Introduction to the JGR Special Section

“Pulsating Aurora and Related Magnetospheric Phenomena”

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Pulsating aurora (PsA) is a class of diffuse aurora showing characteristic modulations in its luminosity [Lessard, 2012, Li et al., 2012 and references therein]. In general, PsA appears immediately after the substorm onset in the equatorward part of the auroral oval and is continuously observed mainly in the morning side during the recovery phase of the substorm. PsA shows a wide variety of shapes, but, in many cases, PsA is composed of luminous patches of irregular shape having similar latitudinal and longitudinal scale sizes [e.g., Royrvik and Davis, 1977]. PsA is known to have two outstanding periodicities: main pulsation (a few to a few tens of second) and higher frequency internal modulation (a few Hz, so-called 3 Hz modulation) [e.g., Royrvik and Davis, 1977]. Besides these modulations, modern high-speed optical imaging technologies have recently identified rapid modulations whose frequency is ~15 Hz [Samara and Michell, 2010] and ~55 Hz [Kataoka et al., 2012]. The origins of these fast modulations have not yet been clarified. Attached Animation gives a typical example of PsA, which was observed by an all-sky TV camera in Tromsoe, Norway, during a 30 min interval from 0250 UT to 0320 UT on March 9, 2008. The Animation well demonstrates that patches of diffuse aurora were drifting eastward with pulsating their optical intensity.

Early sounding rocket observations demonstrated that PsA is caused by intermitted precipitations of electrons whose energy is above a few keV [Sandahl et al., 1980; McEwen et al., 1981]. It is worthwhile to note that optical cameras and particle detectors onboard the Reimei satellite recently demonstrated, for the first time, one-to-one correspondence between the intermittent precipitation of energetic electrons and pulsation in the optical emissions [Miyoshi et al., 2010; Nishiyama et al., 2011]. In fact, PsA has a long history of research since its discovery in late 50’s. However, there are still several unclarified issues regarding the fundamental characteristics of PsA: 1) what process precipitates the PsA electrons into the ionosphere, 2) what mechanism determines the period of main pulsation, 3) what process characterizes the interval of the 3 Hz modulation, and 4) what mechanism creates the wide variety of shapes (patch type, arc type etc.). In particular, identification of the origin of the period of the two distinct pulsations is the most central scientific problem regarding PsA.

 It has been widely believed that intermittent electron precipitations associated with PsA are caused by the pitch angle scattering through wave-particle interactions, although field-aligned potential drop [Sato et al., 2004] and the Fermi-acceleration associated with the dipolarization [Nakajima et al., 2012] have also been suggested to cause PsA. Nishimura et al. [2010] demonstrated that the repetitions of lower-band chorus waves in the magnetosphere measured by THEMIS correspond to the optical modulations detected on the ground. Ground-based observations have also confirmed the relationship between the chorus waves and optical pulsations [e.g., Tsuruda et al., 1981, Ozaki et al., 2012]. Lower-band chorus waves are observed intermittently in the magnetosphere, which may cause the repetition of the intensity modulations of PsA. Li et al. [2010, 2011] reported that the occurrence of the lower-band chorus is closely related to enhancement and/or depression of the thermal plasma density. ECH waves are another candidate to explain the generation of PsA [Liang et al., 2010]. Since the MLT and L-shell dependences of the activities of ECH waves and whistler mode waves are very similar to those of PsA [Ni and Thorne, 2012], both the whistler mode waves and ECH waves are able to produce PsA. Namely, the temporal evolution of PsA can be used to visualize how the plasma waves interact with particles near the equatorial plane of the magnetosphere. In this sense, studies of PsA would contribute to a detailed understanding of the wave-particle interaction in the magnetosphere.

Modulation of the ionosphere by an occurrence of PsA has been reported in recent years [Jones et al., 2009; Hosokawa et al., 2010; Hosokawa and Ogawa, 2010]. In particular, Hosokawa et al. [2010] suggested an existence of field-aligned current flowing into/out of the edges of PsA patches. Such a FAC system was first identified by Fujii et al. [1985]. After that, however, the origin of the FAC has not been investigated in detail. Such a study of the modulation of the electrodynamics in the vicinity of PsA patches can open a new window for studying time-varying magnetosphere-ionosphere coupling system, which would be a good target of the next generation ionospheric measurements by the existing AMISR system and planned EISCAT\_3D system. Oyama et al. [2010] have revealed that thermospheric neutral wind observed by FPI system is disturbed during periods of PsA. Not only that, PsA is known to affect the lower-ionosphere and upper part of the middle-atmosphere because the PsA electrons have relatively high energy up to a few hundreds of keV [Sandahl et al.,1981; Miyoshi et al., 2010, 2015]. That is, PsA is closely related to the dynamics of the neutral atmosphere, which is one of the wide aspects of PsA studies. PsA is associated with high-energy particle precipitations which can induce significant ionization in the lower part of the ionosphere. The PsA ionization below 80 km may create an anomalous increase of NOx gases, which can further destruct ozone [e.g., Isono et al., 2014]. In this sense, the study of PsA is important in terms of the vertical coupling between the Geospace plasma and the Earth’s atmospheric environment.

As mentioned above, PsA is not only phenomenon in the magnetosphere and ionosphere, but also phenomenon in the thermosphere and middle atmosphere. There are several on-going and planned missions for studying the inner magnetospheric dynamics such as Van Allen Probes (VAP) [Mauk et al., 2012] and ERG [Miyoshi et al., 2012]. Simultaneous ground-based supporting measurements are or will be conducted in conjunction with these space missions. In addition, several new ground-based optical measurements have been deployed in the high-latitude region which can be used for high-speed imaging of PsA [e.g., Samara and Michell, 2010, Kataoka et al., 2012, Nishiyama et al., 2014]. Such a situation enables us to focus on the PsA studies and reveal the above-mentioned unresolved issues about PsA, which is the reason for proposing this special issue. This issue contains a lot of PsA related studies from various fields of research, which shows great potential of PsA as a universal phenomenon. We hope that this issue should be useful to share the current understandings of PsA and shed further light on directions of PsA research in the next 5 years that will be the best period for the focused study of PsA.

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