



Royal Observatory of Belgium

ORFEUS Coordination Meeting

Bucharest

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Monitoring with Seismic Noise

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MSNoise in Brief

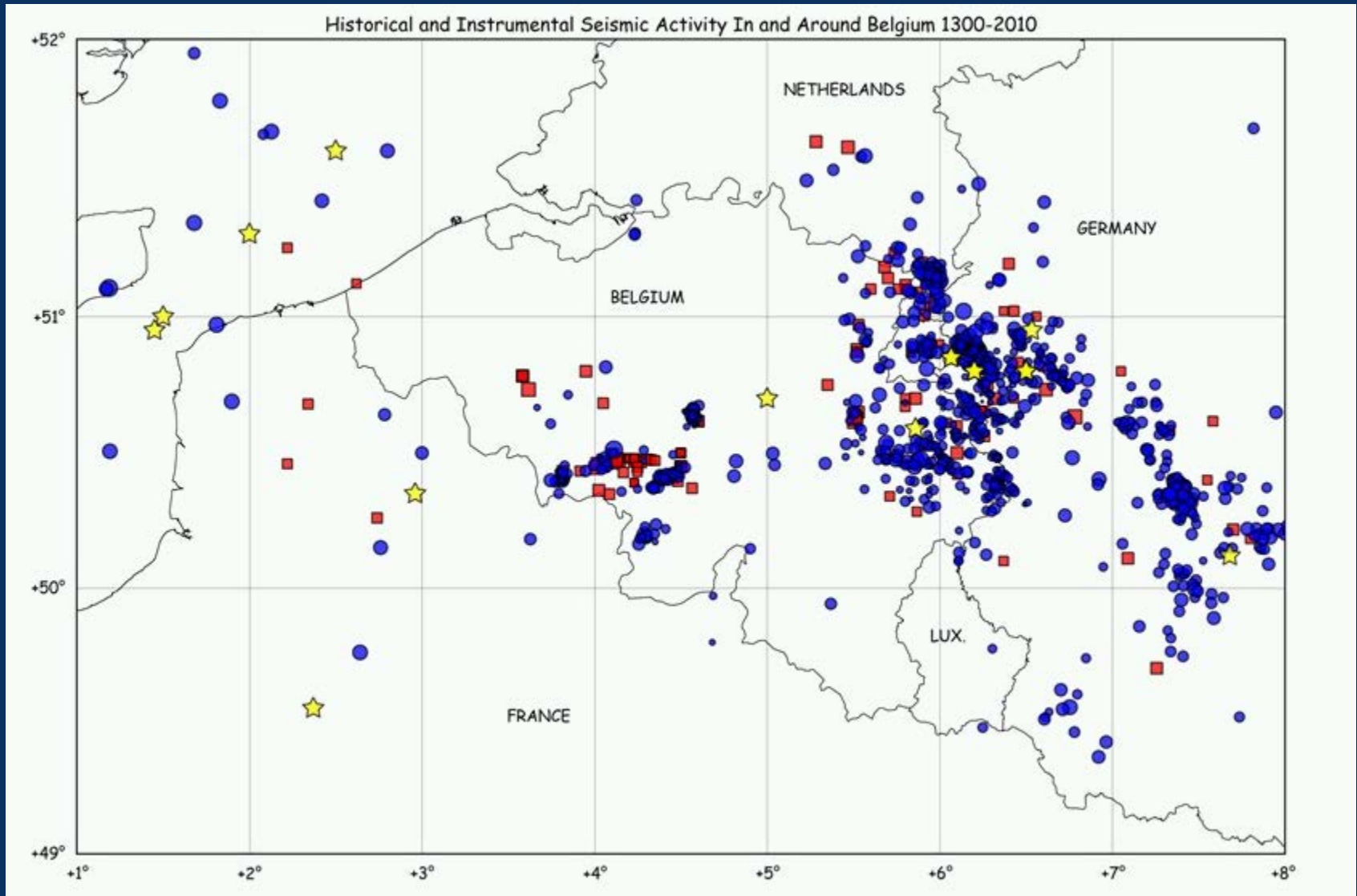
- Python Package
- Based on existing data archive
- Uses ObsPy
- Uses SoA python modules (statsmodels, etc)
- No need to know Python (would help though)
- Documented
- Tested (somehow)
- Help available – GitHub & Mailing list
- Example of Research codes → Operational

MSNoise in Brief 2

- Install & configure SeisComP3
- Acquire data in real time
- Install Anaconda (that is Python)
- Install MSNoise
- Configure (few) parameters
- Run the workflow
- Enjoy

Seismologists in Belgium, uh?

Seismic Activity



Infrastructure at risk



Today

Intro

①

Monitoring

③

Coffee Break

⑤

②

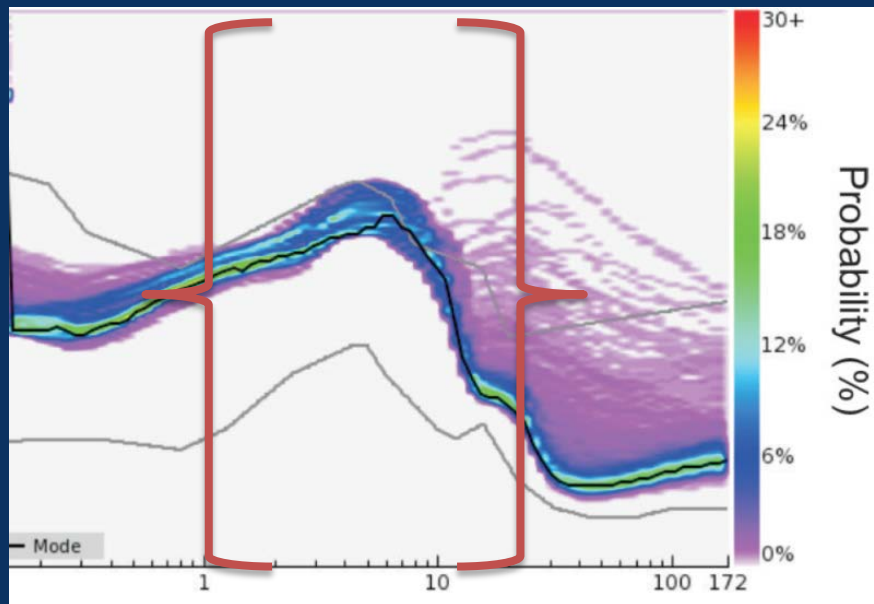
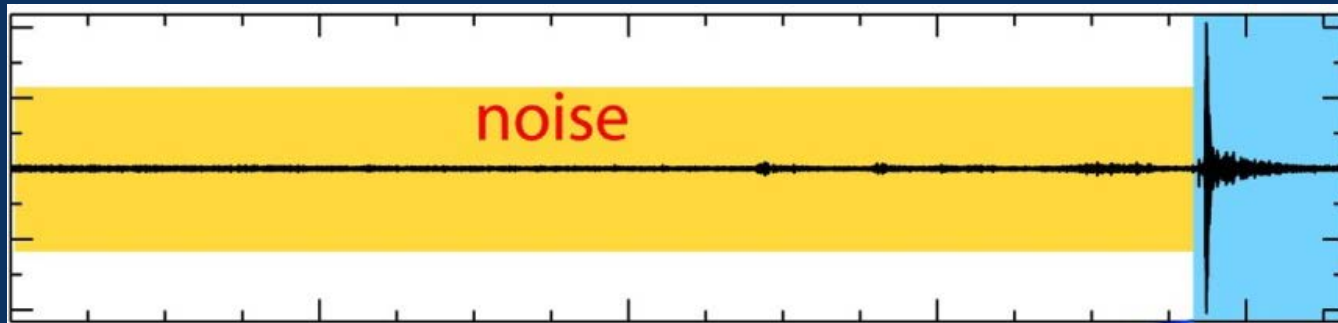
Noise ?

④

R.C.R.

Noise?

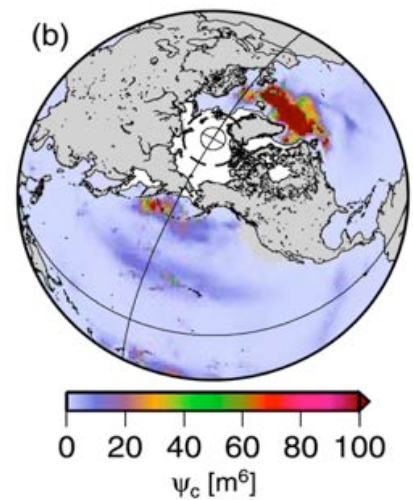
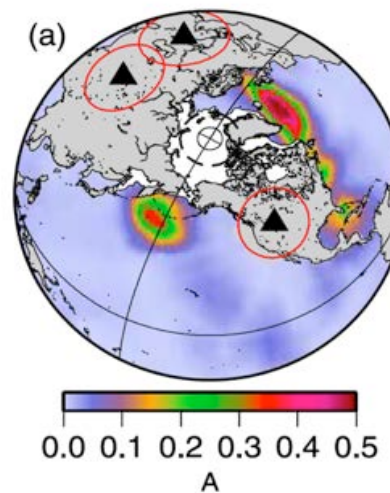
[20-1] s



period (s)

