Correlation of the stochastic proprieties of cGNSS time series with the local environment

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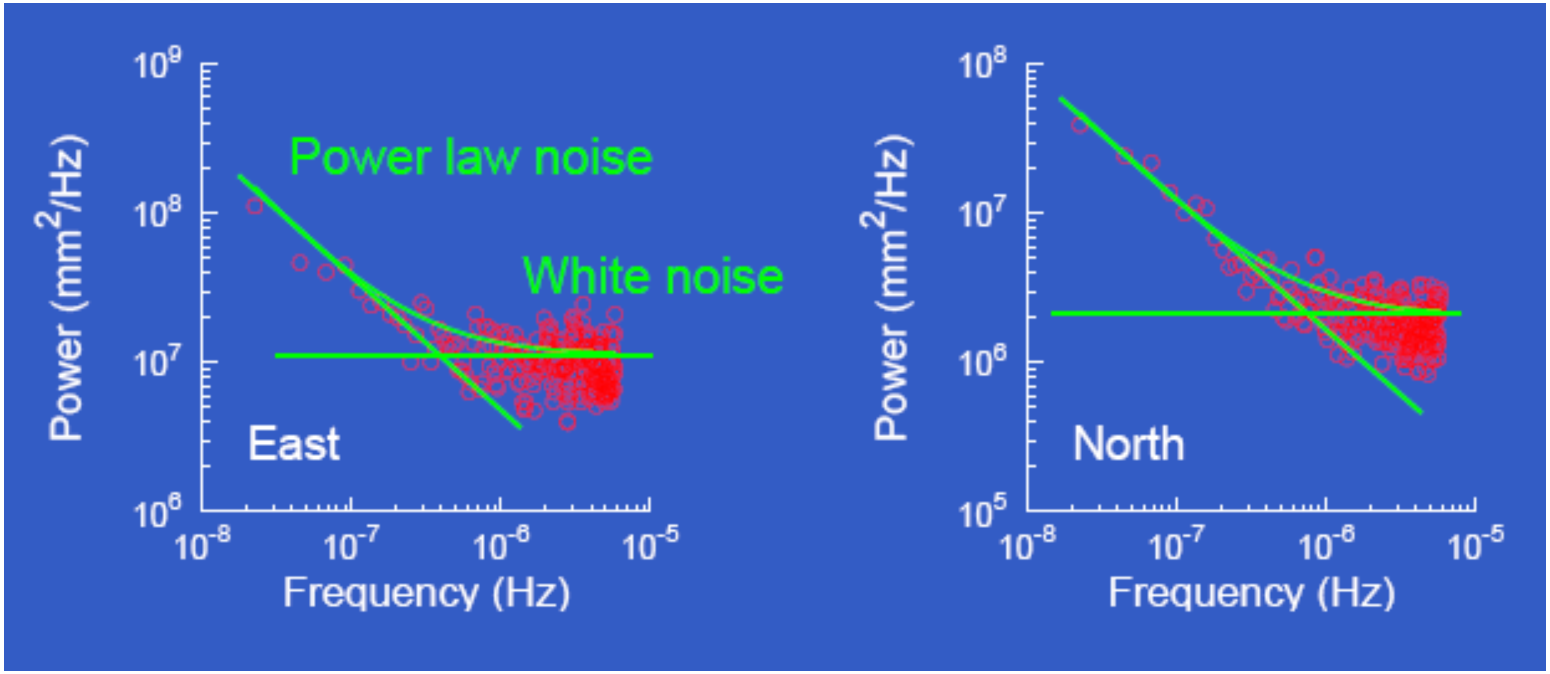
Background

- **GNSS measurements contain temporal correlated noise, mostly represented by a power-law plus white noise model.**
- **This increases the uncertainty of the estimated motion by a factor of ~5-10**



White noise – independent observations

Power law noise – (temporal) correlated observations

Previous Works

Williams et al. (2004)

- Common mode (processing dependent)
- Deep-drilled braced monument significant better.

- 414 sites
- Average data-span < 4yrs

Beaven (2005)

- noise properties similar between monument types (> 4.5yr)

- 15 concrete sites (New Zealand)
- Average data-span: 4.15yrs

Santamaría-Gómez et al. (2011)

Table 4. Percentage of Stations of ULR4 Solution in Which Stochastic Properties Are Described By Specific Colored Noise Model Component

Noise Model	Percentage of Stations
FN	71%
PL	24%
GM	2%
RW	2%
FN+RW	1%
GG	0%

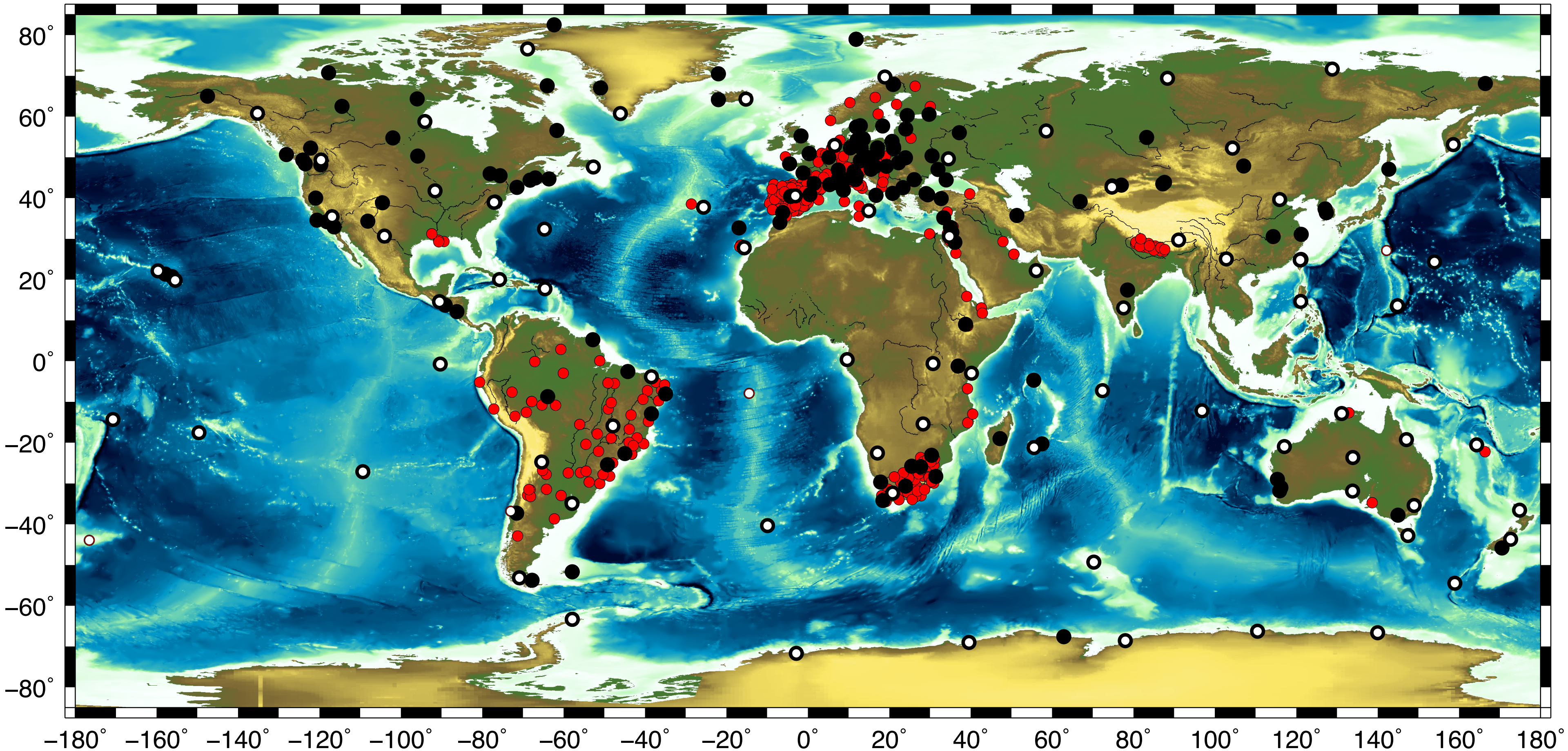
- 275 sites
- Data-span: 2.5-13yrs
- Weekly solutions
- Vertical component

Question

- **Is the conventional power-law plus white noise model still the best stochastic model?**
- **Or should different stochastic models be applied depending of the local environment of the station, in particular of the type of monument?**
  - **Alternatives to the PL+WN (Power-Law + White Noise) analyzed here:**
    - **GGM (Generalized Gauss Markov)**
    - **ARMA (Auto Regressive Moving Average)**

