The need for training integrating knowledge from the Sun to the Earth

80% of the data is not anayzed

IHY /10 years later

UNIVERSAL PHYSICAL PROCESS : DYNAMO

SYSTEMIC APPROACH

Example of Solar Flare

HISTORY

From IGY the CEJ

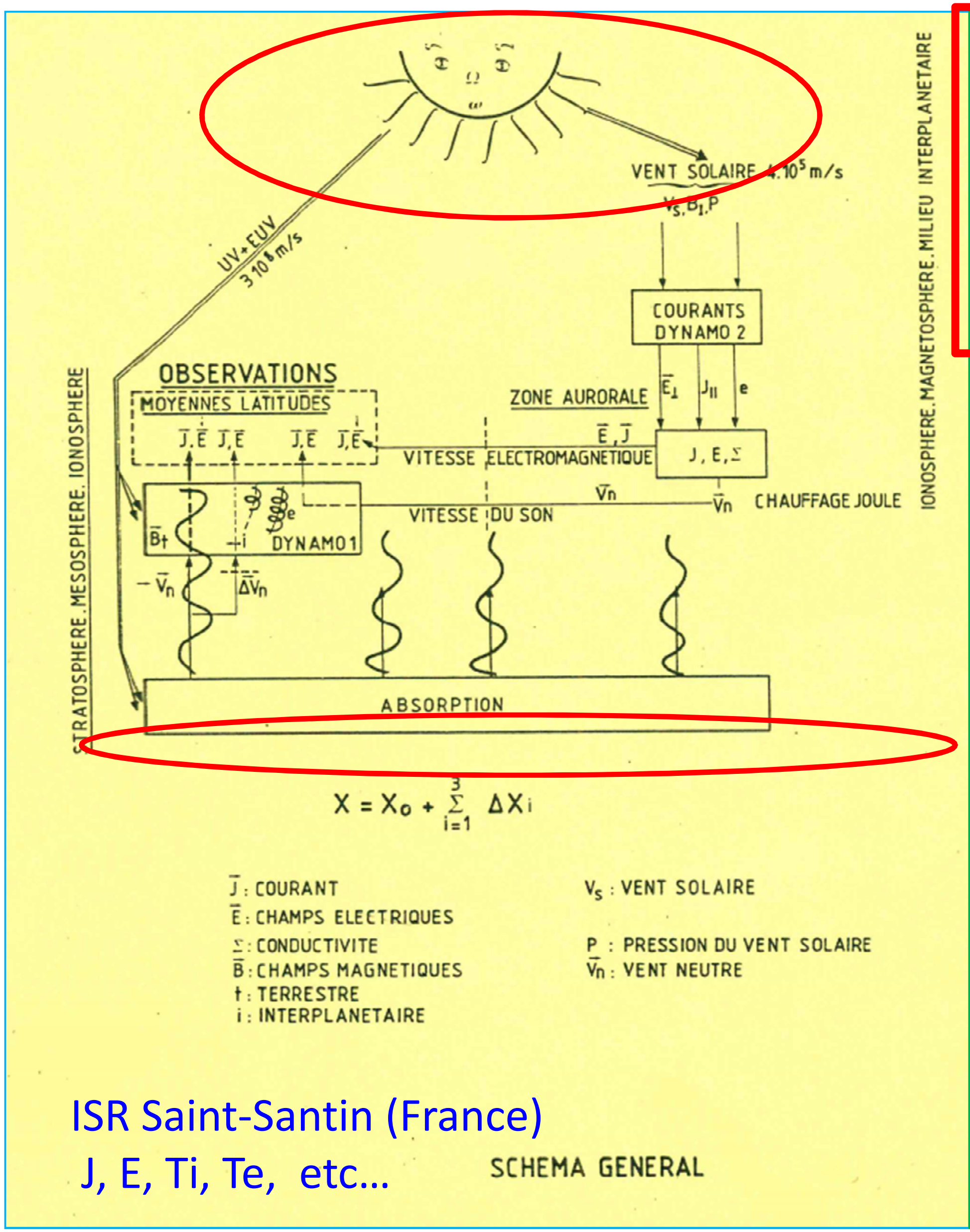
NEW TRAINING

THE PERENNIALTY IS ASSURED

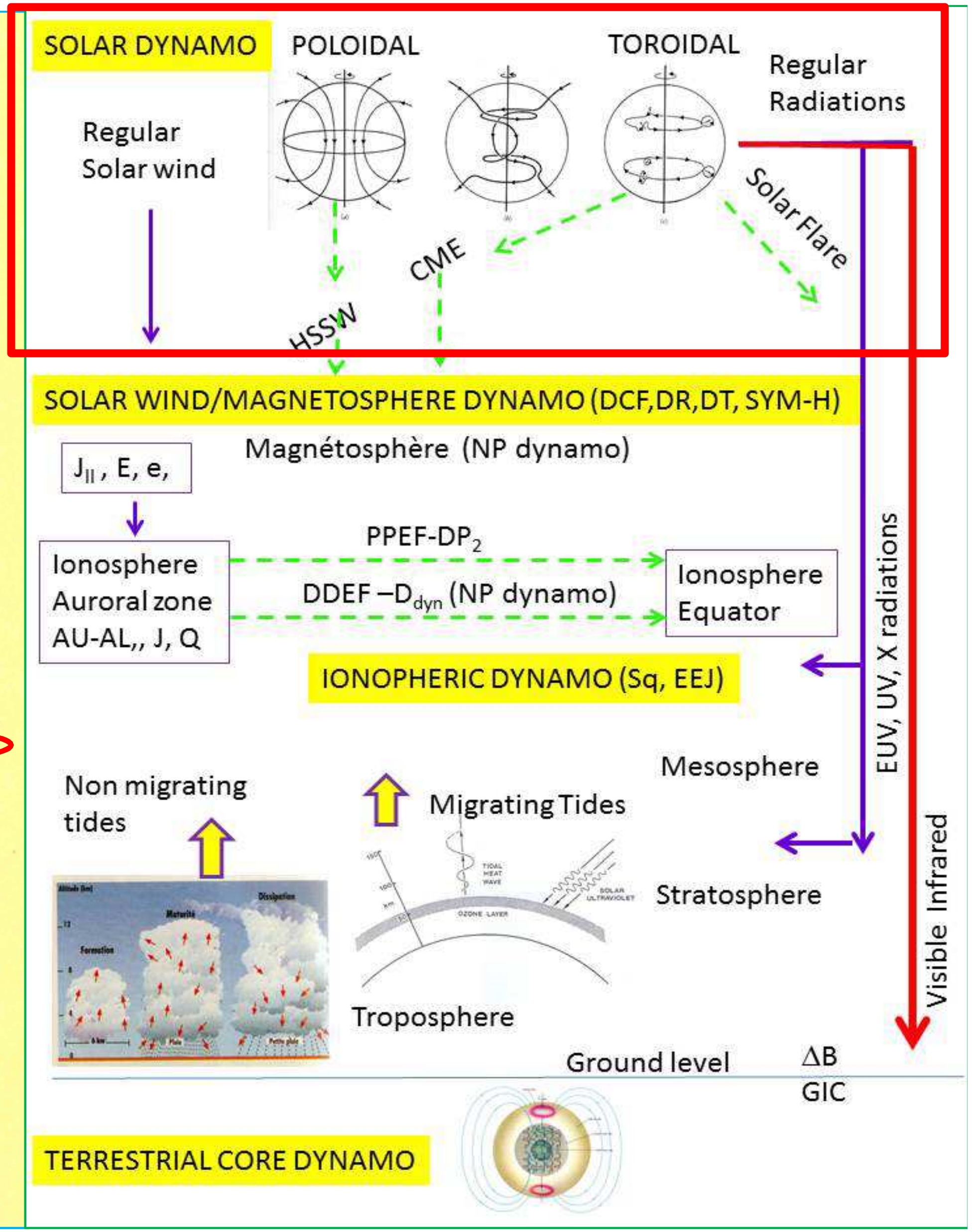
1983

2017

IHY

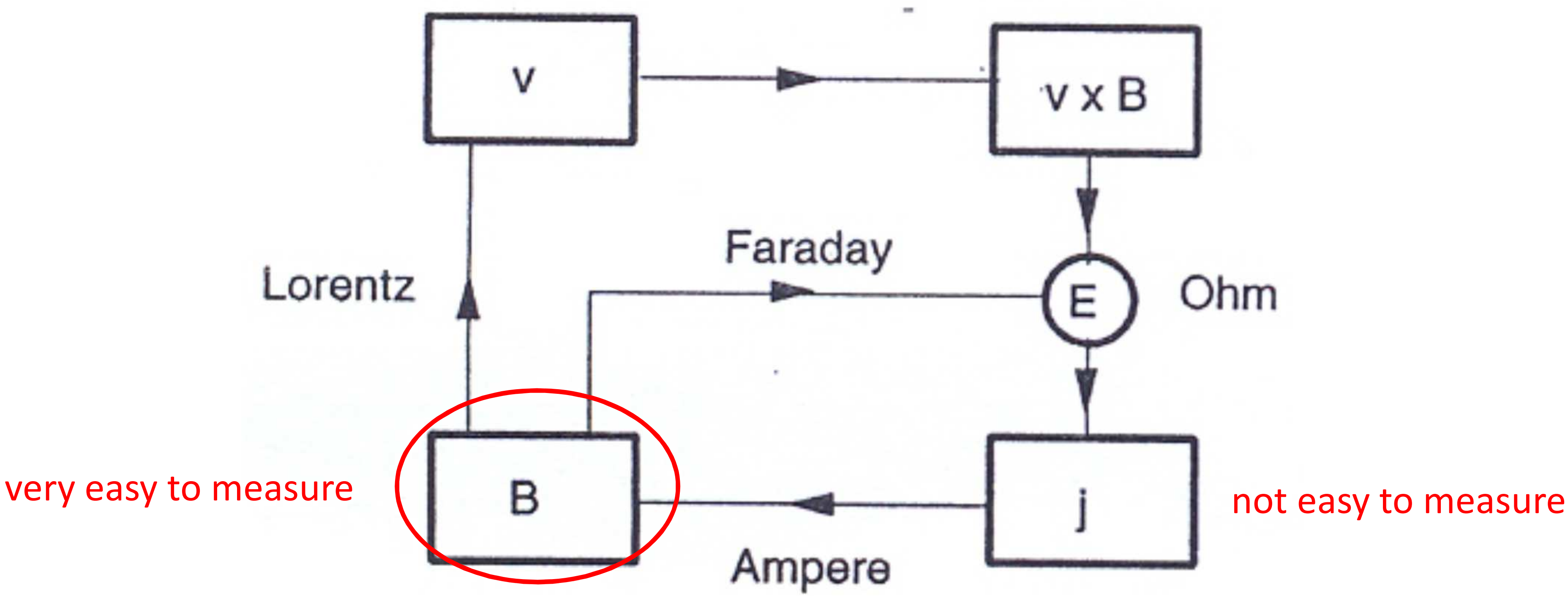


Amory-Mazaudier, 1983



Amory-Mazaudier et al., 2017

Universal physical process : DYNAMO
Large scale phenomena impacting the Earth's magnetic field

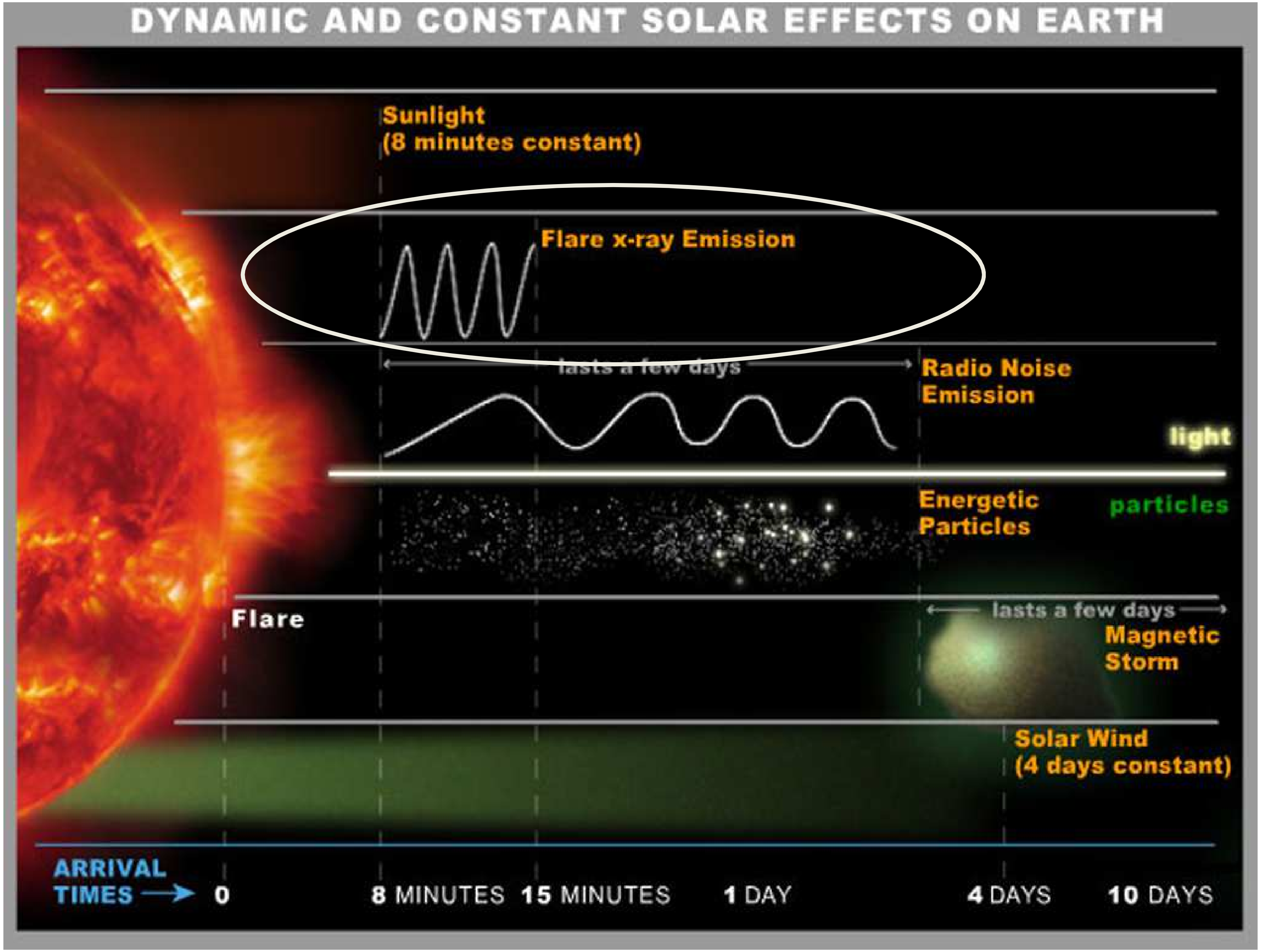


Schematic representation between plasma motion and magnetic field [after Paterno, 2006]. Comments by Paterno 'A motion v across a magnetic field B induces an electric field vxB, which produces an electric current J=σ (E + v×B) via Ohm's law where σ is the electric conductivity and E an electric field. This current produces in turn a magnetic field ∇XB = μJ, where μ is the permeability. The magnetic field creates both electric field E through Faraday's law ∇ E =-δB/δt and Lorentz force J×B which reacts on the motion

Need to integrate physical processes without losing the knowledge built in each field of research during the previous decades

