Ground-based multi-point network observation of the inner magnetosphere at subauroral latitudes by the PWING project

PWING stands for "study of dynamical variation of Particles and Waves in the INner magnetosphere using Ground-based network observations."

Kazuo Shiokawa 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/

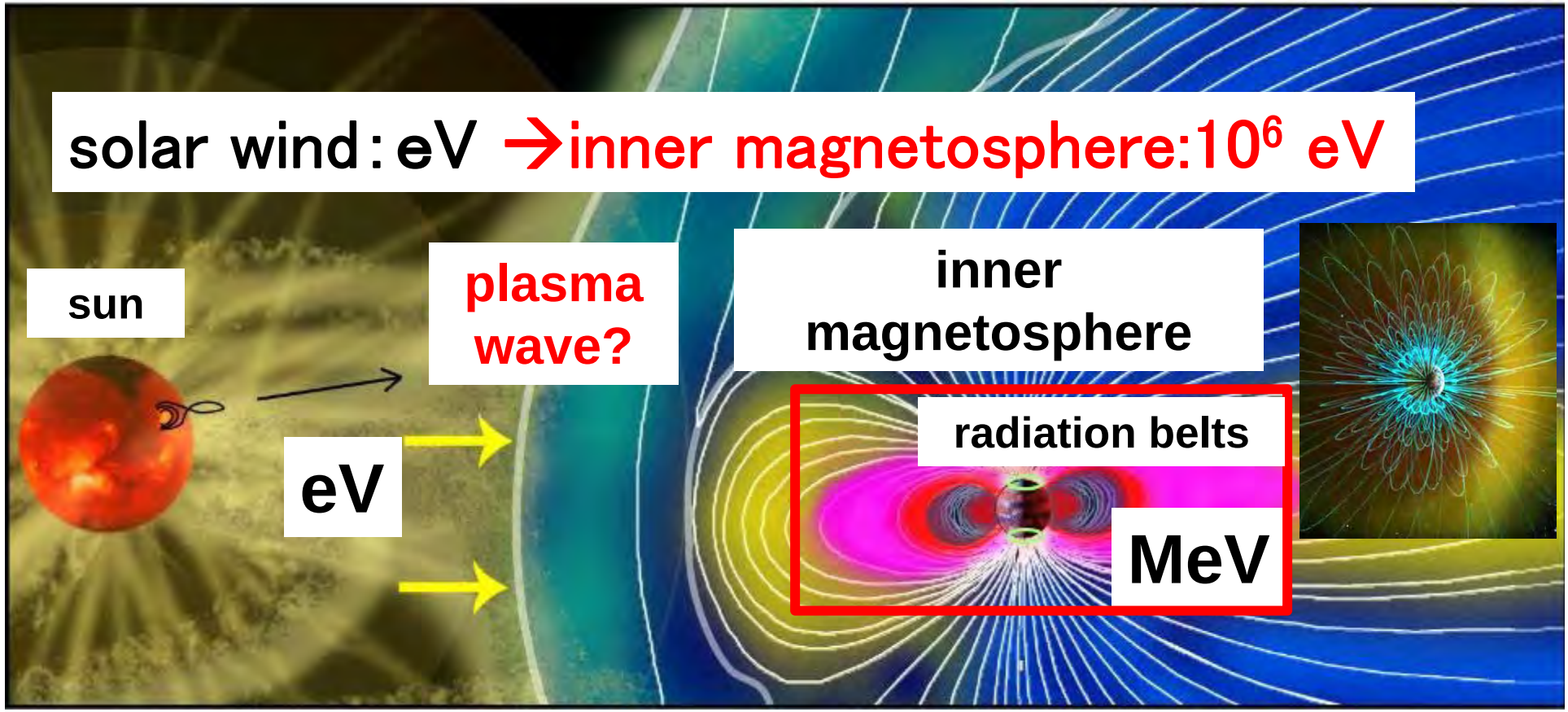
Invited talk at the SuperDARN workshop, Fuji, Japan, June 3, 2019

Image from ISS

background

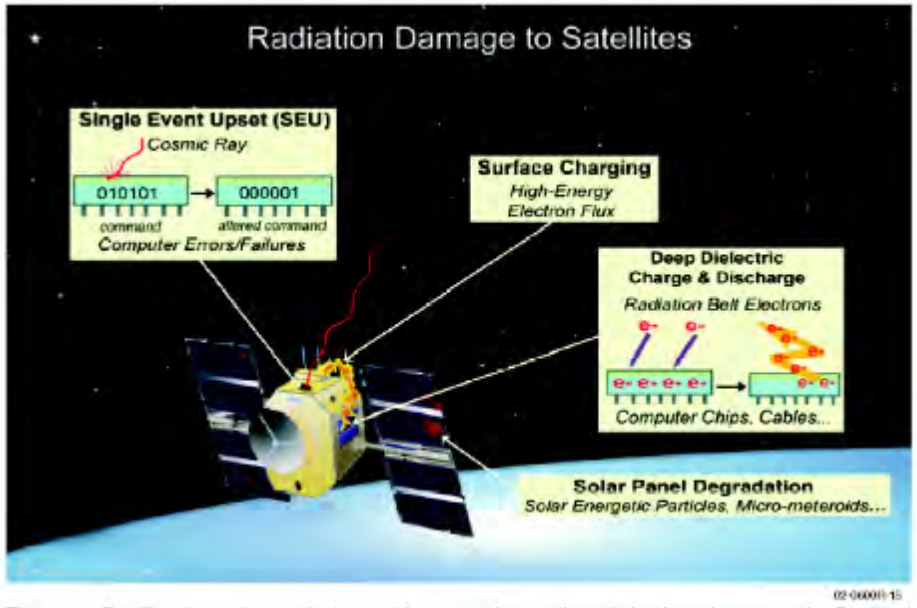
- **Particle acceleration without collision**

→ 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

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

1994. 1. 23 Asahi Evening News

Storm blows Canada's satellites

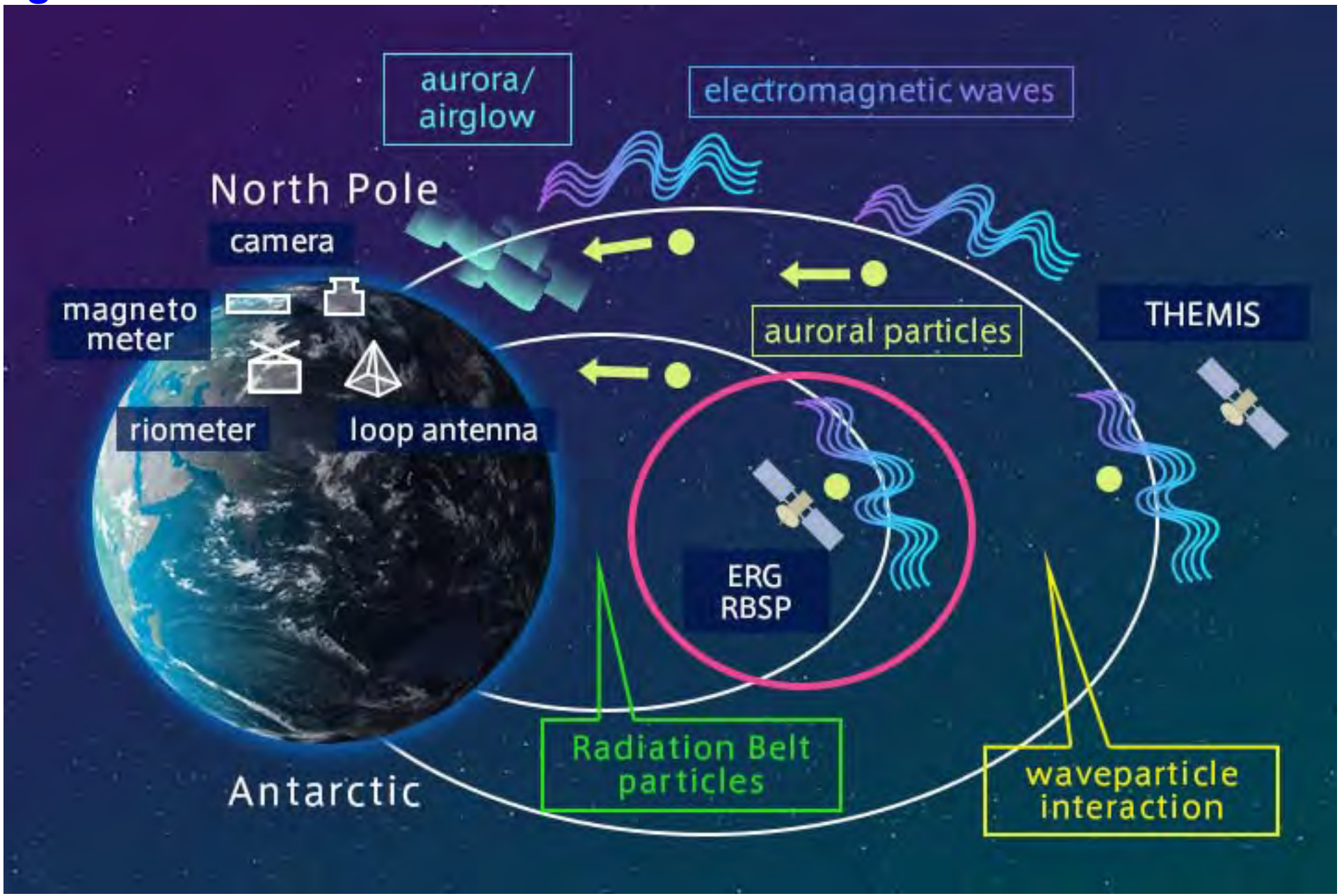
OTTAWA—A massive electromagnetic storm knocked out Canada's two communications satellites, and one of them may be lost for ever and become an expensive piece of space junk, the operating company Telesat Canada said Friday.

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.

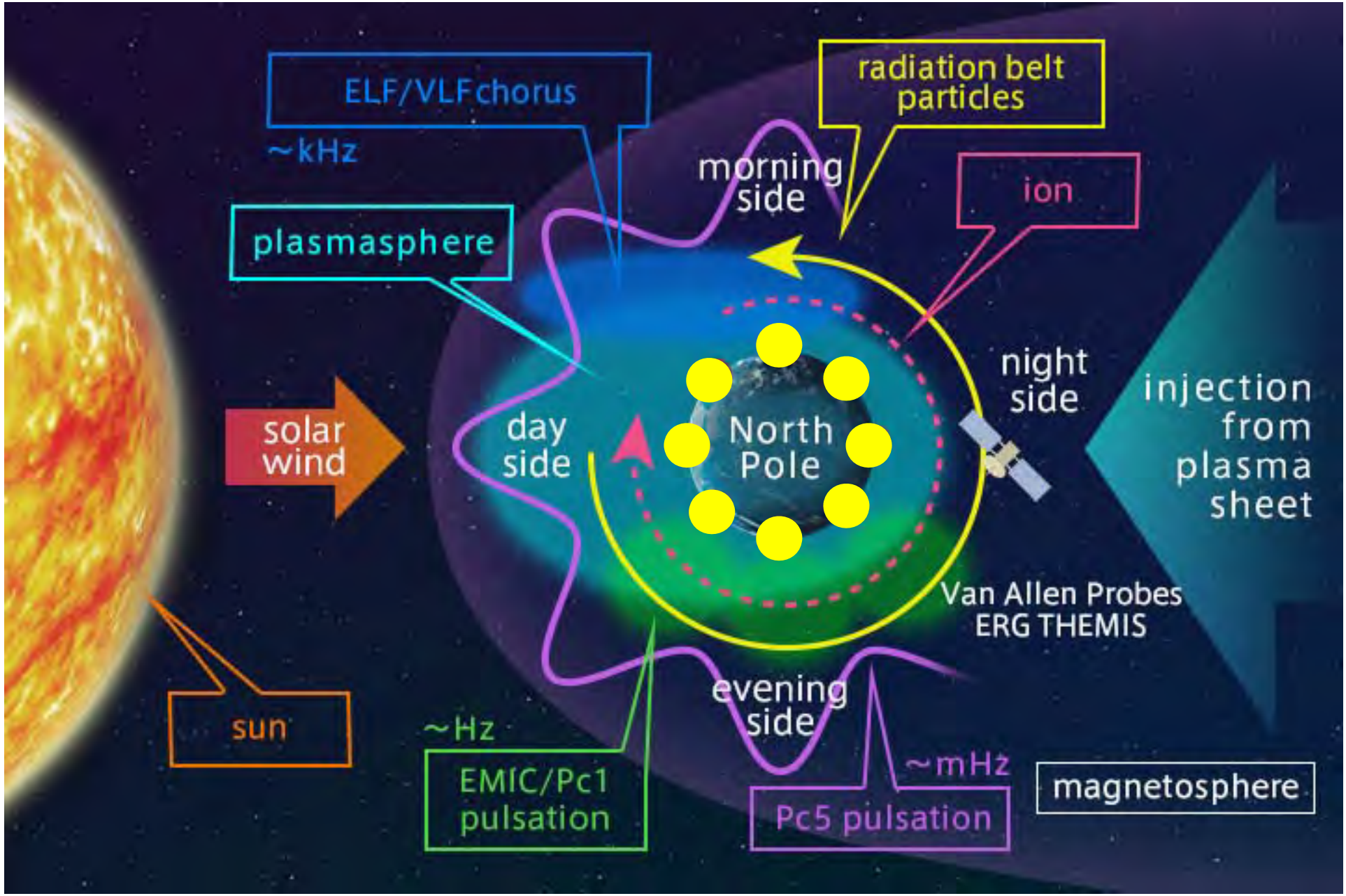
Engineers managed to reposition the first unit eight hours later, but the second, Canada's main broadcasting satellite, is spinning out of control and pointing away from Earth.

