

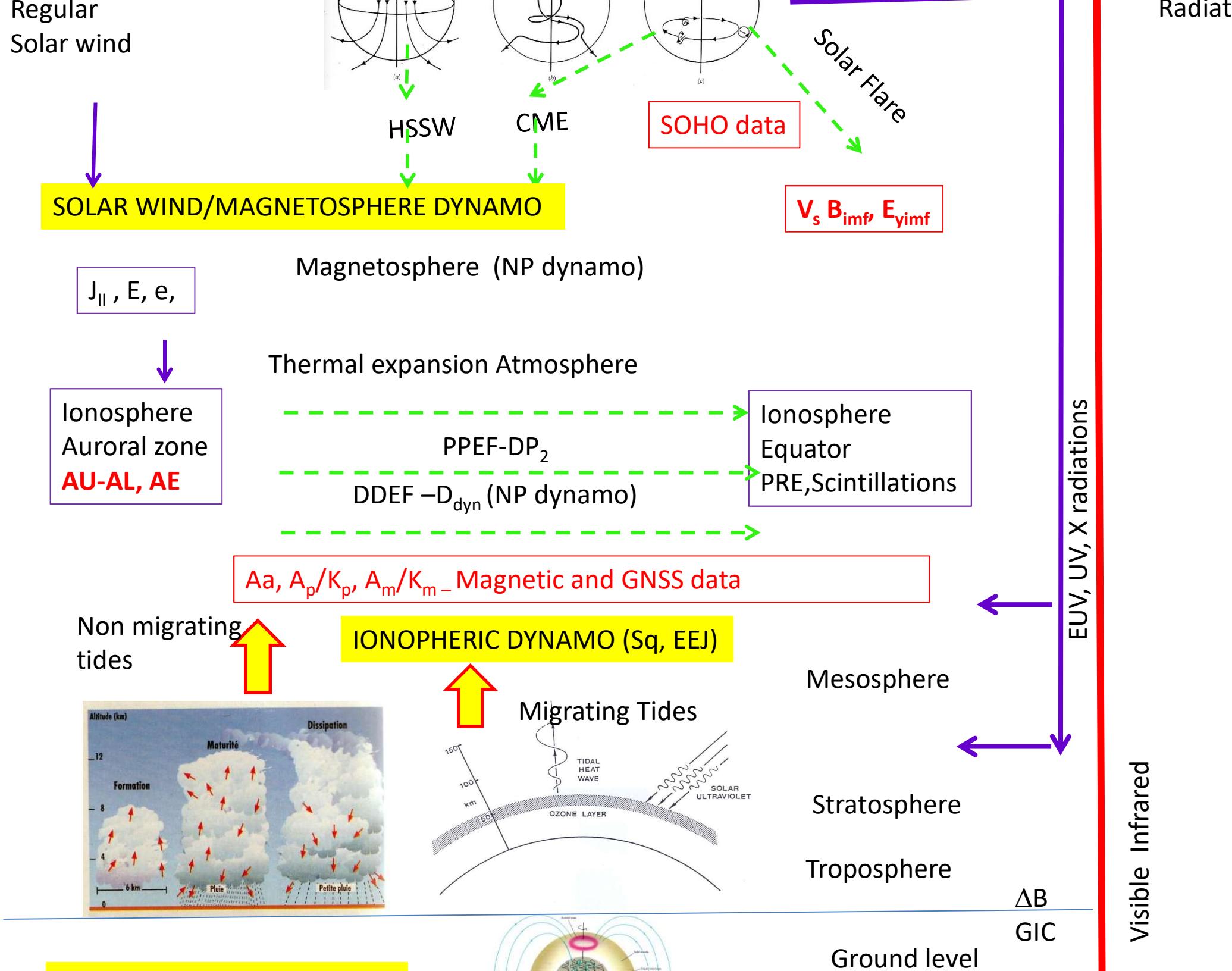
How to study geomagnetic storms

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Eastern Africa Capacity Building Workshop on Space Weather
and Low-latitude Ionosphere

General Guidelines

- 1.- Identify the event in the given period.
- 2.- Characterize the Solar-Terrestrial conditions.
 - Use available solar and magnetic indexes to characterize the impact of the solar event.
- 3.- Select the dataset of the region of study (latitudes, longitudes, stations).
- 4 .- Characterize the regular variation (based on selection of Quiet Days)
- 5.- Analyze the effect of the disturbance on TEC, Ne, earth magnetic field, and others



SOME MAGNETIC INDICES FOR GEOPHYSICS STUDIES



OUTLINES

WHY USE MAGNETIC INDICES ?

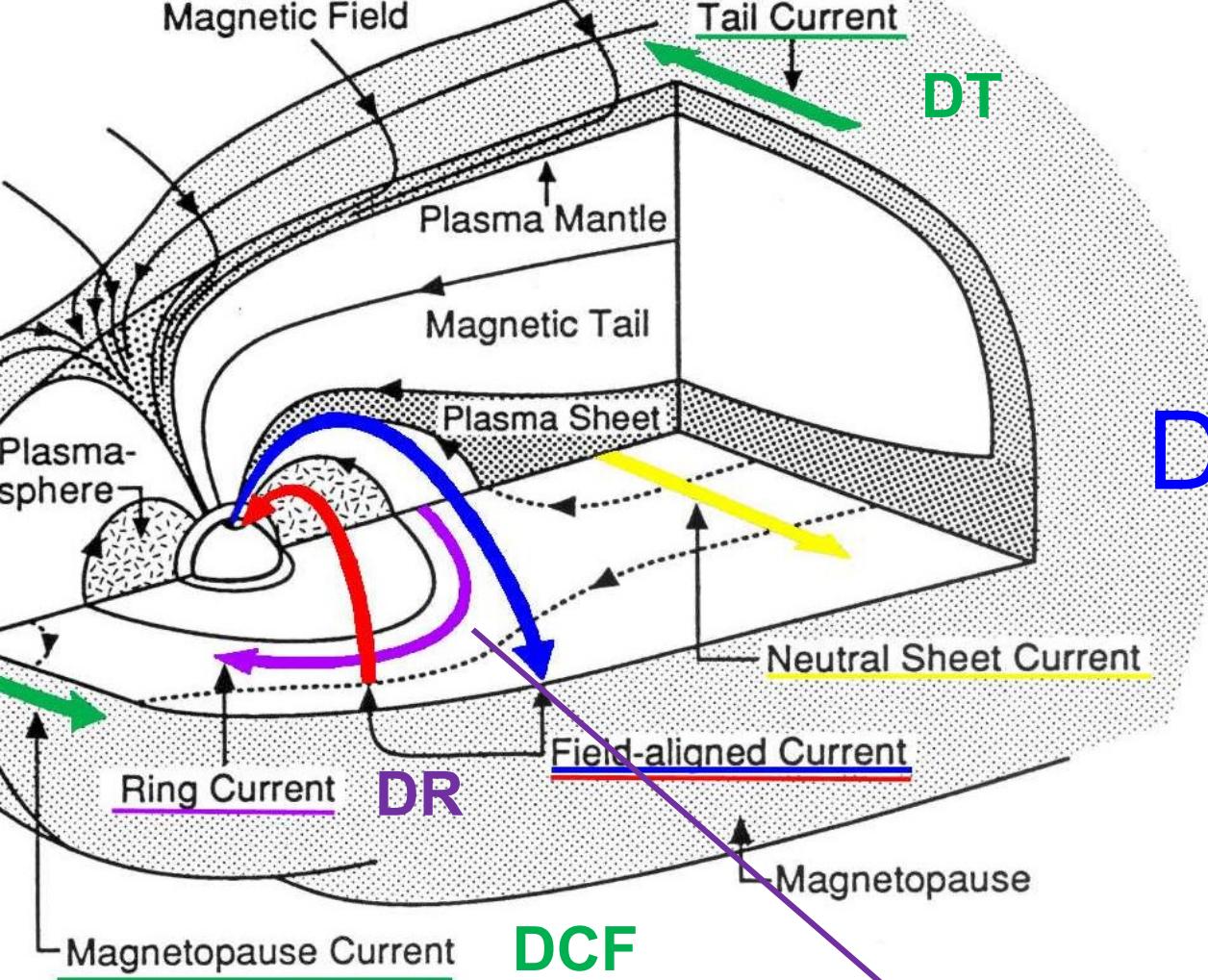
- THE CONCEPT OF MAGNETIC INDICES
 - K index, S_R
- USE OF MAGNETIC INDICES FOR GEOPHYSICS STUDIES
 - $K_p(ap)$ / $K_m(am)$
 - to select quiet days
 - Storm Dst index
 - Auroral indices AU and AL
 - Polar cap indices PCN and PCS

