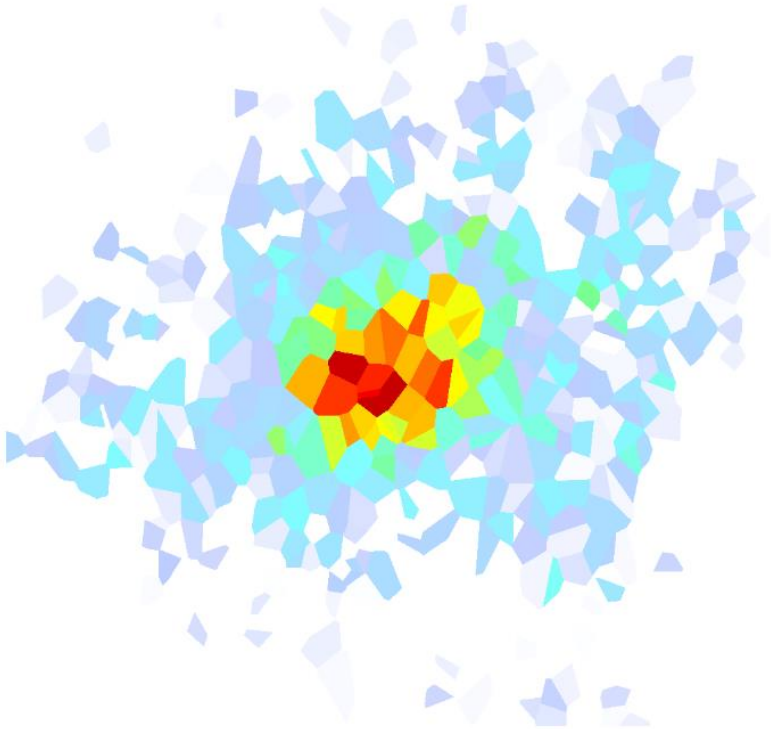
The Belgian Macroseismic Database and its application towards ShakeMap

Royal Observatory of Belgium



Koen Van Noten, Ben Neefs & Kris Vanneste

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kris.vanneste@oma.be

Geo-iNQUIRE · Istituto Nazionale di Geofisica e Vulcanologia · Schweizerischer Erdbebendienst / Service Sismologique Suisse / Servizio Sismico Svizzero / Swiss Seismological Service · Orfeus

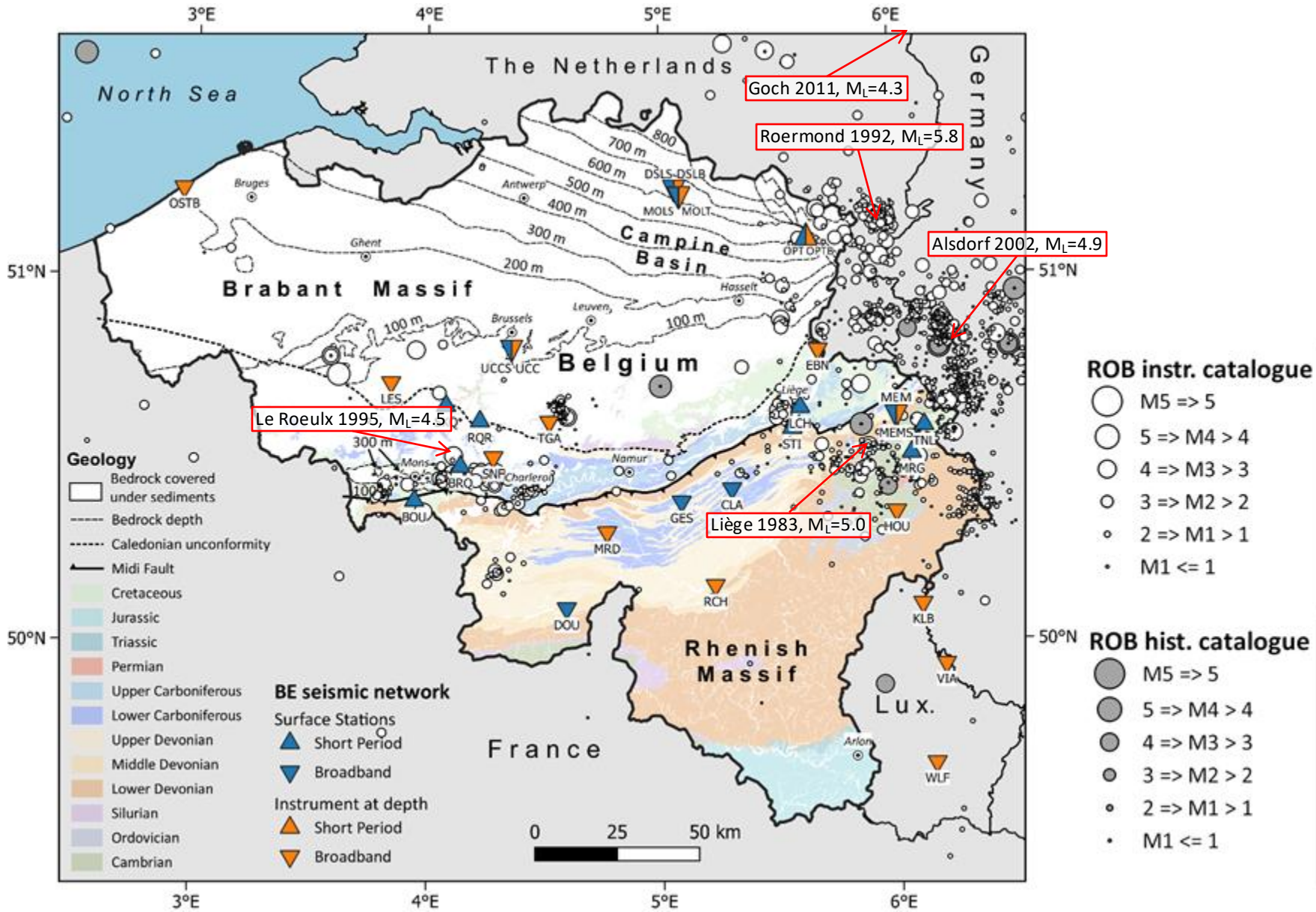
III ShakeMap-EU workshop

Milano, 05 June 2025

Earthquakes in/around Belgium

Royal Observatory *of* Belgium

- ROB is official agency monitoring seismicity in Belgium
- First seismometer installed in 1898
- Continuous recording since 1910
- Digital network since 1985
- Currently 30+ seismometers and 15+ accelerometers
- South: rock sites
  North: soft sediment sites
- Impact events since 1900
  - **5** M5 earthquakes
  - **25** M4 earthquakes
  - **40+** M3 events



History of BE macroseismic data gathering

Royal Observatory of Belgium

From disaster file ordering
to a consistent database

Creation and Validation of the Belgian Macroseismic Database and its Importance for Engineering Seismology

Ben Neefs

Royal Observatory of Belgium

Université catholique de Louvain

UCLouvain

Thesis Submitted in Fulfilment of the Requirements of the Degree of Doctor in Engineering Sciences and Technology

Supervisors

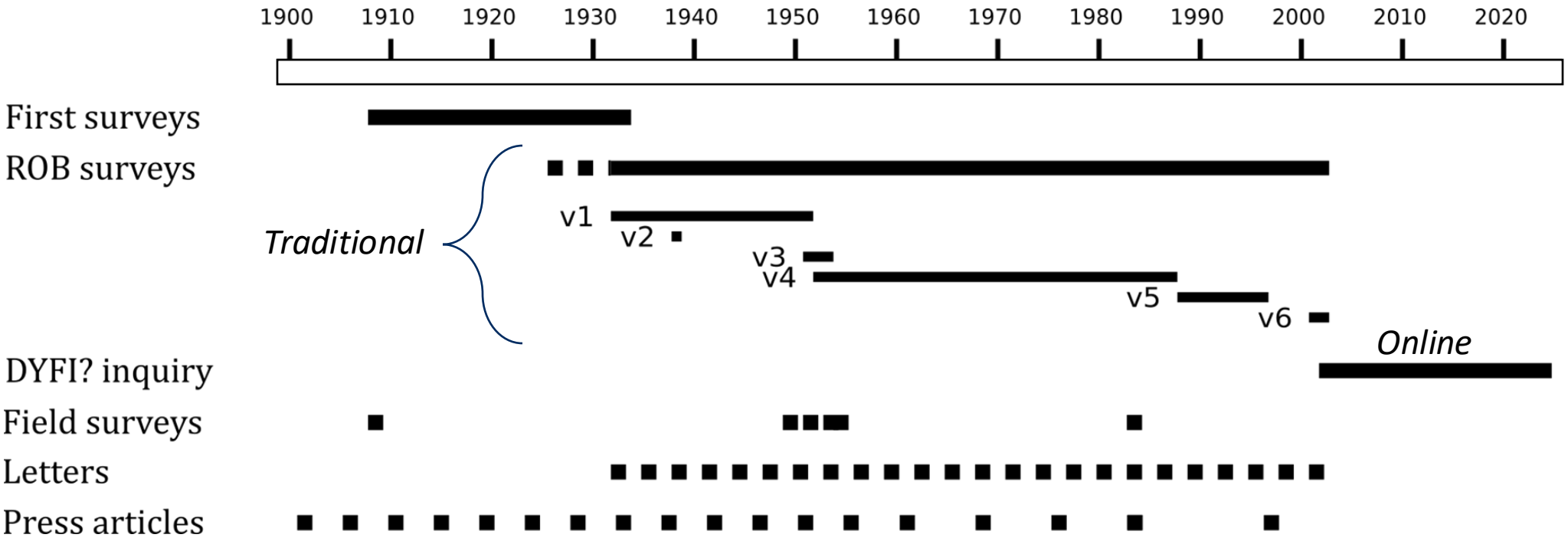
Dr. Koen **Van Noten** — *Royal Observatory of Belgium*
Prof. Dr. João Saraiva Esteves Pacheco de **Almeida** — *Université catholique de Louvain*

Thesis Committee
Prof. Dr. Nicolas **Moës** [jury president] — *Université catholique de Louvain*
Dr. Ryan **Hoult** [secretary] — *Université catholique de Louvain*
Prof. Dr. Hervé **Degée** — *Universiteit Hasselt*
Dr. Thierry **Camelbeeck** — *Royal Observatory of Belgium*

NEW: Compilation of all Belgian macroseismic data

History of BE macroseismic data gathering

Royal Observatory of Belgium



J Seismol
https://doi.org/10.1007/s10950-024-10266-9

RESEARCH

The Belgian traditional macroseismic (BTM) database of the twentieth century

Ben Neefs · Koen Van Noten · Kris Vanneste · Thierry Camelbeeck

PhD Neefs 2025
Neefs et al. 2024

NEW: Compilation of all Belgian macroseismic data

History of BE macroseismic data gathering

Royal Observatory of Belgium

ROB surveys

Version	Time range	Events	Intensity range	Questions	Forms	Quality
v1	1932-1951	3	1-7	31*	2343	B
v2	1938	1	5-7	3	1304	B
v3	1951-1953	2**	1-7	27	677	A
v4	1952-1987	42**	1-7	37	10252	A
v5	1988-1996	7	1-7	9	6183	B
v6	2001-2002	2	1-7	20	565	B

J Seismol
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RESEARCH

Check for updates

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EMS-98 diagnostics

Effects on people		v1	v2	v3	v4	v5	v6
People	perceive the earthquake indoors	✓				✓	✓
	perceive the earthquake outdoors	✓				✓	✓
	are awakened	✓			✓		
	flee outdoors	✓			✓	✓	✓
	lose their balance	✓					
People describe their experience as	swaying or light trembling	✓		✓	✓		✓
	moderate vibration	✓		✓	✓		
	strong shaking or rocking of the whole building	✓			✓		✓
Effects on objects and nature		**v1**	**v2**	**v3**	**v4**	**v5**	**v6**
Hanging objects	swing slightly						
	swing moderately	✓		✓	✓	✓	✓
	swing considerably	✓		✓	✓		
China and glasses	rattle or clatter together	✓		✓	✓		
	break	✓		✓	✓		
Woodwork	creaks	✓		✓	✓		
Windows and doors	rattle	✓		✓	✓		✓
	swing open or shut	✓					✓
	windowpanes break	✓		✓	✓		✓
Furniture	shakes visibly	✓		✓	✓	✓	✓
	shifts	✓		✓	✓		✓
	overturns	✓			✓	✓	✓
Small, top-heavy and/or precariously supported objects shift or fall		✓		✓	✓		✓
Small objects of ordinary stability fall		✓		✓	✓		
Objects fall from shelves in large numbers							
Heavy objects fall to the ground				✓			
Animals indoor are uneasy							
Farm animals are frightened							
Liquids oscillate or spill from well-filled containers							
Liquids splash from containers, tanks and pools							
Damage to buildings		**v1**	**v2**	**v3**	**v4**	**v5**	**v6**
Walls	hair-line cracks in very few walls				✓		
	Cracks in many walls	✓		✓		✓	✓
	large and extensive cracks in most walls				✓	✓	✓
	serious failure of walls					✓	✓
Plaster	fall of small pieces	✓		✓	✓		
	fall of fairly large pieces	✓		✓	✓		
Chimneys	partial collapse	✓	✓	✓	✓	✓	✓
	fracture at the roofline		✓	✓	✓	✓	✓
Roofs	roof tiles detachment						
	structural failure of roofs and floors						
Other	Fall of loose stones from upper parts of buildings			✓	✓		
	failure of individual non-structural elements						
	total or near total collapse						

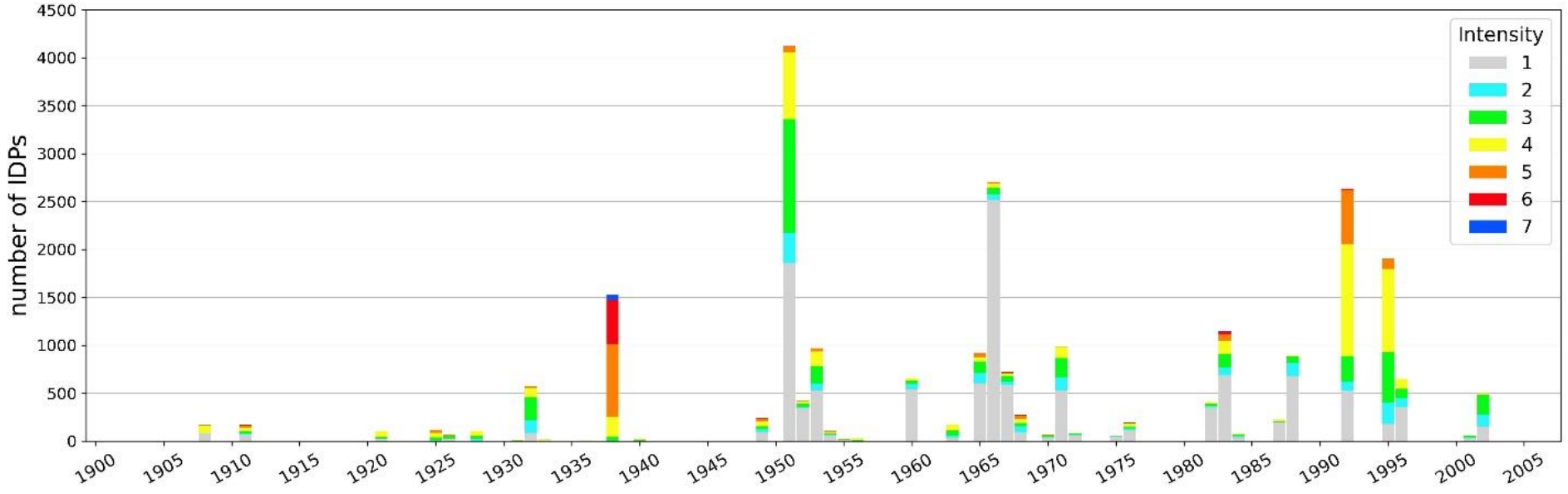
NEW: Compilation of all Belgian macroseismic data

PhD Neefs 2025
Neefs et al. 2024

BTM Belgian Traditional Macroseismic database

Royal Observatory of Belgium

- 1900 – 2002
- 80 felt events
- 23,950 IDPs
  → With sources!



1938 1951 60-70s Hainaut region 1992 Roermond 1995 Le Roeulx 2002 Alsdorf

J Seismol
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RESEARCH

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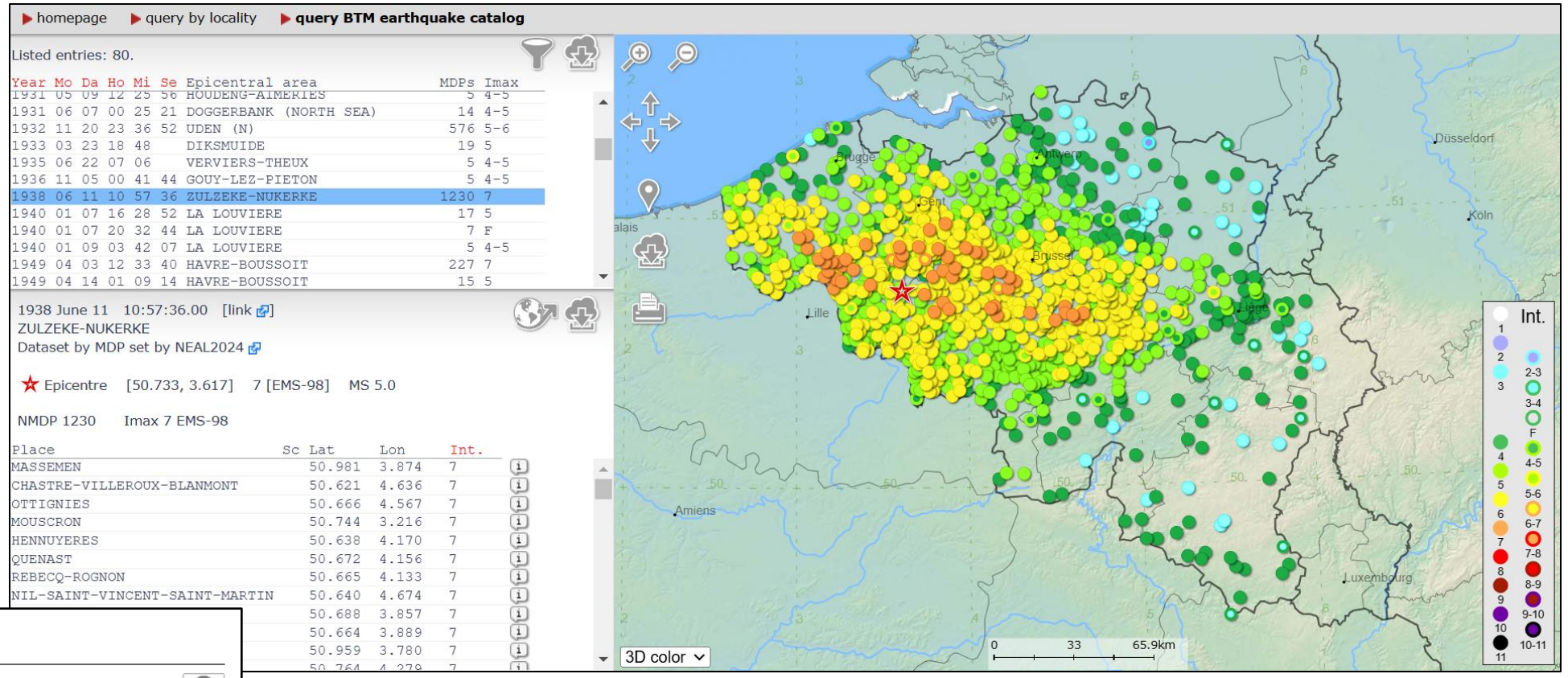


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RESEARCH

The Belgian traditional macroseismic (BTM) database of the twentieth century

Ben Neefs · Koen Van Noten · Kris Vanneste · Thierry Camelbeeck

https://seismology.be/midop

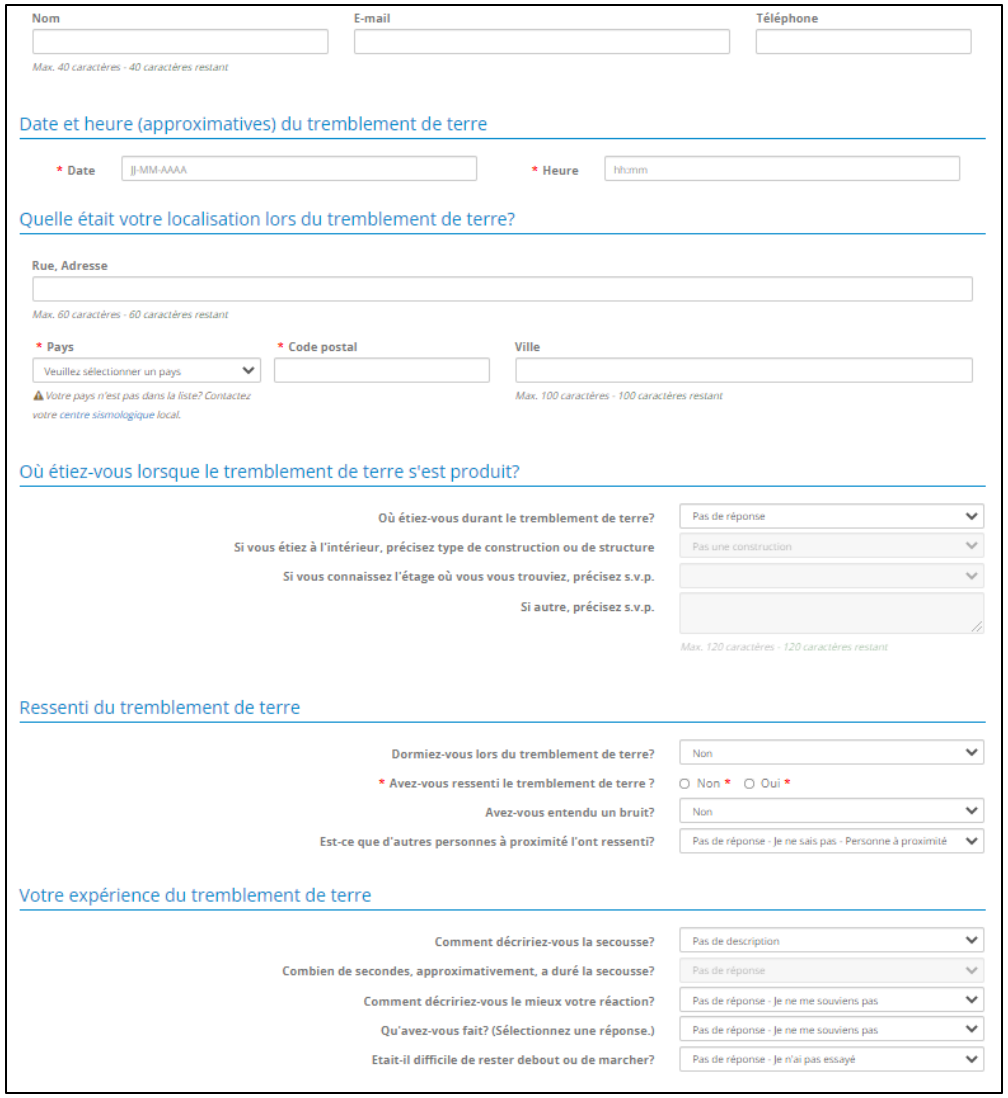
NEW: Compilation of all Belgian macroseismic data

