48th Nordic Seismology Seminar, 12.–13.6.2017

2nd Nordic EPOS meeting, 14.–16.6.2017

Kumpula Science Campus
Helsinki
Finland

Program
Abstracts

UNIVERSITY OF HELSINKI
FACULTY OF SCIENCE

Institute of Seismology
Department of Geosciences and Geography
University of Helsinki

48th Nordic Seismology seminar, 12.6. – 13.6.2017

90 minute sessions, 15 + 5 minute slots.

Meeting hall: CK112, Exactum, Kumpula

Monday 12.6.2017

- 9:30 – 10:15 Registration at Exactum lobby
- 10:15 – 11:30 Opening session

  Chair: Annakaisa Korja (Institute of Seismology, University of Helsinki)
  - Opening by Professor Juha Karhu
    - Head of the Department of Geosciences and Geography at the University of Helsinki
  - Björn Lund (*Uppsala University*)
    - Imaging the state of the rock mass in the Kiirunavaara iron ore mine, Sweden, using local event tomography
  - Jari Kortström (*Institute of Seismology, University of Helsinki*)
    - Status and Development of Seismic Analysis at the Institute of Seismology
  - Ragnar Slunga (*QuakeLook Stockholm AB*)
    - Microearthquakes and crustal stress monitoring
- 11:30 – 13:00 Lunch
- 13:00 – 14:30 Afternoon session

  Chair: Dmitry Storchak (International Seismological Center)
  - Peter Voss (*GEUS*)
    - Status of the recent activities at the seismological service at GEUS
  - Elena Kozlovskaya (*University of Oulu*)
    - Passive seismic interferometry in brownfield mineral exploration
  - Heidi Soosalu (*Geological Survey of Estonia*)
    - Geological context of the 2016 Võrtsjärv and the 2017 Keila earthquakes, Estonia
  - Olga Erteleva (*Institute of physics of the Earth, Moscow*)
    - Seismic Hazard and Seismic Treatments Assessment in the Territory of Leningrad Region
- 14:30 Coffee
- 15:00 Field trip to Suomenlinna
- ca. 18:00 Conference dinner at restaurant Suomenlinnan Panimo

Tuesday, 13.6.2017

- 10:00 – 11:30 Morning session

  Chair: Peter Voss (GEUS)
  - Sakari Väkevä (*Institute of Seismology, University of Helsinki*)
    - Deep Earthquakes of Fennoscandia according to OpenFIRE data
  - Jon Magnus Christensen (*NORSAR*)
    - NORSAR Stations – current status

- Marko Riedel (*Institute of Seismology, University of Helsinki*)
  - Efficient computation of seismic traveltimes in anisotropic media and the application in pre-stack depth migration
- Mathilde B. Sørensen (*University of Bergen, Norway*)
  - Investigation of macroseismic data for earthquakes in Norway and Denmark

- 11:30 – 13:00 Lunch
- 13:00 – 14:30 Afternoon session

  Chair: Mathilde B. Sørensen (University of Bergen, Norway)
  - Dmitry Storchak (*International Seismological Center*)
    - Advancement of the ISC Datasets and Services
  - Svein Mykkeltveit (*NORSAR*)
    - Status of implementation of the verification regime for the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
  - Feliks Aptikaev (*Institute of physics of the Earth, Moscow*)
    - How to Measure the Duration of Seismic Vibration
  - Marko Riedel (*ISUH*)
    - Reflection seismic modeling and imaging for mineral exploration in the Kylylathi Cu-Au-Zn mine, eastern Finland
- 14:30 – 14:40 Closing remarks by organizers and invitation by the next year's host
- 14:40 – 16:00 Coffee & Poster session
  - Ville Jantunen (*ISUH*)
    - A useful tool to identify recurring blasts in seismic event bulletins
  - Tommi Vuorinen (*ISUH*)
    - Online Earthquakes
- 18:00 – 20:00 Rector's Reception at Helsinki University main building (Unioninkatu 34)
  - Hosted by Professor Esko Ukkonen, Vice Dean of the Faculty of Science
  - Room: Opettajien lehtisali

You may also find the following of interest:

Wednesday, 14.6.2017

- *09:00 – 11:15 informal get-together for people working with daily seismic analysis in Nordic countries (Exactum 4th floor room D413)*
- *11:15 – 12:30 Nordic Participation in seismological organizations and programs*

2nd Nordic EPOS meeting, 14.6. – 16.6.2017

Meeting hall: CK112, Exactum, Kumpula

In general, 15 + 5 minute slots.

Tuesday 13.6.2017

- 18:00 – 20:00 Rector's Reception at Helsinki University main building (Unioninkatu 34)
    - Hosted by Professor Esko Ukkonen, Vice Dean of the Faculty of Science
    - Room: Opettajien lehtisali

Wednesday 14.6.2017

- 09:15 – 10:00 Registration at Exactum lobby
- 10:00 – 11:00 Opening session
  Chair: Annakaisa Korja (Institute of Seismology, University of Helsinki)
    - Annakaisa Korja (*ISUH*)
        - Opening and welcome
    - Kuvvet Atakan (*University of Bergen, Norway*)
        - Status of the European Plate Observing System (EPOS) and the Nordic Perspective
- 11:00 – 11:15 Coffee
- 11:15 – 12:35 Nordic Participation in seismological organizations and programs
  Chair: Björn Lund (University of Uppsala)
    - Svein Mykkeltveit (*NORSAR, Norway*)
        - A new seismic array on Bjørnøya as part of EPOS-Norway
    - Pasi Lindblom (*ISUH*)
        - FIN-EPOS project – The current status of upgrading The Finnish Seismic Network
    - Peter Voss (*GEUS*)
        - Seismology in Denmark and the connection to EPOS
    - Angelo Strollo (*GFZ, Potsdam*)
        - Nordic seismic waveform data in EPOS through the ORFEUS/EIDA infrastructure
- 12:35 – 14:00 Lunch
- 14:00 – 15:45 Nordic Countries and EPOS, with a word from funding agencies
  Chair: Svein Mykkeltveit (NORSAR)
    - Merja Särkioja (*Academy of Finland*)
        - Research infrastructure policy and governance in Finland
    - Ari Viljanen (*FMI*)
        - Finnish Meteorological Institute's contribution to EPOS
    - Elena Kozlovskaya (*Oulu Mining School, University of Oulu*)

        - Anthropogenic Hazard Thematic Core Service of EPOS: an Arctic perspective
    - Annakaisa Korja (*ISUH*)
        - EPOS WP4: Legal & Governance
    - Kuvvet Atakan (*UiB*)
        - European Plate Observing System – Norway (EPOS-N)

- 15:45 – 16:45 Poster session & coffee
    - Christian Rønnevik (*UiB*)
        - Integration of Norwegian Macroseismic Data into EPOS
    - Xiaoliang Wang (*UiB*)
        - Granularity database Web Application in EPOS
    - Martin Lidberg (*Lantmäteriet*)
        - The Improved Semi-empirical Fennoscandian Postglacial Land Uplift Model NKG2016LU
    - Elena Kozlovskaya (*OMS, UO*)
        - EPOS Thematic Core Service “ANTHROPOGENIC HAZARDS” and mine induced seismicity in European Arctic
- *19:00 Free form dinner @ Bryggeri (Sofiankatu 2)*
    - *If you are planning on participating, please, select your option from the available menu options by Monday 12.6!*
        1. Over-cooked lamb entrecôte braised in beer, cauliflower puree, new potatoes fried in goose fat and thyme sauce – 28,50€
        2. Lightly smoked salmon, grilled vegetables in sweet pepper sauce and fennel aioli – 25,50€
        3. Grilled portobello, smoked beer and barbeque sauce with seasonal vegetables salsa verde – 19,50€

    Send the selected menu option to nordics-info@helsinki.fi.
    Note: Participants are expected to pay their own meals and drinks.

Thursday 15.6.2017

- 10:00 – 11:15 EUREF, Nordic geodetic commission & Geomagnetic RIs
  Chair: Elena Kozlovskaya (OMS, UO)
    - Markku Poutanen (*FGI*)
        - United Nations expert group "Geodetic Reference Frames in Europe" and relations to EPOS
    - Martin Lidberg (*Lantmäteriet, Sweden*)
        - EPOS WP 10 – Improving the infrastructure for GNSS data and products in Europe
    - Liisa Juusola (*FMI*)
        - Geomagnetic Data and products for Solid Earth Studies

- 11:15 – 12:30 Lunch

- 12:30 – 14:15 Supercomputers, e-infrastructures and open science in Geosciences
  Chair: Kuvvet Atakan (UiB)
  - Daniele Bailo (INGV, Italy)
    - EPOS Integrated Core services
  - Damien Lecarpentier (*CSC*)
    - EUDAT & EOSC & EPOS
  - Tor Langeland (*CMR*)
    - Enlighten-web: A framework for Interactive Visual Analysis of Multidisciplinary Solid Earth Science Data
  - Aleksi J. Aalto (*ISUH*)
    - Finnish Open Science Initiative: OpenFIRE – Building a web service by integrating e-infrastructures through standard interfaces
  - Jari Reini (*FGI*)
    - Spatial data infrastructures and INSPIRE - And why do we need them?
- 14:15 Coffee break
- 15:00 – 16:30 Geological data and Nordic laboratories in EPOS
  Chair: Markku Poutanen (FGI)
  - Henning Lorenz (*Uppsala University, Sweden*)
    - WP15
    - Data from active seismic experiments
  - Satu Mertanen (*GTK*)
    - Geophysical laboratory facilities of the Geological Survey of Finland
  - Toni Veikkolainen (*Department of Physics, University of Helsinki*)
    - Advancing Precambrian paleomagnetism with PALEOMAGIA database
- 16:30 – 18:30 Open discussion on various Nordic topics in EPOS
  - *Chair: Annakaisa Korja (ISUH)*

Friday 16.6.2017

- 09:00 – 12:00 Workshop day
  - Workshop on data, data discovery and metadata practicalities in EPOS (focus on WP15 & Seismic Sounding data)
  - Elena Kozlovskaya (*OMS, UO*)
    - Data of controlled-source seismic experiments in Europe: an example of Finnish DSS profiles archive
- 12:00 Lunch

The Nordic EPOS meeting is hosted alongside with the EPOS-IT meeting (14. – 16.6.)

48th Nordic Seismology seminar
12.6. – 13.6.2017

Abstracts

Imaging the state of the rock mass in the Kiirunavaara iron ore mine, Sweden, using local event tomography

Björn Lund, Karin Berglund, Ari Tryggvason, Uppsala University
Savka Dineva, Luleå University of Technology
Linda Jonsson, LKAB

Abstract
The Kiirunavaara mine is the largest underground iron ore mine in the world. The ore body is a magnetite sheet of 4 km length, with an average thickness of 80 m, which dips approximately 55° to the east. Mining production is now at a depth of 785 – 855 m. During 2015 the seismic system in the mine recorded on average approximately 1,000 local seismic events per day. The events are of various origins such as shear slip on fractures, non-shear events and blasts, with magnitudes of up to 2.5. We use manually picked P- and S-waves from 1.2 million events in the tomography and we require that both phases are present as we found that events from the routine processing need screening for anomalous P- versus S-travel times, indicating occasional erroneous phase associations. For the tomography we use the 3D local earthquake tomography code PStomo eq (Tryggvason et al., 2002), which we adjusted to the mining scale. The study volume is 1.2 x 1.8 x 1.8 km and the velocity model grid size is 10x10x10 meter.

The tomographic images show clearly defined regions of high and low velocities. Low velocity zones are associated with mapped clay zones and areas of mined out ore, and also with the near-ore tunnel infrastructure in the foot-wall. We also see how the low S-velocity anomaly continues to depth below the current mining levels, following the inferred direction of the ore. The tomography shows higher P- and S-velocities in the foot-wall away from the areas of mine infrastructure. We relocate all 1.2 million events in the new 3D velocity model. The relocation significantly enhances the clarity of the event distribution in space and we can much more easily identify seismically active structures. One example of this is the clarity with which deformation of the ore-passes is correlated with the intensity and distribution of relocated seismic events. The relocations also show more structures in areas of the mine where rock stability is a significant problem. The large number of events makes it possible to do detailed studies of the temporal evolution of stability in the mine. We present preliminary results of time-lapse tomography in an area where a few events of magnitude 2+ occurred in September 2015.

Status and Development of Seismic Analysis at the Institute of Seismology

Jari Kortström – Institute of Seismology, University of Helsinki

In recent decades the seismic networks in Finland and neighboring countries have improved greatly. The networks are larger and denser and the instruments more sensitive than at the beginning of the 21st century. Moreover the majority of stations have real time data connections. This development has decreased the threshold magnitude and increased the number of detected seismic events. In 2000 a total of 3174 events were detected and analyzed with the average magnitude of the events being 1.6, while in 2016 the number of events was 15609 and average magnitude 1.0.

