Using small, land-based seismic arrays to monitor microseismicity induced by CO_2 storage

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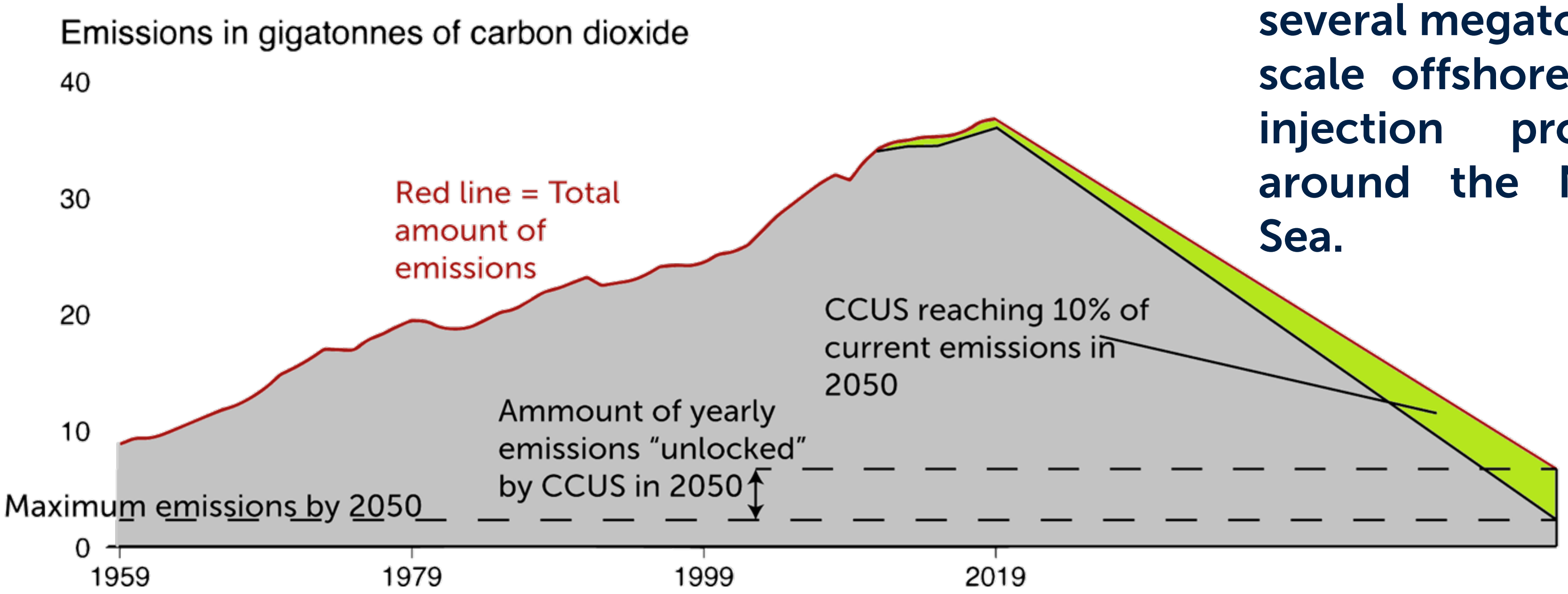
EGU General Assembly 2022

This presentation participates in OSPP

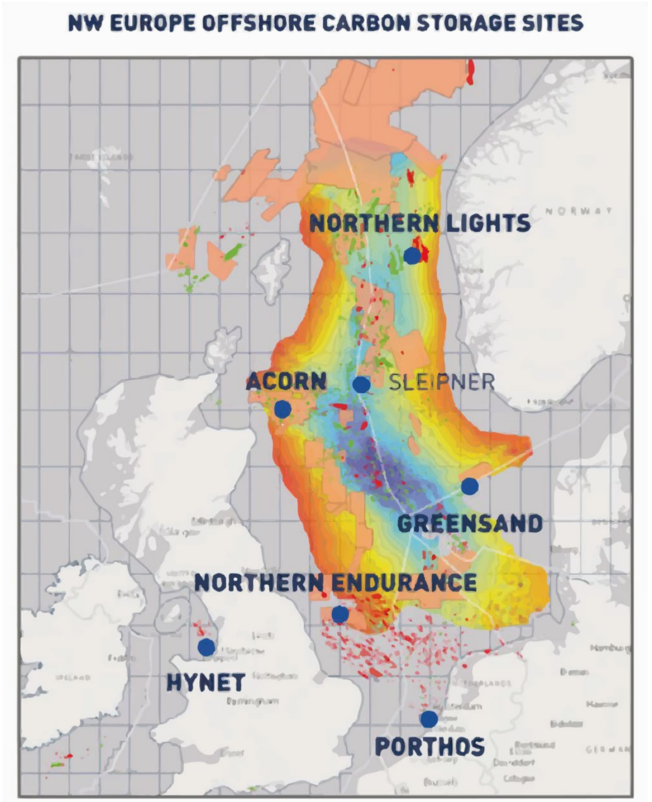
Outstanding Student & PhD candidate Presentation contest

Motivation & Key Questions

✓ Carbon Capture and Storage (CCS) will be critically important for reaching net-zero.



✓ There are plans for several megatonne-scale offshore CO_2 injection projects around the North Sea.



From: https://www.geoexpro.com/articles/2021

Monitoring must be long-term, cheap, and real-time:

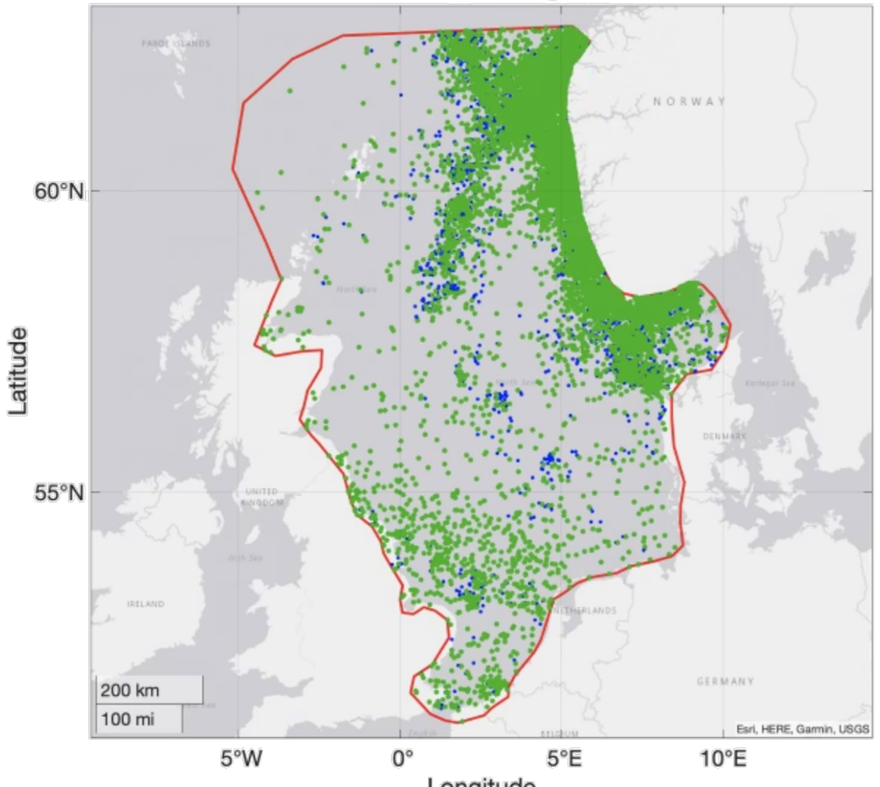
Q: What factors are most important in using seismic arrays to detect seismicity?

