United Nations/ Japan Workshop on Space Weather

Science and Data Products from ISWI Instruments, March 2-6, 2015

Sun impacts on ionized layers and transient variations of the earth's magnetic field

Christine Amory-Mazaudier and GIRGEA members

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United Nations Space Science Initiative 1991-2012

- 1992-1994: IEEY International Equatorial Electrojet Year – IAGA => capacity building
- 1995 : GIRGEA – scientific network Europe Africa

www.girgea.org

- 2005-2009: IHY International Heliophysical Year
- 2010-2012 : ISWI International Space Weather Initiative
- Since 2012 : ISWI in SCOSTEP

CAPACITY BUILDING – 10 PhD [2011-2015]   [28 from 1992-2015 in 9 countries]

- **2015**

***FATHY Ibrahim**, Electrodynamics coupling between high and low latitudes by using all the existing magnetometer networks, University of Helwan, March 1st 2015, **EGYPT**

***SHIMEIS Amira**, Solar Impact on the ionized layers at the Crest of the equatorial anomaly in the African sector of the Northern Hemisphere, University of Helwan, January 22nd , 2015 **EGYPT**

- **2014**

***TRAN THI Lan,** Etude du contenu électronique total (TEC), et caractéristiques des gradients ionosphériques et de leur influence sur la propagation des signaux satellitaires du Global Positioning System au Vietnam", November 2014, Université de Hanoï, **VIETNAM**

***GNABAHOU Allain Doua,** Variabilité et variation à long terme de l'ionosphère en région équatoriale africaine soutenue le 18 janvier 2014 à l'Université de Ouagadougou. **BURKINA FASO**

***ZOUNDI Christian :** Analyse de la variabilité du contenu total en électrons (TEC) à partir des stations GPS de Ouagadougou et de Koudougou au Burkina Faso et de la station GPS de Niamey au Niger et comparaison avec les prédictions de CODG, le 18 janvier 2014 à l'Université de Ouagadougou. **BURKINA FASO**

In red : students used ISWI GPS or/and magnetometers

- **2013**

***GAYE Idrissa**, Influence de l'Irradiation et du coefficient de dommage sur les paramètres électriques d'une photopile au silicium en régime transitoire, Thèse soutenue le 21 juin 2013 à l'Université Cheikh Anta Diop, Dakar , **SENEGAL**

***MENE Niangoran Médard**, Etude Statistique du phénomène de pénétration du champ électrique de convection magnétosphérique à l'équateur, Thèse soutenue de 20 juin 2013 à l'Université Houphouët Boigny, Abidjan**, CÔTE D'IVOIRE**

- **2012**

***ZERBO Jean-Louis**, Activité solaire, Vent solaire, Géomagnétisme et Ionosphère équatoriale, Thèse soutenue le 20 octobre 2012 à l'Université de Ouagadougou, **BURKINA FASO**

*** PHAM Thi Thu Hong**, Analyse et interprétation de la variations régulière du champ magnétique terrestre au Vietnam et modélisation de l'ionosphère, Thèse soutenue le 15 octobre 2012 à l'Université Pierre et Marie Curie, France. **VIETNAM**

- **2011**

***LUU Viet Hung,** Etude du champ électromagnétique et interprétation des données magnétotelluriques au Vietnam, Thèse soutenue le 21 décembre 2011, Université Paris Sud 11, France. **VIETNAM**

3 students of our network (GIRGEA) will present to morrow their results on scintillations
Lan TRAN THI (Vietnam), Ilyasse AZZOUZI (Morocco), Jean Ackah (Côte d'Ivoire)

ELECTRODYNAMICS COUPLING BETWEEN HIGH AND LOW LATITUDES

ELECTRIC FIELD ALONE [PPEF]

Prompt penetration of the magnetospheric convection electric field

+ ΔEc ⟶ ΔJ_{Ec} ⟶ ΔB

magnetospheric convection electric f

The magnetic disturbance is observed simultaneously at all latitudes

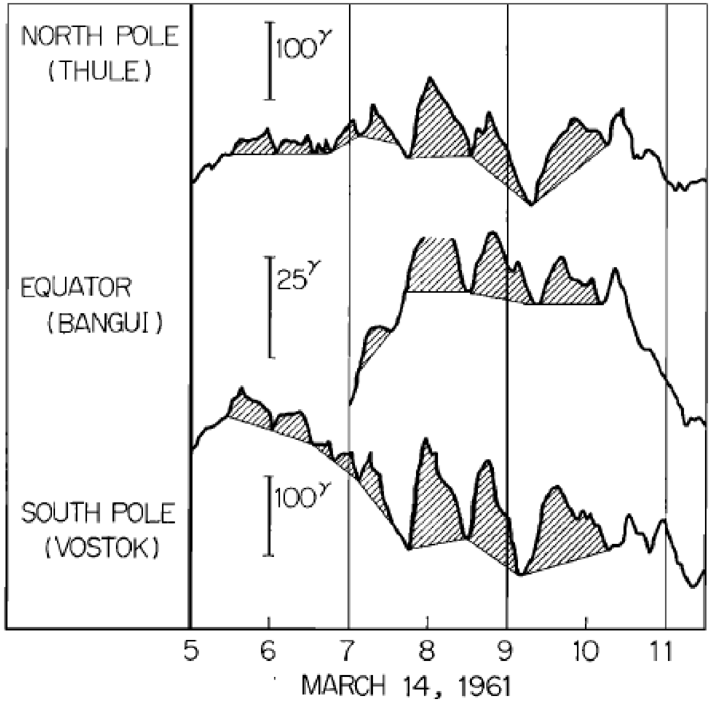


Fig. 1. Train of D_P 2 fluctuations (shaded). Geomagnetic latitudes of these stations are 88.9 (Thule), 05.0 (Bangui), and —89.1 (Vostok).

