GEOMAGNETIC MEASUREMENTS AND MAPS FOR NATIONAL AERONAUTICAL SAFETY

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The National Reference Station – Surlari Observatory and the National Repeat Station Network follow the highest standards set up by IAGA Working Group V and by International Real Time Magnetic Network (INTERMAGNET). Besides the aeronautical data, the Romanian Air Traffic Services Administration (ROMATSA) needs up-to-date maps and declination values necessary to compute periodically the magnetic headings, necessary to fly from an airport to another, and aeronautical maps. In order to fulfill the safety requirements in accordance with European legislation, a research team from the Geological Institute of Romania (Surlari Observatory) and the Institute of Geodynamics (National Repeat Station Network) is responsible with this information at national level. The paper reviews the measuring equipment and the main outcomes of updating the geomagnetic information needed by ROMATSA.

Key words: geomagnetism, data, models, aeronautics, ROMATSA, INTERMAGNET, Surlari Observatory, Romania.

INTRODUCTION

The Romanian Air Traffic Services Administration – ROMATSA – is responsible for information necessary for navigational purposes and its main objective is to fulfilling the national and international safety requirements in accordance with present European legislation. Beside the aeronautical data and information necessary for safe air navigation, the spatial and temporal distribution of the geomagnetic declination should be available in an appropriate form. With these up-to-date maps and declination values, aeronautical authorities are able to compute periodically the magnetic headings, necessary to fly from an airport to another, and to deliver updated Romanian aeronautical maps. For this purpose a research team dealing with Surlari National Geomagnetic Observatory data, geomagnetic measurements in the National Repeat Stations Network and the most recent global field models has been established at national level (Isac *et al.*, 2015).

The Surlari Observatory (Geological Institute of Romania) plays a prominent role as national reference station and provides long time series since 1943 (Constantinescu, 1943). Starting with 1996, as INTERMAGNET member (www.intermagnet.org), Surlari (SUA – International Association of Geomagnetism and Aeronomy (IAGA) assigned code) has to ensure highest quality for produced data, in accordance with the standards set up by IAGA Working Group V-OBS (www.bgs.ac.uk/iaga/vobs/).

The National Repeat Station Network (Institute of Geodynamics, Romanian Academy) consisting of 26 repeat stations uniformly distributed over the national territory provides periodically, since 1964, measurements and their interpretation in terms of geomagnetic secular variation and normal field over Romania (Atanasiu *et al.*, 1976; Demetrescu *et al.*, 2011). As Magnetic Network of Europe (MagNetE) member it has to follow the same IAGA Working Group V-MOD highest standards for magnetic repeat station surveys.

INSTRUMENTS AND MEASUREMENTS

In order to ensure imposed measurement standards, all INTERMAGNET observatories use similar instrumentation to produce similar data products. The fundamental measurements are averaged one-minute, hourly, daily, monthly and annual values of the geomagnetic field vector components and of its scalar intensity. In a geomagnetic observatory the geomagnetic field has to be monitored accurately and continuously over a long time. Changes in the magnetic properties of the observatory area and the neighborhood are not favorable and acceptable. The observatory should be magnetically representative for the region, in sense of secular and short term geomagnetic variations. The comprehensive information about how to organize, run and make magnetic measurements is given by Jankowski and Sucksdorf (1996) and St-Louis (2008).

A geomagnetic observatory procedure, generally, involves (Mandea, Isac, 2011):

– absolute measurements that have to be sufficient in number to establish the baselines and to monitor instrumental drift of vector magnetometers, which give variation measurements of the three field components, in arbitrary units. In Surlari observatory the absolute measurements are performed continuously by an Overhauser proton – precession magnetometer, for the strength of the magnetic field (F), and two–three times per week, manually, by a DI – Flux Bartington flux-gate magnetometer, for inclination and declination;

– continuous variation measurements by means of instruments known as variometers which have to be calibrated against standard instruments. In Surlari observatory a vector measurement (H, D, Z) is made with a FGE fluxgate magnetometer manufactured by Danish Technical University (Fig. 1).

