Dear MAGDAS Host:

Today is officially the last day of IHY (International Heliophysical Year).
A closing ceremony is scheduled to
take place today in Vienna, Austria.
IHY celebrated the 50th anniversary of
historical IGY (International Geophysical Year).

In this issue of the "MAGDAS Newsletter" I bring
to your attention two items:

1. Final IHY Report from the Philippines.

2. IHY-Africa/SCINDA 2009 Workshop this summer
   in Zambia.

1. Final IHY Report from the Philippines.

I attach the final IHY report from the Philippines.
The authors are:
   Dr Roland Otadoy........University of San Carlos, Cebu, PH
   Dr Danieal McNamara.....Manila Observatory, PH
   Prof K. Yumoto...........SERC, Kyushu University, Japan.
The spirit of IHY is for all nations of the world to
participate in space science. For ground observation,
all nations are needed. Doing all observation from
earth orbit is complete nonsense. Ground-based data and
space-based data are both essential for science that
makes sense.

2. IHY-Africa/SCINDA 2009 Workshop this summer
   in Zambia.

The following (indented) text is from the "IHY Africa/SCINDA
2009 Homepage":

The IHY-Africa/SCINDA 2009 Workshops are aimed at promoting
These Workshops will be held in Livingstone, Zambia, between 7th and 12th June 2009. The arrival and departure dates for Workshop participants are Saturday 6th June 2009 and Saturday 13th June 2009, respectively.

African and non-African scientists working in all aspects of Space Physics, and interested in scientific collaborations, are cordially invited to attend these Workshops.

The IHY · Africa 2009 Workshop will, in particular, be unique because it will:
* Mark the end of the IHY period (i.e. 2007 - 2009) and cover a number of projects that have been undertaken during this time;
* Provide a forum for the launch of the new African Geophysical Society;
* Provide a forum for African scientists and their students to come together and make regional and international contacts.

Complete text can be seen here:

Deadline for abstracts is March 1, 2009.

Cordially yours,
George Maeda
Editor-In-Chief.

-------------------------------------end of MAGDAS newsletter.
REPORT ON THE INTERNATIONAL HELIOPHYSICAL YEAR (IHY) ACTIVITIES IN THE PHILIPPINES

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Metro Manila, Philippines

PROF. KIYOHUMI YUMOTO, Ph.D.
Director, Space Environment Research Center
Kyushu University, Fukuoka, Japan
INTRODUCTION

The Philippine participation to the International Heliophysical Year (IHY) was facilitated by our collaboration with the Space Environment Research Center (SERC), Kyushu University. The Philippines is hosting four magnetometers of the Magnetic Data Acquisition System installed by SERC. These magnetometers are in Muntinlupa (hosted by National Mapping and Resource Information Authority), Tuguegarao, Cagayan (hosted by Cagayan State University), Cebu (hosted by the University of San Carlos), and Davao (hosted by the Manila Observatory).

Japanese team led by Prof. Yumoto giving presentation of MAGDAS at the Department of Physics, University of San Carlos, Cebu, Philippines.

MAGDAS-Cebu site.
The Japanese team from Kyushu University led by Prof. Yumoto at the Manila Observatory
SATURN WATCH 2007

The Carolinian Astronomical Society (ASTROSOC), student organization affiliated in the University of San Carlos Department of Physics, conducted Saturn Watch 2007 at the University of San Carlos-Talamban Campus Soccer Field, Cebu City on March 3-4, 2007. This was open to the public and mostly attended by college and high school students.

ATROSOC founder, Christopher Go, made a presentation of the image of Saturn taken during the event.
UN/ESA/NASA WORKSHOP ON BASIC SPACE SCIENCE AND THE INTERNATIONAL HELIOPHYSICAL YEAR 2007

Dr. Roland Otadoy and Fr. Daniel McNamara attended the UN/ESA/NASA Workshop on Basic Space Science and the International Heliophysical Year 2007 held at the National Astronomical Observatory of Japan, Tokyo, Japan on June 18-22, 2007. In this workshop, Dr. Otadoy made a presentation on the University of San Carlos Research Initiatives in Basic Space Science and Activities Related to IHY. Fr. Daniel McNamara made a presentation about the Manila Observatory. Dr. Otadoy’s presentation on the equatorial electrojet was developed into a full paper entitled “Proposal to Use the MAGnetic Data Acquisition System (MAGDAS)/Circum-Pan Pacific Magnetometer Network (CPMN) to Study the Equatorial Electrojet: A Philippine Contribution to the International Heliophysical Year”, which was recently published in Earth Moon Planets.

SAN CARLOS BORROMEO AWARD

On the occasion of the IHY 2007, the University of San Carlos conferred upon Christopher Y. Go the San Carlos Borromeo Award for his important works on Oval BA, popularly known as Red Spot Jr, on August 21, 2007 at the College of Architecture and Fine Arts Theatre, University of San Carlos-Talamban Campus.
During the 25th Samahang Pisika ng Pilipinas (SPP) Physics Congress, held at the University of the Philippines, Los Baños, Laguna on October 24-26, 2007, a session was devoted for planning the activities for the International Heliophysical Year. It was agreed that SPP might a conduit for research dissemination and publication. A workshop would be called to formulate our research and education thrusts for the IHY.
The 2nd National Congress on Space Technology Applications and Research was held in Pan Pacific Hotel, Malate, Manila on November 7, 2007. In this event, Dr. Roland Otadoy gave a presentation on the International Heliophysical Year and Seismoelectromagnetics emphasizing the role of MAGDAS.

