

ISWI Workshop, Ecuador / Quito 8-12 October 2012

# Achievements IHY-ISWI

preliminary talk -> next talk in Ethiopia

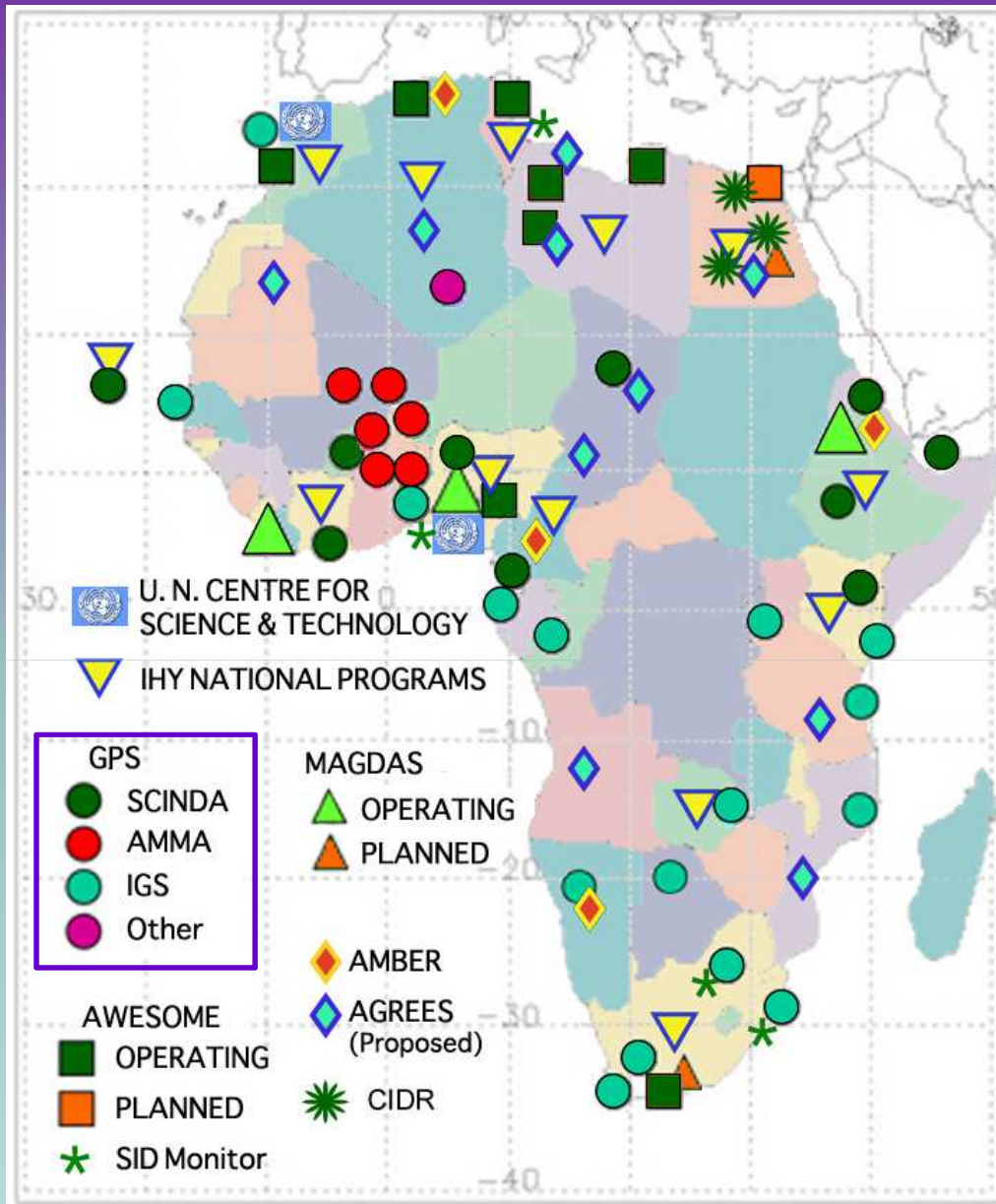


Christine Amory-Mazaudier  
[christine.amory@lpp.polytechnique.fr](mailto:christine.amory@lpp.polytechnique.fr)



# Outlines

- \*Deployment of tools (GPS over Africa)**
- \*Organization of schools**
- \*PhD students and scientific Results**
- \*Media and Politics**
- \*Outreach**



update on  
[iswi-secretariat.org](http://iswi-secretariat.org)

Figure from B Thompson 2007

# - GPS networks

Tool : dual frequency,  
Rinex format to store data  
IHY, ISWI networks  
permanent networks

GSV GPS Silicon Valley

June 9, 2004

Gps

IONOSPHERIC

SCINTILLATION and TEC

MONITOR

GPS Silicon Valley is pleased to offer the GSV 4004B GPS Ionospheric Scintillation and TEC Monitor (GISTM) receiver. This receiver, a NovAtel Euro-3M dual-frequency receiver with special firmware, comprises the major component of a GPS signal monitor, specifically configured to measure amplitude and phase scintillation from the L1 frequency GPS signals, and ionospheric TEC from the L1 and L2 frequency GPS signals. This scintillation and TEC monitoring receiver is packaged in a NovAtel Euro3M - 3M style housing with a low phase noise oscillator, and provides true amplitude, single frequency carrier phase measurements and TEC measurements from up to 11 GPS satellites in view. It also tracks one SBAS (WAAS, EGNOS or MSAS) satellite, providing L1 measurements and scintillation data (but no TEC). The unit comes with complete software that allows the automatic measurement and computation of all the major scintillation parameters and TEC. A variety of antennas, with or without choke rings and cables, are offered as options.



GSV 4004B GPS IONOSPHERIC SCINTILLATION AND TEC MONITOR AND  
OPTIONAL GPS702 ANTENNA

#### GPS IONOSPHERIC SCINTILLATION AND TEC MONITOR (GISTM) FEATURES:

- Tracks and reports scintillation and TEC measurements from up to 11 GPS satellites and one SBAS GEO in view (no TEC on SBAS GEO).
- A 25 Hz raw signal intensity noise bandwidth and a 15 Hz phase noise bandwidth insures that all the spectral components of both amplitude and phase scintillations are measured. These data and amplitude data are sampled at a 50 Hz rate.
- Single frequency (L1) satellite carrier phase is computed against a stable ovenized crystal oscillator (OCXO) to insure that all phase scintillation effects are recorded, not merely the  $1/f$  refractive component measured by dual-frequency differential systems.
- Software is included in the GISTM to automatically compute and log the amplitude scintillation index,  $S_4$ , and phase scintillation index,  $\sigma_\phi$ , computed over 1, 3, 10, 30 and 60 seconds. In addition, TEC and TEC phase are

1131 Seena Avenue, Los Altos, CA 94024, USA  
ajvd@aol.com

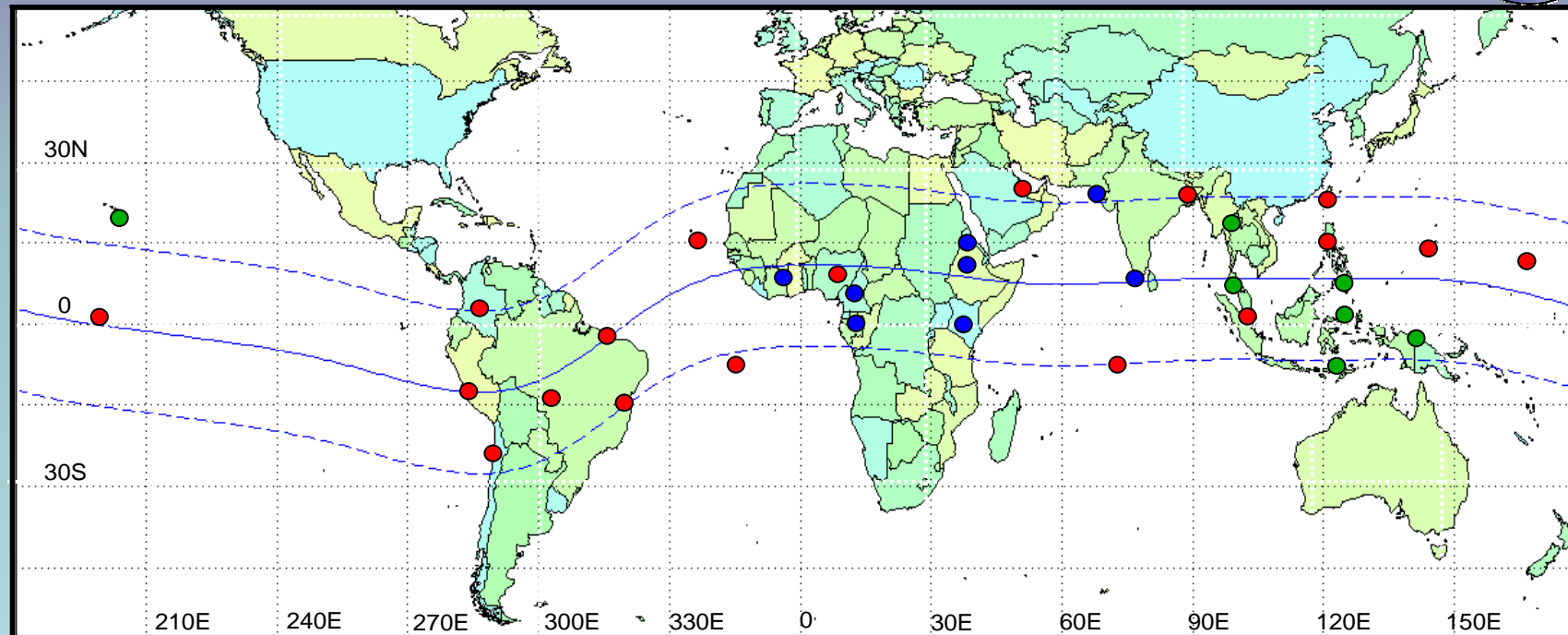
1-650-961-8250  
1-650-961-7461 (FAX)

