# PBO Strainmeter Data

Strainmeter Short Course
UNAVCO, Boulder
June 9-12, 2008

## Strainmeter metrics

- Borehole in compression
- Recording Earth tides
- Atmospheric pressure effect correct sign
- Absence of steps
- Recording teleseisms and microseisms
- Minimal cultural signals
- Recording strain transients

## Borehole Trends

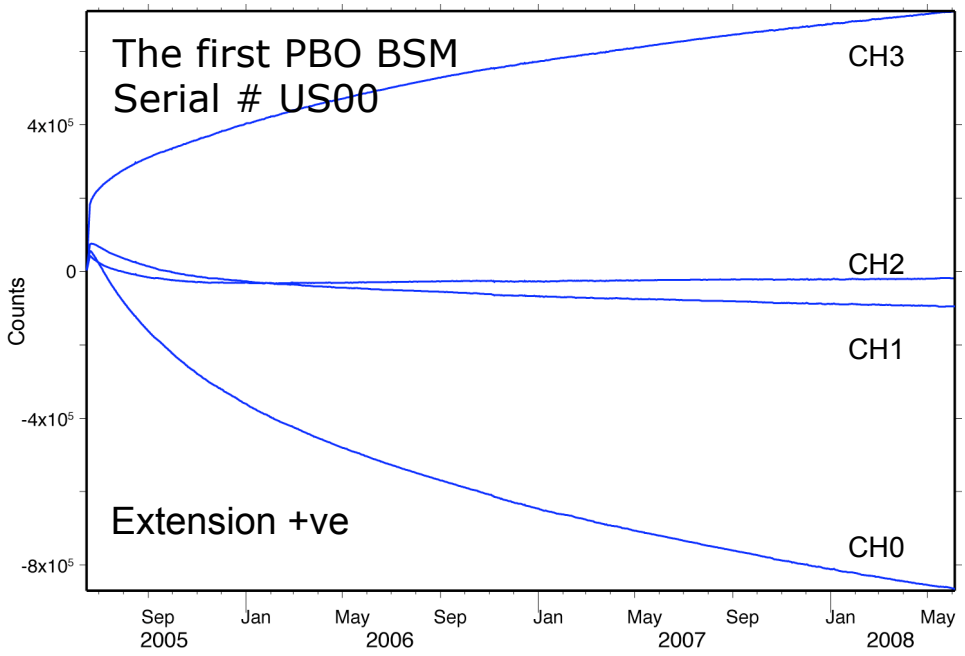
- It is expected that the dominant strain recorded by the strainmeter is that of borehole relaxation.
- 3 gauges in compression after 1 year is a good sign
- B004 displays the expected “classic” borehole compressional signal

## Borehole Trends

- Poro-elastic modelling by Amy Day-Lewis of Stanford shows that the orientation of the strainmeter within the regional stress field can influence the amount of strain on one gauge.
- Conclusion: Only three gauges need be in compression

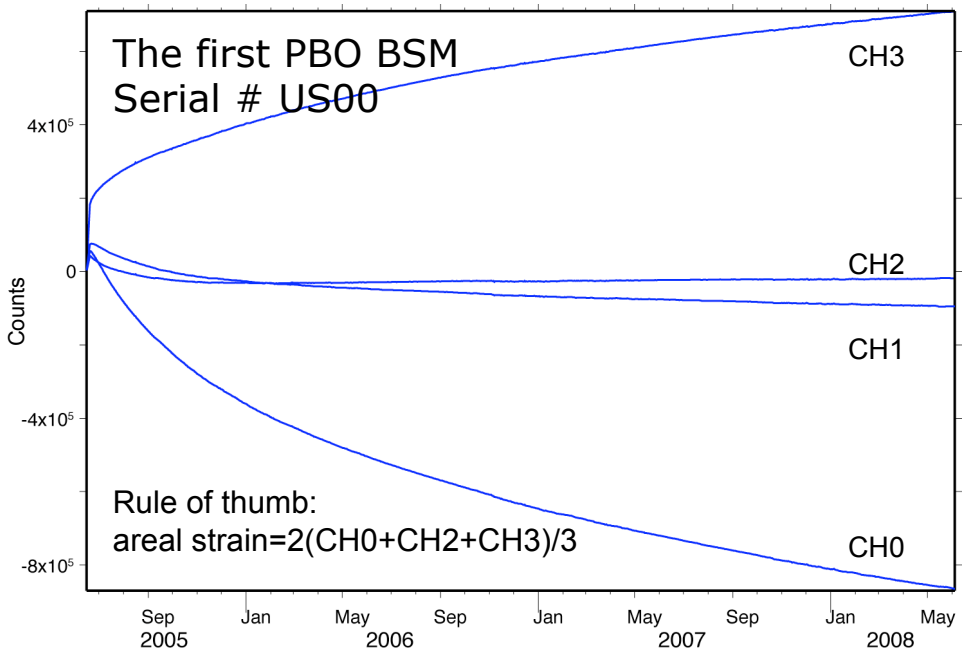
# Borehole Trends: B004

## B004: Olympic Peninsula

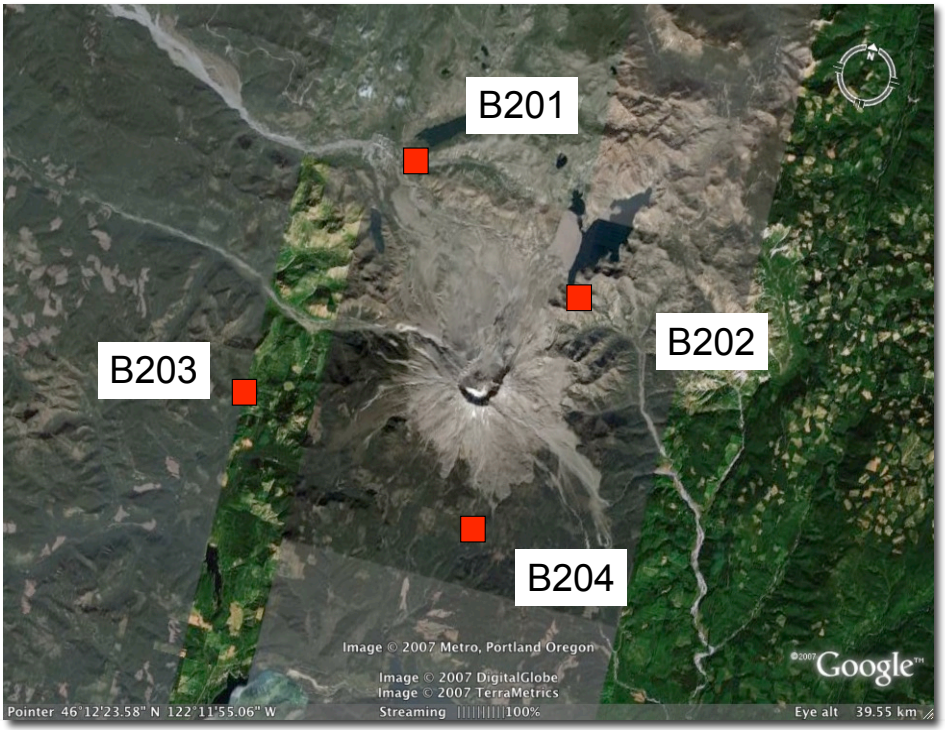



# Borehole Trends: B004

## B004: Olympic Peninsula



# Borehole Trends: Mt St Helens

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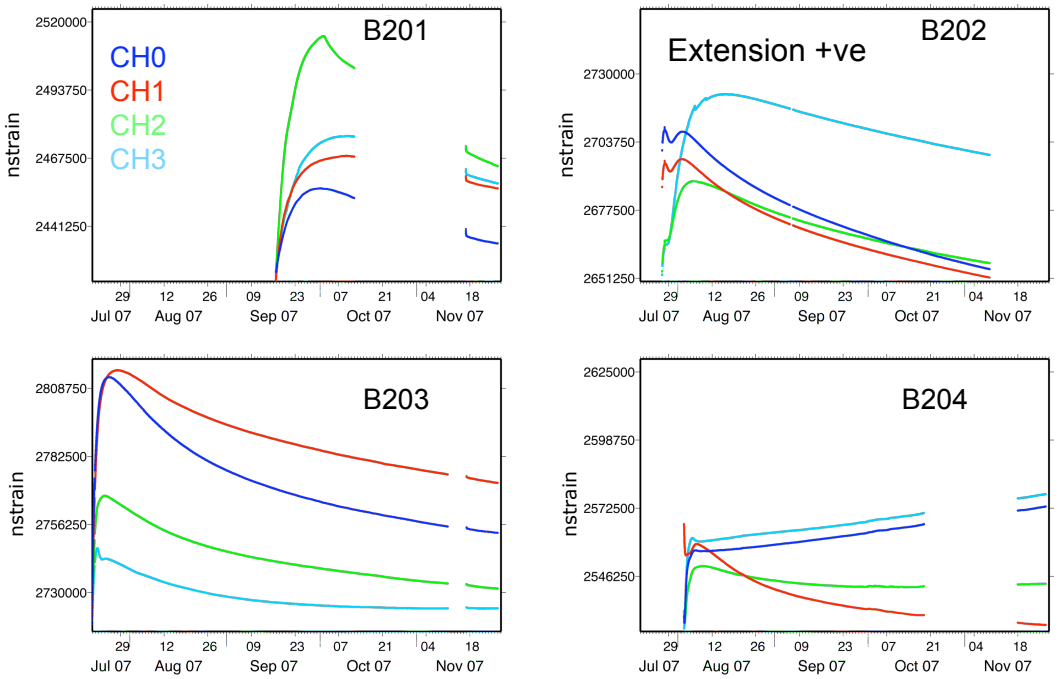
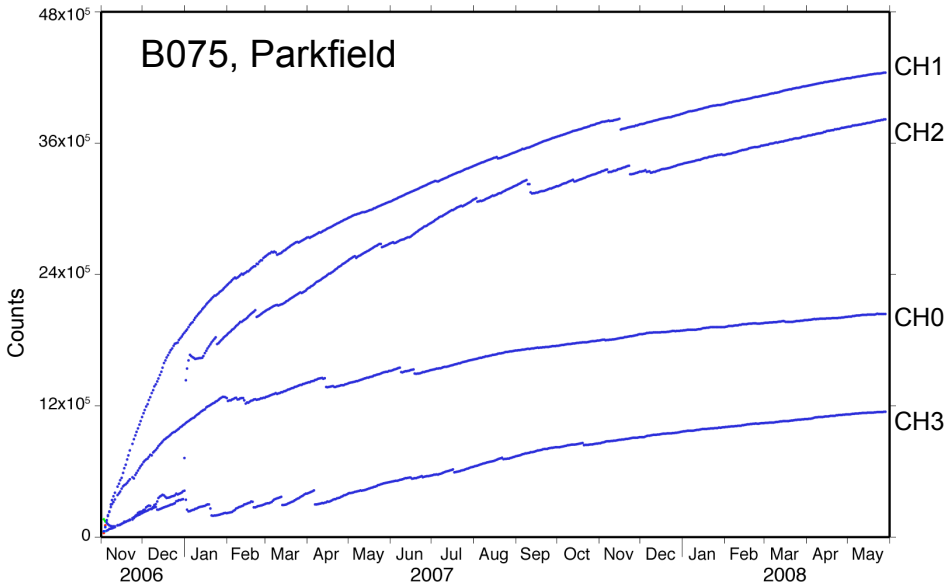


