Monitoring of volcanoes, faults and man-made structures using continuous ambient noise records

C.P. Evangelidis

Institute of Geodynamics, National Observatory of Athens

Yerevan, ALTER Training Session

Outline

Outline

- Geodetic Methods: Strainmeters, Tiltmeters, GPS (limited on surface observation)

Monitoring volcanoes
Seismic and Geodetic methods

- Geodetic Methods: Strainmeters, Tiltmeters, GPS (limited on surface observation)
- Seismicity monitoring: Micro-earthquake activity, Volcanic tremor, Low frequency events (limited for aseismic movements)

Monitoring volcanoes
Seismic and Geodetic methods

- Geodetic Methods: Strainmeters, Tiltmeters, GPS (limited on surface observation)
- Seismicity monitoring: Micro-earthquake activity, Volcanic tremor, Low frequency events (limited for aseismic movements)
- Monitoring changes in travel times from coda waves or in seismic anisotropy (limited for seismically quiescent periods)

Monitoring volcanoes
Seismic and Geodetic methods

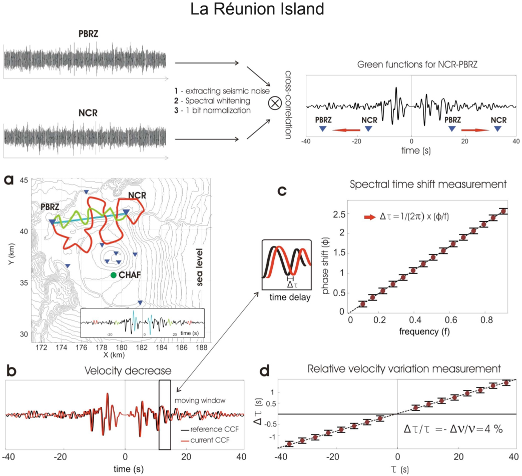
- Geodetic Methods: Strainmeters, Tiltmeters, GPS (limited on surface observation)
- Seismicity monitoring: Micro-earthquake activity, Volcanic tremor, Low frequency events (limited for aseismic movements)
- Monitoring changes in travel times from coda waves or in seismic anisotropy (limited for seismically quiescent periods)
- Repetitive tomographic imaging (Active source:Expensive, Passive source: limited for seismically quiescent periods)

Monitoring volcanoes
Seismic and Geodetic methods

- Geodetic Methods: Strainmeters, Tiltmeters, GPS (limited on surface observation)
- Seismicity monitoring: Micro-earthquake activity, Volcanic tremor, Low frequency events (limited for aseismic movements)
- Monitoring changes in travel times from coda waves or in seismic anisotropy (limited for seismically quiescent periods)
- Repetitive tomographic imaging (Active source:Expensive, Passive source: limited for seismically quiescent periods)
- Temporal velocity variations using continuous ambient seismic noise records.

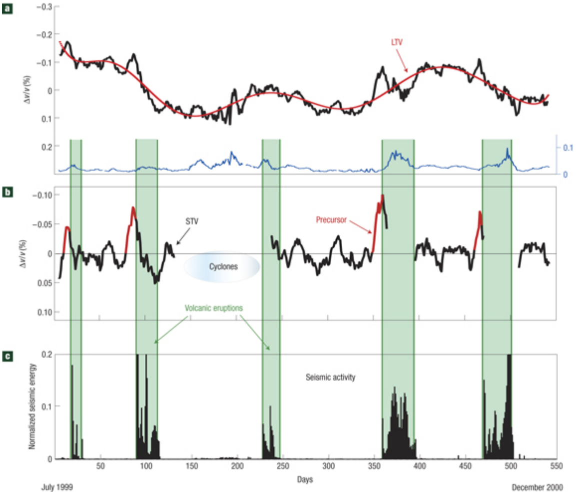
Using ambient noise for volcano monitoring

from Brenguier et al. (2008)



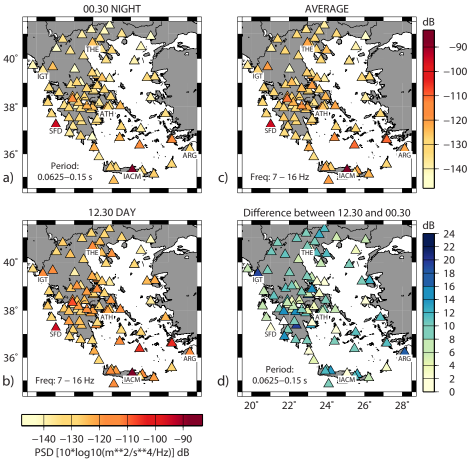
Relating dV/V to volcanic eruptions

from Brenguier et al. (2008)



