CHAMP and Ground-Based Airglow Measurements of Plasma Density Perturbations in the Top-/Bottom-Side Ionosphere Associated with MSTIDs

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Challenging Mini-Satellite Payload (CHAMP)

The Challenging Mini-satellite Payload (CHAMP) was launched in 2000 into a circular orbit with inclination angle of 87°. The altitude of 456 km and gradually decayed to 300 km in 2010. The orbital plane slowly precesses sweeping all local time sectors in 131 days.

Planar Langmuir Probe (PLP) measures the plasma density every 15 s.

—— PLP data were used in this study

Tri-Axial Accelerometer (ACC) measures air mass density every 10s.

Fluxgate Magnetometer (FGM) and **Overhauser Magnetometer (OVM)** measure the magnetic field with sampling frequencies of 50 and 1 Hz, respectively.

MSTIDs with CHAMP Measurements

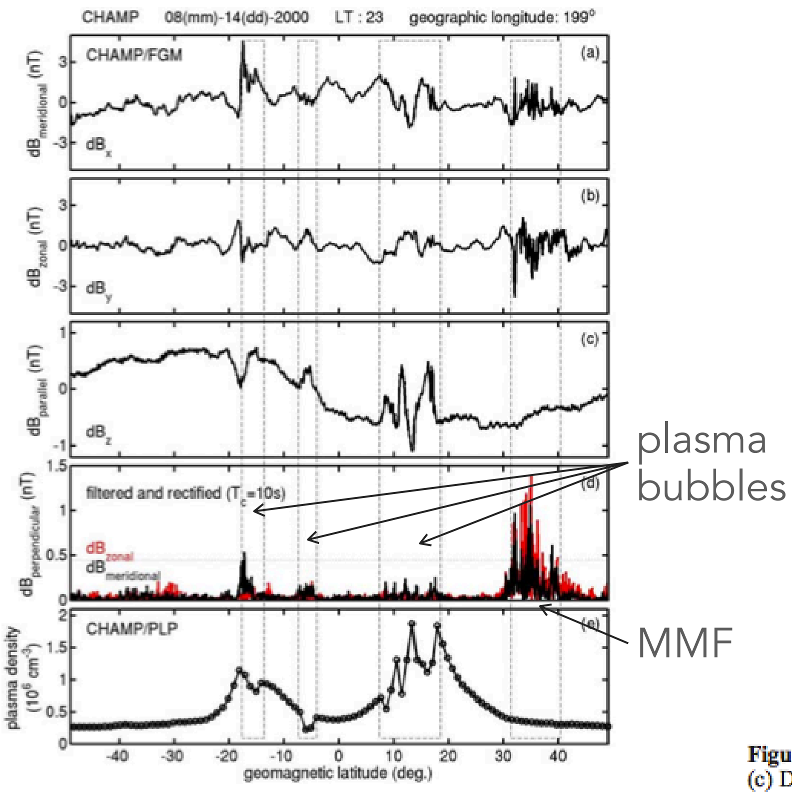


Figure 1. A typical example of midlatitude magnetic field fluctuation (MMF) at ~32°–42° latitude. (a–c) Three respective components of residual magnetic field in mean-field-aligned coordinates. (d) Zonal and meridional components which have been high-pass filtered with a cutoff period of 10 s and then rectified. (e) Plasma density measured by CHAMP/PLP.

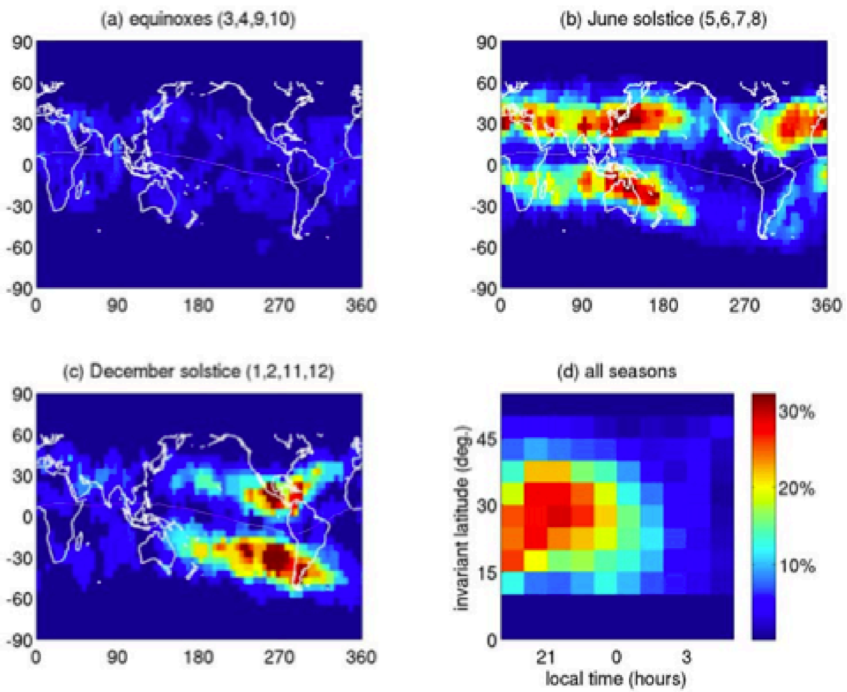


Figure 2. Global distribution of occurrence rates of MMFs during (a) equinoxes, (b) June solstice, and (c) December solstice for the years 2001 and 2002. (d) Occurrence distribution as a function of invariant latitude versus local time. Note that the ILAT range of our analysis is limited to values below |52°|.

