

# Global Collaborative Approaches to Anthropogenic Seismic Hazard Assessment

**Beata Orlecka-Sikora**

Institute of Geophysics, PAS, Warsaw, Poland  
(orlecka@igf.edu.pl)

## Cross-cutting environmental hazards

Anthropogenic seismicity

Air pollution

Fluid transport

Water Quality

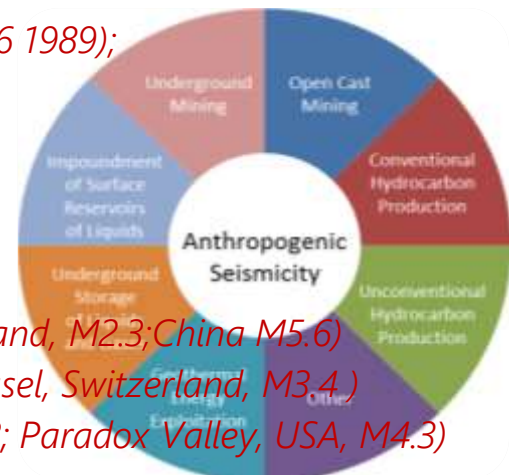
Local Impact

**Mining Induced Seismicity (MIS):** underground mining (*potash mine, Germany, M5.6 1989*); open cast mining (*brown coal mine, Belchatow, Poland, M4.6, 1980*)

**Reservoir Induced Seismicity (RIS):** (*Koyna, India M6.5, 1967; Kremasta, Greece M6.3, 1966*); **Injection/Extraction Induced Seismicity (IEIS):**

- conventional exploitation of oil and gas (*Kettleman North, USA, M6.1*)
- shale gas and other unconventional oil and gas exploitation (*Blackpool, England, M2.3; China M5.6*)
- geothermal energy production (*Geysers, USA M4.6; Berlin, El Salvador M4.4; Basel, Switzerland, M3.4*)
- underground storage of liquids and gases, including CCS (*Denver, USA, M4.8; Paradox Valley, USA, M4.3*)

**Cases in Debate (CiD):** The origin of earthquakes, whether natural or anthropogenic, remains unresolved, (*Gazli Uzbekistan sequence 1976-1984: M7.0, M7.0, M5.7, M7.0; Coalinga, USA, M6.7, 1983; Wenchuan, China, M7.9*)

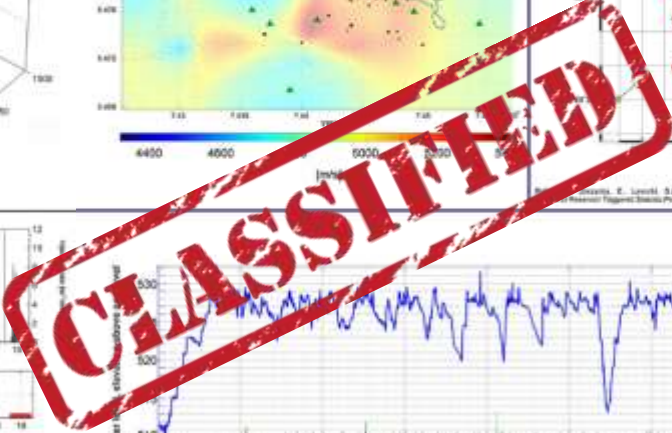
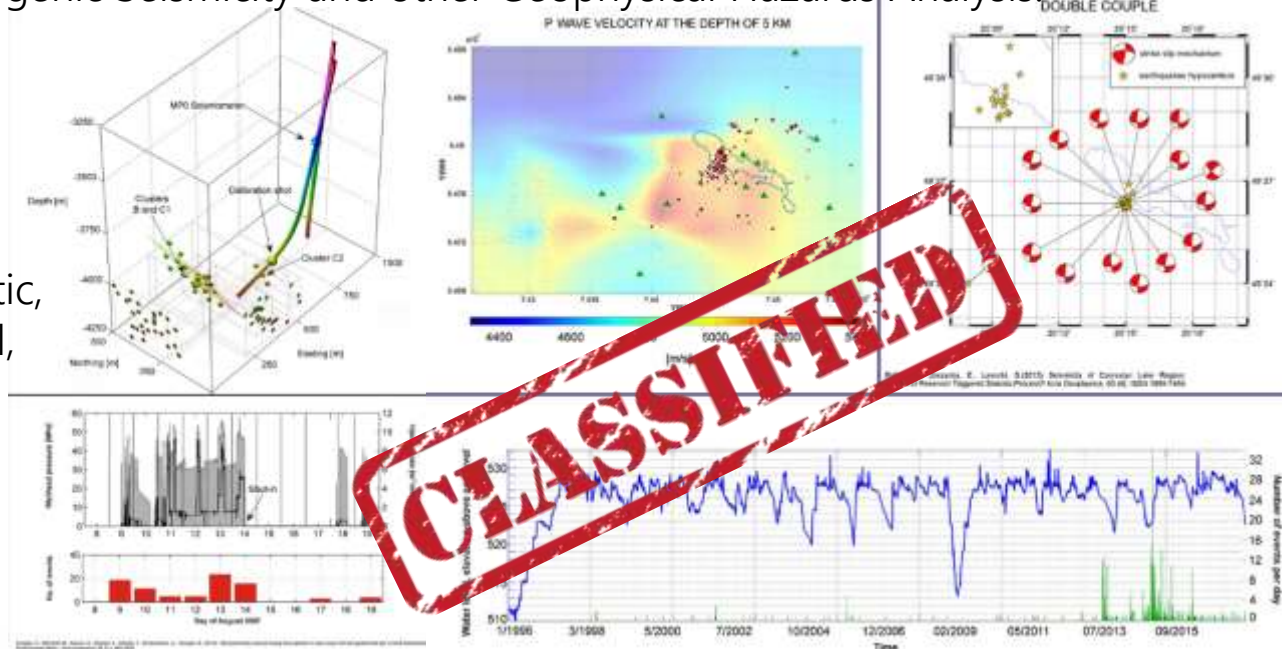


