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The United Nations Basic Space Science Initiative for IHY 2007

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Abstract. The United Nations Office for Outer Space Affairs and the International Heliophysical Year (IHY) community have joined hands to deploy arrays of small, inexpensive instruments such as magnetometers, radio telescopes, GPS receivers, all-sky cameras, and particle detectors around the world to provide global measurements of ionospheric, magnetospheric and heliospheric phenomena. The small instrument programme is envisioned as a partnership between instrument providers, and instrument hosts in developing countries as one of United Nations Basic Space Science (UNBSS) activity. The lead scientist will provide the instruments (or fabrication plans for instruments) in the array; the host country will provide manpower, facilities, and operational support to obtain data with the instrument, located typically at a local university. This paper provides an overview of the IHY/UNBSS programme, its achievements and future plans.

Keywords. Sun: atmosphere, Sun: coronal mass ejections (CMEs), solar-terrestrial relations, interplanetary medium, solar wind, solar system: general, acceleration of particles, plasmas, shock waves, magnetic field

1. Introduction

The International Heliophysical Year (IHY) will commence in 2007, marking the fiftieth anniversary of the International Geophysical Year (IGY, 1957–58). The IGY resulted in an unprecedented level of understanding of geospace and saw the beginning of the Space Age. Like the IGY, the objective of the IHY is to discover the physical mechanisms that link Earth and the heliosphere to solar activity. The IHY will focus on global effects but at a much greater physical scale (from Geophysics to Heliophysics) that encompasses the entire solar system and its interaction with the local interstellar medium (Davila *et al.* 2005).

The IHY activities are centred around four key elements: Science (coordinated investigation programmes or CIPs conducted as campaigns to investigate specific scientific questions), Observatory Development (an activity to deploy small instruments in developing countries), Public Outreach (to communicate the beauty, relevance and significance of the space science to the general public and students), and the IGY Gold Programme (to identify and honor all those scientists who worked for the IGY programme). The CIP is aiming at a large number of scientific campaigns in 2007 and 2008, and hundreds of observatories have expressed interest in participating in these campaigns. Thousands of scientists will analyze the data from these IHY CIP campaigns. The Observatory Development activity will provide additional data for the IHY campaigns and new opportunities for research and education in developing countries. This activity will be carried out as a partnership between IHY and United Nations.

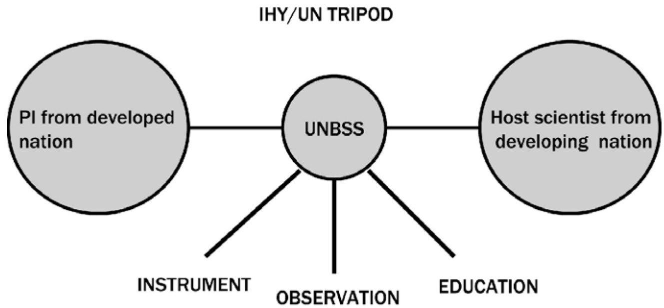

Figure 1. A schematic illustration of the IHY/UNBSS Tripod concept

2. United Nations Basic Space Science (UNBSS) Initiative

The United Nations Office for Outer Space Affairs (UNOOSA) implements the United Nations Programme on Space Applications and works to improve the use of space science and technology for the economic and social development of all nations, in particular developing countries. Under this programme, UNOOSA conducts training courses, workshops, seminars and other activities on applications and capacity building in subjects such as remote sensing, communications, satellite meteorology, search and rescue, basic space science, satellite navigation and space law. The subject of Basic Space Science includes: fundamental physics, astronomy and astrophysics, solar-terrestrial interaction and its influence on terrestrial climate, planetary and atmospheric studies, and origin of life and exo-biology. The IGY 1957 was one of the driving events to establish the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). The UN Basic Space Science (UNBSS) programme is devised according to the requirements of the Member States of UNCOPUOS.

Recognizing the large overlap between the goals of IHY and the UNBSS activities, a partnership was established in 2004 during the UNBSS meeting in China. IHY and UN representatives met in October 2004 at NASA's Goddard Space Flight Center (GSFC) and decided to dedicate UNBSS resources and activities through 2009 to the IHY observatory development programme. The ultimate aim of this collaboration is to deploy small instruments that will provide an opportunity for the scientists in developing countries to effectively participate in IHY activities and promote space science education and research in their home countries.

