



Participants and invited Officials pose for a group photo

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Introduction

An African School on Space Science took place in Rwanda, Kigali City (University of Rwanda –Head Quarters) from 30th June to 11th July 2014. The School was jointly organized by the Abdus Salam International Centre for Theoretical Physics (ICTP, Italy), the Institute of Scientific Research of Boston College (B.C , USA) and the University of Rwanda (UR) College of Science and Technology(CST). The school obtained financial support from various institutions and space science programs including:

- The Abdus Salam International Center for Theoretical Physics (ICTP)
- The Ministry of Education (MINEDUC), Republic of Rwanda
- The Institute of Scientific Research, Boston College (ISR-BC)
- The International Committee on Global Navigation Satellite Systems (ICG)
- The University of Rwanda
- The University of Rwanda, College of Science and Technology (UR-CST)
- The University of Rwanda, College of Education (UR-CE)
- The Scientific Committee of The Solar-Terrestrial Physics (SCOSTEP)
- The Japanese Society for the Promotion of Sciences (JSPS)
- The Institute of Navigation (USA).

The school gathered 63 participants including Lecturers and students from all over the world, with the majority of students coming from the East-African Region. The School covered topics related to the physical phenomena of the solar-magnetosphere - ionospheric coupling and their impact on the near-Earth space environment. The school created an opportunity for senior and young space scientists to interact and share knowledge in space science. On the other hand, the school strengthened the vision and understanding of the importance of research in space science with particular focus on space weather and its impact on our everyday life.

Participants in the school could be aware on how solar explosive phenomena can influence the functioning and reliability of spaceborne and ground-based systems and services or directly endanger human health. Services that can be disrupted include telecommunications (i.e cell phones), navigation and all Global Navigation satellite Systems (GPS) related applications. For this important purpose, the school allowed participants an opportunity to gain hands on experience in data analysis of the multiple space-borne and ground based array of instruments. It should be noted that during this workshop event, one space research instrument was given and installed at the University of Rwanda, college of Education. The instrument is now fully functioning and will be operated by local space scientists to monitor solar bursts and thereby be able to predict their potential influence on the near-Earth environment.

This year 2014, it was a privilege for Rwanda to host this international scientific event not only because the ICTP celebrates its 50th anniversary, but also because Rwanda has been selected among many other contenders countries to host the African branch of ICTP. For Rwandans scientists and science students, this is a local boost towards advancement of science, technology and research . The closing ceremonies of the African School on Space Science were honored by the Honorable Minister of Education, Republic of Rwanda.



A welcome address by Prof. Manasse Mbonye, the Principal, University of Rwanda College of Science and Technology (the School host Institution)

Opening remarks by Prof. Nelson IJUMBA; the University of Rwanda vice chancellor Academics & Research

Opening remark (Video) by the Director of the school Prof Sandro Radicella.





Opening key word by the School Director Patricia Doherty



Opening address by the School Director, C. Amory



Opening remark: UR -Local Organizer

Opening remarks by the representative of the Minister of Education



Eng. Mike Hughes; the advisor of Science & Technology in the Ministry of Education (representative of the Minister)

- Ladies and Gentlemen

I am pleased to welcome delegates to this African School on Space Science: Related Applications and Awareness for Sustainable Development of the Region. The school is a collaboration between the Abdus Salam International Centre for Theoretical Physics, ICTP, Italy, the Institute of Scientific Research of Boston College, USA, the University of Rwanda College of Science and Technology and many other supporting partners. I particularly thank the Directors of this School and the many organisers for all your hard work to ensure the success of this school which is designed to help improve capacity building in support of development of our region. I am sorry that Sandro Radicella of ICTP is unable to be with us and I thank him for his support in this workshop.

I am delighted to welcome participants to this workshop including Space Science experts and junior space scientists from Europe, US and Africa.



With full support by the Ministry of Education: Here Dr. Marie Christine Gasingirwa The DG of Science and Technology, in the Ministry of Education

- **Patricia Doherty, Director Boston College Institute of Scientific Research**
- **Dr Christine Amory, Laboratoire de Physique des Plasma**
- **Deputy Vice Chancellor Academic Affairs and Research, University of Rwanda**
- **Principal University of Rwanda College of Science and Technology**
- **Director General Science, Technology and Research, Ministry of Education**
- **National, Regional and International Experts**
- **Distinguished Researchers**

For those of you who have travelled to be with us today I welcome you to Rwanda and hope you will enjoy your stay in our country.

Ladies and Gentlemen

The Government of Rwanda recognizes the importance of Science, Technology and Research to her development and economic growth. There is top level commitment in Rwanda as demonstrated by the vision and commitment of the President of Rwanda, His Excellency Paul Kagame, towards the value of Science and Technology for Africa's development.

The Government's Vision 2020 Statement, the second Economic Development Poverty Reduction Strategy (EDPRS2) for Rwanda and the National Policy on Science, Technology and Innovation, include strategies to develop strong and efficient networks of skills and knowledge and scientific and technological innovation as key enablers to ensure a sustainable and rapid achievement of Rwanda's development goals.

