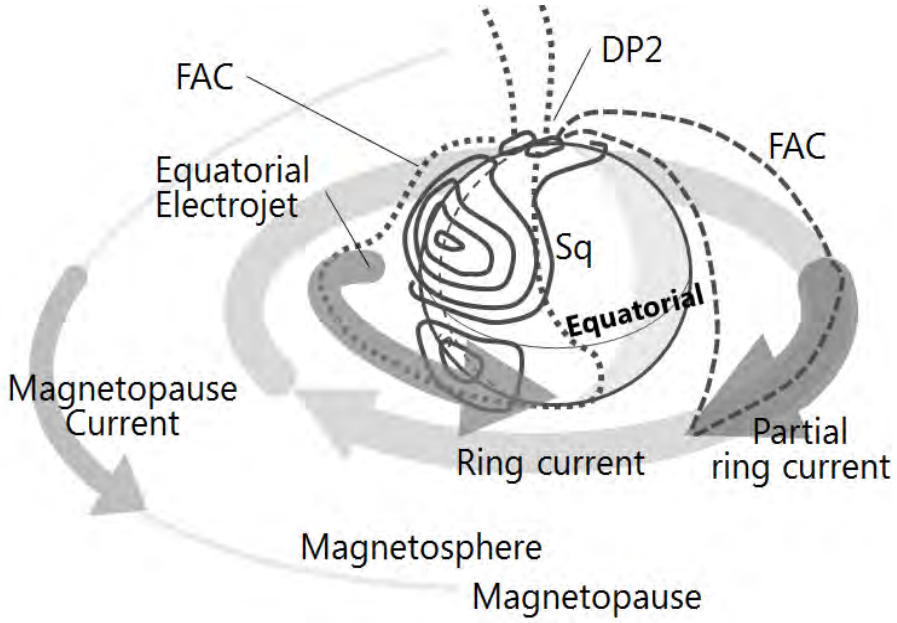
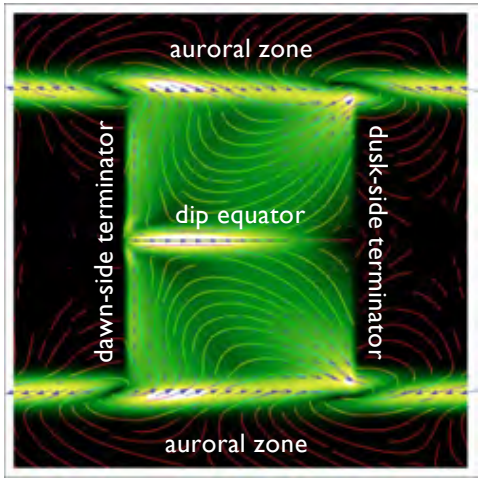
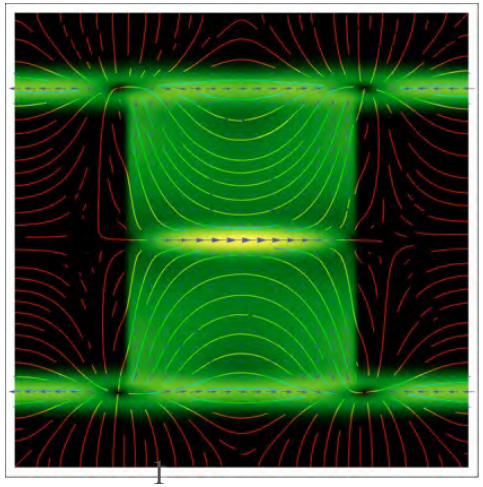
MAGDAS project: Research for global electromagnetic coupling from polar to equatorial ionosphere

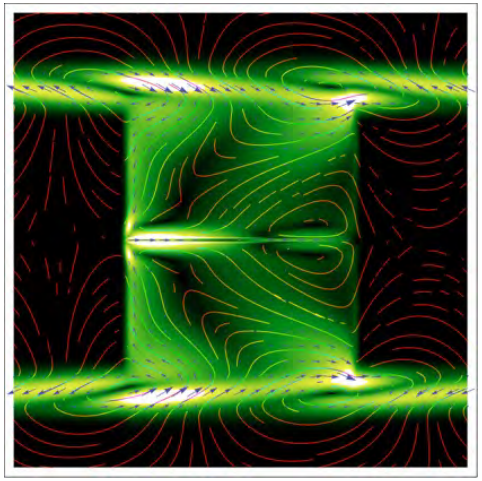


Current distribution from polar to equatorial ionosphere



no-Hall divergence effect | Cowling channel | Hall polarization component





Akimasa Yoshikawa[1,2]

[1] International Center for Space Weather Science and Education,
[2] Department of Earth and Planetary Sciences, Kyushu University, Japan

"International Center for Space Weather Science and Education, Kyushu University (ICSWSE:2012-)

The Space Environment Research Center (SERC: Director Prof. K Yumoto) of Kyushu University (2002-2012:March) was re-organized on 01 April 2012. On that date it became the "International Center for Space Weather Science and Education ".

The purpose for this re-organization is to allow space weather research to continue on a more global basis, and to establish a permanent international center for space weather science and education.

This center was also specifically requested as a part of the International Space Weather Initiative (ISWI) in the "Abuja ISWI Resolution" which was unanimously approved by the participants of the "UN/Nigeria Workshop on ISWI" (Abuja, Nigeria, 2011).

九州大学

ISWI

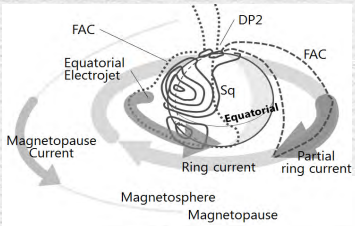
ICSWSE

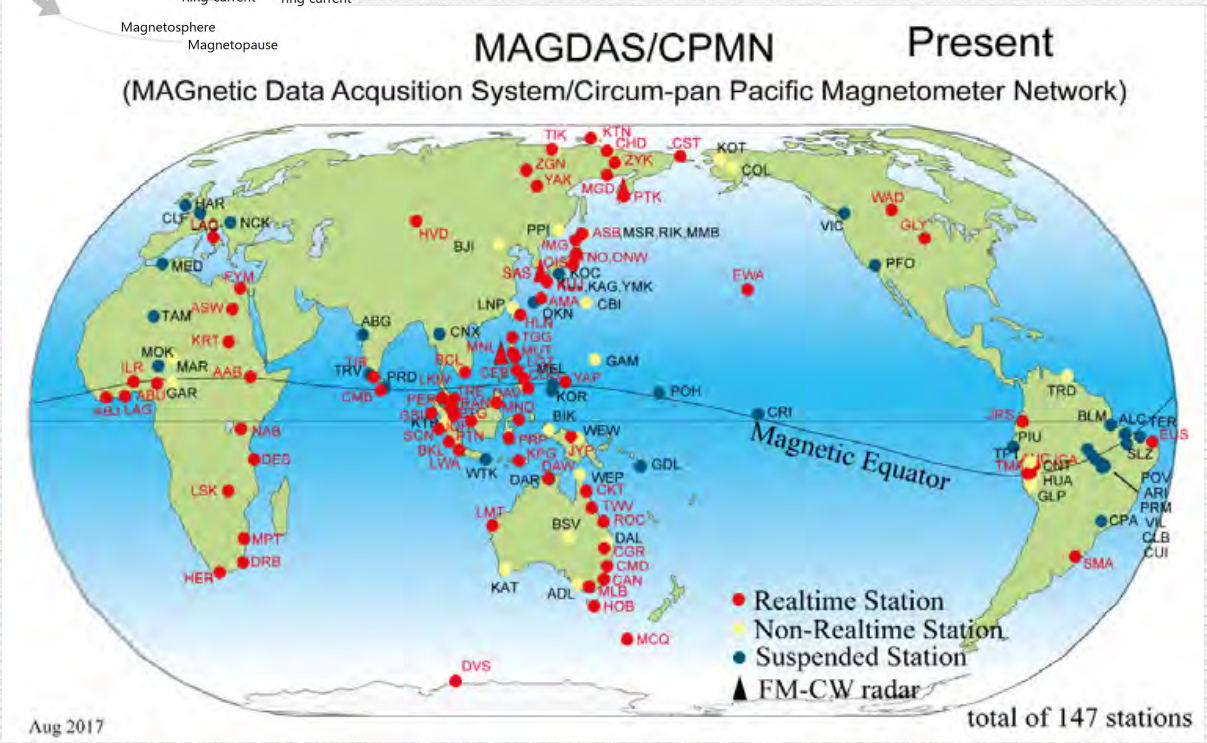
UNITED NATIONS
Office for Outer Space Affairs

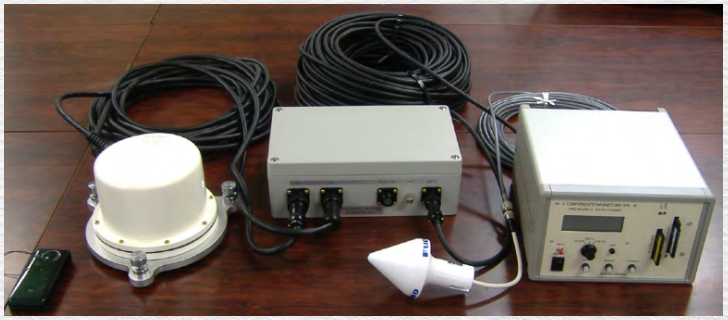
the purpose of ICSWSE

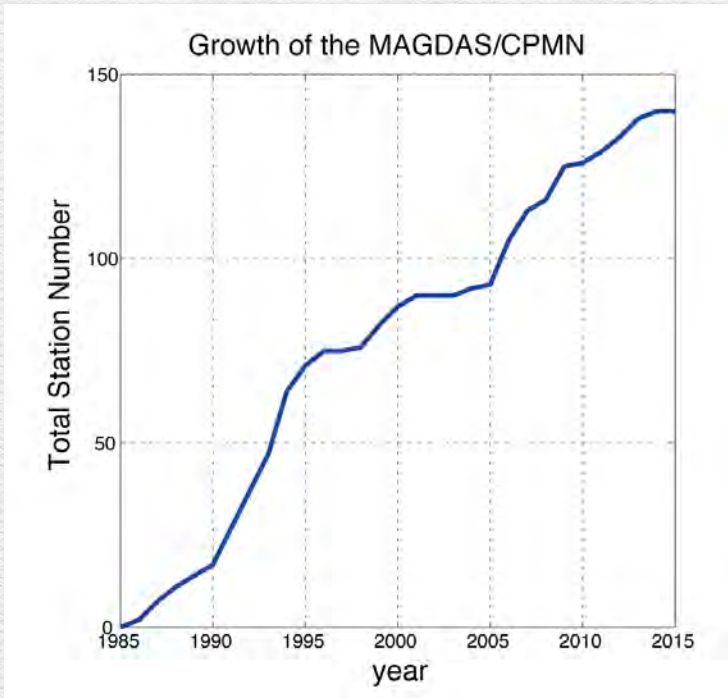
- Expansion and promotion of Space Weather as a field of science
- Closer investigation of changes of climate/geospace/disasters
- Examination of the medical and biological aspects of man working in space
- **Realizing international space weather research and education**

MAGDAS/CPMN
(MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network) project









The equatorial magnetometer network (EMN) started in 1985.
The 210MM network started in 1990.

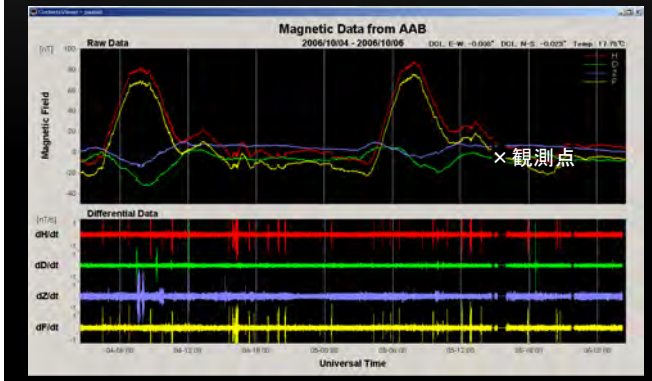
The EMN and 210 MM are combined as the CPMN started in 1996.

We started installing MAGDAS in 2005.

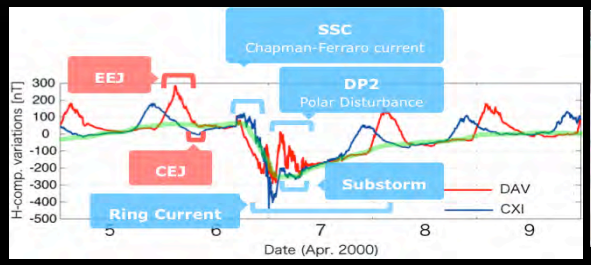
The present total number of observational sites about 150.

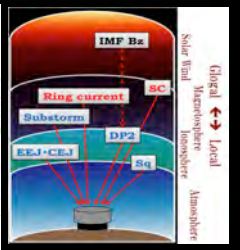
Currently, over 80 magnetometers and 4 FM-CW (Frequency Modulated Continuous Wave) radars are in operation for space weather study

Why global network observations of geomagnetic field disturbances?

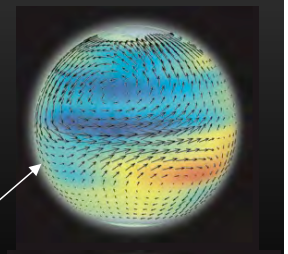


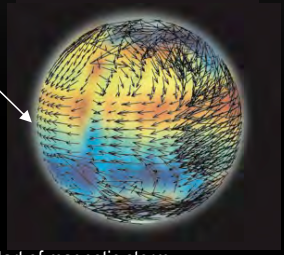
・Visualization of Space weather map from global magnetic field data





Magnetically quiet day

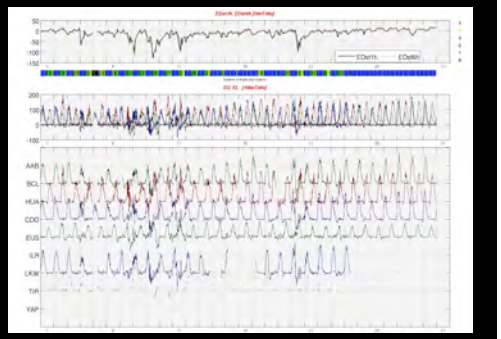




Start of magnetic storm

Magnetic field variations on the ground
are generated by reflecting

・space environment monitoring by using space weather index



We can investigate

・influences to Earth system caused solar eruptions

・relation between solar activity and climate phenomena and/or climate change

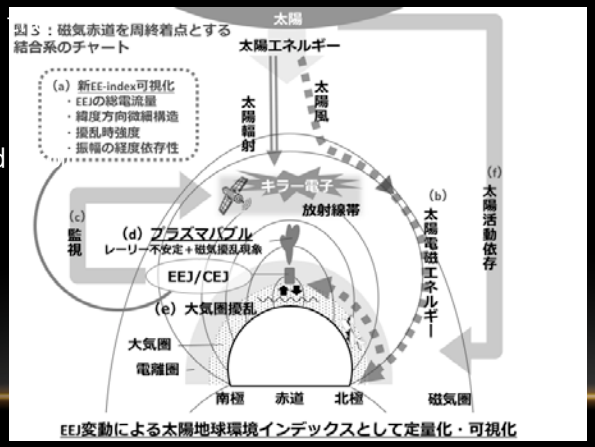
・global circulation of energy and material of upper atmosphere

・relations between seismic activity and solar activity?