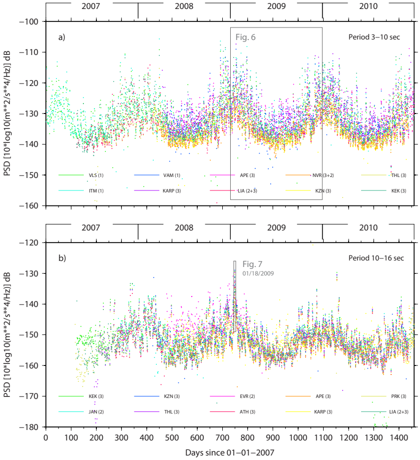
Outline

High frequency noise variations



(e.g. Evangelidis and Melis, 2012)

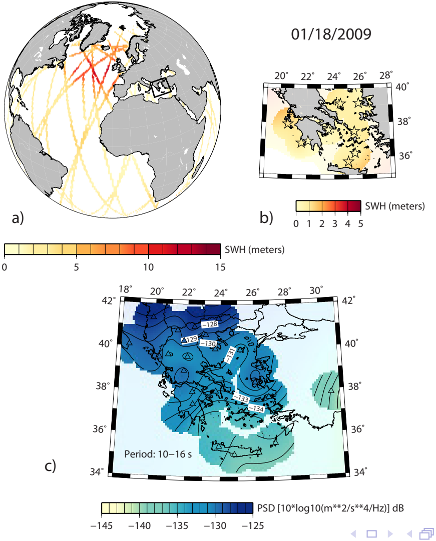
Microseismic noise
Seasonal variations



(e.g. Evangelidis and Melis, 2012)

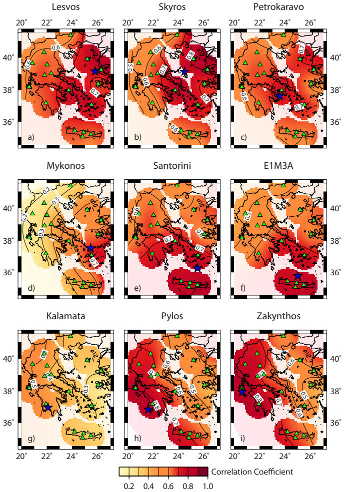
Single frequency band (10-16 s)

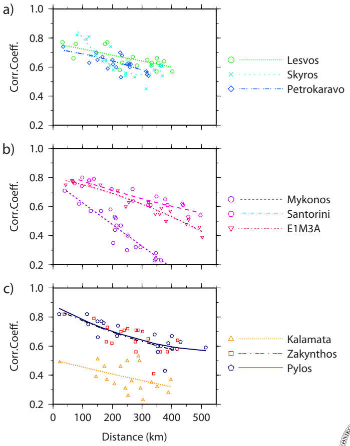
Affected by sea-weather conditions in the North Atlantic



Double frequency band (4-8 s)

Affected by local sea-weather conditions in the Aegean and the Ionian seas

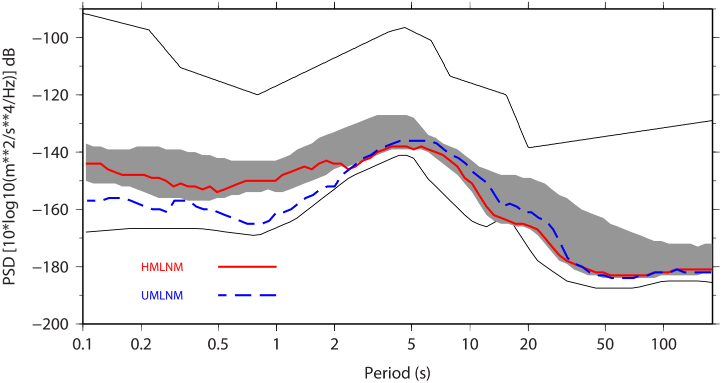




(Evangelidis and Melis, 2012)

Seismic network noise mode

in comparison with MLNM Mode Noise Model (e.g. Evangelidis and Melis, 2012)



