African Leadership Conference Accra 3-5 december 2013

AFRICAN DUAL FREQUENCY GPS NETWORK

Space Weather

GNSS

Low Earth Orbital Satellite

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Introduction

UNBSSI [1990-2012]

United Nations Basic Space Science Initiative

- **IEEY: International Equatorial Electrojet Year [1992-1994]**
- **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

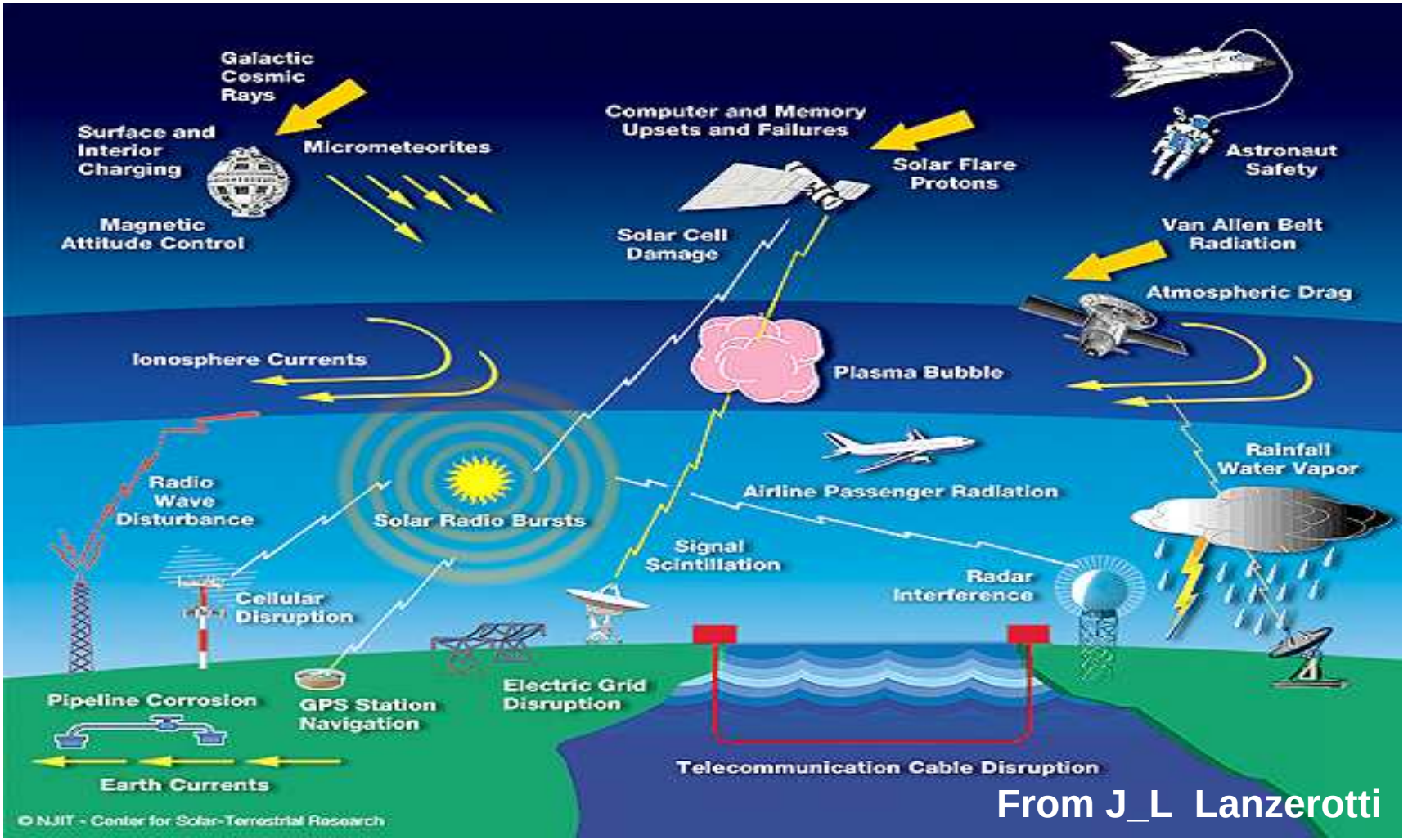
- **Space weather**

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**

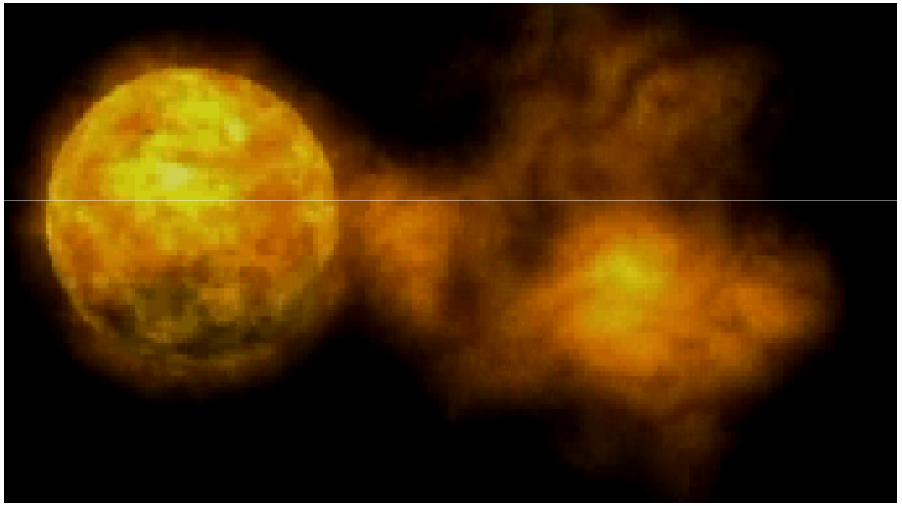
SPACE WEATHER

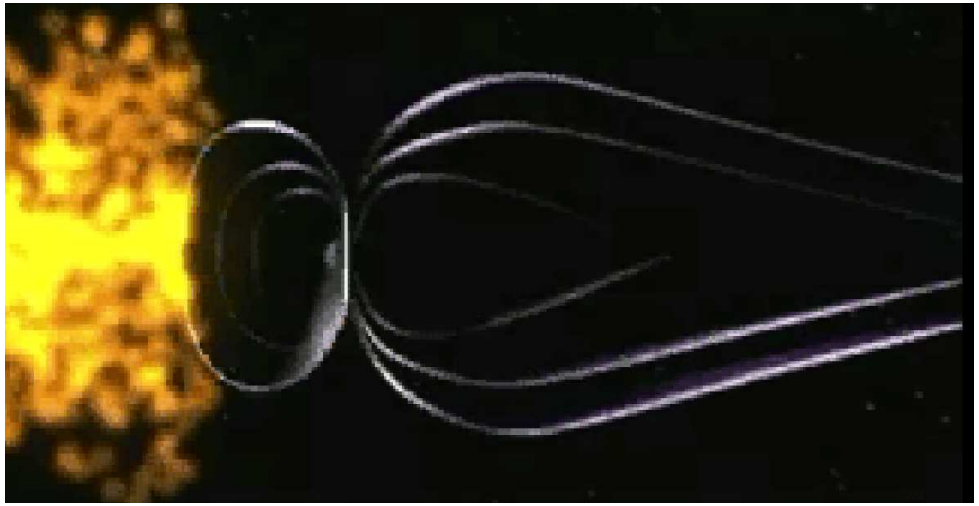
- **Effects on terrestrial systems**



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

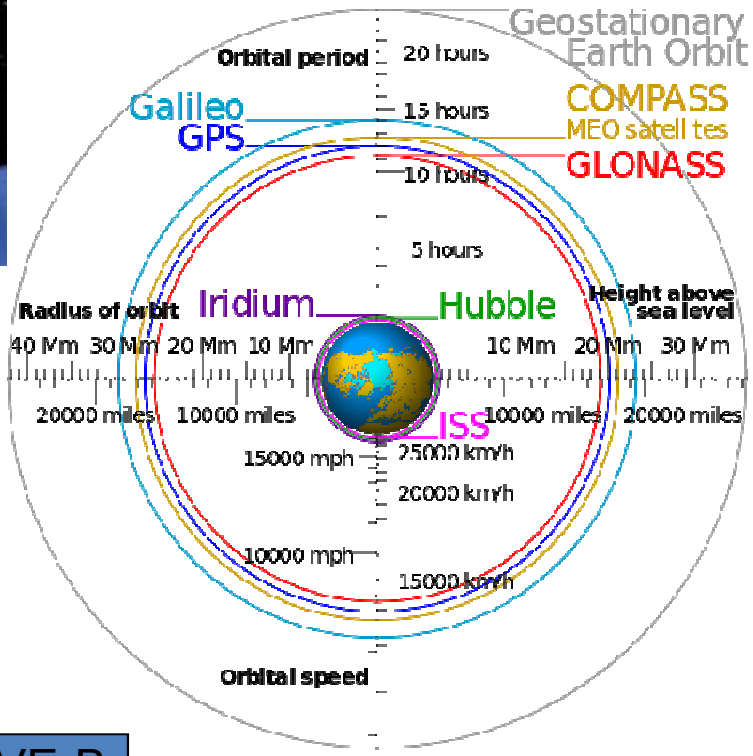
- **Nigeria -> February 2013**
- *organized by NASDR and Bells University*
- **Algeria -> May 2013**
- *Organized by the University of Science and Technology Harri Boumedienne and GIRGEA*
- **Côte d'Ivoire -> September 2013**
