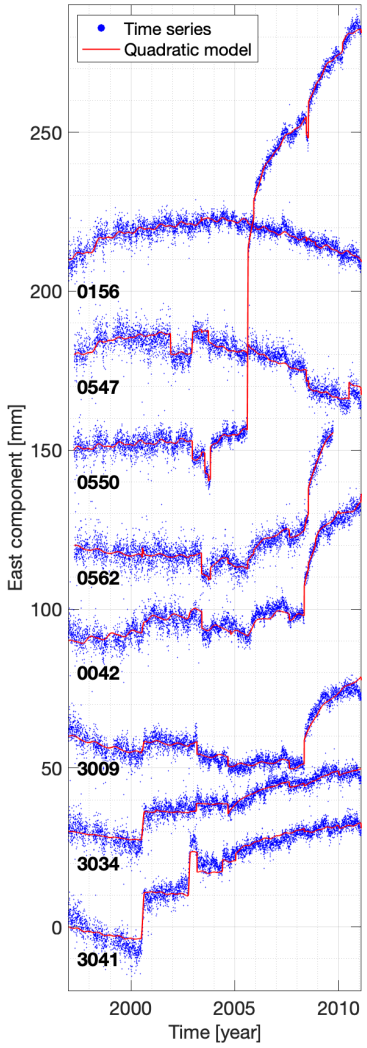
Analyzing GNSS time series with ITSA - Lab



Anne Socquet

Corinth school on strain mapping
2024/10/22

Geo-iNQUIRE

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Institut des Sciences de la Terre

ITSA
(ISTerre Time Series Analysis)

A trajectory model for GNSS time series, designed for regional networks analysis.

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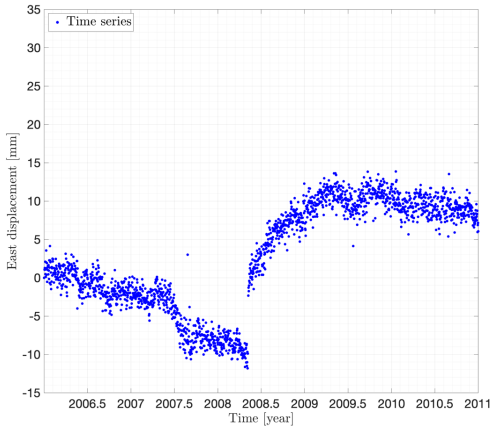
A. Socquet, M Radiguet

https://gricad-gitlab.univ-grenoble-alpes.fr/isterre-cycle/itsa

Objective



- GNSS time series contains a lot of mixed signals:

    - tectonic signals: interseismic motion, co-seismic, post-seismic, slow slip
    - seasonnal signals (local and/or regional hydrological loadings, other effects)
    - equipments maintenance (change in GNSS antenna, …)
    - common modes
    - noise
    - unkown signals

- ITSA is a parametric modeling tool for GNSS time series, designed for regional networks analysis.

- It provide a first order model of ‘’known’’ signals in the GNSS time series

- It allows to extract the amplitude of ‘’known’’ signals and/or to analyse the residuals time series to discover unkown signals

Other trajectory models (non exhaustive…)

- Standard linear trajectory model (SLTM) – dev. at OSU (Ohio State University):

Bevis, M., & Brown, A. (2014). Trajectory models and reference frames for crustal motion geodesy. Journal of Geodesy, 88(3), 283–311. https://doi.org/10.1007/s00190-013-0685-5

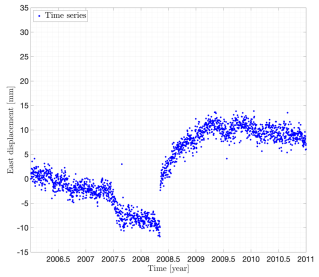
- GrAtSiD (Greedy Automatic Signal Decomposition):

Bedford, J. & Bevis, M. Greedy automatic signal decomposition and its application to daily GPS time series. J. Geophys. Res. Solid Earth 123, 6992–7003 (2018).

How does ITSA work ?

Input data

- GNSS time series



Input metadata

- Input station metadata:
  - Antenna changes
- Catalog of ''known events'':
  - Earthquake catalog
  - Slow slip event catalog
  - Swarm catalog

Model parameters

- Parametric terms to considers
- Radius of influence for earthquakes / SSEs
- Characteristic time for post-seismic relaxations

Outputs

- Model parameters
  - Amplitude of inverted parameters
- Time series (resodual, user-defined correction)
- Figures (time series, maps…)

ITSA trajectory model

- Each GNSS time series is fitted with the following equation:

Model | Inter-seismic | Seasonal variations | Antenna | Co-seismic | SSE & Swarms | Post-seismic

$$x(t) = x_R + v(t - t_R) + \sum_{k=1}^{2} [s_k \sin(2k\pi(t - t_R)) + c_k \cos(2k\pi(t - t_R))] + \sum_{a=1}^{n_A} d_A \mathrm{H}(t - t_a) + \sum_{j=1}^{n_J} b_j \mathrm{H}(t - t_j) + \sum_{s=1}^{n_S} d_s \mathrm{J}(t - t_s) + \sum_{i=1}^{n_i} a_i \log\left(1 + \frac{t - t_i}{\tau}\right)$$

Where SSE & Swarms model: $\mathrm{J}(t - t_s) = \mathrm{H}(t - t_s) \times \left(\frac{1}{2} - \frac{1}{2}\cos\left(\frac{t - t_s}{t_d}\pi\right)\right)$

- Earthquake radius of influence: $r(M_w) = 10^{(0.43M_w - 0.7)/d}$

- Trajectory model parameters are inverted independantly for each station and components using a three step strategy.

Inverted parameters

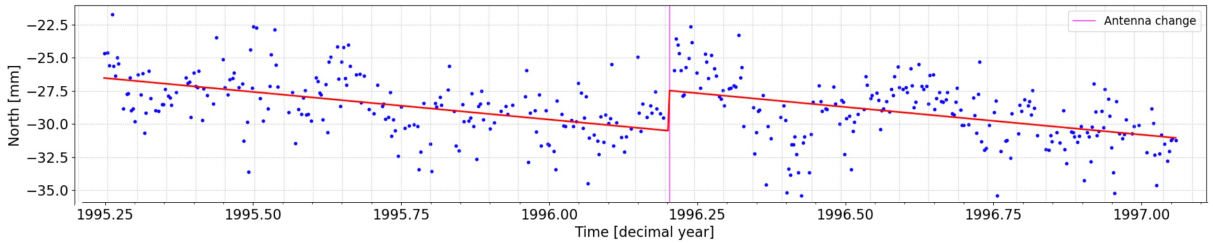
ITSA multi-step optimisation strategy

Step 1: Local optimization of the jumps (co-seismic, antenna changes) on short time windows (default = +/- 200 days):

$$x_{jump\_window}(t) = x_R + v(t - t_R) + \sum_{a=1}^{n_a} b_a \mathrm{H}(t - t_a) + \sum_{j=1}^{n_j} c_j \mathrm{H}(t - t_j) + \sum_{s=1}^{n_s} d_s \mathrm{J}(t - t_s) + \sum_{i=1}^{n_i} m_i \mathrm{H}(t - t_i) \times \log\left(1 + \frac{t - t_i}{T_R}\right)$$