PhD Neefs 2025
Neefs et al. 2024

BOM Belgian Online Macroseismic database

Royal Observatory of Belgium

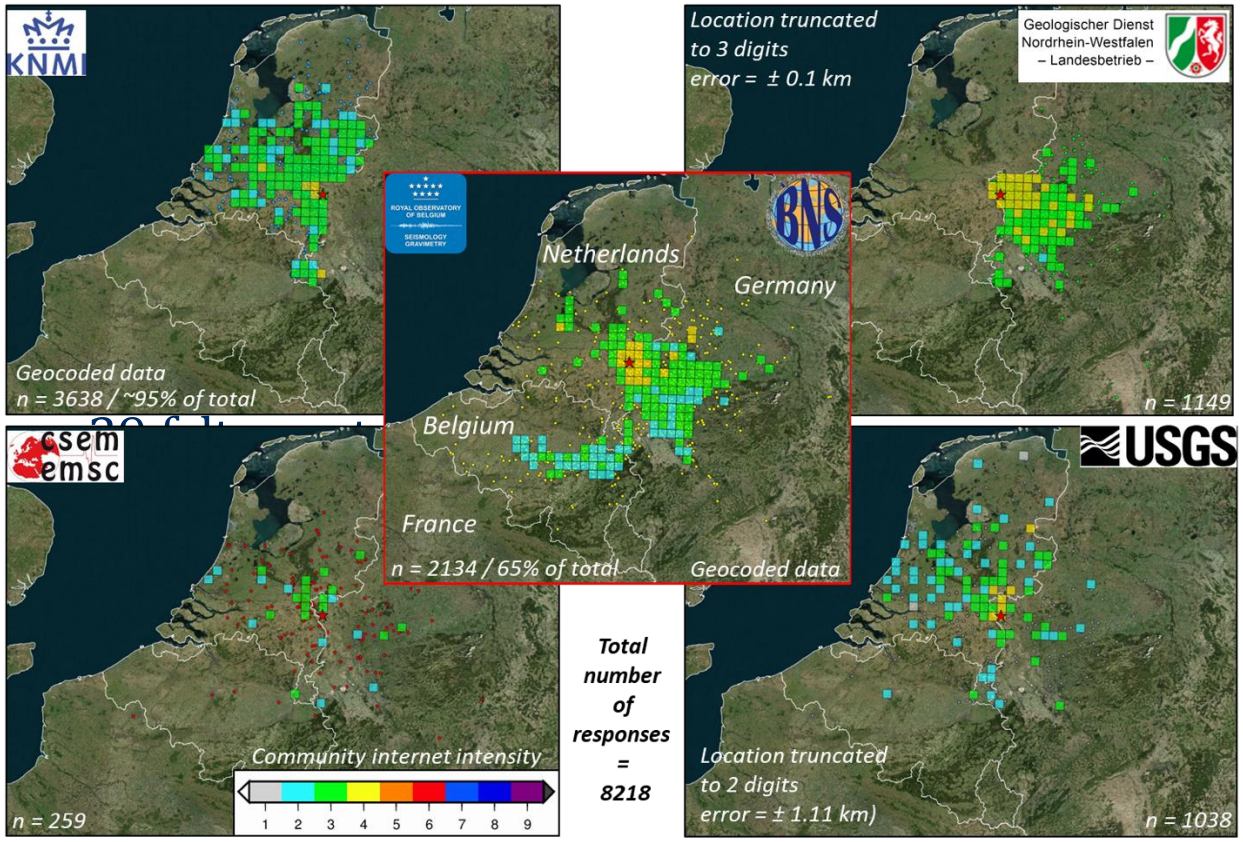
- 2002 – 2025
- USGS DYFI approach
- CWS = 5 * felt + motion + reaction + 2 * stand + 5 * shelf + 2 * picture + 3 * furniture + 5 * damage
- for CWS > 6.53: CII = 3.40 * loge(CWS) - 4.38
  for any “felt” response and CWS < 6.53: CII = 2
  for “not felt” responses: CII = 1
- 39 felt events
- 21,670 individual reports -> 1,220 IDPs
- 3 M4, 3 M3, 14 M2, 16 M1, 3 M0.9



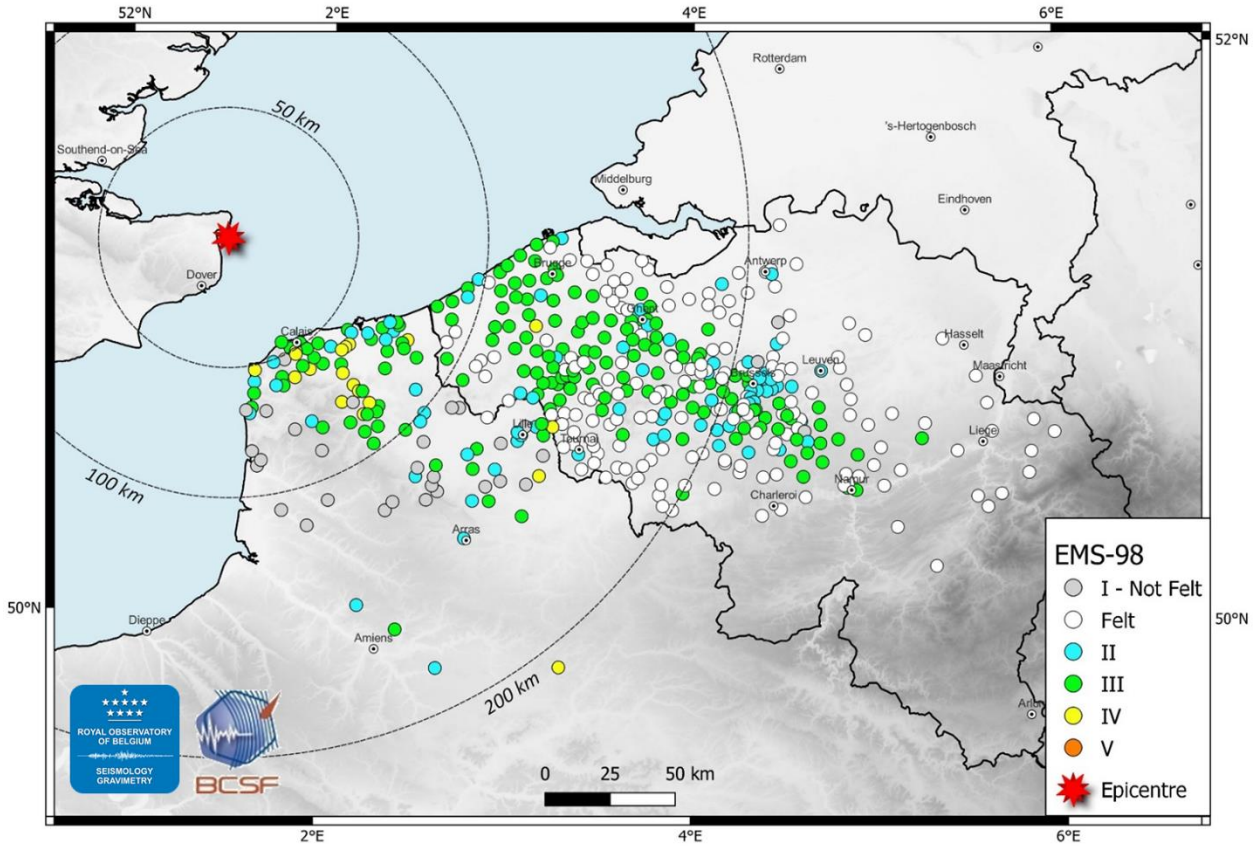
NEW: Compilation of all Belgian macroseismic data

Cross-border macroseismic initiatives

Royal Observatory of Belgium



BE – DE – NL - FR collaboration
e.g. 2011 Goch Mw 3.7



BE – FR collaboration
e.g. 2015 Ramsgate Mw 3.7

Van Noten et al. 2017

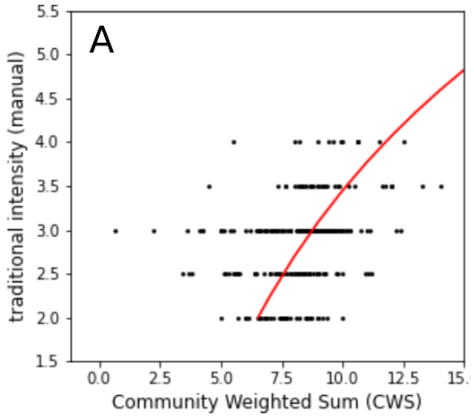
BOM vs BTM Eschweiler-Alsdorf 2002, ML 4.9

Royal Observatory of Belgium

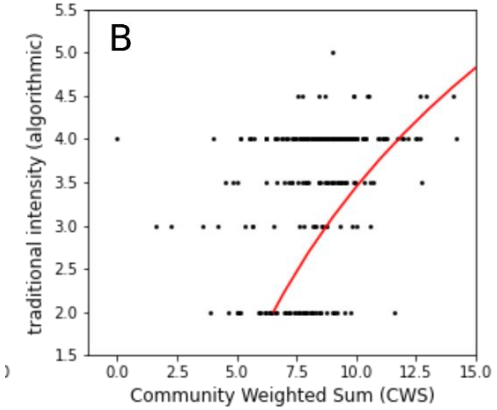
Traditional

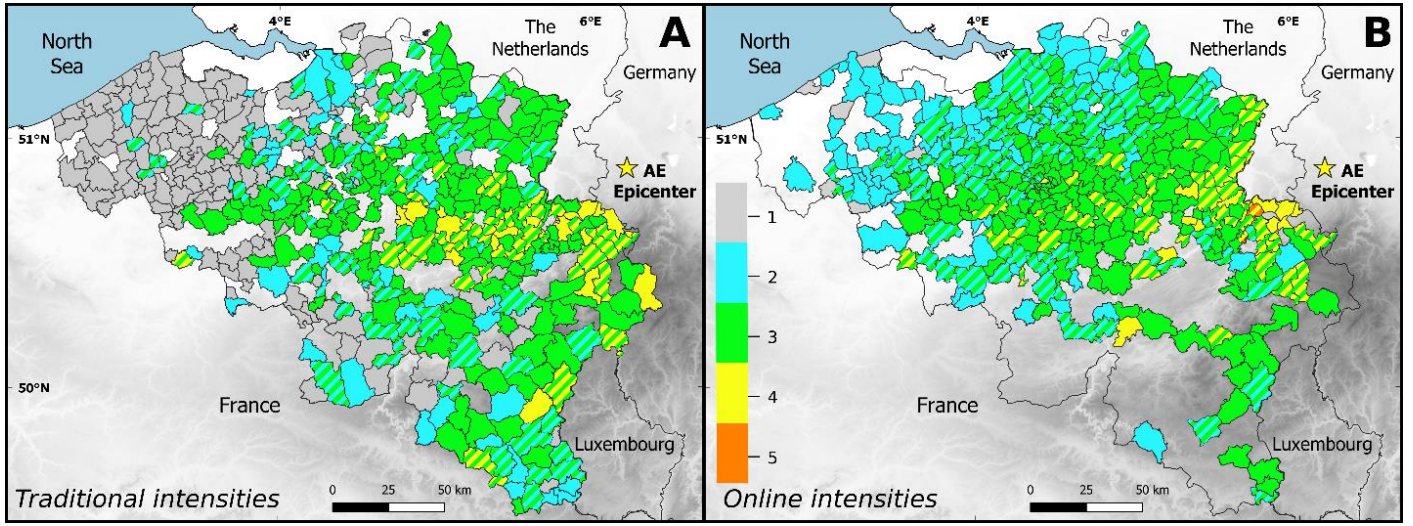
DYFI

Expert / Manual

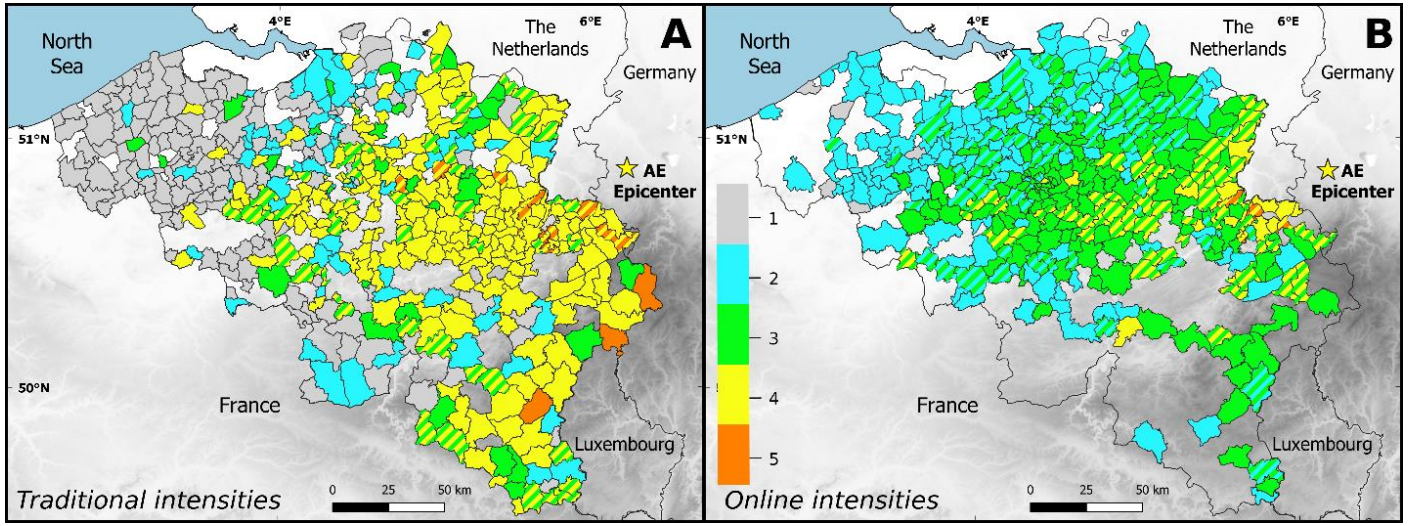


Automated algorithm from an expert approach





DYFI averaging



DYFI aggregation

Smaller macroseismic field
Higher intensities

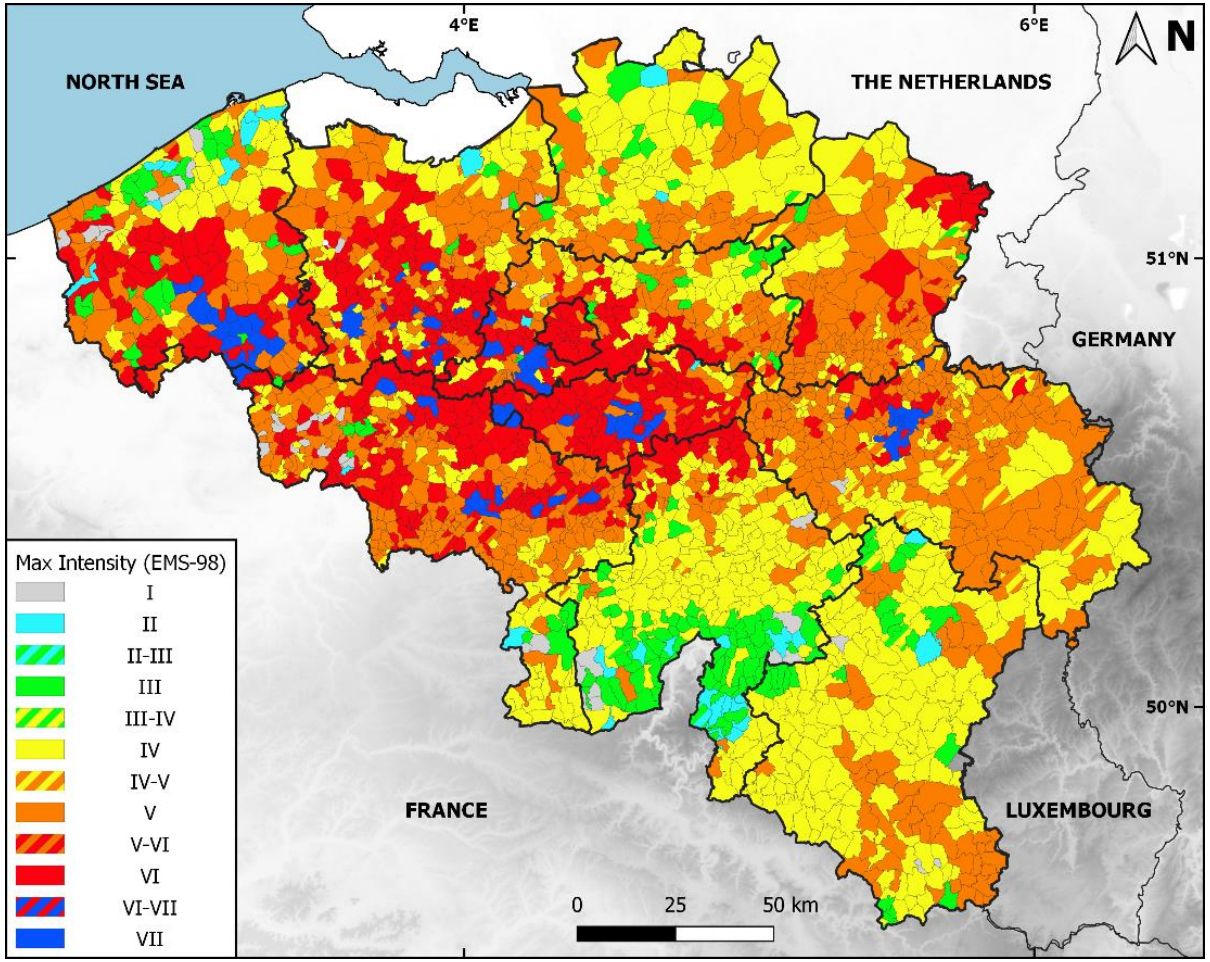
Larger macroseismic field
Lower intensities

