PBO STRAINMETER DATA QUALITY

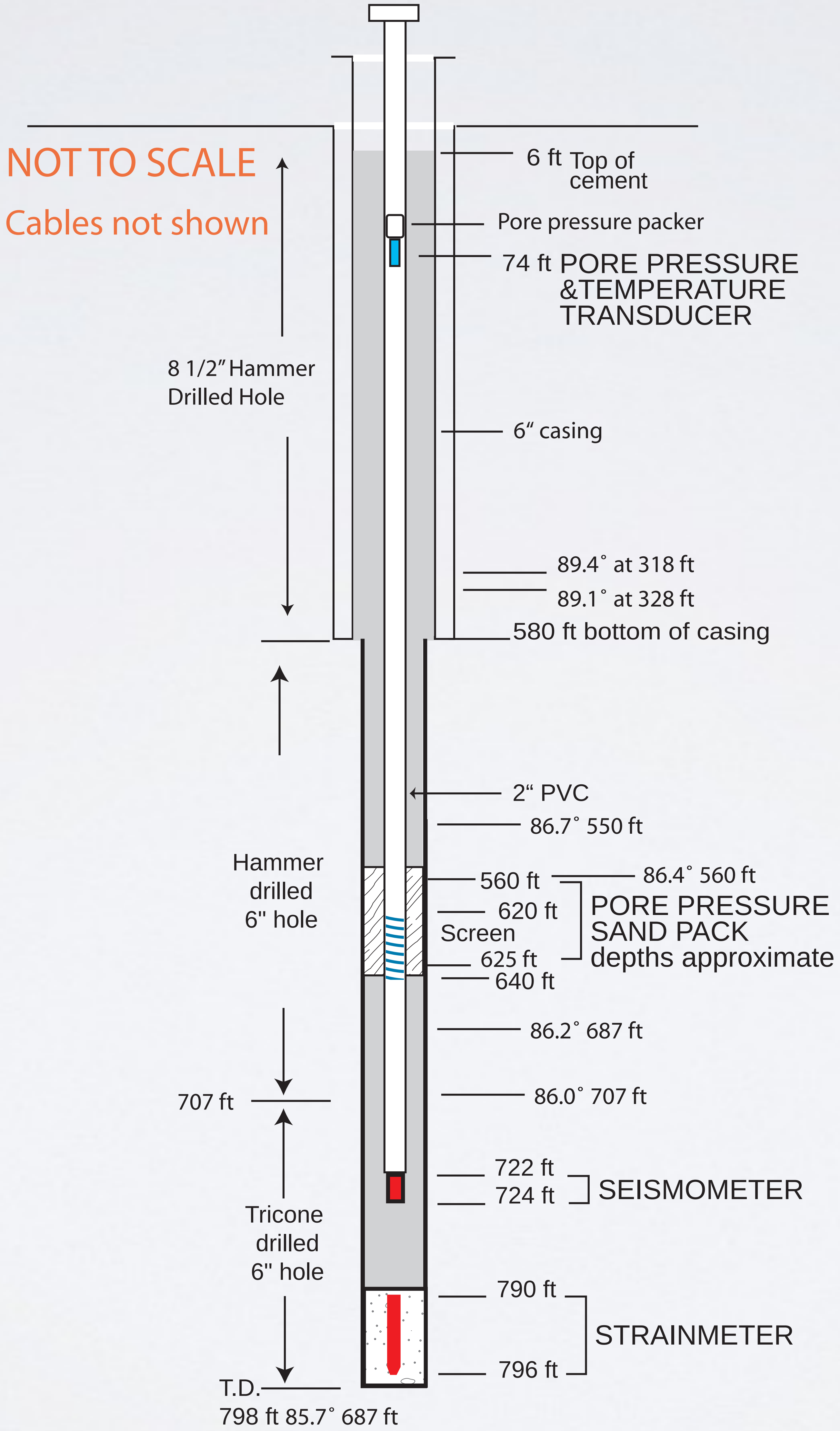
Kathleen Hodgkinson, UNAVCO

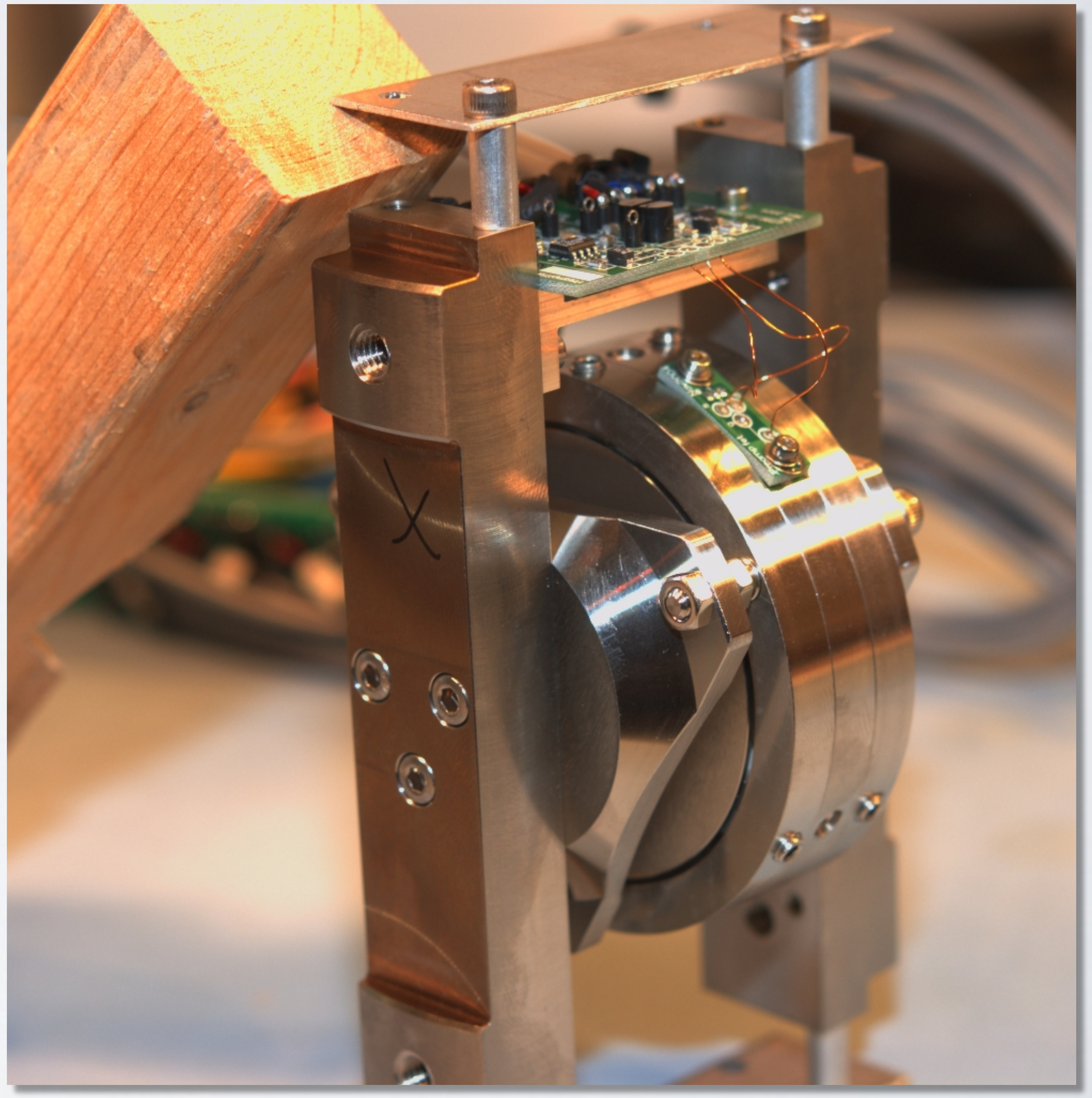
2018 Strainmeter Short Course
Omni, Broomfield, Colorado

OVERVIEW

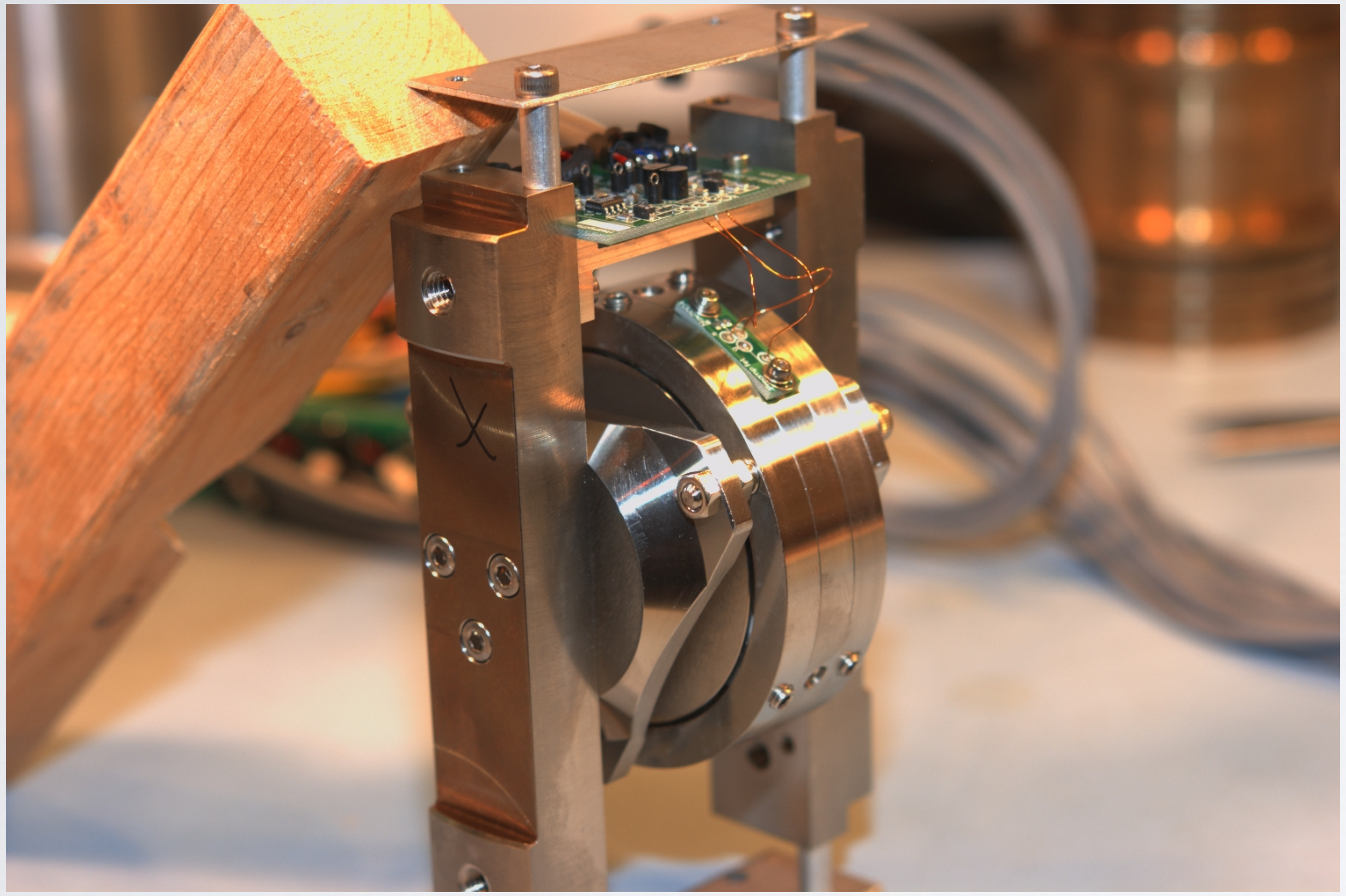
- Identify indicators of good quality strain data
- Assess performance over different frequency ranges
- Look at examples of tectonic and non-tectonic signals observed in borehole strainmeter data

BOREHOLE STRAINMETER

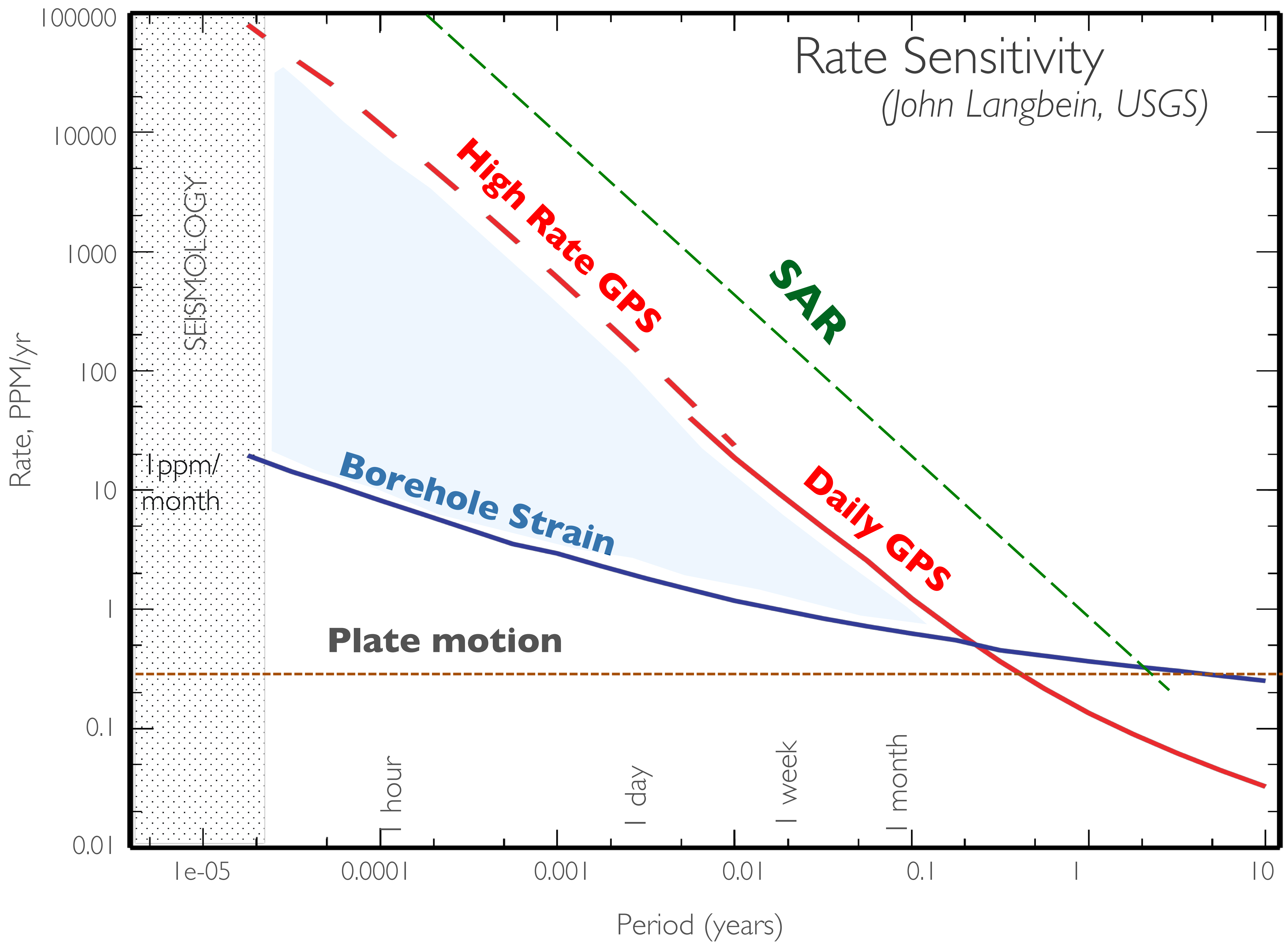




BOREHOLE STRAINMETER



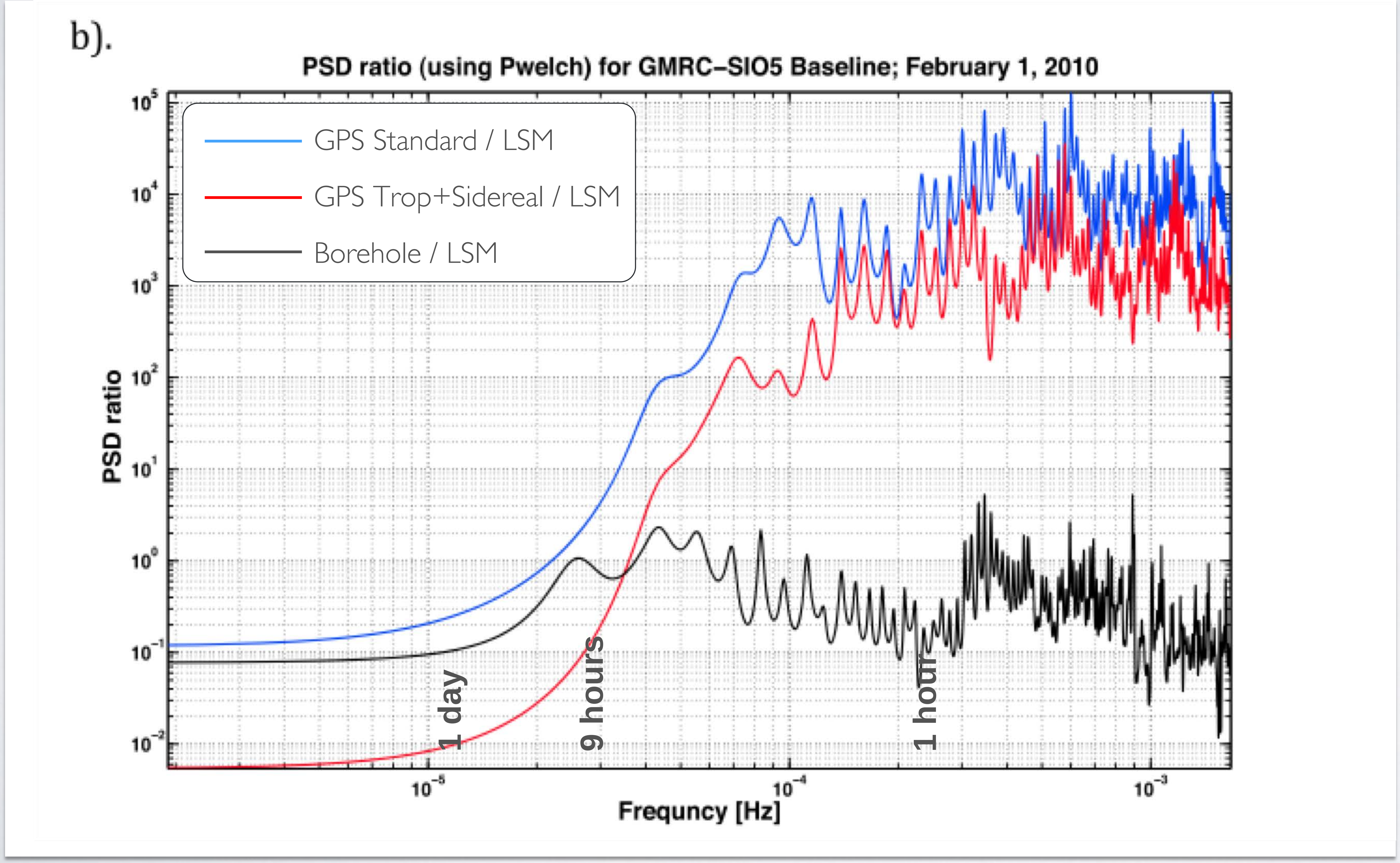
INSTRUMENT SENSITIVITY



Strainmeters are the optimal instruments to record transients with periods of hours to weeks.

They bridge the gap between seismology and GPS.

INSTRUMENT SENSITIVITY



Improving sub-daily strain estimates using GPS measurements.

Reuveni, Y., S. Kedar, S. E. Owen, A. W. Moore, and F. H. Webb (2012), Geophys. Res. Lett., 39, L11311.

PERFORMANCE

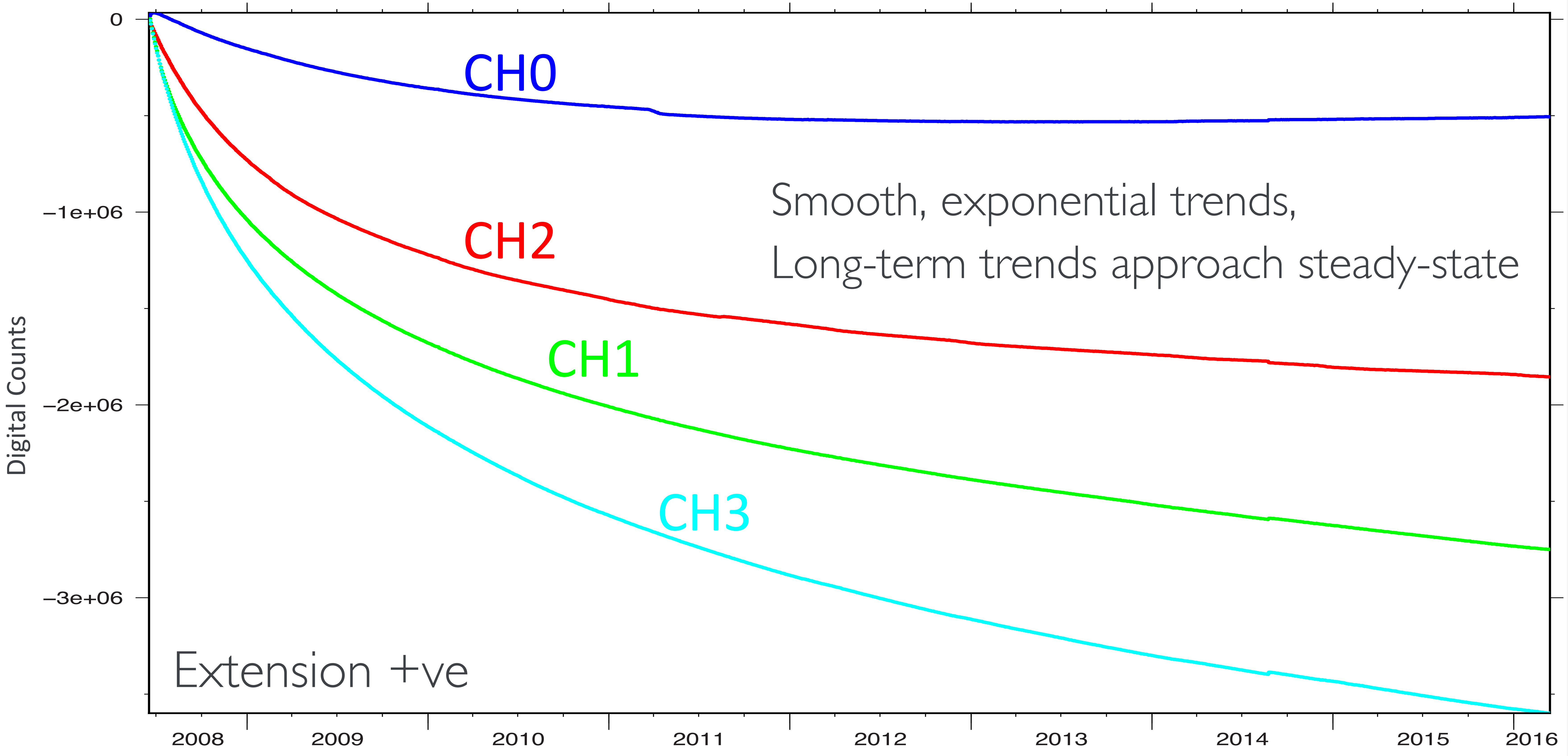
Period			Signals
Months	→	Years	Borehole Compression
Hours	→	Months	Tidal Signal Step-free data sets
Seconds	→	Hours	Seismic Shear

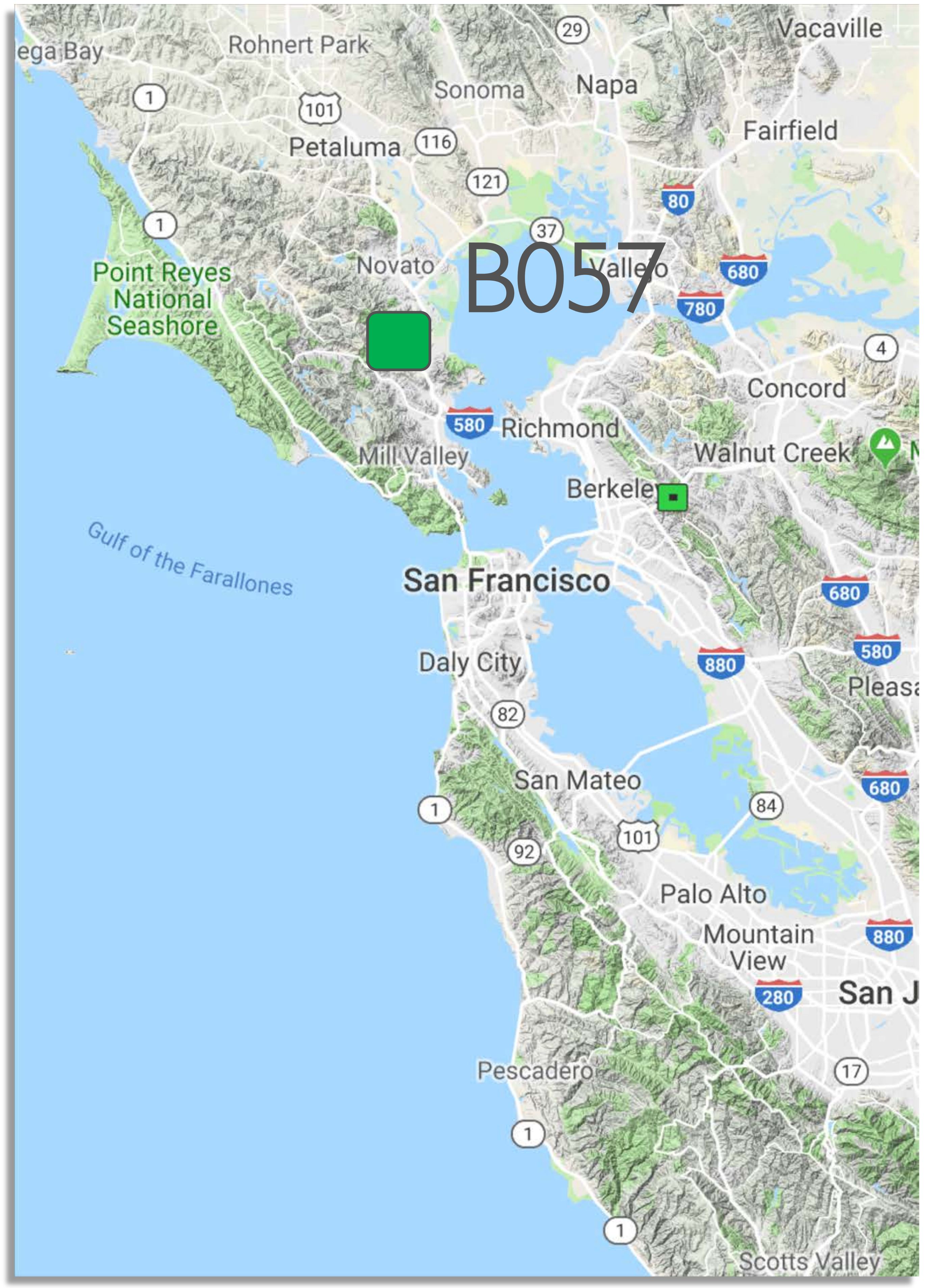
MONTHS TO YEARS: TRENDS

- Gladwin Tensor Strainmeters are designed to operate in a state of compression.
- Ideally three gauges should be in compression over periods of years but depending on the periods of the signal of interest you may still be able to use the data.

