The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

2333-6

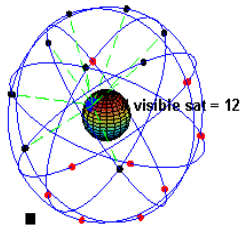
Workshop on Science Applications of GNSS in Developing Countries (11-27 April), followed by the: Seminar on Development and Use of the Ionospheric NeQuick Model (30 April-1 May)

11 April - 1 May, 2012

GNSS in Africa:
Trend of Applications and Prospects

RABIU Akeem Babatunde

National Space Research and Development Agency
Oluobasanjo Space Centre
Abuja 234
NIGERIA



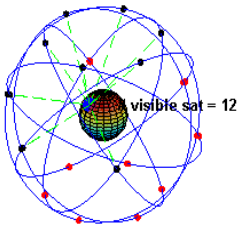
GNSS in Africa: Trend of Applications and Prospects

Babatunde Rabiu,

National Space Research & Development Agency

NASRDA, Abuja, Nigeria

Email: tunderabiu@yahoo.com



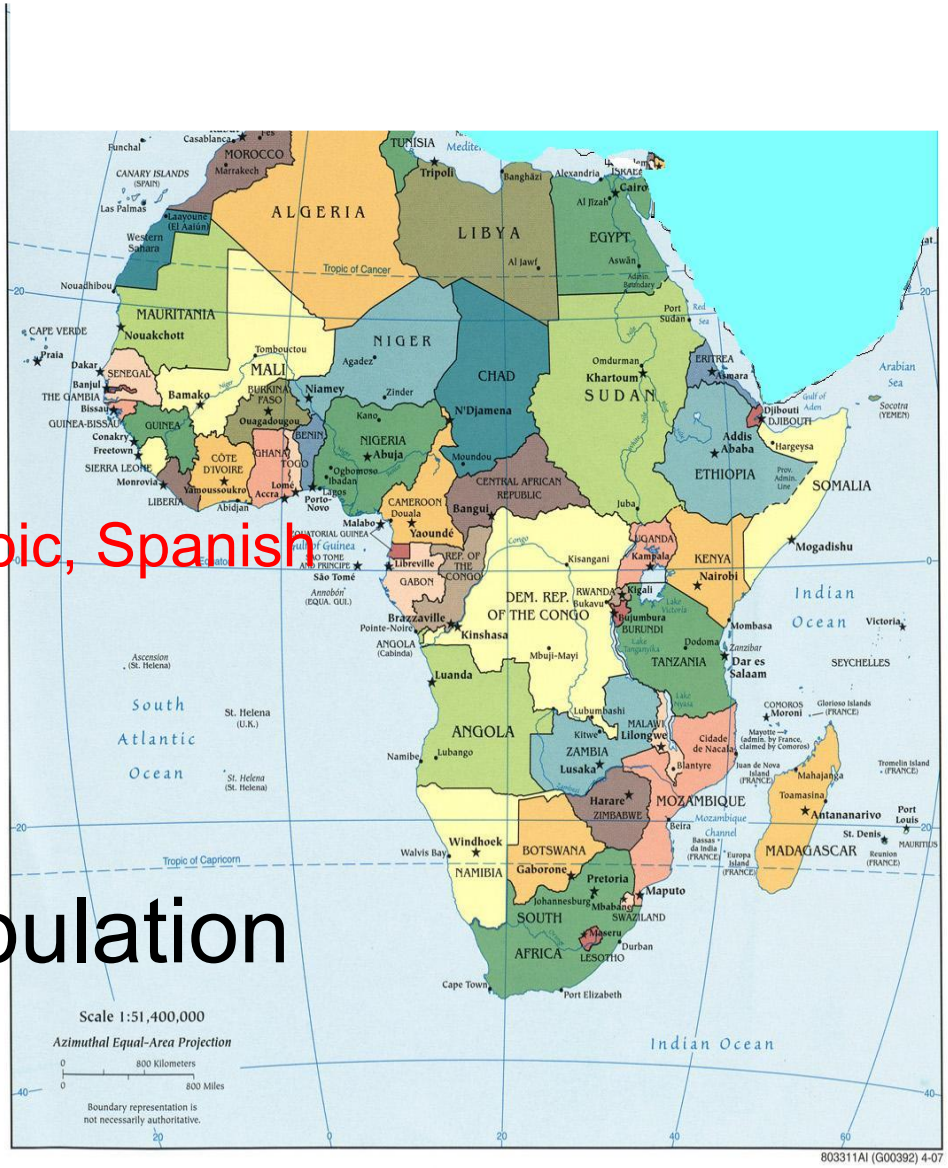
Outline

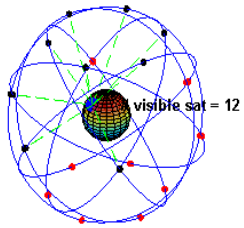
GNSS Challenges in Africa

- About Africa
- Applications of GNSS in Africa
- Status quo
- AFREF and National Reference Frames
- AfricaArray
- IHY/ISWI
- ICTP-BC Joint Program on GNSS
- Prospects
- Conclusion.

Africa !

- A continent
- 54 individual nations
- Multi-lingual structure
- English, French, Portuguese, Arabic, Spanish
- ~ 30 billion km^2
- ~ 850 million people
- ~14% of the World population



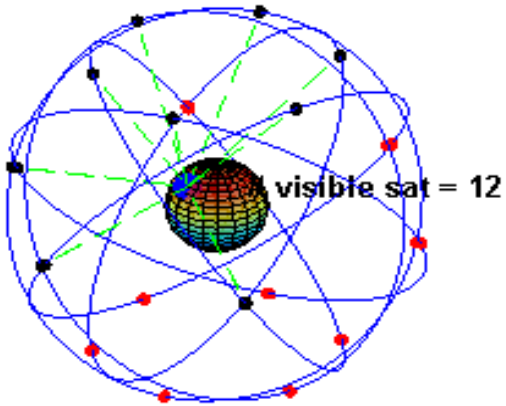


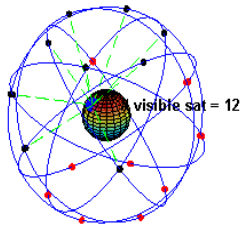
GNSS

Science

Technology

Applications





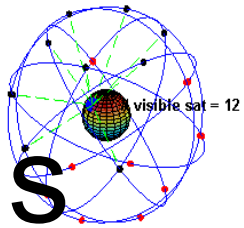
Science with GNSS

➢ Ionospheric research

- Characterization of ionosphere using TEC
- Space weather studies
- Scintillation studies
- Atmospheric delay
- Validation/improvement of existing atmospheric models

Output ⇒

- ✓ PhDs
- ✓ M.Sc
- ✓ Research publications

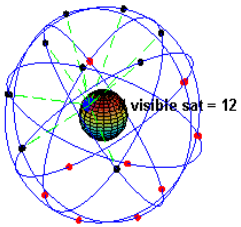


Social-Economic Applications

on increasing level

- positioning services,
- surveying & mapping,
- Boundary mapping
- food security,
- disaster management,
- air, land & sea navigation,
- Land administration
- emergency response
- Wild life management

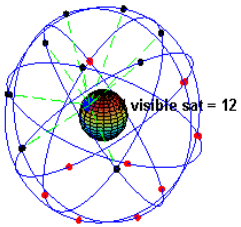
Impact of GNSS



- ✓ Military
- ✓ Aviation
- ✓ Education
- ✓ Economy
- ✓ Agriculture

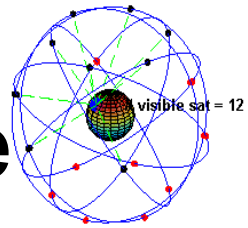
- ✓ Minerals & oil exploration
- ✓ Disaster monitoring systems
- ✓ Land & maritime transportation
- ✓ Land surveying
- ✓ Health
- ✓ Revenue

GNSS Programs in Africa

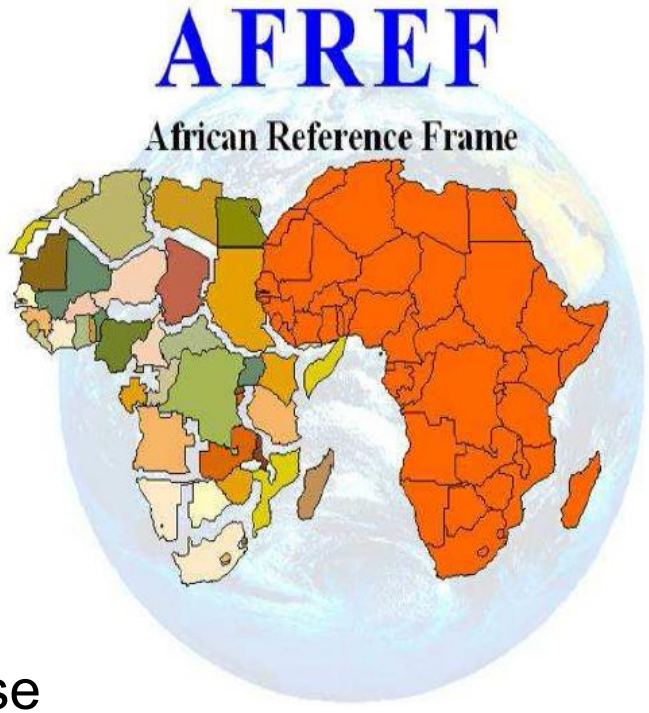


- **AFREF**
- **National Reference Frames**
- **IGS**
- **IHY/ISWI**
- **AfricaArray**
- **ICTP-BC joint GNSS program**

