REPEAT SURVEYS OF MACEDONIA

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Abstract. We present our geomagnetic repeat station work in the Republic of Macedonia performed during the years 2002, 2003 and 2004. A total of 15 stations were established. New stations were created as the localization data of the old stations were not available at the time. The paper will describe the measuring and localization equipment used, the observation techniques applied and the way the data were reduced to obtain the annual means of the components of the geomagnetic field vector over the area. As a result of this work, isogonic maps are available for the benefit of aircraft navigation with compass in Macedonian airspace.

Keywords: Title, Magnetic measurement, Declination, Repeat station, Geomagnetism

1. Short history

1.1. PAST REPEAT STATIONS

The website with the most extensive list of repeat station data is presently the page maintained by the British Geological Survey (BGS) with the URL: http://www.geomag.bgs.ac.uk/gifs/surveydata.html. Worldwide data from 1900 until present are available. Macedonian repeat station data are easily obtained from this database Data collected prior to 1900 are not relevant to this study.

Figure 58 shows data retrieved from the BGS site plotted on a map with latitude/longitude indications. The data can be grouped by period and country:

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- Measurements obtained in Macedonia between 1911 and 1918. (The oldest data on the map.)
- Measurements in Bulgaria between 1930 and 1931. More information on Bulgarian data can be found in the paper by Butchvarov and Cholakov in this Volume.
- Measurements obtained in Albania during 1942.
- Measurements obtained in Greece reduced to 1944.5.
- Measurements obtained in Albania between 1961 and 1995. More information on Albanian data is in the paper by Duka in this Volume

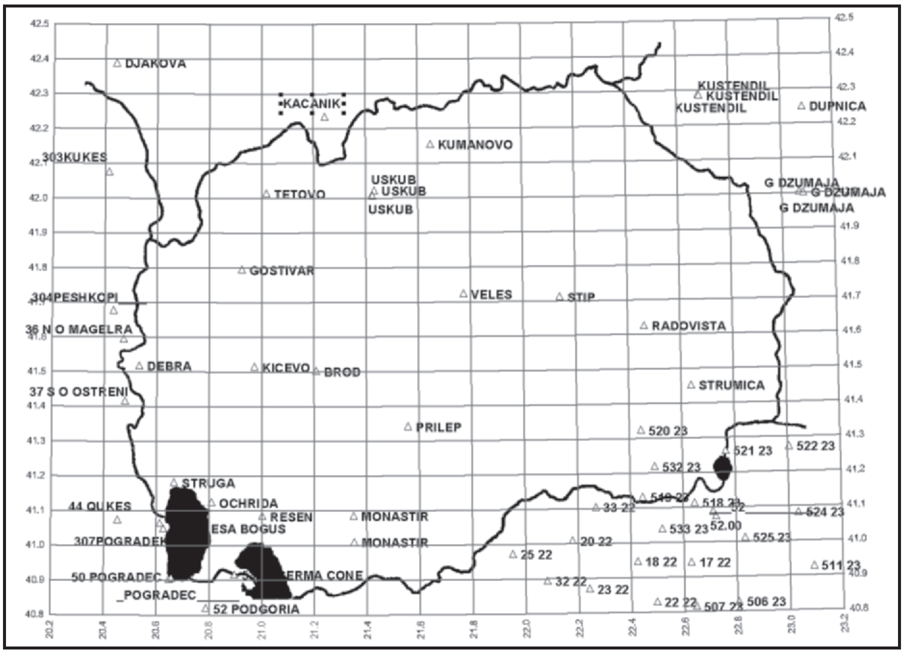

Figure 58. Map of the Republic of Macedonia and neighboring countries showing the magnetic repeat stations occupied in the past.

1.2. THE INITIATIVE OF THE YOUNG REPUBLIC FOR CREATING AN OBSERVATORY

Very early after its creation in 1992, the Macedonian Republic felt it was necessary to gain knowledge of the geomagnetic field in its territory. This responsibility was borne by the Geophysical Institute in Belgrade before 1992. Jean Rasson, the first author of this paper was contacted in the year 2000 to provide expertise, guidance, and help in a project entitled "Establishing a Geomagnetic Observatory in the Territory of the Republic of Macedonia". From then on, a collaboration started between Macedonia (represented by the Faculty of Mining and Geology, Štip) and Belgium (represented by the Royal Meteorological Institute, Centre de Physique du Globe, Dourbes) with the goal of establishing a magnetic observatory. Establishing a regular magnetic repeat survey of the country was also planned.

