

PBO Strainmeter Products

Kathleen Hodgkinson

Strainmeter Short Course

UNAVCO, Boulder

June 10-12, 2008



Overview

- Where are the instruments installed?
- Where can I get the data?
- What is processed data?
- Exercise 1: Download 20-sps data
- Exercise 2: Download, plot level 2 data
- Exercise 3: Lowpass filter for tidal analysis

Where are the PBO strainmeters?

UNAVCO: Plate Boundary Observatory (PBO)

http://pboweb.unavco.org/

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UNAVCO Plate Boundary Observatory Supporting EarthScope Geodetic, Seismic, and Tectonic Research earthscope

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Events

- » **Magnitude 7.2 - XINJIANG-XIZANG BORDER REGION** - (Mar 20, 2008)
» [Related PBO Strainmeter Data](#)
- » **Magnitude 7.0 - KEPULAUAN MENTAWAI REGION, INDONESIA** - (Feb 25, 2008)
» [Related PBO Strainmeter Data](#)
- » **Magnitude 6.0 - NEVADA** - (Feb 21, 2008)
» [Related PBO Strainmeter Data](#)
» **5Hz GPS Data:** Feb 20, 2007 | Feb 21, 2007 | Feb 22, 2007
- » **Magnitude 7.4 - SIMEULUE, INDONESIA** - (Feb 20, 2008)
» [Related PBO Strainmeter Data](#)
- » **Magnitude 6.3 - OFF THE COAST OF OREGON** - (Jan 10, 2008)
» [Related PBO Strainmeter Data](#)
- » [More Events](#)

Operations

- » [GPS Operations](#)
- » [Strainmeter Operations](#)

Education and Outreach

- » [UNAVCO](#)
- » [Data For Educators](#)
- » [EarthScope](#)

About PBO

The Plate Boundary Observatory (PBO), part of the EarthScope project that is funded by the National Science Foundation, studies the three-dimensional strain field resulting from active plate boundary deformation across the Western United States.

From a science perspective the PBO component of EarthScope is a geodetic observatory designed to study the three-dimensional strain field resulting from deformation across the active boundary zone between the Pacific and North American plates in the western United States. The observatory consists of arrays of Global Positioning System (GPS) receivers and Strainmeters which will be used to deduce the strain field on timescales of days to decades and geologic and paleoseismic investigations to examine the strain field over longer time scales.

» [More Details](#)

Construction **Education** **Data Access**

Project Highlights

-  **2005-2006 Mt. Augustine (Alaska, USA) Eruption Studied with high-rate GPS Data**
Apr 18, 2008
-  **PBO Siting Outreach Talk at San Diego State University in Brawley, California**
Mar 11, 2008
-  **PBO Instruments Record Wells NV, Event**
Mar 10, 2008
-  **EarthScope Strainmeter Deployments in Canada Complete**
Jan 15, 2008

Last Five Stations Installed

Data Access

- » [GPS](#)
- » [Streaming GPS](#)
- » [Borehole Strainmeters](#)
- » [Seismic](#)
- » [Laser Strainmeters](#)
- » [Tiltmeters](#)

Tools

Request Custom Datasets

Plotting/Data Access Resources

- » [BSM Data](#)
- » [SQUID](#)
- » [GPS Data \(Single Chart\)](#)
- » [GPS Data \(Multi Chart\)](#)

Mapping Resources

- » [PBO Network Maps](#)
- » [Network Progress \(Static\)](#)
- » [Network Progress \(KMZ\)](#)
- » [Velocity Field \(KMZ\)](#)
- » [Other Google Earth Resources](#)
- » [GPS Station Coordinates \(CSV\)](#)
- » [BSM Station Coordinates \(CSV\)](#)
- » [Nucleus Coordinates \(CSV\)](#)

Other resources

- » [Network QC Statistics](#)

Station Homepages

Station Finder

AB01 - AtkaslandAK2007

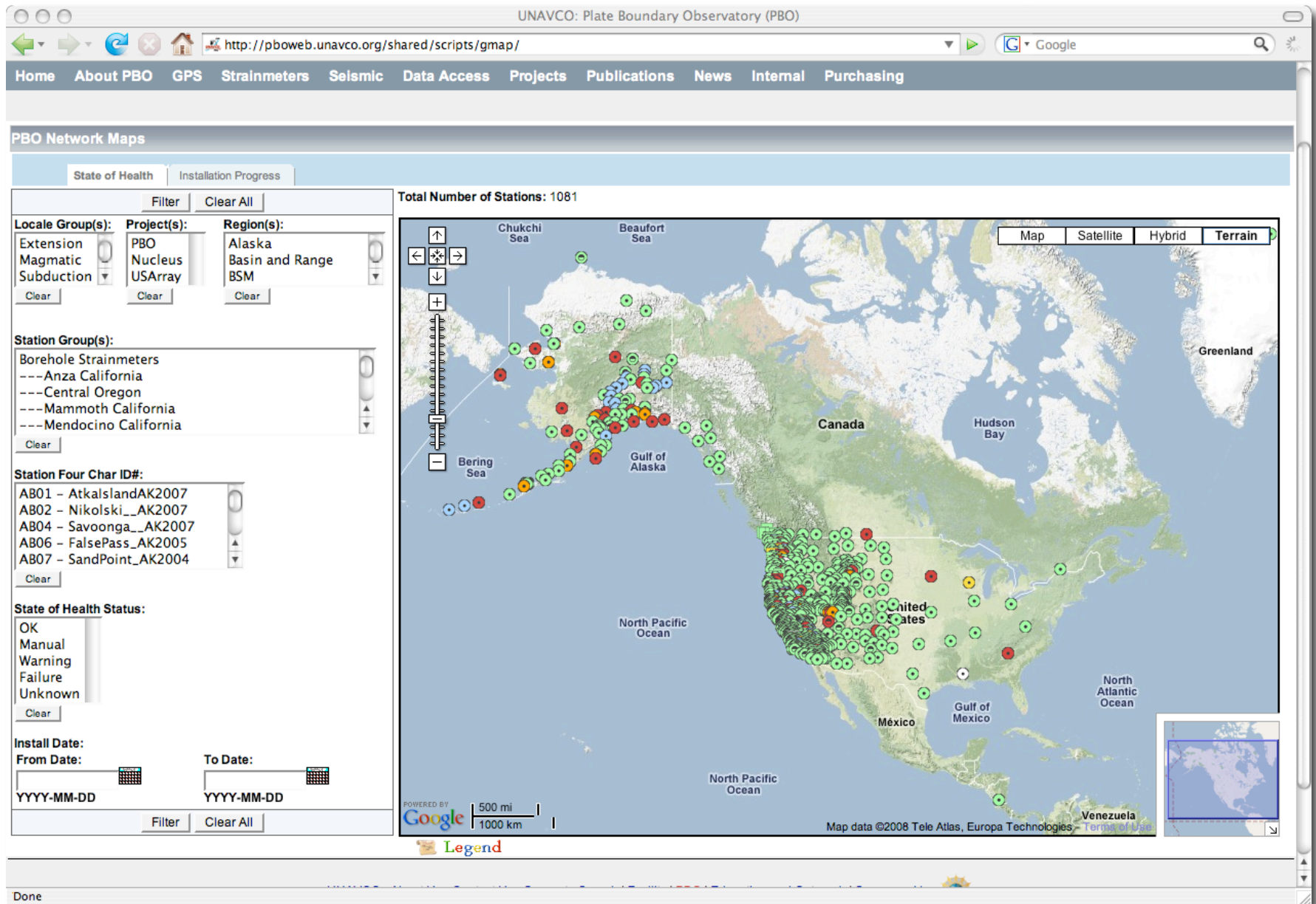
[Find Station](#)