As the automatic detection and location routines have become more efficient, the daily analysis has changed from complete manual analysis of all events to checking of automatic detections: manual phase picking or location is done only for events with special interest (e.g. earthquakes).

The latest development at the Institute of Seismology has concentrated on automatic identification of seismic events at local and regional distances. An automated method based on supervised pattern recognition technique has been applied to daily analysis. Together with information about mining sites and their blasting times, over half of the recurring seismic events in Finland and adjacent areas could be detected, located and identified fully automatically with high level of confidence.

Microearthquakes and crustal stress monitoring.

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Abstract

The crustal bedrock in seimicly active areas have experienced thousands of major earthquakes during the last miljon years. A consequence is that the rock mass is very fractured and the microearthquakes show all kind of source mechanisms (fracture orientations and slip directions). The deformation of the rock mass is due to brittle slip on the fractures. A fracture will slip if the CFS exceeds 0.0 MPa in any direction on the fracture. If a microearthquake occurs we know that in only the slipping direction has the CFS-value reached zero (negative values mean stability). And, we know also, that all the other fractures in the volume have negative CFS in all directions. If the typical block size is 100 cubic meter we will have some 100 thousand such blocks within the volume of a microearthquake (fault radius 200m). All the fractures defining the blocks must have CFS<0. A reasonable assumption is that "all fracture orientations are included among the fractures". Thus, instead of the weak Bolt's criterion the much stronger Coulomb failure criterion (originally formulated for a volume with no fractures) can be used. The Coulomb criterion gives the directions of all three principal stresses plus the requirement that CFS=0 for the observed fault plane solution. This is the main key behind the QuakeLook stress method from 2006. The crust is assumed to contain water and a reasonable assumption is that the water pressure, p, is as low as possible.

A fifth restriction is achieved by putting the vertical stress equal to the lithostatic pressure (the weight of the overburdon) and the sixth restriction is achieved by minimizing the elastic deviatoric deformation energy (compare with soap bubbles, the nature avoids "overkill").

Thus, each observed microearthquake will give an estimate of the complete stress tensor (6 components) that caused the slip. As the stress tensor field within a deforming fractured crust is expected to be highly inhomogenous we normally use many microearthquakes to get a representative stress observation.

A number of examples of stress observations before larger earthquakes in Iceland will be presented. The method have also been applied to induced seismicity in mines and in geothermal areas.

Note that the method only gives the stresses that have caused microearthquakes. Nothing is known about the stresses that are not causing microearthquakes. If one wants representative stress results one need observations over longer time windows.

The most promising application is actually stress monitoring for earthquake warnings.

Status of the recent activities at the seismological service at GEUS

Peter Voss
Geological Survey of Denmark and Greenland – GEUS

This presentation will address some of the main activities undertaken at the seismological service at GEUS, since the recent Nordic Seismology Seminar. On Marts 3rd 2017 we celebrated the 90 years anniversary of first earthquake recording conducted by the seismological service in Denmark. The bulletin from the station located in Copenhagen stats that the signal was of a P Phase from an earthquake in Bolivia. Later on May 15th the University of Copenhagen celebrated our former colleague Dr Inge Lehmann with seminar and a monument outside the main university building in central Copenhagen. The New Carlsberg Foundation financed the monument. Dr Trine Dahl-Jensen presented the work of the seismological service at the seminar. Since the recent seminar the development of our seismological network have been focused on two stations. 1) The SSRD station in southern Jutland, which will be our first borehole instrument, is now closer to the sensor installation since the drilling has been conducted. But we still awaits the building of a instrument hut. 2) The EGRIP station located on the Greenland icecap, have during the winter experience extremely low temperatures, and we have just received reports from the camp that our battery package died. In connection with our involvement in the INTAROS project that was initiated ultimo 2016, we have looked into ways of connection with citizen science initiative that relate to seismology in the Arctic region. A short review on a citizen science seismic monitoring platform is presented.

Application of passive seismic interferometry for brown-field exploration in areas of active mining: problems and solutions

Elena Kozlovskaya (1,2), Nikita Afonin (3), Janne Narkilahti (4), Jouni Nevalainen (4)

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(2) Geological Survey of Finland, P.O. Box 96, FI-02151, Espoo, Finland
(3) Federal Centre for Integrated Arctic Research RAS, Arkhangelsk, Russia
(4) Sodankylä Geophysical Observatory POB 3000, FIN-90014, University of Oulu, Finland

At present, it is recognized that active source seismic experiments can be very useful in mineral exploration projects. However, application of seismic methods for brown-field exploration in the areas of active mining is problematic, because the mine itself is a source of strong seismic and acoustic noise due to the large amount of heavy machinery. This continuous noise creates a problem for high-resolution active source seismic experiments. That is why in our study we investigate the opportunity to use the ambient seismic noise in the area of active mining for the purpose of brownfield exploration. As a case study we consider the data collected at the Pyhäsalmi Mine site in central Finland. The Pyhäsalmi copper and zinc mine is one of the oldest and deepest underground mines in Europe, in which ore is excavated both from the open pit and from the depth of about 1450 m. We installed a linear array of 24 3-component DSU-SA MEMS seismic sensors with the autonomous RAUD eX data acquisition units manufactured by Sercel Ltd. along a 10 km long line crossing the mine area. and recorded 5 days of continuous seismic data with the sampling rate of 500 sps. The data were processed in several steps including single station data analysis, pre-filtering and time-domain stacking. The processed data set was used to estimate empirical Green's functions (EGFs) between pairs of stations in the frequency band of 1-100 Hz. We developed a new procedure of stacking EGFs in time-domain that makes it possible to increase significantly signal-to noise ratio and to extract not only Rayleigh, but also body waves from EGFs. Analysis of polarization and apparent velocity of extracted body waves has shown that they correspond to P- and S-waves. In addition, kinematic modelling with the use of virtual source demonstrated that reflected waves can be explained as reflections from the top of three boundaries with high acoustic impedance. Finally, we calculated surface wave dispersion curves and invert them in order to estimate the S-wave velocity structure of the shallow subsurface.

Geological context of the 2016 Võrtsjärv and the 2017 Keila earthquakes, Estonia

Heidi Soosalu[1,2], Marja Uski[3], Kari Komminaho[3]

[1]Geological Survey of Estonia; [2]Department of Geology, Tallinn University of Technology;
[3]Institute of Seismology, Department of Geosciences and Geography, University of Helsinki

The permanent seismic network of Estonia comprises only three stations. Thanks to a loan of state-of-art equipment from the Institute of Seismology, University of Helsinki, additional seismic stations at eight different sites have been operating in Estonia since 2015. With such a combined network it is possible to detect local minor earthquakes and gather quality data, giving a chance for meaningful interpretation of their mechanisms and geological context.

A magnitude-1.8 earthquake occurred in south Estonia, immediately to the east of the Võrtsjärv lake on 12 November 2016. A magnitude-1.2 earthquake took place in north Estonia, to the north of the Keila town on 22 March 2017. The depth of both events was estimated as 4 km.

The Võrtsjärv earthquake occurred within a region where historical earthquakes have been witnessed. This gives hint of an area of recurring seismicity by standards of a low-seismicity country. Several impulsive P-wave polarity observations togther with S/P phase amplitude ratios provided material for a fault plane solution. The preferred solution for the Võrtsjärv event is in line with the focal mechanism compiled for the magnitude-4.5 Osmussaar earthquake in 1976. It suggests strike-slip movement either in a left-lateral fault in the NNW direction or in a right-lateral fault in the WSW direction. The former option is favoured, as it is in concert with fault lineaments sketched in the map of crystalline basement under the few hundred metres thick sedimentary bedrock.

First P-wave arrivals of the Keila earthquake are unfortunately mostly emergent. Thus it was not possible to compile a fault plane solution for this event. However, the site of its epicenter is well constrained and geologically intriguing. The location is at the suture of two major metamorphic basement complexes, not far from a granite intrusion. The major Åland–Paldiski–Pskov Shear Zone diagonally transsecting Estonia goes through this location. The 2017 Keila earthquake is the first known event that is detected in mainland Estonia within this shear zone. One motivation for increasing the number of permanent seismic stations in Estonia is to follow whether there is seismic activity within the shear zone, which has perhaps been occurring below the detection threshold until now.

Oral

Seismic Hazard and Seismic Treatments Assessment in the Territory of Leningrad Region

Dr. Olga O. Erteleva
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It is considered that north-west regions of Russia are low-seismic ones. As the rule both St. Petersburg and the Leningrad region are referring to such regions. It is accepted also that here the maximal credible earthquake has the magnitude M = 3.5 – 4.0; the recurrence period is more than 5 000 years. At the same time the seismic effect of such event in St. Petersburg is not higher than intensity I = 3 - 4. It was established that the modern earth crust movements aren't significant and don't influence for identifying the seismic source zones (SSZ) in the region under consideration. However, in the recent years the data to re-estimate the seismic hazard and seismic treatments in this region were obtained. The applied technique for the assessment is based on use of empirical data and empirical correlation relations received on their basis for the prediction of the strong ground motions parameters. This technique was developed for the distant earthquakes for the first time. Usually in Russia at work concerning seismic hazard assessment only the earthquakes with $M > 6$ are taken into account. But even the weak local earthquakes can be dangerous in close proximity. From this point of view it is necessary to take into consideration the local background seismicity. For Leningrad area such sources have magnitude M = 4.0, the focal depth h =9.5 km, the mechanism of normal type. Then the expected seismic treatments can be estimated as follows: PGA = 88 cm/sec^2; predominant period T_0 = 0.09 sec; duration t determined as the time interval between the first and last times envelope amplitude is equal to half of the maximum one t = 1.9 sec; seismic intensity I = 6.3. Values of amplitude are compensating by high frequencies and small duration of oscillations. Joint analysis of the seismological, geological and the paleoseismological data allowed to assume that in the nearest neighborhood of St. Petersburg SSZ zones exist. The closest of them, Ladoga's, is in the northern part of Lake Ladoga and in Karelia: there were earthquakes with intensity I = 7. The expected magnitude is M = 6.5 with the recurrence period of 3 000 years and M = 6.0 with the recurrence period of 1 000 years; the depth is 15 km. Then the expected seismic treatments in St. Petersburg can be estimated as follows: PGA = 7.5 cm/sec^2; T_0 = 0.34 sec; t = 14 sec, I = 4.7. According to trenching at Gavrilovo settlement in Vyborg district it is possible to suppose the existence of one more zone SSZ with parameters: M = 7.0 with the recurrence period of 15 thousand years and the focal depth 20 km. Then the seismic effect of such earthquake St. Petersburg can make PGA = 30 cm/c^2, T_0 = 0.48 sec, t = 21 sec, I = 6.4. The seismic treatments from other zones are less.

It is also necessary to remember that seismic loads combine with the wind and other natural ones. Therefore, for some constructions as tall and super-tall buildings (for example, Lahta Building in St. Petersburg, height – 396 m) the distant earthquakes can be dangerous, because such events can generate the seismic treatments of long predominant periods close to natural periods of the buildings. For the St. Petersburg the most dangerous SSZ is the zone of Vrancha, Romania, with the parameters: the magnitude M is 8.0 with the recurrence period of 250 years; the focal depth is 150 km, the source mechanism is thrust, the epicenter distance is 1550 km. For earthquakes of this zone we obtain: PGA = 2.5 cm/sec^2, T_0 = 0.75 – 1 sec and 4 sec (Lg-wave). In spite of the small value of PGA, nevertheless, intensity is 4.5 owing to the long periods and duration of the oscillations (more than 150 sec).

Thus, the seismic hazard assessment of Leningrad region on a complex available seismological, geological and the paleoseismological data indicates higher seismicity of the region under consideration (though obtained estimates belong to very long recurrence period).

NORSAR Stations – current status

Jon Magnus Christensen and Michael Roth

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NORSAR is the Norwegian National Data Centre (NDC) and operates six stations of the International Monitoring System. These are the primary seismic arrays NOA/PS27, ARCES/PS28, the auxiliary seismic array SPITS/AS72, the auxiliary single seismic station JMIC/AS73, the infrasound array IS37 and the radionuclide station RN49. In addition, we run the NORES array, the seismic stations AKN and JETT and the seismic station TROLL in Antarctica. In total the field deployment adds up to more than 100 instrumentation sites and approximately 130 seismometers and infrasound sensors in the field. All NORSAR instrumentation is sending real-time, continuous data totaling about 280 channels.

This presentation will give an overview of NORSARs field installations and station operation. Emphasis will be on the newly revalidated ARCES array and challenges and possible upgrades of the SPITS array, especially issues regarding running an off-grid array in arctic regions.