# Borehole Trends: Extension?

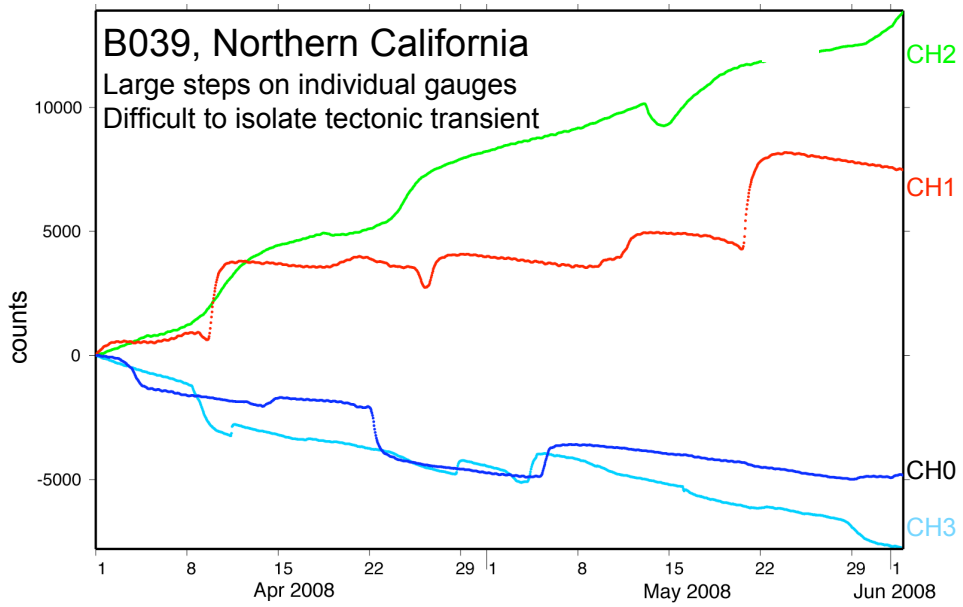
Extension is a problem!

instrument designed to be in compression




# Borehole Trends: Steps

Steps recorded on B039 7 months after installation



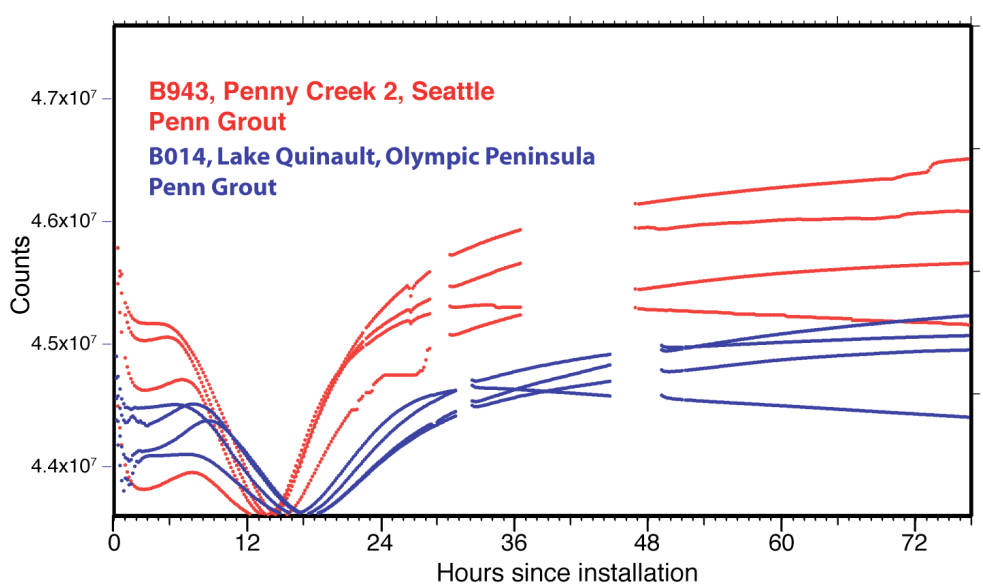
# Borehole Trends: Grout

- The grout proved critical.
- Some sites exhibit “hole trauma” within a few days of install if the coupling of the strainmeter to the surrounding rock was not good.
- PBO engineers worked with grout manufacturers to get the correct mix.

# Borehole Trends: Grout

B943, B014 installed with the PBO - Penn Grout mix

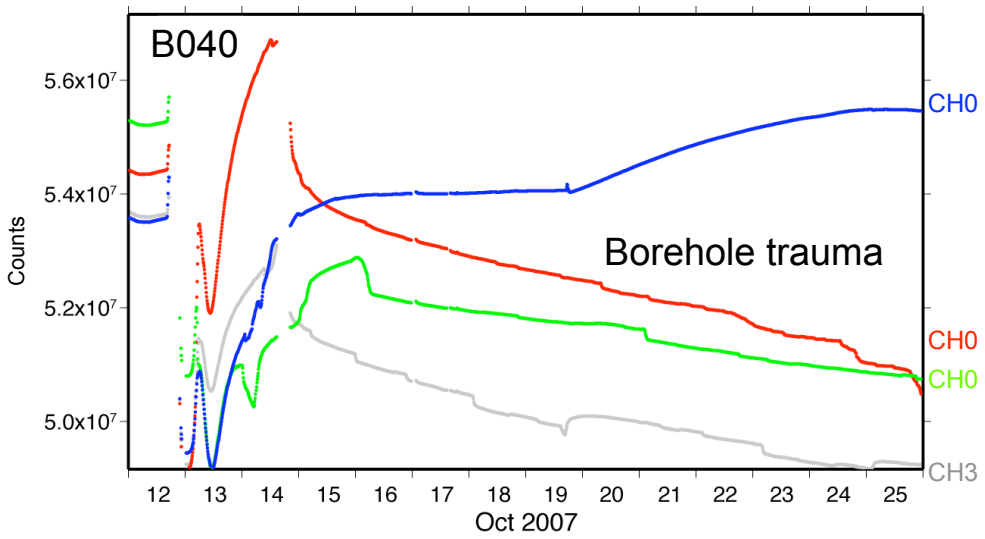
Free of steps, tides visible within 2 weeks



# Borehole Trends: Grout

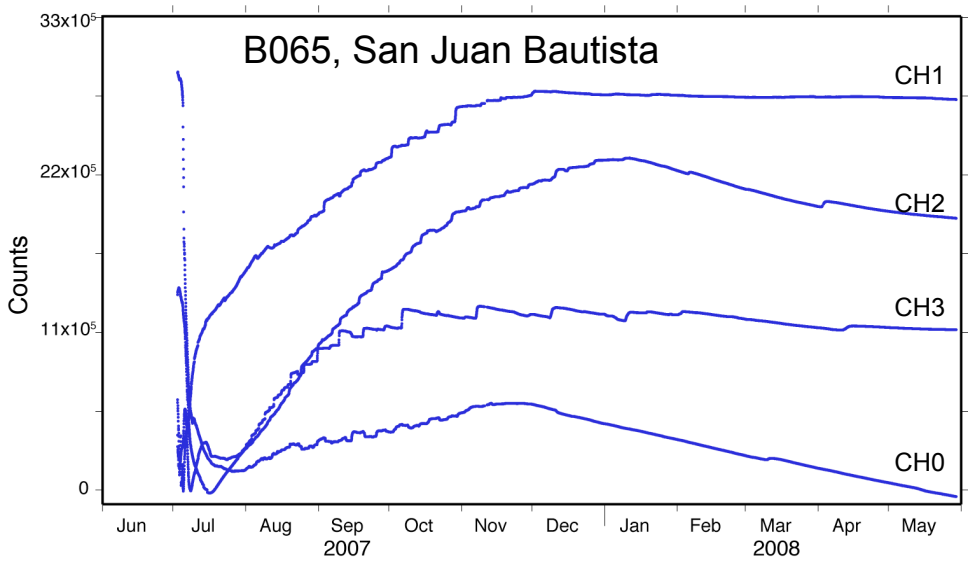
B040 installed using Masterflow grout.

Many steps in data set, tide not visible at 14 days.




# Compression: There is hope!

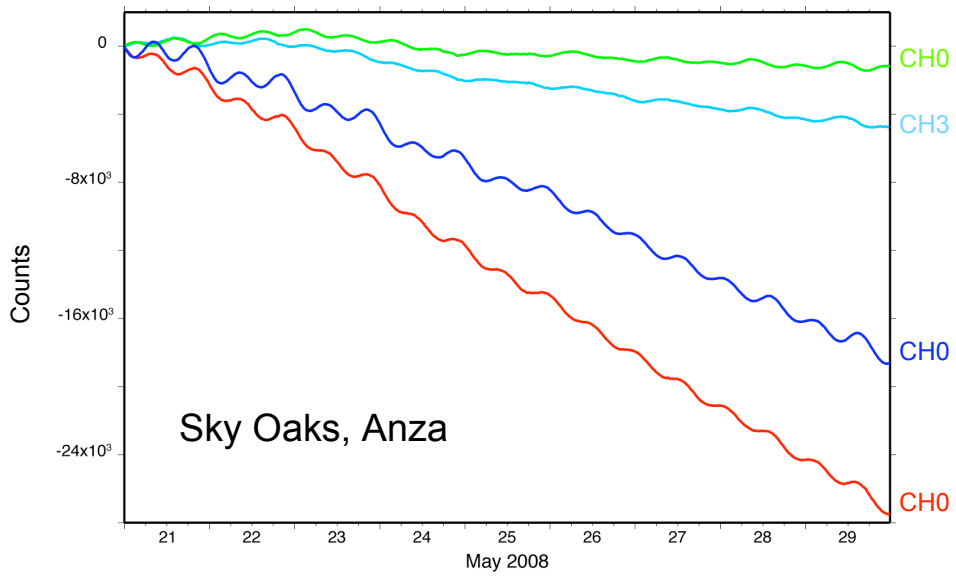
Several PBO strainmeters took ~8 months to turn towards 3-gauge compression