Compiled from Reuter and The Associated Press

Phenomena in the magnetosphere can be monitored on the ground.

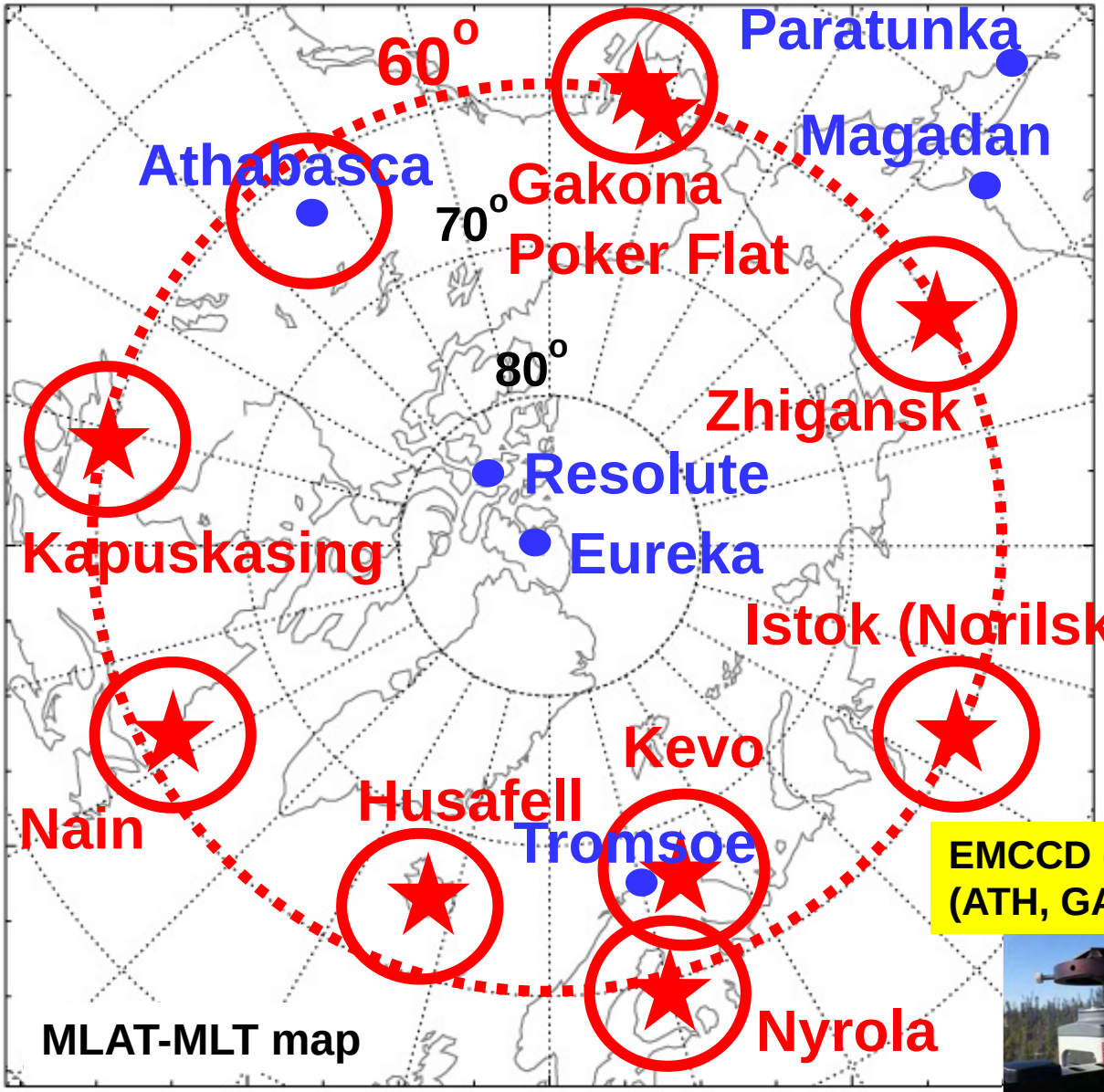


Particles longitudinally round the earth, while waves are localized in particular local time



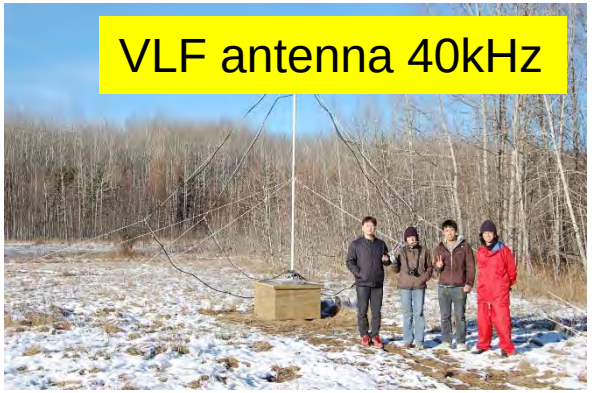
Ground-based stations of the PWING Project (2016-2021).

● **Existing sites** ★ **New sites**



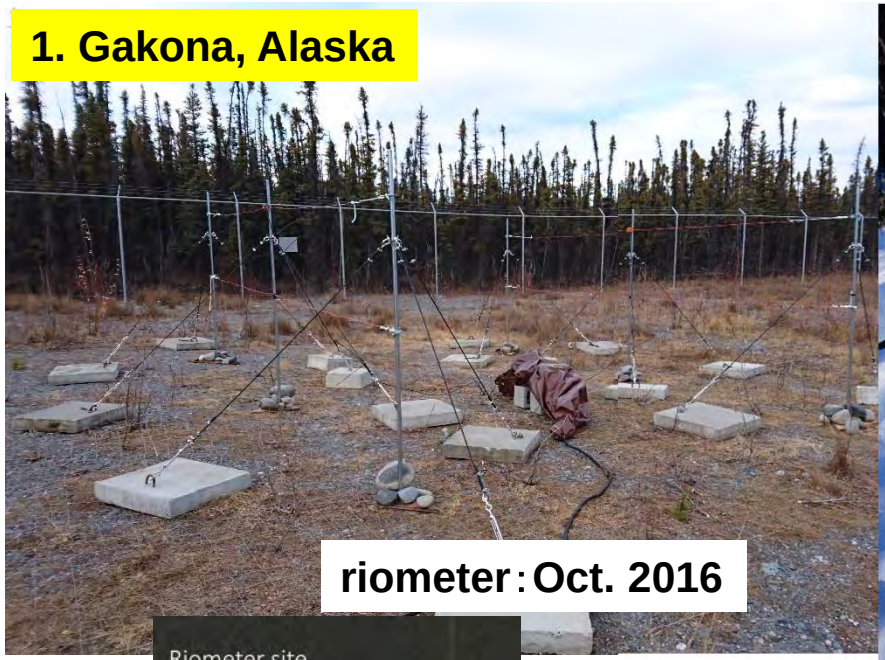
http://www.isee.nagoya-u.ac.jp/dimr/PWING/

Induction magnetometer 64Hz

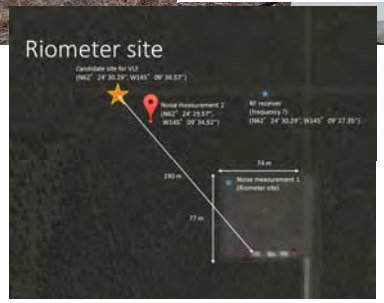


EMCCD (100Hz)
(ATH, GAK, KEV)

