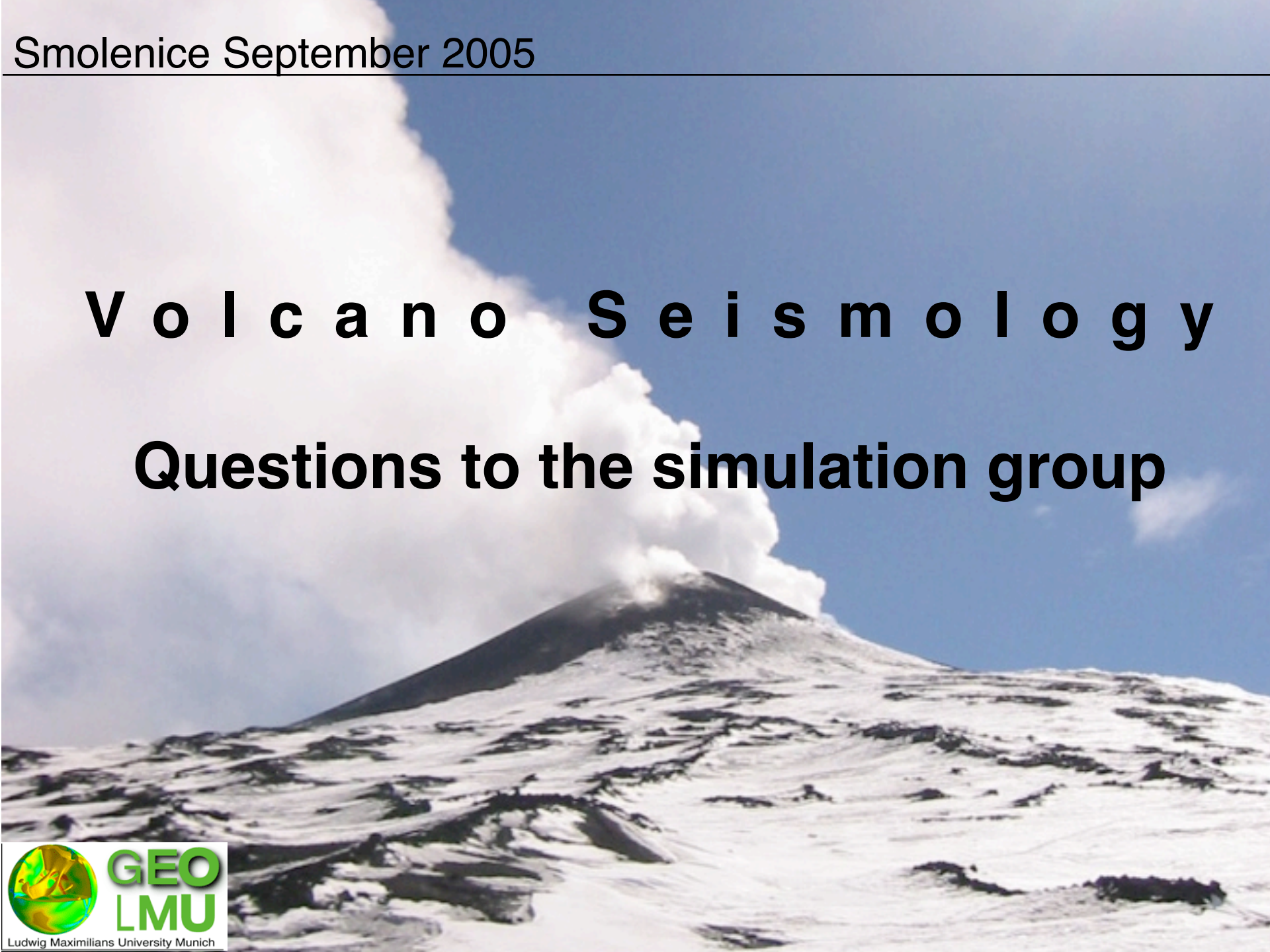
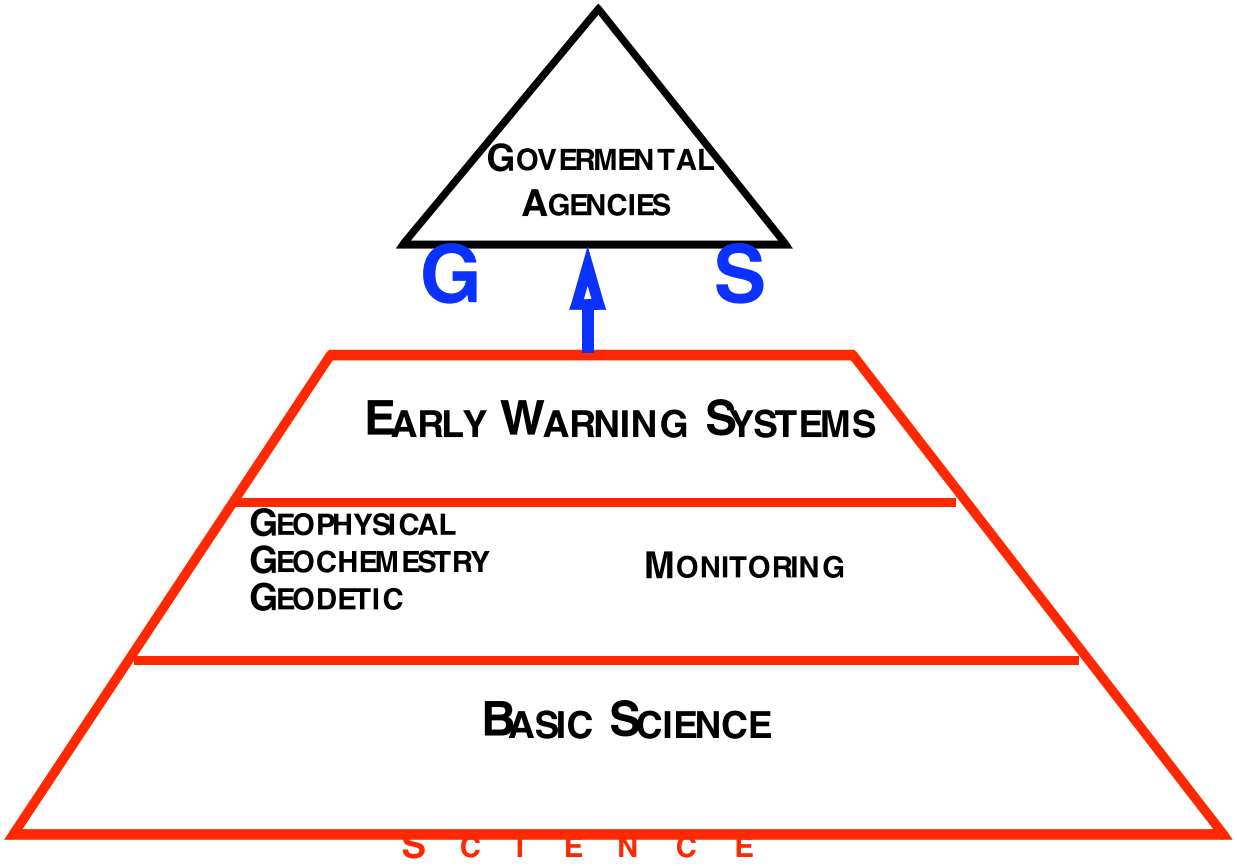


V o l c a n o S e i s m o l o g y

Questions to the simulation group

GEO LMU
Ludwig Maximilians University Munich

How it should (!) work!



modified after Tilling

How to use seismology in order to improve early warning sytems at active volcanoes?

The fundamental idea is that seismic signals are generated:

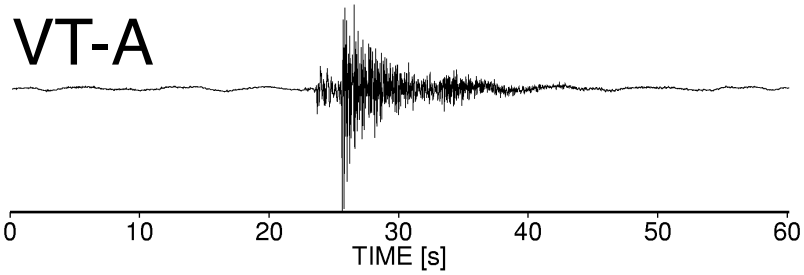
- by (an-)elastic response of the volcanoes edifice to stress induced by ascending magma
- by pressure fluctuations of the moving multiple phase flows within the feeder system
- instabillity of volcanic/structural features located at the surface such as lava domes
- interaction between hot magmatic bodies and cold environment (e.g., magma – water interaction)

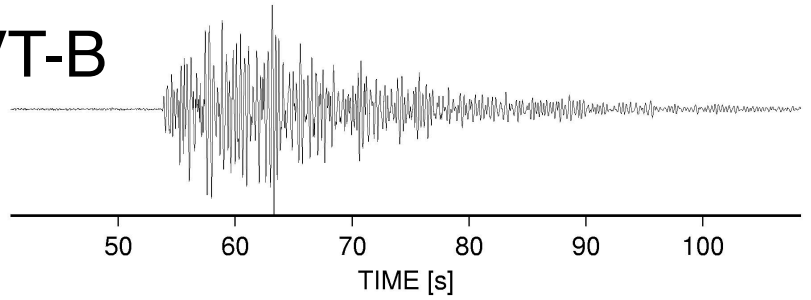
The type, location and rate of seismic signals reflect the dynamic and volumetric behavior of the magmatic system at a volcano.

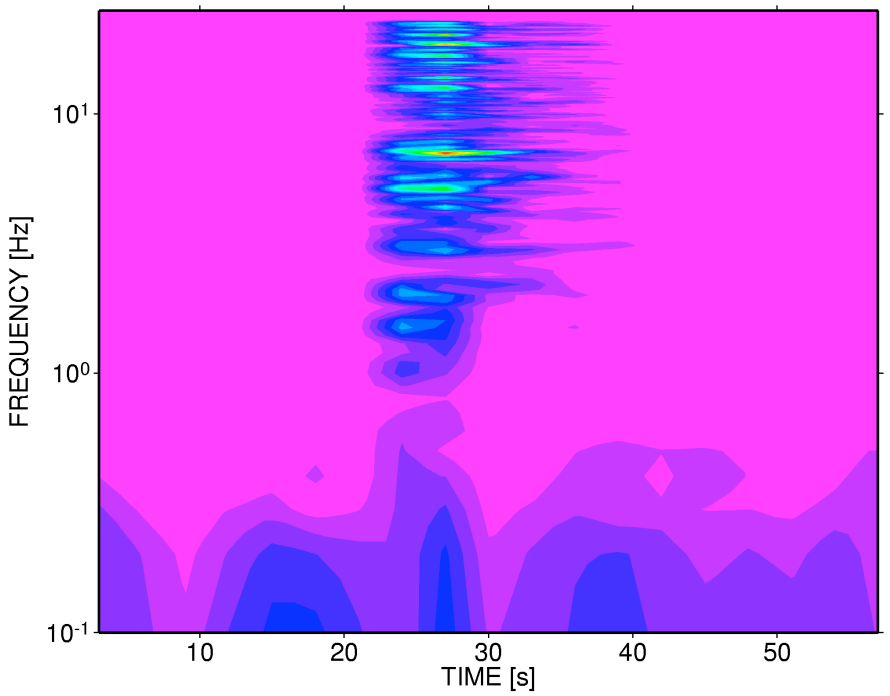
What do we need to know?

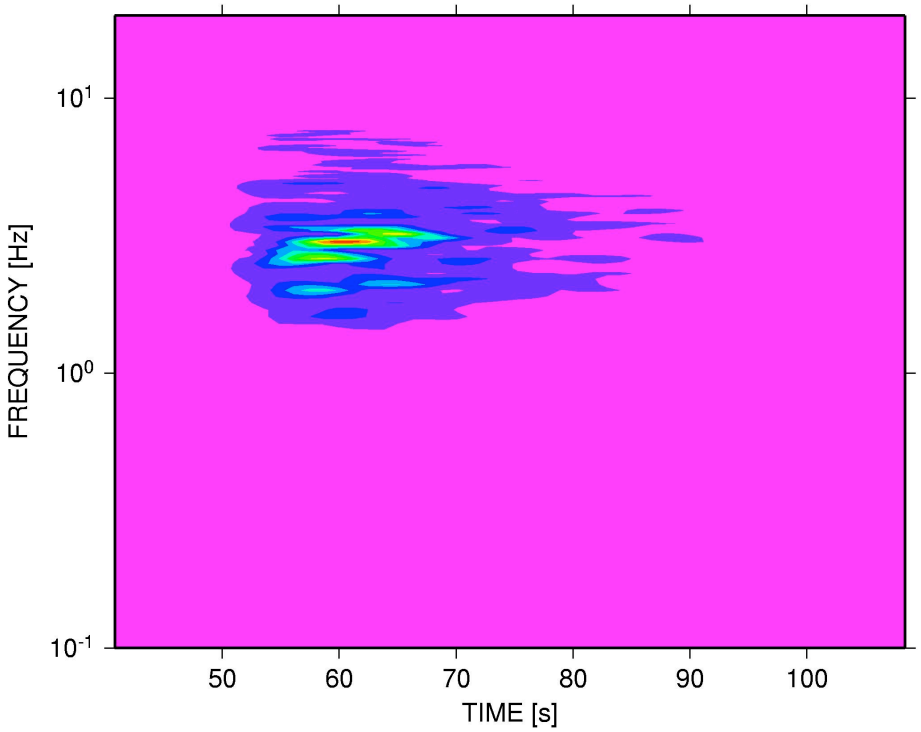
- precise hypocentral estimation in order to detect fluid migration and the extent of magmatic bodies
- source mechanisms of the different types of seismic signals in order to discriminate possible different stages of activity levels
- long term behavior of the volcano‘s seismicity
- what is the influence of external features on the volcanic system as well as on the key monitoring parameter