Need for a systemic approach with all data and all models

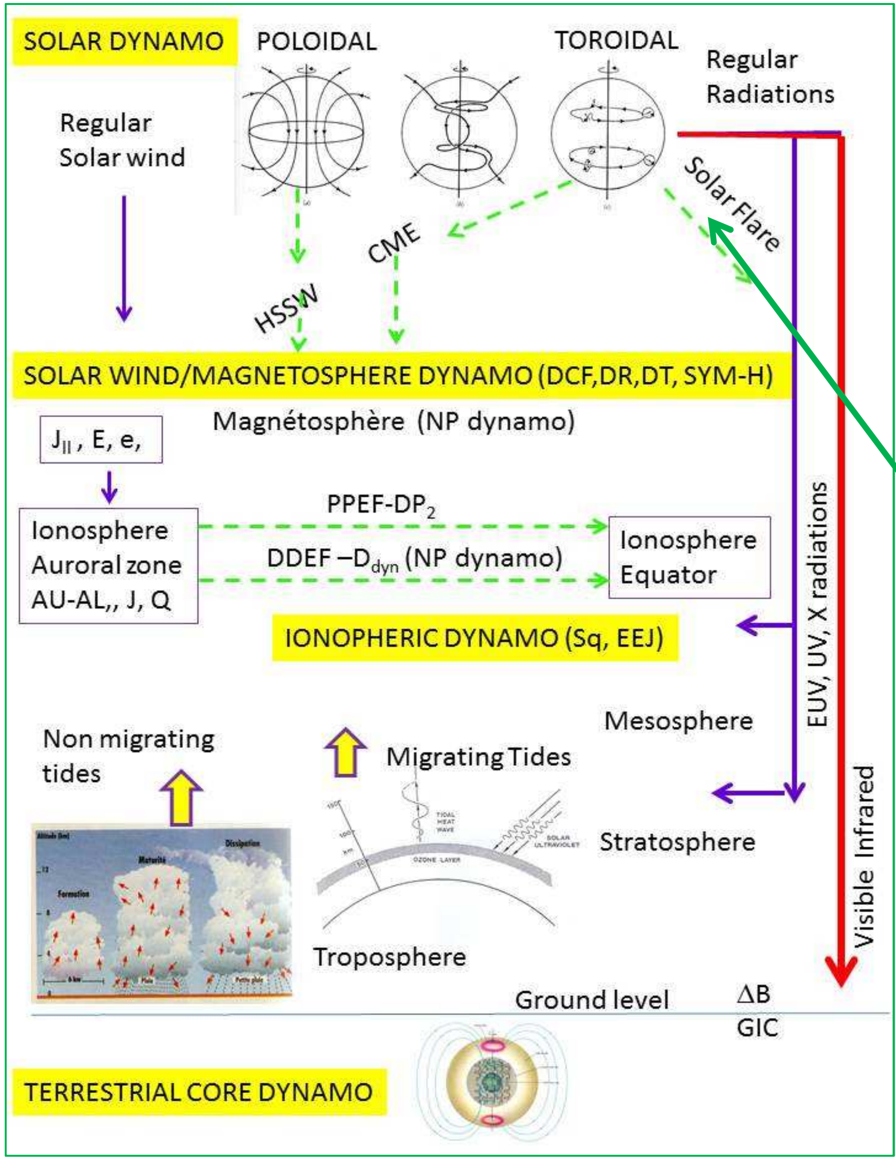
EMISSIONS FROM THE SUN

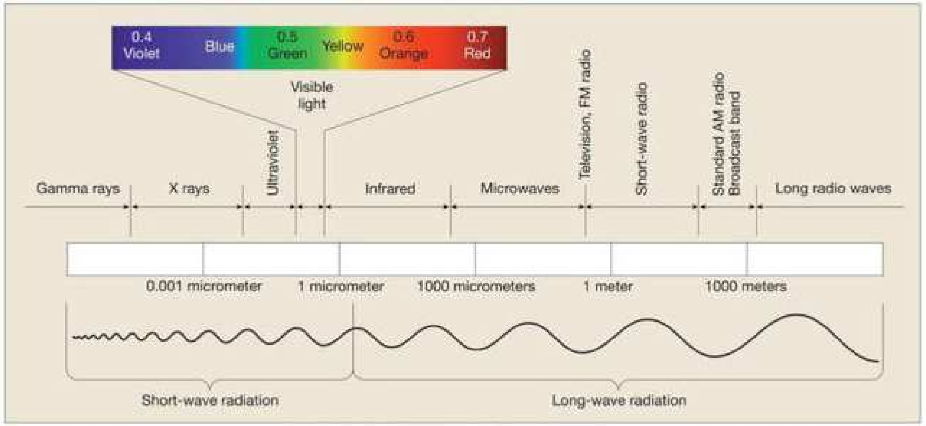


from Nasa website

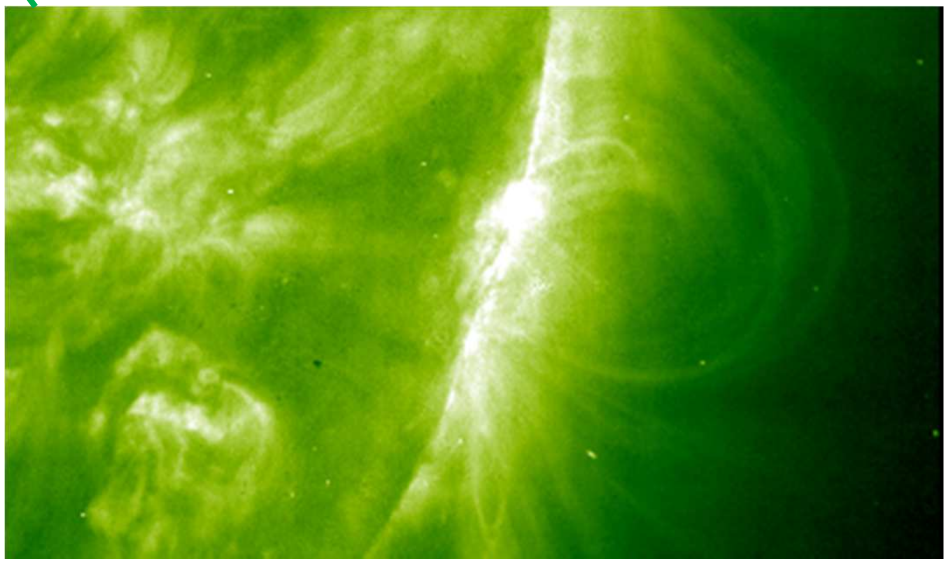
Case studies : solar flare,
no interaction with the magnetosphere

Radiation channel

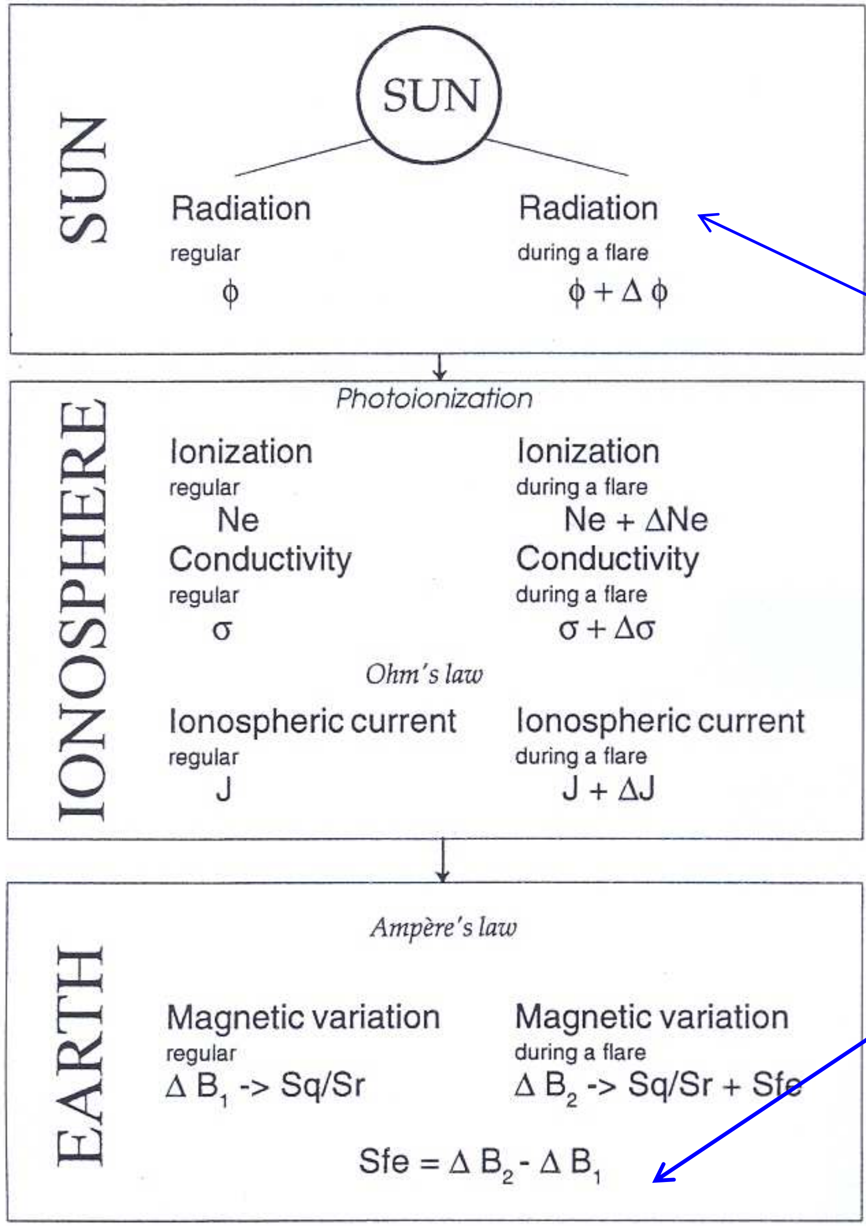


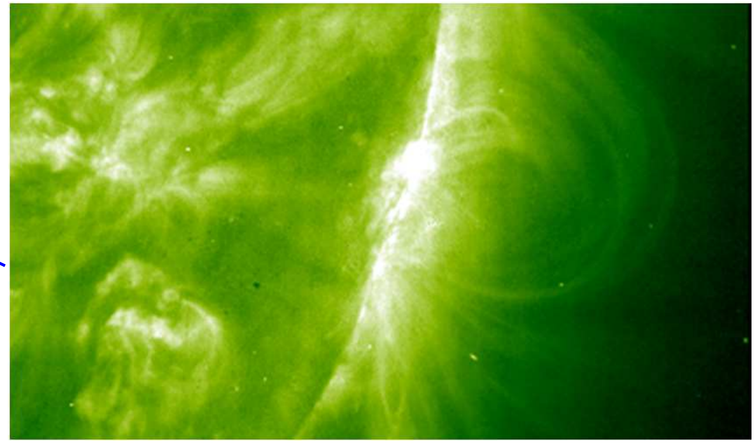


Copyright © 2007 Pearson Prentice Hall, Inc.



