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*Ministry of Infrastructure  
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# Quality assurance and publication of the KNMI 1995-2013 Groningen seismic data

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# Intro

## *Aim of the project:*

- to prepare data on induced seismicity collected before 2013. These data are recorded in a triggered mode and in a local format.
- to convert data into SEED format
- to carry out a quality assurance and publish the dataset

## *Deliverables:*

- a homogeneous waveform database, including up-to-date metadata
- open data access through the KNMI website
- report on data quality for the originally off-line (triggered) dataset

## *Review:*

- NORSAR carried out a review of the quality of the data and metadata



Data are stored in local formats (laspei, smr)

- Instrument response
  - Update of existing information on accelerometer and borehole instrument response
- Polarity and orientation
  - Accelerometers were installed in buildings with the intention to have a measure of the maximum acceleration reached.
  - Borehole orientation was known from check-shots, but polarity required a consistency check.
- Timing
  - Accelerometers: part of the instrumentation provides information on the synchronisation with GPS-time.
  - Boreholes: DCF timing recorded as separate channel.



## Accelerometers

The polarity of the vertical sensor is specified in the manuals.  
There is a 180 degrees difference between the AC23 and AC63 sensor.

## Boreholes

Procedure:

1. Consistency check with polarities from existing broad-band sensors (Z)
2. Comparison of 200m deep borehole level with broad-band Z-components
3. Comparison of 200m deep level of all existing boreholes
4. Consistency check on all borehole levels for each station.

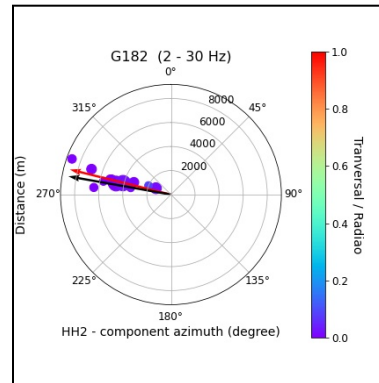
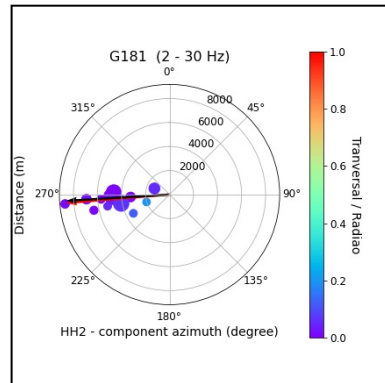
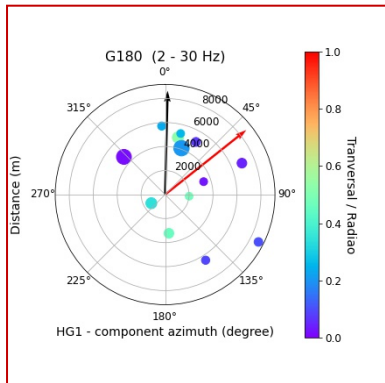
Recordings of deep (>60m) and large ( $M > 6.5$ ) teleseismic events are used.



## Accelerometers

We developed an automated procedure to determine the orientation of the horizontal components. The procedure was tested at boreholes installed in 2014. Results: good for boreholes, but poor for surface sensors, due to high noise levels and waveform complexity (sediments).

Therefore a manual procedure was added and results from two methods are compared and averaged. Uncertainty in results is added to the metadata.