（１）「solar terrestrial coupling」
electromagnetic disturbances across magnetosphere and ionosphere

（２）「horizontal coupling 」
electromagnetic energy is distributed polar to equatorial ionosphere and atmospheric energy is vice versa

（３）「atmospheric vertical coupling」
propagation of lower atmospheric disturbances to upper atmosphere via gravity wave and tidal waves, …



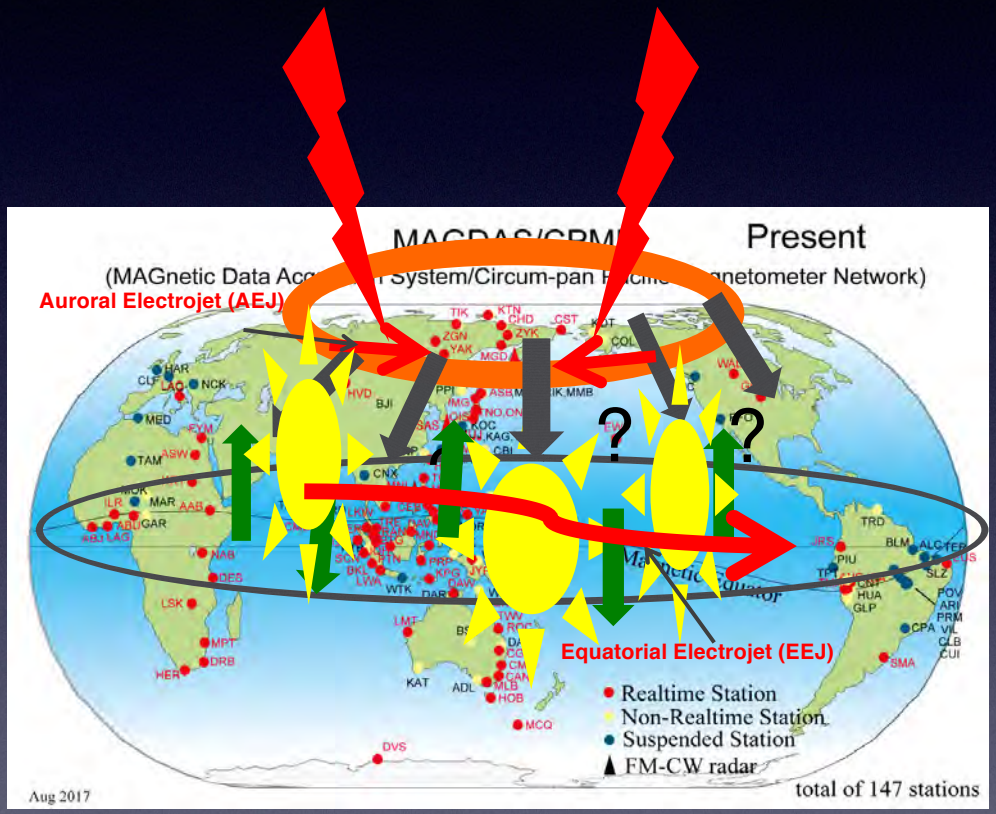
これらを同時に且つ広域に調査できるデータは磁場変動データのみ

Super Multipoint Geomagnetic field Network Observation ：important tool for exploring of Frontier of Solar terrestrial coupling process

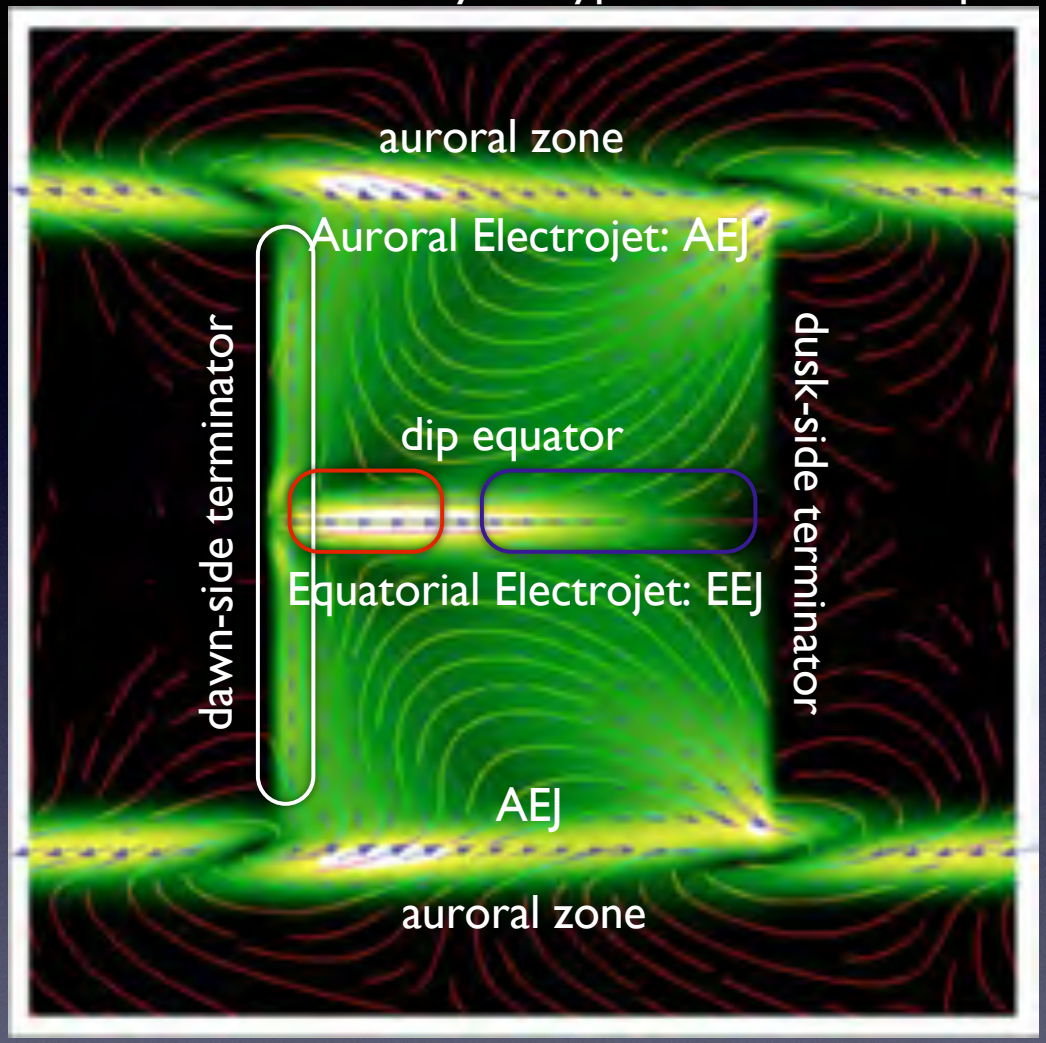
Electromagnetic coupling from polar to equatorial ionosphere

magnetic dip-equator:

- final destination of solar wind-magnetosphere-ionosphere coupling
- Most active region of atmospheric dynamic by solar radiation
- anomalously enhanced zonal conductance is aligned along the dip-equator by the Cowling effect
- sensitive receiver of solar wind variation, storm and substorm distrbances and atmospheric dynamo
- many observational results of electric field penetration from polar to equatorial region
- electromagnetic channel from auroral to equatrial ionosphere is unknown
- closure of equatrial electrojet (EEJ) is still unknown



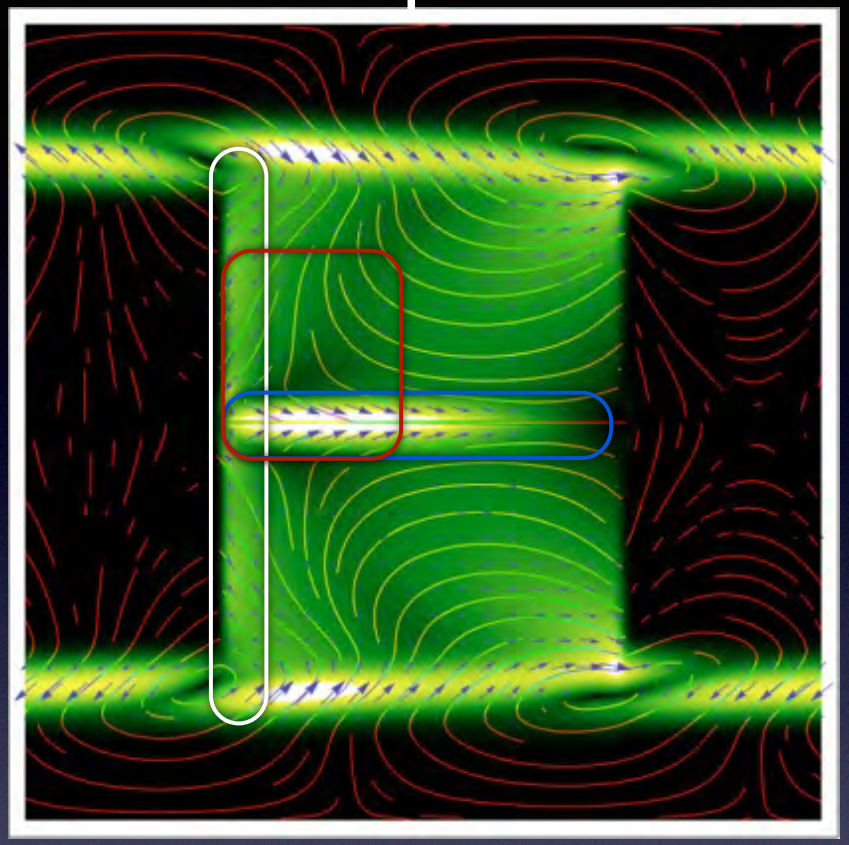
Search for Current Closure from Polar to Equatorial Ionosphere through formation of Cowling Channel (ionospheric current induced by R1-type FAC closure at polar region)



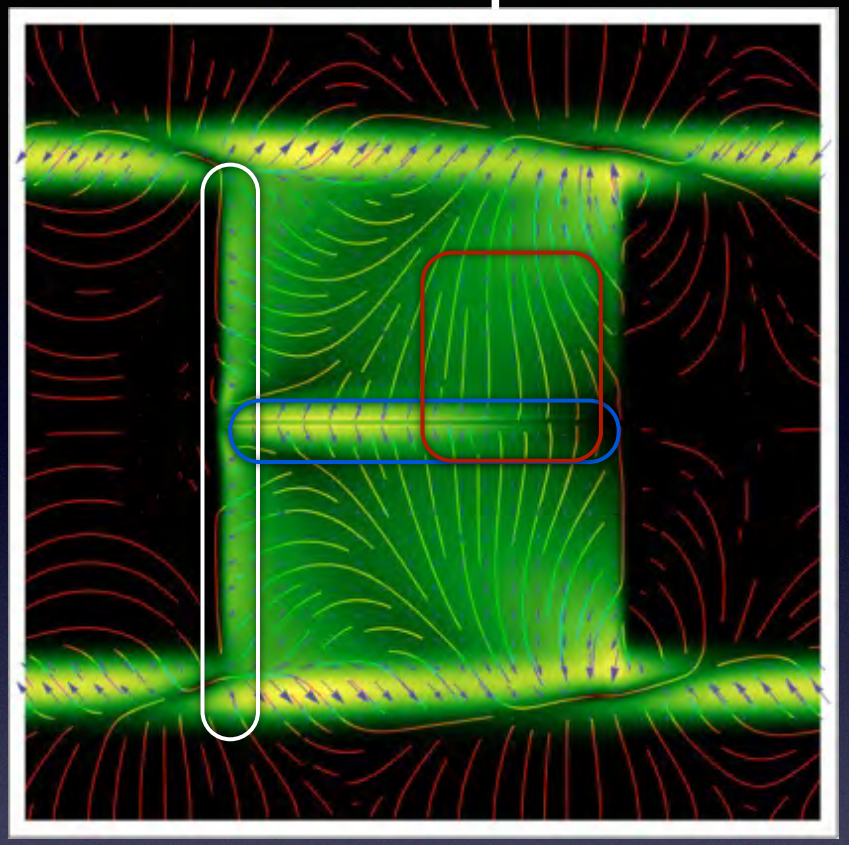
Yoshikawa et al., 2012

- equator ward meridional current flows along the dawn-side terminator line and connecting between AEJ and EEJ
- equator ward meridional current at morning side also runs into the equator, and enhances the EEJ
- EEJ gradually decreases through diversion to the poleward current at evening side

Hall part



Pedersen part



・at the dawn side terminator, Hall and Pedersen currents in the east-west direction are cancelled out each other, while equatorward Hall and Pedersen currents flow in the same direction

・at the dip-equator, Hall and Pedersen currents in the north-south (downward and upward) direction are cancelled out each other, while eastward Hall and Pedersen currents flow in the same direction

・Hall current runs into the equator at the morning side, while the Pedersen current diverging to the poleward at the evening side

The EEJ is the Cowling current of which continuity is preserved by connection via Cowling current along the dawn-terminator, Hall current converging from polar to dip-equator, and Pedersen current diverging from dip-equator to polar region !!

Global equivalent current system of dayside Pi2 pulsations

as a result of R1-type current wedge system oscillation?

Pi2 pulsation is well-know as manifestation of substorm onset.
It is a global pulsations observed not only night side region but also dayside region.

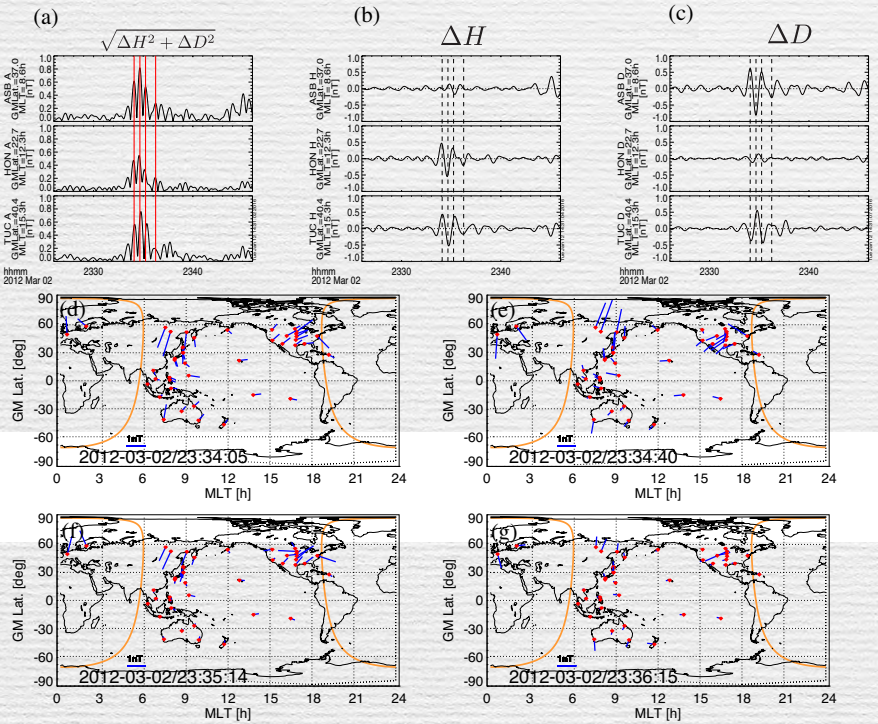


FIGURE 4.9: Filtered magnetic data for 2052−2112 UT on 26 March 2012 and the distributions of equivalent currents at the four successive times in the same format as Figure 4.8

Imajo et al., [JGR, 2018]

depict the equivalent current system of dayside region, which can be interpreted by the global Cowling channel

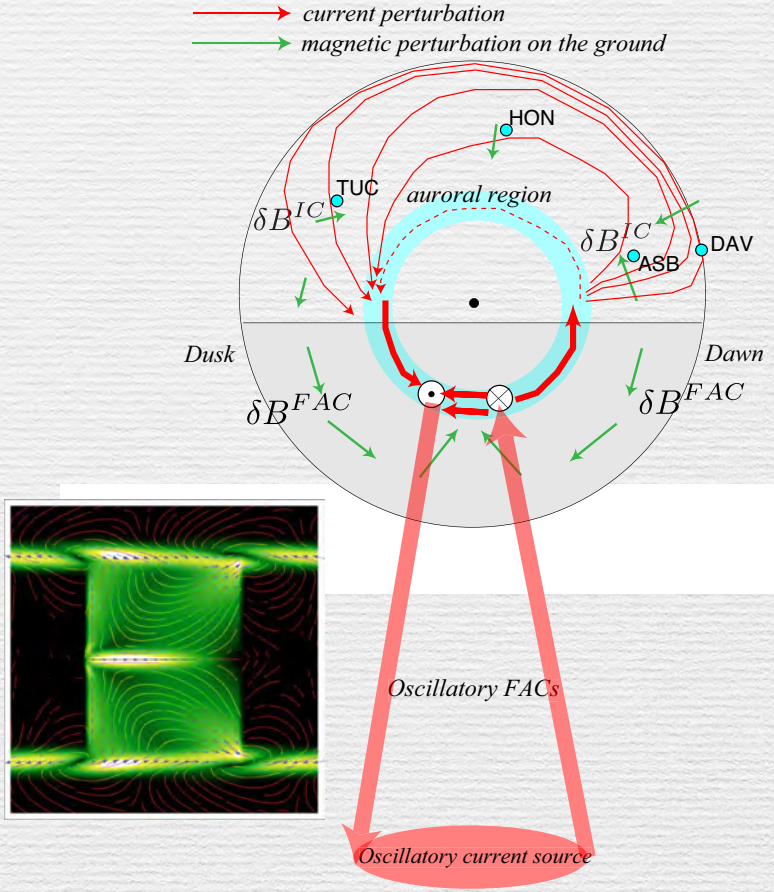
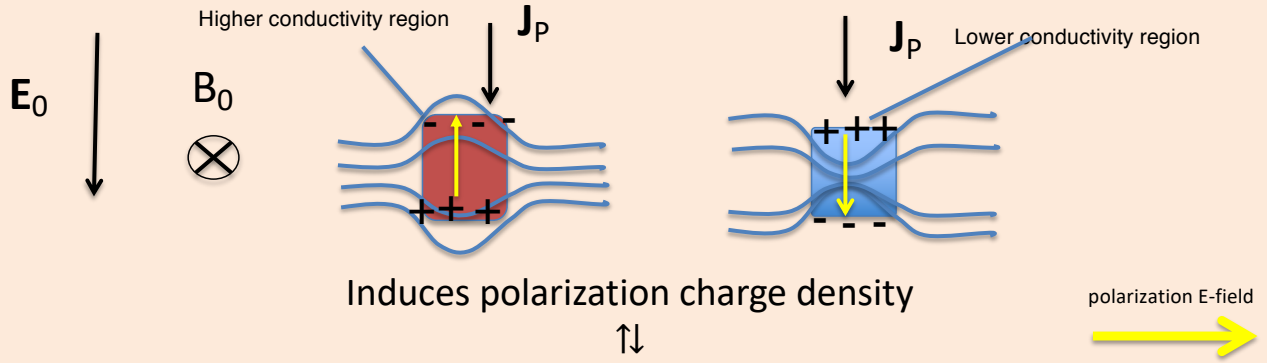


FIGURE 4.16: Schematic illustration of the current system to explain equivalent current distributions of dayside Pi2. Green arrows indicate magnetic perturbations, and red stream lines indicate current closures. Magnetic perturbations produced by mainly FACs are represented by δB^{FAC}, and magnetic perturbations on the ground produced by mainly ionospheric currents are represented by δB^{IC}.