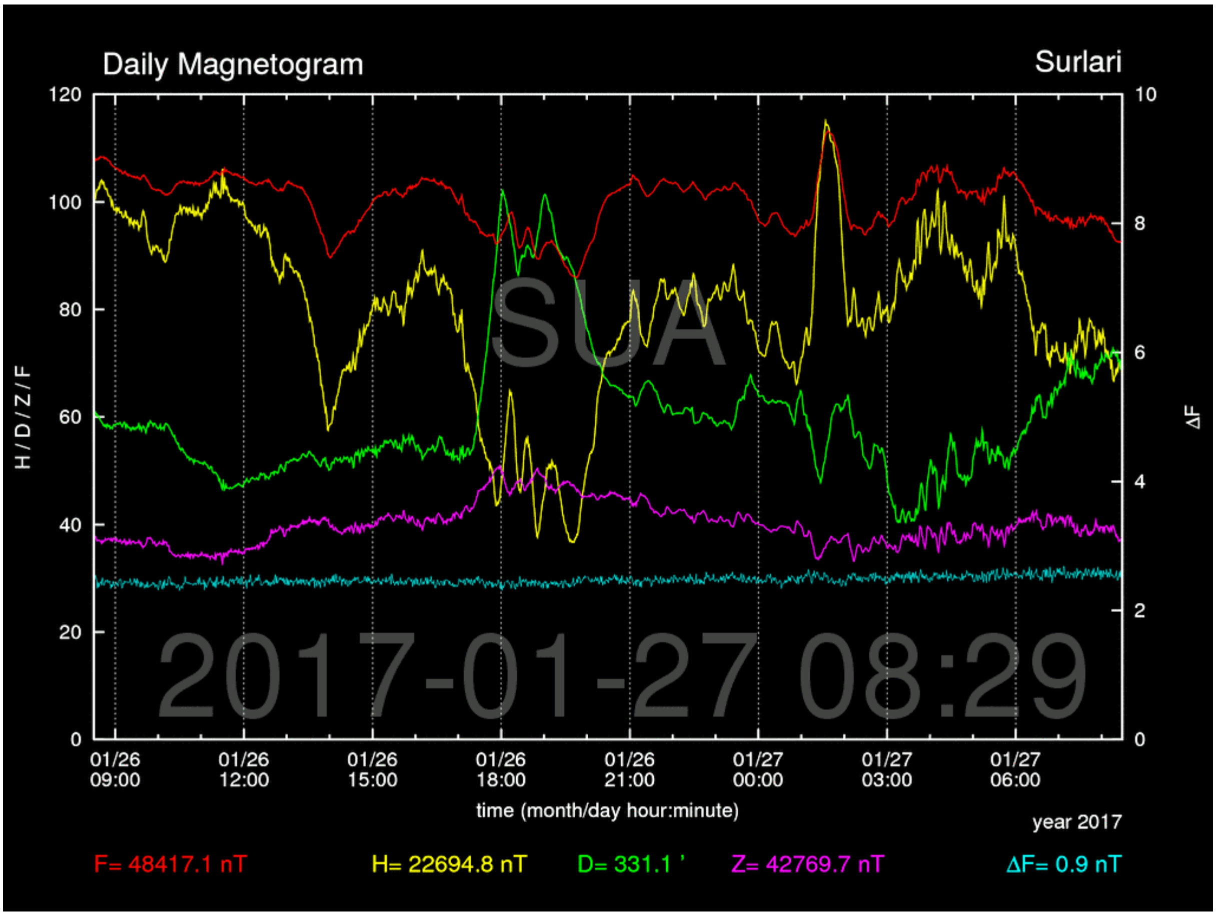

Fig. 1 – A daily magnetogram of Surlari observatory (SUA) displaying the vector variometer components H, D and Z, the independently recorded total intensity F, and ΔF calculated as $\Delta F = \mathrm{sqrt}(H^2 + Z^2) - F$.