Nishida et al., 1968

Storm winds

HADLEY CELL BETWEEN POLE AND EQUATOR

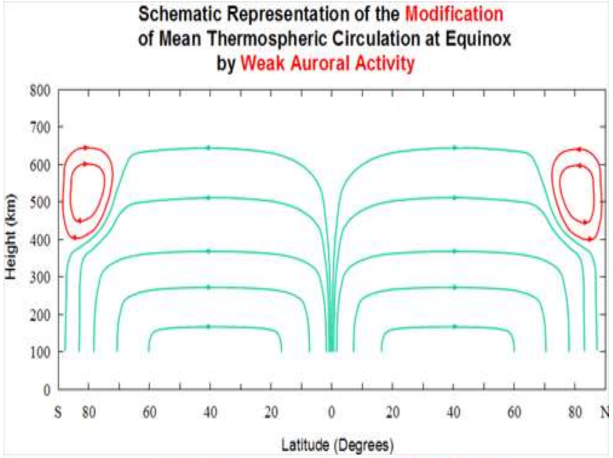
Delay between the auroral and equatorial zones [DDEF]

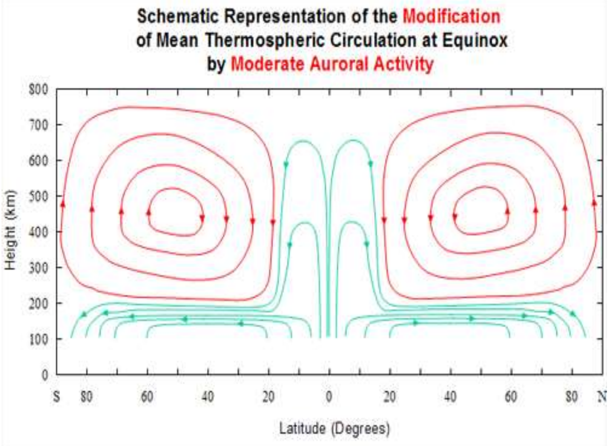
Auroral electrojets

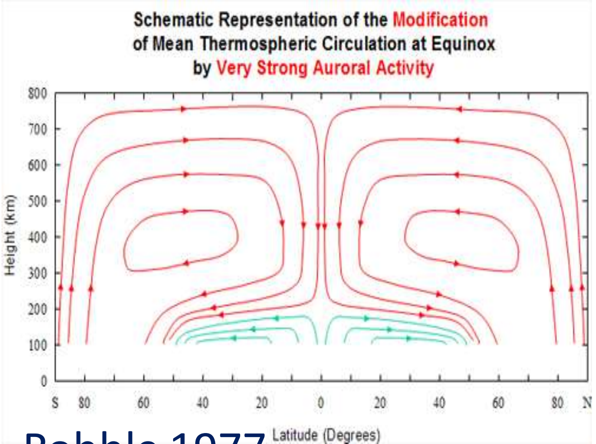
Joule heating most effective

+ $\Delta V_n \longrightarrow \Delta E_{dyn} \longrightarrow \Delta J_{dyn} \longrightarrow \Delta B$

Gravity waves, HADLEY convection cell etc…

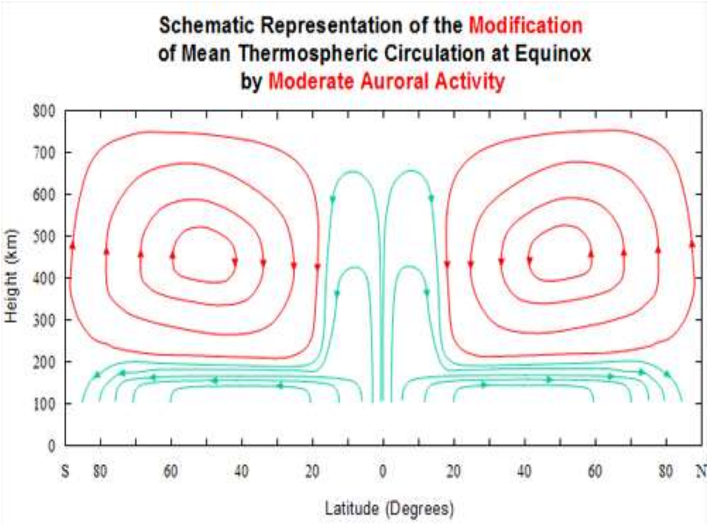




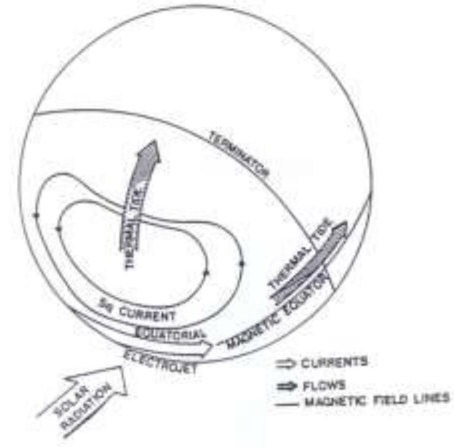


Robble 1977

IONOSPHERIC DISTURBANCE DYNAMO [DDEF]
Blanc and Richmond, 1980 [numerical simulation]



