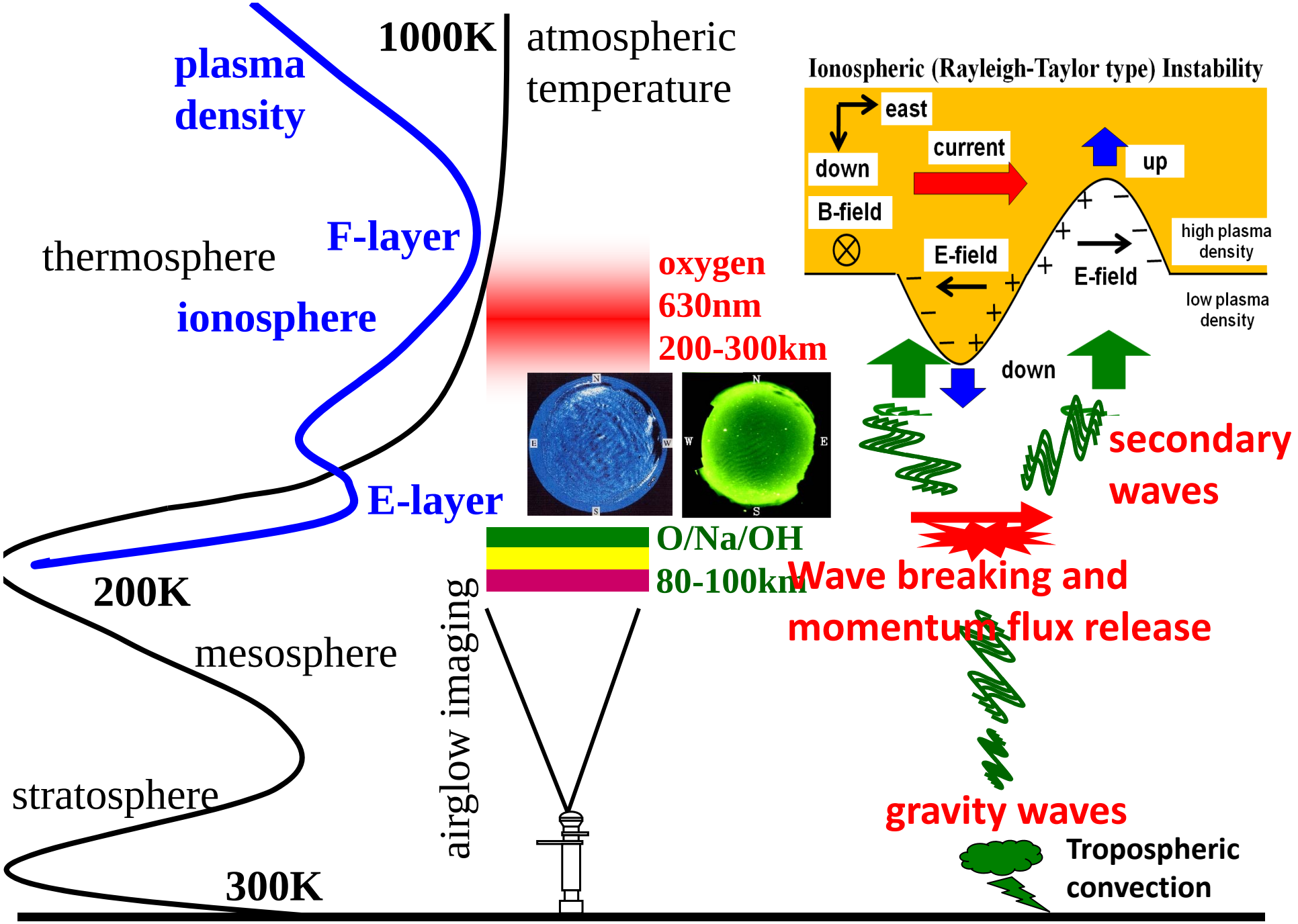
Recent Results from the ground-based multi-point network observation of the upper atmosphere, ionosphere, and magnetosphere by the OMTIs and the PWING project

Kazuo Shiokawa, Yuichi Otsuka, and the PWING Team
Institute for Space-Earth Environmental Research, Nagoya Univ., Japan
PWING Team: http://www.isee.nagoya-u.ac.jp/dimr/PWING/en/

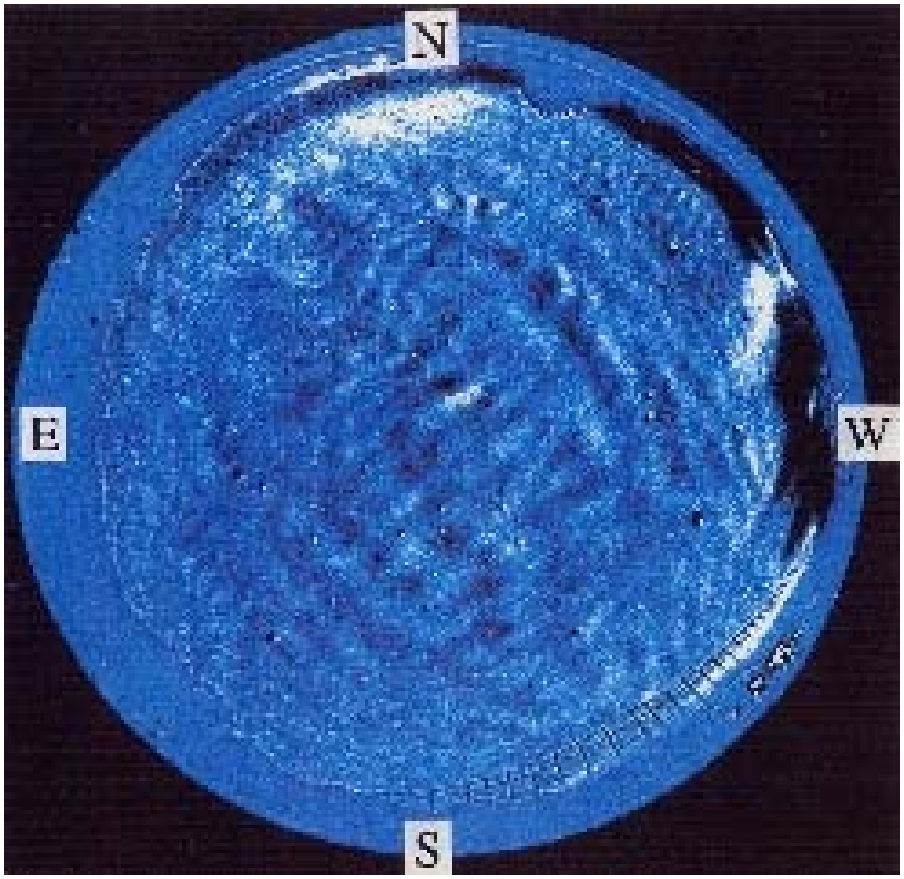
VarSITI Completion symposium , Sofia, Bulgaria, June 11, 2019

Image from ISS

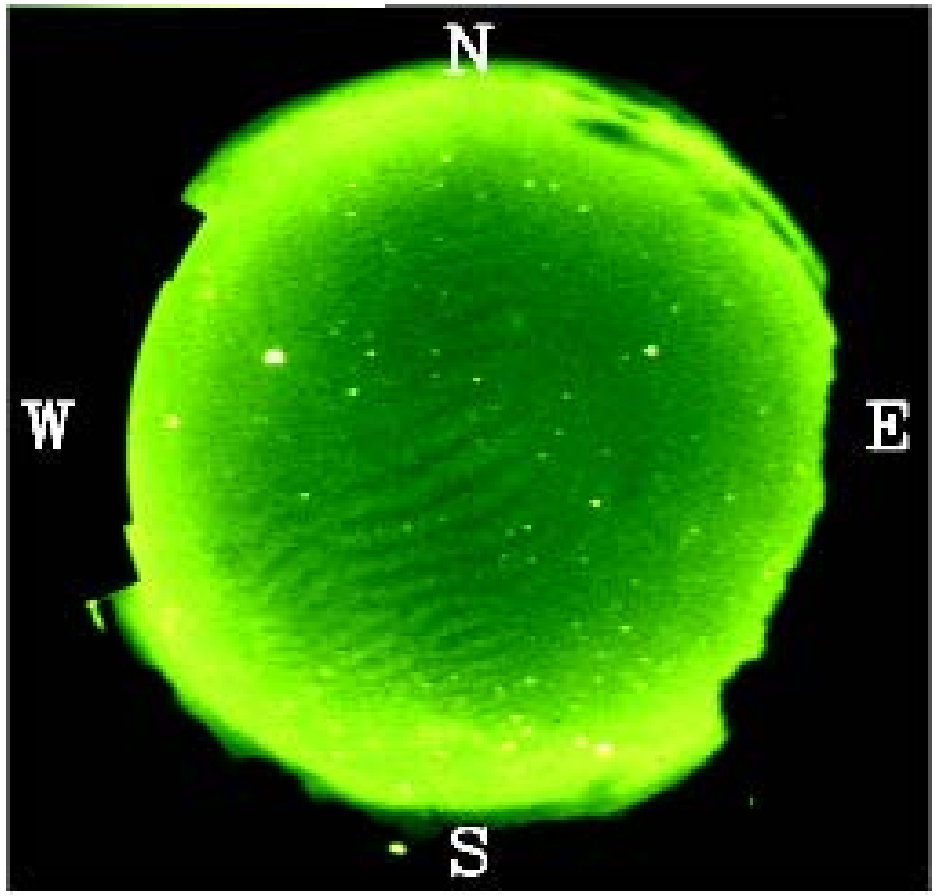

1000K
atmospheric temperature
plasma density
F-layer
thermosphere
ionosphere
E-layer
200K
mesosphere
stratosphere
300K
oxygen
630nm
200-300km
O/Na/OH
80-100km
airglow imaging
Ionospheric (Rayleigh-Taylor type) Instability
east
down
current
up
B-field
E-field
E-field
high plasma density
low plasma density
down
secondary waves
Wave breaking and momentum flux release
gravity waves
Tropospheric convection

airglow images of atmospheric gravity waves

557.7nm

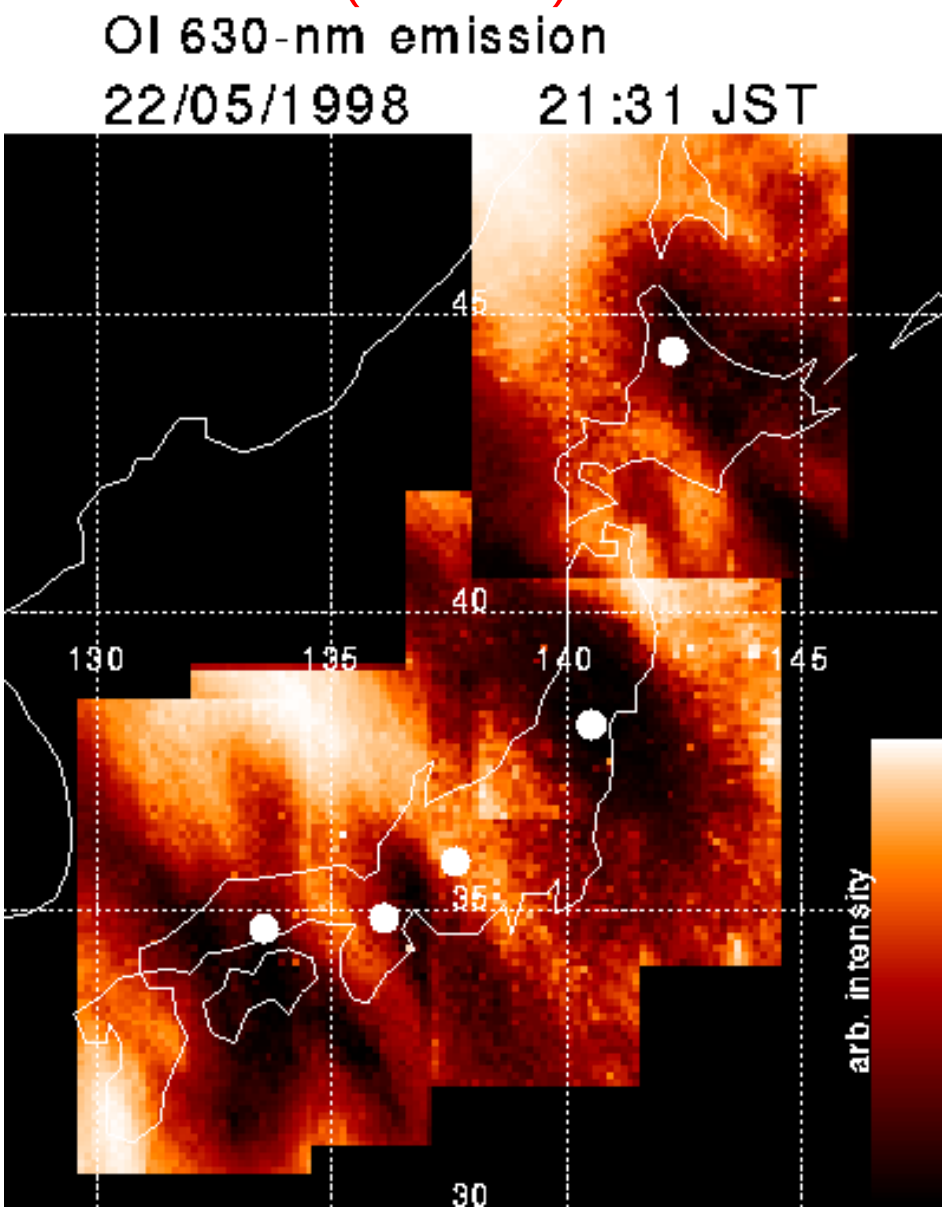


Shigaraki, Japan



Kototabang, Indonesia

Medium-Scale Traveling Ionospheric Disturbances (MSTIDs)

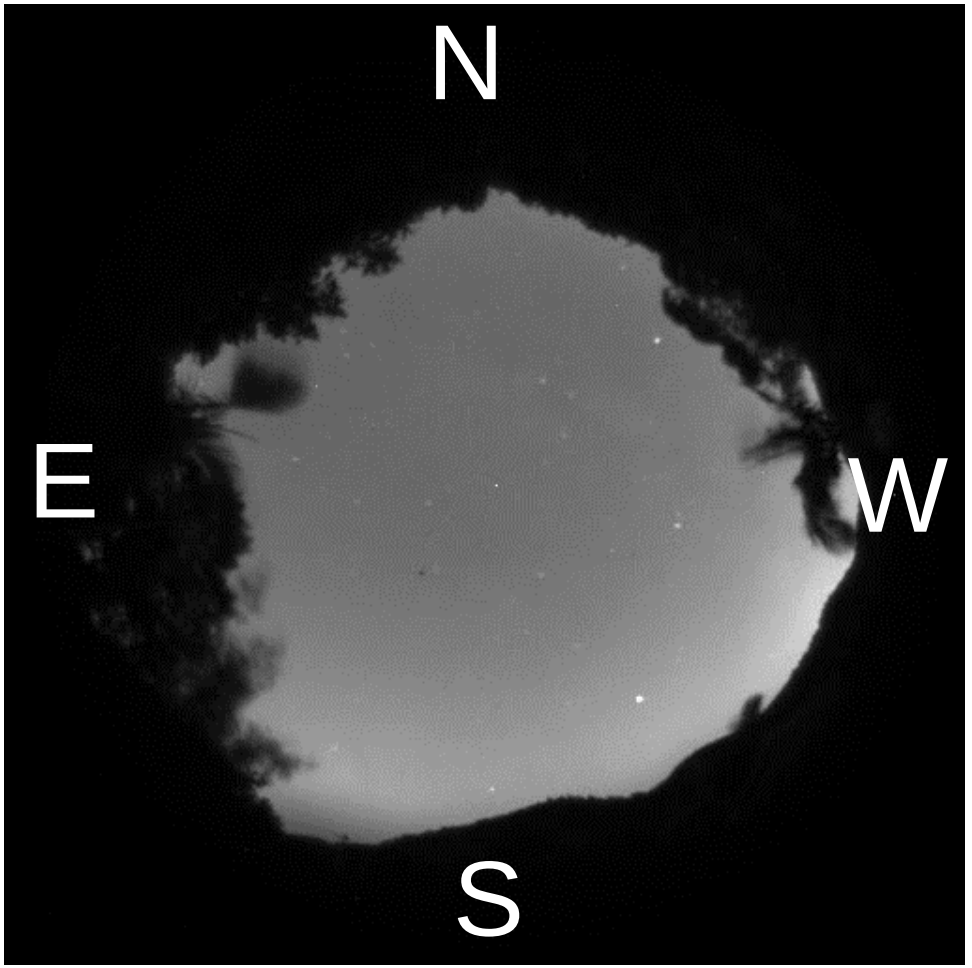


Saito et al. [GRL, 2001]

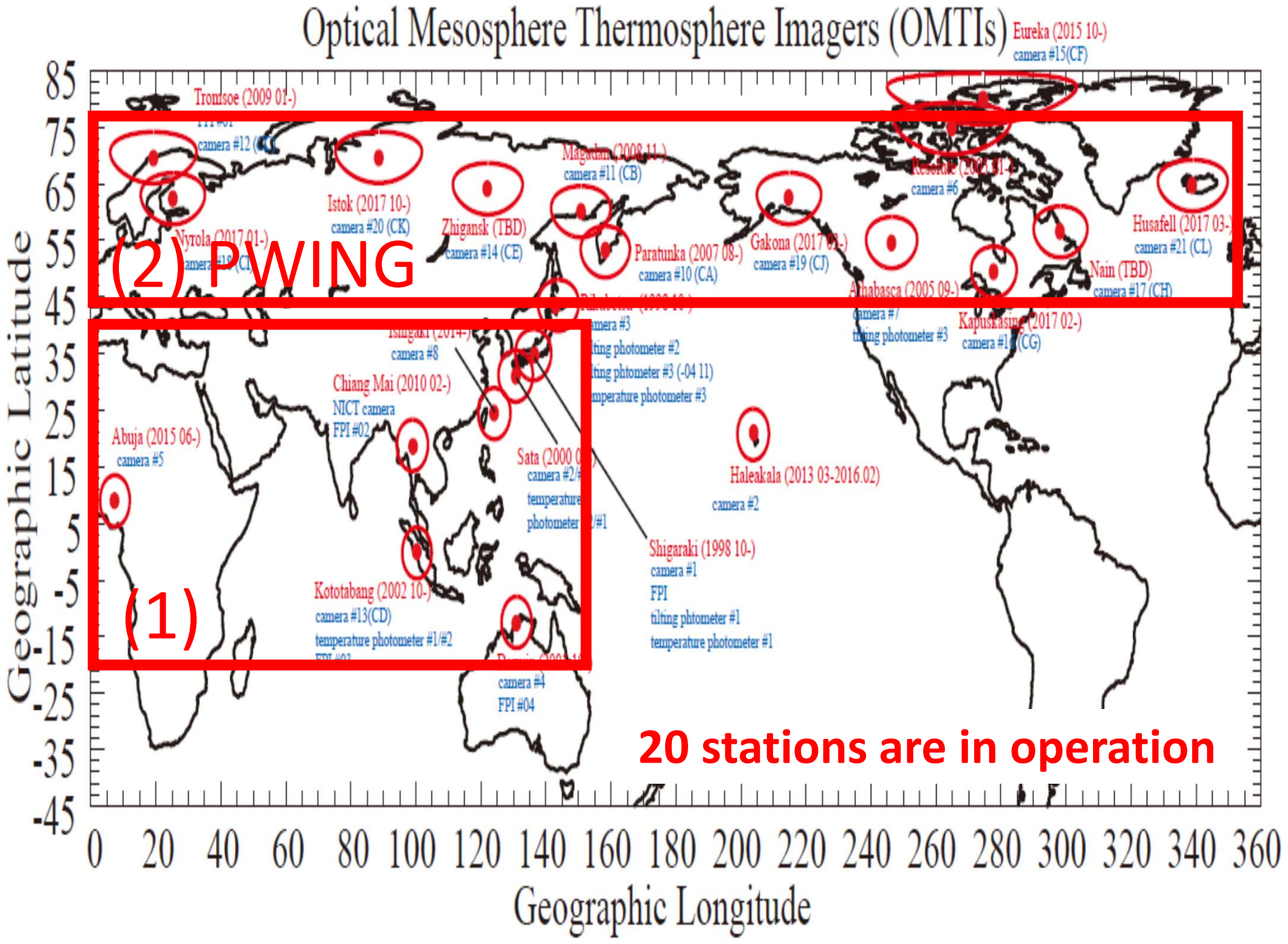
630nm

equatorial plasma bubble

Sata, Japan
November 12, 2001, 630nm



Otsuka et al.
[GRL, 2002]