1. Gakona, Alaska



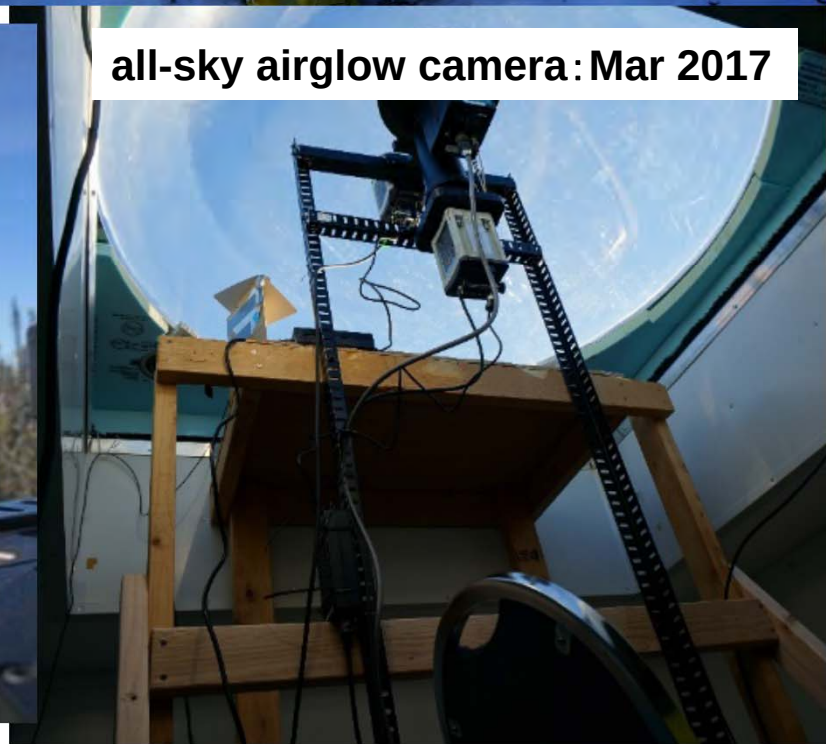
riometer：Oct. 2016



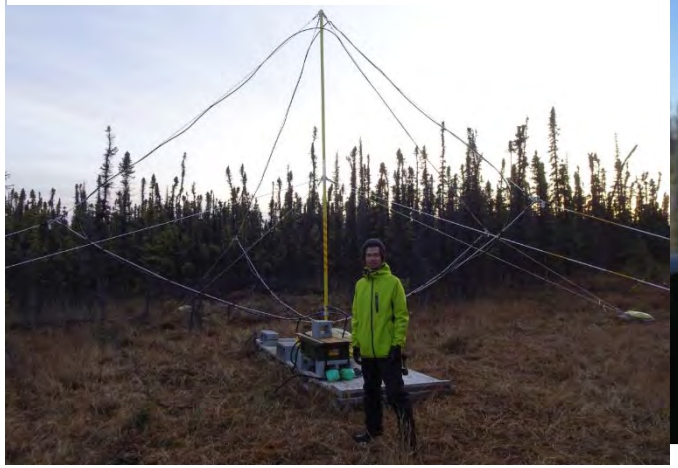
induction magnetometer：Mar 2017

EMCCD camera
Mar 2017

all-sky airglow camera：Mar 2017



VLF loop antenna：Sep.2017

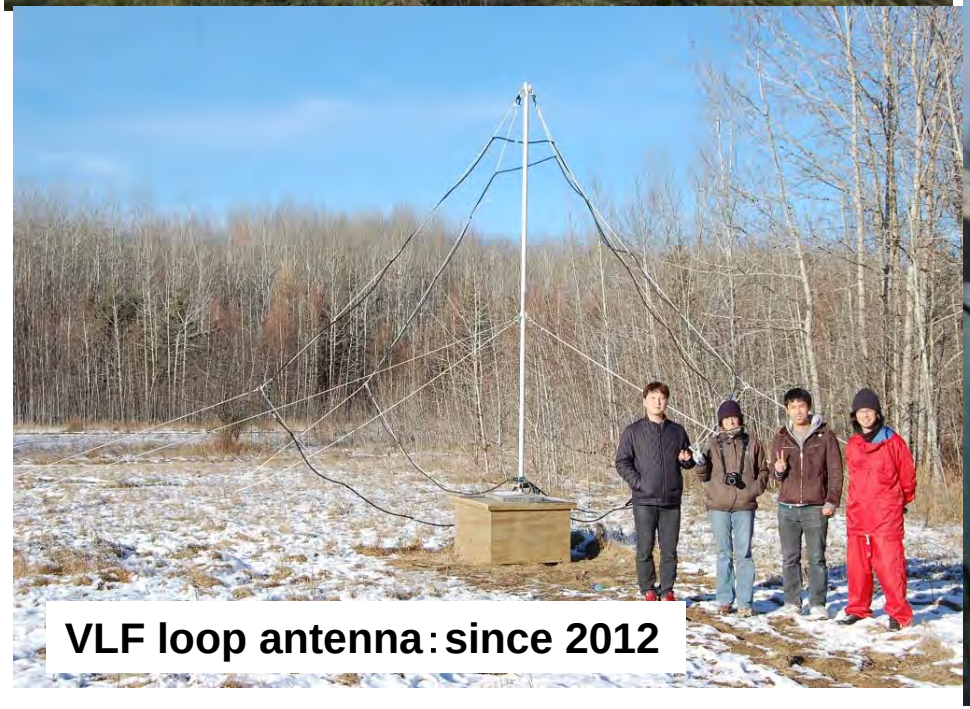


2. Athabasca, Canada

riometer：Oct. 2016

EMCCD camera：since 2014

induction magnetometer：Oct. 2016



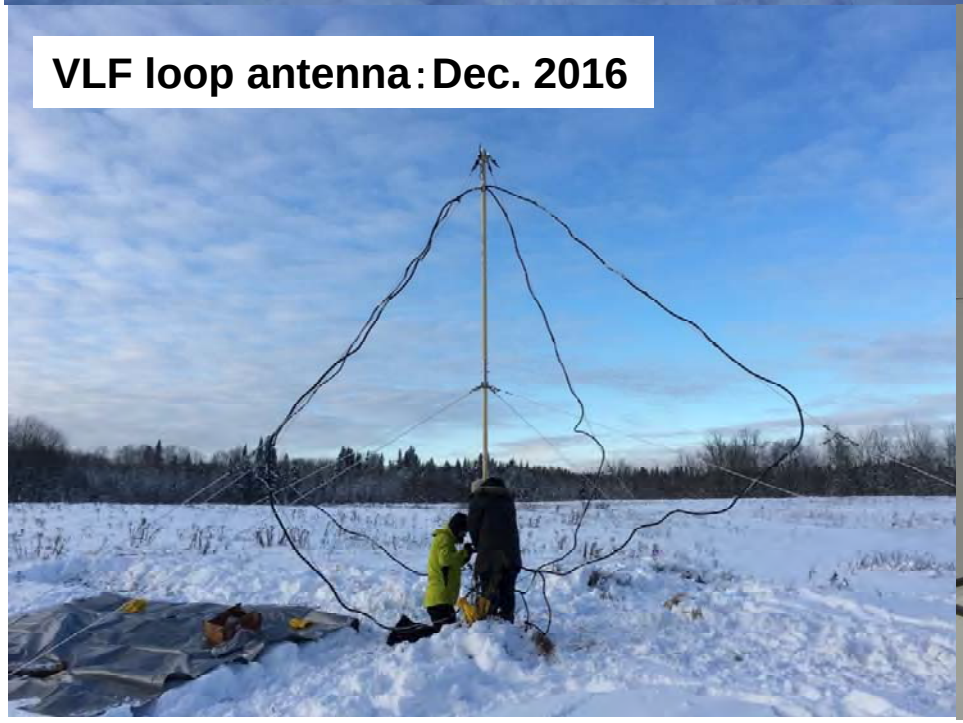
VLF loop antenna：since 2012

all-sky airglow camera：since 2005

3. Kapuskasing, Canada

riometer：Dec. 2016

induction magnetometer：Dec. 2016



VLF loop antenna：Dec. 2016

all-sky airglow camera：Feb. 2017

4. Nain, Canada

4 instruments are at the site, waiting for power installation

north

water tower
(N1 point)

Trousers Lake

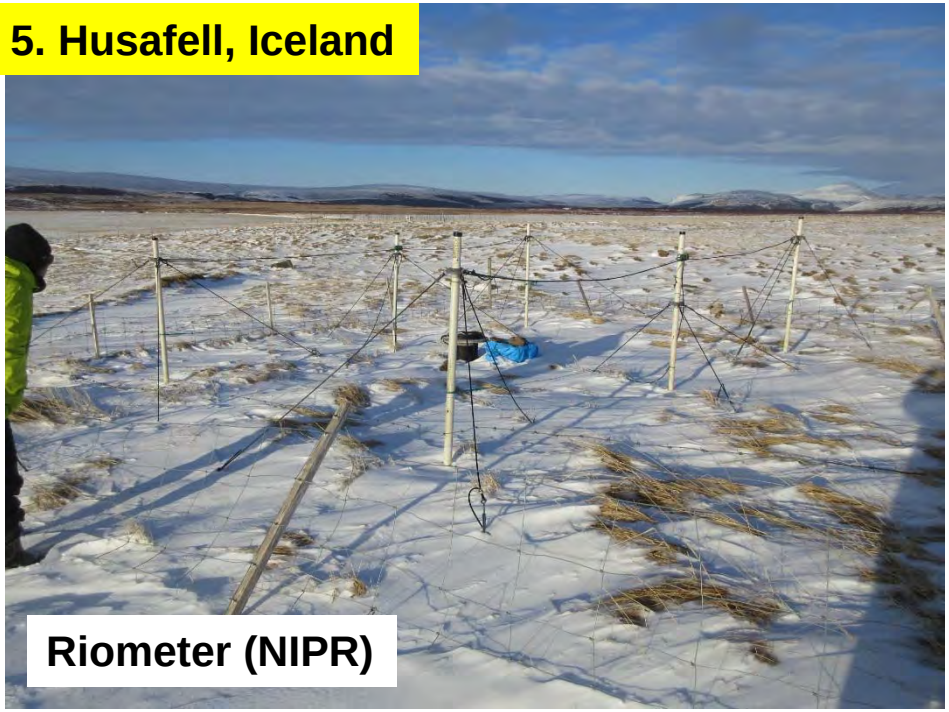
Sep.2016 (test measurements)

Sep.2017 (antenna installation

Nain downtown

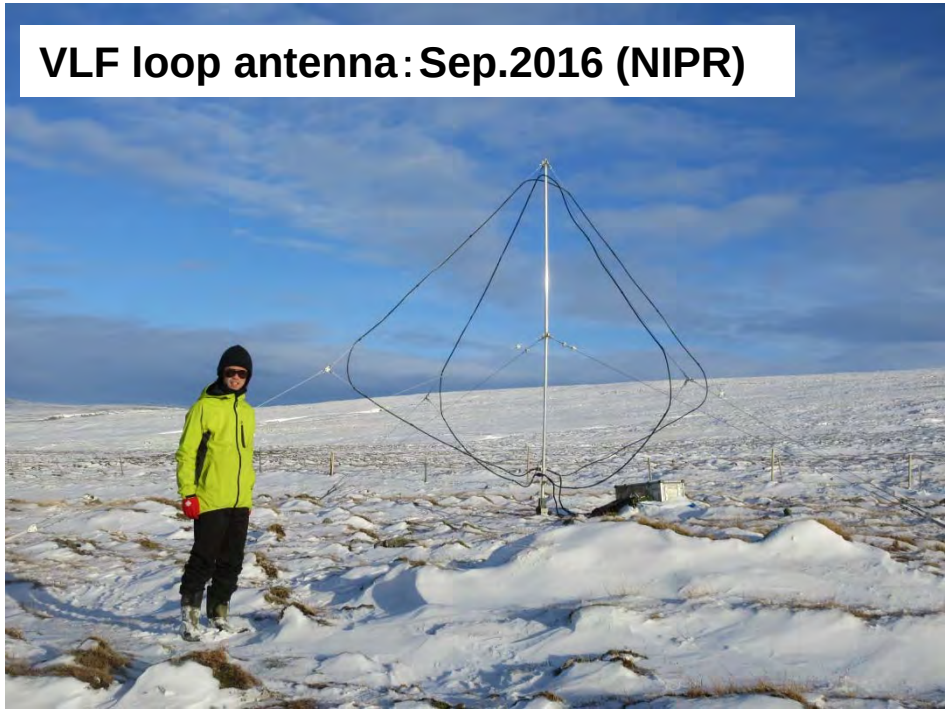
Sep.2018 (hut installation)

5. Husafell, Iceland



Riometer (NIPR)

induction magnetometer (NIPR→ISEE)



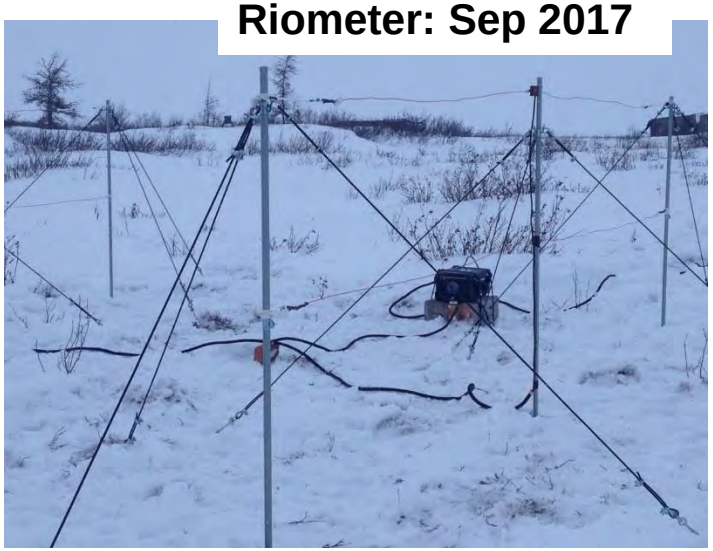
VLF loop antenna：Sep.2016 (NIPR)

all-sky airglow camera：Mar.2017

6. Nyrola & 9.Kevo, Finland

riometer、VLF loop antenna、induction magnetometer data will be provided by . Sodankylä Geophysical Observatory (SGO), Finland

7. Istok, Russia



8. Zhigansk, Russia

riometer：May 2017, test at Maimaga in IKFIA

induction magnetometer：Sep. 2016

VLF loop antenna：Apr. 2016, at Maimaga in IKFIA

all-sky airglow camera：at IKFIA, Yakutsuk

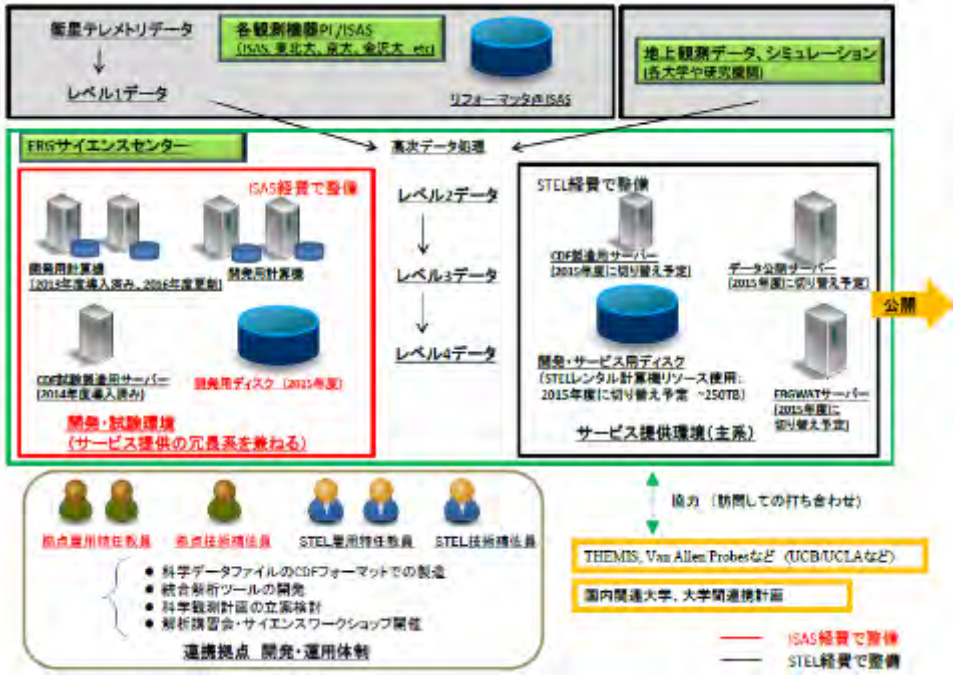
Current status of the installation (as of March, 2019)

