Uncertainty in Uncertainty

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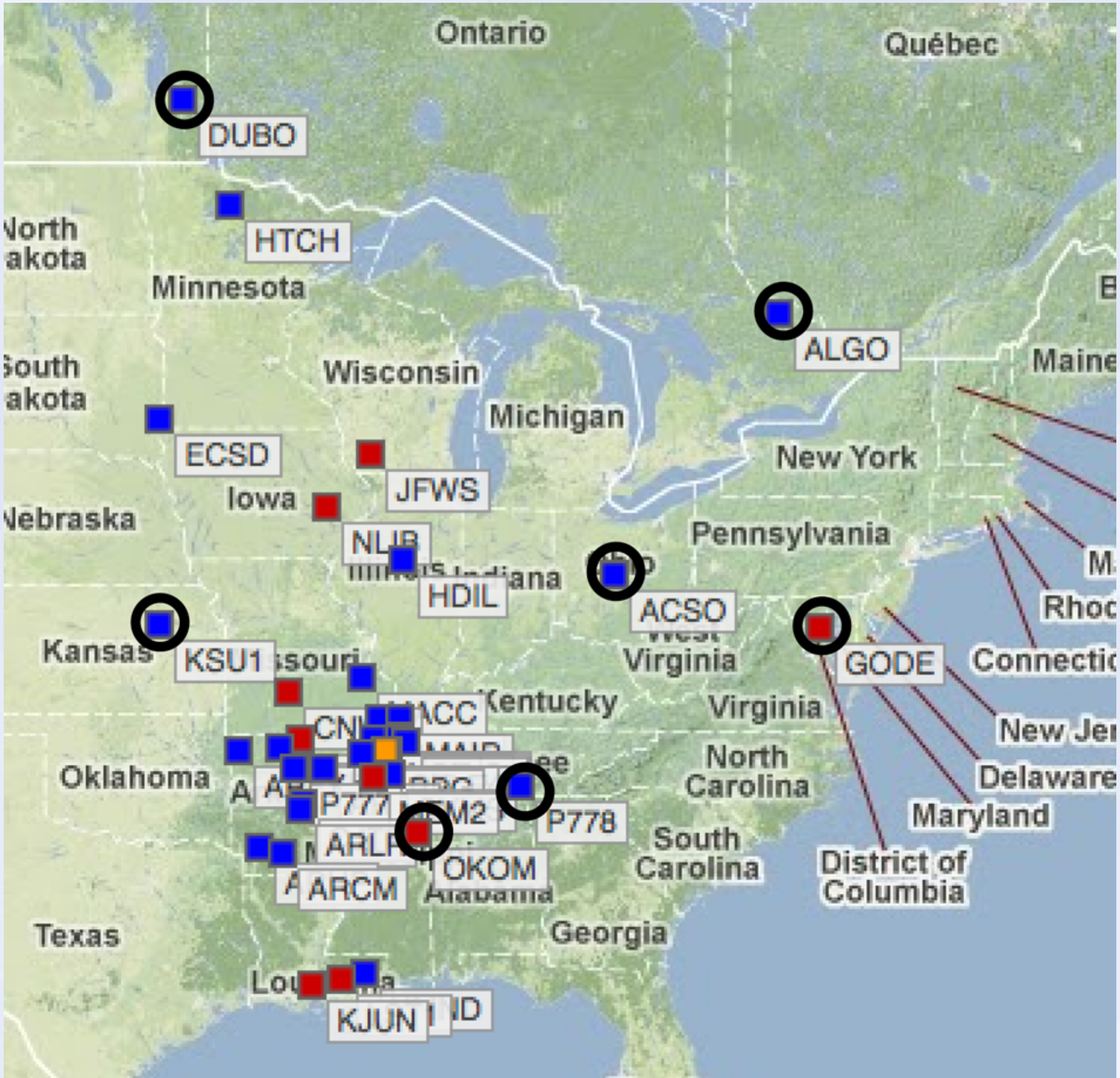
Uncertainty in Uncertainty

Within a factor of 2

Impact of noise on precision; applications to GPS data in New Madrid Seismic Zone

- GIPSY Processing of GPS; central US
- Short tutorial
- Estimating the background noise from GPS
- Using noise to evaluate monument stability
- Velocities and strain rate estimates
- Strategy to improve signal to noise ratio

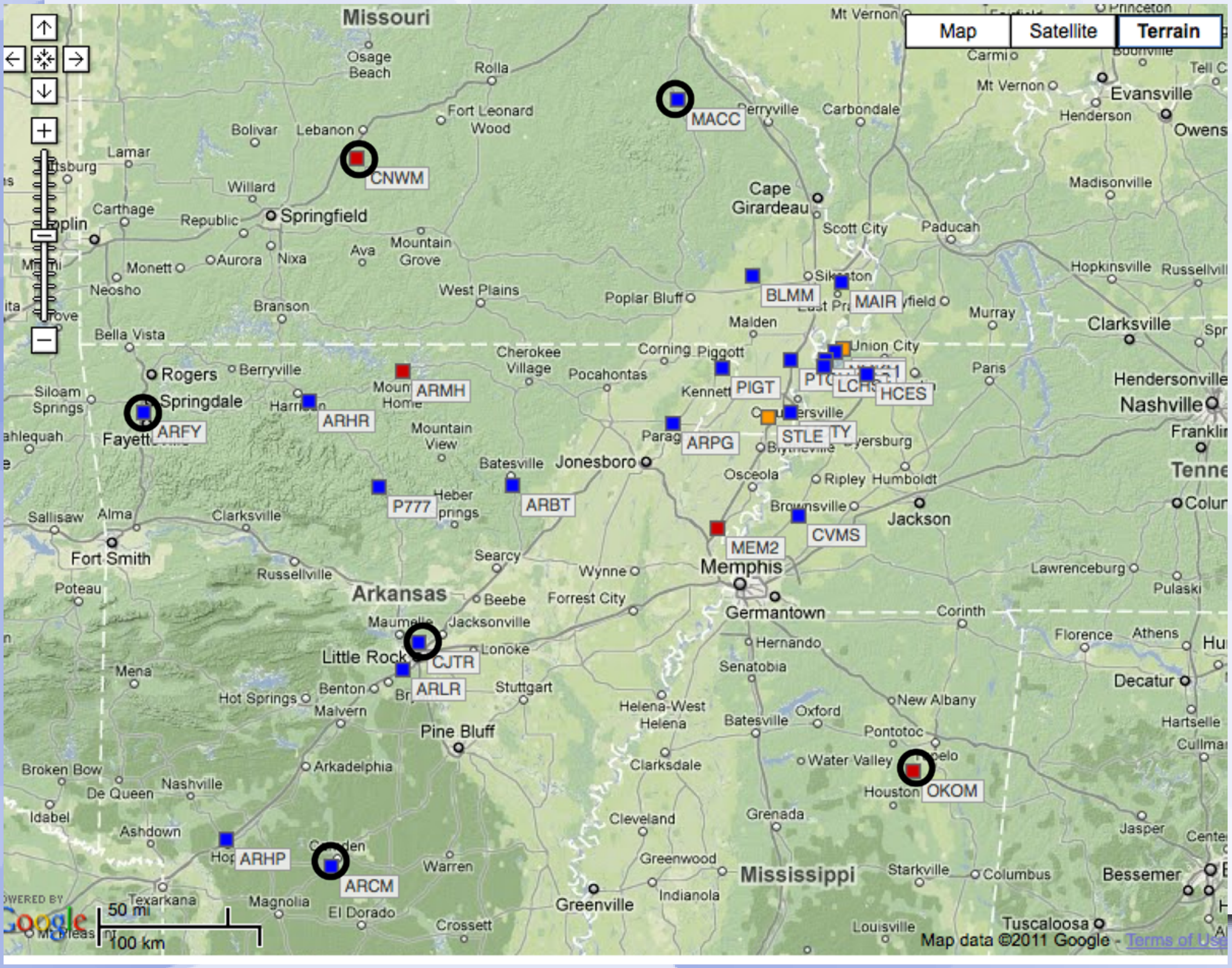
GIPSY processing



Regional filtering;
NA “*fixed*”

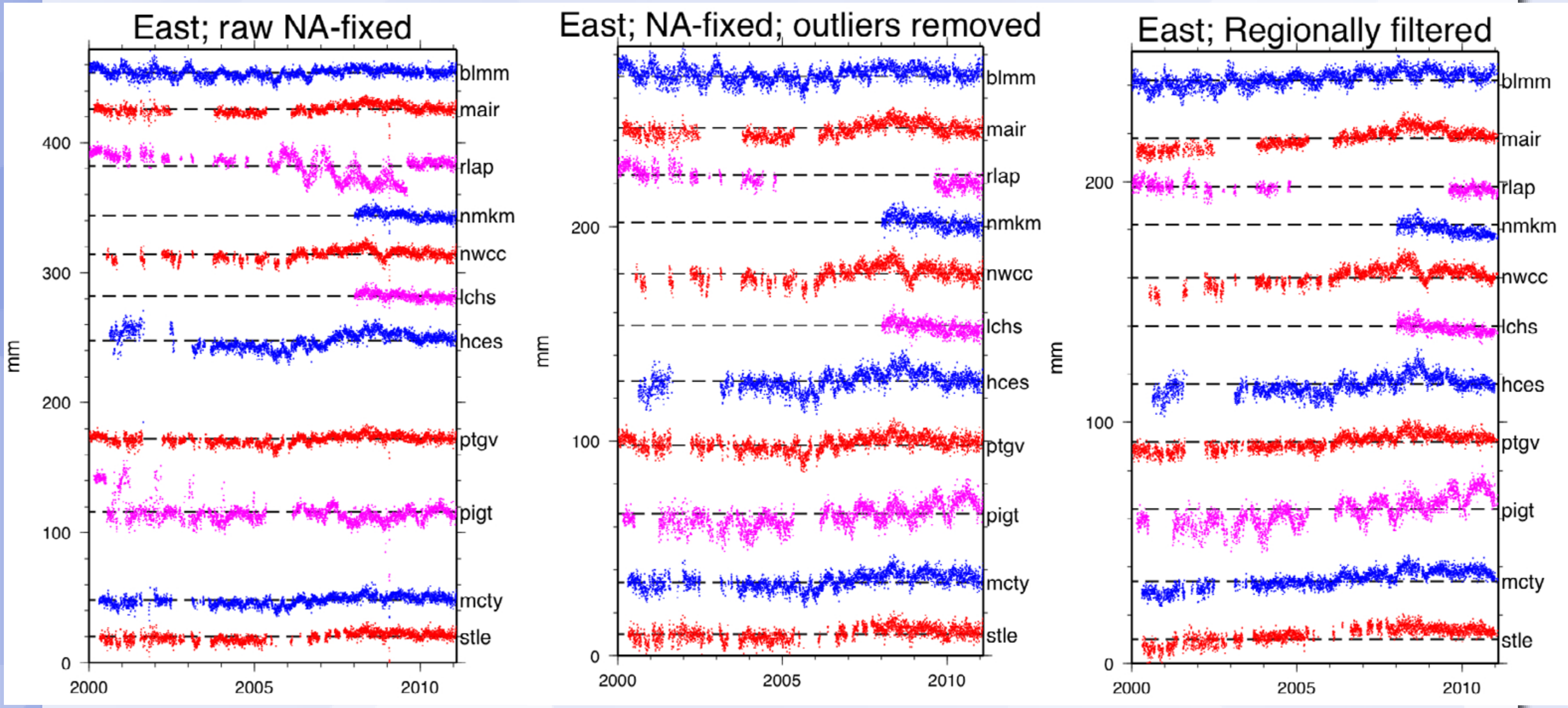
http://earthquake.usgs.gov/monitoring/gps/CentralUS/

Additional processing

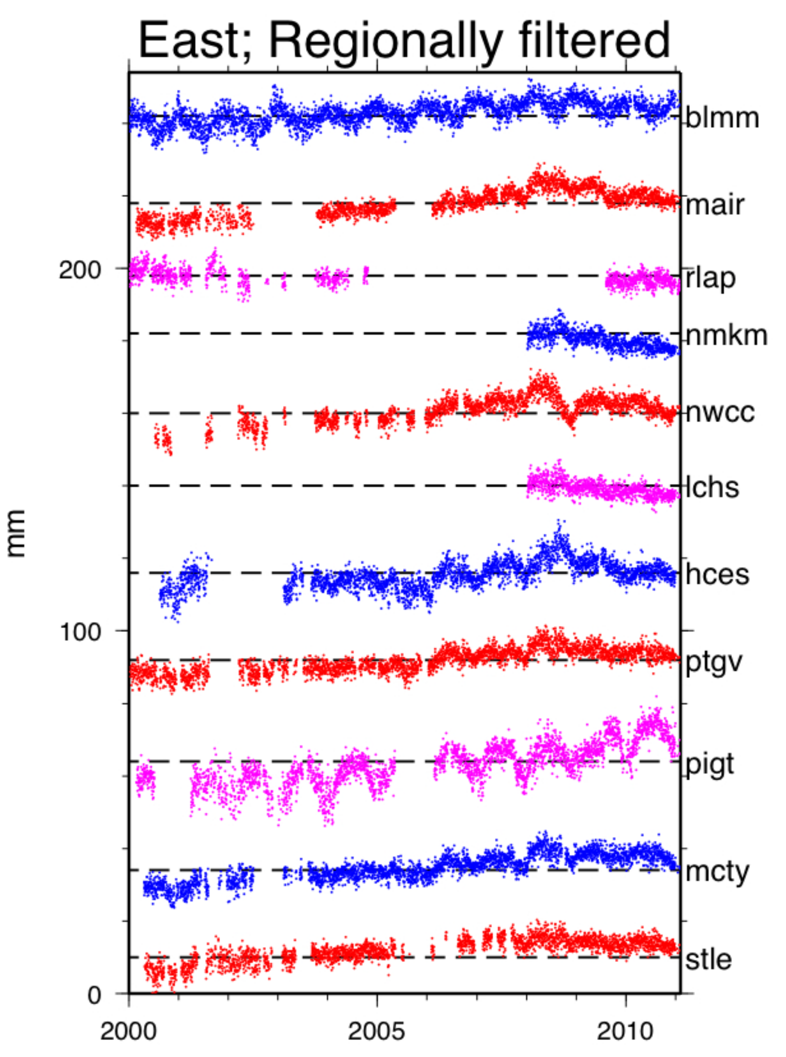


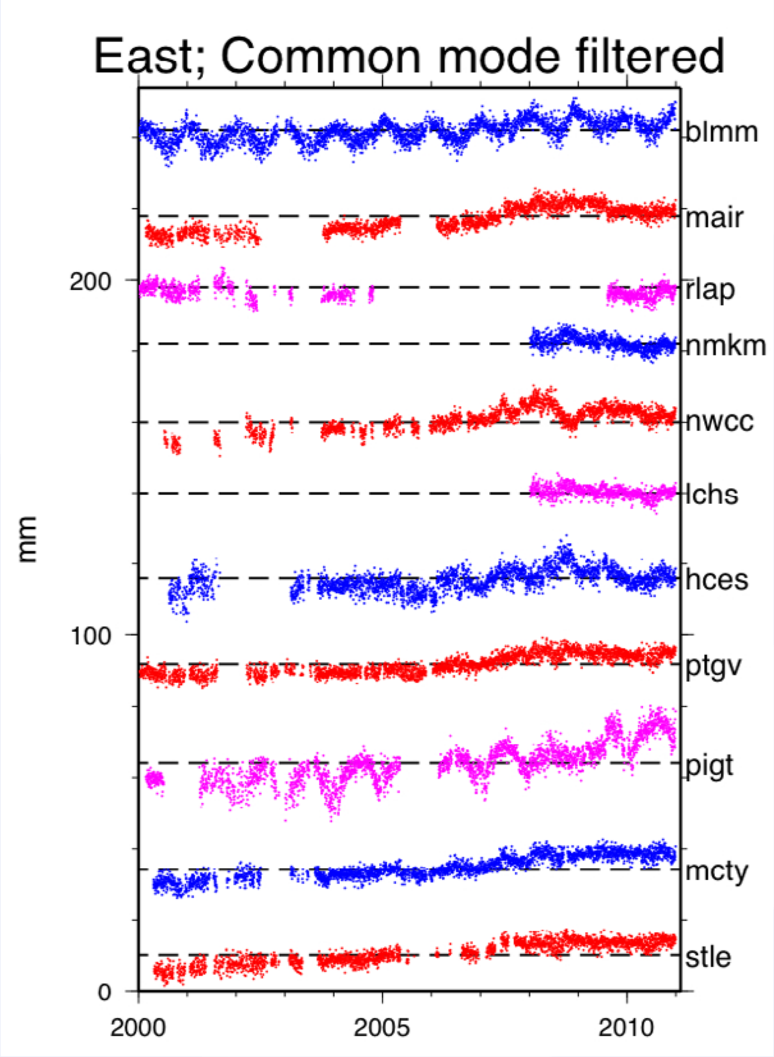
Use local sites to remove additional, common-mode translations