Inverted

Inverted and **saved**



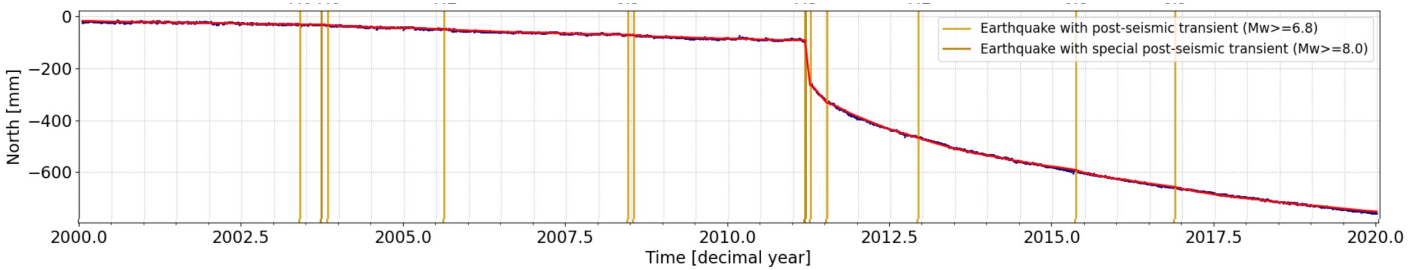
ITSA multi-step optimisation strategy

Step 2 : Optimization of the post-seismic transients
(default = +/- 2 years):

$$x_{post-seismic\_window} = x_R + v\left(t - t_R\right) + \sum_{k=1}^{2}\left[s_k \sin\left(2k\pi\left(t - t_R\right)\right) + c_k \cos\left(2k\pi\left(t - t_R\right)\right)\right]$$
$$+ m_i \mathrm{H}\left(t - t_i\right) \times \log\left(1 + \frac{t - t_i}{T_R}\right)$$

Inverted

Inverted and **saved**



ITSA multi-step optimisation strategy

Step 3 : Optimization of seasonnal and interseismic trend on the complete time series (corrected from steps 1 and 2)

$$x_{step2}(t) = x_R + v(t - t_R) + \frac{a}{2}(t - t_R)^2 + \sum_{k=1}^{2}\left[s_k \sin\left(2k\pi(t - t_R)\right) + c_k \cos\left(2k\pi(t - t_R)\right)\right]$$

Inverted and **saved**

ITSA installation guide

Anne SOCQUET

October 3, 2024

1 Introduction

This document provides a detailed, step-by-step guide on how to install the ITSA program across different operating systems (Windows, Linux, macOS) using a Docker image. It walks through the process from setting up the Docker environment to launching the training notebook in Jupyter Notebook.

NB : You may encounter issues when copying some of the commands from this document to run them in your terminal. To avoid this, a text file containing all the commands has been prepared. You can download it by clicking here.

2 Download ITSA and training notebook

The ITSA programme and its documentation (wiki) are freely available on the Université Grenoble Alpes GitLab server.

To obtain the ITSA program, you have two main methods at your disposal. Please choose the one that best suits your needs and working environment:

1. **Clone the master version from the GitLab repository**:

   If you are familiar with Git, we recommend cloning the GitLab repository directly to obtain the latest version of the ITSA program.

   To clone the GitLab repository, open a terminal and run the following command:

   ```
   git clone https://gricad-gitlab.univ-grenoble-alpes.fr/isterre-cycle/itsa.git
   ```

   This command will create a local copy of the master branch of the ITSA program in your current working directory.

2. **Download the ITSA program as a compressed archive**:

   If you prefer not to use Git or if you simply want to download a static version of the program, you can obtain a compressed archive (in .zip format) containing all the necessary files.

   To download the archive, visit the following link:

   `https://cloud.univ-grenoble-alpes.fr/s/Gy9eEcyRAL9AbKX`

   Once the file is downloaded, extract it into an appropriate directory on your system. Make sure to choose a location where you can easily access the program later.

Once you have downloaded the ITSA programme, you will need to download the notebook that we will use during this training session. To download the notebook, please click on the link below:

`https://cloud.univ-grenoble-alpes.fr/s/NPY6R8yscmJf9s7`

Once the notebook is downloaded, place it in the `ITSA` folder. If you followed Option 1 and cloned the repository, you can place the notebook directly in the cloned directory. If you followed Option 2, place it in the folder where you extracted the archive.

3 Installing Docker

Docker plays a crucial role in standardizing the installation and execution of software across various operating systems. By leveraging containers, Docker ensures that applications run consistently and reliably, regardless of the platform.

The following sections provide a concise step-by-step guide for installing Docker on Windows, Linux, and macOS. For further details, please refer to the official Docker documentation.

NB : If at the end of the installation when you run the **'docker –version'** command you get a **'daemon not running'** error, please run the client in the background (run Docker Desktop) and try again.

3.1 Windows

1. Download Docker Desktop from `https://www.docker.com/products/docker-desktop`.
2. Install Docker Desktop and ensure that WSL 2 is activated (wsl -l -v).
3. Start Docker Desktop and check the installation with the command :

```
docker --version
```

3.2 Linux

To install Docker on Linux, use the following commands:

1. Set up Docker's apt repository. See step one of Install using the apt repository.
2. Download the latest DEB package.
3. Install the package with apt as follows:

```
sudo apt-get update
sudo apt-get install ./docker-desktop-<arch>.deb
```

4. Check the installation by running :

```
docker --version
```

3.3 macOS

1. Download Docker Desktop from `https://www.docker.com/products/docker-desktop`.
2. Install and launch Docker Desktop.
3. Start Docker Desktop and check the installation with the command :

```
docker --version
```

4 Download, loading and launching the Docker Image

4.1 Download the Docker image

After successfully installing Docker and confirming its functionality, the next step is to download the Docker image of the program specifically prepared for this training and ready for immediate use. You can access the download using the link provided below.

`https://cloud.univ-grenoble-alpes.fr/s/T8fB7zEd29iQqyF`

4.2 Load the Docker image

To load a Docker image downloaded in the previous section (in the form of a `.tar` file), run the following command:

```
docker load -i <path-to-image.tar>
```

Replace `<path-to-image.tar>` with the path to your image file.