	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

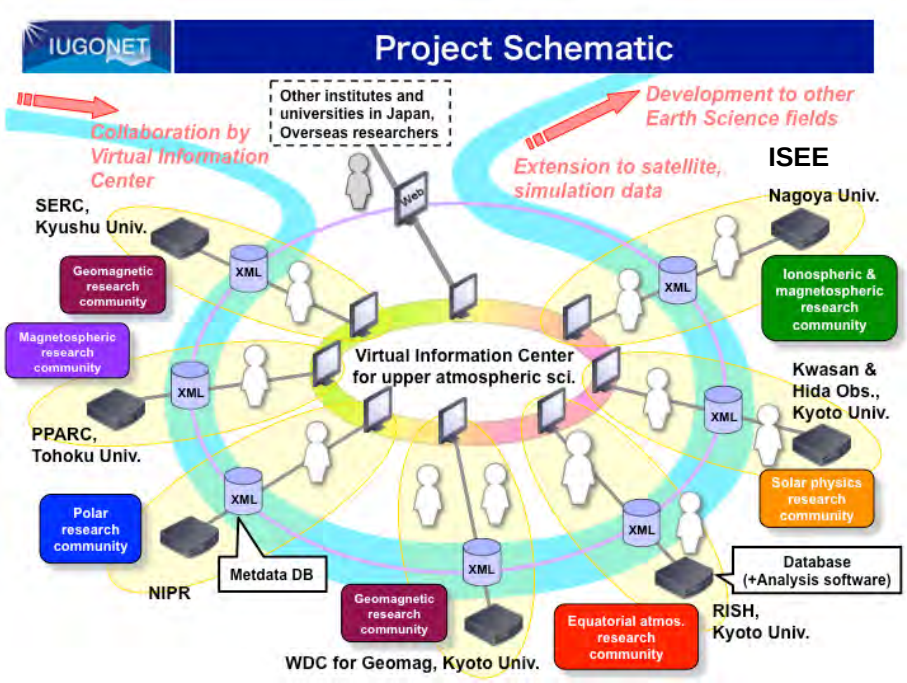
Database Construction

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

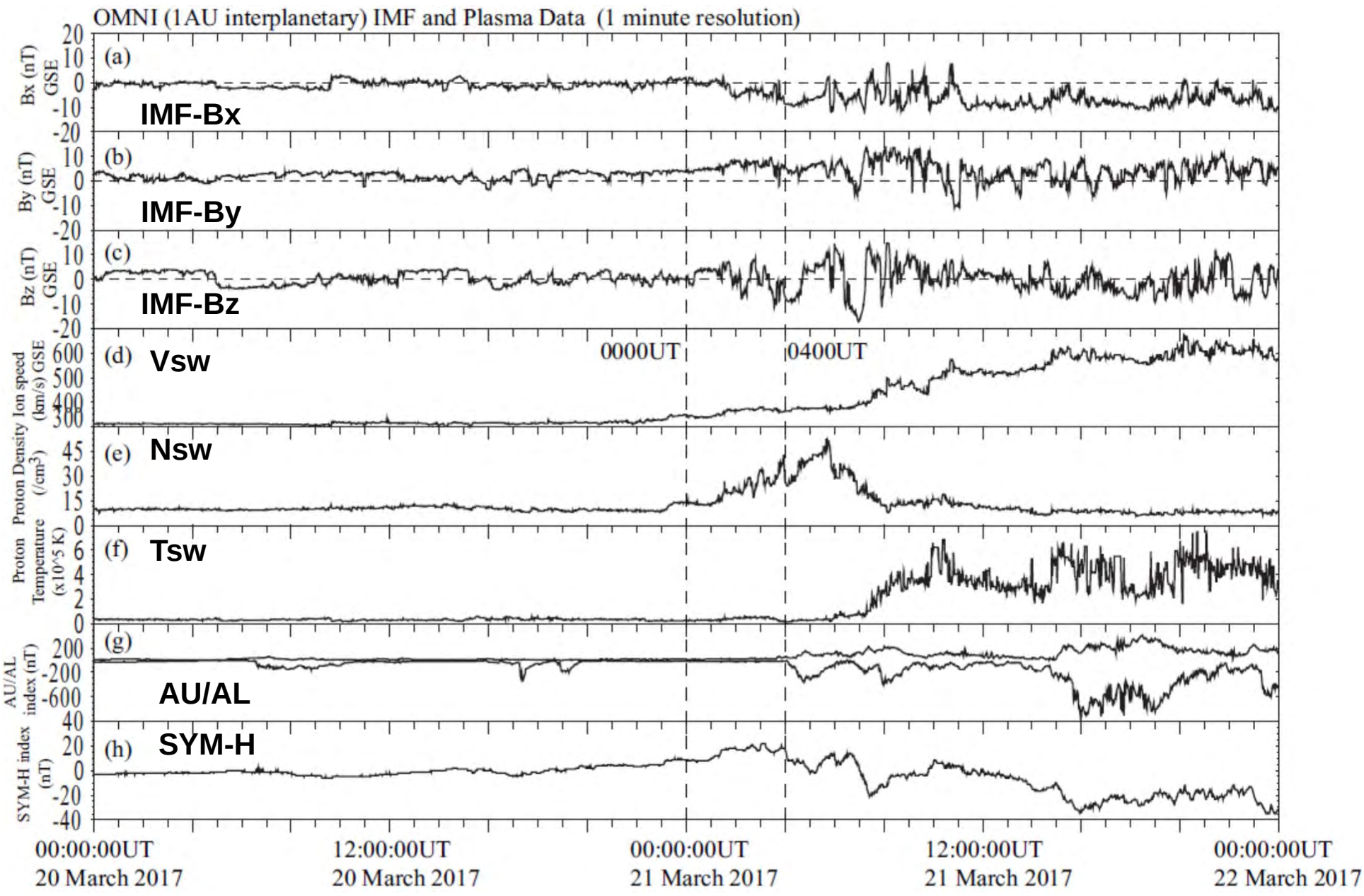
ERG Science Center



IUGONET

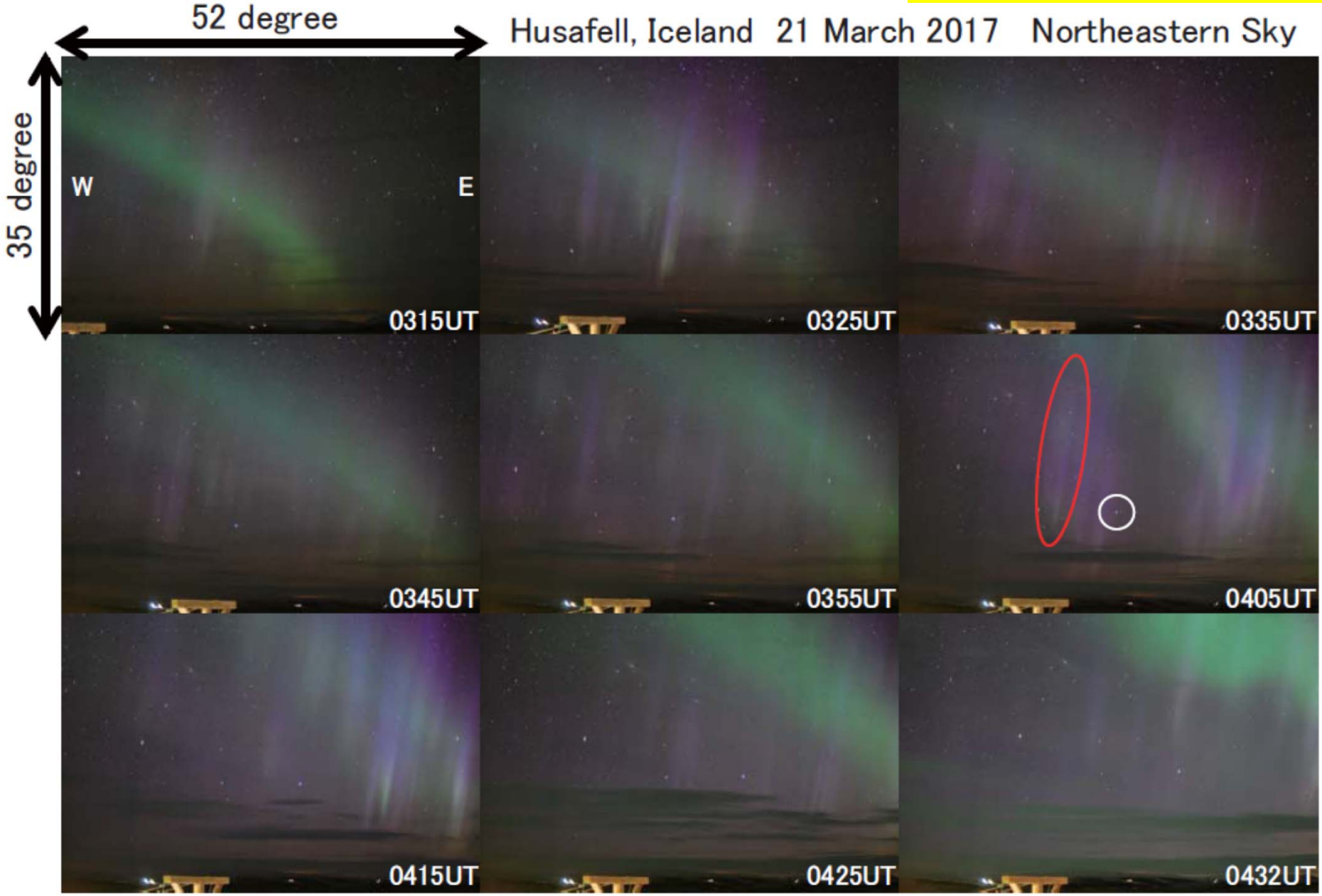


CIR arrival at the beginning of ERG-ground campaign



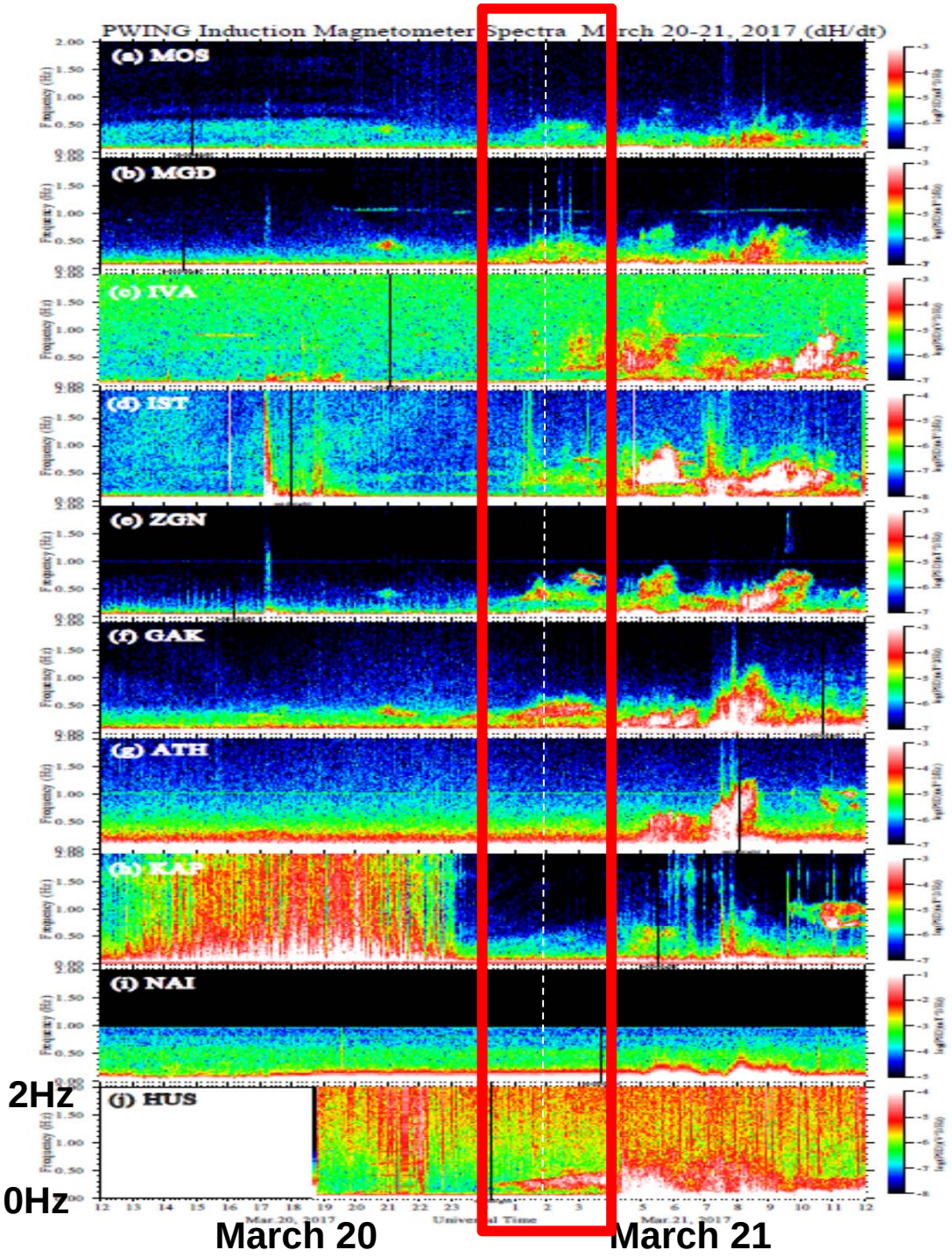
Shiokawa et al. (GRL, 2018)

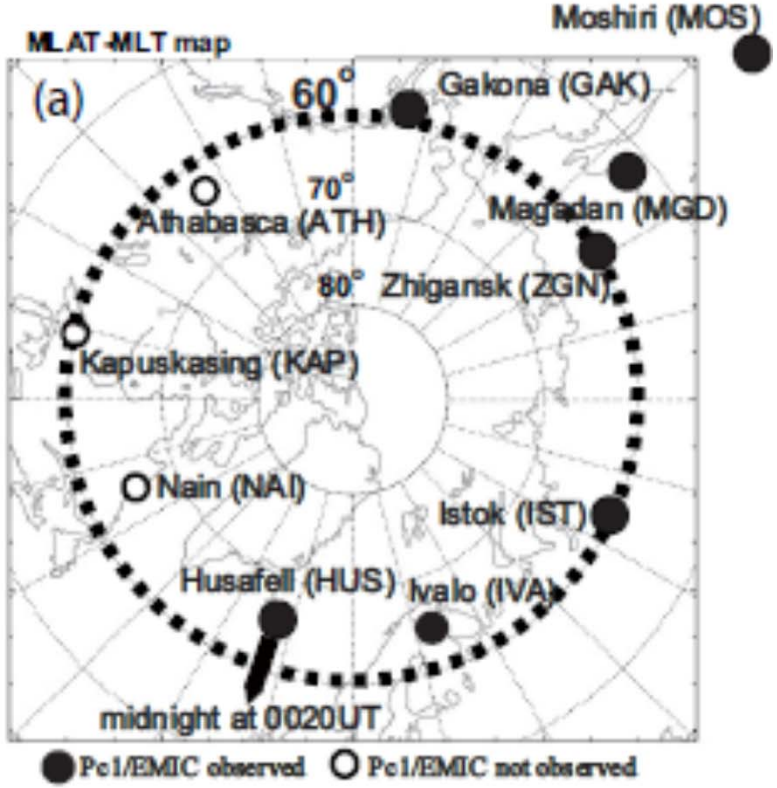
Purple aurora at CIR arrival

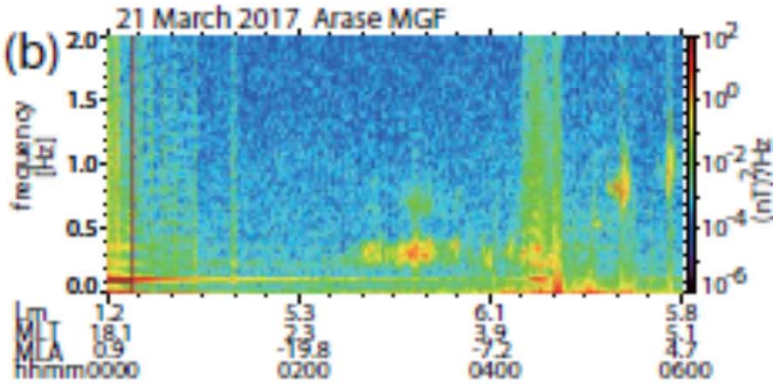


Shiokawa et al. (GRL, 2018)

