2012 ISWI and MAGDAS School

This Logo will be renewed soon!

Equatorial Electrojet Index: EE-index

~ For monitoring temporal and long-term variations of the EEJ ~

Teiji Uozumi, K. Yumoto and MAGDAS/CPMN Group

International Center for Space Weather Science and Education,
Kyushu University: ICSWSE

Special thanks to Mr. T. Ueno, Mr. Y. Fujita and Mr. Y. Numata
who analyzed EE-index in their master thesis

Reference: Teiji Uozumi, K. Yumoto, K. Kitamura, S. Abe, Y. Kakinami, M. Shinohara, A. Yoshikawa, H. Kawano,T. Ueno, T. Tokunaga, D. McNamara, J. K. Ishituka, S. L. G. Dutra, B. Damtie, V. Doumbia, O. Obrou, A. B. Rabiu, I. A. Adimula, M. Othman, M. Fairos, R. E. S. Otadoy, and MAGDAS Group, A new index to monitor temporal and long-term variations of the equatorial electrojet by MAGDAS/CPMN real-time data: EE-Index, *Earth Planets Space*, 60, 785-790, 2008.

Outline :

- ✓ Brief Historical Remarks
- ✓ Structure of the Equatorial Electrojet (EEJ)
- ✓ Occurrence Mechanism of EEJ
- ✓ Magnetic Disturbances observed at the Equator
- ✓ EE-index: Definition / Methodology
- ✓ Some Applications of EE-index
- ✓ Realtime EE-index
- ✓ Summary

Brief Historical remarks

1922

" The magnetometer recording of the daily variation of the earth's magnetic field at Huancayo, Peru, started… "

1947 Edegal, J.

" The great augmentation of the range of H in a narrow zone near the magnetic equator seems to indicate that the variation is caused by a varying electric current flowing in a very narrow zone of the atmosphere above magnetic equator… the current is flowing in a height of about 100km."

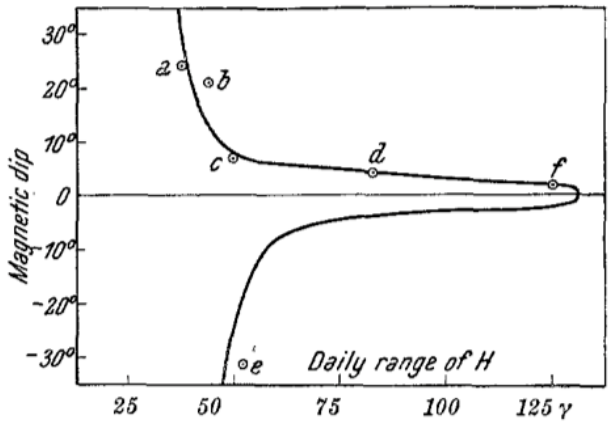


Fig. 3. The distribution of the range of the quiet-day solar daily variation of horizontal force, S_q (H), at six observatories, plotted by J. EGEDAL against the magnetic dip I.

a: Bombay; b: Manila; c: Madras;
d: S. India; e: Java; f: Huancayo.

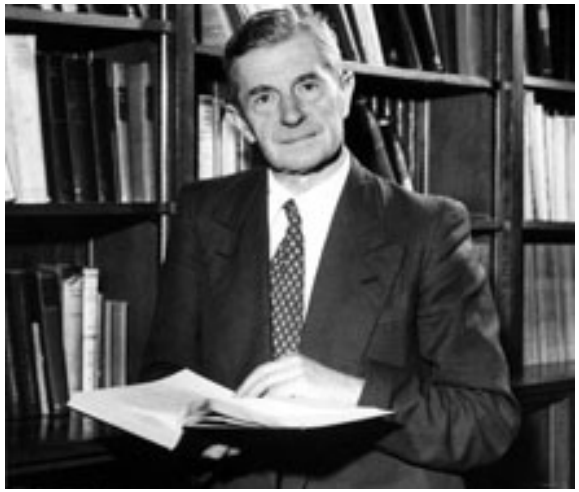
(Edegal, J. ,1947)

Brief Historical remarks

1951 Chapman, S.

" The abnormally large range of the daily variation of the horizontal component of magnetic force over Huancayo, Peru indicates the daily rise and decline of a concentrated eastward electric current…

The name *electrojet* is suggested for this concentrated current."



Sydney Chapman [1888-1970]

Chapman [1951]

550 . 389 : 551 . 594 . 18

The Equatorial Electrojet as Detected from the Abnormal Electric Current Distribution above Huancayo, Peru, and elsewhere.

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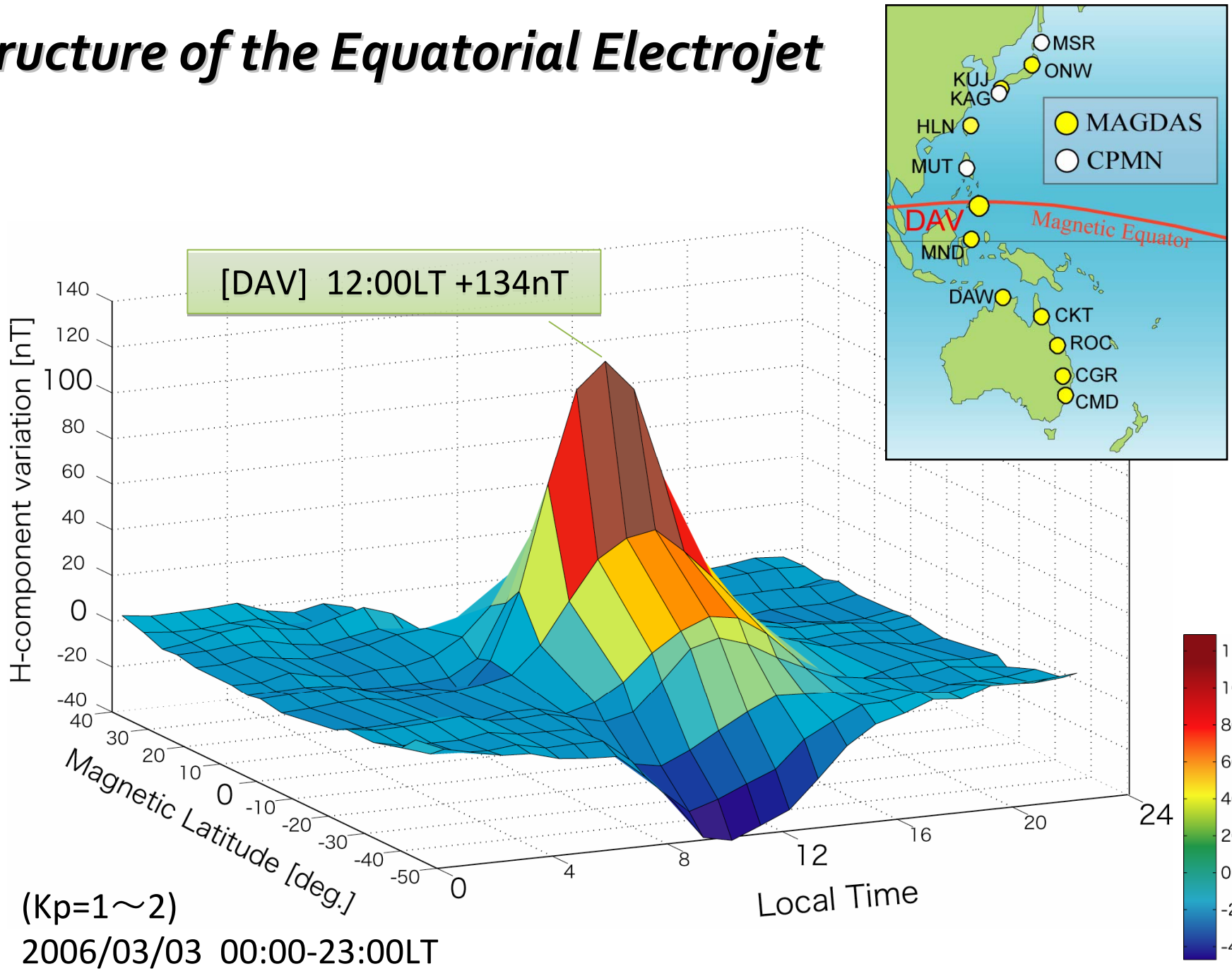
http://celebrating200years.noaa.gov/magazine/igy/sydney_chapman.html

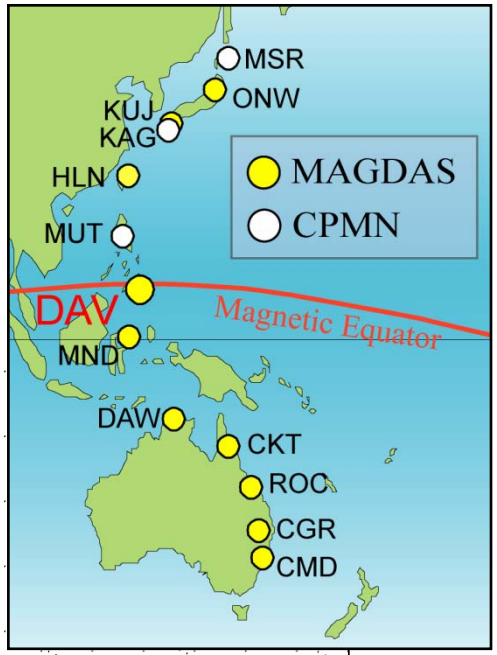
Structure of the Equatorial Electrojet

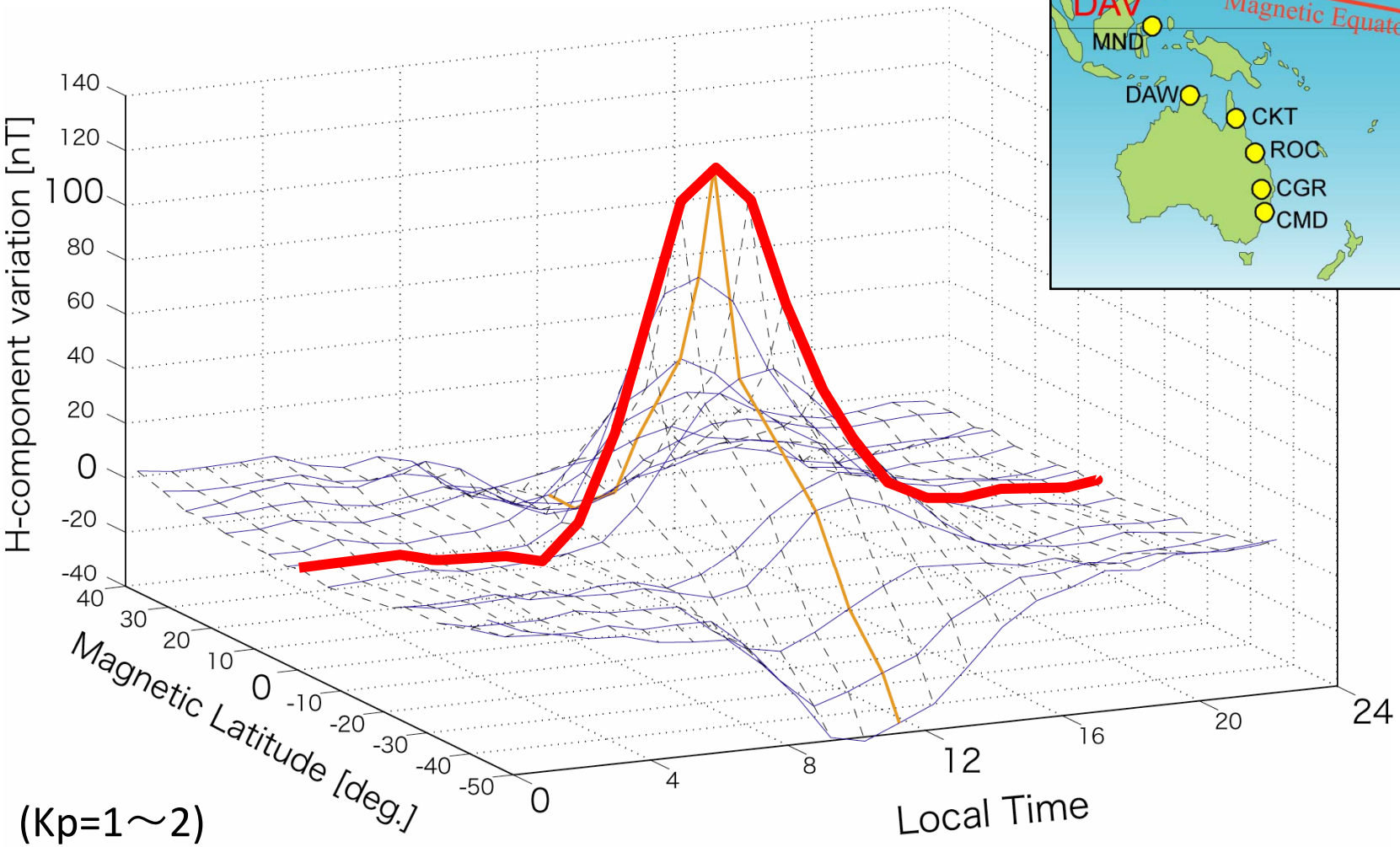


(Kp=1～2)

