

Final Report on the Realization of the Large Research Infrastructure (LRI)

2016-2019

CzechGeo/EPOS

Full name of the LRI: Distributed System of Permanent Observatory Measurements and Temporary Monitoring of Geophysical Fields

LRI's code: LM2015079

Recipient: Institute of Geophysics of the CAS, v. v.i.

Another participant/s of the LRI:

Czech Geological Survey

Masaryk University

Charles University

Institute of Geonics of the CAS, v.v.i.

Institute of Rock Structure and Mechanics of the CAS, v.v.i.

Research Institute of Geodesy, Topography and Cartography, v.v.i.

Principal investigator of the LRI: RNDr. Pavel Hejda, CSc.

Website address of the LRI: www.czechgeo.cz

PART I. - DESCRIPTION

A. Mission of the LRI, Basic Overview

I. Describe the mission and objectives of the LRI, scope of services the LRI provides to the scientific community, focus of the LRI's activities, capacities dedicated by a host institute and the project partners, state of development at the beginning and at the end of the funding period.

CzechGeo/EPOS is a comprehensive system of geophysical field observations operated by geoscience institutions in the Czech Republic. The system consists of permanent observatories, mostly connected to global networks, local stations or networks in selected areas that are important for long-term observation for the needs of basic or applied research, and mobile stations that serve for temporary measurements in selected locations, usually within large international projects. CzechGeo/EPOS provides user-friendly access to data via international data bases/repositories or directly on web pages of participating institutes.

The recent form of the CzechGeo/EPOS results from a long term development, during which the observatories, stations or networks have been built as a response to the needs of the research community or society. CzechGeo/EPOS provides expertise in geodesy, geodynamics, geomagnetism, geomorfology, geotechnics, geothermics, gravimetry, hydrogeochemistry, rock mechanics, climatology, seismology, tectonics, volcanology and related branches of informatics. The observatories and networks were operated by several institutions without sufficient coordination. In 2009 the institutions responded to the first call for proposals for funding of Large infrastructures for research, experimental development and innovation and established the consortium CzechGeo/EPOS. The national initiative coincided with the activity of European geoscience community towards integration of observations data across countries and geoscience disciplines and establishment of the European Plate Observing System – EPOS. The infrastructure was supported by project LM2010008 "CzechGeo/EPOS - Distributed System of Permanent Observatory Measurements and Temporary Monitoring of Geophysical Fields in the Czech Republic – Development and Operation of the National Node of the Pan-European EPOS Project" for the period 2010-2015.

During preparation of the recent project LM2015079 in 2015, Czech Geological Survey was invited to join the CzechGeo/EPOS team, as geophysical and geological data available there are important for geoscience research. For better coordination and management in general, the infrastructure was divided into five sections. Leading institutions of the sections are in brackets:

- 1. Section of Seismology (IG)
- 2. Section of GNSS and Gravimetry (RIGTC)
- 3. Section of Crust Geodynamics (IRSM)
- 4. Section of Geomagnetism (IG)
- 5. Section of Geological and Geophysical Databases (CGS)

The sections and networks will be described in details in Part I.C.I.

According to the decision of MEYS, the support by LM projects is dedicated exclusively for operational costs and research aimed at strategic development of the LRI. Investments in the amount of 42 mio CZK and in-house research have been funded by complementary project CzechGeo/EPOS-Sci funded by Operational Program Research Development and Education. The installation of the equipment and testing phase was partly supported by the LM2015079 Project.

Infrastructure was also supported by other projects and institutional budget of Partners. The mean human resources in FTE dedicated to the infrastructure were following:

	LM2015079	CzechGeo/EPOS-Sci Other projects		Institutional budget	
		OP RDE		(estimate)	
IG CAS	4.8	2.6	4	6	
CGS	3.3	0.9	6	4	
IPE MU	1.3	0.3	1	1	
FMP & FS CU	1.7	1.4		2	
IGN CAS	0.6	0.2		1	
IRSM CAS	5.4	1.6		4	
RIGTC	2.6	0.5		2	
Total	19.7	7.5			

Table A.1 Human resources measured by mean FTE over period 2016 – 2019.

STATE OF DEVELOPMENT OF THE INFRASTRUCTURE BETWEEN 2016 and 2019

The LRI state between 2016 and 2019 has changed especially in the field of acquiring a wider amount of better quality data and in the systematization of metadata (within INSPIRE). The upgrade of stations not only improved the technical parameters (resolution, sampling rate, Internet access) but also increased the number of on-line connected stations. In the area of GNSS (Global Navigation Satellite Systems), this mainly involves upgrading observation stations to ensure data reception from newly built systems: the European system Galileo, the Chinese system BeiDou and the Indian system NAVIC. The amount of data available on-line and often in nearly real-time on the global portals have been increased. The infrastructure participated in the EPOS Implementation Phase Project aimed at integration of data across geoscience disciplines.

The modernization (upgrade, enlargement) will be described network by network in Section C, together with the data utilization.

B. Management Structure and Research Team

I. Describe the management structure and organizational chart of the LRI, its changes during the funded period and its anchorage within the host institution(s).

The CzechGeo/EPOS bodies are:

- 1. The Board,
- 2. The Chair,
- 3. International Scientific Board.

The Board consists of representatives of the host and partner institutions appointed by their statutory authorities.

The Board

1. Takes care about the purpose the infrastructure was established for, about the application of public interest in its activities, and about its proper economic activities,

- 2. determines the course of the infrastructure's activities and makes decisions on its future development with respect to recommendations of the European EPOS Infrastructure,
- 3. discusses draft budgets,
- 4. approves budgets and its changes,
- 5. appoints section leaders,
- 6. approves annual reports.

The Board meets at least twice per year. Section leaders are invited with consultative voice to the Board meetings.

The Chair

- 1. represents the infrastructure with respect to the Ministry of Education, Youth and Sport (MEYS) and other external bodies,
- 2. represents the infrastructure especially in negotiations on accession to the European EPOS-ERIC infrastructure,
- 3. is responsible for the preparation of annual reports and other documents according to the demands of MEYS, and, after being discussed in the Board (and approved, if needed), delivers these documents to the MEYS,
- 4. submits project proposals to the funding agencies.

The Chair of the Infrastructure is the Principle investigator

<u>Section leaders</u> are responsible for the coordination of the activities of individual sections to guarantee an increase mutual awareness and support collaboration between facilities of similar character.

Geophysical observations belonged from the very beginning to basic activities of the host institution and are incorporated in its foundation deed. The institute management provide the infrastructure also by economical and organizational support, including organization of the annual workshop of the infrastructure.

II. Describe the composition and functioning of supervisory and advisory bodies (if established):

International Scientific Board

- 1. monitors the activities of the Infrastructure, in particular with respect to the quality of the offered data products and services and their significance for the scientific community,
- 2. provides recommendations towards the development of the services and improvements of their quality,
- 3. discusses annual reports and draft budgets
- 4. ISB has also the role of the opponent group of the CzechGeo/EPOS-Sci project.

Members of the ISB are following researchers: Carine Bruyninx (Royal Observatory of Belgium), John Clinton (ETH Zurich), Alan Thomson (British Geological Survey, Edinburgh) Jørgen Tulstrup (GEUS – Geological Survey od Denmark and Greenland), Carla Braitenberg (University of Trieste), Jaroslava Plomerová (GFÚ AV ČR). III. Describe generally (not by names) human resources background over the entire funding period
– classification of employed and hired persons, including full-time equivalent (FTE). Fill in the table
(if needed convert amount of hours to FTEs):

Number of FTEs	2016	2017	2018	2019
Senior scientists	5.10	5.85	5.49	6.50
Junior scientists	0.93	1.12	1.09	0.84
PhD students	0.89	0.49	0.52	0.86
Students	0.40	0.18		0.06
Technical staff	11.50	12.02	10.23	9.11
Administratives	1.40	0.50	1.29	0.15
Other	0.20	0.47	0.32	0.53
Total	20.42	20.63	18.94	18.05

C. Structure of Users and Utilization

I. Describe capacities and instrumentation dedicated to LRI by institutes involved, principles of granting access to the LRI, indicate number of accesses from the Czech Republic and from abroad and volume of utilization of LRI (e.g. data produced, time allocated, services provided).

The observatory infrastructure is not designed for a direct use by visiting researchers. The scientific community or commercial customers use the recorded data and products (D&P) via data centres, or on request addressed to the individual providers. The detail list can be found below. If the server registers the number of users or amount of data downloaded, the information is also given.

INSTRUMENTATION OF THE INFRASTRUCTURE

The infrastructure is divided into five sections. Leading institutions of the sections are in brackets.

1. Section of seismology (IG CAS)

Czech Regional Seismic Network - CRSN (all partners but CGS)

CRSN is the backbone of seismic observations. It consists of 20 permanent broadband seismological stations operated by six partner institutions, which cover the territory of the Czech Republic. 3 stations were equipped with new broad-band seismometers and data acquisition systems. Digital data are collected and processed in real time at data centres at IG ASCR, Prague and IPE MU in Brno and exchanged with European and world data centres as well as neighbouring seismic networks. Major tasks of the CRSN are to monitor earthquake activity on the territory of the Czech Republic and neighbouring regions and to provide high quality data for research of world's seismicity, strong earthquake source processes, and the structure of the Earth. **West Bohemian Local Seismic Network – WEBNET** (IG CAS and IRSM CAS)

Local seismic network WEBNET has been monitoring swarm-like seismicity in the West Bohemia/Vogtland which is most active seismogenic region on the territory of the Czech Republic (https://www.ig.cas.cz/en/observatories/local-seismic-network-webnet/). The network was gradually extended up to and 24 stations at present covering an area of about 900 km2. 12 stations were upgraded and 9 stations equipped with the telemetry in the last year. At present, WEBNET consists of 24 broadband station equipped with Guralp CMG-3ESPC sensors and up-todate Centaur digitizers (by Nanometrics) offering seedlink data streaming, remote calibration and diagnostics. All the stations are connected to Internet, the stations powered from batteries are recharged by solar panels. Furthermore, dense network HORC consisting of four accelerometers and a seismometer which are located inside and on the top of the dam Horka was installed in the last year; all the HORC network stations (measuring points0 are connected to Internet.

North Moravia Local Seismic Network – MONET (IPE MU and IGN CAS)

The MONET network is a basic infrastructure for monitoring seismicity in the extensive geodynamically active region of the NE Bohemian Massif adjacent to the Western Carpathians' orogenic front. This region exhibits numerous signs of regionally anomalous, Late Cenozoic to recent tectonic activity. Another important source of regional seismicity comes from the mining activities in the Karvina area and the adjacent Polish coal regions. The network now consists of 12 stations. Most of their instrumentation was modernized in the last years and data are being telemetered to data centres in a real-time. Modern means of sharing of archived data via EPOS infrastructure (ORFEUS/EIDA) were established (see graphs below). We started regular publishing of regional earthquake catalogue based on this improved monitoring network.

Icelandic Local Seismic Network – REYKJANET - IG CAS and IRSM CAS

The REYKJANET network monitors swarm-like seismicity on the Reykjanes Peninsula in South-West Iceland since 2013. The purpose of REYKJANET is to obtain data on earthquake swarms in different tectonic environments; the main objective is to disclose the causes leading to release accumulated strain energy in form of earthquake swarms. The network comprises 15 stations covering an area of 40x25 km similarly to WEBNET. All the stations have been operated in continuous mode. All the stations were fully upgraded last year (seismic instruments), this year 10 stations are planned to be connected to Internet.

Little Carpathians Local Seismic Network – MKNET (IRSM CAS in co-operation with the Geophysical Institute SAS Bratislava)

The network is situated in one of the most seismically active zones on the territory of Slovakia - in the transition zone between the Eastern Alps and the Western Carpathians. The MKNET seismic network is an effective tool for studying seismicity in this region. IRSM operates 5 stations. One station was purchased in the last period.

Patras Seismic Network – PSLNET (FMP CU in co-operation with the University of Patras) RI PLSNET is designed for collecting geophysical, primarily seismic data in the area of western Greece, belongs to the most seismic active zone in Europe. PSLNET is a part of national Greece seismic network HUSN and therefore, our seismic stations contribute to the routine geophysical measurements (seismicity, location, magnitude and source mechanism of earthquakes). The main contribution is the data support for the basic research into understanding the physical processes of moderate earthquakes occurred in Greece. The operation of PSLNET is based on Memorandum of Understanding between CUP and UPAT. A total of seven experts (3 from CUP and 4 from UPAT) are involved in the operation and management of the stations. Only 1.5 FTE is covered by project. **CarbonNet** (Fs CU)

The objective of CarbonNet and the newly established West Bohemia near fault observatory NEFOBS is to carry out a long-term monitoring of magmatic CO2 degassing in the area of West Bohemia and to provide high quality data to constrain models of gas-rock interaction. The hosting university dedicated 0.1 FTE of the key researcher to the project. Additional capacities dedicated to the project by the university involve two monitoring boreholes F1 and F2 including a new hut to protect the instruments in the field. The collaborating project ICDP-Eger provided four new boreholes for installation of the special borehole seismometers.

The data portal providing near-realtime monitoring data in an open access mode showed about 10 accesses monthly with 30% from abroad.

Mobile Seismic Network – MOBNET (IG CAS)

Pool of temporary stations (MOBNET) fill the gap in observational facilities if there is a need to perform a dense seismic monitoring in areas of interest and where permanent network is scarce. Typically, this is the case of passive seismological experiments aimed at the investigation of the deep structure of the tectonically significant regions. The aim is to collect the high-quality data for investigation of the structure of the Earth. The MOBNET now operates in the running scientific project AlpArray (20 stations), its complementary experiments (EASI -20 -stations, IVREA - 10 stations, PACASE - 21 stations) and are planned for their future deployment in the Adria Array. Besides data we provide software for data quality control (Vescey et al., 2017) and for ambient noise processing (Kvapil et al., under prep.). Data recorded by MOBNET in the frame of international experiments: 2.4 TB.