Q: What is the detection threshold for onshore monitoring of CO_2 storage sites?

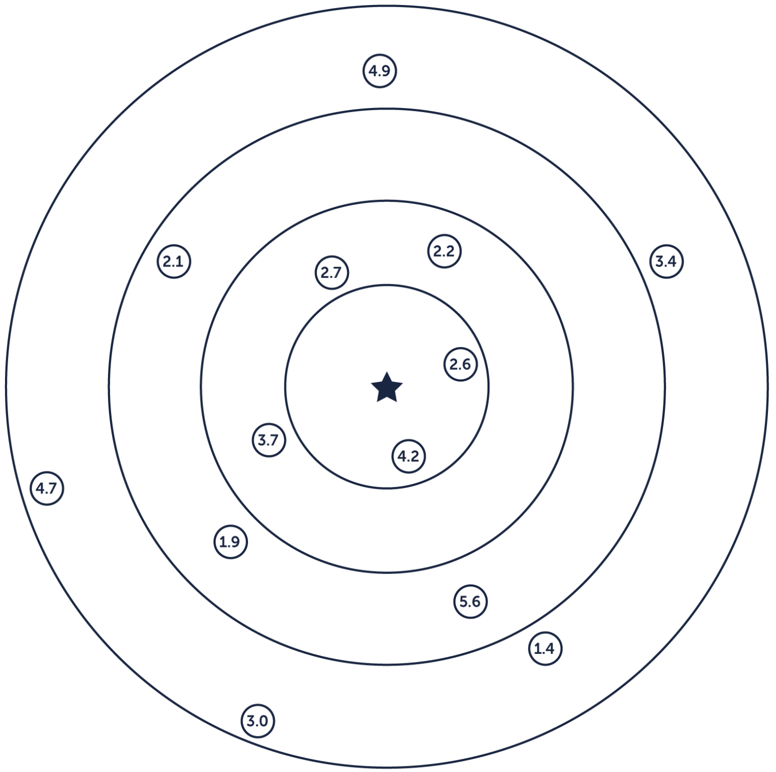
North Sea PSHA

GroundMotionPredictionEquations used:

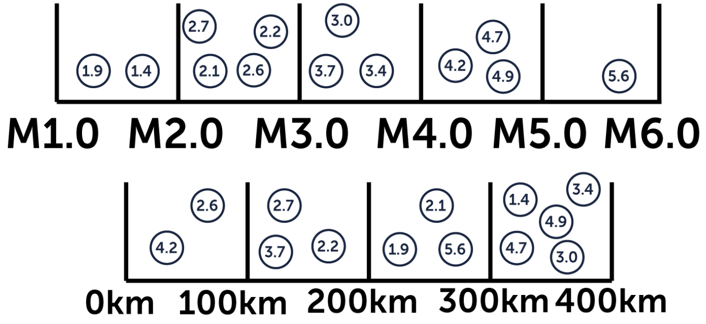
- ✓ Cornell et al., 1979 (early general model for tectonic events)
- ✓ Atkinson, 2015 (based on induced seismicity data)
- ✓ Douglas et al., 2013 (based on geothermal areas)



To know what the induced activity will be, we must know what the background seismicity is first.



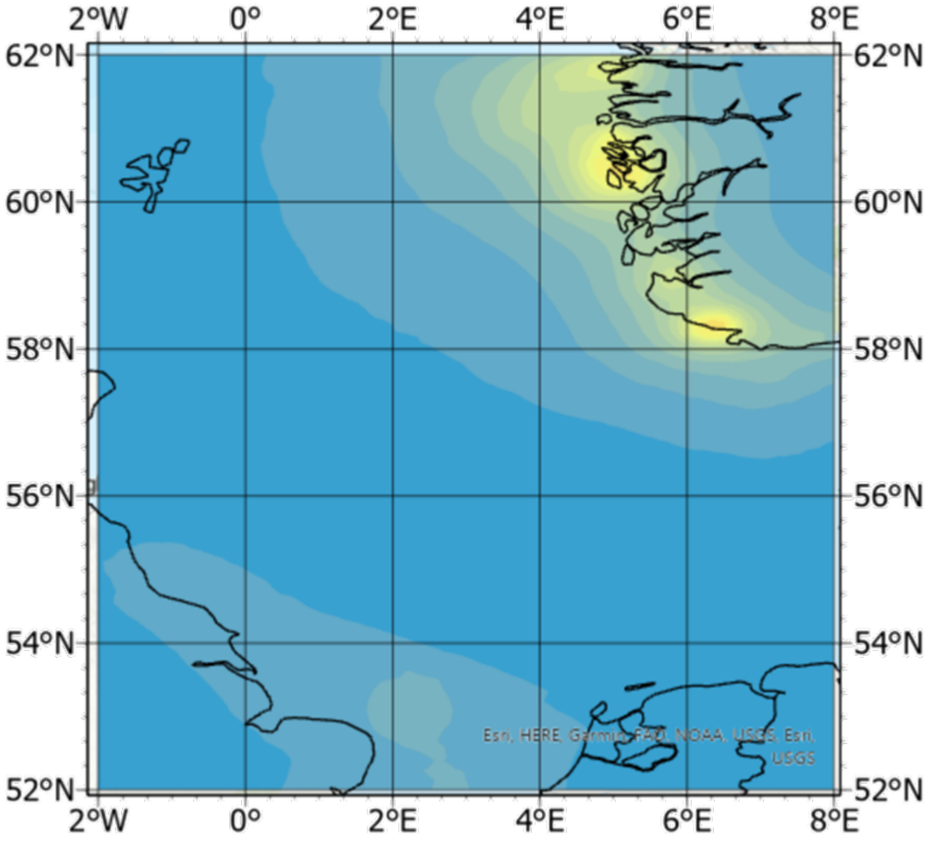
Star = location for which we calculate PGA.



