Determination of realistic uplift rate and noise assessment using GNSS coordinate time series

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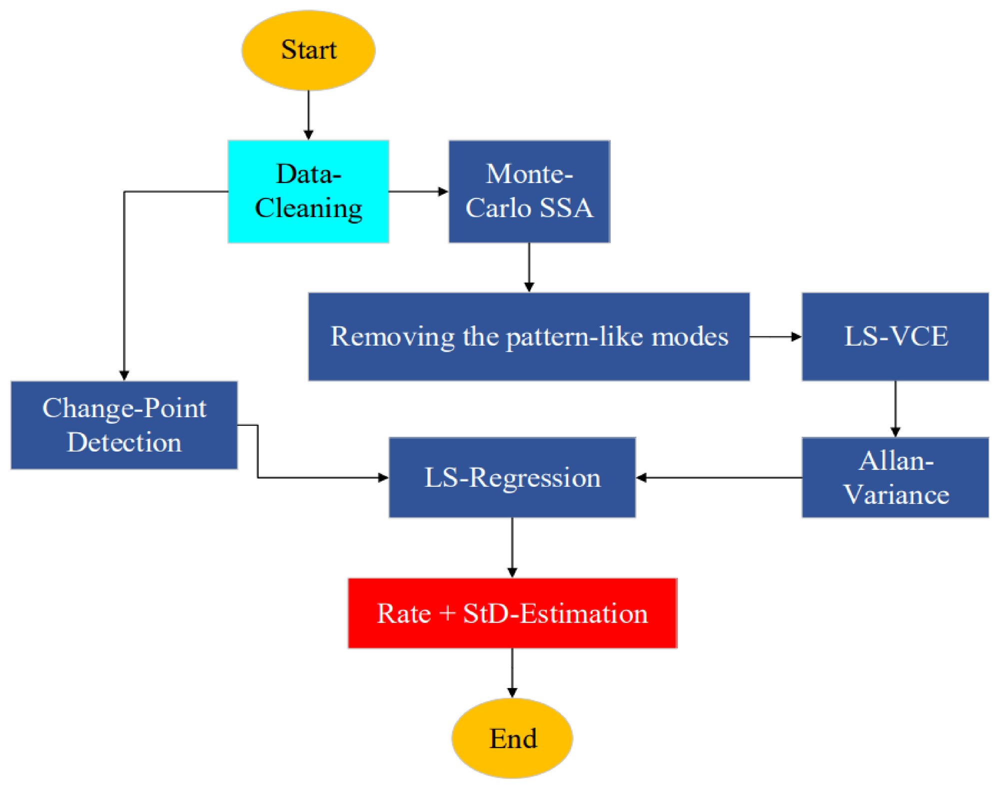
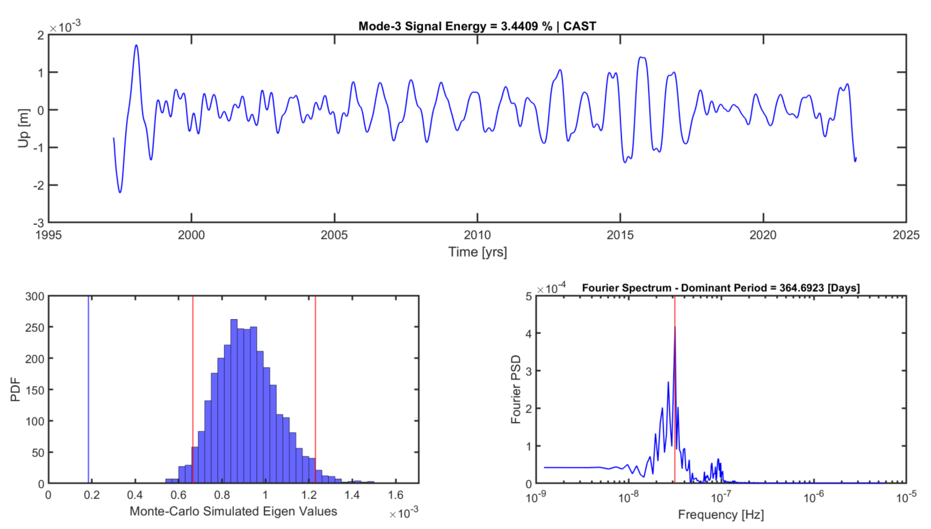
Introduction

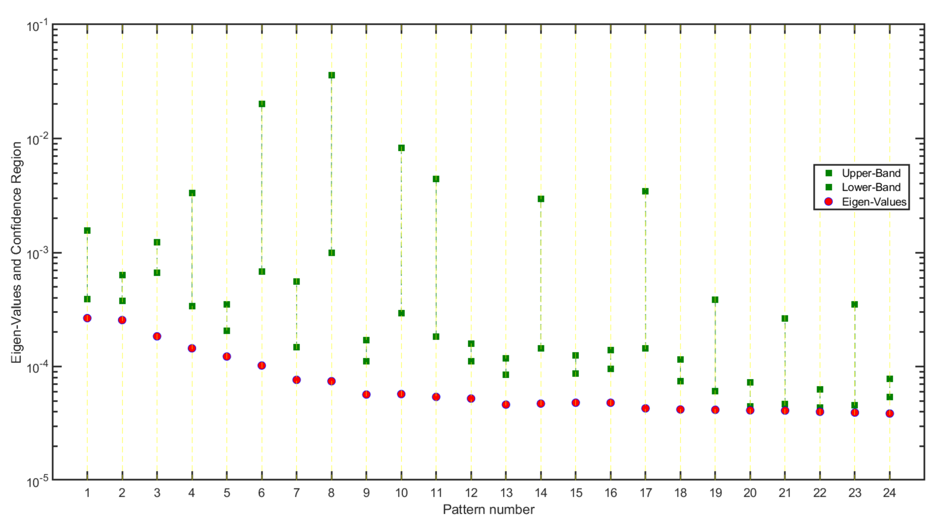
In this contribution, we employed Monte-Carlo Singular Spectrum Analysis (Monte-Carlo SSA) to decompose the time series into the pattern-like modes. The aforementioned modes are removed from the main signal (Khazraei & Amiri-Simkooei 2019). Concerning the changes in the time series rate, Bayesian Estimator of Abrupt change, Seasonal change, and Trend (BEAST) method is taken into account to detect the change points (Zhao et al. 2019). For the primary analysis and noise characteristics assessment to the residual of the GNSS coordinate time series we make use of Least Squares-Variance Component Estimation (LS-VCE) method (Amiri-Simkooei et al. 2007). Furthermore, regarding the non-stationary behavior in the time series noise, Allan-Variance is estimated and analyzed partly according to the change points derived from the BEAST method. The error model for uplift rate derived from the Allan-Variance analysis named Allan Variance of Rate (AVR) and the square root of it, is named Allan DEViation (ADEV) (Hackl et al. 2011). Finally, the Linear Least-Squares (LS) regression is performed to estimate the uplift rate from the time series residual including the trend.

I. Methodology



II. Monte-Carlo SSA signal Separation





Significant annual pattern-like from SSA

- Top: Annual pattern-like time series
- Bottom-Left: Monte-Carlo simulated distribution and confidence region
- Bottom-Right: Fourier spectrum of the pattern-like time series

Confidence interval for eigenvalues (Monte-Carlo test)

- Red points: Eigenvalues derived from SSA
- Green points: Monte-Carlo simulated confidence interval

III. Allan Variance results

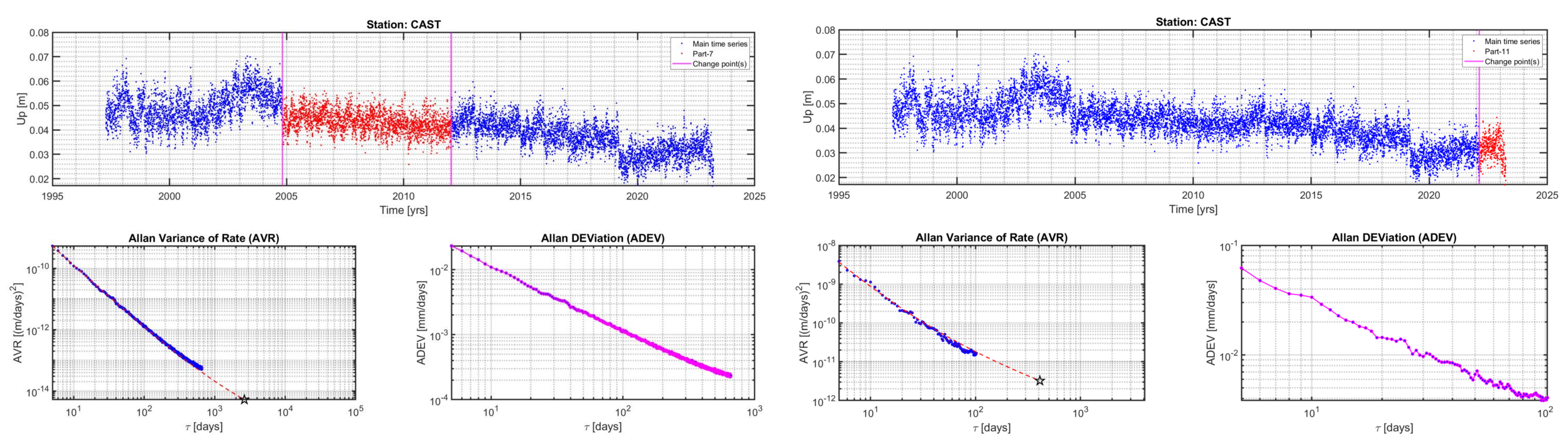


Figure description:

- Top: Partitioned time series
- Bottom-Left: AVAR fitting model: Estimated AVAR for the partitioned time-span
- Bottom-Right: Estimated ADEV

Figures:

Left: In the middle of time series
Right: At the end of time series

IV. Fitted Error model to AVAR

1st difference: $\bar{y}_i = \frac{x_{i+1} - x_i}{\tau}$ 2nd difference: $\bar{z}_i = \frac{y_{i+1} - y_i}{\tau}$

Allan-Variance of Rate

$\bar{z}_i = \bar{y}_{i+1} - \bar{y}_i$

Using error propagation law $\Longrightarrow Q_{\bar{z}_i} = Q_{\bar{y}_{i+1}} + Q_{\bar{y}_i}$

$$\sigma^2(\tau) = \frac{1}{2(N-2m)trace(Q_{\bar{z}}^{-1})} \bar{z}^T Q_{\bar{z}}^{-1} \bar{z}$$

Error Model

$$\sigma^2(\tau) = \alpha_{\omega n}\tau^{-3} + \alpha_f \tau^{-2} + \alpha_{r\omega}\tau^{-1}$$

V. Allan-Variance per Sub-Interval

Time-Span	White	Flicker	Random-Walk	StD
1.0329	***	0.1919	***	0.4244
0.6301	0.1458	0.2724	0.005127	1.9138
1.0493	0.4813	0.0769	0.003472	1.1315
1.0548	0.1163	0.1179	0.00137	0.7612
2.1973	0.0270	0.0565	***	0.1083
1.5840	***	0.0799	***	0.1783
7.2131	0.0100	0.0115	9.34E-06	0.0263
5.1234	0.0268	0.0137	7.24E-05	0.0754
2.0301	***	0.0432	***	0.1025
2.9233	0.1130	0.0139	0.000433	0.2361
1.1233	0.1151	0.0640	0.001166	0.6561