Network State of Health

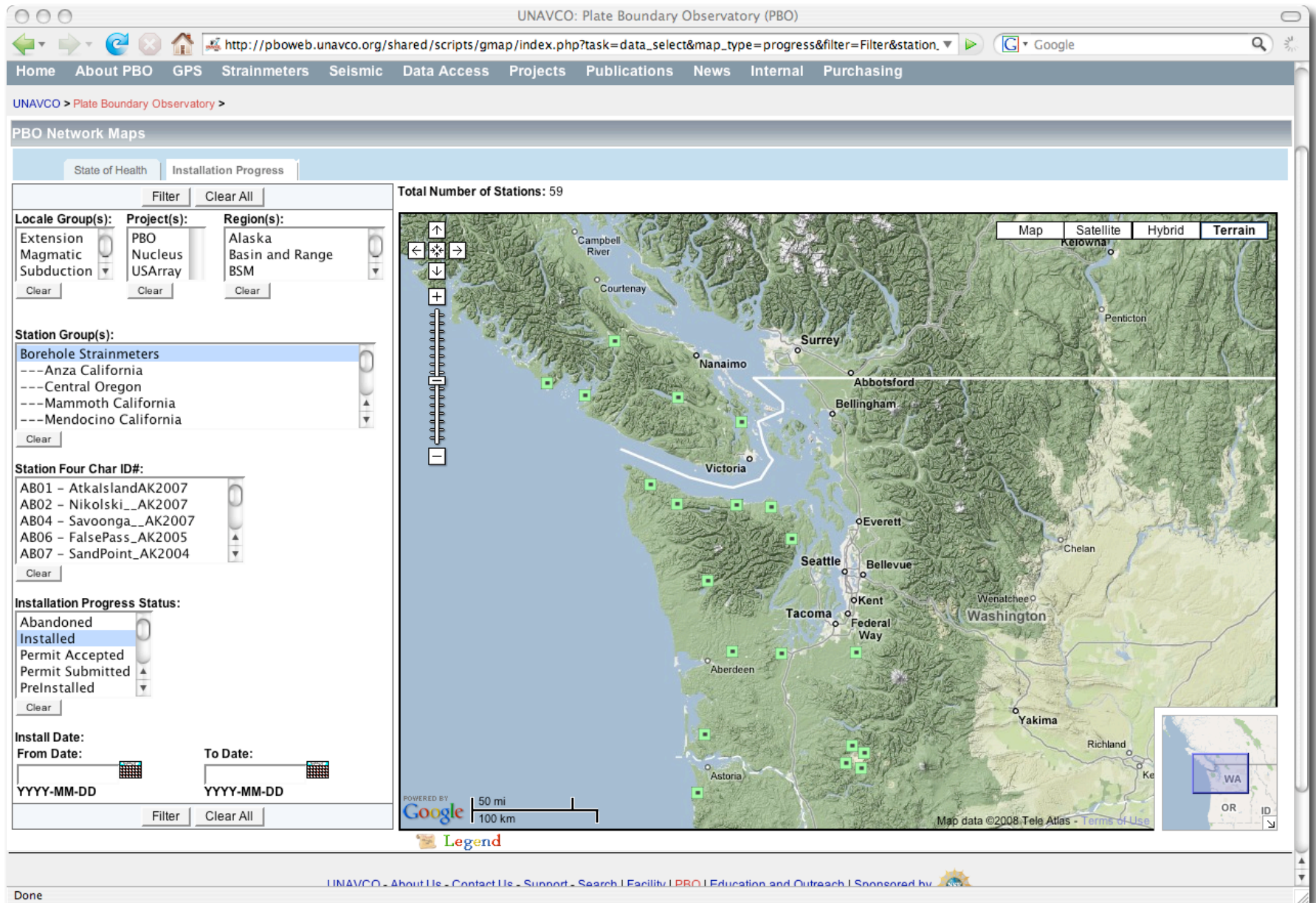
Network maps

http://pboweb.unavco.org

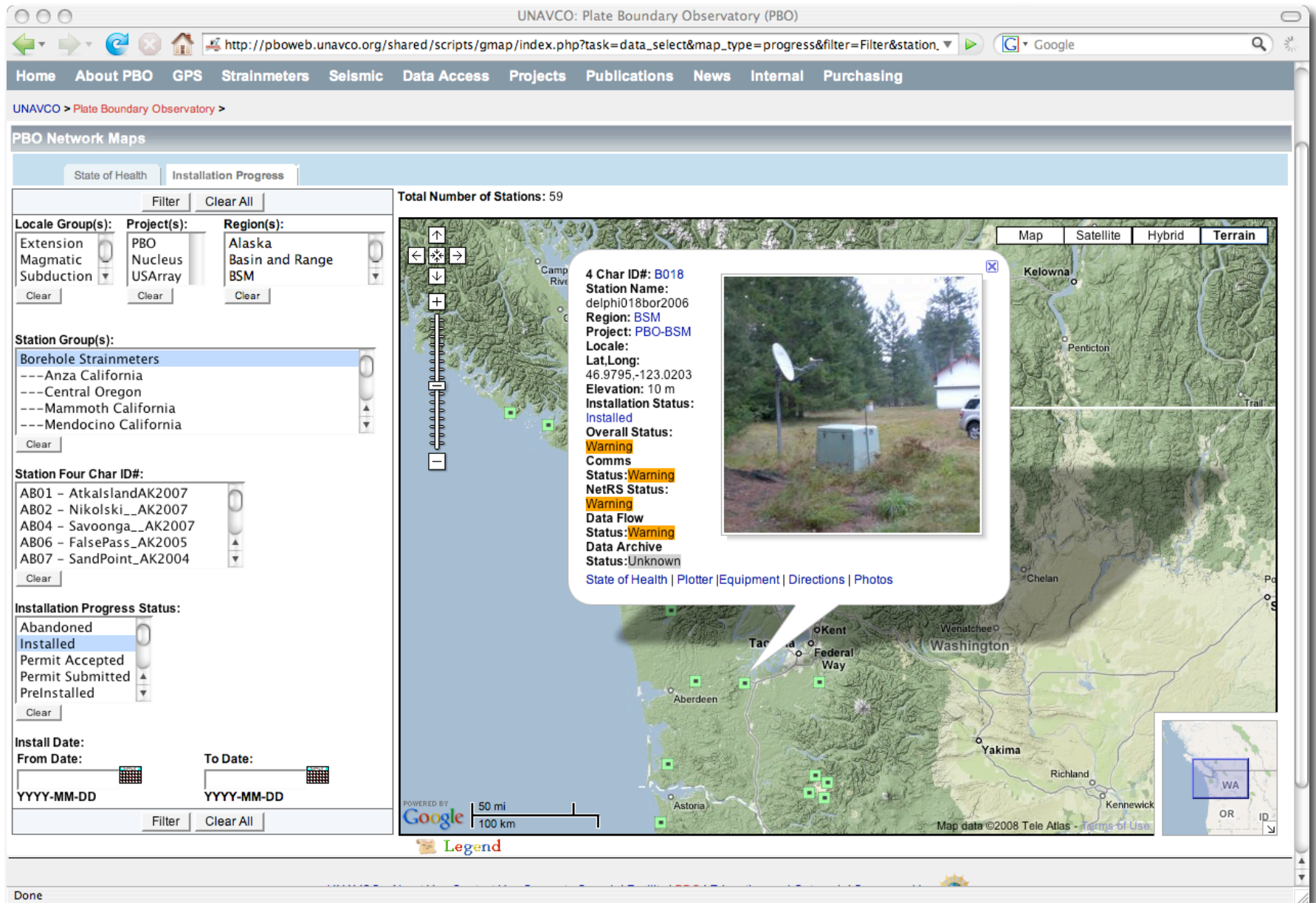
PBO Network Map



PBO Network Map



PBO Network Map



Strainmeter Homepages

UNAVCO: Plate Boundary Observatory (PBO)

http://pboweb.unavco.org/shared/scripts/stations/?checkkey=B018

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BSM Station: B018 - Overview

Overview Data Products Seismic State of Health Equipment Education and Outreach Reports Photos Additional Information



4-Char: B018
Station Name: delphi018bor2006
Station Installation Date: 2006-01-21 00:00:00
Monument Installation Date: 2006-01-21 00:00:00
Station Status: Installed
Project: PBO-BSM
Region: BSM
Latitude, Longitude: 46.9795, -123.0203
Elevation: 10 m / 33 ft
Monument Type: Wellhead
Location (City, State): Olympia, WA
Group(s): Seattle Washington
Co-Located Station(s): No Colocated Station Found.
Station Log: [Station Notes](#)
Station Installation: [Borehole Drawing](#)

Station Map


Map Satellite Hybrid

4-Char: B018
Station Name: delphi018bor2006
Latitude, Longitude: 46.9795, -123.0203

50 mi 100 km

Imagery ©2008 TerraMetrics, Map data ©2008 Tele Atlas - Terms of Use

● = B018 (Current Station) ● = Nearby Stations

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Technical Comments/Questions?: [PBO Web Administrator](#)
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Done

What is recorded at a PBO BSM site?



- Strainmeter
- Seismometer
- Barometer
- Rainfall gauge
- Temperature



What is recorded at a PBO BSM site?



- Strainmeter
- Seismometer
- Barometer
- Rainfall gauge
- Temperature
- Tiltmeter
- GPS
- Accelerometer

What is recorded at a PBO BSM site?

Type	Rate	Format	Frequency
Strain	20 sps 1 sps 600 sec	Bottle SEED Bottle SEED Bottle SEED ASCII	Hourly Hourly Daily
Environmental	300 sec	Bottle SEED ASCII	Daily
Seismic	1 100 200 sps	SEED	Streaming*
Pore pressure	300 sec	ASCII	Daily
Tiltmeter	60 sec	ASCII	Daily

* Some stations

Strainmeter Products

There are two types of strainmeter products:

- Raw Data : Digital counts
- Processed Data (level 2):
 - Gauge strain
 - Areal and shear strain
 - Data edits
 - Tidal correction
 - Borehole correction
 - Atmospheric pressure correction

Where are the data archived?

PBO data set archived at two data centers:

- IRIS Data Management Center (DMC)
- Northern California Earthquake Data Center (NCEDC)

In addition to the DMC and the NCEDC, UNAVCO provides user requested data sets.

The PBO Strainmeter Page

A master list of all PBO strainmeter data sets is displayed on the PBO strainmeter products web page .

