



The status of Space weather observations and research in Africa

Babatunde RABIU

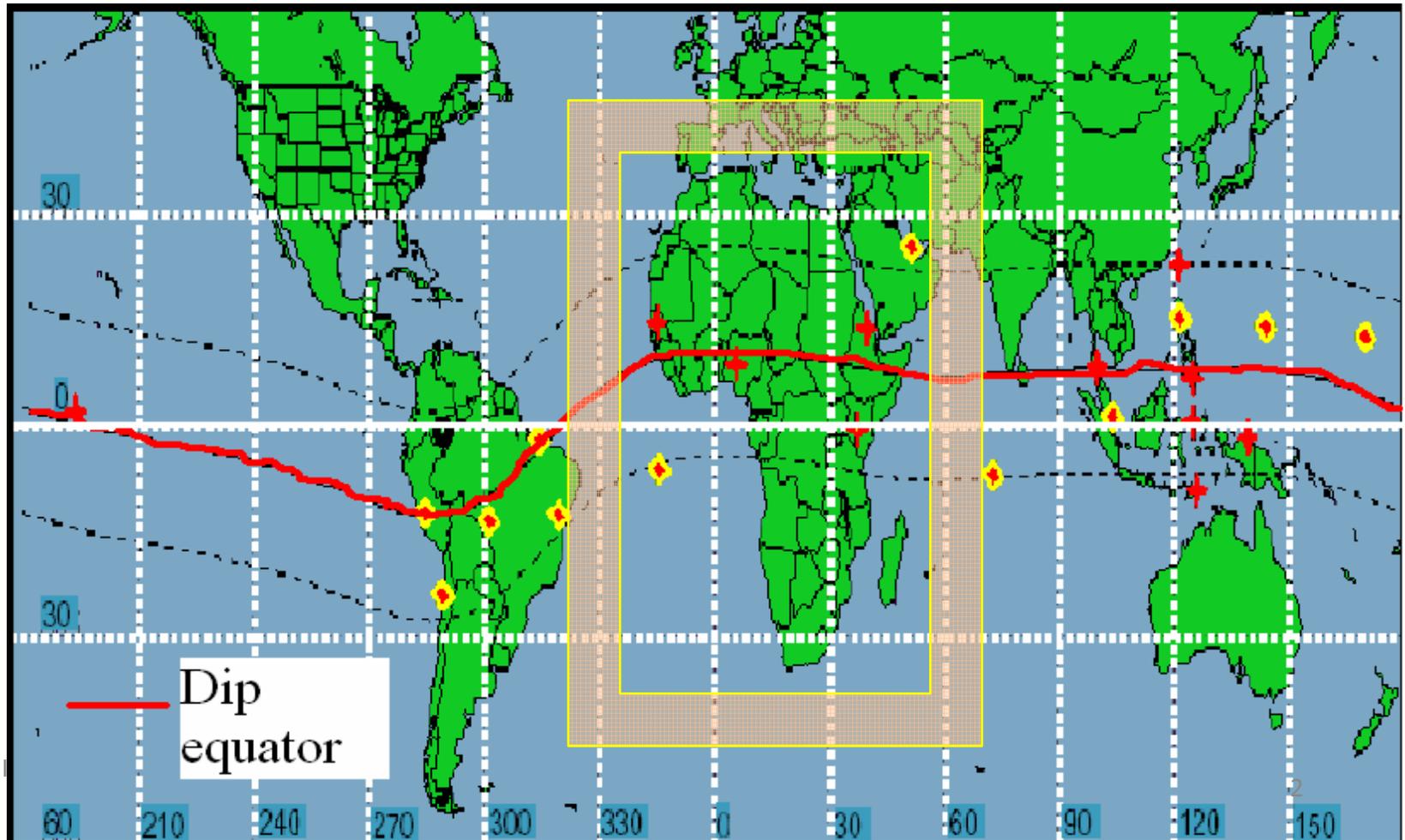
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Uniqueness of SW over Africa

- Broad range of magnetic equator over land
- EIA width can be studied in its full spectrum





UN- IHY/ISWI IN AFRICA

instruments

- ✓ Magnetometers
- ✓ GNSS receivers
- ✓ All sky Optical Imager
- ✓ FPI
- ✓ Ionosonde
- ✓ CALLISTO
- ✓ More than 30 SIDs

Capacity building



UN Workshops

- ✓ Intra- Continental training of MSc and PhD student (more than 30)
- ✓ Short term visit to overseas partner institutions
- ✓ Series of Space Weather schools

- ✓ Egypt 2010
- ✓ Nigeria 2011



Space Weather Monitors in Africa

- ❑ Magnetometers (MAGDAS, AMBER/SAMBA)
- ❑ >50 units of GPS - IGS, SCINDA, BC/ICTP, ESA
- ❑ Many other regional networks