Investigation of macroseismic data for earthquakes in Norway and Denmark

Mathilde B. Sørensen (University of Bergen, Norway) and Peter Voss (GEUS, Denmark)

Norway and Denmark are regions of low to moderate seismicity, where strong earthquakes rarely occur. For both countries, rich collections of macroseismic intensity data provide important insight into the larger historical earthquakes and allows comparing these events to more recent earthquakes for which both macroseismic and instrumental data is available. Recently, efforts have been initiated to exploit the macroseismic datasets for a better understanding of the seismicity and tectonics in these countries. In addition to presenting the available data, we will show examples of automatic drawing of isoseismals using a Kriging technique and present some initial results for macroseismic intensity attenuation and event location based on macroseismic data. We will discuss the advantages, but also some important limitations, in applying such methods in regions of low to moderate seismicity with challenges related to varying geological conditions and data coverage.

ADVANCEMENT OF THE ISC DATASETS AND SERVICES

Dmitry A. Storchak, James Harris, Domenico Di Giacomo, Konstantinos Lentas
International Seismological Centre, United Kingdom, dmitry@isc.ac.uk

The International Seismological Centre (ISC) is a non-governmental organization based in UK and funded by 64 research and operational institutions in 48 countries, including the Institute of Seismology of the University of Helsinki and several other organizations in Nordic countries.

The ISC produces the global definitive Bulletin of earthquakes and other seismic events based on reports from over 130 seismic networks worldwide. The ISC Bulletin remains the most long-term and comprehensive source of information covering the period from 1904 to 2017. We are currently rebuilding the Bulletin to improve the locations and magnitudes and insert previously missing bulletin data from permanent networks and temporary deployments. The results of this work for the 1960s and the 1970s will soon be made available to ISC users.

We also maintain and distribute several derivative datasets and services designed for specific applications:

* The ISC-EHB bulletin - a groomed subset of the ISC Bulletin containing well-recorded teleseismic events; it is widely used in studies of seismicity and structure of the Earth.
* The IASPEI Reference Event List (GT) Ð a bulletin of events for which the hypocentral information is known with high confidence (to 10km or better); used for a variety of calibration purposes, especially in nuclear monitoring studies.
* The ISC-GEM catalogue Ð the most homogeneous and complete record of large instrumentally recorded earthquakes over the 110-year period; designed for use in global and regional assessment of seismic hazard.
* The ISC Event Bibliography - an interactive facility that enables searches for references to scientific articles devoted to specific natural and anthropogenic seismic events that occurred within a region and time period of interest; widely used in education and by scientific article authors, reviewers and journal editors.
* The CTBTO Link to the ISC database Ð an interactive web service that presents long-term data of academic seismic networks in the way relevant to the nuclear monitoring community.

Here we describe the advances recently made to extend and improve these datasets that are widely used in different fields of geophysical research.

Status of implementation of the verification regime for the Comprehensive Nuclear-Test-Ban Treaty (CTBT)

Svein Mykkeltveit, NORSAR

The CTBT, which bans nuclear weapon test explosions and any other nuclear explosions, was adopted by the United Nations and opened for signature in 1996. The build-up of the CTBT verification regime, funded and organized by the Preparatory Commission for the CTBT Organization and its secretariat based in Vienna, Austria, is nearing completion. As of June 2017, 288 of the 321 globally distributed stations of the International Monitoring System (IMS) have been installed, and 17 stations are currently under construction. Almost all of the stations installed are providing data to the International Data Center (IDC), which produces an analyst reviewed bulletin containing on average 100 events per day, based on processing of seismic, infrasound and hydroacoustic data. The IDC also issues daily reports on the results of analysis of spectra from radionuclide monitoring stations. The arrangements for on-site inspections (OSI) to clarify concerns related to 'suspicious events' detected by the IMS/IDC system, have also reached a mature stage. A large OSI field exercise in Jordan in late 2014 provided results that are being used to further develop the OSI component of the CTBT verification regime.

The presentation will provide an overall assessment of the status of implementation of the CTBT verification regime. The emphasis will be on current work and challenges to complete the verification regime in a timely manner, as well as on technical and other factors affecting progress of remaining work. The role of Working Group B, which is the forum for Member States to exercise its policy and oversight functions for verification related tasks, will be underlined.

HOW TO MEASURE DURATION OF SEISMIC VIBRATION

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Development of earthquake-resistant design techniques begins with the selection of a basic description of seismic ground motion. As dictated by the principles of dimensional analysis, the motion of any mechanical system is determined by three independent dimensions: distance, time, and mass (or force). Therefore, the variables that describe the seismic ground motion must include all of these fundamental dimensions. This leads to some general criteria of process parameterization:

1 - ***parameters should reflect the main features of a studied process and must be relevant from the earthquake engineering point of view;***

2 - ***parameters should be mutually independent, in the sense that changes in one of the parameters should not cause significant alteration of other parameters.***

The concept "oscillation duration" is determined in different ways and can have different physical meanings or even at all not to have any sense.

In the Russian Building Code the following definition is given:

a) ***Duration is an interval of time during which the level of seismic oscillation for 5% exceeds background level.***

It is clear that such definition is applicable for seismic prospecting, but it doesn't suit for the description of strong ground motion. Here violation of the first parametrization rule: microseisms don't affect the damage of structures, but their level can change several times the weather conditions.

In some IAEA standards and USA building codes the following definitions of duration have been proposed:

b) The end of a record was considered a moment when the oscillation amplitudes decrease to some fixed threshold A_{thr} ("bracketed duration τ_b"). Here violation of the first parametrization rule: the value τ_b was called and appeared to be functionally correlated with an oscillation level. A substantial drawback of this definition of duration is the fact that it cannot be applied to oscillations with amplitudes lower than the threshold, thus making it impossible to compare durations of small and large ground motions.

c) Duration $\Delta t = t_2 - t_1$ can be defined as a time interval during which a value

$$F(t) = \int_{t_1}^{t_2} A^2 dt \Big/ \int_0^{\infty} A^2 dt$$

increases from $F(t_1) = 0.05$ up to $F(t_2) = 0.95$. Some researchers use other thresholds, but that does not change the meaning of this definition. Such duration has a negative correlation with seismic intensity. This is explained by noting that according such definition duration is a measure of accumulation time for the fixed energy. The greater the value of Δt the more inert is the process that takes place and the lower is the seismic intensity.

d) The duration τ (pulse width) is determined as the time interval between the first and last times its envelope amplitude is equal to half of the maximum one.

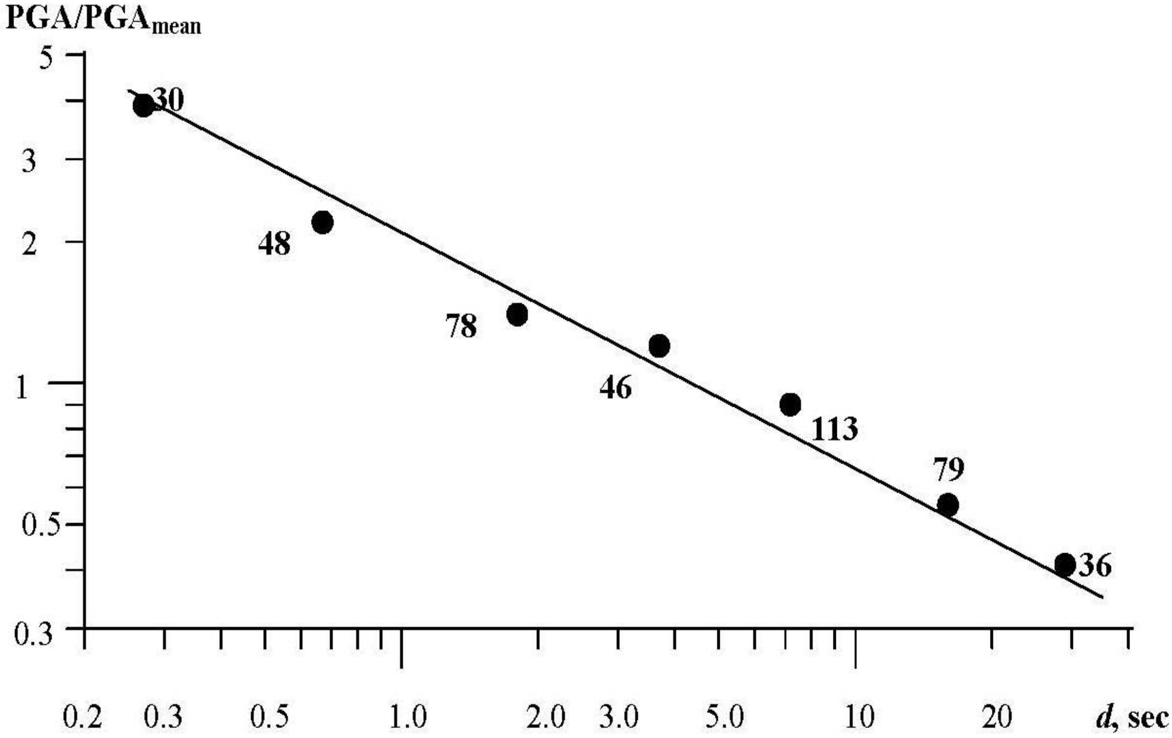
This definition is corresponds to the both parameterization rules. Empirically, it can be shown that the parameter τ causes noticeable effects on seismic intensity I and the degree of damage:

$$\mathbf{I = 2.5 \lg A, cm/s^2 + 1.25 \lg \tau, sec + 1.05.}$$

Pulse width τ may be used as the parameter of amplitude envelope $A_{env}(t)$ and ***the oscillation envelope*** may be described by an empirical formula:

$$A_{env} = A_{max} \frac{3t\tau}{9t^2 - 9t\tau + 4\tau^2},$$ where t is the current time.

As a rule, authors do not specify what definition they use. For example in Eurocode.



Relation PGA – *d* for fixed seismic intensity.
The number of records used is shown on the graph

Reflection seismic modeling and imaging for mineral exploration in the Kylylahti Cu-Au-Zn mine, eastern Finland

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The exploration of mineral resources in hardrock environments poses various challenges to geophysical prospecting methods. The problems are rooted in the predominant geological complexity. To tackle these challenges, the COGITO-MIN (COst-effective Geophyscial Imaging Techniques for supporting Ongoing MINeral exploration in Europe) project aims at the development and testing of new imaging workflows that could improve the identification of reliable drilling targets, with a particular emphasis on reflection seismic methods. The project partners include academic and industrial institutions from Finland (University of Helsinki – project coordinator, Geological Survey of Finland, Boliden FinnEx and Vibrometric) and Poland (Institute of Geophysics, Polish Academy of Sciences and Geopartner). Within the presented work, we focus on VSP (Vertical Seismic Profiling) measurements that were conducted as a part of the extensive COGITO-MIN seismic survey campaign at the Kylylahti Cu-Au-Zn mine site in eastern Finland in fall 2016. The survey included passive and active-source surface seismic data as well as underground VSP measurements. The latter were acquired directly in the Kylylahti mine in close vicinity of a known semi-massive to massive sulphide ore deposit. Hence, they offer the highest resolution and are the most promising method for delineating the known deposit and potential new resources in its vicinity.

In this survey, two different VSP acquisition systems were utilized. First, we deployed a conventional three-component geophone chain in four boreholes. In addition to that, a fiber-optic Distributed Acoustic Sensing (DAS) cable was installed in one of these boreholes. The DAS technology offers efficient data acquisition combined with high spatial resolution, making it a very attractive method for mining exploration. The recorded data of both systems exhibit good quality but their processing and direct interpretation is complicated due to the geological complexity of the area and the directional ambiguity of the VSP method.

To support the processing and interpretation efforts, we conducted a synthetic experiment, utilizing elastic full-waveform seismic modeling, based on a very detailed three-dimensional geological model. As a result, we obtain a realistic synthetic dataset, which is directly comparable to the acquired VSP data. This provides us with a better understanding of in-mine seismic wave propagation and enables us to link the recorded signals to their geological causes. Subsequently, the synthetic data were processed and imaged alongside the acquired data. Comparing the imaging results, we have identified and validated the reflections from known geological structures as well as reflection signals that are not explained by the current geological model. These might include potential new targets.

A useful tool to identify recurring blasts in seismic event bulletins

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A method has been designed to identify recurring blasts in fully automatic event classification process. It exploits weekly and diurnal distribution of seismic events to determine a blasting time window typical for the source area. Automatically classified non-earthquakes falling within the time-space window are likely recurring blasts and need no further analysis. The method can also be applied to earthquake catalogs to reveal signs of anthropogenic contamination in the data.