2006/03/03 00:00-23:00LT

Structure of the Equatorial Electrojet





(Kp=1～2)
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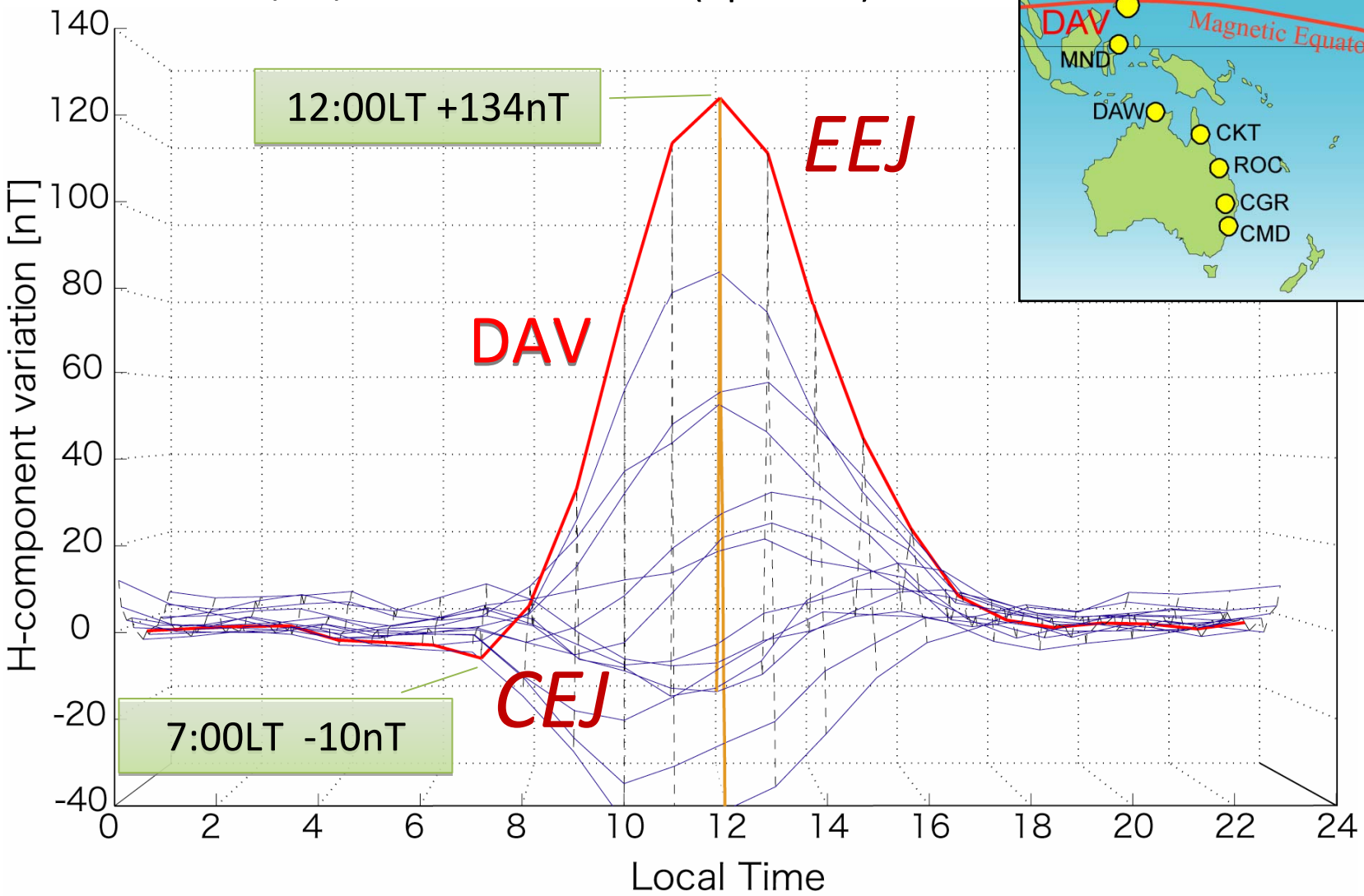
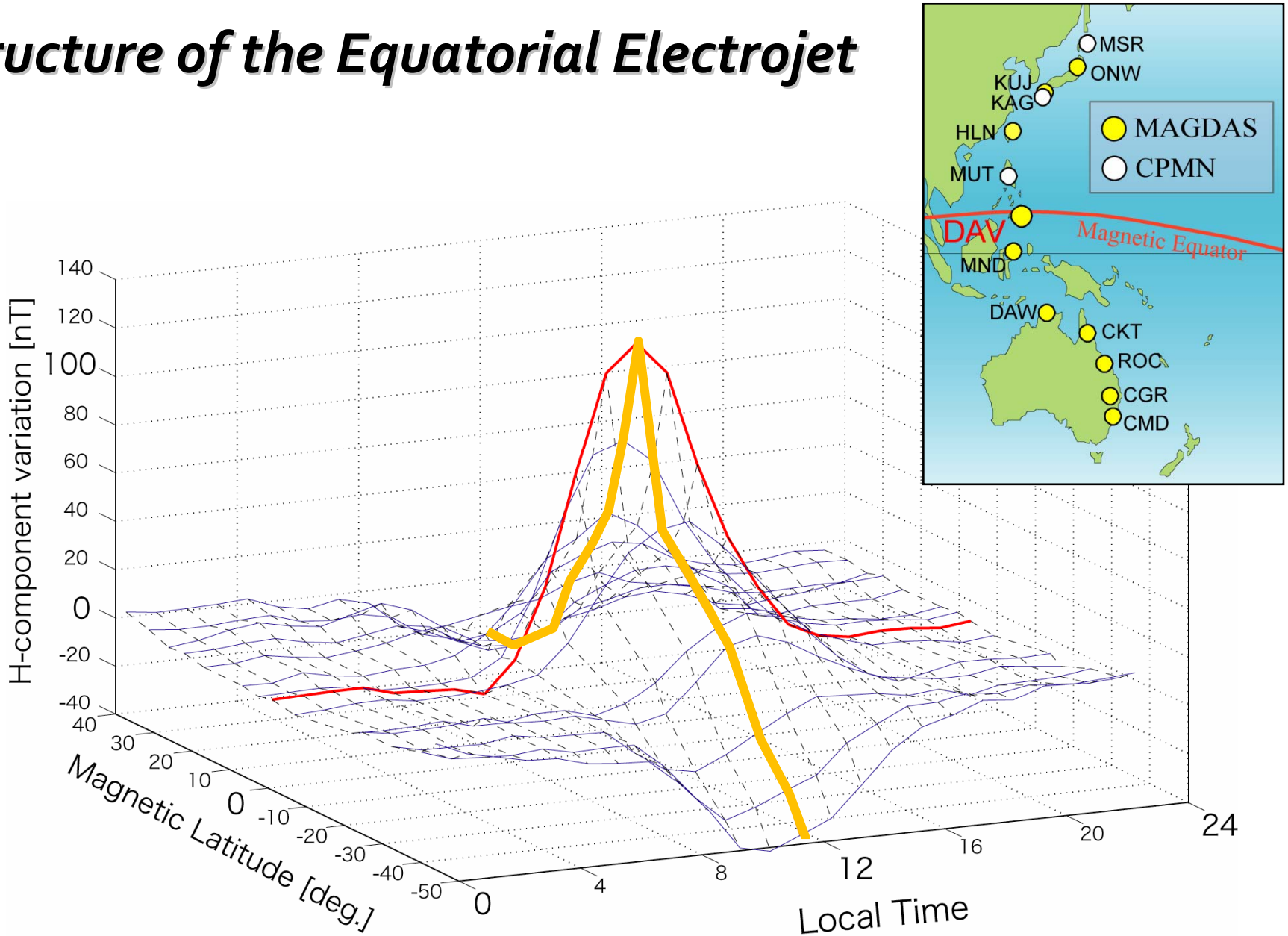
Structure of the Equatorial Electrojet



Structure of the Equatorial Electrojet



(Kp=1~2)

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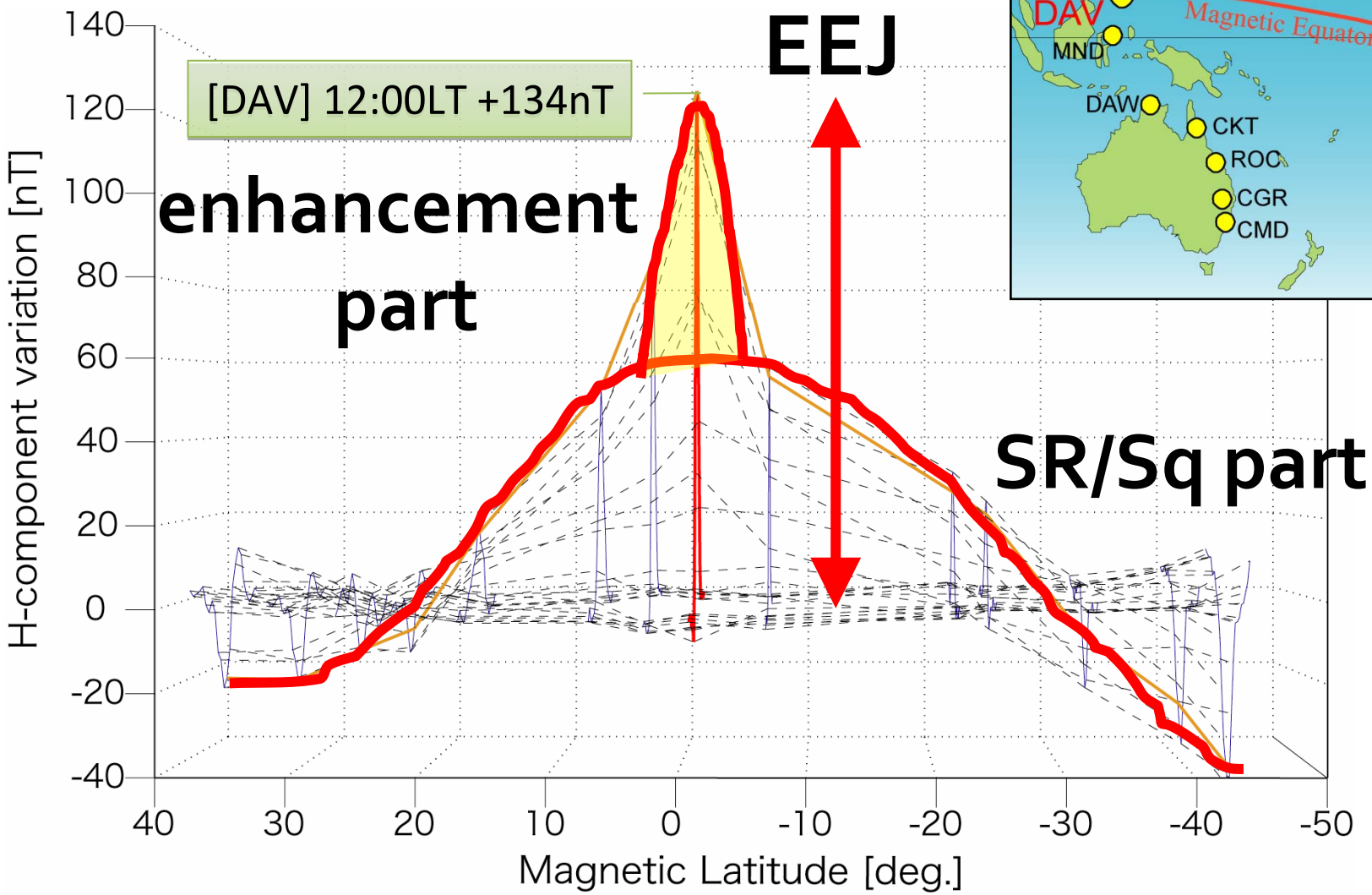
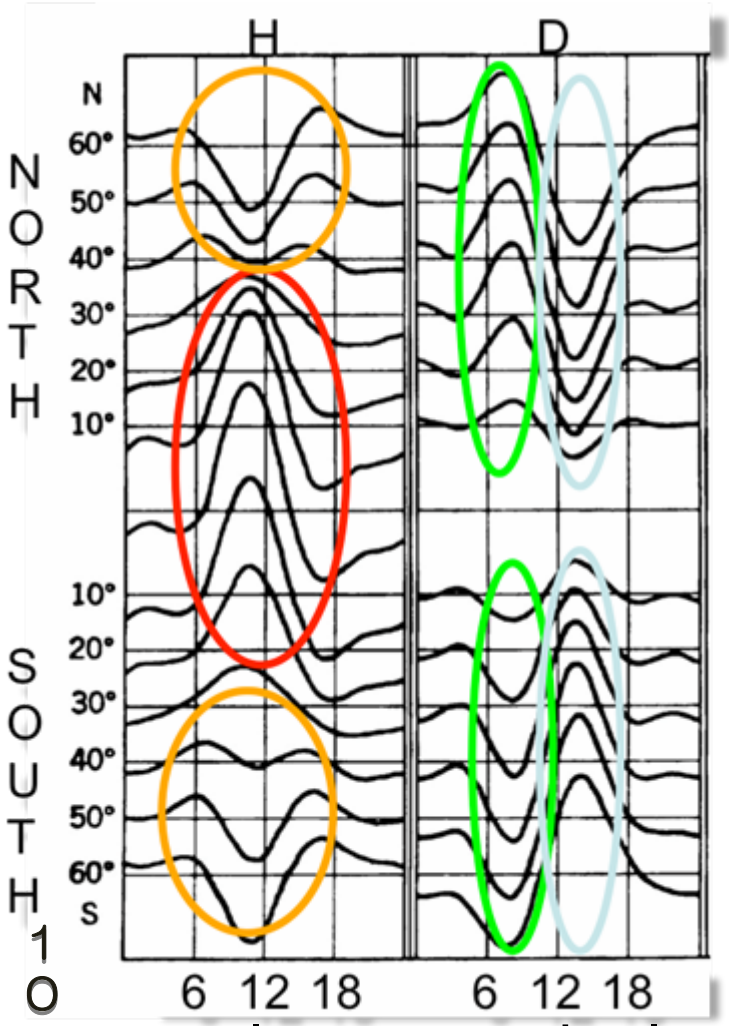
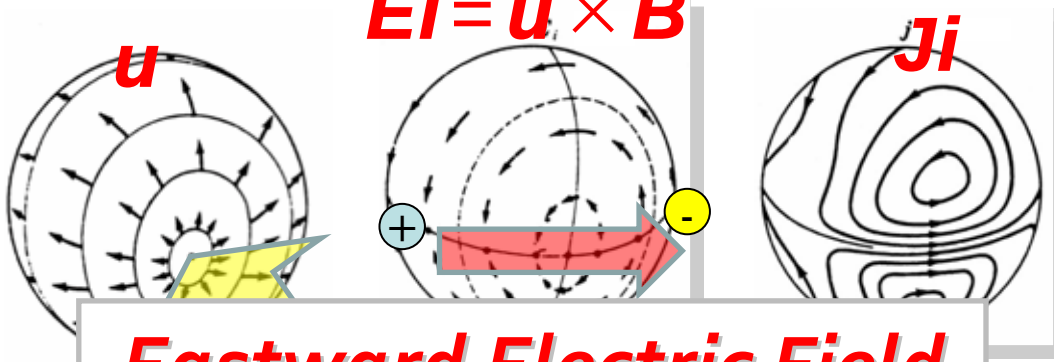
Structure of the Equatorial Electrojet



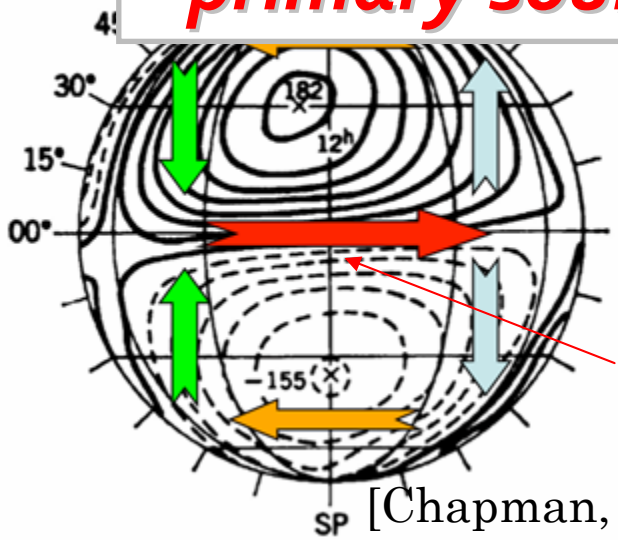
Traditional Understanding of the Occurrence Mechanism of the Sq and Equatorial Electrojet



$Ei = u \times B$



Eastward Electric Field primary source of EEJ



used
on
ere.
EEJ appears on the magnetic equator in the global geomagnetic Sq field.

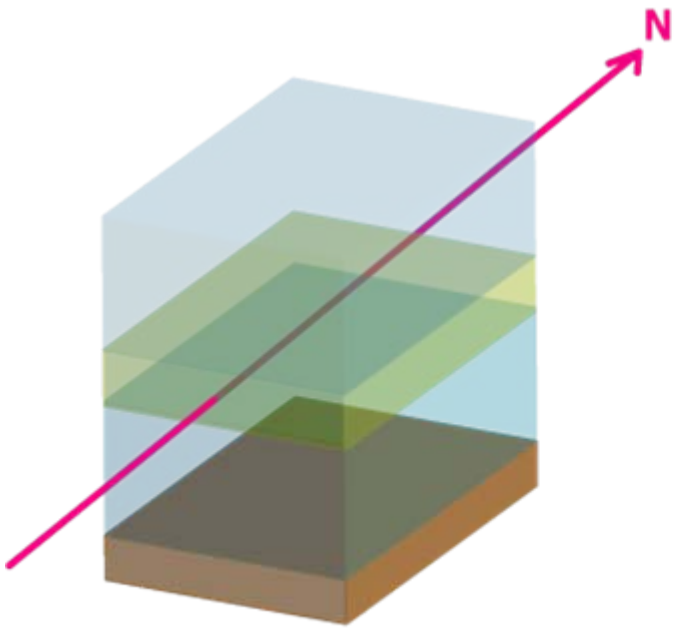
EEJ
(Equatorial ElectroJet)

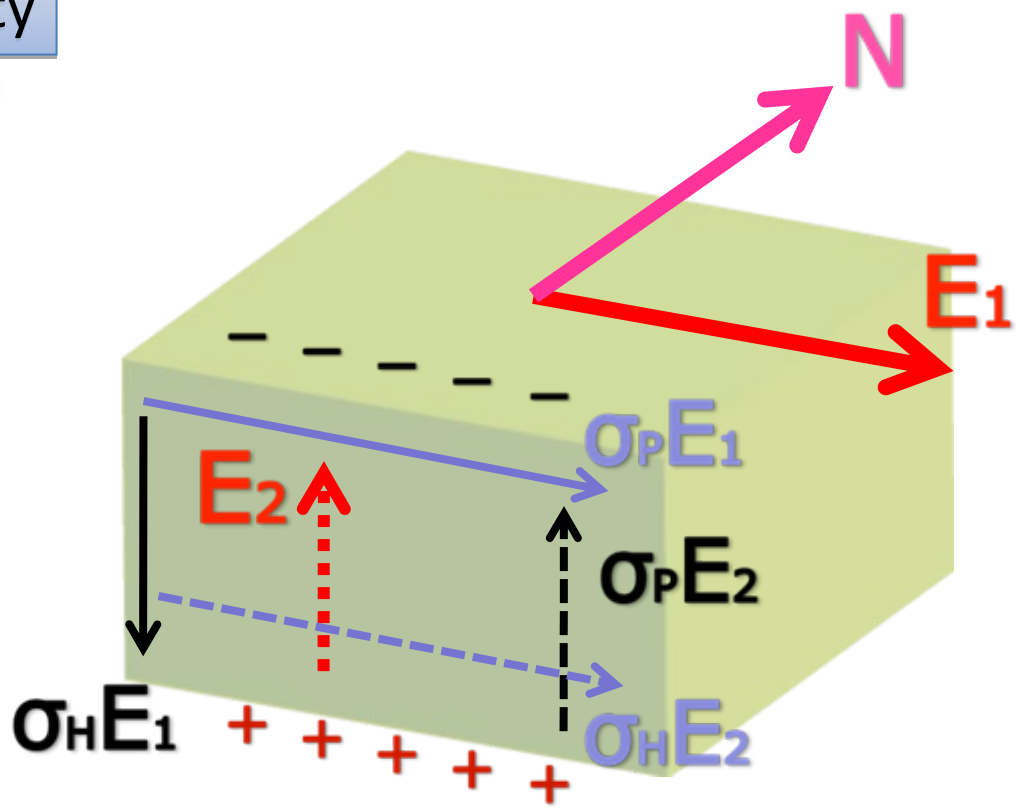
[Chapman, 1951; Fukushima, 1979]

Please see the lecture by Dr. Yoshikawa

Mechanism of the equatorial electrojet

Hirono/Cowling Conductivity





The Hirono/Cowling effect [Hirono, 1950] is dominant within ~3 deg dip latitudes.