Park et al. (2009, JGR)

The midlatitude magnetic field fluctuations (MMFs) and night-time **Medium-Scale Traveling Ionospheric Disturbances (MSTIDs)** are compatible with each other: MMF occurrence is generally consistent with known features of MSTIDs, such as the conjugate climatology and premidnight occurrence peak in the east Asia/Oceania region.

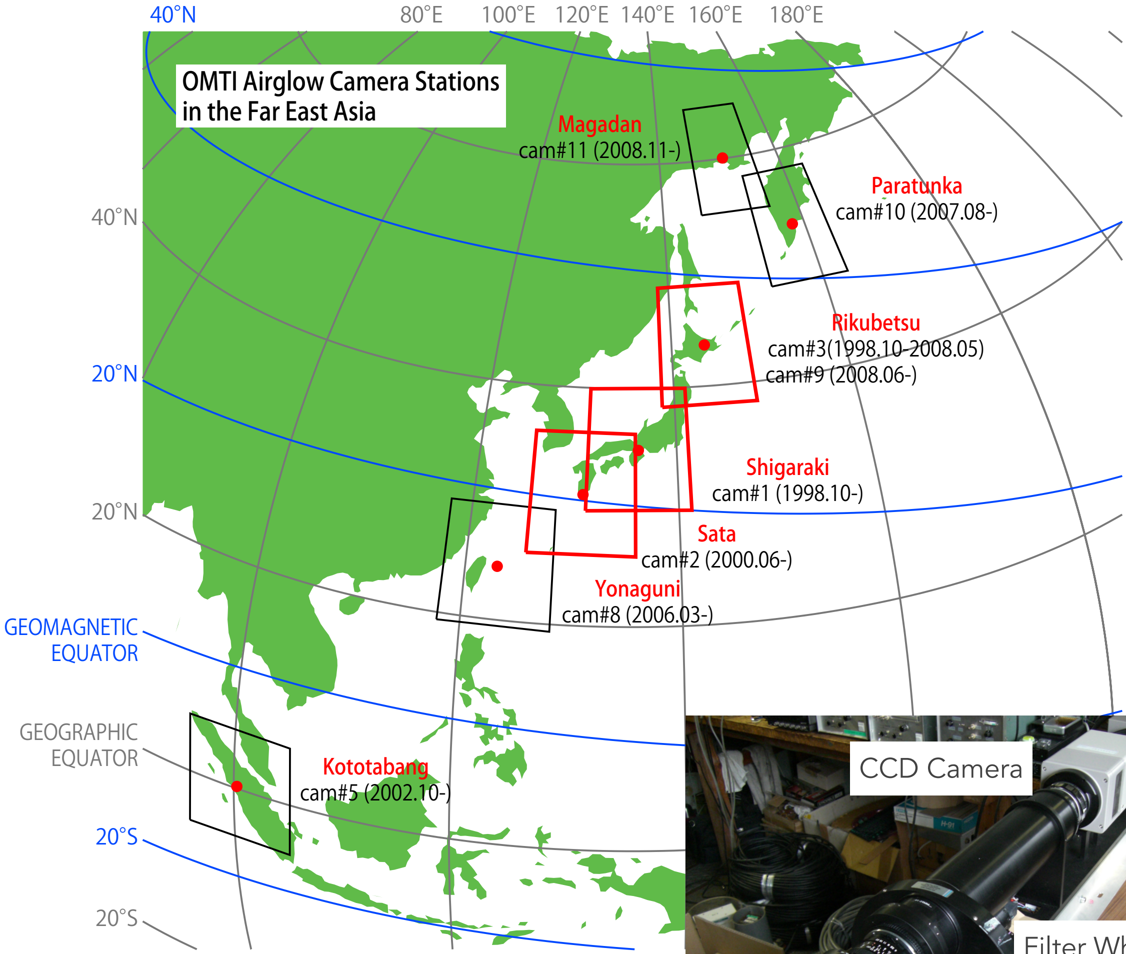
Purpose of This Study

The MMF signatures involving plasma density fluctuation were excluded as plasma bubbles or blobs in the Park et al's work.
However...

- MMFs at the topside ionosphere and MSTIDs at the bottomside ionosphere can coexist at different altitudes [Park et al., 2009]
- Some studies [e.g., Shiokawa et al., 2003] showed that MSTIDs can accompany plasma density fluctuations at the topside ionosphere.

In this study, we aim to **detect plasma density perturbations associated with MSTIDs at the CHAMP altitude (approx. 400 km: topside ionosphere) from the conjugate observations with CHAMP/PLP and ground based airglow imager measurements**.
Airglow imaging technique can distinguish MSTID structures from other ionospheric irregularities. Our setup allows to make conjugate examination of spatial association between plasma density perturbations at the topside and bottomside ionosphere induced by MSTIDs.

Ground-Based Airglow Imaging Network (OMTI)



Optical Mesosphere and Thermospshere Imagers (OMTIs) have monitored mesospheric waves and ionospheric structures.

