Dear MAGDAS Hosts:

In this issue (No. 6) we briefly answer this question:

* What is MAGDAS II? *

As many of you know already, only 50 or so units of MAGDAS were manufactured in Japan for global deployment. And only a few remain un-installed. So after three years of
feverish work by the staff and students associated with SERC, we have exhausted the supply of these magnetometers. They are the original "work horses of SERC".

However, that is not the end of our observation agenda.

We are now furiously developing MAGDAS II. We plan to ship the first unit by July 20 of 2008 (this summer). We seek to install several MAGDAS II units between Egypt and South Africa. For that purpose, Dr Rabiu of Nigeria is with us for three months. He is helping us to find suitable locations for MAGDAS II installations in Africa. Not an easy task.

Our game plan is visible in the world map inside the attached pdf .... this is a manuscript that I submitted to the United Nations Office of Outer Space Affairs. It is expected to be published this year in the "Earth Moon and the Planets Journal".

In parallel with the aforementioned MAGDAS II effort, SERC will also install its third FM-CW radar. The first is at Sasaguri, near SERC. The second is in the Far East of Russia. The third is scheduled to be installed this summer at the Manila Observatory in the Philippines. This instrument is designed to observe the ionosphere --- but it goes beyond the scope of MAGDAS Newsletter No. 6.

As always, hosts (i.e., you) are invited to contribute articles to this newsletter.

George Maeda
Editor-in-Chief

-------------------------------------end of MAGDAS newsletter.
Revised

MANUSCRIPT

For EMP

Submitted by G. Maeda to

Dr Nat Gopalswamy

as a final product
Title:

Progress Report on the Deployment of MAGDAS

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Progress Report on the Deployment of MAGDAS
Abstract:

As Japan’s leading contribution to the IHY, SERC (Space Environment Research Center of Kyushu University, Fukuoka, Japan) is in the process of deploying globally fifty state-of-the-art magnetometers. (This magnetometer is called MAGDAS.) In this brief article, we outline our progress to date (23 Sept 2007). This article is condensed from a talk delivered at the Basic Space Science and the International Heliophysical Year 2007 Workshop held in Tokyo (campus of the National Astronomical Observatory of Japan, NAOJ) from 18 to 22 June 2007 under the auspices of the UN, ESA, and NASA. We also briefly describe our magnetometer, which is able to send its data in near realtime to a central server, where data from all units can be compared with relative ease and quickness.

Keywords:

Space weather
Geomagnetic observation
IHY
MAGDAS
SERC
EE Index
## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AAD</td>
<td>Australian Antarctic Division (Hobart, Tasmania)</td>
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<tr>
<td>A/D</td>
<td>Analog-to-digital converter</td>
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<tr>
<td>CF</td>
<td>Compact Flash card</td>
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<td>CPMN</td>
<td>Circum Pacific Magnetometer Network</td>
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<td>EE Index</td>
<td>Equatorial Electrojet Index</td>
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<tr>
<td>GB</td>
<td>Gigabits</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>IHY</td>
<td>International Heliophysical Year</td>
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<tr>
<td>LSB</td>
<td>Least significant bit</td>
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<tr>
<td>MAGDAS</td>
<td>MAGnetic Data Acquisition System</td>
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<tr>
<td>MAGDAS II</td>
<td>essentially a CPMN magnetometer that has been upgraded to yield data in real-time</td>
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<tr>
<td>MB</td>
<td>Megabits</td>
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<tr>
<td>nT</td>
<td>Nano Tesla</td>
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<tr>
<td>PI</td>
<td>Principal Investigator</td>
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<td>SERC</td>
<td>Space Environment Research Center of Kyushu University</td>
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<tr>
<td>STEP</td>
<td>Solar Terrestrial Energy Program</td>
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<tr>
<td>ULF</td>
<td>Ultra Low Frequency</td>
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<tr>
<td>UN</td>
<td>United Nations</td>
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Motivation

The MAGDAS Group (whose PI is Professor K. Yumoto) at SERC (whose Director is
the same person) seeks to deploy around the world in a strategic fashion a new
generation of tri-axial fluxgate magnetometers (called MAGDAS) that transfer the
digitized data to a central SERC server in real-time for space weather study and
application during the IHY period (2007-2009). This strategy (if simply stated) is
to put the magnetometers in well-defined “bands” that are useful for scientific
exploration.

The first band is the strip that goes north and south of Japan – up to Siberia and
down to the Antarctic. In our geo-space field, this north-south band is also known
as the “210 Magnetic Meridian” and became famous in this field of geo-space
research (Yumoto, K., and the 210° MM Magnetic Observation Group, 1996). After
the international Solar Terrestrial Energy Program (STEP) period
(1990–1997), 1-sec magnetic field data from coordinated ground-based network
stations made it possible to (1) study magnetospheric processes by distinguishing
between temporal changes and spatial variations in the phenomena, (2) clarify
global structures and propagation characteristics of magnetospheric variations from
polar to equatorial latitudes, and (3) understand the global generation mechanisms
of various solar-terrestrial phenomena (Yumoto and the CPMN group, 2001). In
this north-south band, the average spacing of magnetometers is 500 km. The most
northern magnetometer is at Cape Schmidt in northern Russia. The most
southern magnetometer is located at Davis Station of AAD.