# Compression: There is hope!

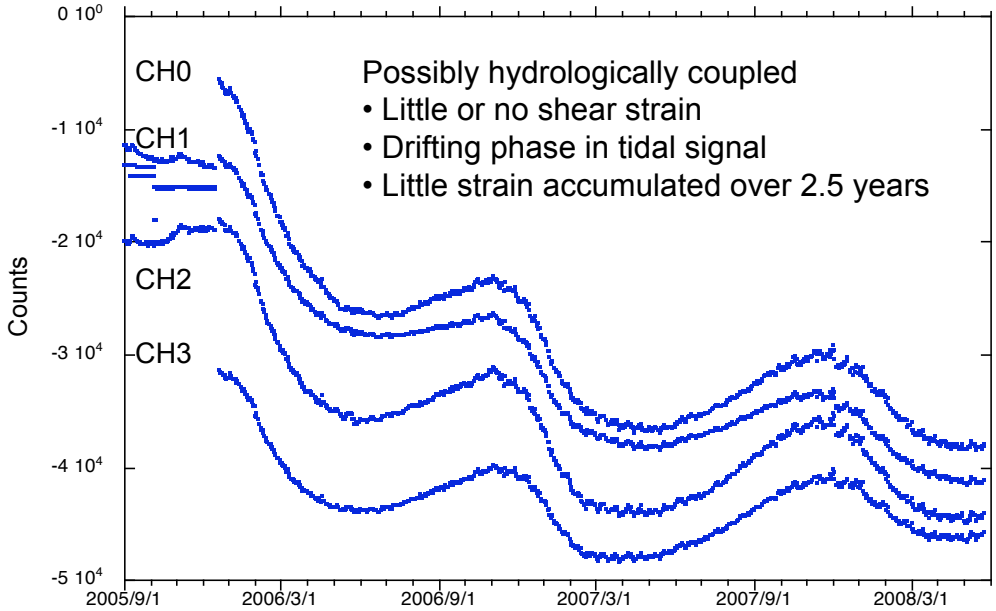
B088, Anza, was one of the first BSMs to display trauma

18 months later , hole in compression, nice tidal signal



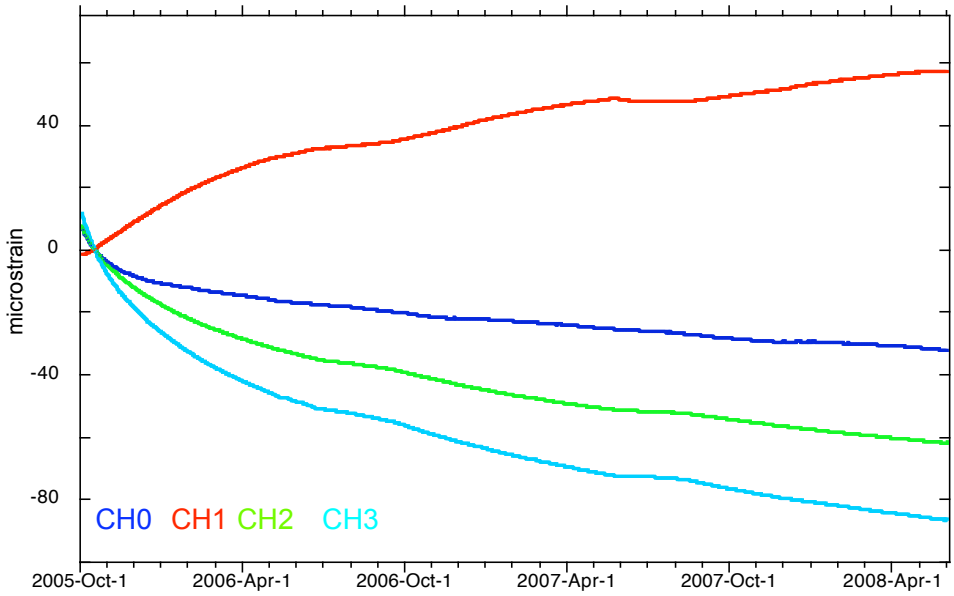

# Borehole Trends: Hydrostatic Coupling

B006, Shores, Washington



# Borehole Trends: Seasonal signals

B009, PGC

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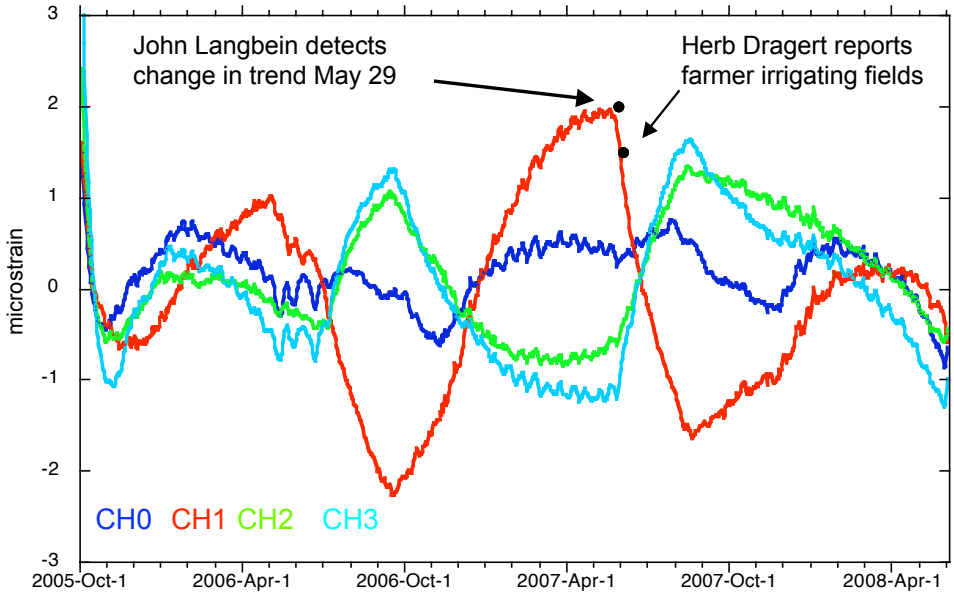
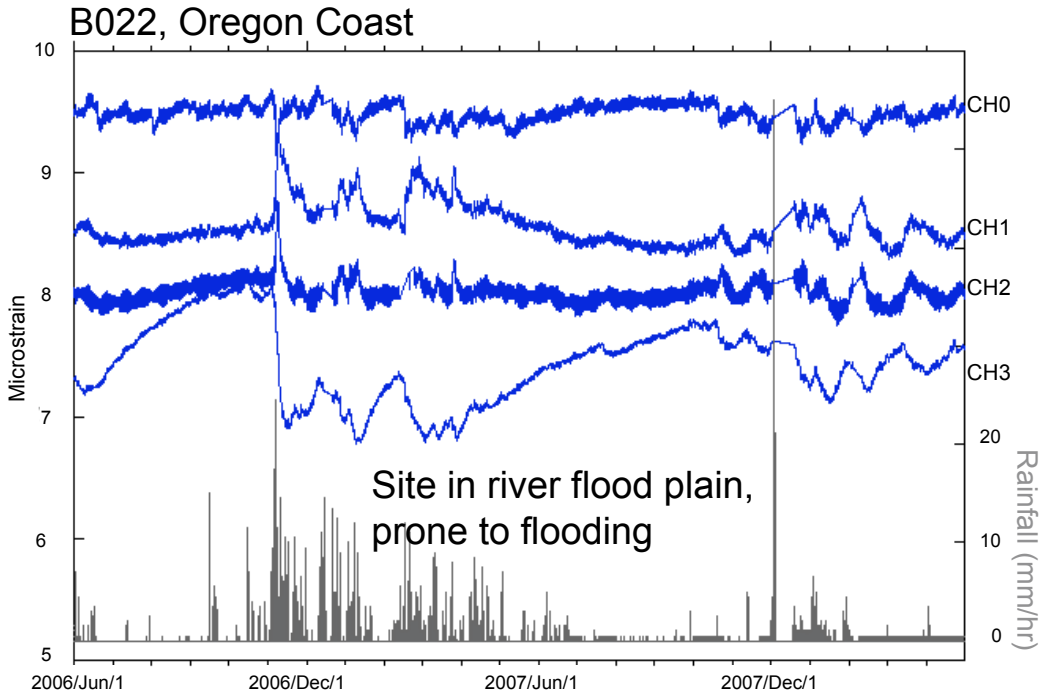


# Non Tectonic Noise: Rain

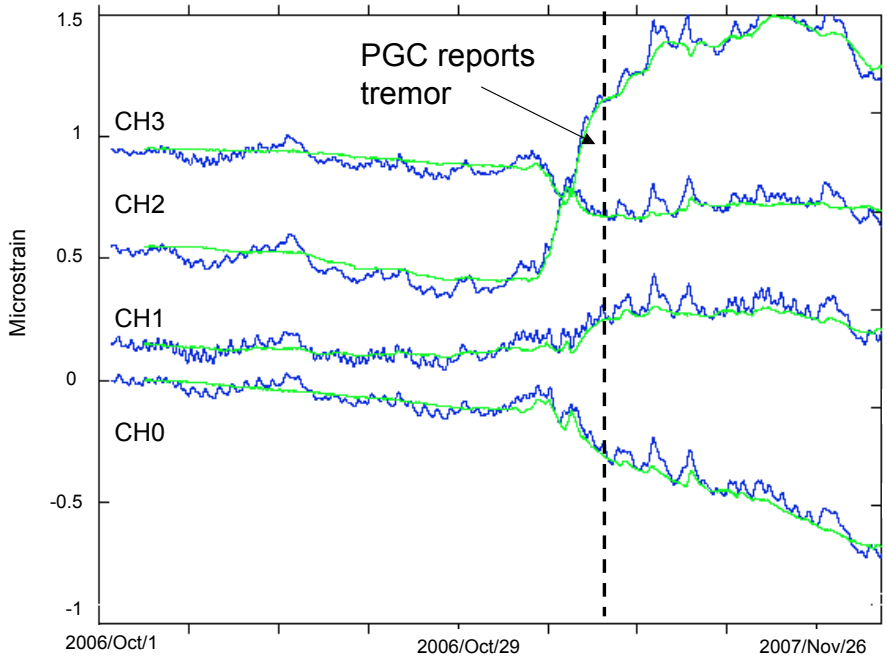
- Several of the PBO BSMs show strain signals correlated with rainfall
- When looking at transients check the rainfall measurements, all PBO sites have rain gauges