Optical Mesosphere Thermosphere Imagers (OMTIs)
Eureka (2015 10-)
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camera #1
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camera #13(CD)
temperature photometer #1/#2
camera #4
FPI #04
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20 stations are in operation
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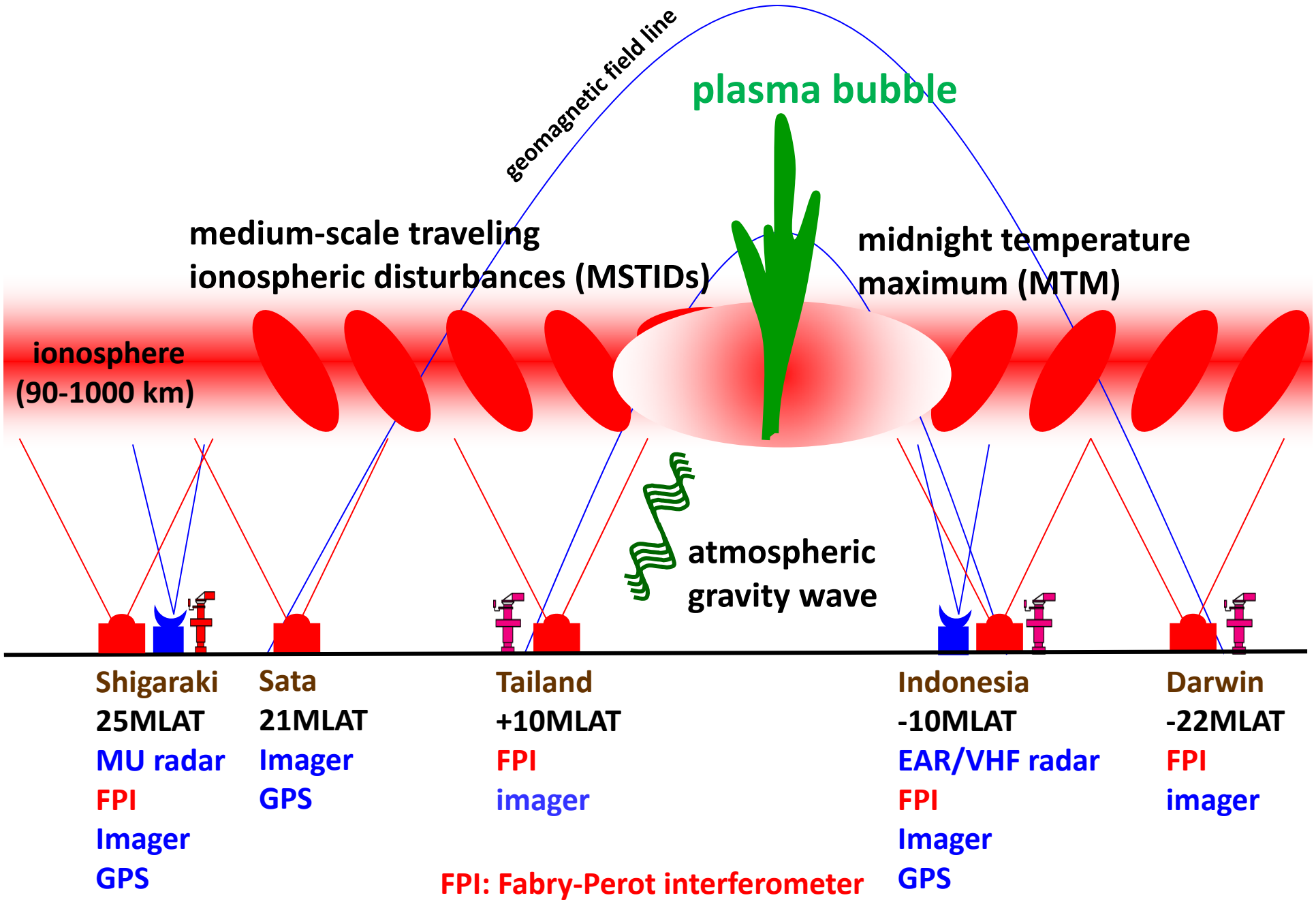
Geographic Longitude


geomagnetic field line
plasma bubble
medium-scale traveling
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midnight temperature
maximum (MTM)
ionosphere
(90-1000 km)
atmospheric
gravity wave
Shigaraki
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EAR/VHF radar
FPI
Imager
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-22MLAT
FPI
imager
FPI: Fabry-Perot interferometer

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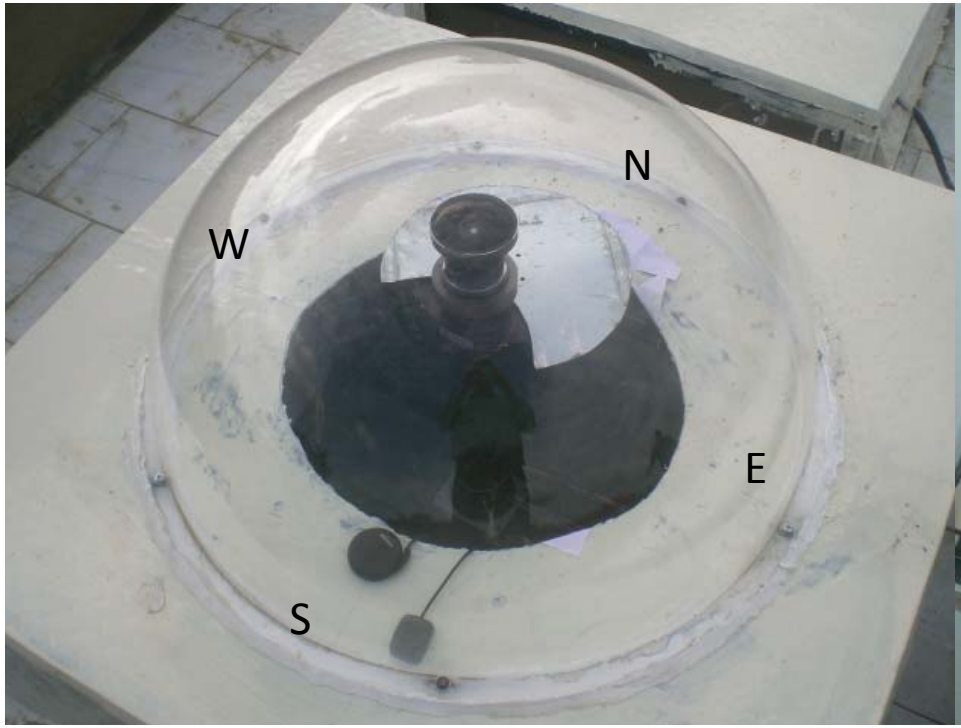
Abuja, Nigeria
NASRDA
All-sky airglow imager at Abuja, Nigeria
June 9, 2015-


Okoh et al. (JGR, 2017): plasma bubbles at Abuja, Nigeria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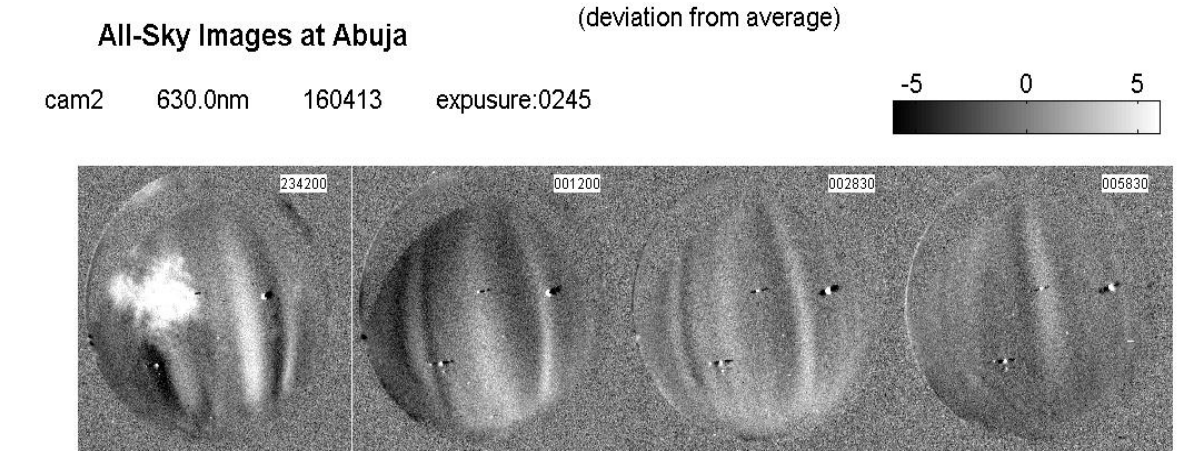
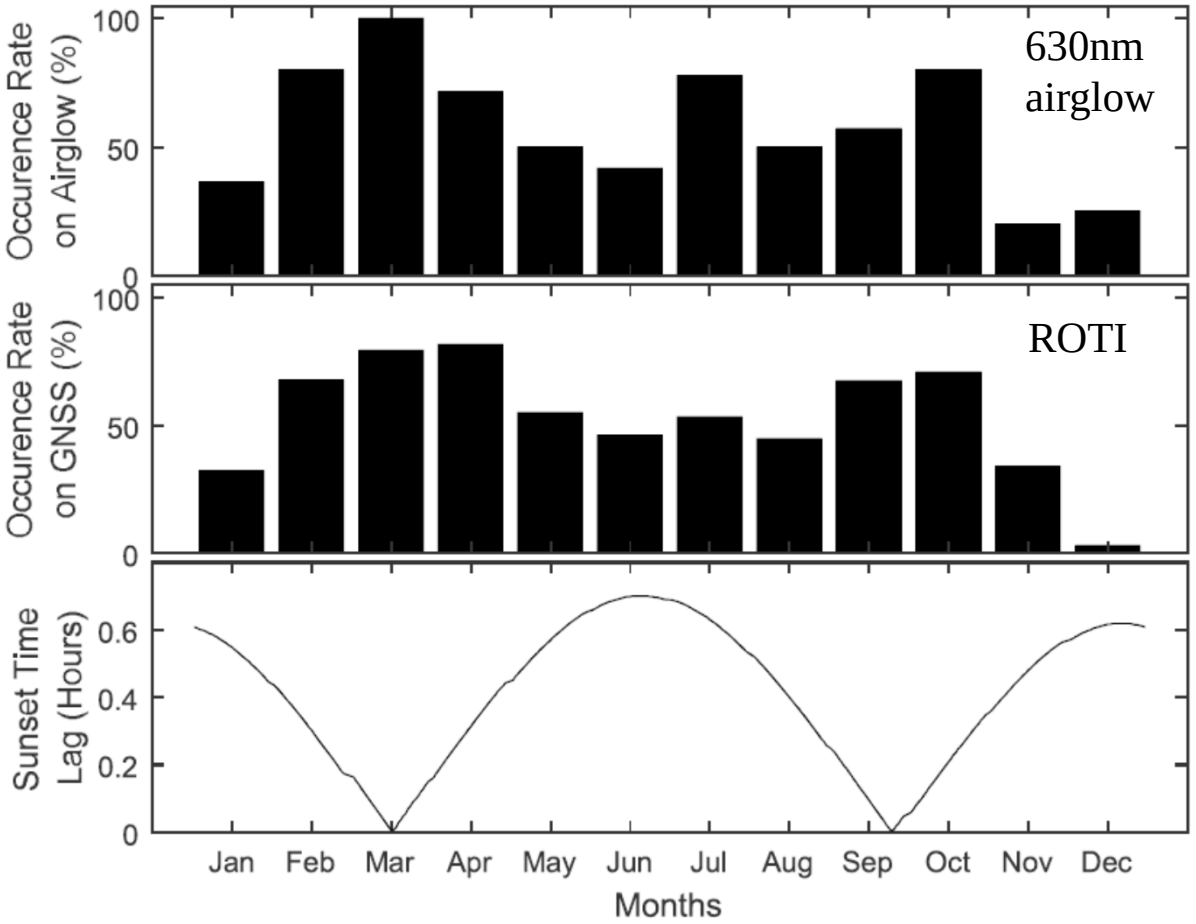
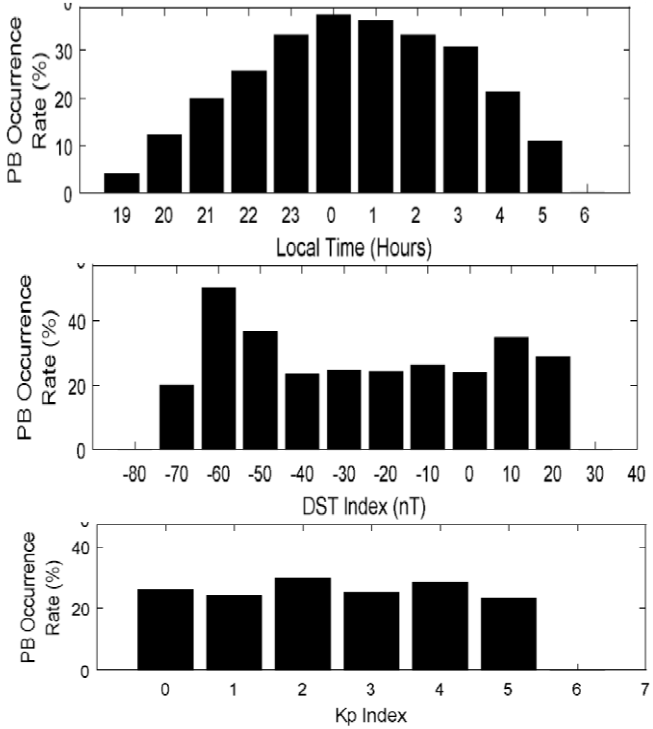
ISELLI, Sept 2015: Abuja, Nigeria, 65 students from 7 African countries

ISELLI-2, Sept 2017: Ota, Nigeria, 38 students from 7 African countries

Okoh et al. (JGR, 2017): plasma bubbles at Abuja, Nigeria







From June 9, 2015 to January 31, 2017

(total: 147 nights of clear sky)

Okoh et al. (JGR, 2017)

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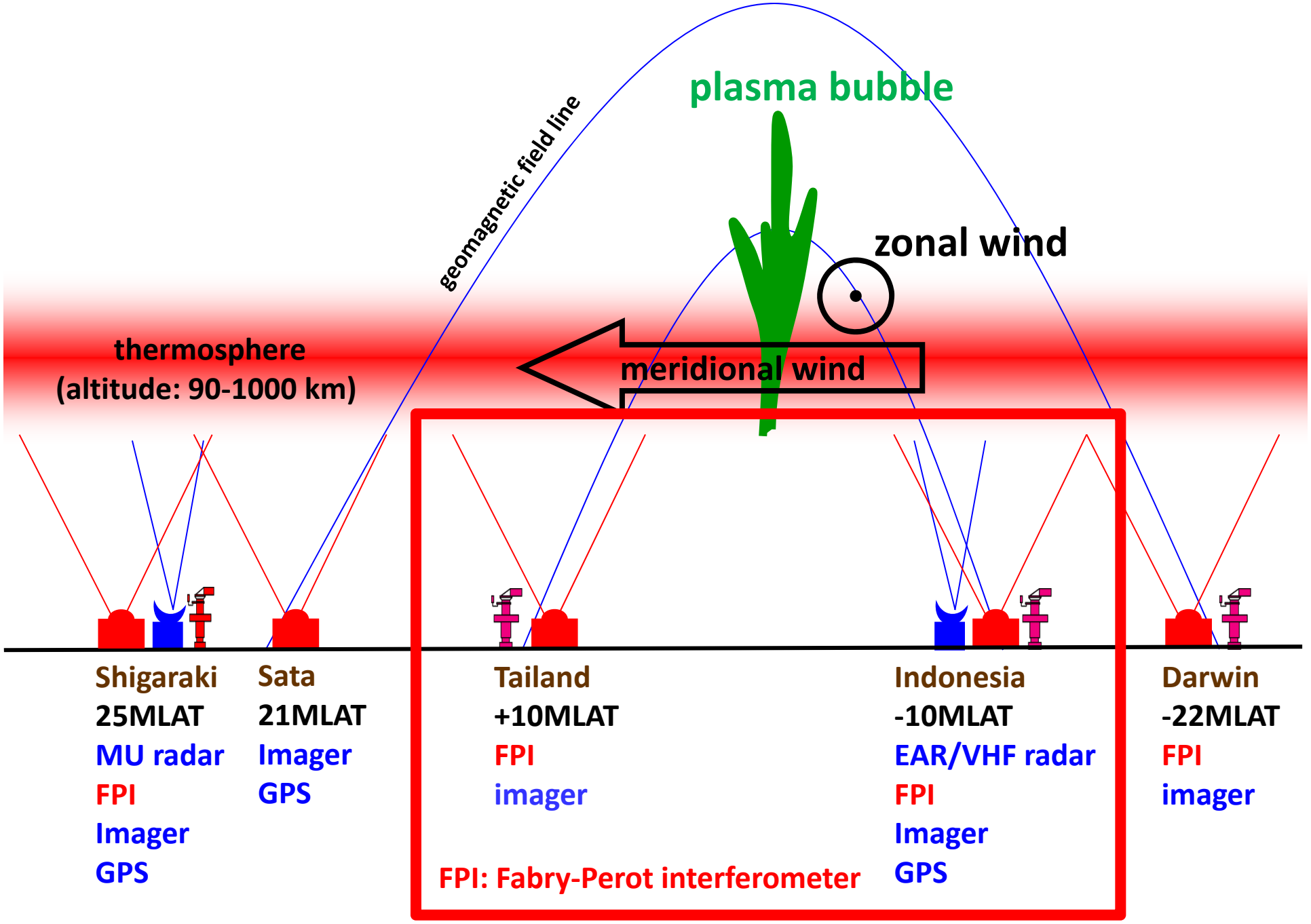
plasma bubble
geomagnetic field line
zonal wind
meridional wind
thermosphere
(altitude: 90-1000 km)
Shigaraki
25MLAT
MU radar
FPI
Imager
GPS
Sata
21MLAT
Imager
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Tailand
+10MLAT
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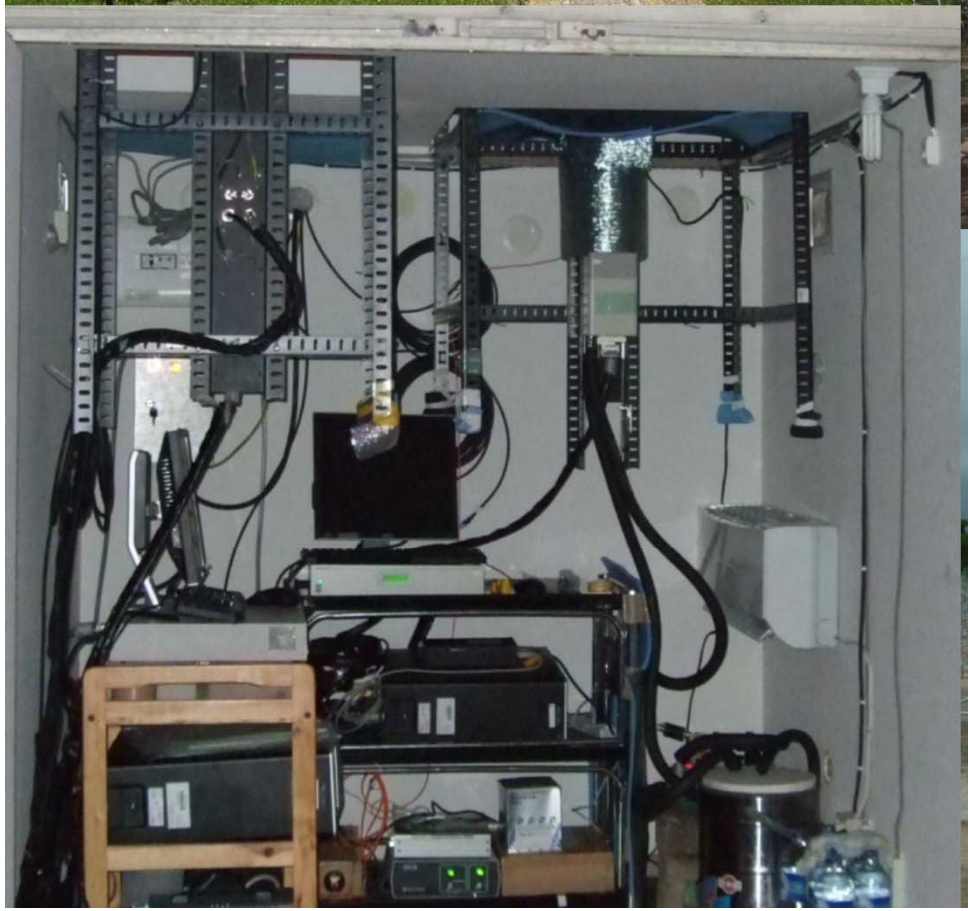
-10MLAT
EAR/VHF radar
FPI
Imager
GPS
Darwin
-22MLAT
FPI
imager
FPI: Fabry-Perot interferometer

Chiang Mai, Thailand

Chiang Mai University

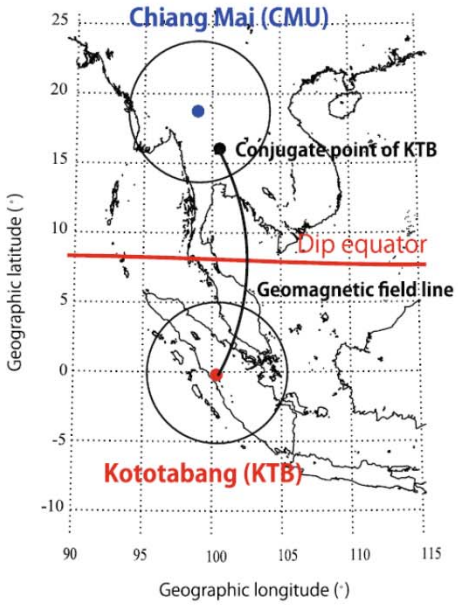
Kototabang, Indonesia

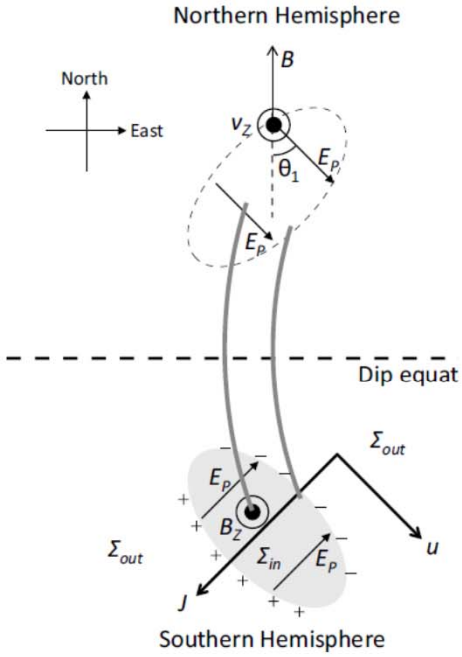
LAPAN, Kyoto Univ.

