United Nations A/AC.105/919

General Assembly

Distr.: General
28 October 2008

Original: English

Committee on the Peaceful Uses of Outer Space

Report on the Fourth United Nations/European Space Agency/National Aeronautics and Space Administration/Japan Aerospace Exploration Agency Workshop on the International Heliophysical Year 2007 and Basic Space Science (Sozopol, Bulgaria, 2-6 June 2008)

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V.08-57740 (E) 260109 270109

I. Introduction

A. Background and objectives

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), in particular through its resolution entitled "The Space Millennium: Vienna Declaration on Space and Human Development", recommended that activities of the United Nations Programme on Space Applications should promote collaborative participation among Member States, at both the regional and international levels, in a variety of space science and technology activities, by emphasizing the development and transfer of knowledge and skills to developing countries and countries with economies in transition.[1]

2. At its fiftieth session, in 2007, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and conferences planned for 2008.[2] Subsequently, the General Assembly, in its resolution 62/217 of 22 December 2007, endorsed the activities of the Office for Outer Space Affairs of the Secretariat for 2008.

3. Pursuant to Assembly resolution 62/217 and in accordance with the recommendations of UNISPACE III, the United Nations/European Space Agency/National Aeronautics and Space Administration/Japan Aerospace Exploration Agency Workshop on the International Heliophysical Year 2007 and Basic Space Science was held in Sozopol, Bulgaria, from 2 to 6 June 2008. The Solar-Terrestrial Influences Laboratory of the Bulgarian Academy of Sciences hosted the Workshop on behalf of the Government of Bulgaria.

4. Organized by the United Nations, the European Space Agency (ESA), the National Aeronautics and Space Administration (NASA) of the United States of America and the Japan Aerospace Exploration Agency (JAXA), the Workshop was the fourth in a series of workshops on basic space science and the International Heliophysical Year 2007 proposed by the Committee on the Peaceful Uses of Outer Space, on the basis of discussions of its Scientific and Technical Subcommittee, as reflected in the report of the Subcommittee (A/AC.105/848, paras. 181-192). The three previous workshops in the series were hosted by the Governments of the United Arab Emirates, in 2005, of India, in 2006, and of Japan, in 2007 (A/AC.105/856, A/AC.105/489 and A/AC.105/902, respectively).[3] Those workshops were a continuation of the series of workshops on basic space science that were held between 1991 and 2004 and that were hosted by the Governments of India (A/AC.105/489), Costa Rica and Colombia (A/AC.105/530), Nigeria (A/AC.105/560/Add.1), Egypt (A/AC.105/580), Sri Lanka (A/AC.105/640), Germany (A/AC.105/657), Honduras (A/AC.105/682), Jordan (A/AC.105/723),

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[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1, sect. I, para. 1 (e) (ii), and chap. II, para. 409 (d) (i).

[2] *Official Records of the General Assembly, Sixty-third Session, Supplement No. 20* (A/63/20), para. 72.

[3] Information on the International Heliophysical Year 2007 and the United Nations Basic Space Science Initiative is available on the website of the Office (www.unoosa.org/oosa/SAP/bss/ihy2007/index.html).

France (A/AC.105/742), Mauritius (A/AC.105/766), Argentina (A/AC.105/784) and China (A/AC.105/829).[4]

5. The main objective of the Workshop was to provide a forum in which participants could comprehensively review achievements and plans for basic space science and the International Heliophysical Year and assess recent scientific and technical results, with a view to reporting on the status of implementation of follow-up projects for the promotion of basic space science (A/AC.105/766) and the International Heliophysical Year (A/AC.105/882).

B. Programme

6. At the opening of the Workshop, statements were made by the representative of the Bulgarian Academy of Sciences, by the Mayor of Sozopol on behalf of the Government of Bulgaria, and by representatives of the International Heliophysical Year secretariat, NASA and the Office for Outer Space Affairs. The Workshop was divided into plenary sessions, each focusing on a specific issue. Presentations by invited speakers, describing their achievements with regard to organizing events, and carrying out research, education and outreach activities related to basic space science and the International Heliophysical Year, were followed by brief discussions. Ninety papers and posters were presented by the invited speakers, some of whom came from developing countries and others from developed countries. Poster presentation sessions and working groups provided participants with an opportunity to focus on specific problems and projects related to basic space science and the International Heliophysical Year.

