TRAINING ON SPACE WEATHER IN DEVELOPING COUNTRIES

Christine Amory-Mazaudier
christine.amory@lpp.polytechnique.fr

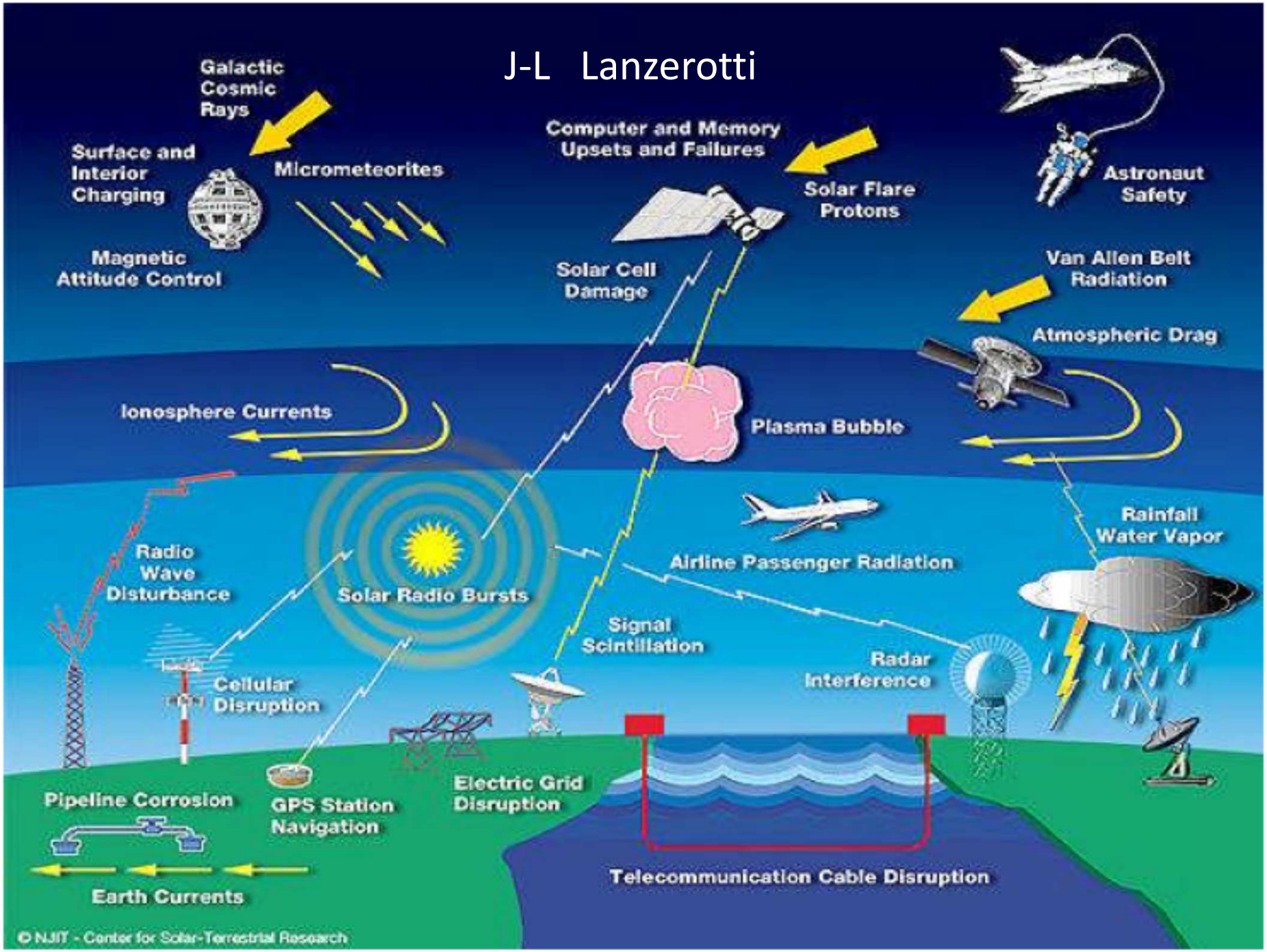
Sorbonne Paris, UPMC Univ. Paris VI, LPP, Paris, France
T/ICT4D, Abdus Salam International Centre for Theoretical Physics /Staff,Trieste, Italy

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

SUMMARY

- Definition of Space Weather
- Use of GPS
- Impact of CME on TEC measured by GPS
- Training on GPS
- Training on Sun Earth's Physics
- Methodology : Schools, PhD, Teams of research
- Conclusion

