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

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DES AFFAIRES ÉTRANGÈRES ET DU DÉVELOPPEMENT INTERNATIONAL

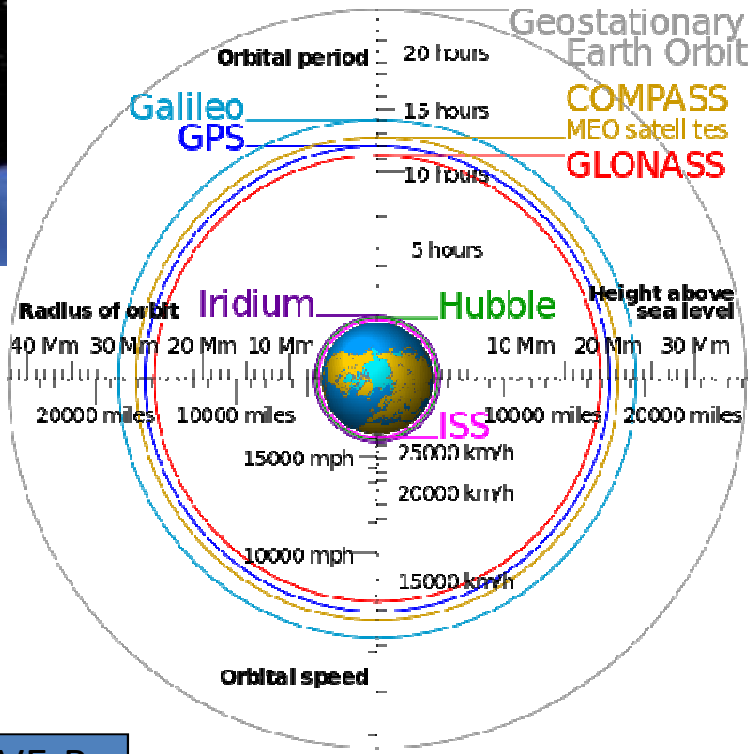
Presented at
European Space Solutions / Bringing Space to the Earth
30 May-03 June 2016 / The Hague, The Netherlands

- GPS -> GNSS
- Space Weather
- Capacity Building

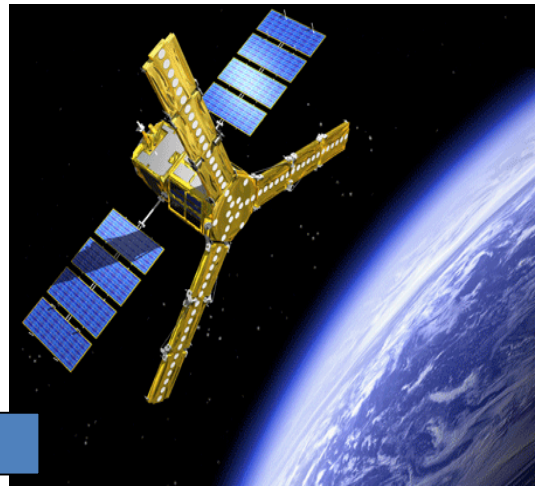
- Last decade : mainly GPS -> Now -> GNSS
- Research and applications

GPS IIR

GLONASS K1



GIOVE-B



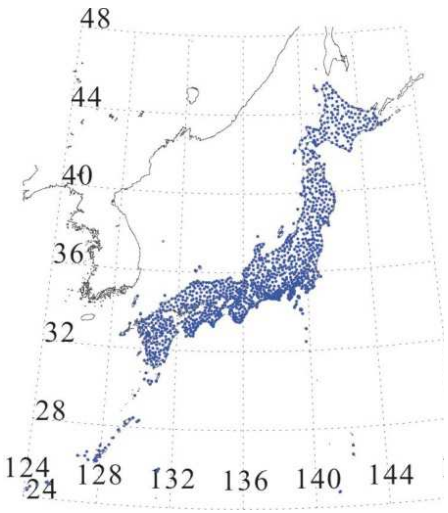
BEIDOU

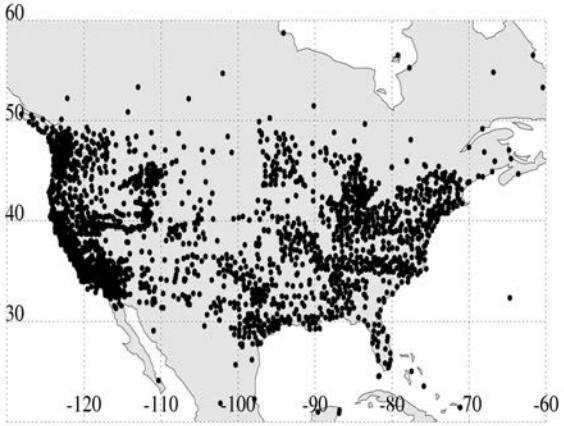
GPS :the most larger network of scientific ground based measurements