The African Geodetic Reference Frame AFREF

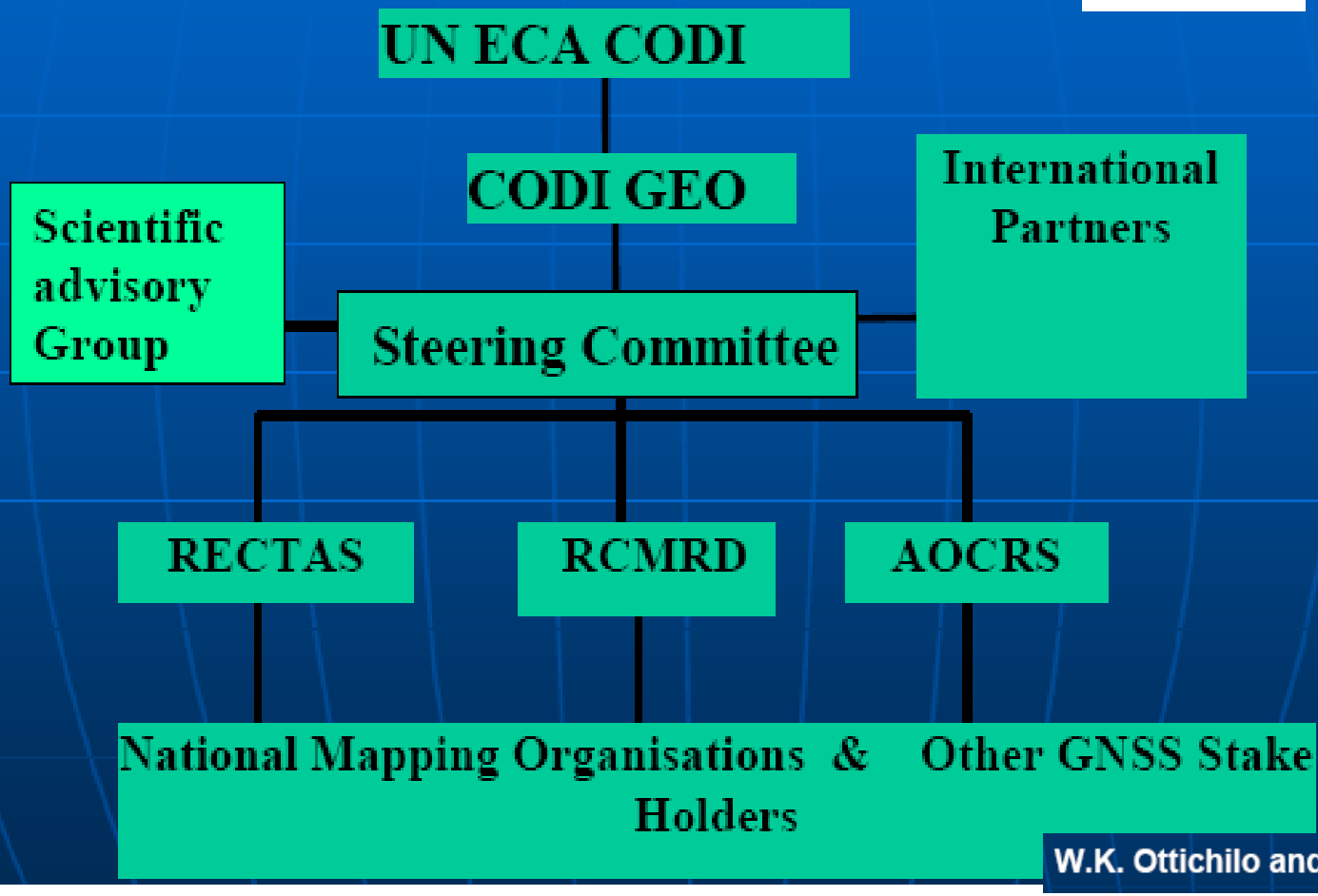


- a unified geodetic reference frame
- fundamental basis for the national & regional three-dimensional reference networks
- fully consistent and homogeneous with the International Terrestrial Reference Frame ITRF
- Densification of GNSS networks with its products in Africa
- Full implementation will include a unified vertical datum and support for efforts to establish a precise African geoid



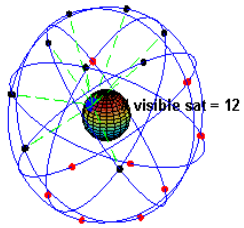
http://geoinfo.uneca.org/afref/

Organizational Structure



W.K. Ottichilo and H.O. Farah

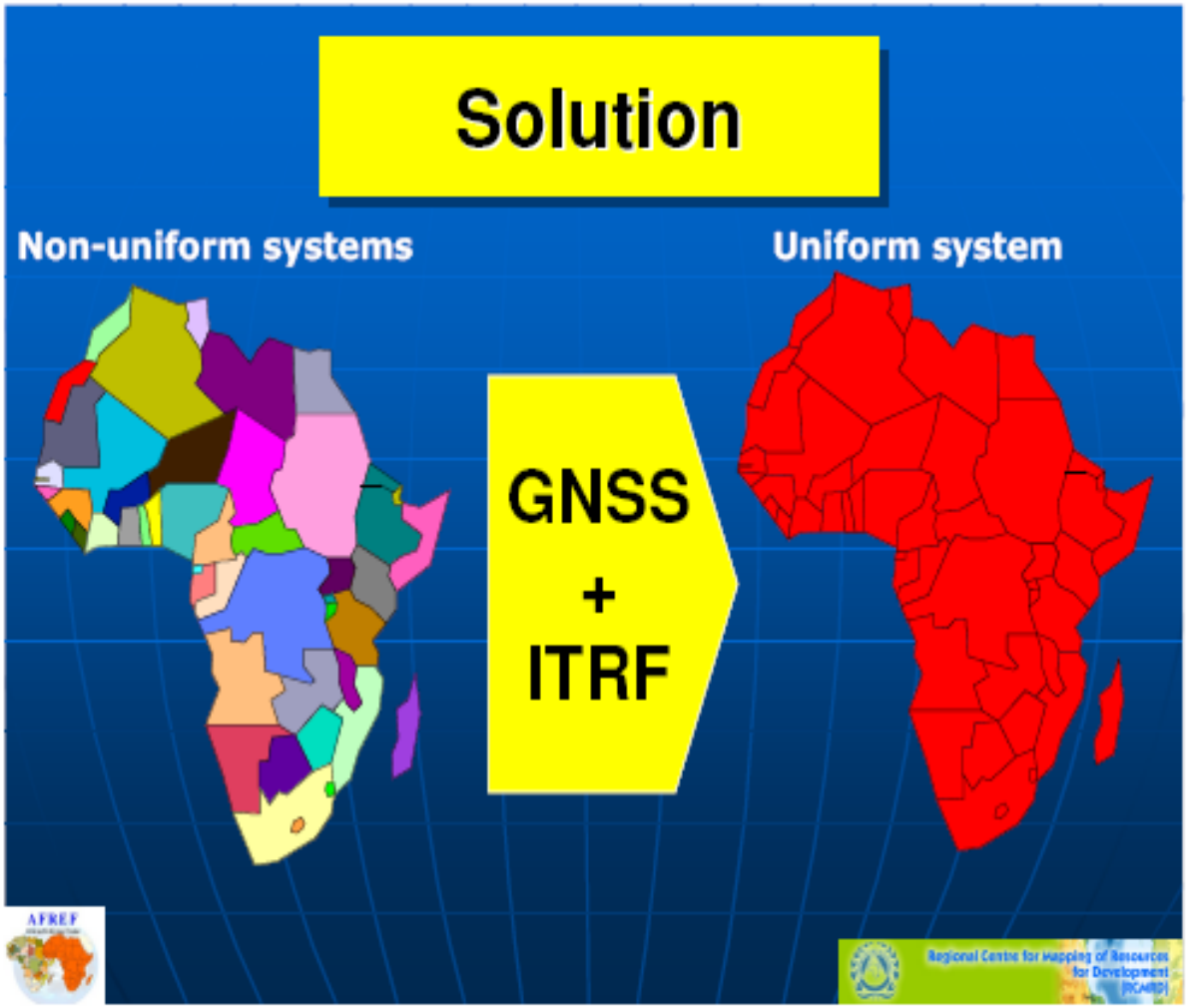
AFREF: African solution



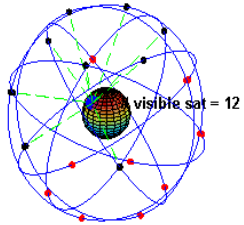
- ✓ each African country has its national geodetic reference system for producing maps and other geoinformation products - some countries even have more than one
- ✓ representation of cross-border features on maps cannot be done accurately
- ✓ For example, roads, watershed and ecosystem boundaries and wildlife reserves appear disconnected when national maps are joined together for regional planning and decision analysis
- ✓ Work on large infrastructure projects is normally undertaken in sections
- ✓ a uniform mapping surface is required to ensure that the sections join up.
- ✓ To unify the reference systems, parameters of the best fitting surface for map projections need to be determined and used by all countries.

