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Data quality control and tools in passive seismic experiments

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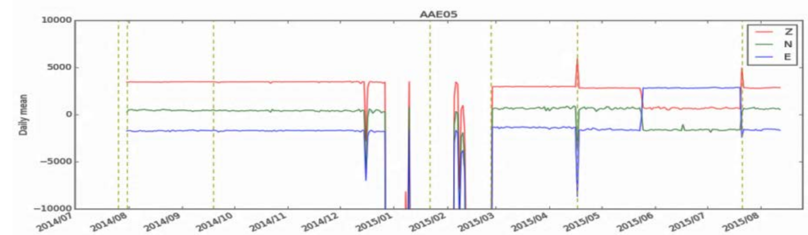
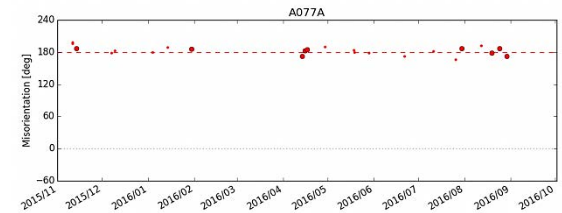
Data quality and assurance





Timing issues

Noise in signals

Sensor orientation

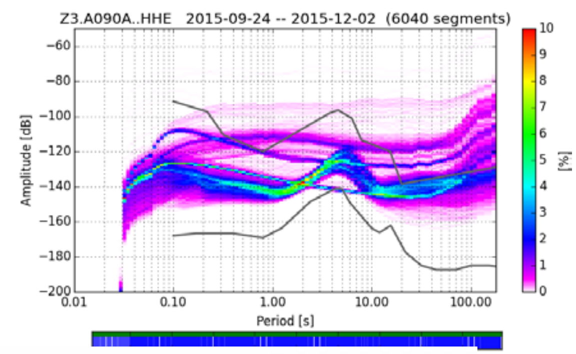
Reversed or interchanged components

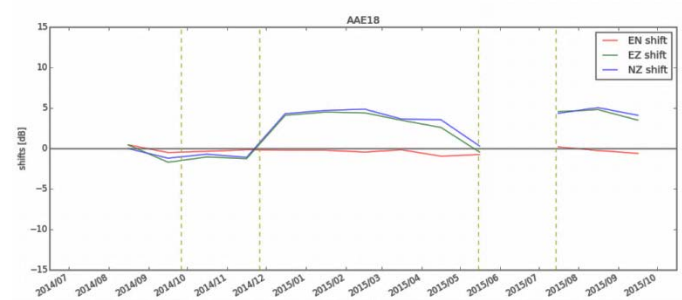
Drift of sensor mass position

Gain imperfection

Glitches in signal

Metadata





Timing issues - switch between the UTC and GPS times

While most clocks derive their time from Coordinated Universal Time (UTC), the atomic clocks on the satellites are set to GPS time. The difference is that GPS time is not corrected to match the rotation of the Earth, so **it does not contain leap seconds** or other corrections that are periodically added to UTC. GPS time was set to match UTC in 1980, but has since diverged.

As of now, **GPS time is 18 seconds ahead of UTC**. Receivers subtract this offset from GPS time to calculate UTC and specific timezone values.

[http://confluence.qps.nl]

Miniseed report

standing for 8.5 hours

09230600.00	2220	AAE02	HHE	100.00	360	2014-09-23T06:59:27.0329	2.8929	
09230600.00	2221	AAE02	HHE	100.00	390	2014-09-23T06:59:43.7400	13.1071	16.0000
09231500.00	337	AAE02	HHE	100.00	408	2014-09-23T15:31:16.8072	-2.8928	
09231500.00	338	AAE02	HHE	100.00	316	2014-09-23T15:31:07.7800	-13.1072	-16.0000

07281800.00	3737	AAE10	HHE	100.00	402	2015-07-28T18:52:12.7692	-2.6608	
07281800.00	3738	AAE10	HHE	100.00	380	2015-07-28T18:52:36.4500	19.6608	17.0000
07282000.00	5690	AAE10	HHE	100.00	412	2015-07-28T20:52:15.5708	2.6608	
07282000.00	5691	AAE10	HHE	100.00	412	2015-07-28T20:52:00.0300	-19.6608	-17.0000

standing for 2 hours

Timing issues - leap second

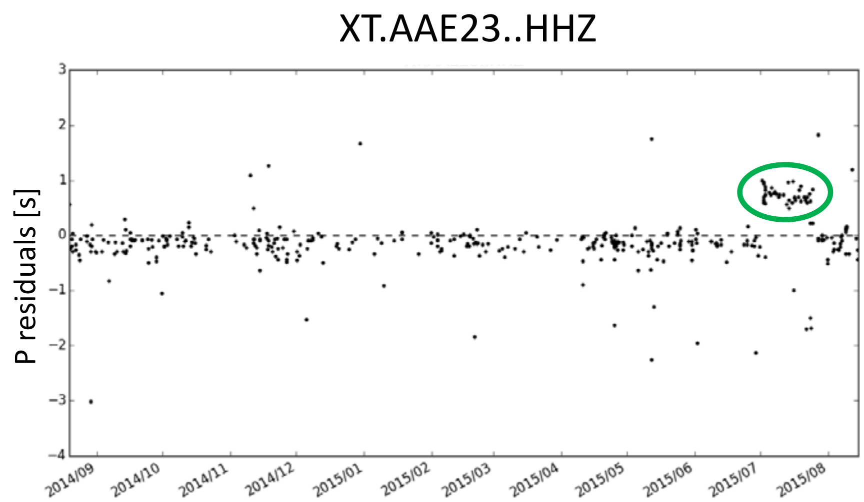
Leap second is introduced into the Coordinated Universal Time (UTC) usually once or twice per year in order to keep the UTC day time close to the mean solar time. The leap second is usually applied at **midnight on Jun 30 or Dec 31**, while clocks in data acquisition systems are being synchronized later, e.g., with a **30-90 minute delay**. Moreover, the leap-second correction is applied at individual stations **differently**.

