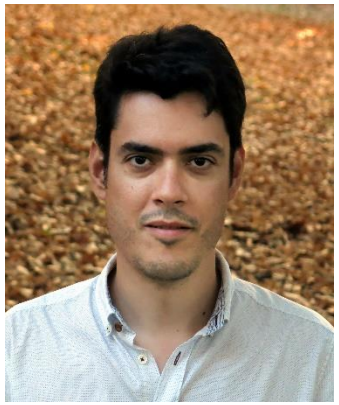
Chameleonic* noise in GPS position series: what is the true color of the GPS error spectra?

**Chameleonic: readily changing color or other attributes*



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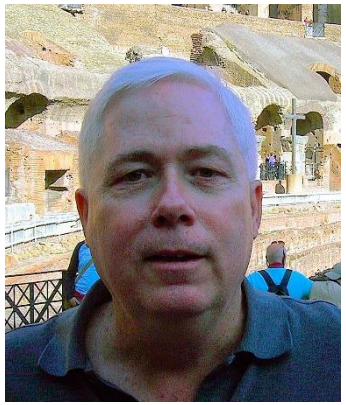

Short answer:

It is not possible to determine the full GPS error spectra because the actual numbers of estimated position offsets, due to Earthquakes and equipment changes, absorb the power spectral density at long periods rendering it unobservable. This severely impacts both velocity estimates and their uncertainties, contrary to some recent studies.

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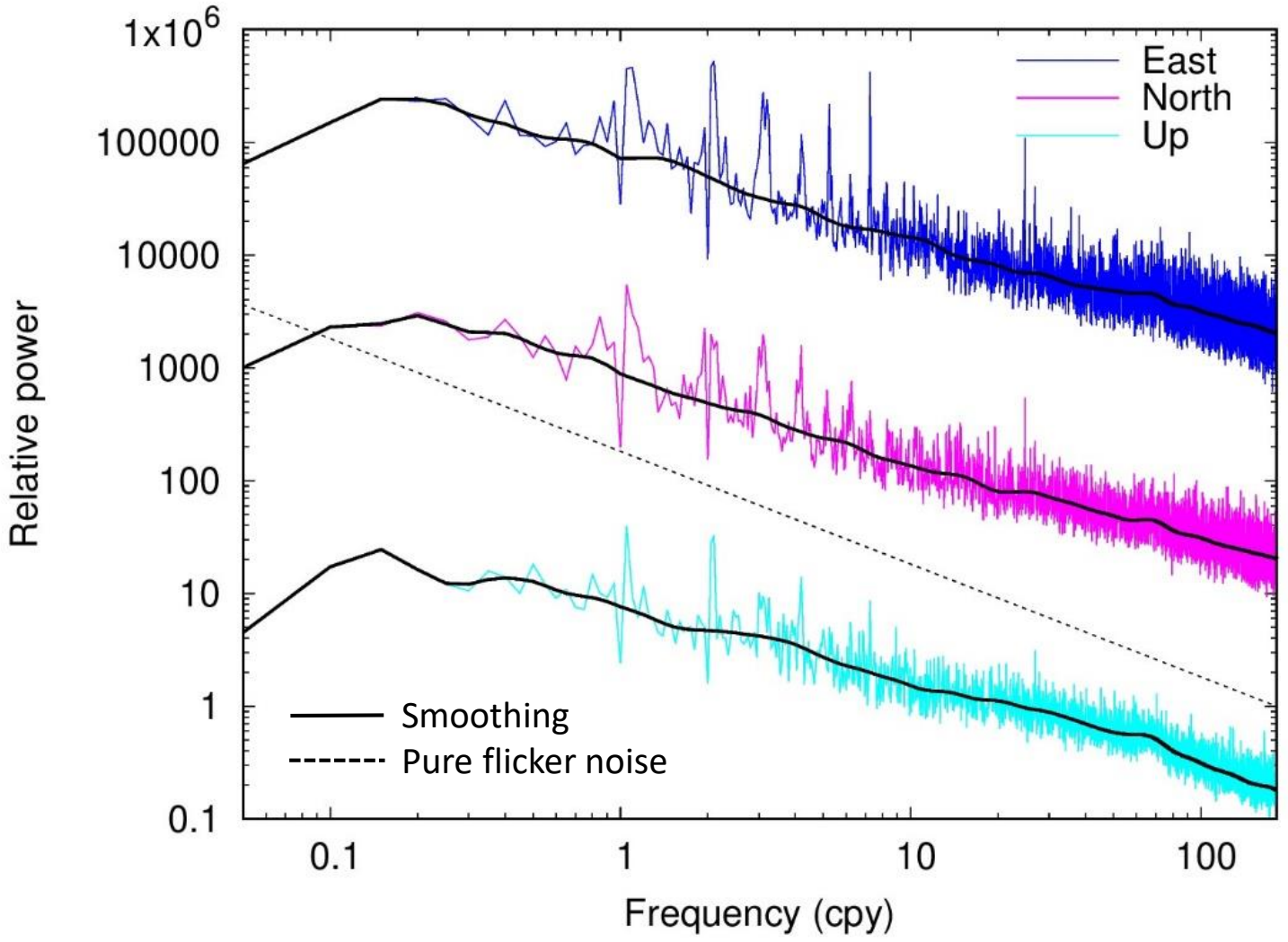
Error spectra of the latest JPL reprocessed solution (IGS14) used in this study

