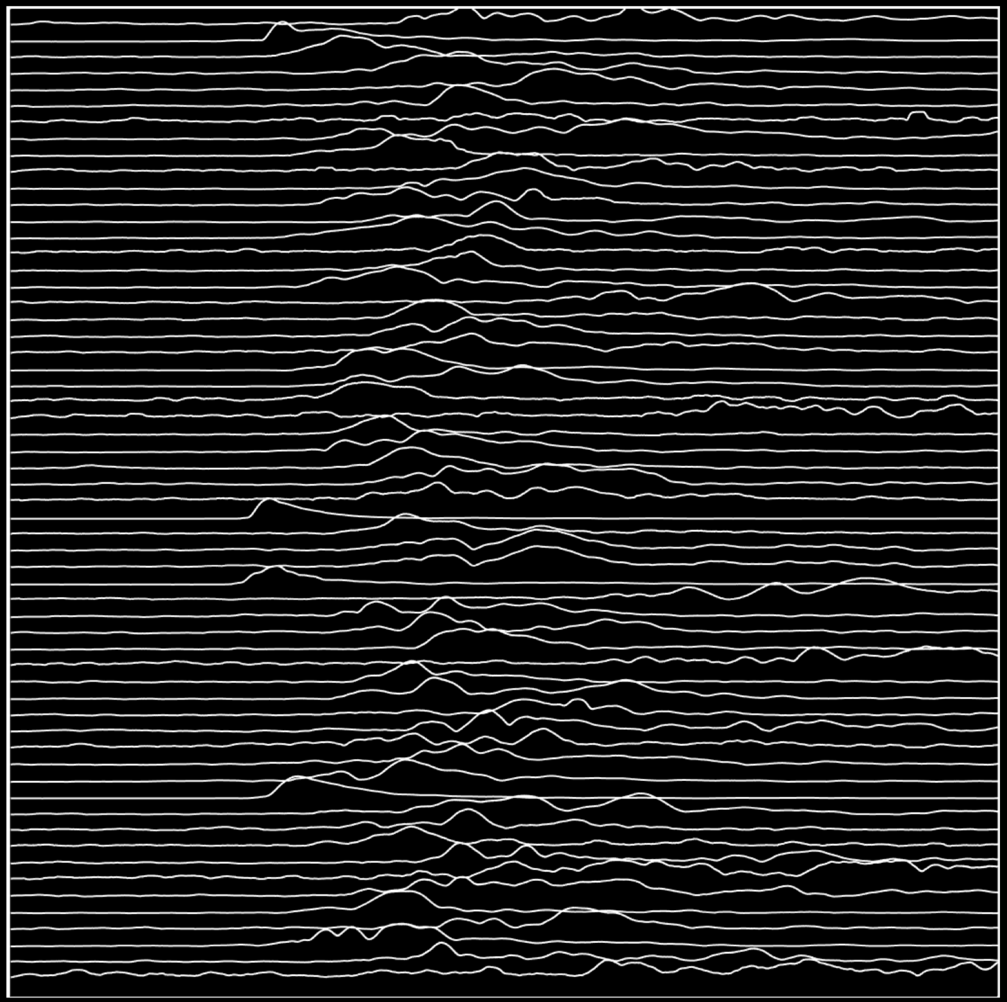


LP Volcanic event, 31st July 2018

Detection using global seismic networks

Piero Poli

University of Grenoble

PASSIVE IMAGING AND MONITORING IN WAVE PHYSICS: FROM SEISMOLOGY TO ULTRASOUND

Cargese, September 16-20, 2019

Outline

- Motivation
- Global scale detection of seismic waves
- Improving preliminary detections
- Glacial Earthquakes & low frequency volcanic tremors
- Conclusions

ISTerre
Institut des Sciences de la Terre
MONIFAULTS
erc
European Research Council
Established by the European Commission

Outline

- Motivation
- Global scale detection of seismic waves
- Improving preliminary detections

Detection is feasible

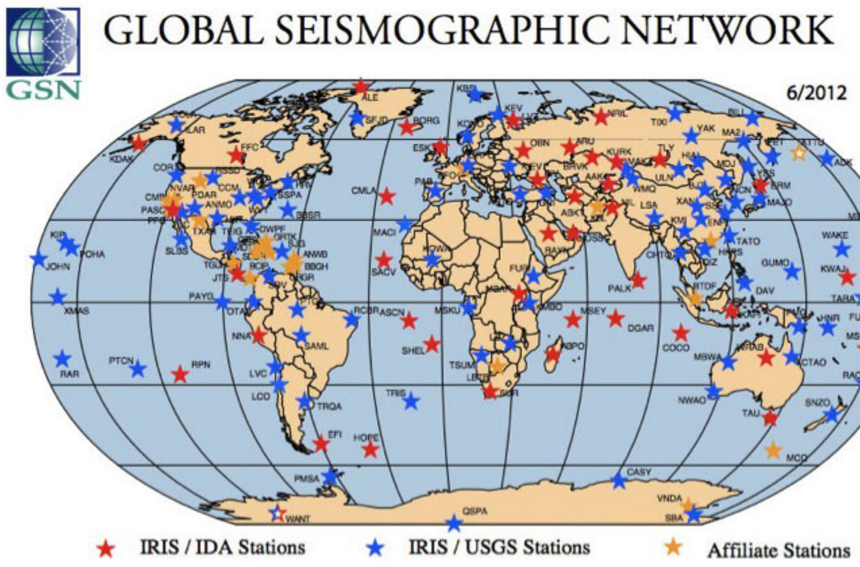
- Glacial Earthquakes & low frequency volcanic tremors
- Conclusions

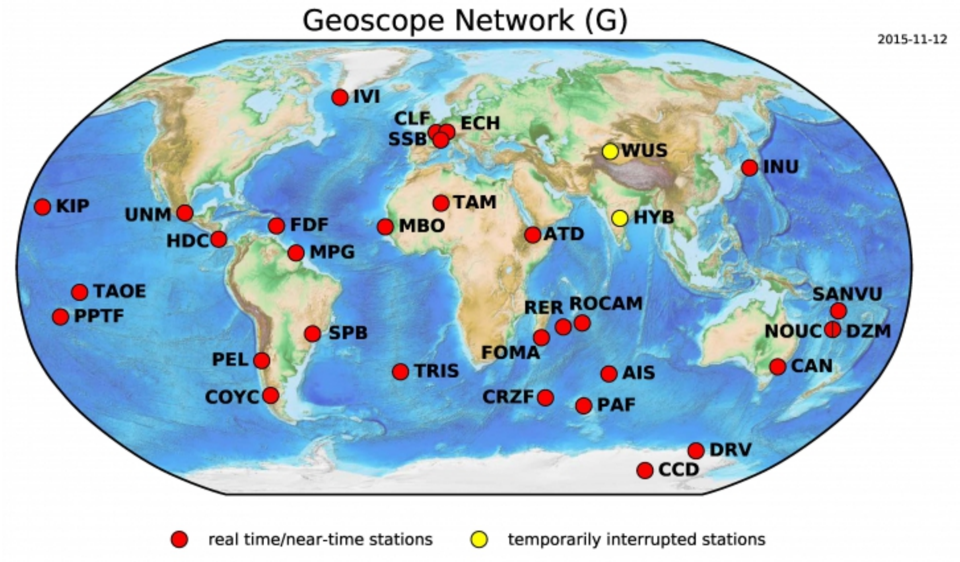
Detections are useful

Institut des Sciences de la Terre

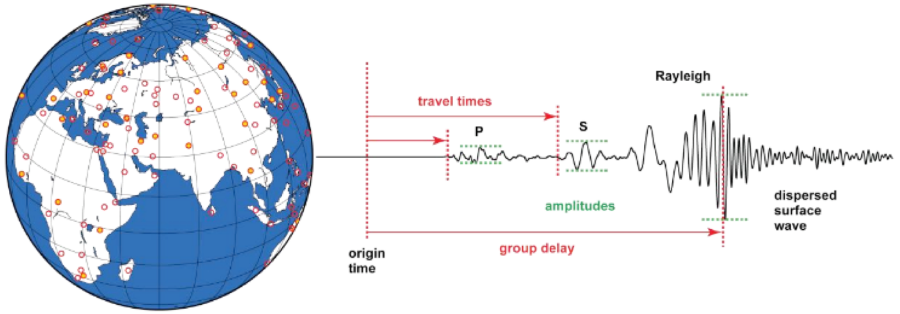
European Research Council
Established by the European Commission

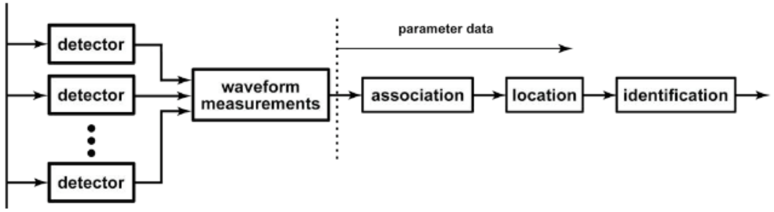
Motivation





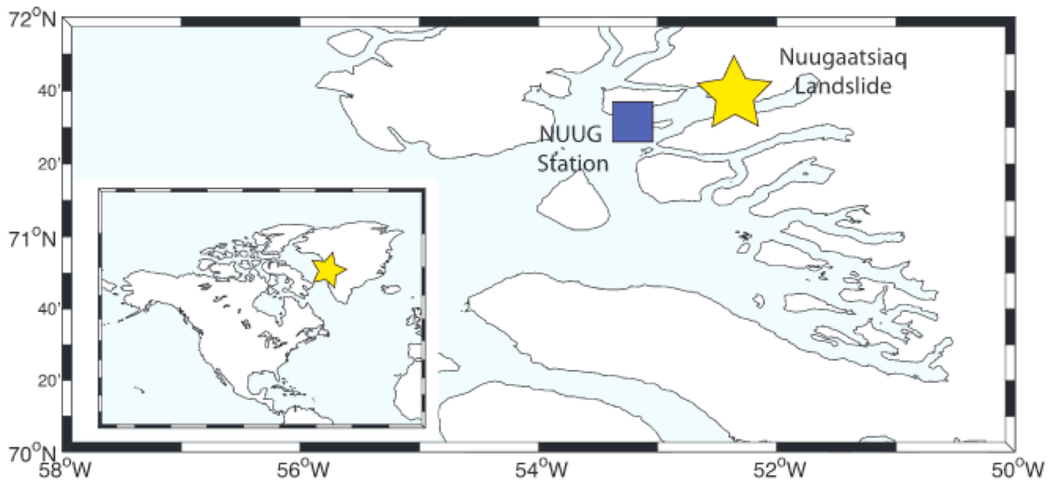
- ***Are we detecting all earthquakes?***
- ***Are other signals existing?***
- ***Signals are located and stored just if picking is possible***

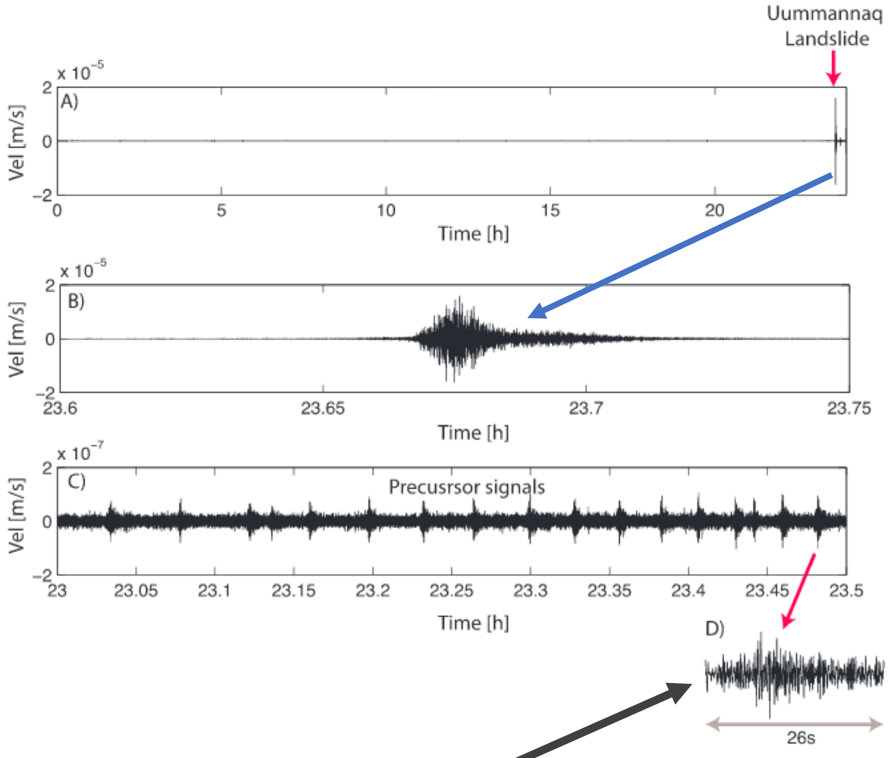




Motivation: Example of unidentified signals

Data from 17 of June 2017



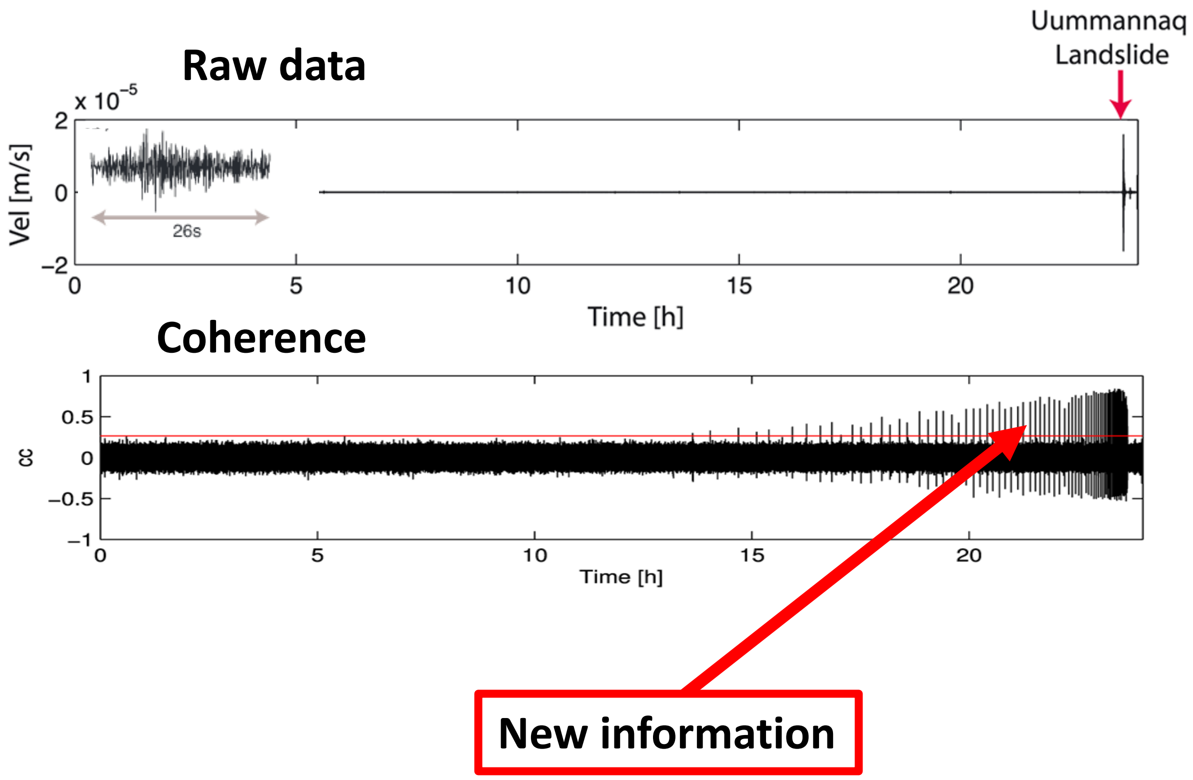


No clear P or S waves -> **No picking possible**

Poli (GRL, 2017)