- *Organized by University Houphet Boigny and MAGDAS team (Japan)*
- **Kenya -> October 2013**
- *Organized by SCOSTEP and Kenya*

GNSS

- **GNSS system in 2013**
- **Research and applications**

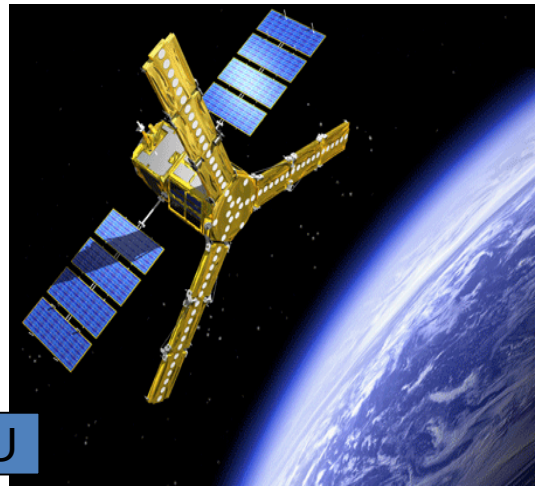
GPS IIR

GLONASS K1

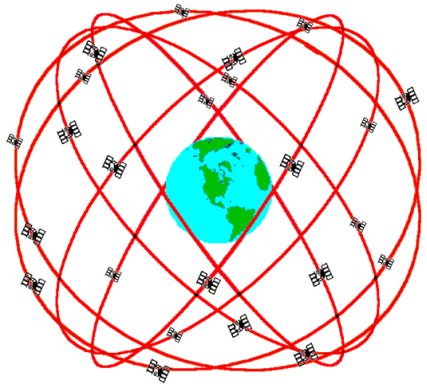


GIOVE-B

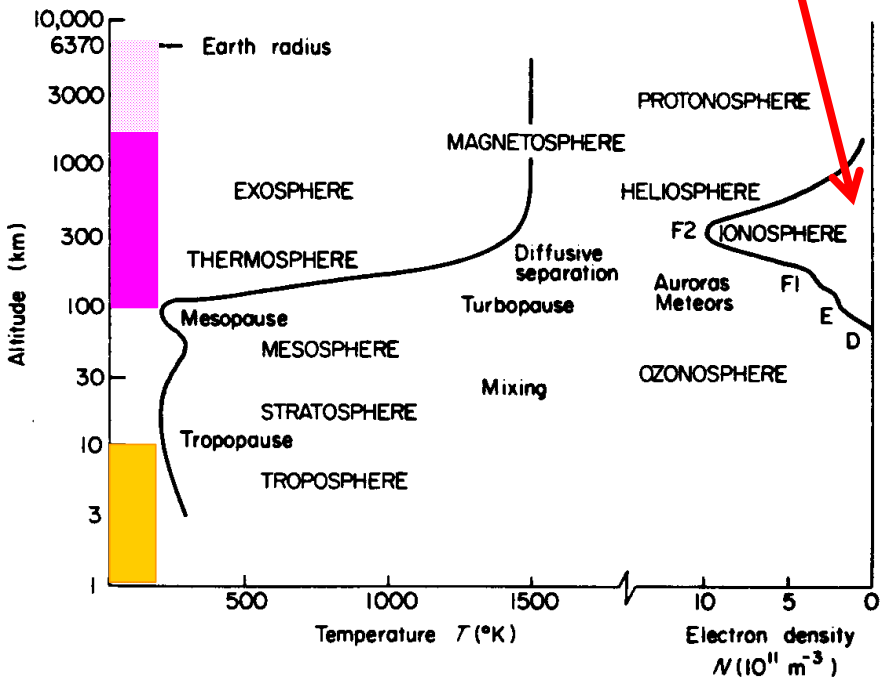
BEIDOU



The satellite signal is strongly modified by ionosphere and troposphere



TEC



Earth's Environment

TEC : Total Electron Content

LAYERS

> 600 km **EXOSPHERE**
few collisions, Particles follow balistic 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)

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

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

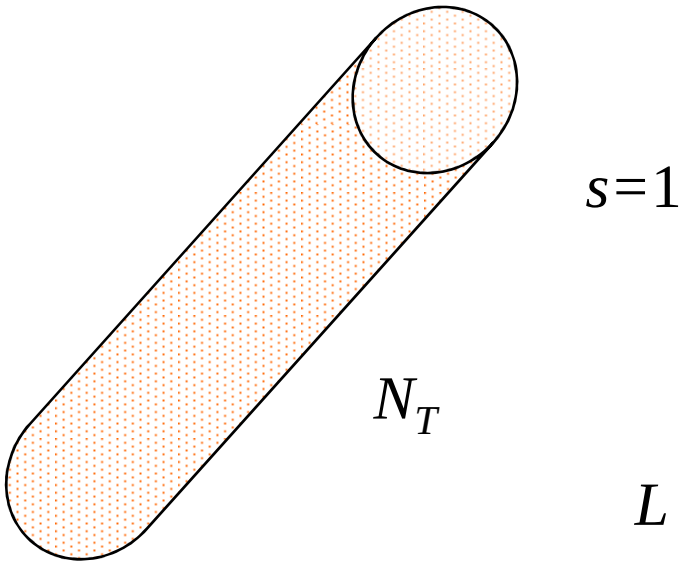
$$\Delta P_\varphi = -\frac{a}{f^2}\int_L N_e\,ds$$

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

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

– **Total Electron Content** (TEC)