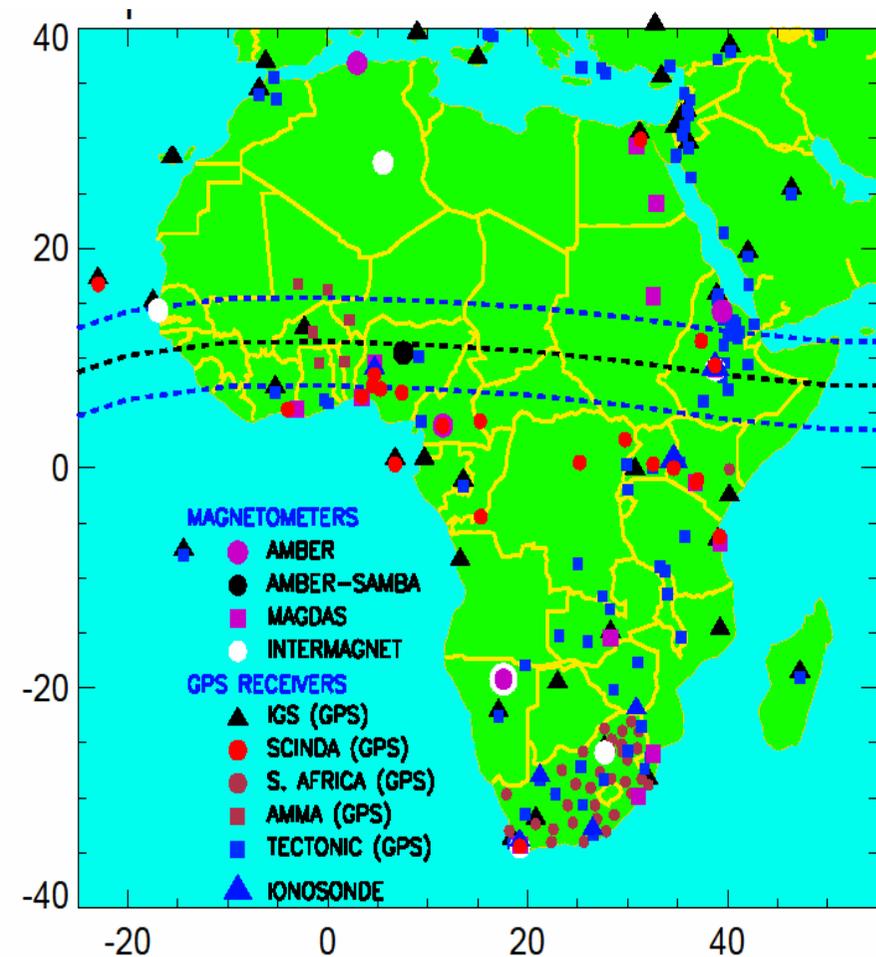
Additional monitors planned:

VIPIR Ionosondes in Addis Ababa, Ethiopia
and Maseno, Kenya

Digisonde in Nigeria

GPS (with new L5 signals)

data obtained from these facilities are
being used to improve our understanding
of global space weather as it affects the
performance of GNSS





Facilities at Washera Geospace and Radar Science Lab, BDU, Ethiopia

- Most of our facilities are obtained from Boston College
 - BNR (Backscatter Coherent Radar)
 - VHF
 - SCINDA GPS receiver



Figure – Sample facilities at WaGRL.

Melessew Nigussie, 2018

<http://www.bdu.edu.et/wagrl/node/9>



Coherent Back Scatter Radar - Blue Nile Radar BNR

- The Coherent scatter radar consists of 64 yagi antennas
- was installed in November 2014 in collaboration with Boston college and American Air force laboratory (AFRL) of USA
- It is used to observe the E and F region electron density irregularities.



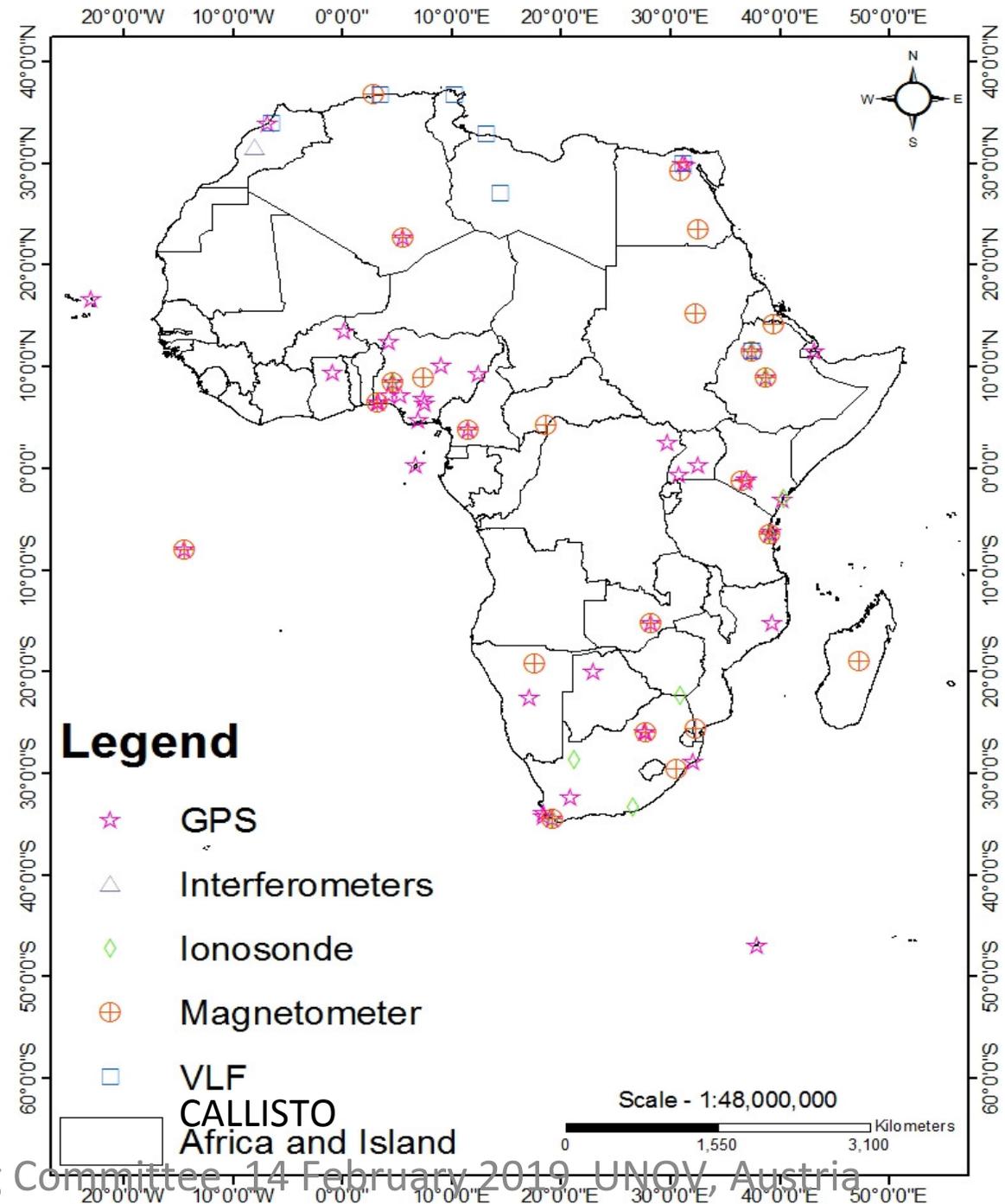
<http://www.bdu.edu.et/wagrl/node/9>



Status of Space Weather Research facilities

- ✓ **54 sovereign nations**
- ✓ **African Professors**
- ✓ **Diligent students**
- ✓ **Research facilities**