- **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-L Lanzerotti
Galactic Cosmic Rays
Surface and Interior Charging
Micrometeorites
Magnetic Attitude Control
Computer and Memory Upsets and Failures
Solar Flare Protons
Solar Cell Damage
Astronaut Safety
Van Allen Belt Radiation
Atmospheric Drag
Ionosphere Currents
Plasma Bubble
Radio Wave Disturbance
Solar Radio Bursts
Airline Passenger Radiation
Rainfall Water Vapor
Signal Scintillation
Radar Interference
Cellular Disruption
Pipeline Corrosion
GPS Station Navigation
Electric Grid Disruption
Telecommunication Cable Disruption
Earth Currents
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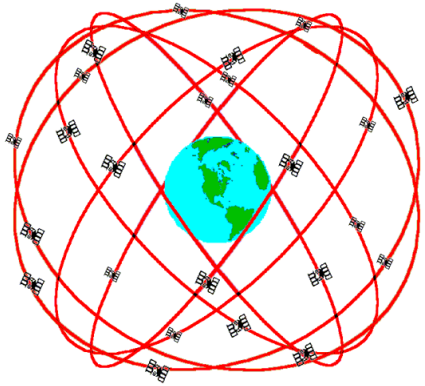
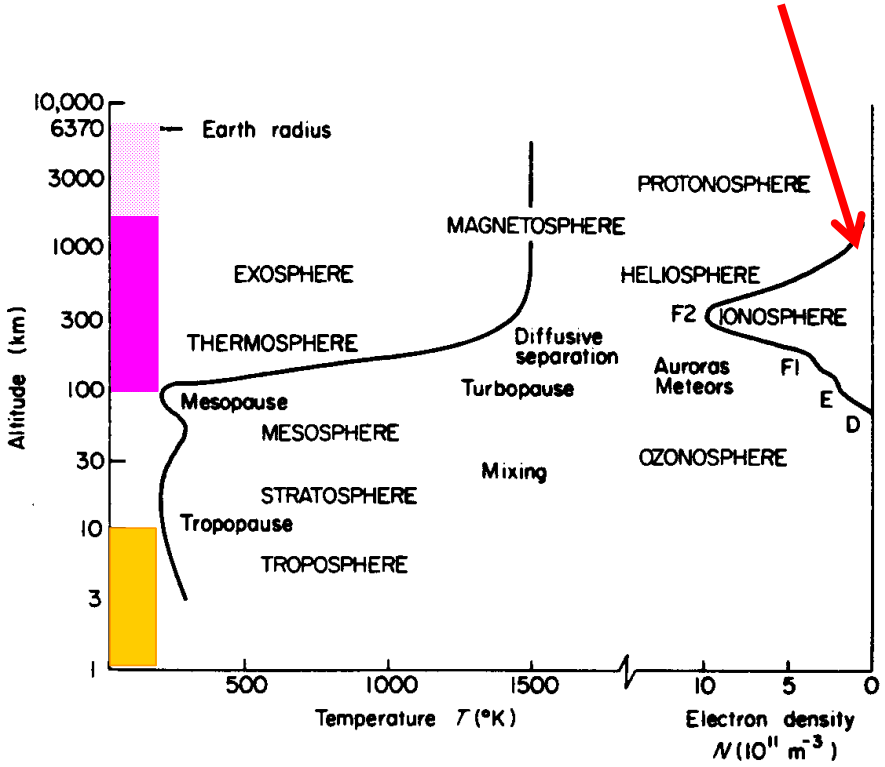


The satellite signal is strongly modified by ionosphere and troposphere

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

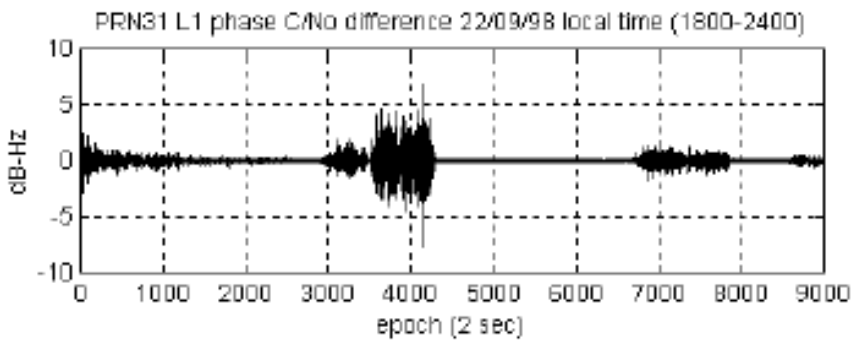
0-11 km TROPOSPHERE
Meteorological phenomena

