The magnetic coupling of Earth-Ionosphere below 2m Hz

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Earth ionosphere coupling

Earth magnetic field affected by various phenomena (magnetic storms, lightning, ground motions…)

- Produce global changes on the magneto-ionospheric conditions
- Involve multi-frequency processes

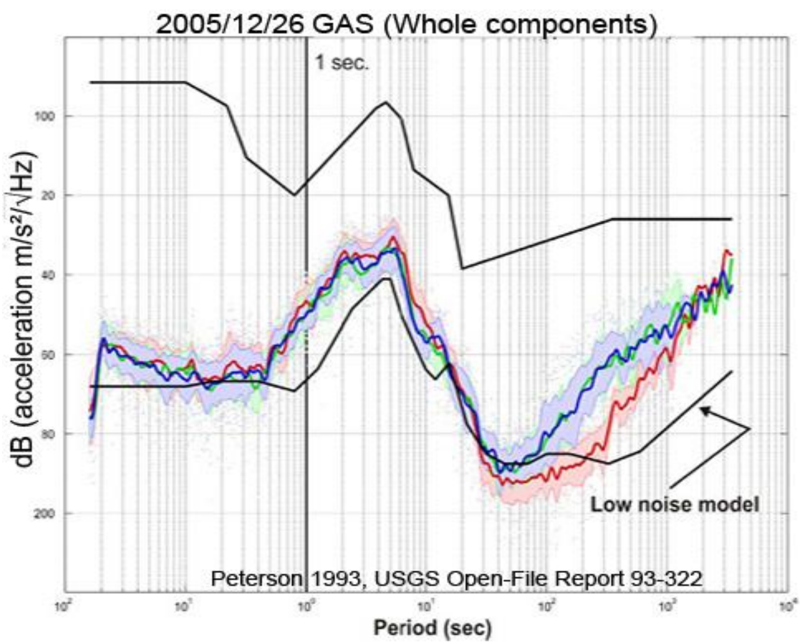
Ionosphere = natural transducer for Earth signal especially for seismic waves

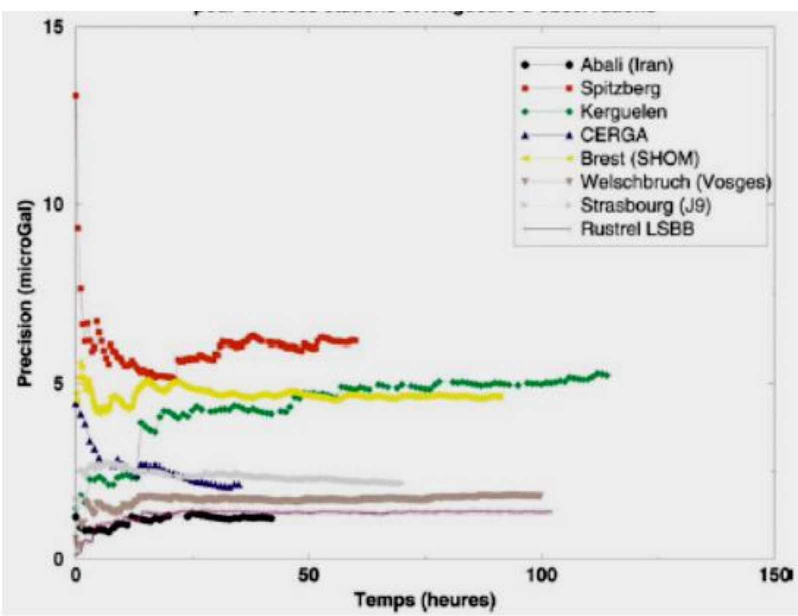
- Generation of vertical oscillations on Earth surface (up to 1 mm at 10000 km for M >8)
- Atmosphere/solid Earth coupling = quasi vertical acoustic wave reaching the ionosphere with amplitude growing when the density decays
- External contribution to the Earth magnetic field of weak amplitude

⇨ Need of a sensitive instrument located in a low noise site

LSBB: A naturally low-noise environment

- No anthropogenic noise
- Surrounding carbonate rock of very-low radioactivity level
- Seismic PSD close to the NLNM minimum (Peterson)
- Very low absolute gravity fluctuations