PhD Neefs 2025

125 year maximum intensity map

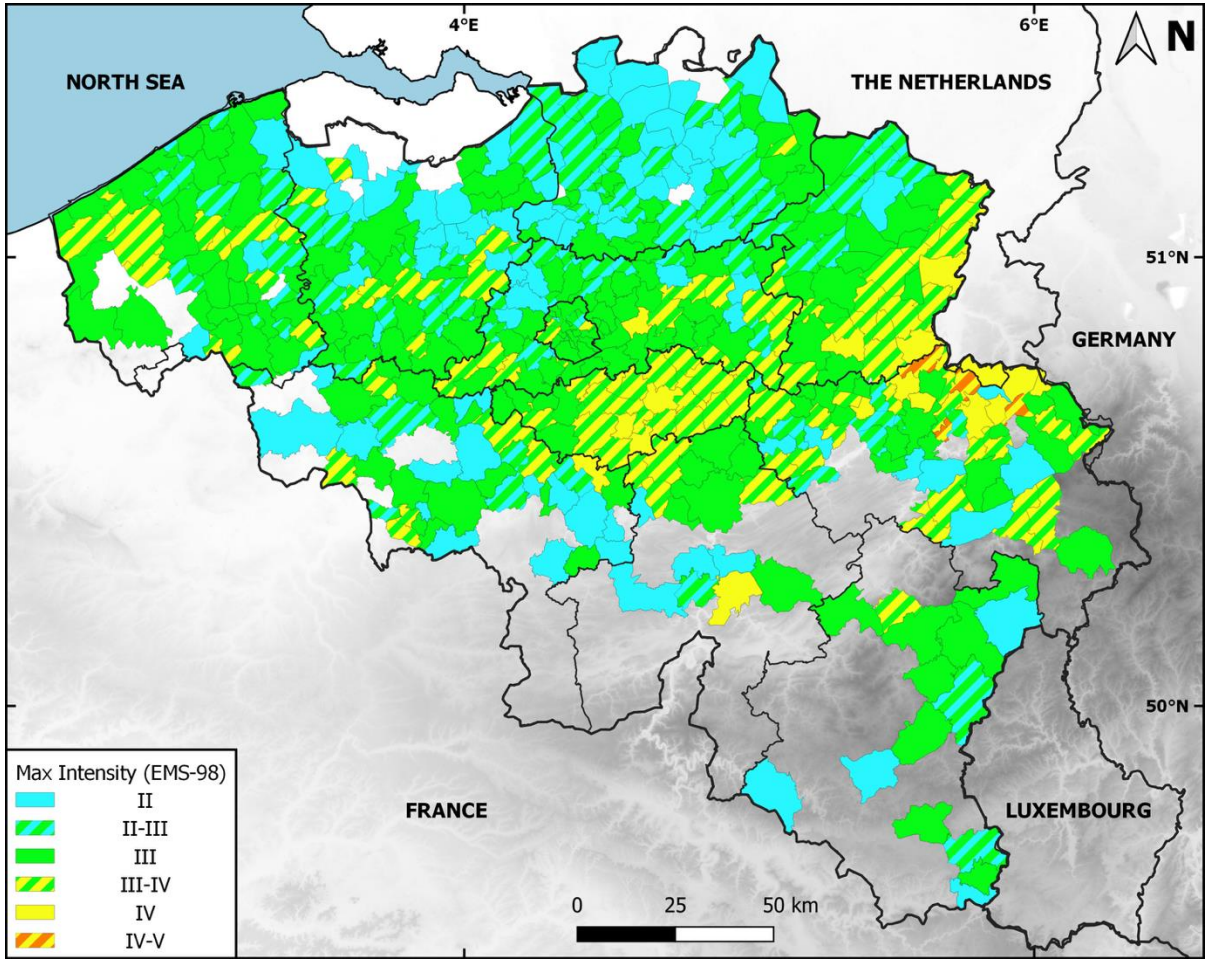
Royal Observatory of Belgium

Traditional



1900 - 2002

DYFI



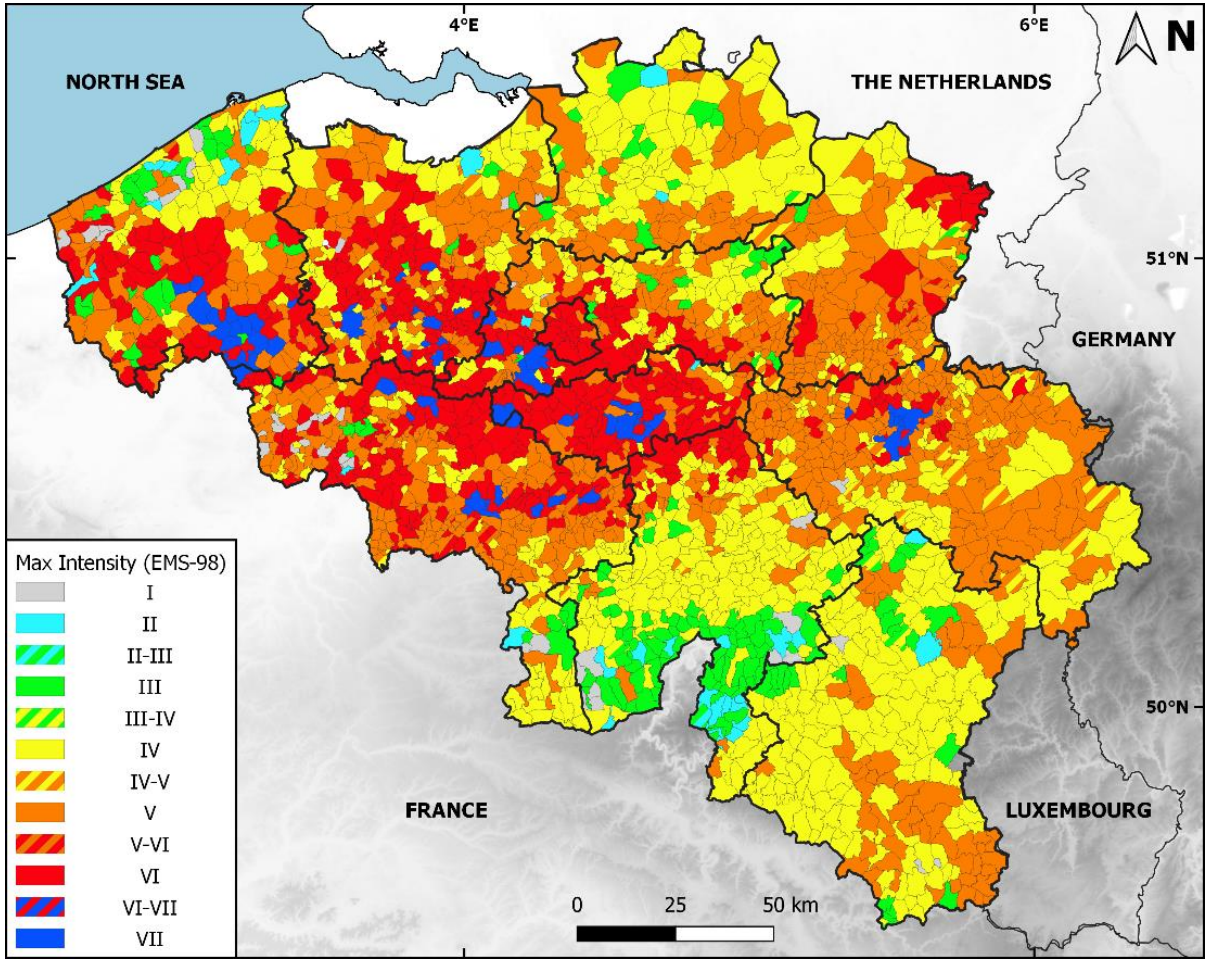
2002 - 2024

PhD Neefs 2025

125 year maximum intensity map

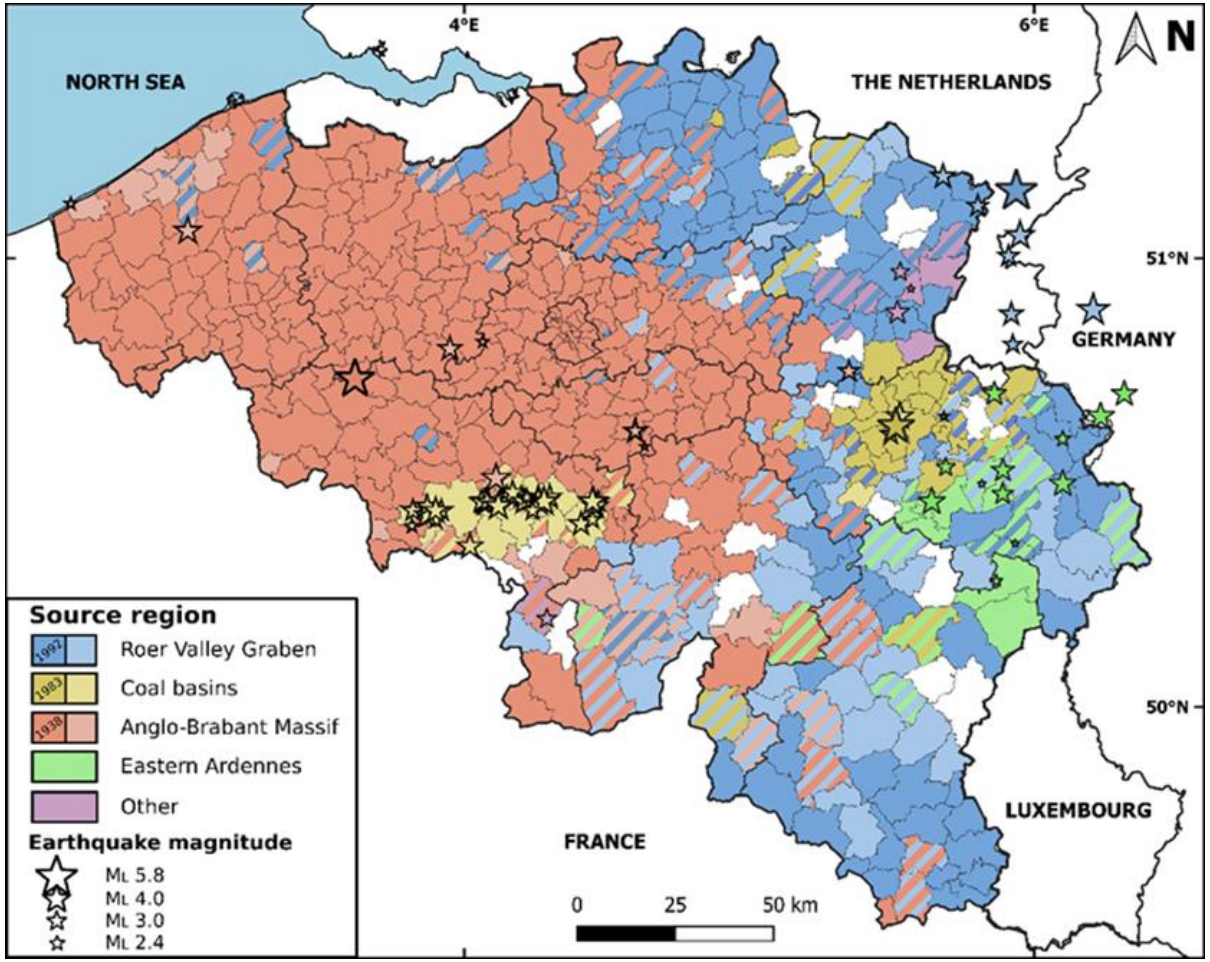
Royal Observatory of Belgium

Traditional



1900 - 2002

Source of the Imax



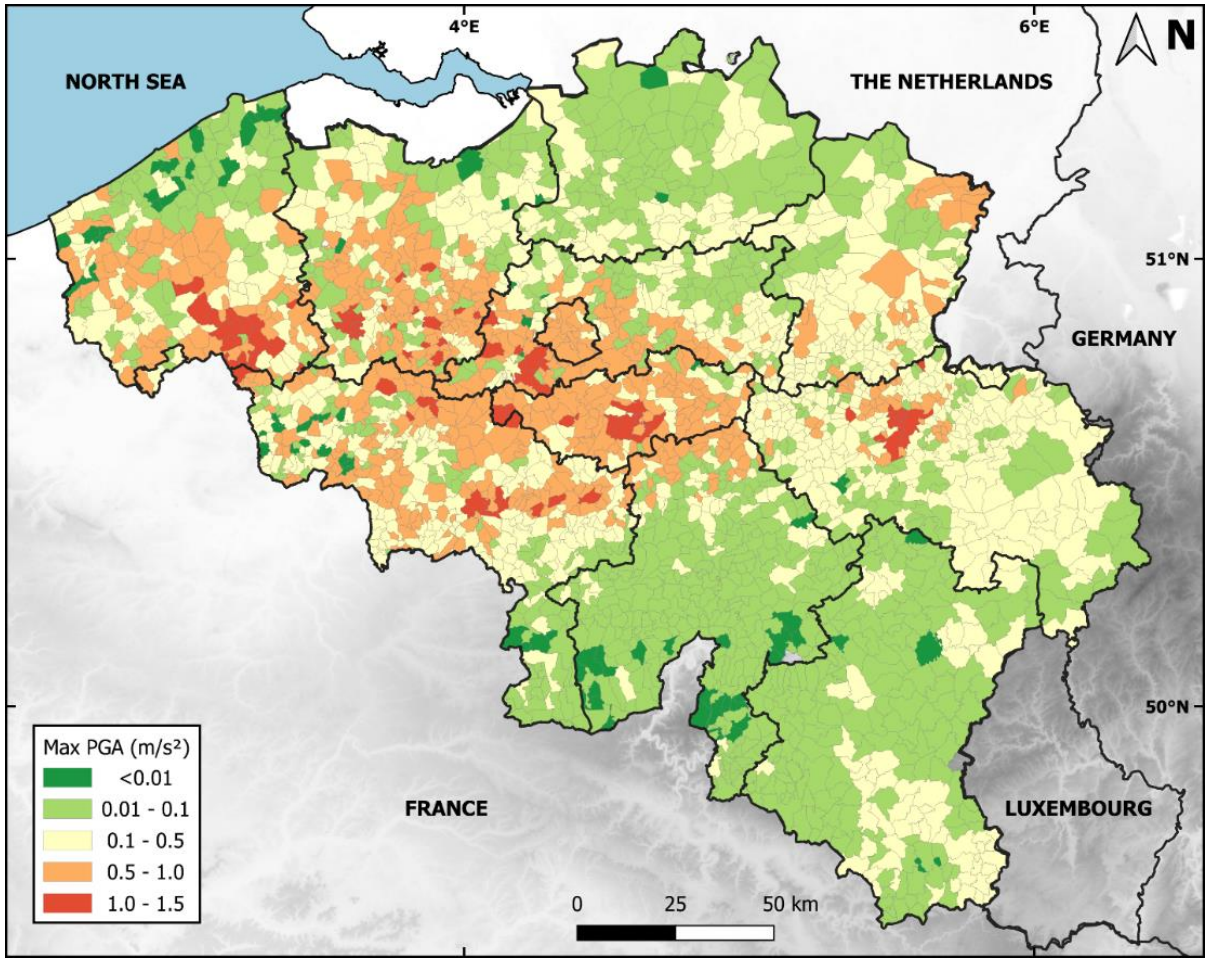
- ML 5.6 Zulzeke-Nukerke 1938 earthquake **(RED)**
- ML 5.8 Roermond 1992 earthquake **(BLUE)**
- ML 5.0 Liège 1983 earthquake & coal mining-triggered **(YELLOW)**

PhD Neefs 2025

125 year maximum intensity “hazard” map ?

Royal Observatory *of* Belgium

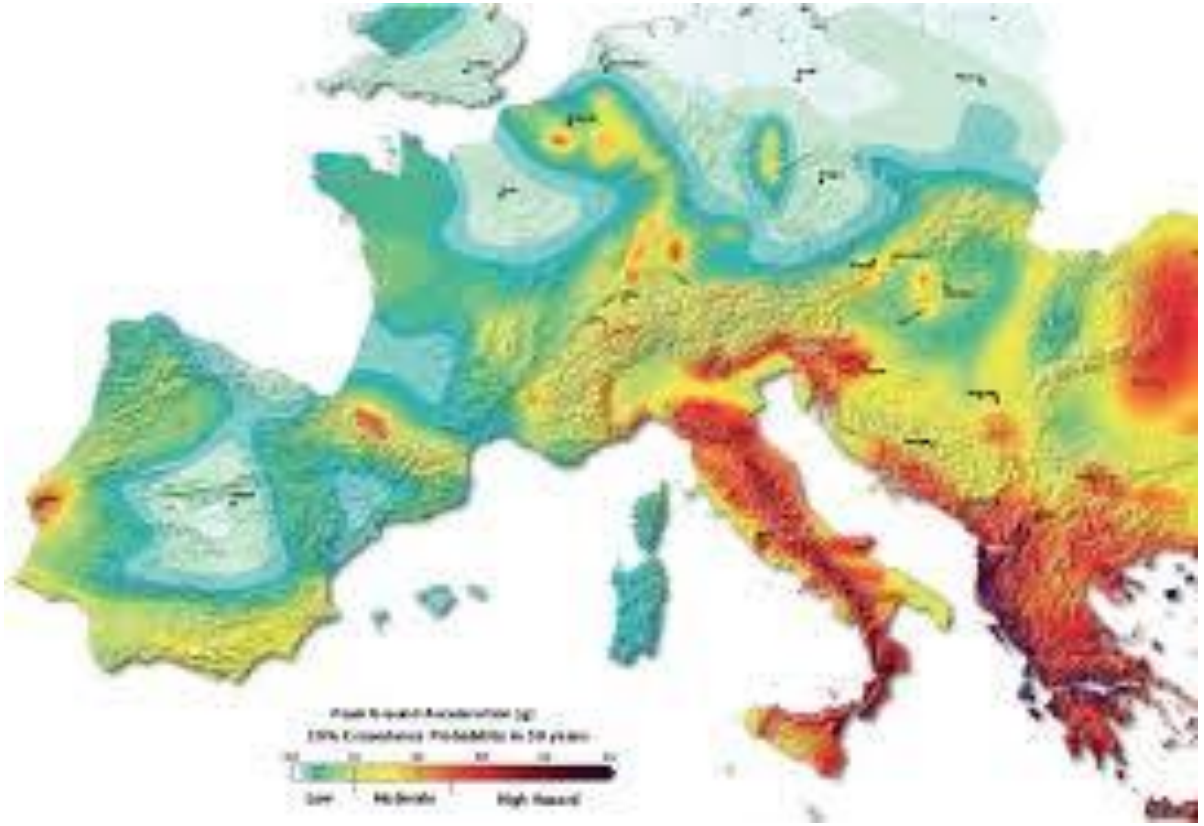
125 year maximum PGA map from Imax



Intensity -> PGA: GMICE of Atkinson and Kaka (2007)

-> Includes site effects

Mean seismic hazard map, **475**-year return period (PGA)



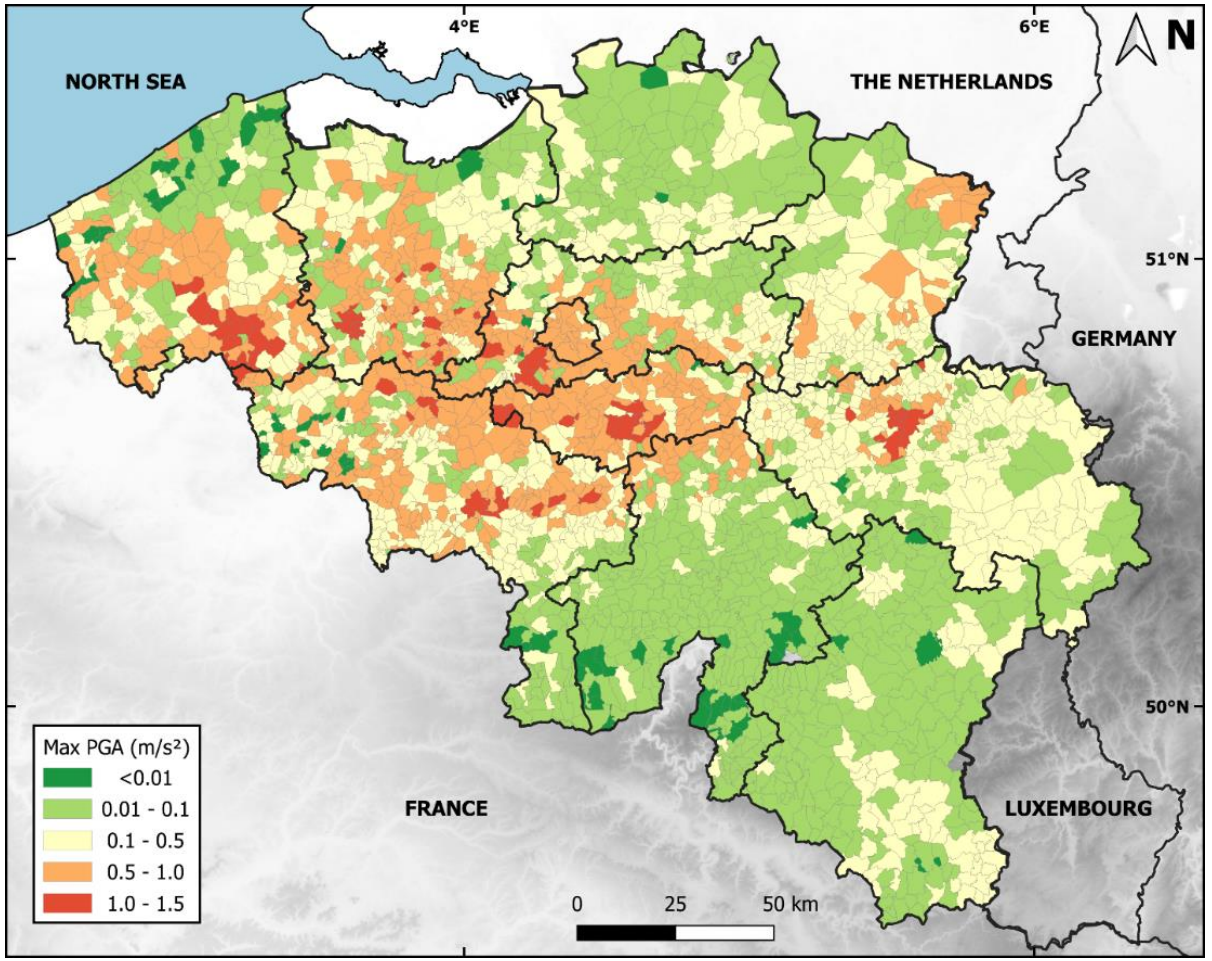
For standard rock conditions (V_{S30} ~800m/s)

-> No site effects

PhD Neefs 2025

125 year maximum intensity “hazard” map ?

125 year maximum PGA map from Imax



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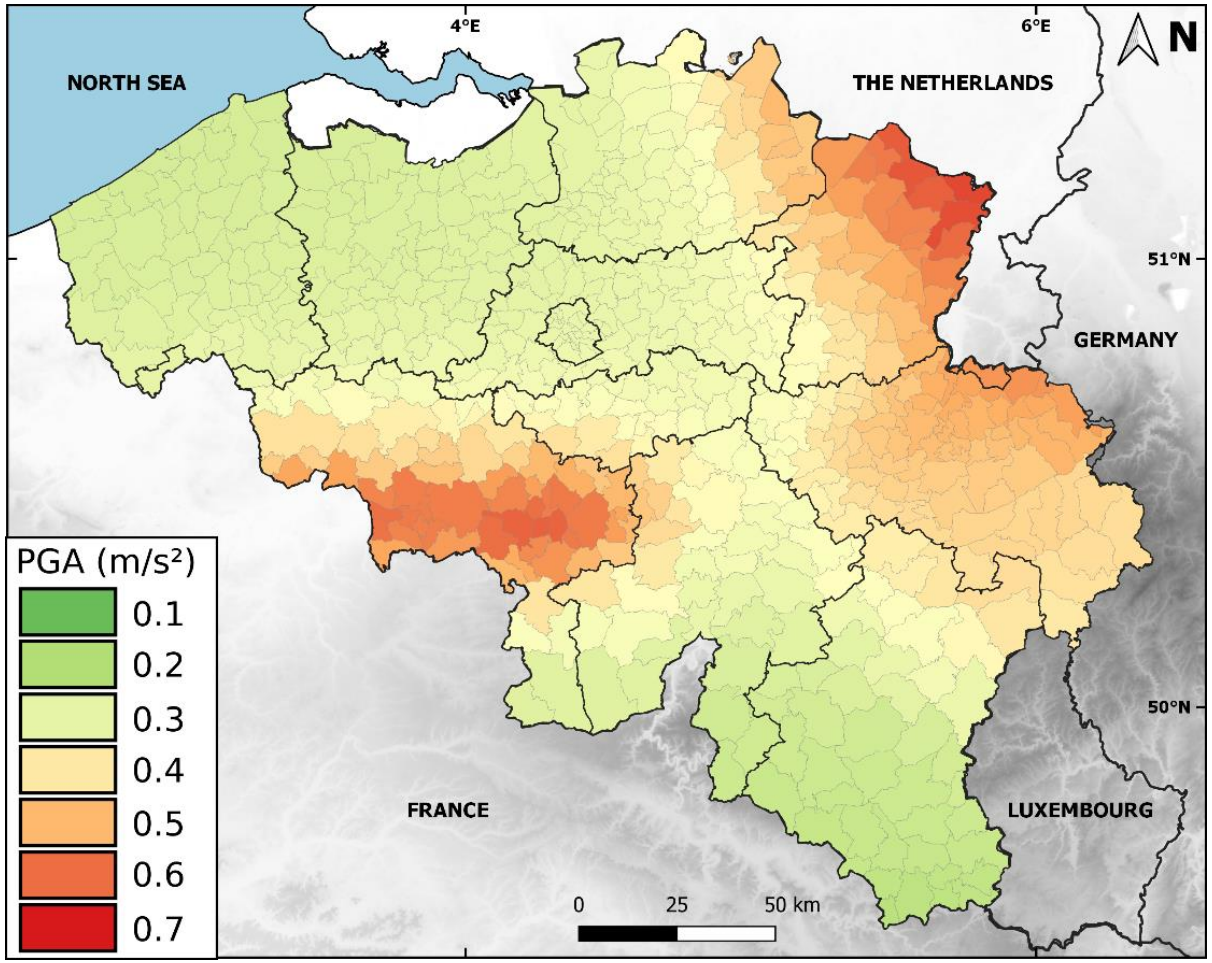


For standard rock conditions (V_{S30} ~800m/s)

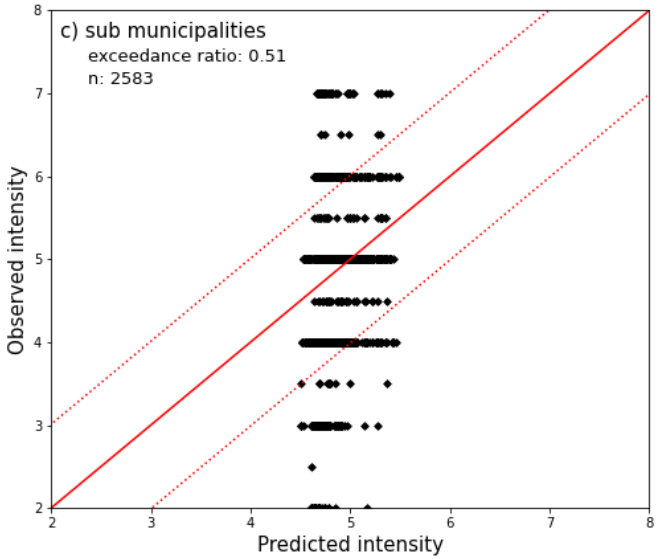
-> No site effects

PhD Neefs 2025

Performance of 125 yr Imax -> PGA map

Royal Observatory of Belgium

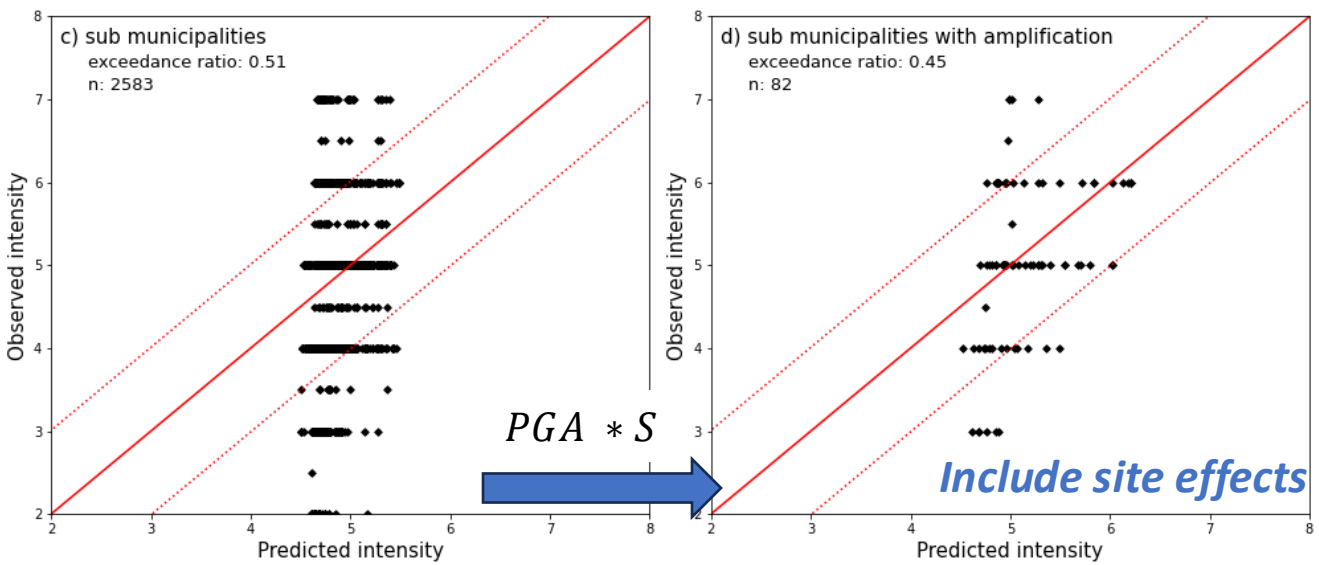
Site characterization
EPOS.BE



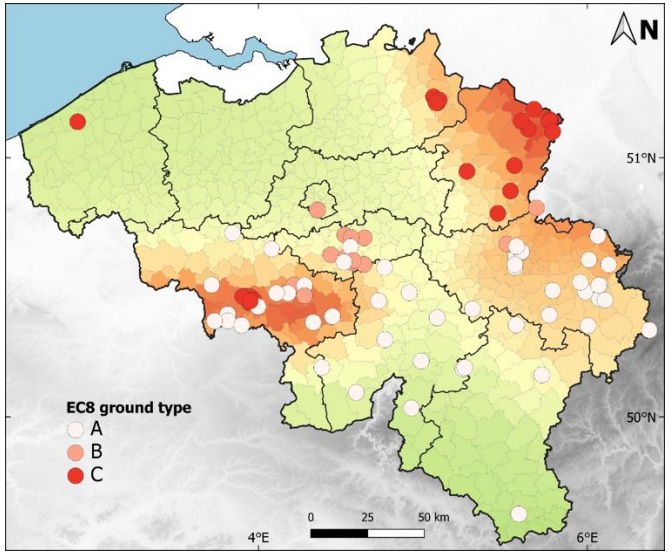
$$Intensity = 2.65 + 1.39 * \log_{10} PGA$$

