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The EPOS Thematic Core Service on Anthropogenic Hazards (TCS-AH): a Hotspot for Geothermal Research

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ABSTRACT

The EPOS Thematic Core Service on Anthropogenic Hazards (TCS-AH) is designed as a functional e-research infrastructure that provides access to a large set of relevant data and allows free experimentations in a virtual laboratory, promoting interdisciplinary collaborations between stakeholders (the scientific community, industrial partners and society).

The platform provides datasets as Episodes, which comprehensively describe Anthropogenic Hazards (AH) cases for infrastructures, people and/or environment. They are grouped in several categories of subsurface exploitations, one of them being geothermal energy production. Datasets describe various projects, including Soultz-sous-Forêts, Gross Schoenebeck, St. Gallen, The Geysers, and Carbfix. Users can access relevant datasets (e.g. seismic waveforms and catalogue), industrial data (e.g. well path, injection rates, wellhead pressure), and other geodata (e.g. geological section, velocity model, faults). The platform grants access to an application portfolio, designed for the AH area, from basic services (data integration and handling, physical modeling) to probabilistic assessments of anthropogenic seismic hazard and to simulator for multi-hazard/multi-risk assessment in exploration/exploitation of geo-resources.

Two local data centers (eNodes: IG-PAS/Poland and CDGP-EOST/France) provide the metadata and data to the TCS-AH platform in commonly used standards and formats (e.g. miniSEED, GeoTIFF, and .mat). A registration/authorization is mandatory to access some data covered by restriction imposed by data industry providers or shared data embargoed by running projects.

TCS-AH is one of the 10 TCS forming the EPOS infrastructure, and hosts data from other EU projects like SHEER and S4CE.

1. INTRODUCTION

The EPOS Thematic Core Service on Anthropogenic Hazards (TCS-AH) aims to bring together a broad community interested in Anthropogenic Hazards (AH), especially - but not only - interested in induced seismicity associated with geo-resources exploration and exploitation. Indeed, human activities may cause environmental hazards and risks: seismic activity, reactivation of faults, groundwater contamination, emission of gaseous species into the air, subsidence, etc. The socio-economic impact of these hazards may by significant, with material loss, injuries, and fatalities. The public is more and more concerned by these topics, and may lose confidence if AH are not accurately assessed and presented. It is therefore crucial to monitor and study the processes involved by geo-resources exploration/exploitation.

The TCS-AH is an answer to these questions. Its partners decided to set-up this e-infrastructure to facilitate a holistic approach to the research in the AH field. It integrates research activities to facilitate studies, to strengthen cooperation between industry and science. Today, TCS-AH is formed by representatives from science and industry coming from 14 European countries. The TCS-AH platform (https://tcs.ah-epos.eu/, Leptokaropoulos et al., 2019) provides data relative to conventional hydrocarbon extraction, unconventional hydrocarbon extraction, underground gas storage, underground mining, CO^2 sequestration, geothermal energy production, reservoir impoundment, wastewater injection, and applications to study them.

The EPOS TCS-AH community is organized in an initial consortium of 12 partners from 8 countries, and its work plan is established into five sections : a) Implementation of TCS-AH Services; b) Administration law & accounting; c) Episodes integration and application implementation; d) Promotion and dissemination; e) Projects & partnership. A *Data Provider Committee* and an *Users Committee* will advise the Consortium Board, and an *Innovation Advisory Committee* consisting of stakeholders from academia, industry, science, local and central administration bodies, society and others will be consulted during the decision making process of the TCS-AH.

2. DATA

On the TCS-AH platform, data are gathered as episodes, comprehensively describing a geophysical process, induced by human technological activity, which are hazardous for people, infrastructure and the environment. Data within the episodes cover usually geophysical data related to the hazard acquired directly from instrumental measurement and industrial data describing the process posing the hazard. Among geophysical data there are: seismological catalogs, PGA and PGV data, waveform data, seismological and strong motion networks, water and air quality from in situ and laboratory measurements. Moreover, geological data including geology and tectonics as well as geospatial data crucial for the proper understanding of the industrial activity in geological environment are delivered within every episode. Episode data should cover complexity of the process along with the causative relation between industrial operations and environmental hazards monitored with state-of-art geophysical instruments. Episodes contain also brief description of the site and inducing process together with references and complementary documentation.