The second band is the geo-magnetic “dip” equator. SERC has completed most of
the installations along this band (see Yumoto and the MAGDAS Group, 2007).
(One big gap however is the Pacific Ocean: we are still searching for a suitable
island in the middle of it.) The third band runs up and down the continent of
Africa; SERC has already completed one installation in South Africa (at the
Hermanus Magnetic Observatory) and one in Egypt near Cairo. The fourth band
runs up and down the Americas; SERC has completed several MAGDAS
installations in North and South America. Figure 1 is a map of MAGDAS and
MAGDAS II stations.

With scientifically significant real-time data arriving at SERC from over forty
identical magnetometers (and identically calibrated magnetometers, and which are
sensitive down to the nT level), SERC seeks to conduct socially beneficial space
weather forecasting. SERC also has a policy to establish an important new research tool for the geo-space community: Our EE-index (EDst, EU, and EL) is being proposed to monitor transient and long-term variations of the Equatorial Electrojet by using MAGDAS/CPMN real-time data (Uozumi et al., 2008). In sum total, the MAGDAS Project of Prof. K. Yumoto and his MAGDAS Group at SERC easily becomes Japan’s most important contribution to IHY.

Update of the Installation

The aforementioned four bands are clearly visible in Figure 1.

![MAGDAS/CPMN network map](image)

**Figure 1**

The non-blue dots are installed or soon-to-be installed MAGDAS magnetometers. They are concentrated in four bands. The black triangles are SERC FM-CW radars (for ground-based observation of the ionosphere). The blue dots are MAGDAS II magnetometers but whose discussion go beyond the scope of this paper.
Explanation of MAGDAS

The MAGDAS system of SERC is divided into two portions: MAGDAS-A and MAGDAS-B. MAGDAS-A is a real-time magnetometer unit installed at CPMN (Circum-pan Pacific Magnetometer Network) stations, while MAGDAS-B is a data acquisition and monitoring system installed at SERC. The sensor unit of MAGDAS-A system consists of tri-axial ring-core sensors, two tilt-meters and a thermometer (Figure 3). MAGDAS-A as a whole consists of this sensor unit, data logger/transfer units, and power supply (Figure 2). Magnetic field digital data (\(H + \delta H\), \(D + \delta D\), \(Z + \delta Z\), \(F + \delta F\)) are obtained with the sampling rate of 1/16 seconds, and then the 1-sec averaged data are transferred from each overseas station to SERC, Japan, in real time (Yumoto and MAGDAS Group, 2006). To facilitate installation in just about any spot on the globe, MAGDAS-A was specially designed to be portable (hand-carried suitcase) and lightweight (just 15 kg). Visible in Figure 2 are all vital components. The required power is just 20 W. The best way for SERC to get the data in real-time from this instrument (we have found out from sheer experience) is via the Internet. (The machine was designed with other options.) However, for redundancy, the data is stored onto a high-capacity Compact Flash semiconductor memory card (1.0 or 0.5 Gb). The cord for the GPS antenna is about 25m. This antenna is usually placed on the roof of the building in which the main case resides. The sensor is placed in a separate structure to be away from building-related noise (e.g., noise from electric motors). To allow ample separation, the sensor cable is 70m in length. In Figure 2, the cable is wound up on the reel (to allow for delivery from SERC to the final site overseas).

The sensor’s analog data is continuously digitized. The ambient magnetic fields, expressed by horizontal (H)-, declination (D)-, and vertical (Z)-components, are digitized by using the field-canceling coils for the dynamic range of \(\pm 64,000nT/16\)bit. The magnetic variations (\(\delta H\), \(\delta D\), \(\delta Z\)) subtracted from the ambient field components (H, D, Z) are further digitized by a 16-bit A/D converter. Two observation ranges of \(\pm 2,000nT\) and \(\pm 1,000nT\) can be selected for high- and low-latitude stations, respectively. The total field (\(F + \delta F\)) is estimated from the \(H + \delta H\), \(D + \delta D\), and \(Z + \delta Z\) components. The resolution of MAGDAS data is 0.061nT/LSB and 0.031nT/LSB for the \(\pm 2,000nT\) range and \(\pm 1,000nT\) range, respectively.
Figure 2

This is photo of MAGDAS Unit 08 (taken at SERC by the author). Easily visible are the: (1) grey AC power cord, (2) round and black sensor with its 1-meter cable, (3) the 70-meter cable reel, (4) main case (modified travelers suitcase), and (5) GPS antenna with 25-meter cord. The output of the sensor is analog. The electronics inside the main case converts this analog data into digital data, which is sent to SERC via the Internet and is stored locally on a CF card for redundancy.

