Establishing a Cosmic Ray Station and Other Space Research Facilities in Ethiopia

B Damtie[1], T Bosinger[2], I Usoskin[3]

[1]*Department of Physics, Bahir Dar University, Bahir Dar, P O Box 79, Ethiopia*
[2]*Department of Physical Sciences, Oulu, 90014 Oulu University, P O Box 3000, Finland*
[3]*Sodankylä Geophysical Observatory, Oulu Unit, P O Box 3000, 90014, University of Oulu, Finland*
e-mail: [1]bayliedamtie@yahoo.com

Abstract. This paper describes the potential of Ethiopia in establishing space research facilities and conducting collaborative research and training. It also describes the goals and objectives of a proposed cosmic ray station in Ethiopia which would greatly improve the abilities of the existing worldwide network for heliospheric and cosmic ray research. The station will be located at the geomagentic equator, which is a very unique place for geomagnetic and heliospheric studies. Moreover, the paper presents an overview of the research and training activities in space physics and the successful collaborative project between Ethiopia and Finland, which facilitated the installation of a pulsation magnetometer and a photometer at Entoto Mountain in a suburb of the Ethiopian capital, Addis Ababa.

Sommaire. Cet article décrit le potentiel de l'Ethiopie à établir des centres d'études spatiales et à conduire en partenariat un travail de recherche et de formation. Il décrit également les objectifs du projet d'installation en Ethiopie d'une station de mesure du rayonnement cosmique qui apporterait une amélioration sensible aux capacités existantes du réseau mondial de recherche sur les rayonnements heliospheriques et cosmiques. La station sera située à l'équateur géomagnétique qui est un endroit unique pour les études géomagnétiques et heliospheriques. De plus, cet article présente une vue d'ensemble des activités de recherche et de formation en physique spatiale et de la collaboration réussie entre l'Ethiopie et la Finlande. Cette collaboration a facilité l'installation d'un compteur magnétique de pulsation et d'un photomètre au sommet de la montagne Entoto dans la banlieue de la capitale éthiopienne Addis Ababa.

Introduction

Ethiopia (formerly Abyssinia) has been a first-class research field for geologists and more especially, seismologists from early in the last century. This is largely due to the presence of the Great Rift Valley, a great tear across the surface of the Earth, extending nearly 6 000 km from Syria, through the Red Sea, Ethiopia, and down to Mozambique. Ethiopia's geographical extent (from about 35°E–45°E and 3°N–15°N) and magnetic location (the magnetic equator crosses Ethiopia) make it perfect for investigations related to many topics of space physics.

The Equatorial Electro Jet (EEJ) is an electric current flowing across the country from north to south at an altitude of about 105 km. It comes, therefore, as no surprise that pioneering work in the exploration of the EEJ was carried out at observation sites including Ethiopia and other African countries located in the equatorial region[3]. At the beginning of the seventies of last century, experiments in space physics were conducted in Ethiopia, thanks to the initiative and interest in coherent radar observations of a French team[2] and the Geophysical Observatory of Addis Ababa University (AAU). The Geophysical Observatory on the campus of AAU is still operational and its present contribution to the scientific community is, among other activities, maintaining an INTERMAGNET station of the world-wide, real time, satellite-linked, magnetometer network (http://www.intermagnet.org/).

Although the facilities installed by French scientists have provided valuable data, the expansion and continuous operation of these facilities did not materialise in Ethiopia. This may be because the involvement of Ethiopian scientists in research and development of these facilities was very limited. Moreover, there was no formal space physics training at Ethiopian universities in that time.

Formal education in space physics commenced in Ethiopia recently with the commencement of a space physics graduate programme jointly by Addis Ababa University and Bahir Dar University. In order to expand and strengthen this programme, a collaborative project in atmospheric research is being initiated with many national and international stakeholders, including commercial enterprises such as Eigenor, heading towards development and operation of weather radars (http://www.eigenor.com/BERCAB/index.php/Main Page). This paper presents an overview of the research and training activities in space physics in Ethiopia and also describes a successful collaborative project between Oulu University (Finland) and Bahir Dar and Addis Ababa Universities (Ethiopia). Moreover, a brief description of future collaborations is presented with the intention of attracting the attention of potential collaborators and funding agencies.