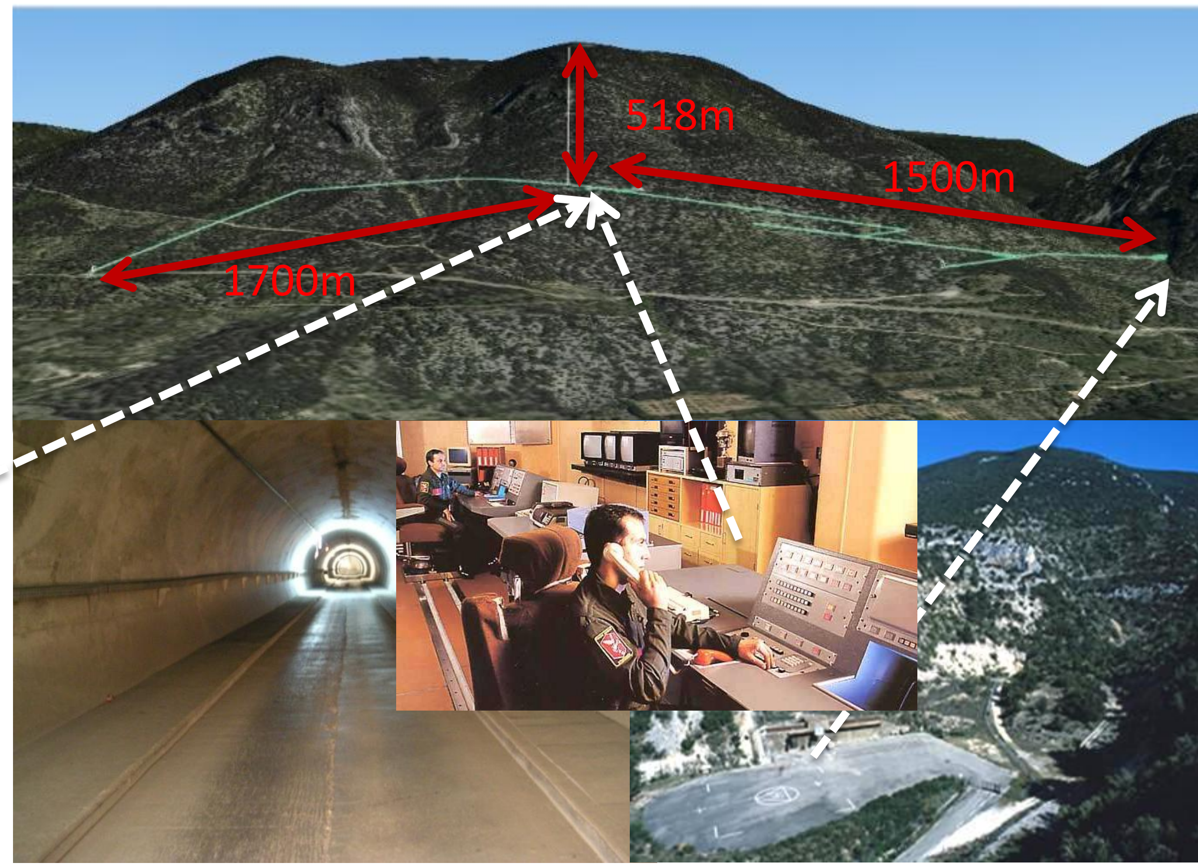


LSBB = Low Noise Underground Lab

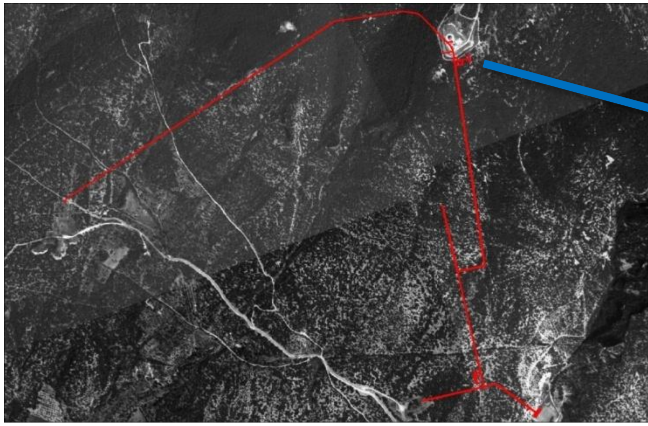
– Single example of a military site conversion