7. The Workshop focused on the following topics: climate; heliobiology; solar physics; heliosphere, cosmic rays, interplanetary magnetic field; magnetosphere; ionosphere, high and middle atmosphere; access to data of the Sun-Earth system; instruments and networks; and participation of States in the International Heliophysical Year 2007 and basic space science.

8. In a ceremony, as part of the Workshop, organizers and participants of the workshops expressed their appreciation for the long-term, substantive contributions made to basic space science, particularly for the benefit of developing countries, by a number of distinguished scientists.

9. In 2004, the International Geophysical Year Gold Club was established to commemorate the achievements of those who participated in the International Geophysical Year. The first recipient, Alan Shapley, was presented with the award at the International Heliophysical Year Workshop held in Boulder, Colorado, United States, in February 2005. To be eligible for the Gold Club award, persons must have participated in commemorating the International Geophysical Year in some way and must provide some historical materials, such as copies of letters or books, to the history committee of the International Heliophysical Year. Those materials should provide a legacy of the International Geophysical Year for generations to come. The collection of historical materials was a cooperative effort

[4] Details of all the workshops of the United Nations Basic Space Science Initiative organized jointly with ESA have been made available on the Internet (www.seas.columbia.edu/~ah297/un-esa/).

of the International Heliophysical Year secretariat, the history committee of the American Geophysical Union and the history committee of the International Association of Geomagnetism and Aeronomy.

10. In a ceremony, as part of the Workshop, representatives of the International Heliophysical Year secretariat awarded International Geophysical Year Gold Club certificates to a number of distinguished scientists.

C. Attendance

11. Researchers and educators from developing and developed countries from all economic regions were invited by the United Nations, NASA and the Solar-Terrestrial Influences Laboratory of the Bulgarian Academy of Sciences to participate in the Workshop. Workshop participants, who held positions at universities, research institutions, national space agencies, planetariums and international organizations, were involved in implementing activities in the framework of the International Heliophysical Year and all the aspects of basic space science covered by the Workshop. Participants were selected on the basis of their scientific background and their experience in programmes and projects in which basic space science and the International Heliophysical Year played a leading role. The preparations for the Workshop were carried out by an international scientific organizing committee, a national advisory committee and a local organizing committee.

12. Funds provided by the United Nations, NASA, JAXA and the Solar-Terrestrial Influences Laboratory of the Bulgarian Academy of Sciences were used to cover the travel, accommodation and other costs of participants from developing countries. A total of 150 specialists in basic space science and the International Heliophysical Year attended the Workshop.

13. The following 36 Member States were represented at the Workshop: Algeria, Angola, Armenia, Austria, Azerbaijan, Brazil, Bulgaria, China, Croatia, Ecuador, Egypt, France, Georgia, Germany, India, Iran (Islamic Republic of), Israel, Italy, Japan, Malawi, Nepal, Nigeria, Poland, Republic of Korea, Romania, Russian Federation, Sri Lanka, Sudan, Suriname, Switzerland, Togo, Turkey, Ukraine, United Arab Emirates, United States and Viet Nam. Puerto Rico was also represented.

II. Observations and conclusions

14. Workshop participants considered the opportunities associated with the International Heliophysical Year to be important for enabling countries, particularly developing countries, to participate in activities recommended by the Committee on the Peaceful Uses of Outer Space and its subsidiary bodies and stressed the importance of preparing for such participation in good time.

15. Workshop participants noted with appreciation the offers made by the Governments of the Republic of Korea, Egypt and Nigeria to host workshops on basic space science and the International Heliophysical Year in 2009 and 2010.

16. Workshop participants recommended examining the feasibility of creating an independent source of funding, supported by interested parties, to facilitate the execution of global and regional studies and projects on the International Heliophysical Year. By making available small grants, the fund could actively stimulate multinational and interregional educational, application and research initiatives.