Performance of 125 yr Imax -> PGA map

Royal Observatory of Belgium



$$Intensity = 2.65 + 1.39 * \log_{10} PGA$$



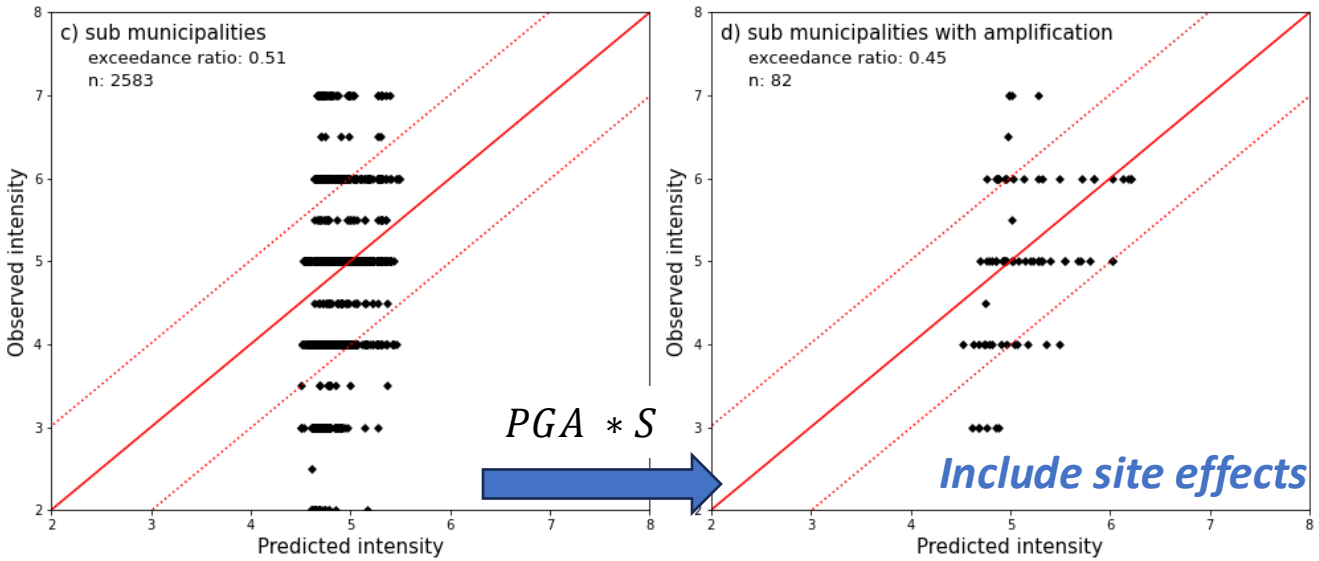
Vs30
EPOS.BE

Site characterization
Belgian Network
Van Noten *et al.* 2023
in EPOS.BE

PhD Neefs 2025

Performance of 125 yr Imax -> PGA map

Royal Observatory of Belgium



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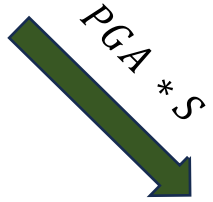
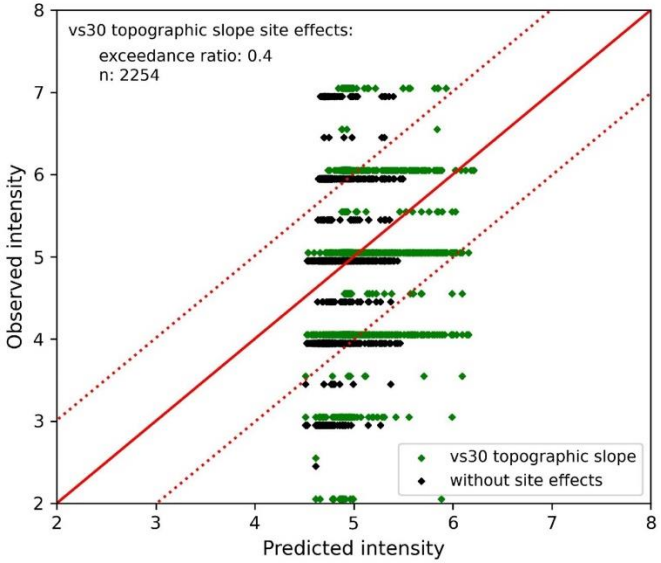
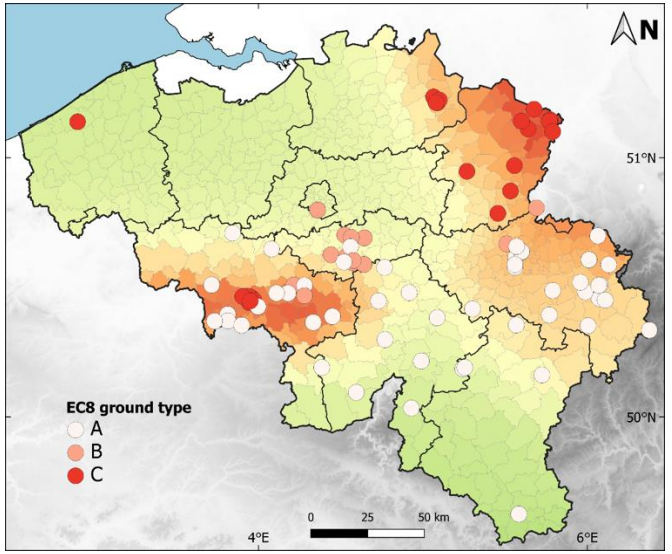
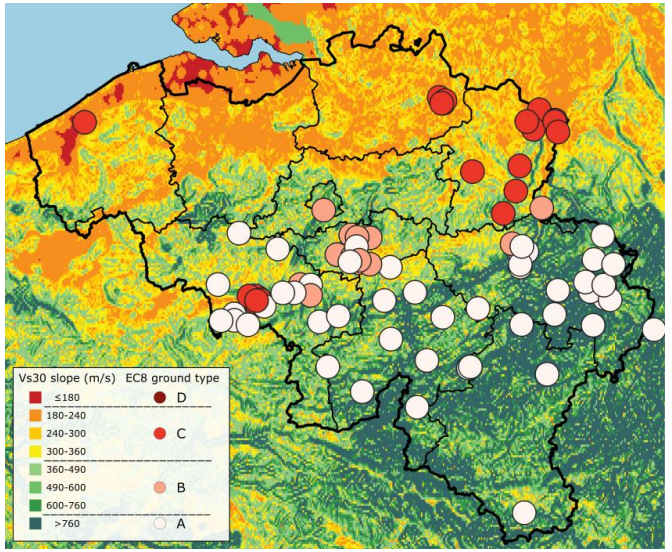


Include site effects from Vs30 from slope





Vs30 EPOS.BE



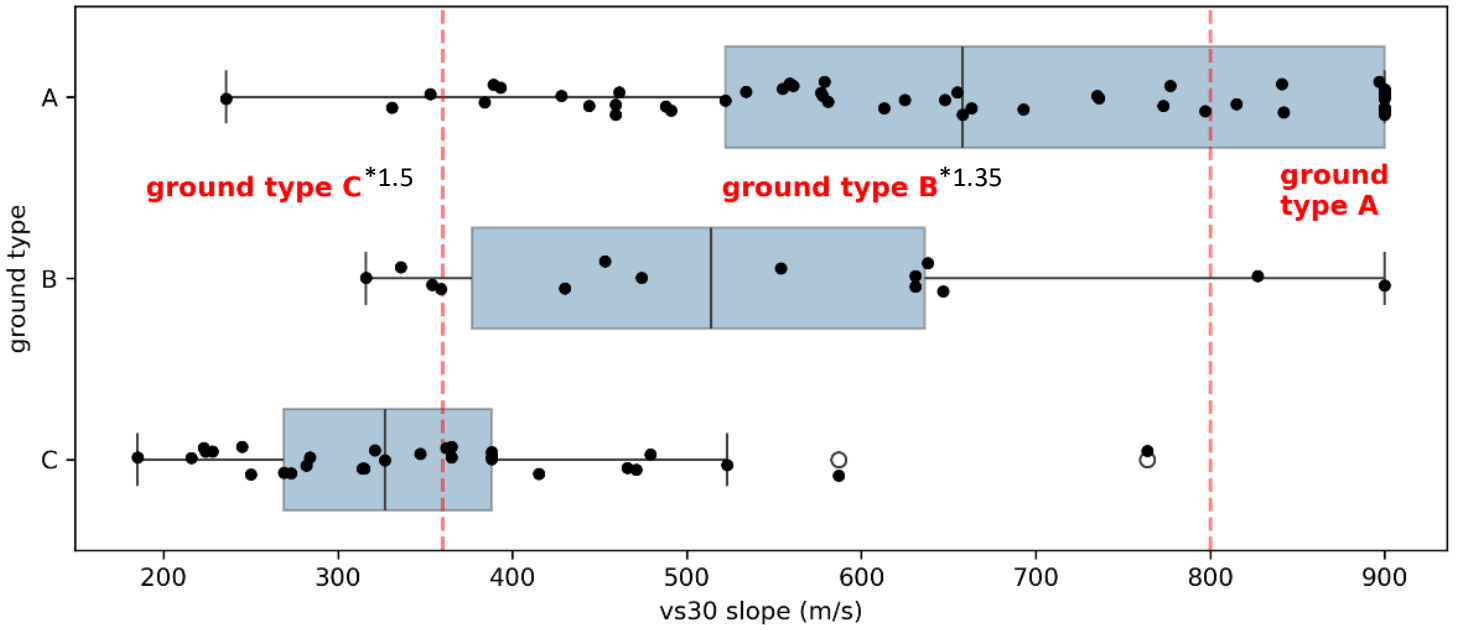
Vs30 slope

PhD Neefs 2025

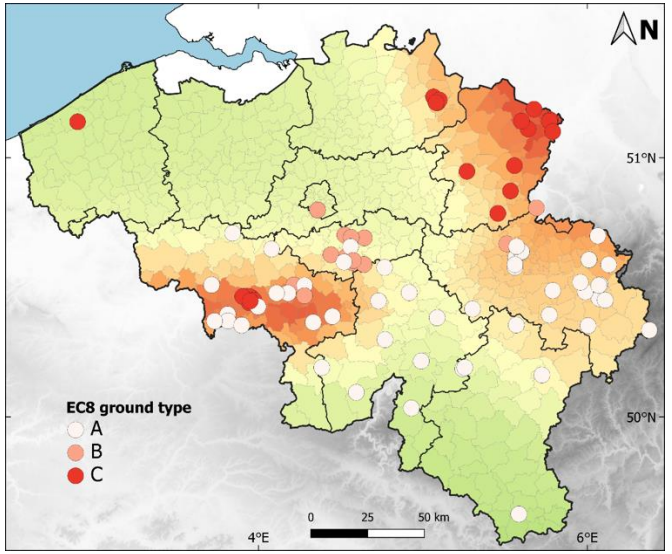
Impact of Vs30 from slope in Shakemap ?

Royal Observatory of Belgium

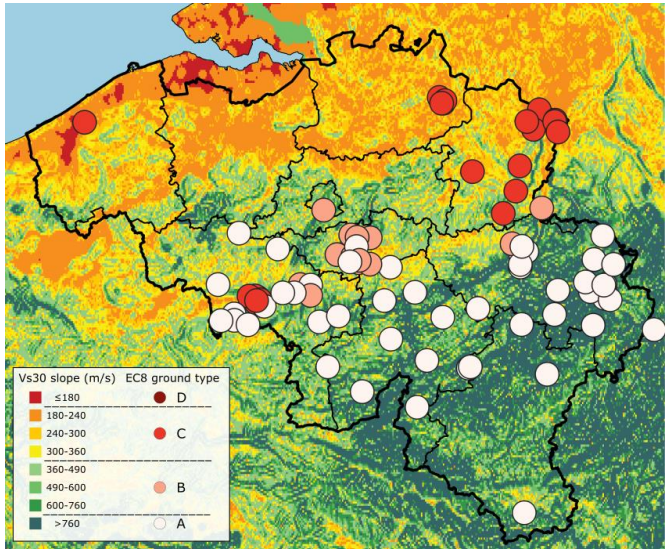
Measured Vs30



Vs30 slope



Vs30 EPOS.BE

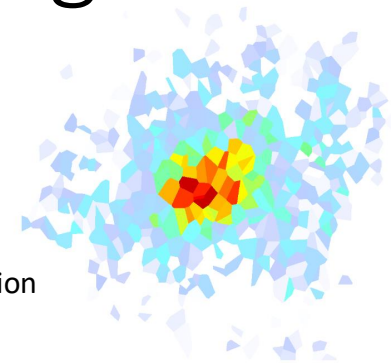


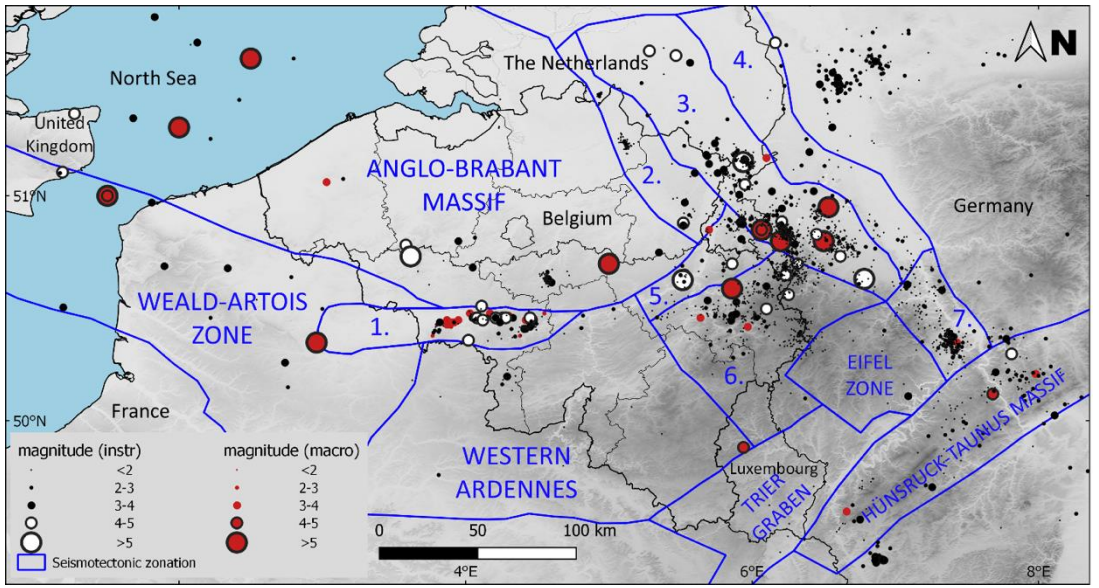
Vs30 slope

-> Impact on Shakemap, especially for macroseismic data on bedrock / ground type A

PhD Neefs 2025

BE ShakeMap configuration





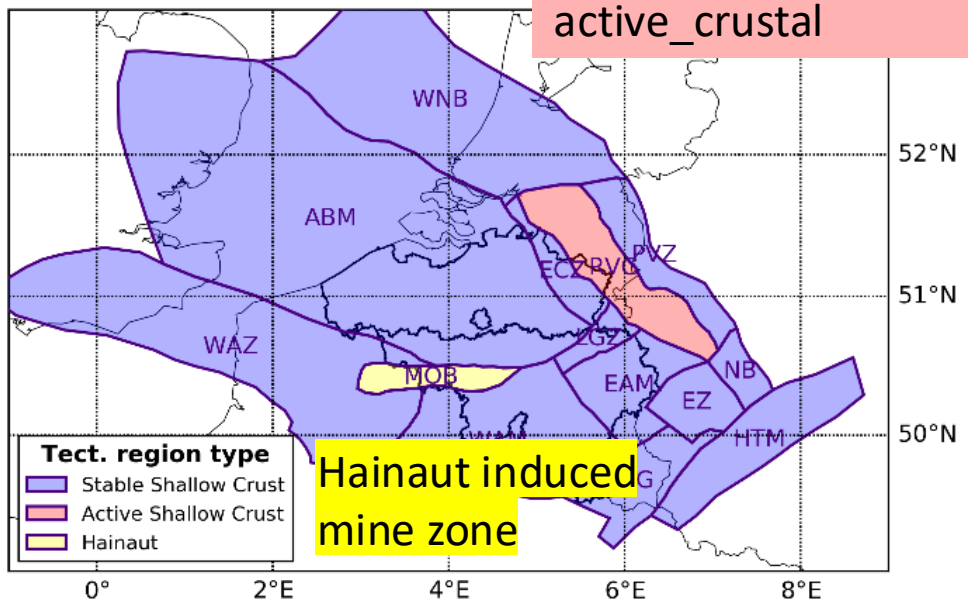
- Configuration files:
  - modules.conf:
    - Added GMPEs used in Belgian PSHA
    - Added Camelbeeck et al. (2022) IPE for Hainaut region
  - gmpe_sets.conf:
    - stable_continental_rock
    - active_crustal
    - Hainaut GMPE sets
    - Default GMPE set: stable_continental_rock
  - select.conf:
    - Added hainaut and rvrs layers
  - model.conf:
    - GMICE: AK07
    - Lowered min_nresp to 1
    - Lowered min_mmi_convert to 3
    - Set default GMPE set to stable_continental_share
    - Set default component to GEOMETRIC_MEAN

- Input files:
  - event.xml from BELSHAKE Database
  - traditional.xml or dyfi.xml
  - Instrumental.xml

Stable_continental_rock

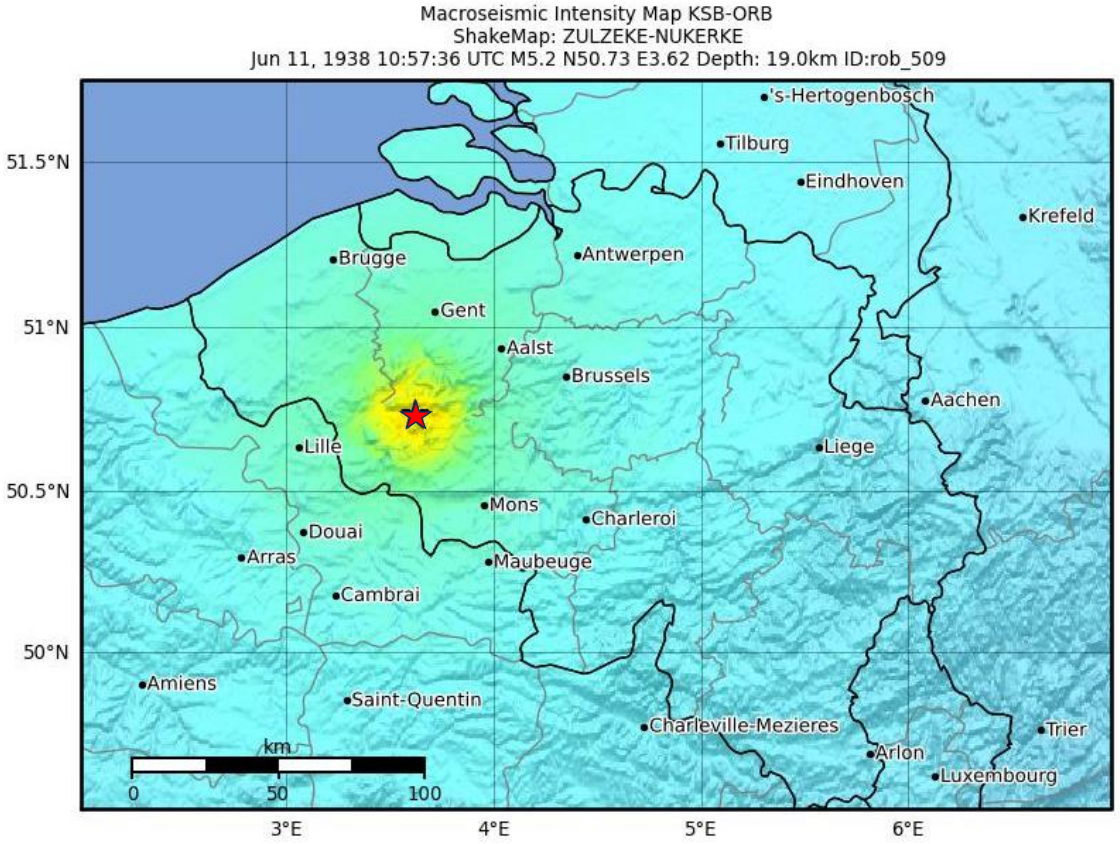
Roer Valley Graben
active_crustal

GMPE for Mw => 4 !