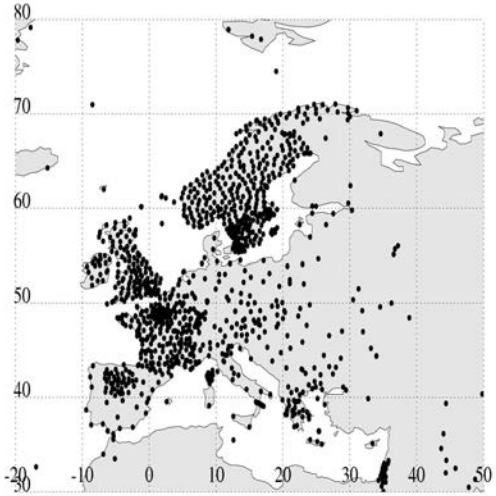
JAPAN
~1,200 receivers

N. America
~2,700 receivers

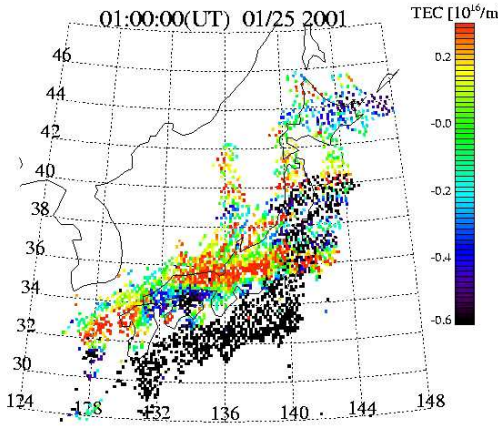
Europe
~1,200 receivers

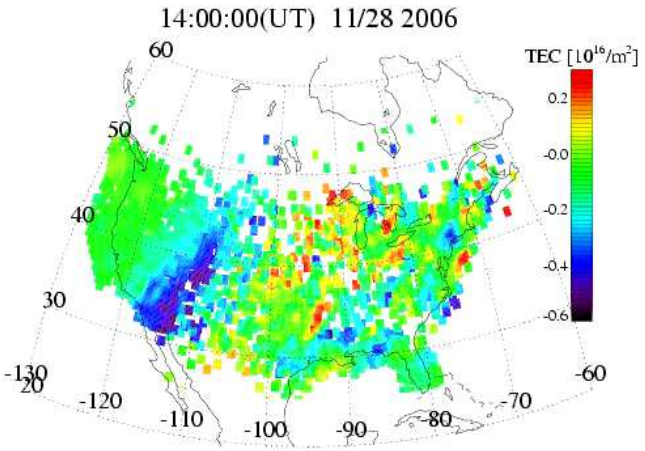


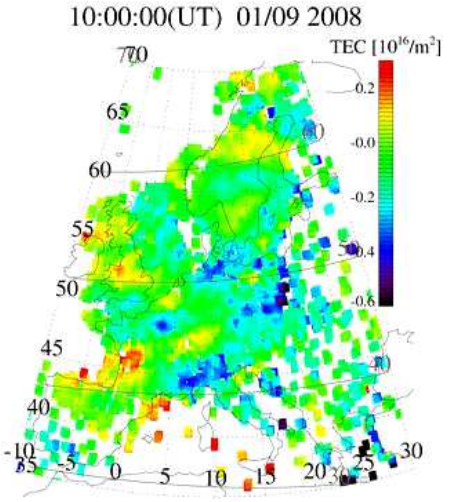




Detrended TEC Map (60-min Window)