# AH is related to the inducing technological process

- ▶ AH research requires multidisciplinary data collection with mandatory inclusion of relevant technological data

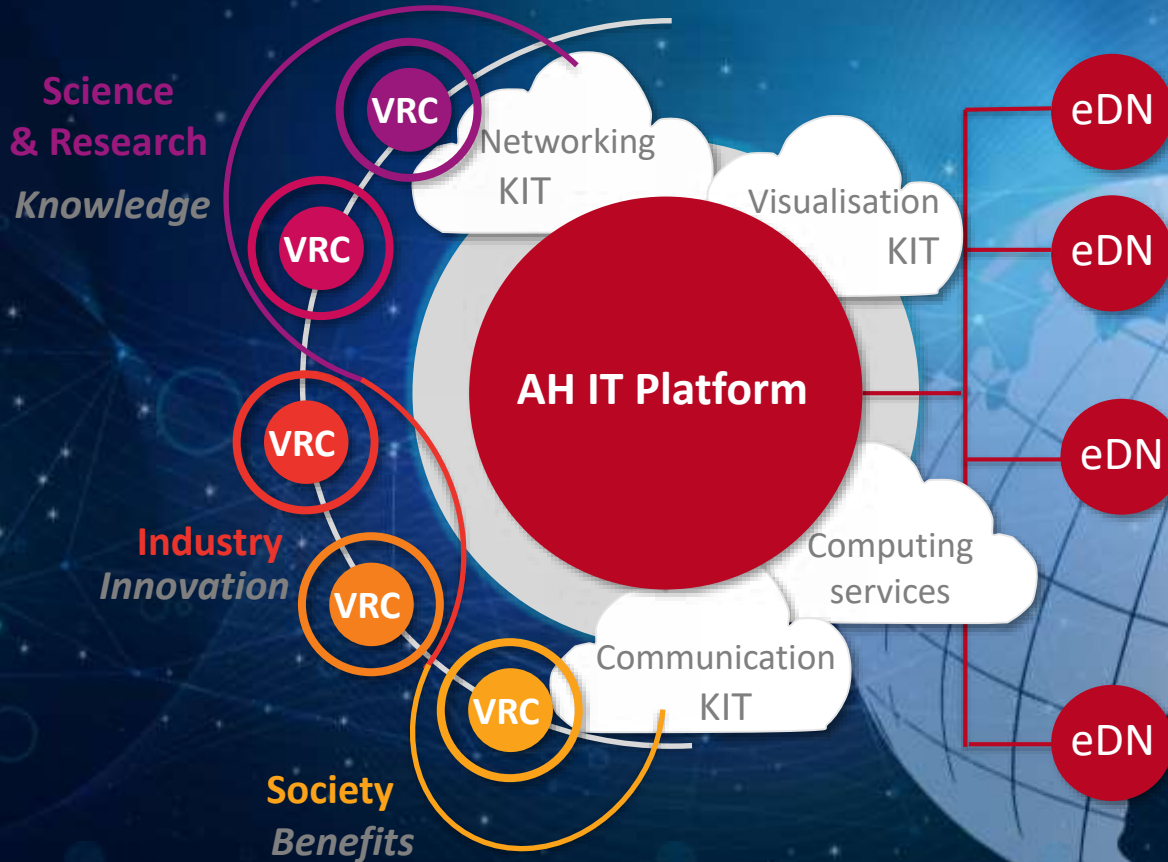
Data required for Anthropogenic Seismicity and other Geophysical Hazards Analysis:

- Seismic/Hazard Data
- Production Data
- Operational Parameters
- Technological Activity
- Other geo data (geodetic, tectonic, geomechanical, geophysical etc)



# Vision - THAS

23.05.2010





# Since 2011 to 2015 WP5b

**GŁÓWNY INSTYTUT GÓRNICWA**  
(CENTRAL MINING INSTITUTE)  
DEPARTMENT OF GEOSCIENCES AND GEOGRAPHY  
GIG  
www.gig.edu.pl