# Non Tectonic Noise: B022 Rainfall



# Non Tectonic Noise: B003 Rainfall

B003, FloeQuarry, Washington

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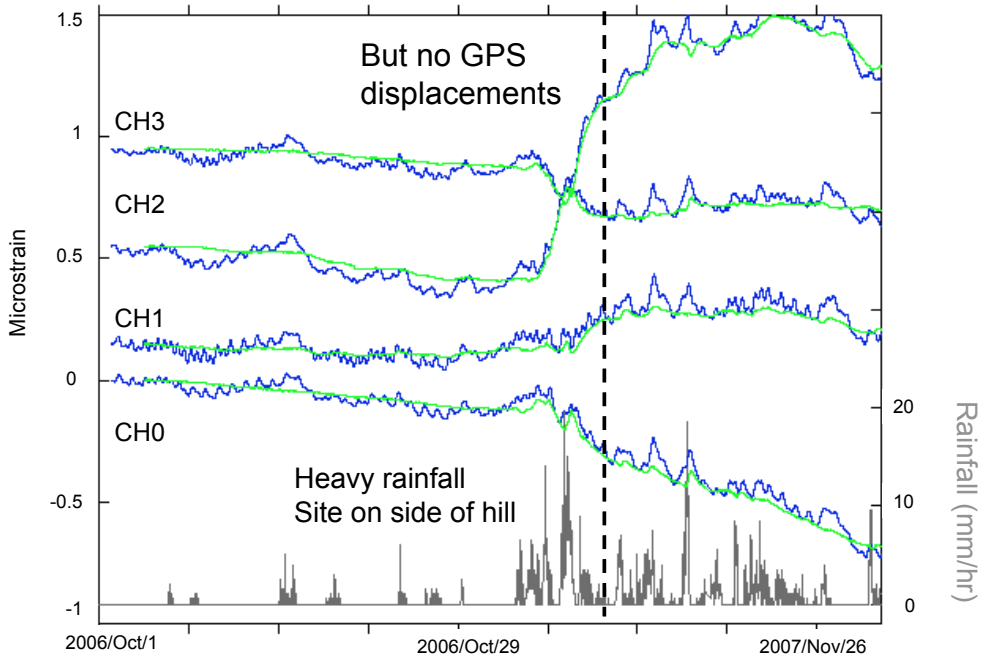
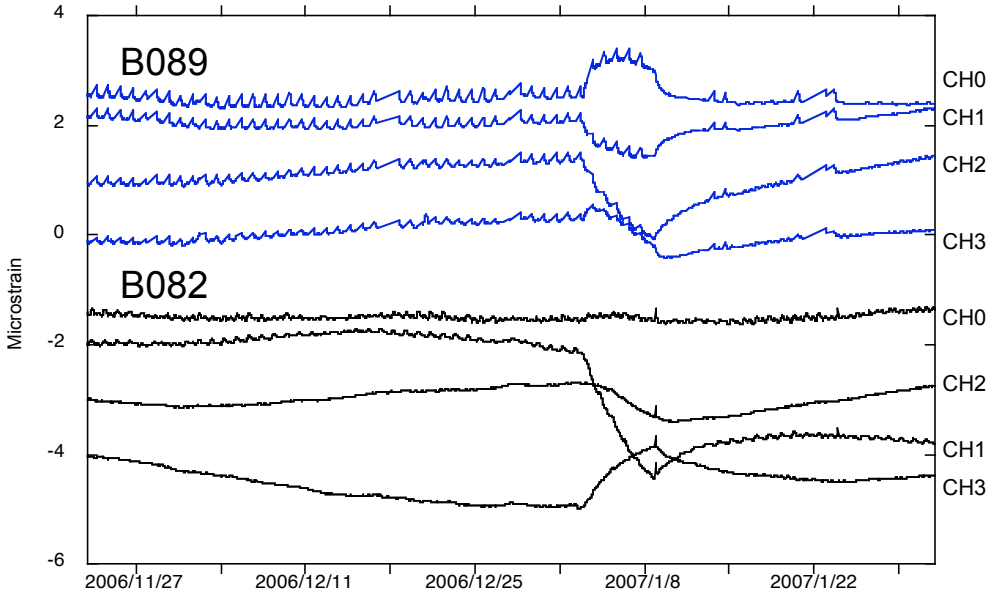
B003, FloeQuarry, Washington



# Non Tectonic Noise: Pathfinder, Anza

B082 and B089, Co-located, Pathfinder site

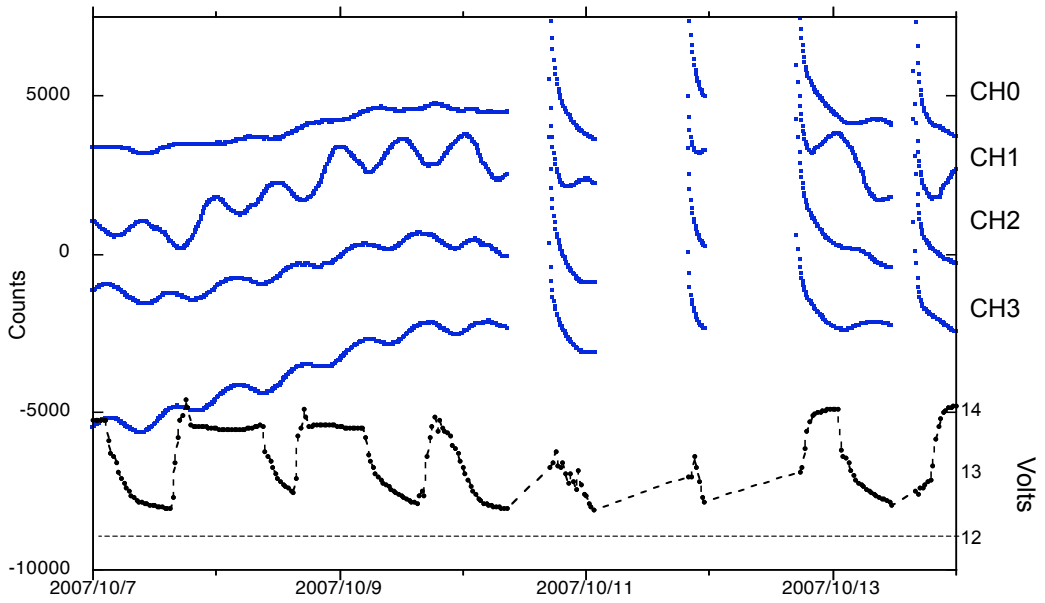



# Non Tectonic Noise: Pathfinder, Anza

B082 and B089, Co-located, Pathfinder site

# Non Tectonic Noise: B036 Restarts

B036 Southern Oregon

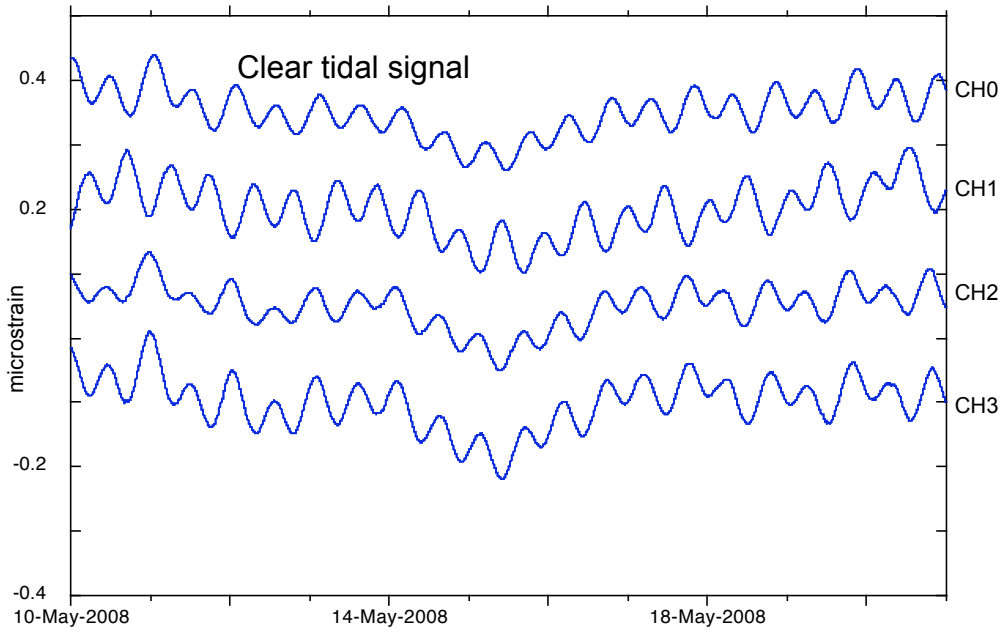



# Strainmeters: Tides

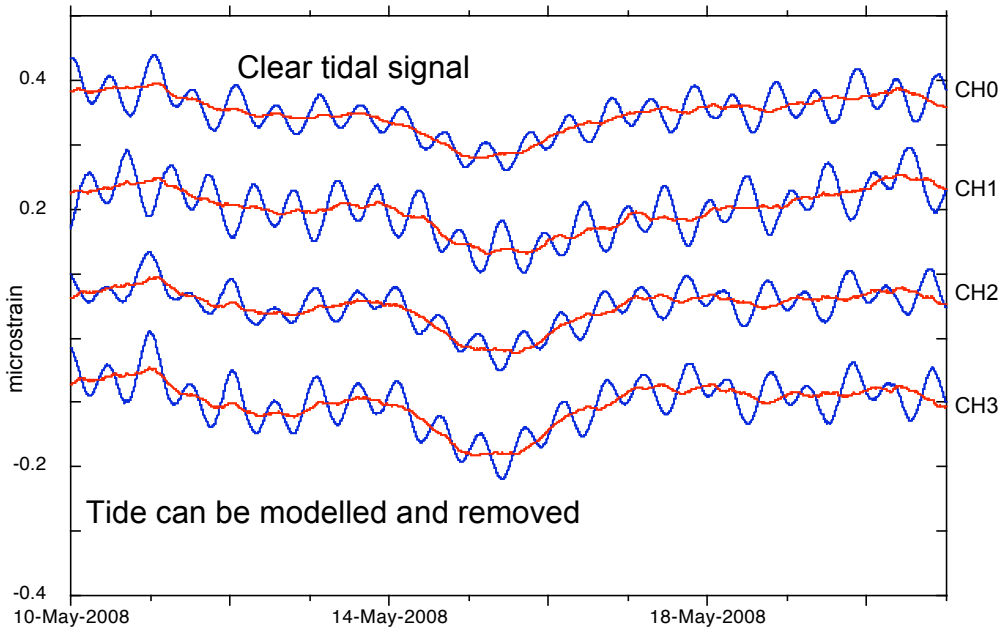
Strainmeters designed to record signals in the tidal band. Some rules of thumb:

- A clear tidal signal should be visible even in the time domain
- You should see at least M2 and O1 peaks in the spectrum
- The tidal phase should not vary by more than a few degrees over years
- The amplitudes should not vary by more than a few percent
- In tidal analysis the error in the phase should be less than a degree and the amplitude error less than one nanostrain