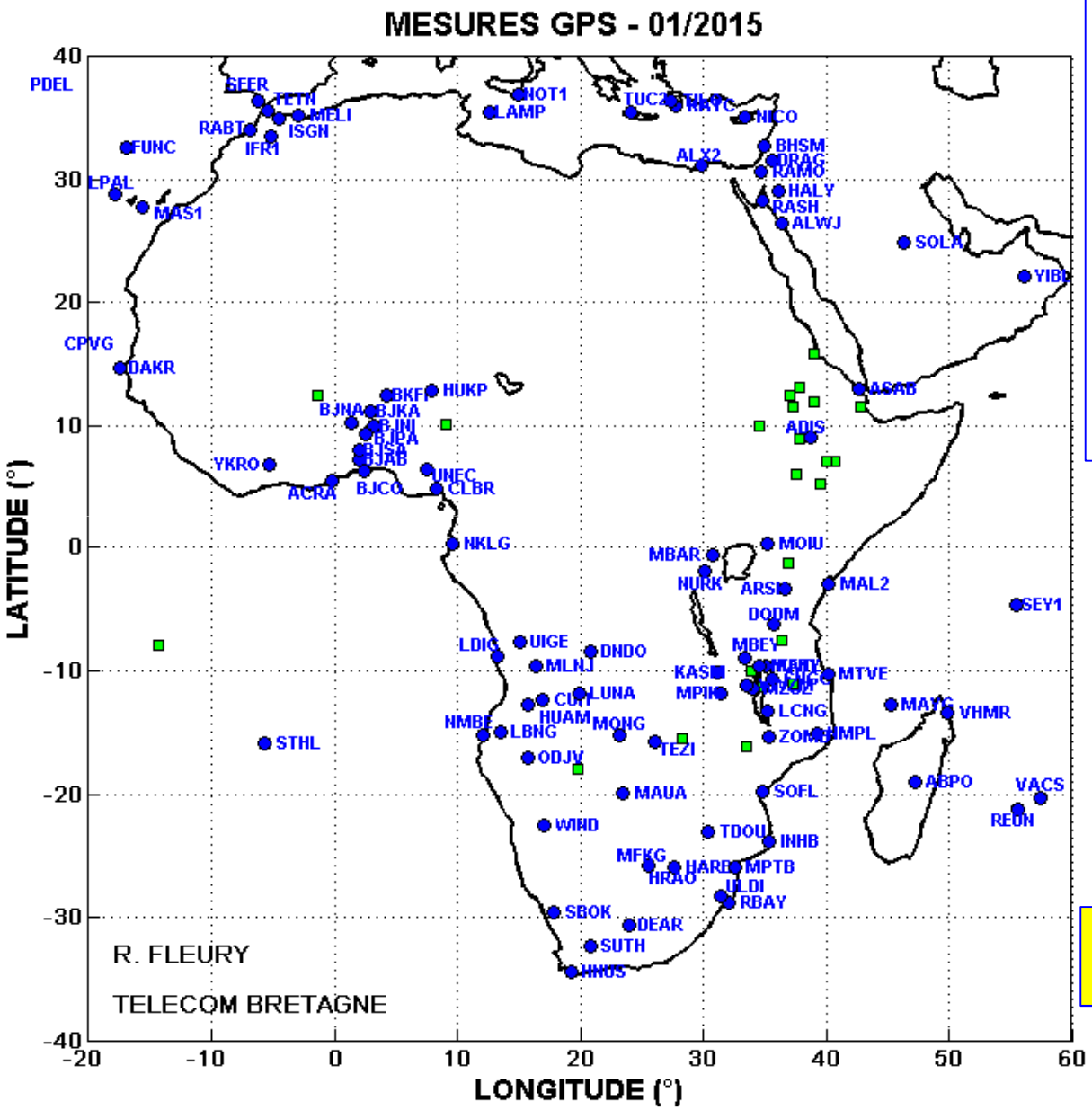






Provided by T. Tsugawa (NCIT, JAPAN)