Observatory of Ebre -J.J Curto PhD 1992 and Curto et al., JGR 1994





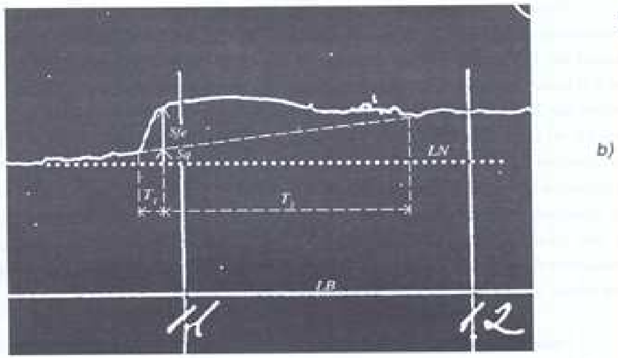


Fig. III.1 *Registro magnético de un sfe en Ebro (dibujo superior) y detalle del mismo sfe para la componente H (dibujo inferior).*

Magnetic variation : crochet

Sometimes the crochet is reversed

WHY ?

Ionospheric dynamo

Dynamo layer 90-160km

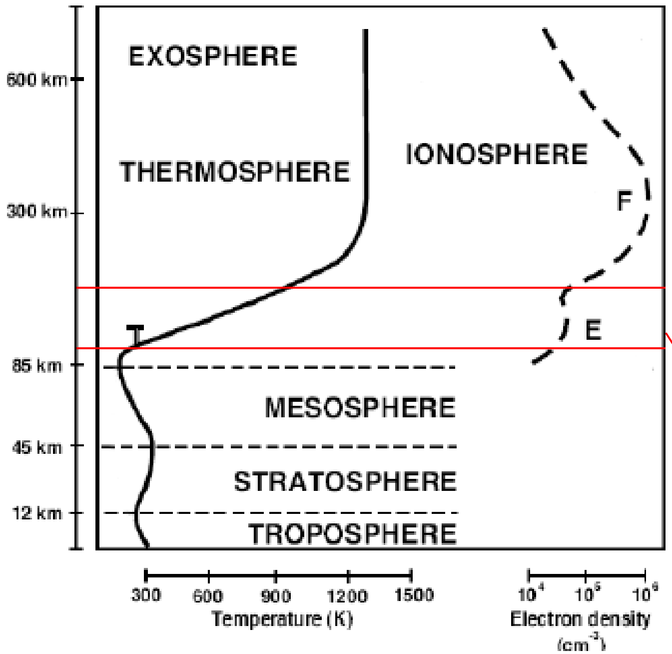


Table 1. Main Processes and Related Models Used.

	Source	
	Sun Processes	
Models		
regular radiation flux	*Heroux et al.* [1974]	1
flare radiation flux	*Donnelly* [1976]	
	Ionosphere Processes	
Equations		
ion production rate	*Dymek* [1989]	
continuity equation	*Dymek* [1989]	2
collision frequencies	*Stubbe* [1968]	
Conductivity tensor (σ)	$\bar{\bar{\sigma}} = \begin{pmatrix} \sigma_P & \sigma_H & 0 \\ -\sigma_H & \sigma_P & 0 \\ 0 & 0 & \sigma_{//} \end{pmatrix}$	
Ohm's law	$J = \sigma\ (E_p + V_n x B)$	3
Models		
Neutral composition	*Hedin* [1987]	
Ion composition	*Oliver* [1975]	
Electric fields (Ep)	*Blanc and Amayemc* [1979]	
Neutral winds (Vn)	*Bernard* [1978]	
Electric current	*Mazaudier and Blanc* [1982]	
	Ground Level Processes	4
Ampere's law	$\Delta B = 2\pi/\ 10f \int jdz$	

1 : the solar flare

Radiation on the Sun

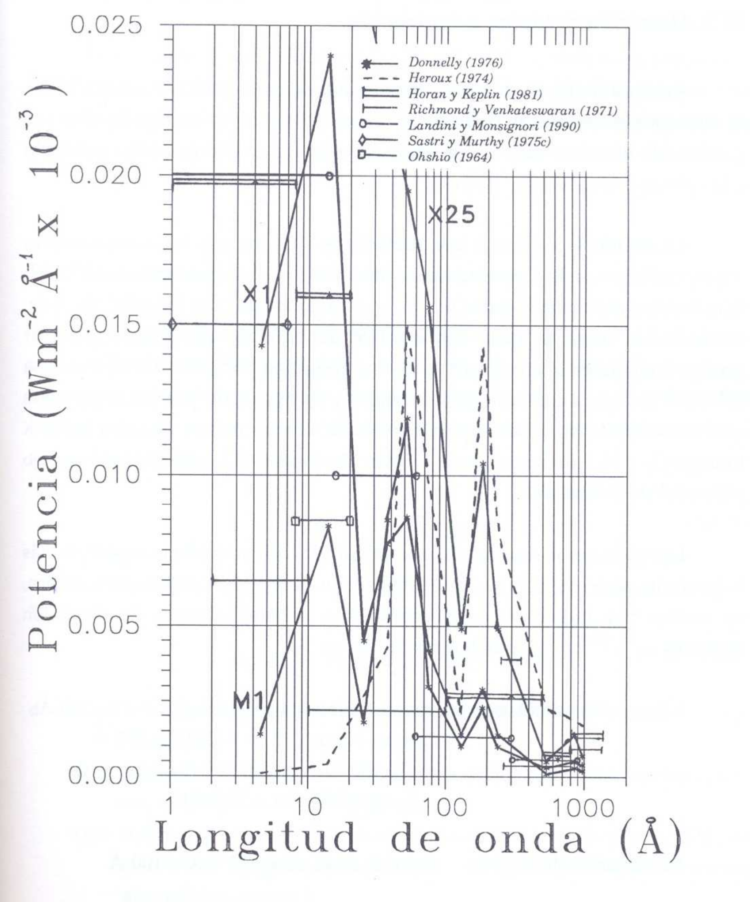


Fig. VI.2 *Valores de la potencia espectral para los distintos modelos de radiación emitida durante una fulguración solar.*

2.: Ionosphere

Increase of ionization

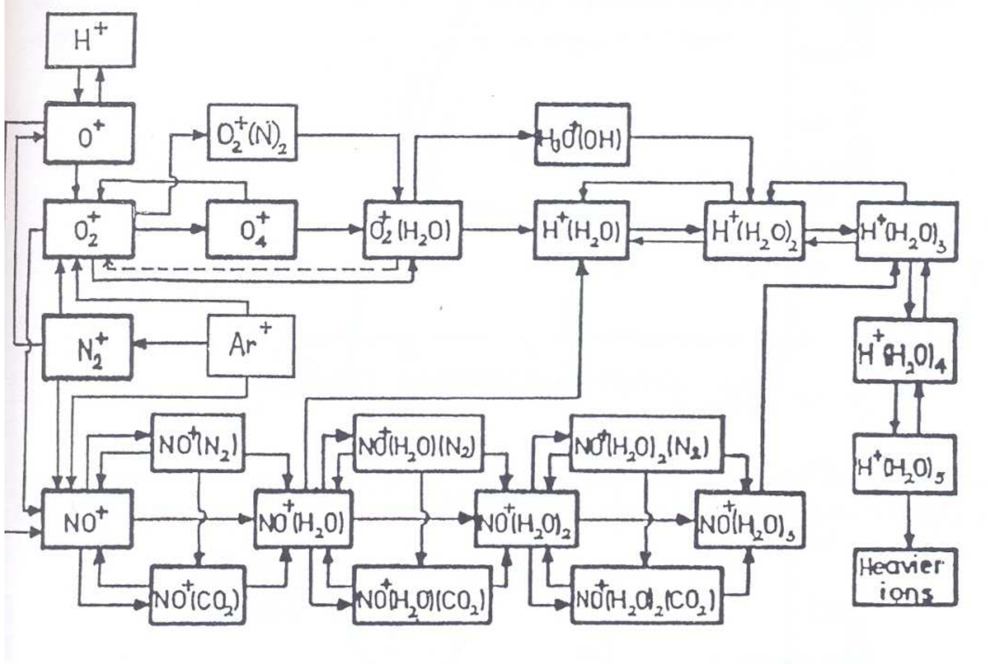


Fig. VI.4 *Esquema de las reacciones químicas principales en el cálculo de los iones positivos. De Dymek (1989).*

