MICHAEL DIETZE
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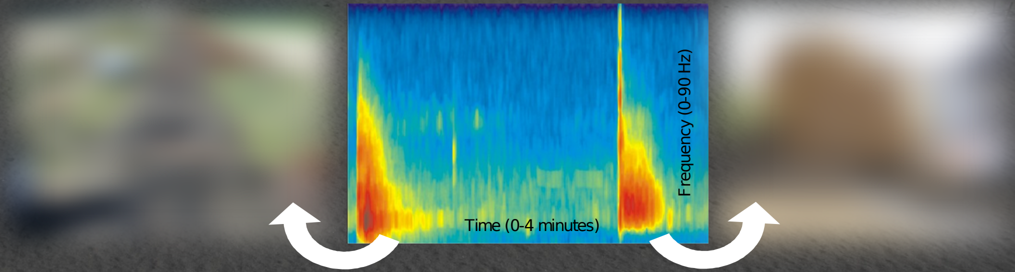
THE R PACKAGE ESEIS

A TOOLBOX TO WELD GEOMORPHIC, SEISMOLOGIC, SPATIAL, AND TIME SERIES ANALYSIS

Most of the processes that shape the Earth are **hard to constrain** by classic approaches.

Seismic methods provide a valuable alternative / complement to existing shortcomings.

Integrating geomorphology and seismology but also adjacent scientif c f elds demands speaking one language: **R**. This is the main motivation that drives the development of ‘eseis‘.



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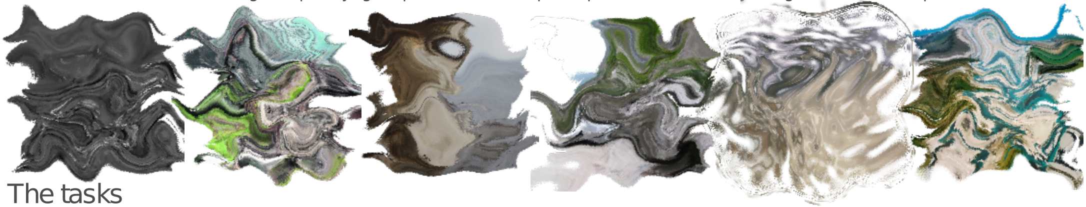
- Environmental seismology
- A typical Workflow
- Why R?
- Example I
- Example II
- Towards where?

The dynamic Earth surface

We are interested in understanding and quantifying the processes that shape our planet in a holistic way, using innovative techniques.

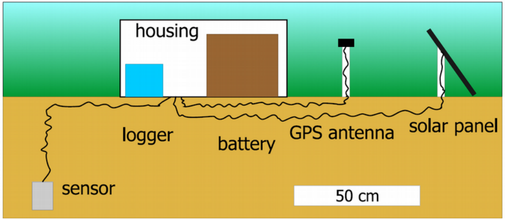


The tasks

Identifying and quantifying when and where and why a given process mobilisises, transports and deposits sediment.

The challenges

Processes can be hard to predict, can be episodically, can cover immense spatial and temporal scales, have different drivers/triggers, destroy the instruments that want to probe them, and are coupled and interconnected.



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Data handling and workflow

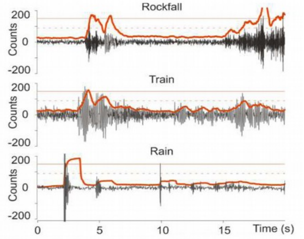
A typical workflow from import to final plots is seamlessly supported by the object structure design. External data can be included, as well.