Workshop to Formulate the Philippine National Research and Education Agenda for the International Heliophysical Year

In order to make the participation of the Philippines to the International Heliophysical Year formal, Dr. Roland Otadoy and Fr. Daniel McNamara organized a workshop at the Manila Observatory on May 26, 2008 to formulate Philippines’ research and education thrusts. The outcome of such workshop is attached in this report as Appendix.

26th SAMAHANG PISIKA NG PILIPINAS (Physics Society of the Philippines) PHYSICS CONGRESS 2008

Call for papers: SPP Congress special session on sun-heliosphere interaction

October 22-24, 2008
University of the Philippines-Baguio
Baguio City, Philippines

In recognition of the International Heliophysical Year, the Samahang Pisika ng Pilipinas is calling for papers in the following areas:

- Solar Physics
- Planetary Magnetospheres
- Heliosphere and Cosmic Rays
- Planetary Ionospheres, Thermospheres and Mesospheres
- Climate Studies
- Heliology
During the 26th Samahang Pisika ng Pilipinas (SPP) Physics Congress held at University of the Philippines, Baguio City, a session was devoted to researches related to IHY. Fr. Daniel McNamara and Dr. Roland Otaduy gave plenary of space weather and seismoelectromagnetics, respectively.

INTERNATIONAL GEOPHYSICAL YEAR (IGY) + 50

The Manila Observatory in the person of Fr. Daniel McNamara, S.J. was represented at the IGY+50 conference in Tsukuba in November 2008. Fr. McNamara found the sessions instructive as the MO is getting back into magnetic and ionospheric work after a lapse of some years due to personnel changes. The emphasis of the Conference was on virtual observatories as the new way to appreciate the data of the space-earth system by making it all available on-line to the scientific world. It was especially appreciated as this allows even less scientifically advanced participants to join in the world community of space weather researchers.

After the formal sessions at the Tsukuba Space Center the MAGDAS group assembled at a hotel conference room for a more focused discussion on the MAGDAS situation. There the MO presented a short history of magnetic studies undertaken by the MO in the past. This was particularly apropos from the IHY perspective as the MO was the only Philippine participant in IGY.

As the meeting ended it was of particular interest to MO to learn of the thriving work being done in Antarctica by the MAGDAS team. This gives reason to think of a joint project to study space storms from the correlation of events recorded at the magnetic equator (Manila, Cebu, Davao) and at the south pole all within the MAGDAS system.

IMPACT OF IHY IN THE PHILIPPINES

For poor countries like the Philippines, which cannot afford to acquire sophisticated equipment, the IHY through MAGDAS and through the establishment of virtual observatories gives ample opportunities for Filipino scientists in the Philippines to do research in basic space science and technology. The emerging field of seismoelectromagnetics will certainly improve the capability of the Philippines to establish early warning system of impending earthquakes.

Promotion of science is vital to attract students to enroll in science programs. In addition, public awareness in science is very important to garner government support for scientific research. Since space is fascinating to the public, IHY promotional programs (e.g. in the Philippines through our stargazing activities) would certainly make an impact on these two vital aspects.
APPENDIX
PHILIPPINE RESEARCH AND EDUCATION THRUSTS FOR THE INTERNATIONAL HELIOPHYSICAL YEAR

Report of the Workshop to Formulate the Philippine National Research and Education Agenda for the International Heliophysical Year
May 26, 2008, The Manila Observatory, Ateneo de Manila University
Katipunan Avenue, Quezon City, Philippines

Workshop Co-Chairs

Roland Emerito S. Otadoy, Ph.D.
Department of Physics, University of San Carlos
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Sponsored by

The Manila Observatory
National Research Council of the Philippines (NRCP)
Philippine Council for Advanced Science and Technology Research and Development (PCASTRD)
ACKNOWLEDGMENTS

The organizers of the workshop wish to express our gratitude and appreciation to the following participants:

Chrysline Margus N. Piñol, Physics Division, Institute of Mathematical Sciences and Physics (IMSP), UP Los Baños

Didi Olaguer, Project Development Officer, Manila Observatory

Raymond Sarmiento, Councilor, Samahang Pisika ng Pilipinas (also a member of the Faculty of Department of Physics, University of San Carlos, Cebu City)

Nelson P. Beniabon, Chief Science Research Specialist, Philippine Council for Advanced Science and Technology Research and Development-Department of Science and Technology (PCASTRD-DOST)

Eduardo Cuansing, Councilor, Samahang Pisika ng Pilipinas, now at the National University of Singapore

We also wish to thank the Manila Observatory for hosting the workshop and the National Research Council of the Philippines (NRCP) for its support in printing this document. We also thank the Philippine Council for Advanced Science and Technology Research and Development (PCASTRD). Most importantly, we thank Prof. Yumoto and SERC for providing MAGDAS to the Filipino scientific community.
This document is the outcome of the workshop to formulate the Philippine Research and Education Agenda for the International Heliophysical Year (IHY). IHY is an internationally coordinated scientific study of the sun-heliosphere interaction. However, investigation of the sun-heliosphere interaction may be too broad for a country with limited scientific resources. Thus, the workshop focused on the more practically relevant investigation of sun-earth interaction. While the influence of the sun on the intervening space is well known, scant attention has been devoted to its influence on atmospheric and lithospheric events. For instance, it is not well known how space storms affect the lower atmosphere and the oceans. Hence, the original format of the workshop was to divide the participants into three groups: the space science group, lithosphere group, and the atmosphere group. However, this format was not realized and the original objectives were not met because of low participation of stakeholders. Of the seventeen invited guests, only seven showed up. So during the workshop, the participants decided to have a round-table discussion.

