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Influence of the Weak Intrinsic Magnetic Field on the Development of Magnetic Storms Based on Global Drift-Kinetic Simulations

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Earth's intrinsic magnetic field strength is one of the most critical parameters in geospace. It has decreased by ~30% over the past 2000 years [Olson and Amit, 2006]. The decrease will change quasi-static parameters of the magnetosphere-ionosphere-thermosphere system [e.g. Cnossen et al, 2012]. It will also change transient phenomena of magnetosphere like substorms and magnetic storms. A previous study examined the dependency of auroral substorms on the intrinsic magnetic field by global MHD simulations [Ebihara et al., 2020]. However, the effect of intrinsic magnetic field strength on the development of magnetic storms is still unclear, because in the inner magnetosphere, kinetic processes, which are not included in the MHD approximation, are dominant.

We investigated the development of magnetic storms and ring current and associated excitations of ULF waves, using a magnetosphere-ionosphere coupled model [Yamakawa et al. 2023] which combines GEMSIS-RC [Amano et al. 2011] and GEMSIS-POT [Nakamizo et al. 2012]. In GEMSIS-RC, the 5D drift-kinetic equation and Maxwell's equations are solved self-consistently. GEMSIS-POT solves ionospheric electric potential for the height-integrated ionosphere. In the coupled model, distribution of plasmaspheric cold plasma is also evolved based on a continuity equation. Simulations were conducted for three cases: the present Earth (Case 1), a planet with a weak (2/3 of Case 1) intrinsic magnetic field and high ionospheric conductivity (Case 2), and with the weak magnetic field and standard ionospheric conductivity (Case 3). Case 1, 2, and 3 correspond to Run 1, 3, and 5 of global MHD simulations (Ebihara et al. [2020]), respectively. For each case, we applied R1-FAC to the ionosphere and set the temperature and density of the plasma sheet according to the corresponding run.

From the obtained distributions of the ring current ions, SYM-H index with the Dessler-Parker-Sckopke relation is estimated to evaluate the development of magnetic storms. The minimum value of SYM-H index turned out to be in the following order: Case 3 <Case 2 <Case1, and SYM-H index declined more rapidly in Cases 2 and 3 than in Case 1. The total kinetic energy of the ring current was the smallest in Case 2, and almost the same in Cases 1 and 3. Although the total kinetic energy of the ring current decreases under weak intrinsic magnetic field cases, the decrease is smaller relative to the reduction of the intrinsic dipole magnetic energy in the denominator of the DPS relation, which results in a larger decrease of the estimated SYM-H index in Case 2 than in Case 1. We also found that in the weak intrinsic magnetic field cases, ring current azimuthal development is faster in the duskside. This is because ring current developed closer to Earth in the cases, which leads to larger drift frequencies of ring current ions. Excitations of fundamental ULF waves due to injection of ring current ions are identified in all cases: dayside Pc5 and dawnside Pc4. Under the weak intrinsic magnetic fields, the amplitude of excited ULF waves was smaller in the dayside and larger in the dawnside. In the presentation, we will also discuss the reason in detail.