The pool of MOBNET stations was completed by 21 broadband stations and 25 data acquisition systems in the last year. Supporting equipments: 2 instruments for setting seismometers,1 instrument for calibration of digitizers, 1 tiltmeter

2. Section of GNSS and gravimetry (RIGTC)

Network of Permanent GNSS Stations – VESOG (RIGTC)

The network of 11 permanent GNSS (Global Navigation Satellite System) stations is located at research and academic institutions in the Czech Republic. The GOP operational centre is responsible for data dissemination and maintenance of the network. Infrastructure produces primary observations (pseudo-ranges and carrier-phases) for precise location, geo-kinematics, reference frame, GNSS-meteorology and other purposes. The network of continuously operating GNSS stations is equipped with Topcon, Leica, Java and, Trimble GNSS receivers. They are operated by an operation centre from the Geodetic observatory Pecny using an in-house developed software. Station GOP6 was upgraded by new receiver.

Network od Permanent GNSS Stations in Greece -PPGNet (RIGTC and FMP CU)

In the framework of CzechGeo/EPOS, RIGTC and FMP CU jointly operate six permanent GNSS (Global Navigation Satellite System) stations in Greece, which are merged into Greek network of permanent GNSS stations. The joined facility consists of 15 stations. The locations were selected in cooperation with Greek and French partners (National Observatory of Athens,

http://www.gein.noa.gr/services/GPS/noa_gps.html, École normale supérieure, https:// gpscope.dt.insu.cnrs.fr/chantiers/Corinthe/). Five of the GNSS stations (Katochi, Paravola, Kato Retsina, Lepenou, Rigani) have been designed to monitor recent motions near the Patras and Corinth Gulf. The stations are located in public or academic buildings. Three stations were upgraded in the last period. The new receivers accept a broader spectrum of frequency signal and also signals from new navigation systems Galileo and BeiDou.

Geodynamic GNSS network – GEONAS (IRSM CAS)

The Geodynamic Network of the Academy of Sciences (GEONAS) is a network of permanent GNSS stations performing continuous observations of geodynamic movements on territory of the Czech Republic. It consists of 20 permanent stations, four of them have been incorporated within EUREF Permanent Network EPN. All stations operate with the 30 second sampling rate. The configuration

was designed to cover various geological structures. All stations are connected online to the IRSM operational centre where the recorded data are automatically checked. Data processing is performed using the Bernese software package. Two stations were upgraded by new receivers. **West Bohemia Geodynamic Observatory – WEBGEODYN** (IG CAS)

The observatory is located in seismogenic region of the Bohemian Massif which exhibits geodynamic unrest mainly manifested by swarm-like seismicity and crustal-fluid activity. It consists of semi-regional GPS, gravity, and precise levelling networks which are designed for epoch-style observations. In addition, the permanent GPS stations NKOS and KVET and 3 hydrological wells are included. The main aim of the WEBGEODYN observations is to assess the impact of earthquake activity on surface movements, groundwater level variations, and temporal changes of the gravity field. Such assessment is important for water-resource management, spa resorts and local communities.

Greek Volcanic Islands Monitoring – GREVOLCAN (IG CAS in co-operation with the Kapodistrian University of Athens)

There are two existing networks for GPS-Gravity monitoring of active volcanoes on the islands of Nisyros and Thira in Greece. They are designed for epoch-style observations. With respect to insufficient number of observation sites, the networks will be equipped with additional stations respecting the latest developments of volcanic and earthquake activity. The objective is to monitor magmatic and tectonic processes in the interior of the volcanoes that represent hazard for local population and properties. The data will be available to local authorities and academia as technical reports.

We started our epoch gravity measurements in 2012 and plan to continue in regular campaignstyle observations until 2022, so that the results will be statistically significant. In addition, we intend to set up a station in the Nisyros crater to perform short-period GPS and gravity measurements.

Gravimetric station Pecný – GSP (RIGTC)

The gravimetric station Pecný is a part of the Geodetic observatory Pecný, located 35 km southeast of Prague. Main objective of the station is to provide continual measurements of gravity variations with low noise levels in a wide range of periods (from minutes to long-term changes). The station Pecný is providing SG data from superconducting gravimeter through the International Geodynamics and Earth Tide Service (IGETS) of the International Association of Geodesy. The service was established in 2015 and the IGETS data base is hosted by GFZ German Research Centre for Geosciences. Data availability is realized by a FTP server which can be accessed by ftp://igetsftp.gfz-potsdam.de. The access to the FTP server requires a username and a password, obtained by a registration procedure on the IGETS data base website (http://igets.gfzpotsdam.de). Available are raw gravity data (sampled at 1 sec and decimated at 1-min) and corrected data at several product levels.

GOP (Geodetic observatory Pecny) Data, Analytic and Software Centre (RIGTC)

The GOP data centre collects and disseminates national, European and global GNSS observations and GOP products in the form of files at ftp://ftp.pecny.cz/LDC and selected data and products also via real-time streams using NTRIP protocol with the source table available at http://ntrip.pecny.cz.

The GOP analytic centre was established in 1997 within the sub-commission for the European Reference Systems (EUREF) of the International Association of Geodesy (IAG) and since that time it has provided operational solutions of the EUREF GNSS permanent network (EPN) in support of the

maintenance of European reference frame. Recently, GOP has been reoriented to the reprocessing activity to provide a unique solution for full EPN network to the 2nd EUREF Reprocessing. During the last years, GOP also provided, in co-operation with the Land Surveying Office, a national solution for the EUREF Densification (http://epncb.oma.be/_densification/). Based on national contributions, the project aims at providing dense velocity field in Europe and it is supposed to contribute to the European Plate Observing System (EPOS) in future. Since 2003, GOP analytic centre has contributed to the EIG EUMETNET GNSS Water Vapour Programme, EGVAP (http://egvap.dmi.dk) providing two operational GNSS tropospheric products (global and regional) in near real-time fashion in support of numerical weather forecasting. GOP has developed and is maintaining the Trop-NET system

(http://www.pecny.cz/Joomla25/index.php/trop-net) for coordinated GNSS-based tropospheric parameter production for the E-GVAP. All the permanent GNSS stations available from the Czech research infrastructure were integrated into relevant GOP solutions – daily coordinates and their long-term combination as the final and rapid products and tropospheric parameters in near real-time products.

GOP also contributes to the EPOS-IP project (https://www.epos-ip.org/) with developing the G-Nut/Anubis software http://www.pecny.cz/Joomla25/index.php/gnss/sw/anubis for data quality control of multi-GNSS constellations, including all modern frequencies, signals and navigation data. The tool is distributed as open-source under the GNU GPL Version 3 licence and since 2014 it has been used by more than hundred users worldwide. It is also a unique contribution from GOP to the development of the future GNSS data dissemination system within the EPOS infrastructure.

3. Section of Crust Geodynamics (IRSM)

Monitoring 3-D Fault Active Displacement – TECNET (IRSM CAS)

Systematic building of a network for monitoring of 3-D fault displacements using crack gauges TM-71s (patented by IRSM CAS) started in 2001. The main advantage of the device is the possibility to record movements on-site directly across a fault plane, and yielding very accurate results of 3D fault movements and of the rotation of the blocks. Measuring devices are placed across the faults preferentially in the underground (caves, galleries) to minimize the undesired influence of exogenous or anthropogenic processes. More than 140 gauges are currently installed on tectonic faults within the Czech Republic, Slovakia, Slovenia and across Europe. In addition, more distal sites are located in Asia and South America (<u>www.tecnet.cz</u>). 22 gauges were purchased in the last period.

Long-term Monitoring of the Slope Deformations – SLOPENET (IRSM CAS)

The network of long-term monitoring of the slope deformations has been steadily growing since the beginnings of the 1970s. The most significant sites cover numerous slope deformations in different geological environments are included into SLOPENET network. The field data will be used for landslide risk assessment, for mitigation measures, and for estimating the influence of global climate changes on the potential changes in landslide frequency of occurrence. The network was recently equipped with a multiparametric column in 30 m deep monitoring hole combining inclinometric, piezometric, accelerometric and magnetic readings.

Czech Earth Tide Observatories – CZET (IG CAS)

The early tiltmeter station in Příbram (PRIB) was established already in the 1950s in a deep mine shaft as the first tilt observatory in Eastern Europe. At present, it is equipped with two tiltmeters. In addition, it hosts seismic station PBCC of CRSN. The Skalná Observatory (SKAL) is located in the West Bohemian seismically active region. It is equipped with a tiltmeter with photo-electric

pickups, weather-station and a gravimeter. In addition, there is a seismograph belonging to RI WEBNET, and a dilatometer belonging to RI TECNET. The data will contribute to worldwide Earth tide database (formerly International Centre for Earth Tides). The Jezeří Observatory provides two important components to the monitoring system of the large ČSA open-pit brown coal mine. The instrumentation was completed by borehole inclinometer.

Geothermal Climate Change Network - GeoCLIMANET (IG CAS)

The GeoCLIMANET consists of 5 experimental test sites that monitor changes of the energy budget at the Earth's surface and propagation of the surface temperature variations connected with the recent climate changes into the subsurface. This signal about recent ground surface temperature changes is contained in the temperature-depth profiles measured in boreholes several hundred metres deep and can be used to reconstruct the ground surface temperature history of several past centuries. The key issue in interpreting the reconstructed histories in terms of the long-term climatic variability is the relationship between the soil and surface air temperatures. In order to get statistically relevant data on this air, soil and bedrock temperature coupling, long-term observational series are necessary. It is the primary purpose of the GeoCLIMANET network consisting of: (i) Two observatories with three boreholes (150 m, 50 m and 40 m) complemented by soil temperature measurements on the grounds of the Institute of Geophysics in Prague that monitor coupling of the air, soil and bedrock temperatures and the effect of a different vegetation types in an area of occasional soil freezing in the environment of the large city agglomeration; (ii) Observatory Kocelovice, 90 km south of Prague in a typical countryside area with 40 m deep borehole and regular soil freezing; (iii) Field observatory Svojšice established to monitor effect of the slope orientation and angle on the soil temperatures in a countryside area with regular soil freezing; (iv) Observatory Malence in Slovenia with 100 m deep borehole. It monitors coupling of the air, soil and bedrock temperatures in a typical Slovenian countryside area in a warm climate with marginal soil freezing. The observatory is run together with the Slovenian Geological Survey, Ljubljana; (v) Observatory Caravelinha in Portugal with 150 m deep borehole. It monitors temperatures in a typical Portuguese countryside area in a subtropical climate without soil freezing. The observatory is run together with the Geophysical Centre of the University Evora. Data provided by GeoCLIMANET network are valuable also in other scientific and technical fields including meteorological models, forestry, agriculture or heat energy storage and extraction. All stations have been maintained and some of them upgraded in the last several years.

4. Section of Geomagnetism

Geomagnetic Observatory Budkov and Mobile Equipment – GEOMAG (IG CAS)

The observatory is located at Budkov near Prachatice, at a place which is distant from sources of man-made disturbances of the geomagnetic field. The observatory is equipped with two digital fluxgate magnetometers and proto precession magnetometers. A set of Quartz variometers of Bobrov type was equipped by photosensors with feedback and put in operation in 2016. Data with 1-second and 1-minute sampling are automatically transmitted to INTERMAGNET.

The observatory data are completed by repeated (bi-annual) measurements at 7 points of the secular network. The repeat station measurements are coordinated in the frame of MagNetE initiative.

Mobile Magnetotelluric Set - MTMOB (IG CAS)

The mobile magnetotelluric set is standardly employed in studies into the distribution of the electrical conductivity of the Earth's crust and upper mantle. In the recent decade, the instruments have participated in several experiments on a continental and regional scale (Central

Europe Mantle geoElectrical Structure, CEMES; Electromagnetic Study of the Trans-European Suture Zone, EMTESZ; MT studies of the eastern margin of the Bohemian Massif and of the West Carpathians crustal structures. The MTMOB set consists of two broad band systems GMS06 and two long period systems LEMI-417 for magnetotelluric field measurents.

5. Section of geological and geophysical databases (CGS)

Geological and geophysical data as well as access to existing relevant information are essential for the scientific research, namely when aiming at predicting and mitigating landslides, subsidence, earthquakes, flooding and pollution. The CGS-DRI (Czech Geological Survey Data Research Infrastructure) provides effective access to geological, geophysical and related applied data with the use of up-to-date technologies of both European and global standards. That is why the Czech Geological Survey was invited to join CzechGeo/EPOS from 2016. The main objective of the research activity is the technological development and modernization of data and technical infrastructure enabling long-term sustainable management, operation and use of the geological information system CGS-DRI. The work was focussed on making the inventory of data resources in CR (structured, unstructured, analogue – described by publicly available metadata), evaluation of data (relevance to INSPIRE, EPOS and national priorities), consolidation of data (optimisation of data management, update of data models, implementation of standardized code lists, definition of process schema, validation and compliance to standards), data harmonization (INSPIRE) and access to data using modern technologies (metadata, web applications, web view and download services).

ACCESS TO DATA AND SERVICES

The observatory infrastructure is not designed for a direct use by visiting researchers. The scientific community or commercial customers use the recorded data and products (D&P) via data centres, or on request addressed to the individual providers. The detail list can be found below. If the server registers the number of users or amount of data downloaded, the information is also given.

1. Section of seismology

Czech Regional Seismic Network (CRSN)

On-line data can be accessed by program Antelope on server <u>http://kozel.ig.cas.cz/</u> by SeedLink on addresses <u>http://kozel.ig.cas.cz/</u>, <u>http://bizon.ig.cas.cz</u>

Access to the archive records of CRSN is available on following addresses:

IG data server: <u>http://silo.ig.cas.cz/wdrm/wdrm_index.php</u>

European data portal EIDA: <u>https://www.orfeus-eu.org/data/eida/</u>

Data center GEOFON: <u>http://geofon.gfz-potsdam.de/waveform/archive/network.php?ncode=CZ</u> Data center IRIS: <u>http://ds.iris.edu/ds/nodes/dmc/data/types/waveform-data/</u> (selected stations)

Statistics from GFZ Potsdam since 2016 (yearly average): >44000 data requests and >1.1TB data download.