Complete catalogues are crucial

New land array data (HNAR)

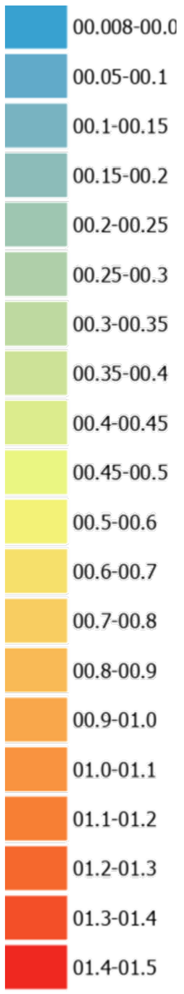
Peak Ground Acceleration Maps of 10% exceedance over 50 years.

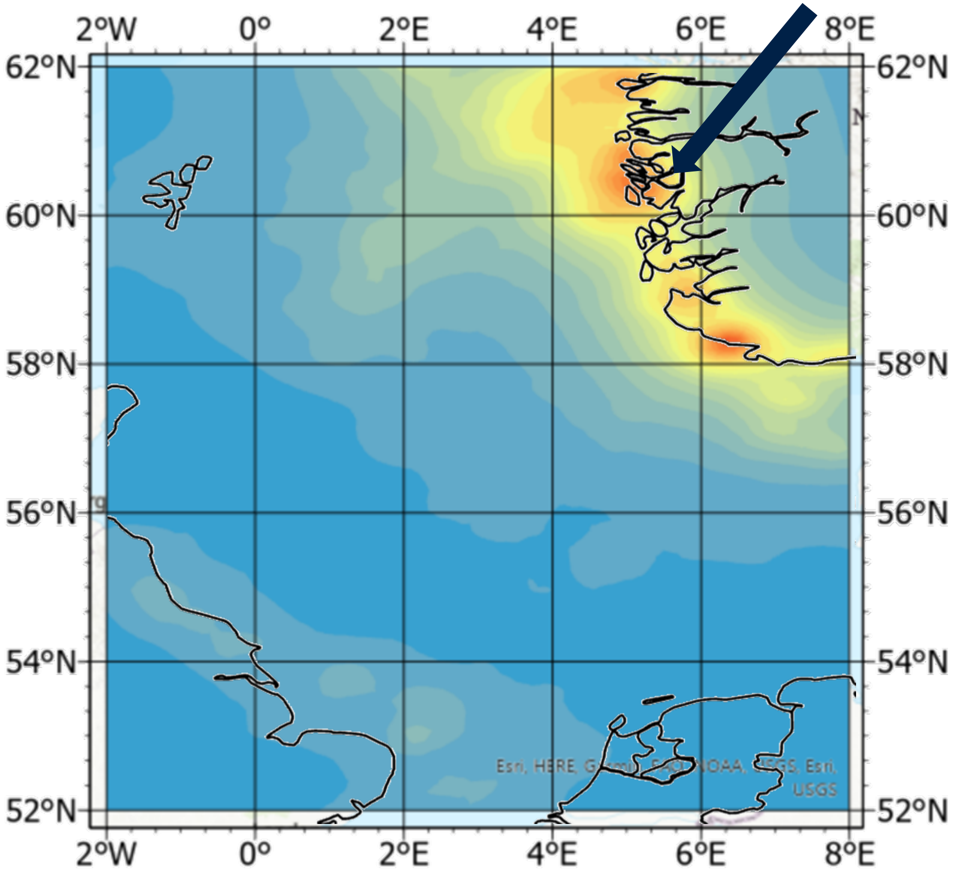


Made using International Seismological Centre publicly available catalogue.

Legend

PGA measured in units of m/s²



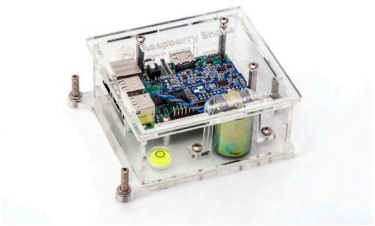


Made using SHARP catalogue.

Monitoring Seismicity Using Land-Based Arrays

1. The Raspberry Shake Citizen Science Network of small portable seismometers, with publicly available data and located all over the UK.

Raspberry Shake®
Watch the Earth Move



2. An array deployed by a team of scientists from the universities of Oxford and Bristol near Scunthorpe, close to the Humber estuary and the East Coast/ Endurance CCUS cluster.

3. The array used for geothermal monitoring at the Eden Project, in Cornwall, obtained courtesy of Andrew Jupe (altcom Limited).