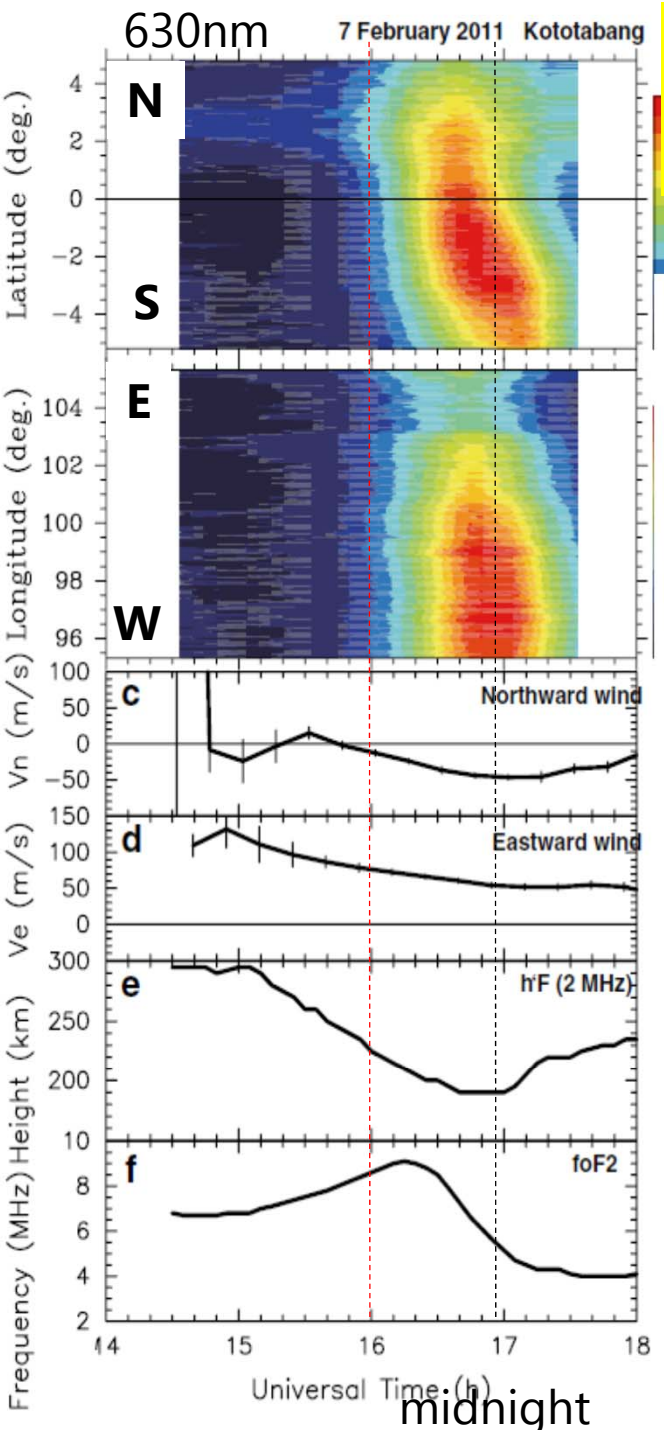


ISELION, March 2015: Bandung, Indonesia, 39 students from 9 Asian countries.

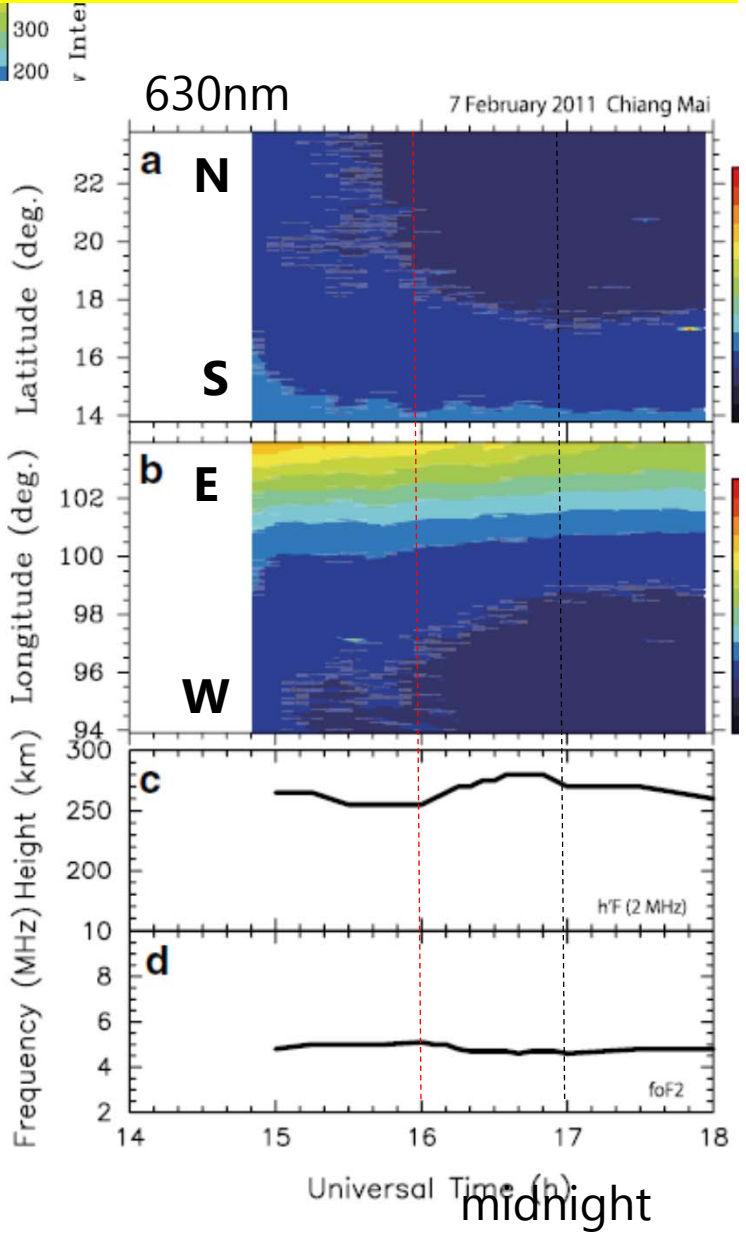
ISELION2018, March 2018:
Bandung, Indonesia, 40 students
from 7 Asian countries.

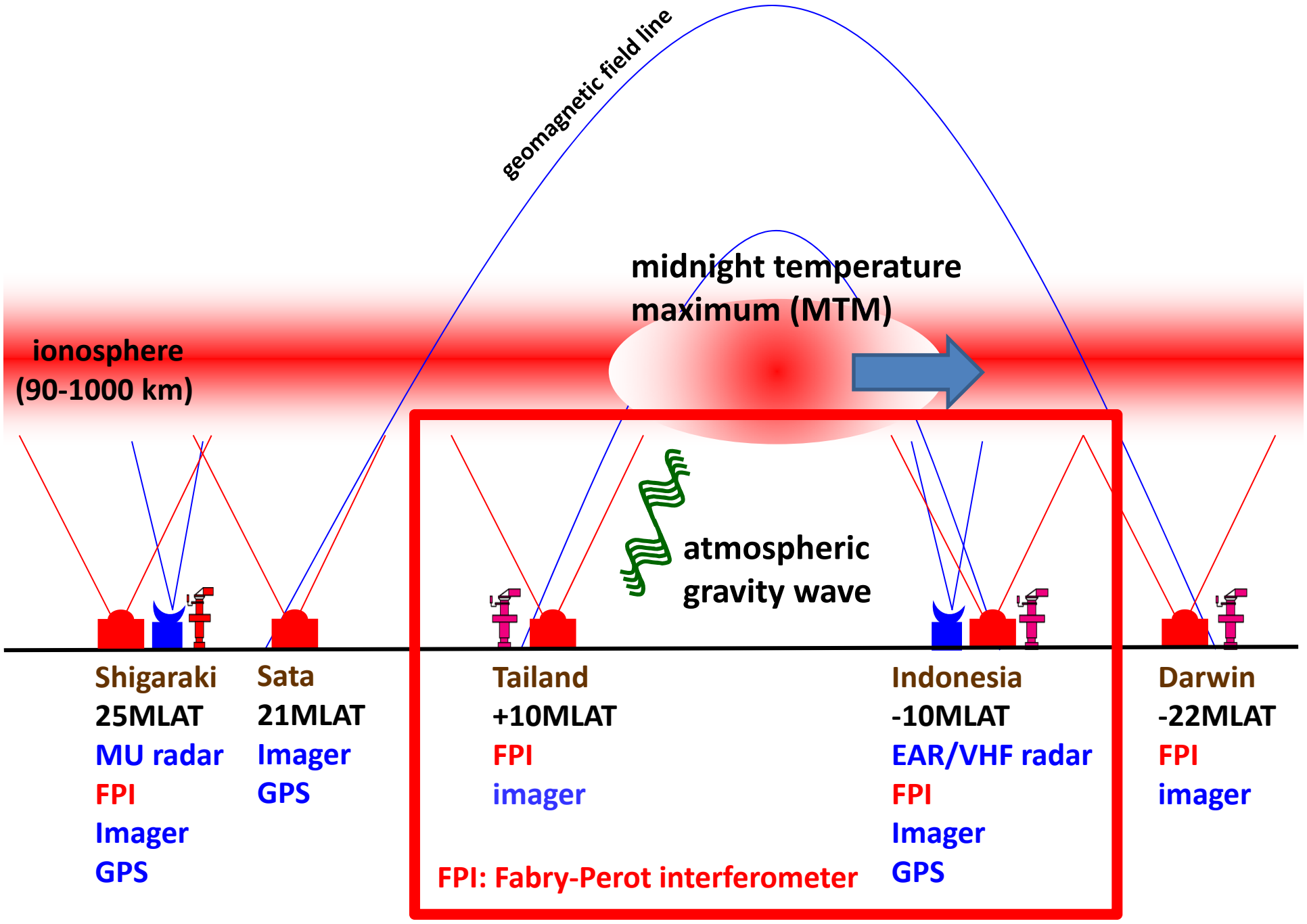






Fukushima et al. (EPS, 2017): non-conjugacy of a midnight brightness wave at Thailand and Indonesia




geomagnetic field line
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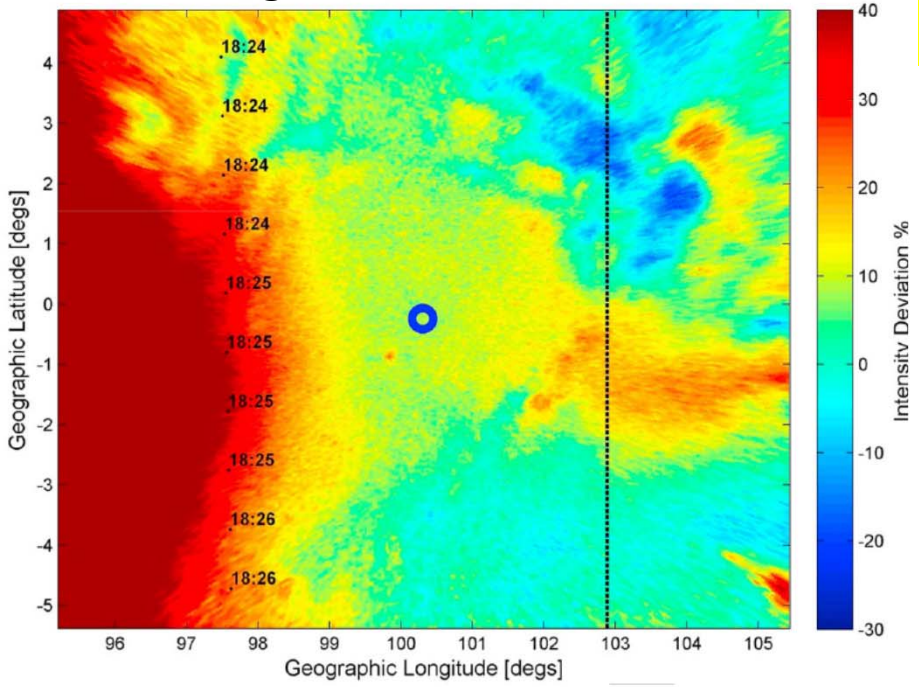
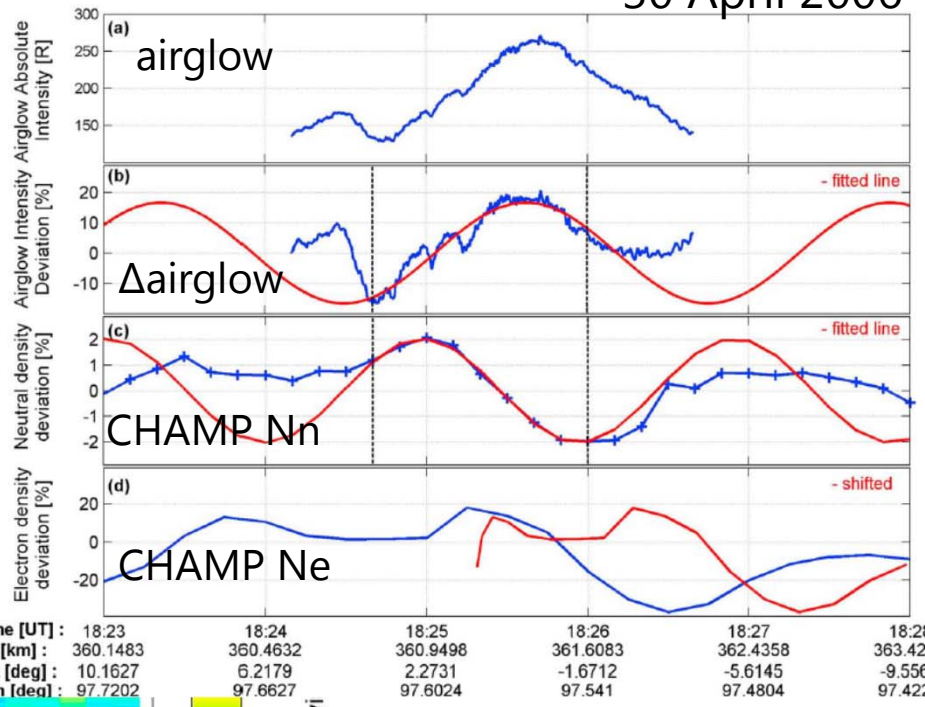
imager
FPI: Fabry-Perot interferometer

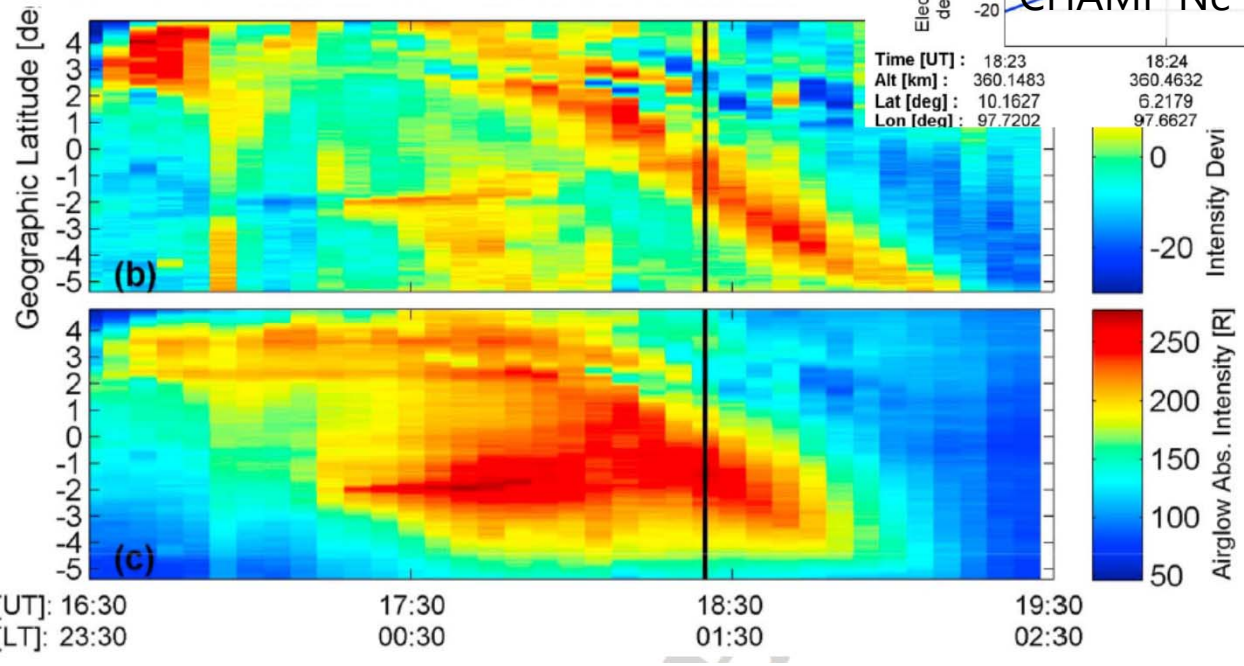
Kototabang, Indonesia 630 nm

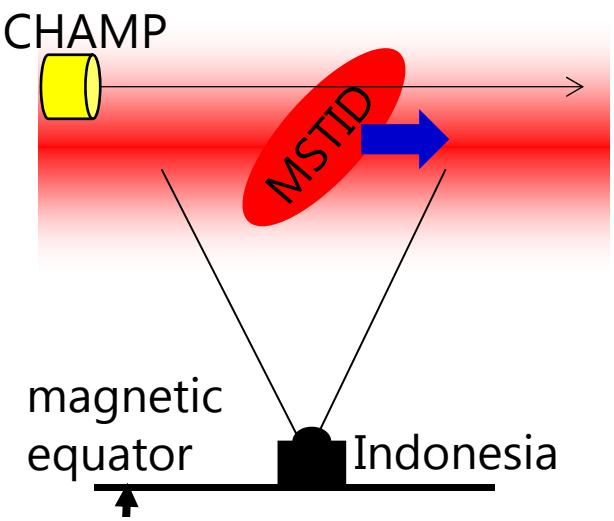
Moral et al. (JGR, 2019): MSTIDs observed at Indonesia with the CHAMP satellite