During the deliberations, two things surfaced as possible research directions: studies on space weather, particularly equatorial electrojet, and seismoelectromagnetics. These directions are brought about by our collaboration with the Space Environment Research Center (SERC), Kyushu University. Being a country experiencing frequent natural disasters such as earthquakes, the Philippines can benefit tremendously in developing expertise in the new field of seismoelectromagnetics. It is our hope that when the Philippine Government considers launching our own satellite, these research directions will be taken into account in deciding the instrumentation on board.

The participants also realized that IHY can be a vehicle to popularize science among students and galvanize favorable public opinion towards scientific research. Hopefully, IHY promotes the development of science in the country.

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1. Introduction

The International Heliophysical Year (IHY) is an internationally coordinated scientific campaign to understand fundamental issues of sun-heliosphere interaction. It builds on the success of the International Geophysical Year (IGY) in 1957 in which a similar unprecedented internationally coordinated campaign to study global phenomena of the Earth and geospace was conducted. About 60,000 scientists from 67 countries were involved in IGY, working from pole to pole and around the equator. In the 50th Anniversary of that glorious year, the international scientific community again comes together to undertake a massive, system-wide study of the extended heliophysical domain. The term *heliophysical* is a broadening of the concept "geophysical", extending the connections from the Earth to the Sun and into interplanetary space.

IHY has three primary objectives:

a. Advancing the understanding of the fundamental heliophysical processes that govern the Sun, Earth and heliosphere;

b. Continuing the tradition of international research and advancing the legacy of IGY on its 50th anniversary; and

c. Demonstrating the beauty, relevance, and significance of space and Earth science to the world.

In capsule form these objectives are research on the new frontier – the local interstellar medium, international research cooperation and space education. These objectives shall be accomplished in various activities starting March 2007 and culminate in a series of analysis and legacy activities in 2009 and 2010.

From these primary objectives one can derive the following goals of IHY:

a. Develop the basic science of heliophysics through cross-disciplinary studies of *universal processes*;

b. Determine the response of terrestrial and planetary magnetospheres and atmospheres to external drivers;

c. Promote research on the sun-heliosphere system outward to the local interstellar medium - the new frontier

d. Foster international scientific cooperation in the study of heliophysical phenomena now and in the future;

e. Preserve the history and legacy of IGY on its 50th anniversary; and

f. Communicate unique IHY results to the scientific community and the general public.

To realize the above objectives and goals, IHY is implementing the following four programmatic thrusts:

a. **Science activities**, consisting primarily of Coordinated Investigation Programmes (CIPs) dedicated to the study of the extended heliophysical system and the universal processes common to all of heliophysics;

b. **The IHY/United Nations Basic Space Science Initiative (UNBSSI) programme**, dedicated to the establishment of observatories and instrument arrays to expand greatly
our knowledge of global heliophysical processes, while increasing the viability of space science research and education in developing countries and regions that traditionally have not been active in space research;

c. **Education and public outreach**, increasing public awareness of heliophysics and educational activities for “students” of all ages; and

d. The **“IGY Gold” history initiative**, preserving the history and legacy of IGY 1957 by identifying and recognizing planners of and participants in the first IGY, preserving and making available items of historical significance from the IGY and organizing commemorative activities and events.

The Philippines is an archipelagic country consisting of 7,107 islands with a total land area of approximately 300,000 square kilometers. It generally lies between 116° 40' and 126° 34' E longitude and 4° 40' and 21° 10' N latitude. It is bounded by the Pacific Ocean/Philippine Sea in the east, South China Sea in the west and north, and the Celebes Sea in the south. The Philippines is also sitting on the western fringes of the Pacific Ring of Fire and lies on the Western Pacific typhoon belt. It is also located in proximity to the geographic equator and lies on the dip equator, an imaginary line on the earth’s surface where the geomagnetic field is completely horizontal. This unique geophysical position makes the Philippines an interesting natural geophysical laboratory. However, this also indicates that the country is a disaster prone area. On the average, twenty typhoons visit the country annually. The fact that the country is sitting on crustal fault lines makes it also susceptible to frequent earthquakes. The focus of our research thrusts for the International Heliophysical Year is in risk and disaster management. In particular, emphasis is placed on studies in pre-disaster science and the search for early warning systems for impending space storms and earthquakes. Space storms have their origin from the sun and the new science of seismoelectromagnetics requires removal of extraneous signals triggered by space events to detect electromagnetic earthquake precursors. Thus, these two areas fall on the research objectives of IHY.
2. Research Thrusts

Decades of space research has produced technologies that are now part and parcel of modern society. Space-based technology has greatly improved our communication infrastructure. The Global Positioning System (GPS), technology relying on the continuous operation of a system of satellites, is one of the most valuable legacies of the space program. Through GPS it is now possible to determine location, speed, and direction with accuracy never attained before. It greatly improves navigation and surveying and is an indispensable tool in geological and atmospheric studies in the global scale. Satellite-based instruments also improve weather forecasting. Human society now depends on the stable, continuous operation of satellites.