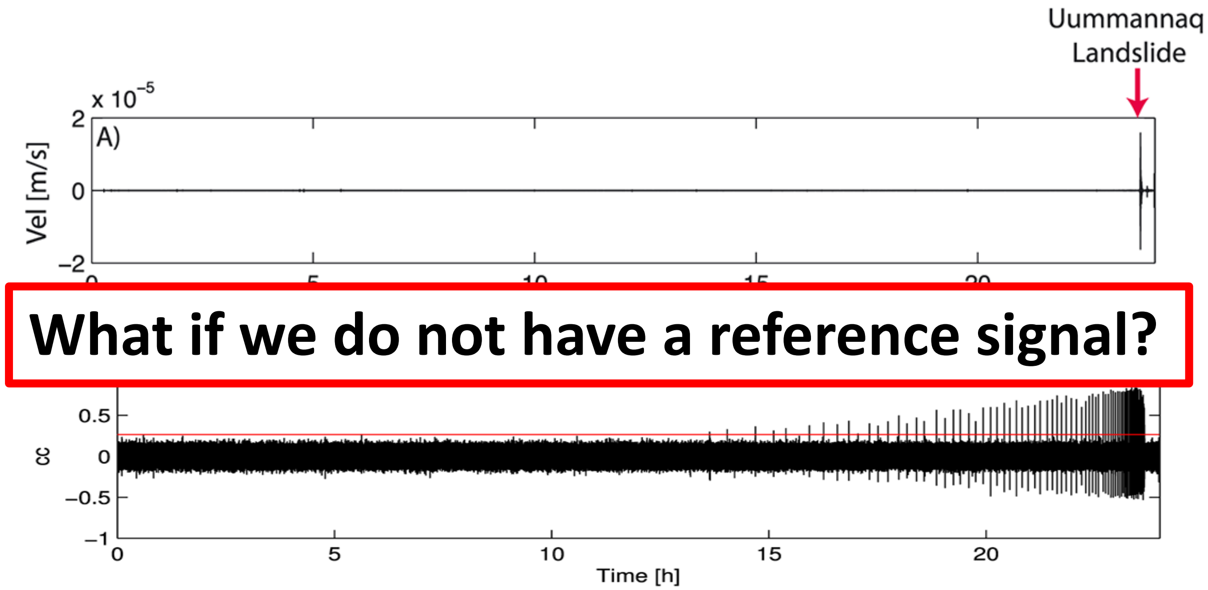
Motivation: Example of unidentified signals

Correlation based detection



Poli (GRL, 2017)

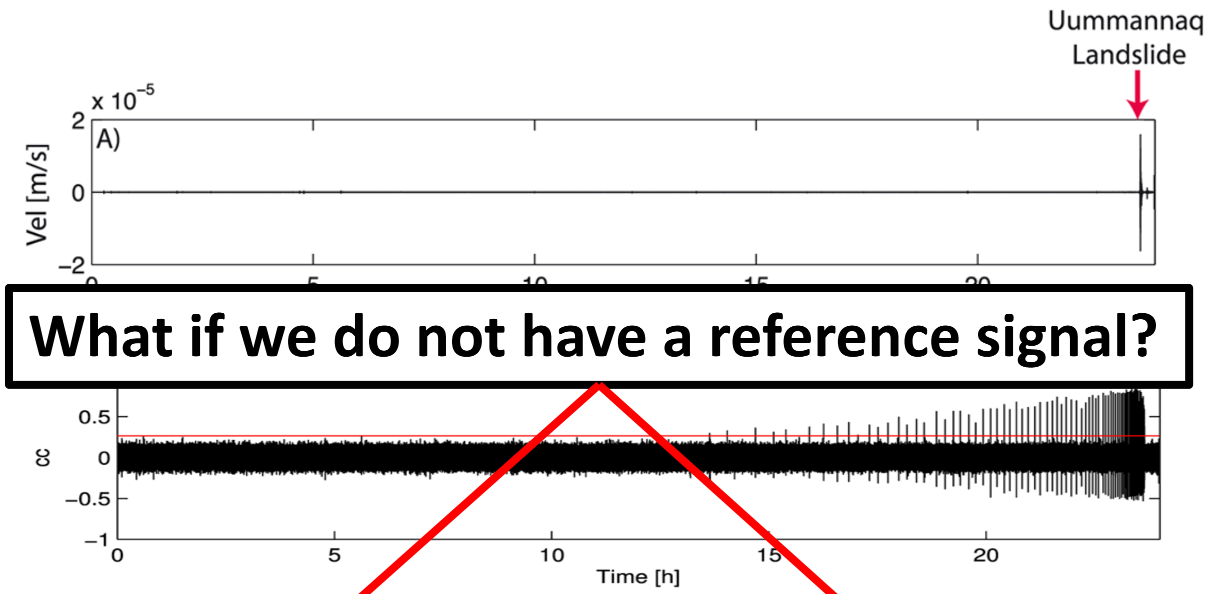
Motivation: Example of unidentified signals



What if we do not have a reference signal?

Poli (GRL, 2017)

Motivation: Example of unidentified signals



What if we do not have a reference signal?

Generate signals from knowledge

ML

wait Friday L. Seydoux presentation

Poli (GRL, 2017)

Motivation: Example of unidentified signals

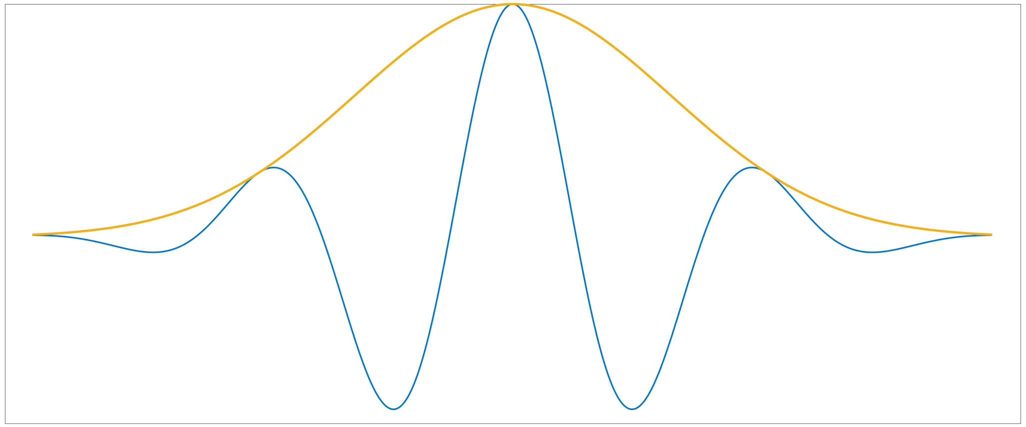
What if we do not have a reference signal?

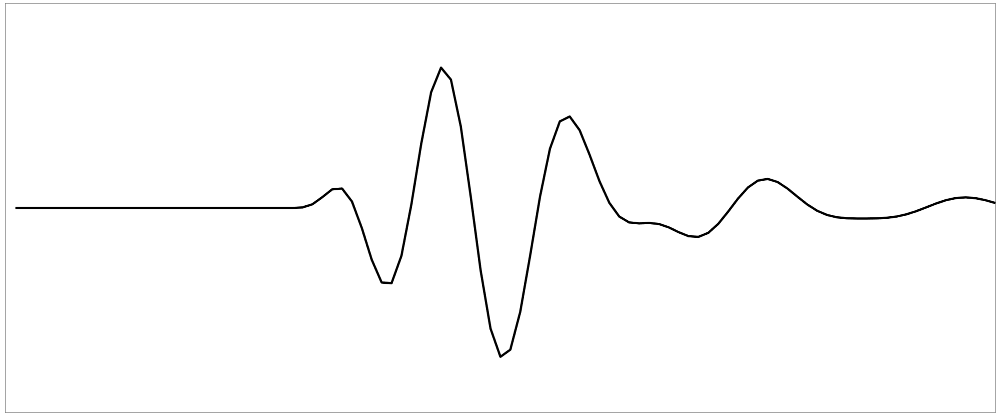
Model templates

Baggeroer, Kuperman & Schmidt, *Matched field processing: Source localization in correlated noise as an optimum parameter estimation problem* (1988)

Rodgers, A., D. Harris, and M. Pasyanos. "A model-based signal processing approach to seismic monitoring." *Proceedings of 28th Seismic Research Review: Ground-Based Nuclear Explosion Monitoring Technologies* (2006): 455-464.

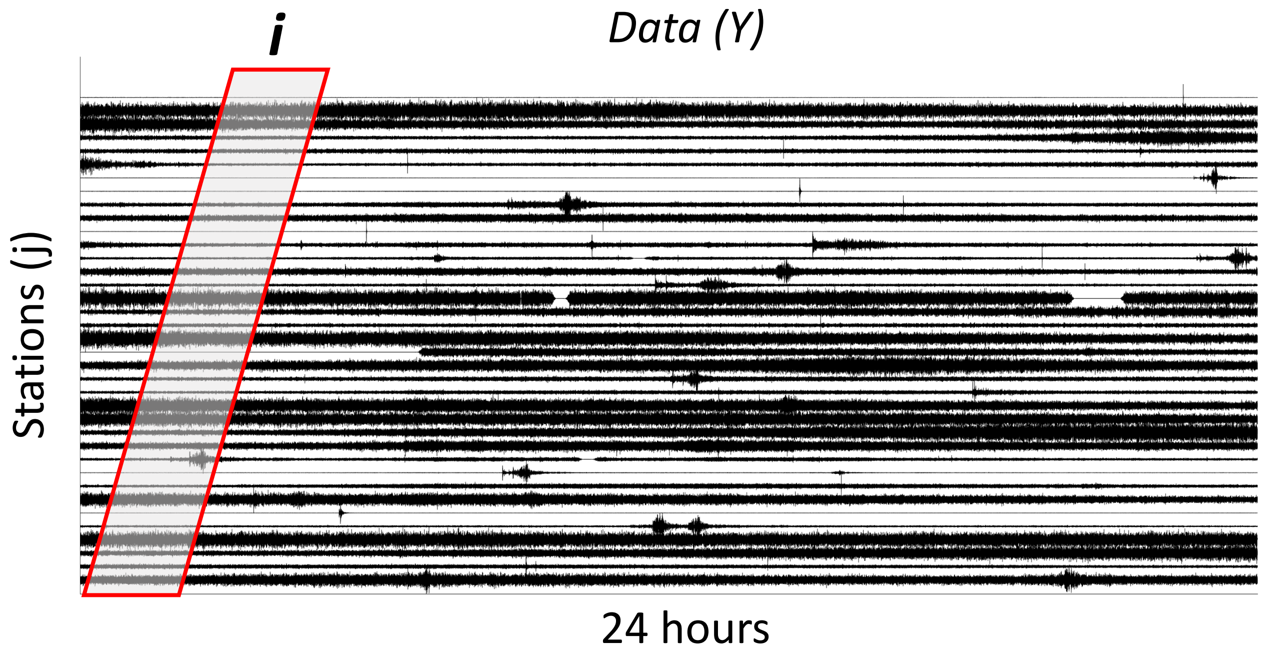
See also Shearer (1994) & Ekstrom (2006)





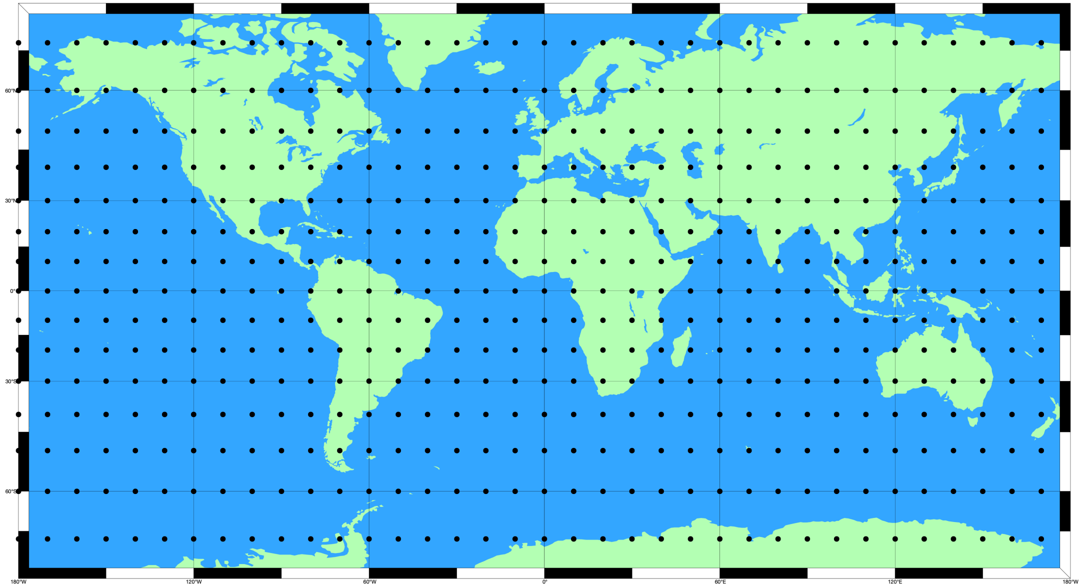
Global scale detection of long period signals

$$C_i = \sum_{j=1}^{n} \frac{X^j \cdot Y_i^j}{\sqrt{(X^j \cdot X^j)(Y_i^j \cdot Y_i^j)}}$$



Global scale detection of long period signals

$$C_i = \sum_{j=1}^{n} \frac{X^j \cdot Y_i^j}{\sqrt{(X^j \cdot X^j)(Y_i^j \cdot Y_i^j)}}$$

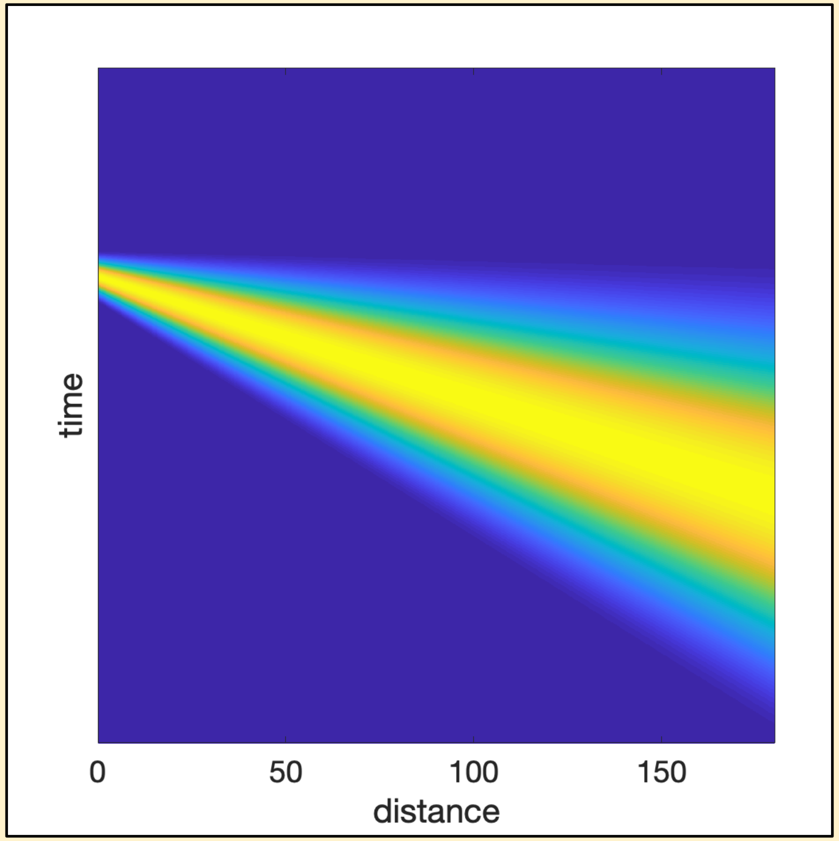


$$CN(t) = \max[C_i(t)]$$

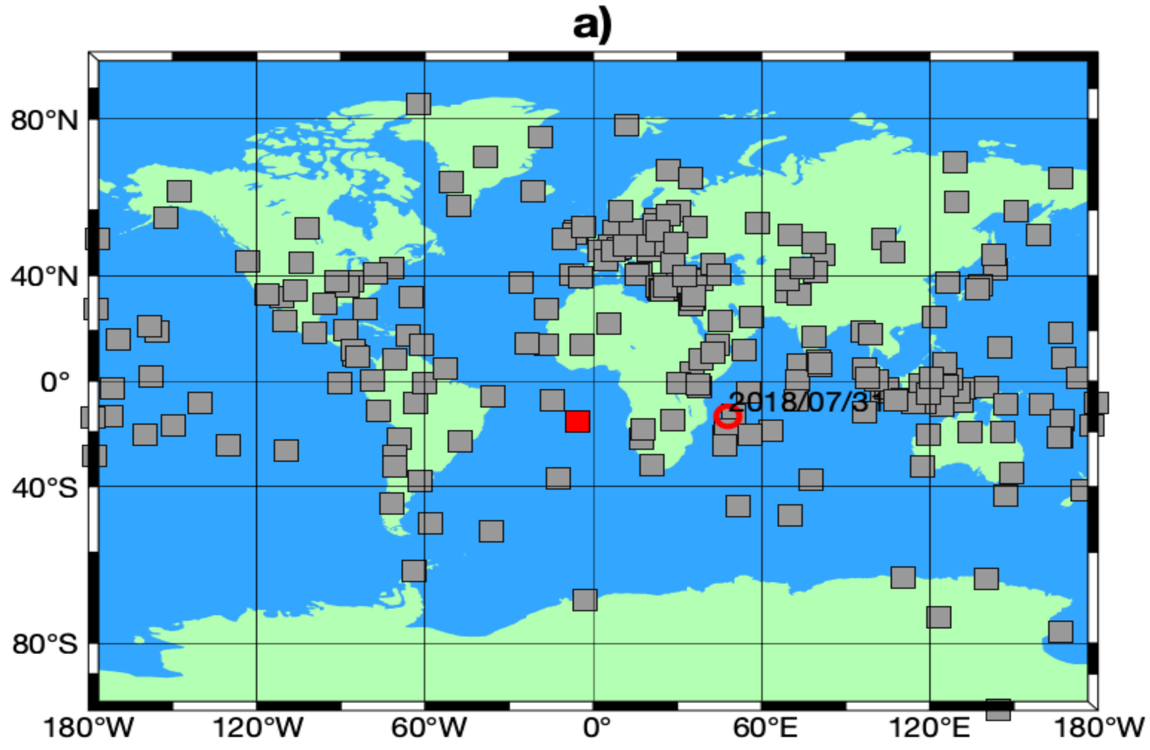
TEMPLATES (X)