UNAVCO: Plate Boundary Observatory: Data Management and Information Technology: Strainmeter Products

http://pboweb.unavco.org/strain_data

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» **Strainmeter Information Mailing List**

Dot #	Station Name	Type	Date Installed	Array	Raw Data			Geophysical Logging	Pore Pressure	Processed Data	Station Notes	Time Series
(Click on the Above Labels to Sort Table)					NCEDC	IRIS DMC	UNAVCO					
B001	golbeck01bwa2005	BSM	2005-06-29	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B003	floequarybwa2005	BSM	2005-09-13	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B004	hokofallsbwa2005	BSM	2005-06-15	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B005	shoresnw1bwa2005	BSM	2005-07-19	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B006	shoresne2bwa2005	BSM	2005-07-28	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	XML ASCII	PDF	Plots
B007	shoresso3bwa2005	BSM	2005-07-23	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	XML ASCII	PDF	Plots
B009	pacgeosi1bbc2005	BSM	2005-09-14	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	XML ASCII	PDF	Plots
B010	pacgeosi2bbc2005	BSM	2005-09-26	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B011	pacgeosi3bbc2005	BSM	2005-09-13	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B012	ucluelet1bbc2005	BSM	2005-09-22	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B013	pnycrk013bwa2007	BSM	2007-01-05	Seattle Washington	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	N/A N/A	PDF	Plots
B014	quintit014bwa2008	BSM	2008-03-04	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	N/A N/A	PDF	Plots

http://pboweb.unavco.org/strain_data

Raw Data: High frequency, 20 and 1-sps

- Only available from the DMC and the NCEDC
 - SEED data: Merged, long-term data sets
 - Bottle data: Individual 24-hour long files
- Strain SEED data can be used in any SEED software, e.g., rdseed, PQL

Raw Data: High frequency, 20 and 1-sps

- Only available from the DMC and the NCEDC
 - SEED data: Merged, long-term data sets
 - Bottle data: Individual 24-hour long files
- Strain SEED data can be used in any SEED software, e.g., rdseed, PQL
- SAC users beware!
 - The numbers in the raw files are greater than the precision of a 32-bit floating point.

Raw Data: Low Frequency

- Available from DMC and NCEDC
 - SEED data: Merged, long-term data sets
 - Bottle data: Individual 24-hour long files
- In addition to the primary data sets UNAVCO provides:
 - Bottle data: Long-term merged bottle data
 - ASCII data: Long-term merged ASCII data

Linear Strain

- SEED and bottle data are in digital counts.
- The linear gauge strain, u , at time t , is calculated with respect to a fixed raw data point (d_o) .

$$u_t = \left(\frac{d_t/(1e+8)}{1-(d_t/1e+8)} - \frac{d_o/(1e+8)}{1-(d_o/1e+8)} \right) * \frac{R}{M}$$

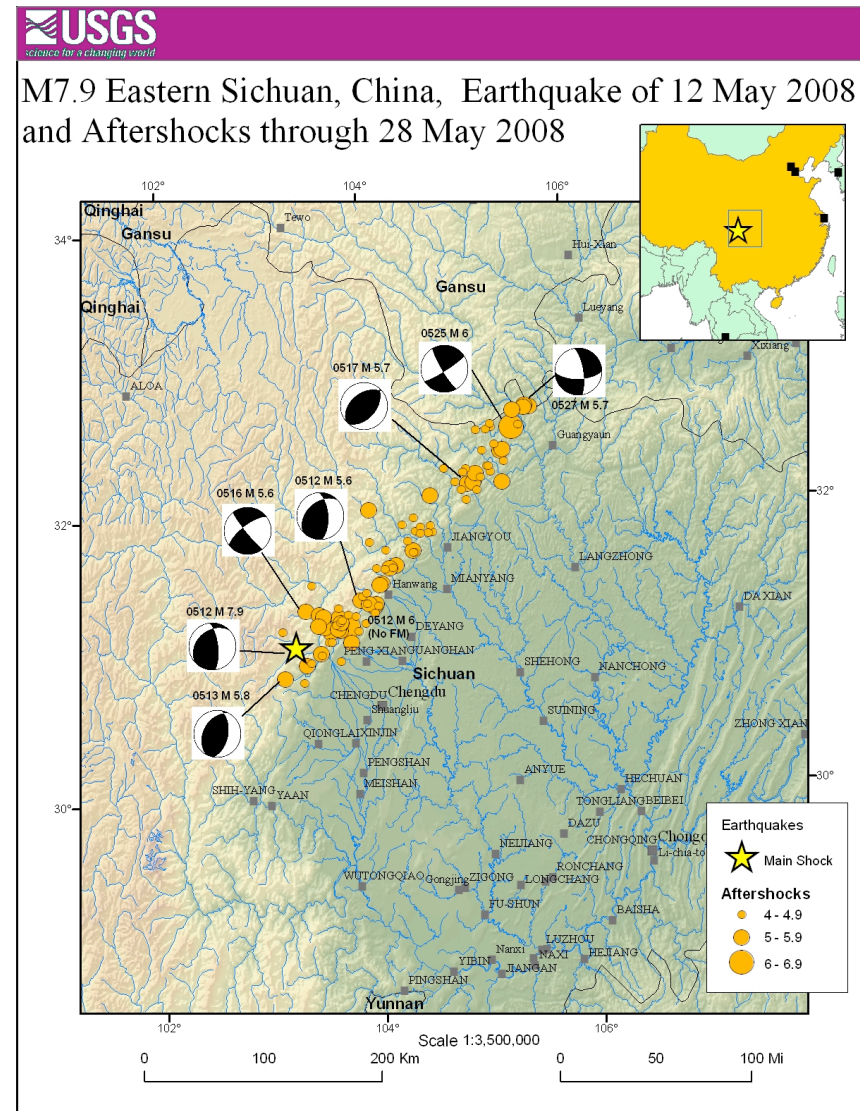
d_t raw data value at time t

R instrument reference gap (0.01 or 0.02 cm)

M instrument diameter (0.087 m)

Exercise 1: Download 20-sps data and generate linear strain

Goal: Download 20-sps data recorded by B081 during the May 12, 2008, M7.9 China earthquake. Convert data to nanostrain and plot.



Exercise 1: Download 20-sps data and generate linear strain

1. To download mSEED data go to the IRIS DMC Quack page,

<http://www.iris.edu/servlet/quackquery/>

2. Select "Explore Data" .

3. Select

Network: PB

Station: B081

Location: T0

Channel: BS1

Exercise 1: Download 20-sps data and generate linear strain

4. Select Data Day "2008.133" in the measurements window
5. In the display data window select B081.PB.T0.BS1.2008.133
6. Download the files for the other 20-sps channels, BS2, BS3 and BS4. When the data are downloaded, you should have 4 files: BS1, BS2, BS3, BS4.

The data are in mSEED format, digital counts .

Exercise 1: Download 20-sps data and generate linear strain

Make a directory for B081 in your working area and move the B081 files into it.

```
% mv download_dir/B081* path/level2/working/.
```

Exercise 1: Download 20-sps data and generate linear strain

7. Use the script `mseed2linear.sh` to produce ASCII formatted linearized data.

```
%mseed2linear.sh B081.PB.T0.BS1.2008.133 133 6 10
```

8. The output will be in an ASCII file named `B081.PB.T0.BS1.2008.133.txt`

Output:

N = number of seconds from the 1st point

Counts = raw value

Nanostrain = linearized strain (ns)

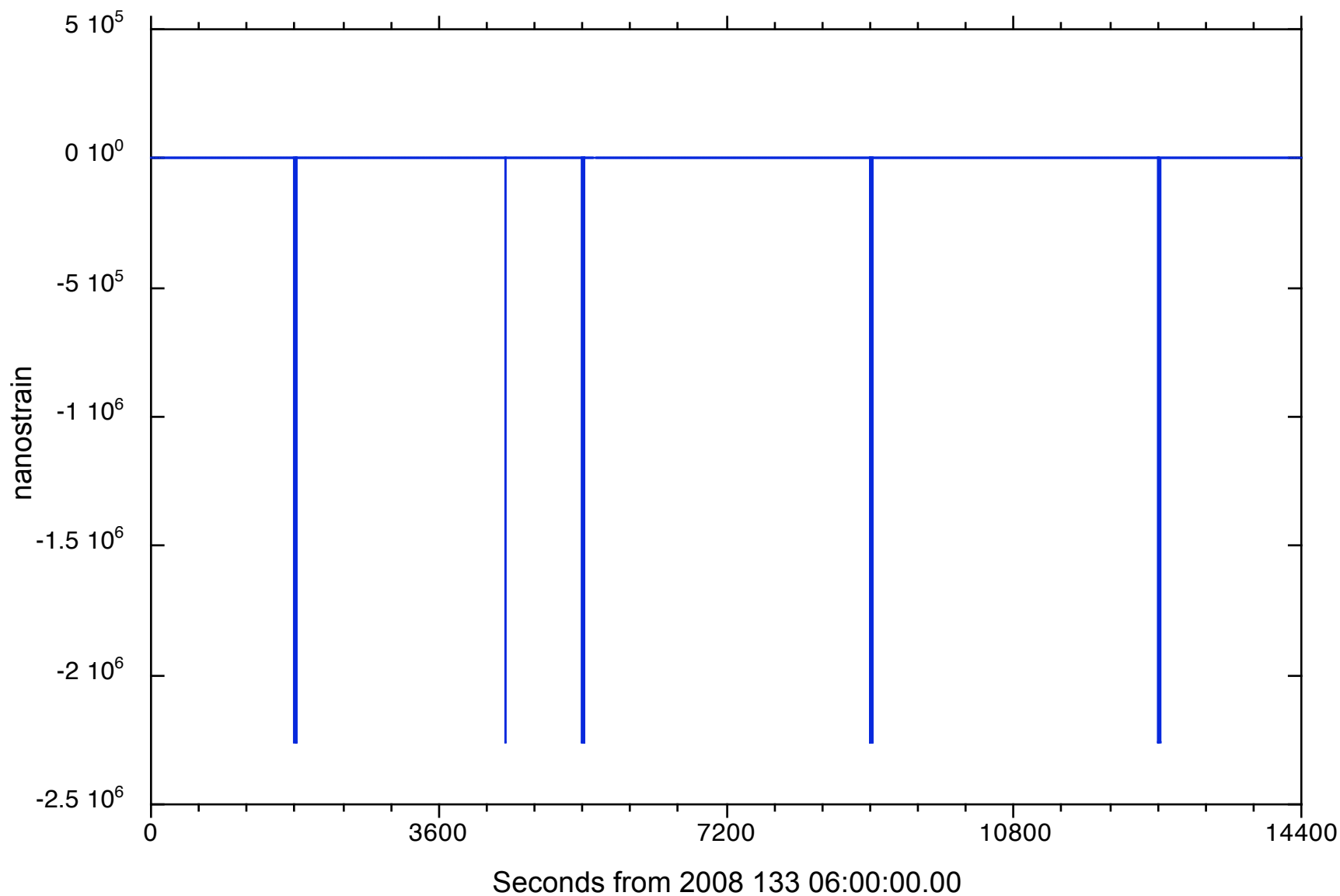
Exercise 1: Download 20-sps data and generate linear strain