Known Waveforms

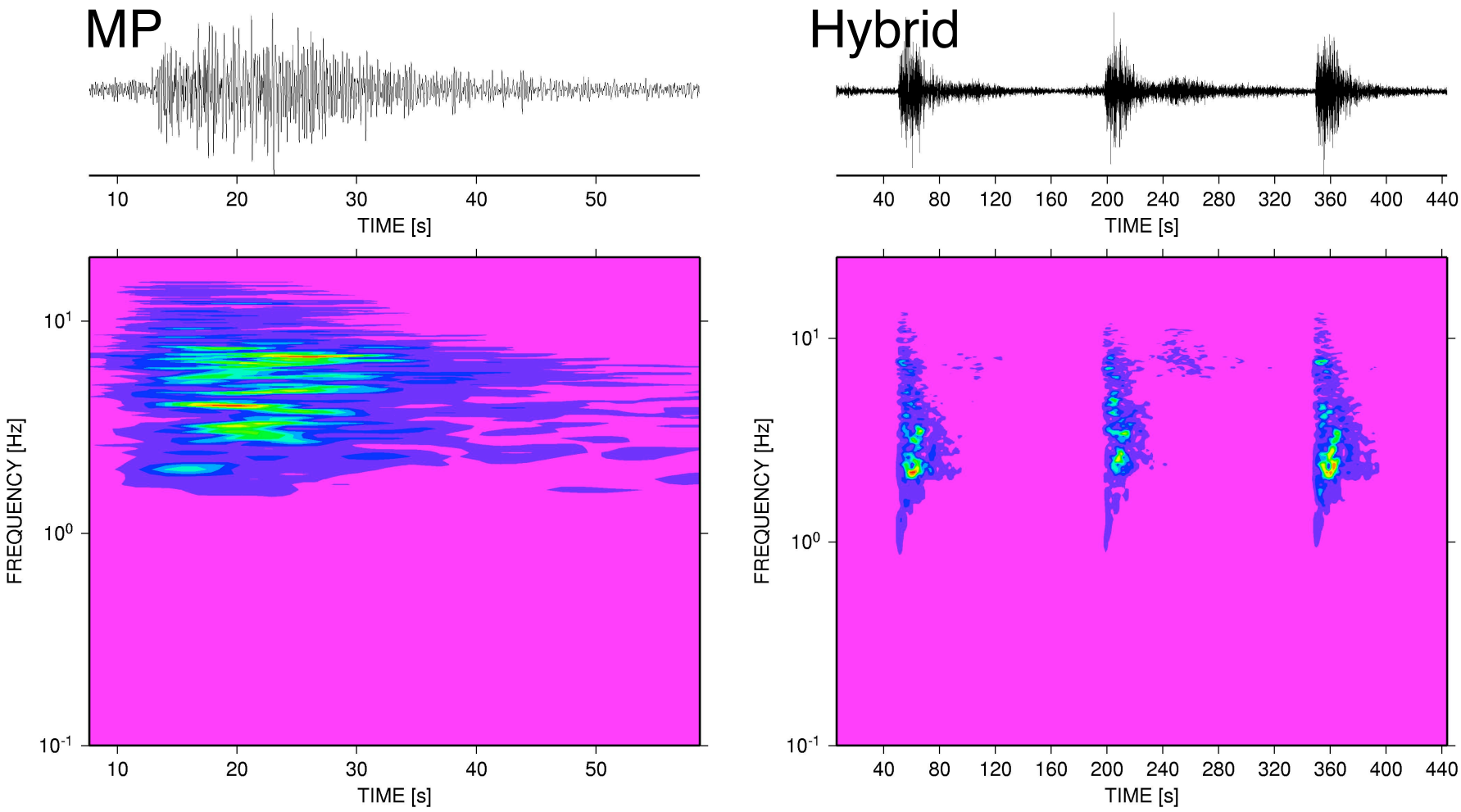




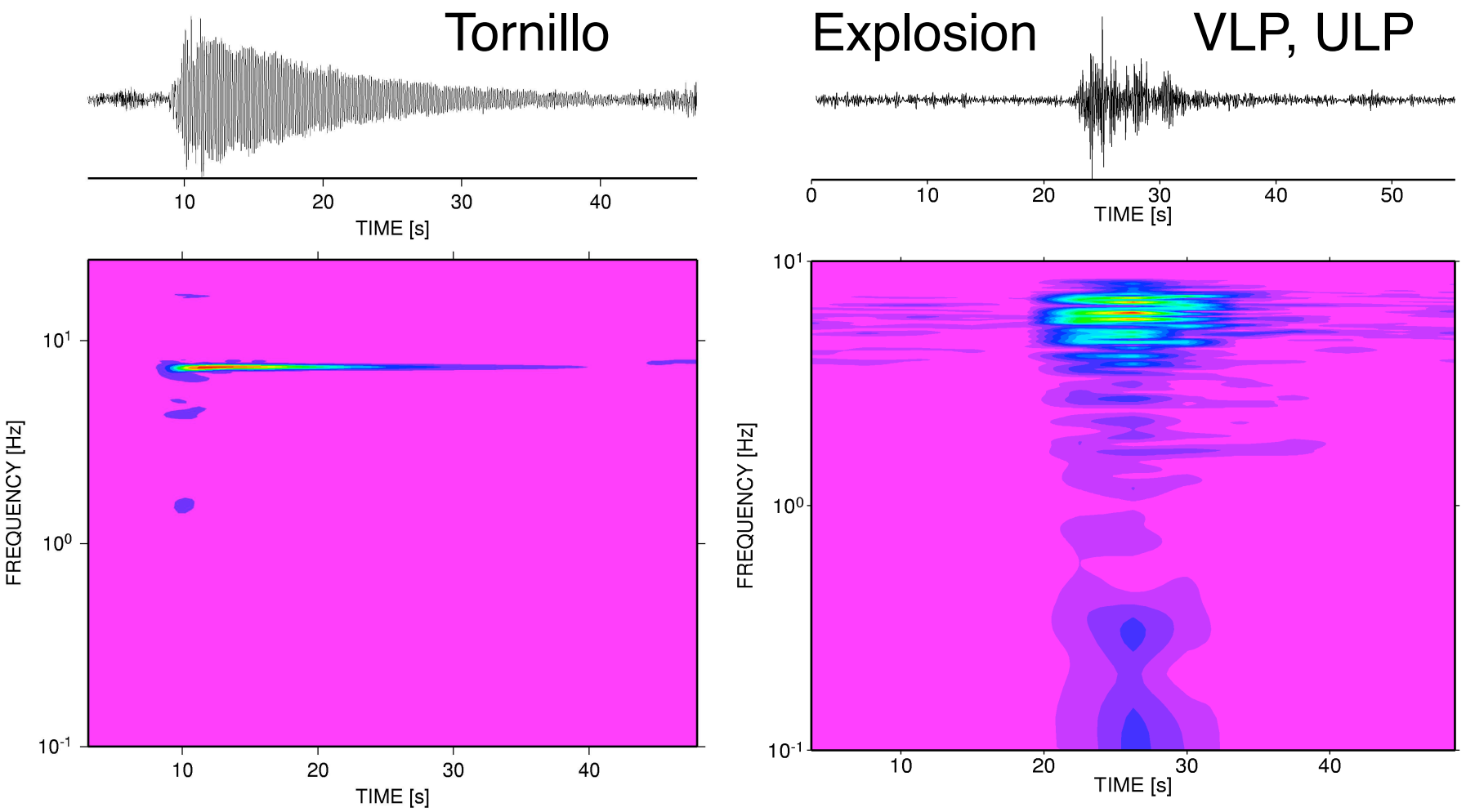




Known Waveforms

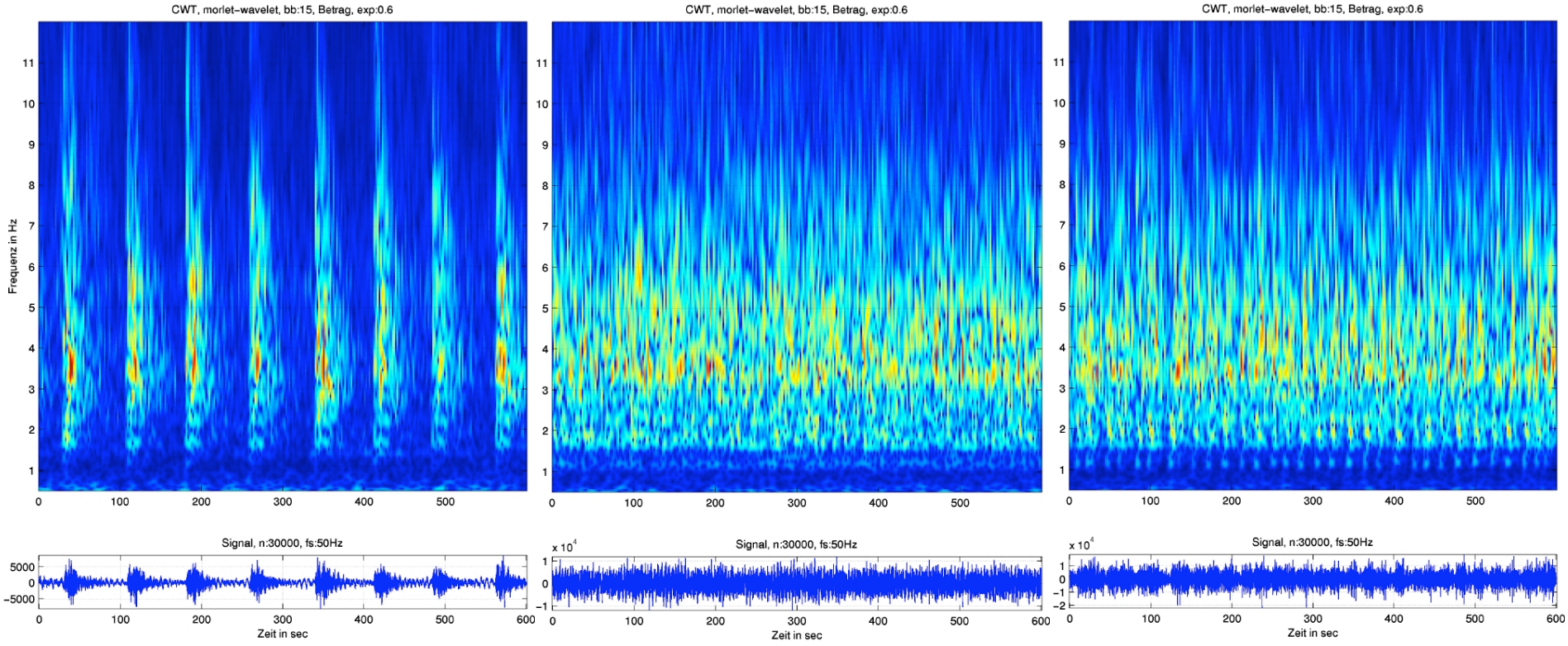


Known Waveforms



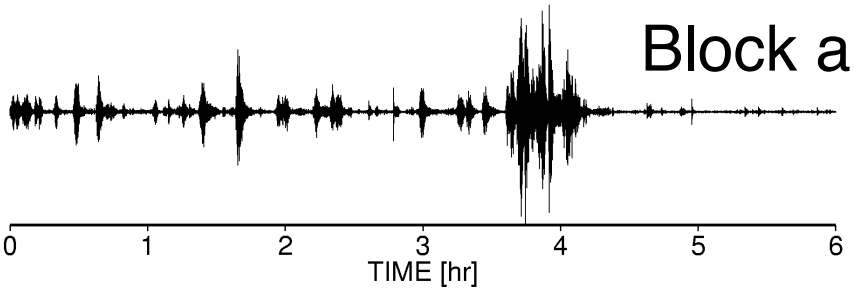
Known Waveforms

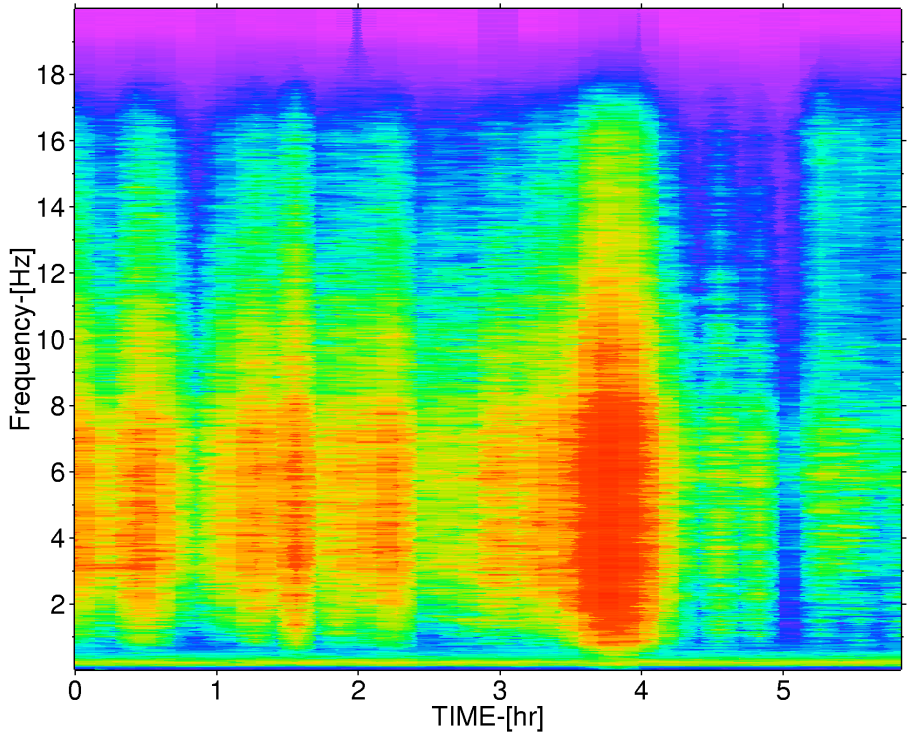
One Type of Volcanic Tremor



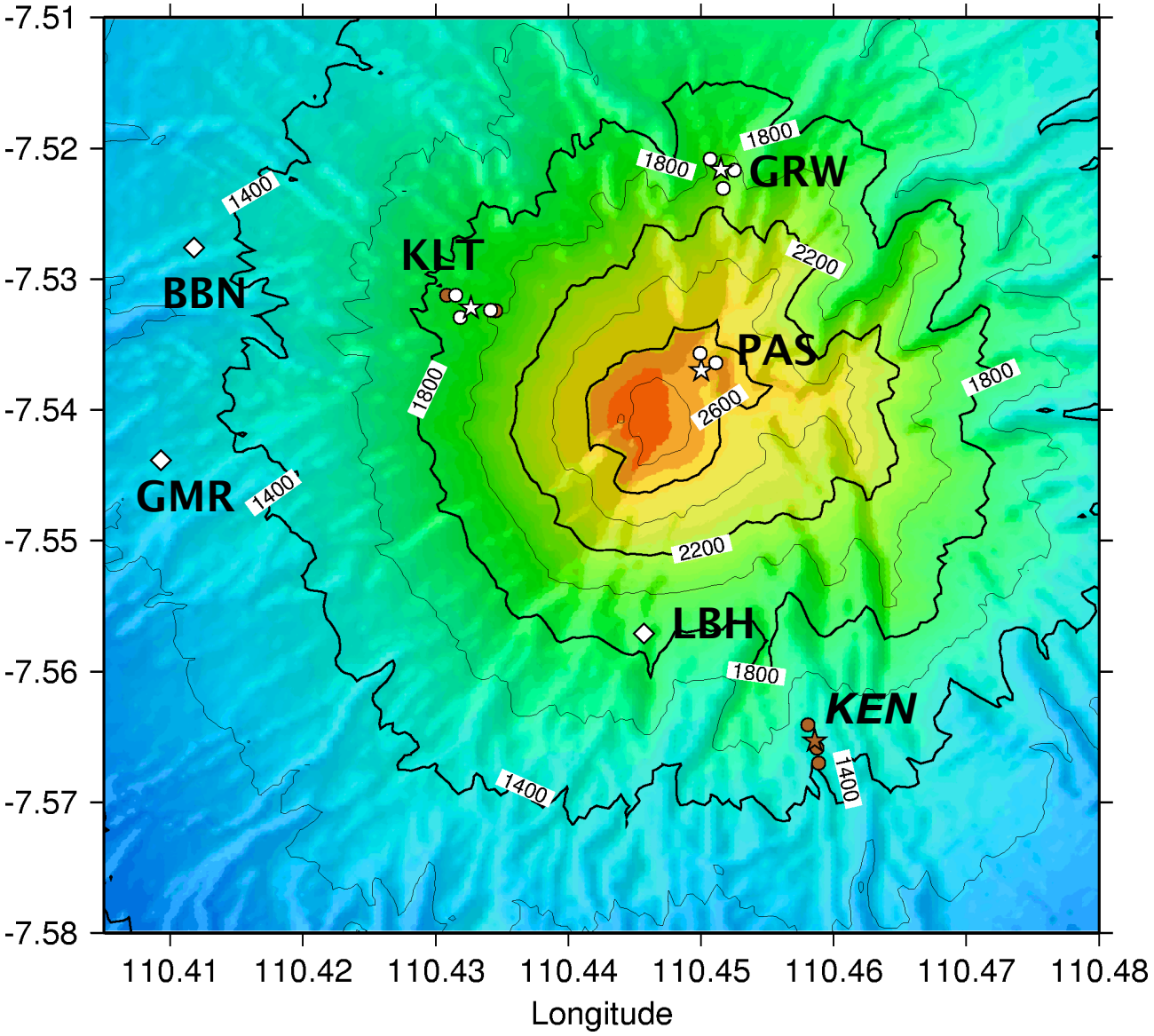
Known Waveforms

Block and Ash Flow

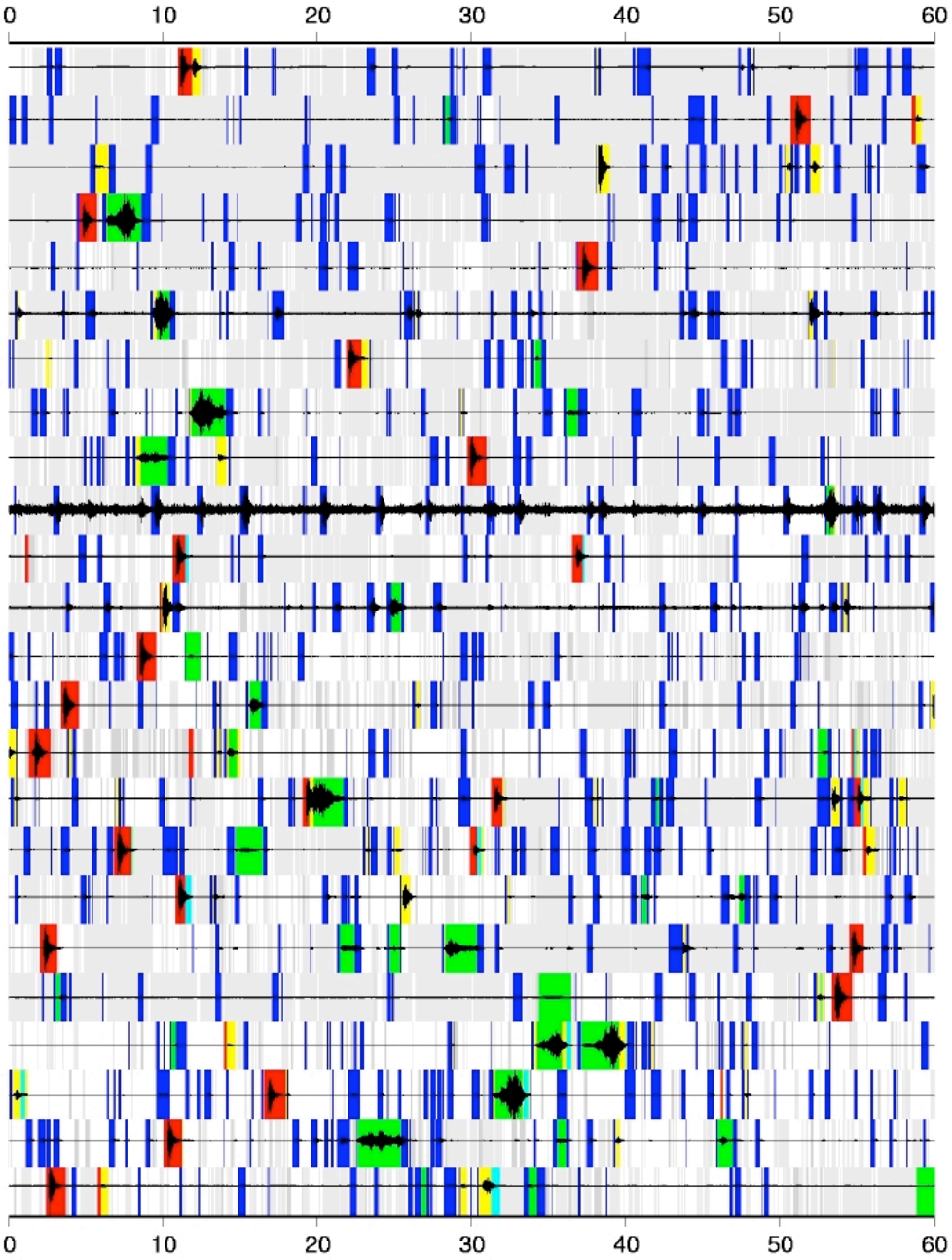




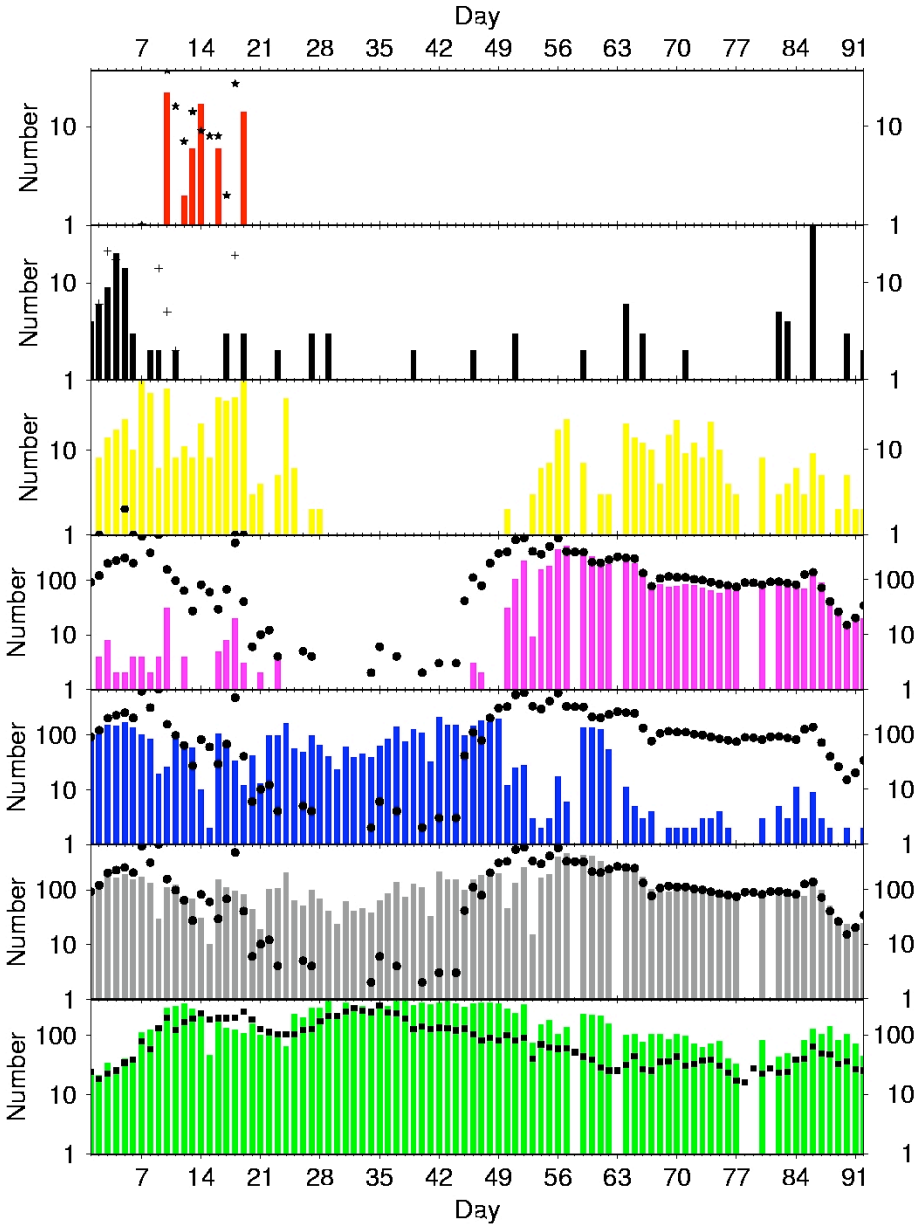
Seismic Network at Mt. Merapi



Event-Classification



01 July – 30 September 1998



BaF

VT-B

Unknown

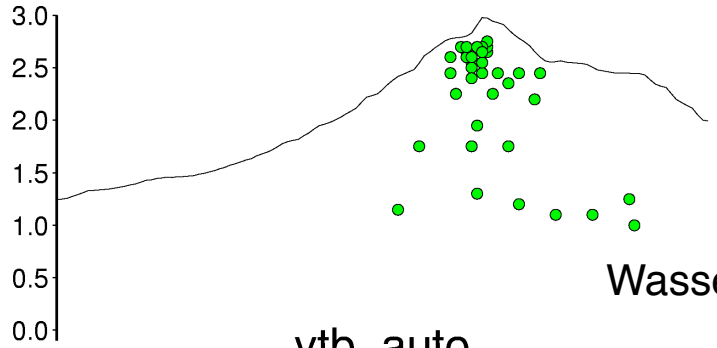
Hybrid