**EPoS**

### Current issue: Shale gas exploration and seismicity

Économique Sud-est (1000-2000 km)

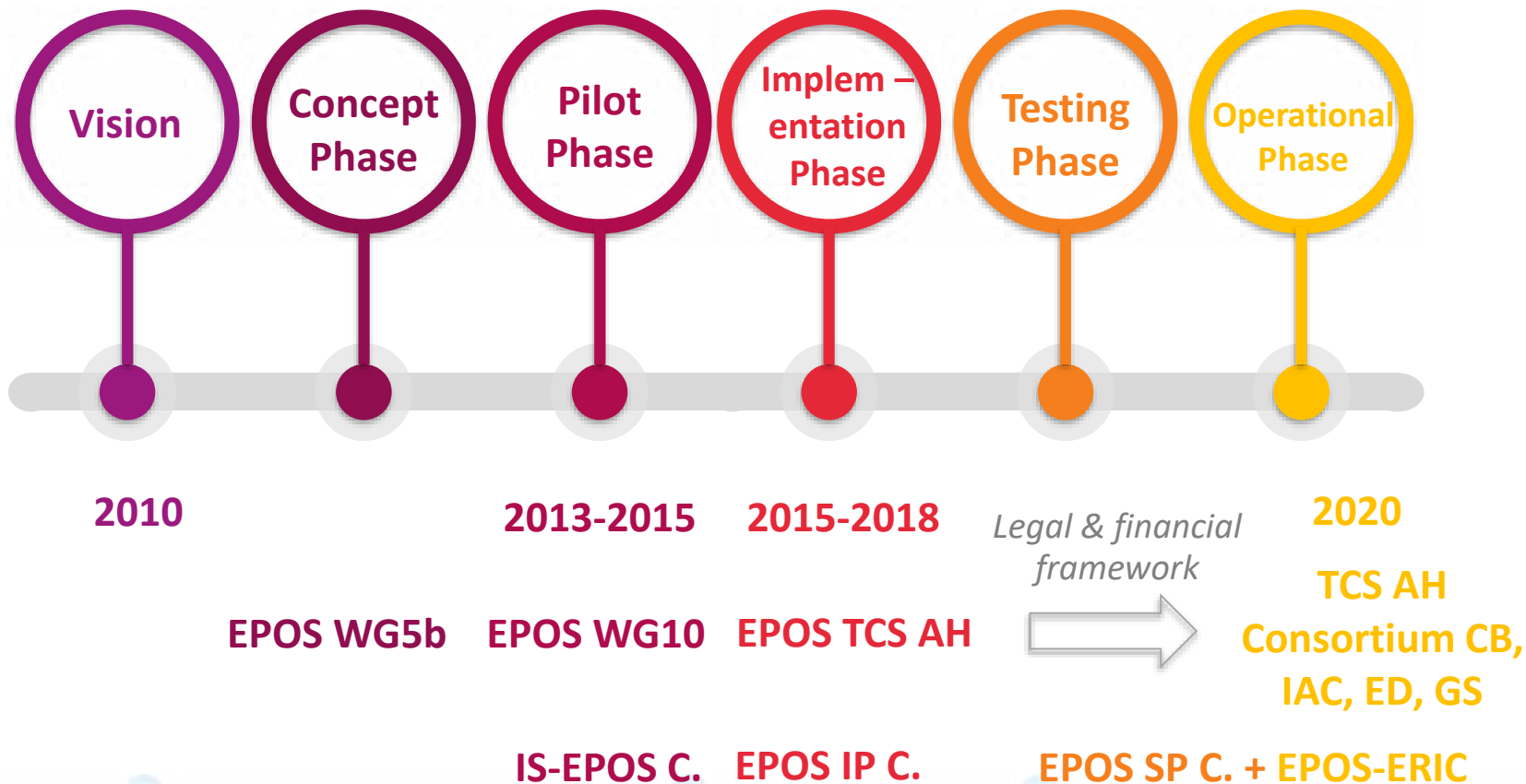
Gas de schiste  
Exposition autorisée  
Permis déposés pour l'exploration