There are already 10 published Episodes related to geothermal energy, with a significant presence of SOULTZ-SOUS-FORÊTS stimulation and circulation experiments (Figure 1):

- 1993 SOULTZ-SOUS-FORÊTS Stimulation,
- 2000 SOULTZ-SOUS-FORÊTS Stimulation,
- 2003 SOULTZ-SOUS-FORÊTS Stimulation,
- 2004 SOULTZ-SOUS-FORÊTS Stimulation,
- 2005 SOULTZ-SOUS-FORÊTS Stimulation,
- CARBFIX: geothermal energy production and CCS,
- GROSS SCHOENEBECK: geothermal energy production experiment,
- THE GEYSERS Prati 9 and Prati 29 cluster: Treated wastewater injection for geothermal power production,
- THE GEYSERS: geothermal energy production,
- ST. GALLEN: geothermal project.

Some SOULTZ-SOUS-FORÊTS Episodes are currently ready and will be added before the end of 2019: 1995 and 1996 Stimulations, 1994 Circulation.

Episodes related to geothermal energy production are distributed worldwide, in continental Europe, Iceland and USA.

Datasets include generally:

- Seismic catalogues, event related waveforms, event related accelerogram, seismic network, ground motion network;
- Industrial data, such as injection rate or volume, wellhead pressure, flowback rate, well path and position, steam production;
- Geodata such as velocity models, drillhole lithology, faults.

Datasets may have two specific characteristics:

- Some of them are owned by industrial partners that explore or exploit a geothermal site. These industrial partners have intellectual property rights on the data, and may restrict their distribution only to academic use, or case-by-case. On the other hand, they may be obliged by states (depending on local regulations) to open some datasets for environmental monitoring purposes;
- Some of them may be vintage, from the late 1980s to early 2010s, essentially in the case of Soultz-sous-Forêts exploration and research experiments that were conducted between 1987 and ~2010. These old data had to be recovered from shelves, old tapes, reports, than quality-controlled, described (metadata), converted into actual exchange formats. These actions needed significant human resources, as well as skills from senior persons that participate to the operations.

Datasets are archived and distributed in community-shared and open formats: miniSEED (Standard for the Exchange of Earthquake Data), XML, text or comma-separated values, pdf, GeoTIFF, etc. The TCS-AH platform uses Matlab .mat files for better visualization and processing performances.