In this study, we use 630-nm airglow data obtained at midlatitude stations:

Rikubetsu (RIK)
43.5°N, 143.8°E
MLAT: 34.7°

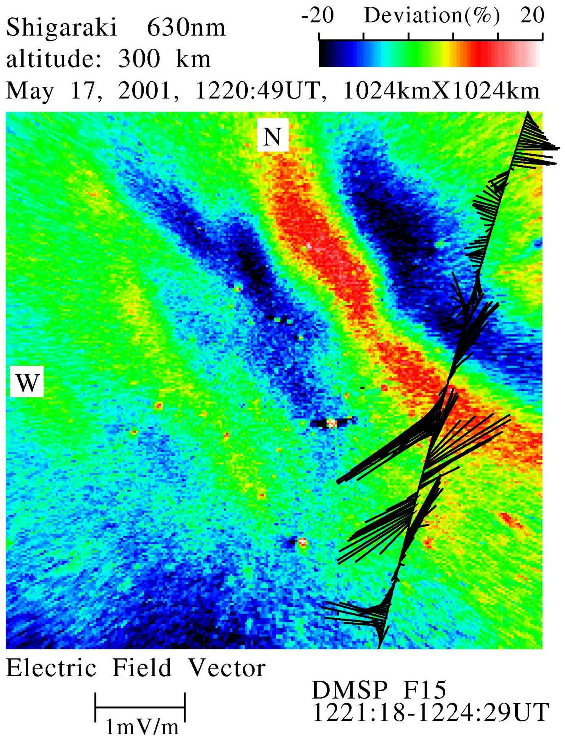
Shigaraki (SGK)
34.8°N, 136.1°E
MALT: 25.4°

Sata (STA)
31.0°N, 130.7°E
MLAT: 21.2°

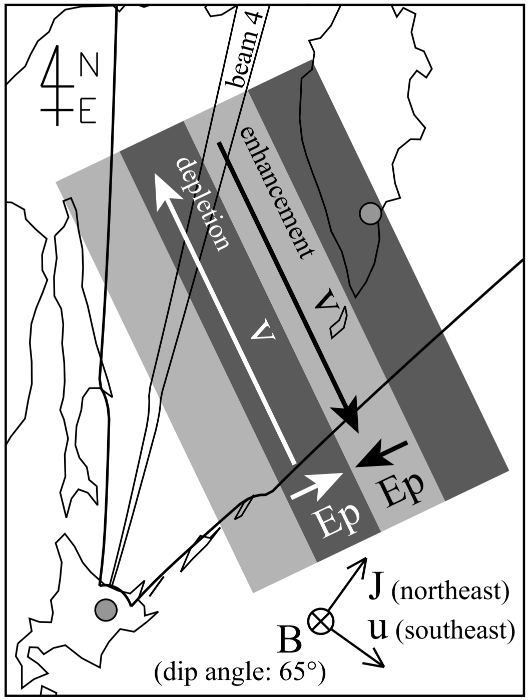
MSTID Structures in 630-nm Airglow

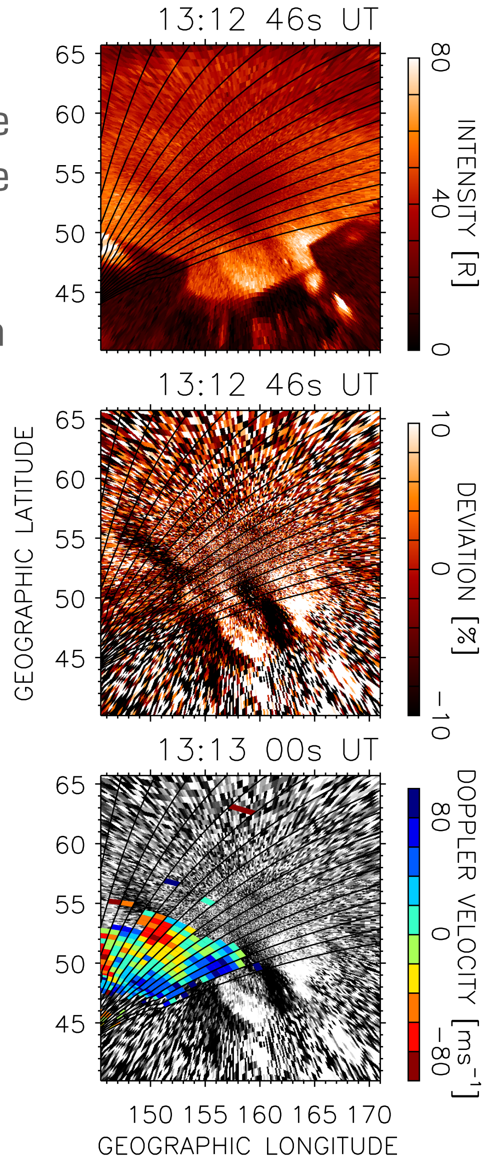
The MSTIDs are accompanied by electric field perturbations:

The DMSP ion drift measurements show that the polarization electric filed oscillation correlated with the MSTID structure in the airglow images [Shiokawa et al., 2003]. The Doppler velocities of FAI echoes observed by the SuperDARN radar showed that systematic polarity changes due to **E** x **B** plasma drifts were in agreement well with the airglow intensity variations [Suzuki et al., 2009].



Shiokawa et al. (2003, JGR)





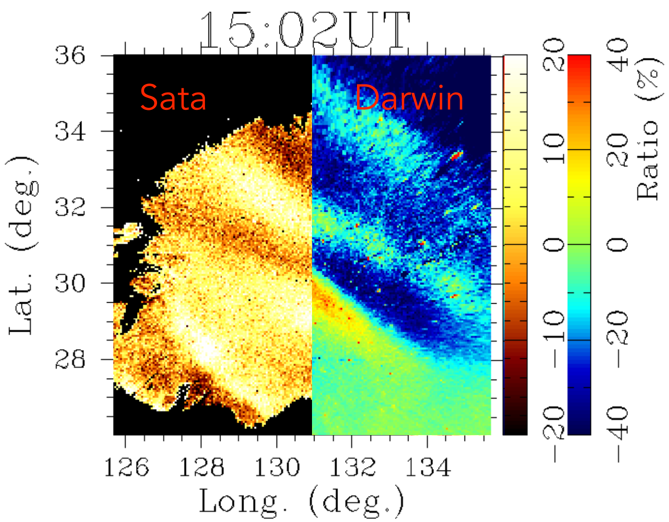
Suzuki et al. (2009, JGR)