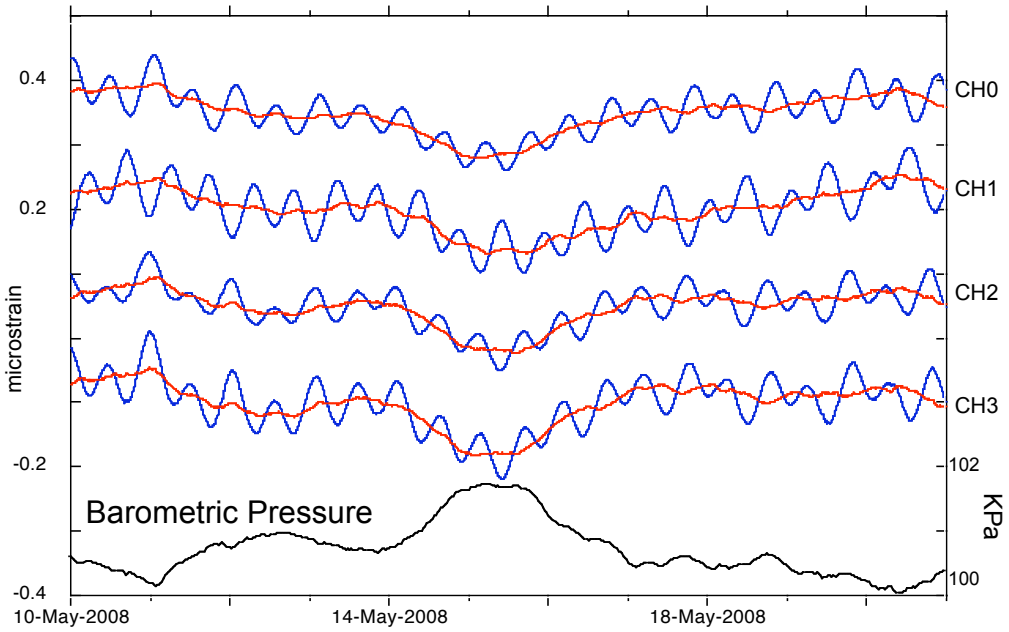
# B018 Tidal signal




# B018 Tidal signal

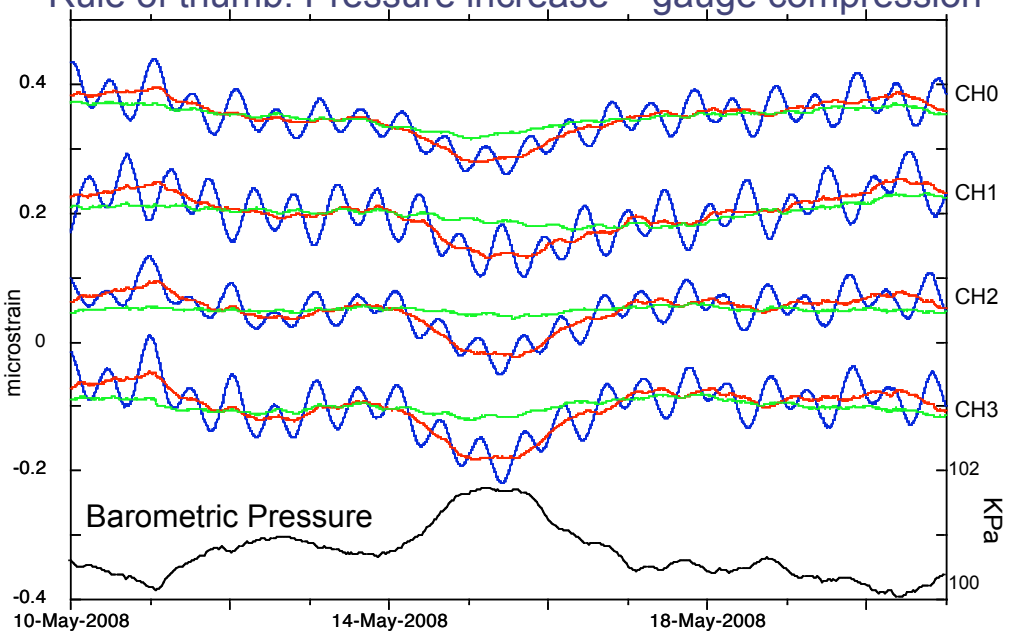


# B018 Tidal signal

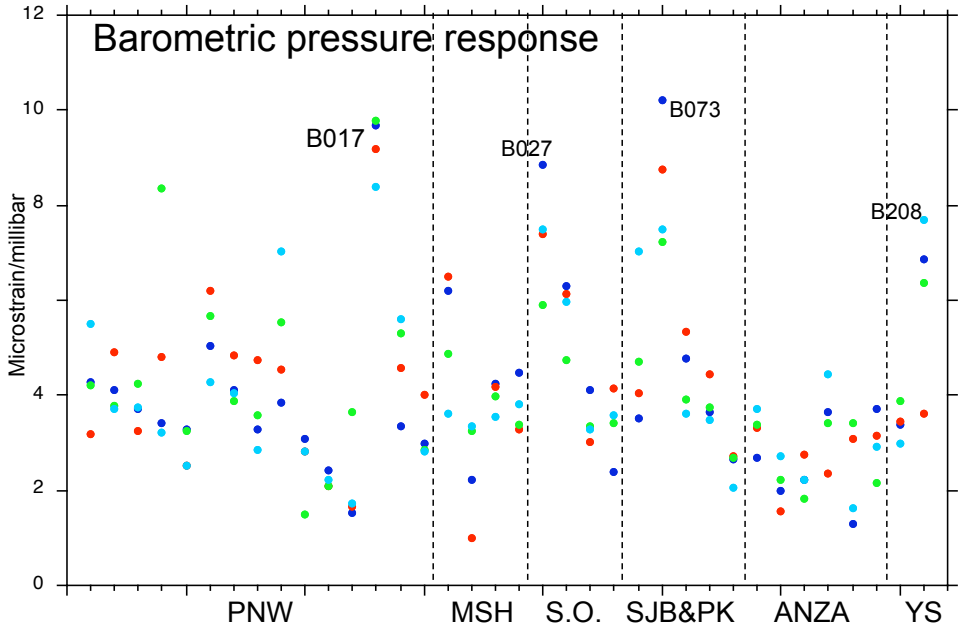



# B018 Tidal signal: Atm Correction

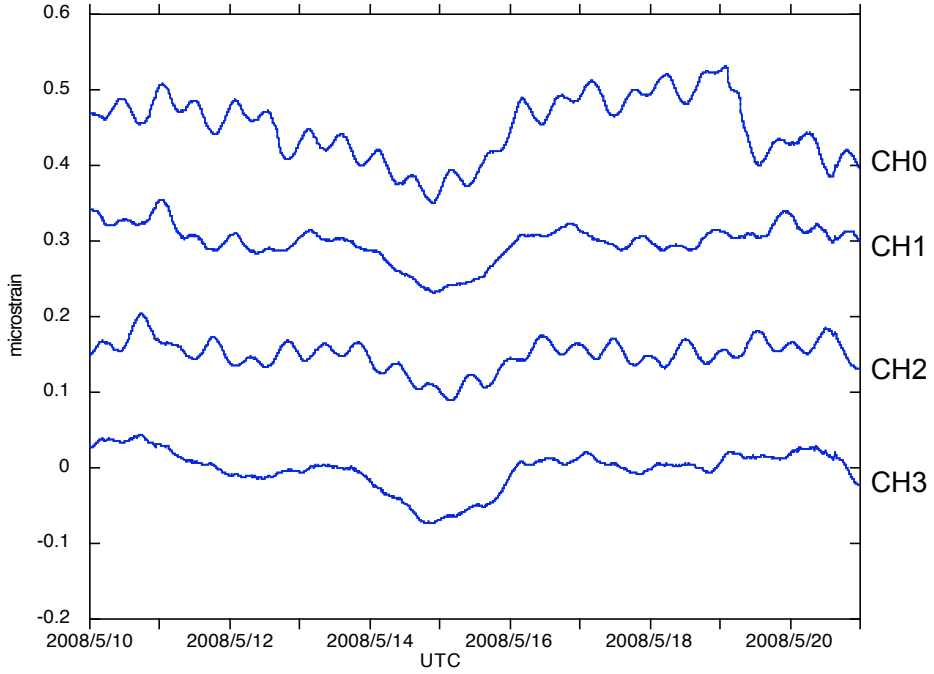
Rule of thumb: Pressure increase = gauge compression



# Strainmeters: Barometric Pressure




# B028: Small tidal amplitude



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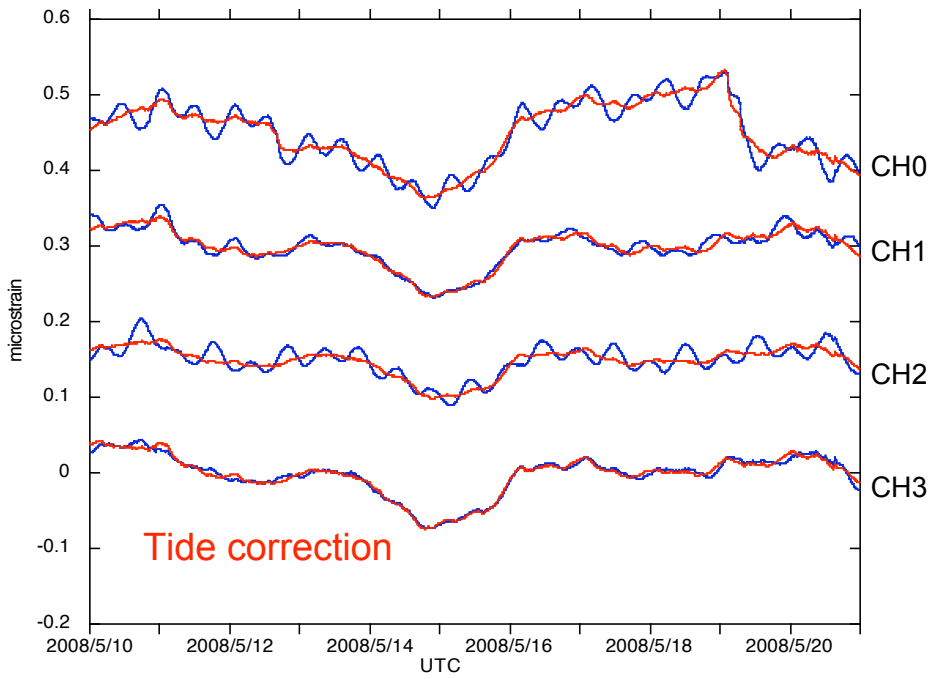