Since March 2009, Surlari is one of the fourteen European observatories transmitting its data in near – real time.

Regarding geomagnetic measurements in the secular variation network, a repeat station plays the role of a magnetic observatory with an elementary infrastructure (a non-magnetic tripod) in a magnetically clean area and with one measurement session at least every two years. The instrumentation used during repeat survey is similar to that used in a magnetic observatory:

– for a spot value of declination measurement a Lemi DI magnetometer is used. The Lemi theodolite is useful also for the sun sighting (the astronomically known position which can deliver the azimuth of a necessary distant target);

– the strength of the magnetic field (F) is continuously recorded for several hours by means of Geometrics proton – precession magnetometer;

– two Quartz Horizontal Magnetometers (QHMs) for the measurement of H component;

– LEMI and Bartington three-axis fluxgate variometers are continuously recording X, Y, Z geomagnetic field components for several hours during the absolute measurement session.

The spot value measurements are used to establish the baseline of the variometers. Standard procedures link the spot measurements in the repeat station to the reference station Surlari where the annual mean of the desired epoch is well known. All the methods used try to mitigate the source of errors, mainly diurnal and disturbed field variation. A detailed guide for magnetic repeat survey practice was also published by IAGA (Newitt *et al.*, 1996).

A look at the repeat station network data provides a characterization of the geomagnetic field temporal and spatial evolution over Romanian territory. This is shown in Figure 2 where the geographic distribution of magnetic declination (D) over Romanian territory at geomagnetic epoch 2012.5 and its averaged secular variation in the period 2010.5 – 2014.5 are presented. The secular variation of magnetic declination varies over the Romanian territory between -2 ÷ 11 minutes.

The temporal variation of the declination at Cluj station and Surlari (SUA) can be seen in the upper part of Fig. 3. The plots show slope differences which suggests that the secular variation has a lateral variation due to local peculiarities of the magnetic properties of crustal rocks nearby repeat station, see also the right panel of Fig. 2. For air traffic purposes, because of secular variation and obvious differences between measured and modeled data (Fig. 3, bottom) measurements at repeat station and airports location impose themselves as necessary in accounting for local peculiarities of the geographical distribution of declination over Romania.

PROVIDED PRODUCTS AND SERVICES

Geomagnetic observatories and repeat station networks contribute on one hand to the knowledge of the temporal and spatial variation of the magnetic field, its internal and external origin, and on the other hand they have a practical purpose such as space weather, geomagnetic metrology and, the most notable, navigation. Generally, for air traffic services and airports, geomagnetic studies are able to provide values of the magnetic declination for various epochs and locations, the secular variation of the magnetic declination, magnetic charts based on International Geomagnetic Reference Field (IGRF), time series of the geomagnetic field, high precision field measurements of the declination to certify magnetic orientation of the airports runways (Rasson, 2006), etc.

Based on accurate geomagnetic measurements taken at the national repeat stations network we can provide isogonic charts (Demetrescu *et al.*, 2011; Greculeasa *et al.*, 2015), as well as the local information regarding the annual means of geomagnetic declination at several airports and adjacent areas. Then, by means of the latest standard main field geomagnetic models, the declination and its annual change is predicted and made available on request.