Miniseed report

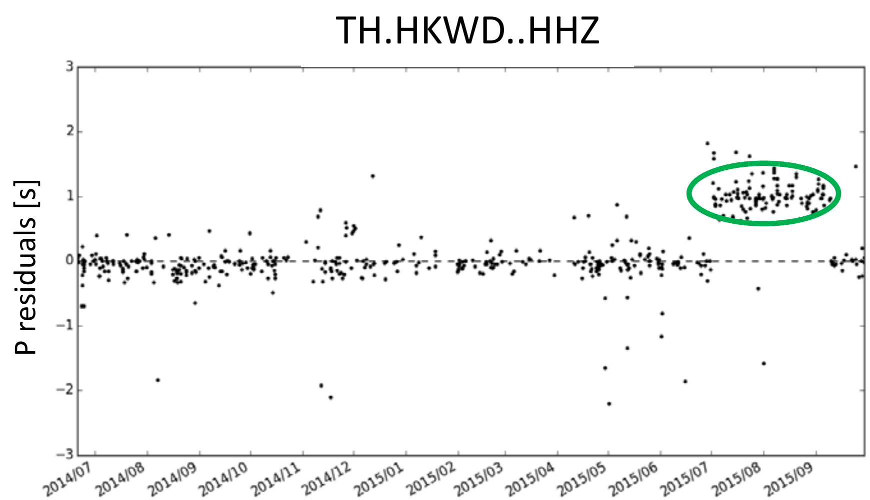
```
07010100.00   1098  AAE02  HHZ 100.00    364 2015-07-01T01:24:35.7200        -1.0000
07010100.00   6714  AAE03  HHZ 100.00    390 2015-07-01T01:16:25.6400        -1.0000
07010000.00   2086  AAE04  HHZ 100.00    408 2015-07-01T00:34:26.3800        -1.0000
07010000.00   8015  AAE05  HHZ 100.00    408 2015-07-01T00:49:24.8800        -1.0000
07010100.00   5892  AAE06  HHZ 100.00    408 2015-07-01T01:15:45.7700        -1.0000
07010100.00   9541  AAE07  HHZ 100.00    408 2015-07-01T01:22:34.2700        -1.0000
07010100.00   8889  AAE08  HHZ 100.00    396 2015-07-01T01:08:07.9200        -1.0000
```

1990	0	+1
1991	0	0
1992	+1	0
1993	+1	0
1994	+1	0
1995	0	+1
1996	0	0
1997	+1	0
1998	0	+1
1999	0	0
2000	0	0
2001	0	0
2002	0	0
2003	0	0
2004	0	0
2005	0	+1
2006	0	0
2007	0	0
2008	0	+1
2009	0	0
2010	0	0
2011	0	0
2012	+1	0
2013	0	0
2014	0	0
2015	+1	0
2016	0	+1
Year	Jun 30	Dec 31

Leap second seen by P residuals

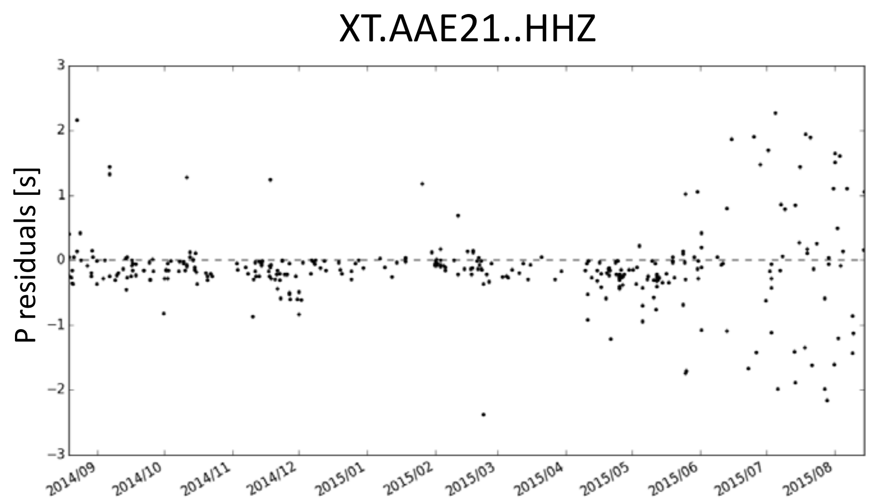


+1 s stays for about 27 days

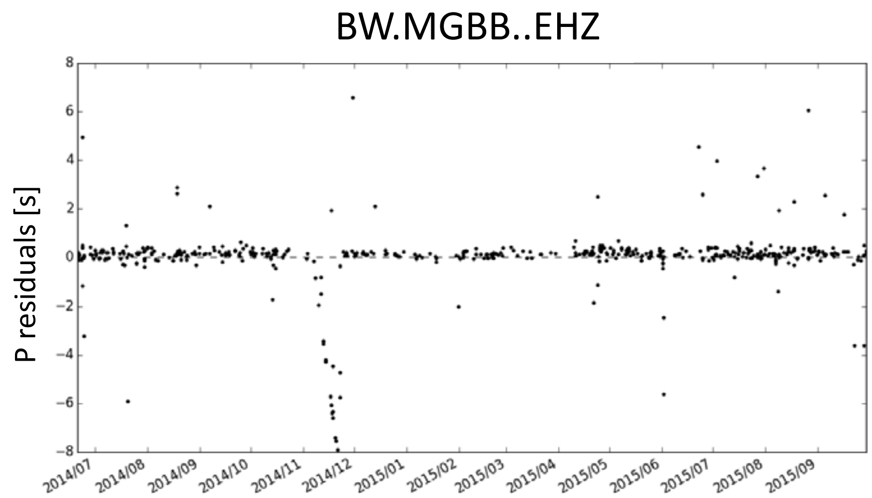


+1 s stays for 71 days!

Other timing issues



loss of time synchronization



malfunction of an oscillator
tuning the station time

Sensor orientation – compass & gyrocompass

EASI stations (CZ)	Remeasured original installation with compass	Sensor reorientation to N acc. to gyrocompass	Remeasured-END of registration	difference
AAE01 STS2	359,9	359,9	x	x
AAE02 STS2	7,4	0,4	0,4	0
AAE03 CMG-40T	4,0	359,8	0,7	0,9
AAE04 STS2	x	x	340,8	x
AAE05 STS2	357,1	359,3	0,6	1,3
AAE06 CMG-3T	3,2	0,9	0,9	0
AAE07 STS2	355,6	0,4	2,6	2,2
AAE08 STS2	358,0	0,6	0,8	0,2
AAE09 STS2	2,1	0,3	359,6	-0,7
AAE10 STS2	8,7	0,4	3,1	2,7
AAE11 STS2	5,2	0,7	359,5	-1,2
AAE12 STS2	2,9	0,7	359,5	-1,2
AAE13 STS2	282,0	0,7	352,3	-8,4 *
AAE14 STS2	2,3	359,5	357,2	-2,3
AAE15 STS2	3,2	359,9	359,4	-0,5
AAE16 STS2	2,2	359,4	0,5	1,1
AAE17 CMG-3ESP	6,2	0,2	0,8	0,6
AAE18 STS2	7,2	0,4	6,9	6,5 *
AAE19 CMG-3ESP	6,0	359,8	359,6	-0,2
AAE20 STS2	3,5	0,2	0,4	0,2