IHY GPS NETWORKS in 2007

Now 15 GPS over Africa see [iswi-secretariat.org](http://iswi-secretariat.org)

SCINDA -> Scintillation Network Decision Aid

[www.fas.org/spp/military/program/nssrm/initiatives/scinda.htm](http://www.fas.org/spp/military/program/nssrm/initiatives/scinda.htm)



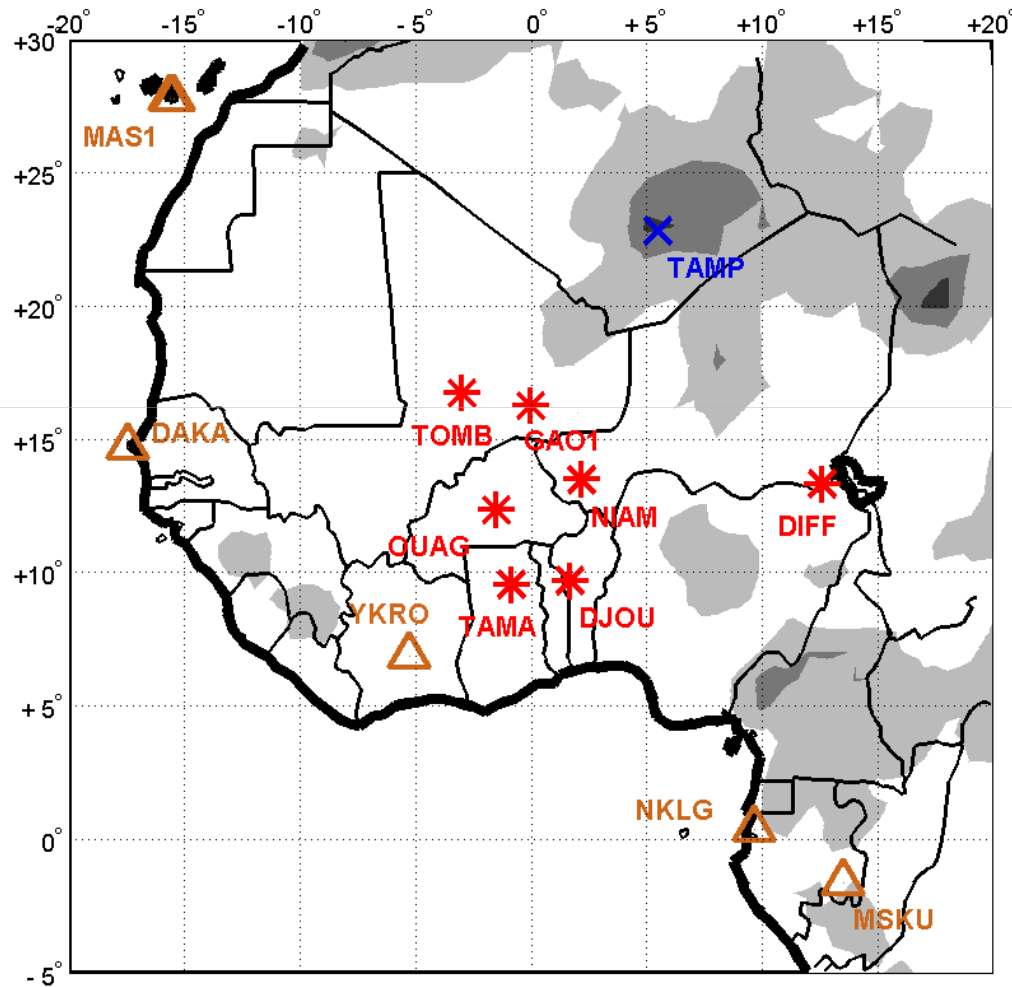
● Existing Sites

● UN IHY Sites

● Other/collaboration

**AMMA network -> Olivier BOCK**  
Niamey, Djougou, Gao since June 2005  
Tamale Tombouctou since April 2006  
Ougadougou since June 2006