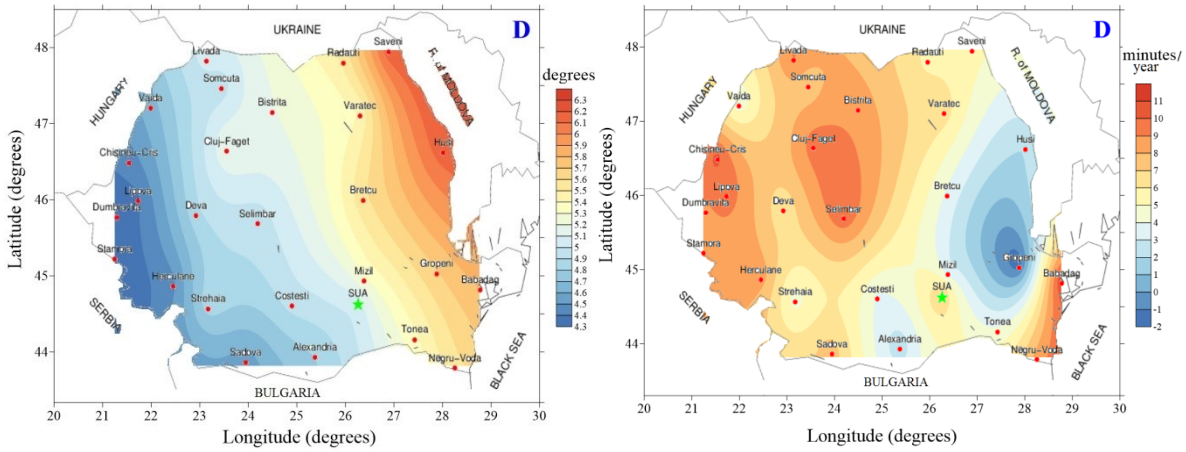

Fig. 2 – The geographical distribution of magnetic declination over Romanian territory at 2012.5 geomagnetic epoch (left) and the average secular variation in the interval 2010.5 – 2014.5 (right).

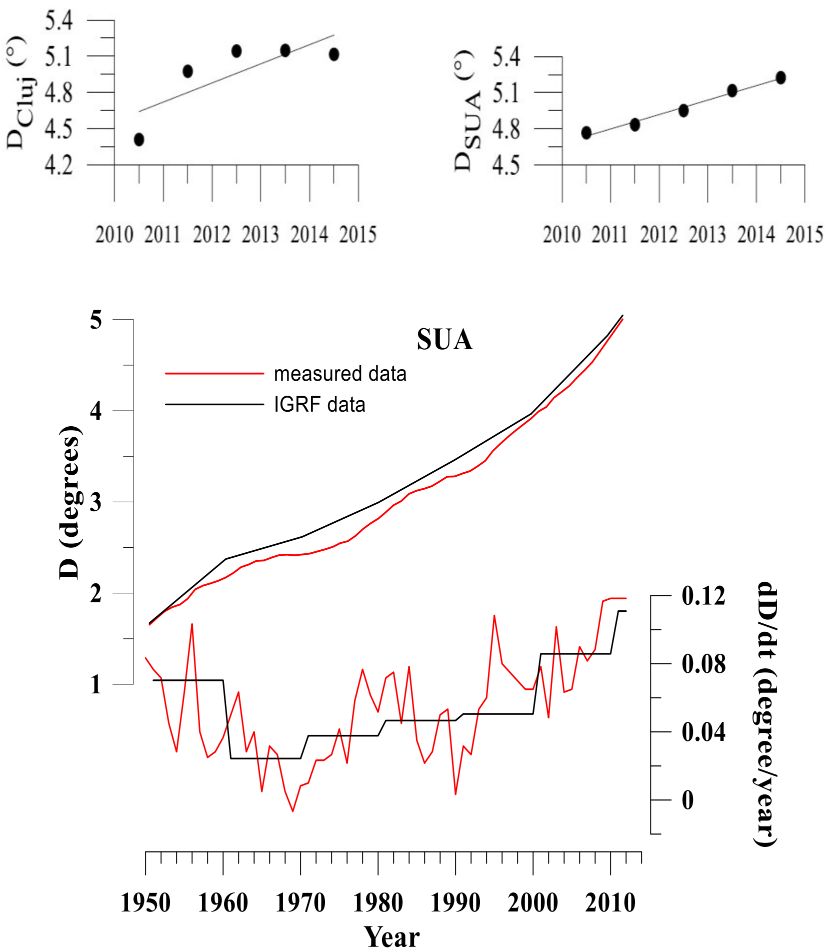

Fig. 3 – Yearly mean values at Cluj station compared to Surlari (SUA) ones for D: top – five years time interval (2010–2015); bottom – a comparison between yearly mean declination values (D) and its secular variation (dD/dt), for SUA measured data (red) and IGRF data (black), six decades time interval.