Cowling [1933] studied the Hall current in the chromosphere of the sun. --> Cowling effect [see the lecture by Dr. Yoshikawa]

Hirono [1950] applied the idea to the actual equatorial ionosphere.

Along the mag. eq. in the ionosphere, a narrow region, in which the conductivity near the level of the E layer is much greater than in the other latitude.

The enhanced current was explained as being because of an abnormally large electrical conductivity [Hirono, 1950].

Hirono [1950]

On the Influence of the Hall Current to the Electrical Conductivity of the Ionosphere. I

By Motokazu HIRONO

Geophysical Institute, Kyoto University

Abstract

Direct electrical conductivity of the ionosphere is examined mainly concerning the effect of Hall current. It is suggested that the effect of the electric field produced by vertical component of the Hall current, together with the smaller effect by its horizontal component, may construct, along the magnetic equator in the ionosphere, a narrow region, in which the conductivity near the level of the E layer is much greater than in the other latitudes. This result is considered to be very fit for the distribution with latitudes of the range of diurnal variation of the terrestrial magnetism.

Actual geometry of the equatorial ionosphere

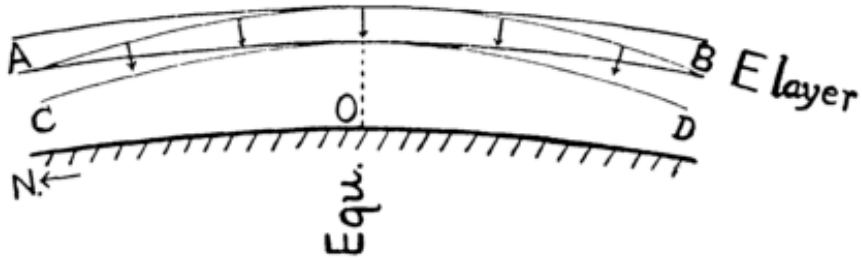


Fig. 1

Hirono [1950]

Latitudinal profile of the relative conductivity: numerical result

The Hirono/Cowling effect is dominant within ~3° dip latitudes.

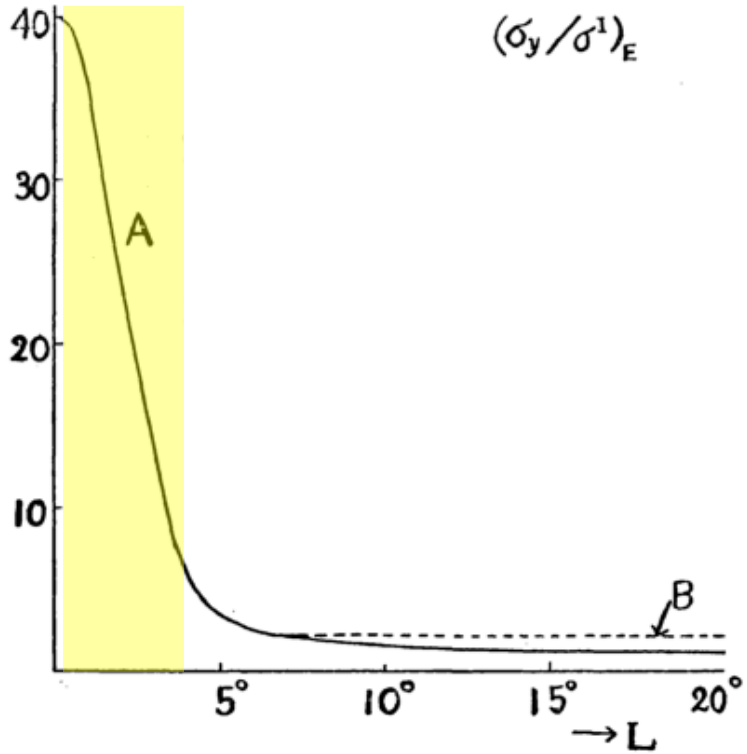


Fig. 7

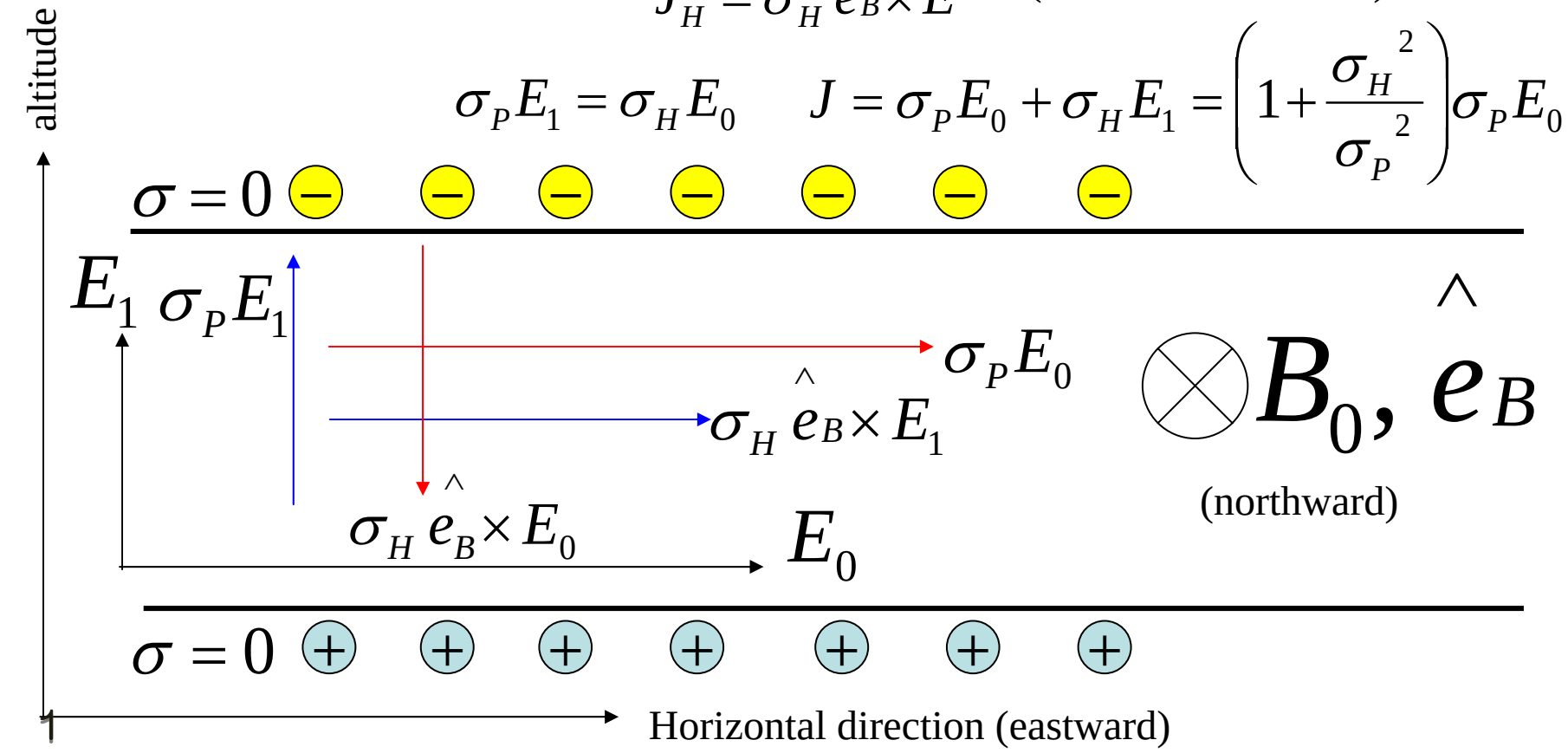
Hirono [1950]

The mechanism of Hirono/Cowling effect

Pedersen Current $J_P = \sigma_P E$ (Parallel to electric field)

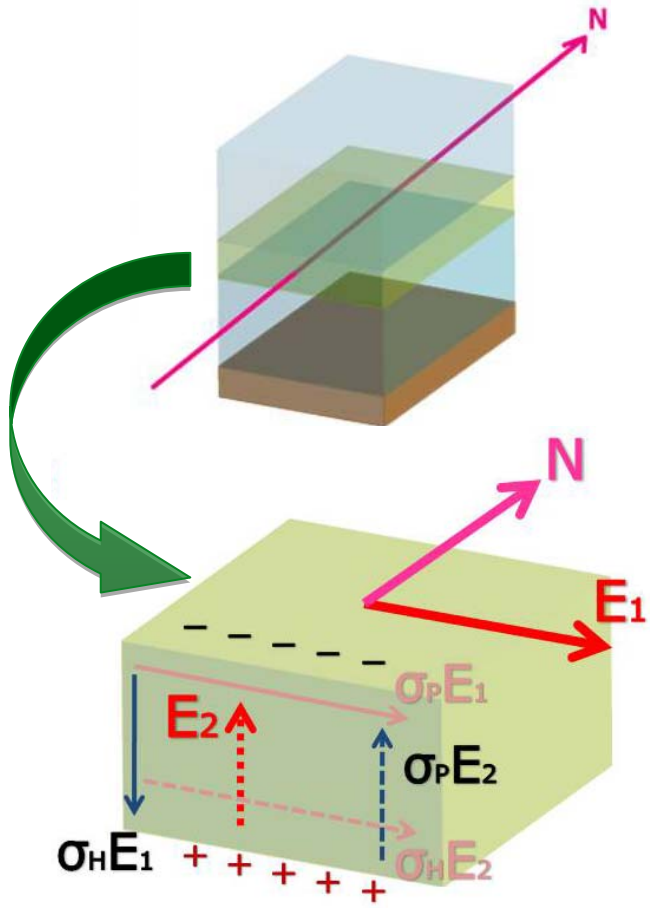
Hall Current $J_H = \sigma_H \hat{e}_B \times E$ (Direction of -E × B)

$$\sigma_P E_1 = \sigma_H E_0 \qquad J = \sigma_P E_0 + \sigma_H E_1 = \left(1 + \frac{\sigma_H^{\,2}}{\sigma_P^{\,2}}\right)\sigma_P E_0$$



Equatorial Electrojet (EEJ)