2.1. *The UNBSS Tripod*

The basic framework of the UNBSS activity can be described by the Tripod concept, as illustrated in Figure 1. The three legs of the Tripod are (i) Instrument, (ii) Observation, and (iii) Education (Al-Naimy *et al.* 2004). During the period 1991-2004, the instrument leg was astronomical telescopes. From 2005 onwards, it represents various IHY instruments deployed in developing countries. The observation and education legs remain the same: data acquisition from IHY instruments and training in data analysis and instrumentation at the university level. Under the Tripod programme, scientists from developed countries or those who are willing and able, donate instruments to developing countries. These instruments will be used for scientific research and for university level education for young people. These deployments will serve as nuclei for a sustained development of scientific activities in the host countries. The data acquired from these instruments will also augment IHY data bases developed from IHY campaigns.

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The instrument deployment projects need to adhere to the following basic principles so that the joint goals of the IHY and UNBSS programmes will be readily accomplished:
A) Quality Science: The projects must produce scientifically significant and publishable results pertaining to the objectives of the IHY activities.
B) Host Countries: The projects that can be readily carried out in developing nations (many of which are near the equator) need to be identified.
C) Cost/Technical Compatibility: The costs and technical requirements of the projects must be compatible with the resources available in the participating nations.
D) Legacy Potential: The projects must lead to a beneficial long-term relationship for the participants in developing nations.
E) Educational Component: The instrument deployment, observation and data acquisition, and analysis should ideally involve students, especially at the university level.

2.2. *Instrument concepts*

A detailed description of the instrument concepts proposed and accepted in 2005 can be found in the 2005 Seminars of the United Nations programme on Space Applications (Gopalswamy, 2005). The current instrument concepts can be grouped into the following classes: (i) Solar Telescope Networks, (ii) Ionospheric Networks, (iii) Magnetometer Networks, and (iv) Particle Detector Networks. These four groups together cover a substantial number of themes listed in section 1. In this section we provide a brief outline of the concepts and new initiatives considered in 2006.

2.2.1. *Solar telescope networks*

The solar telescope network consists of radio telescopes that detect radio bursts associated with solar eruptions. Of particular importance are the bursts produced by shocks and electron beams produced at the Sun, which can be remotely sensed by the radio telescopes. The telescopes will be deployed at several locations in the world, so that the Sun can be monitored continuously. There are currently two projects:

(*a*) The Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) is a dual-channel frequency-agile receiver based on commercially available consumer electronics (PI: Arnold Benz, ETH-Zentrum, Switzerland). The complete spectrometer is very compact, very cheap and easy to replicate for deploying in many locations. Arrangements are being made to deploy one in India at the Radio Astronomy Center in Ooty. This network, in addition to the existing spectrometers at Hiraiso in Japan, ARTEMIS in Greece and Culgoora in Australia will form an excellent radio network for IHY science. Other locations in Mexico and Costa Rica are also being explored for a 2007 deployment.

(*b*) A related radio instrument is the Bruny Island Radio Spectrometer operating in Tasmania, which can be deployed complementary to CALLISTO (PI: R. MacDowall, NASA/GSFC). The frequency of operation is just above the ionospheric cutoff, which depends on the latitude. Currently the electromagnetic characteristics of a site in Gauribidanur, India are being studied for installation of such a spectrometer to work in conjunction with CALLISTO in Ooty.

2.2.2. *Ionospheric networks*

The ionospheric layer is most important for radio communications and broadcasting. Mapping the ionospheric properties around the globe is important for all kinds of communications. Deployment of several ionospheric networks is underway, as described below.

(*a*) The Atmospheric Weather Educational System for Observation and Modeling of Effects (AWESOME) instrument is an ionospheric monitor that can be operated by students around the world (PI: U. Inan, Stanford University). The monitors detect solar flares and other ionospheric disturbances. AWESOME monitors will be deployed in many African and Asian countries, so that the current data obtained in the western hemisphere can be combined with other data. This effort will provide a basis for comparison to facilitate global extrapolations and conclusions.

(*b*) Africa GPS is an effort to link many Global Positioning System (GPS) networks in Africa and the effort is coordinated by Tim Fuller-Rowell (NOAA-Boulder) and Christine Amory-Mazaudier (CETP, France). The overarching plan is to increase the number of real-time dual-frequency GPS stations worldwide for the study of ionospheric variability. Of particular interest is the response of the ionospheric total electron content (TEC) during geomagnetic storms over the African sector. This programme is particularly compatible with magnetometry.

(*c*) Scintillation Network Decision Aid (SCINDA) is a real-time, data driven, communication outage forecast and alert system (PI: K. Groves, AFRL). Its purpose is to aid in the specification and prediction of communications degradation due to ionospheric scintillation in the equatorial region of Earth. Scintillation affects radio signal frequencies of up to a few GHz and seriously degrades and disrupts satellite-based navigation and communication systems. SCINDA consists of a set of ground-based sensors and quasi-empirical models, developed to provide real-time alerts and short-term (< 1 hour) forecasts of scintillation impacts on UHF satellite communication and L-Band GPS signals in the Earth's equatorial regions. SCINDA will be deployed near Earth's magnetic equator (within 20 degrees on either side). The current thrust is in African countries, where there is a clear dearth of ionospheric data.

(*d*) The Remote Equatorial Nighttime Observatory for Ionospheric Regions (RENOIR, PI: Jonathan Makela, University of Illinois at Urbana-Champaign) is a suite of instruments dedicated to studying the equatorial/low-latitude ionosphere/thermosphere system, its response to storms and the irregularities that can be present on a daily basis. Through the construction and deployment of a RENOIR station, it is possible to achieve a better understanding of the variability in the nighttime ionosphere and the effects this variability has on critical satellite navigation and communication systems.

(*e*) The South America VLF Network (SAVNET, PI: Jean-Pierre Raulin, MacKenzie University, Brazil) is for monitoring the solar activity on long and short time scales and studying ionospheric perturbations over the South Atlantic Magnetic Anomaly region. The network will also be used for studying Earth's atmosphere. The basic data output is composed of the phase and amplitude measurements of VLF signals.

2.2.3. *Magnetometer networks*

A magnetometer network is a relatively low-cost method for monitoring solar-terrestrial interactions. A multi-continental network would provide an excellent basis for meso- and global-scale monitoring of magnetospheric-ionospheric disturbances and provide scientific targets for mid- and low-latitudes and opportunities for developing countries to host instruments and participate in the science investigations. Current projects are:

(*a*) The Magnetic Data Acquisition System (MAGDAS) is being deployed for space weather studies during 2005 to 2008 (PI: K. Yumoto, Kyushu University, Japan). The MAGDAS data will be used to map the ionospheric equivalent current pattern every day. The current and electric fields at all latitudes are coupled, although those at high, middle and low latitudes are often considered separately. By using the MAGDAS ionospheric current pattern, the global electromagnetic coupling processes at all latitudes will be clarified. MAGDAS will utilize the Circum-Pan Pacific Magnetometer Network involving several countries around the globe (Australia, Indonesia, Japan, Philippines, Russian Federation, United States and Taiwan Province of China).

(*b*) The Canadian Array for Real-time Investigations of Magnetic Activity (CARISMA, PI: Ian Mann, University of Alberta, Canada). CARISMA is the magnetometer element of the Canadian Geospace Monitoring (CGSM) project. Each proposed IHY magnetometer observatory shall consist of magnetometer station pairs separated meridionally by approximately 200 km. Other requirements are: a 2×3-component fluxgate magnetometer, data logger, GPS timing and power source.

2.2.4. *Particle detector networks*

Particle detectors have a wide range of applications: they can detect energetic particles from the Sun, galactic and extra-galactic sources and from the heliosphere. They can also indirectly observe large magnetic structures such as magnetic clouds and shocks from the Sun through the well-known process of Forbush decrease of cosmic ray intensity. The energetic particles also interact with Earth's atmosphere and produce air-showers (secondary particles). Some large solar energetic particle events interact with Earth's atmosphere leading to ozone depletion (Jackman *et al.* 2005).

(*a*) The SEVAN worldwide particle detector network (PI: Ashot Chilingarian, Aragats Space Environmental Center, Alikhanian Physics Institute, Armenia) is a combined neutron-muon detecting system. A flexible 32-bit microcontroller-based data acquisition electronics will utilize the correlation information from cosmic ray secondary fluxes, including environmental parameters (temperature, pressure and magnetic field). The high precision time synchronization of the remote installations via GPS receivers are crucial ingredients of the new detector. It is proposed to deploy such detectors in neighboring countries such as Bulgaria and Croatia.

(*b*) The muon detector network collaboration (PI:. Kazuoki Munakata, Shinshu University, Japan) consists of nine institutes from seven countries (Armenia, Australia, Brazil, Germany, Japan, Kuwait and the United States). Many of the countries are already operating muon detectors and some have recently installed them. The muon detector network can identify the precursory decrease of cosmic ray intensity that takes place more than one day prior to the Earth-arrival of shock driven by coronal mass ejection. This is an important forecasting tool for predicting space weather attributed to energetic solar eruptions.

2.2.5. *Recent Accomplishments*

AWESOME: The first deployment of AWESOME under the IHY/UNBSS programme commenced in October 2005 with the installation in Tunisia. Instruments were delivered to Algeria and Morocco in summer 2006. More deployments are planned in Libya, Egypt and South Africa. A large network of AWESOME monitors is expected to be in place during 2007–2008.

MAGDAS: IHY-Japan has made significant progress towards the completion of its 51-magnetometer MAGDAS global network with a new installation site on MacQuarie Island, a sub-Antarctic island between Tasmania and Antarctica. Recent deployments were made in Ethiopia, Nigeria, and Ivory Coast (August 2006). The next installation will be in Malaysia.

RENOIR: The RENOIR ionospheric observing station programme has received support for development, and will be making plans for instrument host sites later this year.

SAVNET: The South America VLF NETwork (SAVNET) has been recently approved by the São Paulo state funding agency FAPESP in Brazil for a duration of two years.

The deployment of the SAVNET VLF receiver chain will begin in 2006 with the target of being operational in 2007.

SCINDA: The SCINDA scintillation network is expected to double the size of their equatorial network. An instrumenters meeting was held in July 2006 in Cape Verde in preparation for new deployments. Deployments in Cape Verde and Nigeria have just been completed.

2.3. *Recent developments*

2.3.1. *The Flare Monitoring Telescope*

After the 2005 IHY/UNBSS workshop, a new instrument concept was proposed by Japan. This is an H-alpha telescope to be donated by Japan (PI: S. Ueno, Japan) and hosted in Peru. This will be a good complement to the radio telescope network, discussed in section 2.2.1. The H-alpha instrument consists of six telescopes in the telescope dome: 3 for observations in the H-alpha line center, blue wing, and red wing; one with the occulting disk for prominence observations, one for the continuum, and the last one has an optical guider for accurate tracking of the Sun.

2.3.2. *Data projects*

In addition to instrument deployments, a new element will be introduced during the 2006 workshop. The idea is to replace the Instrument leg of the IHY/UNBSS Tripod with a data base. Accessing and manipulating data from such data bases will be equally rewarding, similar to acquiring data from instruments. One of the examples is the Solar Anomalous and Magnetospheric Particle Explorer (SAMPEX) data base (effort leader S. Kanekal, University of Colorado). SAMPEX is the first in NASA's relatively low-budget, fast-track series of Small Explorer class of spacecraft, launched on July 3, 1992, to provide cosmic ray fluxes at the polar cap and radiation belts fluxes. The SAMPEX mission ended in July 2004, leaving behind a 12-year continuous record of observations. By providing the data with analyzing tools, scientists will be able to study Earth's radiation belts.

2.3.3. *Gnu Data Language*

There is a plan to develop the Gnu Data Language (GDL), which is a free, UNIX-based software that will be available for processing image and time series data. This will enable many scientists from developing countries to access, display and analyze IHY data.

3. UNBSS workshops

Implementation of the BSS Tripod concept is being done using the annual UNBSS workshops. Such workshops have been conducted since 1991 for enabling astronomical telescope deployments. From 2005 onwards, the UNBSS workshops have been devoted to IHY Observatory Development activity. Several things happen during the UNBSS workshops: (1) Scientists from developing and developed countries meet face-to-face to discuss collaborative projects under the UNBSS programme, (2) Scientific instrument host groups provide descriptions of the sites for instrument deployment and the facilities available for hosting the instrument, (3) Potential providers of scientific instruments describe their instruments and the key requirements in terms of infrastructure for a successful deployment and continued operation, (4) Progress reports after the previous workshop are presented and discussed, and (5) Several participants provide the necessary scientific background through a series of tutorial talks.

The first IHY/UNBSS Workshop on Basic Space Science, sponsored by UN, ESA, and NASA, was held in Abu Dhabi and Al-Ain, United Arab Emirates during 20–23

November, 2005. Workshop participants represented 44 countries, including a significant portion of North Africa, the IHY-West Asia region, as well as leadership from the remaining six IHY international regions. There were special sessions on IHY instruments and host institutions, as well as IHY science, global scientific initiatives, education programmes, astrophysical research in Arab nations, and the 2005 World Year of Physics. Special discussions also included planning for the IHY-Africa initiative, education and outreach activities, and the establishment of a working group on Infrastructure and Sustainability Issues in Global Space Sciences. Overall the conference accomplished more than expected, and the future workshops will build on this success.

The Second IHY/UNBSS Workshop was held from November 27 – December 1, 2006 in Bangalore, India and was sponsored by UN, NASA and several institutions in India. After several sessions on background science topics, presentations by the instrument donors on the current progress and future plans for the deployment projects were made. Like the 2005 workshop in UAE, this meeting focussed on identifying instrument host and deployment sites for IHY instrumentation.

4. Conclusions

The IHY activities recognize the importance of global efforts with participation from as many countries as possible and as many observatories (from ground and space) as possible. All four elements of IHY are built upon this global cooperation. The new instruments deployed by the IHY/UNBSS programme will also participate in the CIPs. Scientists and students from developing countries will also participate in the observations and data analysis, providing valuable training and education. The IHY schools programme will also help build a solid scientific background for young people throughout the world. The synergy between IHY and UNBSS activities is expected to make great progress during the IHY years and beyond.

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