MONTHS TO YEARS: TRENDS

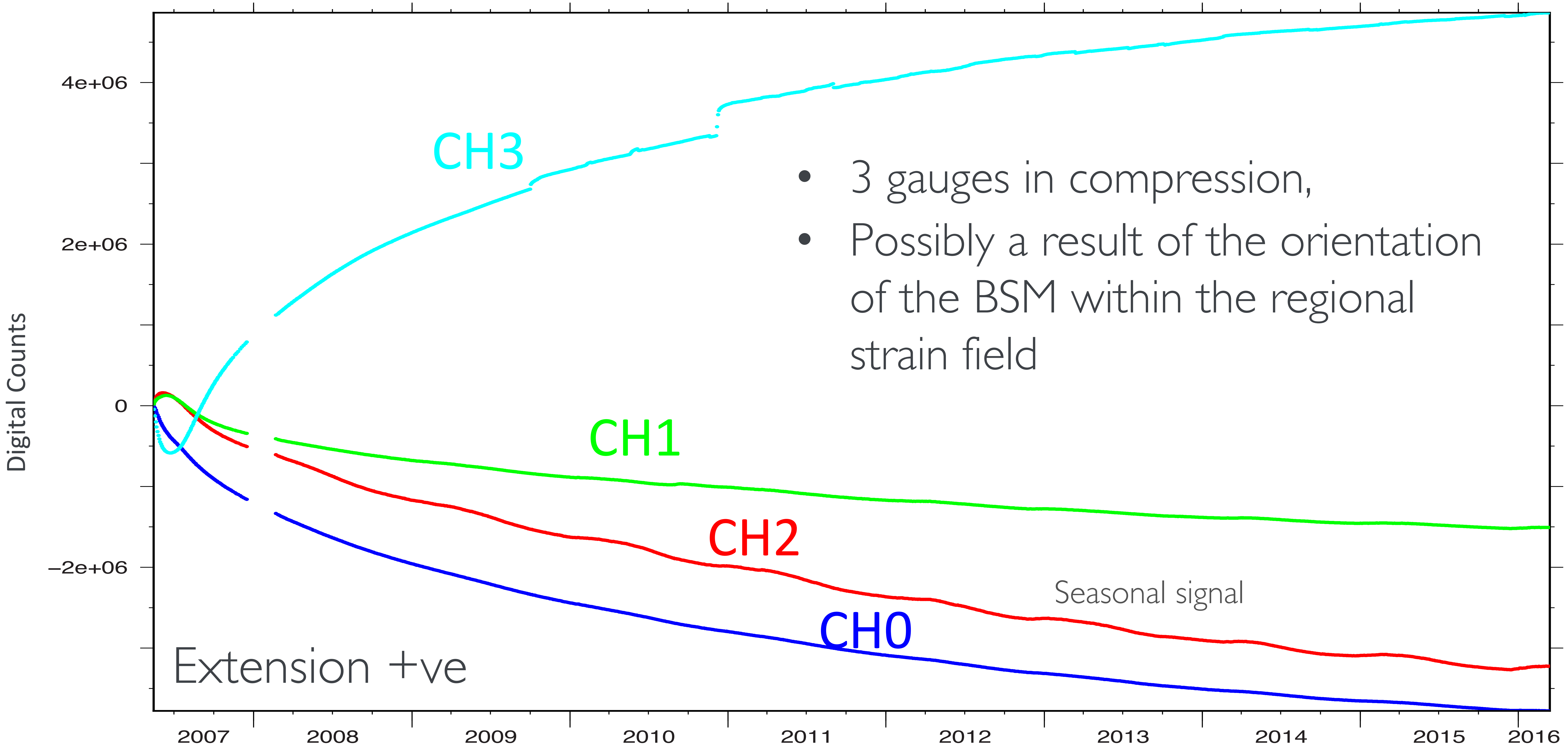
B057, Lucas Valley, San Francisco Bay Area



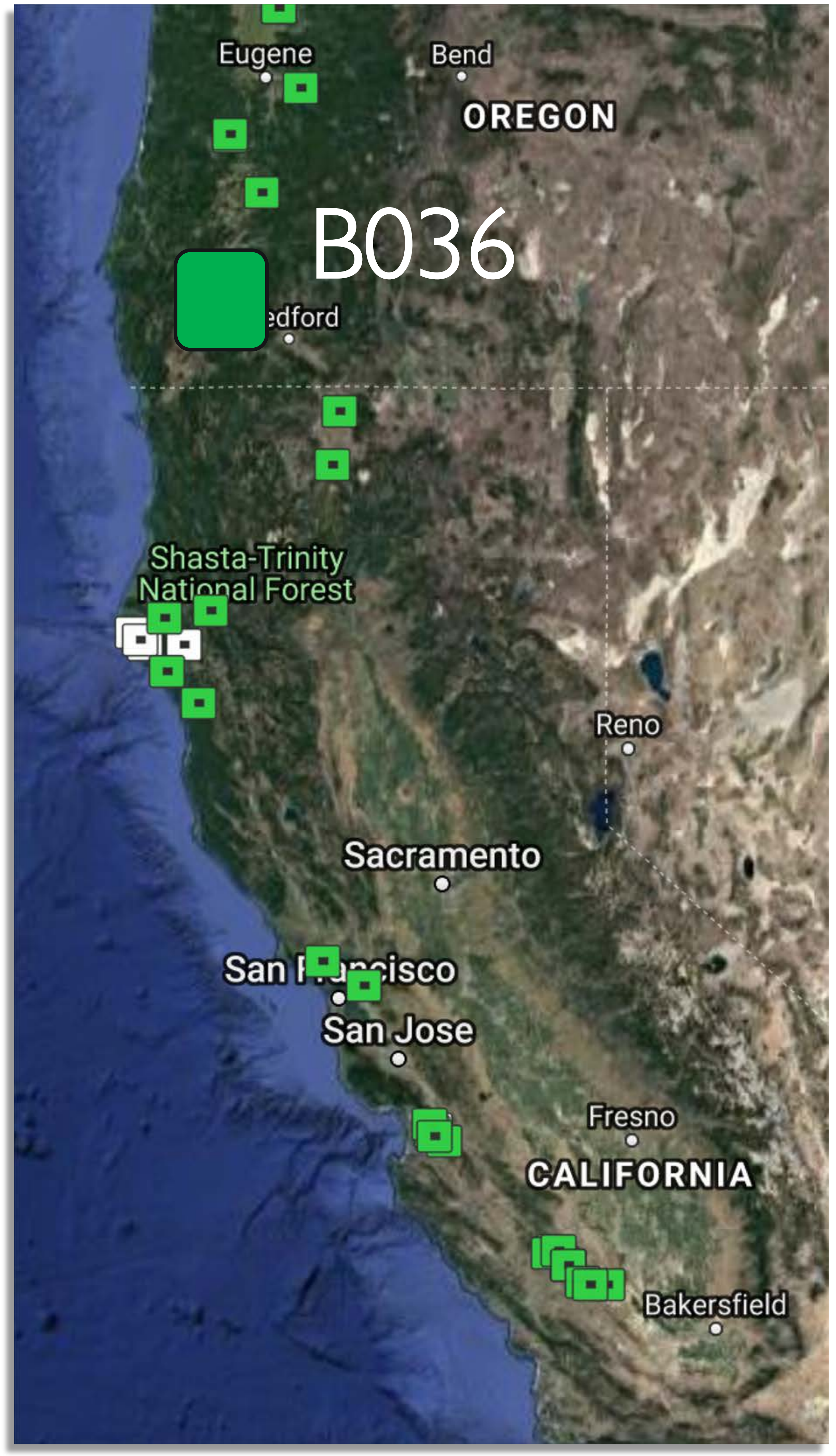


MONTHS TO YEARS: TRENDS

B036, Grants Pass, Oregon

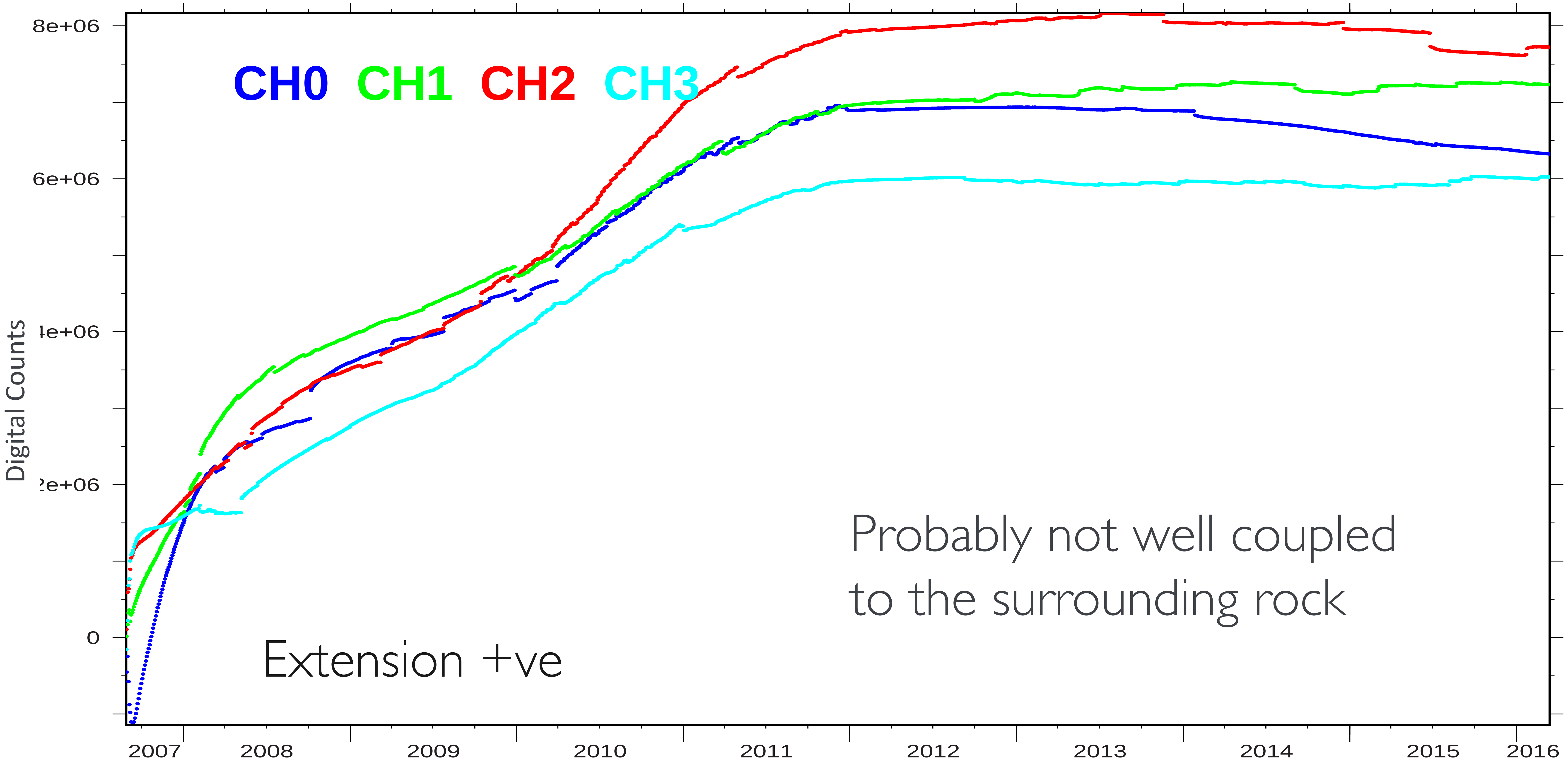


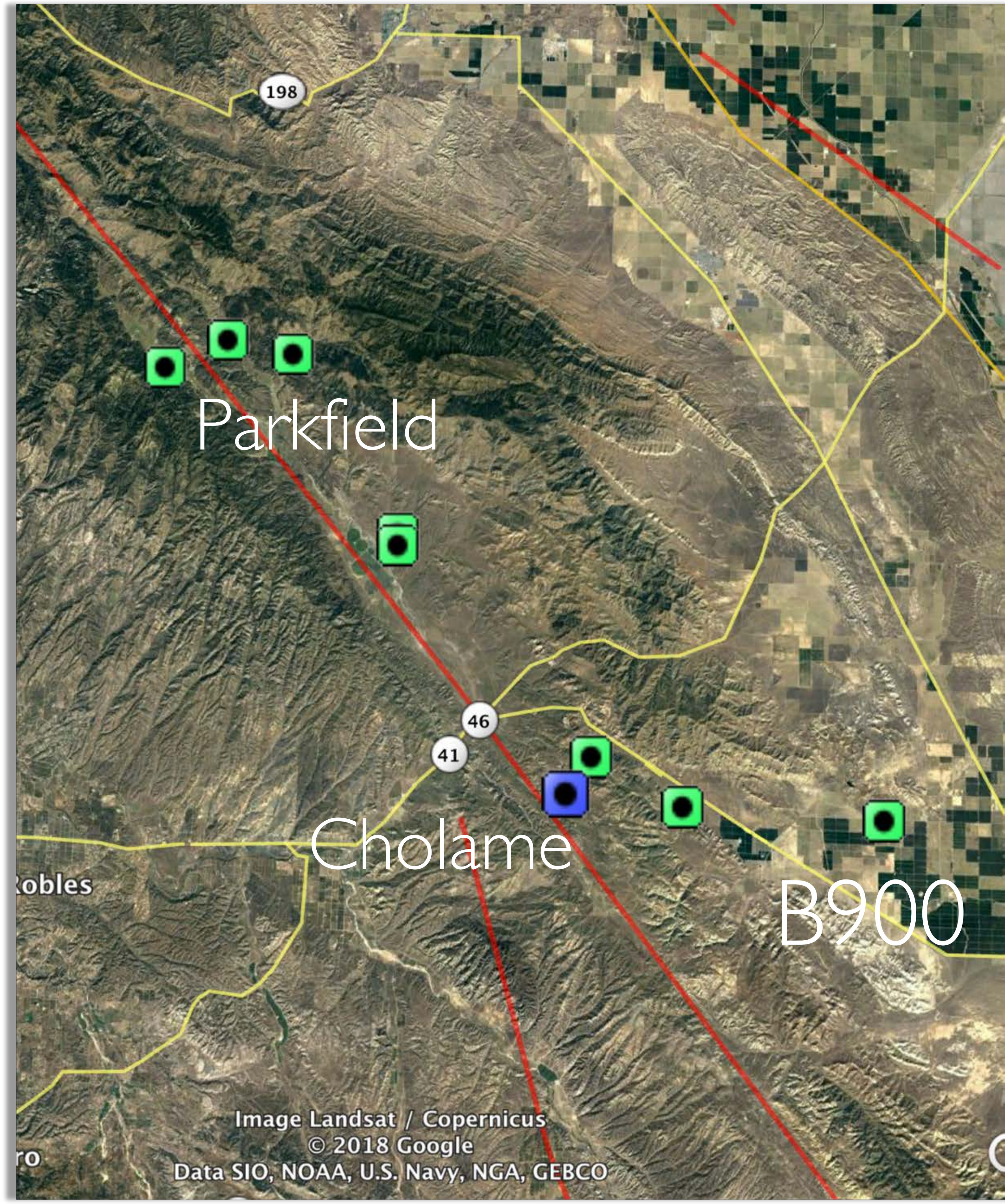
- 3 gauges in compression,
- Possibly a result of the orientation of the BSM within the regional strain field



MONTHS TO YEARS: TRENDS

B900, Parkfield



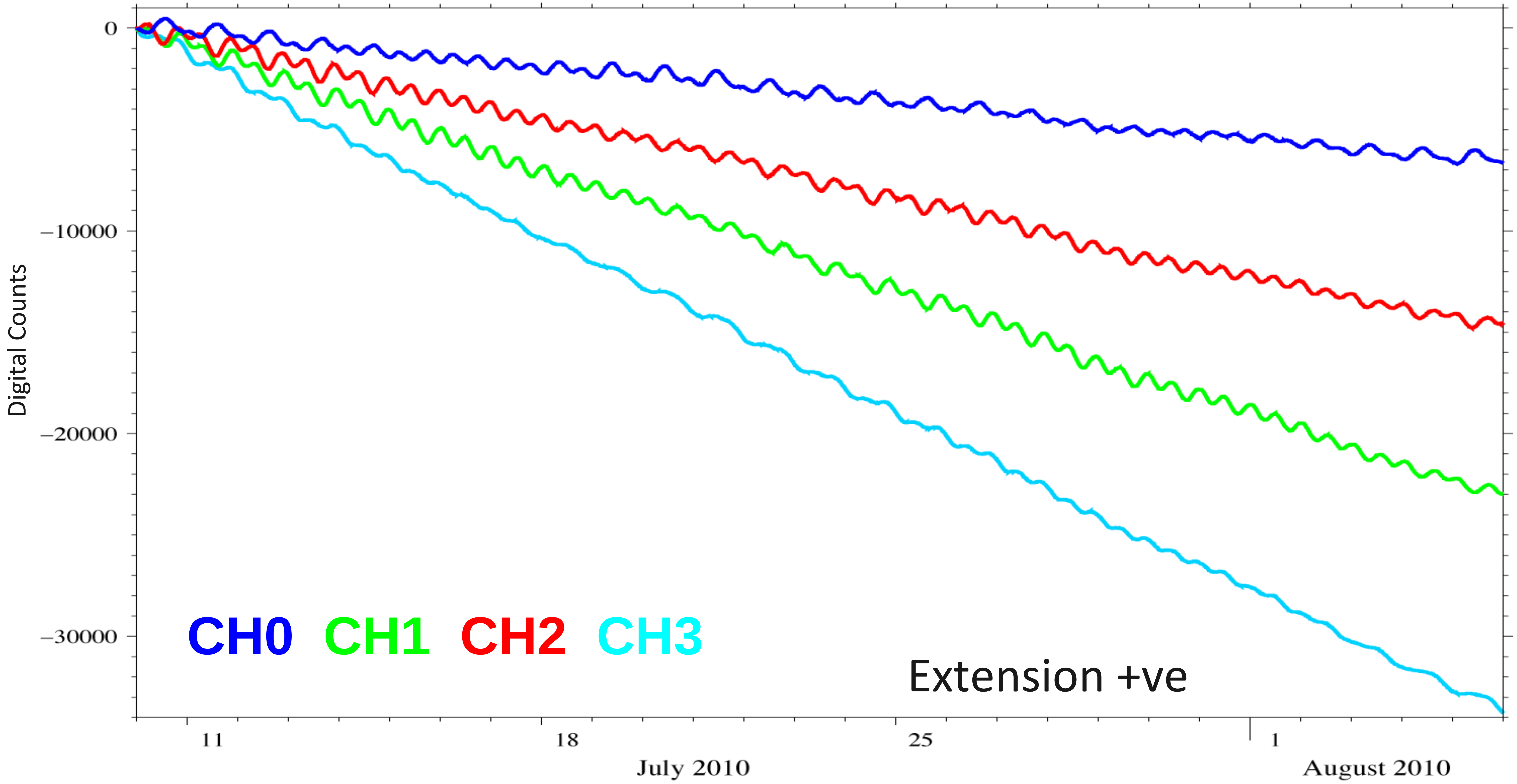


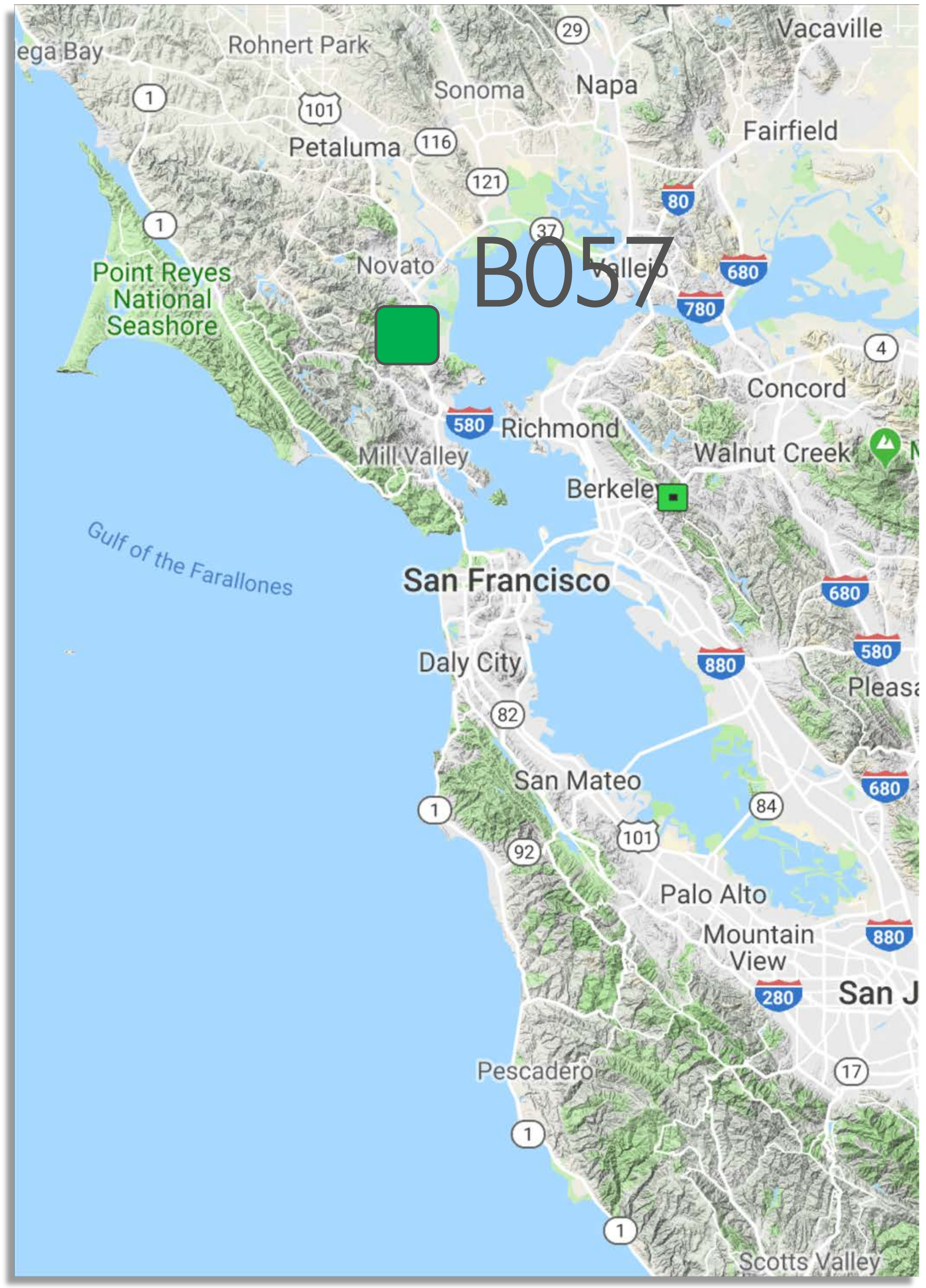
HOURS TO WEEKS: TIDES

- Strainmeters are optimized for good performance at tidal frequencies
- Tides should be dominant signal over hours to weeks
- Expect peaks in the M_2 and O_1 frequencies to stand well above the background noise.