30 April 2006









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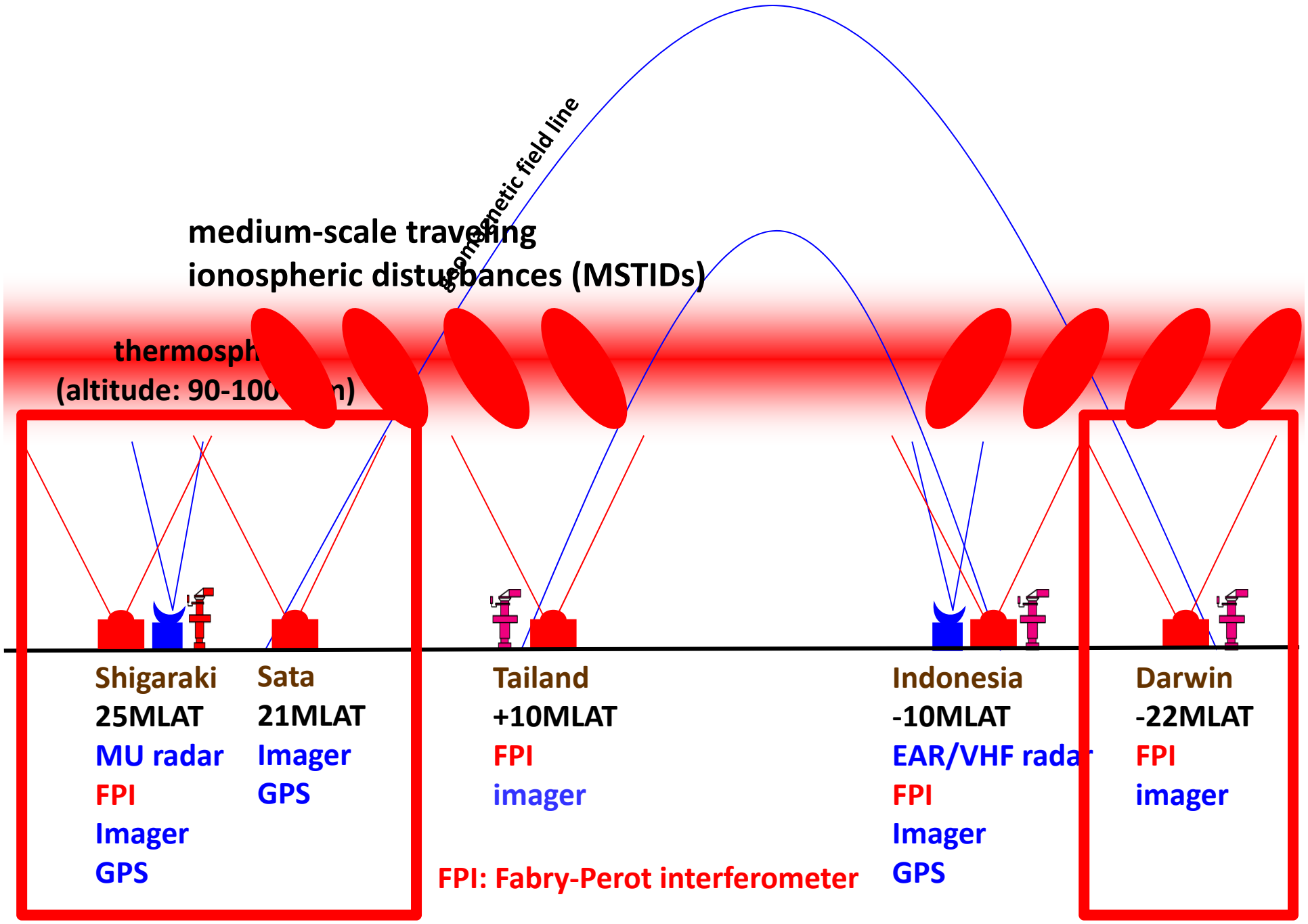
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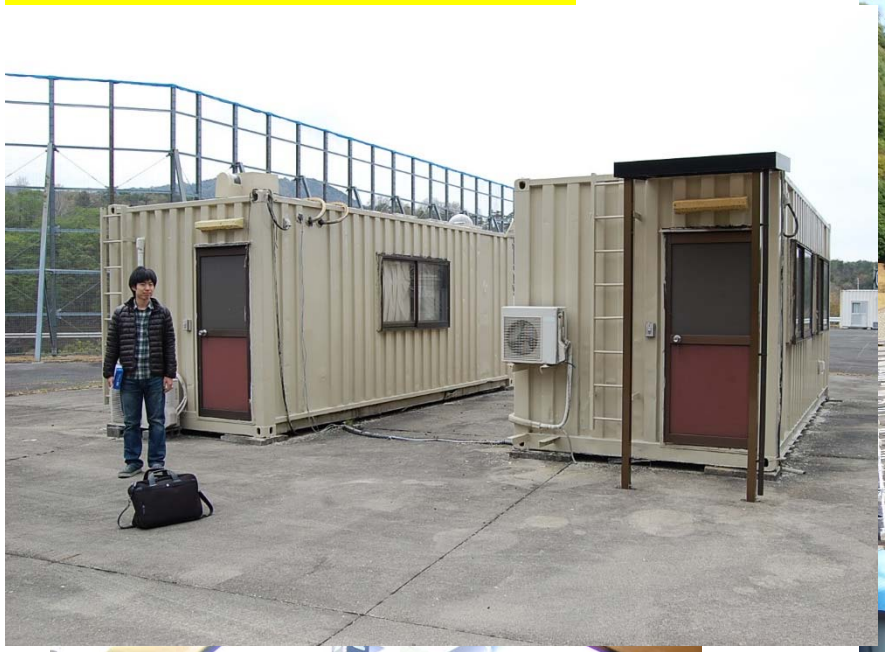
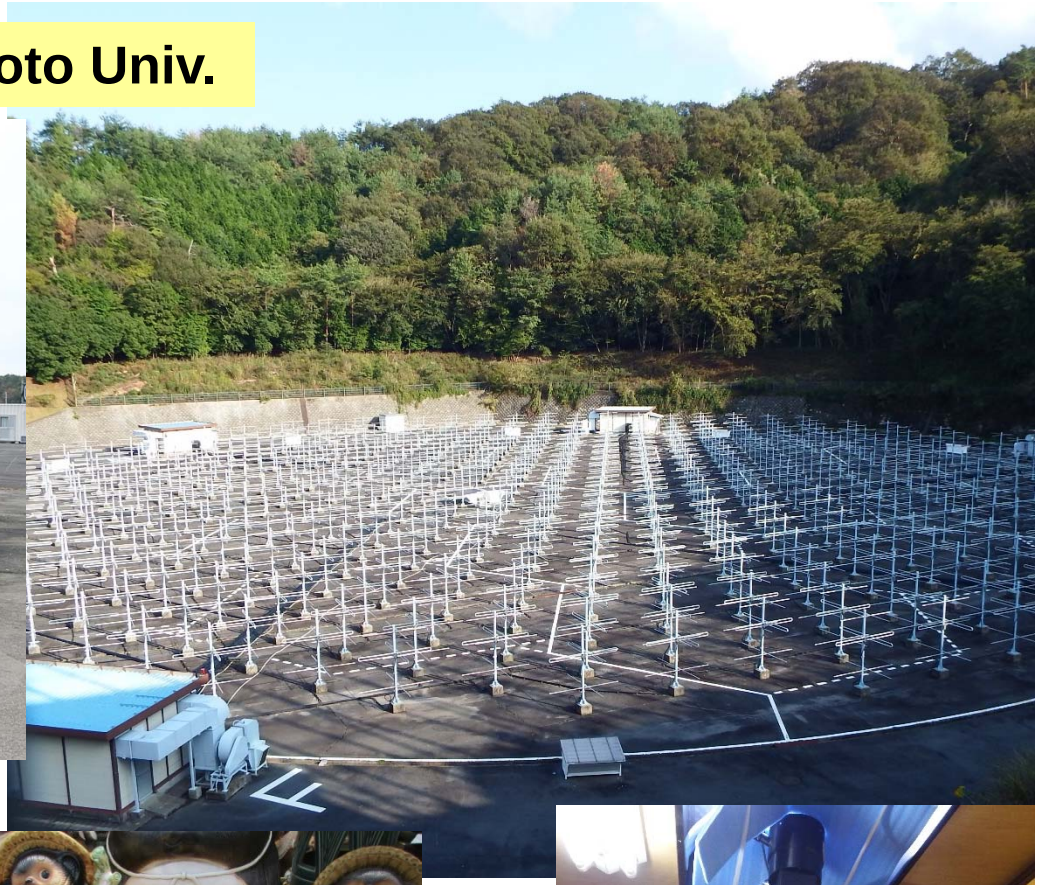
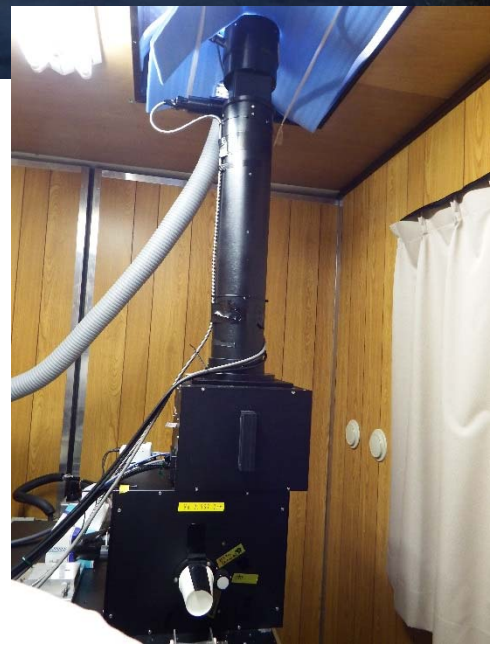
RISH, Kyoto Univ.







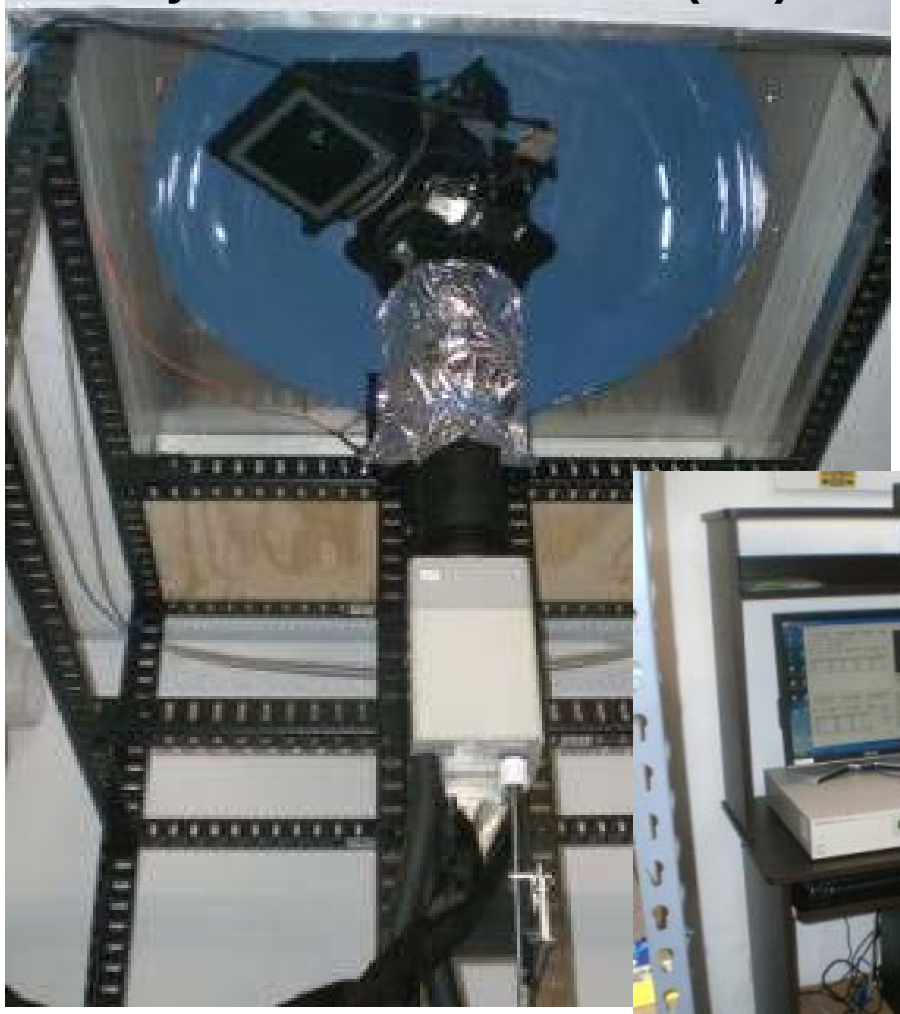
Darwin, Australia

IPS Radio and Space Services

container house

Darwin, Australia **IPS Radio and Space Services**

Fabry-Perot interferometer (FPI)

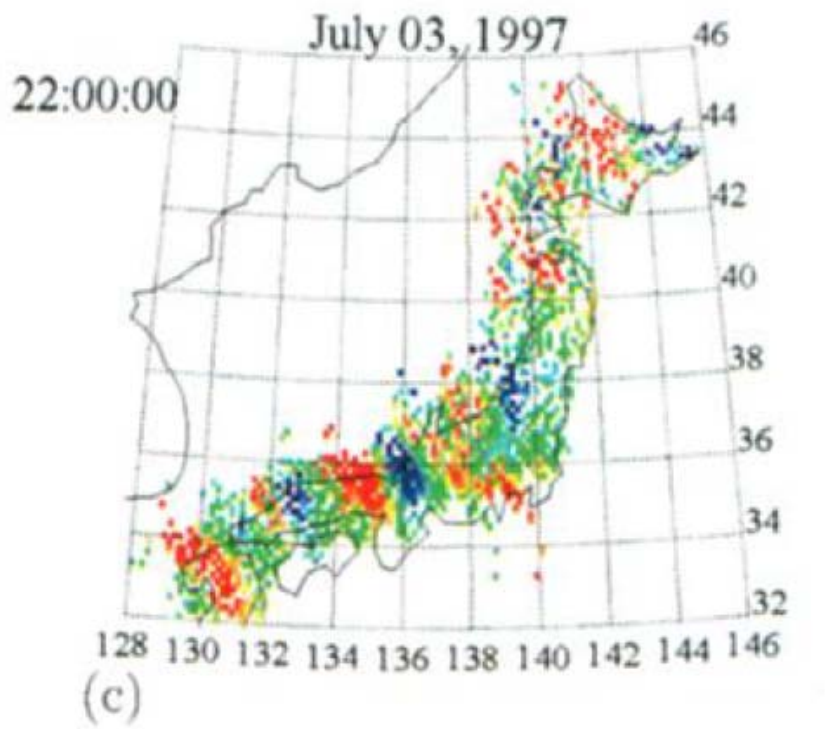


laser (top) and UPS/transfomer (bottom)

PC for FPI

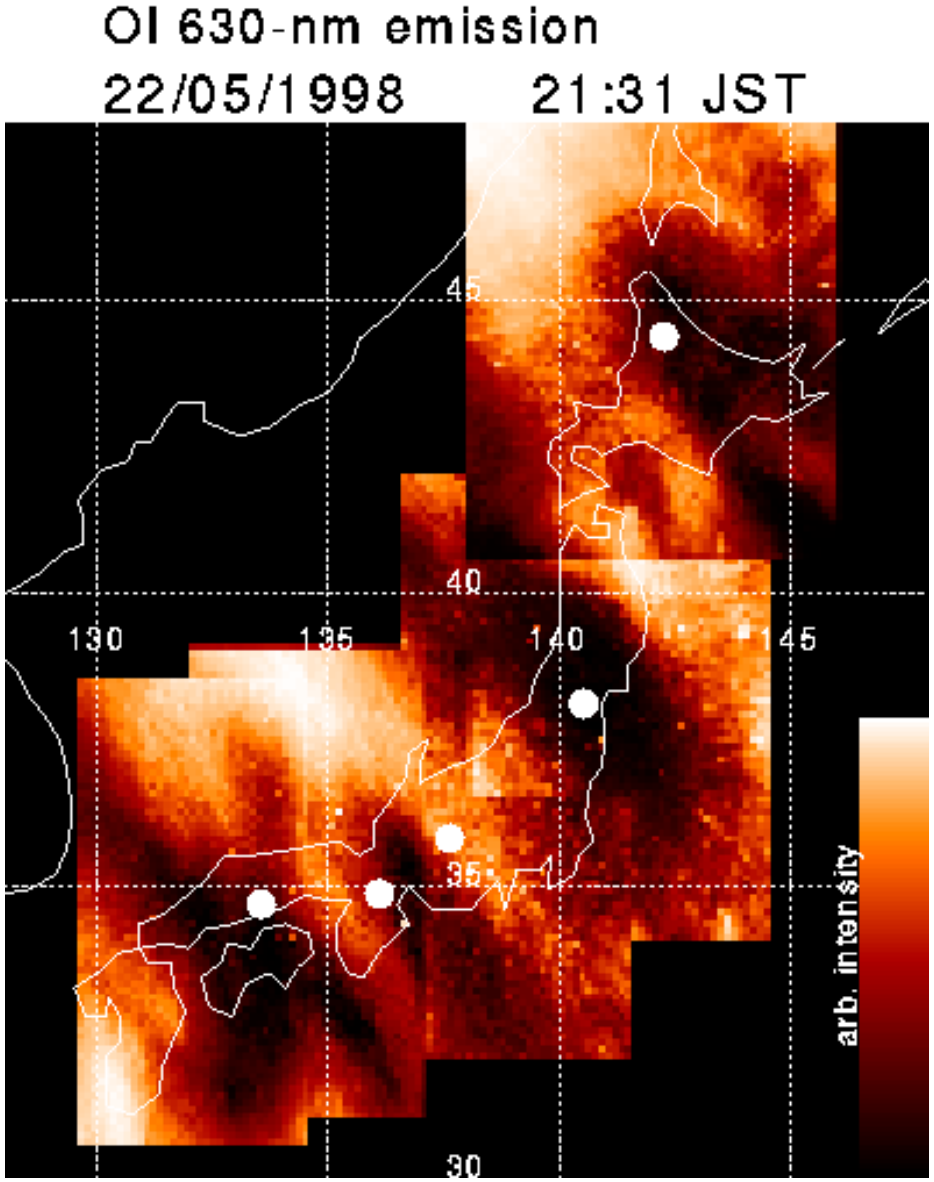
water circulator for FPI

Nightime Medium-Scale Traveling Ionospheric Disturbances (MSTIDs)



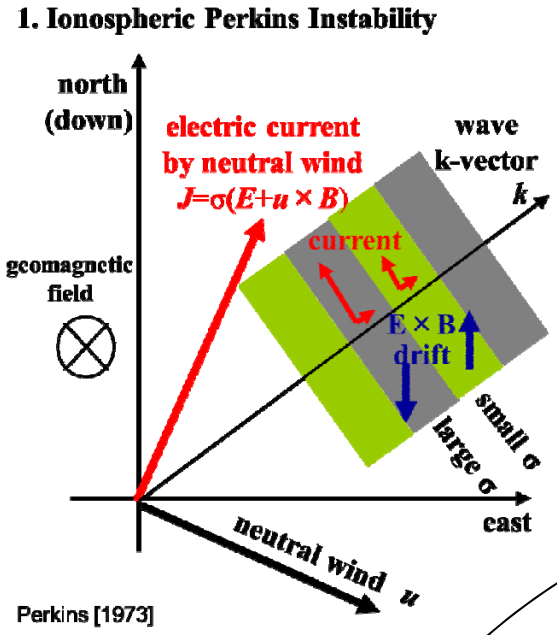
Saito et al. (GRL, 1998)

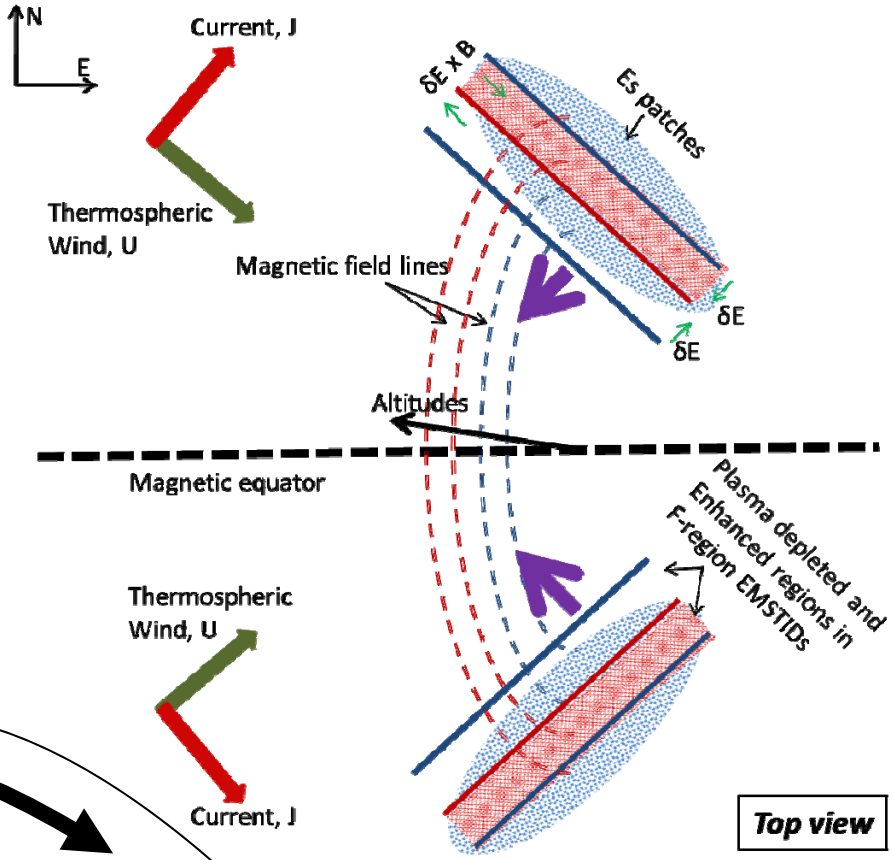
First nighttime MSTID
imaging using GPS TEC map

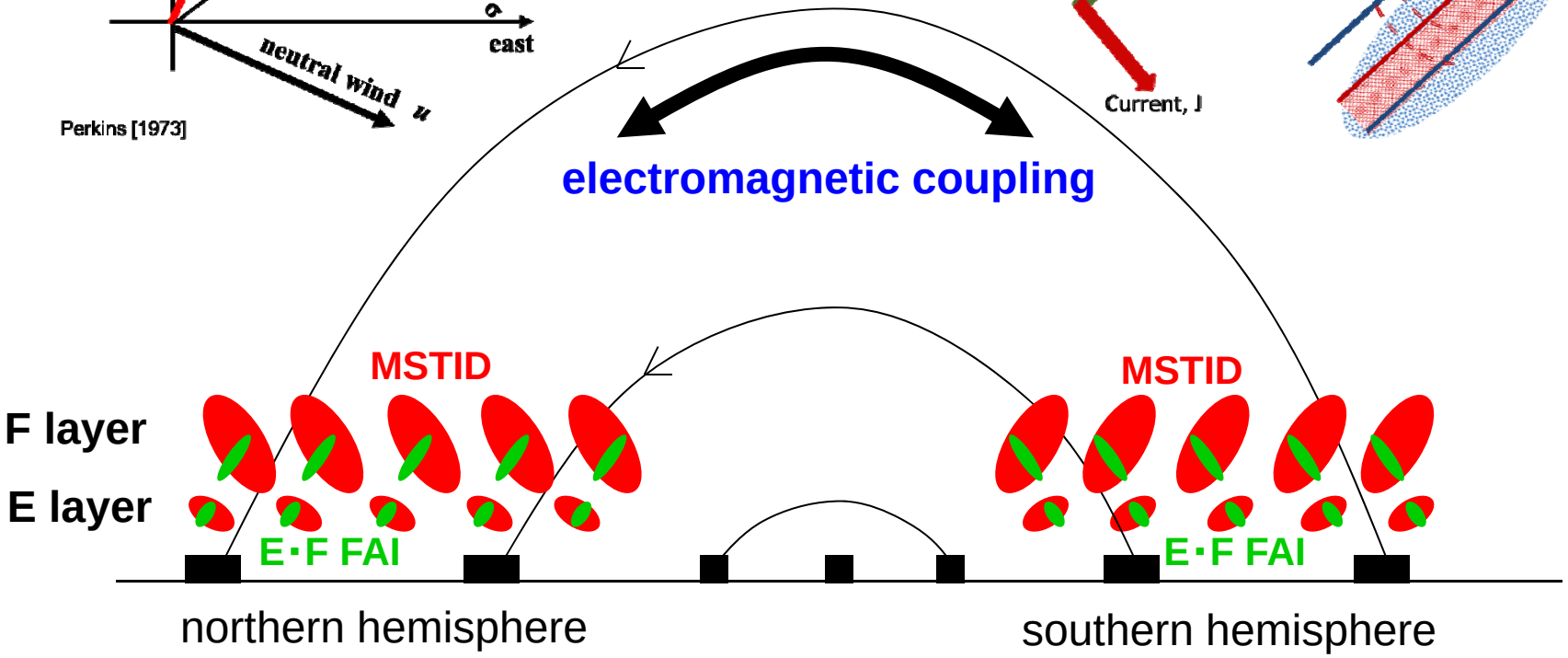


Kubota et al.(GRL, 2000); Saito et al. (GRL, 2001)
First airglow imaging of nighttime MSTIDs

Narayanan et al. (JGR, 2018):
conjugate observation of
MSTIDs in Japan and Australia