Hirono/Cowling Conductivity



High conductivity in Ionosphere

+

Induced Electric Field

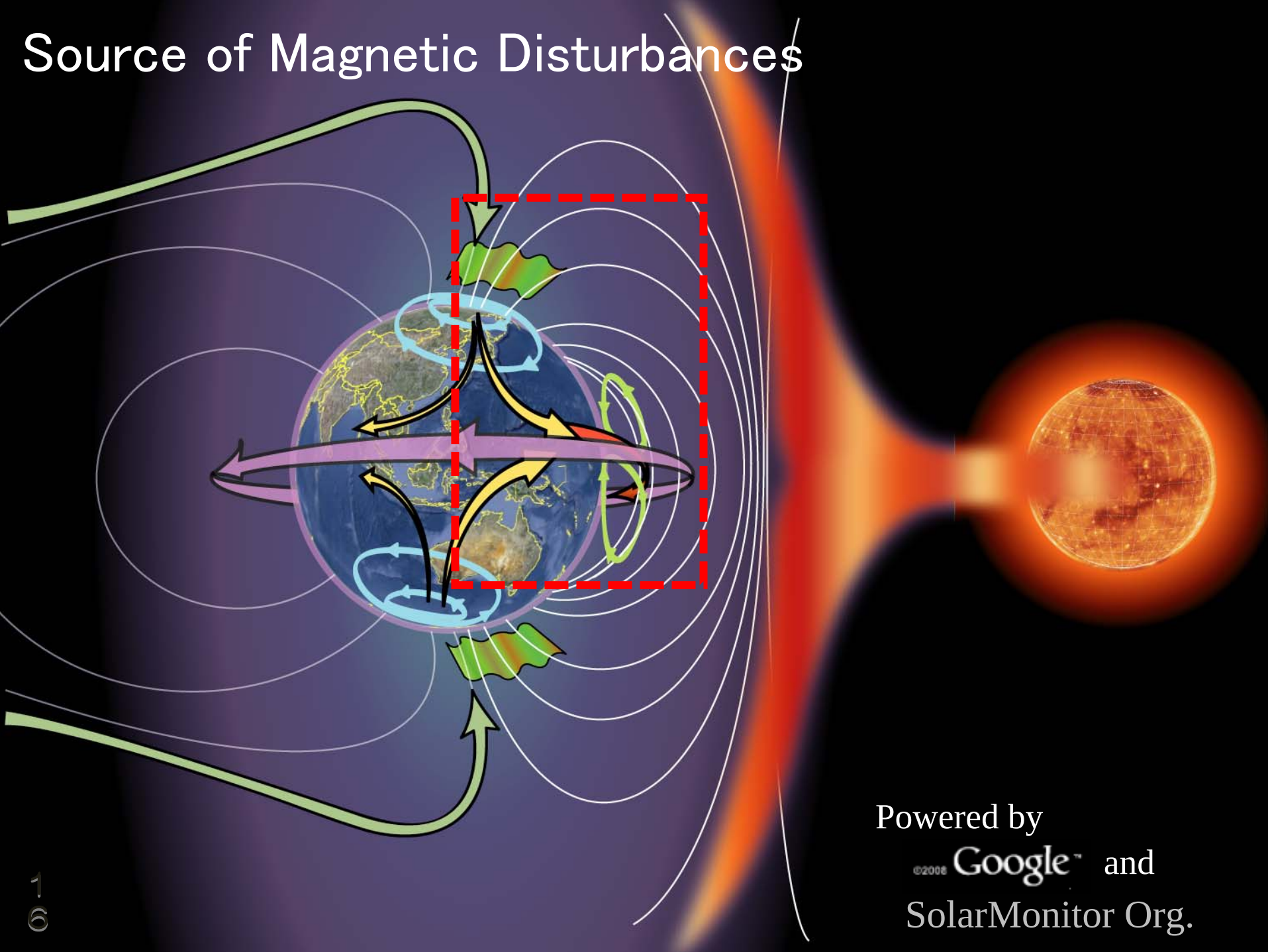
=

Hirono/Cowling Effect

↓

Equatorial Electrojet

Source of Magnetic Disturbances



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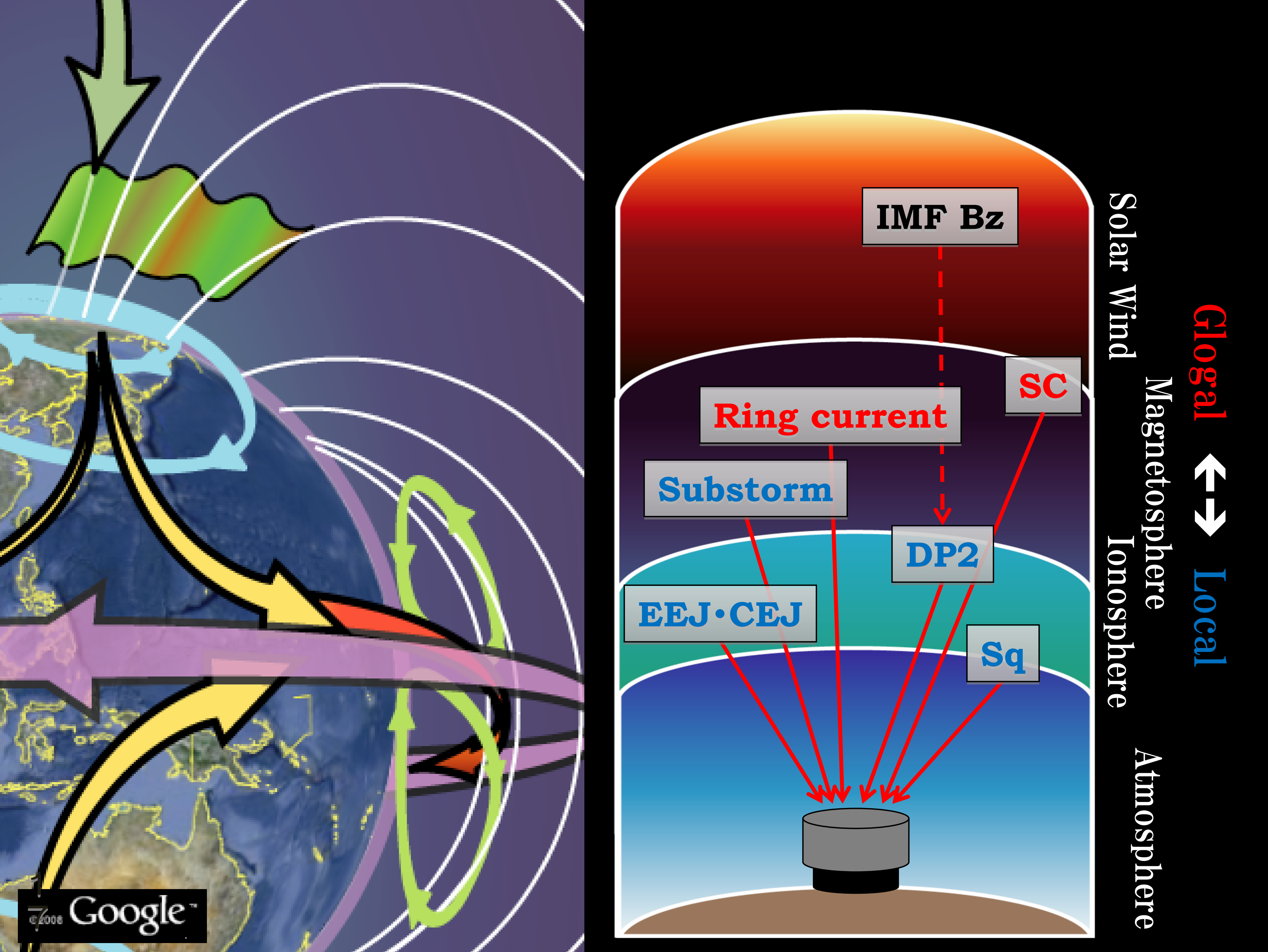
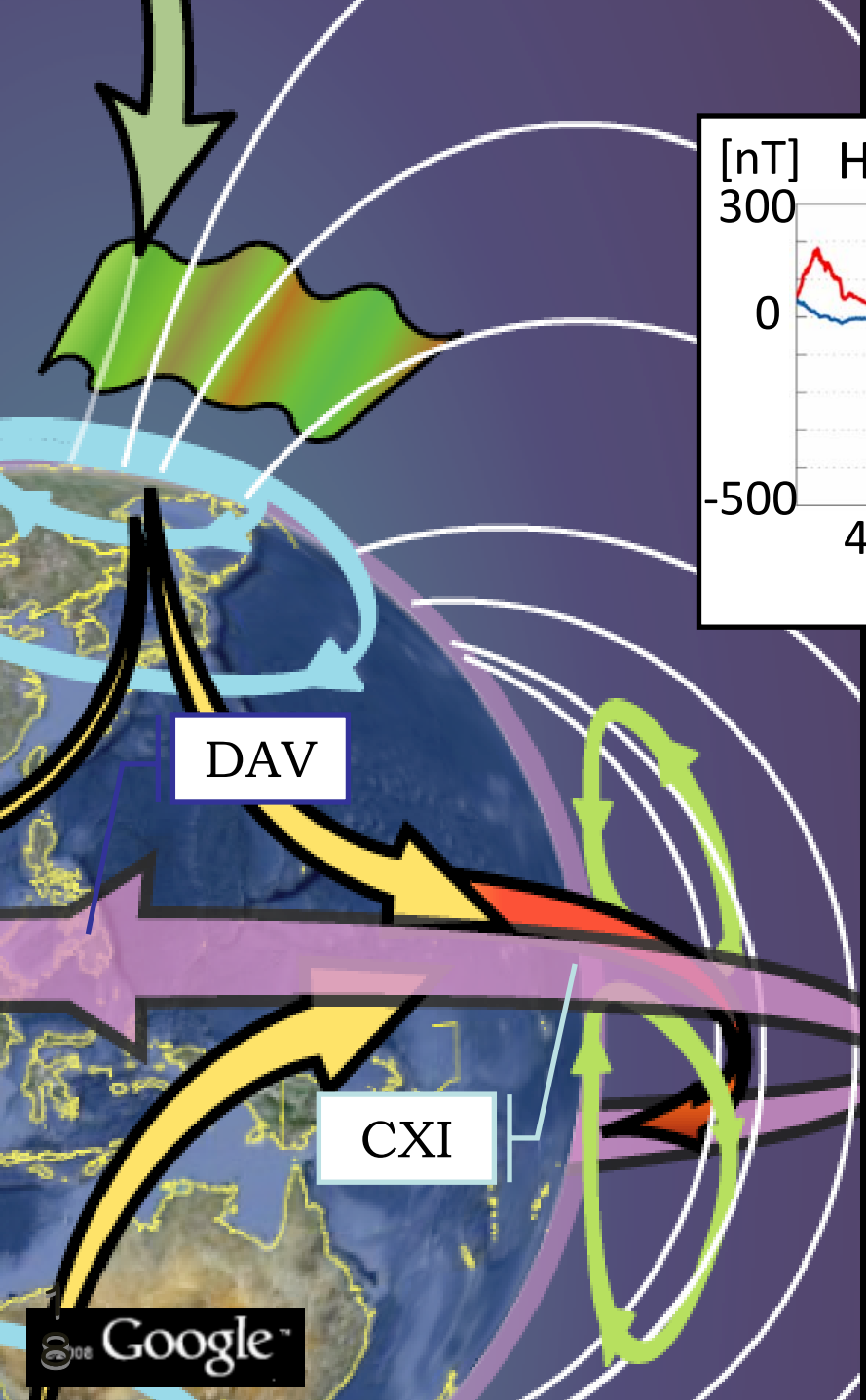
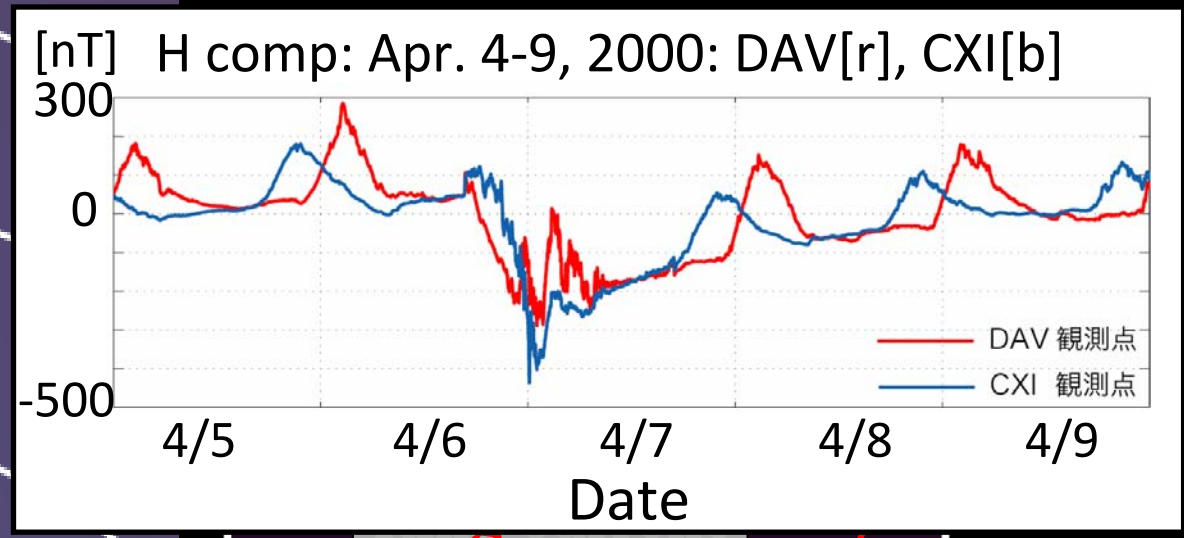
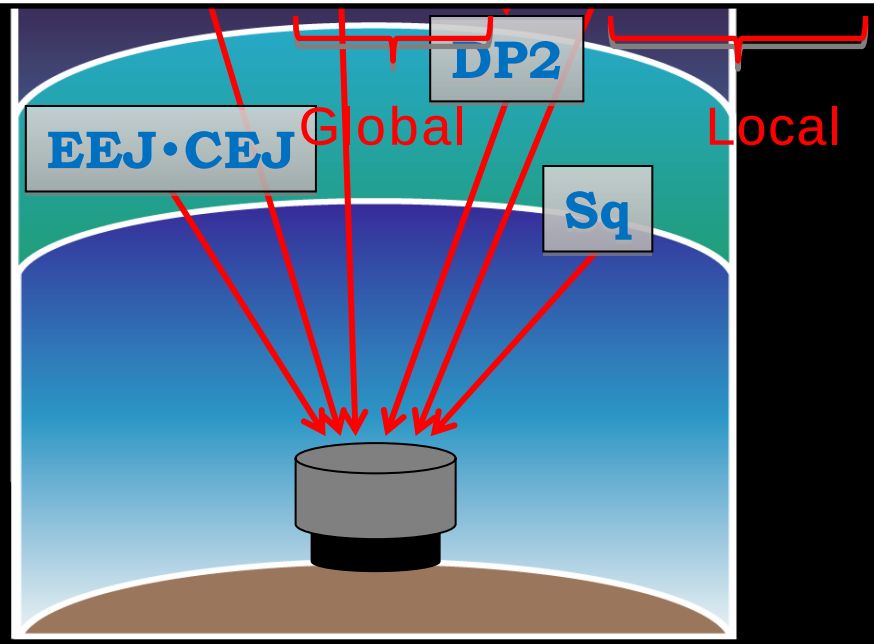

Google
IMF Bz
Ring current
SC
Substorm
DP2
EEJ·CEJ
Sq
Solar Wind
Magnetosphere
Ionosphere
Atmosphere
Glogal ↔ Local

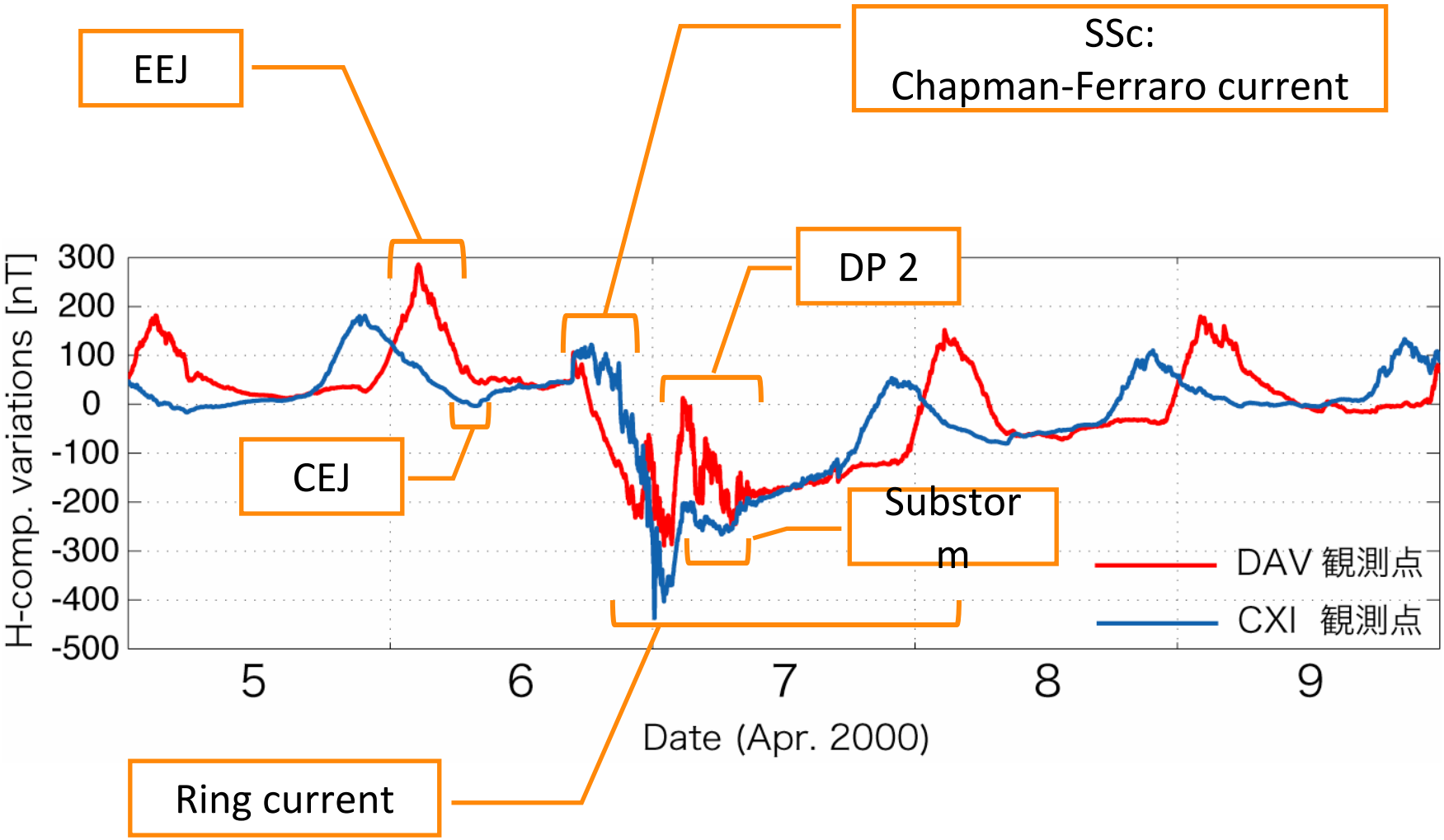

DAV
CXI
Google


[nT]
H comp: Apr. 4-9, 2000: DAV[r], CXI[b]
300
0
-500
4/5
4/6
4/7
4/8
4/9
Date
DAV 観測点
CXI 観測点

$$D = EDst + EUEL$$


DP2
Global
Local
EEJ・CEJ
Sq

EEJ and others



What is the EE-index??