HOURS TO WEEKS: TIDES

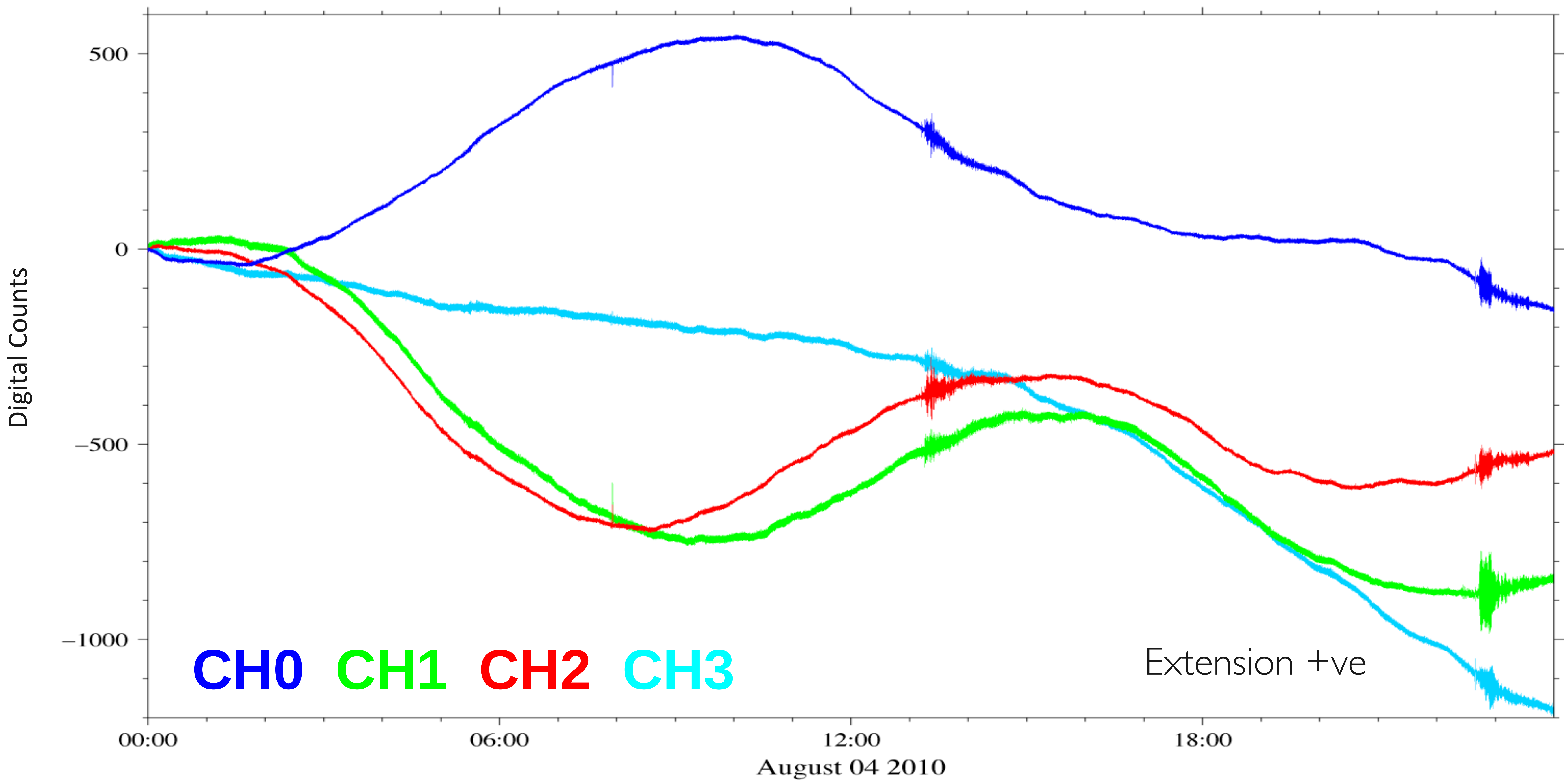
B057, Lucas Valley, San Francisco

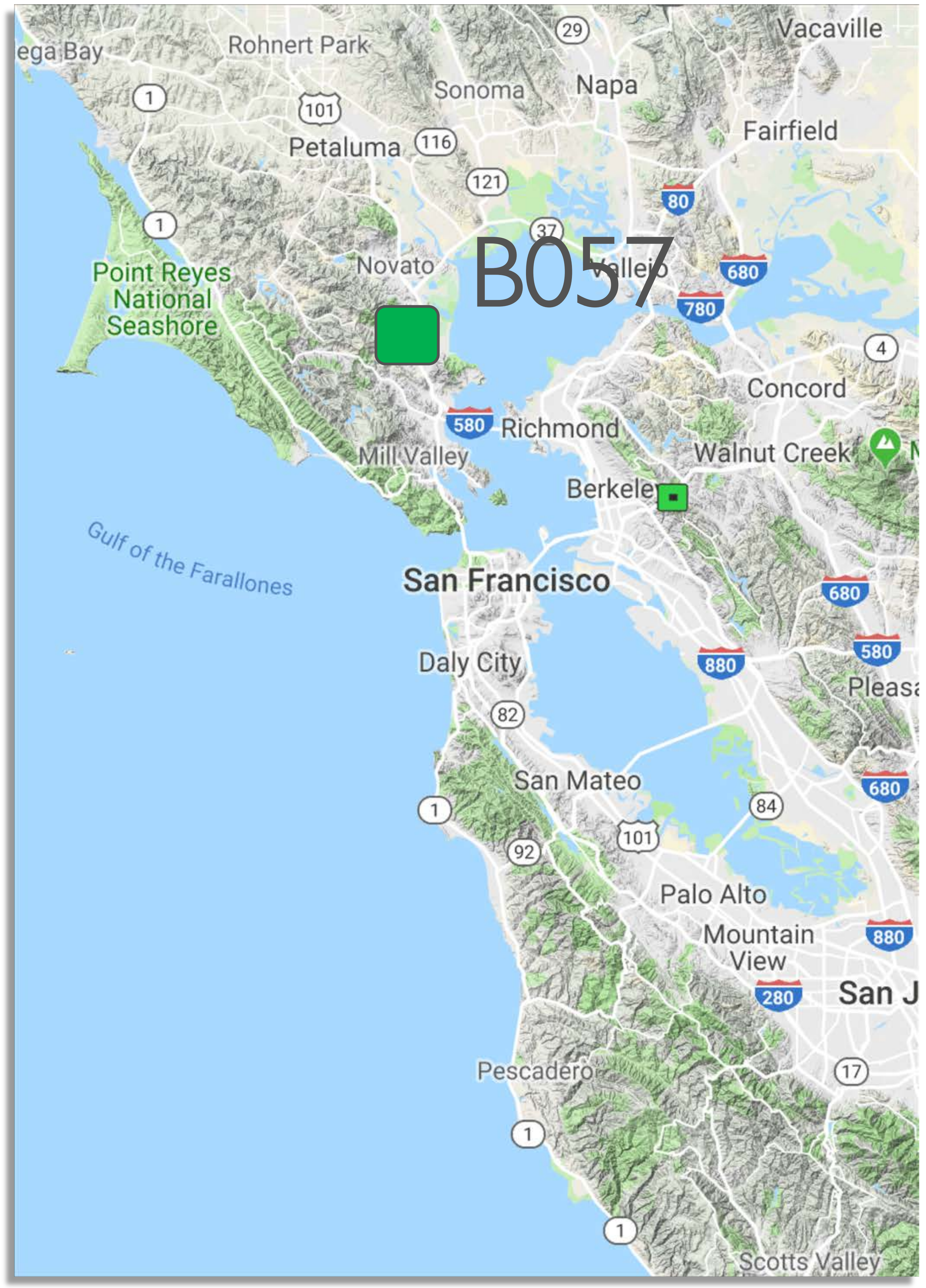




HOURS TO WEEKS: TIDES

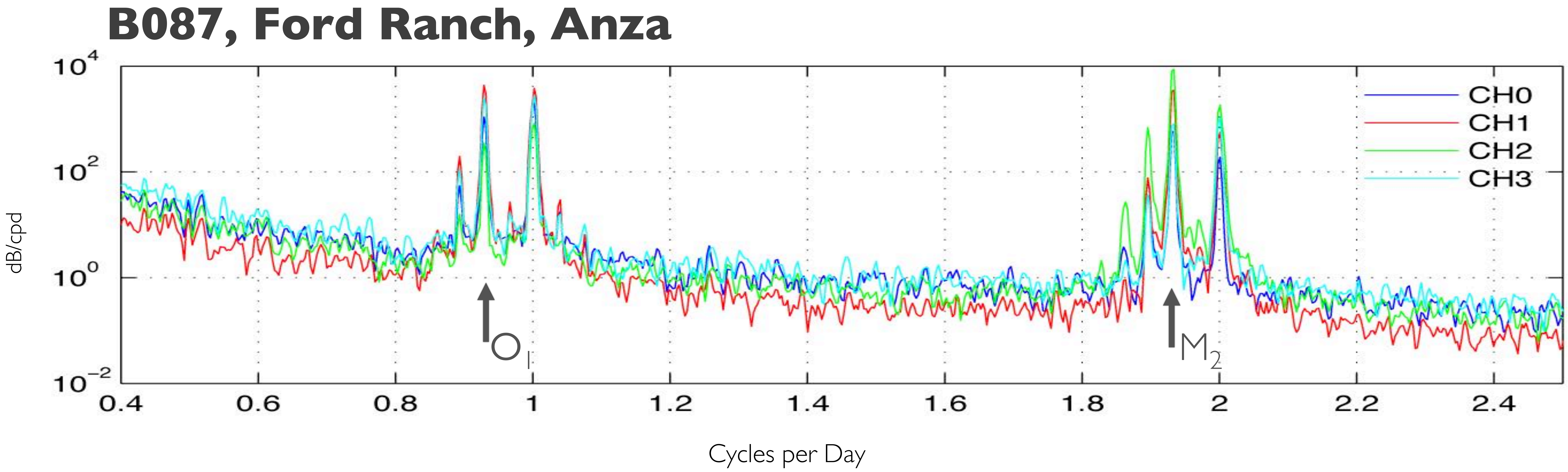
B057, Lucas Valley, San Francisco





HOURS TO WEEKS: TIDES

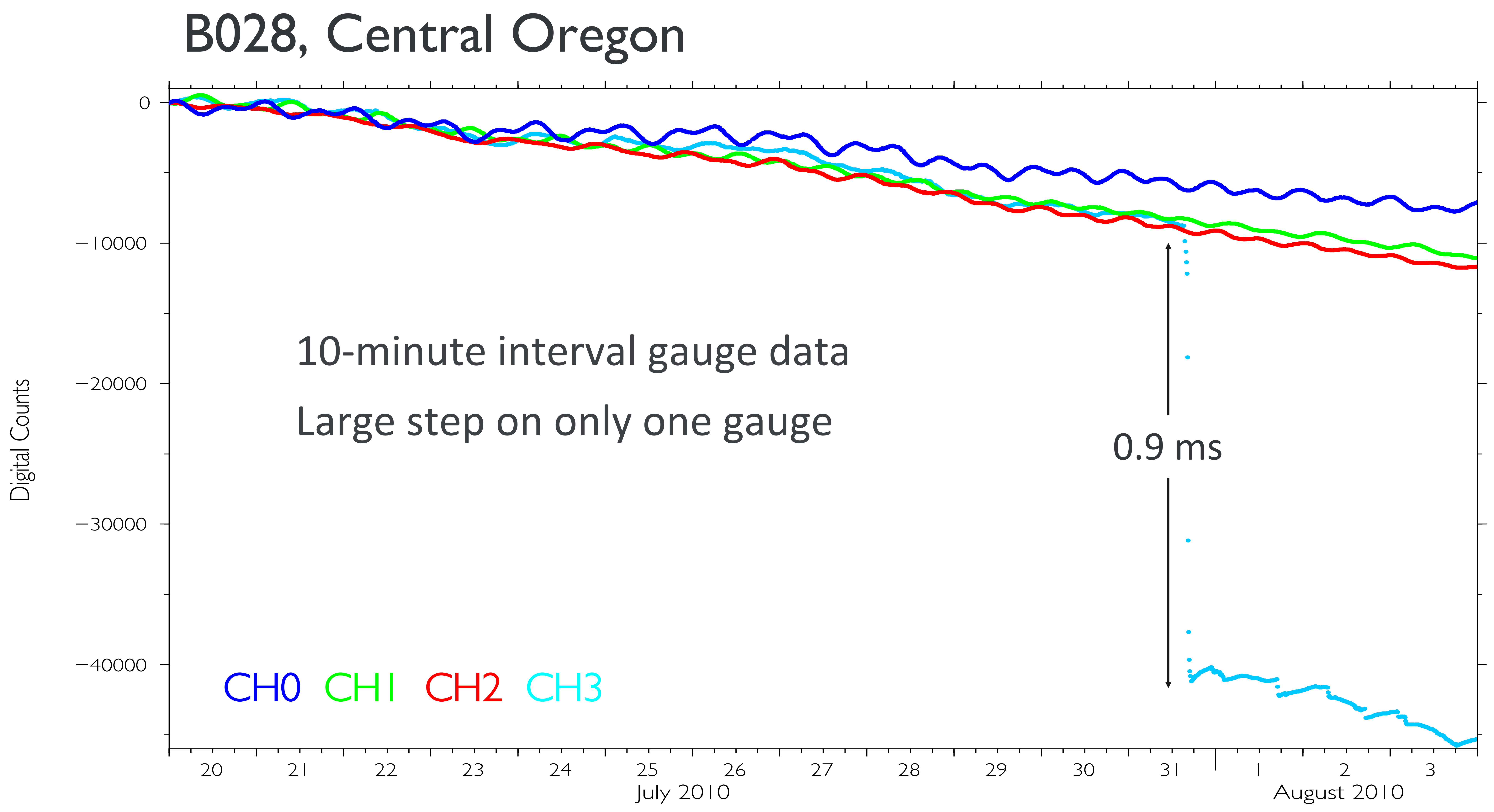
M_2 and O_1 tidal bands should stand well above the background noise in the frequency domain



HOURS TO WEEKS: STEPS

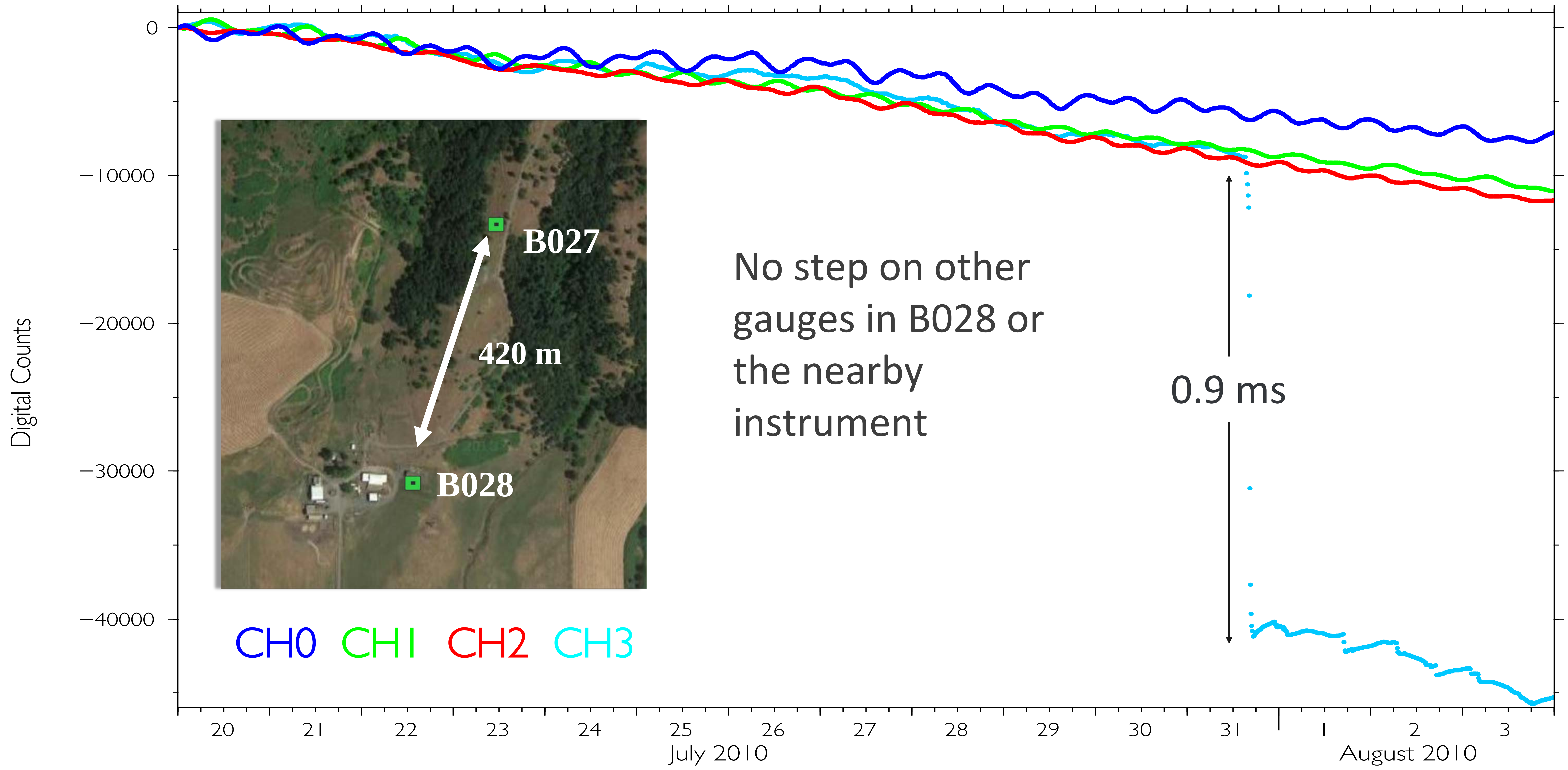
All strainmeter data will have some unexplained steps in the time-series