Huiles de schiste  
Exposition autorisée  
Permis déposés pour l'exploration

07/2013

EPoS

# Roadmap



# TCS Anthropogenic Hazards



IS-EPOS Virtual Laboratory – Web-service



IS-EPOS  
PLATFORM

IS-EPOS  
~ 4 mln EUR

EPOS IP  
~ 1.8 +1.2 mln EUR

MUSE-EPOS PL  
~ 11 mln EUR

SERA  
~ 1 mln EUR

EPOS PL+  
~ 9 mln EUR

EPOS SP  
~ 400 tys. EUR

**SHEER  
Consortium**

Ver 1 NCN

RAFTIS FNP

GREAT  
~ 120 tys. EUR

EPOS ON  
~ 150 tys. EUR

**S4CE  
Consortium**

Ver 2 NCN

UMO-2019/.../00515 NCN

MYCA 1-4  
~600 tys. EUR

ARTIQ Excellence  
Center  
~ 500 tys. EUR

Sonata Bis NCN

UMO-2020/39/I/ST10/01318

**ERIS  
Consortium**

Preludium NCN

DigiTwins4PEDs

DT-GEO  
~ 360 tys. EUR

TCS AH MEiN 1  
~ 1 mln EUR

TCS AH MEiN 2  
~ 4 mln EUR

LIDER13/0075/2022

Preludium BIS  
NCN

TWIN-Waters

**Σ > 35 mln EUR**

**EGI &  
EOShub  
Consortia**



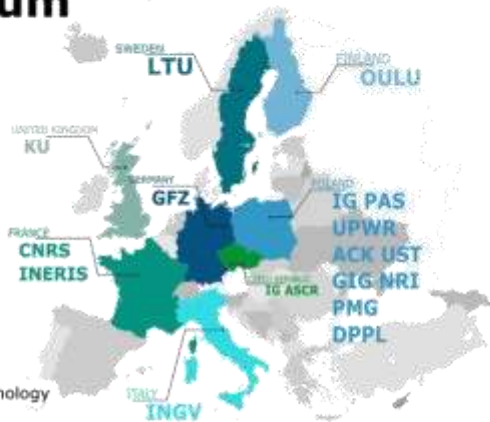
# EPOS Thematic Core Service Anthropogenic Hazards (TCS AH) Consortium

16 Institutions from 8 European and 1 Non-European Country



## TCS AH Consortium

### EUROPE



- SWEDEN  
Lulea University of Technology
- FINLAND  
University of Oulu
- UNITED KINGDOM  
Keele University
- FRANCE  
Centre National de la Recherche Scientifique  
French National Institute for Industrial Environment and Risks
- GERMANY  
German Research Centre for Geosciences
- CZECH REPUBLIC  
Institute of Geophysics of the Czech Academy of Sciences
- ITALY  
National Institute of Geophysics and Volcanology
- POLAND  
Institute of Geophysics Polish Academy of Sciences  
Wrocław University of Environmental and Life Sciences  
Academic Computer Centre Cyfronet AGH  
Central Mining Institute National Research Institute  
Polish Mining Group  
DPPL

### SOUTH AMERICA



**TCS AH mission:**  
integrate the research infrastructure s related to studies of geo-hazards of anthropogenic origin, in particular those caused by the exploration and exploitation





# Access to the integrated research infrastructure of EPOS TCS AH: episodes (datasets), applications (software), workspace, HPC, collaboration functionalities, document repository

EPISODES  
PLATFORM

EPISODES Platform

Documents

Support

EN

LOGIN

SIGN UP

**EPISODES Platform** provides open access to the integrated research infrastructures of **EPOS TCS AH**, giving users the possibility to:

- analyze anthropogenic seismicity and related hazards
- assess the potential impact of geo-resources exploitation
- use educational resources on anthropogenic hazards

EPISODES Platform

EPOS TCS AH

Language:  
English,  
French,  
Polish,  
Italian  
(Spanish – under preparation)

