The contribution of L'Aquila (Italy) Geomagnetic Observatory to MAGDAS project

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Abstract: The geomagnetic Observatory of L'Aquila (Italy) was founded by Istituto Nazionale di Geofisica e Vulcanologia (INGV) in 1958, on the occasion of the International Geophysical Year. It is the main Italian geomagnetic observatory. Since 1999 L'Aquila Observatory belongs to the Intermagnet system, an International network grouping worldwide geomagnetic observatories able to provide Earth's magnetic field measurements according to precise quality standards. Geomagnetic field measurements in L'Aquila are used to study the variations of the Earth's geomagnetic field, both of internal and external origin. In November 2008 a new magnetometer was installed in L'Aquila within the MAGDAS project, coordinated by SERC. The location of this installation can be useful to complete the MAGDAS monitoring system to study solar-terrestrial events.

Keywords: Geomagnetic observatories, MAGDAS, geomagnetic variations, MHD waves, solar wind-magnetosphere interaction

Introduction

Italian Istituto Nazionale di Geofisica e Vulcanologia (INGV) runs the principal Italian geomagnetic observatory, located in L'Aquila (IAGA observatory code: AQU; geographic coordinates: 42°23'N, 13°19'E, 682 m a.s.l.; corrected geomagnetic coordinates: 36.3°N; 87.3°E). AQU observatory is fundamental for continuous monitoring of the geomagnetic field in Italy and is the reference for local surveys; it was built during the International Geophysical Year (1958) and is in operation since 1959, when began the standard activity of measuring the absolute values of the geomagnetic field and its variations [1].

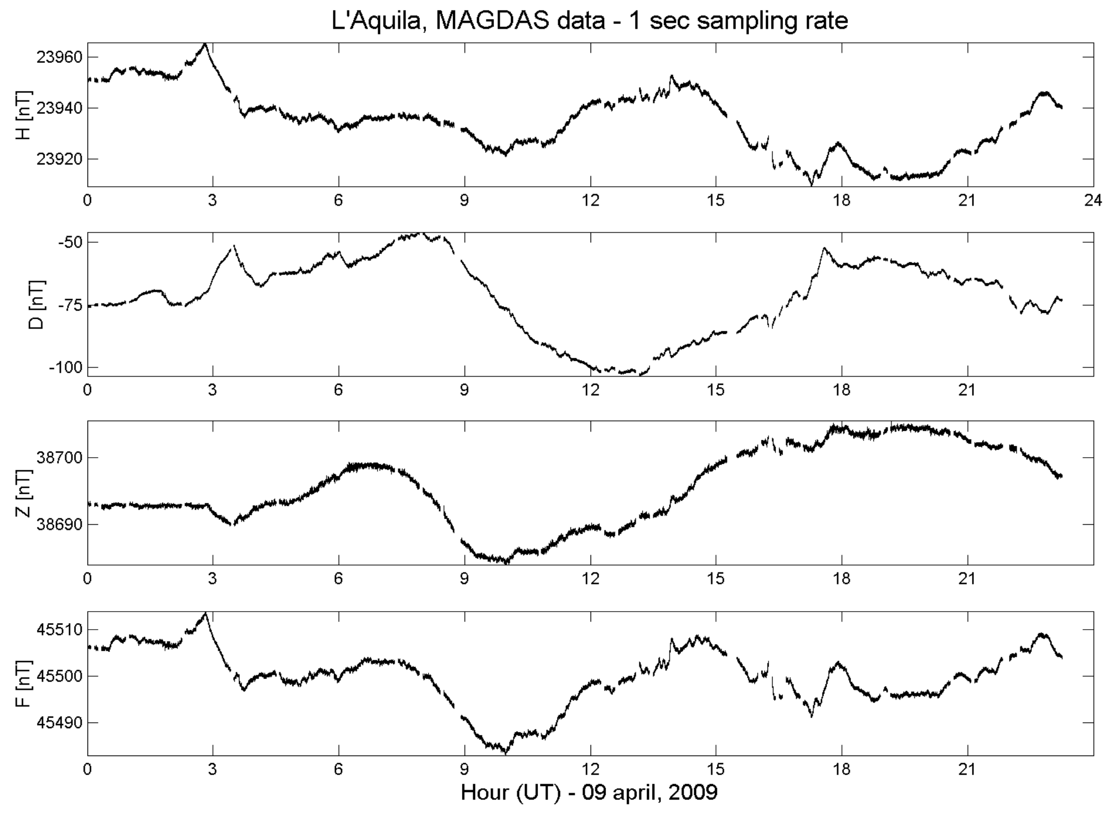

Fig.1. Example of daily magnetogram of 1 sec data from MAGDAS magnetometer at AQU.

