

# INDIGO: BETTER GEOMAGNETIC OBSERVATORIES WHERE WE NEED THEM

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## ABSTRACT

*Good magnetic observatories are needed more than ever for global modeling and navigation. Magnetic satellite missions, once said to be the death of ground based observations, are now demanding quality data from fixed observations points on the Earth.*

**Keywords:** Observatory, Geomagnetism, Magnetometer, Network, INDIGO

## 1 INTRODUCTION

A good magnetic observatory is a place where precise, continuous long-term measurements of the geomagnetic field are made and from where definitive data are regularly published to the wider scientific community. The INDIGO project (Riddick et al., 2009) aims to provide the means for achieving this goal in a selected set of places on the Earth. Equipment, software, training, and data processing, when missing on site, are given to colleagues worldwide so that they might improve or start their own geomagnetic observations. Usually existing premises are used and/or reconfigured to provide an adequate hosting of the INDIGO equipment (Figure 1). If necessary, local staff are trained in observatory operations and observing skills. We find that the installation of a successful observatory also depends on the motivation of the local observatory staff; with the help of the INDIGO project, most common problems can be overcome.

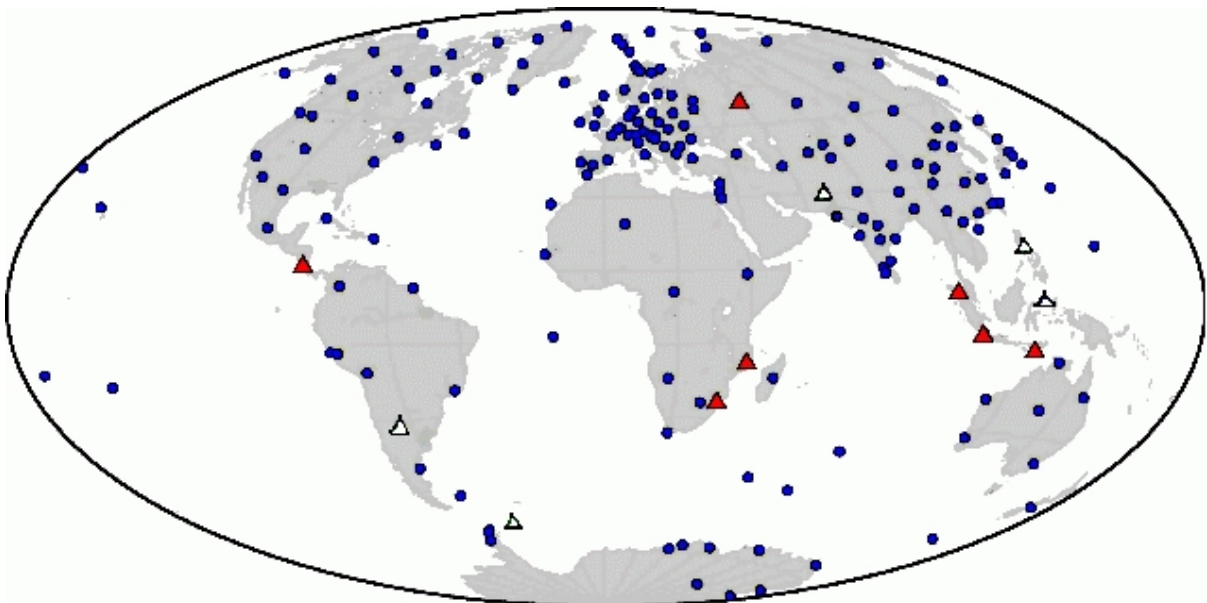
## 2 WHERE DO WE NEED THEM?

A state-of-the-art magnetic observatory is an expensive piece of infrastructure in equipment and in manpower since automatic observations are not possible at the moment. Therefore the good ones tend to be clustered in richer countries (Rasson et al., 2011). INDIGO tries to provide help where there are gaps in the observatories world map.

