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Science outreach and capacity building in geomagnetism and space sciences—An Indian Institute of Geomagnetism endeavor

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Abstract We present an overview of science outreach and capacity building activities at the Indian Institute of Geomagnetism (IIG) against the backdrop of a long history of geomagnetic studies. We also present the future plans of the institute for strengthening these activities.

Introduction

The Indian Institute of Geomagnetism (IIG) has a long history of over 175 years in the field of geomagnetism and space sciences. IIG implemented outreach and capacity building activities to disseminate the results of its science investigations. These have assumed new prominence given the spacefaring activities of India including new Moon and Mars missions. The capacity building activities are especially important because there are few if any committed syllabi at Indian universities in the field of geomagnetism and space research.

Below, we provide a summary of our historical achievements and highlight our current science activities. We then describe our science outreach and capacity building activities and list planned activities to be implemented in the near future.

Historical Perspective

The impact of solar flares on the Earth was first recognized by Richard Carrington when he saw Earth bathed in a magnetic storm after the 1 September 1859 solar explosion. One of the most famous records of this historic event was recorded (Figure 1) by our Colaba-(Alibag) magnetic observatory. The observatory was set up in 1841 and is one of the world's longest functioning (see details in *Uberoi* [2011]). The long-term geomagnetic observations archived at Colaba-Alibag, including valuable geomagnetic field variations taken during solar storms provide unique records to unravel the occurrences of past extreme space weather events. Such records of past intense geomagnetic storms are of paramount importance to researchers to quantitatively understand the frequency of occurrence and possible impact on the Earth's environment. Our world can be highly vulnerable to extreme interplanetary and geomagnetic disturbances. If a Carrington-like super intense storm were to hit the Earth in the present era, it could damage spacecraft and ground-based power grids, hamper communication and navigation systems, and threaten the lifestyle of those dependent on space-based electronic equipment.

The Colaba magnetic observatory was shifted to Alibag in 1904 because the advent of electric trams in Bombay (now Mumbai) was vitiating the magnetic recordings at Colaba. The shift to Alibag was carried out under the close watch of Nanabhoy Moos, the first Indian director of the observatory [*Moos*, 1910a]. Moos was witness to an aurora, at Mumbai, on 4 February 1872, and reckoned the emergent storm was weaker than the 1859 magnetic storm [*Moos*, 1910a, 1910b]. His early estimates were confirmed when *Lakhina et al.* [2005] estimated the intensity of the former storm at 1020 nT and *Tsurutani et al.* [2003] estimated the latter's intensity to be 1720 nT, which is the highest known to date. It is interesting to note that the modern understanding of the term magnetic storm is attributed to Moos [*Daglis et al.*, 2003]. Even Chapman applied Moos's methods to study features of geomagnetic storms recorded at varying geographic locations [*Daglis et al.*, 2003].

IIG now has under its fold 14 permanent magnetic observatories, strategically spread along the length and breadth of the country (Figure 1). These observatories collect continuous data that are used for the solid earth as well as upper atmospheric studies that are published in peer-reviewed science journals. This information,

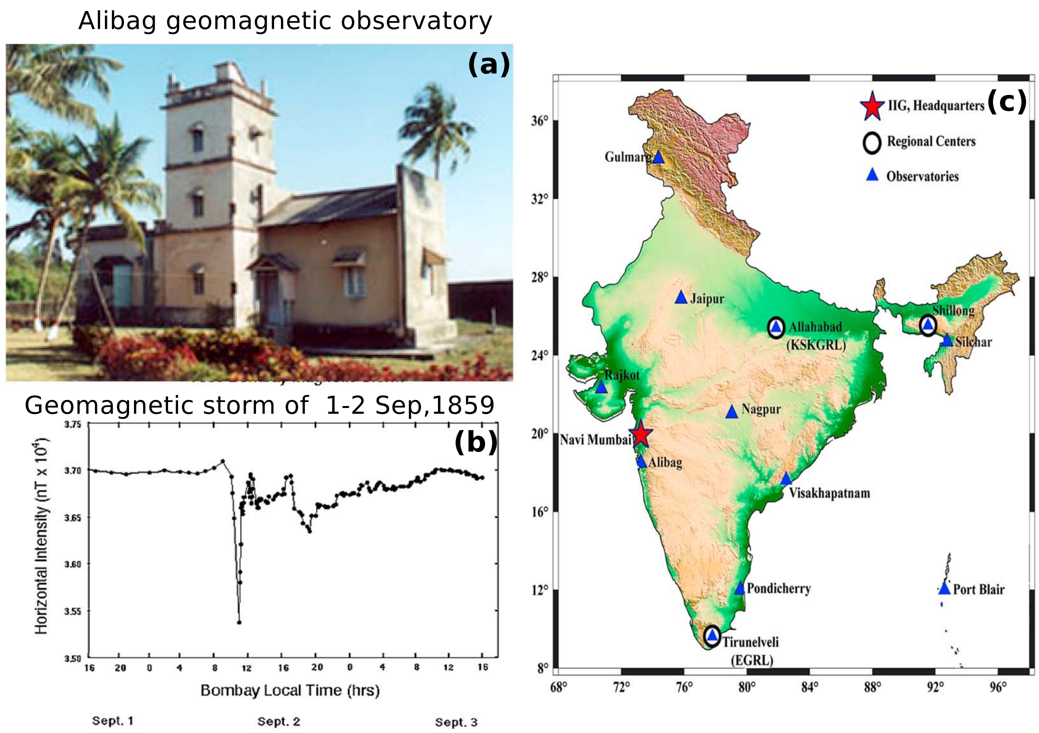

Figure 1. (a) Absolute tower for measurements of geomagnetic field variations located at Alibag geomagnetic observatory, Alibag, India. (b) The super geomagnetic storm of September 1859 recorded by ground-based magnetometer located in Colaba geomagnetic observatory, Mumbai, India (source: *Tsurutani et al.* [2003]). (c) Geomagnetic observatory network in India that monitors geomagnetic field variations from equator to midlatitudes.

however, does not often reach the general public, who would benefit immensely from this knowledge. Our government has instituted many different platforms to disseminate the latest scientific information to the people starting with the first Indian Science Congress (ISC) at Calcutta (Kolkata) in 1914. This has become an annual event, held in different parts of the country, and IIG has been an active participant from the beginning. IIG also participated in all Indian scientific expeditions launched to Antarctica from the time these were initiated in 1981. Since very little is known about Antarctica in India, expedition members are constantly invited by various schools and colleges to deliver talks and share their experiences. The Antarctic images of the frozen ocean, vast ice fields, huge icebergs, penguins, auroras, and other features are a big draw for teachers, students, and the public.

Science Highlights

The specter of space weather looms most over high latitude countries although efforts by all countries even low latitude countries like India are critical in tracking the changes whirling in the dark reaches of space. As discussed in *Carter et al.* [2015] and *Zhang et al.* [2016], low latitude regions do experience geomagnetically induced currents. Because space weather events have the potential to impact life and technology, it is imperative to the cognoscenti to understand the cause and effect of space weather conditions. Making use of the magnetic observatory data recorded from the equator to high latitudes within India, as well as at Antarctica, many IIG research groups are working to understand the physicochemical changes in the ionosphere, magnetosphere, and lower atmosphere regimes. This network has contributed immensely in understanding the dynamics of ionospheric current systems [for example, *Patil et al.*, 1983; *Campbell et al.*, 1993; *Bhattacharyya and Okpala*, 2015] as well as equatorial and low latitude phenomena [for example, *Gurubaran et al.*, 2001]. These, in turn, provide deeper insight into the dynamics of space weather at low latitudes. The transfer entropy approach has been adopted to address the long-standing question of coupling between equatorial electrojet and solar quiet current systems [*Vichare et al.*, 2016]. In the leadership of many of the national scientific missions to Antarctica, the geomagnetic data gathered there have revealed the dynamics of substorms, particle precipitation, and pulsations. IIG research has revealed the relationships between substorm activity and the interplanetary magnetic field [e.g., *Lakhina et al.*, 2005]. The broad climatology of very high latitude, isolated substorms was studied by *Singh et al.* [2011, 2012]. The cosmic noise absorption associated with particle precipitation intensity significantly depends on interplanetary conditions that contribute to the interplanetary electric field [*Behera et al.*, 2015].

To inform solar cycle predictions which are crucial elements in forecasting geomagnetic activity, *Kakad et al.* [2015] developed a novel model based on Shannon entropy to forecast the descent time of solar cycles. In related work, *Vichare et al.* [2005] defined the quantum of solar wind kinetic energy during the main phase of the storms, and recently, *Kumar et al.* [2015] estimated solar wind conditions associated with large storms using the Indian geomagnetic records. *Joshi et al.* [2015] studied *F* layer height rise and equatorial spread *F* onset time. The study indicates the presence of a large-scale zonal standing wave in the *F* layer. Geomagnetic storm of 17 March 2015, the largest in current solar cycle 24 created a steep rise in the *F* layer height over Tirunelveli (magnetic equator) with plasma irregularities seen at places like Allahabad and Lucknow [*Singh et al.*, 2015]. A pioneering scintillation study that adopted a new technique was carried out by *Bhattacharyya et al.* [2003]. Forecasting ionospheric scintillations in L band over the magnetic equator is demonstrated by *Bagiya et al.* [2014].

These themes collectively form the core of space weather studies at IIG. The institute plans to continue this work to understand the many physical processes associated with space weather with the ultimate aim of forecasting their impact.

Science Outreach Activities

Science Outreach at IIG is an endeavor to instill the scientific temper, which is essential in moulding the mindset for a comprehensive development of society. We try to promote scientific knowledge and rational thinking in an objective way. We are keen to ignite excitement about recent advances in geomagnetism and its allied research fields, firmly believing that public communication will enable the laity, policy makers, and industrial leaders to consider the scientific and technological applications beneficial to society. Since the 1980s, to avoid the mutual isolation of science and the public the Government of India marks 28 February as a National Science Day to commemorate the “Raman Effect.” IIG participates and celebrates the last week of February as Science Week.

At IIG, we strive to develop learning through scientific inquiry since this creates opportunities to reason in a cogent manner based on scientific principles. This is done through organizing seminars, science competitions, power point presentations (PPTs), exhibitions, talks, lectures, hands-on experiments, model handling, and other means (see Figure 2). Lectures and PPTs on space science themes provide a good platform for young students to interact with researchers and learn about space weather, which is not yet widely taught in the schools or colleges. Exhibits covering historical and ongoing research expose students to the wonder and excitement of space research. Models and toys depicting the fundamentals of geomagnetism and space dynamics help smaller children intuitively visualize the complex processes operative in far off regions. These toys and models are developed in-house by our research scholars and faculty. In addition to this, more than 14,000 copies of Hindi and English science comics, originally produced under the Climate and Weather of the Sun-Earth System (CAWSES) program, were reprinted by IIG and freely distributed to schools, students, and libraries. Solar projections and telescope viewing is facilitated at IIG and is demonstrated at exhibitions elsewhere. Live solar images, generally encompassing sunspots, flares, and prominences shown in both white light and Hydrogen-alpha wavelength (656.28 nm), are major attractions for students and the public since they can observe the dynamic Sun and the evolution of associated features in real time (Figure 3). These public activities reach over 25,000 students and laity each year. As a result of these, many students have been influenced to take up scientific research as their career.

Capacity Building

IIG intends to realize optimum capacity building in the Indian region, by organizing seminal activities on related science topics for teachers. This updates knowledge on the Earth and space sciences, which is then disseminated in schools and colleges. IIG’s summer trainee program is hugely popular, wherein many postgraduate students initiate innovative ideas in many diverse areas of space weather and geomagnetism.

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Figure 2. Various activities conducted by IIG like poster exhibits, popular science lectures and interaction sessions, Inspiring the Minds of Postgraduates for Research in Earth and Space Sciences (IMPRESS) program, and reprinted science comics, for students and public to educate them about geomagnetism and space weather.

This program hones the skills and trains the students in space science research by exposing them to different techniques and instruments. The success of this program can be gauged by the number of summer trainees who have joined IIG for further graduate and postgraduate studies in later years.

An advanced national level program was launched in 2013 called IMPRESS (Inspiring the Minds of Postgraduates for Research in Earth and Space Sciences), which impresses upon the participants the excitement and sublime experience of research in space science and geomagnetism. This initiative annually exposes bright young minds to geomagnetism and its allied fields. In addition, postdoctoral positions instituted in the name of Nanabhoy Moos are offered, with special incentives, to carry out cutting-edge research at IIG to explore the Sun-Earth connection.

Figure 3. Exhibit of H-alpha solar telescope and overwhelming response by public and media. Images of the sunspot, prominences, and solar granulation observed through the telescope are depicted here.

Future Activities

In the near future, IIG will be reaching out to the students and teachers of rural India through specially designed scientific skits that explain the complex Sun-Earth connection. A target audience of 5000 per year will be reached through this approach. In another special effort, the government of India has allocated funding to establish a regional research center at Shillong, which is in a remote and seismically vulnerable region of northeast India. An array of state-of-the-art instruments will help scientists understand the coupling and dynamics of the Lithosphere-Atmosphere-Ionosphere-Magnetosphere (LAIM) regions. This will help mitigate disasters in that region. To actively engage skilled personnel in India's space research, IIG is establishing an Advanced Training School (ATS) to impart additional specialized knowledge in areas of Space and Earth sciences to offset the shortage of structured academic programs in these two important areas. International collaborations (e.g., with Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)) have opened discussions for a student exchange program as a part of our capacity building initiatives. India's emergent space program, including the satellite around Mars and its preparations to take humans to Moon, makes it imperative for the country to focus attention on space physics. Its space programs will need replenishment of spirited and enthusiastic scientific and engineering personnel that come from ignited young minds. It is the endeavor of IIG to solidly contribute in this direction. IIG will strengthen its activities in coordination with international initiatives. In the coming months and years, science popularization will remain a continuous and important theme at IIG!

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