GNSS, SPACE WEATHER and CAPACITY BUILDING

Christine Amory-Mazaudier and GIRGEA TEAM
christine.amory@lpp.polytechnique.fr

Sorbonne Paris, UPMC Univ. Paris VI, LPP, Paris, France
T/ICT4D, Abdus Salam International Centre for Theoretical Physics /Staff, Trieste, Italy
• GPS → GNSS
• Space Weather
• Capacity Building
• Last decade: mainly GPS -> Now -> GNSS
• Research and applications
GPS: the most larger network of scientific ground based measurements

**JAPAN**
~1,200 receivers

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

**Europe**
~1,200 receivers

Detrended TEC Map (60-min Window)

Provided by T. Tsugawa (NCIT, JAPAN)
Increase of GNSS stations in Africa ~50 to ~150 2010 to 2015 Mainly due to GEODESY

Many other GPS networks
Algeria (~60), Burkina Faso (~10), Egypt (~10), Morocco (~25) Rwanda (~10), South Africa (~60) DRC (~15) > 200 => Work of AGS

Necessity TO SHARE
Space Weather : effects on GNSS
Integration of Physical processes in the Sun Earth system / effects on new technologies

J-L Lanzerotti
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
  Water Vapour content

**TEC** : Total Electron Content
Ionospheric propagation

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

Scintillations of amplitude

Scintillations of phase

Echelles: ± 3 rad.
FROM the SUN to the EARTH

CME Departure

CME transport

Magnetosphere

NECESSITY TO TRAIN IN SPACE WEATHER ALL OVER THE WORLD
⇒ Merging of different scientific disciplines
⇒ Connection between Research and Applications

SOHO
Coronal Mass Ejection
Billions tons of matter ejected

Auroral Zone
At equatorial latitudes: TEC variations on St Patrick’s day storm
Physics of the connections between auroral and equatorial regions

Nava et al., JGR, 2016

At the Equator: necessity to deploy scientific tools
Capacity building, Space Weather and use of GNSS
Training and Research
Training by scientists: scientific research
School for all scientists using GPS

Basic GPS observables

- Code (pseudo-range):
  \[ P_i = \rho + c \cdot (dt - dT) + d_{\text{iono}} + d_{\text{tropo}} + \nu_P \]

- Phase (differenced wrt phase of local oscillator)
  \[ \Phi_i = \rho + c \cdot (dt - dT) + \lambda \cdot N + d_{\text{iono}} + d_{\text{tropo}} + \nu_\Phi \]

- Distance Receiver-satellite
- Clock offsets \( dt = \text{receiver} \), \( dT = \text{satellite} \)
- Integer phase ambiguity number
- Ionospheric delay
- Tropospheric delay
- Noise errors

O. Bock, 30/07/2010
Space Weather Summer School
Egypt, Sept. 2010
PHD in AFRICA

ABIDJAN -2008

DAKAR –2009

KINSHASA -2016

OUAGADOUGOU-2012
Scientific projects in the framework of UNBSSI
United Nations Basic Space Science Initiative

IHY: International Heliophysical Year /2007–2009/
=> Friendly framework ISWI

Methodology
Schools
Distribution of tools and constitution of data base
PhD students
Positions at University
Curricula in Universities
Network ISWI: http://www.iswi-secretariat.org
84 countries
Results of the GIRGEA network 24 countries of ISWI network

9 PhD /15 years
Côte d’Ivoire : 5
Spain :1
France : 3
Senegal : 1

33 [27+6] PhD / 10 years
Algeria : 2
Benin: 1
Burkina Faso: 7
Cameroon: 2
Côte d’Ivoire : 6
Egypt: 3
India : 1
Morocco: 1
RDC: 3
Senegal : 1
Vietnam: 6

Numbers of PhDs from 1992 to 2016 for 24 countries of the GIRGEA network.

Years: 1992-1994 IEEY
2007 IHY
2010 ISWI

24 countries of the ISWI network.
Results of the GIRGEA network 24 countries of ISWI network

1 observatory in Côte d’Ivoire with expensive tools

Networks of Cheap instruments
GPS
Magnetometers
Etc...

2007

5 countries
84 countries

2007

Schools
Physics
GPS
PERMANENT : TRAINING BY INTERNATIONAL ORGANIZATIONS and RESEARCH NETWORKS

T/ICT4D Abdus Salam ICTP + Boston College essentially: inospheric effects on GNSS/Space weather, several schools each year at Trieste (20-24 May 2016)

Master of GNSS in the Regional Centers (affiliated to UN), by the past essentially on global positioning and now Space Weather, Master (Web) in Plasma Physics,

Permanent project of SCOSTEP and UN: 1 event each year [school or workshop on Space Weather] (7-17 November 2016 in India)

A school on Space Weather, each 2 year organized in North or West Africa by scientists with the CRASTE-LF (12-28 October 2017)
- African countries with a coordinator ISWI (20 among 82 = 24%)
- Countries with tool and no coordinator ISWI (13)
- Training at university (12)  
  UN / Regional Schools

Success Story
Conclusion

• There are 54 countries in AFRICA:
  • only 33 are concerned by ISWI,
  • only 12 are developing curricula at University

=> we have to pursue capacity building in AFRICA in order to reach all the countries

• Interest of connection between research and application:
  to predict the impact of solar events on Earth’s environment and perform GNSS/EGNOS