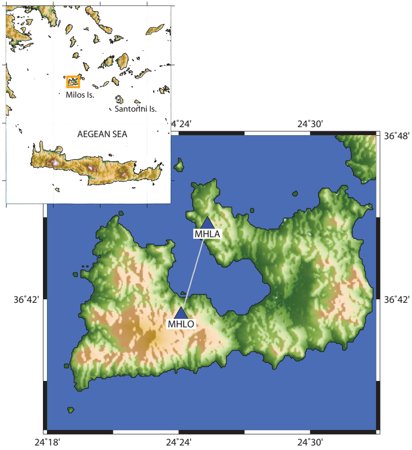
Outline

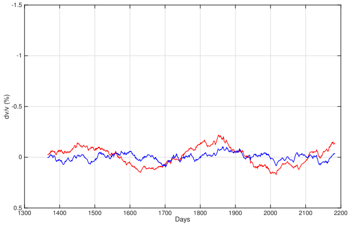
Data Treatment - Method

- separate the 24-hours long segment of each station into eight 3-hours segments. Keep segments with less than 10% gaps
- Filter the data in the band $0.1 - 1.0$ Hz
- Apply one-bit normalization
- Cross-correlate with the corresponding segment from the paired station
- Stack to get the daily cross-correlation function (CC)
- Spectral whitening on the CC inside the bandwidth of interest (Removing seasonal variations)
- Take the mean of all available daily CC to get the reference CC_{ref}
- The current CC_{cur} on the other hand is the mean of $N_{cc} = 21$ days around the day of the measurement.
- Apply the stretching method to make two measurements of dV/V using the positive and the negative time axis in a time window focused on the coda part ($15 - 35$s and $-35, -15$)
- The final result is the average of the two measurements as long as the correlation coefficient is higher than 0.7

Milos Broadband network

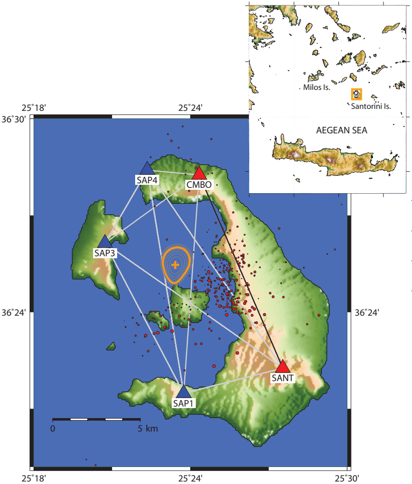
last days of 2011 and the entire 2012 and 2013 (827 days in total)

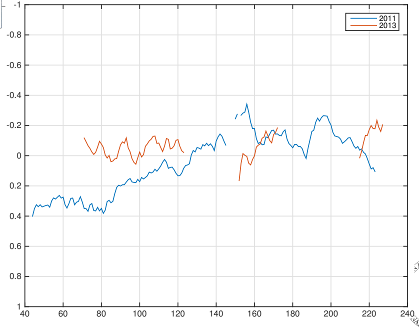




Santorini Broadband network
2011-2012 period

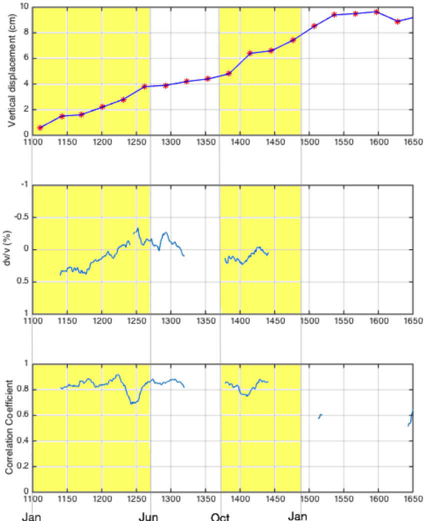
Removing microseismic seasonal variation





SANT-CMBO pair
Relating to vertical displacement and seismicity rates

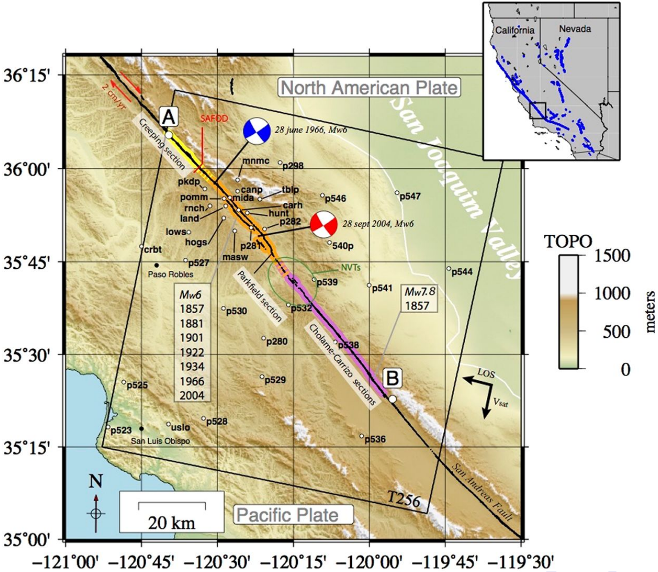
figure based on Saltogianni et al. (2014)