WHY USE MAGNETIC INDICES: TO APPROACH A COMPLEX REALITY

MAGNETIC INDICES ARE PROXIES

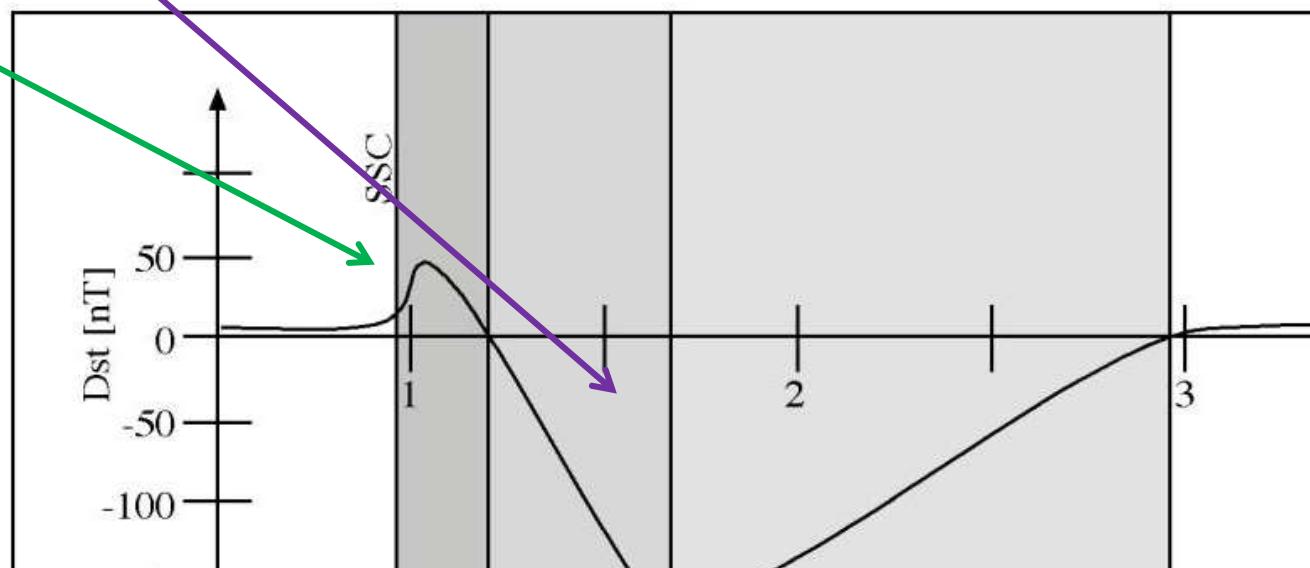
MAGNETIC INDICES ARE COMPLEMENTARY

MAGNETOSPHERE

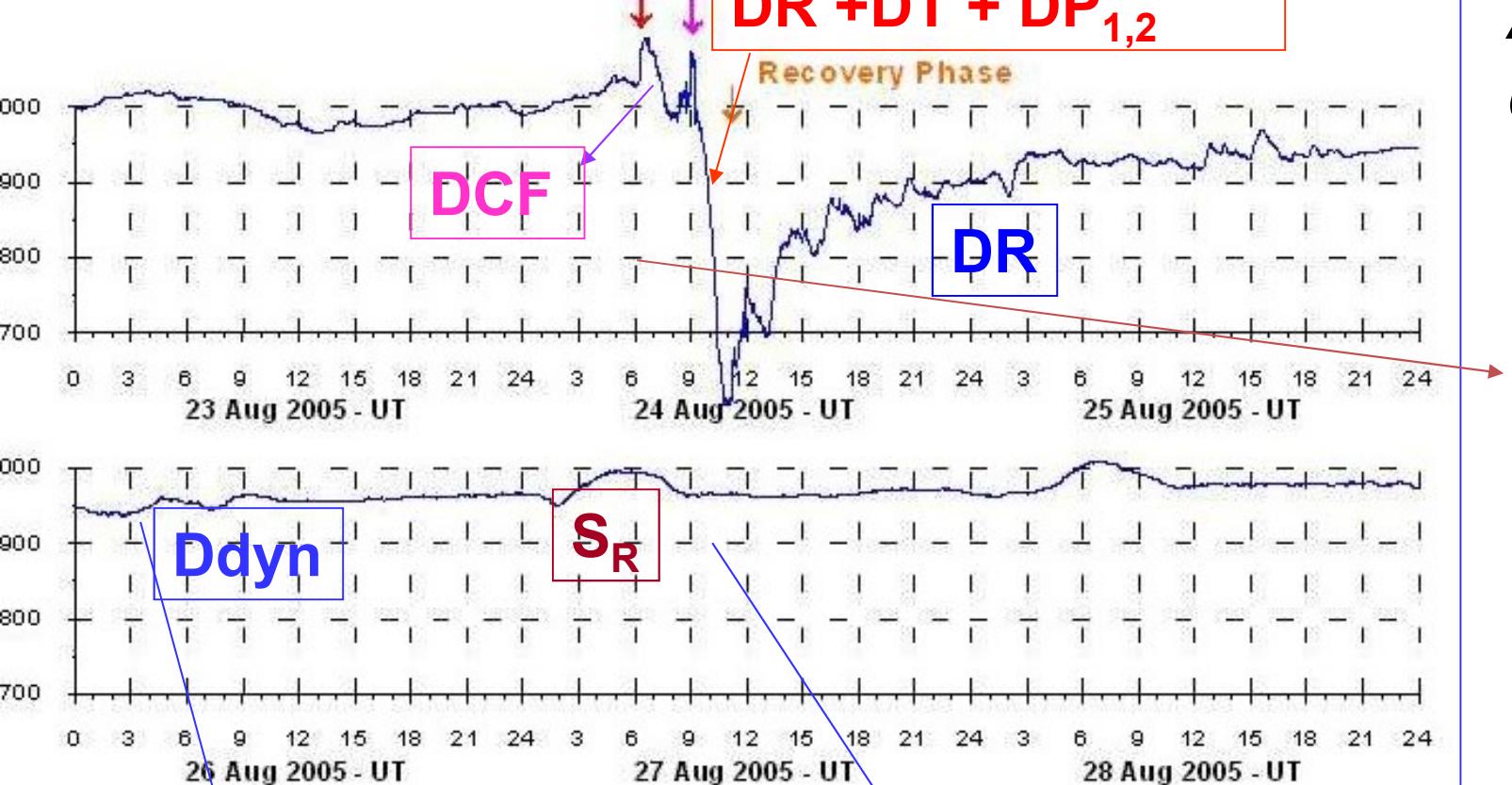


Dst , SYMH, ASYM
magnetospheric
electric currents

Chapman Ferraro current
ring current
tail current



A knowledge built
during centuries



Time variation of the H-component observed at Phu Thuy
(Hanoi – Vietnam) from 23th to 28th August 2005

COUPLING SOLAR WIND
MAGNETOSPHERE IONOSPHERE

RADIATIONS
IONOSPHERE
DOMINATING

THE CONCEPT OF MAGNETIC INDICES

K INDEX / S_R

A measure of the range of irregular and rapid storm-time magnetic activity.