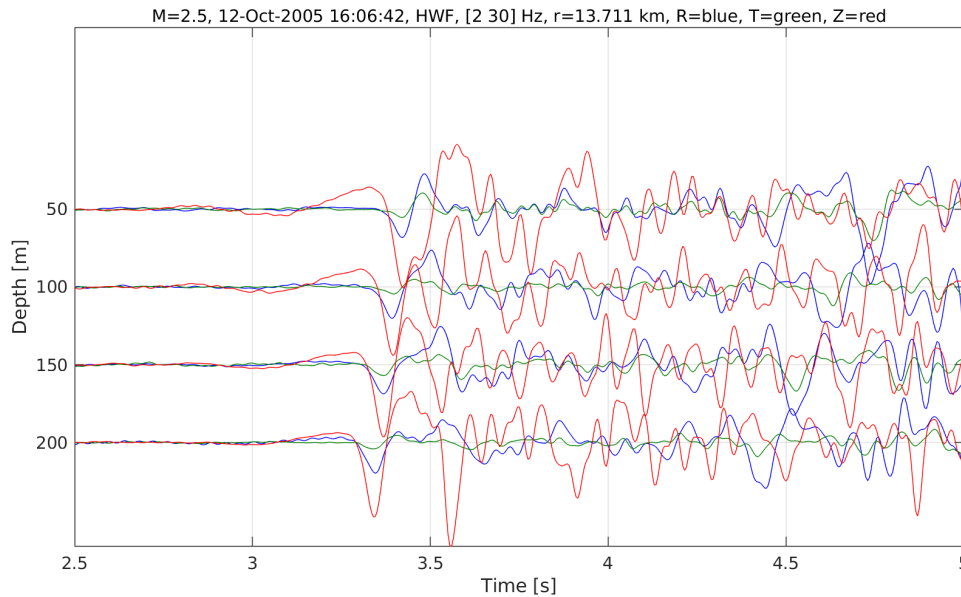




## Boreholes

The orientation of the borehole levels was determined by using check-shots at short distances (<1 km) from the sensors.

After resolving the polarity issue, a 180 degree uncertainty in orientations could be resolved. A check on waveform consistency has been carried out and results are added to the meta-data.



Vertical (red), radial (blue) and transverse (green) components of 4 depth levels at station HWF.

Vertical and radial components are in phase, as required.

# Data completeness and conversion: accelerometer data



year	#events	ROS1	ROS2	ROS3	ROS4	ROS5	ROS6	MID1	MID3	ZAN1	ZAN2	WSE	FRB2	HKS	KANT	WIN	GARST	STDM
1996	2	2																
1997	7	6	2	5														
1998	3	3	3	2														
1999	6	6	5	4	1													
2000	3	1	3	1	1													
2001	1	1	1		1	1	1											
2002	3	1	3			1	2											
2003	5	1	1					1	4		2							
2004	1	1	1			1												
2005	0																	
2006	10	2	2		1	2		2						5				
2007	3										2	2						
2008	4							2	1	1	3	1				1		
2009	8							2	1	3	3	6		1		3		
2010	5							1	1	1	1	2	1	1				1
2011	10							4	2	1	2	7	1	1	1	2	3	1
2012	3							2				2	1	1	1	2	3	1
2013	7									2		4		2	2	4	4	
2014	1													1	1	1	1	
Total	82	24	21	12	4	2	6	12	10	8	13	24	3	12	5	13	12	2

# Data completeness and conversion: borehole data

year	#events	#files	year	#events	#files	year	#events	#files
1995	18	18	2001	23	20	2007	32	32
1996	41	41	2002	25	25	2008	49	49
1997	42	41	2003	57	55	2009	91	80
1998	23	23	2004	31	30	2010	29	23
1999	31	31	2005	36	36			
2000	26	25	2006	56	55			
						<b>Total</b>	<b>Total</b>	
						<b>610</b>	<b>584</b>	