Stacked power spectral density (PSD) from 129 GPS residual daily series of the JPL online database (IGS14 reprocessing). Linear trends, offsets and seasonal variations have been removed.

All 129 series have 20 years with minimum missing data. They were selected after visual inspection of their quality. Several outliers were removed and 8 offsets were added after assessing their significance against colored noise using SARI (https://alvarosg.shinyapps.io/sari).

The smoothed PSDs have a crowbar shape with significant loss of power at low frequencies. At high frequencies, white noise is absent due to JPL's 3+24+3 h arc processing. The draconitic harmonics are visible up to the 9th as well as fortnightly peaks.



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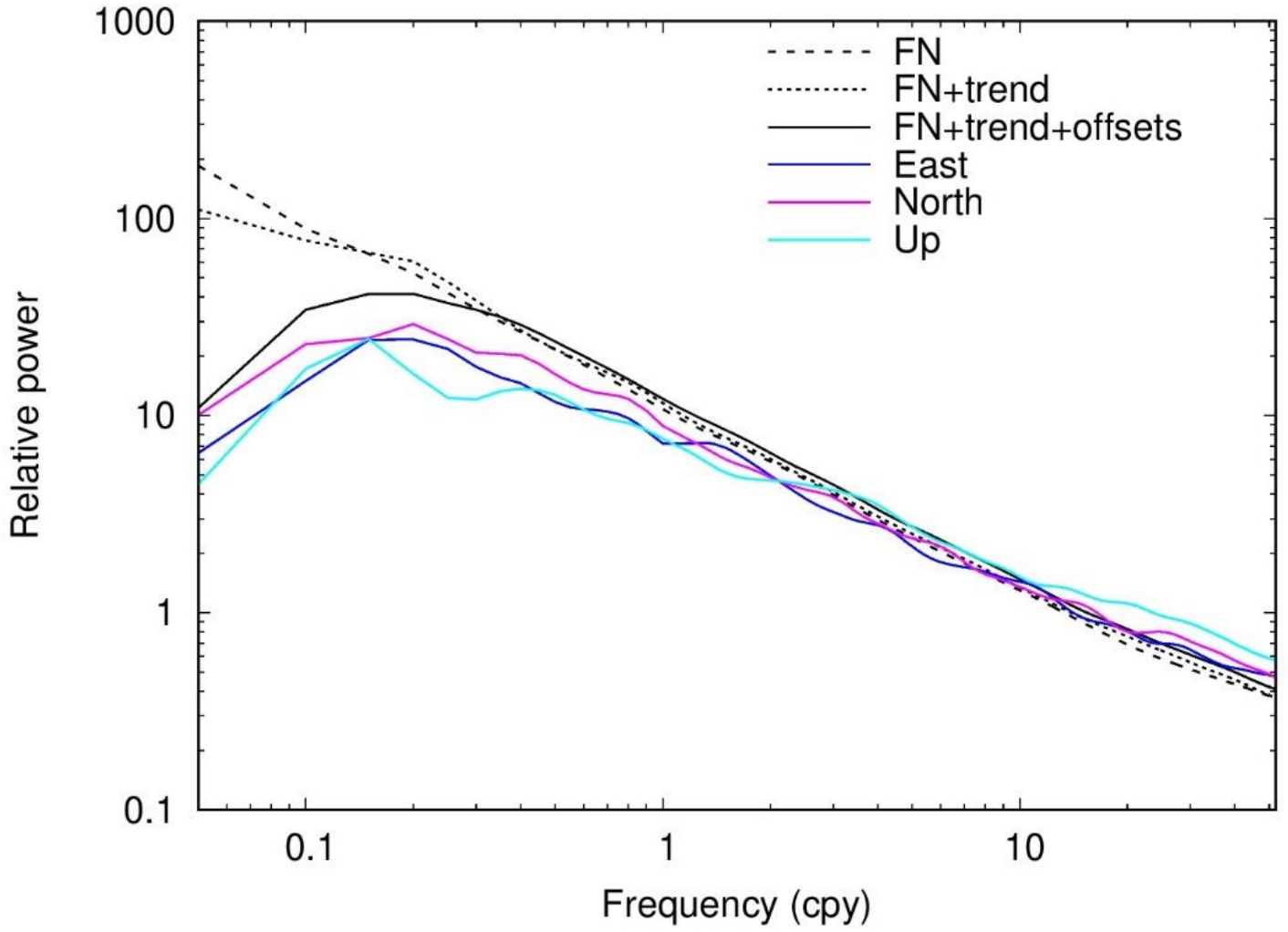
Estimated position offsets drain the spectral power at low frequencies