How ionospheric polarization effect deform the ionospheric convection ?

Polarization effect by
Pedersen current divergence

$$\Sigma_P \nabla^2 S_1 + \nabla\Sigma_P \cdot \left(\mathbf{E}_0 - \nabla S_1\right) \simeq 0$$

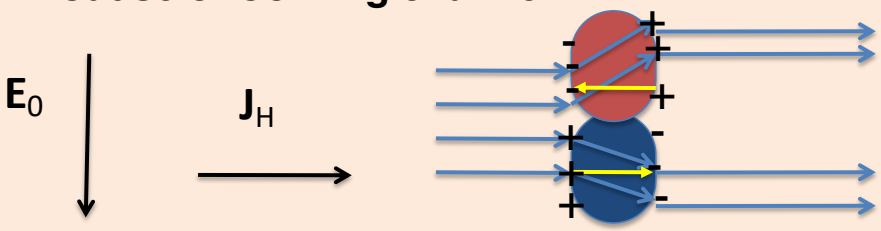


Induces polarization charge density
↑↓
expansion/compression of stream line
↑↓
deceleration/acceleration of ionospheric convection

Cause of Cowling channel

Polarization effect by
Hall current divergence

$$\Sigma_P \nabla^2 S_2 - \left(\hat{n} \times \nabla\Sigma_H^{'}\right) \cdot \left(\mathbf{E}_0 - \nabla S_1\right) \simeq 0$$

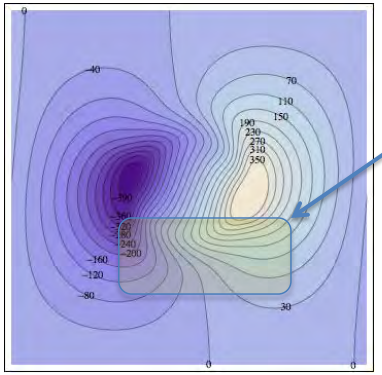


Induces polarization charge density
↑↓
reflation of stream line
↑↓
Rotation/deformation of ionospheric convection

Yoshikawa et al., [JGR 2013a,b]
Yoshikawa and Fujii, [AGU book 2018]

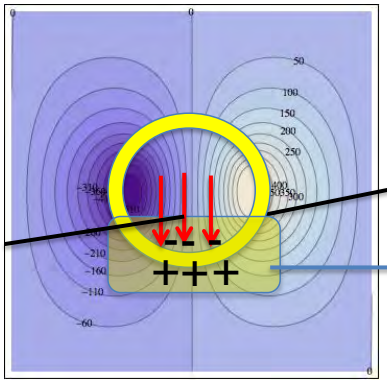
Application: Formation of Harang reversal by Hall polarization field at auroral boundary region ?

Cause of twisting potential



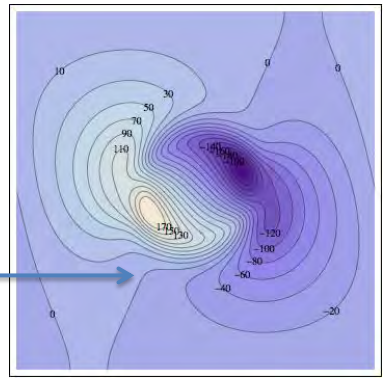
Harang reversal of convection
can be produced by Cowling effect??

Background potential



Total potential

Hall polarization potential



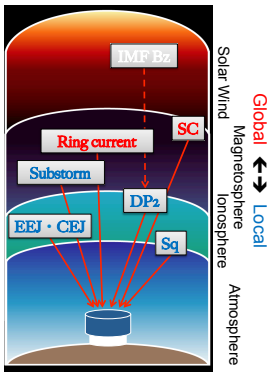
auroral oval

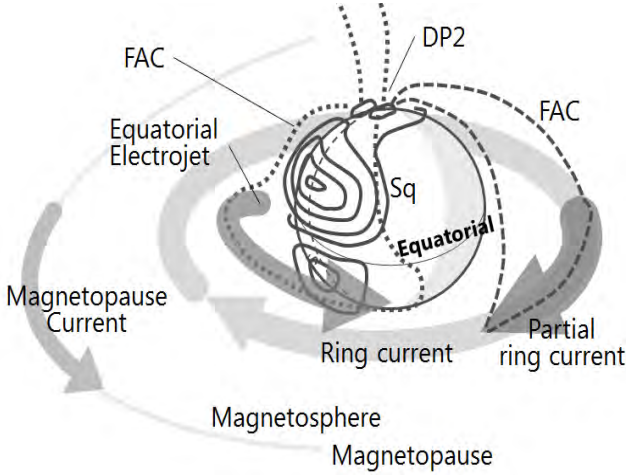
Hall current produced by symmetric background potential across the auroral oval

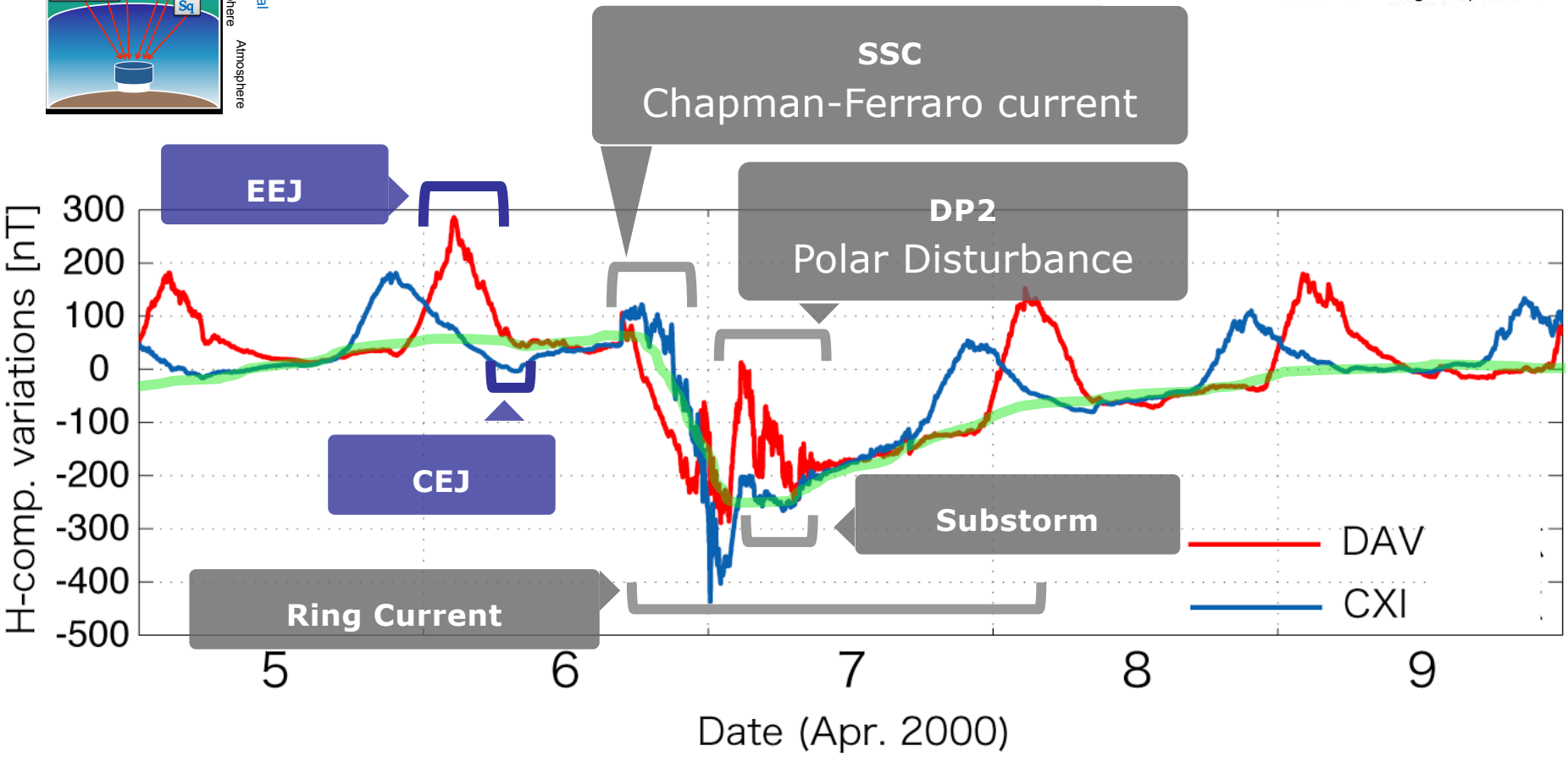
Cause of secondary potential

Do they feed back to the magnetospheric system or not ?

Geomagnetic disturbances at magnetic dip-equator



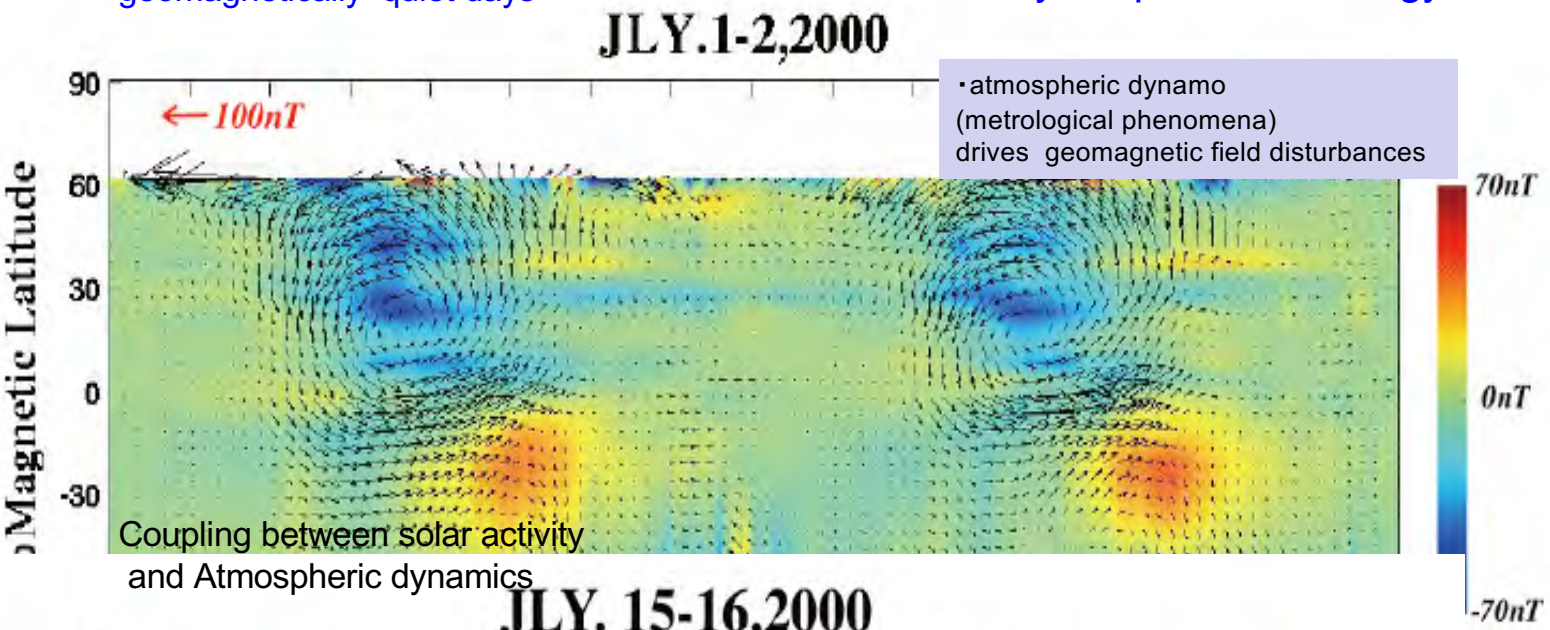




Visualization of Sq-Equivalent current

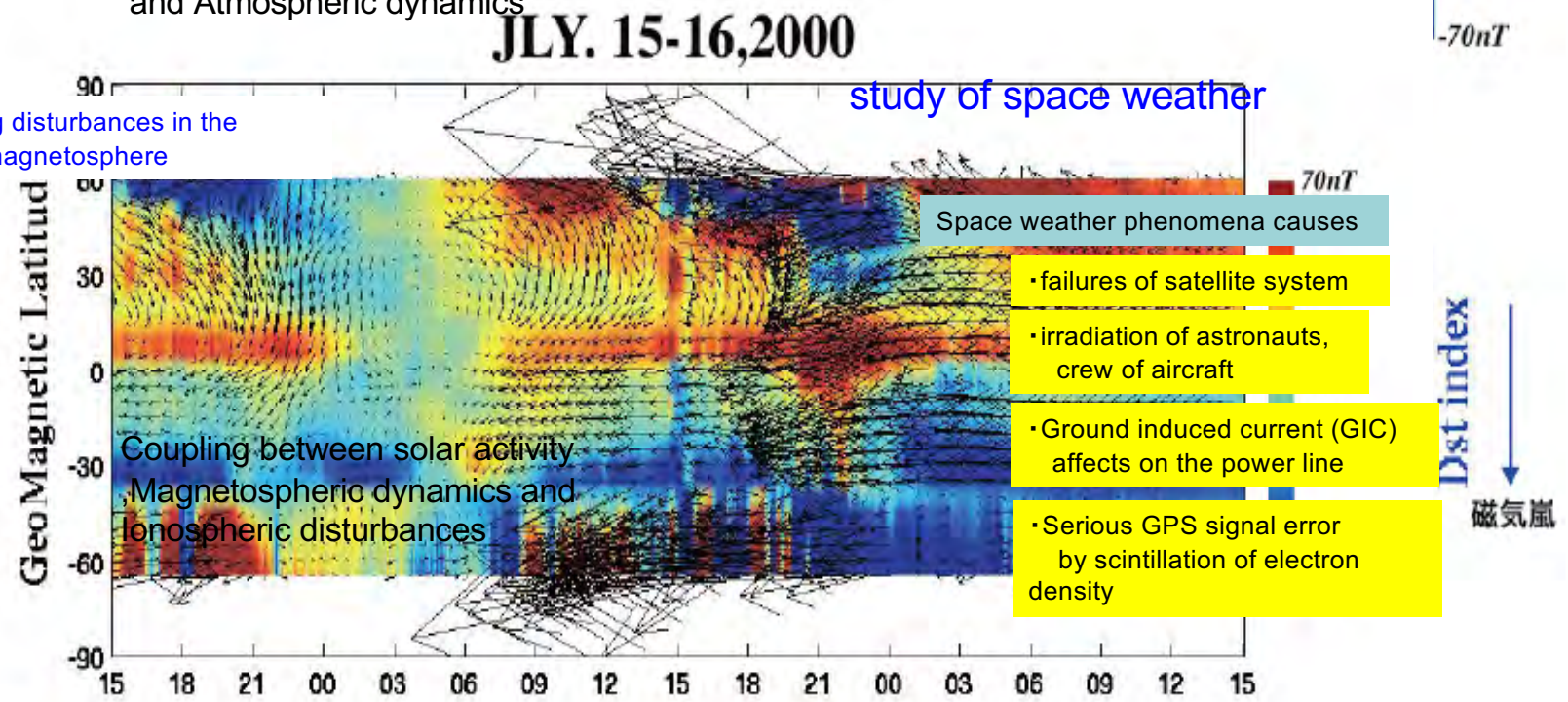
geomagnetically quiet days

study of space climatology



・atmospheric dynamo
(metrological phenomena)
drives geomagnetic field disturbances