Therefore, the final supplied products by the National Geomagnetic Team are:

1. Runway azimuth determination for all national airports every three or four years. Airport infrastructure quality is not only nice buildings and runways, it also relates to more sophisticated facilities like the knowledge of the correct and up to date value of the magnetic declination. Local and regional features of the declination are useful for some sorts of aeronautical charts like Instrument Approach, SID, STAR, Visual Approach charts, etc. Some of them are depicting the area around the airport and give up-to-date declination information. Here, periodic geomagnetic measurements are necessary. The measurement procedure is identical as that one for repeat stations. Due to the large concrete thickness of tens of centimeters and substantial steel reinforcement, the declination is measured not on the runways but a bit away from it (Fig. 4), in a less magnetically perturbed area.

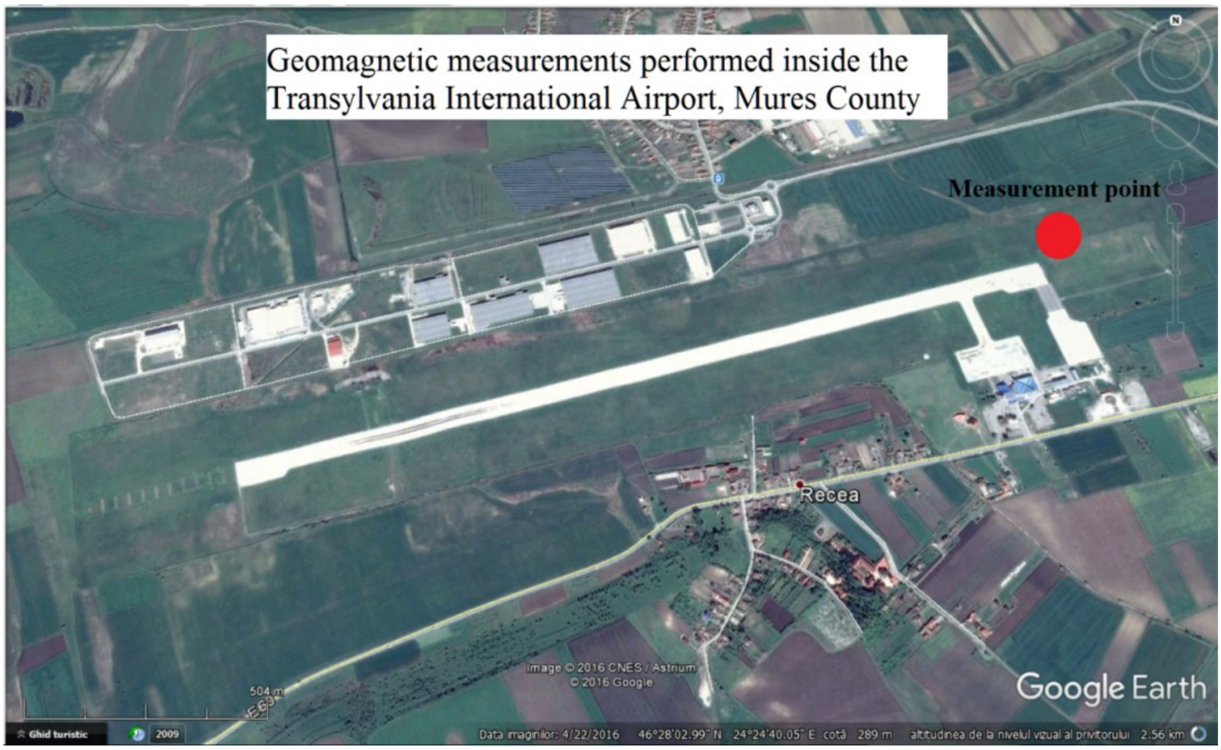

Fig. 4 – A station (red dot) placed nearby runway at which magnetic declination must be measured accurately and periodically to update the aeronautical traffic maps.

