Deployment of MAGDAS in Africa

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Abstract: The deployment of MAGDAS (MAGnetic Data Acquisition System) began in Africa in the Year 2006 with installations along the dip equator (or "geomagnetic equator") in three countries. In 2008, the 96 Deg. MM Chain was established, running from Hermanus, South Africa, to Fayum, Egypt. In 2010, a major upgrade was performed on the equatorial stations of MAGDAS.

Keywords: 210 degree, 96 degree, Capacity Building, MAGDAS, ISWI

1. Introduction

The overseas deployment of MAGDAS began in 2005 with the installation at Hualien, Taiwan. (The PI of the MAGDAS Project is Prof. K. Yumoto.) The description of the MAGDAS-I instrument, the scientific objectives of MAGDAS, data availability information, etc., have been published already [1, 2, 3] and so we will not be repeat those topics in this report. This report will focus on recent expansion of the MAGDAS Project in Africa.

Figure 1 shows the current status of global deployment. Yellow and red dots represent MAGDAS-I type (Meisei Electric) magnetometers. Blue and white dots represent MAGDAS-II type magnetometers, which are usually CPMN-type magnetometers that have been upgraded to have real time data transmission capability. However, since 2010, one more type of MAGDAS has been introduced into the global deployment plan: MAGDAS 9 (50 units have been built). This series was manufactured by Tierra Tecnica of Tokyo, Japan. MAGDAS 9 is being used to replace some aging MAGDAS-I units in the field and also is being used for new observatory sites (e.g., six have already been shipped to Yakutsk, Russia, for deployment in Siberia). As of the 1st ISWI workshop (which took place at Helwan University, Cairo, Egypt, in November of 2010), there were 54 MAGDAS stations in operation around the world. Each sends data to Space Environment Research Center (SERC) in real time.

2. MAGDAS in Africa (Phase 1 and 2)

Figure 2 shows the essential history of MAGDAS deployment in Africa. The Red Box is Phase 1 (summer of 2006); MAGDAS-I magnetometers were installed along the dip equator at Abidjan (Cote d'Ivoire), Ilorin (Nigeria), and Addis Ababa (Ethiopia), by a single 3-man team (Yumoto/Kakinami/Maeda). The Blue Box is Phase 2 (summer of 2008); seven (7) units of MAGDAS-II were installed in a *one-month* period by two teams of three: (1) "Africa A Team" (Yumoto, Fujimoto, and Tokunaga) and (2) "Africa B Team" (Maeda, Ikeda, and Yamazaki).

Phase 2 established the "96 Deg. Magnetic Meridian" chain of magnetometers for the MAGDAS Project. (Previously established were the "210 Deg. MM" chain, which runs north and south of Japan, and the Dip Equator chain, which runs around the globe along the magnetic equator.) At the southern terminus of the 96MM chain, there is the MAGDAS station at Hermanus, which is located on the grounds of the Hermanus Magnetic Observatory (HMO) of the Government of South Africa. At the northern terminus, there is the MAGDAS station at L'Aquila (Italy), which is located on the grounds of a magnetic observatory belonging to

INGV (Istituto Nazionale di Geofisica e Vulcanologia), an agency of the Government of Italy.

ut the remarkable feat of Phase 2 is that seven new stations were deployed in just one month: The aforementioned *Africa A Team* did Nairobi (Kenya), Dar Es Salaam (Tanzania), and Khartoum (Sudan), while the *Africa B Team* did Lagos (Nigeria), Durban (S. Africa), Maputo (Mozambique), and Lusaka (Zambia). At each of these seven new stations, a MAGDAS-II magnetometer system was installed. This system was developed by the students and staff of SERC at Kyushu University in Japan. The analog portion is a refurbished YU-8T magnetometer (see Figure 3). Many of these YU-8Ts were used for the CPMN Project (PI: Prof. K. Yumoto; Circum Pacific Magnetometer Network). Seven YU-8Ts were prepared for Phase 2 (mainly by Dr. A. Fujimoto, then a graduate student under the supervision of Prof. Yumoto).