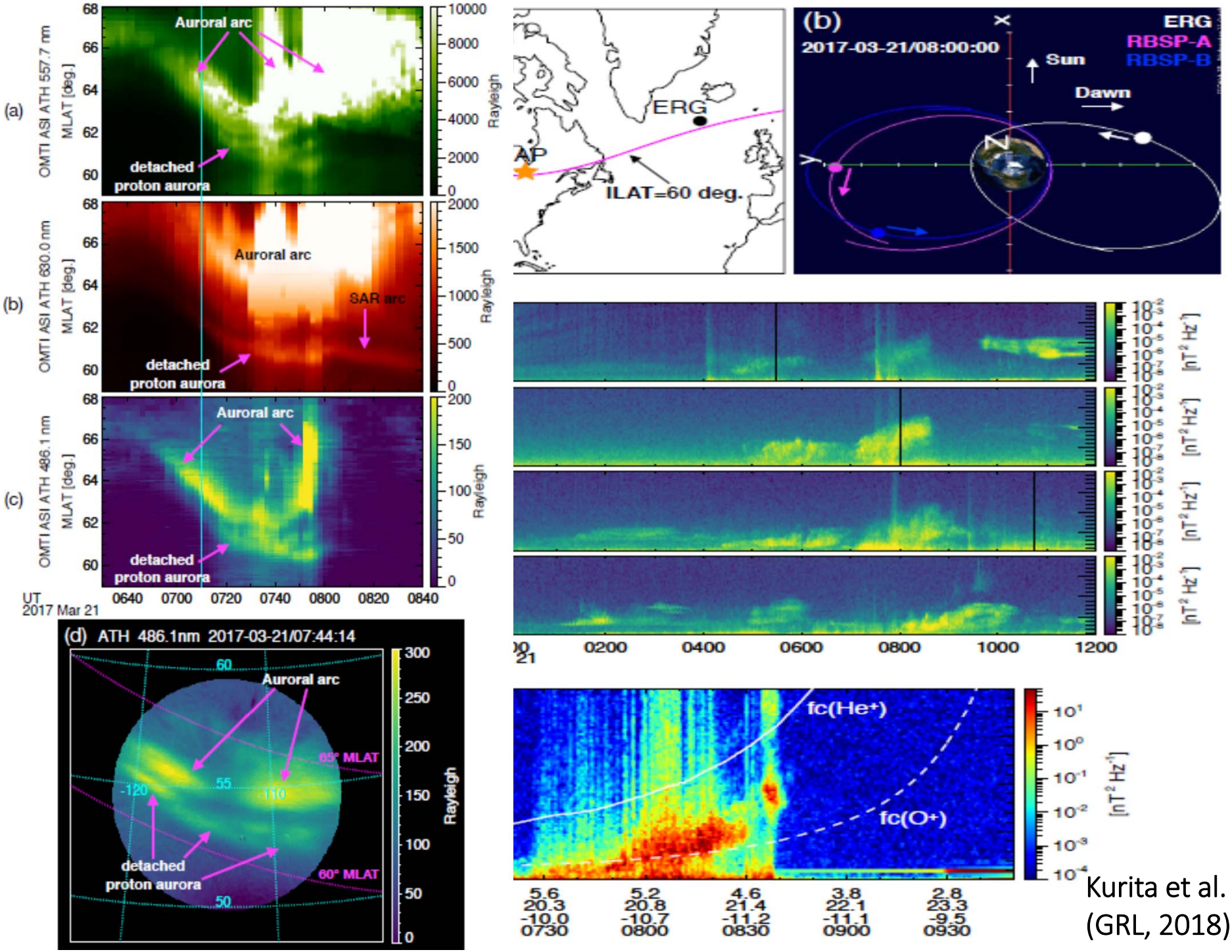
Pc1 on global scale (~13 hour LT) at CIR arrival



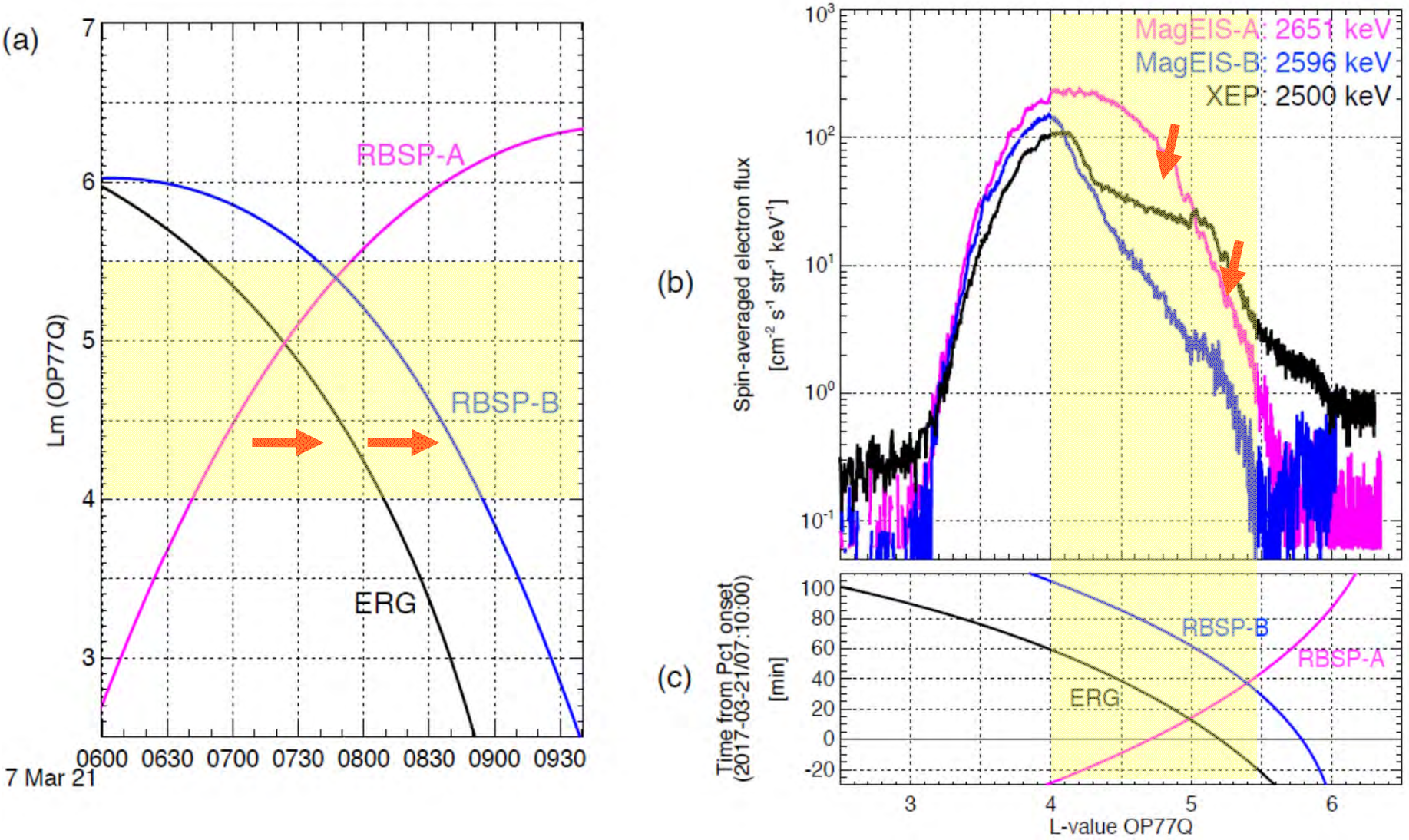




Shiokawa et al. (GRL, 2018)



Kurita et al.
(GRL, 2018)

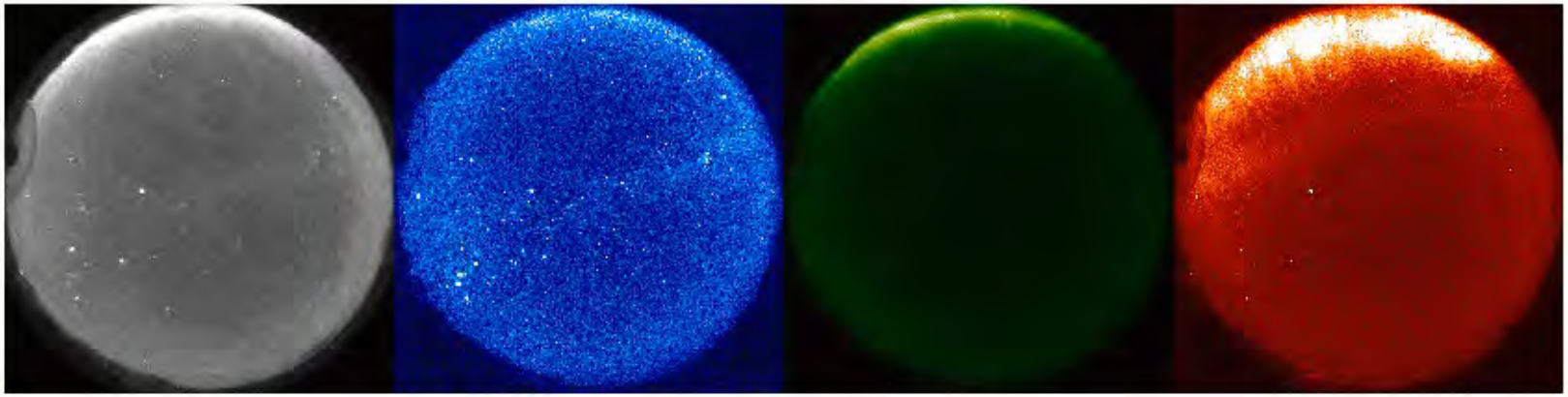


Kurita et al. (GRL, 2018)

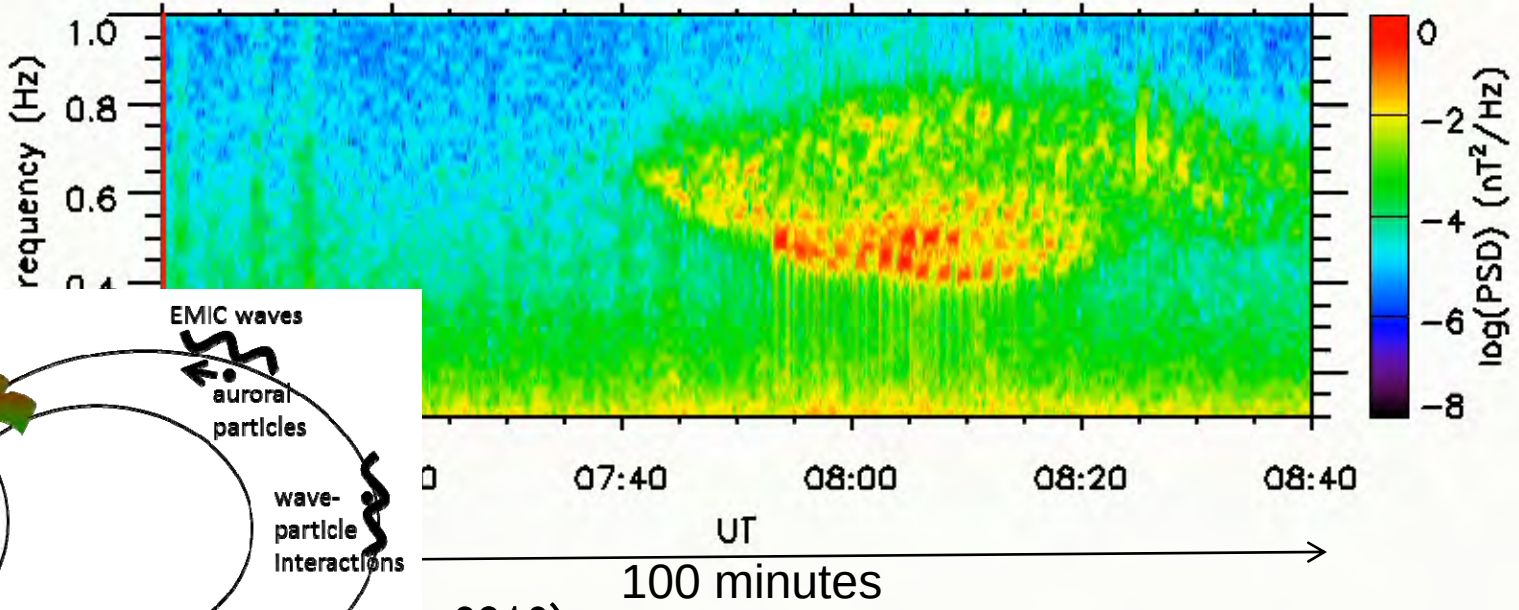
~2.5 MeV electron fluxes substantially decreased within a few tens of minutes where the EMIC waves were present.