Ionospheric propagation

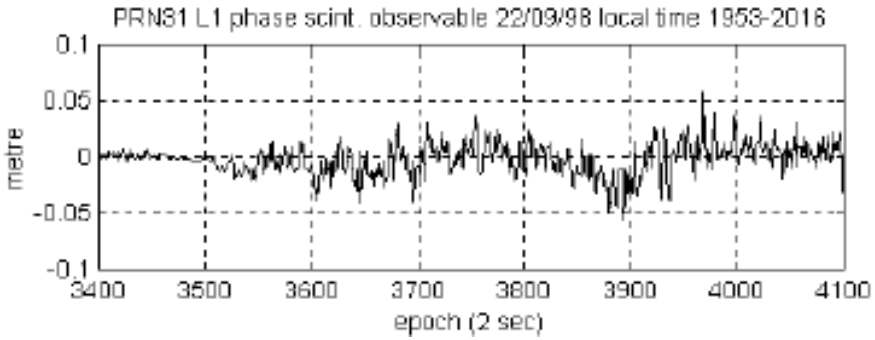
Scintillations

Fluctuations of the signal dues to the inhomogeneity of the medium

Scintillations of amplitude



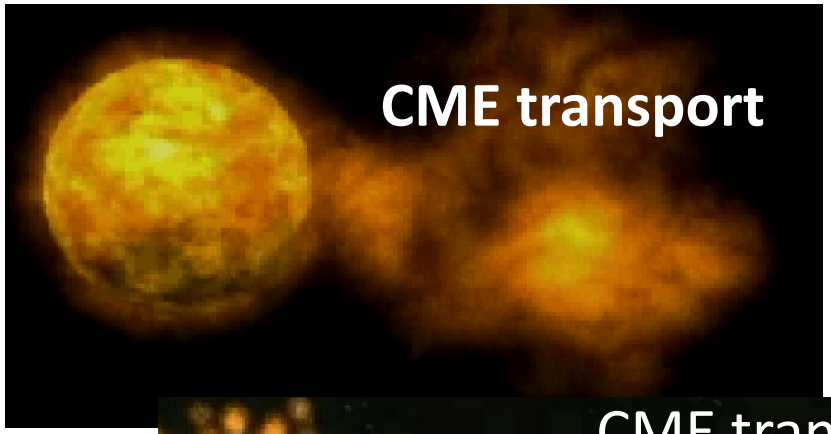
Scintillations of phase

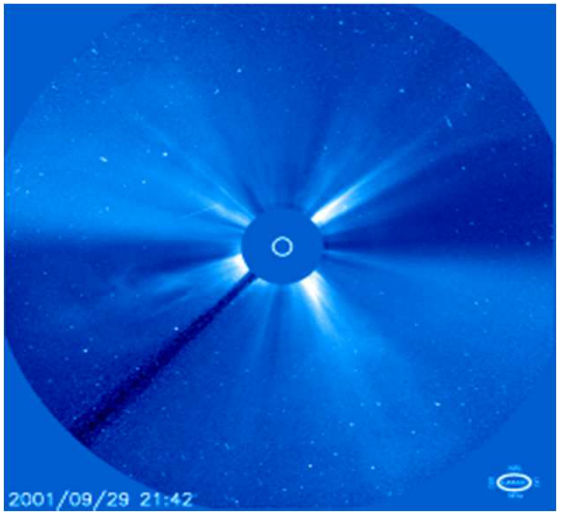


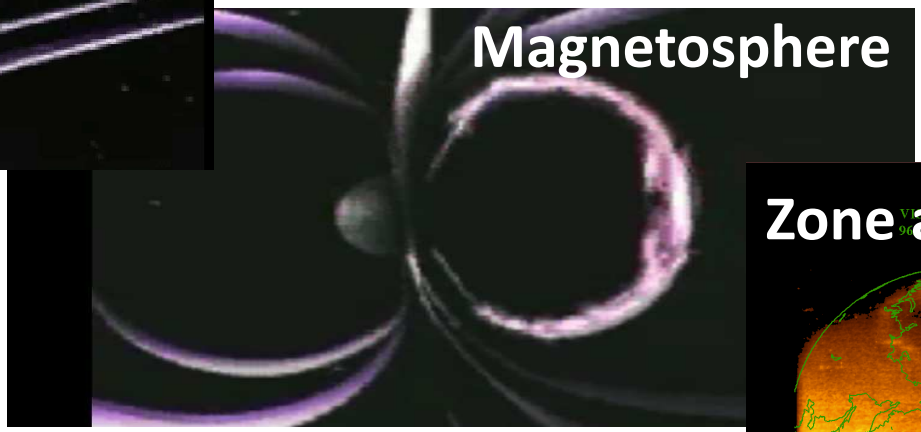
Echelles : ± 3 rad.

