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Construction and start-up of the Edea magnetic observatory, Cameroon

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Abstract. The Edea magnetic observatory (IAGA code: EDA) is located in Cameroon between the two biggest cities of the country: Yaounde and Douala. It is situated at 2600 km of the nearest magnetic observatory, TSU, Namibia. Following the closure of Bangui observatory, Edea area became an important site for magnetic measurements. A joint effort by the “Institut de Physique du Globe de Paris” (IPGP) and the “Institut de Recherches Géologiques et Minières” (IRGM) of Cameroon was undertaken, starting from 2018 in order to create the observatory with the goal to provide real-time data access. This paper presents a description of the site, the details of the construction of the observatory and the installation of the instruments.

1 Introduction

15 In order to follow up the evolution of the earth magnetic field, magnetic stations and observatories have been created around the world. Most of them are in Europe and in North America. One of the aims is to observe and understand the electric current flowing in the ionosphere layer and convection movements in the Earth's core. It is therefore necessary to have observatories over the Earth. Following the loss of the magnetic observatory at Bangui in Central African Republic in 2011 (IAGA code: BNG) and at Addis-Ababa in Ethiopia in 2016 (IAGA code: AAE), few observatories in Africa are operational (Fig. 1).

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Figure 1: Magnetic observatories in Africa. In grey, observatories closed and, in red, those operational in 2021. Those circled in yellow are managed by the Bureau Central de Magnétisme Terrestre (BCMT, www.bcmt.fr) along with local institutes. Those circled in blue belong to Namibia and South Africa (copyright 2022 Google maps).

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The closest observatories to the equatorial electrojet in Africa are located in Tamanrasset, Algeria, created in 1935 by the Institut de physique du globe d'Alger (IAGA code: TAM) and in M'Bour, Senegal, created in 1952 by the Office pour la recherche scientifique outre-mer named now "Institut de Recherche pour le Développement" (IRD) (IAGA code: MBO). Due to the lack of magnetic observatory in the area, and thanks to the collaboration with the IRGM, a magnetic observatory could be set up in a suitable location, in Edea, Cameroon. In this paper, we will show the different steps of the building and the starting up of this magnetic observatory.

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2 Edea city, history of the site with the CTBTO

The Edea city is located on either side of the River Sanaga in the Littoral Region of Cameroon, along the Yaounde – Douala highway, some 65 kilometers from Douala, the main commercial city of Cameroon. Edea is accessible by road and train lies on the railway line and the main motorable highway connecting Douala and Yaounde.

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Edea hosts one of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) International Monitoring System (IMS) station. CTBT is the Treaty banning any nuclear activities within the world. Although the Comprehensive Nuclear – Test – Ban Treaty Organization's (CTBTO) headquarters are in Vienna, the procurement activities are global in scope since the IMS stations spread across the globe.

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The initial choice for the location of the IMS station in Cameroon was Douala which did not meet the technical requirements for the installation of the station. CTBTO and IRGM finally selected Edea after a preliminary and an on – site survey of 3 alternative sites near Douala town, Edea included.

The construction of the infrastructure to host the IMS Edea station started in early 2007 after the acquisition of 1.7 hectare of land in 2006. The main components that constitute the infrastructure include the auxiliary power generator housing, the VSAT platform, the fence, the air sampler and equipment housing. The station presently, operational with 2 technologies, the Particulate station (CMP13) and the Noble Gas station (CMX13) were certified in November 2007 and October 2013 respectively. Quite recently, with the permission of CTBTO, IRGM and IPG Paris have installed at this IMS station Edea, a magnetic observatory.

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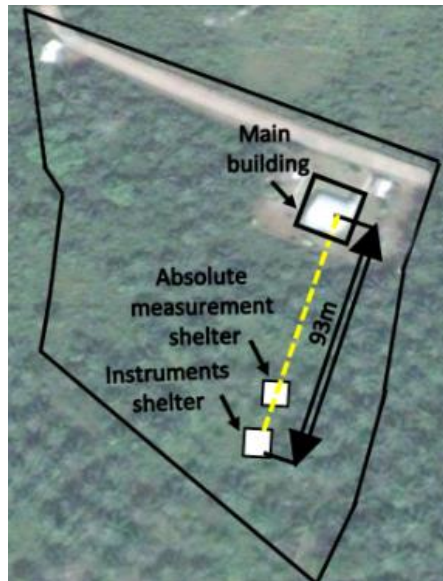
3 Observatory infrastructure

Before building a magnetic observatory, it is important to ensure that the magnetic environment around the future magnetic observatory is and will be stable in the future. It is necessary to investigate about projects of constructions, buildings or road close to the observatory which can create some noise and steps on the data.