<https://EpisodesPlatform.eu/>

45

Worldwide episodes

76

Dedicated services

341 000

Data items

1900+

Professional users



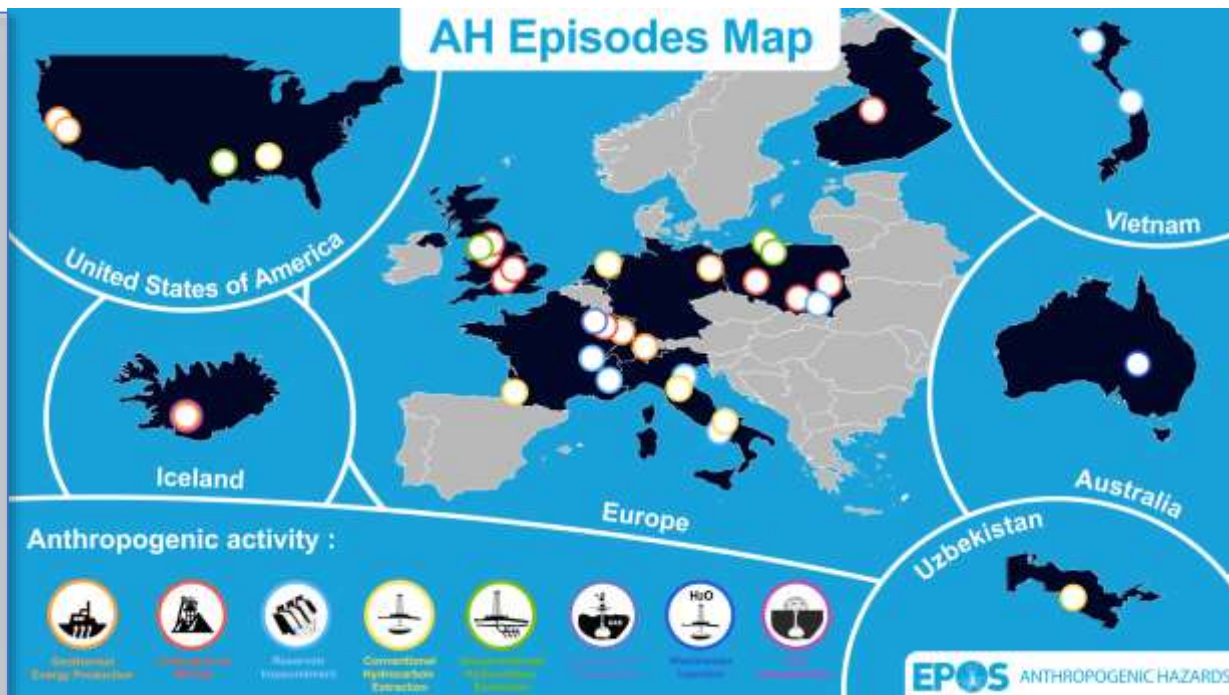


ANTHROPOGENIC  
HAZARDS

**Episodes:** Sets of time-correlated seismic, technological, and other relevant geo-data that relate comprehensively anthropogenic seismic processes to their industrial causes

## Inducing technologies:

CO2 sequestration	- 1
Conventional hydrocarbon extraction	- 6
Geothermal energy production	- 11
Reservoir impoundment	- 6
Underground gas storage	- 1
Unconventional hydrocarbon extraction	- 5
Underground mining	- 13
Wastewater injection	- 2



# EPISODES platform – user workspace

The screenshot displays the EPISODES platform user workspace. The browser address bar shows the URL: <https://tcs.ah-epos.eu/#userspace:BOBREK/Signal%20download/SpectralAnalysis>. The workspace tree on the left shows a project named 'BOBREK' with a 'SpectralAnalysis' workflow selected. The main workspace area is titled 'Spectral Analysis' and contains the following components:

- File Description:** 'Band 5 seismic spectral levels and corner frequencies using Sroka algorithm'
- INPUTS:**
  - Using Seisf Waveform: BOBREK/Signal/download/KW\_20091216020635\_20091216020635.mat
  - Using Velocity Model: test\_BOBREK\_BOBREK\_121\_velocity\_model.mat
  - Using Seismic event: BOBREK/Signal/download/ismic\_event
- Map:** A map showing the location of seismic stations (marked with colored triangles) in the Bytom area, with a 'Preliminary Station' label.
- Show channels:** A section for picking points and phases, displaying waveforms for channels: KW5001\_DHZ, KW5002\_DHZ, KW5003\_DHZ, KW5008\_DHE, and KW5008\_DHEJ.
- OUTPUTS:** A panel titled 'P Wave Parameters:' showing a table of seismic parameters and a 'Plot' of the spectral analysis.

**P Wave Parameters:**

Parameter	Value
Duration (s)	120
Source moment (Nm)	1.11E10
Source energy (J)	4.084
Mass (kg)	3.207E5
Acceleration (m/s <sup>2</sup> )	6.34E3
W <sub>0</sub> (m)	1.97E3
Wavelet regularity	0.7

**Plot:** A graph titled 'Spectral analysis' showing 'Power Spectral Density' on the y-axis (log scale from 10<sup>-10</sup> to 10<sup>-6</sup>) versus 'Frequency (Hz)' on the x-axis (log scale from 1 to 20). The plot includes a blue line for '20091216' and a red line for '20091216'.



Report for: 2024-08-01 - 2024-08-31



- **1920 users of the EPISODES Platform from 69 countries**
- **1323 users with institutional affiliation from 468 institutions**
- **97 new users registered in 2024**
- **485 file downloads from an external repository**
- **693 file downloads from workspace**
- **881 files added to workspace**
- **365 uploaded files**



# EPISODES Platform – RI in the scientific works

- ☐ > 60 publications of JCR;
- ☐ PhD theses, habilitations



## Geophysical Research Letters

### RESEARCH LETTER

10.1002/2017GL073929

#### Key Points:

- We examined significance of temporal static stress drop changes in relation to injection rate variations at The Geysers geothermal field
- Variations of static stress drop in time are statistically significant

## Temporal static stress drop variations due to injection activity at The Geysers geothermal field, California

M. Staszek<sup>1</sup>, B. Orlecka-Sikora<sup>1</sup>, K. Leptokaropoulos<sup>1</sup>, G. Kwiatek<sup>2</sup>, and P. Martínez-Garzón<sup>2</sup>

