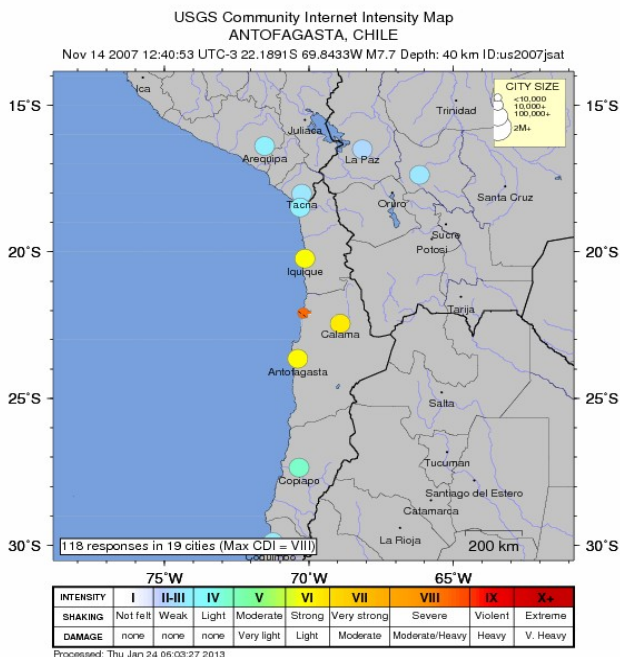


## Lab sequence 1 Workshop on Megathrust Earthquakes and Tsunami

On November 14th 2007, at 15:40:53 UTC, North Chile has been struck by a strong earthquake. We have only the intensity map given by USGS :



**Your mission :** use GPS data to better locate and understand this earthquake

### 0- Modify your environment variable to access the scripts and executables

In your home, open a terminal and type :

```
source /afs/ictp/public/shared/
```

Then

```
which tserie
```

The computer should return

```
/afs/ictp/public/shared/smr2609/tdday/sources/tserie
```

Create a directory in which you will work in your home for instance « GPS » using

```
mkdir GPS
```

You have to copy the documentation doing :

```
cp /afs/ictp/public/shared/smr2609/tdday/job.pdf .  
cp /afs/ictp/public/shared/smr2609/tdday/williams_cats.pdf .  
cp /afs/ictp/public/shared/smr2609/tdday/list_coord.txt .  
cp /afs/ictp/public/shared/smr2609/tdday/map_toco.csh .  
cp /afs/ictp/public/shared/smr2609/tdday/falla-10-48.txt .
```

Ok, now you are ready to start.

### 1- Download the time-series of continuous GPS stations of the region

3 research teams (at least) are making their processing results available on the web :

→ DT-INSU (France) : <https://gpscope.dt.insu.cnrs.fr/chantiers/chili/> clicking on each station will show the time serie. To download it click on « mb » in the left pannel.

→ Nevada Geodetic Observatory (USA) :

<http://geodesy.unr.edu/billhammond/gpsnetmap/GPSNetMap.html> clicking on each station will show the time serie. To download it, click on the time serie to access the page for each station.

Download the « IGS08 env » file and call them XXXX\_nevada.enu

→ GPS Explorer (San Diego) : you have to login to access the time-serie plotter. Useful but not so much for Chile. <http://geodemo-c.ucsd.edu:80/>

## **2- Convert them in a readable format for CATS software**

CATS documentation is available in your working directory as : williams\_cats.pdf and here <http://cyclesresearchinstitute.org/cats/index.shtml>

You have 2 scripts to do that : `mb2neu.csh` for DT-INSU coming files ; and `nevadaenu2neu.csh` for Nevada coming files.

In a terminal, in your working directory :

```
mb2neu.csh STATION_NAME
```

Will create a STATION\_NAME.neu file in the time-series/raw directory.