MP

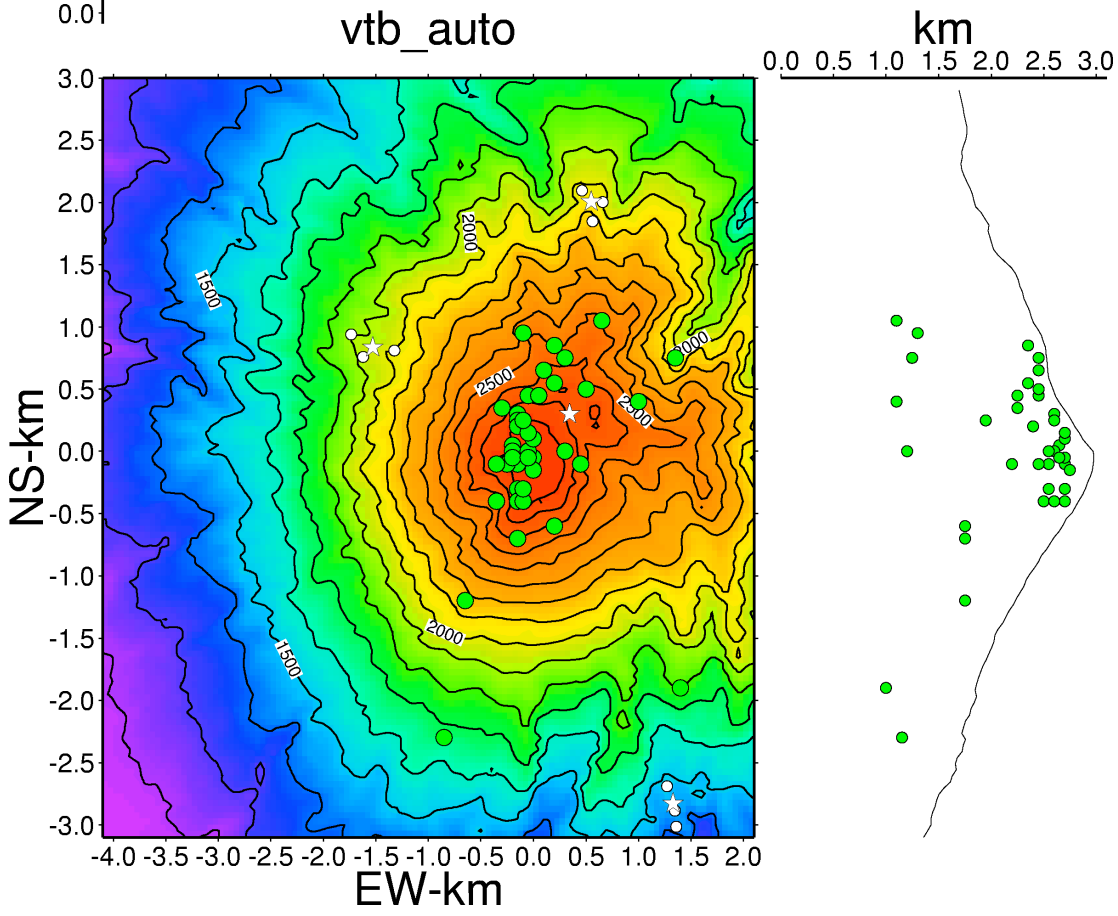
All-MP

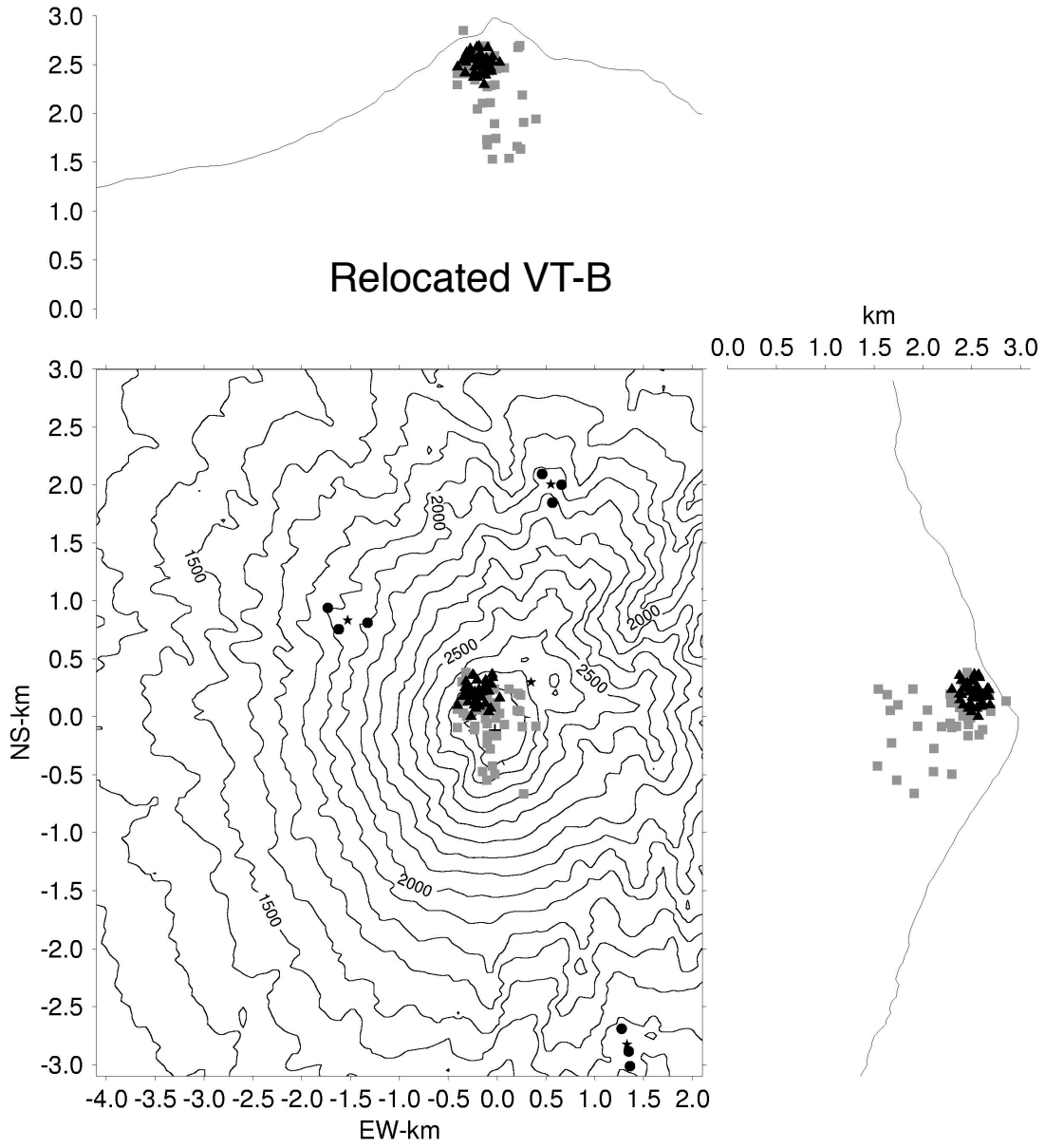
Rockfall

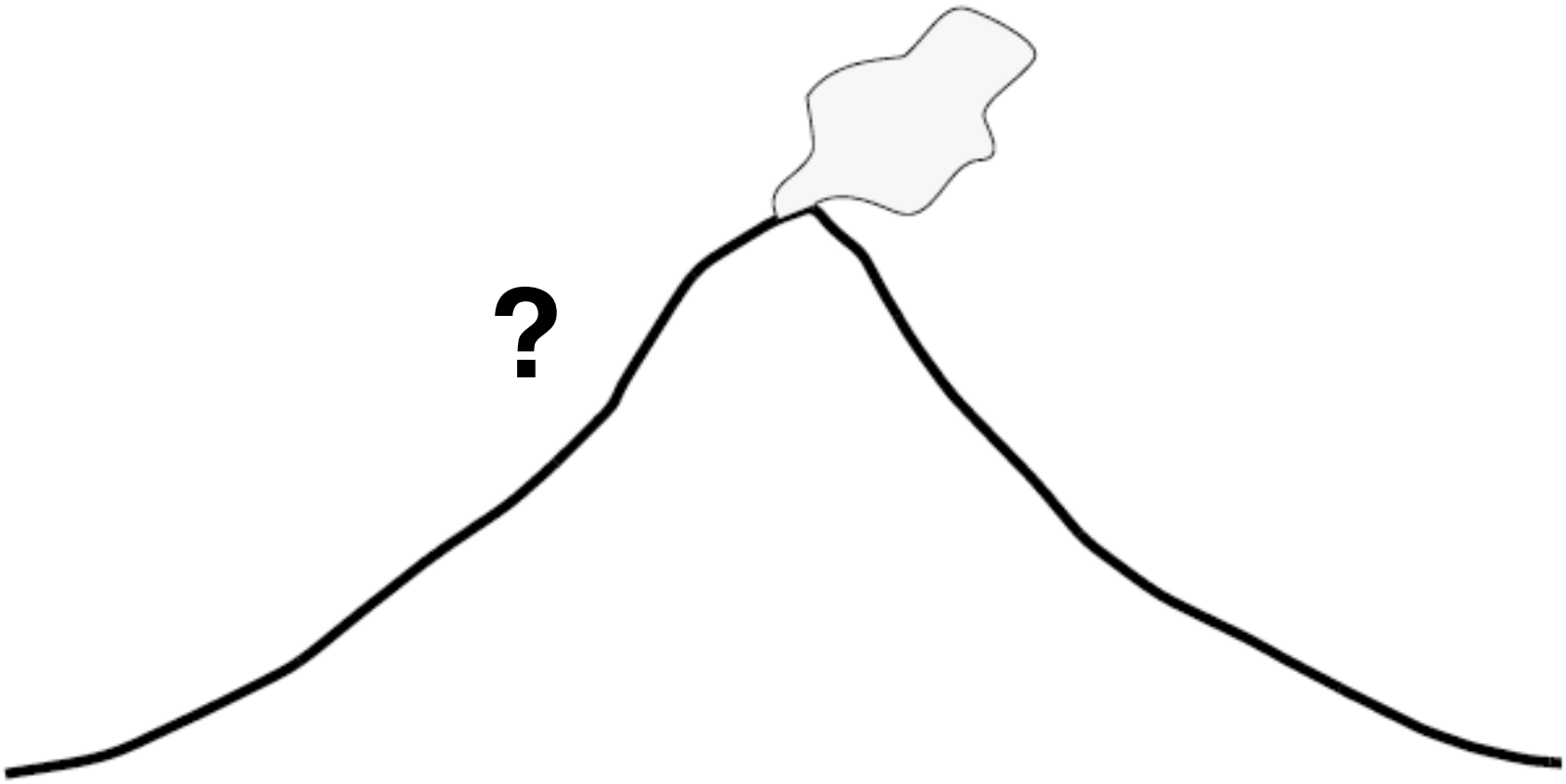
Automatic Localization (VT-B Events)

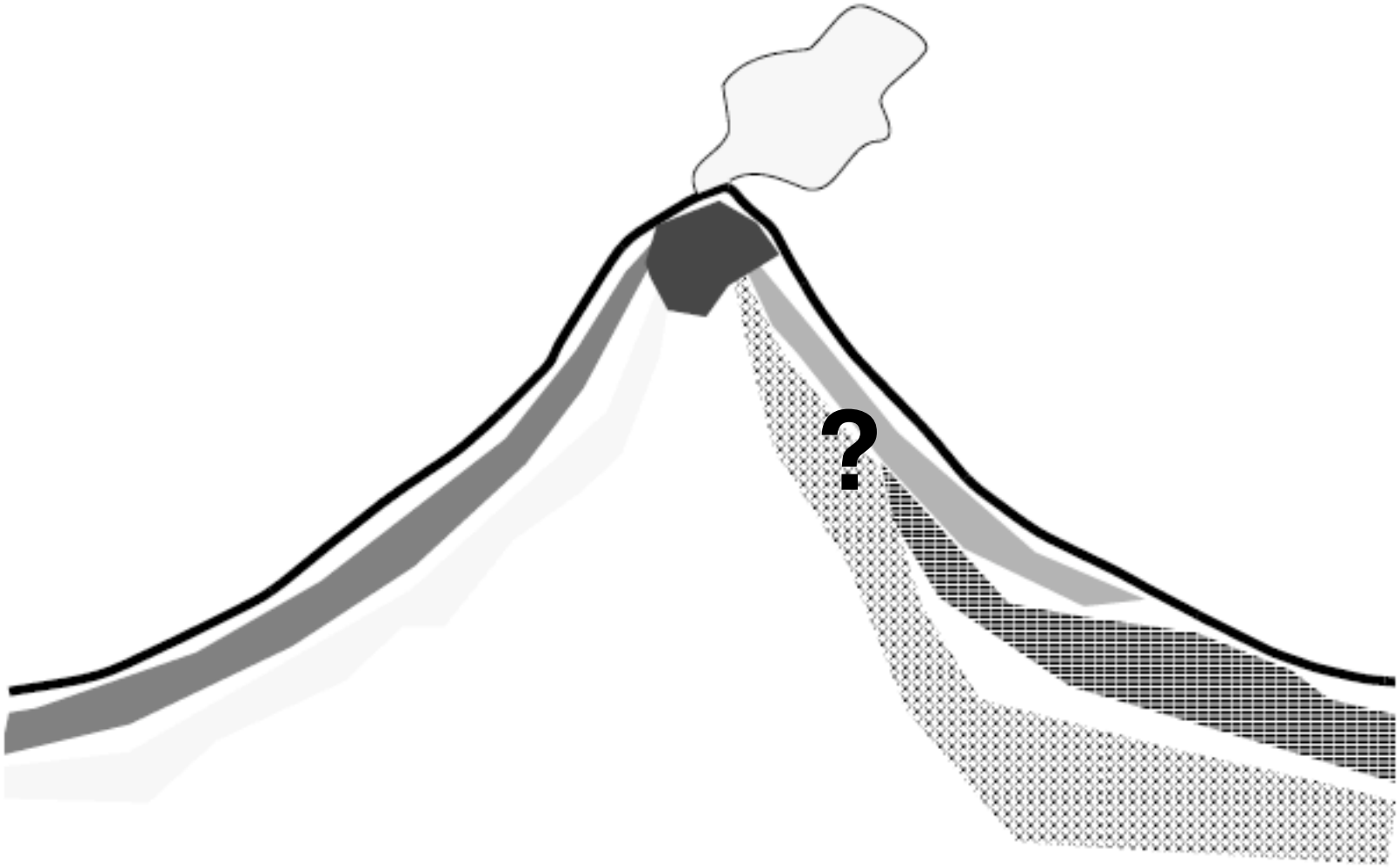


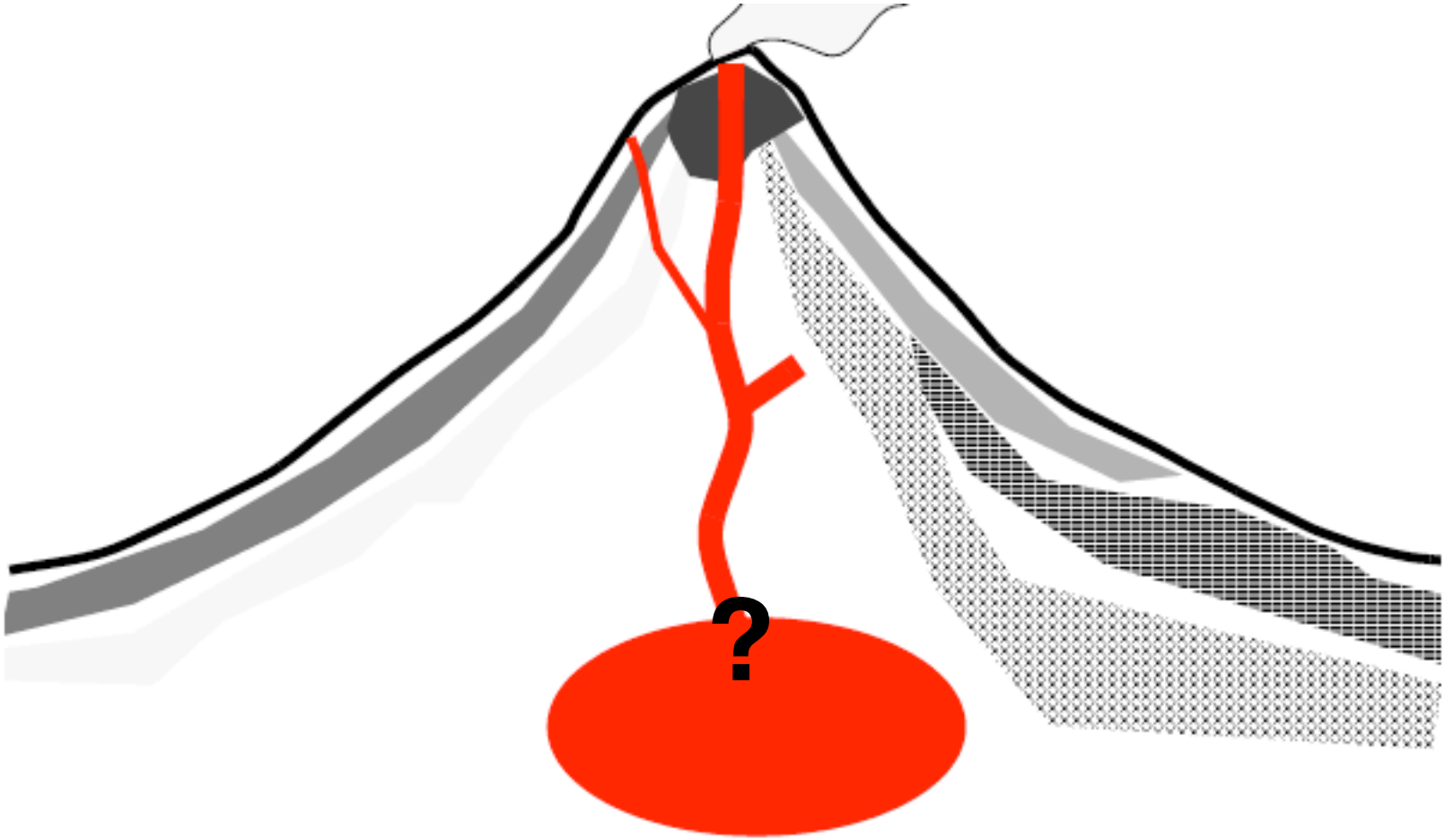
Wassermann and Ohrnberger, JVGR, 2001

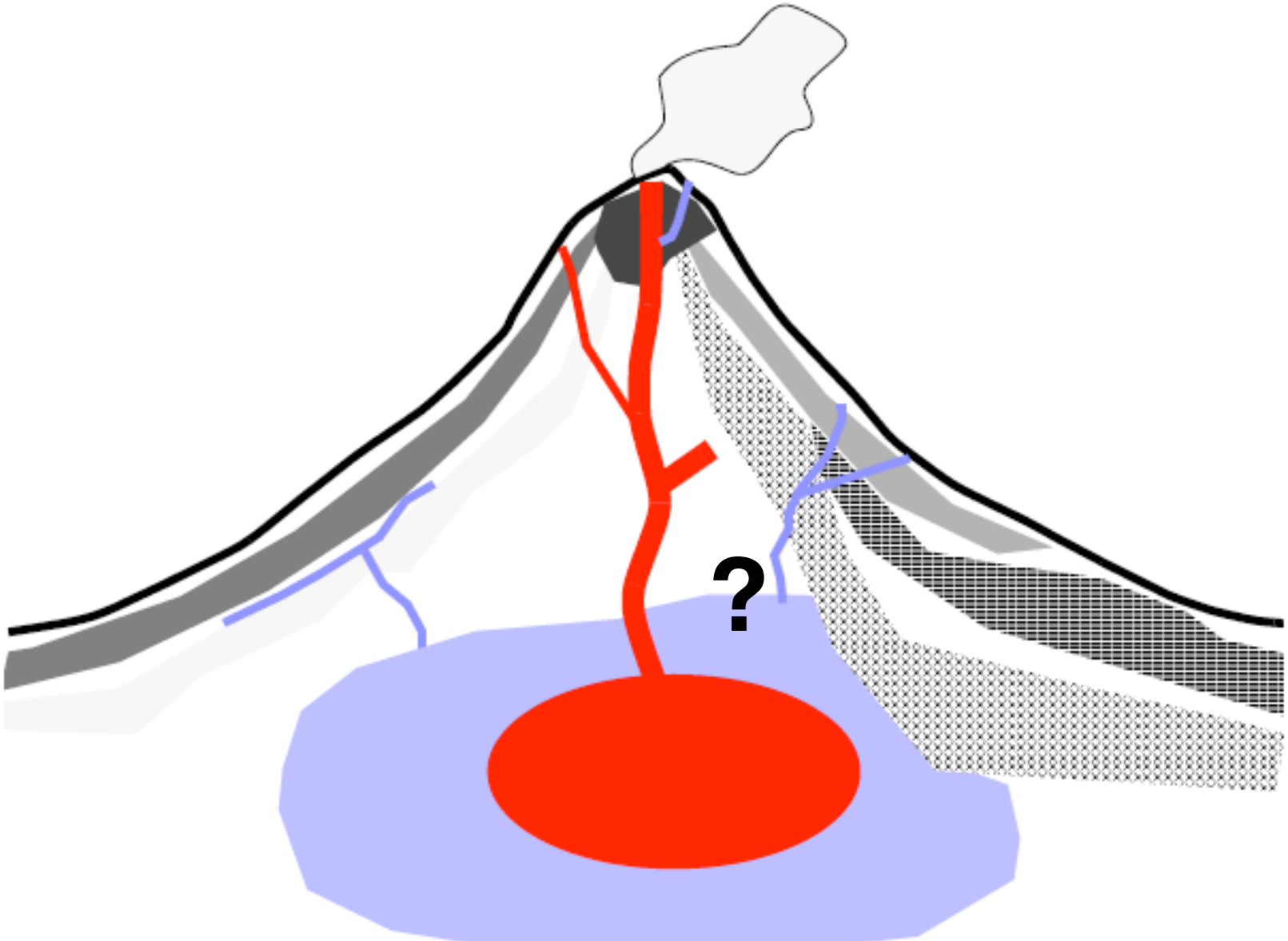


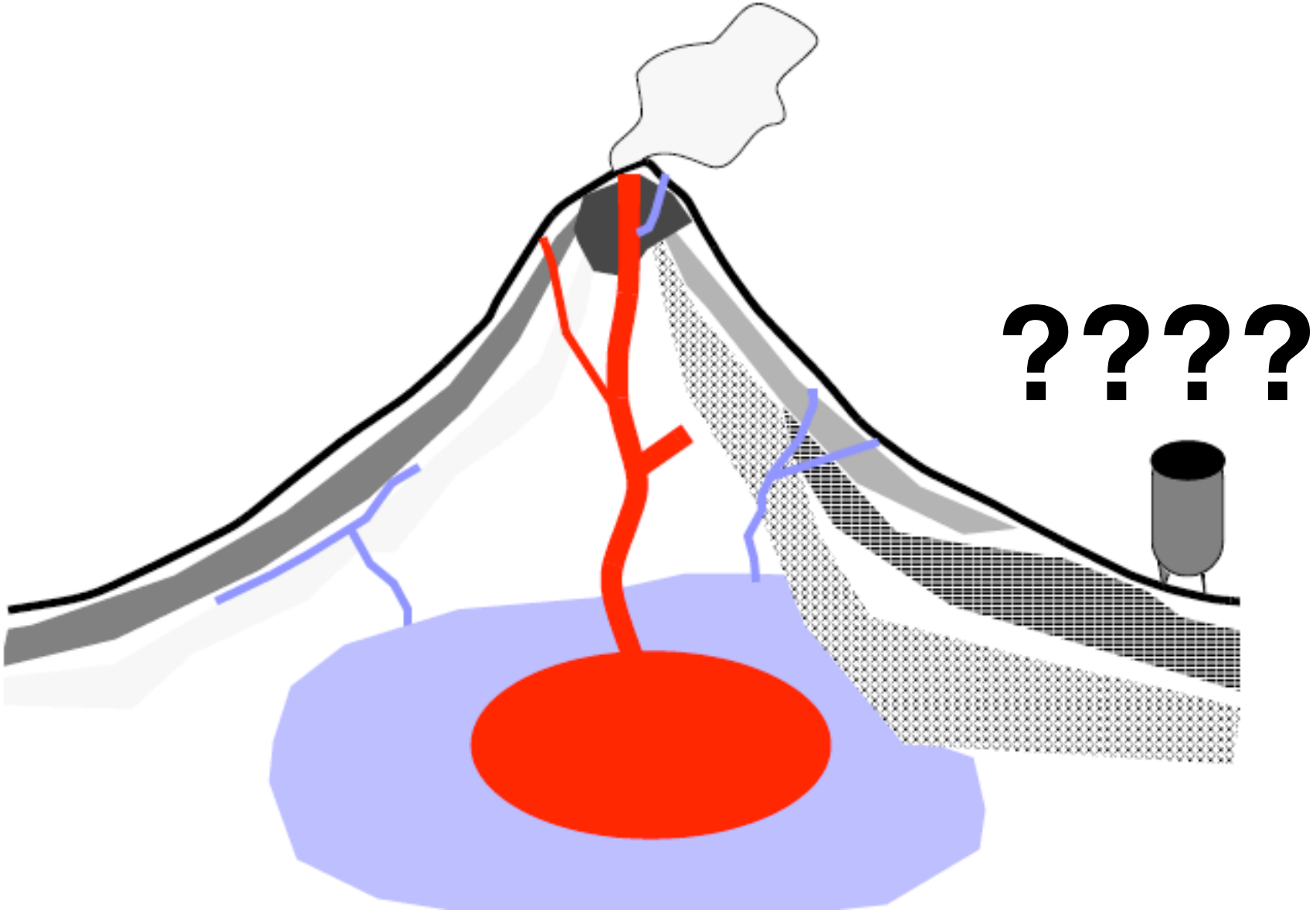

Relocated VT-B
km
0.0 0.5 1.0 1.5 2.0 2.5 3.0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
NS-km
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
1500
2000
2500
-4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
EW-km



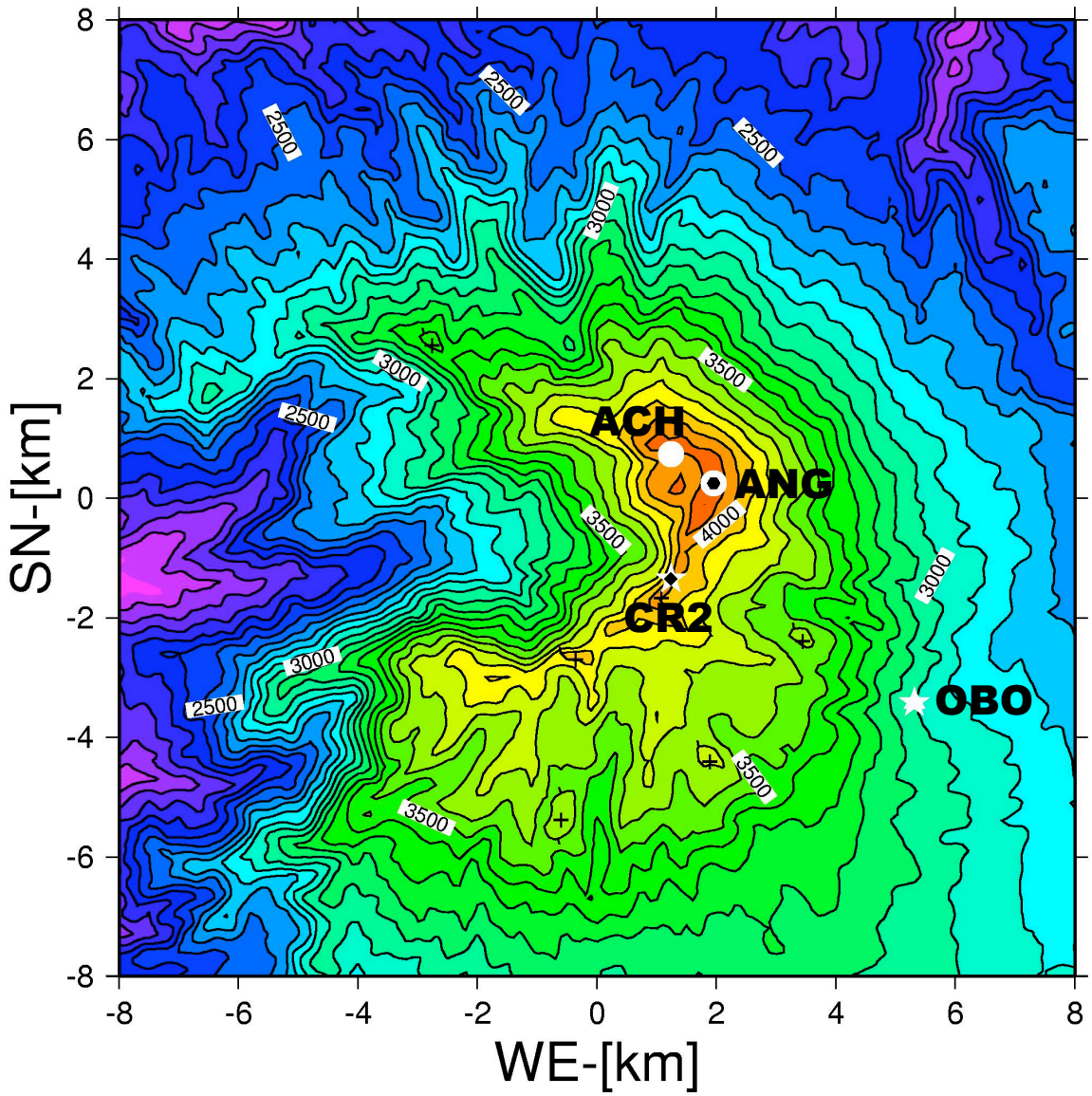




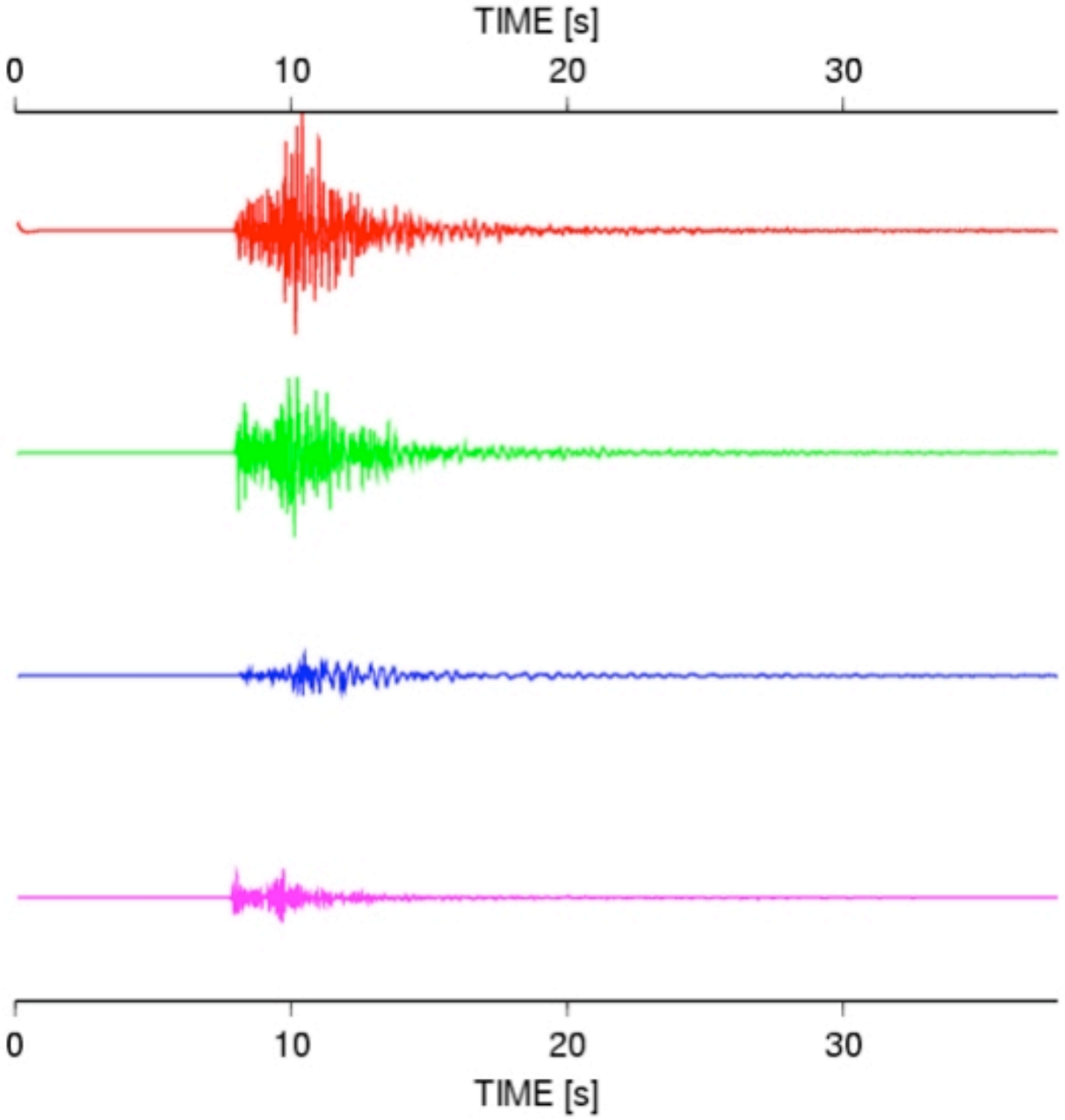




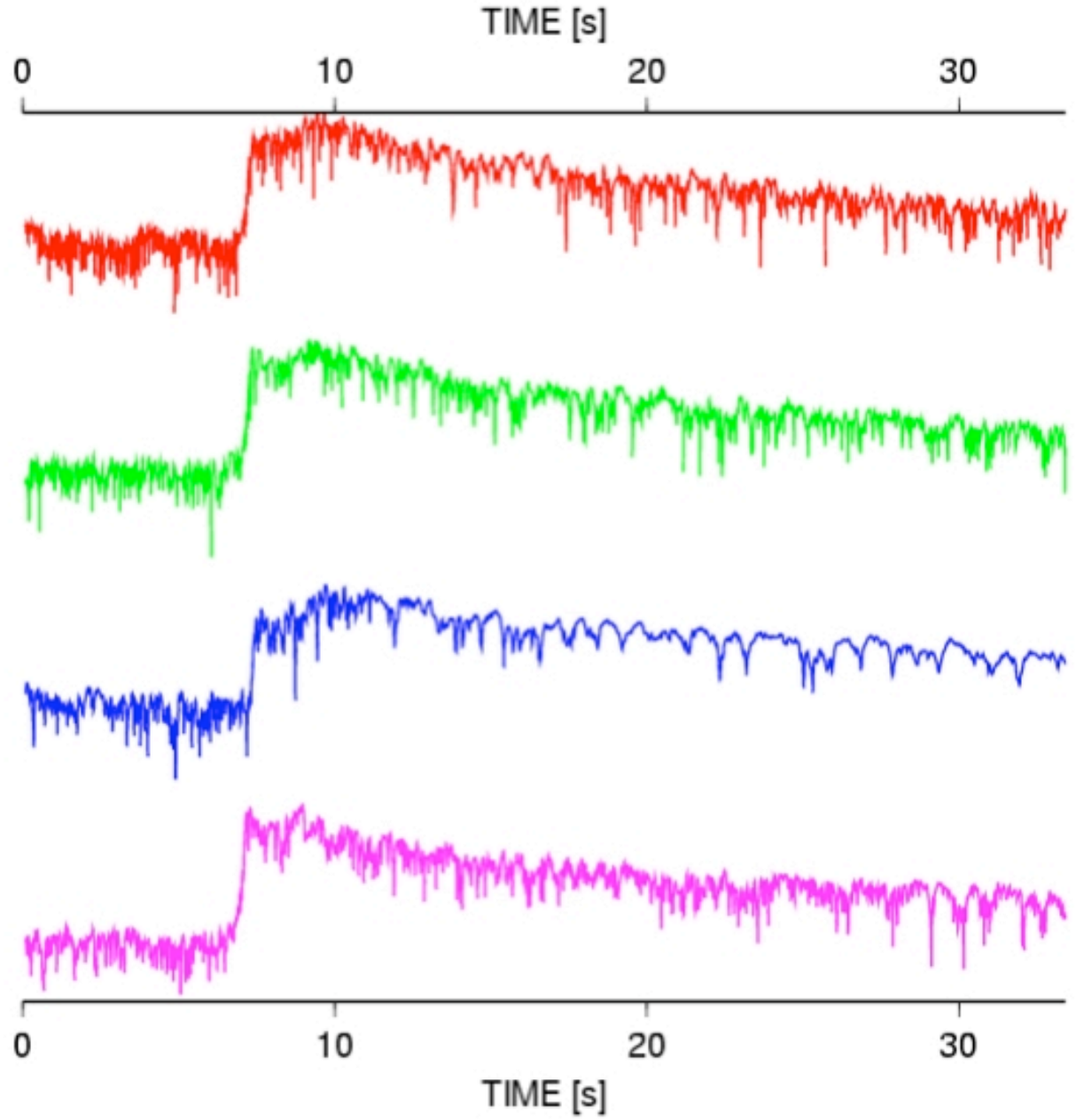
Seismic Network at Galeras Volcano



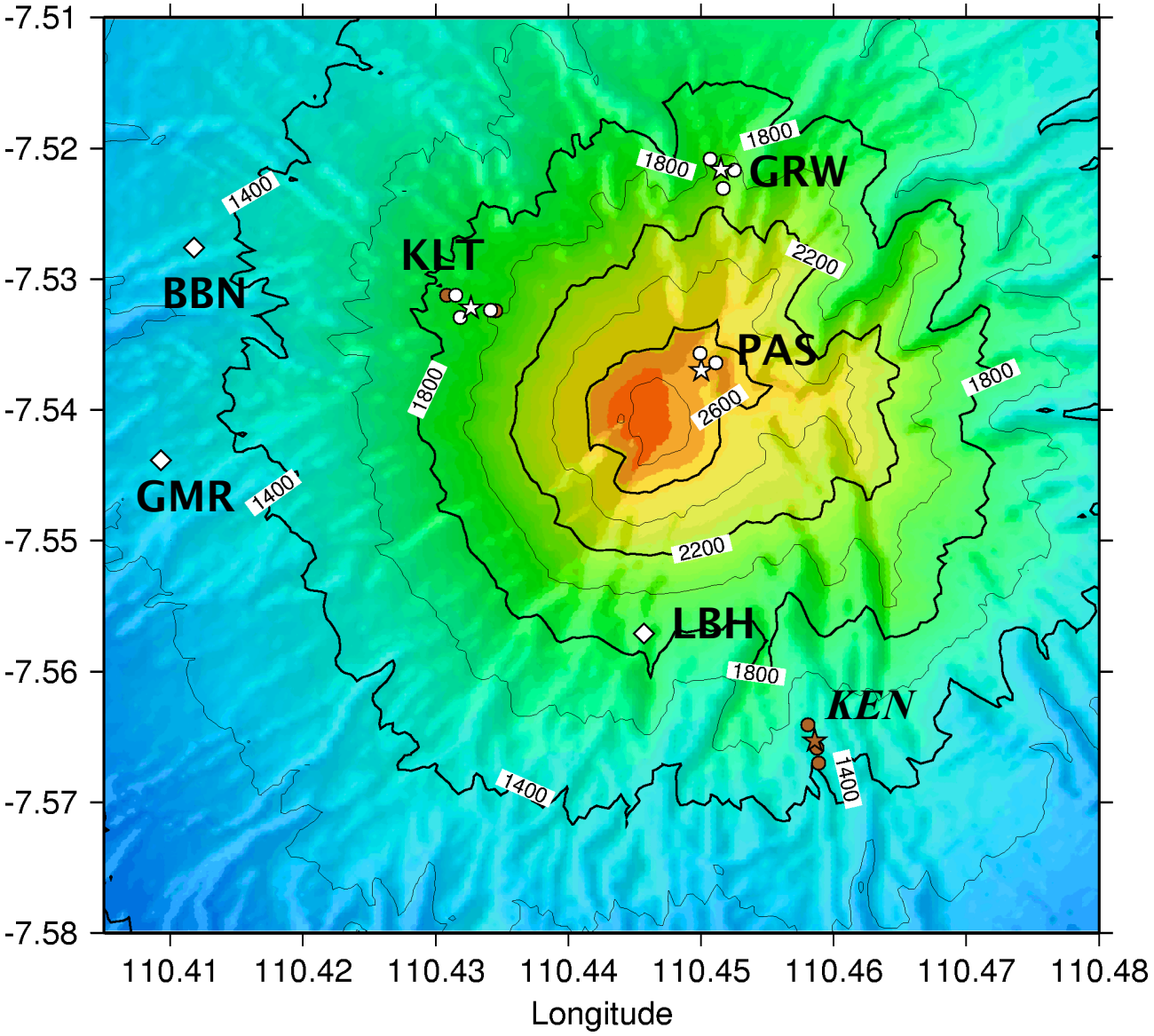
VT-A



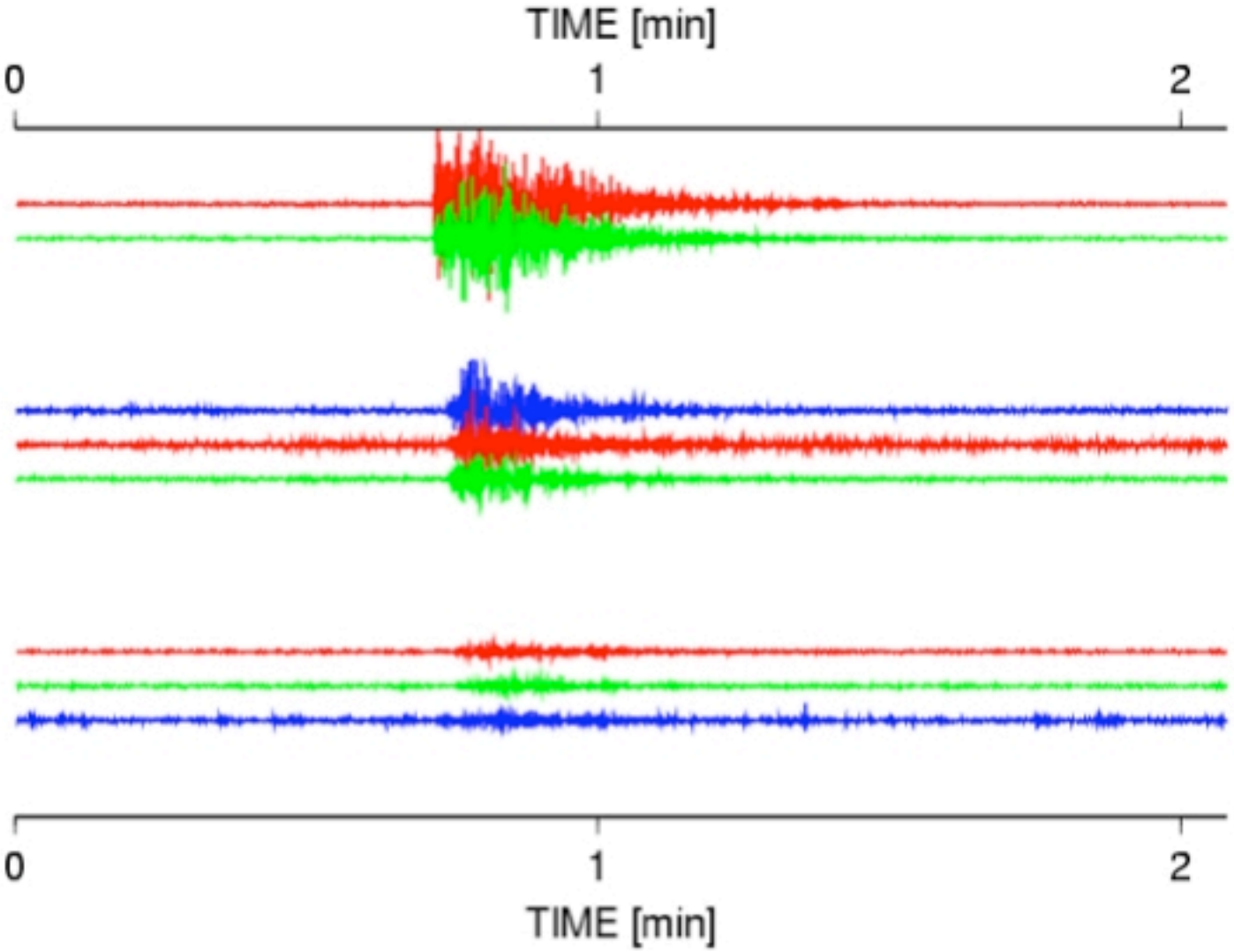
VT-A



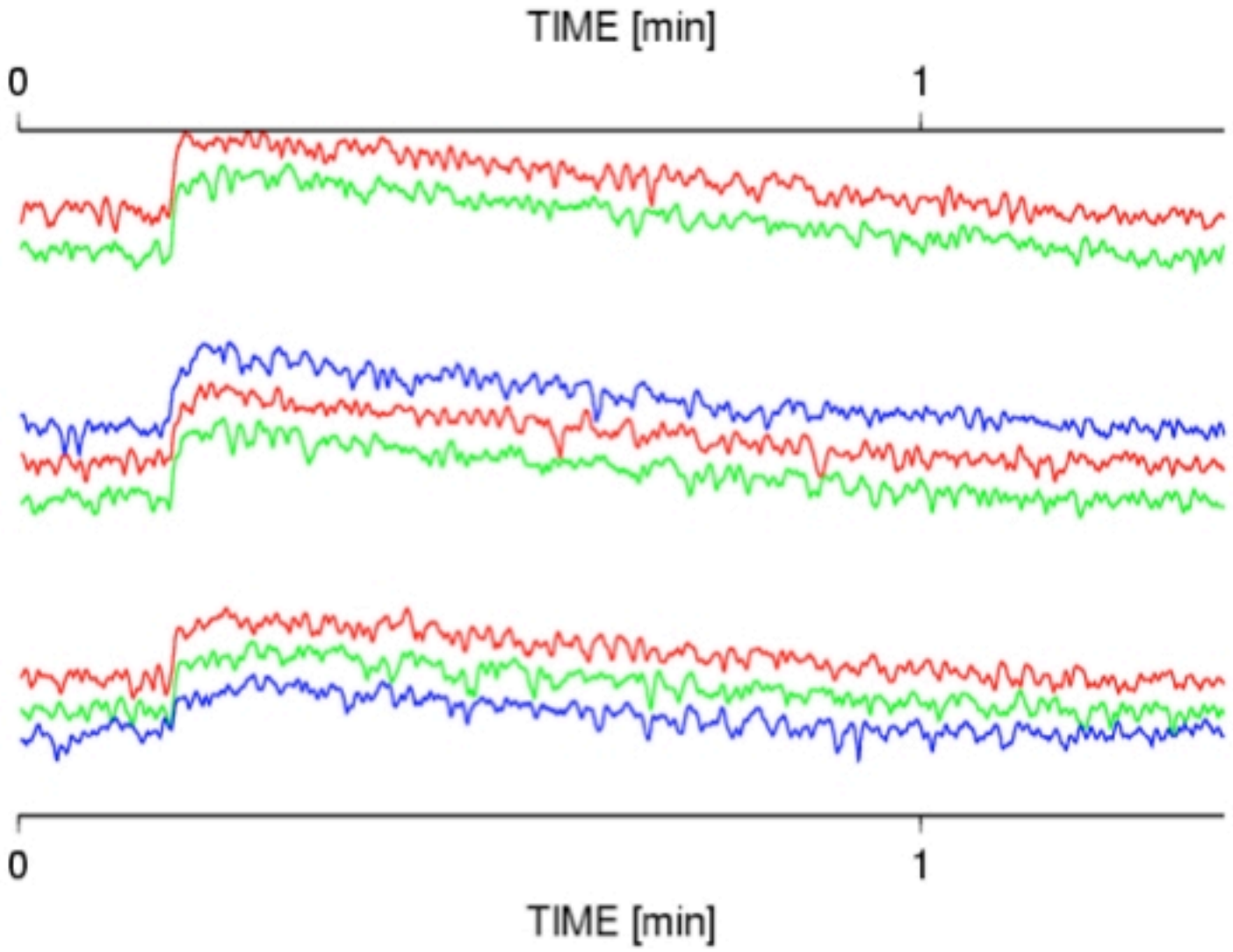
Seismic Network at Mt. Merapi



VT-B

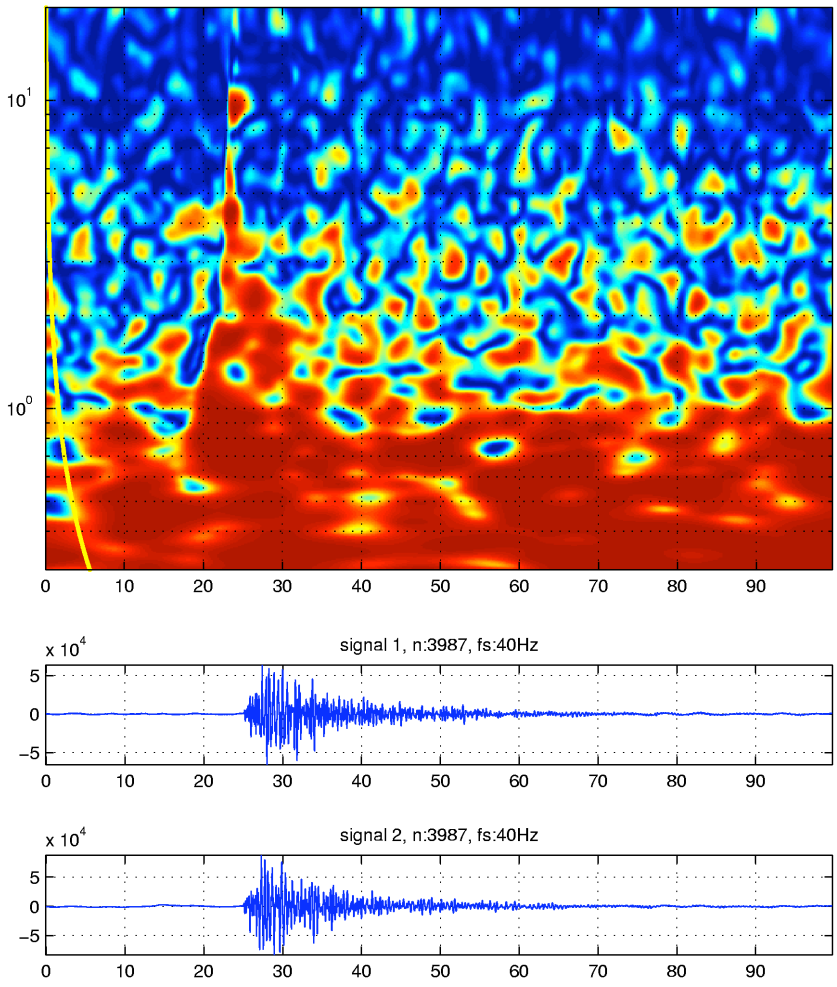


VT-B

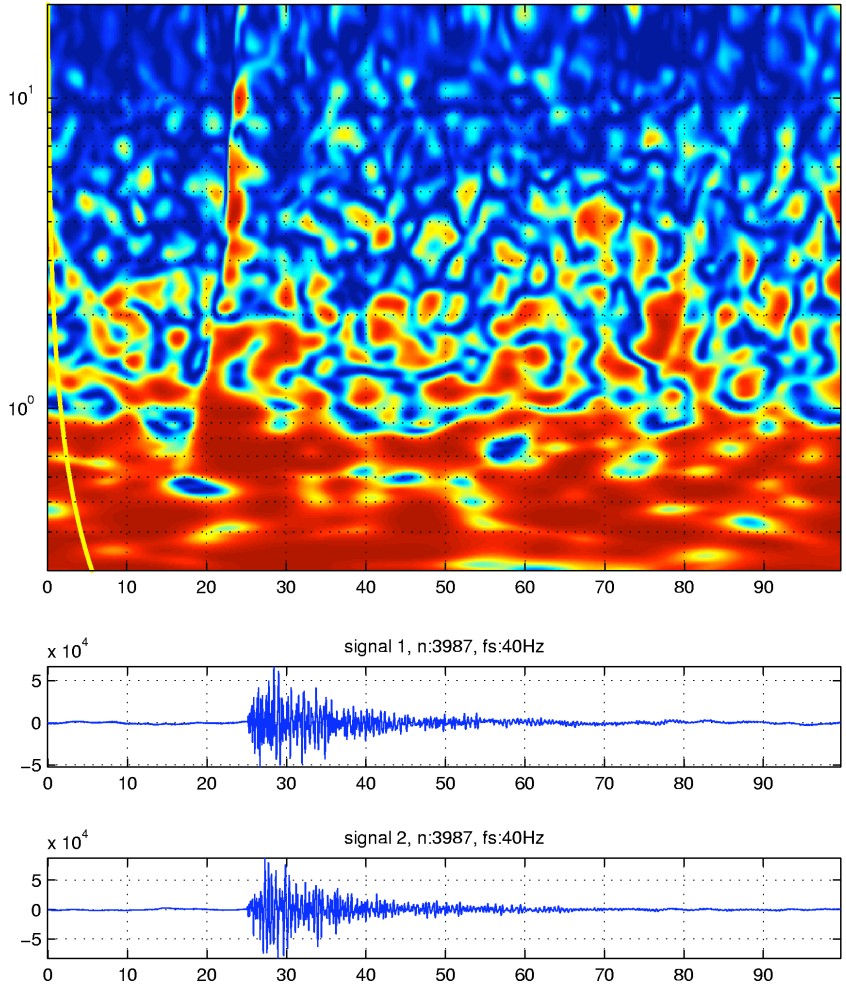


Array-Advantages

GRW0 – GRW1



GRW1 – GRW2



Array-Advantages

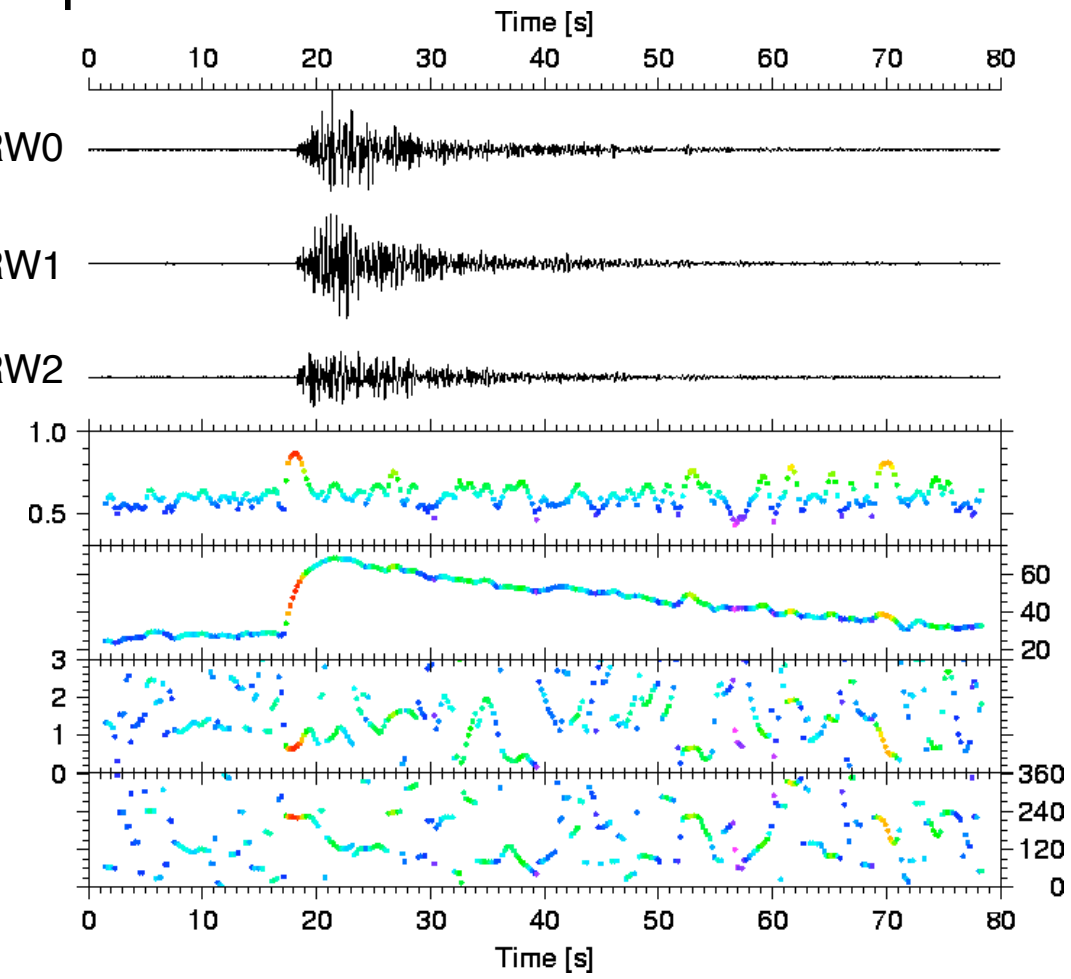
Wavefield Properties

coherence (RP)

