Study of mid-latitude ionospheric convection during super quiet, quiet and disturbed period with the SuperDARN Hokkaido radar

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Possible factors for generating mid-latitude ionosphere convection

- Influence from high latitude convection (the penetration electric field)

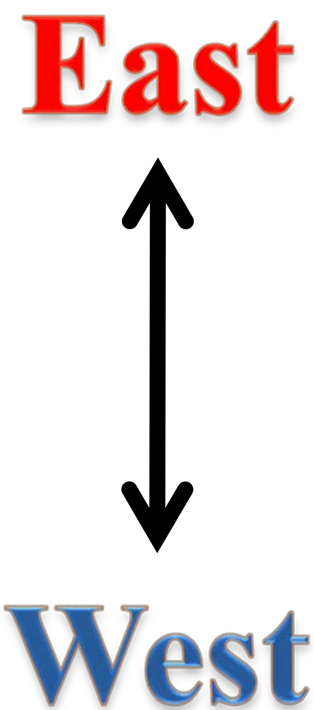
- Formation of convection by tide (which dominate at low latitude)

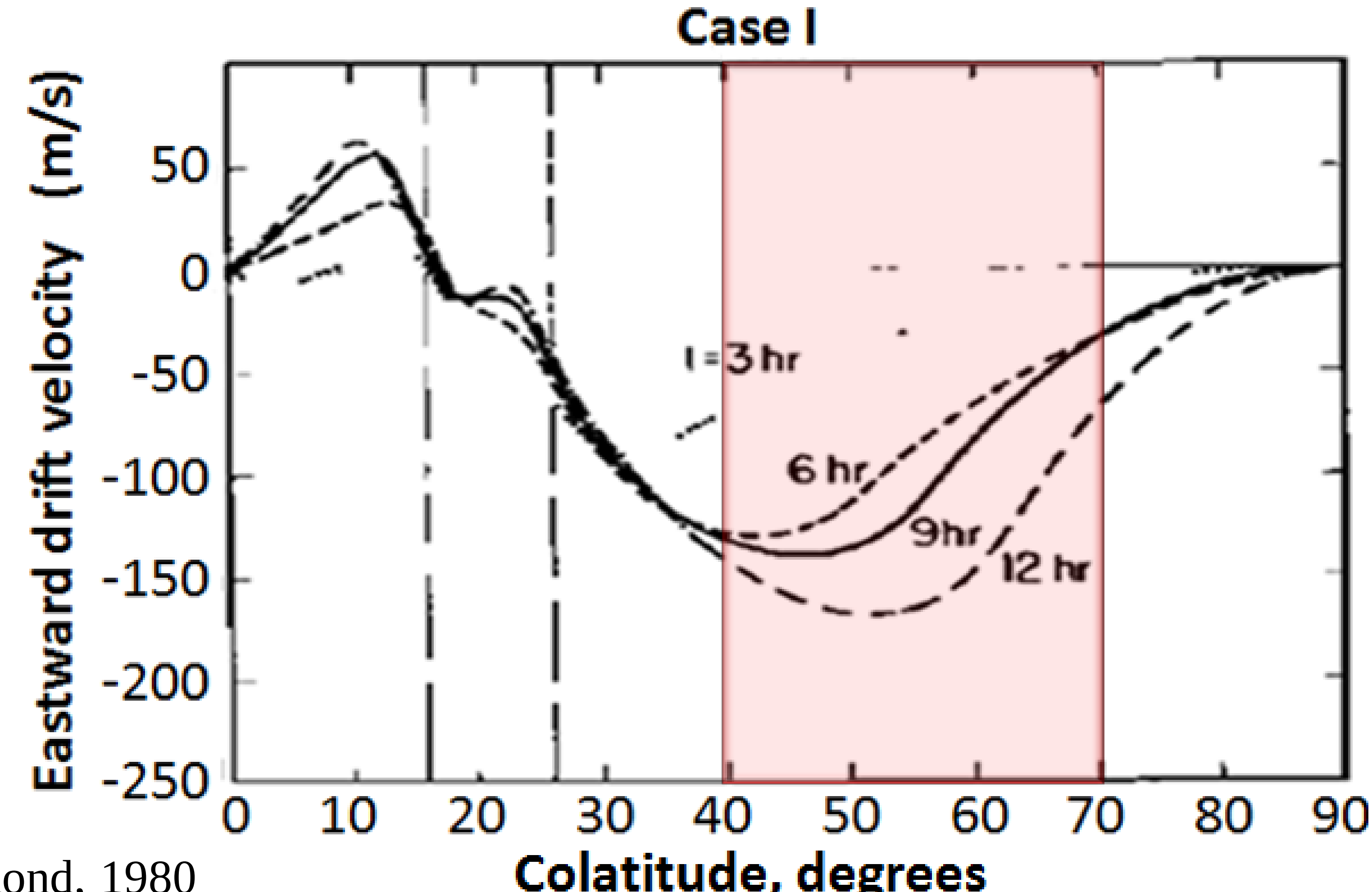
- **Disturbance dynamo(which provides very large influence at mid-latitude)**

Our study of mid-latitude ionosphere convection will focus on Disturbance dynamo effects.

Background(2/3)

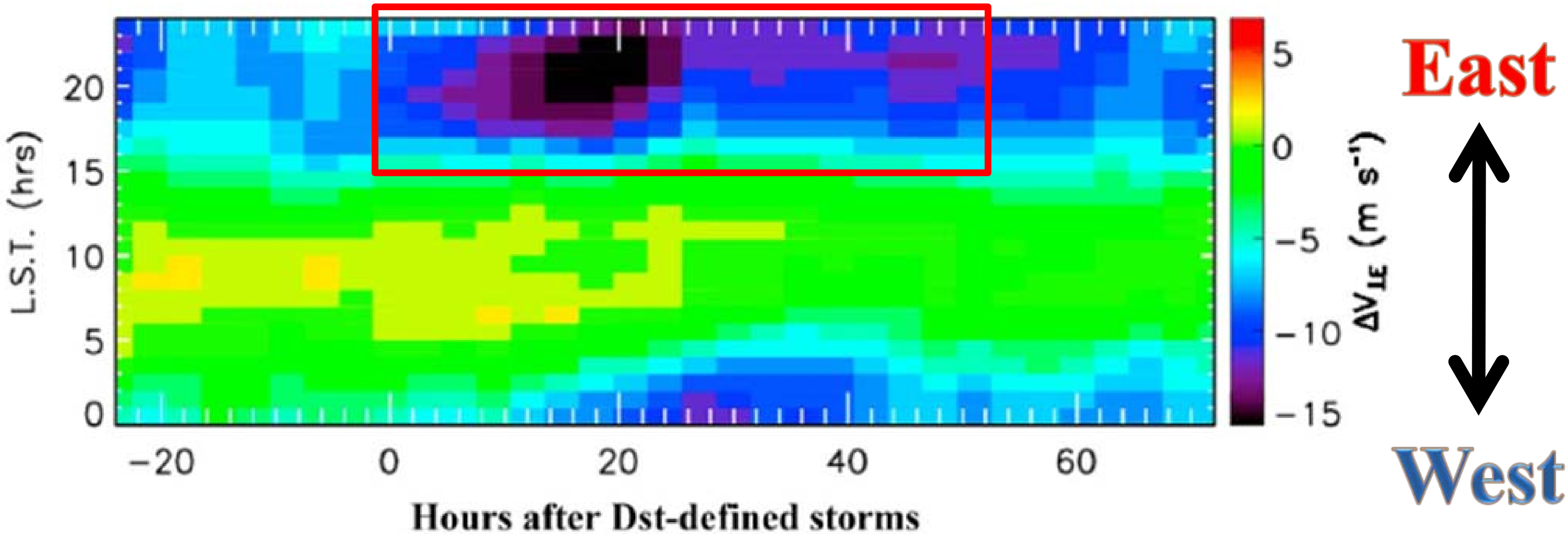
- The result of the simulation shows that westward drift of F-region ionospheric plasma at mid-latitude develops with the growing of storms.
- In mid-latitude of Case I (night side), the speed of the westward plasma drift increases as the geomagnetic disturbance develops.





Blanc and Richmond, 1980

Ionospheric disturbance dynamos lasted up to 50 hours in the midlatitude region at night



- ➢Observation point : Bundoora (145.1° E, 37.7° S geographic, 49° S magnetic), Australia
- ➢Observation equipment : Digisonde drift measurements
- ➢Statistical methods : Superposed Epoch Analysis (SEA)
- ➢Database : 5 years (1999 to 2003)
- ➢Number of Dst-defined storms : 262

Kumar et al., 2010

Purpose of this study

To study mid-latitude ionosphere plasma convection (especially the westward flow on the night side)

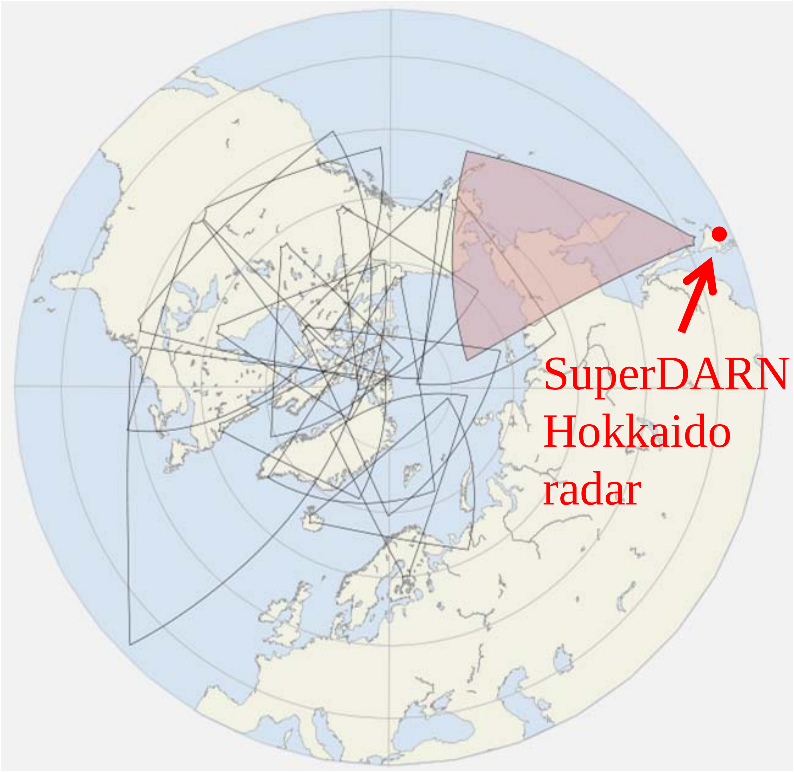
•<u>Kp dependence</u>

•<u>Geomagnetic latitude dependence</u>

•<u>Seasonal dependence</u>

•<u>Influence from Dst-defined storms</u>

•<u>Influence from AL-defined storms</u>



SuperDARN Hokkaido radar

➢**Location :** 43.5° N geographic, 36° N magnetic

➢**Observation area :** about 40° to 80° N

Method of this study

To study the geomagnetic activity dependence and the geomagnetic latitude dependence of the mid-latitude ionospheric convection, we apply the vector fitting to beam 1 to 14 line-of-sight Doppler velocity data obtained by the SuperDARN Hokkaido radar to get the westward and northward components of ionospheric convection velocities.

- In order to minimize the effects of sidelobes, data from beam 0 and 15 are not used.

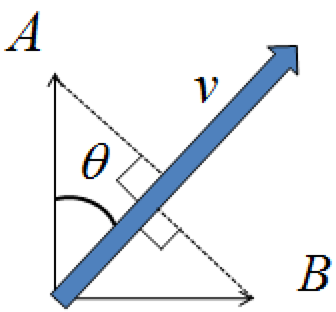
- For beam 1 to 14, the vector can be obtained for eastward and northward components from the equations:

$$v_1 = A\cos\theta_1 + B\sin\theta_1$$
$$v_2 = A\cos\theta_2 + B\sin\theta_2$$
$$\cdots\cdots$$
$$v_{14} = A\cos\theta_{14} + B\sin\theta_{14}$$

- To Calculate these vector components we use equation:

$$B = \frac{(\sum v_i\cos\theta_i)(\sum\cos\theta_i\sin\theta_i) - (\sum v_i\sin\theta_i)(\sum\cos^2\theta_i)}{(\sum\cos\theta_i\sin\theta_i)^2 - (\sum\sin^2\theta_i)(\sum\cos^2\theta_i)}$$

$$A = \frac{(\sum v_i\sin\theta_i)(\sum\cos\theta_i\sin\theta_i) - (\sum v_i\cos\theta_i)(\sum\sin^2\theta_i)}{(\sum\cos\theta_i\sin\theta_i)^2 - (\sum\sin^2\theta_i)(\sum\cos^2\theta_i)}$$



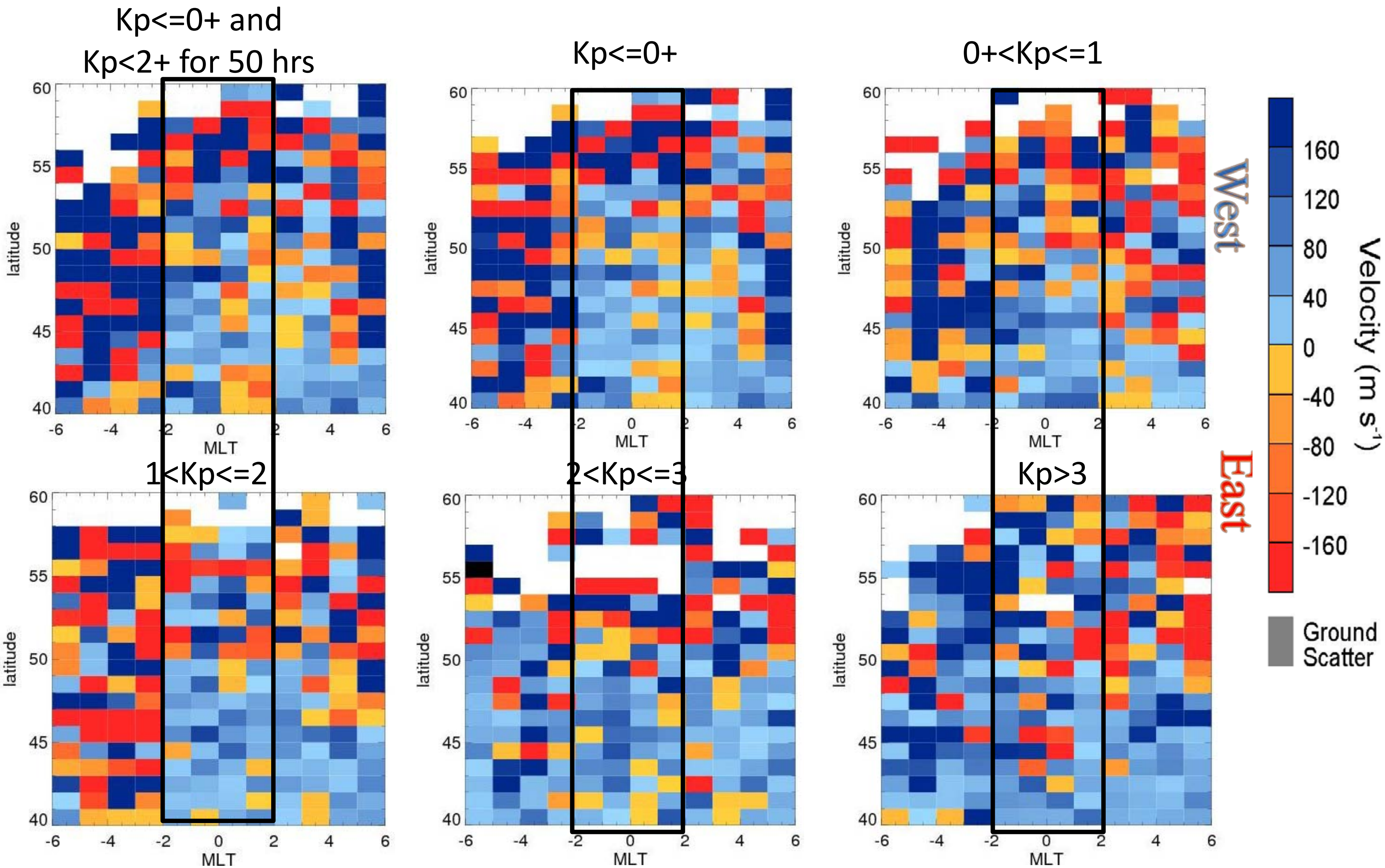
Here, θ is the azimuth at each range of each beam.

Result

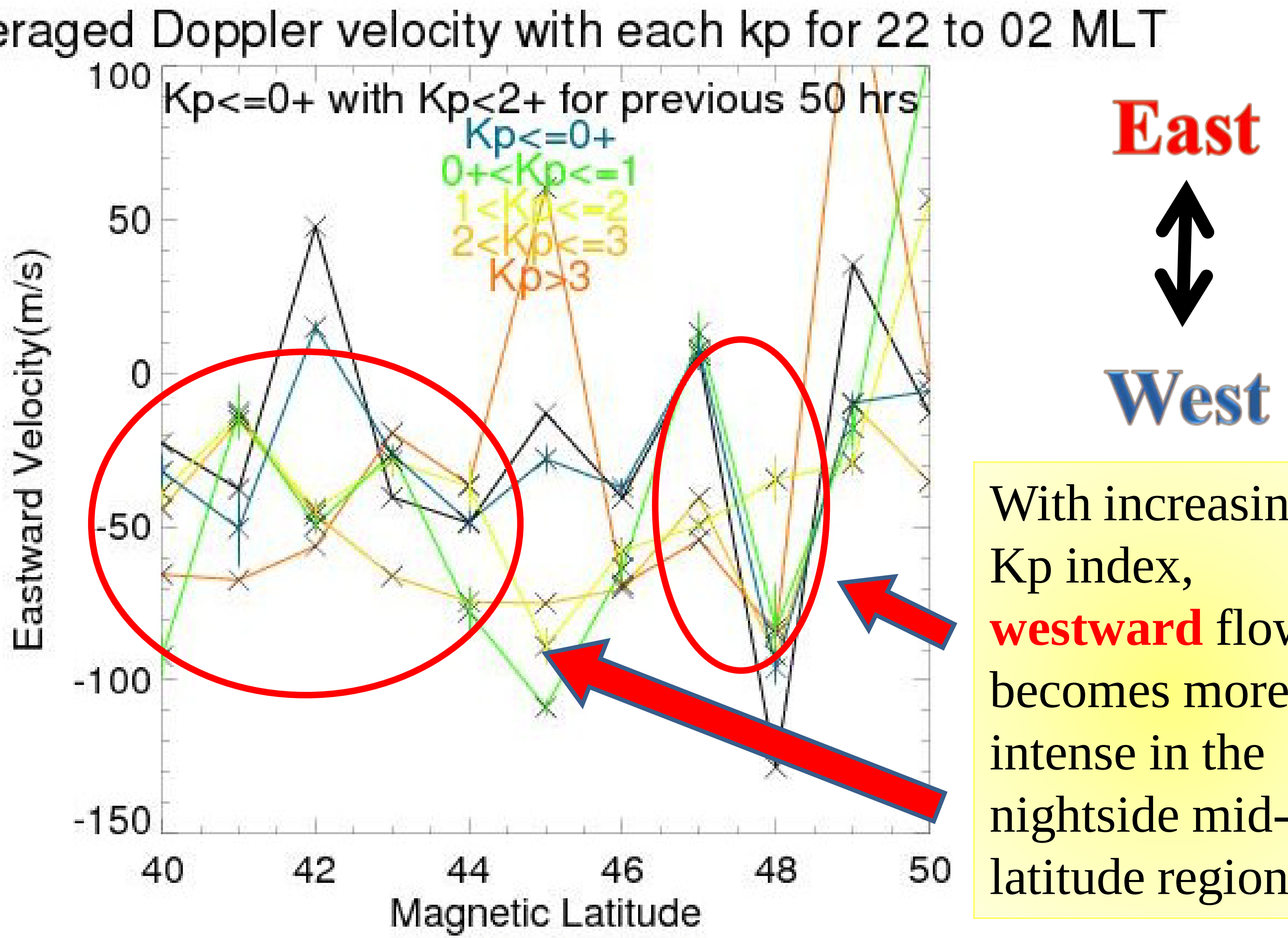
- Kp dependence
- Geomagnetic latitude dependence
- Seasonal dependence
- Influence from Dst-defined storms
- Influence from AL-defined storms

Result(1/4)

Statistical distribution of east-west velocities with several Kp ranges in winter (Nov to Jan) from December, 2006 to May, 2011.



Result(2/4)



With increasing Kp index, **westward** flow becomes more intense in the nightside mid-latitude region.

Because the data count of the averaged Doppler velocity for Kp>3 is much less than other conditions, so that the variation is much greater.

Result

- Kp dependence
- Geomagnetic latitude dependence
- Seasonal dependence
- Influence from Dst-defined storms
- Influence from AL-defined storms

Criteria

●To study the geomagnetic latitude dependence of the chronological influence of magnetic storms and substorms, we use the Superposed Epoch Analysis (SEA) method .

Storm Time(t)	All Storms	Short-Duration	Medium-Duration	Long-Duration
-7h≦t≦-1h	Dst>-30nT*1	Dst>-30nT*1	Dst>-30nT*1	Dst>-30nT*1
0h≦t≦6h	Dst≦-30nT*2	Dst≦-30nT*2	Dst≦-30nT*2	Dst≦-30nT*2
7h≦t≦13h	—	Dst>-60*3	Dst≦-60*4	Dst≦-60*4
14h≦t≦20h	—	—	Dst>-60*3	Dst≦-60*4
Number of Storms	54	48	4	2

*1 : 1 or less in seven hours satisfy the stated condition
*2 : 3 or less in seven hours satisfy the stated condition
*3 : All 7 consecutive hours satisfy the stated condition
*4 : At lest 1 hour satisfy the stated condition

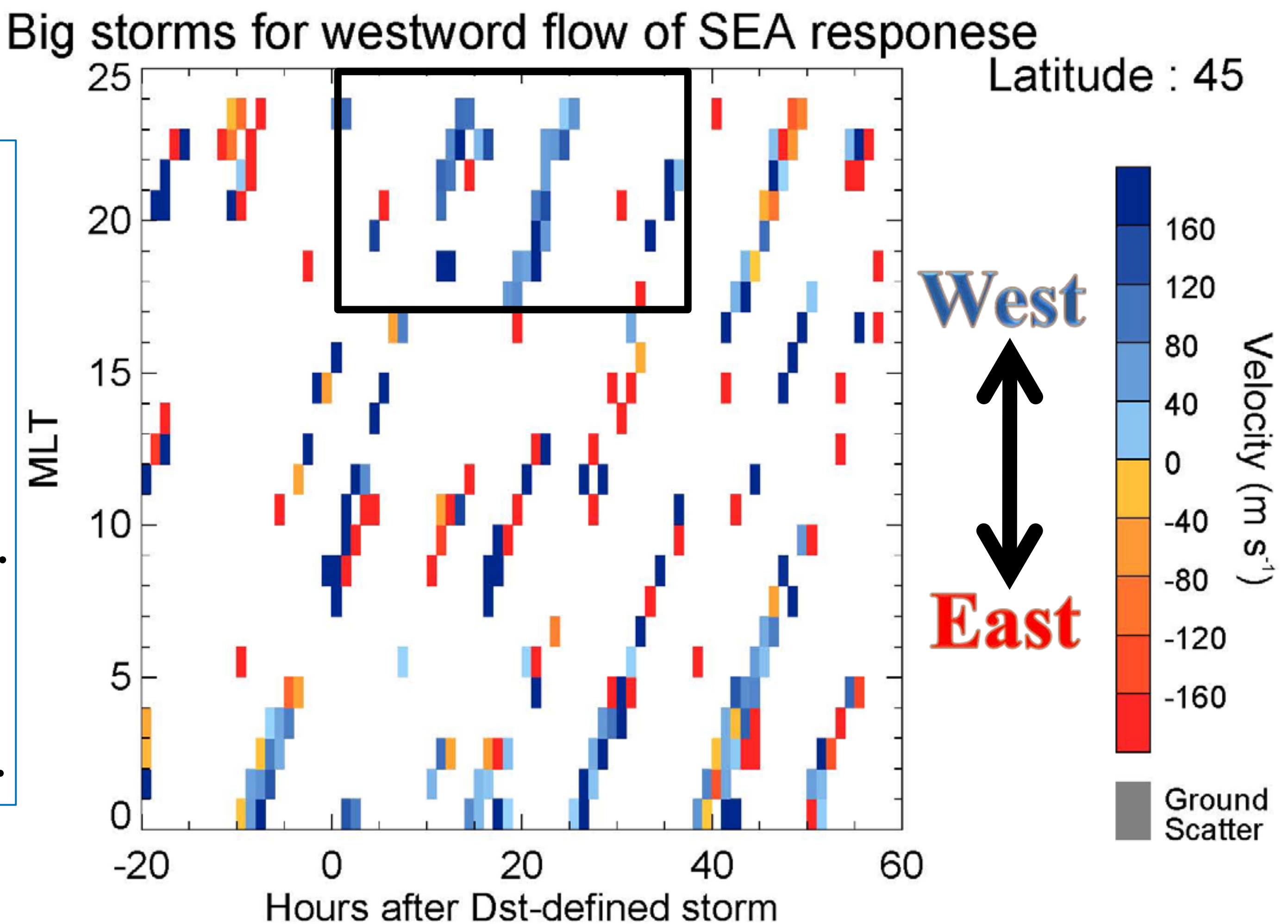
Storm Time(t)	-6h≦t≦0h	0h<t≦6h
All substorms	AL>-150	AL≦-150

Number of Storms : 94

Result(3/4)

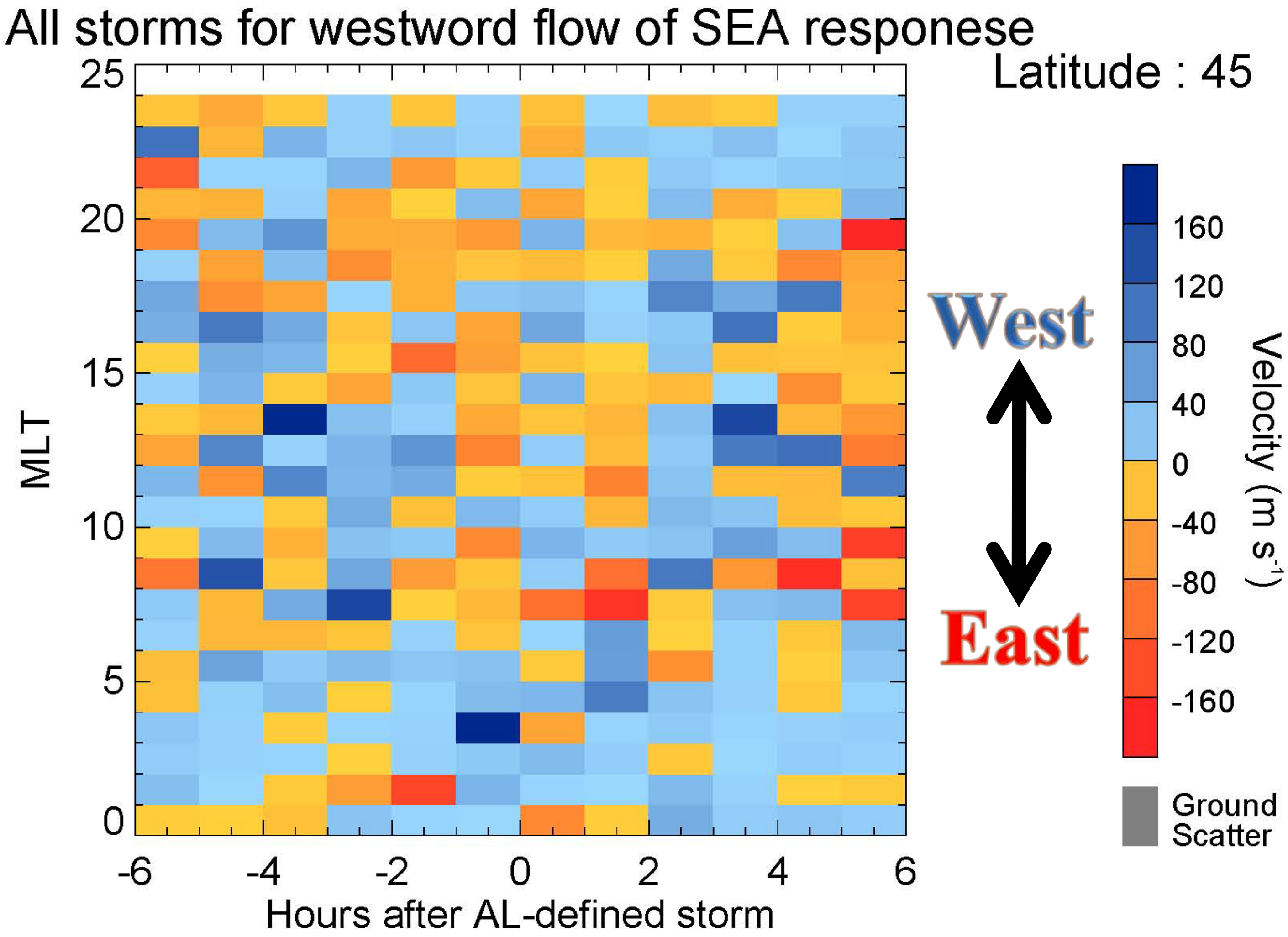
From the result of 6 events of medium- and long-duration storms we can confirm that the influence of storm lasts up to 30 hrs after onset between 43 and 59 degrees.

- 54 storms defined by the hourly Dst index which satisfy the criteria, from December, 2006 to May, 2011.
- We use the criteria adopted by Kumar et al., 2010.



Result(4/4)

Statistical analysis of 94 AE-defined substroms 6 hours before and after the substorm onset (12 hours total)



The result was not particularly noticeable.
There is a need for reconsider on a detailed understanding of the features of substorm and it’s influence on mid-latitude ionospheric convection.

Summary

- The statistical analysis shows the geomagnetic index Kp and geomagnetic latitude dependence of the mid-latitude ionospheric plasma convection from the observation of SuperDARN Hokkaido radar in all seasons. The mid-latitude night side westward flow has Kp dependence intensified for disturbed periods in all seasons.
- The Superposed Epoch Analysis (SEA) result shows a latitude dependence of the influence from the storm. From the result of 6 events of medium- and long-duration storms we can confirm that the influence of storm lasts up to 30 hrs after onset at several latitude of mid-latitude.
- Significant influence from the AL-defined substorm at mid-latitude is not identified in 6 hours after substorm begins. Kumar et al. [2010] shows the most great effect from the AE-defind storm is at 20 hrs after the substorm onset. The simulation result from Blanc and Richmond [1980] also shows the westword drift at mid- and low-latitude grows to a maximum at 12 hrs after the magnetic storm onset. There is a need for reconsider on a detailed understanding of the features of substorm and it’s influence on mid-latitude ionospheric convection.

Future work

- More events of each duration storms need to be studied to extend the detailed result of data analysis.

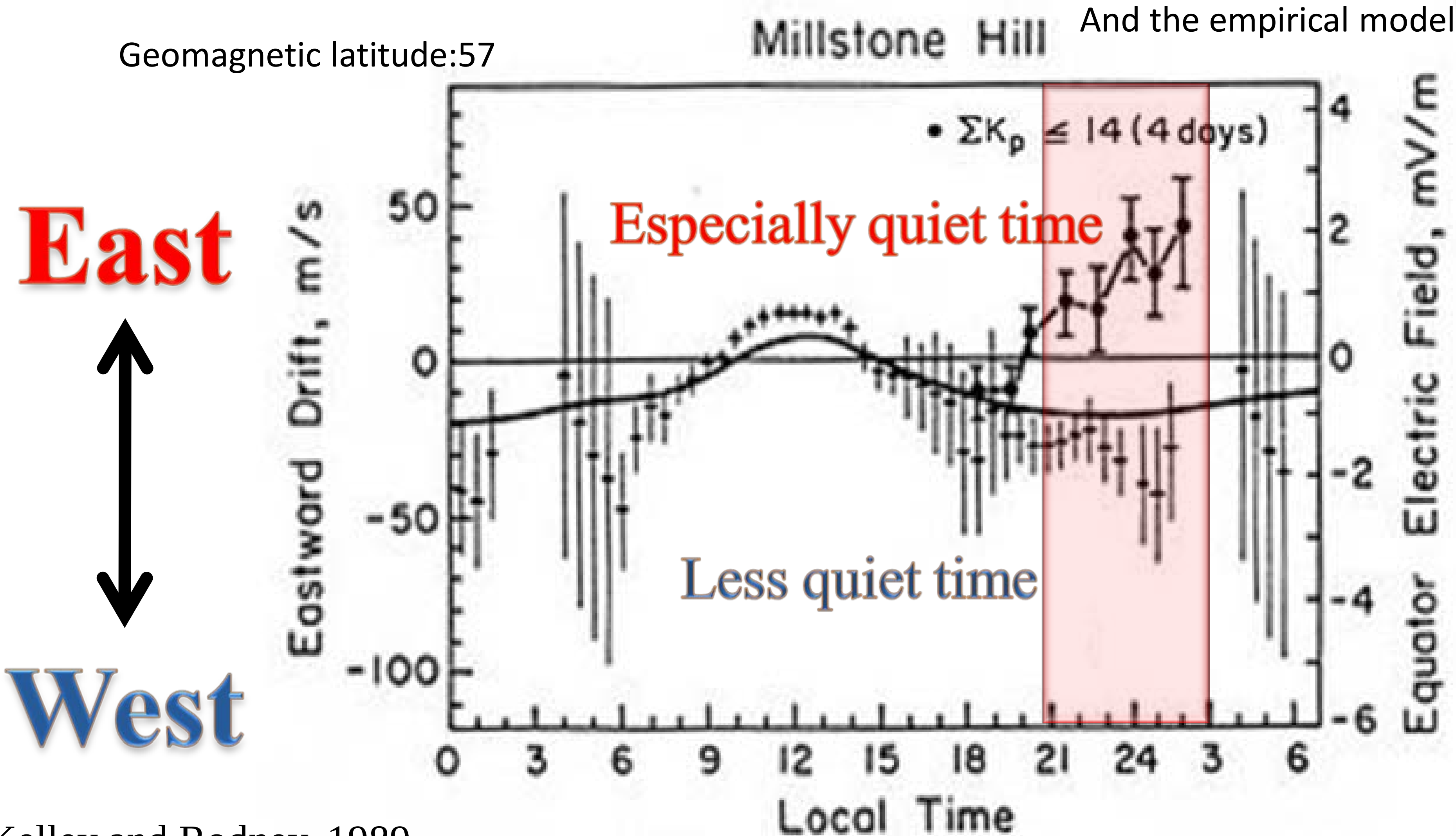
- Other possible factors to affect mid-latitude convection besides the disturbance dynamo should be investigated.

Overview of disturbance dynamo at mid-latitude from Previous studies

- Dominates at mid-latitude
- Provides strong influence of westward flow
- The influence becomes larger with the growth of storms
- The influence may last for 50 hours

Geomagnetic latitude dependence was not shown by the observation

Observation result using Millstone Hill radar by Gonzales et al. [1978] and Richmond et al. [1980]



Kelley and Rodney, 1989

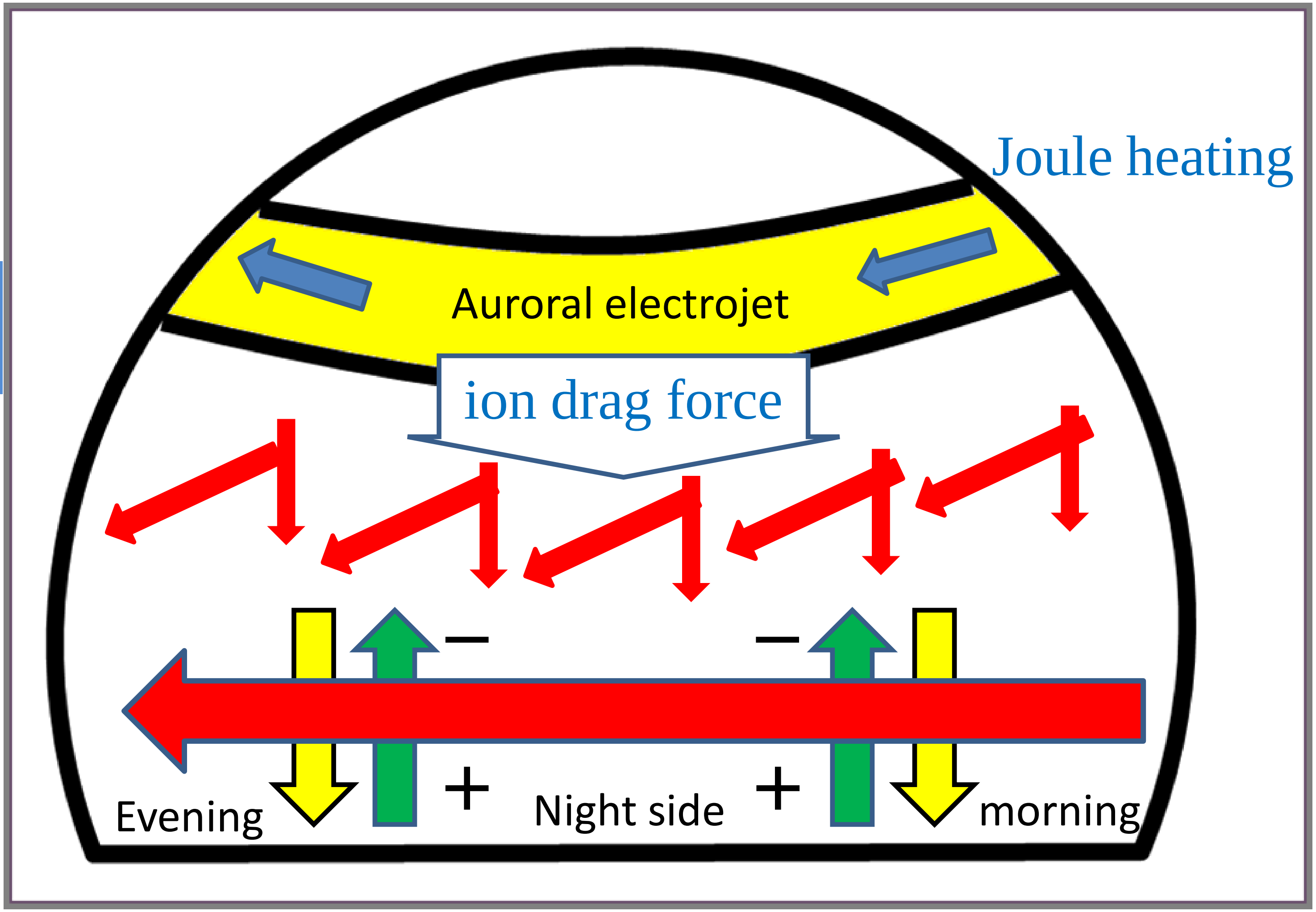
The Mechanism of disturbance dynamo

Coriolis force change southward neutral wind to westward

UxB electric field (Pedersen current)

Charge appears due to the conductivity gradient

westward ExB drift in the mid-latitude

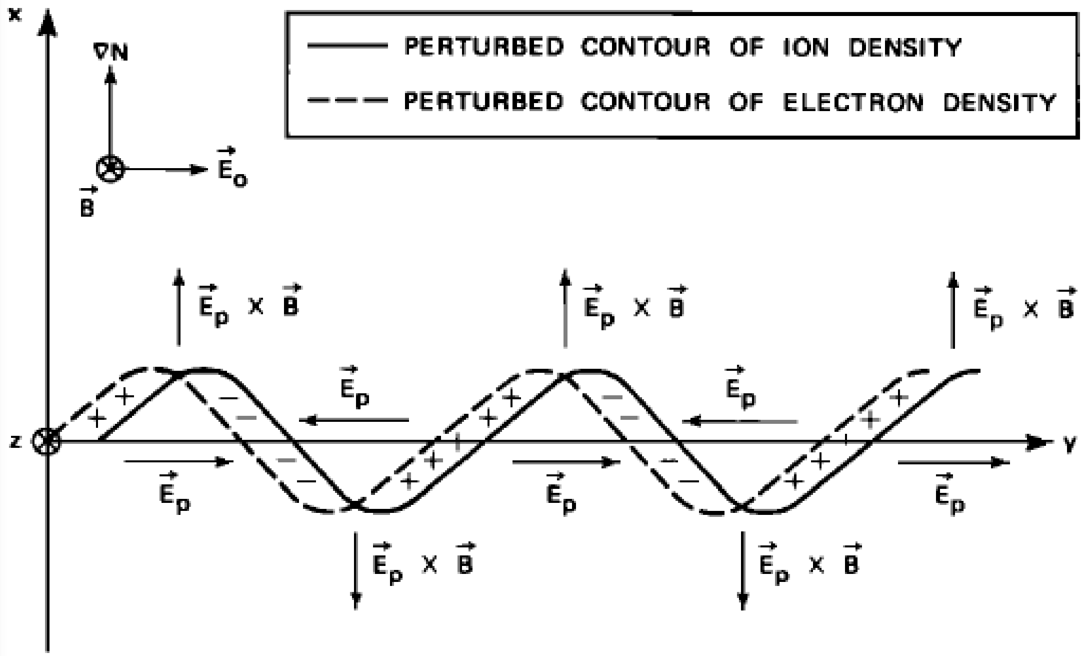


Blanc and Richmond, 1980

Discussion

Comparison with past studies

- In contrast to the result of Gonzales et al., night side eastward flow was not observed during deadly quiet periods.



A Pedersen ion drift (to the right) leads to charge separation and the development of polarization electric fields, Ep. The sense of Ep drives Ep×B motion that further enhances the original plasma perturbation.

TSUNODA, 1988

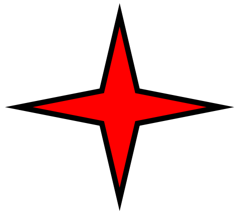
Why?

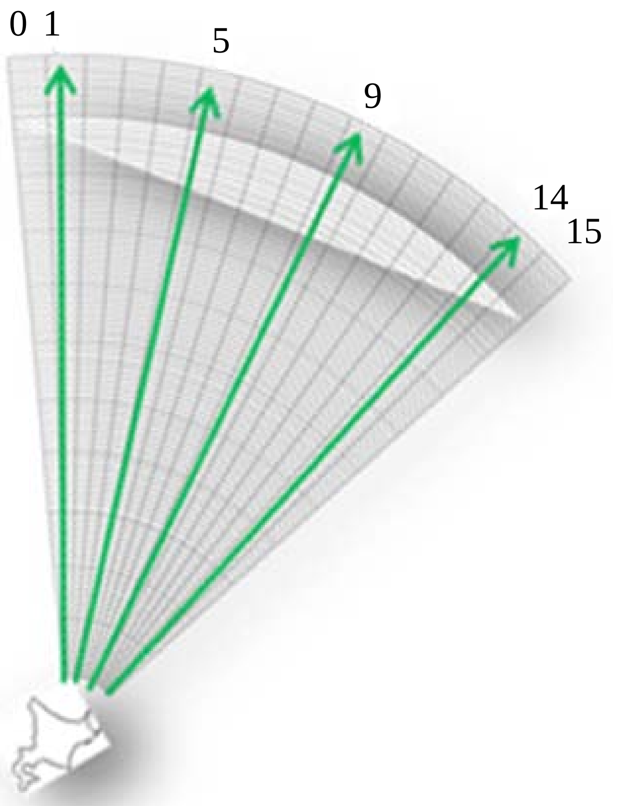
- One important factor of gradient drift instability is most likely to generate ionospheric irregularities.
- Gradient drift instability occurs when the electric field is strong enough, so that the ionospheric echoes are observed preferably when the electric field is strong(Fukumoto et al., 2000).
- Westward flow is observed preferably when the electric field is strong.

Method of this study(2/3)

Here θ means the zenith angle of each beam at different range, here we are using Spherical trigonometry to calculate the zenith angle.

Magnetic north





SuperDARN Hokkaido radar