4.3 Mount the downloaded or cloned folder at launch

To mount the ITSA folder when the Docker image is launched, use the `-v` (volume) option. This is the command to use:

```
docker run -p 8888:8888 -v <itsa-path>:/app/wkdir itsa_img
```

- `<itsa-path>` : Replace with the absolute path of the cloned Git folder or the ITSA download folder on your machine.
- `/app/wkdir` : Path to the container where the file will be mounted.
- `itsa_img` : Name of the Docker image you have loaded.
- `-p 8888:8888` : maps port 8888 on the container to port 8888 on your local machine

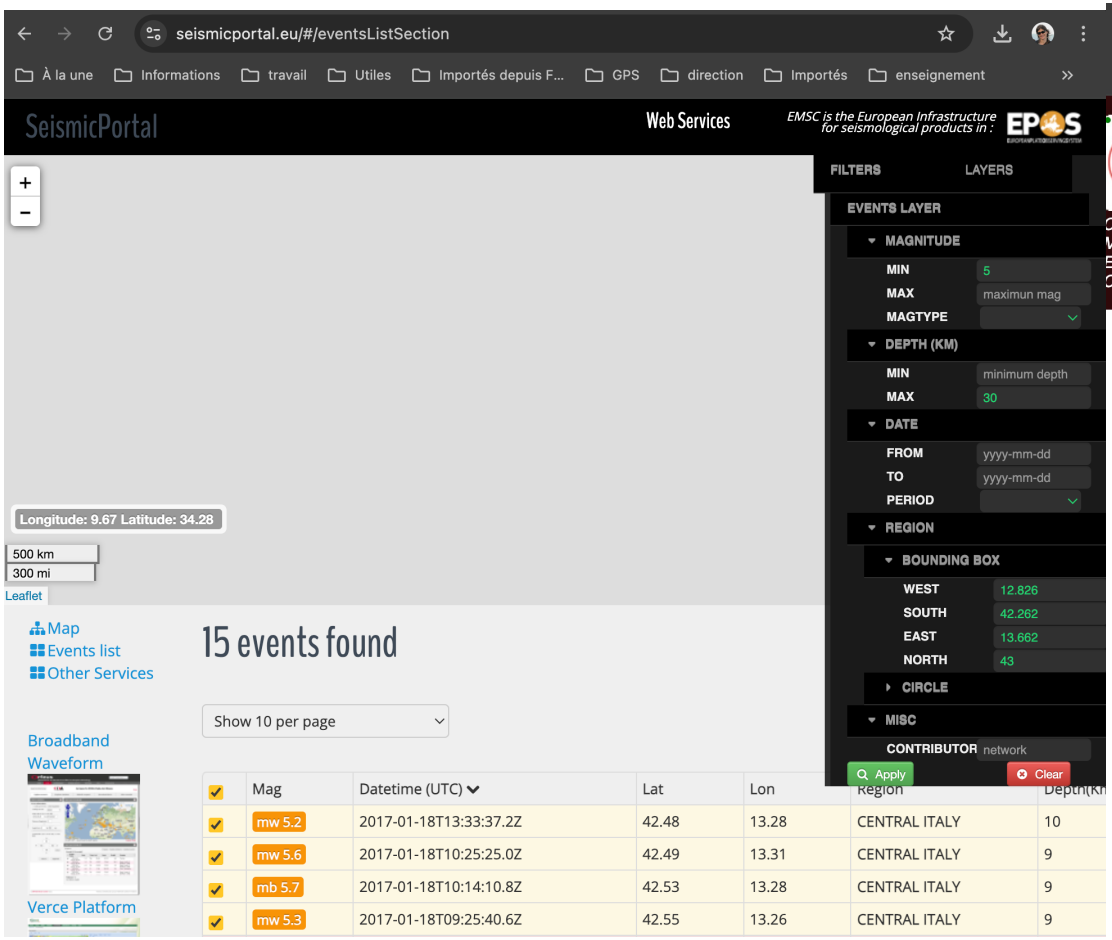
NB : If you are on a Windows system, you will need to add simple quotes to enclose the mounted directory and the docker working directory.

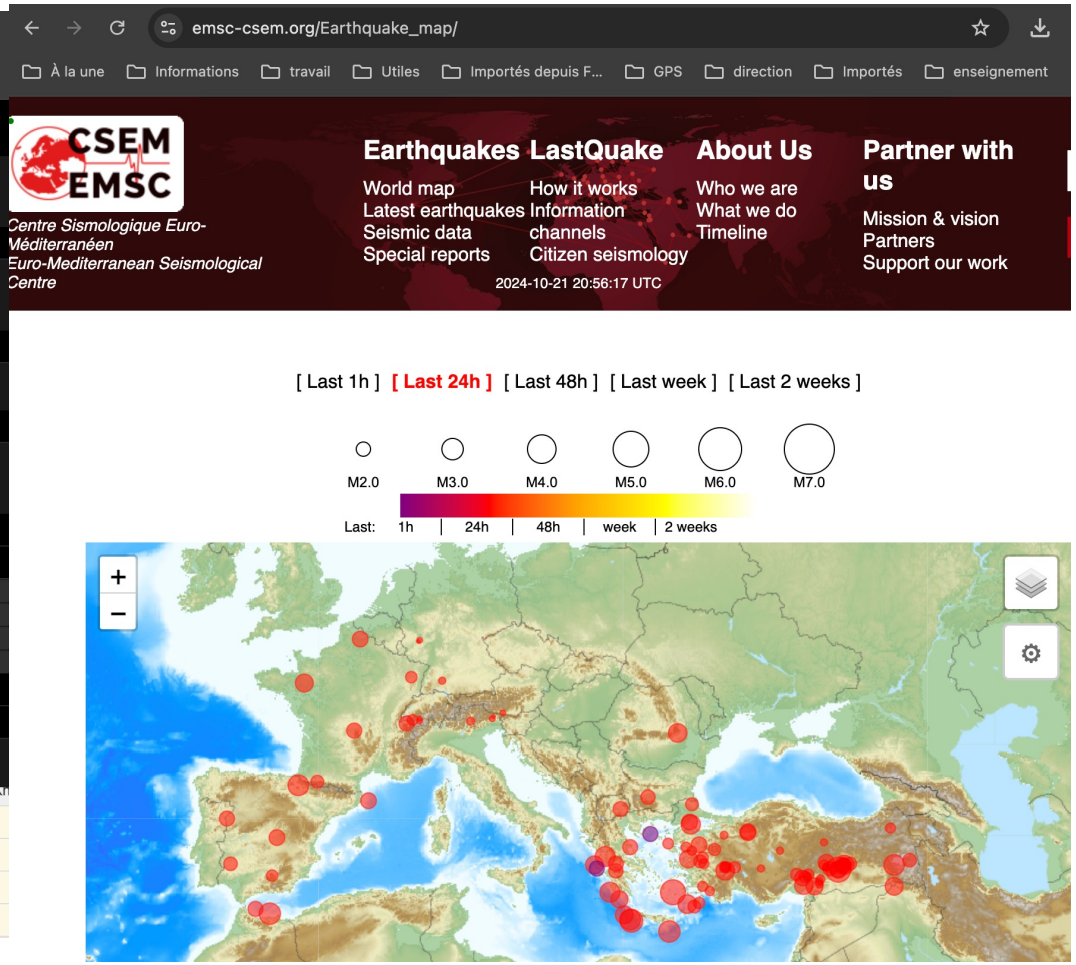
```
docker run -p 8888:8888 -v '<itsa-path>:/app/wkdir' itsa_img
```

The code executed above starts Jupyter Notebook. To proceed, please copy the second HTTP link (**http://127.0.0.1:8888/tree?token= ...**) generated by the previous command and paste it into your preferred web browser. This will allow you to access the notebook and commence the training.