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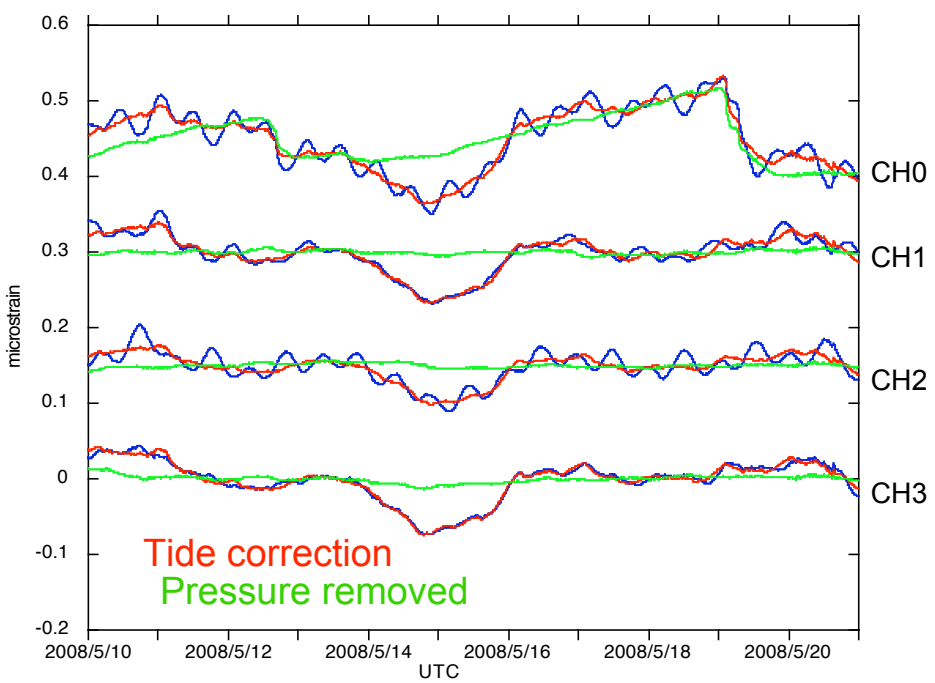

# Tides: Amplitude and phase

- CH3 M2 amplitude is < 2 nanostrain, error in phase is ten times that of the other 3 channels

| | B018 | | B028 | |
|---|---|---|---|---|
| | Phase° | Amp (ns) | Phase ° | Amp (ns) |
| CH0 | -2.9 ± 0.1 | 27.31±0.04 | 37.9 ± 0.1 | 15.42 ± 0.03 |
| CH1 | 138.0 ± 0.1 | 34.59±0.07 | -11.7 ± 0.3 | 5.38 ± 0.02 |
| CH2 | 57.6 ± 0.1 | 23.85 ± 0.05 | -140.1 ± 0.1 | 11.20 ± 0.03 |
| CH3 | 37.1 ± 0.1 | 32.02 ± 0.08 | 149.9 ± 1.1 | 1.68 ± 0.03 |

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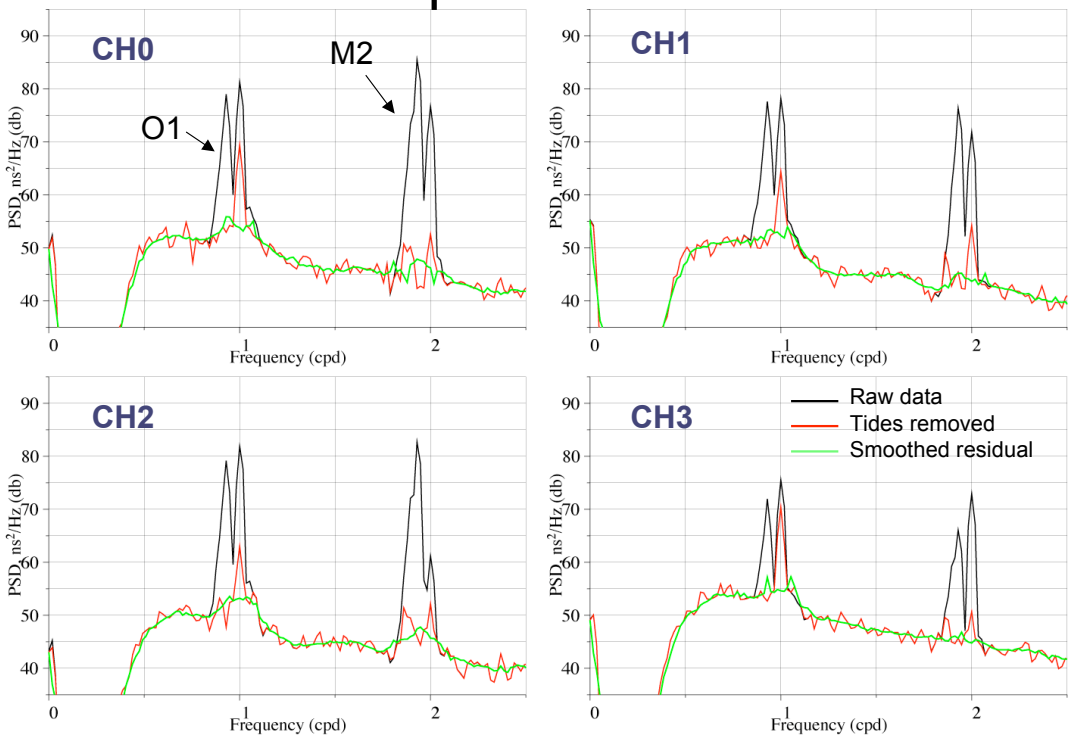
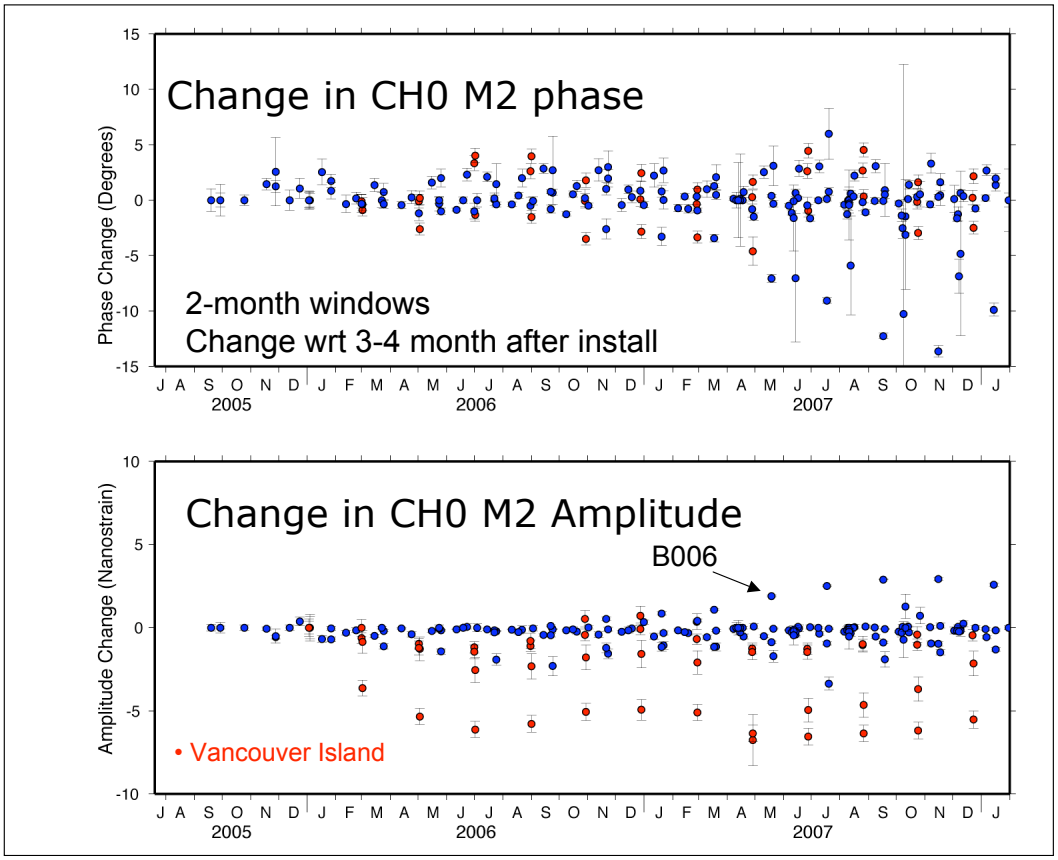
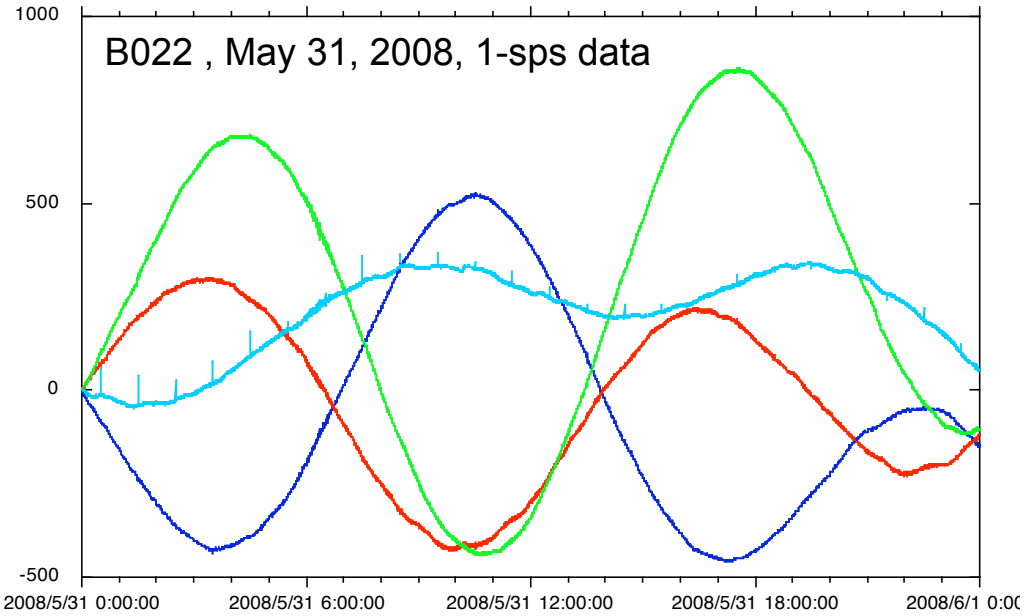
# B028 Tidal Spectra