9. Open in Kaleidagraph.

When opening the files select "Read header" and "space delimited" data in the "Text File Input Format Window" .

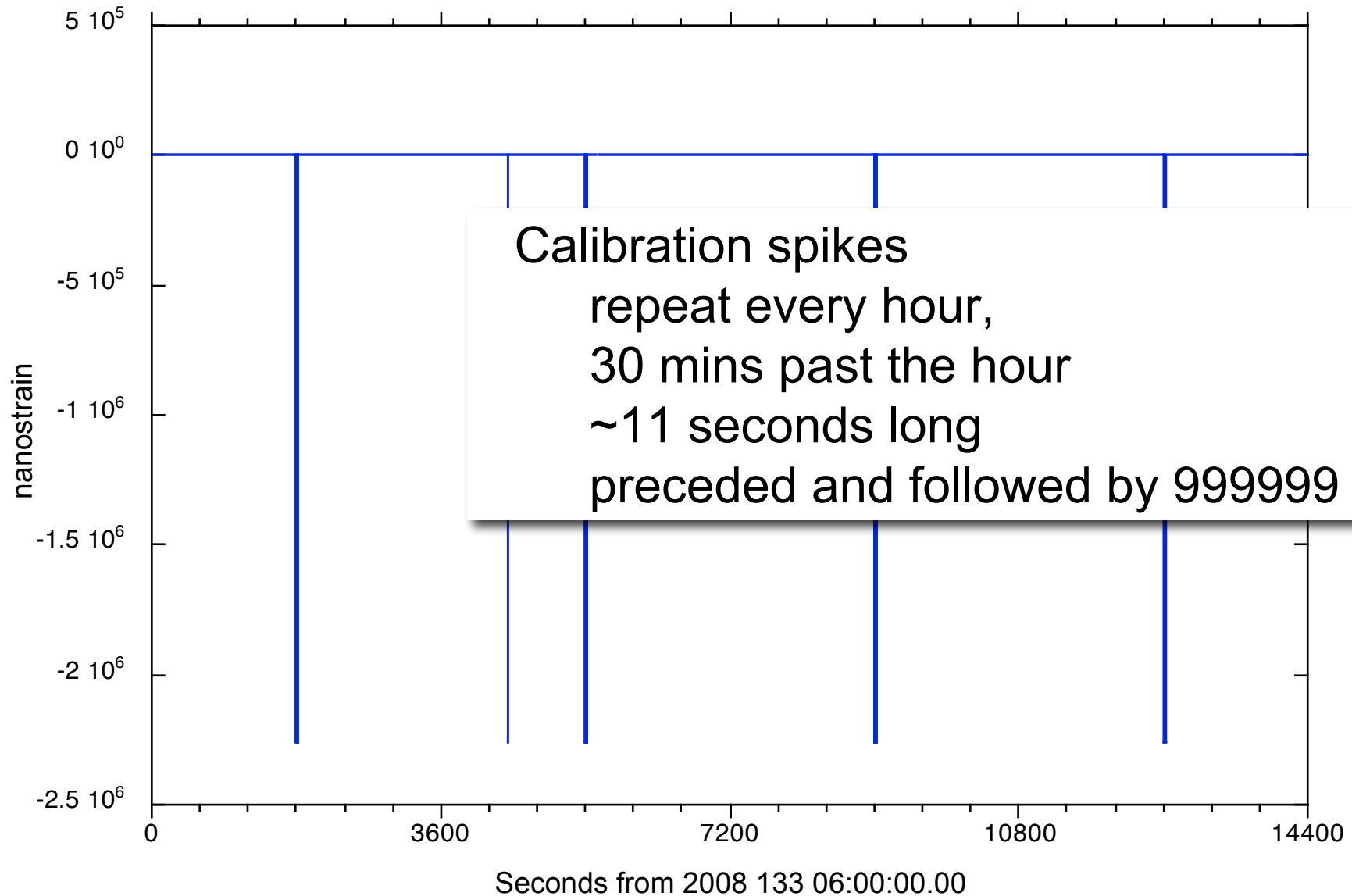
B081, May 12, 2008, 20sps data

B081.PB.T0.BS1.2008.133



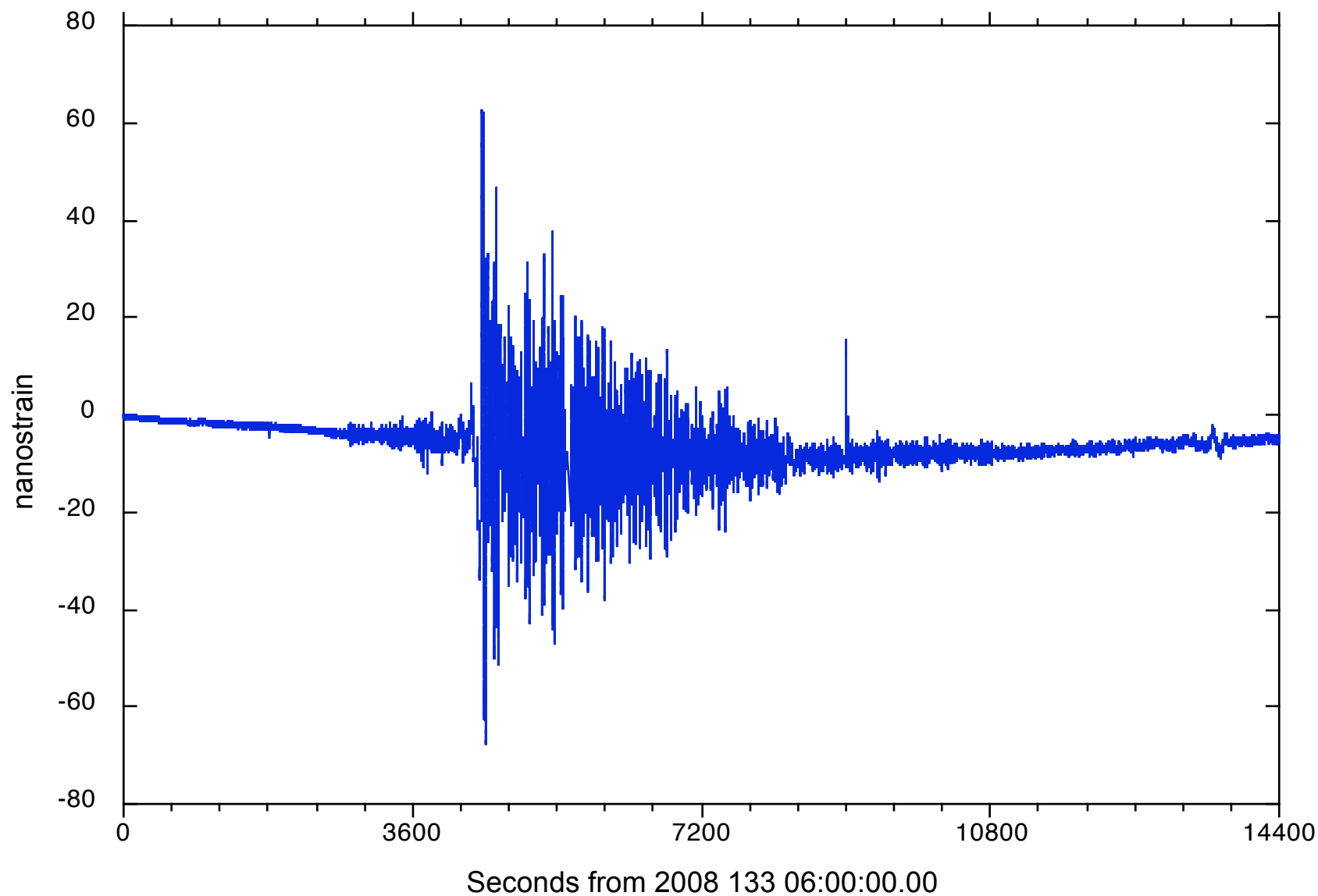
B081, May 12, 2008, 20sps data

B081.PB.T0.BS1.2008.133



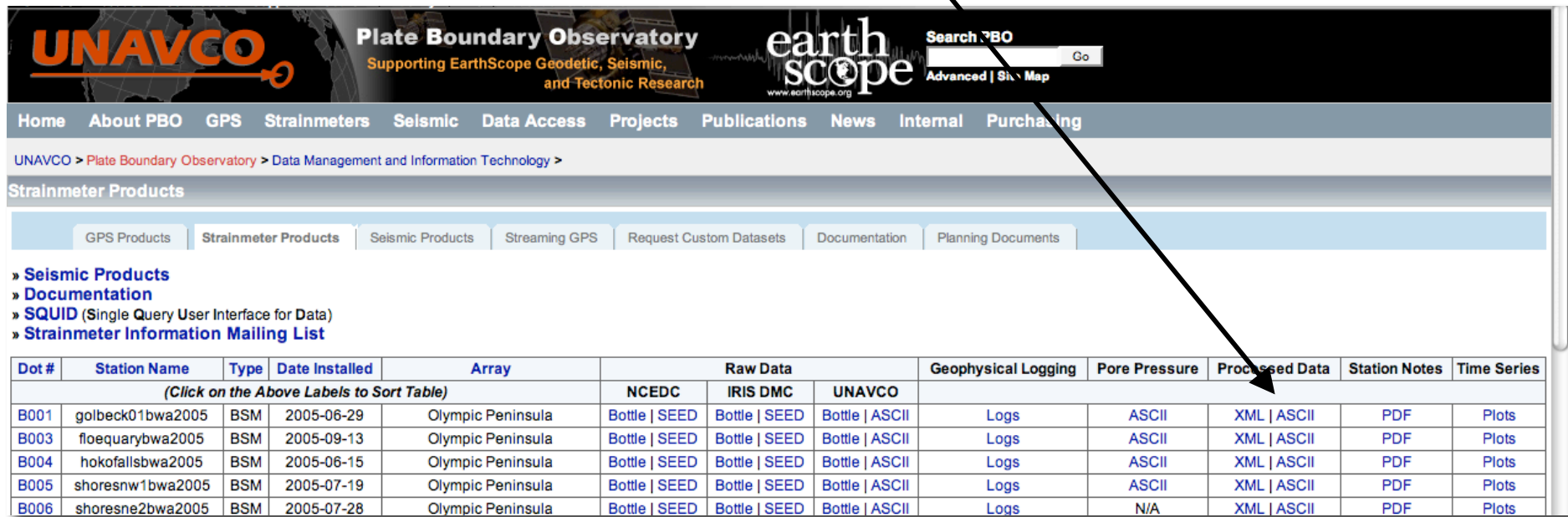
B081, May 12, 2008, 20sps data

B081.PB.T0.BS1.2008.133



Processed Strainmeter Data

- The most recent XML file is named BBBB.YYYY.xml.bz2 (enables download via cron)
- Flat ASCII version of most recent processed data set available from UNAVCO



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Dot #	Station Name	Type	Date Installed	Array	Raw Data			Geophysical Logging	Pore Pressure	Processed Data	Station Notes	Time Series
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B001	golbeck01bwa2005	BSM	2005-06-29	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B003	floequarybwa2005	BSM	