- Mostly foreign intervention
- National Participation





Workshop/Schools/Conferences held in Africa

- IHY - SCINDA Workshop, Sal Island, Cape Verde, **2006**.
- IPY-IHY Regional Workshop, Somerset West, Cape Town, South Africa, **2006**
- African IHY Conference, Addis Ababa, Ethiopia **2007**
- African IHY conference, Livingstone, Zambia, **2009**
- IHY Regional School, Enugu, Nigeria November **2008**
- ISWI School, Bahir Dar, Ethiopia, **2010**
- UN/Egypt Workshop on Space Weather, Helwan, Egypt **2010**
- International MAGDAS School, Lagos, Nigeria, August **2011**



Workshop/Schools/Conferences held in Africa

- UN/Nigeria Workshop on Space Weather, Abuja, Nigeria
October **2011**
- AGU Chapman Conference on Space Weather, Ethiopia, **2012**
- ISWI/SCOSTEP School on Space Sciences, Nairobi, Kenya **2013**
- ICTP/BC/ICG African School on Space Science, Rwanda **2014**
- International School on Equatorial & Low Latitude Ionosphere, Nigeria, **2015**
- International Symposium on Equatorial Anomaly, Ethiopia, **2015**
- UN CRASTE-LF Use of Global Positioning System (GPS) Data for Ionospheric Studies, Morocco, **2017**
- 2nd International School on Equatorial & Low Latitude Ionosphere, Nigeria, **Sept, 2017**



Summer Schools

- 41 African graduate students & Postdocs
- From 14 African countries
- 15 Instructors



1st African Regional IHY School in Africa, Enugu, Nigeria, 2008



1st International School on Equatorial & Low Latitude Ionosphere, Nigeria, 14 – 19 sept **2015**, ISELLI -1





Meeting Report 4:



2nd International School on Equatorial and Low-Latitude Ionosphere (ISELLI-2)

K. Shiokawa¹ and B. Rabi²

¹Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan

²Center for Atmospheric Research (CAR), National Space Research and Development Agency (NASRDA), Abuja, Nigeria

- ✓ 60 participants
- ✓ 10 countries
- ✓ 1-week long activities
- ✓ 10-16 Sept 2017
- ✓ CU, Ota, near Lagos



Kazuo Shiokawa



Babatunde Rabi

School on Equatorial and

Low-Latitude Ionosphere (ISELLI-2) was held



Figure 1. Participants of ISELLI-2.

Cote D'Ivoire, and Nigeria introduced ionospheric dynamics, measurement techniques, Spread-F/ plasma bubbles, and space weather. A training of SPEDAS GUI system under IUGONET was held on Thursday. Participants enjoyed lively discussions with the lecturers and mutual communications during this one-week school. This school was supported by Centre for Atmospheric Research (CAR) of NASRDA, Covenant University, Institute for Space-Earth Environmental Research (ISEER) of Nagoya



ICTP-BC GNSS Workshops for Africa

- Partnership between Boston College, USA & Abdus Salam ICTP, Trieste, Italy.
- Series of annual Workshops since 2009 - 10 editions
- Deployment of GPS stations in Africa
- Over 400 African scientists have been trained at ICTP
- Leading experts in GNSS teach at the annual workshops
- A training model





about 47 Africans, 37 non-Africans



1 ICTP-BC GNSS Workshop Satellite Navigation Science and Technology for Africa

23 March - 9 April 2009

ICTP, Trieste - Italy



The Abdus Salam
International Centre
for Theoretical Physics



10 ICTP-BC GNSS Workshop

Workshop on Space Weather Effects on GNSS Operations at Low Latitudes

23 April - 4 May 2018

Miramare, Trieste - Italy



Participating African Countries

- Algeria
- Cameroon
- Cote-D'ivoire
- Egypt
- Ethiopia
- Ghana
- Kenya
- Morocco
- Nigeria
- Rwanda
- Senegal
- South Africa
- Uganda
- Zambia





Direct Benefits to African Academics & Students

- Deployment of Research Infrastructure
- Software availability GG, BC
- Training
- Short term visits to BC/ICTP by African scientists
- Facilitation of exchange of Students & postdocs
- Workshops in Africa





Output

- M.Sc. And PhD. Degrees
- Space Physics program at graduate levels
- Instrument/Data Availability
- Research Publications in Journals
- Increase in number of African based professors
- Positive Catalyzation of National government participation in SW
- Inter/intra-national cooperation
- Scientist / student exchange
- Brain drain control
- International competitive research in Africa





Several Publications ... for examples

Ann. Geophys., 35, 701–710, 2017
https://doi.org/10.5194/angeo-35-701-2017
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Studying the variability in the diurnal and seasonal variations in GPS total electron content over Nigeria

Victor Adetayo Eyelade¹, Adekola Olajide Adewale², Andrew Ovie Akala², Olawale Segun Bolaji², and A. Babatunde Rabi¹

¹Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria
²Department of Physics, Faculty of Science, University of Lagos, Akoka, Lagos State, Nigeria

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Received: 4 July 2016 – Revised: 2 May 2017 – Accepted: 3 May 2017 – Published: 6 June 2017

Abstract. The study of diurnal and seasonal variations in total electron content (TEC) over Nigeria has been prompted by the recent increase in the number of GPS continuously

1 Introduction

Ann. Geophys., 35, 535–545, 2017
www.ann-geophys.net/35/535/2017/
doi:10.5194/angeo-35-535-2017
© Author(s) 2017. CC Attribution 3.0 License.