GPS stations available on the web-2015



Increase of GNSS stations in Africa

~50 to ~150

2010 to 2015

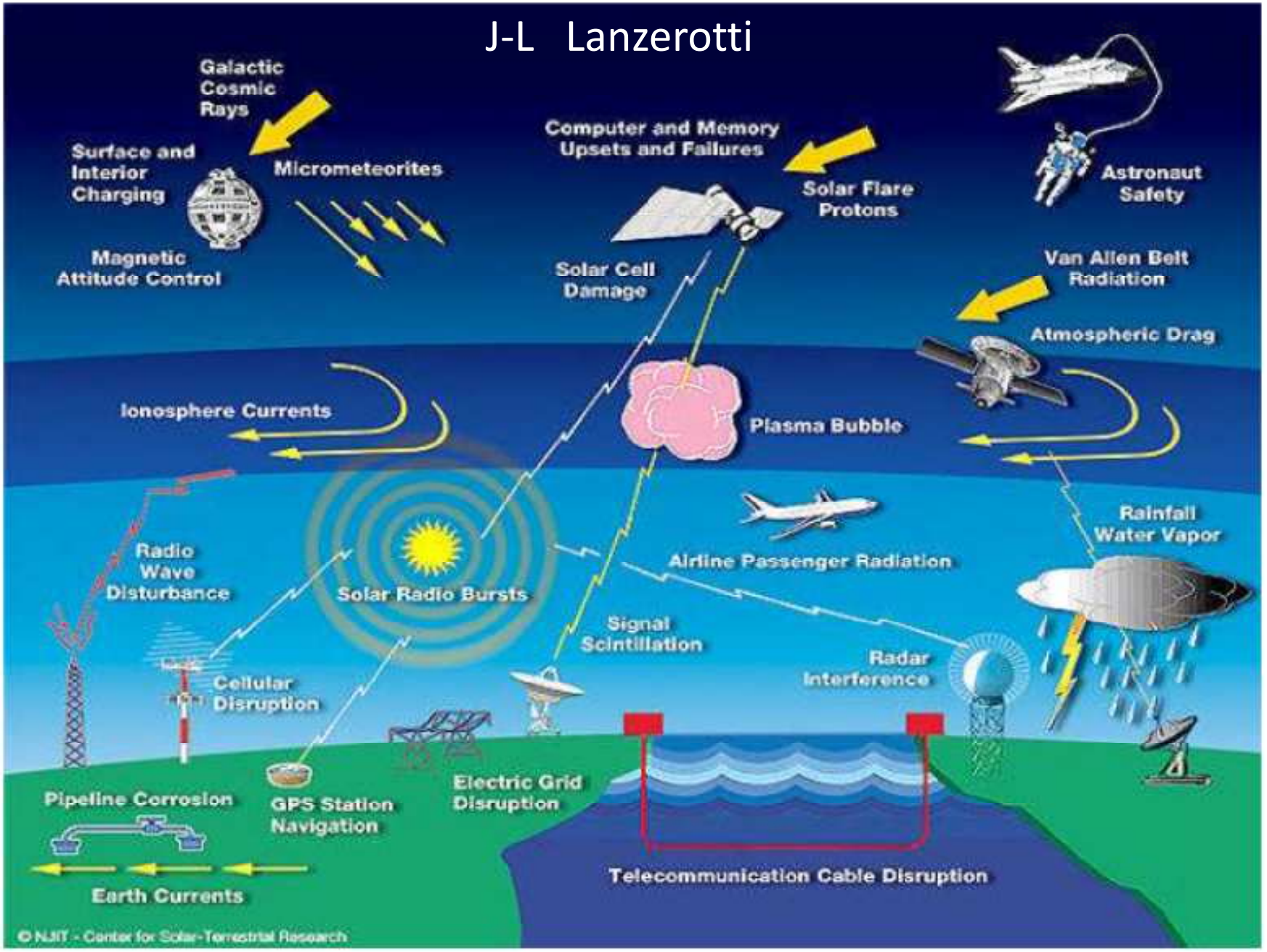
Mainly due to GEODESY

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

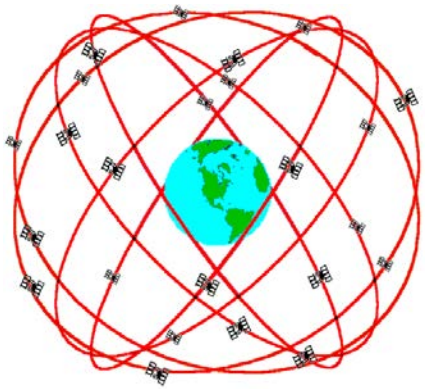
Necessity TO SHARE

Space Weather : effects on GNSS

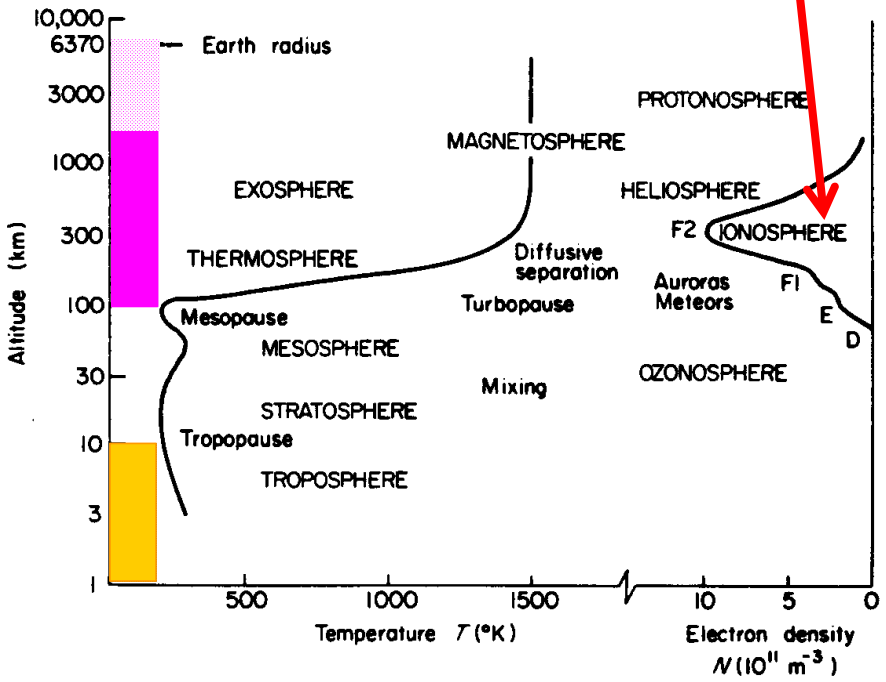
Integration of Physical processes in the Sun Earth system / effects on new technologies



The satellite signal is strongly modified by ionosphere and troposphere



TEC



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 ,TEC and scintillations**

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

11-30 km STRATOSPHERE
Turbulence

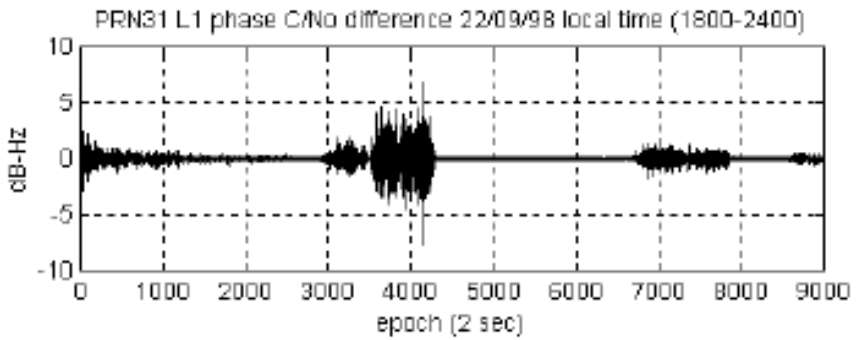
0-11 km TROPOSPHERE
Meteorological phenomena
Water Vapour content