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For the location found at the CTBTO site, we performed magnetic surveys using a GEM Systems GSM-19 scalar magnetometer. It allows to discard any magnetic anomalies on the site. These anomalies could be related to geological inhomogeneities or existing installations. The surveys were set on a 50 m² zone far from infrastructures and human activities, when the magnetic field was not agitated to obtain stable data. The recorded data was downloaded and compared to models like World Magnetic Model (State of the geomagnetic field, 2021) or the International Geomagnetic Reference Field (Alken et al., 2021) to check if there are no anomalies on the site (<https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml>). The site being viable, we were able to start designing the observatory's infrastructure.

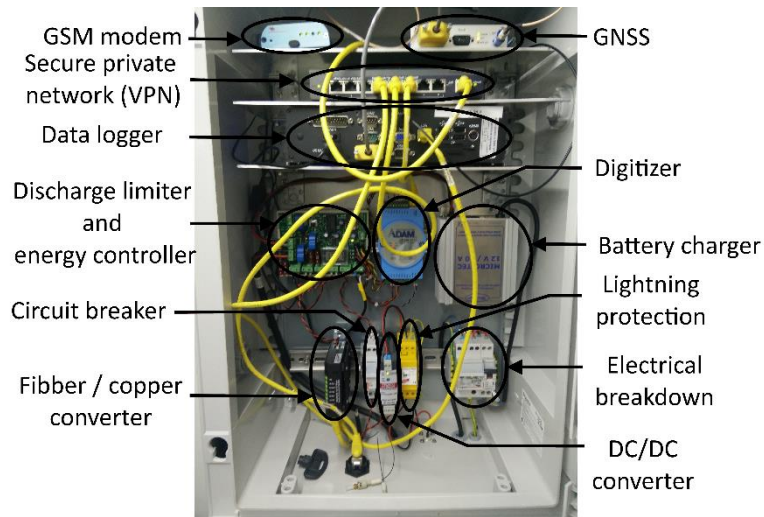
60 We decided to install two magnetometers, a vector and a scalar, at a distance of 93 meters from the main building for power and communication connections and far enough from disturbances like power generators, cars and human activities (Fig. 2). The scalar magnetometer provides separate measurements of the absolute F, and also served as a reference to compare with the fluxgate vector data which measure F on three axes, (Reay S et al., 2010).



65 **Figure 2: Site map of the Edea magnetic observatory (copyright 2022 Google maps).**

The main building houses the CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization) devices and staff accommodation. It contains an air-conditioned shelter where our equipment are installed: a data logger for data acquisition, a GSM modem and a VPN for data transmission, GPS for time stamping, fiber optic/copper converter for the communication, DC/DC converter 12V/24V to avoid too high a voltage drop between the main building and the instruments shelter, circuits breaker, discharge limiter, lightning protection, electrical breakdown limiter, battery charger and a battery to manage the energy (Fig. 3).

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Figure 3: Equipment of our electrical box in the main building.

A screen is installed to allow the observer to see the observatory magnetogram in real-time (Fig. 4).



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Figure 4: Electrical box in the left and the visualization of magnetograms in the main building.

The magnetic sensors are in a 3.6x1.1m non-magnetic/composite (Fig. 8). The scalar magnetometer, a GSM-90 (GEM-System) overhauser magnetometer, oriented East-West for best signal is installed at one extremity, on its aluminium support. At the other extremity, we installed a fluxgate vector magnetometer resting on a 25cm diameter pillar. In 2018, a LEMI-035 (LEMI LLC) was chosen. It provided good quality data in Chambon-La-Forêt during tests, but, in Edea we observed disturbances due

to proximity of the scalar magnetometer. The scalar magnetometer is closer to the vector magnetometer than in Chambon-La-Forêt. In 2019, a VM391 (IPGP) vector magnetometer which uses also the fluxgate technology was installed.