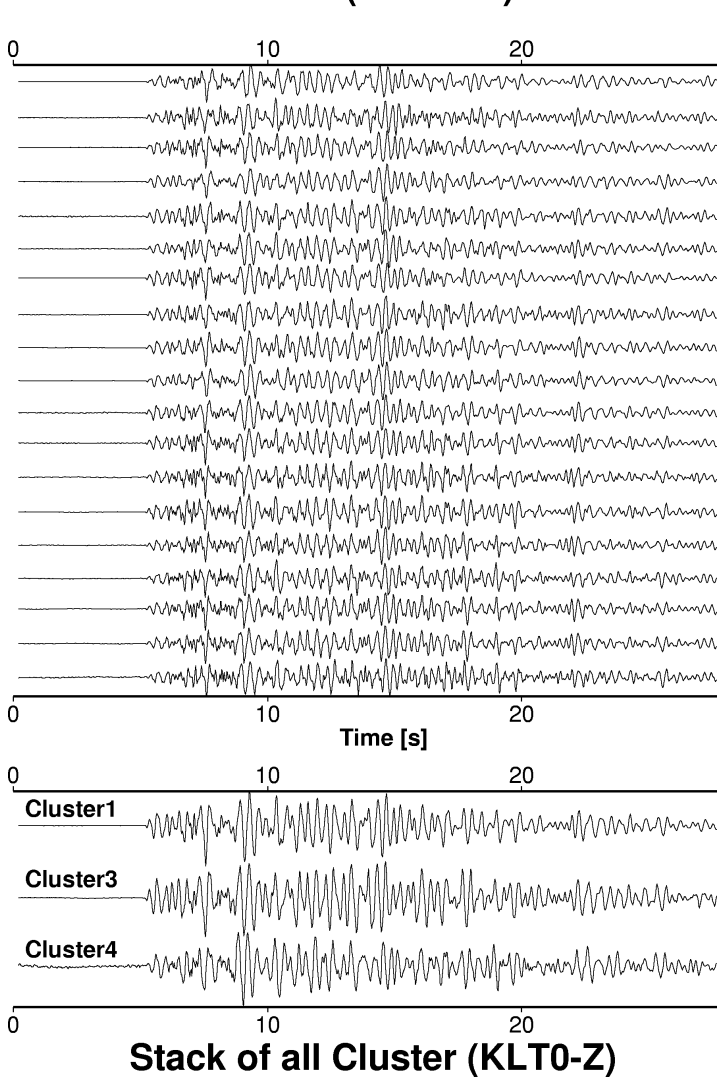
power (AP)

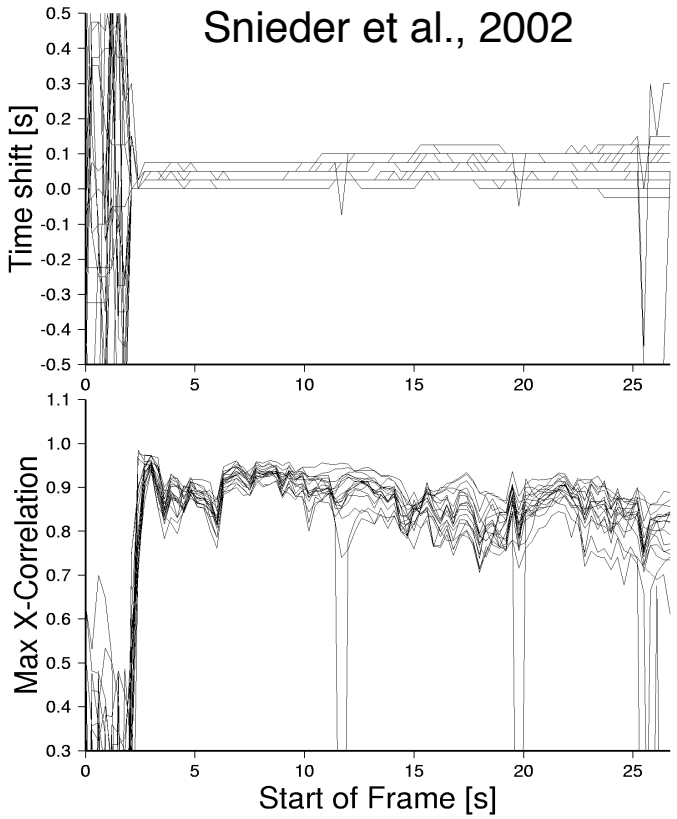
slowness (s/km)

backazimuth (°)



Seismic Swarms

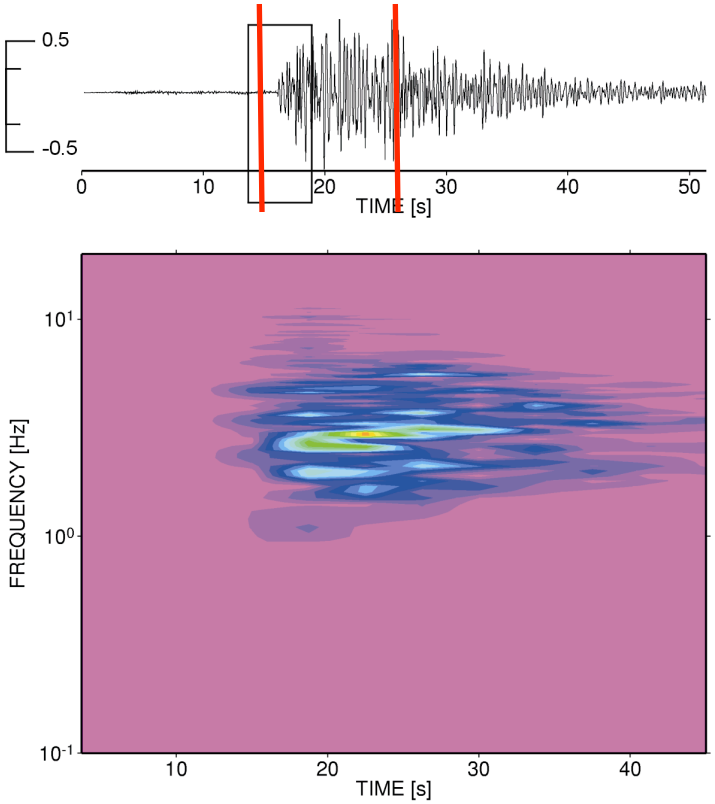




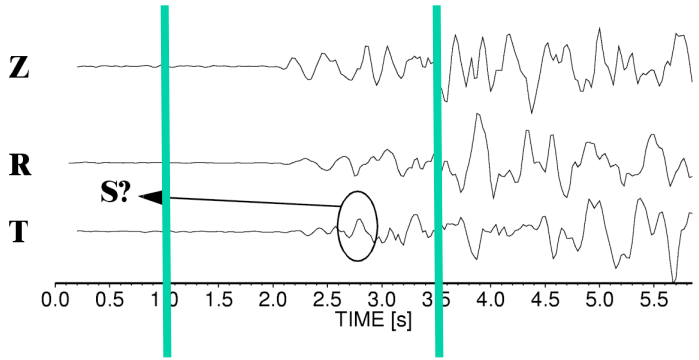
$$C_{eg}^{\bar{\omega}} = 1 - \frac{r_{eg}^2 \bar{\omega}^2}{2\nu^2}$$

Scattering - a different view

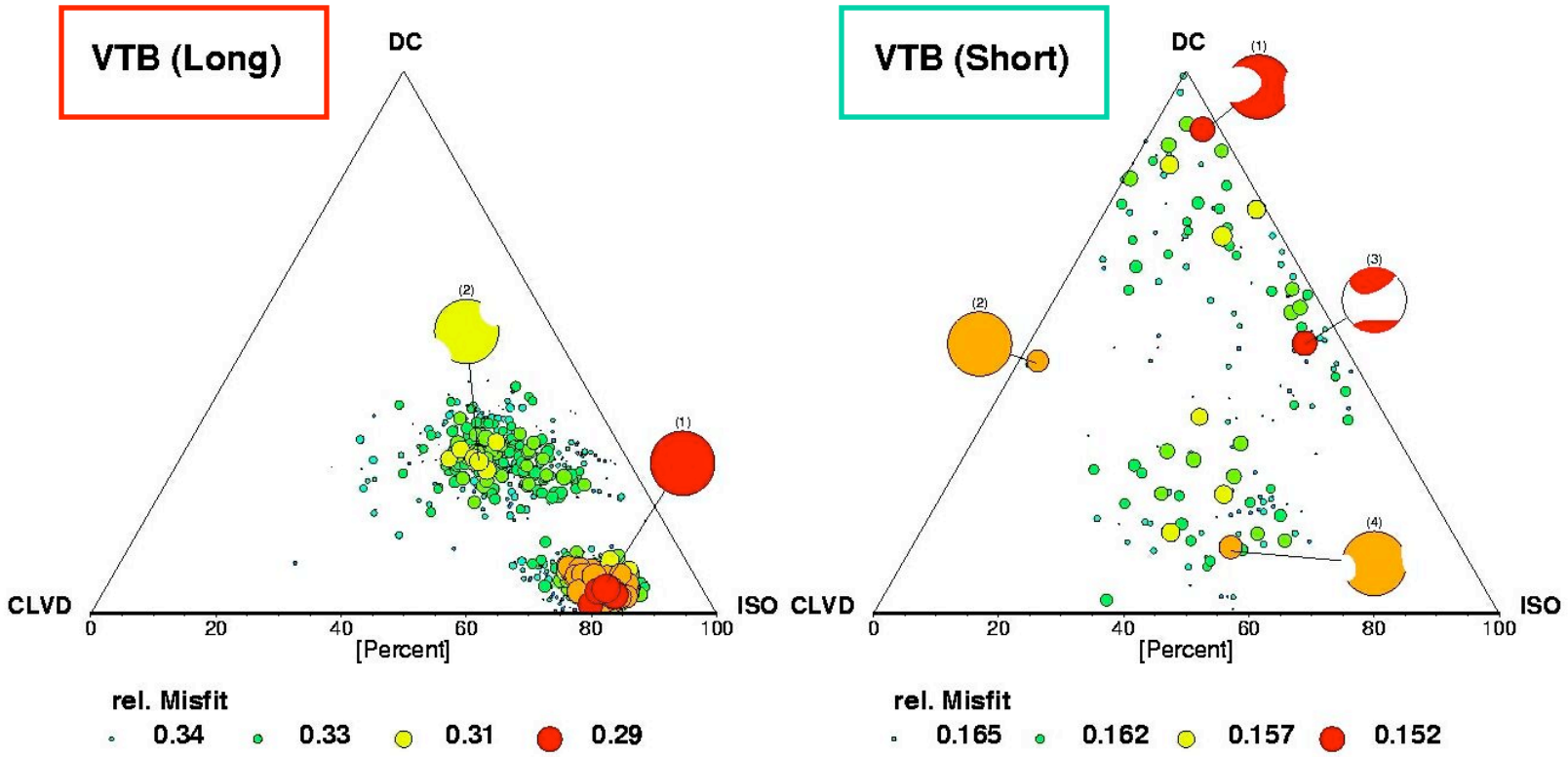
a)



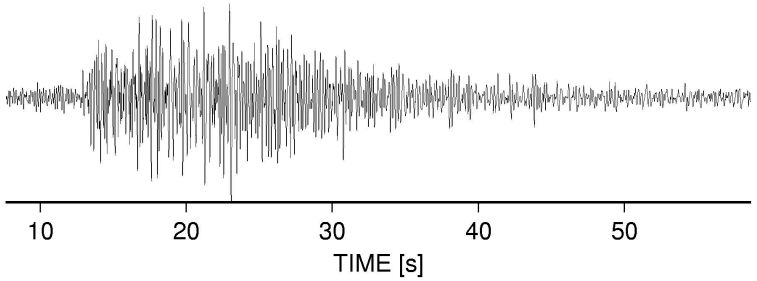
b)

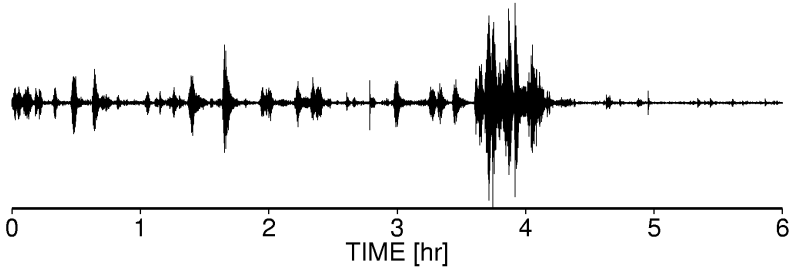


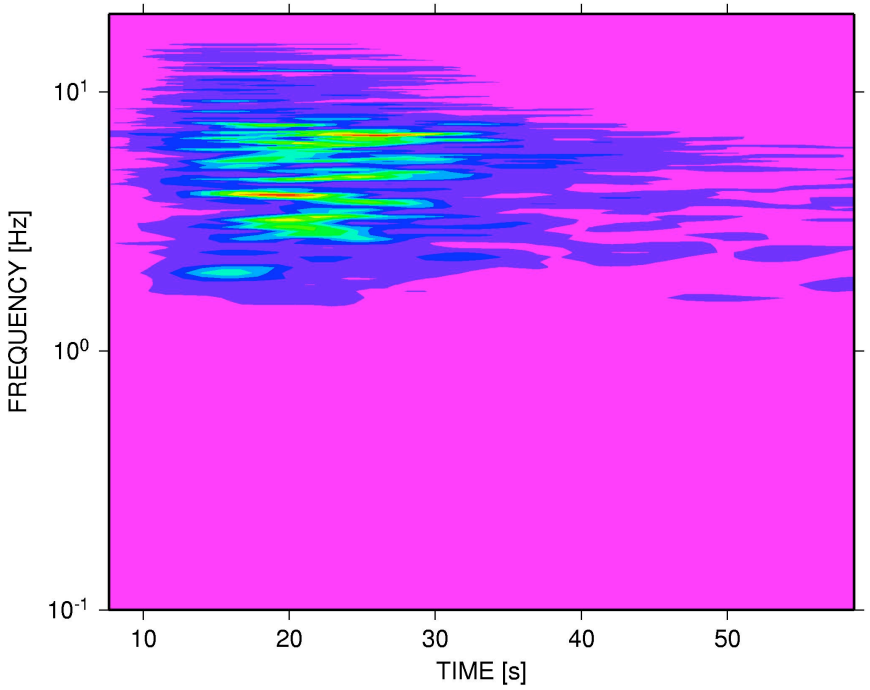
Scattering and Source Mechanism

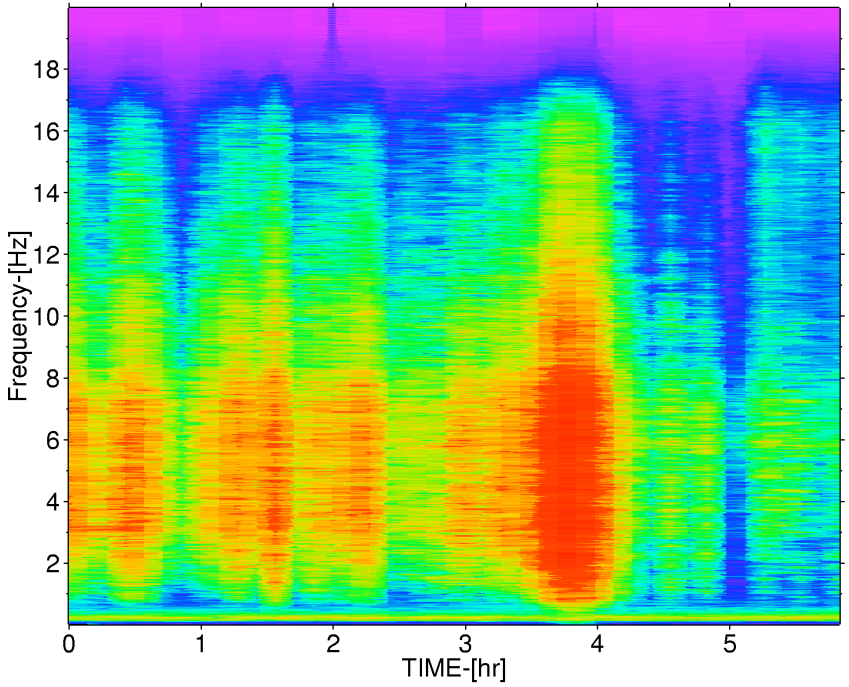


What to do with these Signals?