1938 Zulzeke-Nukerke M_w 5.2

Royal Observatory of Belgium

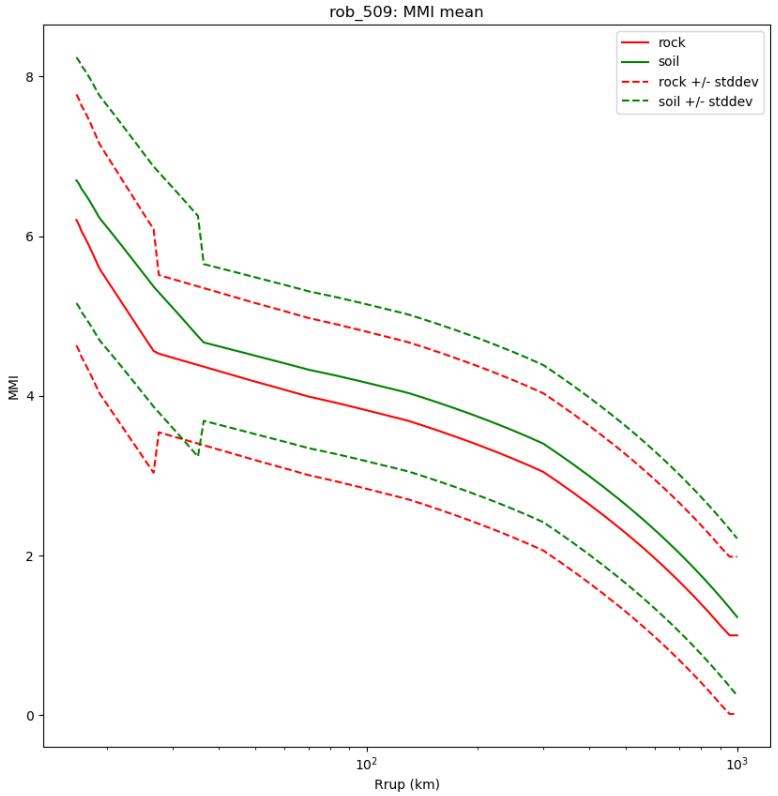


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.00663	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 1: Processed 2025-05-28T15:50:53Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

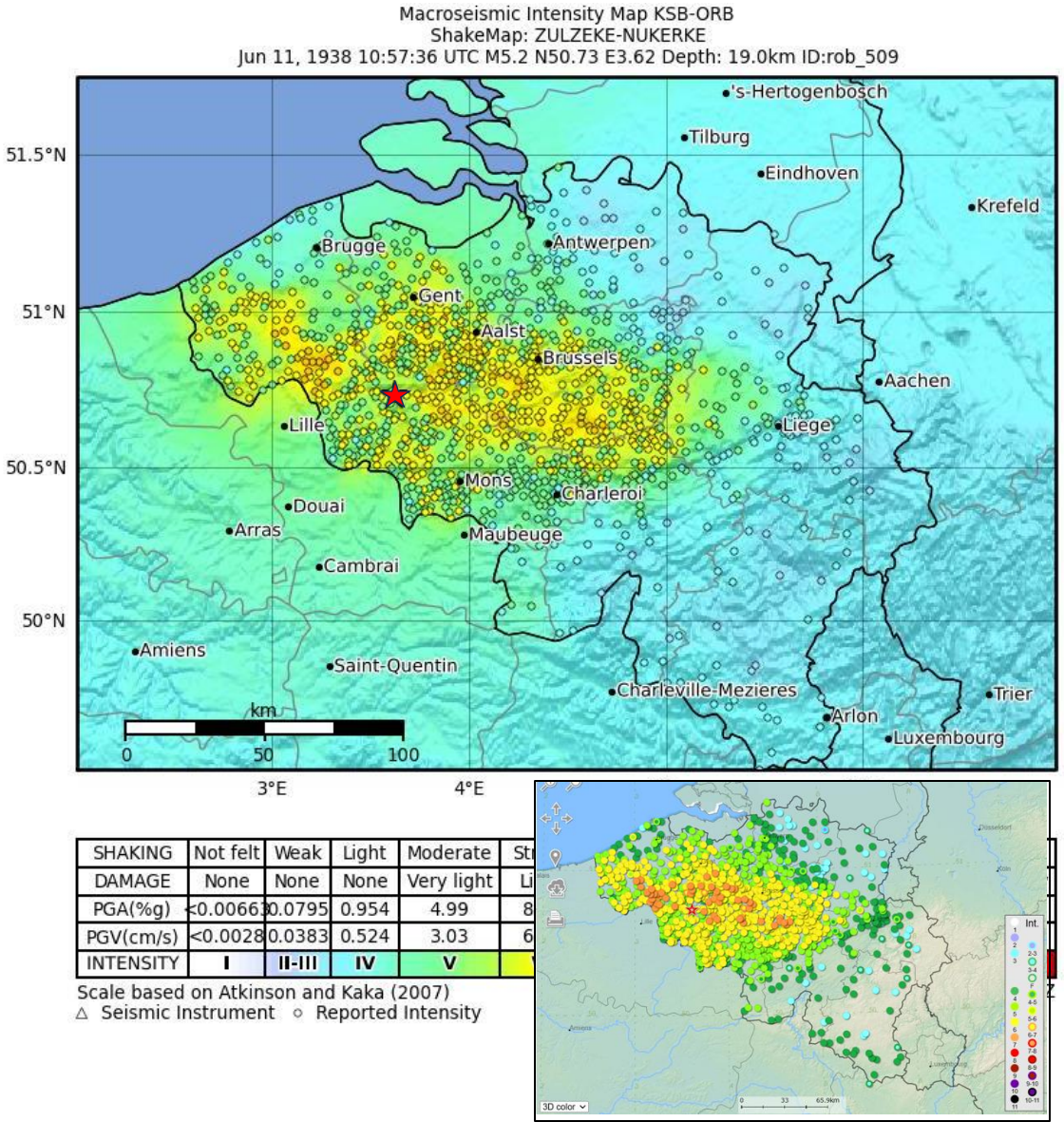
Only GMPE



Shakemap using traditional macroseismic data

1938 Zulzeke-Nukerke M_w 5.2

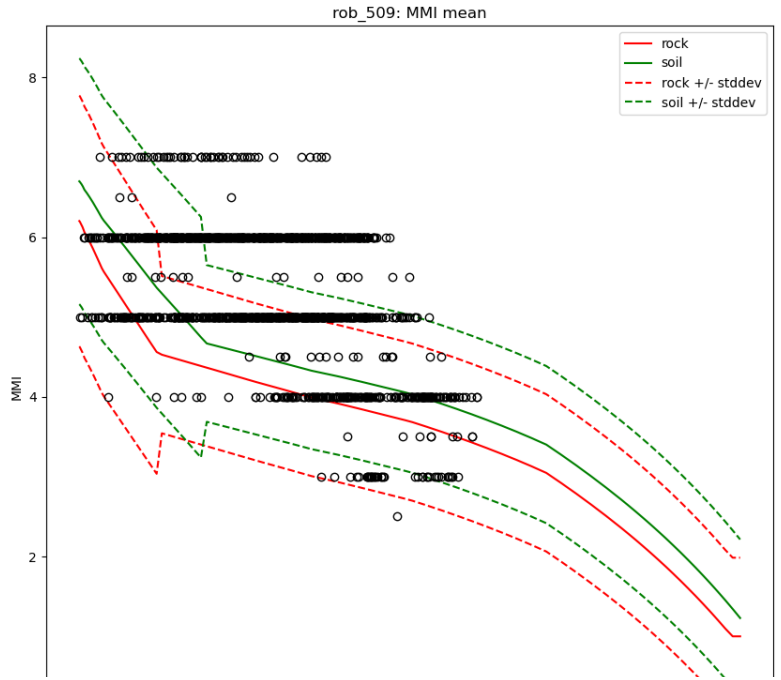
Royal Observatory of Belgium



SHAKING	Not felt	Weak	Light	Moderate	St
DAMAGE	None	None	None	Very light	Li
PGA(%g)	<0.0066	0.0795	0.954	4.99	8
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6
INTENSITY	I	II-III	IV	V	

Scale based on Atkinson and Kaka (2007)
△ Seismic Instrument ○ Reported Intensity

Traditional communal questionnaires



Site effects underestimated if only GMPE are used for historical events

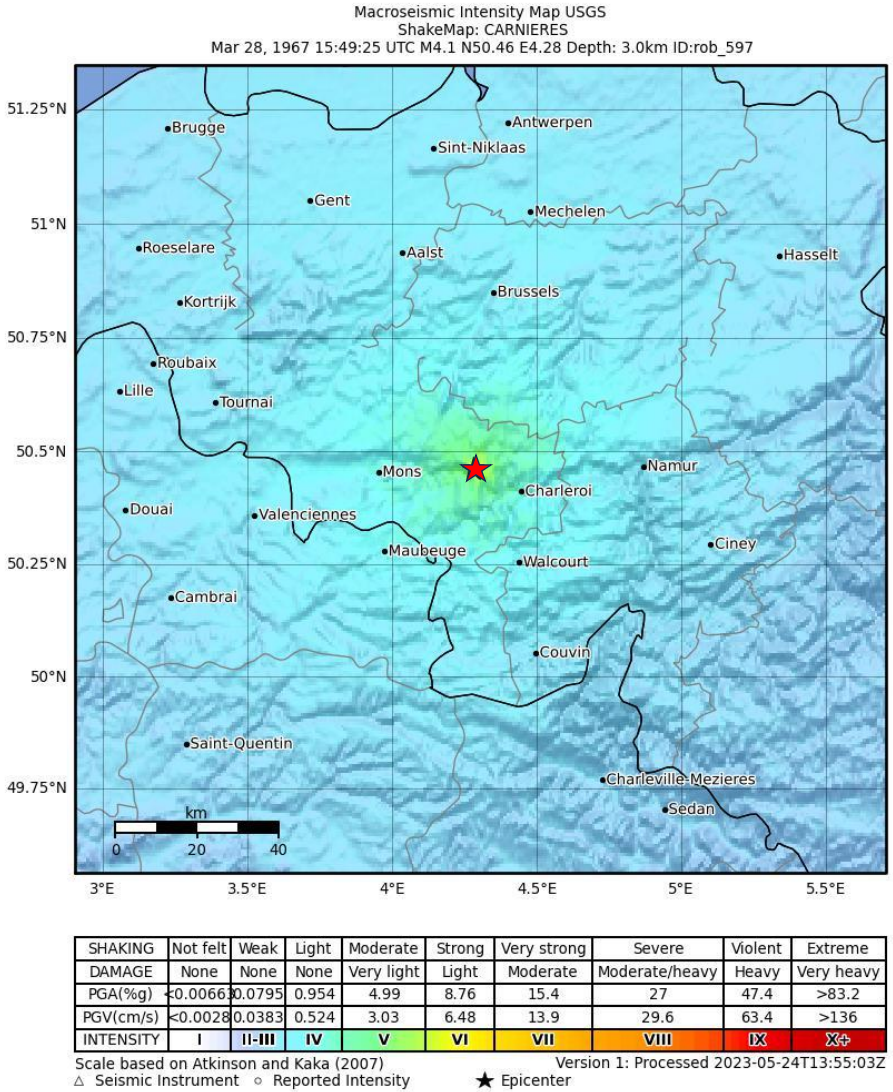
➔ *No station information for 1938*

➔ *Macroseismic field needed*

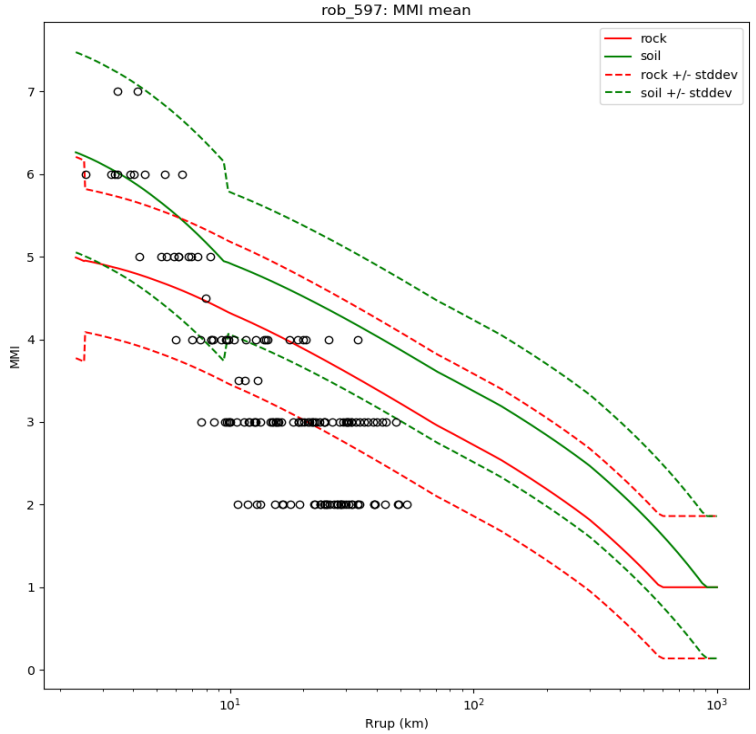
Shakemap using traditional macroseismic data

1967 Hainaut earthquake M_w 4.1

Royal Observatory of Belgium



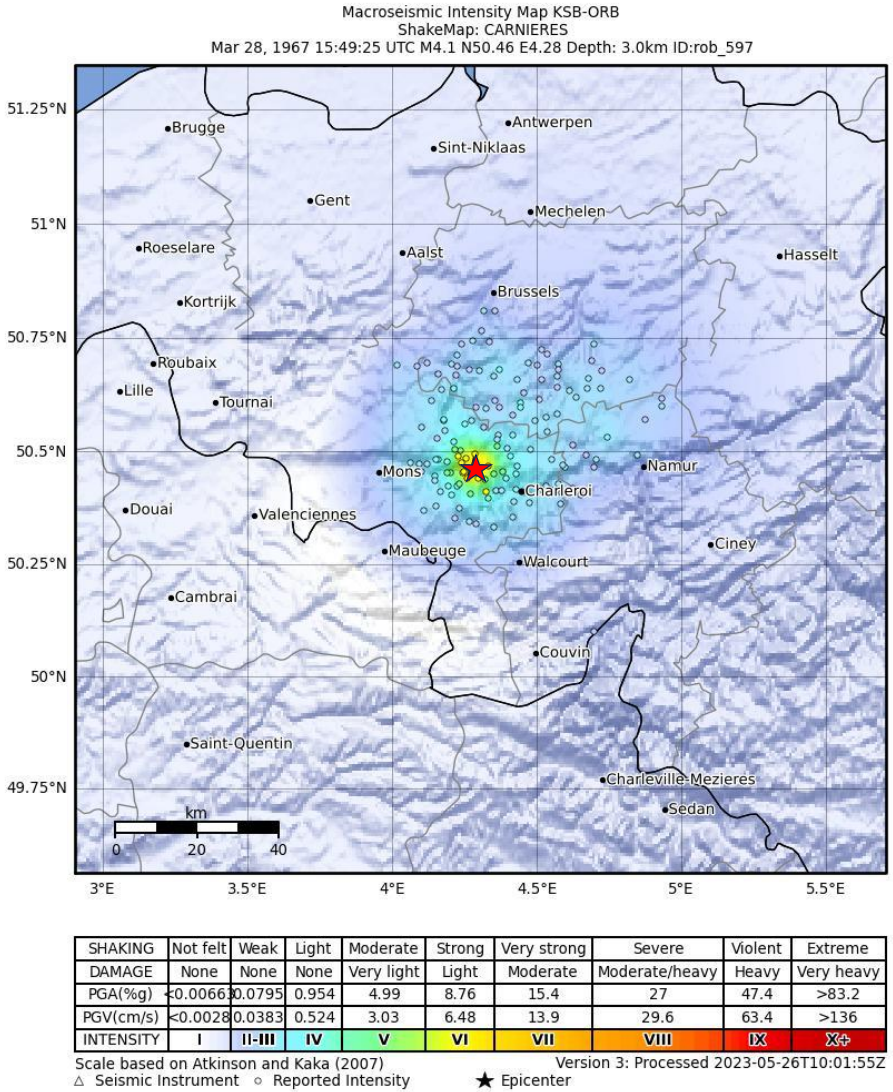
Default GMPE
+ IDP data



Shakemap using traditional macroseismic data

1967 Hainaut earthquake M_w 4.1

Royal Observatory of Belgium

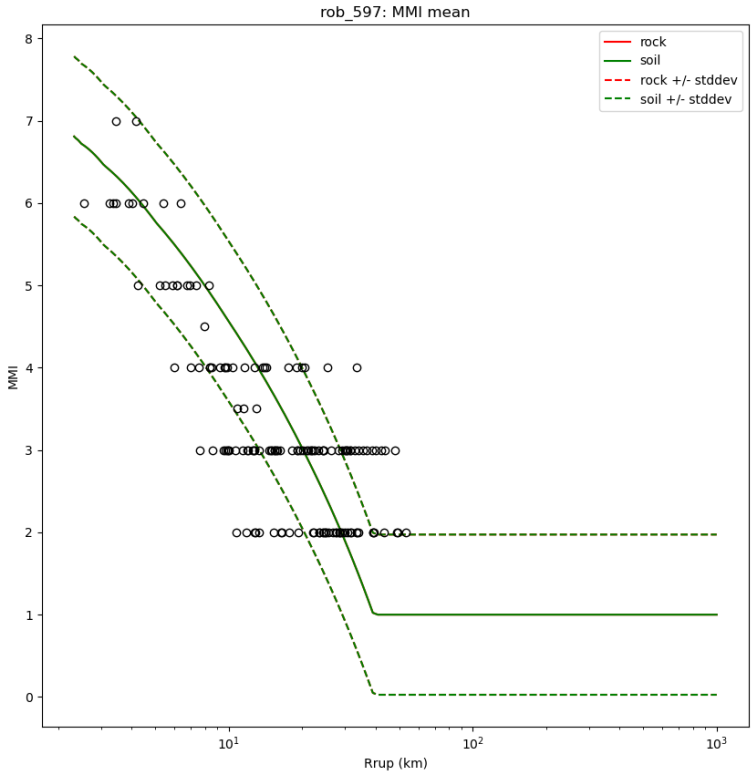


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.00663	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 3: Processed 2023-05-26T10:01:55Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Hainaut-specific GMPEs
+ Camelbeeck et al. (2022) Hainaut IPE (triggered seismicity)
+ IDP data



Site specific GMPEs work!

Shakemap using traditional macroseismic data

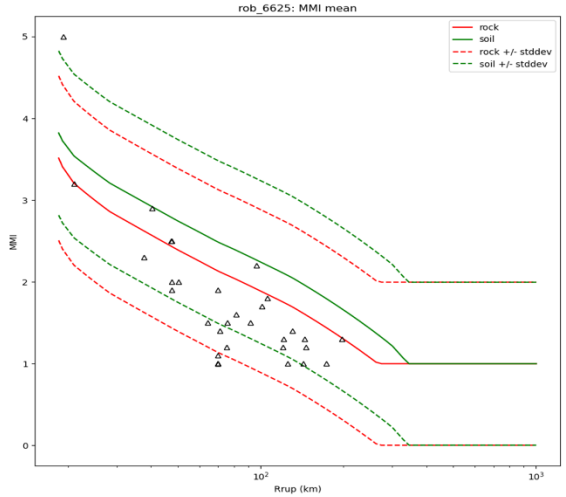
Royal Observatory of Belgium

2008 CSE M_w 2.9

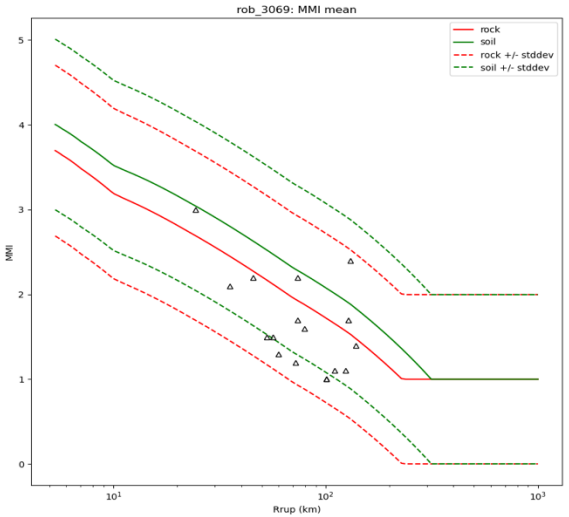
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 1: Processed 2025-05-28T13:32:47Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter



Only Instrumental



2018 Kinrooi M_w 3.0

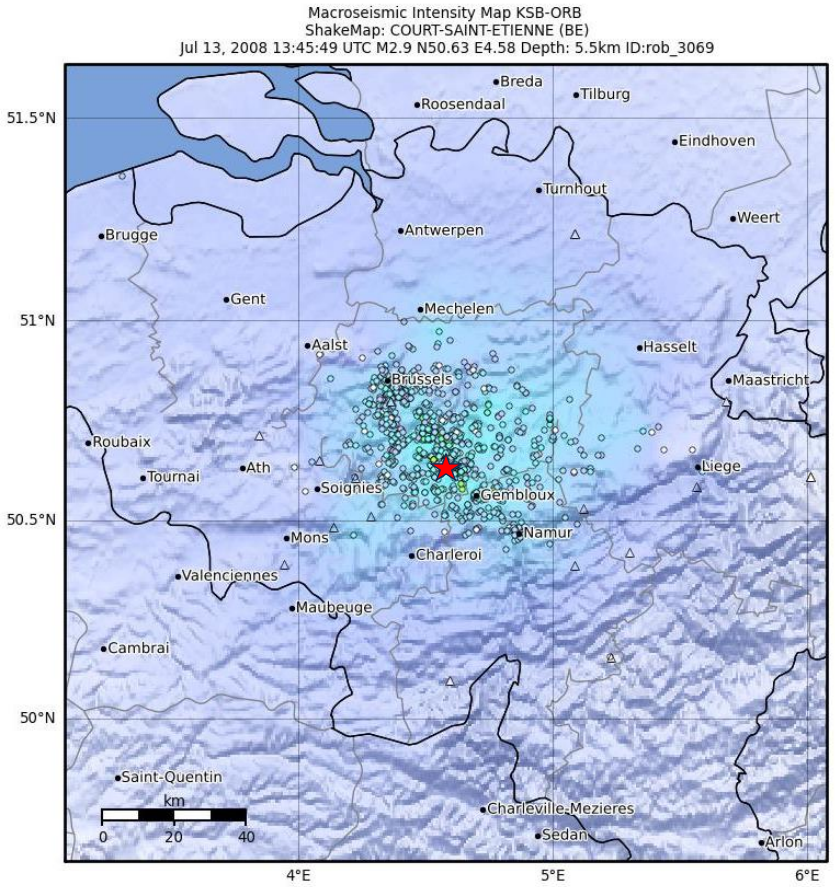
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 6: Processed 2025-05-28T13:14:09Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Shakemap using DYFI

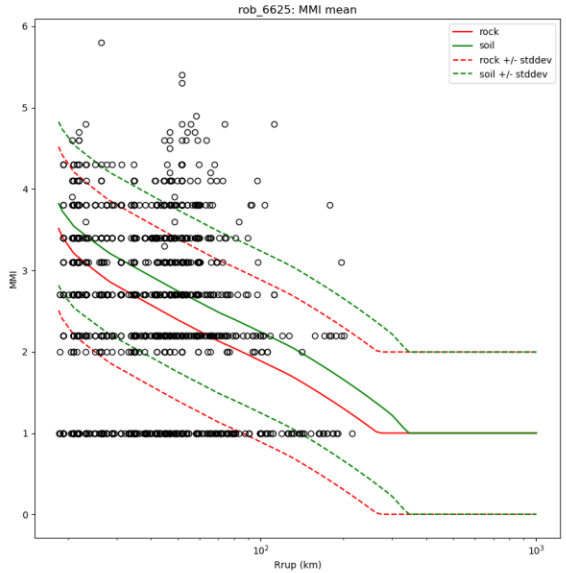
2008 CSE M_w 2.9



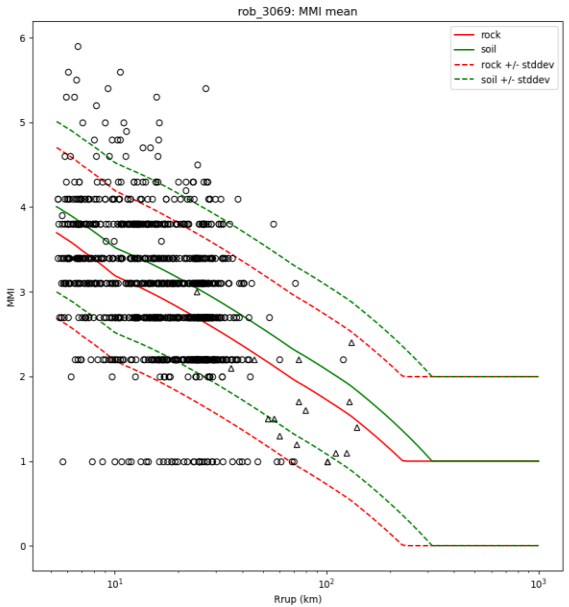
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 2: Processed 2025-05-28T13:38:33Z