Ionospheric propagation

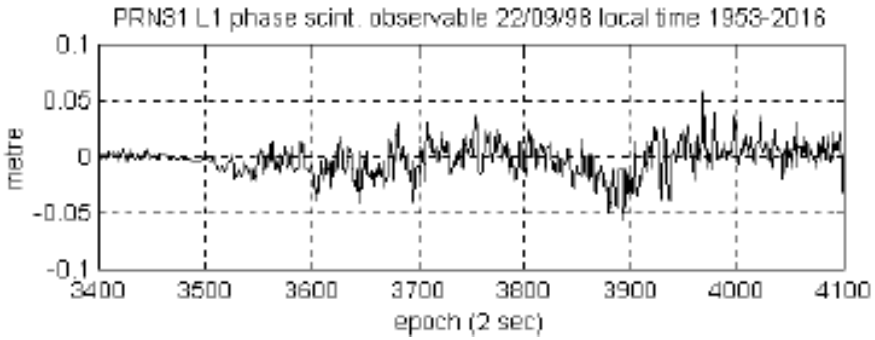
Scintillations

Fluctuations of the signal dues to the inhomogeneity of the medium

Scintillations of amplitude

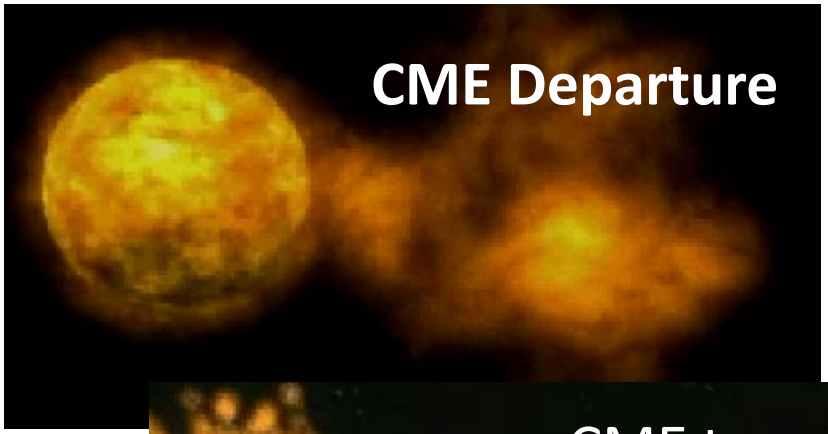


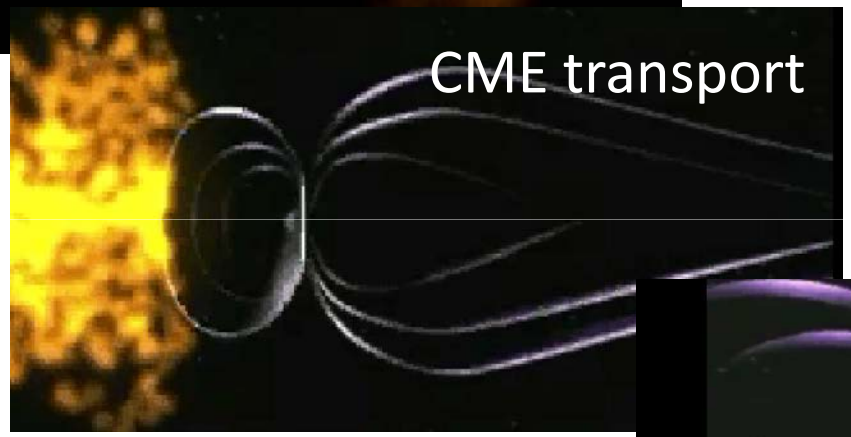
Scintillations of phase

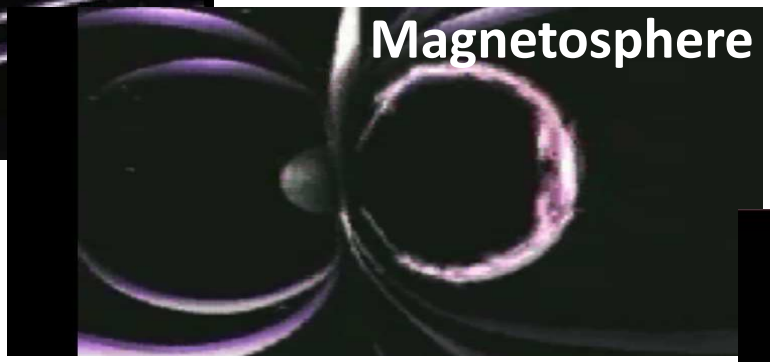


Echelles : ± 3 rad.

