Sub-daily signals in GPS observations and their effect at semi-annual and annual periods

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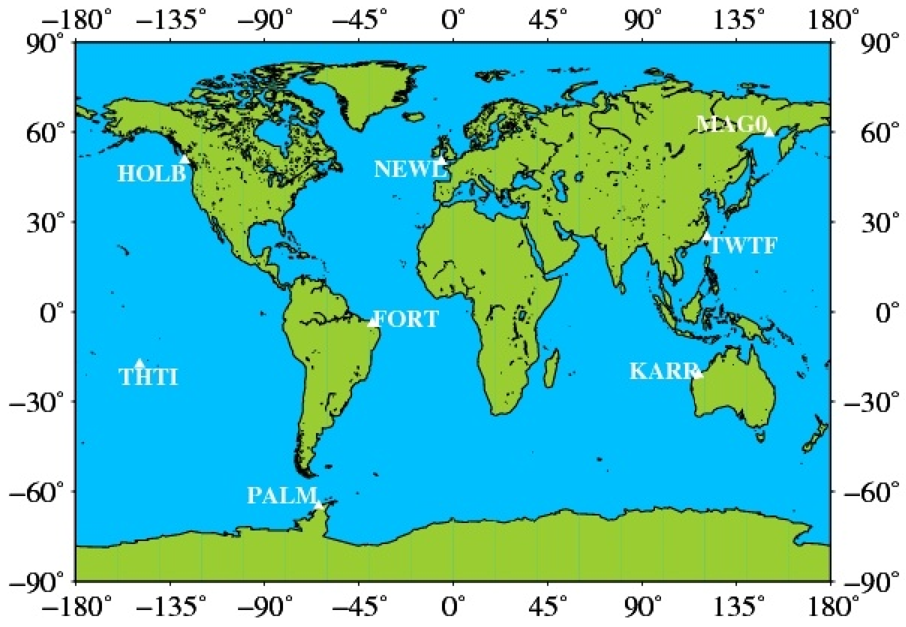
Propagation of unmodelled signals

- Unmodelled sub-daily harmonic signals propagate into GPS height time series [Penna et al., 2007, JGR]
  - Tested 8 sites
  - Admittances of up to ~120% **into heights** in PPP solutions
  - Unmodelled signals in N are most ‘efficient’ (~120%), followed by E (~40%) and U (~5%)
- Will bias GPS estimates of low frequency geophysical signals