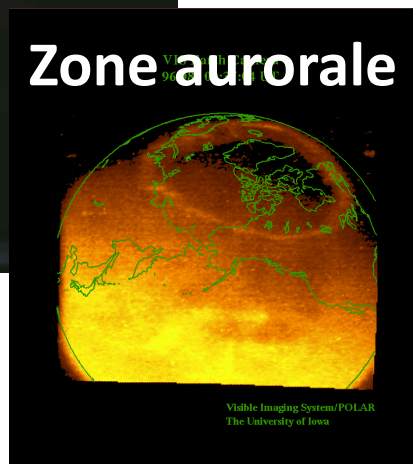
FROM the SUN to the EARTH

SOHO
Coronal Mass Ejection
Billions tons of matter







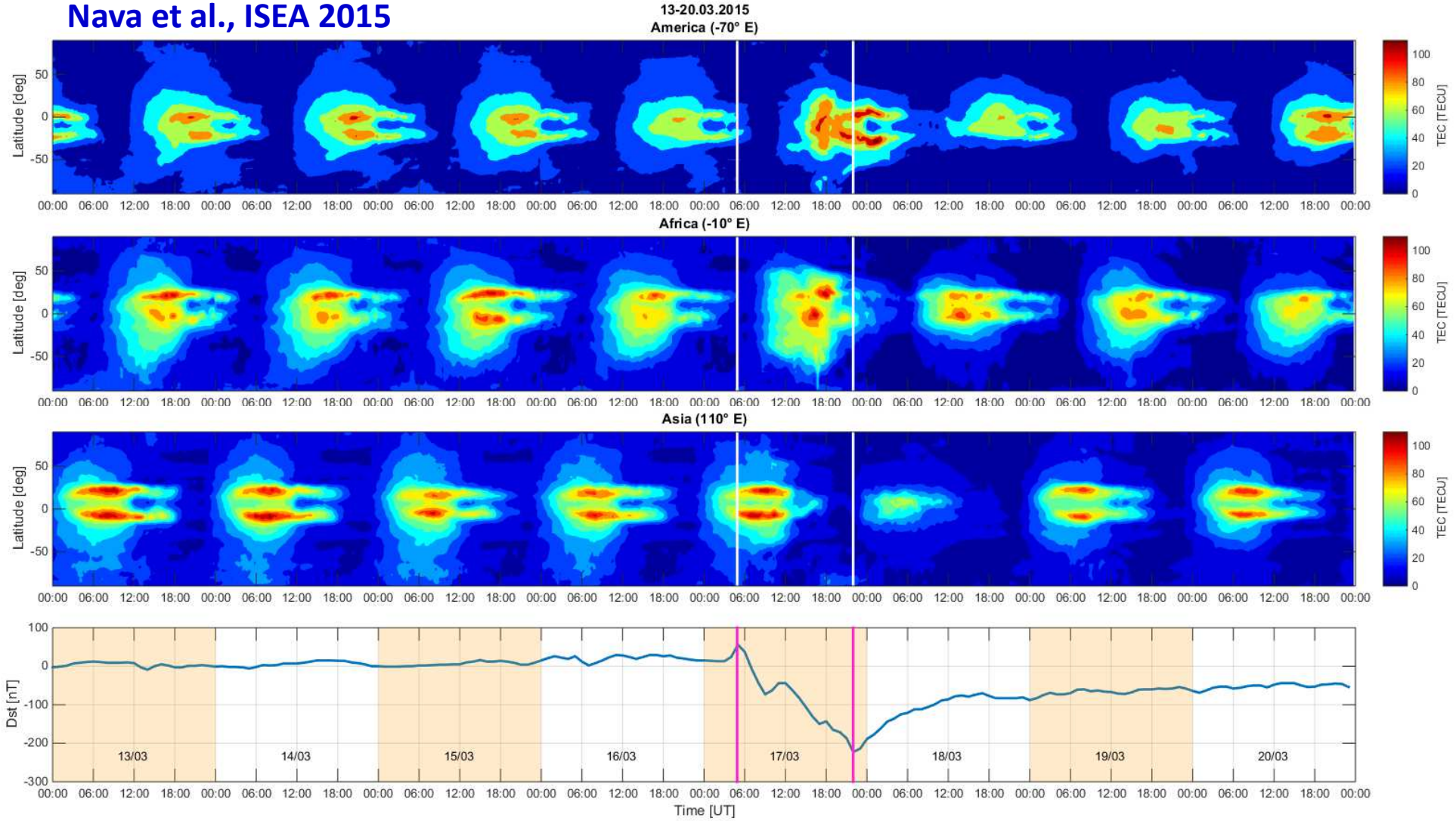


Necessity of knowledge on many physical processes

At equatorial latitudes : TEC variations on St Patrick's day storm

Physics of the connections between auroral and equatorial regions

Nava et al., ISEA 2015



Many developing countries are affected by equatorial phenomena

UNITED NATIONS BASIC SPACE SCIENCE INITIATIVE
UNBSSI (1991-2012)