Distinguished Scientists, Ladies and Gentlemen

I note that this school covers subjects related to the impact of Space weather phenomena. This relates to adverse changes in the solar activity and near Earth space environment that may severely affect our communication and navigation technologies among

many others. It is therefore of prime importance for us to be able to understand the effects, and be able to develop methods to predict and mitigate the impact of these solar and related disturbances.

The school will provide students and scientists a forum to be actively involved in various international space science programs such as: the International Space Weather Initiative (ISWI), International Heliophysical Year (IHY), Scientific Committee on Solar-Terrestrial Physics (SCOSTEP), Variability of the Sun and Its Terrestrial Impact (VarSITI), Groupe International de Recherche en Géophysique Europe (GIRGEA), Scintillation Network Decision Aid (SINDA), and many others.

Specific objectives of the school will be to:

- i. Allow participants to be introduced to solar-terrestrial physics and its impact on the near-Earth space environment and technology driven activities.
- ii. Allow participants an opportunity to gain hands on experience in data analysis of the multiple space-borne and ground based array of space science instruments
- iii. Strengthen the vision and understanding of the importance of research in space science and its applications for the development of mankind.

- iv. Create an opportunity for senior and young space scientists to interact and share knowledge in this field.
- v. Provide a background in the use of the Global Positioning Satellite System for practical applications and scientific exploration.

I am particularly encouraged that, during the course of this Space Science school, lectures, tutorials and hands on activities shall be provided by global expert space scientists.

The school will provide a unique opportunity for young Africans, both students and Lecturers, to be involved in various space related projects and programs with the aim of strengthening capacity building, education and research in the domain of Space science and various related applications.

Distinguished Scientists, Ladies and Gentlemen

I would like to highlight the importance that Rwanda places on working in regional and international partnerships to support STI development related to challenges facing Rwanda and the region.

One of these very important partnerships we are currently developing is to establish an East Africa Centre for Fundamental Research based on activities associated with the International Centre for Theoretical Physics (ICTP).

The Centre will cover the main research areas of ICTP including High Energy Physics, Condensed Matter, Statistical Physics, Material Science, Pure and Applied Mathematics and Earth System Physics including climate change and geophysics.

The Centre will also cover new research areas being developed by ICTP in areas of Renewable Energies, High Performance Computing (HPC) and Quantitative Biology

We recognise that the partnership with ICTP in the establishment of this centre will support the Government's vision and strategy to develop high level science, technology and research skills in Rwanda. This is very important in support of the development of Rwanda and the Region.

Distinguished Scientists, Ladies and Gentlemen

I wish you fruitful deliberations, a successful outcome for the school and hereby declare this "African School on Space Science: Related Applications and Awareness for Sustainable Development of the Region" open.

Thank you for your kind attention.

School Concept Note

1. Background

The Solar activity is variable with maxima of its activity characterized by multiple explosive phenomena such as Coronal Mass Ejection (CMEs) and solar flares. By interacting with the near-Earth space environment, these phenomena can lead to the disruption of modern man made technology infrastructures including HF radio propagation, Global Positioning System (GPS), high transmission power lines (GICs), satellites operation etc...

In line with the above space weather impact on the modern society, the International Center for Theoretical Physics (ICTP) has been approached and accepted to help organize a related school in Rwanda. The theme of the school is “**Space science awareness for sustainable development**”. The purpose of

scientists with focus on developing countries. In addition, such activities provide an opportunity for exchange of ideas, cross border co-supervision and sharing of resources.

The school Lecturers will cover topics relative to the physical phenomena of the solar-magnetosphere-ionospheric coupling and its impact on the near-Earth space environment including Space Weather and near Earth climate.

2. OBJECTIVES OF THE SCHOOL

Generally, the School will be organized in order for East-African and other African students junior space scientists to be actively involved into various international space science programs such (i.e. ISWI, IHY, SCOSTEP / VarSITI,

a) To allow participants to be introduced to the solar-terrestrial physics and its impact on the near-Earth space environment.

b) Allow participants an opportunity to gain hands on experience in data analysis of the multiple space-borne and ground based array of instruments: e.g. STEREO, CALLISTO, SCINDA-MAGDAS magnetometers, Ionosondes as well as GPS / GNSS data.

c) To strengthen the vision and understanding of the importance of research in space science to the development of mankind.

d) To create an opportunity for senior and young / students space scientists to interact and share knowledge in this field.

3. Main topics / activities to be covered in the school

(i) Introduction (Fundamentals of) to atmospheric / ionospheric physics:

e.g. Atmospheric layers, the physics of ionosphere, dynamics & irregularities, ionospheric parameters: TEC, foF2 etc...) ionospheric radio-propagation..., ionospheric models ..etc.)

(ii) GPS / GNSS history and applications:

e.g. History + development, applications (all); application of GPS / GNSS to ionospheric research

(iii) Fundamentals of solar physics and Solar variability

(iv) Geomagnetism and geomagnetic storms

(v) Space Weather

such ICTP organized schools is to strengthen capacity building in Space Science and provide a forum for space scientists from abroad to train young and prospective space

GIRGEA..etc...), for both reasons of fundamental space science research and space science education. Specific objectives of the school are:

(vi) Space science / space weather instruments (monitors) deployments in Africa:

e.g. SCINDA-GPS; MGDAS +AMBA magnetometers, ionosondes, CALLISTO project

(vii) Accessing and processing space weather data:

e.g. Solar, ionospheric , geomagnetic data

(viii) Space Science development and opportunities in Africa:

e.g: Research, Instrumentations, Training (e.g. SANSA, NASSP etc..)