Standard processing

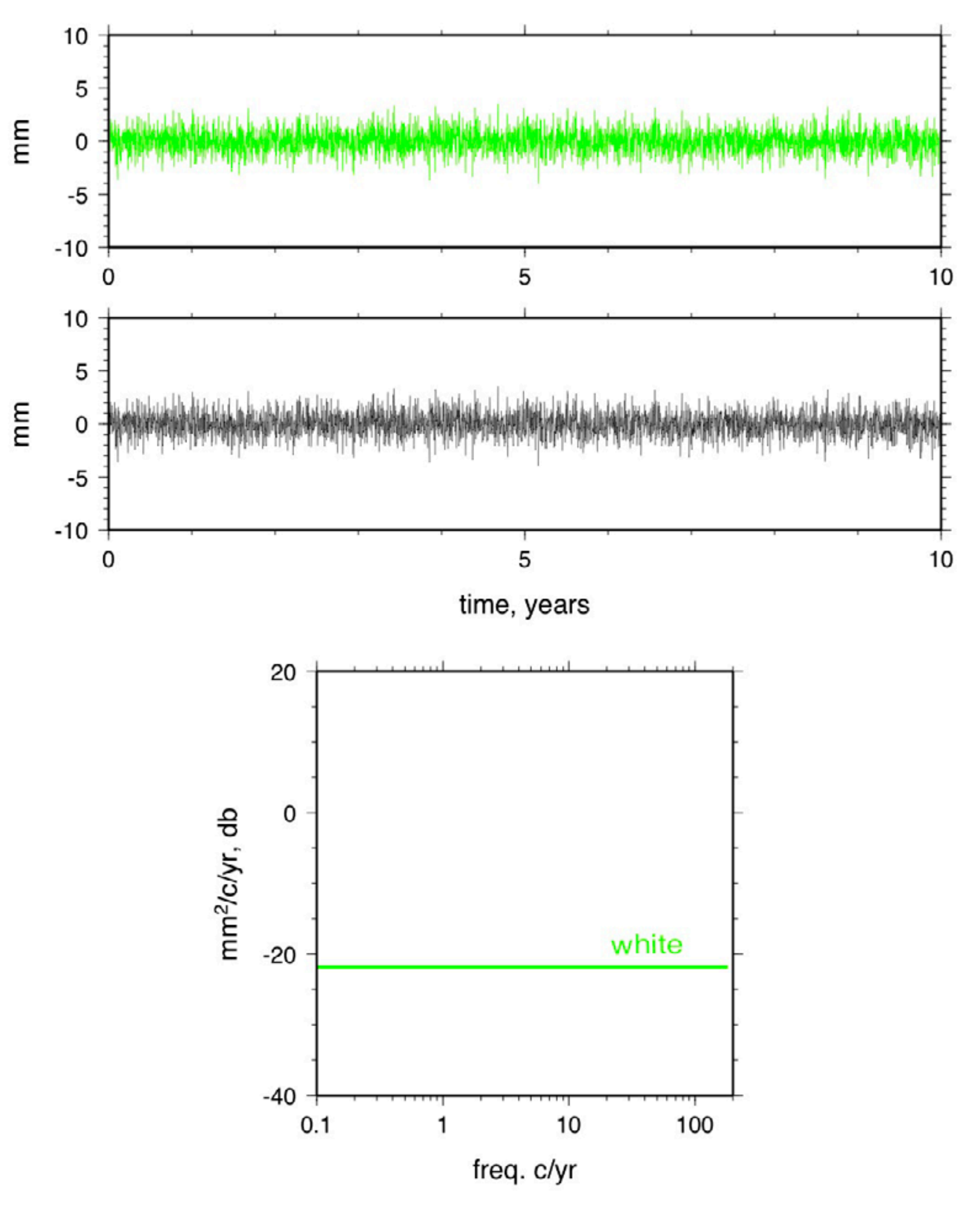


Additional processing



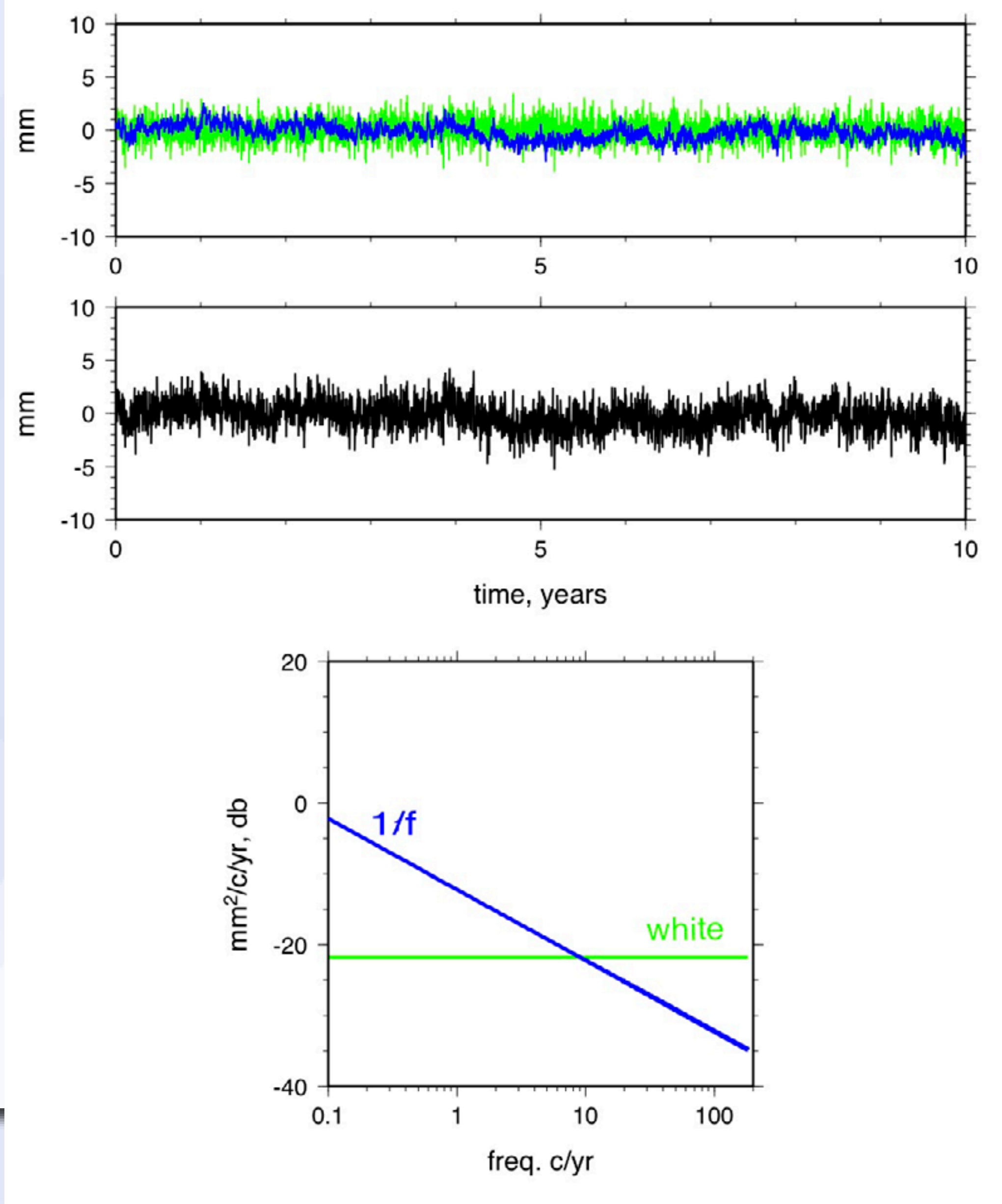


Noise Models



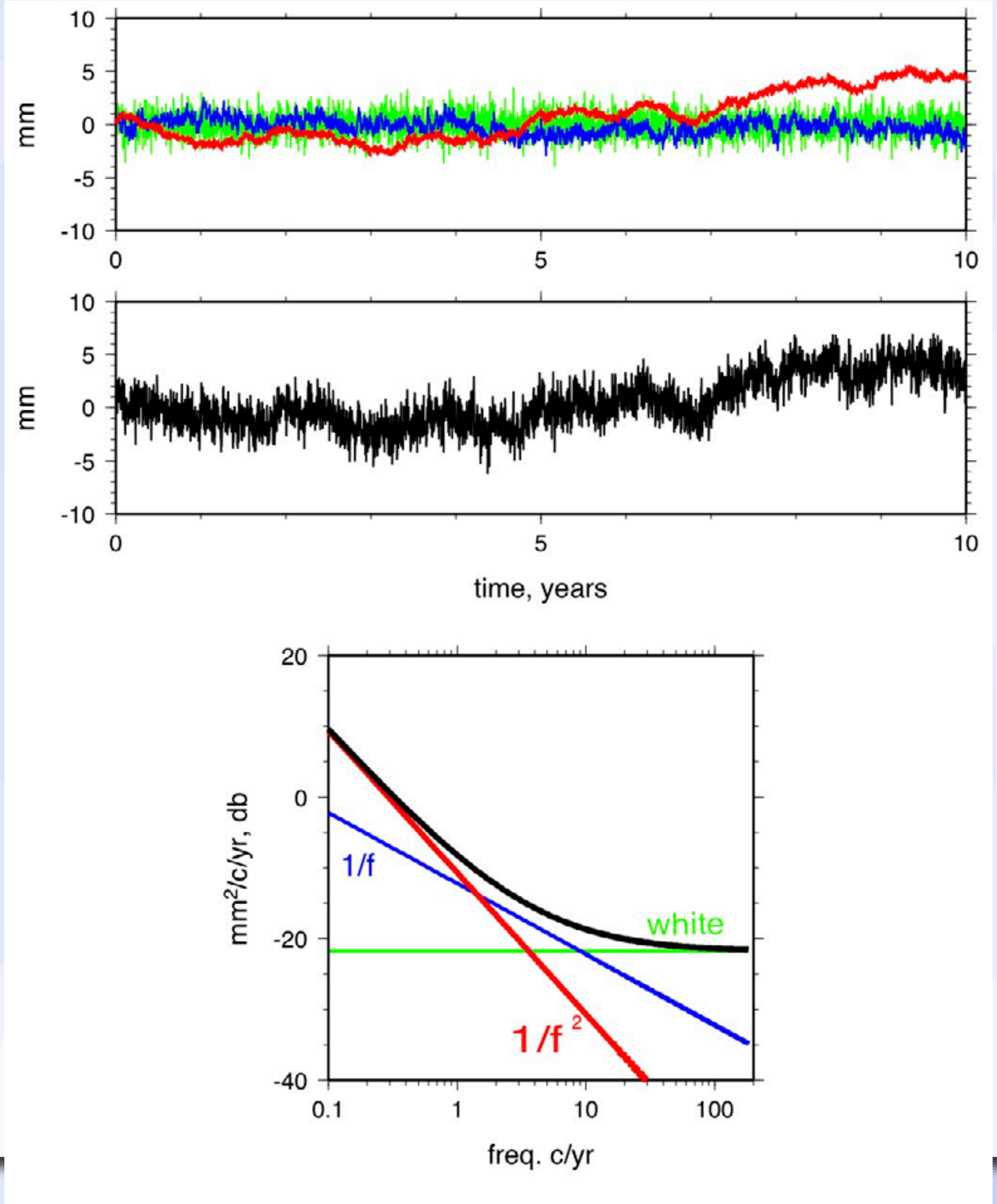
White Noise

Noise Models



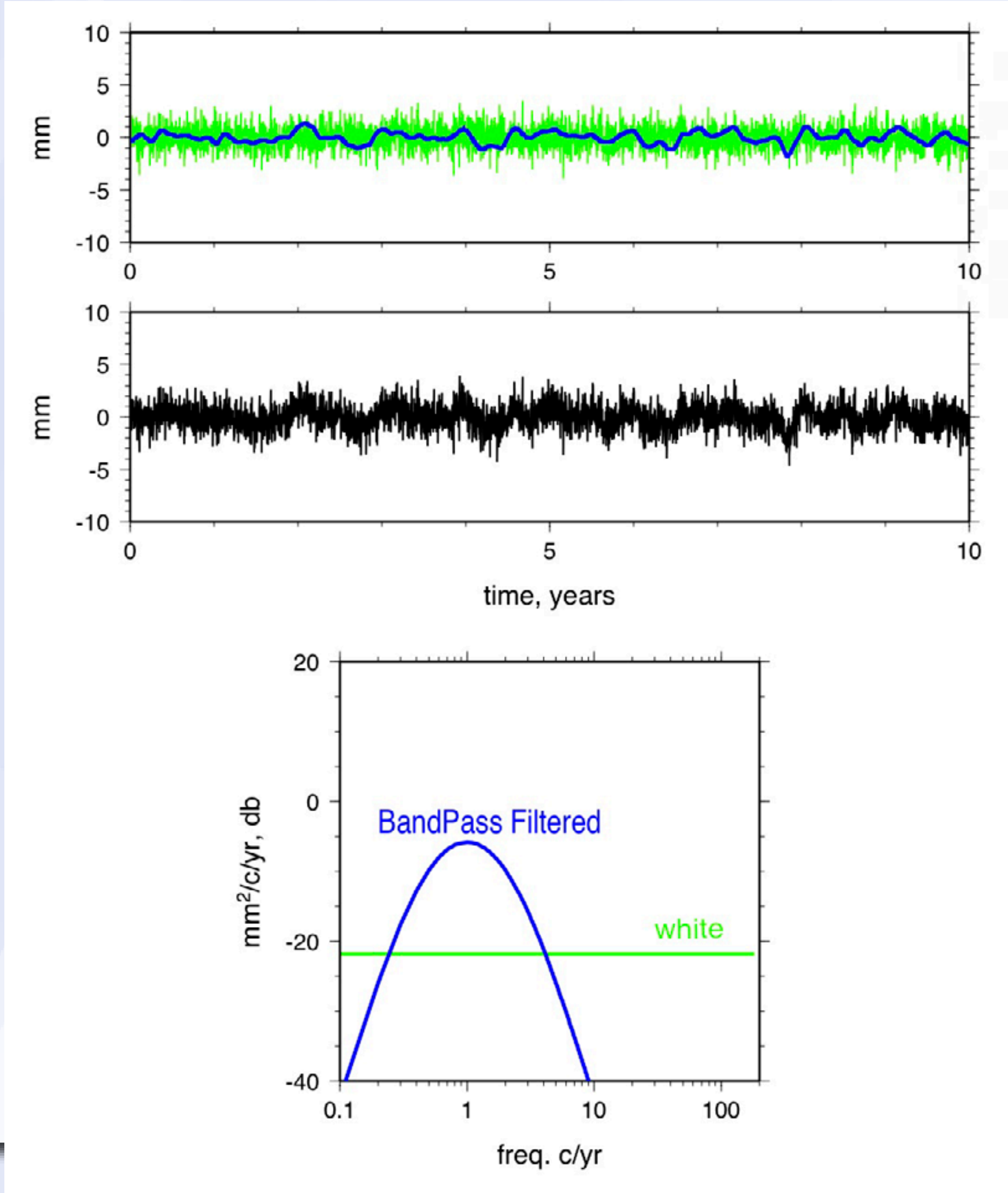
FLICKER

Noise Models



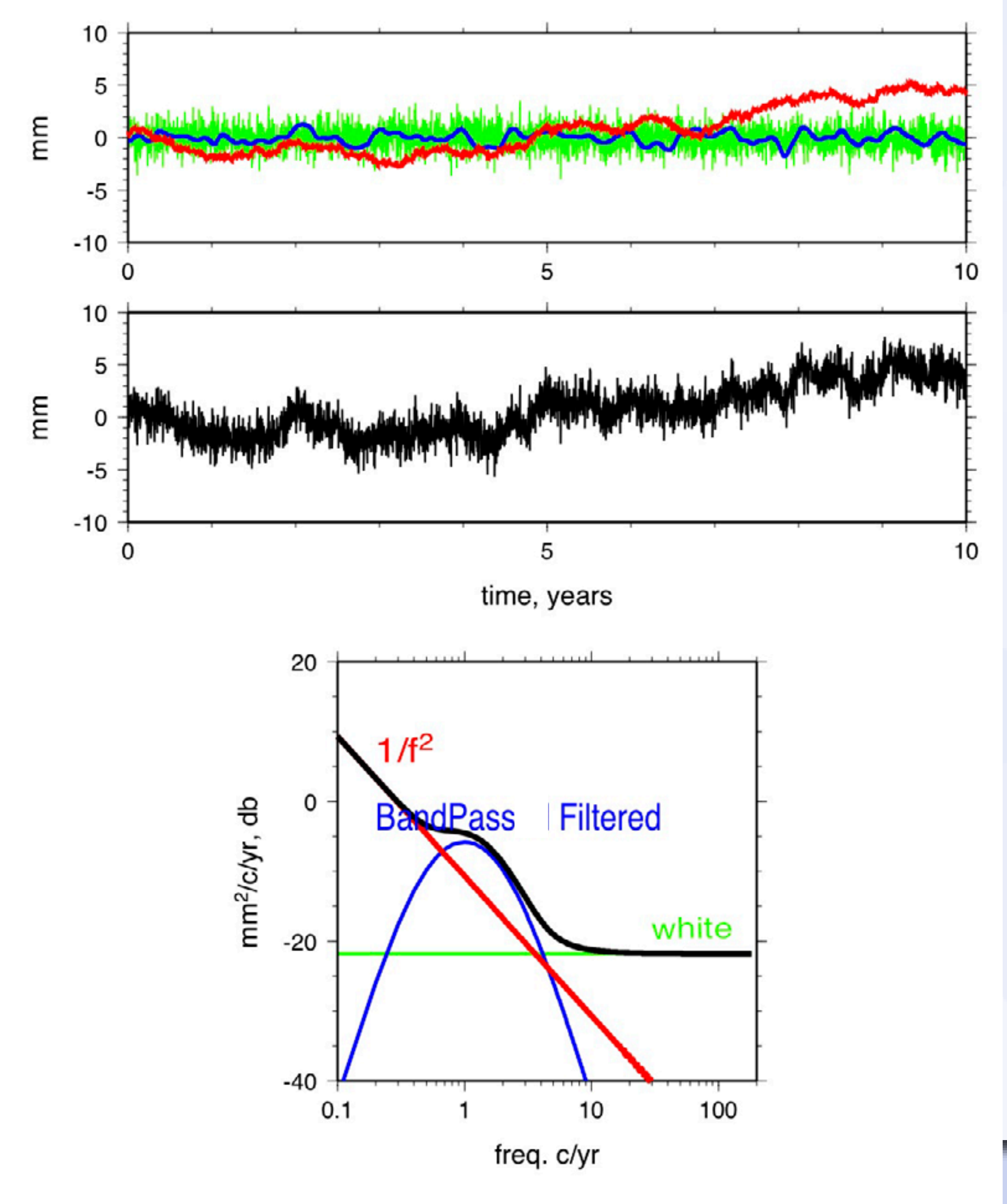
Random Walk

Noise Models



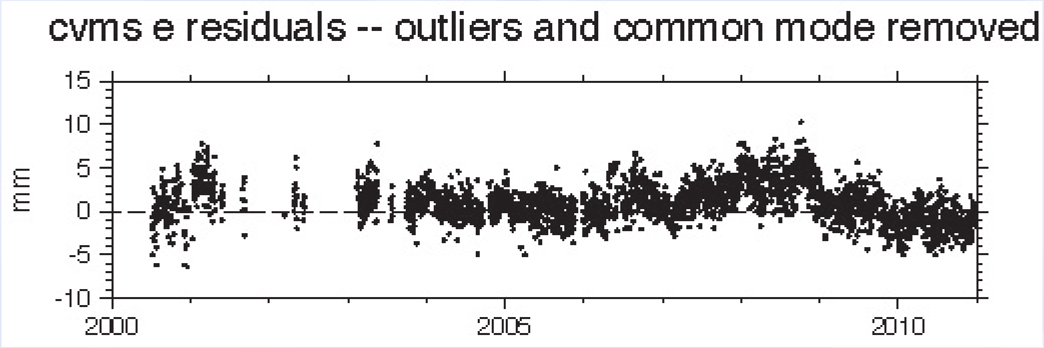
Band Pass filtered;
Seasonals

Example of GPS noise



Random Walk

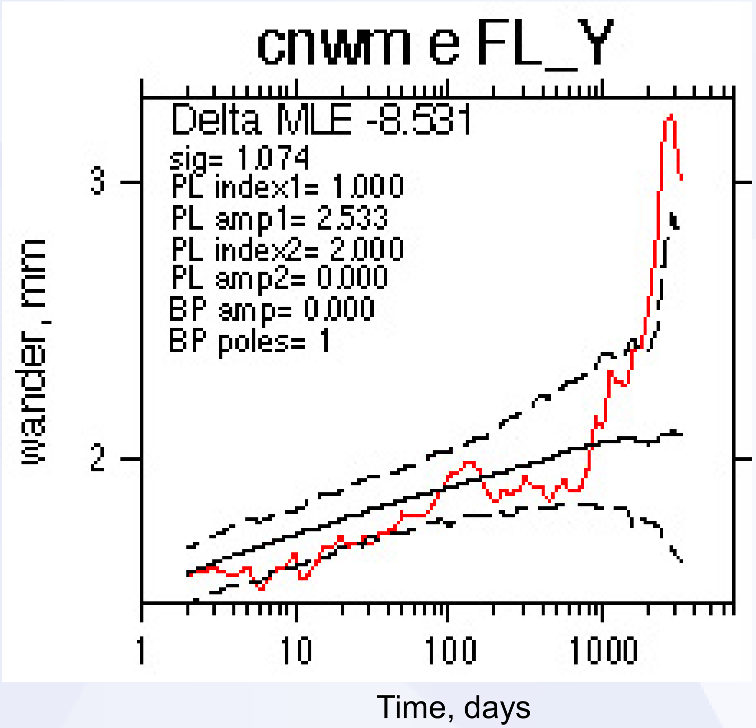
Noise modeling of time series



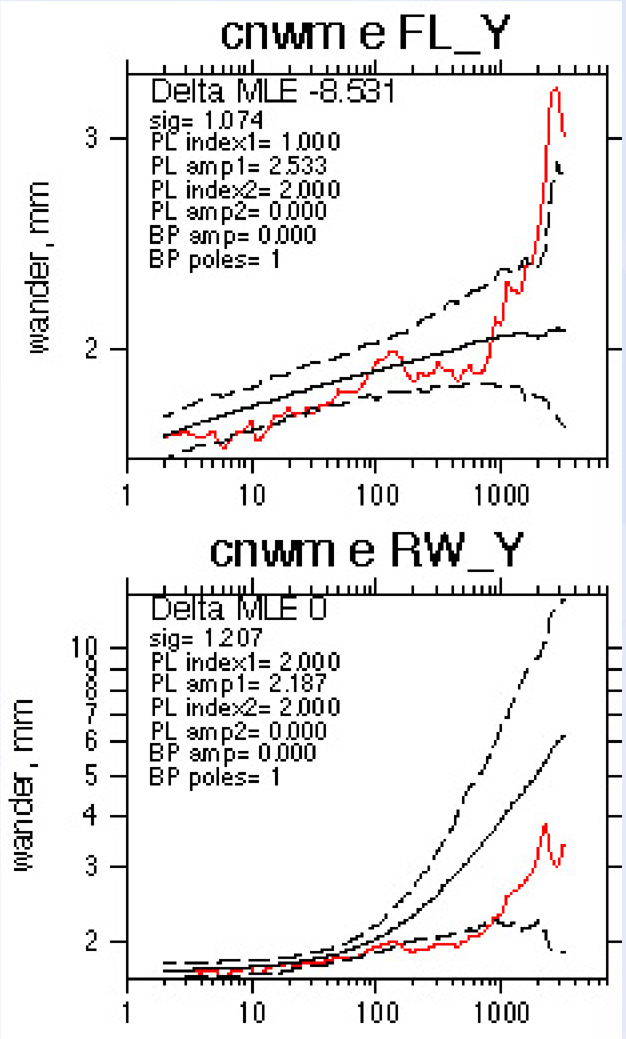
RMS of [x(t + τ) - x(t)]

Red are the data

