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Systematic Magnetic Observations in Italy

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A b s t r a c t

Istituto Nazionale di Geofisica e Vulcanologia (INGV) is responsible for systematic magnetic observations in Italy made in observatories and repeat stations. At present, two regularly working geomagnetic observatories cover central and northern Italy: L'Aquila (the main Italian observatory since 1958) and Castello Tesino (since 1964). A new observatory is, at the moment, being installed in the southern Mediterranean (near Sicily) at Lampedusa Island. Once this installation is successfully completed, the three observatories will be able to provide a full coverage of the whole Italian latitudinal extension.

A network of magnetic repeat stations is regularly distributed across Italy and measurements in some locations have been made for more than a century. Since the end of the 1970's, INGV has been developing a modern repeat station network used for the compilation of the Italian magnetic maps. The most recent survey was made between 2004 and 2005 using L'Aquila Observatory as reference.

1. Introduction

The history of geomagnetic measurements in Italy dates back to 1640 when the Fathers Borri and Martini made the first magnetic survey by measuring the values of declination at 21 sites, but it was only in 1880 that the idea of funding an Italian geomagnetic observatory was first proposed. Before the foundation of L'Aquila geomagnetic observatory in 1958 for the International Geophysical Year by *Istituto Nazionale di Geofisica e Vulcanologia* (INGV), the Italian national research institute devoted to the study of geophysics, the geomagnetic field in Italy was measured at the observatory of Pola (1880-1925), in the Istria Peninsula (now Croatia), and then at the observatory of Castellaccio (1932-1962), near Genova, maintained by *Istituto Idrografico*

della Marina. Therefore, an almost complete time series starting in 1880 is available for the horizontal component *H* and declination *D* (see Cafarella *et al*. 1992). Now, nearly at the fiftieth anniversary of L'Aquila observatory, INGV is in charge of systematic magnetic field observations in Italy. This task is accomplished by both running geomagnetic observatories and by periodically measuring the field at several repeat stations. At present, there are two geomagnetic observatories regularly running on the Italian territory: L'Aquila (central Italy) and Castello Tesino (northern Italy). In the near future the observatories will become three with the addition of the forthcoming observatory of Lampedusa Island in the southern Mediterranean, that is being tested at this time. In order to give a complete overview of the geomagnetic field observation activities the next two sections illustrate, respectively, the main features of each observatory and the Italian magnetic network in some detail; the last section summarises some future development of our observation activities and equipments.

2. The Italian Geomagnetic Observatories

As already mentioned, the three geomagnetic observatories (for simplicity we will refer to Lampedusa as if it were a real running observatory), extend latitudinally as shown in Fig. 1. At present only L'Aquila (IAGA code AQU) complies with the standards for Intermagnet observatories. We plan also to have Castello Tesino (IAGA code CTS) and Lampedusa (LMP) to follow the strict standards required for the observatories of the Intermagnet network also in matter of absolute measurements, so that they could provide data to the whole geomagnetic community regularly. This could happen, for instance, when procedures for automatic absolute measurements will be available. In fact, at this time Castello Tesino and Lampedusa are not manned and only occasionally absolute measurements are made by visiting staff. Each of the three observatories has pillars for absolute measurements and more than an azimuth mark is available. Absolute values of declination and inclination are measured by means of a standard magnetic theodolite (DI-flux). An idea of the short and long term time variability of the geomagnetic field in Italy can be given by Fig. 2: the left panel summarises the daily variations recorded at the three sites of L'Aquila, Castello Tesino and Lampedusa during a quiet day, the right panels show the secular variation recorded at L'Aquila and Castello Tesino for *H*, *D*, *Z* and *F*.

2.1 L'Aquila geomagnetic observatory

L'Aquila geomagnetic observatory (geographical latitude and longitude 42°23′ N and 13°19′ E; altitude 682 m a.s.l.; corrected geomagnetic latitude 36°19′ N at 2006.0) is the main Italian magnetic observatory since 1958. The observatory consists of four amagnetic buildings. Two of these are devoted to host variometers and to perform absolute measurements while the others are for laboratories and general service buildings. Differently from Castello Tesino and Lampedusa observatories, L'Aquila is manned and absolute measurements are performed several times a week by on-site personnel.