4. Composition of participants

Even though the school is opened to who ever may be interested, this will be mainly dedicated to African students and junior space scientists in Africa, with principal focus to East-African region. Therefore, the limited available funds for participants will be provided accordingly. The maximum number of participants should be about fifty five (55), including international experts who will deliver the Lecturers and Tutorials. Lecturers in the above mentioned topics are expected from Africa, Europe and USA .

5. Sources of funding

The ICTP has accepted to partially fund the school. It is expected for example that ICTP will be in charge of paying air ticket for African participants as well as meal for all participants for 11 days. Therefore, organizers still have to mobilize additional resources both locally and internationally. Additional support is expected to come from the following (an official financial support has already been formulated):

A. Local sources

i) The University of Rwanda (College of Science and Technology and the College of Education) have been requested to provide a support, e.g. logistic including (e.g writing pads), computer Lab + UR conference hall, and transportation to and from the Hotel accommodation , Cultural-entertainment).

(ii) The Ministry of Education / Directorate General of Science and Technology (MINEDUC / DGST) was requested and accepted to support half accommodation for about 28 participants.



Advancing Space science research and education through instruments deployment: Here installation of a CALLISTO solar spectrometer at the University of Rwanda

This governmental institution will also provide support meals + drinks for opening ceremonies.

(iii) Private and public companies, institutions, ministries etc.. that are in one way or another linked with the subject area of the School will be requested to provide partial sponsorship.

B. International sources

(i) Over the last few years, Boston College (BC)- US has been actively involved in promoting the advancement of space science research and education in Africa. This was done by providing and installation of various instruments and organizing related workshop and schools. A request has therefore been addressed the BC to partial sponsor the school consisting mainly in providing some space science / space weather instruments and funding the travel for US Lecturers.

(ii) The conference is in line with the aspiration of the United Nation for Outer Space Affairs (UNOOSA) in encouraging the development of Space Science globally. Therefore, we will request a support from UNOOSA to provide support. e.g. Travel grant for 5 up to 10 participants.

(iii) The South African National Space Agency (SANSA) via its connected programs (e.g. NASSP) has played a major role in training many African space scientist and still being involved in developing space science in Africa. The Space Science Directorate of SANSA (Hermanus) has been requested to provide the school sponsorship including for example travel grant for three participants (e.g Lecturers / trainers in the school) and any other support to the school.

6. Organizers

a) School Directors

1. Sandro Radicella, ICTP, ITALY
2. Christine Amory Mazaudier, LPP/CNRS , France
3. Patricia Doherty, BC, USA
4. Jean Uwamahoro, UR- CE, Rwanda

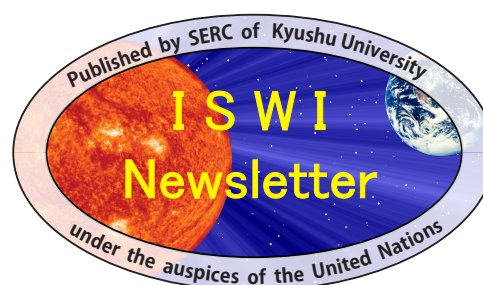
b) Local Organizing Committee

1. Jean Uwamahoro, University of Rwanda
2. heneas Nkundabakura , University of Rwanda
3. Mr Vivien Munyaburanga, University of Rwanda
4. Mr Fabien Habyarimana, University of Rwanda , CST.

c) Scientific advisory committee

1. Paul Baki (KPUC)
2. Vafi DOUMBIA (COTE D' IVOIRE)

3. Babatunde Rabi (NSRDA-NIGERIA)
4. Jean Uwamahoro, (UR- CE, RWANDA)
5. J. Bosco Habarulema, (SANSA-SA)
6. L. A. McKinnell , (SANSA-SA)
7. N. Gopalswamy , (SCOSTEP, USA).
8. K. SHIOKAWA, (STEL, Nagoya-Japan)
9. E. Yizengaw, (ISR-BC, USA)
10. C. A. Mazaudier, (LPP/CNRS , France)
11. P. Doherty, (B.C, USA)
12. S. Radicella (ICTP-ITALY)



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School Program

Organizers: C. Amory (LPP-CNES), P. Doherty (ISR-Boston College),
S. Radicella (ICTP); UR-CST

Local organiser: J. Uwamahoro; ICTP Local Organizer: B. Nava
Kigali - Rwanda, 30 June 2014 - 11 July 2014

Opening Ceremonies and Presentations - Chair: Jean Uwamahoro; 30 June 2014

08:30 - 09:45 --- Registration and Administrative Formalities ---

09:45 - 10:30 Workshop Directors and Guests of Honors

Opening Ceremony

- Welcoming Remarks (Manasse Mbonye - Principal, University of Rwanda, College of Science and Technology) 05'
- Remarks (Patricia Doherty - Director, Boston College, Institute of Scientific Research) 05'
- Remarks by Video Recording (Sandro M. Radicella - Head, Telecommunications/ICT for Development, ICTP) 15'
- Remarks (Christine Amory - LPP, France) 05'
- Remarks (Nelson Ijumba - Deputy VC AAR University of Rwanda) 05'
- Opening Address (Hon Vincent Biruta - Minister of Education Rwanda) 10'