- ***PREM Rayleigh waves vel. @0.03Hz***
- ***Gaussian window***

SEVERAL OTHER TEMPLATES TESTED



Data



SEISMIC NETWORKS (2001-2019):

- ***GEOSCOPE (G)***
- ***GEOFON (GE)***
- **Global Seismograph Network (GSN - IRIS/IDA, II)**
- **Global Seismograph Network (GSN - IRIS/USGS, IU)**

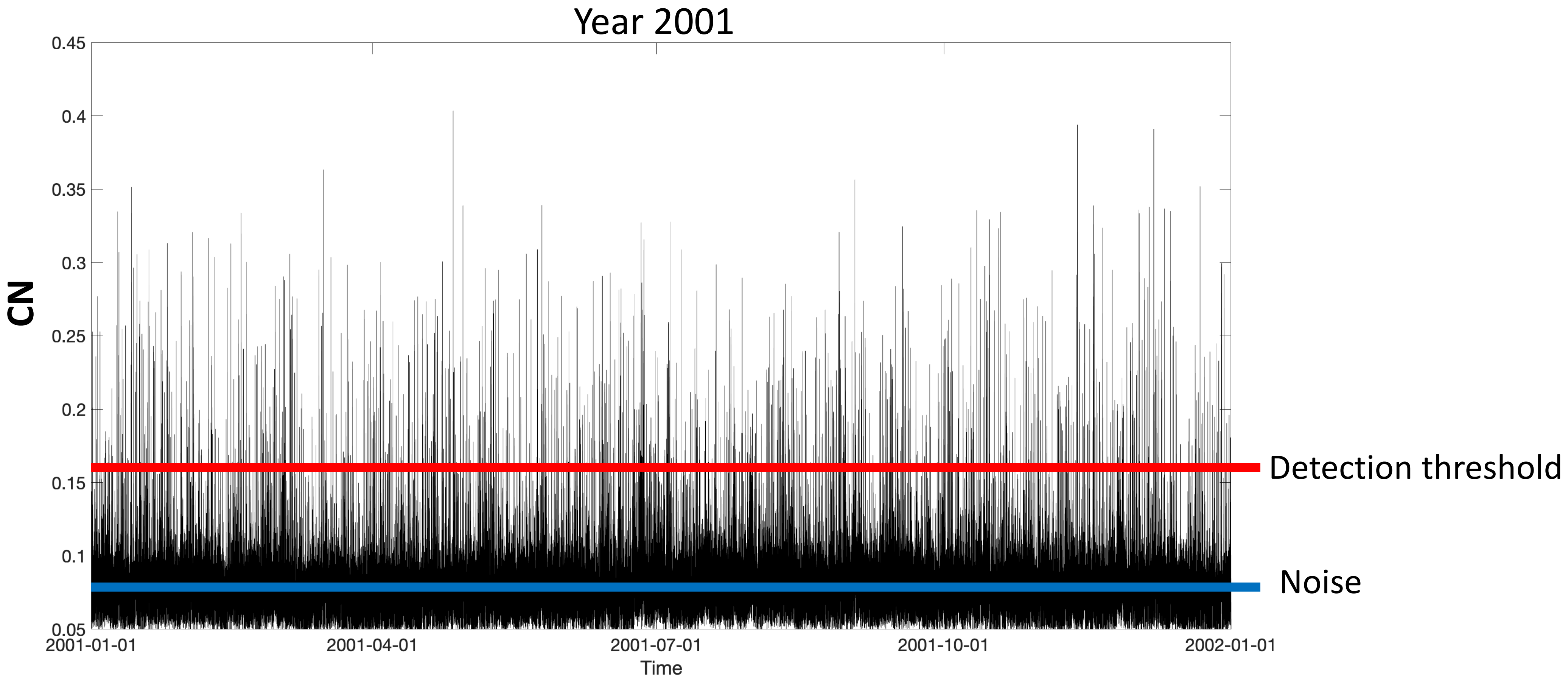
DATA PROCESSING:

- ***Remove instr. response***
- ***Resample 0.5Hz***
- ***Filter 0.01-0.05Hz*** (high signal-to-noise ratio (SNR) in the frequency band (Shearer 1994; Ekstrom 2006; McGuire 2008))

One year of detection

$$CN(t) = \max[C_i(t)]$$

Detections = CN>4std(CCC)

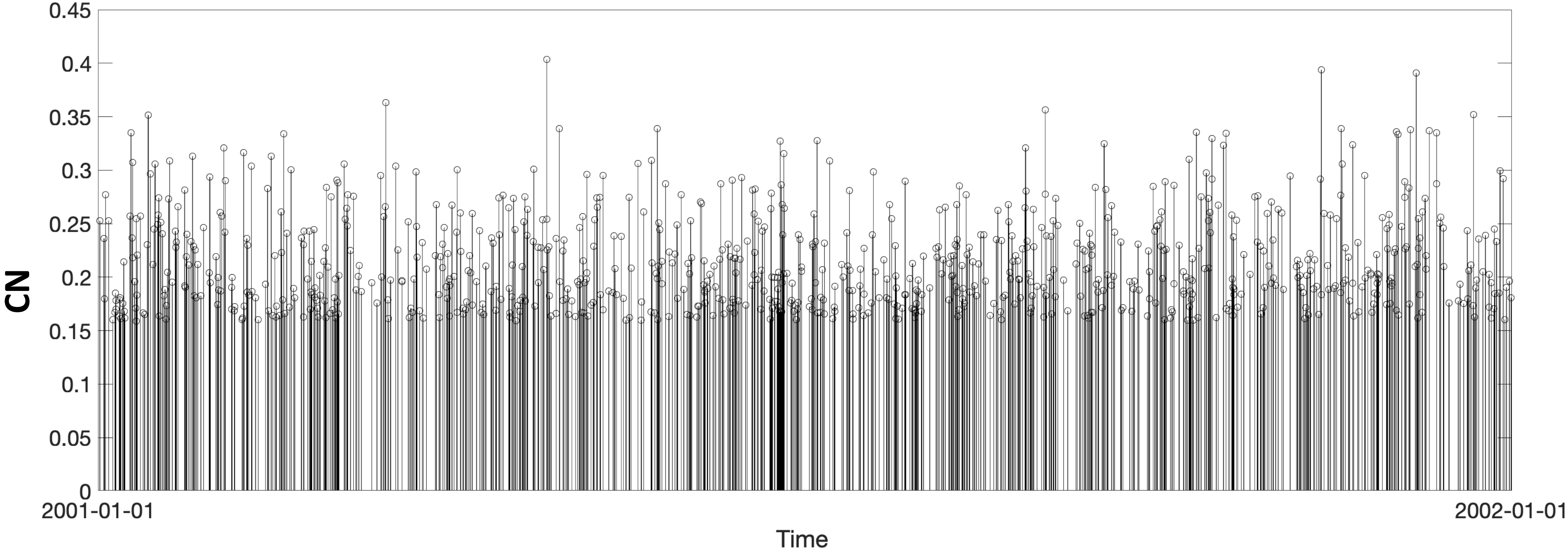


One year of detection

De-clustering new “events”:

Max coherence per ~1000sec (template length)

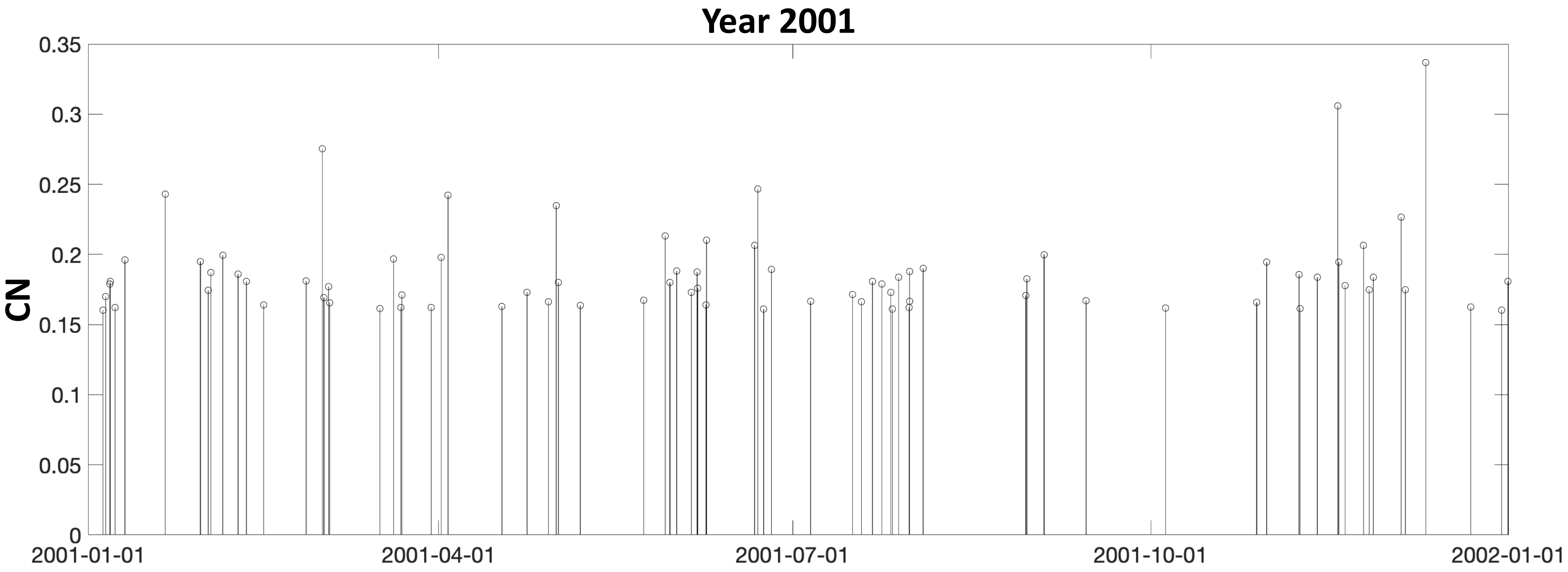
TOTAL NUMBER OF DETECTIONS: ~100000 in 19 years



One year of detection

Remove known earthquakes:

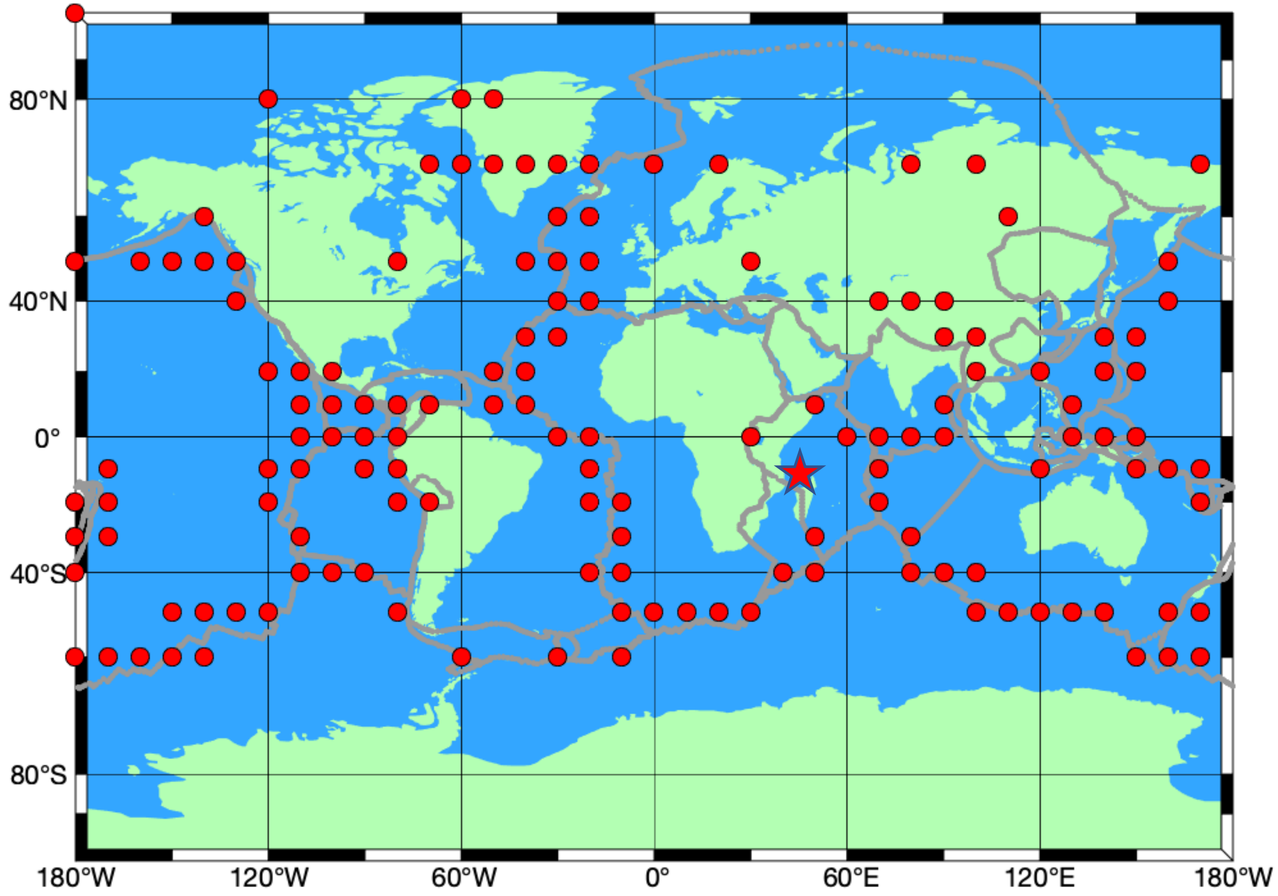
- Remove detections within ±1 hour and <20deg from known M4+
- Remove antipodal detection (R2, R3)