HOURS TO WEEKS: STEPS



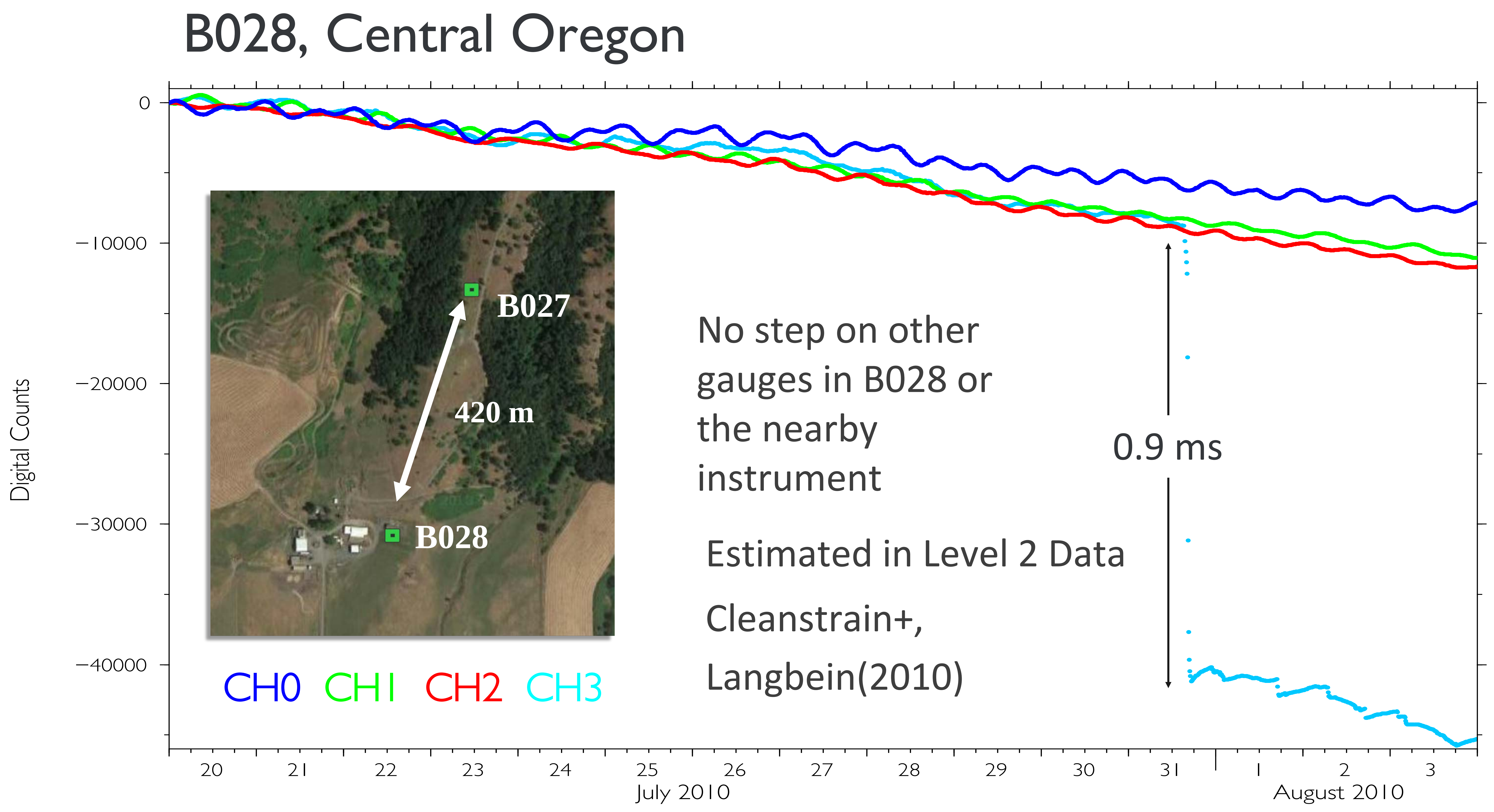
HOURS TO WEEKS: STEPS

B028, Central Oregon

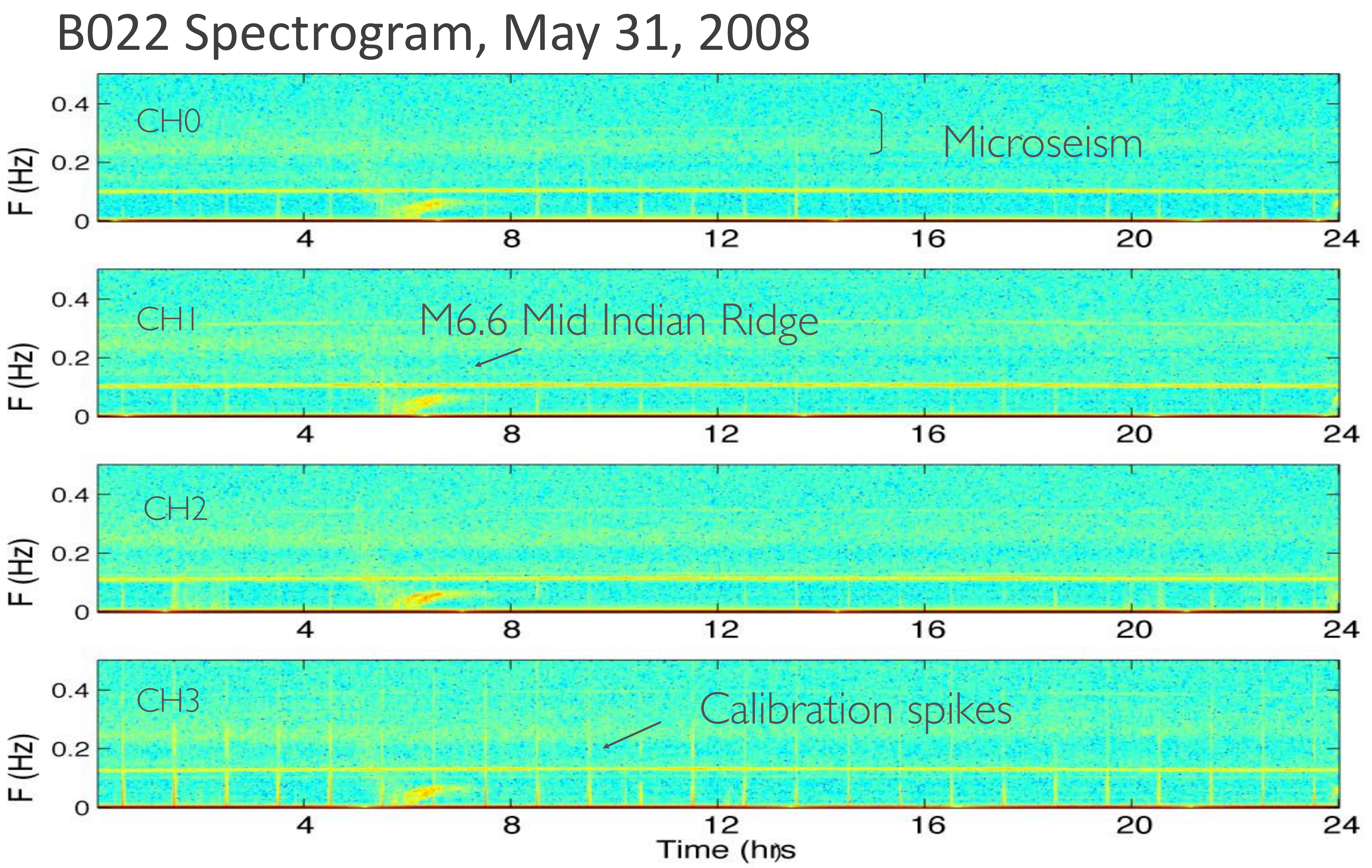


No step on other gauges in B028 or the nearby instrument

HOURS TO WEEKS: STEPS

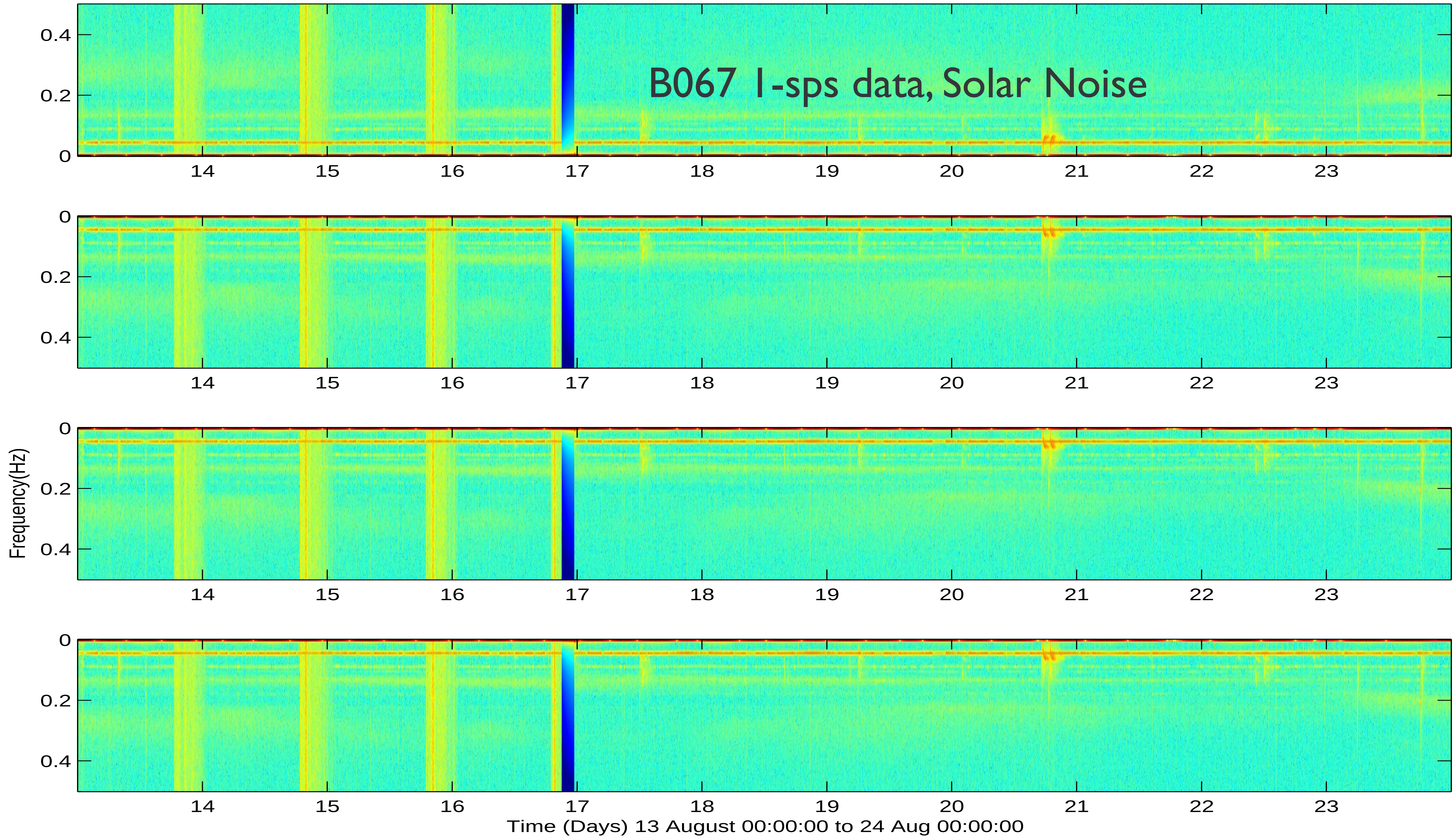


HIGH FREQUENCY STRAIN DATA



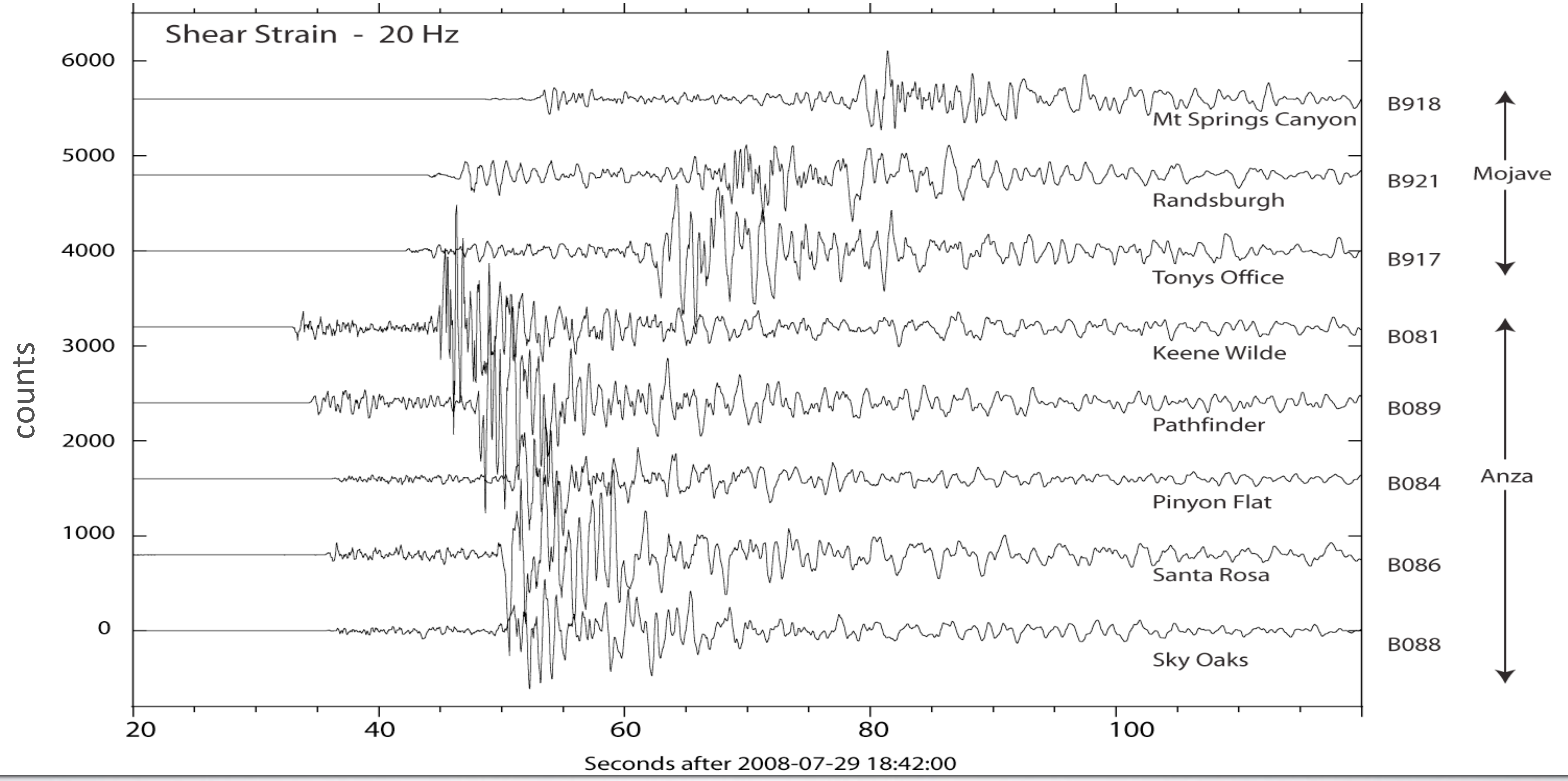
HIGH FREQUENCY STRAIN DATA

B067 Spectrogram, Aug 13, 2008



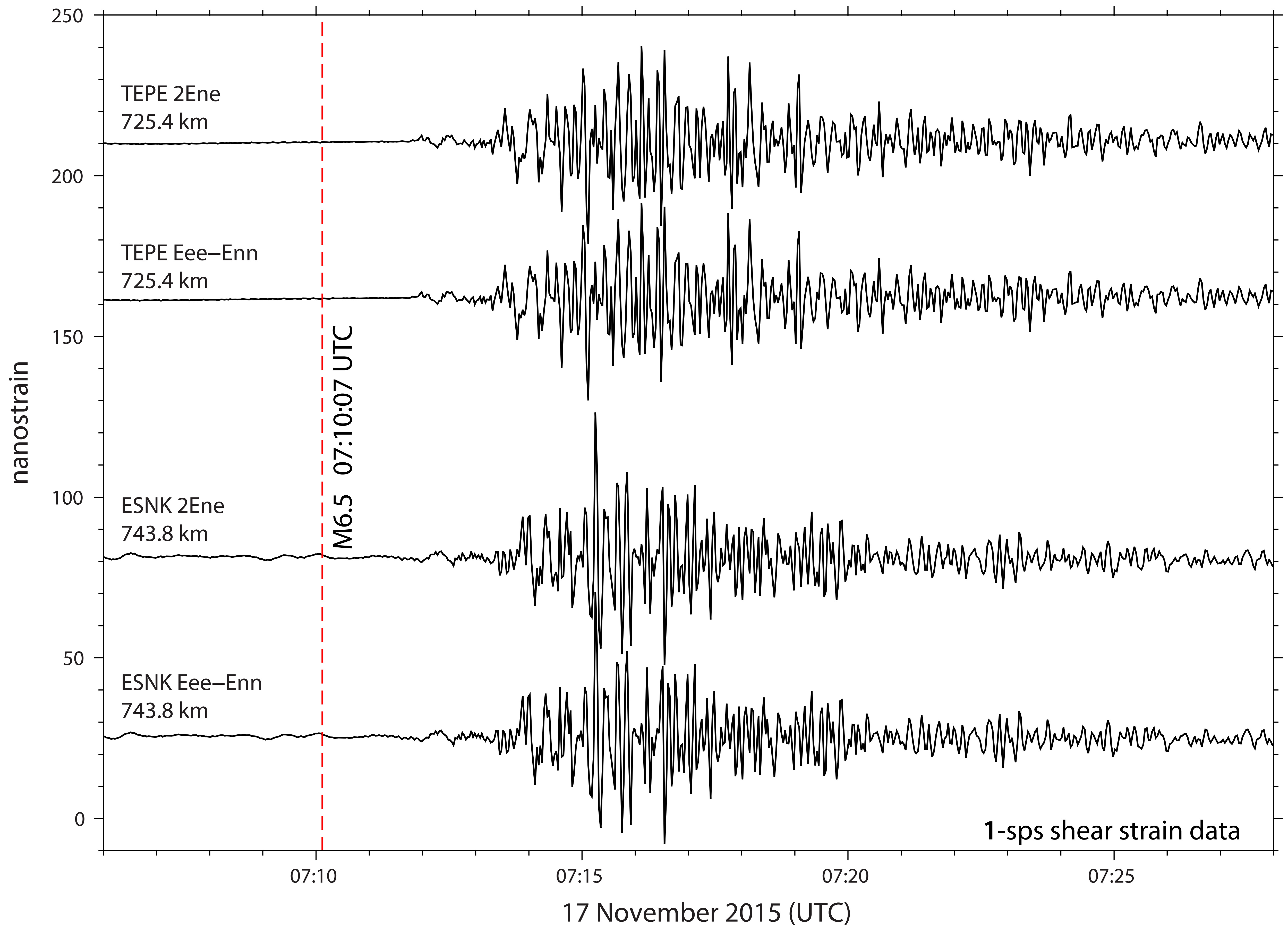
HIGH FREQUENCY STRAIN DATA

Seismic Shear: M5.4 LA, July 29, 2008

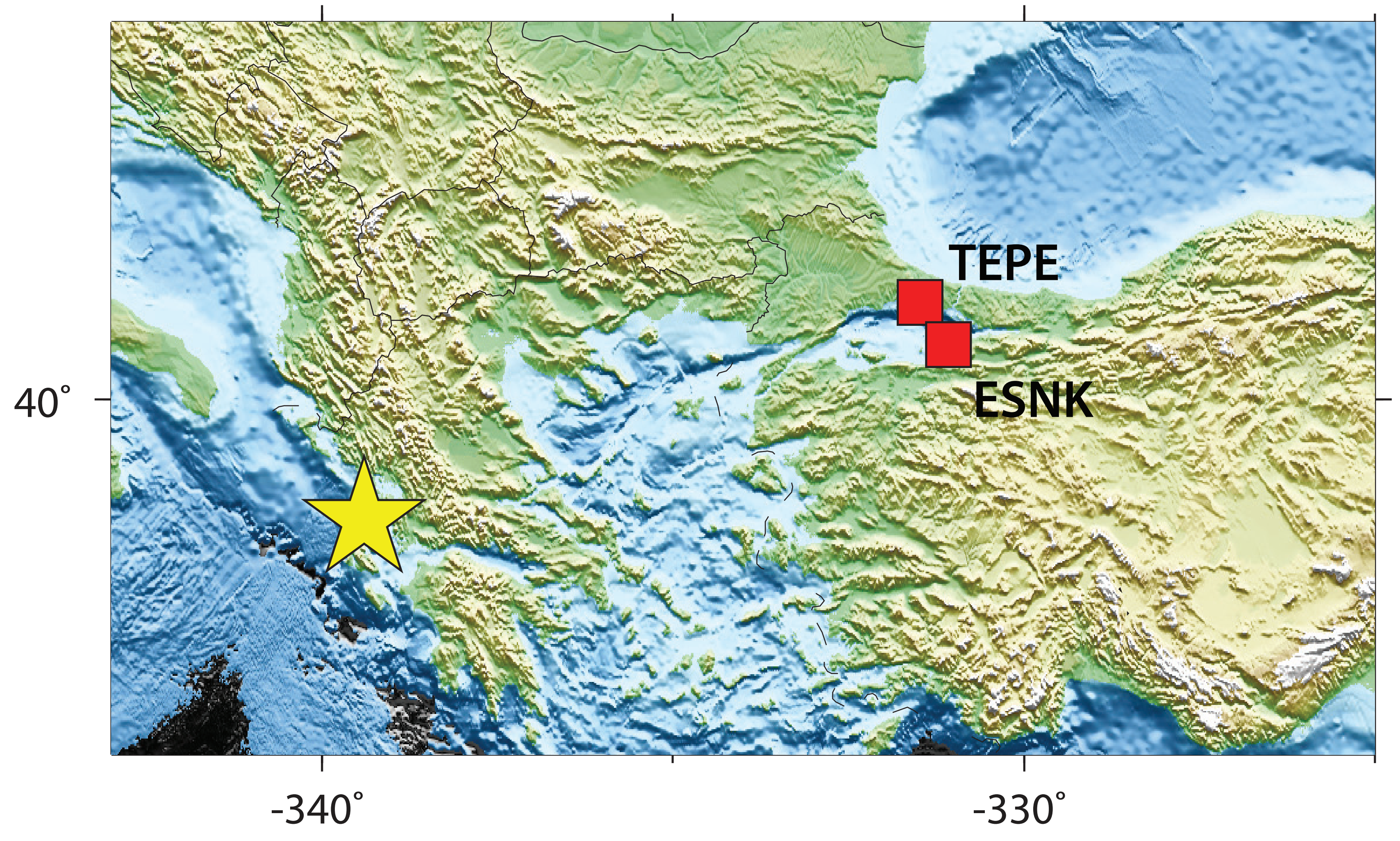


HIGH FREQUENCY STRAIN DATA

Seismic Shear Strains, Turkey

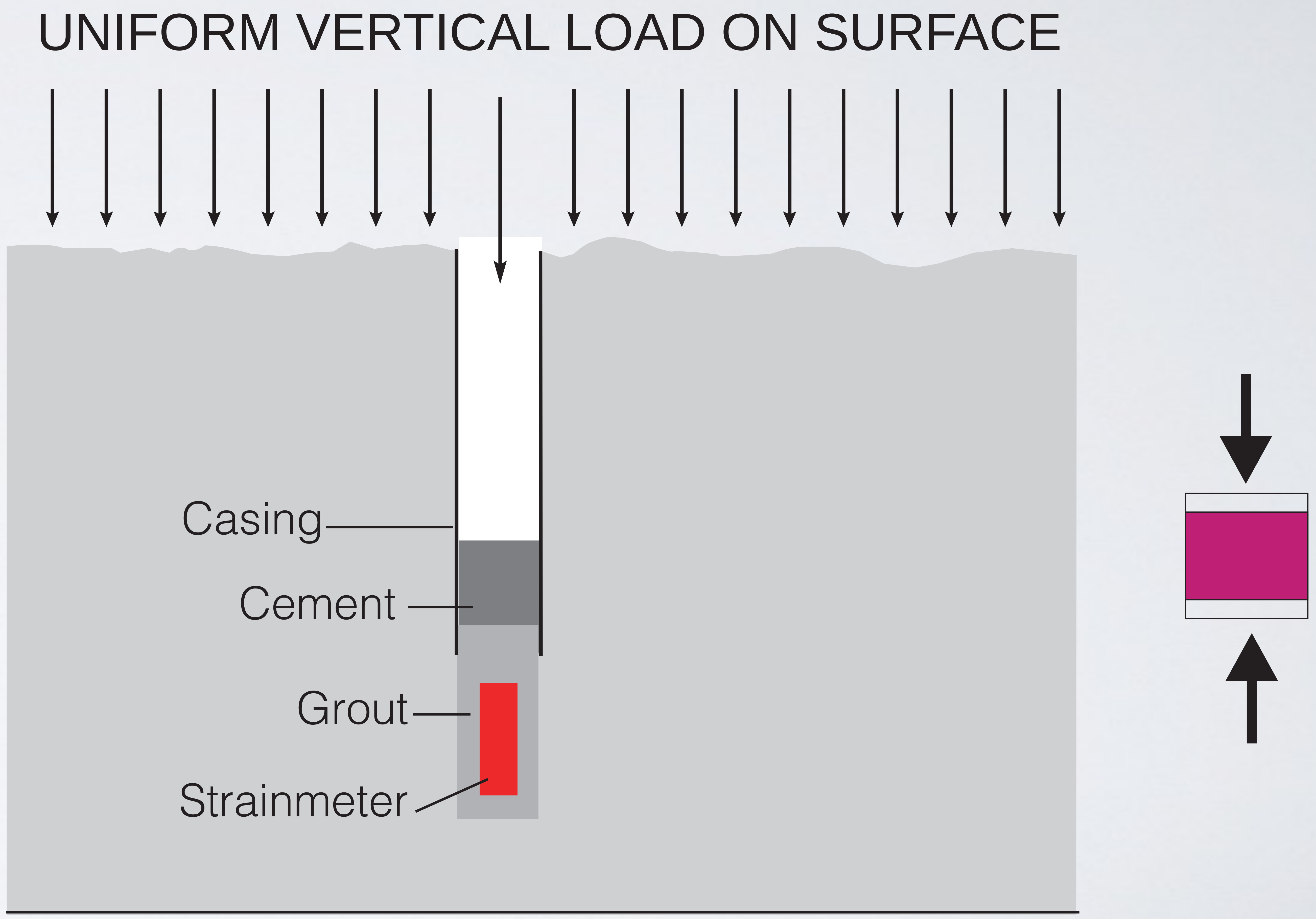


Seismic Shear: M6.5
Greece, Nov 17, 2015



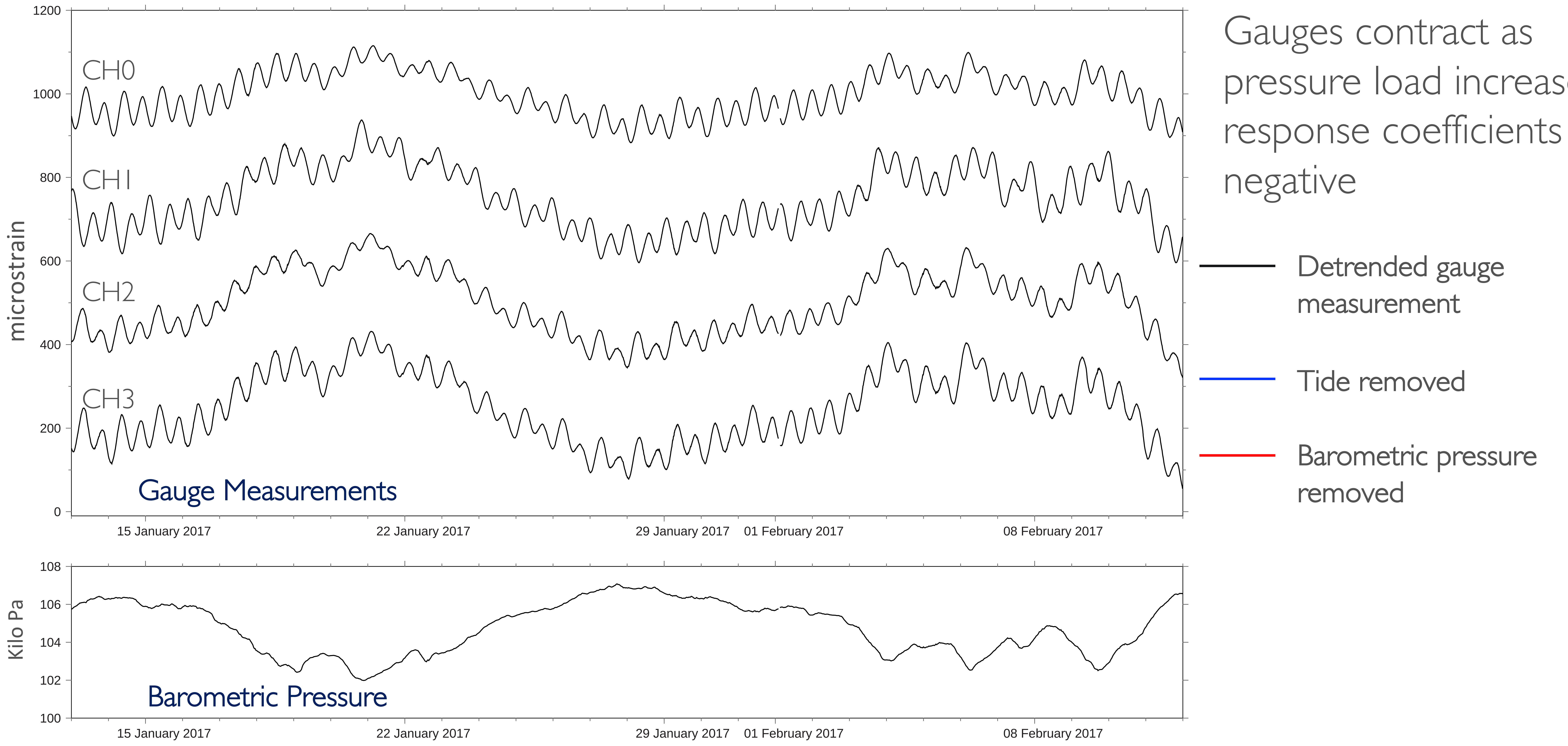
NON-TECTONIC SIGNALS

- Barometric Pressure
- Rainfall
- Irrigation
- Construction
- Seasonal Signals



BAROMETRIC SIGNAL

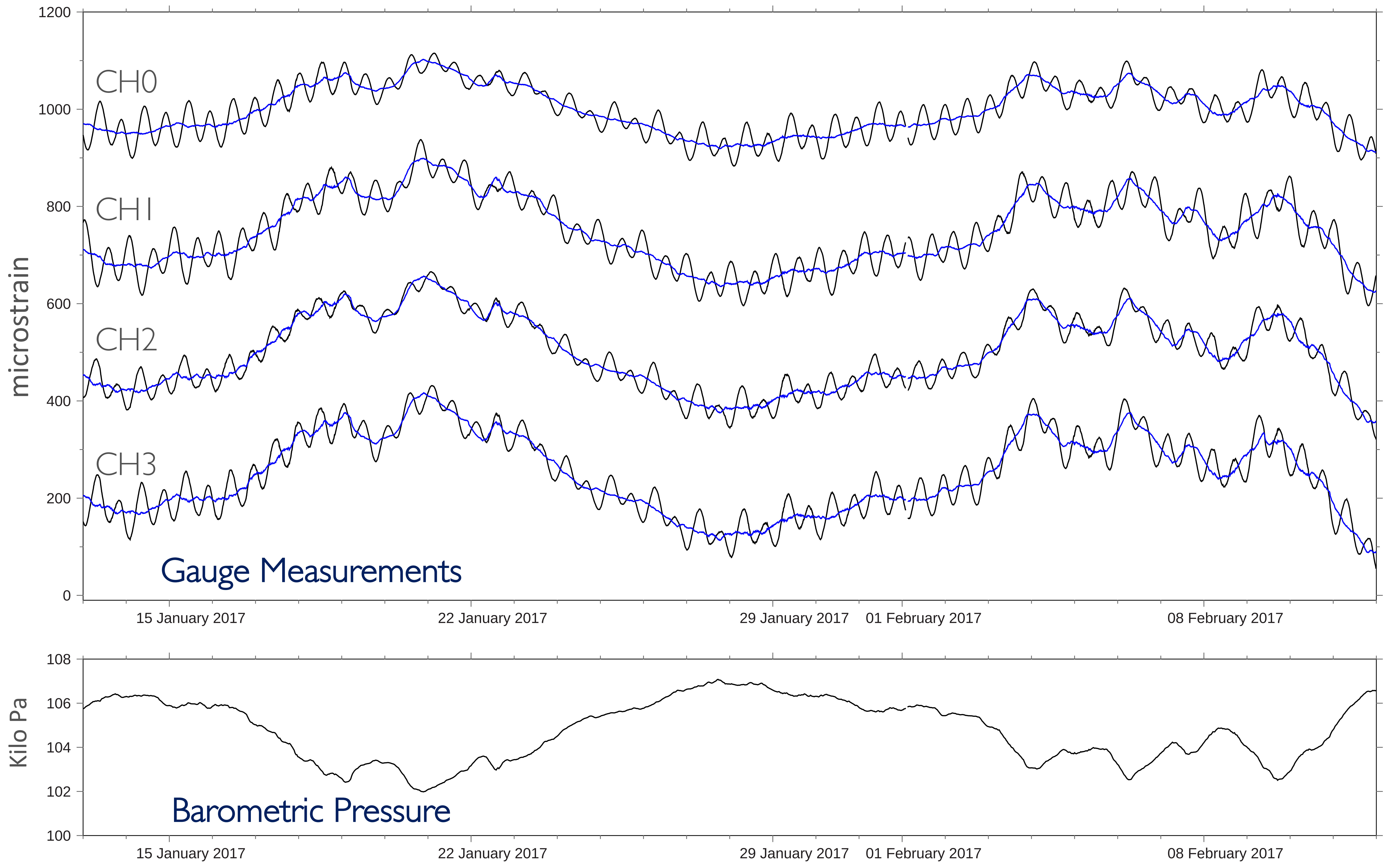
B018, Delphi, Washington