10:30 - 11:00 --- Coffee Break ---

11:00 - 11:45 Endawoke Yizengaw / *USA* Introduction to Space Weather and its Impact on our Daily Lives

11:45 - 13:00 Panel Discussion, Moderator: P. Doherty, Panelists: C. Amory (FR), K. Grove (USA), M. Hughes (Rwanda), C. Monstein (CH), B. Rabiu (Nigeria), P. Sibanda (Zambia), J. Uwamahoro (Rwanda), E. Yizengaw (USA)

13:00 - 14:15 --- Lunch Break ---

14:15 - 15:00 Babatunde Rabiu / *Nigeria* Current Status of Space Science Development in Africa

15:00 - 15:30 Nkundabakura Pheneas / *Rwanda* Astronomy and Space Science Education, Research and Outreach in Rwanda: Current Status and Beyond

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:00 Christine Amory / *France* Project Descriptions: Introduction to research projects that will be performed throughout the workshop

17:00 - 17:00 Close

Solar Phenomena - Chair: Christine Amory; 1 July 2014

09:00 - 10:30 Nat Gopalswamy (given by J. Uwamahoro) Solar Eruptive Phenomena

10:30 - 11:00 --- Coffee Break ---

11:00 - 12:00 Christine Amory / *France*: The Sun-Earth Connections through the Dynamo Process

12:00 - 13:00 Jean Uwamahoro / *Rwanda*: Analysis of the Trends, Characteristics and Predictability of Geo effective Solar Transients

13:00 - 14:00 --- Lunch Break ---

14:00 - 15:00 Christian Monstein / *Switzerland*: Monitoring the Sun with the CALLISTO Solar Spectrometer
15:00 - 15:30 Endawoke Yizengaw: Accessing Space Weather Data

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:30 Project Time: Time to work on group projects
17:30 - 17:30 Close

The Ionosphere - Chair: Babatunde Rabi; 2 July 2014

09:00 - 10:30 Keith Groves / *USA*: Tutorial: The Ionosphere

10:30 - 11:00 --- Coffee Break ---

11:00 - 12:00 Vafi Doumbia / *Cote D'Ivoire*: The Equatorial Electrojet
12:00 - 13:00 Christine Amory: Electrodynamic Coupling Between High and Low Latitudes

13:00 - 14:00 --- Lunch Break ---

14:00 - 15:30 Patrick Sibanda / *Zambia*: Tutorial on Open Source Tools to Process GNSS Data for Space Science Studies in Africa

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:30 Project time: Time to work on group projects
17:30 - 17:30 Close

19:00 - 21:00 --- Reception Dinner ---

Space Weather and Magnetometers - Chair: Keith Groves; 3 July 2014

09:00 - 09:45 Christine Amory / *France*: Geomagnetic and Magnetic Indices
09:45 - 10:30 Endawoke Yizengaw / *USA*: AMBER Magnetometers Network and Longitudinal Differences of Equatorial Electrodynamic and Ionospheric Vertical Density Distribution

10:30 - 11:00 --- Coffee Break ---

11:00 - 11:45 Anthea Jane Coster / *USA*: Geomagnetic Storms
11:45 - 12:30 Yannick Beniguel / *France*: The Monitor Project
12:30 - 13:00 Administrative Details/Discussions

13:00 - 14:00 --- Lunch Break ---

14:00 - 14:45 Yannick Beniguel: Multiple Phase Screen Scintillation Modeling
14:45 - 15:30 Daniel Okho / *Nigeria*: Processing Ionospheric Data using MATLAB: Space Applications and Hands-on Demonstration

15:30 - 16:00 --- Coffee Break ---

16:00 - 16:30 Processing Ionospheric Data using MATLAB : continued
16:30 - 18:00 Project time: Time to work on group projects
18:00 - 18:00 Close

GNSS Calculations, Integrated GNSS Systems - Patricia Doherty; 7 July 2014

09:00 - 09:30 Sharafat Gadimova / *Austria* (given by Patricia Doherty): The International Committee on GNSS
09:30 - 10:30 John Raquet / *USA*: GNSS Fundamentals

10:30 - 11:00 --- Coffee Break ---

11:00 - 13:00 John Raquet: GNSS Fundamentals continued

13:00 - 14:00 --- Lunch Break ---

14:00 - 15:30 Todd Walter / USA: GNSS Effects on Navigation Systems

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:00 Todd Walter: GNSS Effects on Navigation Systems continued

17:00 - 18:00 Project Time: time to work on group projects

18:00 - 18:00 Close

GNSS Calculations, Integrated GNSS Systems - Mikel Miller; 8 July 2014

09:00 - 10:30 John Raquet: GNSS Calculations Lab

10:30 - 11:00 --- Coffee Break ---

11:00 - 13:00 Frank Van Diggelen / USA: Integrated GNSS - GPS, Galileo, GLONASS, QZSS and BeiDou for Consumer Applications.