From Curto 's PhD 1992

3 :Ionosphere : electric current density (ISR model)

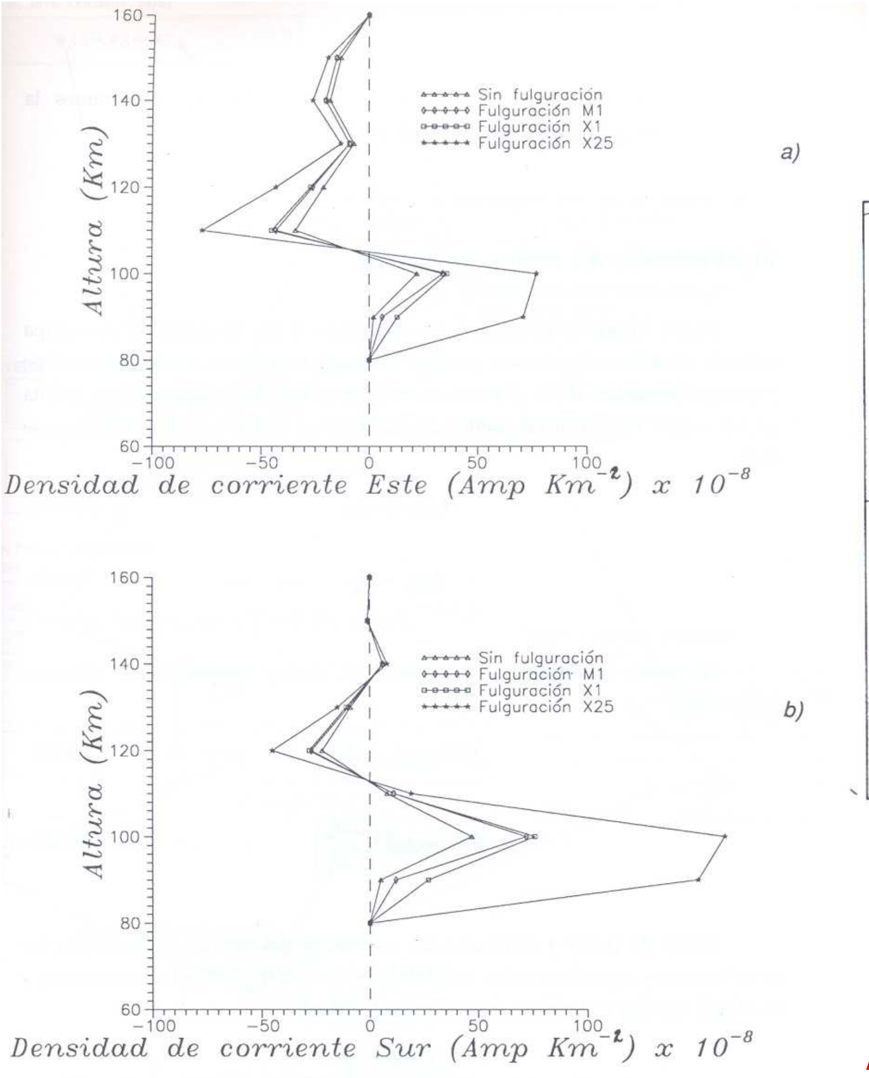
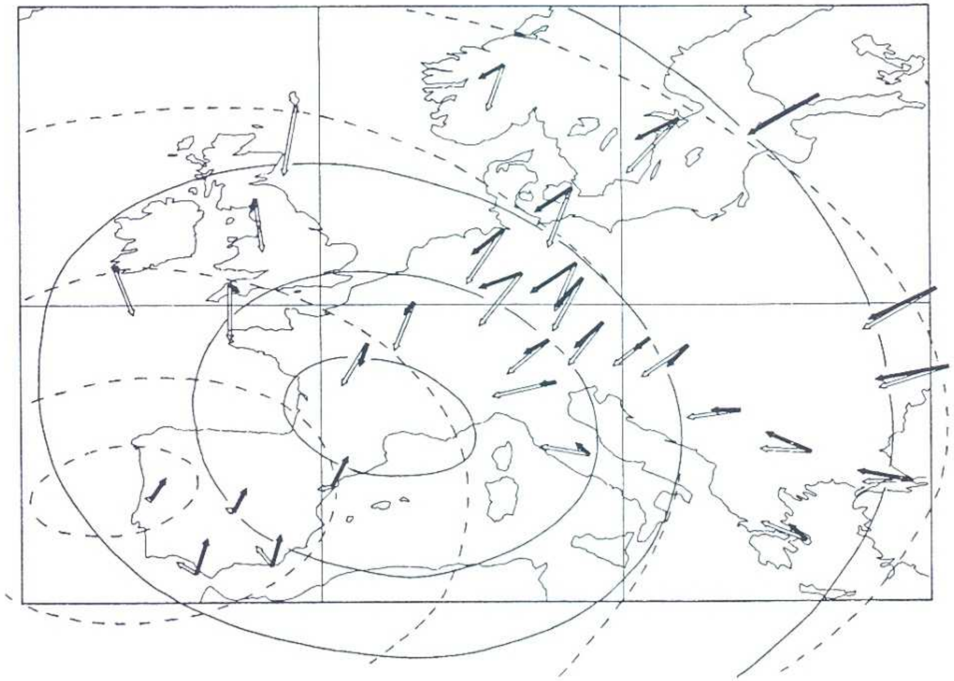


Fig. VI.15 *Densidad de corriente Este (a) y Sur (b) para cada uno de los tipos de fulguración para un día equinoccial medio a las 11 horas locales (en nuestra latitud).*

4 : Magnetic signature of the solar flare
Solar flare -> black arrows



Curto et al., JGR, 1994

ANSWER:

The reversed crochet is related to the profile of the neutral wind in the dynamo layer

There is a real need to train on the use of magnetic data

BIOT and SAVART’s Law : the Earth’s magnetic field integrates the effects of all the electric current systems

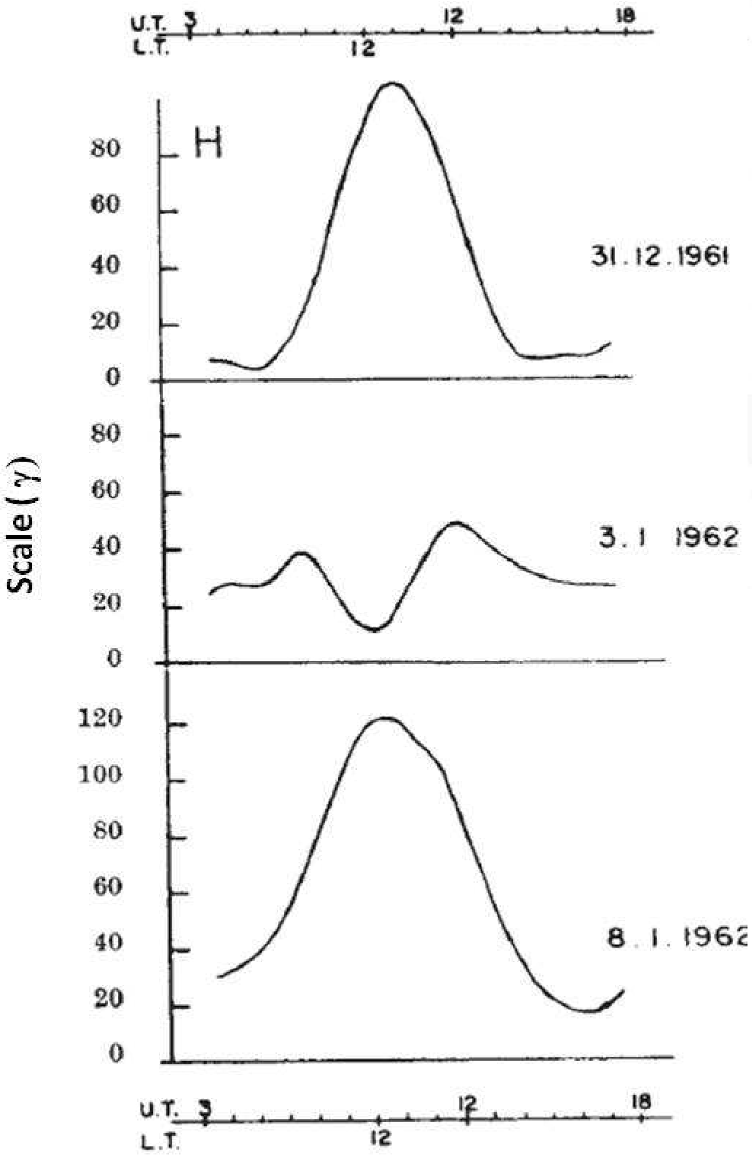
The shape of a curve does not give certainty on mechanism physics : It is necessary to analyze the whole system