About 1.5 MB of data is generated each day as a result. Data from all MAGDAS units flow into a central server at SERC. This raw data must be processed to become scientifically useful. All the processing takes place here at SERC. This data can be accessed by anyone via the Web (http://magdas.serc.kyushu-u.ac.jp/), with some conditions attached. Please contact the authors for data access information.

Installation of the sensor (see Figure 3) is complicated because it must be carefully aligned in three ways. First, it must be pointed exactly north with precision threading. Second and third, it must be perfectly level (resulting in two orthogonal adjustments). This levelness is achieved with the precision threading of a tripod base. The long-term inclinations (I) of the sensor axes can be measured by two tilt-meters with resolution of 0.2 arc-sec. The temperature (T) inside the sensor unit
is also measured. GPS signals are received to “keep correct” the standard time inside the data logger/transfer unit. These data are recorded on to the Compact Flash Memory Card as data backup.

Figure 3
This is the MAGDAS sensor with the round and black cover removed. The two brass-colored devices are precision tiltmeters. The rest form a tri-axial fluxgate magnetometer. This photo was taken at SERC by the author last year when the magnetometer had to be repaired.

Anticipated science
The MAGDAS System (MAGDAS·A units at local sites and MAGDAS·B at SERC) provides amplitude-time records of ordinary magnetic field variations (the aforementioned four components—the output of MAGDAS·A) and time-derivative
magnetic field variations (computed by MAGDAS-B). Ordinary data is useful for studies of long-term variations, e.g. magnetic storm, auroral substorms, Sq, etc., while time-derivative data is useful for studies of ULF waves, transient and impulsive phenomena. By using these new MAGDAS data, we can perform real-time monitoring and modeling of: (1) the global 3-dimensional current system and (2) the ambient plasma density for understanding the global electromagnetic and plasma environment changes in geospace, respectively. Furthermore, by using Doppler-mode FM-CW radar observations at Sasaguri (L=1.26) and at Paratunka (L=2.09) in conjunction with MAGDAS observation, we can deduce (3) ionospheric electric fields in the east–west direction that are caused by penetrating electromagnetic disturbances from polar to equatorial ionosphere. This is extensively discussed in two of the references (see Yumoto and the MAGDAS Group, 2006 and 2007).

Discussion and Conclusions

In this paper we explained the motivation for the global deployment of MAGDAS magnetometers. We also explained the deployment strategy (fifty magnetometers arranged in four global bands or strips). Built to tight SERC specifications, fifty units were manufactured in Japan by Meisei Electric Co.; during the past three years (Year 2005 through 2008), over forty of them were installed in the aforementioned four bands by the staff and graduate students associated with SERC.

The remaining units shall be installed overseas after the units complete final quality control checks. Several of the bad units are overly affected by changes in ambient temperature – the so-called “temperature drift problem”. Ideally, an observational magnetometer should only be sensitive to changes in the earth’s magnetic field – and nothing else. We have faced many challenging technical problems with this MAGDAS instrument. (Resolution, or mitigation, of these problems resulted, however, in lots of good education for our students.)

The location of each deployed MAGDAS unit is detailed in the IHY Tokyo Workshop final report (Report on the Third UN/ESA/NASA Workshop on the International Heliophysical Year 2007 and Basic Space Science, from the UN Committee on the Peaceful Uses of Outer Space, dated 12 December 2007). This report is available in six languages (one, the original, being in English). It is an official document of the United Nations.
This pace of installation ("rapid deployment of technologically advanced magnetometers") by SERC shall be maintained for at least the next two years. To achieve this ambitious goal, MAGDAS II is currently under development here at SERC. Most of MAGDAS II units shipped this year shall be installed in Africa (between Egypt and South Africa) during the summer of 2008.

Acknowledgements

A project that involves the installation of fifty units all over the globe cannot be executed by one person. In the case of MAGDAS, there is the MAGDAS Group. It is headed by the PI (Dr K. Yumoto, Professor at Kyushu University, Director of SERC, and IHY National Organizer for Japan). Other key group members are the staff of SERC, Kyushu University students associated with SERC, and all the people who helped with MAGDAS installations in Asia, North America, South America, Africa, and Antarctica. There are too many names to mention and so we refrain from mentioning any select persons. (But special warm thanks to Dr B. Rabiu and Dr Adimula for the wildly successful installation in Nigeria during the summer of 2006 at Ilorin.)

References


Yumoto, K. and the MAGDAS Group, “MAGDAS project and its application for space weather, Solar Influence on the Heliosphere and Earth’s Environment: