Nature of dayside ionospheric current system of Pi2 pulsations: Comparison between equivalent currents and numerical simulation

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Introduction

Pi2 pulsations are defined as damping oscillations of geomagnetic fields with a period of 40 to 150 sec.

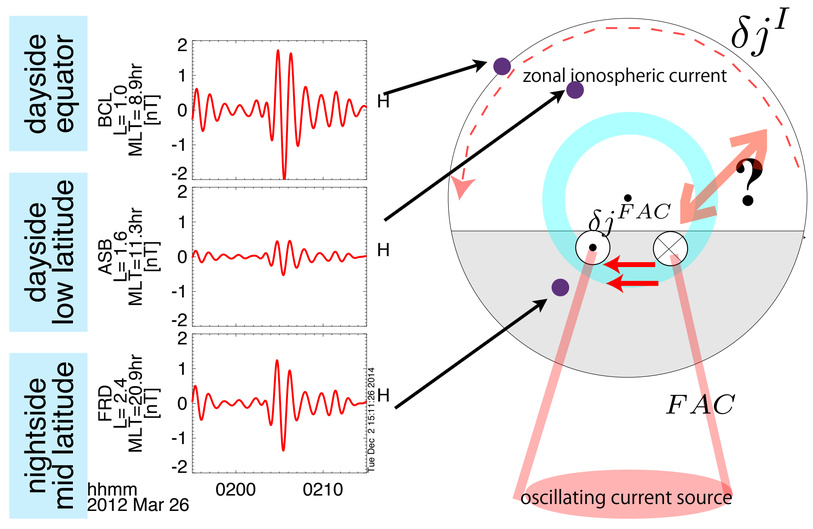
As with many types of geomagnetic disturbances, the amplitude of dayside Pi2s is maximized at the magnetic equator. This implies a coupling between the polar and equatorial regions. The coupling process is important for the propagation of disturbances from the magnetosphere to the equatorial ground.

Previous studies interpreted the *H* (north-south) component of dayside Pi2s as magnetic oscillations which is caused by zonal ionospheric currents [e.g. Shinohara et al., 1997]. This ionospheric current may be driven by the electric field penetrating from the polar region in the atmospheric waveguide [Kikuchi and Araki, 1979].

However, the following issues still remain:

1. Few studies investigated the *D*-component (east-west) magnetic field corresponding to north-south ionospheric current, which contributes to ensuring current continuity.
2. Few studies numerically estimated the dayside ionospheric current system produced by nightside field-aligned currents (FACs), including the equatorial region.

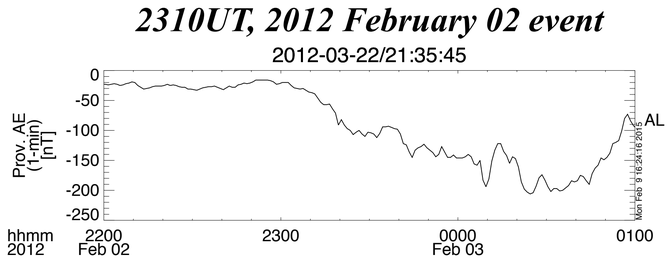
In this study, we estimated the ionospheric current system associated with Pi2 pulsations using both **equivalent current maps produced by ground magnetic data** and a **numerical calculation by the global potential solver**.



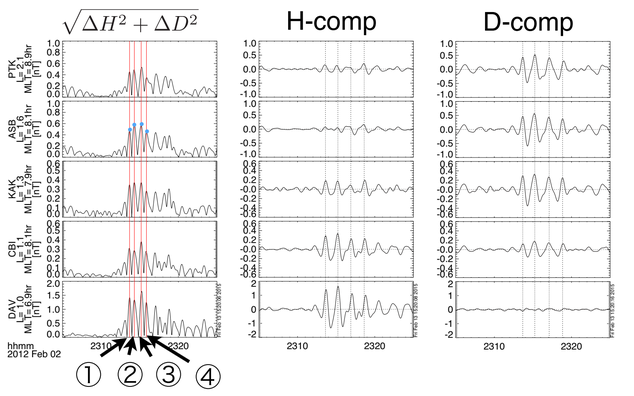
Observational Results

We analyzed the equivalent currents which cause magnetic oscillations with a period of 40 to 150 sec. Equivalent currents are estimated by rotating the vector of horizontal magnetic perturbation ((ΔD, ΔH), where ΔD and ΔH are bandpass filtered H- (north-south) and D-(east-west) component data, respectively, with a period of 40 to 150 sec) to 90 degrees clockwise. We consider equivalent current distributions at the times that the intensity of the equivalent current system reaches a local maximum. We define here these times as local maxima of the horizontal amplitude ($\sqrt{\Delta H^2 + \Delta D^2}$) at ASB station as a representative of all stations. The estimated equivalent current vector are depicted on the map in IGRF geomagnetic coordinate.