2005-09-13	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B004	hokofallsbwa2005	BSM	2005-06-15	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B005	shoresnw1bwa2005	BSM	2005-07-19	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B006	shoresne2bwa2005	BSM	2005-07-28	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	XML ASCII	PDF	Plots

Processed Strainmeter Data

- Archived at the DMC and NCEDC in year long XML files.
- A new file is sent every 2 weeks with new data.
- The XML files can be read using rdstrain.pl
<http://pboweb.unavco.org/?pageid=101>

Processed Strainmeter Data

Two categories of processed data:

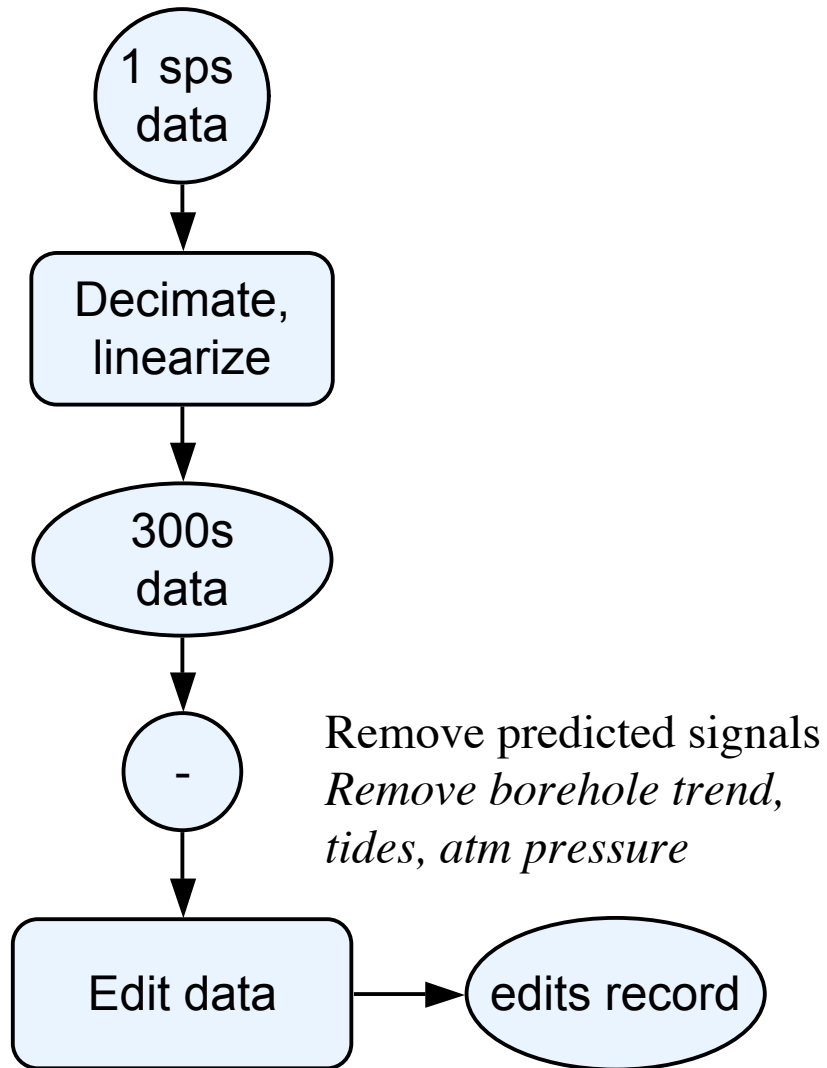
- 2a: A rapidly processed data set
Updated every 14 days
- 2b: Every 3-4 months the data are reviewed
The trends and tides are recalculated
Opportunity to post-process the data sets

Trends, tides and atmospheric correction in 2a data is predicted based on recalculations in the level 2b processing.