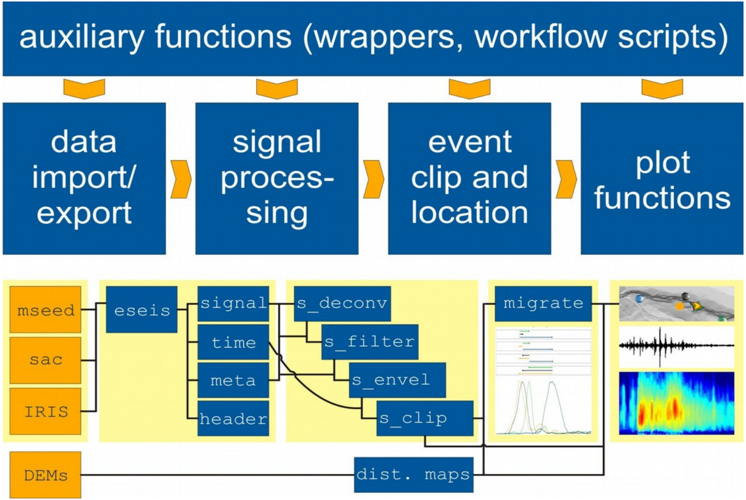
The tasks

Handling established data formats, designed for high-resolution data.

Delicate processing to isolate the signals of interest and remove noise.

Identify sources of “noisy“ data in space.





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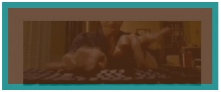
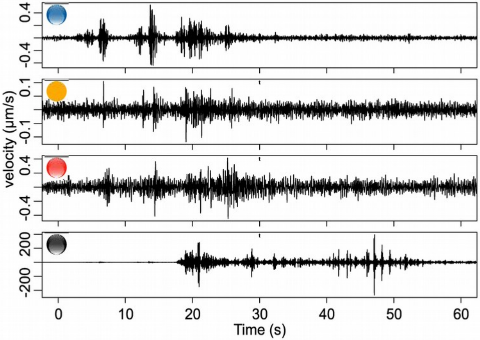
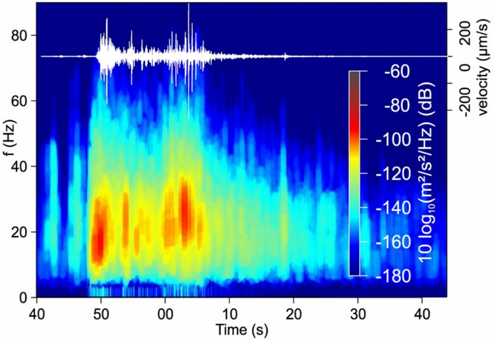
eseis

STA/LTA picking | Location | **Description** | Linking to drivers







Environmental seismology

A typical Workflow

Why R?

Example I

Example II

Towards where?

Why another seismic software and why in R?

There is a rich body of software to handle seismic data, in Python, Matlab or compiled code and devoted to seismics – and seismics, only.

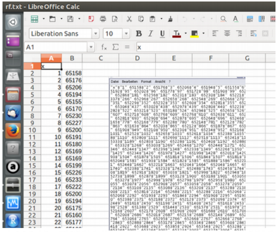
Have you ever tried….

… to work with 10^7 samples in spreadsheet software?

… to understand and modify third party software, not intended to be modified in its code?

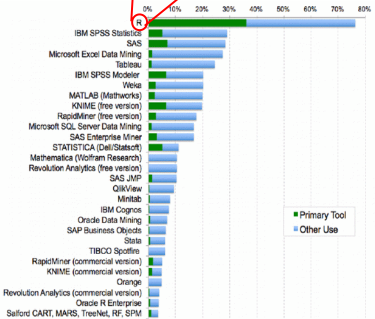
… to expand your analysis beyond just one type of data?

… to work with proprietary software without feeling guilty?



GPL V3 Free Software

GPL V3 Free Software Free as in Freedom



The building blocks and items of ‘eseis‘

The package contains all the usual function to import/export data, manipulate it and plot it but also a set of auxiliary functions for efficiency.

Import/export

read_sac
read_mseed
write_sac

Signal process.

signal_aggregate
signal_clip
signal_deconvolve
signal_demean
signal_detrend
signal_envelope
signal_filter
signal_hilbert
signal_hvratio
signal_integrate
signal_motion
signal_padd
signal_rotate

Signal process.

signal_snr
signal_spectro-gram
signal_spectrum
signal_stalta
signal_sum
signal_taper

Time process.

time_aggregate
time_clip
time_convert

Spatial process.