Reducing 54 Reference frames to

1

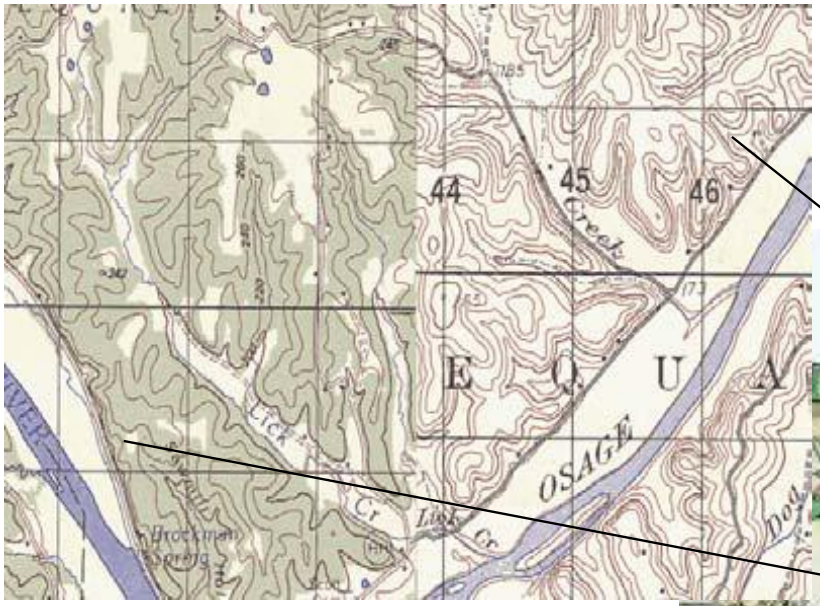


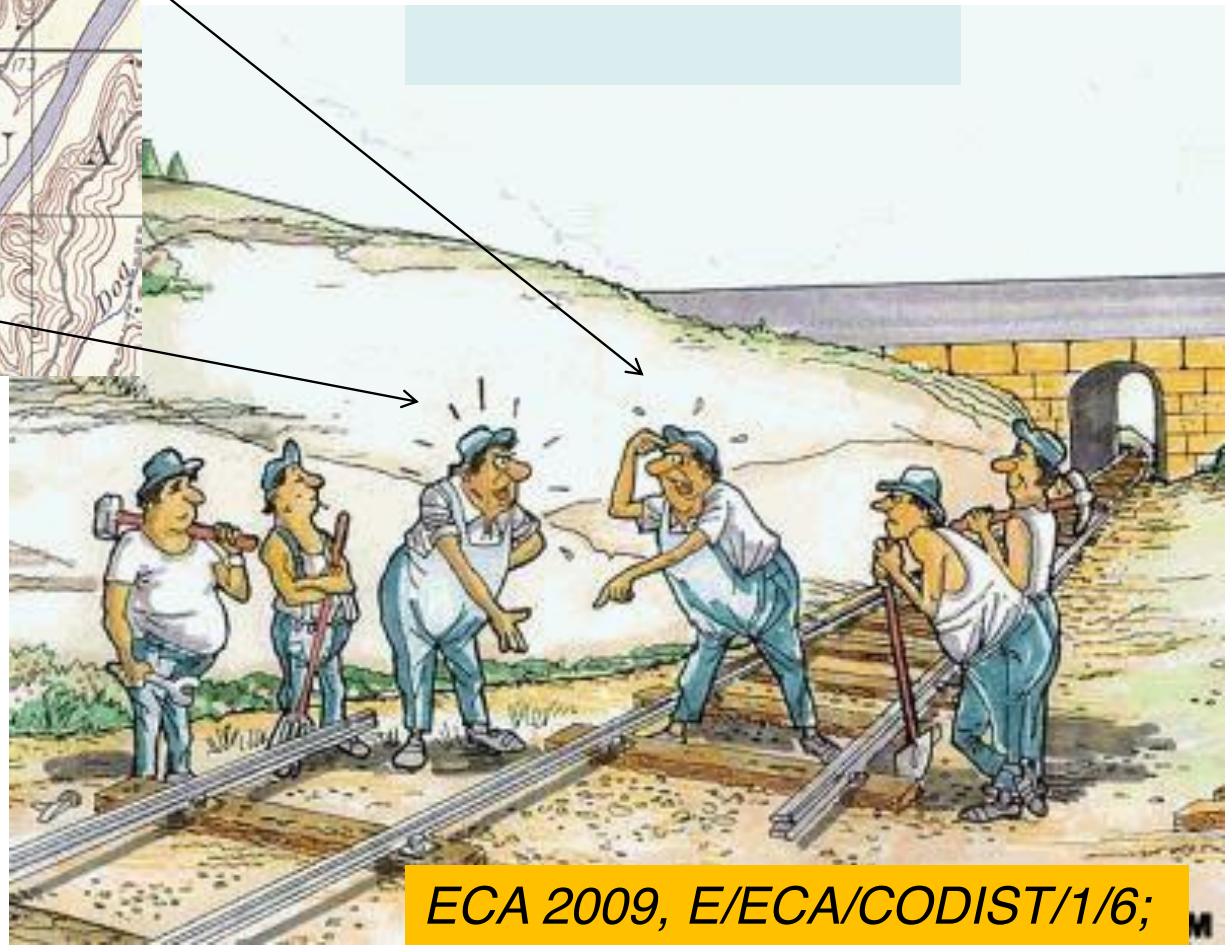
Combrinck (AFREF Presentation Berlin GNSS 2008)



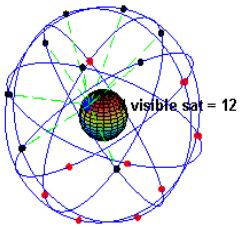
Consequences of using reference systems that are not consistent !

Products of incoherent maps - confusion





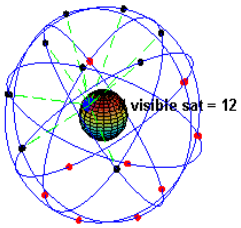
ECA 2009, E/ECA/CODIST/1/6;



Strategy

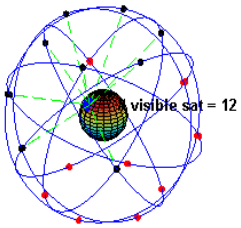
- Densification of GNSS CORS
- Central processing of data

Int'l Supports and AFREF



- AFREF is an African initiative
- ICG Working Group D addresses reference frame issues, including AFREF
- In 2008 through the UN Office for Outer Space Affairs (UNOOSA)/ICG, the U.S. facilitated the travel of twenty Africans to an AFREF workshop at the Africa Array Conference held at the University of Witwatersrand, Johannesburg, RSA
- U.S. plans to continue to support AFREF development through Africa Array, the UNOOSA and other existing international initiatives

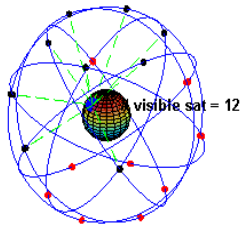
Ray Clore, 3rd International Satellite Navigation Forum, Moscow, Russia, May 12-13, 2009.