Longitudinal variation of equatorial electrojet and the occurrence of its counter electrojet

A. Babatunde Rabi¹, Olanike Olufunmilayo Folarin^{1,2}, Teiji Uozumi³, Nurul Shazana Abdul Hamid⁴, and Akimasa Yoshikawa³

¹Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria
²Ionospheric and Space Physics Laboratory, Department of Physics, University of Lagos, Akoka, Lagos State, Nigeria
³International Center for Space Weather Science and Education (ICSWSE), Kyushu University, 744, Motooka, Nishi-ku,



Journal of Geophysical Research: Space Physics

RESEARCH ARTICLE

10.1002/2017JA024602

Key Points:

- First airglow observations of equatorial plasma bubbles in the West African ionosphere
- First empirical analysis on relation between GNSS ROTI characteristics and airglow plasma bubble observations
- New observations of maximum postmidnight plasma bubble occurrences during the periods from December to March

First Study on the Occurrence Frequency of Equatorial Plasma Bubbles over West Africa Using an All-Sky Airglow Imager and GNSS Receivers

Daniel Okoh¹, Babatunde Rabi¹, Kazuo Shiokawa², Yuichi Otsuka², Bolaji Segun³, Elijah Falayi⁴, Sylvester Onwuneme⁵, and Rafat Kaka⁶

¹Center for Atmospheric Research, National Space Research and Development Agency, Abuja, Nigeria, ²Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan, ³Department of Physics, University of Lagos, Lagos, Nigeria, ⁴Department of Physics, Tai Solarin University of Education, Ijebu_Ode, Nigeria, ⁵Department of Physics, University of Port Harcourt, Port Harcourt, Nigeria, ⁶Department of Mathematical and Physical Sciences, Afe Babalola University, Ado Ekiti, Nigeria

Abstract This is the first paper that reports the occurrence frequency of equatorial plasma bubbles and their dependences of local time, season, and geomagnetic activity based on airglow imaging observations at West Africa. The all-sky imager, situated in Abuja (Geographic: 8.99°N, 7.38°E; Geomagnetic: 1.60°S), has a 180° fisheye view covering almost the entire airspace of Nigeria. Plasma bubbles are observed for 70 nights

Correspondence to: D. Okoh, okodan2003@gmail.com



Space Weather

RESEARCH ARTICLE

10.1002/2017SW001729

Key Points:

- Nighttime annual variability amplitude is higher during disturbed than quiet condition regardless of solar activity period
- IRI-CCIR option performed best during disturbed activity conditions especially for $F10.7 < 85$ sfu, $A_p > 7$ nT condition
- Model/observation relationship performed best between local midnight and postmidnight period for all solar/magnetic activity conditions

Supporting Information:

- Supporting Information S1

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Ionospheric Peak Electron Density and Performance Evaluation of IRI-CCIR Near Magnetic Equator in Africa During Two Extreme Solar Activities

B. O. Adebesein¹, A. B. Rabi², O. K. Obrou³, and J. O. Adeniyi¹

¹Space Weather Group, Department of Physical Sciences, Landmark University, Omu-Aran, Nigeria, ²Centre for Atmospheric Research, National Space Research and Development Agency, Anyigba, Nigeria, ³Laboratoire de Physique de l'Atmosphère Université FHB Cocody, Abidjan, Côte d'Ivoire

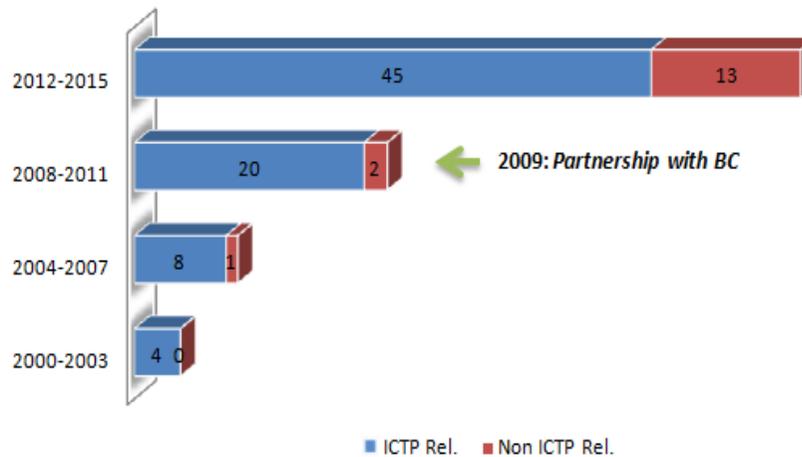
Abstract The F_2 layer peak electron density (NmF_2) was investigated over Korhogo (Geomagnetic 1.26°S, 67.38°E), a station near the magnetic equator in the African sector. Data for 1996 and 2000 were respectively, categorized into low solar quiet and disturbed and high solar quiet and disturbed. NmF_2 prenoon peak was higher than the postnoon peak during high solar activity irrespective of magnetic condition, while the postnoon peak was higher for low solar activity. Higher NmF_2 peak amplitude characterizes disturbed magnetic activity than quiet magnetic condition for any solar activity. The maximum peaks appeared in equinox. June solstice noontime bite out lagged other seasons by 1–2 h. For any condition of solar and magnetic activities, the daytime NmF_2 percentage variability ($\%V_p$) measured in the relative standard deviation maximizes/minimizes in June solstice/equinox. Daytime variability increases



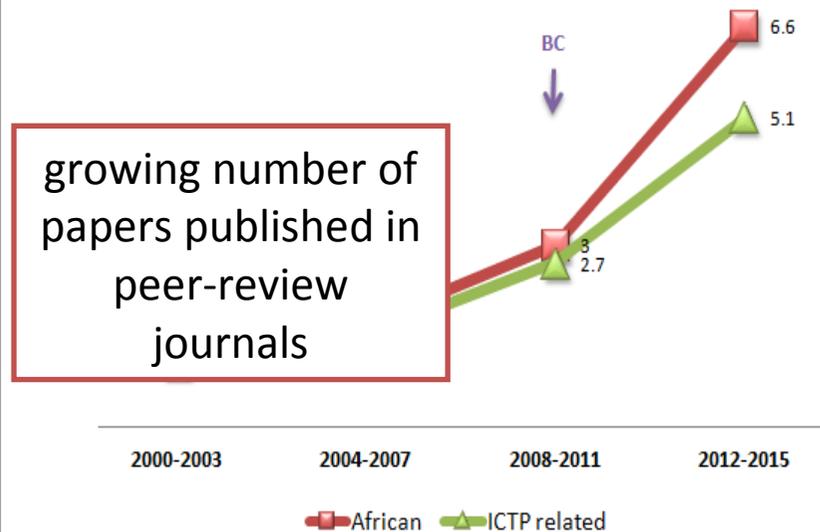
Research output evolution

Papers published by African scientists working in Africa on “equatorial ionosphere” from World of Science website