Tamanrasset -> protocole with the CRAAG



**All the AMMA data  
are now in IGS  
Free for evreybody**

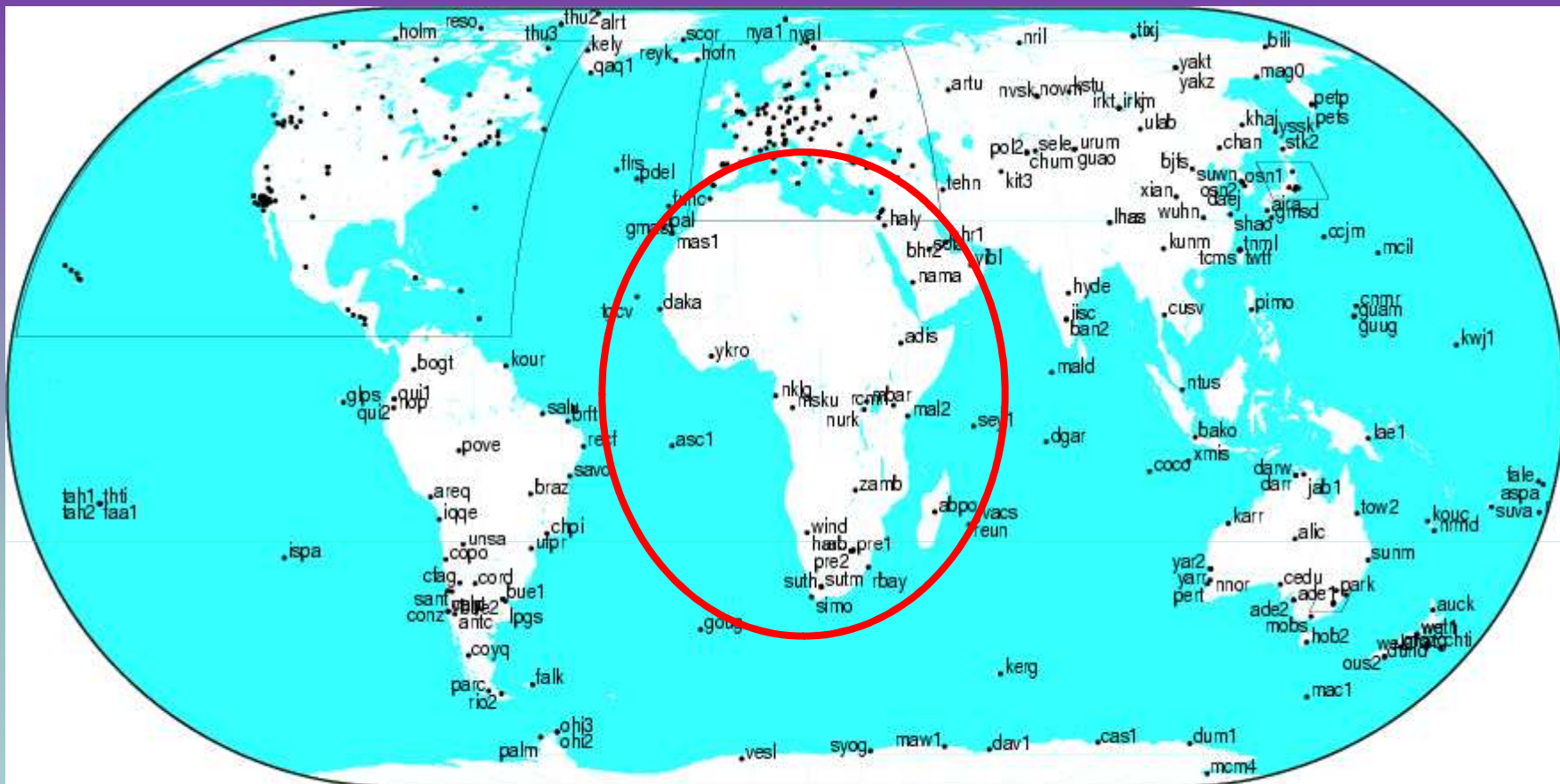


Contact  
**Olivier.Bock@aero.jussieu.fr**

<http://www.amma-international.org>



## IGS network 2010 -> World



GMT 2009 May 24 16:48:21

IGS network - > free on the web <http://www.unavco.org/>

**Africa ~ 20 permanent sites**

Click

- data
- permanent stations
- Africa

- **GPS / on the web for all**

- **IGS**

- <http://sopac.ucsd.edu>

- <http://cddis.gsfc.nasa.gov> or  
<http://igs.ensg.ign.fr>

- **NOAA et UNAVCO**

- <http://www.ngs.noaa.gov/CORS>

- <http://www.unvaco.org>





**University Building**



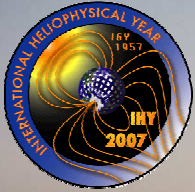
**ENST GPS**

**Antenne  
Antenna**

**Station GPS of KOUDOUGOU/ AFRICA  
Available on the web**

**GPS receiver and data acquisition**





GPS dual

frequency antenna

SCINDA

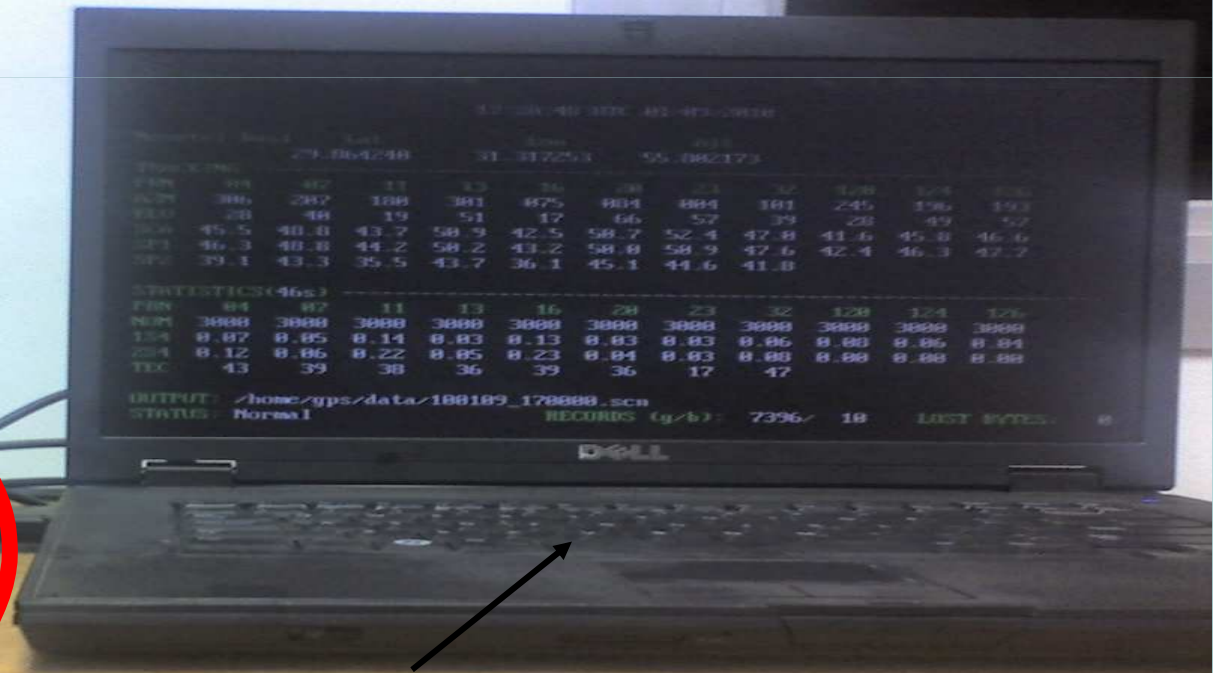


Helwan University

1 paper in JGR with SCINDA and MAGDAS stations  
Shimeis et al., 2012



GPS receiver



computer running Linux

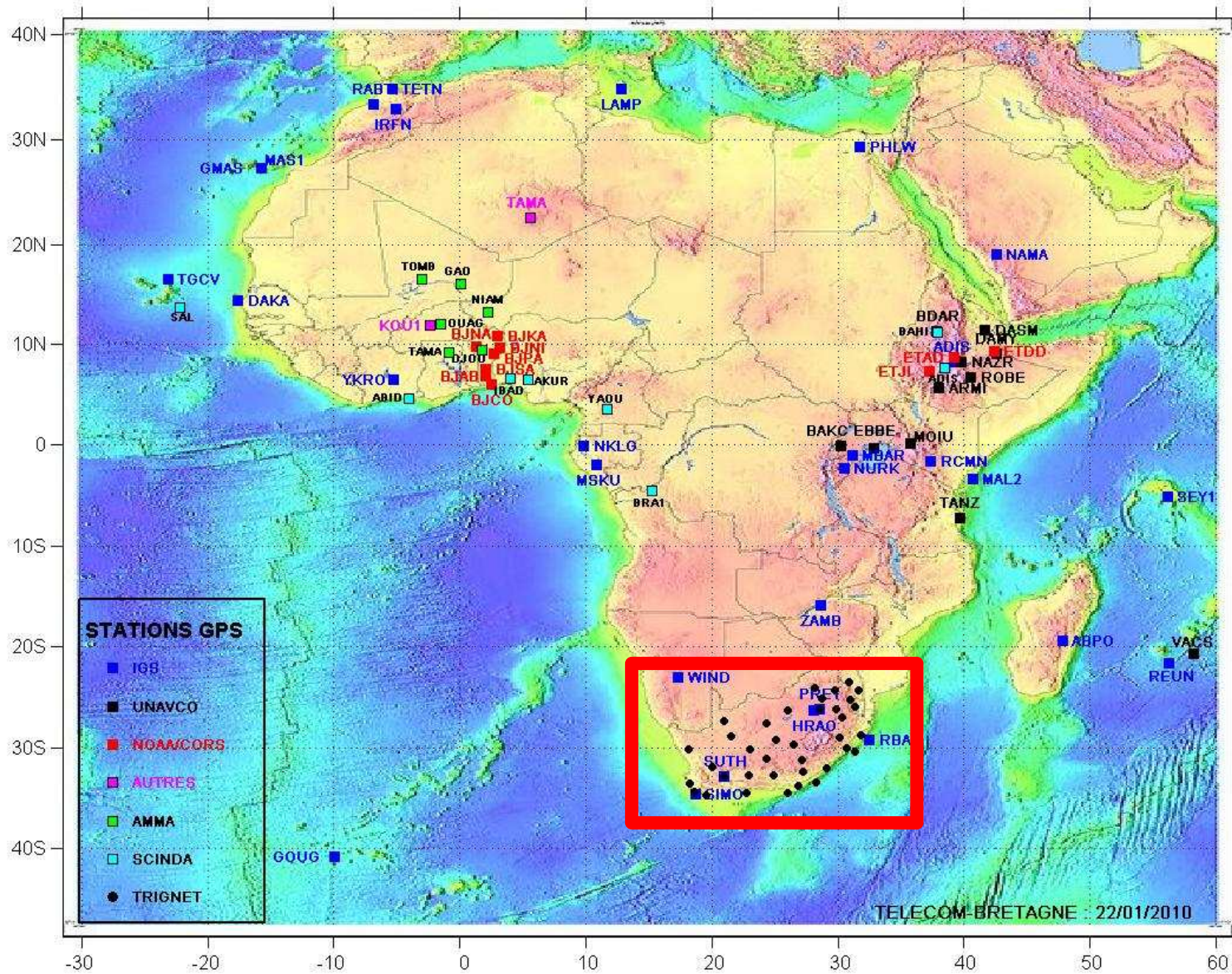
```

17:28:40.000 01-01-2008
Station: Helwan  Station ID: 178888
Easting: 29.064248  Northing: 31.317253  Height: 55.082173
PRN  04  07  11  13  16  28  23  32  128  124  125
AZ  306  287  188  301  475  484  484  181  245  176  193
ELEV  28  48  19  51  17  56  57  39  28  49  57
SNR  45.5  40.8  43.7  58.9  42.5  58.7  52.4  47.8  41.6  45.8  46.6
C/N0  46.3  40.8  44.2  58.2  43.2  58.8  58.9  47.6  42.4  46.3  47.7
CPS  39.1  43.3  35.5  43.7  36.1  45.1  44.6  41.8

STATISTICS (46s)
PRN  04  07  11  13  16  28  23  32  128  124  125
NORM  3000  3000  3000  3000  3000  3000  3000  3000  3000  3000  3000
RMS  0.87  0.85  0.14  0.83  0.13  0.83  0.83  0.86  0.88  0.86  0.84
DOP  0.12  0.86  0.22  0.85  0.23  0.84  0.83  0.88  0.88  0.88  0.88
DOPX  43  39  38  36  39  36  17  47