Black are the results of simulations of Flicker and white noise; the average from the simulation and the 95% limits



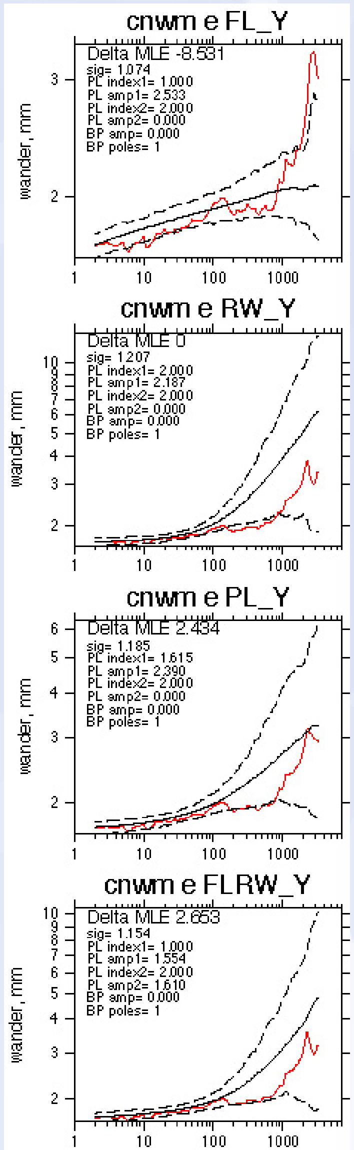
Noise modeling of time series



Comparison between two "end-member" noise models

Results suggest that the RW model is more successful than the FL model at the longer periods.

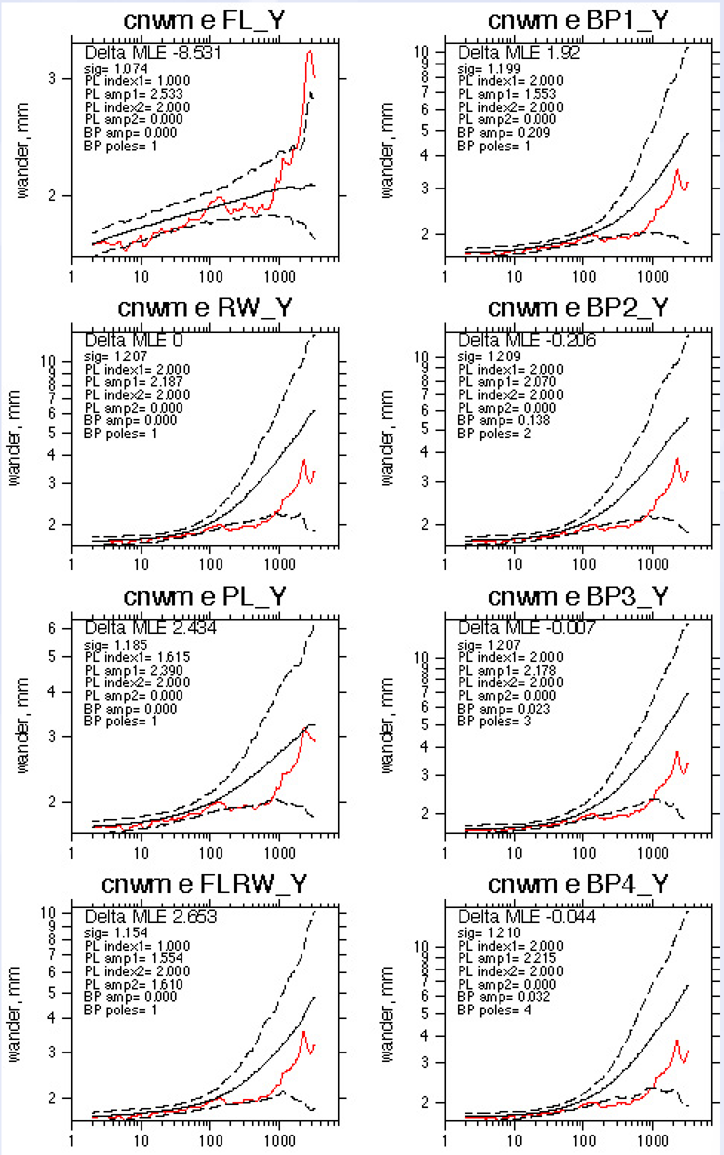
Noise modeling of time series



Variogram of data compared with 4 different noise models;

Either PL or FL+RW models are more successful representing these data.

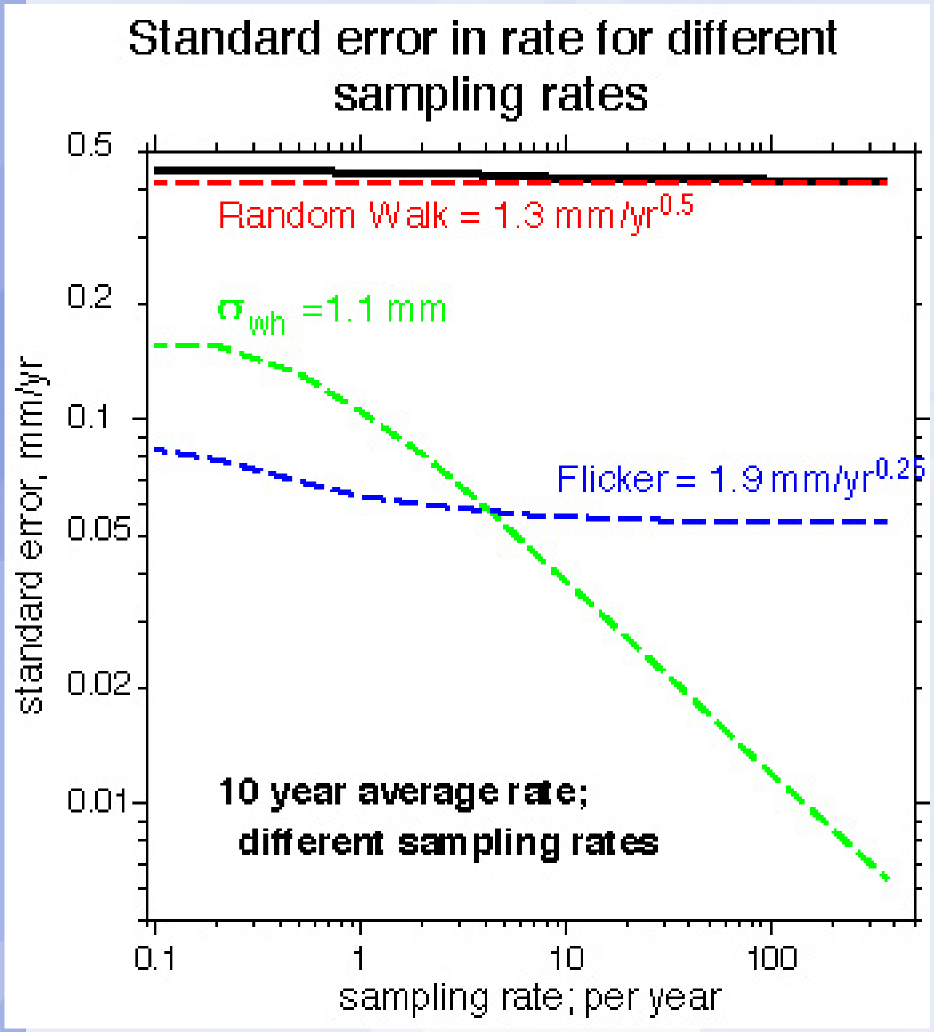
Noise modeling of time series



Variogram of data compared with 8 different noise models;

