AFRICAN DUAL FREQUENCY GPS NETWORK

Space Weather

GNSS

Low Earth Orbital Satellite

Christine Amory-Mazaudier ¹ and Rolland Fleury ²

1. LPP/Polytechnique/UPMC/CNRS
Christine.amory@lpp.polytechnique.fr

2. Telecom-Bretagne- LAB/STICC
Rolland.fleury@telecom-bretagne.eu
Introduction

UNBSSI [1990-2012]
United Nations Basic Space Science Initiative
• IHY: International heliophysical Year [2005-2009]
  http://www.ihy2007.org
• ISWI : International Space Weather Initiative [2010-2012]
  http://www.iswi-secretariat.org

Scientific Associations
IAGA, SCOSTEP, COSPAR
• **Space weather**

is the physical and phenomenological state of natural space environments. The associated discipline aims, through observation, monitoring, analysis and modelling, at understanding and predicting the state of the sun, the interplanetary and planetary environments, and the solar and non-solar driven perturbations that affect them; and also at forecasting and nowcasting the possible impacts on biological and technological systems

• J. Lilenstein
SPACE WEATHER

- Effects on terrestrial systems
Necessity to train students in the physics of the Sun Earth System: Systemic approach is essential

Coronal Mass Ejection: Billions tons of matter
SCIENCE IS WITHOUT FRONTIERS
We have to share data and knowledge
Schools organized in 2013 in AFRICA ISWI

• Nigeria -> February 2013
  • organized by NASDR and Bells University

• Algeria -> May 2013
  • Organized by the University of Science and Technology Harri Boumedienne and GIRGEA

• Côte d’Ivoire -> September 2013
  • Organized by University Houphet Boigny and MAGDAS team (Japan)

• Kenya -> October 2013
  • Organized by SCOSTEP and Kenya
GNSS
• GNSS system in 2013
• Research and applications

- GPS IIR
- GLONASS K1
- GIOVE-B
- BEIDOU
The satellite signal is strongly modified by ionosphere and troposphere.

**Layers:***

- **> 600 km** EXOSPHERE
  - Few collisions, Particles follow ballistic orbit

- **80-600 km** THERMOSPHERE
  - Ionization by the solar X-EUV radiation

- **30-80 km** MESOSPHERE
  - Absorption of the radiation UV by the ozone layer

- **11-30 km** STRATOSPHERE
  - Turbulence

- **0-11 km** TROPOSPHERE
  - Meteorological phenomena

**TEC**: Total Electron Content

**Earth’s Environment**
Effects of the ionosphere on propagation (TEC)

– Reduction of the phase path length (with respect to propagation in vacuum)

\[ \Delta P_\varphi = P_\varphi - L = \int_L (n - 1) \, ds \]

\[ n = 1 - a \frac{N_e}{f^2} \]

\[ \Delta P_\varphi = -a \frac{N_e}{f^2} \int_L N_e \, ds \]

\[ \Delta P_\varphi = -a \frac{N_T}{f^2} \]

Phase path length: Distance that a wave needs to propagate in a vacuum to have the same total phase shift (\( \varphi \))

– Total Electron Content (TEC)

\[ N_T = \int_L N_e \, dl \]

1 TECU = \( 10^{16} \) electron/m\(^2\)

From ENST/Télécom
Ionospheric propagation

Scintillations
Fluctuations of the signal due to the inhomogeneity of the medium

Scintillations of amplitude

Scintillations of phase

scales: ± 3 rad.

From ENST/Télécom
GPS networks for Space weather studies

- GPS networks
  Tool: dual frequency, Rinex format to store data
  IHY, ISWI networks
  permanent networks
Antenne Antenna

University Building

Station GPS of KOUDOUGOU/ AFRICA Available on the web

GPS receiver and data acquisition
Provided by T. Tsugawa (NCIT, JAPAN)

**JAPAN**
~1,200 receivers

**N. America**
~2,700 receivers

**Europe**
~1,200 receivers

Detrended TEC Map (60-min Window)
2013

GPS available on the web and private networks

Some other networks are in Algeria, Egypt, Burkina Faso etc…
Recommendations made at Quito during the ISWI meeting in 2012

It is important to increase:

- SCINDA GPS network, even the data are not yet share on the web => constitution of a data base for scintillation

- National networks of GPS with all the users of GPS in the different fields of research
  - Ionosphere, Atmosphere, Geography, Geodesy etc...
  - GPS Networks available on the Web Contact UNAVCO

Figure adopted from Paznokhov’s ICTP lecture
Equatorial Fountain
map of TEC in East Africa is now possible

Amory-Mazaudier et Fleury, 2013
In 2005 UN IHY meeting: there was no map of TEC for AFRICA

**Asian sector**

**American sector**

*Fig. 12. Maps of total electron content (TEC) in the Asian sector (top panel) and the American sector (bottom panel) during the storm of 24 August 2005. Two vertical dashed lines underline the sudden storm commencement and the beginning of the recovery phase of the storm.*
VTEC Variations

- Solar and Seasonal variations on VTEC

Station NKLG in Cameroun
VTEC Variations

- Maps of ROTI (Rate of TEC Index)
- TEC is calculated with phase measurements
- with a GPS network above Africa (position with blue square)
- Between 18 UT and 05TU, In red, Roti index > 1.5 TEC/mn on IPP points
WE HAVE TO INCREASE THE NUMBER OF GNSS RECEIVERS OVER AFRICA AND TO SHARE THE DATA
Equatorial Low Orbital Satellite
C/NOFS Mission

- **C/NOFS Mission**
- Equatorial LEO satellite to nowcast and forecast ionospheric scintillation continuously
- **Orbit**
  - 13 deg inclinaison
  - Altitude between 400 and 850 km
C/NOFS Mission data are available on the web (FREE)

- Mission components: 6 sensors
  - GPS receiver
  - STEC in Occultation Receiver for ionospheric profile
  - Electric Field instrument
    Vecteur electric and magnetic fields
  - RF beacon
    Scintillation and STEC on ground
  - Planar langmuir Probe (PLP)
    Ion density and electron temperature
  - Ion Velocity Meter (IVM)
    Ion density and ion temperature
  - Neutral Wind Meter (NWM)
    Vector neutral wind velocity

From de La Beaujardiere et al, 2012
C/NOFS Mission

- Sample from PLP above Africa
C/NOFS Mission

- Ionospheric structures above Africa before midnight

Dawn depletion

Many plasma depletions above 450 km
Low Equatorial Orbital Satellite

• Low Equatorial Orbital satellite provide in situ measurements of the equatorial ionosphere. They are essential to progress in the knowledge of the low latitudes ionosphere.

• C/NOFS might be terminated in June 2013 (budget cuts)
• Bibliography:

