

The quality of velocities from GNSS campaign measurements when gaps in data exist

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Motivation

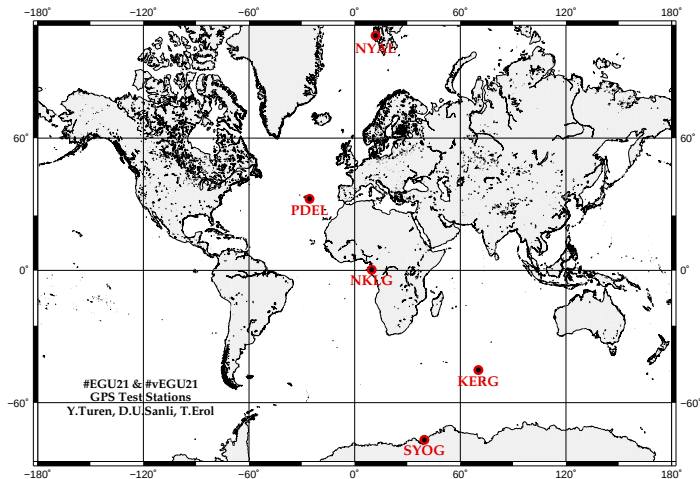
Motivation

In this study, we investigate the effect of gaps in data on the accuracy of deformation rates produced from GNSS campaign measurements. Our motivation in investigating gaps in data is that campaign GNSS time series might not be collected regularly due to various constraints in real life conditions.

Testing for Analysis Results

We tested whether the velocities obtained from GNSS campaign series containing data gaps differ significantly from the velocities derived from continuous data which is taken as to be the “truth”.

Test Stations



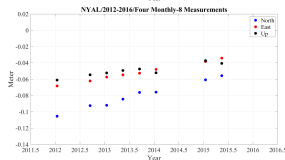
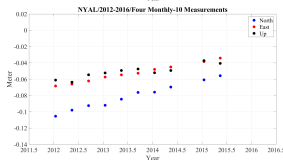
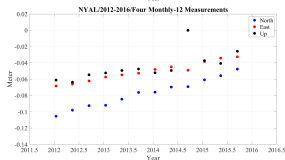
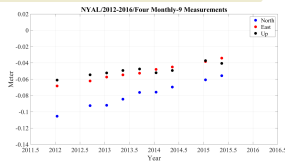
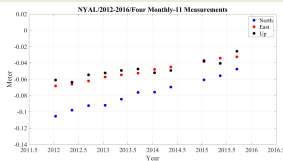
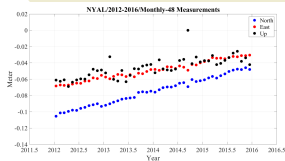
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Sampling Campaign Data

Data Generating

We used the baseline components produced from continuous GPS time series of JPL, NASA from a global network of the IGS to generate data gaps. The solutions of the IGS continuous GNSS time series were decimated to the solutions of the campaign data sampled randomly from one to four measurement per three measurements per year.



Velocities and GPS Rate Errors

Calculating Velocities and GPS Rate Errors

The velocities are obtained via regression analysis. Furthermore, GPS rate errors are obtained depending on white noise (WN), flicker noise (FN) and white+flicker noise (WN+FN) using RMS values [Dixon et al., 2000].

Table-1. NYAL Station Velocities and GPS Rate Errors.