17. Workshop participants noted with satisfaction the further development of international and interregional initiatives using International Heliophysical Year instruments established over the previous five years. They also noted that it would be helpful to formalize networks and working groups with common goals to further coordinate research work and thus promote greater participation in such initiatives.

18. In particular, workshop participants noted with satisfaction the ongoing collaboration among members of systems of ground-based worldwide instrument arrays, a collaboration that had resulted in the supply of a continuous data-taking capability, which was essential for understanding objects such as the ionosphere. Extending such collaboration to include other instrument arrays at different longitudes would contribute significantly to worldwide coverage of ionospheric phenomena.

19. Workshop participants noted with satisfaction the successful continuation of the establishment and operation of low-cost, ground-based, worldwide instrument arrays for achieving the goals of the International Heliophysical Year.

20. Workshop participants commended NASA on its Astrophysics Data System (ADS), which served as a digital library portal for researchers in astronomy and physics, and expressed their hope that ADS would continue to be supported in the future. ADS was a crucial resource for the worldwide scientific and technical community. Continued support of ADS mirror sites and similar databases was important and should be seriously considered in all countries where scientists and engineers experienced difficulties in accessing networks due to obstacles arising from international boundaries.

21. Workshop participants emphasized that the initiatives of various virtual observatories in a number of countries could contribute significantly to accelerating the development of the objectives of the International Heliophysical Year.

22. Workshop participants noted with satisfaction that the regional centres for space science and technology education, affiliated to the United Nations, were operational.[5] The centres were located in Brazil and Mexico for Latin America and the Caribbean, in India for Asia and the Pacific, and in Morocco and Nigeria for Africa. The participants emphasized that it would be beneficial to establish a regional centre in West Asia.

23. Workshop participants took note of the establishment of the International Committee on Global Navigation Satellite Systems (GNSS) under the umbrella of the United Nations and expressed the opinion that the International Committee might be able to support the development of GNSS technology for low-cost,

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[5] Information on the regional centres for space science and technology education, affiliated to the United Nations, including their education, research and applications programmes, is available on the website of the Office (www.unoosa.org/oosa/en/SAP/centres/index.html).

ground-based, worldwide instrument arrays for achieving the goals of the International Heliophysical Year (see http://www.icgsecretariat.org).

III. Summary of deliberations

A. Basic space science

24. The deliberations of Workshop participants gave rise to the sharing of information about past and future activities in basic space science, about plans that had been developed over long periods in different countries and regions and about the results that had emerged in various developing and developed countries. The results that were addressed at the Workshop were achievements of a truly international nature for all those involved in previous workshops. Over time, the mutual support that workshop participants offered each other helped them significantly to implement recommendations made at the workshops. Workshop participants came from all regions, a fact that underscored the importance of a regional and, at times, global approach to basic space science for the benefit of developing and developed countries. The topic "Participation of nations in the International Heliophysical Year 2007 and basic space science" was selected for sessions of the Workshop because of the long-standing success of the donation of telescopes, planetariums and instruments to developing countries.

25. At the series of workshops, participants developed the "tripod" concept, comprising three elements. The first element was the provision of the means to carry out basic research appropriate for developing countries, such as astronomical telescope facilities. The second element was the implementation of original research programmes in basic space science appropriate for the state of existing facilities and of scientific development in a given country, for example, the implementation of variable star observing programmes supplemented by information from the fields of computer science, mathematics, physics and astronomy. The third element was the development and provision of teaching material to allow the introduction of basic space science into the physics and mathematics curricula of universities in countries that implemented the "tripod" concept. Access to scientific literature, such as that provided by ADS, and to databases, such as those of the virtual observatories, represented an essential supplementary component of "tripod".

26. State-of-the-art observing facilities on the ground and in space were producing large quantities of high-quality data that were being stored in science archives with the goal of exploiting them in the best way possible. The logical next step was to link those archives so that users could retrieve the data in a simple and uniform way and so that the scientific use of those expensive resources could be maximized. It would also be useful to supply a suite of scientific visualization and analysis tools in order to facilitate the further handling of the data. Virtual observatory concepts were being developed in a number of countries. To avoid redundancy, care was being taken to coordinate such efforts.