$$N_T = \int_L N_e\,dl$$



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

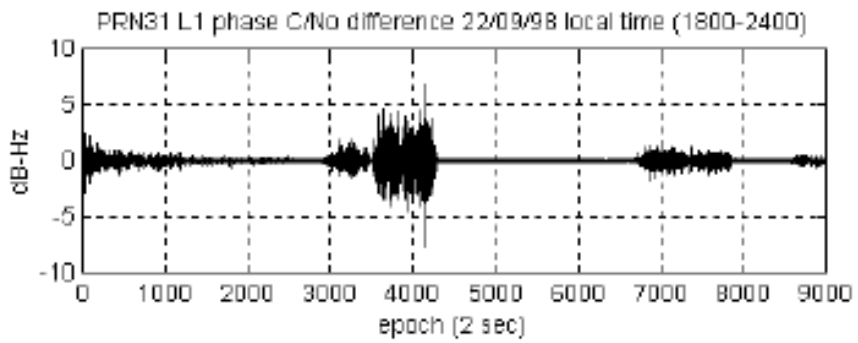
From ENST/Télécom

Ionospheric propagation

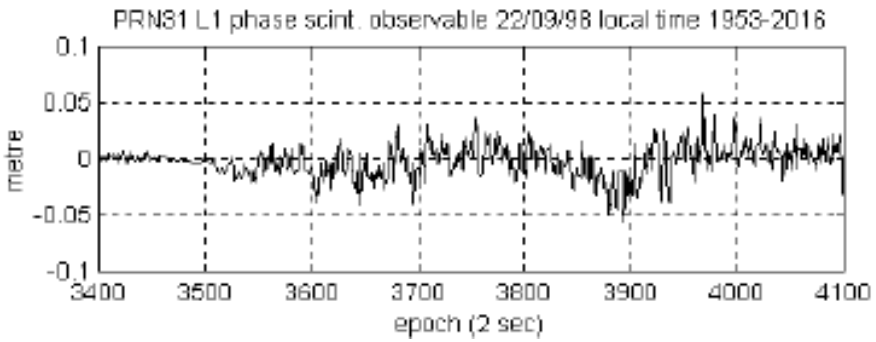
Scintillations

Fluctuations of the signal due to the inhomogeneity of the medium

Scintillations of amplitude



Scintillations of phase



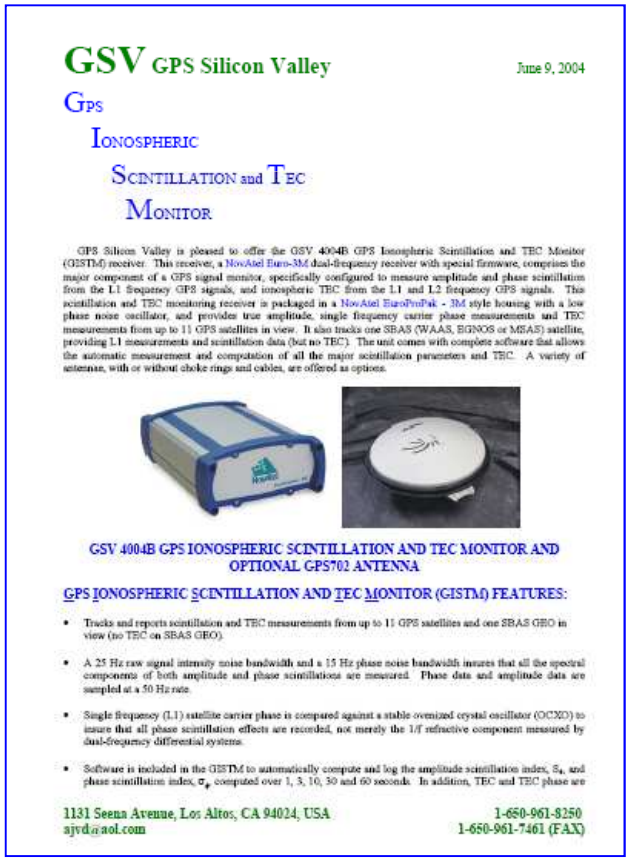
scales: ± 3 rad.

From ENST/Télécom

GPS networks for Space weather studies

- GPS networks

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



GSV GPS Silicon Valley June 9, 2004

GPS
IONOSPHERIC
SCINTILLATION and TEC
MONITOR

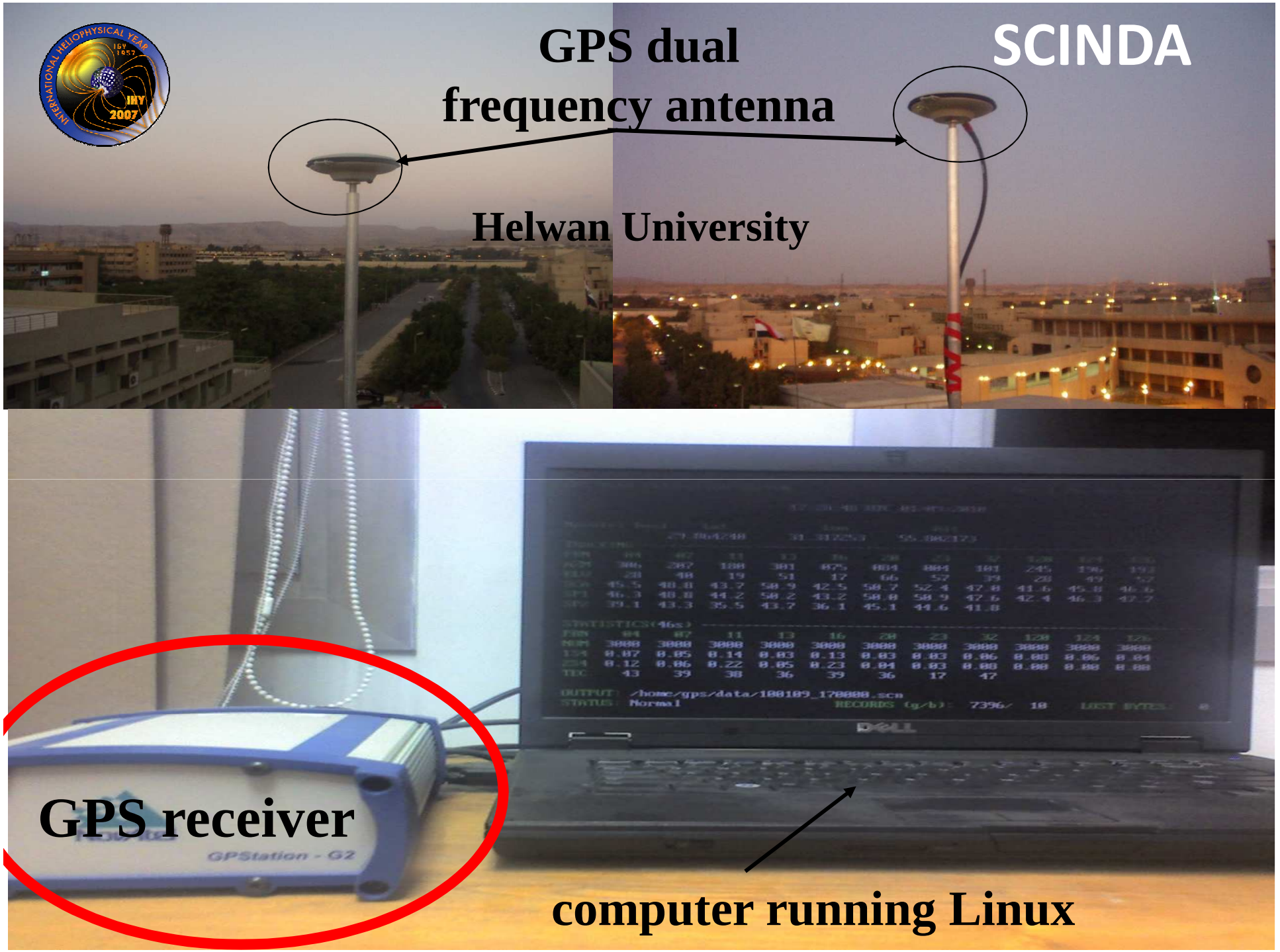
GPS Silicon Valley is pleased to offer the GSV 4004B GPS Ionospheric Scintillation and TEC Monitor (GISTM) receiver. This receiver, a NovAtel Euro-3M dual-frequency receiver with special firmware, comprises the major component of a GPS signal monitor, specifically configured to measure amplitude and 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 EuroPinPak - 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 antennae, 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. Phase data and amplitude data are sampled at a 50 Hz rate.
- Single frequency (L1) satellite carrier phase is compared 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, σ_ϕ, computed over 1, 3, 10, 30 and 60 seconds. In addition, TEC and TEC phase are

1131 Seena Avenue, Los Altos, CA 94024, USA 1-650-961-8250
ajvd@aol.com 1-650-961-7461 (FAX)


GPS dual
frequency antenna
SCINDA
Helwan University
GPS receiver
GPStation - G2
computer running Linux