Quiet magnetic variations,
regular electric current
$J = \sigma (E + V_n \times B)$



Joule heating in auroral zone
Storm wind

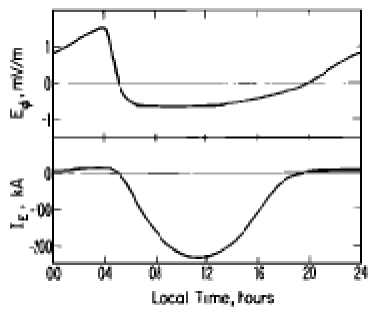
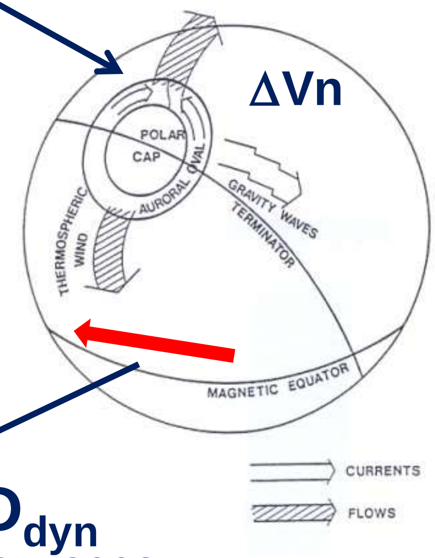


Fig. 9. Local time distributions of the equatorial electrojet parameters E_ϕ, eastward electrostatic field, and I_E, total eastward current flow between +10° and -10° magnetic latitude. Both are basically reversed from their observed normal quiet-day variation.

ΔV_n

In equatorial zone
$\Delta J = \sigma (\Delta E + \Delta V_n \times B)$



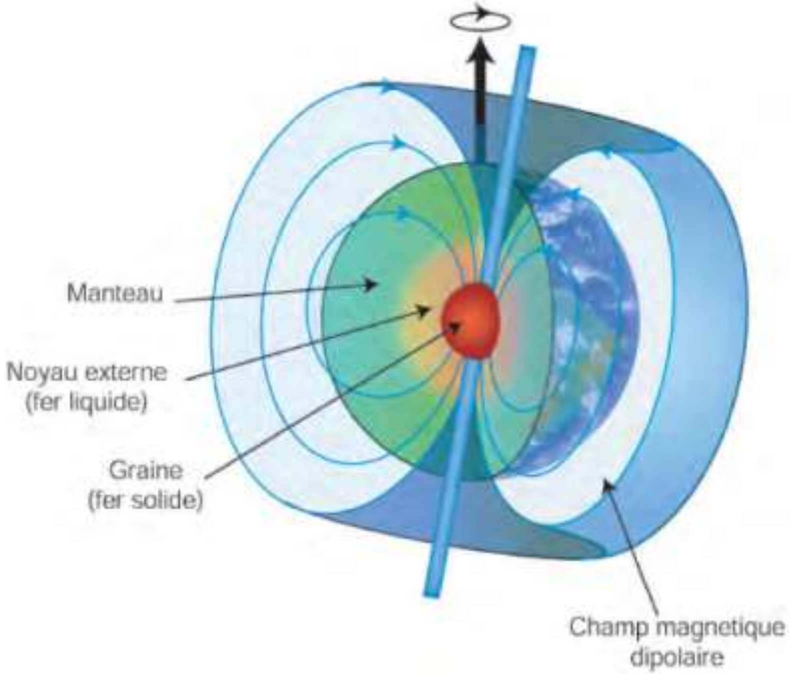
Reversed equatorial electrojet D_{dyn}

Le Huy and Amory-Mazaudier JGR, 2005 and JGR 2008

EARTH'S MAGNETIC FIELD

- $B = Bp + Ba + Be + Bi$

Bp : Main field (core)
Ba : Aimantation field (Lithosphere)
Be : field related to external sources
Bi : induced by Be