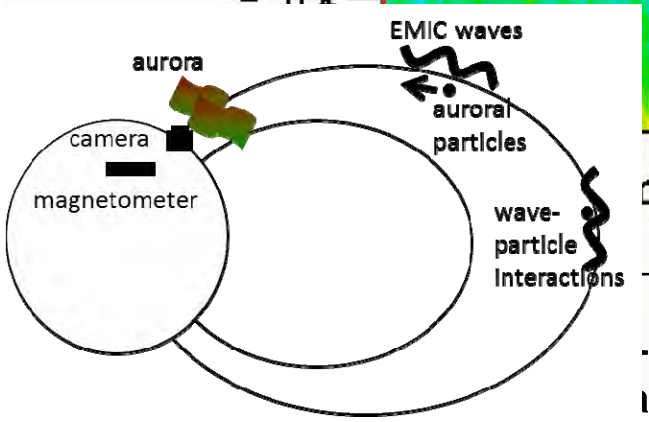
Isolated proton aurora and EMIC(Pc1) waves

07:00:00 UT, 12 November, 2015



BG3 HBETA (486.1 nm) 557.7 nm 630.0 nm

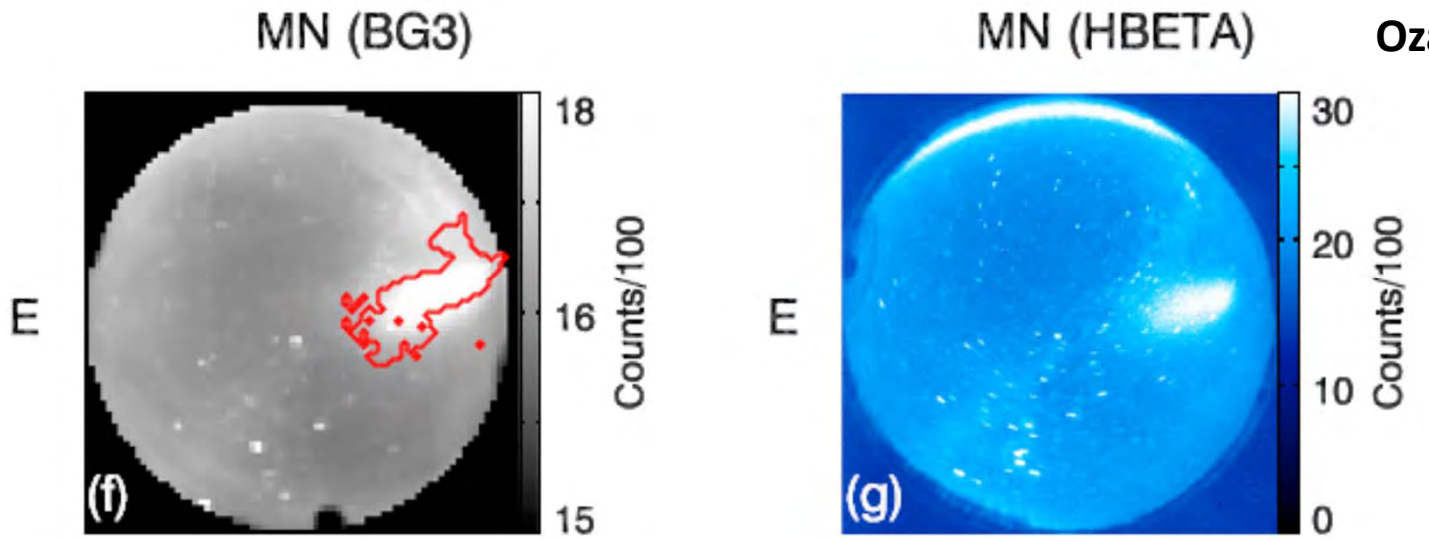


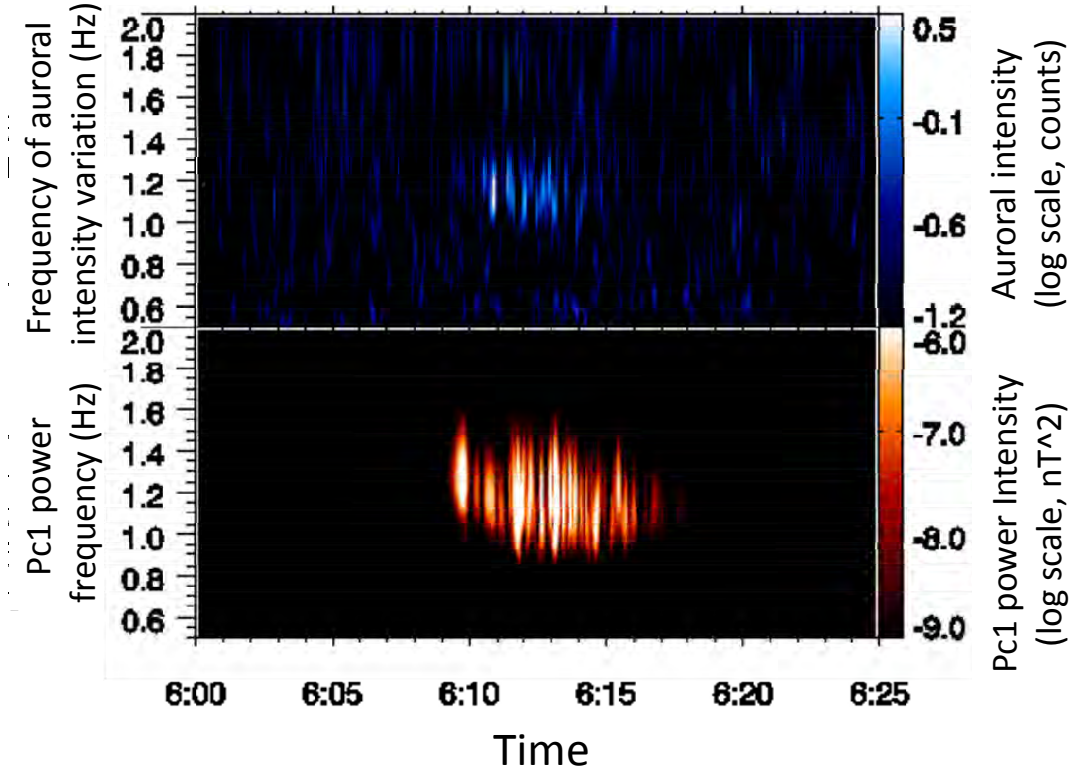


., 2016)

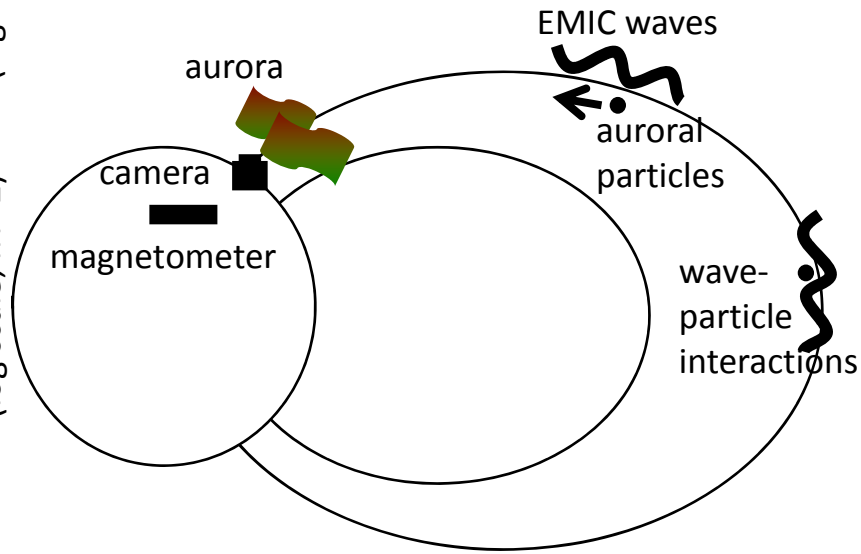
et al. (JGR, 2016) and Sakaguchi et al. (AGUbook, 2016)

Ozaki et al.(GRL, 2018a)

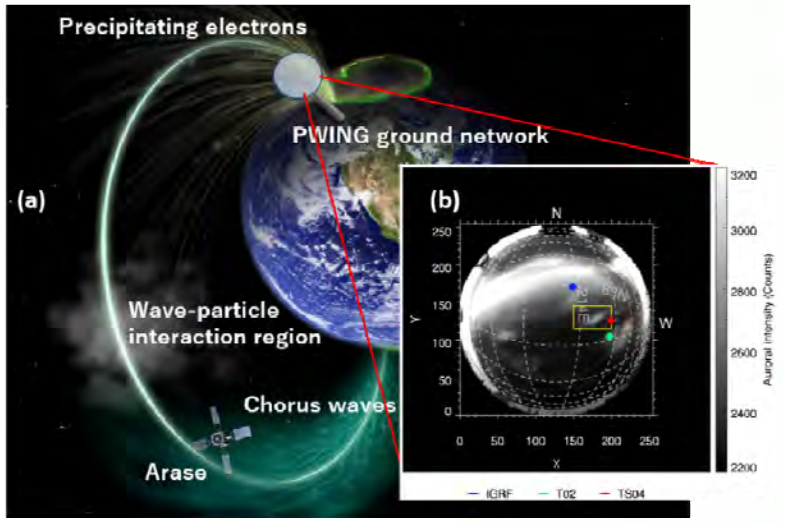


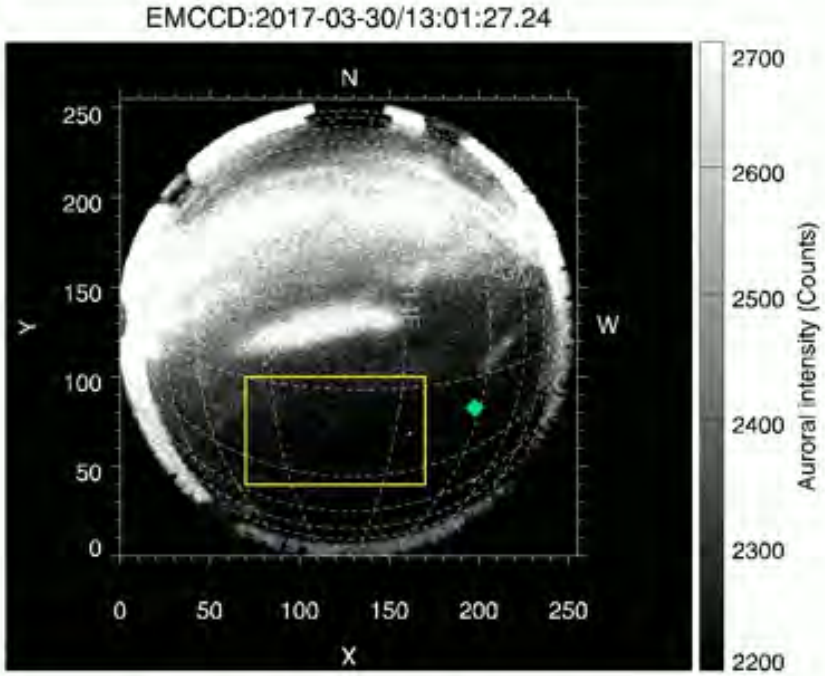


1-Hz oscillation in both Pc1/EMIC waves and corresponding isolated proton aurora.