Coupling between solar activity
and Atmospheric dynamics



study of space weather

・Strong disturbances in the magnetosphere

Coupling between solar activity
,Magnetospheric dynamics and
Ionospheric disturbances

Space weather phenomena causes

・failures of satellite system

・irradiation of astronauts,
crew of aircraft

・Ground induced current (GIC)
affects on the power line

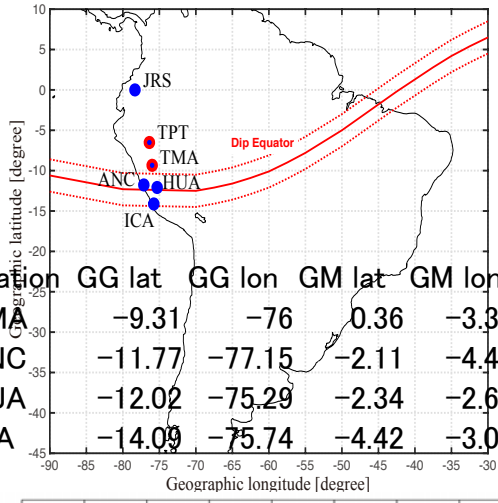
・Serious GPS signal error
by scintillation of electron
density

Dst index

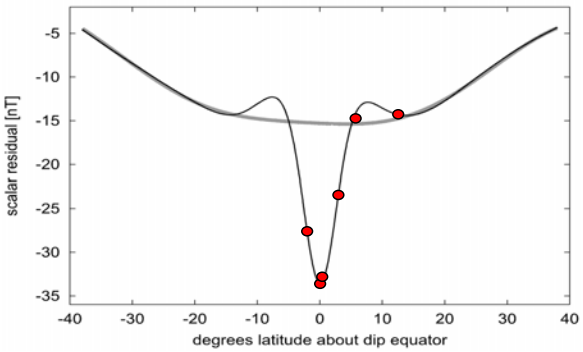
磁気嵐

Development of dense array of EEJ across dip equator after 2016

Peru region



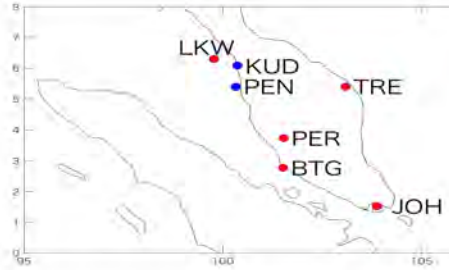
Station	GG lat	GG lon	GM lat	GM lon	Dip lat
TMA	−9.31	−76	0.36	−3.33	2.45
ANC	−11.77	−77.15	−2.11	−4.43	0.03
HUA	−12.02	−75.29	−2.34	−2.61	−0.31
ICA	−14.09	−75.74	−4.42	−3.03	−2.35



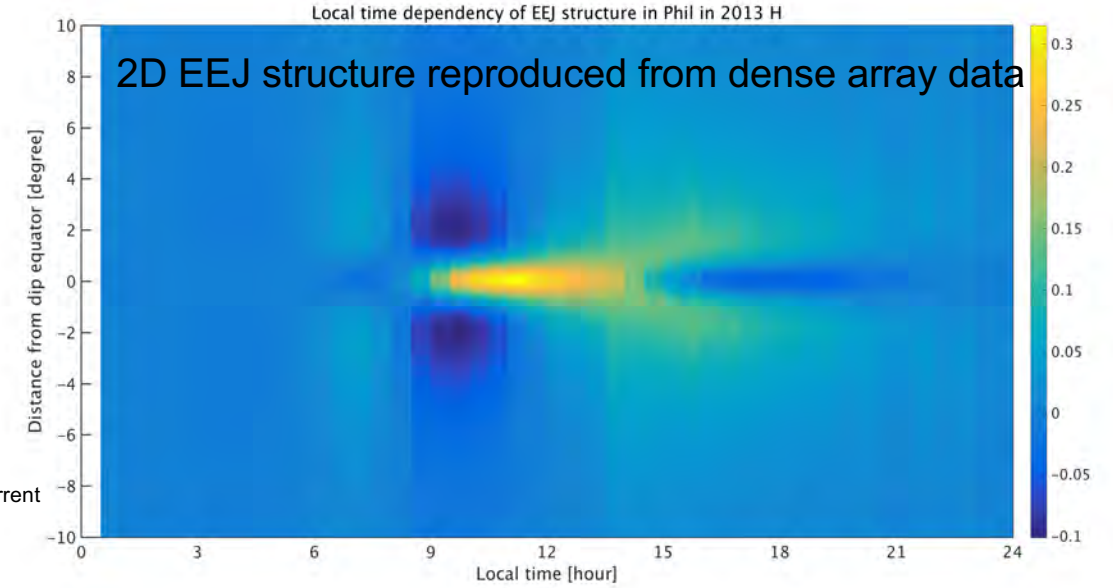
(Right) Noon time latitudinal variation of magnetic field change by ionospheric current (after Luhr et al., 2004). Red dots denote MAGDAS observatories in Peru.

(newly installed after 2016)

Malaysia region



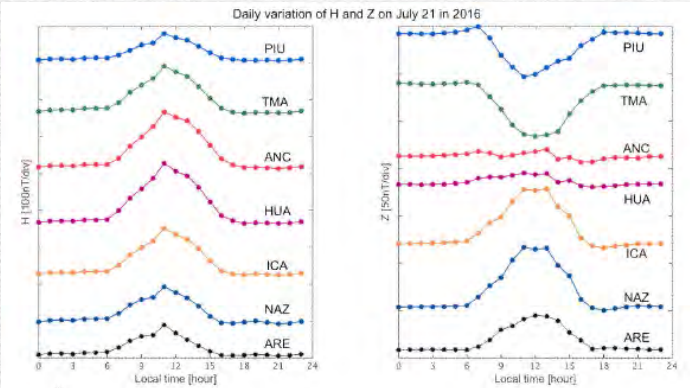
Station	GG lat	GG lon	GM lat	GM lon	Dip lat
LKW	6.3	99.78	−3.3	172.44	−1.07
LAN	5.95	116.68	−3.61	189.27	−1.02
TER	5.4	103.08	−4.26	175.71	−1.86
PER	3.72	101.53	−5.92	174.14	−3.59
BTG	2.78	101.51	−6.86	174.1	−4.53
JOH	1.53	103.87	−8.14	176.46	−5.7



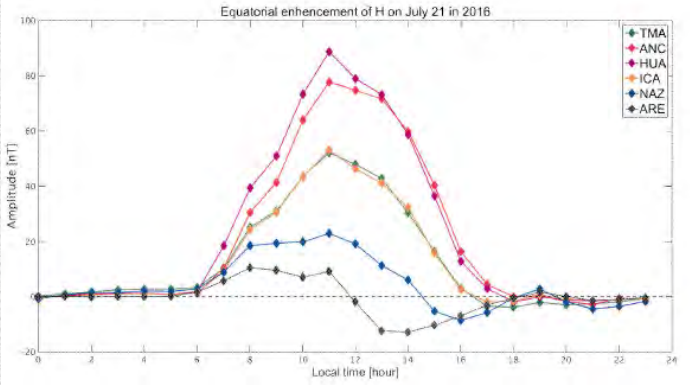
- Average variation of EEJ, including current density and its structure, can be derived by satellite observation, but ground observations are necessary for monitoring EEJ activity every time.
- Dense array across EEJ enables real time monitoring of “breathing/ pulsing of EEJ”. that might be closely related to the scintillations caused by “Spread F” and /or “Plasma Bubble”.

EEJ structures observed Peruvian dense magnetometer array

Example of EEJ current structure during quiet and normal EEJ



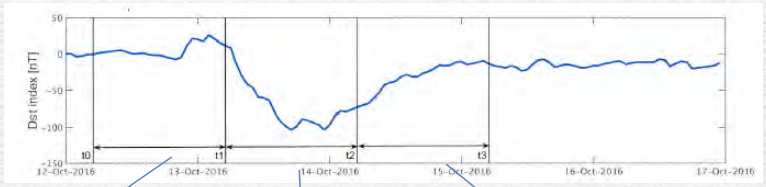
Daily variation of H- and D-component.

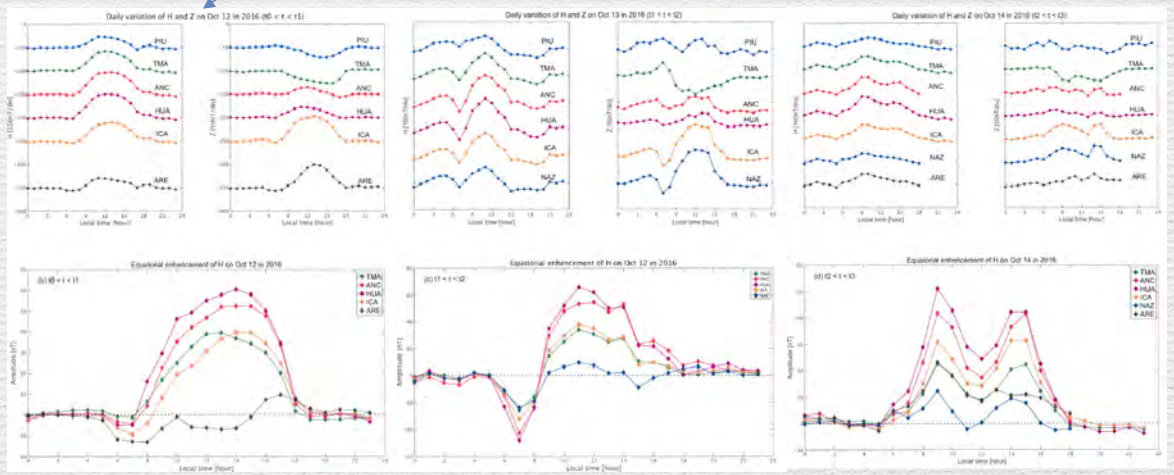


Equatorial enhancement of daily variation derived by subtracting of PIU, as the reference of Sq variation.

Previous maintenance

Example of EEJ curret structure during storm time





Shifted EEJ peak

Initial phase of magnetic storm

Negative variation in the morning

main phase of magnetic storm

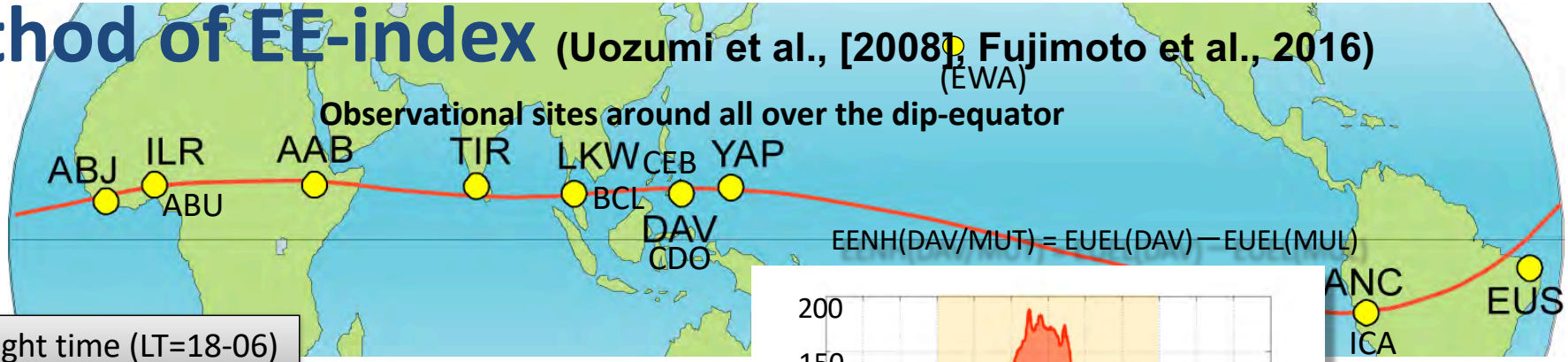
Double peak structure

recovery phase of magnetic storm

Matsushita, Ph.D. thesis, 2017

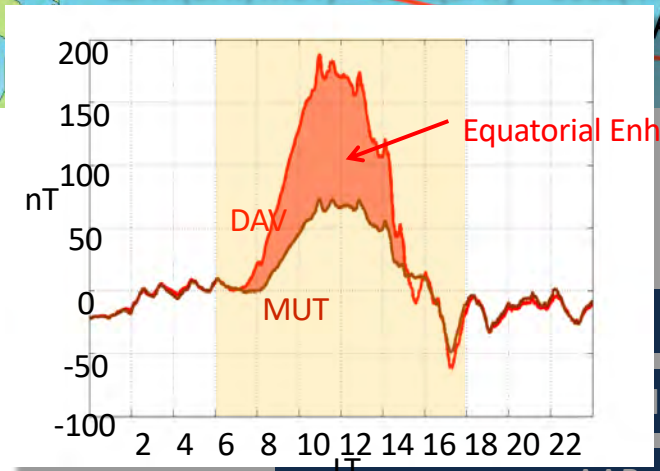
Real-time 24-hours Monitoring of Equatorial Electrojet variations

Method of EE-index (Uozumi et al., [2008], Fujimoto et al., 2016)



Night time (LT=18-06)

Use as the dynamic reference base level for the daily variation Representing global magnetospheric disturbances



ANC, ICA

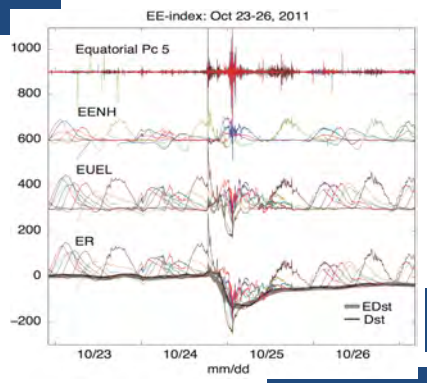
EUS

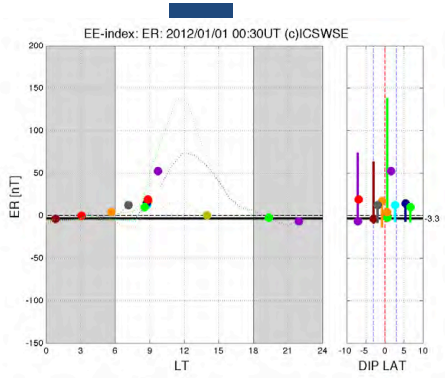
ABJ

ILR, ABU

AAB

EE-index in Storm-time





EUS

ABJ

ILR, ABU

AAB

TIR

LKW, BCL

CEB, DAV, CDO

YAP

(EWA)