```

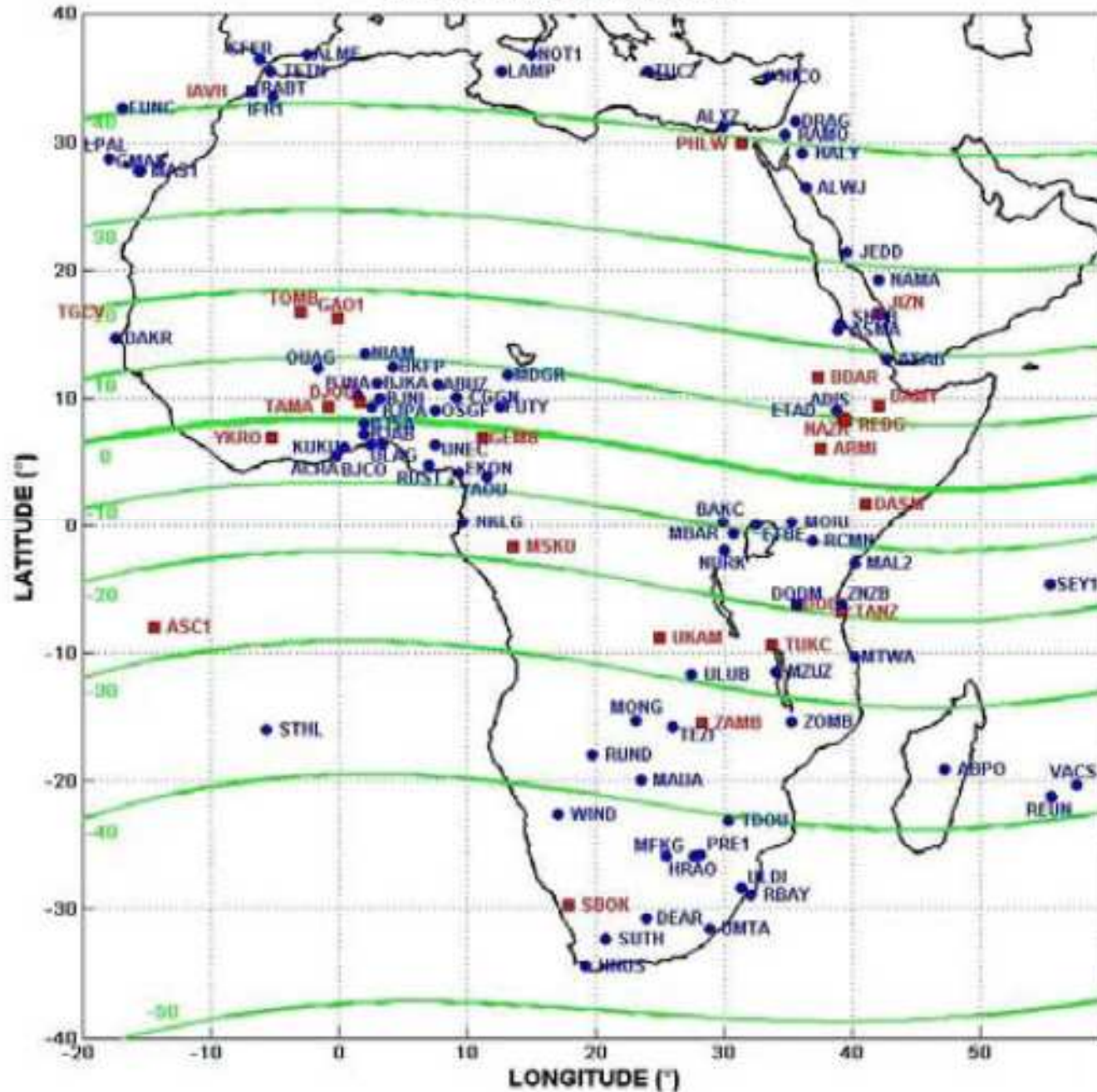




GPS in 2010 all networks



GPS MEASUREMENTS - 01/2012



**GPS in 2012**  
GPS on the Web

**SCINDA + 15**  
**South Africa + 50**  
**Egypte + 9**  
**Algeria + 30**  
**Morocco + ~ 5**  
**Not on this map**

**In red GPS since 2012**

# We have to continue to increase the number of GPS In Africa

## 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  
<http://www.unvaco.org>

- **SCHOOLS**





## Schools organized by GIRGEA in the framework of IEEY, IHY, ISWI programs

### **GPS, GIS, INTERNET, DATA BASE, NEW TECHNOLOGIES AND SPACE WEATHER : INTRODUCTION**

**Congo 2009, Egypt 2010, RDC 2011, Burkina Faso 2014**

**Different communities : Physic, Geography, Agronomy, Mathematics  
and ICT**

### **SPACE WEATHER : Physic of the Sun Earth System**

**Ivory Coast 1995, Morocco 2011, Algeria 2013**

**Physicists level M2**

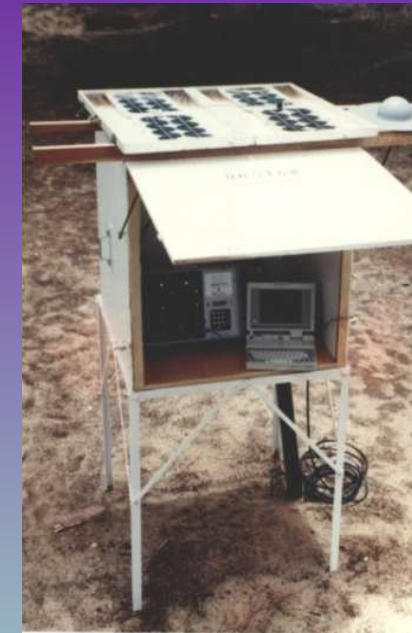
### **GPS DATA PROCESSING FOR IONOSPHERIC STUDIES**

**France 2011, France 2012, probably France 2013**

**PhD students using GPS data (few students : 5 and 2 professors  
during 5 days)**

School in Paris in 1992 before the IEEY project  
2 weeks on Physics processes and 4 weeks on the tools

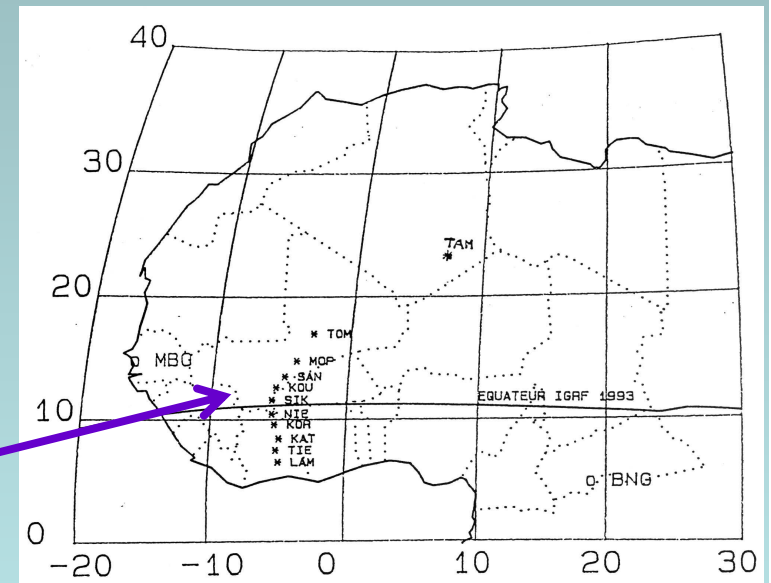
School in Ivory Coast October 1995 [IEEY]



Magneto telluric station

Countries involved in the African sector  
Algeria, Benin, Burkina Faso, Côte d'Ivoire  
Ethiopia, Nigeria, Senegal  
England, France, Spain, USA

Tools (as that time no GPS were used)  
Magnetometers with telluric measurements  
Ionosondes, Interferometer, HF radar ...