1- Browse the EMSC / seismic portal

and try to find earthqakes that you may be interested in to study the central Italy sequence

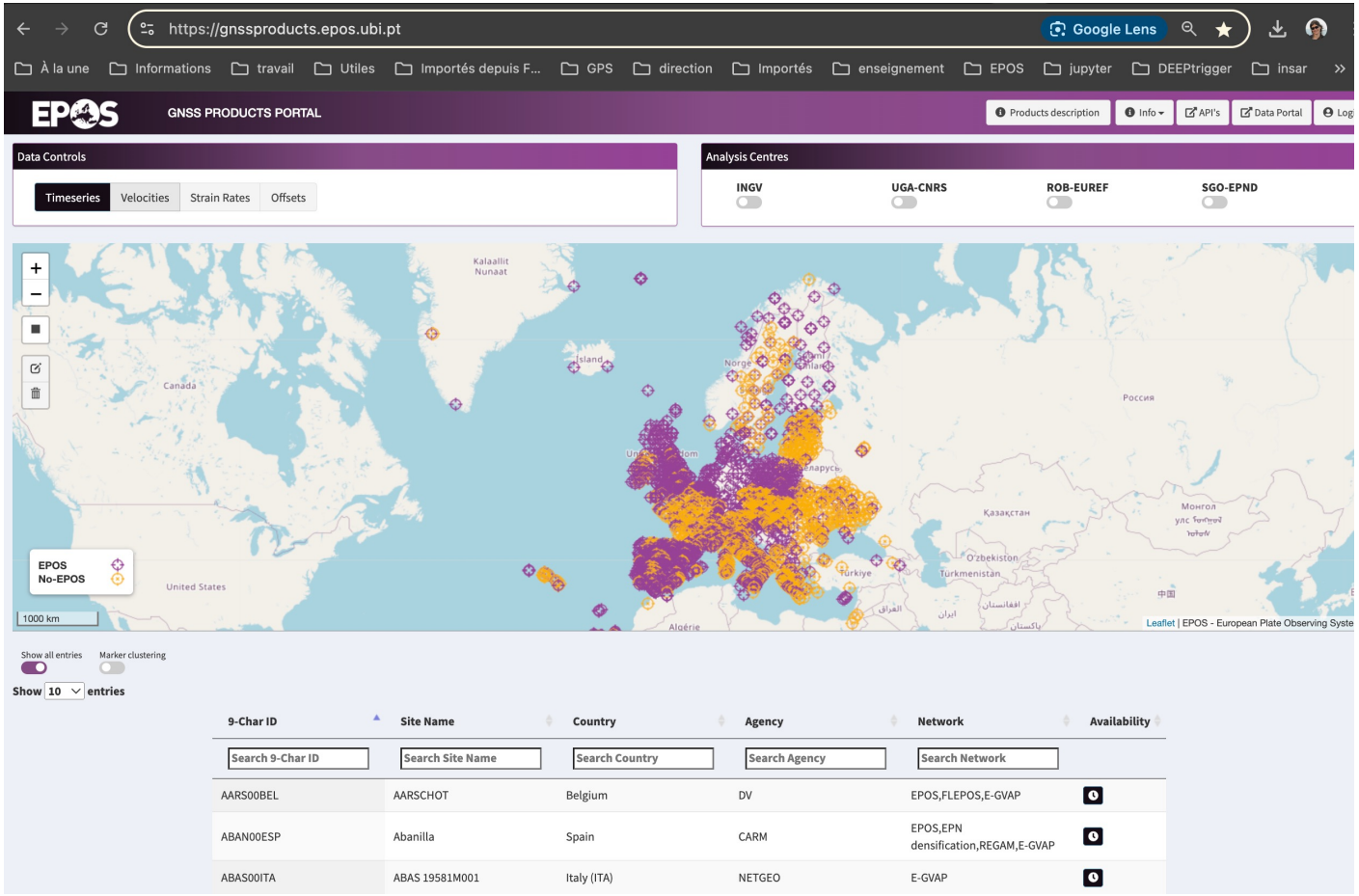




2- Browse the EPOS GNSS product portal

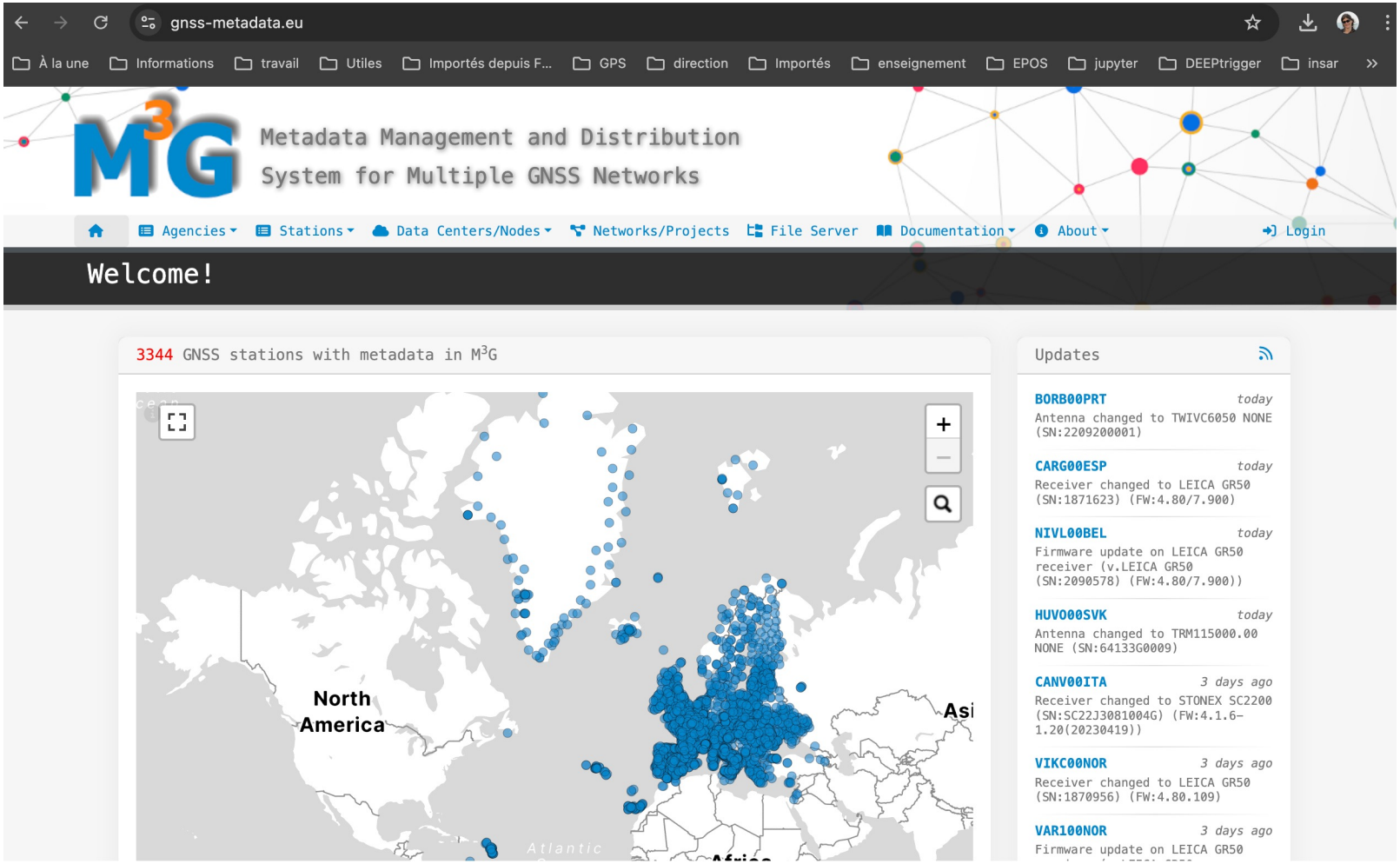
and try to find stations/data that you may be interested in to study the central Italy sequence