UT

EE=EUEL+ EDST

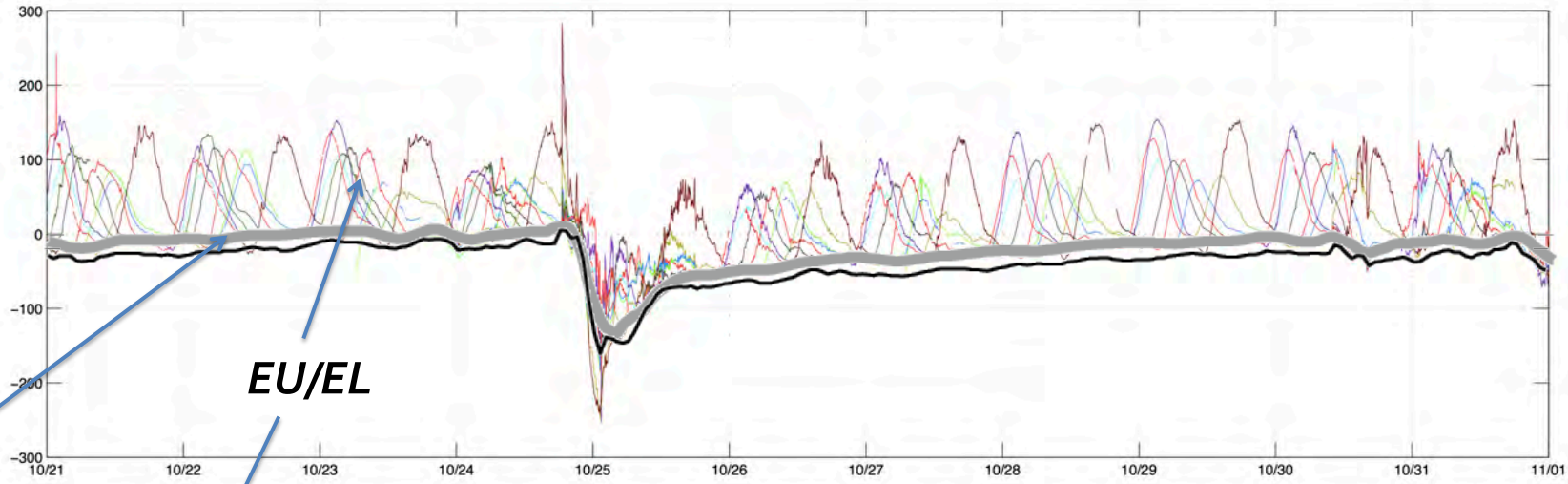
local component

Global component

- monitor the equatorial magnetic field variations changing *from "moment to moment"* with the same ruler regardless of magnetospheric condition(quiet/disturbance)

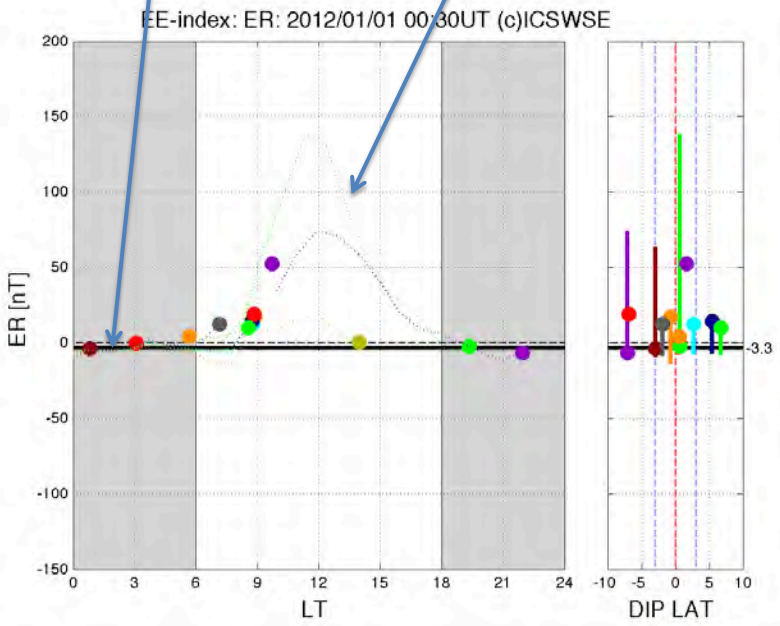
"EE= +EUEL+EDst" calculated by MAGDAS

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



EDst

EU/EL



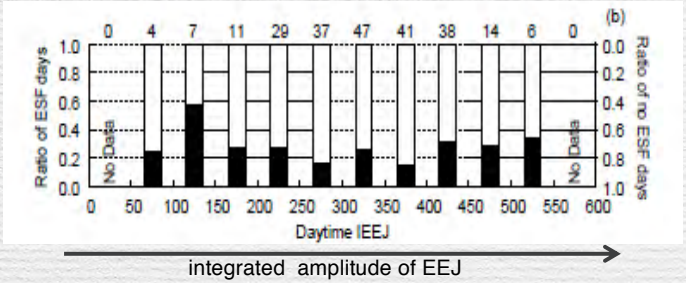
EDst **represents global magnetic variation**
(almost same the Dst index)

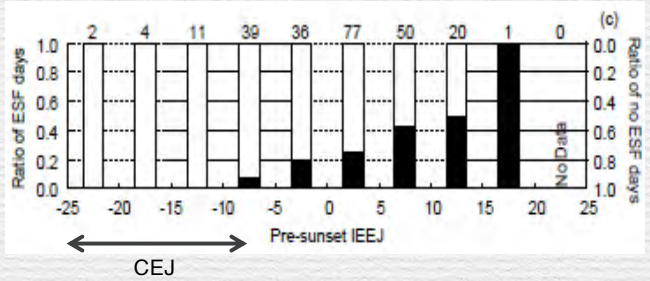
EU/EL **represents local magnetic variation**
(like AU/AU @ auroral zone)
(but keep the variation form)

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

This is one of the application research of EE-index.

Relationship between the occurrence of plasma bubble and EEJ/CEJ at South-Eastern Asia





Uemoto et al. (2010)

relationship EEJ and plasma bubble occurrence using resudual EEJ (EEJ-Sq value)

（1） **No-relation** between amplitude of **equatorial enhancement of component of "dayside" EEJ** and **plasma bubble occurrence**

（2） Enhancement of pre-sunset CEJ strongly suppress bubble occurrence

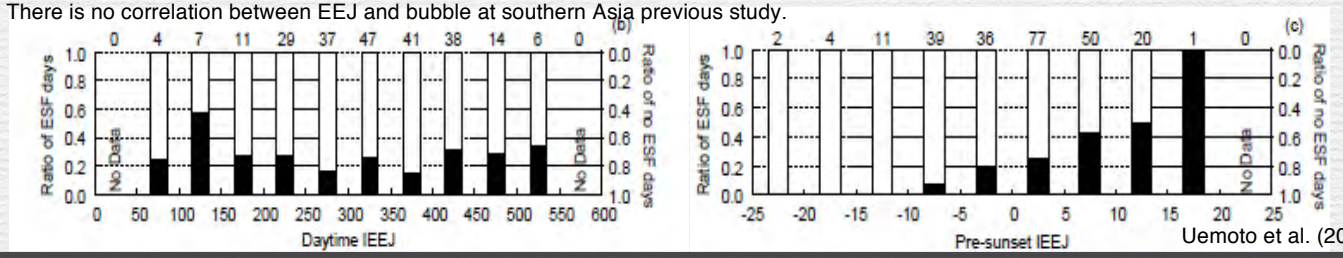
→ how about total amplitude of EEJ including Sq field itself ??

Relationship between the occurrence of plasma bubble and EEJ/CEJ

There is no correlation between EEJ and bubble at southern Asia previous study.

@ Indonesia

EEJ only for equatorial enhancement part

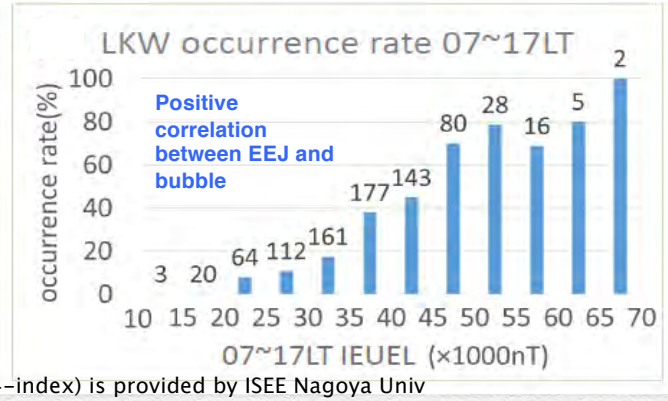


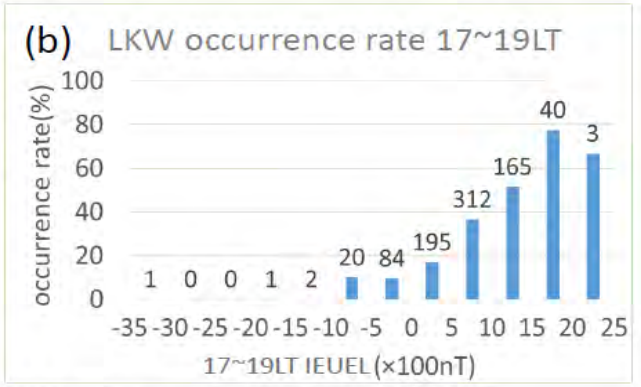
Uemoto et al. (2010)

South eastern Asia

LKW@ Malaysia

Total EEJ amplitude including Backgrounfd Sq component



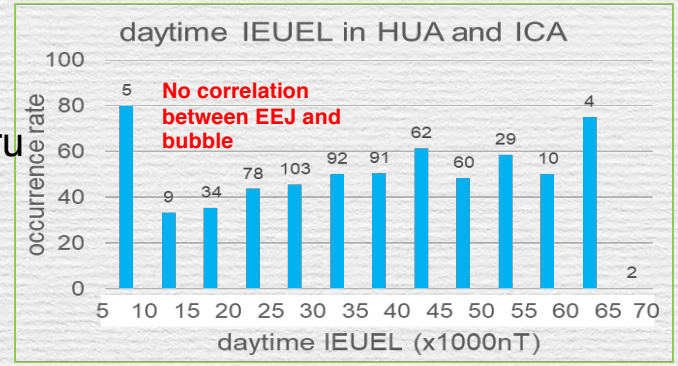


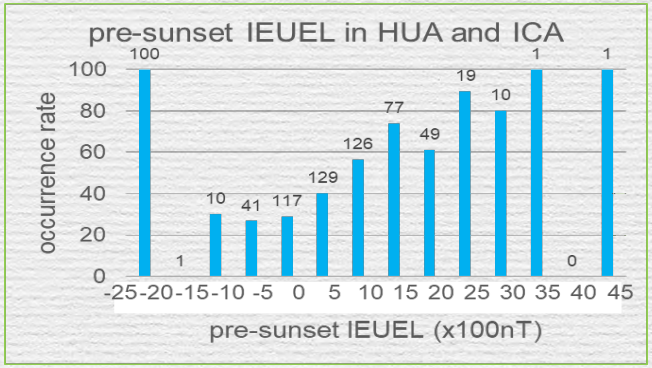
Bubble data (S4-index) is provided by ISEE Nagoya Univ

South America

ICA and HUA@ Peru

Total EEJ amplitude including Backgrounfd Sq component



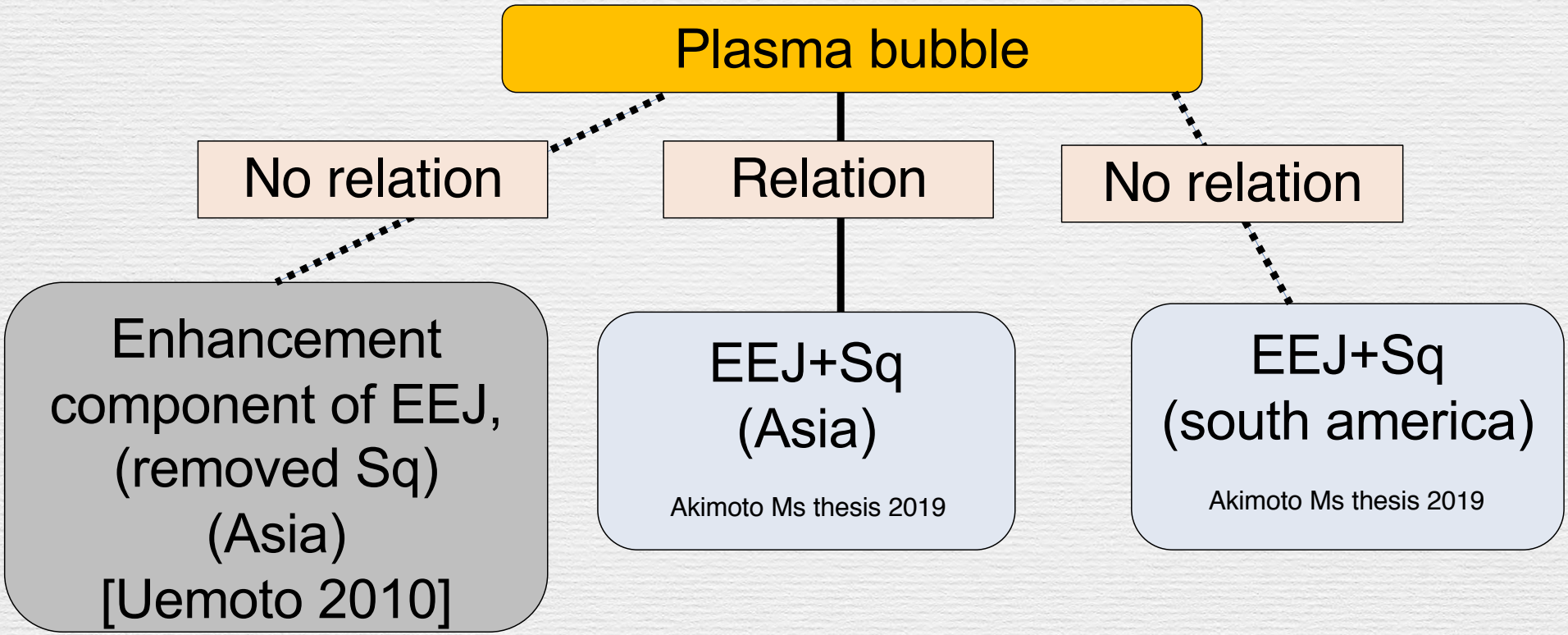


Bubble data is provided by Lowell Digisonde International

relationship EEJ strength using resudual EEJ (top panel), and integrated EUEL (middle and bottom panel) and plasma bubble occurrence rate.

Akimoto Ms thesis 2019

Relationship between the occurrence of plasma bubble and EEJ/CEJ



Hamid [et al., 2014] report Sq-field is strong in Asian region but small in south American region

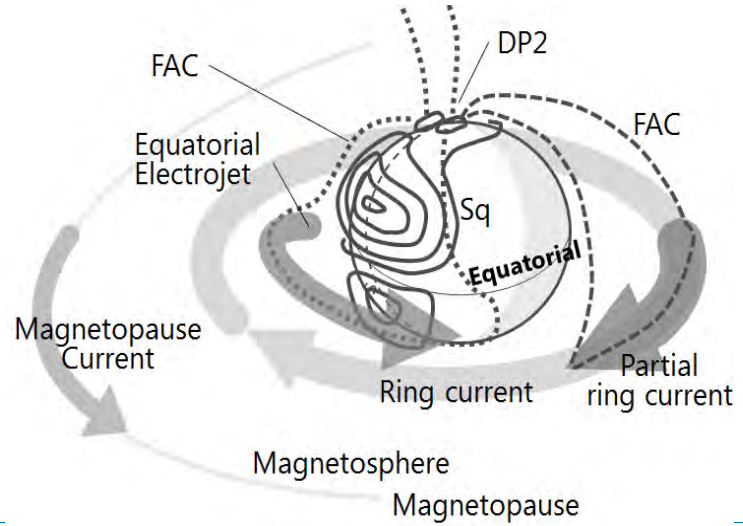
Dayside EEJ+Sq components at dayside region may strongly related to the plasma bubble occurrence at nightside region?