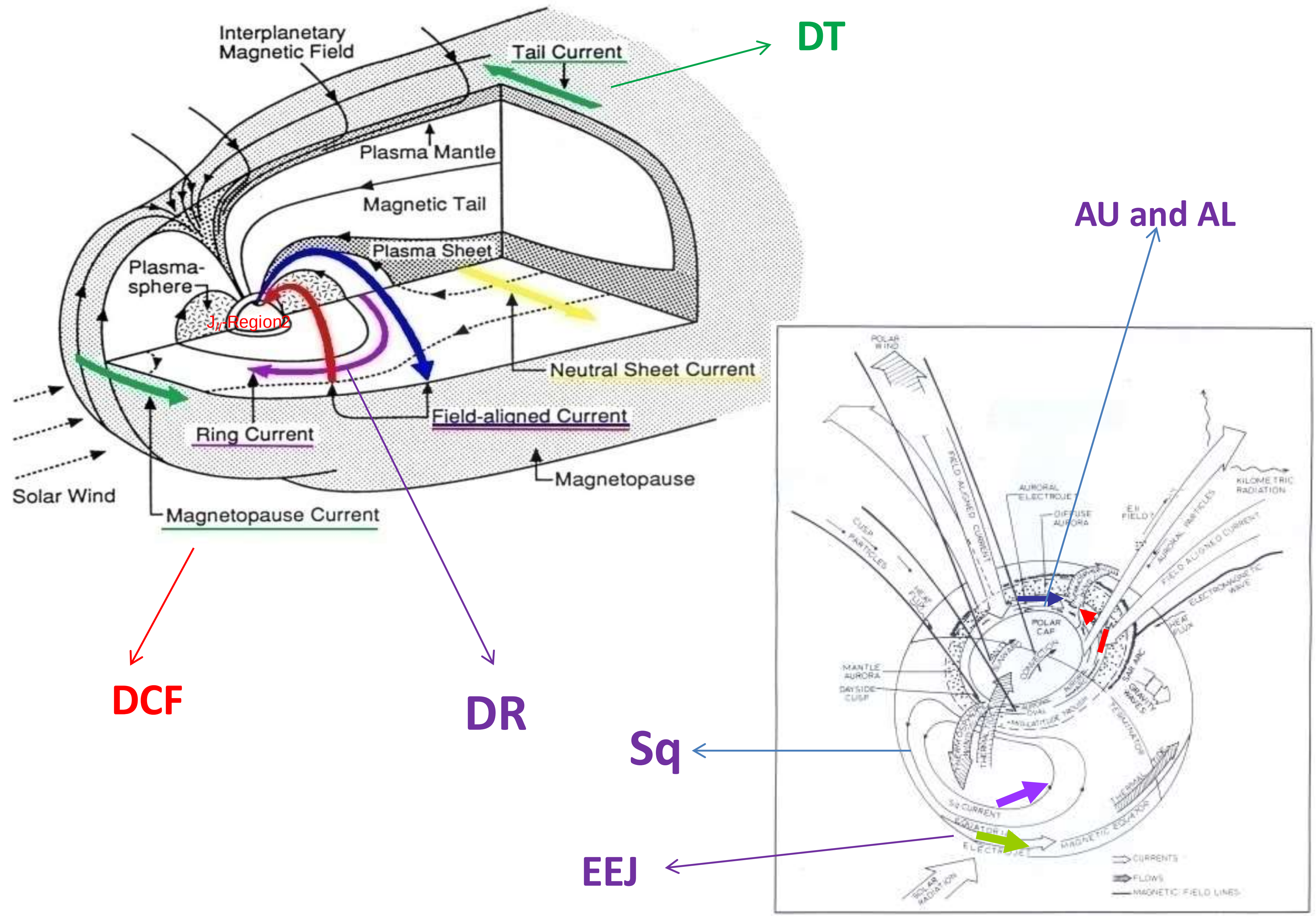


$\Delta B = Be + Bi$

$\Delta B = S_R + D$

Solar regular variation + Disturbance

External electric current systems and transient magnetic variations



$\Delta H = D + S_R$ Horizontal component of the Earth's magnetic field measured

$D = D_{CF} + D_R + D_T + D_{iono} + DG$ (Cole, 1966; Kamide and Fukushima, 1973)

$D_{magne} = D_{CF} + D_R + D_T$ estimated by magnetic Hsymcosλ λ:colatitude

$\Delta H = S_R + D_{magne} + D_{iono}$

$D_{iono} = \Delta H - S_R - D_{magne}$

$D_{iono} = DP_2 + D_{dyn}$ (at low latitudes DP_0, DP_1, DP_3, DP_4 can be neglected)

[PPEF + DDEF]

S_R Ionospheric dynamo / regular variation (data during magnetic quiet time)

$D_{CF} + D_R + D_T$: Solar wind magnetosphere dynamo with magnetospheric electric currents: ring current, Chapman Ferraro current, tail current

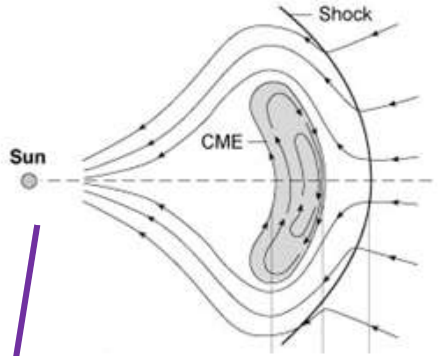
DG : due to ground induced electric currents

D_{iono} Solar wind magnetosphere dynamo/ Ionospheric disturbance

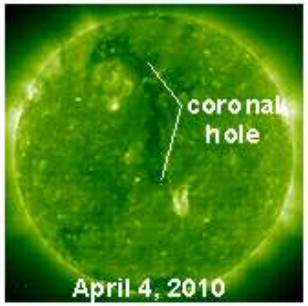
DP_2 Ionospheric disturbance/ Prompt penetration **[PPEF]**