MSTID Structures in 630-nm Airglow

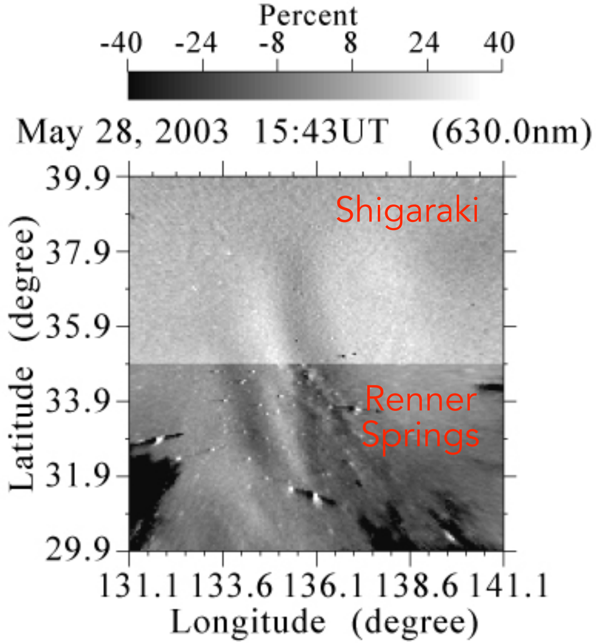
The MSTIDs show the geomagnetic conjugacy:

The polarization electric field maps along the geomagnetic field lines and moves the F region plasma upward or downward by **E** x **B** drift, causing plasma density perturbations with MSTID structures mirrored in the northern and southern hemispheres [Otsuka et al., 2004].

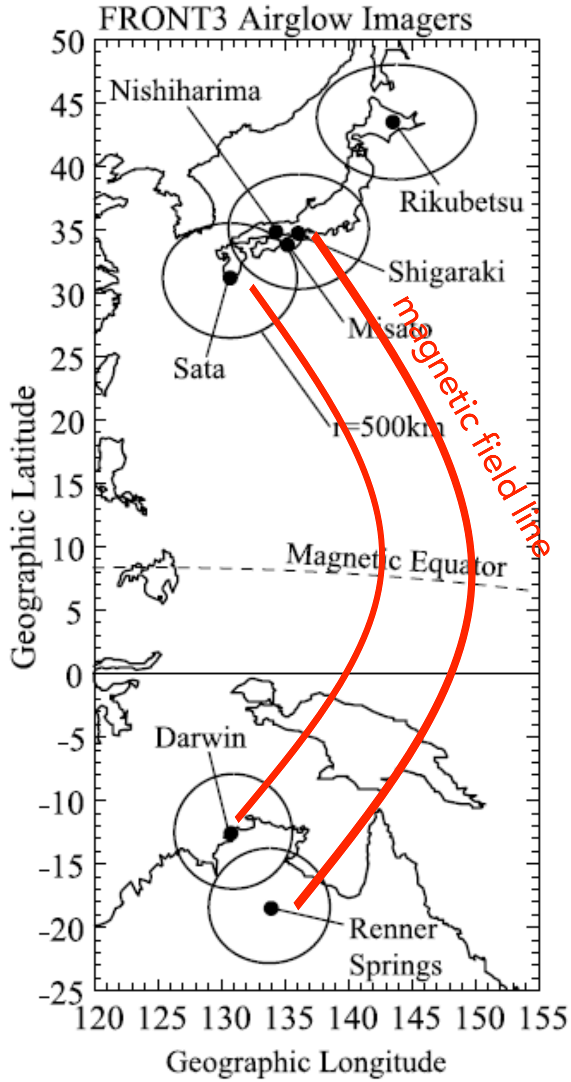
>> The polarization electric field plays an critical role in the generation of MSTIDs.



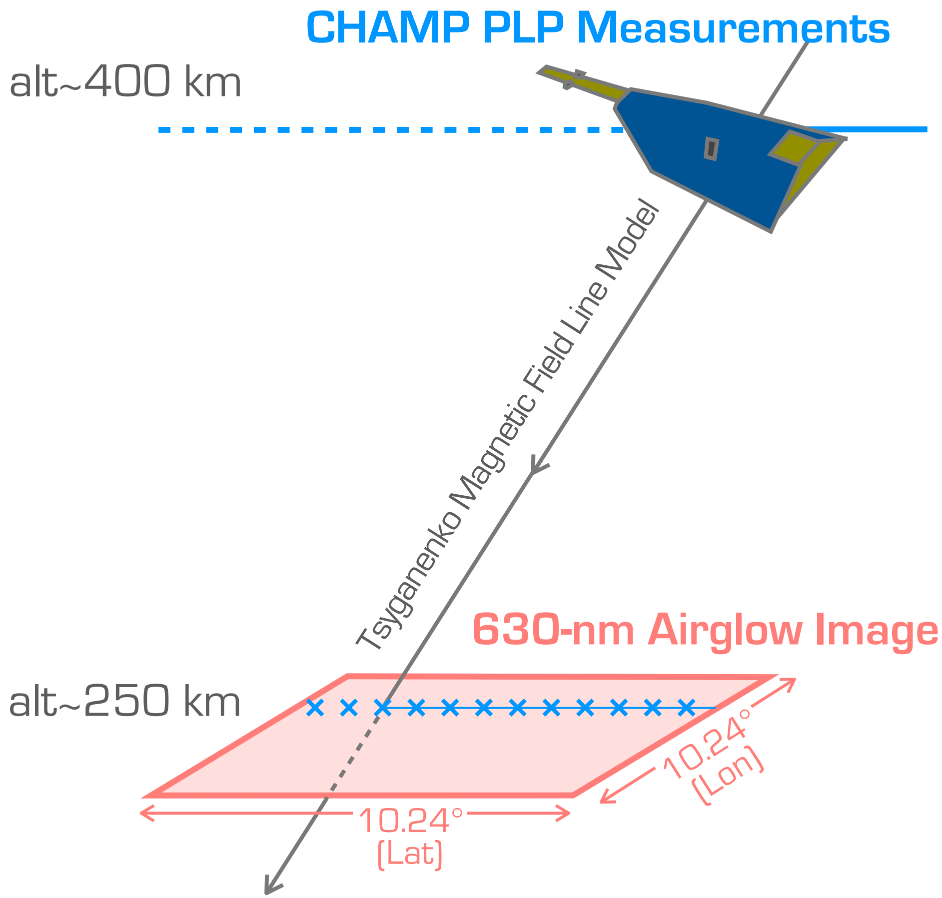
Otsuka et al. (2004, GRL)