1.3. THE BILATERAL AGREEMENT WITH BELGIUM

Following the decision described in section 1.2, an approval process was initiated for signing an official agreement between Macedonia and Belgium. Due to delays caused by political events, the bilateral agreement was not approved and signed until the year 2002, and a first meeting between the parties was organized in April 2002 at the Dourbes magnetic observatory.

The agreement, valid for 3 years and renewable, set-out the tasks (work program), conditions, benefits, and obligations for both parties.

1.4. THE TEMPUS PROJECT (2003)

Fortunately, it was also possible to have a project approved under the EU TEMPUS Cards Education and Culture program. This was a joint undertaking entitled "Geomagnetic Measurements and Quality Standards" with the same parties as in section 1.3 but with the addition of the Austrian colleague, Dr. G. Duma from the Zentralanstalt für Meteorologie und Geodynamik (ZAMG) in Vienna, Austria. The duration of the project was set for 3 years.

This important project not only provided funding and involved a large number of Macedonian academics and students but provided:

- Education - of a core of Macedonian experts in geomagnetic measurements, magnetic pollution basics, and electro-smog detection
- Geomagnetic instrumentation – such as DIflux, magnetic variometers, data acquisition systems (for the purpose of training students) and other instruments for magnetic environment characterisation
- Funds - for international travel to train magnetic experts and for management visits.

2. Looking for a repeat network and establishing the stations

2.1. THE FIRST MEASUREMENT POINTS IN THE YEAR 2002

At the onset of our collaborations, we overlooked the database described in section 1.1 and the repeat station locations from the former Yugoslavia were not available. In absence of information about past repeat networks, our first repeat measurements network had to be planned from scratch. We focussed on an optimal geographical distribution of stations and on the necessity to perform magnetic tests in order to find a location for the future magnetic observatory. For the latter we had to take into account not only geological and magnetic considerations but also what sites were practical, available, and affordable. The three station network pictured on Figure 59, was established. The quality of the measurements was not always optimal, and the D measurement in Ohrid afterwards proved to be bad. Hence, the data collected in 2002 should be regarded as tentative at best.

Figure 59. The first repeat stations of the Republic of Macedonia (diamonds), created in 2002. Also represented are nearby magnetic observatories (dots).

2.2. THE CAMPAIGN OF THE YEAR 2003

Building on the first 3 stations mentioned in section 2.1, we planned a second campaign for 2003 with the goal of covering the whole country with an even distribution of stations. It was felt that 15 stations would be adequate and affordable considering the available means and time. The resulting network of stations is shown in Figure 60.

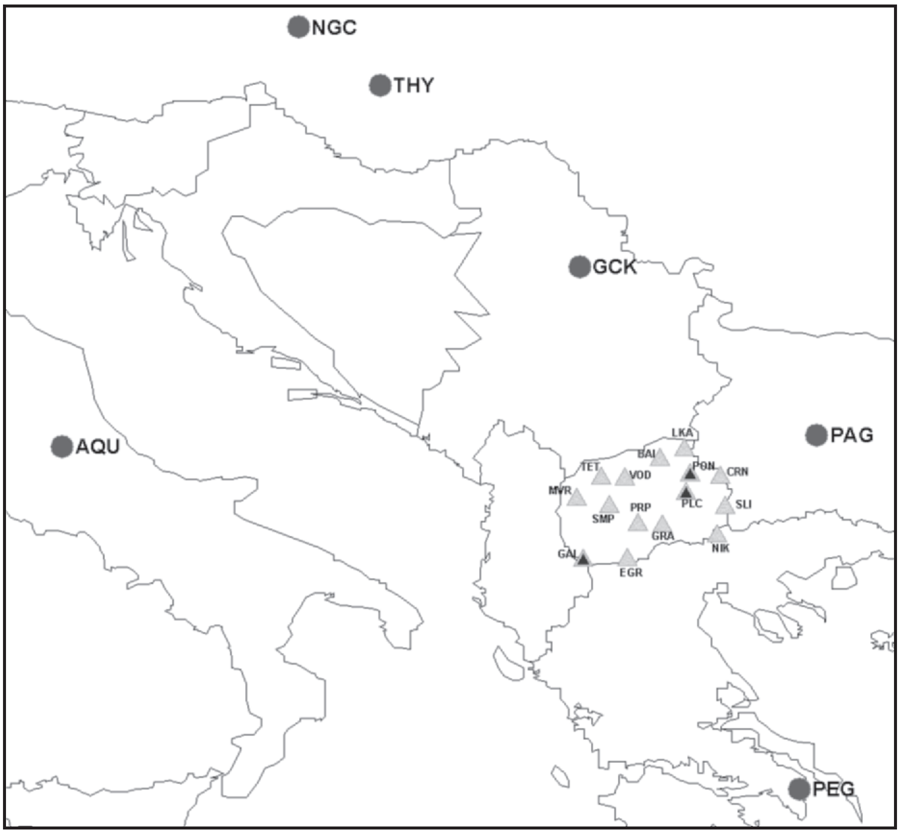

Figure 60. Map of the repeat station network created in 2003.