- **GPS – IHY and ISWI**

**Useful for different scientific topics**

*- Geodesy, Geography, Atmospheric studies, ionospheric studies etc...*

**^Many applications**

**- navigation, agriculture etc...**

**^easy to maintain, not very expensive**

# Basic GPS observables

- Code (pseudo-range):

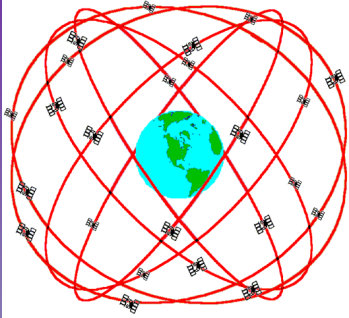
$$P_i = \rho + c \cdot (dt - dT) + d_{iono} + d_{tropo} + v_P$$

- Phase (differenced wrt phase of local oscillator)

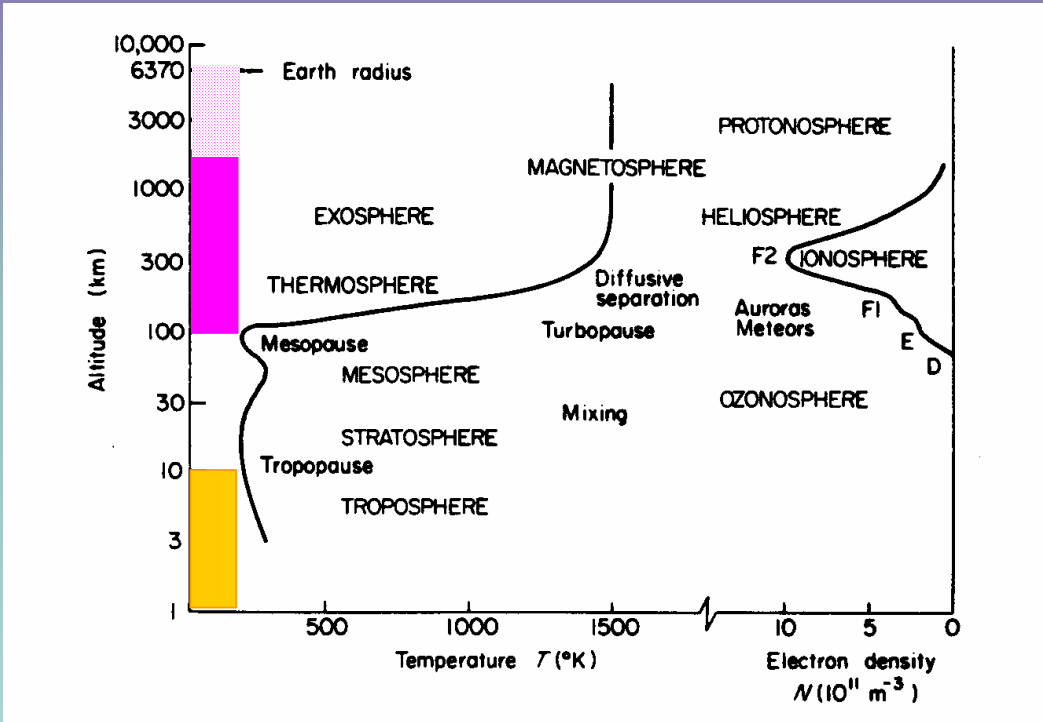
$$\Phi_i = \rho + c \cdot (dt - dT) + \lambda \cdot N - d_{iono} + d_{tropo} + v_\Phi$$

The diagram illustrates the components of the GPS phase observable equation. Each term in the equation is enclosed in a blue box, and a blue arrow points from the box to its corresponding physical meaning:

- $\rho$ : Distance Receiver-satellite
- $c \cdot (dt - dT)$ : Clock offsets (dt = receiver, dT = satellite)
- $\lambda \cdot N$ : Integer phase ambiguity number
- $-d_{iono}$ : Ionospheric delay
- $+d_{tropo}$ : Tropospheric delay
- $v_\Phi$ : Noise errors



# Satellites



# Earth's Environment

## LAYERS

**> 600 km EXOSPHERE**  
 few collisions, Particles follow ballistic orbit

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

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

**11-30 km STRATOSPHERE**  
 Turbulence

**0-11 km TROPOSPHERE**  
 Meteorological phenomena

# Effects of the ionosphere on propagation (TEC)

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

$$\Delta P_\varphi = P_\varphi - L = \int_L (n - 1) ds$$

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

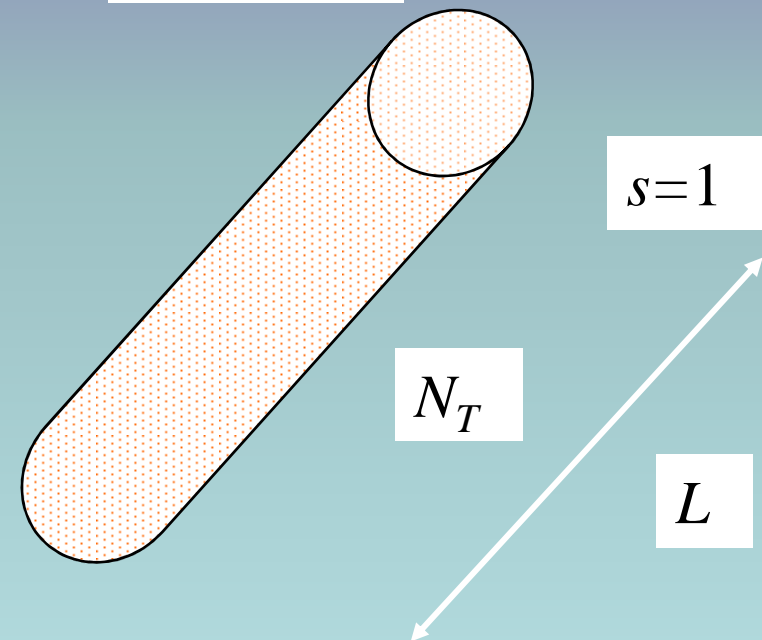
$$\Delta P_\varphi = -\frac{a}{f^2} \int_L N_e ds$$

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

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)

$$N_T = \int_L N_e dl$$



$$1 \text{ TECU} = 10^{16} \text{ electron/m}^2$$

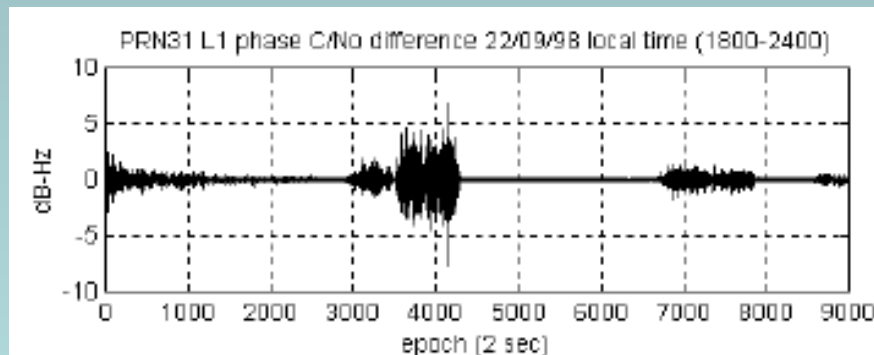


# Ionospheric propagation

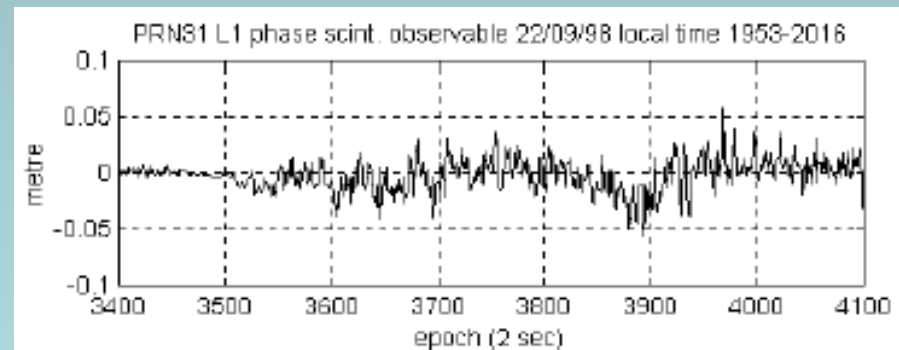
## Scintillations

Fluctuations of the signal dues to the inhomogeneity of the medium

### Scintillations of amplitude



### Scintillations of phase



Echelles :  $\pm 3$  rad.



**CONGO 2009 [IHY]**

**French spoken : 100%**



**English spoken : 100%**

**GPS, GIS, INTERNET,  
DATA BASE  
NEW TECHNOLOGIES  
SPACE WEATHER: introduction**

**ISWI letter Vol 2 n°75**



**EGYPT 2010[ISWI]**



# GPS, GIS, DATA BASE INTERNET, NEW TECHNOLOGIES INTRODUCTION TO SPACE WEATHER



**RDC: September 2011[ISWI]  
English spoken : 20%, French spoken :80%  
ISWI letter Vol n°91 – 90 participants – 3 countries**