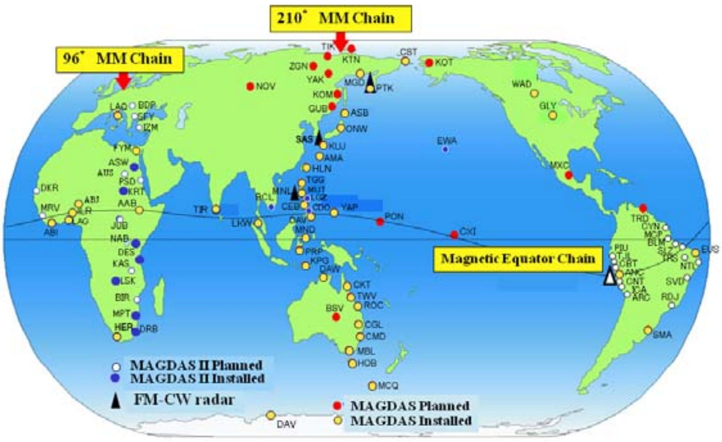

Fig. 1. MAGDAS Deployment Map.

Fig.2. Development of MAGDAS in Africa.

Fig. 3. YU-8T analog magnetometer (3-component magnetic field sensor at left and its analog amplifier at right)

Fig. 4. Digital portion of MAGDAS-II system (DCR5SD analog-to-digital converter at left and Armadillo 9 Linux computer at right)

The 3-component analog output of the YU-8T goes to the digital portion of the MAGDAS-II system, which is shown in Figure 4. Both devices presented in Figure 4 are “off the shelf” commercial products. However, the Armadillo computer required specialized software to be used in the field for data processing and system operation -- this software was mainly developed by Dr. S. Abe, who is presently a Research Associate at SERC.

The main task of the Armadillo computer is to handle the digital data produced by the analog-to-digital converter (the DCR5SD of Figure 4). This data needs to be stored on to a CF data card as well as be transferred to SERC via the Internet. Therefore, the computer is responsible for data storage and data transfer.

Figure 5 and Figure 6 illustrate the extensive work involved in an African installation. In the center column of Figure 5 you can see Prof. Yumoto (upper photo) explaining to the local host where the sensor house should be located; in the lower photo you can see Dr. Fujimoto (now with JAXA) explaining to local university personnel the data generated by MAGDAS-II. In the left photo of Figure 6 you can see a car battery – this is standard in any MAGDAS installation. The car battery keeps the system running if the local AC power fails. When the AC power is alive, MAGDAS (of any kind) trickle charges the car battery. Not shown in any of the photos of this report is the essential GPS antenna. Its main task is to provide the exact time, which is recorded with the taken magnetic data. It is usually mounted 2 to 5 meters off the ground so that it can easily receive signals from orbiting GPS satellites.

The four environmental requirements for any MAGDAS installation are these:

1. **Security** (the equipment must be untouched for at least ten years).
2. **Internet connectivity** (by this method data is sent to SERC in real time).
3. **Electric power** (no more 50W is needed).
4. **Reasonably noise-free setting** (for example, the nearest electrified rail line must be at least 10 km away and the nearest vehicular road must be at least 100 m away from the sensor).

Typically, in Africa, trade-offs and compromises are involved. For example, a place free of noise would likely have security issues and likely have no Internet availability. Hence, most MAGDAS-II units in Africa were installed on a college campus, which provides adequately for (1) security, (2) Internet, and (3) electric power, but does not provide very well for (4) a noise-free setting. The ideal situation (i.e., all four MAGDAS requirements satisfied) is very difficult to achieve in the real world.

Fig. 5. Africa “A” Team installing MAGDAS-II (Left column: Dar Es Salaam, Tanzania; Middle column: Khartoum, Sudan; Right column: Nairobi, Kenya.)

Fig.6. Installation examples of MAGDAS-II (work by Africa B Team) (Left: Data Logging system at Maputo in Mozambique; Center: Cement base for sensor house at Lusaka in Zambia; Right: Water bottles for thermal stabilization at Maputo.)

3. MAGDAS in Africa (Phase 3)

Fig. 7. Participants of the Ilorin Upgrade (March of 2010).

Table 1 shows all the MAGDAS stations in Africa, and the responsible host for each station at the time of writing.