The observatory consists of five stone, amagnetic buildings: absolute measurements, variograph, laboratory, pulsation and service building. Variation measurements are made by means of at least two independent systems contemporarily running, with a sampling rate of 1 sec; absolute measurements are carried out by on-site personnel about twice a week with a magnetic theodolite and are used to calculate the base lines of magnetic variations. Real time data from AQU, together with K index, are available on the web (www.ingv.it), where daily magnetograms of 1 min data (obtained from 5 sec measurements filtered with a Gauss filter) are shown. Since 1999, AQU observatory is part of INTERMAGNET (International Real-time Magnetic Observatory Network; www.intermagnet.org), a worldwide database which collects data from the principal geomagnetic observatories fulfilling strict requirements on data quality (accuracy, resolution, long term stability, timekeeping, etc). In November 2008 a new magnetometer was installed in L'Aquila within the MAGDAS project, coordinated by SERC (Figure 1; http://magdas.serc.kyushu-u.ac.jp; [2-5]). The location of this installation is particularly interesting within the MAGDAS monitoring system to study solar-terrestrial events in that it is the highest latitude magnetometer of the MAGDAS 96° MM chain and is almost magnetically conjugate to the installation in Maputo (Mozambique; corrected geomagnetic coordinates: 36.0°S; 99.6°E).

Scientific applications of AQU geomagnetic data

Data from a geomagnetic observatory can be used for a variety of scientific applications; in particular, AQU data have been widely used to study the temporal variations of the geomagnetic field and their generation mechanisms [6]; together with data from other worldwide observatories, to elaborate global models of the geomagnetic field, such as IGRF (International Geomagnetic Reference Field); together with data from repeat stations to compile magnetic maps [7]; to study possible electromagnetic signals related to earthquakes [8].

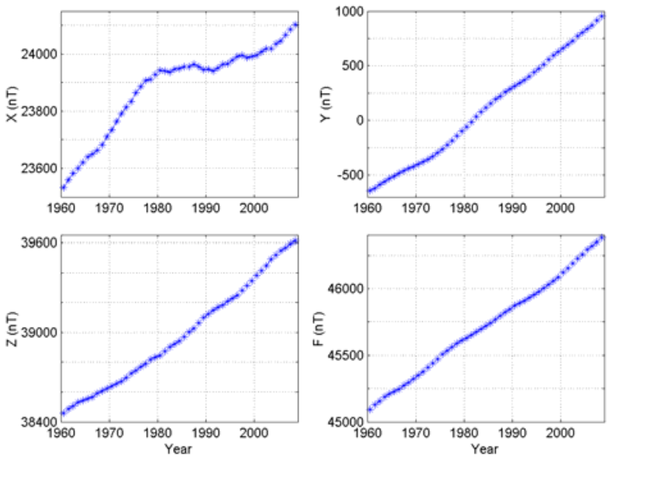

Fig.2. Long term variation of the geomagnetic field components (X: geographic northward; Y: eastward, Z:vertically down) and of the total intensity F at AQU. Data points are yearly