Gauges contract as pressure load increases, response coefficients are negative

BAROMETRIC SIGNAL

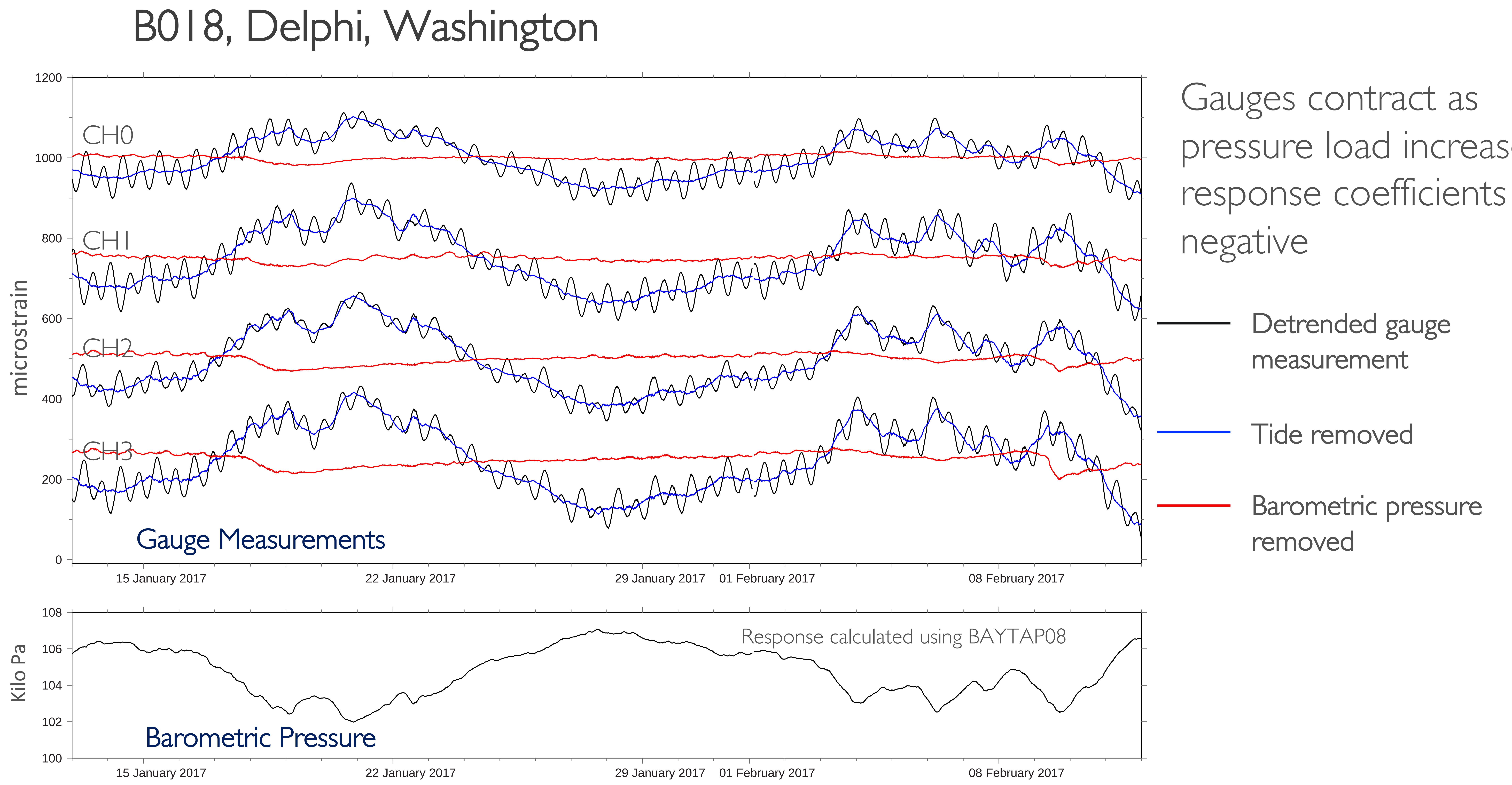
B018, Delphi, Washington



Gauges contract as pressure load increases, response coefficients are negative

- Detrended gauge measurement
- Tide removed
- Barometric pressure removed

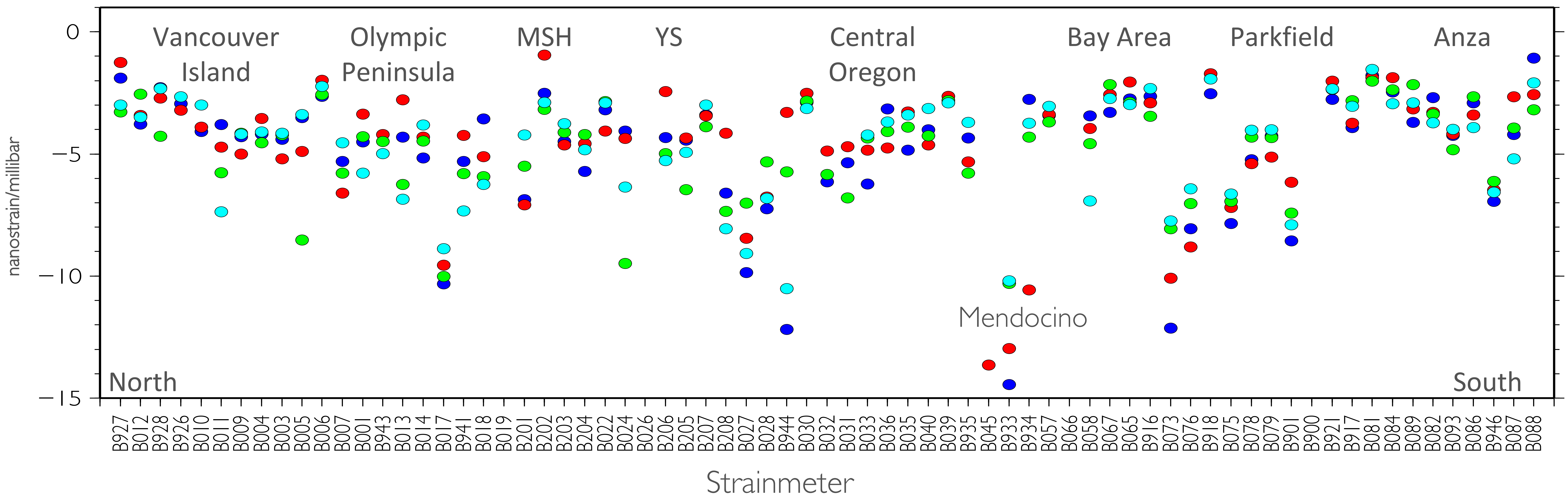
BAROMETRIC SIGNAL



Gauges contract as pressure load increases, response coefficients are negative

BAROMETRIC SIGNAL

PBO BSM Barometric Response Coefficients

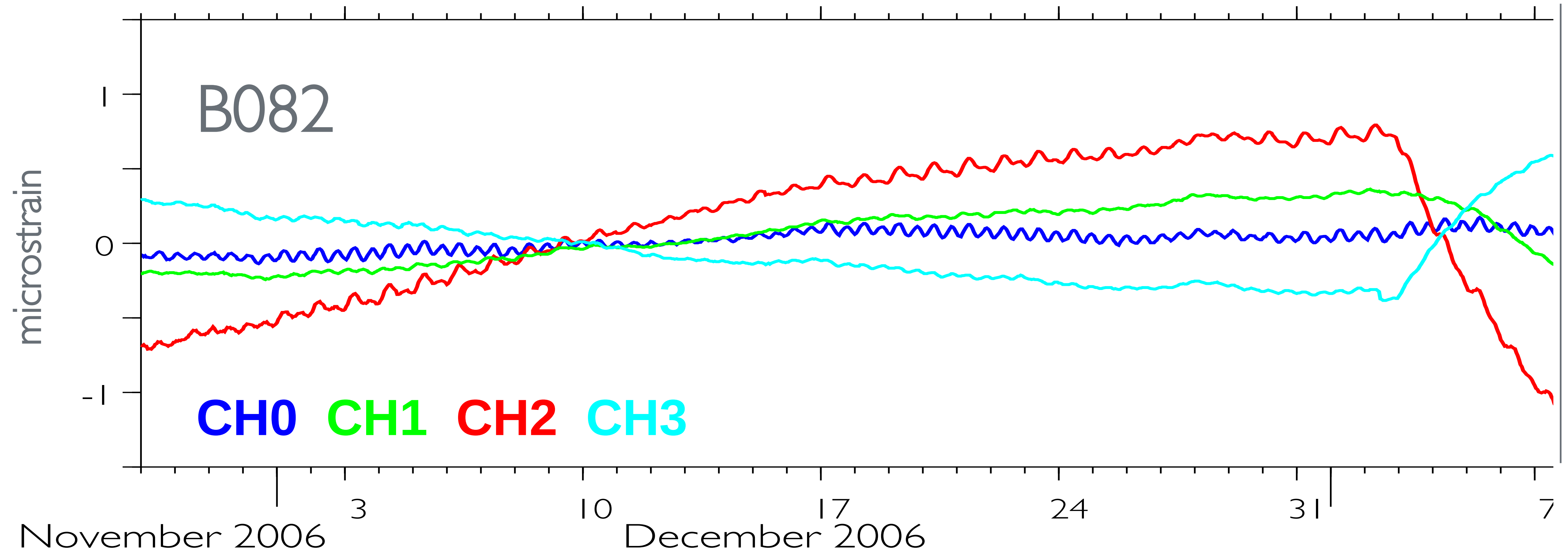


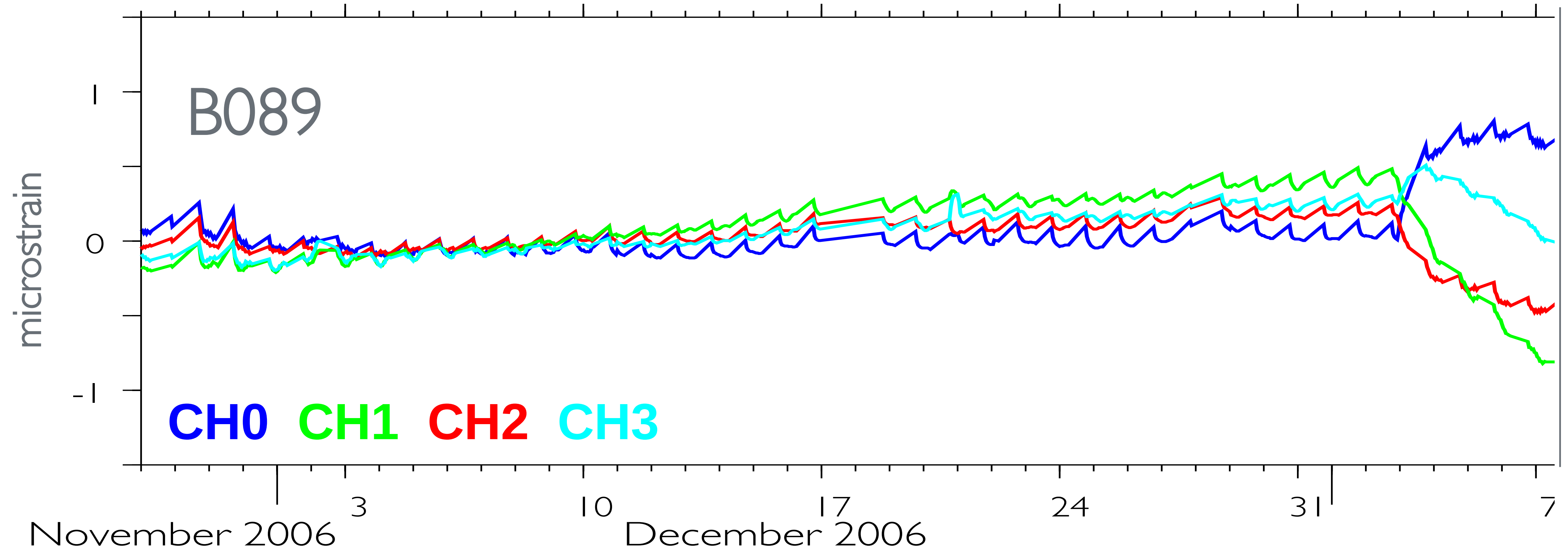
Barometric pressure loading causes gauge contraction

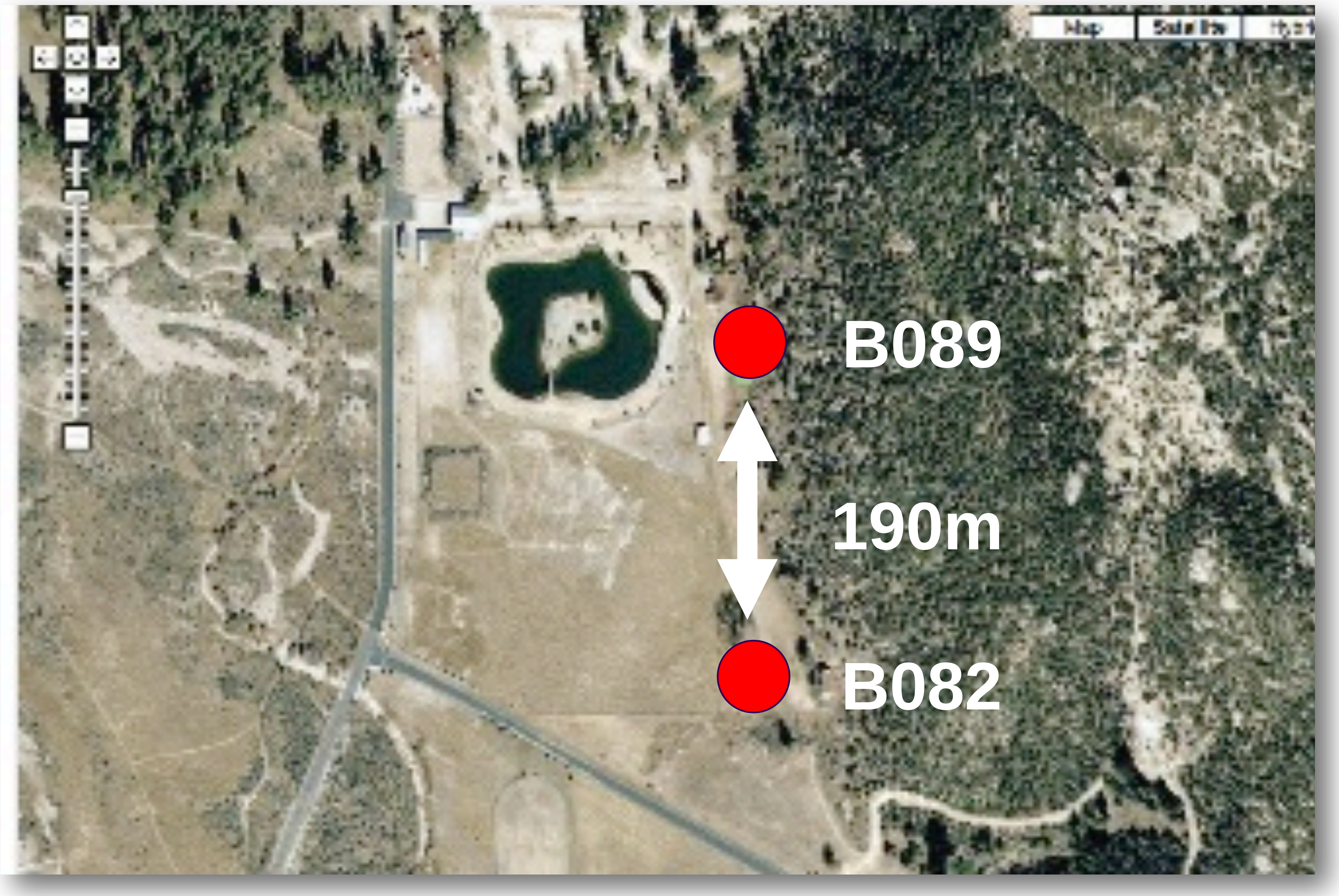
CH0 CH1 CH2 CH3

SURFACE LOADING

Co-located Strainmeters, Pathfinder, Anza

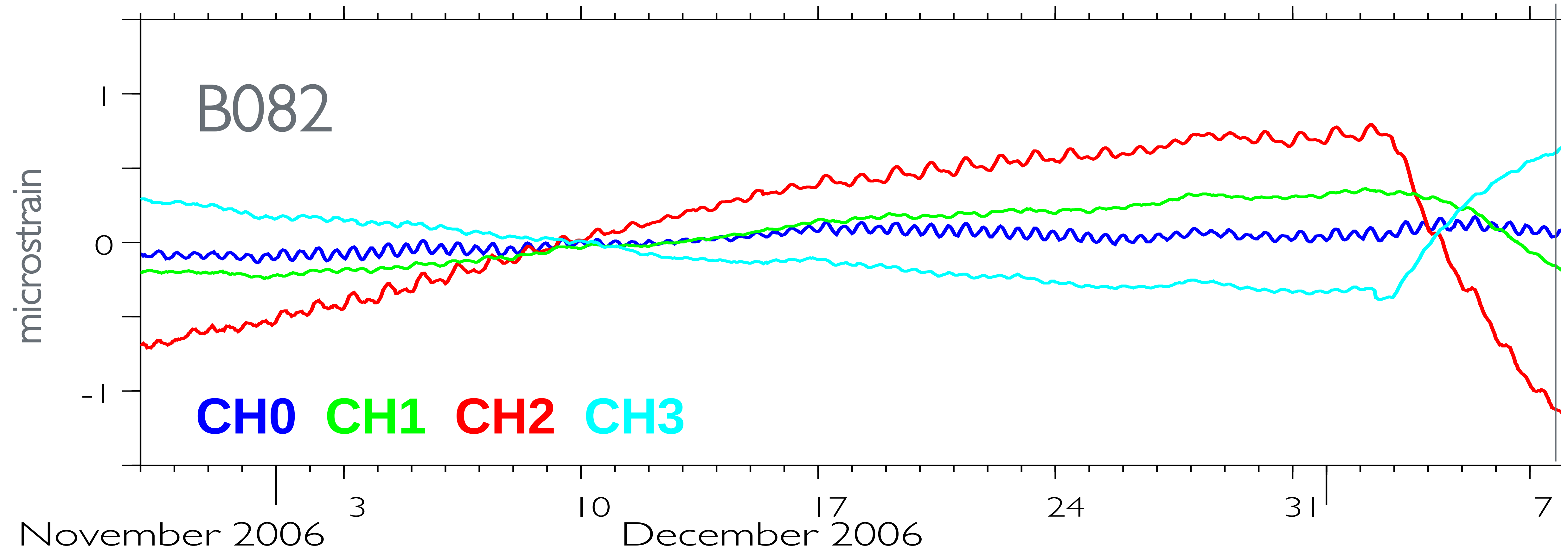


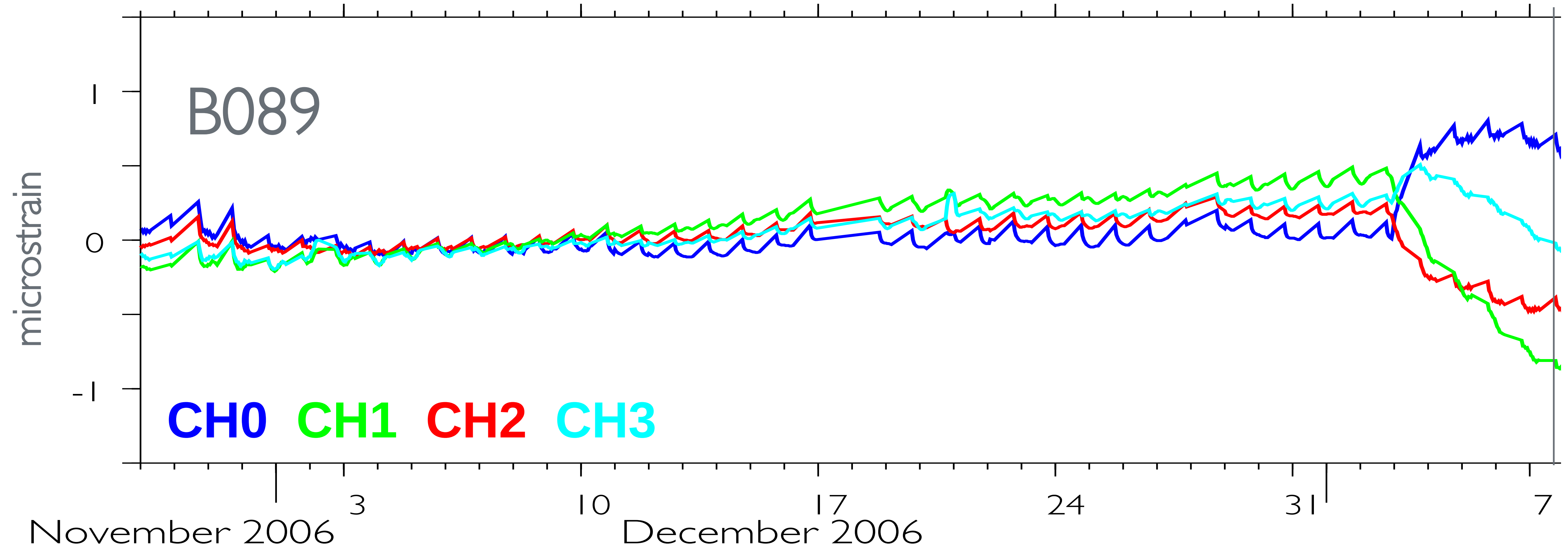




SURFACE LOADING

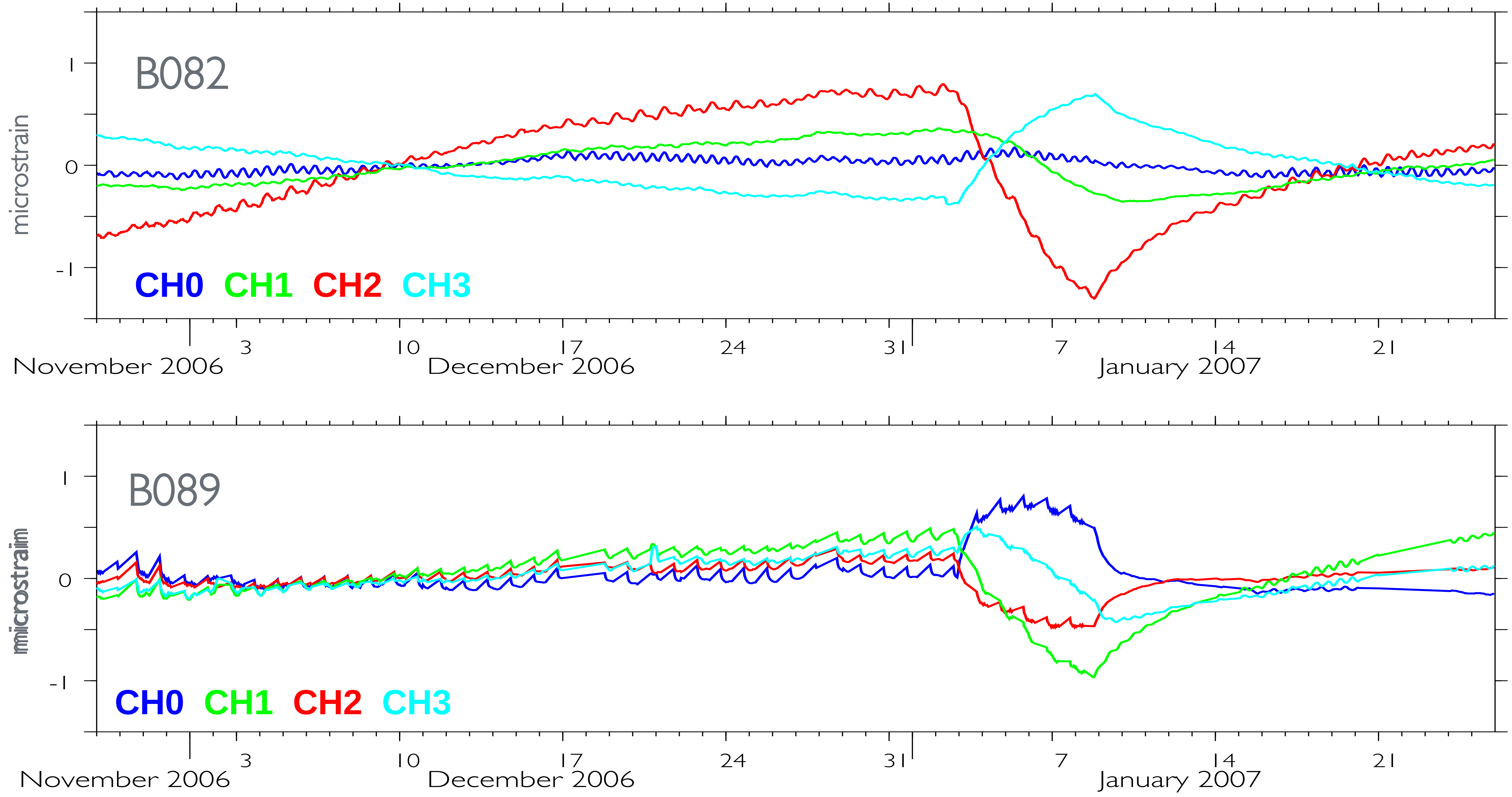
Co-located Strainmeters, Pathfinder, Anza