The Ethio-Finno Observatory (EFO)

Researchers from Bahir Dar and Addis Ababa Universities, in collaboration with their counterparts from the University of Oulu in Finland, successfully established an ionospheric monitoring station called EFO (Ethio-Finno Observatory) at Entoto Mountain using a scanning photometer and pulsation magnetometer from Finland. The project was funded by the Academy of Finland. After safe transport, the instruments were tested thoroughly at Addis Ababa University. After a search for an optimal site for the observatory, the Entoto Mountain on the outskirts of Addis Ababa was chosen. Finally, the instruments were successfully installed there.

Figures 1 and 2 show the scanning photometer and the pulsation magnetometer, respectively, on Entoto Mountain.

Fig. 1. The Photometer operating at EFO (Ethio-Finno Observatory) at the top of Entoto Mountain in Ethiopia.

Fig. 2. The pulsation magnetometer operating at EFO (Ethio-Finno Observatory) at the top of Entoto Mountain in Ethiopia.

These instruments make measurements on a regular basis and the data are recorded automatically with the acquisition system shown in Figure 3. An example of an analysis of data from the pulsation magnetometer is shown in Figure 4.

Fig. 3. One of the authors (B.D.) with the data acquisition system of EFO.

Education and Research in Space Physics

The Departments of Physics at Bahir Dar University and Addis Ababa University have started a graduate programme in space physics. The curriculum is designed so that students take core general physics graduate courses at Addis Ababa University in their first years and in the final year, they take two space physics graduate courses at Bahir Dar University. Also, they write their theses in space physics during their stay at Bahir Dar University. A similar arrangement may be adopted in many African countries with a shortage of resources and manpower. In future, we plan to strengthen our programme by collaborating with other countries.

Studies on ionospheric physics are carried out with special emphasis on system development for ionospheric radars[1]. Investigations are being carried out to develop a method of suppressing the sidelobes in filtering chirp waveforms by means of matched filters. Magnetic pulsations are also studied. The group is also initiating research in the system development of weather radar. A precursor for this initiative is the invention of a method that can solve the Doppler range dilemma[6] which states that there is an inverse relationship between the unambiguous range and the unambiguous velocity.

Establishing A Cosmic Ray Research Facility in Ethiopia

The fact that the Ethiopian site is located at the geomagnetic equator provides a good opportunity to study solar and heliospheric physics by means of the ground-based cosmic ray measurements. Cosmic rays (CR) are an important object to be studied. On the one hand, they form an outer space factor affecting the Earth's environment; on the other, they carry unique information on the physical conditions in the regions of their origin and transport. It is proposed to extend the existing collaboration and to establish a cosmic ray station in Ethiopia. The corresponding research proposal was submitted to the Academy of Finland. The scientific objective for research of this kind is two-fold: (a) heliospheric modulation of cosmic rays; and (b) solar neutrons.

Heliospheric Modulation of Cosmic Rays (CR)

Both the intensity and energy spectrum of CR are subject to the modulation in course of the solar activity cycle. Accordingly,

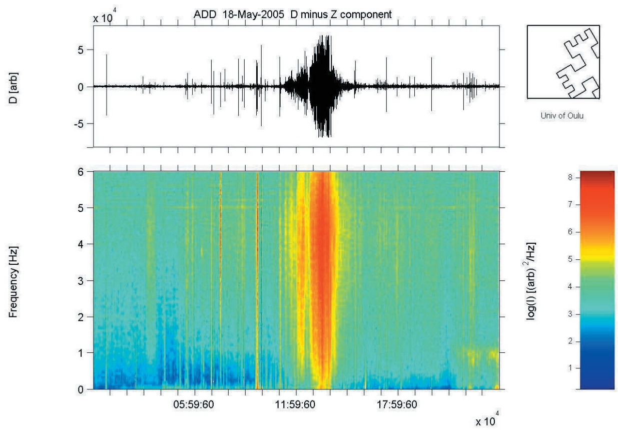

Fig. 4. An example of the spectral analysis of pulsation magnetometer data.