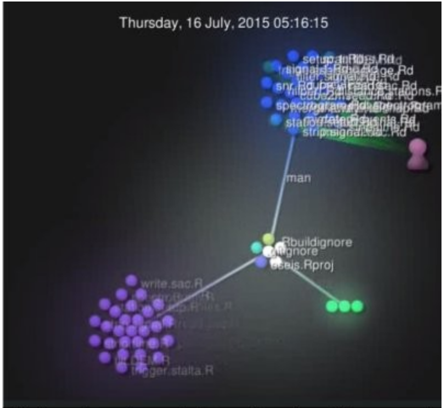
spatial_clip.R
spatial_convert.R
spatial_distance.R
spatial_migrate.R

Plot functions

plot_components
plot_signal
plot_spectrogram

Plot functions

aux_fixmseed
aux_getevent
aux_getirisdata
aux_getirisstations
aux_gettempe-rature
aux_hvanalysis
aux_organisecen-taurfiles
aux_organise-cubefiles
aux_stationinfo-file



Video of package history (made with gource)

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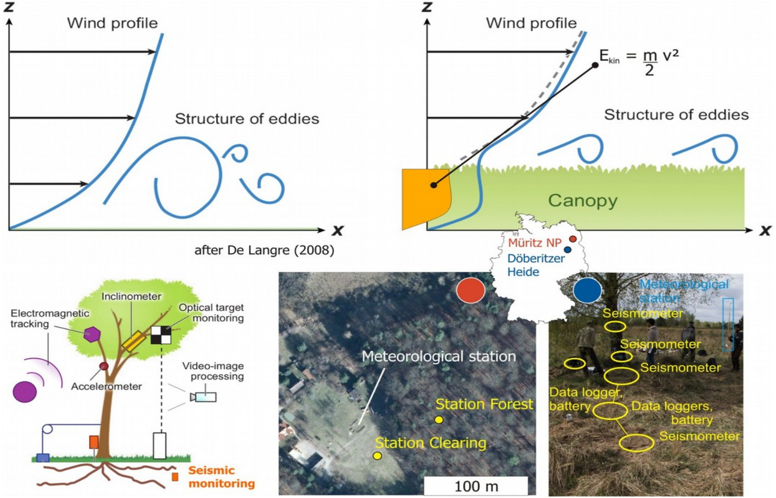
A TOOLBOX TO WELD GEOMORPHIC, SEISMOLOGIC, SPATIAL, AND TIME SERIES ANALYSIS

How do atmosphere and the Earth interact?

Seismic methods allow resolving the time-dependent energetic coupling between wind fields and the biomass-covered Earth surface.



Interaction of wind and vegetation is a thoroughly investigated field, but only above the Earth surface.

Seismic sensors allow quantifying the energy that is emitted into the ground by wind, with and without canopy.

Two test sites were instrumented to evaluate the fraction of energy that is diverted into the ground and how vegetation modulates the frequency content of this energy.

Turowski et al. 2016. System Earth

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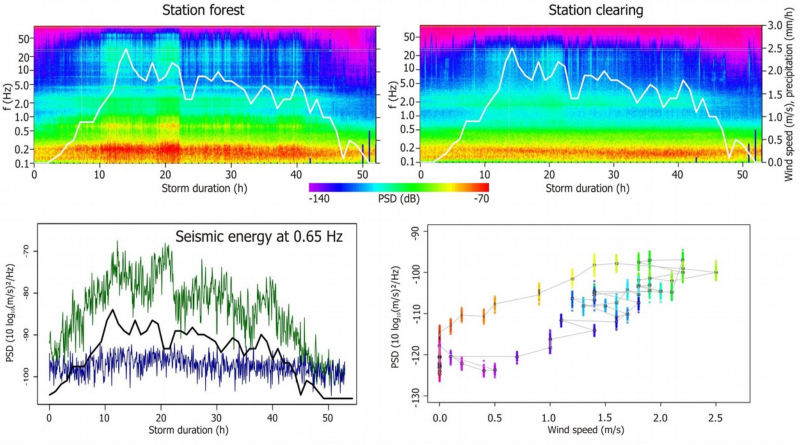

Trees emit energy to the ground mainly below 1 Hz, the eigen frequency of their trunks.