2. Declination maps and isogonal information at a certain epoch by means of periodically repeat stations network measurements (Fig. 5). The Spherical Harmonic Analysis technique, as in the case of IGRF, is the most used method for modeling the main field and its secular variation at global scale, taking into account the quasi-spherical geometry of the Earth. When we are interested on a smaller portion of the Earth's surface, *e.g.*, using a quasi-uniform distribution of repeat stations over a national territory, a regional analysis may represent the field, with its local peculiarities, at a better resolution. One of the techniques for obtaining regional models is a simplest analytical method using a polynomial expression in latitude and longitude. These algorithms generate uniform grids from the non-uniformly distributed data (the repeat stations measurements) by numerical interpolation.

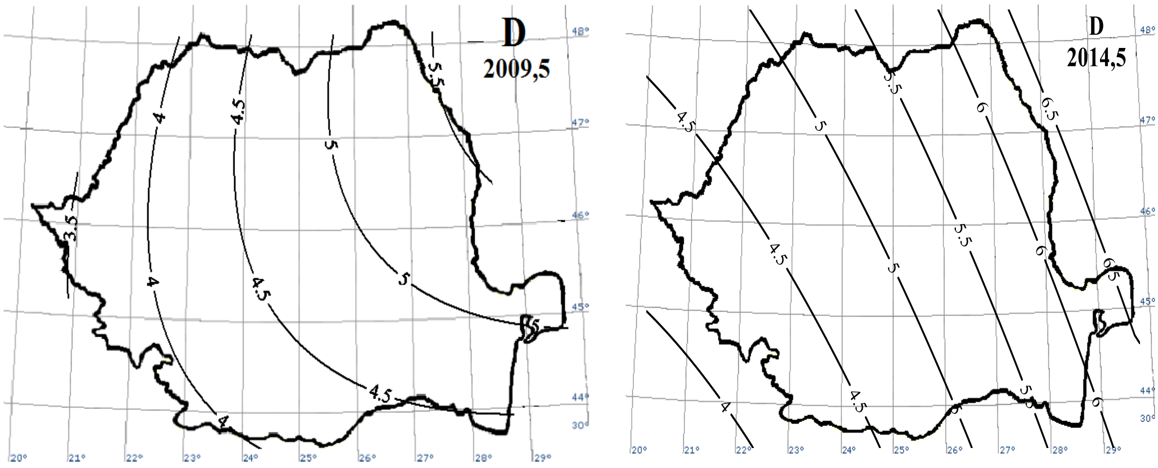

Fig. 5 – The spatial distribution of geomagnetic element D at geomagnetic epochs 2009.5 and 2014.5. The isogones are well approximated by second degree polynomials.