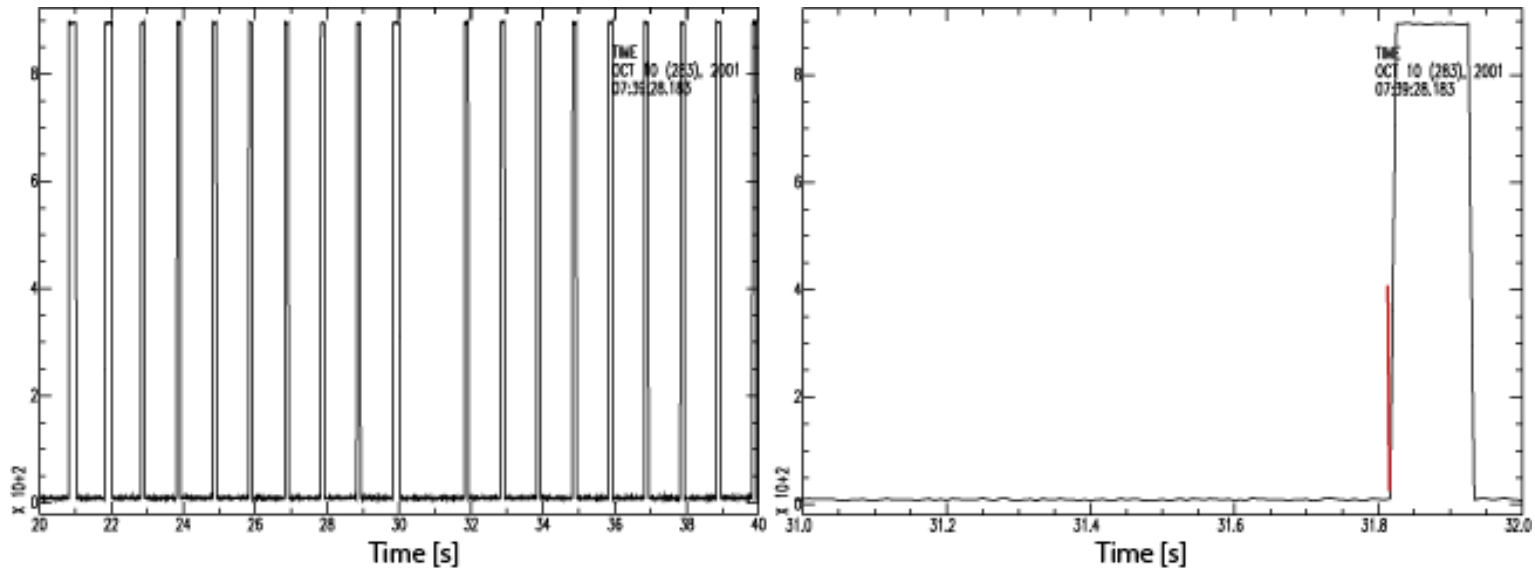
All original KNMI collected triggered files could be retrieved and have been processed.  
 For the accelerometers this means data for 82 events, recorded in 183 files. The total data volume is app 0.9 Gb.

All original KNMI collected triggered files could be retrieved and have been processed.  
 For the boreholes this means data for 610 events, recorded in 584 files. The total data volume is app 3.3 Gb.

Data conversion to mini-SEED using obspy software.  
 Metadata added in standardized FDSN station xml format.



## Timing quality: boreholes

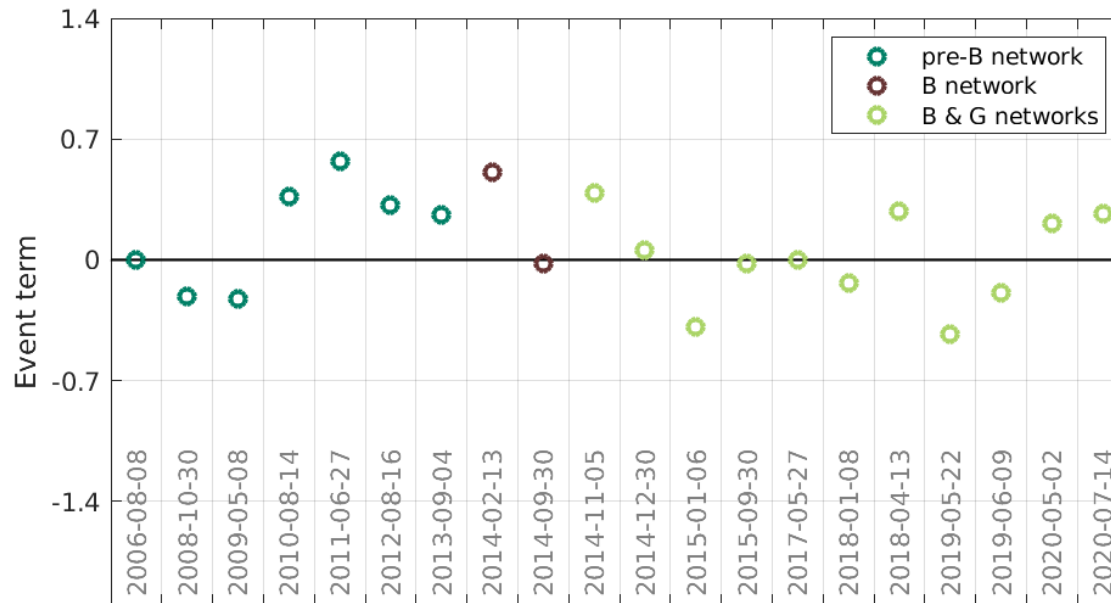


We decided to add recorded time signal to each borehole record. This allows a check on the timing quality at any time in future.

For suspicious timing, the timing signal was inspected and corrected.

If data are used for time critical applications, the user should check the timing signal.