Smoothed stacked PSD from 129 weekly series:

- FN = synthetic pure flicker noise (same sampling as real JPL series)
- FN + trend = FN series with trends removed
- FN + trend + offsets = FN series with trends and same JPL offsets removed
- East, North, Up = smoothed residual JPL series for each component (from slide 2)

Crowbar-shaped PSDs from real JPL residual series are consistent with synthetic FN series with trends and offsets removed.

When fitting a noise model to the residual JPL series (e.g., using CATS or HECTOR), the Gauss-Markov model is artificially favored instead of a power-law model, but none of these models correctly fits the crowbar shape.



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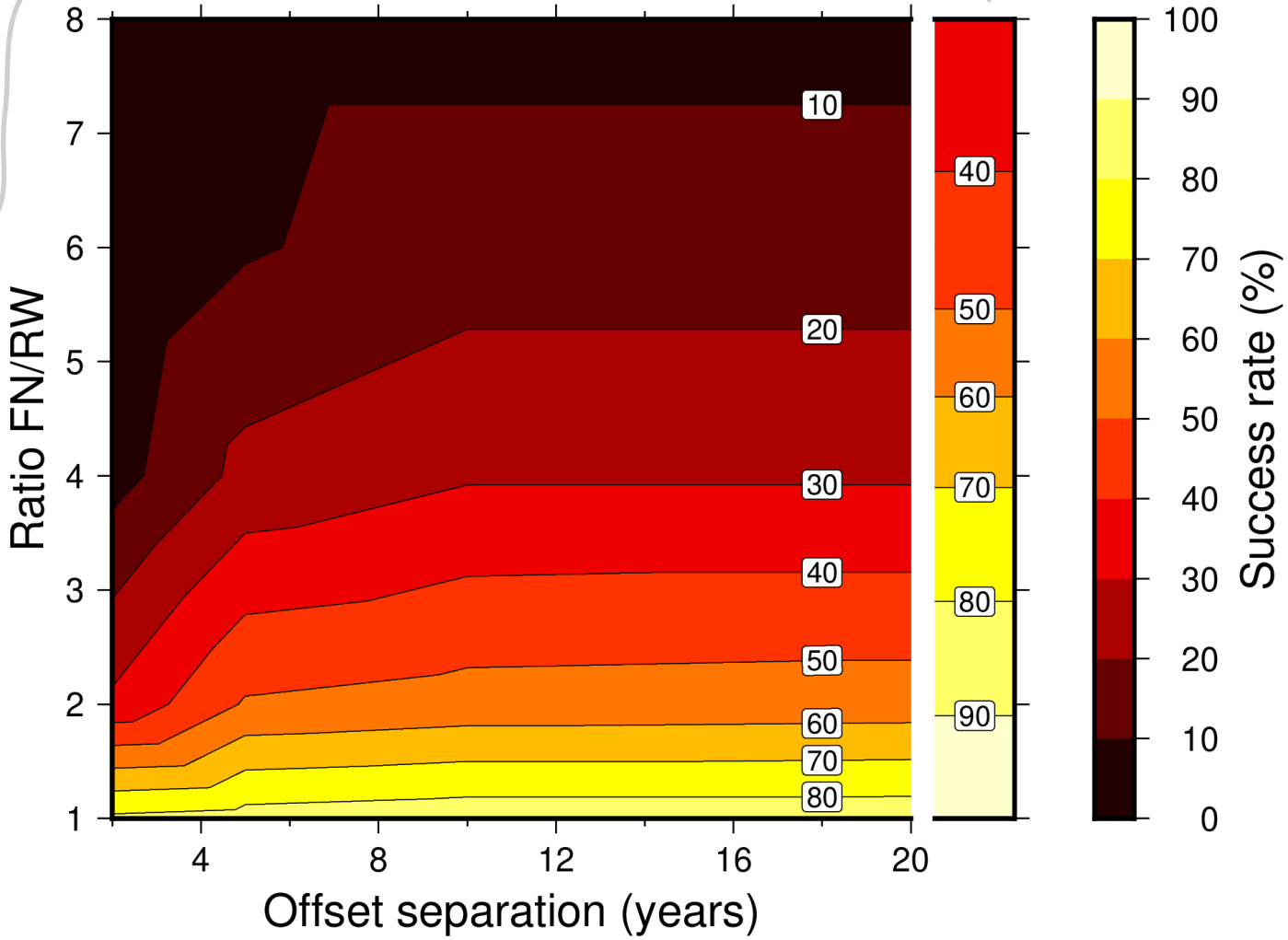
Estimated position offsets make it more difficult to detect random walk noise

Success rate of detecting random walk (RW) noise in synthetic series of 20 years length having different amplitude ratios of FN over RW and different numbers of estimated position offsets (1 offset every 2 to 20 years).

The separated box to the right represents the success rate in the ideal case when the rate and the offsets are not removed from the series (only the ratio FN/RW plays on the success rate).

For a typical 20-yr daily series having an estimated offset every 6 years, a RW amplitude equal to 1/6 of the FN amplitude (hor. ~0.7 mm yr^{-2} & ver. ~2 mm yr^{-2}) will have less than 10 % chance to be detected (against ~45 % with no offsets).