FROM the SUN to the EARTH



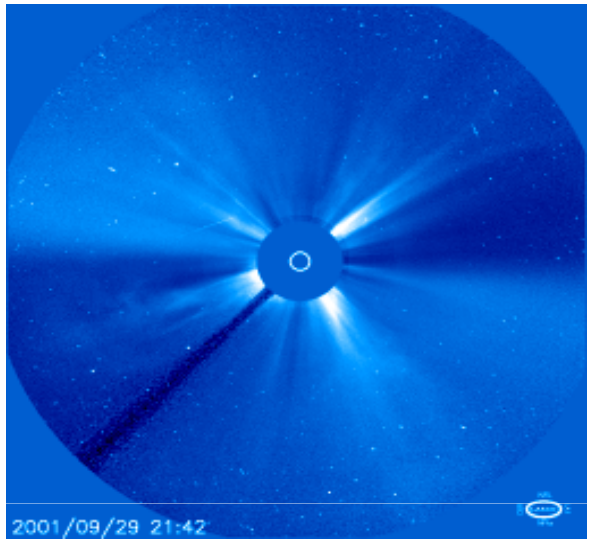


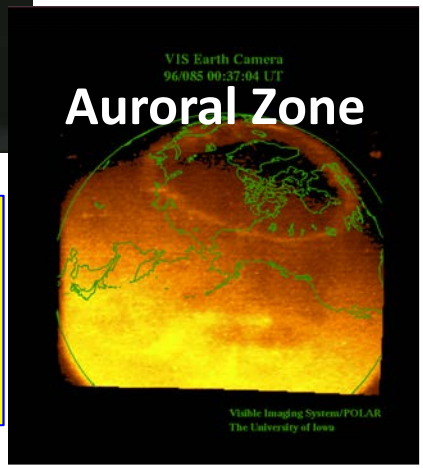


SOHO

Coronal Mass Ejection

Billions tons of matter ejected





NECESSITY TO TRAIN IN SPACE WEATHER ALL OVER THE WORLD

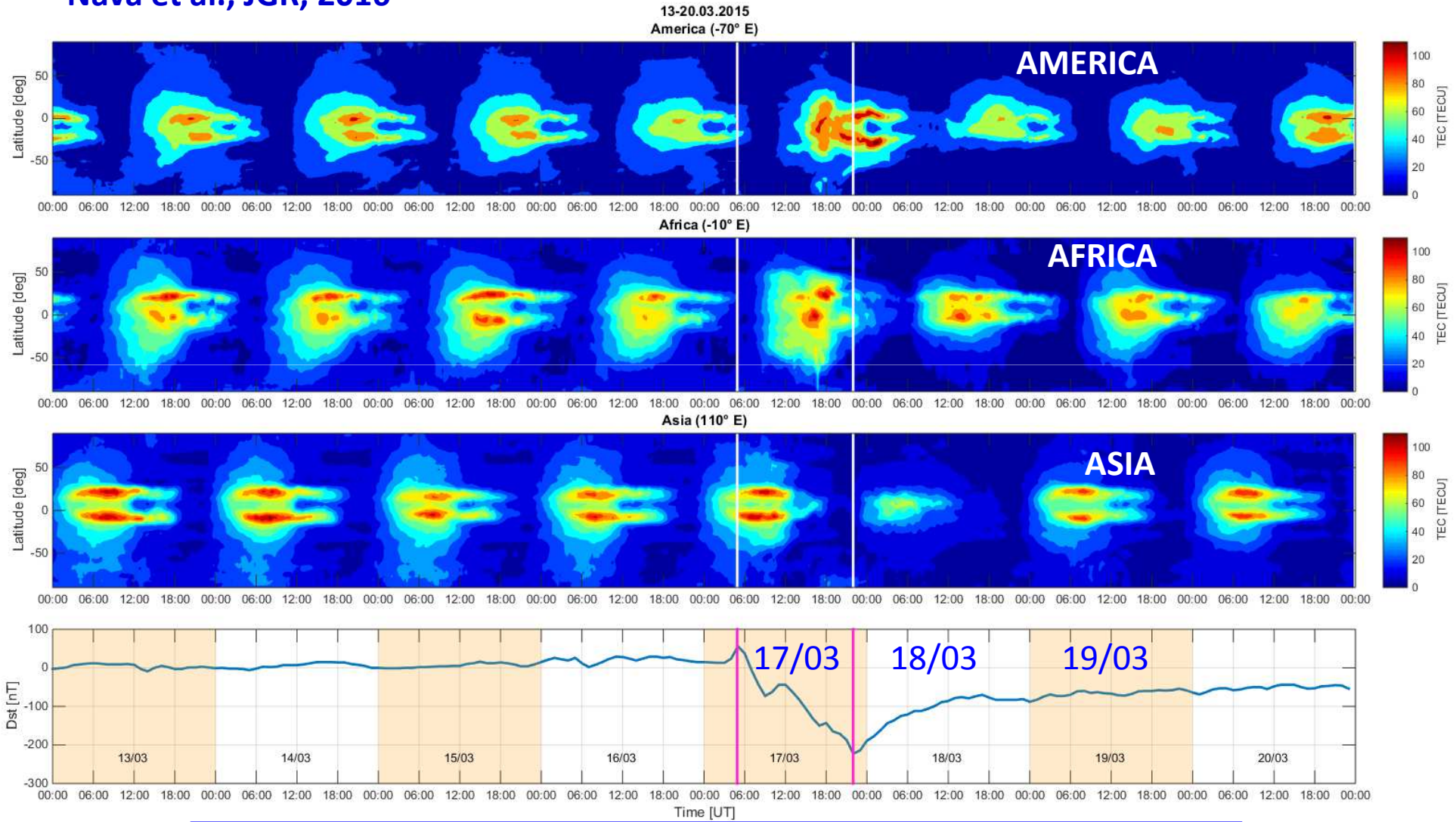
⇒ Merging of different scientific disciplines