African publications on Equatorial Ionosphere



% African Papers on Equatorial Ionosphere

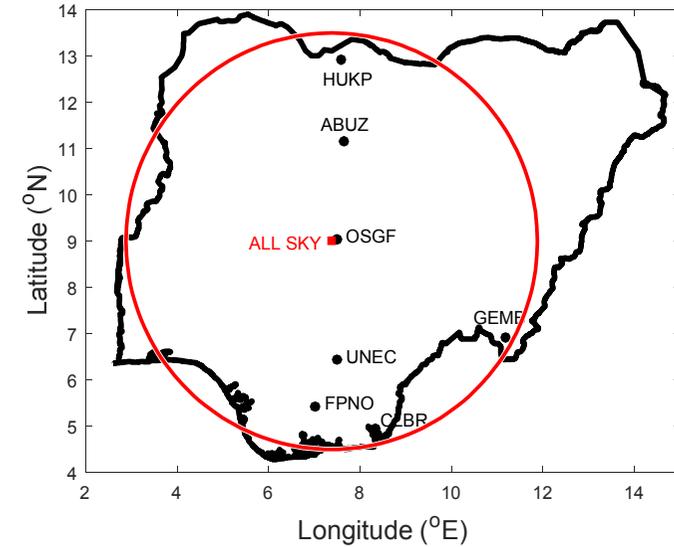
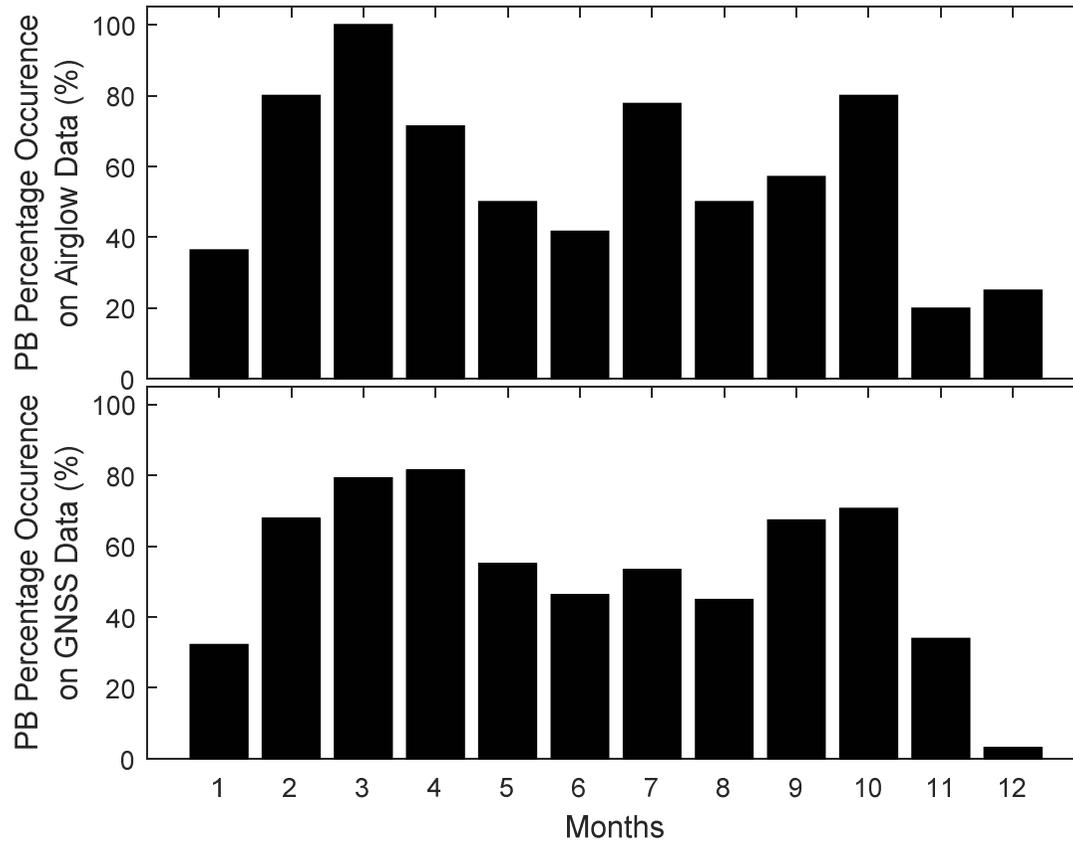


“ICTP Rel.” means scientists related to ICTP having attended one or more training activities organized by ICTP or having been ICTP associates or in other ICTP programs like STEP. □