Bulletins of seismic events registered by CRSN stations and catalogues of regional events are available on:

http://www.czechgeo.cz/gfu-bulletin/

hhttp://www.czechgeo.cz/gfu-catalog/

http://www.isc.ac.uk/cgi-bin/collect?Reporter=IPEC

https://www.ipe.muni.cz/WEB/gse

https://www.ipe.muni.cz/WEB/seismo

On-line daily seismograms are available on http://ig.cas.cz/en/noright/daily-seismograms and http://ig.cas.cz/en/noright/daily-seismograms and http://ig.cas.cz/en/noright/daily-seismograms and https://www.ipe.muni.cz/monitorovani-zemetreseni/seismicke-stanice-a-data/denni-

<u>seismogramy</u>

WEBNET

Seismograms are available on request on jhr@ig.cas.cz , catalogs of local events since 2000 are available on: https://www.ig.cas.cz/en/observatories/local-seismic-network-webnet/ On-line daily seismograms on http://ig.cas.cz/en/noright/daily-seismograms About 20 data requests (seismograms) /year, which represents about 850 GB/year

MONET

Archive data: European data server EIDA: <u>https://www.orfeus-eu.org/data/eida/</u>

this open access archive is completed in real-time regime.

Metadata: Data centre GEOFON

http://geofon.gfz-potsdam.de/waveform/archive/network.php?ncode=M1

Completeness of data in this repository (since launch of archiving) is 100%.

Statistics from GFZ Potsdam since 2017 (yearly average): >770 data requests and >17GB data download.



On-line data are available by Antelope or by SeedLink server. For establishment of data flow send e-mail to <u>seismo@ipe.muni.cz</u>.

On-line daily seismograms are available on

https://www.ipe.muni.cz/monitoring/stations/seismograms

Catalogue of local events is available on: <u>https://www.researchgate.net/publication/323906777</u>

REYKJANET

Data are available on request on jhr@ig.cas.cz

about 5 and 10 data requests/year from the Czech Republic and from Iceland, which is about 150 GB/year

<u>MKNet</u>

Data from stations Podolie (POD); Banka (BAN); Jalšové (JAL) are open for public on request on email address: <u>czechgeo-mknet@irsm.cas.cz</u>.

PSLNet

The annual data volume from all stations is around 100GB. The data are open and free through the NOA-EIDA node for all users. <u>http://eida.gein.noa.gr</u>

MOBNET – the pool of mobile stations

Data from mobile stations participating in the AlpArray project are subject to rules given in memorandum signed by all partners. Partial data are now available only to "Core Group" members (i.e those who participate at least by ten mobile stations) in EIDA nodes <u>https://www.orfeus-eu.org/data/eida/nodes/.</u> Data will be available in Open Access 3 years after the complete database of AlpArray is finished.

2. Section of GNSS and Gravimetry

GNSS Permanent Station GNSS – all Networks

Database on GNSS CzechGeo portal

http://www.pecny.cz/CzechGeo/t2-data/

access to data after registration



3. Section of Crustal Geodynamics

TecNet

Data from on-line stations (photos) are available on

http://www.tecnet.cz

Other data available on request – download from FTP server (ftp.irsm.cas.cz).

Contact: tecnet@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz, hartvich@irsm.cas.cz)

SlopeNet

Information on landslides on portals (only in Czech):

http://www.sesuvy.cz/

http://www.tecnet.cz/index.php?page=google_mapa_sesuv

Contact: <u>blahut@irsm.cas.cz</u>, <u>hartvich@irsm.cas.cz</u>

CZET

All information available on address

https://www.ig.cas.cz/en/observatories/earth-tides-observatories/

Carbonnet

https://web.natur.cuni.cz/uhigug/carbonnet (from July 2017))

Statistics from March to August 2019:

Number of requests: 28 (from that 1 from abroad)

Older data available on request on e-mail: josef.vlcek@natur.cuni.cz

4. Section of Geomagnetism

Geomagnetic Observatory Budkov

Data are submitted in real-time on-line to the global network INTERMAGNET

http://www.intermagnet.org

Magnetotelluric data

are stored on local media in device formats (ADU06, LEMI417). Raw data (time series of 5 MT components) are available on request on e-mail "Radek Klanica" <u>rk@ig.cas.cz</u>, including instruction for data reading. On-line data will be prepared after data standard is agreed in the frame of European research infrastructure EPOS.

5. Data Research Infrastructure of Czech Geological Survey (CGS-DRI)

The main use of CGS-DRI is to provide access to relevant structured, unstructured and analogue geological and geophysical data. The most important basic source of information is thematically relevant metadata, which contains data on the existence, type, form, origin and possibilities of accessing the data source and is in line with the new INSPIRE standards. Metadata is available: in the CGS Metadata Catalogue https://micka.geology.cz,

in the National Geoportal INSPIRE <u>https://geoportal.gov.cz/web/guest/catalogue-client</u> and in the EGDI Portal (European Geological Data Infrastructure) <u>http://www.europe-geology.eu/metadata/</u>.

To the maximum extent possible, view and download web services are provided, in accordance with international standards defined by legislation (INSPIRE) and accepted principles of European projects and initiatives (EPOS, GeoERA, EGDI and others).

To ensure user-friendly access, selected data is also presented in the form of web map applications. To make the user access to a large amount of data more transparent and to access it, a new signpost was created, which is directly generated from the metadata catalogue http://www.geology.cz/extranet/vav/informacni-systemy/data/datove-zdroje.

Czech and English part of the CGS information portal was created, where interested visitors can find information on geophysical methods and on ways of accessing data from the CGS

http://www.geology.cz/extranet/vav/zemska-kura/geofyzika and

http://www.geology.cz/extranet-eng/science/earths-crust/geophysics). Open access to data is

applied whenever possible.

Relevant data can be downloaded/viewed in European networks

http://inspire-geoportal.ec.europa.eu/

http://www.europe-geology.eu/

in national networks

https://geoportal.gov.cz/web/guest/catalogue-client/

http://www.czechgeo.cz/

in local networks

http://www.geology.cz/extranet-eng/science/information-systems/data-management/data-

<u>sources</u>

http://www.geology.cz/extranet-eng/services/web-applications/

http://www.geology.cz/extranet-eng/maps/online/map-applications

http://www.geology.cz/extranet-eng/maps/online/esri

http://www.geology.cz/extranet-eng/maps/online/wms

A guide to accessing the data is available on

http://www.geology.cz/extranet-eng/services/data/how-to-get-data and http://www.geology.cz/extranet-eng/maps/online/download-services

Year	Number of user	Served by the	Specific custom data	
	requests	automatic system of	processing	
		data delivery		
2016	11 067	10 222	845	
2017	12 493	11 615	878	
2018	13 240	12 275	965	
2019	14 645	13 444	1 201	

Tab. 2: Number of visits of CGS map server providing web map services and data access applications

1		1	
Year	Number of unique	Number of visits	Number of visited pages
	visitors		
2016	82 997	223 191	351 258
2017	82 597	243 760	410 992
2018	73 906	237 880	416 665
2019	55 939 *	234 064	409 500

* The apparent drop in number of visitors is due to the implementation of GDPR - if a visitor refuses to accept cookies, then they are not counted in the statistics.

II. Describe the structure of LRI's users, the range of their scientific specialization, stratification by their affiliation (universities, public research institutions, industry). Indicate number of users from the Czech Republic and from abroad.

Data from basic networks (CRSN, MONET, VESOG, Geomagnetic Observatory) submitted to international data systems are used from most European institutions and many institutions in other parts of world for basic research, monitoring or civil protection purposes. As the data can be downloaded freely and the data download is not registered, the name of users is not known. The AAA (Authentication, Authorization, Accounting) System is under development, e.g. in the frame of EPOS ERIC.

The data are, of course, used by researchers and students of all CzechGeo/EPOS partners as well as cooperating institutions listed in D.I.

Universities

Leipzig University, Institute of Geophysics and Geology (waveforms, catalogs),

University of Potsdam, Institute for Geosciences and the Institute for Environmental Sciences and Geography (waveforms, catalogs)

Freie Universität Berlin, Division of Geophysics (catalogs),

TU Bergakademie Freiberg, Institute of Geophysics and Geoinformatics (waveforms, catalogs) Leibniz University Hannover (waveforms)

University Vienna

University of Campania "L. Vanvitelli" (Caserta) joint with University of Salerno (Fisciano), Italy (Radon monitoring data)

Faculty of Science of Masaryk University, Faculty of Science of Charles University, VSB – Technical University of Ostrava, Czech Technical University (Geophysical and geological data for study purposes and diploma thesis)

Public Research Institutions

The Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences (waveforms, catalogs),

Federal Institute for Geosciences and Natural Resources is Hannover (waveforms, catalogs) Icelandic Meteorological Office - IMO (waveforms),

ZAMG Vienna

KRSZO Budapest

State Geological Institute of Dionýz Štúr, Bratislava, Slovakia

Karst Research Institute ZRC SAZU, Postojna, Slovenia

National Institute of Geophysics, Geodesy, and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria

Aristotle University of Thessaloniki, Greece, School of geology (approx 40 users))

University of Patras, Patras Seismological Laboratory – UPAT, Greece (approx 15 users)

Geology Laboratory of Ecole Normale Supérieure, Paris – ENS, France (approx 30 users)

Institute of geodynamics (G.I.), Hellenic Unified Seismic Network – HUSN, Greece (approx 50 users)

Institut de Physique du Globe de Paris (approx 120 users)

Industry, state authorities:

Progseis s.r.o. Trnava

Iceland GeoSurvey - ÍSOR (waveforms)

NAGRA, Switzerland

Seismology and Geology Office, Slovenian Environment Agency, Ljubljana, Slovenia

VODNI DILA - TBD a.s. - Czech leading engineering and consulting company, which provides dam safety supervision (catalogs)

OKD, as - Ostravsko-Karvinské doly

Czech Government (Expert opinion of the IRSM on the causes of the 2013 landslide at D8 highway) Cave Administration of the Czech Republic

Slovak Cave Administration, Slovakia

ČEZ (seismic hazard of nuclear power plants)

SÚRAO (projecting of underground storage of nuclear waste)

UNIGEO a.s., GEOtest a.s., MND a.s., Ochrana podzemních vod s.r.o. – Grounwater Protection Ltd, ARCADIS CZ a.s., KOLEJKONSULT servis s.r.o., SIHAYA spol s r.o., G Impuls Praha spol. s r.o., GET s.r.o. (geological and geophysical databases)

III. Provide an overview of workshops, conferences, seminars and meetings organized by the LRI, incl. the number and affiliation portfolio of participants from the Czech Republic and abroad.

CzechGeo/EPOS Workshop – 16 November 2016 – IG CAS Prague – 50 participants / 1 from abroad

The Workshop was aimed at getting together the infrastructure team with data users – mostly research workers and students of geophysics, geodesy and geology. The morning session was devoted to the information about data and services the infrastructure can offer the users. Scientific results based on the CzechGeo/EPOS data and services were presented in the afternoon. 18 oral presentations, 5 posters.

CzechGeo/EPOS Workshop – 22 November 2017 – IG CAS Prague – 34 participants / 2 from abroad

The morning session was devoted to the information about data and services the infrastructure can offer the users. Main topic of this part was Geological and geophysical databases. Scientific results based on the CzechGeo/EPOS data and services were presented in the afternoon. 16 oral presentations.

CzechGeo/EPOS Workshop – 5 December 2018 – IG CAS Prague – 35 participants / 2 from abroad

The information about data and services the infrastructure can offer the users was completed by reports on scientific results based on the CzechGeo/EPOS data and services. The foreign participant followed the Workshop by means of audio-visual live chat electronic communication. There were 13 oral presentations and 3 posters.

CzechGeo/EPOS Workshop – 4 December 2019 – IG CAS Prague – 35 participants / 2 from abroad

Introduction presentation gave the overview of the solution of the project LM2015079, followed by reports about data and services the infrastructure can offer the users and reports on scientific results based- on the CzechGeo/EPOS data and services. The foreign participant followed the Workshop by means of audio-visual live chat electronic communication. There were 13 oral presentations.

INSPIRE geophysical data specification - technical workshop – 8-9 June 2017 – CGS Prague - 12 participants / 4 from abroad

This workshop provided a platform for presentations and discussions about the implementation of INSPIRE directive as regards geophysical data. Best practices and strategies of different European geological surveys (MFGI, GEUS) and OGS (National Institute of Oceanography and Applied Geophysics) have been presented. Discussions were held regarding the geology data specification and its extension for geophysics, harmonization of different data models, creation of controlled vocabularies etc. <u>http://www.czechgeo.cz/article/default/prezentace</u>

Metadata of geological and geophysical datasets of the Czech Republic and INSPIRE directive - technical workshop of project CzechGeo/ EPOS – 20 September 2017 – CGS Prague – 11 participants

Technical workshop of the CzechGeo/EPOS project. CGS and CENIA presented the INSPIRE Directive, data specification for geophysical data, metadata standards and access points to metadata (National INSPIRE Geoportal - NGI, European INSPIRE Geoportal, EGDI Portal). A discussion was started between the CzechGeo/EPOS consortium members about the inventory and analysis of the geophysical data sources and their metadata description on the NGI. A practical example of the creation of metadata on the NGI was also part of the workshop. <u>http://www.czechgeo.cz/article/default/prezentace</u>

Metadata for 3D geological models - technical workshop – 22-23 February 2017 – IG CAS Prague – 12 participants / 8 from abroad

This workshop provided a platform for presentations and discussions about the strategies of different European geological surveys and EPOS project for building 3D geological models and for describing them with metadata. Discussions were held regarding the available standards that should be used for storing and describing of the models, which controlled vocabularies could be used, and about defining a standardized metadata description.

http://www.czechgeo.cz/article/default/prezentace

GeoERA GIP – Meeting about EGDI and metadata – 29 July 2019 – CGS Prague – 8 participants / 2 from abroad