27. International Heliophysical Year data systems and basic space science data systems were available in many countries. One of the most prominent was ADS, the NASA-funded project that provided free searches of abstracts available on the Internet. ADS databases contained references on the following topics: astronomy

and planetary sciences; physics and geophysics; space instrumentation; and astronomy preprints. Each database contained abstracts from hundreds of journals, publications, colloquiums, symposiums, workshops, expert meetings, training courses, proceedings, doctoral theses and NASA reports. ADS had 11 mirror sites, in Argentina, Brazil, Chile, China, France, Germany, India, Japan, the Republic of Korea, the Russian Federation and the United Kingdom of Great Britain and Northern Ireland, thus improving global access to ADS resources.

B. International Heliophysical Year

28. It was noted that the International Geophysical Year, one of the most successful international science programmes ever, had broken new ground in the development of new space science and technology and that, 50 years later, the International Heliophysical Year continued that tradition.

29. It was also noted that the International Heliophysical Year had three primary objectives: (a) to advance understanding of the fundamental heliophysical processes governing the Sun, the Earth and the heliosphere; (b) to continue the tradition of international research and add to the legacy of the International Geophysical Year on its fiftieth anniversary; and (c) to demonstrate the beauty, relevance and significance of space and Earth science to the world.

30. One of the main components of the International Heliophysical Year was the United Nations Basic Space Science Initiative, which was dedicated to the establishment of observatories and instrument arrays in order to expand knowledge of space science and the viability of space science research, engineering and education in developing countries and regions not yet active in space research.

31. Through a cooperative programme with the United Nations Basic Space Science Initiative for the period 2005-2009, the International Heliophysical Year would provide a framework for facilitating the deployment of a number of arrays of small instruments to take global measurements of space physics-related phenomena (see A/AC.105/902, annex I). Such efforts could include developing a new network of radio dishes to observe interplanetary coronal mass ejections and using existing arrays of Global Positioning System (GPS) receivers to observe the ionosphere. The concepts behind such efforts were mature, developed and ready to be implemented. A coordination meeting had been held among representatives of the International Heliophysical Year secretariat and the United Nations Basic Space Science Initiative at Greenbelt, Maryland, in the United States, in October 2004. As a result of that meeting, a commitment had been made to focus the United Nations Basic Space Science Initiative up to 2009 on providing the International Heliophysical Year organization with a link to developing countries. The Initiative had made available the contact details of more than 2,000 scientists in 192 countries, many of whom were eager to participate in international space science activities.

32. A new initiative begun during the 2006 Workshop involved developing countries in the analysis of data obtained from space missions. The data were routinely made available on the Internet or on DVD for use by the scientific community. During the 2006 Workshop, several experimenters had agreed to identify data analysis projects that would use their data sets in order to enable researchers from developing countries to participate in a large-scale data analysis

project. A project to make data analysis software (GNU Data Language) available free of charge was undertaken.

IV. Case study: space weather monitor programmes

33. In the Space Weather Monitor programme, led by Stanford University, two global networks of sensors were deployed to universities and high schools around the world to provide quantitative diagnostics of solar-induced ionospheric disturbances, thunderstorm intensity and magnetospheric activity. The instruments tracked changes in the Earth's ionosphere by monitoring very low frequency (VLF) signal strength as the waves bounced off the ionosphere and noting changes during solar and lightning-related events. The result was a worldwide collaboration among scientists, teachers and students to investigate the variability of the ionosphere.

34. It was noted that the Atmospheric Weather Electromagnetic System of Observation, Modelling and Education (AWESOME) instrument was an ionospheric monitor that could be operated by students around the world. The monitors detected solar flares and other ionospheric disturbances.