Space Weather Environment Index

Higher Freq. Variations of magnetic field monitor the space

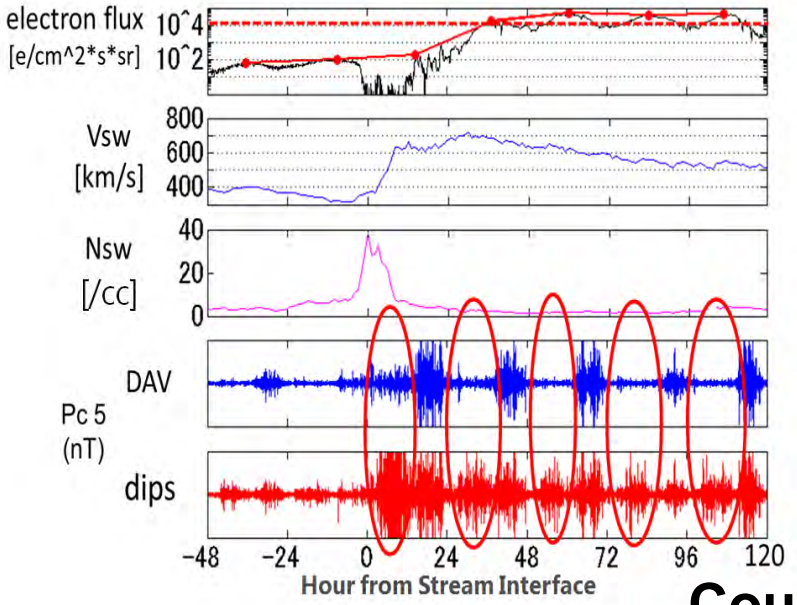
Pc5 ULF waves

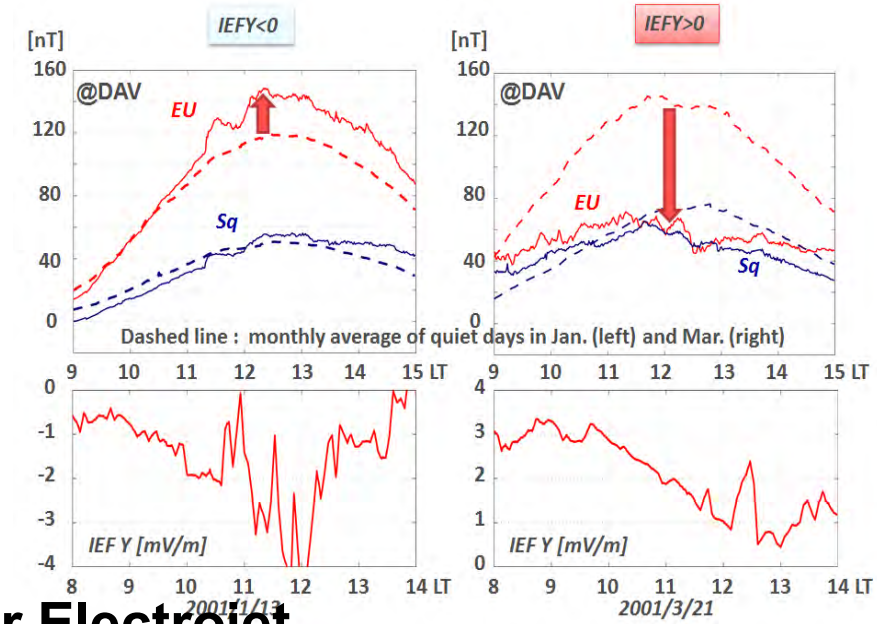
The proxy of the high energy electron acceleration in the radiation belt during magnetic storms



DP2 disturbances

Penetration of solar wind energy
(the Interplanetary Electric Field) into the equatorial ionosphere via the polar ionosphere





Counter Electrojet

Polar disturbance effects to Equatorial Electrojet

Space Climatological Environment Index

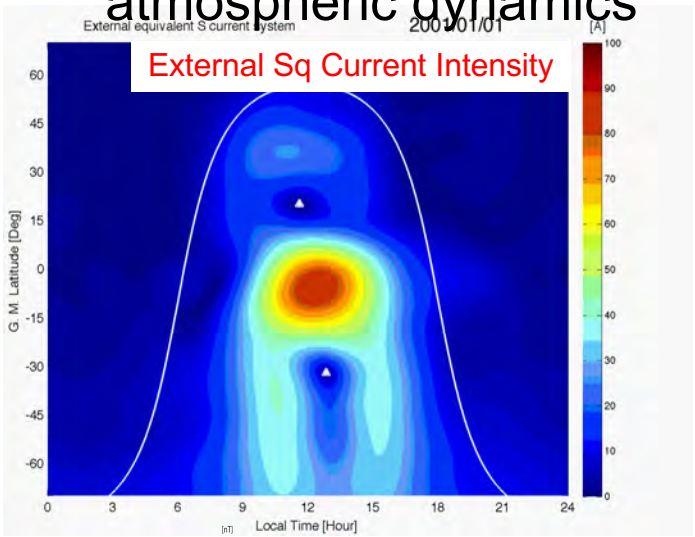
From day to day variation to Solar cycle variation

Solar cycle →atmospheric cycle → EEJ variability
atmospheric dynamics

Solar cycle Variation

The dependence of the EEJ structure and the atmospheric motion related to EEJ on the solar activity/solar cycle

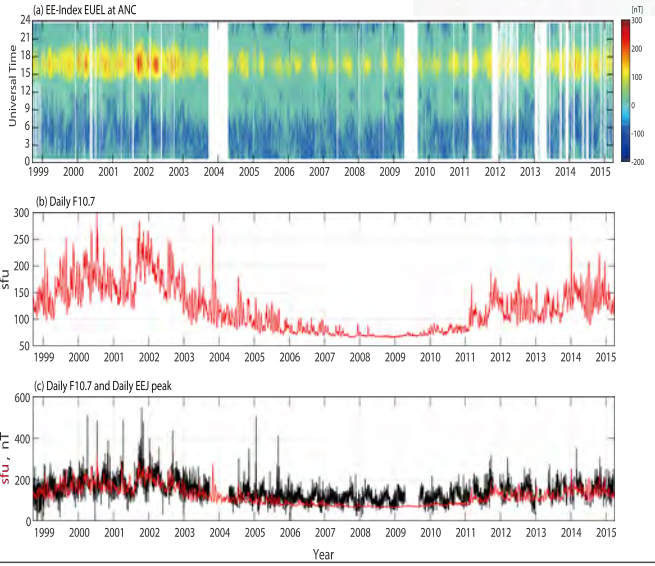
[Fujimoto et al., 2016]



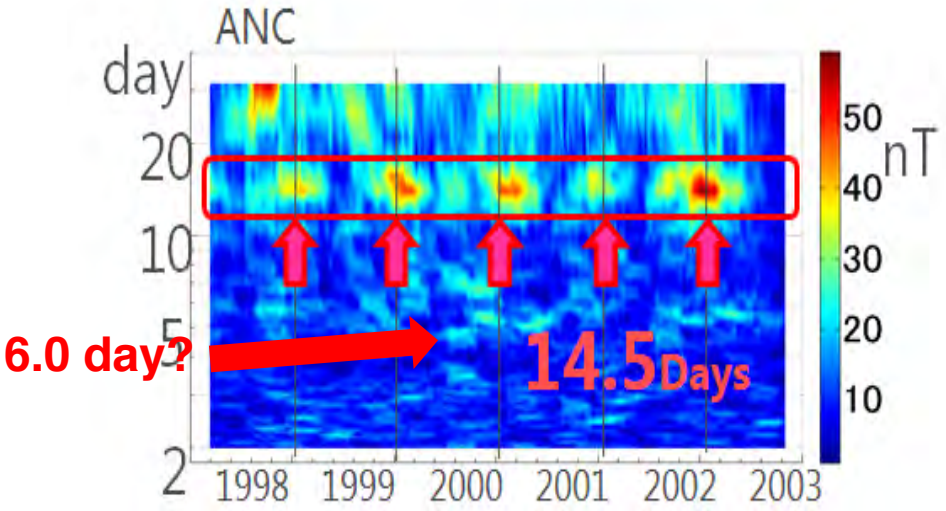
Day-to-day variation

The atmospheric disturbances affecting ionospheric dynamics

Avg. EUEL@DAV



The long-term variation of daily EEJ peak intensity has a trend similar to that of F10.7 (the solar activity).

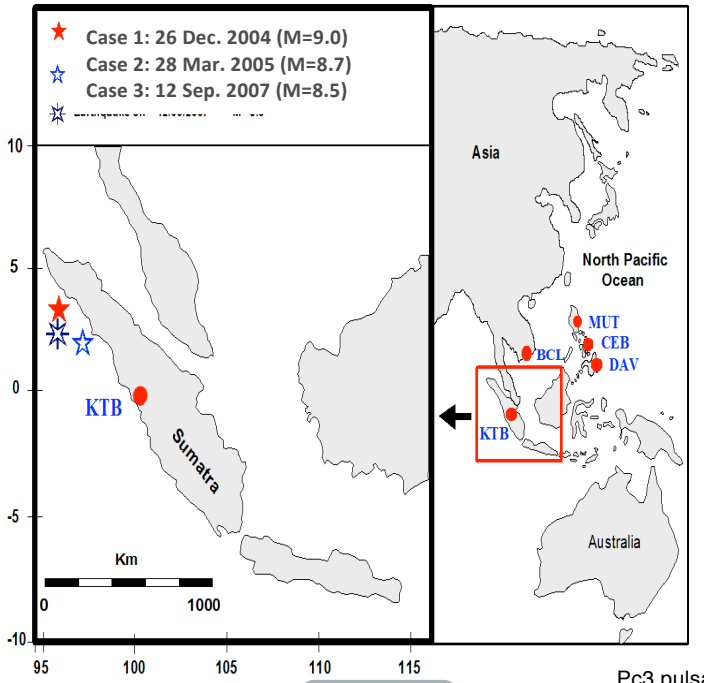


Seismo-Eloctromagnetic Monitoring Network

Indonesia-Japan MAGDAS Project for Litho-Space Weather

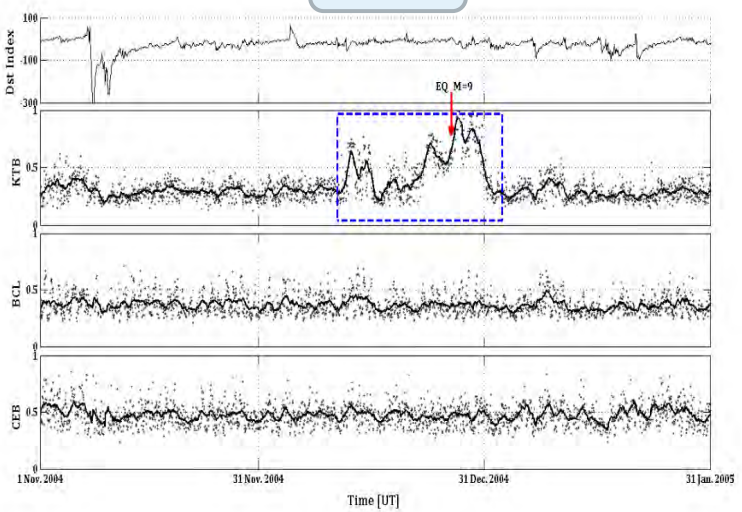
ICSWSE, BMKG, Chiba U.

Geomagnetic disturbances related with Seismic activity

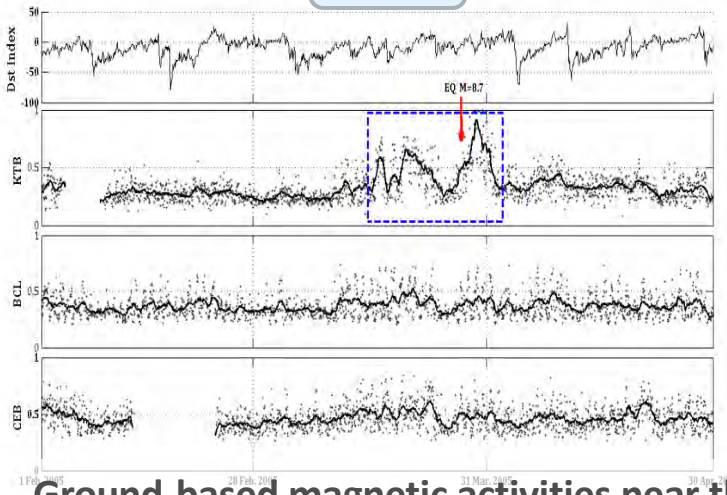


Pc3 pulsations

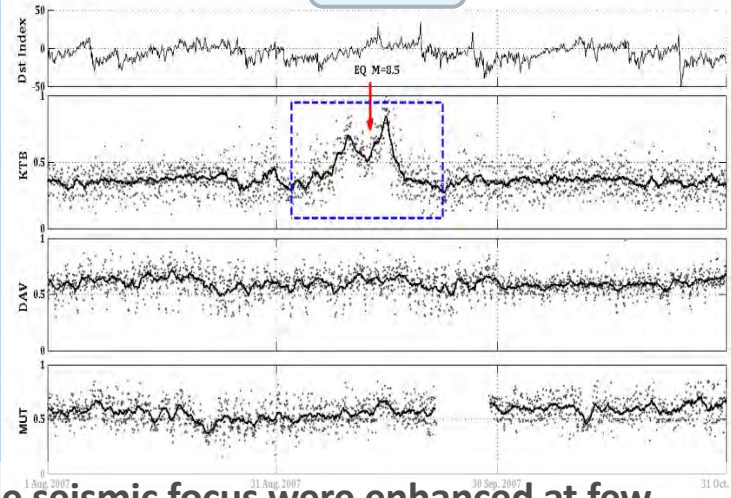
Case 1



Case 2

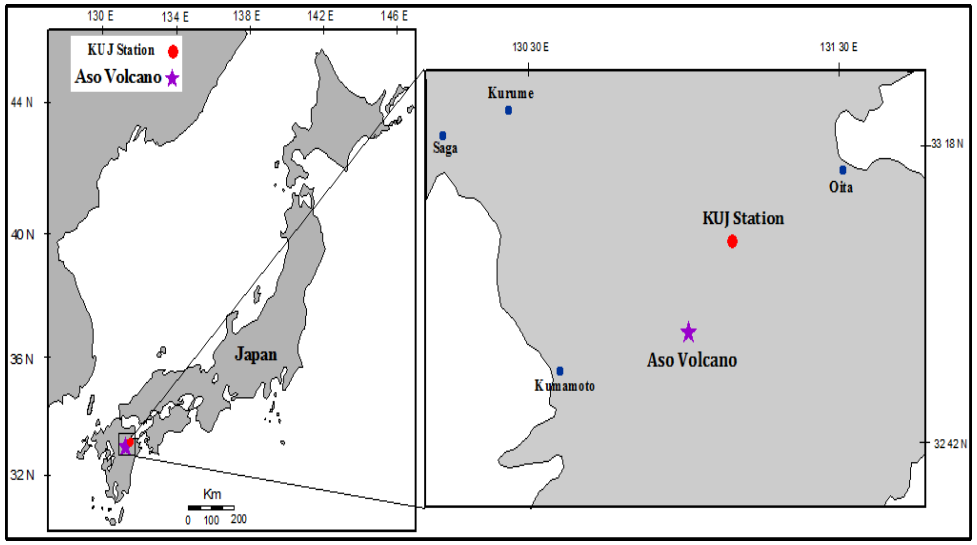


Case 3

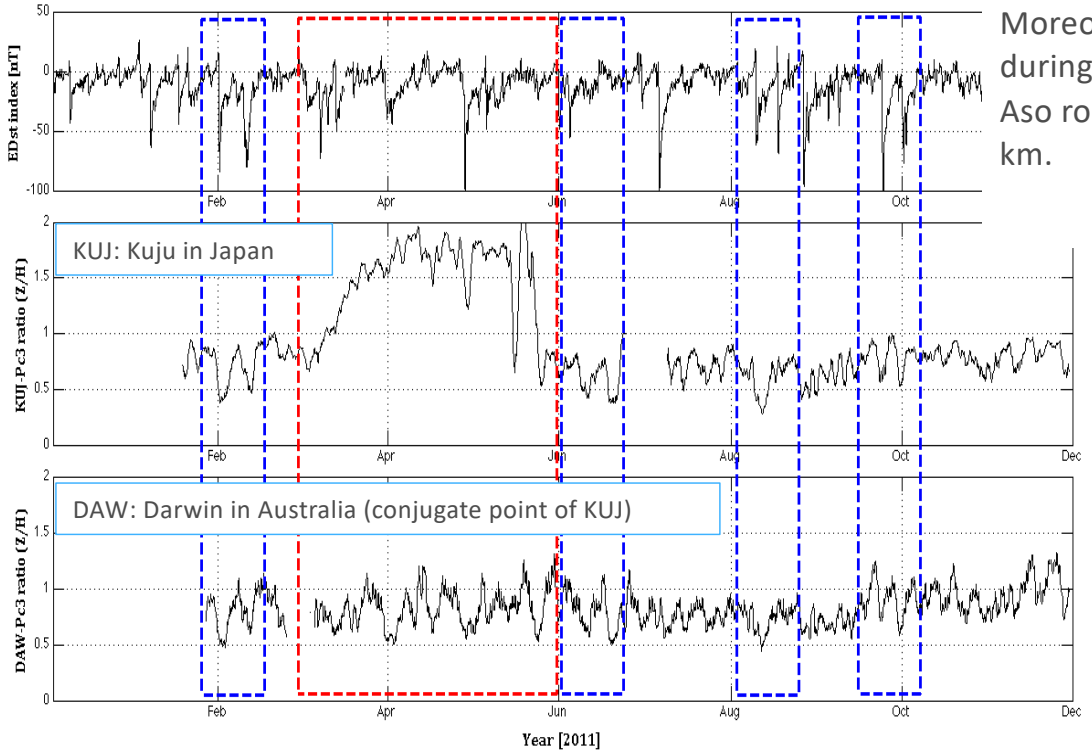


Ground-based magnetic activities near the seismic focus were enhanced at few weeks before the earthquake occurred .