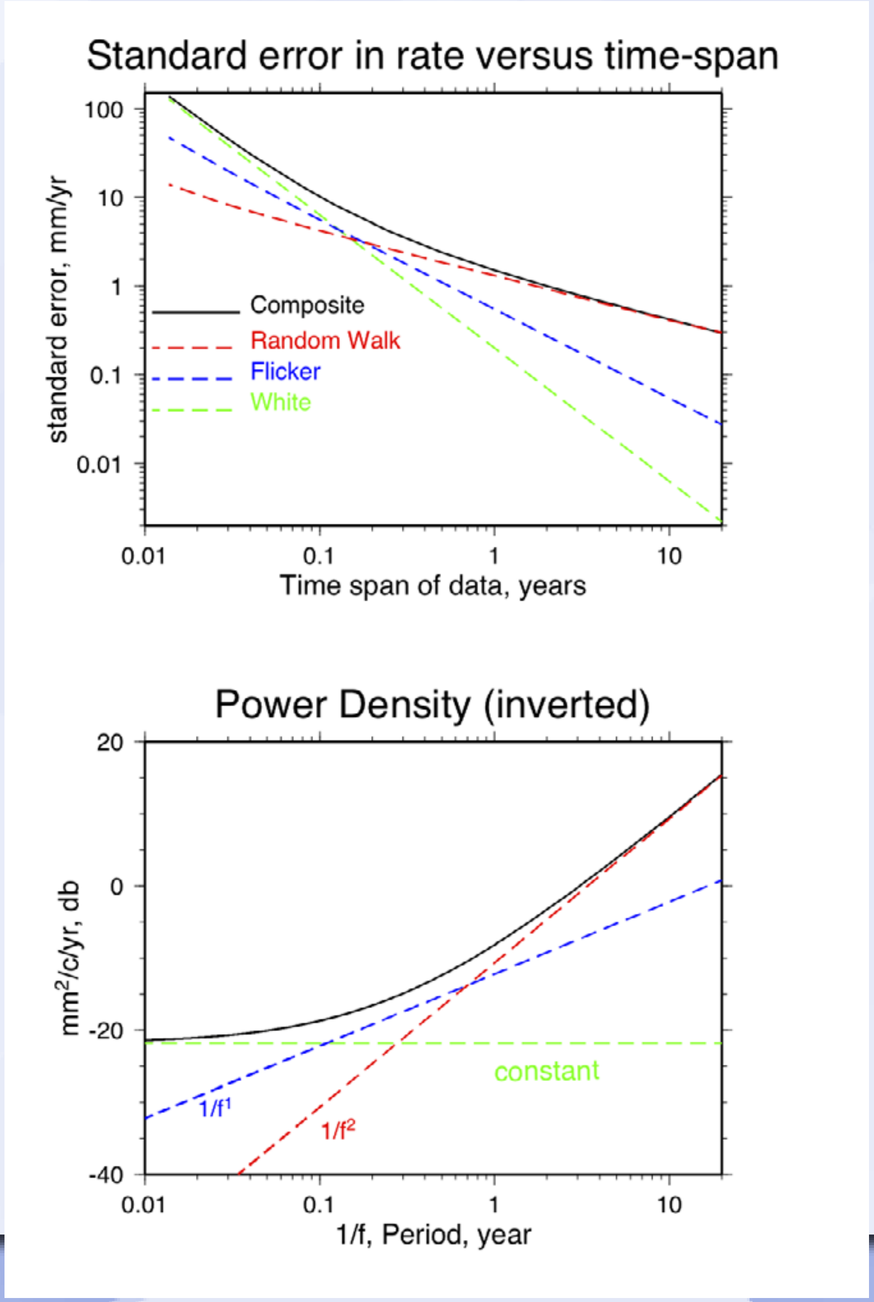
Either PL or FL+RW models are most successful representing these data.

Sensitivity of rate uncertainty to sampling

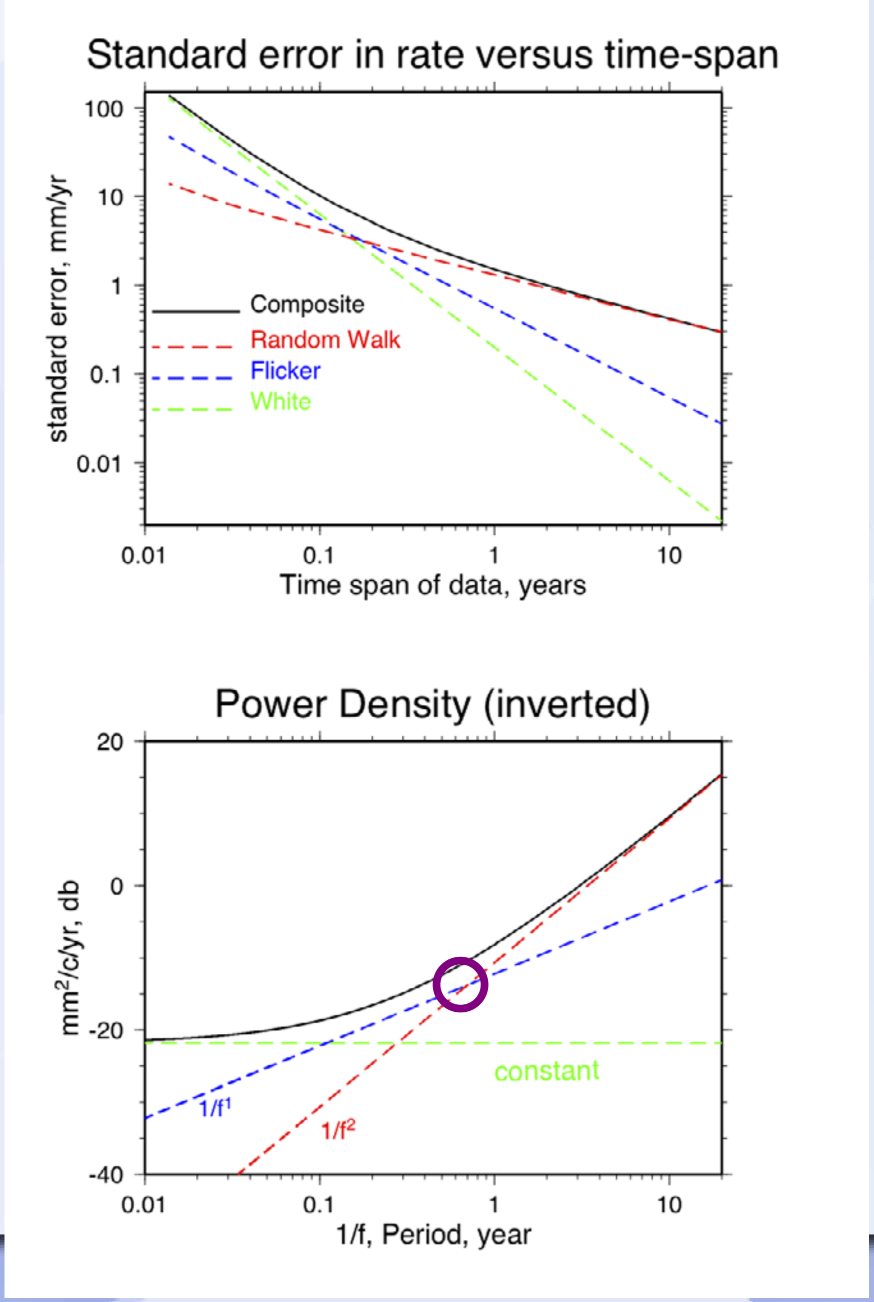


- Flicker noise insensitive to rates > 1 month
- White noise; sensitive - 1/n^0.5
- Random walk insensitive to sampling rate

Error in Rate; length of data

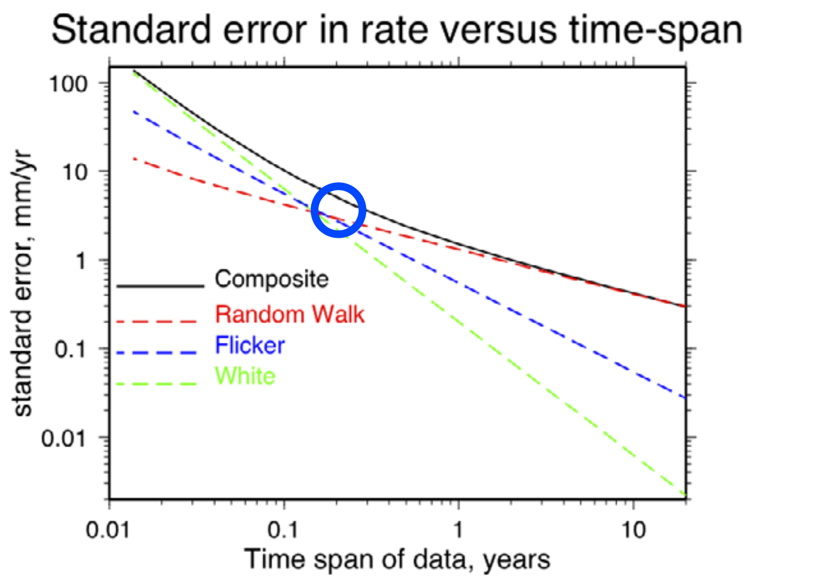


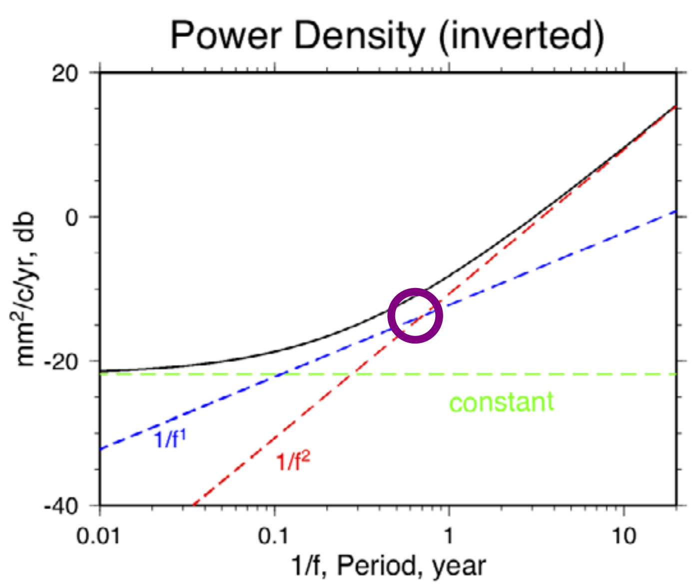
Error in Rate; length of data



Random walk becomes marginally detectable at periods > 300 days

Error in Rate; length of data

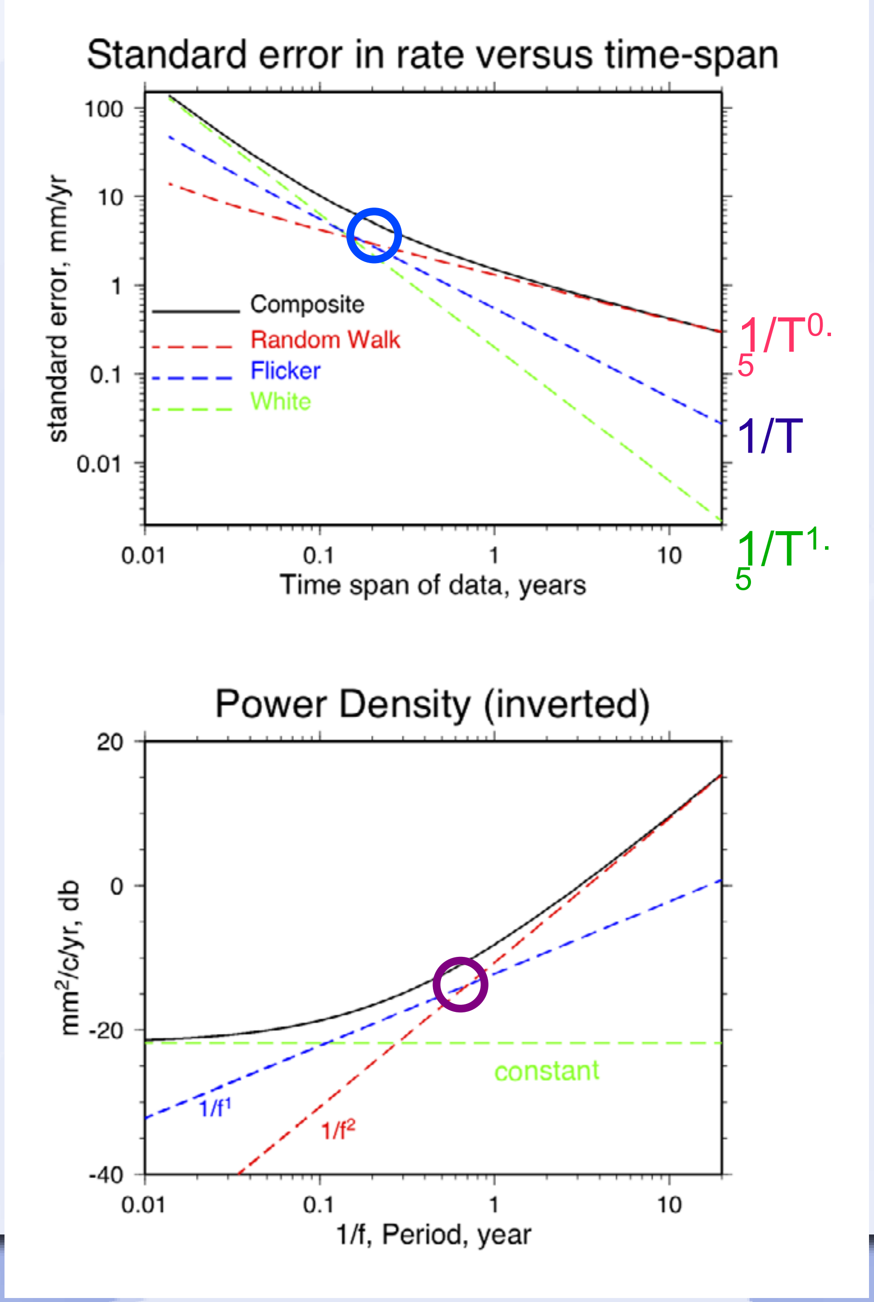




Random walk becomes marginally detectable at periods > 300 days

But random walk does affect rate errors for periods > 40 days

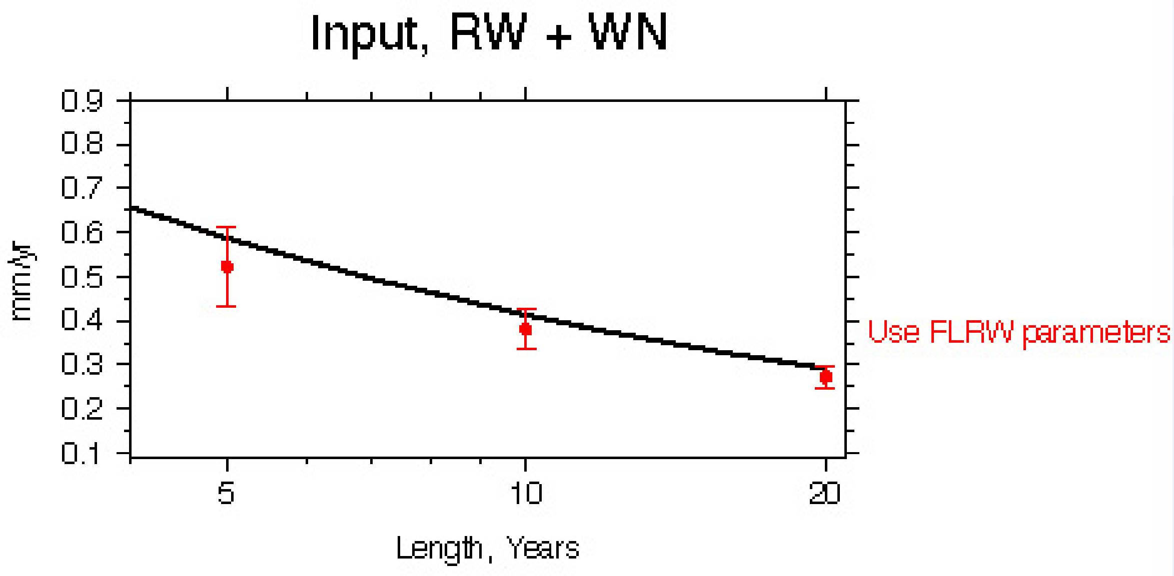
Error in Rate; length of data



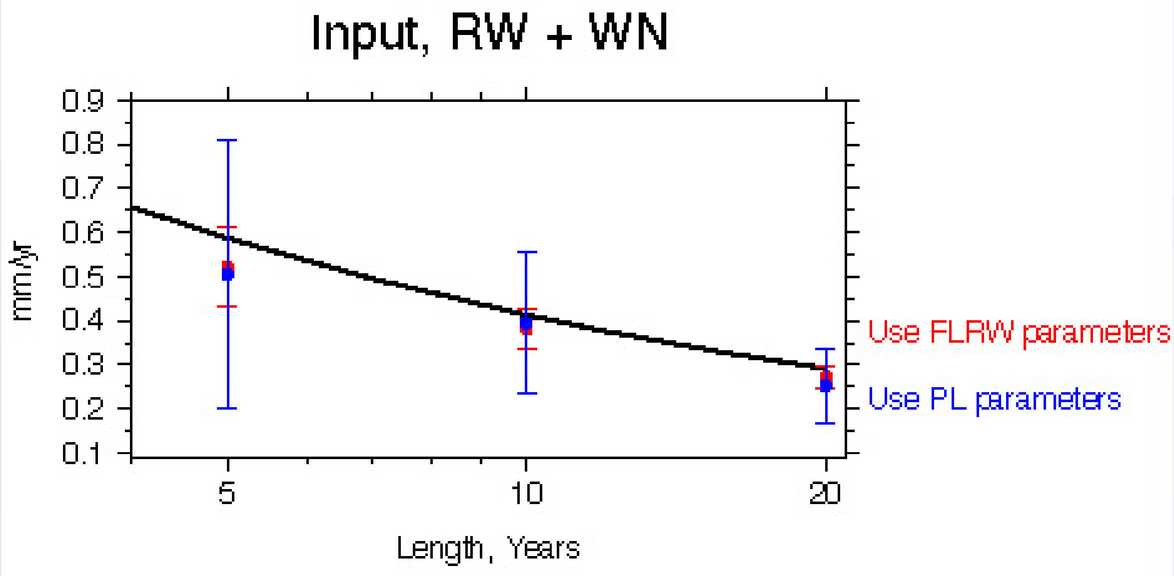
Random walk becomes marginally detectable at periods > 300 days