13:00 - 14:00 --- Lunch Break ---

14:00 - 15:30 Frank Van Diggelen: Integrated GNSS continued

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:00 Mikel Miller / USA: Got GPS? The Navigation Gap

17:00 - 18:00 Project Time: time to work on group projects

18:00 - 18:00 Close

Techniques and Tools - Endawoke Yizengaw; 9 July 2014

09:00 - 09:45 John Bosco Habarulema / SANSA, South Africa: An Overview of Using Multiple Data Sources to Study Ionospheric Dynamics over the African Sector

09:45 - 10:30 Patrick Sibanda: Closing the Geophysical Data Gap: Recent Developments on Space Science Observations and Studies Based on GPS data in Zambia

10:30 - 11:00 --- Coffee Break ---

11:00 - 12:00 Bruno Nava / ICTP, Italy: Data Assimilation Modeling

12:00 - 13:00 Luigi Ciruolo / ICTP, Italy: TEC Estimation Using GNSS

13:00 - 14:00 --- Lunch Break ---

14:00 - 15:30 Luigi Ciruolo: TEC Data Processing Laboratory

15:30 - 16:00 --- Coffee Break ---

16:00 - 17:00 Project Time ? Time to work on projects with team members

17:00 - 17:00 Close

Techniques and Tools - Bruno Nava; 10 July 2014

09:00 - 09:30 Patricia Doherty / USA: Multi-Instrument Arrays to Monitor and Predict Ionospheric Behavior

09:30 - 10:30 Anthea Jane Coster: The Madrigal Database

10:30 - 11:00 --- Coffee Break ---

11:00 - 12:00 Pierre Cilliers / SANSA, South Africa: Space Science Research, Training and other Related Activities at SANSA: Opportunities for Africans

12:00 - 12:30 Claudia Papparini / ICTP, Italy: Training on EGNOS-GNSS in Africa (TREGA)

12:30 - 13:30 --- Lunch Break ---

13:30 - 13:30 Afternoon activities to be determined. This may include a cultural tour or other tour of choice by the local organizers.

Results of Research Projects; Closing Ceremonies - Chairs: Directors; 11 July 2014

09:00 - 09:30 Patricia Doherty: The Future of GNSS for Space Science Research

09:30 - 09:45 Jean Uwamahoro: Introduction of the Final Projects

09:45 - 10:00 Research Project Group 1

10:00 - 10:15 Research Project Group 2

10:15 - 10:30 Research Project Group 3

10:30 - 11:00 --- Coffee Break ---

11:00 - 11:20 Research Project Group 4

11:20 - 11:40 Research Project Group 5

11:40 - 12:00 Research Project Group 6

12:00 - 13:00 Open Discussion - The Future - Where do we go from here?

13:00 - 14:00 --- Lunch Break --

14:00 - 15:00 Distribution of Certificates of Participation

15:00 - 15:00 End of Workshop



Panel session in the opening of the School; From left to right: Endawoke Y.(USA), Christian M. (Switzerland), Mike H. (Rwanda), Amory C. (France), Babatunde R. (Nigeria), Sibanda P. (Zambia), Groves K. (USA) and Uwamahoro J. (Rwanda)

Panel moderated by Patricia Doherty (USA, not in the photo)

Participants by countries

Country	Number of participants
Ethiopia	1
Burundi	1
Kenya	6
Uganda	6
Tanzania	1
Rwanda	15
Switzerland	1
France	2
Italy	5
Zambia	2
Algeria	1
Malawi	1
USA	8
Guinee	1
Nigeria	5
South Africa	2
Egypt	1
Ivory Cost	4
Total	63



Public talk

Introduction to Space Weather and its Impact on our Daily Lives

Abstract

The Sun has its own season (solar maximum and minimum) that varies in 11 year cycles. During the solar maximum period, (i) the Sun's far ultraviolet (FUV) portion of the solar spectrum intensifies, making the Earth's ionized atmosphere denser and thicker, (ii) the Sun frequently ejects up 10 billion tons of energetic plasma (equivalent to energy of 1000 billion atomic bombs) that propagate to the Earth's atmosphere at the speed of about 1600km/sec and severely disrupt our technological systems which is referred as space weather

By Endawoke Yizengaw, Senior Scientist Institute for Scientific Research, Boston College, USA

impact. Space weather is described by the set of conditions on the Sun, and in the solar wind, magnetosphere, ionosphere and thermosphere, which can affect the performance and reliability of space and ground based technological systems and can imperil human life. Space weather can also impact, sometimes severely, communication (e.g., cellphone, wire money transactions) and navigation (e.g., aviation transportation and agriculture) systems, and

consequently causes severe economic loss. For example, when scintillation (the rapid amplitude and phase fluctuations of radio signals from space due to turbulence generated by irregularities on the ionized region of Earth's atmosphere) happens the following frequently used technological systems will be severely affected; this includes (1) regional SATCOM (satellite communication) outages for extended periods (hours), (2) increased Global Navigation Satellite Systems (GNSS) navigation errors, (3) degraded High Frequency (HF) radio communication. Thus, our communication and navigation technologies depend on understanding, modeling, and mitigating the effects of ionospheric irregularities. Although significant progress has been made in understanding the nature of these irregularities during the past few decades, the uneven distribution of groundbased instruments hinders our ability to obtain a global understanding of the dynamics and structure of these irregularities. In this presentation, we will address the following critical scientific and societal issues; (1) the significant efforts that have been made during the past few decades to obtain the global



A public talk on space weather was open to local companies, institutions, etc.



