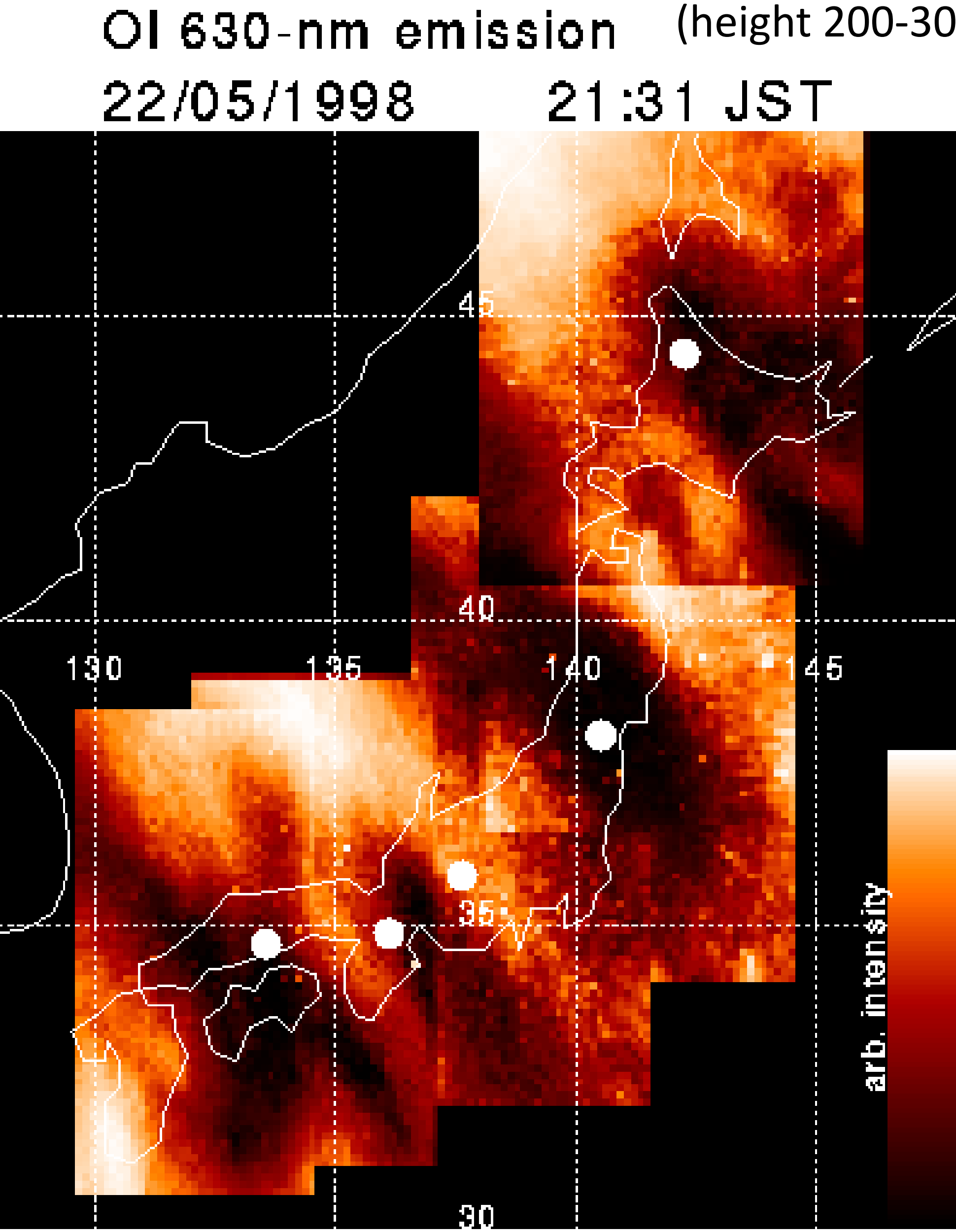
Polarization electric field of MSTIDs estimated from simultaneous observations by using all-sky airglow imager and the SuperDARN Hokkaido HF radar over midlatitudes

*Takeshi MINOURA (1), Shin SUZUKI (1), Kazuo SHIOKAWA (1), Yuichi OTSUKA (1), Nozomu NISHITANI (1) and Keisuke HOSOKAWA (2)
(1) Solar-Terrestrial Environmental Laboratory, Nagoya University (2) Department of Communication Engineering and Informatics, University of Electro-Communications

Medium Scale Traveling Ionospheric Disturbances (MSTIDs)



Kubota et al. [2000]

MSTID is a kind of ionospheric disturbances with a horizontal scale of 150-500 km.
Almost all MSTIDs observed in nighttime in the northern hemisphere have wavefronts elongated in the northwest-southeast direction, and propagate southwestward [Shiokawa et al., 2003a, Shiokawa et al., 2003b, Otsuka et al., 2004].

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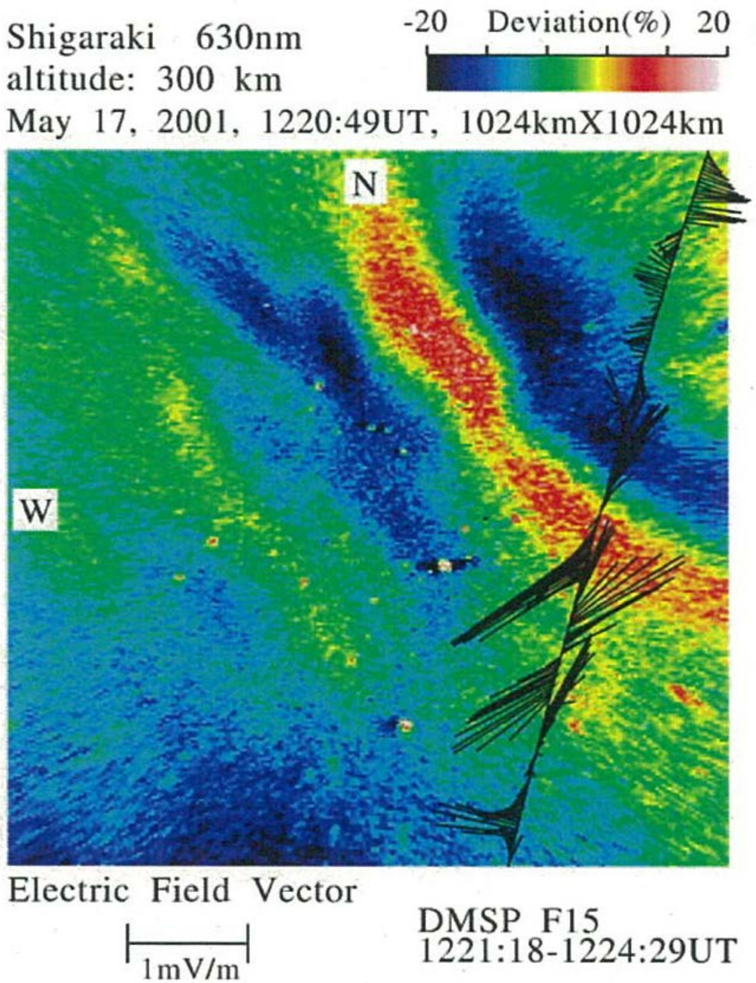
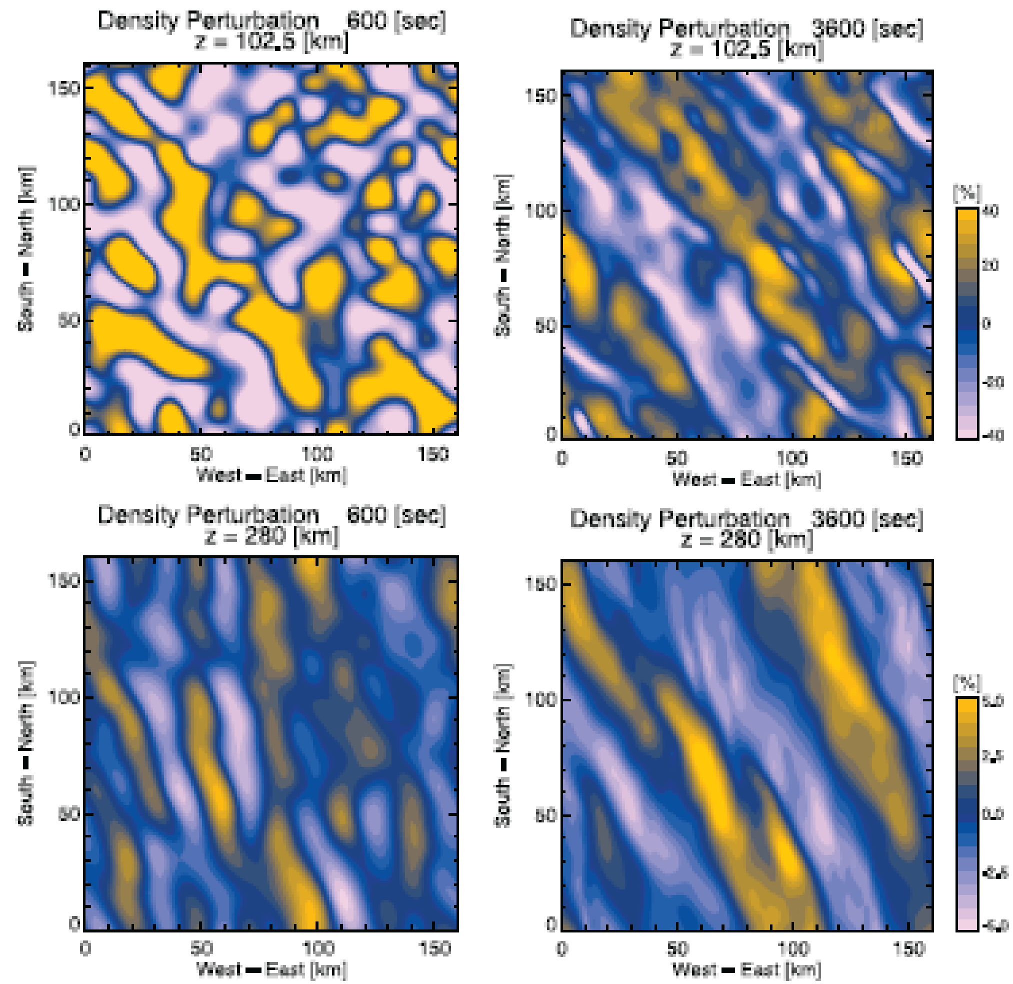


[Shiokawa et al., 2003c]



[Yokoyama et al., 2009]

(left) Polarization electric field along with the wavefronts of MSTID was observed [Shiokawa et al., 2003b]. (right) EF layer coupling played an important role in the structure and generation of MSTID from simulation [Yokoyama et al., 2009].

Previous study

Otsuka et al. [2009] suggested that the E-F coupling processes involved in the generation of the polarization electric field $\mathrm{E_p}$ in the F region.
Suzuki et al. [2009] reported that estimated polarization electric field was greater than the electric field perturbation in the F region as a case study.

Purpose of this study

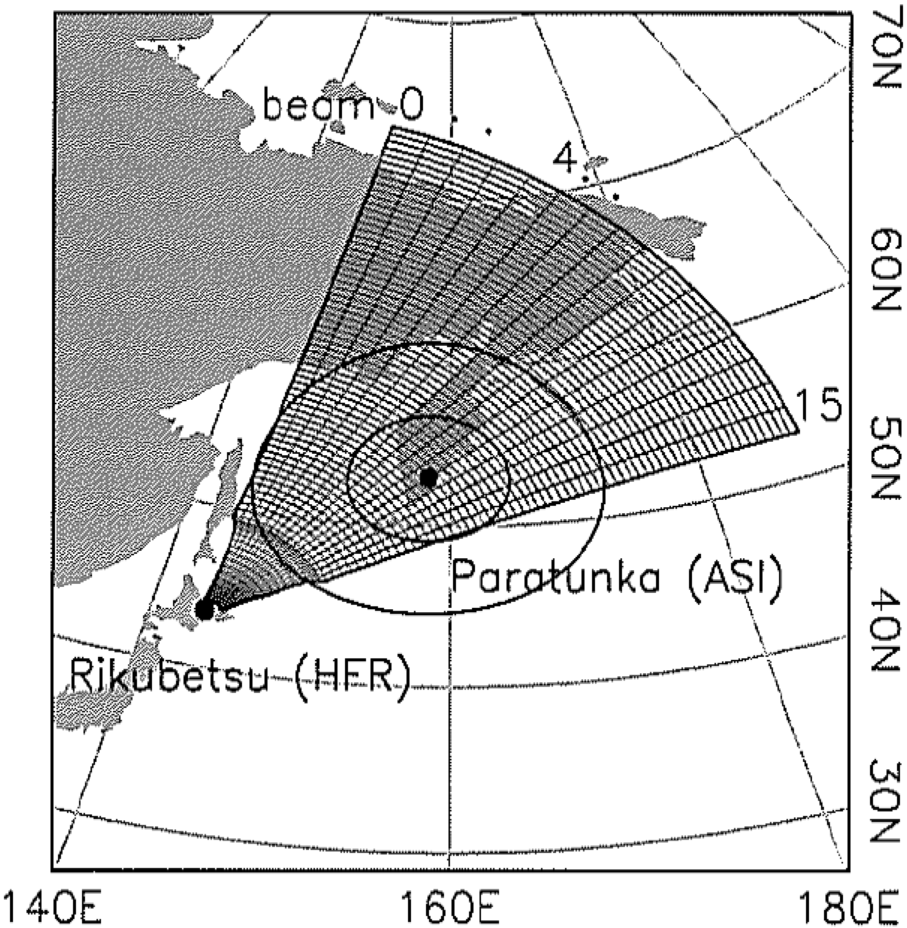
We investigate statistical polarization electric fields observed by using the SuperDARN HF radar at Rikubetsu (43.5N, 143.6E), Japan, and an OI 630-nm airglow imager located at Paratunka (53.0N, 158.2E), Russia, within the radar field of view (Jan. 2010-Jun. 2014).

Observations

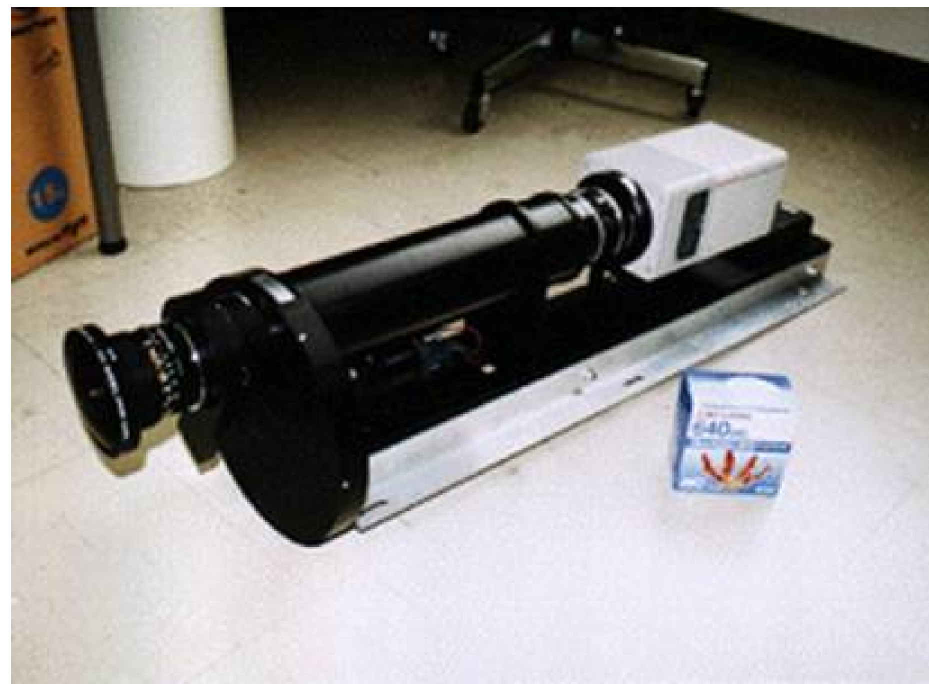
Observation period：Jan.2010-May. 2014 (1000-1800UT)

HF radar at Rikubetsu (43N, 143.6E)

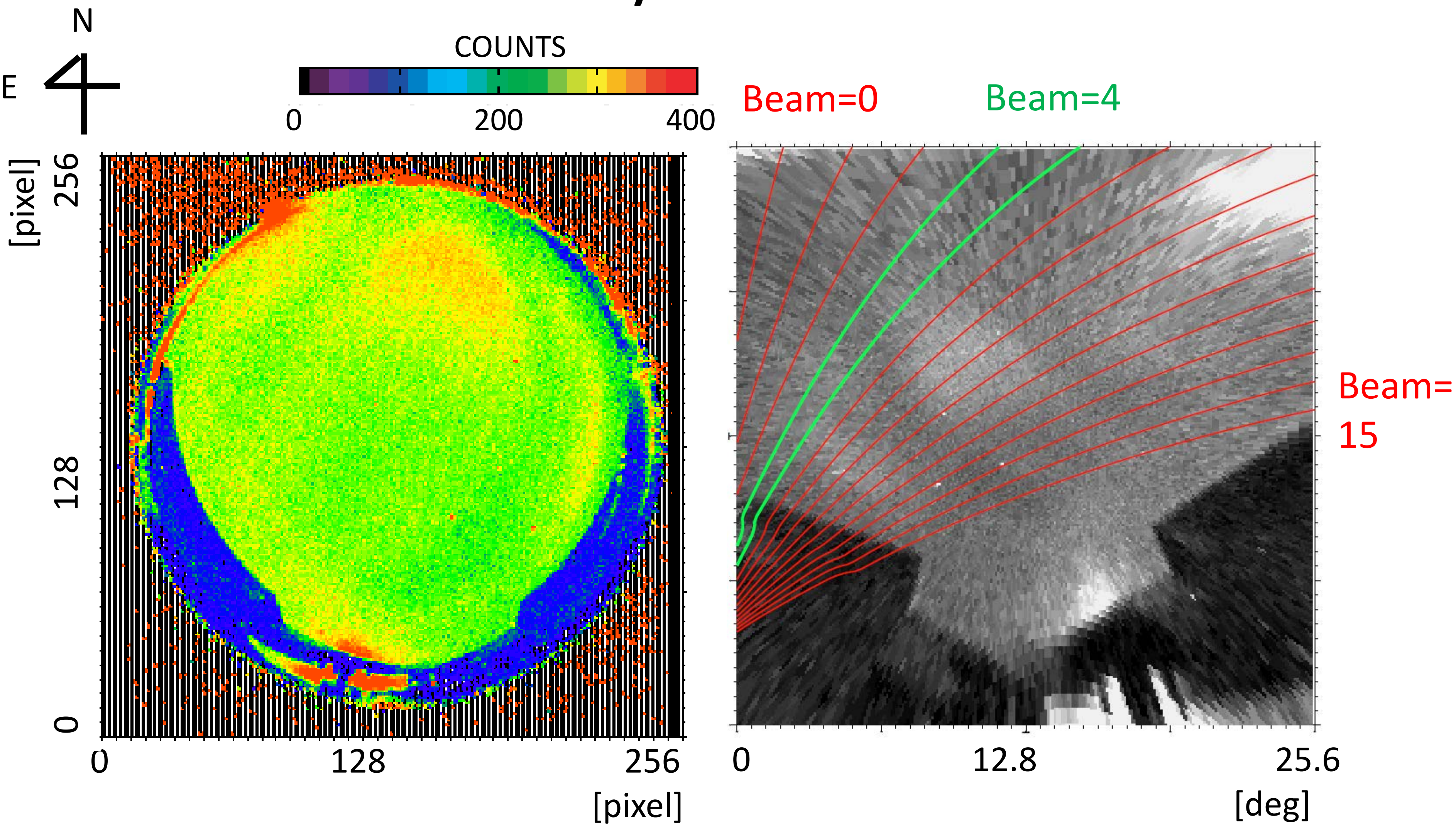
all-sky airglow imager at Paratunka (53N, 158.2E)



[Suzuki et al., 2009]

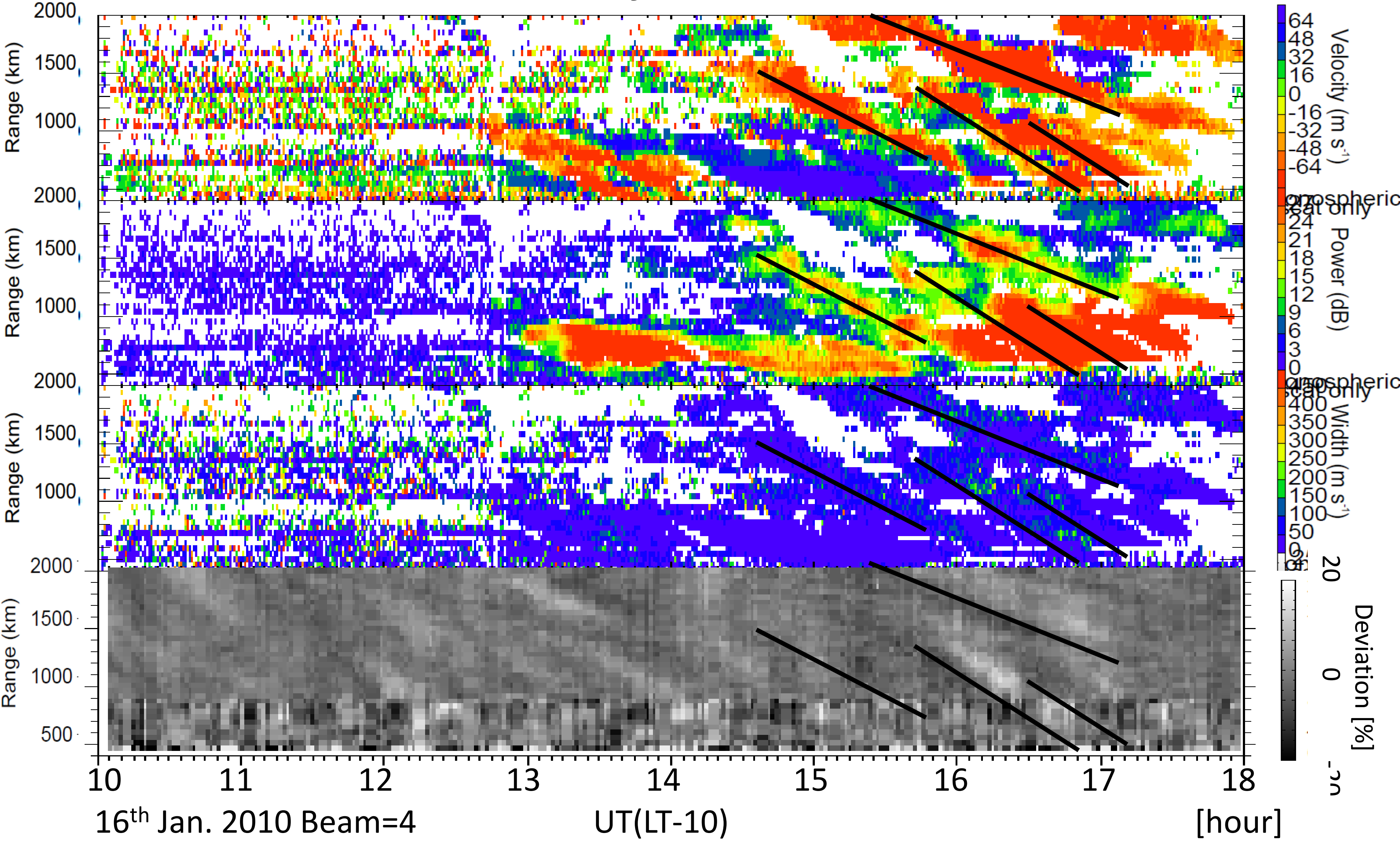


Analysis method



(left) An example of 630-nm all-sky airglow image. (right) The projection of the image onto the geographical coordinates. The red and green lines indicate beams of the HF radar in the field of view (16th Jan. 2010 1602UT).

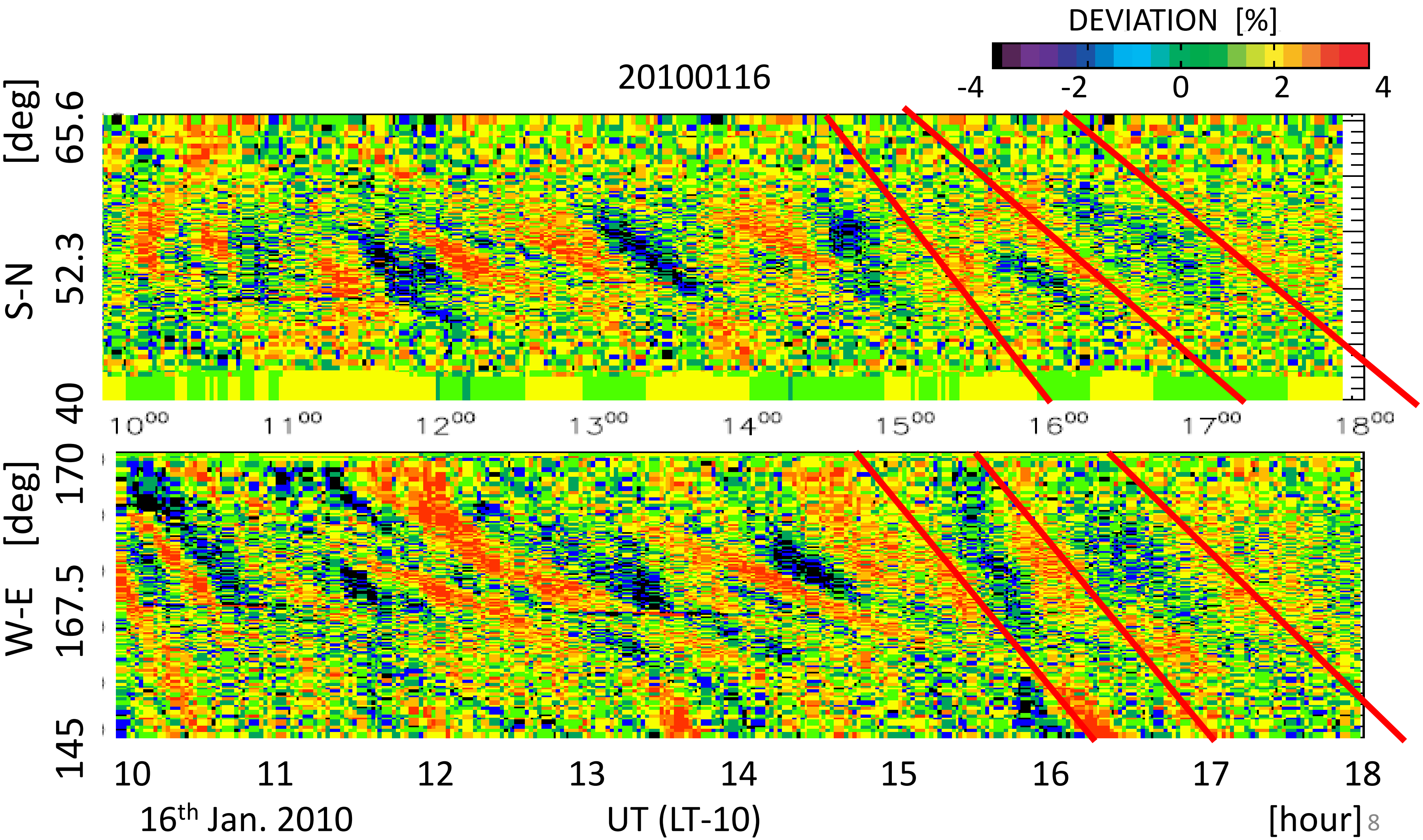
Analysis method



Negative (positive) Doppler velocities are good agreement with strong (week) echo power and airglow intensity depressions (enhancements). These correspondences are agree with previous study.

Analysis method

These keograms show the intensity deviations from the 1 hour average (16th Jan. 2010). The red lines indicate the wavefronts of MSTIDs to estimate their period, horizontal phase velocity and propagation direction and calculate horizontal wavelength.



Result

We found 5 conjugate events of MSTIDs which show associations between the HF radar echoes and airglow intensity variations. The estimated parameters of MSTIDs are typical values at midlatitudes in the Northern Hemisphere.

	Period [min]	Horizontal phase velocity [m/s]	Horizontal wavelength [km]	Airglow intensity variation [%]	Propagation direction [deg]
6th Jan. 2010	46.3	48.2	134	5.9	S [200]
16th Jan. 2010	48.5	72.5	211	7.7	SW [208]
18th Feb. 2010	51.3	57.2	176	10.4	SW [221]
20th Feb 2010	51.3	70.0	218	11.5	SW [231]
4th Feb. 2011	52.5	64.7	204	11.3	SW [211]

Estimation of polarization electric field

Plasma drift velocity is observed by HF radar as line-of-sight Doppler velocity.

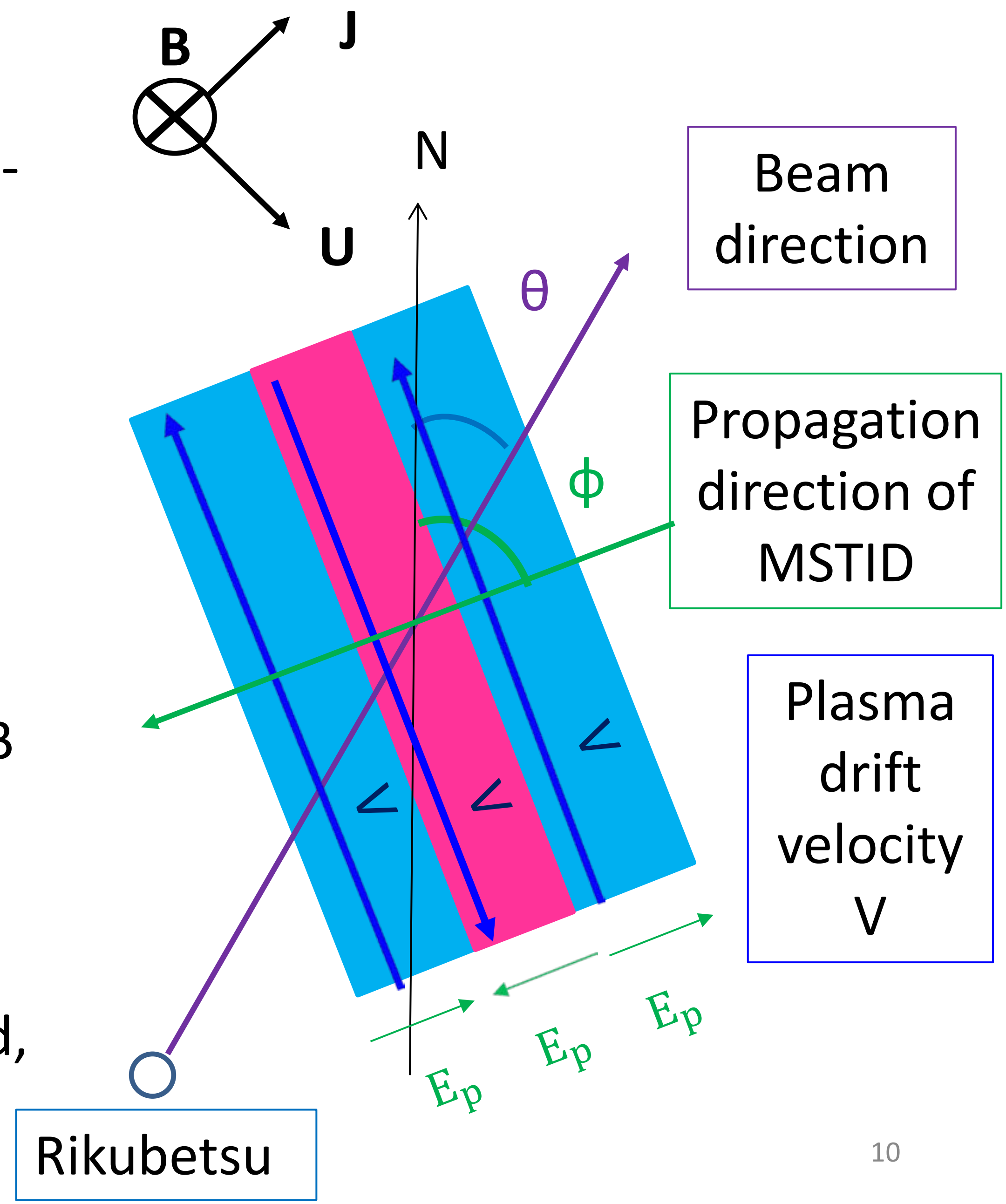
$V = V_{los}/\sin(\phi - \theta)$

(ϕ: propagation direction of MSTID, θ: beam direction of HF radar)

Plasma moves along the wavefronts of MSTID by E × B drift. Plasma drift velocity V along the wavefronts is

$$\mathbf{V} = (\mathbf{E_p} \times \mathbf{B})/\mathbf{B}^2$$

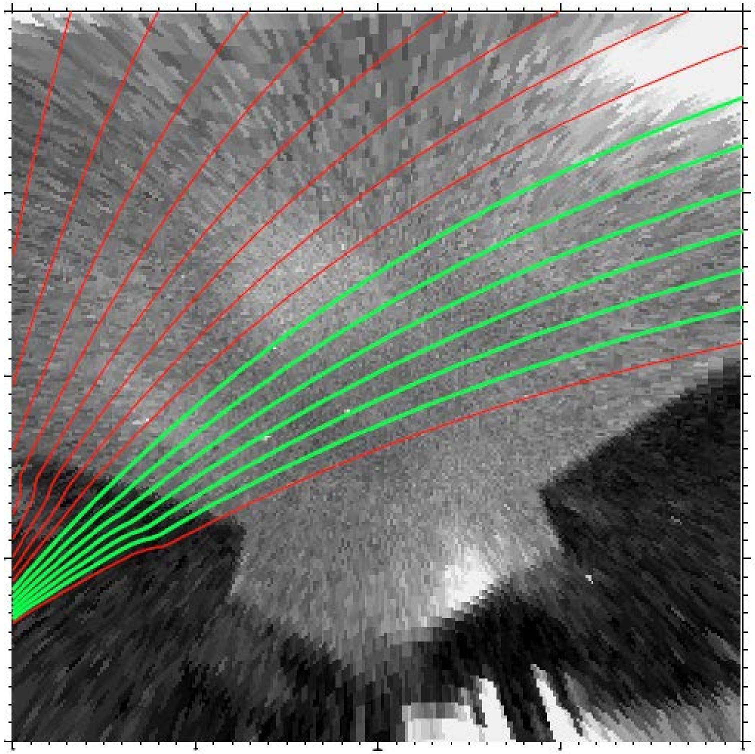
(E_p: polarization electric field, B:4.67 × 10^4 nT (IGRF))



Estimation of polarization electric field

16th Jan. 2010 (propagation direction of MSTIDs is 211 degree)

Beam number	Beam direction [deg]	Doppler velocity [m/s]	Plasma drift velocity [m/s]
10	47	57.5	173.1
11	50.3	60	155.5
12	53.6	90	173.1
13	56.9	85	173.7
14	60.2	66.7	123.8



Average of plasma drift velocity

V_{avg}=168.3 [m/s]

$E_p = 168.3\ (m/s) \times 4.67 \times 10^4\ (nT)$=7.9 [mV/m]

In case of MSTID propagation is parallel with beam direction, we limited the angle more than 20 degree between the propagation direction ϕ and the beam direction θ. And we didn't use the data of beam 0 and 15 because the influence of the side lobe is considered to be larger than other beam.

Estimation of effective electric field

	Polarization electric field [mV/m]	Airglow intensity variation [%]	Effective electric field [mV/m]
6th Jan. 2010	5.1	5.9	86
16th Jan. 2010	7.9	7.7	101
18th Feb. 2010	7.7	10.4	74
20th Feb. 2010	7.6	11.5	66
4th Feb. 2011	13.6	11.3	120

Effective electric field $\mathrm{E_e}$ (=$\mathrm{E_0} + \mathrm{U} \times \mathrm{B}$) in the F region is given by

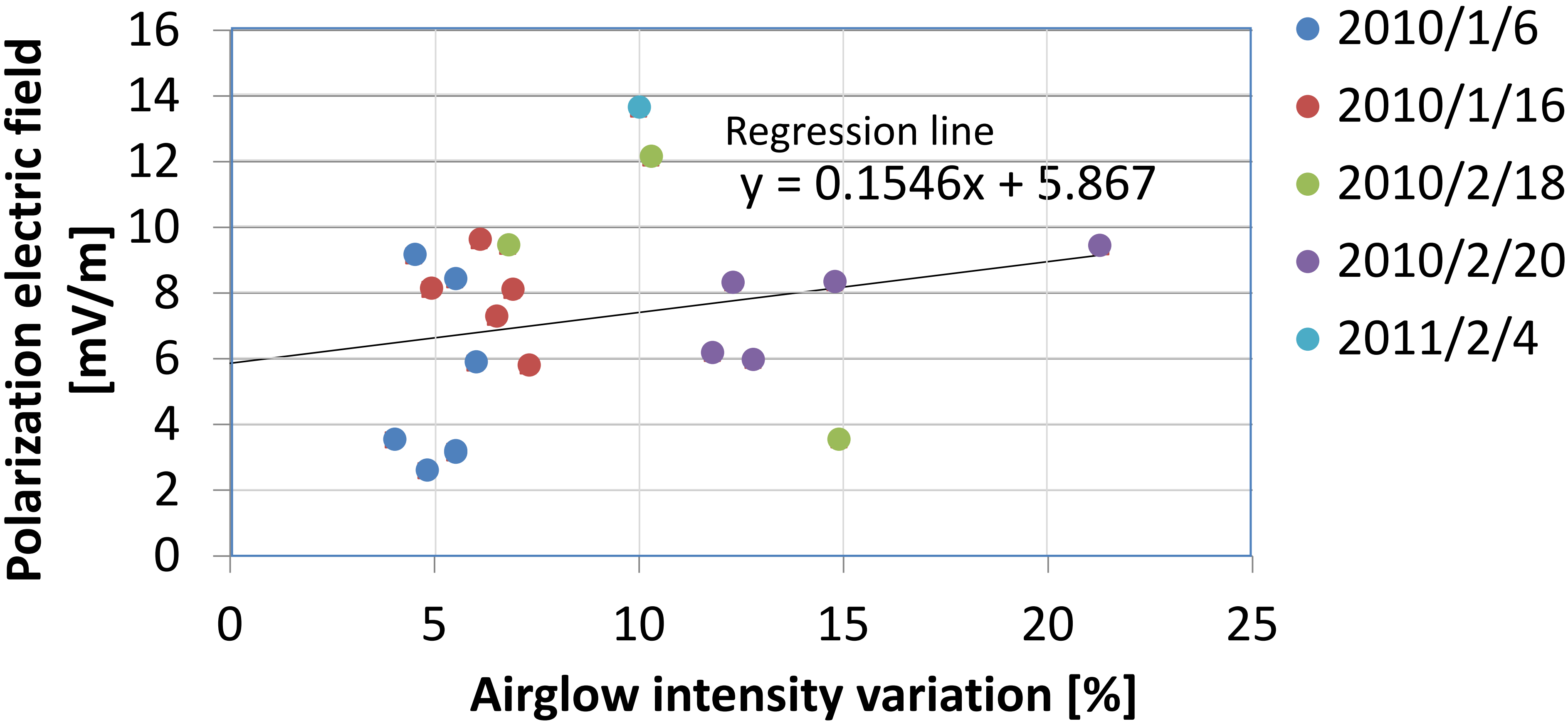
$$\left|\mathrm{E_p}\right| = \mathrm{E_e}\frac{\Sigma_{\mathrm{p}}{}'}{\Sigma_{\mathrm{p}}} \cdot \left(\frac{\mathbf{k}}{|\mathbf{k}|}\right)$$ [Otsuka et al., 2009]

($\Sigma_p{}'/\Sigma_p$: Productivity perturbation which are equivalent to airglow intensity variations, **k** : wave vector)

Our results suggest importance of the E-F coupling via MSTID-related polarization electric field, because the above estimations require quite large effective electric field and seems to be improbable at midlatitudes considering the continuity of the electric current in the F region alone.

Polarization electric field and airglow intensity variation

There is a positive correlation between the estimated polarization electric field and the observed airglow intensity variations. Correlation coefficient is 0.59.



Conclusion

We investigate statistical polarization electric fields observed by using the SuperDARN HF radar at Rikubetsu, and an OI 630-nm airglow imager at Paratunka, within the radar field of view for Jan. 2010-Jun. 2014. We found 5 conjugate events of MSTIDs.

- ◆ The systematic polarity changes of Doppler velocities observed by the HF radar were consistent with airglow intensity variations.
- ◆ Observed negative (positive) Doppler velocities corresponded to strong (week) echo power and airglow intensity depression (enhancement).
- ◆ The estimated polarization electric field associated with MSTIDs are 5.1-13.6 mV/m and have a positive correlation with the airglow intensity variation.
- ◆ Our results suggest importance of the E-F coupling via MSTID-related polarization electric field, because the above estimation requires quite large effective field and seems to be improbable at midlatitudes considering the continuity of the electric current in the F region alone.