Example

KARR: M2

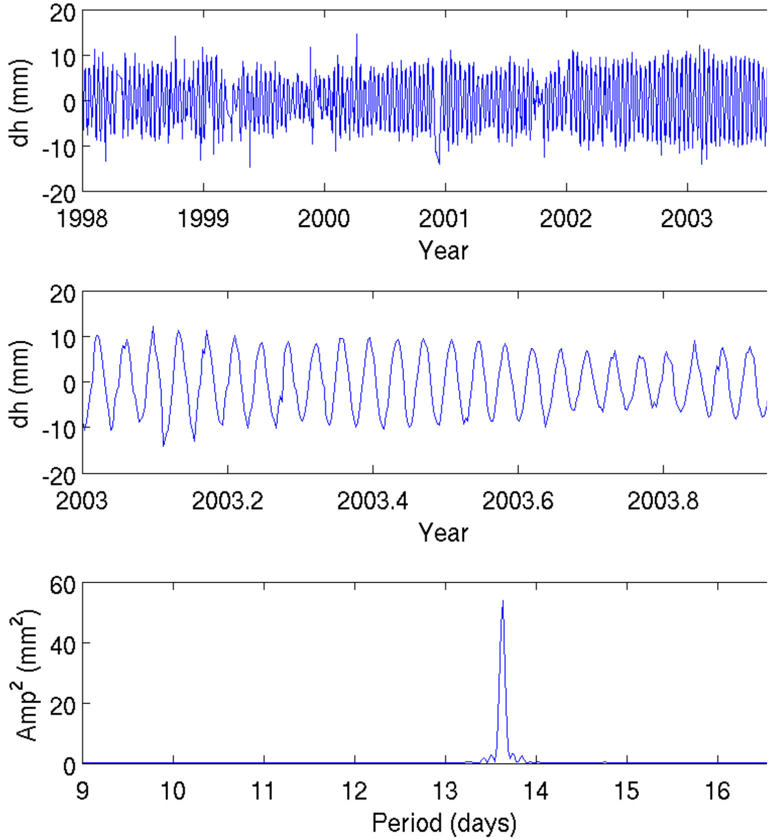
amp h 15 mm
amp E 2 mm
amp N 7 mm

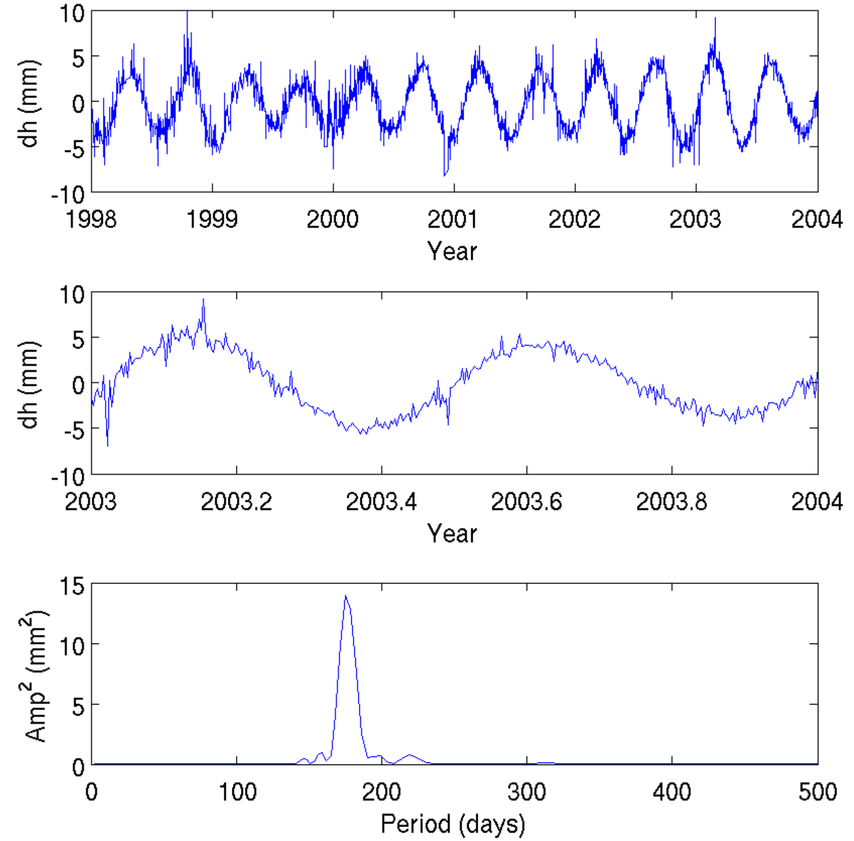
Unmodelled signals

KARR: S2

amp h 8 mm
amp E 1 mm
amp N 3 mm

Unmodelled signals



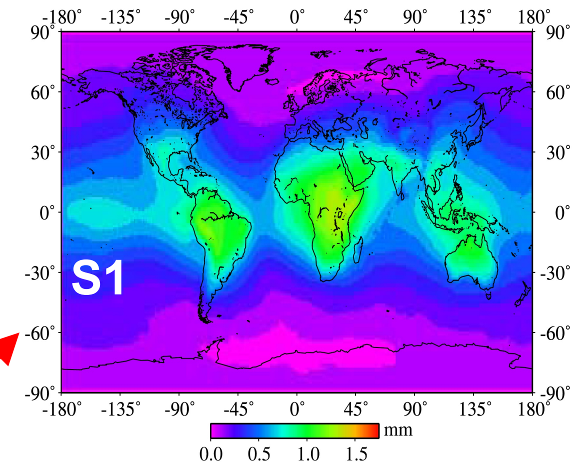


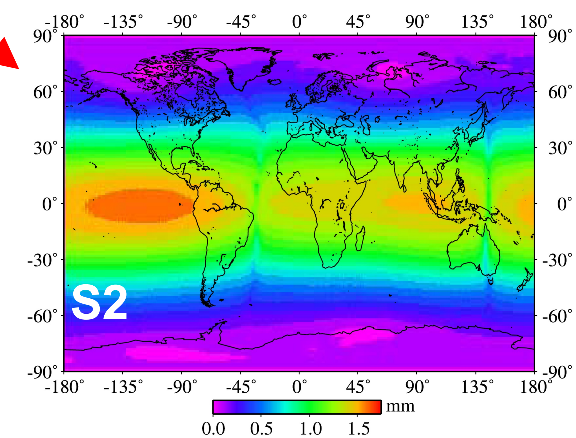
Ambiguity Float Solutions

Sub-daily signals

Atmospheric Loading Displacements [Petrov and Boy, 2003]

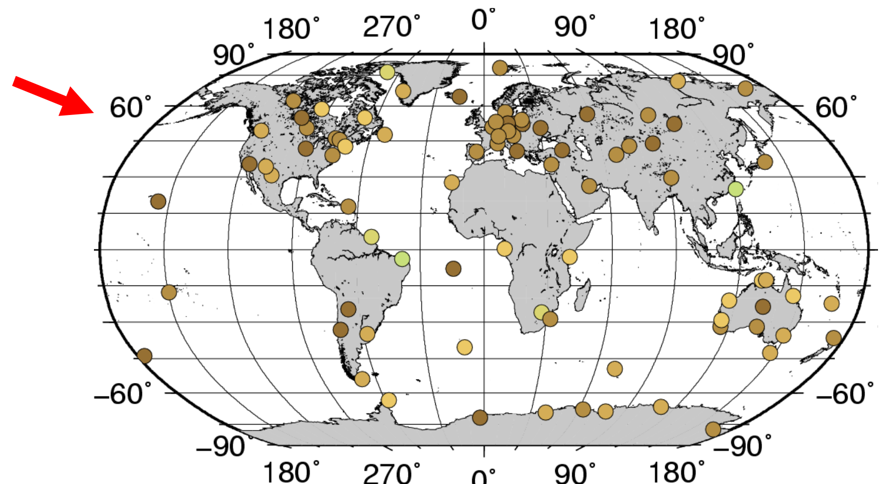
