Long-period disturbances in records of Swiss seismic network: “Swiss mice”

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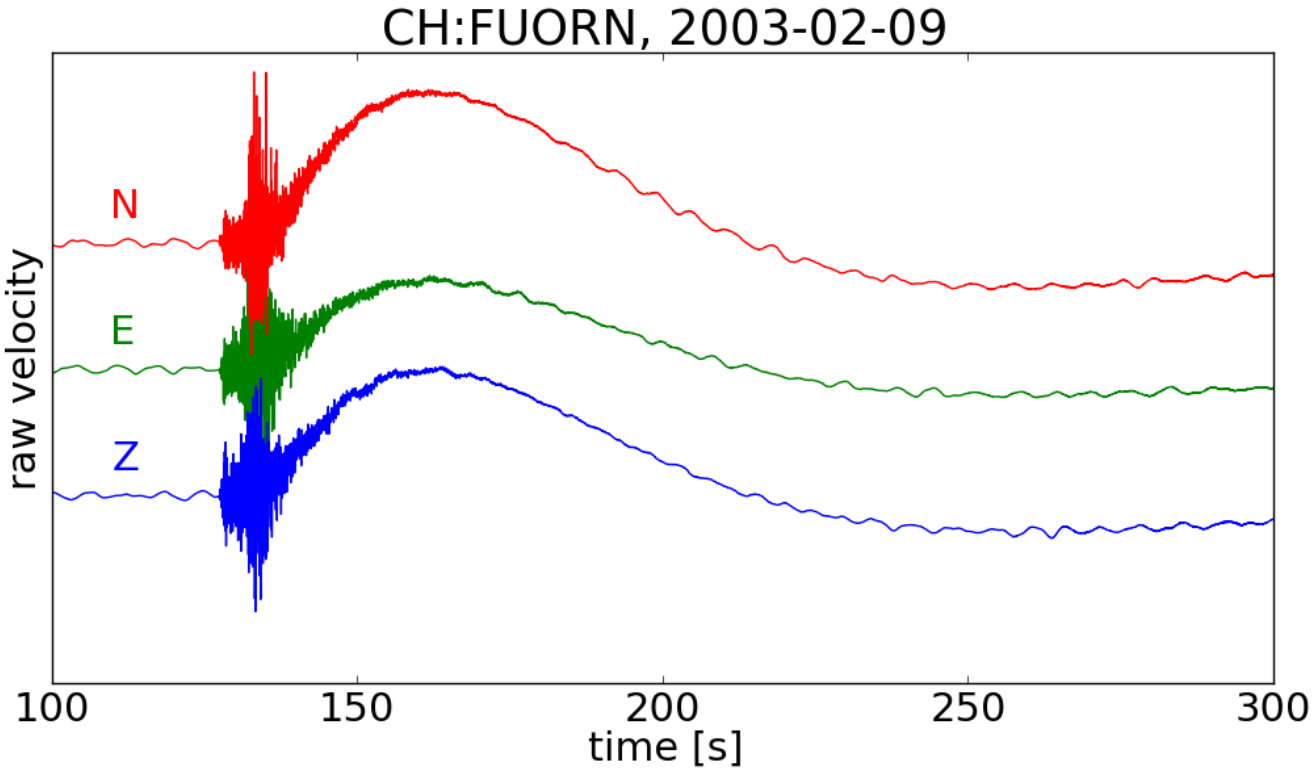
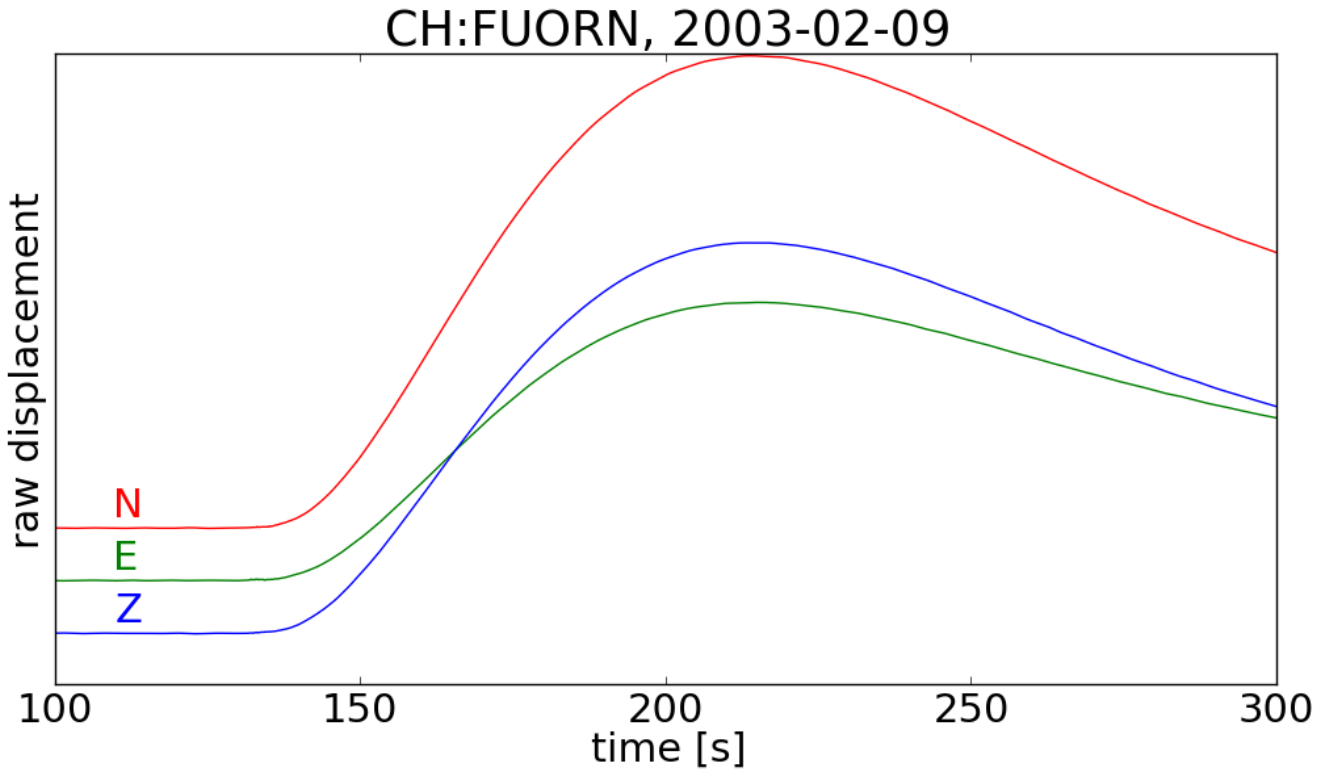
Observation: long-period pulse (mouse)

Long, one-sided pulses observed in some records.
We call it “mouse”.



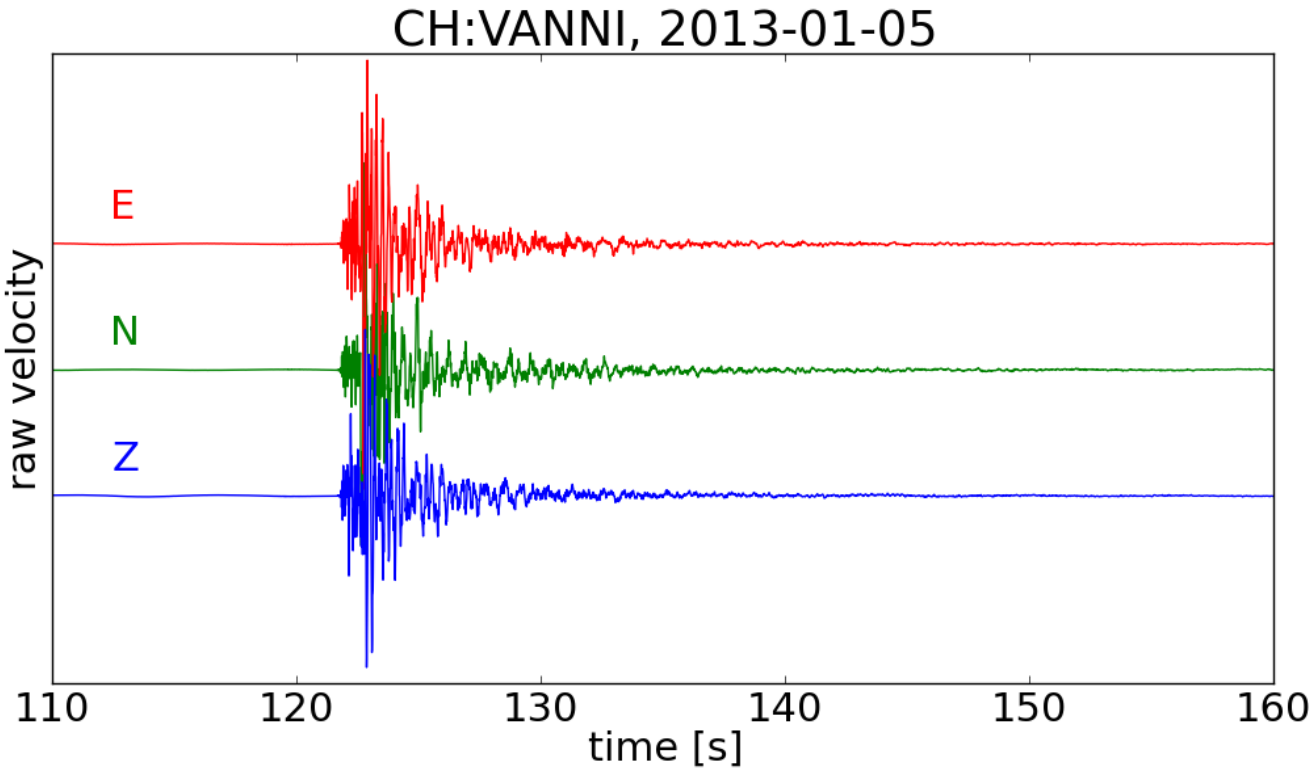
Observation: long-period pulse (mouse)

Long, one-sided pulses observed in some records.
After integration, the mouse is stronger than the signal.