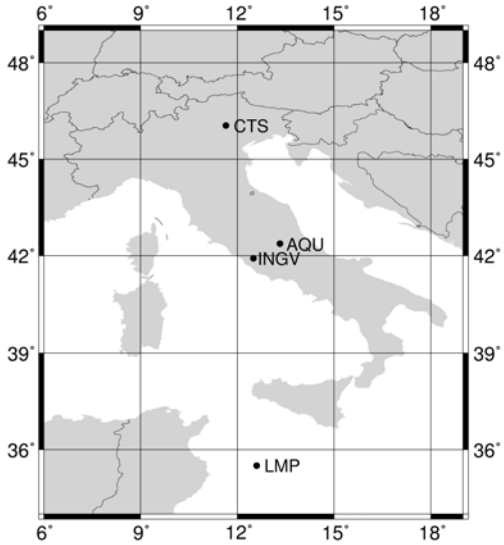

Fig. 1. Location of the head office of INGV in Rome, and of the geomagnetic observatories: Castello Tesino (IAGA code CTS), L'Aquila (IAGA code AQU) and Lampedusa (LMP).

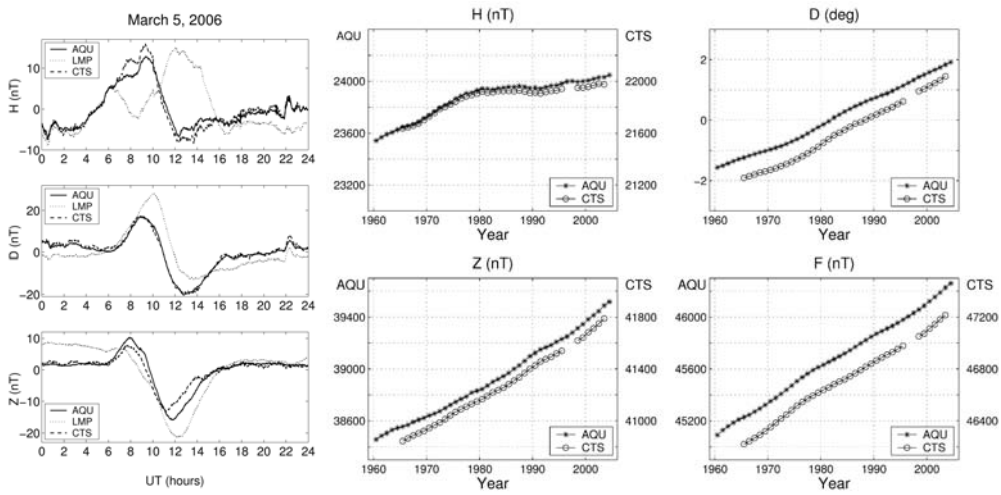

Fig. 2. Left panel: a comparison among the daily variations of the three Italian observatories during a magnetically quiet day. Right panels: secular variation for L'Aquila and Castello Tesino observatories.

Variation measurements of *H*, *D* and *Z* are made by means of three independent systems contemporarily running: two three-axial fluxgate magnetometers (one with toroidal and the other with linear sensors) and a two-axial fluxgate magnetometer for the measurement of *D* and *I*, all supported by a proton magnetometer for the measurement of total intensity *F*. Measurements of *H*, *D*, *Z* and *F* are also made by a proton precession vector magnetometer with a resolution of 0.1 nT. All these measuring systems have a sampling rate of 1 sec. An accurate time mark of the measurements is

guaranteed by the use of GPS on all systems. Besides the traditional monitoring of the geomagnetic field, at L'Aquila other observations are performed such as pulsation recording, radiometer measurements in the ULF, ELF and VLF bands, magnetotelluric field measurements and telluric self potential measurements. The observatory provides magnetic variation data for the study of the distribution and morphology of pulsations, magnetic storms and all short period transient magnetic variations. L'Aquila staff also provides for the operation and maintenance of a magnetic network for the detection of magnetic field changes due to tectonomagnetic effects. The network is located in Central Italy, it consists of four magnetic stations for long term measurement of total magnetic field, by means of proton precession magnetometers.

As already mentioned, L'Aquila observatory has been participating to the Intermagnet network since 1999. For this purpose a dedicated three-axial fluxgate magnetometer acquisition system has been realized at INGV. It has an excellent long-term stability and a good sensitivity. The core of the coils is a torus made of Vitrovax 60/25 that is an amorphous material with a glass structure.

On the web site of INGV real time L'Aquila magnetograms, real time automated *K* indices estimated with the FMI (Finnish Meteorological Institute) method (Pirjola *et al*. 1990, Sucksdorff *et al*. 1991), manually calculated *K* indices and annual means are available (http://www.ingv.it/geomag/laquila.htm). Besides this online data publication, since 1960 the yearbook of this observatory, compiled with data from the proton precession vector magnetometer, has been regularly published.

