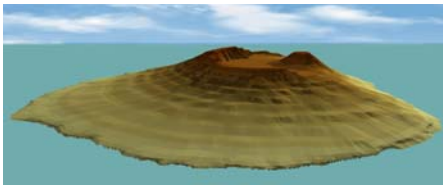
# Tidal Modulation of Volcanic Tremor in Fogo Island, Cape Verde

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**XXVIII GENERAL ASSEMBLY OF THE EUROPEAN SEISMOLOGICAL COMMISSION**
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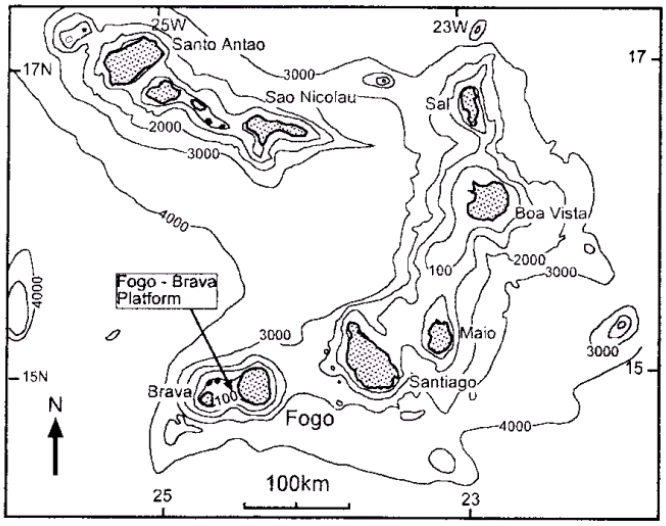
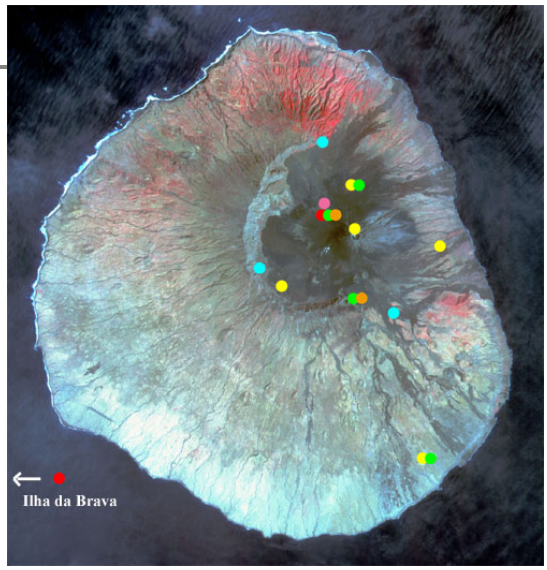
# Cape Verde archipelago



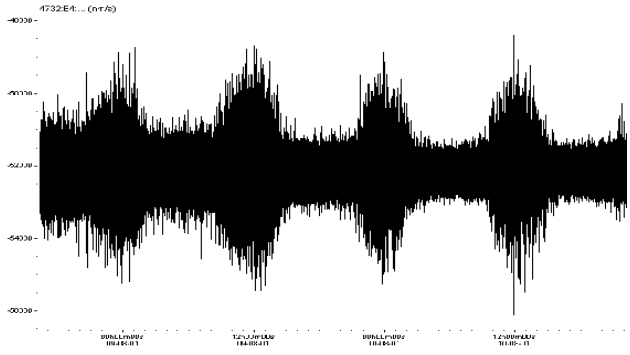
# Fogo Volcano

Monitoring network

- short-period seismometer
- broadband seismometer
- tiltmeter
- combiner repeaters
- gas sensors
- automatic meteo station

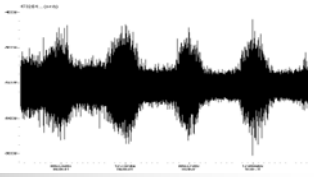



# Seismic noise modulation



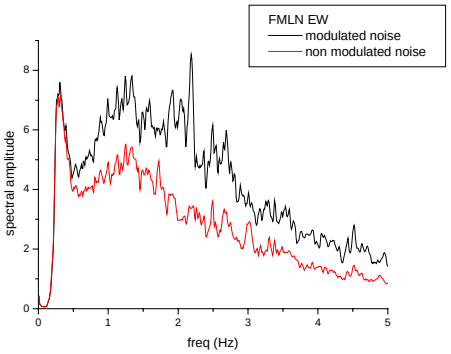
How can we explain this modulation?