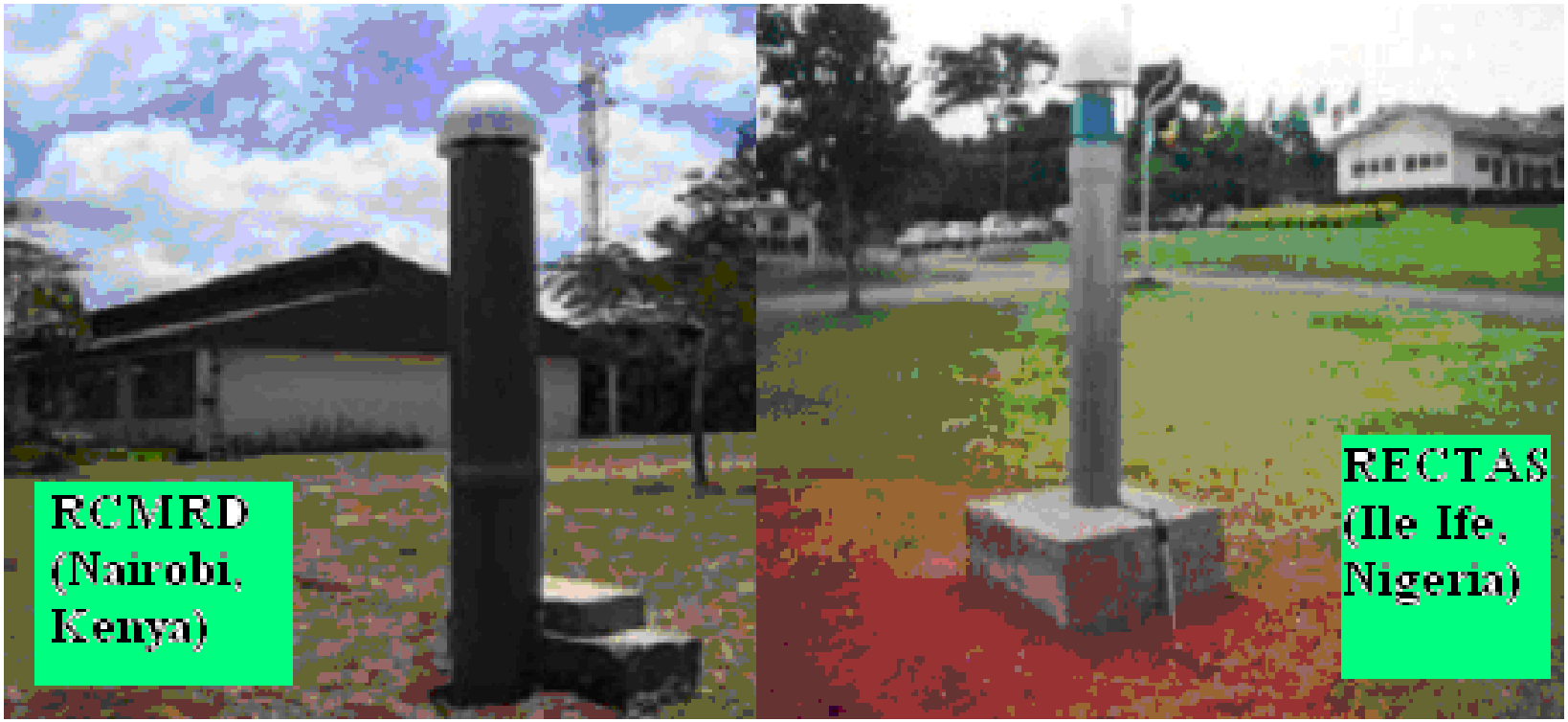
National Participation

- More than 5 countries have established a network of CORS
  - Ghana
  - Tanzania
  - South Africa
  - Nigeria
  - Egypt
  - (???)

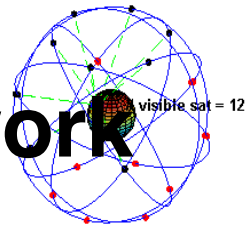
- About 20 countries now have at least one CORS



Typical AFREF CORS

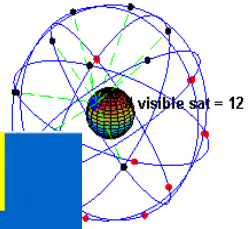


Benefits of Good national geodetic network



- ✓ Provides foundation for all geo-referencing activities.
- ✓ It is the base for coherent multipurpose Land Information System (cadastre) and its subsequent maintenance.
- ✓ positioning services,
- ✓ surveying & mapping,
- ✓ Community-Boundary mapping
- ✓ food security, disaster management,
- ✓ air, land & sea navigation,
- ✓ Effective land administration, registration & taxation
- ✓ emergency response, management of resources
- ✓ promotion of Good Governance
- ✓ revenue planning and collection.
- ✓ Checkmating corrupt practices

Capabilities of AFREF (Combrinck, 2008)



Applications in Land Surveys

AFREF Base Station

Applications in Mapping

Real time Differential corrections will improve GPS solutions for Mapping

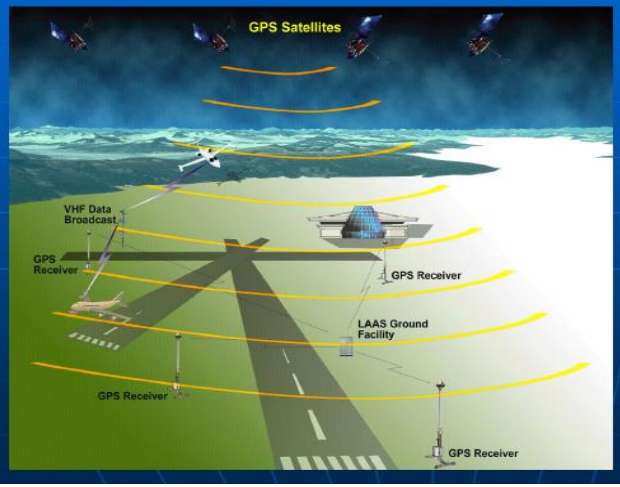
AFREF Base Station

Will provide Ground control for Mapping

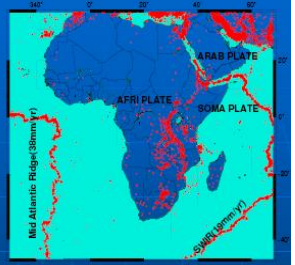
Applications in Water Navigation

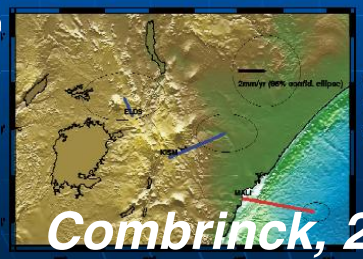
Real time Differential corrections will improv
GPS accuracy and precise docking

Applications in Air Navigati



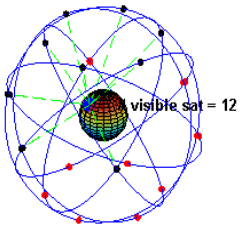
Applications in Crustal dynamics





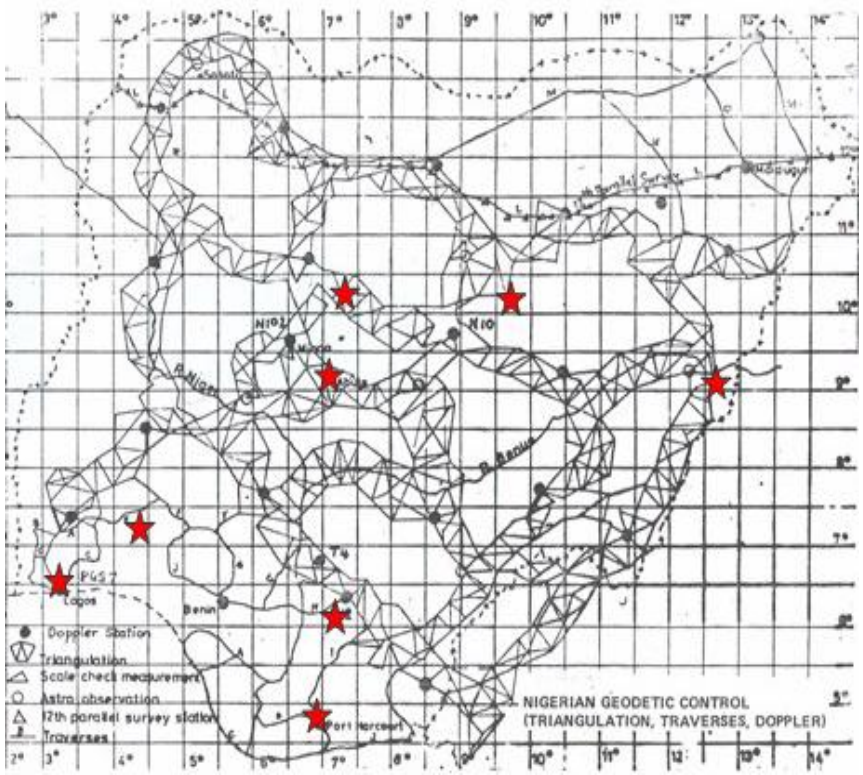
GPS data from AFREF base stations will be used to continuously monitor earth crustal movements.