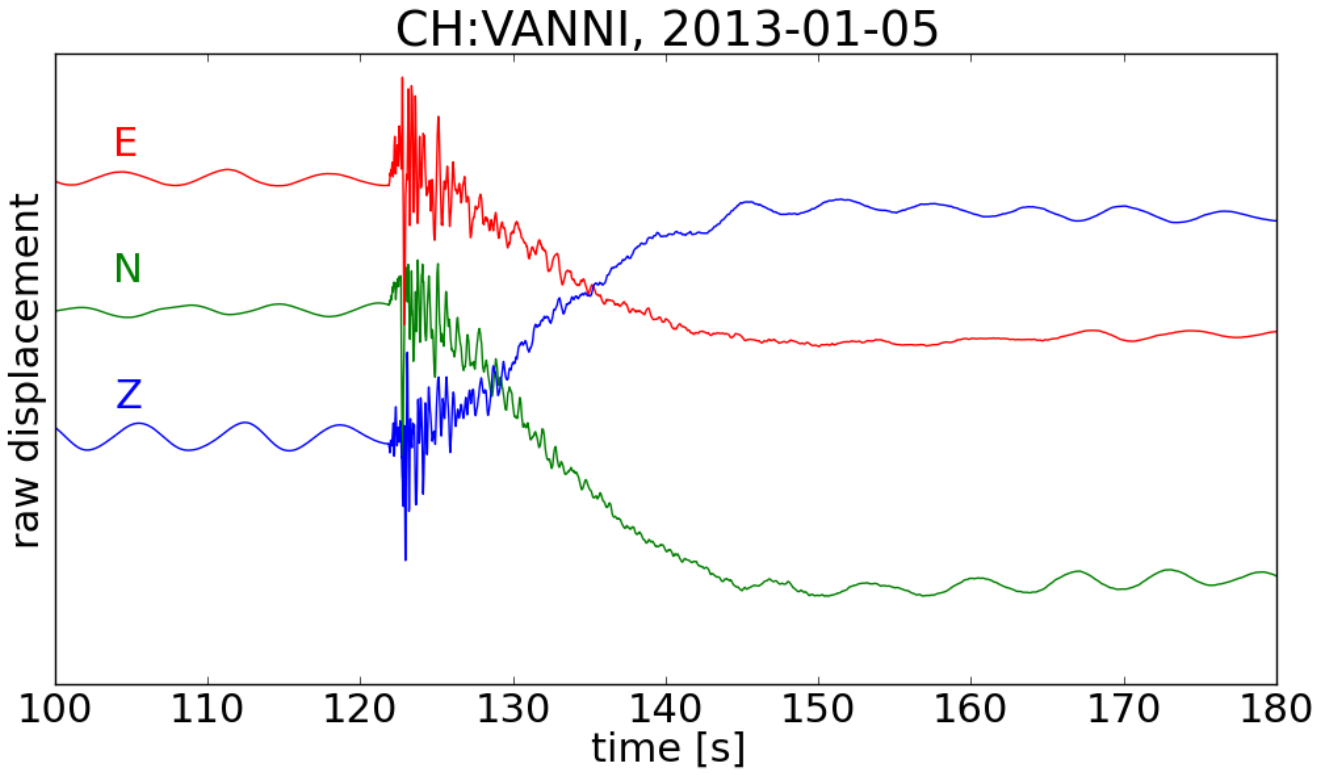
Observation: clearly visible after integration

Another example: no disturbance visible in velocity trace.



Observation: clearly visible after integration

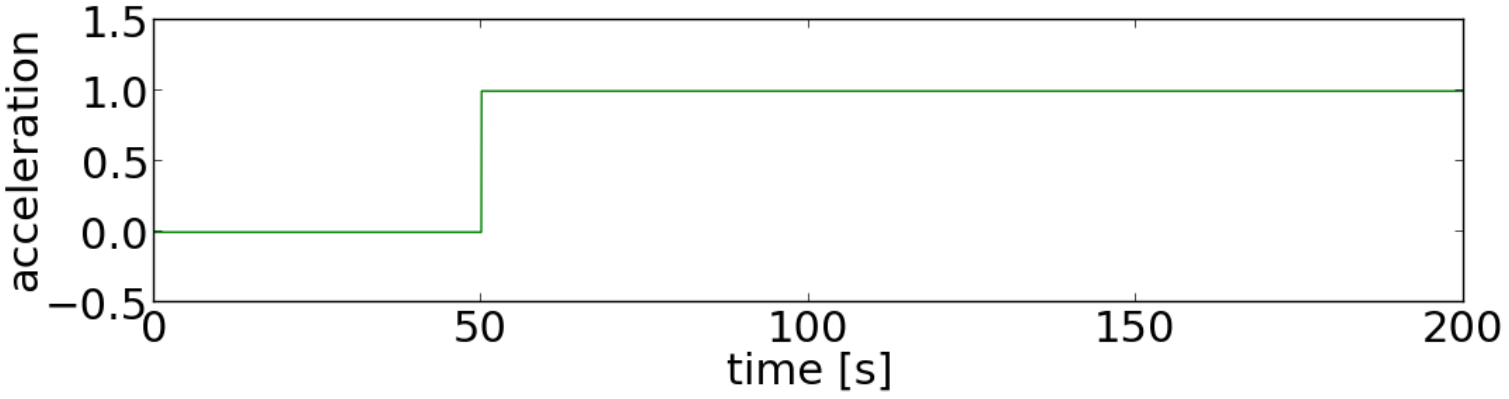
After integration, the disturbance is clearly visible.



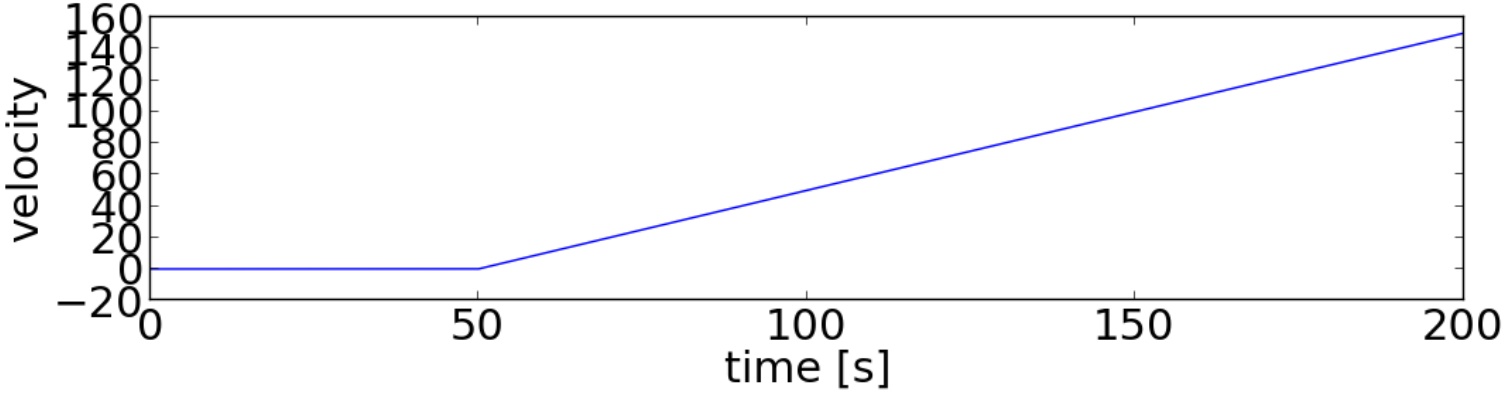
Instrument response to acceleration step on input