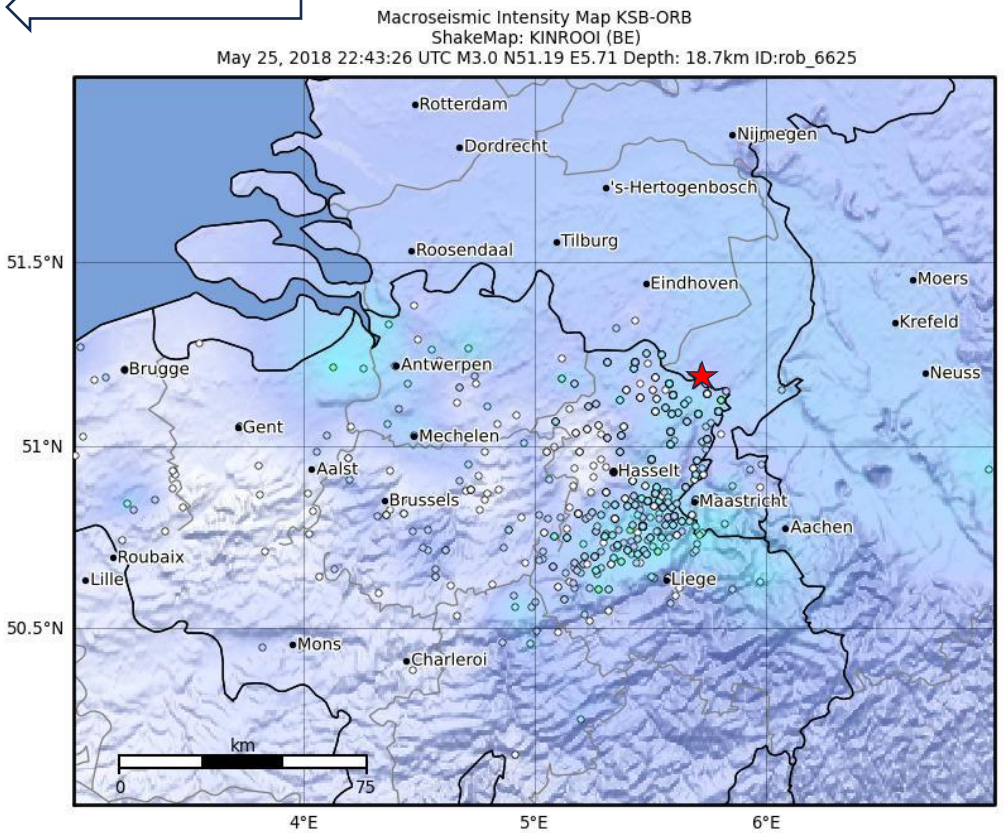
△ Seismic Instrument ○ Reported Intensity ★ Epicenter



DYFI raw



2018 Kinrooi M_w 3.0



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 2: Processed 2025-05-28T12:56:09Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter

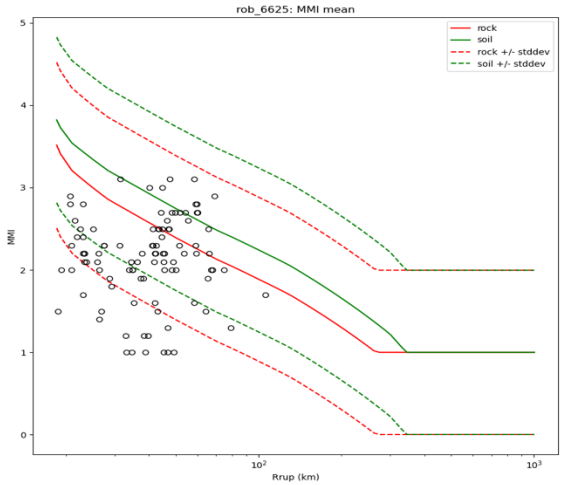
Shakemap using DYFI

2008 CSE M_w 2.9

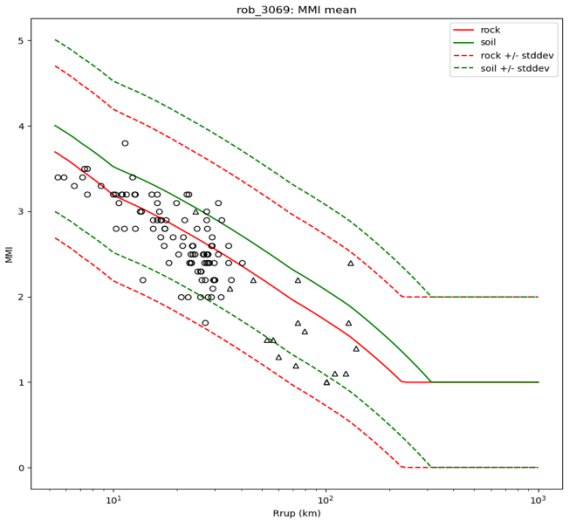
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 3: Processed 2025-05-28T13:43:21Z

△ Seismic Instrument ○ Reported Intensity ★ Epicenter



DYFI aggregated by commune



2018 Kinrooi M_w 3.0

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 3: Processed 2025-05-28T13:01:03Z

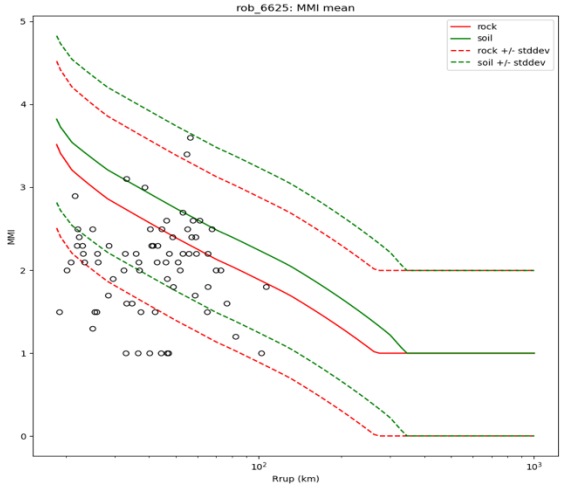
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Shakemap using DYFI

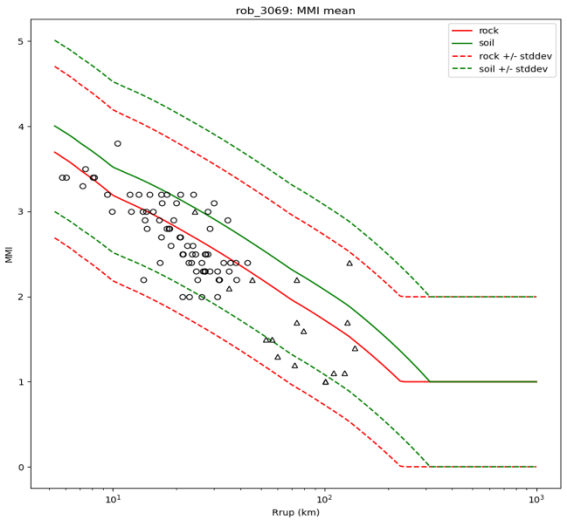
2008 CSE M_w 2.9

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

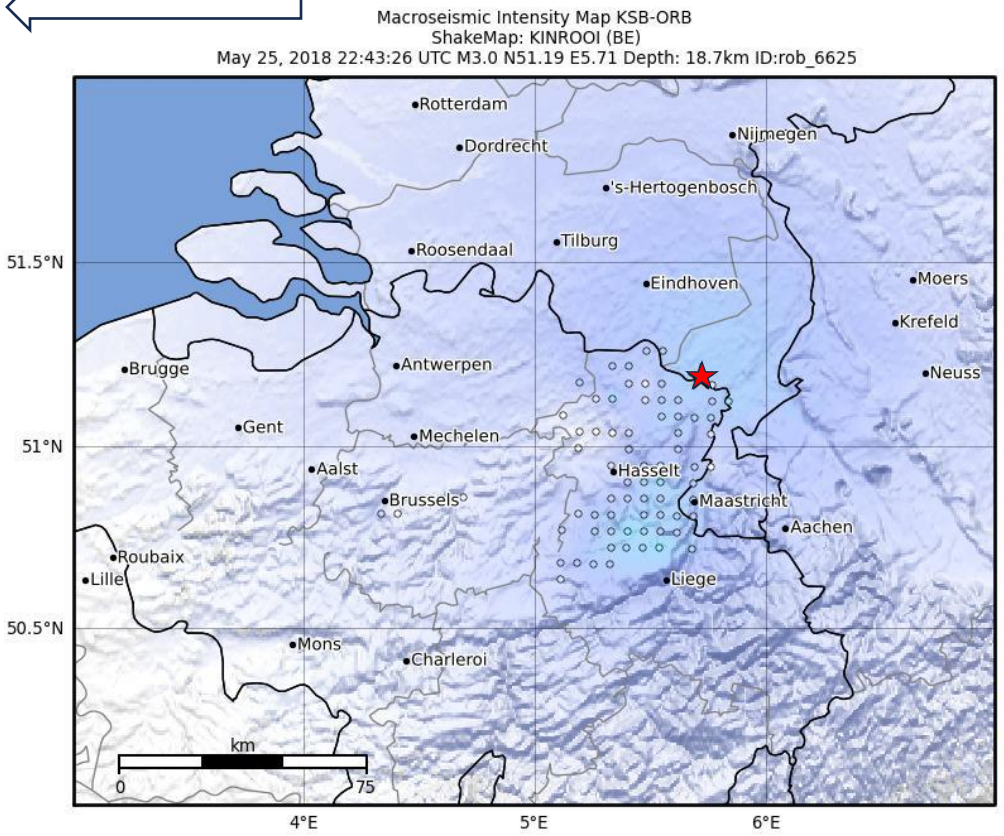
Scale based on Atkinson and Kaka (2007) Version 5: Processed 2025-05-28T13:50:50Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter



DYFI aggregated by 5km grid cell



2018 Kinrooi M_w 3.0



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

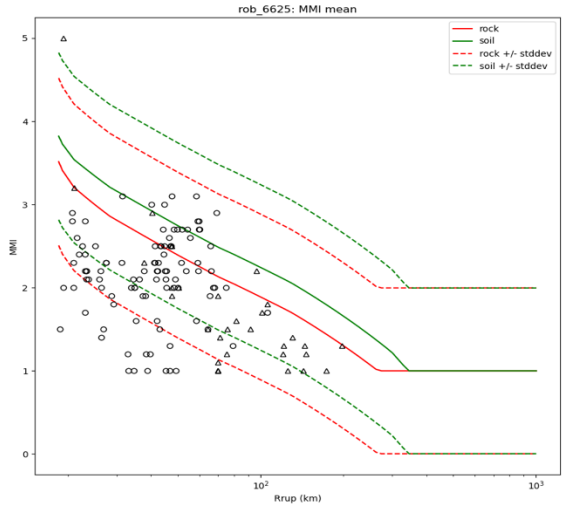
Scale based on Atkinson and Kaka (2007) Version 5: Processed 2025-05-28T13:09:01Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Shakemap using DYFI

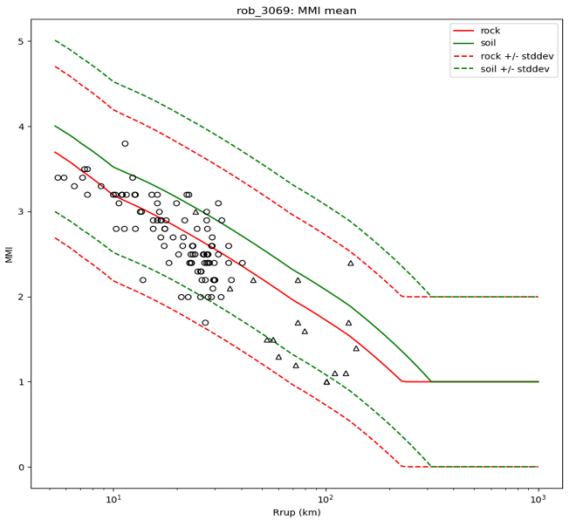
2008 CSE M_w 2.9

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 6: Processed 2025-05-28T13:55:22Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter



DYFI aggregated
+ instrumental



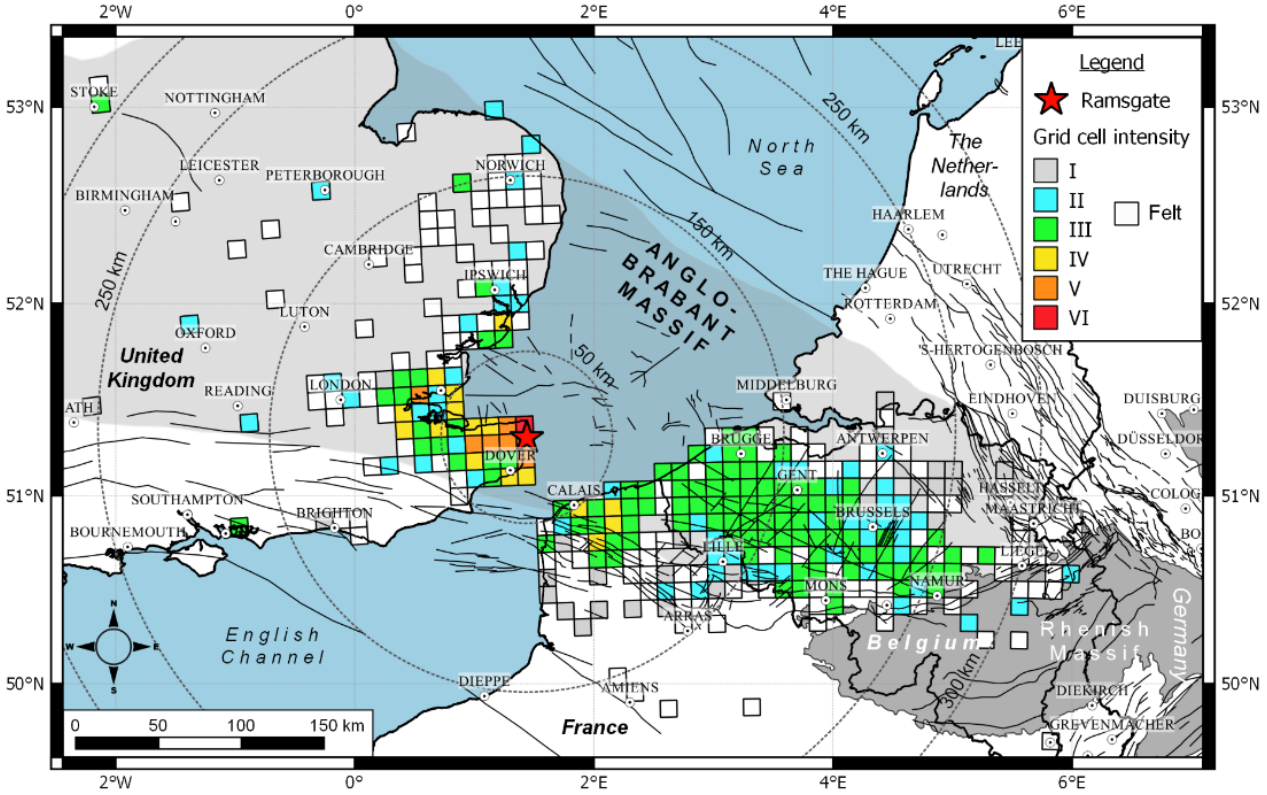
2018 Kinrooi M_w 3.0

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

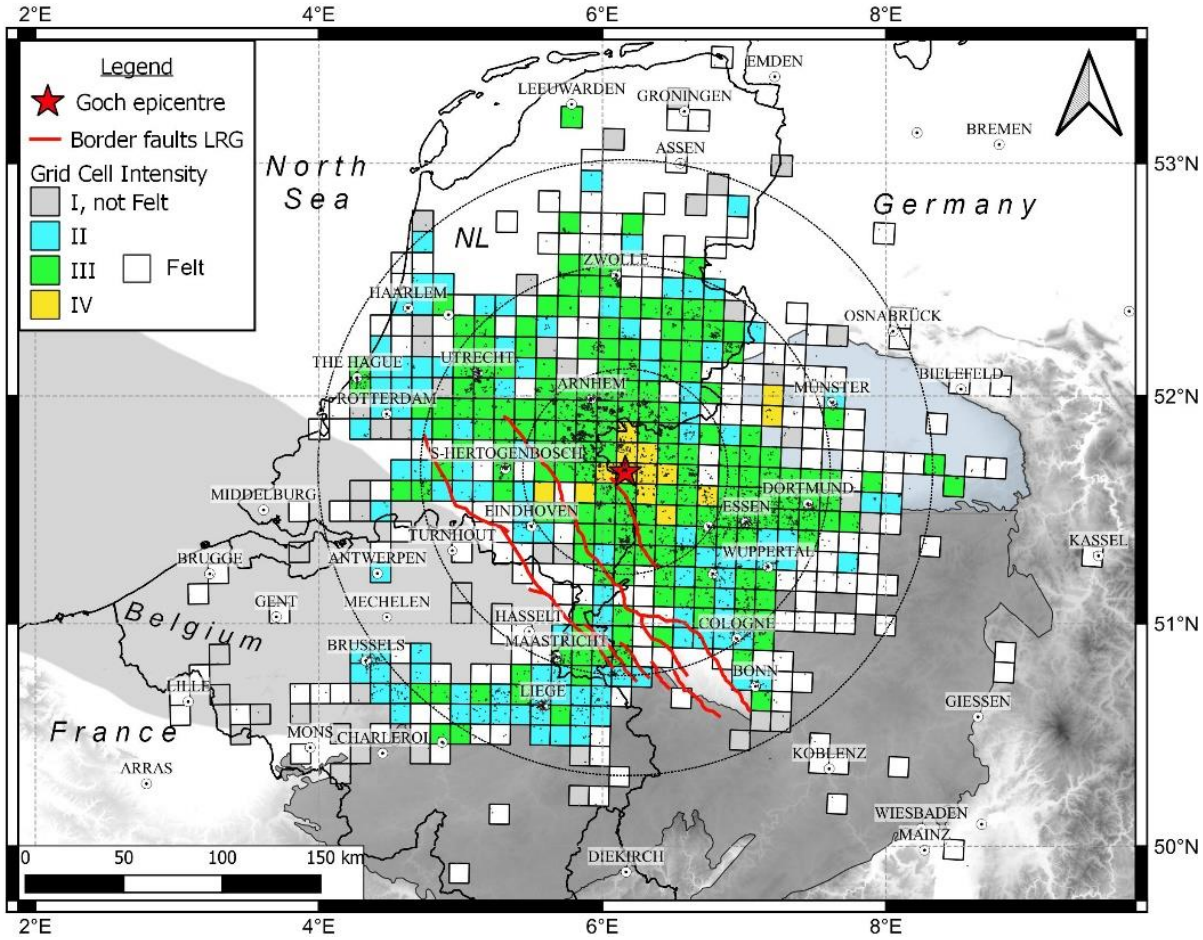
Scale based on Atkinson and Kaka (2007) Version 6: Processed 2025-05-28T13:18:50Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Shakemap using DYFI

2015 Ramsgate M_w 3.7

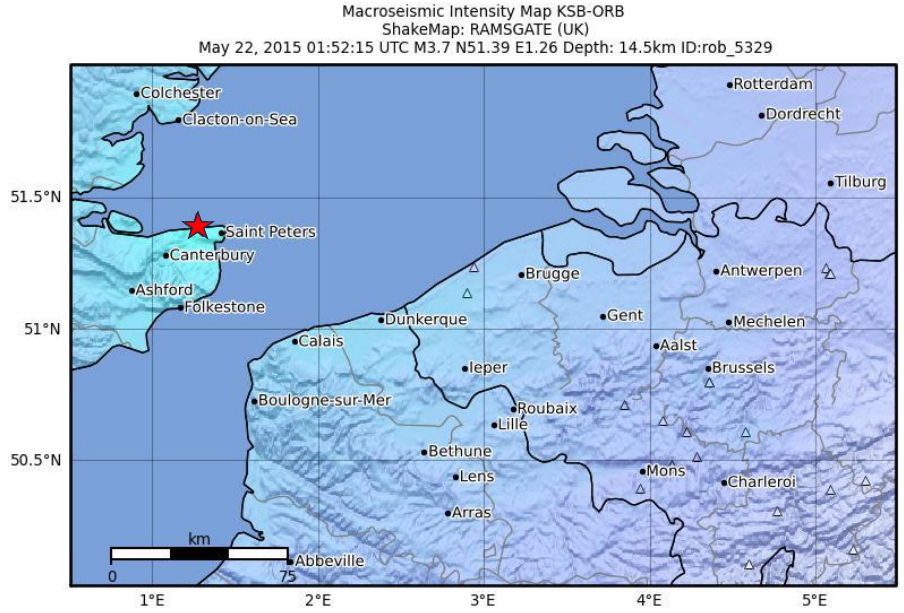


2011 Goch M_w 3.8



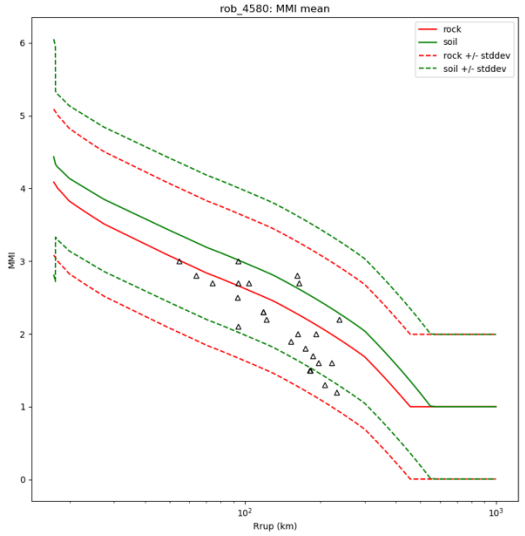
Shakemap using DYFI

2015 Ramsgate M_w 3.7

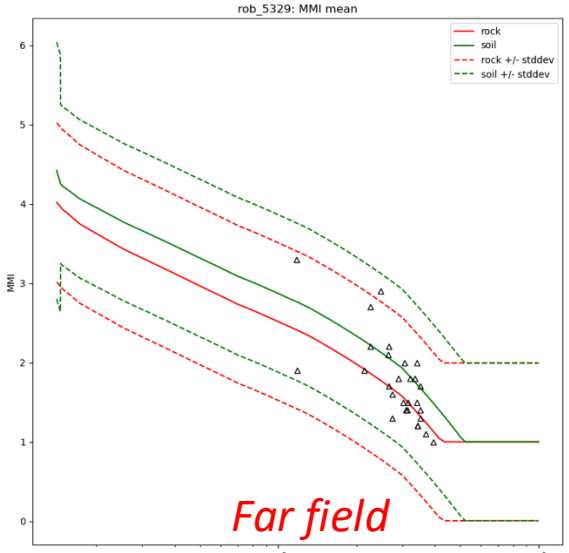


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 7: Processed 2025-05-28T15:12:47Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter



Instrumental



Far field

2011 Goch M_w 3.8

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 8: Processed 2025-05-28T15:20:17Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

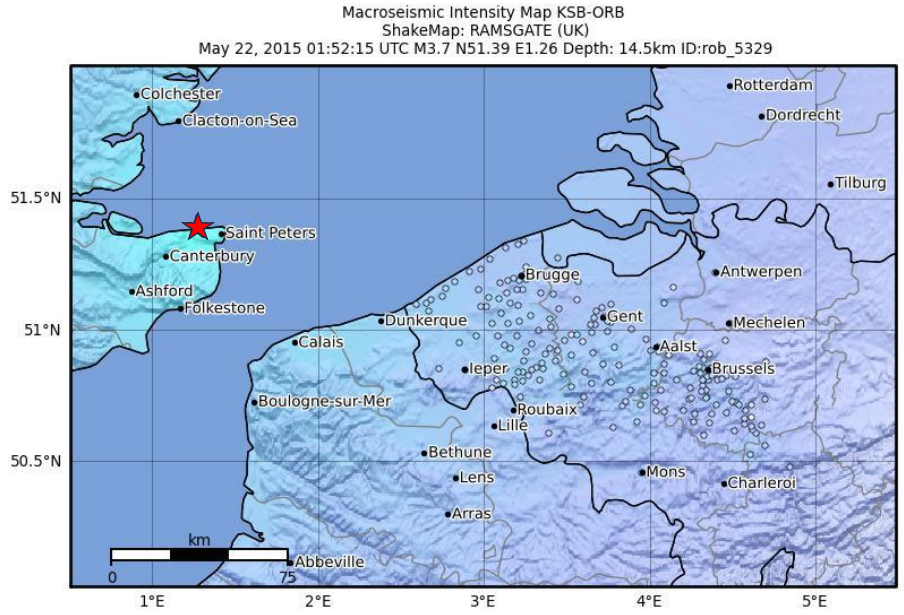
Only instrumental -> too high intensities