Accuracy of sensor orientation adjusted by

compass: ~ 4°

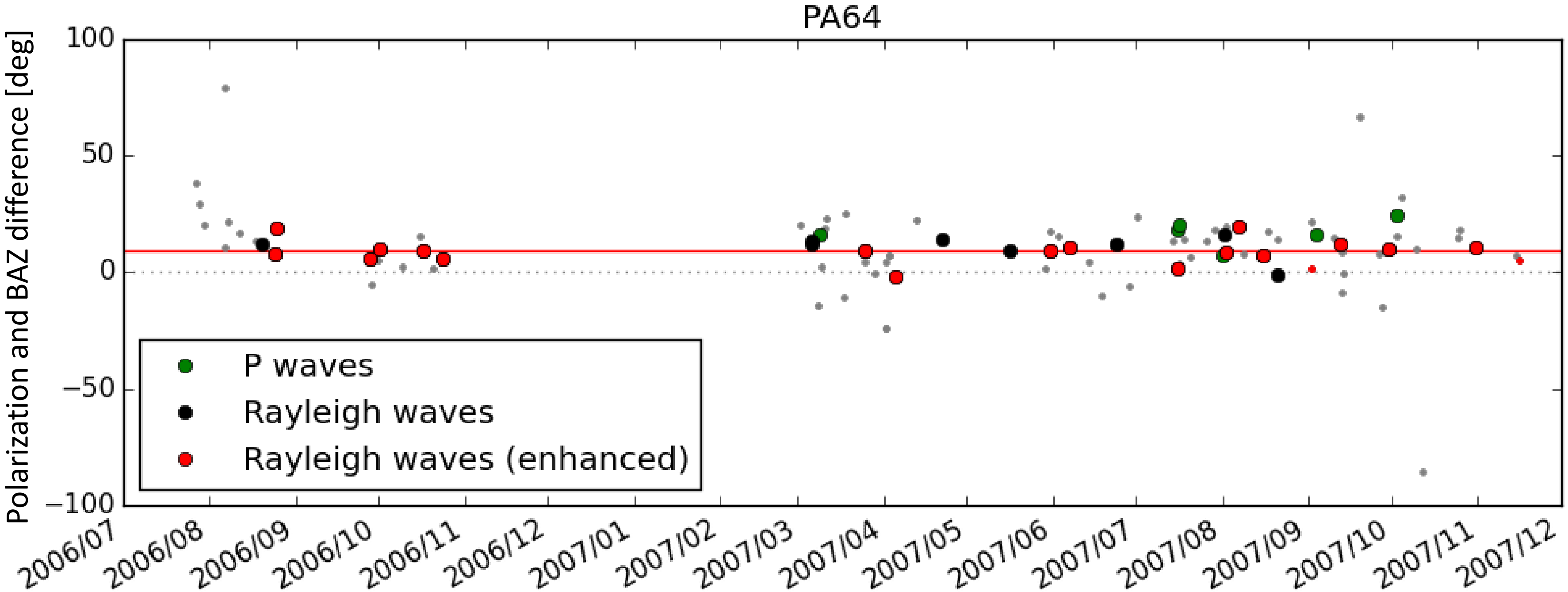
- 9/20 stations mis-oriented by ≥ 5°
- 2 big failures: 282°, 341°
- magnetic declination: +3.7° (2015)

gyrocompass: ~ 1°

- accuracy of gyrocompass itself: 0.1°
- the 1-2° differences reflect accuracy of a way of orientation measurement

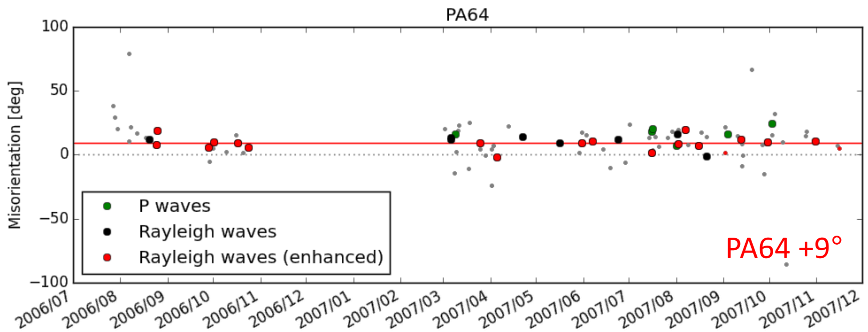
* Something or somebody pushed the sensor …