35. It was noted that about 60 kilometres above the ground lay the Earth's ionosphere, where continual blasts of particles and energy from the Sun hit the Earth's atmosphere so strongly that electrons were stripped away from their nuclei. The free electrons in the ionosphere had a strong influence on the propagation of radio signals. VLF signals bounced back off the ionosphere, allowing radio communication over the horizon and around the curved Earth. The ionosphere reacted strongly to the intense X-ray and ultraviolet radiation released by the Sun during a solar flare, solar storm or coronal mass ejection. By monitoring the signal strength from distant VLF transmitters and noting unusual changes as the waves bounced off the ionosphere, those disturbances could be monitored and tracked. To monitor a VLF signal, a radio receiver was needed that could tune to VLF stations, together with an antenna to pick up the VLF signals and a computer to keep track of the data. Since most consumer radios could not pick up VLF signals, a radio receiver and an antenna had to be built. That combination of receiver and antenna constituted a VLF receiver.

36. It was noted that the key elements of the AWESOME monitoring system were the computer, the Stanford monitor and the antenna. An Internet link was important; otherwise a good quality DVD burner could be used. The line receiver received VLF signals from two antennas. There was usually one antenna in the north-south orientation and another in the east-west orientation. Those signals were sent to a 200-kilohertz (kHz) analogue-to-digital converter (ADC) card attached to the Peripheral Component Interconnect (PCI) slot of the computer. The ADC would capture data from the two antennae at 100 kHz each. The GPS timing signal was also fed into the ADC card, allowing for very precise acquisition of data. A Universal Serial Bus (USB) interface to replace the ADC card was in development; it would enhance the ease of use and substantially reduce the cost.

37. There were two types of data saved by the receiver. Collecting narrowband data involved monitoring the amplitude and phase of a single frequency, corresponding to a VLF transmitter. Broadband data involved saving the entire waveform from the antenna, thus enabling studies of many more ionospheric

phenomena. The VLF data acquisition software controlled precisely when the system should acquire broadband and narrowband data. Upon data acquisition, various types of user-specified signal processing could be performed on the data. The data could be sent to another computer at Stanford University, via the Internet, where it would be made available to all through a Web interface, so that interested parties at different sites could share their data and collaborate. The data produced by the AWESOME programme was of the same quality as that being used by researchers at Stanford University; receiver sensitivity had reached the point where any detectable signal above the ambient noise floor would be recorded.

38. In addition to the AWESOME monitor, there was an inexpensive version known as "the sudden ionospheric disturbance (SID) monitor". The Stanford Solar Center, in conjunction with the Very Low Frequency Group of the Department of Electrical Engineering of Stanford University and local educators, had developed inexpensive SID monitors that students could install and use at their local high schools. Students could join the project by building their own antenna, a simple structure costing less than 10 dollars and taking a couple of hours to assemble. Data collection and analysis were handled by a local personal computer, which did not need to be fast or elaborate. Stanford University would provide a centralized data repository and blog site on which students could exchange and discuss data.

39. Deployment of one of the AWESOME monitors had been completed in Tunisia. Umran S. Inan of Stanford University and Zohra Ben Lakhdar of the University of Tunis had started that collaboration under the International Heliophysical Year/United Nations Basic Space Science Initiative programme. The project would provide a basis for quantitative comparison of lightning-induced disturbances of the ionosphere and the radiation belts in the American and European sectors. Most of the current data on such phenomena had so far been obtained in the western hemisphere, and the weight of scientific information indicated that lightning-induced effects at high altitudes and in the radiation belts might affect other processes on a global scale. The proposed programme would facilitate the establishment and conduct of VLF observations in the European sector, thus providing a basis for comparison to facilitate global extrapolations and conclusions. As part of that collaboration, Hassen Ghalila of the University of Tunis visited Stanford University to learn about operation of the VLF receiver and all its scientific applications.