GMPE = bedrock GMPE

DYFI = site effect

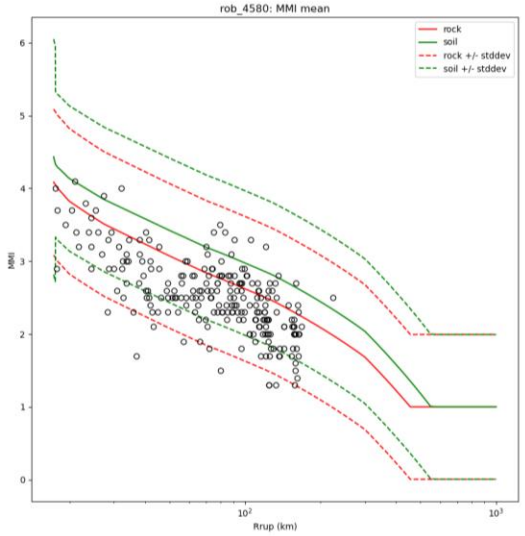
Shakemap using DYFI

2015 Ramsgate M_w 3.7

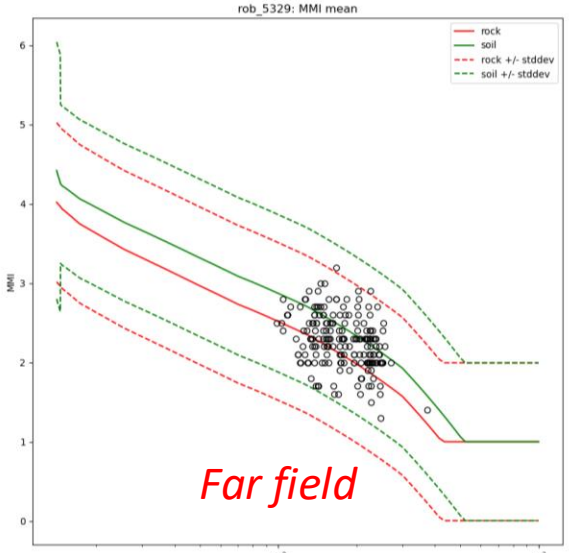


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 2: Processed 2025-05-28T14:34:31Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter



DYFI aggr. commune



Far field

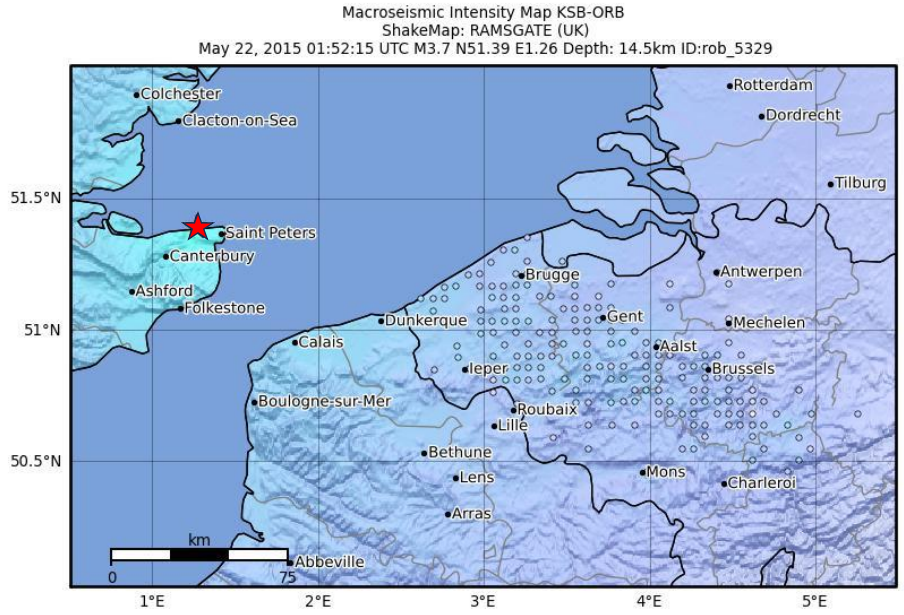
2011 Goch M_w 3.8

SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 8: Processed 2025-05-30T10:11:09Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

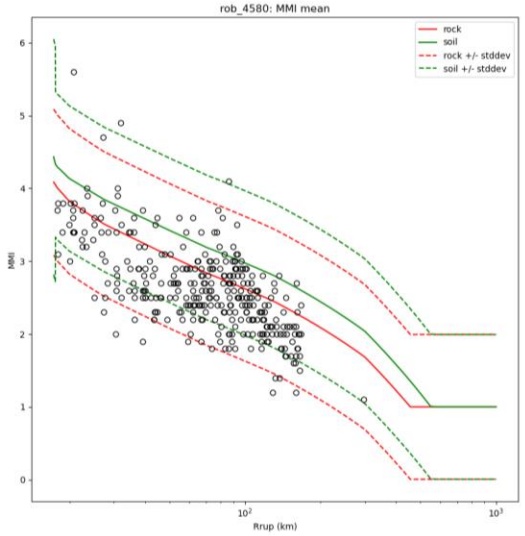
Shakemap using DYFI

2015 Ramsgate M_w 3.7

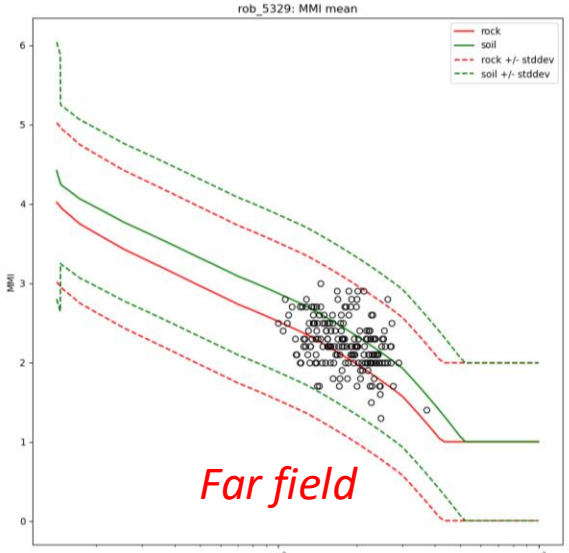


SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 4: Processed 2025-05-28T14:59:13Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

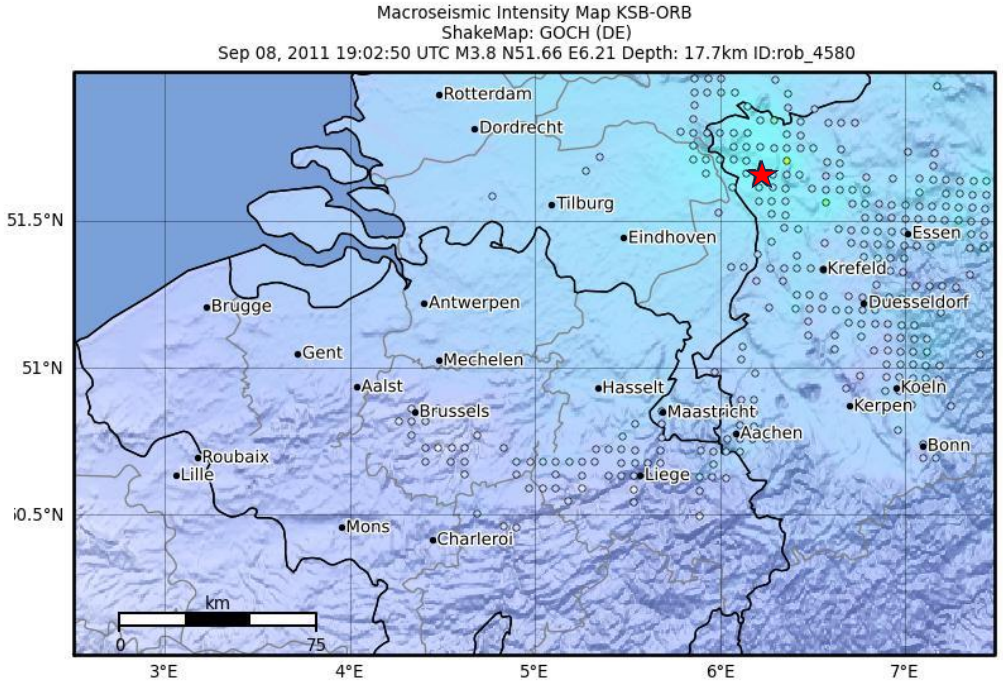


DYFI aggr. 5 km grid



Far field

2011 Goch M_w 3.8

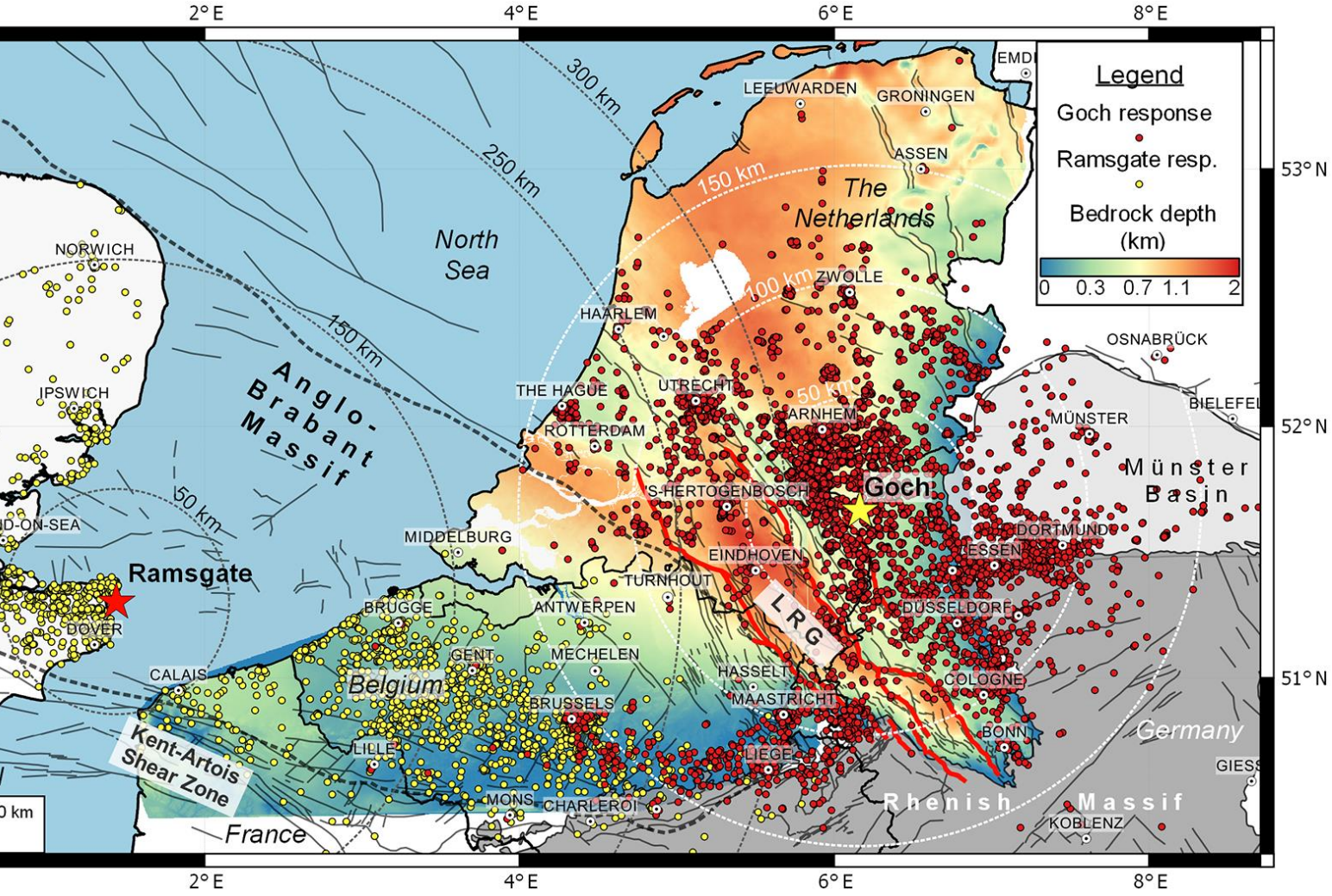


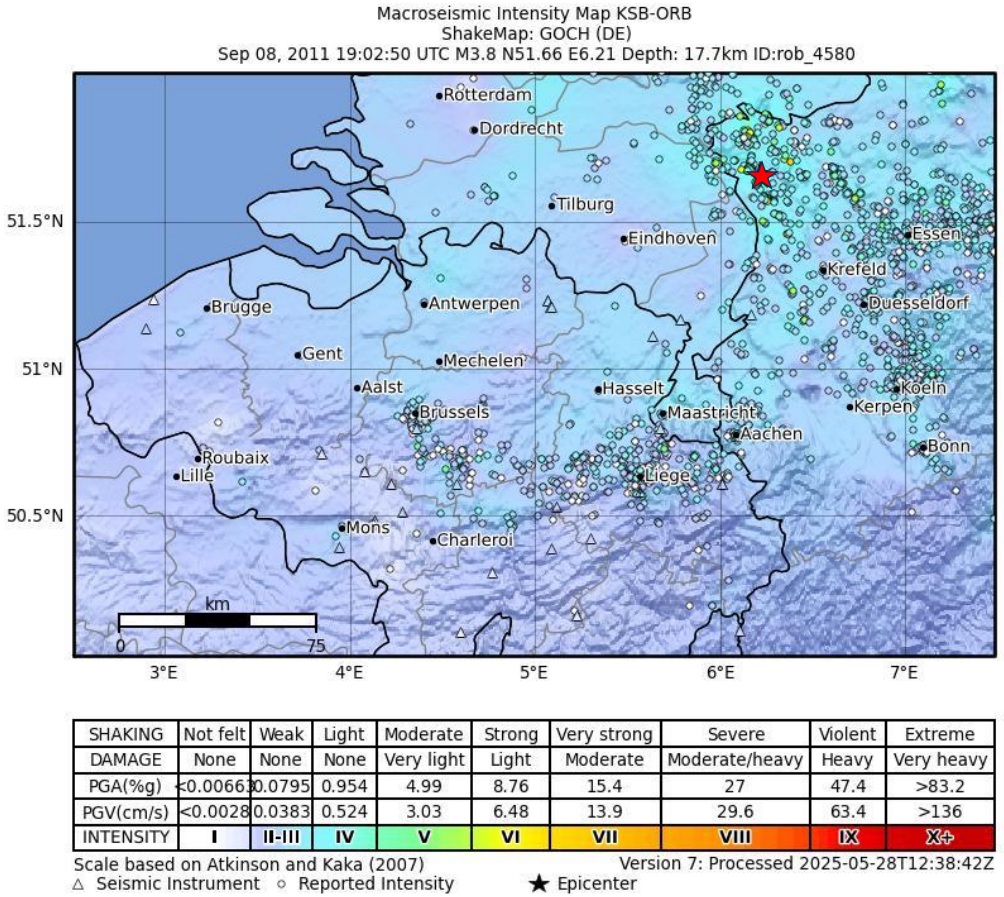
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0066	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Atkinson and Kaka (2007) Version 10: Processed 2025-05-30T10:26:36Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Shakemap using DYFI

2011 Goch M_w 3.8





SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.00663	0.0795	0.954	4.99	8.76	15.4	27	47.4	>83.2
PGV(cm/s)	<0.0028	0.0383	0.524	3.03	6.48	13.9	29.6	63.4	>136
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

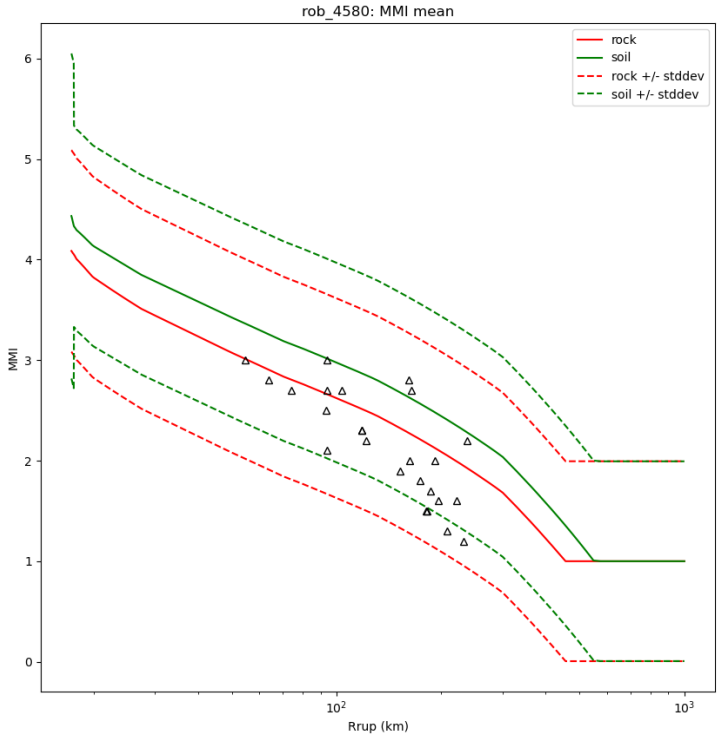
Scale based on Atkinson and Kaka (2007) Version 7: Processed 2025-05-28T12:38:42Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

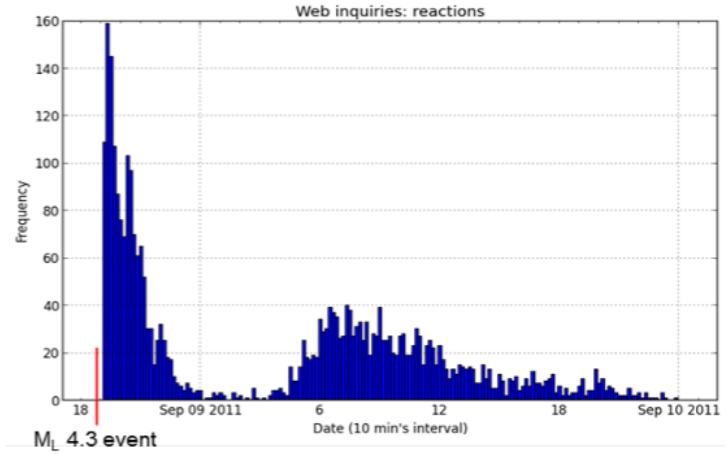
Site effect overestimated

Vs30-slope vs large sediment thickness !