University Building

Station GPS of KOUDOUGOU/ AFRICA
Available on the web

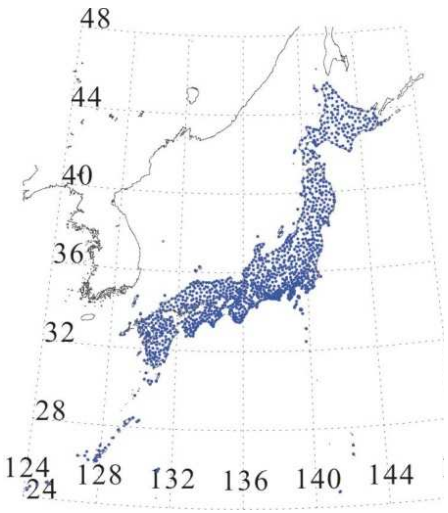
GPS receiver and data acquisition

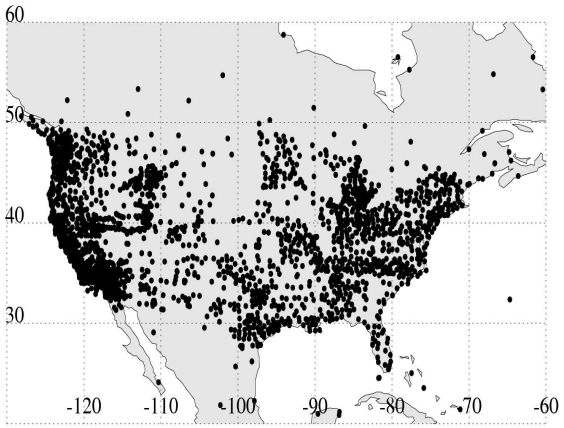
Provided by T. Tsugawa (NCIT, JAPAN)

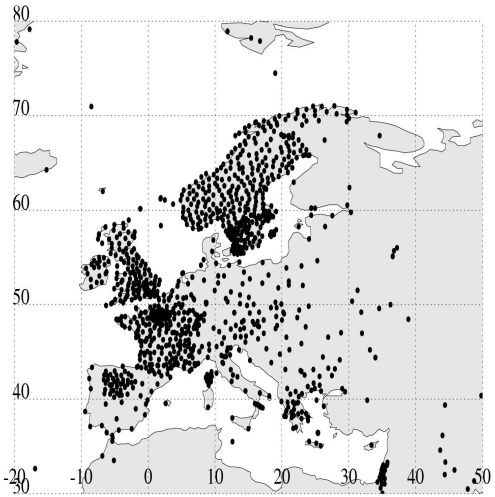
JAPAN
~1,200 receivers

N. America
~2,700 receivers

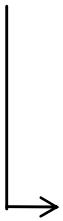
Europe
~1,200 receivers

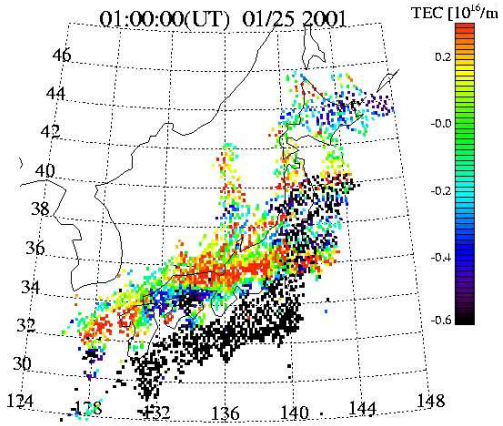


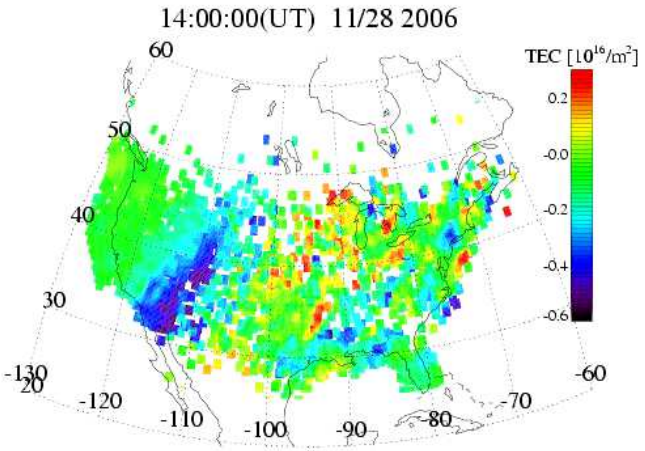


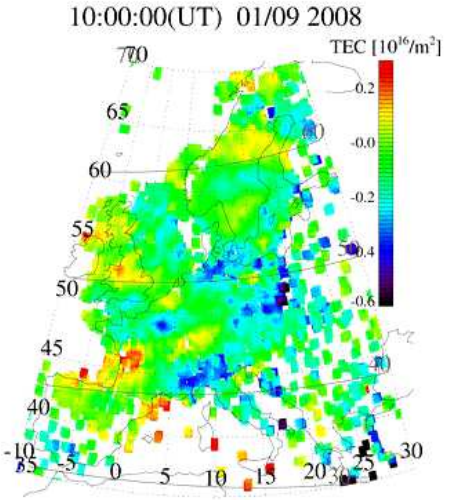


Detrended TEC Map (60-min Window)



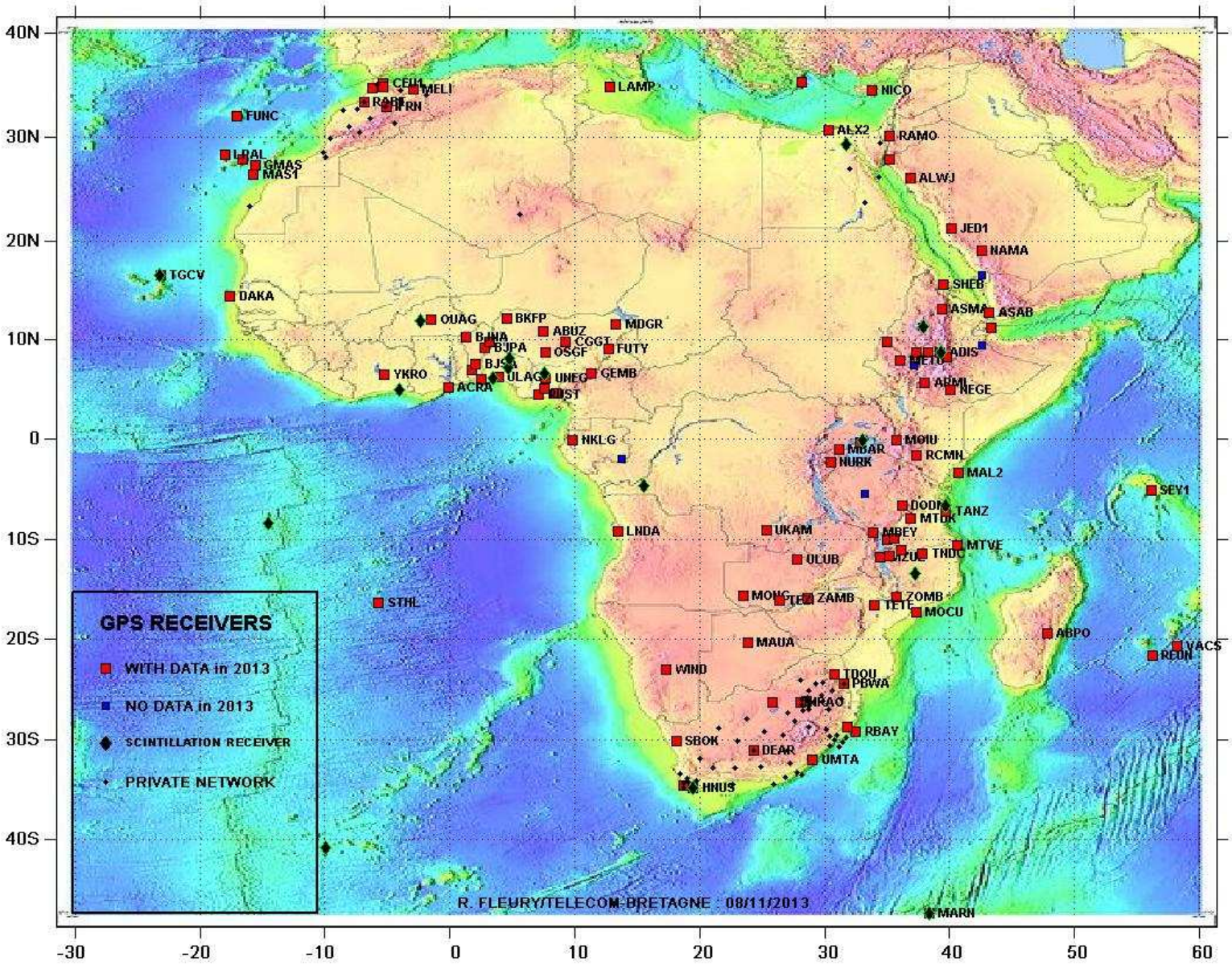






2013

GPS available on the web and private networks



Some other networks are in Algeria, Egypt, Burkina Faso etc…

IGS
http://sopac.ucsd.edu
http://cddis.gsfc.nasa.gov
http://igs.ensg.ign.fr
AMMA stations are now in IGS
NOAA et UNAVCO
http://www.ngs.noaa.gov/CORS http://www.unvaco.org