A. Atmospheric Weather Electromagnetic System of Observation, Modelling and Education research monitors

40. Stanford University had developed two versions of the ionospheric monitors. The research-quality AWESOME instruments had been selected as a participating programme by the United Nations Basic Space Science Initiative and were being distributed to universities worldwide, with a focus on developing nations. Through that programme, 16 AWESOME monitors had been, or were being, placed in 15 countries, with a particular focus initially on North Africa, followed by sub-Saharan Africa and Central Asia. Those 16 International Heliophysical Year sites were being integrated into an existing network of 14 monitors. A particular focus of that international receiver network was global mobilization in response to unique geophysical events. For instance, AWESOME monitoring was part of the

Whole Heliosphere Initiative sponsored by NASA. VLF receivers were utilized globally for the total solar eclipse of 1 August 2008, with data from many sites being made available to the public.

B. Sudden ionospheric disturbance student monitors

41. It was noted that the International Heliophysical Year Coordinator for international education and public outreach had designated the student-oriented and less expensive SID monitors as of particular interest for use in the Year's education programme. SID monitors were being provided to high school teacher/student teams around the world, in particular in developing countries. By April 2008, Stanford University had placed 150 SID monitors in 44 countries for the International Heliophysical Year. Prior to the International Heliophysical Year, 150 SID monitors had been placed in the United States. Another 60 monitors were planned for international placement during the second year of the programme to complete a worldwide network. The focus had been on developing countries and, in the United States, on schools serving underrepresented students. The distribution of SID monitors was accompanied by extensive teacher and student training materials to ensure a firm science background and encourage starting points for research.

42. It was underlined that the SID and AWESOME programmes brought real scientific instruments and data to students and researchers throughout the world in a cost-effective way. Instruments met the objectives of being sensitive enough to produce research-quality data while being inexpensive enough for widespread placement.

C. Atmospheric Weather Electromagnetic System of Observation, Modelling and Education in Africa

43. It was noted that the chief goal of setting up AWESOME monitors was the quantitative comparison of local ionospheric disturbances, magnetospheric activity and thunderstorm intensity across much of the globe through the method of Extremely Low Frequency (ELF)/VLF monitoring. Although such VLF monitoring methods were widely employed, a number of scientific questions and techniques could be explored only by means of the deployment of a worldwide network of instruments. For instance, the appearance of atmospheric optical phenomena such as sprites, elves, and jets over Europe corresponded to VLF disturbances that could be clearly detected in North Africa. Two International Heliophysical Year hosts, in the Libyan Arab Jamahiriya and Algeria, had written a draft report detailing some of those observations. However, the most intense region of lightning activity on the Earth was in central Africa, and although its properties were expected to differ in general from the mid-latitude atmosphere of Europe and the United States, that lightning region had, comparatively speaking, been poorly studied due to a lack of on-the-ground instrumentation. The installation of receivers along the perimeter of Africa enabled, for the first time, the tracking of that thunderstorm activity and its effect on the ionosphere. To support those efforts and the International Heliophysical Year goal of deployment of small instrument networks in developing countries, the AWESOME project team made use of the International Heliophysical Year to help close the largest gaps in ground-based instruments on the continent.

Monitors had been placed in Algeria, the Libyan Arab Jamahiriya, Morocco, Nigeria and Tunisia, and placements were planned for Egypt, Ethiopia and South Africa. Other hosts were being contacted so that suitable receiver locations could be identified. A major challenge was to find locations with infrastructure (i.e. the Internet) suitable for hosting of an AWESOME receiver in sub-Saharan countries, where Internet access, or even electrical power, might not yet be reliable.

D. Atmospheric Weather Electromagnetic System of Observation, Modelling and Education in Asia

44. It was noted that the next phase of AWESOME receivers would focus on Asia. Asia was home to a region of intense thunderstorm activity stretching from India to northern Australia. Unlike the intense region in Central Africa, much of this lightning activity occurred over water, which had been studied in much less detail than had the ionospheric and magnetospheric effects of land-based lightning, also due to a lack of instrumentation. Receivers had first been established in India, in both Kolkata and Allahabad. In addition, receivers that had recently been delivered to Serbia and Uzbekistan would soon be fully operational. Additional monitors were planned for Fiji, Indonesia and Malaysia, and other hosts were being contacted.