2.3. REOCCUPATION OF THE NETWORK IN 2004

The entire network mentioned in section 2.2 was reoccupied during August 2004. It was a short time span between the occupations but this allowed us to check the network and to strengthen the recently acquired skills of the Macedonian team.

3. Measuring the stations

3.1. LOGISTICS

The Faculty of Mining and Geology in Štip handled repeat station logistics. Transport between the stations and to the base locations was by car. Because the country of Macedonia is so small, its people know each other well. Consequently good contact persons were available throughout the country. The Faculty of Geology has alumni in every city in Macedonia, so we always found support and a warm welcome in the immediate vicinity of our repeat stations.

Base locations were in Štip, Kavadarci, and Ohrid. Typically we measured at one station in the morning and at another one in the afternoon. This was possible because of the short distances between stations. It was possible to measure the whole network of 15 stations in 3 weeks time, including 1/2 week for preparation and 1/2 week for preliminary data processing.

3.2. INSTRUMENTS

We used the instruments from the Dourbes Observatory fieldwork pool. The equipment were thoroughly checked and calibrated before leaving Dourbes. We had the following instrumentation list:

- <u>Proton magnetometer G816</u>. We favour this device because it is simple to use yet robust and accurate. The electrical supply is provided by D-cell batteries which are readily available.
- <u>Zeiss 010 Diflux (Mingeo demagnetisation) with Pandect fluxgate sensor</u>. This is our preferred DIflux because of its 1" accuracy and convenient telescope which allows easy and fast sunshots for azimuth determination.
- <u>Zeiss tripod (non-magnetic)</u>
- <u>Adapter bracket to mount proton magnetometer sensor on tripod</u>. This bracket is necessary to ensure that the total field measurement and the D and I measurements are made at the same location.
- <u>Level for tripod rough levelling</u>. This level comes in handy for positioning the tripod over the station mark with its bearing plate roughly levelled.
- <u>Telescope with internal compass display (KVH DATASCOPE)</u>. This instrument facilitates finding targets when setting up the stations or

when revisiting them. The KVH is convenient, fast, and provides approximate magnetic azimuths. See Figure 61.

- Coudés (90° eyepieces) for Zeiss 010 Telescope and Microscope (non-magnetic). Coudés are necessary to sight elevated targets, like the Sun at midday. See Figure 61. If coudés are not available (they are hard to find nowadays) then sighting of the Sun can be done in the morning after sunrise or in the late afternoon before sunset.
- Solar filter for sunshots. See Figure 61. This small optical device is needed to make sunshots with the Zeiss 010 theodolite. An experienced observer will take about the same amount of time for sighting the Sun as for sighting the target. Therefore, this method is much cheaper and faster than other gyro or GPS-based methods, and have similar accuracy - provided the Sun is visible.