Shiokawa et al. (2005, JGR)



Analysis Method



To investigate MSTID-associated plasma density perturbation in the topside F region, we analyze CHAMP/PLP data as follows:

- CHAMP passes over the airglow imagers' FOV (10.24°x10.24°) are selected.
- CHAMP locations are down to the airglow height (assumed to be 250 km) with the Tsyganenko magnetic field line model using OMNI 2 solar wind parameters.
- The plasma density perturbations are calculated as deviation from approx. 1000 km (8-point) moving average of the PLP data and are compared with 630-nm airglow intensities at the footprints.

Event Selection

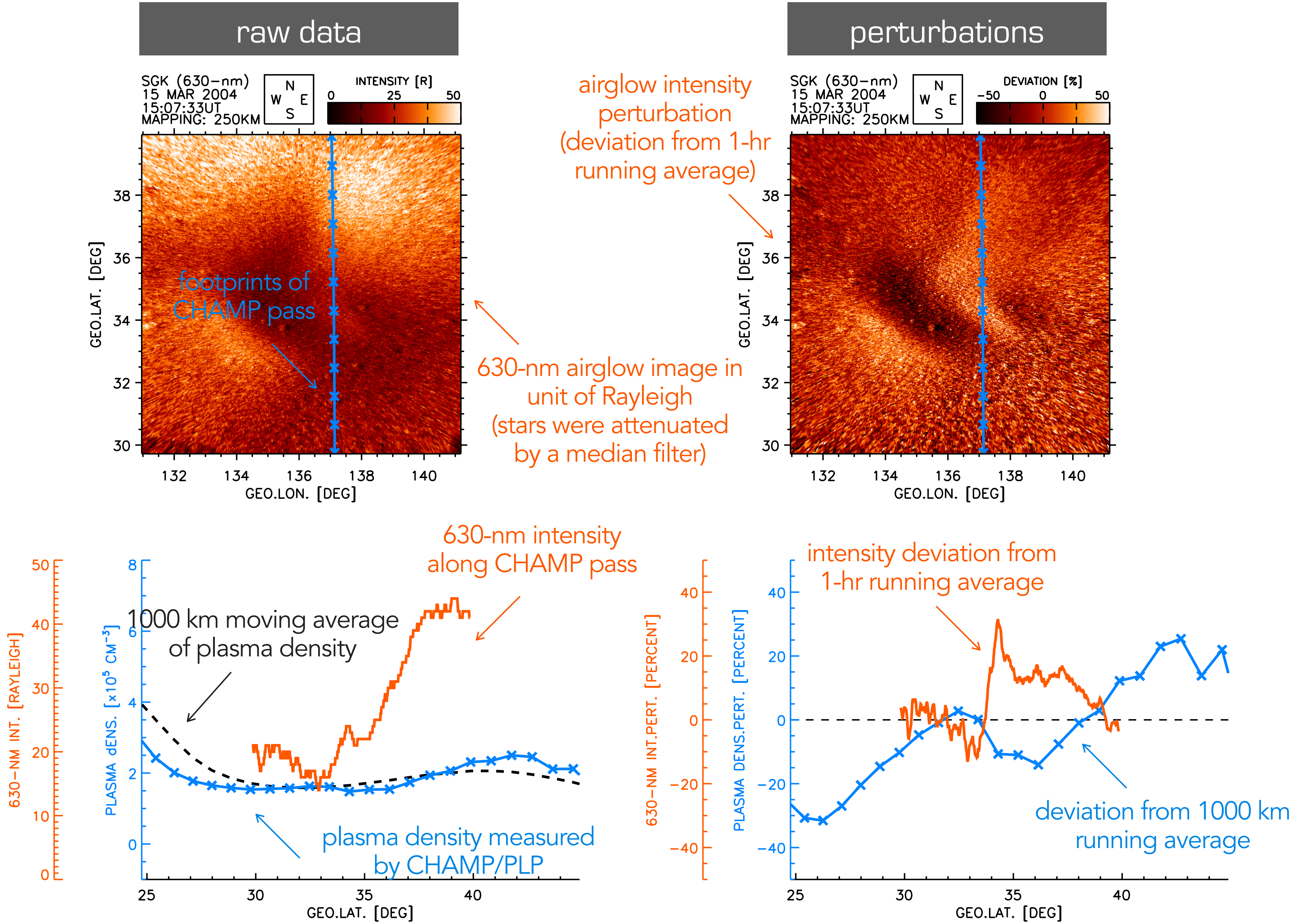
CHAMP PLP plasma density measurements:
2001-2010