seismological observations

oceanographic modeling



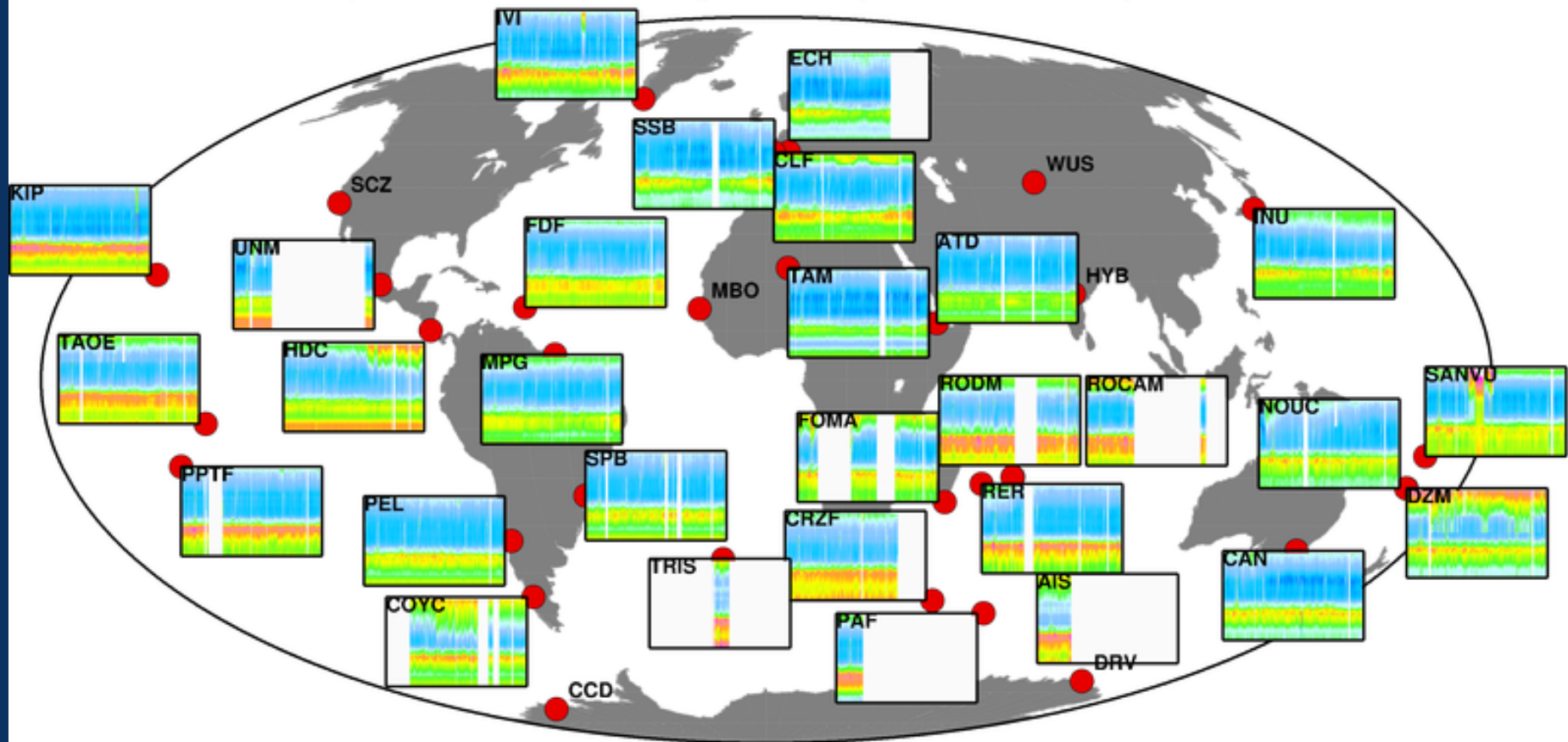
Hillers et al., 2012

Why Noise @ ROB?



Noise: Always present but...

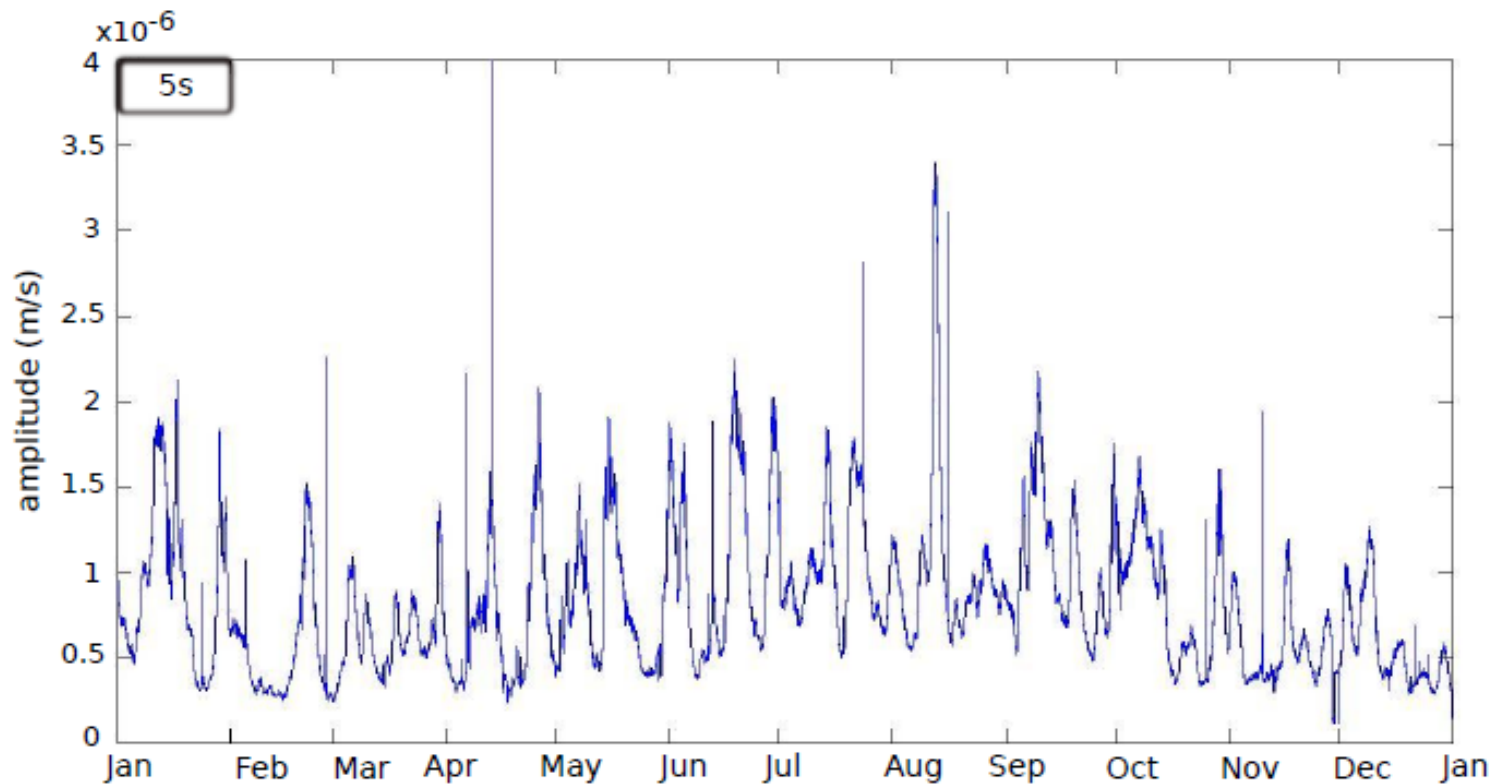
Z component seismic signal daily variation in year 2013



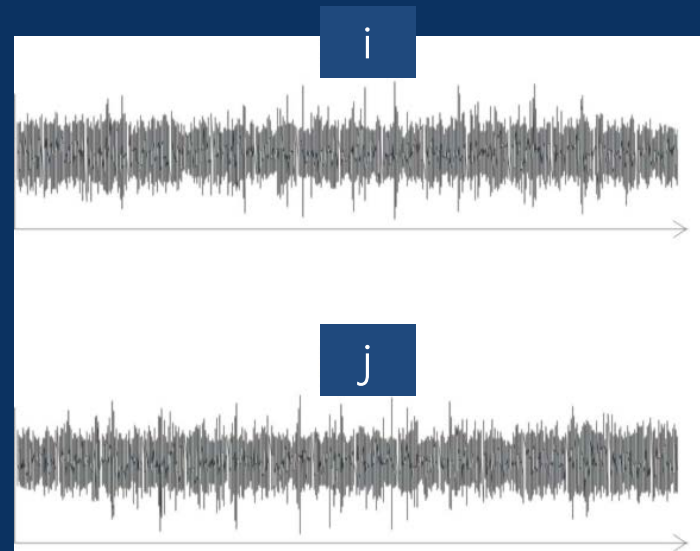
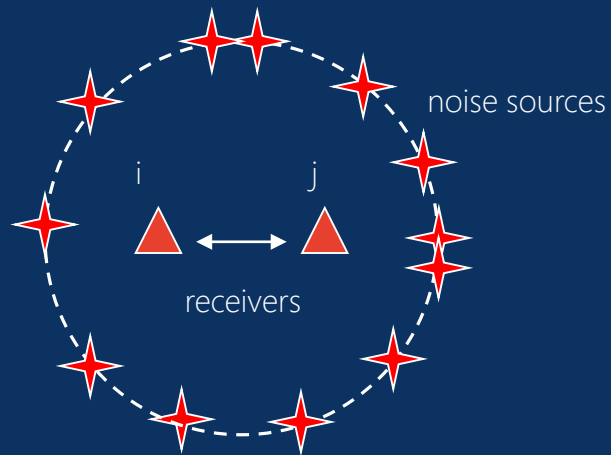
GMT 2014 Jul 3 13:39:42

Ambient seismic noise ([20-1] s)

Temporal changes in amplitude and azimuths



Extracting coherent waveforms from noise



Extracting coherent waveforms from noise

Extraction of Green's functions from correlations of seismic noise

$$\frac{d}{d\tau} C(\tau, \vec{r}_A, \vec{r}_B) = \frac{-\sigma^2}{4a} (G_a(\tau, \vec{r}_A, \vec{r}_B) - G_a(-\tau, \vec{r}_A, \vec{r}_B))$$