2.1 Studies in Space Environment and Space Weather: Equatorial Electrojet

The array of scientific instruments deployed for space research has also potential terrestrial applications. In addition, physical processes occurring in space have correlations with terrestrial and atmospheric phenomena. This is more apparent in studies on the earth's space environment, which primarily includes the ionosphere and the overlying region, the magnetosphere. The importance of space environment was first recognized when radio waves were first used in wireless communications. Although not known during the pioneering works on long distance radio transmission, the ionosphere-earth system acts as a waveguide for radio waves which make long-distance communication possible. Nowadays, studies in space environment become more urgent because of its impact on terrestrial and space-based installations. Earth's space environment is formed and strongly influenced by the interaction of the sun-earth system. Thus, an understanding of space environment requires investigation of the processes occurring in the sun, earth, and the intervening space.

The temperature of the outermost solar atmosphere, called the solar corona, is about a million Kelvin. At this temperature, solar atmospheric gas (mainly hydrogen) is almost completely ionized into negatively charged electrons and positive ions that form a globally neutral gas or fluid of negatively and positively charged particles called plasma. Due to the extremely hot condition in the sun's atmosphere, solar plasma cannot be in static equilibrium. Stream of charged particles comprising the plasma flows at supersonic speeds (about 500km per second) bringing along the sun's electromagnetic fields into interplanetary space. The outflow of the stream of plasma into interplanetary space is called the solar wind. Through it, the sun's magnetic field extends into interplanetary space and is called the interplanetary magnetic field (IMF). The interaction of the solar wind and the earth's magnetic field shapes the magnetosphere. The charged particles from the solar wind streaming past the earth are deflected from the boundary of the magnetosphere and the IMF, the magnetopause, generating current through a magnetohydrodynamic process called the solar wind-magnetosphere generator or auroral generator (Akasofu 1968). In this process the kinetic energy of the solar wind particles is converted into electric current generating more than a million of megawatts of electric power. Injection of large amount of energy into the ionosphere by the auroral generator occurs through a pair of electric currents, called eastward and westward electrojets. These jet currents produce magnetic field variations on the ground.
Cataclysmic release of energy from the sun, such as due to solar flares and coronal mass ejections, induces abrupt changes in the solar wind that drastically alter the electromagnetic and particle environment of the earth, a phenomenon called geomagnetic or space storm. In analogy with atmospheric phenomena, the term space weather is coined to refer to conditions in the earth's space environment. During transient releases of energy from the sun, a shock wave is generated and propagates in the solar wind with velocity range of 500-1000 km/s just behind the wavefront. As the shock wave collides with the Earth's magnetosphere, the power of the solar wind-magnetosphere generator may surge to about 10 million megawatts or higher giving rise to geomagnetic storm. During this space weather disturbance, large-amplitude and prolonged southward component of the IMF enhances magnetospheric convection of energetic ions and electrons from the near-earth magnetotail to the inner magnetosphere which forms and intensifies the ring current. The ring current brings about large deviations in the geomagnetic field on the ground.

Geomagnetic disturbance brought about by space storms has been known to pose danger on space-based and terrestrial installations. For instance highly energetic charged particles can damage equipment, such as solar cells, carried by spacecrafts. They also pose health hazards to astronauts working in space and can increase orbital drag of earth-orbiting satellites resulting to their diminished lifetime. Geomagnetic disturbance also produces potential gradients, thereby inducing geoelectric fields on the earth's crust driving geomagnetically induced currents (GIC). The magnitude of GICs depends on the intensity of the space storm, latitude of the location, and ground resistivity. GICs are higher in the auroral regions where geomagnetic variations are large and rapid. Quasi-dc geomagnetically induced currents were reported to enter neutral points in grounded power transformers and therefore flow through transformer windings and into power transmission lines. This resulted to saturation of transformer cores and instability of the power system which eventually led to power failure. The most prominent case of the impact of GIC on power plants was the breakdown of Hydro-Quebec power system during an intense storm in March 1989 (Boteler et. al. 1989). All these dangers posed by geomagnetic storms warrant investments for research in space environment and space weather.

