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EDITORIAL

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Introduction to the thematic series "Coupling of the magnetosphere–ionosphere system"

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Abstract

This thematic series contains 4 papers mostly presented at the 2016 AOGS meeting in Beijing. The four papers investigate four key regions in the magnetosphere–ionosphere coupling process: mid-tail magnetosphere, near-Earth magnetosphere, inner magnetosphere, and the polar ground region. Guo et al. (Geosci Lett 4:18, 2017) study the current system in reconnection region using 2.5D particle-in-cell simulations. Yao et al. (Geosci Lett 4:8, 2017) use conjugate measurements from ground auroral imagers and in situ THEMIS spacecraft to reveal the mechanism for the wave-like auroral structures prior to substorm onset. Zhang et al. (Geosci Lett 4:20, 2017) investigate the profiles of resonance zone and resonant frequency in the Landau resonance between radiation belt electrons and magnetosonic waves and between protons and cyclotron waves. Rae et al. (Geosci Lett 4:23, 2017) determine the relative timing between sudden increases in amplitude, or onsets, of different ultra-low-frequency wave bands during substorms.

Introduction

The dynamic coupling between the magnetosphere and the ionosphere system is crucial for understanding energy dissipation in the Earth system and in both solar system planets and exoplanets. The Earth's polar ionosphere couples to the entire magnetosphere; the distant tail > 25 R_E, near/mid-Earth magnetotail 6.6–25 R_E, and inner magnetosphere < 6.6 R_E. Particle acceleration, field-aligned current generation, and ground magnetic perturbations are the most pivotal and challenging in understanding how the magnetosphere–ionosphere system is coupled. The past two decades have seen the development and launch of a number of space missions and deployment of ground stations dedicated to the investigation of a particular link in the chain of interactions between magnetosphere and ionosphere. With these new assets, it is now possible to understand the energy conversion process between magnetosphere and ionosphere on both global and localized scales with conjugate measurements in all key regions, i.e., the mid-magnetotail, near-Earth magnetotail, ionosphere, and Earth's polar ground.

The thematic series of Geoscience Letters are mostly based on presentations from the session on the same topic (ST06: Magnetosphere–Ionosphere Coupling Dynamics) organized at the Asia Oceania Geosciences Society (AOGS) General Assembly held in Beijing during July 31–August 5, 2016. The papers are organized in the order from the outer magnetosphere to the inner magnetosphere and the ionosphere.

Mid-tail magnetosphere

Energy in driving terrestrial magnetospheric dynamics originates from the solar wind and is stored in the magnetosphere via magnetopause reconnection (Dungey 1961). In the magnetotail, reconnection is essential in energizing particles, producing high-speed flows, and the formation of plasmoids. How electrons are accelerated via reconnection and how reconnection outflow drives magnetotail dynamics are two fundamental topics in terrestrial magnetosphere field.

From 2.5D particle-in-cell (PIC) simulations, Guo et al. (2017) examine current systems forming near the electron separatrix and investigating a non-gyrotropic

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electron distribution. These authors suggest that a dramatic change in the orientation of the electron velocity could be a diagnostic to detect the electron separatrix. In the reconnection exhaust region, Guo et al. (2017) show that ions are the main carriers for the out-of-plane current, while the parallel current is mainly carried by electrons.

Near-Earth and inner magnetosphere

Reconnection outflow from night-side tail reconnection propagates from mid-tail to near-Earth magnetotail and inner magnetosphere. The propagation of these flows causes perturbations of plasma and fields, which can lead to particle energization in the inner region.

A major impact of the reconnection outflow is caused by its braking and deceleration in the near-Earth magnetotail. These include flux pileup (e.g., Shiokawa et al. 1997) and the development of plasma instabilities (e.g., Lui 1991) in the inner magnetosphere. By analyzing simultaneous measurements from the near-Earth THEMIS probes (Angelopoulos 2008) and ground auroral imagers, Yao et al. (2017) reveal that a kinetic-scale ballooning instability was excited at the arrival of a reconnection outflow. This caused the development of wave-like auroral structures in the atmosphere. Their analysis shows consistent wavelength from aurora and in situ measurements. Moreover, they also present similar wave-like auroral feature at Saturn and Jupiter, which may imply that a common process exists at other planets.

Zhang et al. (2017) investigate the profiles of resonance zone and resonant frequency in the Landau resonance between radiation belt electrons and magnetosonic waves and between protons and cyclotron waves. Their results demonstrate that resonant interactions between magnetosonic waves and magnetospheric charged particles depend heavily on L-shell, wave normal angle, kinetic energy, and equatorial pitch angle of the particles. Resonance zones for the Landau resonance between magnetosonic waves and radiation belt electrons are confined to a very narrow (mostly less than 1°) extent of magnetic latitude, which tends to shift to lower latitudes with increasing equatorial pitch angle and decreasing electron energy.

Ground magnetic perturbation

Measurements of ground magnetic perturbations provide a unique view for understanding the global development of ionospheric and magnetospheric current system during a substorm. Rae et al. (2017) determine the relative timing between sudden increases in amplitude, or onsets, of different ultra-low-frequency (ULF) wave bands during substorms. They show that differing onset times and spatial expansion exist for Pi1, Pi1-2, and Pi2 waves in the ionosphere during substorms. Their results demonstrate how careful analysis of ULF waves during substorm onset can provide vital information on the physical processes occurring and time history of these processes through substorm onset.

Authors' contributions

All the authors acted as Guest Editors for the contributed papers. The Introduction was first drafted by ZY but all the authors read and agreed the contents. All authors read and approved the final manuscript.

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Competing interests

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