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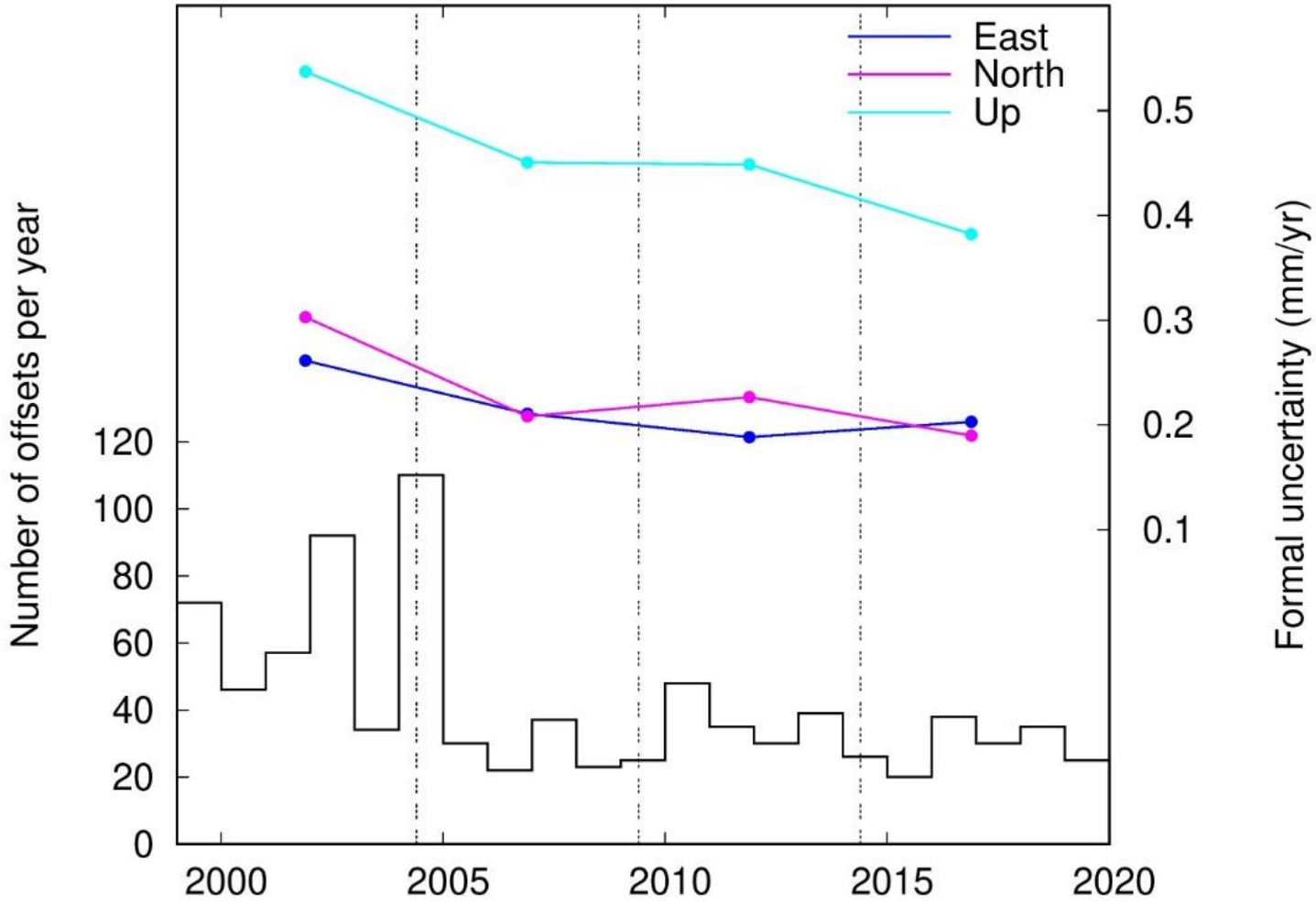
GPS error spectra changes with time

The 129 JPL 20-year series are split into 4 segments of 5 years each and fitted by different noise models. For each segment, the median formal rate uncertainty is computed from the best fitted noise models.

Total offsets are more frequent <2010, particularly <2005, than >2010. For >2005, the number of removed offsets stabilizes. If the noise amplitude and type were constant, the noise should get redder, increasing the formal rate uncertainty for >2005, but we observe the contrary, especially in the vertical.

The reduction of the median formal rate uncertainty (from the noise models) indicates that GPS colored noise is becoming whiter.



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Concluding remarks

Position offsets due to equipment changes must be avoided at all costs for scientific applications because:

1. The impact of position offsets on the linear trend estimates is more severe than previously thought as they bias the estimation of formal rate errors to lower while still exacerbating the true errors.

2. At the current level of position offsets in the series, it is not possible to observe the PSD at long periods. This has a dramatic impact on several scientific questions in geodesy:
   - Does the PSD flatten at some point? Why?
   - Does it not? Why?
   - Is the PSD lower with an extremely-expensive-and-difficult-to-install GPS monument?
   - Are there interesting Earth deformation signals at long periods (e.g. ~5.9 years)?

3. Longer GPS series will not add more information to the PSDs we have today, unless offset numbers reduce drastically.

Since GPS noise is becoming whiter, it is wrong to compare noise estimates from series of different periods and lengths. Conclusions derived from such comparisons are probably flawed (different GPS monuments, different GPS solutions, etc.).

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Take-home messages

OR I WILL HAVE TO QUIT GEODESY AND DO GEOLOGY
(Jim is safe, he has already retired)

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