<sup>1</sup>Institute of Geophysics  
Helmholtz-Centre

## Geophysical Journal International

Issues Subject Advance articles Submit Purchase About



## Modelling fluid-induced seismicity rates associated with fluid injections: examples

# SCIENTIFIC DATA

CONFIDENTIAL  
COPY OF SUBMISSION FOR PEER REVIEW ONLY

Tracking no: SDATA-19-00814

## EPOS TCS for Anthropogenic Hazards: A Step-change in Tackling Hazards Associated with Georesource Exploitation

**Authors:** Beata Orlecka-Sikora (Institute of Geophysics, Polish Academy of Sciences), Stanisław Lasocki (Institute of Geophysics Polish Academy of Sciences), Joanna Kocot (Akademickie Centrum Komputerowe CYFRONET AGH), Tomasz Szapiezniak (Akademickie Centrum Komputerowe CYFRONET AGH), Jean-robot Grasso (Isere), Alexander Garcia-Aristizabal (Istituto Nazionale di geofisica e Vulcanologia, Sezione di Bologna), Marc Schaming (Institut de Physique du Globe), Paweł Urban (Institute of Geophysics Polish Academy of Sciences), Genda Jones (Keele University), Ian Simpson (Keele University), Saska Dineva (Luleå University of Technology), P. Salek (Institute of Geophysics Polish Academy of Sciences), Konstantinos Leptokaropoulos (Institute of Geophysics Polish Academy of Sciences), Grzegorz Liazek (Institute of Geophysics Polish Academy of Sciences), Dorota Oszevska (Institute of Geophysics Polish Academy of Sciences), Jean Schmittbuhl (Institut de Physique du Globe), Grzegorz Kwiatek (GFZ Potsdam), Aglaja Blanke (Helmholtz Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ), Gilberto Saccoroti (Istituto Nazionale di geofisica e Vulcanologia), I Chodźarska (Institute of Geophysics Polish Academy of Sciences), Lukasz Rudziński (Institute of Geophysics Polish Academy of Sciences), Izabela Dobrzycka (Institute of Geophysics Polish Academy of Sciences), Grzegorz Mułke (Główny Instytut Górnictwa), Barański (Polska Grupa Górnicza S.A.), Aleksandra Pierzyna (Polska Grupa Górnicza S.A.), Elena Kozlovskaya (University of Osnabrück), James Kinscher (INSTITUT DE PHYSIQUE DU GLOBE DE PARIS), Jan Sliwcy (Institute of Geophysics Polish Academy of Sciences), Michał Staszek (Akademickie Centrum Komputerowe CYFRONET AGH), Szymon Głuchowski (Institute of Geophysics Polish Academy of Sciences)

# SCIENTIFIC REPORTS

Article OPEN Published: 05 June 2018

## Induced seismicity response of hydraulic fracturing: results of a multidisciplinary monitoring at the Wysin site, Poland

J. A. López-Comino, S. Cesca, J. Jarosławski, N. Montcouquiol, S. Heimann, T. Dahm, S. Lasocki, P. Canuano & W. L. Ellsworth

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Review Article | Published: 05 December 2023

## The physical mechanisms of induced earthquakes

Mohammad J. A. Moein, Cornelius Langenbruch, Ryan Schultz, Francesco Grigoli, William L. Ellsworth, Ruijia Wang, Antonio Pio Rinaldi & Serge Shapiro

Nature Reviews Earth & Environment 4, 847–863 (2023) | Cite this article

3273 Accesses | 123 Altmetric | Metrics

18 Pages

64

865



# The Digital Europe

## Programme

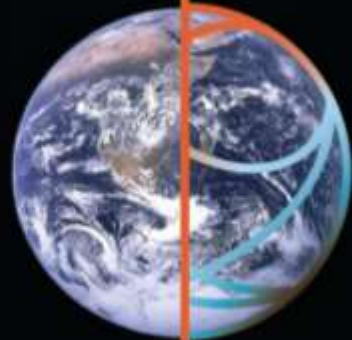
Destination Earth to sztandarowa inicjatywa Komisji Europejskiej mająca na celu opracowanie cyfrowego modelu Ziemi w skali globalnej. Model ten będzie podstawą do monitorowania, symulowania i przewidywania interakcji pomiędzy zjawiskami naturalnymi a działalnością człowieka. Przyczyni się do osiągnięcia celów transformacji zielonej i cyfrowej, w ramach Zielonego Ładu i strategii cyfrowej Komisji Europejskiej.

Partnerstwo: European Commission (EC), European Space Agency (ESA), European Centre for Medium-Range Weather Forecasts (ECMWF), European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