- What signals are expected in GPS coordinate time series at sub-daily frequencies?
  - Residual solid earth tides (<~0.5mm)
  - Residual ocean tide loading displacements (typically <~1mm)
  - Atmospheric tidal loading displacements (S1 and S2 <~1.5mm)
  - GPS systematic errors
  - Even sub-mm signals matter when admittance could be >100%
- Varying degrees of certainty in our knowledge of these signals





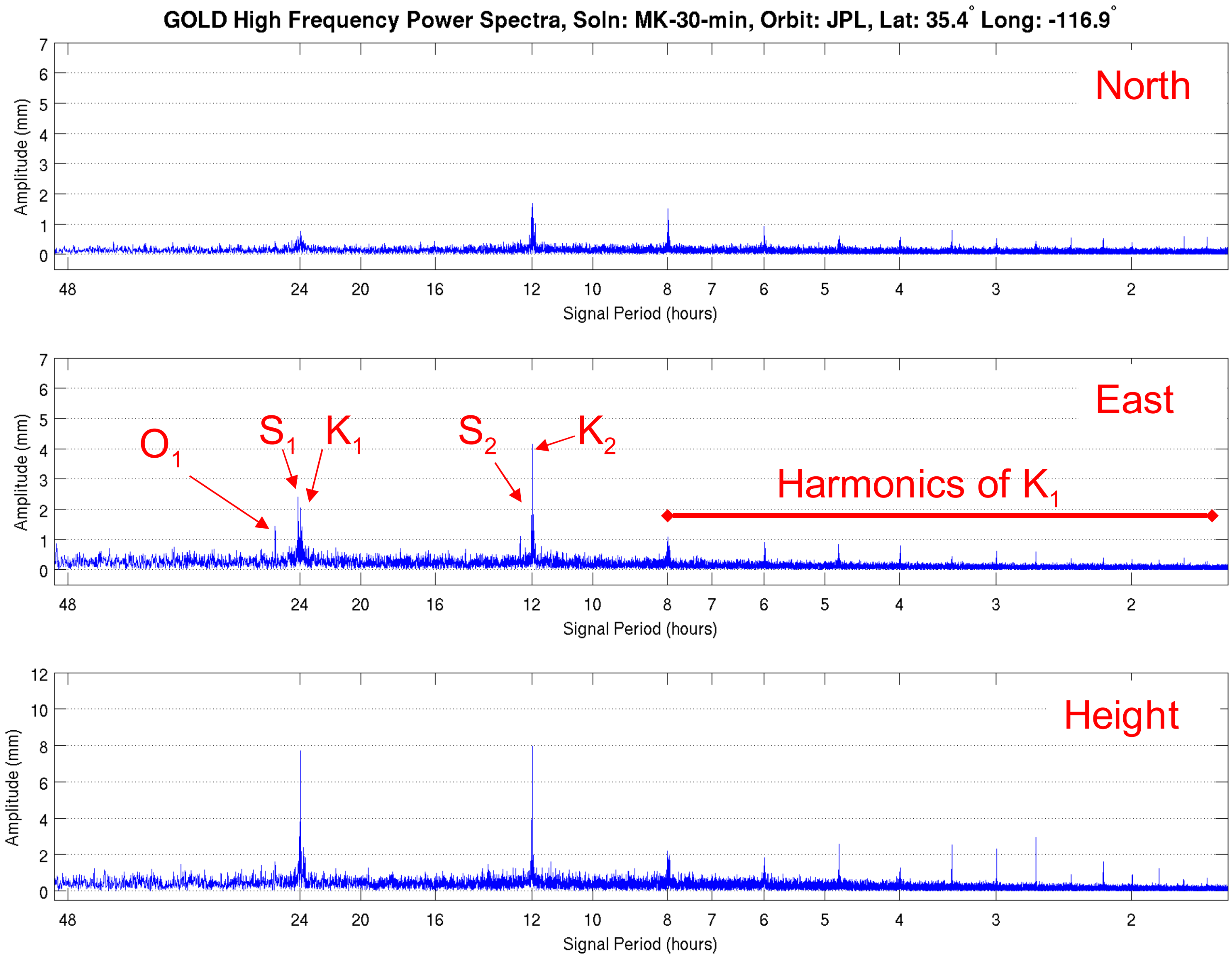
What sub-daily signals are really present in the data?