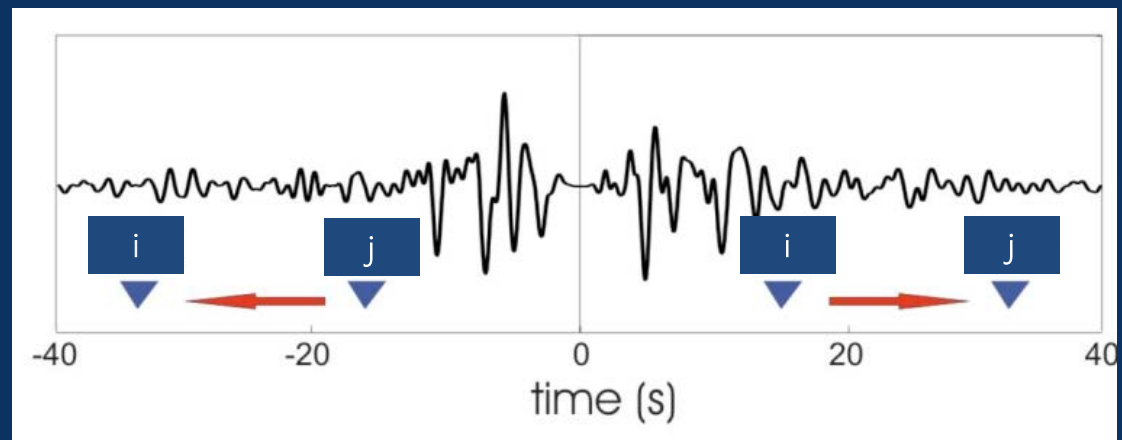
Campillo, 2006

Virtual source

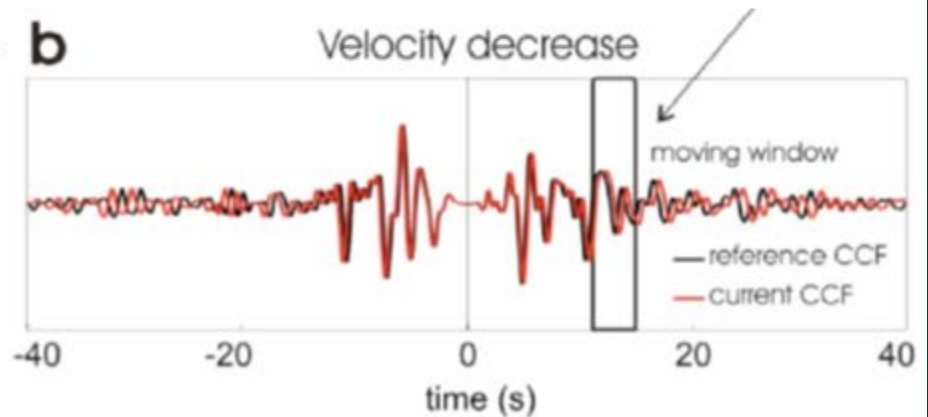
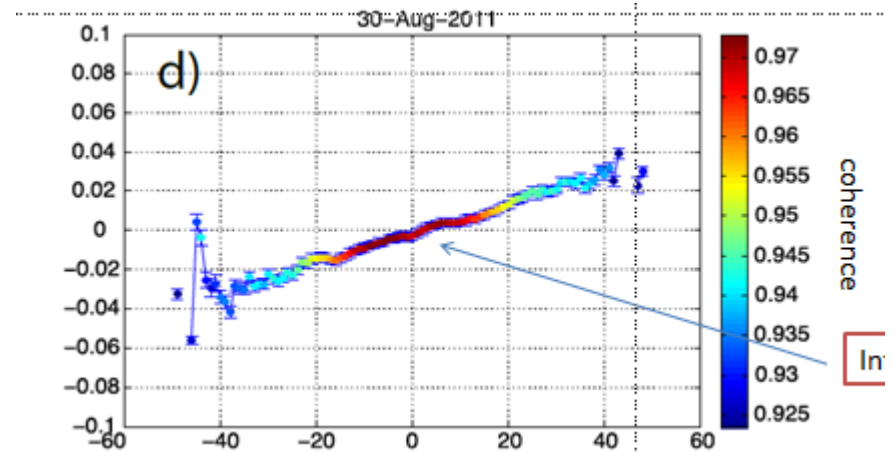
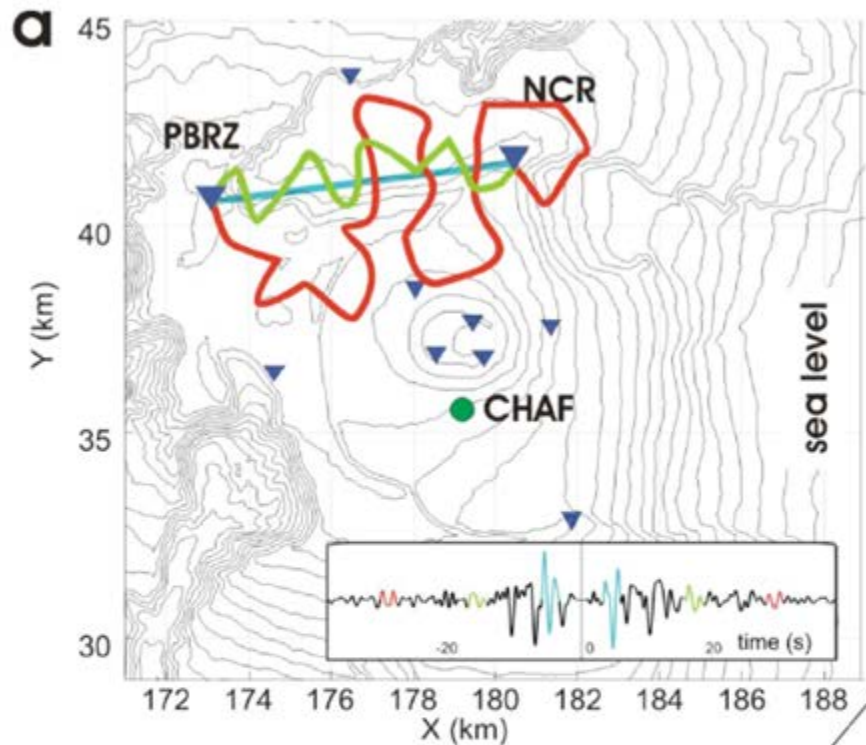


$$G_{ij} = \begin{pmatrix} Z_i Z_j & Z_i R_j & Z_i T_j \\ R_i Z_j & R_i R_j & R_i T_j \\ T_i Z_j & T_i R_j & T_i T_j \end{pmatrix}$$

receiver



dv/v from noise



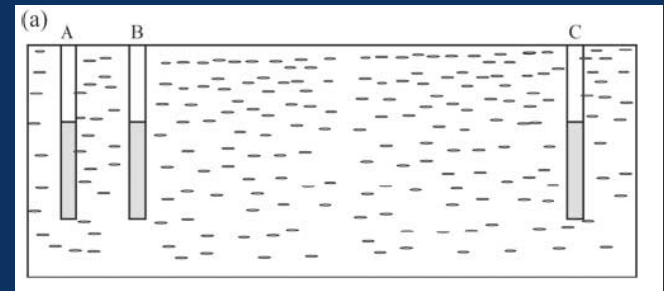
Monitoring with Seismic Noise

Using ambient noise cross-correlation

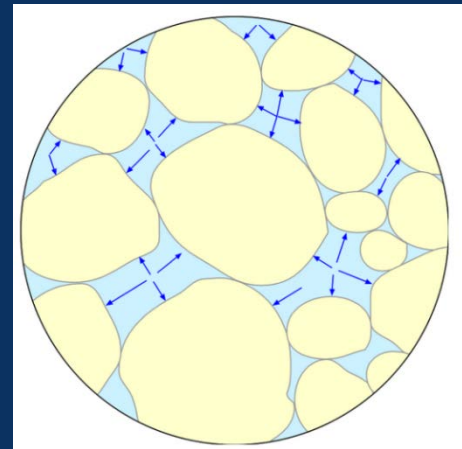
Measured Seismic V Changes

Crustal seismic velocity changes can be due to:

- Air pressure changes (Silver et al. *BSSA*, 2007)



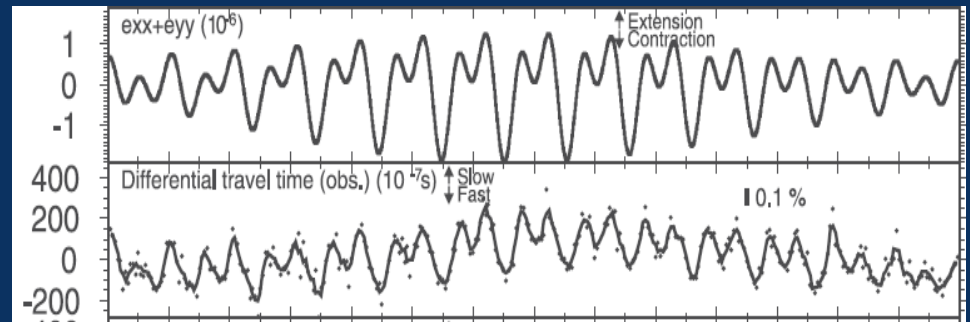
- Rainfall (Hillers et al. *EPSL*, 2014)



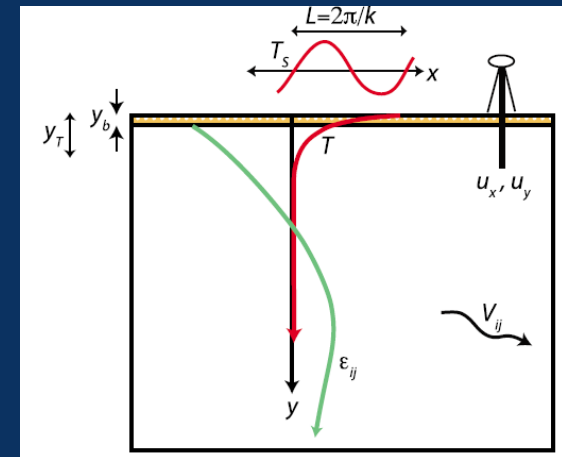
Measured Seismic V Changes

Crustal seismic velocity changes can be due to:

- Tides (Yamamura et al. *JGR*, 2003)



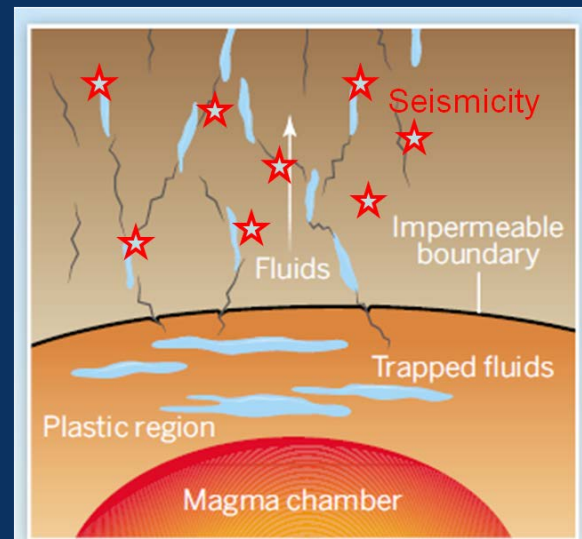
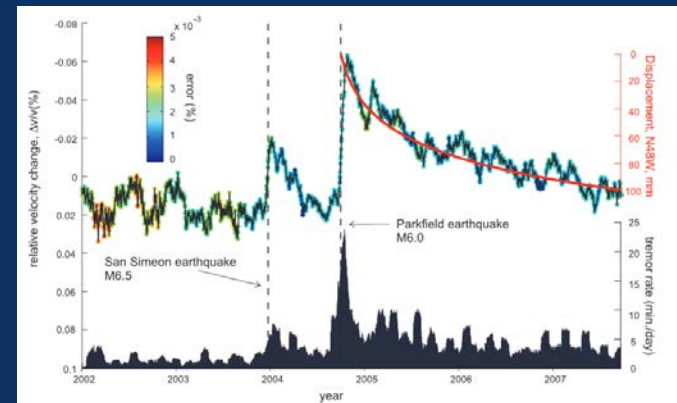
- Air temperature changes (Tsai *JGR*, 2011)



Measured Seismic V Changes

Crustal seismic velocity changes can be due to:

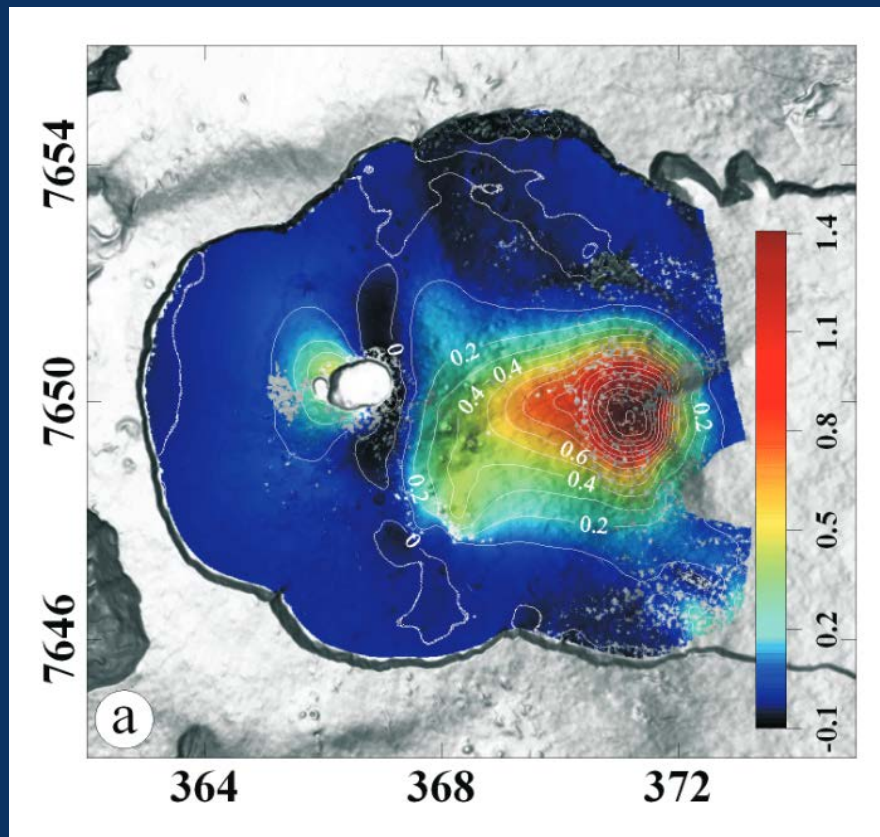
- Seismic waves
(Brenguier et al. *Science*, 2008)
- Volcanic eruption preparation
(Brenguier et al. *Nature Geosc.*, 2008)



Measured Seismic V Changes

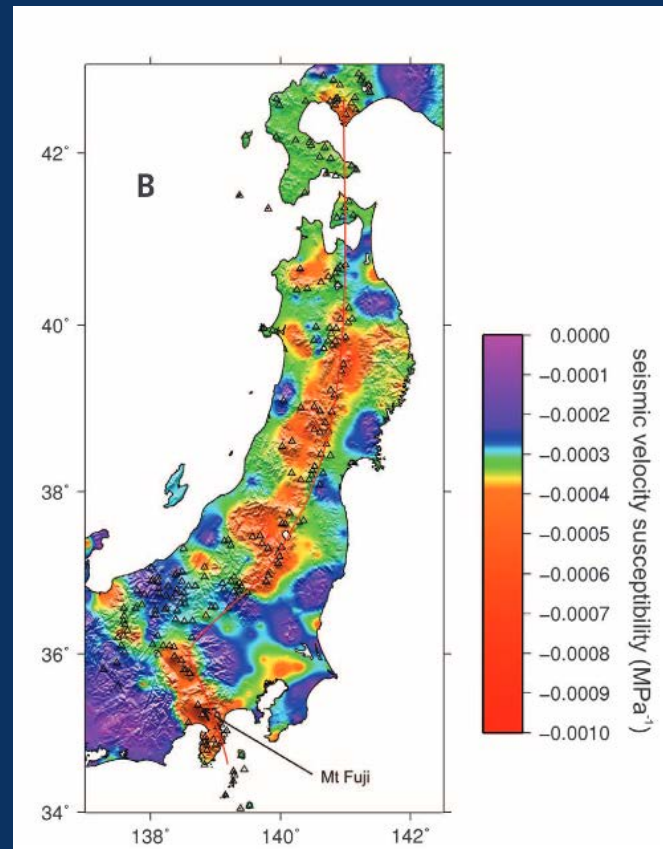
Crustal seismic velocity changes can be due to:

- Slope movements (Clarke et al. *GJI*, 2013)



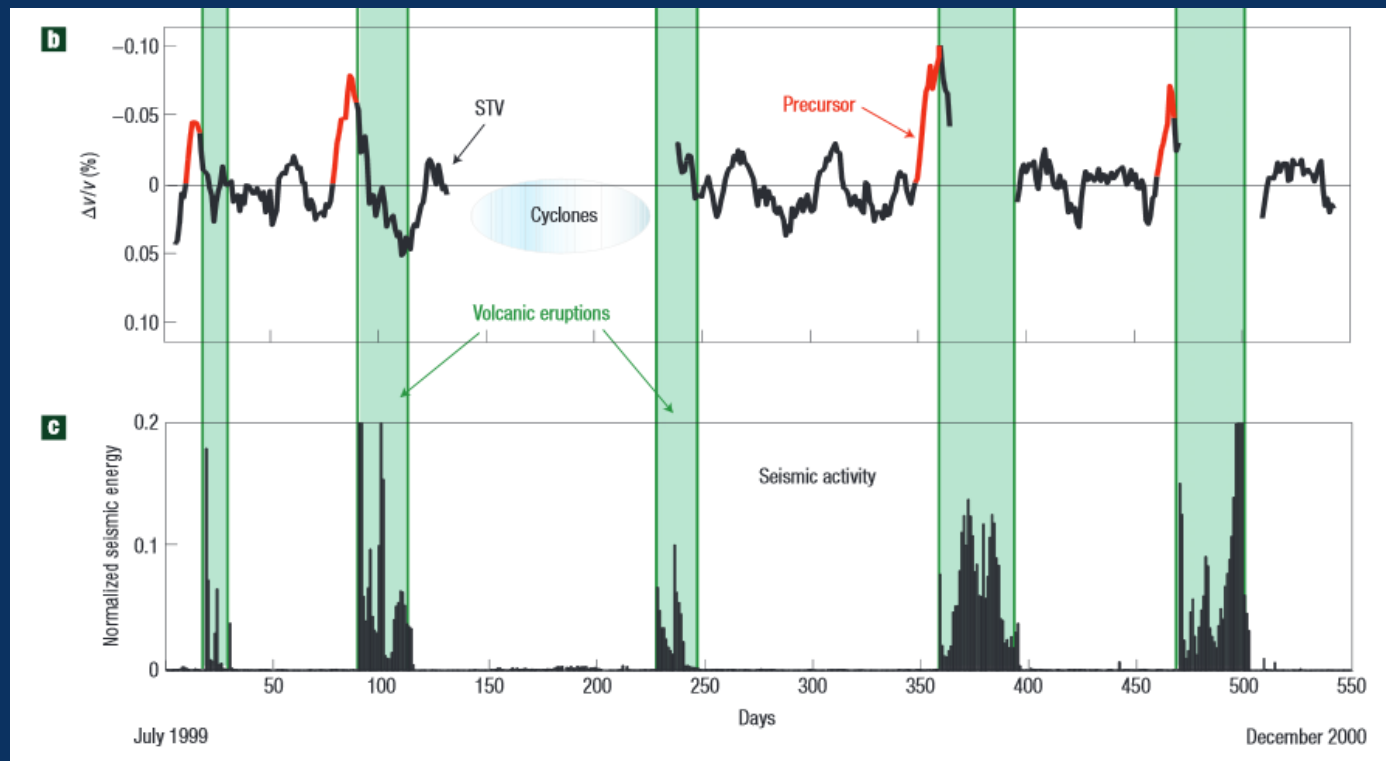
What it is useful for?

Studying the response of the crust to seismic shaking
(Brenugier et al. *Science*, 2014):



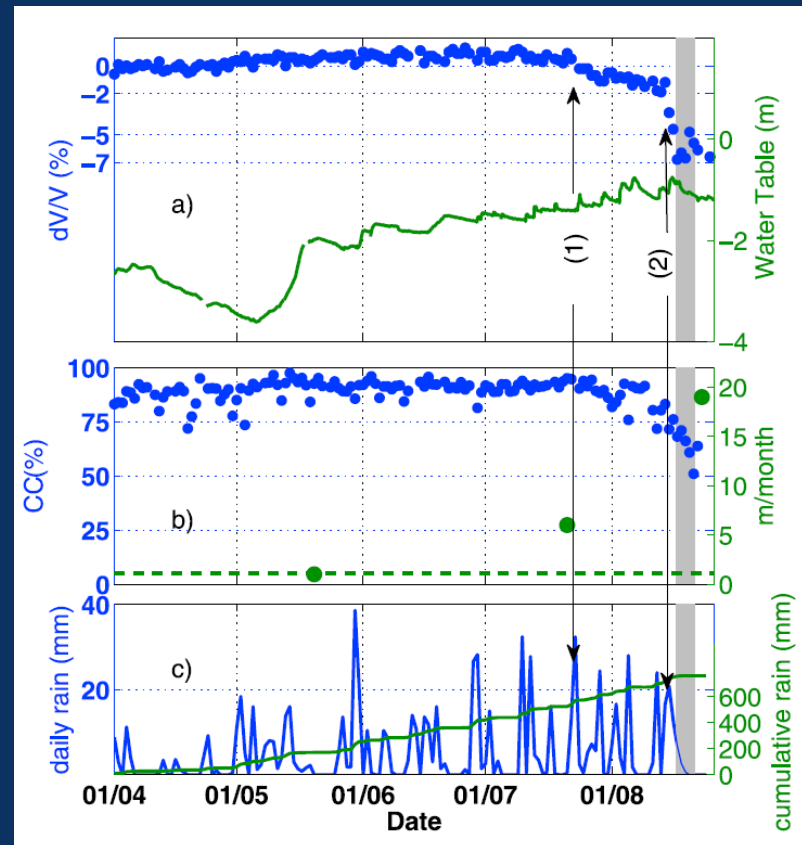
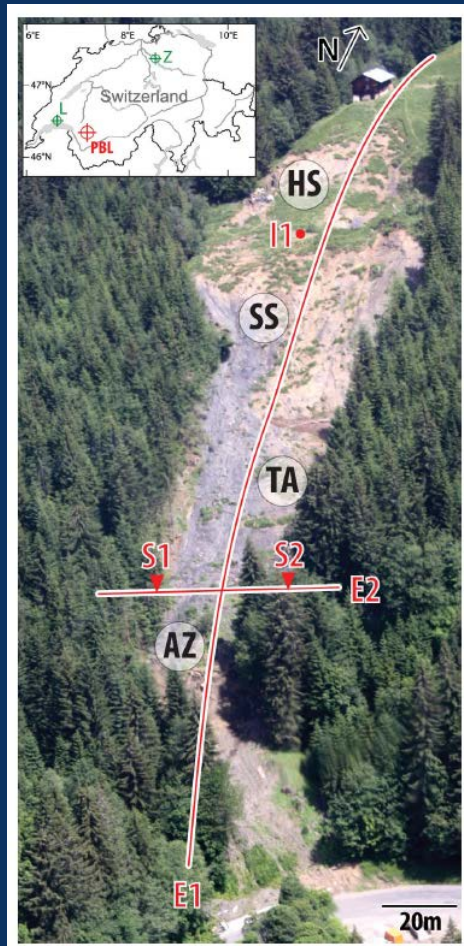
What it is useful for?

Monitoring volcanic eruption preparation (Brenguier et al. *Nature Geosc.*, 2008):



What it is useful for?