2000 to 2019

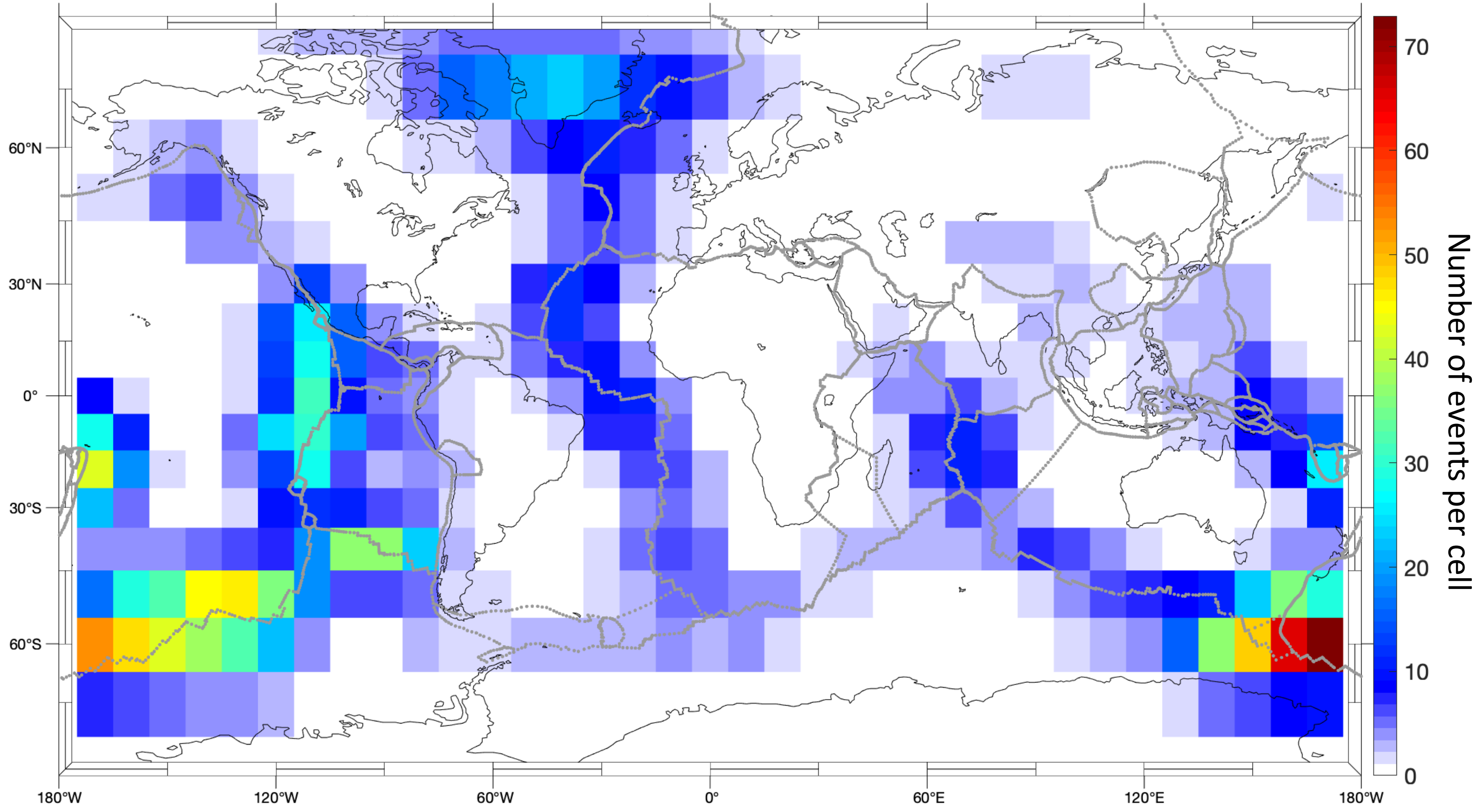
The catalog after quality control:

610 unidentified signals



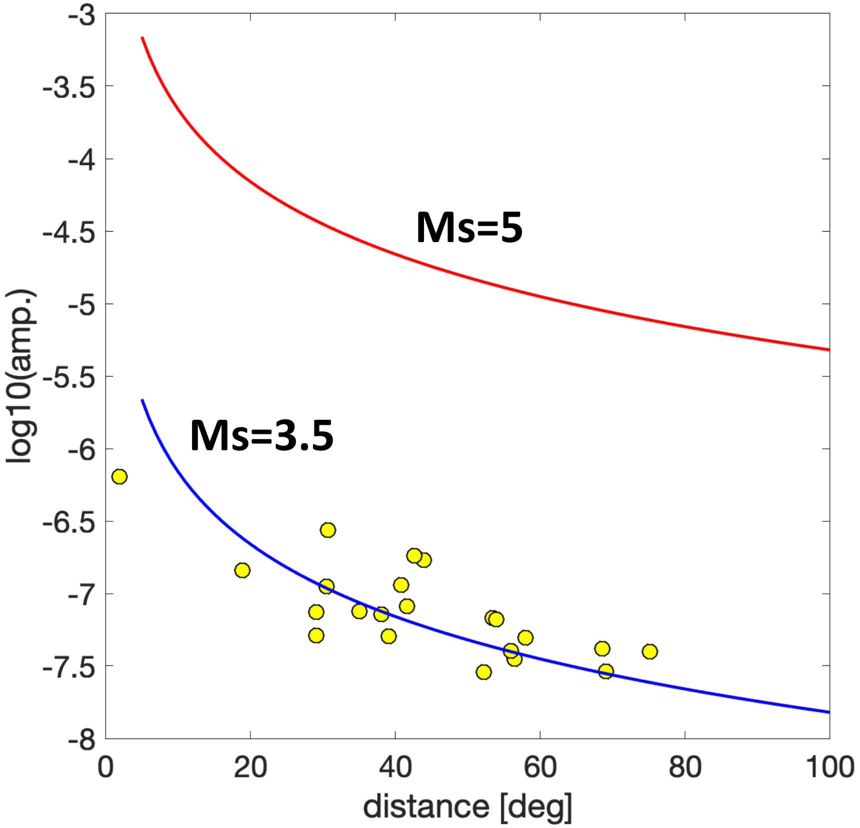
Global scale detection of long period signals

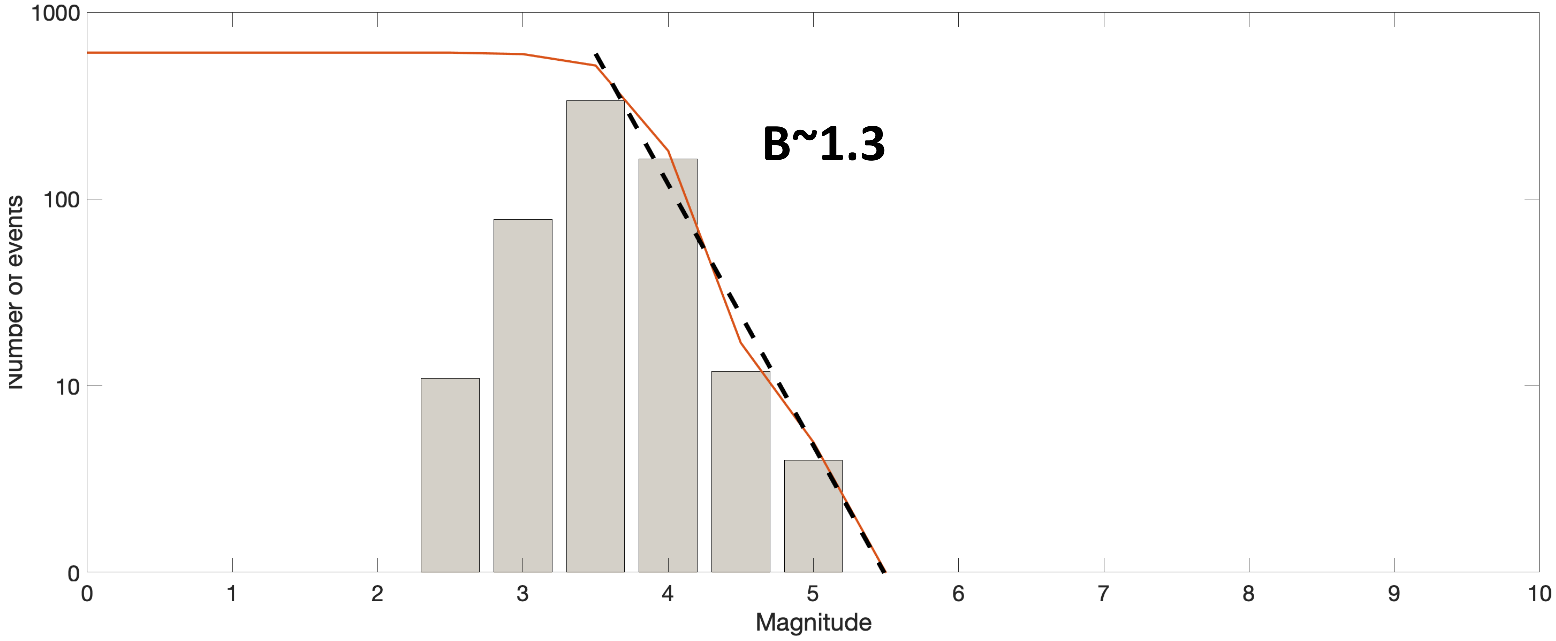
Source density



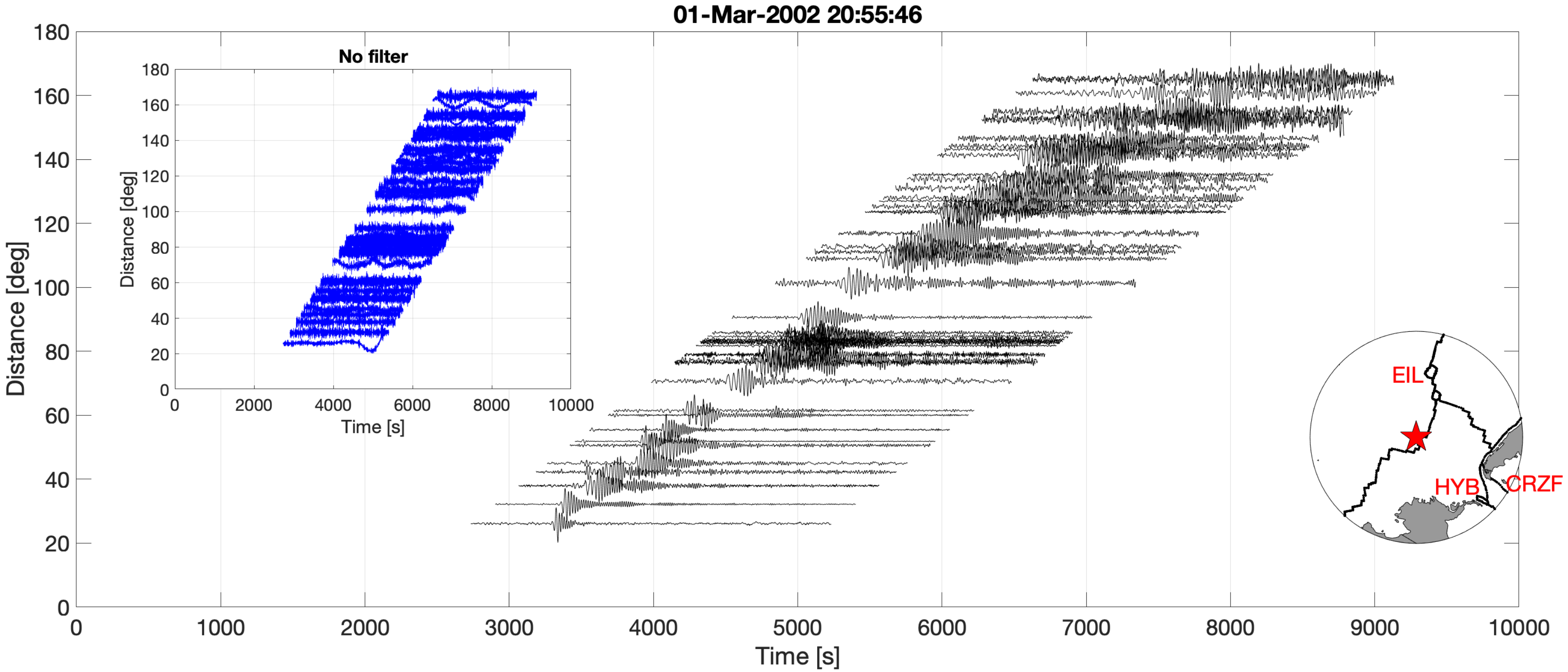
Global scale detection of long period signals

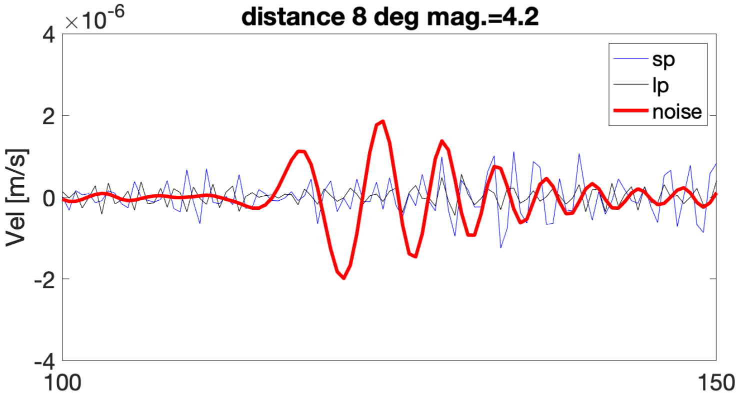
Surface waves magnitude (Nuttli, 1973)