- Produce sub-daily coordinate time series for ~90 IGb00 sites using kinematic PPP
  - Site coordinates each 5 minutes over 2000-2006
  - GIPSY software with JPL orbits and clocks
  - Modelling OTL and SE tides
  - Other than 5min coordinate estimate, identical to standard 24hr PPP

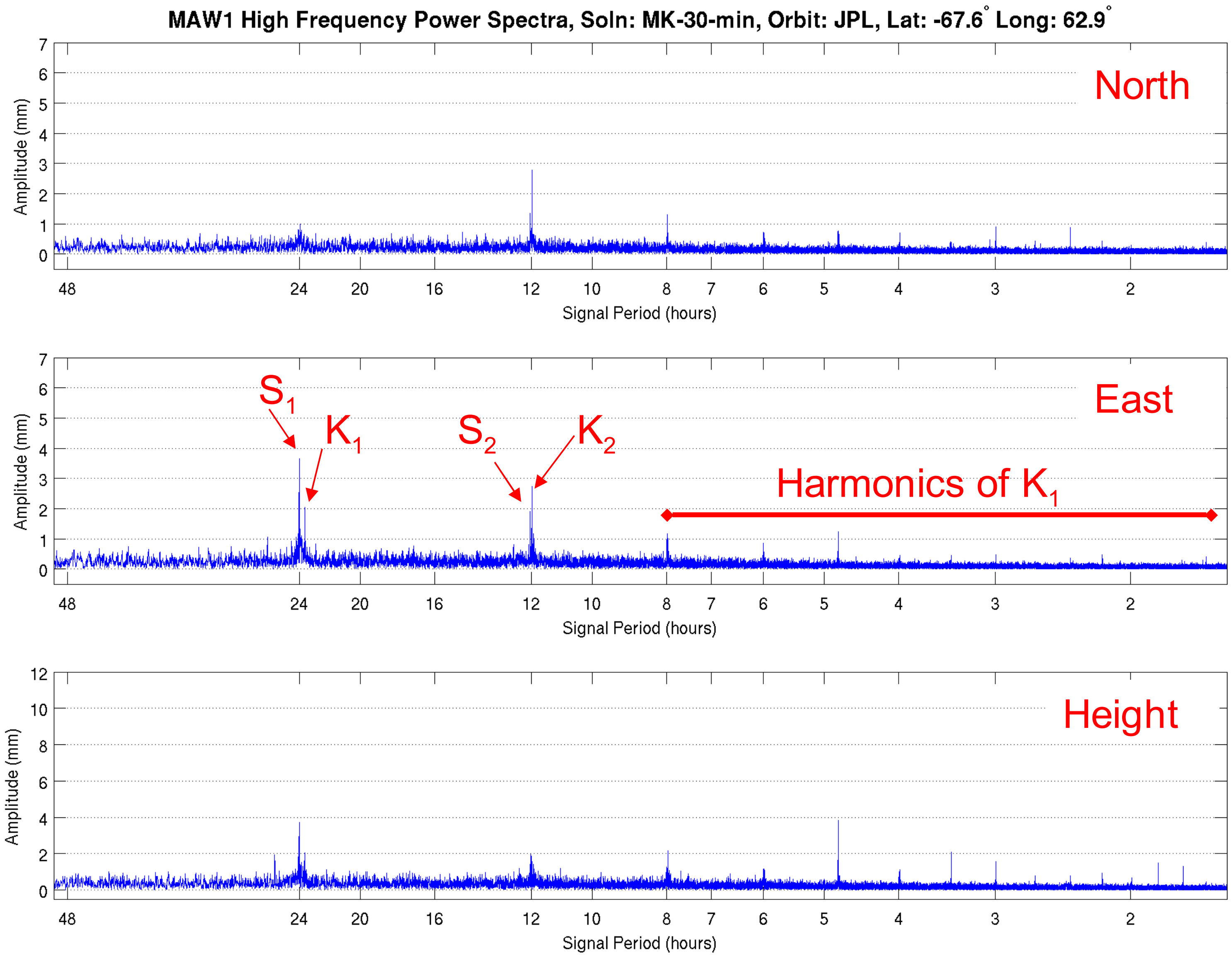


IGb00 sites

Typical Sub-daily Spectra

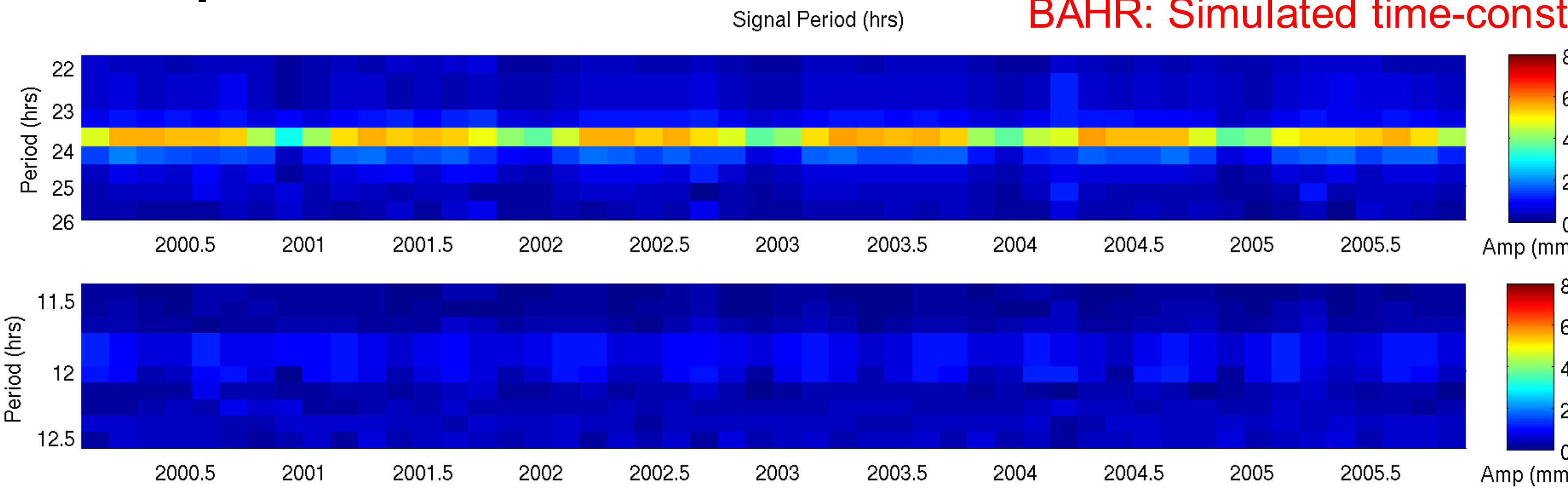


Typical Sub-daily Spectra

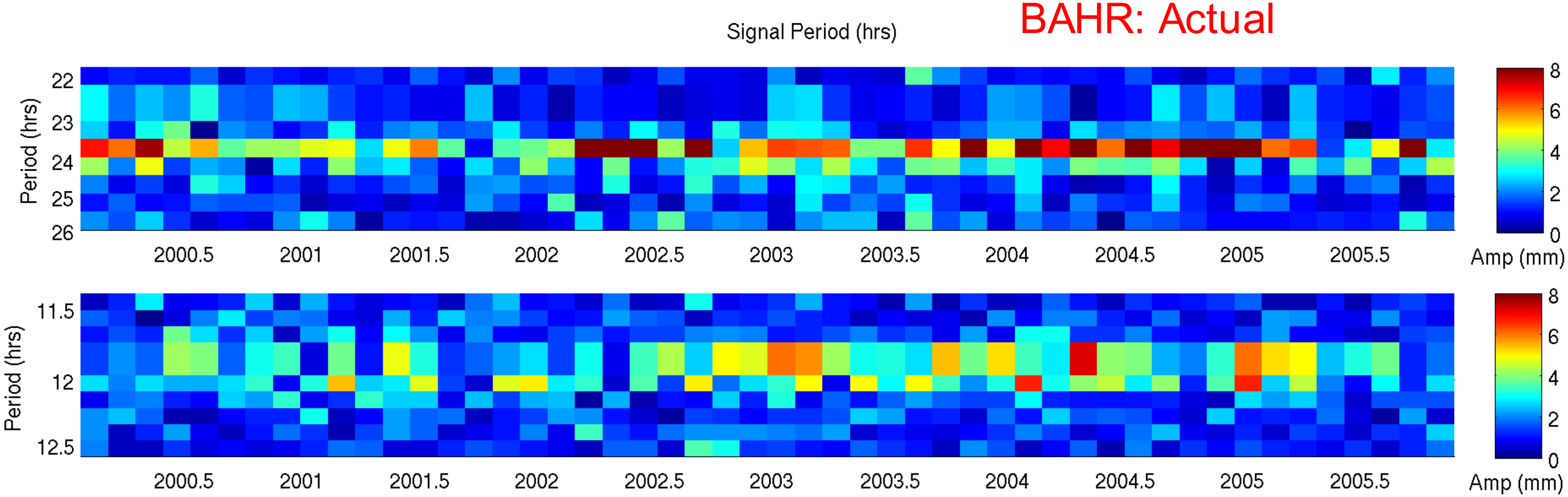


Time-varying behaviour

BAHR: Simulated time-constant



BAHR: Actual



Predicted frequencies of resulting signal in 24h solutions

Theory of Stewart *et al.*, *J. Geod., 2005*

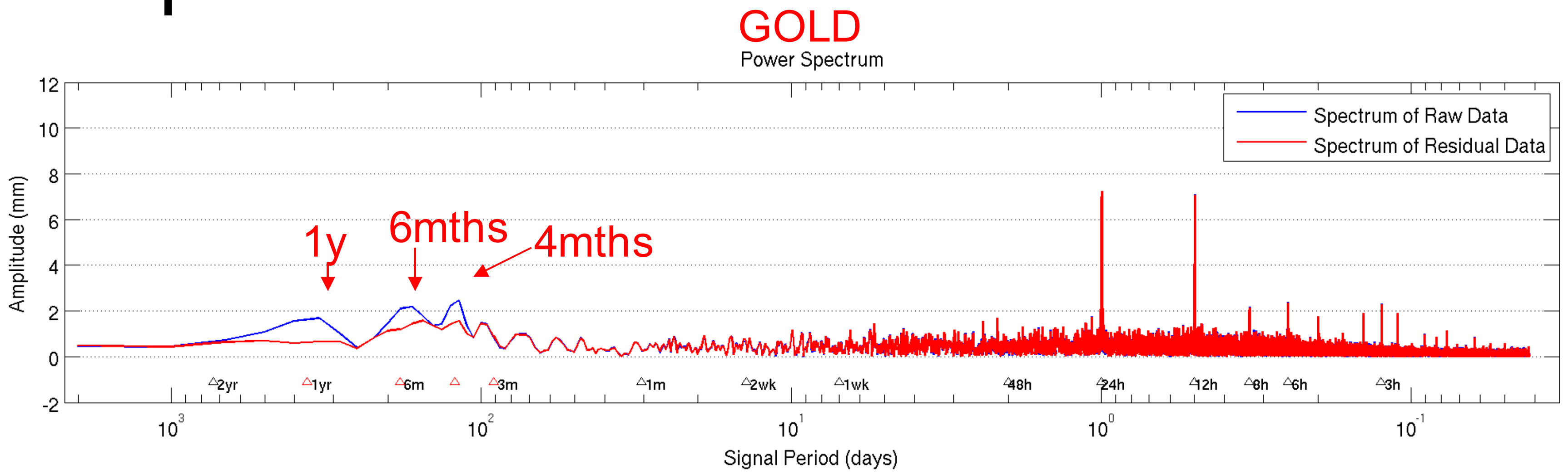
Highest admittances