Let us have a step in the ground motion acceleration

Input acceleration



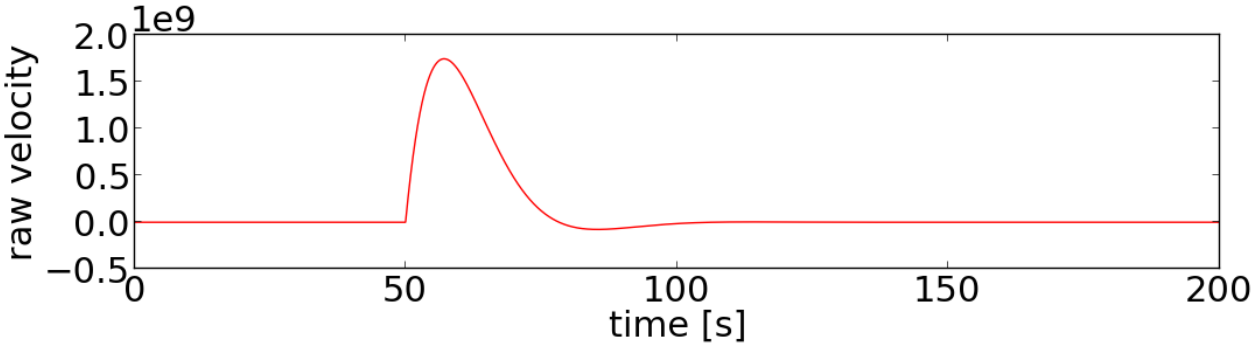
Input velocity



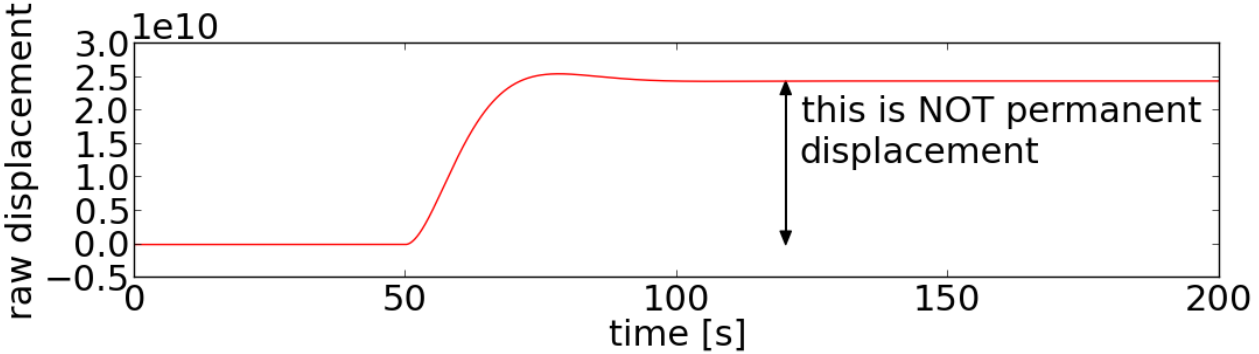
Instrument response to acceleration step on input

Apply instrumental response

Raw velocity record (we changed y-scale)



Raw displacement record

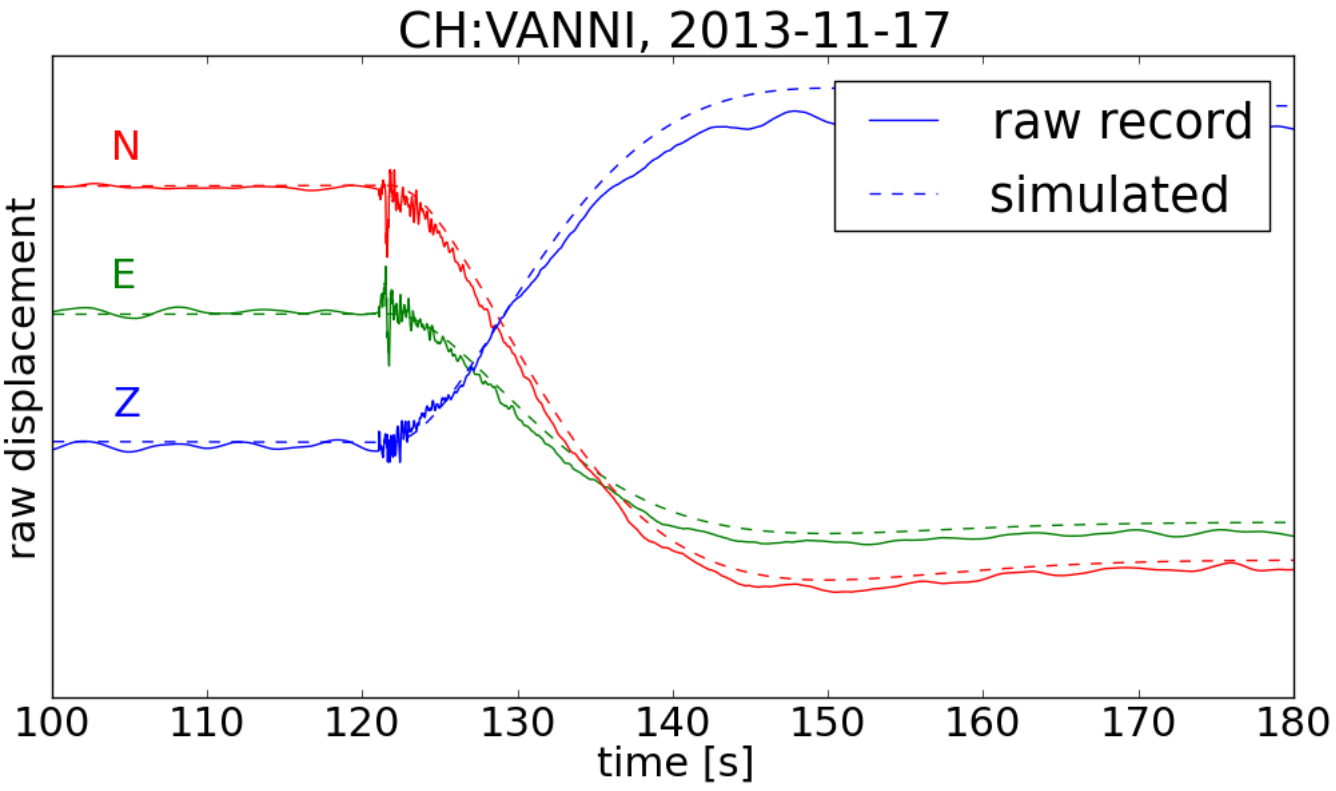


The integrated output is proportional to:

- displacement at frequencies above f_c and
- acceleration at low-frequency limit.

The mouse can be explained by acceleration step

The observation is perfectly explained by an acceleration step on input of the instrument.



3 components are jointly inverted for 3-D mouse (time, amplitude, and 2 space angles)

Possible cause

The acceleration step may be caused by

- tilt of the device [Wielandt and Forbriger, 1999; Kalkan and Graizer, 2007; Zahradník and Plešinger, 2005; Javelaud et al., 2011; Pillet and Virieux, 2007]
  - near field effect
  - local tilt of rock block
  - very local tilt (seismometer installation)
- any other instrumental effect
- similar problem of the baseline instability in strong motion records is not discussed here [Boore, 2001, and others]

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Problems caused by mice

- Mice are often overlooked in band-passed records
- Signal-to-noise ratio is apparently very high (mouse is a kind of signal-generated noise)
- Moment tensor inversion of contaminated record may results in wrong MT
- Determination of source scalar moment and radius may be biased

Possible goals

- Automated detection of mouse in order to remove record from processing
- Decontamination of records: mouse effect removal
- Understanding of physical nature of mice

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Program scheme

- look for $M > 1$ events and nearby stations
  (SED SQL database)
  max. distance chosen according to magnitude and GMPE's
- download waveform data and poles-and-zeros
- test signal-to-noise ratio, skip noisy records
- calculate record properties, which might influence mouse existence
- fit the mouse
- save results to database, plot the fit

Program scheme

- look for $M > 1$ events and nearby stations
- download waveform data and poles-and-zeros (from ArcLink server)
- test signal-to-noise ratio, skip noisy records
- calculate record properties, which might influence mouse existence
- fit the mouse
- save results to database, plot the fit

Program scheme

- look for $M > 1$ events and nearby stations
- download waveform data and poles-and-zeros
- test signal-to-noise ratio, skip noisy records (ObsPy)
- calculate record properties, which might influence mouse existence
- fit the mouse
- save results to database, plot the fit

Program scheme

- look for $M > 1$ events and nearby stations
- download waveform data and poles-and-zeros
- test signal-to-noise ratio, skip noisy records
- calculate record properties, which might influence mouse existence
  (ObsPy)
  PGA/PGV/PGD in different frequency bands
  epicentral distance, azimuth
- fit the mouse
- save results to database, plot the fit

Program scheme

- look for $M > 1$ events and nearby stations
- download waveform data and poles-and-zeros
- test signal-to-noise ratio, skip noisy records
- calculate record properties, which might influence mouse existence
- fit the mouse
  (Fortran)
  by input acceleration step with instrumental effect applied
- save results to database, plot the fit

Program scheme

- look for $M > 1$ events and nearby stations
- download waveform data and poles-and-zeros
- test signal-to-noise ratio, skip noisy records
- calculate record properties, which might influence mouse existence
- fit the mouse
- save results to database, plot the fit

Saving the results

We use SQL database in order to easily manipulate, select, and filter large amount of data