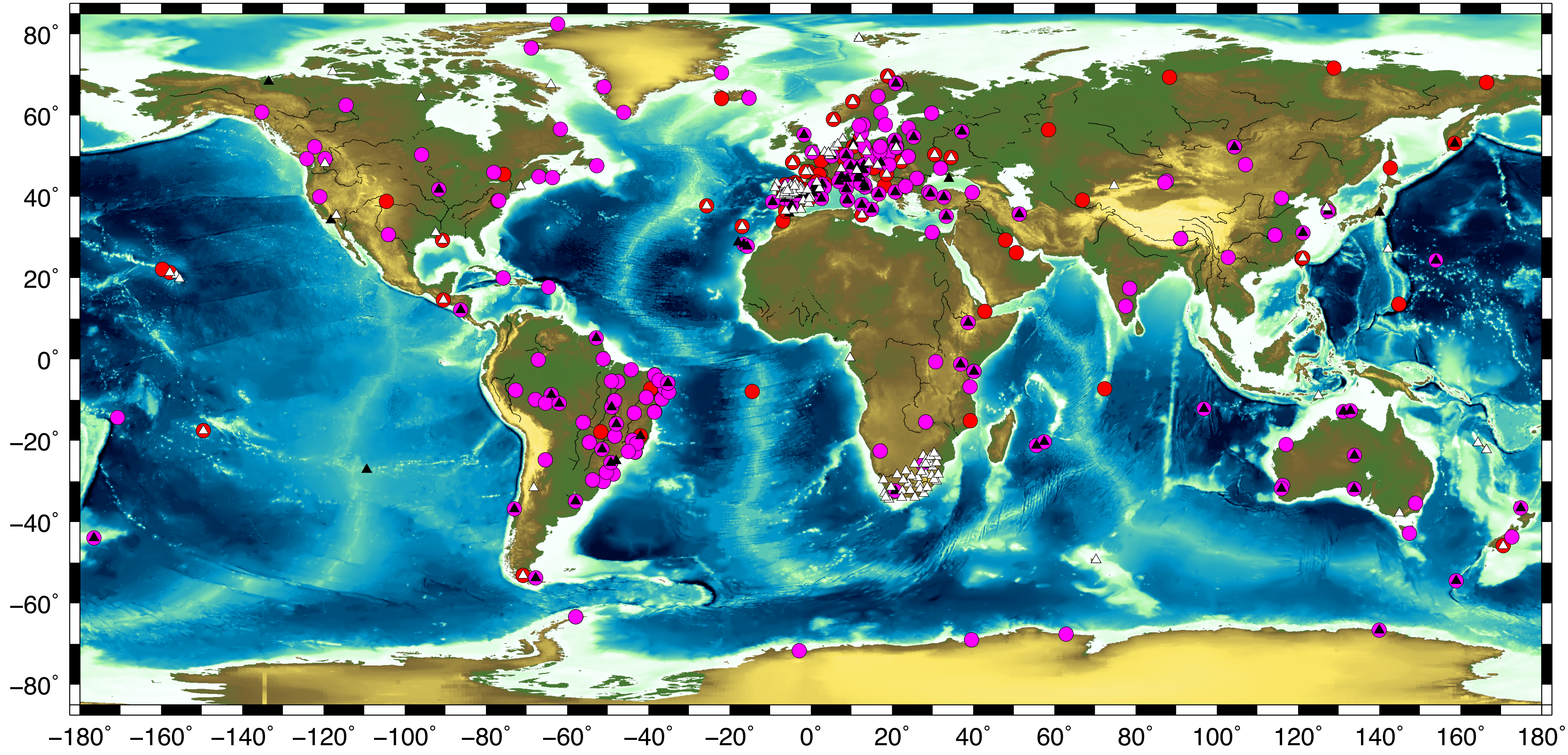
Analyzed Network

- **595 cGNSS sites with a data-span larger than 7.5 years**
  - **227 IGS sites (black dots)**
  - **81 IGS08 core sites (white dots)**



Monument Type

- **161 Roof (red dots)**
- **193 Pillar (purple dots)**
- **126 Concrete (black triangles)**
- **142 Metal mast (white triangles)**

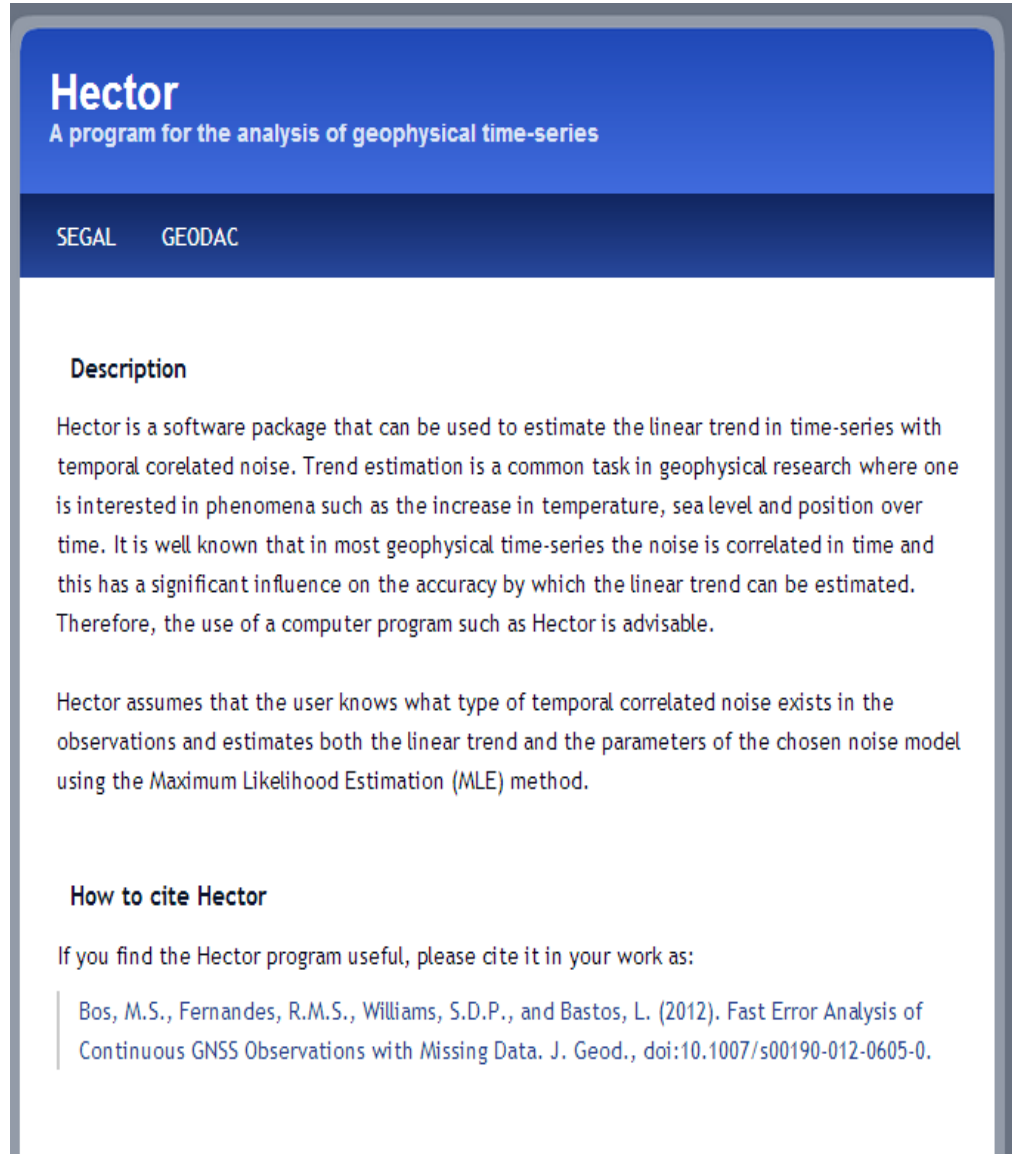


HECTOR – Time-Series Analysis (http://segal.ubi.pt/hector/)

Computation of:

- **Secular Trend**
- **Seasonal Signals**
- **Offsets**
- **Exponential / Logarithmic Post-relaxation**
- **Power-law errors**
- **Spectrum Index**

HECTOR uses the maximum likelihood method, which permits to determine how much a stochastic model performs better over another.



Hector

A program for the analysis of geophysical time-series

SEGAL GEODAC

Description

Hector is a software package that can be used to estimate the linear trend in time-series with temporal corelated noise. Trend estimation is a common task in geophysical research where one is interested in phenomena such as the increase in temperature, sea level and position over time. It is well known that in most geophysical time-series the noise is correlated in time and this has a significant influence on the accuracy by which the linear trend can be estimated. Therefore, the use of a computer program such as Hector is advisable.

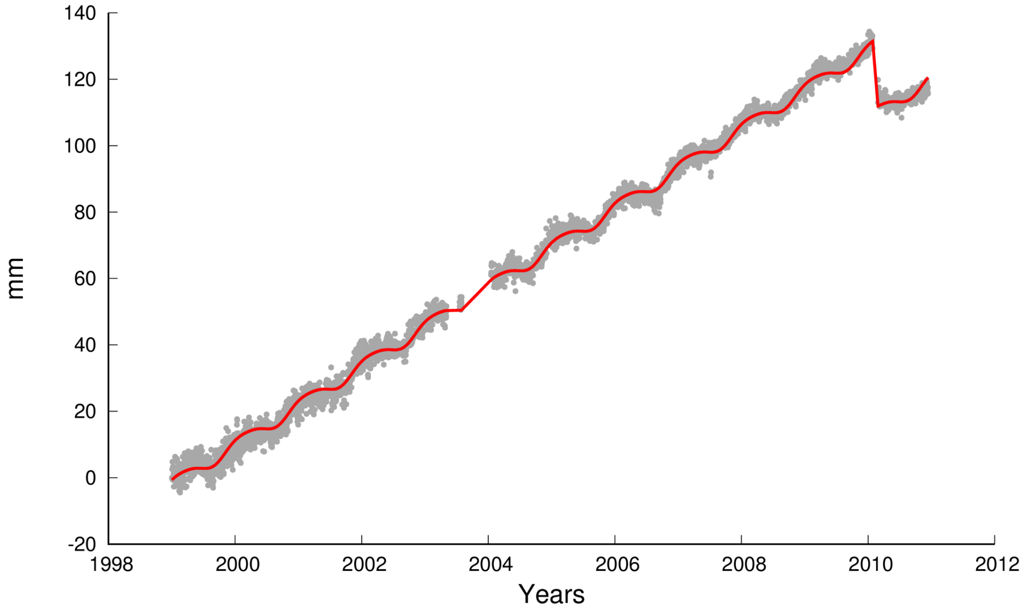
Hector assumes that the user knows what type of temporal correlated noise exists in the observations and estimates both the linear trend and the parameters of the chosen noise model using the Maximum Likelihood Estimation (MLE) method.