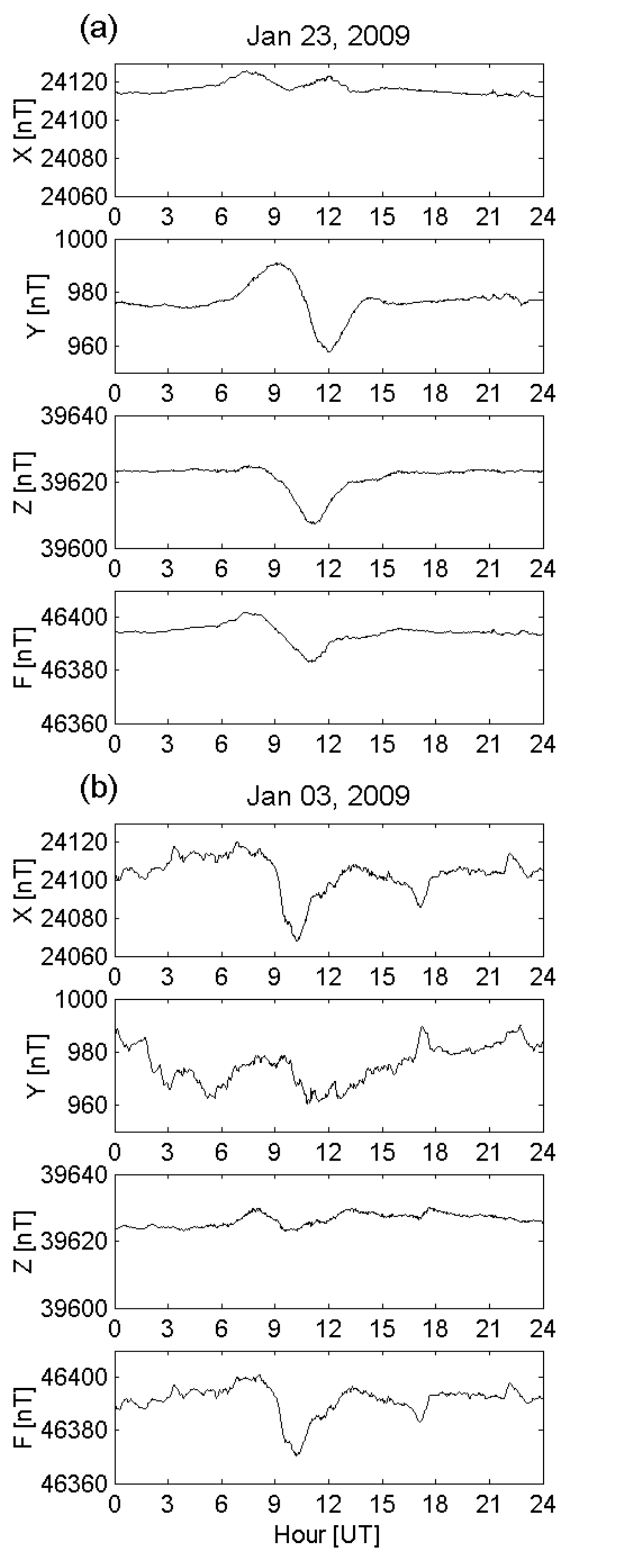

Fig.3. Daily magnetograms at AQU during a quiet (a) and a disturbed (b) day.

Regarding temporal variations of the geomagnetic field, they can be divided in two main groups: of internal origin and of external origin, with respect to the Earth's surface, generally corresponding to longer (more than a about decade) and shorter time periods, respectively.

Figure 2 shows the long term variation of the geomagnetic field components and of the total field intensity F recorded at AQU since 1960; this variation, of the order of tens nT/year, can be set in the context of the geomagnetic field secular variation [9].

A shorter term geomagnetic variation, typical of low-mid latitudes, is the daily variation, a 24-hr modulation with amplitude of tens of nT [10, 11]; this variation, which is clearly observed during quiet days (Figure 3a), is due to an electrical current system in the dayside ionosphere, fixed with respect to the Sun-Earth line, under which any observation point on the Earth's surface rotates every 24-hrs. On disturbed days, more irregular, higher frequency variations, are predominant (Figure 3b).

Among magnetic field variations typical of active periods, there are geomagnetic pulsations, which are fluctuations with periods ranging from seconds to minutes, triggered by the solar wind (SW). Observations of geomagnetic pulsations at AQU have shown evidence for ULF ground signatures of different kind of pulsations, related to different generation mechanisms. In the following we will show some results obtained in the mid (Pc3-4 pulsations; f=7-100 mHz) and low frequency range (Pc5 pulsations, f=2-7 mHz).

Mid frequency pulsations can be triggered by the penetration in the magnetosphere of upstream waves, which are ULF fluctuations generated by SW ions reflected back by the Earth's bow shock through a ion-cyclotron instability mechanism; these waves are characterized by a linear relation between their frequency and the strength of the interplanetary magnetic field (IMF; see the review [12]). An analysis of the frequency of selected pulsation packets at AQU during variable IMF conditions (Figure 4) has shown that their frequency is linearly related to the IMF strength, which gives a strong evidence for upstream origin of the observed pulsations [13].

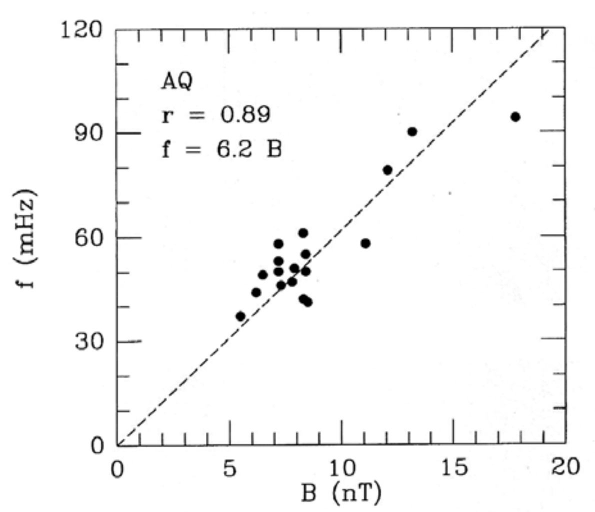

Fig.4. Relation between frequency of pulsations packets at AQU and IMF strength [adapted from 13].