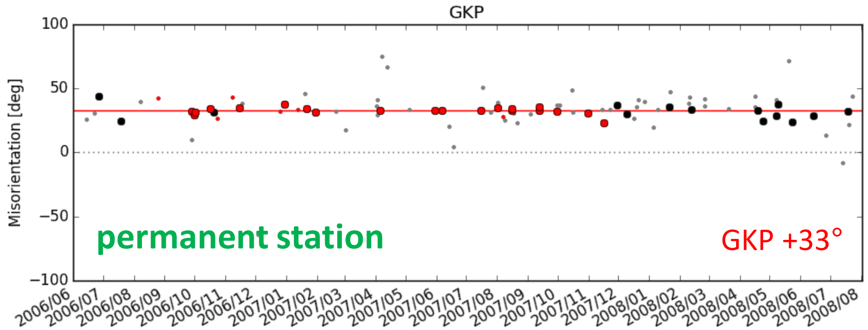
Sensor orientation

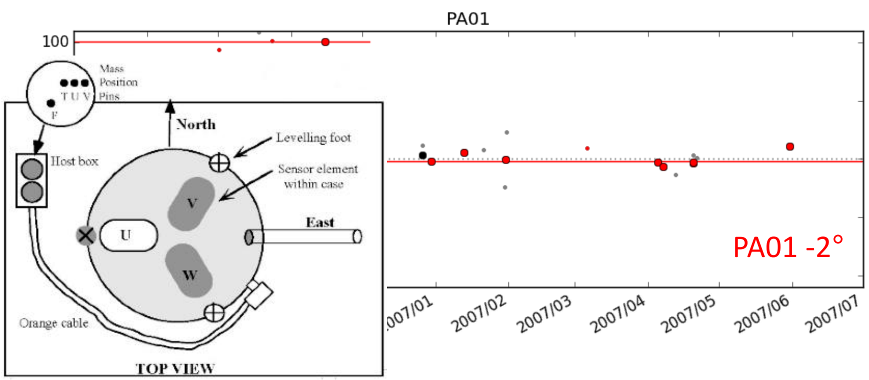


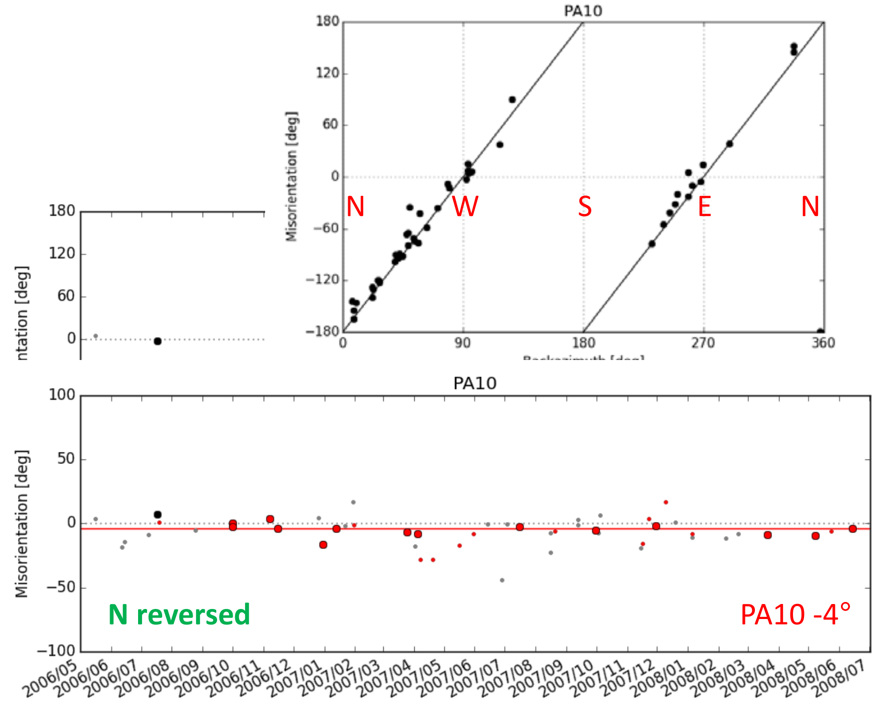
Rayleigh-wave polarization method – Stachnik et al., 2012

Sensor orientation









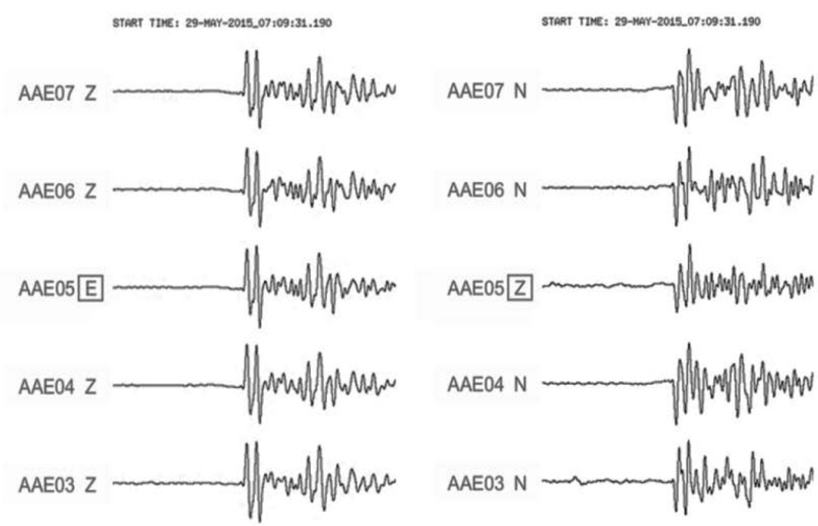
PASSEQ experiment 2006-2008

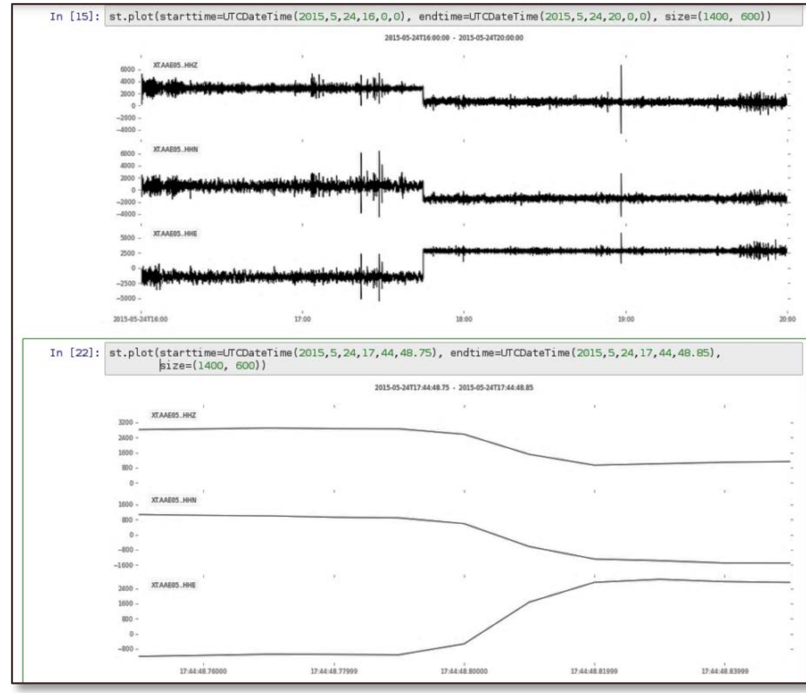
GKP	**33° ± 2°**	PA64	9° ± 4°
HSKC	1° ± 4°	PA10	-4° ± 6°
JAC	**44° ± 4°**	PC21	**20° ± 2°**
NKC	-3° ± 2°	PC23	**37° ± 4°**
ROC	2° ± 2°	PC26/	4° ± 4°
PA01/	**101° ± 4°**	/PC26	**20° ± 4°**
/PA01	-2° ± 2°	PA69	**20° ± 2°**
PA07	-3° ± 8°	PA70	**-10° ± 4°**