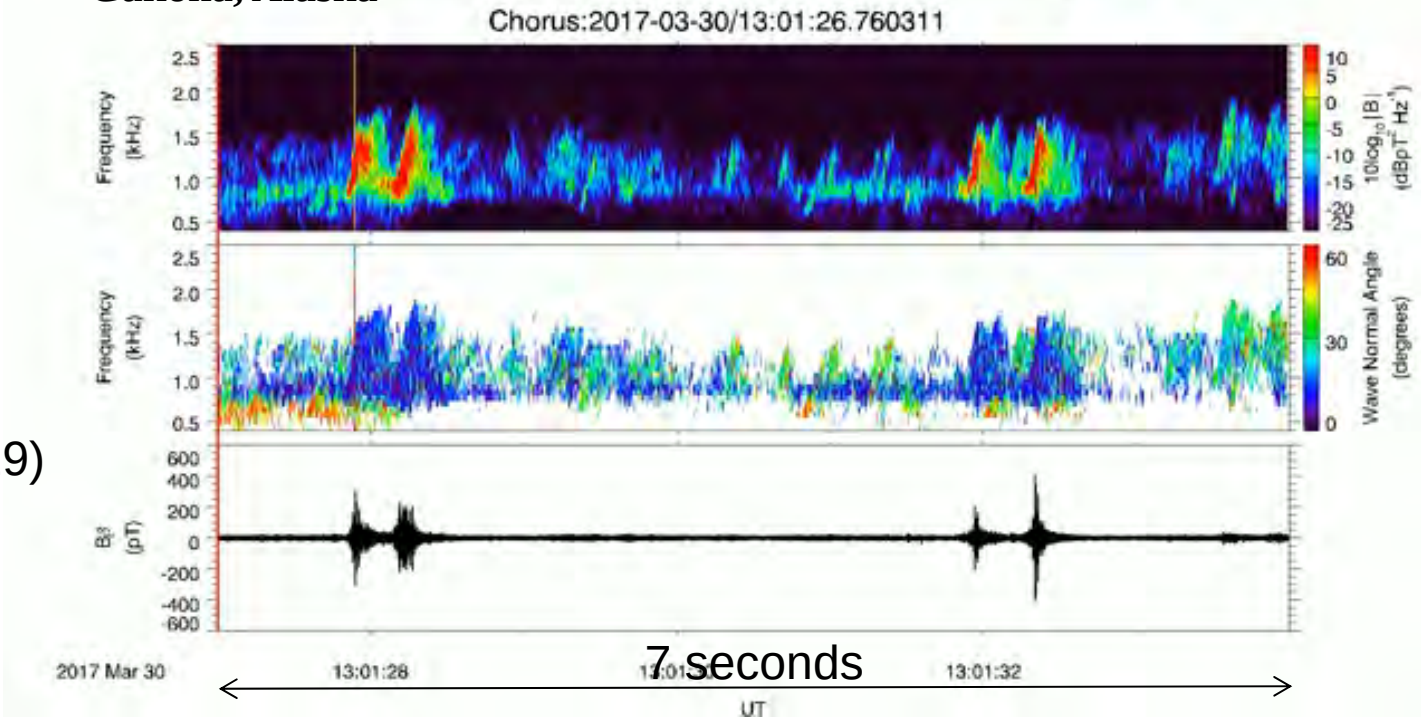


Pulsating aurora and chorus correspondence



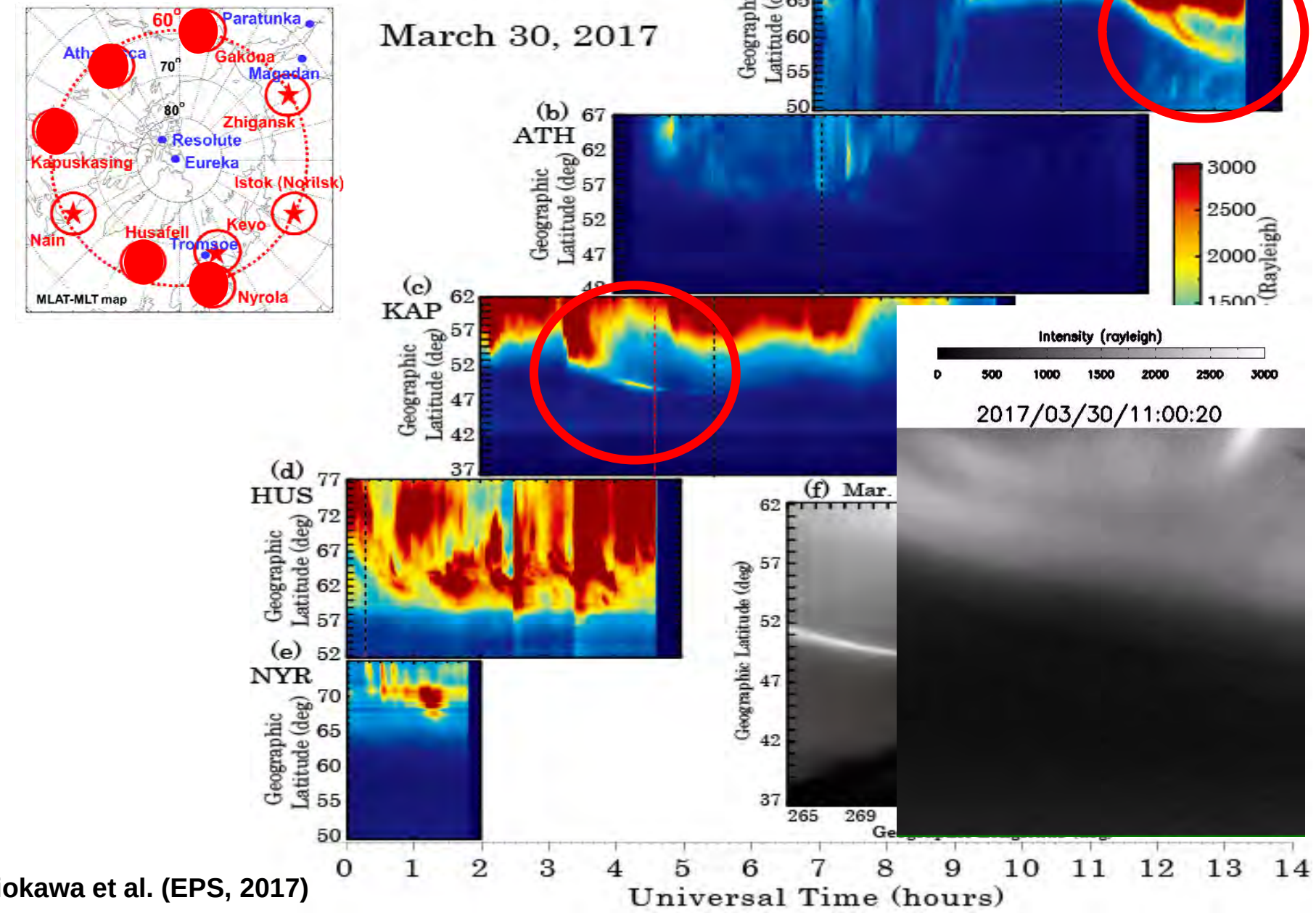


Gakona, Alaska



Ozaki et al.
(Nature Comm., 2019)

SAR arc detachment



Shiokawa et al. (EPS, 2017)

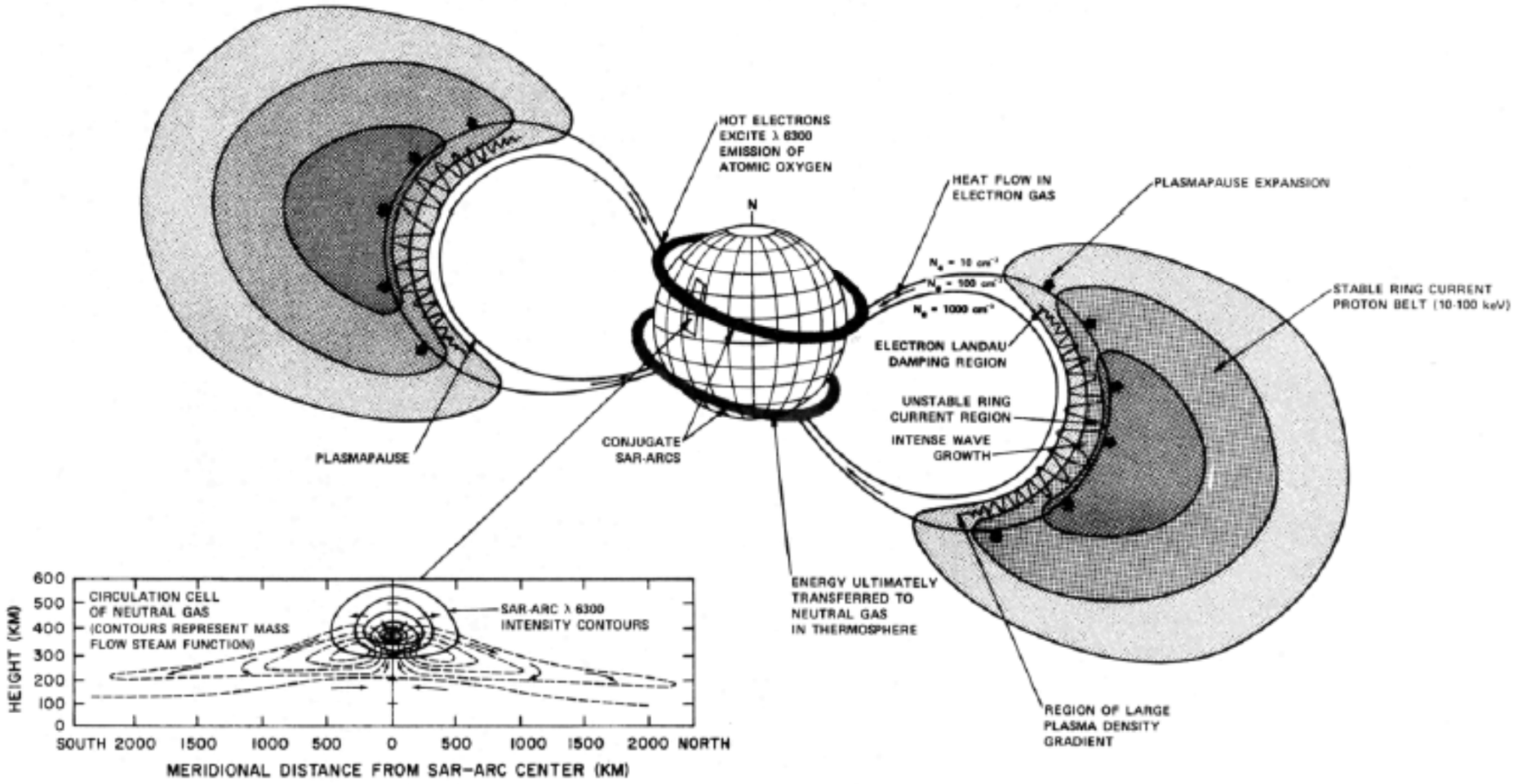
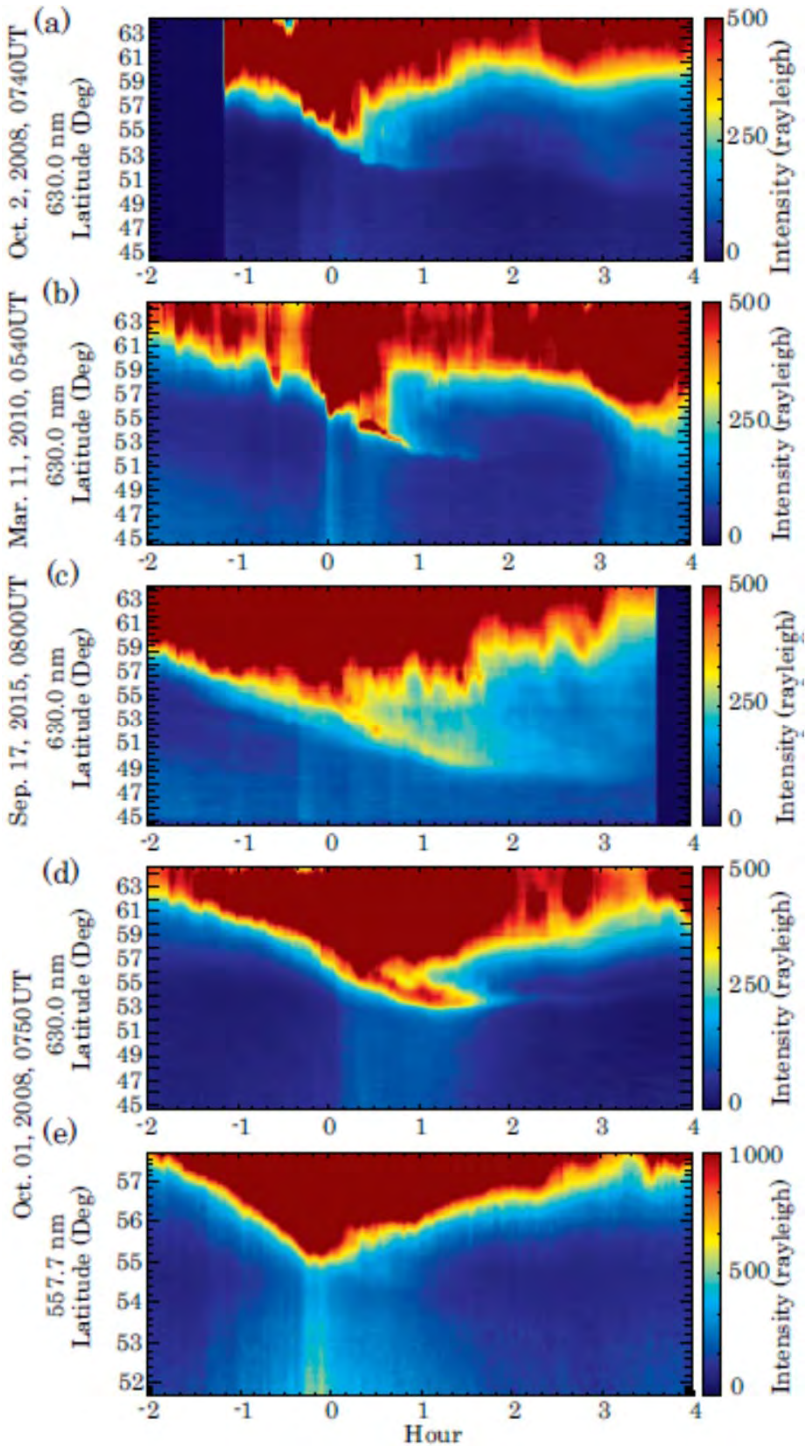
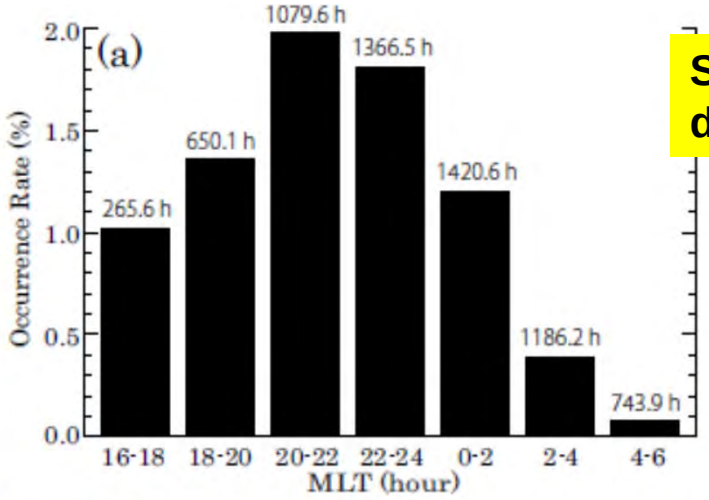
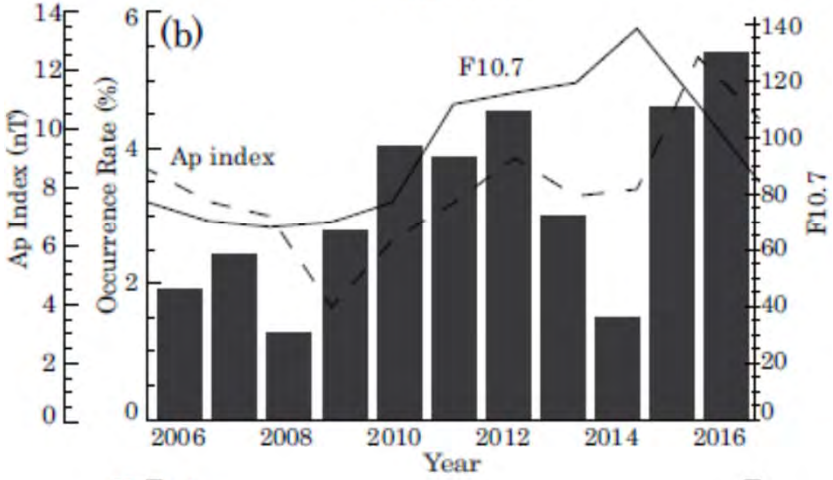