Public talk by Endawoke Yizengaw from Boston Collge, USA

understanding of space weather, (2) the challenging endeavour that slows down the effort toward understanding the global space weather phenomenon that affect our technological systems, (3) the future expectation and concern of the scientific community, and (4) how can we spark interest of space science education and research into the next generation, especially into the young generation in developing nations. Finally, we will suggest how the different geosciences research disciplines can collaborate to foster our knowledge and understanding of our planet and its environment.



Much interested in space weather phenomena

And many more exciting lectures...

Experts/Lecturers from all around the world; here Dr. Cirado Louigi of ICTP



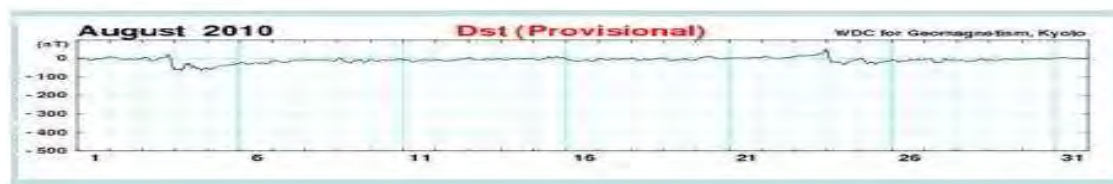
School venue: The University of Rwanda Headquarters



Research project

Objectives

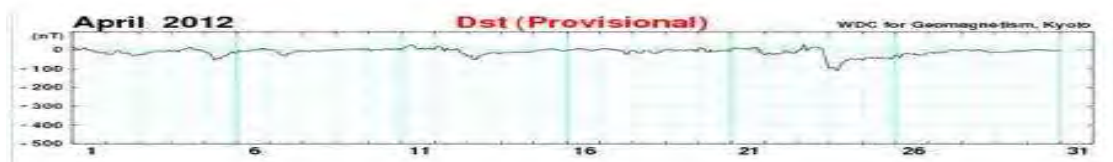
- Training students / school participants to the analysis of space weather events
- Ability to interpret the observed magnetospheric-ionospheric behaviour
- Consideration of all the dynamo processes in the solar-terrestrial physics
- Through analysis of multi-instruments data



August 20 to 30, 2010



April 1 to 10, 2010



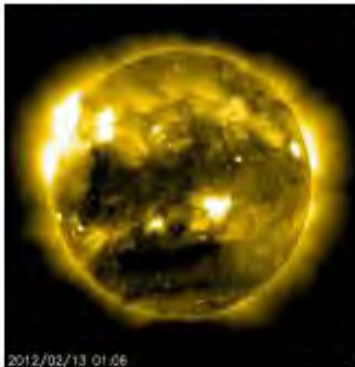
April 20 to 30, 2012

Participants at work in the computer lab. Each group was given a particular space weather event as measured by the Dst index

**Necessity of systemic approach with large data sets
The classification of the data is essential**

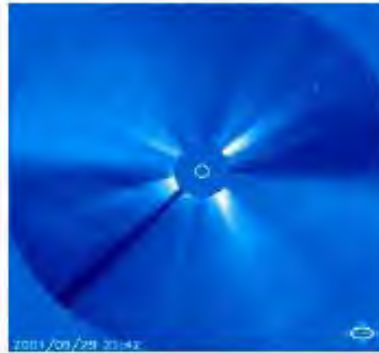
WHAT ARE THE SOLAR EVENTS ?