# GPS, GIS, DATA BASE INTERNET, NEW TECHNOLOGIES INTRODUCTION TO SPACE WEATHER, RDC/2011

Lecture room of the ERAIFT



# GPS, GIS, DATA BASE INTERNET, NEW TECHNOLOGIES INTRODUCTION TO SPACE WEATHER RDC/2011

## Rooms for practical work



Room of OSFAC



Room of ERAIFT

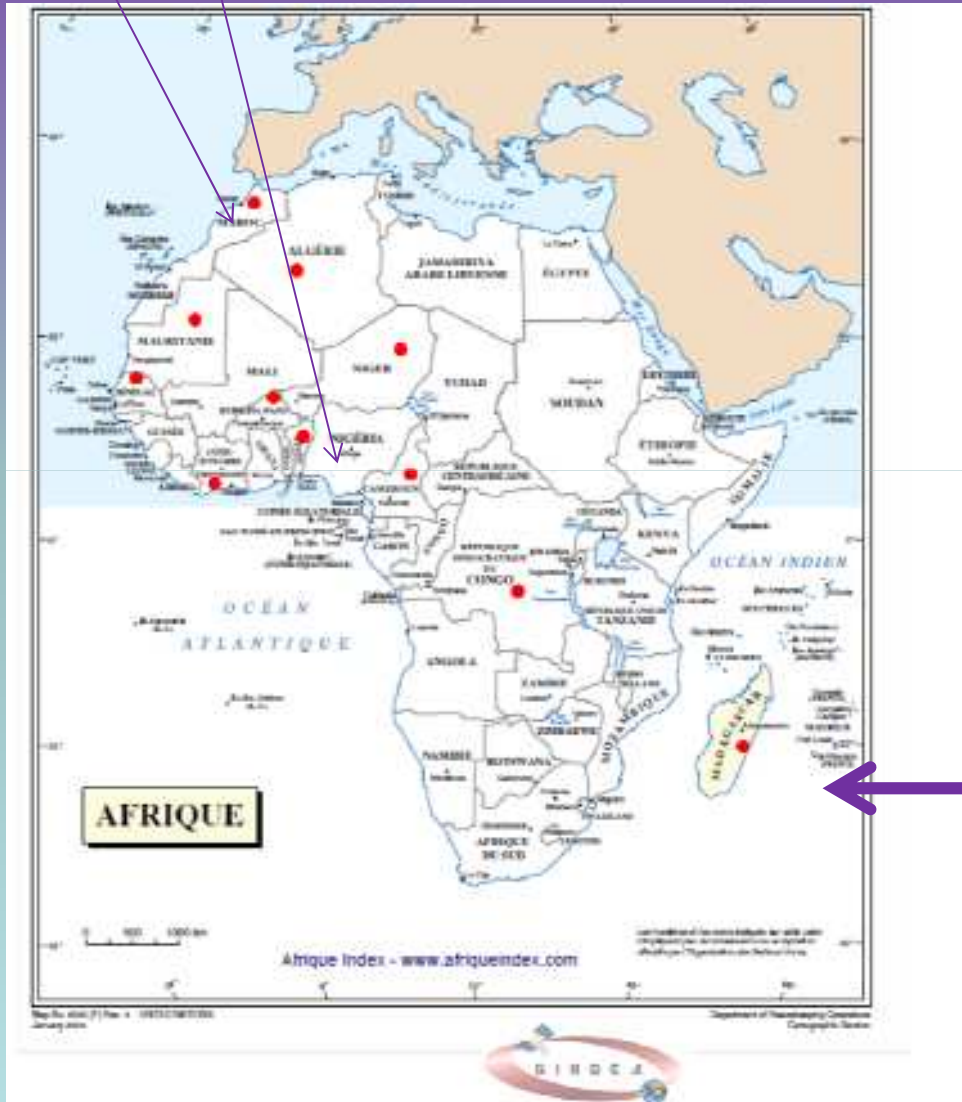






# Craste-LF

Vietnam 2003 and school in 2007[IHY]



ISWI letter Vol 4 n°75



Morocco / December 2011 [ISWI]  
28 participants from 11 countries



# UN school in Morocco -> French spoken training



## Computer room



# PhD and Results

**21 PhD in 9 different countries**

**(19 students / 2 students defended 2 PhD)**

**17 students are doing resresearch in their country  
(10 new positions)**

**Papers published in International journals are required to obtain a PhD**

**(total : 98 + 21 + 19 + 4 = 142 publications)**  
papers PhD proceedings reports

**98 papers since 1990 => 49 since 2007**

**21 PhD since 1995 => 11 since 2007**



International Heliophysical Year 2005-2009 IHY  
+ CAWSES, 7 PhD



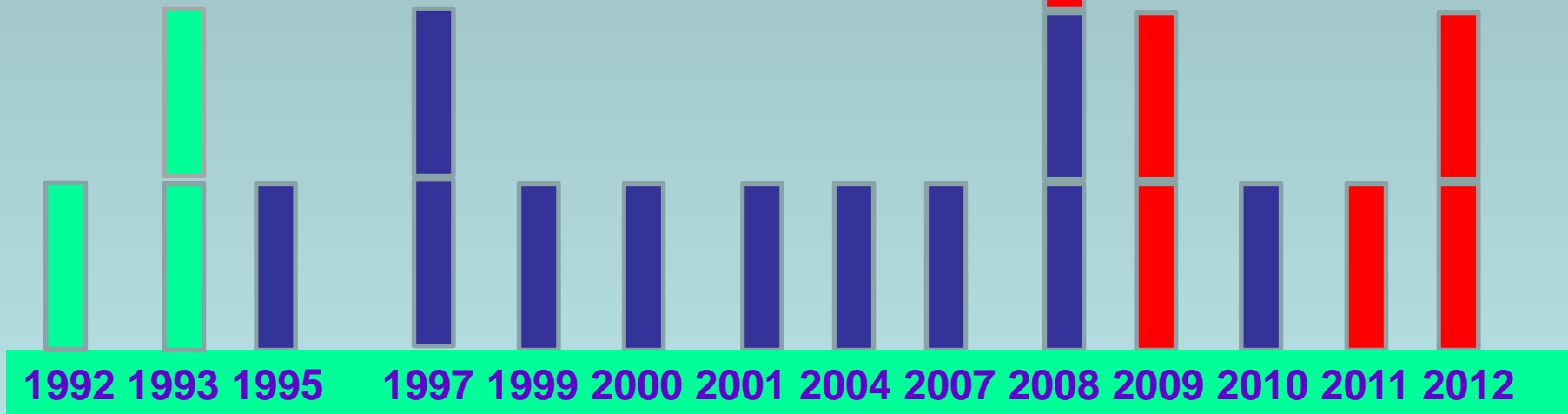
International Equatorial Electrojet Year 1992-1994 IEEY  
11 PhD



Preparation of IEEY  
3 PhD

Countries of Students

- Benin: 1
- Burkina Faso: 2
- Côte d'Ivoire: 8
- Egypte: 1
- France: 2
- France: 1
- Inde: 1
- Senegal: 1
- Spain: 1
- Vietnam: 3



**First professor : A. Koba Toka in 2001 - Côte d'Ivoire**  
**Five professors in 2010 => in Benin, Burkina Faso**  
**and Côte d'Ivoire**



## Fields of Research

(first review on the published in JASTP in 2005, Amory-mazaudier et al., second review in preparation -> AGU Chapman conference)