Station	Component	Data Set	Regression Analysis Result			Analysis Result Using RMS								
			Velocities	White Noise (WN)		White Noise (WN)	Flicker Noise (FN)	WN+FN		Amplitudes		Calculated RMS		
			b	σ	Test results	σ	Test results	σ	Test results	WN	FN			
NYAL 2012-2016	East	Continuous	9.81	0.03										
		Monthly-Campaign	9.99	0.23	0.77	0.29	0.60	0.44	0.40	0.53	0.33	1.17	1.50	1.77
		FourMonth-12 Measurements	9.91	0.54	0.18	0.35	0.27	0.54	0.18	0.64	0.15	1.41	1.82	2.08
		FourMonth-11 Measurements	10.13	0.15	2.11	0.07	4.87	0.08	4.14	0.10	3.15	0.26	0.26	0.58
		FourMonth-10 Measurements	10.20	0.19	2.07	0.07	5.50	0.08	4.57	0.11	3.51	0.28	0.28	0.60
		FourMonth-9 Measurements	10.00	0.17	1.06	0.04	4.11	0.04	4.23	0.06	2.95	0.18	0.15	0.47
		FourMonth-8 Measurements	10.14	0.22	1.49	0.06	5.44	0.07	4.78	0.09	3.59	0.24	0.23	0.55
	North	Continuous	14.77	0.03										
		Monthly-Campaign	14.74	0.21	-0.12	0.32	-0.08	0.59	-0.04	0.67	-0.04	1.27	1.99	1.64
		FourMonth-12 Measurements	14.44	0.57	-0.59	0.40	-0.83	0.78	-0.43	0.88	-0.38	1.61	2.63	2.21
		FourMonth-11 Measurements	14.67	0.21	-0.49	0.19	-0.55	0.31	-0.34	0.36	-0.29	0.76	1.04	0.81
		FourMonth-10 Measurements	14.66	0.27	-0.39	0.20	-0.53	0.33	-0.32	0.39	-0.27	0.80	1.12	0.88
		FourMonth-9 Measurements	14.92	0.28	0.54	0.18	0.83	0.29	0.51	0.34	0.44	0.73	0.99	0.76
		FourMonth-8 Measurements	14.76	0.38	-0.01	0.20	-0.03	0.33	-0.02	0.39	-0.01	0.80	1.13	0.89
Up	Continuous	7.93	0.14											
	Monthly-Campaign	7.68	1.03	-0.24	1.28	-0.20	3.21	-0.08	3.45	-0.07	5.11	10.85	8.17	
	FourMonth-12 Measurements	9.18	3.05	0.41	2.05	0.61	3.93	0.32	4.43	0.28	8.20	13.30	11.83	
	FourMonth-11 Measurements	7.93	0.98	0.00	0.35	0.01	2.34	0.00	2.36	0.00	1.40	7.91	3.76	
	FourMonth-10 Measurements	7.06	1.06	-0.82	0.28	-3.07	2.27	-0.38	2.29	-0.38	1.13	7.69	3.44	
	FourMonth-9 Measurements	6.43	1.27	-1.18	0.29	-5.17	2.28	-0.66	2.30	-0.65	1.16	7.72	3.48	
	FourMonth-8 Measurements	4.73	1.25	-2.56	0.57	-5.65	2.54	-1.26	2.60	-1.23	2.27	8.59	4.79	

Root Mean Square (RMS)

Calculating Velocities and RMS

We estimate the velocities using our linear regression model. The RMS values are computed via Equation (2).

Linear Regression Model

$$y(t) = a + bt + c_1 \sin\left(\frac{2\pi t}{T_1}\right) + d_1 \cos\left(\frac{2\pi t}{T_1}\right) + v(t); (T_i = \frac{1}{f_i}) \quad (1)$$

Root Mean Square (RMS)

$$RMS = \sqrt{\frac{\sum_{i=1}^n [y_i - (a + bt_i + c \sin(\omega t_i) + d \cos(\omega t_i))]^2}{n - 4}}; (\omega = 2\pi f_i) \quad (2)$$

GPS Rate Errors depending on RMS

Calculating Noise Amplitudes and GPS Rate Errors

The amplitudes of all components are calculated via Equation (3). All of the GPS rate errors are also estimated by Equation (4) using its first and second terms as shown in Table-1 [Dixon et al., 2000].

Amplitude Values

$$\begin{aligned}
 n_{WN} &= 0.613[\text{WRMS}_n] + 0.259 \\
 e_{WN} &= 0.767[\text{WRMS}_e] - 0.182 \\
 u_{WN} &= 0.843[\text{WRMS}_u] - 1.772 \\
 n_{FN} &= 1.139[\text{WRMS}_n] + 0.117 \\
 e_{FN} &= 1.041[\text{WRMS}_e] - 0.342 \\
 u_{FN} &= 0.668[\text{WRMS}_u] + 5.394
 \end{aligned} \quad (3)$$

GPS Rate Error

$$\sigma_r^2 \cong \frac{12\sigma_w^2}{gT^3} + \frac{a\sigma_f^2}{g^b T^2} + \frac{\sigma_{rw}^2}{gT} \quad (4)$$

Accuracy of GPS Rate Errors

Average of White and Flicker Noise GPS Rate Errors

Average values for white and flicker noise GPS rate errors are computed from the results of regression analysis and results of [Dixon et al., 2000] equations.