continuous data on the cosmic ray differential spectrum allows studies of physical conditions in the heliosphere, including the solar global magnetic field, the solar wind and the heliospheric structure. Unfortunately, direct measurements of the CR energy spectrum are difficult since they must be done outside the Earth's atmosphere using satellites. However, obtaining long-term, continuous data is a problem because of finite satellite life times. The situation can be resolved by using data from the world-wide network of ground-based neutron monitors which presently consists of about 50 stations around the globe. A neutron monitor measures superthermal neutrons produced as a result of nuclear interactions of the cosmic ray particles with the air. Since cosmic rays are charged particles, they are affected by the geomagnetic field; therefore, the low energy CR are deflected by the field and cannot reach the ground. Since the deflecting effect strongly depends on the geomagnetic (*i.e.* with respect to the geomagnetic dipole axis) latitude λ_g, the world-wide network of neutron monitors acts as a rough spectrometer to evaluate the spectrum of cosmic rays in the vicinity of the Earth. It is important, in this respect, to use a large number of neutron monitors covering a wide range of geomagnetic latitudes. The present network covers the range of geomagnetic latitudes from 90° (polar stations) to about 15°. At present, there is no cosmic ray station at the geomagnetic equator (there was one in Ahmedabad, India, but it was unfortunately closed in 1976). Therefore, the Ethiopian site, located at the geomagnetic equator, will allow for a better determination of the long-term galactic cosmic ray energy spectrum.

Solar Neutrons

Eruptive energy releases, which occur during solar flares, may accelerate ambient protons to high energy (up to several GeV) in the solar atmosphere. A fraction of these particles can escape into the interplanetary space and can be observed as solar cosmic rays. The other fraction can be trapped in a flare magnetic loop structure and suffer nuclear interaction in the dense loop's foot points. As a result of such interactions, energetic neutrons can be produced[5]. Since neutrons are not affected by magnetic fields, their path is a straight line, and they carry direct information on the physical conditions at the flare site, and are therefore of great interest in solar physics[4]. Ground-based neutron monitors are able to detect strong energetic solar neutron events[7]. Since the neutron signal should be separated on the background of ever present galactic cosmic rays, several measures can be undertaken to increase the signal-to-noise ratio. One can increase the neutron signal, attenuated in the atmosphere, by placing a neutron monitor at higher altitude but this equally increases the galactic cosmic ray background. In order to decrease the background level, one has to place a cosmic ray station at low geomagnetic latitude. The best location to study solar neutrons, therefore, is a high-altitude site at the geomagnetic equator, which allows for the lowest background and the highest neutron signal.

Figure 5 shows the sensitivity of the world neutron monitor network to a solar neutron event similar to that of 3 June 1982[7]. One can see that the existing network is able to detect a strong solar neutron event reliably about 55% of the time (lower panel of Figure 5). While the summer months are well covered by numerous stations in the northern hemisphere, winter months are less covered. The upper panel shows the sensitivity of the network including the proposed cosmic ray station in Addis Ababa – its coverage is shown by the dashed oval. It covers the late morning (09 – 12 UT) hours over the whole year, so that the overall coverage reaches 63.5%, which implies an 8.5% absolute or a 15% relative increase.

The proposed cosmic ray station will be a result of a wide international collaboration, planned and designed in Finland (University of Oulu and Sodankylä Geophysical Observatory). It will be built in South Africa (North-West University), installed in Ethiopia (Addis Ababa University) and operated by Ethiopian personnel (Addis Ababa and Bahir Dar Universities). It will complete a meridional chain of cosmic ray stations located at the same longitude and covering the whole range of latitudes, which includes stations from Finland, Germany, Italy, Israel, Russia, Slovakia, South Africa and Switzerland.

Establishing a Weather Radar System

A significant development has been made recently in the system development of a weather radar. Markku Lehtinen from Oulu University in Finland has developed a method of solving the long-standing problem in the weather radar, the "Doppler range dilemma." His method, which has a US patent[6], enables one to determine the spectrum of the signal scattered from a target. However, this method needs to be thoroughly tested and investigated. The climatological conditions in Ethiopia are suitable for routinely testing and refining the method. Hence, we would like to initiate a collaborative project to establish a weather radar system in Bahir Dar, Ethiopia.