But random walk does affect rate errors for periods > 40 days

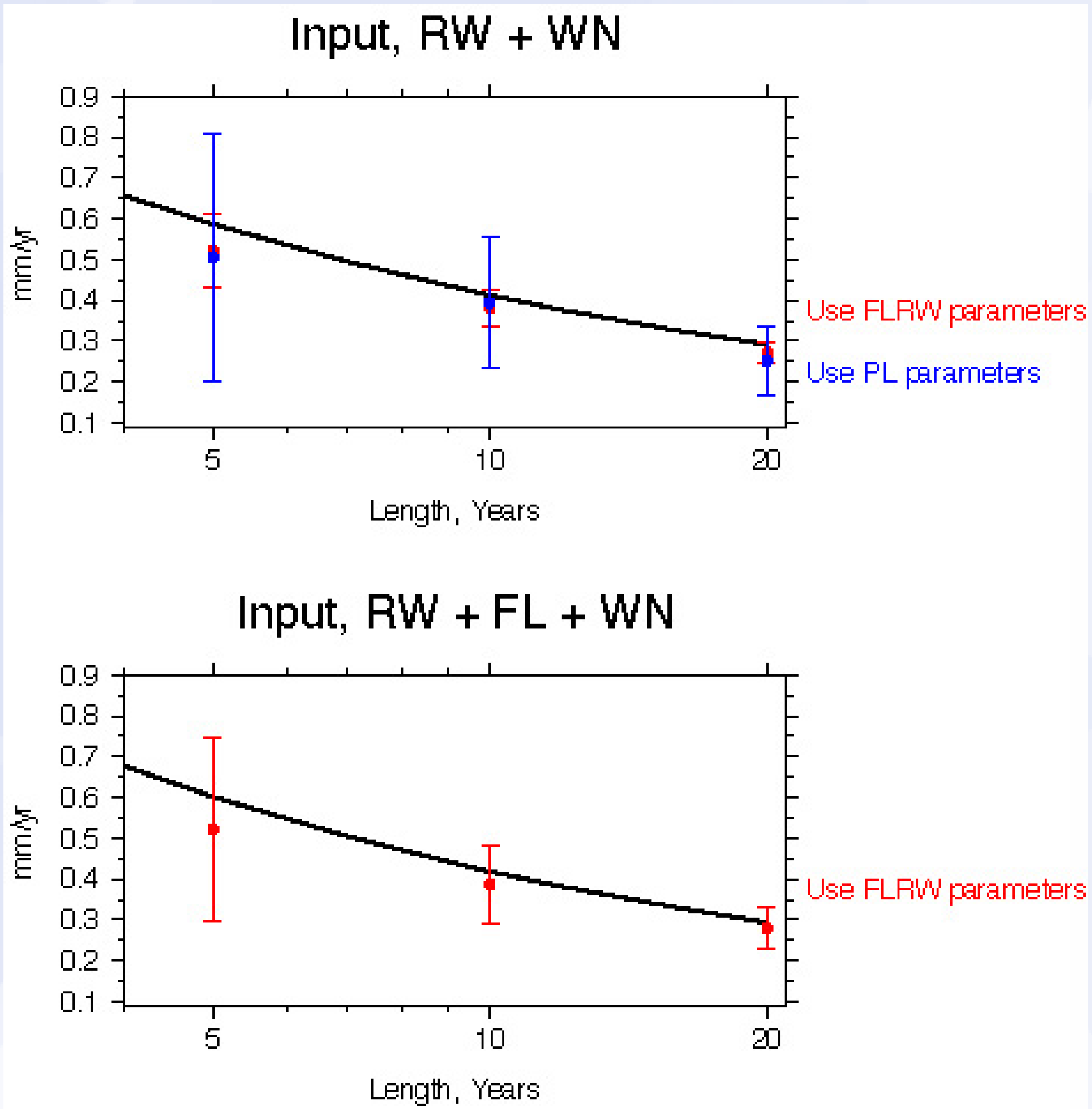
Choice of Noise Model



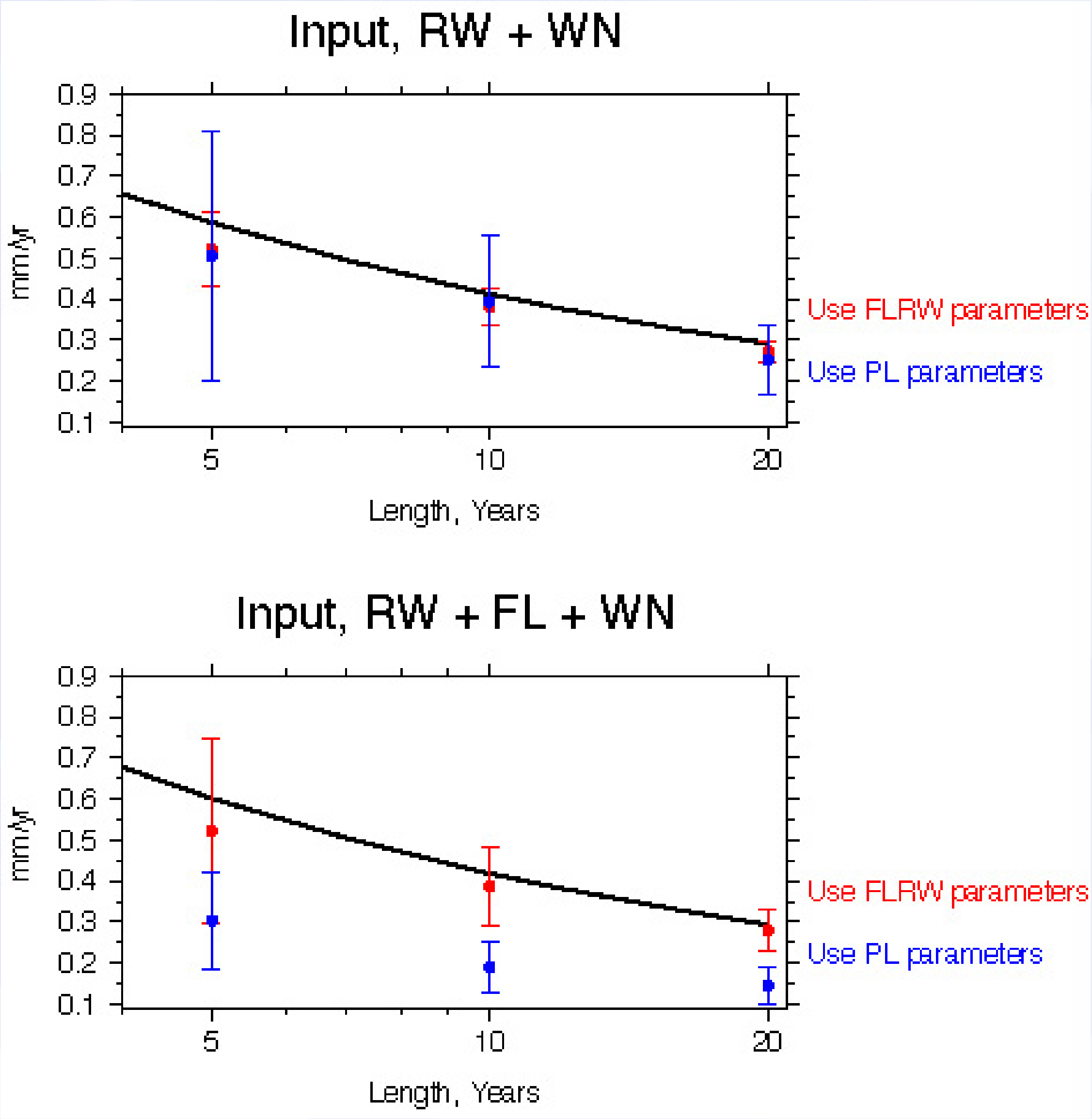
Choice of Noise Model



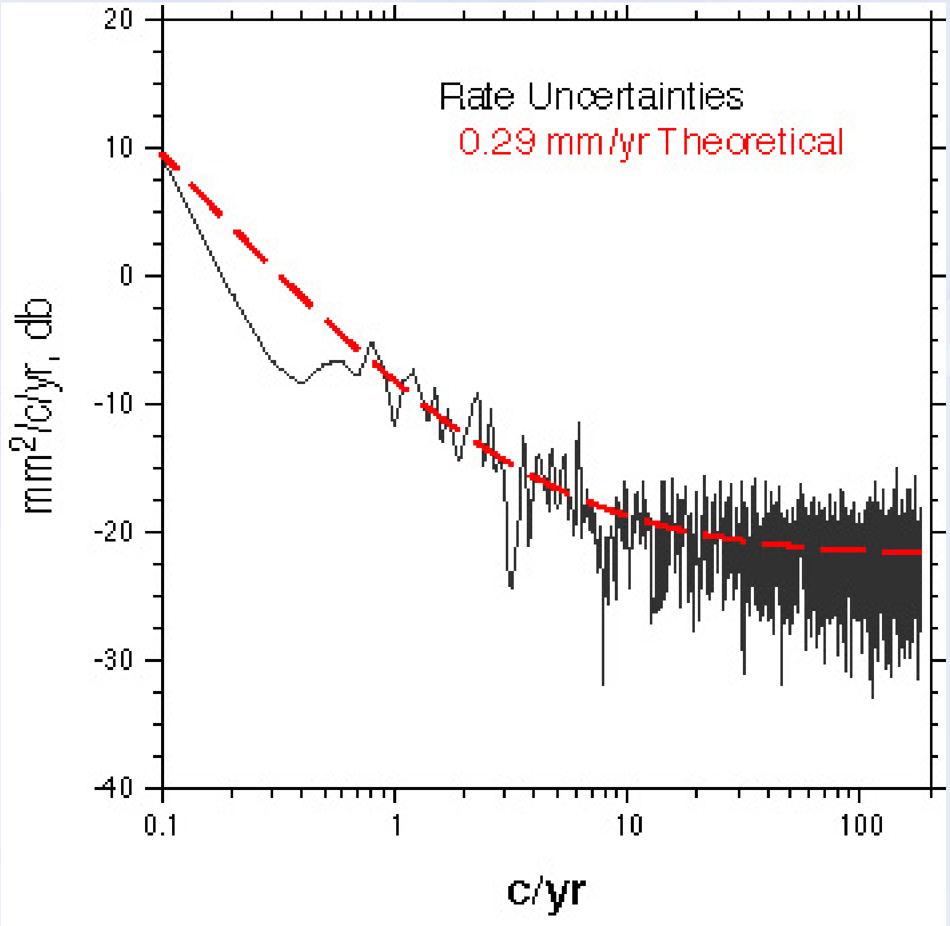
Choice of Noise Model



Choice of Noise Model

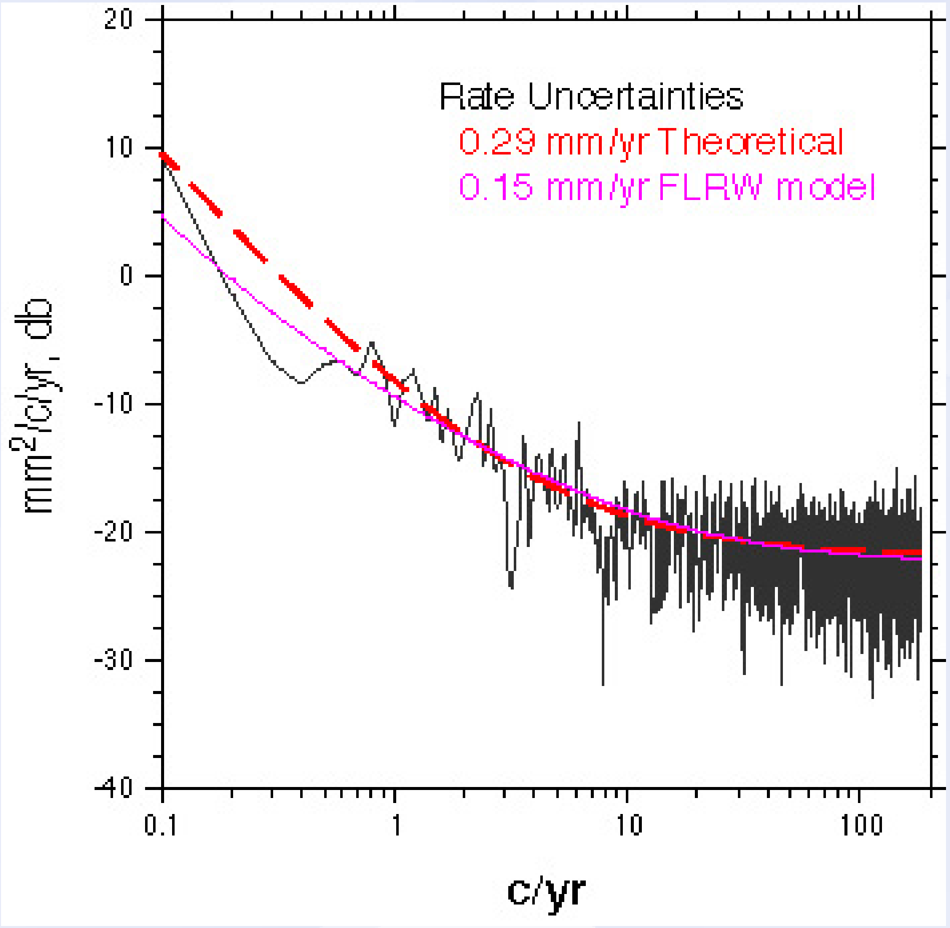


Choice of Noise Model; an extreme example



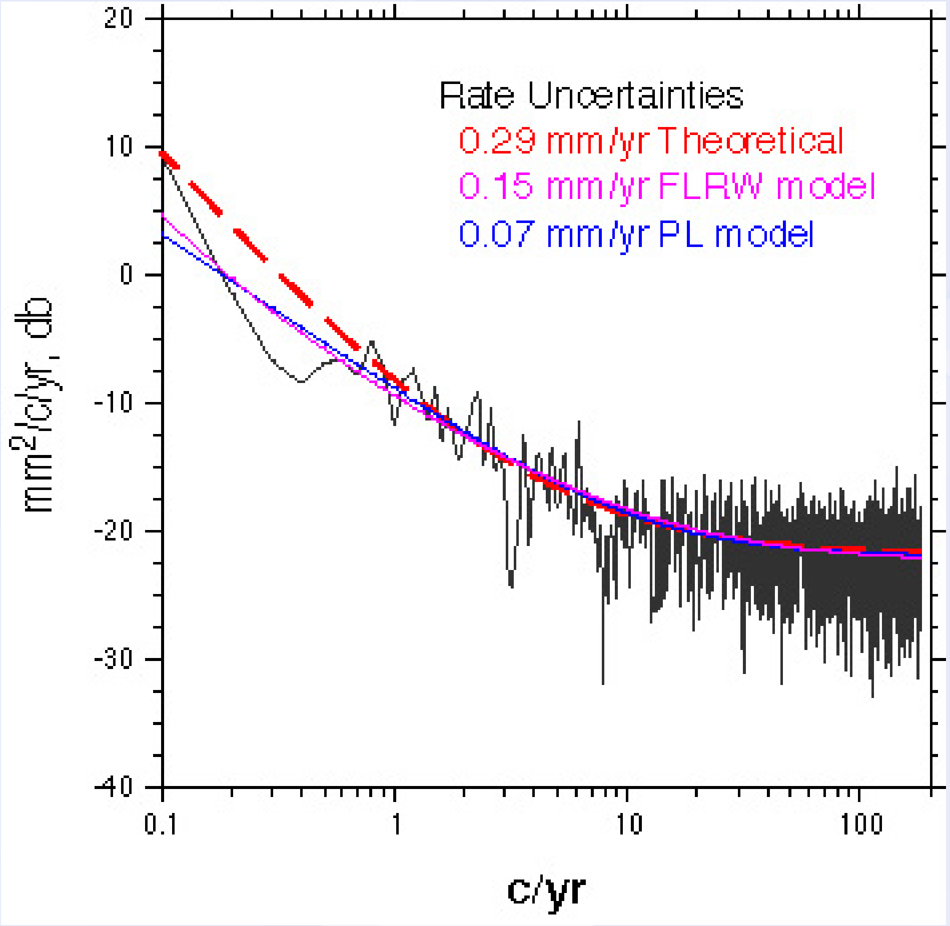
- Simulate 20 yrs of data using WN + FL + RW
- Compute PSD (black)
- Red is prescribed noise