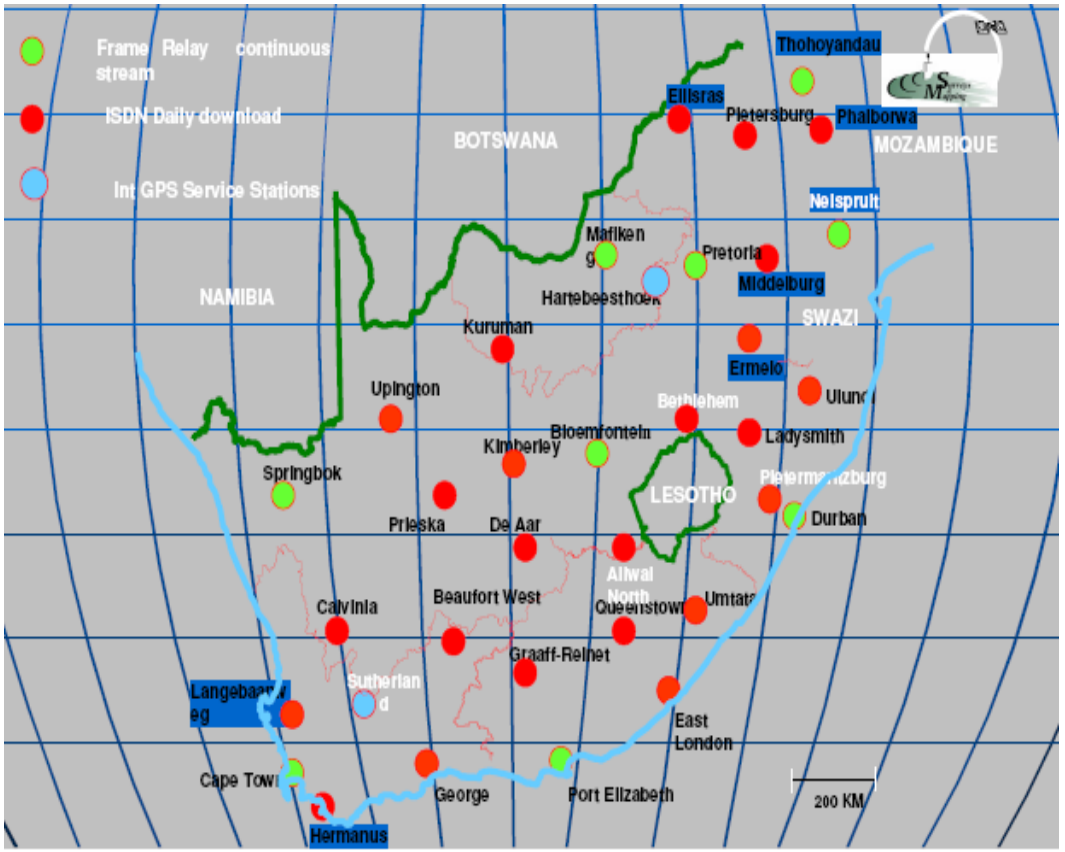
Combrinck, 2008, Berlin



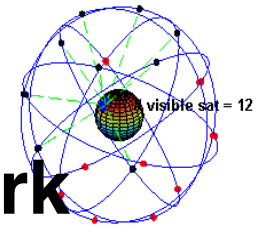
NATIONAL REFERENCE FRAMES

Densification of National networks





Ottichilo and Farah



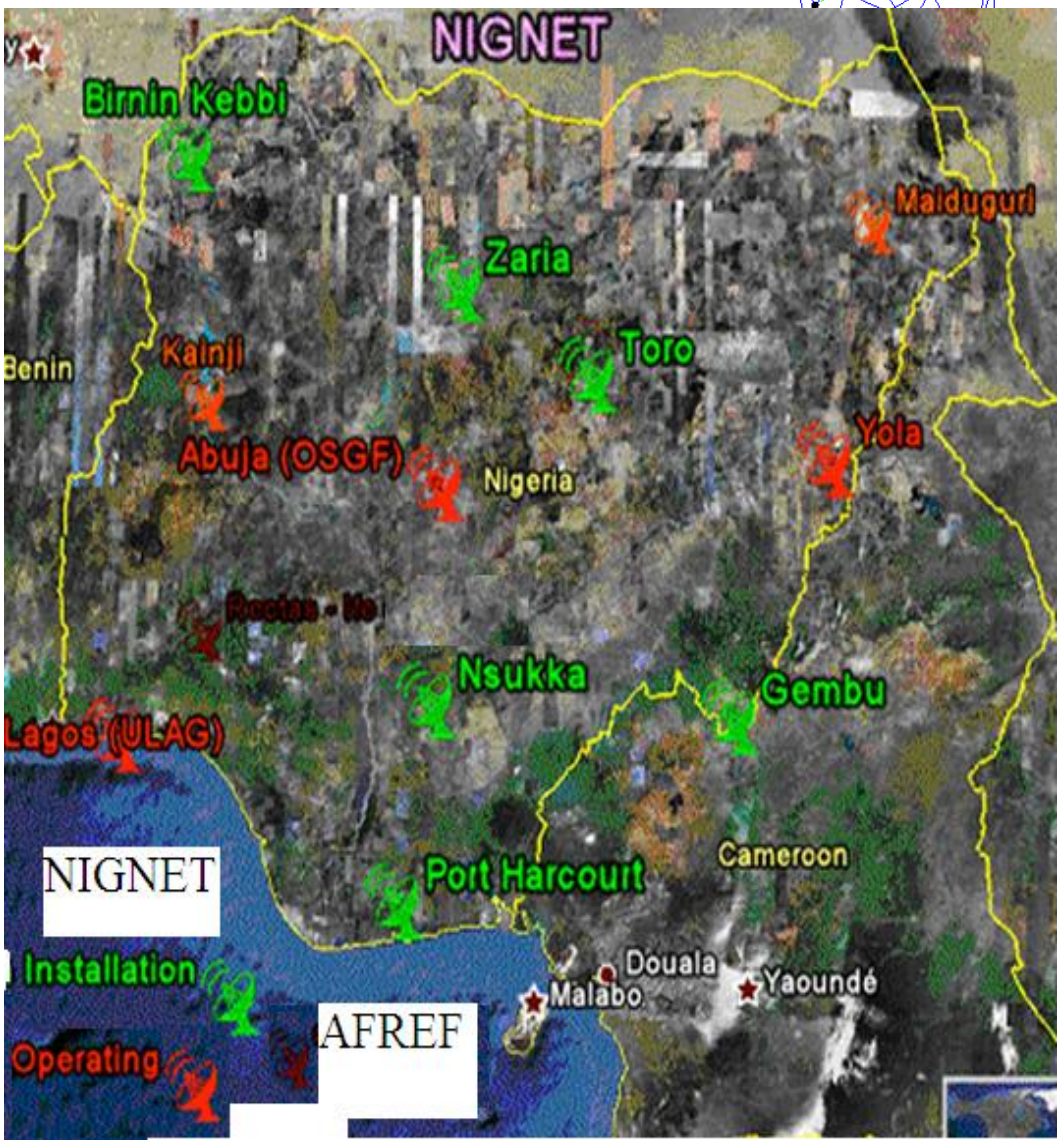
NIGNET: NIGerian GNSS Reference NETwork

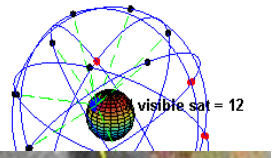
- ✓ Promoted by OSGoF (Office of the Surveyor General of the Federation)
- ✓ to implement a new reference frame for Nigeria in line with the recommendation of the United Nation Economic commission of Africa (UNECA) through its Committee on Development, Information Science & Technology (CODIST).
- ✓ The installation is being done in collaboration with SEGAL, a collaborative project between University of Beira Interior and Institute Geophysical Infante D. Luíz in Portugal.
- ✓ The core of NIGNET is formed by a network of GNSS CORS
- ✓ NIGNET will contribute to ITRS through AFREF

(Jatau et al, 2010, Sydney, Australia)

NIGNET

- The first geodetic surveys of Nigeria were performed by the British Royal Engineers in 1910-1912
- Observation of existing geodetic networks (horizontal and vertical networks) started in the late 1920's
- Most of the network was materialized between the late 1940's and early 1960's
- OSGoF - the National Mapping Agency of Nigeria, initiated NIGNET in 2008

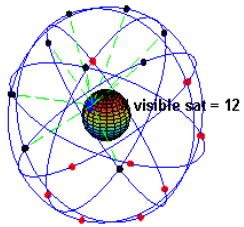




(Jatau et al, 2010, Sydney, Australia)

NIGNET

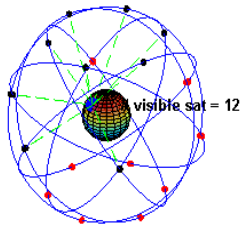
- **Top – OSGF station installed at OSGoF headquarters, Abuja**
- **Middle – UNILAG station installed at the campus of University of Lagos.**
- **Bottom Left –FUTY station installed at Federal University of Technology of Yola**
- **Bottom Right - location at Toro.**



NIGNET equipment and operations

- located at Universities and Research Centers in order to also link NIGNET to the scientific community and foster the use of this network by more applications
- The NIGNET network is being installed with capabilities to support RTK positioning, both in single and network modes.
- The data from the permanent stations will be collected at a central station in Abuja where corrective data for the location of rover stations will be computed and will be provided to the users.
- The target is 200 CORS (*Personal Communication with SGoF, 2010*)

(Jatau et al, 2010)