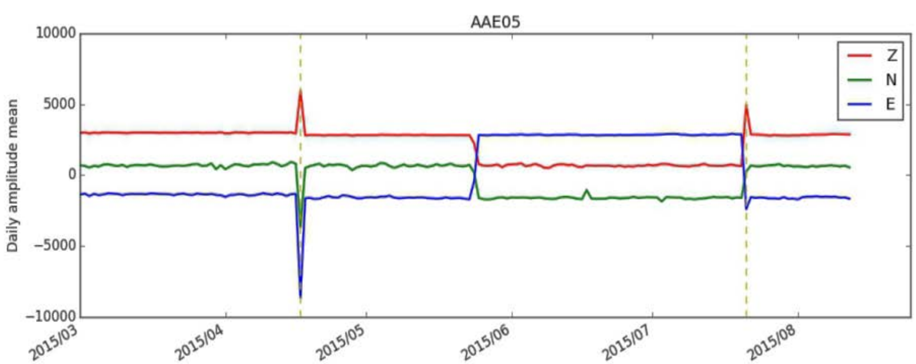
…

Vecsey et al., 2017, in press

Interchange of components







Exchange of components:
Z -> E, N -> Z, E -> N

start: 2015-05-24T17:44:48.83
end: 2015-07-21T06:42:23.75

Vecsey et al., 2017, in press

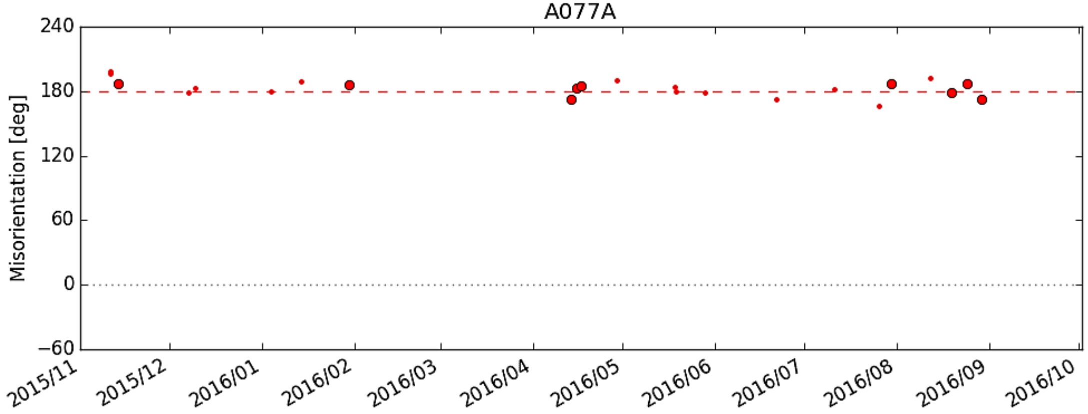
Reversed channel polarity

Can be detected by different methods:

- wave similarities in array of stations
- wave polarization

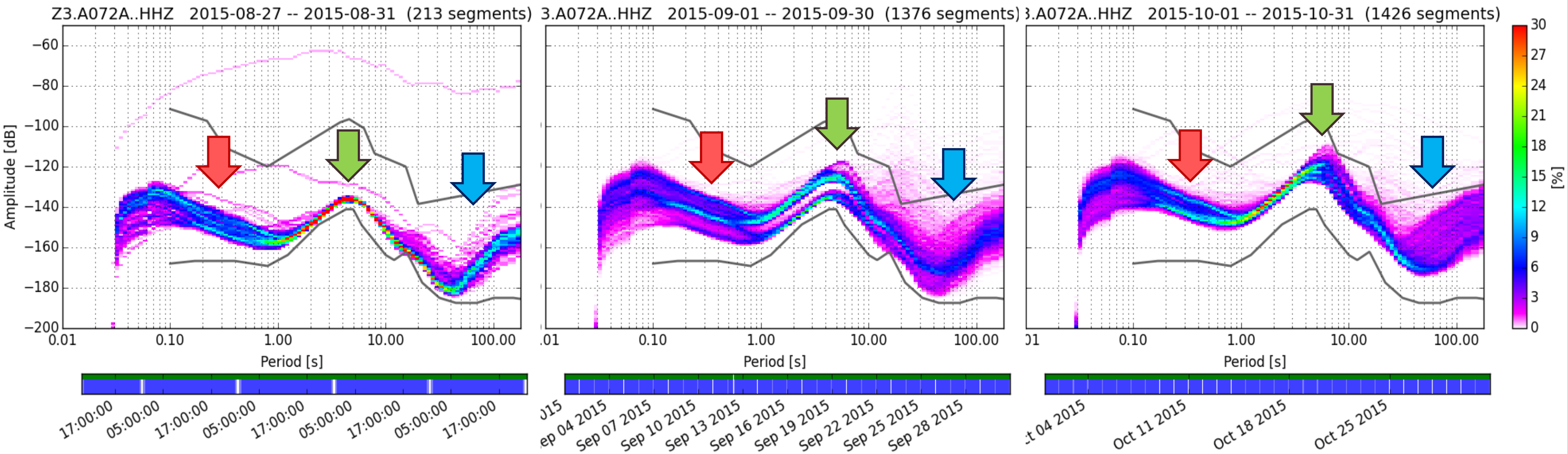
Found in A077A:
N -> -N, E -> -E

Rayleigh wave polarizations



➢ Corrections of reversed polarities can be done either in MSEEDs or in METADA, **we prefer MSEEDs.**

Probabilistic Power Spectral Density (PPSD)



McNamara, D. E. and Buland, R. P. (2004),
Ambient Noise Levels in the Continental United States,
Bulletin of the Seismological Society of America, 94 (4), 1517-1527.

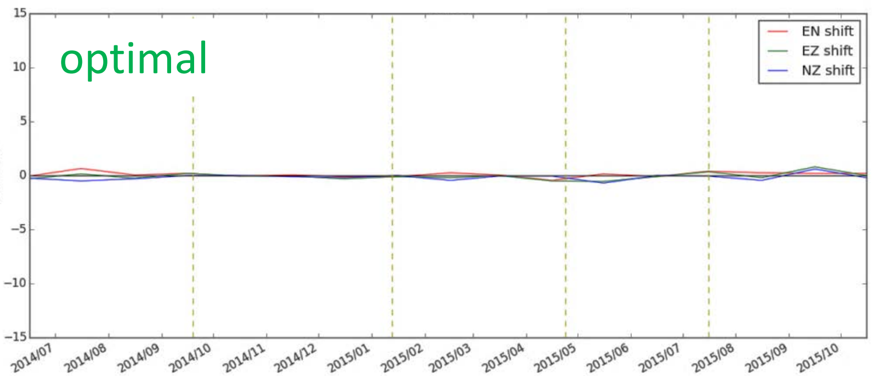
Peterson, J. (1993),
Observations and Modeling of Seismic Background Noise,
U.S. Geological Survey open-file report 93-322, Albuquerque, N.M.
-> NHNM, NLNM: new high/low noise model

- cultural noise, day-night variations
  natural noise (wind turbulence, tree roots)
- secondary microseisms, similar long-term variations in all stations
- temperature, barometric pressure, air mass changes, seasonal variations
  horizontal channels: ground tilting due to thermal instabilities, building responses/relaxations

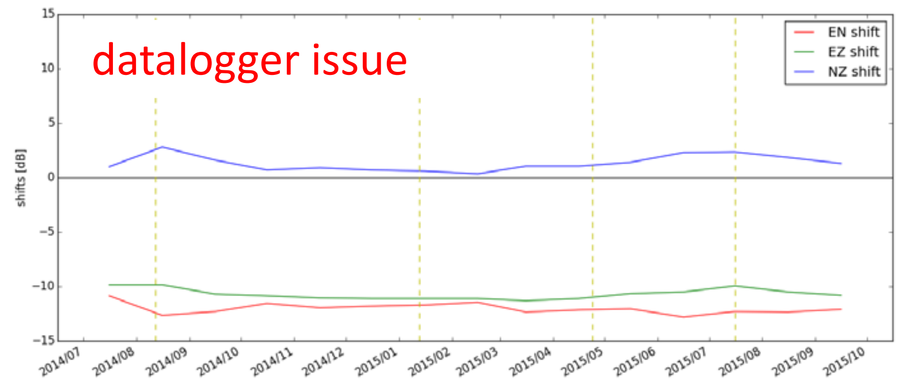
Ambient noise gain method

It compares ratios of normalized power spectra between the three components in a range of 4-8 seconds (where the secondary microseisms are substantially larger than noise from local sources).