Radicella & Nava, 2017



Plasma bubbles over Nigeria using Optical imager data

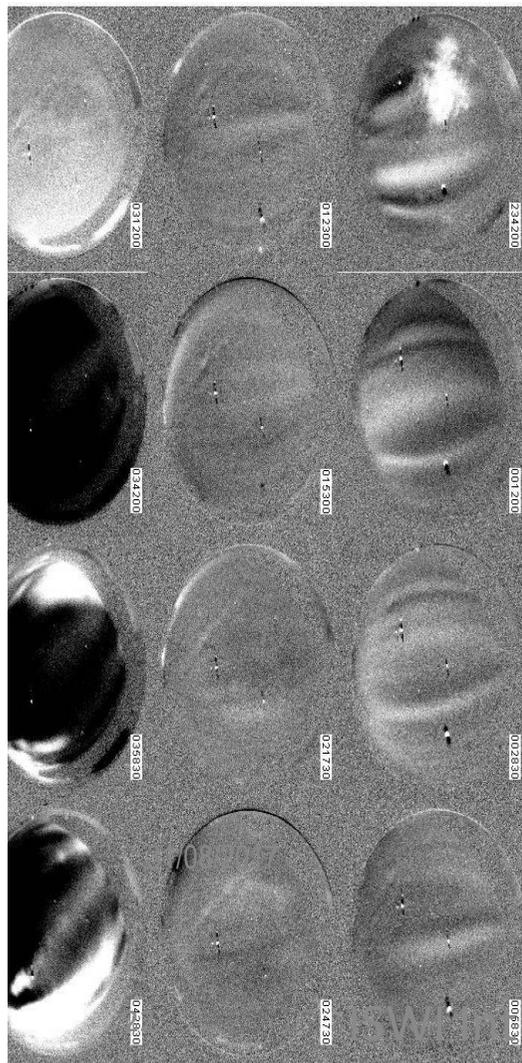


Percentage Occurrence of Plasma Bubbles as observed on the Airglow and GNSS data for the period from June 2015 to January 2017.

Okoh et al, JGR, 2017

All Sky Imager Research

First airglow observations of plasma bubbles on the African continent



cam2 630.0mm 160413 exposure:0245
All-Sky Images at Abuja
(deviation from average)

AGU PUBLICATIONS



Journal of Geophysical Research: Space Physics

RESEARCH ARTICLE

10.1002/2017JA024602

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Citation:

Okoh, D., Rabi, B., Shiokawa, K., Otsuka, Y., Segun, B., Falayi, E., ... Kaka, R. (2017). First study on the occurrence frequency of equatorial plasma bubbles over West Africa using an all-sky airglow imager and GNSS receivers. *Journal of Geophysical Research: Space Physics*, 122. <https://doi.org/10.1002/2017JA024602>

Received 19 JUL 2017

Accepted 21 NOV 2017

Accepted article online 27 NOV 2017

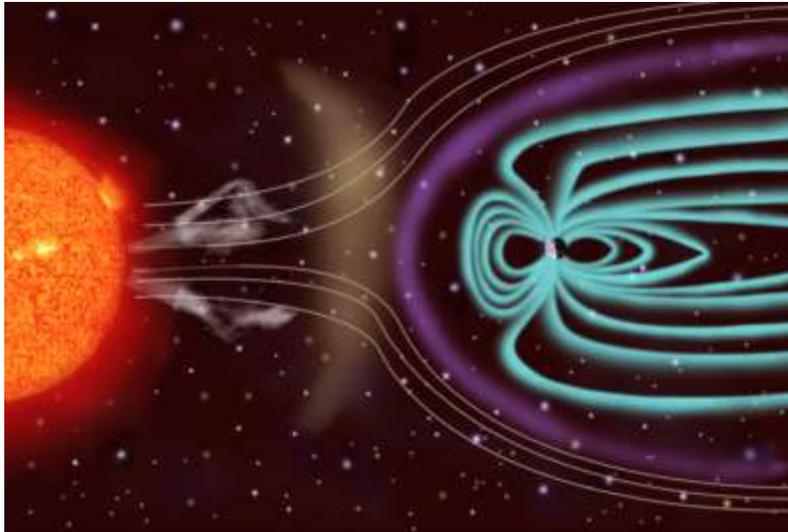
First Study on the Occurrence Frequency of Equatorial Plasma Bubbles over West Africa Using an All-Sky Airglow Imager and GNSS Receivers

Daniel Okoh¹, Babatunde Rabi¹, Kazuo Shiokawa², Yuichi Otsuka², Bolaji Segun³, Elijah Falayi⁴, Sylvester Onwuneme⁵, and Rafiat Kaka⁶

¹Center for Atmospheric Research, National Space Research and Development Agency, Abuja, Nigeria, ²Institute for Space-Earth Environmental Research, Nagoya University, Nagoya, Japan, ³Department of Physics, University of Lagos, Lagos, Nigeria, ⁴Department of Physics, Tai Solarin University of Education, Ijebu_Ode, Nigeria, ⁵Department of Physics, University of Port Harcourt, Port Harcourt, Nigeria, ⁶Department of Mathematical and Physical Sciences, Afe Babalola University, Ado Ekiti, Nigeria

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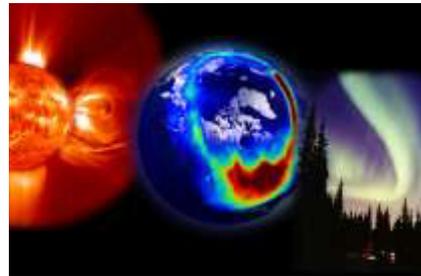
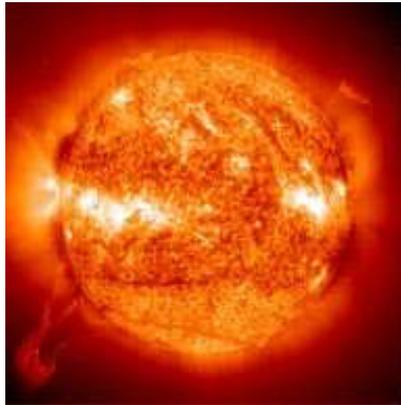
SANSA SPACE SCIENCE



The Space Science Directorate of SANSa is part of the worldwide network of magnetic observatories and is responsible for research infrastructure and data used to monitor the near Earth space environment. The scope of activities include fundamental and applied space physics research, post-graduate student training, science advancement, Space Weather and the provision of geomagnetic field related services on a commercial basis.