→ CHAMP passed through over Japan (30-45°N, 130-145°E):
4627 events

→ Airglow imagers (RIK, SGK, and STA) were working and no clouds were in the airglow images:
447 events

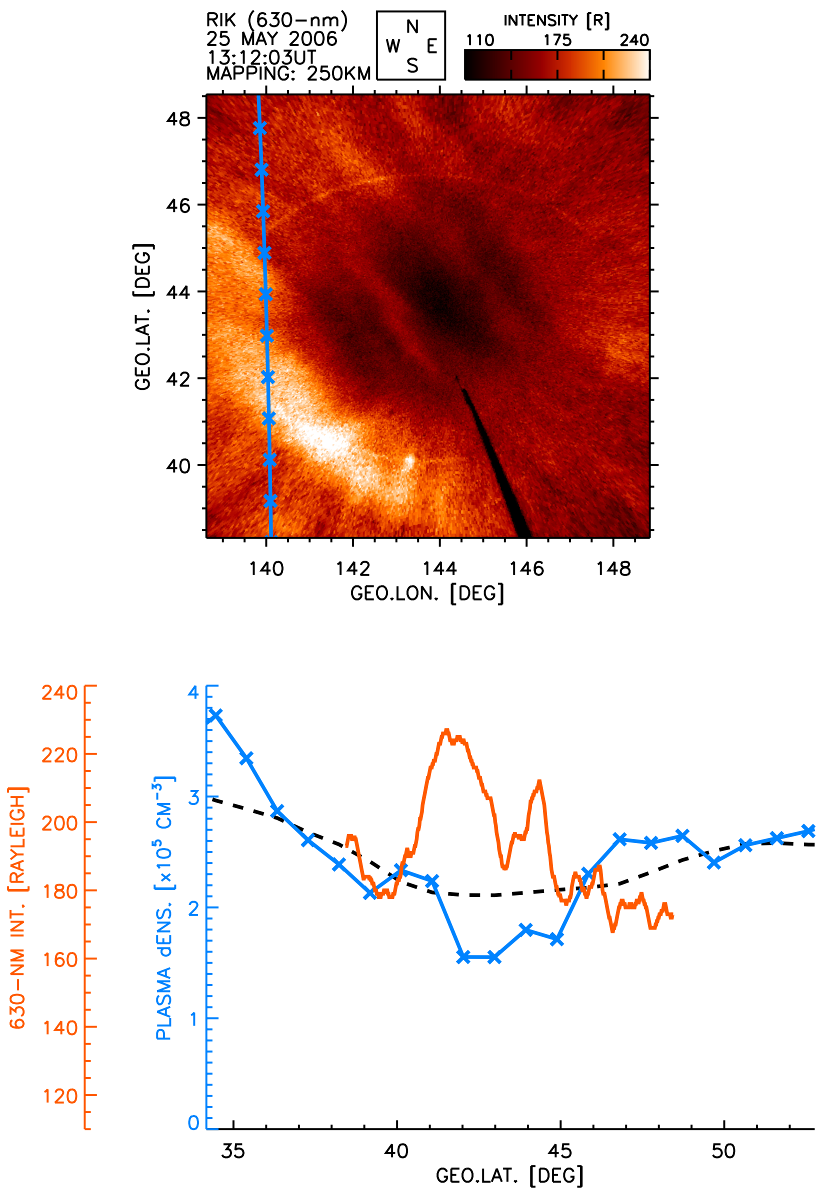
→ CHAMP ionospheric footprints were in the imager's FOV and conspicuous MSTID structure was in the 630-nm images:
14 events

Results (2004.05.15@Shigaraki)