2.2 Castello Tesino geomagnetic observatory

The observatory of Castello Tesino is located in North-eastern Italy (geographical coordinates 46°03′ N, 11°39′ E, altitude 1175 m a.s.l.; corrected geomagnetic latitude 40°50′ N at 2006.0) and since 1964 it has been working almost continuously. It was designed to run automatically and to be remotely checked from the INGV head office in Rome. The observatory consists of three amagnetic stone buildings: one is for absolute measurements, one for the automatic digital systems (personal computers, instruments and sensors) and the last is a general services building (UPS, LAN devices as hubs and routers).

The variations of *H*, *D* and *Z* components are measured by two independent systems consisting of two three-axial fluxgate magnetometers and stored on two different personal computers. One system consists of a fluxgate magnetometer LEMI-008i (resolution of 0.1 nT) built at Lviv Centre of the Institute of Space Research (Ukraine) connected to a personal computer that allows real time data downloading. This is possible due to its connection to the INGV LAN by means of a high speed connection. The second system comprises a vector magnetometer built at INGV laboratories connected to another personal computer; data coming from this second system are downloaded daily via modem. This magnetometer will be soon substituted with the more modern meteomagnetic station LEMI-017. Total field intensity is monitored by means of an Overhauser magnetometer (GEM-GSM19). All the sensors (the two fluxgate and the Overhauser magnetometer sensors) are located in a room equipped with a non magnetic heater connected to a thermostat. The two acquisition systems store both

1-minute and 1-second sampled data into daily files. To guarantee a precise time mark of the measurements, each computer is equipped with a GPS providing real UT. One minute sampled data coming from both systems can be viewed through the INGV internet pages (http://www.ingv.it/geomag/ctesino.htm) where daily magnetograms are available.

At present, at the observatory also a fluxgate magnetometer property of the Space Research Institute of the Austrian Academy of Sciences (in the framework of the CHIMAG network, see http://saturn.iwf.oeaw.ac.at/iwfmag/chimag/) is hosted. These data, together with those from the other instruments of the network, are used to study magnetic field line resonances.

2.3 Lampedusa geomagnetic station

On Lampedusa Island – south of Sicily – a geomagnetic observatory is now being installed (geographical latitude and longitude 35°31′ N and 12°32′ E; altitude 35 m a.s.l.; corrected geomagnetic latitude 27°25′ N at 2006.0). Until now, it has undergone a series of different tests implying also changes in the magnetic instruments or in the acquisition systems in order to find the optimal configuration. These tests have begun at the end of 2005 when the first instruments were installed; the observatory will probably start running in its final configuration in 2007.

The observatory consists of a small stone building with a wooden roof containing all the automatic digital systems. The sensors are buried in thermically isolated boxes just outside the building. At present the observatory is equipped with an Overhauser magnetometer for the total intensity of the field (GEM System, Canada) and a vectorial flux-gate magnetometer (EDA FM100/B, Canada) for the variations of *H*, *D* and *Z*. When properly operating, this new observatory will be the most southern European observatory and, together with L'Aquila and Castello Tesino, will allow peculiar mid-latitude magnetic studies like for example the study of the local drift of the ionospheric focus currents (responsible for the daily variation). Moreover, it is located inside a protected natural reserve with the advantage of a very low electromagnetic noise level. From a practical point of view, the disadvantage of this location is the absence of any kind of service (electric supply and telephone line). Consequently electric power is now supplied by four solar photovoltaic panels and the instruments are connected to a special acquisition unit able to store data and to provide communication and file transmission via GSM connection.

3. The Italian magnetic repeat station network

Since the end of 1970's, INGV has systematically made magnetic field measurements in Italy with the main purpose of elaborating magnetic cartography. These measurements are repeated at intervals of five years at a number of repeat stations which constitute the Italian Magnetic Network. To maintain the degree of detail needed to take into account the shape of the Italian peninsula and islands, the first order network is made of 110 main points distributed on a regular grid with an average spacing of about 58 km. Repeat stations, regularly distributed over the Italian territory

and integrated by geomagnetic observatories, allow the determination of the spatial structure and the time variation of the Earth's magnetic field over Italy.

The most recent survey took approximately one year (September 2004 – November 2005) and was reduced to 2005.0 using the observatory of L'Aquila as reference; the corresponding magnetic maps are in press. The number of repeat stations is 133 including the two observatories, thus reaching a station density of about one station on 2800 km^2. The number has grown since in the same period magnetic measurements were made also outside Italy, in collaboration with other research institutes or universities. In particular in Albania measurements were made on 11 repeat stations (in collaboration with the National Academy of the Sciences of Albania and with the Tirana University) and in Corsica on 3 repeat stations (in agreement with the *Institut de Physique du Globe de Paris – IPGP*). All these measurements have been included in the elaboration of cartography, as well as of secular variation and normal fields, thus contributing to a better definition of the magnetic field spatial and temporal variation in the Ionian and Tyrrhenian areas. The left panel of Fig. 3 shows the location of the main points of the first order magnetic Italian network, the right panel shows the magnetic inclination map for epoch 2005.0.