D_{dyn} Ionospheric disturbance/ Ionospheric disturbance dynamo **[DDEF]**

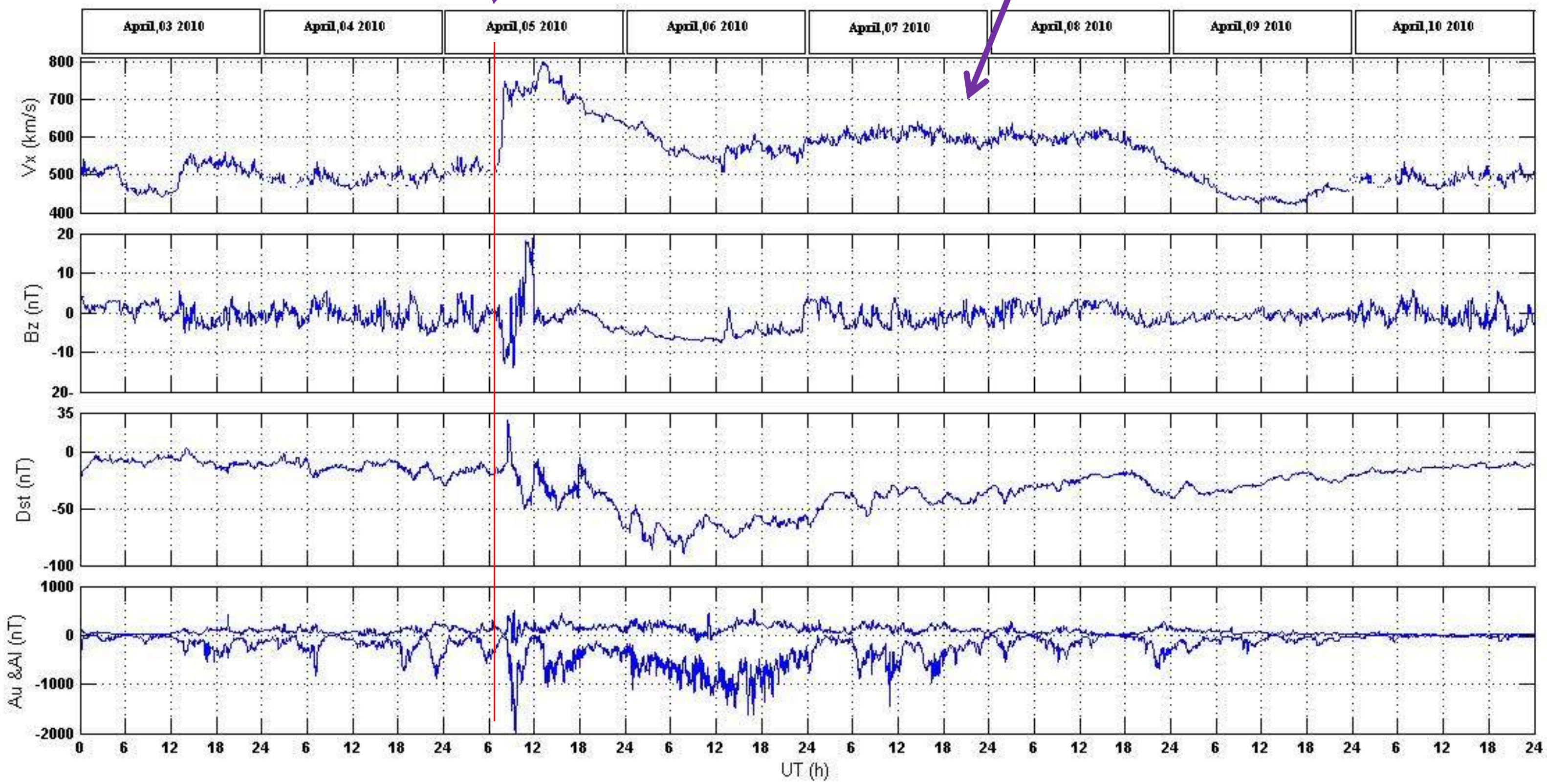
Shimeis et al., JGR 2012



Coronal Holes:

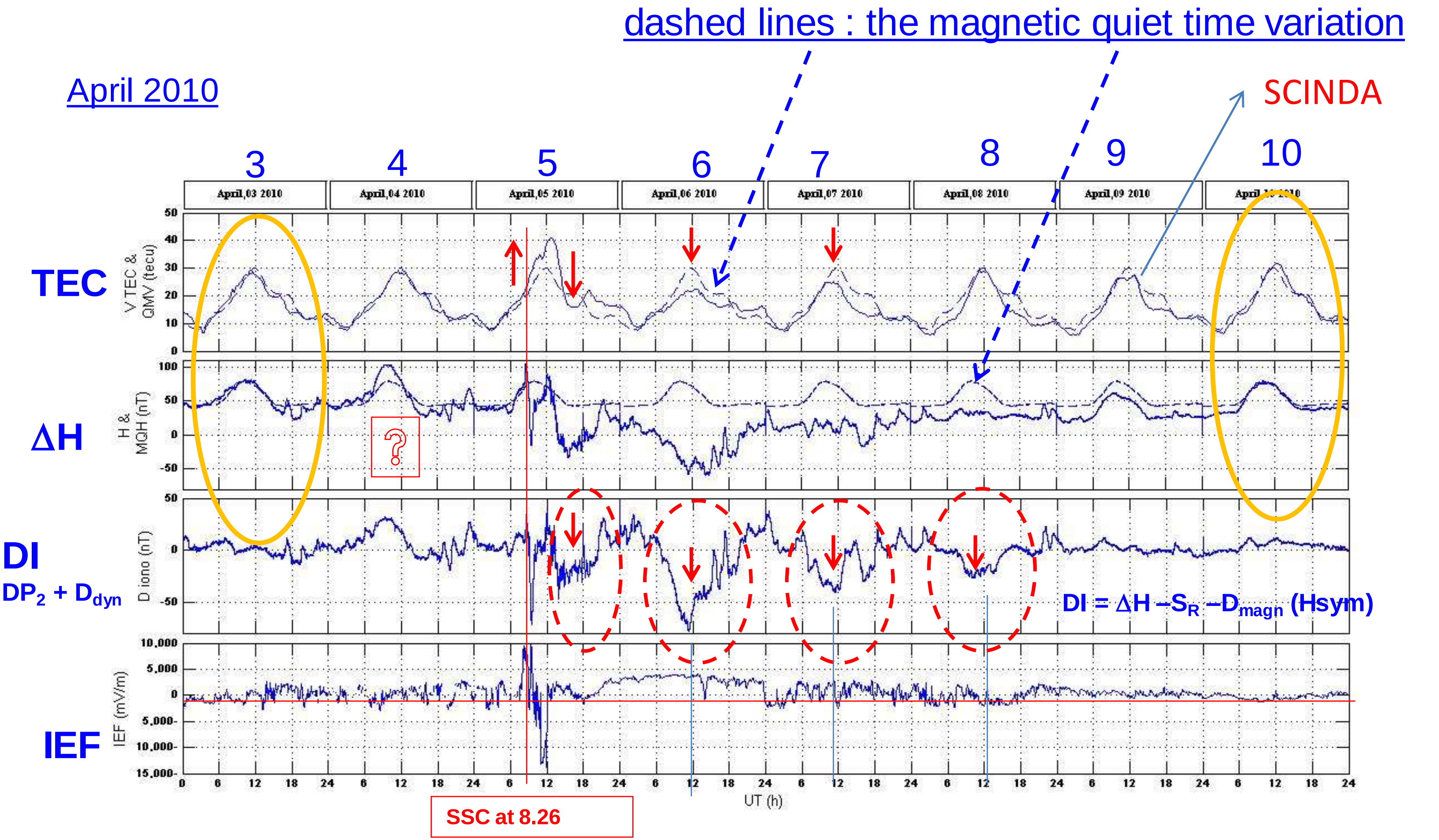


A solar wind stream flowing from the indicated coronal hole should reach Earth on April 6th or 7th. Credit: SOHO Extreme UV Telescope



SSC at 08:26

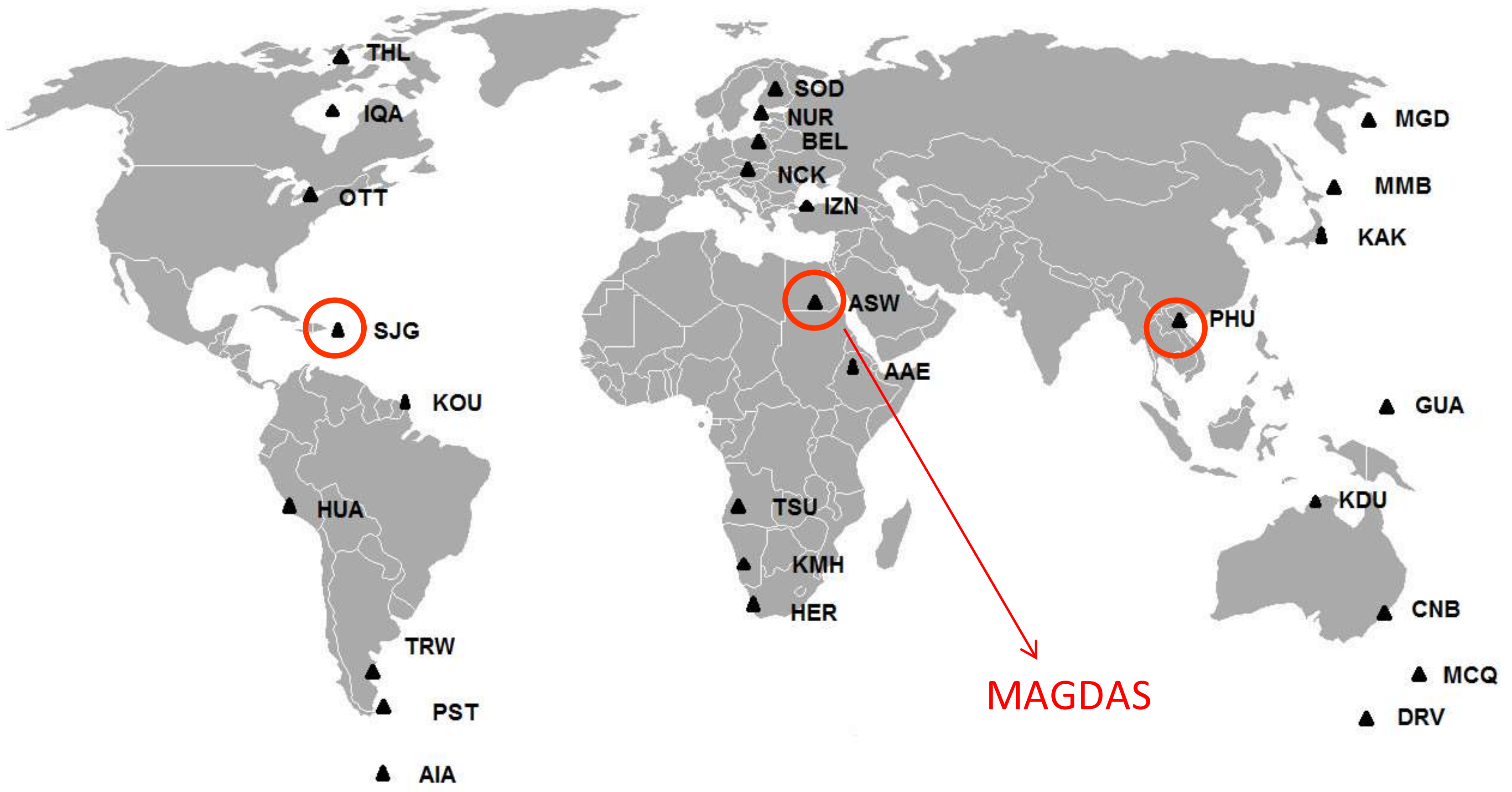
April 2010



At the beginning of the storm
-> Prompt penetration of the magnetospheric electric field, (Vasyliunas, 1970)
DP2 (Nishida, 1968) [PPEF]

