G13B-0512: Estimating Solid Earth Tidal Constituents from PBO Station Borehole Strainmeters

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STUDY GOALS

Earth tides are dynamical bulges characterized by changes in the Earth's gravitational potential from external bodies. Today these are typically characterized with the use of predetermined models.

The **first goal** is to identify solid Earth tide diurnal and semi-diurnal frequencies empirically by means of high-precision harmonic analysis of high-resolution borehole microstrain records.

The **second goal** is to predict and calculate the lag of the response of the solid Earth to gravitational forcing, and characterize the differences.

BOREHOLE STRAINMETERS

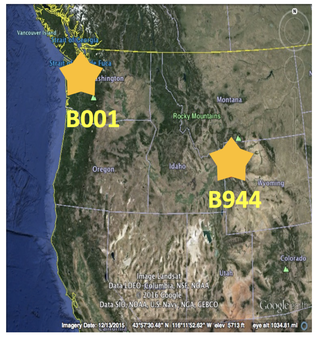
Vertically equally spaced gauges CH0-CH3 measure horizontal strain, extension and compression at different orientations, as well as atmospheric pressure and temperature. The gauges are grouted into boreholes in competent rock (~100 m depth).

Stations in **Sequim, WA (B001)** and **Yellowstone, WY (B944)** were selected for proximity to ocean and tectonic regime (subduction zone in WA, mantle plume in WY).

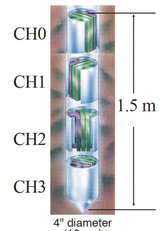
Microstrain data from **January 1, 2011 to December 31, 2015** are examined from each station.

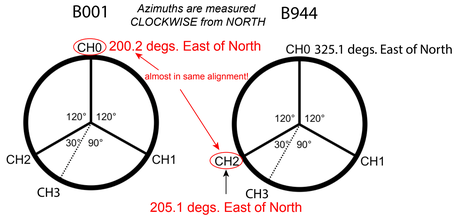
Selected for analysis:

- CH0 from Station B001, oriented 200.2° east of north
- CH2 from Station B944, oriented 205.1° east of north