90 A local contractor was found to clean the land, dig holes for the concrete slabs and pillars. The base of the pillar is in concrete and the tube in fiberglass is hollow. We had to be particularly careful during this step to remove all nails and other metal to have non-magnetic material. Fiber-reinforced concrete was used (Fig. 5).



Figure 5: Creation of the vector magnetometer pillar on the left and absolute measurement pillar with a GPS to locate the place on a marble support on the right.

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Another slab and pillar have been installed 20 m away from the absolute measurement pillar.

The concrete dried, we installed the fibreglass container for the sensors on the slab. A marble support was fixed on the top of the pillar to rest the VM391. The scalar sensors were at a distance of 3 meters. The electronics of both magnetometers were installed in between to avoid disturbances. Once completed, we added a maximum of 5-litre water containers inside. The aim
100 is to increase temperature inertia.



Figure 6: Electrical box which provide energy for the magnetometers.

105 Electronic instruments are connected to a small electrical box close to the fiberglass container (Fig. 6). In this box we have a power management device. The data is sent to the main building through fiber optics.
We dug a trench over one hundred meters for power and data transmission to the main building where we installed our data logger.

4 Data transmission

110 Connected to batteries to ensure the continuity of recordings, our data logger box contains a digitizer to collect environment data like battery's current and voltage, and a charger to feed the batteries. We also have a Virtual Private Network (VPN) to secure and encrypt the connection by creating a private network from a public internet connection. We also installed a GPS modem for time stamping. A GPS synchronized data logger which is also battery power saved, records several types of data, mainly the 1-sec magnetic data, but also power consumption, temperature and some logs. These data are transmitted using a
115 3G modem to our server at Paris every hour using an HTTP file upload service. A real-time magnetic data transmission is also implemented using Earthworm software. Earthworm is the most widely used seismic data acquisition and automatic earthquake processing open source software for regional seismic networks (from www.earthwormcentral.org/) developed by the Instrumental Software Technologies, Inc. (ISTI).

At this stage, a magnetic station is functioning, but to reach the level of observatory, we do need absolute measurements.
120 Absolute measurements are needed to determine the vector magnetometer offsets and their long-term drift. To do so, we create a little noon-magnetic building located between the magnetometers and the main building.

5 Absolute measurement building

Two GPS were installed during the night on the absolute measurement pillar and close to the azimuth. The azimuth mark is installed on the main building, 80 meters from the pavilion of absolute measures. With these two GPS coordinates, we can
125 determine the angle between the geographic North and our azimuth and then extract the declination D and the inclination I of the observatory (Newitt et al., 1996).

We determined the following data of the observatory: the latitude is 3.779057° , the longitude is 10.153333° and the altitude: 35 meters.

To create the absolute measurement building, we designed a non-magnetic building which can protect the observer against bad
130 weather during the calibration measures (Fig. 7) and which can be easy to assemble. We had to fix the 4 walls of the pavilion on the slab, put the roof on this wall and install the door. The difficulty was to have a perfect angle between the walls to put easily the roof. Inside the pavilion are: a theodolite equipped with a single axis fluxgate magnetometer, the Mag-01 from (Bartington) and a scalar magnetometer, a G856 from Geometrics. The absolute measurement building is close to 10 meters from the magnetometers (Fig. 8).

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Figure 7: Inside the absolute measurement pavilion. On the left picture, the theodolite is resting on the absolute measurement pillar. On the right picture is seen the hole to aim the azimuth mark.

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Figure 8: On the first plan, the absolute measurement pavilion and in the background, the fibreglass container housing the sensors.

6 Data

Since 2019, Edea observatory provides data. These data are available on www.bcmt.fr under Creative Commons Attribution-Non Commercial 4.0 International License which allow to share and adapt the data for non-commercial use (https://creativecommons.org/licenses/by-nc/4.0). The VM391 three-axis and homocentric fluxgate magnetometer provides 1-second vector data (Chulliat et al., 2009). And the GSM-90 provides 5-second data within INTERMAGNET specificities (INTERMAGNET Technical Reference Manual, 2020) (Fig. 9).