Three hours after the beginning of the storm
-> ionospheric disturbance dynamo (Blanc and Richmond, 1980) is acting at low latitudes
Ddyn (Le Huy Minh and Amory-Mazaudier, 2005, 2008)]DDEF]

Planetary signature of the ionospheric disturbance dynamo April 1 to 10, 2010
Fathy et al., JGR 2014

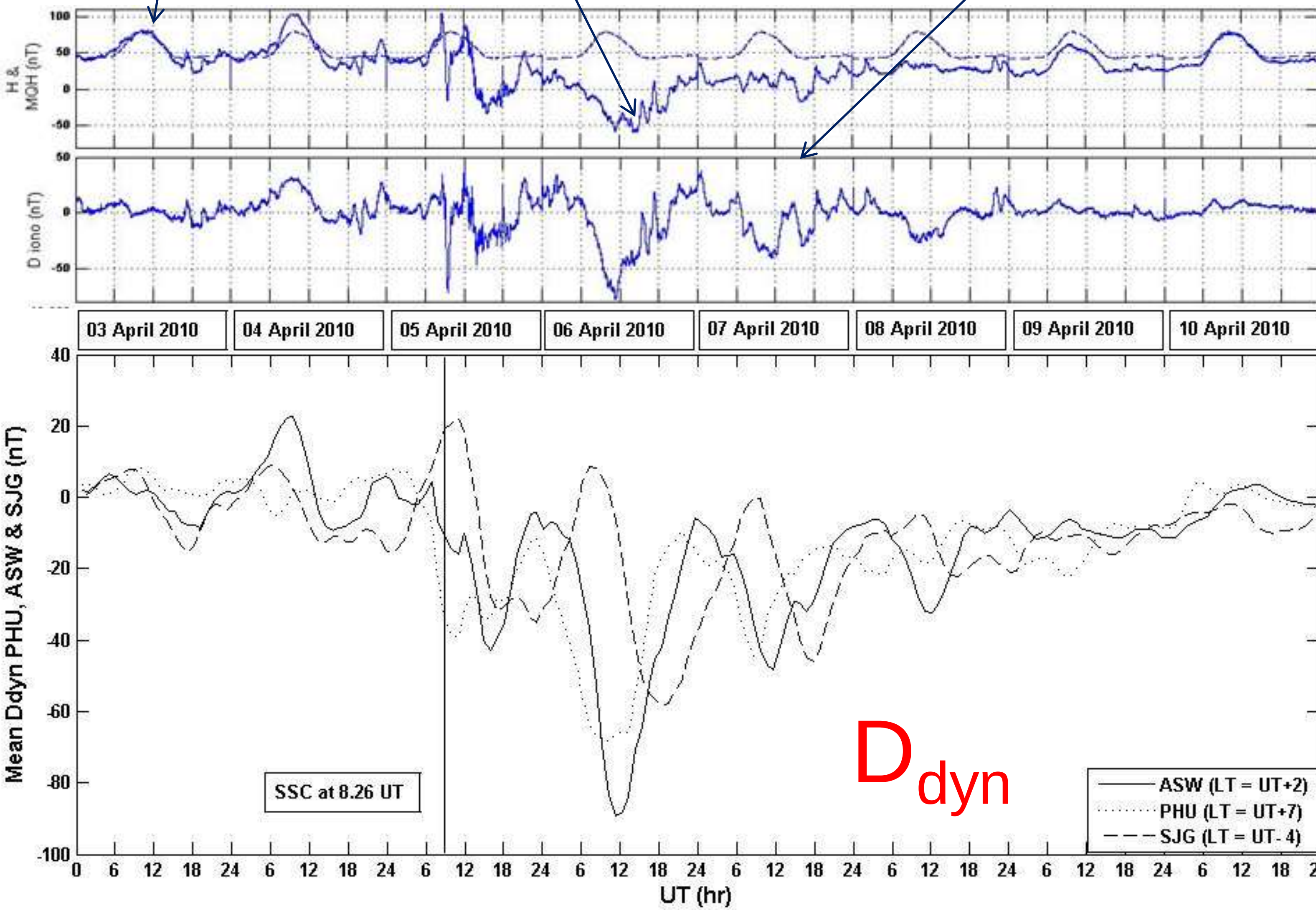


Regular variation

$D_{iono} = \Delta H - S_R - D_{magne}$

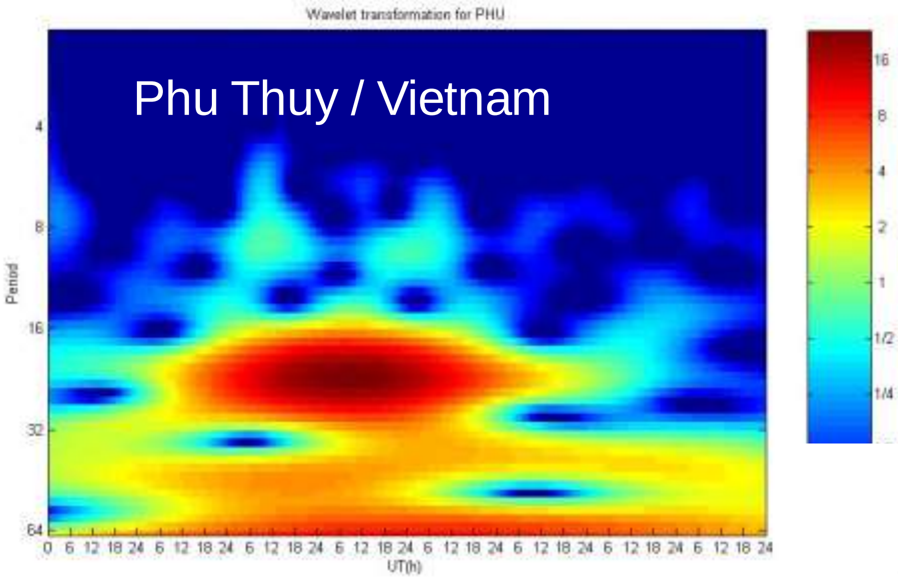
$D_{iono} = DP_2 + D_{dyn}$

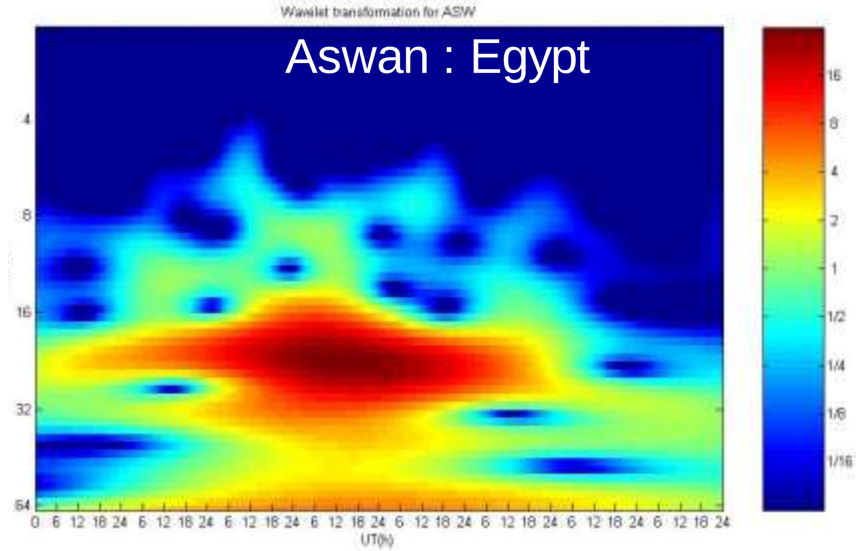
Observed ΔH MAGDAS

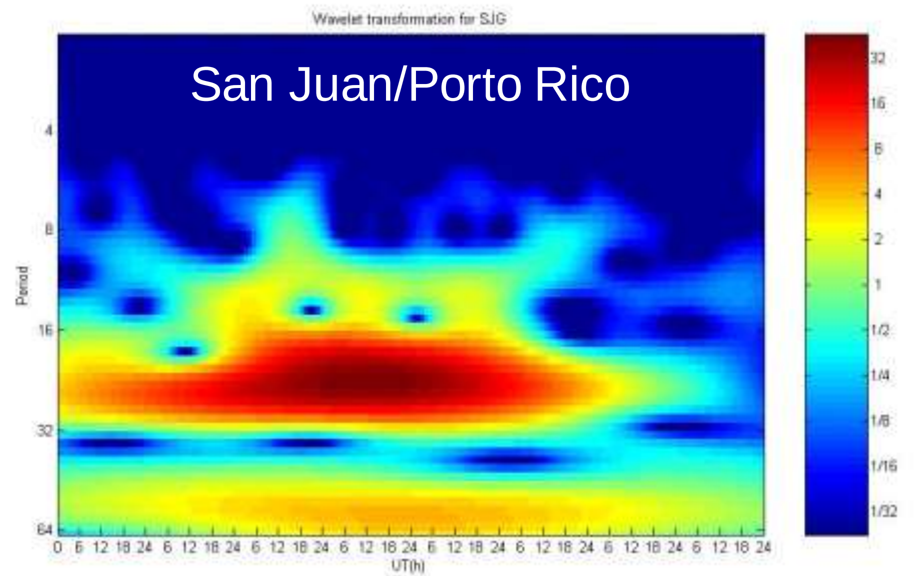


D_{dyn}

illustration of the continuous wavelet transformation of PHU station (a), ASW station (b) and SJG (c) . The vertical axis illustrates the period of the signal in hours and the horizontal axis is the universal time in hours. It's clear that the dominant frequency of the signal around the period of 22 hours in the time interval from (45-125hrs) as it is clear from the color index







Conclusion

2011-2015 : 10 PhD based on ~ 30 papers in International Journals (Burkina Faso, Egypte, Côte d'Ivoire, Vietnam)

Main result presented here
Extraction of a magnetic perturbation related to the storm wind disturbance generated by Joule heating dissipation in the auroral zone . This disturbance D_{dyn} was predicted in 1980 by numerical simulation.
Objective : to improve the models (Nequick as well as TIEGCM)

Necessity to maintain the existing tools and to add new stations, particularly GPS and magnetometers