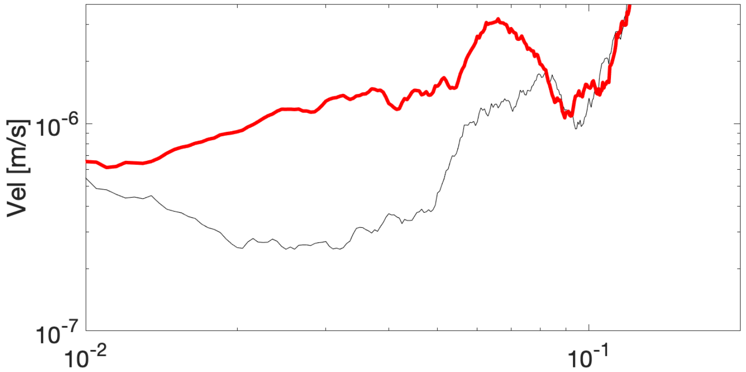




Oceanic ridge events



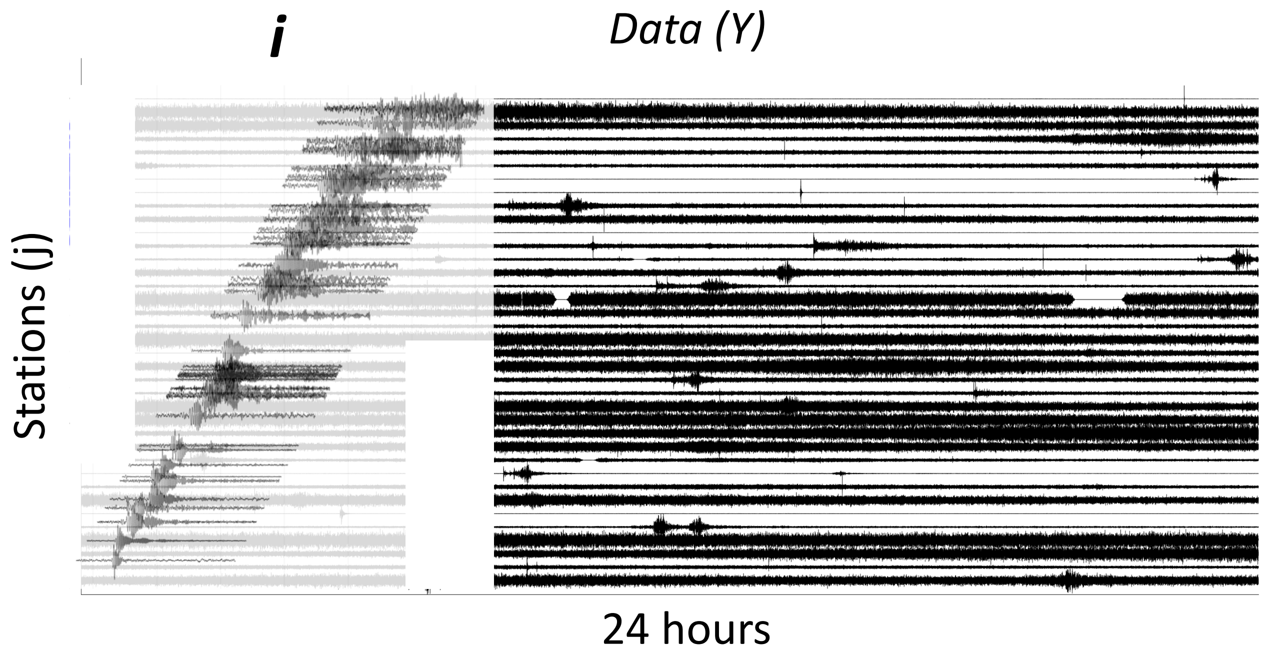


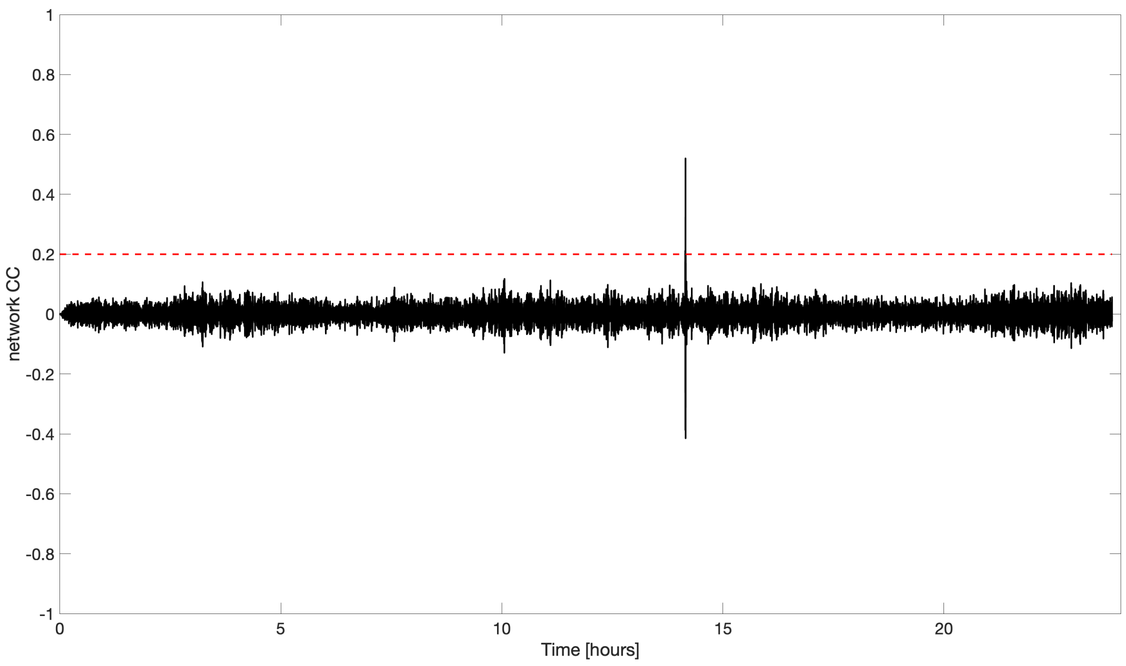


Improving detection: full waveform matching

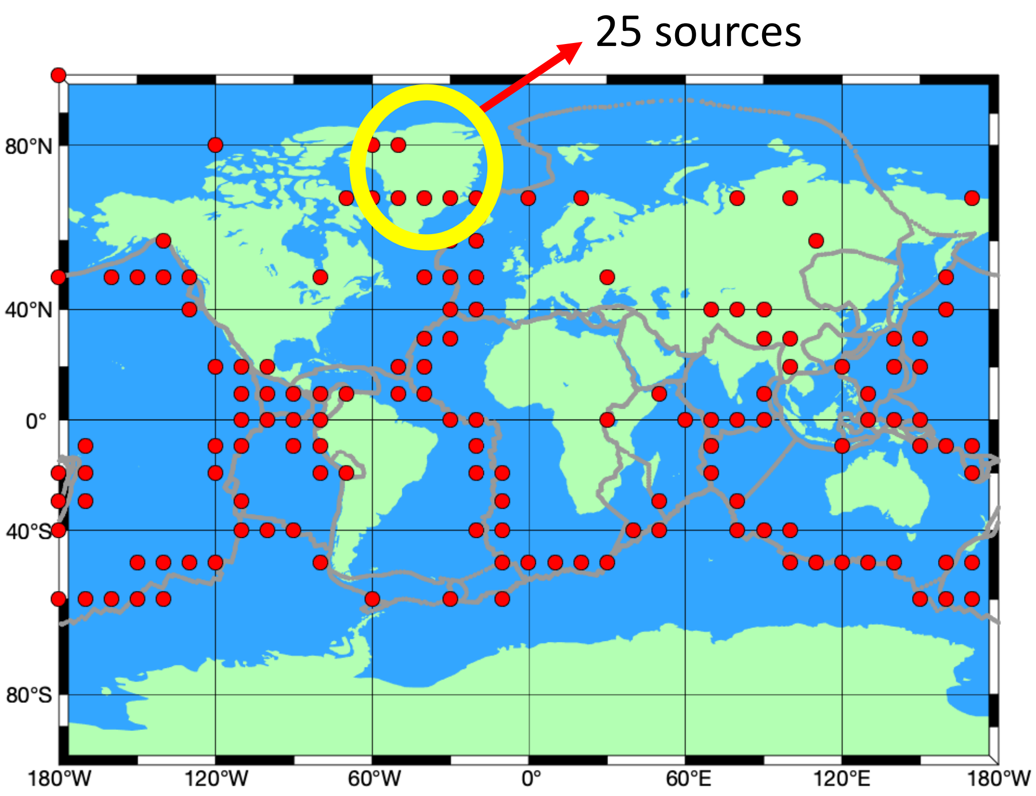
$$C_i = \sum_{j=1}^{n} \frac{X^j \cdot Y_i^j}{\sqrt{(X^j \cdot X^j)(Y_i^j \cdot Y_i^j)}}$$

X = detected events

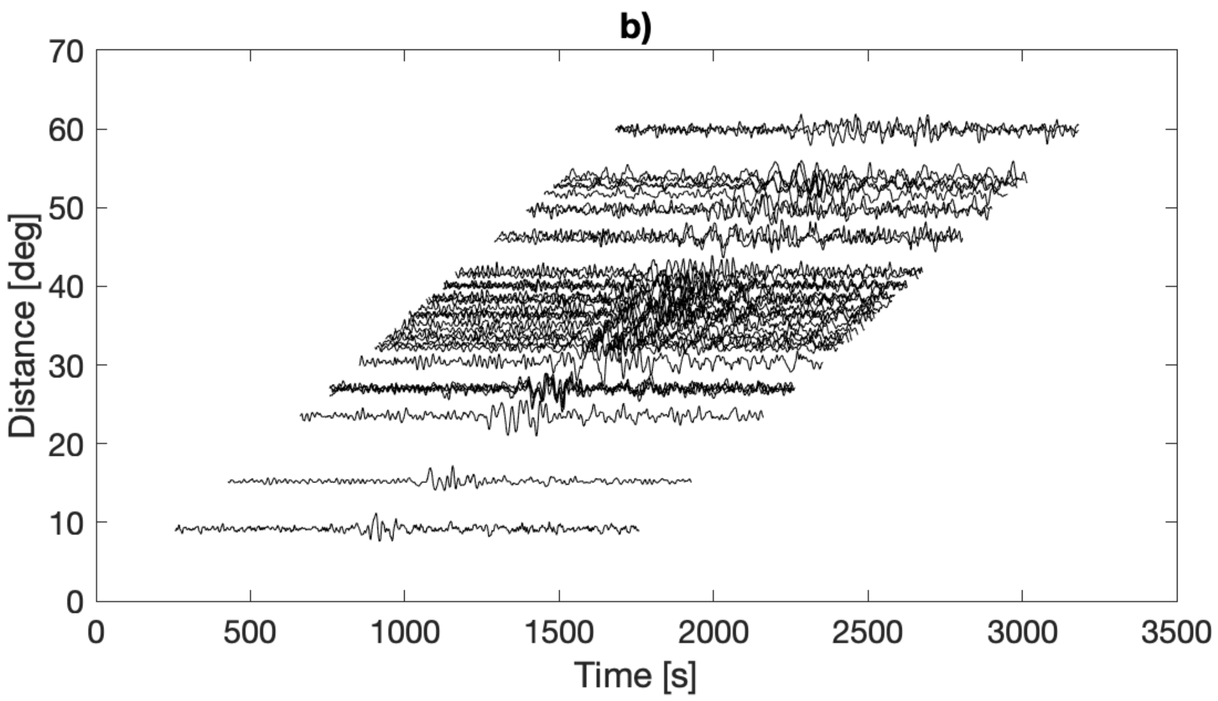




Greenland



Sample detection

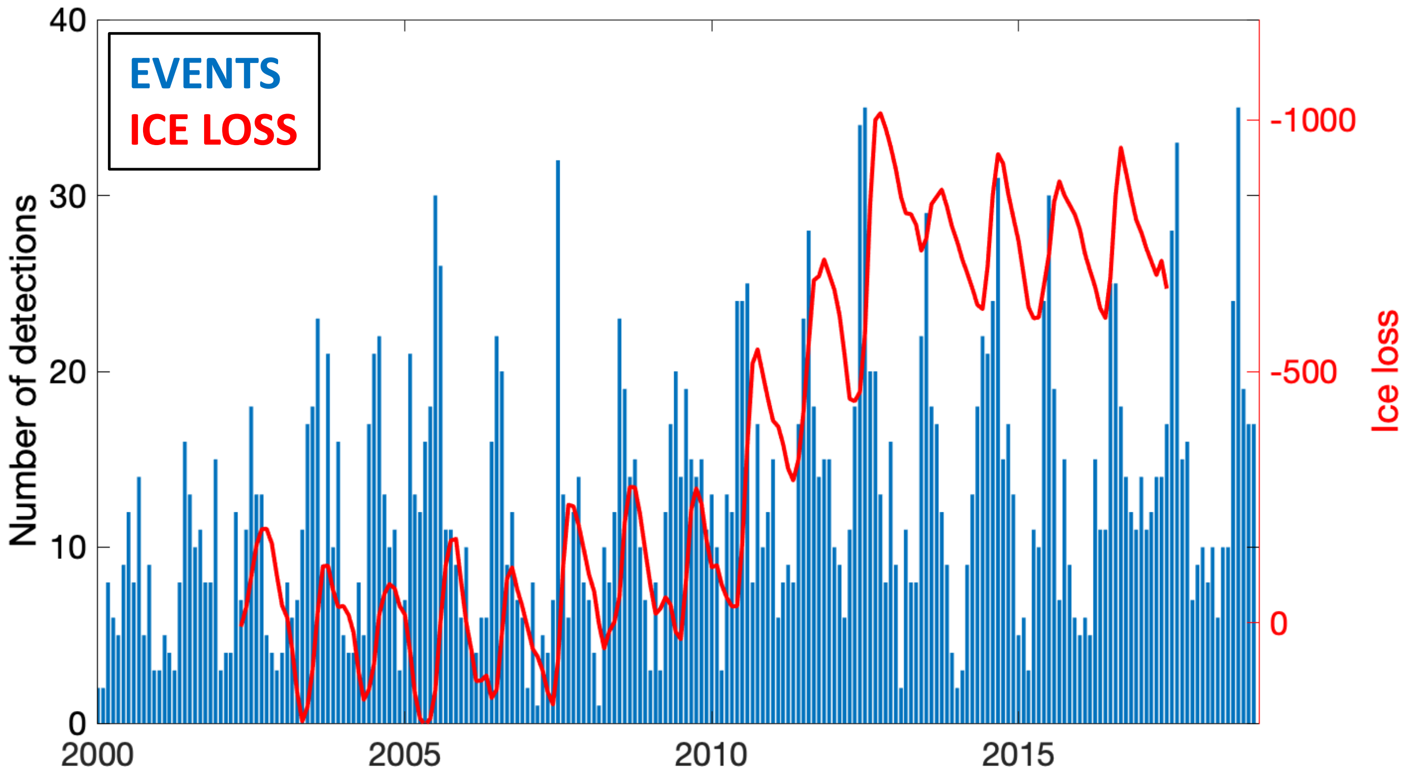


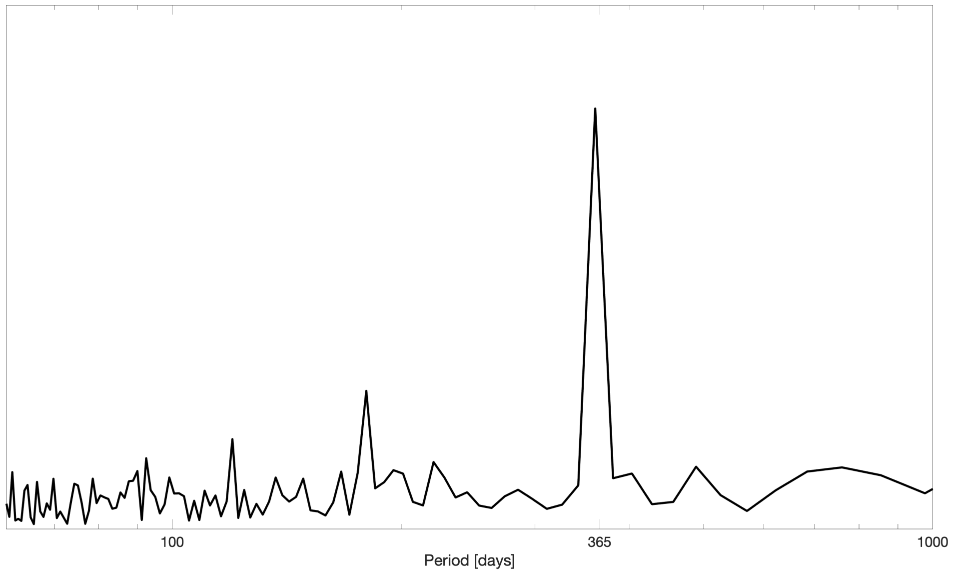
- **Empirical detection (25 events)**

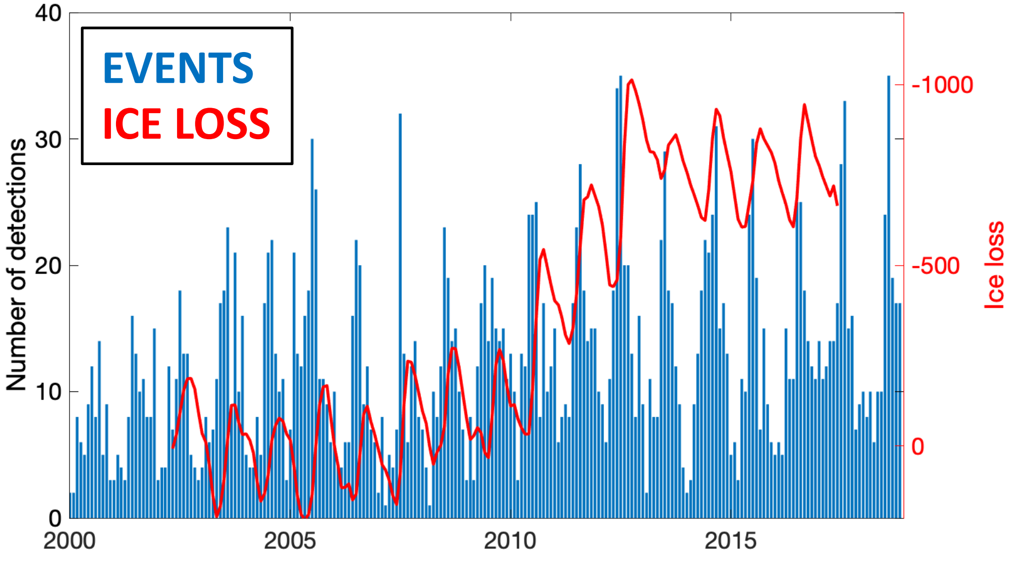
- **Full waveform template matching (2620 events)**