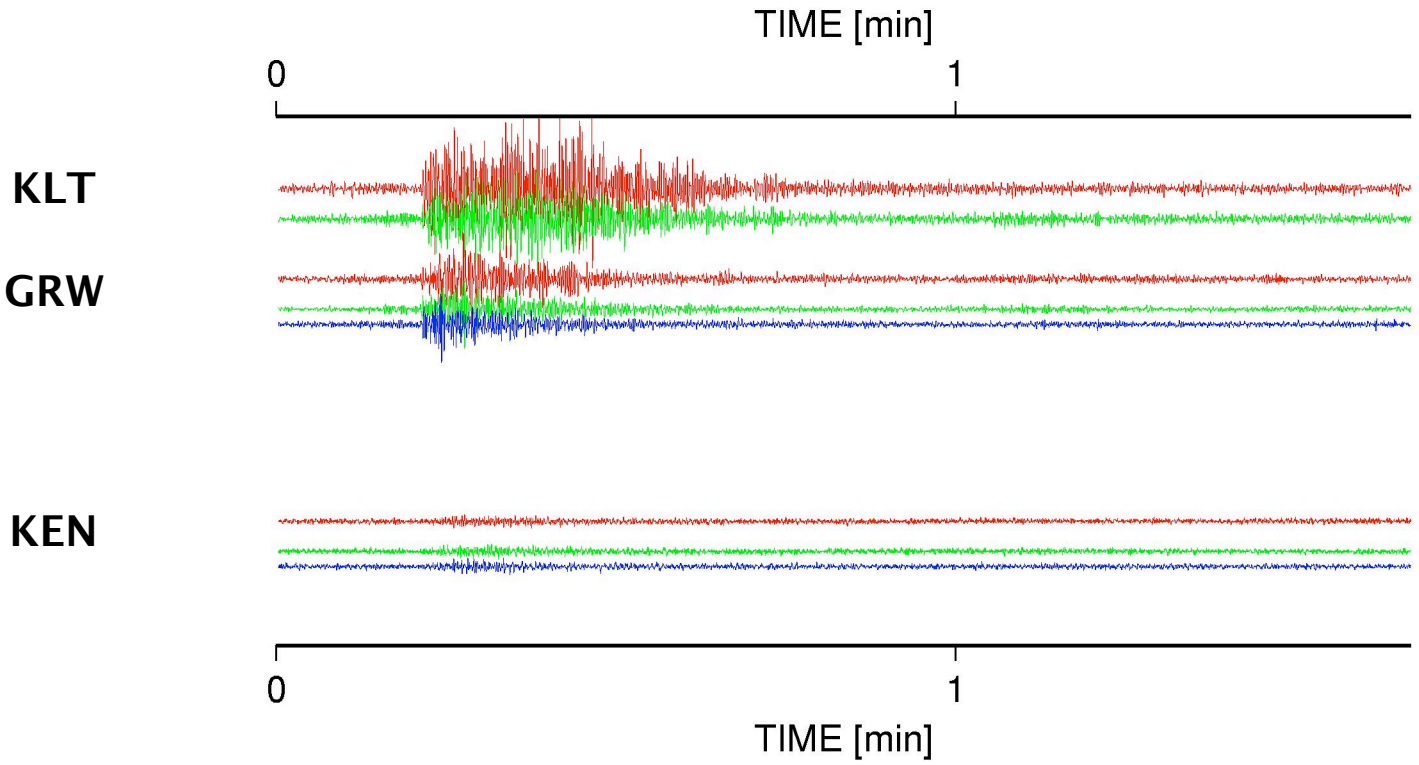




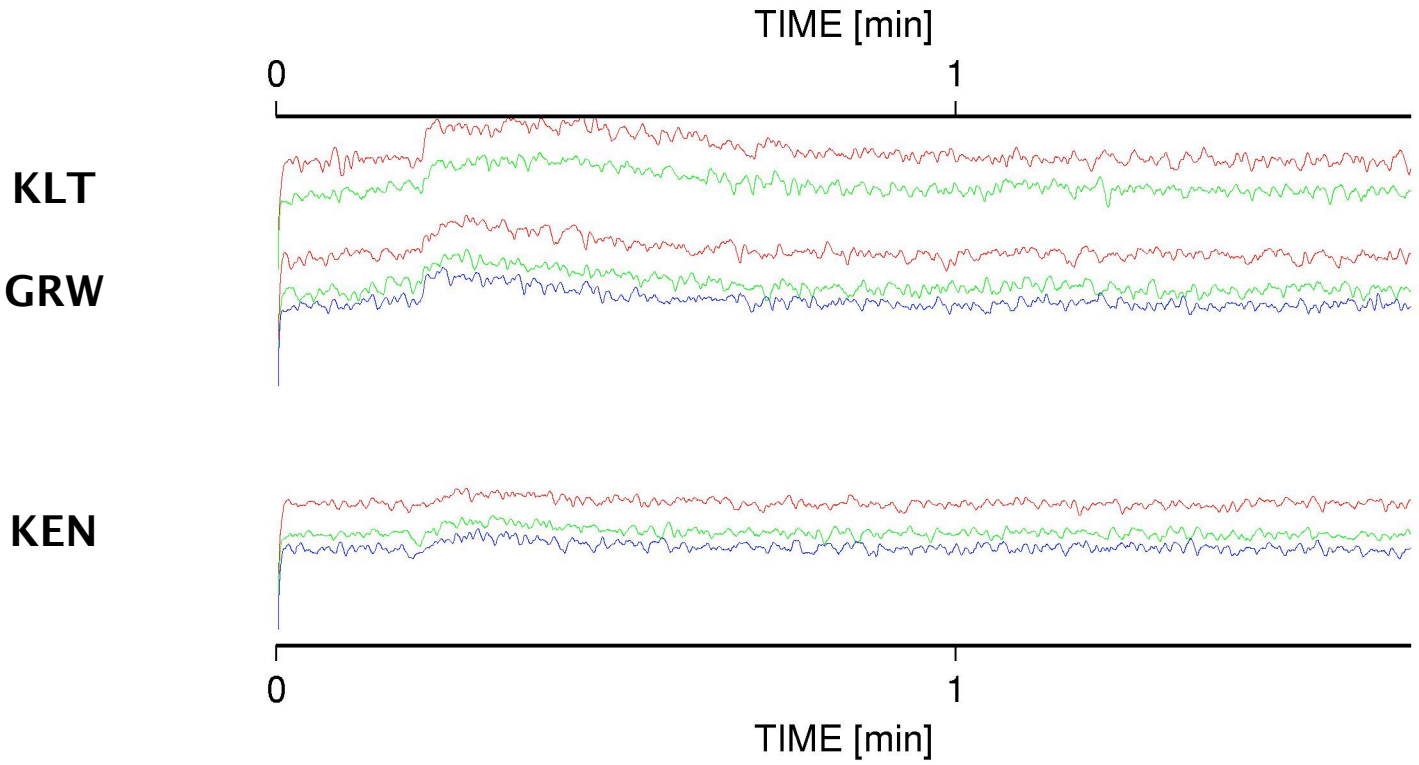




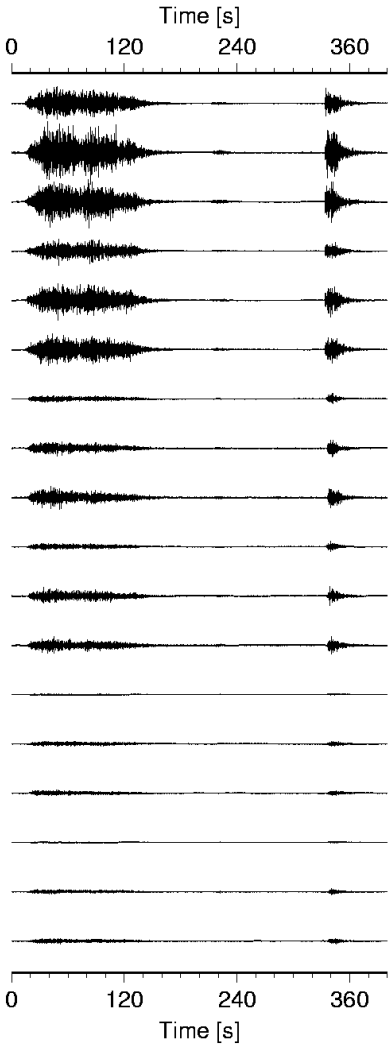
Many-Phases (MP)



Many-Phases (MP)

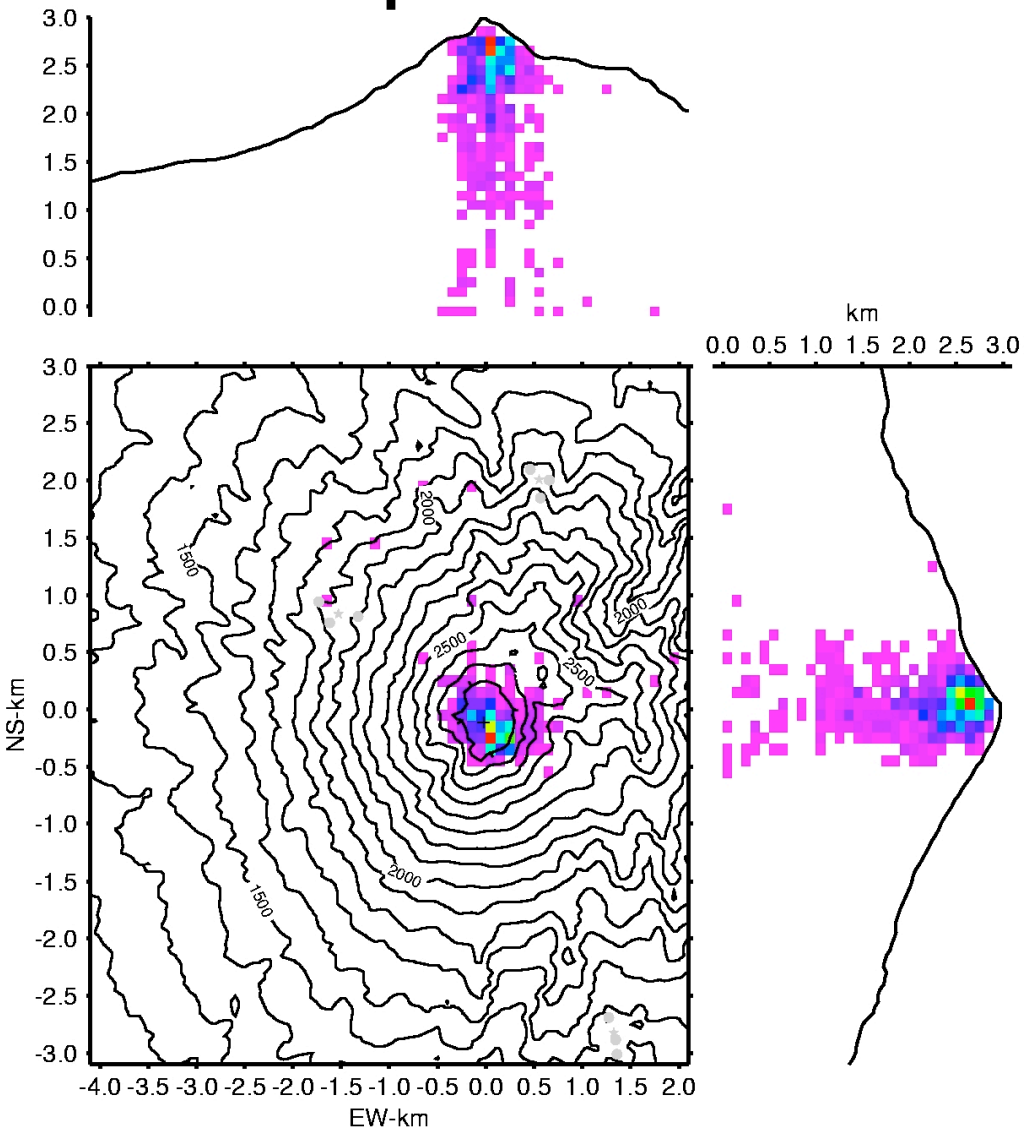


Amplitude Localization

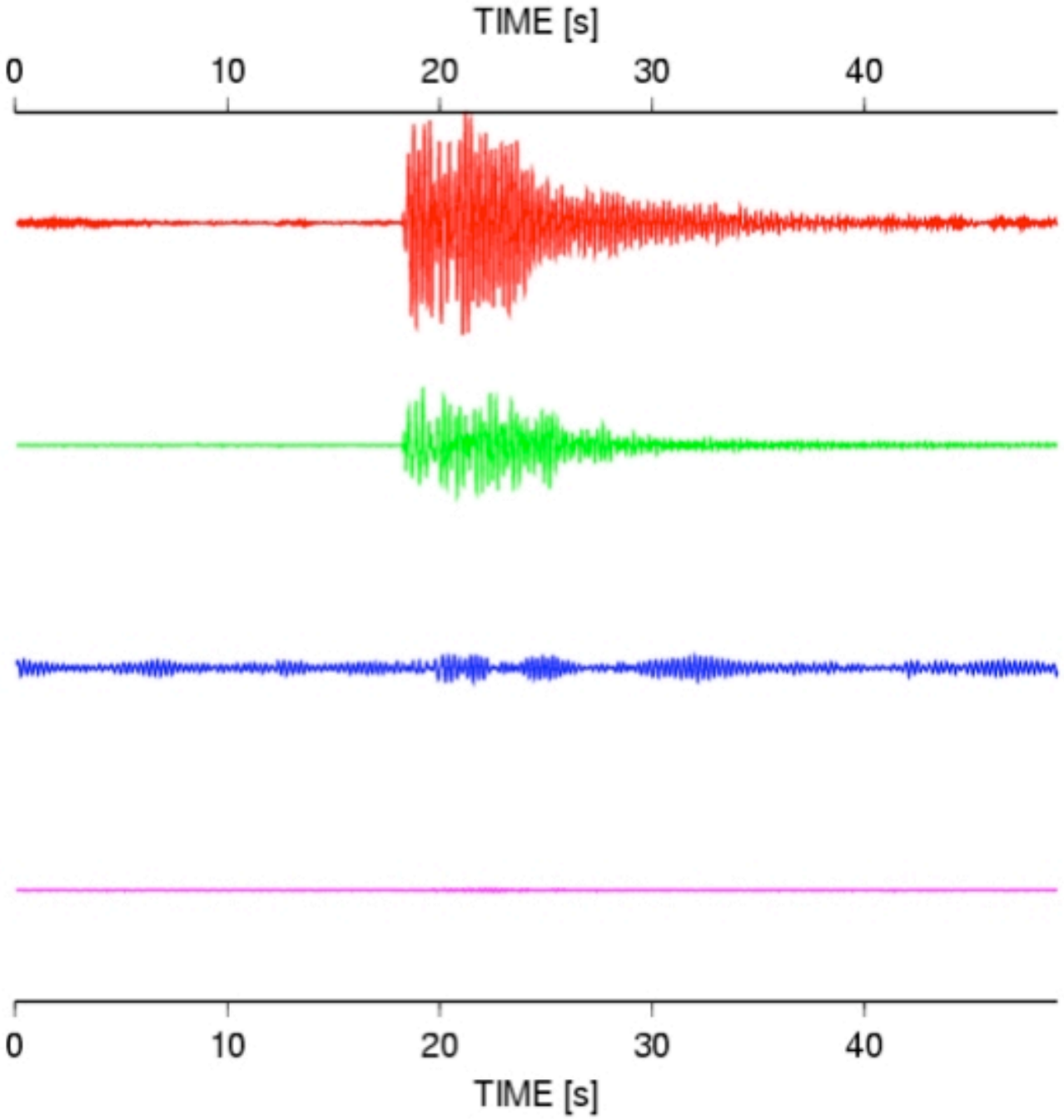


- Body Waves: $A^2 \sim A_0^2/r^2$
- Surface-Waves: $A^2 \sim A_0^2/r$ (Jolly et al., 2002)
- Near-Field: $A^2 \sim (A_0/r + B_0/r^2)^2$
- Scattering: $A^2 \sim A_0^2 (\eta max/2\pi r)^{3/2} \exp\{-r\, \eta max\}$
  (Wegler and Lühr, 2001)