CGS is responsible for the development of the EGDI metadata catalogue, enabling all the GeoERA projects to fill in metadata on all their results. To provide the working version of metadata catalogue is quite demanding, as it is essential to incorporate all expected needs of the GeoERA projects that are not always clearly expressed. To ensure the consolidated operation of the system all relevant processes should be described and rules must be applied for any action related to data and metadata. To keep the proper relation between the data presented on the EGDI portal and related metadata we need to define the process schema and definition of the data life cycle. Main topic of the meeting was focused on the principles ruling the flow of data and metadata in EGDI, the existing status and proposed flow in GeoERA projects. The process schema of GIP was discussed, specifically the part related to the metadata entry, upload of data, creating services, publishing these on EGDI web, any update or delete. Important aspects concerning the connection between EGDI portal and metadata were taken into account. http://www.europe-geology.eu/metadata/, https://www.europe-geology.eu/metadata/, https://www.europe-geology.eu/

Spatial Information Expert Group (SIEG) Meeting – 29-30 April 2019 – CGS Prague – 23 participants / 19 from abroad

EuroGeoSurveys research covers a wide range of topics through the work of Expert Groups. The Spatial Information Expert Group (SIEG) main purpose is to contribute to the definition of the European policies which aim at developing the European Information Infrastructure (Horizon Europe, INSPIRE Directive, EGDI, EPOS, EOSC etc.). It is also a common platform to share expertise among EGS members. The meeting was organized soon after election of a new chair to reactivate the group after some time of being inactive. It was presented that the work of the SIEG remains very relevant to EGS and this group is a key player in the continued design and development of the European Geological Data Infrastructure (EGDI), which is at the core of the EGS pillars strategy. By incorporating all the information from other EGs, SIEG fosters the inclusion of all key partners. SIEG also remains participating in a number of projects, including EURare, EUOGA, Landslide database, North Sea Regulators data, EPOS borehole index, GeoCradle and EMODnet. EGS members provided funding on a voluntary basis for the basic operations of EGDI. Many members of SIEG are occupied by the GeoERA Information Platform project which has been built as an extension of EGDI. Regarding the data sharing, the EGDI infrastructure has become a universal platform for EGS to visualise and publish data. It was presented that the formal development and coordination between EGDI and EPOS is under development and in line with pillar III of the EGS strategy. The main discussion topics were also focused on the development priorities answering to the new Horizon Europe call with the proposal of the European Partnership on a Geological Service for Europe (EP-GSE). The brainstorming was organized to list the scientific preferences of

the SIEG for the future development of EGDI regarding the content, user access and technology. http://www.eurogeosurveys.org/expertgroups/spatial-information-inspire/

Spatial Information Expert Group (SIEG) Meeting – 26-27 November 2019 – CGS Prague – 28 participants / 25 from abroad

The main topic of the second meeting of the Spatial Information Expert Group (SIEG) in 2019 was to discuss the science topics relevant to the geoinformation development for the next period. The proposal of the European Partnership on a Geological Service for Europe was based on the previously formulated priorities of the European Geological Data Infrastructure, specifically the advanced technological development and the advanced data ecosystem. The theme of the digital subsurface information system should define the infrastructure supporting all the essential components as the data capture, storage, standardization and harmonization of data, their analysis, the processing and modelling techniques, the data dissemination and visualization. Connection to the other European information initiatives and infrastructures as INSPIRE, EGDI, EPOS, EMODnet, EOSC etc. has to be considered. The meeting was also focused on the EGS business as the key performance indicators defined for the expert groups and the mission and vision amendments. The update of the GeoERA Geoinformation Platform project was presented. The EGDI strategic topics and the proposed rules for the further development were also widely discussed. The position of EGS and its strategy and potential for collaboration with the EPOS, defined in the prepared Memorandum of Understanding and the Thematic Core Service Geological Information and Modelling Consortium Agreement, was commented. http://www.eurogeosurveys.org/expertgroups/spatial-information-inspire/

EPOS Thematic Core Service (TCS) Geological Information and Modelling Consortium Meeting – 28 November 2019 – Prague – 14 participants / 13 from abroad

The main topics of the EPOS Thematic Core Service (TCS) Geological Information and Modelling Consortium Meeting in 2019 were to recap the guidelines to be followed in order to cooperate with EPOS ERIC as defined in the Consortium Agreement (CA) and to proceed accordingly. All of the 10 full members were represented, some of them via web conference facilities. The roles and responsibilities defined in the CA were clarified and the timing was specified. The EPOS ERIC Strategic Plan, proposed for the 2020-2022 period, describing the activities to the transition into the operational phase (EPOS POP – Pre-Operational Phase) in 2023 was presented. The discussion was held also about the organization and governance of the work, which is following up on the development work that took place under the now finalized EPOS Implementation Project. Clarification of the future role of EGDI as the EGS platform and GSOs as service providers resulted in the agreement. The chair, co-chair and coordinator were elected. The person, responsible for convening the Stakeholder Panel and the Data Provider Committee was also elected. The implementation of the work programme for the first year was discussed in detail. The presentation of the TCS activities were coordinated and the next steps were planned. http://www.eurogeosurveys.org/expertgroups/spatial-information-inspire/

5th CE-GIC Meeting – 11-12 April 2019 – CGS Praha – 26 participants / 18 from abroad 5th conference meeting of GIS and IT specialists from geological survey organizations in Central Europe. The participants came from 7 Central European countries: Austria (The Geological Survey of Austria - GBA), Croatia (Croatian Geological Survey - HGI-CGS), Czechia (Czech Geological Survey - CGS), Hungary (Mining and Geological Survey of Hungary - MBFSZ), Romania (Geological Institute of Romania - GIR), (Slovakia Geological Survey of Slovakia - ŠGÚDŠ) and Slovenia (Geological Survey of Slovenia - GeoZS). The conference has focused on WebGIS, 3D geological models, Metadata, INSPIRE and projects solved by participants (CzechGeo, GeoERA, GEOIS II). <u>http://ce-gic.org</u>

EPOS TCS Geomagnetic Observations Meeting with Data Users and Providers – IG CAS Praha -18-19 June 2019 – 24 participants / 17 from abroad

The meeting was aimed at informing the geomagnetism user community about development of Geomagnetism Thematic Core Services in the frame of EPOS Implementation Phase Project. Presentation of the members of development team and their discussion were on program on the first day. The meeting was organized on the occasion of the 180th anniversary of the regular magnetic observations at Prague Observatory. The lecture about history of Prague magnetic observations were held in the historical building of Klementinum.

New knowledge and measurements in seismology, engineering geophysics and geotechnics – 12 – 14 April 2016, 4 – 6 April 2017, 10 – 12 April 2018, 28 – 31 May 2019, annual conferences – IGN Ostrava in cooperation with the Czech Association of Geophysicists – about 60 participants from scientific institutions, universities and commercial sphere from the Czech Republic, Slovakia and Poland.

D. Linkages to Other Infrastructures and Projects, Internationalization

I. Describe established and running cooperation within the Czech Republic with research institutions, research infrastructures, industry and other entities utilizing the LRI or its results. If applicable, provide a list of agreements with cooperating entities (collaboration agreements, contracts, memoranda etc.).

Public administration

State Office for Nuclear Safety (SÚJB) – Monitoring of global seismicity for verification of nuclear tests and fulfilling the commitments of Czech Republic to the Comprehensive Nuclear-Test-Ban Treaty (contract MU-SÚJB).

Monitoring of brittle structure within the Bukov underground laboratory for SÚRAO, 2018 - 2022 Extenzometric monitoring of stability of Horka Dam in Western Bohemia – collaboration with Povodí Ohře s.p.

Czech Office for Surveying, Mapping and Cadastre - supplying data from VESOG infrastructure to the network of permanent GNSS stations CZEPOS – activity of RIGTC for its founder – it is not treated by agreement.

Military Geographical and Hydrometeorological Office in Dobruška - cooperation on the operation of the Polom GNSS station enshrined in the Framework Cooperation Agreement.

SURAO (contractual cooperation):

- Geological interpretation of field geophysical data for update of 3D structural-geological models of possible localities of deep deposits (Contract 4.1.7.1 / č.j. ESS: SURAO-2017-2196).
- Update of the assessment of localities from the point of view of long-term security (Contract 4.1.7.5 / č.j. ESS: SURAO-2019-3182)
- Data acquisition from deep horizons of mine Rožná (Contract SO2017-023)
- 3D structural-geological models of rock massive for deep deposit (Contract 4.1.5.3 / č.j. ESS: SURAO-2014-2304)

<u>Industry</u>

Commercial monitoring of microseismicity and related research based on bilateral contracts with the operator of Czech nuclear power plants (MU-ČEZ a.s.)

Cooperation with VODNI DILA - TBD a.s. focused on safety of the Horka dam because of strong ground motion caused by local earthquakes in West Bohemia earthquake-swarm area. The objective is to evaluate seismic risk on the Horka dam or reduced it if possible.

ČEZ a.s. – Support in satisfying conditions for building ETE 3,4 according to decision SÚJB č.j. SÚJB/OLNZ/22296/2014.

<u>Research</u>

Research cooperation on recording of passing seismic wave by optical fibres (contract MU – CESNET).

Data sharing with research infrastructure RINGEN

II. Describe established and running cooperation with international and foreign research institutions, research infrastructures, industry and other entities utilizing the LRI or its results. If applicable, provide a list of agreements with cooperating entities (collaboration agreements, contracts, memoranda etc.).

EPOS, the European Plate Observing System, is a long-term plan to integrate the diverse and advanced European Research Infrastructures for solid Earth science, and build on new e-science opportunities to monitor and understand the dynamic and complex solid Earth System. EPOS will identify existing gaps and promote implementation plans with environmental, marine and space science to help solve the grand challenges facing the Earth and its inhabitants. The EPOS Implementation Phase Project (October 2015 – September 2019) was aimed at establishing Thematic Core Services (TCS) in 10 geoscience disciplines and linked them under the umbrella of Integrated Core Services. Two CzechGeo/EPOS Partners – IG CAS and RIGTC participated in the EPOS IP Project (cf. D.III), CGS joint the EPOS activity later without financial contribution. EPOS ERIC was established in November 2018 and its bodies took over responsibility of EPOS management. Despite of activity of 3 CzechGeo/EPOS partners and our contribution to EPOS data systems, Czech Republic did not join EPOS ERIC.

On the level of TCS the activities will be coordinated by TCS Consortia. CzechGeo/EPOS partners signed following Consortia Agreements:

- TCS GNSS Data and Products RIGTC
- TCS Geomagnetic Observations IG CAS
- TCS Anthropogenic Hazard IG CAS
- TCS Geological Information and Modelling CGS (chair)

Spatial Information Expert Group EuroGeoSurveys (SIEG): a group of geoinformatics experts from 32 member countries of the EuroGeoSurveys (European Geological Survey Association). RNDr. Dana Čápová from the CGS was elected chair of the SIEG in 2019. In her capacity, she cooperates in the preparation of the Memorandum of Understanding between EPOS-ERIC and EuroGeosurveys and in the drafting of the European partnership - Geological Service for Europe project (Horizon Europe). The SIEG is the body that creates the rules for building the European Geological Data Infrastructure (EGDI) and the EuroGeoSurveys geoinformatics strategy. The activity is financed from national sources.

EGDI: CGS is one of the five European geological surveys that form the core team of the European Geological Data Infrastructure (EGDI), which plays an important role as a recognized platform for providing geological interoperable distributed data from EuroGeoSurveys members for EPOS and other European infrastructures such as EMODnet, Copernicus, GEO, etc. EGDI is developed in accordance with INSPIRE and other international standards. It is one of the basic pillars of the GeoERA infrastructure. CGS is primarily responsible for the metadata catalogue development and operation. The implementation of EGDI is partly funded by the EuroGeoSurveys budget and co-financed by national sources.

The AlpArray is European initiative within which scientists form ~50 institutions - universities and research institutes in 17 countries cooperate.

List of MoU: AA, EASI, PACASE

LASMO project realised with NAGRA (Switzerland), University of Straightclyde, Glasgow, UK and SÚRAO (Czech Republic) within Grimsel Test Site in Switzerland 2013 – 2018, since 2019 on the base of bilateral cooperation between NAGRA and IRSM CAS.

As part of the operation of the PPGNet network, cooperation has been established with the National Observatory in Athens, the University of Patras and the private surveying company METRICA A.E. Collaboration provides access to data from other partners and is embedded in Memorandums of Understanding.

Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO): Providing authenticated realtime data to the IDC CTBTO in Vienna as a part of the international monitoring system for verification of nuclear tests (MU).

International Seismological Centre (ISC): Providing earthquake bulletins for each broadband station of CRSN used for compilation of global earthquake catalogue (IG, MU).

European Mediterranean Seismological Centre (EMSC): Providing fast information on earthquakes. Based on these data the seismic warnings to public institutions are issued and basic information to European/Global public and seismological community is provided (IG, MU).

Zentralanstalt fur Meteorologie und Geodynamik Vienna (ZAMG): Collaboration on seismological monitoring in the Alps – Carpathians - Bohemian Massif junction region. Memoranda on exchange of seismic records and analytical results (MU, IG).

GeoForschungsZentrum Potsdam (GFZ): Sharing of MORC station records within the GEOFON project. Memorandum on exchange of seismic records (MU).

Central and Eastern Europe Earthquake Research Network (CE3RN): Collaboration on seismological monitoring and support of civil protection needs. Memorandum on exchange of seismic records and analytical results (MU).

In 2019 a collaboration with INGV Rome and its **Near Fault Observatory project** has been established. The memorandum of understanding is being prepared.

III. Provide number of international research grants connected to the LRI, with a brief description and financial volume.

Two CzechGeo/EPOS institutions participated in the **EPOS IP Project (October 2015 – September 2019)**. IG was entrusted to lead the WP 13 Geomagnetic Observations. It is responsible for legal and governance issues as well as for coordination and interaction with the geomagnetic community. IG CAS participates also in WP14 Anthropogenic hazard on task 14.5 Assessment of the relations between technical operations and induced seismic/deformation processes. RIGTC is leading the task 10.4 Dissemination of GNSS data in WP10 GNSS data and products. It is responsible for data and quality-check issues as well as for coordination and interaction with the

geodetic community. Services developed at the GOP Data, Analysis and Software Centre are of key importance for development of GNSS Thematic Core Services. Pavel Hejda was a member of Service Coordination Board and Board of National Scientific Representatives. Grant awarded: IG CAS 132 500 Eur, RIGTC 125 000 Eur.