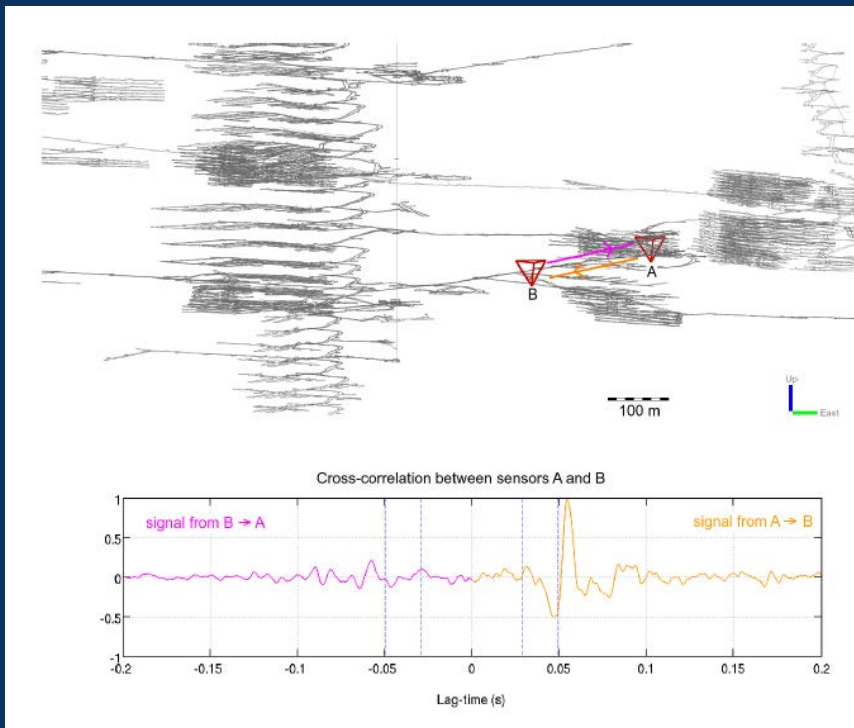
Monitoring landslides (Mainsant et al. *JGR*, 2012):



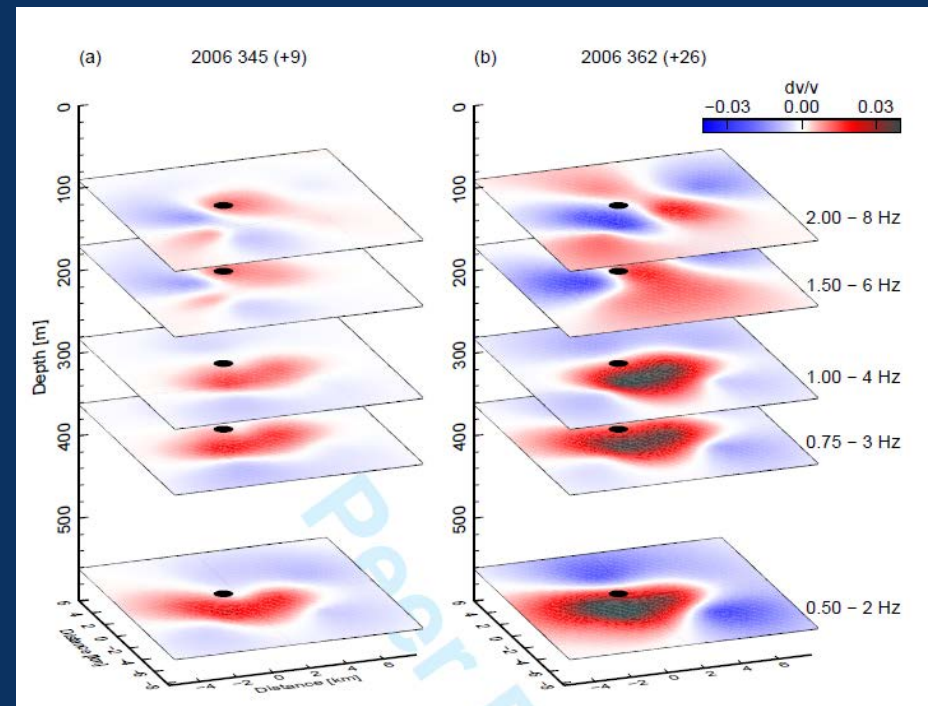
What it is useful for?

Monitoring industrial activities

Mining (Olivier et al. , 2015)

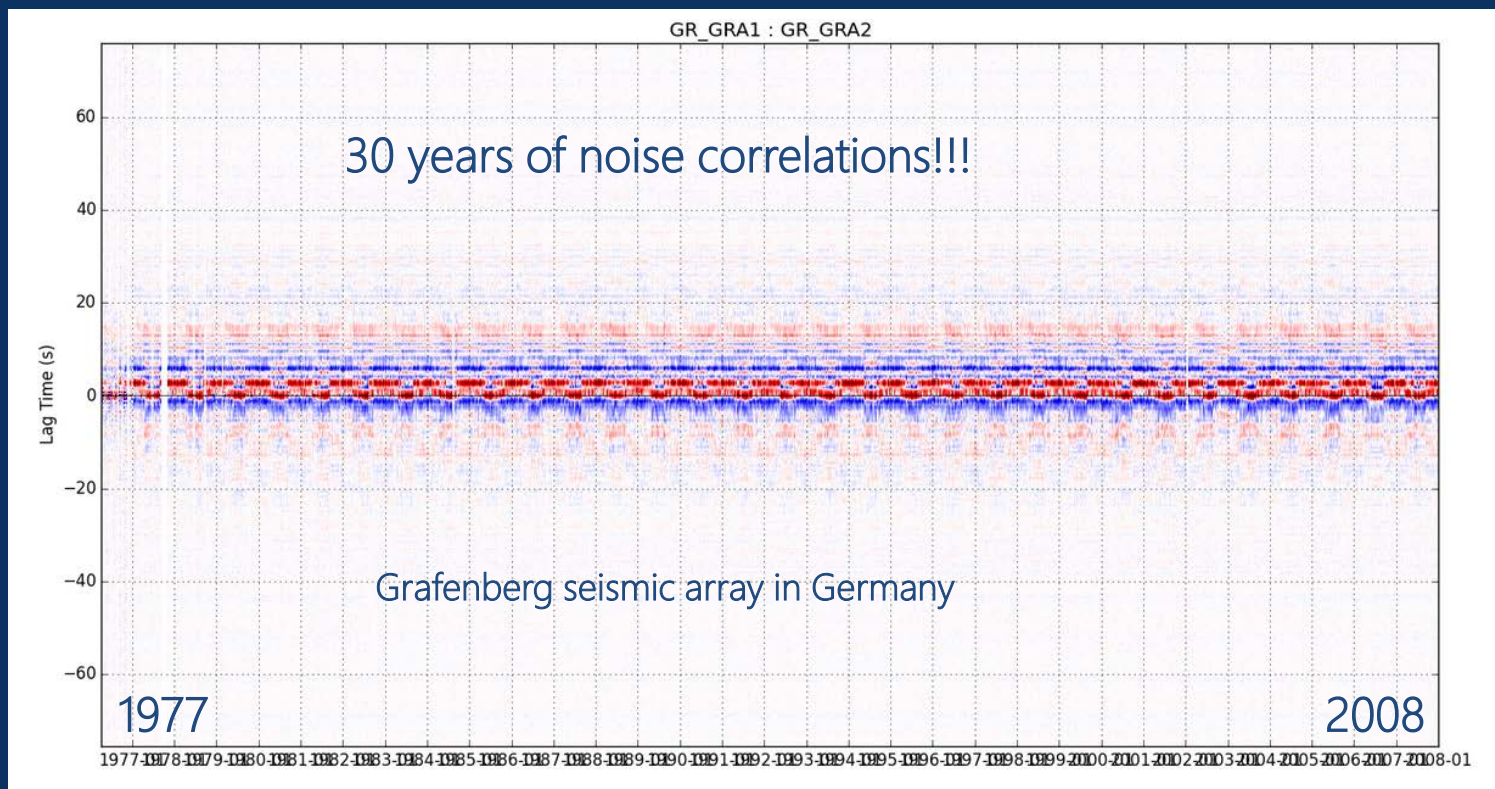


Fluid injection (Hillers et al. , 2015)



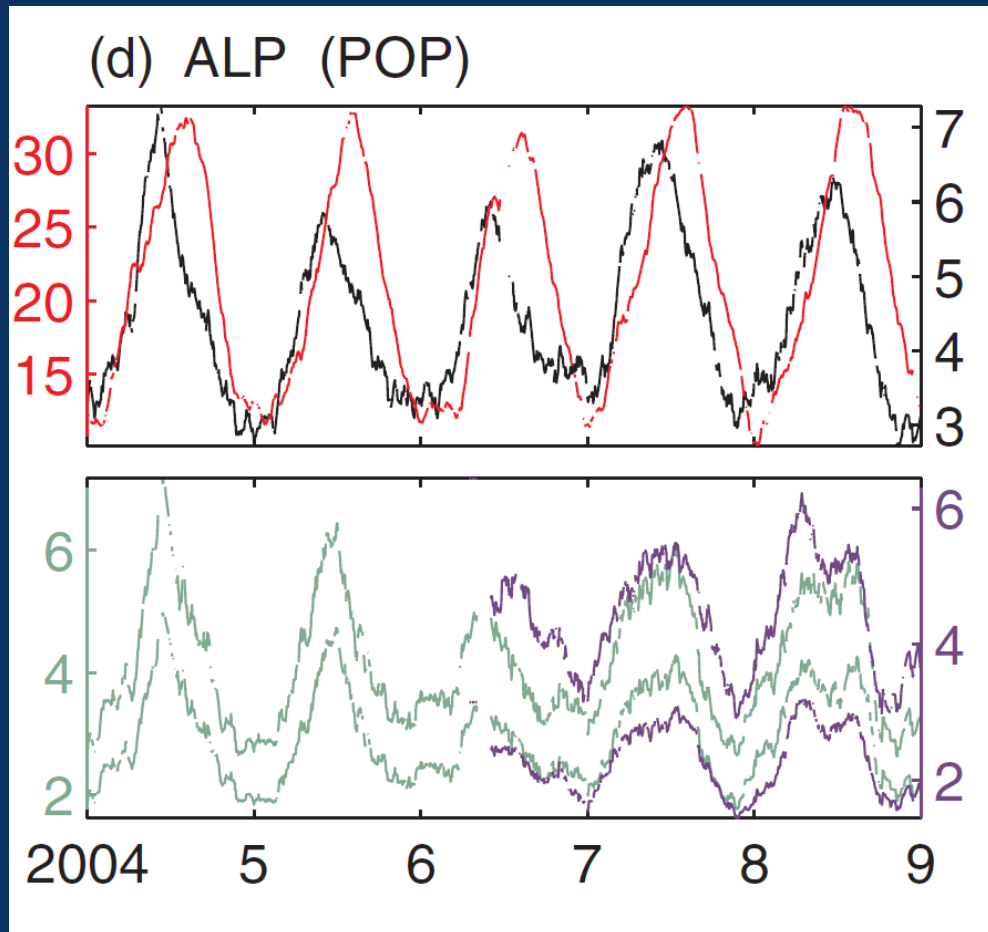
What it is useful for?