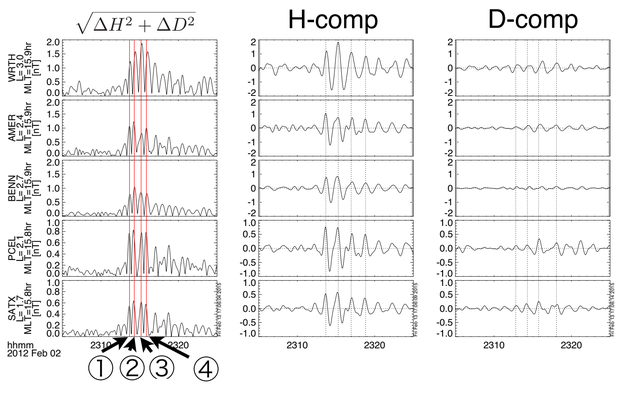
2310UT, 2012 February 02 event



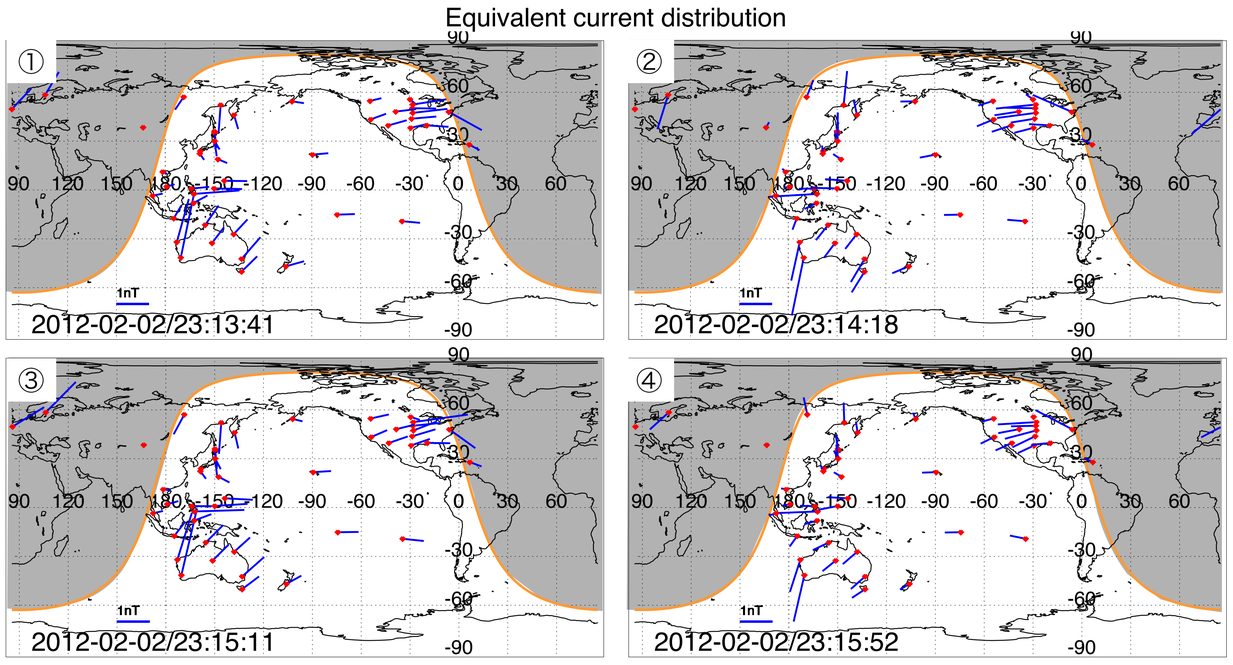
prenoon magnetogram (filter range: 40-150s)



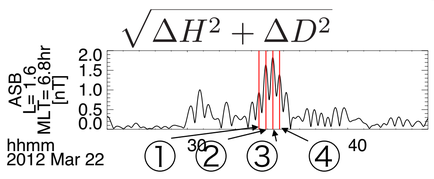
postnoon magnetogram (filter range: 40-150s)