How to cite Hector

If you find the Hector program useful, please cite it in your work as:

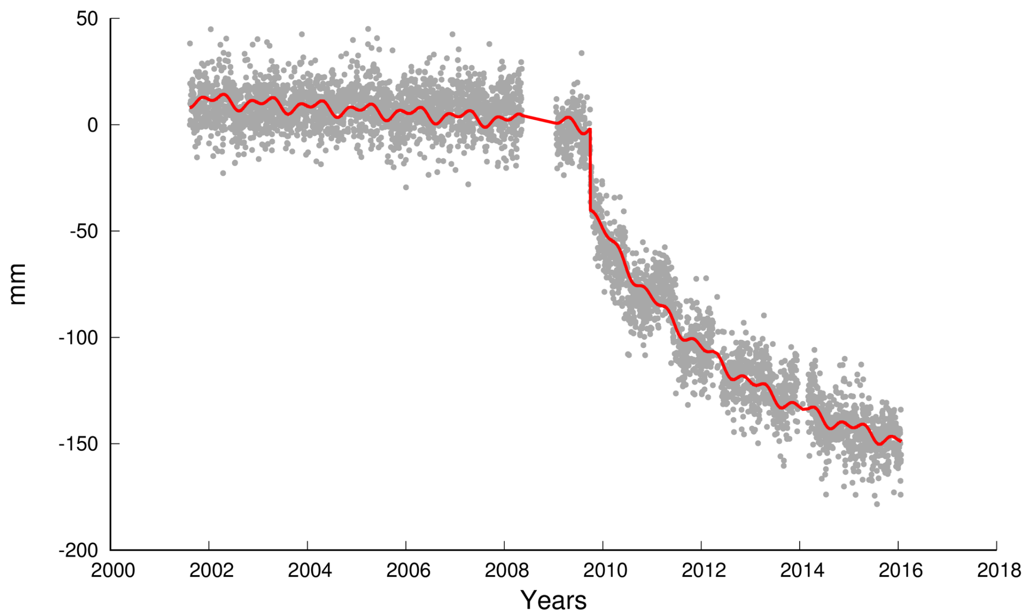
Bos, M.S., Fernandes, R.M.S., Williams, S.D.P., and Bastos, L. (2012). Fast Error Analysis of Continuous GNSS Observations with Missing Data. J. Geod., doi:10.1007/s00190-012-0605-0.

Time-Series (examples)



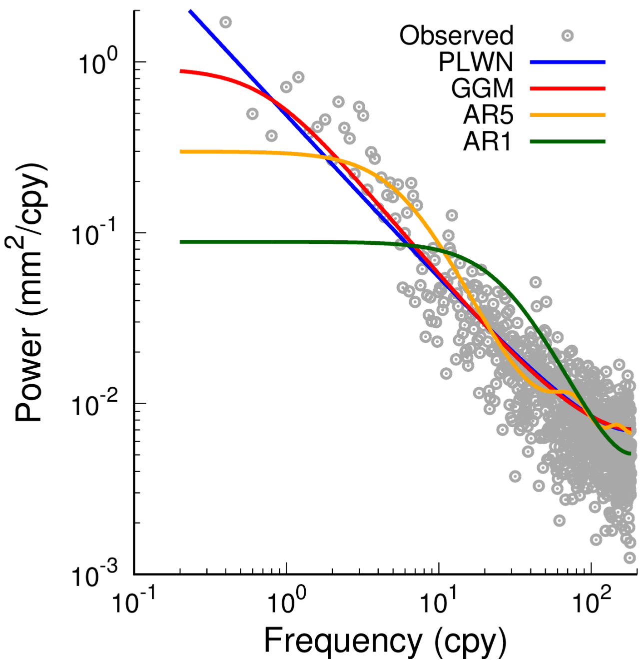
- **CFAG (Argentina)**
- **North Component**

- **ASPA (American Samoa)**
- **Up Component**



Methodology

- **Processing of the 3 components of the positional time-series, using 4 different noise models:**
  - **PL+WN**
  - **GGM**
  - **ARMA (1 + 0)**
  - **ARMA (5 + 0)**



- **Now that time-series begin to have data-spans of >20 years, we wonder if the power-law behavior in the power spectrum at the low frequencies is still an adequate noise model or if already some flattening of the noise is visible.**
- **That is why we test for the ARMA (with 1 and 5 parameters) and the GGM. The latter mimics power-law noise but flattens below a chosen threshold.**

Methodology

- **Comparative analysis, including for several sub-networks:**
  - **IGS / IGS08 core / No IGS**
  - **Roof vs Pillar & Concrete vs Steel Mast**

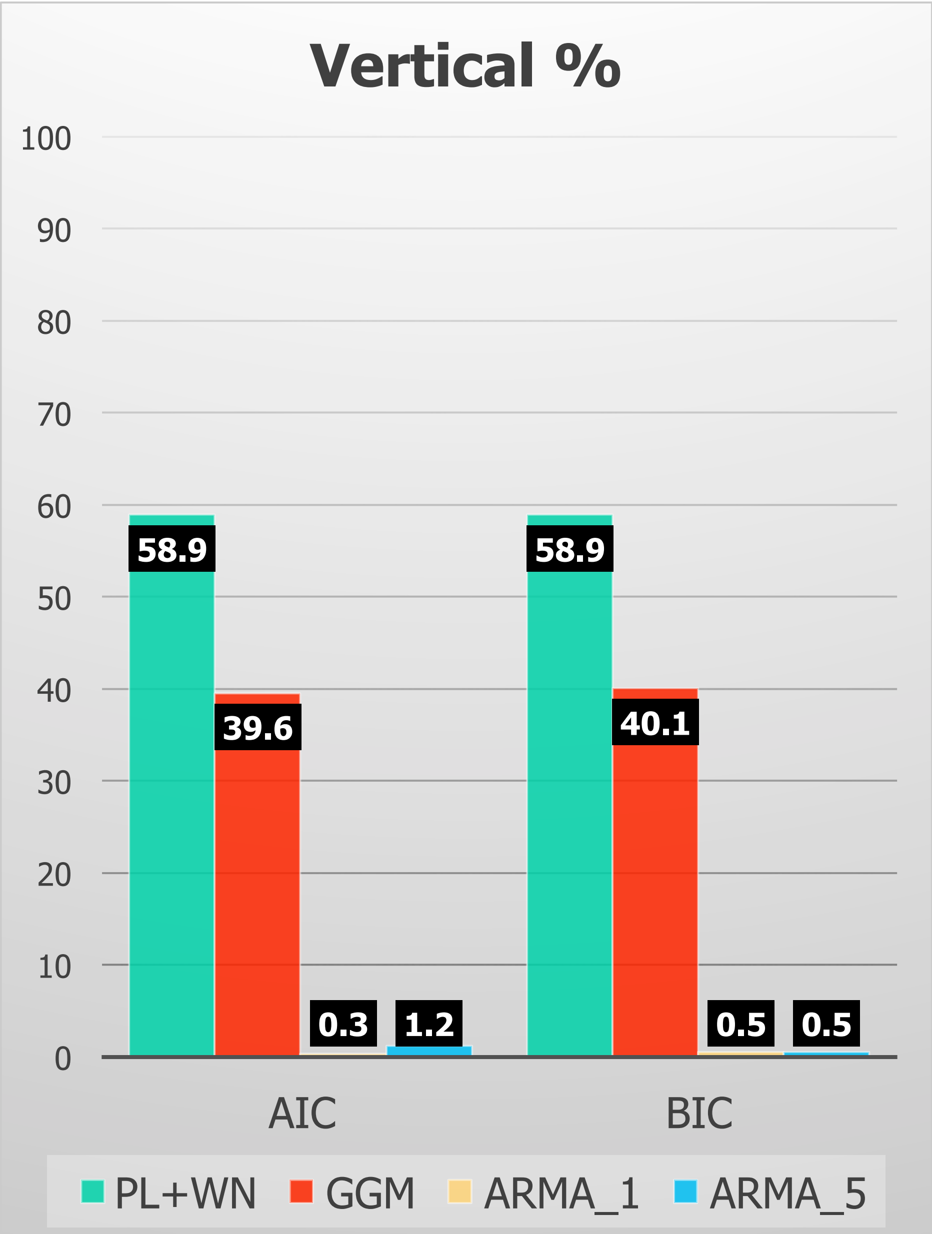
- **We look at *Akaike (AIC) and Bayesian (BIC) Information Criteria***
  - **AIC/BIC are used to evaluate how well a noise model describes the stochastic properties of the noise in the GNSS time series.**