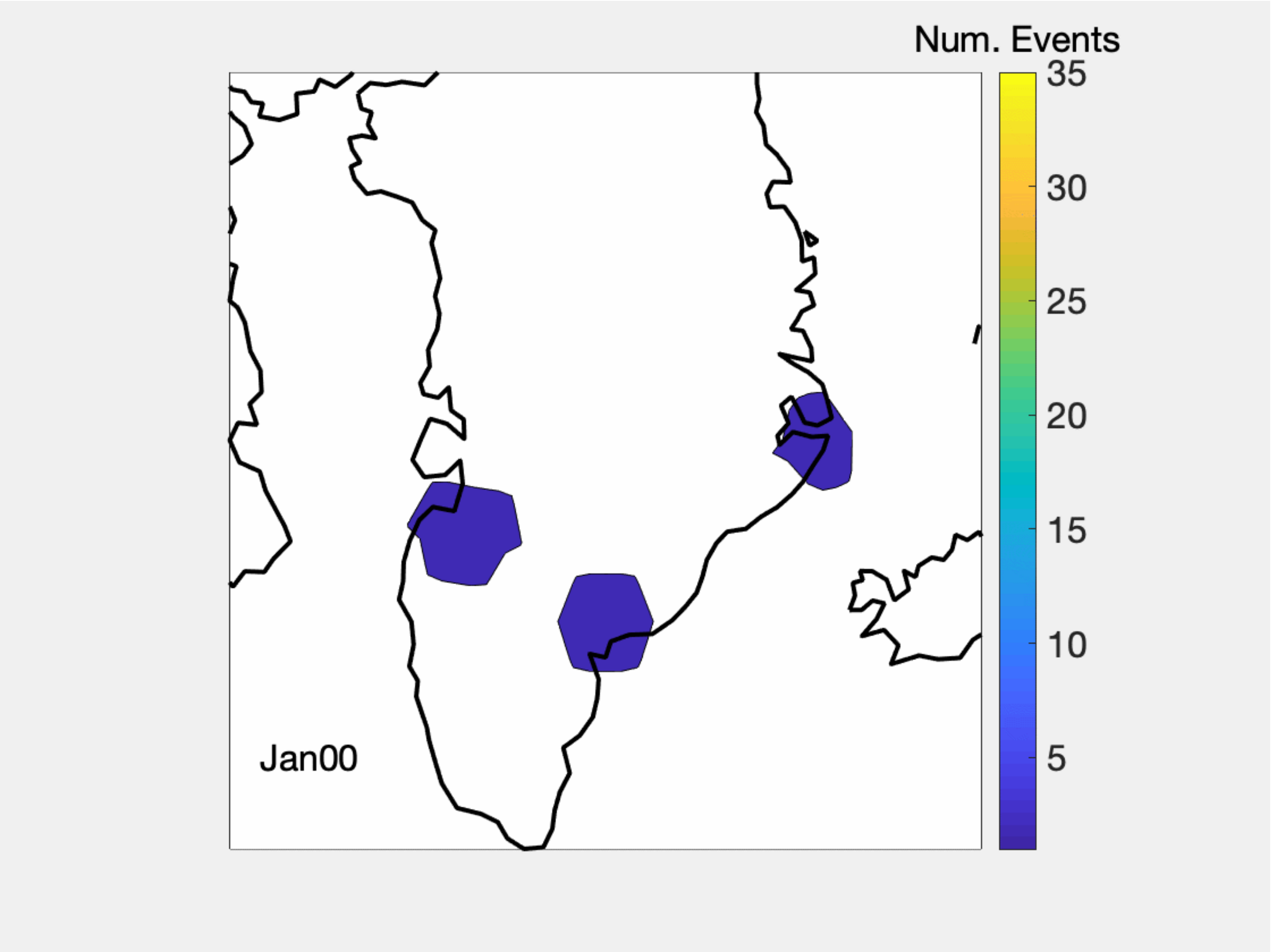
Greenland

- **Empirical detection (24 events)**
- **Full waveform (2620 events)**



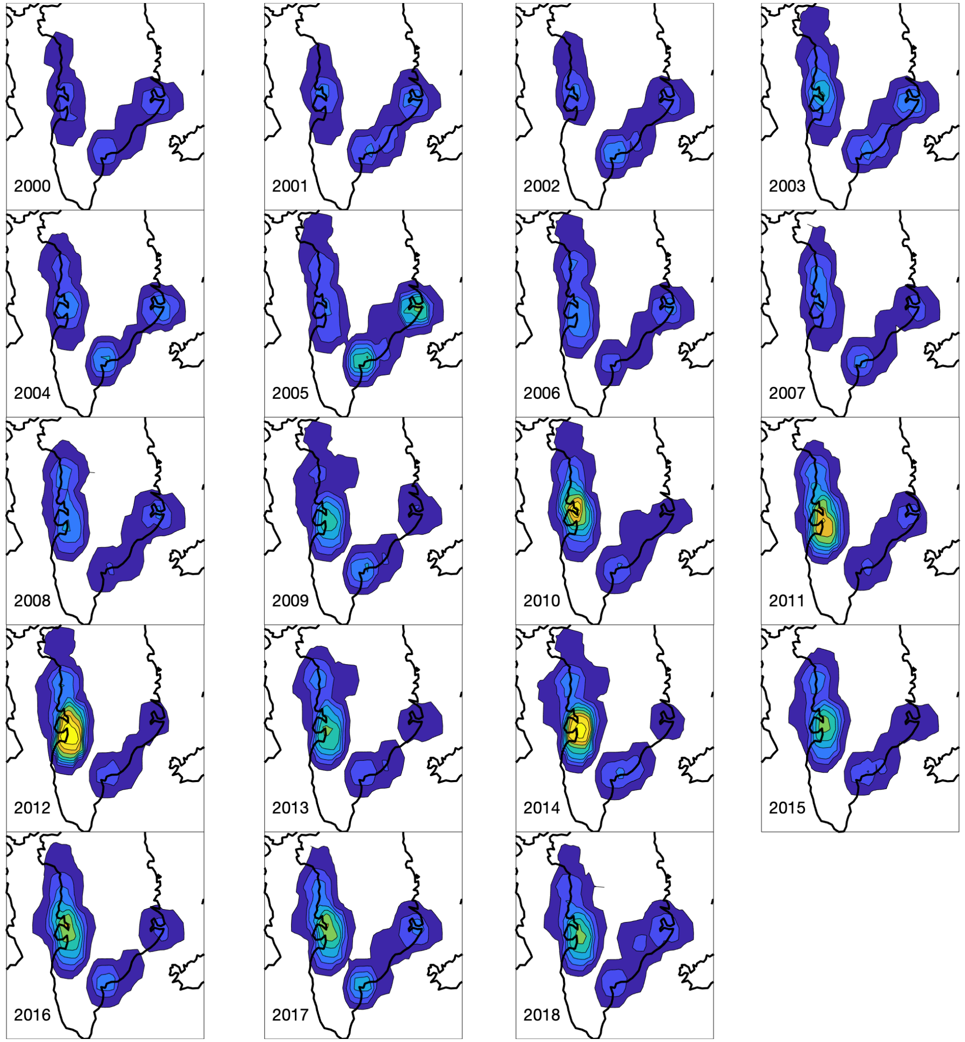



EVENTS
ICE LOSS
Number of detections
Ice loss
40
30
20
10
0
-1000
-500
0
2000
2005
2010
2015

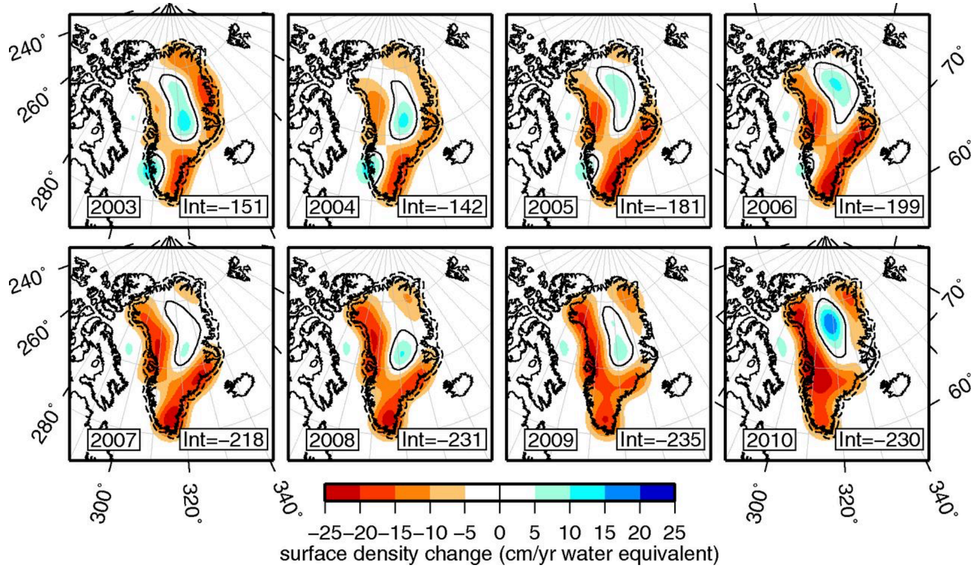

Num. Events
35
30
25
20
15
10
5
Jan00

Greenland: Comparison with GRACE data

Seismological observations



GRACE data inversion



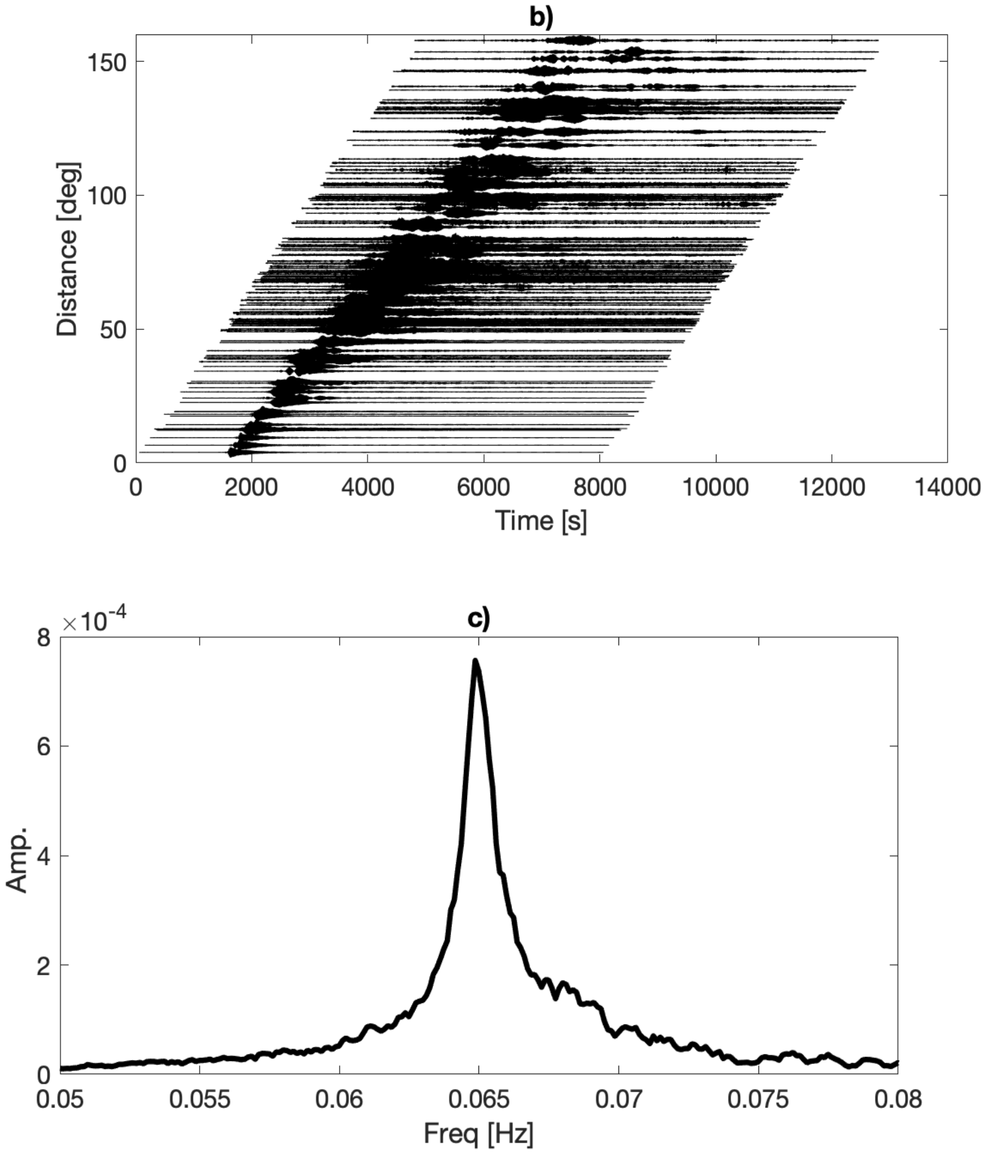
Harig & Simons (2012)

NO INVERSION / DIRECT OBSERVATION

INVERSION / DATA CORRECTION

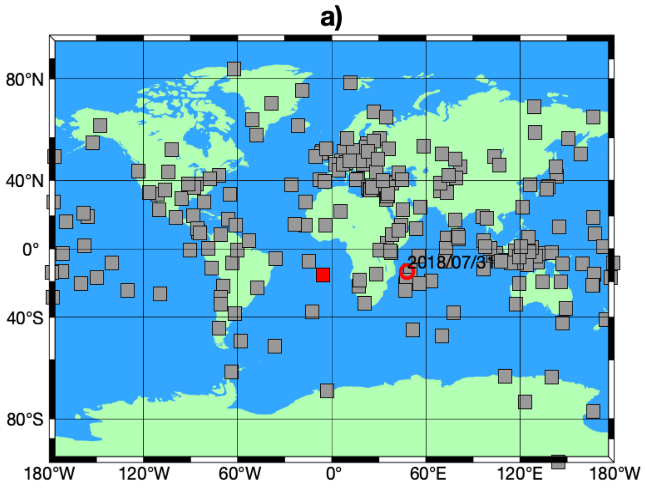
Low frequency signals from deep oceans volcanoes

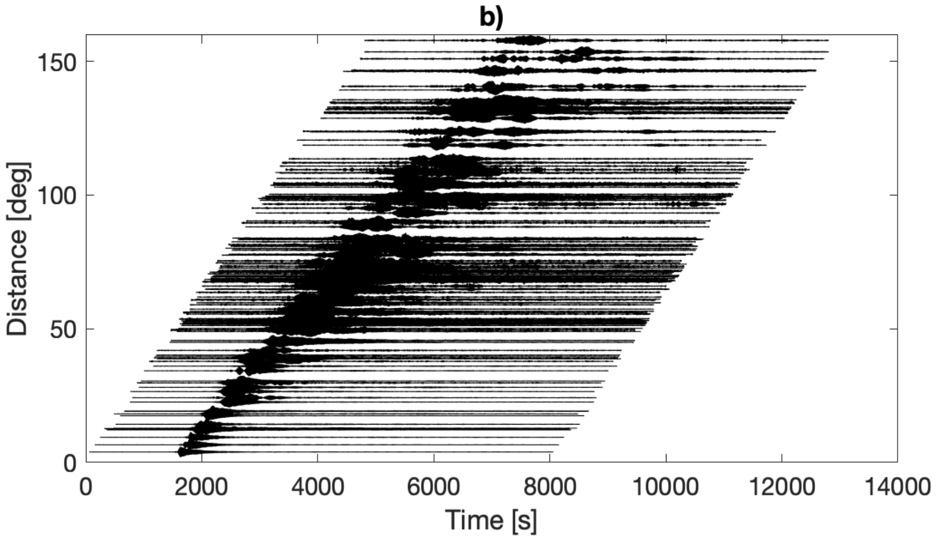
Low frequency volcanic tremors



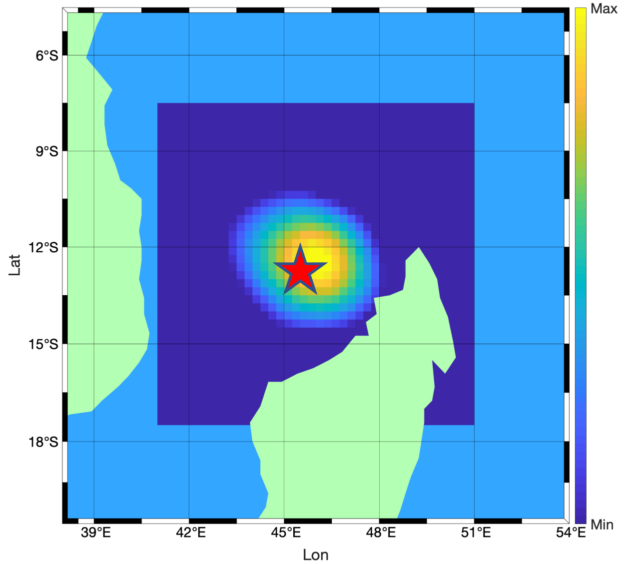
Poli, Shapiro & Campillo (one day will be puslished!)