- Mayaud, 1980, *Derivation Meaning and Use of geomagnetic indices*
- Men vielle et al, 2008, *A guide to geomagnetic indices derived from Earth surface data*

USE OF MAGNETIC INDICES

TO SELECT MAGNETIC QUIET DAYS

=> physical processes related to solar radiations are dominant

except for quiet days after big storms
ionospheric disturbance dynamo

K index weak => magnetic quiet day

S_R dominates / radiation

K index large => magnetic disturbed day

Disturbance dominates / solar wind

Magnetic indices based on index K

Kp Ap

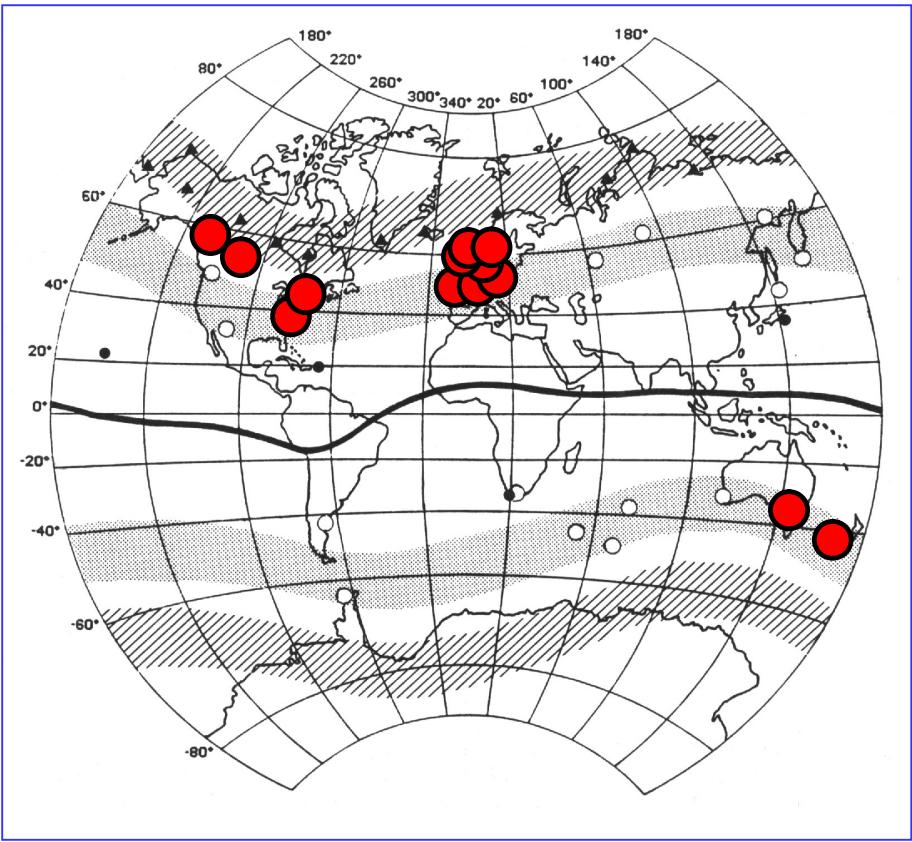
Km Am

Aa

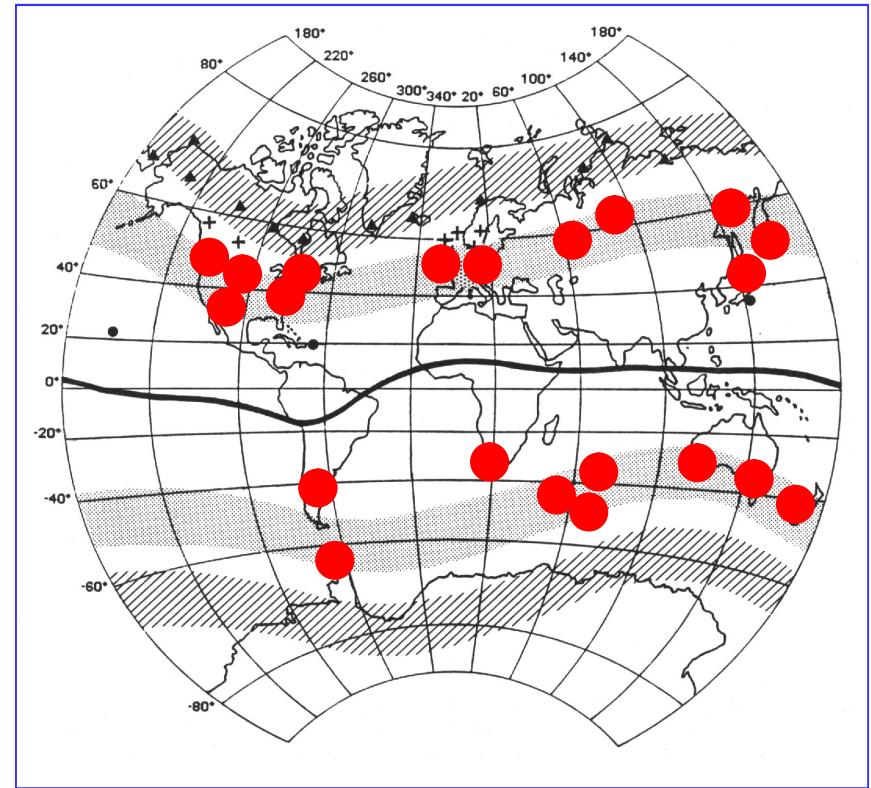
Stations used for the K_p (ap) and K_m(am)