MP-Amplitude Localization



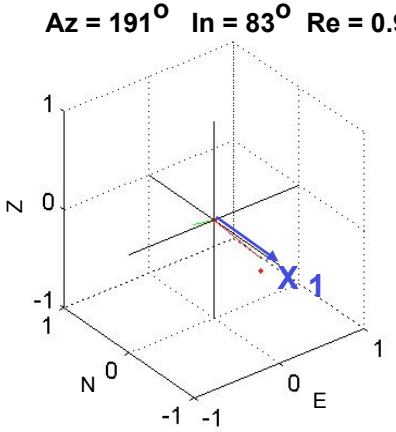
Tornillo

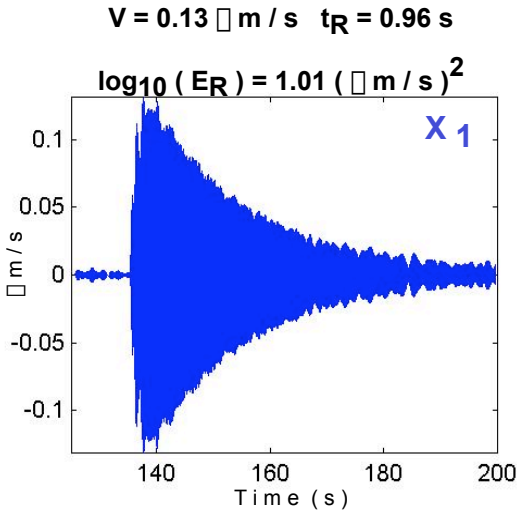


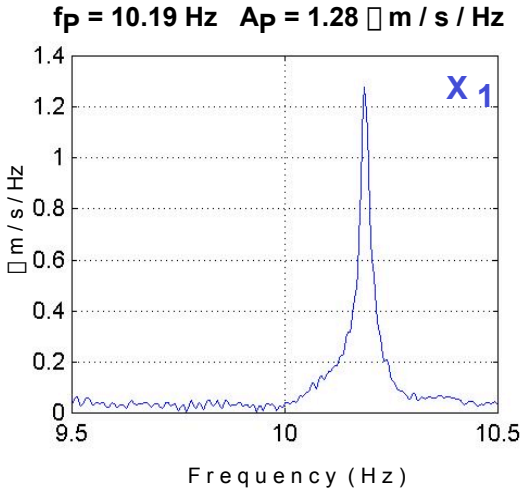
Galeras – Project

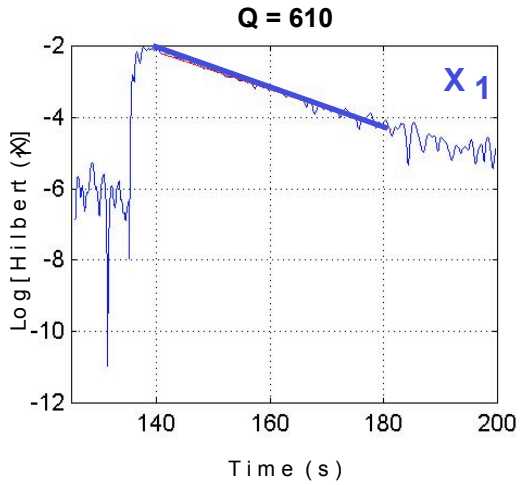
Parametrization of Tornillo-Signals

Station Achalay

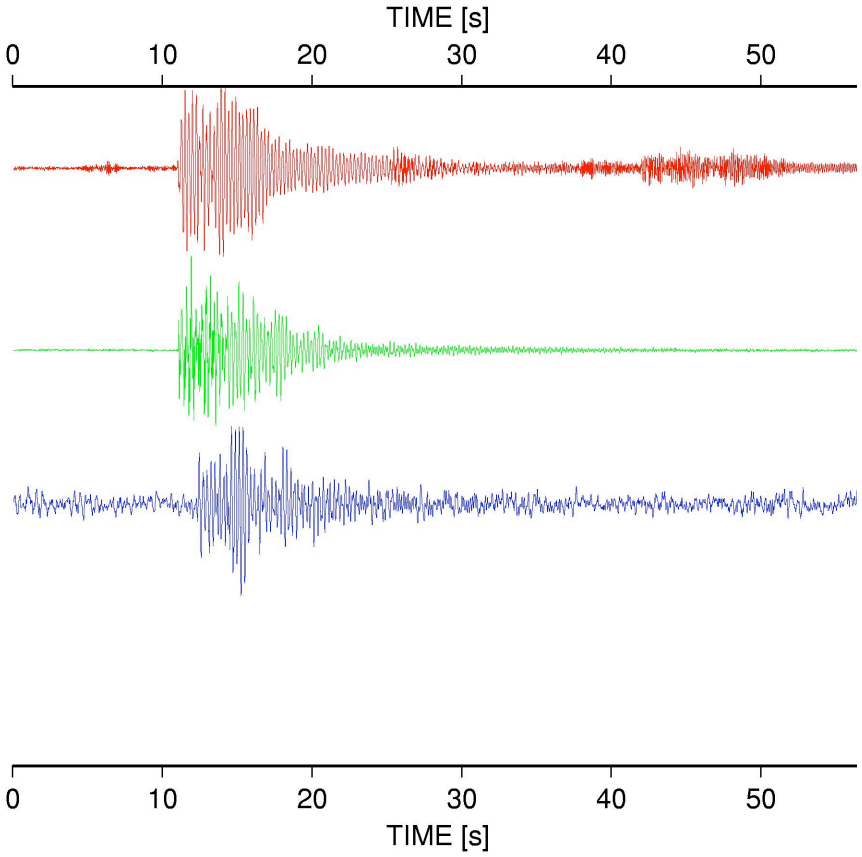








Seidl, 2003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20
30
40
50
0
10
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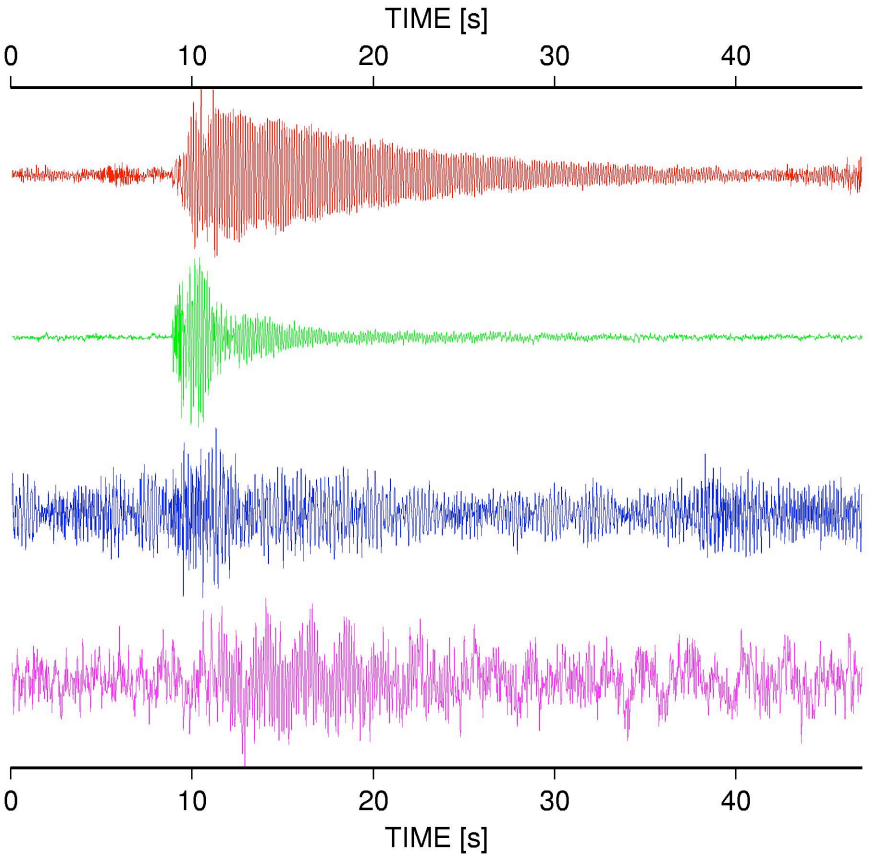
30
40
50
TIME [s]


TIME [s]
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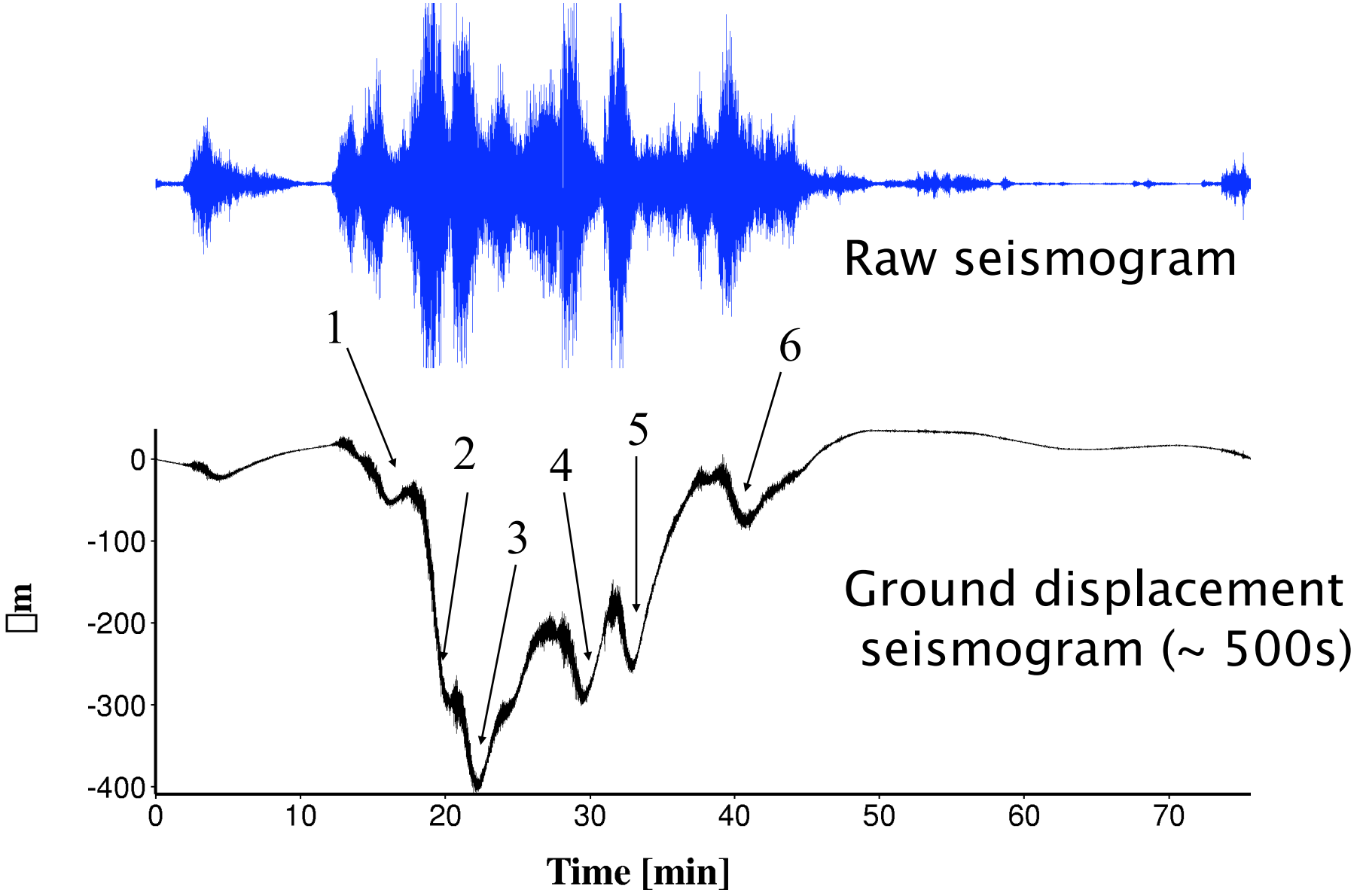
TIME [s]

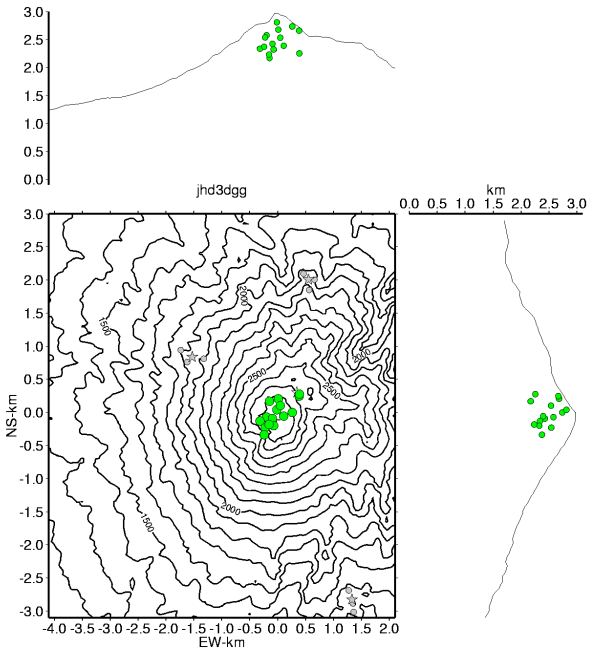
Block and Ash Flow Signals



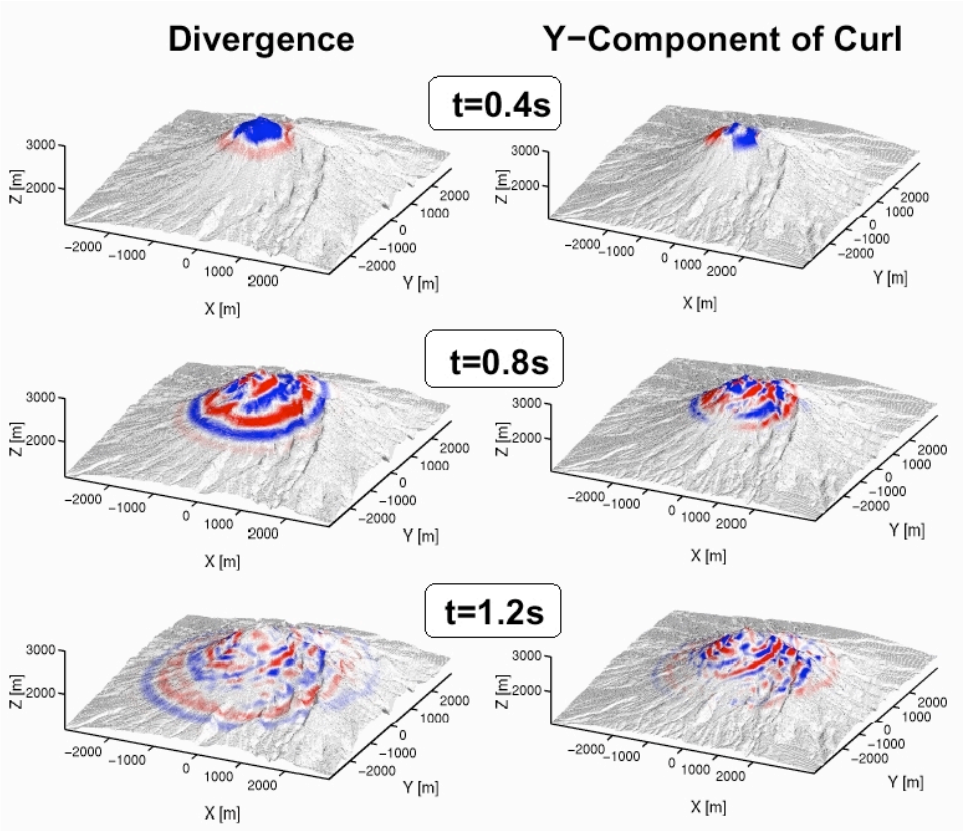
What to do next?

⇨ **We MUST** model the seismic wave field in 3D

Simulation of seismic wave propagation

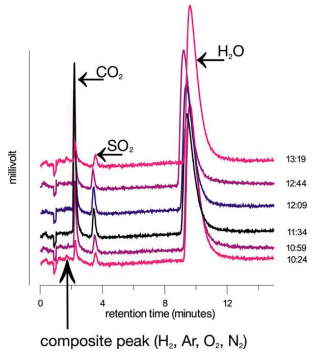


From: Wassermann



Ripperger et al., 2003

What next?



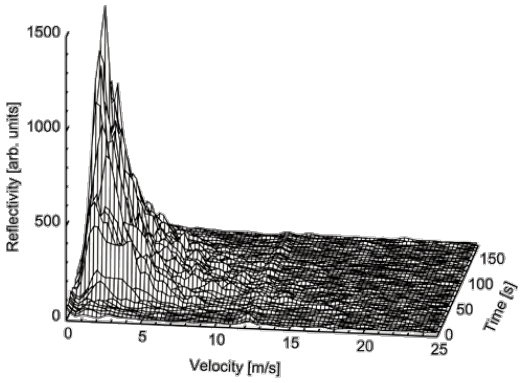
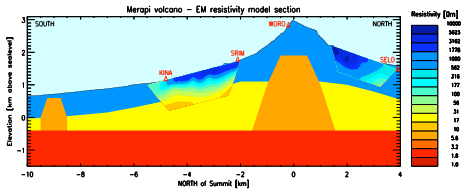
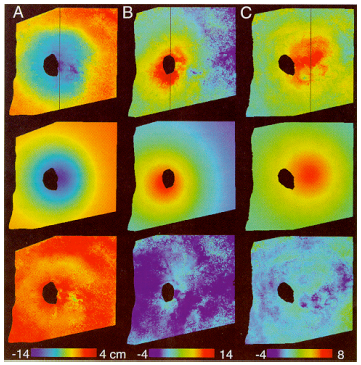
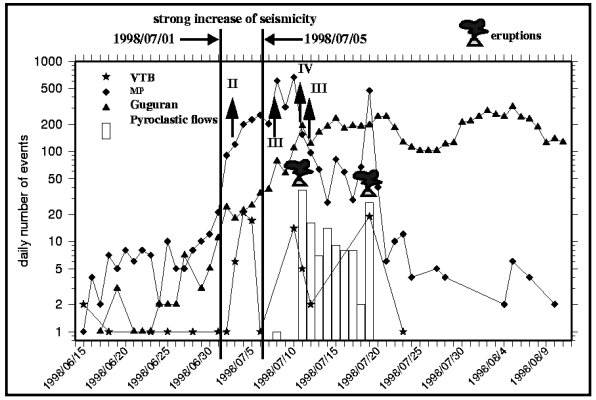


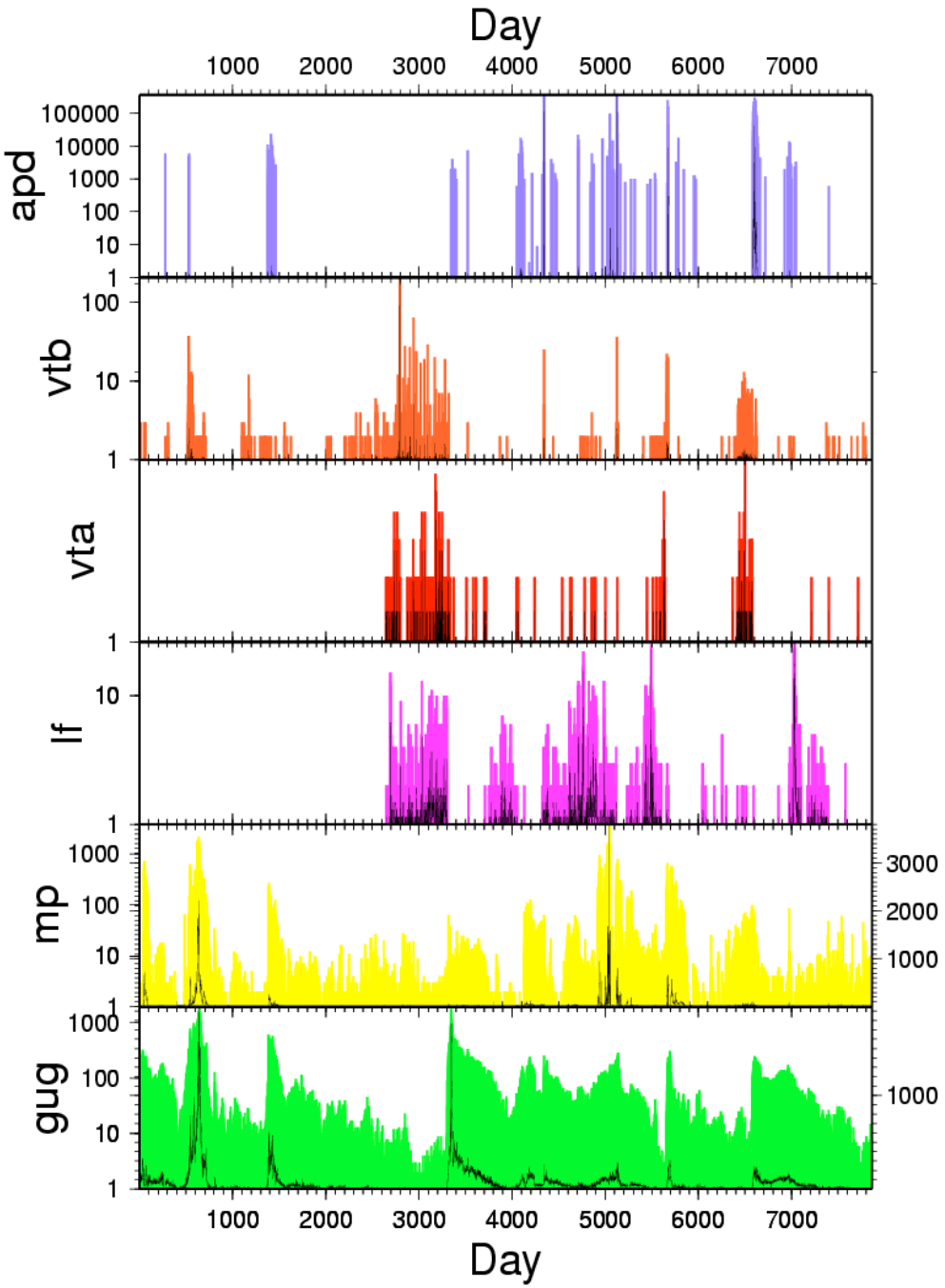
Figure 6: Recording of a rockfall event at Merapi volcano on March, 30th, 2002. Shown is the variation of the velocity during the rockfall event as a function of time.

Combining all activity parameters to form an objective alert system (incl. HMM and AI systems)





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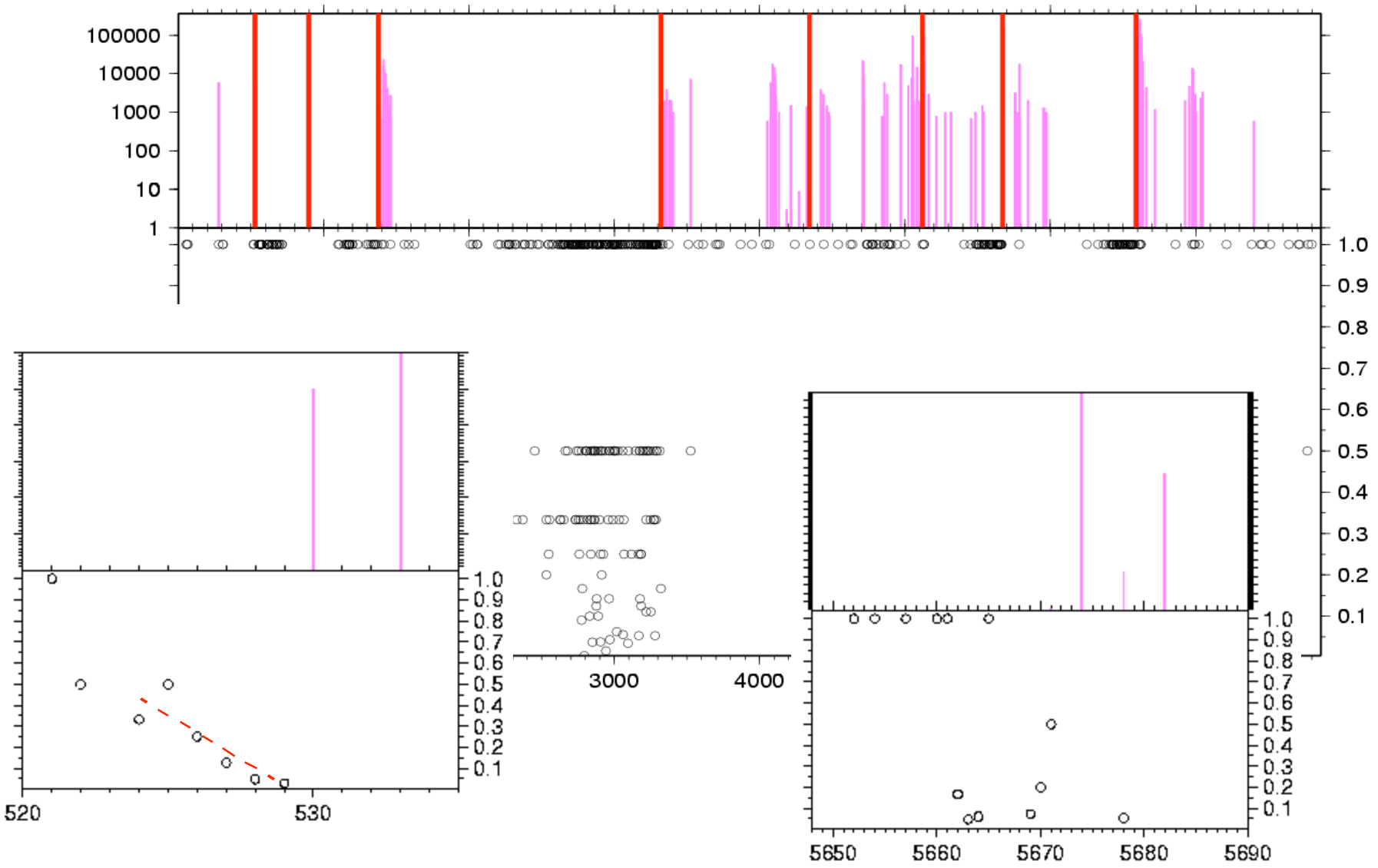
Day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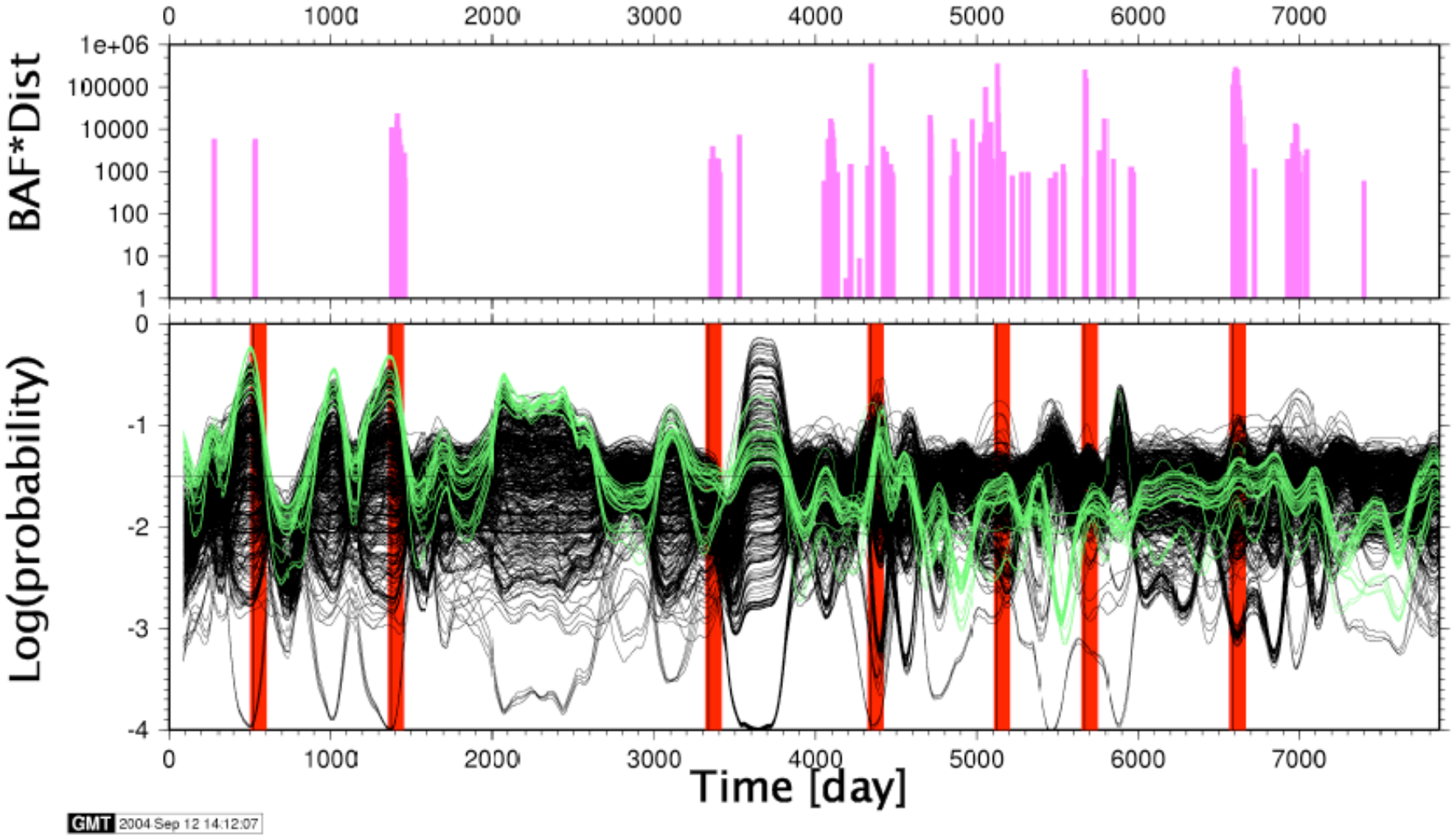
5670
5680
5690