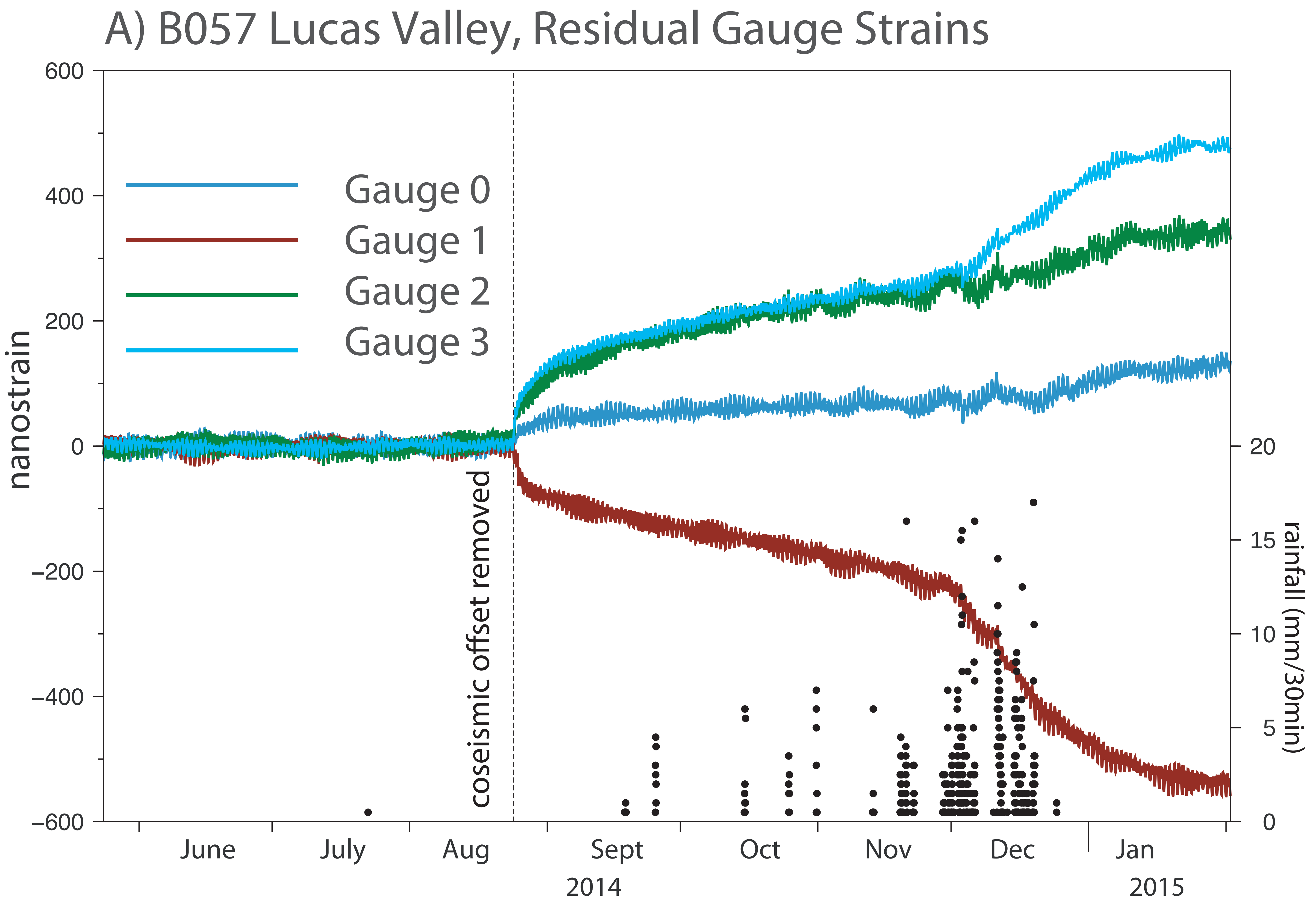
SURFACE LOADING

Co-located Strainmeters, Pathfinder, Anza



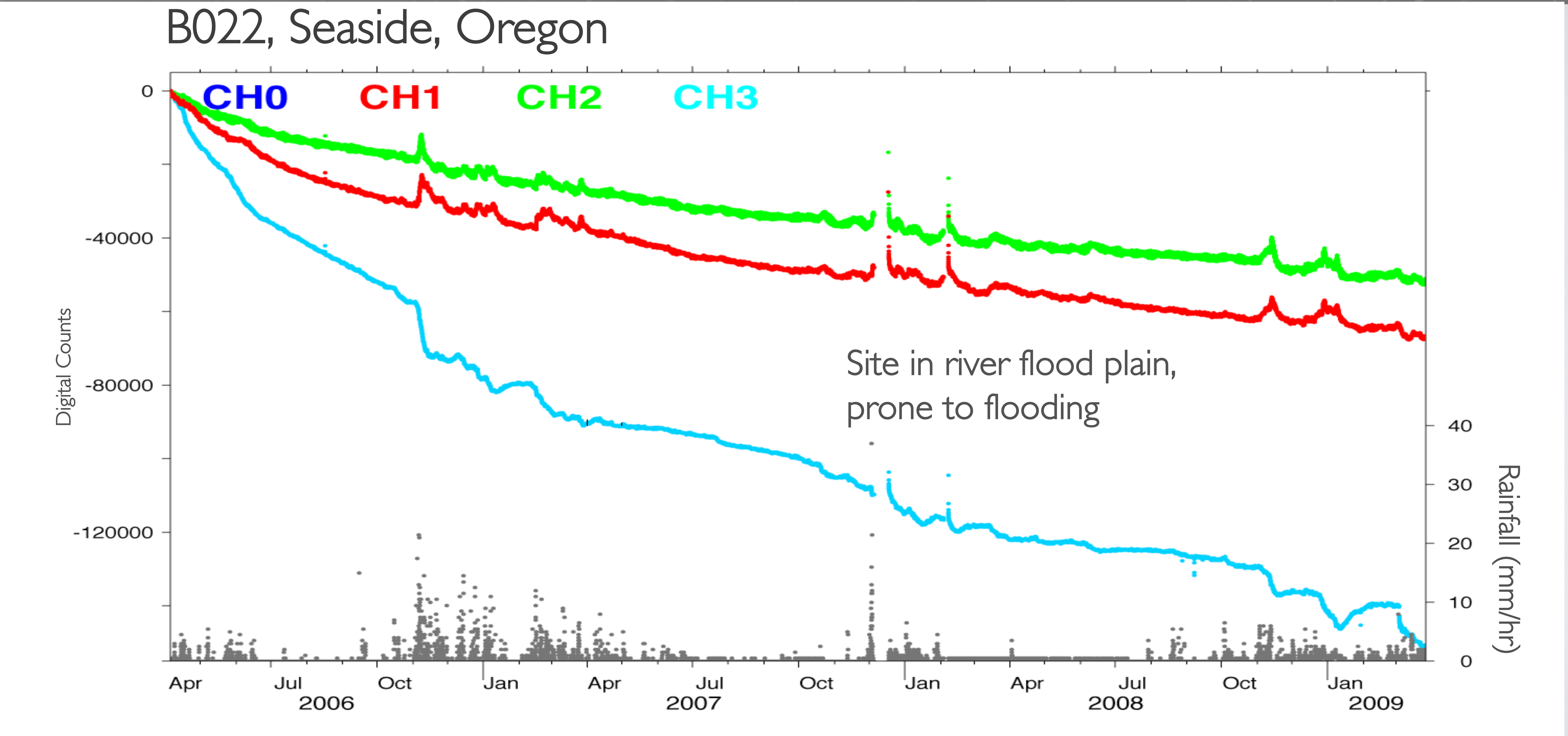
SURFACE LOADING

B057, San Francisco Bay Area, Napa Earthquake

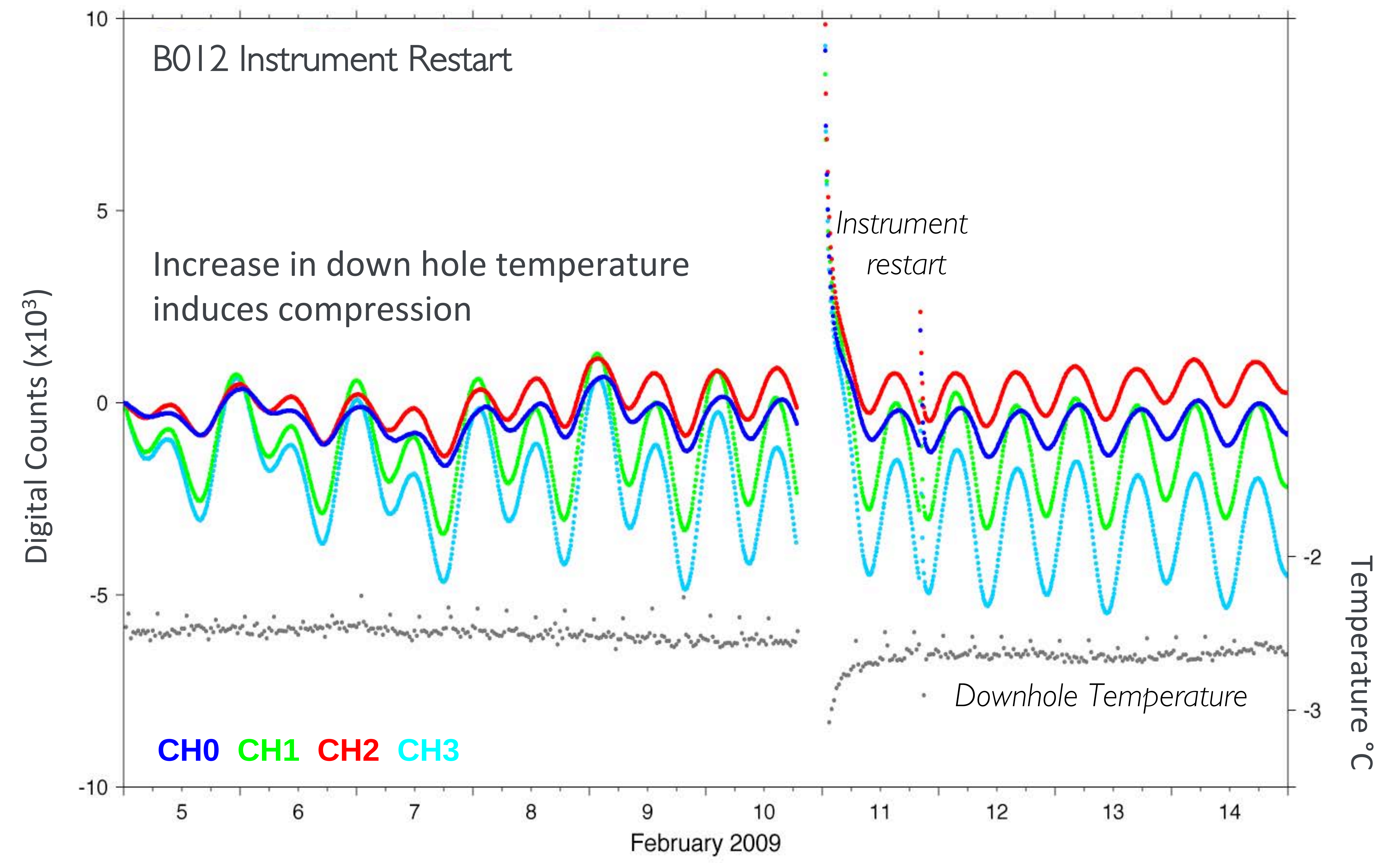


Historic Rainfall Days before AGU 2014

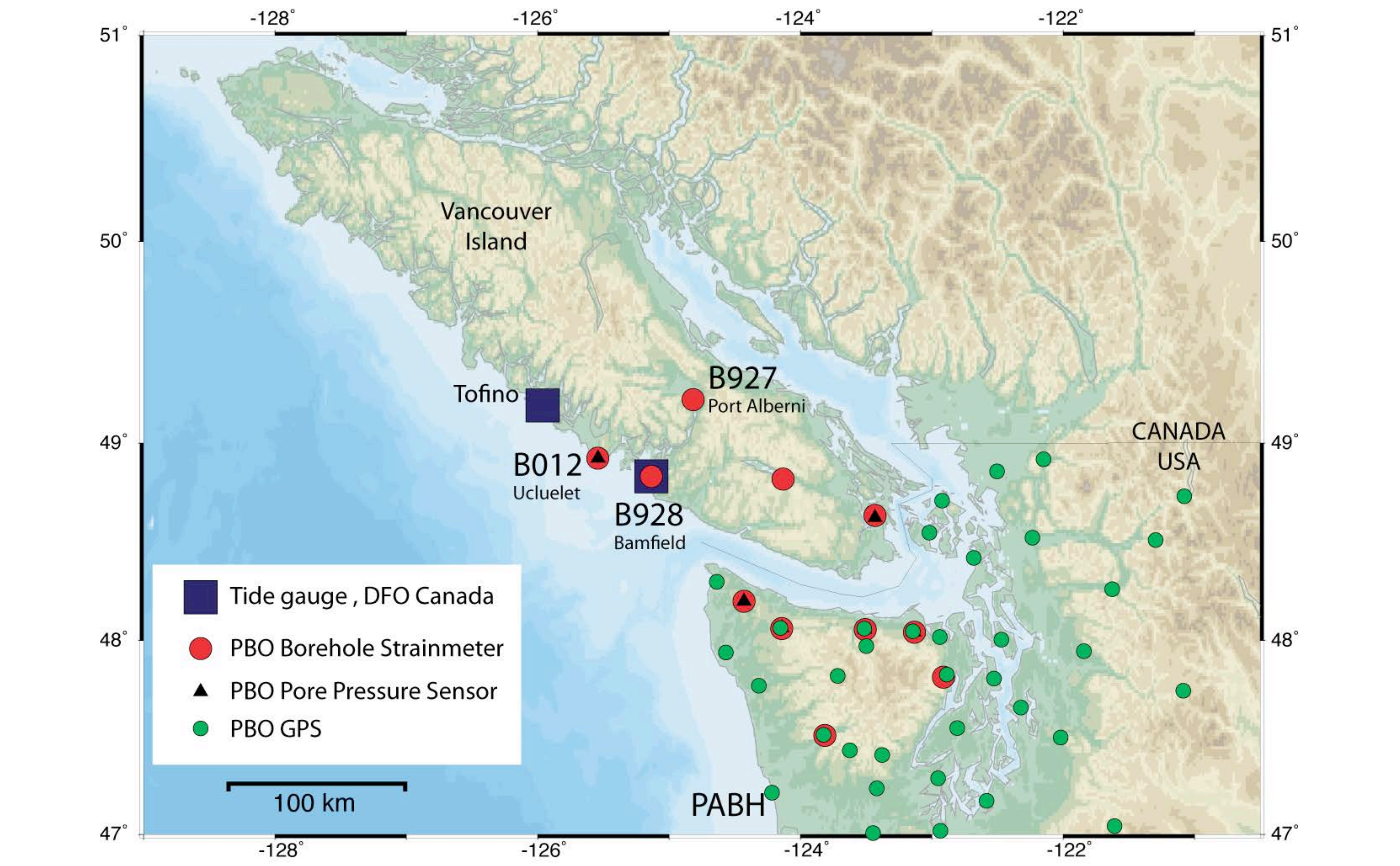
SURFACE LOADING



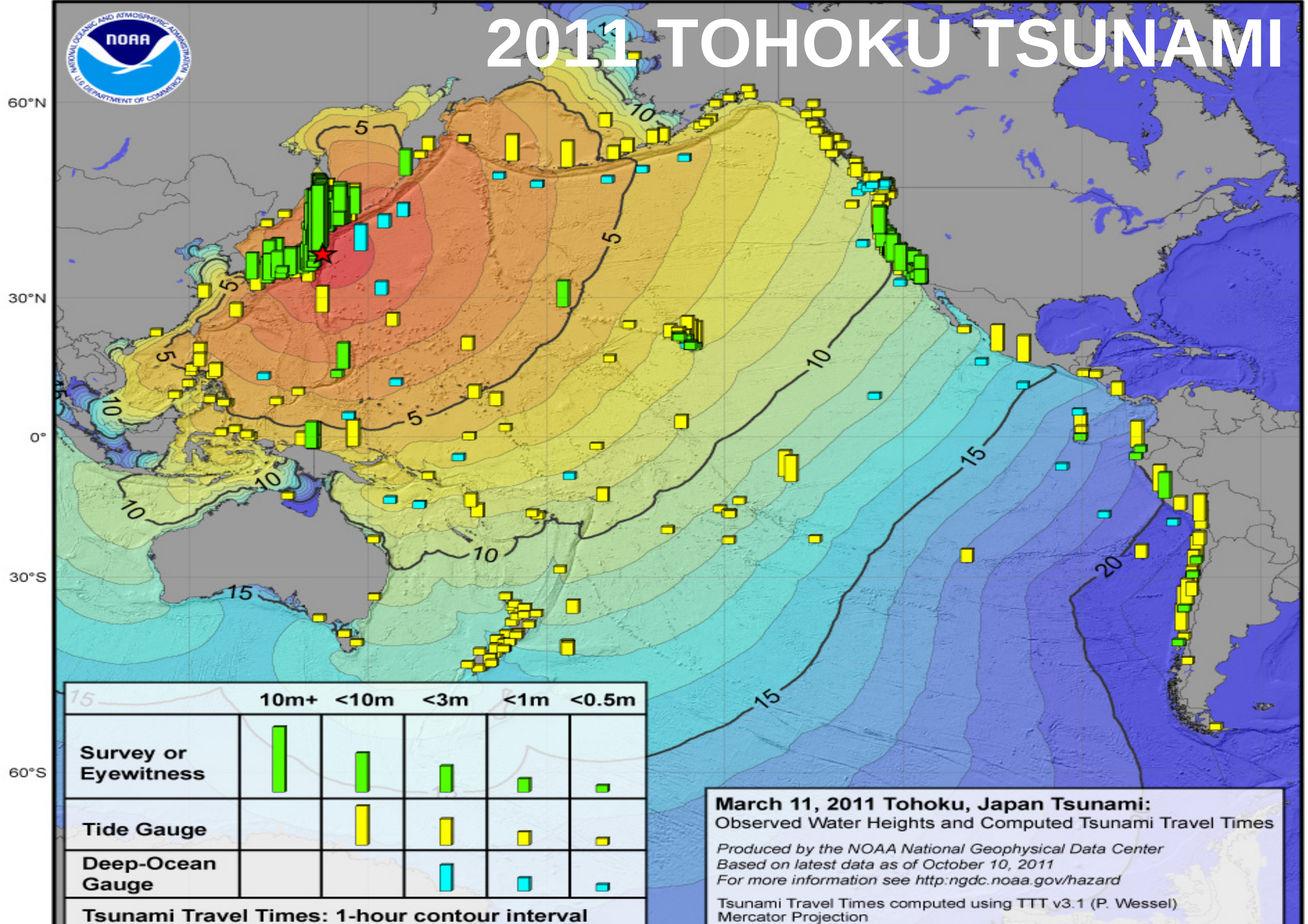
DOWNHOLE TEMPERATURE

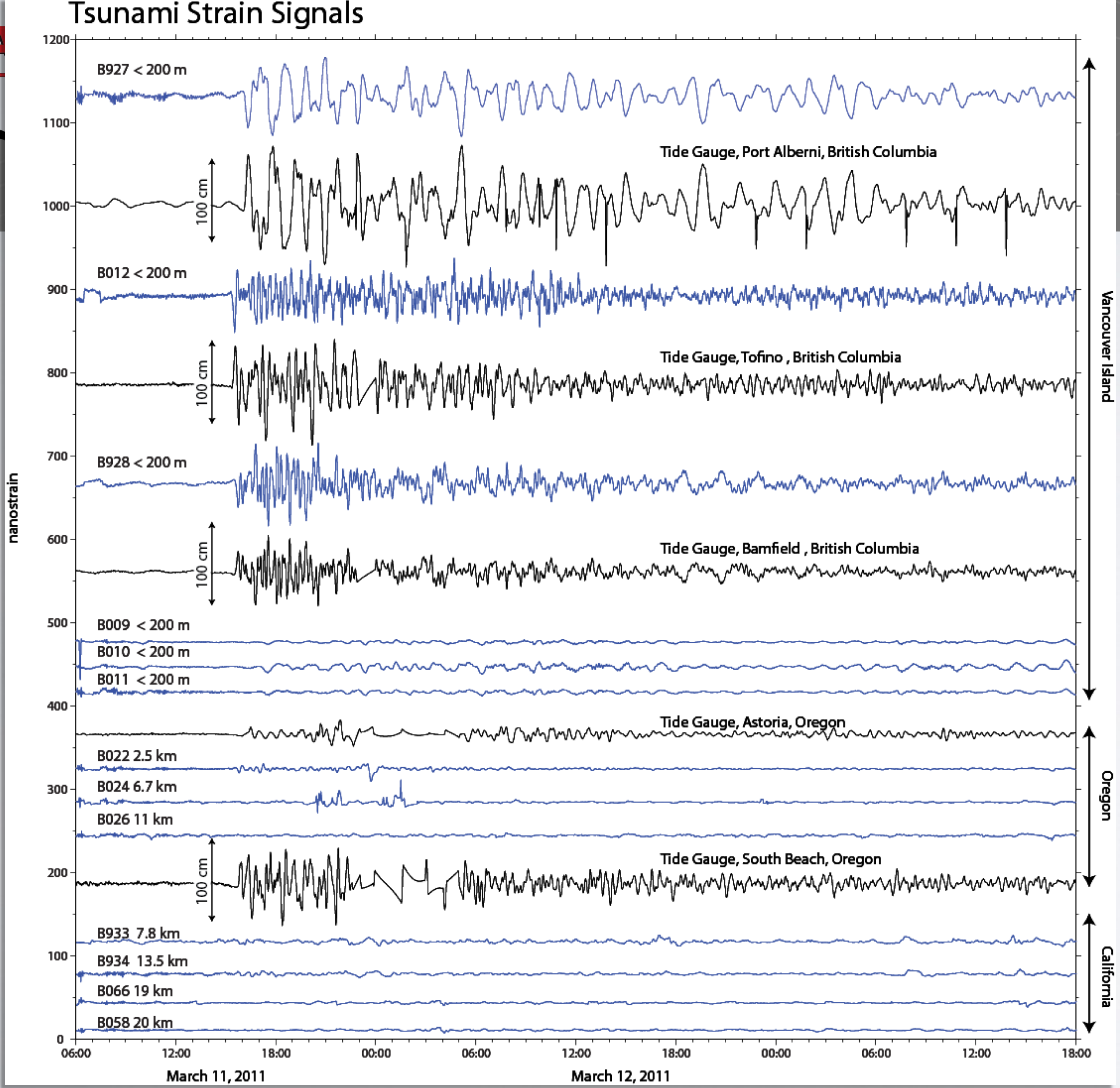


TSUNAMI AND SEICHES



2011 TOHOKU TSUNAMI

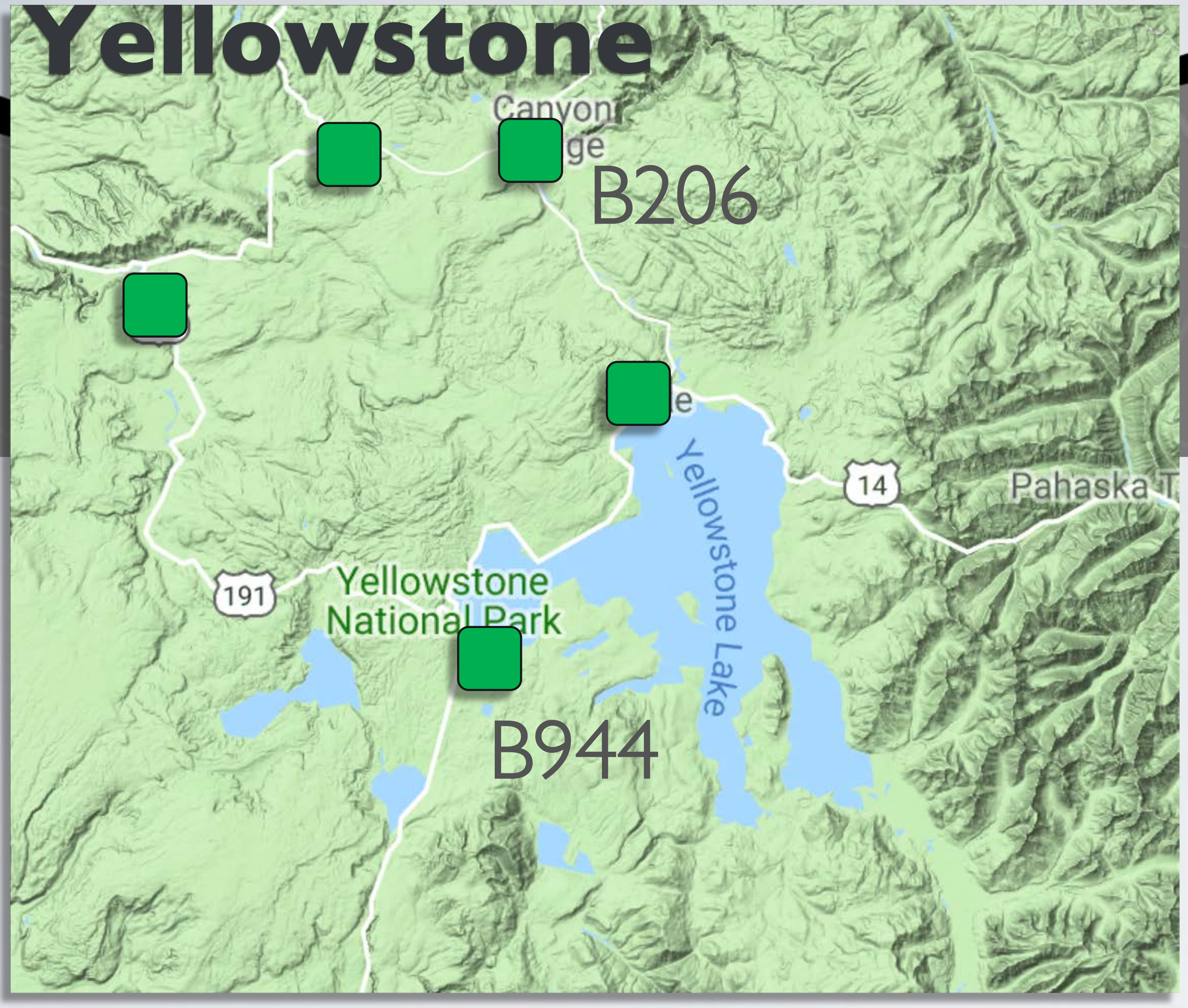




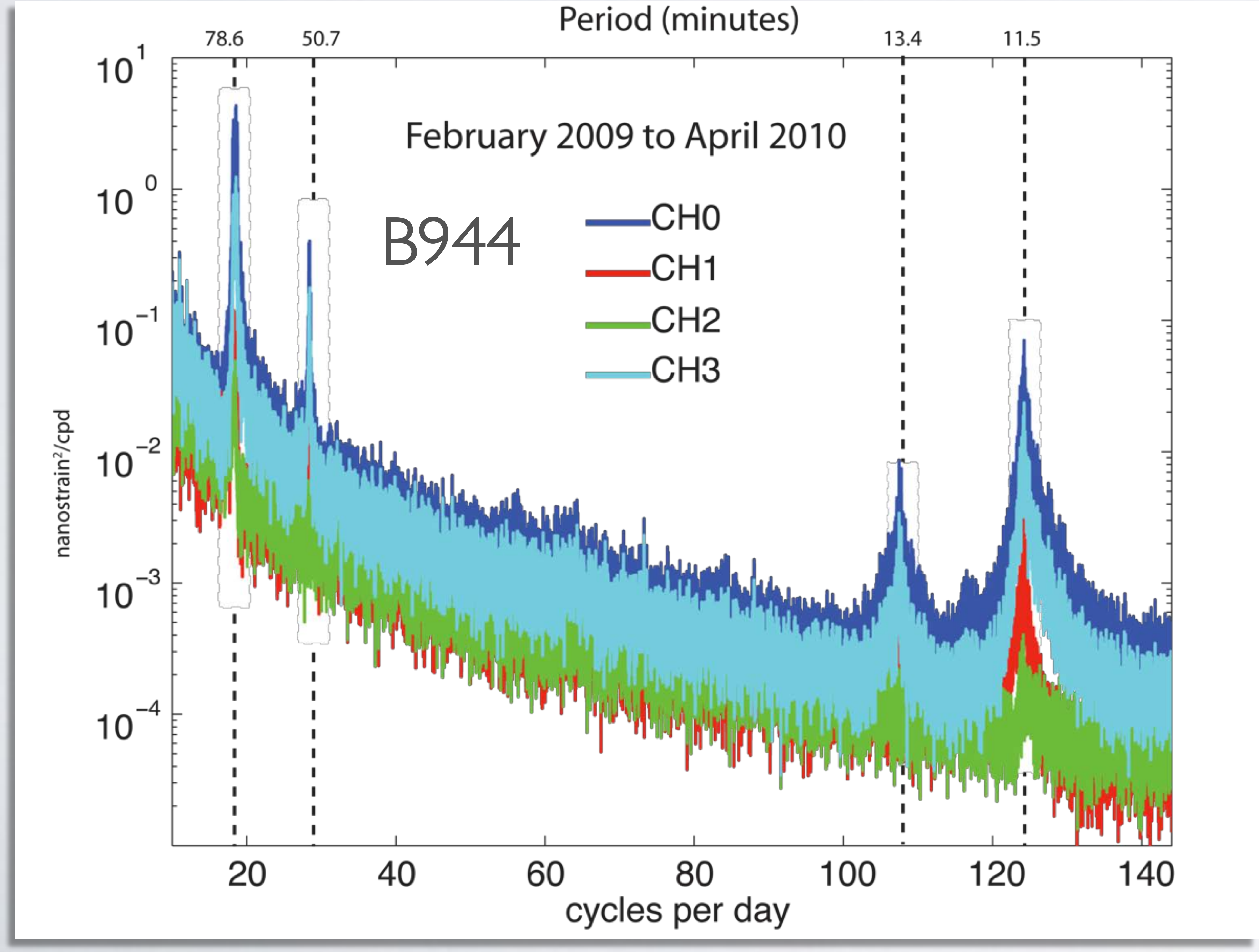
Bandpass areal strain at 300 seconds to 2 hours

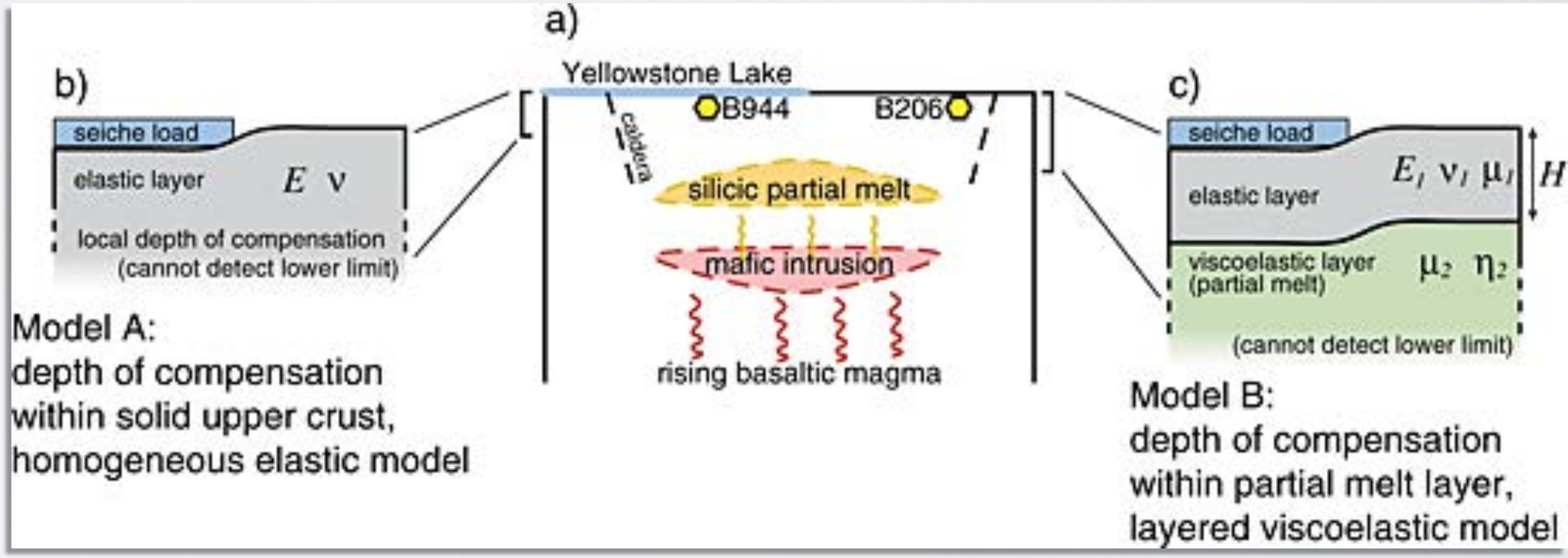
Strain measurements consistent with tide gauge data