The Eger project (Drilling the Eger Rift) supported by the International Continental Drilling Program (ICDP) was granted in 2016 by 1 mil USD to built a downhole observatory in West Bohemia/Vogtland.

Data from two GNSS stations (in the Czech Republic and Greece) are used since 2018-08-21 as part of **the Galileo Reference Center - Member States (GRC-MS) project – identification GSA/GRANT/04/2016/SG1** – which provides reference services and validation of the European GNSS Galileo. It is a consortium of 18 European institutions. The financial volume for RIGTC is CZK 1.6 million CZK per year.

GeoERA: CGS is an active participant in the Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe (GeoERA), implemented by 48 national and regional geological surveys from 33 European countries in 2018-2021 (ERA-NET H2020 infrastructure). 15 research projects (from Geo-energy, Groundwater, Raw Minerals and Information Platform topics) are supported within GeoERA. In the Information Platform (GIP-P) project, CGS has an important role as a developer and administrator of the metadata catalogue. The total funding for CGS is 300 ths. EUR (with 70% co-funding), of which the sub-project GeoERA Information Platform (GIP-P) has a budget of 115 ths. EUR.

European Partnership – Geological Service for Europe (EP-GSE) under Horizon Europe: this project is being prepared as a continuation of GeoERA activities. It should be a step towards creating a permanent infrastructure for cooperation between geological surveys and other research and academic institutions in Europe. The aim is to provide up-to-date, high-quality geological information within Europe and thereby cooperate in the implementation of European strategies and programs. CGS is actively involved in this work.

PART II. - OUTCOME

A. Scientific Outcome Achieved

I. Describe generally scientific results achieved <u>by the LRI's research team</u> on the basis of the LRI's use over the funding period.

12 scientific papers based on the WEBNET and REYKJANET data have been published by members of the LRI team, 3 papers have been in a peer review. Most of papers deal with West Bohemia earthquake swarms. The authors disclosed location and geometry of the seismoactive faults in the main Nový Kostel focal zone, dynamics of the strain energy (seismic moment) release and physical processes taking place during individual earthquake-swarm activities (Šílený and Horálek, 2016; Bachura and Fischer, 2016a; Vavryčuk et al., 2017; Fischer and Hainzl, 2017; Jakoubková et al. 2018). Besides they revealed interaction between earthquake swarms and activity of fluids in Earth crust in the area (Hainz et al., 2016, Fischer et al., 2017) and derived seismic models and properties of the upper Earth crust in the area (Novotný et al., 2018). Furthermore, the members of the LRI team developed an advanced automated event detector based on neural network and applied it to the WEBNET and REYKJANET seismograms (Doubravová et al., 2016, Doubravová and Horálek, 2019) and uncovered principal bias and limitations of the hypoDD location technique if waveform cross-correlation for differential time measurement is used (Bachura and Fischer, 2019).

In addition of that the members of the LRI team investigated an intense West Bohemia earthquake swarm of 2018 (Bachura et al., 2019), derived 1D and 3D models of the Reykjanes Peninsula (Málek et al., 2019; Růžek, 2020) and disclose similar and dissimilar characteristics of West Bohemia and SW Iceland earthquake swarms (Horálek and Jakoubková, 2020).

Bachura, M., Fischer, T., 2016a. Detailed velocity ratio mapping during the aftershock sequence as a tool to monitor the fluid activity within the fault plane. Earth Planet. Sci. Lett., doi: 10.1016/j.epsl.2016.08.017

Bachura, M., Fischer, T., 2016b. Coda Attenuation analysis in the West Bohemia/Vogtland earthquake-swarm area. Pure and Applied Geophysics 173: 425-437. DOI: 10.1007/s00024-015-1137-3

Bachura, M., Fischer, T., 2019. Waveform cross-correlation for differential time measurement: Bias and limitations. *Seismol. Res. Lett.*, 90 (5), doi:10.1785/0220190096/4824930/srl-2019096.1.

Bachura, ., Fischer, T., Doubravová, J., Horálek, J., 2020. From earthquake swarm to a mainshock-aftershock: the 12018 activity in West Bohemia/Vogtland., J. Geophys. Res. Solid Earth, submitted.

Doubravová, J., Wiszniowski, J. and Horálek, J., 2016. Single layer recurrent neural network for detection of swarm-like earthquakes in W-Bohemia/Vogtland – the method. Computers&Geosciences, 93,138–149.

Doubravová, J. and Horálek, J., 2019. Single Layer Recurrent Neural Network for detection of local swarm-like earthquakes—the application. Geophys. J. Int., 219, 672–689, doi.org/10.1093/gji/ggz321

Fischer, T. and Hainzl, S., 2017. Effective Stress Drop of Earthquake Clusters, Bull. Seism. Soc. Am., doi: 10.1785/0120170035

Fischer, T., Matyska, C., and Heinicke, J., 2017. Earthquake-enhanced permeability – evidence from carbon dioxide release following the ML 3.5 earthquake in West Bohemia. Earth Planet. Sci. Lett., 460, 60–67, doi: 10.1016/j.epsl.2016.12.001

Hainzl, S., Fischer, T., Čermáková, H., Bachura, M. and Vlček, J., 2016. Aftershocks triggered by fluid-intrusion: Evidence for the aftershock sequence occurred 2014 in West Bohemia/Vogtland, J. Geophys. Res. Solid Earth, 10.1002/2015JB012582

Horálek, J. and Jakoubková, H., 2020. Earthquake swarms in West Bohemia-Vogtland and Southwest Iceland: are they of similar nature? Tectonophysics, submitted.

Jakoubková, H., Horálek, J. and Fischer, T., 2018. 2014 mainshock-aftershock activity versus earthquake swarms in W-Bohemia, Czech Republic. Pure and Applied Geophysics, **175**, 109–131, doi: 10.1007/s00024-017-1679-7.

Málek, J., Brokešová, J., Novotný, O., 2019. Seismic structure beneath the Reykjanes Peninsula, southwest Iceland, inferred from array-derived Rayleigh wave dispersion. Tectonophysics, DOI 10.1016/j. tecto.2018.12.020

Růžek, B., 2020. Seismic anisotropy within the Rift of Reykjanes Peninsula, SW Iceland. Geophys. J. Int., submitted.

Šílený, J. and Horálek, J., 2016. Shear-tensile crack as a tool for reliable estimates of the nondoublecouple mechanism: West Bohemia-Vogtland earthquake 1997 swarm. *Phys. Chem. Earth*, **95,** 113-124.

Vavryčuk, V., Adamová, P., Doubravová, J., Jakoubková, H., 2017. Moment tensor inversion based on the principal component analysis of waveforms: Method and application to microearthquakes in West Bohemia, Czech Republic, *Seismol. Res. Lett.*, **88**(5), 1303-1315, doi: 10.1785/0220170027.

Seismic data recorded by the LRI, including the temporary network MOBNET, has been exploited for studies of the lithosphere and upper mantle structure of the Alps (Hetenyi et al., 2018a,b) as well as the Bohemian Massif (Plomerova et al., 2016) and around the Trans-European Suture Zone (Chyba et al., 2017), evaluating the anisotropic fabrics of the mantle lithosphere domains (Babuska and Plomerova, 2017) and inferring origin of the continental lithosphere (Babuska and Plomerova, 2019). Vecsey et al (2017) published tools for data quality control. At least three more ms. are in progress to be submitted into the impacted geophysical journals during 2020.

Plomerová J., Munzarová H., Vecsey L., Kissling, E., Achauer U., Babuška, V., 2016. Cenozoic volcanism in the Bohemian Massif in the context of P- and S-velocity high-resolution teleseismic tomography of the upper mantle. Geochem. Geophys. Geosyst. (G3), 17, doi:10.1002/2016GC006318

Babuska V., Plomerova J., 2017. Lateral displacement of crustal units relative to underlying mantle, Gondwana Research 5, 125–138 doi.org/10.1016/j.gr.2017.08.008

Chyba, J. Plomerová, J., Vecsey, L., Munzarová, H.: Tomography study of the upper mantle around the TESZ based on PASSEQ experiment data, 2017. Physics of the Earth and Planetary Interiors 266, 29–38, doi.org/10.1016/j.pepi.2017.01.002

Vecsey L, Plomerová J, Jedlička P, Munzarová H, Babuška V and the AlpArray Working Group, 2017. Data quality control and tools in passive seismic experiments exemplified on Czech broadband seismic pool MOBNET in the AlpArray collaborative project. Geosci. Instrum. Method. Data Syst., 6, 505–521, 2017, doi.org/10.5194/gi-6-505-2017

György Hetényi^{1,2,3,4}, Irene Molinari², John Clinton³, Götz Bokelmann⁵, István Bondár⁶, Wayne C. Crawford⁷, Jean-Xavier Dessa⁸, Cécile Doubre⁹, Wolfgang Friederich¹⁰, Florian Fuchs⁵, Domenico Giardini², Zoltán Gráczer⁶, Mark R. Handy¹¹, Marijan Herak¹², Yan Jia¹³, Edi Kissling², Heidrun Kopp^{14,15}, Michael Korn¹⁶, Lucia Margheriti¹⁷, Thomas Meier¹⁵, Marco Mucciarelli^{18,†}, Anne Paul¹⁹, Damiano Pesaresi¹⁸, Claudia Piromallo¹⁷, Thomas Plenefisch²⁰, Jaroslava Plomerová²¹, Joachim Ritter²², Georg Rümpker²³, Vesna Šipka²⁴, Daniele Spallarossa²⁵, Christine Thomas²⁶, Frederik Tilmann^{11,27}, Joachim Wassermann²⁸, Michael Weber^{27,29}, Zoltán Wéber⁶, Viktor Wesztergom⁴, Mladen Živčić³⁰, AlpArray Seismic Network Team, AlpArray OBS Cruise Crew, AlpArray Working Group, 2018a. The AlpArray Seismic Network - a large-scale European experiment to image the Alpine orogen", Surveys in Geophysics 9, 1009–103, doi.org/10.1016/j.tecto.2018.07.001

György Hetényi, Jaroslava Plomerová, Irene Bianchi, Hana Kampfová Exnerová, Götz Bokelmann, Mark R. Handy, Vladislav Babuška, AlpArray-EASI Working Group, 2018b. From mountain summits to roots: Crustal structure of the Eastern Alps and Bohemian Massif along longitude 13.3°E, Tectonophysics 744 (2018) 239–255, <u>doi.org/10.1016/j.tecto.2018.07.001</u>

Babuska V. and Plomerova J., 2019. Growth of primordial continents by cycles of oceanic lithosphere subductions: Evidence from tilted seismic anisotropy supported by geochemical and petrological findings, Solid Earth Sciences, doi.org/10.1016/j.sesci.2019.12.003

Plomerová J., 2020. Upper mantle discontinuities – anisotropic view on the lithosphereasthenosphere system. Bollettino di Geofisica Teorica e Applicata, in print

Two research papers based on the data of the CarbonNet were published by members of the LRI team. These include mainly the analysis and numerical modelling of the unique coseismic increase of CO2 flow in the Hartoušov mofette related to the running 2014 seismic activity (Fischer et al., 2017). Another paper dealing with coseismic CO2 flow increase is the study on temporal changes of seismic attenuation in the Nový Kostel area interpreted by CO2 saturation of the shallow crust (Wcislo et al., 2018).

Wcisło M., Eisner L., Málek J., Fischer T., Vlček J., Kletetschka K., 2018. Attenuation in West Bohemia: Evidence of High Attenuation in the Nový Kostel Focal Zone and Temporal Change Consistent with CO2 Degassing, Bull. Seism. Soc. Am., Vol. 108, pp. 450-458, doi: 10.1785/0120170168

Fischer T., Matyska C., and Heinicke J., 2017. Earthquake-enhanced permeability - evidence from carbon dioxide release following the ML 3.5 earthquake in West Bohemia. Earth Planet. Sci. Lett., 460, 60–67, doi: 10.1016/j.epsl.2016.12.001

8 scientific papers based on the GNSS data have been published by members of the LRI team in some cases on cooperation with international partners. Most of papers deal with systematic errors in GNSS measurements (i.e. multipath and troposphere effect) and in the field of GNSSmeteorology (using the troposphere effect for determination of water vapour content).

Kostelecký J. (ml.), Kostelecký J., Václavovic P.: Testování multipath při různých observačních podmínkách. In: Družicové metody v geodézii a katastru, sborník ze semináře s mezinárodní účastí, Brno, 4.2.2016. Vydal ECON publishing, s.r.o., Pod nemocnicí 13, 625 00 Brno, p. 49-55, ISBN 978-80-86433-60-8.