EE-index: EDst and EUEL

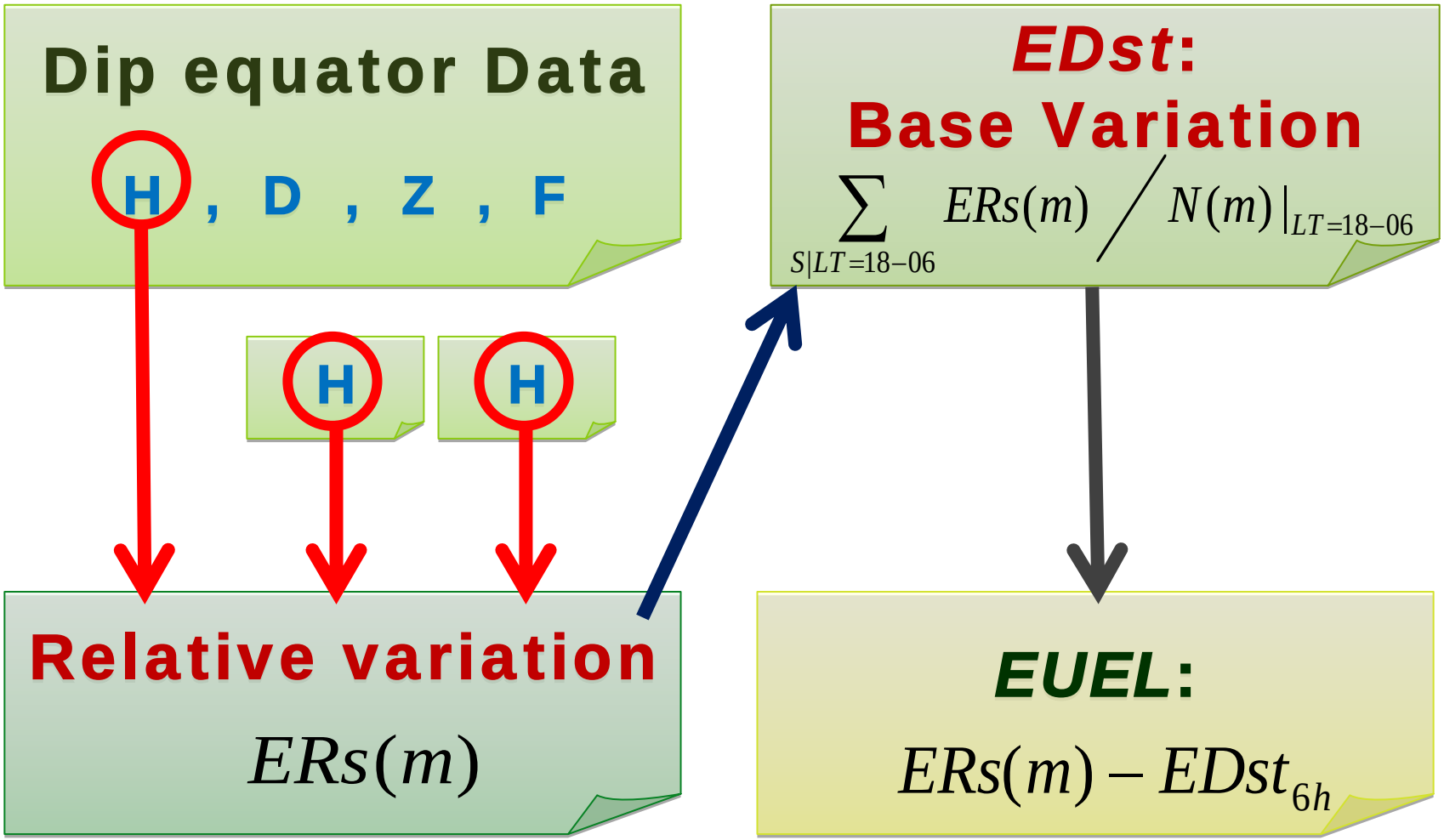
- ✓ **Proposed by ICSWSE [ref. Uozumi et al., 2008]**
- ✓ **Using MAGDAS/CPMN data along the magnetic equator**
- ✓ **Useful for monitoring temporal/long-term variations of the EEJ**

$$D = DCF + DR + DS + DP + EEJ/CEJ + \ldots$$

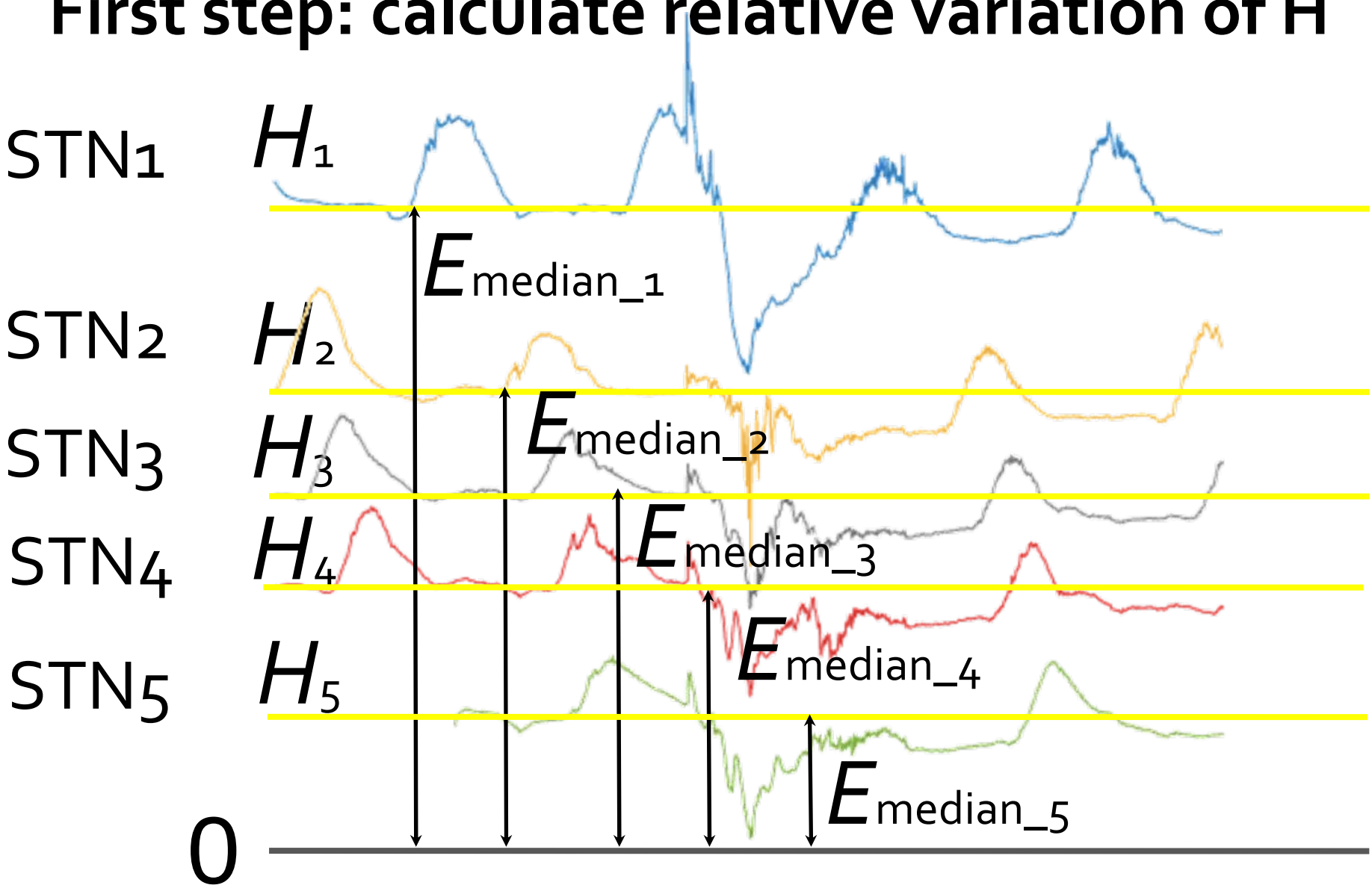
EDst (global)

EUEL (local)

Method to calculate EE-index

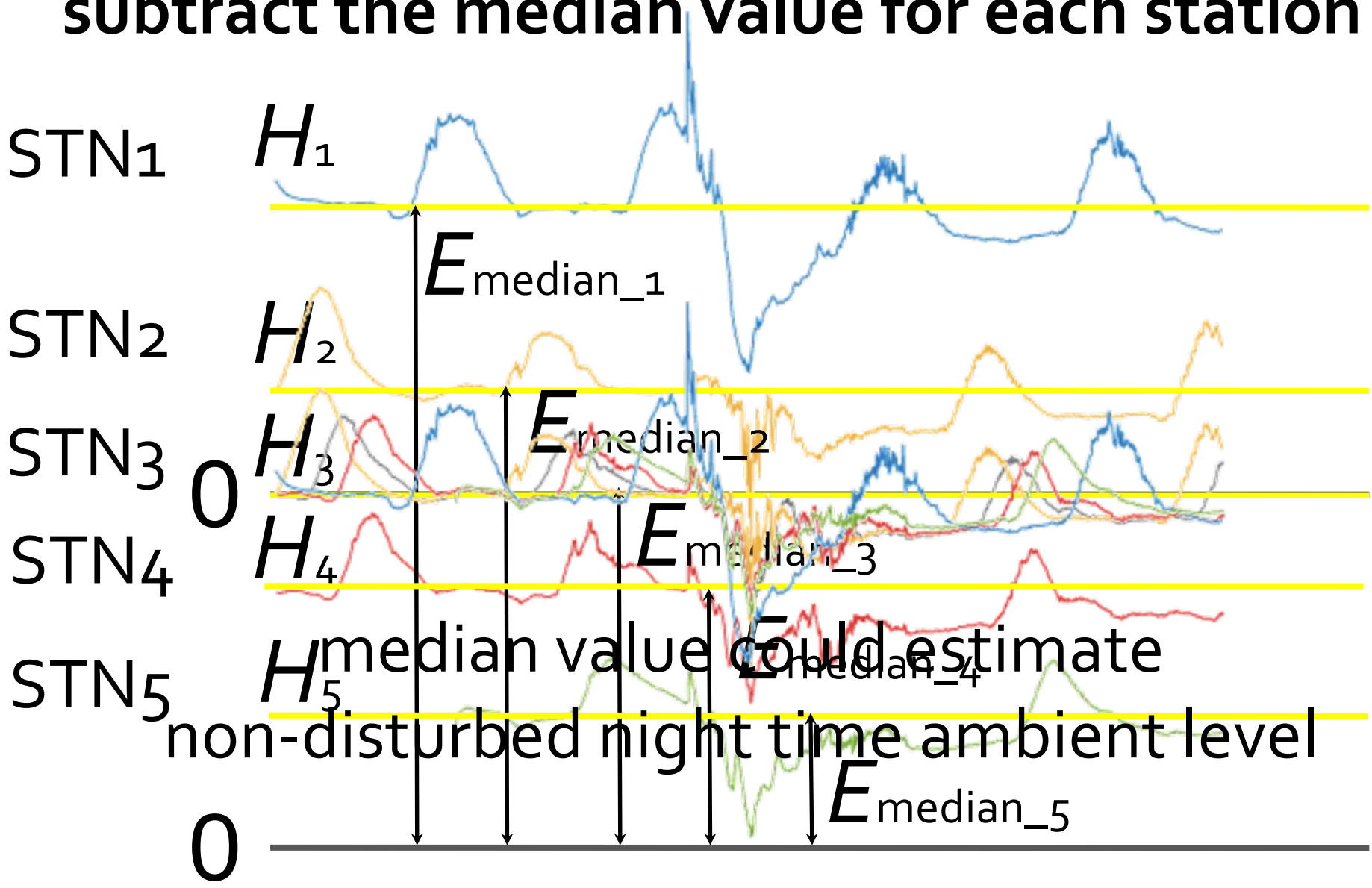


First step: calculate relative variation of H



calculate the median value of H_S

subtract the median value for each station

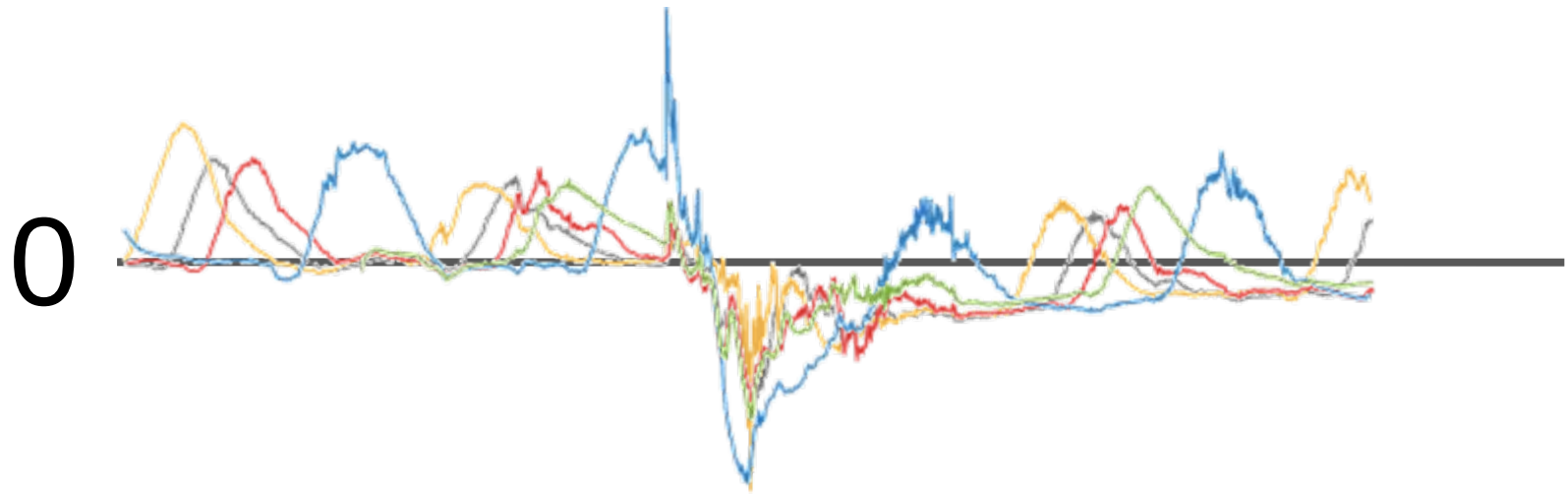


median value could estimate non-disturbed night time ambient level

calculate: $Hs(m) - E_{median\_S}$

Relative magnetic variation of each station

We define this value as ER

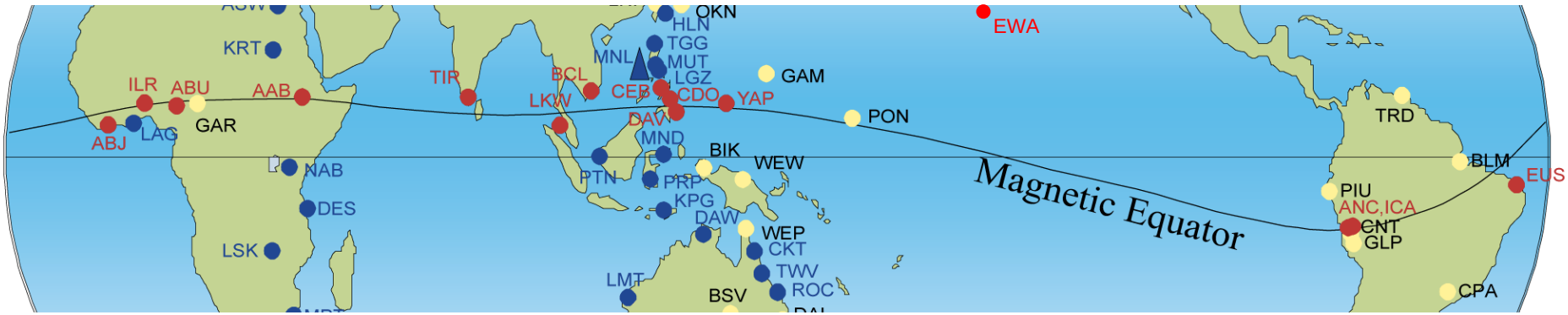


$$ER_S(m) = H_S(m) - E_{median\_S}$$

S: index of station

m: point of time in UT

MAGDAS/CPMN Equatorial Network

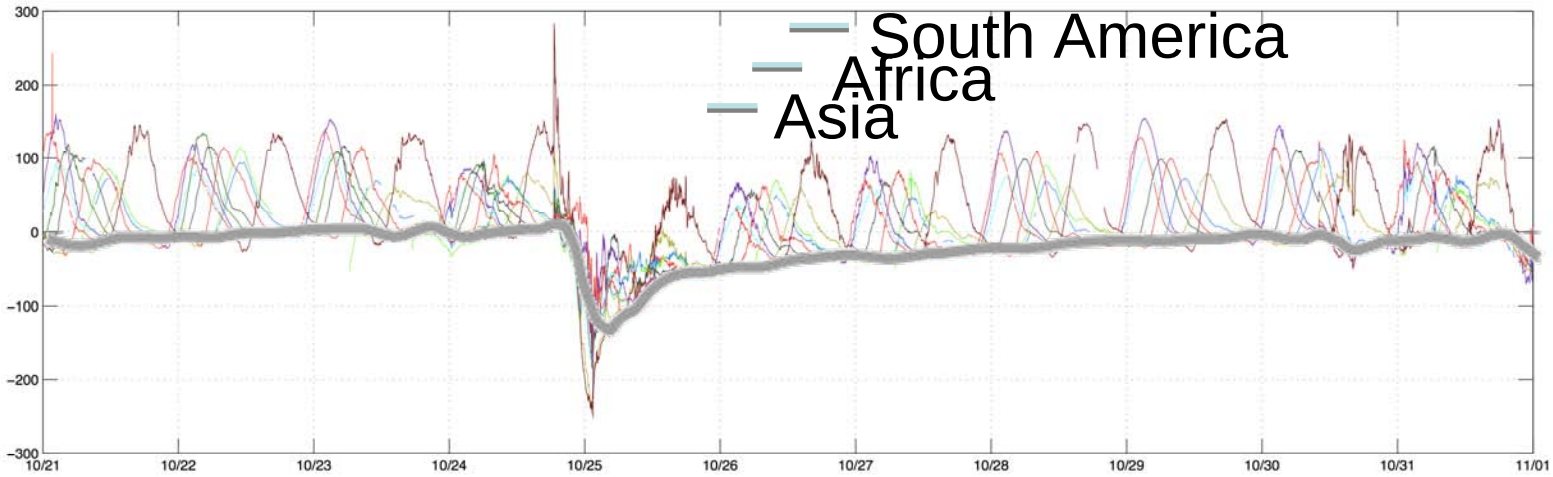


ABJ, ILR, ABU, AAB, TIR, LKW, BCL, CEB, CDO, DAV, YAP, (EWA*), ANC, ICA, EUS

ICSWSE organizes Equatorial Network covering whole LT sectors along the Mag. Eq.