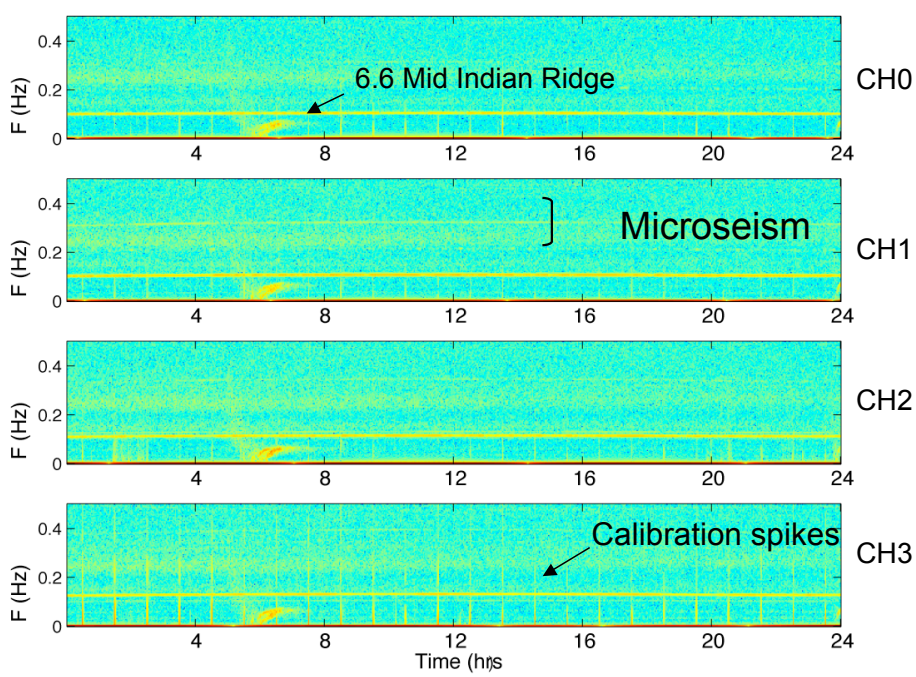



# 1-sps Strainmeter Data

9-12 second calibration signal, 30 minutes past the hour
Null point before and after signal