SPACE SCIENCE CORE FUNCTION: Sun-Earth Interactions & Related Technologies

Research



- Monitoring the Earth-Space system
- Space Weather
- Distributing data on the system
- Creating new knowledge on the system
- Developing human capital

Technology



- Advanced & customised system solutions
- Innovative product integration
- In-service training



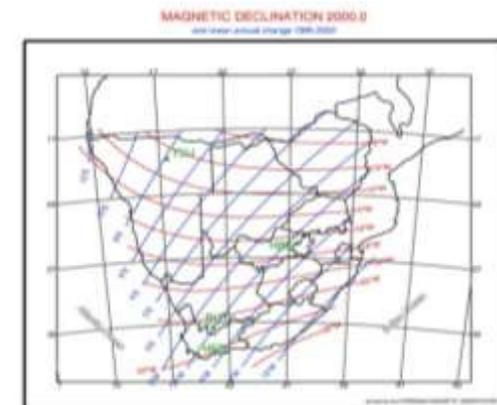
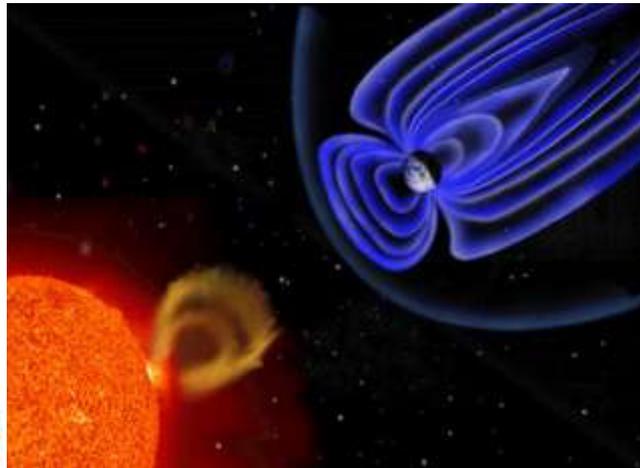
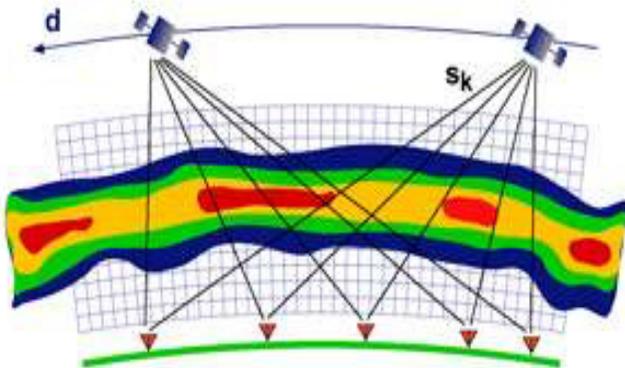
Science Advancement



- Getting the youth into science
- Enhancing science learning
- Increasing science awareness & interest among the public
- Changing lives
- Transforming society

RESEARCH

- Geomagnetic Research
- Ionospheric Research incl Characterisation
- Waves and Space Plasmas
- Space Weather (Solar, Prediction etc)





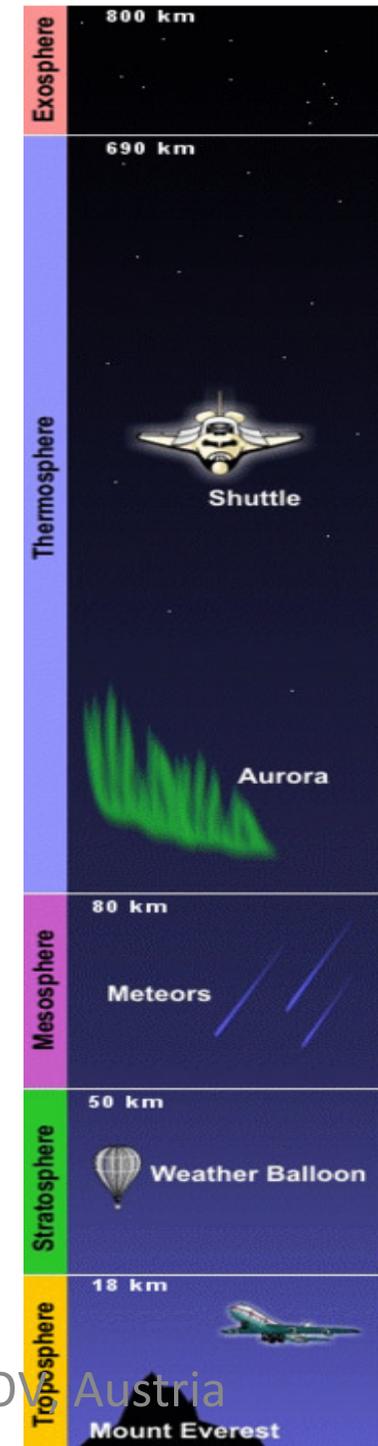
SANSA Space Science, Hermanus

- operates a wide range of infrastructure across southern Africa and in Antarctica,
- hosts the only Space Weather Warning Centre in Africa since 2011, providing early warnings and forecasts on space weather activity for public and private sector clients
- training ground for African scientists/researchers