Coronal hole



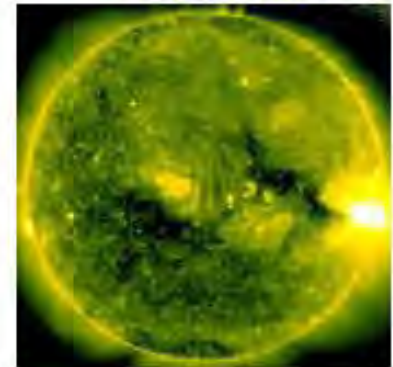
High solar wind speed

CME



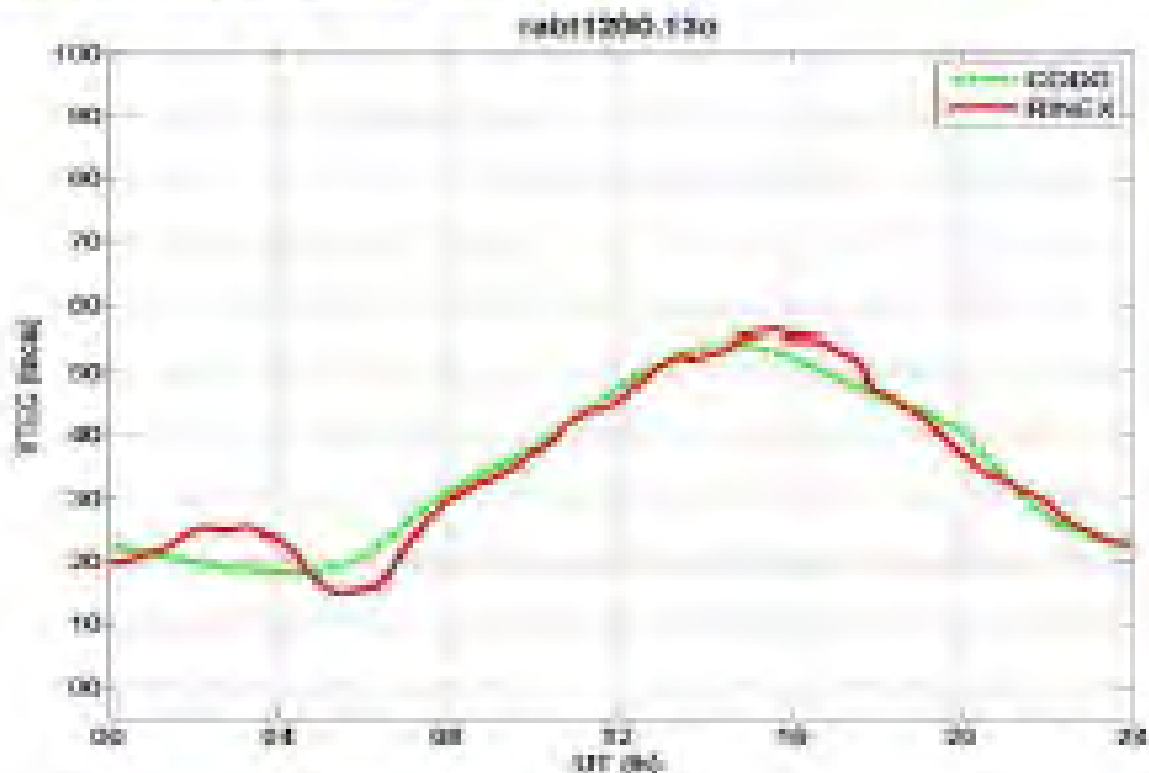
Ejection of solar matter

Solar flare



**Emission of radiation
X rays**

**Interpretation of observations => knowledge on the
variability of the observations**



Group work members



Group 1: *Oladipo (Cpt), Colette, Abibo, Rashidah, Ayuba, J.Pierre*



Group 2: *Bolaji (Cpt), Banda P., Rachid, Gebreegzabihar, Rene Tato, Zaka*



Group 3: Cesaroni (Cpt), Emmanuel, Valence, Jacob, Rene Tato, Zaka



Group 4: Patrick (Cpt), Celestin, Abdenaaser, Antoine, Evariste, Aurore



Group 5: *Paparini (Cpt), Goretti, Angelique, Chifundo, Orondo, Asino*



Group 6: *Oluendo (Cpt), J. Paul, Jean S., Carolyne, Nicholas, Sulungi*

School achievements

Patricia Doherty, Boston College
Jean Uwamahoro, University of Rwanda
Christine Amory-Mazaudier, University of Paris
Bruno Nava, ICTP

University of Rwanda
Kigali, Rwanda
11 July 2014



Promoting Space Science Education and Research in Africa

Timely and important due to increasing dependence on signals from space for modern technology and for scientific exploration.

GNSS Applications and Research

- Increase food security; manage natural resources; wildlife conservation
- Provide efficient emergency location services; disaster relief
- Improve mapping and surveying; accurate timing
- Provide greater precision and safety in land, sea and air navigation
- Scientific research and exploration; marine biology, archeology, seismology, climate

How have we supported our primary goal to promote space science activities in Africa?

- Keynote: Space Weather and its Impact on our Daily Lives
- Current status of Space Science Developments and Education in Africa (Nigeria, Rwanda, Zambia, South Africa)
- Tutorials on Solar Phenomena, Sun-Earth Connection, Geo-Effective Solar Transients, the Ionosphere, Equatorial Electrojet, Electrodynamical Coupling,

Geomagnetic Indices, Geomagnetic Storms, Scintillation Modeling, Data Assimilation Modeling, GNSS Fundamentals

- Discussions on accessing space weather data, processing GNSS data, Madrigal data base
- Instrumentation – Callisto Solar Spectrometer, Magnetometer networks, GNSS Fundamentals and applications, multiple instrument arrays (LISN), Monitor Project
- Training – Trega Project, SANSa
- Provided opportunities for interaction and knowledge sharing between senior and young space scientists
- Strengthened your vision and understanding of the importance of space science
- Provided a background on solar events that are the root cause of space weather
- Provided background on instrumentation – GNSS, ionosondes, solar spectrometers, magnetometers, etc
- Provided hands-on experience on data-analysis, experimentation and group projects

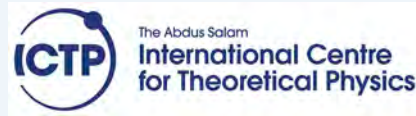
Where do we go from here?