Recommendations made at Quito during the ISWI meeting in 2012

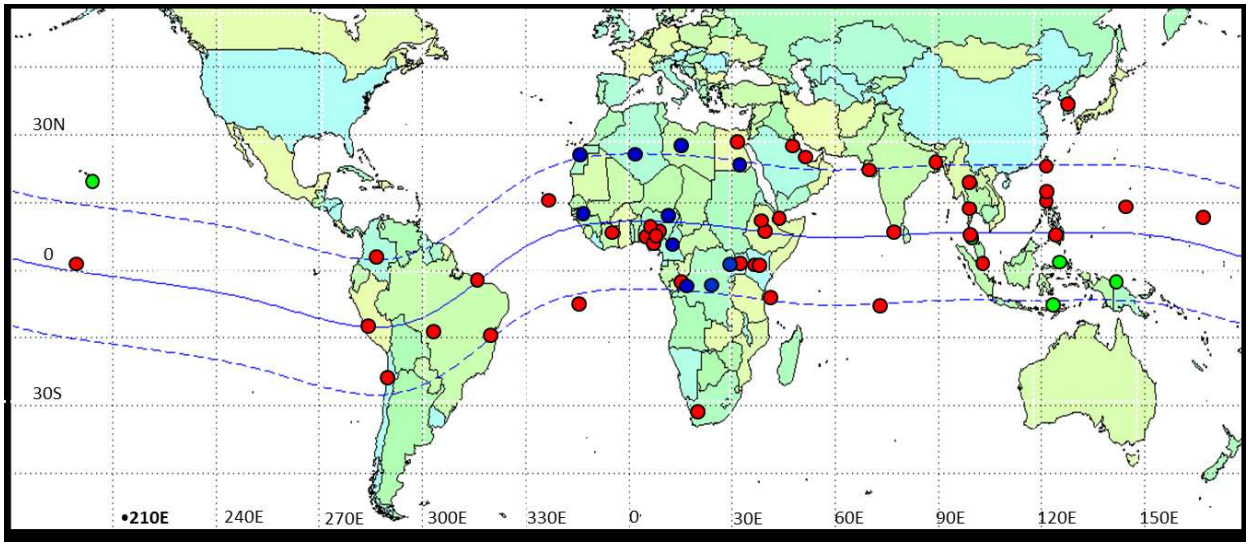
It is important to increase:

- **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…

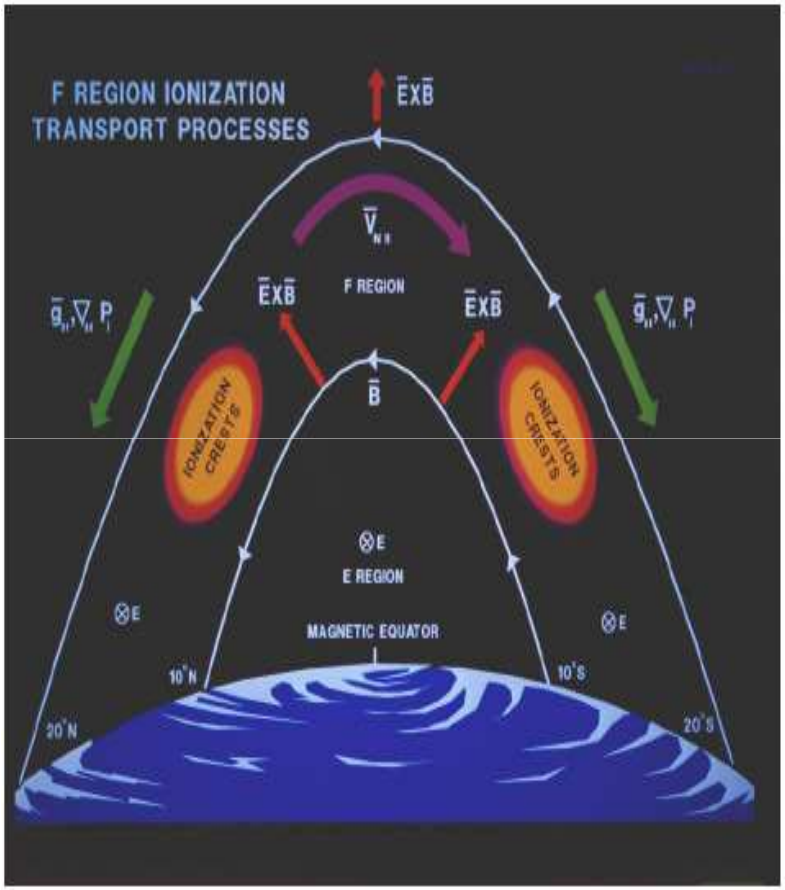
- **GPS Networks available on the Web** Contact UNAVCO http://www.unvaco.org

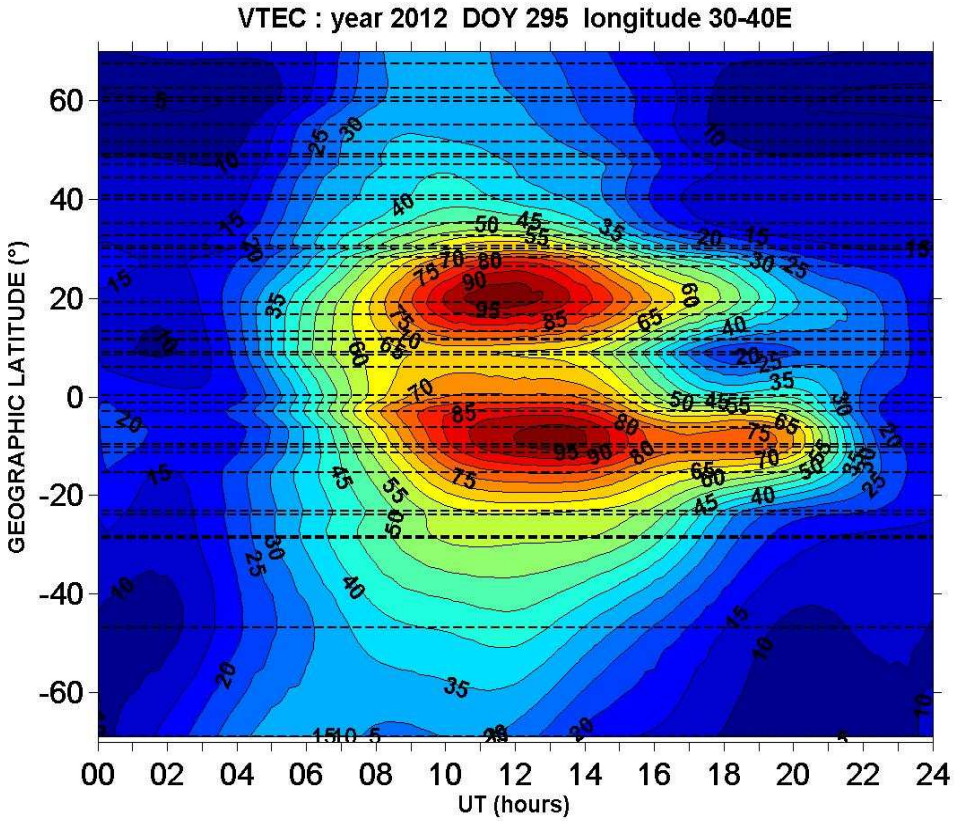
Figure adopted from Paznokhov's ICTP lecture