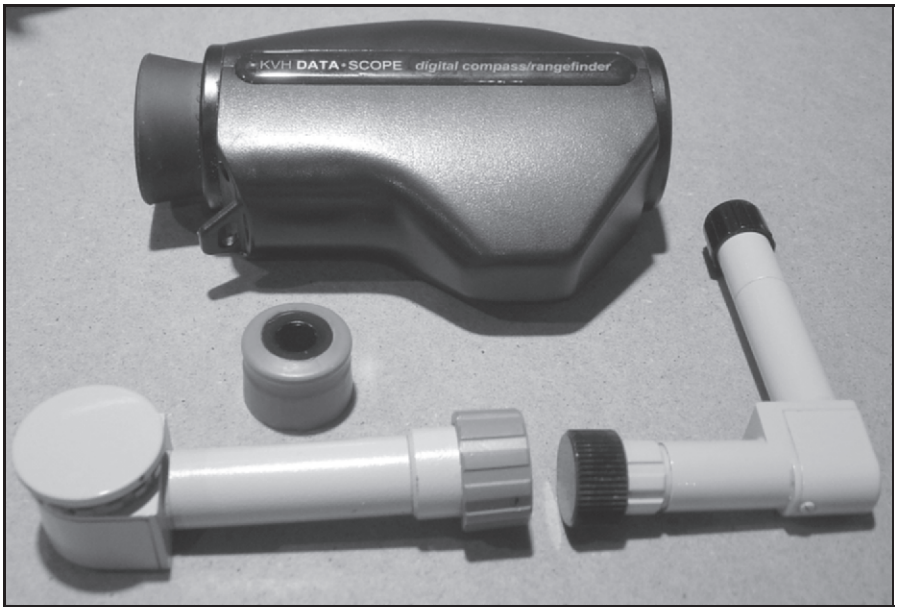

Figure 61. The KVH DATASCOPE Telescope with internal magnetic compass displays the magnetic azimuth of the telescope's optical axis. Also shown are the coudé eyepieces and the solar filter. Essential components for successful sunshots.

- FLM3/A fluxgate electronics with GPS receiver and battery. This device, looks like a small suitcase (Figure 62). It was designed and built by Dourbes instrumentation lab and has 4 functions:
    - o Holds the fluxgate electronics and digital readout.
    - o It contains a GPS receiver giving UTC time, lat/long, and elevation information.

- o It has a battery for powering the above mentioned devices.
- o It has a carrying case for the ZEISS 010 DIflux. The FLM3/A can be operated closed with the readouts and switches accessible. The cover provides waterproof protection for the battery and electronic circuits during measurements.

Figure 62. The ZEISS 010B DIflux with FLM3/A fluxgate electronics and GPS receiver.

- Aluminium Markers. Permanent markers should be set into the ground at each repeat station. The line between the permanent marker and the azimuth mark will have a known azimuth after the sunshot measurements have been calculated. Markers should be nonmagnetic. They should be easy to install but difficult to remove. They should be easily found in overgrown vegetation, yet should not attract too much attention. Finally, they should be durable but not made of expensive materials. The best markers are ground level pillars made of nonmagnetic stone or concrete with engravings on the emergent surface. Unfortunately these monuments are cumbersome and difficult to install. For our network we used 25 mm diameter, aluminium rods which were driven into the ground with a hammer and painted blue. The problem with using these was that people removed them to get the valuable aluminium.

- Sledge-hammer. This is a necessary tool for driving markers into the ground. In Macedonia the ground is not soft and is often stony. We used a 10 kg hammer successfully, but we had to be careful not to leave it in the vicinity when measuring the magnetic field!

3.3. OBSERVATION TECHNIQUES

Based upon past experience in measuring at repeat stations, we have refined our procedures for the Macedonian network.

- With only 2 weeks to make measurements, we wanted to streamline our operations without compromising accuracy. Therefore we opted for geodetic azimuth measurements by sunshots. (Macedonia is sunny in the summer so we expected the clear skies required for sunshots.) In fact we were only twice deprived of them. Also, we limited the magnetic measurements to a maximum of 4 independent sessions, unless a problem developed during the session at the station and we had to do more.
- Measurements were done in early morning and/or late afternoon, because these times favour elimination of the daily variation differential between the station and observatory used for the reduction. Also, accuracy of sunshot measurements are improved since theodolite levelling errors are reduced and sunshots can be made without coudés (90° eyepieces) since the sun is low in the sky.
- A preliminary proton magnetometer survey was performed before occupying each station to check the magnitude of the horizontal and vertical gradients to rule out magnetic pollution at the site.
- The standard DIflux 12 step session (protocol): 2 x target, 4 x D, 2 x targets, 4 x I was used. This protocol is very strict and eliminates almost all DIflux and theodolite dimensional and mechanical errors.

- We selected distant (>5 km) targets. Far away targets provide high accuracy orientation in space for declination measurements. The only drawback to them is that they are difficult to observe in hazy weather; therefore, an additional, closer target should be established as a back-up.

An example of a sunshot measurement session follows for the target at the repeat station in Ponikva. The target is the centre of the left tower of the right building of a Bulgarian border post at 35° magnetic azimuth. The following text must be entered in the basic program for processing sunshot data (Rasson 2005). Note that the Zeiss 010A DIflux has a circle graduation in grads. A total of 6 independent sunshots sets with circle left/right are given so that a standard deviation can be calculated.