\*Equatorial Electrojet

\*Sq field: regular variations of the earth's magnetic field

\*Long term variations of ionospheric parameters

\*Electrodynamics coupling between High and low latitudes

\*Solar wind and geomagnetism

\*Relations between solar magnetic field and equatorial ionosphere

\*Impacts of the Sun on Ionospheric layers

\* Impacts of high energy particles on satellite

\* Telluric electric field

\* Dynamics of the ionosphere with HF radar

\*Study of the atmosphere with interferometer

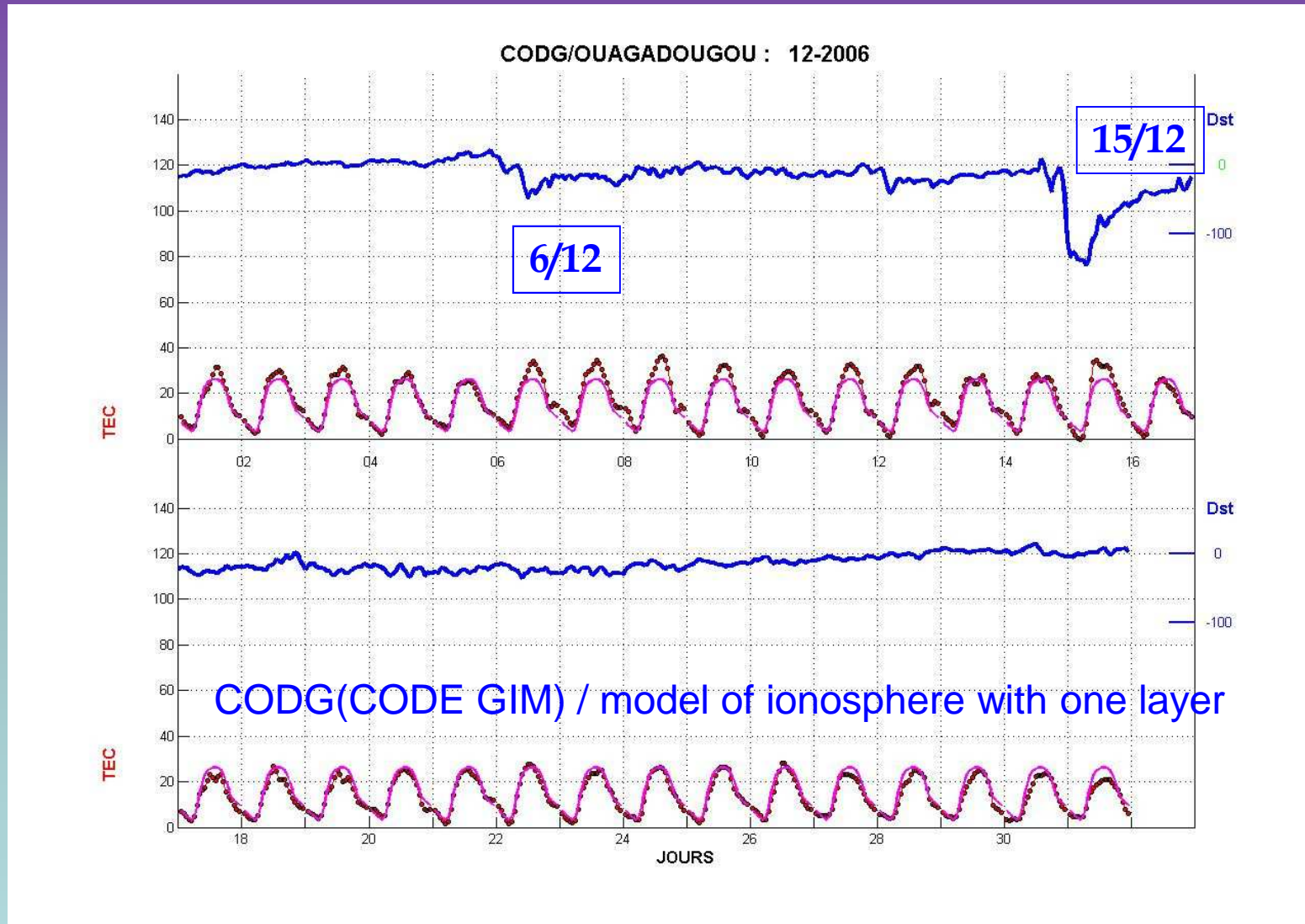
- Monsoon

- Gravity waves

etc....



# Daily variation / TEC - Outtara, 2009-PhD-

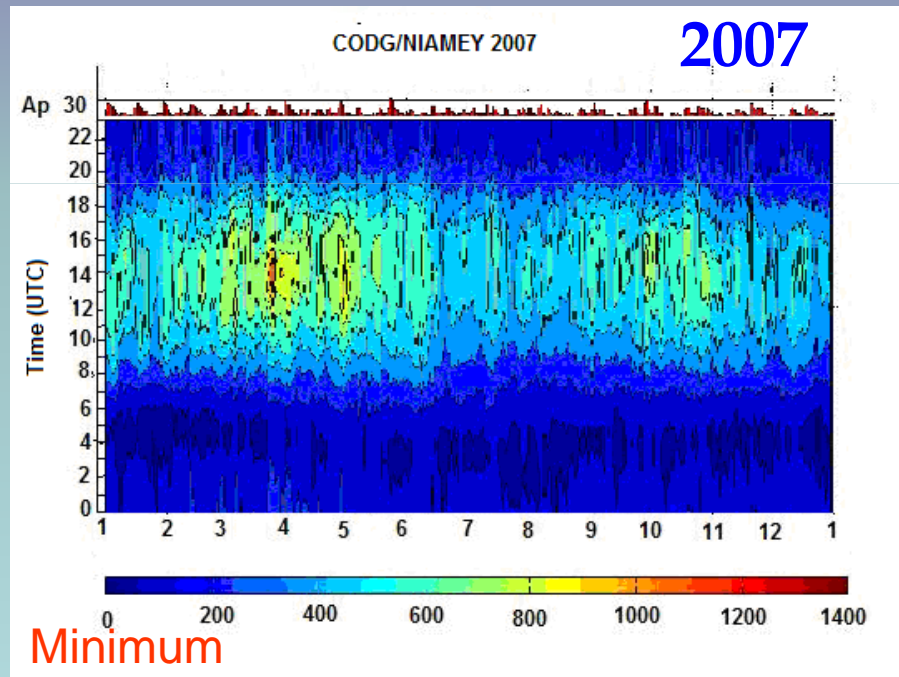
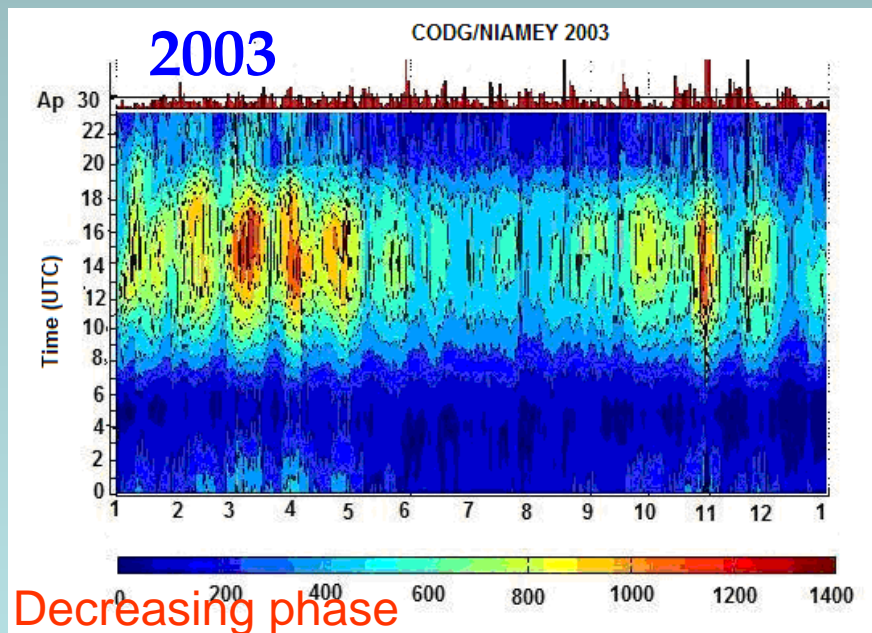
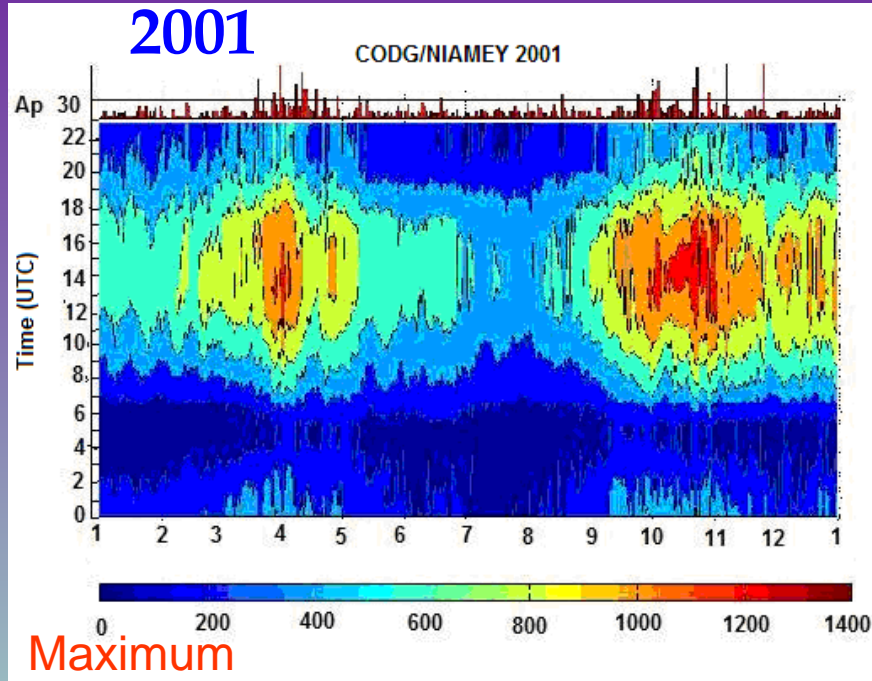


Red and points -> TEC /GPS      Magenta-> TEC/CODG  
CODG : Centre for Orbit Determination in Europe