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time

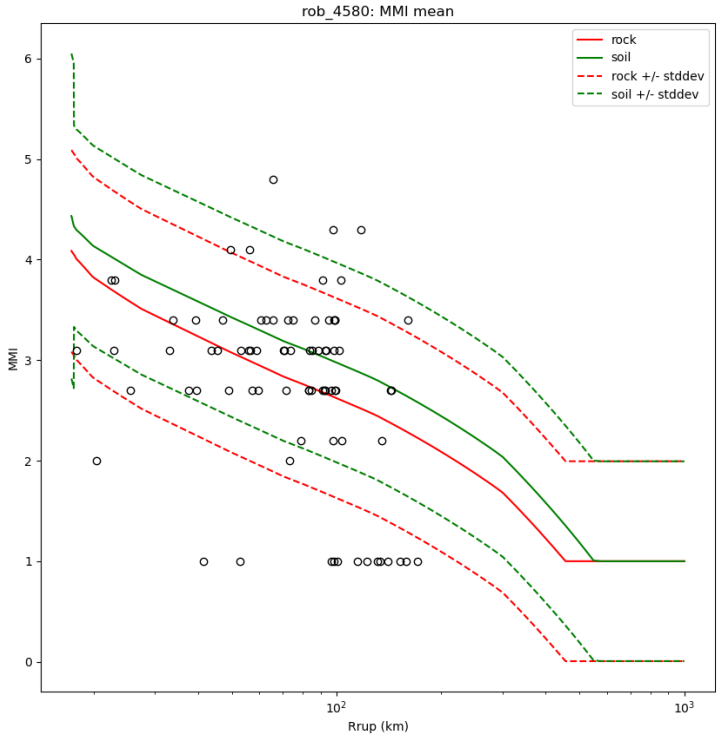


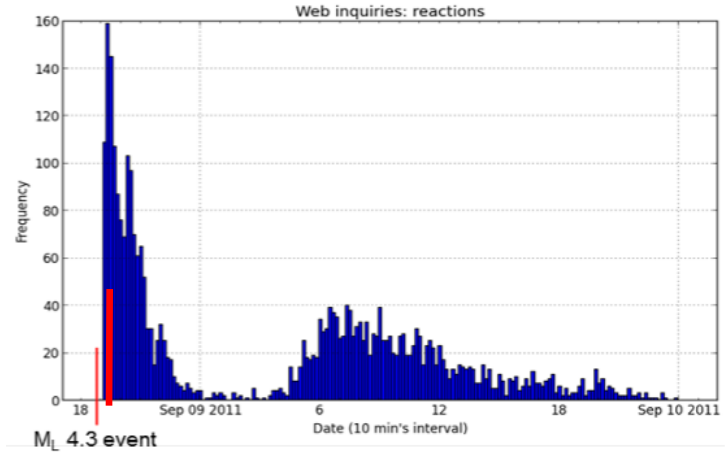


Instrumental 15 min 30 min 1 h 5h All data

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time

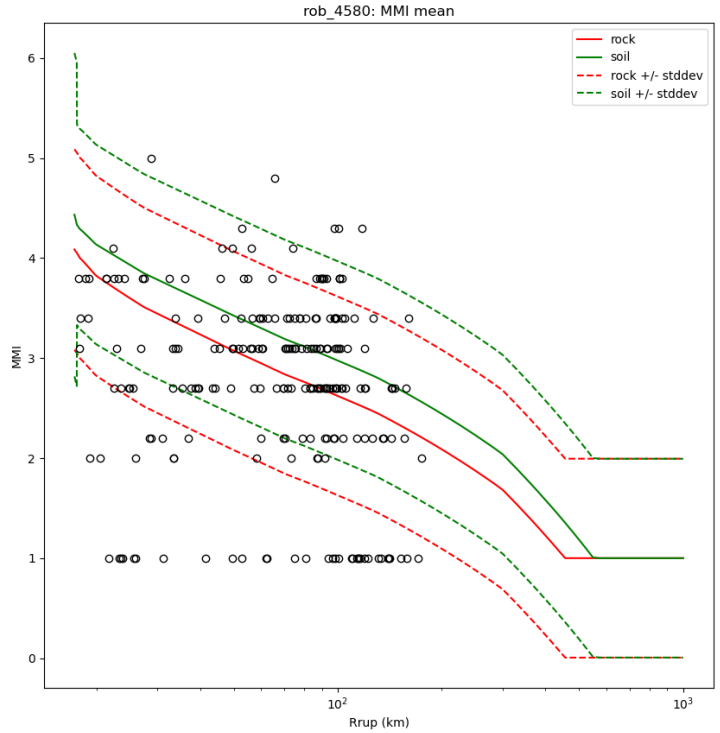


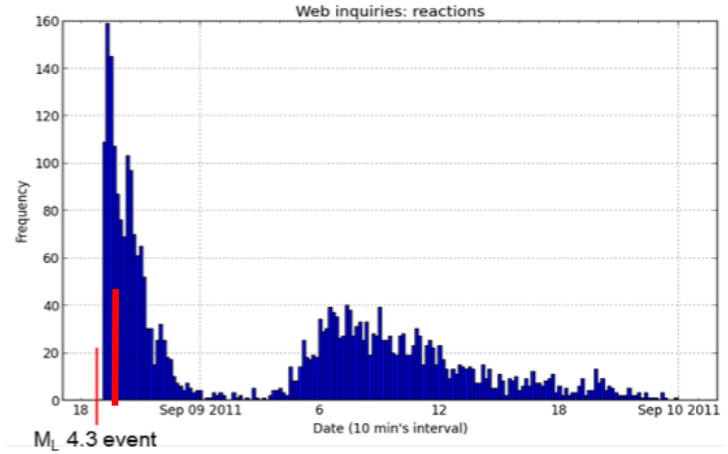


Instrumental **15 min** 30 min 1 h 5h All data

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time

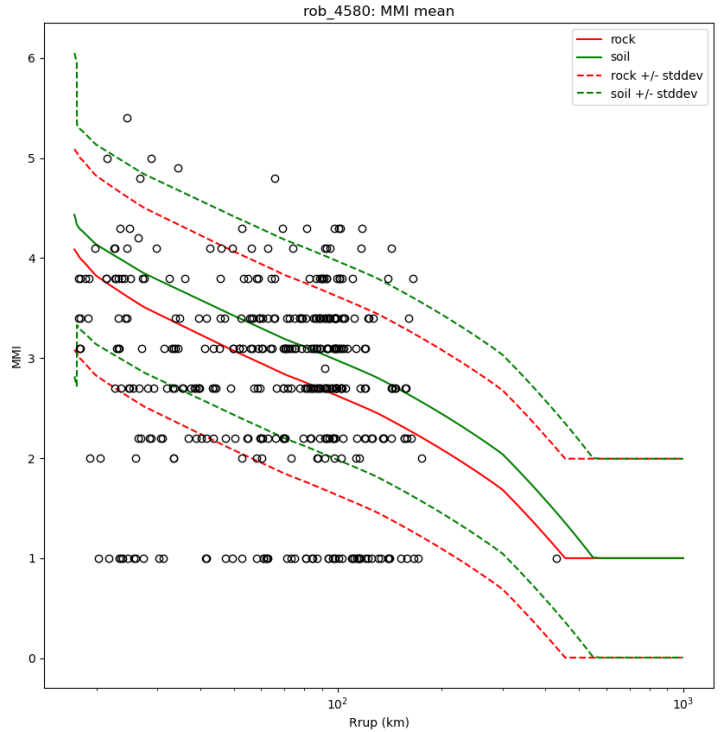


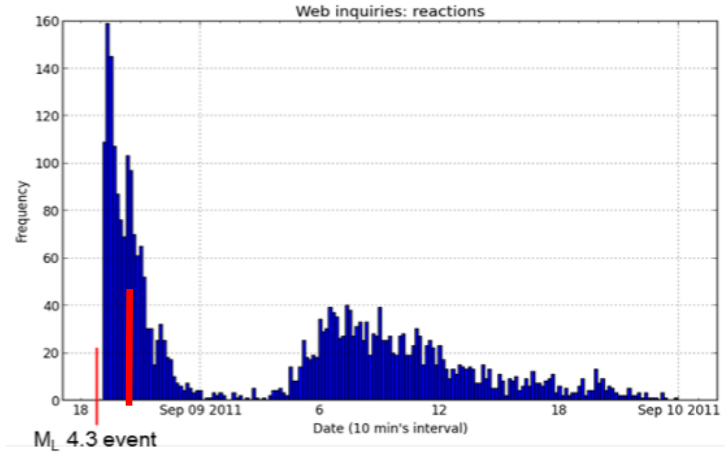


Instrumental | 15 min | **30 min** | 1 h | 5h | All data

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time

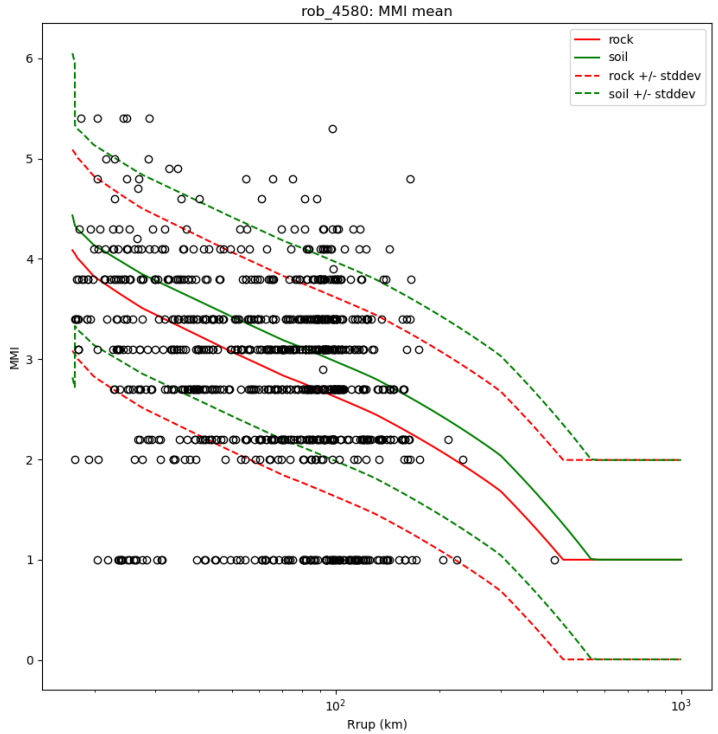


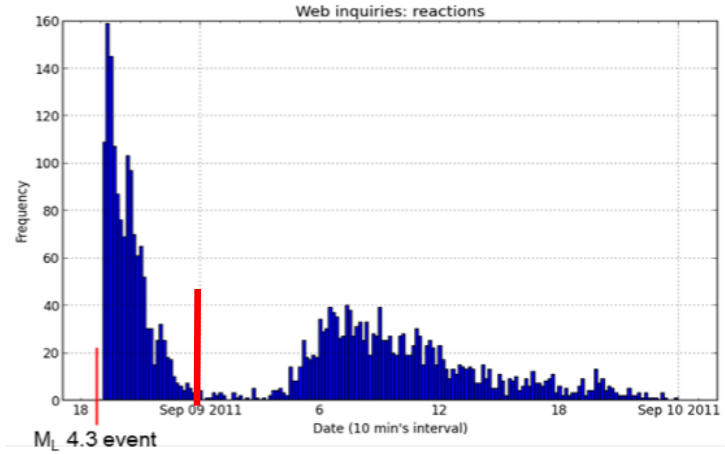


Instrumental | 15 min | 30 min | **1 h** | 5h | All data

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time



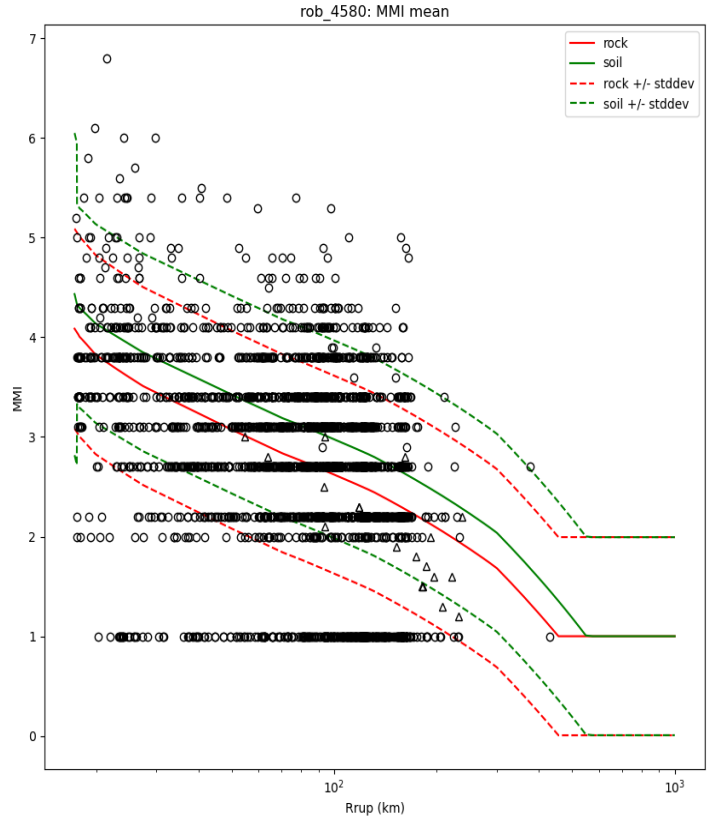


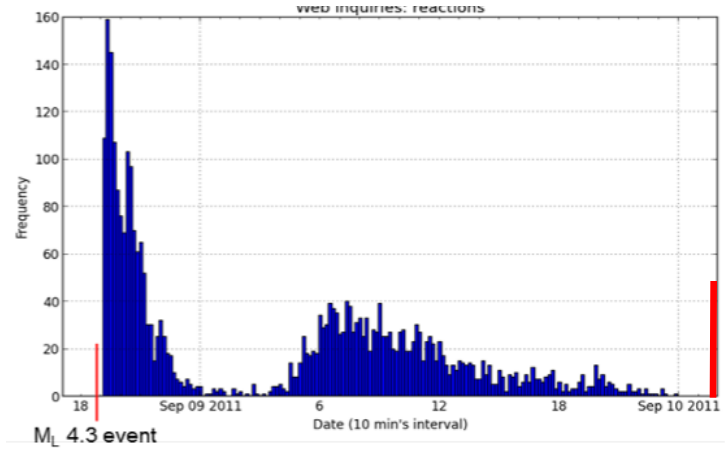
Instrumental | 15 min | 30 min | 1 h | **5h** | All data

Shakemap using DYFI

2011 Goch M_w 3.8: evolution with time

First few hours sufficient for Shakemap





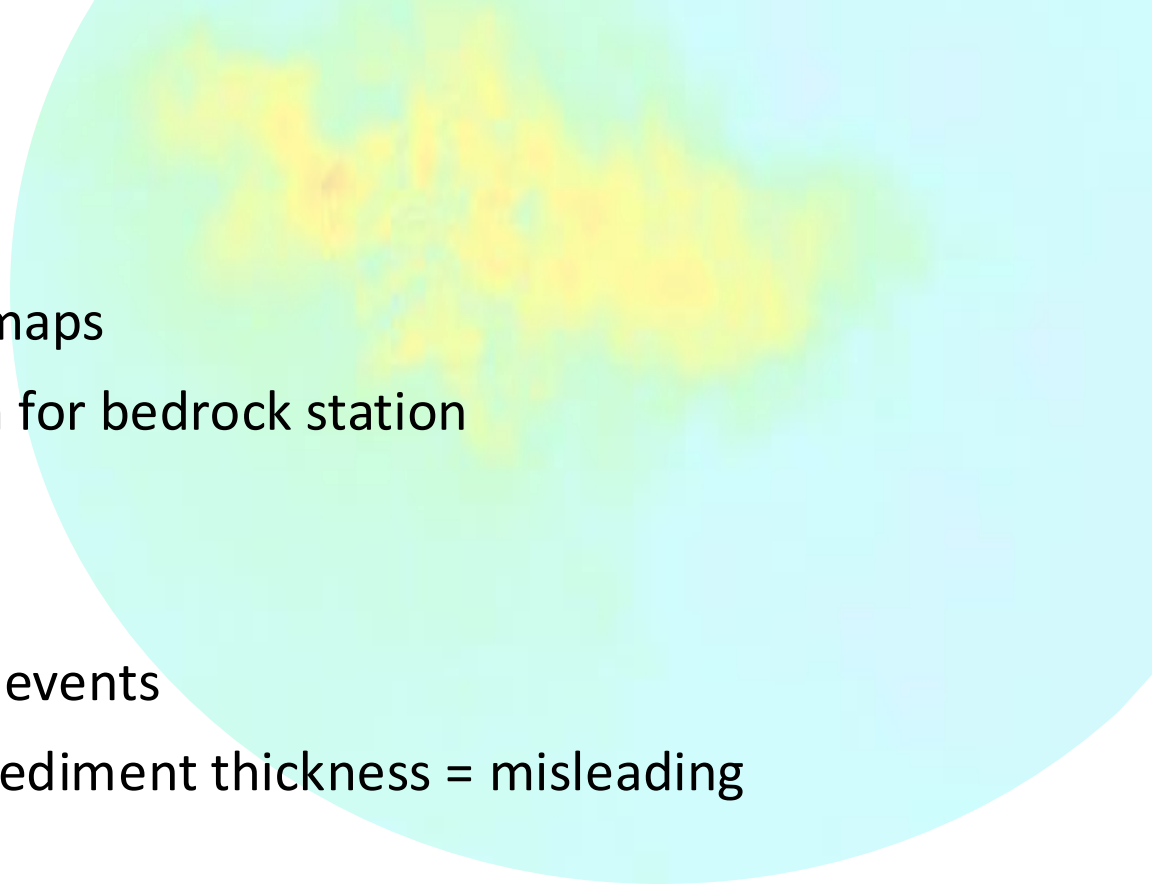
Instrumental | 15 min | 30 min | 1 h | 5h | **All data**

Shakemap using DYFI

The Belgian Macroseismic Database and its applications towards ShakeMaps

Royal Observatory *of* Belgium

Koen Van Noten, Ben Neefs & Kris Vanneste



DATA COLLECTION

- BE macroseismic database (traditional + DYFI)
- Good correlation between Imax and 450yr “hazard” maps
- Watch out with Vs30 – slope: too large site correction for bedrock station

SHAKEMAP

- Felt data needed for Shakemap of early-instrumental events
- Vs30 correction for low magnitude events and large sediment thickness = misleading
- Cross-border: Felt + Instrumental data essential
- DYFI raw >> DYFI aggregation (commune, grid cell)

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NEW papers in macroseismology!

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Royal Observatory *of* Belgium

J Seismol
https://doi.org/10.1007/s10950-024-10266-9

RESEARCH

The Belgian traditional macroseismic (BTM) database of the twentieth century

Ben Neefs · Koen Van Noten · Kris Vanneste · Thierry Camelbeeck

Received: 17 June 2024 / Accepted: 1 November 2024

Abstract Macroseismic intensity data have been gathered continuously in Belgium since the start of the twentieth century. In this study, we review the applied survey practices used over the previous century: from small-scale ad-hoc improvised surveys to the mass distribution of collective questionnaire versions sent to local authorities. The variety of survey methodologies causes a high degree of heterogeneity within the resulting macroseismic data, increasing the uncertainty in macroseismic applications that rely on homogeneous data. We thoroughly re-evaluated the original source material and intensity scale conversions in order to create the Belgian Traditional Macroseismic (BTM) database, a comprehensive compilation of 20th-century macroseismic data in which all sources are properly referenced. The BTM database currently consists of 23,950 intensity data points (IDPs) on the European Macroseismic Scale for 80 felt earthquakes, ranging from 2.4 to 5.8 on the local magnitude (M_L) scale. Each IDP is provided with a source type and each earthquake is attributed a data quality parameter that indicates the level of uncertainty associated with its IDP source quality. The publication of the BTM database facilitates the use of Belgian macroseismic data for a variety of seismological purposes and allows us to summarize the overall seismic impact on Belgium for the duration of a century. Like in many other parts of the world, traditional procedures have practically been discontinued in Belgium in favour of an online enquiry. However, the potential for high-quality data following a traditional survey methodology is still large and we strongly recommend its continuation.

Highlights

- Review of traditional macroseismic survey methodologies applied in Belgium.
- Publication of all 20th-century intensity data, summarizing the seismic impact on Belgium.
- Assignment of quality indicators for each felt earthquake based on IDP source evaluations.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10950-024-10266-9.

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Keywords Macroseismology · Intensity · Survey methodology · Macroseismic questionnaire · Seismic impact

Published online: 18 December 2024

Springer

Neefs et al. 2025 – BTM database

J Seismol
https://doi.org/10.1007/s10950-024-10278-5

RESEARCH

The damaging 1932 Uden Earthquake in the Netherlands – revision of cross-border macroseismic data and its impact on source parameters

Bernard Dost · Ben Neefs · Koen Van Noten · Elmer Ruigrok

Received: 10 September 2024 / Accepted: 28 December 2024

Abstract A re-assessment of the macroseismic intensity data was conducted for the second-largest instrumentally recorded event in the Netherlands: the 20 November 1932 Uden earthquake. This event was felt across the Netherlands, Belgium and Germany. Intensity values on the EMS98 scale were assigned based on original data (reports/enquiries/letters), manually for the Netherlands and automatically for Belgium, with existing German data added for completeness. The updated dataset was used to calculate macroseismic location and magnitude using the Bakun and Wentworth (1997, 1999) algorithm. To capture epistemic uncertainty, four newly calibrated intensity attenuation relations were applied and their results averaged. The results using only intensity data from the Netherlands provided stable solutions within the region of maximum observed intensity (I_{max} = VII). However, including Belgian and German data shifted the source location outside this region and becomes less reliable, likely due to differences in data collection methods and local/regional site effects. Comparison of confidence levels from the BW method with bootstrap modelling showed that almost all bootstrap results fall within the 50% confidence region. A more realistic estimate for the location uncertainty was derived from the bootstrap analysis. The revised source parameters are 51.63°N and 5.61°E ± 7.3 km for the source location and M_L = 5.1 ± 0.3 (M_S 4.9 ± 0.3) for the magnitude.

Highlights
- Cross-border intensity data show significant differences due to varying data collection methods.
- Revised macroseismic location and magnitude determinations are presented for the second strongest recorded event in the Netherlands.
- Application of a bootstrap technique is preferred to provide a reliable estimate of uncertainty.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10950-024-10278-5.

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Keywords Macroseismology · Intensity · Early instrumental · Attenuation calibration · Source parameters

Published online: 13 January 2025

Springer

Dost et al. 2025 – Uden 1932 revised

GEOLOGICA BELGICA
2025, Vol. 28/1-2, 1–23
https://doi.org/10.20341/gb.2025.001

The 1965–1970 seismic episode in the Hainaut coal basin (Belgium): a key period to analyse the triggered nature of a century-long seismic activity

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ABSTRACT

Damaging earthquakes happened in the Hainaut coal basin (Belgium) in the 19th and 20th centuries but stopped after coal mining. We relocated 54 Hainaut earthquakes of the period 1965 and 1985 by using regional and local seismic phase measurements from recordings in and around Belgium. These new results finalise the Hainaut earthquake catalogue, derived from macroseismic data for the 1887–1965 period and instrumental records after 1965. This updated database allows us to discuss the origin of this intriguing seismicity. Computed focal depths show that the strongest earthquakes before 1985 occurred inside the Upper Palaeozoic part of the Brabant Parautochton, probably below the deepest parts of the coal mines. The shallowness of this seismicity, its spatial link with the coal basin, the compressive to strike-slip focal mechanisms of the stronger earthquakes between 1965 and 1985 and the large quantity of coal mass removal all match with worldwide observations of mining-triggered earthquakes. The earthquake mechanisms agree with the local, compressive to transpressive stress regime derived from differences in upper crustal density and topography that make the Hainaut area more sensitive to fault reactivation at shallow depths, as observed in similar tectonic settings elsewhere in the world.

KEYWORDS

early-instrumental, earthquake relocation, focal mechanism, local stress analysis, triggered seismicity, coal mining, Hainaut, Belgium

Article history

Received 31.01.2024, accepted in revised form 02.09.2024, available online 08.04.2025.

1. Introduction

Since seismic activity in stable plate interiors is episodic, known seismicity in many areas occurred before the installation of modern seismic networks. This challenges earthquake source parameter determination and seismotectonic analyses. This is the case for the Hainaut coal mining area in Belgium where significant earthquake activity for Western Europe occurred from the end of the 19th century until the beginning of the 1980s, before the installation of a dense modern digital monitoring seismic network in 1985 (Camelbeeck et al., 1990). From 1887 to 1985, five shallow Moment Magnitude (Mw) 4.0 earthquakes caused moderate to severe damage to buildings corresponding to maximum intensity VII on the European Macroseismic Scale 1998 (EMS-98). In this period, people experienced 111 other felt events, some of them producing slight damage (Camelbeeck et al., 2022). Since 1985, seismicity has strongly decreased and only three Mw < 3.0 earthquakes, that occurred in 1987, were locally felt (Camelbeeck, 1988). Events with Mw > 2.0 were no longer recorded during the last 20 years. Most of the seismicity in Hainaut occurred inside the coal mining area. However, two significant earthquakes with magnitudes Mw 3.9 and 4.1 occurred just outside the surface limits of the Hainaut coal area, respectively on 24 October 1976 near Givry south of the coal basin, and on 20 June 1995 near Le Roeulx to the north of the basin (Fig. 1).

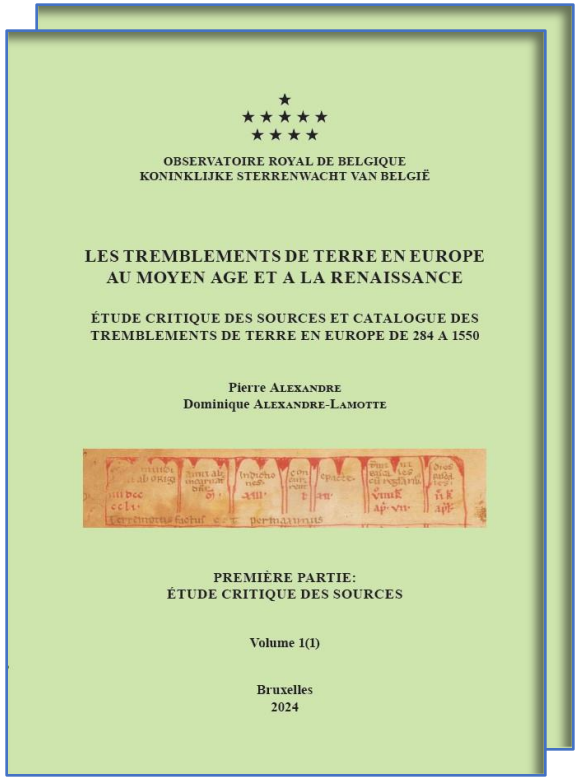
Mining in the Hainaut coal basin was distributed in three different administrative districts, here further referred to as the Borinage–Mons (Dupont, 2021), Centre–La Louvière and Charleroi basins, which is described in detail in Delmer (1977, 2004, 2013). The deepest mines were in the Charleroi Basin up

Camelbeeck et al. 2025 – Hainaut = triggered

NEW BOOK! Alexandre & Alexandre-Lamotte 2024

Les tremblements de terre en Europe au Moyen Âge et à la Renaissance

A Critical Review of Historical Sources and Earthquake Catalogues between 284 and 1550



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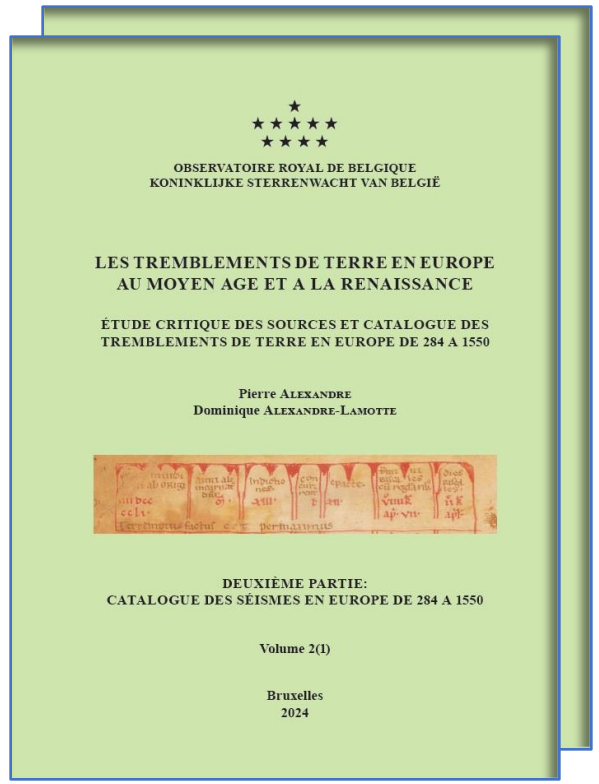

Vol 2

Reference:

Alexandre, P., Alexandre-Lamotte, D. 2024. Les tremblements de terre en Europe au Moyen Âge et à la Renaissance. Étude critique des sources et catalogue des tremblements de terre en Europe de 284 à 1550 (Koen Van Noten, Ed.). Observatoire royal de Belgique, Bruxelles, Belgique, p. 2074. doi: 10.24414/srvz-2k77

Royal Observatory of Belgium, 2024, doi: 10.24414/srvz-2k77