E. Sudden ionospheric disturbance student monitor network

45. In support of the objectives of the International Heliophysical Year (set out in paragraph 29 above), SID student monitors were deployed to high schools and universities around the world. The student-oriented SID monitors responded primarily to solar-induced changes to the Earth’s ionosphere. The focus of the project was installing networks of instruments in developing nations, particularly in Africa. Of the approximately 150 SID monitors so far installed worldwide for the International Heliophysical Year, about 60 of them were located at high schools and universities in Africa. Many SID materials had been translated into the six official languages of the United Nations.

F. Data of the sudden ionospheric disturbance and Atmospheric Weather Electromagnetic System of Observation, Modelling and Education programmes

46. It was noted that the Stanford Solar Center, which collected data from students, had incorporated the SID data and part of the AWESOME data into a large database system destined to be used also for the NASA solar dynamic observatory. Tools were provided for collecting data and sending it by File Transfer Protocol (FTP) to the central repository and for students to view and graph data via the Web. A blog facilitated communications. The AWESOME data viewer included phase data together with data on the narrowband amplitude, as well as an innovative and interactive Google Earth mapping tool.[6]

[6] Stanford University hosts the website of SID data (http://sid.stanford.edu/database-browser/) and AWESOME data (http://vlf-ihy.stanford.edu/).

G. Africa Space Weather Science and Education Workshop, Addis Ababa

47. It was recognized by the International Heliophysical Year that, in order to develop space science research infrastructure in Africa, space science education must also be developed to support the long-term operation and use of scientific instruments. In response to these needs, both the SID and AWESOME programmes have focused on Africa for placement of their ionospheric monitors.

48. In conjunction with the International Heliophysical Year – Africa Space Weather Science and Education Workshop, held in Addis Ababa in November 2007, lecturers from Stanford University had given a two-hour SID workshop to 50 conference attendees, African researchers interested in hosting SID monitors at their universities and local high schools. Half the attendees received SID monitors during the workshop, and the remaining monitors were later provided by mail. Enthusiasm for the instruments was high. Stanford University currently had a network of more than 60 monitors on the African continent.

49. To further support the improvement of education infrastructure in Ethiopia, Stanford University lecturers organized a teacher workshop for Ethiopian high school physics educators, also held in conjunction with the International Heliophysical Year – Africa Space Weather Science and Education Workshop. The teacher workshop gathered 70 teachers from around Ethiopia for a one-day intensive professional development programme focusing on fundamental physics concepts relevant to space weather. The day's programme included an introduction to the SID monitors and an overview of the International Heliophysical Year and its relevance for their students, as well as discussions about space physics, examples of inquiry-based lesson plans and access to hands-on activities.[7]

H. Very Low Frequency Workshop, Sebha University, Libyan Arab Jamahiriya

50. It was noted that the first International Heliophysical Year – Very Low Frequency Workshop was hosted by Sebha University, the Libyan Arab Jamahiriya, and organized by Stanford University, with financial support from NASA, Stanford University, Sebha University, the European Office of Aerospace Research and Development and logistical support from the State Department of the United States. The workshop included 30 participants from 13 countries, all with a shared interest in the understanding of VLF receiver data and its scientific applications. Presentations and detailed tutorials focused on a broad array of topics, from lightning, ionospheric VLF propagation, earthquakes, cosmic gamma-rays and sprites, as well as community building. The workshop combined presentations on cutting edge research with detailed tutorials, starting with the basic science topics, and provided an opportunity for the beginning of a new high-level AWESOME research community. By the end of the workshop, scientists from developing countries had begun work on several papers, to be published in internationally recognized and refereed journals.

[7] A video documentary of the teacher workshop prepared by NASA has been made available (http://sun.stanford.edu/~deborah/spa-epo/GIFTWorkshopEthiopia.mov).