$$AIC = 2k - 2\ln(L)$$
$$BIC = \ln(n)k - 2\ln(L)$$

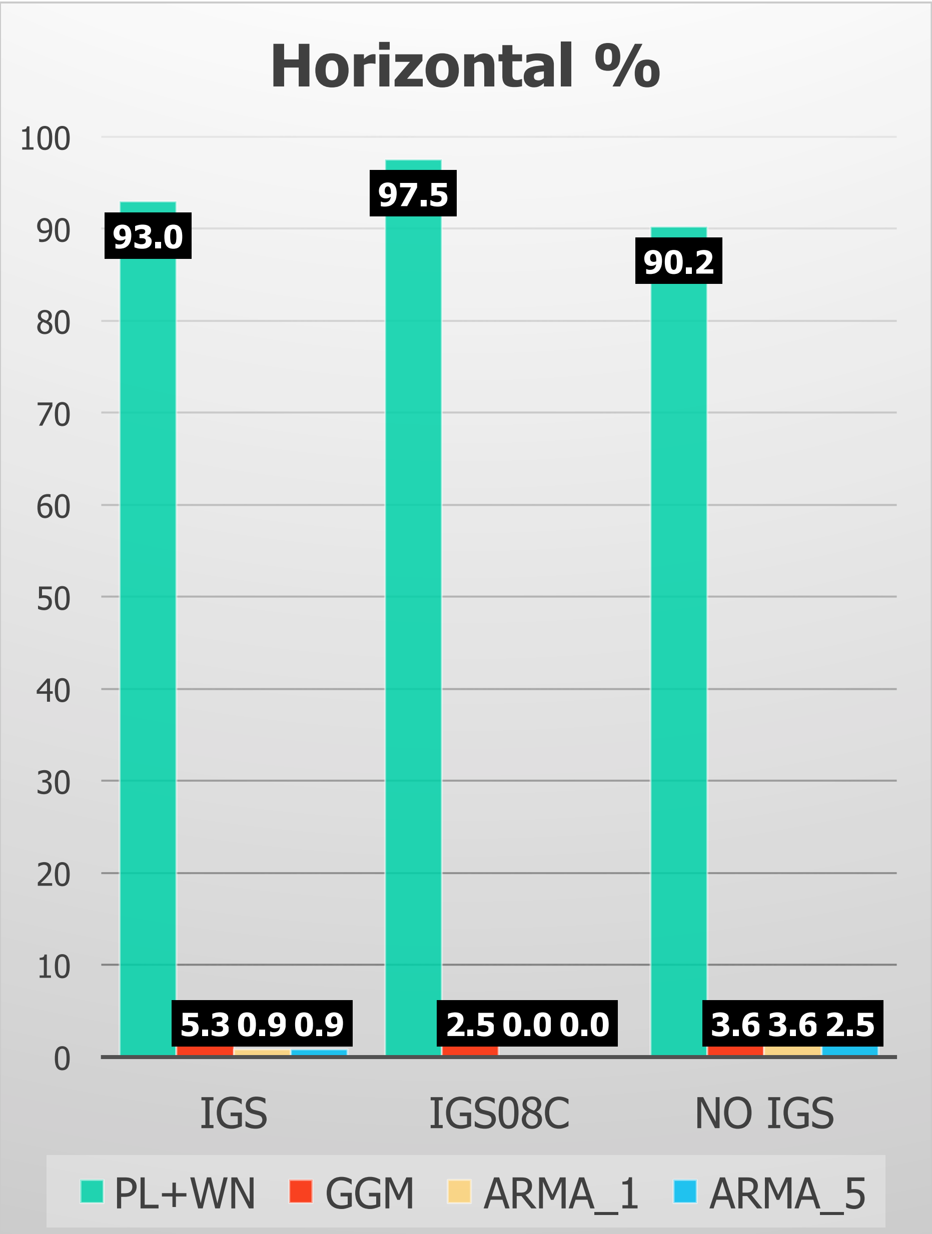
L is the likelihood, k the number of parameters in the noise model and n the number of observations:

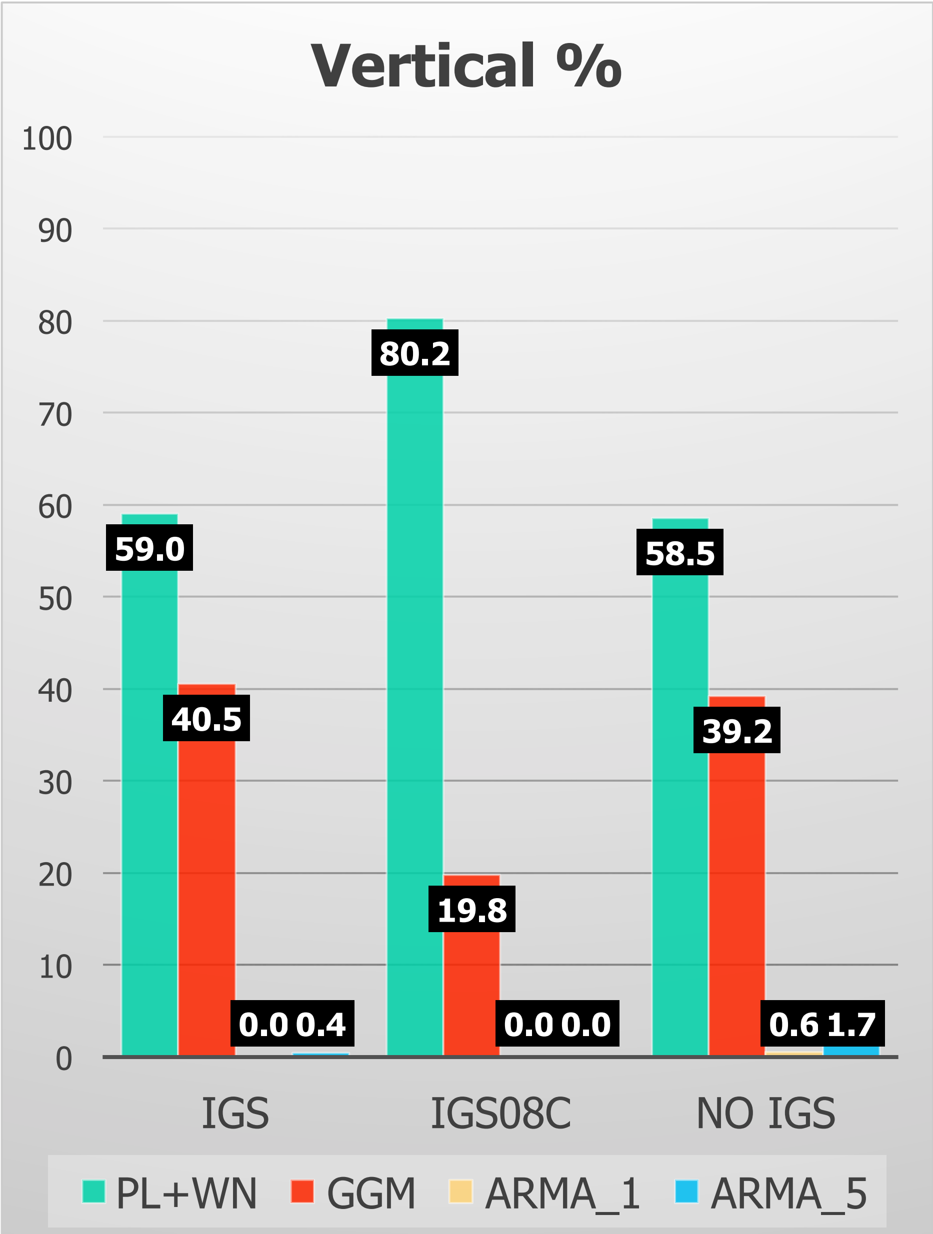
- **The higher the likelihood L (better the noise model), the lower the AIC/BIC value.**
- **AIC & BIC only differ in the penalty function for the number of parameters. This avoids overfitting of the noise model.**
- **No general agreement exists which criterion is better.**

Noise Model (All Sites - 595)