→ you can download time series and offset file



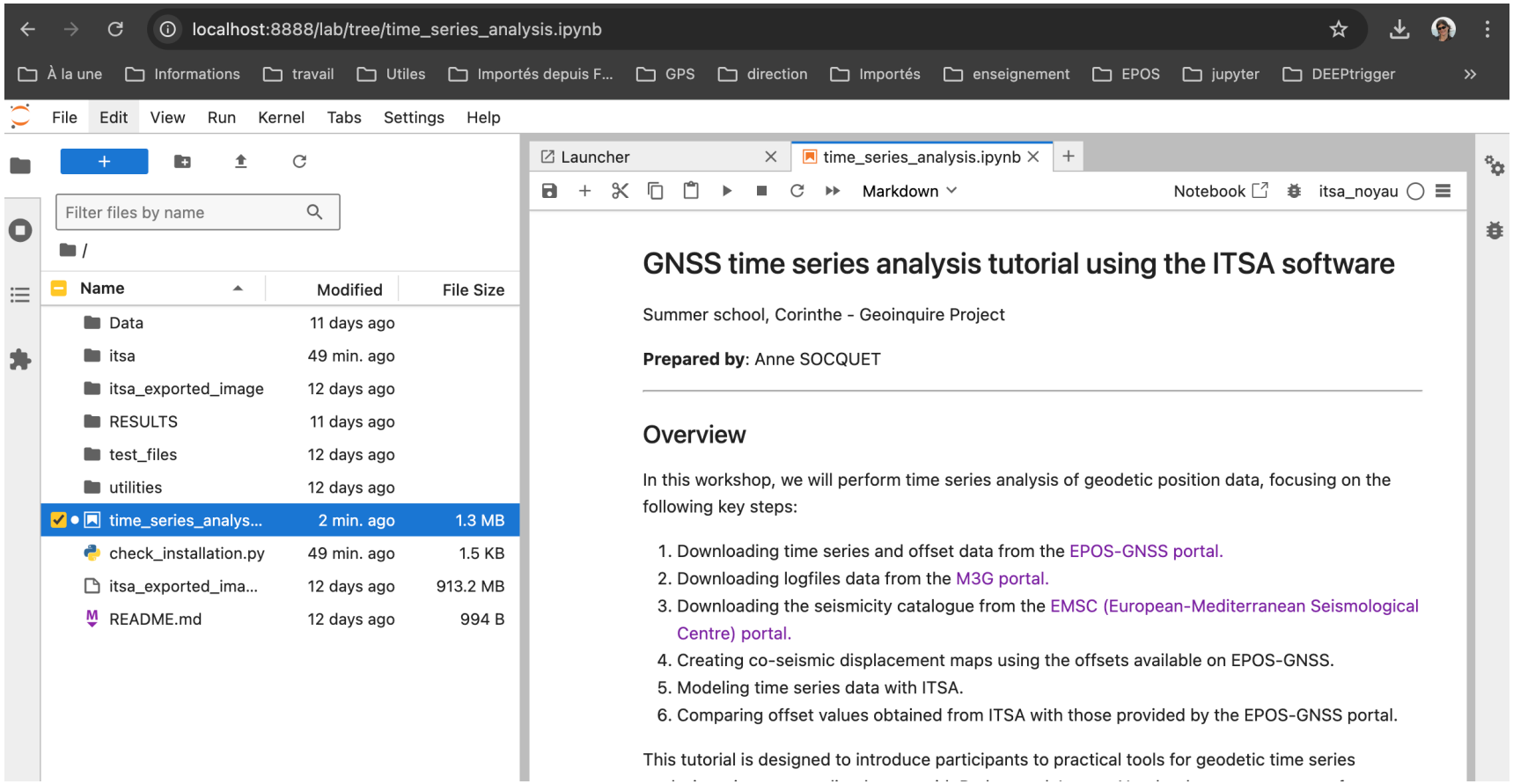
3- Browse the M3G portal

and try to find GNSS stations metadata data that you may be interested in

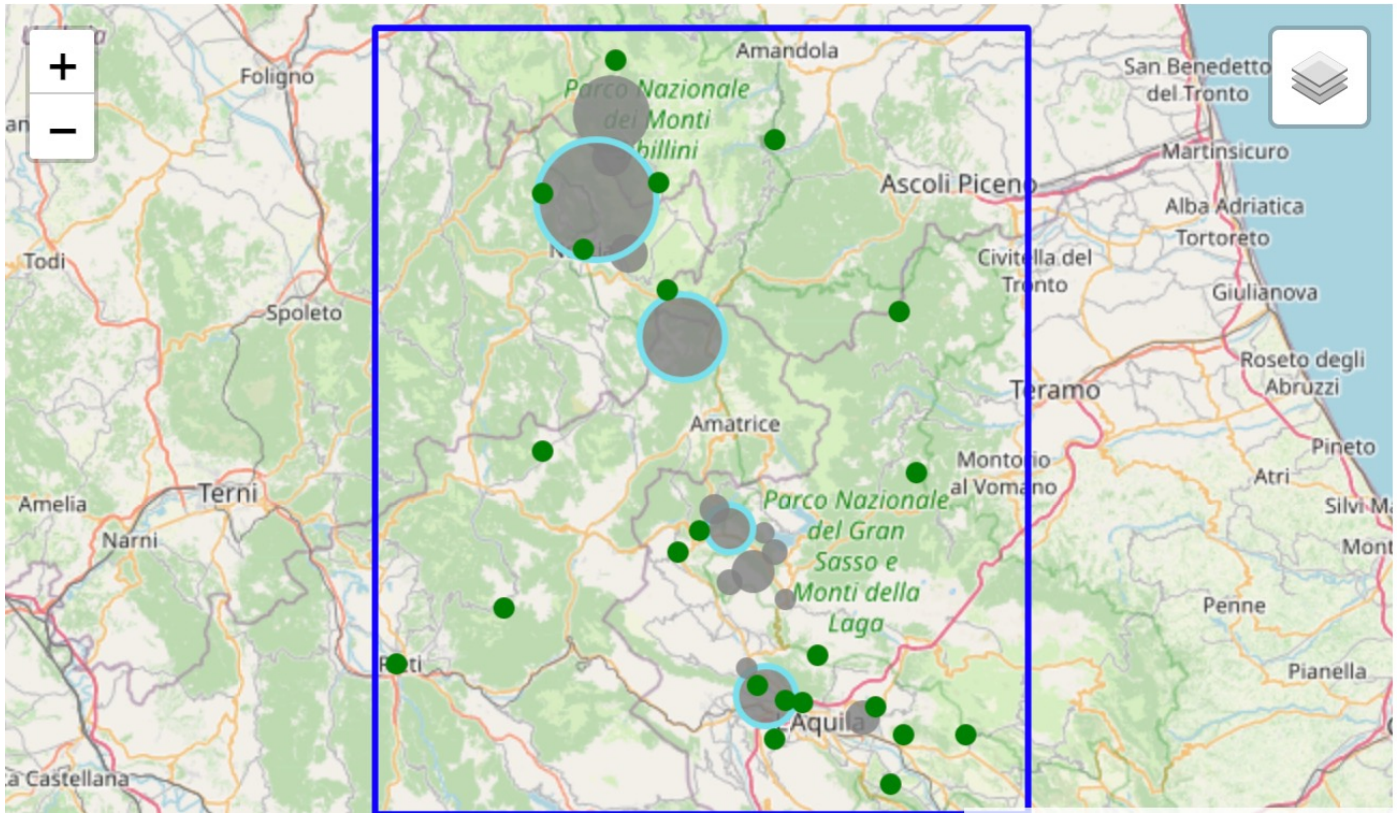


4- Do this automaticaly

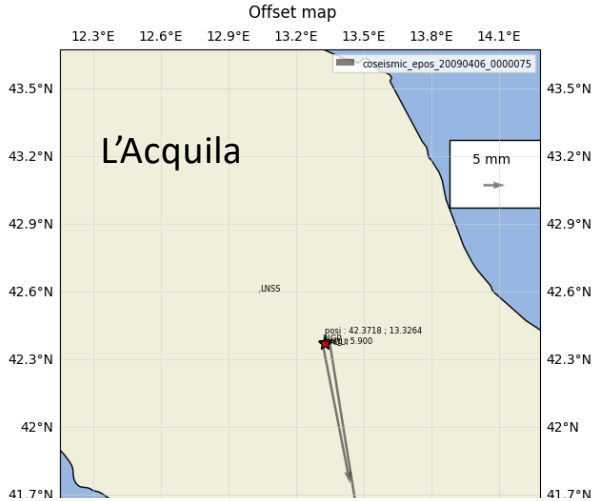