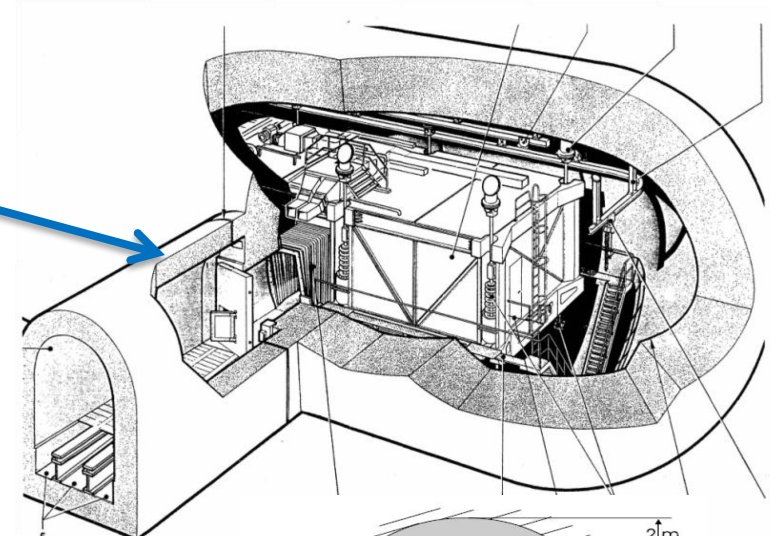
– Cabin: an area designed to withstand the effects of a nuclear blast

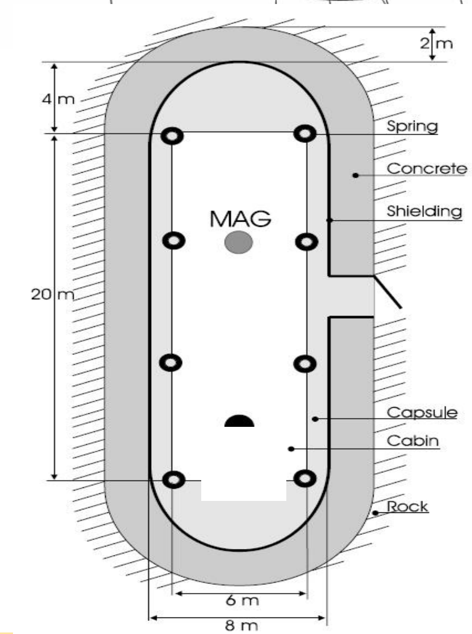
- Mechanical
- Thermal
- Radiative
- Electromagnetic