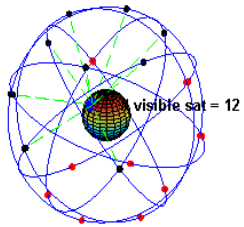
New Land Reform Policy

- Chairman of the Presidential Committee on Land Reform, Prof. Peter Adeniyi,
- The reform will involve the identification and removal of existing bottlenecks in the current land titling and registration procedures within the land delivery process
- undertaking a comprehensive survey, including the mapping of the country on a scale, large enough to show land holdings of individuals or corporate bodies among others
- The Committee is working with OSGoF to densify CORS

March 12, 2012 Punch Newspaper

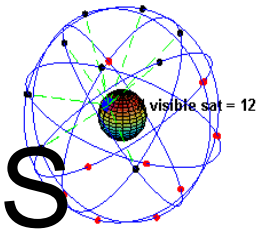
http://www.punchng.com/news/land-reform-fg-picks-ondo-kano-for-pilot-scheme/*March 12, 2012 Punch Newspaper*

Abuja Geographic Information Systems (AGIS)



- A viable tool for promotion of Good Governance
- a system for land & property management, registration & taxation
- being used to increase revenue, revenue planning and collection.
- Additional System features include data storage, information management, quick and easy data access, as well as retrieval of Statistical data and updated reports from the office & field.
- proved to be highly efficient and has greatly changed the landscape of town-planning services and land administration
- Uncovered some past corrupt practices
- is being extended to other cities

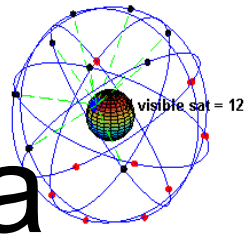
http://www.abujagis.com/index.html



Digital mapping & enterprise GIS

Lagos State Government of Nigeria, July 19th 2008 – a project with following components

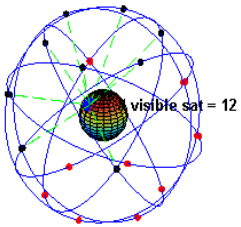
- Geodetic Control & Digital Aerial Photo Acquisition;
- Determination of Geoid Model &
- establishment of Continuous Operating Reference Station & Orthophoto
- Contour Lines and Digital (vector) Mapping;
- GIS Database and Enterprise GIS
- Bathymetry Survey of Lagos lagoons & creeks
- supply of equipments; training & public enlightenment/education.



Other Applications in Nigeria

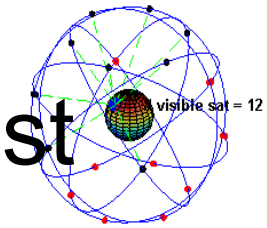
- Fadama rice plantation (Agriculture)
- control of meningitis disease
- desertification control and
- monitoring of encroachment of ocean along the coast
- Mapping of Bitumen deposit in SW Nigeria
- Climate change related studies

GSM & GPS



- GSM telecommunication systems are synchronized with GPS systems
- GSM users are now track-able – position and time
- Location identification
- Crime control and public safety

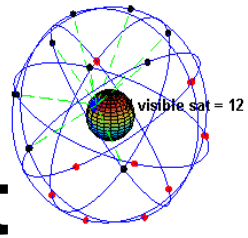
Workshop on Science Applications of GNSS in Developing Countries, Abdus Salam ICTP, Trieste, Italy, 11-27 April 2012



Phone call to Abu Qaqa gave Terrorist Kabiru Sokoto away

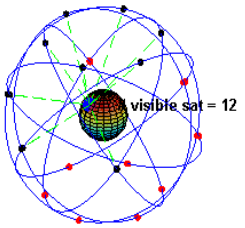
- The escapee Boko Haram's Christmas bomber, Kabiru Sokoto was re-arrested by the Nigerian Secret Police gave himself away when he called their spokesman, Abu Qaqa.
- Mallam Kabiru Sokoto not been aware that the spokesman of the Islamic terror group, boko haram, Abu Qaqa have been arrested, called Qaqa while he was in custody.
- The secret police with their improved **technology tracked him through GPS of his mobile down** to Mutum-Biu, in Gassol LGA Area of Taraba, where he was hiding inside a wardrobe
- Was re-arrested at about 4:00am on on 10th February 2012

http://www.naijaurban.com/phone-call-to-abu-qaqa-gave-kabiru-sokoto-.

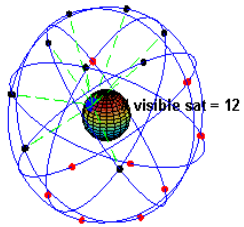


Ghana: Land Administration Project

- Ghana is adopting GNSS and GPS technology
- Govt of Ghana is bidding to support the implementation of the Land Administration Project (LAP)
- LAP involves establishing an acceptable geodetic reference frame for Ghana.
- A main objective for this is to recompute, adjust, and densify the existing national geodetic reference network
- The primary goal is to support surveying and national land information systems (LIS)



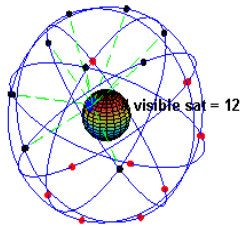
INTERNATIONAL PROGRAMMES



AfricaArray

- Launched in July 2004
- *AfricaArray* mission: To create new geoscientific research and training programmes and rebuild existing ones in Africa with Africans and for Africans
- While the long-term vision is to support training in many geoscience fields
- development of new geophysical training programmes and expanded support of existing ones
- promotion of geophysical research; and design and establishment of a network of geophysical observatories

http://www.africaarray.psu.edu



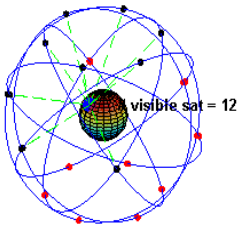
AfricaArray: partners.

- *AfricaArray* grew out of a partnership of three organizations viz:
- University of the Witwatersrand (Johannesburg, South Africa)
- Council for Geoscience, formerly the South African Geological Survey (Pretoria, South Africa)
- Pennsylvania State University (University Park, PA, USA).

Council for Geoscience

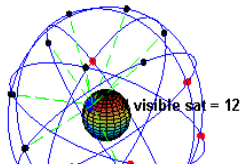
http://www.africaarray.psu.edu

AfricaArray: Operations



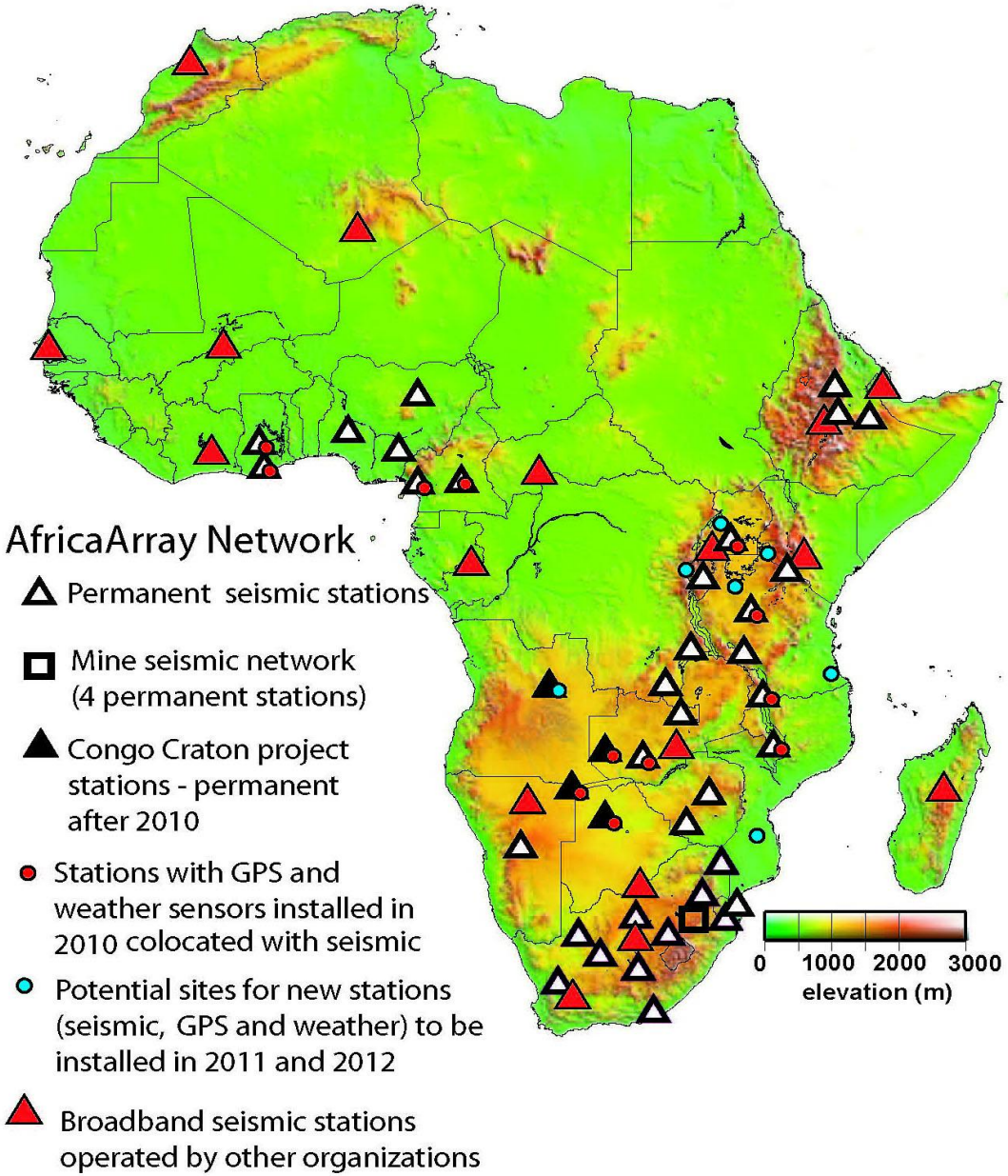
- A network of shared scientific observatories across Africa linked through common instrumentation, data access, and operation
- Data from the observatories provide the underpinning for much of the science supported by *AfricaArray.* Some of the observatories are permanent, while others are installed and operated on a temporary basis
- The first phase of *AfricaArray* (2005-2007) established a network of 20 to 30 permanent observatories spanning much of southern and eastern Africa
- the second phase of *AfricaArray* (2008-2010), the network of permanent observatories was expanded into other parts of Africa,