In this poster, the capabilities of the algorithm are demonstrated by showing examples from four active blasting sites in northern Europe. The event data are extracted from manually reviewed seismic event bulletins provided by the Institute of Seismology, University of Helsinki.

Online Earthquakes

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Institute of Seismology, University of Helsinki, provides several online earthquake maps.

EQ-Search Tool (http://www.seismo.helsinki.fi/EQs/query.php) is an online map service which allows the user to search for earthquakes within the North European earthquake catalogue (FENCAT). Data in the catalogue is further supplemented with more recent events found by seismic analysts during the daily processing of seismic events.

ISUH also provides a global map of significant earthquakes from a Finnish perspective in the past 7 days. The map, LUOVA-järistyskartta (http://www.seismo.helsinki.fi/EQs/jaristyskartta.php), is based on LUOVA-system, which is an official natural hazard alert program in Finland. Currently this map is available only in Finnish.

2nd Nordic EPOS meeting
14.6. – 16.6.2017

Abstracts

Status of the European Plate Observing System (EPOS) and the Nordic Perspective

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The *European Plate Observing System* (EPOS) aims to create a pan-European infrastructure for solid Earth science to support a safe and sustainable society. Following a four-year Preparatory Phase (EPOS-PP), EPOS is now in its Implementation Phase (EPOS-IP - 2015-2019 – www.epos-eu.org - EU Horison2020 – InfraDev Programme – Project no. 676564). The main vision of the European Plate Observing System (EPOS) is to address the three basic challenges in Earth Science: (i) unravelling the Earth's deformational processes which are part of the Earth system evolution in time, (ii) understanding geo-hazards and their implications to society, and (iii) contributing to the safe and sustainable use of geo-resources. The mission of EPOS is to monitor and understand the dynamic and complex Earth system by relying on new e-science opportunities and integrating diverse and advanced Research Infrastructures for solid Earth science. There are 10 Thematic Core Services (TCS) that cover a broad spectrum of Earth sciences which will provide European-level data, data-products, software and services combining the underlying National-level Research Infrastructures (NRI), into a single integrated system in EPOS, the so-called “Integrated Core Services” (EPOS-ICS).

Following a formal selection process, Institute of Geophysics and Volcanology (INGV) of Italy was given the responsibility of hosting the EPOS-ERIC (European Research Infrastructure Consortium) as a European-level legal organisational entity situated in Rome. The formal application for the establishment of EPOS-ERIC is now submitted to the European Commission and the EPOS-ERIC Central Office (ECO) is expected to be operational in the second half of 2018. During the last Board of Governmental Representatives (BGR) meeting held in Warsaw Poland, in February 2017, 18 countries in Europe have agreed to sign the EPOS-ERIC membership including Norway, Finland, Iceland and Denmark as founding members. Statutes for EPOS-ERIC are also approved by the BGR in the same meeting. Membership fees for EPOS-ERIC will be based on a combination of a flat-rate (50%) and a variable-rate (50%) based on GDP and the total membership fee will vary between 50 kEUR (minimum) and 200 kEUR (maximum) per country. BGR has also established an advisory body, the Board of National Scientific Representatives (BNSR), where individual scientists appointed by the relevant ministries in each country, meet regularly to provide recommendations to BGR.

Hosting of the Integrated Core Services (ICS) for EPOS e-Infrastructure is also decided, following a formal selection process, where a consortium of three institutions consisting of the three Geological Surveys in UK (BGS), France (BRGM) and Denmark (GEUS) has won the competition and will take the responsibility of hosting EPOS-ICS after the Implementation Phase (EPOS-IP) is finished, when EPOS enters its Operational Phase (EPOS-OP) in 2020.

Currently, a comprehensive list of standardised data, data products, software and services (DDSS) that were provided by the TCS communities, is being implemented into a common metadata structure. These elements will be integrated in the EPOS-ICS data/web-portal, which will allow users to browse, select and download relevant data for solid Earth science research and through a virtual research environment (VRE) provide processing, analysis and advanced visualisation capabilities. A prototype of the EPOS-ICS was developed and demonstrated to the EPOS community in Prague in 2016 and a complete version with limited functionalities will be available for validation by October 2017. The final version of the EPOS-ICS with additional VRE functionalities allowing the users to connect to external resources (HPC/HTC computations, data storage, visualisation etc.), is expected to be delivered by the end of EPOS-IP project in 2019.

Oral Presentation in the Nordic-EPOS-Conference-2017, Helsinki Finland

A new seismic array on Bjørnøya as part of EPOS-Norway

Svein Mykkeltveit, NORSAR

NORSAR is, through its participation in the EPOS-Norway project, preparing for the installation of a new seismic array station on Bjørnøya (Bear Island), which is located in the Barents Sea half way between mainland Norway and Spitsbergen. Seismic stations on Bjørnøya close a large gap for monitoring seismic events on the western Barents Sea shelf, Mohn's Ridge and the Knipovich Ridge, as well as the main Barents Sea region to the east of Bjørnøya. A temporary seismic array was deployed on Bjørnøya during the summer of 2008. The temporary array showed significantly improved event detection capability in comparison with that of the permanent three-component station, which is located on the northern tip of the island. A number of additional earthquakes could be detected and located in the surrounding region. A nine-element seismic array on Bjørnøya will be essential for a number of research areas. In this presentation we provide an overview of the planning work for this array, as it has progressed during 2016 and so far in 2017.

European Plate Observing System – Norway (EPOS-N)

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The *European Plate Observing System* (EPOS) aims to create a pan-European infrastructure for solid Earth science to support a safe and sustainable society. EPOS is in its Implementation Phase (EPOS-IP – EU Horison2020 – InfraDev Programme – Project no. 676564). The main vision of the European Plate Observing System (EPOS) is to address the three basic challenges in Earth Science: (i) unravelling the Earth's deformational processes which are part of the Earth system evolution in time, (ii) understanding geo-hazards and their implications to society, and (iii) contributing to the safe and sustainable use of geo-resources. The mission of EPOS-Norway (RCN-Infrastructure Programme - Project no. 245763) is therefore in line with the European vision of EPOS, i.e. monitor and understand the dynamic and complex Earth system by relying on new e-science opportunities and integrating diverse and advanced Research Infrastructures for solid Earth science.

The EPOS-Norway project started in January 2016 with a national consortium consisting of six institutions. These are: University of Bergen (Coordinator), NORSAR, National Mapping Authority, Geological Survey of Norway, Christian Michelsen Research and University of Oslo. EPOS-N will during the next five years focus on the implementation of three main components. These are: (i) Developing a Norwegian e-Infrastructure to integrate the Norwegian Solid Earth data from the seismological and geodetic networks, as well as the data from the geological and geophysical data repositories, (ii) Improving the monitoring capacity in the Arctic, including Northern Norway and the Arctic islands, and (iii) Establishing a national Solid Earth Science Forum providing a constant feedback mechanism for improved integration of multidisciplinary data, as well as training of young scientists for future utilization of all available solid Earth observational data through a single e-infrastructure.

Currently, a list of data, data products, software and services (DDSS) is being prepared. These elements will be integrated in the EPOS-N data/web-portal, which will allow users to browse, select and download relevant data for solid Earth science research. In addition to the standard data and data products such as seismological, geodetic, geomagnetic and geological data, there are a number of non-standard data and data products that will be integrated. In parallel, advanced visualization technologies are being implemented, which will provide a platform for a possible future ICS-D (distributed components of the Integrated Core Services) for EPOS.

In order to enhance the monitoring capacity in the Arctic, planning and site selection process for the new instrument installations are well underway, as well as the procurement of the required equipment. In total, 17 new seismological and geodetic stations will be co-located in selected sites in Northern Norway, Jan Mayen and Svalbard. In addition, a seismic array with 9 nodes will be installed on Bear Island. A planned aeromagnetic survey along the Knipovich Ridge is being conducted this year, which will give new insights to the tectonic development of the mid-ocean ridge systems in the North Atlantic.

Oral Presentation in the Nordic-EPOS-Conference-2017, Helsinki Finland

Integration of Norwegian Macroseismic Data into EPOS

Christian Rønnevik (Christian.Ronnevik@uib.no)

Integration of the Norwegian Macroseismic data to the new European Archive of Historical Earthquake Data (AHEAD), is conducted within the framework of the European Plate Observing System (EPOS) Implementation Phase Project (EPOS-IP – EU-Horison2020, InfraDev, Project.no. 676564) and linked to the national integration of Norwegian data to the National EPOS project, EPOS-Norway (EPOS-N – RCN Infrastructure Programme Project No. 245763). The archive grants all users free access to the datasets of European and Mediterranean historical earthquakes. A fundamental component of these datasets is macroseismic intensity data, which describe intensity evaluations reported by individuals at several places. Such information is normally stored locally within different institutions. To share these data with a broader scientific community, the AHEAD team has developed a tool called Macroseismic Intensity Data Online Publisher (MIDOP). It comprises a PHP environment combined with a MySQL database that generates a lightweight web application with interactive maps.

At UoB, macroseismic intensity data are stored within SEISAN, which is a seismic analytic system with a set of programs for analysing earthquakes. These data have been extracted and implemented into the MIDOP tool. Additionally, historical records on paper are currently being reviewed and continuously added. The macroseismic data are presented through a graphical interface and are available at the webpage, http://nnsn.geo.uib.no/midop/. Users have the opportunity to query macroseismic data from either earthquakes or by place names. In the Query by earthquakes section (Fig.1), only earthquakes with corresponding macroseismic intensity data sets are presented. These data are accessible by browsing a list of earthquakes given, sorted after occurrence. Macroseismic intensity data points, together with the location of the epicentre, are visualized on a map with colours that represent their intensities. A list of each data point is also presented in a table. Data can be exported as QuakeML or as an Excel spreadsheet file.

In the query by place section (Fig. 2), the user can choose between a long list of place names, which are organized in capitalised groups. Selection of places present the users with a seismic history of the area. The historic presentation includes a list of earthquakes within the area, along with diagram that plots intensities with time. A map is also included to display the nearby places. The user can export these data as a Excel spreadsheet file.

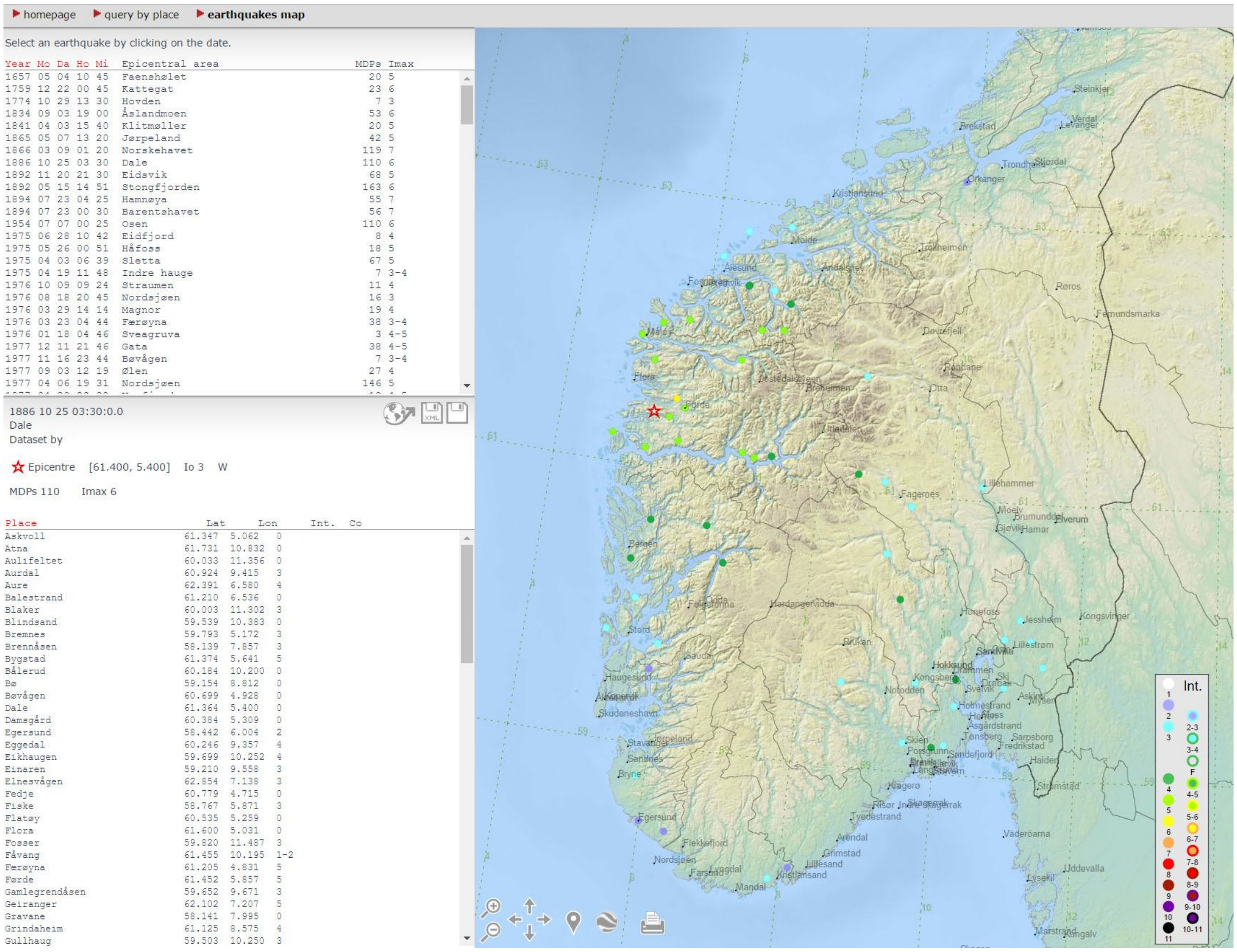

Fig. 1 – Graphical interface for the query. The interface depicts the macroseismic data for the earthquake in 1886 with an epicentral earea in Dale.