Browse

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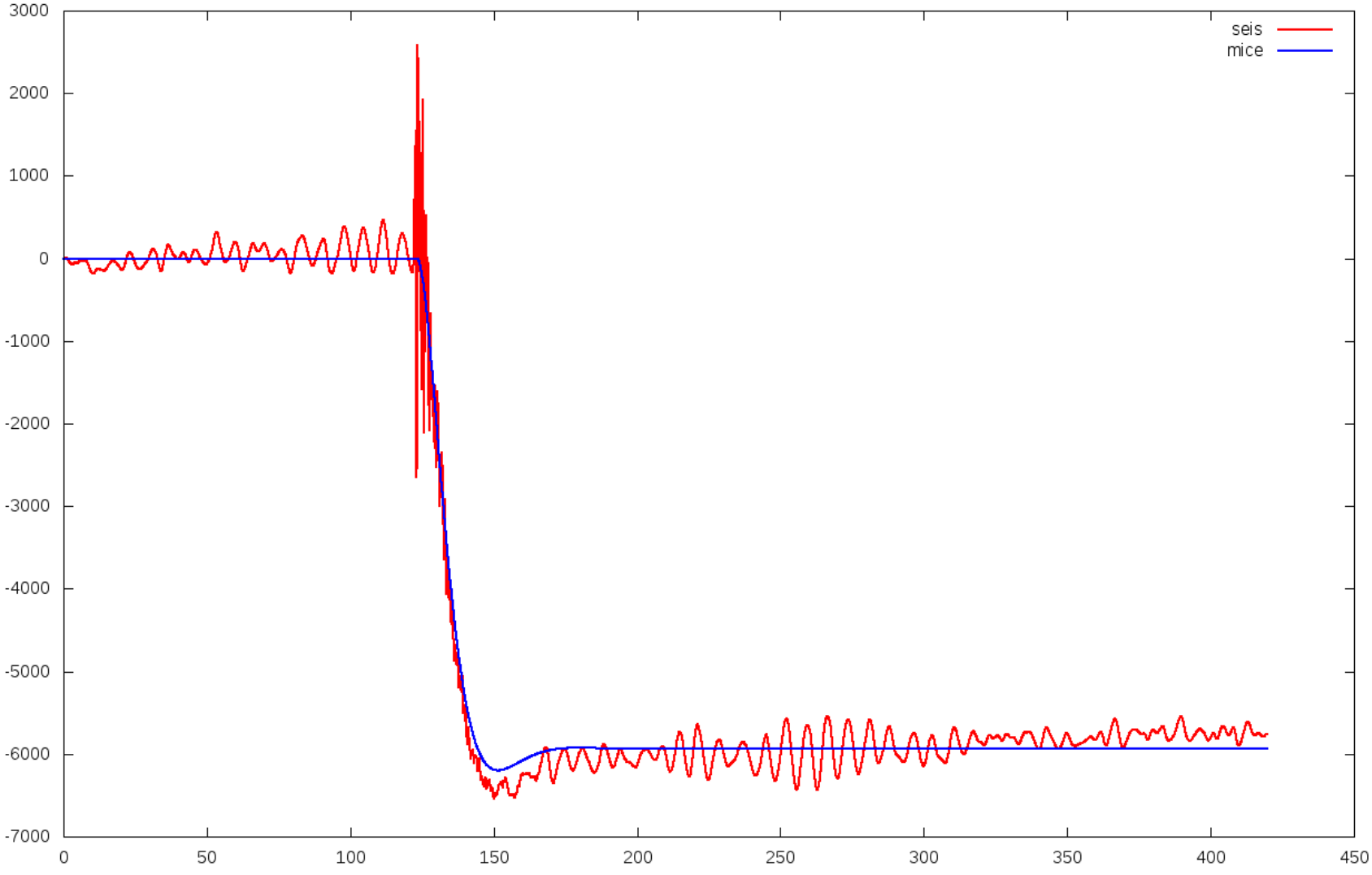
time	magtype	mag	distance_km	sta	sensor	mouse	mouse_direction	mouse_inclination	warning
2012-06-28 09:10:13	MLh	2	11	CH:SGT02	Compact	possible	60	1	Different poles and zeros from SAC RESP file and via ArcLink.
2012-10-05 19:10:41	ML	3	63	MN:BNI	Streckeisen STS-2	possible	81	176	Different poles and zeros from SAC RESP file and via ArcLink.
2012-10-11 14:18:41	MLh	2.6	6	MN:BNI	Streckeisen STS-2	present	90	-0	Different poles and zeros from SAC RESP file and via ArcLink.
2012-10-25 01:10:57	MLh	3.6	34	CH:AIGLE	STS-2, 120	present	136	-4	*NULL*
2012-10-26 23:34:57	MLh	1.9	2	IV:MRGE	TRILLIUM-40S	present	29	13	*NULL*
2013-01-05 07:46:51	MLh	2.7	12	CH:EMBD	CH -	present	154	-35	*NULL*
2013-01-05 07:46:51	MLh	2.7	6	CH:VANNI	CH -	present	29	145	*NULL*
2013-01-16 00:14:35	MLh	1.9	6	CH:VANNI	CH -	present	29	146	*NULL*
2013-02-25 01:01:42	MLh	3.5	28	GU:TRAV	TRILLIUM-40S	possible	4	6	*NULL*

Waveform fit plotting

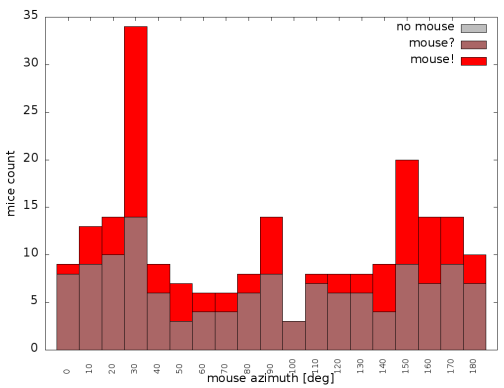
The fit is plotted automatically for easy future visual inspection

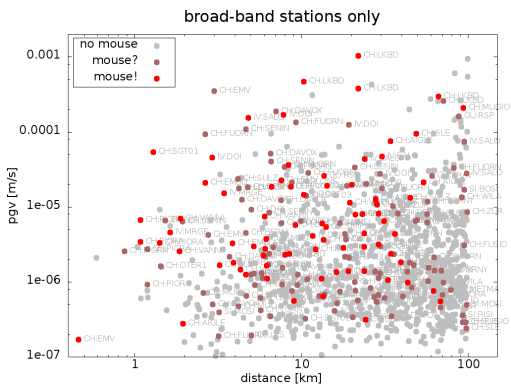


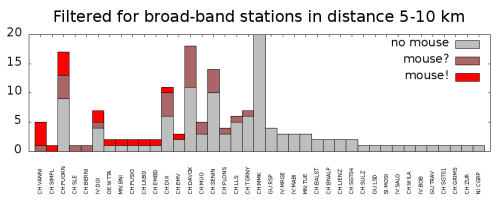
Plotting the results

Correlations and histograms can be automatically plotted using pre-defined SQL queries

```
stack = 10
histogram('histogram_azimuth.png', 'ROUND((mouse1fit.phi) / %s)' % stack,
column_func='pocty.col * %s' % stack, order by='pocty.col',
xlabel='mouse azimuth [deg]', ylabel='mice count')
```







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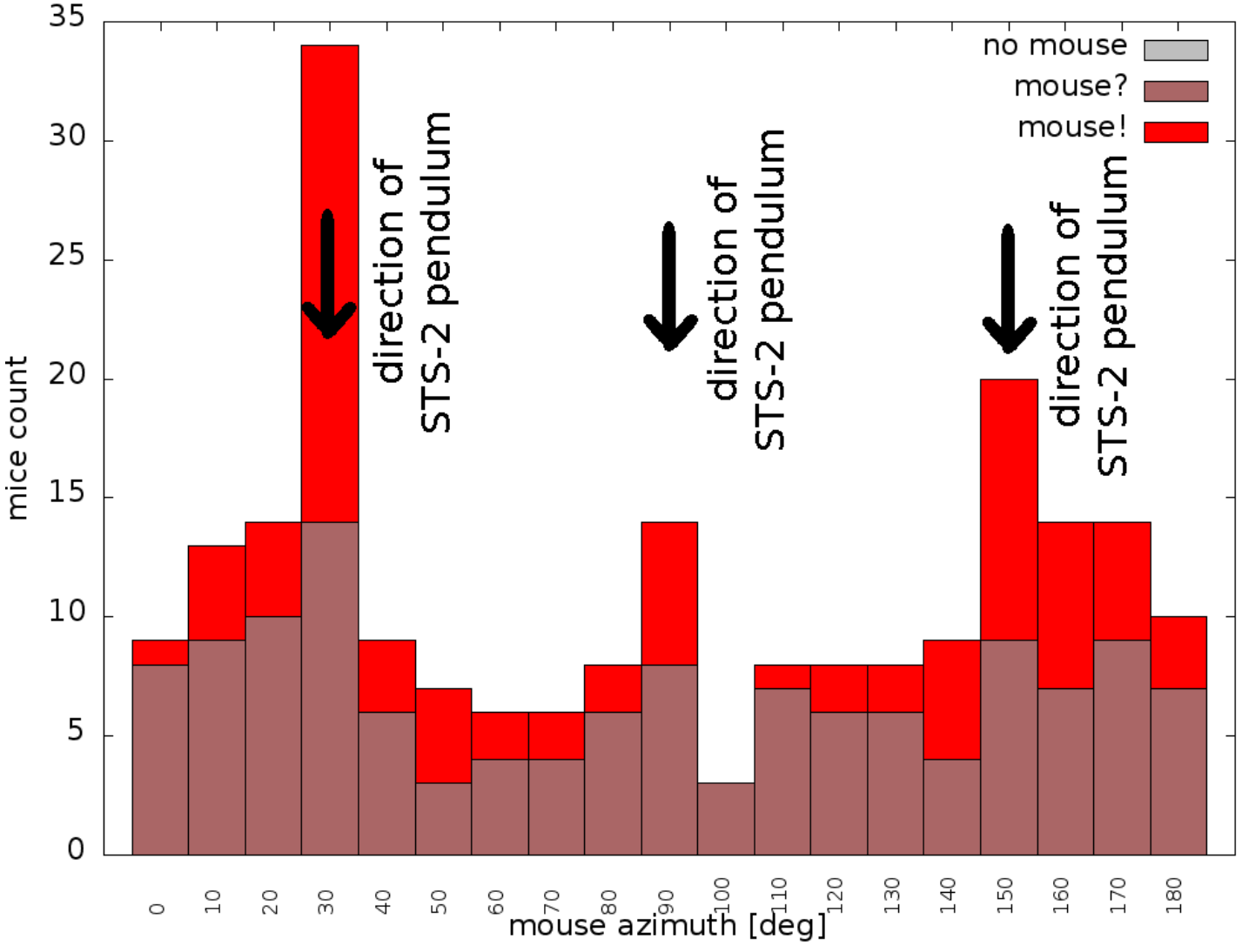
ETH Data used