# Seismic noise modulation analysis

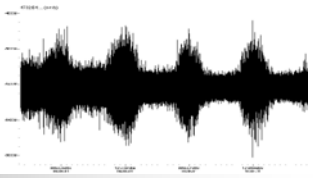


- Determination of the dominant modulated frequencies:

calculation of the average spectra for both maximum and minimum seismic modulation periods of 2 hours




# Seismic noise modulation analysis

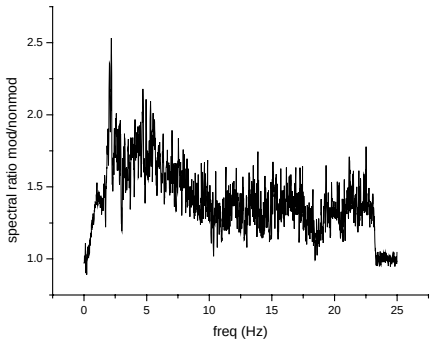


- Determination of the dominant modulated frequencies:

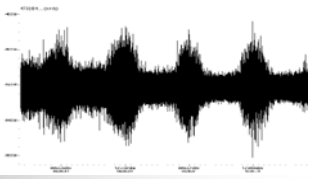
calculation of the spectral ratio between maximum and minimum seismic modulation periods

←

there are frequencies which are specially amplified (e.g. 2.2Hz)



## Seismic noise modulation analysis

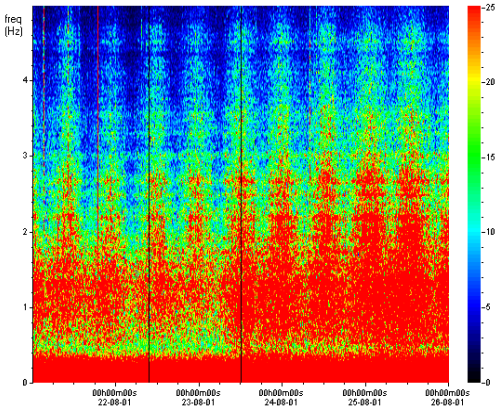


- Determination of the dominant modulated frequencies:

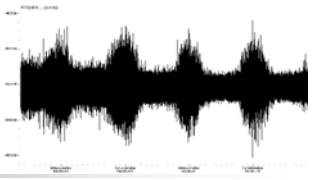
calculation of spectrograms
sampling freq: 1 $min^{-1}$
moving window of 102.4 s

←

- volcanic tremor modulation
- white noise modulation

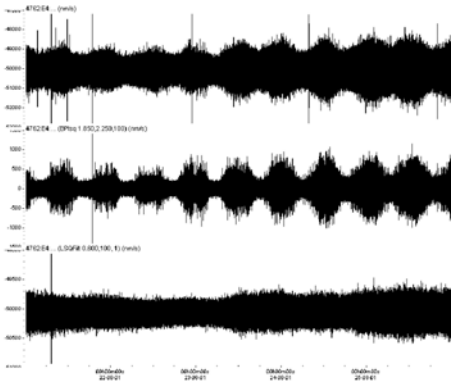



## Seismic noise modulation analysis

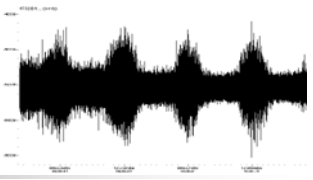


- Determination of the dominant modulated frequencies.
- Signal filtering in the most modulated frequency band:

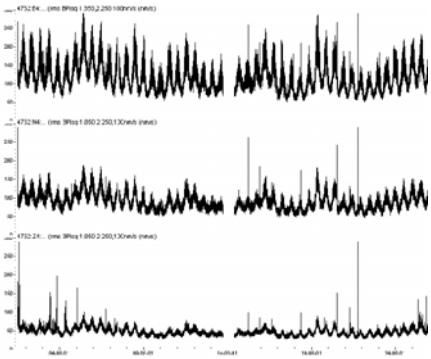
we obtain a very clearly modulated seismic signal



## Seismic noise modulation analysis

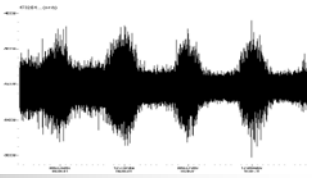


- Determination of the dominant modulated frequencies.
- Signal filtering in the most modulated frequency band.
- Calculation of the rms of the filtered signal:

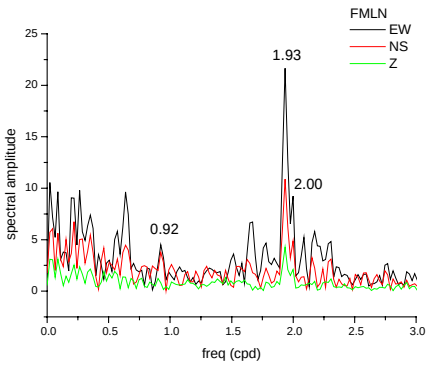


variance computed over a 2 min window moving with steps of 1 min

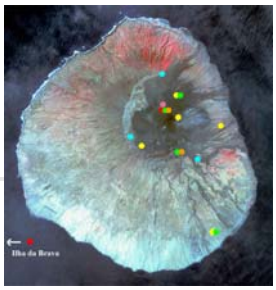
## Seismic noise modulation analysis



- Determination of the dominant modulated frequencies.
- Signal filtering in the most modulated frequency band.
- Calculation of the rms of the filtered signal.
- Calculation of the spectrum of the rms series.