Scientific programs to transfer the knowledge

International Equatorial Electrojet Year 1992-1994

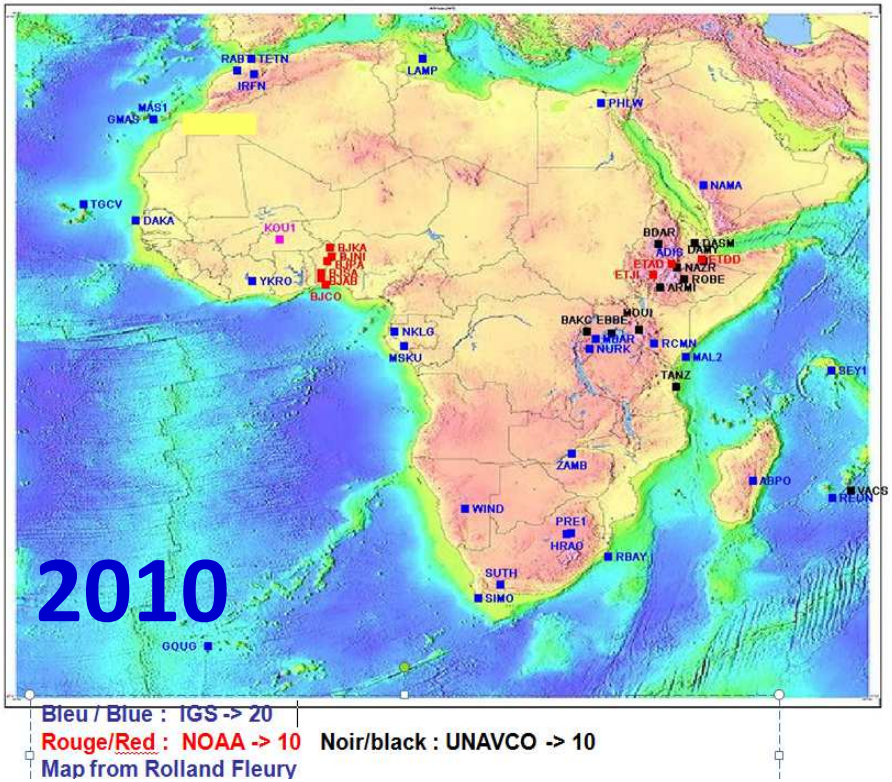
International Heliophysical Year 2007-2009

http://ihy2007.org

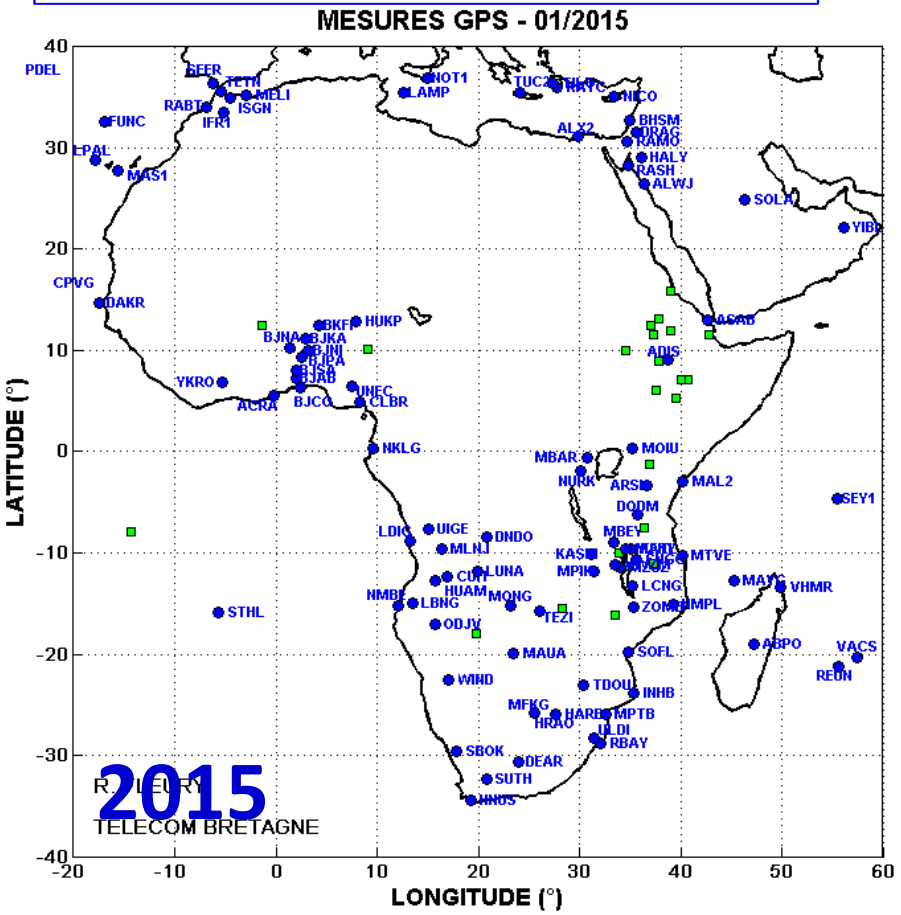
International Space Weather Initiative 2010-2012