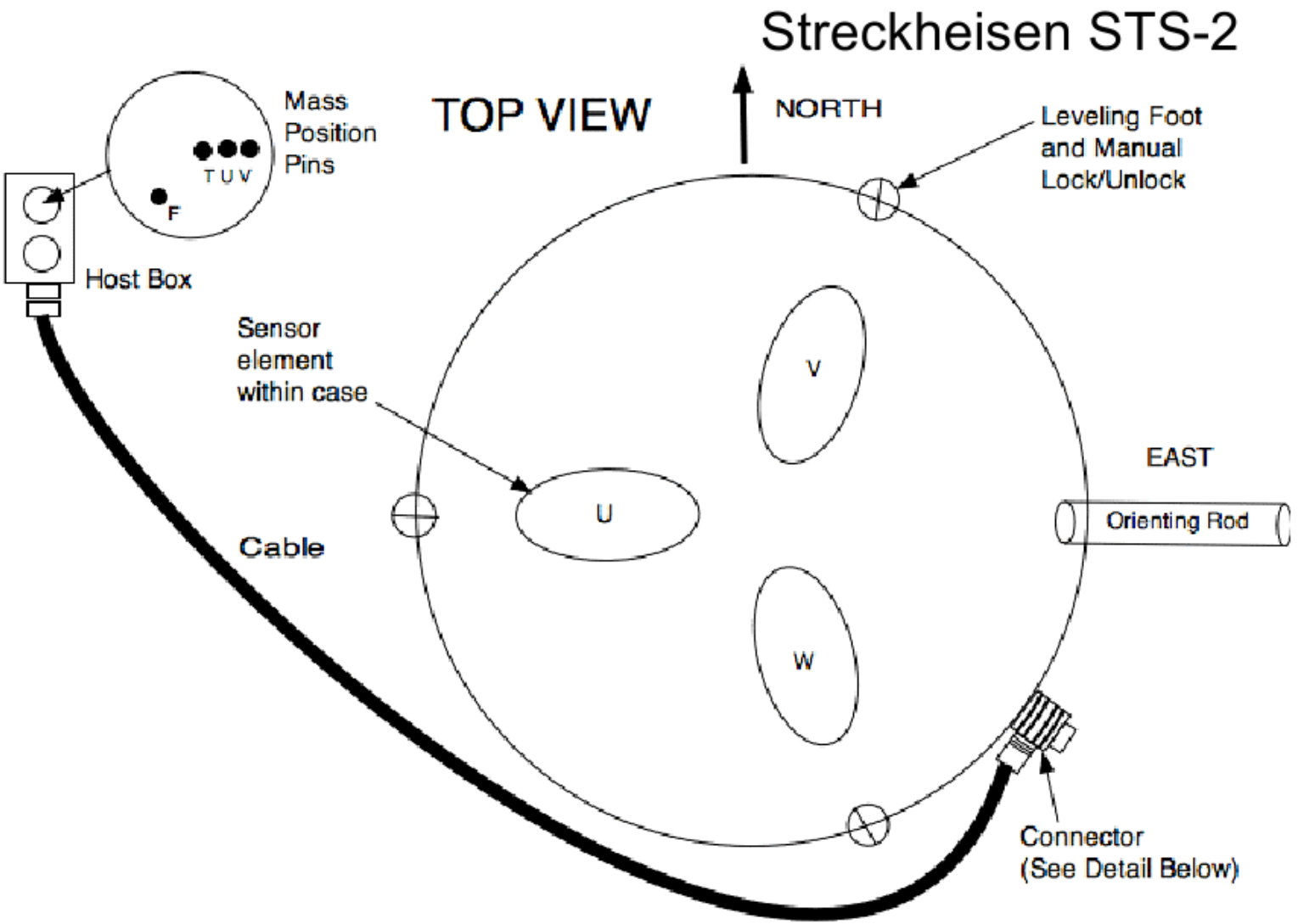
- Nearby records of $M > 1$ events of the last 18 years analyzed
- 8 328 records (broad-band + short period) fitting the magnitude-distance criterion (based on GMPE's)
- 1 654 records passed to further analysis

  [others unable to download (1 467) or skipped because of unfavorable signal-to-noise ratio (5 083), gap in data (59) and no PAZ file (65)]
- 1 440 records: no mouse detected
- 130 records: mouse occurrence possible (visual inspection necessary)
- 84 records: mouse detected with no doubt (broad-band records mostly)