Geomagnetic activity related with Volcanic activity



In 2011, the activity of the Aso volcano started in April and ended in June as it reported by the Japanese Meteorological Agency (JMA). A small phreatic eruption occurred at Naka-dake's crater lake in April 2011. On Friday 13 May, the Naka-dake vent of Aso produced small (phreatic) explosions with a 500 m tall steam-and-ash plume. The alert level for the volcano was raised to 2 by the JMA. Moreover, the JMA reported that during 7-9 June, plumes from Aso rose to altitudes of 1.5-1.8 km.



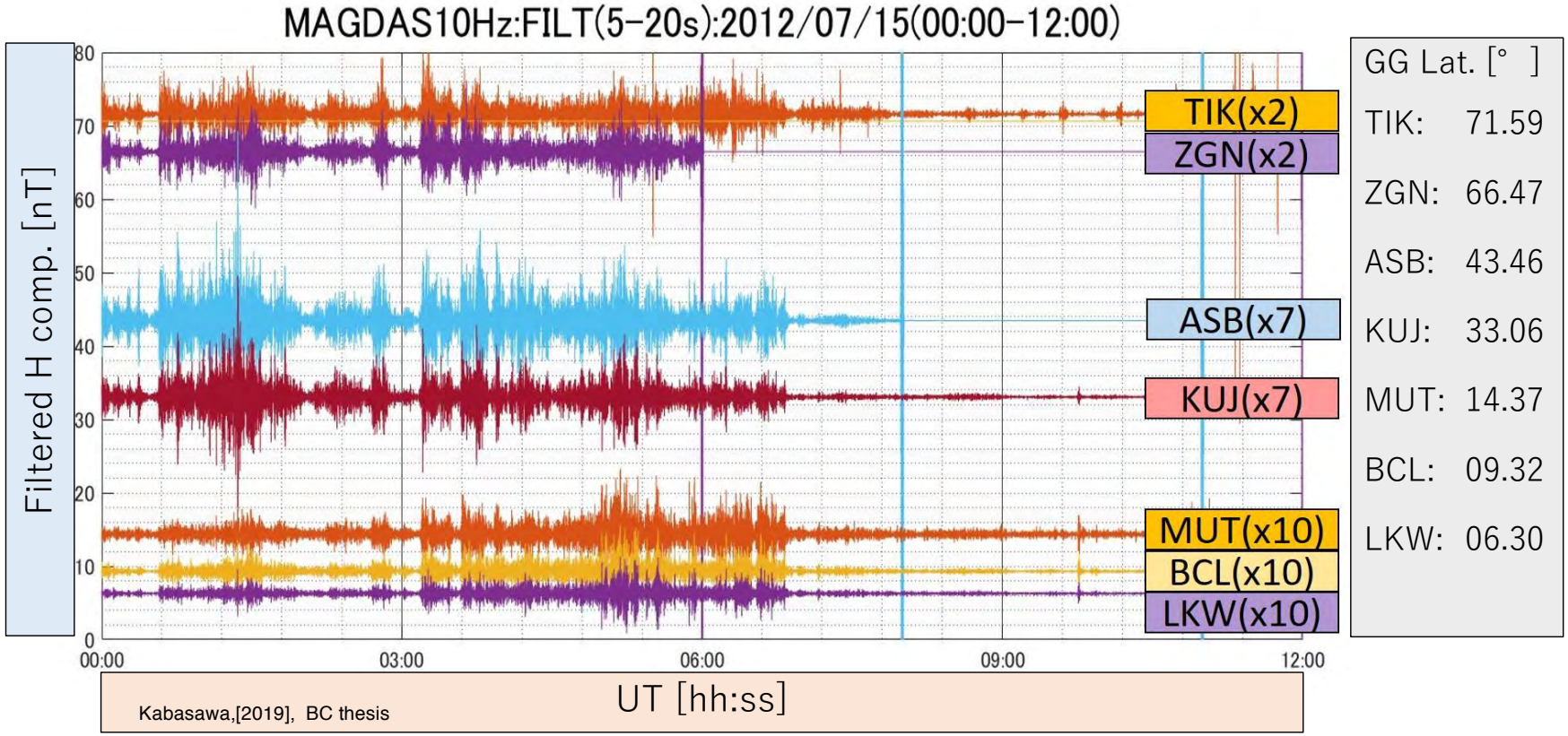
Emad et al., 2017

Toward Ground monitoring of EMIC excitation
: Global Monitoring of Pc2 pulsation (periods: 5-10 seconds)

EMIC wave excited during Storm especially stomtime substorm causes energization of heavy ion at the inner magnetosphere. The frequency range of EMIC wave for O+ and He+ is in Pc2 pulsations (5-10 seconds).

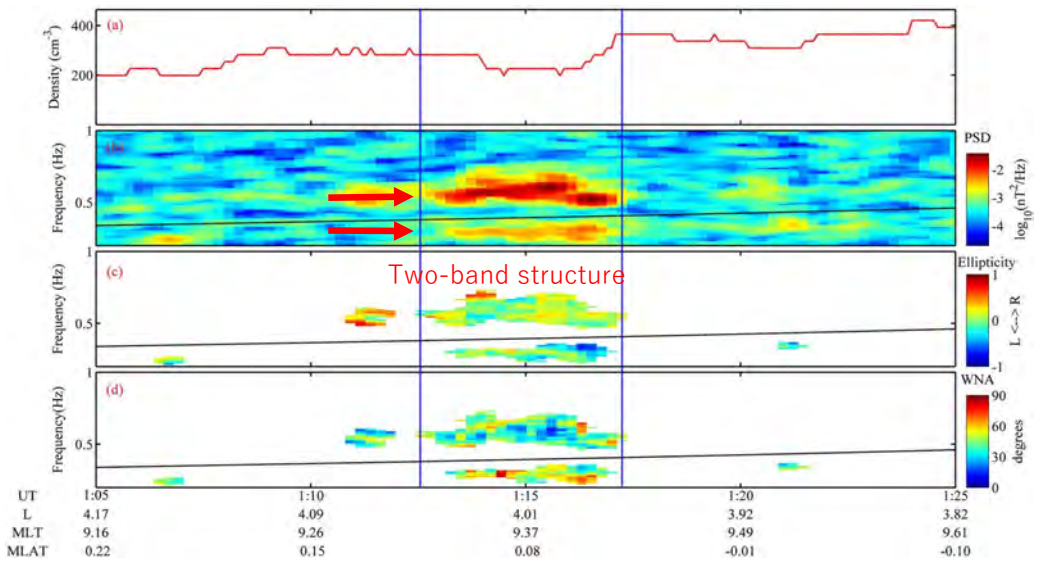
1. Pc2 observed from polar to equatorial region by MAGDAS

By using the 10Hz data of MAGDAS-9 magnetometers, Pc2 pulsation observed almost simultaneously from high-latitude area near polar region to middle-and-low latitude area near the equator can be identified.



Kabasawa,[2019], BC thesis

Two band structure of EMIC emission observed by Van Allen Probe



Yu et al. [2018]

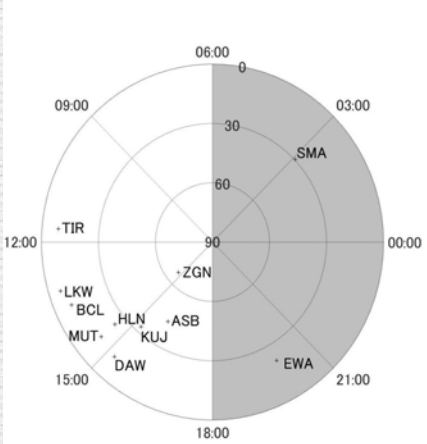
A typical case of EMIC emissions with both He^+ band and O^+ band waves was observed by Van Allen Probe A on 14 July 2014(Yu et al., 2018). This is the case that EMIC waves by heavy ions were observed in the internal magnetosphere. Also, it has two-band structure, with one band above f_{o+}(= the local gyrofrequencies of O^+) and the other below f_{o+}. It is suggested that this global Pc2 pulsation on the ground is likely to have close relation to the wave particle interaction phenomenon by the high-energy heavy ions in the internal magnetosphere.

Frequency range is in Pc2 pulsations (5~10 sec)

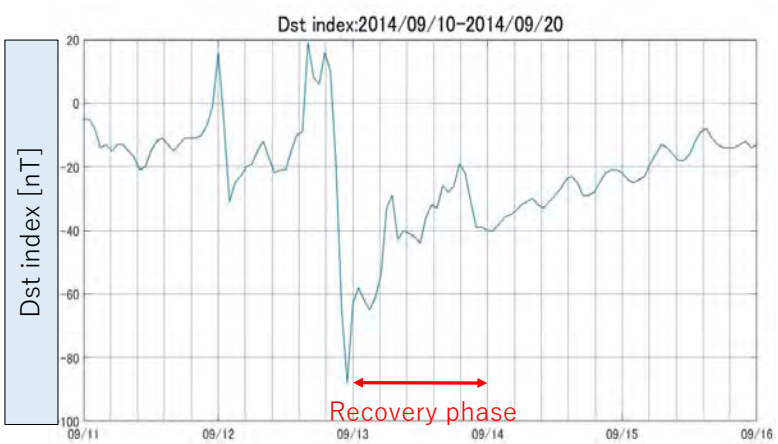
Two band structure of Pc2 pulsation also observed on the ground

2. Initial analysis of typical event (09/13/2014)

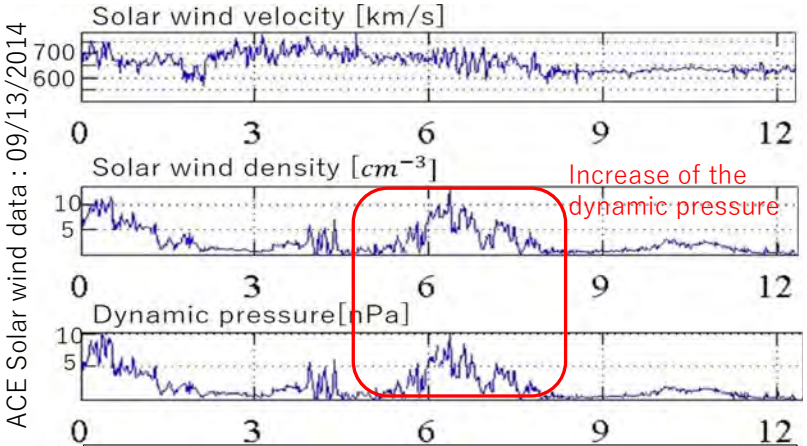
By using the 10Hz data of MAGDAS-9 magnetometers, a global Pc2 pulsation with two-band structure can be identified almost simultaneously during about 06:30-08:00UT on 13 September 2014.



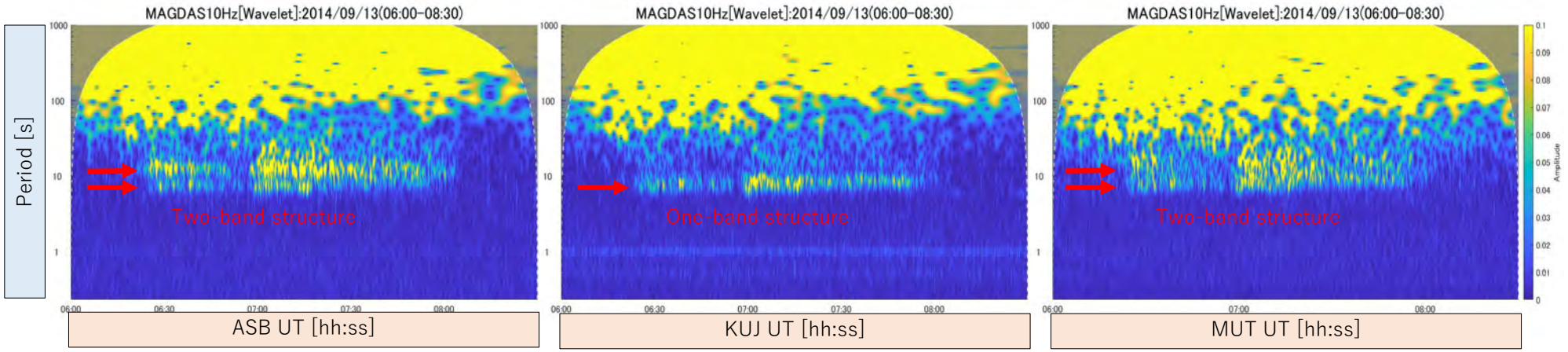
LT distribution [06:30UT]



UT [MM/DD]



UT [hh]



ASB UT [hh:ss] | KUJ UT [hh:ss] | MUT UT [hh:ss]

This observed Pc2 has two-band structure, with one band above the frequency of 10 seconds and the other below the frequency of 10 seconds. However, the two-band structure is not be confirmed depending on observation points.

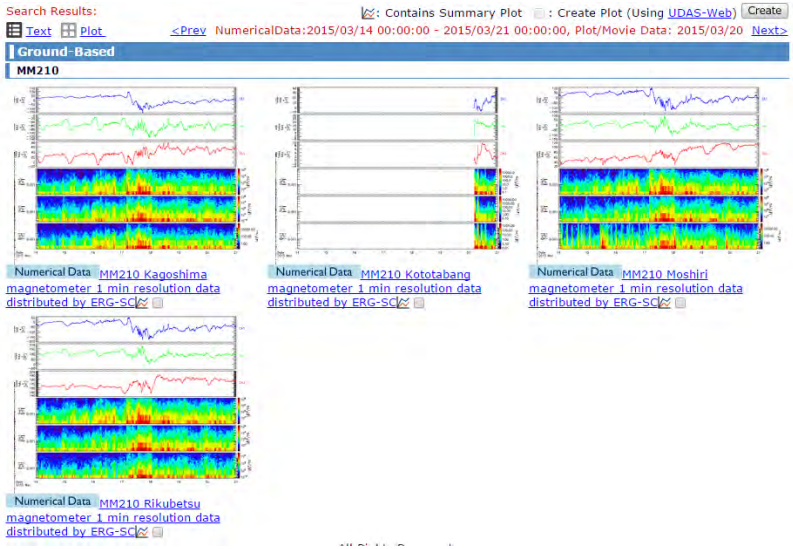
Data distribution

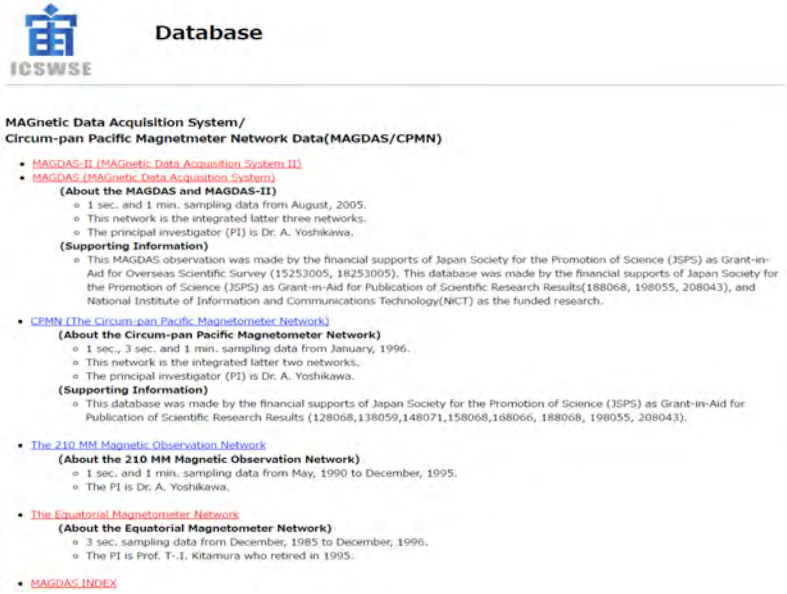
・The realtime quick-look plot (ordinary and time derivative) are available at http://data.icswse.kyushu-u.ac.jp/.