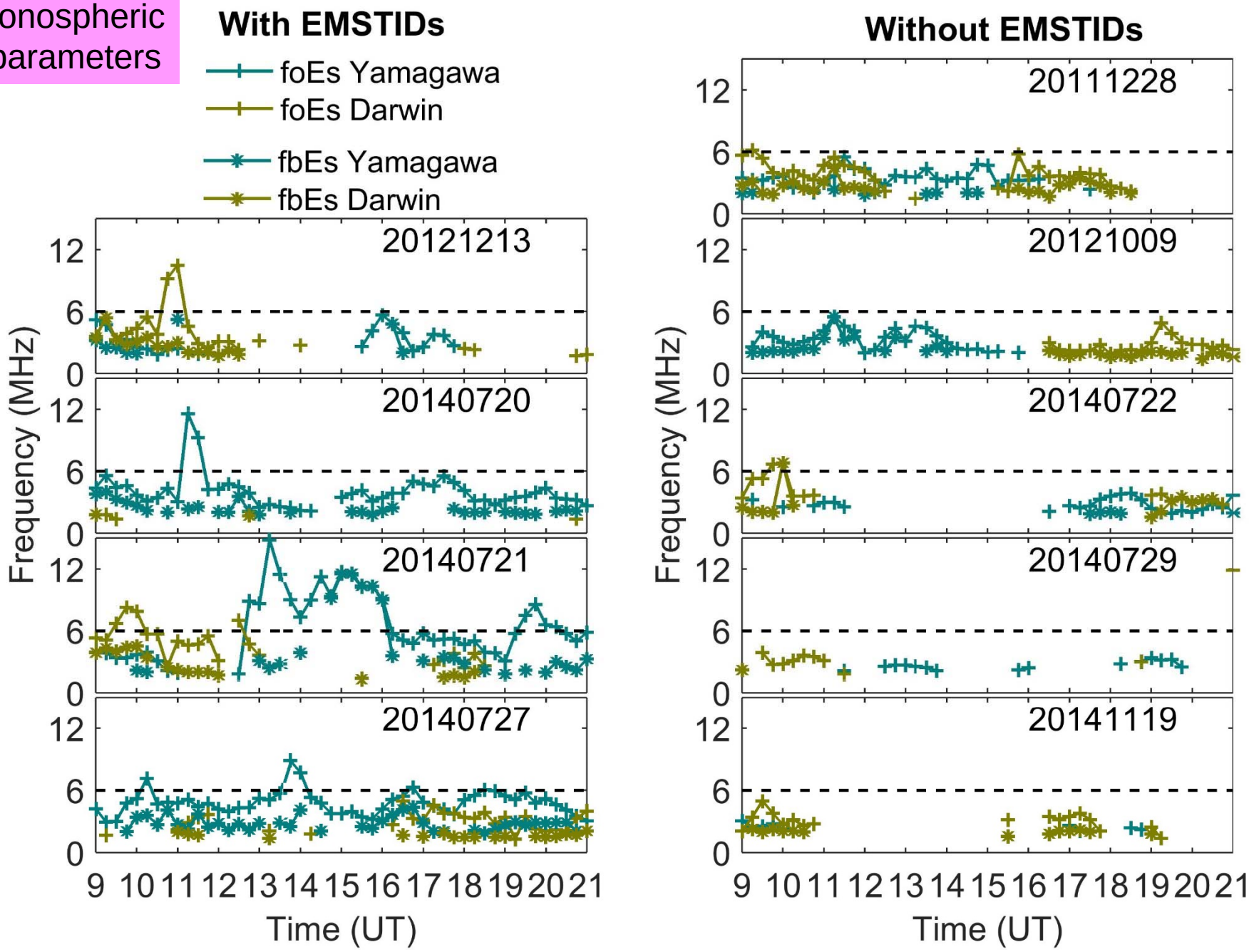






Narayanan et al. (JGR, 2018): conjugate observation of MSTIDs in Japan and Australia

Ionospheric parameters

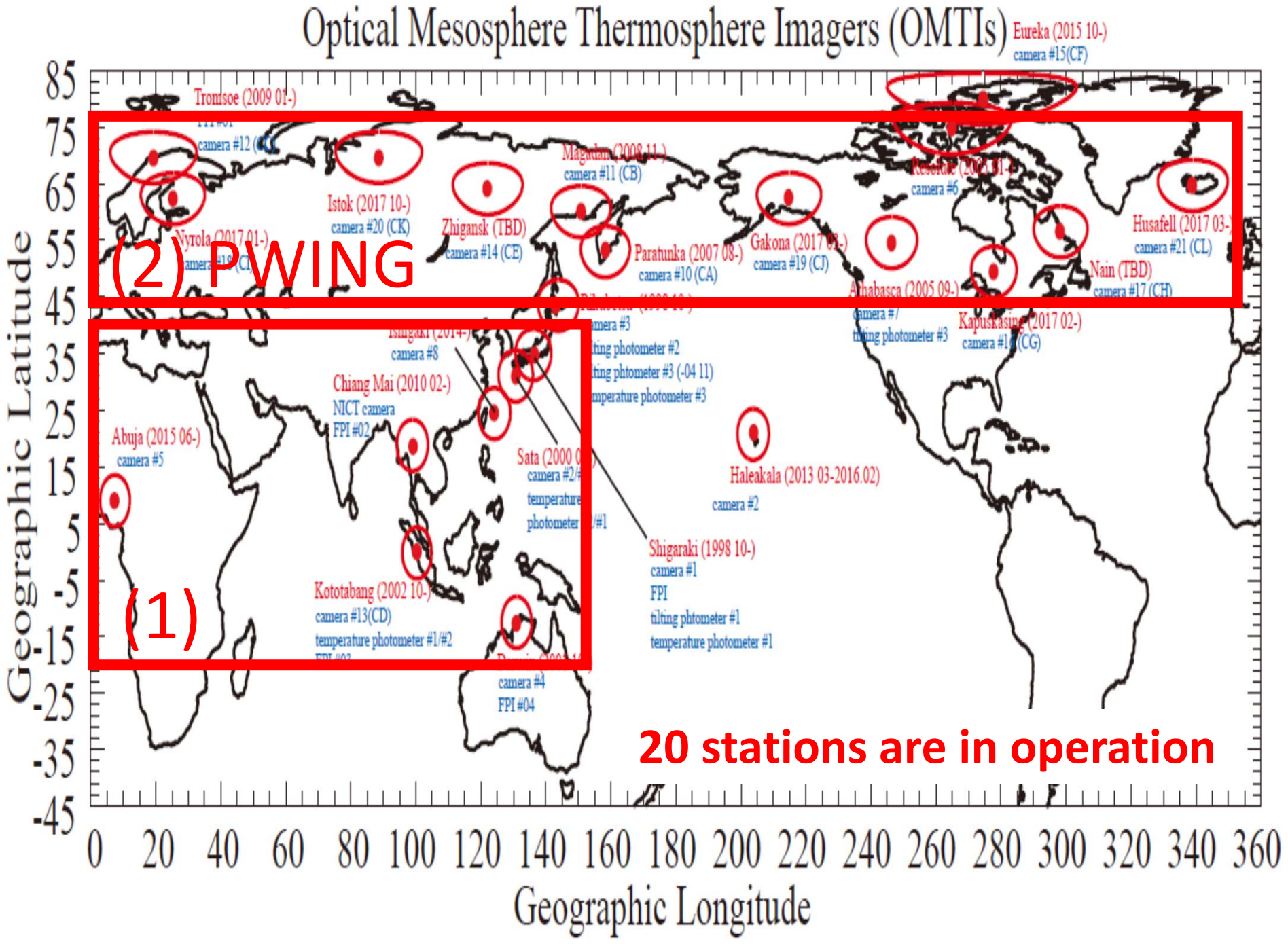


Narayanan et al. (JGR, 2018): conjugate observation of MSTIDs in Japan and Australia

Conclusions

We studied 9 nights of conjugate measurements with imager, FPI, and ionosondes at two hemispheres. Among those 9 nights, 4 nights witnessed formation of EMSTIDs while the remaining 5 nights did not show EMSTID activity.

- Our results show that the amplitudes of the EMSTIDs are often different between the hemispheres. Thermospheric meridional winds appear to control the EMSTID amplitudes in the respective hemisphere.
- However, EMSTIDs are generated only when there is significant sporadic E activity with foEs often reaching greater than 6 MHz and (foEs – fbEs) reaching above 5 MHz at least for a short duration occurred.
- Existence of strong sporadic E activity on one of the hemispheres is found to be sufficient enough for generation of EMSTIDs in the conjugate F regions.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(1)
20 stations are in operation
Geographic Latitude
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180
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220
240
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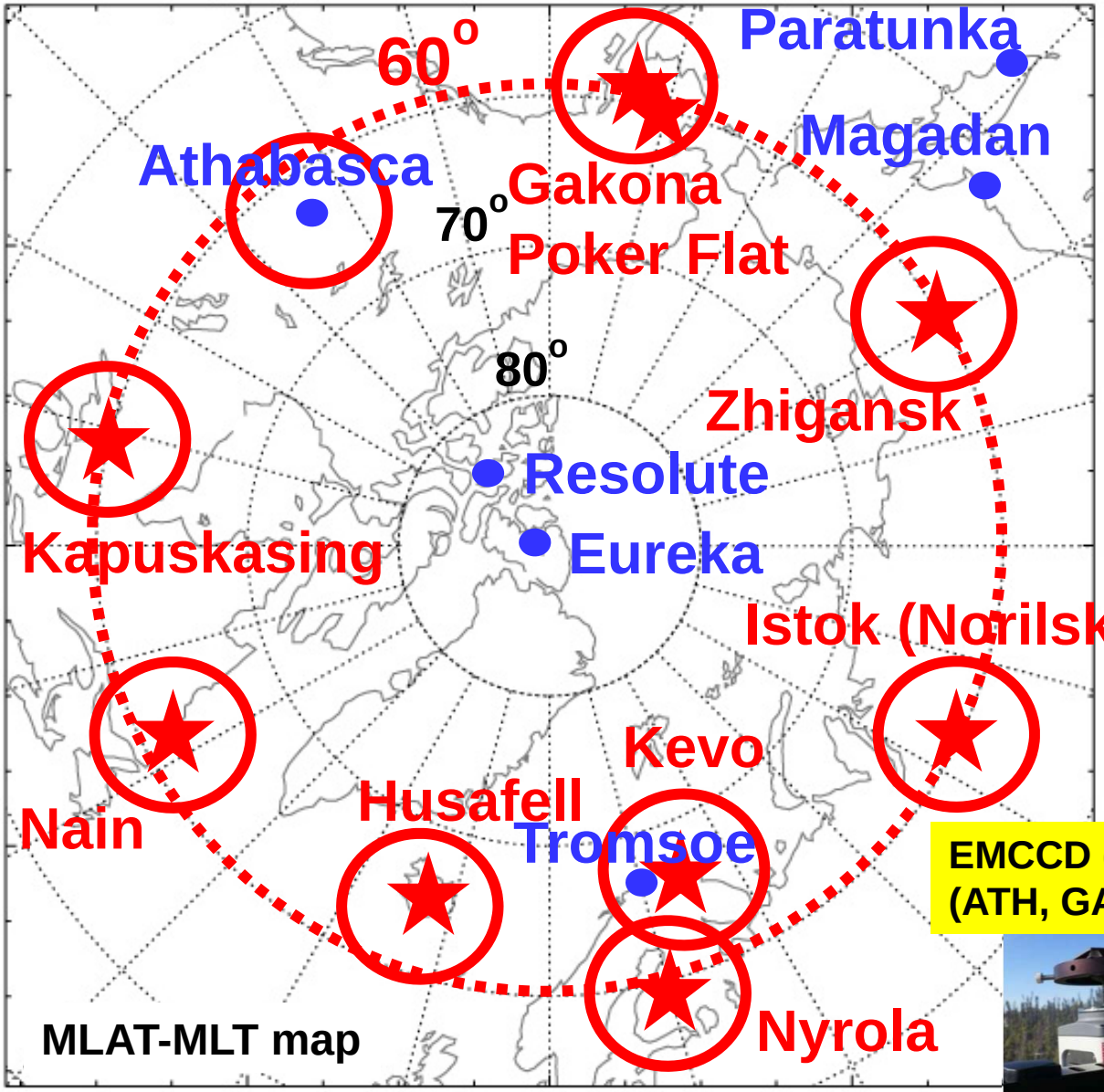
280
300
320
340
360
Geographic Longitude

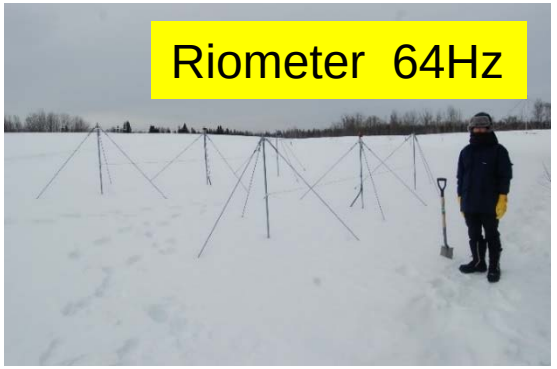
Ground-based stations of the PWING Project.

● Existing sites ★ New sites



http://www.isee.nagoya-u.ac.jp/dimr/PWING/

Induction magnetometer 64Hz

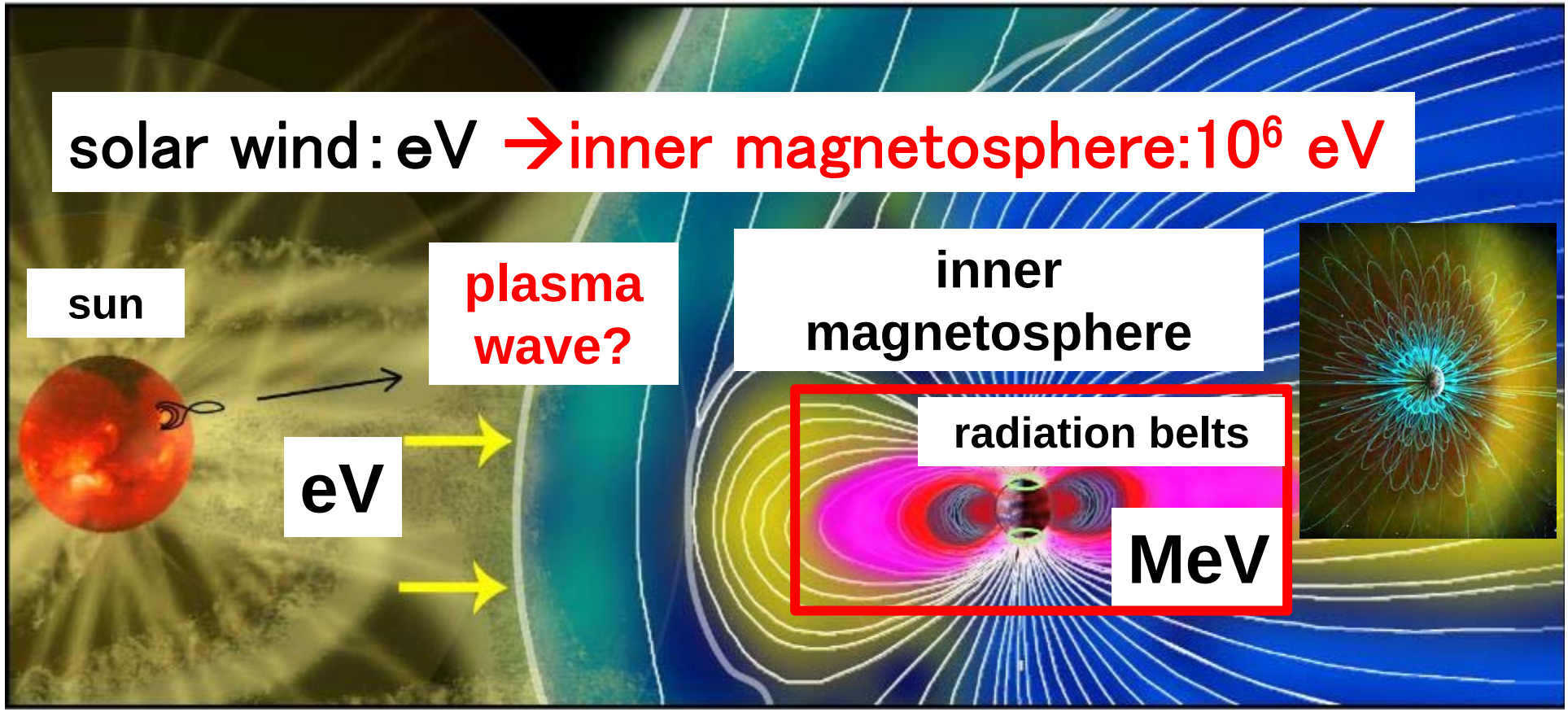


EMCCD (100Hz)
(ATH, GAK, KEV)

background

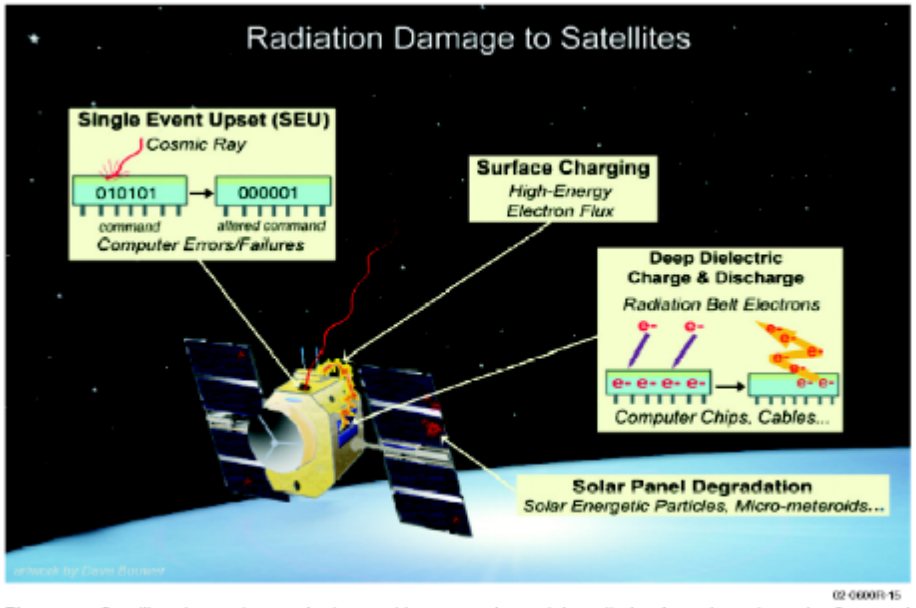
- **Particle acceleration without collision**

→ wave-particle interaction is essentially important



background

High-energy particles gives danger in space for human beings



Satellite anomaly by high-energy particles

Radiation dose for astronauts

1994. 1. 23 Asahi Evening News

Storm blows Canada's satellites

OTTAWA—A massive electromagnetic storm knocked out Canada's two communications satellites, and one of them may be lost for ever and become an expensive piece of space junk, the operating company Telesat Canada said Friday.

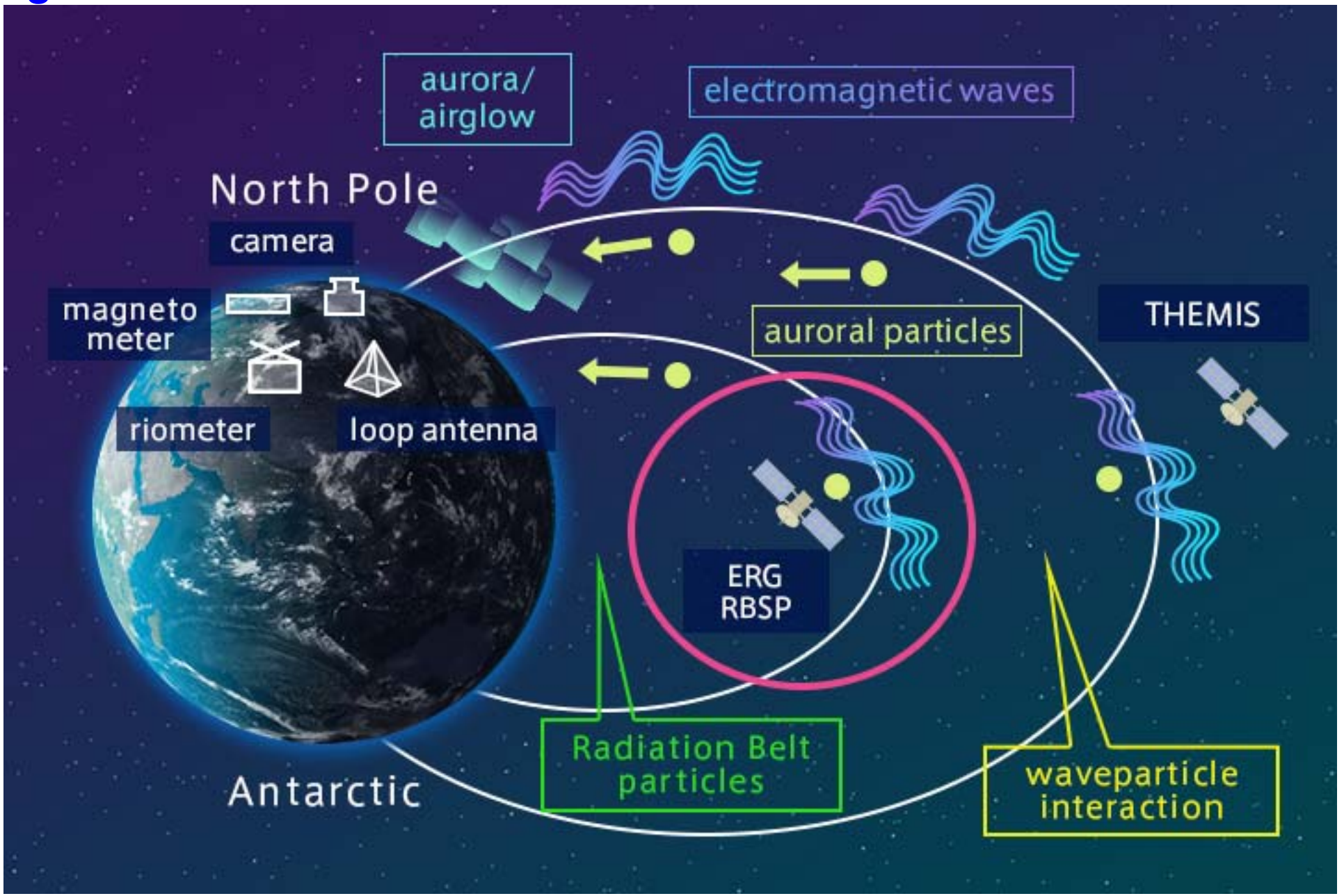
Telesat executives said a unusual localized storm caused short-circuits on its Anik E-1 and E-2 satellites Thursday, disrupting telephone, television and data transmission services across Canada.