- Is this type of workshop helpful and should we continue?
- Much discussion on building infrastructure
- Cooperation will be the key to success
- More coverage if we leverage resources
- Consider the importance of establishing space science programs in local universities
- Discussion on establishing space science research groups (within countries, across borders)
- Importance of defining clear scientific objectives
- Defining a strategic plan



Thank you to ICTP

Director: Dr. Sandro Radicella
 ICTP Local Organizer – Dr. Bruno Nava
 ICTP Administration – Ms. Stanka Tanaskovic



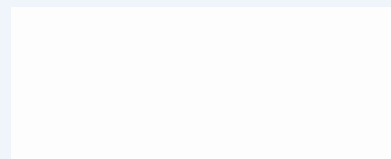
Thank you to our Rwandan Hosts



- Minister of Education: Honorable Vincent Biruta
- Director General S&T Ministry of Education: Dr. Marie Christine
- Vice Chancellor Academic Research University of Rwanda: Dr. Nelson Ijumba
- Principal Univ. Rwanda, College S&T: Dr. Manasse Mbonye
- Advisor Minister of Education: Michael Hughes
- Local Organizing Committee: Fabian Habyarimana, Vivien Munyaburanga, Pheneas Nkundabakura
- Local Organizer and Director. Dr. Jean Uwamahoro

Thank you to Boston College

Father William Lahey
 ISR Members Endawoke Yizengaw, Keith Groves
 Cesar Valladares, Rezy Pradipta and Susan Delay
 ISR Administrators – Jill, Daneille, Sean and Charlie



Thank you to all our sponsors



Closing ceremony

Appreciation Remarks by Hon. Minister of Education, Dr. Vincent BIRUTA



**Patricia Doherty,
Director Boston
College Institute of
Scientific Research**

**Bruno Nava, ICTP
Local Organiser**

**Dr Jean Uwamahoro,
Rwanda, School
Director**

**National, Regional
and International
Scientists and Re-
searchers**

**Ladies and Gentle-
men**

I thank you for this opportunity to attend this review session of the African School on Space Science: Related Applications and Awareness for Sustainable Development of the Region. I am very grateful to the organisers of this

school including the Directors from Boston College, Dr Christine Amory Laboratoire de Physique des Plasma (LPP) of France, Professor Sandro Radicella International Centre for Theoretical Physics (ICTP) of Italy and the organising team from the University of Rwanda. I especially thank all of you who have travelled from Europe, US and all parts of Africa to be in Rwanda for this event.

Ladies and Gentlemen

As I highlighted in the Opening Remarks the Government of Rwanda recognizes the importance of Science, Technology and Research to her development and economic growth. There is top level commitment in Rwanda as demonstrated by the vision and commitment of the President of Rwanda, His Excellency Paul Kagame, towards the value of Science and Technology for Africa's development.

This Space Science School is therefore very significant in helping us to achieve this goal.

I note that the topics of this school cover subjects which are very important to our national and regional development, namely related to the impact of Space weather. This relates to adverse changes in the solar activity and near Earth space environment that may severely affect our communication and navigation technologies among many others. It is therefore of prime importance for us to be able to understand the effects, and be able to develop methods to predict and mitigate the impact of these solar and related disturbances.

Ladies and Gentlemen

This school has provided an opportunity for Senior and Young Space Scientists to interact and share knowledge in this field including strengthening vision and understanding of the importance of research in Space Science and its applications for the development of mankind

The Group Research projects which focused on analysis of specific solar events and their impact on telecommunication and navigation technologies have particular importance in strengthening the knowledge and understanding in this area.

I am pleased to learn that practical sessions of the school have allowed participants to gain hands on experience in data analysis of the multiple space-borne and ground based array of space science instruments

On the theoretical side it has allowed participants to be introduced to solar-terrestrial physics and its impact on the near-Earth space environment and technology driven activities. Sessions were included to provide a background in the use of the Global Positioning Satellite Systems for practical applications and scientific exploration.

Ladies and Gentlemen

Rwanda greatly values the importance of working together in regional and international partnerships to support STI development related to challenges facing Rwanda and the region.

This school represents an initial programme in the ongoing development of a close partnership with the Abdus Salam International Centre for Theoretical Physics, (ICTP), and work is underway to establish an East Africa Centre for Fundamental Research based on activities associated with the ICTP. Construction works on the physical refurbishment of a building in the University of Rwanda College of Science and Technology, that will host the Centre, started this week.

We recognise that the partnership with the international organisers in the hosting and delivery of this space science school, and the partnership with the ICTP in the establishment of the regional centre in Rwanda, will support the Government's vision and strategy to develop high level science, technology and research skills in Rwanda.

Ladies and Gentlemen

I am aware that you are at the conclusion of this school and I therefore formally declare this "African School on Space Science: Related Applications and Awareness for Sustainable Development of the Region" closed.

I hope you have enjoyed your stay in Rwanda and I wish all of you who have travelled to be with us, a safe and comfortable journey home.

Thank you for your kind attention.



A Memory photo with the Minister of Education



Moments of entertainment ...



Some participants had time to visit the mountain Gorillas in the Volcano park (Northern part of Rwanda)





The End

May God bless you all