⇒ Connection between Research and Applications

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

Basic GPS observables

- Code (pseudo-range):

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

- Phase (differenced wrt phase of local oscillator)

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

Distance Receiver-satellite

Clock offsets (dt = receiver dT = satellite)

Integer phase ambiguity number

Ionospheric delay

Tropospheric delay

Noise errors

CONGO 2009 [IHY]

EGYPT 2010[ISWI]

DRC 2011 [ISWI]

PHD in AFRICA

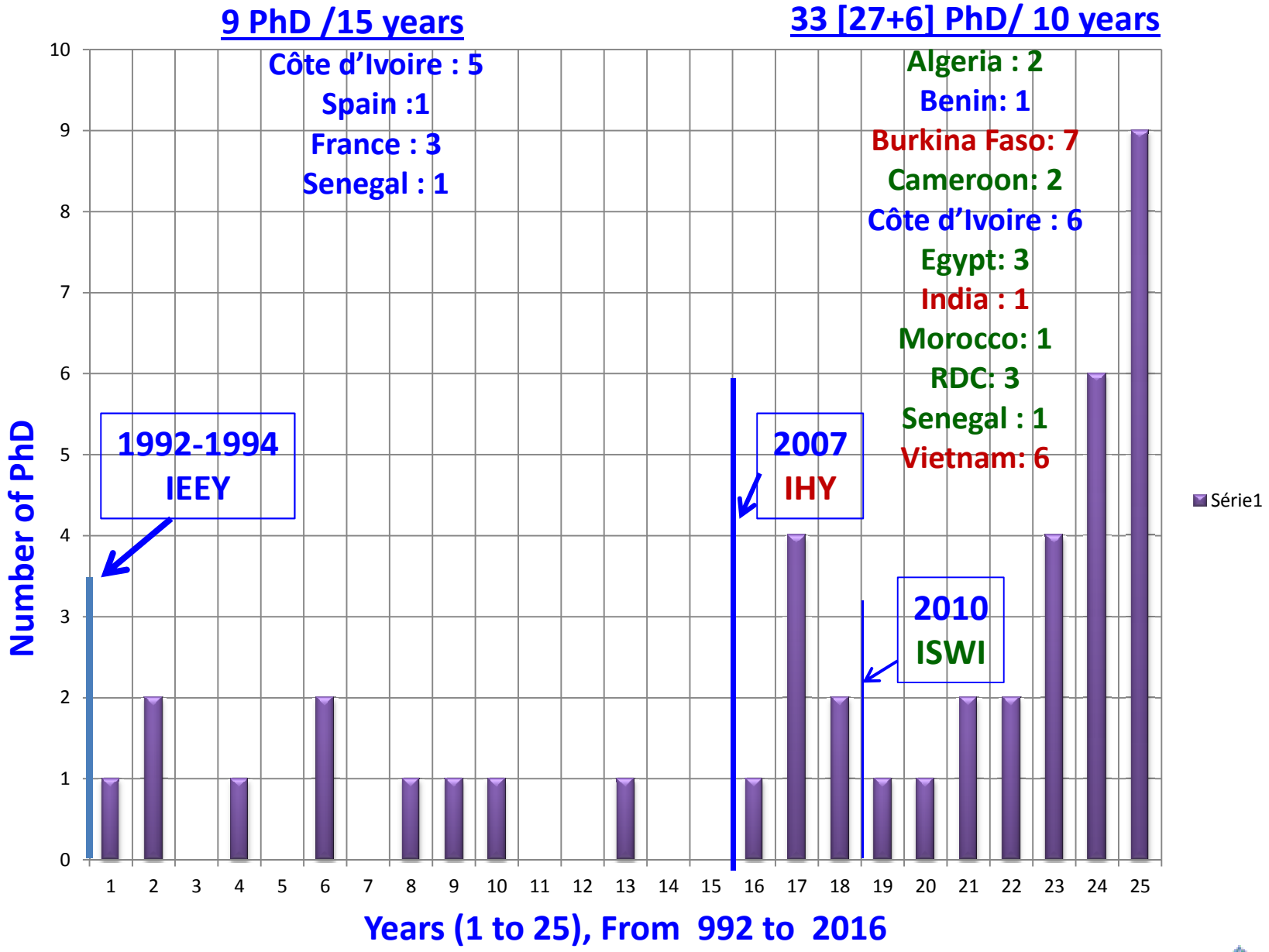
Scientific projects in the framework of UNBSSI
United Nations Basic Space Science Intitiative