http://www.iswi-secretariat.org

IHY and ISWI scientific programs: deployment of instruments



Increase of GNSS stations in Africa



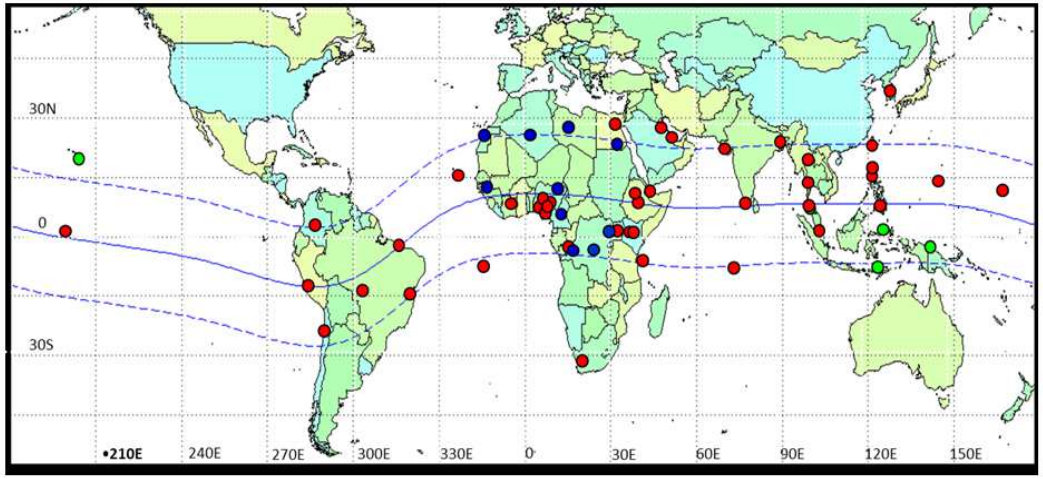
Many other GPS networks
Algeria, Burkina Faso, Egypt, Morocco
Rwanda, South Africa etc…

GPS stations available on the web

http://www.fas.org.org/spp/military/program/nssrm/initiatives/scinda.htm study of ionospheric scintillations

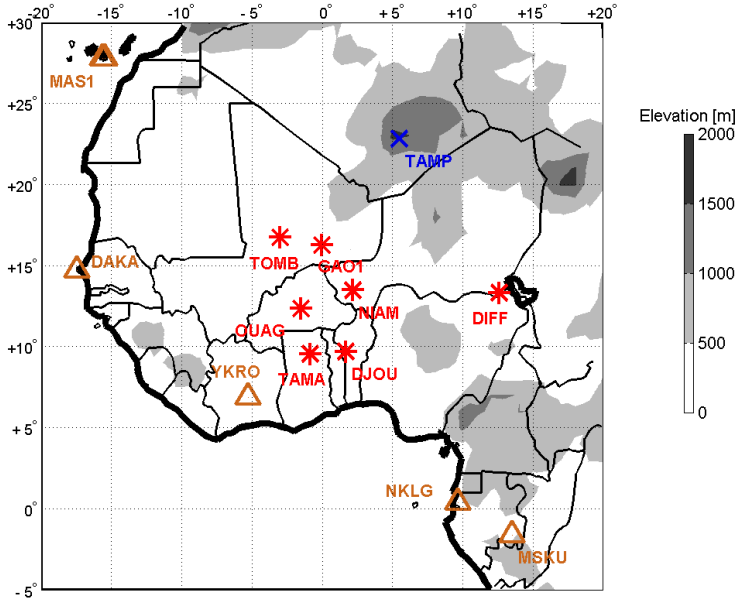
SCINDA Equatorial Ground Stations
Update 2013

Adopted from Paznokhov's ICTP lecture



Existing Sites; Future ISWI Sites;
Other/collaboration

http://www.amma-international.org
study of the African Monsoon



IHY/ISWI GPS networks
Data exchange policy

TRAINING BY INTERNATIONAL ORGANIZATIONS
GNSS

T/ICT4D Abdus Salam ICTP + Boston College
essentially on inospheric effects on GNSS
several schools each year at Trieste

The Abdus Salam International Centre for Theoretical Physics

Master of GNSS in the UN Centres
(on each continent)
essentially on global positionning