Studying climate change??? (Lecocq et al., *coming soon*):



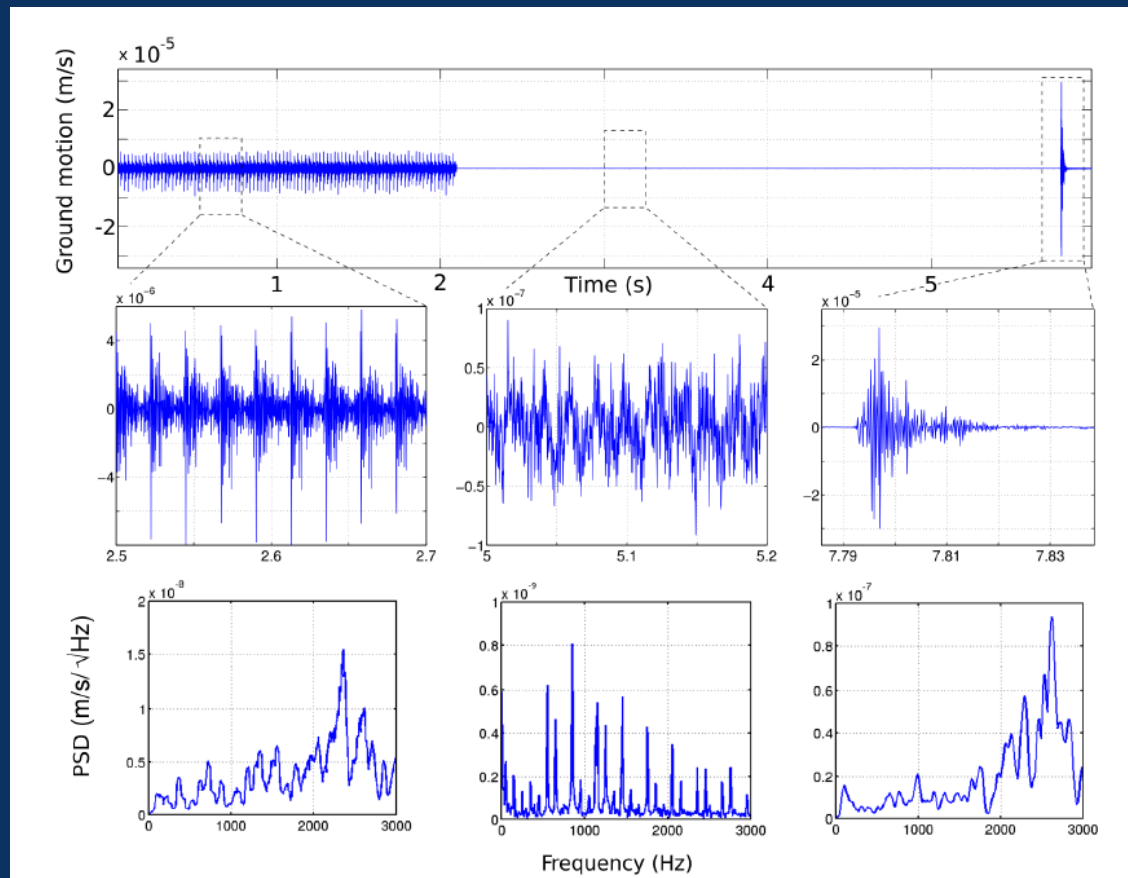
Ambient seismic noise ([1-50] Hz)

Wind and temperature changes (Hillers and Ben-Zion, *GJI*, 2011)

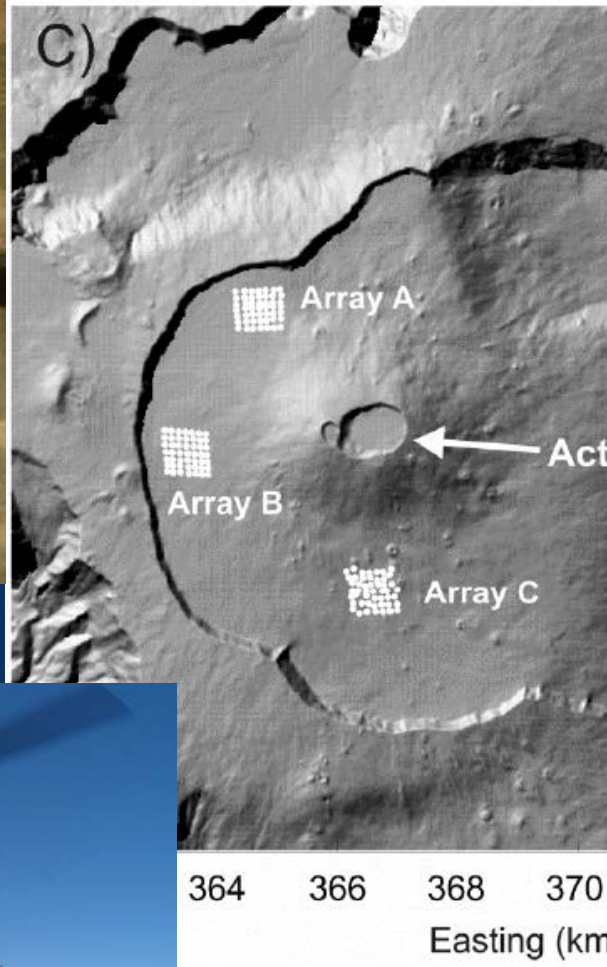


Ambient seismic noise >100 Hz)

Industrial activity (Olivier et al., *Geophysics*, 2015)



Towards 4D ?



MSNoise

Not a black box – A new Framework

MSNoise ?



Plot

Scan
Archive

Process Jobs

- CC
- MWCS
- dt/t
- Parallel !!

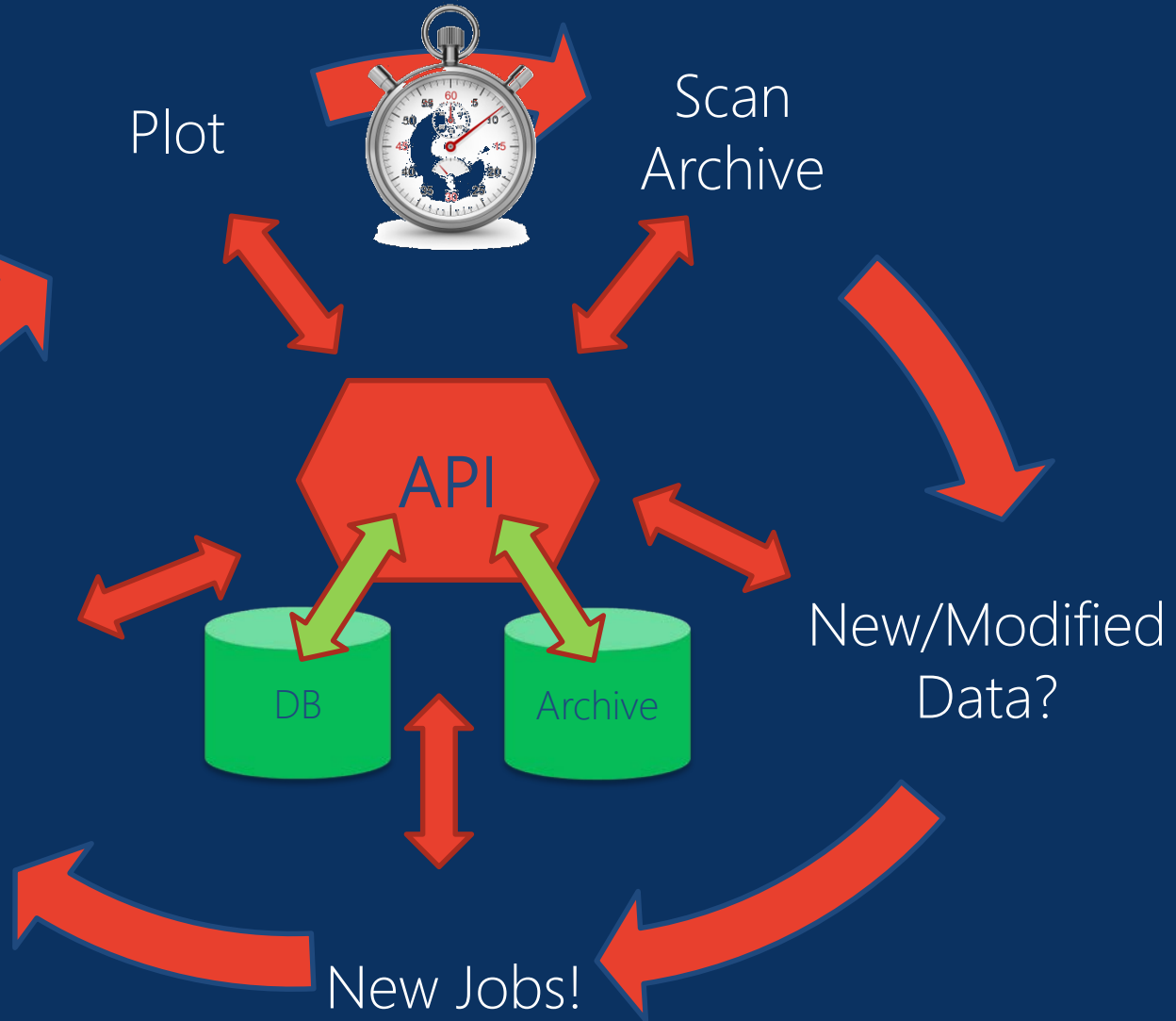
API

DB

Archive

New/Modified
Data?

New Jobs!



Who is MSNoise ?



Florent Brenguier

Seismologist

Original Author of the
Matlab scripts

Learns Python 😊



Thomas Lecocq

Seismologist

Main Developer

Applies on intraplate EU
and volcanoes



Corentin Caudron

VolcanoSeismologist

Used MSNoise for his
PhD Thesis on Kawah Ijen
Develops new modules



You !

Let us know !

Original Objectives of MSNoise



Prepare a Software Package

to measure seismic velocity changes continuously
A whole workflow in a **single** language: Python



Automatically search/find new/modified data in archives

Adapts to current archive format and structure
No duplication of data



Process only what is needed

Cross Correlate new data
Compare daily stacks with a reference
Estimate dv/v every day



Reporting & API

Clear readable outputs
Extensible framework with central API

MSNoise 1.0 → 1.2.x

Not a regular Python Package !

- It doesn't have a setup.py file.
- It should not be installed in the lib/site-packages folder of the current python installation.
- It **will** create folder within its root folder (CROSS_CORRELATION, STACKS, MWCS, DTT folders).