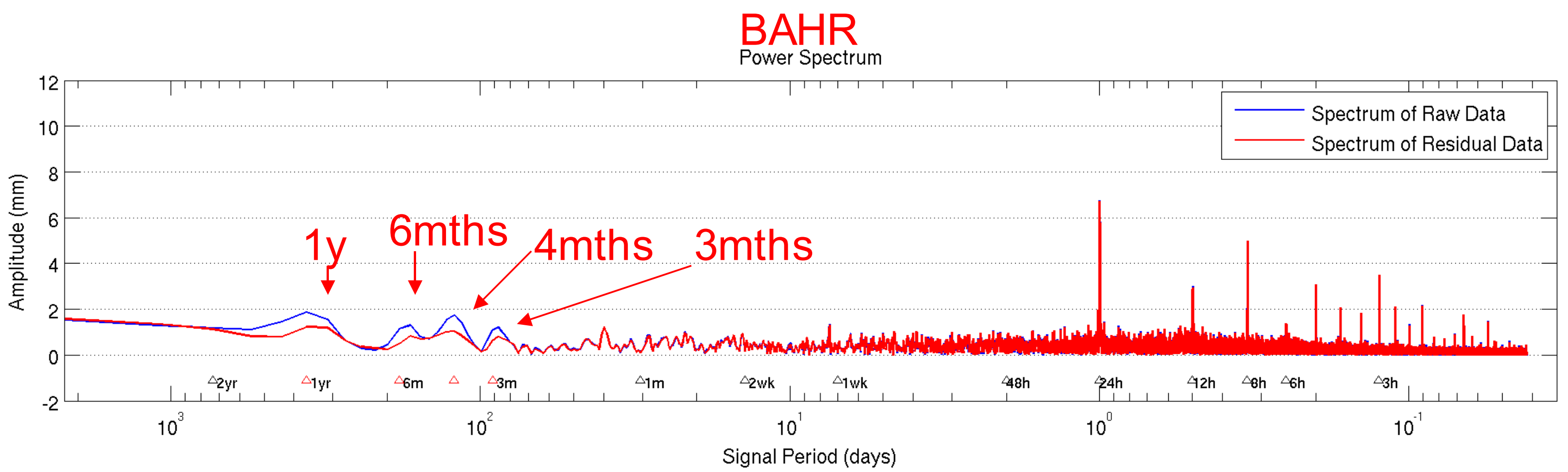
- S1 -> Annual
- K1 -> Annual
- O1 -> 14.19 d & 13.66 d (beat annually)
- S2 -> Semi-annual
- K2 -> Semi-annual
- Time-varying sub-daily signals should give time-varying long period signals – broad spectral peaks

Propagation into 24hr solutions

- Differenced solutions
  - Solution 1: 5 minute coordinate solutions
  - Solution 2: produced as for 5 minute solutions but coordinate estimates once per 24hr and then interpolated to 5 minutes
  - Difference of solutions: gives propagation effect of unmodelled signals
    - Common **low frequency geophysical signal is eliminated** in the difference
    - Following slides only showing **effect of E,N,U on U component**