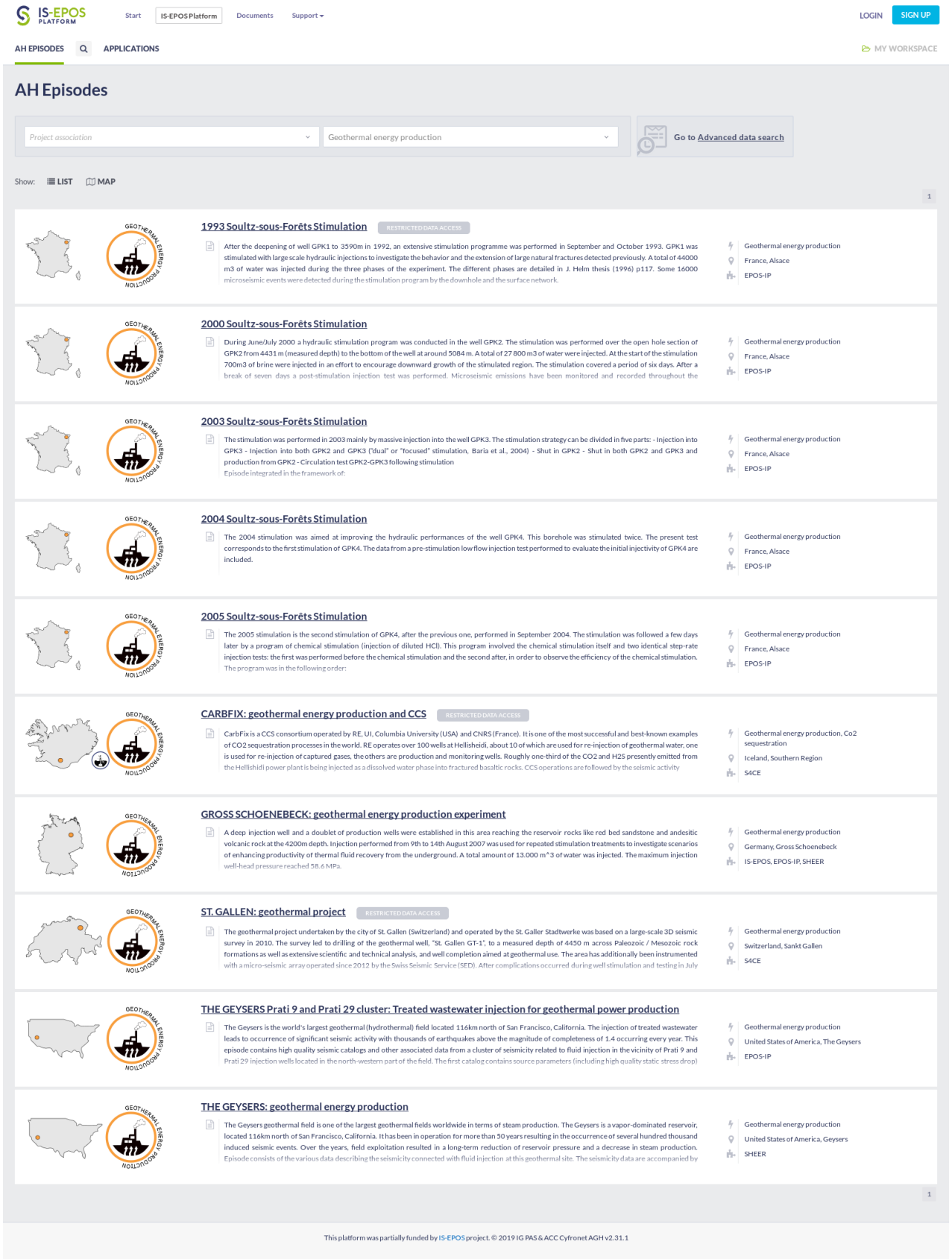

Figure 1: list of some Episodes related to Geothermal Energy Production and available on the TCS-AH platform

3. APPLICATION PORTFOLIO

The TCS-AH platform provides tools (application) that can be used to display, analyse and process the data provided in the Episodes. The applications are fully integrated in the platform, using the dataset as input, or providing data compatible with the other applications.

The currently 44 applications that are actually implemented on the TCS-AH platform are grouped into 13 thematic categories (Table 1). Some implement simple and common operation like converters, display or completeness magnitude estimation, other provide advanced processing like “Template-Matching based Detection Algorithm” or “Stress and strain changes induced by fluid injection and temperature change driven by geothermal injection”.

Collective Properties of Seismicity	Anderson-Darling test for exponentiality of inter-event time
	Coefficient of randomness
	Completeness Magnitude estimation
	Magnitude conversion
	Priestley-Subba Rao (PSR) test
Converters	CSV to Catalog converter
	Catalog to ASCII converter
	Catalog to Vectors converter
	GDF to Vectors converter
	GDF to XLS converter
	Catalog to XLS converter
	Ground Motion Parameters Catalog builder
	Time Series builder
	Seed converter
Correlation Analysis	Autocorrelation
	Cross-correlation
Data Processing Applications	Basic Vector Operations
Download Tools	Signal download tool
	Waveform download tool
Earthquake Interactions	Earthquake interactions: Georesource scale
	Earthquake interactions: Mainshock scale
	Earthquake swarm (reshuffling analysis)
	Time correlated earthquakes (Seasonal trends)
Event Detection Algorithms	Template-matching based detection algorithm
Filtering Tools	Catalog filter
Probabilistic Seismic Hazard Analysis	Source size distribution functions/Stationary Hazard
	Stationary Hazard: Exceedance Probability
	Stationary Hazard: Maximum Credible Magnitude
	Stationary Hazard: Mean Return Period
	Time dependent hazard in mining front surroundings
	Time dependent hazard in selected area
	Estimation of source parameters in time-varying production parameters geometry
Seismogram Analysis Tools	Seismogram picking tool
Source Parameter Estimation	Effective stress drop estimate
	Estimation of source parameters in time-varying production parameters geometry
	FOCI
	Localization
	Spectral Analysis
Stress Field Modelling	Stress inversion
Visualizations	Estimate of maximum possible magnitude for reservoir triggered seismicity
	Fracture Network Models - Mechanical Stresses
	Front Advance histograms
	Integrated Google Maps data visualization
	Seismic Activity with Front Advance