More mice at directions 30, 90, and 150 deg

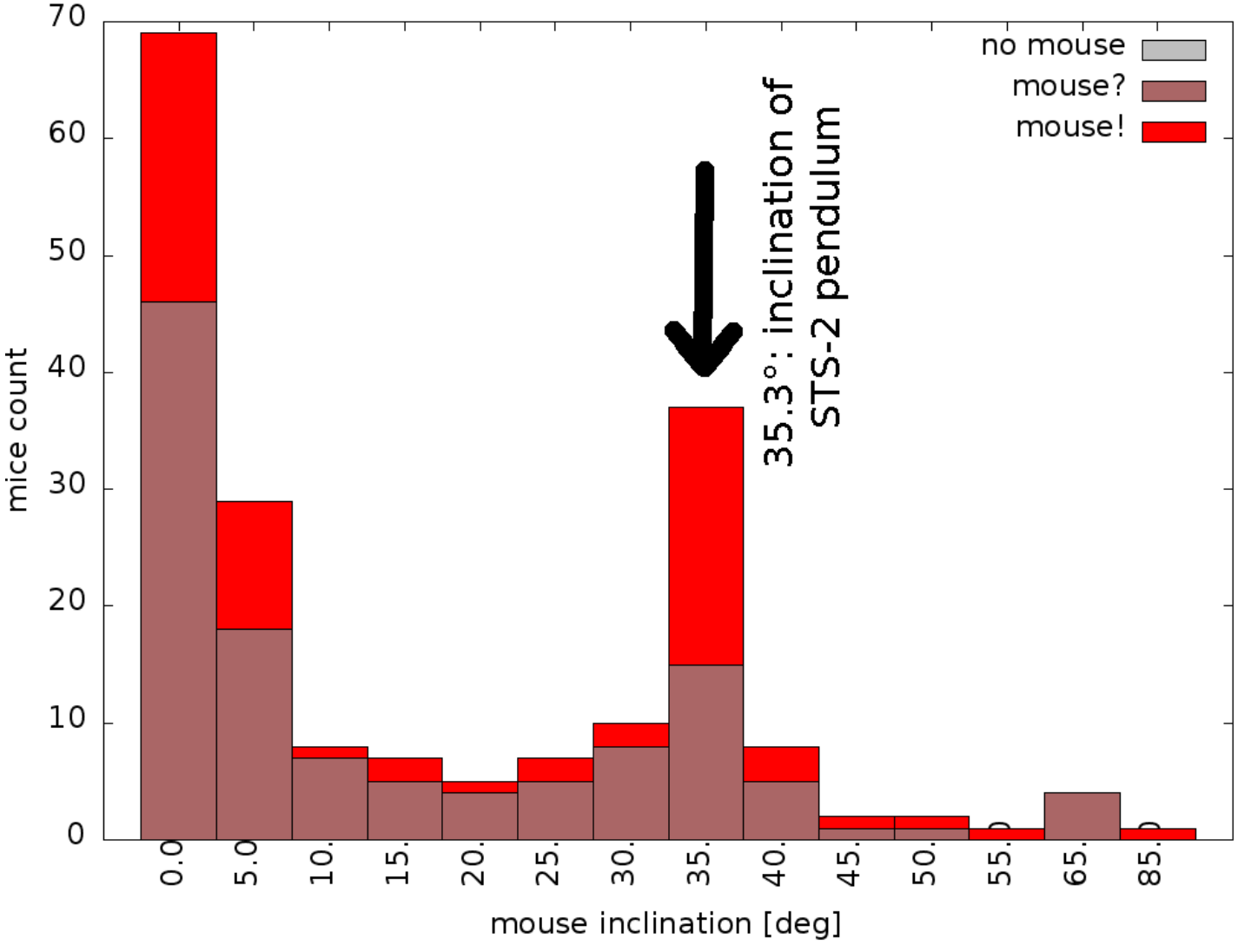


STS-2 sensor element orientation

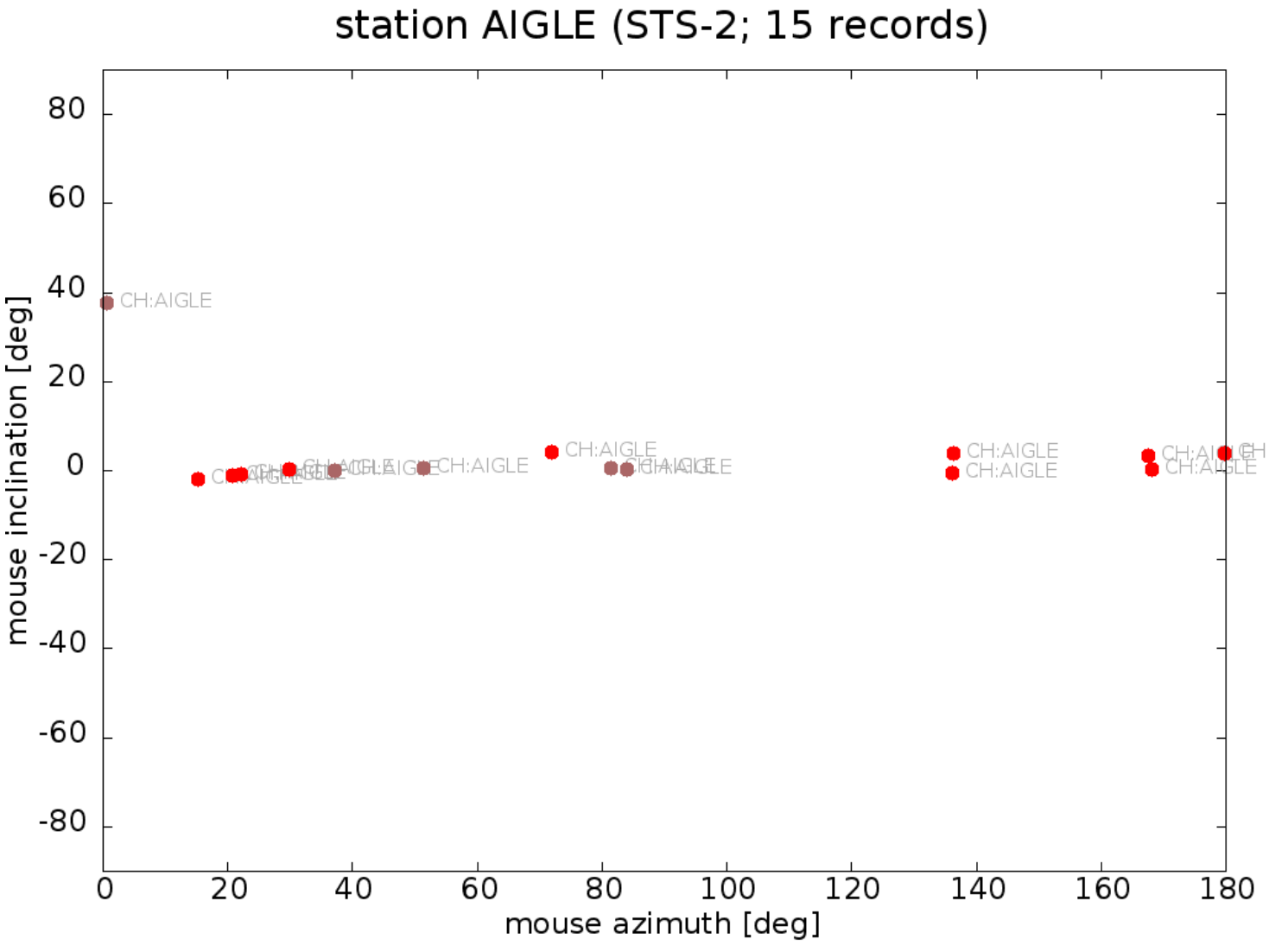


https://www.passcal.nmt.edu/content/instrumentation/sensors/broadband-sensors/