Kacmarik, M; Dousa, J; Dick, G; Zus, F; Brenot, H; Moller, G; Pottiaux, E; Kaplon, J; Hordyniec, P; Vaclavovic, P: Inter-tehnique validation of tropospheric slant total delays. ATMOSPHERIC MEASUREMENT TECHNIQUES, Vol. 10, No. 6, pp: 2183-2208, DOI: 10.5194/amt-10-2183-2017

Kostelecky, J; Kostelecky, J; Vaclavovic, P: Testing of GNSS multipath in different observational conditions a tone stationary station. ACTA GEODYNAMICA ET GEOMATERIALIA, Vol. 14, No. 4, pp: 425-429, DOI: 10.13168/AGG.2017.0023

Dousa, J; Dick, G; Kacmarik, M; Brozkova, R; Zus, F; Brenot, H; Stoycheva, A; Moller, G; Kaplon, J: Benchmark campaign and case study episode in central Europe for development and assessment of advanced GNSS tropospheric models and products. ATMOSPHERIC MEASUREMENT TECHNIQUES, Vol. 9, No: 7, pp: 2989-3008, DOI: 10.5194/amt-9-2989-2016

Dousa, J; Elias, M; Vaclavovic, P; et al.: A two-stage tropospheric correction model combining data from GNSS and numerical weather model. GPS SOLUTIONS, Vol. 22, No. 3, UNSP 77, DOI: 10.1007/s10291-018-0742-x, WOS:000437202700021, ISSN: 1080-5370, eISSN: 1521-1886

Kacmarik, M; Dousa, J; Zus, F; Vaclavovic, P; Balidakis, K; Dick, G; Wickert, J: <u>Sensitivity of GNSS</u> <u>tropospheric gradients to processing options. ANNALES GEOPHYSICAE</u>, Vol. 37, No. 3, pp. 429-446, DOI: 10.5194/angeo-37-429-2019, WOS:000472078700001, ISSN: 0992-7689, eISSN: 1432-0576

Zus, F; Dousa, J; Kacmarik, M; Vaclavovic, P; Balidakis, K; Dick, G; Wickert, J: <u>Improving GNSS</u> <u>Zenith Wet Delay Interpolation by Utilizing Tropospheric Gradients: Experiments with a Dense</u> <u>Station Network in Central Europe in the Warm Season</u>. <u>REMOTE SENSING</u>, Vol. 11, No. 6, Article Number: 674, DOI: 10.3390/rs11060674, WOS:000465615300051, ISSN: 2072-4292 Zus, F; Dousa, J; Kacmarik, M; Vaclavovic, P; Dick, G; Wickert, J: <u>Estimating the Impact of Global</u> <u>Navigation Satellite System Horizontal Delay Gradients in Variational Data Assimilation</u>. <u>REMOTE</u> <u>SENSING</u>, Vol. 11, No. 1, Article Number: 41, DOI: 10.3390/rs11010041, WOS:000457935600041, ISSN: 2072-4292

5 scientific papers based on the data from absolute gravimeters have been published by members of the LRI team in cooperation with partners from Czech Metrological Institute. Main focus of the papers are on the systematic errors in absolute gravity measurements and its determination and remove.

Kren, P; Palinkas, V; Masika, P: On the effect of distortion and dispersion in fringe signal of the FG5 absolute gravimeters. METROLOGIA, Vol. 53, No. 1, pp: 27-40, DOI: 10.1088/0026-1394/53/1/27

Kren, P; Palinkas, V; Masika, P: On the determination of verticality and Eotvos effects in absolute gravimetry. METROLOGIA, Vol. 55, No. 4, pp: 451-459, DOI: 10.1088/1681-7575/aac522, WOS:000434677400001, ISSN: 0026-1394, eISSN: 1681-7575

Kren, P; Palinkas, V: Comment on 'Relativistic theory of the falling retroreflector gravimeter'. METROLOGIA, Vol. 55, No. 2, DOI: 10.1088/1681-7575/aaac46, WOS:000427368000001, ISSN: 0026-1394, eISSN: 1681-7575

Palinkas, V; Kren, P; Valko, M; Masika, P: <u>On the determination of vertical gravity gradients by</u> <u>corner-cube absolute gravimeters. METROLOGIA,</u> Vol. 56, No. 5, Article Number: 055006, DOI: 10.1088/1681-7575/ab32fb, WOS:000480384900003, ISSN: 0026-1394, eISSN: 1681-7575

Kren, P; Palinkas, V; Masika, P; Valko, M: <u>FFT swept filtering: a bias-free method for processing</u> <u>fringe signals in absolute gravimeters. JOURNAL OF GEODESY,</u> Vol. 93, No. 2, pp. 219-227, DOI: 10.1007/s00190-018-1154-y, WOS:000459191400006, ISSN: 0949-7714, eISSN: 1432-1394

Papers based on cooperation between the Faculty of Mathematics and Physics of the Charles University and University of Patras and related papers on seismology.

Halló, M., Gallovič, F. (2016). Fast and cheap approximation of Green functions uncertainty for waveform-based earthquake source inversions, Geophys. J. Int. 207, 1012-1029.

Sokos, E., J. Zahradník, F. Gallovič, A. Serpetsidaki, V. Plicka, and A. Kiratzi (2016). Asperity break after 12 years: The Mw6.4 2015 Lefkada (Greece) earthquake. Geophys. Res. Lett., 43, 6137–6145; doi:10.1002/2016GL069427.

Zabranova, E., Matyska, C.: Low-Frequency Centroid Moment Tensor Inversion of the 2015 Illapel Earthquake from Superconducting-Gravimeter Data, Pure Appl. Geophys., 173, 2016, 1021–1027.

Klimes, L. (2016). Determination of the reference symmetry axis of a generally anisotropic medium which is approximately transversely isotropic. Stud. geophys. geod., 60, 391-402.

Klimes, L. & Bulant, P. (2016). Prevailing-frequency approximation of the coupling ray theory for electromagnetic waves or elastic S waves. Stud. geophys. geod., 60, 419-450.

Liu, J., L. Li, J. Zahradník, E. Sokos, V. Plicka (2018). Generalized Source Model of the North Korea Tests 2009–2017. Seis. Res. Lett. 89(6), 2166–2173. doi: https://doi.org/10.1785/0220180106

Bollini, C., N. Sabbione, V. Plicka, J. Zahradník (2018). Low-parametric modeling of the 2015, Mw 8.3 Illapel, Chile earthquake. Journal of South American Earth Sciences, 88, 144-156. https://doi.org/10.1016/j.jsames.2018.08.006

Zahradník, J. and E. Sokos (2018). Fitting waveform envelopes to derive focal mechanisms of moderate earthquakes. Seismol. Res. Lett. 89, 1137-1145. doi:10.1785/0220170161

E. Sokos, Gallovič, F., Evangelidis, C.P., Serpetsidaki, A., Plicka, V., Kostelecký, J., Zahradník, J. (2020). The 2018 Mw 6.8 Zakynthos, Greece, earthquake - Dominant strike-slip faulting near subducting slab, Seism. Res. Lett., in press.

Papers devoted to the dynamics of the Earth crust.

Briestenský, M., Hochmuth, Z., Hók, J., Dobrovič, R., Stemberk, J., Petro, Ľ., Bella, P., 2018: Present-day stress orientation and tectonic pulses registered in the caves of the Slovenský kras Mts. (South-Eastern Slovakia). Acta geodynamica et Geomaterialia, 15, 2, 93-103, DOI: 10.13168/AGG.2018.0007.

Klimeš, J., Hartvich, F., Tábořík, P., Blahút, J., Briestenský, M., Stemberk, J., Emmer, A., Vargas, R., Bálek, J., 2017: Studies on selected landslides and their societal impacts: activity report of the Prague World Centre of Excelence, Czech Republic. Landslides, DOI: 10.1007/s10346-017-0837-4, 2017.Moje publikace 2017-2020

Málek J., Vackář J. (2019): Site-specific probabilistic seismic hazard of Prague (Czech Republic). Journal of Seismology. DOI: 10.1007/s10950-019-09859-6

Ambosino, F., Thinová, L., Briestenský, M., Sabbarese, C., 2019: Analysis od radon time series recorded in Slovak and Czech caves for the detection of anomalies due to seismic phenomena. Rariation Protection Dosimetry, ncz2245, doi:10.1093/rpd/ncz245

Ambosino, F., Thinová, L., Briestenský, M., Sabbarese, C., 2019: Anomalies identificationof Earth's rotation rate time series (2012-2017) for possible correlation with strong earthquakes occurence. Geodesy and Geodynamics, 10, 455-459.

Kostov, K., Dobrev, N., Stemberk, J., Briestenský, M., Ivanov, I., 2018: Monitoring of microdisplacements in Golyamata Tsepnatina cave, Madara plateau, NE Bulgaria. Acta Carsologica, 47, 1, 69-81, DOI: 10.3986/ac.v47i1.5149.

Trčka T., Macků R., Koktavý P., Skarvada P., Baroň I., Stemberk J. (2017): Field measurement of natural electromagnetic emissions near the active tectonic and mass-movement fractures in caves. Solid State Phenomena 258, 460-464.

Cooperation with the Faculty of Electrical Engineering of CTU, Department of Measurements, on the development and testing of sensors for measurements of the Earth's magnetic field.

Janošek, M.; Butta, M.; Vlk, M.; Bayer, T. Improving Earth's magnetic field measurements by numerical corrections of thermal drifts and man-made disturbances. Journal of Sensors. 2018, 2018 ISSN 1687-725X.

Janošek, M.; Petrucha, V.; Vlk, M. Low-noise magnetic observatory variometer with race-track sensors. In: Proceedings of 5th International Conference on Materials and Applications for Sensors and Transducers. Bristol: IOP Institute of Physics, 2016. IOP Conference Series: Materials Science and Engineering. ISSN 1757-899X.

Four papers dealing with data obtained at the GeoCLIMANET stations have been published in the reported period. Three papers deal with data from the monitoring site at the Institute of Geophysics in Prague and one paper, written by cooperating colleague and his doctoral student from the Slovenian Geological Survey interprets data from the Slovenian station Malence. The papers focus mainly on temporal behaviour of the offset between the air and ground surface temperatures, but investigate also e.g., the effects of soil freezing and melting and the influence of heavy rainfall on temperatures in the upper parts of the shallow subsurface.

V.Čermák, L.Bodri, M.Krešl, P.Dědeček, J.Šafanda: Eleven years of ground–air temperature tracking over different land cover types, International Journal of Climatology, DOI: 10.1002/joc.4764, 2016.

V.Čermák, L.Bodriand: Air-Ground Temperature Coupling: Analysis by Means of Thermal Orbits. Atmospheric and Climate Sciences, 6, 112-122. <u>http://dx.doi.org/10.4236/acs.2016.61009</u>, 2016.

A. Strgar, D. Rajver and A. Gosar: Investigations of the air – ground temperature coupling at location of the Malence borehole near Kostanjevica, SE Slovenia. GEOLOGIJA 60/1, 129-143, Ljubljana, https://doi.org/10.5474/geologija.2017.010, 2017.

V. Čermák, L. Bodri, J. Šafanda, M. Krešl and P. Dědeček: Variability trends in the daily air temperatures series. AIMS Environmental Science, 6(3), 167-185, DOI: 10.3934/environsci.2019.3.167, 2019.

Geological and geophysical data represent a valuable and unique source of information to support scientific research, in particular for the interpretation of geological and geophysical research and surveys, but also serve as information support for decision-making processes related to natural resources as well as potential risks arising from geological composition. The main objective of the research activity is the technological development and modernization of the infrastructure enabling the operation and use of the geological information system CGS-DRI.

Hudečková, E. – Kolejka, V. – Paleček, M. – Ambrozek, V. – Moravcová, O. – Kondrová, L. – Čápová, D. (2018): Access to geophysical data – web map application of CGS "Geophysical measurements". – EGRSE. Exploration Geophysics, Remote Sensing and Environment (CD ROM) XXV.1, 1, 61-71. ISSN 1803-1447. DOI 10.26345/EGRSE-061-18-105

Kolejka, V. – Hudečková, E. – Čápová, D. – Moravcová, O. – Svítil, R. (2019): Geophysics (web page of the portal of the Czech Geological Survey). Praha. URL http://www.geology.cz/extraneteng/science/earths-crust/geophysics

Moravcová, O. – Kafka, Š. – Kramolišová, P. – Čápová, D. (2016): The European Geological Data Infrastructure (EGDI) Metadata Catalogue. Praha. URL http://egdi.geology.cz/ Paleček, M. – Ambrozek, V. – Hudečková, E. – Kolejka, V. (2018): Geophysical measurements.

Praha. URL https://mapy.geology.cz/geophysical measurements/?locale=en

Paleček, M. – Krejčí, Z. (2019): Geological map 1:200 000. Praha. URL https://mapy.geology.cz/arcgis/rest/services/Geologie/geologicka_mapa200/MapServer

Moravcová, O. – Svítil, R. – Krejčí, Z. – Kondrová, L. – Kramolišová, P. (2019): Signpost of data resources in CGS – web page. Praha. URL http://www.geology.cz/extranet/vav/informacni-systemy/data/datove-zdroje

Svítil, R. – Kramolišová, P. – Moravcová, O. – Kondrová, L. – Paleček, M. (2018): Map services based on Esri technology - web page. Praha. URL http://www.geology.cz/extraneteng/maps/online/esri

Čápová, D. – Kondrová, L. – Kramolišová, P. – Moravcová, O. – Kafka, Š. (2016a): EGDI Metadata Catalogue – the European Geological Data Hub. In Joint Research Centre: INSPIRE Geospatial World Forum 2016 Proceedings online,

http://inspire.ec.europa.eu/events/conferences/inspire_2016/schedule/submissions/351.html, s. 1. – European Commission; Exhibition Committee - Institut Cartogràfic (Barcelona). Barcelona

Kaláb, Z. – Čápová, D. – Moravcová, O. – Kondrová, L. (2019a): Metadata of the geophysical data sources in the Czech Republic: Case study in the IGN (Institute of Geonics of the Czech Academy of Sciences, Ostrava, Czech Republic). In AUAG: Proceedings of XVIIIth International Conference 'Geoinformatics: Theoretical and Applied Aspects'. 13-16 May 2019

http://geoinformatics.org.ua/eng/conferences/Ggeoinformatics-2019/, volume No. 15738. -

The European Association of Geoscientists and Engineers (EAGE) and the All Ukrainian Association of Geoinformatics (AUAG). Kyiv, Ukraine

Kaláb, Z. – Čápová, D. – Moravcová, O. – Kondrová, L. (2019d): Metadata of the geophysical data sources in the Czech Republic: Case study in the IGN (Institute of Geonics of the Czech Academy of Sciences, Ostrava, Czech Republic). In Institute of Geonics, Czech Academy of Sciences: Proceedings of abstracts 37th Czech- Polish - Slovak Symposium on "Mining and Environmental Geophysics" and 28th Conference "OVA'19 - New Knowledge and Measurements in Seismology, Engineering Geophysics and Geotechnical Engineering", May 28 – 31, 2019, – CAAG – Czech Association of Geophysicists. Ostrava, Czech Republic. ISBN 978-80-86407-76-0

Kondrová, L. – Čápová, D. – Moravcová, O. – Kujal, R. – Hudečková, E. (2017): INSPIRing Geophysics. In Joint Research Centre, JRC of the European Commission: INSPIRE conference 2017 - INSPIRE a digital Europe: Thinking out of the box. Proceedings online, http://inspire.ec.europa.eu/conference2017/psessions, s. 272. – European Commission, DG Environment, Unit E.4 – Compliance and Better Regulation. Strasbourg

Kondrová, L. – Moravcová, O. – Hudečková, E. – Čoupek, P. – Kolejka, V. – Čápová, D. (2018): Growing up with INSPIRE - Implementation of INSPIRE at the Czech Geological Survey. In Joint Research Centre, JRC of the European Commission: INSPIRE conference 2018 - Inspire users: Make it Work Together. Proceedings online, https://inspire.ec.europa.eu/conference2018/viewpsessions, – European Commission, DG Environment. Antwerpen

Čápová, D. – Kramolišová, P. – Kondrová, L. – Moravcová, O. – Kafka, Š. (2016c): EGDI Metadata Catalogue - the European Geological Data Hub. 29.9. 2016. Barcelona, Španělsko

Čápová, D. – Kramolišová, P. – Moravcová, O. – Kondrová, L. – Kafka, Š. (2016d): European Geological Data Infrastructure ´EGDI´ Metadata Catalogue - Step to the Pan-European EPOS project. 16.11. 2016. Workshop CzechGeo/EPOS, Geofyzikálního ústavu AV ČR, Praha

Kaláb, Z. – Čápová, D. – Moravcová, O. – Kondrová, L. (2019b): Metadata of the geophysical data sources in the Czech Republic: Case study in the IGN (Institute of Geonics of the Czech Academy of Sciences, Ostrava, Czech Republic). 13.5.2019. GEOINFORMATICS 2019 (EAGE), Kiev, Ukraine

Kondrová, L. – Kujal, R. – Moravcová, O. – Hudečková, E. – Čápová, D. (2017): INSPIRing Geophysics. 6.9. 2017. INSPIRE conference 2017, Strasbourg

II. Describe main scientific results (max. 20) achieved <u>by external LRI's users</u> on the basis of the LRI's use (its Czech node in case of distributed research infrastructures).