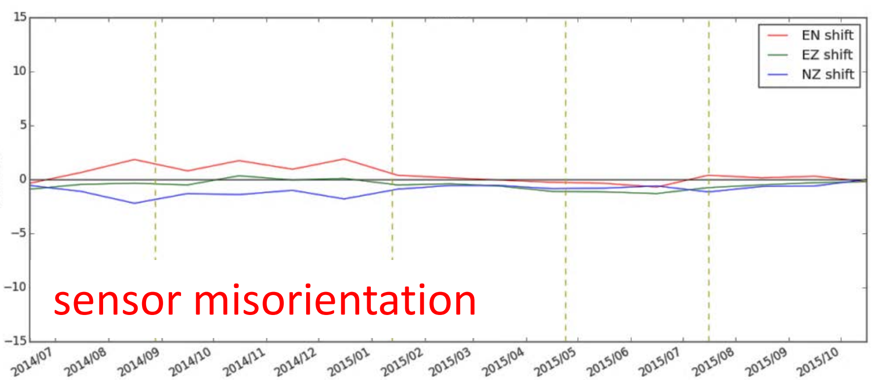
AAE11



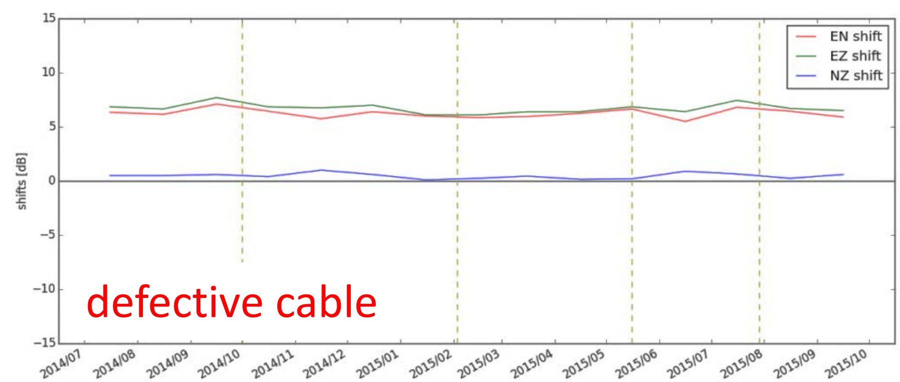
AAE14



AAE13



AAE15



Vecsey et al., 2017, in press

Developed control and calibration units

CMG host box

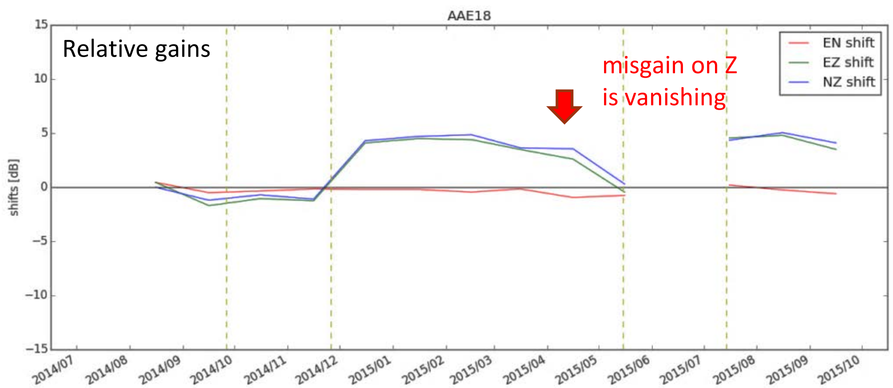
CMG control and calibration unit

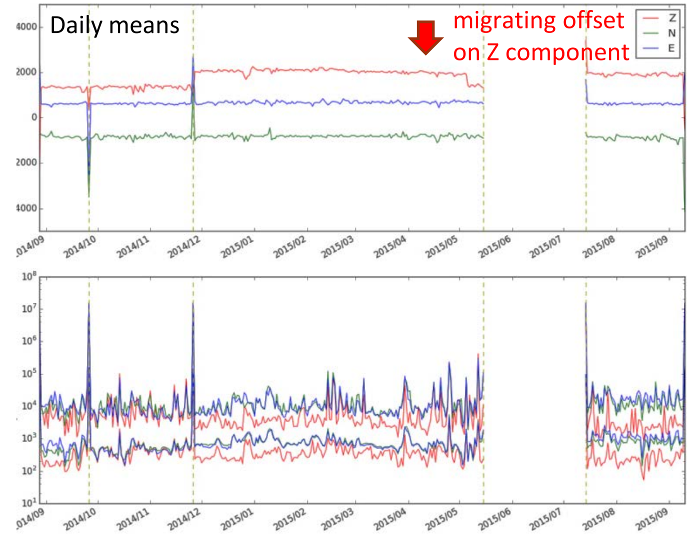
CMG centring unit

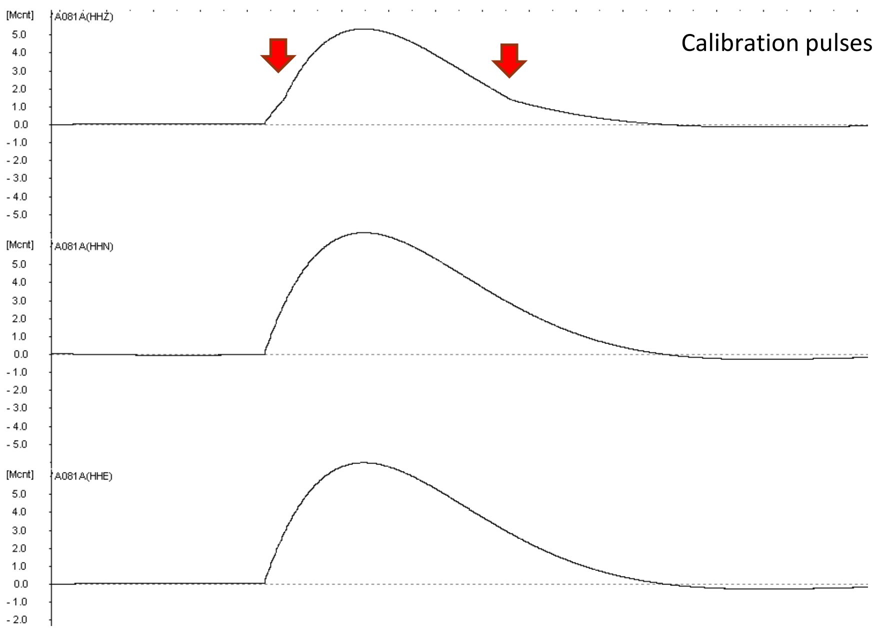
STS2 control and calibration unit

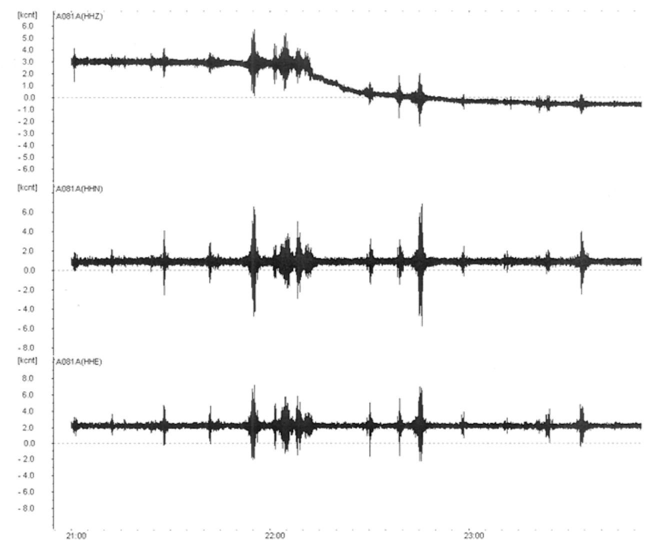
GAIA gain and calibration unit

Imperfect gain example



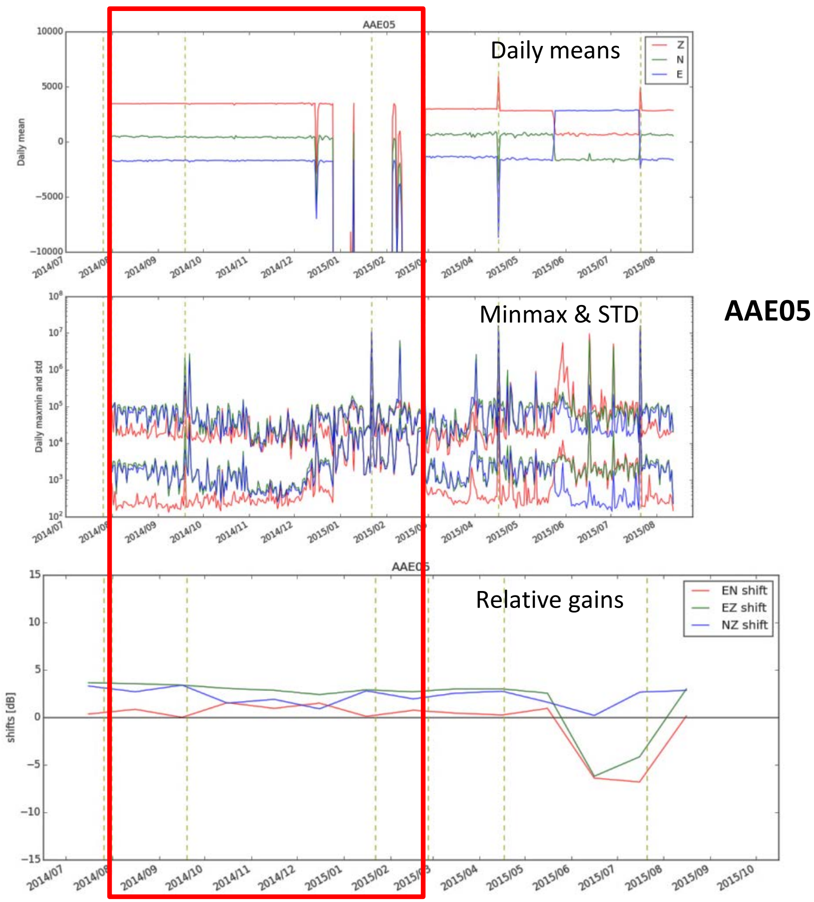


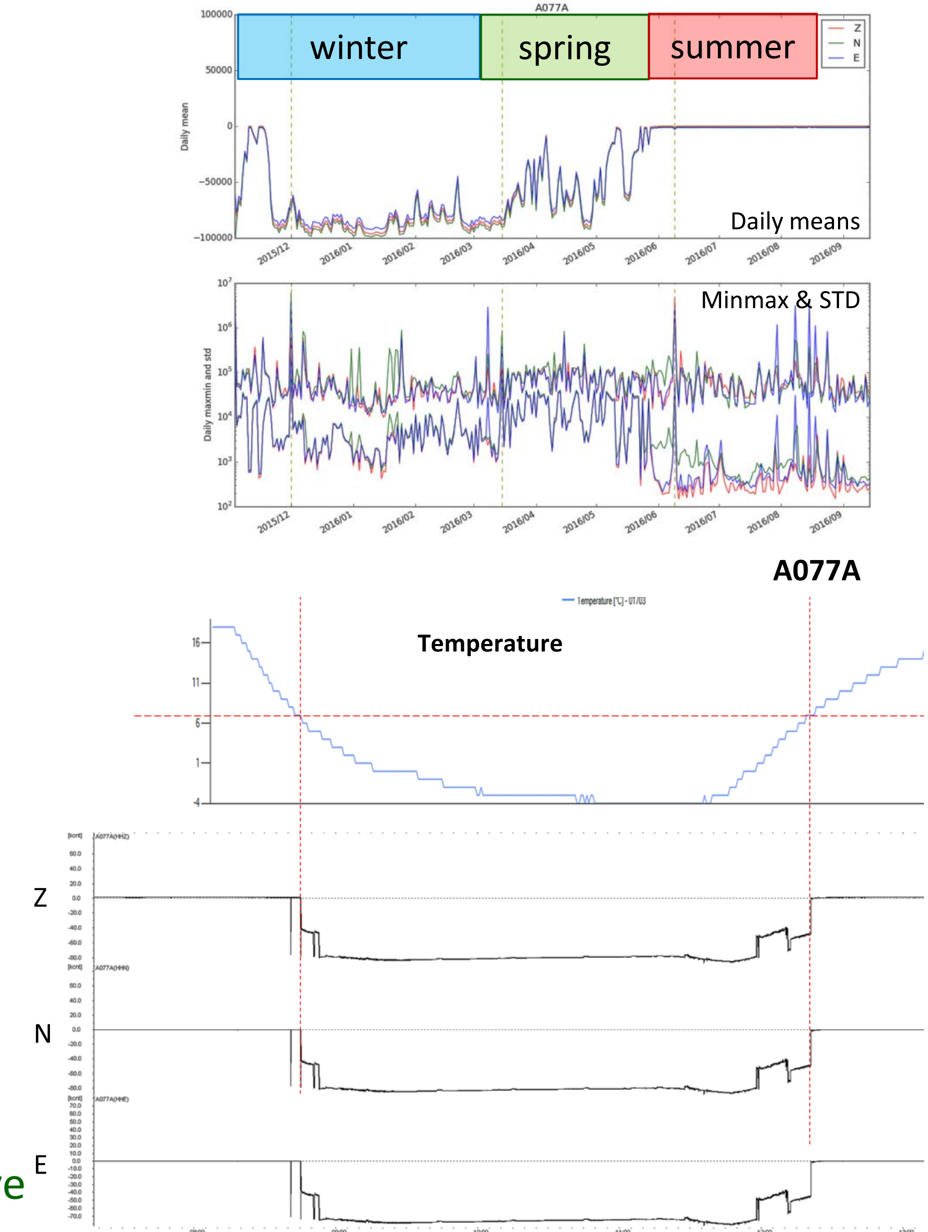




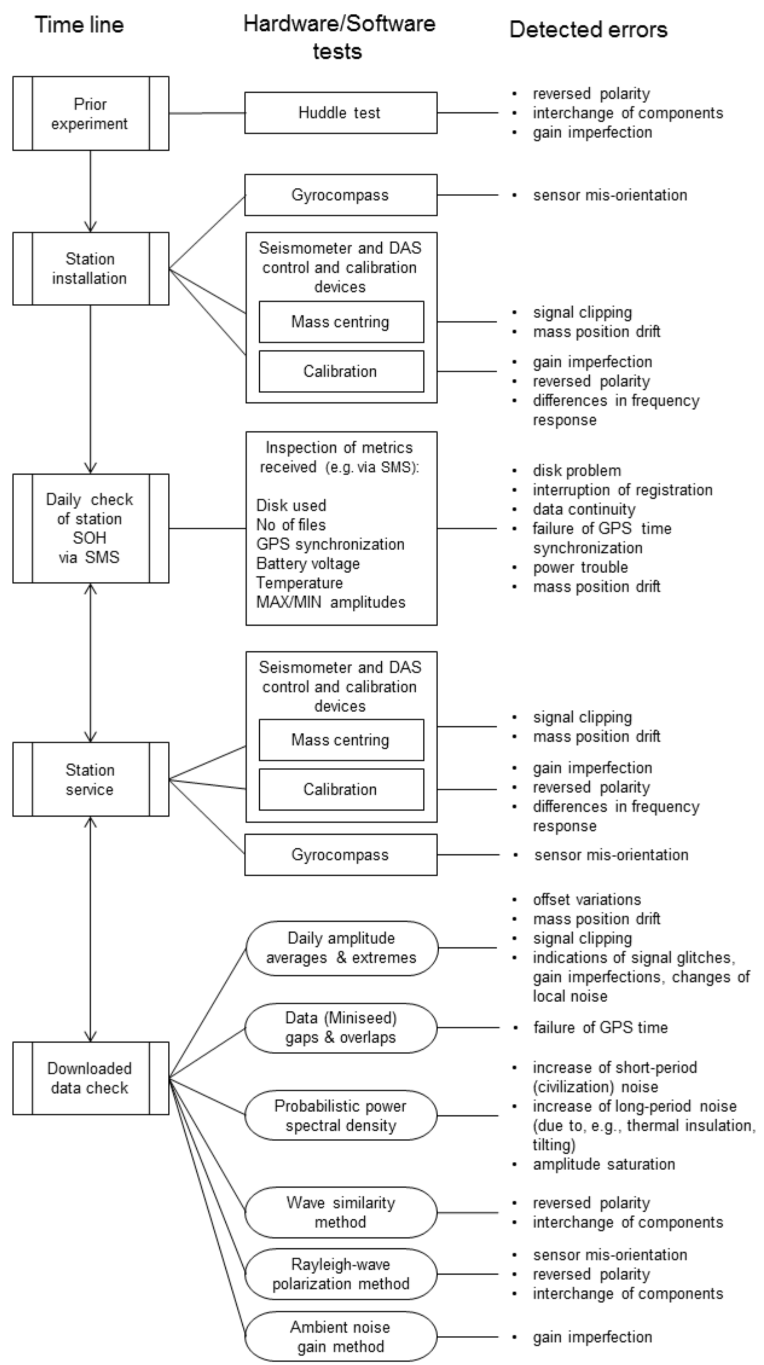
- ➢ Rotten original seismometer connector

Imperfect gain example





- Defected tantalum capacitor in a negative power supply (changing el. resistance in dependence on temperature)


Time line
Hardware/Software tests
Detected errors
Prior experiment
Huddle test
reversed polarity
interchange of components
gain imperfection
Gyrocompass
sensor mis-orientation
Station installation