Low frequency volcanic tremors: Location



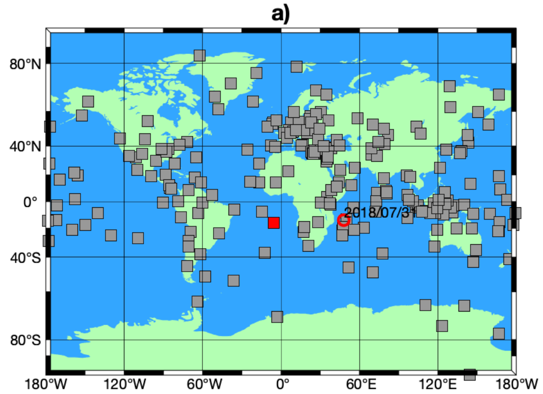


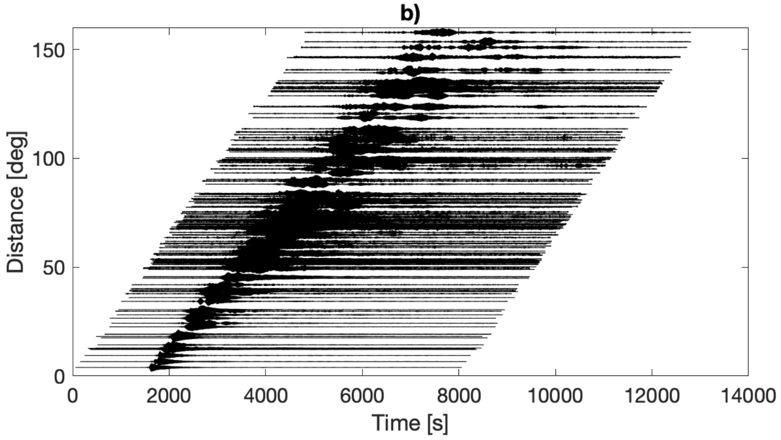
Location close to a seismic swarm (★)



Poli, Shapiro & Campillo (one day will be puslished!)

Low frequency volcanic tremors: Full waveform detection

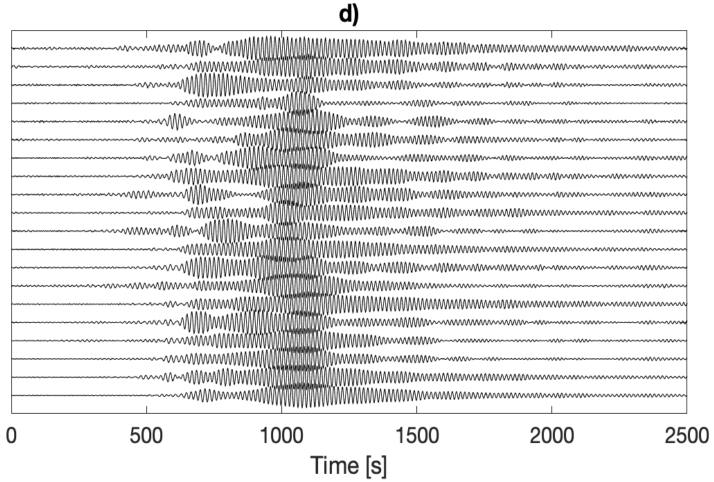




Search for repeaters:

-Template matching using the waveforms for the 31st of July events

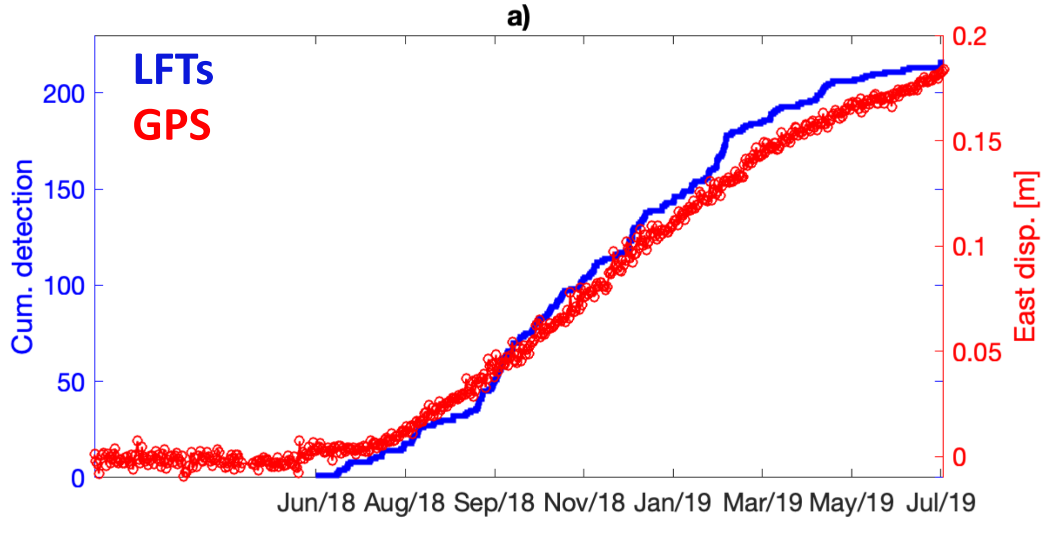
-From 2018 to August of 2019

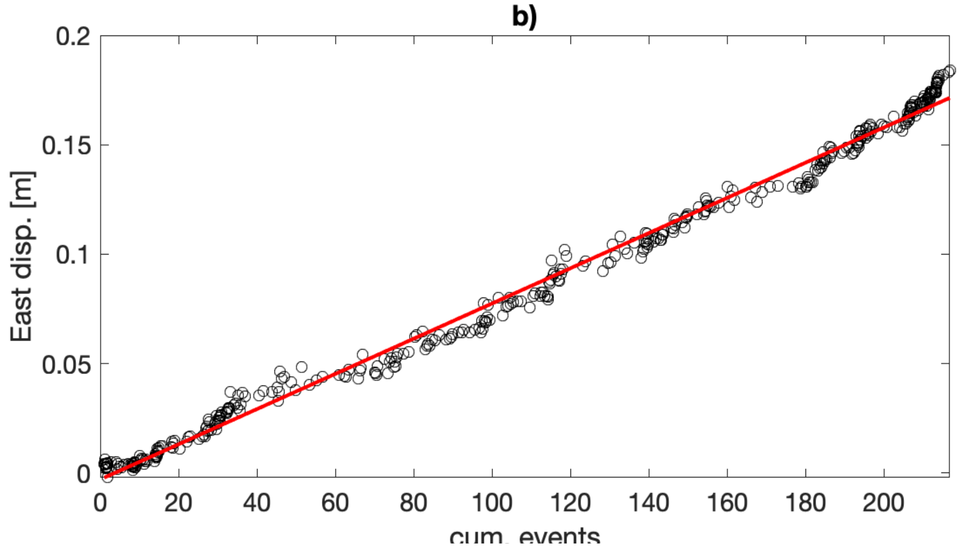


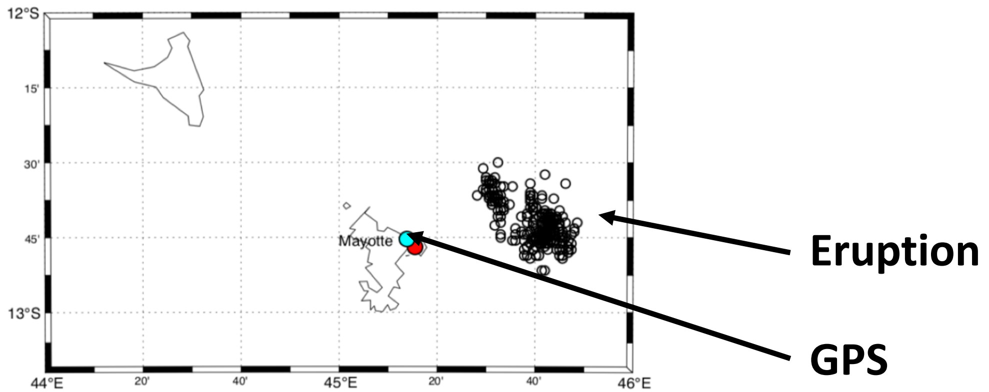
New detections

217 events

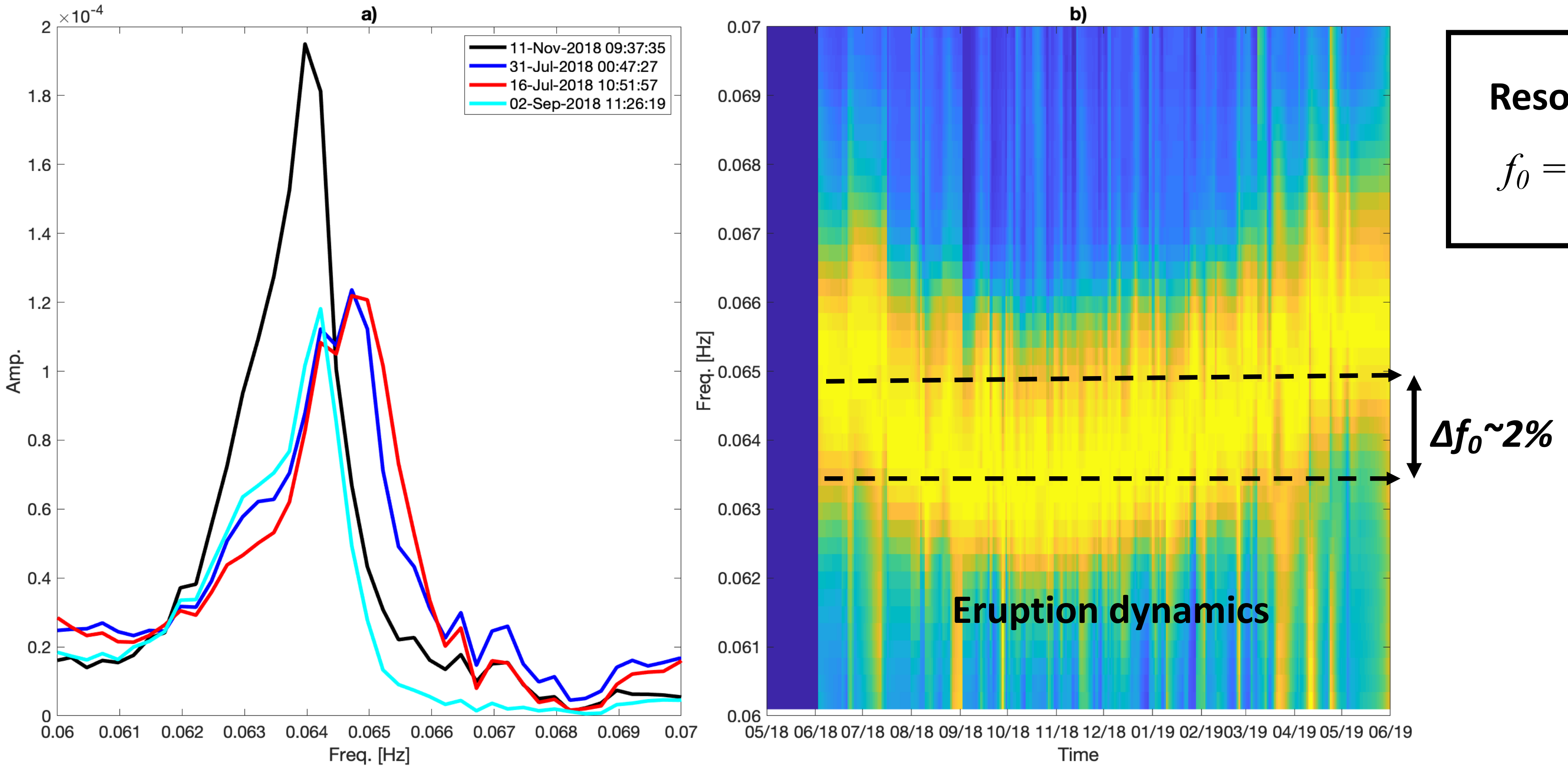
Low frequency volcanic tremors







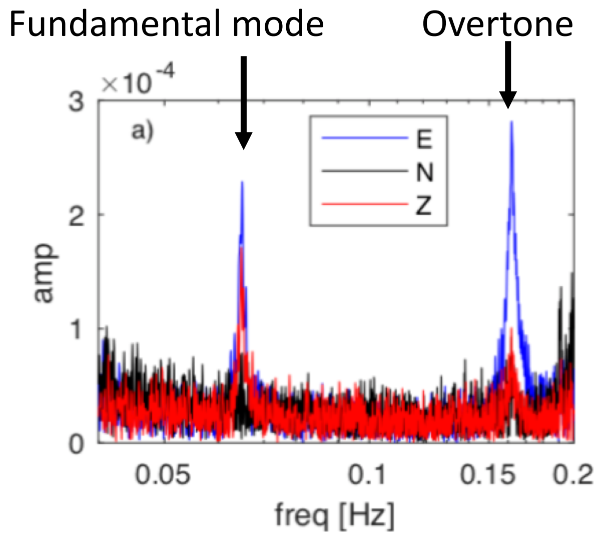
Low frequency volcanic tremors: Spectral properties

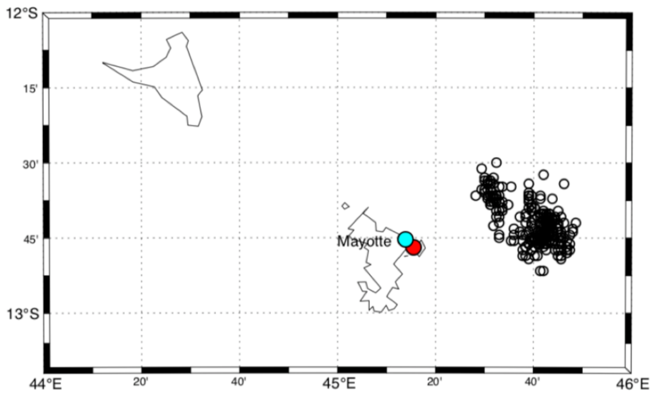


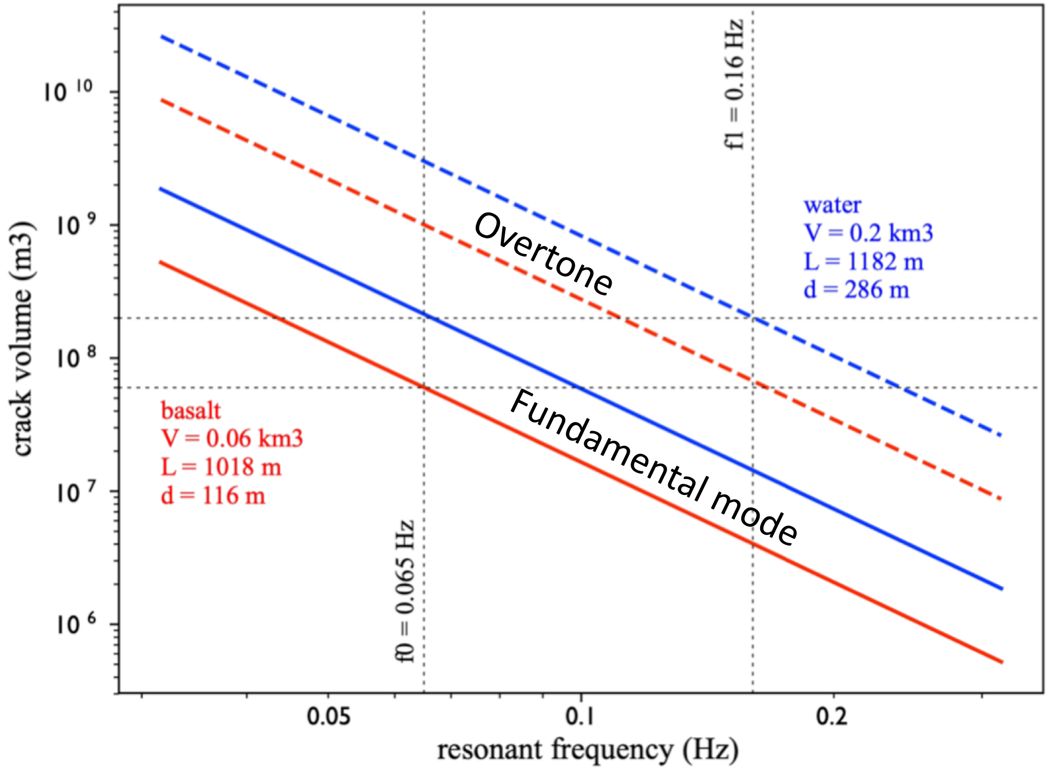
Resonance freq.

$$f_0 = v_0(C)\ \alpha/L$$

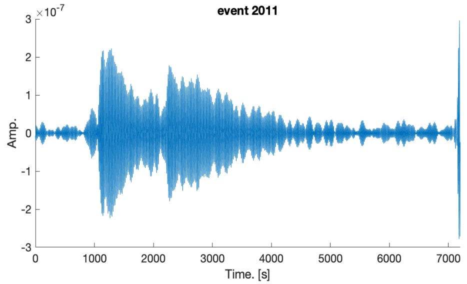
Low frequency volcanic tremors: Source properties