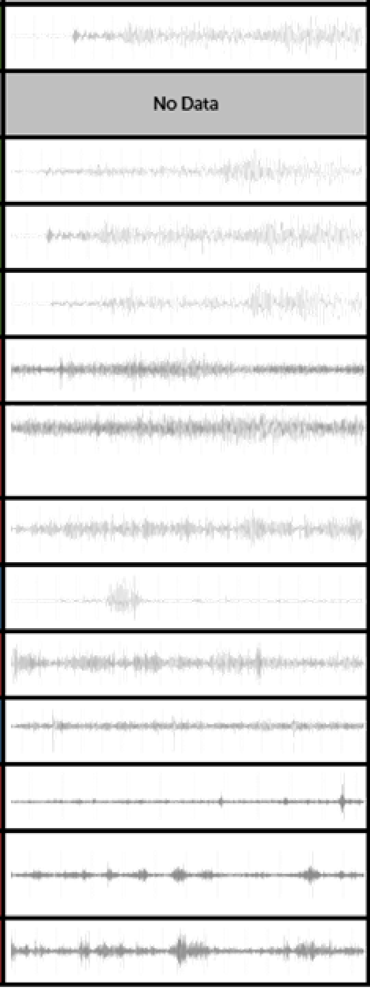
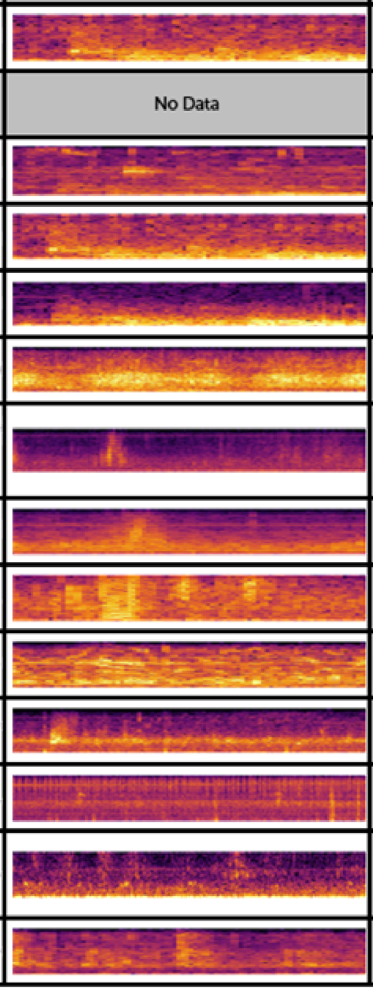
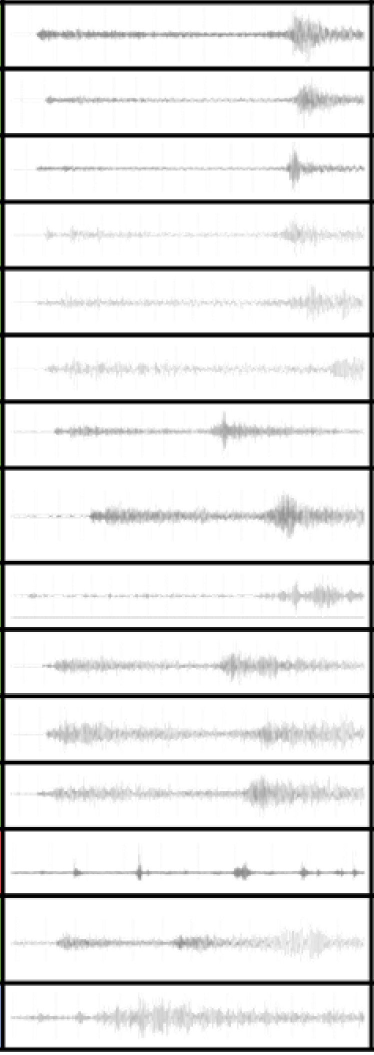
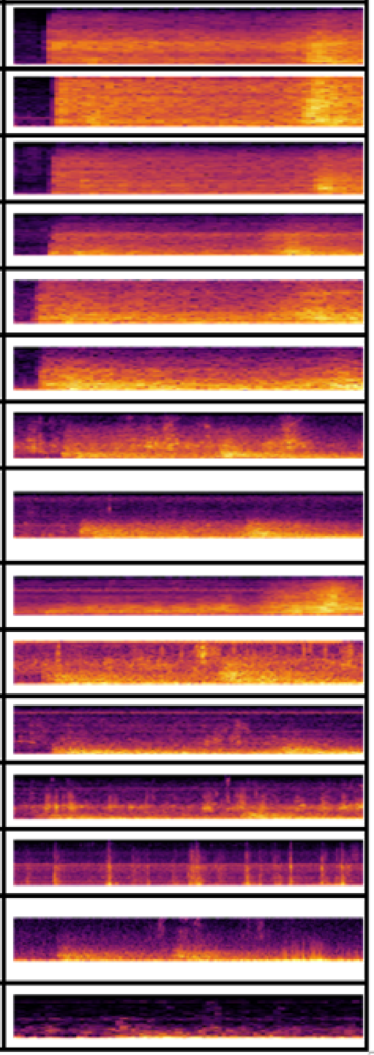
eden geothermal

4. The Eskdalemuir array, one of four international arrays set up in the early 1960s to monitor the International Nuclear Test Ban Treaty, obtained courtesy of Brian Baptie (British Geologic Survey).