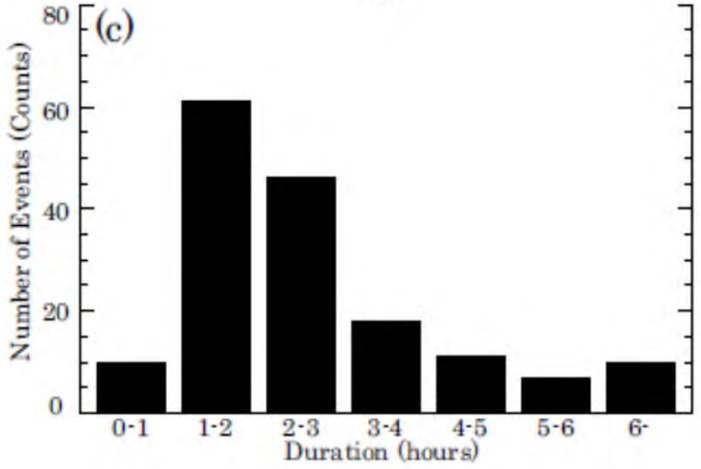
Fig. 43. Schematic diagram of the processes acting within an SAR arc.

Rees and Roble (RG, 1975)





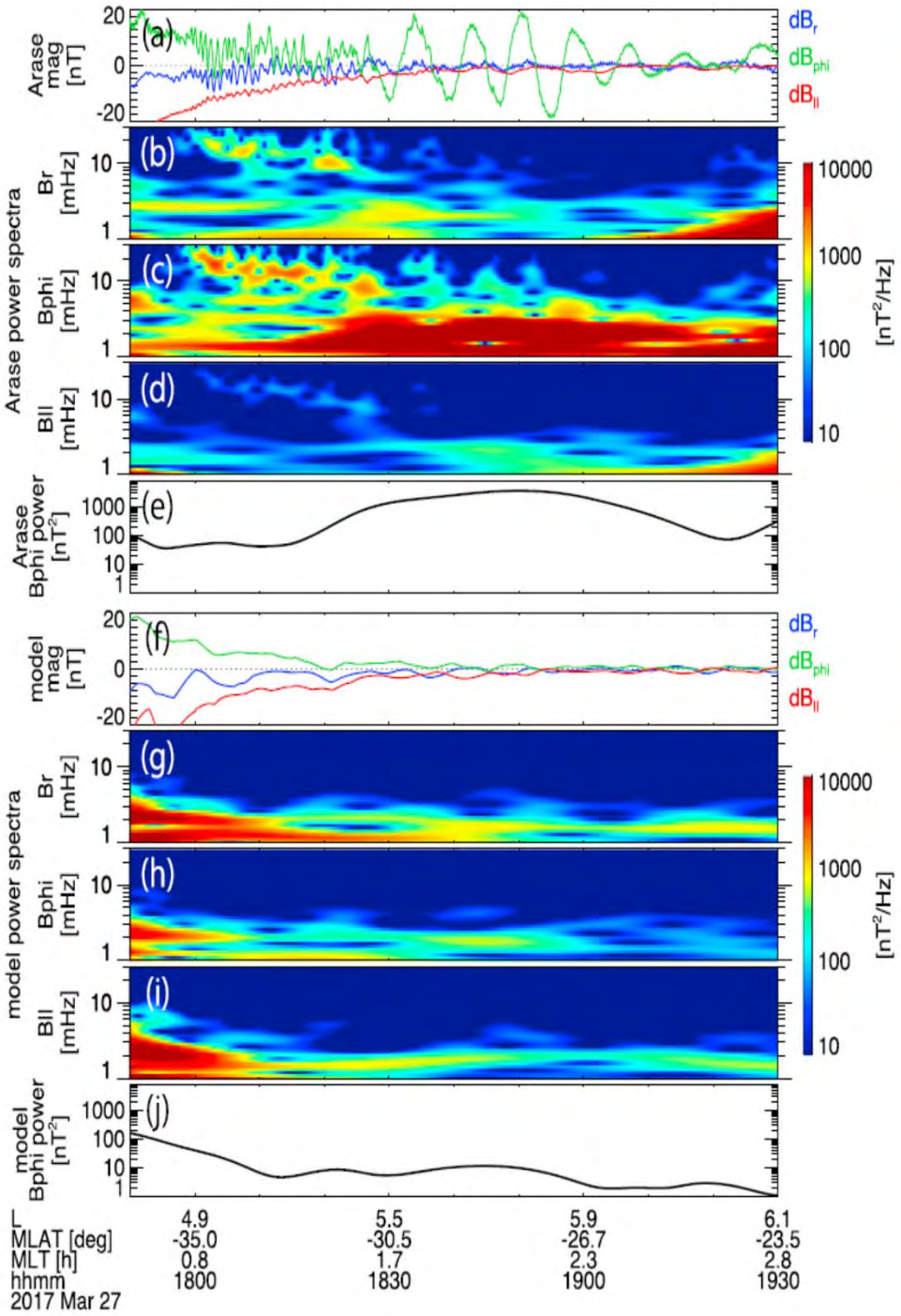


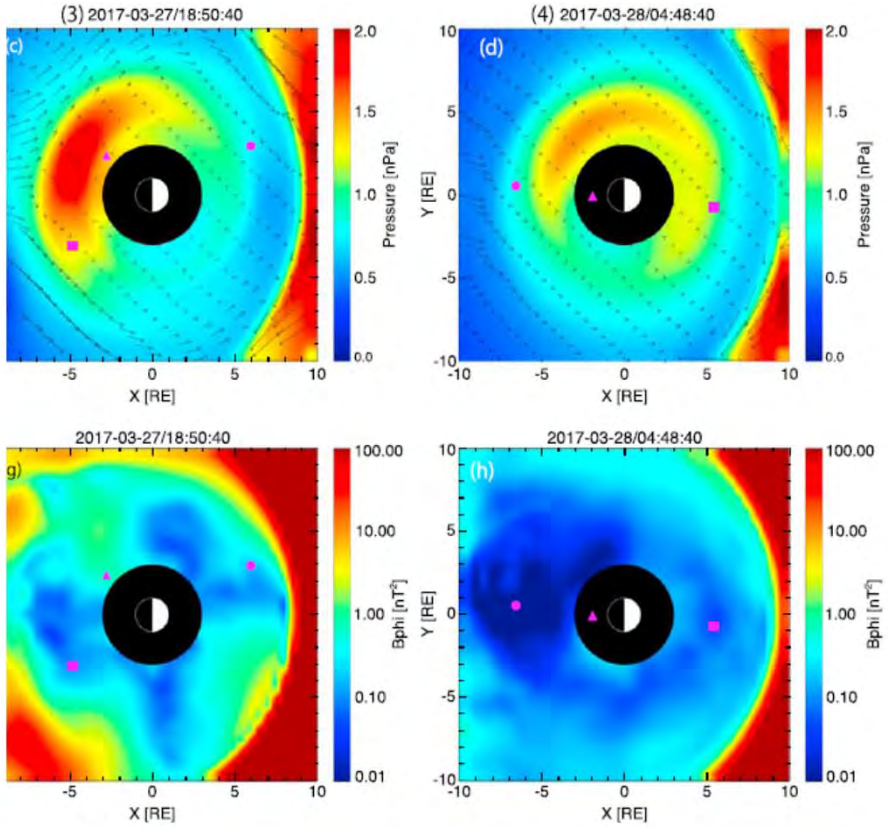


SAR arc detachment

163 events from 11 years

Takagi et al. (GRL, 2018)

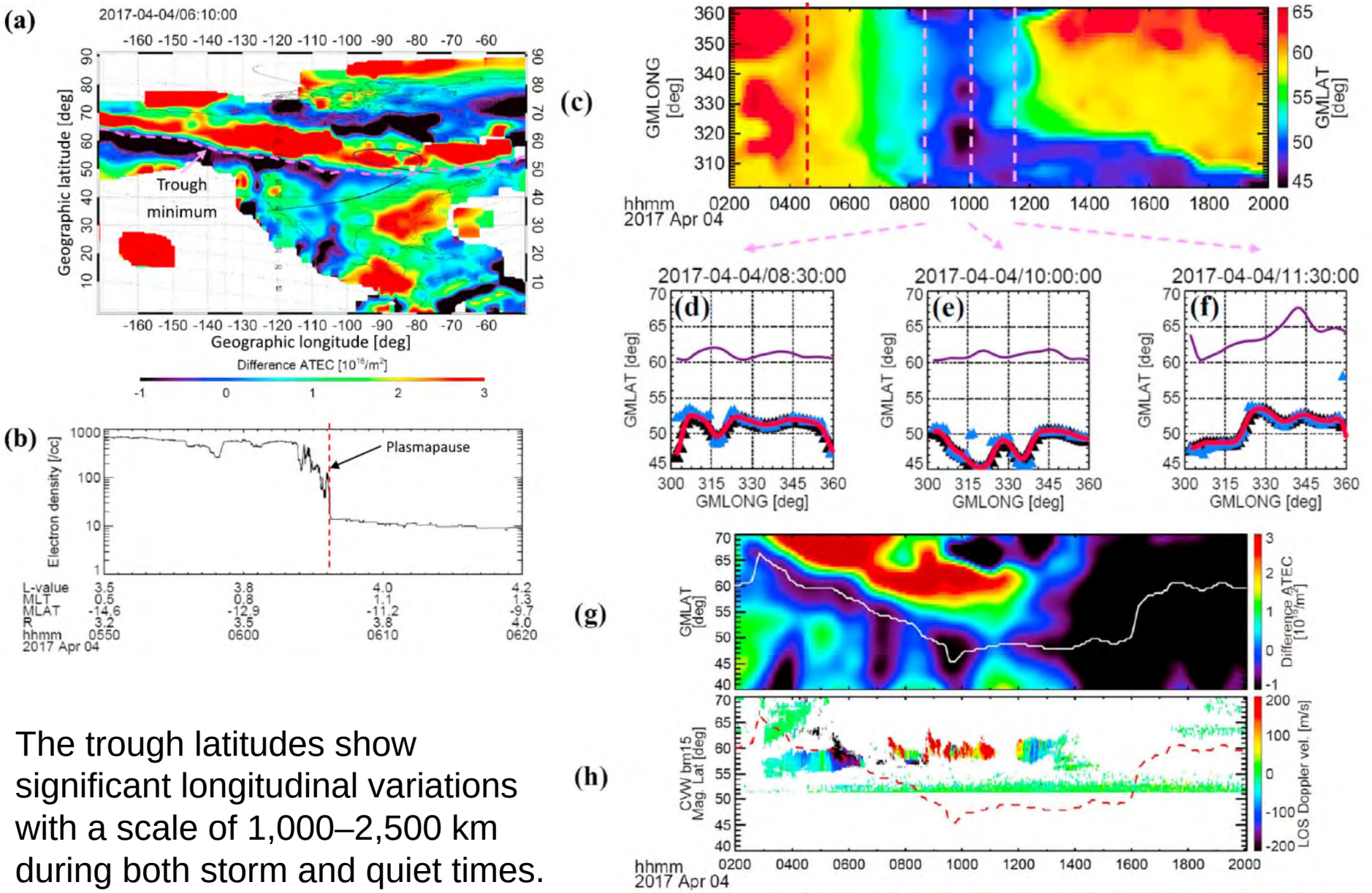




The BATURAS/CRCM simulation reproduced the 2-3mHz ULF waves observed by Arase associated with SW dynamic pressure, but the wave power is 1–2 orders smaller.

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

Takahashi et al. (GRL, 2018)



The trough latitudes show significant longitudinal variations with a scale of 1,000–2,500 km during both storm and quiet times.

Shinbori et al. (GRL, 2018)

Figure 4. (a–c) Time series plot of the *AE* and *SYM-H* indices and contour plot of the trough minimum location as a function of time and geomagnetic longitude; (d–f) the cross sections in (c) at 08:30, 10:00, and 11:30 (UT); and the (g and h) GNSS-TEC keogram and ionospheric plasma flow in the beam-15 direction observed with the SuperDARN radar at Christmas Valley west. The color bars in (c), (g), and (h) show the geomagnetic latitude of the trough minimum location, the difference TEC value, and Doppler velocity in the beam-15 direction. The red dashed line in (a)–(c) indicates the storm commencement, and the three dashed pink lines in (c) represents the time of the three bottom panels. The blue and black triangles (or red line) in panels (d) and (e) show the trough minimum location determined by the raw and smoothing data. The purple line indicates the trough minimum location during a geomagnetically quiet day on 16 April 2017. The white and red dashed lines in (g) and (h) represent the trough minimum location.

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).