Quiet magnetic activity

ap < 20 nT => quiet day ; am/ap < 13 nT => very quiet day
with all the K_m/K_p < 2+

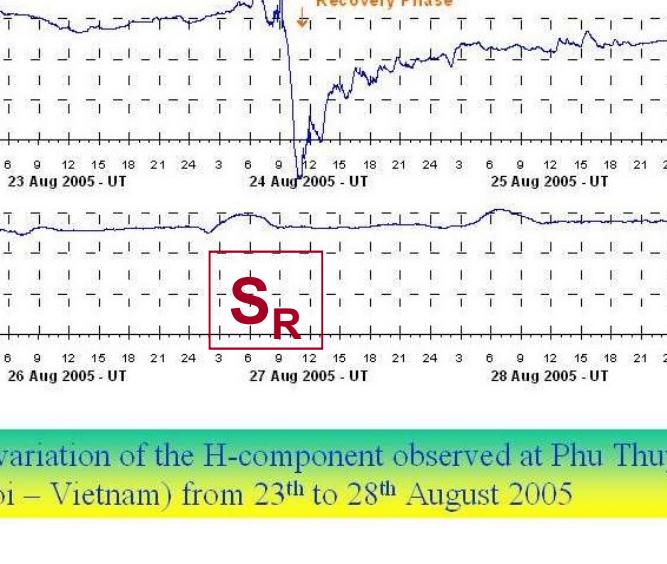


K_p: 12 observatories
9 in the northern hemisphere
2 in the southern hemisphere



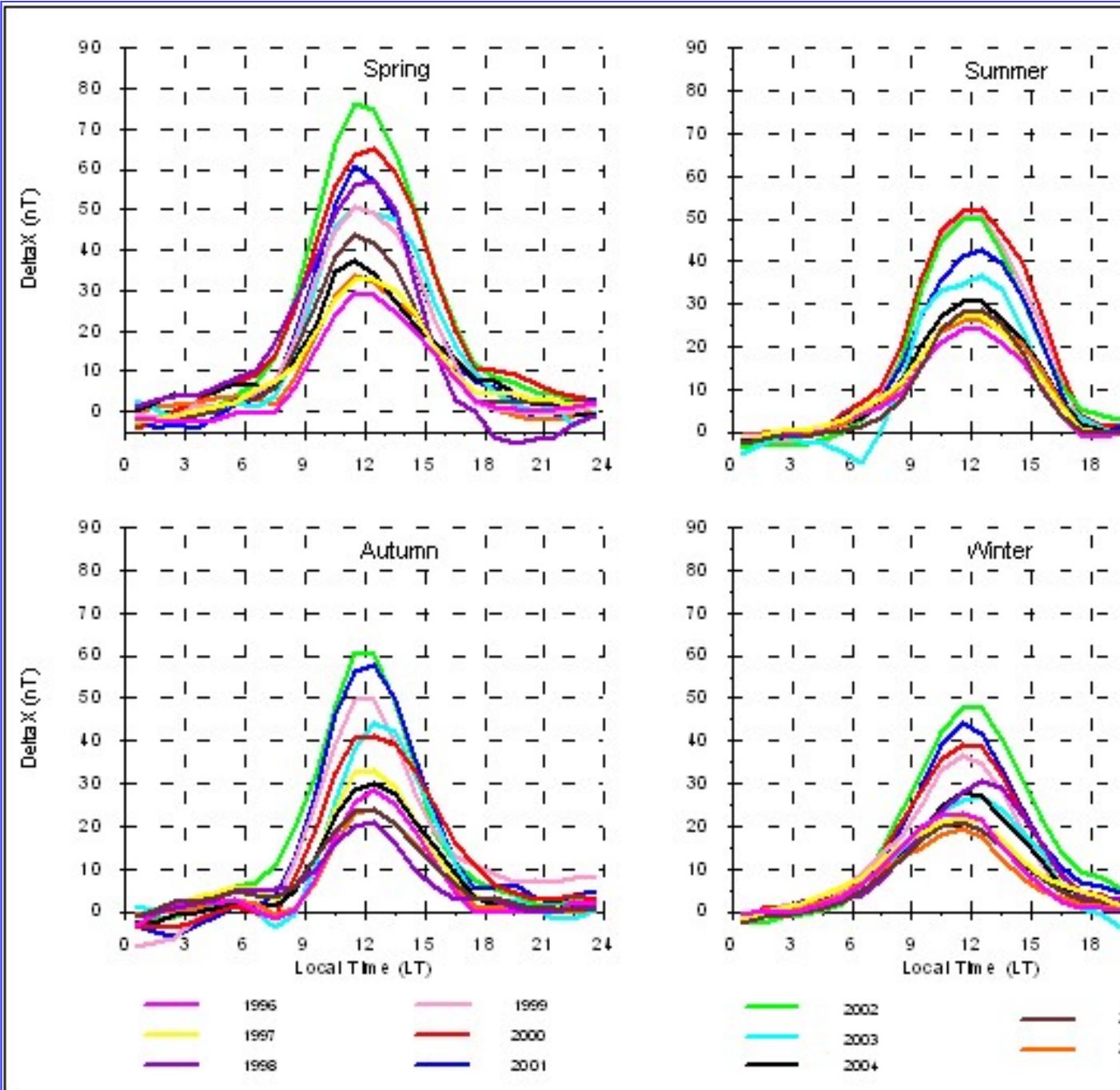
Ap: 23 observatories
12 in the northern hemisphere
9 in the southern hemisphere
K_N and K_S