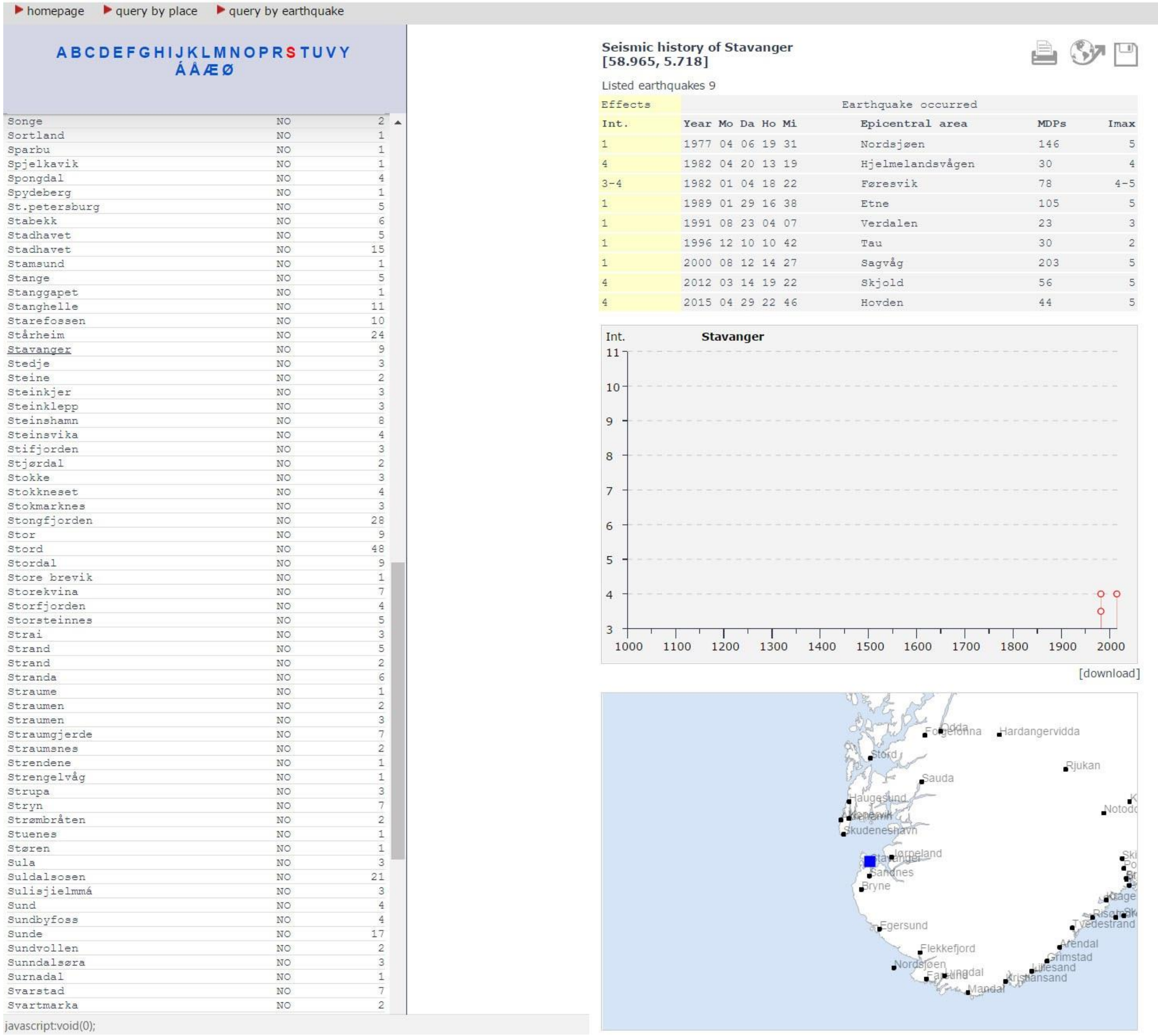

Fig. 2 – Graphical interface for the query by place section. The interface depicts a seismic history of a chosen place name, which in this example is Stavanger.

Granularity database Web Application in EPOS

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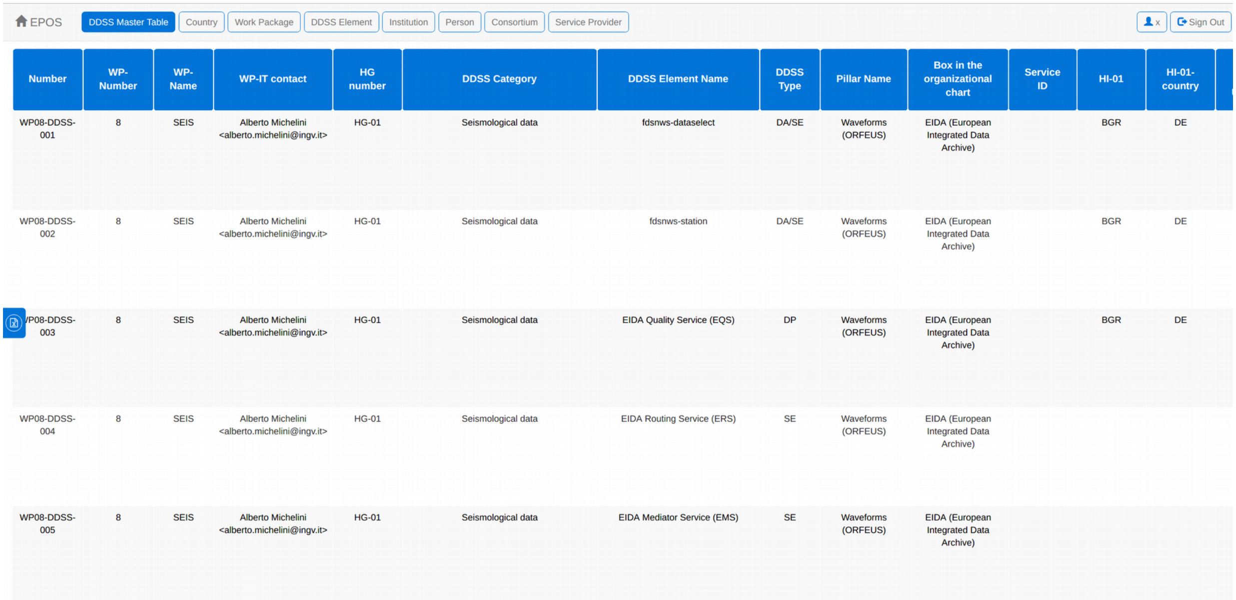
Granularity database Web Application is conducted within the framework of the European Plate Observing System (EPOS) Implementation Phase Project (EPOS-IP – EU-Horison2020, InfraDev, Project.no. 676564) and linked to the national integration of Norwegian data to the National EPOS project, EPOS-Norway (EPOS-N – RCN Infrastructure Programme Project No. 245763).

In EPOS, many Thematic Core Services (TCS) shall provide various services and data while hundreds of people and organizations will participate the development of EPOS. It will be complicate to organize information such as which TCS provides what data or service, who and which organization is related to a certain data or service. In order to systematically manage such information in an efficient way, we develop a web application, called granularity database (GDB). The front page is shown in Figure 1. With the web application, persons from TCSs can view and update their information.



Number	WP-Number	WP-Name	WP-IT contact	HG number	DDSS Category	DDSS Element Name	DDSS Type	Pillar Name	Box in the organizational chart	Service ID	HI-01	HI-01-country
WP08-DDSS-001	8	SEIS	Alberto Michelini <alberto.michelini@ingv.it>	HG-01	Seismological data	fdsnws-dataselect	DA/SE	Waveforms (ORFEUS)	EIDA (European Integrated Data Archive)		BGR	DE
WP08-DDSS-002	8	SEIS	Alberto Michelini <alberto.michelini@ingv.it>	HG-01	Seismological data	fdsnws-station	DA/SE	Waveforms (ORFEUS)	EIDA (European Integrated Data Archive)		BGR	DE
/P08-DDSS-003	8	SEIS	Alberto Michelini <alberto.michelini@ingv.it>	HG-01	Seismological data	EIDA Quality Service (EQS)	DP	Waveforms (ORFEUS)	EIDA (European Integrated Data Archive)		BGR	DE
WP08-DDSS-004	8	SEIS	Alberto Michelini <alberto.michelini@ingv.it>	HG-01	Seismological data	EIDA Routing Service (ERS)	SE	Waveforms (ORFEUS)	EIDA (European Integrated Data Archive)			
WP08-DDSS-005	8	SEIS	Alberto Michelini <alberto.michelini@ingv.it>	HG-01	Seismological data	EIDA Mediator Service (EMS)	SE	Waveforms (ORFEUS)	EIDA (European Integrated Data Archive)			

Figure 1: Granularity Database (GDB)

The front page gives an overview about all the data, data product, software and services (DDSS) elements. In addition, users can also view and/or update information about entities such as Country, Work Package, DDSS Element, Institution, Person, Consortium and Service Providers by clicking corresponding buttons on the top of the front page. Each entity contains a list of items. On the page of each entity, the following functions are optionally available:

- view the related information of the items
- update the information of an item
- add more items
- load and update the information of items from an Excel file
- view the statistics of the entity

It should be noticed that, the web application is designed to be used by some authorized users in each TCS to manager their information respectively, therefore, to ensure the information security.

The improved semi-empirical Fennoscandian postglacial land uplift model NKG2016LU

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NKG2016LU is a semi-empirical land uplift model computed in Nordic-Baltic cooperation in the Nordic Geodetic Commission (NKG) Working Group of Geoid and Height Systems. The model gives the vertical land uplift rate in two different ways: (1) NKG2016LU_abs with the absolute land uplift in ITRF2008 (i.e. relative to the Earth's center of mass), and (2) NKG2016LU_lev with the levelled land uplift, i.e. uplift relative to the geoid.

NKG2016LU has been computed using a remove-compute-restore technique based on (1) an empirical land uplift model derived from geodetic observations and (2) a geophysical GIA model called NKG2016GIA_prel0306. The empirical model has been computed from uplift results of Global Navigation Satellite System (GNSS) time series from the Baseline Inferences for Fennoscandian Rebound Observations, Sea-level and Tectonics (BIFROST) and levelling data. Compared to the previous model NKG2005LU, no tide gauge information was used. The geophysical model is based on a spherically symmetric (1D), compressible, Maxwell-viscoelastic earth model applying the viscoelastic normal-mode method. Ice history information is taken from Glaciological Systems Model (GSM) results, a set of 25 different 3D thermo-mechanically coupled glaciological models calibrated against ice margin information, present-day uplift, and relative sea-level records. The best-fitting geophysical Earth model to both the BIFROST uplift and Fennoscandian relative sea-level histories simultaneously has a 160 km thick lithosphere, a viscosity of 7×10^{20} Pa s in the upper mantle, and of 7×10^{22} Pa s in the lower mantle.

No apparent model (i.e. uplift relative to Mean Sea Level over a certain time period) is released for the time being. This is mainly motivated by the (accelerating) contemporary climate-related sea level rise, which implies that the apparent land uplift is different from the levelled land uplift and dependent on the chosen time interval.

Our presentation will introduce the model and its computation as well as discuss the problematic issue of handling tide gauge information. We will present climate-related sea-level changes by comparing NKG2016LU_lev with apparent uplift in tide gauges for a number of selected time periods. In the perspective of EPOS, we think this is a good example of what we can achieve by combining different observations and skills between different groups and countries.