TOWARDS  
A GREEN &  
DIGITAL  
FUTURE

DESTINATION  
EARTH

# Towards a European Digital future



Project number: 101058129

Project name: **A Digital Twin for GEOphysical extremes**

Project acronym: DT-GEO

Call: HORIZON-INFRA-2021-TECH-01, Topic: HORIZON-INFRA-2021-TECH-01-01

Type of action: HORIZON Research and Innovation Actions

Granting authority: European Research Executive Agency

Project duration: 36 months, 1 September 2022 - 31 August 2025



## WP8: Anthropogenic geophysical extremes

IGF PAN, CNRS, ACK CYFRONET, GFZ, INGV & TCS AH



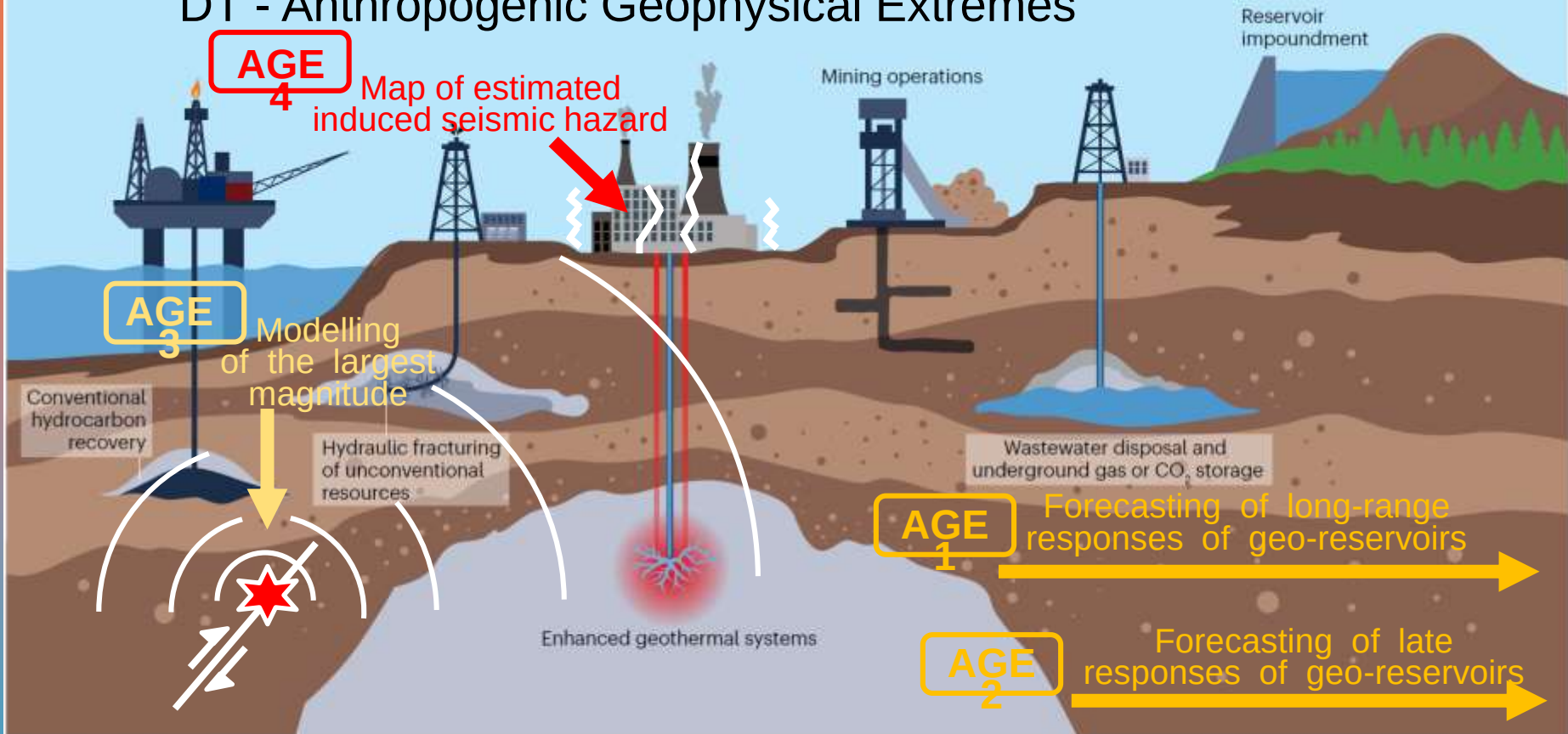
Project funded by Horizon Europe under the grant agreement No 101058129

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# DT - Anthropogenic Geophysical Extremes