TSUNAMI AND SEICHES

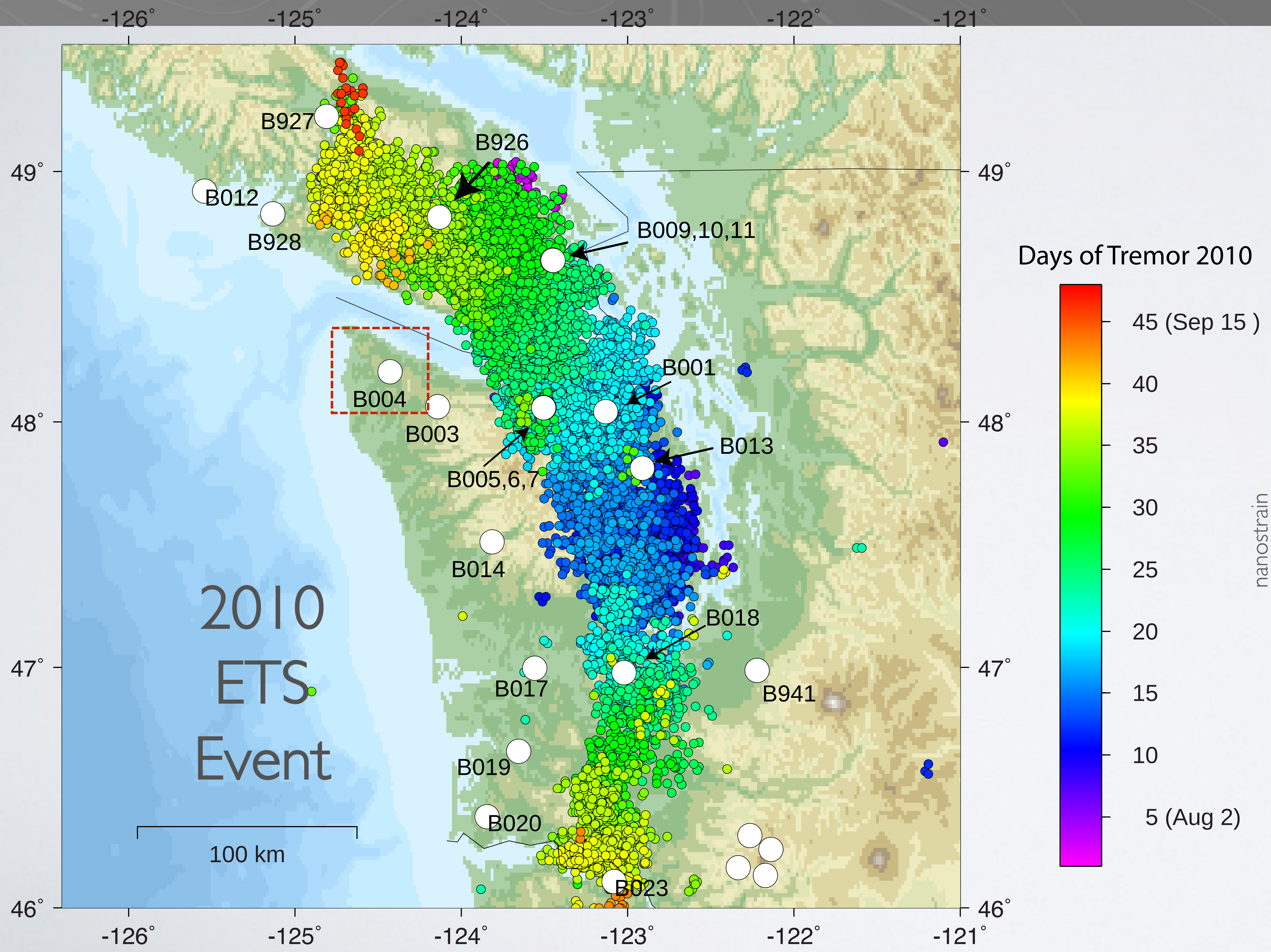


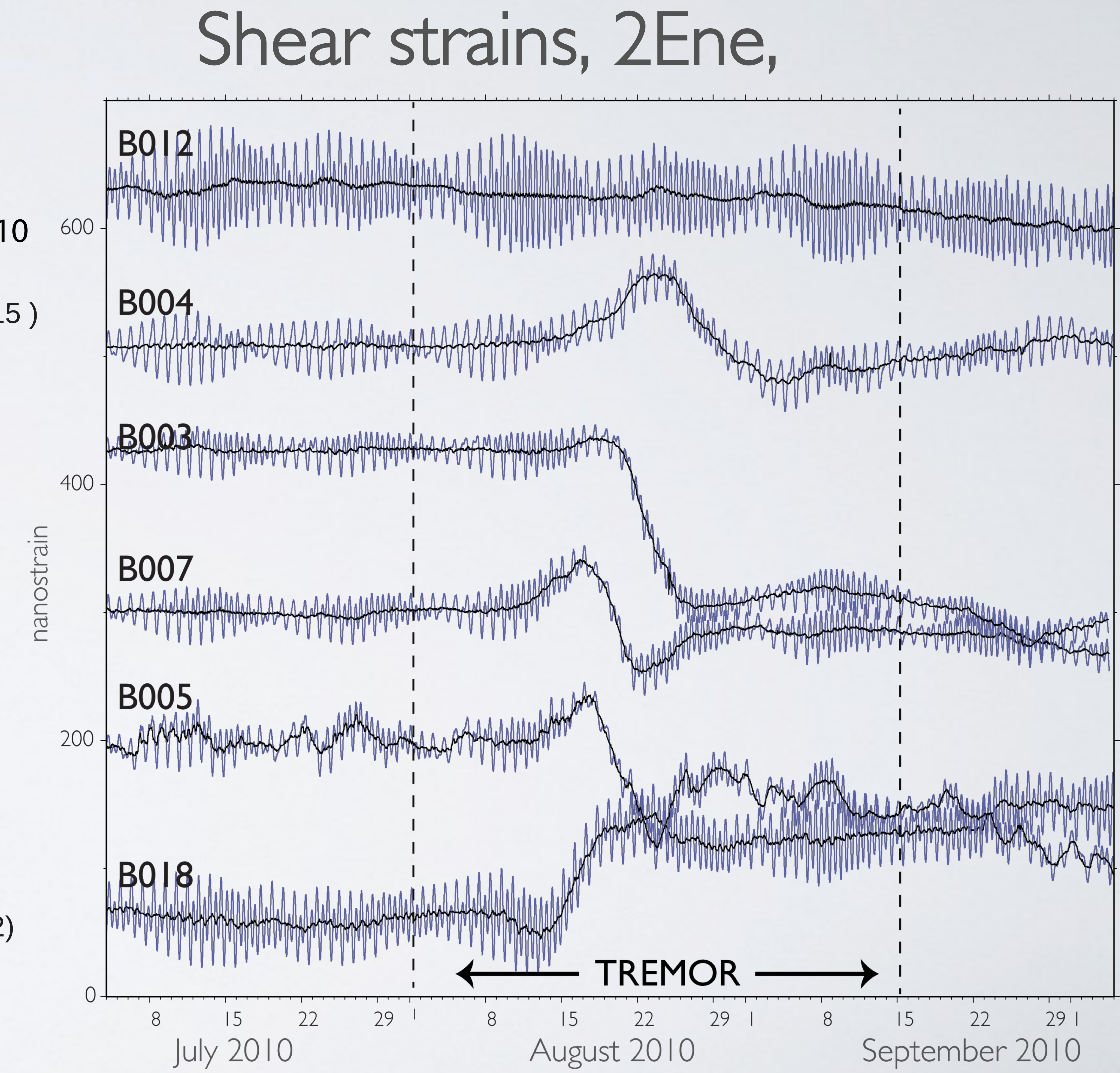
Luttrell, K., et al (2013), Constraints on the upper crustal magma reservoir beneath Yellowstone Caldera inferred from lake-seiche induced strain observations, Geophys. Res. Lett., **40**, 501-506.

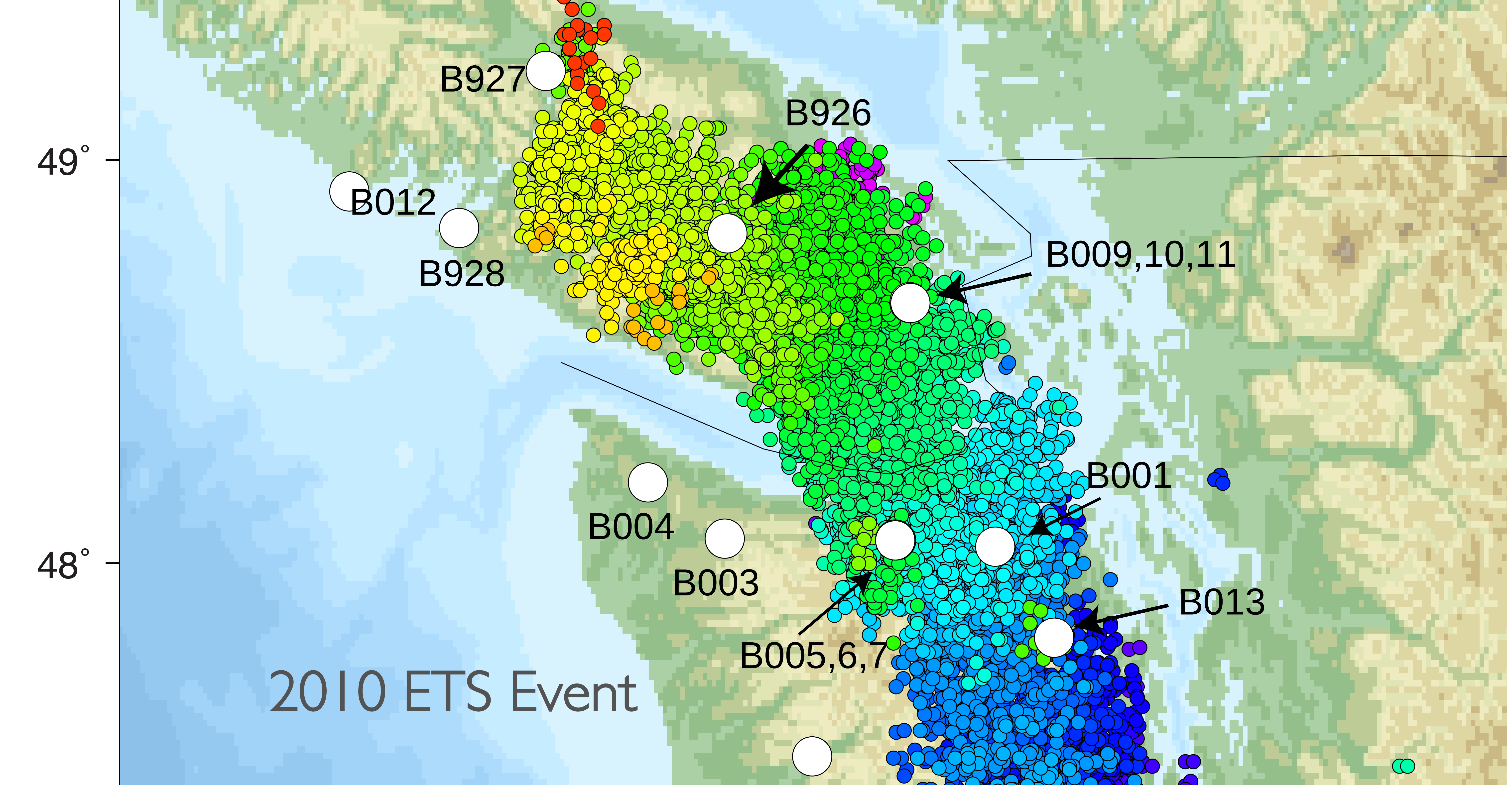




CASCADIA EPISODIC TREMOR AND SLIP



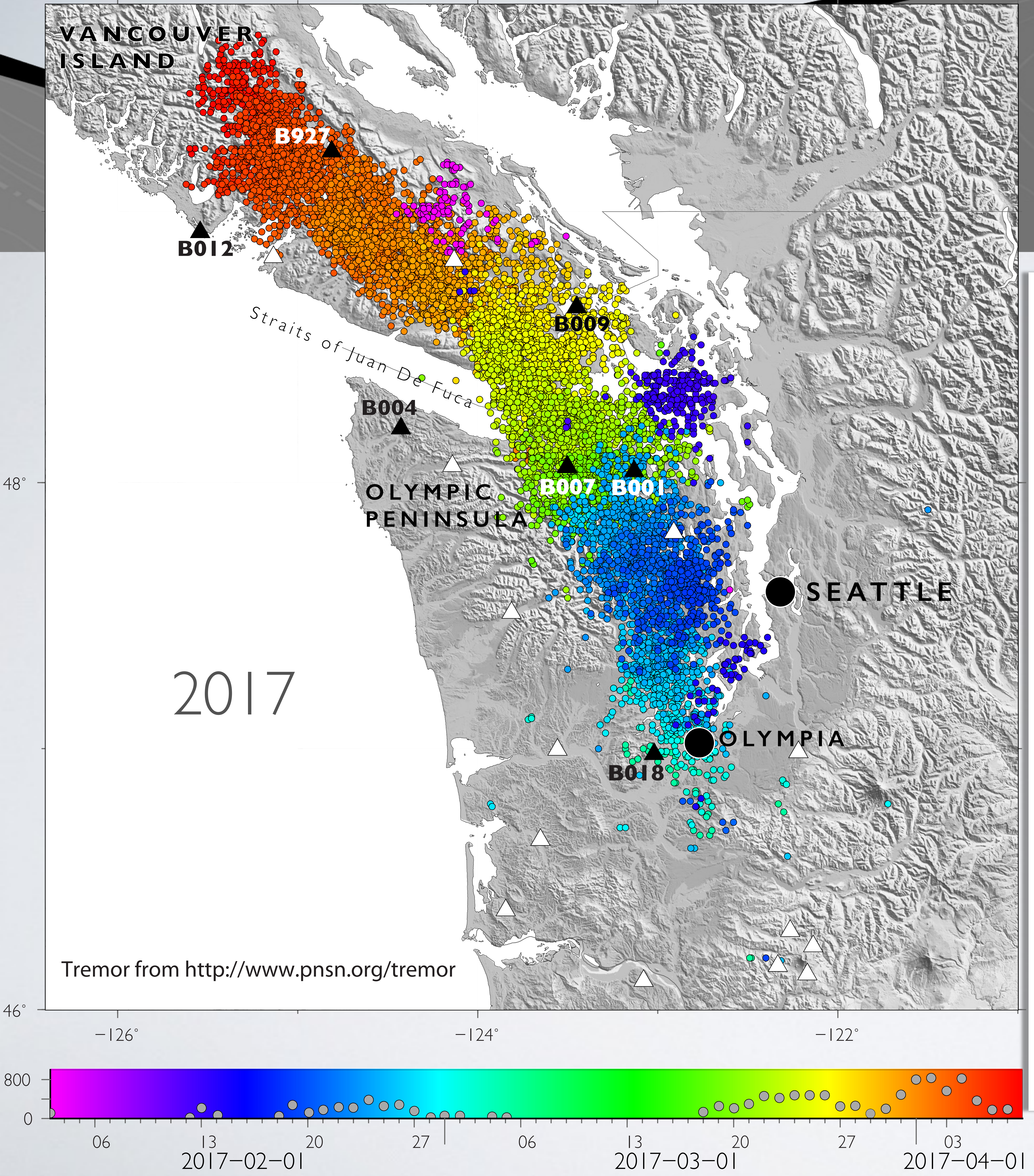


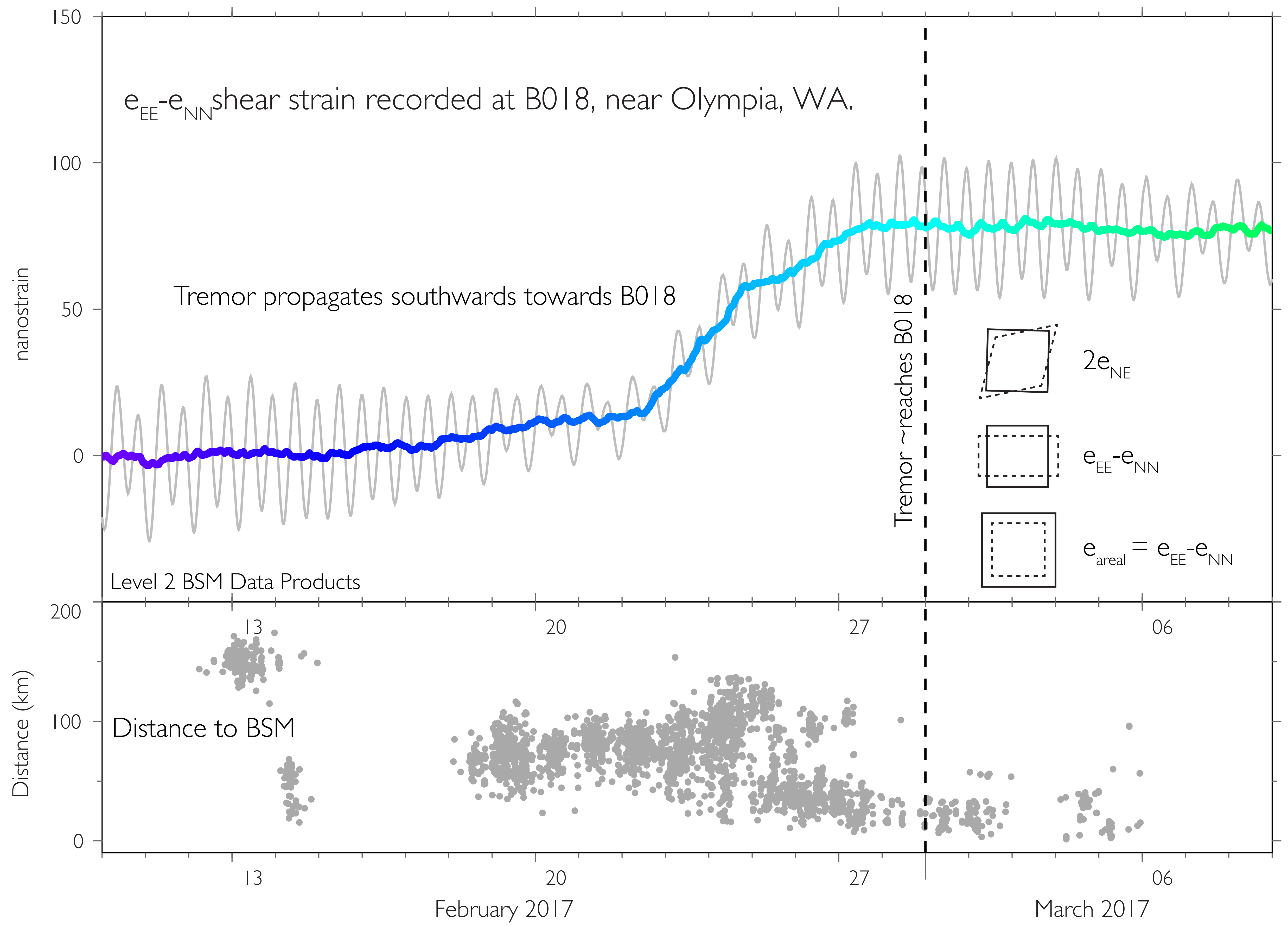


CASCADIA EPISODIC TREMOR AND SLIP

B004, Olympic Peninsula, ETS Events, 2006-2015

CASCADIA EPISODIC TREMOR AND SLIP





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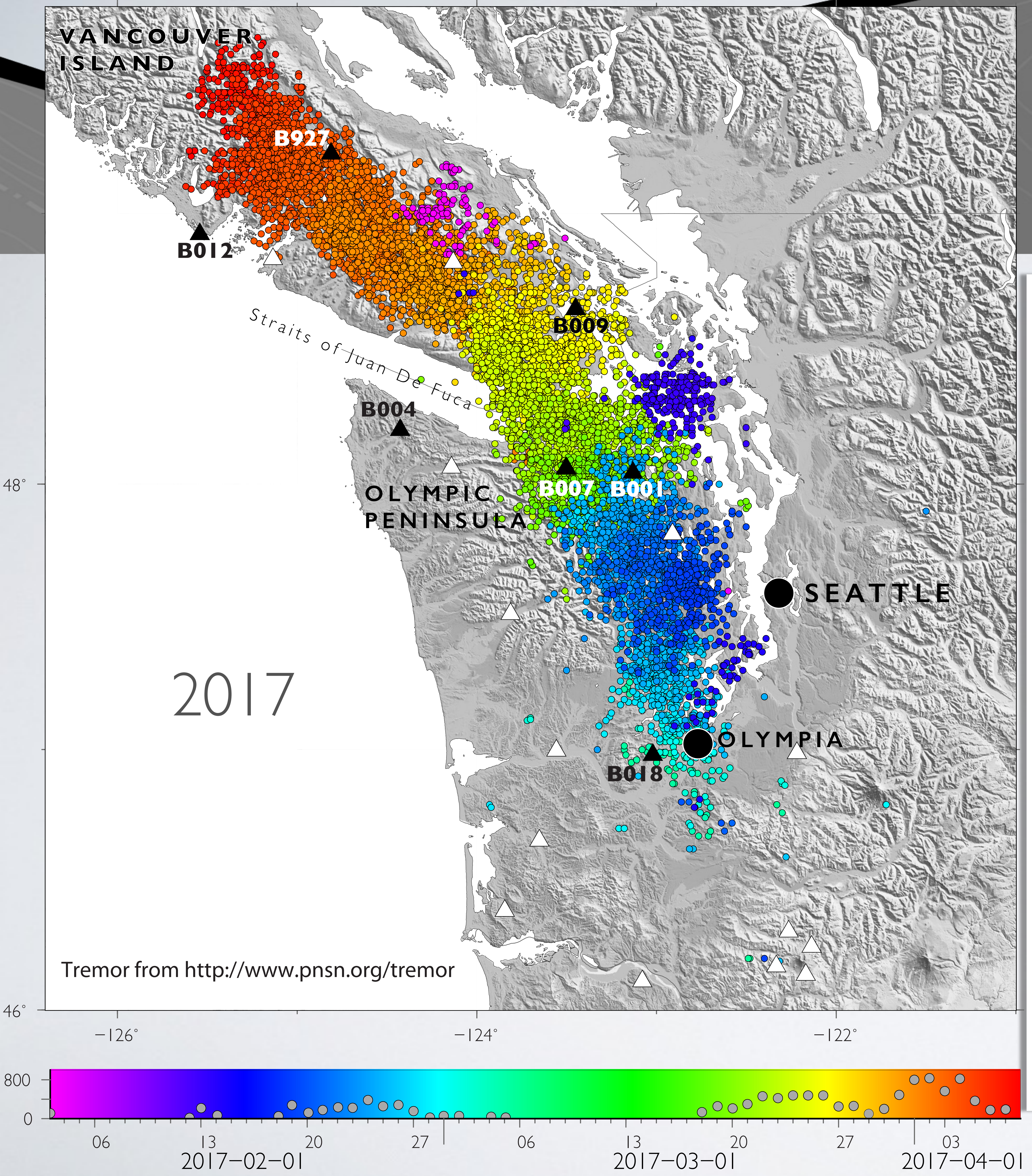
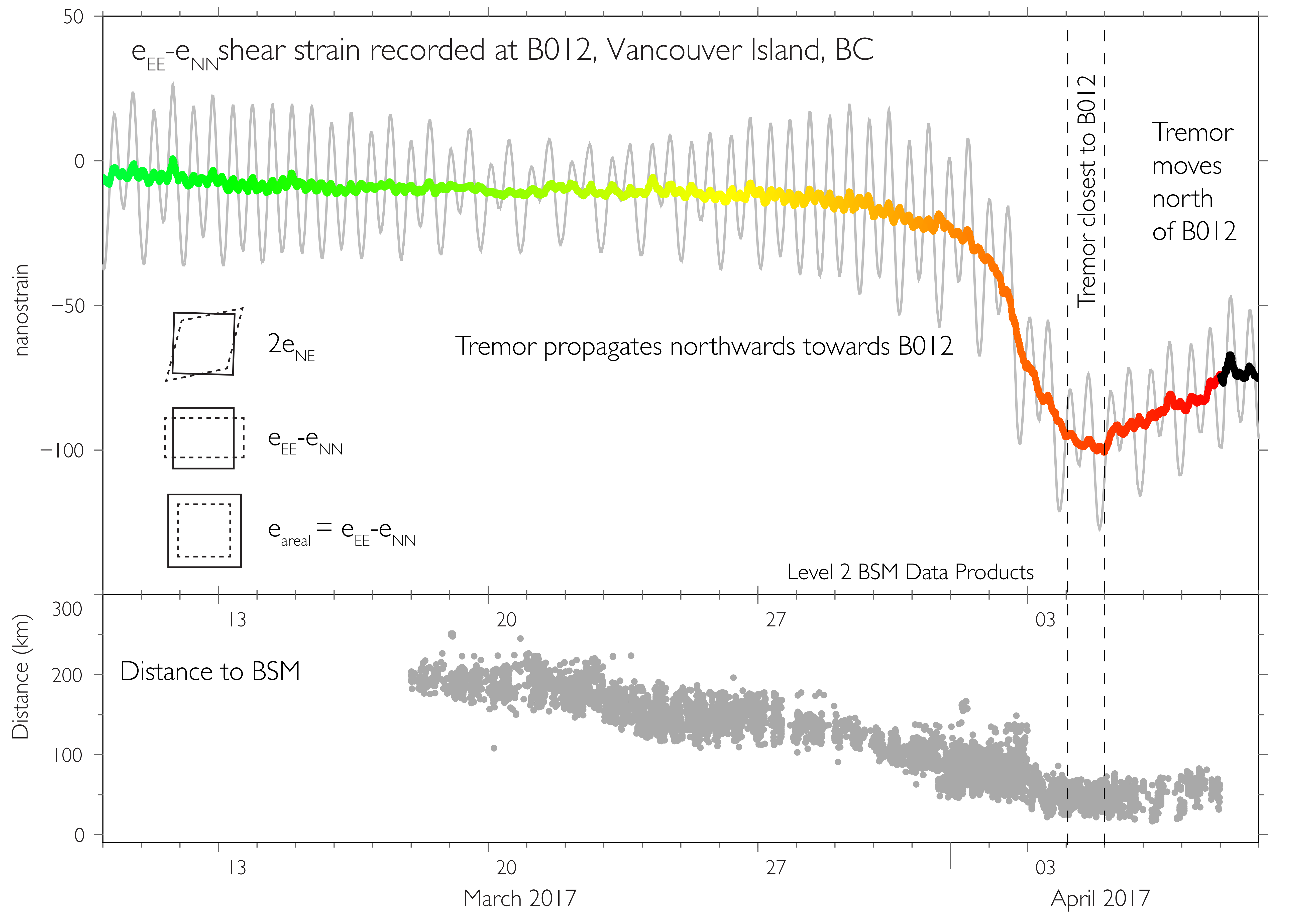
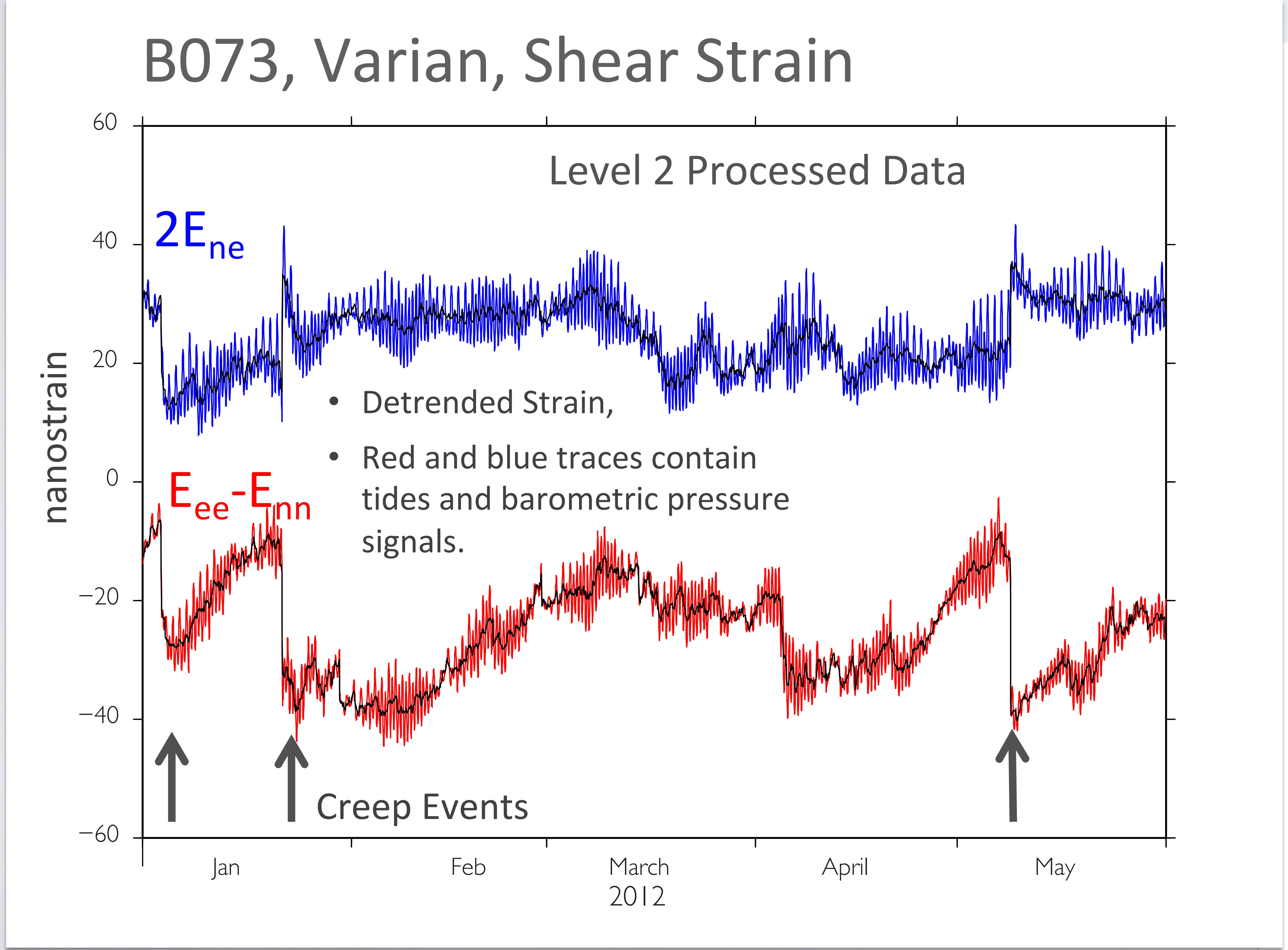
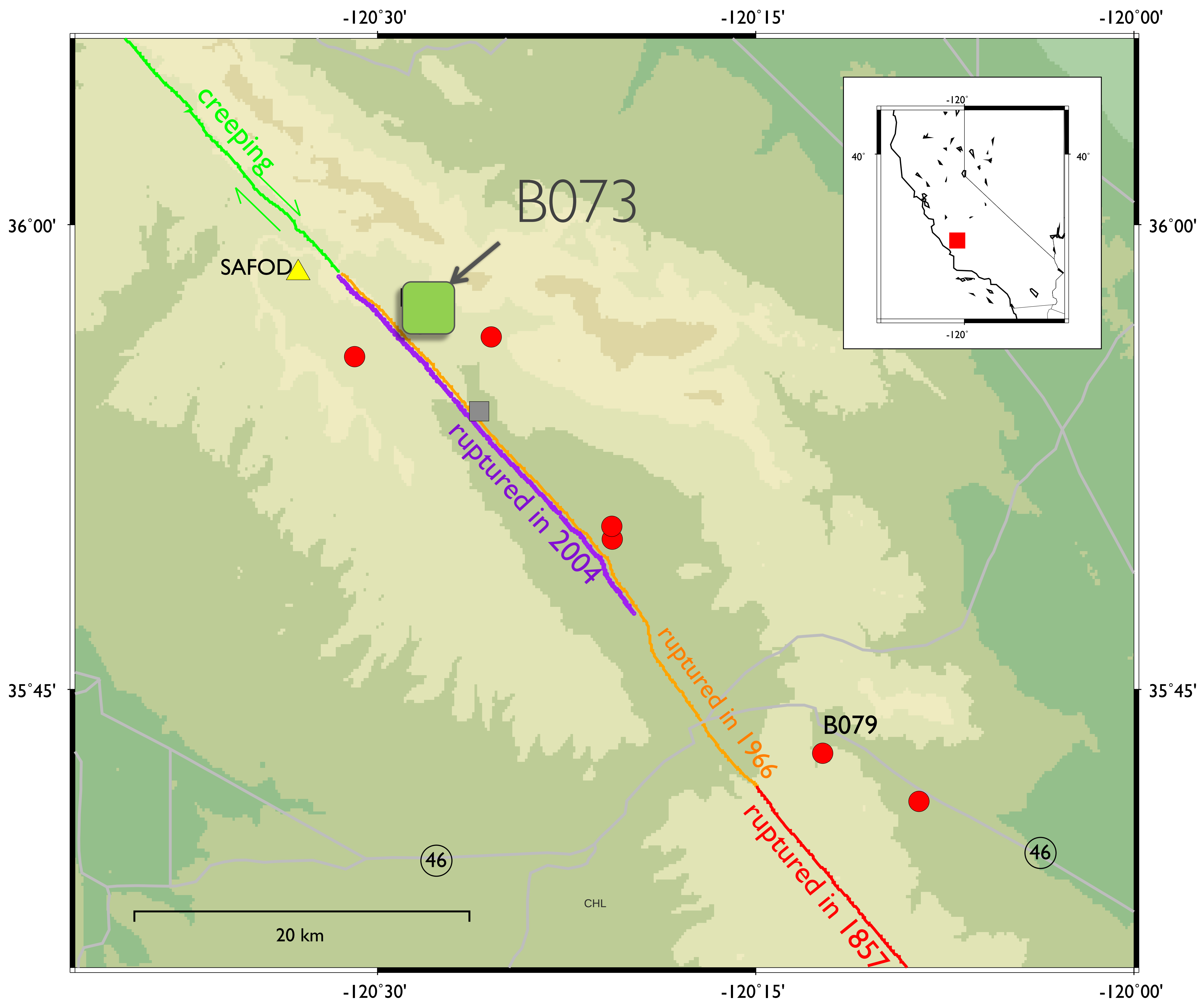