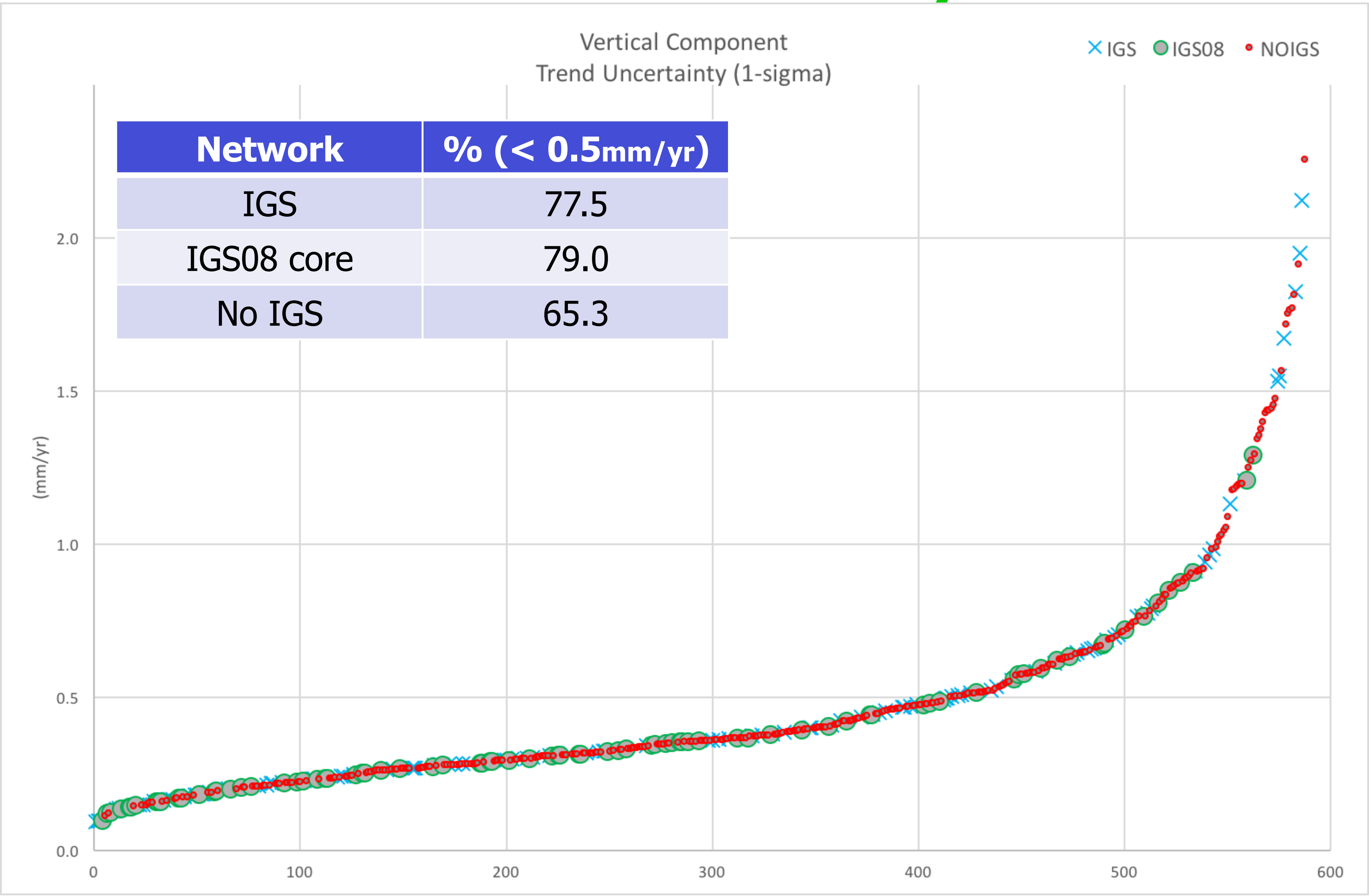
Noise Model (Sub-Networks)