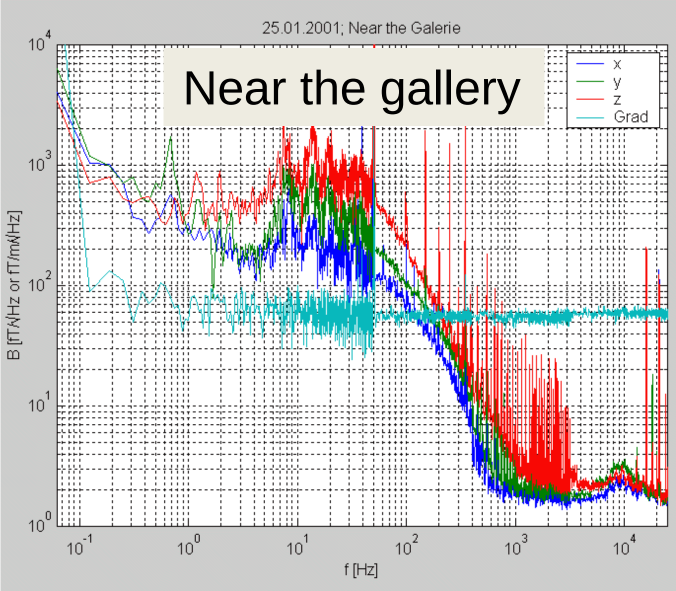
The capsule and the cabin

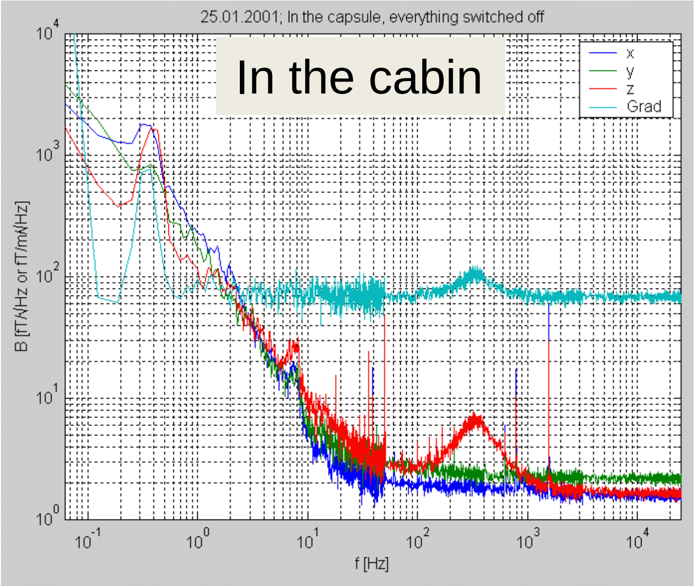






Electromagnetic shield qualification





Shield = Combination 518m karstic rock + capsule

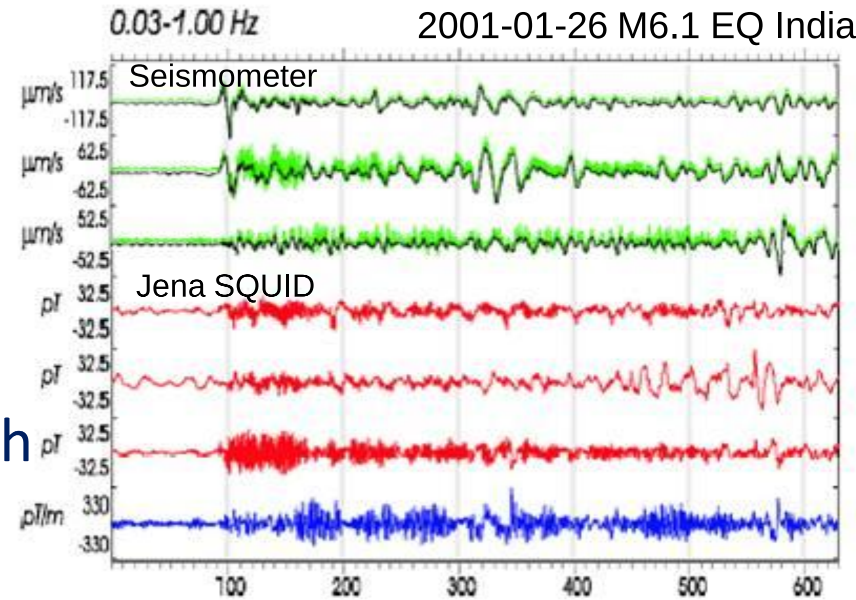
– Acts as a low pass filter under 30 Hz

– Residual noise < 3fT/√Hz above 40 Hz (intrinsic noise level of Jena SQUID's)

Effectiveness of SQUID's with the shield

Magneto-hydro-seismic effect (Gaffet et al. Géophys J. Int. 2003): magnetic response synchronous with the P seismic wave arrival at LSBB seismic station

- identified as a relative ions movement present in the water of the surrounding karstic rock
- Local effect depending on quake magnitude and azimuth and water charge