Example:

CEJ : magnetic quiet time phenomena

Disturbance dynamo: magnetic disturbed time phenomena

Counter Electrojet : CEEJ



Horizontal component

Gouin, Nature, 1962

t. 23, fasc. 1, 1967] EXISTENCE D'UN CONTRE-ÉLECTROJET 3

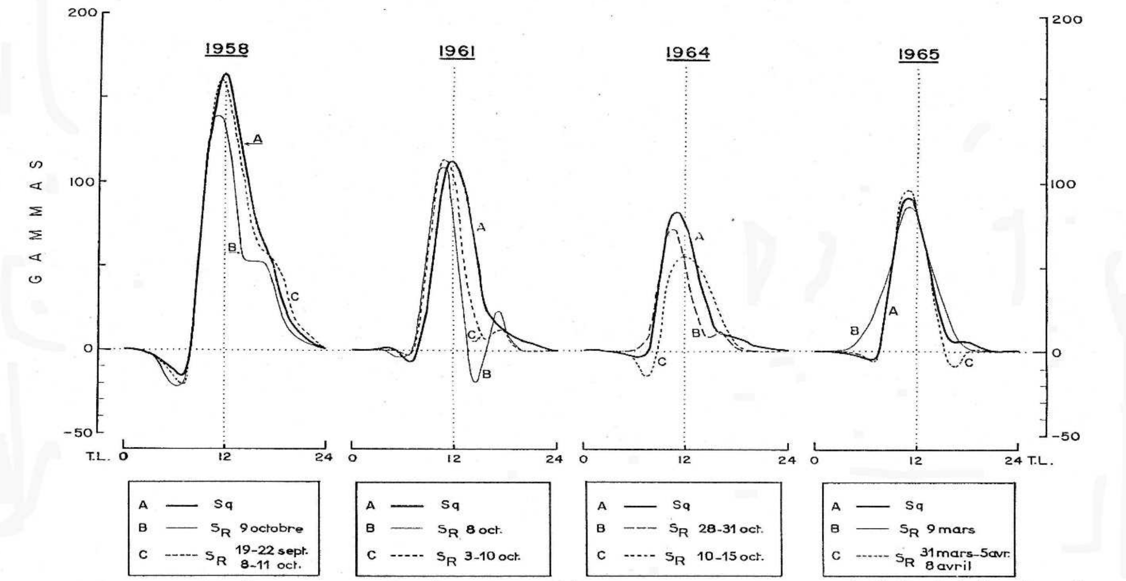
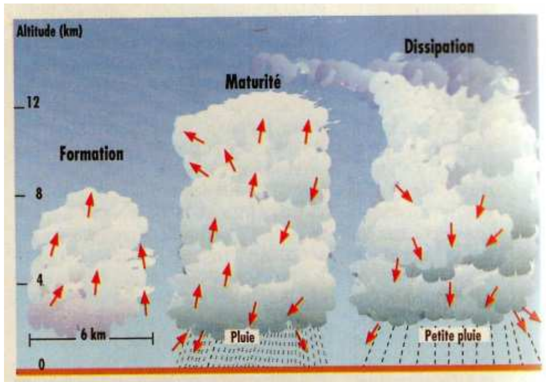
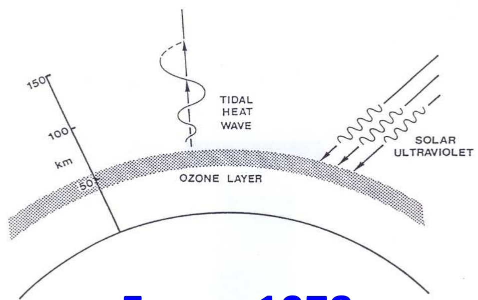


FIG. 1. — Courbes Sq d'équinoxe et courbes S_R pour un jour individuel ou pour une série de jours individuels de la même saison de la composante H à Addis-Abeba, corrigées de la variation non-cyclique.

Gouin and Mayaud, 1967

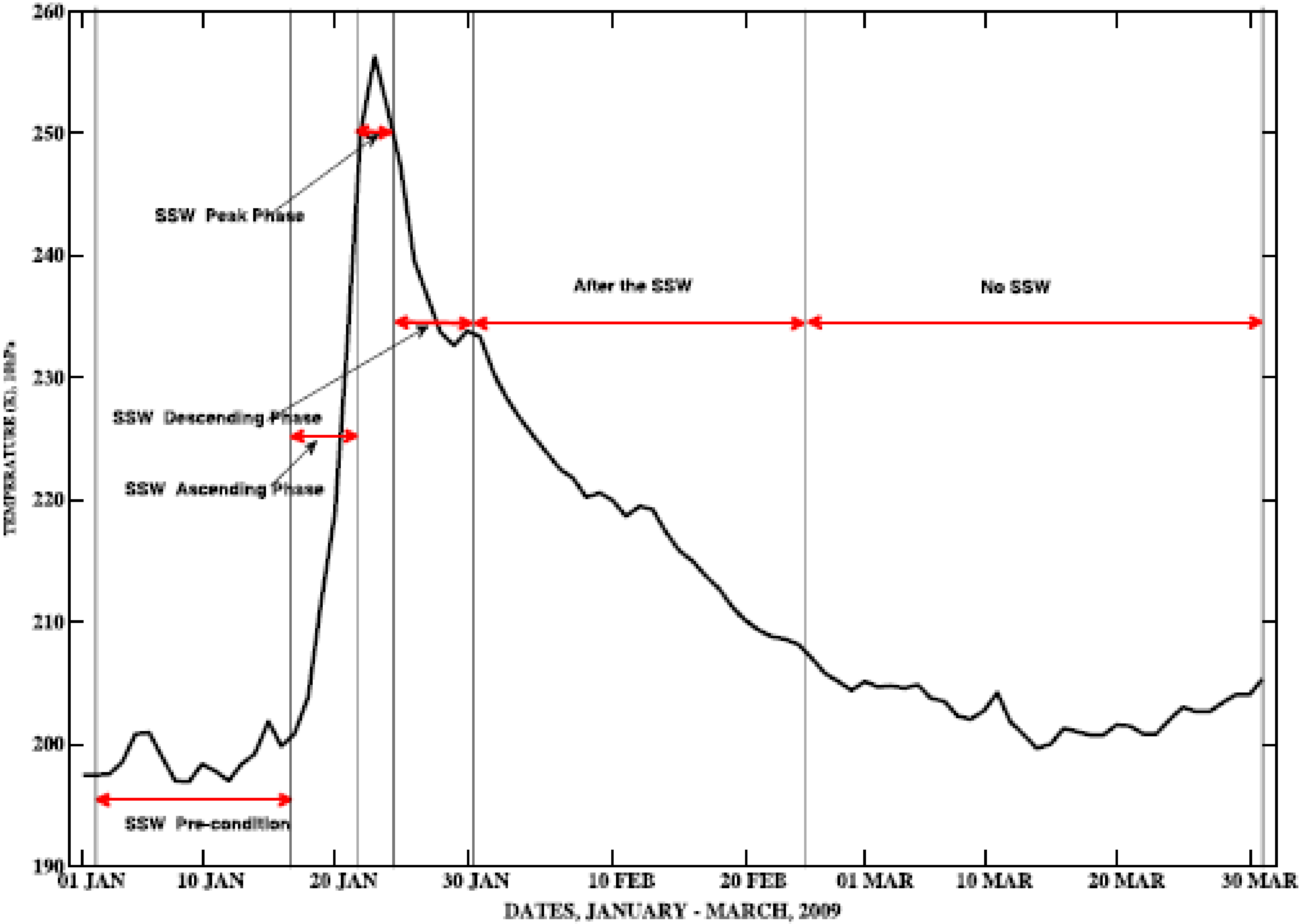
CHANNEL RADIATION /SOURCE LOW ATMOSPHERE





Evans, 1978

Bolaji et al., 2016, JGR



a: Stratospheric zonal mean air temperature for January – March, 2009 showing the SSW Pre-condition, SSW Ascending, SSW Peak, SSW Descending, After the SSW and No SSW Phase.

