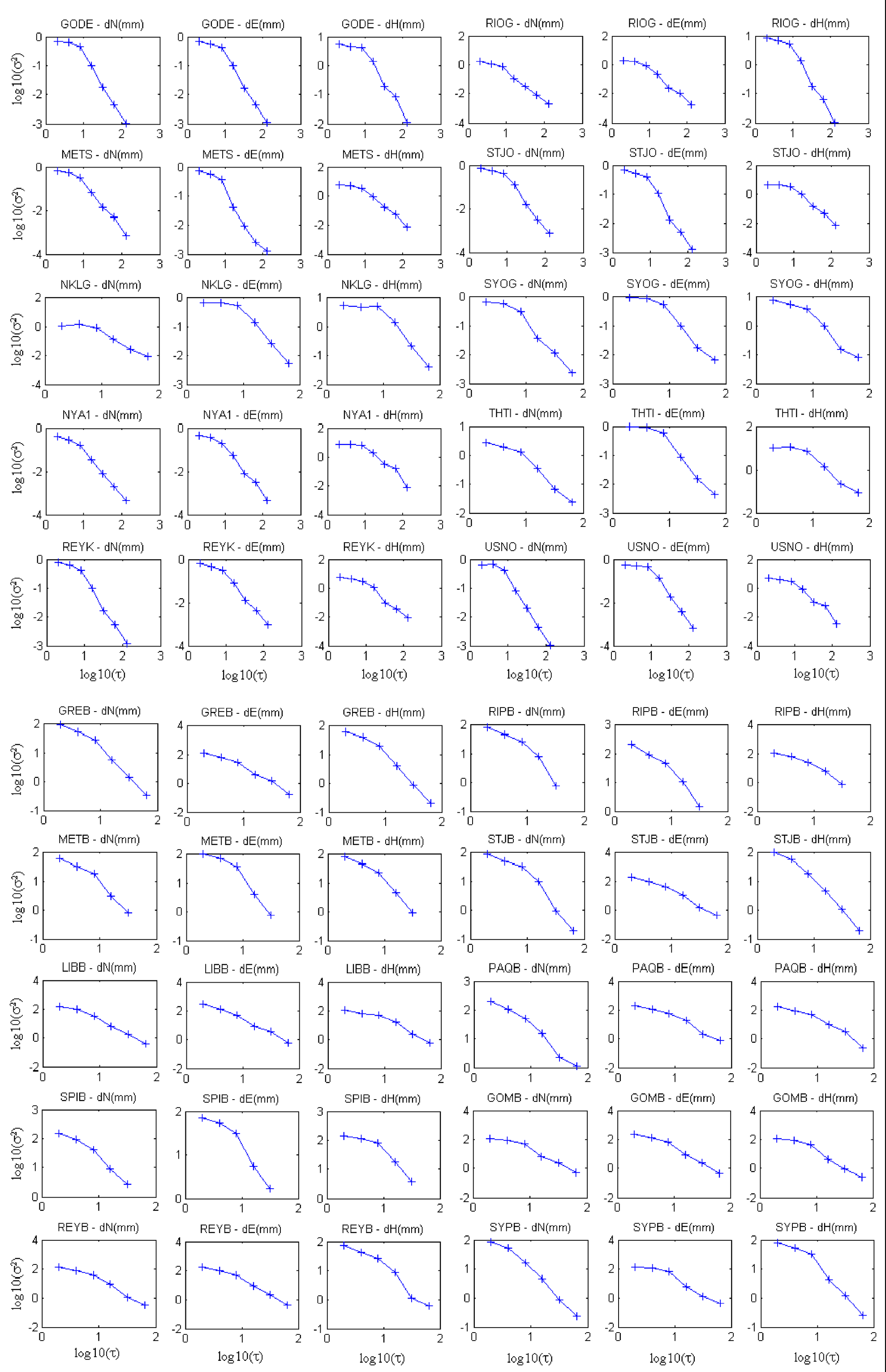
Acronym GPS	Acronym DORIS	Site	Country	Lat, deg	Long, deg
GODE	GREB	Greenblet	United-states	38.9	283.2
METS	METB	Metsahovi	Finland	60.2	24.7
NKLG	LIBB	Libreville	Gabon	0.3	9.7
NYA1	SPIB	Ny-Alesund	Norway	78.9	11.9
REYK	REYB	Reykjavik	Island	64.2	338.0
RIOG	RIPB	Rio Grande	Argentina	-53.8	292.2
STJO	STJB	St John's	Canada	47.6	307.3
THTI	PAQB	Papeet	France (Tahiti)	43.6	1.0
USNO	GOMB	Goldstone	United-states	35.3	243.2
SYOG	SYPB	Syowa	Antarctica	-69.00	39.58

4. Results and Conclusions

Original time series of studied GPS-DORIS collocated stations and their decompositions at level 5



Allan variances of components (North, East and Vertical) of studied GPS-DORIS collocated stations



Allan deviation for a one-year sampling time (noise level) of studied time series after removing their periodic signals

GPS Stations	Noise level (mm) dN	dE	dH	DORIS Stations	Noise level (mm) dN	dE	dH
GODE	0.8	1.1	3.3	GREB	2.7	1.7	3.1
METS	0.7	0.3	1.1	METB	4.0	2.3	2.0
NKLG	0.7	0.4	2.4	LIBB	1.2	3.2	2.8
NYA1	0.4	0.4	1.8	SPIB	1.4	1.2	3.7
REYK	0.9	0.7	3.1	REYB	5.2	3.4	5.6
RIOG	0.6	1.0	2.4	RIPB	4.5	1.0	3.0
STJO	0.7	0.5	2.0	STJB	4.1	1.9	6.0
THTI	0.6	1.1	3.2	PAQB	2.6	4.9	3.3
USNO	0.5	0.4	1.5	GOMB	3.0	2.6	2.6
SYOG	1.0	0.2	1.8	SYPB	2.3	4.5	5.4

Conclusion

- The studied GPS-DORIS time series contain an annual signal.
- The studied time series does not contain a clear linear trend (ascendant or descendant).
- The noise type, inferred from the slope of the Allan graph, is a combination of flicker and white noise, while the DORIS time series have a white noise.
- The noise level measured by the Allan deviation for a one-year sampling time of the non-linear, non seasonal coordinate time series, shows that the GPS stations are more stable than the DORIS stations.

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