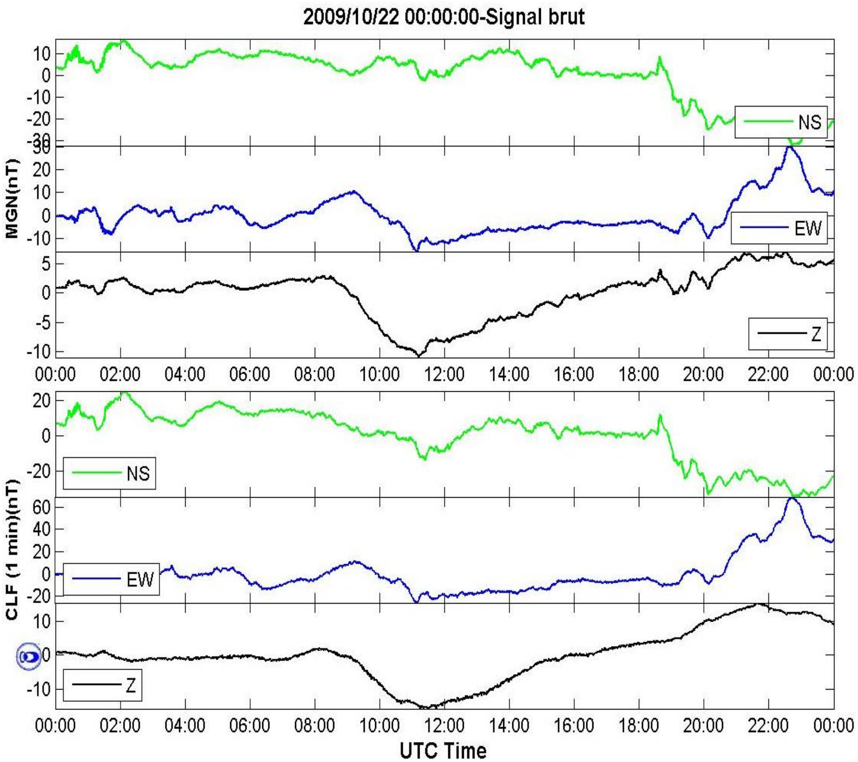
Permanent Watch by [SQUID]^2: **SQUID**'s in a **S**hielding **QU**alified for **I**onosphere **D**etection

3 axis SQUID low T_c magnetometer

- 3 weeks of data before He refilling
- remote control
- acquisition station identical to seismic ones, GPS synchronization
- sample rate 1, 125 or 500 Hz
- permanent operating in low sensitivity: ±166 nT range, 5 fT resolution
- punctual observation in high sensiti: ±1.66 nT, 0.05fT

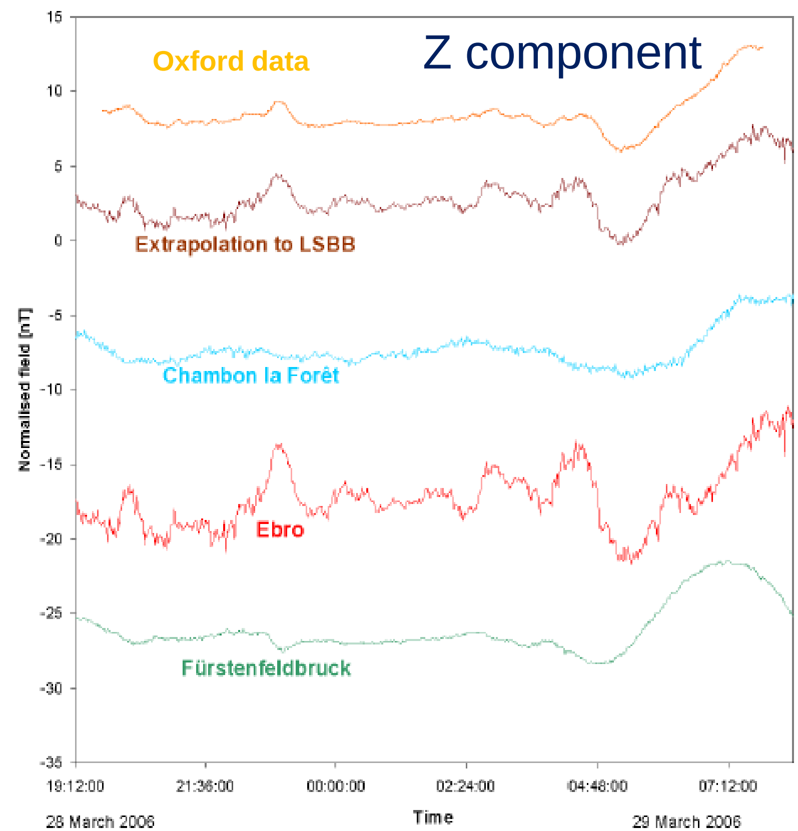
Comparison with geomagnetic observatories