Existing Sites; **Future ISWI Sites;** **Other/collaboration**

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

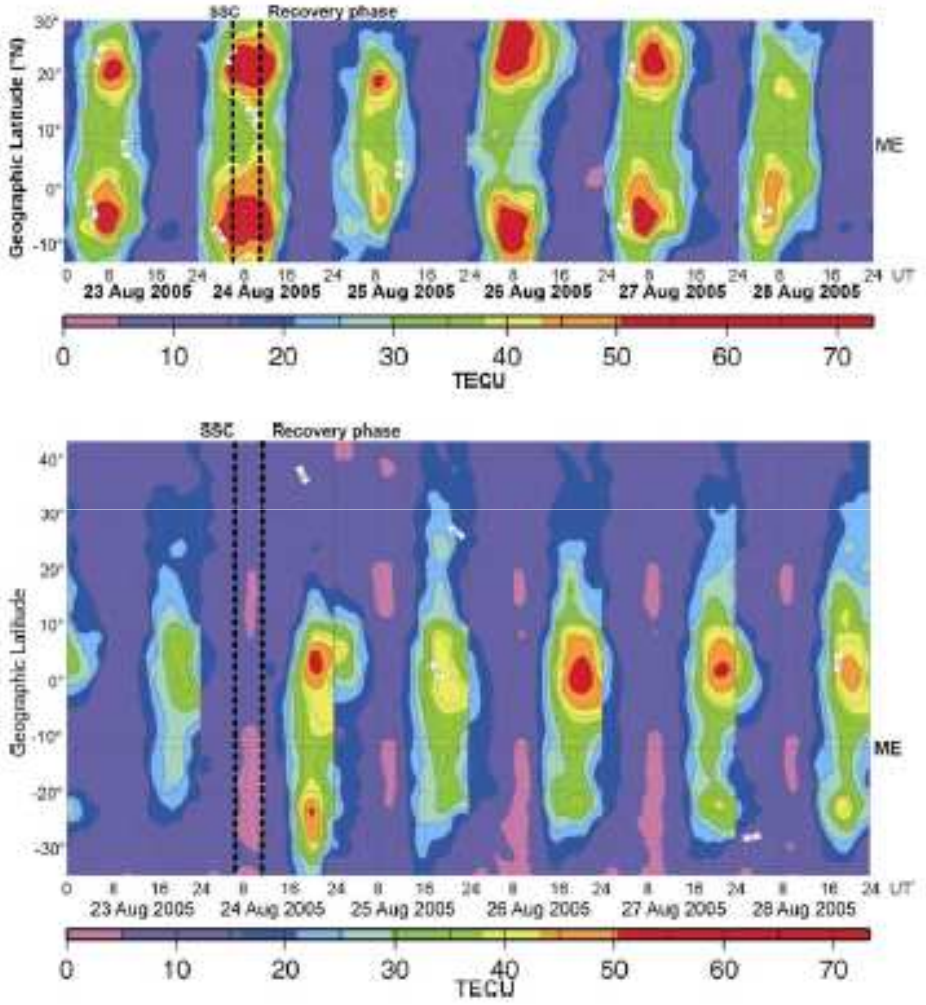
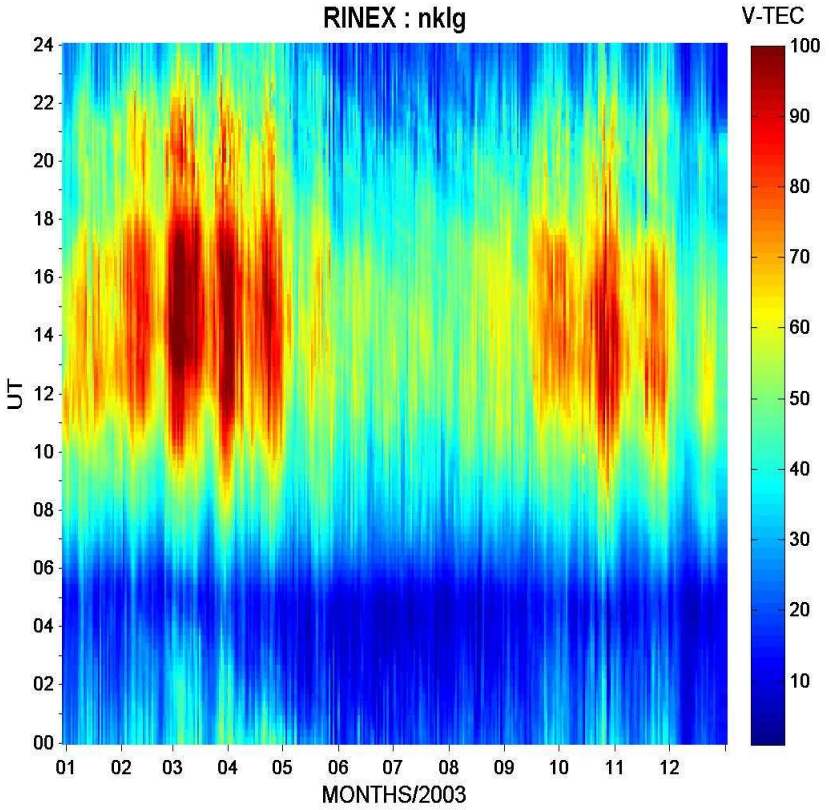


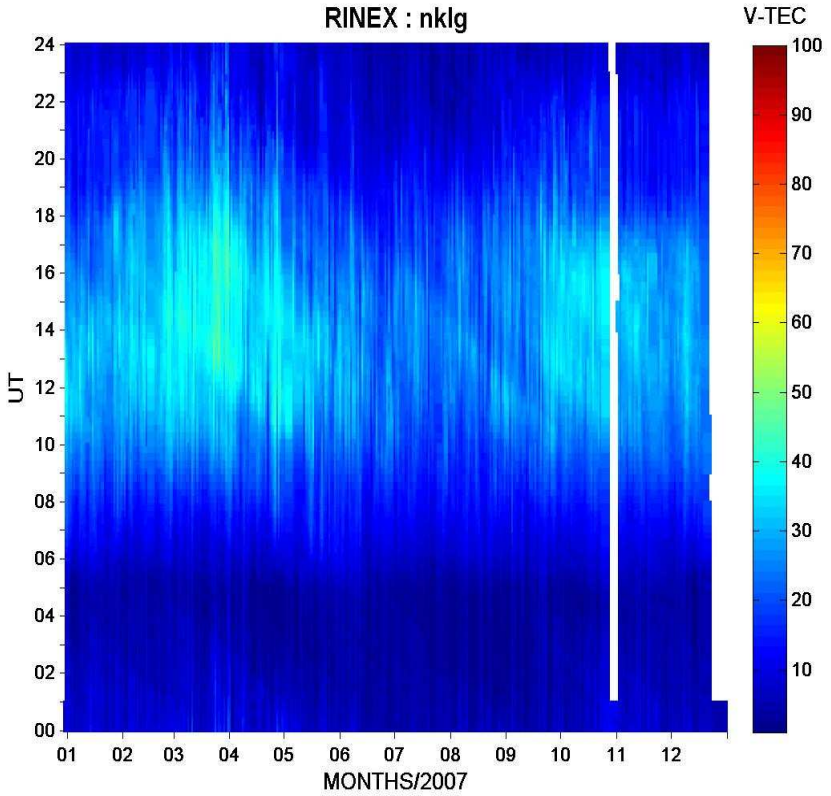
Fig. 12. Maps of total electron content (TEC) in the Asian sector (top panel) and the American sector (bottom panel) during the storm of 24 August 2005. Two vertical dashed lines underline the sudden storm commencement and the beginning of the recovery phase of the storm.