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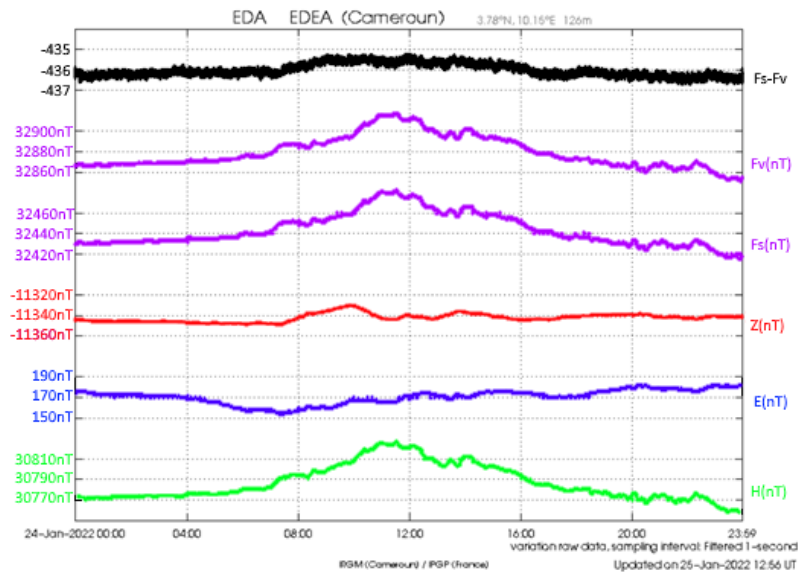


Figure 9: Magnetogram from the Edea observatory during 24th January 2022. H, E and Z (sampled every second) are the three components of the vector magnetometer, approximately oriented in the North, East and downward vertical directions. Fs (sampled

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every five seconds) is the measured scalar field from the GSM-90. F_v is the scalar field calculated from the vector components from the VM391. $F_s - F_v$ is the difference between these two magnetometers which are about 15 meters away.

Our VM391 provide data with 0.1 nT of resolution, a band pass to DC to 0.1 nT, and a thermal stability and a long-term drift respectively inferior to 0.25 nT/°C and 5 nT / year. The GSM-90 provides data with 0.2 nT of accuracy, and a long-term drift close to 0.05 nT / year. This pair of magnetometers has been deployed throughout the IPGP observatory network and is recognized by INTERMAGNET.

7 Absolute measures

One of the specificities of the Edea observatory is that observers make absolute measurement by night. Indeed, during the day, it is particularly difficult to do some measurement due to high temperature. We installed a few electricity poles to light the access road to the absolute measurement pavilion for the observers. The aim of this installation is to protect the observer against venomous animals like snakes. The electricity poles are solar powered.

Absolute measurements of the magnetic declination D and inclination I are taken by means of a non-magnetic theodolite with a fluxgate sensor mounted on its telescope that is nearly parallel to the optical axis (Brunke et al., 2018). The observatory is located in the geographical Northern Hemisphere but also located in the magnetic South Hemisphere. Therefore, measures have to be adapted to the magnetic South Hemisphere (Rasson, 2005). Since 2018, Edea's observer make absolute measurement, we can see the step created by the swap between the LEMI-035 and the VM391 (Fig. 10).