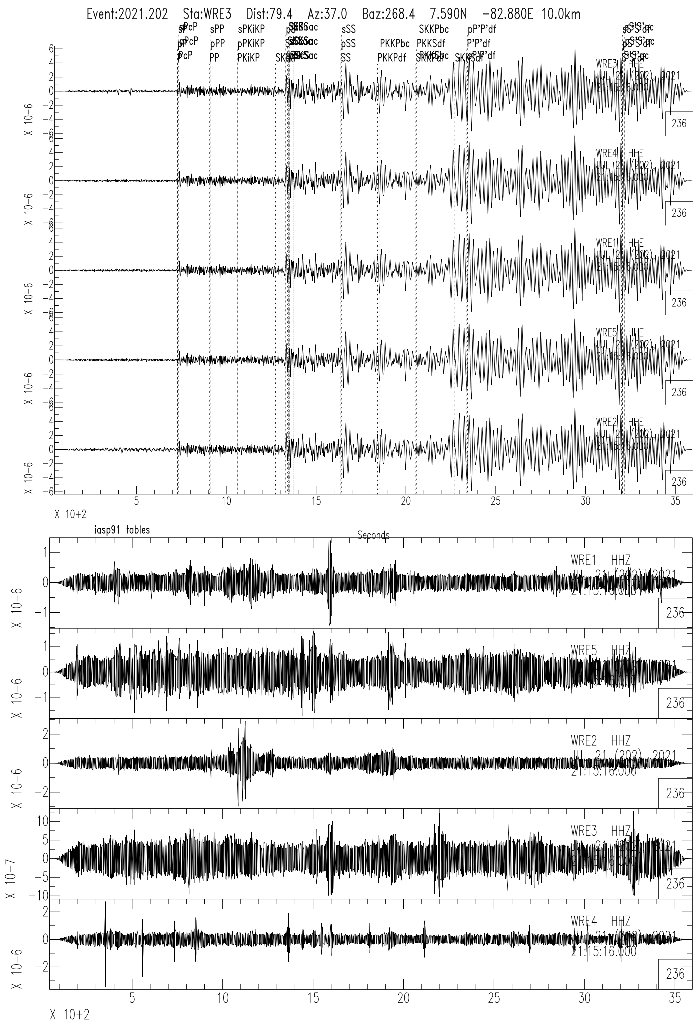
Increasing Capabilities

Raspberry Shake Network

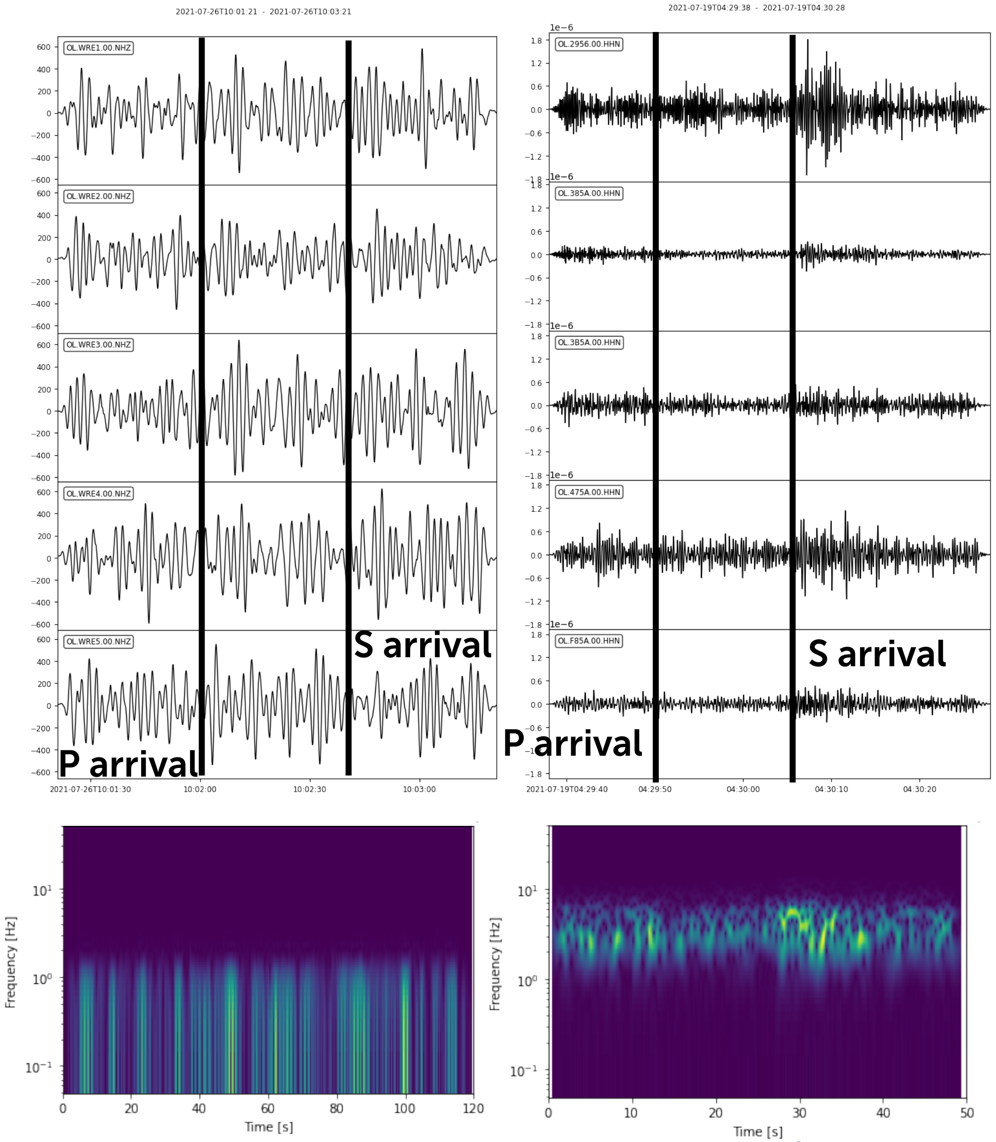
No	Station Code Name	Lat.	Long.	Bedrock Geology	Superficial Geology	Distance to Jan 31st Event	Jan 31st Event Visible?	Jan 31st Expected Arrival Waveform	Jan 31st Expected Arrival Spectrogram	Distance to Mar 21st Event	Mar 21st Event Visible?	Mar 21st Expected Arrival Waveform	Mar 21st Expected Arrival Spectrogram
1.	AM.R2A72	57.370	-2.055	Semipelite Metamorphic Bedrock	Clay, Sand, & Gravel	239.3 km	No Data	No Data	No Data	525.3 km	Yes		
2.	AM.R5CFD	57.144	-2.542	Micro-granodiorite Intrusion	Hummocky Glacial Deposits	266.2 km	Yes			561.0 km	Yes		
3.	AM.R92E0	56.946	-2.263	Interbedded Conglom. & Sandstone	Superficial Till Deposits	249.4 km	No Data	No Data	No Data	573.4 km	Yes		
4.	AM.R013B	56.442	-2.999	Sandstone, Siltstone, & Mudstone	Intertidal Silt & Clay Deposits	302.1 km	Yes			643.4 km	Yes		
5.	AM.RE4FA	55.893	-3.198	Andesite & Basaltic Andesite	Superficial Till Deposits	333.3 km	Yes			704.0 km	Yes		
6.	AM.REF28	55.027	-2.138	Sandstone Sedimentary Bedrock	Alluvial & River Terrace Deposits	329.9 km	Yes			770.0 km	Yes		
7.	AM.RBE3F	54.675	-1.231	Sandstone. Sedimentary Bedrock	Glaciofluvial Deposits Sand & Gravel	320.8 km	No			792.0 km	Yes		
8.	AM.R47BE	54.244	-0.370	Ooidal Limestone Sedimentary Bedrock	Superficial Till Deposits	335.0 km	No			827.7 km	Yes		
9.	AM.R1793	53.820	-0.367	Chalk Sedimentary Bedrock	Clay, Silt, Sand, & Gravel Alluvium	364.1 km	No			874.2 km	Yes		
10.	AM.R8086	53.045	-0.789	Mudstone Sedimentary Bedrock	Clay, Silt, Sand, & Gravel Alluvium	469.3 km	Not clear			963.9 km	Yes		
11.	AM.R8948	52.144	-1.498	Mudstone Sedimentary Bedrock	No Superficial Deposits	580.0 km	No			1,071.1 km	Yes		
12.	AM.RD0D2	51.847	-2.231	Mudstone Sedimentary Bedrock	No Superficial Deposits	629.4 km	Not clear			1,113.6 km	Yes		
13.	AM.RD886	51.406	-3.264	Mudstone Sedimentary Bedrock	Clay, Silt, & Sand Tidal Flat Deposits	703.9 km	No			1,178.1 km	No		
14.	AM.REE67	50.595	-4. 471	Slate Siltstone Sedimentary Bedrock	No Superficial Deposits	822.7 km	No			1,287.5 km	Yes		
15.	AM.RB5E8	50.117	-5.536	Slate & Siltstone Met bedrock	No Superficial Deposits	905.8 km	No			1,360.6 km	Not clear		