[SQUID]² signal



Reliability of the local observation

Extrapolation of the capsule signal from data of 3 observatories of Intermagnet (Henry et al. 2008)



The magnetic background noise

- Approach equivalent to the NLNM: find the lowest level of magnetic perturbation
- [SQUID]^2 data confrontation vs

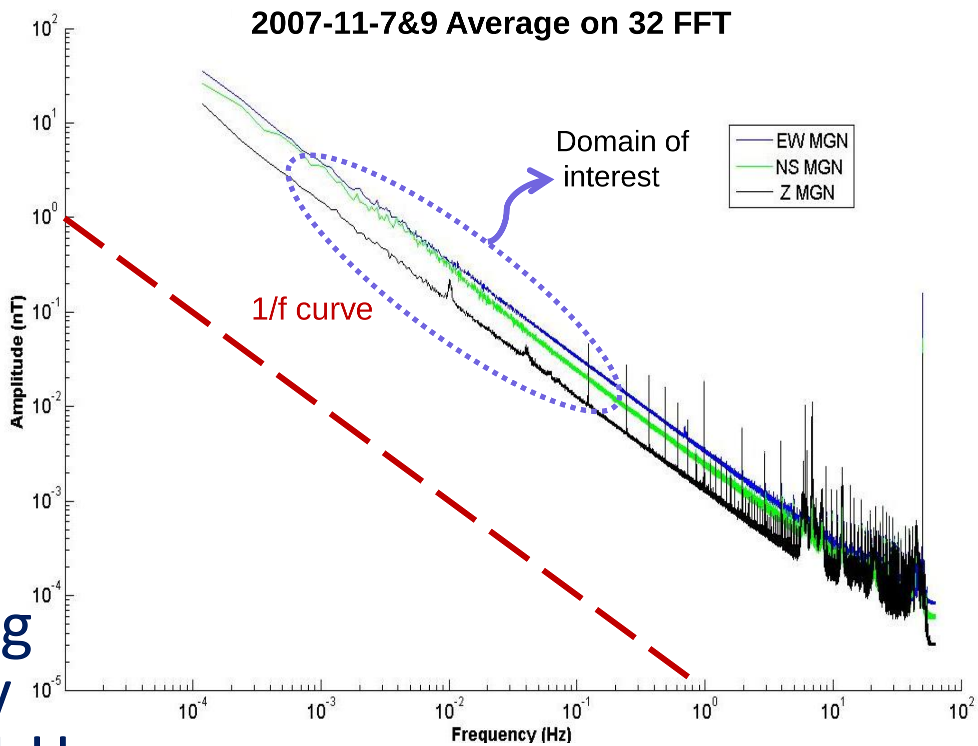
  - EQ data base (USGS, RENASS)

  - Space weather (NOAA, GFZ Quietest Days)
- November 2007, 7 to 9th = a 72h quiet period

  - no EQ up to M=5.5
  - no space weather alert
  - circadian alternation
  - no seasonal variation