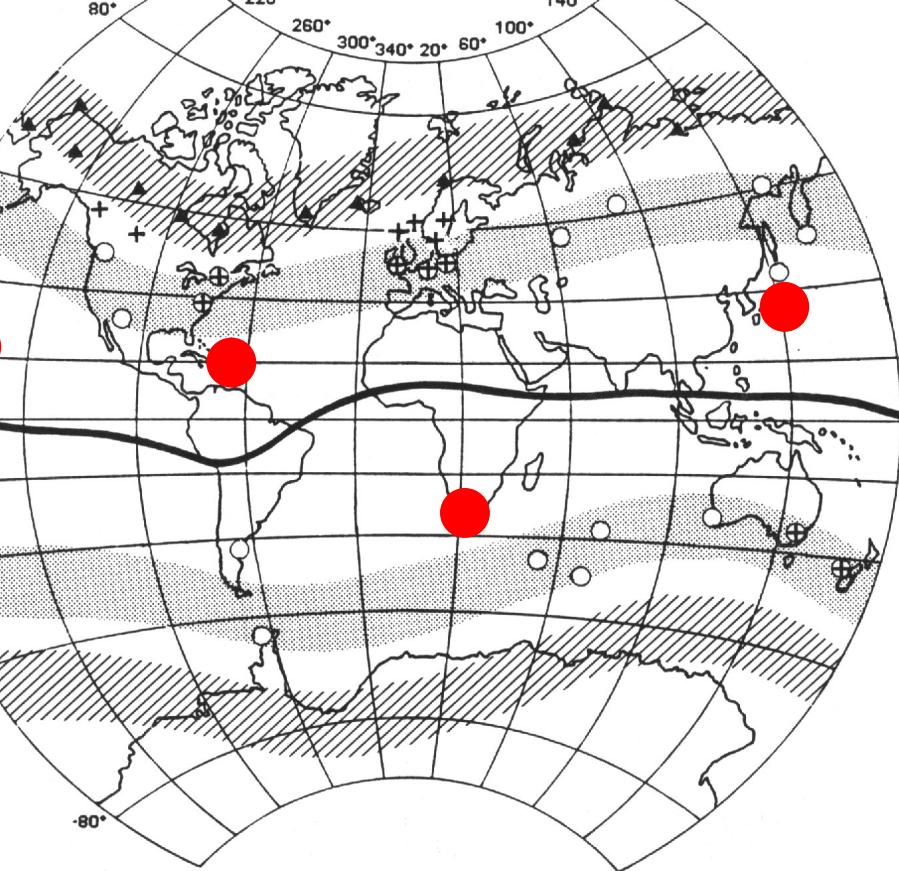
Daily am/ap < 20 nT



ly on the regular
spheric dynamo
e origin of the **S_R**

selection of days
essential for all
studies in GEOPHYSICS





Dst index \longleftrightarrow symmetric part
of the ring current

is computed using 1-minute values from four low latitude observatories locations of which are sufficiently distant from the auroral and equatorial electrojets to inhibit noise from these two sources.

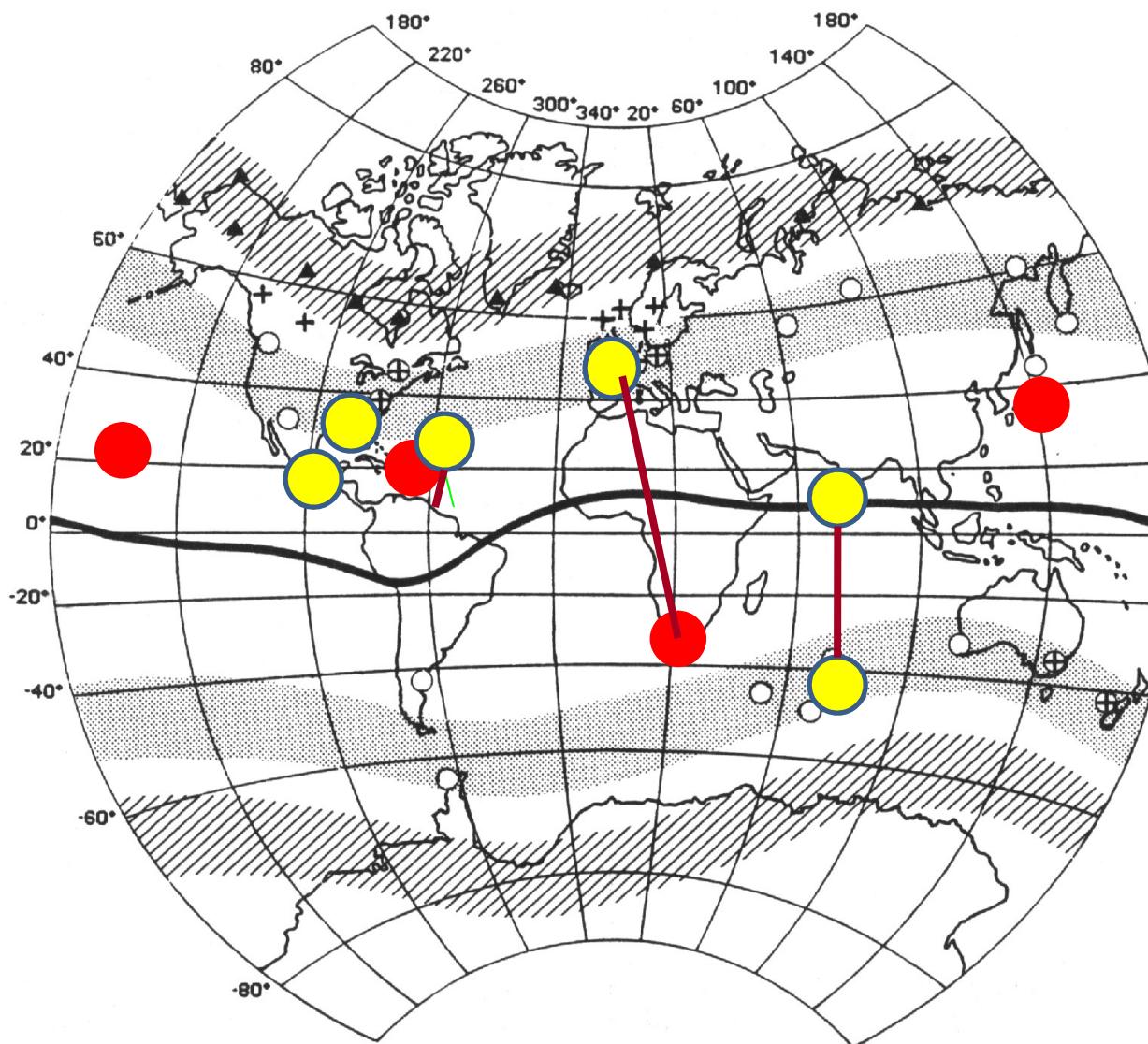
Local Dst values are computed at each “Dst” observatory at one instant in time. Contributions to H from the background field (non-transient field of core and crust) and the solar regular daily variation S_R are first subtracted from the observed H . The local Dst value is deduced from the so-obtained residual D through normalization to the dipole equator. For each 1-hour UT interval, the Dst index is the average of the local Dst hourly mean values at the four “Dst observatories.” (Manviello et al., 2008)

SYMH + ASYH

Dst

SYM and ASY indices

SYM (1') \leftrightarrow Dst (1h)