Keywords: Land uplift model, GIA model, sea level rise, reference frames

EPOS Thematic Core Service “ANTHROPOGENIC HAZARDS” and mine induced seismicity in European Arctic (poster)

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The Thematic Core Service “Anthropogenic Hazards” (TCS AH) integrates data and provides various data services in a form of complete e-research infrastructure for advanced analysis and geophysical modelling of anthropogenic hazard due to georesources exploitation. TCS AH is based on the prototype built in the framework of the IS-EPOS project POIG.02.03.00-14-090/13-00 (https://tcs.ah-epos.eu/). The TCS AH is currently being further developed within EPOS Implementation phase (H2020-INFRADEV-1-2015-1, INFRADEV-3-2015). The TCS AH aims to have a measurable impact on innovative research and development by providing a comprehensive, wide-scale and high quality research infrastructure available to the scientific community, industrial partners and public.

One of the main deliverable of TCS AH is the access to numerous induced seismicity datasets called “episodes”. The episode is defined as a comprehensive set of data describing the geophysical process induced or triggered by technological activity, which under certain circumstances can become hazardous for people, infrastructure and the environment. The episode is a time-correlated, standardized collection of geophysical, technological and other relevant geodata forming complete documentation of seismogenic process. The currently integrated episodes into the TCS AH are related to conventional hydrocarbon extraction, reservoir treatment, underground mining and geothermal energy production. The heterogeneous multi-disciplinary data from different episodes are subjected to an extensive quality control (QC) procedure composed of five steps and involving the collaborative work of data providers, quality control team, IT team, and control manager.

Investigating mining induced seismicity and integrating correspondent induced seismicity episodes into EPOS TCS AH is particularly relevant for the European Arctic that has a great mineral resource potential. In this area exploration and mining is not only an important, but also a rapidly growing industry. The Arctic areas of Sweden and Finland have a long withstanding tradition in exploration and mining and in investigating induced seismicity in hard rock mines. We present one of mine induced seismicity episodes in TCS AH database related to the Pyhäsalmi mine in Finland that is the deepest copper mine in Europe. The Pyhäsalmi Episode includes seismic waveform data from Pyhäsalmi microseismic network and relevant geological, geophysical and technological data. Data from Swedish mines possibly will be added at a later stage of the project.

Services to be implemented are grouped within six blocks: (1) Basic services for data integration and handling; (2) Services for physical models of stress/strain changes over time and space as driven by geo-resource production; (3) Services for analysing geophysical signals; (4) Services to extract the relation between technological operations and observed induced seismic/deformation; (5) Services to quantitative probabilistic assessments of anthropogenic seismic hazard - statistical properties of anthropogenic seismic series and their dependence on time-varying anthropogenesis; ground motion prediction equations; stationary and time-dependent probabilistic seismic hazard estimates, related to time-changeable technological factors inducing the seismic process; (6) Simulator for Multi-hazard/multi-risk assessment in ExploRation/exploitation of GEoResources (MERGER) - numerical estimate of the occurrence probability of chains of events or processes impacting the environment. TCS AH will also serve the public sector expert knowledge and background information. In order to fulfill this aim the services for outreach, dissemination & communication will be implemented.

EPOS WP 10 – Improving the infrastructure for GNSS data and products in Europe

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EPOS-IP WP10 – "GNSS Data & Products" is the Working Package 10 of the European Plate Observing System – Implementation Phase project in charge of implementing services for the geo-sciences community to access existing Pan-European Geodetic Infrastructures. WP10 is currently formed by representatives of participating European institutions but in the operational phase contributions will be solicited from the entire geodetic community. In fact, WP10 also includes members from other institutions/countries that formally are not participating in the EPOS-IP but will be key players in the future services to be provided by EPOS. Additionally, several partners are also key partners at EUREF, which is also actively collaborating with EPOS.

The geodetic component of EPOS is dealing essentially with implementing an e-infrastructure to store and disseminate the continuous GNSS data from existing Research Infrastructures. Present efforts are on developing geodetic tools to support Solid Earth research by optimizing the existing resources. However, other research and technical applications (e.g., reference frames, meteorology, space weather) can also benefit in the future from the optimization of the geodetic resources in Europe.

We present and discuss the status of the implementation of the thematic and core services (TCS) for GNSS data within EPOS and the related business plan. We explain the tools and web-services being developed towards the implementation of the best solutions that will permit to the end-users, and in particular geo-scientists, to access the geodetic data, derived solutions, and associated metadata using a transparent and standarised processes.

Geomagnetic data and products for solid earth studies

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The IMAGE magnetometer network consist of 35 stations in Northern Europe, maintained as international collaboration. The main objective of IMAGE is to monitor the rapidly varying geomagnetic disturbances associated with auroras and space weather events. The disturbance magnetic field is mainly associated with electric currents in the ionosphere at 100 km altitude, powered by solar wind energy. However, telluric currents induced in the conducting ground by the time-varying ionospheric currents give a significant contribution as well.

IMAGE covers the geographic area of 54-79 deg latitude and 5-35 deg longitude. Under nominal solar wind condition, geomagnetic disturbances in the IMAGE area tend to be confined to the latitudes of Lapland (65-72 deg). However, under enhanced driving conditions, the disturbances intensify and extend southward, and under weak driving, they weaken and retreat northward. Thus, the long latitude profile of IMAGE makes it particularly suitable for monitoring the location and intensity of the geomagnetic disturbances under various solar wind conditions.

Together with its predecessor, the EISCAT magnetometer cross (1982-1991), IMAGE (1991-) provides high-quality data useful for studies of magnetosphere-ionosphere physics, geomagnetic induction, and long-term geomagnetic activity in the auroral region. IMAGE can supplement other measurements, including magnetotellurics, geomagnetic depth sounding, and campaign-based networks such as the Baltic Electromagnetic Array Research in 1998.

Archived IMAGE data are freely available for scientific use (space.fmi.fi/image), as well as real-time data from a subset of the stations. Apart from a few geomagnetic observatories, the majority of the instruments are variometers that provide relative vector magnetic field data at a 10 s cadence. The baseline is arbitrary, and thus, quiet time curves need to be subtracted from the data in order to extract the disturbance magnetic field.

For EPOS, especially useful data products include an activity indicator (IE) that provides a measure of the strength of the geomagnetic disturbances in the area. It can be used to exclude geomagnetically disturbed intervals from studies that require quiet conditions. Instantaneous latitude-longitude maps of the ionospheric (equivalent) currents and induced telluric (equivalent) currents are derived by separating the disturbance magnetic field into internal and external parts. While the external ionospheric currents are associated with magnetosphere-ionosphere physics, the internal induced currents can provide information on the subsurface electrical conductivity.

Enlighten-web: A framework for Interactive Visual Analysis of Multidisciplinary Solid Earth Science Data

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Introduction

The EPOS-Norway project concerns the Norwegian implementation of EPOS. The project has three main components:

- Component-1: Develop a Norwegian EPOS e-infrastructure.
- Component-2: Improve the monitoring capacity in the Arctic.
- Component-3: Establish a Solid Earth Science Forum.

The aim of the Norwegian EPOS e-infrastructure is to integrate data from the seismological and geodetic networks, as well as the data from the geological and geophysical data repositories. In this abstract, we will present ongoing work on developing a tool for interactive visual analysis that will constitute an important part of the Norwegian EPOS e-infrastructure.

The visualization tool under development in EPOS-Norway is based on Enlighten-web, a platform for Interactive Visual Analysis developed by CMR. Enlighten-web is designed for effective visualization of multidisciplinary solid Earth science data and data products. It will enable explorative visualization, e.g. for extracting trends and outliers in the data. It will also enable confirmative visualization for analysis of hypotheses. Moreover, it can be used for visualization for communication of research results to e.g. research peers, decision makers and the public.

The design and planned deployment of Enlighten-web fits with the concept of Virtual Research Environments (VRE). A VRE can be described as an online system facilitating collaboration among researchers. The implementation of a VRE typically involves Cloud Services such as high-performance and high-throughput computing, data storage, visualization and other services.

It is our ambition to make Enlighten–web available not only as part of the Norwegian e-infrastructure, but also as part of the overall European EPOS e-infrastructure. Briefly, the ICS-C (Central Integrated Core Services) is the entry point for users for accessing the e-Infrastructure under establishment in the EPOS IP (Implementation Phase) project. ICS-C includes a metadata catalog describing EPOS assets and software, and it will let users create and manage workflows. The workflows will usually include accessing data and services located in the EPOS Thematic Core Services (TCS). The ICS-C and TCSs will be extended with additional computing facilities through the ICS-D (Distributed Integrated Core Services) concept. Visualization is one of the candidates for ICS-D developments. We aim at suggesting Enlighten-web as an ICS-D for visualization. It will thus be a Norwegian in-kind contribution to EPOS.

VRE concept used in the EPOS-Norway project

The VRE established in the EPOS-Norway project will be available as cloud services. (We also plan to make parts of the software available for download for running locally on the user's computer. In this abstract, we describe the solution where the software is accessed on a server in the cloud.)

Figure 1 shows the system architecture. A JupyterHub is a multi-user Jupyter Notebook environment [1]. Users logs on using the JupyterHub front-end running on a cloud server. The Jupyter Hub front-end creates a virtual machine (VM) for each user. A Jupyter Notebook Server is started on this VM. The user is forwarded to this server in a web-browser session where she can create and share notebooks.

A notebook is a document that can contain code, visualizations and explanatory text. An Enlighten-web server can be started for each notebook.

The resources available to the user in the notebook can be determined when the user logs in to the Jupyter Hub through an Authentication Authorization, and Accounting (AAA) process. Limitations can e.g. be imposed by either available hardware or by billing limitations asserted by the user.

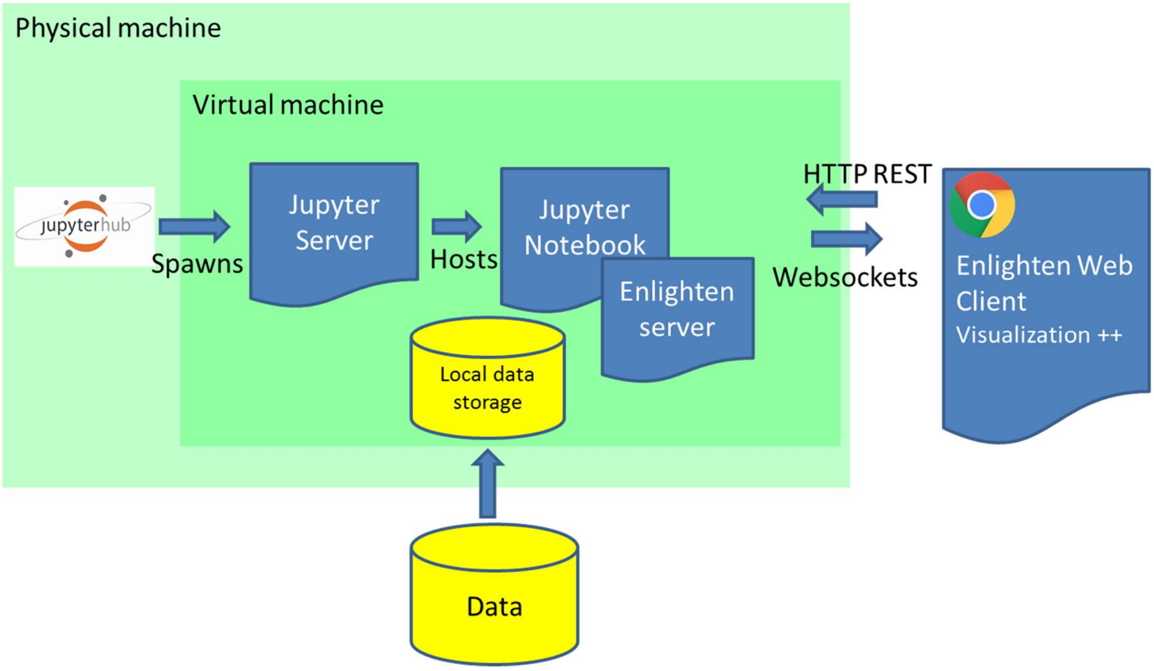

Figure 1. System architecture for VRE established in the EPOS Norway project.

Jupyter Notebook for collecting and preparing data for visualization

The Jupyter Notebook provides a dynamic programming interface where the user can load data using external APIs into the provided file-system/memory for further analysis, computation and visualization. It gives the user access to files, development and execution of arbitrary code and applications. The Jupyter notebook technology supports 40 different programming languages including those popular in science such as Python, R, Julia, FORTRAN and Scala.