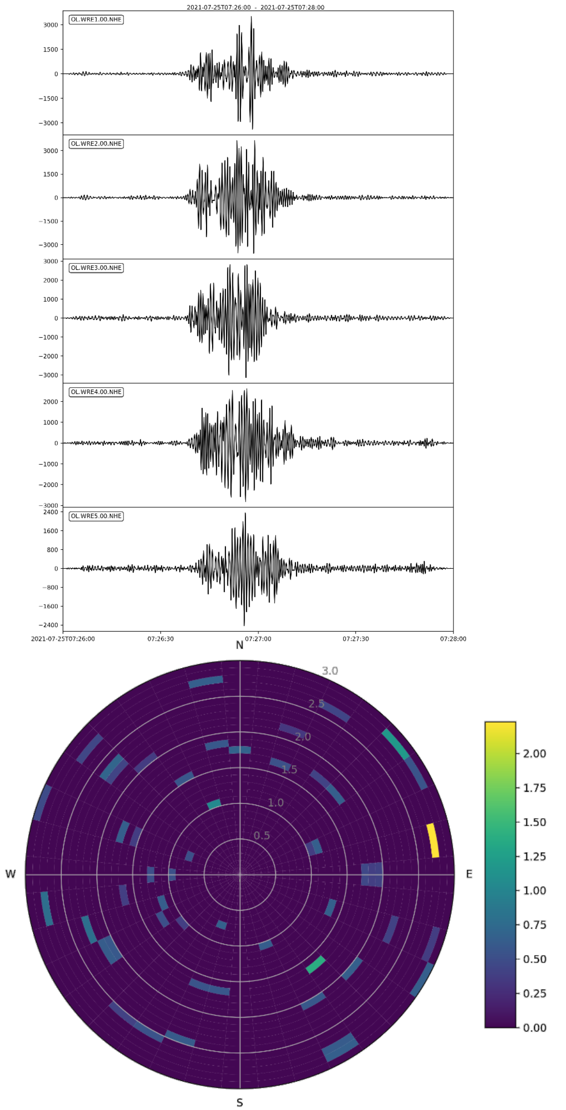
Scunthorpe (Humber Estuary) Array



Teleseismic event arrivals filtered in visible range (top) and in the range used for teleseismic detection (bottom)

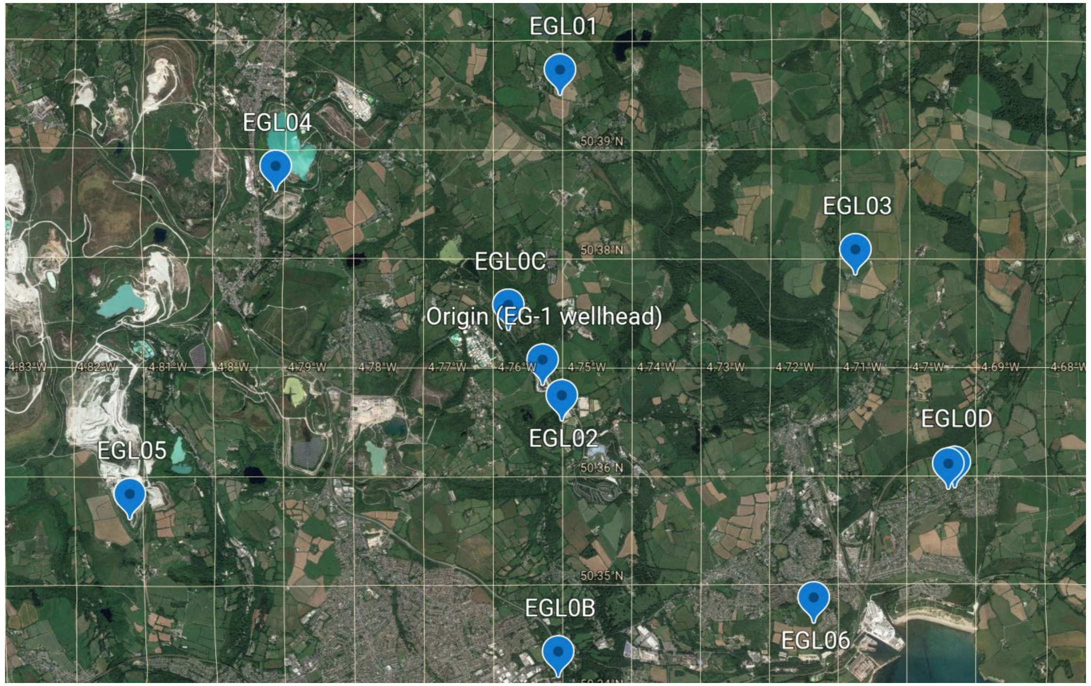


Expected arrivals and spectrograms for 2 small local events (<M2.5)