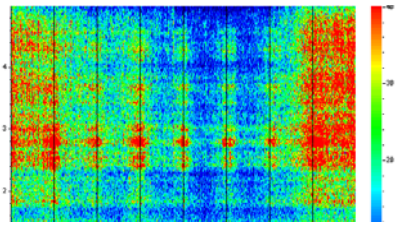


## Seismic noise modulation characteristics



- Lunar influenced spectra
  (M2 - 1.93 cpd and O1 - 0.92 cpd )
- Semi-diurnal frequencies are mainly present: M2 - 1.93 cpd (and also S2 - 2.00 cpd)
- Diurnal frequencies are present too: O1 - 0.92 cpd
- The modulation is most intense in the EW component, and less intense in the Z component
- This is observed in every station, even though with different intensities
- There is no significant phase delay between different stations, nor between different velocity components

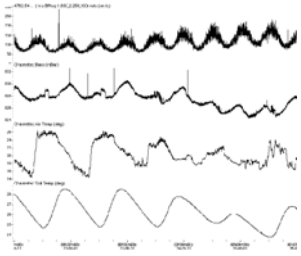
## What about tremor?



- Station dependent characteristics => path effects:
  -> varying amount of spectral lines
  -> varying tremor intensity
- Station independent characteristics => source effects:
  -> identical spectral lines for each velocity component
- Main tremor frequencies between 2 and 3 Hz
- Tremor frequencies don't change in time => stable source

## How can we explain the semi-diurnal modulation? Environmental parameters?

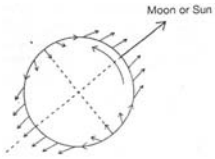
- Temperature
  - main frequency 1.00 cpd
    (2.00 cpd also present)
- Air pressure
  - main frequency 2.00 cpd
    (1.00 cpd also present)



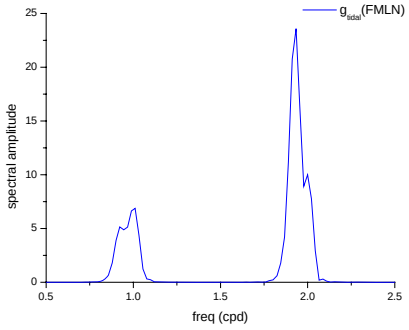
Environmental factors show mainly solar periodicities.
But the seismic modulation is mainly lunar.

=> Environmental factors can't explain the modulation.

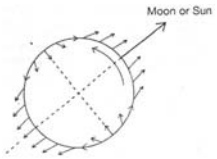
## How can we explain the semi-diurnal modulation? Tides?




- Spectral analysis

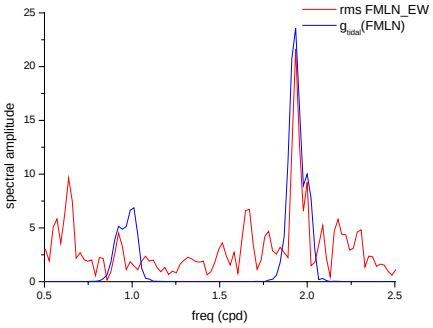


## How can we explain the semi-diurnal modulation? Tides?




- Spectral analysis

  -> main frequencies are identical




- Cross correlation

  -> the seismic modulation has a delay of approximately 4 hours to the rate of tidal potential variation.

## => The modulation seems to answer a tidal mechanism

How can tides modulate the seismic noise?

- Earth tides?

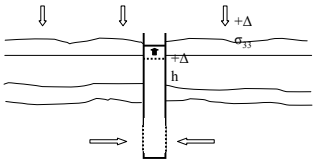
  -> bigger deformations along EW direction

  -> but not big enough to cause the observed modulation

- Ocean load?

  -> bigger deformations than earth tides in oceanic islands

  -> but mostly felt along Z direction




- Hydraulic movements in the ground?
  - The effect of a vertical water load on a porous media is to increase the pressure in the pores.
  - A tidal load applied on a rock matrix originates a flux with tidal periodicity.

=> Tides may induce water penetration in the interstitial volcanic pores originating a tidally modulated hidrothermal flux that drives the volcanic tremor.