* EWA data is used only for calculating EDst

“ER” observed by MAGDAS



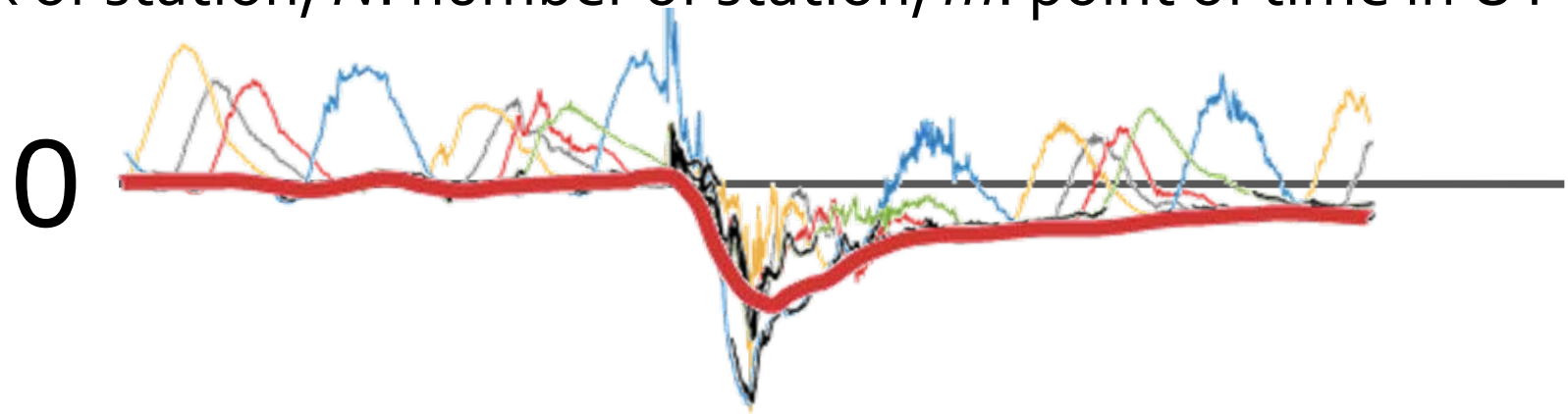
It is noticed that a common base variation confirmed in this plot

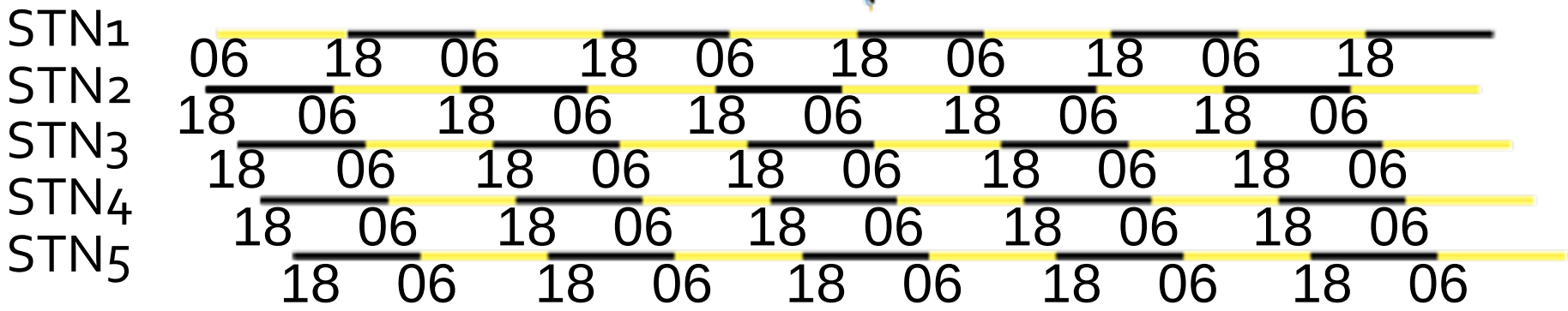
The night time variation of each station is almost aligned with each other

Second step: Calculate base variation for EEJ and CEJ

$$EDst_{1m}(m) = \frac{\sum_{S|_{LT=18-06}} ER_S(m)\,|_{LT=18-06}}{N(m)\,|_{LT=18-06}}$$

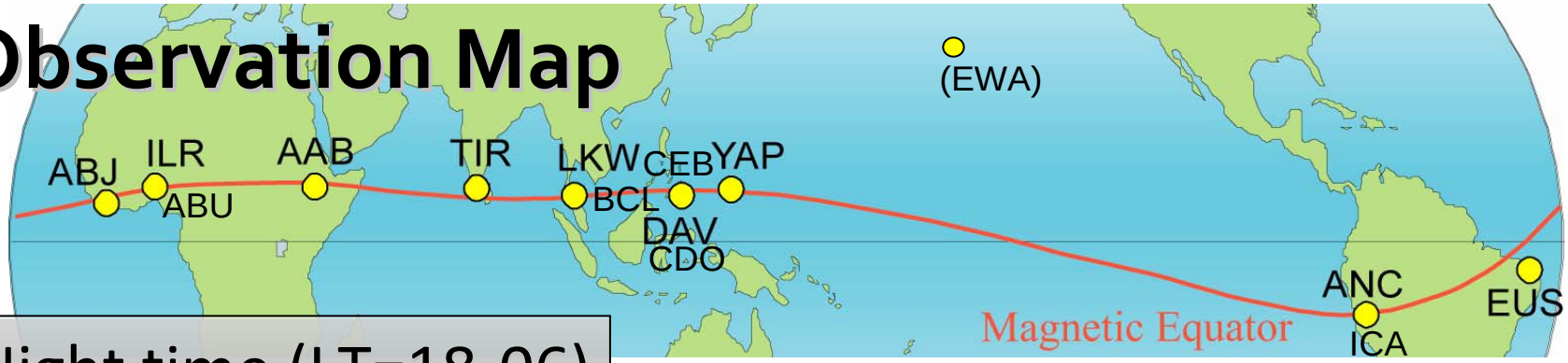
S: index of station, *N*: number of station, *m*: point of time in UT



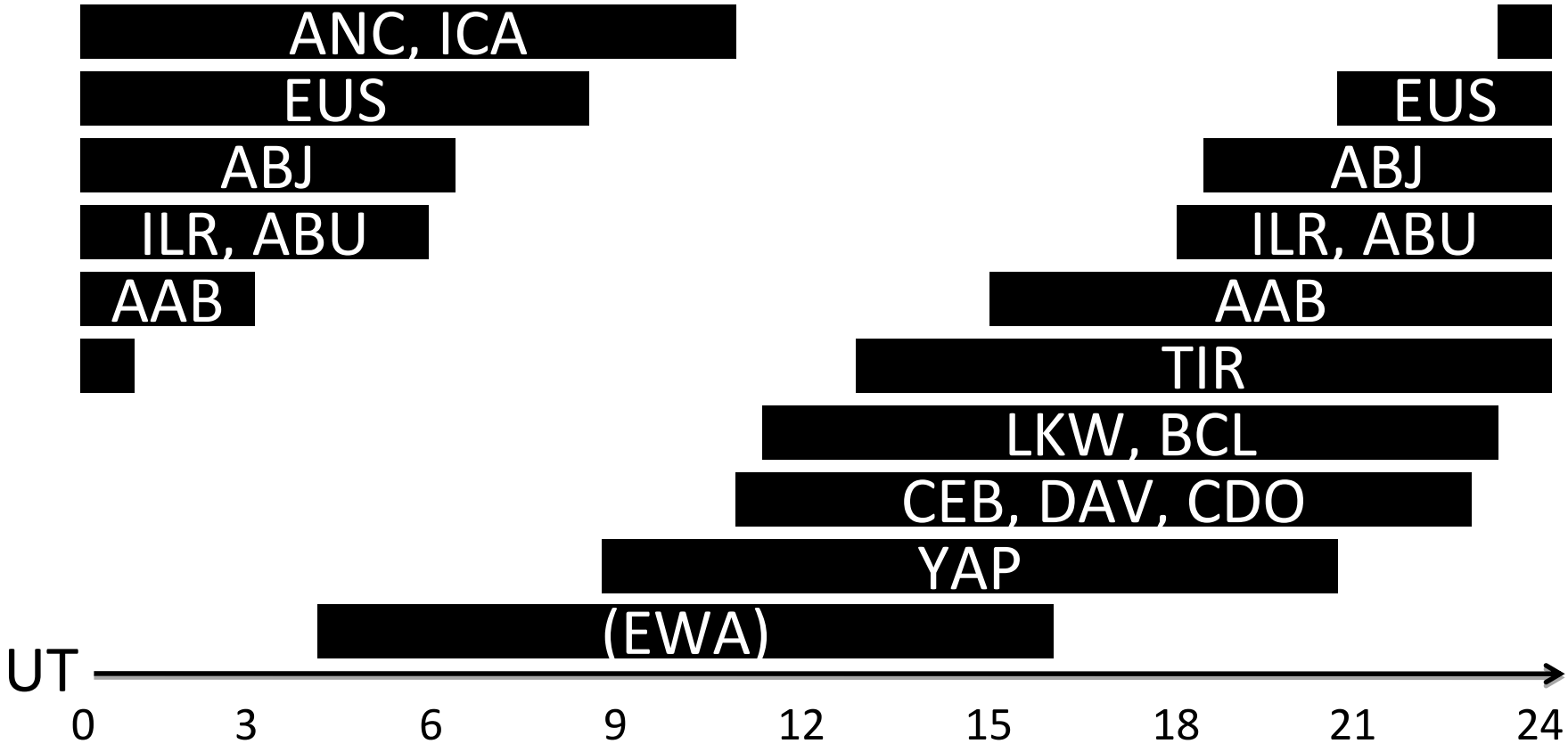


MAGDAS/CPMN Equatorial Network

Observation Map



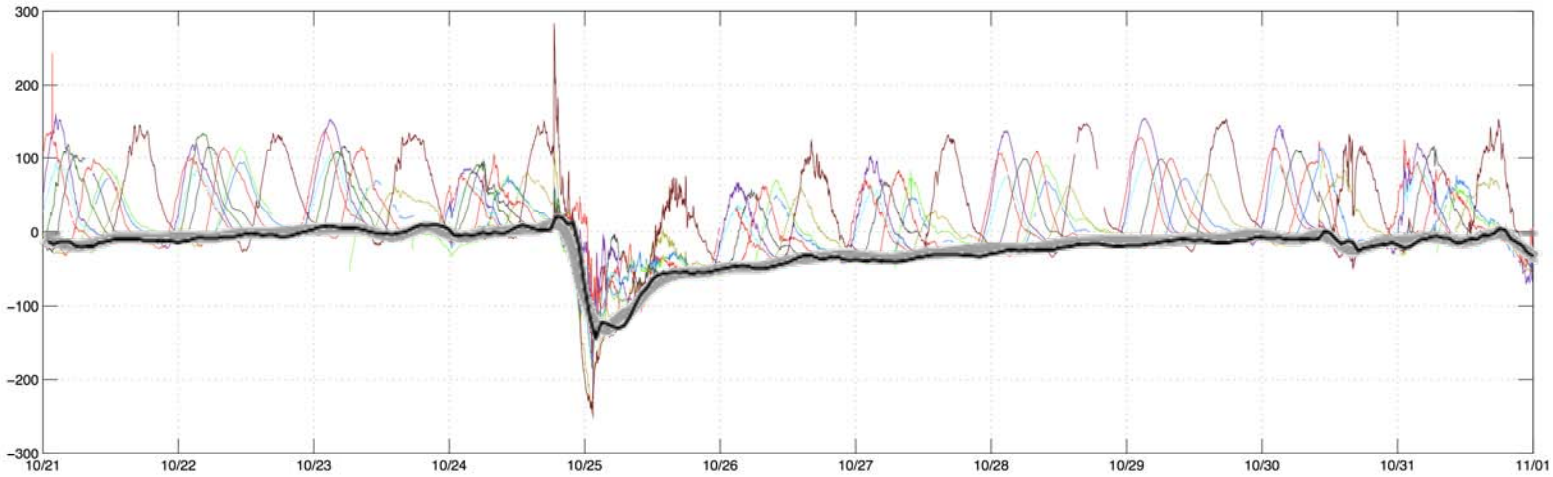
Night time (LT=18-06)