Table-2. Average of GPS Rate Errors from all Stations.

Component	Regression Analysis Results	Analysis Results Using RMS [Dixon et al., 2000]		
	White Noise (WN)	White Noise (WN)	Flicker Noise (FN)	White+Flicker Noise (WN+FN)
	σ (mm/year)	σ (mm/year)	σ (mm/year)	σ (mm/year)
<i>East</i>	0.55	0.30	0.46	0.55
<i>North</i>	0.51	0.32	0.61	0.69
<i>Up</i>	1.83	0.86	2.82	2.98

Student's t Test

Test Statistics

Eventually we tested whether the velocities obtained from monthly, four monthly and four monthly solutions containing gaps differ significantly from the velocities derived from continuous GPS.

Table-3. Value of Test Statistic and Critical Region [Turen and Sanli, 2019].

	Value of Test Statistic	Critical Region
b_d = Daily velocity. b_m = Monthly (or Four-Monthly) velocity. s = Unit variance from LSE. q_i = Element of the cofactor matrix.	$t = \frac{b_m - b_d}{s\sqrt{q_i q_i}}$	$t > 1.96 \text{ or } t < -1.96$

Test Rates

Table-4. Percentiles Variation of Significant Rates as per Four Monthly 12 Measurements.

Component	Data Set	Regression Analysis Result	Analysis Result Using RMS		
		White Noise (WN) (%)	White Noise (WN) (%)	Flicker Noise (FN) (%)	White+Flicker Noise WN+FN (%)
East	FourMonth-11 Measurements	20.0	0.0	20.0	20.0
	FourMonth-10 Measurements	20.0	0.0	20.0	20.0
	FourMonth-9 Measurements	0.0	0.0	20.0	20.0
	FourMonth-8 Measurements	0.0	0.0	20.0	20.0
North	FourMonth-11 Measurements	20.0	20.0	0.0	0.0
	FourMonth-10 Measurements	20.0	0.0	0.0	0.0
	FourMonth-9 Measurements	20.0	0.0	0.0	0.0
	FourMonth-8 Measurements	20.0	0.0	0.0	0.0
Up	FourMonth-11 Measurements	0.0	20.0	0.0	0.0
	FourMonth-10 Measurements	0.0	40.0	0.0	0.0
	FourMonth-9 Measurements	0.0	60.0	0.0	0.0
	FourMonth-8 Measurements	20.0	60.0	0.0	0.0

Discussions

- Gaps in data cause a change in the significance of the velocity.
- Percentiles are different for white noise, flicker noise, and white + flicker noise.
- Judgement made using the white noise from the regression analysis differs from that of RMS computation. [Aydin et al., 2021] state the judgement made using the white noise fails to represent the actual rate of change most of the time.
- This could be ascribed to the bias denoted by [Williams, 2003].
- The experiment needs to be repeated once producing our own noise amplitudes from the IGS continuous data.

Acknowledgments

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References



S. D. P. Williams (2003)

The effect of coloured noise on the uncertainties of rates estimated from geodetic time series

Journal of Geodesy 76(-), 483 – 494.



Timothy H . Dixon, Meghan Miller, Frederic Farina ,Hongzhi Wang and Daniel Johnson (2000)

Present-day motion of the Sierra Nevada block and some tectonic implications for the Basin and Range province, North American Cordillera

Tectonics 9(1), 1 – 24.



Yener Turen and D. Ugur Sanli (2019)

Accuracy of Deformation Rates from Campaign GPS Surveys Considering Extended Observation Session and Antenna Set-Up Errors

Remote Sensing 11(10), 1225.



Cuneyt Aydin, Huseyin Duman, Ozge Gunes and D. Ugur Sanli (2021)

Effect of Stochastic Model Errors on Significance Test for Velocities in Analysis of GPS Position Time Series

Journal of Surveying Engineering 147(1), 04020025.

End of Presentation

Thanks for your attention!

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