Center for Atmospheric Research, Nigeria

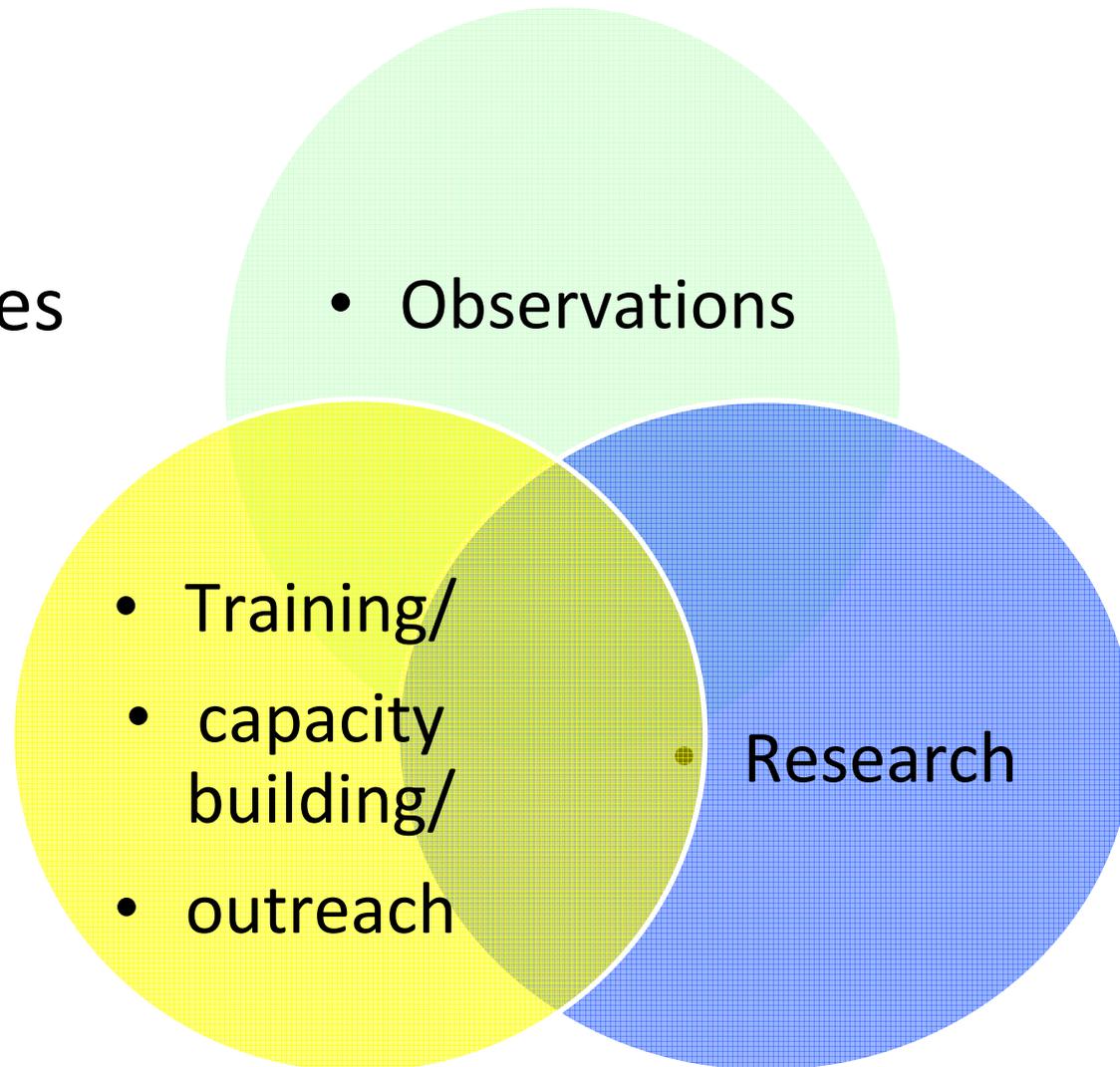
- A world class R & D center of NASRDA committed to **research and capacity building** in the **atmospheric and related sciences**
- dedicated to understanding the **atmosphere**—the air around us—and **the interconnected processes** that make up the Earth system, **from the ocean floor through the ionosphere to the Sun's core**
- provides **research facilities** and **services** for the atmospheric and Earth sciences community





CAR

is envisioned to
operate in 3 modes





Research Projects of CAR

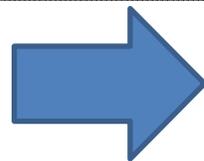
- **Space Weather Observation Network over Nigeria- SWONON**
 - Space Weather Observation Network over Africa- SWONOA
- Tropospheric Data Acquisition Network – TRODAN
- Atmospheric Chemistry and Environmental Research – ACER
- Microgravity and Human Space Technology - MHST
- Atmospheric Research Software and Instrumentation Development - ARSID



Space Weather Observation Network over Nigeria- SWONON

- to monitor and nowcast space weather over Nigeria
- To develop in-country expertise for implementation, operations, processing and analyses of space weather processes.

Network of ground-based space observatories (facilities include magnetometers, digisondes, ionospheric GNSS monitors, optical imagers, SID monitor)



SWONOA



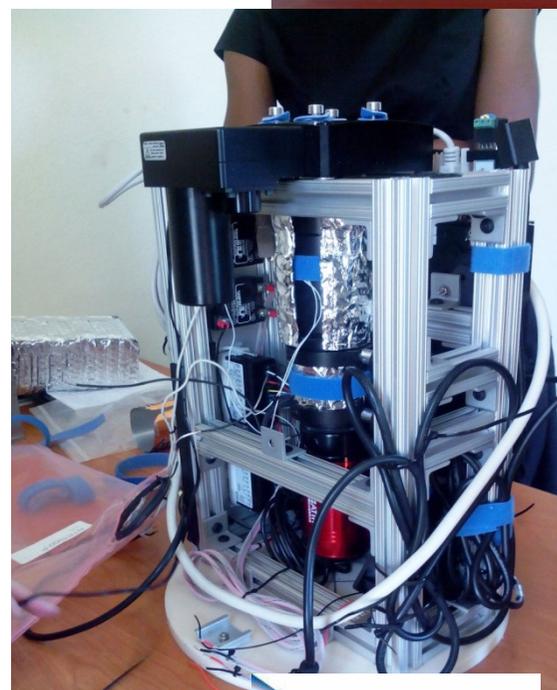
Space Environment Research Lab, Abuja

- June 2015.
- Optical Imager, FPI,
Magnetometers (2), GNSS
Space Weather Monitor



Equipment: Fabry-Perot Interferometer (FPI)

Installed November 2015



**PI:
Dr Qian
Wu**

**National Center for Atmospheric
Research, Boulder, USA**



**Cloud
detector**

13/09/2017

ISWI Int'l Steering Committee 14 February 2019 UNODC, Austria

Equipment: Magnetometers



**Relocated Sept. 2015
from the Advanced
Computation Lab**



AMBER

1st installed: August 2011

MAGDAS

1st installed: August 2010

**PI: DR ENDAWOKE
YIZENGAW Institute
for Scientific
Research, Boston
College,
USA**



**PI: DR AKIMASA
YOHIKAWA
International Center for
Space Weather Science and
Education (ICSWSE), **Kyushu
University, Japan****



Equipment: GPS



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