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

Schools on GPS/ all disciplines (GIRGEA)

Scientific project	Country/year	Training Organizer in the country	Participants	Main financial supports
IHY French	Congo 2009	GPS, GIS and Introduction to Space Weather/ 7 days Bienvenue Dinga	30	Congo ~ 18% France Microsoft
ISWI* English	Egypt 2010	GPS, GIS, new technologies Data base and Introduction to Space Weather/2weeks Ayman Marhous	50	Egypte ~50% France Microsoft
ISWI* French English	DRC 2011	GPS, GIS, new technologies Data base and Introduction to Space Weather/2weeks Bruno Kahindo	90	DRC ~75% France Microsoft
ISWI French	France 2011	GPS data processing PhD students / 5 days Roland Fleury	4	Participants (ticket) France
ISWI French	France 2012	GPS data processing PhD students/5days / R. Fleury	4	Participants (ticket) France
ISWI French	France 2013	GPS data processing PhD students/5days / R. Fleury	4	Participants (Ticket) France
ISWI French	Morocco CRASTE-LF 2015	GPS data processing and use of data for different fields of research M2 and PhD	30	UN, France Craste-LF

CONGO 2009 [IHY]

French spoken : 100%

ISWI letter Vol 2 n°75

EGYPT 2010[ISWI]