Interplanetary shocks impacting the magnetosphere can be an additional source of pulsations; indeed, they can trigger resonant phenomena, such as field line resonances or magnetospheric cavity/waveguide modes. Field line resonances are standing oscillations of the magnetospheric field lines [review 14], which can be excited by any external broadband source containing the corresponding resonant frequency, which is latitude dependent and at AQU is of the order of 80 mHz. Magnetospheric cavity/waveguide modes are global oscillations of the entire cavity between an outer boundary, such as the magnetopause, and an inner turning point [15]; they are at discrete frequencies, of the order of few mHz (around 1.3, 1.9, 2.5 mHz), and are typically observed at auroral latitudes [16]. A statistical analysis of AQU data has shown during daytime hours power peaks at discrete frequencies, more evident during high SW pressure conditions (Figure 5), which have been interpreted in terms of ground signatures of magnetospheric cavity modes [17].

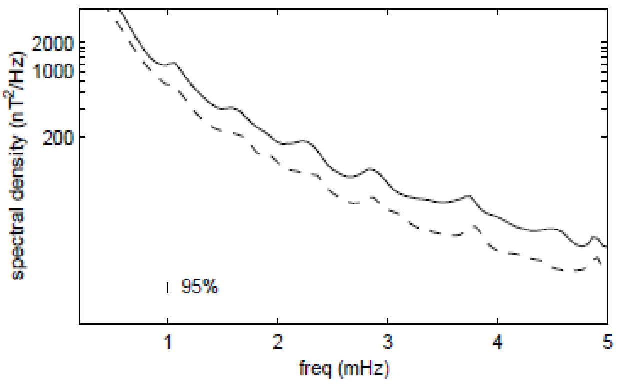

Fig.5. Average power spectra of the two horizontal components at AQU during high SW pressure conditions [17].

The analysis of simultaneous ground observations at widely spaced stations in both hemispheres during a pulsation event triggered by th Earth's passage of a coronal mass ejection, has shown that the same oscillation mode was detected in a major portion of the magnetosphere (Figure 6, left panels); the spectral analysis (Figure 6, right panels) shows that two major power peaks emerge at all stations, around 3.2 and 4.2 mHz; this result has allowed to ascertain the global character of the observed pulsations and to strengthen their interpretation as global magnetospheric modes [18].

Data from AQU observatory have been used also to study possible electromagnetic signals related to earthquakes [19-21 and references therein]; recently, these studies have focused to search magnetic anomalies in correspondence of the Ml=5.8 earthquake which struck the city of L'Aquila, with an epicenter 6 Km from the geomagnetic observatory, on 6 April, 2009 [22,23]. Using data from AQU and from another geomagnetic observatory situated at 130 Km distance from AQU, the residual magnetic field was estimated by means of the inter-station impulse response functions. It was obtained (Figure 7) that extremely feeble magnetic signals (0.1-0.2 nT) were emitted in correspondence of the arrival of the P seismic waves, at 0132 UT.