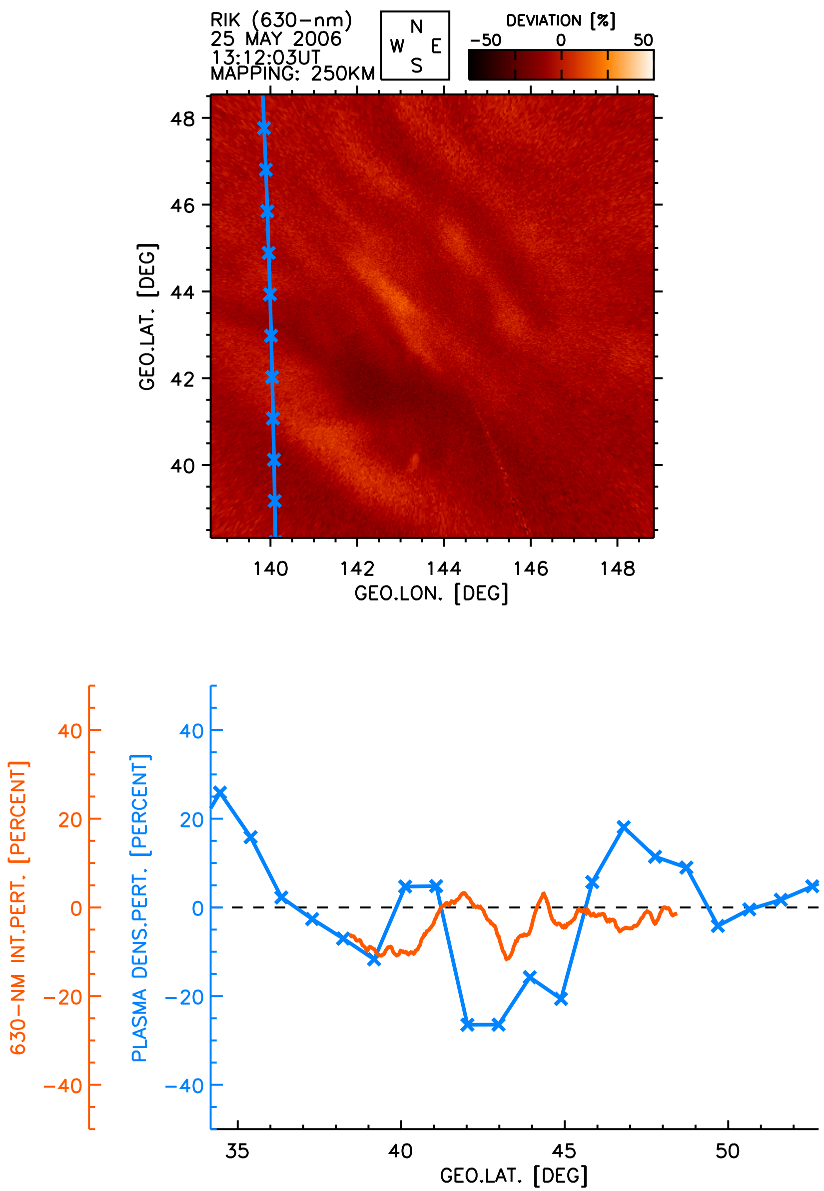


Results (2006.05.25@Rikubetsu)

raw data

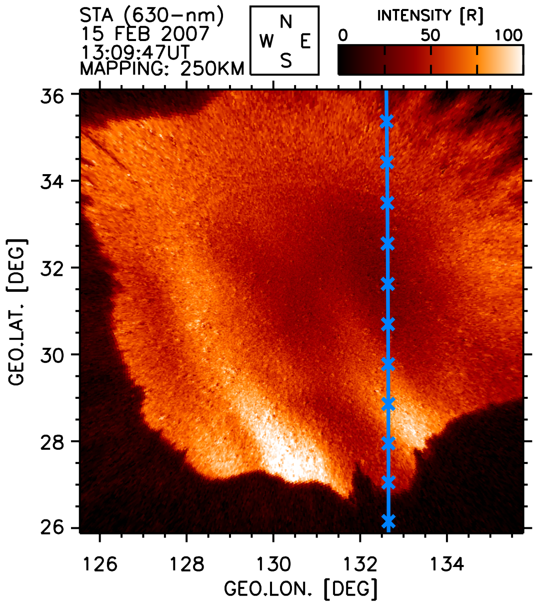


perturbations

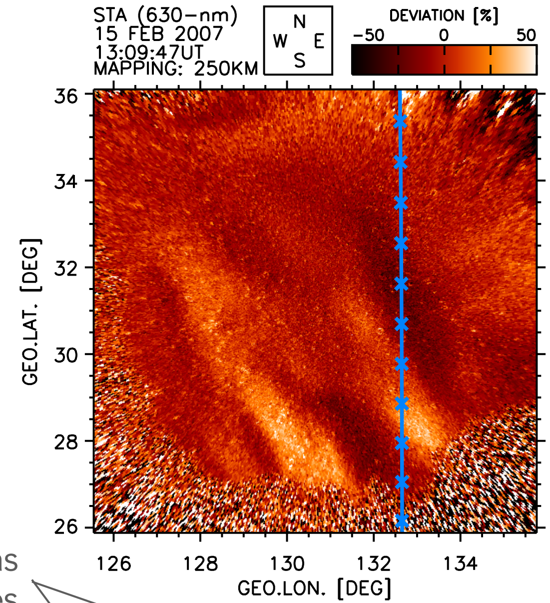


Results (2007.02.15@Sata)