"EDst" calculated by MAGDAS

***EDst* is defined as mean night time variation along Mag. Eq.**

EDst* shows similar variation as *Dst

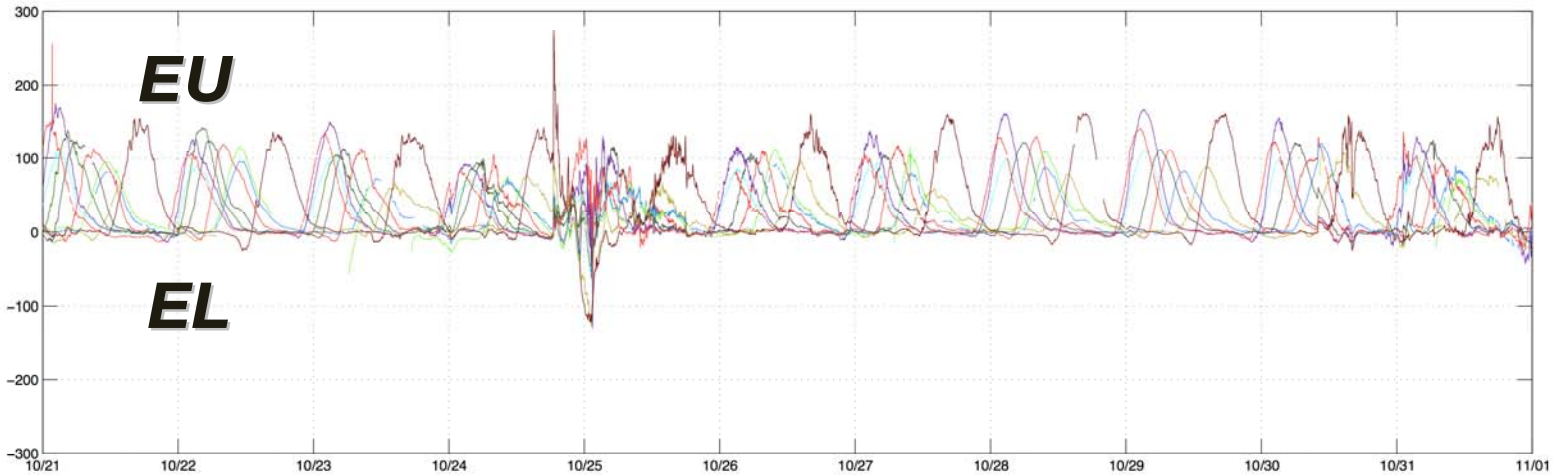


***EDst* represents global magnetic variation**

***EDst* can be utilized as the base level for the EEJ and CEJ**

Third step: Subtract base variation (*EDst*) from *ER*

"EUEL" calculated by MAGDAS

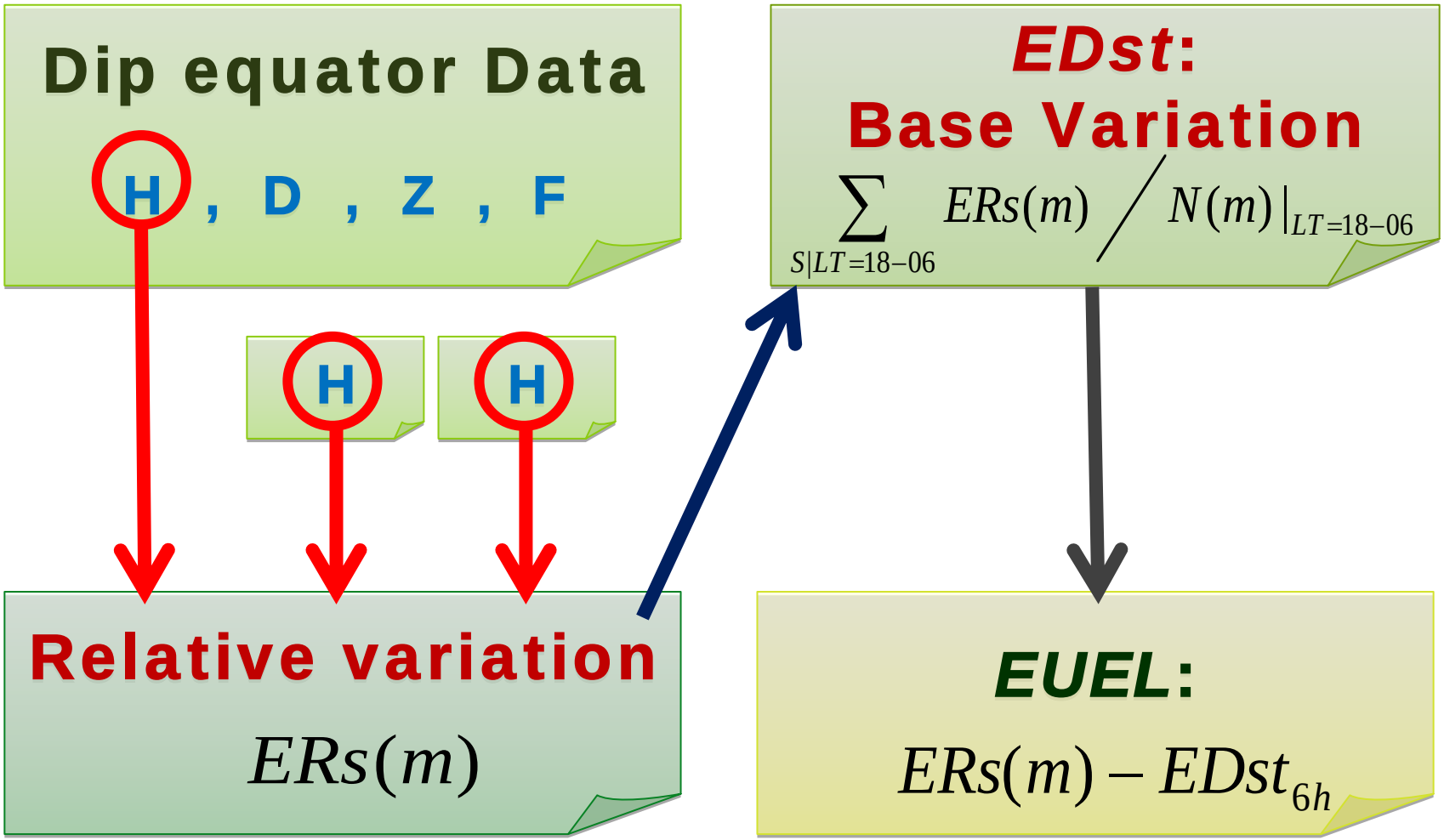


$$EUEL(m) \equiv ERs(m) - EDst_{6h}(m)$$

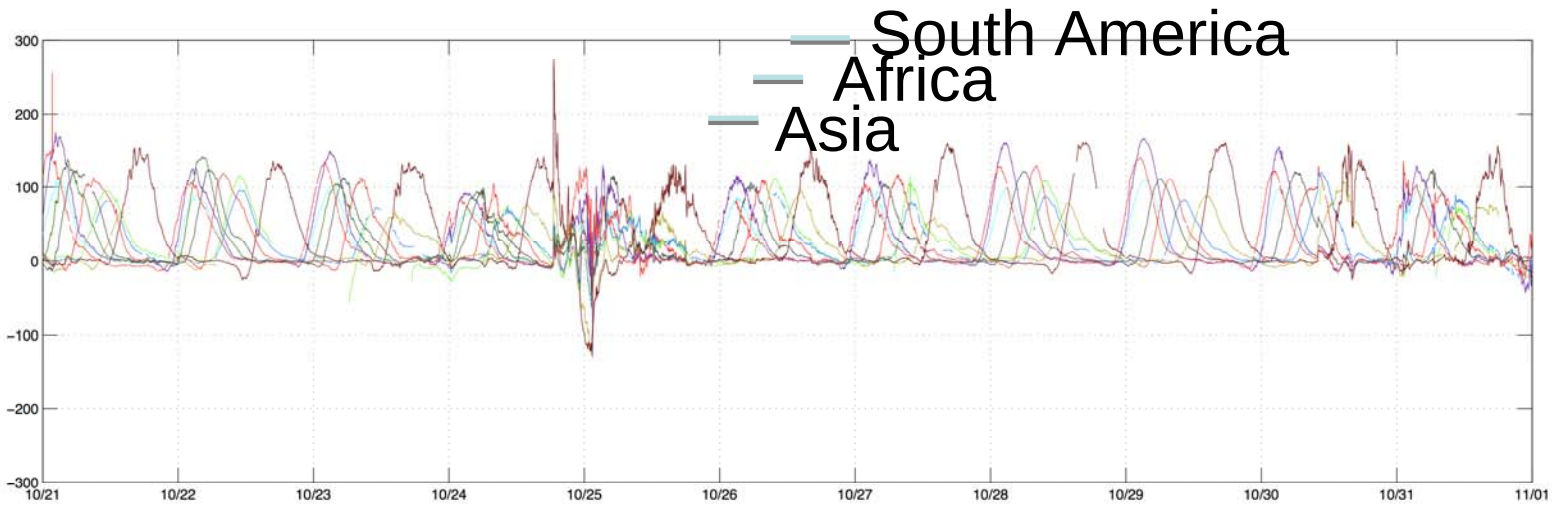
The positive and negative deviation represent the EEJ and CEJ

EE-index method enables to monitor EEJ/CEJ even in disturbed time → continuous monitoring of EEJ/CEJ

Method to calculate EE-index



“EUEL” calculated by MAGDAS

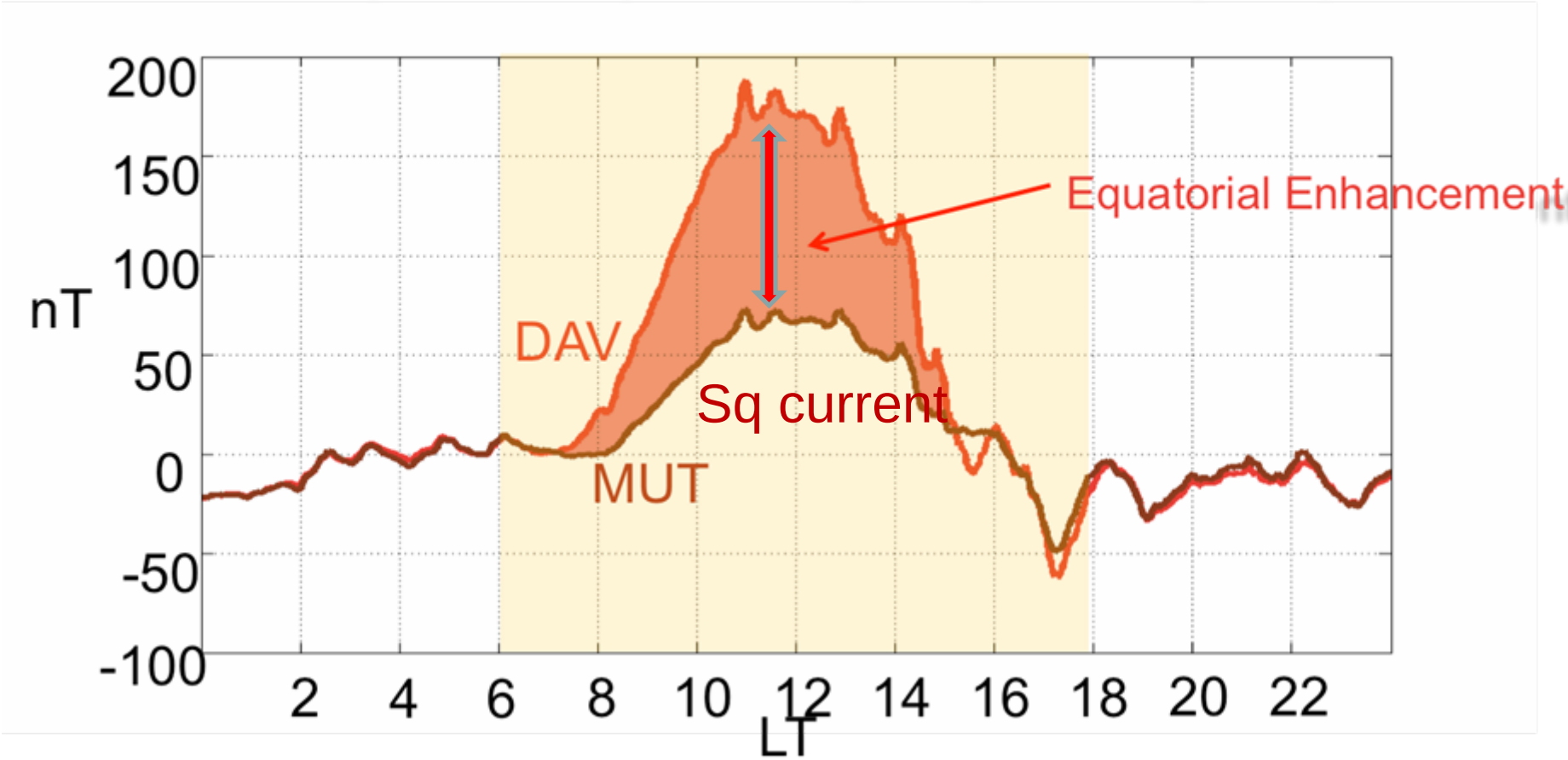


Some Applications of EE-index

~Equatorial Enhancement: EENH~

- Extraction of the Equatorial Enhancement part

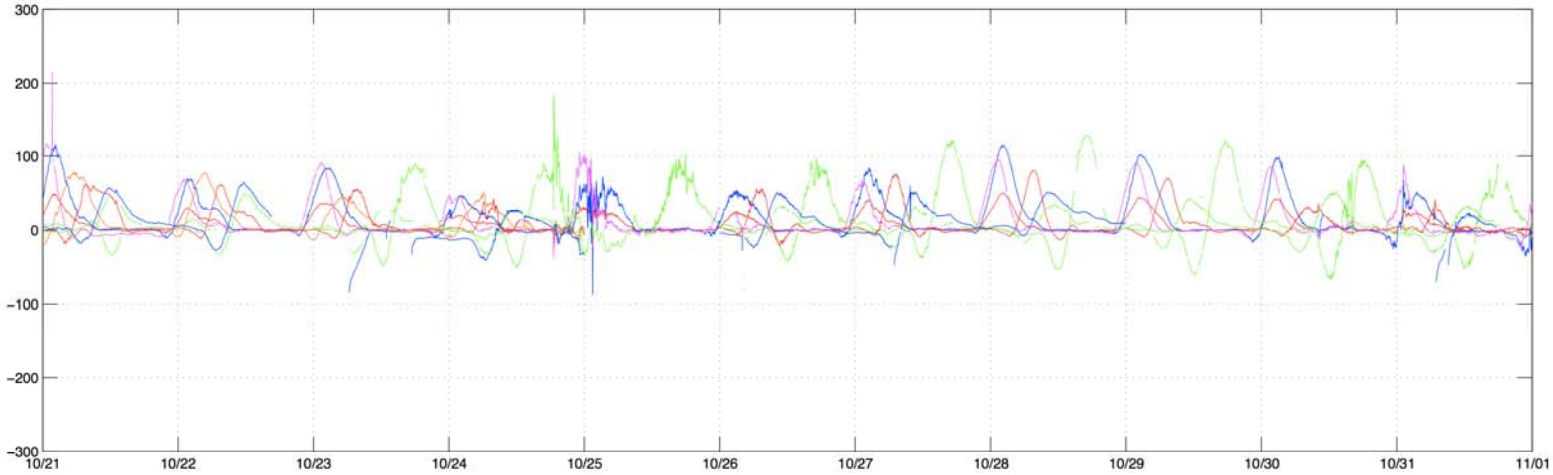
EENH(DAV/MUT) = EUEL(DAV) − EUEL(MUL)



Subtract EUEL(MUT) from EUEL(DAV)

"EENH" calculated by MAGDAS

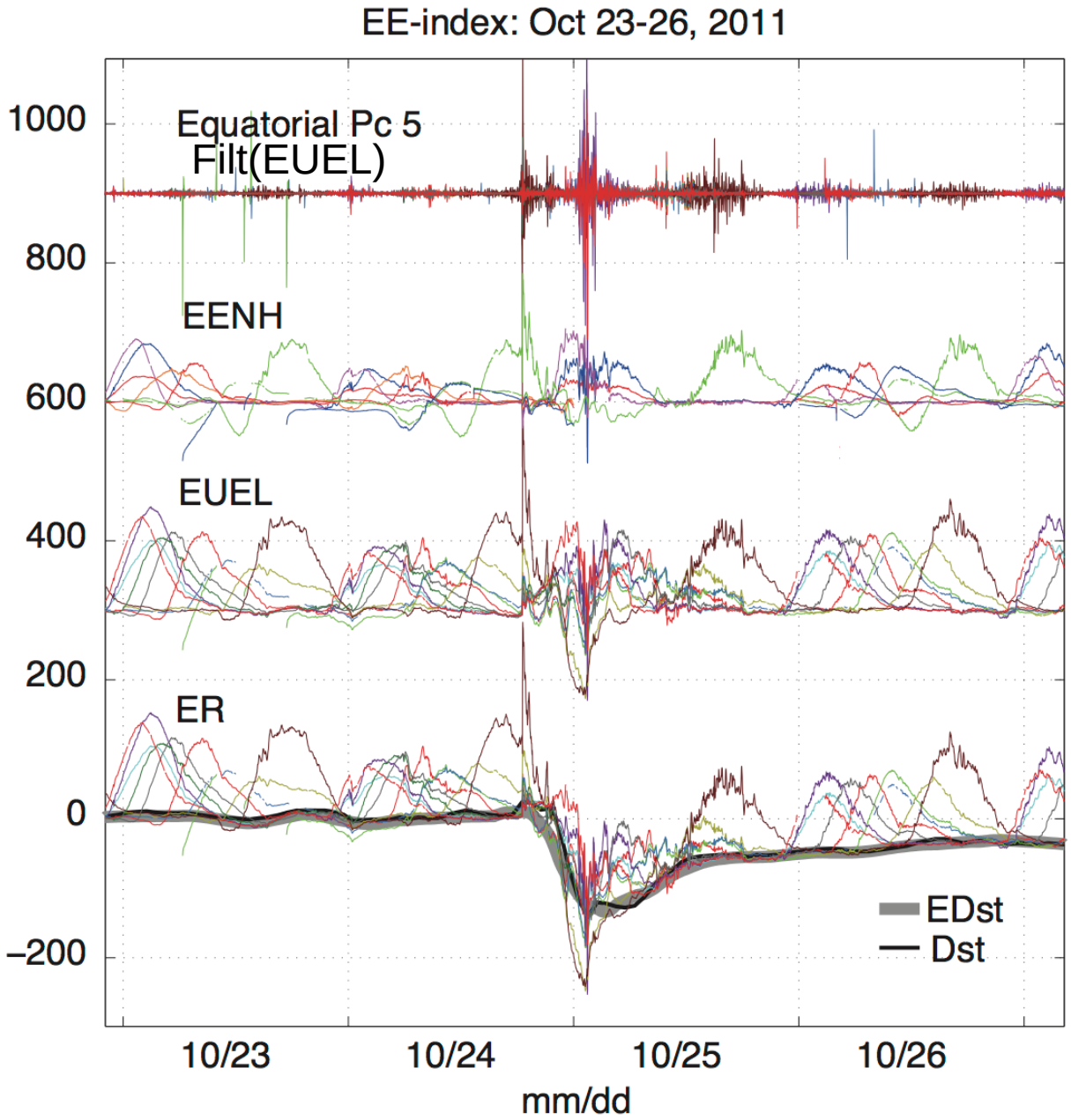
EENH represents the magnitude of the equatorial enhancement



Defined as EUEL(dip.-eq) – EUEL(off dip.-eq.)