The Philippine participation in studies in space weather will be carried out through collaboration with the Space Environment Research Center (SERC), Kyushu University, Fukuoka, Japan. In 1990, SERC installed a magnetometer network spanning across the 210° magnetic meridian and the magnetic equator, which was then known as the Circum-Pan Pacific Magnetometer Network (CPMN). The network practically covers the polar, mid-latitude, and equatorial regions. Four magnetic stations were established in the Philippines: Cebu, Davao, Tuguegarao, and Muntinlupa. The 1-sec and 1-minute magnetic field data generated by this ground-based array of instruments allow a coordinated investigation of magnetospheric processes. Recently, SERC is establishing a new real-time Magnetic Data Acquisition System in the CPMN (MAGDAS/CPMN) region and an FM-CW radar network along the 210° magnetic meridian for space weather research and applications (Yumoto and the MAGDAS group 2007). New fifty flux-gate magnetometers with a spacing of about 500 km were installed from Davis Station (Australia Antarctic Division station) in the Antarctica all the way to Cape Schmidt in northern Siberia (Figure 1).
The MAGDAS/CPMN magnetometer unit consists of 3-axial ring-core sensors, fluxgate-type magnetometer, data logging/transferring unit, and power supply as shown in Figure 2. Magnetic field digital data are obtained at the sampling rate of 1/16 second. The averaged data are transferred from overseas stations to SERC in near real time using the internet. The ambient magnetic field, expressed by horizontal (H), declination (D), and vertical (Z) components, is digitized by using the field-canceling coils for the dynamic range of 64,000 nT/16 bit. Three observation ranges of 2,000 nT, 1000 nT, and 300 nT for high, middle, and low-latitude stations, respectively, are available. The resolution of MAGDAS data are 0.061 nT/LSB and 0.031 nT/LSB, and 0.0091 nT/LSB for the 2,000-nT and 1,000-nT, and 300-nT ranges, respectively. The estimated noise level of the MAGDAS magnetometers is 0.02 nTpp. The data logger/transfer unit is provided with a GPS antenna for time adjustment. Data are logged into the Compact Flash Memory Card of 1 GB. The total weight of the compact MAGDAS magnetometer system is less than 15 kg. The MAGDAS/CPMN is expected to be serviceable for 10 years, that is, beyond the International Heliophysical Year.

To date, MAGDAS/CPMN is the most extensive magnetometer network in the world. This new installation can now be used to monitor the global electromagnetic and plasma environment in geospace in order to gain a better understanding of the complex sun-earth coupling. MAGDAS/CPMN aims to continuously monitor the earth’s electromagnetic environment and utilize the observations for forecasting changes in space and lithosphere conditions. This project is actively providing information about the space weather condition through the following: (1) global 3-dimensional current system—to know electromagnetic (EM) coupling of field-aligned currents, auroral electrojet current, Sq current, and equatorial electrojet current; (2) plasma mass density along the 210° MM—to understand the plasma environment change during space storms; (3) ionospheric electric field intensity with 10-sec sampling at L=1.26—to understand how the external electric field penetrates into the equatorial ionosphere (see Yumoto and the MAGDAS group, 2006).
Figure 2. The MAGDAS/CPMN magnetometer components.

Table 1. MAGDAS/CPMN magnetic stations in the Philippines (http://magdas.serc.kyushu-u.ac.jp/station/index.html).

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Station Name</th>
<th>Geog. Latitude</th>
<th>Geog. Longitude</th>
<th>Geomag. Latitude</th>
<th>Geomag. Longitude</th>
<th>L</th>
<th>Dip Latitude</th>
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<td>MUT</td>
<td>Muntinlupa</td>
<td>14.37</td>
<td>121.02</td>
<td>6.79</td>
<td>192.25</td>
<td>1.01</td>
<td>6.79</td>
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<tr>
<td>TUG</td>
<td>Tuguegarao</td>
<td>17.66</td>
<td>121.76</td>
<td>10.26</td>
<td>193.05</td>
<td>1.03</td>
<td></td>
</tr>
<tr>
<td>CEB</td>
<td>Cebu</td>
<td>10.36</td>
<td>123.91</td>
<td>2.53</td>
<td>195.06</td>
<td>1.00</td>
<td>2.74</td>
</tr>
<tr>
<td>DAV</td>
<td>Davao</td>
<td>7.00</td>
<td>125.40</td>
<td>-1.02</td>
<td>196.54</td>
<td>1.00</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

Shown in Table 1 are the magnetic stations of MAGDAS/CPMN located in the Philippines with the corresponding geographic latitudes/longitudes, geomagnetic latitudes/longitudes, L-values, and the dip latitudes. SERC initiated collaborations with the Coast and Geodetic Survey Department, National Mapping and Resource Information Authority (for the Muntinlupa Station), Cagayan State University (for the Tuguegarao Station), University of San Carlos (for the Cebu Station), and the Manila Observatory at Davao (for the Davao Station).

Due to the Philippine's proximity to the equator, the focus of the country's involvement in space weather research will be on the study of equatorial electrojet (Otadoy et al.). Equatorial electrojet (EEJ) is a band of enhanced ionospheric current in a narrow strip along the dip equator caused by an enhancement of east-west Cowling conductivity (Forbes 1981). MAGDAS/CPMN magnetic data will be used to study the equatorial electrojet and counter electrojet as the Philippine contribution to the International Heliophysical Year. By utilizing this network of ground-based instruments, it is
hoped that their regular day-to-day and seasonal variabilities and variations during magnetic storms and substorms will be understood.

One can see in Figure 1 that the magnetometer array along the dip equator encompasses the full longitudinal range (i.e. practically around the globe). A study of the equatorial electrojet using the MAGDAS/CPMN thus allows investigation of the global characteristics of this ionospheric current system. It is well known that the equatorial region is the terminal region of energy flows in the earth’s space environment. With the MAGDAS/CPMN’s north to south ground-based magnetometer network along the 210° magnetic meridian, the equatorial electrojet can be studied as part of a global circuit (Kobea et al. 1998). The equatorial electrojet will be monitored using the newly established EE index (Uzzumi et al. 2007). To understand the spatial structure of EEJ additional MAGDAS units will be installed between Cebu and Davao and between Cebu and Muntinlupa. Since solar-terrestrial disturbances penetrate the equatorial ionosphere, understanding of these disturbances at the Dip equator allows nowcasting of these phenomena in the solar wind region.