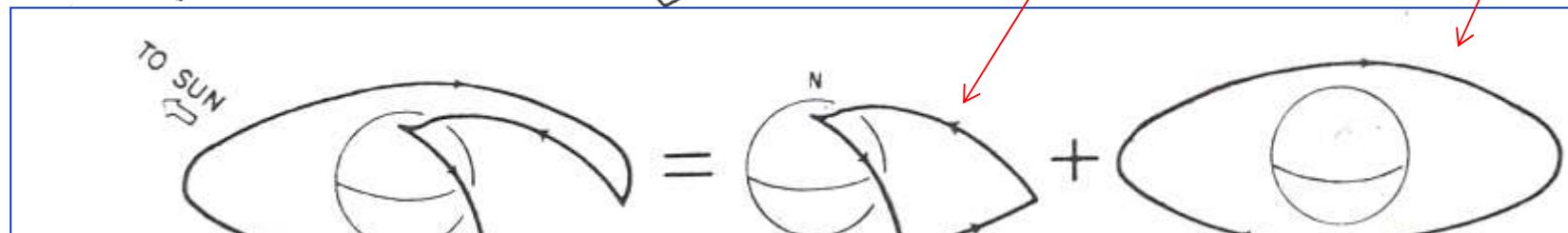
Describe the geomagnetic disturbances in terms of longitudinally asymmetric (ASYH) and symmetric (SYM) disturbances for both *H* and *D* components respectively parallel and perpendicular to the dipole axis.

ASYH

SYM

~

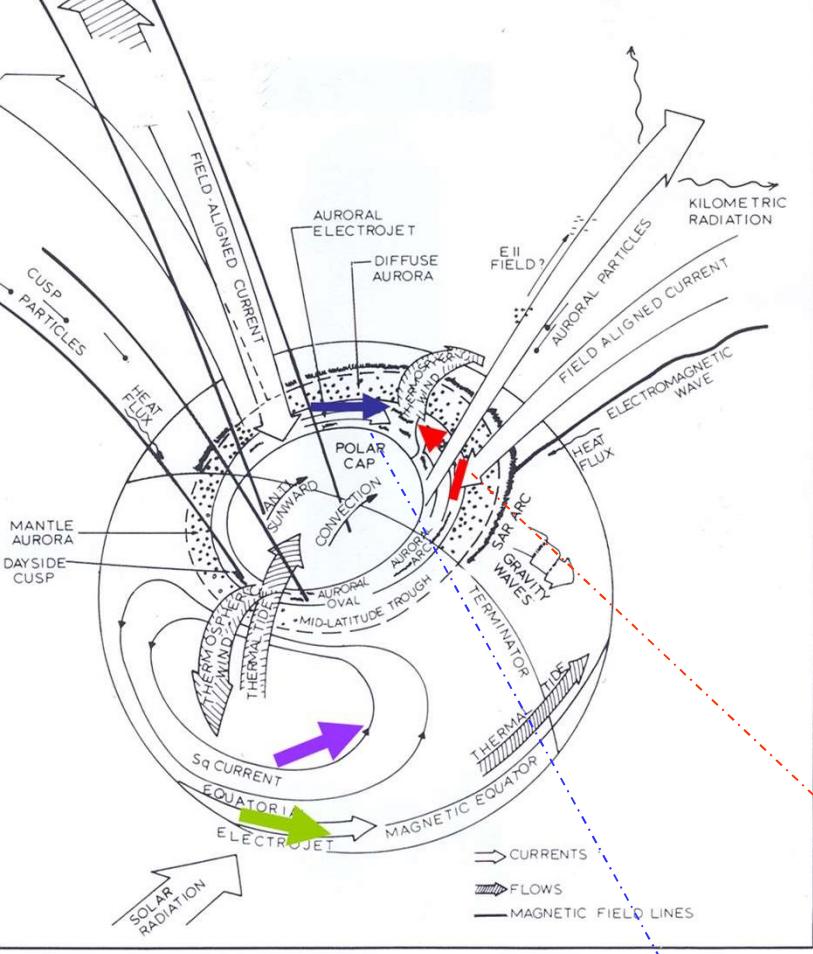
Dst



Auroral indices



Auroral electrojets

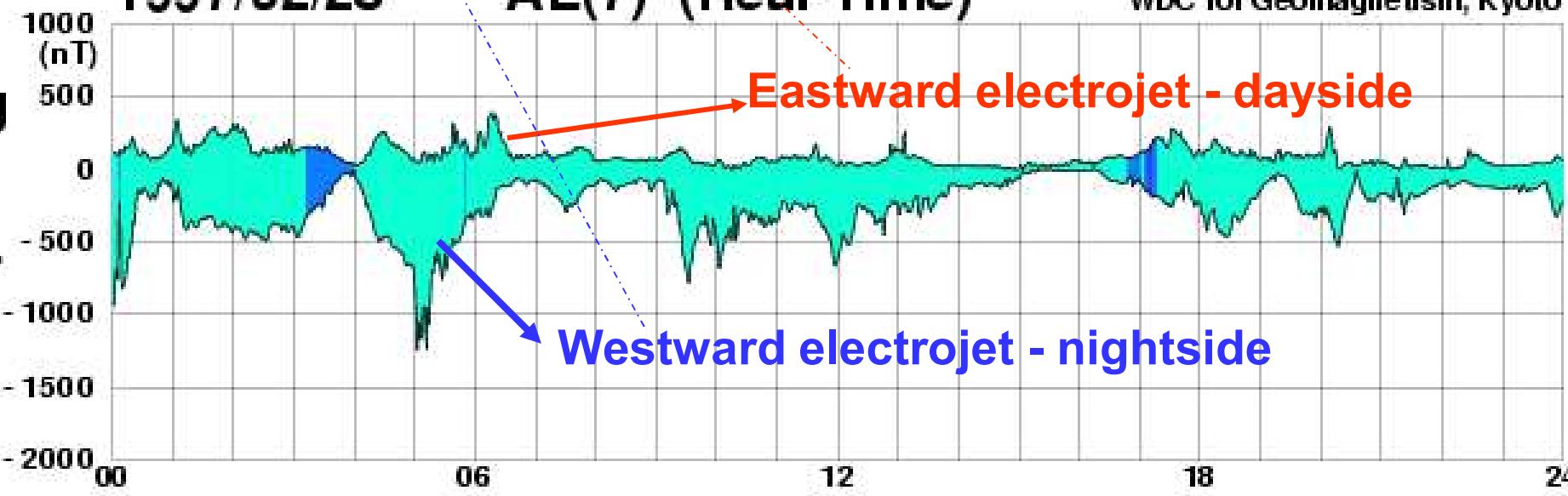


1997/02/28

AE(7) (Real-Time)