Time of the shot (hh.mmssd): 06.0950
Horizontal circle reading of sunshot (grades): 176.5044
Horizontal circle reading of target sighting (grades): 108.7860
Latitude of sunshot (sdd.mmss): 42.0135
Longitude of sunshot (sddd.mmss) (! sign: - E longitude, + W): -22.2130
GW sidereal time @ 00:00 UT: 21.46474
Right Ascension for Sun on the sunshot day @ 00:00 UT: 9.50384
Right Ascension for Sun on the next day @ 00:00 UT: 9.54214
Declination for Sun on the sunshot day @ 00:00 UT: 13.0331
Declination for Sun on the next day @ 00:00 UT: 12.4400
*** Sun azimuth: 096 ° 13 ' 28 " *** Target azimuth: 35°16'40 "
*** Sun azimuth: 096 ° 29 ' 39 " *** Target azimuth: 35°16'44"
*** Sun azimuth: 098 ° 33 ' 11 " *** Target azimuth: 35°16'57"
*** Sun azimuth: 098 ° 49 ' 06 " *** Target azimuth: 35°16'45"
*** Sun azimuth: 100 ° 36 ' 44 " *** Target azimuth: 35°16'28"
*** Sun azimuth: 100 ° 59 ' 21 " *** Target azimuth: 35°16'24"
*** Sun azimuth: 103 ° 50 ' 21 " *** Target azimuth: 35°16'50"
*** Sun azimuth: 104 ° 11 ' 7 " *** Target azimuth: 35°16'22"
*** Sun azimuth: 106 ° 41 ' 22 " *** Target azimuth: 35°16'33"
*** Sun azimuth: 106 ° 55 ' 39 " *** Target azimuth: 35°16'42"
*** Sun azimuth: 108 ° 41 ' 03 " *** Target azimuth: 35°16'39"
*** Sun azimuth: 109 ° 00 ' 48 " *** Target azimuth: 35°16'33"
Target azimuth final result (mean): 35°16'38" standard deviation = 10”

4. Calculations

4.1. REDUCTION TECHNIQUE

Magnetic observatories are in operation in neighbouring countries, so we decided to use their data to reduce our field instantaneous data to annual mean data. We had to wait until the observatories published their definitive data, about typically 6 months after the year end.

The data reduction procedures and formulae follow:
Given that the repeat survey gives us a measurement of *D* in station *Stat* at the epoch *t*:

$$D_{Stat}(t)$$

and that a nearby Observatory *Obs* supplies us with a measurement in the observatory at the same epoch *t* :

$$D_{Obs}(t)$$

as well as an annual mean in the observatory for epoch *a*:

$$\overline{D_{Obs}}(a)$$

We want to calculate the annual mean in the station *Stat* for epoch *a*:

$$\overline{D_{Stat}}(a)$$

We postulate that:

$$\overline{D_{Stat}}(a) - \overline{D_{Obs}}(a) = D_{Stat}(t) - D_{Obs}(t) \qquad (1)$$

Hence we find the annual means at epoch *a* at station *Stat* for the component *D*:

$$\overline{D_{Stat}}(a) = D_{Stat}(t) - D_{Obs}(t) + \overline{D_{Obs}}(a) \qquad (2)$$

The validity of the above postulate (1) depends mainly on the differential in daily variation between *Stat* and *Obs* and hence is influenced by:

- Distance in longitude and latitude between *Stat* and *Obs*
- Geomagnetic Field activity
- Time in the day
- t – a

We performed this reduction for each measured component. Data from several observatories were used to reduce repeat station measurements:

L'Aquila, Italy (AQU),
Pedeli, Greece, (PEG),
Grocka, Serbia, and Montenegro (we could not get the data for 2003),
Tihany, Hungary, (THY),
Nagycenk, Hungary (NGC) and
Panagyurishte, Bulgaria (PAG).

Each reduction provides an annual mean. In an ideal situation where the postulate is correct and there are no measurement errors, the same annual means should be calculated regardless of which observatory was used to reduce the data. But of course this is not the real situation. We believe that inspection of the magnitude of the differences between means will be a good evaluation of the quality of the measurements and in how far the postulate (1) is valid.

Table 8. Summary of the Declination measurements at the repeat station Santa-Maria Precesna on august 9th 2003 and the differences with the synchronously measured declination at neighboring observatories.

Time UTC	Declination measurement at location:						Difference in Declination between *Stat* and Observatory				
	Stat	AQU	PEG	NGC	THY	PAG	Stat-AQU	Stat-PEG	Stat-NGC	Stat-THY	Stat-PAG
13:42		1.784	3.198	2.600	2.779	3.184					
13:43		1.785	3.200	2.602	2.781	3.184					
13:45		1.782	3.198	2.598	2.778	3.184					
13:46		1.782	3.198	2.598	2.777	3.184					
Mean:	3.035	1.783	3.199	2.600	2.779	3.184	1.252	-0.163	0.436	0.257	-0.149
Session #2											
14:18		1.804	3.220	2.637	2.818	3.218					
14:19		1.806	3.222	2.638	2.820	3.218					
14:21		1.806	3.222	2.637	2.819	3.218					
14:22		1.805	3.222	2.637	2.819	3.218					
Mean:	3.062	1.805	3.221	2.637	2.819	3.218	1.257	-0.159	0.425	0.243	-0.155
Session #3											
14:50		1.805	3.220	2.640	2.820	3.218					
14:53		1.809	3.222	2.643	2.824	3.218					
14:58		1.807	3.222	2.643	2.823	3.218					
15:00		1.809	3.223	2.645	2.825	3.218					
Mean:	3.067	1.808	3.222	2.643	2.823	3.218	1.260	-0.155	0.424	0.244	-0.150
Session #4											
15:23		1.814	3.223	2.652	2.831	3.218					
15:25		1.811	3.223	2.647	2.827	3.218					
15:26		1.811	3.223	2.647	2.827	3.218					
15:27		1.812	3.225	2.648	2.829	3.218					
Mean:	3.068	1.812	3.224	2.648	2.828	3.218	1.256	-0.156	0.420	0.240	-0.149
Final result, average of all sessions:							**1.256**	**-0.158**	**0.426**	**0.246**	**-0.151**

AQU: l'Aquila (IT), PEG: Pedeli GR), NGC: Nagycenk (HU), THY: Tihany (HU), PAG: Panagyurishte (BG)

The differences in annual means at the station *Stat* can be statistically processed to deliver the final value as an average, and a standard deviation is also computed. The standard deviation was our principal evaluation tool torank the quality of each station.

We believe this procedure is better than computing the standard deviation of the successive field measurements reduced to one observatory only. But, our method is only possible if many observatories encircle the repeat stations and it involves more work.

To illustrate our reduction method we include tables of the August 2003 measurements from the Macedonian repeat station "Santa Maria Precesna" in the mountains North of Makedonski Brod and the subsequent reduction data from the neighbouring observatories.

In Table 8, four sessions of declination measurements are listed for the Santa Maria Precesna repeat station. The declination values observed for the same epoch at the neighbouring observatories are listed. In the last five columns, the differences between repeat station and observatory observations are indicated and the mean of each session is also given. Those values will be added to the observatory annual mean to produce the Station annual mean.

In Table 9 the repeat station annual means, at the stated epoch, are calculated. To assess the quality of the observations we inspected the column headed by "At Station by reducing on", there we found essentially the same annual mean values of the declination. The low standard deviation (0.006°) shows the excellent reduction we obtained using the various neighboring observatories and confirms the good quality of our measurements and validity of the postulate (1). The standard deviations for the reduction to annual means of Inclination and total field were 0.004° and 2.2 nT respectively.

Table 9. Final result for the annual mean of magnetic declination at the station Santa-Maria Precesna for epoch 2003.5.

2003.5 Declination Annual Means [°]											
At Observatories					At Station by reducing on					**At Station**	
AQU	PEG	NGC	THY	PAG	AQU	PEG	NGC	THY	PAG	**Average**	StanDev
1.833	*3.233*	*2.660*	*2.843*	*3.231*	*3.089*	*3.076*	*3.086*	*3.089*	*3.081*	***3.084***	*0.006*

Not all reductions were so successful; however, observations from the Egri repeat station were made close to local noon during a period of high diurnal variation of the magnetic field at the Pedeli and l'Aquila observatories (Figure 63). The data reduction is not as good as from Santa-Maria Precesna (where observations were made when the diurnal activity was lower). At the Egri repeat station, the standard deviation for the annual means reduction to the neighboring observatories was 0.037°, 0.014° and 7.5 nT, respectively, for D, I and F.

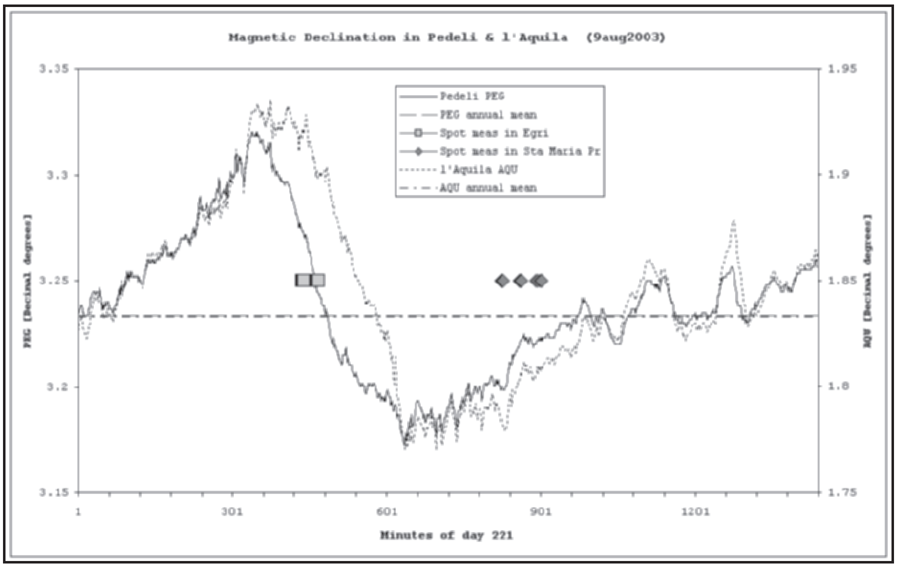

Figure 63. Diagram showing the diurnal variation as measured at l'Aquila and Pedeli. The squares and diamonds indicate the epoch (not the value) of the measurements made at Egri and Santa-Maria Precesna repeat stations in Macedonia.

4.2. FIRST RESULTS

Our goal was to obtain the three magnetic elements D, I and F for all the magnetic repeat stations, evaluating the accuracy of the measurements using the method explained above. Results are given in Table 10.

Table 10. Final results for the Macedonian repeat stations magnetic elements reduced to annual means for 2003.5. The standard deviation calculated from the annual means reduction to the neighboring observatories AQU, PEG, NGC, THY, and PAG is also shown.

Repeat Station @ 2003.5		Coordinates WGS84		**Total Field** [nT]		**Inclination** [°]		***Declination*** *[°]*	
Code	Locality	Long	Lat	Mean	st dev	Mean	st dev	Mean	*st dev*
BAI	BAILOVCE	42.221	21.921	**46723.5**	3.2	**59.248**	0.013	**2.918**	*0.026*
CRN	CRNA SKALA	41.995	22.791	**46886.4**	4.8	**58.883**	0.005	**3.188**	*0.017*
EGR	EGRI	40.966	21.448	**46399.2**	7.4	**57.748**	0.014	**3.004**	*0.037*
GAL	GALICICA	40.956	20.814	**46264.7**	2.8	**57.694**	0.005	**2.881**	*0.027*
GRA	GRADOT island	41.388	21.952	**46414.2**	5.0	**58.079**	0.015	**3.535**	*0.025*
LKA	LUKA	42.344	22.275	**47015.4**	4.2	**59.387**	0.006	**3.265**	*0.011*
MVR	MAVROVO	41.716	20.727	**46533.8**	4.2	**58.564**	0.010	**2.977**	*0.015*

Repeat Station @ 2003.5		Coordinates WGS84		**Total Field** [nT]		**Inclination** [°]		***Declination*** *[°]*	
Code	Locality	Long	Lat	Mean	st dev	Mean	st dev	Mean	*st dev*
NIK	NIKOLIC	41.265	22.743	**46569.5**	3.2	**58.197**	0.002	**3.078**	*0.006*
PLC	PLACKOVICA	41.795	22.304	**46645.9**	3.1	**58.618**	0.004	**3.162**	*0.010*
PON	PONIKVA	42.026	22.358	**46799.8**	1.9	**58.987**	0.003	**2.821**	*0.015*
PRP	PRILEP lake	41.403	21.609	**46634.6**	5.6	**58.275**	0.009	**3.042**	*0.013*
SLI	SLIVNICA	41.615	22.863	**46665.4**	4.7	**58.499**	0.006	**3.381**	*0.008*
SMP	ST MARIA PRE	41.627	21.193	**46532.1**	2.2	**58.444**	0.004	**3.084**	*0.006*
TET	TETOVO	41.986	21.079	**46717.7**	2.4	**58.757**	0.003	**3.109**	*0.005*
VOD	*VODNO*	*41.978*	*21.416*	***46712.3***	*2.6*	***58.789***	*0.002*	***3.199***	*0.009*

To extrapolate the data to cover he entire Macedonian territory, the normal field must be calculated and a gridding program such as Surfer used. Isogonal maps can then be drawn and used for aeronautical applications. These maps can be found elsewhere in this Volume.