2.2 Seismoelectromagnetics

The Philippines is sitting on the Pacific Ring of Fire. This makes it vulnerable to frequent tremors due to volcanic activity or due to movements of the earth’s crust. An early warning system for earthquakes can save both lives and property. Geologists have been studying earthquakes for years in the hope of understanding this crustal phenomenon and eventually be able to predict its occurrence. However, decades of research can only give the probability that an earthquake occurs in a particular area in the long term. Short-term earthquake warning system can certainly save lives and property. In recent years, electromagnetic (EM) earthquake precursors in the wide band of frequencies (from ULF to optical) were observed (Gokhberg 1982; Park et al. 1993; Oike and Yamada 1994; Hayakawa et al. 1996; Hayakawa et al. 2000; Hashimoto et al. 2002; Bleier and Freund 2005). In addition, changes in magnetospheric and ionospheric parameters correlated well with the impending occurrence of an earthquake and strain induced on the ground due to crustal activity also produces changes in ground conductivity (Park et al. 1993). The study of these types of earthquake precursors is called seismoelectromagnetics.

Various mechanisms were enunciated to explain the origin of these electromagnetic earthquake precursors. The slow grinding of the earth’s crust leading to sudden rupture accumulates stresses on the ground (Kanamori and Brodsky 2001). This process results to deformation or even breakage of crystalline rocks releasing considerable magnitude of electric current. One theory asserts that a flood of electrons and holes is released due to the breaking of atomic/molecular bonds brought about by this deformation or breakage. Indeed, rock crushing experiments showed that sundering of oxygen-oxygen bonds in minerals of fracturing rocks could produce electron-hole pairs. Electrons may manage to flow towards the mantle while holes flow towards the ground making it positively charged. Aside from electromagnetic emissions associated with these currents, charges produced may induce changes in the electrical properties of the ground such as change in conductivity (Park et al. 1993) and ionization of air in the immediate vicinity of the ground (Bleier and Freund 2005). Electric fields may be produced through the piezoelectric effect in which rock materials may develop voltages when subjected to stresses (Park et al. 1993). Magnetic fields may also be produced through piezomagnetic effect (Park et al. 1993).
Among the EM earthquake precursors, ULF emission is the most promising one because its skin depth is comparable to the depth at which crustal activities take place (Yumoto et al. 2007). In the following, possible mechanisms for ULF emissions are elucidated:

1. Electrokinetic effect has been pointed out by Mizutani et al. (Mizutani et al. 1976) as a possible mechanism of the generation of electric current and magnetic fields prior to the occurrence of an earthquake. Electrokinetic effect occurs when an electrolyte flows through a capillary under a pressure gradient producing electric current. A model suggesting that a porous medium can be considered as a bundle of capillaries (Scheidegger 1974) implies that an electric current is produced when a gradient in pore pressure is induced in the medium. Before an earthquake, the pore pressure at the dilatant focal region decreases while the pore pressure is the same at the surrounding region not affected by the dilatancy. Groundwater therefore flows toward the focal region inducing electric current. Byerlee (Byerlee 1995) earlier proposed that through silica deposition the gradient in pore pressure at the fault zone results to the formation of sealed compartments of various sizes and porosities. Fenoglio et al. (Fenoglio et al. 1995), basing on this model, suggested that magnetic and electric fields could be generated from nonuniform fluid flow due to the rupture of these seals. A consequence of this unsteady fluid flow is the generation of transient fields through piezomagnetic, magnetohydrodynamic, and electrokinetic mechanisms. The electrokinetic signals were comparable to the ULF emissions observed before the Loma Prieta earthquake in October 1989.

2. Molchanov and Hayakawa (Molchanov and Hayakawa 1995) also attributed ULF electromagnetic earthquake anomalies to microfracture electrification. In this process, ULF emissions are produced by fast fluctuations of electric charges due to an ensemble of opening stress-induced microfractures or microcracks. If the rate of production of microcracks is high, the opening microcracks induce wide-band electromagnetic noise that dissipates outside the source region. This in turn produces noise-like ULF emissions on the ground surface with a cut-off frequency of about 1 Hz.

3. The formation of conductive region in the ground associated with earthquake may cause anomalous reflection of ULF waves from space. EM waves from space incident on the earth's surface constitute the normal magnetic-noise background. The electric field of the ULF wave from the plasmasphere induces current in the ionosphere \((\delta \mathbf{J}_i = \sigma_i \delta \mathbf{E})\), which generates magnetic field \(\delta \mathbf{B}_i\) on the ground. The magnetic field \(\delta \mathbf{B}_i\) also induces a current under the ground \((\delta \mathbf{J}_g)\) which in turn produces a magnetic field \(\delta \mathbf{B}_g\). The latter is the reflected magnetic field. The induced geoelectric current depends on the skin depth,

\[
\delta (\text{km}) = \left(\frac{T}{\mu \pi \sigma_i}\right)^{1/2}
\]

where \(T\) is the period of the wave, \(\mu\) magnetic permeability of the ground and \(\sigma_i\) is the geoconductivity. Thus the total magnetic field on the ground is \(\delta \mathbf{B}_g = \delta \mathbf{B}_i + \delta \mathbf{B}_l\). The magnetic anomaly, which appears as change in polarization of the PC 3-4 magnetic pulsations, associated with earthquakes is therefore caused by the drastic change in the geoconductivity.