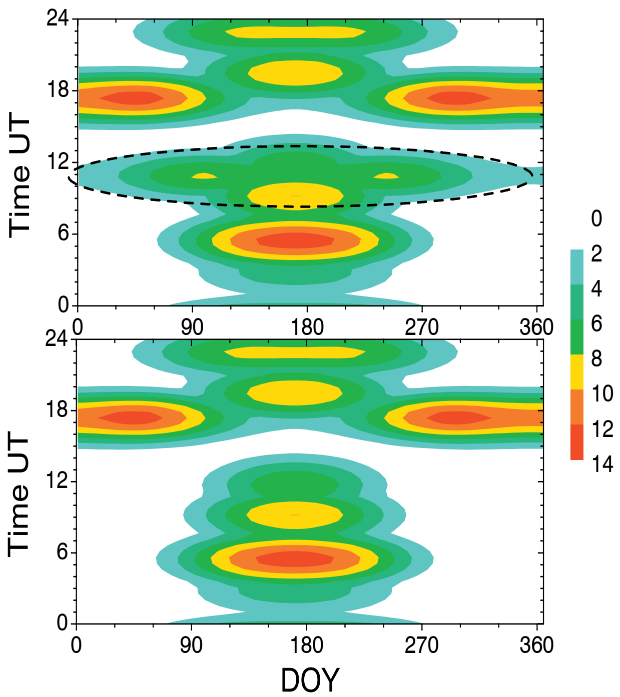

Fig. 5. Sensitivity of the world neutron monitor network to a solar neutron event similar to that of 3 June 1972. The lower panel corresponds to the existing network, and the upper includes the proposed station in Ethiopia whose contribution is denoted by the dashed oval. Values are given in standard deviations from the background of galactic cosmic rays[7] (refer colour scale). The X- and Y-axes correspond to the day of year and to the time in UT, respectively.

Conducting a Sandwiched Graduate Programme in Space Physics

In order to improve both the quality and the quantity of the graduate study programme in space physics, it is vital for Ethiopian scientists to work in collaboration with researchers from other countries. Conducting collaborative research projects and running sandwiched graduate programmes can be carried out. This kind of arrangement will provide a platform for graduate students and scientists to exchange ideas and skills with researchers and students from other countries.

Conclusion

The location of Ethiopia, together with the presence of many worthy students interested in space physics, needs to be exploited by the international space physics community. Ethiopian decision-makers and other stakeholders are very supportive of scientific endeavours. Institutions, research groups, individuals and funding agencies are most welcome to collaborate with the authors in a friendly working atmosphere to realise the project concepts presented and discussed briefly in this paper.

References

1. Damtie, B., Lehtinen, M.S. and Nygrén, T., Decoding of Barker-coded incoherent scatter measurements by means of stochastic inversion, *Ann. Geophysicae*, 22, 3–13, 2004.
2. Hanuise, C. and Crochet, M., Multifrequency HF radar studies of plasma instabilities in Africa, *J. atmos. terr. Phys*., 39, 1977.
3. Crochet, M., Radar studies of longitudinal differences in the equatorial electrojet: a review, *J. atmos. terr. Phys*., 39, 1977.
4. Kocharov, L.G., Torsti, J., Tang, F., Zirin, H., Kovaltsov, G.A. and Usoskin, I.G., Impact of Magnetic Environment on the Generation of High-energy Neutrons on the Sun, *Solar Phys.*, 172, 271, 1997.
5. Kovaltsov, G.A., Usoskin, I.G., Kocharov, L.G., Kananen, H. and Tanskanen, P.J., Neutron Monitor Data on the 15 June 1991 Solar Flare: Neutrons as a Test for Proton Acceleration Scenario, *Solar Phys.,* 158, 395–398, 1995.
6. Lehtinen, M.S., Method and system for measuring radar reflectivity and doppler shift by means of a pulse radar, US patent, Patent No. US 6,232,913B1, May 15, 2001.
7. Usoskin, I.G., Kovaltsov, G.A., Kananen, H., and Tanskanen, P., The World Neutron Monitor Network as a Tool for the Study of Solar Neutrons, *Annales Geophysicae*, 15, 375–386,