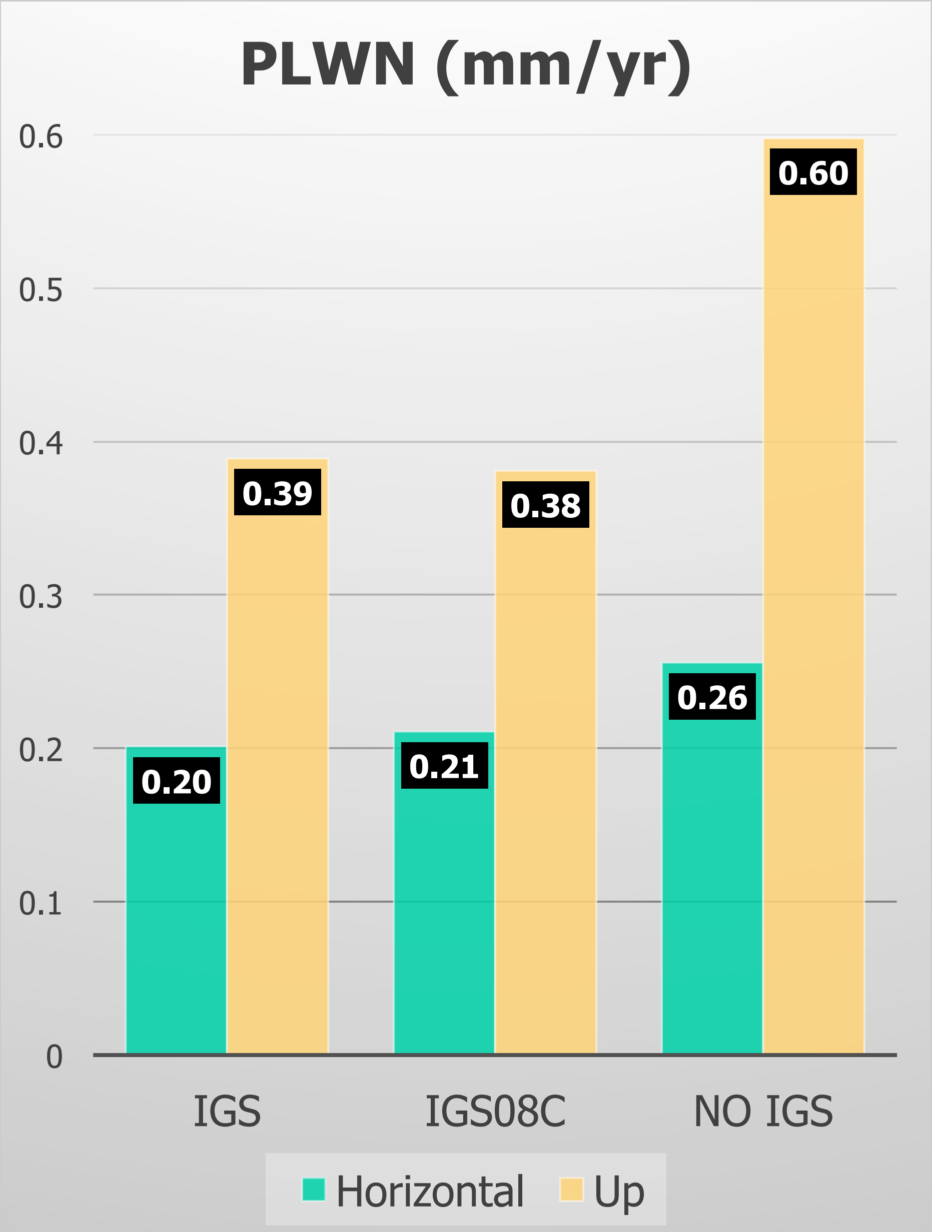


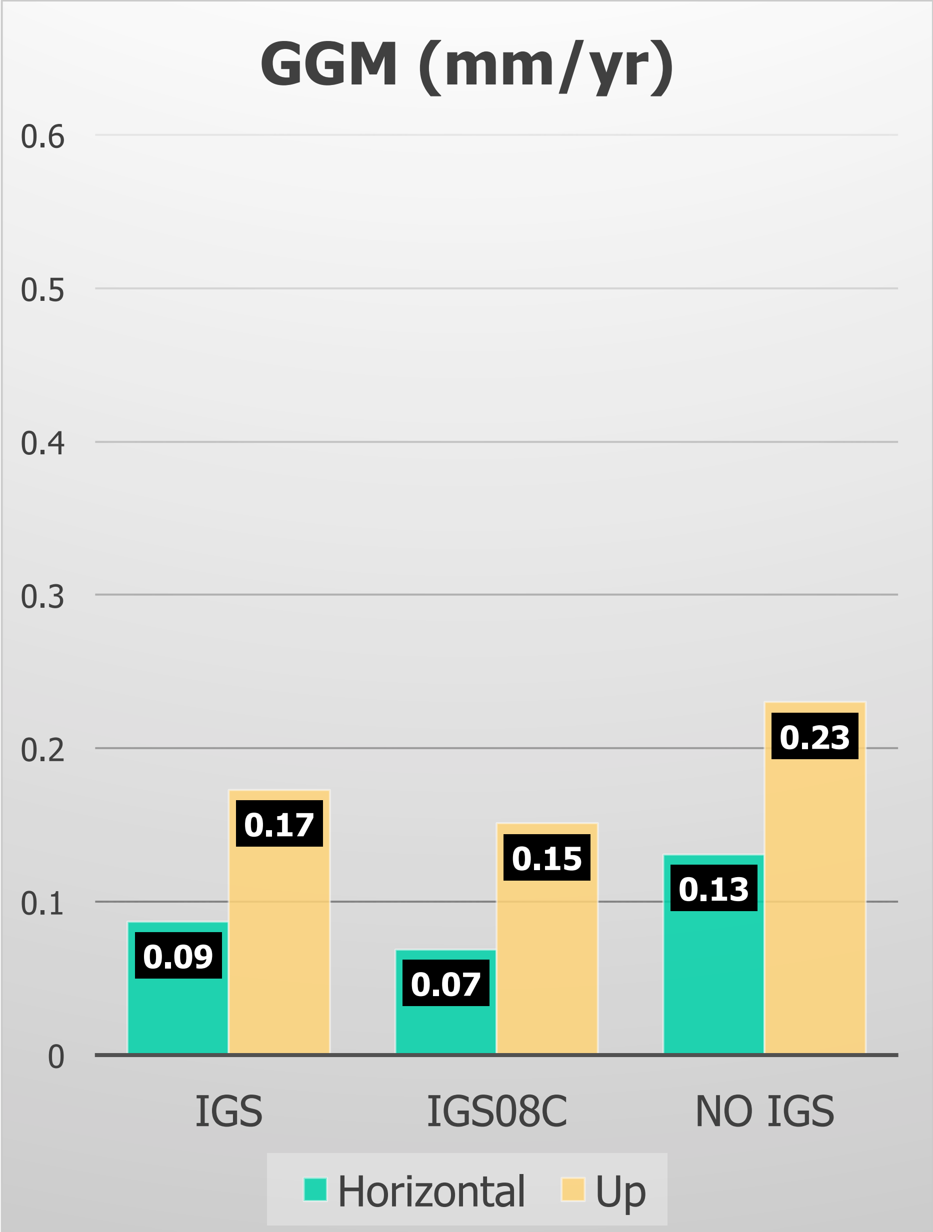
Trend Uncertainty

Network	% (< 0.5mm/yr)
IGS	77.5
IGS08 core	79.0
No IGS	65.3

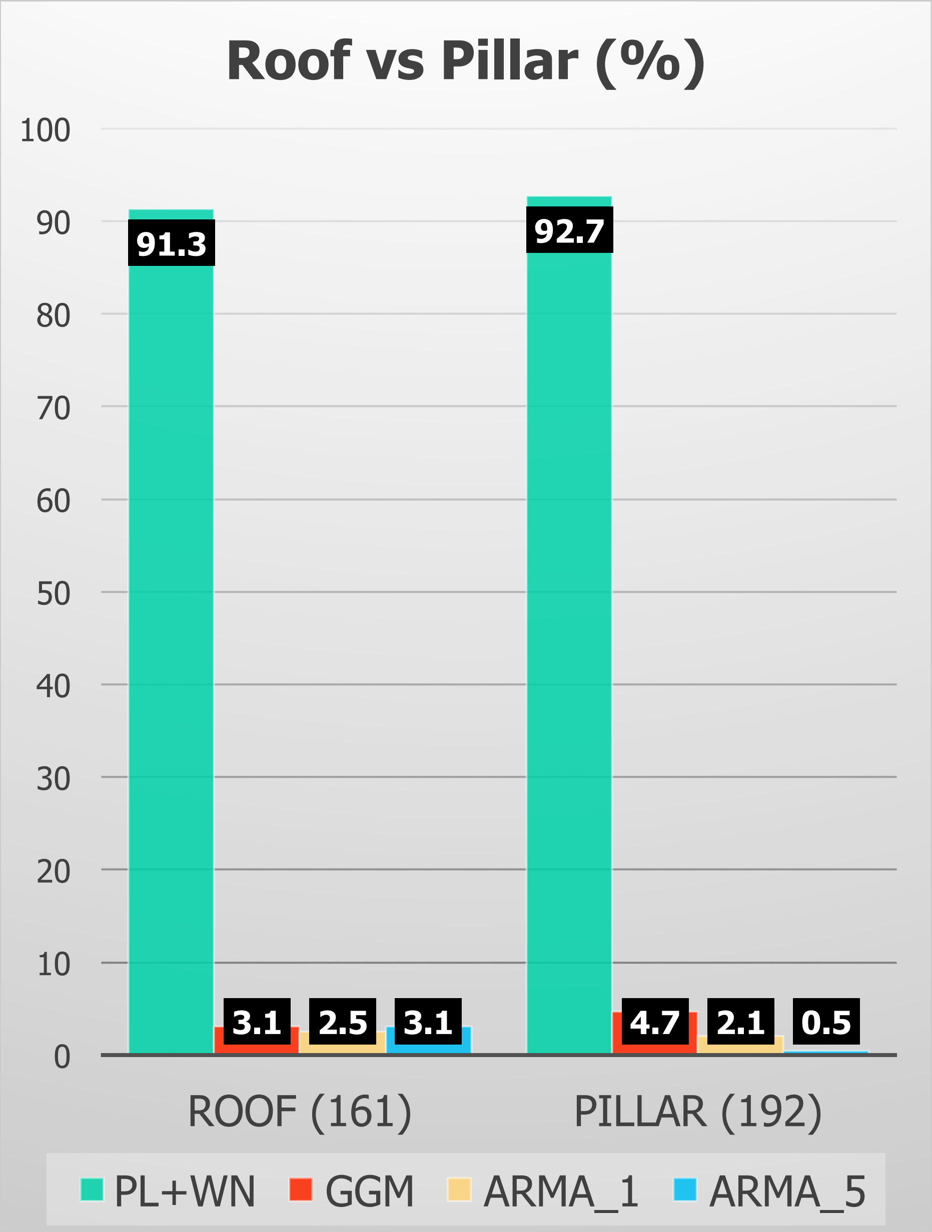


Mean Trend Uncertainty

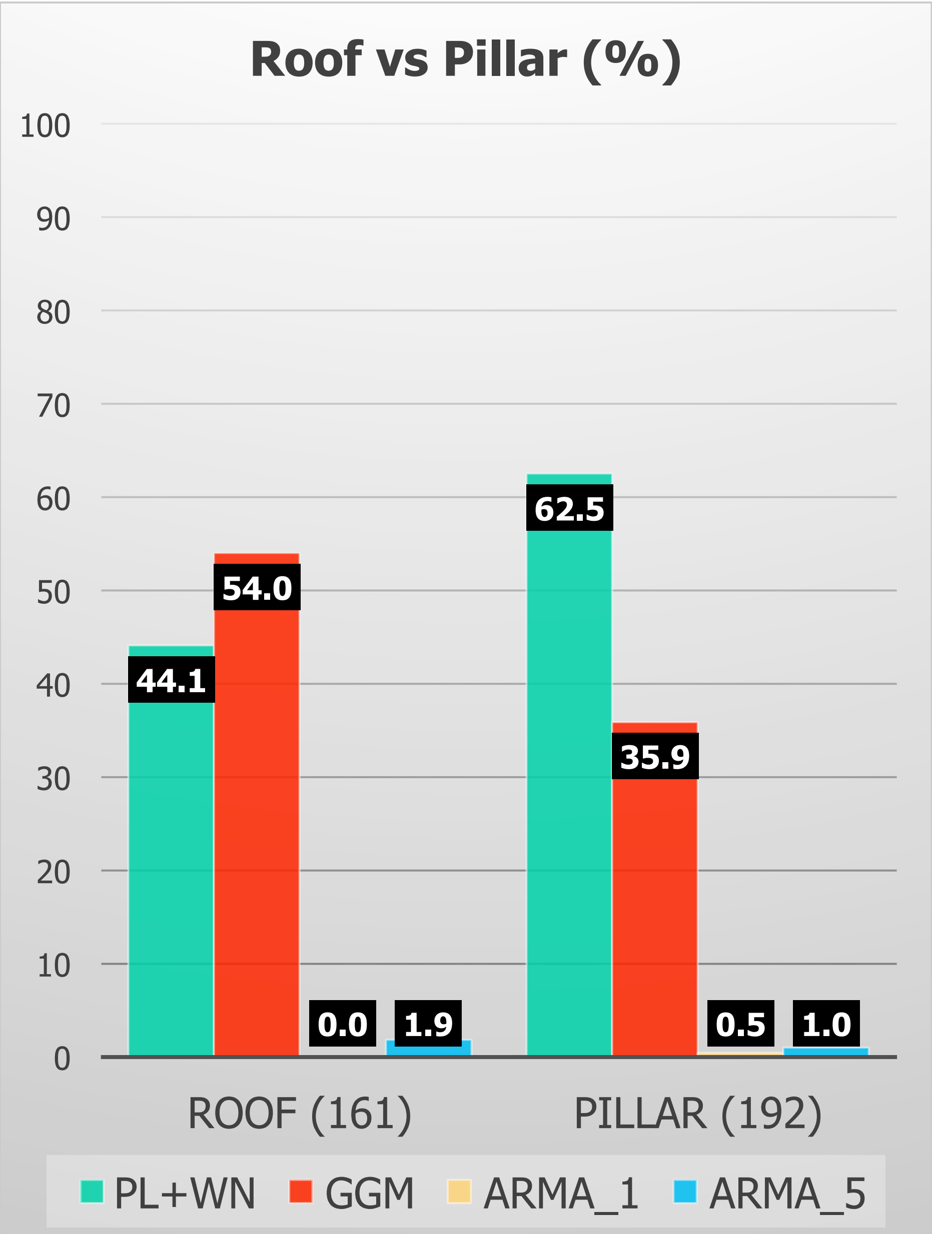


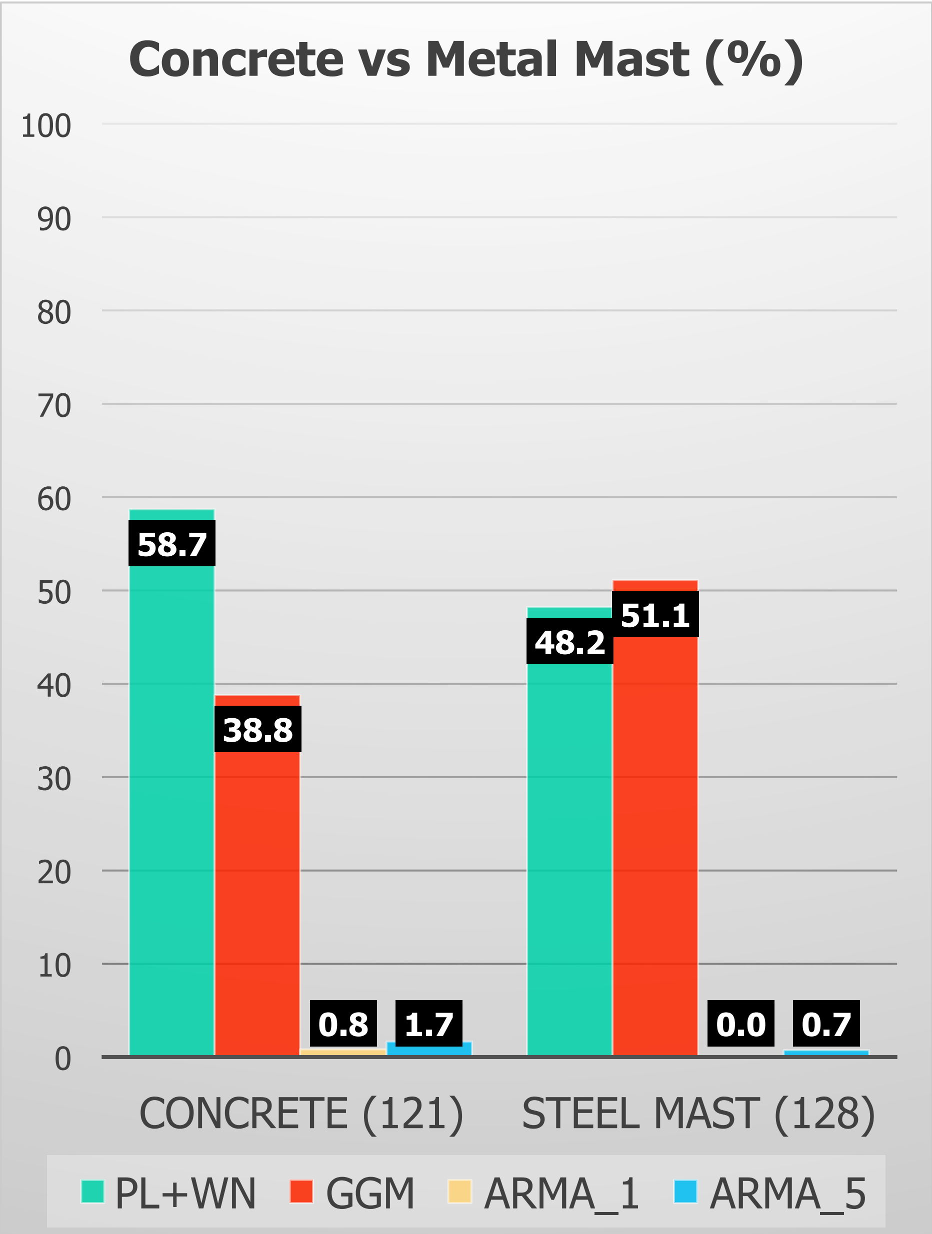


Monument Type - Horizontal

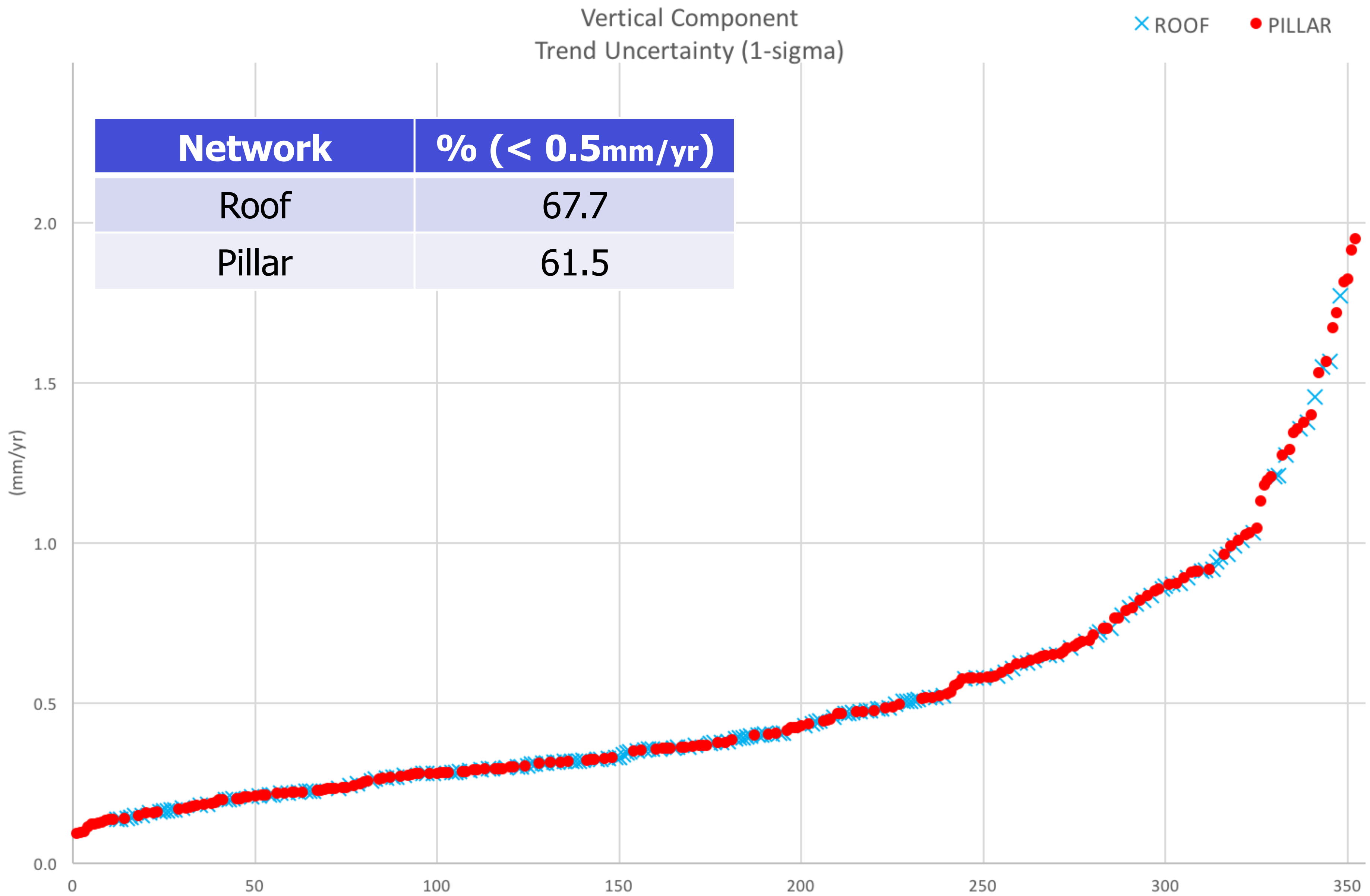


Monument Type - Vertical





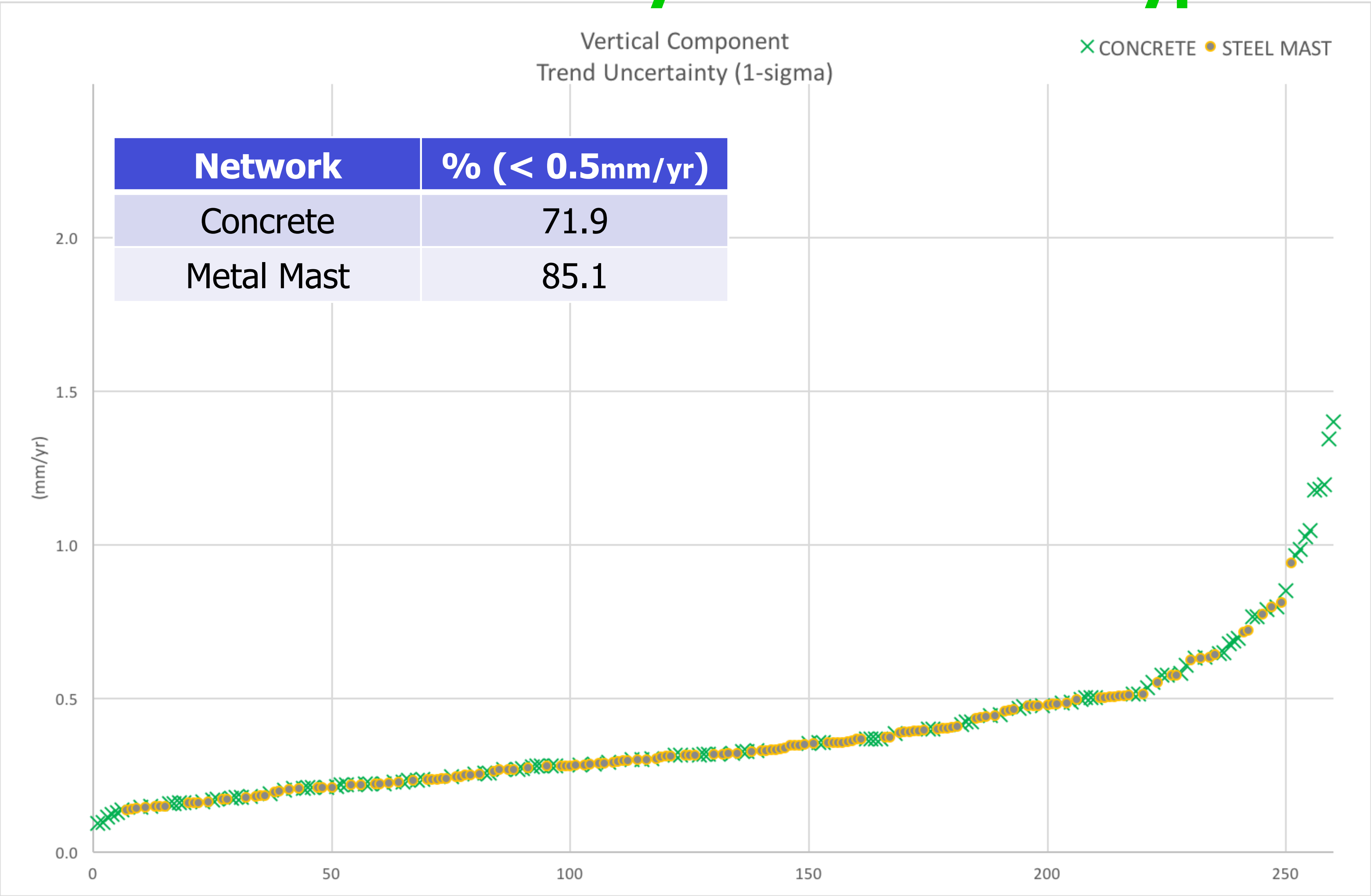
Trend Uncertainty – Monument Type



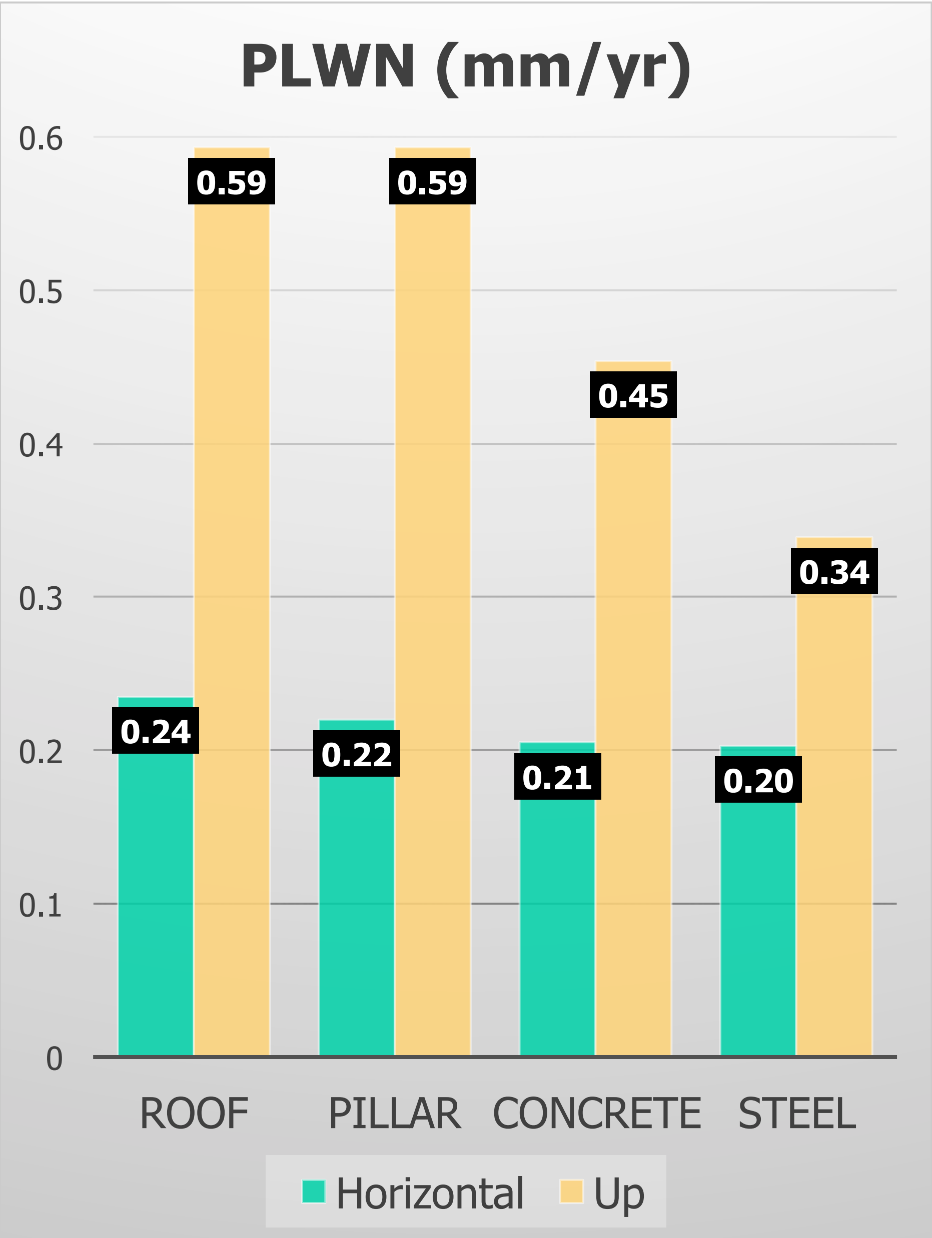
