Study of the solar wind influence on the Jovian inner magnetosphere using an ionospheric potential solver. K. Terada[1], C. Tao[2], N. Terada[1], Y. Kasaba[1], H. Kita[1], A. Nakamizo[2], A. Yoshikawa[3], S. Ohtani[4], F. Tsuchiya[1], M. Kagitani[1], T. Sakanoi[1], G. Murakami[5], K. Yoshioka[7], T. Kimura[6], A. Yamazaki[5], and I. Yoshikawa[7], [1]Graduate School of Science, Tohoku University, [2]Applied Electromagnetic Research Institute, National Institute of Information and Communications Technology, [3]Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, / International Center for Space Weather Science and Education, Kyushu University, [4]The Johns Hopkins University Applied Physics Laboratory, [5]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, [6]Nishina-Center for Accelerator Based Science, RIKEN, [7]Graduate School of Frontier Sciences, The University of Tokyo.

Introduction: The corotation of Jovian magnetospheric plasma dominates the convection in the Jovian inner magnetosphere (< 30 R_J). Therefore, the solar wind hardly influences the plasma convection there [1]. In the vicinity of Io's orbit (~5.9 R_J), the corotation electric field is ~150 mV/m, ~400 times of the solar wind electric field [2]. However, the extreme ultraviolet spectroscope (EXCEED) aboard the Hisaki satellite showed that the brightness intensity of the Io plasma torus (IPT) changed asymmetrically between the dawn and the dusk sides. Furthermore, it was confirmed that this asymmetric change coincided with a rapid increase in the solar wind dynamic pressure. Such change can be explained by the existence of a dawn-to-dusk electric field of ~4-9 mV/m around Io's orbit [3]. This dawn-to-dusk electric field shifts the position of IPT toward dawn side by ~0.1-0.3 R_J. Associated with this shift, the plasma in the IPT is adiabatically heated at dusk and cooled at dawn, which makes the dawn-dusk brightness asymmetry. The following processes have been suggested as a possible cause of the dawn-to-dusk electric field. First, the Jovian magnetosphere is compressed by the increase of solar wind dynamic pressure. Then, the magnetosphere-ionosphere coupling current system is modified, and the field-aligned current (FAC) connected to the high-latitude ionosphere increases. As a result, the ionospheric electric field increases and penetrates to lower latitude regions. It is mapped to the equatorial plane of the inner magnetosphere along magnetic field lines, and the dawn-to-dusk electric field is created around Io's orbit.

Model: We have constructed a 2-D ionospheric potential solver in order to demonstrate this scenario quantitatively. We used a time-averaged intensity of the total FAC obtained from Galileo observations [4] and adopted a Gaussian function for its horizontal distribution in a similar way to the Earth's ionospheric model [5]. The intensity of the dawn-to-dusk electric field at Io's orbit depends on the global distribution of the ionospheric conductivities, because Io's orbit connects to the ionosphere at a lower latitude region than the FAC and the aurora regions. We modeled the ionospheric conductivities from collision frequencies, cyclotron frequencies and density distributions in the upper atmosphere. We deduced the collision frequencies from ion-H_2 and electron-H_2 collisions [6]. Because the limited area of the ionosphere was observed by Galileo and Voyager, we used a photo-chemical model to estimate the global distributions of the ionospheric densities, which took into account ionizations caused by the solar EUV and aurora electrons precipitating at the upward FAC region [6].

Results and Discussion: We have calculated the ionospheric electric potential distribution and the magnetospheric dawn-to-dusk electric field, with the FAC and conductivity distributions described above. The calculated dawn-to-dusk electric field was ~270 mV/m at post-dawn and ~70 mV/m at the pre-noon. It was two orders of magnitude larger than that expected from the Hisaki observations. We considered that this difference would be caused by the underestimation of the ionospheric electron density. Our model has not considered the following four physical phenomena: (1) soft electron precipitation [7], (2) vertical plasma drift, (3) H^+ ions, and (4) metallic ions originating from meteoroid ablation. However, the first and second phenomena are unlikely to be the reason explaining the difference between our result and the Hisaki observations. Because the soft (~50-60 eV) electron precipitation ionizes the ionospheric neutral species above ~1,500 km [6], the height-integrated conductivity is hardly influenced. The vertical plasma drift decreases the ionospheric electron density [8] and cannot resolve the problem. We have regarded the third and fourth phenomena as the reason to underestimate the electron density. H^+, a dominant species above 600 km [9], has a long life time until its loss by the recombination. Therefore, the electron density at the dusk side and the night side maintains higher value [10]. Similarly, Mg^+ and Fe^+ ions of meteoric origin, whose density peaks are 4×10^4 cm^{-3} at 390 km and 4×10^4 cm^{-3} at 375 km, respectively [11], are neutralized only slowly by radiative recombination and increase the electron density on the night side under the quasi-neutral condition.

Given that the conductivity is a function of the electron density, the enhancement of the electron density by the contribute of H^+ and/or meteoric ions may modulate the conductivity.

In order to estimate the influence of H^+ and the meteoric ions, we added the densities of these ions to the result of our photo-chemical model. As a result, the ionospheric electron density increased by a factor of two at the H^+ density peak of ~700 km and the density peak of meteoric ions of ~400 km at noon and had a negligible local time dependence at these altitudes. The dawn-to-dusk electric field was ~20-27 mV/m at Io's orbit, which is still higher but marginally agrees with the Hisaki observations. Our results suggest that H^+ and the meteoric ions are important to consider the ionospheric conductivity and the dawn-to-dusk electric field in the inner magnetosphere.

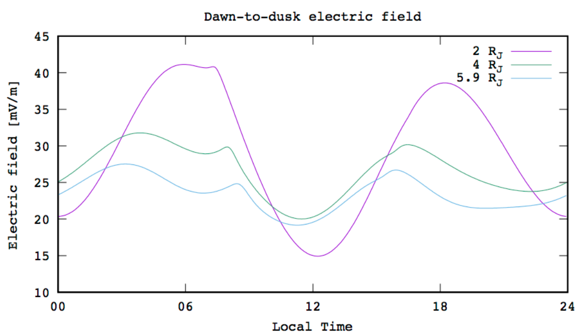

Fig. 1: Local time profile of the dawn-to-dusk electric field in the inner magnetosphere when we added H^+ and meteoric ions to the result of our photo-chemical model. Blue line shows the electric field at IPT (5.9 R_J).

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