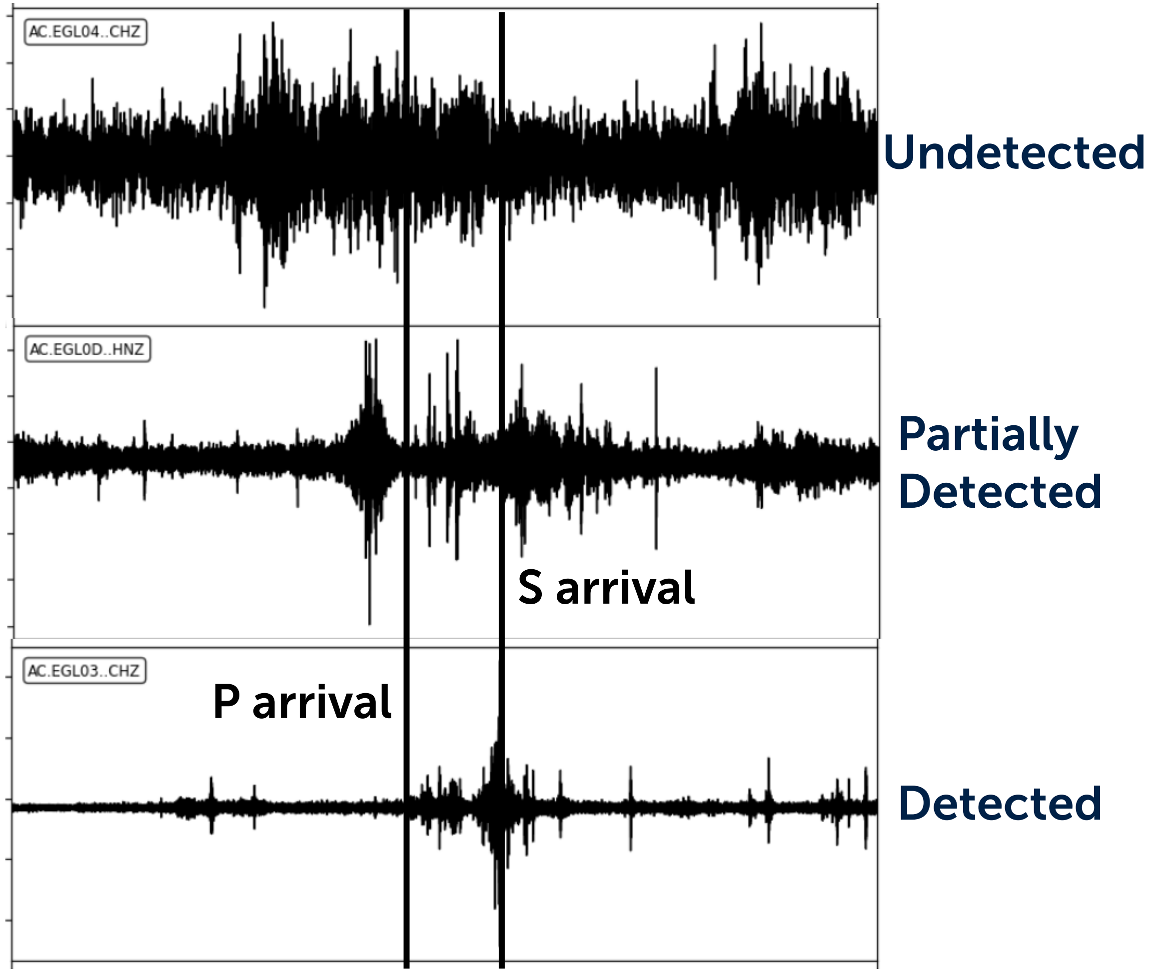


Quarry blast arrivals and beamforming on quarry blast arrivals

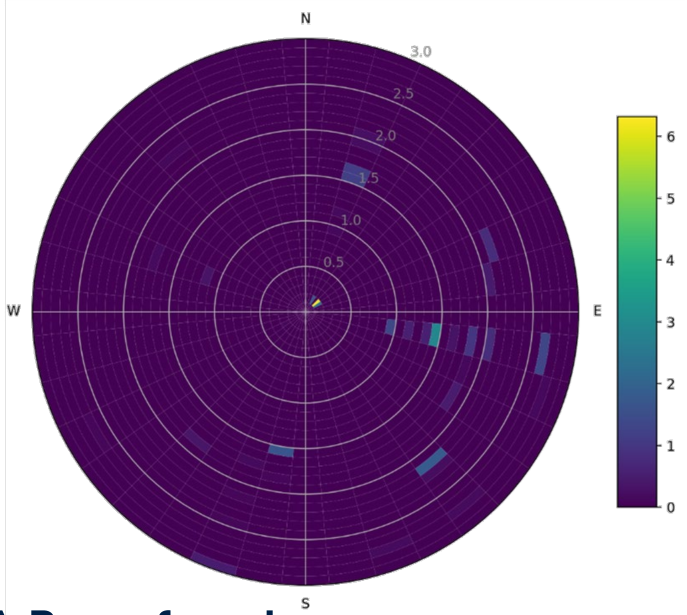
Eden Project (Cornwall) Array

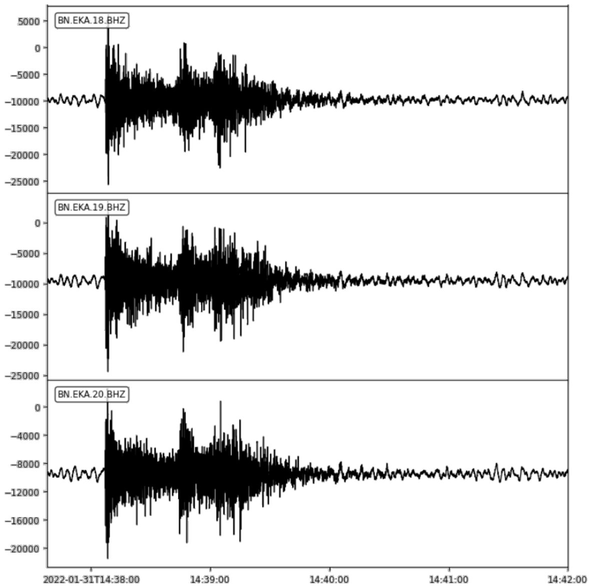


Location of instruments in the Eden Array (blue dots)



Eskdalemuir Array

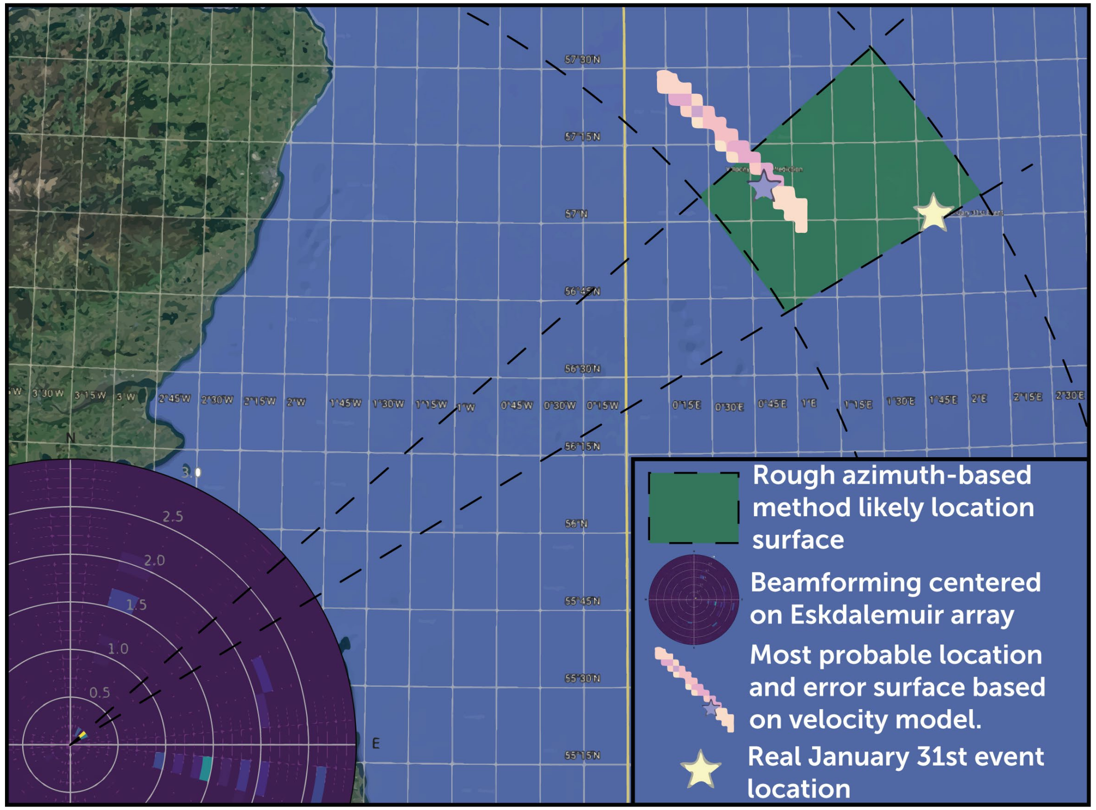




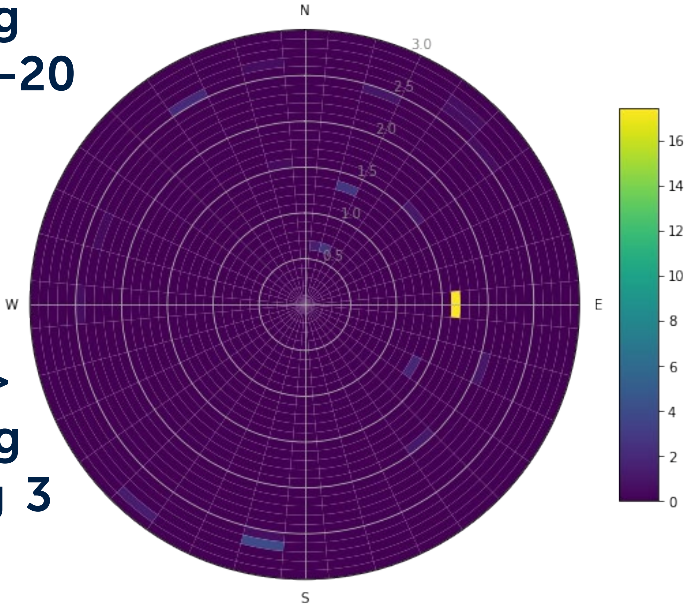
^ Beamforming results using 4-20 instruments

^ clearly visible arrivals

Summary of event location results using a rough azimuth-based method (green area) and a more precise velocity model-based computational method (blue star).