Engineers managed to reposition the first unit eight hours later, but the second, Canada's main broadcasting satellite, is spinning out of control and pointing away from Earth.

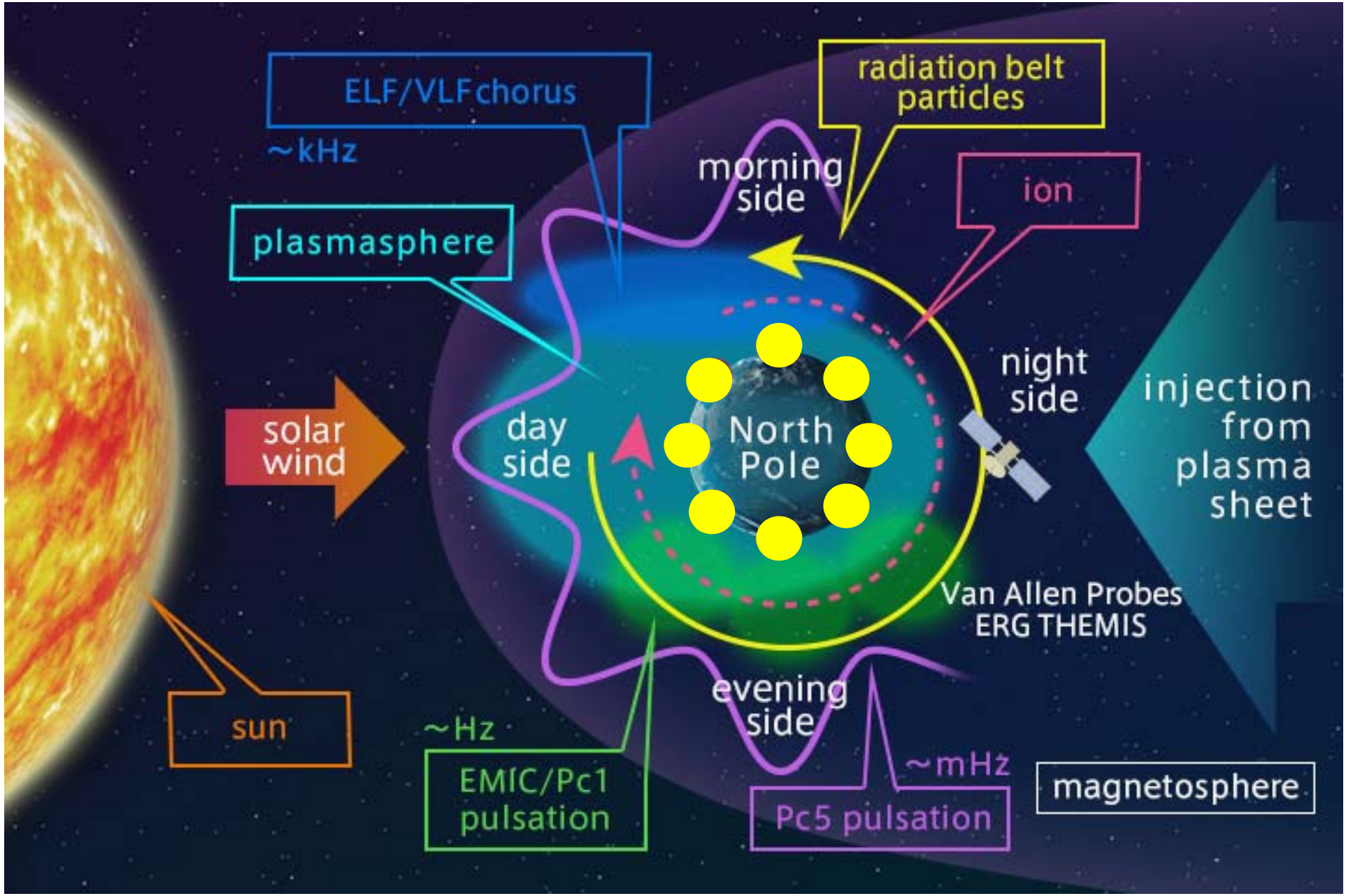
Compiled from Reuter and The Associated Press

Satellite failure by magnetic storm (Jan. 23, 1994 Asahi Evening News)

Phenomena in the magnetosphere can be monitored on the ground.

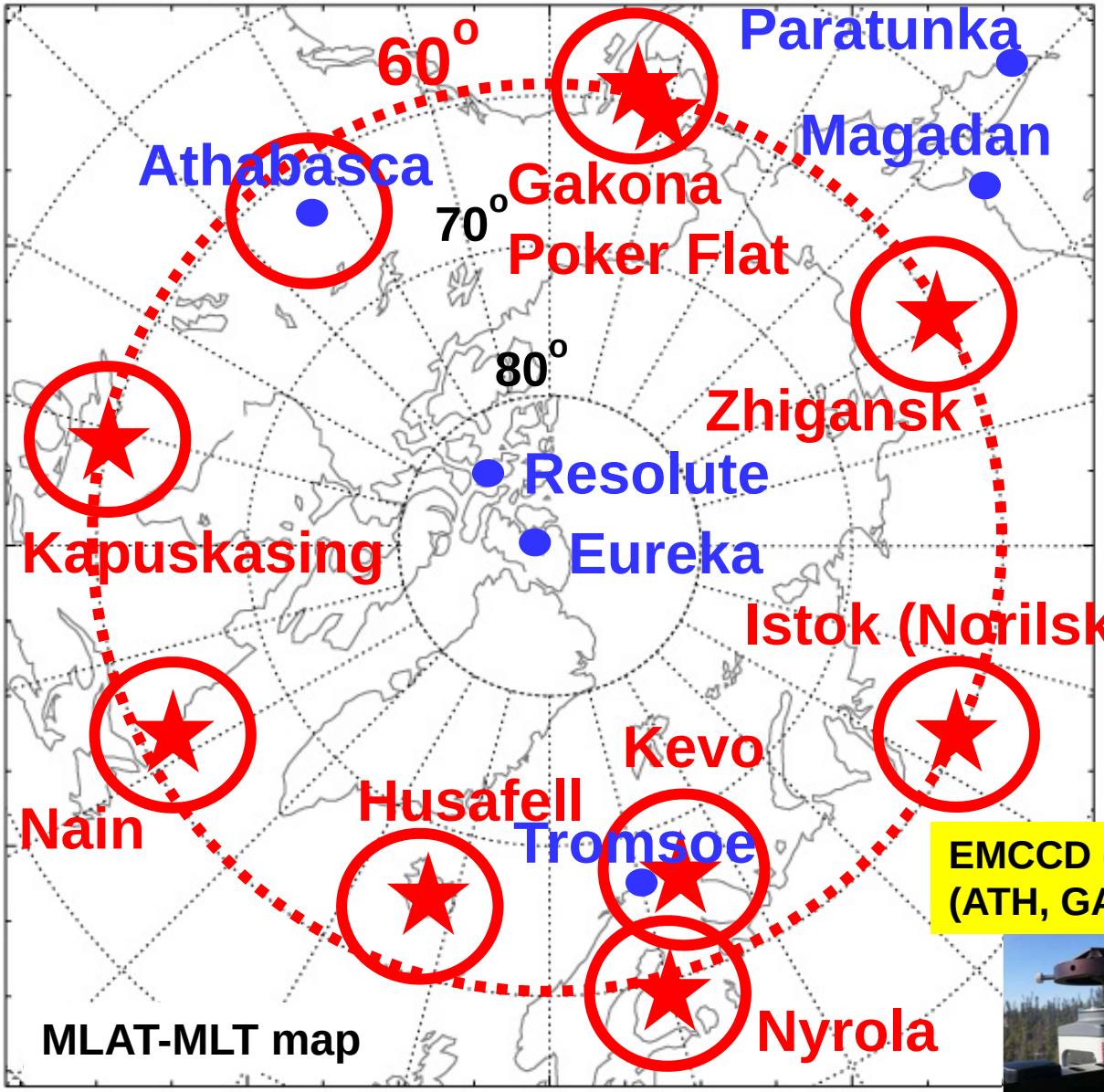


Particles longitudinally round the earth, while waves are localized in particular local time



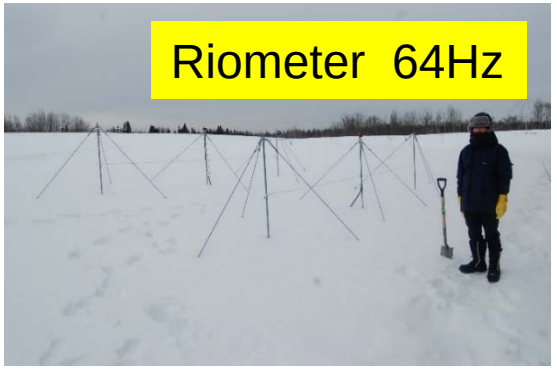
Ground-based stations of the PWING Project (2016-2021).

● **Existing sites** ★ **New sites**



http://www.isee.nagoya-u.ac.jp/dimr/PWING/

Induction magnetometer 64Hz



EMCCD (100Hz)
(ATH, GAK, KEV)

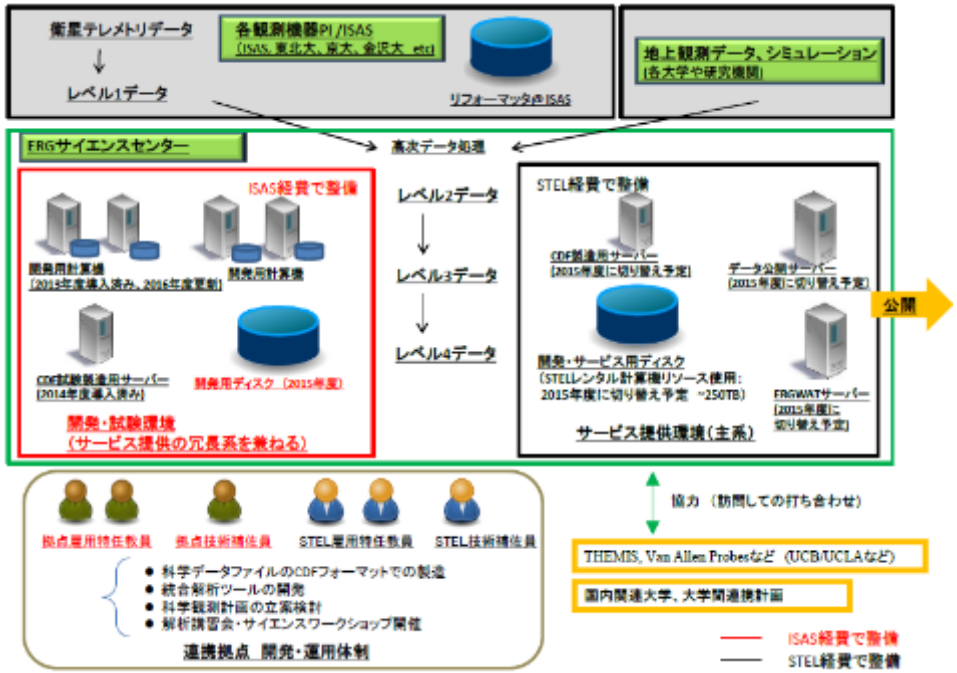
Current status of the installation (as of March, 2019)

	stations	All-sky cooled-CCD camera	riometer	Induction magnetometer	VLF/ELF loop antenna	EMCCD camera
Russia	Zhigansk	In operation	In operation	In operation	In operation	–
Russia	Istok	In operation	In operation	In operation (by ISTP)	In operation	–
Finland	Nyrola	In operation	In operation (by SGO at JYV)	In operation (by SGO at NUR)	In operation (by SGO at TVAR and Kannuslehto)	–
Iceland	Husafell	In operation	In operation (by NIPR)	In operation (by NIPR)	In operation (by NIPR)	In operation (by NIPR at Tjornes)
Canada	Kapuskasing	In operation	In operation	In operation	In operation	–
Canada	Nain	Installation finished. Waiting for power line	Installation finished. Waiting for power line	Installation finished. Waiting for power line	Installation finished. Waiting for power line	–
Canada	Athabasca	In operation	In operation	In operation	In operation	In operation
USA	Gakona	In operation	In operation	In operation	In operation	In operation
USA	Poker Flat	–	–	–	–	In operation
Finland	Kevo	–	–	–	–	In operation

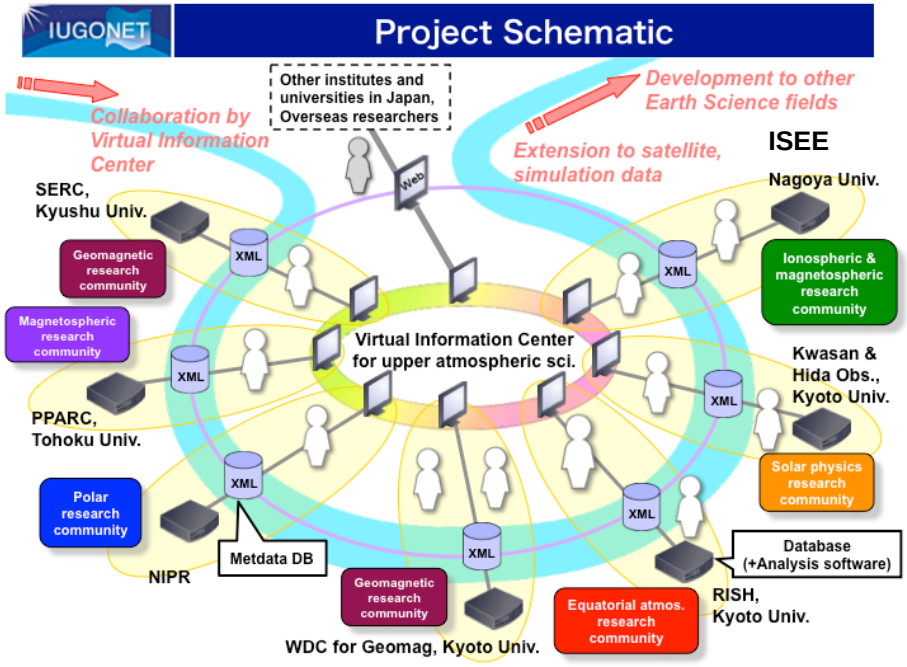
Database Construction

All data from ground network, ERG satellite, and modeling will be stored into the ERG science center. The data will be stored in CDF and available through SPEDAS. Metadata will be put into IUGONET.

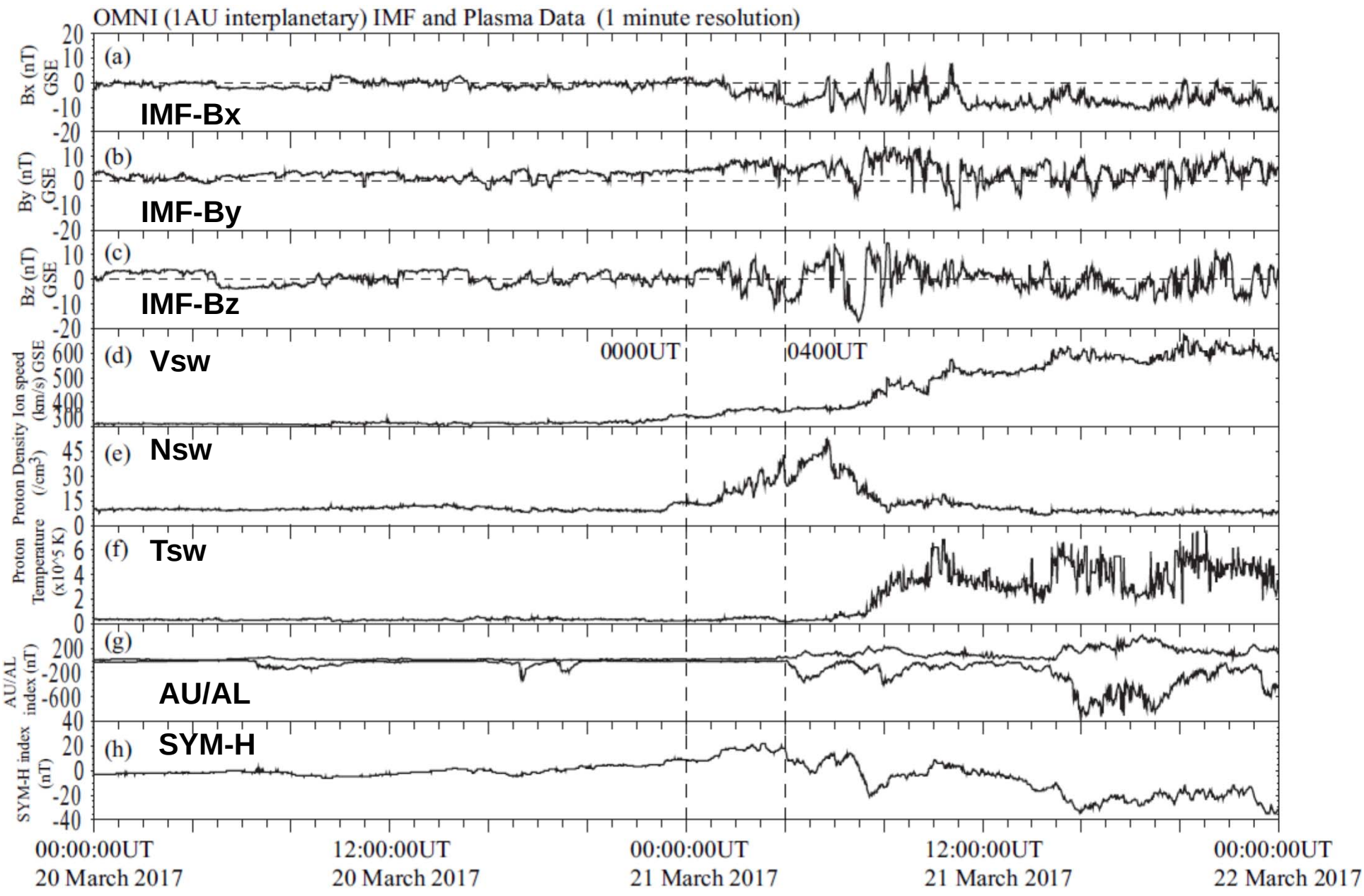
ERG Science Center



IUGONET

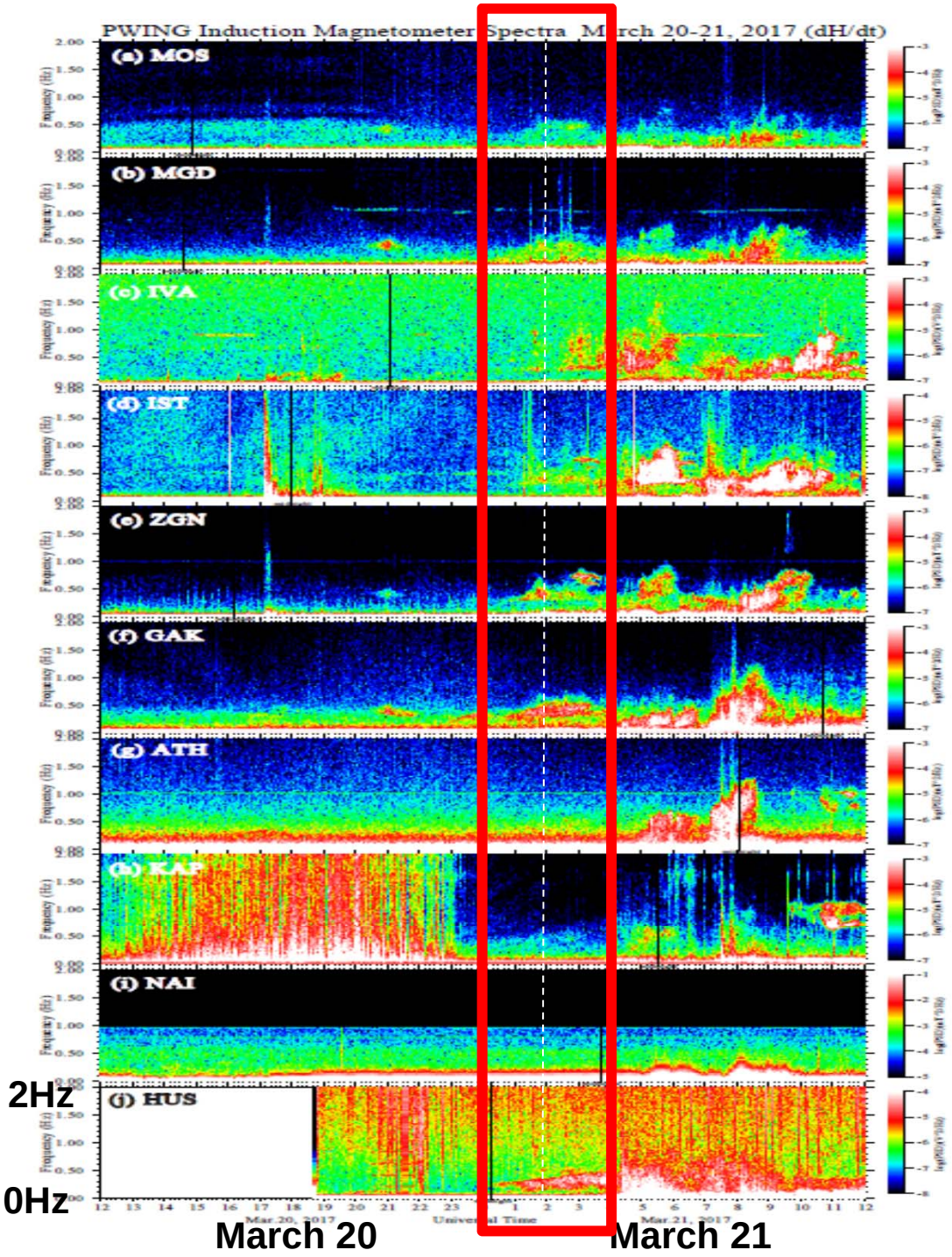


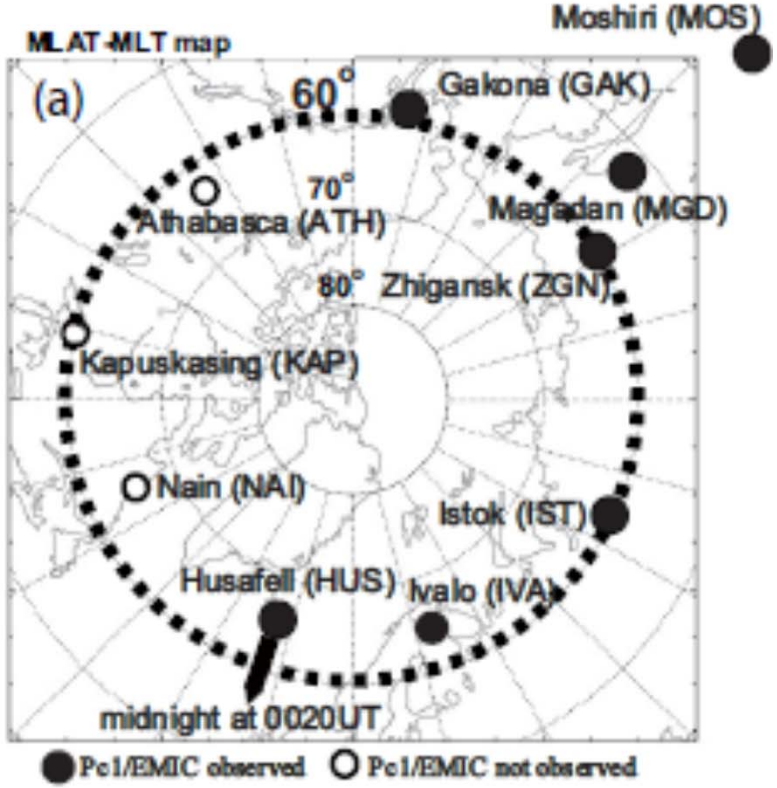
CIR arrival at the beginning of ERG-ground campaign