Thus:

- To be installed in a folder that is writable to the user.

Major Drawbacks of MSNoise

General Python knowledge is low
but it's getting better!

Databases are scary!

MSNoise 1.0 → 1.2.x :

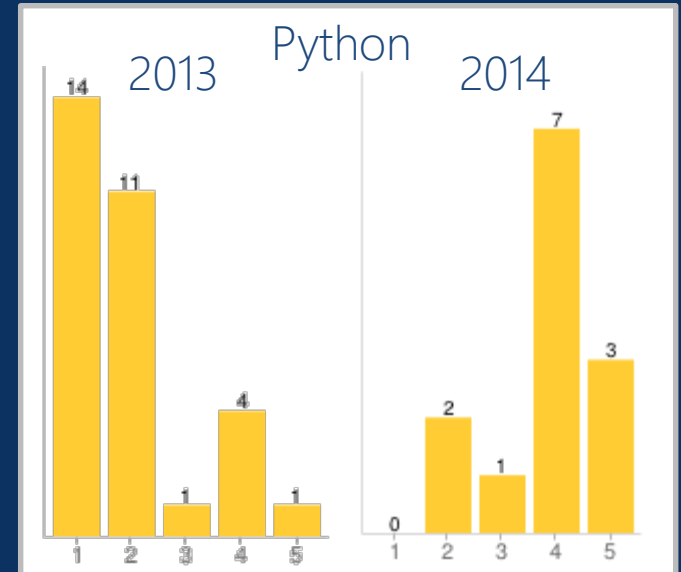
- Whole set of .py in one folder

- Loads of scripts to launch

- One per step

- Plots not easy to do

- No export functions



MSNoise 1.3 →

It's a Python Package !

- It does have a setup.py file.
- It should be installed in the lib/site-packages folder of the current python installation.
- It will create folder within the current folder (CROSS_CORRELATION, STACKS, MWCS, DTT folders).

Thus:

- A single MSNoise install for all users !

A single *msnoise* command !

```
C:\Users\thomas>msnoise --help
```

```
Usage: msnoise-script.py [OPTIONS] COMMAND [ARGS]...
```

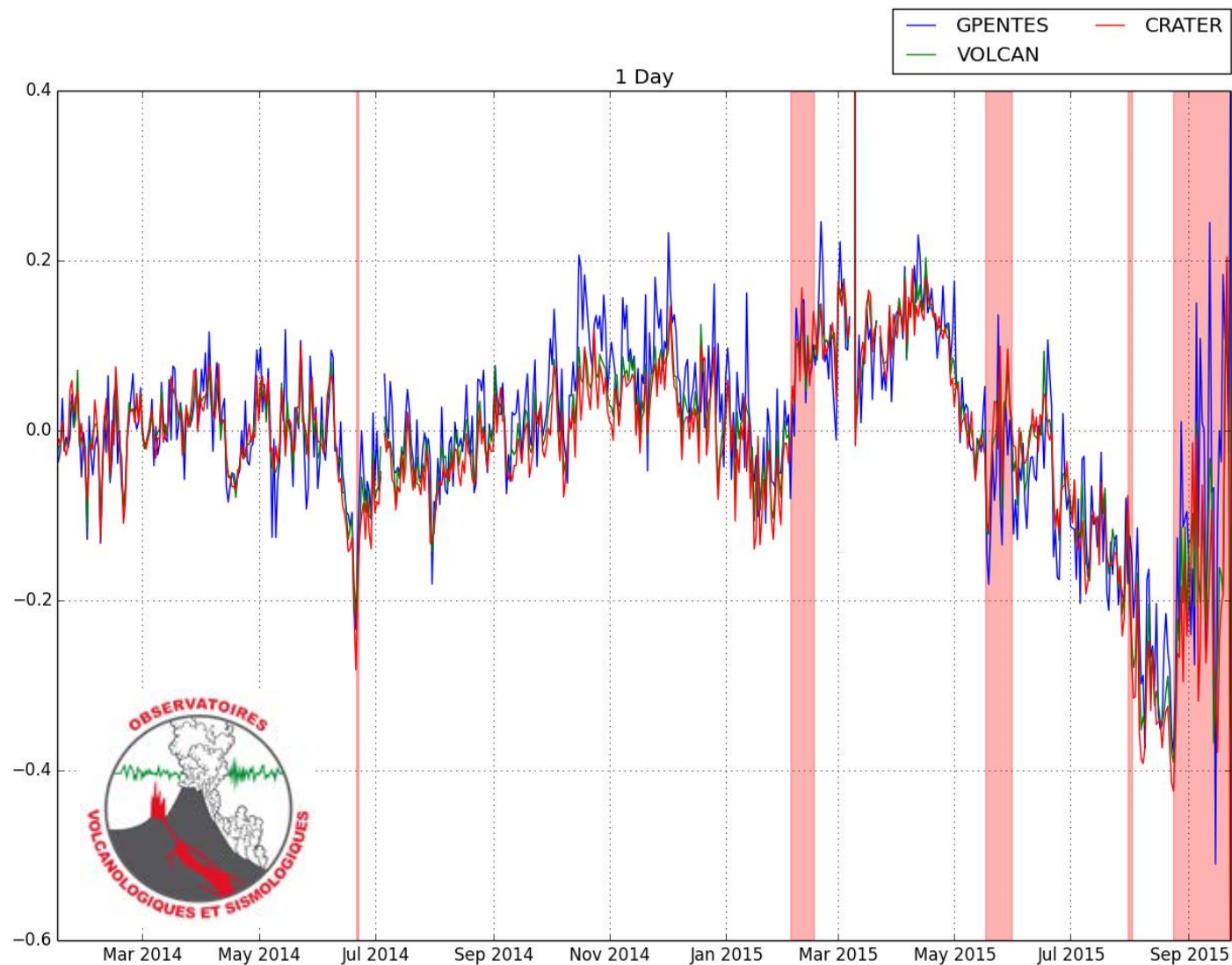
Options:

- t, --threads INTEGER Number of threads to use (only affects modules that are designed to do parallel processing)
- help Show this message and exit.

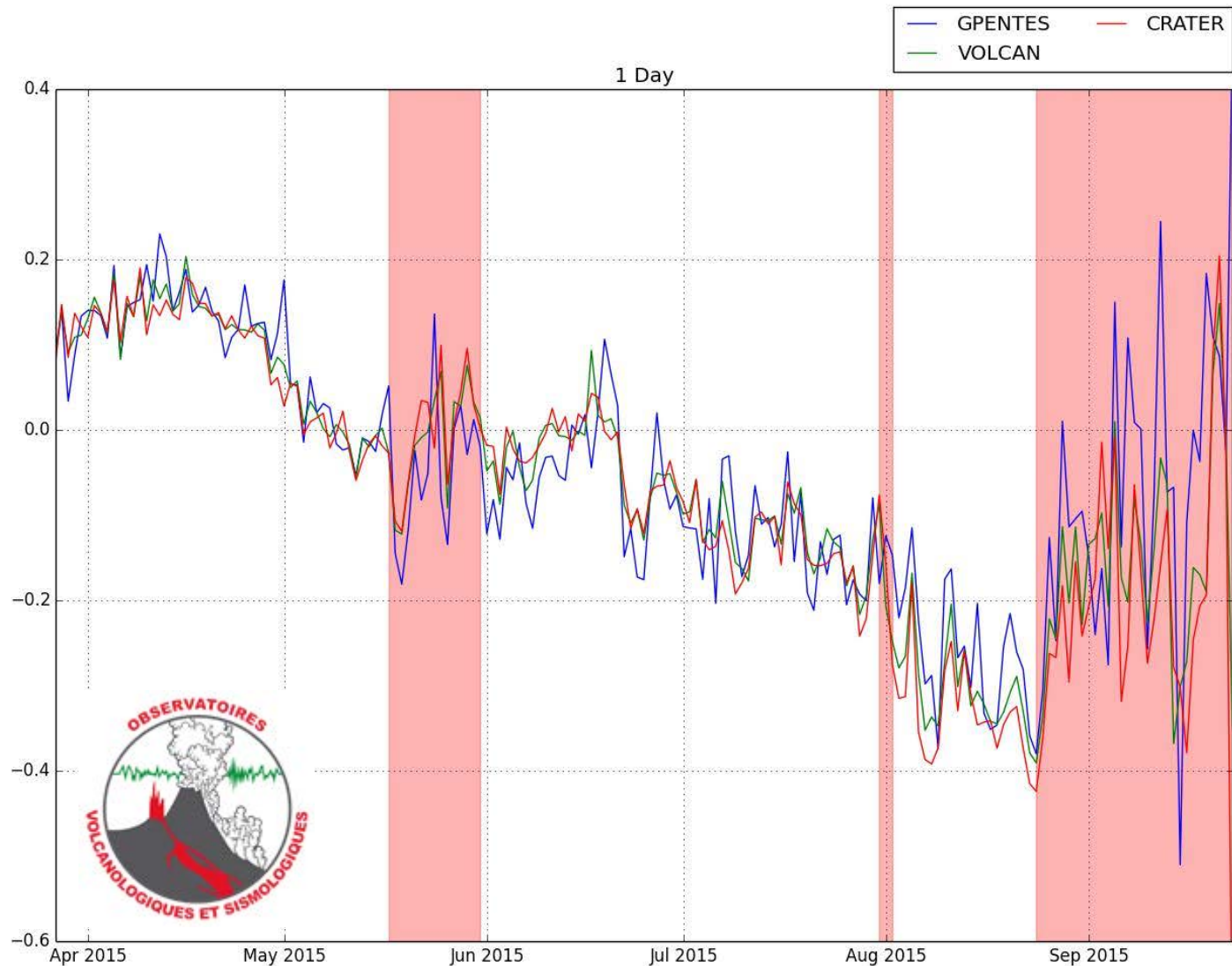
Commands:

- bugreport This command launches the Bug Report script.
- compute_cc Computes the CC jobs (based on the "New Jobs"...
- compute_dtt Computes the dt/t jobs based on the new MWCS...
- compute_mwcs Computes the MWCS based on the new stacked...
- ...