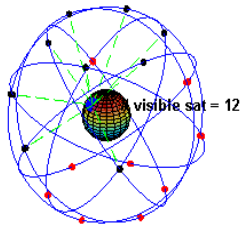
AfricaArray stations



- starting in August, 2010, many of the observatories are being equipped with GPS receivers and automated weather stations.

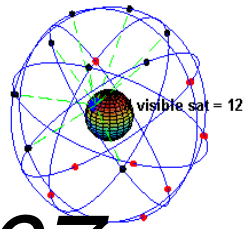
- data are archived at the UNAVCO Data Management Facility





ICTP-BC GNSS in Africa

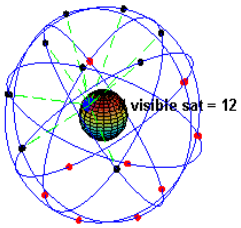
- Partnership between Boston College, USA and Abdus Salam ICTP, Trieste, Italy.
- Series of 3-weeks annual Workshops
- Deployment of GPS stations in Africa
- Over 100 African scientists have been trained at ICTP
- Leading experts in GNSS teach at the annual workshops
- A training model



International Heliophysical Year 2007 (IHY, 2005-2009) & International Space Weather Initiative (ISWI, 2010-2012).

www.ihy2007.org

http://www.spaceweather-eg.org/iswi/

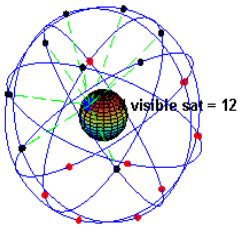


IHY/ISWI

- Initiated in 1990, the United Nations Basic Space Science Initiative (UNBSSI) has led to the establishment of planetariums, astronomical telescope facilities, and IHY/ISWI instrument arrays worldwide, particularly in developing countries
- ISWI is envisioned to continue the tradition of IHY in the worldwide deployment of space weather monitoring instrument arrays
- To date, ISWI contributes to the observation of space weather through 14 instrument arrays with close to 1000 operating instruments in 97 countries

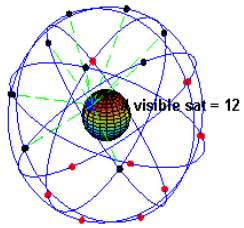
www.ihy2007.org

http://www.spaceweather-eg.org/iswi/



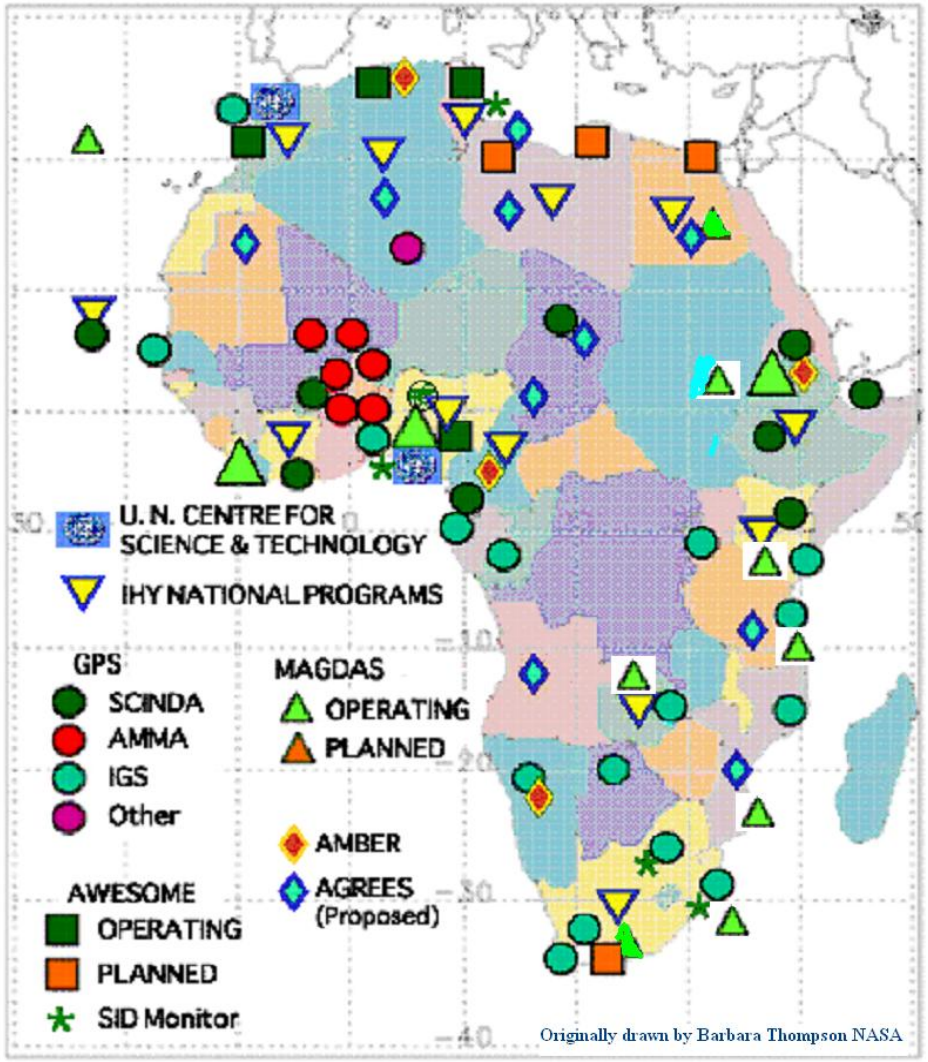
IHY/ISWI ANCHORS

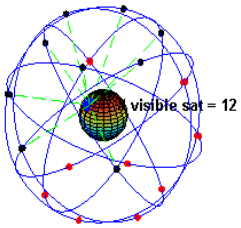
- United Nations office for Outer Space Affairs UNOOSA, Vienna, Austria
- International Committee on Global Navigation Satellite Systems (ICG)
- NASA



IHY/ISWI

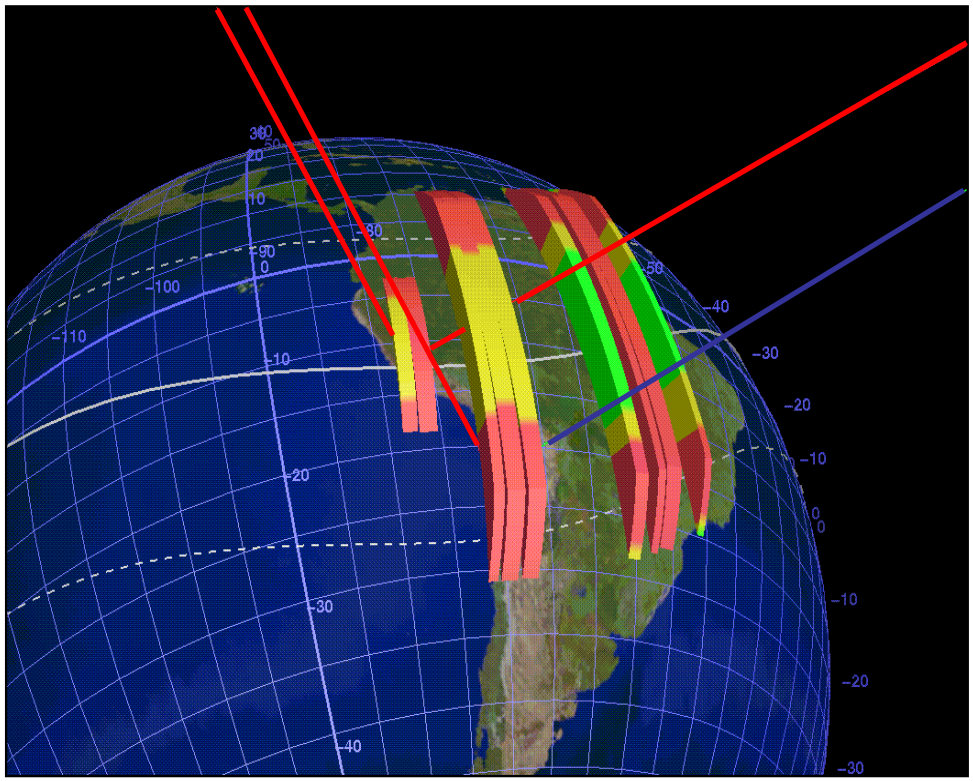
- increase of stations that can serve as CORS in Africa in recent time
- IHY/ISWI activity has increased the potential CORS in Africa by more than 14