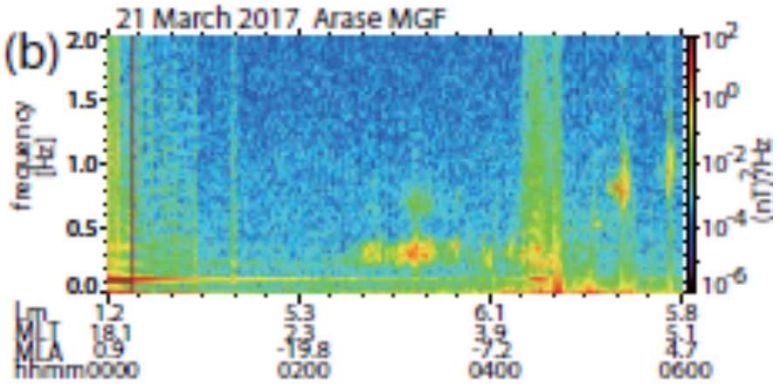


Shiokawa et al. (GRL, 2018)

Pc1 on global scale (~13 hour LT) at CIR arrival

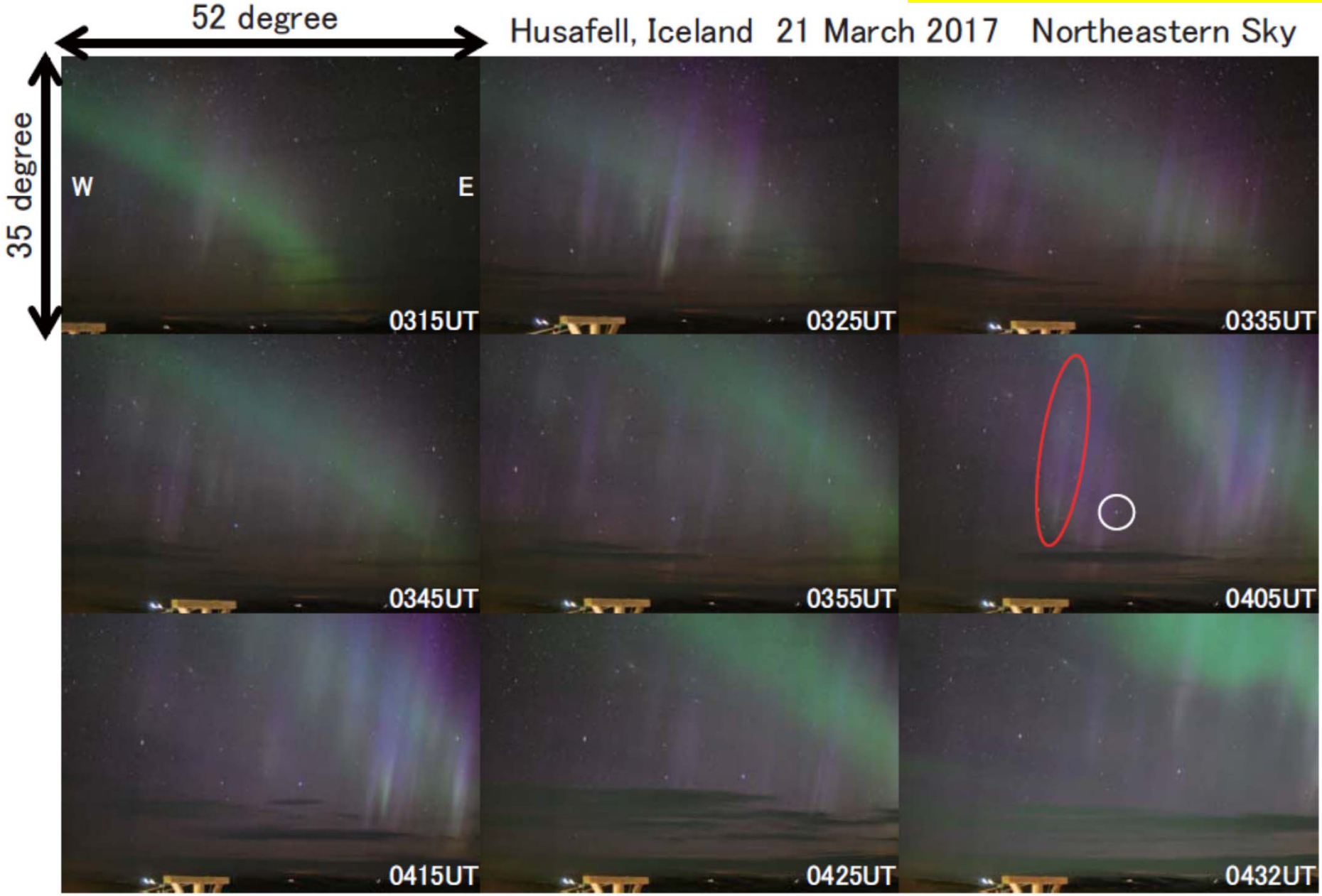




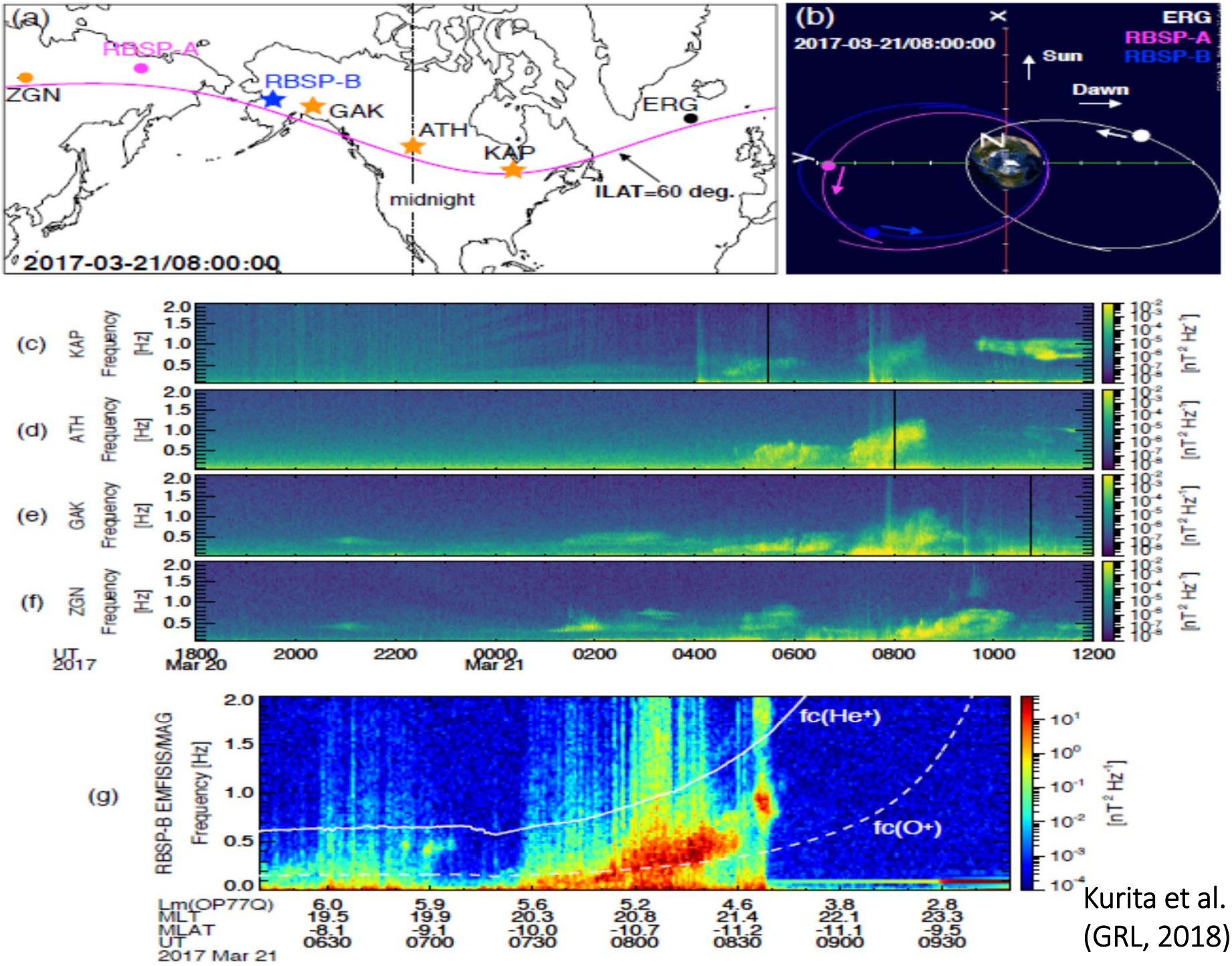


Shiokawa et al. (GRL, 2018)

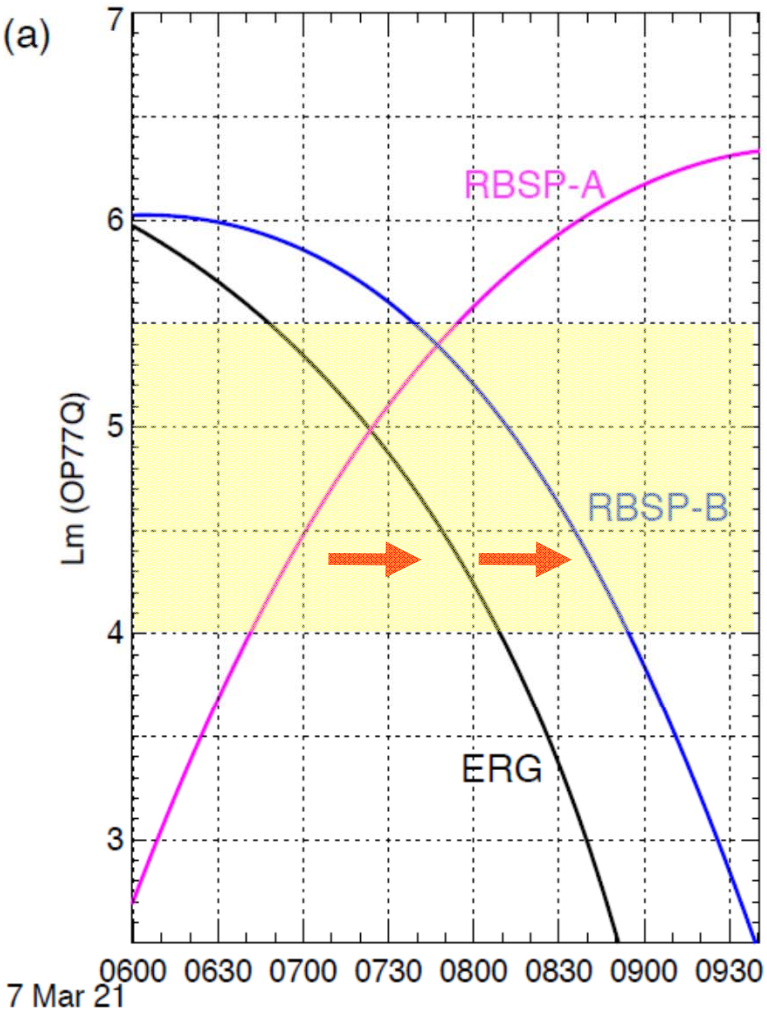
Purple aurora at CIR arrival

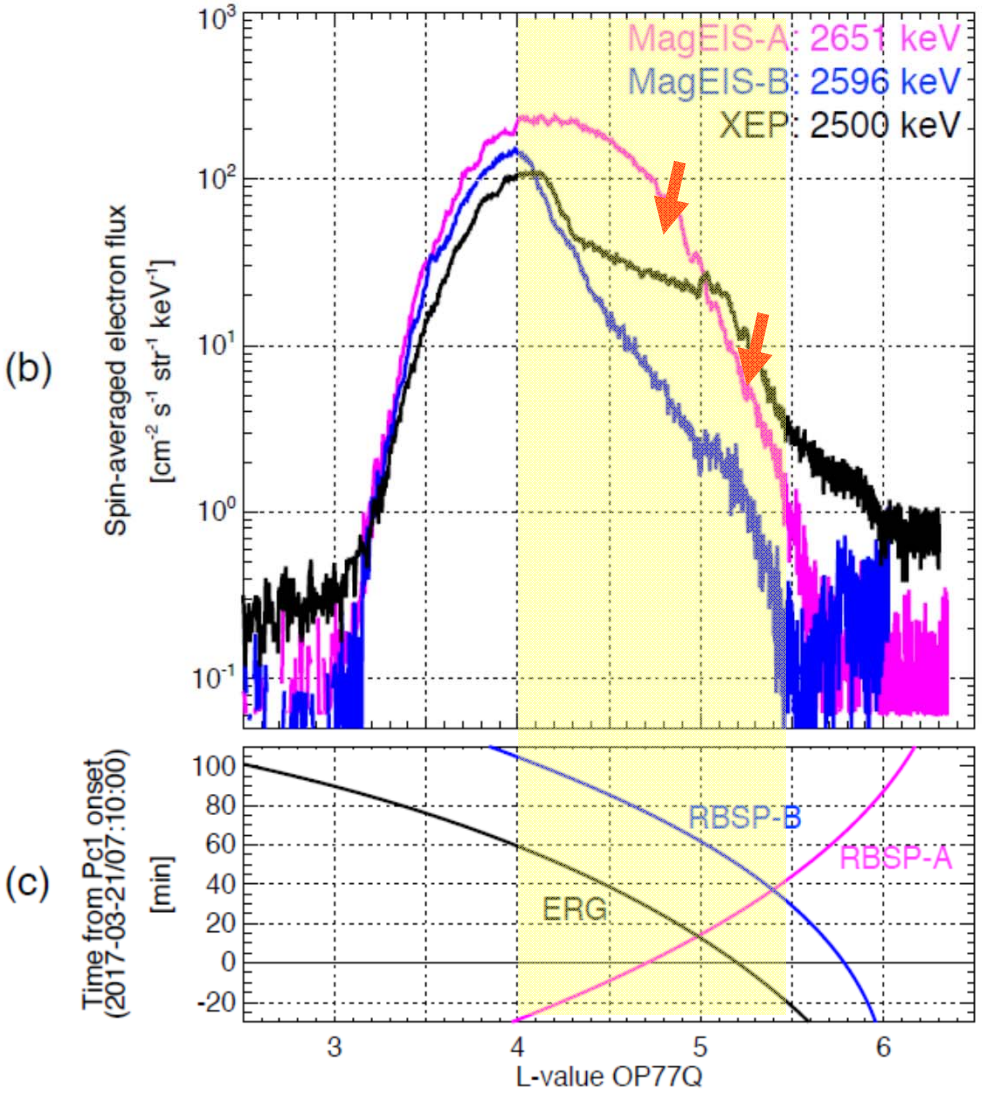


Shiokawa et al. (GRL, 2018)



Kurita et al. (GRL, 2018)

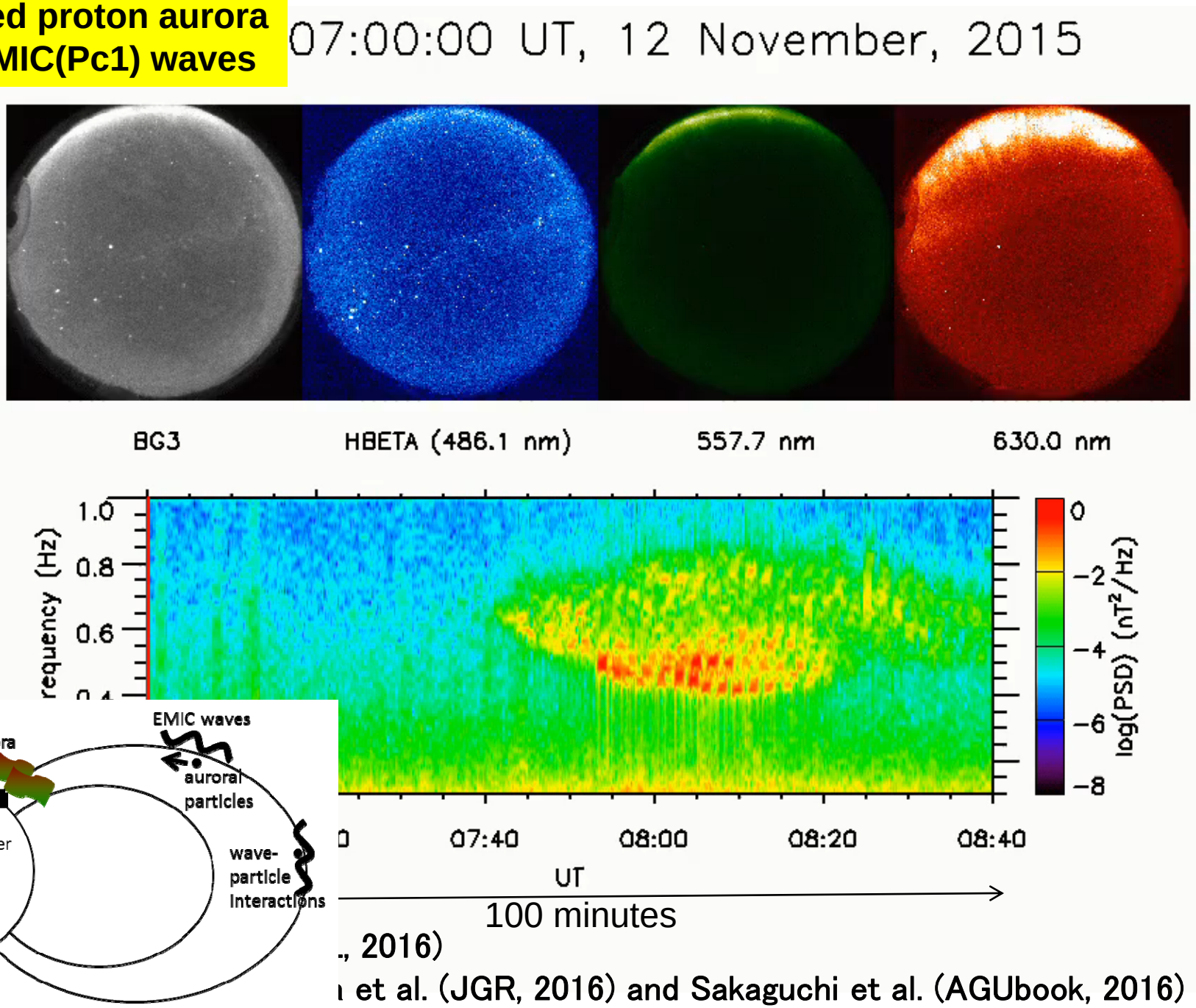




Kurita et al. (GRL, 2018)

~2.5 MeV electron fluxes substantially decreased within a few tens of minutes where the EMIC waves were present.