Bindi, D., Zaccarelli R., Strollo A., Di Giacomo, D. 2019: Harmonized local magnitude attenuation function for Europe using the European Integrated Data Archive (EIDA), Geophysical Journal International, Volume 218, 519–533. https://doi.org/10.1093/gji/ggz178

Bondár I. et al. (2018): Relocation of Seismicity in the Pannonian Basin Using a Global 3D Velocity Model. Seismological Research Letters 89 (6): 2284-2293. DOI: https://doi.org/10.1785/0220180143 (uvedení v Data availability a obrázky)

Bräuer, K., Kämpf, H., Niedermann, S., & Strauch, G. (2018). Monitoring of helium and carbon isotopes in the western Eger Rift area (Czech Republic): relationships with the 2014 seismic activity and indications for recent (2000–2016) magmatic unrest. Chemical Geology, 482, 131-145.

Bussert, R., Kämpf, H., Flechsig, C., Hesse, K., Nickschick, T., Liu, Q., ... & Flores, H. E. (2017). Drilling into an active mofette: pilot-hole study of the impact of CO 2-rich mantle-derived fluids on the geo–bio interaction in the western Eger Rift (Czech Republic). Scientific Drilling, 23, 13.

Evangelidis, C. (2017). Seismic anisotropy in the Hellenic subduction zone: Effects of slab segmentation and subslab mantle flow. Earth and Planetary Science Letters, 480, 97-106. DOI: 10.1016/j.epsl.2017.10.003

Fuchs, F., Schneider, F.M., Kolínský, P. et al. 2019: Rich observations of local and regional infrasound phases made by the AlpArray seismic network after refinery explosion. Sci Rep 9, 13027 doi:10.1038/s41598-019-49494-2

A. Ganas, P. Briole, G. Bozionelos, P. Elias, S. Valkaniotis, V. Tsironi, A. Moshou and N. Andritsou (2019). The October 25, 2018 M6.7 Zakynthos earthquake sequence (Ionian Sea, Greece): fault modelling from seismic and GNSS data and implications for seismic strain release along the western Hellenic Arc. 15t h International Congress of the Geological Society of Greece, Athens, 22-24 May, 2019, Harokopio University of Athens, Greece. Bulletin of the Geological Society of Greece, Sp. Pub. 7 Ext. Abs. GSG2019-324

G. Giannaraki, I. Kassaras, Z. Roumelioti, D. Kazantzidou-Firtinidou, A. Ganas (2018). Deterministic seismic risk assessment in the city of Aigion (W. Corinth Gulf, Greece) and juxtaposition with real damage due to the 1995 Mw6.4 earthquake. Bulletin of Earthquake Engineering, 17, 603-634. <u>https://doi.org/10.1007/s10518-018-0464-z</u>

D. Giannopoulos, D. Rivet, E. Sokos, A. Deschamps, A. Mordret, H. Lyon-Caen, P. Bernard, P. Paraskevopoulos and G-A. Tselentis (2017). Ambient noise tomography of the western Corinth Rift, Greece. Geophys. J. Int., 211, 284–299. doi: 10.1093/gji/ggx298.

S. E. Hansen, C. Evangelidis, G. A. Papadopoulos (2019). Imaging Slab Detachment Within the Western Hellenic Subduction Zone. Geochemistry, Geophysics, Geosystems, 20, 895-912. https://doi.org/10.1029/2018GC007810

Heinicke, J., Stephan, T., Alexandrakis, C., Gaupp, R., & Buske, S. (2019). Alteration as possible cause for transition from brittle failure to aseismic slip: the case of the NW-Bohemia/Vogtland earthquake swarm region. Journal of Geodynamics, 124, 79-92.

Janošek, M.; Butta, M.; Dressler, M.; Saunderson, E.; Novotný, D.; Fourie, C. 1-pT noise fluxgate magnetometer for geomagnetic measurements and unshielded magnetocardiography. IEEE Transactions on Instrumentation and Measurement. 2019, 2019 ISSN 0018-9456.

Kriegerowski, M., Cesca, S., Ohrnberger, M., 1, Dahm, T. and Krüger, F., 2019. Event couple spectral ratio Q method for earthquake clusters: application to northwest Bohemia. Solid Earth, 10, 317–328, 2019 https://doi.org/10.5194/se-10-317-2019

Lu Y. et al. (2018). High-resolution surface wave tomography of the European crust and uppermost mantle from ambient seismic noise. Geophysical Journal International 214(2), 1136–1150. doi:10.1093/gji/ggy188

Mousavi, S., Bauer, K., Korn, M., and Hejrani, B., 2016. Seismic tomography reveals a mid-crustal intrusive body, fluid pathways and their relation to the earthquake swarms in West Bohemia/Vogtland. Geophys. J., Int., 203, 1113-1127, doi: 10.1093/gji/ggv338

Mousavi, S., Haberland, C., Bauer, P., Hejrani, B. and Korn, M., 2017. Attenuation tomography in West Bohemia/Vogtland. Tectonophysics, 695, 64–75. doi: 10.1016/j.tecto.2016.12.010

Schippkus S., Hausmann S., Duputel Z., Bokelmann G. and AlpArray Working Group, 2019: The Alland earthquake sequence in Eastern Austria: Shedding light on tectonic stress geometry in a key area of seismic hazard. Austrian Journal of Earth Sciences Vienna, 112/2, 182-194. DOI: 10.17738/ajes.2019.0010

Schneider F.M. et al. (2018): Seismo-acoustic signals of the Baumgarten (Austria) gas explosion detected by the AlpArray seismic network, Earth and Planetary Science Letters 502, 104-114, doi.org/10.1016/j.epsl.2018.08.034 (uvedení v Data availability a obrázky)

Umlauft, J., & Korn, M. (2019). 3-D fluid channel location from noise tremors using matched field processing. Geophysical Journal International, 219(3), 1550-1561.

Wcisło, M. and Eisner, L., 2019. Fast determination of attenuation from microseismicity for large datasets. Acta Geodyn. Geomater., 16, 257–268, doi: 10.13168/AGG.2019.0022

Seismic waveforms recoded by the LRI and corresponding metadata are accessible publically in the open way in data centres, as EIDA (with 10 nodes including the GFZ), IRIS or directly in our archive, without possibility of exact tracking of their usage. Nevertheless, within the AlpArray project, the network doi are referred in ~50 publications, some of them are listed at http://www.alparray.ethz.ch/en/outreach/publications/

B. Compliance with the Project Plan

Describe all deviations and changes to the original plan of realization (in scope, objectives, personnel) over the course of realization period and explain their reasons.

No deviations against the original plan occurred.

- The LRI continued in reliable and stable operation of observatories and stations and thus in continuation and extension of long time series essential for any geoscience research.
- The networks were upgraded and extended.
- The data were provided to the user community either on-line or on request; the on-line service was extended.
- The LRI cooperates with and participate to European and global data systems

C. Socio-economic Impacts

I. Impact on economy: Indicate number of jobs in the LRI for the entire period (researchers/other staff) and number and financial volume of contracts with industry concluded in the framework of public procurement to maintenance and renewal of the LRI.

The project LM2015079 funded 19 FTE per year on the average. For details see table in I.B.III As no investment money were available in this project, there were no big contracts. The volume of services was about 9 mio CZK. The largest items are repairs of instruments, energy supply and telecommunications (on-line connections to observatories and stations).

II. Impact on educational activities: Estimate number of master and PhD students using the LRI's data, trained in courses by LRI, new publications (textbooks) using LRI's data.

10 PhD students of Charles University used LRI data for their theses. Several of them were directly involved in data acquisition and pre-processing. The number of Master and Bachelor theses is similar.

Students are educated and trained in observational activities also at Masaryk University and VŠB - Technical University of Ostrava.

Besides, the WEBNET data have been used for 3 PhD thesis at German universities. As a rough estimate the WEBNET and REYKJANES data are used by 15 master and bachelor students at universities in Czech Republic, Germany and Iceland. Data collected by AlpArray partners were used in about 50 PhD theses.

Data and information, specifically those provided in the form of a map applications and web services, are used by students of geology and geoinformatics both in the Czech Republic and abroad

III. Other socio-economic impacts (in applicable): Impact on technology sphere and quality of life, other outputs in connection with the LRI's operation.

Cooperatation with VODNI DILA - TBD a.s. and Faculty of Civil Engineering (Department of Hydraulic Structures) on estimation of the seismic risk of the water dam Horka – numerical modelling with using real accelerograms; possible revision of safety standards.

The availability of high quality data from the Czech Republic in European infrastructures contributes to the integration of European data and participation in international activities increases the reputation of the Czech Republic.

See also cooperation in the section I.D.I.

D. Future Prospects (Outlook)

Describe the foreseeable future of the LRI's facility, project team and expected further utilization of the results achieved. Describe intent of continuation, plans for future, intended grant applications etc.

The activity of CzechGeo/EPOS will have to be limited in connection with the termination of funding from the LM Program on Support of Large Research Infrastructures. We are aware that geoscience observation is a never-ending task, because data that were not measured now cannot be replaced later and information about significant event would be lost. Continuous geophysical monitoring is a necessity for any geoscience research and application.

We will therefore do our best and try to continue in observations with limited institutional sources and find other grant opportunities. The infrastructure can be partly supported from grants of Czech Science Foundation or Czech Technology Agency that uses the observatory data. We are also going to submit application to the next call for proposals in the LM Program on Support of Large Research Infrastructures announced on 2021.

The upgrades within the CzechGeo/EPOS and CzechGeo/EPOS-Sci projects were planned so as to reduce the operation costs in future. However, the higher number of stations, higher volume of data that need to be telemetered in and out of the LRI and analysed, the growing personnel costs, higher member fees to be paid to international consortia etc. require stable funding which is not arranged for after the ending of the CzechGeo/EPOS project.

Most critical situation is in RIGTC. The project team will be disbanded in the context of the termination of LRI funding - more precisely, the team members will be redirected to other research projects. Ensuring the operation of at least part of the infrastructure will depend entirely on the willingness of the founder - Czech Office for Surveying, Mapping and Cadastre - to finance such activity. Certainly this will not apply to part of the infrastructure abroad (PPGNet in Greece) and outside the geodesy area (seismic station). There will also be no funds for possible repairs of used equipment.

Science and societal reasons for continuation of CzechGeo/EPOS operation:

The LRI is essential for regional- to local-scale monitoring of seismicity in the Czech Republic, which is a basic input to seismic hazard assessment and important contribution to European and global datasets. A seismic safety is the limiting factor of an expansion of nuclear energetics. The CzechGeo/EPOS infrastructure provides input data for seismic hazard assessment.

Plans for MOBNET part and all LRI involvement into international passive experiments: AlpARray complementary experiments: continuation of the eastern part of the Z3 network of the AlpArray for the PACASE (2019-2021) and AdriaArray (2021-2025) networks to study orogeny processes and fate of diminishing Adriatic plate.

The upgrade of CarbonNet to NEFOBS funded from the CzechGeo/EPOS project brought the infrastructure to a higher level capable of providing high quality data on the flow rate of CO2 and its isotopic composition. Existing seismic and fluid monitoring on the surface was supplemented by subsurface monitoring in boreholes. The network will continue in operation, which is a necessary condition for any geophysical monitoring and developing collaboration with other field observatories in Europe.

Cooperatation with VODNI DILA - TBD a.s. and Faculty of Civil Engineering (Department of Hydraulic Structures) on estimation of the seismic risk of the water dam Horka – numerical modelling with using real accelerograms; possible revision of safety standards.

Given the status of CGS-DRI, it is essential to continue activities and finance them from the institutional budget even after the end of the LM Program on Support of Large Research Infrastructures. Continuation of the project in case of success of the next call for proposals in the LM Program on Support of Large Research Infrastructures announced on 2021 in coming years will allow to continue processing of more data and thematic sets to ensure access to the geoinformation important to support decision-making and research. In order to maintain the status of the consortium members in European structures, the continuation of activities and their financial support is a prerequisite.

The management of the EPOS ERIC (European Landmark) expressed interest in continuing cooperation with CzechGeo/EPOS also after the end of EPOS IP Project and in active involvement of Czech partners into EPOS issues.