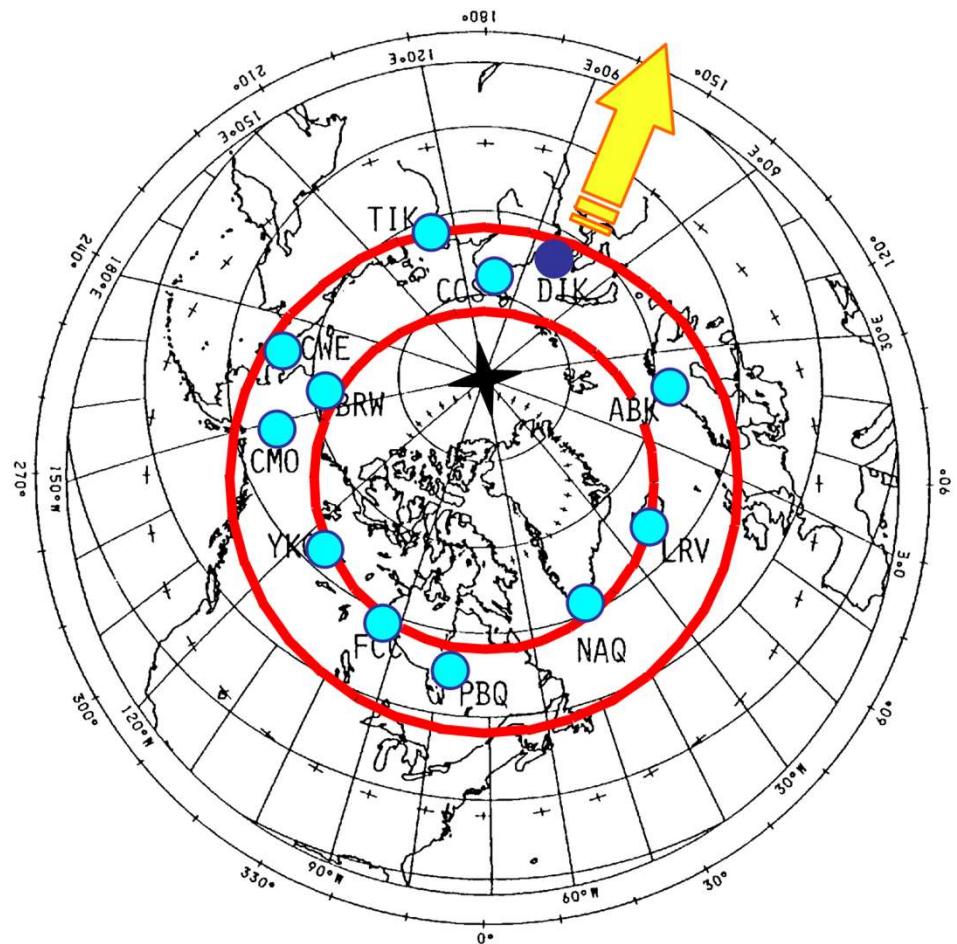
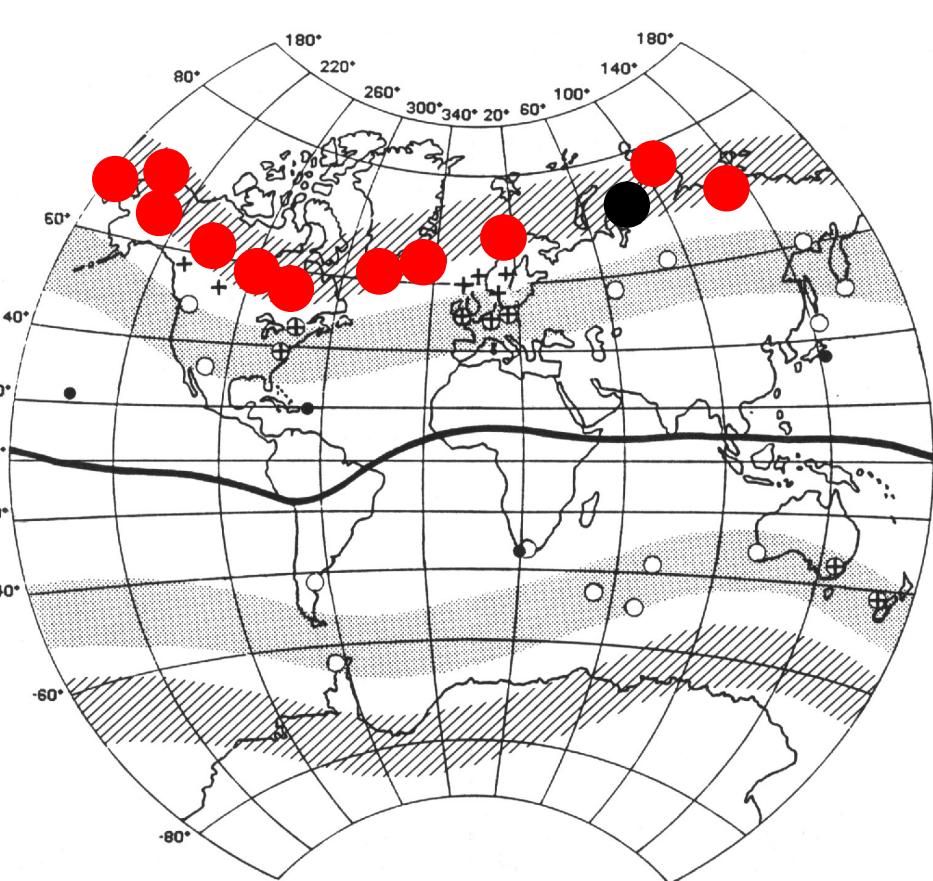
WDC for Geomagnetism, Kyoto

AU



12
11
10
9
8
7
6
5
4
3
2
1

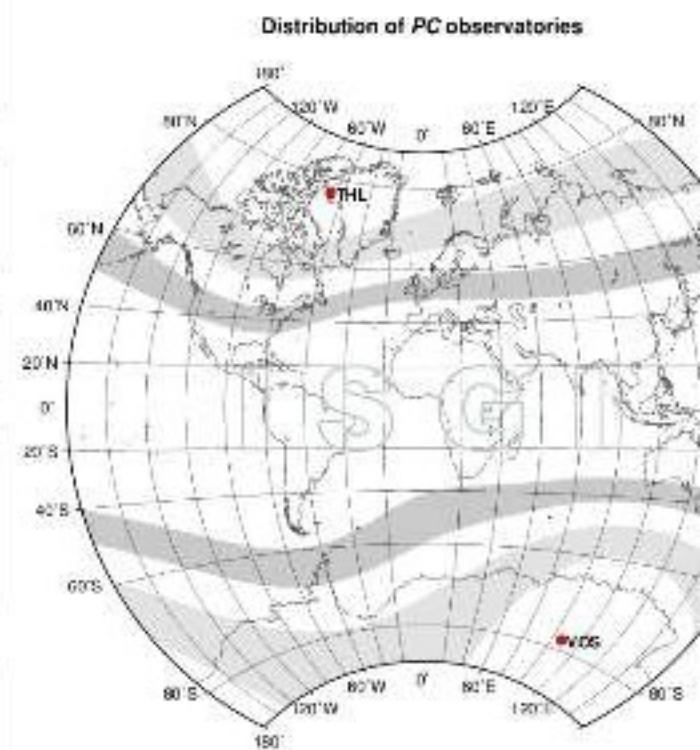
AU, AL auroral electrojets



The H magnetograms from the “AE” stations are superimposed: the upper envelope defines the AU index, and the lower envelope defines the AL index, $\Xi = (\text{AU}-\text{AL})$ and $\text{AO} = (\text{AU}-\text{AL}) / 2$. From 2005 onwards, the AE indices are calculated from data from up to 12 sites in the northern auroral zone. AE is expressed in units of nT ” (Menyelle et al., 2008)