run the time series analysis and plot some results, run the Jupyter notebook under docker

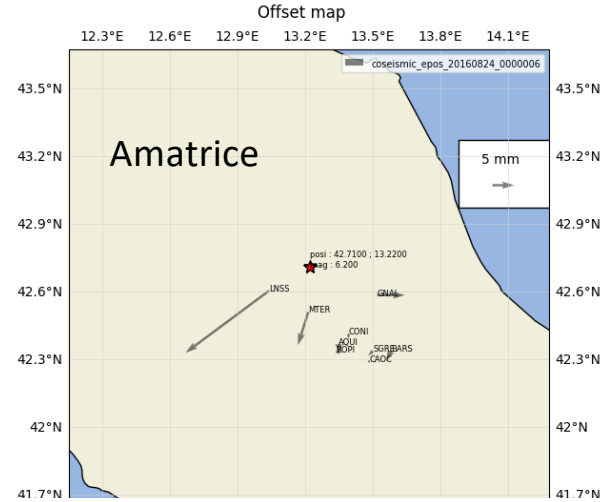


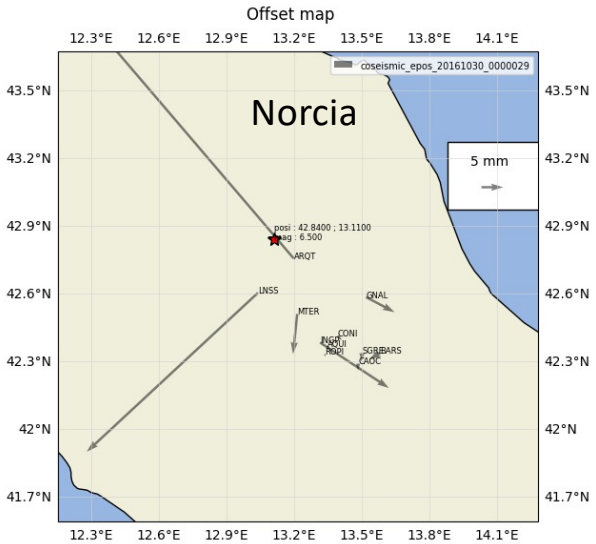
5- Display earthquakes and seismic stations

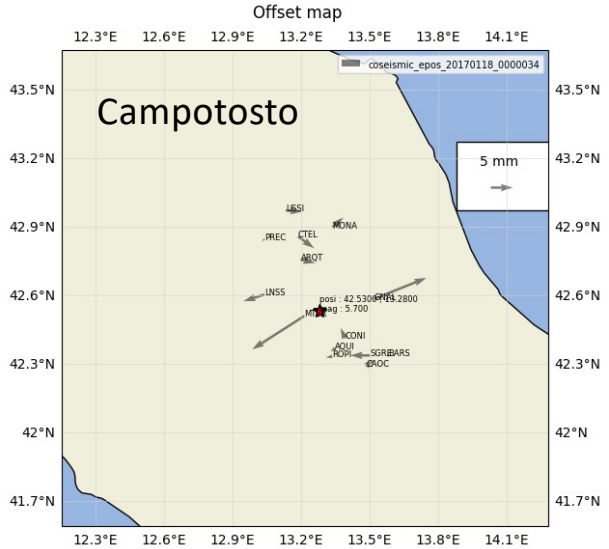


6- Display offset products (previously downloaded from EPOS portal)