## **3- Draw time-series**

For each station, you can use the CATS software developed by S.Williams to evaluate the interseismic loading, seasonal signals, coseismic jumps etc... The script doing such an operation (and calling CATS) is `tserie` located in the sources directory. Type `tserie` in a terminal to get the syntaxe and help.

```
USAGE: plot_tserie -s sta [-i input_dir] [-n noise] [-o cl/ww] [-off] [-lin] [-res] [-up] [-noplot] -b
      -s          = site ID
      -i          = input directory [raw/clean]
      -n          = [w/wf/wr/wk] white only/white+flicker/white+random/white+free
index noise model [default = w]
      -o          = outliers detection criteria [default cl=1.75; ww=1 year]
      -off        = plotta serie senza offset [default offset in plot]
      -lin        = sets inversion without periodic signals [default with]
      -w          = write clean/residuals in output
      -res        = plot residuals (without model)
      -noplot     = no plot
      -b          = uses already stored cats output files
```

#### EXAMPLE

```
plot_tserie -s tori -i raw -res  
plot_tserie -s tori -i raw -n wf -o 1.75/1 -lin
```

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Start by the simple command line for each station :

```
tserie -s stat -i raw -lin -w
```

It will plot a time-serie that is probably showing a large offset at the time of the earthquake (2007.8699 in decimal years). You have to tell the program to estimate a jump there. To do so, you have to insert a line at the end of the header of the raw/STATION\_NAME.neu file saying :

```
# offset 2007.8699
```

Or any other date you think an offset has to be estimated.

To convert dates in decimal years, you can use the useful online tool from SOPAC :

<http://sopac.ucsd.edu/convertDate.shtml?indate=>

Tserie allows you to test several parameters to fit the data. You can :

- look at the residuals produced by your model `-res`
- estimate seasonal and annual simusoide signal by removing `-lin`
- remove more outliers `-o 0.5`
- make a model for cleaned time-serie (to run after first raw command) `-i clean`
- estimate flicker noise, white noise... `-n wf`

You can also exclude a time interval from the calculation by modifying the raw/STATION.neu file. For instance, if you want to remove the postseismic motion following the Tocopilla quake to better estimate the interseismic slope :

```
awk '{if ((NR>3) && ($1>2008.5)) print $0 ; else if ((NR>3) &&  
($1<2007.8)) print $0 ; else if (NR<=3) print $0}' PMEJ.neu > toto  
mv toto PMEJ.neu
```

#### **4- Gather the coseismic offsets**

Tserie creates a file that summarize all the parameters of the best-fit model in `mle/STATION_NAME*.mle` , including the amplitude of seasonal oscillations and of the offsets.

```
grep OFFSET mle/PMEJ.raw.w.mle
```

You can compare the offset values obtained with and without estimates of the seasonal oscillations.