VTEC Variations

- **Solar and Seasonal variations on VTEC**

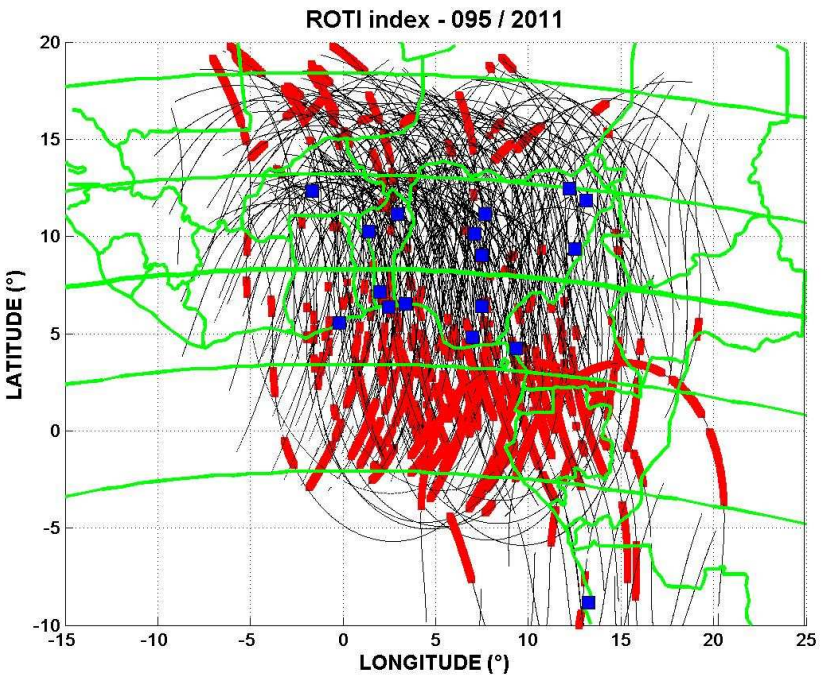
Station NKLG in Cameroun

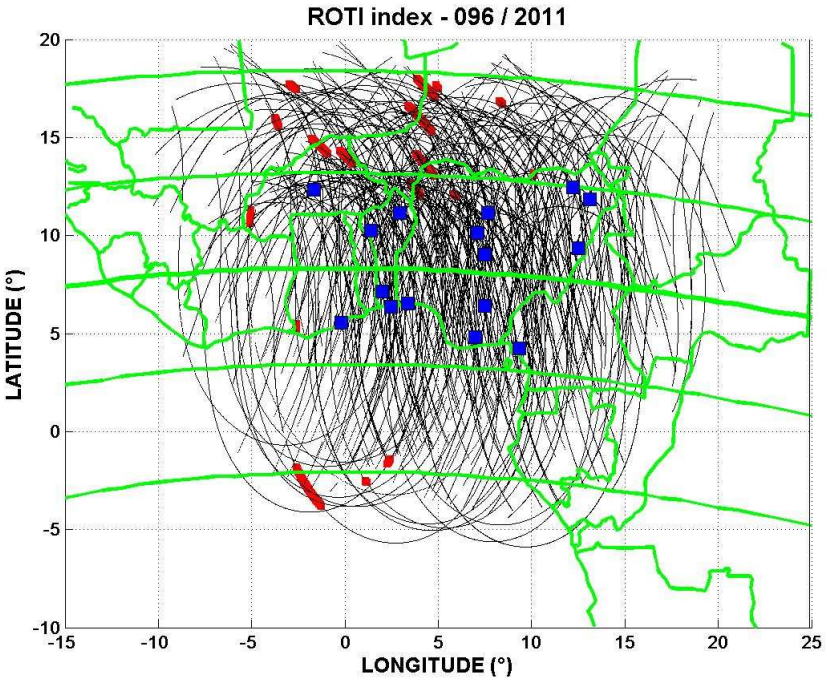




VTEC Variations

- **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**



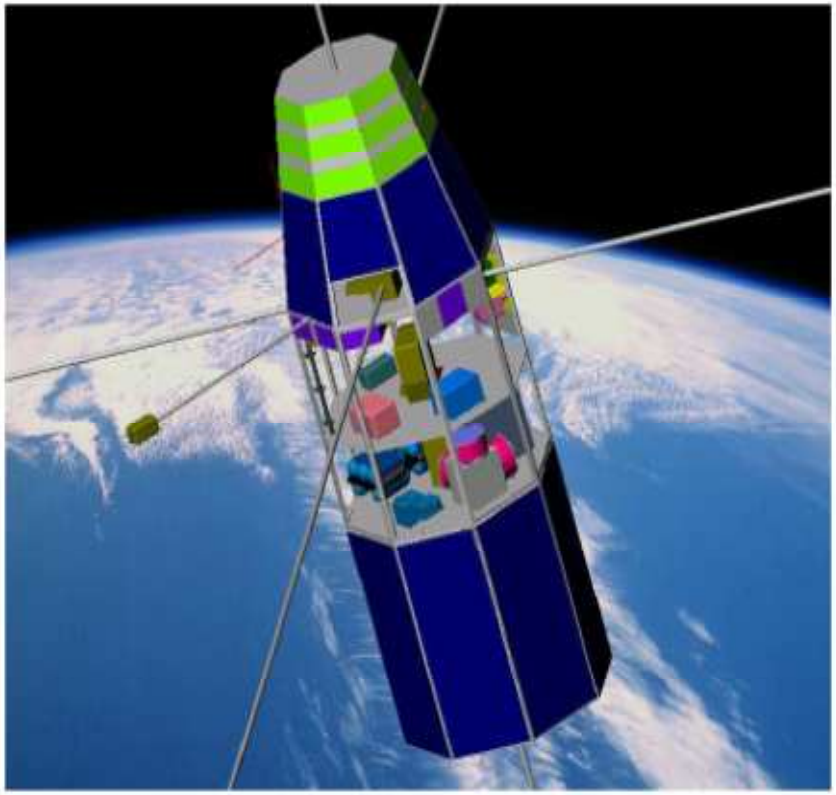


WE HAVE TO INCREASE THE NUMBER OF GNSS RECEIVERS OVER AFRICA AND TO SHARE THE DATA

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 iomospheric profile

➢ **Electric Field instrument**

Vecteur electric and magnetic fields

➢ **RF beacon**

Scintillation and STEC on ground

➢ **Planar langmuir Probe (PLP)**

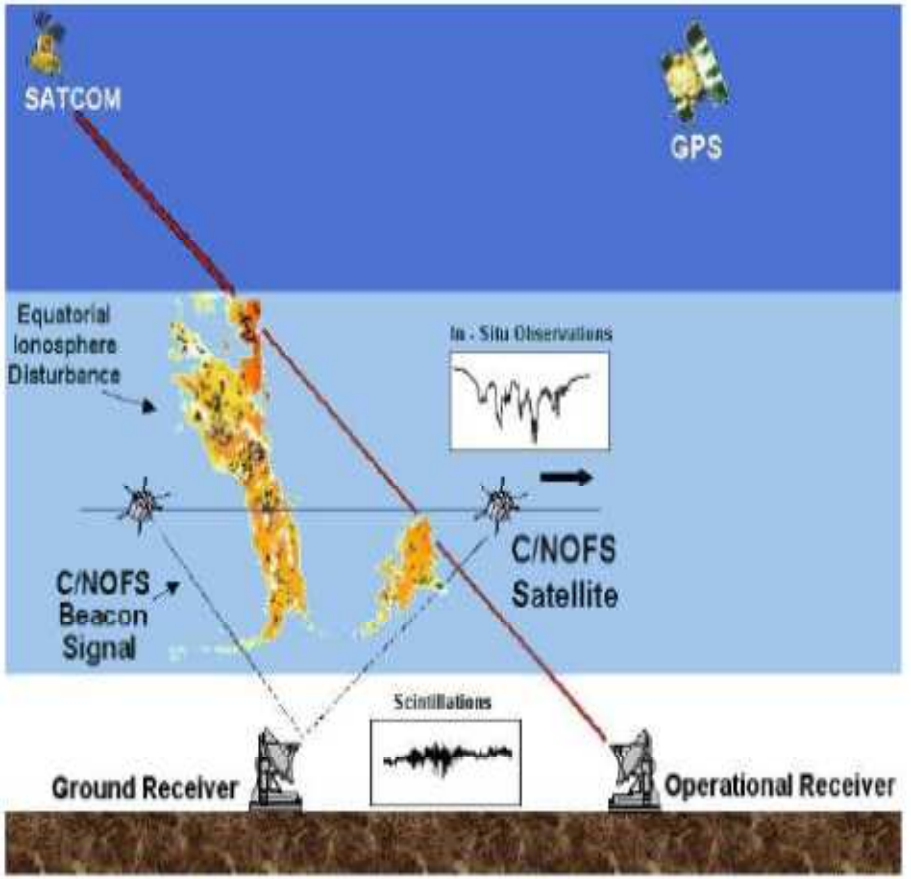
Ion density and electron temperature

➢ **Ion Velocity Meter (IVM)**

Ion density and ion temperature

➢ **Neutral Wind Meter (NWM)**

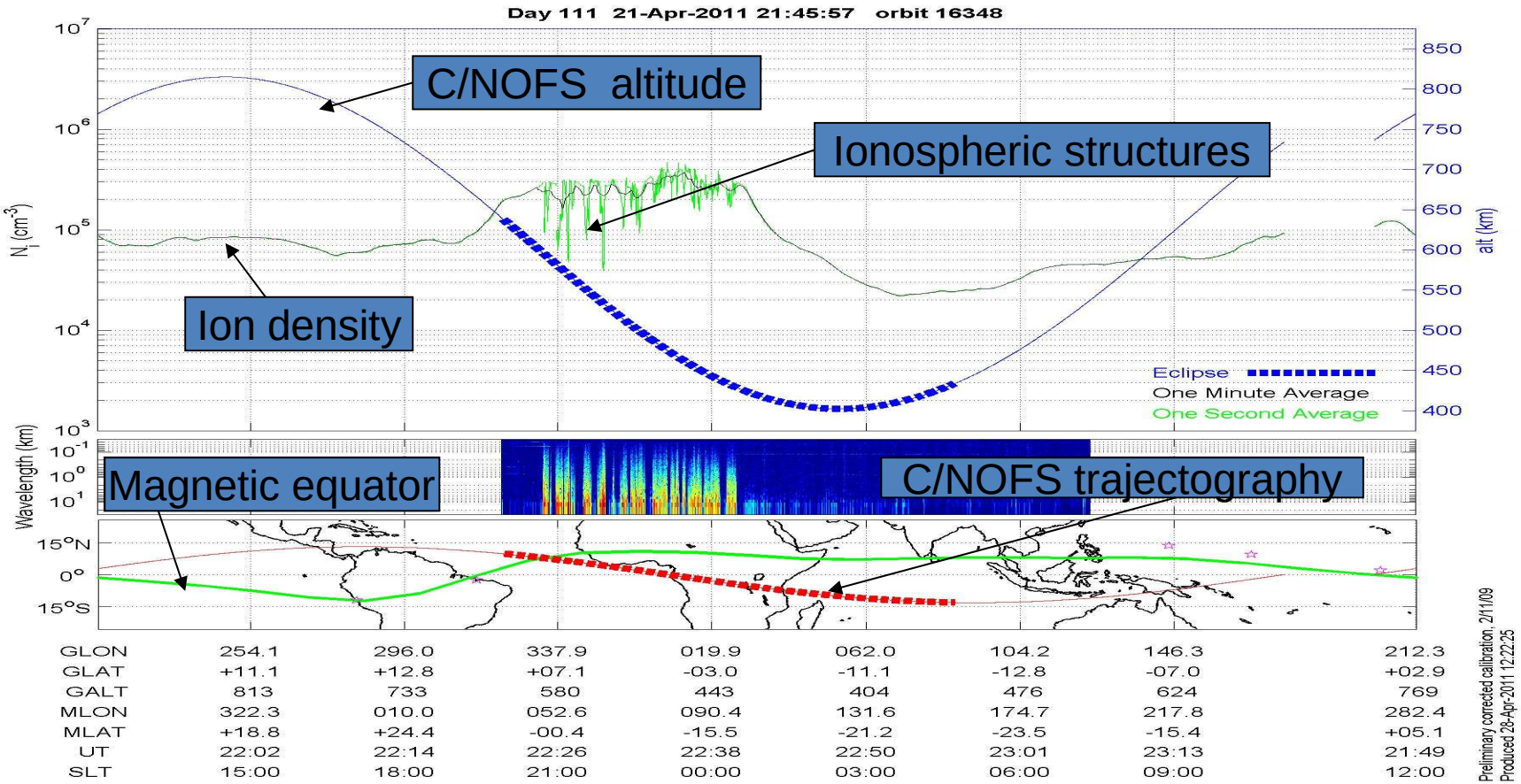