The wind-tree signal attenuates drastically at short distances (less than 100 m).

The trees generate a hysteresis effect in the wind-energy relationship.

Environmental seismology

A typical Workflow

Why R?

Example I

Example II

Towards where?

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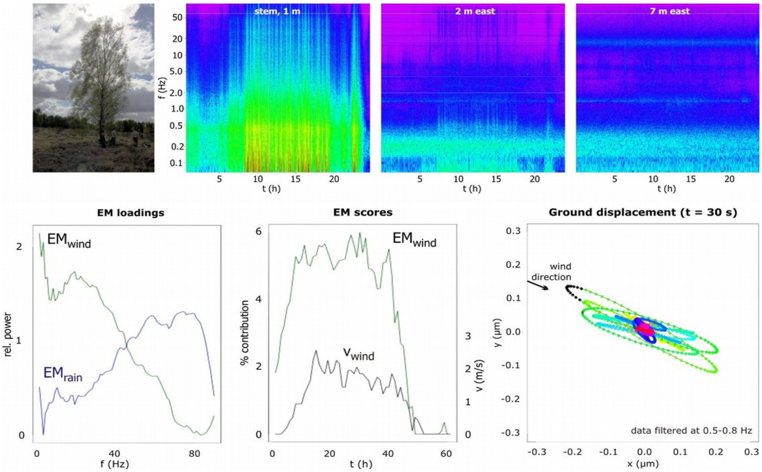

Even a single tree can emit significant energy into the ground, ovewhelming the oceanic signal by far.

Seismic instruments can also be used to record the wind speed and motion of the tree, which is closely related to wind direction.

End-member modelling allows unmixing the contribution of different sources to the compound seismic signal.

Dietze et al. 2016. Quaternary Research

Environmental seismology

A typical Workflow

Why R?

Example I

Example II

Towards where?

Validating and precision of small rockfall detection and location in alpine landscapes

Alpine rockfalls are an essential process but also a hazard. Their detection, location and characterisation is important for many disciplines.

The Lauterbrunnen Valley, Switzerland is a rockfall prone deglaciated limestone valley with 800 m high cliffs.

It has been instrumented with six stations for several months and surveyed by laser scanning (TLS).

The goal is to match TLS with seismic results for events below 1 m³.

Dietze et al. 2017a, Esurf Discussions

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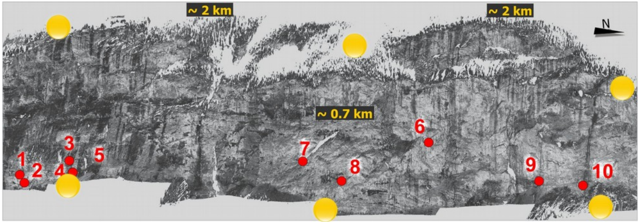
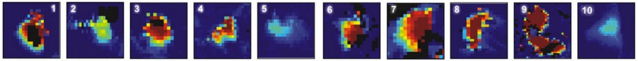
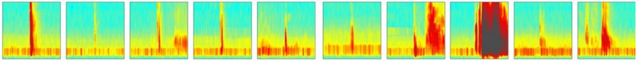


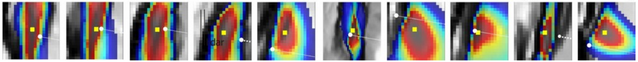


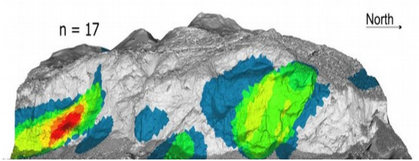
1	2	3	4	5	6	7	8	9	10
0.201	0.063	0.120	0.175	0.053	0.416	0.891	0.258	2.338	0.192
(0.005)	(0.001)	(0.009)	(0.011)	(0.004)	(0.021)	(0.038)	(0.014)	(0.085)	(0.010)

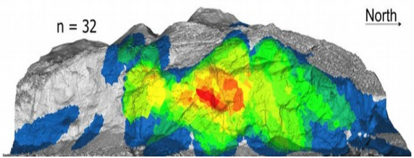
Seismic-detected rockfall events (60 sec spectrograms, centered at event, 0-90 Hz)



Seismic-based localisation estimate (Polygons: >97 % location likelihood, pixel size 10 m)







Seismic and lidar allow detection of rock falls as small as 0.05 m³ with average precisions of 81 m.