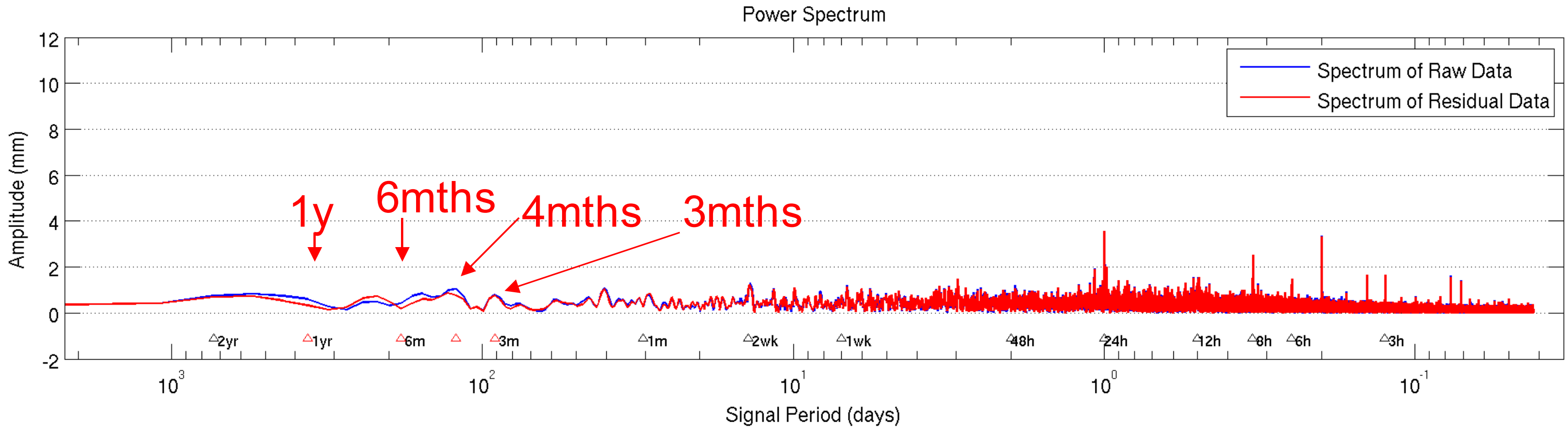
Example spectra of differences



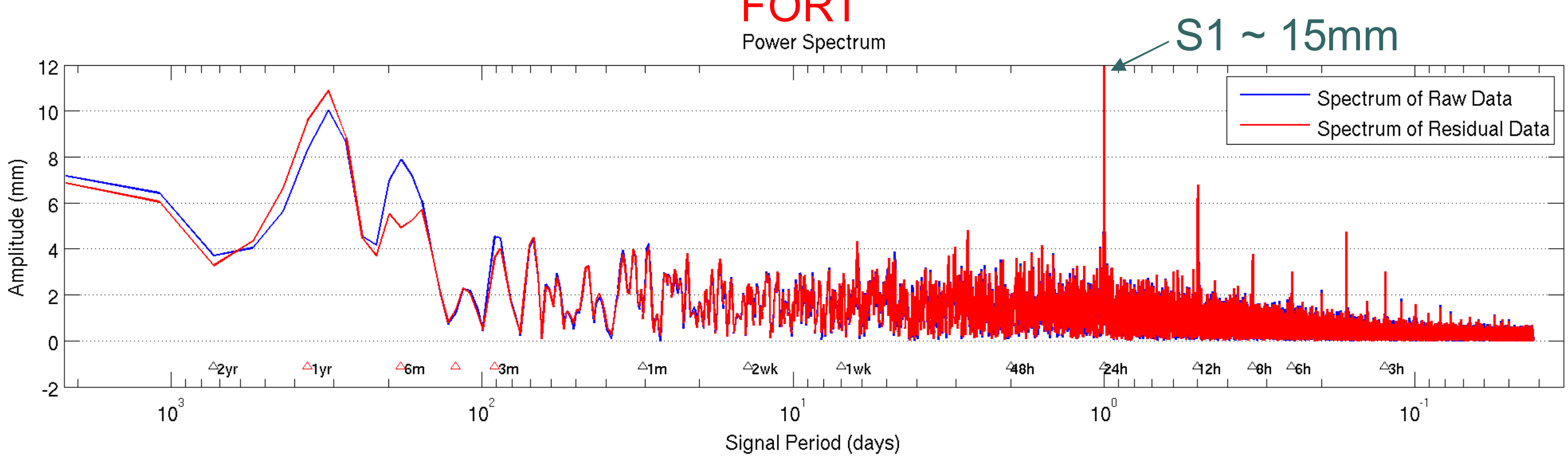


Example spectra of differences

