Geomagnetism, the study of the Earth’s magnetic field, its causes and effects, has a long history. The earliest ‘network’ of observatories (Göttingen Magnetischer Verein) started in the 1830s. To this day Geomagnetism continues to be well organised globally: World Data Centres (WDC) cater for the needs of researchers for access to both digital and paper records; international science associations, such as the International Association for Geomagnetism and Aeronomy (IAGA), endorse methods for characterising the dynamic field; and standards bodies, such as INTERMAGNET, lay out the requirements for modern, high quality observation. Given the existing infrastructure you might be tempted to ask why Geomagnetism and EPOS need each other?

The Thematic Core Service (TCS) for Geomagnetism in EPOS is organised into three areas:

1. The European Geomagnetic Data and Model Archive (EGMODA) provides access to provisional and definitive observatory data from INTERMAGNET and the WDC and to magnetic variation data from the auroral magnetometer network IMAGE. EGMODA services also include access to global geomagnetic models such as the International Geomagnetic Reference Field and the World Magnetic Model.

2. The European Service of Geomagnetic Indices (ESGI) provides access to geomagnetic activity indices and lists of remarkable geomagnetic events. These data products are produced by a number of geoscience institutes around the world and endorsed by IAGA, the International Association of Geomagnetism and Aeronomy.

3. The European Magnetotelluric Data and Models (EMTDAMO) service offers access to a growing number of magnetotelluric measurements, including both measured data and calculated conductivity models.

What has the EPOS Implementation Phase (2015 to 2019) added to these services?
• In the area of magnetotellurics, no coordination existed across Europe prior to EPOS. Under the EPOS project, a user community has been established, formats for dissemination of data have been agreed and a web service for data distribution has been set up.

• In areas where services are already well developed, the EPOS project has contributed to a modernisation of the current facilities. This has included promoting and informing the discussion about the attachment of Digital Object Identifiers (DOIs) to data sets. A number of DOI's have been created during the project, some covering large sets of data with complex provenance. EPOS has also provided guidance for updating data license conditions, from earlier informal or locally written documents, to a modern, international and machine-readable system. The new license conditions have been applied to nearly all data, products and services supplied by Geomagnetism through EPOS.

• Some of the Geomagnetism services, for example the global geomagnetic models, were distributed as source code, making it complex for non-specialist users to access them. Under EPOS web services have been developed for these models, allowing simple, modern access to the model values.

The advances described above enhance the individual services that Geomagnetism provides. But one of the main goals of EPOS is to allow users to interact with services across a range of science areas. For users to do this, services must be ‘interoperable’. Much work has been done during the EPOS Implementation Phase to make data sets from Geomagnetism interoperable with data sets from all other EPOS science areas. This has included creating ‘rich’ metadata for these data sets according to the standards designed during the project. The metadata describes, amongst other things, the data sets, their associated web services, the institutes and people responsible for them. As a result the EPOS system is able to show metadata from any of the hundreds of data sets in EPOS alongside each other, irrespective of which science area the corresponding data originates from.

Alongside this technical work, a community has been established around the TCS for geomagnetism, including user feedback groups (who have peer reviewed the creation of a community metadata system) and user testing groups (who have reviewed the EPOS portal and the ease of access to geomagnetism data within the portal).

A community has also been established between the IT staff in the EPOS project and scientists in the Geomagnetism and other TCSs. Collaboration between these staff is working well now, and will help to ensure the success of ongoing initiatives for Geomagnetism in EPOS, which include:

• Adding standard, interoperable methods for visualising all
time series data in EPOS, work that the Geomagnetism TCS has been leading.

- Creation of systems within the EPOS user portal where data from across EPOS can be processed in a simple, familiar way (e.g. by the implementation of Python notebooks or something similar).
- Augmentation of the metadata to include searchable information about instruments and equipment used for making measurements.
- Completion of work already started to authenticate and authorise access to data sets using the EPOS standard system for user identification.

In addition to these goals which cut across many of the different sciences areas in EPOS, The Geomagnetism TCS hopes to enhance its own services in the future, through initiatives such as:

- Access to the World Digital Magnetic Anomaly map.
- The addition of more magnetotelluric data and more sophisticated web services for these data.
- Creation of new DOIs, particularly in areas which have been considered ‘difficult’ in the past (e.g. real-time data).

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Observatory and repeat station data are important for basic geomagnetism research into, for example, processes generating the magnetic field in the Earth’s core and processes leading to core-mantle electromagnetic interaction. Geomagnetic data also allow derivation of global geomagnetic and magnetic anomaly models, study of space weather processes and development of geomagnetic activity forecasts. Magneto-telluric observations are important for understanding and modelling the electric conductivity of the crust and the upper mantle.

Therefore, the TCS ‘Geomagnetic Observations’ activity has considerable socio-economic impact:

- Maps of crustal magnetic anomalies and the electric conductivity of the crust are useful tools in the interpretation of geological and tectonic structures, with direct application in exploration for natural resources
- Directional drilling for oil and gas often uses magnetic referencing, whereby near real-time magnetic data are used to correct the drilling direction
- The accuracy of GPS positioning can be sensitive to high levels of geomagnetic activity. Data on geomagnetic activity can thus provide context on the quality of GPS data
- Geomagnetic activity and other phenomena related to solar activity may affect the continuous operation of electricity distribution networks. Reliable forecasts of activity are therefore important for mitigation of this natural hazard
- Direction finding on land with a compass relies on the
magnetic field and accurate knowledge of how this varies spatially and temporally. Improved estimates of the local direction of magnetic north, as presented on maps, will be valuable for European national mapping agencies.

• Sophisticated smartphone applications, such as navigation and augmented reality apps, use measurements of the Earth’s magnetic and gravity fields to work out the orientation of the phone.