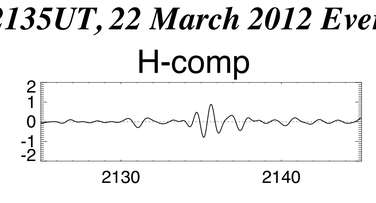


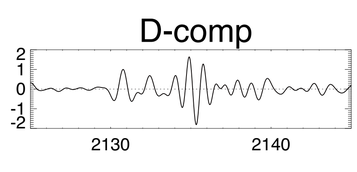
Equivalent current distribution

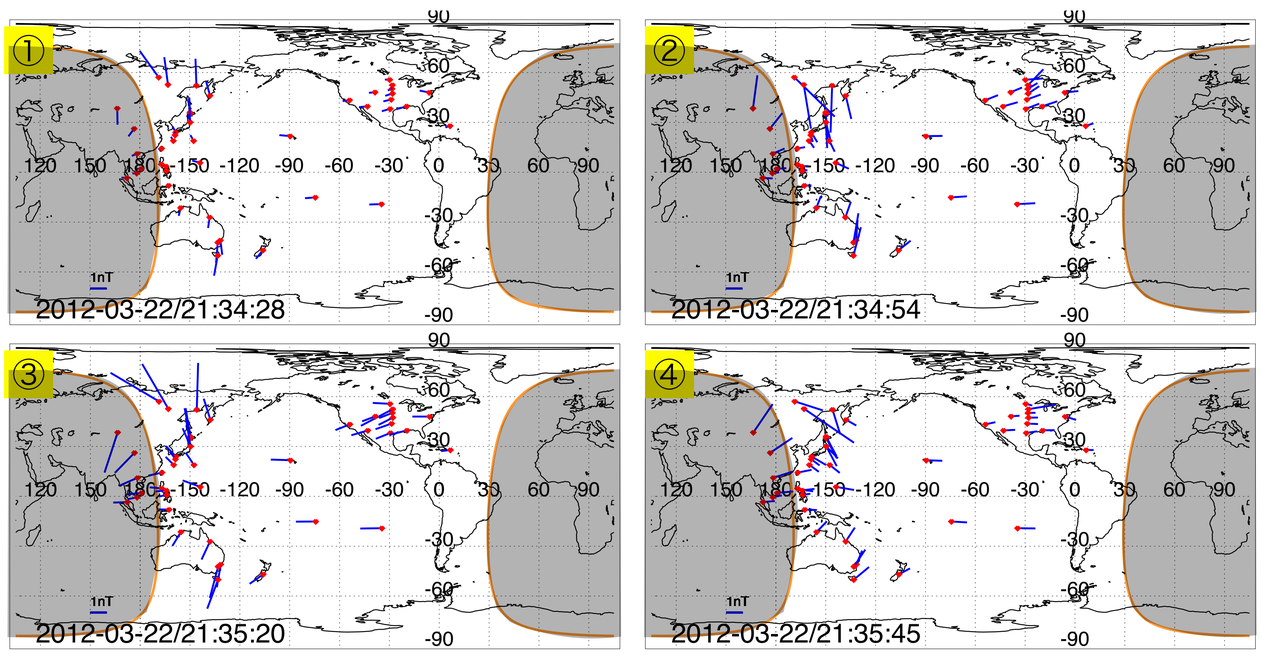


2135UT, 22 March 2012 Event









Numerical calculation by global potential solver

Thin shell model [e.g., Nakamizo et al., 2012]

We calculated the distribution of a conductivity tensor, using the same method as Nakamizo et al. [2012] with input parameters at 2320UT on 13 February 2012.

current continuity equation

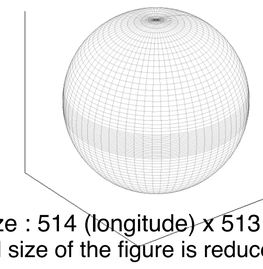
$$-j_{\parallel} \sin I = \nabla \cdot (\Sigma \cdot \nabla \Phi).$$

$j_{\parallel}$: FAC current density; I: Inclination; Φ: Electrostatic potential; Σ: hight integrated conductivity tensor

Ohm's law

$$\begin{pmatrix} J_\theta \\ J_\phi \end{pmatrix} = \begin{pmatrix} \Sigma_{\theta\theta} & \Sigma_{\theta\phi} \\ \Sigma_{\phi\theta} & \Sigma_{\phi\phi} \end{pmatrix} \begin{pmatrix} E_\theta \\ E_\phi \end{pmatrix} = \Sigma \cdot (-\nabla \Phi),$$

J: current density; E: electric field; θ: latitudinal; ϕ: longitudinal

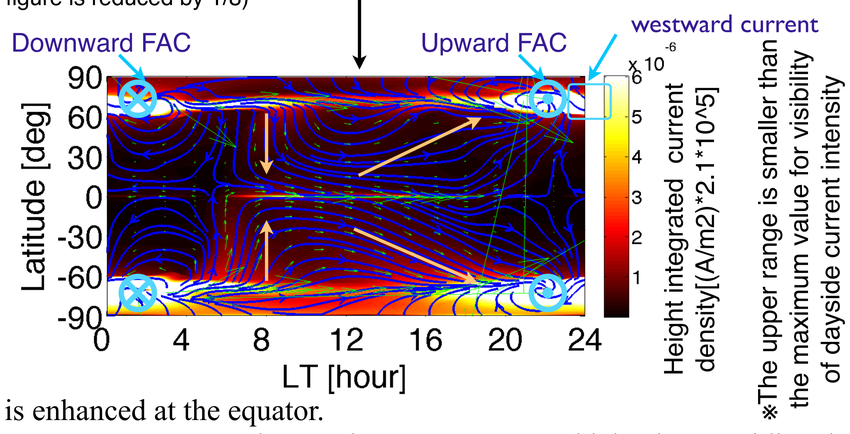


grid size : 514 (longitude) x 513 (latitude)
(The grid size of the figure is reduced by 1/8)

$$-r^2 j_{\parallel} sinI sin\theta = (sin\theta \Sigma_{\theta\theta}) \frac{\partial^2 \Phi}{\partial \theta^2} + \left(\frac{\Sigma_{\phi\phi}}{sin\theta}\right) \frac{\partial^2 \Phi}{\partial \phi^2} + \left\{ \frac{\partial}{\partial \theta}(sin\theta \Sigma_{\theta\theta}) - \frac{\partial \Sigma_{\theta\phi}}{\partial \phi} \right\} \frac{\partial \Phi}{\partial \theta} + \left(\frac{1}{sin\theta} \frac{\partial \Sigma_{\phi\phi}}{\partial \phi} + \frac{\partial \Sigma_{\theta\phi}}{\partial \theta} \right) \frac{\partial \Phi}{\partial \phi}$$

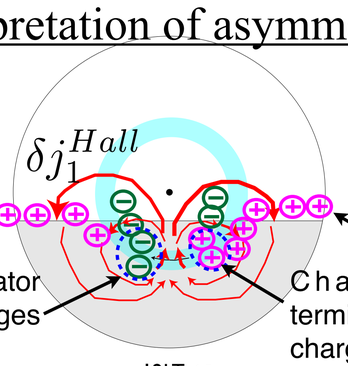
← solving Φ

← substituting Φ into Ohm's raw



- The current is enhanced at the equator.
- The dayside current system shows the asymmetry which the meridional component of currents in the prenoon sector is larger than in the postnoon sector.

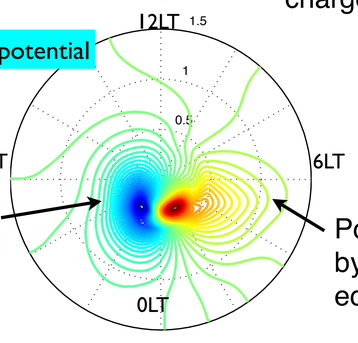
Discussion: interpretation of asymmetry of current



Charges at the dusk terminator are opposite in sign to charges provided by the FAC

Charges at the dawn terminator are same sign as charges provided by the FAC

Distribution of potential



Potential fields produced by the FAC are confirmed in the polar region.

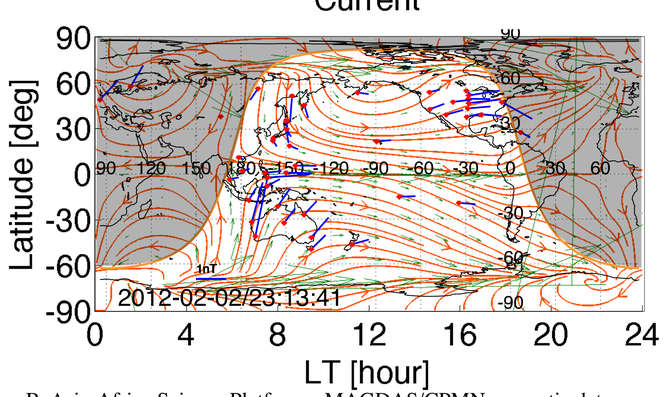
Potential fields produced by the FAC penetrate equatorward

Polarization charges generated by Hall currents deform the potential pattern. The secondary current (Total Hall currents and Pedersen currents produced by Hall polarization electric field) contribute to asymmetry of the current system. [Yoshikawa et al., 2013]

Summary

Both the observation and the numerical calculation showed the meridional component of current connecting to an equatorial zonal current. The dayside current system appears to be asymmetric, which the meridional current in the prenoon sector is larger than in the postnoon sector. This prenoon-postnoon asymmetry is explained by the deformation of potential fields due to polarization charges along the terminator.

We conclude that dayside Pi2s along major axis can be interpreted by magnetic oscillation induced by the oscillatory ionospheric current system produced by a pair of nightside FACs.



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