SCINTILLATION NETWORK DECISION AID (SCINDA)

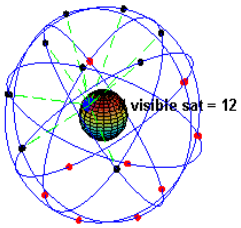
A regional nowcasting system to support research and users of space-based communication and navigation systems

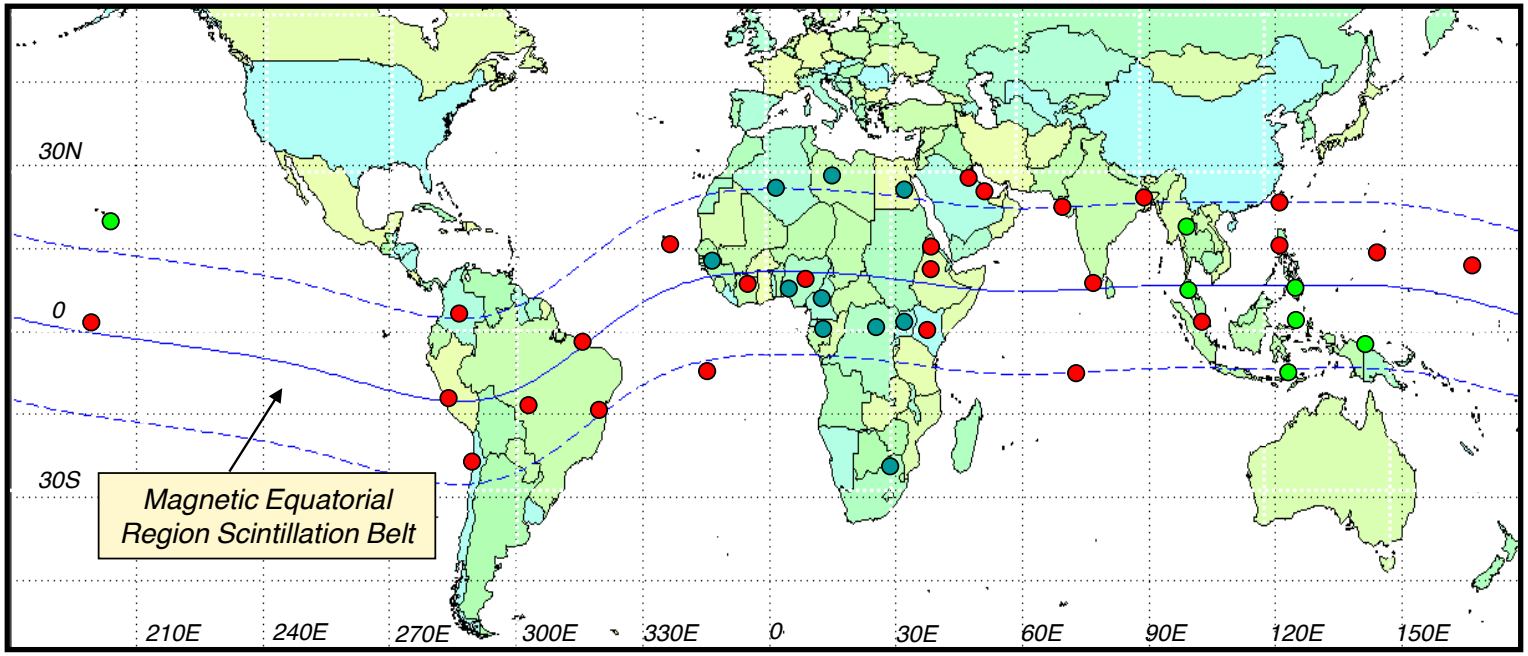


Real-time to 2-Hr Forecasts

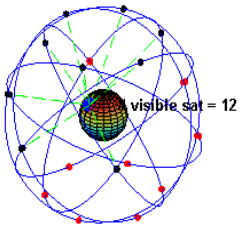
- *Ground-based sensor network*
  - *Passive UHF / L-band /GPS scintillation receivers*
  - *Measures scintillation intensity, eastward drift velocity, and TEC*
  - *Automated real-time data retrieval via internet*
- *Data supports research and space weather users*
  - *Understand on-set, evolution and dynamics of large-scale ionospheric disturbances*
  - *Empirical model provides simplified visualizations of scintillation regions in real-time*

SCINDA Ground Stations

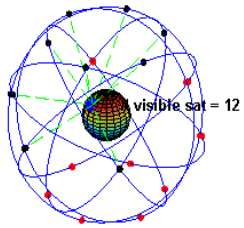




Existing Sites UN IHY Sites Other/collaboration



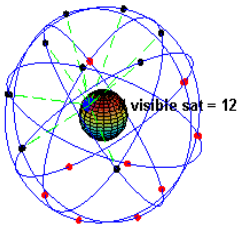
SCINDA facility at Akure, Nigeria



Mega-solution to Regional mega-problems

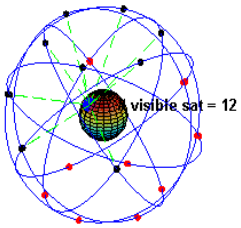
Capabilities of GNSS products

- producing good governance
- inhibits corruption
- create job opportunities
- advance wealth creation
- promote quality of living
- Secure society
- provide platform for sustainable manpower and economic development



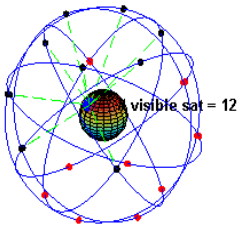
Recommendations

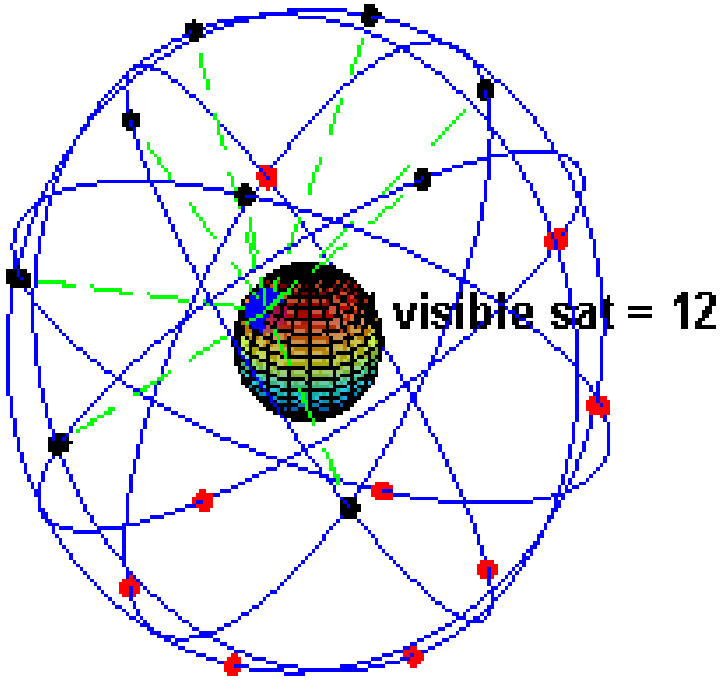
- Intensify complimentary efforts at densifying the GNSS ground infrastructures
- African leaders need to develop political will
- Development of Pre-requisite physical infrastructures for GNSS facilities



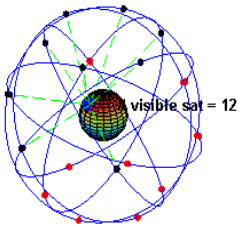
Summary

- GNSS is being used for ionospheric and space weather research in Africa
- Socio-economic application of GNSS is increasing in Africa
- International GNSS programs with impact in Africa include those of:
  - ✓ AFREF
  - ✓ National Reference Frames
  - ✓ IGS
  - ✓ IHY/ISWI
  - ✓ AfricaArray
  - ✓ ICTP-BC joint GNSS program
- GNSS has enormous capability to provide platform for sustainable manpower and socio-economic development
- **GNSS is still being under-explored in developing Africa!**





Thank You



Acknowledgements

- Boston College
- Abdus Salam ICTP