Outline

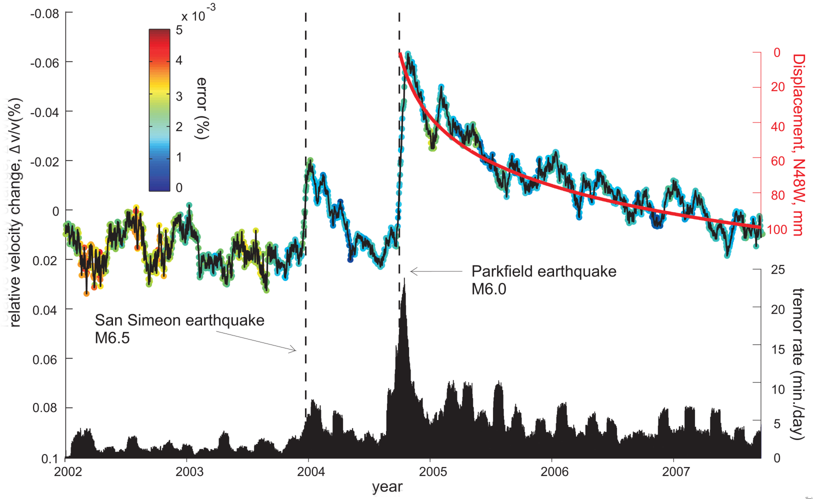
Postseismic Relaxation Along the San Andreas Fault

2003 San Simeon and 2004 Parkfield earthquakes



Postseismic Relaxation Along the San Andreas Fault

2003 San Simeon and 2004 Parkfield earthquakes



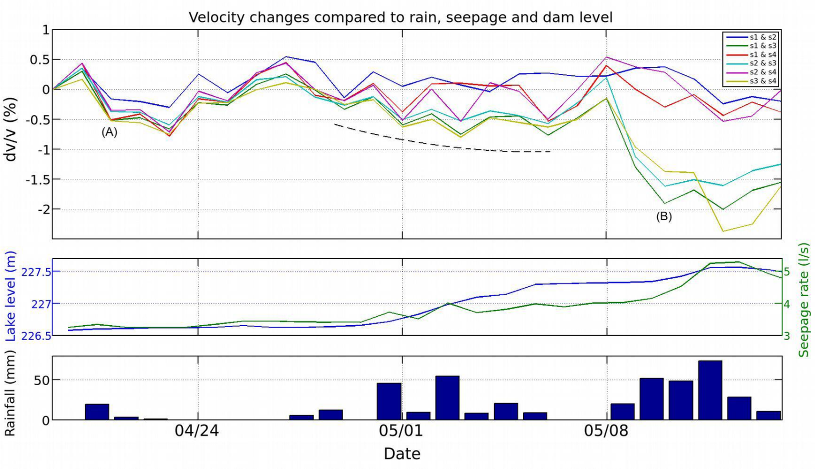
Outline

Monitoring the stability of tailing dam walls
Tasmania, Australia

Using uniaxial and triaxial geophones (Olivier et. al., 2017)

Monitoring the stability of tailing dam walls

Relative velocity variations for 6 station pairs from the 19th of April to the 14th of May compared to seepage flow rates, lake level and daily rainfall



Summary

- Explore volcanic unrests and post-seismic relaxation after major events
- Suitable for monitor volcanoes even with limited resources and data
- Network operators and authorities should consider this promising application

- Future steps in Armenia
  - Improve Seismic Network
    - Vault construction
    - Broadband sensors
    - New sites
  - Apply a continuous noise monitoring platform
  - Apply the low-cost ANI method at tailing dams of Armenia

References

Brenguier, F., Shapiro, N. M., Campillo, M., Ferrazzini, V., Duputel, Z., Coutant, O., and Nercessian, A. (2008). Towards forecasting volcanic eruptions using seismic noise. *Nature Geosci*, 1(2):126–130.

Evangelidis, C. P. and Melis, N. S. (2012). Ambient noise levels in greece as recorded at the hellenic unified seismic network. *Bull. Seismol. Soc. Am.*, 102(6):2507–2517.

Saltogianni, V., Stiros, S. C., Newman, A. V., Flanagan, K., and Moschas, F. (2014). Time-space modeling of the dynamics of Santorini volcano (Greece) during the 2011-2012 unrest. *J. Geophys. Res.*, 119(11):8517–8537.

Thank you