Choice of Noise Model; an extreme example



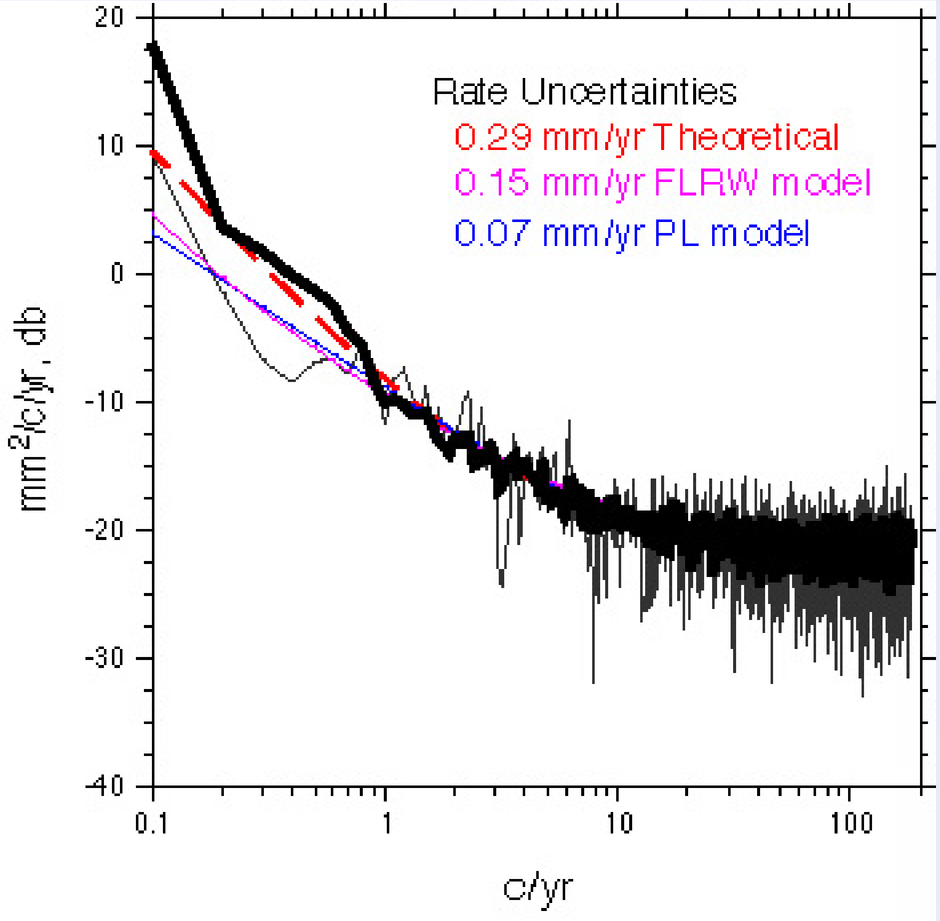
- Simulate 20 yrs of data using WN + FL + RW
- Compute PSD (black)
- Red is prescribed noise
- Model as WN + FL + RW

Choice of Noise Model; an extreme example



- Simulate 20 yrs of data using WN + FL + RW
- Compute PSD (black)
- Red is prescribed noise
- Model as WN + FL + RW
- Model as WN + PL

Choice of Noise Model; an extreme example



- Simulate 20 yrs of data using WN + FL + RW
- Compute PSD (black)
- Red is prescribed noise
- Model as WN + FL + RW
- Model as WN + PL
- Same simulation extended to 100 yrs
- PSD

Monument Pictures

gode

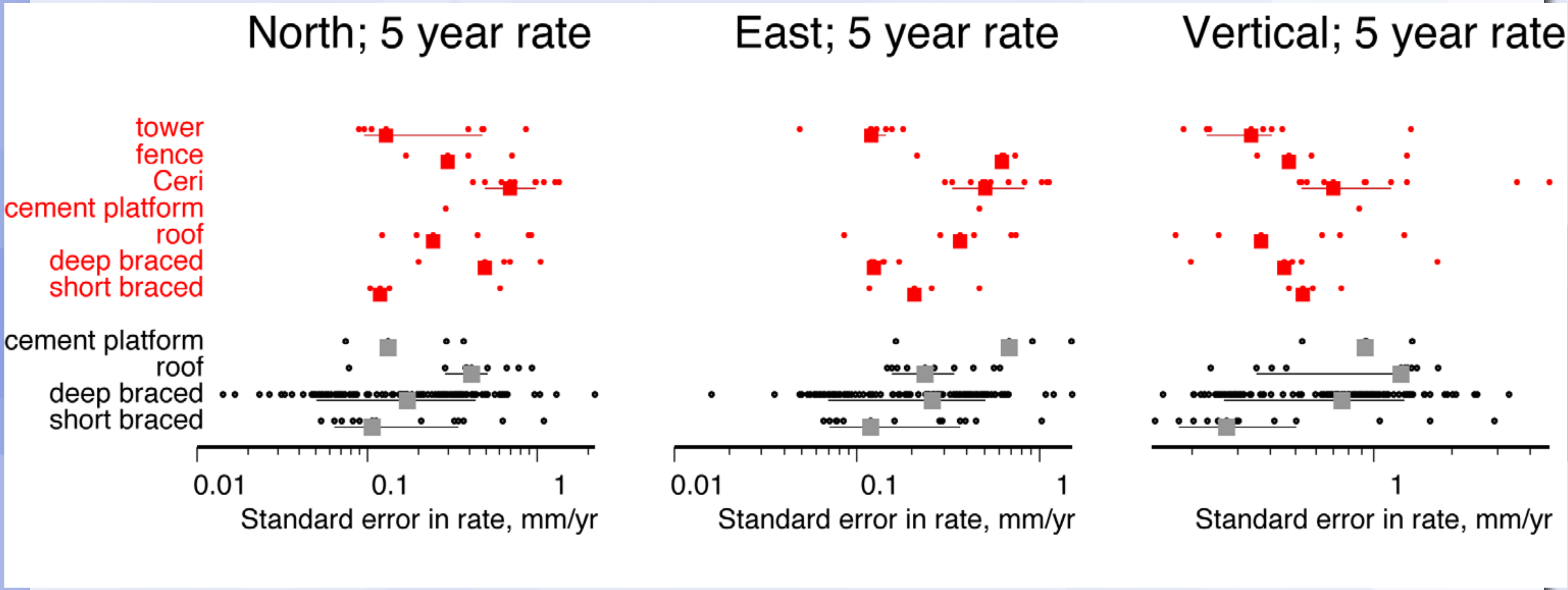
Figure 4. Co-located cGPS monuments at Hillcrest Elementary School in Troy, TN. The monument in the foreground is HCES, the original GAMA I-beam style monument installed in 2000. The monument in the background (to the right) is HCEX, the newly installed UNAVCO-style deep, drill-braced monument.

blmm, cnwm,
okom ??

arbt/cors

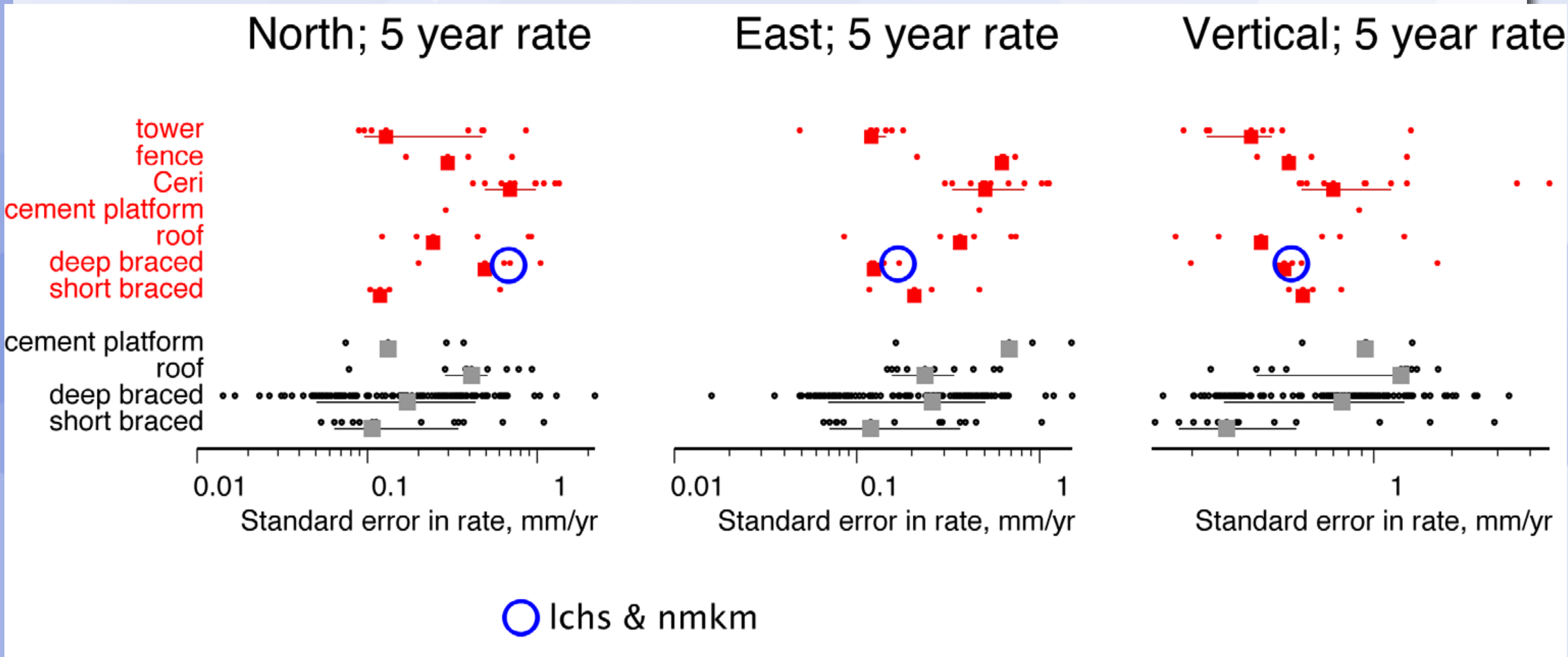
arfy/cors

Monument comparisons



Red – Central U.S.
Black – SCIGN

Monument comparisons

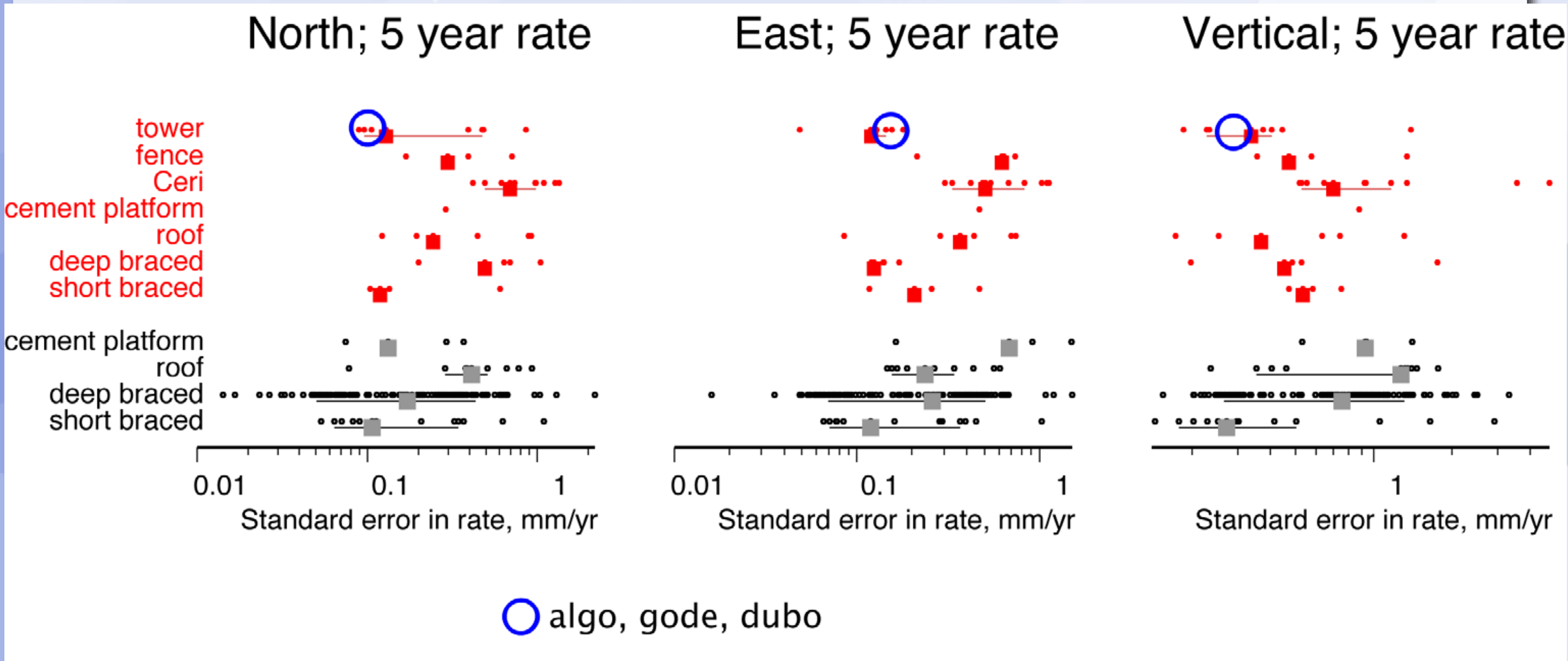


Red – Central U.S.
Black – SCIGN

Comparison of 2 sites in NMSZ having braced monuments;