MAW1

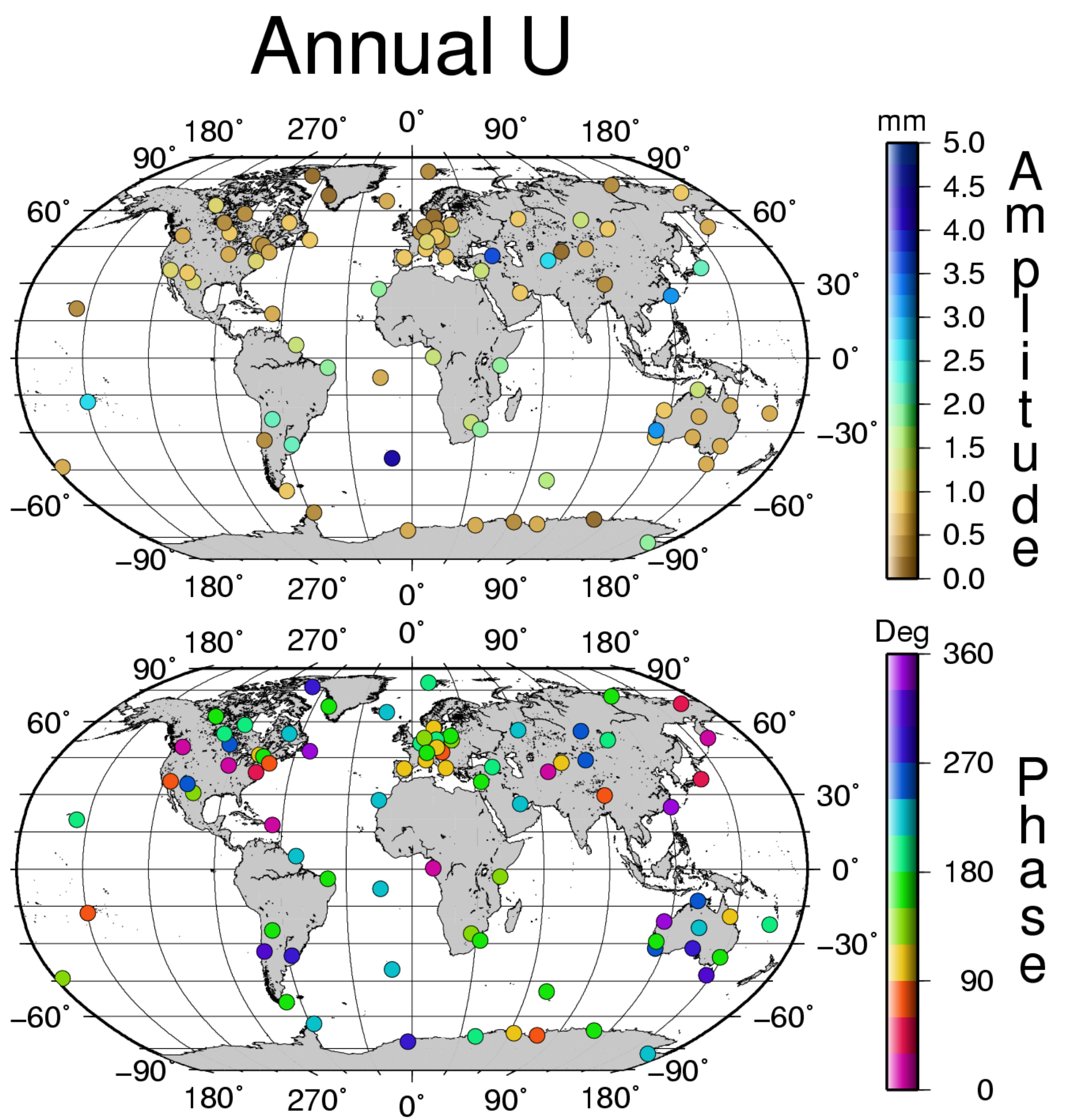


FORT



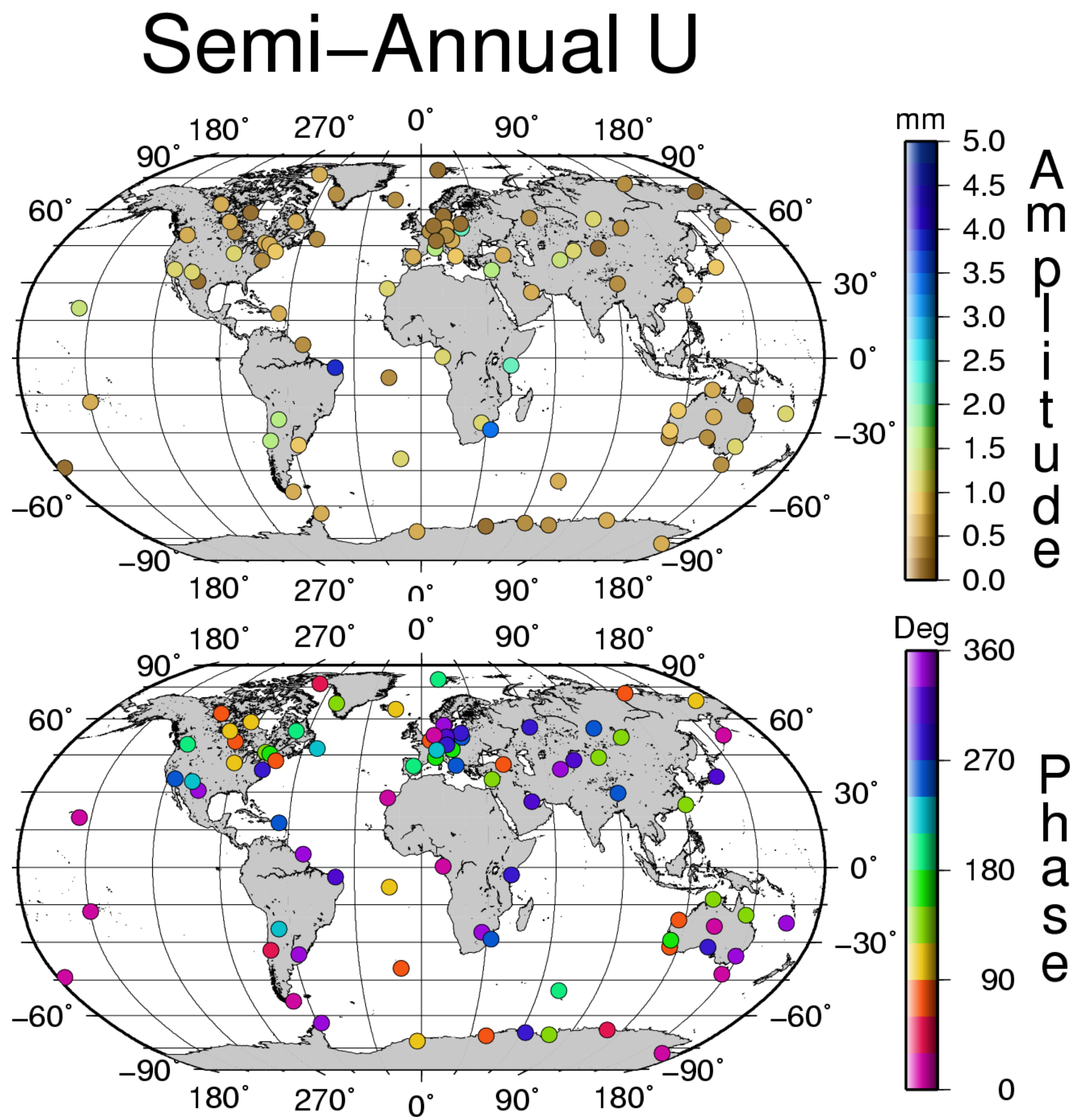
Propagated Annual signal due to sub-daily signals