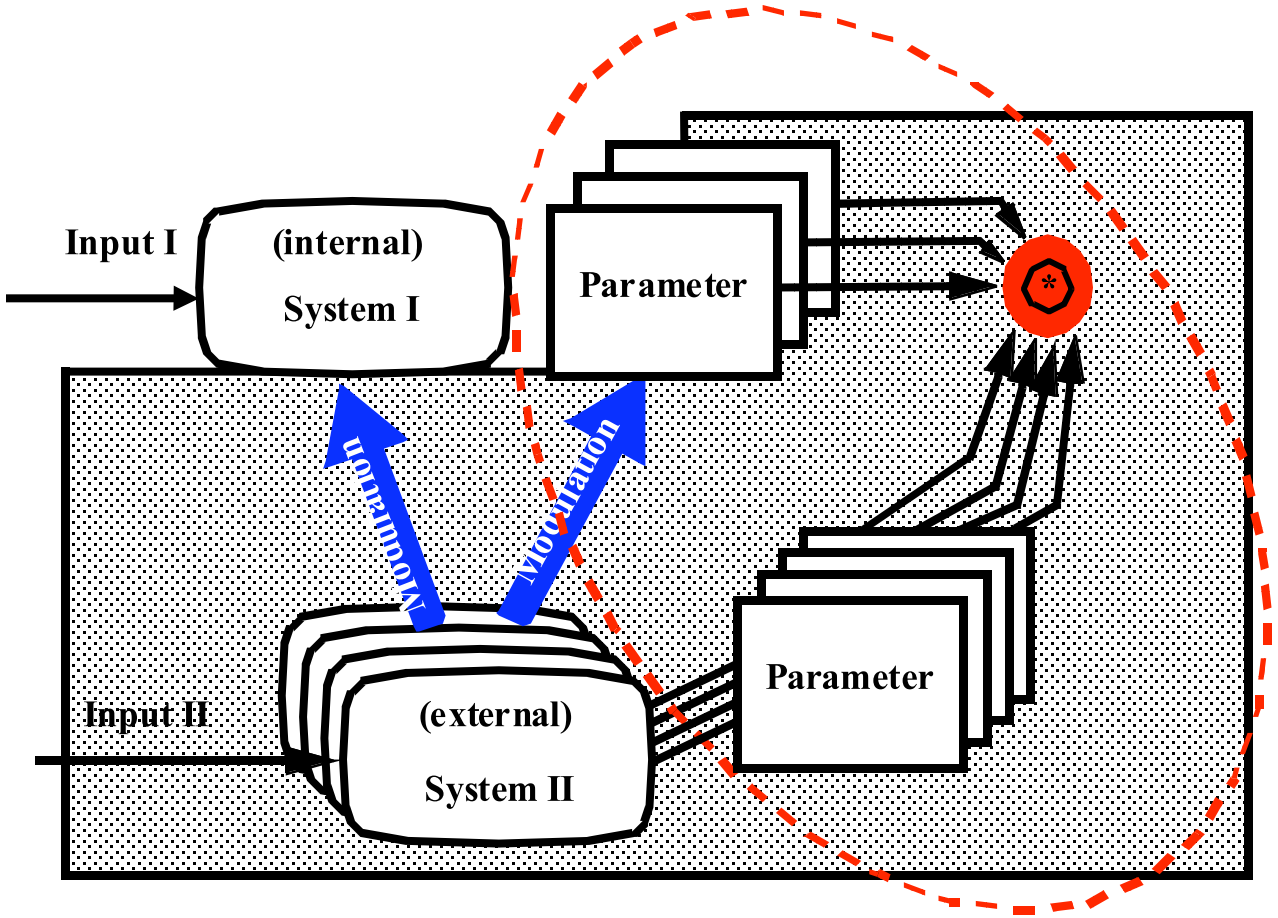
Early warning using speech recognition

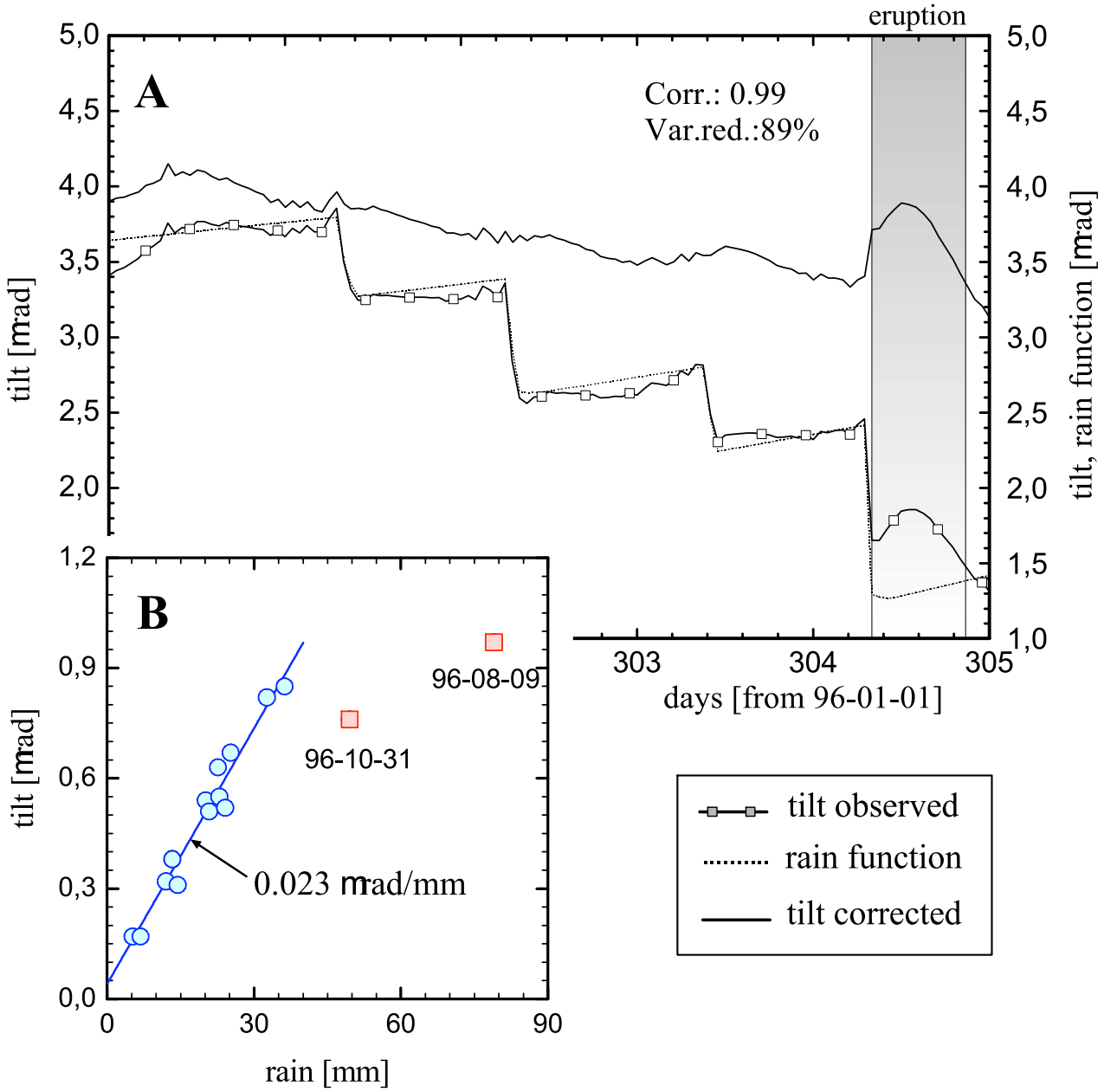


What to do next?

Research on external influences on activity parameters and eruptive behavior

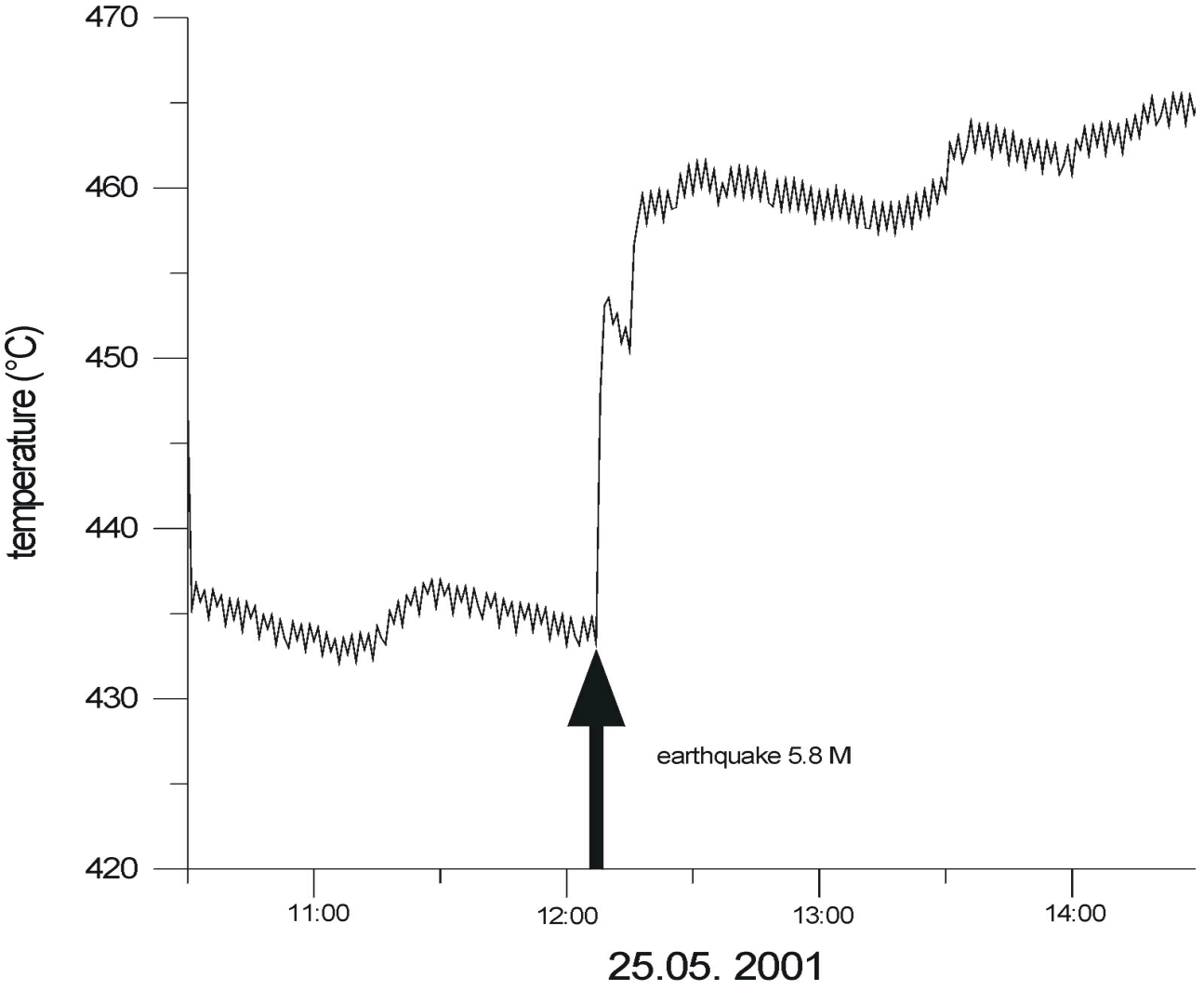
External modulation of volcanic activity and monitoring parameters





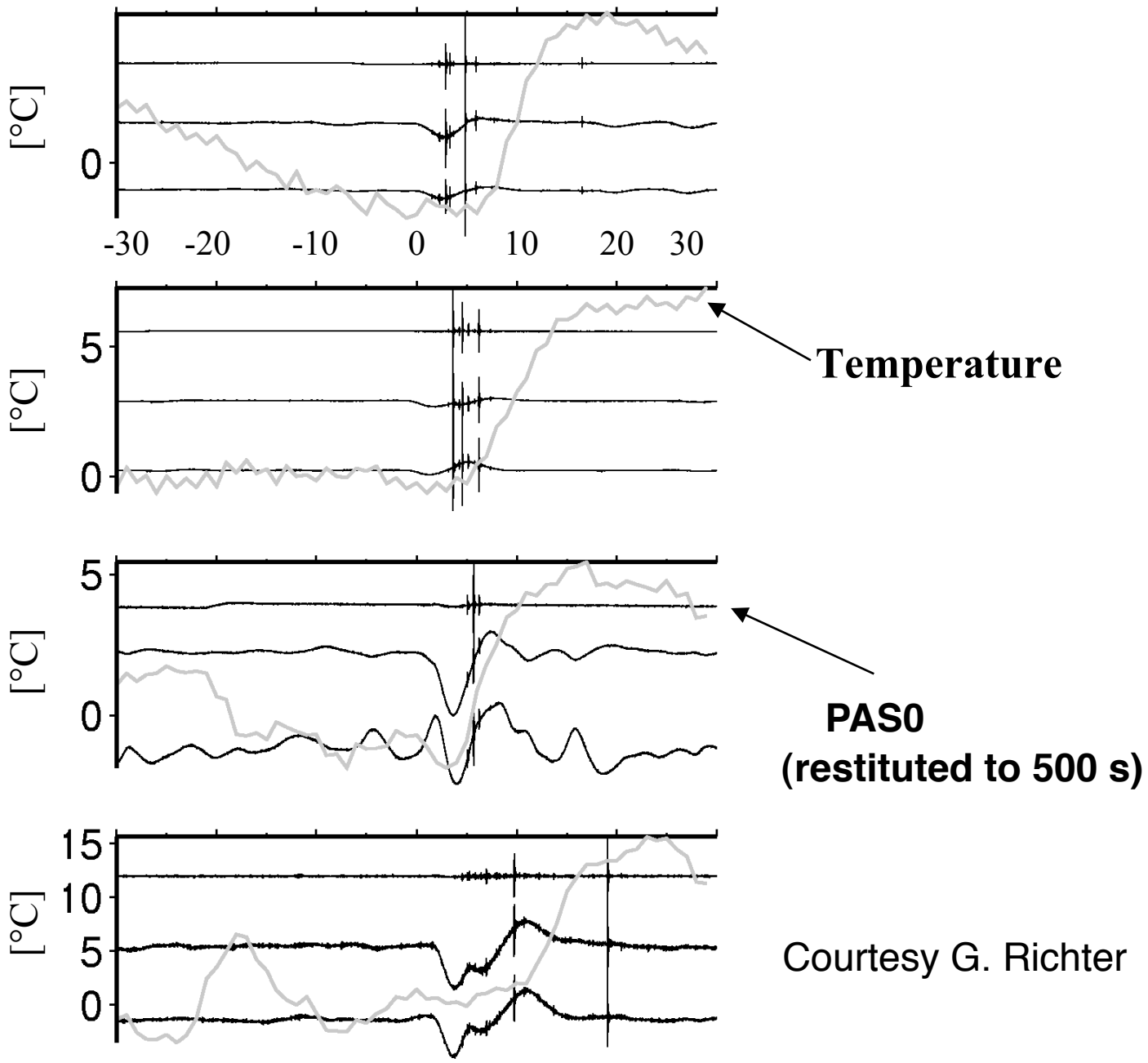
M.Westerhaus, 2002

Coseismic Step in Fumarole Temperature

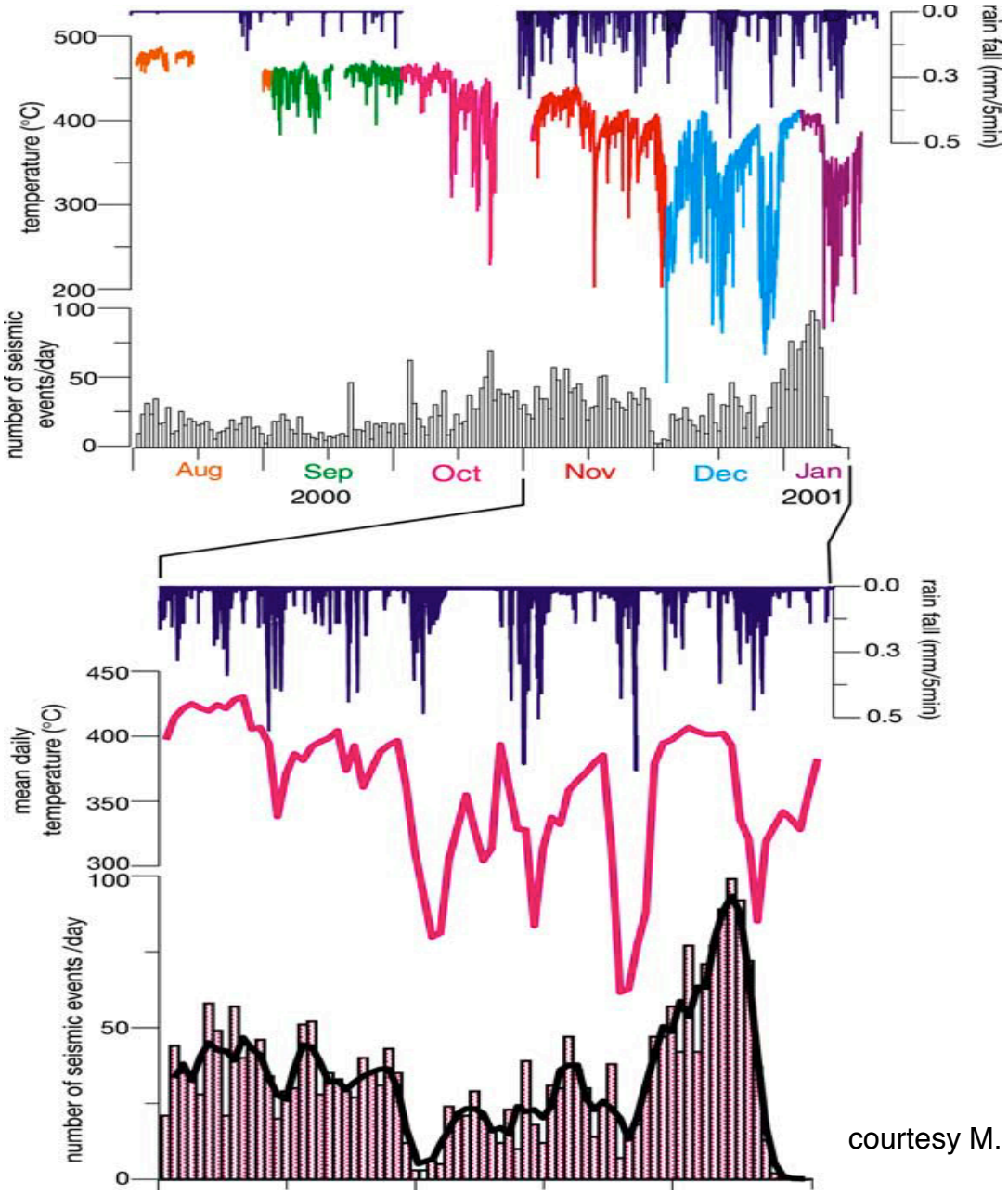


courtesy M. Zimmer

Correlation: Gas + Seismic?



Mixing of External and Internal Influences



courtesy M. Zimmer, GFZ