Most of the mice are horizontal



Mouse direction remain the same at some stations



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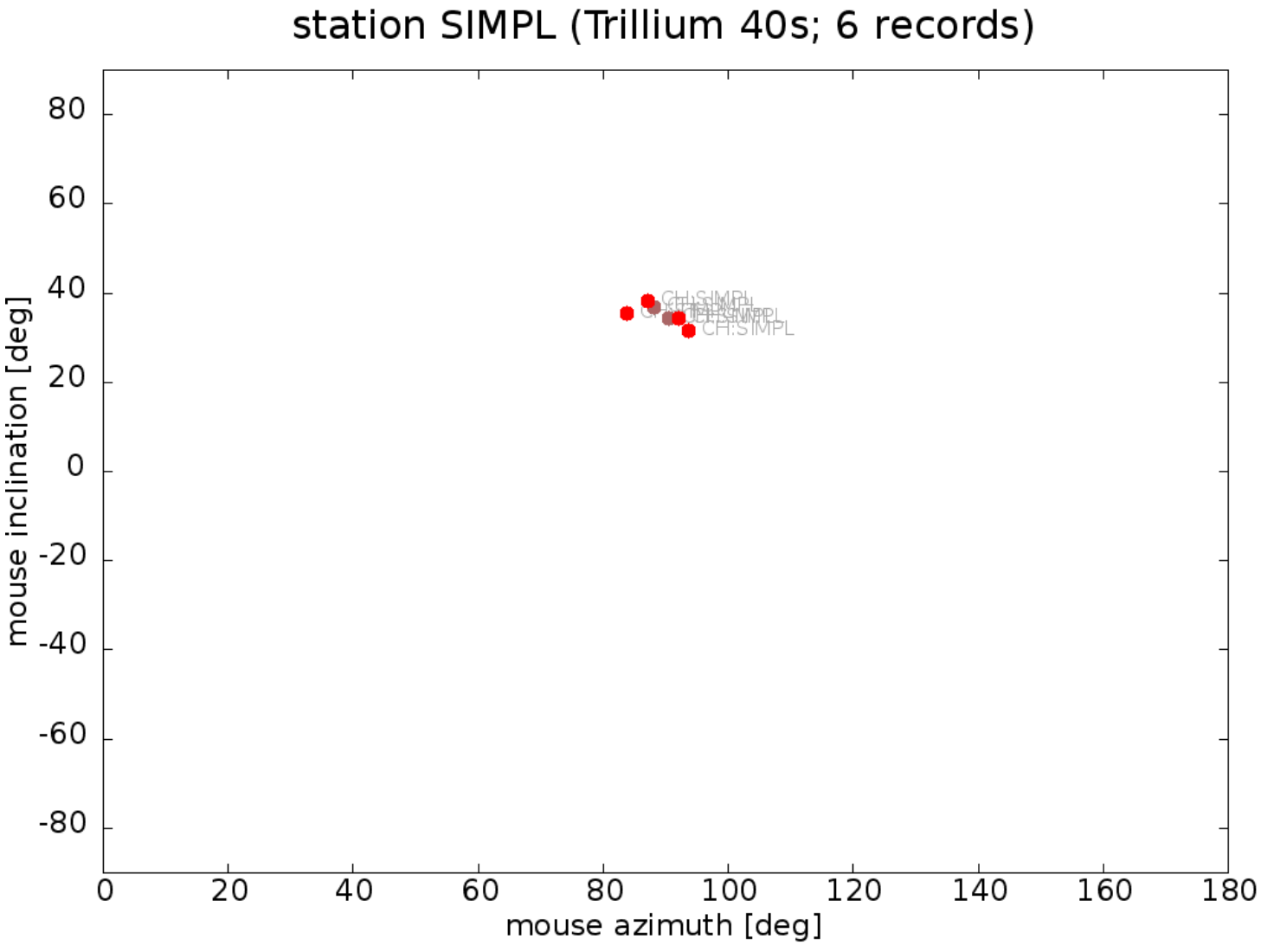
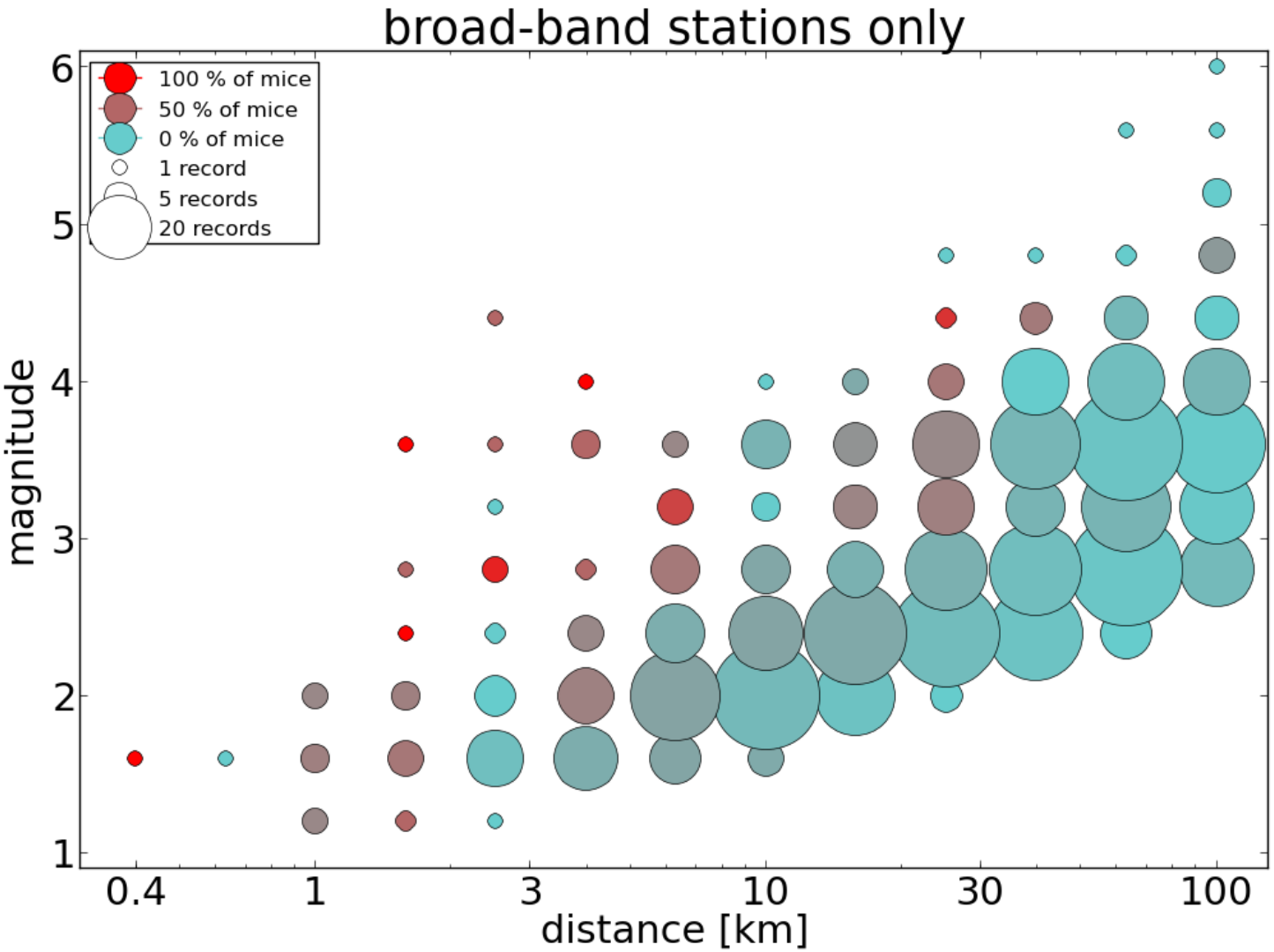
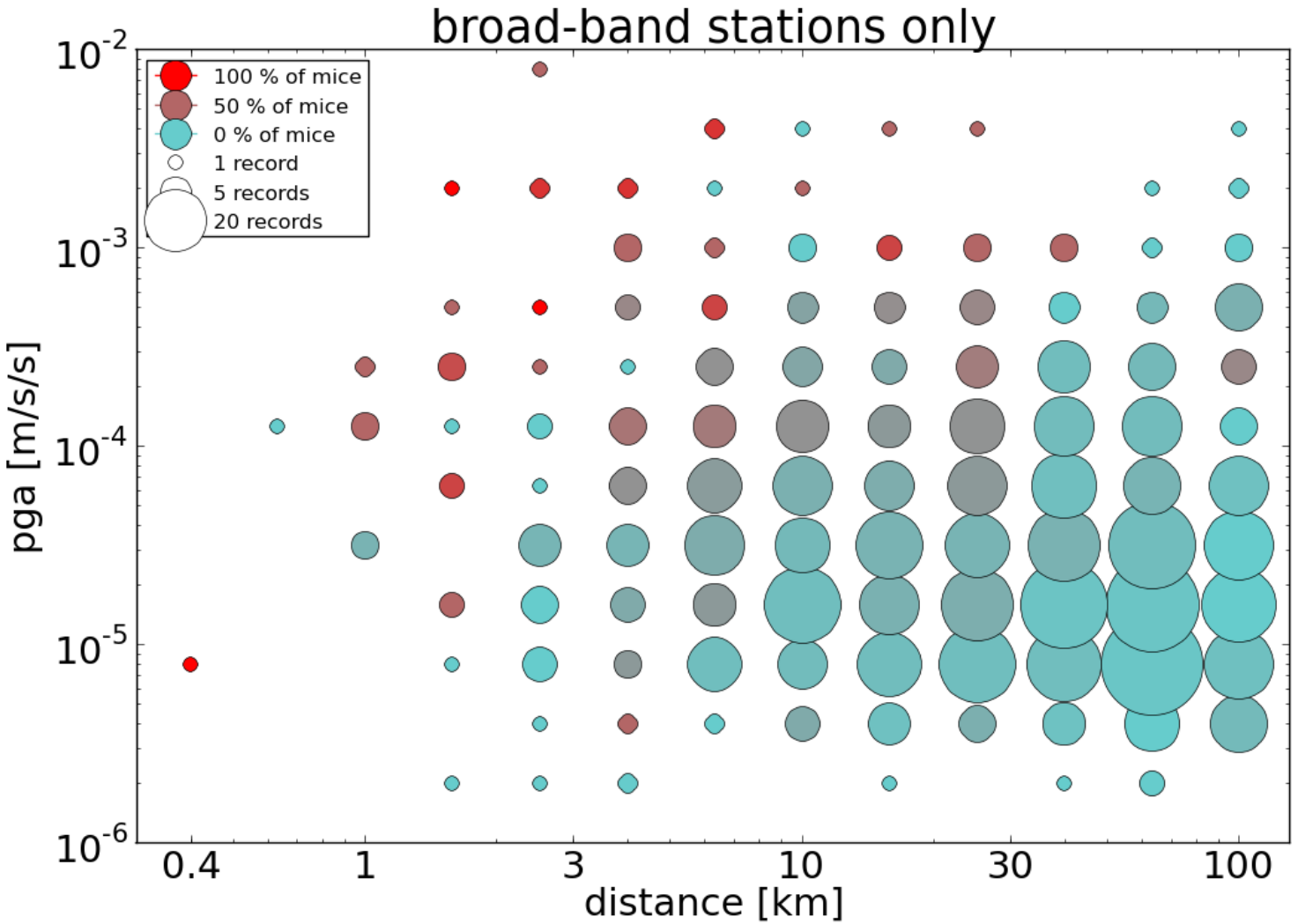