Gladwin multi-component tensor strainmeter

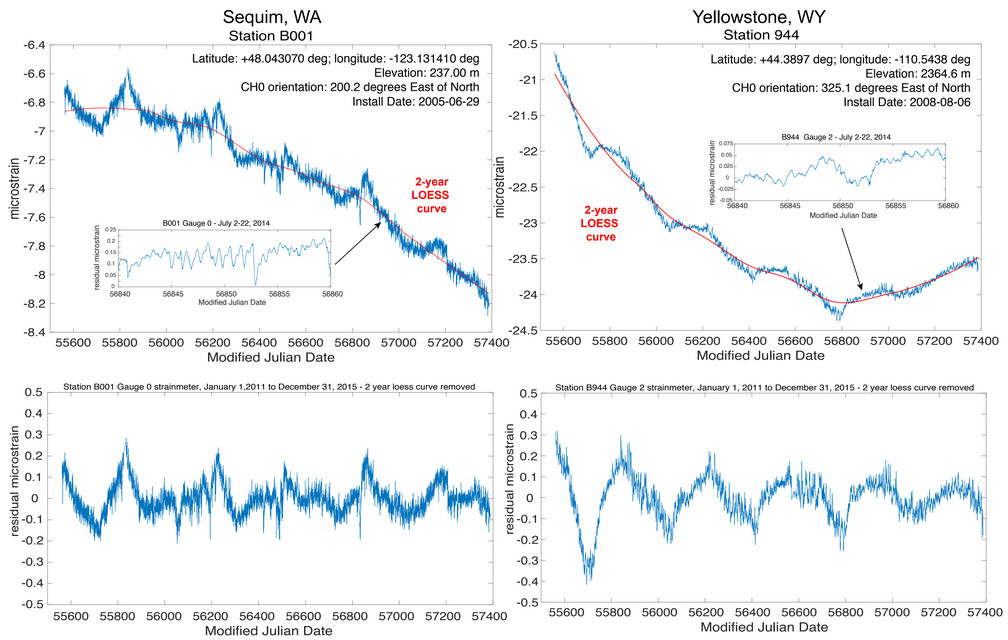




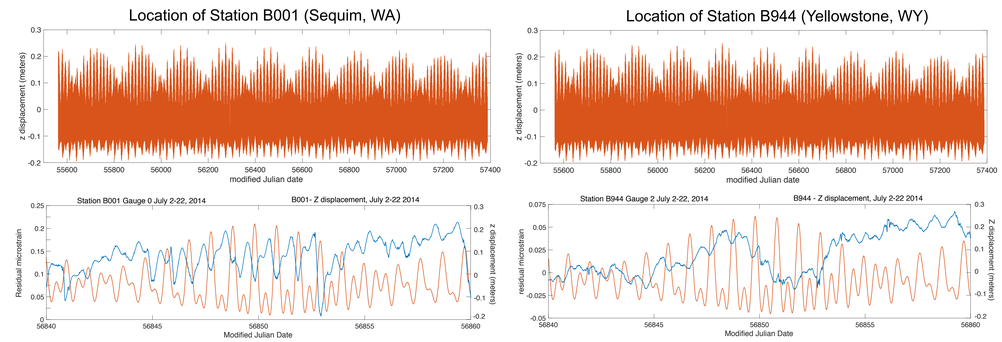
SOLID EARTH TIDAL MODEL

- Program *solid.f* computes cyclic and permanent tidal deformation
- Based on *dehanttideinelMJD.f* by V. Dehant, S. Mathews, J. Gipson and C. Bruyninx
- The 2018 version of *solid.f* references UTC time
- Output solid earth tide u,v,w components in meters (to 0.000001 m) are Noth, East, and Up in the local geodetic (ellipsoidal) horizon system at 1 minute intervals.
- Includes degree 2 and 3 Love/Shida displacement corrections
- No ocean, atmospheric loading, or polar motion deformation
- More accurate routines needed for geocentric positions of the Moon and Sun