Longer seismic surveys provide spatio-temporal activity maps.

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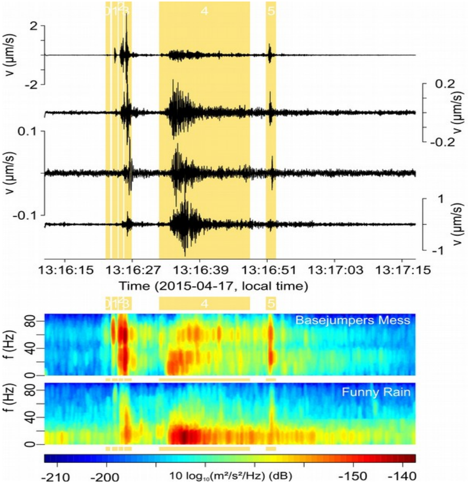
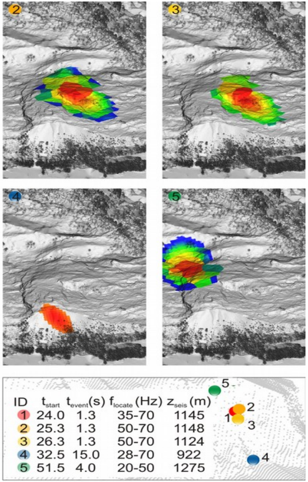
Validating and precision of small rockfall detection and location in alpine landscapes

Alpine rockfalls are an essential process but also a hazard. Their detection, location and characterisation is important for many disciplines.





We see a complex rock fall as measured by four seismic stations. Multiple short impacts (0-3) occur at elevations above 1100 m, before the rain of particles (4) sprays onto the talus slope for more than 20 s, destabilises the cliff and triggers another rock fall (5) higher up on the cliff.

Such detail would hardly be possible with any other monitoring technique.

Any other posteriour mapping approach would have missed the linked processes.

Validating and precision of small rockfall detection and location in alpine landscapes

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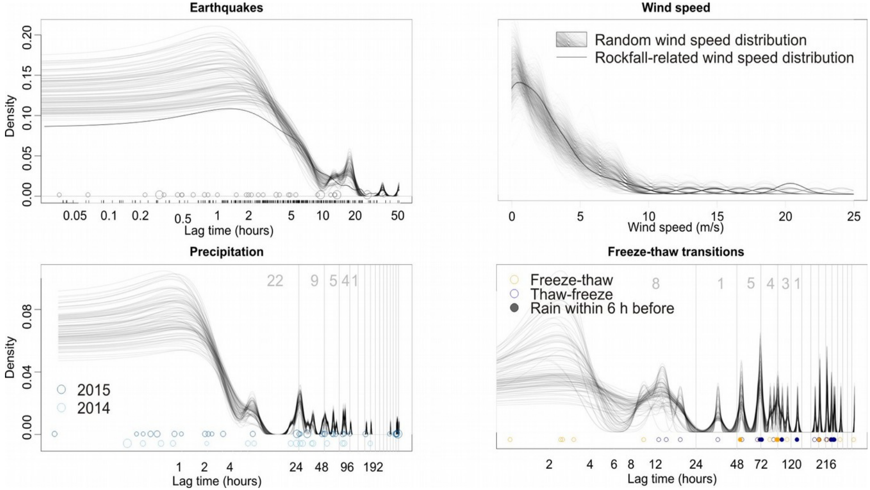


Lag times of rock falls to potential triggers:

Earthquakes did not cause a single rock fall.