Stations have been reoccupied regularly and measurements are now available for 2002 and 2004. The secular variation of the components can now be studied in the absence of an active observatory. Once the network is well established and the Macedonian observers are familiar with procedures, a reoccupation schedule of 2 years should be adopted.

5. Quality checks

Checking the quality of the data is important, especially for a new network, where extrapolation of the past data cannot be used to spot errors. Therefore any time a quality check can be done it should be done. We have identified the following ways to detect errors:

- Check true north determination. An error in the determination of True North is difficult to spot, unless it is large. If the sunshot method is used, care should be taken to make several fully independent measurements well spaced in time. During post-processing of the sunshots, any error will show up as a wandering direction for supposed true North. For instance, an error in time or in longitude will show up as a shifting value of the target's azimuth with the Sun's apparent motion. In the first years of the network, sunshots should be repeated and results checked for similarity with previous year's determinations. The use of the KVH compass telescope also guards additionally against large azimuth errors.

- Examine Diflux collimation errors. The so-called DIflux collimation and magnetisation errors should remain constant, if the DIflux is treated carefully and is not subjected to shocks and/or sensor position adjustment. A collimation error outside the norm indicates a bad declination or inclination measurement. Because we make a minimum of 4 complete measurements, it is possible (at reduction time) to simply discard a bad value and use only good values.
- Examine the field differences between the Station and the nearby Observatory. These differences should remain fairly constant, especially if the Observatory is close (distance < 500km) and at the same longitude because the diurnal variation will then be similar. This is a powerful error finder. We were able to detect errors in the *nearby Observatory* data, because we were sure of the correctness of repeat station measurements when checked using other observatories!
- Examine secular variation. If data is available at the station for previous years, use it to compute the secular variation. Detection of anomalies in the latter may point to measurement errors.
- Examine reduction data and standard deviation. If values are significantly different and standard deviation large, errors may exist. This is probably the most sophisticated way in detecting anomalous measurements. Measurement errors of all types will dramatically increase the standard deviation like the one displayed in Table 10.

6. The Future

The repeat station network in Macedonia should be connected to networks in neighbouring countries. During this Advanced Research Workshop this goal is being addressed. Further, the network should be integrated into the recently created MagNetE project, which plans the coordination of European magnetic repeat stations and the creation of a European database.

The network data should be used in providing magnetic services and products to Macedonian airports and other aeronautical agencies.

Finally, construction of a Macedonian magnetic observatory at the Plackovica repeat station site should improve reduction procedures and provide important geomagnetic data.

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DISCUSSION

Question (Angelo De Santis): Your opinion is that in Macedonia it is not relevant to use a variometer to reduce repeat station data to nighttime. This is because of the vicinity of observatories from neighboring countries and because of the possible temperature drift of a fluxgate magnetometer that could affect the diurnal variation recorded. Have you considered the possibility to install a proton magnetometer continuously recording in a fixed centered site of the country in order to have a stable check at least of the reduction of total intensity?
Answer (Jean Rasson): Yes it is true that the mediocre performance of a variometer after its first days of installation make me think it is not worth the effort of the additional instrumentation cost and logistics. However a proton magnetometer should not be affected by this drawback.

But the results obtained show that the reduction of our total field measurements to the proton magnetometers of 5 nearby observatories agree within a few nT (stan.dev. of 2.2nT mentioned in 4.1). The use of a dedicated proton magnetometer recording in the center of Macedonia would only marginally improve this deviation, and is hence not deemed necessary.
Question (Valery Korepanov): Your opinion: is it better to make repeat surveys with variometers or without?
Answer (Jean Rasson): My opinion is to do repeat surveys without a local variometer. I believe it is better in terms of accuracy, speed, simplicity and cost to measure in conditions where the diurnal variation is absent or negligibly small at both the repeat station and the Observatory(ies) serving for data reduction. This may imply measurements at dusk or dawn or even night measurements.
Question (Alan Berarducci): What is distance to observatories used for data reduction?
Answer (Jean Rasson): The approximate distances from the center of the Republic of Macedonia to the various observatories (see Figure 60) used in the repeat station data reductions are:

PAG	225	km
PEG	435	km
GCK	335	km
THY	655	km
NGC	770	km
AQU	700	km

Question (J. Miquel Torta): Have you found different deviations from the mean depending on the distance between the repeat station and the observatory used to reduce the data?

Answer (Jean Rasson): No, we did not see any obvious correlation.