caution – sites only have 3 years of data;
many sites have ~10 years of data

Monument comparisons

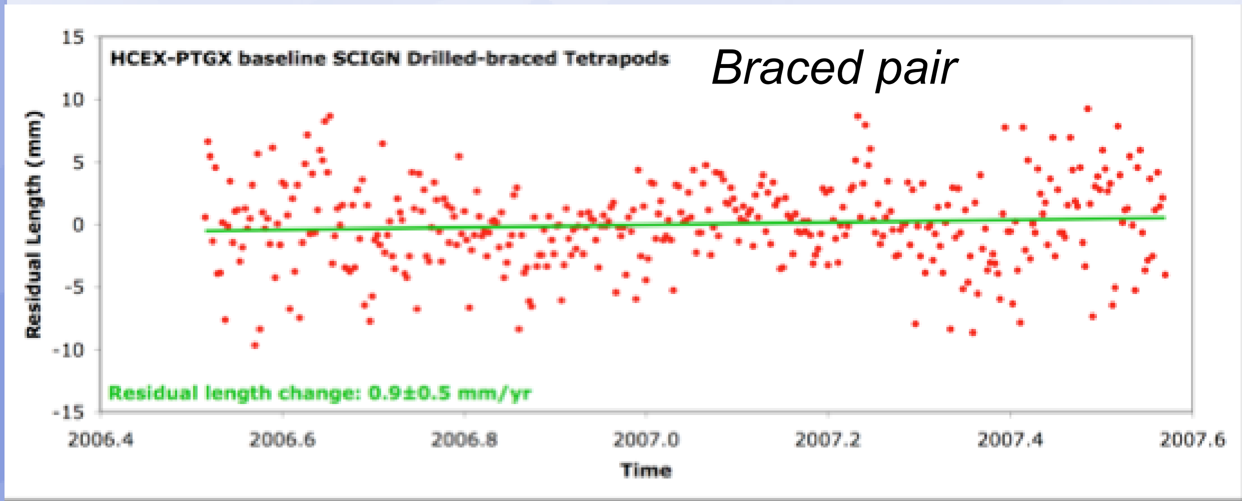


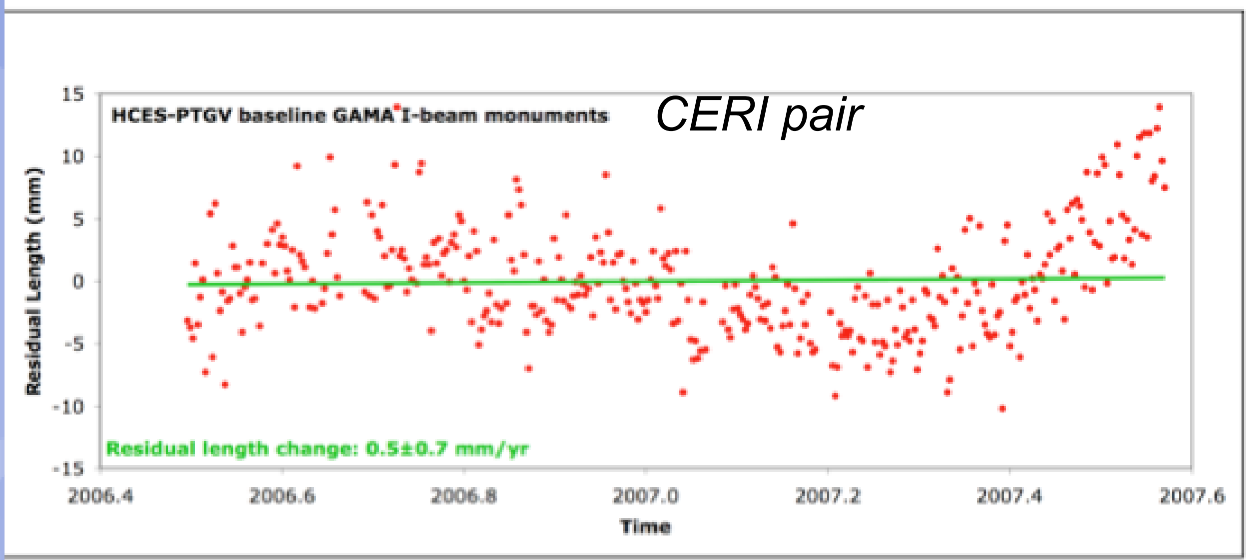
Red – Central U.S.
Black – SCIGN

Three sites used as regional filter sites with long time-series and excellent stability

Classified as "tower" but might not be the same construction used at CORS sites.

Braced/CERI Comparison





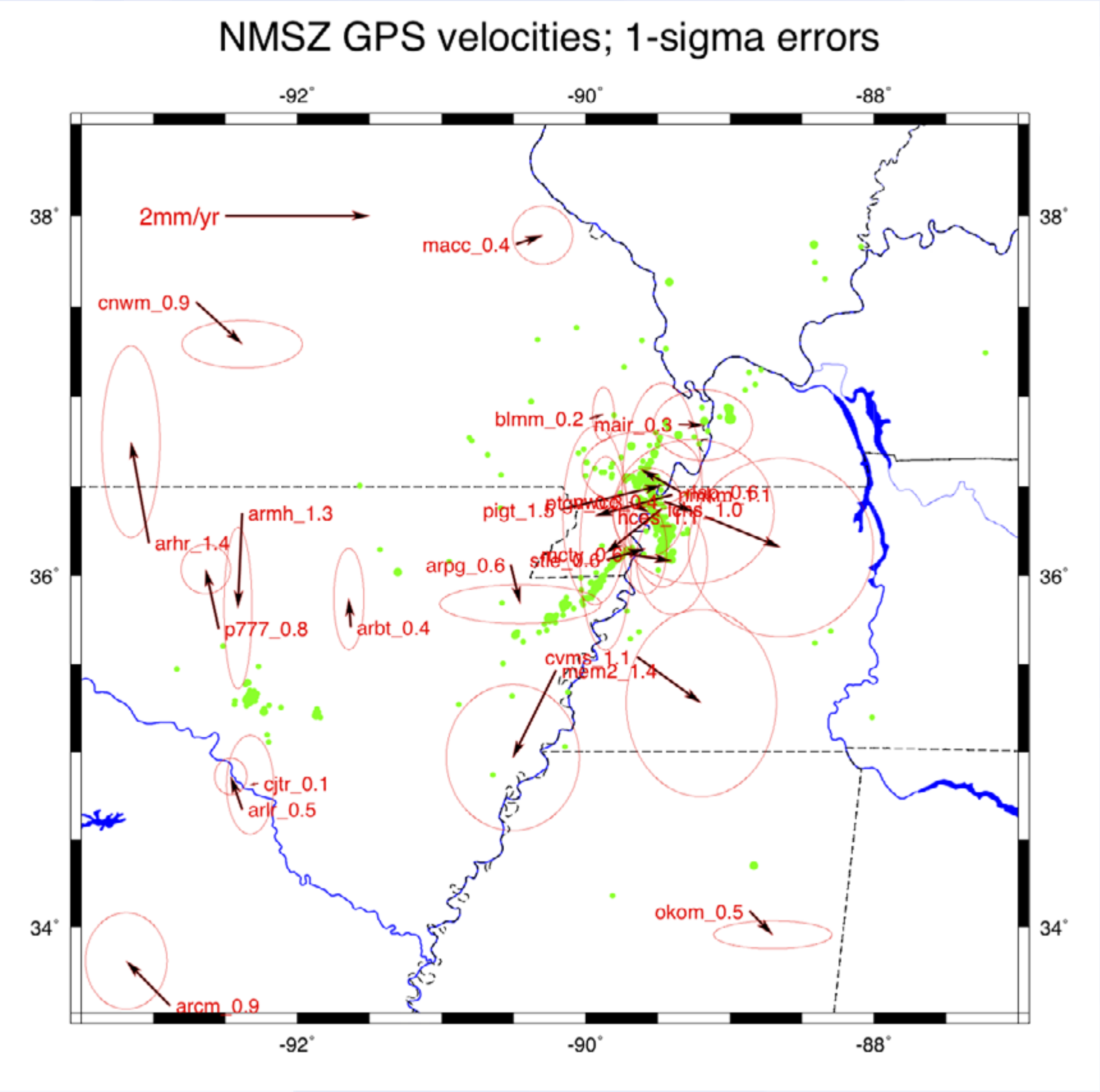
Baseline Length
Length= 48.2KM
hces – ptgv

1-year of data

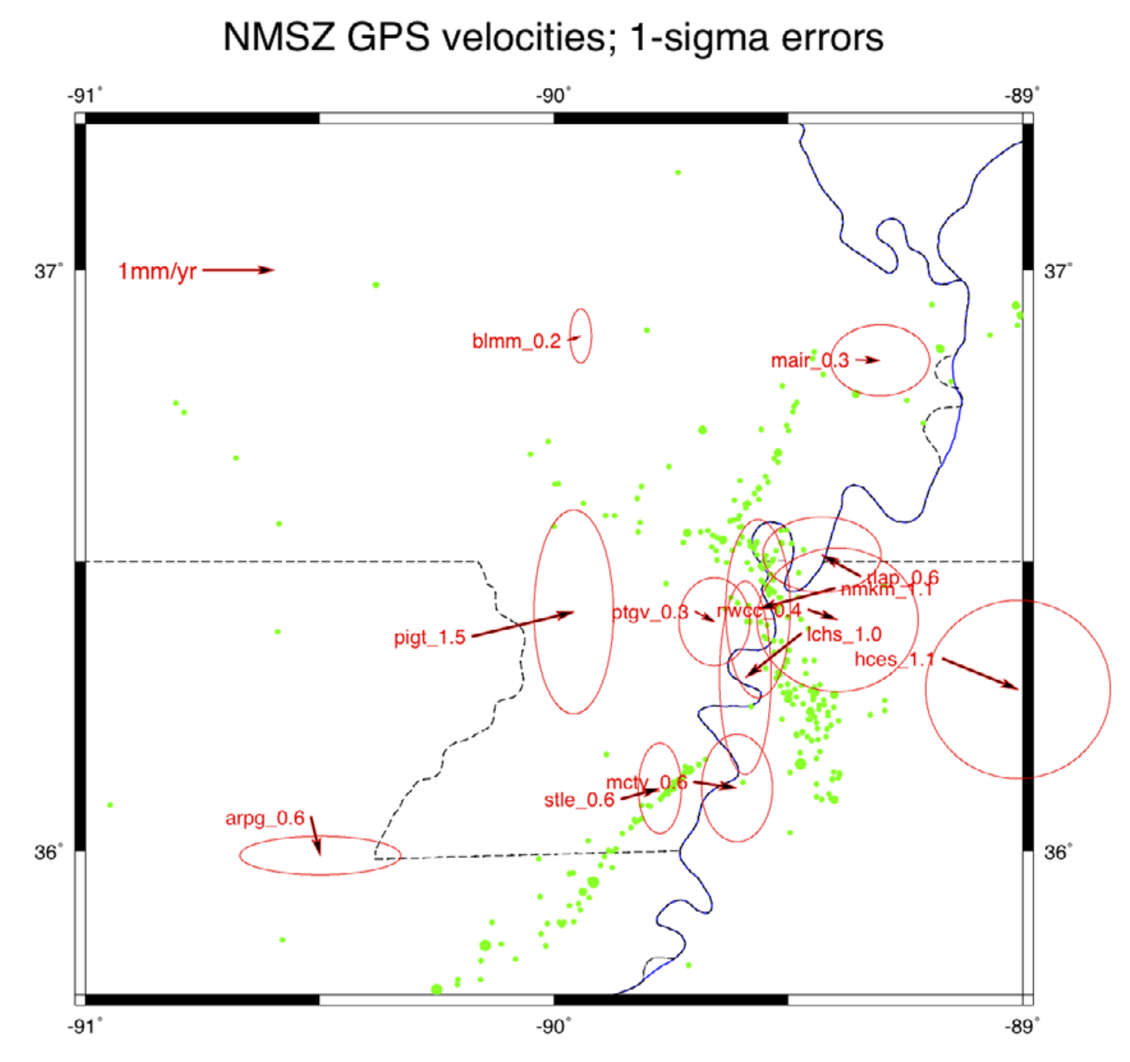
Figure 4. Co-located cGPS monuments at Hillcrest Elementary School in Troy, TN. The monument in the foreground is HCES, the original GAMA I-beam style monument installed in 2000. The monument in the background (to the right) is HCEX, the newly installed UNAVCO-style deep, drill-braced monument.

Reference G. Mattioli; Aug 2007 NEHRP report# 02JQGR0107

Velocities

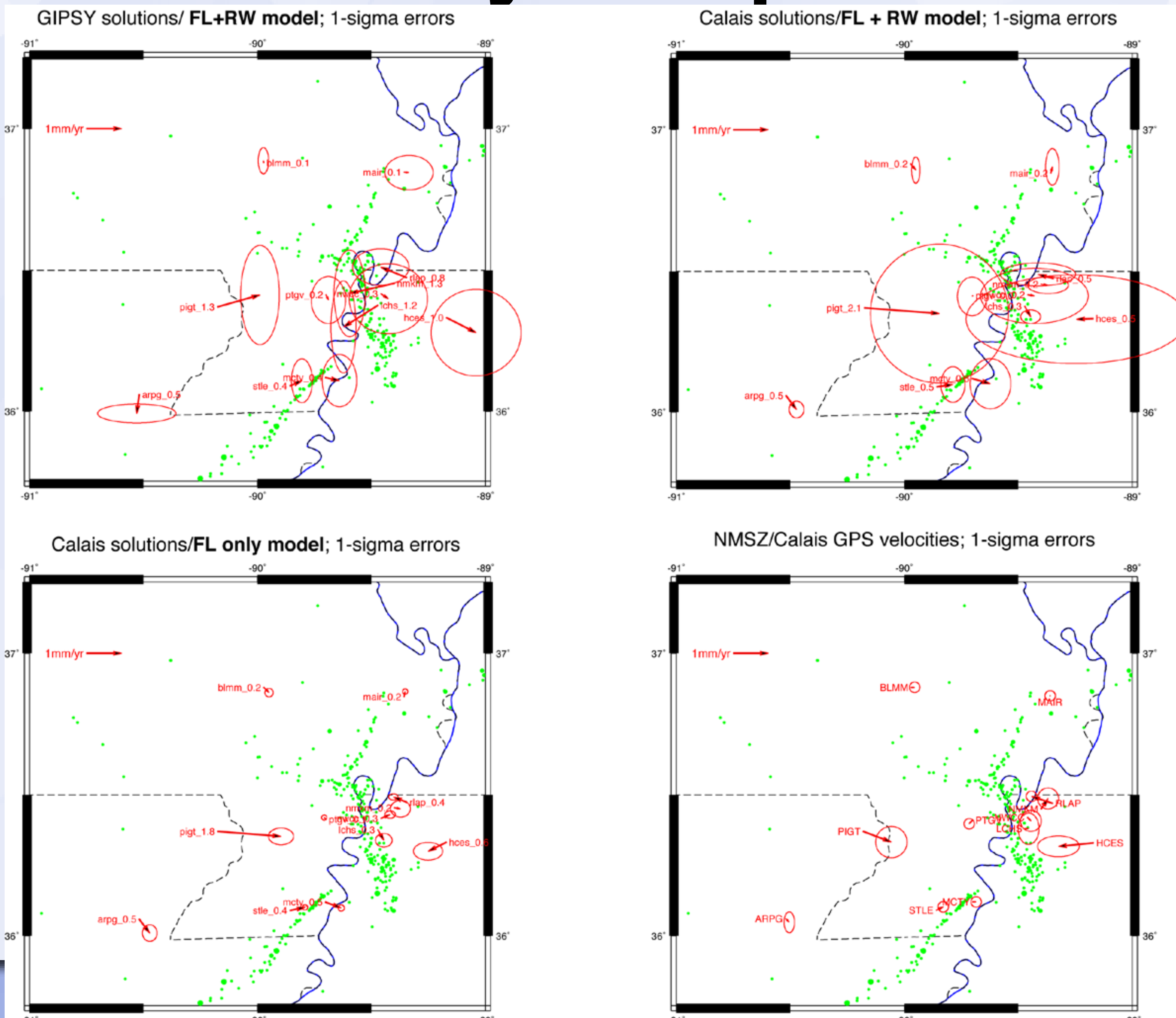

NMSZ GPS velocities; 1-sigma errors
-92˚
-90˚
-88˚
38˚
36˚
34˚
2mm/yr
macc_0.4
cnwm_0.9
blmm_0.2
mair_0.3
pigt_1.8
hces_1.1
arpg_0.6
armh_1.3
arhr_1.4
p777_0.8
arbt_0.4
cvms_1.1
mem2_1.4
cjtr_0.1
arlr_0.5
okom_0.5
arcm_0.9