IEEY: International Equatorial Electrojet year /1992-1994/
IHY: International Heliophysical Year /2007-2009/
ISWI: International Space Weather Initiative / 2010-2012/
=> Friendly framework ISWI

Methodology

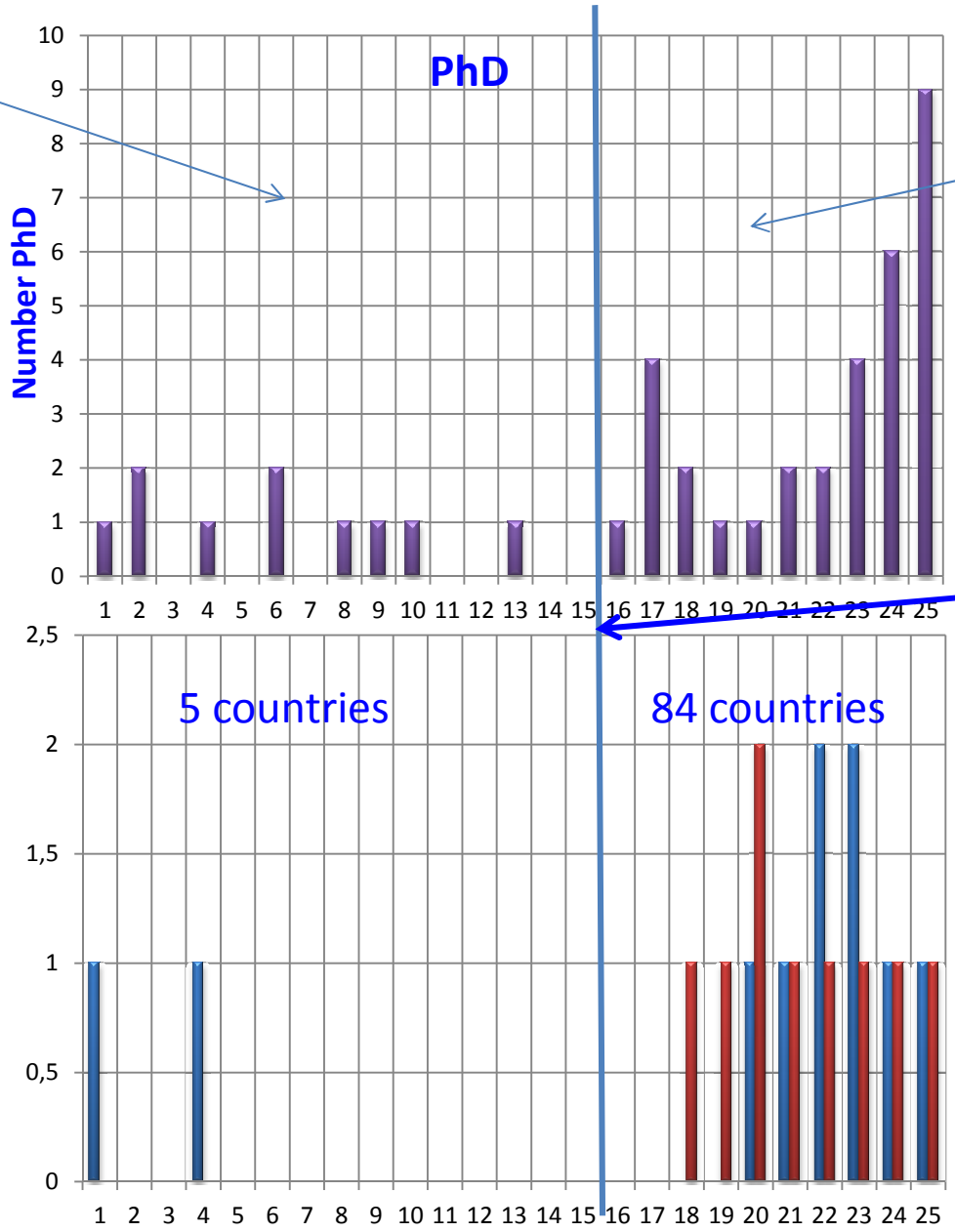
Schools
Distribution of tools and constitution of data base
PhD students
Positions at University
Curricula in Universities

Network ISWI : http://www.iswi-secretariat.org
84 countries



Results of the GIRGEA network 24 countries of ISWI network

1observatory in Côte d'Ivoire with expensive tools



Networks of Cheap instruments GPS Magnetometers Etc…

2007

Schools
Physics
GPS

Results of the GIRGEA network 24 countries of ISWI network

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 June 2016)

CRASTE-LF

Master of GNSS in the Regional Centers (affiliated to UN), by the past essentially on global positionning 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

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