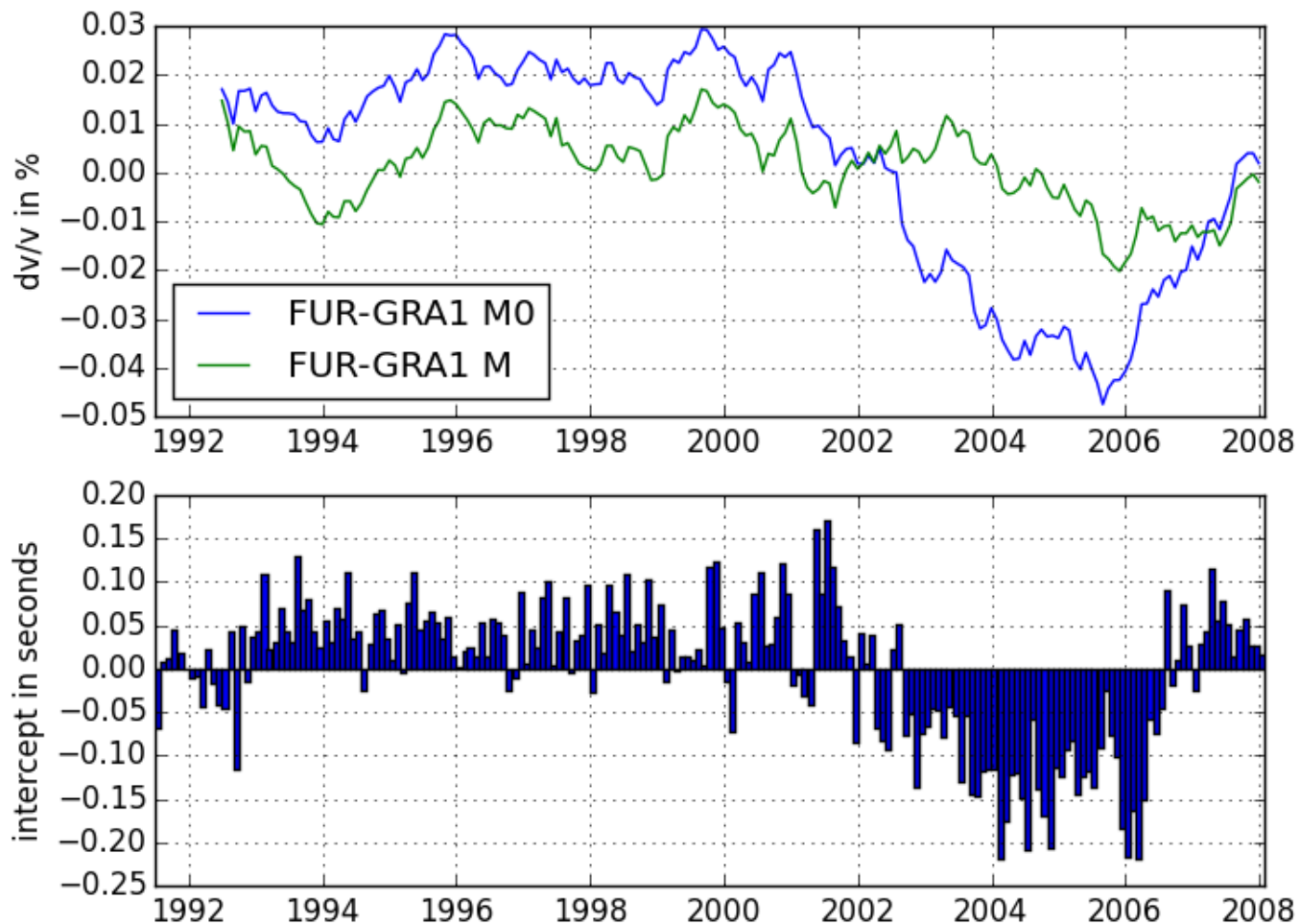
MSNoise in the Real World



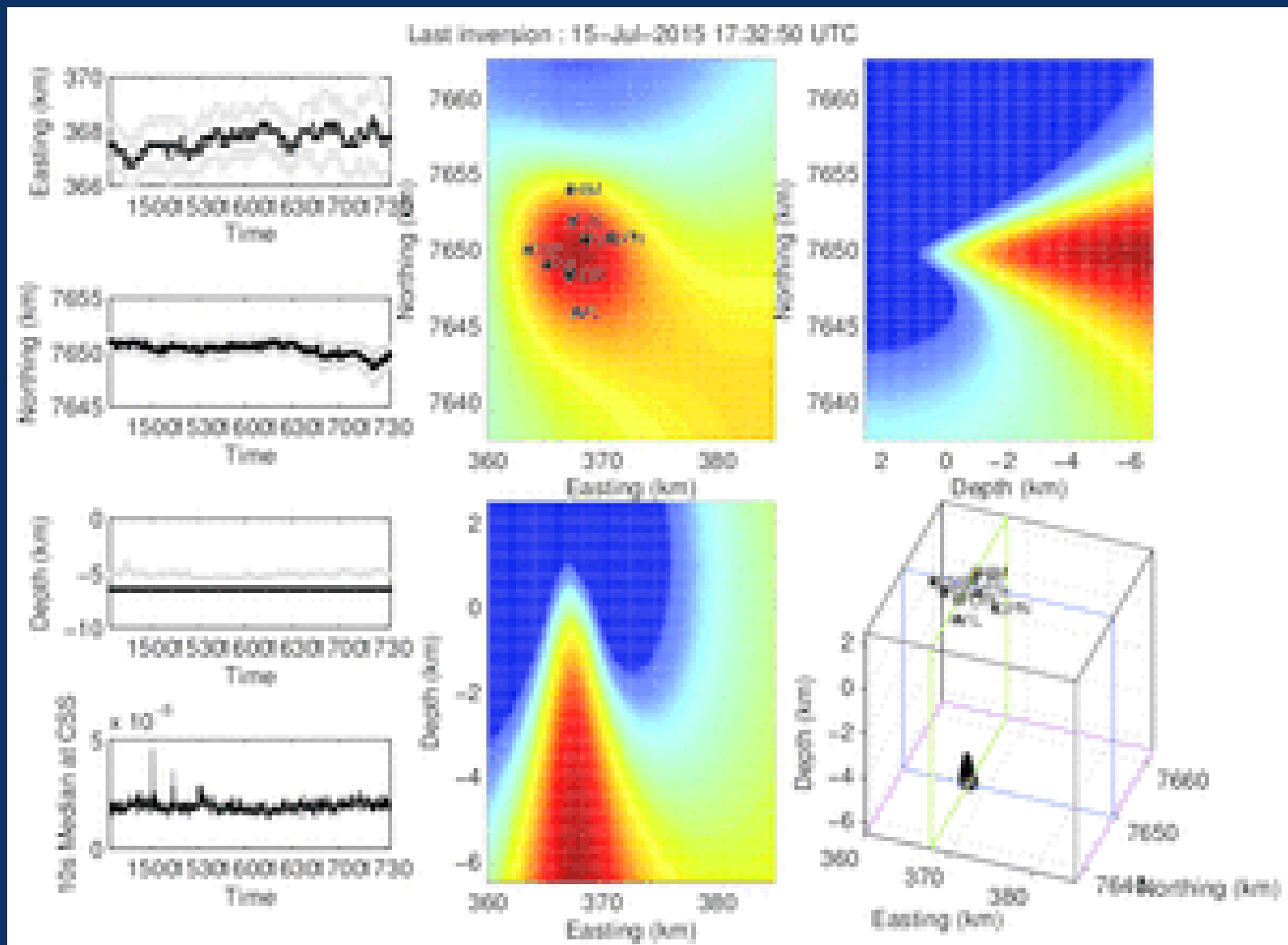
MSNoise in the Real World



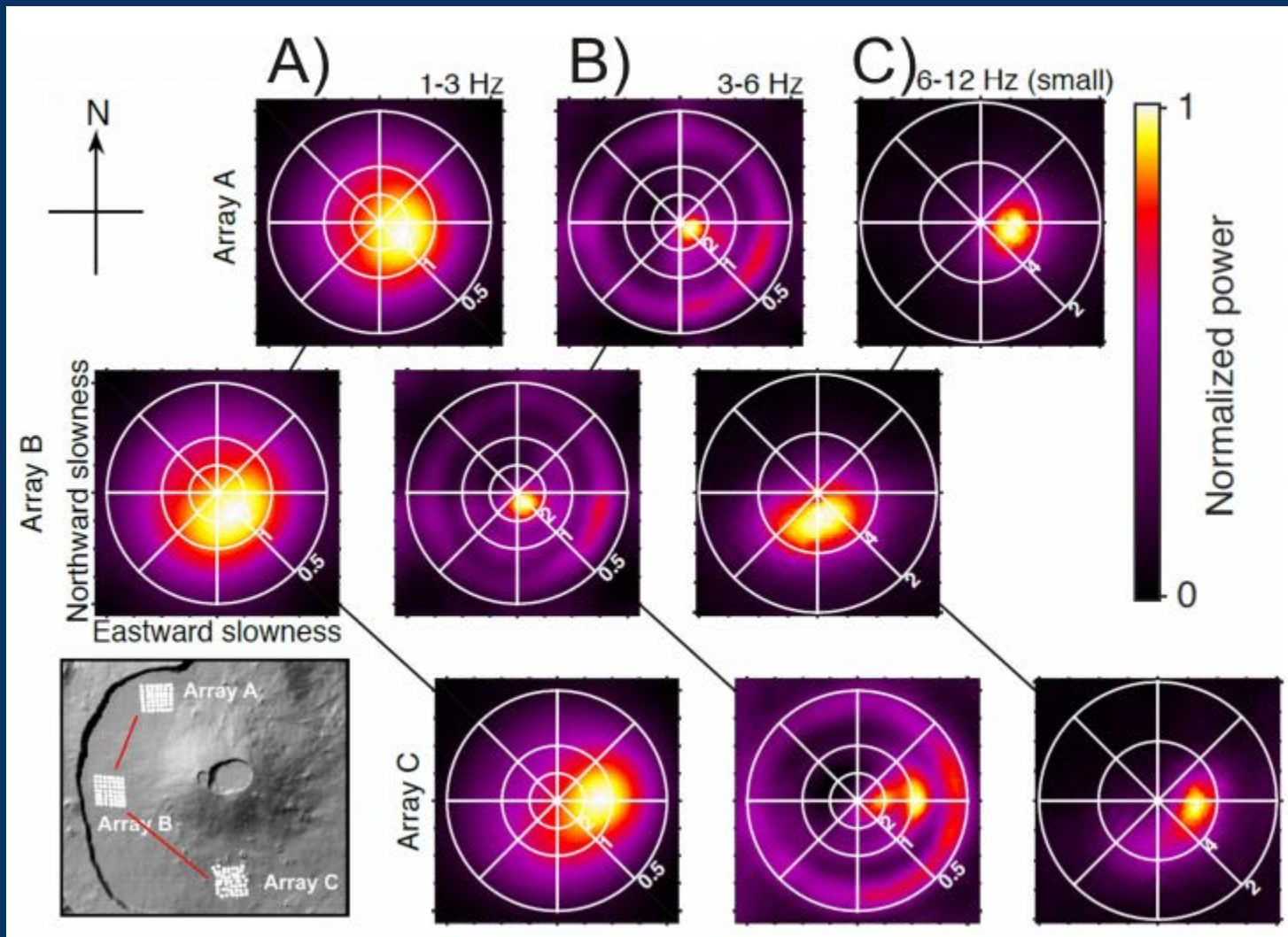
Not only « Real Time »



Extending MSNoise



Body Waves, but?





**KEEP
CALM
AND**

**MAKE SOME
NOISE**

MS **NOISE**.ORG