PART III. – FINANCIAL EFFICIENCY

A. Overview of Financial Costs in Total

Spent recognised costs (in kCZK)	2016	2017	2018	2019	Total
Personnel costs	11 467	11 765	10 368	10 317	43 917
Investments					
Membership fees	755	797	847	842	3 241
Operating costs	11 204	10 814	9 511	9 511	41 040
Refunded funds		50		2 756	2 806
Total	23 426	23 426	20 726	23 426	91 004

I. Explain generally schedule and justification of usage of financial resources over the realization period, explain the total amount for main activities covered by funding provided, in a way that enables to assess overall financial efficiency of the LRI.

CzechGeo/EPOS operates more than 300 stations placed not only in Czech Republic and Central Europe, but also in Greece, Portugal, Iceland. A few stations are located in Asia and America. Vast majority of operational resources was used to keep the stations working. CGS used most resources for purchase or licencing software and other IT equipment and services. Details are given below.

II. Elaborate on personnel costs, investments (if applicable), membership fees (if applicable), operating costs, explain briefly the main expenditures and changes between years in funded period. In operation costs elaborate on the kinds of expenditures (consumables, services, travel costs etc. – according to the table in Annex 1 of this report).

According to the conditions of the project the personnel costs were not destined for geoscience research. They were used exclusively to operation of stations, installation of new equipment and development of new experimental methods, data processing and IT activities including building of databases structures etc. The personnel costs were not sufficient for operation of the infrastructure and some staff members were paid from institutional budget.

Membership fees were used for International Continental Drilling Program, European Mediterranean Seismological Centre, International Seismological Centre or International Consortium on Landslides. Membership fee to European Geological Data Infrastructure was paid partly in money partly in-kind in the form of labour on the system development. As the ratio between these part has changed, we have every year asked for change between these two items.

The travel costs were spent on frequent journeys to observatories and stations, either regular for data download and recharge of batteries or irregular in case of instruments breakdown, exceptionally also for vandalism. Small amount was used for participation on workshops related to observatory issues.

The volume of services was about 9 mio CZK. The largest items were repairs of instruments, energy supply and telecommunications (on-line connections to observatories and stations), software licences and trainings. Installation of station also requires help of local craftsman. Low value tangible assets include small electrical items like modems, data storages or data loggers, UPS including large batteries etc.

Consumables consist of various materials (electro, building, ...). This item involves also fuel for travels to observatories and stations.

The overhead 12.3 MCZK was 13.7 percent of the budget.

III. Describe briefly amount and reasons of returns (refunded funds) in particular years (differentiate funds returned in the year or within final financial settlement).

Year 2017 - 50 000 CZK was returned on expenses account as membership fees to International Consortium on Landslides were covered by other projects.

Year 2019 - At the time of grant application, we supposed that the Czech Republic would be member of EPOS ERIC and the amount of 2700 ths. CZK was planned for membership fee. As it is not the case, the money was returned to the grant provider on expenses account in November 2019. The saving of membership fees 16 532 CZK (IG CAS) and 680 CZK (CGS) is due to better CZK rate, 39 363 CZK (IRSM CAS) was paid by other sources. Money will be sent on settlement account.

PART IV. – ADDITIONAL RELEVANT INFORMATION

Calls for Tenders, Gender Issues, Outreach

I. Provide an overview of calls for tenders pursuant the Act No. 134/2016 Coll., on Public Procurement, list of contracts concluded with suppliers and service providers.

2016

IG CAS: Repair of interior of registration hut at Budkov Observatory, Company Margita Dragounová, Vlachovo Březí, 99 276 CZK.

RIGTC: Repair of seismometer – replacement of faulty parts. Based on the order No. 24-056/2015 dated April 1, 2015 was carried out by Guralp Systems Limites, Reading, UK, for the amount 3610,59 EUR.

RIGTC: Repair of coldhead SN 3TE08013C – a part of superconducting gravimeter. Based on the order No. 24-046/2016 dated April 11, 2016 was carried out by Sumitomo (SHI) Crygenics of Europe GmbH, Darmstadt, Německo, for the amount 3860 EUR.

RIGTC: Repair of azimut driver of radiometr of water vapourr. Based on the order No. 24-047/2016 dated April 5, 2016 was carried out by TRG – Representation of Radiometrics Corp., USA, Meckenheim, Německo, for the amount 6000 EUR (including transport to the USA and back).

RIGTC: Repair of coldhead SN 3TE06002C – a part of superconducting gravimeter. Based on the order No. 24-170/2016 dated September 8, 2016 was carried out by Sumitomo (SHI) Crygenics of Europe GmbH, Darmstadt, Německo, for the amount 3860 EUR.

CGS: Analysis of feasibility of of migration Oracle Portal, SEFIRA spol. s r.o., 107 690 CZK

CGS: Hardware supply, company Jan Heran, 213 147 CZK.

2017

CGS: Office and IT consumables, firma Jan Heran, 121 806,81 CZK

CGS: MS Office, DNS a.s., 245 480,64 CZK

CGS: Server loan for disaster recovery, Proact Czech Republic, 72 600 CZK CGS: OS SuSe for disaster recovery, Datron, 111 030 CZK

2018

CGS: Office and IT consumables, IT Děčín s.r.o., 196 454,50 CZK ČGS: MS Office, SoftwareOne Czech Republic s.r.o., 220 000 CZK

II. Describe the LRI's approach to gender issues within the project, gender composition of core team, the policy that has been applied to enable equal opportunities within the core team.

Approach of all partners is gender neutral. The equal opportunities were followed by all partners throughout the entire period of project solution.

Faculty of Science MU is a holder of the HR Excellence in Research Award by the European Commission and implements the people processes strategy, HRS4R.

Gender composition - employees participating on the project CzechGeo/EPOS or CzechGeo/EPOS-Sci (in physical persons): 21 women and 54 men.

III. Describe the outreach activities, advertising and promotion actions taken, steps towards better visibility of the LRI at a national and international level.

Information about the infrastructure for research community and public are available on the web <u>www.czechgeo.cz</u> – new web pages are recently developing in the frame of CzechGeo/EPOS/Sci project.

Infrastructure and networks are also presented on the web pages of partner institutions and on web of Czech Association of Geophysicists <u>https://caag.cz/soubory/czechgeo_clanek2011.pdf</u> Observation activities are regularly propagated at the Earth Day, the Week of Science and Technology of the Czech Academy of Sciences which is the most extensive science festival in the Czech Republic, or Science Fair.

In cooperation with municipalities, two geophysical museums were established, where visitors can learn about seismic phenomena and methods of their registration and research. In the Museum of Seismometry in Kasperske Hory, visitors can view historic seismometers and data acquisition systems, learn a lot about almost two thousand year old history of the seismometers, how they worked and the evolution of the construction of seismometers since the 19th century. In the Museum of Geophysics in Skalna visitors are guided by an interactive exhibit through seismology, from plate tectonics to the latest findings about seismic swarms in West Bohemia/Vogtland.

PART V. - CONCLUSION

Final Assessment (Summary)

Summarize conclusions of the project described in more details above. Describe the course of the realization, summarize the objectives achieved, the degree of expectations being met, assess efficiency of utilization of the funding and mention the targets that are yet to be achieved.

Modern science is based on experimental data and observations. In most disciplines, these data are acquired in laboratories by means of pre-planned and prepared experiments. By contrast, the laboratory of geophysical research is the entire planet Earth and the experiments are prepared by Mother Nature herself. For data, which have not been observed and recorded today, no full-valued replacement can ever be found. Continuous and reliable data collection on one's own territory is the obligation of each country and proof of its cultural and technical development. International data exchange, i.e. the global availability of data via international data centres, is condition sine qua non for the future development of basic and applied geosciences research.

Geophysical observations on our territory have a long history. Regular magnetic observations were started in 1839. Gravimetric observations were started in a deep mine shaft in Příbram in 1910 and the oldest still operating seismic station was founded at the Faculty of Science of the Charles University in 1927. The geophysical research, including the observations activities, was accelerated during the International Geophysical Year 1957-58 and since then number of station grew continuously up. Having in mind the whole history, the period 2016-2019 was exceptional in modernization and general progress of the infrastructure. The amount of 42 mio CZK from the Operational Program Research, Development and Education were complemented by 5 mio CZK from the budget of the Czech Academy of Sciences for upgrade of the Reykjanet network. As Iceland is not a member of EU, these investments could not be supported by Operational Programs.

The stations were upgraded either if they were close to the end of their lifetime or if they became technically obsolete. The new data acquisition systems are always equipped with Internet connection and thus enable on-line data transmission. The technician thus has continuous control of operation of the station and can immediately start to execute repairs. The temporary networks are usually connected via mobile network. As the stations are often situated on remote localities, the signal is not good enough for continuous transfer of large amount of data. Nevertheless, the operator gets regularly information about the state of the observations and is immediately informed via message about problems. The station must be regularly visited for data download and recharge of batteries, however, if there is continuous control of the state of the data quality and number of station with on-line access, decreased the risk of outage and shortened the time of repairs and, at the same time, slightly reduced the operation costs in the future.

During preparation of the recent project LM2015079 in 2015, Czech Geological Survey was invited to join the CzechGeo/EPOS team, as geophysical and geological data available there are important for geoscience research. The mission of the Geological and Geophysical Data Infrastructure (CGS-DRI) for research support, developed by the Czech Geological Survey as part of the CzechGeo / EPOS research infrastructure, is primarily to provide effective access to geological, geophysical and other related data available in the Czech Geological Survey and other organizations, using the state-of-the-art technologies. These valuable data sources had to

be consolidated and harmonized in line with evolving European and global standards. At the beginning of the project, it was relatively problematic to ensure the smooth running of outdated technical infrastructure. At present, the technical infrastructure is of a very good standard and uses the implemented modern technologies. Inventory of the data sources was completed, all identified data resources were described by metadata. The relevance to the requirements given by legislation, priorities of European and global infrastructures and user needs was evaluated. The data was consolidated or harmonized in accordance with the standardized data specifications. The Data is provided in accordance with the principles of modern technology and user requirements.

Most data are available in open access mode. Data from international projects like AlpArray will be for some period available only to the project team and after that open for anybody. Other data are available on request. The number of open access data increased in the last period and we are going to continue in this process. Section I.C.I gives overview of data access and if possible gives also the number of users and amount of data downloaded. The statistics is incomplete, as some Data Centres do not collect and public the statistics and data users do not inform the data provides about data usage, even if they are asked to do so. List of users from universities, public research institutions, public administration or industry documents usefulness of our data for research, education and society. The same hold for numerous cooperation. The data were also subject of more than 10 PhD dissertation and similar number of Bachelor or Master theses at Czech universities and several dissertations abroad. The members of LRI team are (co)authors of 70 research papers.

The LRI team organized 13 workshops. Annual CzechGeo/EPOS workshops were devoted to the presentation of the infrastructure, its sections and networks and results obtained by data users. Second group of workshops dealt with the data and metadata of geological and geophysical datasets in connection with the INSPIRE directive. Specifically, the technical workshop on metadata specification for 3D geological models defined the basis for the standard accepted later in GeoERA projects. The best practices, shared at the international technical workshop on INSPIRE geophysical data specification helped significantly to implement these standards in CGS. Important international geoinformatics meetings were organized by CGS, specifically both annual meetings of SIEG, GeoERA GIP workshop and CE-GIC annual meeting. All of these meetings were important for sharing the European experiences both related to the usage of the modern information technology and to organizational and political conditions on establishing the common platform for data and knowledge sharing in geology.

The period of LM2015079 project coincides with the EPOS IP (Implementation Phase of European Plate Observing System) aimed at integrating the diverse and advanced European Research Infrastructures for solid Earth science, and building on new e-science opportunities to monitor and understand the dynamic and complex solid Earth System. Two CzechGeo/EPOS Partners – IG CAS and RIGTC participated in the EPOS IP Project, CGS joint the EPOS activity later without financial contribution. After the end of EPOS IP an important role will be played by TCS Consortia. LRI partners signed four Consortia Agreements. In spite of the fact that our government did not join the EPOS ERIC, the EPOS management repeatedly expressed interest in CzechGeo/EPOS cooperation.

Active research and organizational work in the Spatial Information Expert Group (SIEG), and in particular the election of a CGS employee as SIEG chairman, increased the Czech Republic's prestige in European geoinformatics. The group is a key player in the continued design and

development of the European Geological Data Infrastructure (EGDI), it contributes significantly to the compilation of the proposal for the European Partnership under Horizon Europe programme aiming at creation of the Geological Service for Europe.

CGS is one of the five European geological surveys that form the core team of the European Geological Data Infrastructure (EGDI), which plays an important role as a recognized platform for providing geological interoperable distributed data from EuroGeoSurveys members for EPOS and other European infrastructures such as EMODnet, Copernicus, GEO, etc. The project provided metadata and harmonized web services for the European geospatial portal INSPIRE (INfrastructure for SPatial InfoRmation in Europe).

The CzechGeo/EPOS team participates on the AlpArray – the large European initiative within which scientists form ~50 institutions - universities and research institutes in 17 countries cooperate. More than 50 MOBNET stations are employed and our software for data quality control is used.

After termination of funding from the LM Program on Support of Large Research Infrastructures our activity will have to be partly limited. The upgrades were planned so as to reduce the operation costs in future. Most partners thus will be able to keep operation of stations and data systems, however, problems could arise in case of need for large repairs. The future of RIGTC stations is recently unclear. The same holds for the operation of the unique software system developed for the European GNSS community in the frame of EPOS IP Project.

We will try to continue in observations with limited institutional sources and find other grant opportunities. We are also going to submit application to the next call for proposals in the LM Program on Support of Large Research Infrastructures announced on 2021.

We do not need large upgrade of infrastructure in the near future. We will concentrate on increasing the percentage of data submitted on line to global or regional data systems and to simplify user access to data in our repositories. We have already started development of new web pages that should help to make our data better findable and accessible.

We will continue in cooperation with European data infrastructure as well as in cooperation with the European research projects and infrastructures.

Appendices

Mandatory: Table of the real financial costs of the LRI over the entire period **Optional:** Appendices relating to the realization of the LRI at discretion (max. 10 A4 pages).

In Prague Date: 30.1.2020

Signature of principal investigator:

Gallel Hz.