Table 1: Available applications on the TCS-AH platform (after Orleka-Sikora et al., 2019)

When necessary, an input form is displayed to allow definition all mandatory and/or optional parameters that have to be set prior the execution of the application. A prototype scenario for a modifiable application is implemented, and an "Autorun" option was added to allow creation of workflows of applications by setting the output of an application as the input of another one. Application are often linked to a documentation that gives details about application's objective and algorithm.

4. ACCESS THE TCS-AH E-RESEARCH INFRASTRUCTURE

Data are collected from providers by two local data centers (eNodes), IG-PAS in Poland and CDGP-EOST (https://cdgp.u-strasbg.fr) in France, and these eNodes provide the metadata and data to the TCS-AH platform. Metadata are more or less static on the platform, updated only when changed, but data are dynamically served to the platform each time they are requested.

Some episodes have open access for everybody, but some other are restricted either to an ongoing project embargo (e.g. BOIS, EPOS-IP, POL-VIET, S4CE) or have specific restriction (like only for academics in the case on industrial data from Soultz-sous-Forêts). Therefore, users need to register, and provide additional informations such as academic affiliation or belonging to a project. After verification, access capabilities are validated.

Each registered user is granted with a personal workspace. Selected data, processing results are stored in this workspace. It is also possible to upload external datasets (as far as they are in accordance with the data formats supported by the platform). Applications can be applied to the datasets, and the user can download the results (Figure 2).

As an additional but important point, TCS-AH platform serves as a tool for collaborative research work by providing intercommunity social functions: common workspace of project shared by participants, project brokering, upload/download data to the common workspace. As such, it can be used as a teaching tool for students practice or as shared space for demonstration.

TCS-AH and eNodes applies general FAIR principles and Research data management. Data are findable, accessible, interoperable, and reusable. Agreements are signed with providers, which confirms that the TCS-AH is able to distribute the data, and give to the providers the ability to define specific access rights. Within the EPOS and TCS-AH data policies, rights are open (CC:BY or CC:BY:NC) by default.

5. CONCLUSION

The EPOS Thematic Core Service on Anthropogenic Hazards (TCS-AH) provides many services to the AH community: data, applications, services, and a live and active community working on AH. It represent a true hotspot for geothermal research, and invites all stakeholders to become users, to provide Episode data, and to join the AH Consortium.

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REFERENCES

Leptokaropoulos, K., Cielesta, S., Staszek, M., Olszewska, D., Lizurek, G., Kocot, J., Lasocki, S., Orlecka-Sikora, B., Sterzel, M., and Szepieniec, T.: IS-EPOS: a platform for anthropogenic seismicity research, Acta Geophys. 67:299 (2019), 10.1007/s11600-018-0209-z.

Orlecka-Sikora, B., Lasocki, S., Kocot, J., Szepieniec, T, Grasso; J.-R., Garcia, A., Schaming, M., Urban, P, Jones, G., Dineva, S., Schmithbul, J., Lizurek, G., Sałek, P., Olszewska, D., Dobrzycka, I., Saccaroti, G., Leptokaropoulos, K., Chodzińska, K., Simpson, I., Blanka, A., Kwiatek, G., Rudziński, L., Mutke, G., Barański, A., Pierzyna, A., Kozlovkaya, E., Nevalainen, J., Kinscher, J., Sileny, J., Sterzel, M., and Fischer, T.: EPOS Services for Assessing Anthropogenic Hazards: A Step-change in Tackling Hazards Associated with the Exploitation of Geo-resources, Scientific Data (2019), submitted.