Bolaji et al., 2016, JGR

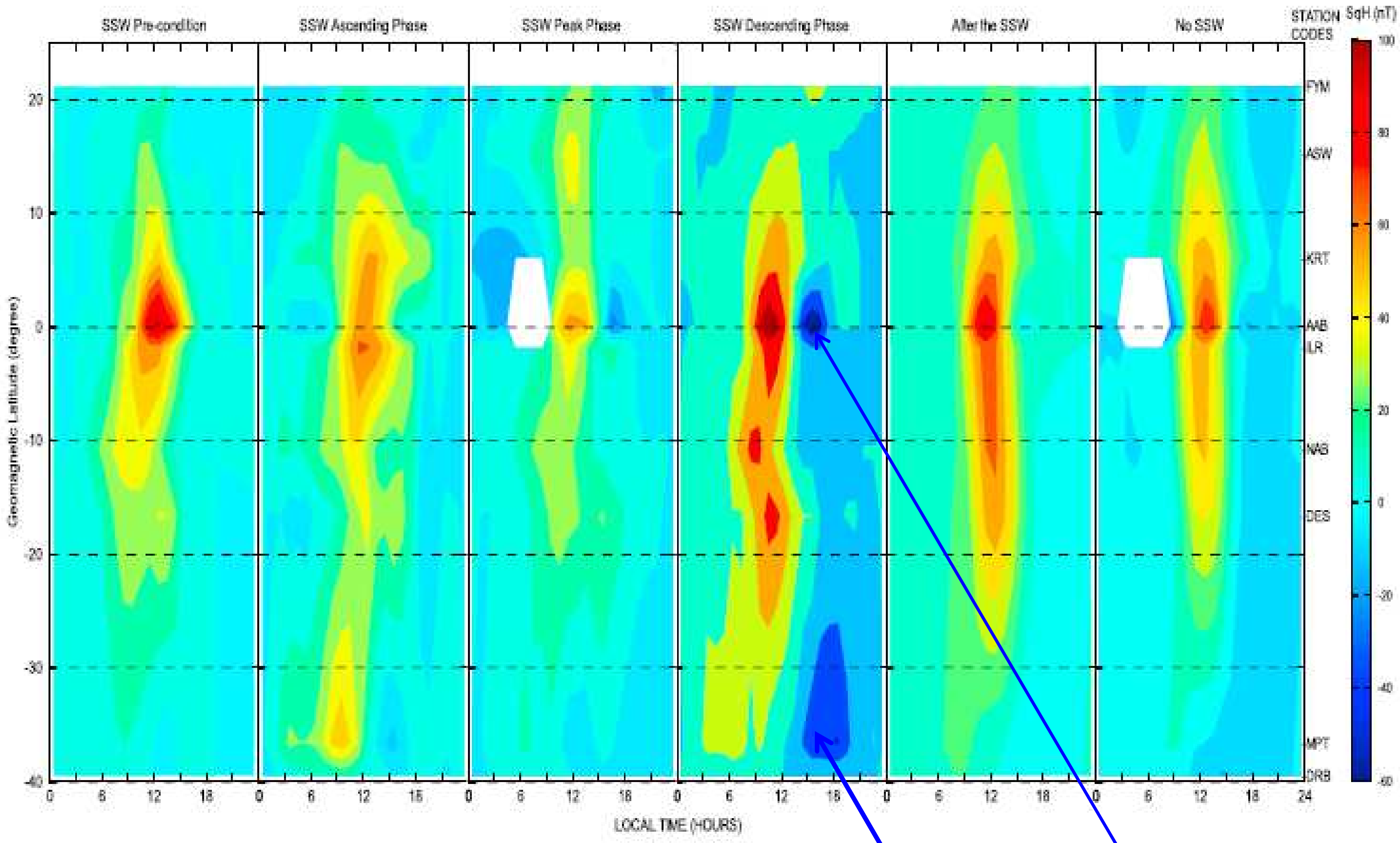


Figure 3. Two-dimensional plot of S_q (H) as a function of local time across nine stations in Africa during the year 2009 SSW

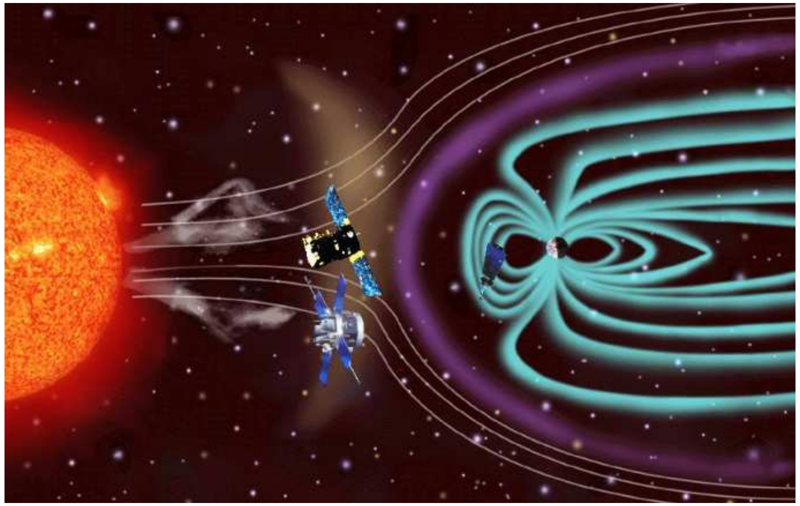
MAGDAS network

COUPLING between AURORAL and EQUATORIAL regions

Storm winds and ionospheric disturbance dynamo

=> delay between the auroral and equatorial regions

DDEF: Disturbance Dynamo Electric Field



Auroral electrojets

↓

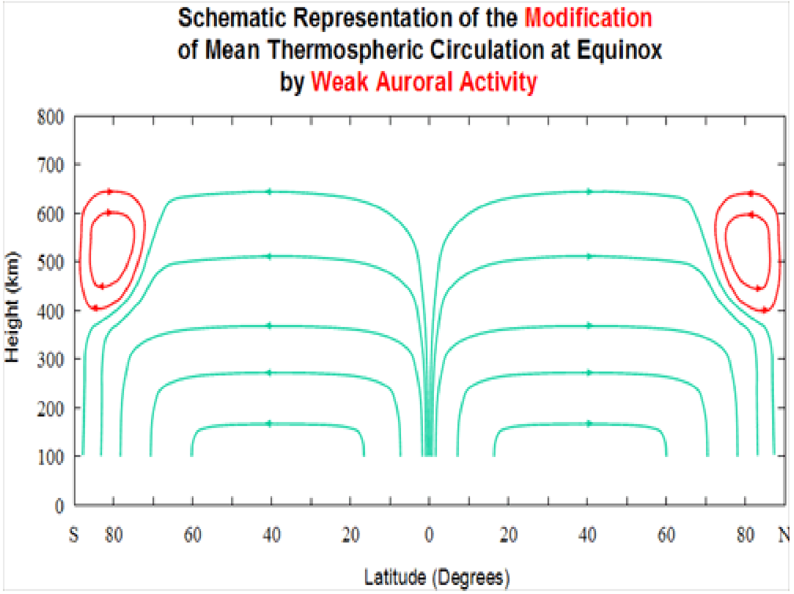
Joule heating most effective

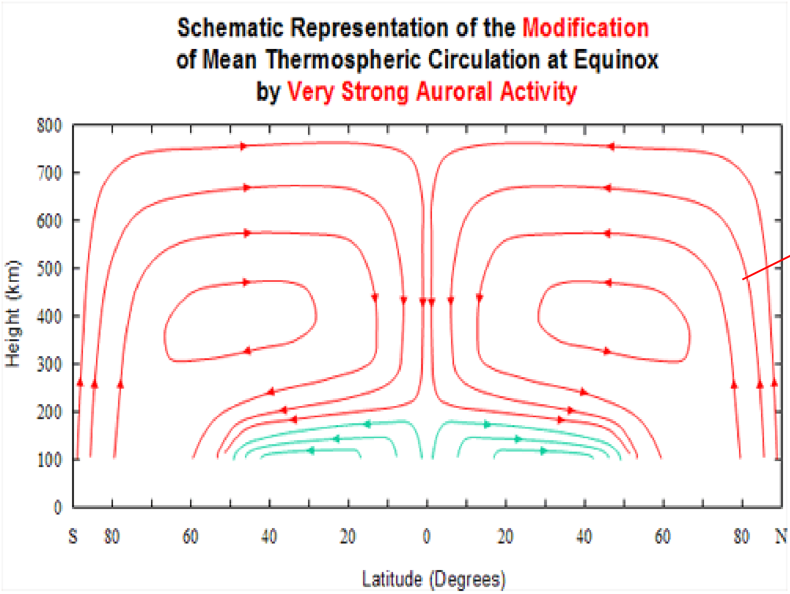
↓

$+ \Delta Vn \longrightarrow \Delta E_{dyn} \longrightarrow \Delta J \longrightarrow \Delta B$