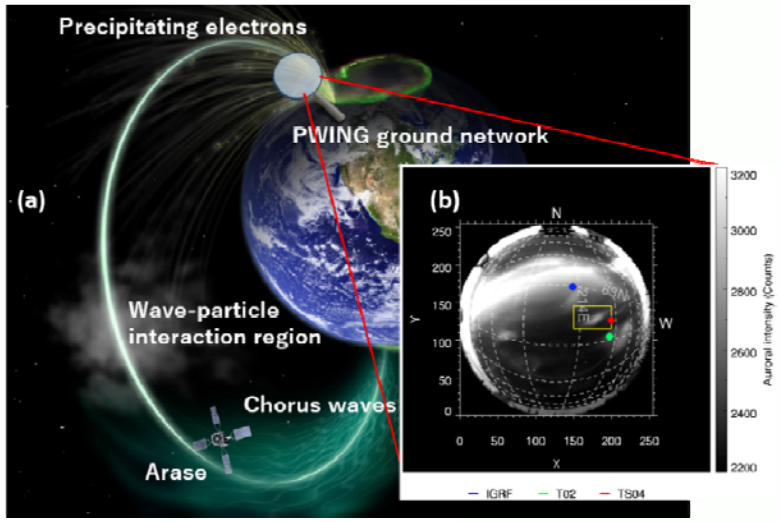
Isolated proton aurora and EMIC(Pc1) waves

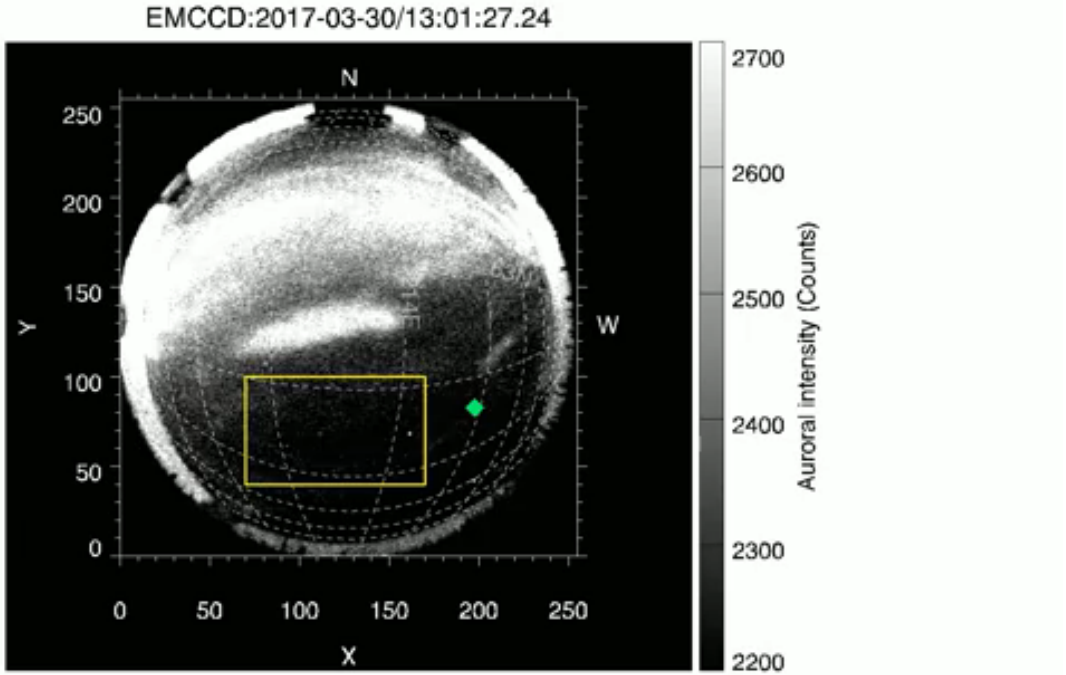


., 2016)

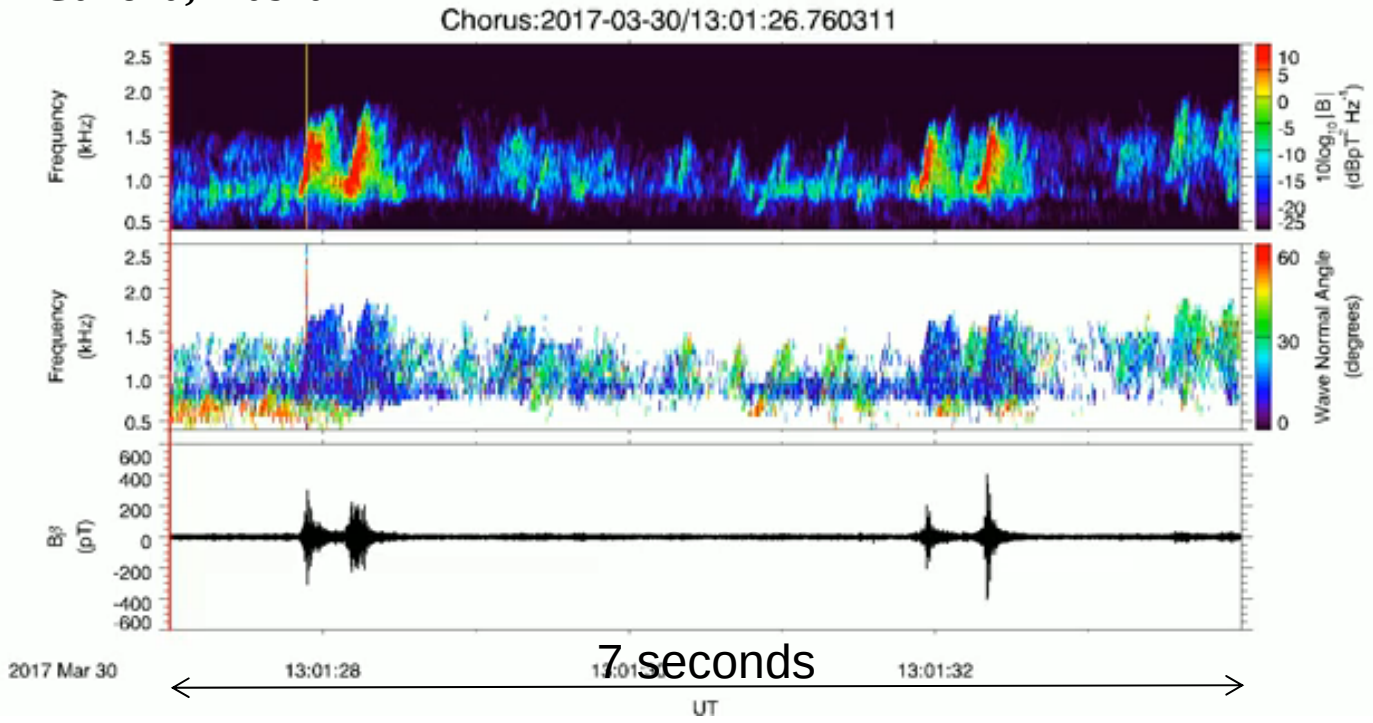
et al. (JGR, 2016) and Sakaguchi et al. (AGUbook, 2016)

Pulsating aurora and chorus correspondence



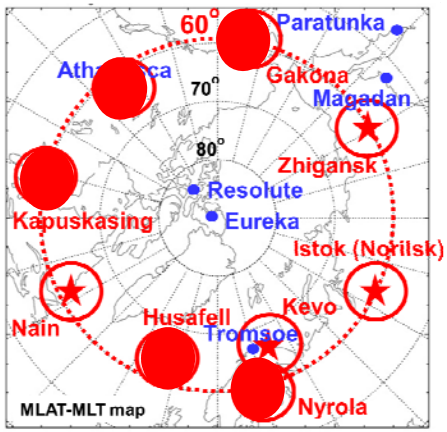


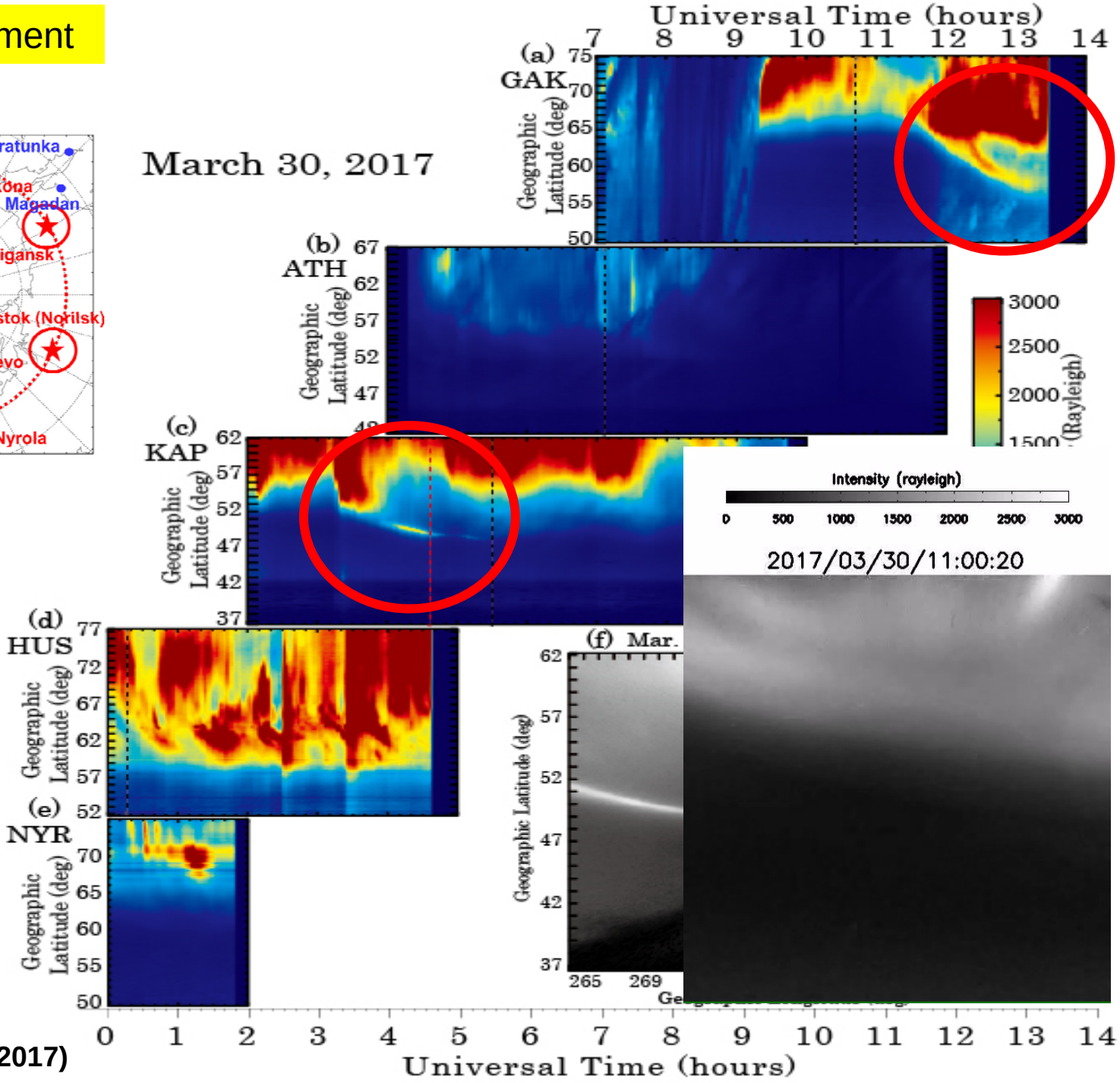
Gakona, Alaska



Ozaki et al.
(Nature Comm., 2019)

SAR arc detachment





Shiokawa et al. (EPS, 2017)

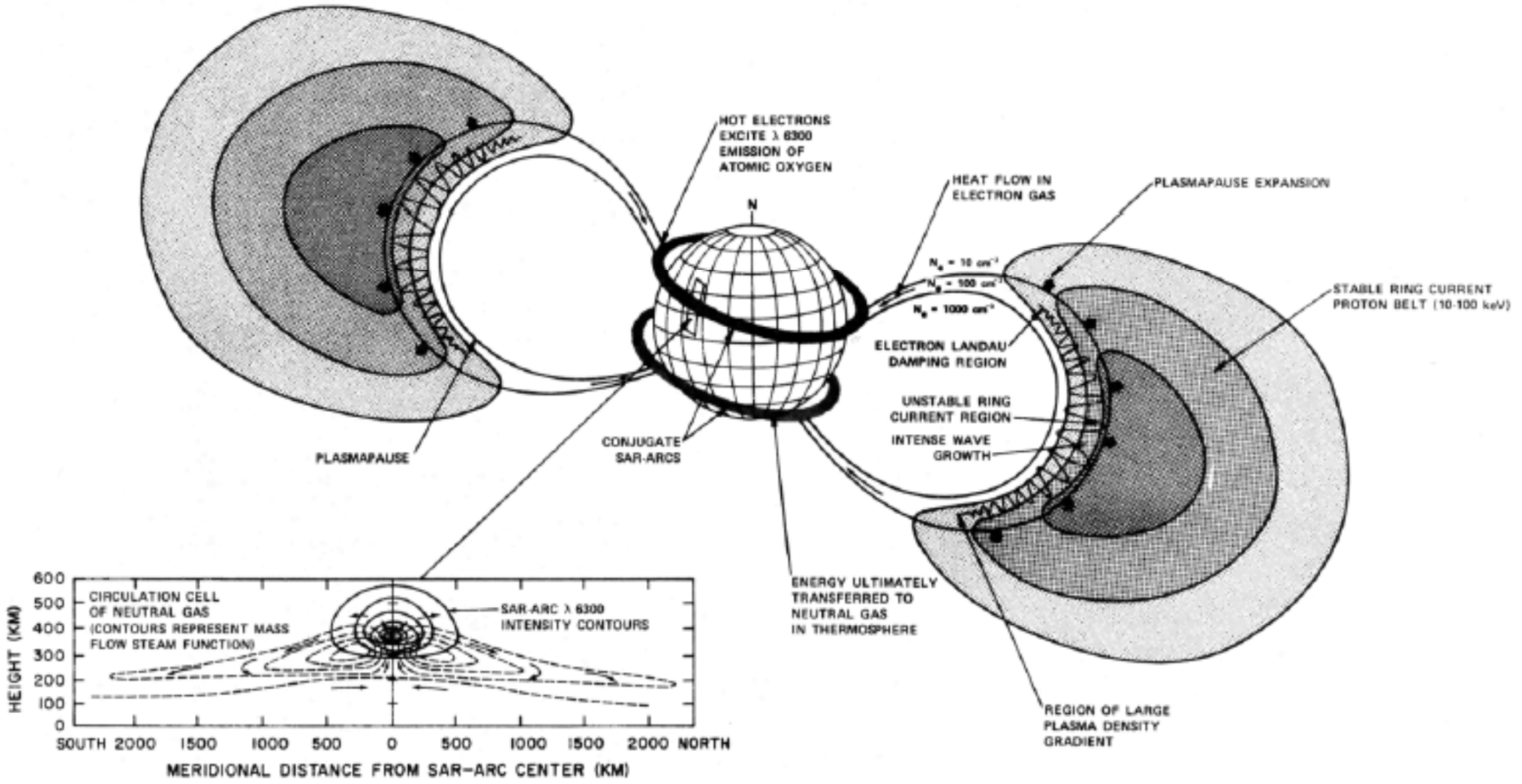
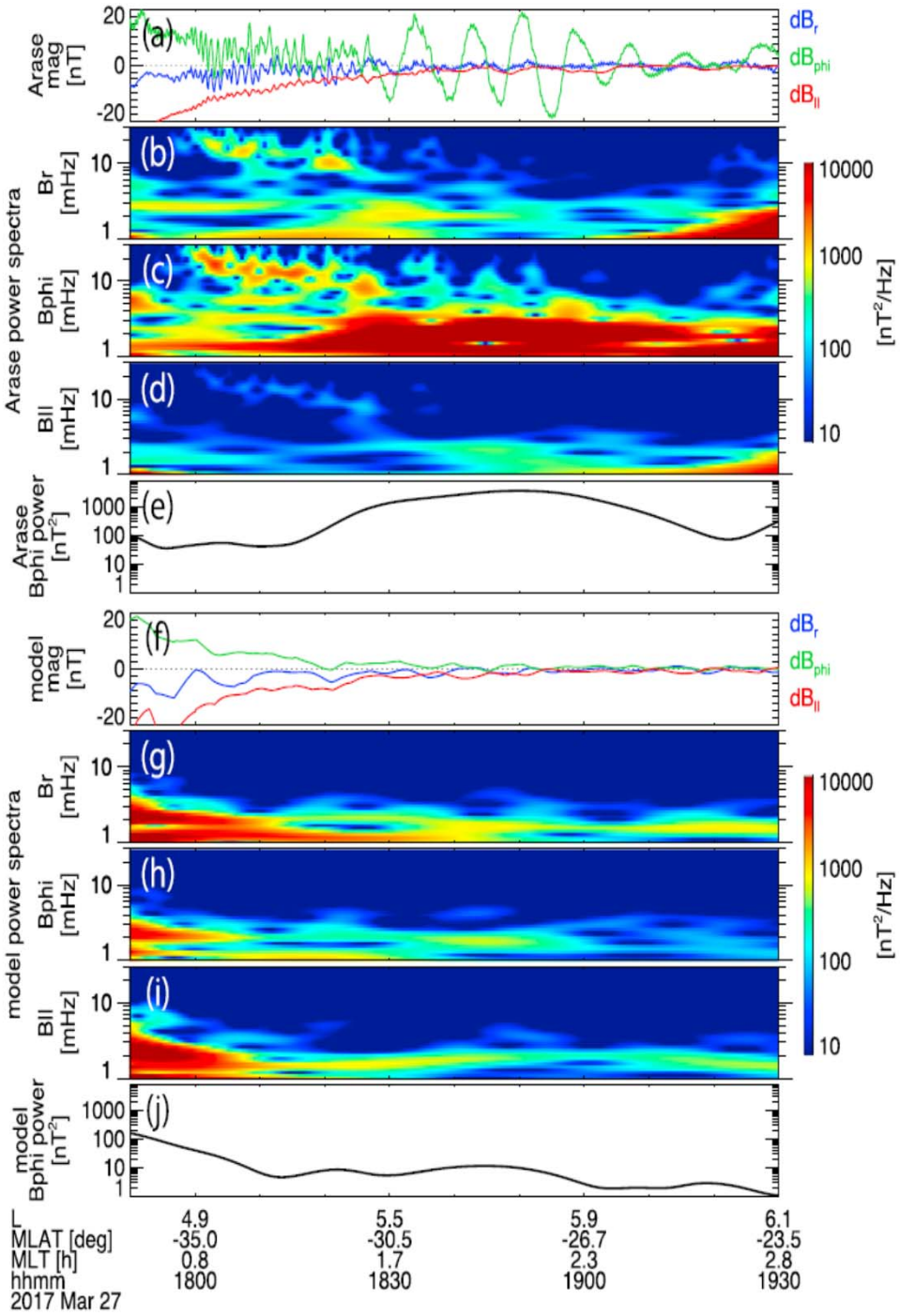
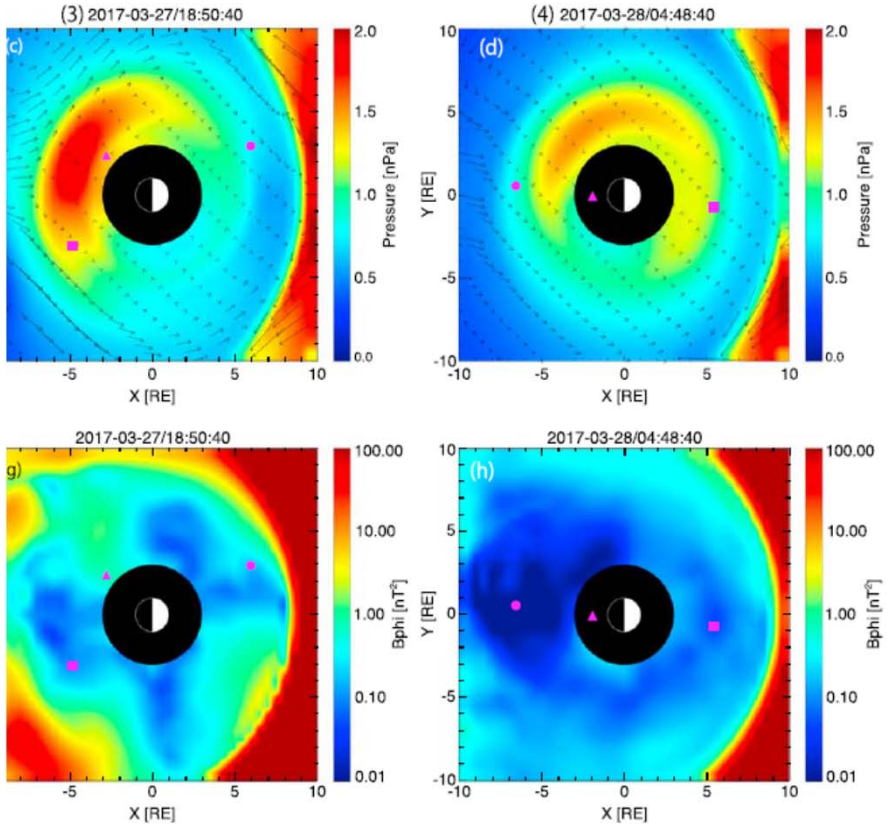


Fig. 43. Schematic diagram of the processes acting within an SAR arc.

Rees and Roble (RG, 1975)





The BATURAS/CRCM simulation reproduced the 2-3mHz ULF waves observed by Arase associated with SW dynamic pressure, but the wave power is 1–2 orders smaller.

The simulation does not reproduce K-H & substorm ULF waves.

Takahashi et al. (GRL, 2018)

Summary: The PWING project (2016-2021) operates eight longitudinal sites at subauroral latitudes (~60 MLAT). So far 98 papers has been published (below are examples). JSPS evaluation is on-going.

- Global Pc1/EMIC (~13 h) at a CIR arrival (Shiokawa et al., GRL, 2018)
- Rapid loss (within a few tens of min) of ~2.5 MeV electrons by EMIC waves (Kurita et al., GRL, 2018)
- Isolated proton aurora and Pc1/EMIC waves: One-to-one correspondence of subpacket structures and main oscillation (1.2Hz) (Ozaki et al., GRL, 2016; 2018a)
- Pulsating aurora and chorus correspondence using ERG and EMCCD camera data (Ozaki et al., GRL2018b / Nature Comm. 2019)
- Longitudinal extent of ELF/VLF waves (Takeshita et al., submitted to JGR, 2019)
- SAR arc detachment from the oval (Shiokawa et al., EPS, 2017; Takagi et al., GRL, 2018)
- Evaluation of the BATSRUS/CRCM model for Pc4-5 waves using Arase and PWING ground data (Takahashi et al., GRL, 2018).
- Discovery of 1000-2500-km scale longitudinal structures in ionospheric trough in GPS-TEC (Shinbori et al., GRL, 2018).