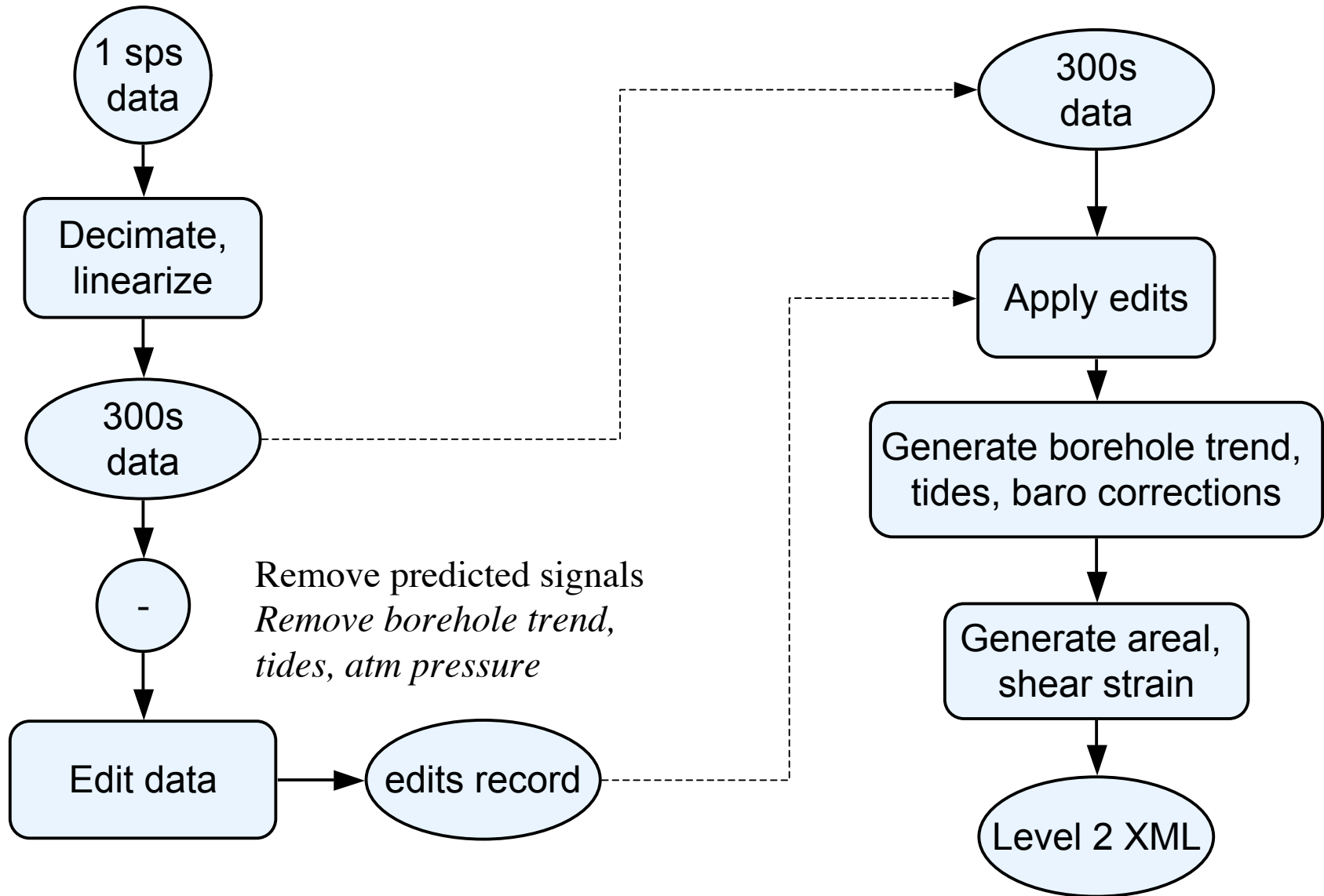
Time series and corrections

Product	Method
Borehole Trends	Modeled using a linear term plus 2 exponentials
Tidal Model	BAYTAP-G, PIASD
Atmospheric Response	BAYTAP-G, PIASD
Offset Estimation	TSVIEW, PIASD
Areal and shear strain	Generated using nominal scale factors

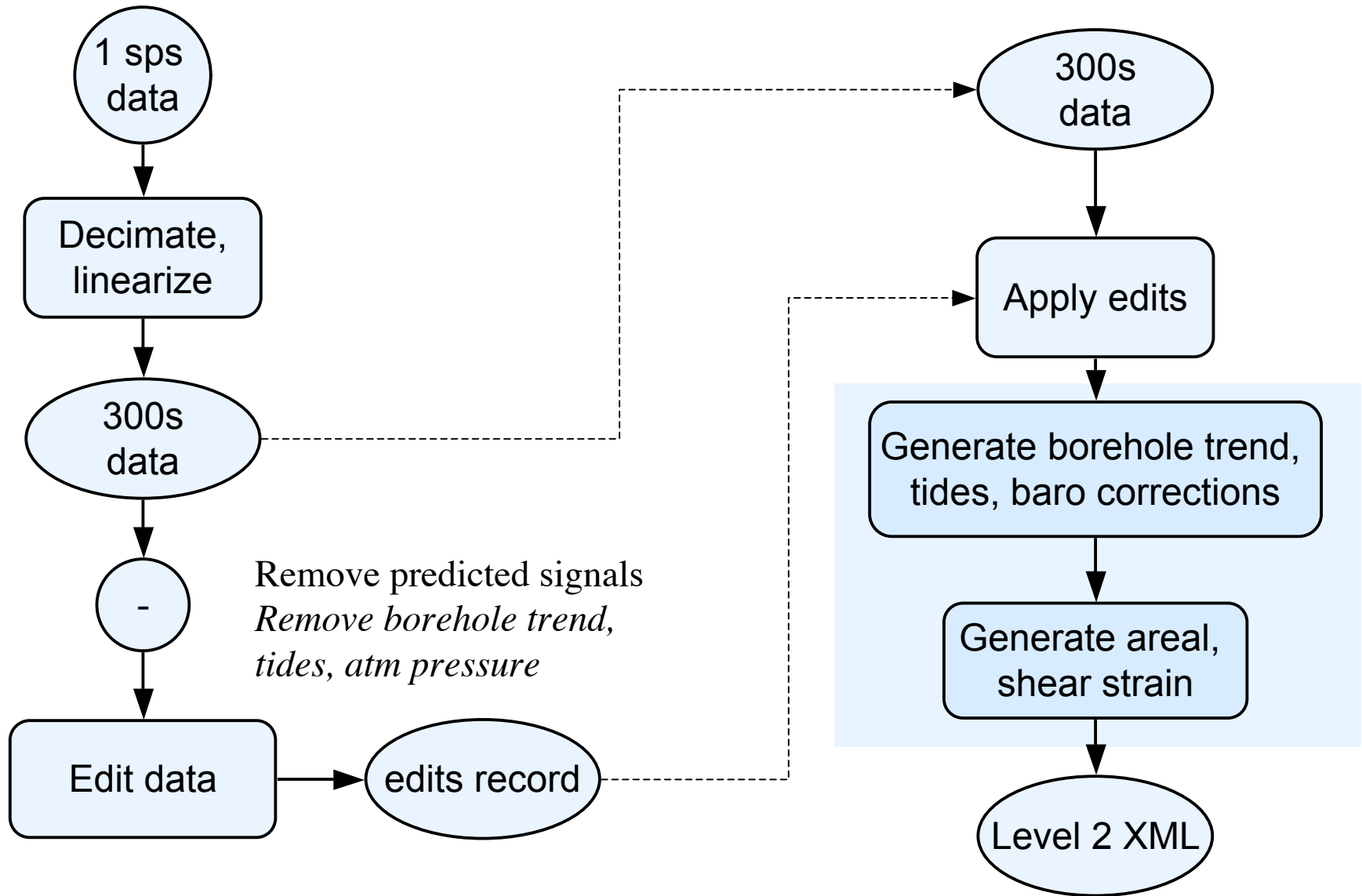
Processed Data: Processing steps



Processed Data: Processing steps



Processed Data: Processing steps



Processed Data: Areal and shear strain

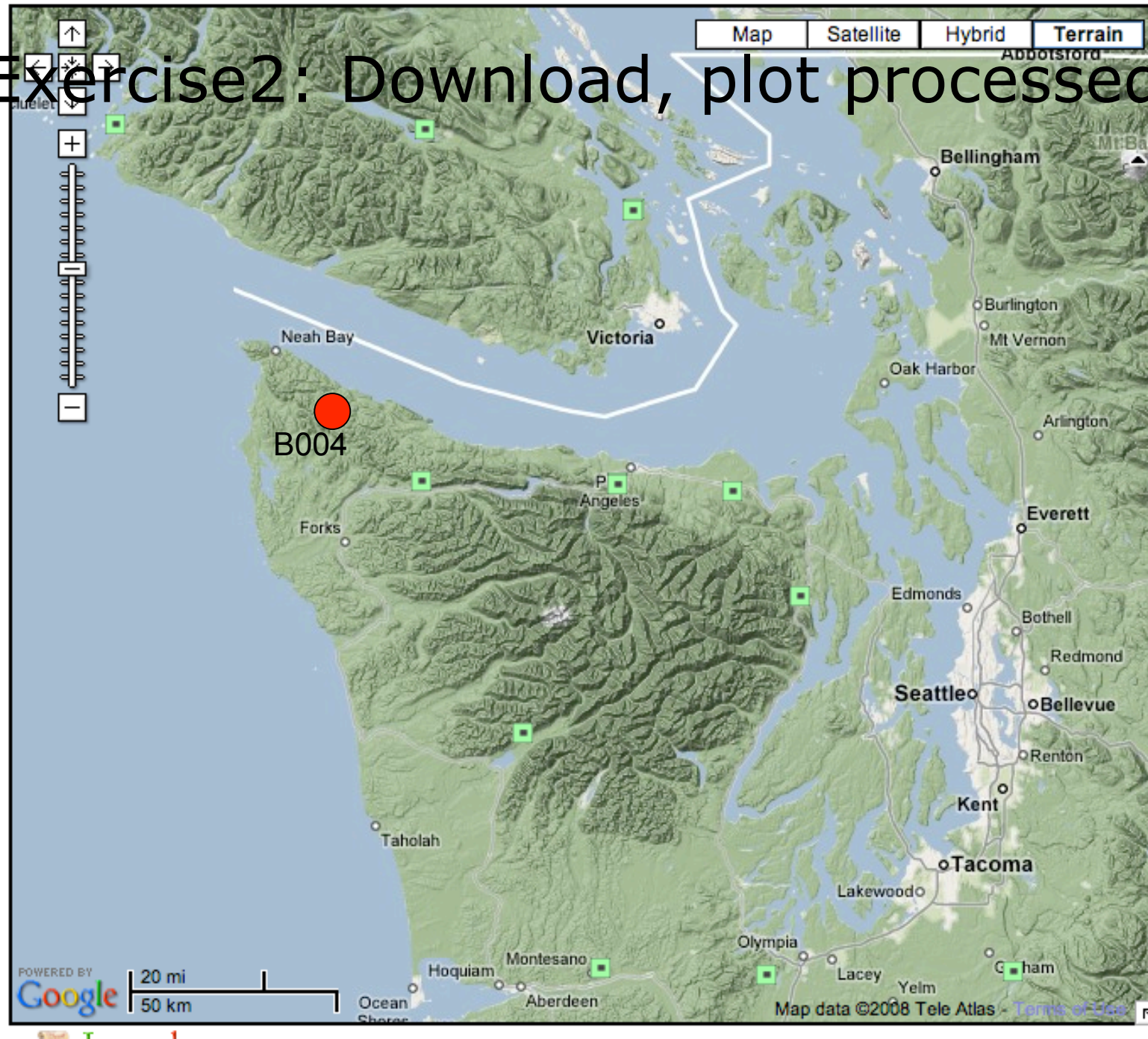
$$\begin{pmatrix} g_0 u_0 \\ g_1 u_1 \\ g_2 u_2 \\ g_3 u_3 \end{pmatrix} = \frac{1}{2} \begin{pmatrix} 1 & \cos 2\theta_0 & \sin 2\theta_0 \\ 1 & \cos 2\theta_1 & \sin 2\theta_1 \\ 1 & \cos 2\theta_2 & \sin 2\theta_2 \\ 1 & \cos 2\theta_3 & \sin 2\theta_3 \end{pmatrix} \begin{pmatrix} C & 0 & 0 \\ 0 & D & 0 \\ 0 & 0 & D \end{pmatrix} \begin{pmatrix} E_{nn} + E_{en} \\ E_{nn} - E_{ee} \\ 2E_{en} \end{pmatrix}$$