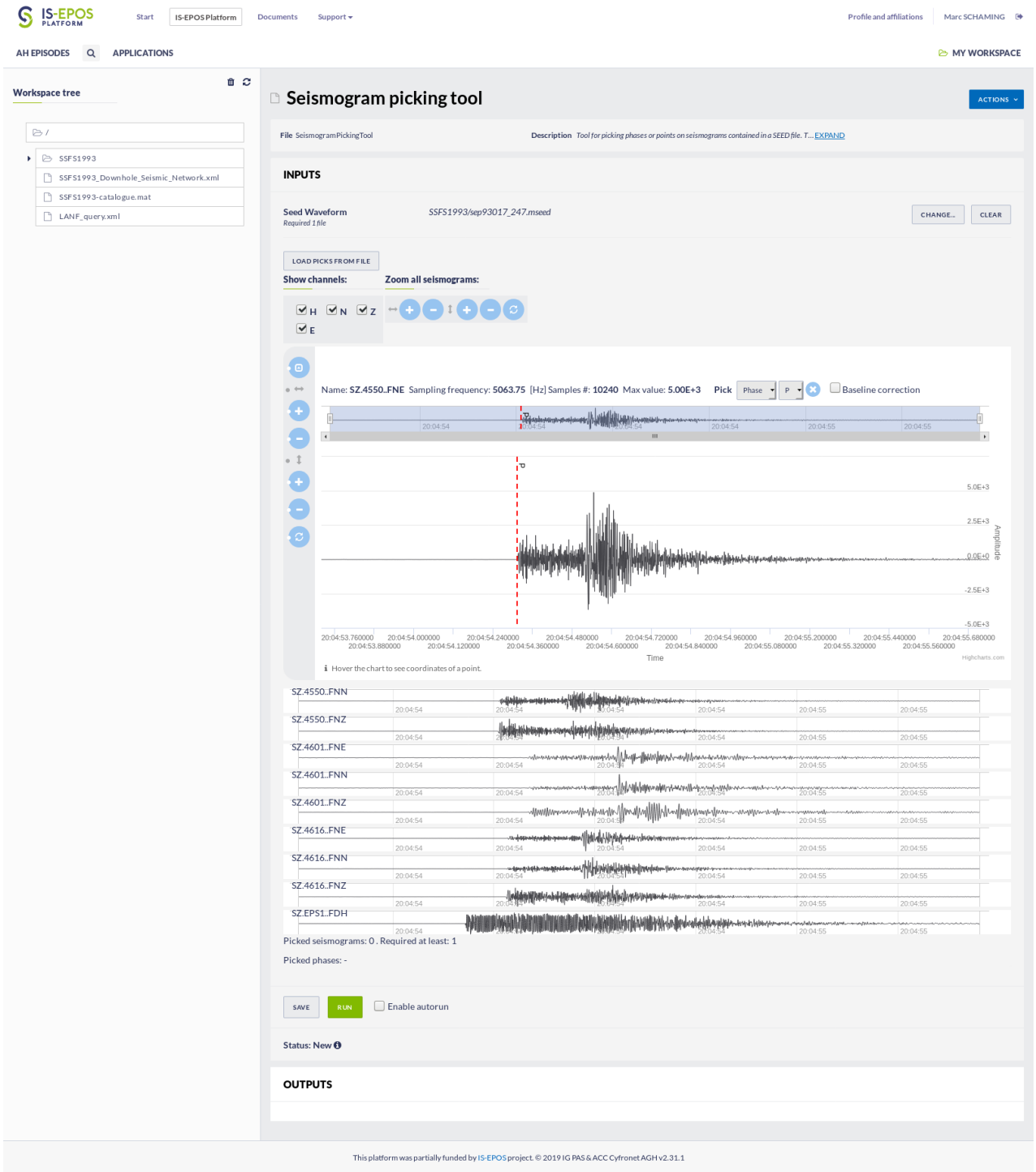

Figure 2: example of Seismogram picking tool in a user's workspace