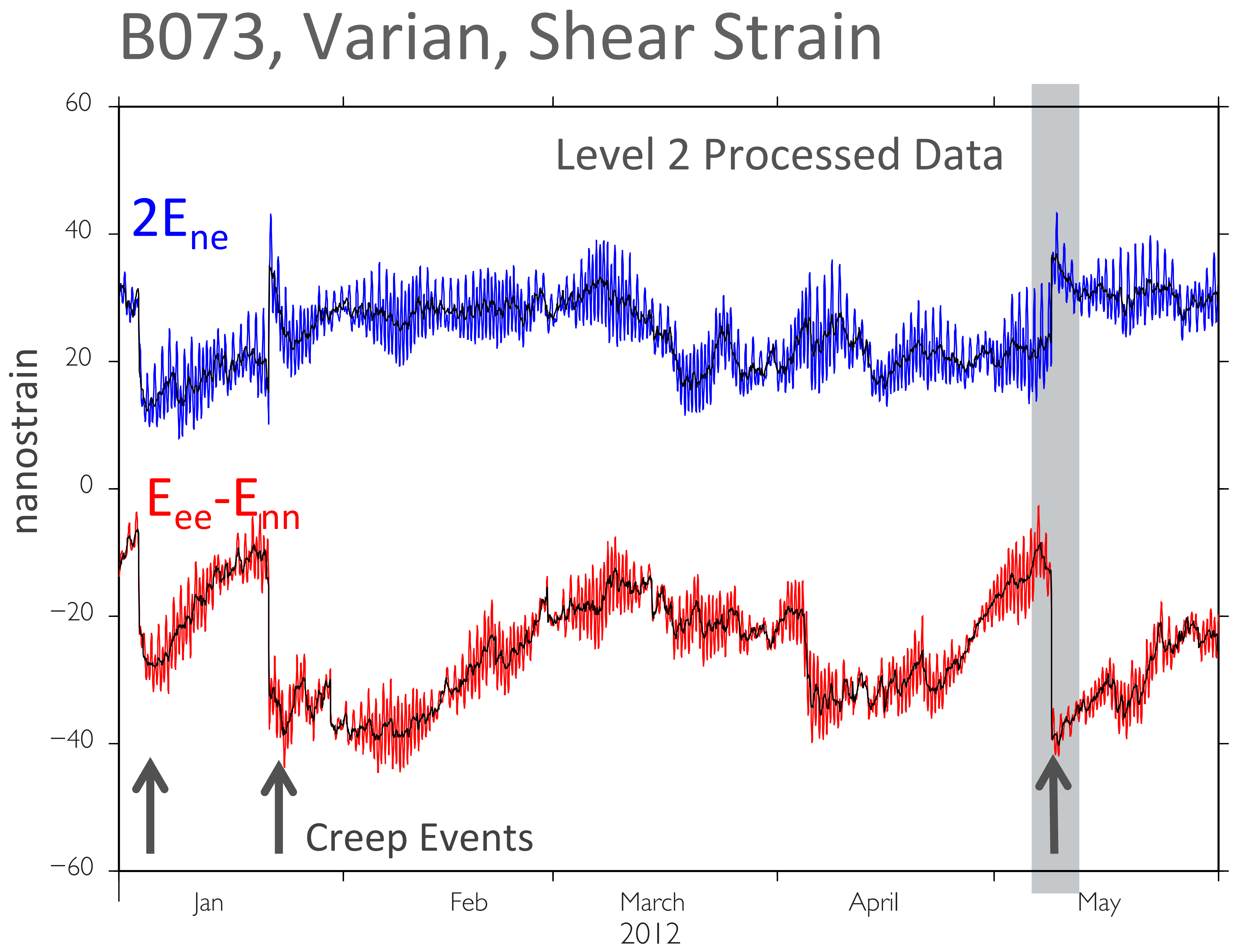


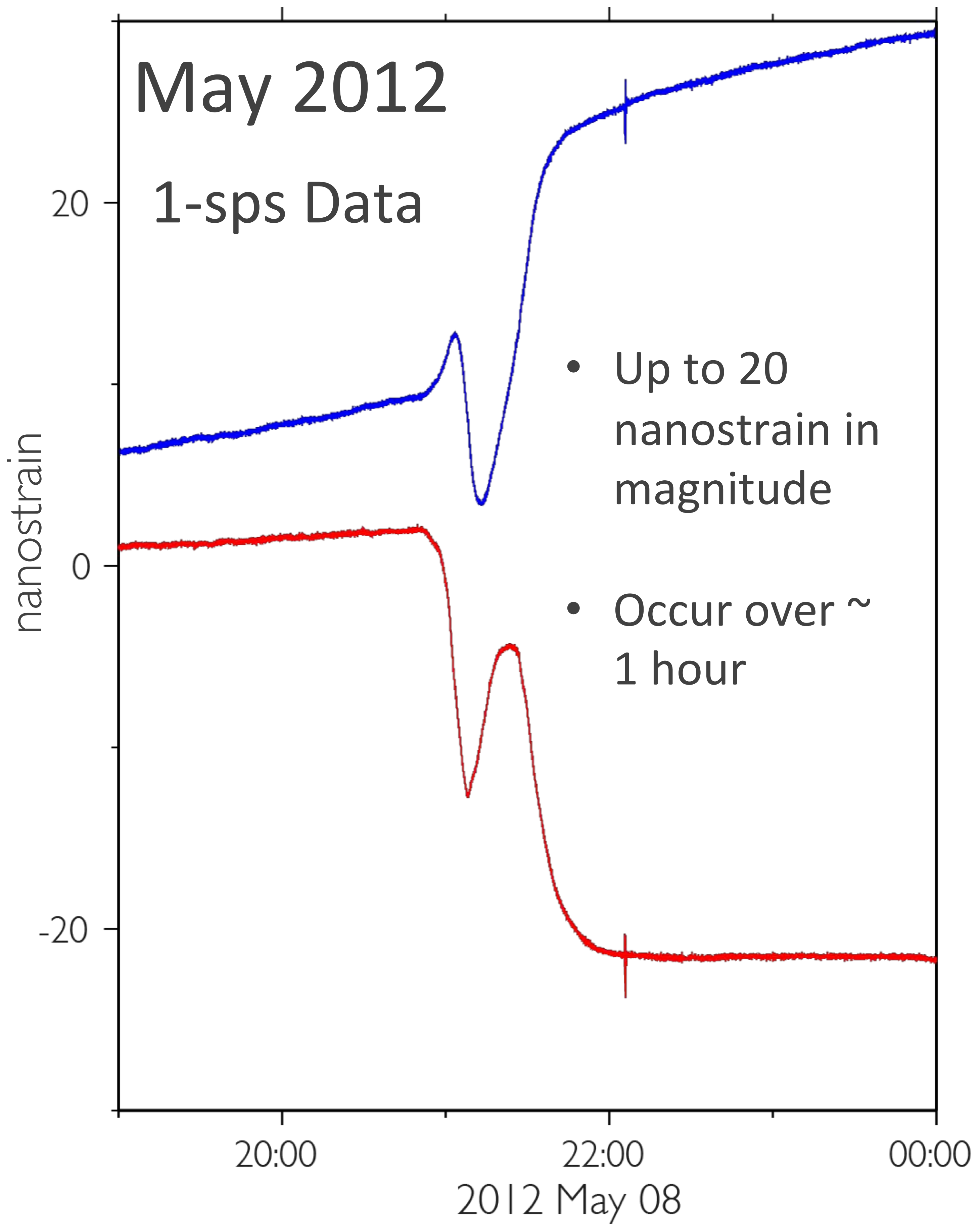
ASEISMIC CREEP SIGNALS





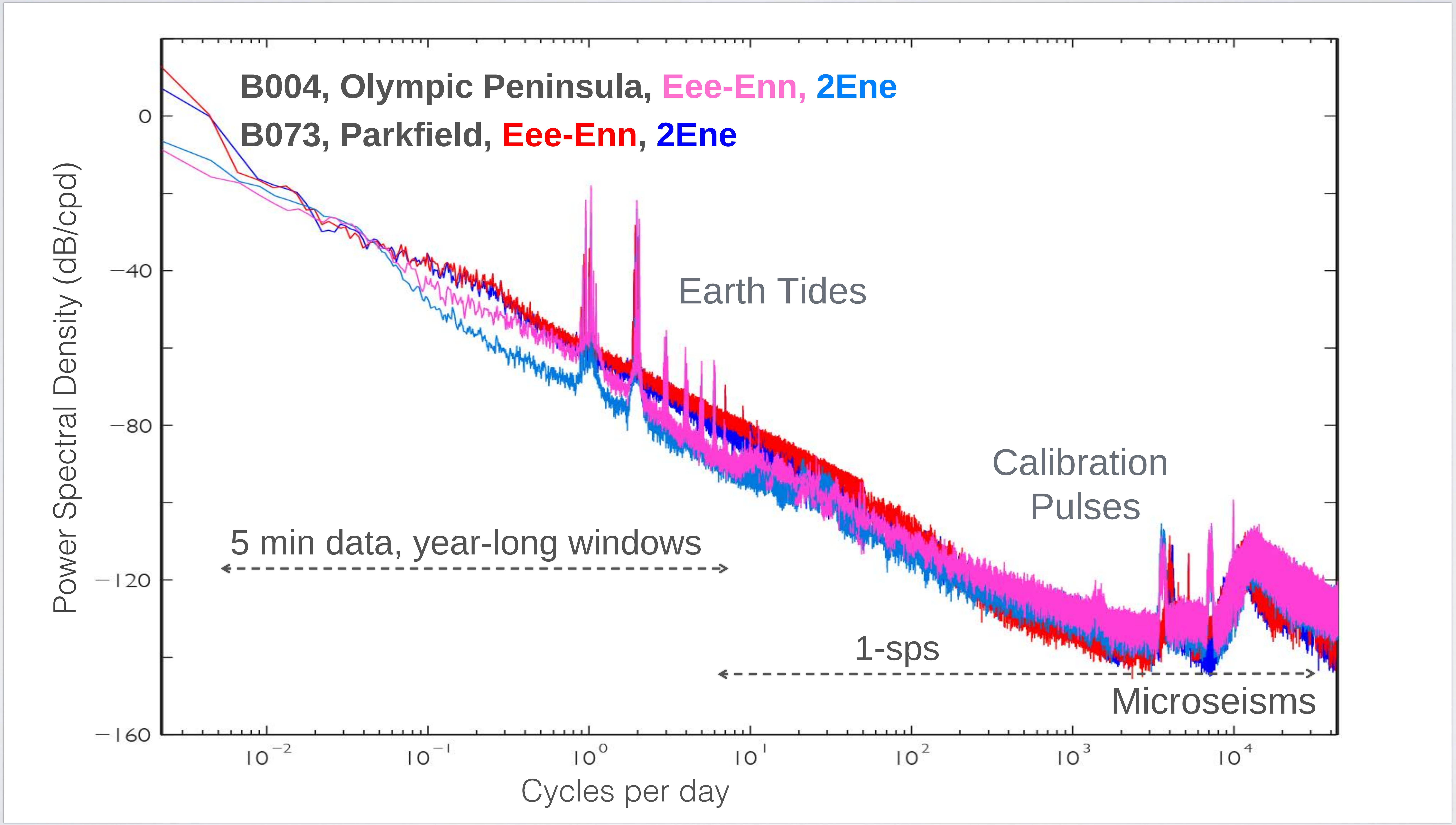
ASEISMIC CREEP SIGNALS





- Up to 20 nanostrain in magnitude
- Occur over ~ 1 hour

SUMMARY



B004, Olympic Peninsula, Eee-Enn, 2Ene
B073, Parkfield, Eee-Enn, 2Ene
Earth Tides
Calibration Pulses
5 min data, year-long windows
1-sps
Microseisms
Power Spectral Density (dB/cpd)
Cycles per day
0
−40
−80
−120
−160
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}

DATA QUALITY SUMMARY

BSM Data Quality Metrics | ...

www.unavco.org/data/strain-seismic/bsm-data/quality-metrics/quality-metrics.html

Most Visited · Getting Started · Latest Headlines · JIRA · Newest question... · Seismological S... · Seismological S...

- Laser Strainmeter Data
- **Borehole Strainmeter Data**
  - BSM Metadata
  - BSM Access & Data Tools
  - **BSM Data Quality Metrics**
- Borehole Seismic Data
- Borehole Pore Pressure Data
- Borehole Tilt Data

Related Links

- *BSM Data Processing Overview*
- *BSM Literature*
- *PBO Data Management System Critical Design Review [PDF]*
- *Borehole Strainmeter Instrumentation*
- *PBO BSM Station Coordinates*
- *BSM data at IRIS*

metrics are compiled into a detailed BSM Data Quality Metrics table.

2015 January BSM Data Quality Metrics Summary (csv format)

The table below gives a brief overview of data quality for each BSM. Ideally each BSM should be in compression and record signals in the tidal and seismic frequency bands.

Anza · Mendocino · Mojave · Mt. St. Helens · Pacific Northwest · Parkfield · San Francisco · San Juan Bautista · Vancouver · Yellowstone

Anza

BSM	Overview	Compression	Tides	Seismic
B081	Good quality data. Pore pressure sensor in borehole. Calibrated by Roeloffs [2012]. Data analyzed by Barbour and Agnew [2012].	√	√	√
B082	Co-located with B089, hydroligcal pumping with a few 100 meters of site contaminates data.	√	√	√
B084	Located near PFO laser strainmeter. Calibrated by Roeloffs [2010]. Data analyzed by Barbour and Agnew [2010].	√	√	√
B086	Good quality data. Calibrated by Roeloffs [2012]. Data analyzed by Barbour and Agnew [2012].	√	√	√
B087	Good quality data. Pore pressure sensor in borehole. Data analyzed by Barbour and Agnew [2012].	√	√	√
B088	Postseismic pore pressure transients recorded at this site after earthquakes in southern California, Gulf of California and after the 2010 M7.2 El Mayor-Cucapah earthquake. Occasional pumping signal in data. Data analyzed by Barbour and Agnew [2010].	√	√	√
B089	Co-located with B082, hydrological pumping with a few 100 meters of site contaminates data.	√	√	√
B093	Took 3 years to reach compression. Single channel outages in 2012. Otherwise good quality data. Data analyzed by Barbour and Agnew [2012].	√	√	√
B946	Not in compression, cultural noise that mimics creep events. Data steps on all channels, but more common on CHO and CH1.		√	√

EXAMPLE

Download raw gauge data in digital counts from strainmeter B012, process the gauge data to generate time-series.

EXAMPLE

February 4th to February 7th 2006, 1-sps, all 4 strain channels from B012

1. Edit get_data_ws.bash in the general directory.

```
> cp   get_data_ws.bash    get_data_ws_B012.bash
```

You will need to modify the following:

- Station name
- Network code
- Start Date
- End Date

Make the code more generic

```
#!/bin/bash

nw=$1          Network code
bsm=$2         Strainmeter
start=$3       Start date
end=$4         End date

for g in  0 1 2 3
do
  c=$(( g + 1 ))
  ftp  -o ${bsm}.CH$g.txt
"http://service.iris.edu/irisws/timeseries/1/query?net=${nw}&sta=${bsm}&cha=LS${c
}&start=${start}T00:00:00&end=${end}T00:00:00&output=ascii2&loc=T0"
   linearize.bash ${bsm}.CH$g.txt
done
```

EXAMPLE

1. get the data

   > get_data_ws_B012.bash PB B012 2006-02-03 2006-02-06

2. make the tensor strain, type

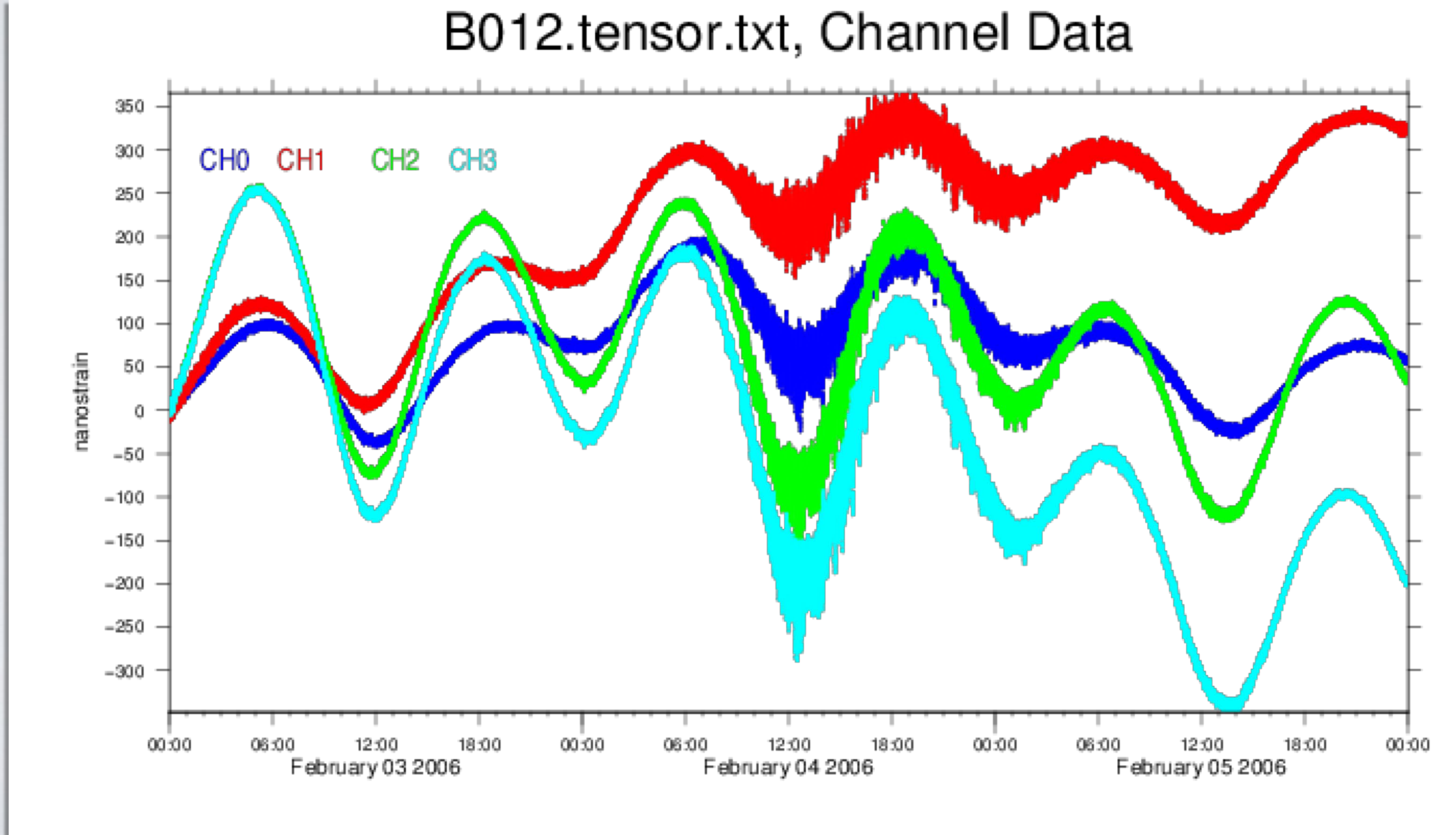
   > make_tensor.pl   B012

EXAMPLE

Plot the data using,

plot_gauge.bash B012

EXAMPLE


B012.tensor.txt, Channel Data
CH0
CH1
CH2
CH3
nanostrain
350
300
250
200
150
100
50
0
−50
−100
−150
−200
−250
−300
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
February 03 2006
February 04 2006
February 05 2006