POLAR CAP (PC) MAGNETIC ACTIVITY INDICES

Indices	PCN, PCS time resolution: 1 minute (UT) interval unit: mV/m
available	PCN: from 1975 onwards PCS: from 1995 onwards
use of index	Polar Cap index horizontal component disturbances
purpose	To monitor the geomagnetic activity over the polar caps caused by changes in the interplanetary magnetic field (IMF) and solar wind, driven by the geoeffective interplanetary electric field irrespective of time, season and solar cycle.
network	Made of 2 polar cap stations. (see list of actual and previous PC magnetic observatories)
derivation	The PC index is deduced (*) from the deviations in the horizontal H and D magnetic field components from the quiet level at the two polar cap stations (Thule and Vostok for respectively the PCN and PCS). (*) More specific and detailed information may be found on the PC-index website devoted to PC index.



Polar cap index is a proxy of the merging electric field

$$V_{sw} B_T \sin^2(\theta/2) (2)$$

wind velocity, V_{sw} , and the transverse component, B_T , ($B_T = (B_Y^2 + B_Z^2)^{1/2}$) of the interplanetary magnetic field (IMF) in the solar wind and includes a strong dependence on the direction represented by the polar angle θ of the transverse component of the IMF with respect to the direction of the Z-axis in a "Geocentric Solar Magnetospheric" (GSM) coordinate system.

CONCLUSION

Magnetic indices are

- Continuously computed
- Available on the web
- Essential to
 - To define the geophysical context
 - To approach physical parameters
 - Classify days
 - etc....

TRANSDISCIPLINARY TOOLS



<https://solarscience.msfc.nasa.gov/SunspotCycle.shtml>

Sunspot cycle

www.spaceweather.com

SW general situation (CME-Coronal Hole)

<https://www.swpc.noaa.gov/products/predicted-sunspot-number-and-radio-flux>

F10.7cm, sunspot number

OMNIWEB

<https://omniweb.gsfc.nasa.gov>

V_s B_{imf}, E_{yimf}, SYM-H, Dst, AU, AL AE

http://isgi.unistra.fr/geomagnetic_indices.php

Aa, A_p/K_p, A_m/K_m

WORLD DATA CENTER KYOTO

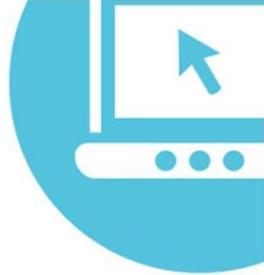
<http://wdc.kugi.kyoto-u.ac.jp/>

All indices and some magnetometers

MAGNETOMETERS INTERMAGNET

<http://www.intermagnet.org/>

Magnetometers all over the world



https://cdaw.gsfc.nasa.gov/CME_list/

List of CME

<http://www.geodin.ro/varsiti/>

List HSSW

https://xrt.cfa.harvard.edu/flare_catalog/

List of SF

http://guvitimed.jhuapl.edu/data_products

GUVI O/N2

<https://gold.cs.ucf.edu/data/search/>

GOLD O/N2

<https://arplsrv.ictp.it>

ICTP Calibratec TEC service

GNSS websites with available free data

About RINEX format: <ftp://igs.org/pub/data/format/>

Hatanaka Format Information at UNAVCO

<https://www.unavco.org/data/gps-gnss/hatanaka/hatanaka.html>

IGS network:	http://www.igs.org/about/data-centers
CDDIS (USA)	- 1992-now: ftp://cddis.gsfc.nasa.gov/gnss/data/daily/
SOPAC (USA)	- 1988-now: ftp://garner.ucsd.edu/pub/rinex/
CORS	ftp://www.ngs.noaa.gov/cors/rinex/ ftp://alt.ngs.noaa.gov/cors/rinex/
GARNER	ftp://garner.ucsd.edu/pub/rinex/yyyy/doy/file ftp://garner.ucsd.edu/rinex/
IGN (France)	- 1990-now: ftp://igs.ensg.eu/pub/igs/data/
KASI (South Korea)	- 1993-now: ftp://nfs.kasi.re.kr/gps/data/daily/
BKG (Germany)	- 1991-now: ftp://igs.bkg.bund.de/IGS/obs/C
China	- 1990-now: ftp://igs.gnsswhu.cn/pub/gps/data/daily/
UNAVCO (USA)	- 1992-now: ftp://data-out.unavco.org/pub/rinex/obs/
EUREF	ftp://igs.bkg.bund.de/EUREF/obs/
<i>specific website</i>	
AFREF (South Africa)	- 2004-now: ftp://ftp.afrefdata.org/ <i>only stations in Africa</i>
SONEL	ftp://ftp.sonel.org/gps/data/
MGEX Campaign	ftp://igs.ign.fr/pub/igs/data/campaign/mgex/daily/rinex3/
AuScope (Australia)	- 1993-now: ftp://ftp.ga.gov.au/geodesy-outgoing/gnss/data/daily/ <i>stations in Australia and Pacific</i>
TIGA	- 1990-now: ftp://ftp.sonel.org/gps/data/ <i>stations near sea</i>
NOAA	- 1994-now: ftp://geodesy.noaa.gov/cors/rinex/ <i>stations mainly in the USA</i>
IONEX (MAPS)	ftp://cddis.gsfc.nasa.gov/gps/products/ionex/ ftp://ftp.unibe.ch/aiub/CODE/

<http://mycoordinates.org/>

Space Weather: From the Sun to the Earth : the key role of GNSS

Backup Slides

PPEF and DDEF

PPEF : Prompt Penetration of the magnetospheric electric field

Current system DP2

DDEF: Disturbance Dynamo Electric field

Current system Ddyn

H component at middle and low latitudes

$$\Delta H = Sq/S_R + SYM-H + D_{iono}$$

Sq = $\langle S_R \rangle$ on quiet days
Dayside only

$$D_{iono} = \Delta H - Sq/S_R - SYM-H \cos(\lambda)$$

λ : dip latitude

$\cos(\lambda)=1$ at the Equator

$\cos(\lambda)= 0$ at the pole

at Low latitudes : $D_{iono} = DP_2 + D_{dyn}$