Vector neutral wind velocity



From de La Beaujardiere et al,2012

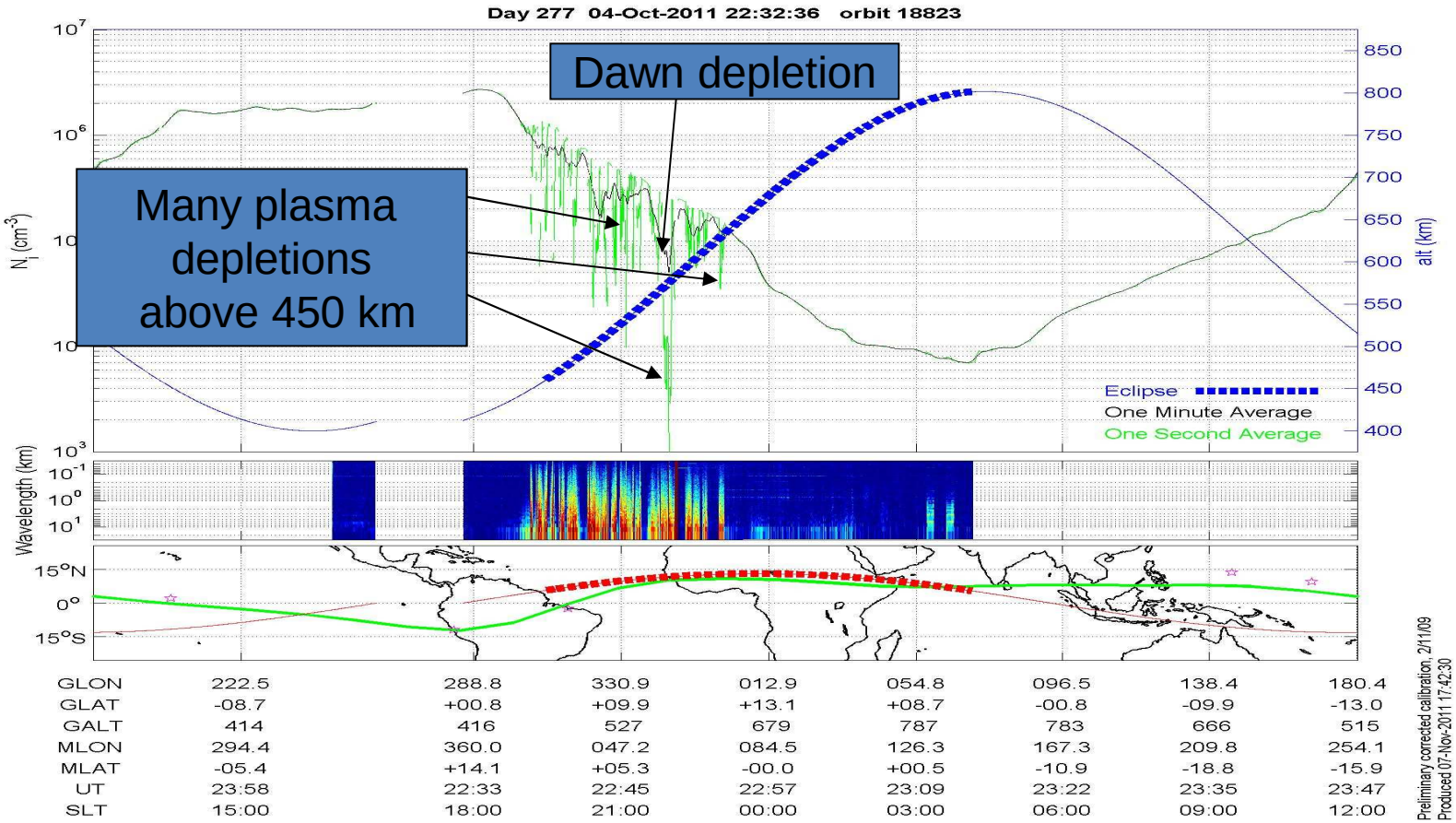
C/NOFS Mission

- **Sample from PLP above Africa**



C/NOFS Mission

- **Ionospheric strutures above Africa before midnight**



Low Equatorial Orbital Satellite

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

- **C/NOFS might be terminated in june 2013 (budget cuts)**

- Bibliography:

[1] Amory-Mazaudier and Rolland Fleury, Space Research in Africa, Some Achievements from 2007 to 2012, Sun and geosphere, 8(2), 65-70, 2013

[2] De La Beaujardiere et al.,Significant findings from the C/NOFS satellite mission,Conf. Boston,march 2012

[3] Guhathakurta M., J.M. Davila and N. Gopalswamy, the International Space Weather Initiative (ISWI) , Space Weather, 11, doi:10.1002/swe.20048, 2013.