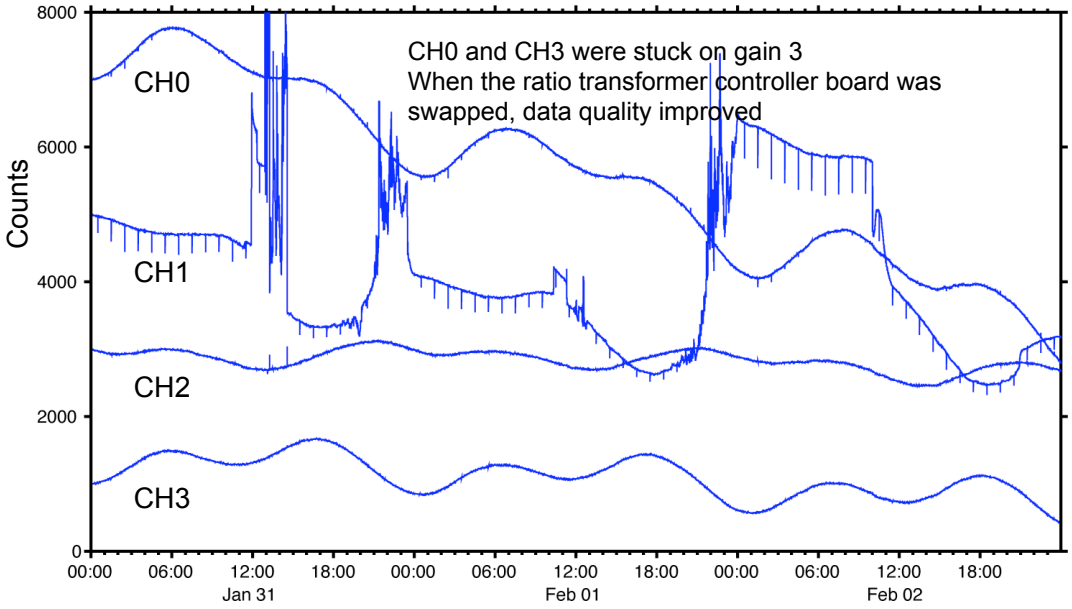



# B022 Spectrogram, May 31, 2008



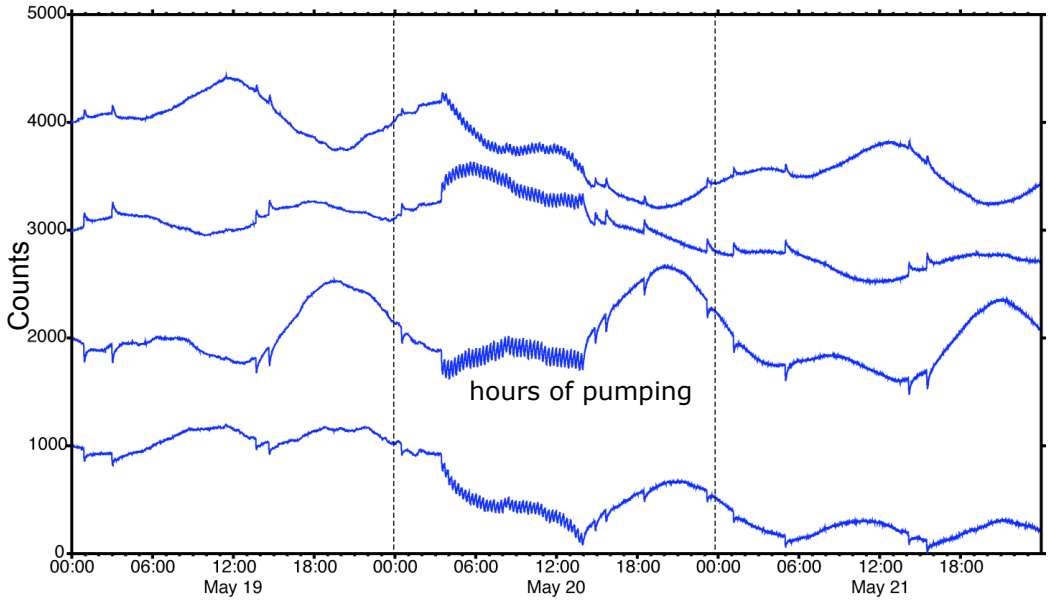
# Ratio Transformer Problem

B035, Grants Pass, Southern Oregon



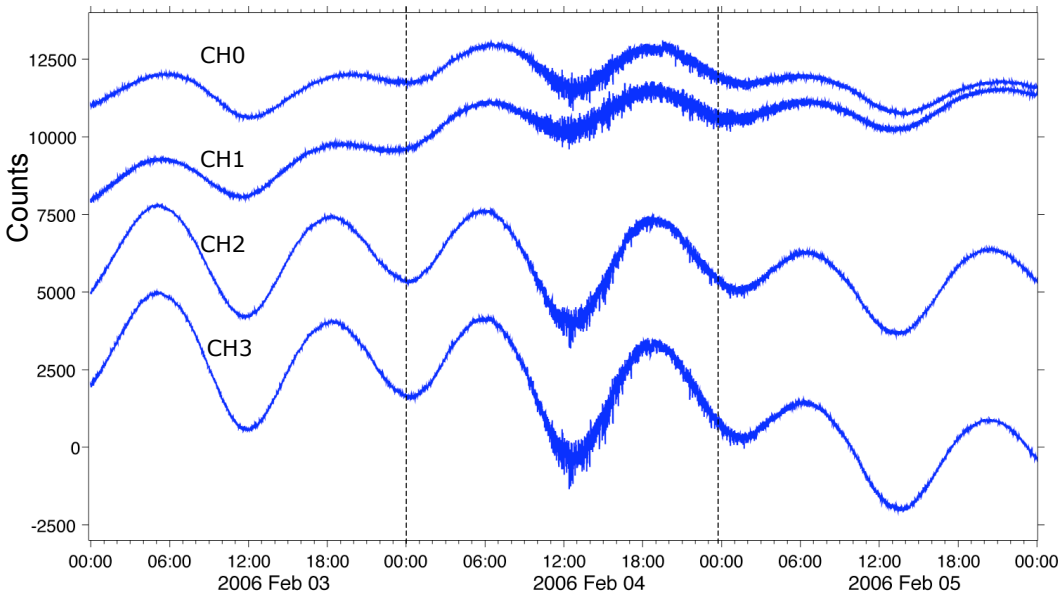

# Non Tectonic Noise: B001 Pumping

B001, Golbeck, Washington

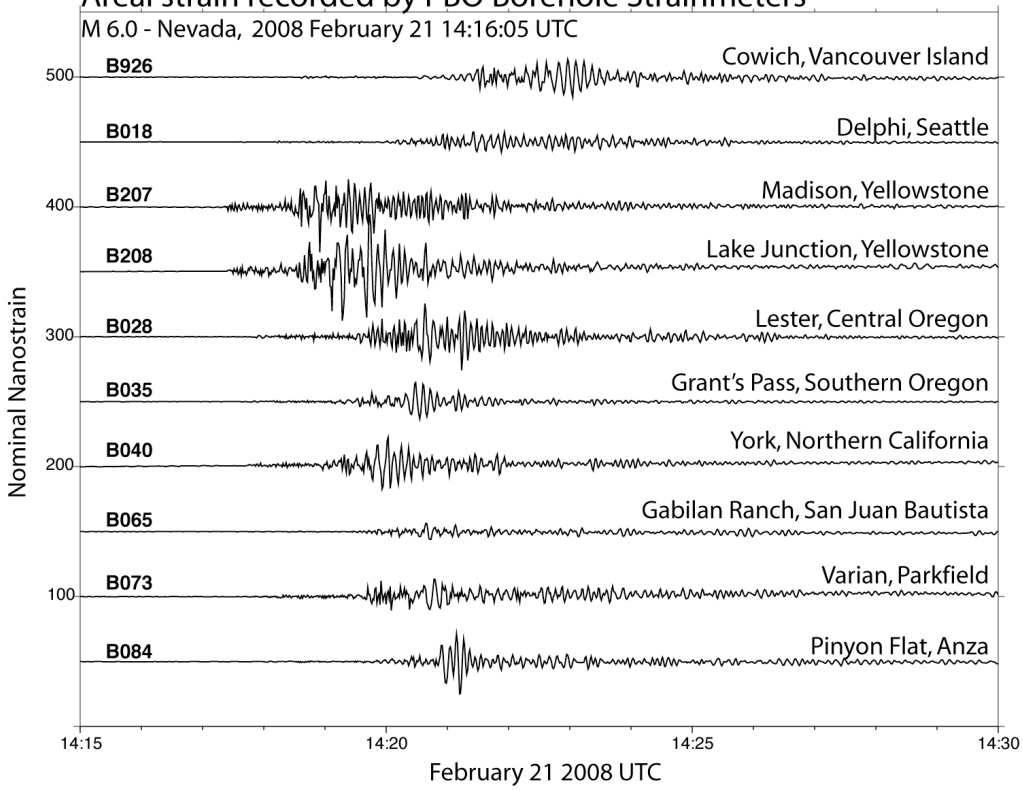


# Noise on the 1sps channels

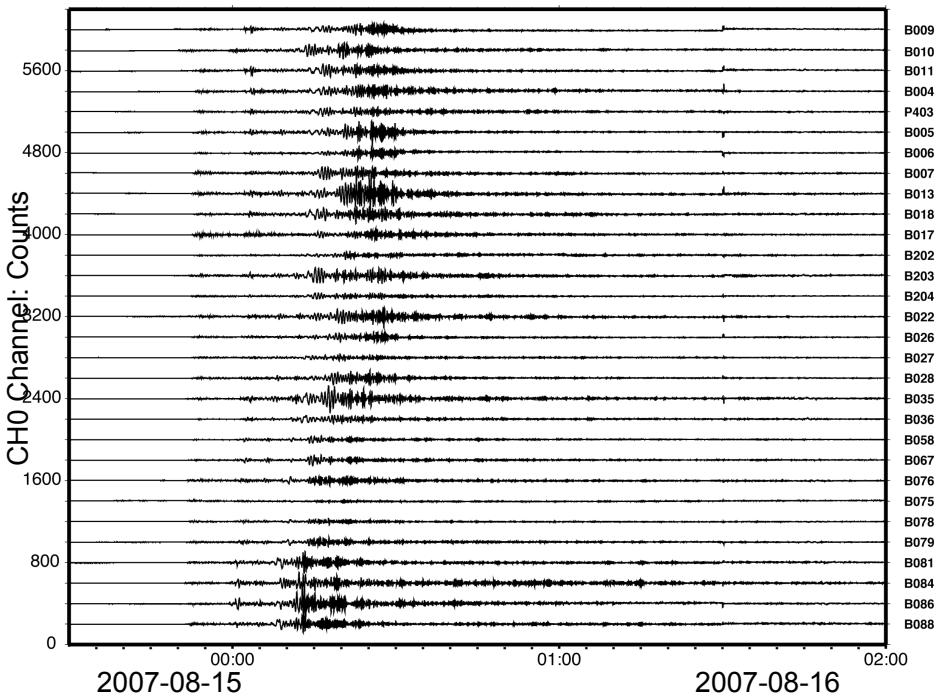
B012, Vancouver Island , BC




Areal strain recorded by PBO Borehole Strainmeters



M8 NEAR THE COAST OF CENTRAL PERU, 2007 AUG 15 23:40:57 UTC




# 20-sps Data Set: Timing

- PBO monitors timing on a daily basis, loggers drift a few seconds at all BSMs

- If GPS time is lost logger can fall behind UTC by a few seconds each day (B201)

# 20-sps Data Set: Timing

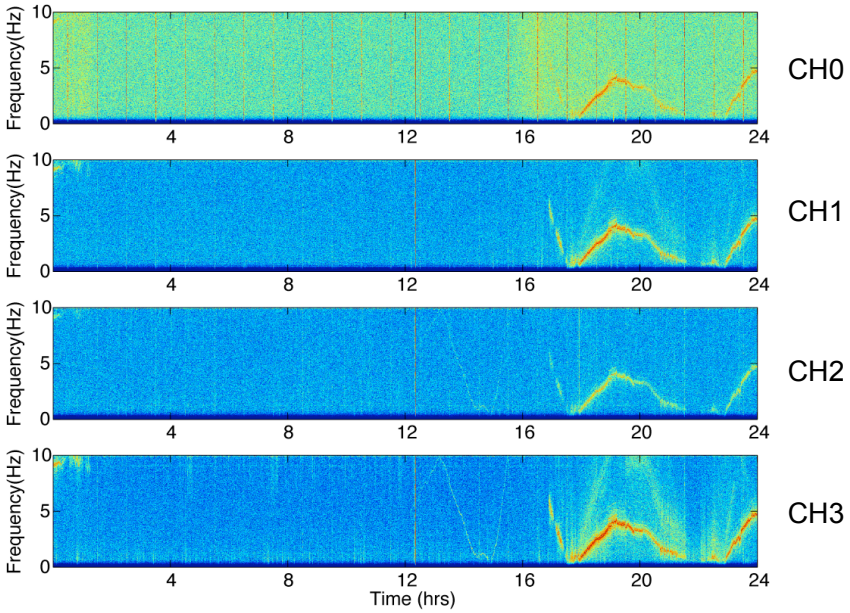
- 20-sps data collected in 60 second files
  Logger calculates sample rate as n/60
  n = number of data points
  => variation in sample rate
- PBO only converts data with sample interval of 0.05s to mSEED
- For 4 BSMs this ~1% of data are not converted to mSEED

# 20-sps Data Set: Solar Noise

- It was found that noise was introduced when the solar panels started to charge up in early morning.
- The noise is visible in the 20-sps data set.
- PBO engineers found that rerouting cables helped.

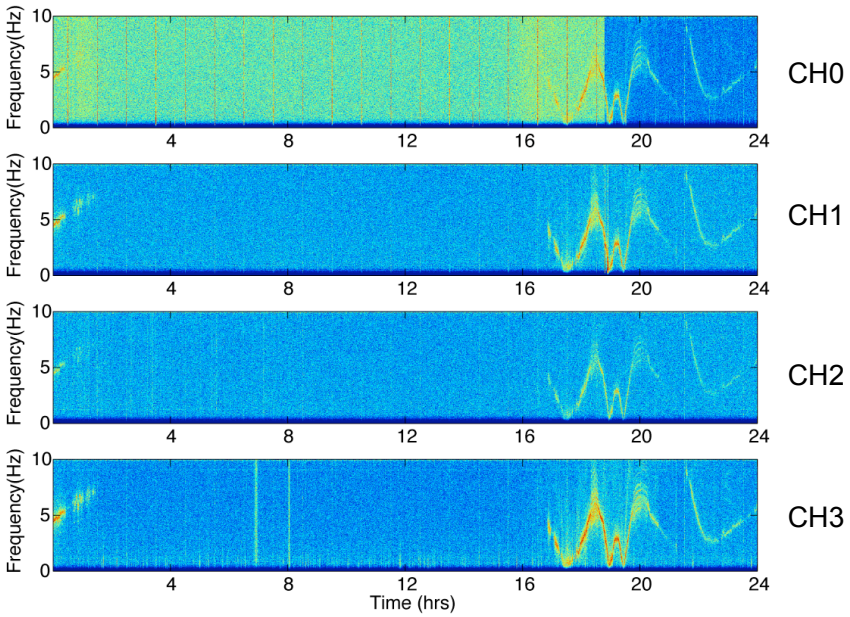
# 20-sps Data: Solar Noise

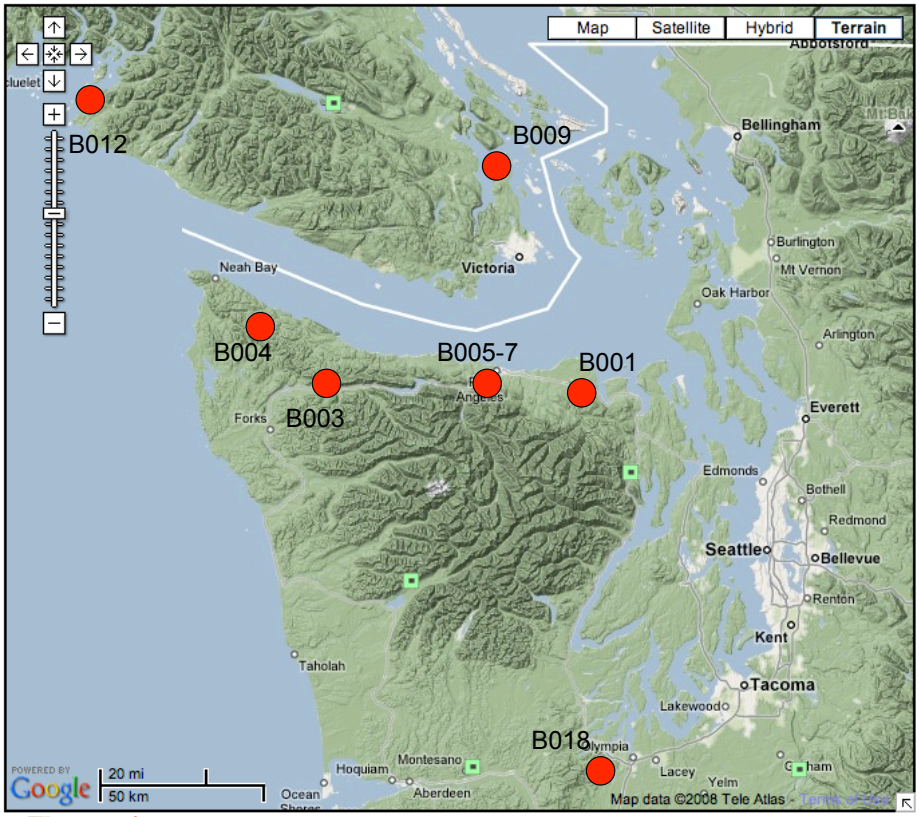
B916, Mojave, March 20, 2008



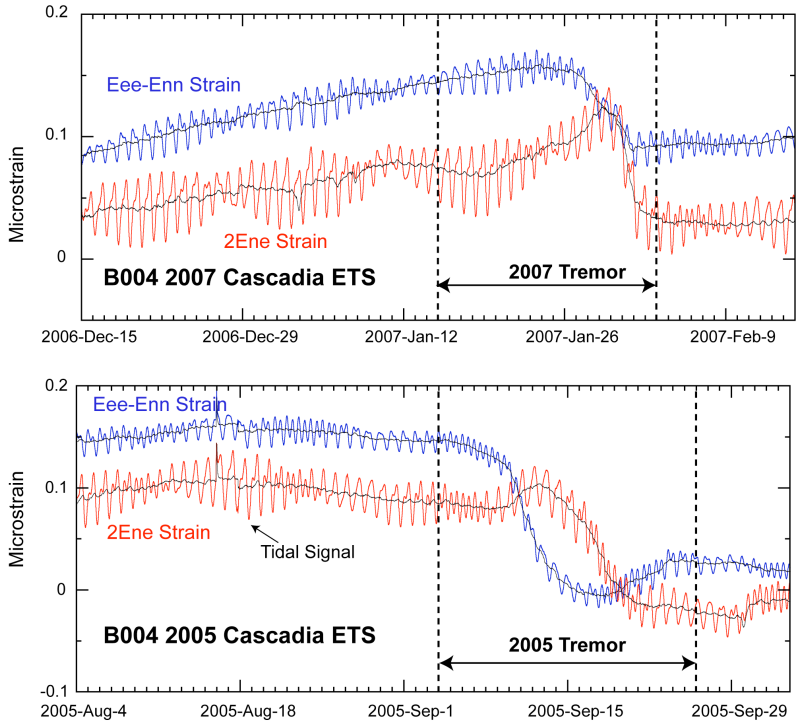

# 20-sps Data: Solar Noise

B916, Mojave, March 25, 2008






# A Strain Transient: Cascadia ETS



# A Strain Transient: Cascadia ETS

## Olympic Network: Shear strain