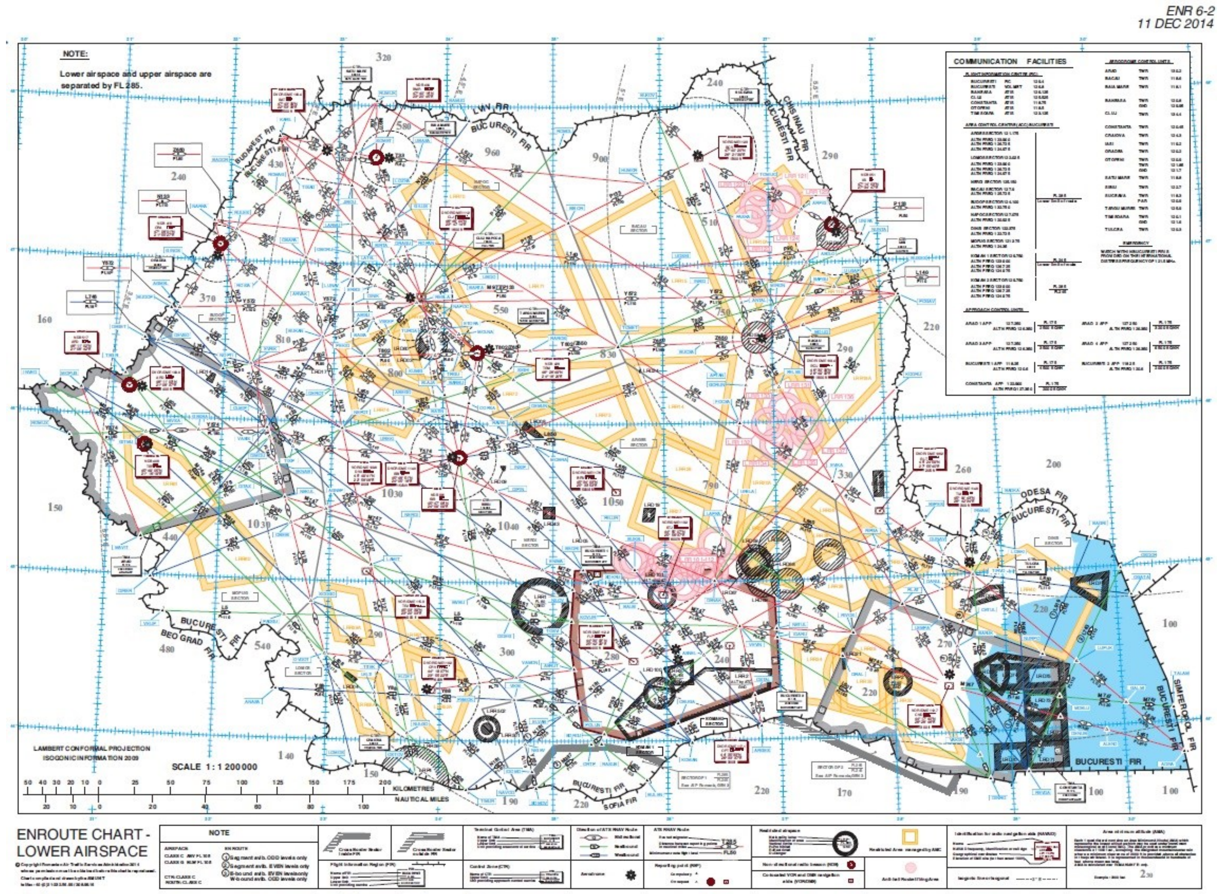

Fig. 6 – Air traffic chart-lower airspace of Romania. The isogonic chart at epoch 2014.5 is shown in light-gray (courtesy of ROMATSA).

3. Supply of magnetic declination data in any point and any time over the Romanian territory. For this aim, International Geomagnetic Field (IGRF)-12 (Thebault *et al.*, 2015), the latest standard main field model and the most popular, is used to predict the declination and its annual change. The model provides a reliable description of the main field (only internal long wavelength Gauss coefficients) by means of special mathematical techniques used to distribute data on spherical surfaces (www.ngdc.noaa.gov/IAGA/vmod/igrf.html). For delivering such values to ROMATSA, a secured dedicated online calculator using IGRF-12 coefficients integrate into Fortran source code provided by British Geological Survey, has been developed, hosted and operated by Surlari observatory.

CONCLUSIONS

The aim of the National Geomagnetic Team is to develop a new standard procedure to reflect in nearly real-time the spatial and temporal variations of the main geomagnetic field, especially declination, over national territory or in restricted areas (airport runways), more precisely than is possible using standard global models. With these up-to-date maps and declination values, aeronautical authorities are able to compute periodically the magnetic headings, necessary to fly from an airport to another, and to deliver updated Romanian aeronautical maps (Fig. 6).

Nowadays this research team is becoming a reliable partner of Romanian Air Traffic Services Administration – the primary organism responsible for the safety of the air navigation services over Romania.

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