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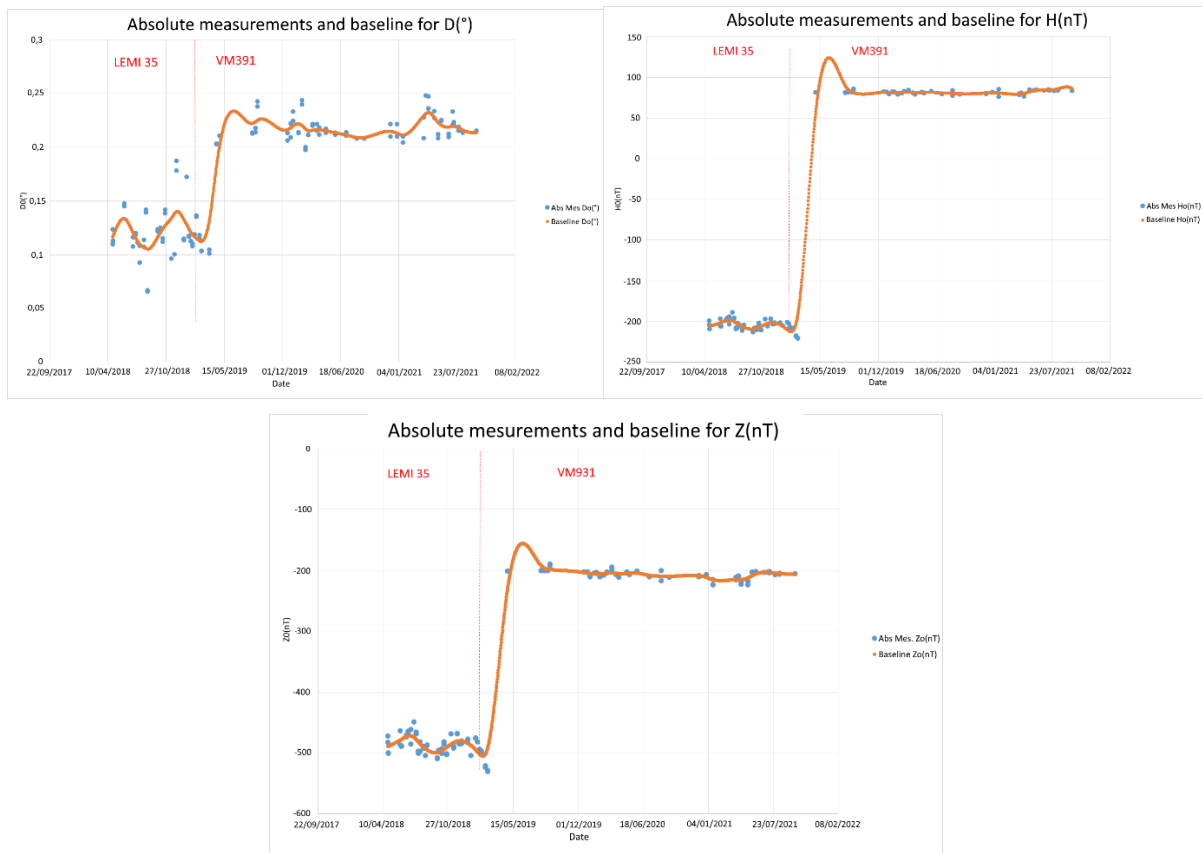


Figure 10: Baseline from the Edea observatory in 2018. From 2018 to April 2019, the LEMI-035 was installed and then swapped with the VM931. Blue dots are absolute measurements and orange lines are baseline for H(nT), D(°) and Z(nT).

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8 Problems encountered

One of the main difficulties for the installation was to protect the observatory from thunders. Cameroon is one of the countries with the most lightning strikes in the world. Our installation has been damaged in 2019 by thunder. To avoid this difficulty, a lightning protection in the data logger box and in the electrical box close to the magnetometers was installed. We also added a copper ground rod near to electrical box which provides energy for the magnetometers. This non-magnetic rod allows thunder to go directly to ground and avoid our equipment. To enhance lightning protection, an isolation transformer has been installed which allows to decouple the disturbances related to the electrical network and create our own electrical environment. In each electrical box a surge protector is installed (Protection Against Lightning Effects, 2009). In addition to fiber optics which ensure a protection for communication, lightning protection has been added directly to the magnetometer electronic boards such as fuses or transient voltage suppressor (TVS) diodes (Protection by TRANSIL, 2004).

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9 Conclusion

Since 2018, IPGP and IRGM have collaborated to set-up the Edea magnetic observatory. The observatory meets all the technical requirements to become a member of the INTERMAGNET network of magnetic observatories. Due to some difficulties to set regular absolute measurement, the observatory has not yet reached INTERMAGNET standards of weekly
190 measures. However, the observatory will change this status as soon as the quality of the absolute measurements are in constant progress. Therefore, the Edea observatory provides data, since April 2019, which allows creating a reasonable baseline.

Data availability. Magnetic observatory data used for this paper are available at the Bureau Central de Magnetisme Terrestre (BCMT) website (www.bcmt.fr) or on BCMT – Magnetic databank <https://doi.org/10.18715/BCMT.MAG.VAR> .

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Author contributions. TL built and started-up the EDA observatory, and wrote the article; JN manages the observatory locally and ensures the quality of the absolute measurement; AT manages the data acquisition and transmission.

Competing interests. The authors declare that they have no conflict of interest.

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