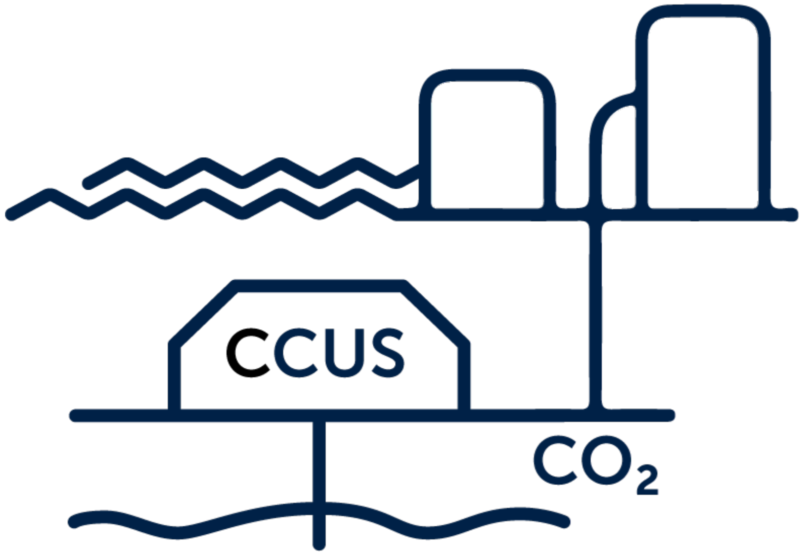


\> Beamforming results using 3 instruments

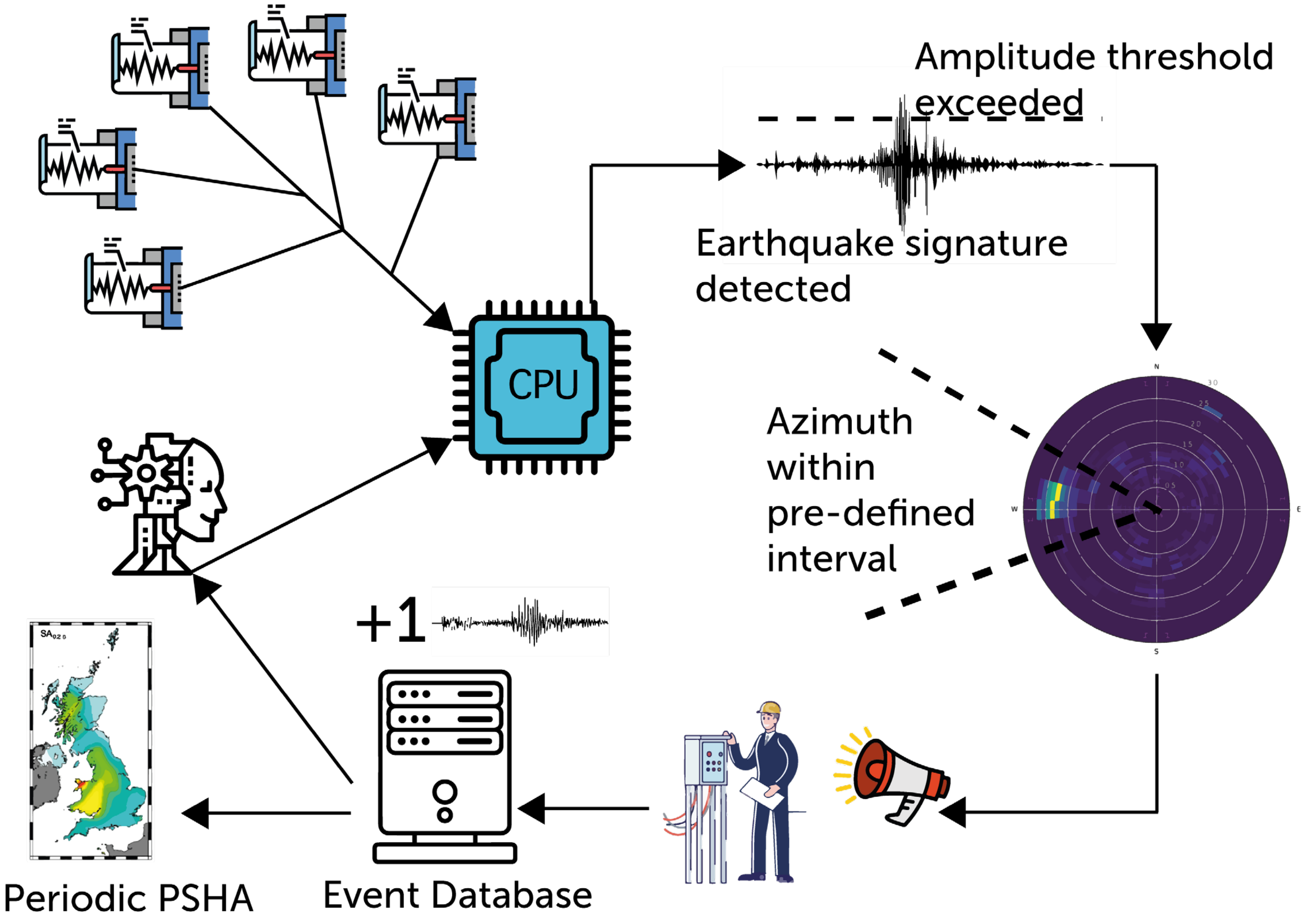


Conclusions

- ✓ Most land instruments are ineffective at detecting and locating sub-M3.5 events at epicentral distances greater than 800km.
- ✓ At distances between 200 and 500km, events up to M2.5 can be recorded only if ambient noise levels are low.
- ✓ Between 5 and 7 is a good number of instruments in an array to roughly be able to locate events.
- ✓ Regardless of how good the instruments are, efforts must be taken to ensure they are very well isolated from surrounding noise, because the frequency band of distant seismic activity often matches that of land noise



Impact: Future Early Warning System



Thank you! My email: victor.vescu@worc.ox.ac.uk