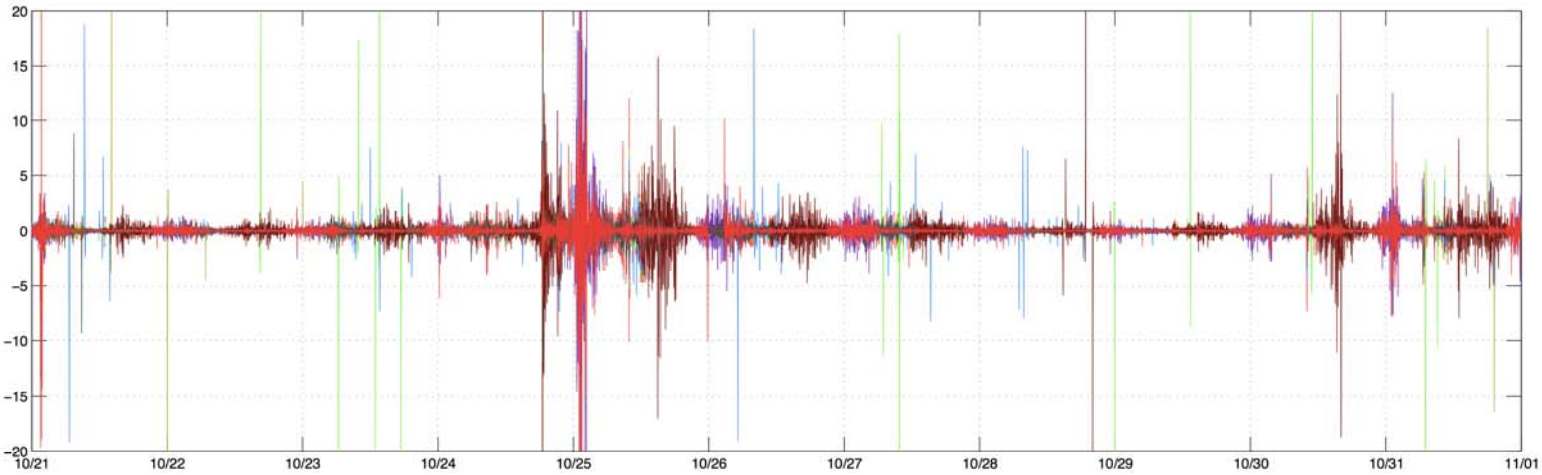
ex. EENH(DAV/MUT)=EUEL(DAV)-EUEL(MUT)

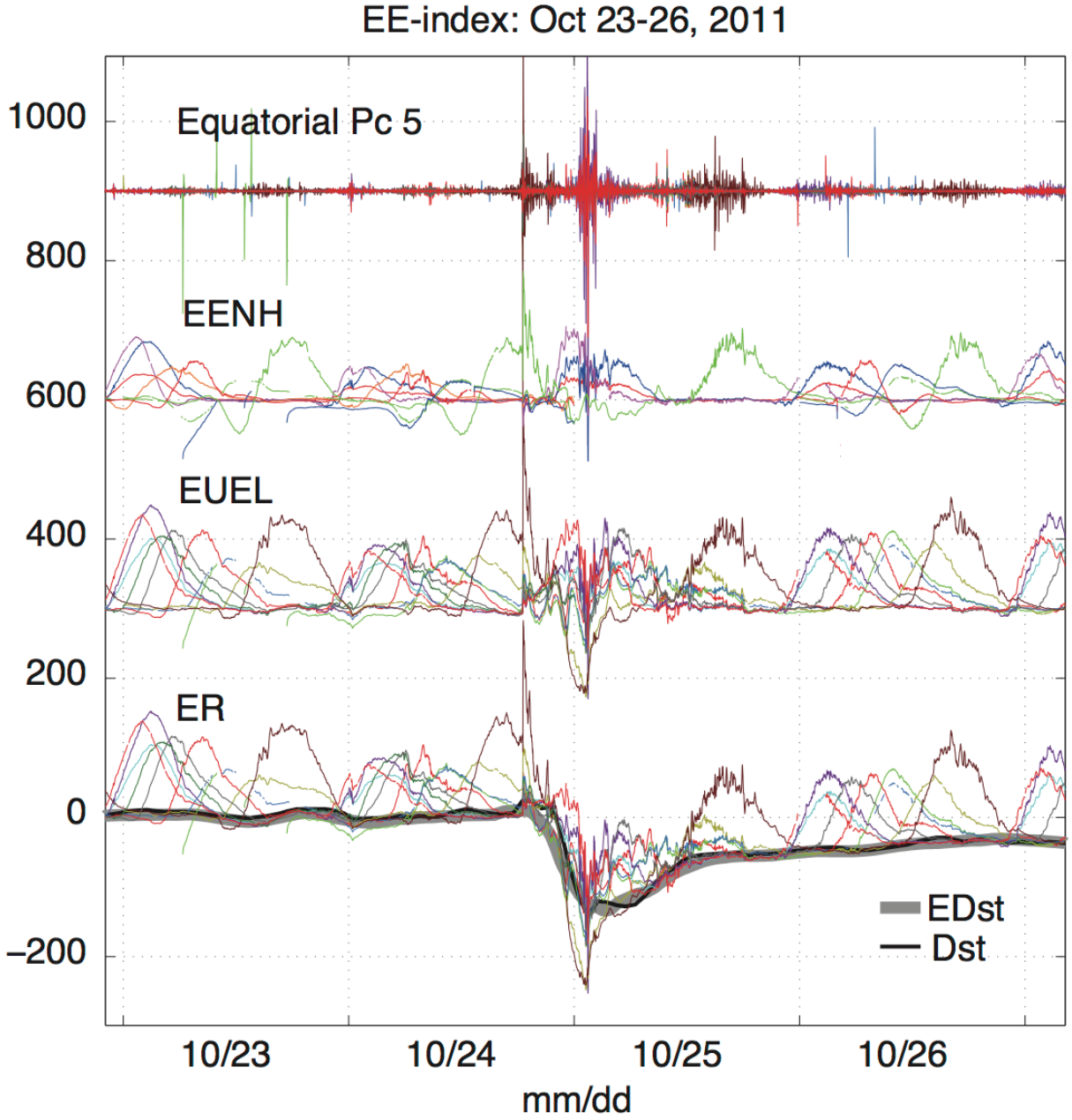
EE-index in Storm-time



“Equatorial Pc 5” observed by MAGDAS

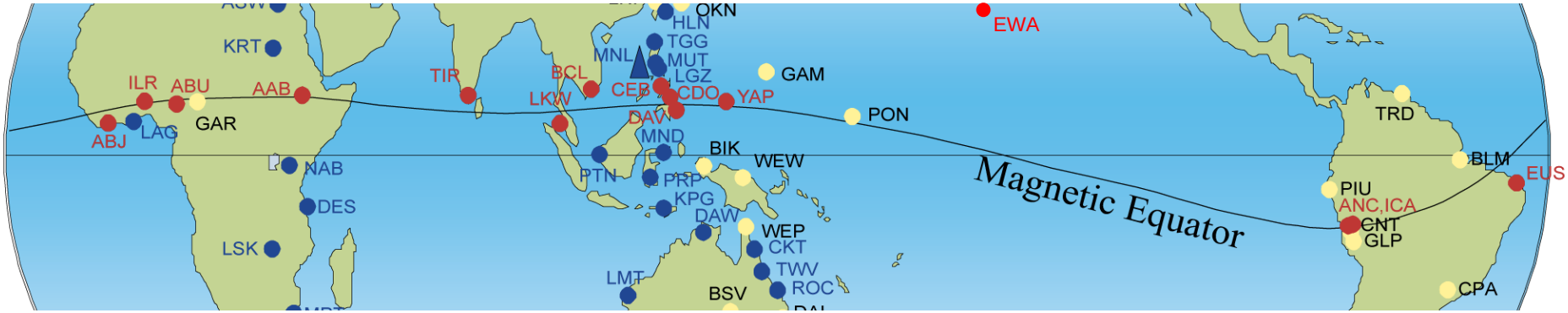
Bandpass filtered EUEL (3-10min ≈ Pc 5 range)




EE-index: Oct 23-26, 2011
1000
800
600
400
200
0
–200
Equatorial Pc 5
EENH
EUEL
ER
EDst
Dst
10/23
10/24
10/25
10/26
mm/dd

Realtime EE-index at ICSWSE

MAGDAS/CPMN Equatorial Network: Realtime magnetometer network



ABJ, ILR, ABU, AAB, TIR, LKW, BCL, CEB, CDO, DAV, YAP, (EWA*), ANC, ICA, EUS

* EWA data is used only for calculating EDst

Realtime EE-index at ICSWSE

http://www.serc.kyushu-u.ac.jp/ee/index.html

Realtime EE-index at ICSWSE

EE-index [Plot and Data]

http://www.serc.kyushu-u.ac.jp/ee/EDst/201107.html

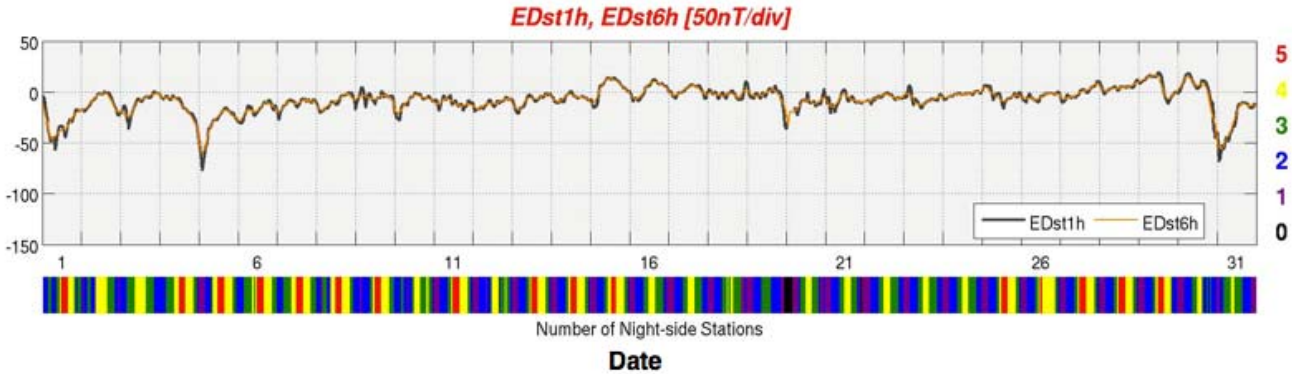
Google

Plot and Data

EDst (Realtime Ver.)

Plot and Data Top EE-index Home

July 2011 Last Month - Next Month



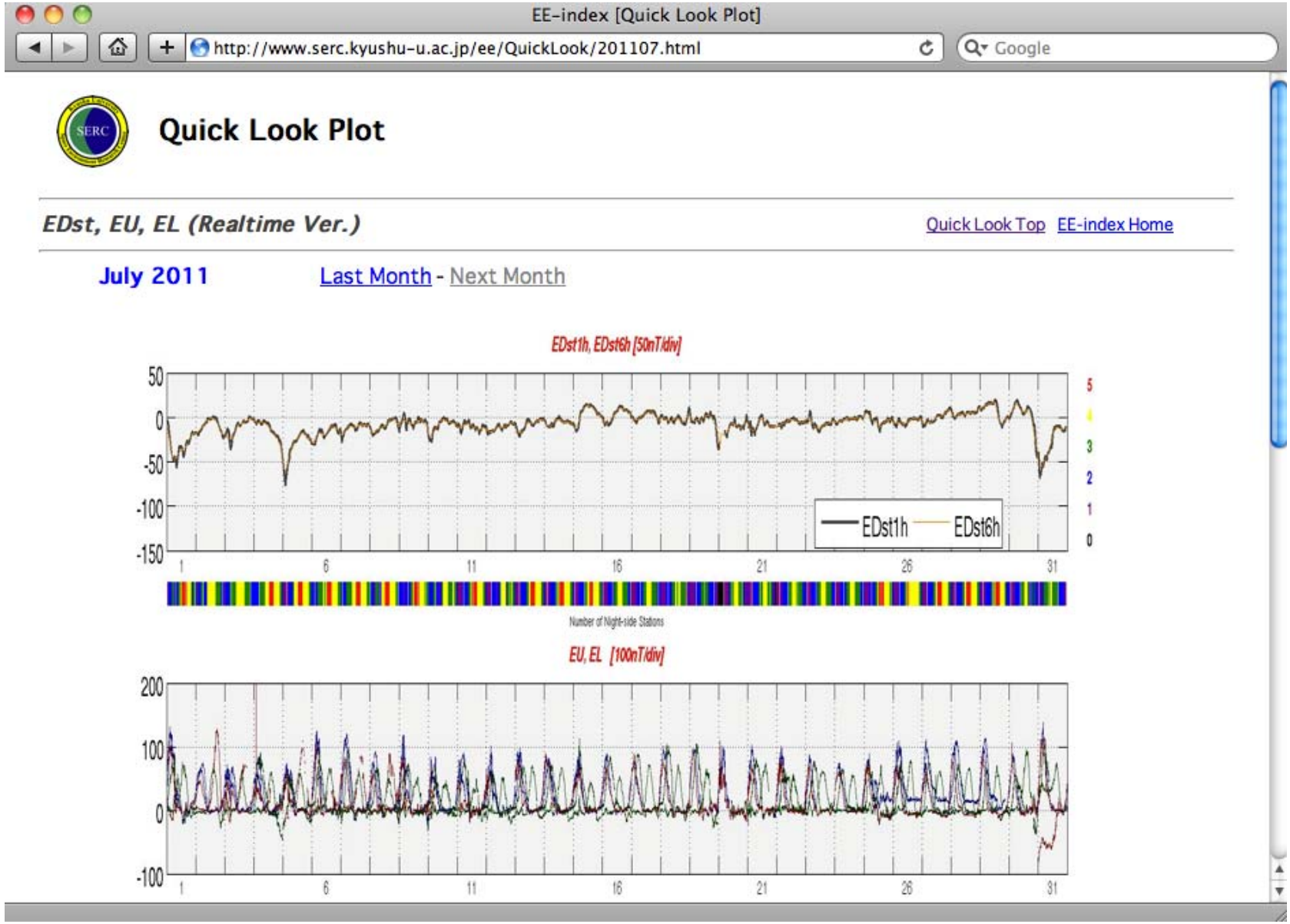
Space Environment Research Center, Kyushu University
EDst1h (Realtime Ver.)
Unit: nT

July 2011

Universal Time

DAY	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-4	-6	-17	-29	-40	-48	-47	-44	-57	-45	-35	-34	-34	-36	-45	-40	-32	-27	-30	-27	-22	-17	-19	-19
2	-17	-18	-20	-16	-15	-13	-10	-9	-7	-5	-2	-2	-2	-2	0	-1	-1	-1	-5	-10	-14	-16	-23	-23
3	-19	-21	-13	-15	-29	-37	-27	-21	-16	-12	-9	-6	-9	-10	-7	-5	-5	-5	-6	-4	0	0	-1	-2
4	-3	-5	-7	-6	-4	-6	-7	-7	-4	-5	-7	-7	-6	-10	-15	-16	-17	-19	-21	-21	-22	-27	-27	-37
5	-50	-61	-77	-67	-54	-50	-37	-35	-31	-27	-28	-27	-25	-23	-20	-18	-16	-15	-19	-19	-23	-20	-25	-26
6	-30	-30	-31	-29	-23	-20	-13	-16	-14	-21	-24	-21	-20	-17	-15	-13	-9	-11	-11	-8	-10	-16	-18	-13
7	-19	-28	-21	-16	-13	-13	-10	-9	-7	-9	-10	-12	-15	-14	-11	-7	-7	-7	-10	-7	-10	-11	-7	-8

Realtime EE-index at SERC



Attention!

Realtime EE-index are calculated with non-calibrated data.

Valid only for monitoring purpose

If you need provisional EE-index, which are not final version but calculated with calibrated data, please contact with PI of MAGDAS/CPMN project.

Summary

We've proposed a new geomagnetic index, the EE-index. [Reference: Uozumi et al., 2008]

MAGDAS/CPMN equatorial network allows for the first time realtime monitoring of geomagnetic phenomena in the magnetic-equatorial region.

EE-index will provide information that should clarify the situation of solar-geospace coupling and atomosphere-ionosphere coupling along magnetic equatorial region.

Long-term and continuous study of EE-index should greatly expand the understanding of the fundamental mechanisms pertaining to various equatorial geomagnetic phenomena.

Thank you very much

Acknowledgements:
We thanks World Data Center for Geomagnetism Kyoto for providing geomagnetic index: Dst. We thank the ACE MAG and SWEPAM instrument team and the ACE Science Center for providing the ACE data. We thank the the Herzberg Institute of Astrophysics for providing *F10.7* solar radiation data. The PI of MAGDAS/CPMN project, K. Yumoto, ICSWSE, Kyushu University very much appreciates over 30 organizations and Co-investigators around the world for their ceaseless cooperation and contribution to the MAGDAS/CPMN project.

Reference: Teiji Uozumi, K. Yumoto, K. Kitamura, S. Abe, Y. Kakinami, M. Shinohara, A. Yoshikawa, H. Kawano,T. Ueno, T. Tokunaga, D. McNamara, J. K. Ishituka, S. L. G. Dutra, B. Damtie, V. Doumbia, O. Obrou, A. B. Rabiu, I. A. Adimula, M. Othman, M. Fairos, R. E. S. Otadoy, and MAGDAS Group, A new index to monitor temporal and long-term variations of the equatorial electrojet by MAGDAS/CPMN real-time data: EE-Index, *Earth Planets Space*, 60, 785-790, 2008.