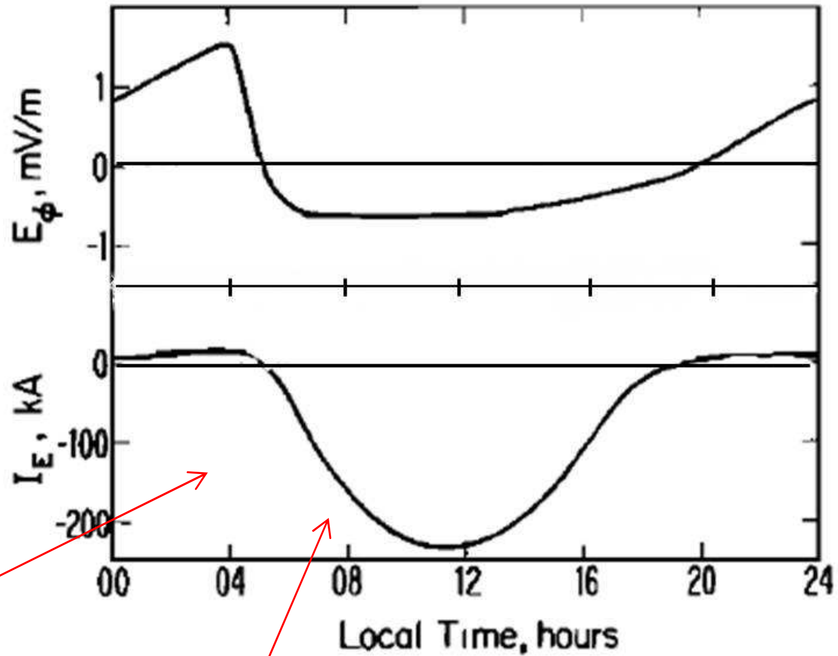
Gravity waves, HADLEY convection cell etc…

CHANNEL : SOLAR WIND / SOURCE : AURORAL ZONE





Equatorial Electric field and Electrojet



Ionospheric Disturbance Dynamo

Blanc and Richmond, 1980

REVERSED ELECTROJET

Need of historical studies on geomagnetism
Legacy of IGY 1957

- On the historical origins of the CEJ, DP2 and Ddyn current systems and their roles in the predictions of ionospheric responses to geomagnetic storms at equatorial latitudes, J. Geophys. Res., doi: 10.1002/2017JA024132
- C. Amory-Mazaudier, O.S. Bolaji and V.Doumbia

- <u>Base of Knowledge</u>

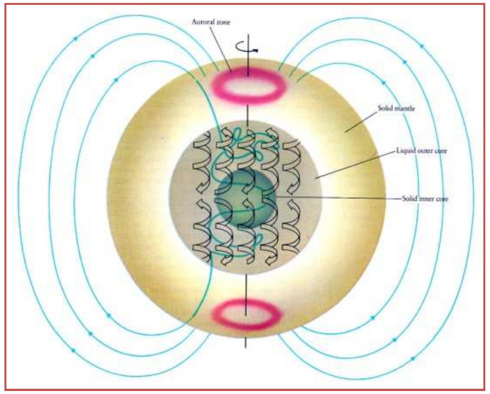
4 PERMANENT DYNAMOS + (Non Permanent DYN.)

SUN
poloidal /toroidal

MAGNETOSPHERE (+NP)
Solar wind
IMF

IONOSPHERE (+NP)
Earth's magnetic field
Neutral wind

EARTH
Motions of the core



Not exhaustive

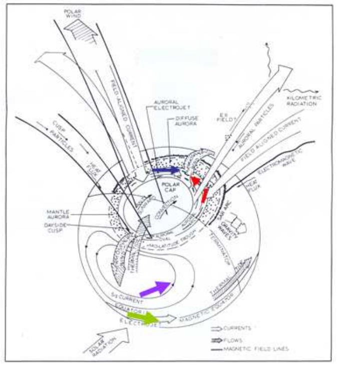
NEW SYSTEMIC TRAINING

CURRENT SYSTEMS

MAGNETOSPHERE
Chapman Ferraro
Ring current
Tail current

BIRKERLAND CURRENT

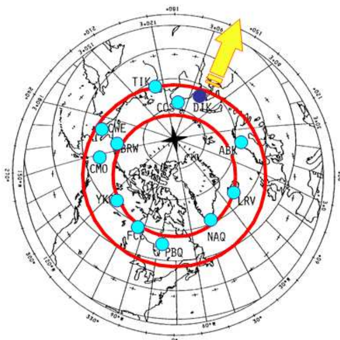
IONOSPHERE
Auroral electrojets
Midlatitude currents
Equatorial electrojet



EARTH's MAGNETIC FIELD -> Transient variations

Indices -> disturbances
Dst, SYM-H, ASYM-H
Aa, Kp, Ap
Km, Am
AU, AL

Equivalent currents
DP1, DP2,Ddyn
S_R <Sq>, Sq^P



PERMANENT DYNAMOS : some order of magnitude

Dynamo	Motions – V	Magnetic field B	Order of Magnitude
Sun	Sun Rotation and convection	Sun : 2 components Dipolar Toroïdal = sunspot	rotation speed : ~ 7280km/h at the equator Dipolar component : ~10 G Toroidal component : ~3-5 kG
Solar wind Magnetosphere	Solar wind	Interplanetary medium -> Bi	speed ~ [400km/s to 1000km/s] Bi ~ qq 10 nT
Atmospheric wind Ionosphere	Atmosphere	Earth's -> Bt	speed ~ 100m/s Bt ~ qq 10 000 nT
Earth's Dynamo inside the Earth	Metallic core	Earth's -> Bt	Indirect measurements deduced from the Earth's planetary magnetic field and the secular variation Velocity ~ qq km/year Bt ~ qq 10 000 nT

Summary : 10 years after IHY

The perenniality is assured

- Science : new training
- Data analysis : new systemic approach
- Knowledge : work on history => base of Knowlege on the web

- GIRGEA team : **29 PhD** (2007-2017, **22 in Africa**) + 4 before the end of the year (students from Burkina Faso, Côte d'Ivoire, RC, RDC)
- Next school in Abidjan (**16-28 October 2017**) organized by V. Doumbia from Côte d'Ivoire

- Curricula at University (Algeria, Burkina Faso, Côte d'Ivoire, Morocco, RC, RDC, Senegal and soon in Cameroun and Guinea Conakry ….)

- Outreach : conference on space weather and use of GPS in schools (power point in French, English and soon Spanish and Italian)

Some references

- Amory-Mazaudier, C., .S. Bolaji, V. Doumbia, (2017), On the historical origins of the CEJ, DP2 and Ddyn current systems and their roles in the predictions of ionospheric responses to geomagnetic storms at equatorial latitudes, J. Geophys. Res., doi: 10.1002/2017JA024132
- M. Blanc, A.D. Richmond, The ionospheric disturbance dynamo, J. Geophys. Res., 85, A4 (1980), pp. 1669-1686, doi: 10.1029/JA085iA04p01669
- O.S. Bolaji, E.O. Oyeyemi, O.P. Owolabi, Y. Yamazaki, A.B. Rabiu, D. Okoh, A. Fujimoto, C. Amory_Mazaudier, and A. Yoshikawa, Solar quiet current response in the African sector due to a 2009 sudden stratospheric warming event" , J. Geophys. Res., Space Physics, 121, 8055-8065, doi:10.1002/2016JA022857
- J-J. Curto, C. Amory-Mazaudier, M. Menvielle, J.M. Torta, Study of Solar Flare Effects at Ebre: 1. Regular and reversed SFe, Statistical analysis (1953, 1985) and a global case study, J. Geophys. Res., 99, A3 (1994a) pp. 3945-3954.
- J-J. Curto, C. Amory-Mazaudier, J.M. Torta, M. Menvielle, Study of Solar Flare Effects at Ebre: 2. Unidimensional physical integrated model, J. Geophys. Res., A12 (1994b) pp. 23289-23296.
- /JA073i005p01795.
- Gouin P. (1962), Reversal of the magnetic daily variations at Addis Ababa. Nature 139: 1145-1146.
- Gouin, P. and P.N. Mayaud (1967), A propos de l’existence possible d’un contre-électrojet aux latitudes magnétiques équatoriales, Ann. Géophys., 23, n° 1, p. 41-47.
- M. Le Huy, C. Amory-Mazaudier, Magnetic signature of the ionospheric disturbance dynamo at equatorial latitudes: “Ddyn”, J. Geophys. Res., 110, A10301 (2005). doi:10.1029/2004JA010578.
- L. Paterno, History of solar cycle, in Historical events and people, W. Schröder, ISSN-1615-2824, AKGGP/SHGGCP, science Edition Bremen/Postdam (2005) pp. 261-275.
- A. Richmond, Ionospheric Electrodynamics , in Atmospheric Electrodynamics, Vol II, Chapter 9 (1995) pp 249-280, Edited by Hans Volland.