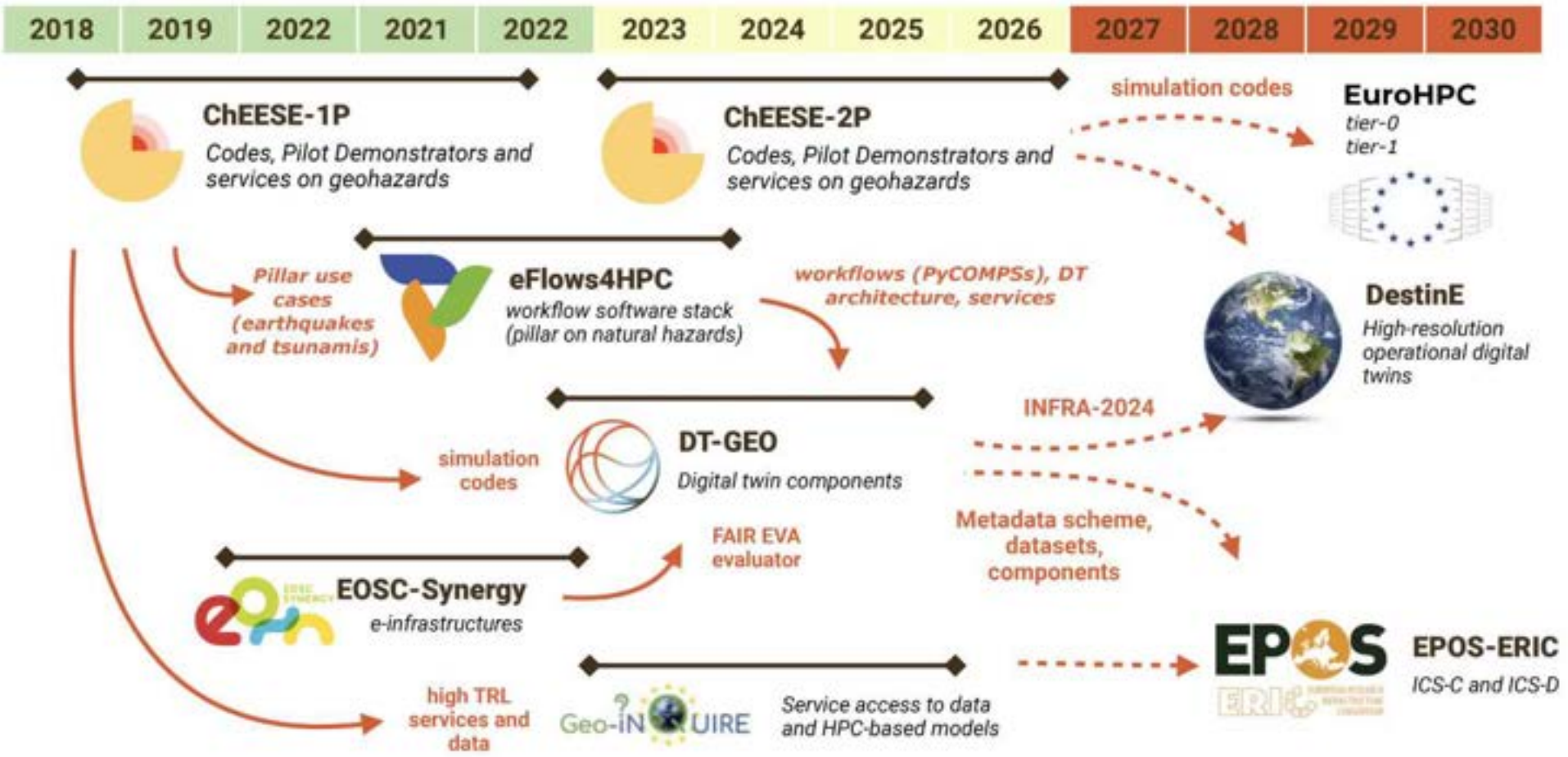


**Fig. 1 | Industrial activities that can cause induced seismicity.** Induced earthquakes can occur during conventional hydrocarbon recovery, hydraulic fracturing of unconventional resources, enhanced geothermal systems, mining

operations, wastewater disposal, underground gas or CO<sub>2</sub> storage operations and reservoir impoundment. Figure adapted with permission from ref. 16, Wiley.

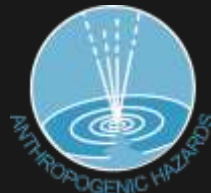
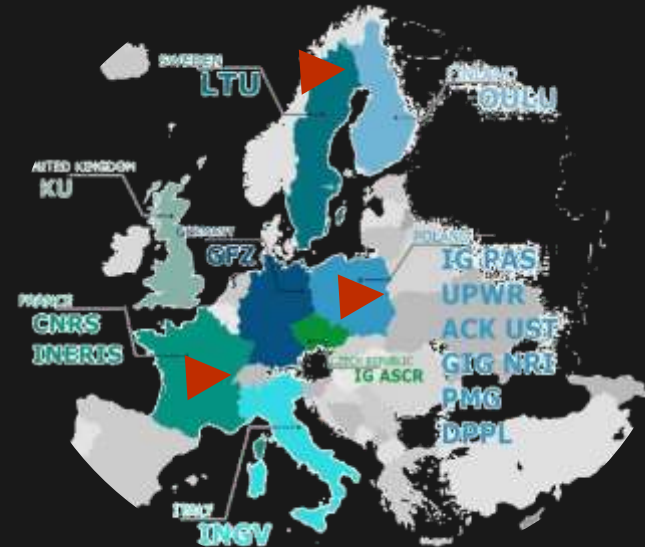


# Interakcje z innymi programami, inicjatywami i projektami



# NOVA-Quake

## Network for Observing of Versatility of Anthropogenic EarthQuake Predictability



This project has received funding from the European Union's Horizon research and innovation programme under the grant agreement No 101058129



Institute of Geophysics  
Polish Academy of Sciences

Dziękuję za uwagę



[orlecka@igf.edu.pl](mailto:orlecka@igf.edu.pl)



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