I. Coordination of monitoring networks for the total solar eclipse of 1 August 2008

51. It was noted that solar eclipse studies had shown that not only did the Earth's ionosphere respond when in the path of totality of an eclipse, but also that a small ionospheric disturbance appeared in the conjugate hemisphere. The network of AWESOME and SID monitors placed around the world provided an ideal opportunity to coordinate observations during the total solar eclipse of 1 August 2008. Stanford University placed monitors in regions near or in the path of totality and coordinated a campaign among SID and AWESOME sites to collect data during the eclipse. It was noted that the results provided a great deal of information on how the Earth's ionosphere responded to solar-induced changes. In addition, a coordinated campaign enabled students, together with researchers, to obtain and study scientific data, with the possibility of publishing their results.

J. Data sonification for blind students

52. It was noted that experts in data sonification who worked with the NASA Time History of Events and Macroscale Interactions during Substorms (THEMIS) team provided Stanford University with a tool to sonify SID data, primarily to make it accessible to blind students. Stanford University also had contacts at the University of Puerto Rico to produce such materials.

K. World Space Week 2007 and 2008

53. It was noted that the Stanford Solar Center and the University of California Berkeley Space Sciences Laboratory collaborated on producing a set of activities for World Space Week, celebrated from 4 to 10 October each year. The 2007 celebration marked the fiftieth anniversary of the launch of Sputnik I and the beginning of the space age. Groups of scientists designed a Web-based activity relating to the THEMIS mission and the SID monitors, with the aim of introducing students to using real scientific data.[8] Students in Nigeria with SID monitors also participated in World Space Week activities. It was noted that in conjunction with World Space Week, SID monitors and their applications would be exhibited.

L. Extended sudden ionospheric disturbance programmes in Germany and Italy

54. It was noted that a nine-site, active SID monitor project had been undertaken in Germany, supported by a consortium of the University of Göttingen, the German Aerospace Center site at Neustrelitz, the Hamburg Planetarium and the European Aeronautic Defence and Space Company Astrium.

55. Italy had installed a large high-school network of 32 SID instruments, including at the Turin Astronomical Observatory. The Italian network was supported by the Fondazione per la Scuola della Compagnia di San Paolo.

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[8] For more information see the project's website (http://cse.ssl.berkeley.edu/segway/WSW.html).

M. Locations of Atmospheric Weather Electromagnetic System of Observation, Modelling and Education research monitors

56. It was noted that AWESOME research monitors had been set up directly in conjunction with International Heliophysical Year, or with related funding from Stanford University, in the following locations: Algiers; Dublin; Kolkata, India; Sebha, Libyan Arab Jamahiriya; Akure, Nigeria; Rabat; Swider, Poland; Tunis; Tashkent; Belgrade; Alabama Agricultural and Mechanical University, United States; Wilcox Solar Observatory, Stanford University, United States; Cairo; South African Astronomical Observatory, Sutherland, South Africa; Suva; and Addis Ababa.

57. It was noted that the following sites had been set up without International Heliophysical Year funds, but with which collaboration was similar: Crete, Greece; Elazig, Turkey; Allahabad, India; Varanasi, India; Nainital, India; with an additional research station in Antarctica operated by India.

58. International collaboration sites operated through collaborations between Stanford University and well-established/advanced research groups, related to the worldwide network of instrument arrays, had been established in the following sites: Atibaia, Brazil; a research station in Antarctica operated by Brazil; a research station in Antarctica operated by Ukraine; Adelaide, Australia; Hobart, Australia; Perth, Australia; Tel Aviv and Sede Boqer, Israel. There were in total 30 AWESOME monitors in 21 countries.

N. Locations of sudden ionospheric disturbance student monitors

59. SID student monitors were located in the following countries and areas: Algeria, Brazil, British Virgin Islands, Bulgaria, Burkina Faso, Canada, China, Colombia, Congo, Croatia, Egypt, Ethiopia, France, Germany, India, Indonesia, Ireland, Italy, Kenya, Lebanon, Libyan Arab Jamahiriya, Mexico, Mongolia, Mozambique, Namibia, Netherlands, New Zealand, Nigeria, Portugal, Republic of Korea, Romania, Senegal, Serbia, South Africa, Sri Lanka, Switzerland, Thailand, Tunisia, Uganda, United Kingdom, United States, Uruguay and Zambia. There were a total of 305 monitors in 43 countries.