# QC: Accelerometer amplitudes: Event terms



There were no co-located stations or recorded teleseismic events to compare amplitudes for the accelerometer data. We therefore looked at event-terms. Event term is defined as the average PGV level for which an individual event is different from the mean model ( $\ln(\text{PGV}_{\text{meas}}) - \ln(\text{PGV}_{\text{model}})$ ). A modified version from the Groningen empirical PGV model was used (BMR2)

Observations are:

- There is no difference in event-term trend between pre-B and B stations
- Going from the pre-B/B network to the B&G network there is an average drop of 0.2 in event term

# QC: Borehole amplitudes

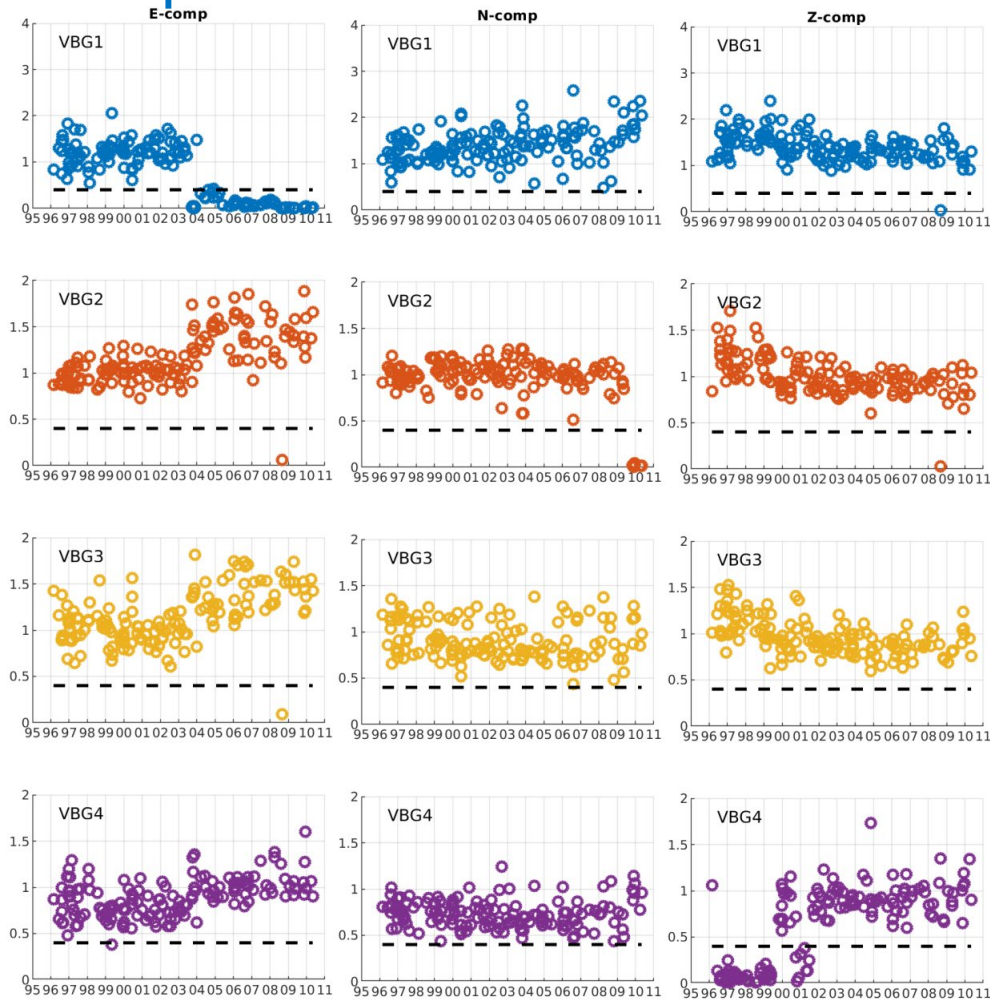


Figure 42. Maximum absolute amplitude values of individual borehole channels for station VBG, normalized with respect to the average maximum absolute amplitude of this channel recorded over all borehole levels.



## Conclusion

- Triggered seismic data are converted into SEED.
- Metadata are checked and updated where necessary (QuakeML)
- Polarity and orientations are estimated/checked and added to QuakeML, including an estimate of their uncertainty
- Consistency of amplitude information was evaluated
- A list of component malfunctioning over time is made and included in the report.
- A detailed report will be available when data are published on the KNMI website ([rdsa.knmi.nl](http://rdsa.knmi.nl)).
- NORSAR's review will also be published in a separate report