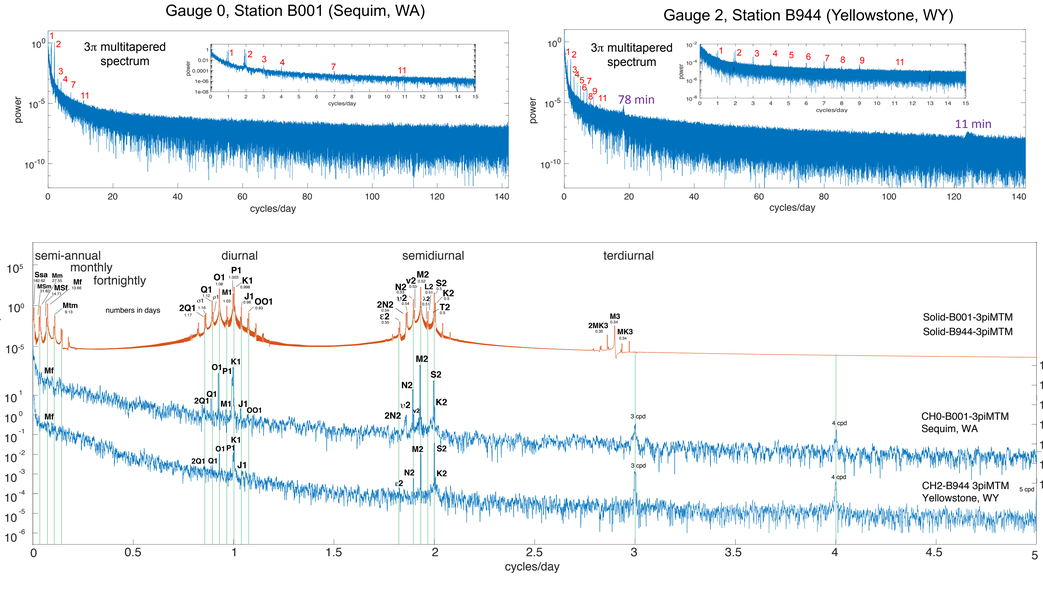
STRAINMETER DATA



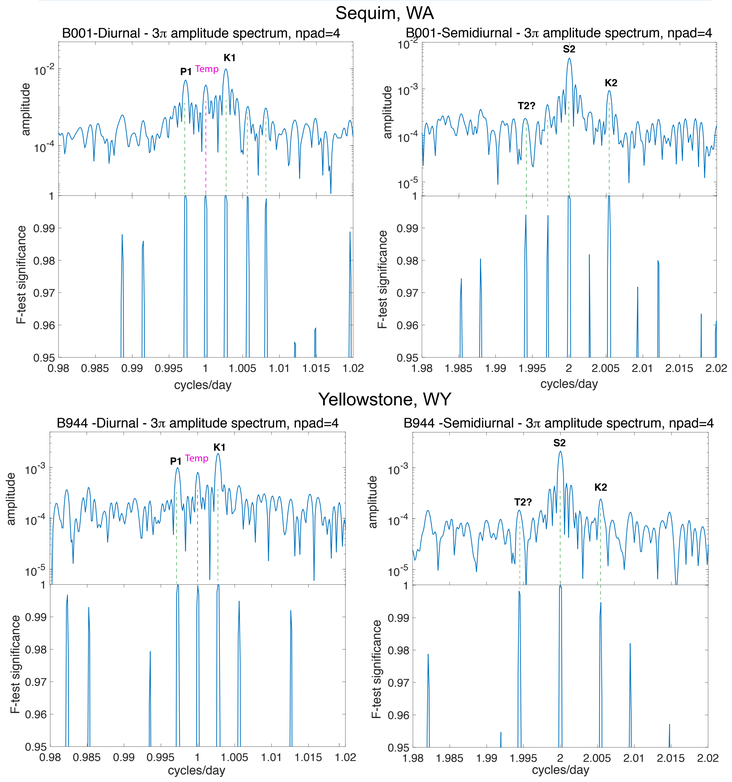
SOLID TIDE MODEL



POWER SPECTRAL ANALYSIS



HARMONIC ANALYSIS



PREDICTED VS. OBSERVED LAG

Observed:

K1 diurnal tide time lag

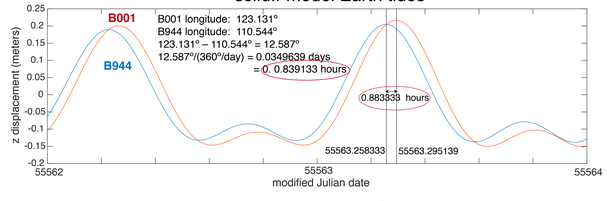
Station	Frequency	Period	Phase	Time Lag
B001	1.00273822	0.997726925	81.5843921°	2.60526844 hours
B944	1.00273822	0.997726925	42.3982800°	

K2 semidiurnal tide time lag

Station	Frequency	Period	Phase	Time Lag
B001	2.005004882	0.498751903	-129.825599°	5.0808449 hours
B944	2.005004882	0.498751903	175.7879293°	

Predicted:

solid.f model Earth tides



- The predicted time lag between B944 and B001 is 0.839 to 0.883 hours
- The observed time lag between 944 and B001 is at least 2.6 hours

CONCLUSIONS

1. Borehole strainmeters have recorded solid Earth tides with multiple constituents in the diurnal and semidiurnal frequency bands due to Moon and Sun gravitational forcing.
2. At Station B944, 78 minute and 11 minute periodicities were recorded, from seiche activity in nearby Yellowstone Lake (and other unidentified phenomena).
3. Multitaper harmonic analysis resolves major tidal constituents with high statistical significance including a diurnal component from daily temperature/barometric changes.
4. The observed lag between B944 and B001 tides is much longer than the predicted lag owing to B001 proximity to the ocean, and crustal heterogeneities between the stations.

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