Magnetic amplitude spectrum

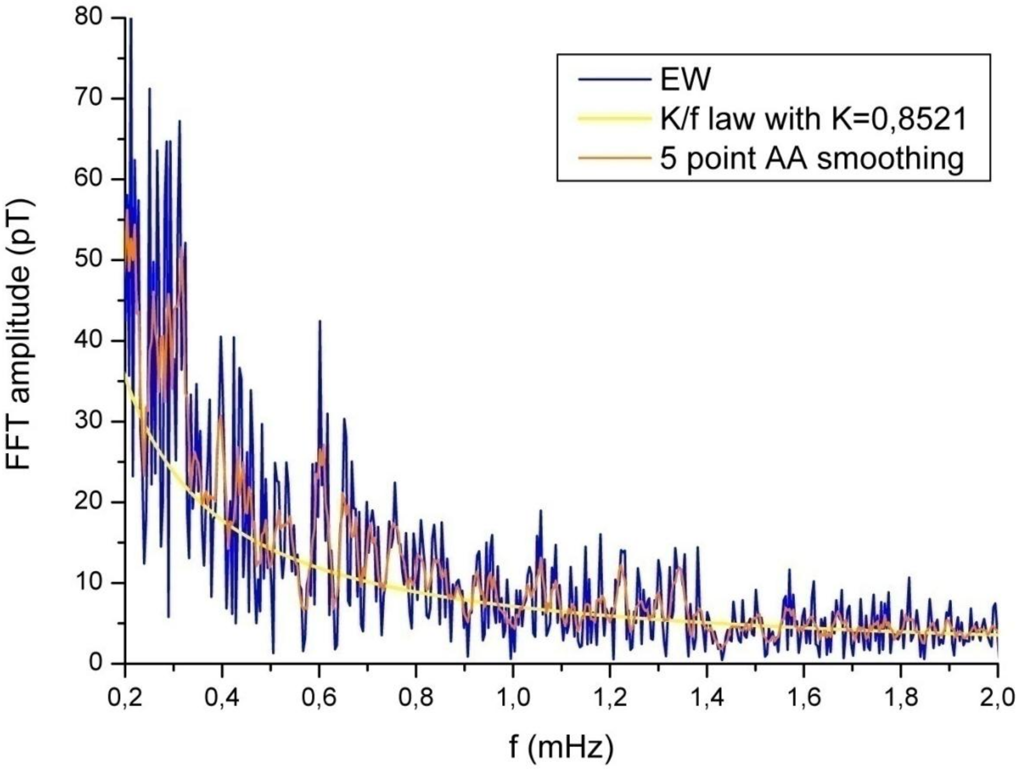
– Main characteristics
  - Monotone decreasing : no noise source
  - EW and NS level greater than Z one = vertical contribution
  - Host of peaks outside the [0.1-1 Hz] band

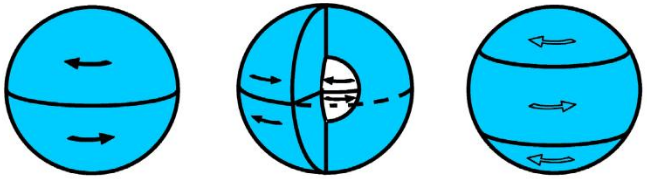


– Increase FFT resolution under 0.1Hz and dealing with computer capacity
$\Rightarrow$ Data resampling at 1 Hz

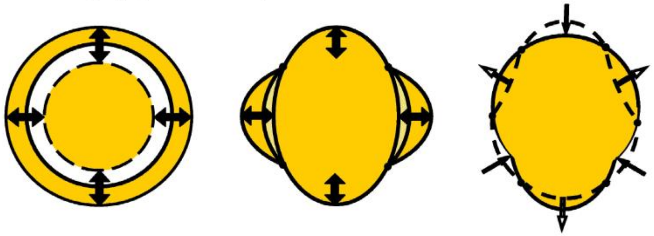
Analysis in the millihertz range

Gravest S & T Eigen modes





Toroidal modes ${}_0T_2$ (44.2 min), ${}_1T_2$ (12.6 min) and ${}_0T_3$ (28.4 min)



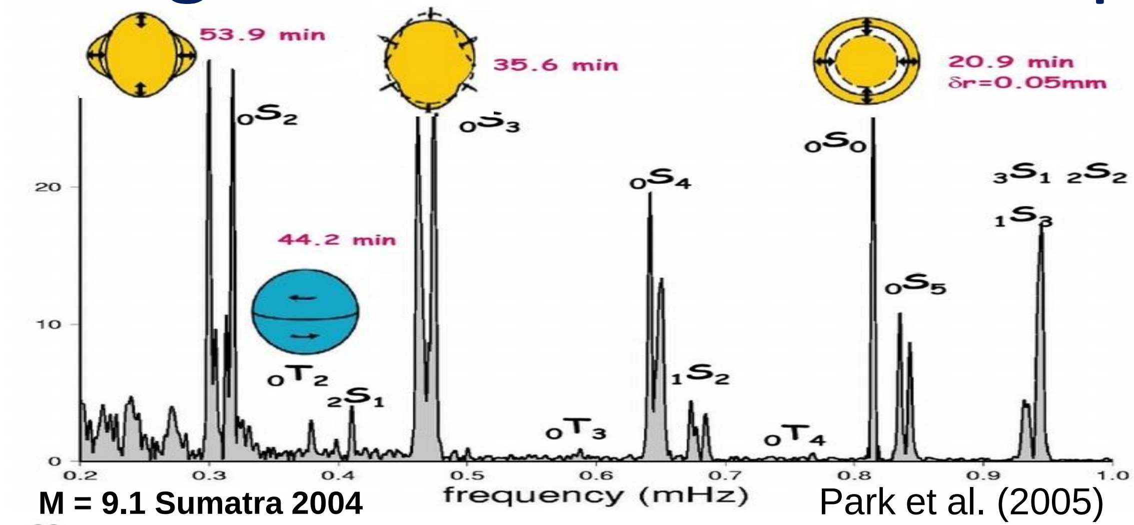
Spheroidal modes ${}_0S_0$ (20.5 min), ${}_0S_2$ (53.9 min) and ${}_0S_3$ (25.7 min)