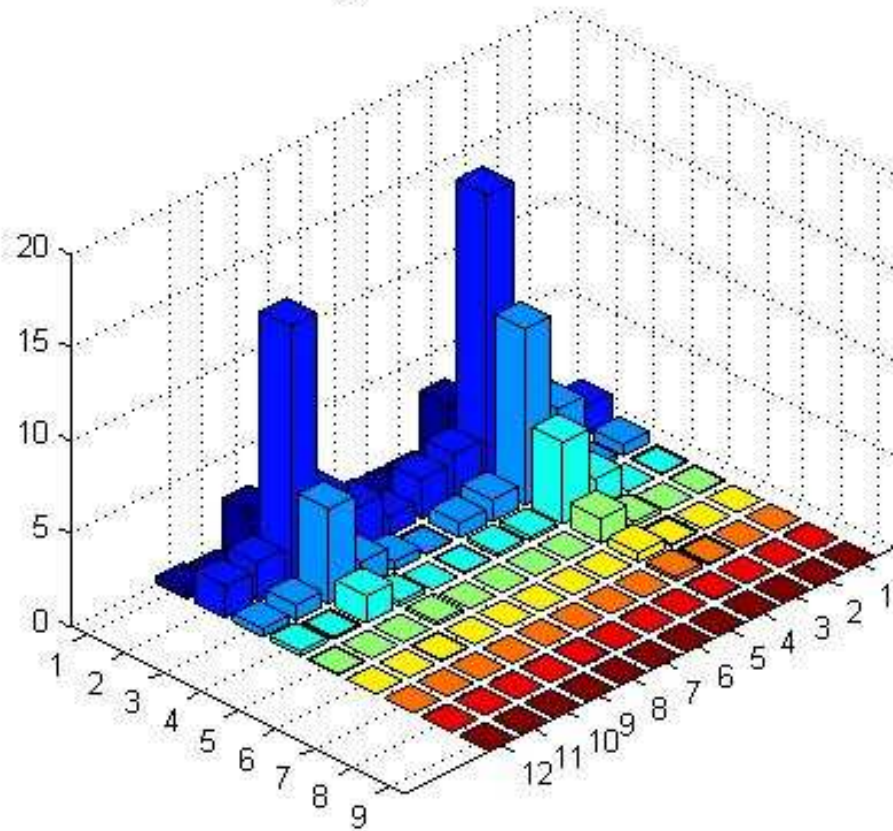
# Seasonal variations / TEC

## Study of the Equinoctial asymmetry in AFRICA



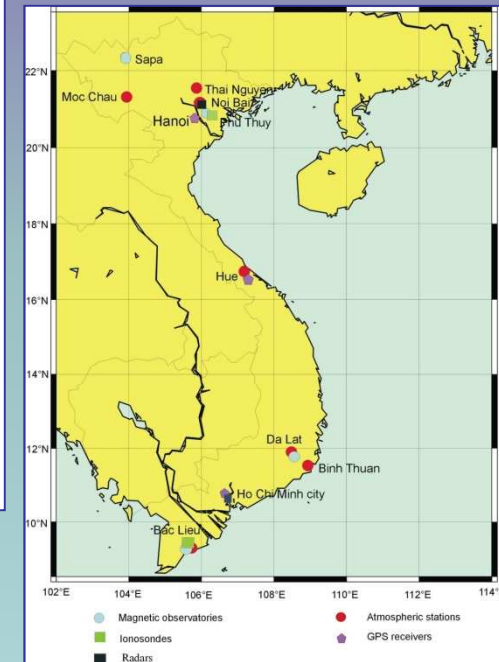
Outtara, 2009-PhD

Histogram of s4 vs month - Hue



## S4 : Small Scale

$$I = \frac{A^2}{2}$$



**Scintillation index S4 observed at Hue during the period 2006-2008**  
**S4 -> fluctuations of the GPS power signal**

From A. Bourdillon

$$s4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}}$$

# Medias and Politics





**Senegal – 2009**  
**Members of the Jury from**  
**Côte d'Ivoire, Burkina Faso**  
**and Senegal,**

**Contact with the media for PhD**

**L'OB**  
**SERVATEUR CBS**

**WWW.LOBSERVATEUR.SN**

N° 1807 - ISSN N° 0854-786 X - Vendredi 02 Octobre 2009 - PRIX : 100 FCFA



**AVIS DE SOUTENANCE**  
**DE THESE DE DOCTORAT D'ETAT**

Dr. Frédéric OUATTARA, Maître Assistant à l'Université de Koudougou (Burkina Faso) soutiendra une Thèse de Doctorat d'Etat de Physique intitulée : CONTRIBUTION A L'ETUDE DES RELATIONS ENTRE LES DEUX COMPOSANTES DU CHAMP MAGNETIQUE SOLAIRE ET L'IONOSPHERE EQUATORIALE le samedi 03 Octobre 2009 à 09 heures 30 mn à l'Amphi 7 de la Faculté des Sciences et Techniques.

La Thèse a été dirigée par le Professeur Christine AMORY-MAZAUDIER du Laboratoire de Physique des Plasma, CNRS, Université Pierre et Marie Curie (France) et la soutenance sera présidée par le Professeur Grégoire SISSOKO du Laboratoire de Semiconducteurs et d'Energie Solaire, Département de Physique de la Faculté des Sciences et Techniques (Dakar, Sénégal)

**Le public est cordialement invité.**



# Media and Politics

**School in RDC**

**79% of the financial support by RDC**

**Two ministers for the opening ceremony of the school**



**National Television  
followed the whole school  
=> Education of population**



Students at the IHY viewing center in Legon, Ghana. (Rabello-Soares et al, 2007)

Dr. Davila giving a public talk in Tunis, Tunisia. (Rabello-Soares et al, 2007)



Waiting For the March 29 2006 Solar Eclipse at Saki, Nigeria



# Solar Eclipse March 29 2006 Saki, Nigeria



From B. Rabiou

**Sun-viewing  
glasses, & several  
teaching aids  
- IHY International  
Secretariat**

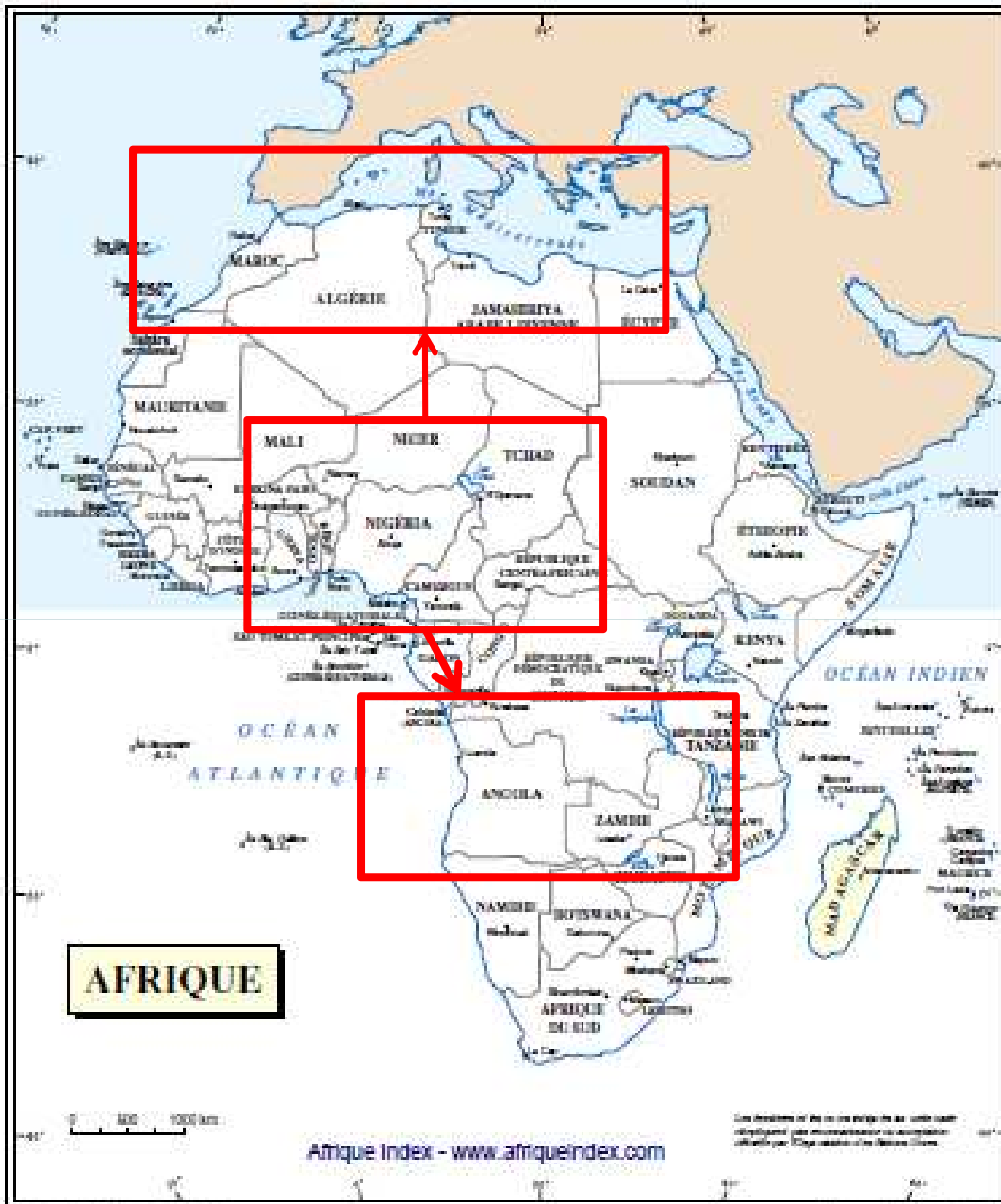




## • Conclusions

- Scientific tools leads to sustainable research in Africa
- Introduction of new fields of research in African countries
- PhD, publications and positions for young scientists
- Education of the population and development of the country
- Creation of new communities: Heliophysics and Space Weather breaking walls between disciplines
- Now there is the necessity to reanalyze ionospheric and magnetic data including the knowledge on the sun





**MAGHREB**

**WEST AFRICA**

**CENTRAL AFRICA**

**Next schools**  
**Algeria 2013**  
**Burkina Faso 2014**  
**Morocco 2015**