- u_i linearized gauge readings
- g_i gauge weightings (currently 1)
- θ_i orientation of gauge counter-clockwise from east
- C areal scale factor (currently 1.5)
- D shear scale factor (currently 3)

Exercise2: Download, plot processed data

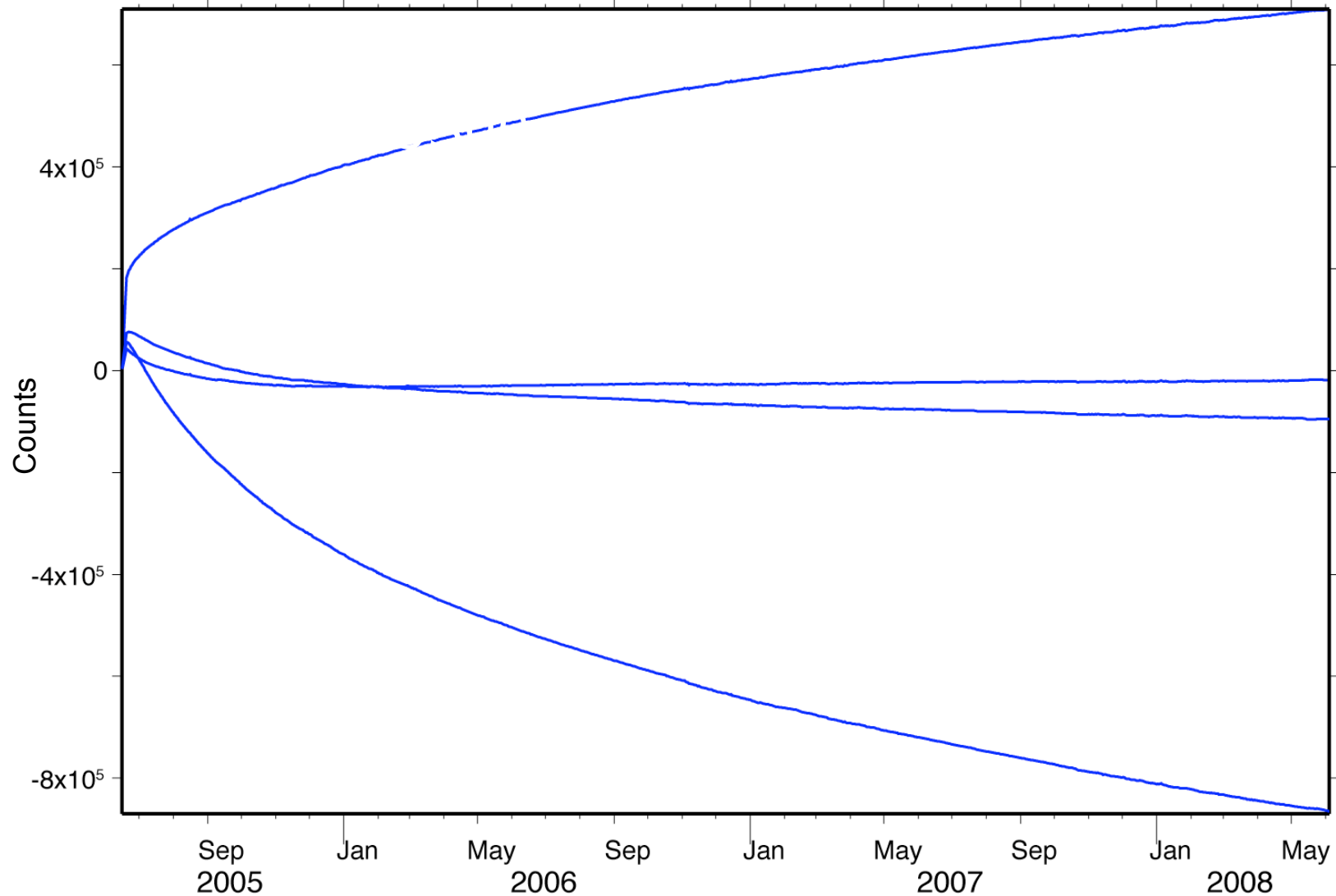
Goal: Download 2008 Level 2 data from strainmeter B004. Parse and plot the data, examine tidal, trend and atmospheric signal.

Exercise2: Download, plot processed data



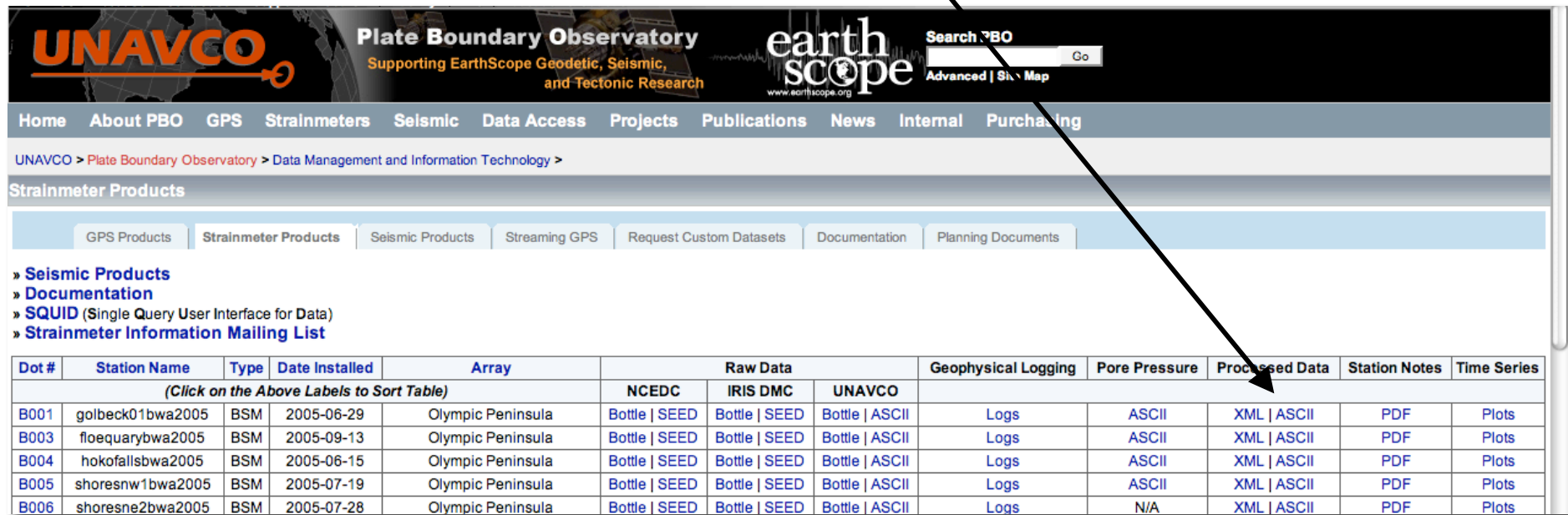
Borehole Trends: B004

B004: Olympic Peninsula



Download, plot processed data

1. Go to the PBO strainmeter web page.
http://pboweb.unavco.org/strain_data.
2. If Level 2 data are available the links in the “processed data” column will be activated.