English spoken : 100%

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

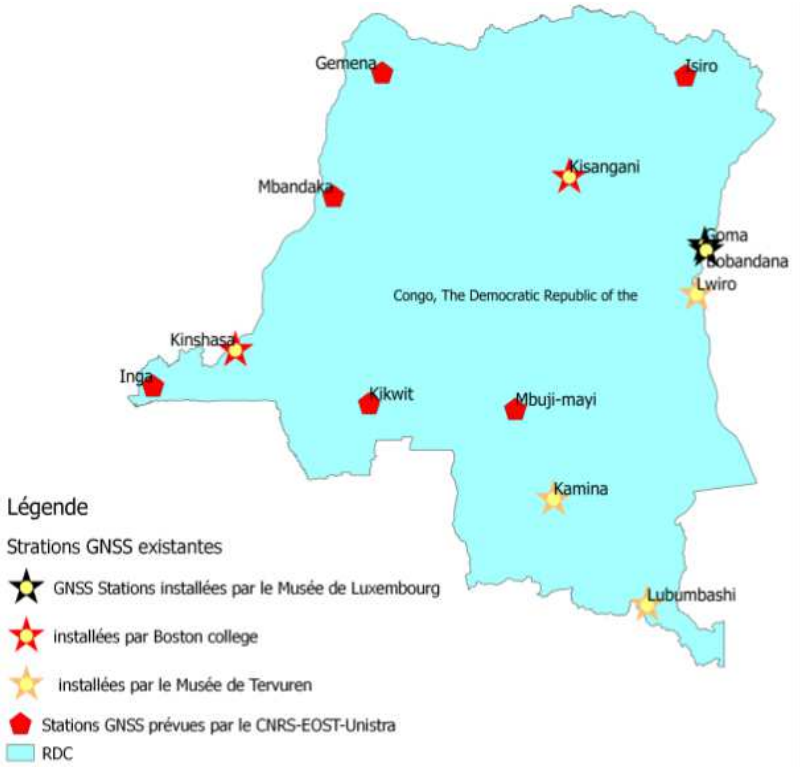
Lecture room of the ERAIFT

Rooms for practical work

Room of OSFAC

Room of ERAIFT

School in Republic Democratic of Congo, at Kinshasa
September 2011 / 2 weeks



Opening ceremony with 2 Ministers

Minister of education and higher education: Léonard Mashako Mamba

Minister des Hydrocarbons: Célestin Mbuyu Kabango

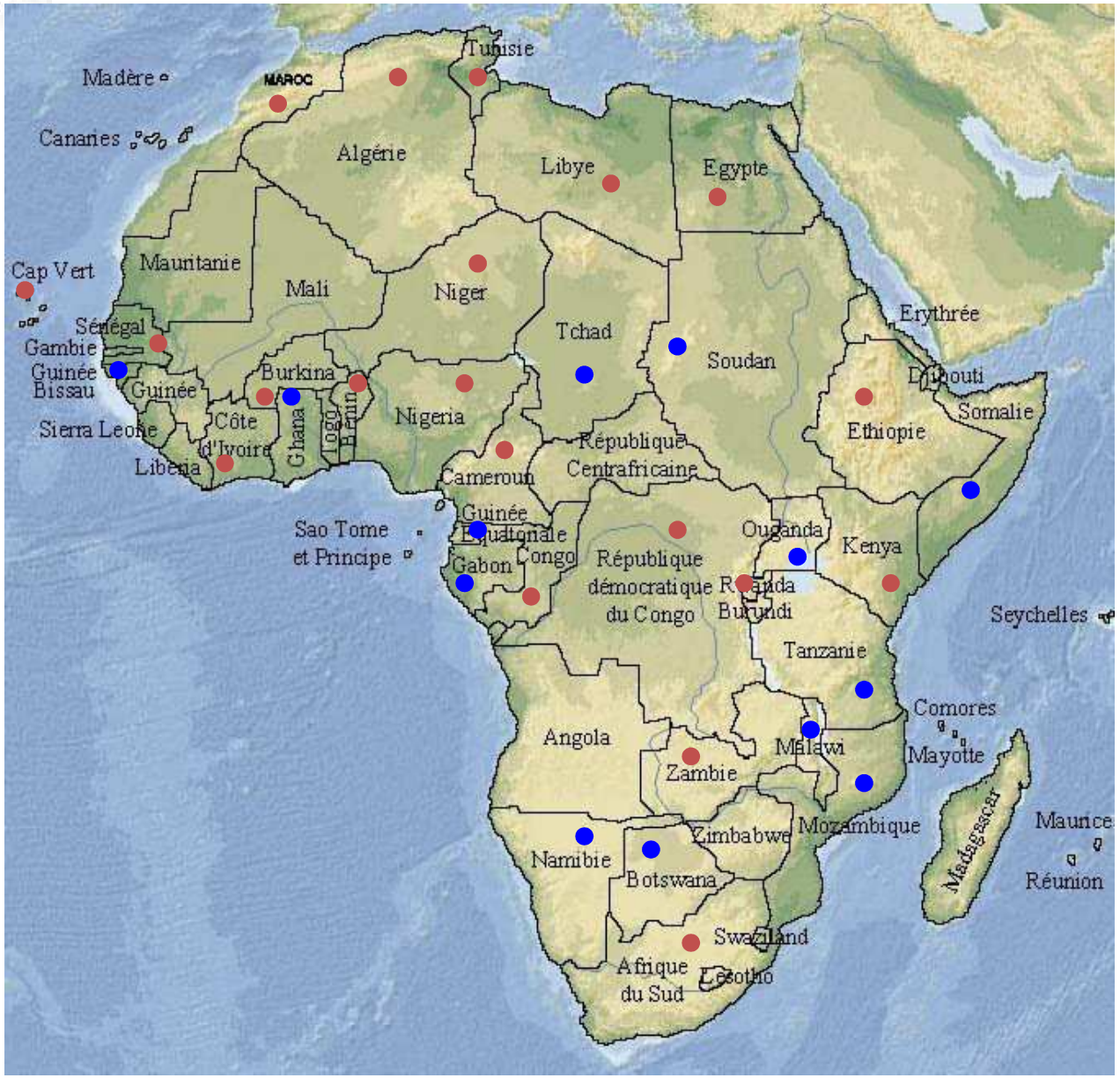
General secretary of Academia : Prosper Kanyakongote Mpangazehe

Capacity building in DRC : 11 students (9 in physics, 2 computer science)

SOLAR TERRESTRIAL PHYSICS/ EXAMPLE GIRGEA-AFRICA

Scientific project	Country/year	Training Organizer in the country	Participants	Main financial supports
IEEY French	France 1992	Physical process in the Sun earth system + technical training in laboratories PhD students / 6 weeks Christine Amory-Mazaudier	5	France ~100%
IEEY French	Côte d'Ivoire 1995	Physical process in the Sun earth system/2 weeks Students M2 Antoine Achy Séka	30	Côte d'Ivoire ~ 50% France
ISWI* French	Morroco CRASTE-LF 2011	Physical process in the sun earth system / Student M2/2 weeks C. Amory-Mazaudier A. Touzani N. Vilmer	28	France NASA UN
ISWI* French	Algeria 2013	Physical process in the Sun earth system / Students M2/2weeks Naima Zaourar	30	Algeria ~94% France
ISWI French English	Morocco 2014	Physical process in the sun earth system /Student M2/6 days Azziza Bounhir	30	Morocco France others
ISWI English	NIGERIA National school each year since 2012	Space Weather Babatunde Rabiu	70	Nigeria
ISWI French	Maghreb /West Africa Each 2 years 2017:Côte d'Ivoire	Space Weather Vafi Doumbia + Naima Zaourar		National and international

- African countries with a coordinator ISWI (20 among 82 = 24%)
- Countries with tool and no coordinator ISWI (13)



• Conclusions

- Scientific tools leads to sustainable research in Africa, particularly GPS receivers (not expensive)
- 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
- Work of international organizations (politic and scientific)
- **ISWI next meeting of the steering committee on 19 February 2016, Vienna**