Global Ionospheric Current Systems During Magnetosphere-Ionosphere Coupling

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Introduction

Southward turnings in the Interplanetary Magnetic Field (IMF) leads to reconnection between inter planetary and magnetospheric magnetic fields which in turn exchanges energy and momentum. This leads to Prompt penetration of electric fields (PPEF) from high latitude to low-latitude (Nishida, 1968) and further impacts the global ionospheric electrodynamics and structures. The southward IMF first generally induces an increased polar convection electric field via Region-1 Field Aligned Currents (FAC). However, as this electric field strengthens, the Earth's magnetosphere responds by establishing a shielding effect with opposite polarity in association with Region-2 FAC. This shielding effect essentially works to counterbalance or mitigate the influence of the external electric field, thereby competing with it. The differences in temporal and spatial evolution between these two processes are not well understood. Before shielding has been established, the resultant electric field promptly penetrates to equatorial and low-latitudes, changing the ionospheric electrodynamics there. Depending on the upstream solar wind conditions, such as IMF, solar wind dynamic pressure, etc., the relative strength of convection and shielding electric fields changes which leads to variable prompt penetration electric fields. Further, Disturbance Dynamo Electric Field (DDEF) (Blanc and Richmond, 1980) caused by global-scale neutral wind dynamo driven by enhanced particle and Joule heating at high latitudes, appears few hours after the onset of geomagnetic storm. Often, the electric field disturbances due to PPEF and DDEF coexist and a resultant net electric field governs the low-latitude ionosphere.

Science Questions

How does ionospheric current systems vary during geomagnetic storm times?
Does Disturbance dynamo or PPEF contributes more during different stages of a geomagnetic storm?

Data and Methodology

GAMERA :**G**rid **A**gnostic **M**HD for **E**xtended **R**esearch **A**pplications.
Solves Magnetohydrodynamic (MHD) equations in magnetosphere. Electric potential and auroral particle precipitation from GAMERA are used as high-latitude boundary conditions in TIEGCM

TIEGCM: Thermosphere **I**onosphere **E**lectrodynamics **G**eneral **C**irculation **M**odel
Solves the three-dimensional momentum, energy and continuity equations for neutral and ion species in the thermosphere-ionosphere system. Wind, Conductivities, high latitude potential etc. from TIEGCM are used in the 3D dynamo.

3D Dynamo: A consistent formulation to solve for the electric field and calculate 3D ionospheric currents that satisfies the divergence in current over each element

Ionospheric currents during one solar rotation in 2013 May-June period is examined

Ionospheric current patterns during quiet time and two moderate/low geomagnetic storms are analysed

Figure 1: SMR Index obtained from GAMERA simulation and Supermag for the period 2013 May 23 to 2013 June 18

- The vectors in panel (panel 3a-3i) represents the height integrated horizontal current density and the contours is the radial current at the top of the ionosphere.
- The ionospheric currents in panel (3a, 3d) show Sq pattern due to E region wind dynamo during geomagnetically quiet day times.
- During quiet period (panel 3a, 3d), Counter Electro-Jet (CEJ) can be seen during early morning (9-11 MLT) and Equatorial Electro-Jet (EEJ) pronounces during daytime.
- Effect of penetration electric field is low during quiet periods (Panel 3g).
- In general (see contours in panel 3a-3i), radial currents show positive/negative in opposite hemispheres indicating Interhemispheric Field Aligned Currents (IHFACs).
- For both events 1 &2, significant CEJ can be seen during daytime with a corresponding anti-clockwise Sq in the southern hemisphere mid-latitudes (see panel 3b, 3c). However, the northern hemisphere shows a disturbed pattern of currents. There is also comparatively less-strength EEJ around Sq in the afternoon sector (15- 18 Magnetic Local Time- MLT). It is feeble for event 1 (panel 3b).
- For event 1, PPEF (panel 3h) also produces westward currents in the dayside equatorial region.
- Even though Cross Polar Cap Potential (CPCP) (panel 5a-5c) is 2-3 times higher during disturbed times than quiet time, the effects due to winds on the currents are larger.

Conclusion and Future Work

- ❖ Currents show significant changes in strength and pattern from quiet period.
- ❖ Disturbed winds play more role in ionospheric currents than PPEF during main and recovery phase for the given events.
- ❖ Currents in the high–latitude needs further investigation.

References

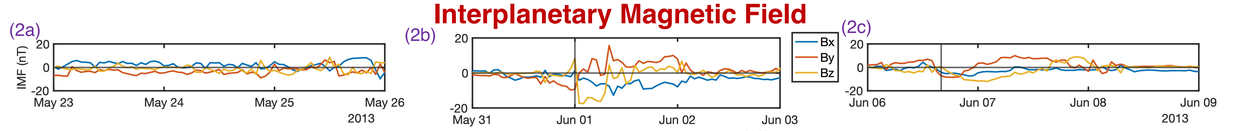
Nishida, A. (1968). Geomagnetic DP 2 fluctuations and associated magnetospheric phenomena. *Journal of Geophysical Research*, *73*(5), 1795-1803. https://doi.org/10.1029/JA073i005p01795

Blanc, M., & Richmond, A. D. (1980). The ionospheric disturbance dynamo. *Journal of Geophysical Research: Space Physics*, *85*(A4), 1669-1686. https://doi.org/10.1029/JA085iA04p01669

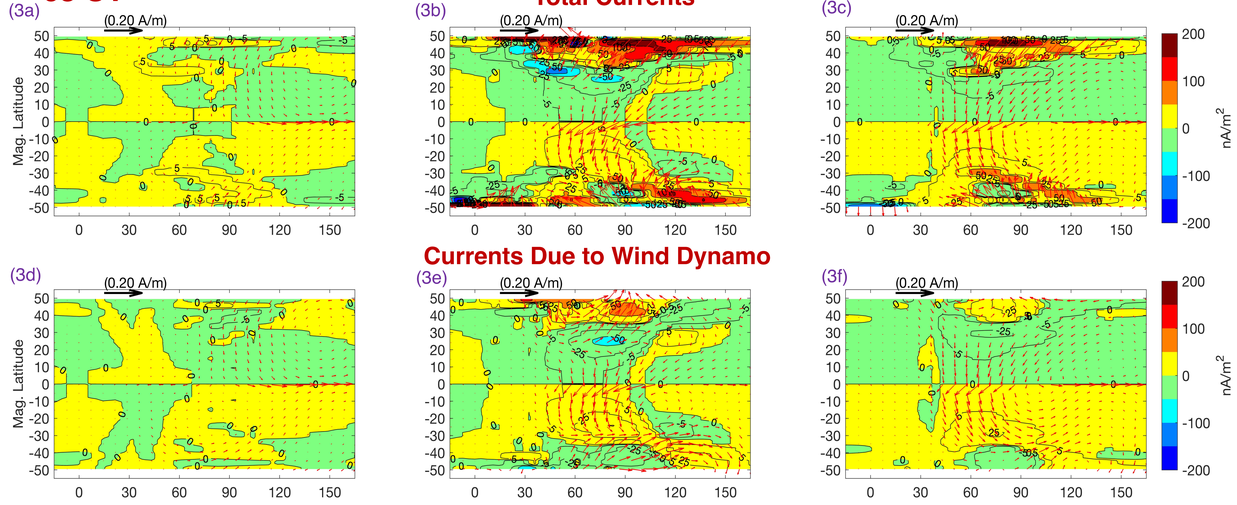
Results

Quiet Day: 2013 May 23 | **Event 1: 2013 June 01** | **Event 2: 2013 June 07**

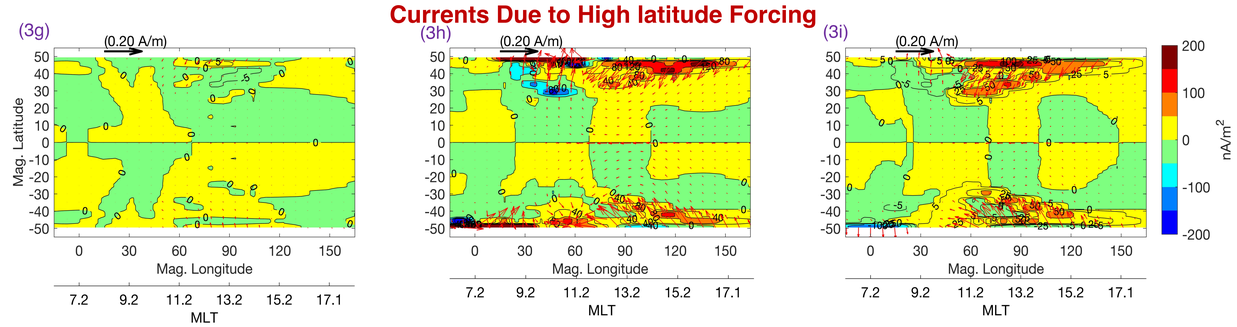
Interplanetary Magnetic Field



08 UT — Total Currents

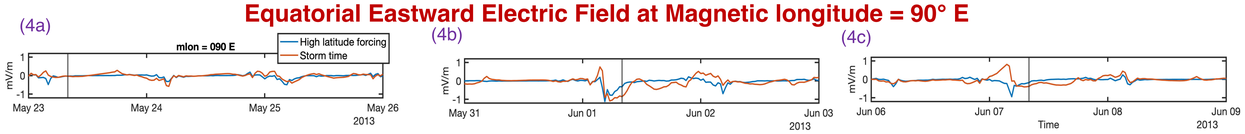


Currents Due to Wind Dynamo



Currents Due to High latitude Forcing

Equatorial Eastward Electric Field at Magnetic longitude = 90° E



Cross Polar Cap Potential Drop

Horizontal Winds at ~150 km