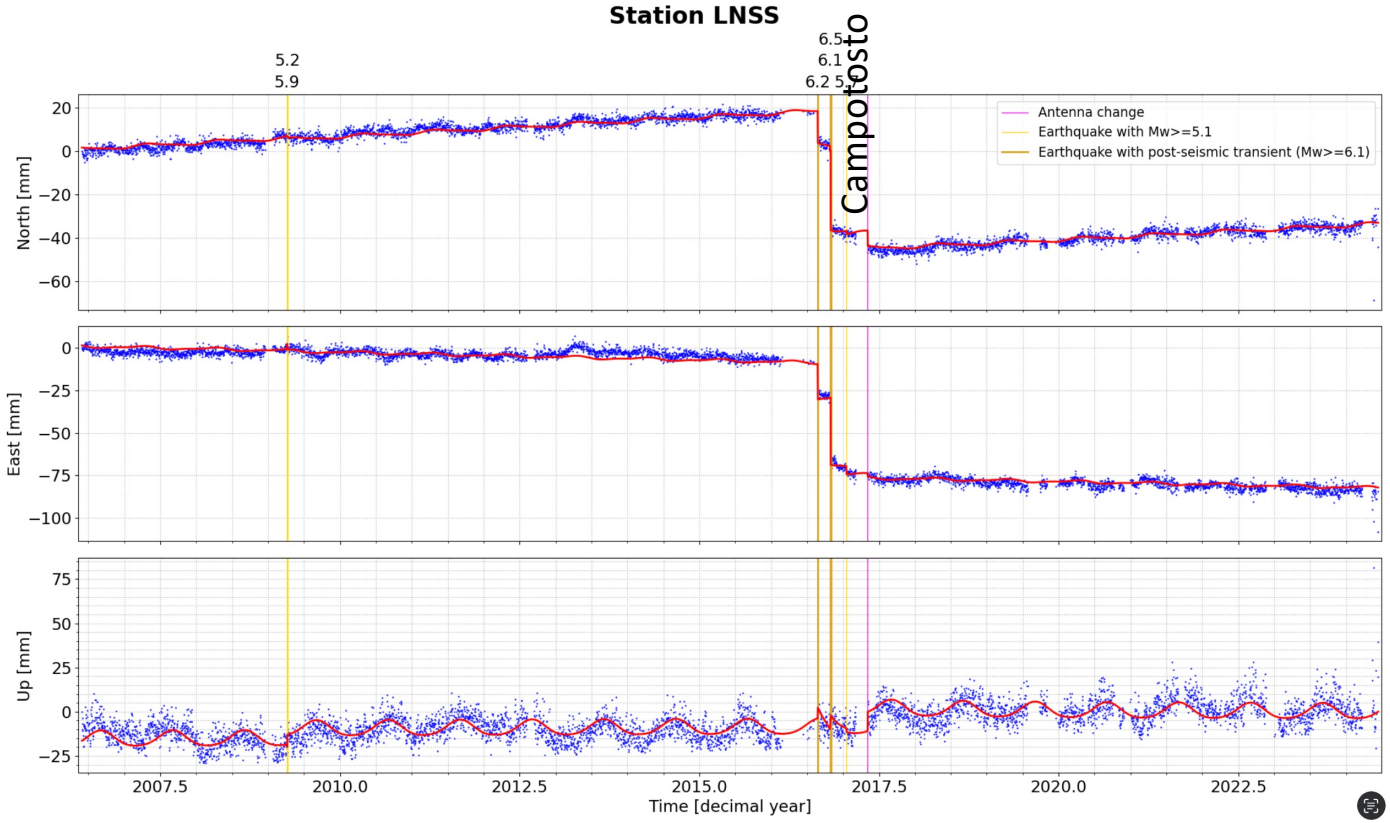
More and more data:

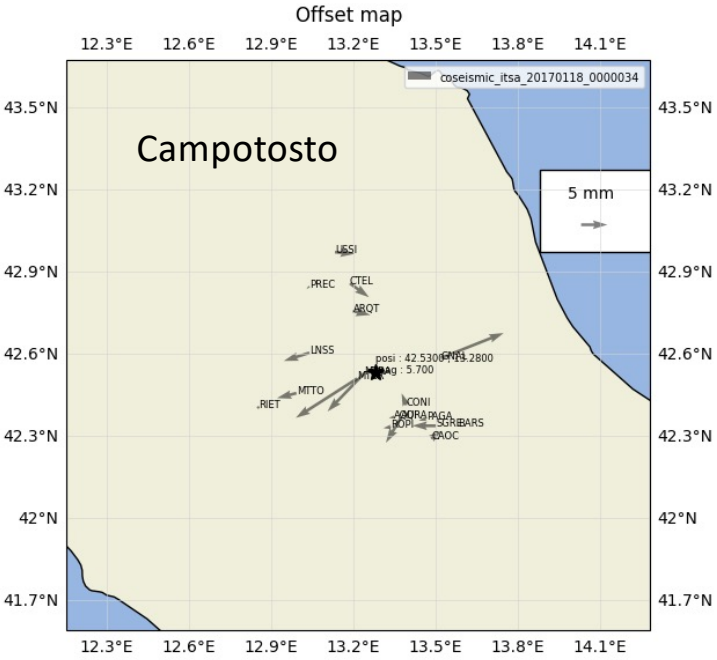
Field engineers and researchers are working!!!

Do you want to do a more detailed analysis…?

7- Model the time series with ITSA and visualize the results

using previously downloaded time series / metadata / earthquake info
(browse the RESULTS directory & plot the map)