Network	% (< 0.5mm/yr)
Roof	67.7
Pillar	61.5

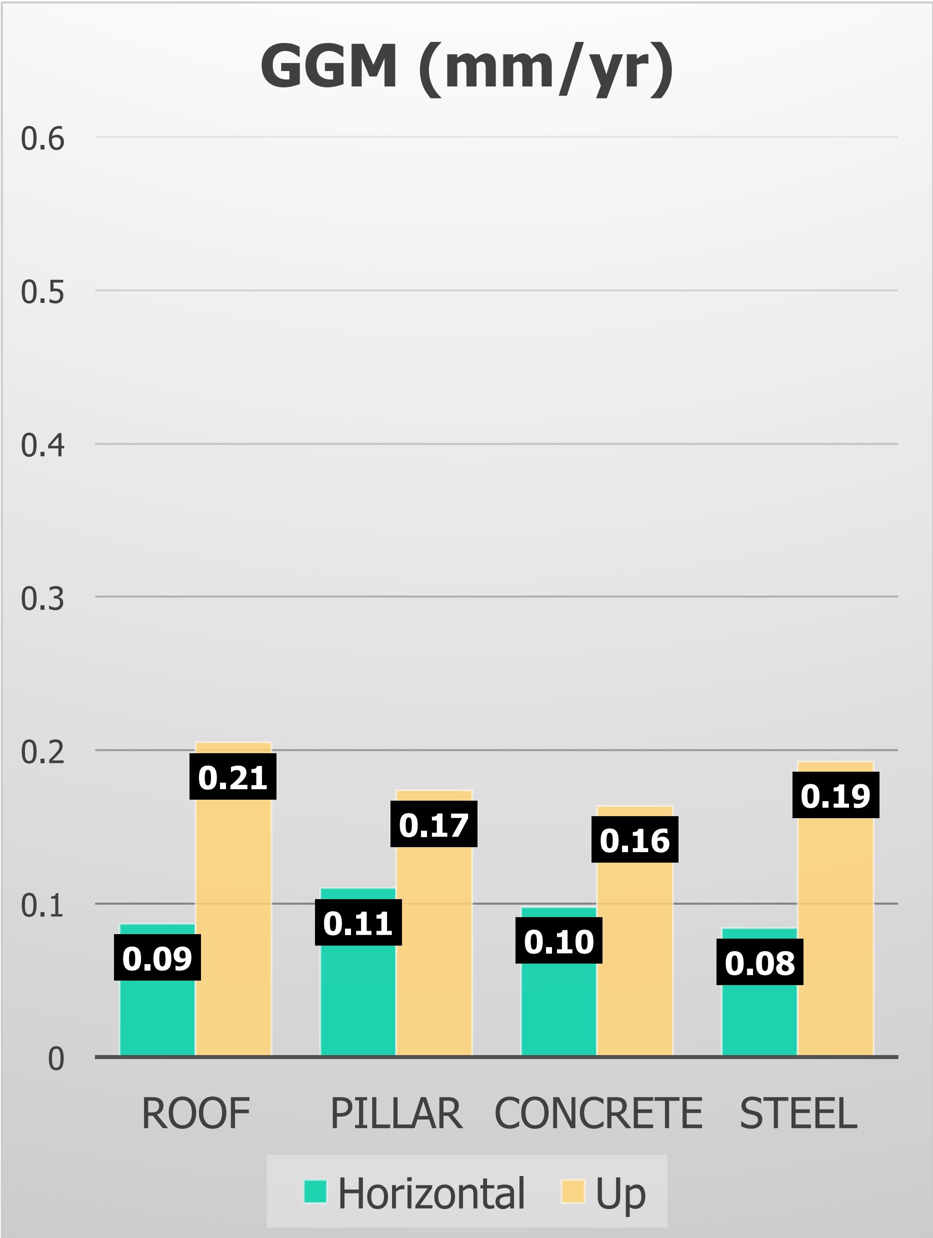
Trend Uncertainty – Monument Type

Network	% (< 0.5mm/yr)
Concrete	71.9
Metal Mast	85.1



Mean Trend Uncertainty





Summary

- **IGS08core and IGS sites show similar quality (and better than the average site processed at SEGAL, as expected!).**

- **Power Law plus White Noise still appears to be the best noise model, in particular for the Horizontal components.**
- **However, Generalized Gauss Markov performs better for a significant number of sites (~40%) on the vertical component.**

  SOLUTION: Compute the vertical component using both Noise Models and select the one with lower AIC.

- **No particular type of monument (pillar vs roof; concrete vs metal mast) is clearly the best one. The averaged* associated uncertainty is similar (particularly on the horizontal component) for all the analyzed monument types.**

***based on more than 100 sites per characteristic**

Thanks

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