Mice are more common near the epicenter and at stronger events

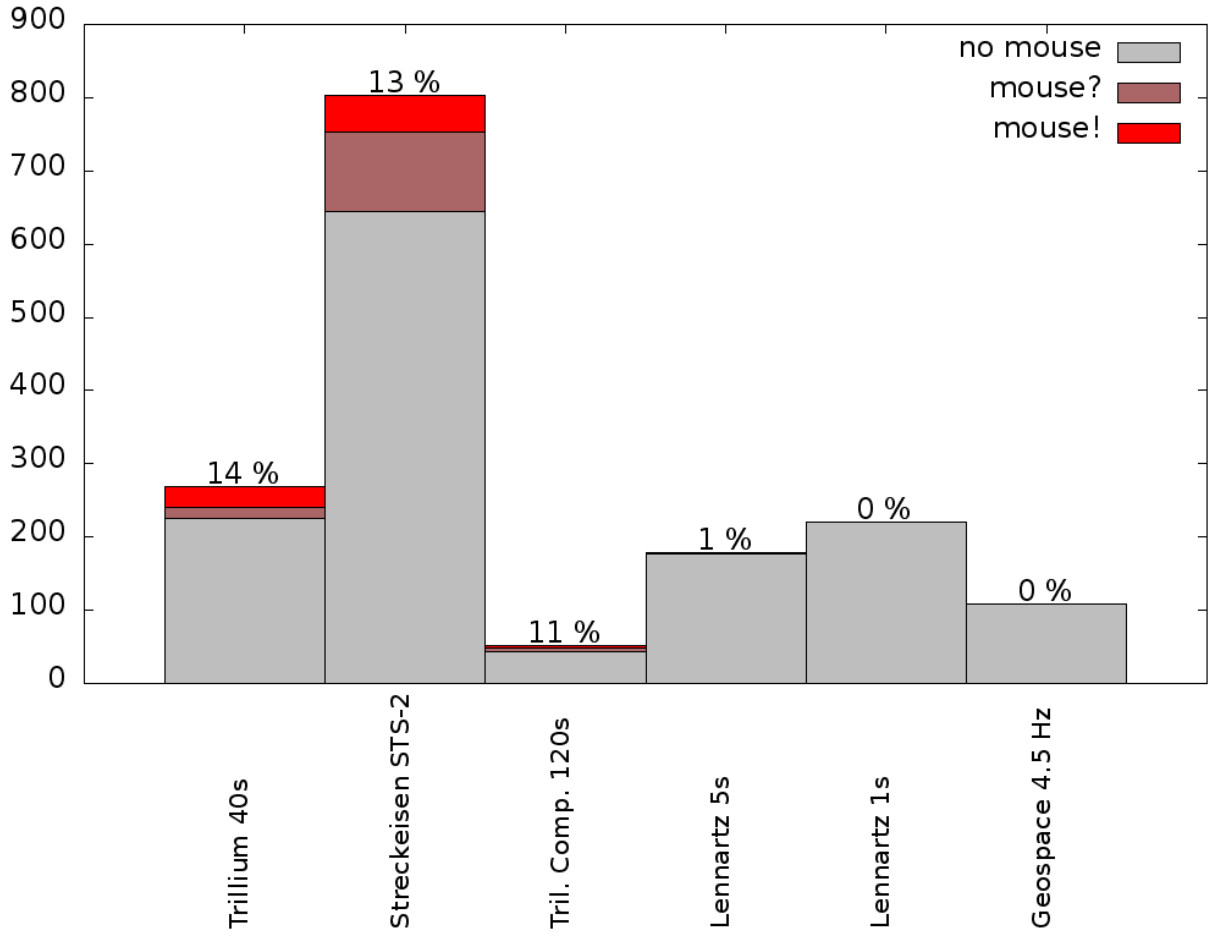


Mice are more common at higher PGA



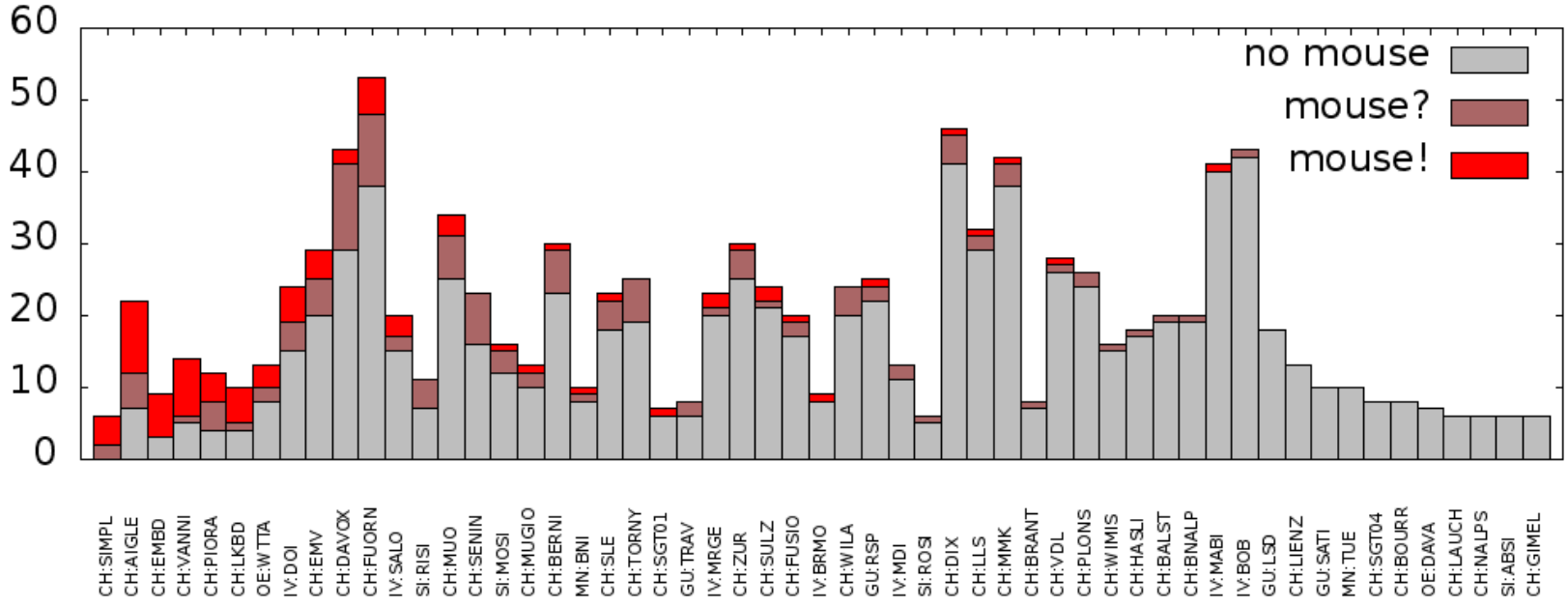
These cases are under the clipping level of the sensor.

Mice present at all broad-band sensors



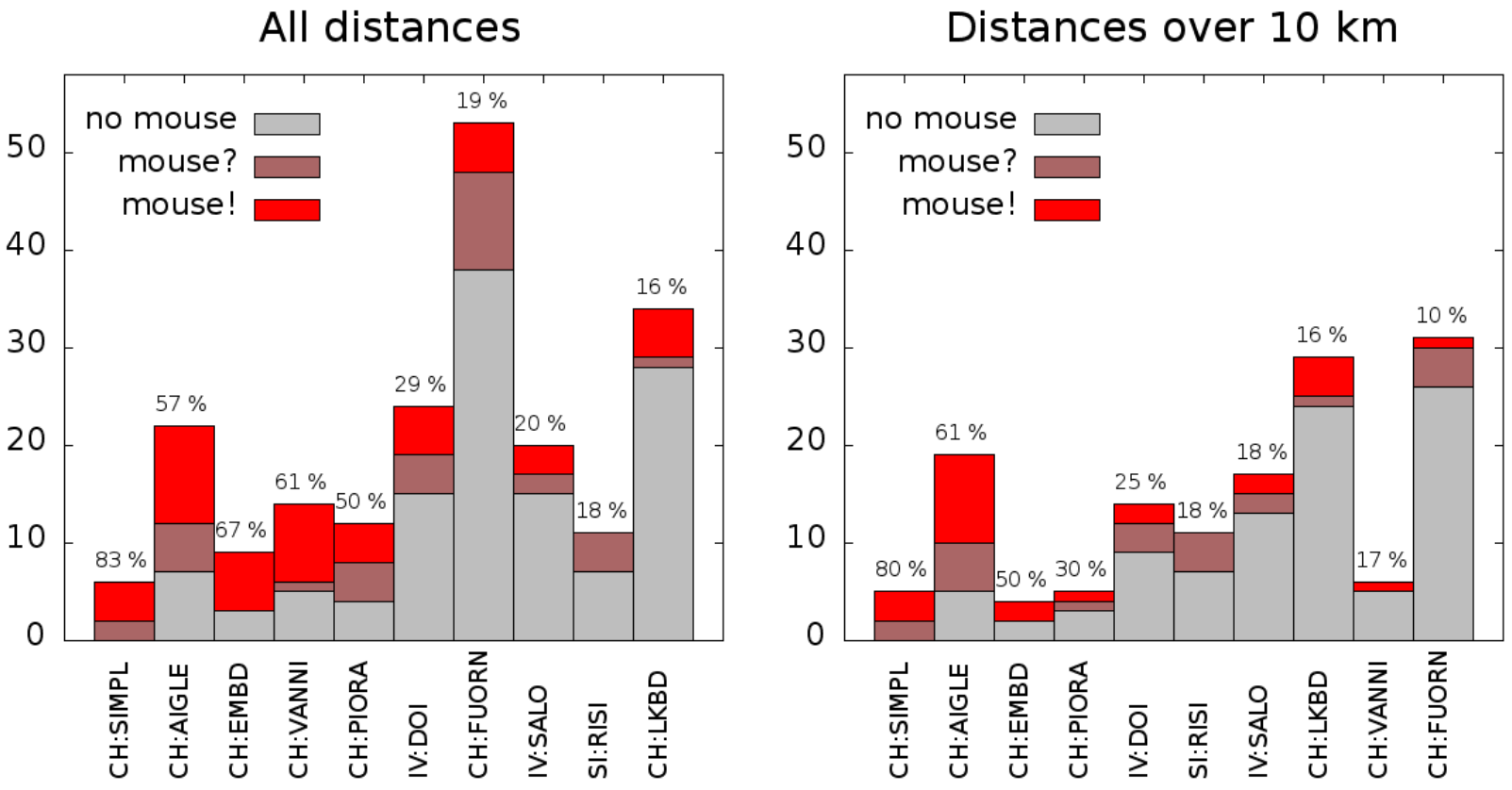
This result is partly influenced by the presence / absence of events near to the investigated stations.

Mice more common at some stations



Some of stations where mice are common are very close to many earthquakes.

Mice more common at some stations



At some stations, mice are mostly caused by near events.
At others, mouse occurrence is independent on event distance.

Conclusions

- Automatically analyzed mouse existence in records of Swiss seismic network at stations close to events of last 18 years
- Mice are present at all types of studied broad-band instruments, at many different stations
- Higher percentage of mice at some stations
- Directions of mouse remain the same at some (not all) stations
- Higher occurrence of mice at azimuths 30°, 90°, and 150°
- Most of the mice are horizontal; significant number have inclination $\sim 35°$
- More common at higher PGA / PGV, near the source, and at higher magnitudes (M 1–4 examined)

Acknowledgement

Thank to Philipp Kästli, Yannik Behr, and Carlo Cauzzi for useful advices.

Thank you

Conclusions

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Work in progress

- Improve fit of STS-2 seismometers (probably combination of acceleration and velocity step)
- Examine relation of mouse occurrence and strong high-frequency ground vibrations