Seismometer and DAS control and calibration devices
Mass centring
signal clipping
mass position drift
Calibration
gain imperfection
reversed polarity
differences in frequency response
Daily check of station SOH via SMS
Inspection of metrics received (e.g. via SMS):
Disk used
No of files
GPS synchronization
Battery voltage
Temperature
MAX/MIN amplitudes
disk problem
interruption of registration
data continuity
failure of GPS time synchronization
power trouble
mass position drift
Station service
Seismometer and DAS control and calibration devices
Mass centring
signal clipping
mass position drift
Calibration
gain imperfection
reversed polarity
differences in frequency response
Gyrocompass
sensor mis-orientation
Downloaded data check
Daily amplitude averages & extremes
offset variations
mass position drift
signal clipping
indications of signal glitches, gain imperfections, changes of local noise
Data (Miniseed) gaps & overlaps
failure of GPS time
Probabilistic power spectral density
increase of short-period (civilization) noise
increase of long-period noise (due to, e.g., thermal insulation, tilting)
amplitude saturation
Wave similarity method
reversed polarity
interchange of components
Rayleigh-wave polarization method
sensor mis-orientation
reversed polarity
interchange of components
Ambient noise gain method
gain imperfection

Conclusions

- The hardware control in-situ and the ex-post software data checking represent the **double check** of data quality.
- We have developed **special control devices** for seismometers and for the GAIA DAS. The devices calibrate both the sensors and data acquisition systems in-situ and allow us to check the gain and the polarity of all three components.
- Information extracted from probabilistic power spectral density, spectra ratios, averages of daily amplitudes and of other parameters allow us to identify (and correct) problems in data, e.g., imperfectly set gains, interchange of components and polarity reversals, sensor mis-orientations, insufficient sensor mass centring, and time issues.