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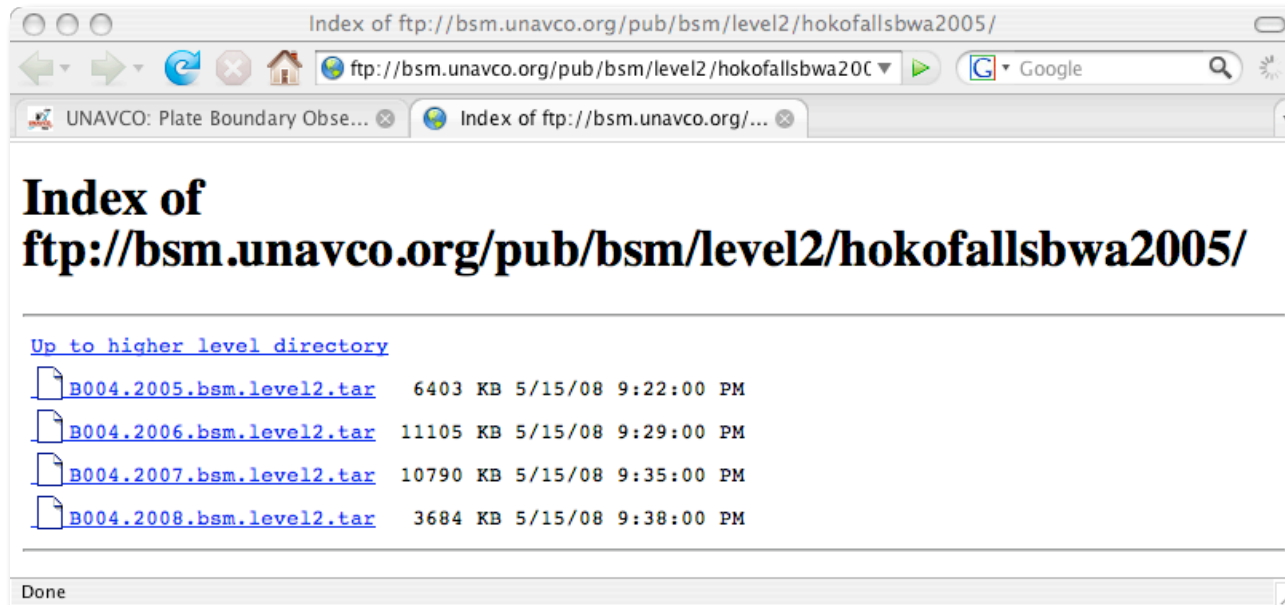
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B003	floequarybwa2005	BSM	2005-09-13	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B004	hokofallsbwa2005	BSM	2005-06-15	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B005	shoresnw1bwa2005	BSM	2005-07-19	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	ASCII	XML ASCII	PDF	Plots
B006	shoresne2bwa2005	BSM	2005-07-28	Olympic Peninsula	Bottle SEED	Bottle SEED	Bottle ASCII	Logs	N/A	XML ASCII	PDF	Plots

Download, plot processed data

3. Select strainmeter B004 , click on the “Processed data ASCII Link”. This should take you to :

<ftp://bsm.unavco.org/pub/bsm/level2/hokofallsbwa2005/>

4. You will see one tar file for each year of data, select B004.2008.bsm.level2.tar



* If you know the pathname you can use the ftp command

Download, plot processed data

5. The tar should download to your computer.

6. Cd into the level2 working directory

```
% cd level2/working
```

7. Move the tar file into the working directory,

```
% mv download_dir/B004.2008.bsm.level2.tar .
```

8. Untar the file,

```
% tar -xf B004.2008.bsm.level2.tar
```

Download, plot processed data

9. Cd into the new directory

```
% cd B004.2008.bsm.level2
```

10. You should see seven ASCII gzipped files,

B004.2008.xml.2Ene.txt.gz

B004.2008.xml.Eee+Enn.txt.gz

B004.2008.xml.Eee-Enn.txt.gz

B004.2008.xml.gage0.txt.gz

B004.2008.xml.gage1.txt.gz

B004.2008.xml.gage2.txt.gz

B004.2008.xml.gage3.txt.gz

Download, plot processed data

11. Unzip the ASCII files

```
% gzip -d *.gz
```

12. Remove the “T” in the time stamp

e.g.,

```
% perl -pi -e 's/T/ /g' *.txt
```

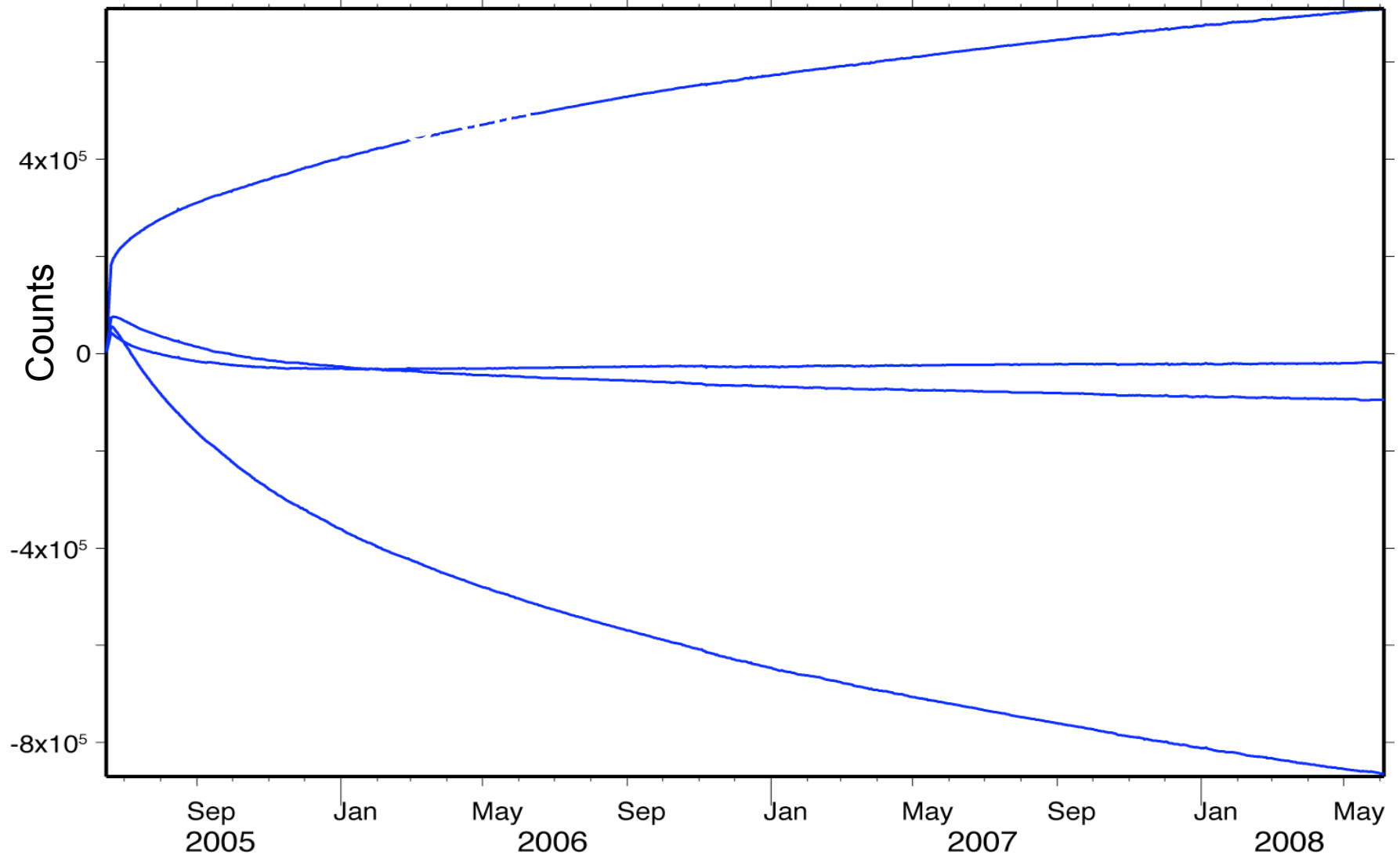
Download, plot processed data

13. Open in Kaleidagraph

When opening the files select "read header line" and "tab delimited" data in the "Text File Input Format Window" .

Borehole Trends: B004

B004: Olympic Peninsula



Download, plot processed data

The column headings are:

strain	label
date	UTC
doy	Day of year
MJD	Modified Julian Date
Microstrain	Linearized strain, no edits, trend, tide or atmospheric corrections applied
s_offset	Running sum of offsets
strain_quality	g=good, b=bad
tide_c	Tide correction
detrend_c	Detrend correction
atmp_c	Atmospheric pressure correction
atmp_c_quality	Atmospheric pressure quality
level	2a or 2b
version	Generation date of processed data

Exercise 3: Filter data for tidal analysis

1. Cd into the level 2 working directory

```
% cd level2/working
```

2. Cd into the data directory,

```
% cd B004.2008.bsm.level2
```

3. Run the lowpass_level2.sh script,

```
% lowpass_level2.sh B004.2008.xml 2008-01-02
```

```
00:00:00 2008-05-01 00:00:00
```

Exercise 3: Filter data for tidal analysis

4. The output files are 1-hour sampled data for each of the gauges and barometric pressure.

B004.g0

B004.g1

B004.g2

B004.g3

B004.baro

5. To prepare the input files for BAYTAP use the script, `asc2baytap.pl` .

Exercise 3: Filter data for tidal analysis

```
% asc2baytap.pl
  Station name? B004
  Latitude? 48.2019
  Longitude? -124.427
  Elevation (m)? 30.0
  Sample interval (hours) ? 1
  Start date (YYYY MM DD hh ) ? 2008 1 2 0
  End date (YYYY MM DD hh ) ? 2008 5 1 0
  Strain data file names ( CH0 CH1 CH2 CH3 ) ?
    B004.g0 B004.g1 B004.g2 B004.g3
    Created B004.g0.b08
    Created B004.g1.b08
    Created B004.g2.b08
    Created B004.g3.b08
  Barometric data file name ? B004.baro
  Created barometric file B004.baro.b08
  Name for BAYTAP parameter script ?
    01.B004.baytap08
    Created input parameter file 01.B004.baytap08
```

Exercise 3: Filter data for tidal analysis

The script should have created:

- 4 gauge, 2 areal and 2 shear strain files,
- 1 barometric file
- 1 script to run BAYTAP, 01.B004.baytap08 .

It also produces areal and shear strain files,

$$3gekk = 2(u0 + u1 + u2)/3$$

$$2gekk = (u1 + u3)/2$$

$$2gexxmeyy = (u1 - u3)$$

$$3gexxmeyy = (4u1 - 2u2 - 2u0)/3$$