Figure 2 to Figure 5 show extracts from a notebook accessing seismic networks using the ObsPy [2] framework. ObsPy is an open source Python framework for working with seismological data. The notebook has the following main elements:

- In Figure 2, the FSDN Web service client is imported from ObsPy. Then we import URL mappings and list all available EIDA nodes with corresponding URLs.
- In Figure 3, we create ObsPy clients for Orfeus and GFZ, and query station information based on geographic area and network names to get a collection of Nordic stations. We use the ObsPy method get_stations for these queries. The resulting data set consisting of data for the stations could then easily be made available in Enlighten-web. Figure 6 shows a plot of the stations in Enlighten-web.
- Figure 4 shows a simple example of retrieving waveforms for a specific station for a specific time range. We use the ObsPy method get_waveforms for these queries.
- In Figure 5, we retrieve events for the last year from the EMSC EIDA node. The result is 54 352 events. We use the ObsPy method get_events for these queries. (Because of

limitations on the allowed size of query results, we perform a sequence of sub queries instead of one big.) The result is plotted using Enlighten-web in Figure 7.

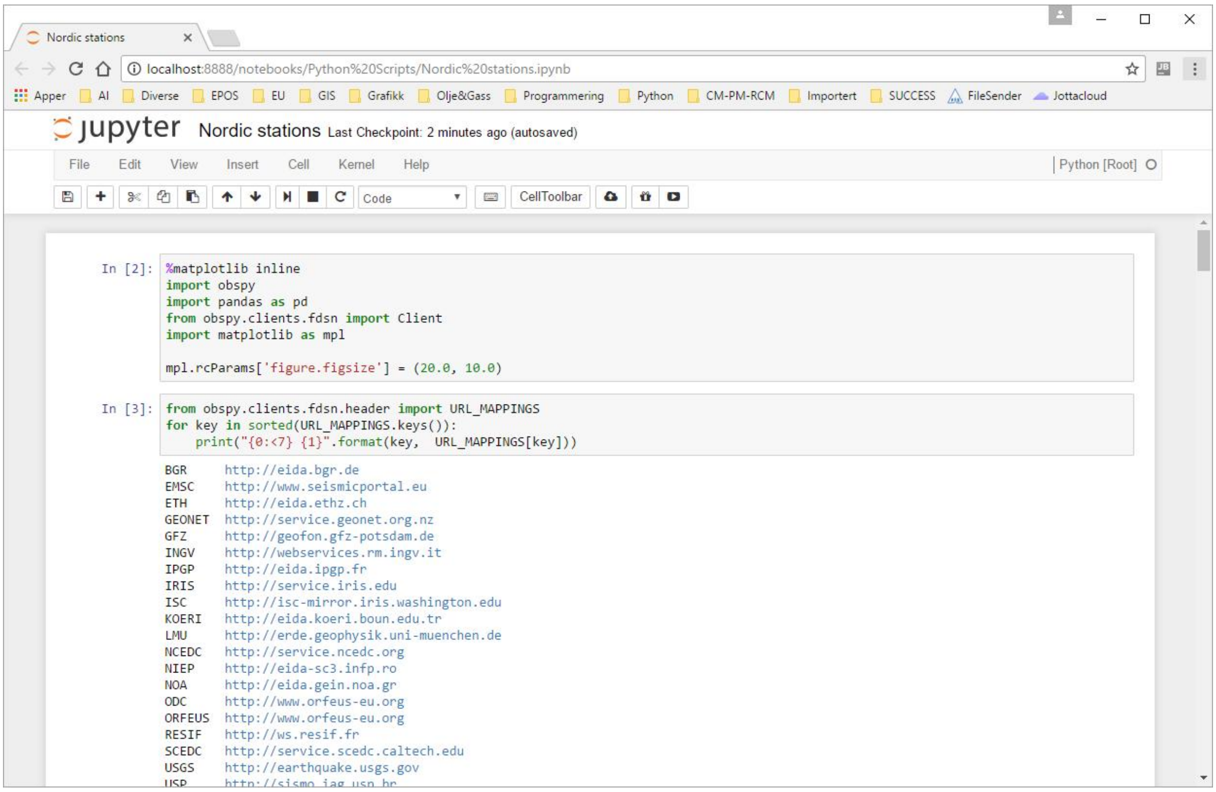

Figure 2. Notebook accessing EIDA nodes using the ObsPy package.

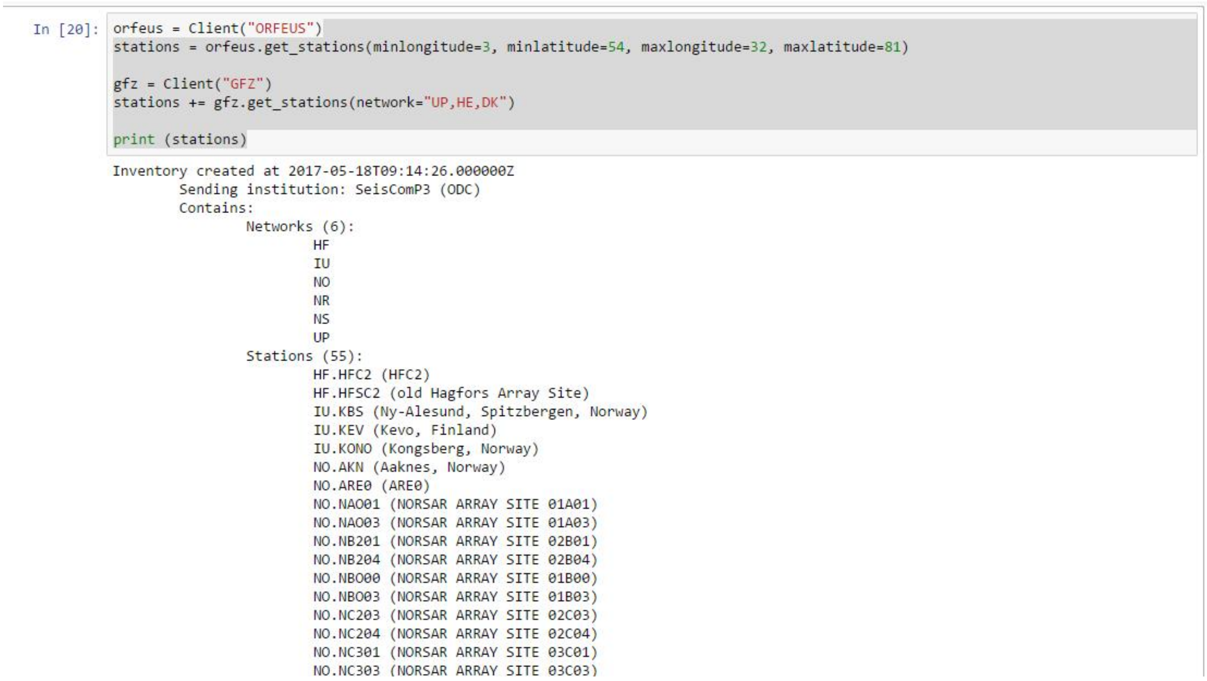

Figure 3. Retrieval of stations based on geographic location and network codes.

```
In [43]: from obspy import UTCDateTime
         t1 = UTCDateTime("2017-04-29T22:55:00")
         st = orfeus.get_waveforms("NO", "AKN", "*", "*", t1, t1+10*60)
```

```
In [44]: st.plot()
```

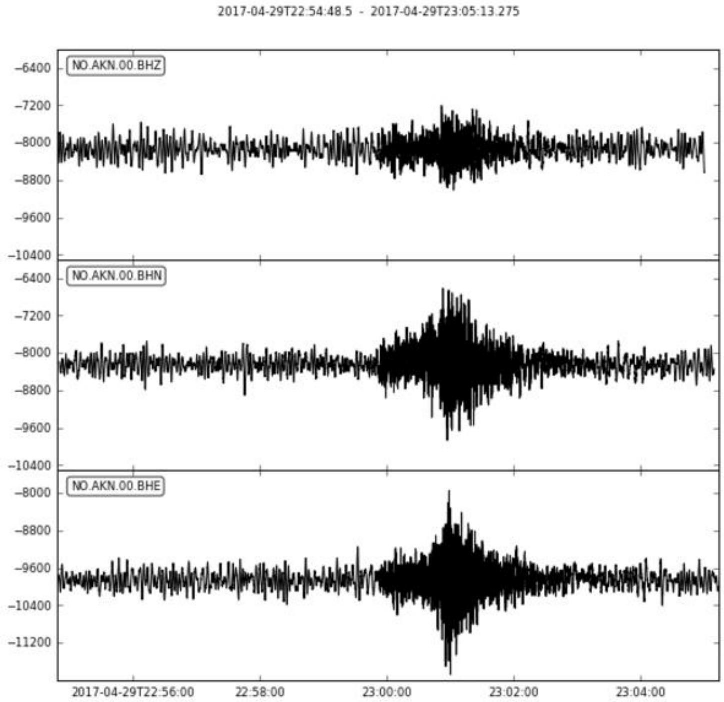

Figure 4. Retrieval of waveforms from specific station for specific period.

```
In [12]: import pandas as pd
         import matplotlib as mpl

         import obspy
         from obspy.clients.fdsn import Client
         emsc = Client('EMSC')

         from obspy import Catalog
         events = Catalog()

         from obspy import UTCDateTime
         t0 = UTCDateTime("2016-05-01T00:00:00.000")
         t1 = UTCDateTime("2017-05-18T00:00:00.000")
         dt = 3*24*60*60
```

Query events from EMSC. Need to split in shorter time spans for each query because of limitations on responce size

```
In [13]: while True:
             ev_period = emsc.get_events( t0,t0+dt )
             events += ev_period
             print(t0, ", len = ", len(ev_period))

             t0+=dt
             if t0 >= t1:
                 break

         2016-05-18T00:00:00.000000Z , len =  388
         2016-05-21T00:00:00.000000Z , len =  406
         2016-05-24T00:00:00.000000Z , len =  380
         2016-05-27T00:00:00.000000Z , len =  416
         2016-05-30T00:00:00.000000Z , len =  378
         2016-06-02T00:00:00.000000Z , len =  426
```

Figure 5. Retrieval of events for one year from EMSC.

Data collection and preparations initiated through the ICS-C portal

The usage scenario described in the previous section requires Python programming skills. The EPOS ICS and TCS shall support researchers in discovering and analyzing data without requiring programming skills. We therefore want to introduce an API that enables preparatory work initiated by ICS-C.

This usage scenario starts with the user placing data based on meta-data searches into her "shopping cart", using the ICS-C portal. Based on information about the data in the shopping cart, the user is informed about data storage requirements, data transfer time and pricing. On checkout, the selected data is automatically made available in a Jupiter Notebook session, through an API based on an abstract workflow description language, e.g. [3]. When the upload process is completed, the user is notified with a link to the notebook containing the data. The user can then perform further analysis and processing in the notebook, and she can start Enlighten-web for visual analysis.

The Enlighten-web client for visualization

Enlighten-web facilitates interactive visual analysis of large multidimensional data sets, and supports interactive mapping of millions of points. Enlighten-web runs inside a web browser. The user can create layouts consisting of one or more plots or views. Supported plot types are scatter plots and map views. Currently, map views can be Google Maps or OpenLayers. OpenLayers supports WMS layers. We are also assessing CESIUM [4], as CESIUM supports 3D visualization in addition to WMS layers. Scatter plots can be mapped on top of map views. Figure 6 shows an example of Enlighten-web with several views. The view on the right is the stations retrieved in Figure 3. Figure 7 shows the stations retrieved in the notebook in Figure 5.

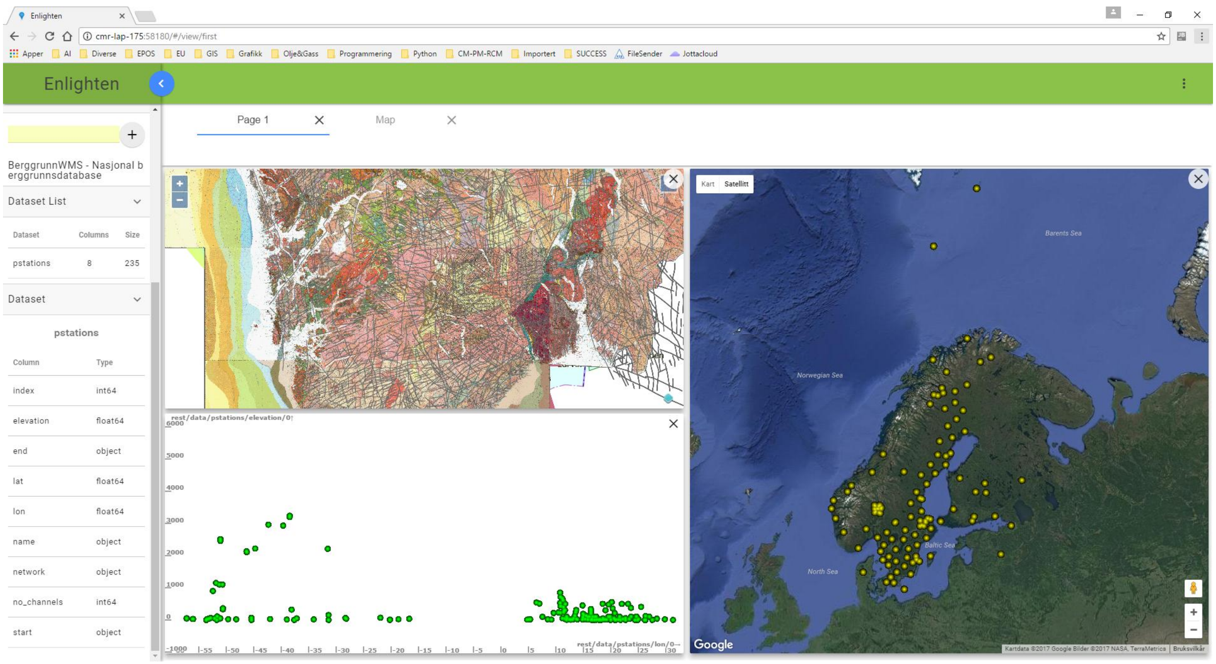

Figure 6. Example of Enlighten-web layout. Upper left plot is a WMS dataset. The two other plots shows output from the notebook in Figure 3.