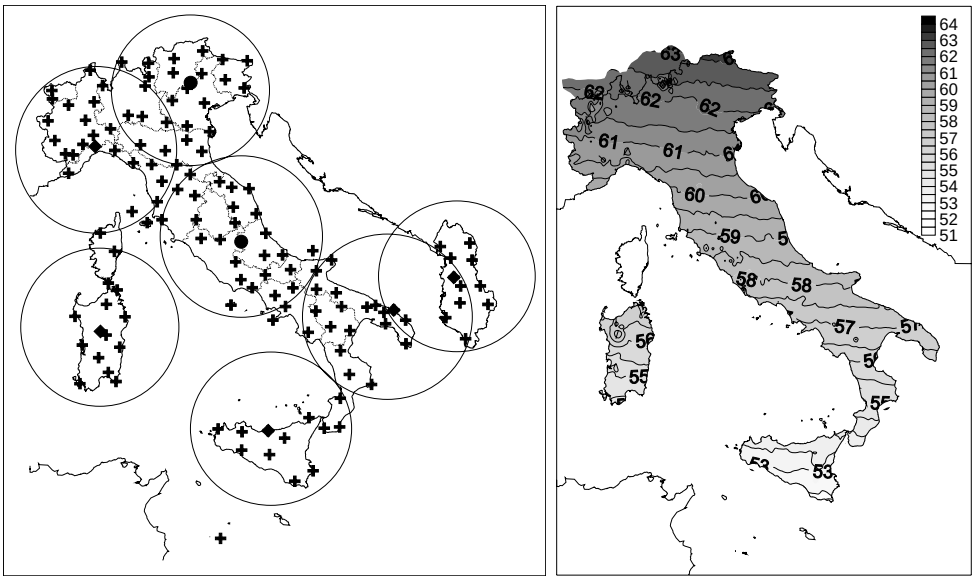

Fig. 3. Left panel: repeat stations (crosses); observatories (circles); temporary stations (diamonds). The circumferences specify the coverage for the estimation of rapid time variation of the geomagnetic field and are centred on observatories and temporary stations. Right panel: magnetic inclination *I* (in degrees) over Italy for epoch 2005.0.

An edition of three magnetic maps to the scale 1/1,500,000 (one map for each element: *F*, *H* and *Z*) was published at 1979.0. At the same date also a magnetic anomaly map of total field was published (Molina *et al*. 1994). The 1979.0 survey was updated in collaboration with IGM (*Istituto Geografico Militare*) and also declination

was remeasured at all repeat stations, bringing to a four magnetic maps collection (*F*, *H*, *Z* and *D*) to the scale 1/2000000 (Arca *et al*. 1988). In the following years the regular updating of the magnetic measurements was made by INGV only for scientific purposes without the involvement of IGM for the compilation of the corresponding new magnetic maps (Meloni *et al*. 1994, De Santis *et al*. 1997). New maps were available at 2000.0 (Coticchia *et al*. 2001) and the maps from the last survey referred to 2005.0 will appear soon.

4. The Future of Magnetic Measurements in Italy

Geomagnetic observatories record continuously and over long term the time variation of the Earth's magnetic field and maintain the accurate absolute standard of the measurements. Reaching the highest possible accuracy is an important goal in geomagnetic measurements since phenomena such as secular variation and impulses in the secular variation have amplitudes of few nanoteslas. Moreover, only magnetic observatory data can allow a comprehensive modelling of the geomagnetic field, not only from a mathematical standpoint but also on a physical basis, necessary to distinguish and physically represent all sources of the measured geomagnetic field correctly.

Activities planned for the near future will be devoted to improvements in instruments and operations in both observatories and networks. For what concerns observatories activities they will involve in particular the displacement of the instruments of Castello Tesino observatory in a new building about a hundred meters far from the present one and, of course, the completion of the installation of Lampedusa observatory.

The Intermagnet standard is now the excellence for geomagnetic observatories. In Italy this is so far achieved only at L'Aquila. We have the reasonable expectation to upgrade progressively also the other two structures of Castello Tesino and Lampedusa to this standard.

What concerns the magnetic repeat station activities and the consequent normal field (an analytical expression of second order degree polynomial type, in latitude and longitude) computation and maps production for the Italian region, we expect to reasonably proceed with the five years survey, in time with IGRF new generations. Moreover, developments in this activity will also follow the new coordination of European networks recently created, MAGNET (acronym of Magnetic Network in Europe), to which Italy has adhered putting its results in common with other European nations.

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