Velocities

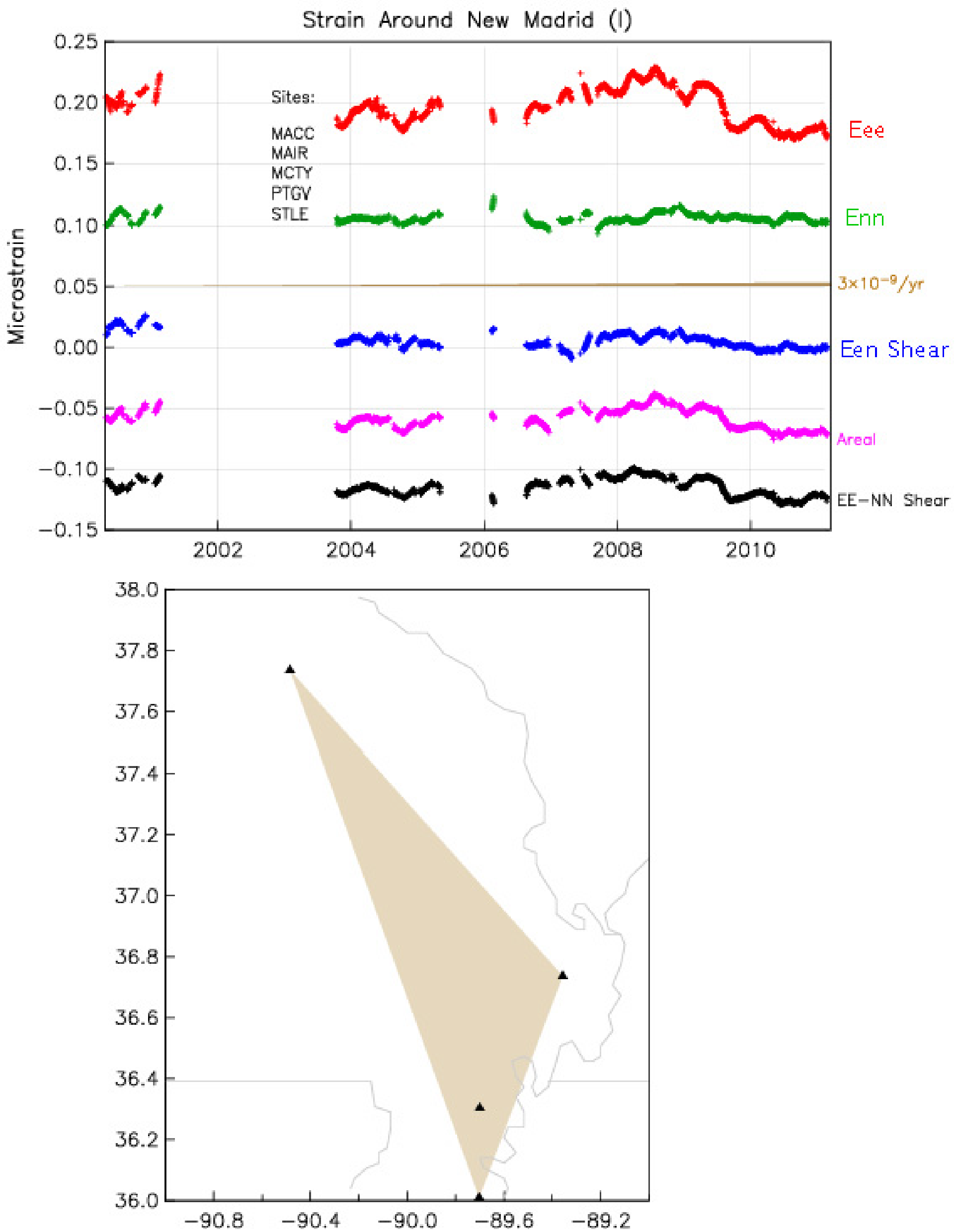


NMSZ GPS velocities; 1-sigma errors
-91°
-90°
-89°
37°
36°
1mm/yr
blmm_0.2
mair_0.3
pigt_1.5
ptgv_0.3
nwcc_0.4
lchs_1.0
hces_1.1
stle_0.6
mcty_0.6
arpg_0.6

Velocity comparisons



Strain



- Eee; detectable RW component of 18 ns/rt(yr) → -2.2+-5.5 ns/yr
- Enn; RW not significant but, could be 5 ns/rt(yr) → 0.1+-1.6 ns/yr
- Een; RW not significant but, could be 4 ns/rt(yr) → -1.8+-1.2 ns/yr

Calculation by D. Agnew, University of California San Diego, 2011.

Concluding Remarks

- Although difficult to quantify, the presence of RW has a significant impact on the precision of the velocity estimates.
- Long time series will constrain the maximum amplitude of RW noise.
- Long time series, in the presence of RW noise will see a $1/t^{0.5}$ improvement in rate uncertainty.
- Frequent observations do not improve rate uncertainty but do provide estimates of precision.
- On the other hand, if RW is not justified, then frequent observations provide marginal improvement of rate uncertainty.
- Justification for RW noise comes from long baseline strainmeter data that precisely measure the change in distance between two monuments.

Items to consider:

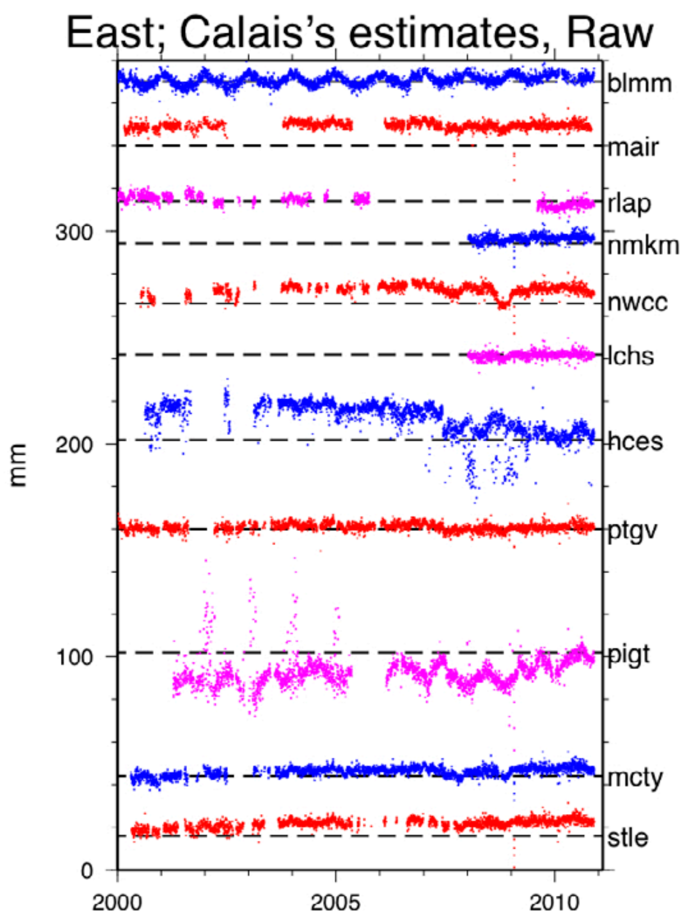
Short term items –

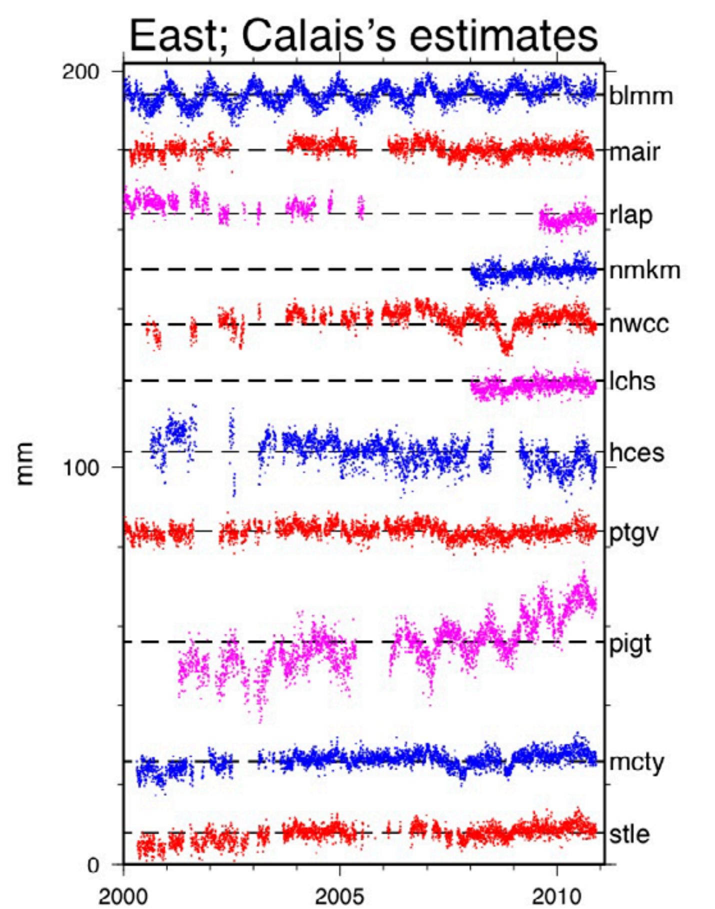
- Why does PIGT drift east?
  - Install second site at/near PIGT
  - Monitor tilt of PIGT pier
  - Persistent scatter InSar near PIGT
- Reactivate the Mattioli sites; HCES and PGTV
- Replace antenna at HCES (noisy)?
- Redo USGS solutions to obtain better precision

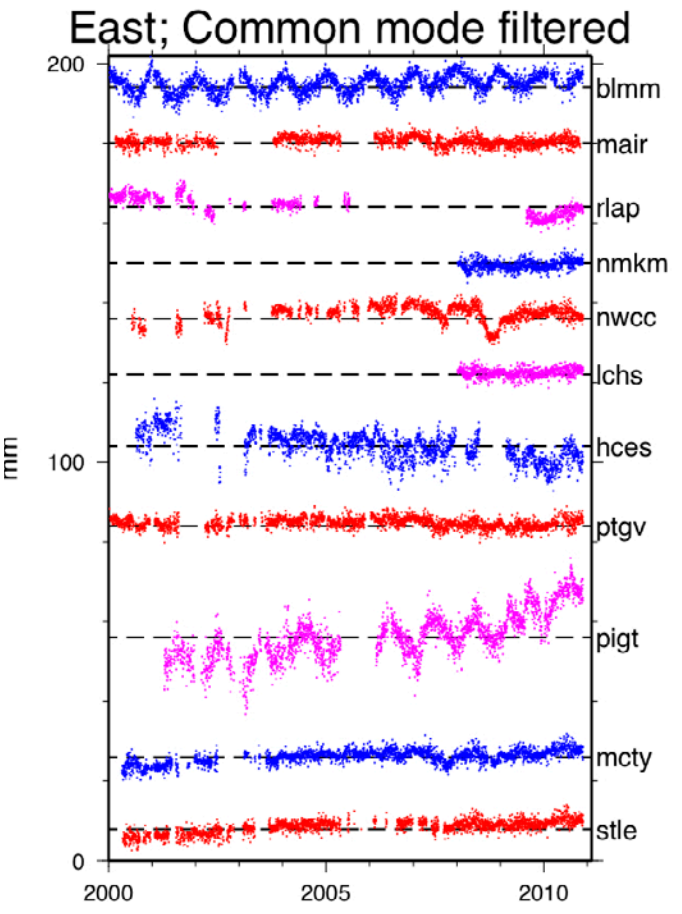
Long term items

- Campaign/Survey mode GPS
- Reoccupy existing campaign, GPS sites
- Additional continuous GPS, where?

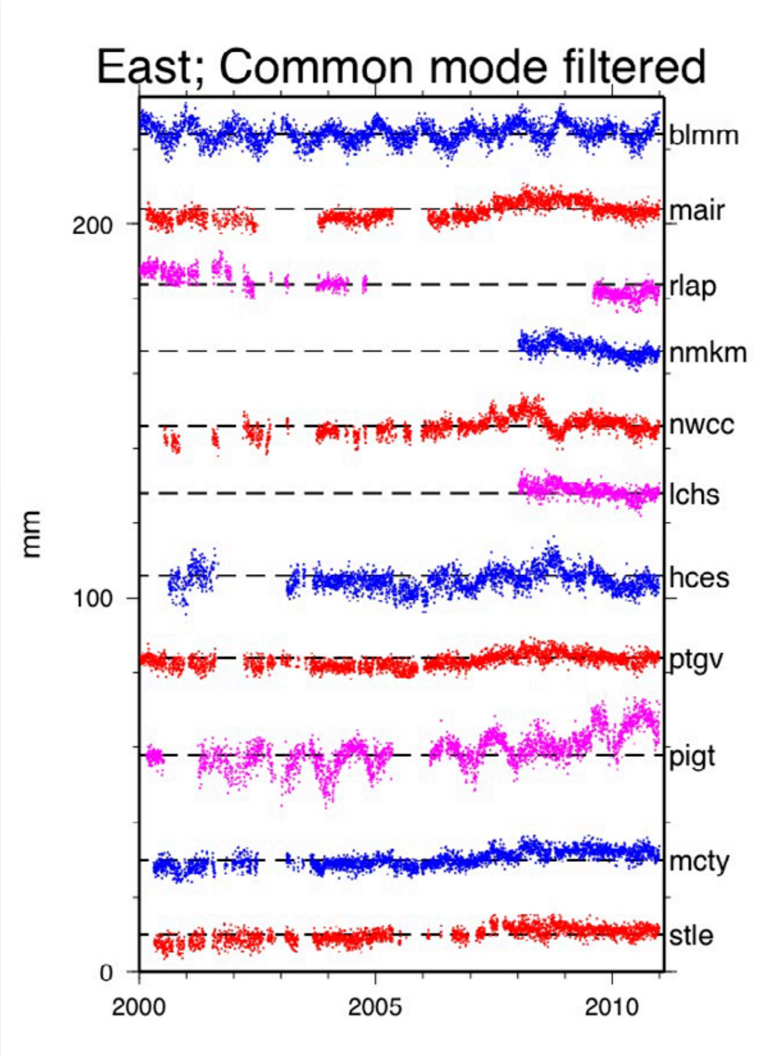
Calais's estimates



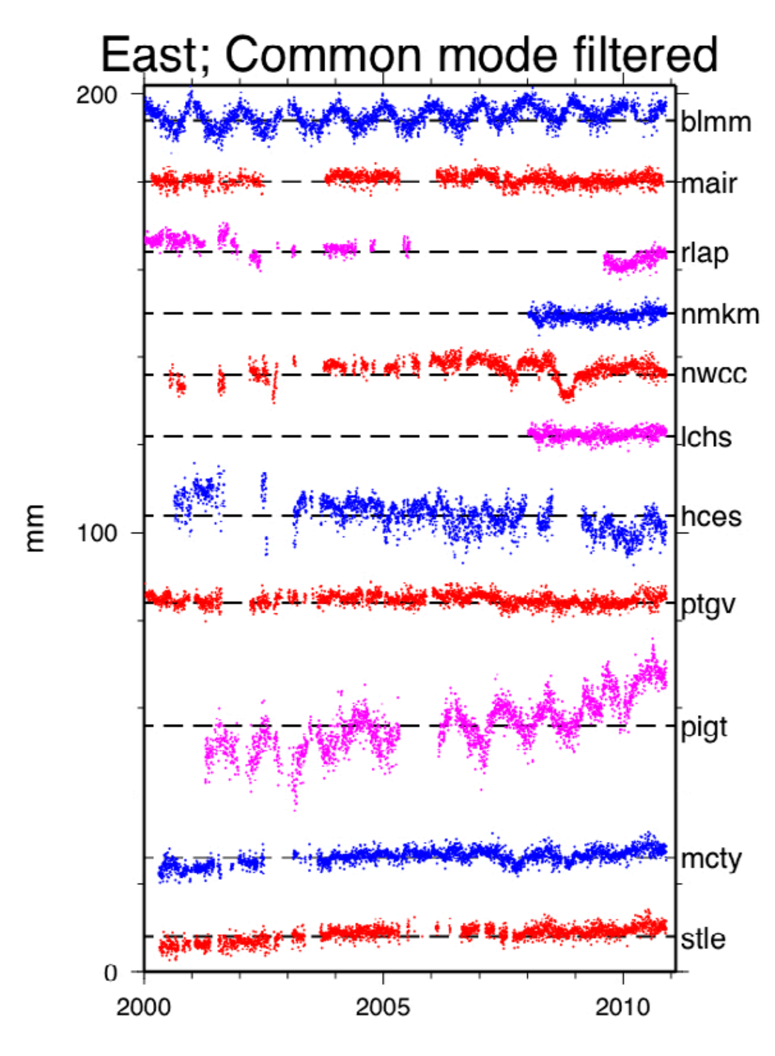




Compare GIPSY and Calais's



GIPSY/USGS



GAMIT/Calais