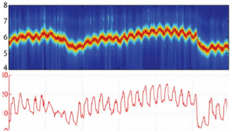
Wind speed during events is not distinct from random speeds.

Precipitation and freeze-thaw transitions are the dominant triggers with peak lag times of 1 and 2-3 h.

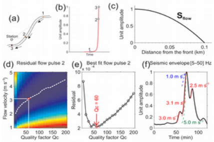
The construction patches of the package

I am kind of experienced in working with R, but there are a couple of questions I am not able to tackle without help from the community.

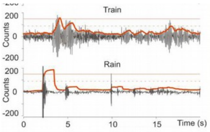
Benchmarking with other seismic software, concern. speed and similar results



Add **seismic noise cross correlation** approaches to the package functionality



Implement **further location approaches**, also in 3D media



Include **further picking approaches**, including full waveform properties

(Maybe) switch to **S4 objects** to i) expand functionality and ii) object coherence

Implement signal processing **history propagation** as pilar for reproducible analysis.

Speeding up computation

For some functions, transfering code snippets to C++ would add significant improvement in speed.

Integrating Python packages

Many other performant seismic data processing tools are written in Python. Integrating such functio-nality to 'eseis' would be a great benefit. What are proper ways to integrate entire Python packages to R packages?

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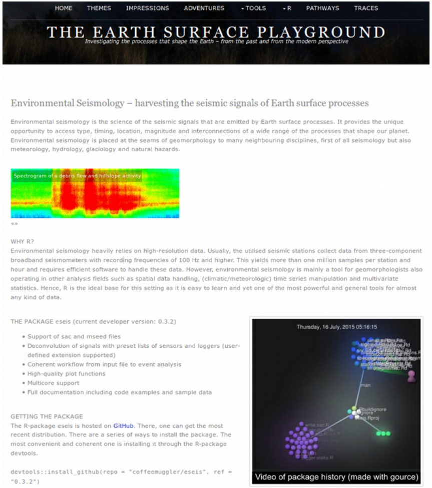
Getting the R package ‘eseis‘ – www.micha-dietze.de

The package is hosted and updated on Github, and accompanied by a website that provides further information as well as compiled code.



HOME THEMES IMPRESSIONS ADVENTURES TOOLS R PATHWAYS TRACES

THE EARTH SURFACE PLAYGROUND

Investigating the processes that shape the Earth – from the past and from the modern perspective

Environmental Seismology – harvesting the seismic signals of Earth surface processes

Environmental seismology is the science of the seismic signals that are emitted by Earth surface processes. It provides the unique opportunity to access type, timing, location, magnitude and interconnections of a wide range of the processes that shape our planet. Environmental seismology is placed at the seams of geomorphology to many neighbouring disciplines, first of all seismology but also meteorology, hydrology, glaciology and natural hazards.

Spectrogram of a debris flow and hillslope activity

WHY R?
Environmental seismology heavily relies on high-resolution data. Usually, the utilised seismic stations collect data from three-component broadband seismometers with recording frequencies of 100 Hz and higher. This yields more than one million samples per station and hour and requires efficient software to handle these data. However, environmental seismology is mainly a tool for geomorphologists also operating in other analysis fields such as spatial data handling, (climatic/meteorologic) time series manipulation and multivariate statistics. Hence, R is the ideal base for this setting as it is easy to learn and yet one of the most powerful and general tools for almost any kind of data.

THE PACKAGE eseis (current developer version: 0.3.2)

- Support of sac and mseed files
- Deconvolution of signals with preset lists of sensors and loggers (user-defined extension supported)
- Coherent workflow from input file to event analysis
- High-quality plot functions
- Multicore support
- Full documentation including code examples and sample data

GETTING THE PACKAGE
The R-package eseis is hosted on GitHub. There, one can get the most recent distribution. There are a series of ways to install the package. The most convenient and coherent one is installing it through the R-package devtools.

```
devtools::install_github(repo = "coffeemuggler/eseis", ref =
"0.3.2")
```

Thursday, 16 July, 2015 05:16:15

Video of package history (made with gource)