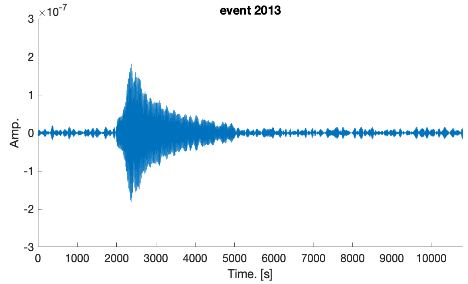


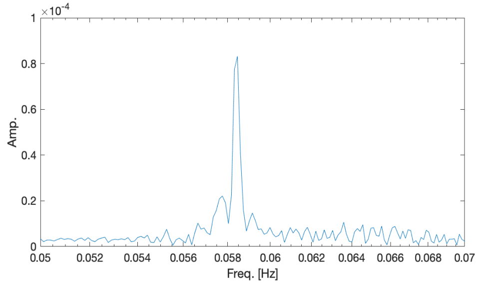


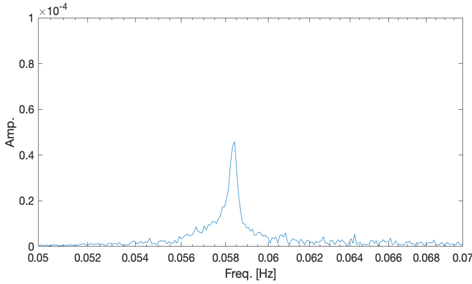


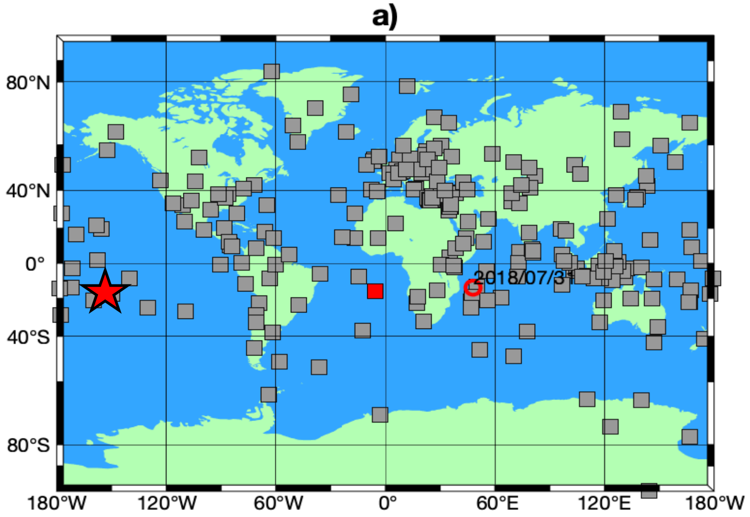
Are these LFTs unique?

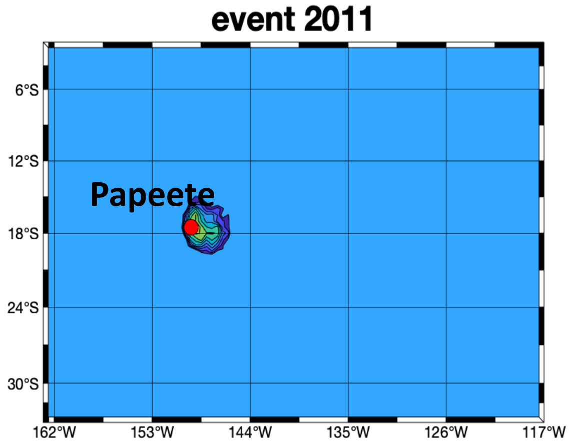


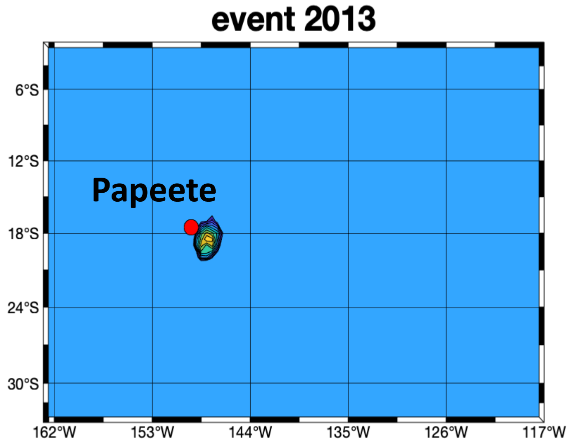






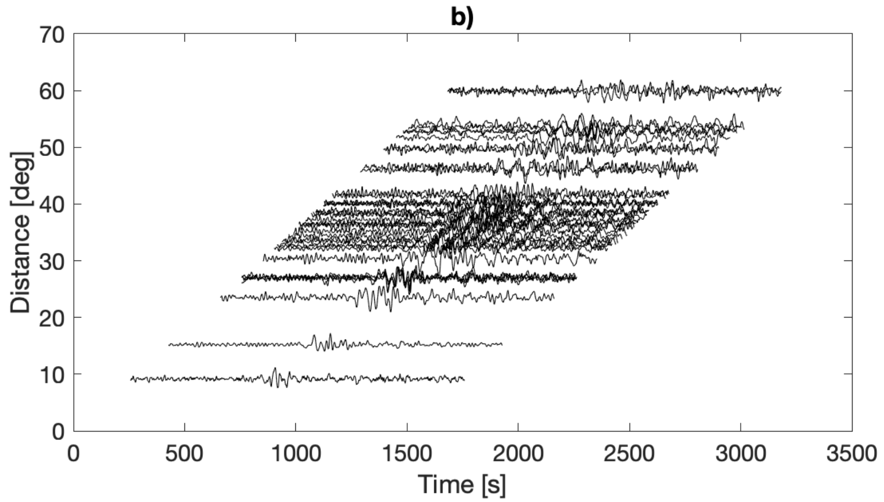






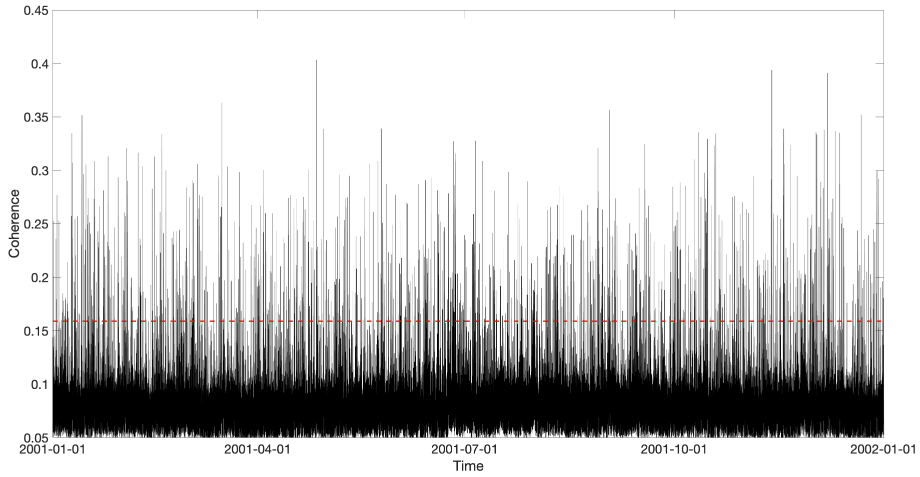
Conclusions (I)

- Preliminary search for signals is fast (one day one minute) and enrich earthquake catalogs
- Detections of signals beyond ‘regular’ earthquakes
- Primary detections for full waveform TM



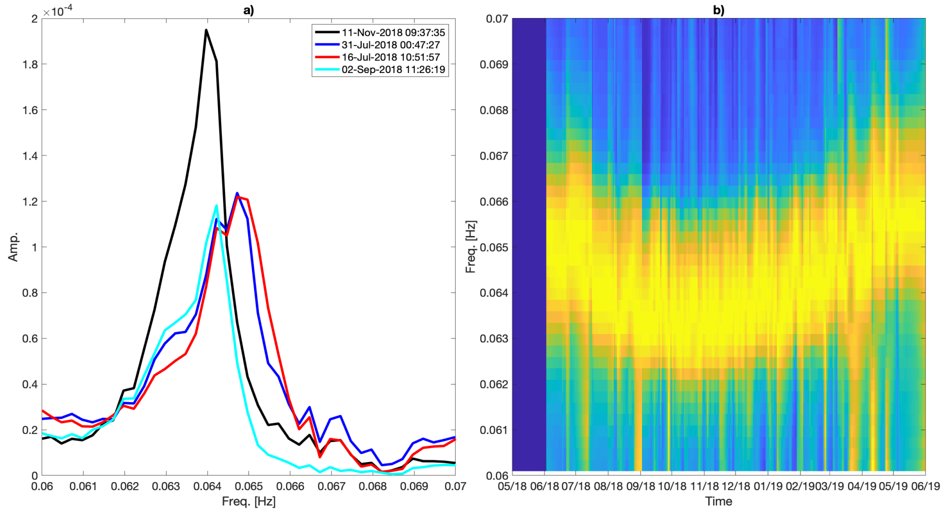
Issues:

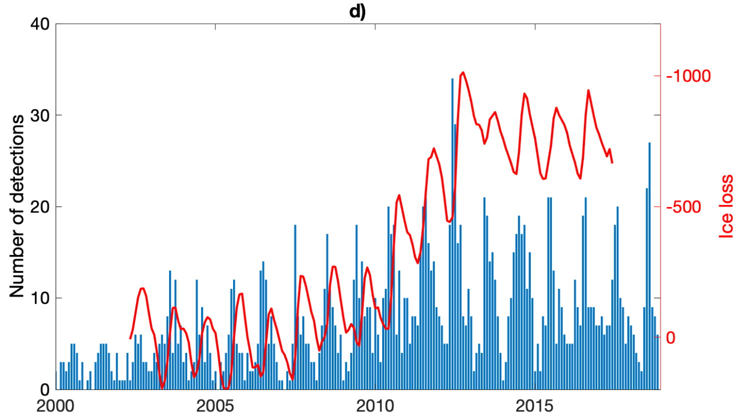
- Choice of detection function (better location/detection)
- Explore a larger frequency range
- Quality control of detections
- Relocation and depth resolution
- Separation of earthquakes from other signals



Conclusions (II)

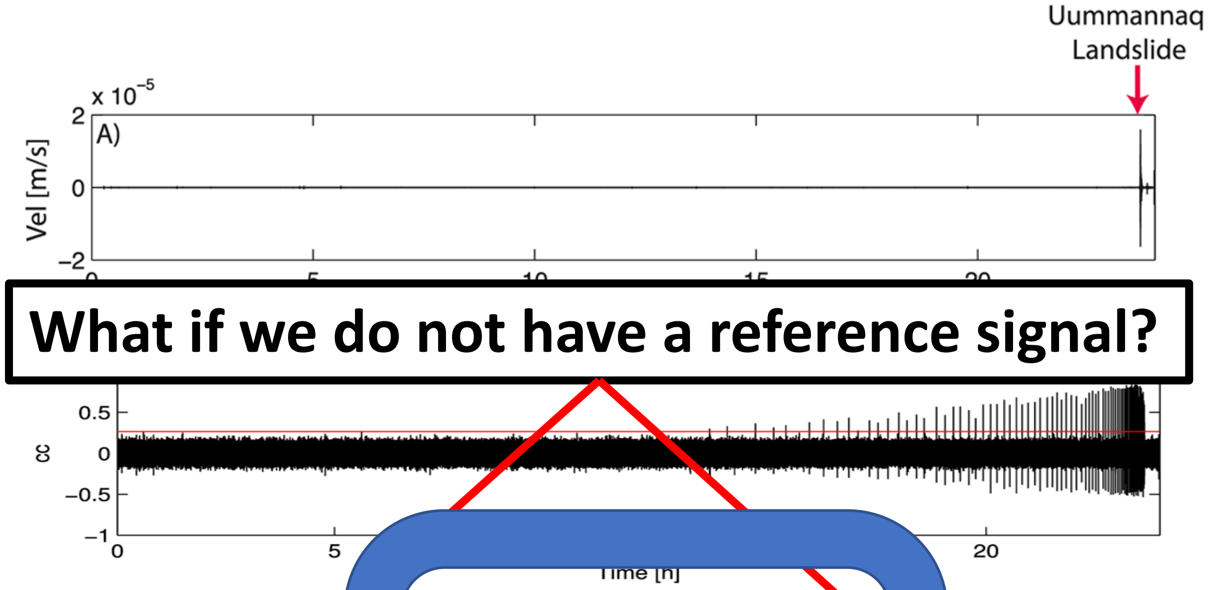
Detected signals provide information about (geo) physical processes





Catalog is open as it is the possibility to collaborate!
piero.poli@univ-grenoble-alpes.fr

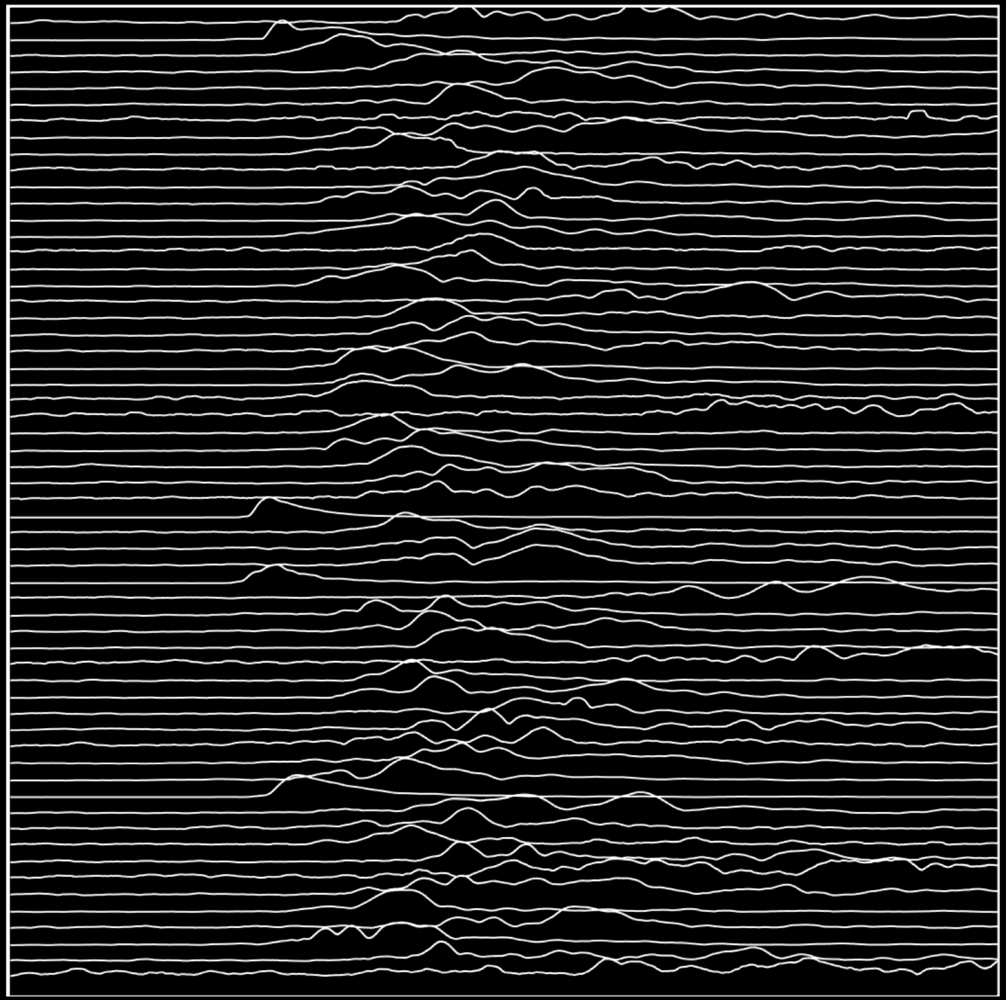
Conclusions (III)



What if we do not have a reference signal?

Generate signals from knowledge

ML
wait Friday L. Seydoux presentation



LP Volcanic event, 31st July 2018

THANKS

A FIXED VIEW POINT CAN BE A TRAP WHERE WE ONLY SEE WHAT WE ARE LOOKING FOR

(from Unflattened, Sousanis)

Greenland

- **Empirical detection (24 events)**
- **Full waveform (2620 events)**