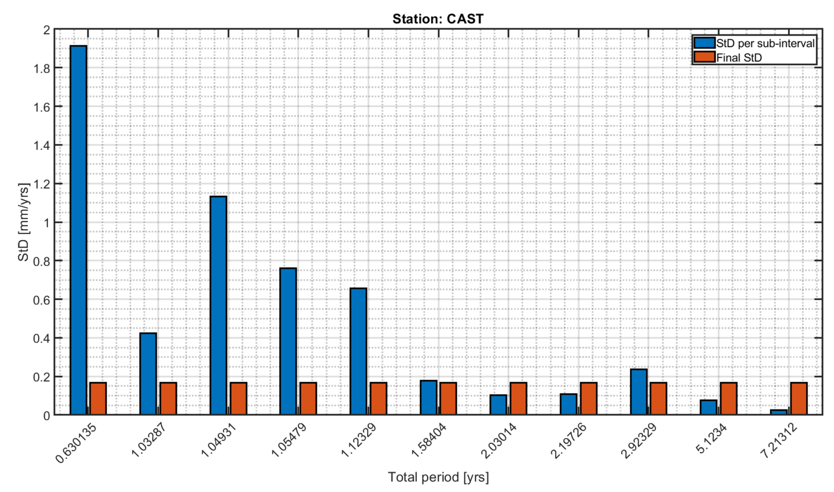


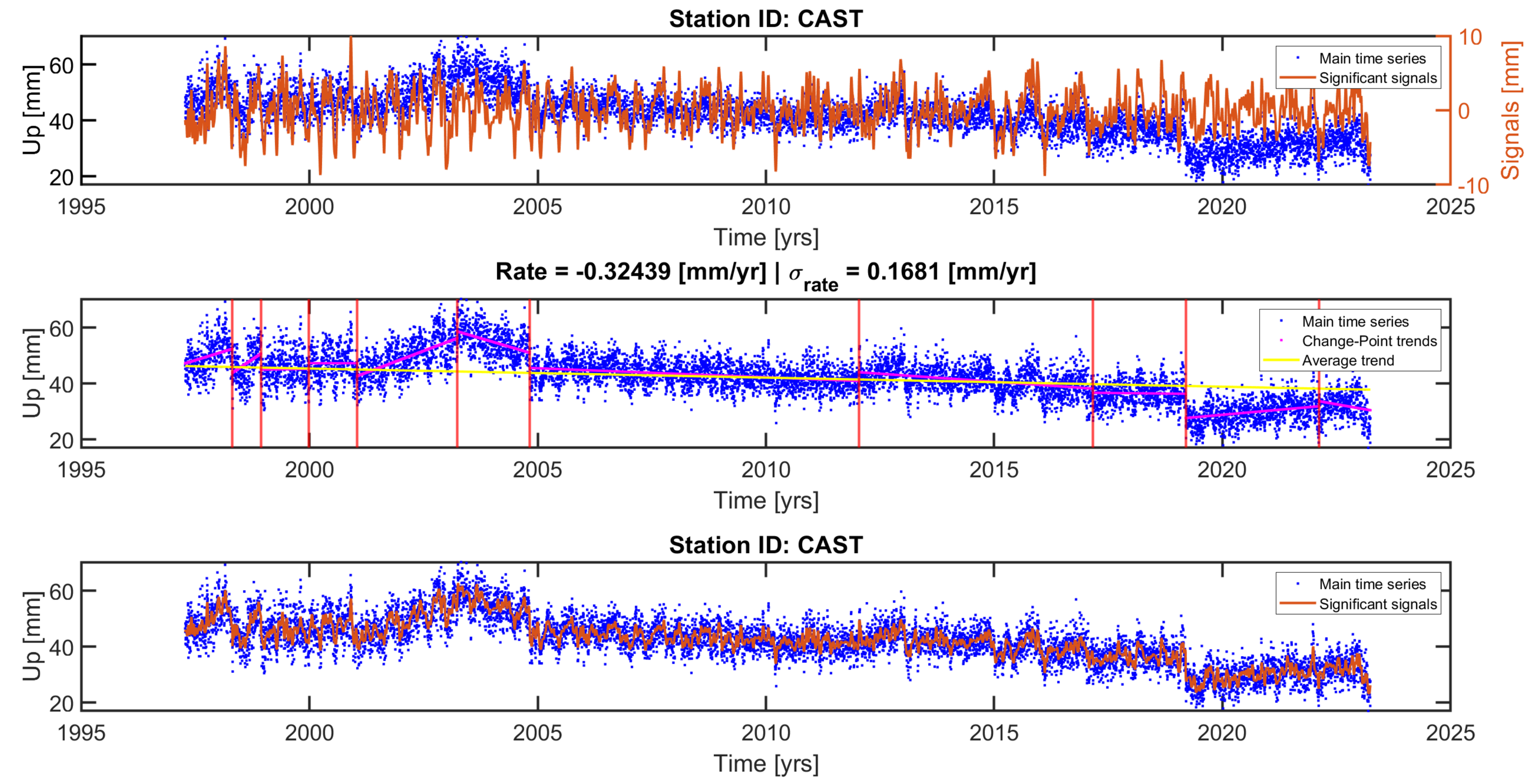
Table description:

- Time-Span: yrs
- White: $(mm)^2.day$
- Flicker: $(mm)^2$
- Random-Walk: $(mm)^2/day$

Table statistics:

- F: 4 parts
- W+F+RW: 6 parts
- F+RW: 1 part

VI. Uplift rate and numerical results



Subplot-1

- Left axis: Main time series amplitude
- Right axis: significant pattern-like harmonics amplitude

Subplot-2

- Main time series
- Trend per sub-interval (concerning the change points)
- Average trend

Subplot-3

- Main time series
- Harmonics + Trend

VII. Conclusion

Concerning the realistic estimation of the vertical velocity derived from GNSS coordinate time series, it is necessary to employ signal processing methods and additionally noise assessment to have a well-fitted model for the dataset. Allan variance is a well-established one to derive the variance of rate. In order to estimate a realistic uncertainty of rate, there is also this possibility to incorporate the other uncertainties caused by the other error-budget using error-propagation law which is already presented in this poster.

In this work-in-progress study, it is planned to have a more complex method to determine more realistic noise characteristic for the considered time series and an alternative strategy instead of simple linear LS regression.

Acknowledgement

We would like to acknowledge National Geodetic Laboratory (NGL) for the data availability. The time series used in this contribution (station ID: CAST) is provided by NGL aligned to IGS14 realization (Rebischung et al. 2016) of the ITRF14 reference frame (Altamimi et al. 2016) is accessible via the link: http://geodesy.unr.edu/gps_timeseries/.

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