Park et al. Sciences 2005

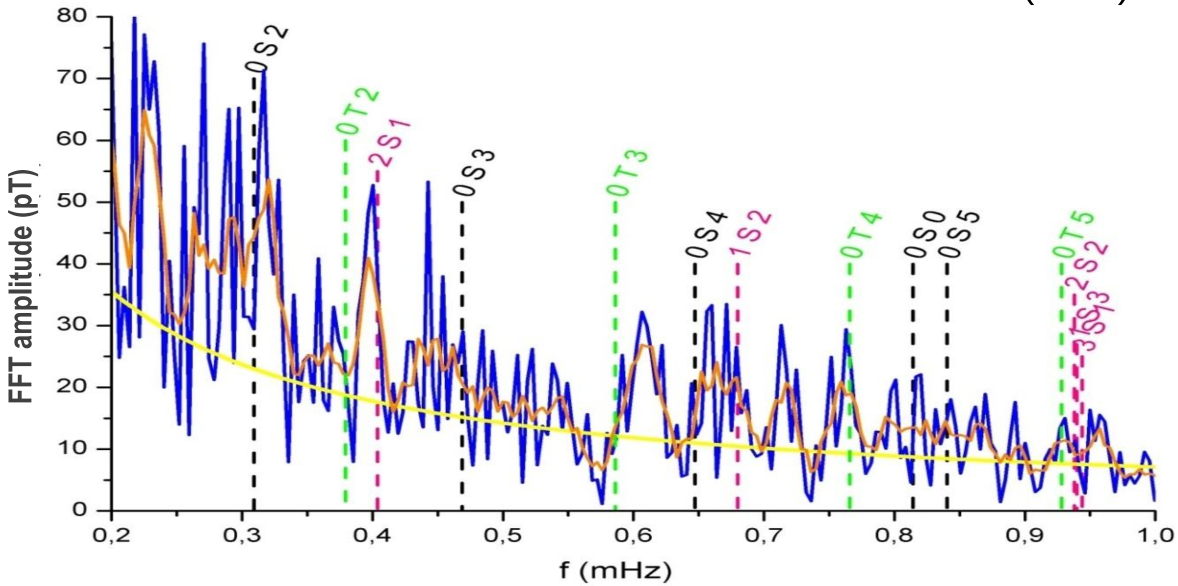
First mode 0S2 at 0.308 mHz
14 modes with f < 1 mHz 60 between 1 and 2 mHz

Laboratoire Souterrain à Bas Bruit RUSTREL Pays d'APT

Eigen modes: Earth-ionosphere coupling



Seismic detection
FFT on 10 days
after a M9.1 EQ
S-modes prevail



Magnetic detection
FFT on 3 quiet days
no EQ above M5.5
S-modes but also T-ones (PREM model theoretical values within 1%)

Conclusions

New capability for SQUID's: 50 Earth eigen modes detected with [SQUID]^2 via Ionosphere/Earth coupling (54 theoretical values under 2 mHz)

– Supplement seismic experiment (T-modes presence)

– Learn of earth structure without EQ

Perspectives

Methodological developments

– Extension of the analysis beyond the 2 mHz band

– Comparison with strong EQ periods and very ionized conditions to study relative amplitude of these modes

Instrumental developments: SQUID network for

– Results validation

– Exploration of the azimuthal correlation

– [SQUID]^2= reference place