Median Amplitude:
0.75mm



Propagated Semi-Annual signal due to sub-daily signals

Median Amplitude: 0.61 mm



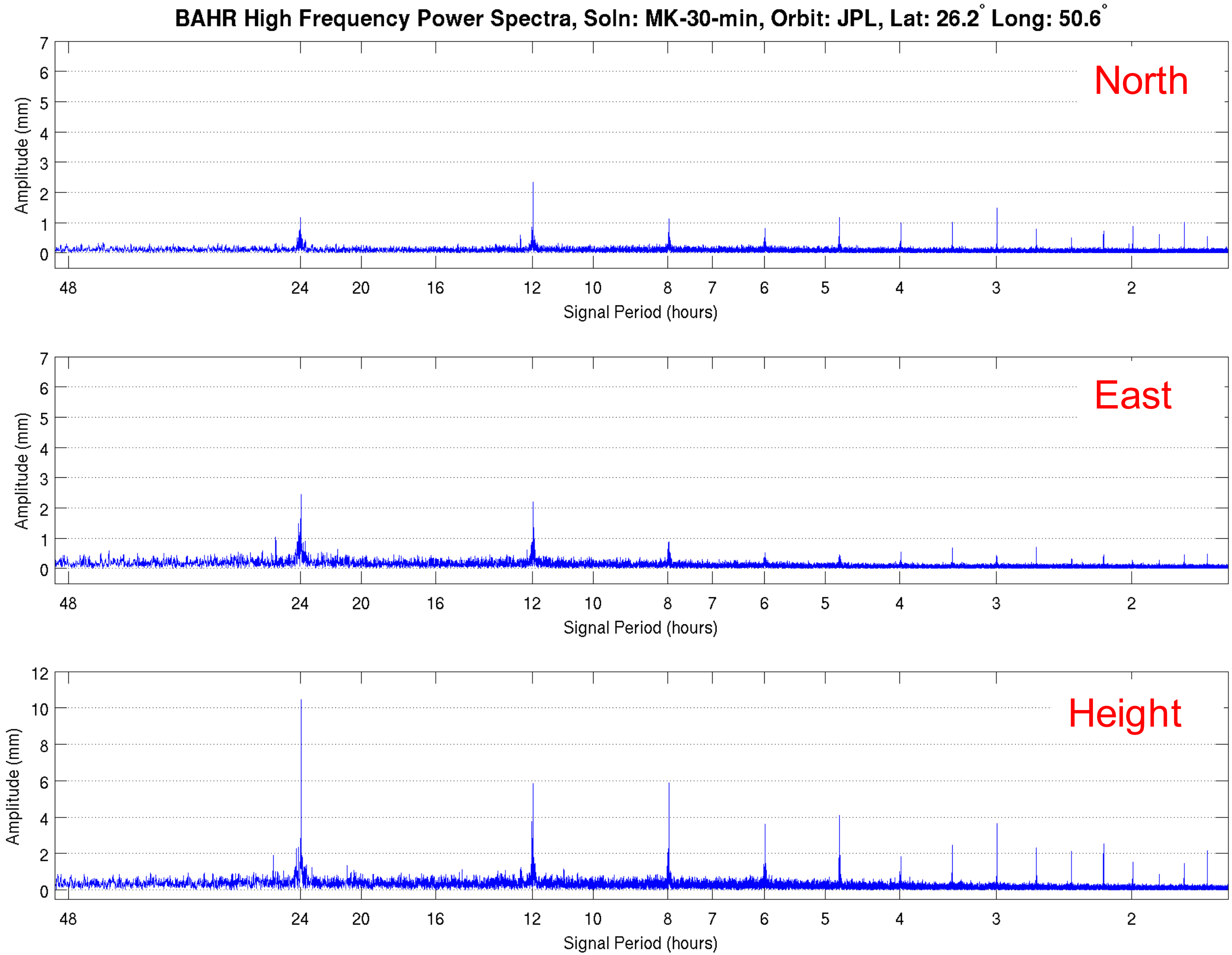
Potential Origin of Signals

- Candidates
  - Solid Earth tides
    - IERS2003 model errors <1mm level at K1
  - Loading signals
    - Residual ocean tide loading displacement signal likely <1mm in most regions
    - Atmospheric tidal loading displacement signals <~1mm and <<1mm in horizontal components
  - Tropospheric mapping function errors
    - Does not explain K1 and K2
  - Multipath
    - Does not explain S1 and S2 and not well-defined mechanism for K1 and K2 (multipath repeats at K1, but is not a K1 harmonic)
  - Satellite orbits
    - Provides a potential mechanism for K1, K2 and S1, S2 through solar radiation mismodelling

Comparison of orbits/clocks at sub-daily frequencies: BAHR

JPL Orbits and Clocks

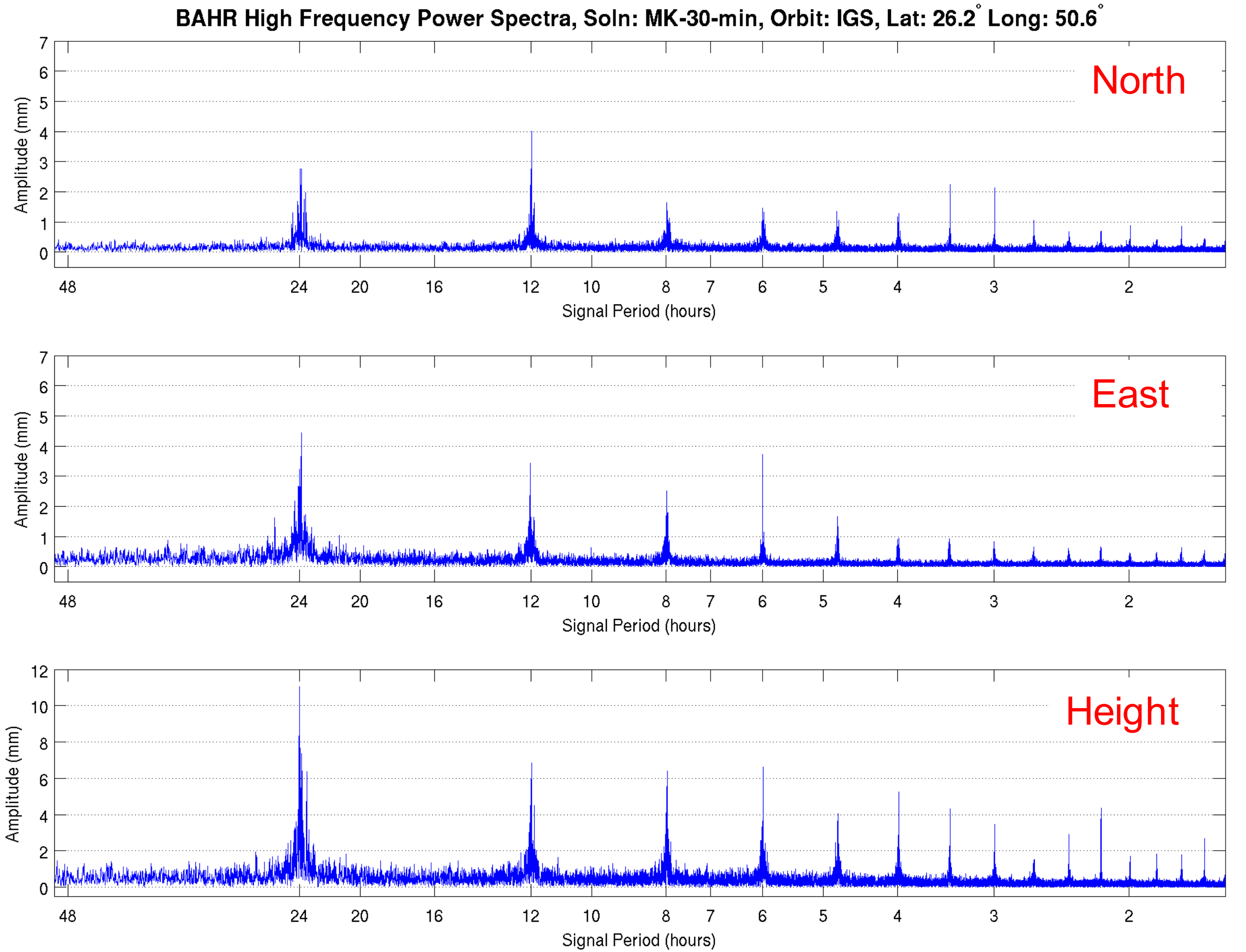
Defined peaks



Comparison of orbits/clocks at sub-daily frequencies: BAHR

IGS Orbits and Clocks

Broad peaks



Conclusions

- Sub-daily harmonic signals are evident in common GPS time series with amplitudes up to >10mm at S1, S2, K1 and K2 (and other frequencies)
- Sub-daily spectra are **time-dependent**
- These propagate into long-period signals at ~annual, ~semi-annual and other periods
- These may bias geophysical loading estimates **at individual sites** at the level of ~0.6-0.8mm on average (at 1cpy and 2cpy)
- Little evidence of spatial coherence of propagated annual/semi-annual signals
  - low degree spherical harmonic estimates may not be biased, although made noisier
- Likely origin is in satellite orbits/clocks with smaller contributions from geophysical and multipath signals
- Different sub-daily spectra using different products suggests different propagated signals