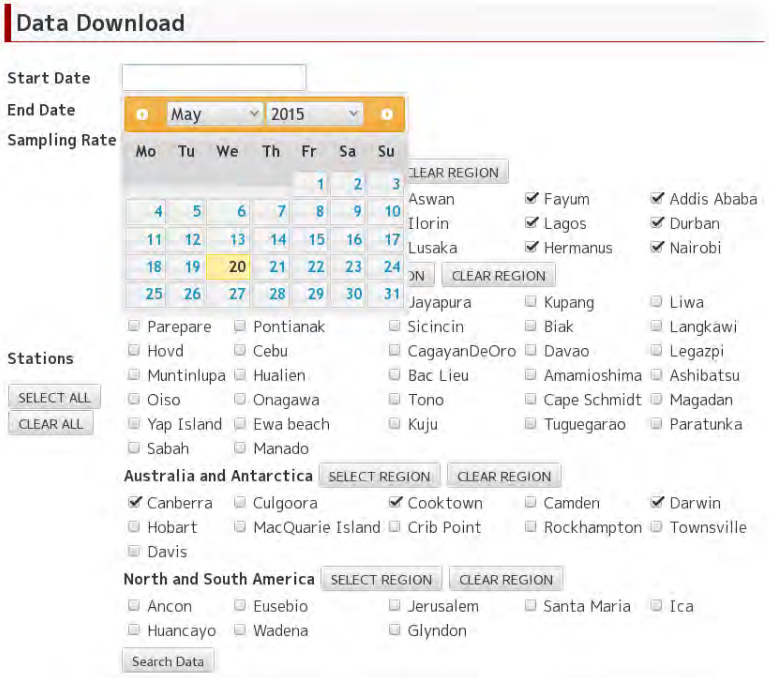
・ All MAGDAS data are available on request. We are developing web-based data sharing system, and will be opened in near future.

・A part of MAGDAS data have been opened through the ERG Science Center (for more details, http://ergsc.isee.nagoya-u.ac.jp/) as CDF format.

・Metadata of MAGDAS data have been opened through the IUGONET.







Capacity Building activity (2015-2018)

- MAGDAS training@ Malaysia and Peru (5x @ Malaysia, 2x @Peru)
- UN/JAPAN WS for the ISWI (2015)
- SCOSTEP School@Peru(2015), @ India(2016)
- COSPAR School@Russia(2016)
- JSPS Core to Core School@ Nigeria(2017), Indonesia(2018)
  (PI: Prof. Shiokawa-san)
- MAGDA-WS@ Malaysia(2017、2018)
- UN/USA WS for the ISWI (2017)


How to handle the data..


How to install…

- 1Master student from Korea (2017-)
- Ph.D students from Malaysia (2017-), from Sri-Lanka
- Visiting Researcher from Egypt (2016-2017)
- Employment of Foreign Associate Prof.
  2015-2016 from Russia
  2016-2017 from Philippine
  2017-2018 from Finland


How to do science...

Education & Capacity Building

Japan-Malaysia Joint Seminar on Space Weather and Electromagnetism and Intensive Course on Space Magnetohydrodynamics,2018/March/22-2018/March/29 at ICSWSE

MHD seminar by Dr. Yoshikawa

What's the fluxgate?

IUGONET Hands on

Education & Capacity Building

- **Dispatch graduate student to field work**
- **Space weather summary report**
  - Since October 2002, daily reports on space weather have been issued by students.
- **Outreach activities on space weather**
  - Over 50 public lectures on Space weather science for children and general citizens in Japan.
- **Foreign students from Asian/African nations**
  - 5 Ph D. holder from 4 nations
  - (Egypt, Sudan, Philippines, 2 from Malaysia)

- **Over 80 MAGDAS paper were published after 2013**

Over 80 MAGDAS paper were published after 2013-

1. M Abbas, ZZ Abidin, MH Jusoh, OS Bolaji, A Yoshikawa, Features of horizontal magnetic field intensity over northern island of Malaysia, Indian Journal of Physics, 1-112019.
2. Yoshikawa A., and R. Fujii (2018), Earth's Ionosphere: Theory and Phenomenology of Cowling Channels, in Electric Currents in Geospace and Beyond (eds A. Keiling, O. Marghitu, and M. Wheatland), John Wiley & Sons, Inc, Hoboken, N.J., doi: 10.1002/9781119324522.ch25
3. R Shi, B Ni, D Summers, H Liu, A Yoshikawa, B Zhang, Generation of electron acoustic waves in the topside ionosphere from coupling with kinetic Alfven waves: a new electron energization mechanism, Geophysical Research Letters 45 (11), 5299-5304、doi: 10.1029/2018GL077898
4. Ohtani, S., Motoba, T., Gjerloev, J. W., Ruohoniemi, J. M., Donovan, E. F., & Yoshikawa, A (2018). Longitudinal development of poleward boundary intensifications (PBIs) of auroral emissio*n. Journal of Geophysical Research: Space Phy*sics, 123. https://doi.org/10.1029/2017JA024375
5. Seki, K., Miyoshi, Y., Ebihara, Y., Katoh Y., Amano T., Saito S., Shoji M., Nakamizo A., Keika K., Hori T., Nakano S., Watanabe S., Kamiya K., Takahashi N., Omura Y., Nose ., Mei-Ching Fok., Tanaka T., Ieda A., and Yoshikawa A (2018), Earth Planets Space (2018) 70: 17, https://doi.org/10.1186/s40623-018-0785
6. EM Takla, A Khashaba, MA Zaher, A Yoshikawa, T Uozumi (2018), Anomalous ultra low frequency signals possibly linked with seismic activities in Sumatra, Indonesia, NRIAG Journal of Astronomy and Geophysics doi: 10.1016/j.nrjag.2018.04.004
7. NSA Hamid, VA Wen, NIM Rosli, A Yoshikawa, Changes in Ionospheric Currents System at Southeast Asia Region during Geomagnetic Storm in Solar's Minimum Phase SAINS MALAYSIANA 47 (8), 1923-1929, 2018
8. R Umar, SF Natasha, SSN Aminah, KN Juhari, MH Jusoh, NSA Hamid, MH Hashim, ZM Radzi, AN Ishak, SN Hazmin, WZAW Mokhtar, MKA Kamarudin, H Juahir, A Yoshikawa (2018), Magnetic Data Acquisition System (MAGDAS) Malaysia: installation and preliminary data analysis at ESERI, UNISZA, Indian Journa
9. Takahashi, N., Seki, K., Teramoto, M., Fok, M.-C., Zheng, Y., Matsuoka, A., Nana Higashio, Kazuo Shiokawa, Dmitry Baishev, Akimasa Yoshikawa, Tsutomu Nagatsuma (2018). Global distribution of ULF waves during magnetic storms: Comparison of Arase, ground observations, and BATSRUS + CRCM simu*lation.* https://doi.org/10.1029/2018GL078857
10. NMN Annadurai, NSA Hamid, Y Yamazaki, A Yoshikawa, Investigation of Unusual Solar Flare Effect on the Global Ionospheric Current System, Journal of Geophysical Research: Space Physics, https://doi.org/10.1029/2018JA025601
11. NMN Annadurai, NSA Hamid, A Yoshikawa, Observation of Ionospheric Current during Strong Solar Flare Using Ground Based Magnetometer, SAINS MALAYSIANA 47 (3), 595-601
12. ZZ Abidin, MH Jusoh, M Abbas, A Yoshikawa (2018), Application of solar quiet (Sq) current in determining mantle conductivity-depth structure in Malaysia, Journal of Atmospheric and Solar-Terrestrial Physics, https://doi.org/10.1016/j.jastp.2018.01.019.
13. ZZ Abidin, MH Jusoh, M Abbas, OS Bolaji, and A. Yoshikawa (2018), Features of the inter-hemispheric field-aligned current system over Malaysia ionosphere, Journal of Atmospheric and Solar-Terrestrial Physics, https://doi.org/10.1016/j.jastp.2018.01.012.
14. Kasran F.A.M., Jusoh M.H., Yoshikawa A., Radzi Z.M., MAGDAS/CPMN Group (2018), The Time Derivative of the Horizontal Geomagnetic Field for the Low Latitude MAGDAS Langkawi Station for the Estimation of Geomagnetically Induced Current. In: Suparta W., Abdullah M., Ismail M. (eds) Space Science and C
https://doi.org/10.1007/978-981-10-6574-3_6
15. Yagova, N.V., Heilig, B., Pilipenko, V.A, Yoshikawa A., Nosikova N.S., Yumoto K., and Reda J. (2017), Earth Planets Space 69: 61, https://doi.org/10.1186/s40623-017-0647-x
16. Imajo, S., A. Yoshikawa, T. Uozumi, S. Ohtani, A. Nakamizo, and P. J. Chi (2017), Application of a global magnetospheric-ionospheric current model for dayside and terminator P*i2 pulsations, J. Geophys. Res.* Space Physics, 122, 8589–8603, doi:10.1002/2017JA024246.
17. S.A. Bello, M. Abdullah, N.S.A. Hamid, A. Yoshikawa, A.O. Olawepo (2017), Variations of B0 and B1 with the solar quiet Sq-current system and comparison with IRI-2012 model at Ilorin, Advances in Space Research, Volume 60, Issue 2, 2017, Pages 307-316, ISSN 0273-1177, https://doi.org/10.1016/j.asr.2017.02.0
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MAGDAS database and data

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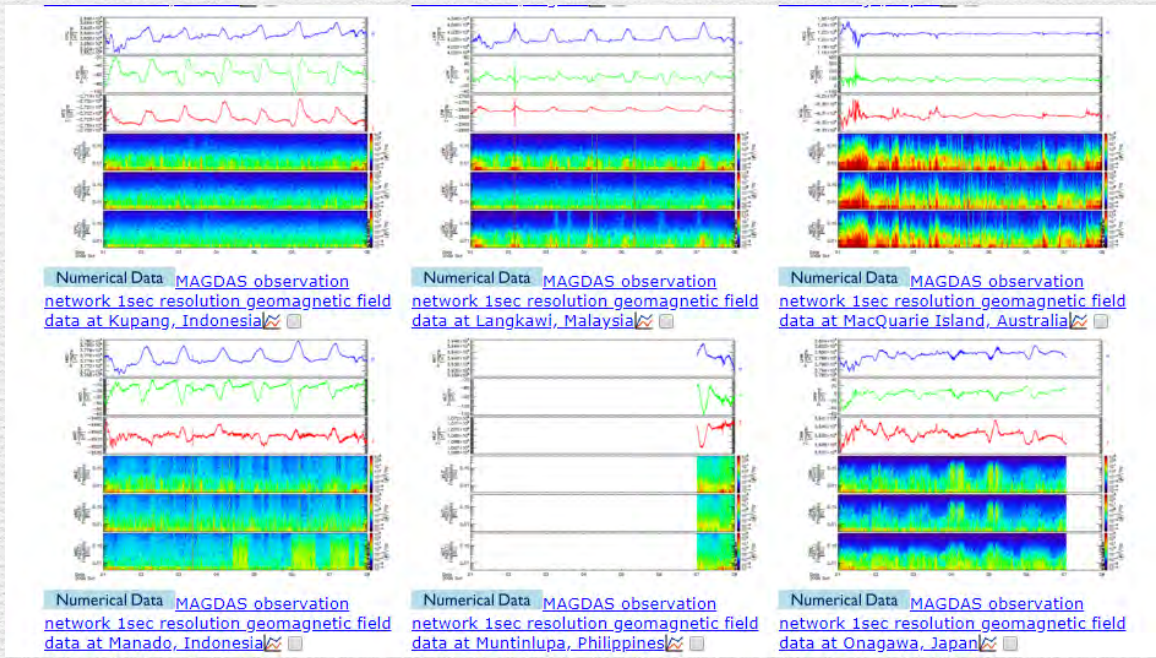
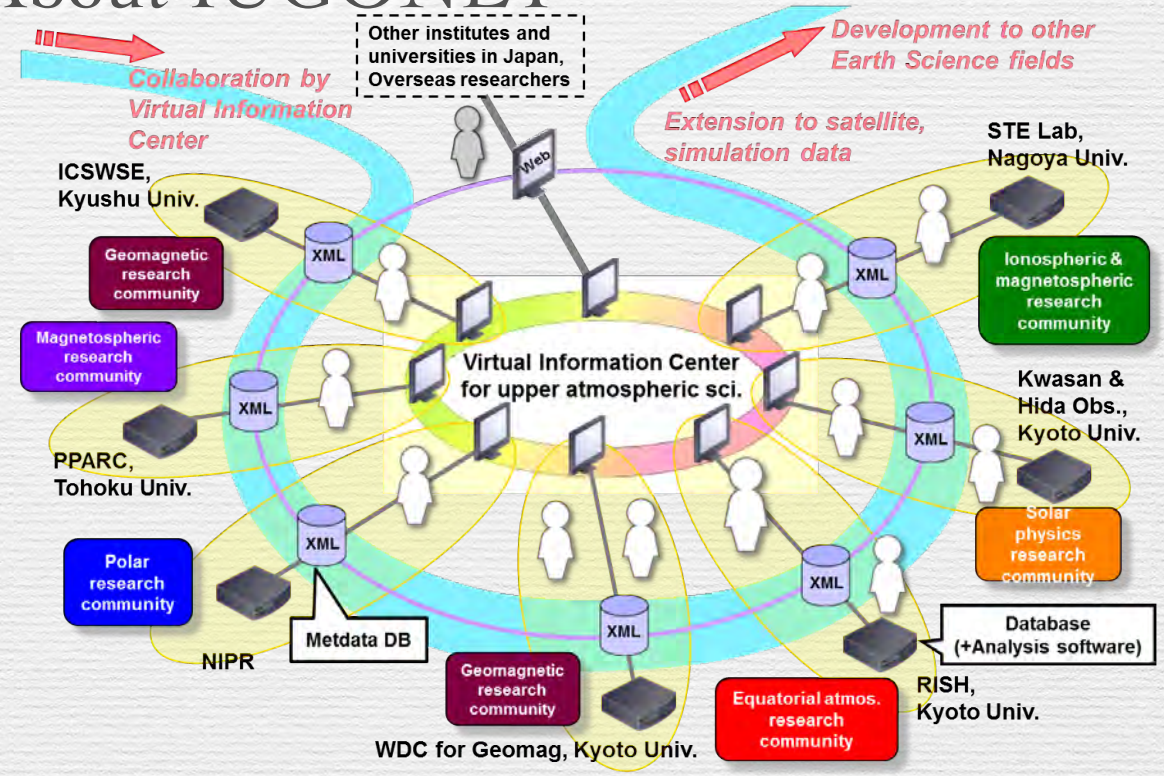
ERG-SC (https://ergsc.isee.nagoya-u.ac.jp/data_info/ground.shtml.en), and SuperMAG (http://supermag.jhuapl.edu/) in near future.

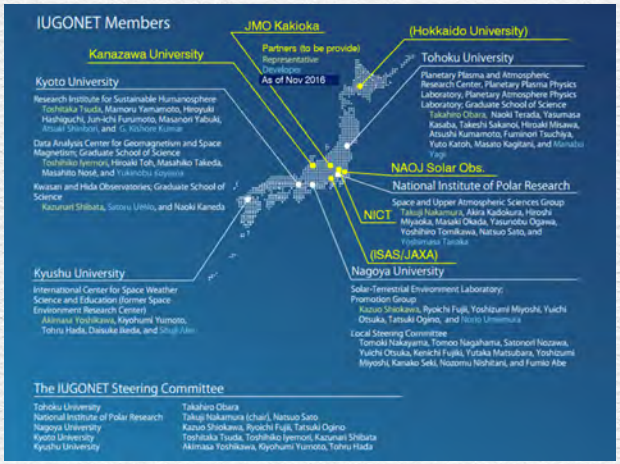
Realtime data is not registered. If you want to use them, please contact us



Inter-university Upper atmosphere Global Observation NETwork

About IUGONET





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- Develop a metadata database ground-based upper atmosphere observation data.
- Promote effective use of the observational data spread across the institutes/universities.
- Investigate mechanism of long-term variation in the upper atmosphere.

Summary

- Introduce MAGDAS project and related science

- Research for coupling between atmospheric dynamics and plasma dynamics, and its lithospheric electromagnetic responses will break ground a new area of science

- We strongly hope realization of Equatorial ionospheric HF radar network presented by Dr. R. Todd Parris, and development of SuperDARN covering much more lower and equatorial region

Thank you for your attention!!