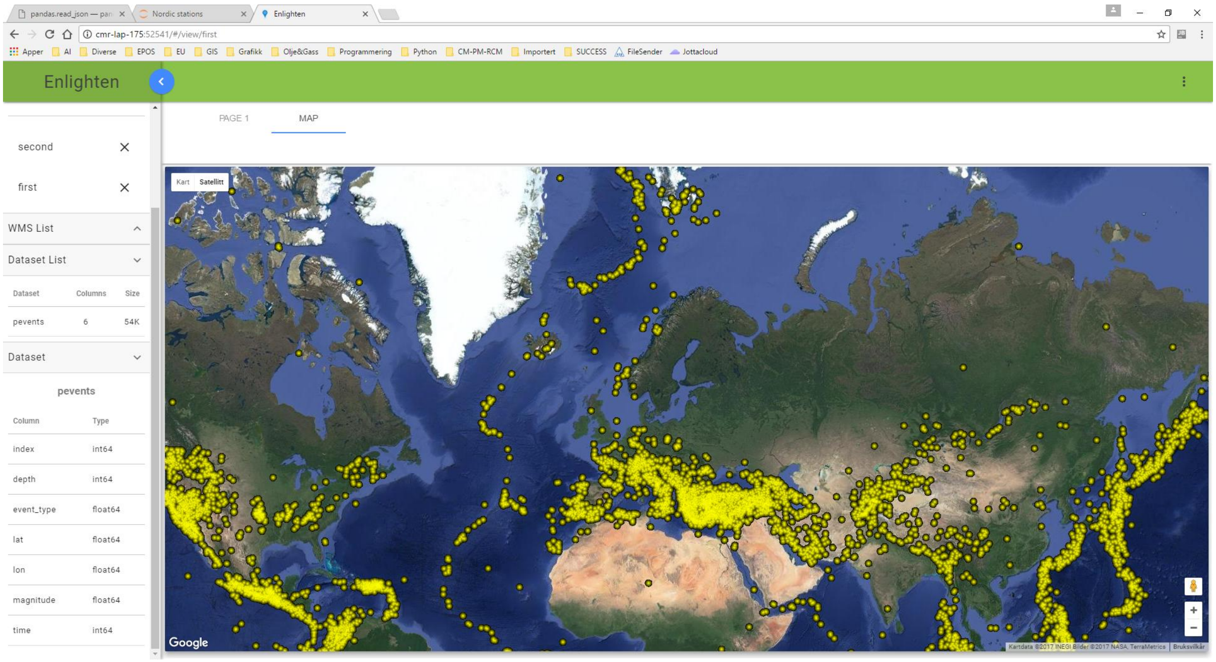

Figure 7. The events created in the notebook in Figure 5 is easily made available in Enlighten-web. Here plotted on top of a Google map. Since the events are drawn using WebGL, full interactivity in achieved.

One central element in the Enlighten-web functionality is brushing and linking [5]. Brushing and linking is useful for exploring complex data sets to discover correlations and interesting properties hidden in the data. Brushing refers to interactively selecting a subset of the data using the mouse e.g. to dynamically alter a bounding box. Linking involves two or more views on the same data set, showing different attributes. The views are linked to each other, so that highlighting a subset in one view automatically leads to the corresponding subsets being highlighted in the linked views.

Brushing and linking can be especially useful if the updates in the linked plots are close to real-time while brushing. The user can then perceive complex trends in the data by seeing how the selections in the linked plots vary depending on his interactions in the brushed subset. This interactivity, especially for large data sets, requires GPU acceleration of the graphics rendering. In Enlighten-web, this is realized by using WebGL [6].

The programming languages used for developing Enlighten-web client are Typescript/JavaScript and GLSL (OpenGL Shading Language for GPU programming [7]). We have applied the web application framework Angular [8]. Server side code is in Python.

Future work

Integration of Enlighten-web with ICS-C is an important task. The EPOS IP project is working on requirements for ICS-D integration with ICS-C. Based on this work, we will be able to instrument Enlighten-web with an appropriate API. Enlighten-web can then be a part of workflows defined using the ICS-C portal.

Plans for development of Enlighten-web is coordinated with the Solid Earth Sciences Committee (SESC) in the EPOS Norway project, to secure that the development targets relevant functionalities. SESC will define use cases both for defining functionality specifications, and for testing of the software by PhD students working with solid earth sciences. We plan a workshop for getting started with the testing this fall.

The EPOS-Norway project shall implement a Norwegian web portal for accessing Norwegian data, data products, services and software. The web portal functionalities will be realized through extending Enlighten-web. As described in this abstract, Enlighten-web takes as input multidimensional data sets. These data sets can be extended with metadata specifying e.g. data sources and how the data can be accessed. Enlighten-web can then use this information to access remote data. This way we can realize data portal functionality where the GUI differs from traditional data portals for discovering and accessing data sets on the web. The brushing and linking concept can be extended to brushing and linking in metadata for data discovery and access.

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Finnish Open Science Initiative: OpenFIRE – Building a web service by integrating e-infrastructures through standard interfaces

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Various e-infrastructures serving data-related services for citizens, researchers, and organisations are being built in Europe and worldwide. For the end-users, the utility value of these services is very cumulative in nature, as combining services provided by various different infrastructures makes it possible to design novel applications.

These infrastructures are administrated and backed by various types of organisations, including governmental agencies, universities, non-governmental organisations. These infrastructures may or may not be backed by national or transnational legislation or contracts. Thus identifying infrastructures that are mature enough to rely on for building new services requires discretion.

We have utilised and contributed to this ecosystem by building a service to enhance the discoverability, accessibility, interoperability, and reusability of the results of the deep seismic sounding project FIRE (Finnish Reflection Experiment). The service, known as OpenFIRE, builds on various infrastructures and initiatives intended for research and society, such as INSPIRE and the Open Science Initiative of Finland. Special effort has been made to achieve interoperability with both academic and non-academic data and discovery services suitable for research. The front-end of this service-oriented application is implemented as a mobile-responsive web GIS application, making it possible to download the data, and rapidly provide insight into the dataset by combining geophysical and geological models and observations.

An in-production version of the application can be found from the website of the Open Science Initiative of Finland (https://avaa.tdata.fi/).

Spatial data infrastructures and INSPIRE - And why do we need them?

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This presentation covers briefly what are spatial data infrastructures (SDI) and the building blocks of an SDI. Furthermore, INSPIRE - an SDI initiative in Europe is looked more into the details.

Data from active seismic experiments

Henning Lorenz, Uppsala University, Sweden

Active seismic experiments are the first choice for studying the subsurface in industry and research applications. Enormous amounts of data from more than half a century of investigations exist and their volume is growing ever faster. However, at present only a minor amount of these data is accessible for research, and data discovery is a major hurdle. EPOS could fill the missing function of a data discovery portal, but surprisingly, data from active seismic experiments are not part of the EPOS IP project.

WP15 Geological data and modelling is dealing with subsurface data in form of borehole data and models. It is representing both, the geological surveys and the scientific community. Data from active seismic experiments are highly relevant for studying the subsurface and closely related to the WP15-topics drilling and modelling of the subsurface. Thus, WP15 takes the initiative to implement a discovery function for data from active seismic experiments in EPOS.

THE DATA

Industry data are the clear majority of all data, in particular with regard to marine seismics. These data are usually proprietary and not accessible at all. In some countries, regulations exist that legacy data have to be archived at a public authority (e.g. a geological survey).

Many public authorities (mainly geological surveys) maintain large databases on data from active seismic experiments. Data are typically archived legacy data from the industry (see above), inherited data (e.g. after company dissolution) and data from own experiments. These databases usually include both closed and open data.

Scientific data are in volume comparatively small and are often the only coverage of land areas outside the mining districts, i.e. the majority of the Earth's land surface. Unfortunately, these data usually tend to end up at best in local off-line archives after publication of the scientific results and interpretation.

THE APPROACH

We suggest an approach similar to the BoreholeView and ModelView services that were developed by WP15 for the discovery of borehole data and subsurface models, respectively, using as much as possible the INSPIRE specifications. Such a discovery service does not provide direct data access but forwards the user to the respective data provider for retrieval of the data set, which is favourable in a start-up community where questions on IP rights, licensing and community standards were not previously explored.

To make this work, a record with URI has to be available for each data set that allows either the retrieval of the data set or describes how and under what conditions access is possible. Such records are usually available at established repositories like those of the geological surveys, but not for academic data. For a community in want of metadata standards, a viable solution would be to publish the data set at a DataCite-affiliated data centre with an ISO 19115 metadata profile.

The discovery service builds on an index of discovery data, i.e. attributes that allow the user to search for data sets and filter the results. What information these attributes will contain is up for discussion. Examples are geographic location, type of survey, recording length/depth, equipment types, and the above mentioned URI of the data set. The discovery attributes are usually filled by mapping from existing databases. Alternatively, they are provided to the service provider by the data provider for each data set (e.g. for published academic data).

The discovery data will then be available through the "LineView" service (working name) for harvesting via established protocols and as an OGC compliant web-service (WFS).

The "LineView" service is meant to be an attractive offer to data owners to make their data available to the scientific community (and citeable) with very little effort. Discussions on the approach and content of the discovery data are very welcome!

PALEOMAGIA database – a global online resource for Precambrian paleomagnetic research

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Paleomagnetic databases have a variety of applications such as paleogeographic reconstructions, derivation of apparent polar wander paths (APWPs) and paleolatitude curves of continents, inclination frequency analysis in testing the functionality of the Geocentric Axial Dipole (GAD) hypothesis, analysis of paleosecular variation, investigating the true polar wander, studying field reversals, comparison of reversal frequency and the virtual axial dipole moment and studies of dynamo processes such as the onset of the solid inner core. However, knowledge of these topics has for a long time been very limited in the Precambrian, which spans nearly 90% of geologic time.

The PALEOMAGIA database (Veikkolainen et al. 2017) answers the call for a utility that allows an easy access to Precambrian paleomagnetic data worldwide. The most recent edition of this relational database, available at http://www.helsinki.fi/paleomagia, incorporates 3508 paleomagnetic poles linked to 618 age references. All data have been categorized paleogeographically to continents and cratons, and ranked using a revised version of the Van der Voo grading scheme where six out of the seven criteria have been included and the seventh one has been left out as being non-unique and highly subjective in the Precambrian. The inclusion of referenced isotopic age information to PALEOMAGIA in years 2015-2017 is of particular importance as it has significantly facilitated the construction of models of Rodinia and Columbia/Nuna supercontinents, and tests of smaller cratonic configurations, even in the Archaean. For this purpose, paleomagnetism is the only quantitative tool available.

The PALEOMAGIA online user interface is supplemented with a comprehensive documentation, a list of all poles and a Google map of paleomagnetic sampling locations. Links to original publications are provided via Digital Object Identifiers (DOIs) wherever available. Data can be viewed in the browser on a dynamically created web page, and can be easily imported to spreadsheet software, paleogeographic reconstruction programs (GMAP, Gplates), Python scripts or other data analysis tools. The query form allows several options such as filtering the data geographically, restricting the query to peer-reviewed results only, to hide or show different properties such as age references, and to order data by different criteria. There is also a form available for the paleomagnetic community to suggest new data to be added.

Currently, PALEOMAGIA only incorporates directional paleomagnetic data, not paleointensity data. Despite the general preference for original data, some reasonable recalculations have been done in a few cases, which e.g. refer to obvious errors in the original publication. The extension of PALEOMAGIA to Phanerozoic geologic periods is under consideration.

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