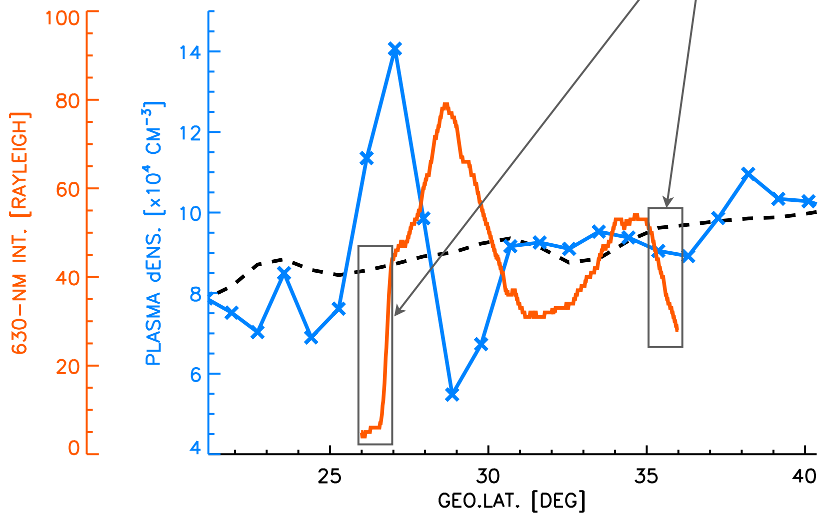
raw data

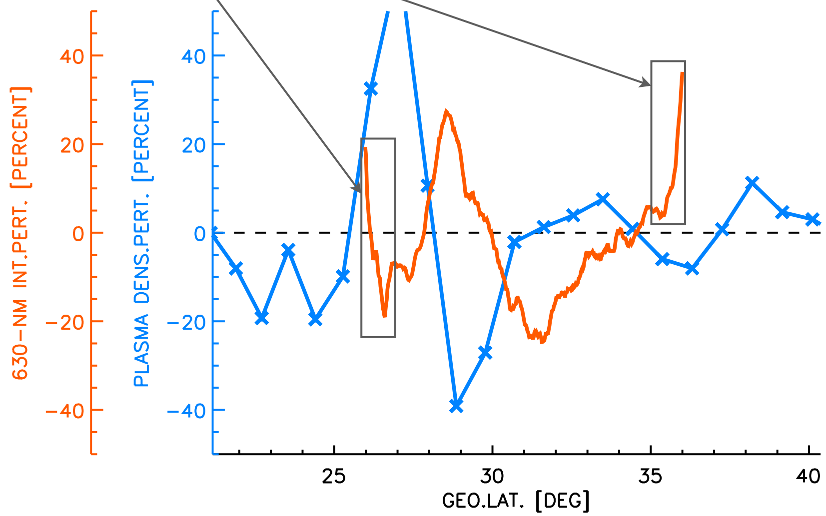


perturbations

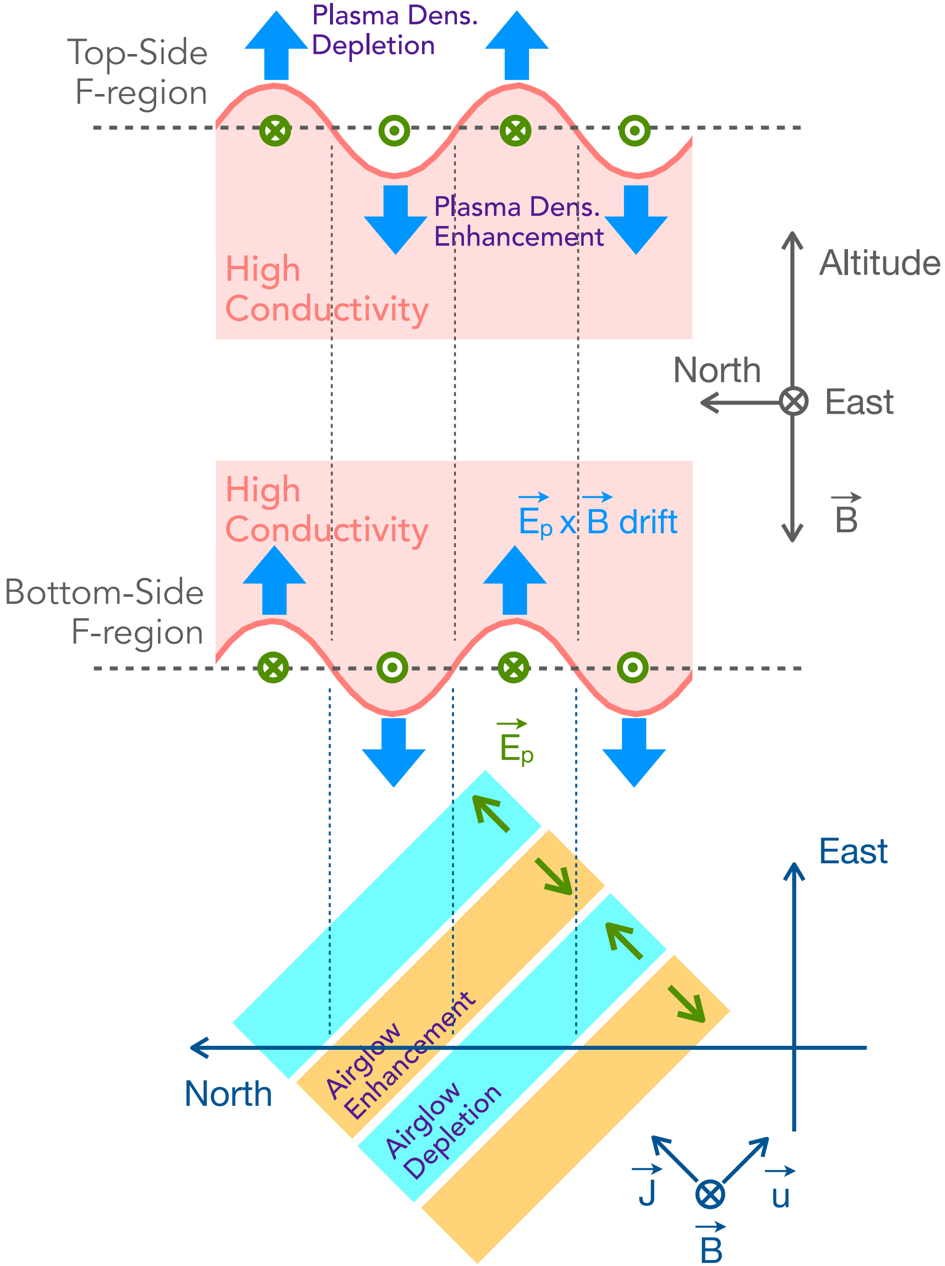


airglow structure was masked by obstacles





Summary



Based on **CHAMP/PLP measurements** and **ground-based airglow imaging by OMTIs**, we investigate plasma density perturbations at the topside ionosphere associated with MSTIDs at the bottom-side ionosphere.

- We found clear 14 conjugate events of MSTIDs in which CHAMP passes were in the OMTI FOVs.
- In most cases, plasma density in the topside ionosphere showed systematic polarity changes which were consistent with airglow intensity variations: plasma density enhancements (depletions) coincided with the airglow depletion (enhancement) regions.
- Plasma density fluctuation of MSTIDs induced by the polarization electric field is extended up to the topside.

Future Works

We will discuss the plasma density perturbations at the top- and bottom-side ionosphere quantitatively.

By using other OMTI camera data (Darwin, Yonaguni, Paratunka, etc.), we will investigate the observed relation more statistically.

Simultaneous CAHMP ACC (neutral density) and PLP (plasma density) measurements will reveal **differences of night-time and day-time MSTID features** (generation mechanisms, propagation characteristics, etc.)

— now under investigation