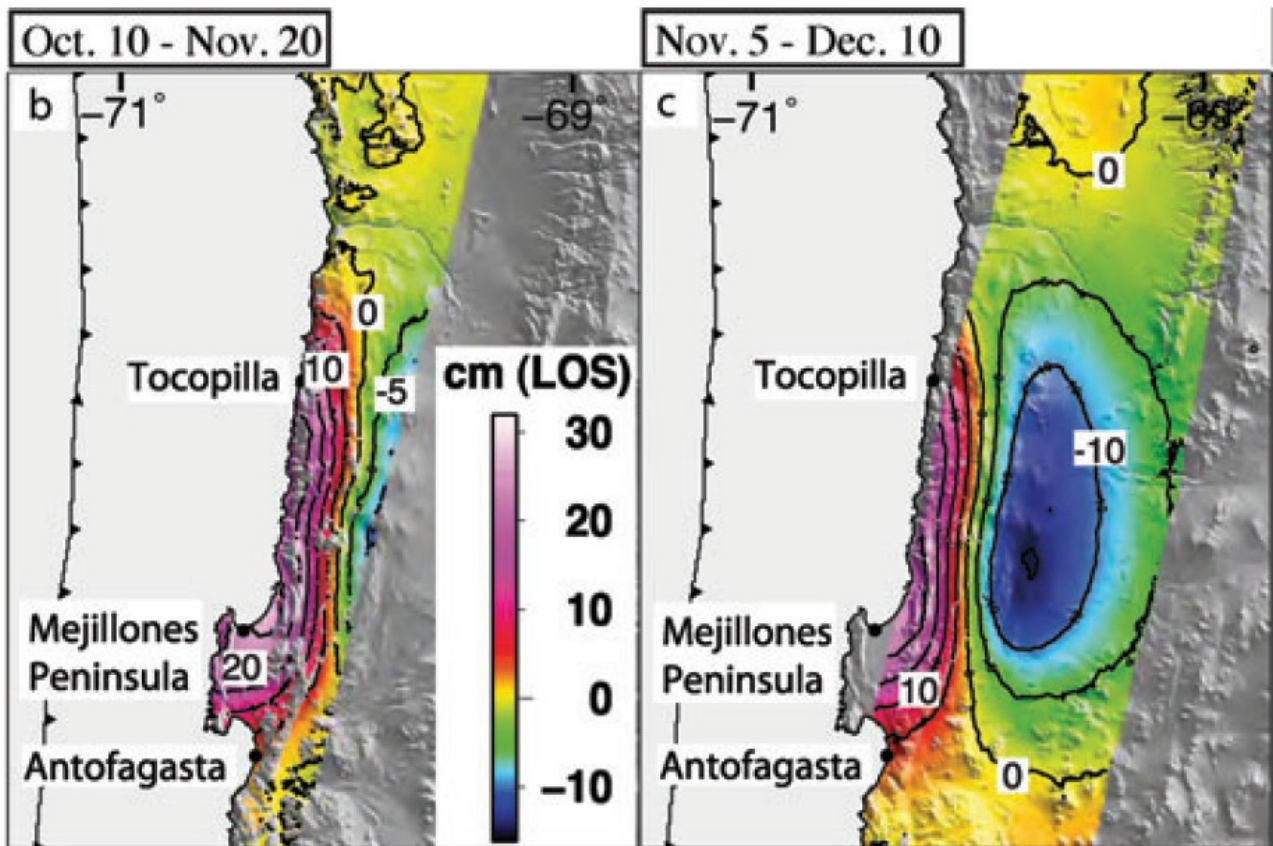
Now, you may plot this coseismic jump on a map using the script `map_toco.csh` (located in GPS)

You will have to modify the script to add the stations you are interested in or modify the scale for instance.

## 5- Interpret

Based on your findings, can you answer the following questions ?

- Where is the epicenter ?
- What is the probable depth of the earthquake ?
- How big is the expected tsunami ?
- Can you define the probable length and width of the rupture ?
- Compare your results with the InSAR map used by Bejar et al. 2011 to study the earthquake.



## 5- Have a look to the interseismic loading...

Tserie estimates the average trend over the time serie and writes it in the vel directory. Try to plot the interseismic velocities by creating a new file based on the map\_toco.csh script.

In doing so, you consider that the interseismic coupling has remained unchanged after the Tocopilla earthquake. Is it reasonable ? Do you see some differences between the trend before and after the Tocopilla quake ?

## 6- ... in the stable South American plate reference frame

The interseismic velocities determined by CATS are in the International Terrestrial Reference Frame 2008. In order to compute the velocities relative to the stable South American craton, you

have to apply to the velocities the absolute rotation pole of the South American plate. Several poles have been published :

SOAM	NNR Nuvel1A	-25.400°N	-124.60°E	0.110°/Myr
SOAM	ITRF2008	-21.306°N	-128.014°E	0.118°/Myr

In the `vel` directory, create a file `pole.neu` with the SOAM pole characteristics (N, E, °/Myr). Create a single file with all the interseismic velocities (with `cat *.w.vel` for instance) . Rotate them using :

```
eulerofit -v your_velo_file -p2 pole.neu
```

The rotated velocities will be in the file `rescalc.out`.