The INDIGO effort has therefore been directed towards Asia, Africa, and Latin-America; see Figure 2:



**Figure 1.** Pictures of INDIGO installations. Top left: Variometer house at Maputo, Mozambique; top right: the newly erected variometer house in Pelabuhan Ratu, Indonesia. Middle left: Arti observatory in Russia; middle right: the absolute house at Tondano, Indonesia. Bottom left: the new Kupang observatory in Timor-West, Indonesia; bottom right: the observatory of Chiripa, Costa Rica.



**Figure 2.** Location of the INDIGO observatories: Blue dots: existing observatories; red triangles: INDIGO installations; White triangles: projected installations

### 3 METHODS AND INSTRUMENTS

The original objective of the INDIGO project was to make use of fifteen EDA fluxgate variometers donated to the British Geological Survey (BGS), coupled with a low power digitiser to make filtered one-minute digital daily recordings.



**Figure 3.** Typical INDIGO hardware. Clockwise from top left: The EDA triaxial fluxgate sensor in Nampula, Mozambique; Absolutes in Nampula with a Ruska DIFlux and a Geometrics proton; DMI and GEM recording magnetometers in Kupang, Timor-W; EDA console and INDIGO logger in Maputo, Mozambique.

Use of the more precise and stable DMI variometer was later adopted for some installations. Absolute instruments like ZEISS, Ruska, and Tavistock DIFluxes as well as Geometrics and GEM proton magnetometers are used.

The digitizer is based on a 16 bits ADAM ADC module and a GPS receiver with all sampling controlled by a PIC16F877 microcontroller programmed in BASIC or C. It also controls the optional proton magnetometer.

The data logger is based on a JAVA platform. Usually a PC is used with two programs running in parallel: EDA2GDAS and GDASVIEW. The former communicates with the latter and with the digitizer so that filtering and formatting to various file formats (including INTERMAGNETs imfv1.22) is performed along with graphical display (Figure 3).

The connection between the logger and the PC can be by copper cable, optical fibre or HF radio.

More recently it was realized that it would be possible to do away with the PC altogether, by connecting a USB memory stick directly to the digitizer through a custom stick writer. This allows us to log the data in the required format without use of a PC. This results in huge savings in terms of power and cost and would allow a modest battery to power the system for days. Monitoring of the data log can be done on an optional PC running a new piece of java soft: INDIGOWatch.

## 4 DATA

The relative success of the INDIGO project has made possible the availability of its data to the scientific community. Although the definitive data has yet to be processed, preliminary results are encouraging. Variometer data has been delivered to commercial companies, and in situ absolute measurements have allowed the computation of annual means where none were available previously (notably South-East Asia). Figure 4 gives the statistics for the availability of data from INDIGO observatories.

The data is stored on a BGS server and is currently accessed with a password. There is also a website centralising all present and past data on the different INDIGO observatories: instruments in use, serial numbers, scale values, preliminary baselines, monthly bulletins, site plans, pictures, and history.



**Figure 4.** Data availability for INDIGO observatories. GIN stands for the Geomagnetic Information Node at Edinburgh.

## 5 OUTLOOK

The goal of INDIGO, at this stage, is the creation or upgrade of its magnetic observatories with INTERMAGNET certification. Our observatories have not yet reached the stage where the certification criteria can be met, but some are very close. The main short term objective is training the observatory staff in preparing their definitive data.

We have observatories actively involved in becoming INDIGOs: Quetta (Pakistan), Pilar and Orcadas-del-Sur (Argentina).

We foresee more observatories becoming involved, particularly in Africa where difficult conditions are threatening the operation of some of the few existing observatories. Such observatories often benefit from lower cultural noise in comparison to established Western observatories; they are far more sparsely distributed than Western observatories and are located close to regions of particular scientific interest such as the dip equator or South-Atlantic anomaly.

## 6 REFERENCES

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