At the start of 2010, the PI of the MAGDAS Project (Prof. K. Yumoto) decided that maintenance and upgrade work was needed for the MAGDAS units operating in Africa. As a result, in the Year 2010, four trips were completed by students and staff under the supervision of Prof. Yumoto: (Trip 1) Upgrade of the MAGDAS instrument at Ilorin, Nigeria, from a MAGDAS-I to a MAGDAS-9 (see Figure 7 for those who did this work, including the local work force), (Trip 2) Upgrade of Equatorial Stations and installation of the Abuja Station (see Figure 8 for sample photos), (Trip 3) Maintenance of the original Africa A Team installations (2010 team members were: Yumoto/Yamazaki/Fujita), and (Trip 4) Maintenance of the original Africa B Team installations (2010 team members were: Maeda/Ikeda/Matsuyama).

Figure 8 shows the equatorial stations that were visited by Maeda, Sakai, and Eto. At Abidjan and Addis Ababa, MAG-I was upgraded to MAG-9. At Lagos, MAG-II was upgraded to MAG-9. Abuja was a new installation (MAG-9 was installed). The persons in this figure are as follows: (A) Miss Sakai (then a masters student at Kyushu University), (B) Miss Eto (a masters student at Kyushu University), (C) Prof Vafi (in charge of the MAGDAS at Abidjan), (D) Prof. Kolawole (in charge of the MAGDAS at Redeemer's University near Lagos), and (E) Mr Osinowo (works under Prof. Kolawole as his assistant).

TABLE 1. The MAGDAS Hosts of Africa.

MAGDAS Hosts of Africa from West to East			
Station Code	**Station Name**	**Country**	**Host**
ABJ	Abidjan	Cote d'Ivoire	Prof. Vafi Doumbia
LAG	Lagos	Nigeria	Prof. Kolawole
ILR	Ilorin	Nigeria	Prof. Adimula
ABU	Abuja	Nigeria	Dr. Rabiu
AAB	Addis Ababa	Ethiopia	Dr. Gizaw

MAGDAS Hosts of Africa from South to North			
Station Code	**Station Name**	**Country**	**Host**
HER	Hermanus	South Africa	Dr. McKinnell
DRB	Durban	South Africa	Prof. Afullo
MPT	Maputo	Mozambique	Dr. Macamo
LSK	Lusaka	Zambia	Dr. Mweene
DES	Dar Es Salaam	Tanzania	Dr. Makundi
NAB	Nairobi	Kenya	Dr. Baki
KRT	Khartoum	Sudan	Dr. Baki
ASW	Aswan	Egypt	Dr. Mahrous
FYM	Fayum	Egypt	Dr. Mahrous

4. Conclusions

In this report, we (the persons from Japan who traveled to Africa for installation work) summarized the work that has been done in Africa with respect to the global MAGDAS Project. The work began in 2006 with installations at three equatorial sites: Abidjan, Ilorin, and Addis Ababa. (These three installations represented Phase 1.) In Phase 2, the *96 Deg. Magnetic Meridian* was established (a long vertical chain whose center is 96 Deg.). Last year, Phase 3 was executed. In this phase, the MAGDAS stations established in Phase 1 and Phase 2 were upgraded or repaired. In general, all MAGDAS stations require maintenance because most operate in harsh environments (high temperature, high humidity, etc.). In addition, electrical (thunder) storms occasionally damage our equipment in the field despite the precautions we take.

Fig. 8. Summer of 2010 – Upgrade of MAGDAS Equatorial Stations

Finally, in conclusion, we briefly outline the scientific motivation for long-term MAGDAS observation in Africa. There are three basic investigations that need to be done:

a) *Long-term variation*. By comparing the data of the 210MM chain and 96MM chain, local time dependence of storm-time and Sq variations can be explored.
b) *Transient variation.* These two vertical chains (210MM and 96MM) provide a much better global view of events, such as SC, ULF waves, DP2, etc.
c) *Equatorial Electrojet*. Africa is the best place for this investigation because it has the longest terrestrial equatorial span [4, 5]

Acknowledgments

We wish to express our deepest gratitude to each host (*Person of Highest Authority* with respect to the installed MAGDAS) in Table 1 of this report. Of course each host is supported by various assistants (lecturers, technicians, engineers, students, etc.) but space does not permit the inclusion of their names. The work of many enable the long-term operation and productivity of MAGDAS.

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