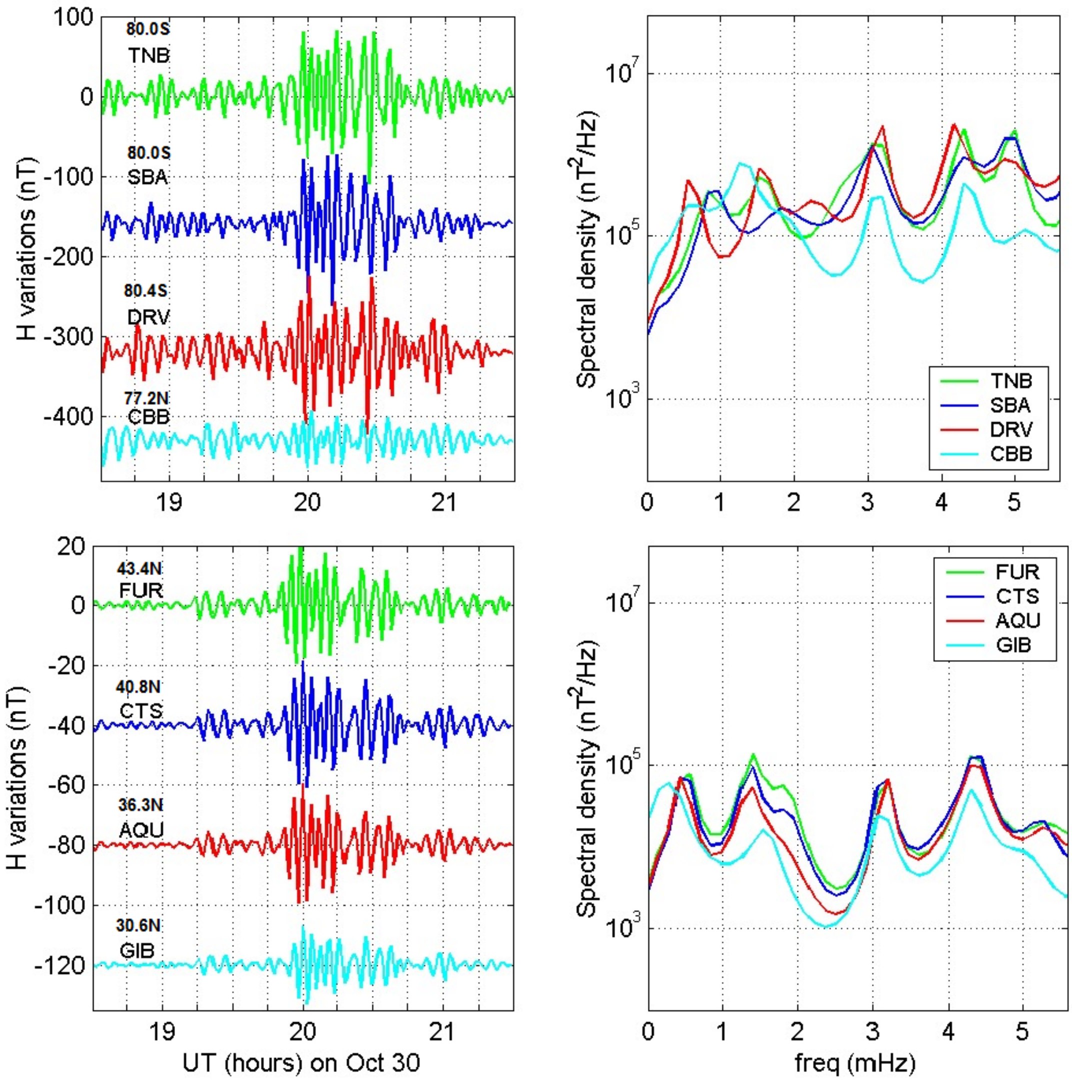

Fig.6. Example Left panels: the 2.5-5 mHz filtered data on 30 Oct., 2003; right panels: power spectra (1930-2130 UT). Upper plots show data from polar cap stations (TNB, SBA; DRV in Antarctica, CBB in the northern hemisphere), lower plots from mid latitude European stations, including AQU. In the left plots, the IGRF 2003 corrected geomagnetic latitude of the stations is indicated. [Adapted from 18].

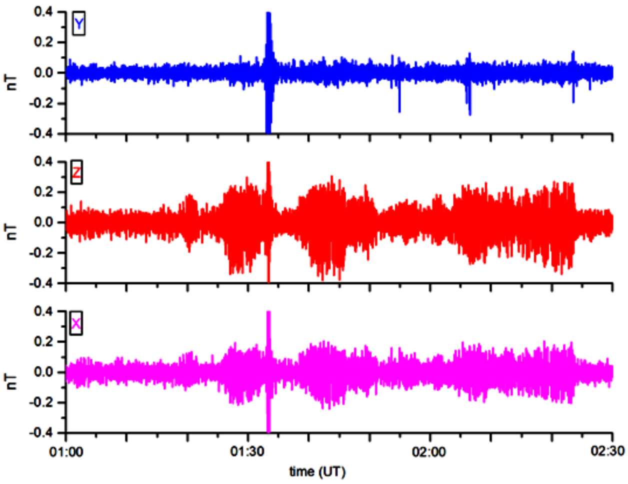

Fig.7. Residual field at AQU depurated from inductive and external fields on 6 April, 2009, in a time interval around the 0132 UT earthquake.

In conclusion, we have shown that geomagnetic field continuous measurements are fundamental for different scientific studies and practical applications. In this context, the geomagnetic observatory of AQU is in operation since 1959, is part of the INTERMAGNET network since 1999 and hosts a MAGDAS station since 2008. AQU data have been widely used for studies of geomagnetic field, both of internal origin and in the context of space weather. For this kind of studies data exchange and the availability of data in real time are fundamental, and this the reason for the establishment of geomagnetic global networks. The location of AQU within MAGDAS monitoring system is peculiar in that it extends the 96° MM chain to higher latitudes and is almost magnetically conjugate to an installation in the southern hemisphere.

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