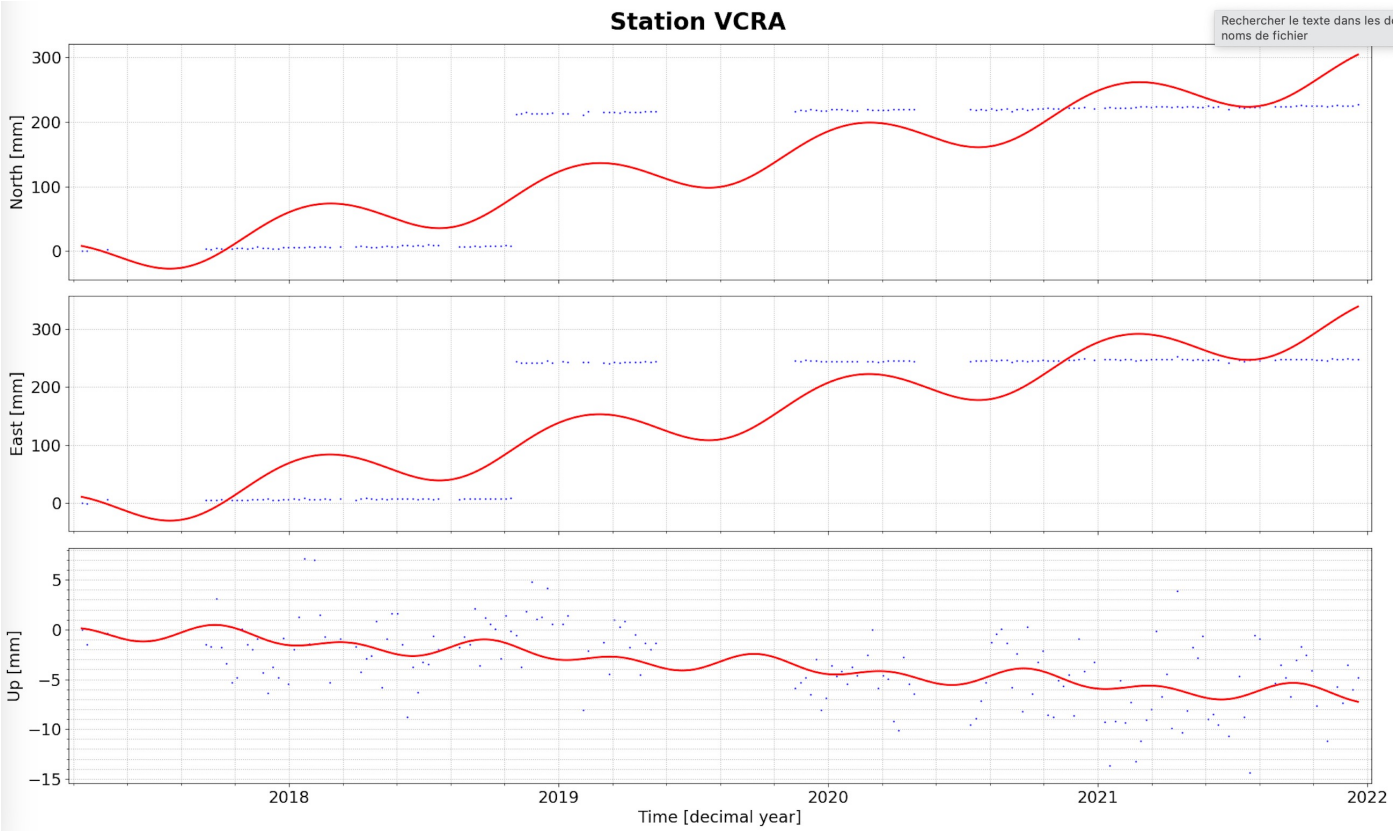


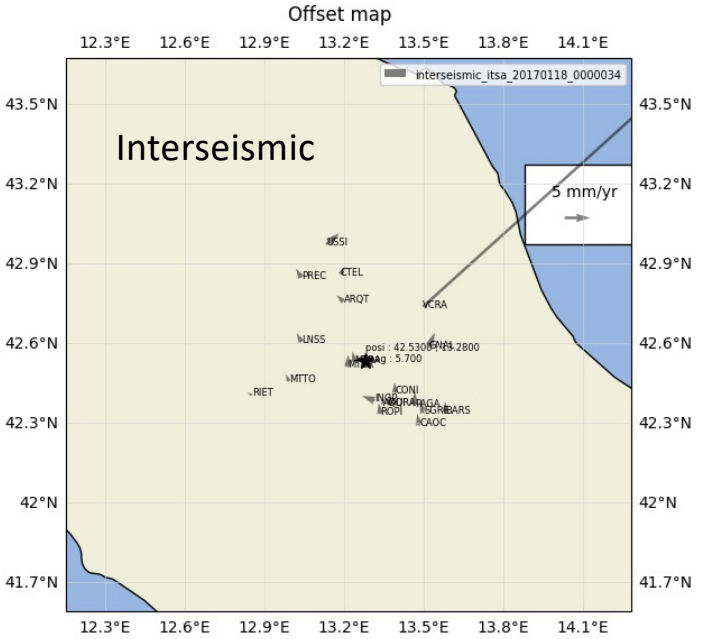
Do you really want to do a more detailed analysis…?

8- Be skeptical (Compare different results)

VRCA is an outlier

Not an EPOS station, so metadata are not checked…





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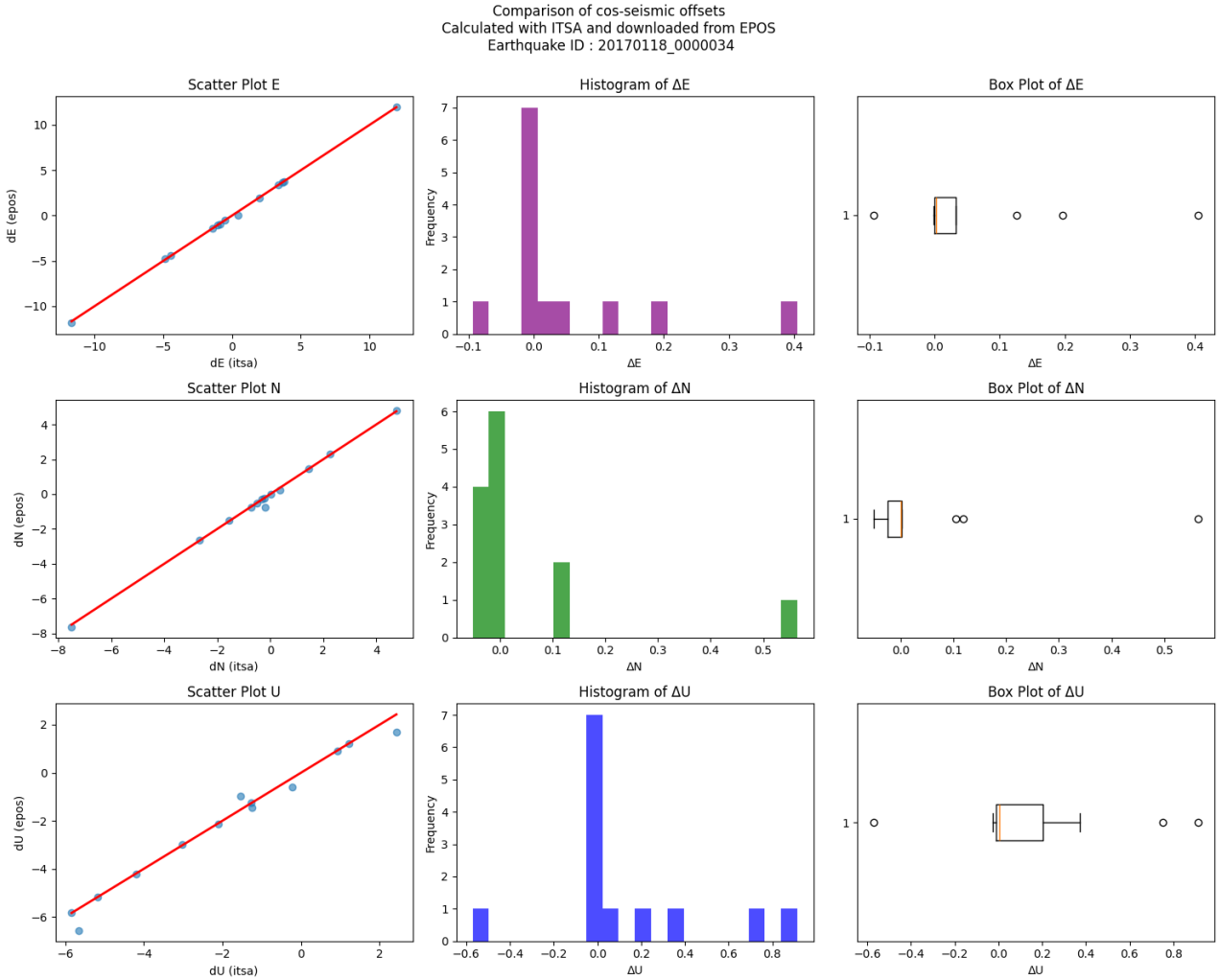

Do you really want to do a more detailed analysis…?

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