The good quality geomagnetic data obtained from MAGDAS magnetometers offer opportunity for
analysis of electromagnetic anomalies associated with earthquakes. However, a clear understanding of the interaction between space environment and the lithosphere is necessary because changes in geomagnetic field are influenced more by space events than by lithospheric processes. With the MAGDAS data, it is possible to identify which of the above mechanisms for ULF emission is at work. In addition, since volcanic activities often times involve earthquakes, installation of MAGDAS units near volcanoes may be worthwhile if a comprehensive warning system is to be in place. It is suggested that the magnetometer units will be placed about 1 to 2 km from the crater.

The ionosphere is one of the sectors of the space environment exhibiting precursory events of the occurrence of earthquakes (Pullinets and Boyarchuk 2004). It was reported that total electron content (TEC) (Liu et al. 2004) decreased prior to a big earthquake. By analyzing data from the HINOTORI satellite, Oyama et al. (Oyama et al. 2008a) also reported decrease in electron temperature prior and after three big earthquakes in the Philippines and Taiwan which occurred in 1981 and 1982. The generation of electric at the ionospheric height has been pointed out as the most likely mechanism of the decrease in the electron temperature prior to an earthquake. Due to the presence of positive charges on the ground, decrease in the altitude of the ionosphere was also reported as earthquake precursor (Oyama et al. 2008a). Analysis of the data available form the Dynamic Explorer 2 (DE-2) satellite, Oyama et al. (Oyama et al. 2008b) pointed out that $O^+$ decreased prior to an earthquake. In fact, the ratio $H^+ / O^+$ increased before the earthquake event suggesting variation of the neutral gas (Bankov et al., 2008). Despite the fact that the number of publications has drastically increased and quality of the papers has improved, many ionospheric scientists are not fully convinced of the existence of precursory events in the ionosphere due to the scarcity of the events and reliability issues of the data (Risbeth 2007). Continuation of efforts and allocation of more resources on this area is the only way to ascertain the ionospheric parameters exhibiting earthquake precursory events.

In view of the above-mentioned precursory events of the occurrence of an earthquake, the following research programs are suggested as the Philippine contribution to IHY:

1. The good quality magnetic data available from MAGDAS will be used to study ULF anomalies associated with earthquakes. With the MAGDAS data it is possible to identify which of the three mechanisms of ULF emissions is at work. For the ULF anomaly associated with the change in geoconductivity, precursory feature can be extracted by the following (Yumoto et al. 2007):
   a) calculation of the polarization ratio, the power ratio between the horizontal ($H$) to the vertical ($Z$) components of the Pc 3-4 magnetic pulsations observed at a station near the epicenter;
   b) calculation of the $H- Z$ power ratios of Pc 3-4 magnetic pulsations observed at station near the epicenter to the reference station remote from the epicenter;
   c) calculation of the $H- Z$ power ratios of each day to the one-year averaged data at a station close to the epicenter.
   Since changes in the geomagnetic field are influenced more by space sources than by lithospheric processes, the above techniques will hopefully filter out the influence of the former.

2. Installation of additional MAGDAS units 1 to 2 km from the crater of the most active volcano.
3. Each GPS satellite transmits two signals. The relative phase difference of these signals depends on the total electron content (TEC) of the ionosphere. Installation of GPS receivers scattered strategically around the country allows continuous monitoring of the ionosphere’s TEC (Liu et al. 2004).

4. Monitoring of the air conductivity near the ground. This can be done by installing a number of capacitors a few centimeters from the ground.

5. Investigation of the possible link between the EEJ and earthquake occurrence. This can be done by the MAGDAS magnetic data.

6. Investigation of the application of modern techniques of nonlinear science to the analysis of data to extract EM precursory signals. For instance Ida and Hayakawa (Ida and Hayakawa 2006) used fractal analysis to study ULF data during the 1993 Guam earthquake.

2.3 Satellite

In view of the Philippine Government’s plan to launch a satellite, a section is devoted in this document on satellite instrumentation for equatorial electrojet studies and determination of ionospheric earthquake precursors. Since plasma parameters in the ionosphere can only be directly measured by space-based instruments, our government’s effort to launch a satellite will allow direct measurement of these parameters. The effect of earthquakes in the ionosphere suffered from lack of reliable and routine data due to the absence of satellites dedicated for this purpose. In the past only HINOTORI and Dynamic Explorer 2 satellites provided data although their original purpose was not for earthquake research. Nowadays, a number of countries have launched satellites, such as DEMETER (Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions; http://smsc.cnes.fr/DEMETER/) launched by France and QuakeSat launched by QuakeFinder1, to detect earthquake precursors and hopefully predict the occurrence of an earthquake in the future. In order to gather data over a wide swath of area, a constellation of satellites must be put into orbit. Realization of this plan requires cooperation among different countries (Oyama et al., 2008b). For instance the Philippines may launch a mini-satellite (10-100 kg) or micro-satellite (100-500 kg) while other Asian countries may also launch their own. To be effective there must be close coordination on matters such as orbit information, instrumentation, data format, software, receiving facility and others among the different participating countries. Although more scientific instruments are needed, it is suggested that the following basic scientific instruments will be placed on board our planned satellite:

a. Resonance rectification probe – as mentioned above, it was reported that there was reduction in the electron temperature prior to an earthquake (Oyama et al., 2008a and 2008b). This instrument measures the electron temperature;

b. Impedance probe – it was also reported that electron density increases before the occurrence of an earthquake (Oyama et al., 2008a  and 2008b). This instrument measures electron density;

c. Electric field probe (DC to AC) – this instrument is used to measure the electric field, the most likely mechanism for the decrease in the electron temperature. The measurement accuracy should be more than 0.2 mV/m in order to capture the deviation of 1 mV/m;

1 QuakeFinder is a private company in California engaged in earthquake forecasting research.
d. Plasma drift meter – this instrument measures the electron drift velocity \( \vec{v}_d = \vec{E} \times \vec{B} / B^2 \). This allows calculation of the component of the electric field perpendicular to the magnetic field, which complements the electric field measurement by the electric field probe.

Other scientific instruments, in addition to those mentioned above, can be borne on board by other countries' satellites.

### 2.4 Computation and Large Scale Simulation

Data analysis, theoretical computation, and modeling are crucial in understanding the mechanism behind space weather phenomena and earthquake precursory events. It is suggested that computing resources such as high-performance cluster computer will be made available to researchers involved in these areas. For instance computer clusters in PAGASA, University of the Philippines, Ateneo de Manila University, De La Salle University, and Mindanao State University-Iligan Institute of Technology be connected via PREGINET so that computing resources can be shared.

### 2.5 Amateur Astronomers

A number of discoveries were made by amateur astronomers. A popular example is the efforts of Christopher Go of Cebu City. On March 31, 2004 he discovered a white spot in Jupiter located at the central meridian of the north equatorial belt. Two days later the spot doubled in size and four days later it became a rift. By April 8 the original white spot became a bigger rift ten times its former size. By early March this year Mr. Go, using only an 11-inch telescope and a ccd camera, found that the white spot became red (http://www.redspotjr.com/), which means that the storm was getting stronger. The new spot is officially known as Oval BA but in comparison with the famous Great Red Spot (GRS), which is twice as large, many people prefer to call it Red Jr. Oval BA appeared in the year 2000 when three smaller spots collided and coalesced. A similar mechanism of collision and merger might have formed the GRS centuries ago. Mr. Go is now a guest lecturer at the Department of Physics, University of San Carlos where he is an alumnus. He is now collaborating with the group of Imke de Pater of the University of California at Berkeley for studies of the planet Jupiter (Sanchez-Lavega et al., 2008). Activities of amateur astronomers must be encouraged and supported.

### 2.6 Government and Nongovernment Agencies/Institutes

For the research programs mentioned above to be successful there must be cooperation and collaboration among government and nongovernment agencies and institutes, such as PAGASA, PHIVOLCS, The Manila Observatory, and higher educational institutions.

### 2.7 Scientific Organizations

Scientific societies like the Samahang Pisika ng Pilipinas (SPP) can be a conduit for publication. SPP is regularly holding a physics conference every October and a physics education festival in May. In addition, it is also publishing a journal called PISIKA. Involvement of scientific organizations in IHY is highly encouraged.
3. Education

The education sector plays a crucial role in the production and transmission of knowledge from one generation to the next. Thus in order for the gains of the research programs enunciated above to be fully utilized for public good, educational institutions must be strengthened. Existing geophysics, astronomy, and geology programs must be reviewed and new academic programs may be offered. A case in point is the Manila Observatory (MO). Due to its heavy involvement in space weather and seismoelectromagnetics studies, it may be supported to offer programs/courses on these fields. MO can tap the faculty from the Space Environment Research Center, Kyushu University to handle the new offerings.

Attracting students to enroll in science and engineering has been a perennial problem in the country. The IHY may be a good publicity stunt to tickle their curiosity about science. In fact, during the launched of Sputnik and the subsequent landing of American astronauts on the moon in 1969, the public was mesmerized by these achievements. Earthquake and space weather may be good tools to introduce science to high school students. Simplified data analysis results and popularization media contents can be made available through the internet for high school students (Oyama et al., 2008b). Popularization of science may also help in shaping favorable public opinion toward scientific research.
References


Otadoy, R. E. S., D. McNamara, K. Yumoto, and the MAGDAS Group, Proposal to Use the MAGnetic Data Acquisition System (MAGDAS)/Circum-Pan Pacific Magnetometer Network (CPMN) to Study the Equatorial Electrojet: A Philippine Contribution to the International Heliophysical Year, *Earth Moon Planets* (accepted for publication with DOI: 10.1007/s11038-008-9271-x).

Oyama , K., Y. Kakinami , J. Liu, M. Kamogawa, and T. Kodama, Reduction of electron temperature in low latitude ionosphere at 600km before and after large earthquakes *J. Geophy. Res.*, (accepted for publication with DOI: 10.1029/2008JA013367) 2008a.


