Turning seismometers into strainmeters using tidal strain and ambient noise – a feasibility study

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Motivation

Properties of local subsurface
Of seismic stations have significant influence on seismic recordings

Knowledge of elastic properties
Of rocks in the subsurface would enable better station calibration for effects of local geology and allow to concentrate more on actual earthquake signals

Tidal strain and ambient noise (trivia)

Solid Earth tides (SET)

- Nanostrain deformations
- Tools for synthetics of SET-induced strains

Ambient noise

- Omnipresent
- Easily collectible

However...

Solid Earth tides (SET)

- Oceanic loading tides (OLT) also exist
    - Estimates are less accurate

Ambient noise

- Noise level might not be sufficient
- Noise sources can change their ***x*** and/or *f* over time
    - (Tidal-like) oceanic noise, also > 1 Hz

Theoretical concept

Tidal loading of the Moon and Sun
Deforms the Earth's surface (can be estimated theoretically)
E.g., Sens-Schönfelder and Eulenfeld (2019)

Earth's surface
Responses to the deformations with volumetric changes of its pores

The volumetric changes
Induce velocity changes of propagating seismic waves

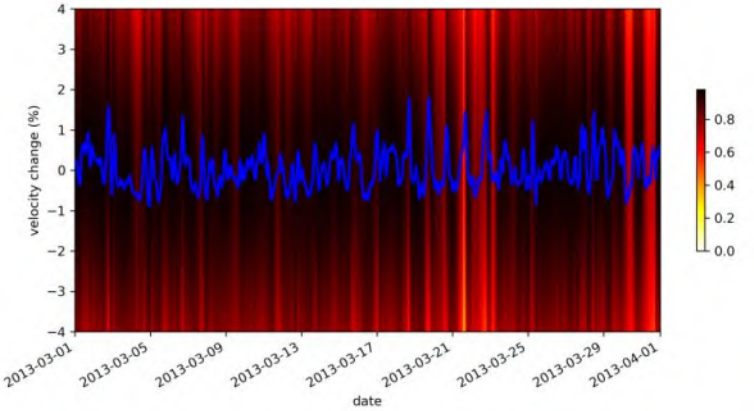
Such velocity changes
In subsurface of seismic stations can be determined by ambient noise processing

Knowledge of such tidal strains and induced velocity changes
Would enable to estimate elastic properties in the station's subsurface

Method

Passive image interferometry (“stretching method“)
Preprocess continous waveforms → correlate short segments → reference trace → stretch the segments to match the reference trace → time series of relative velocity changes (DVV)

By Sens-Schönfelder and Wegler (2006)



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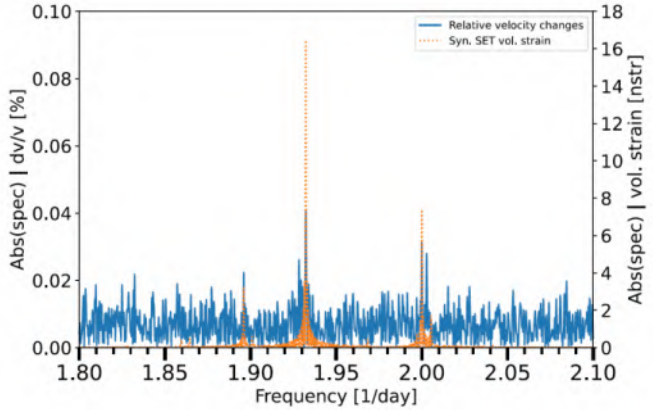
Find tidal frequency components
In the retrieved DVV time series

Calculate theoretical SET-induced strains
And study rock elastic properties thanks to the DVVs and SETs



My real-world results (very briefly)

Data from dozens of stations
Were processed (varying freqs., lapse times…)

Tidal frequencies in DVV time series
Were observed only at stations not further than 65 km away from an ocean/sea

Phases of tide-related frequencies
Were inspected for DVV time series and synthetic SET, OLT and SET+OLT time series, without clear relationships, suggesting complex conditions

Conclusions

Unfeasibility to observe tidal frequencies
In DVV time series at mainland stations raises questions about plausibility of tide-related DVV changes observed at the coastal stations

Tidal frequencies observed near the coast
Might might be a combination of real DVVs caused by SET and OLT, with contribution of noise source effects, although a sound proof is still missing

References

Sens-Schönfelder, C. and Eulenfeld, T., 2019. Probing the in situ elastic nonlinearity of rocks with Earth tides and seismic noise, Phys. Rev. Lett., 122, 138501

Sens-Schönfelder, C. and Wegler, U., 2006. Passive image interferometry and seasonal variations of seismic velocities at Merapi volcano, Indonesia, Geophys. Res. Lett., 33, L21302

Thank you for your attention

Suggestions are welcome