MULTI-SCALE SOLAR WIND PLASMA INTERACTION WITH THE MOON. Y. Saito\textsuperscript{1}, S. Yokota\textsuperscript{1}, M. N. Nishino\textsuperscript{1}, K. Uemura\textsuperscript{1}, T. Yamamoto\textsuperscript{1}, H. Tsunakawa\textsuperscript{2}, and Kaguya Map-Pace Team, \textsuperscript{1}Institute of Space and Astronautical Science / Japan Aerospace Exploration Agency, \textsuperscript{2}Tokyo Institute of Technology.

**Introduction:** Interaction between the solar wind and a solar system object varies largely according to the object’s properties, such as the existence of a global intrinsic magnetic field and/or thick atmosphere. It is well known that the Moon has neither global intrinsic magnetic field nor thick atmosphere. Different from the Earth’s case where the intrinsic global magnetic field prevents the solar wind from penetrating into the magnetosphere, solar wind directly impacts the lunar surface. The interaction similar to that between the solar wind and the Moon must be found around numerous solar system small objects as well as larger moons of other planets, and in some special solar wind conditions around Mercury. The space around the Moon is one of the best places for studying the detailed process of such interactions since detailed in situ measurements with multiple mass-demanding high-spec science instruments are possible.

Interaction between the solar wind and the Moon is observed on multiple scales including global-scale as large as the Moon, meso-scale comparable to characteristic plasma scale length, and micro-scale as small as atomic scale. The plasma related phenomena observed by MAP-PACE on Kaguya ranged over all of these scales.

**Global Scale Interaction:** One of the global scale interactions between solar wind and the Moon recently recognized is the proton reflection/scattering at the lunar surface \cite{1,2} and their entry into the lunar wake \cite{3,4}. When the solar wind arrives at the Moon, some of the solar wind protons are backscattered at the lunar surface and some of the solar wind ions are magnetically reflected by lunar magnetic anomalies. The reflected/scattered ions are pick-up accelerated by solar wind convection electric field and enter into the lunar wake. This pick-up process is slightly different from the pick-up process so far reported around a comet since the reflected/scattered ions have initial velocity when they are picked up by the solar wind. The ions entered into the lunar wake form proton governed region, which generate counter-streaming electrons along magnetic field in order to keep charge neutrality. These counter-streaming electrons will generate plasma waves. This new view on the plasma environment around the Moon is one of the global scale solar wind interactions with the Moon that must be common to the non-magnetized airless bodies.

**Meso Scale Interaction:** An example of the mesoscale interaction between the solar wind and the Moon is the interaction between the solar wind and the lunar magnetic anomalies. Many of the lunar magnetic anomalies have the scale size of \~100km that is comparable to the ion inertia length in the solar wind. MAP-PACE revealed the plasma structure over lunar magnetic anomalies on the dayside of the Moon using the low altitude data \cite{5}. At \~25km altitude over magnetic anomalies on the Moon, deceleration of the solar wind ions, acceleration of the solar wind electrons parallel to the magnetic field, and heating of the ions reflected by magnetic anomalies were simultaneously observed. The acceleration energy of the electrons was almost the same as the deceleration energy of the ions. It indicates the existence of anti-moonward electric field over the magnetic anomalies above the altitude of Kaguya that can be explained by the ion inertial scale (meso-scale) interaction between the solar wind and the magnetic anomalies. The reflected ions had higher temperature and lower bulk velocity than the incident solar wind ions. It suggests the existence of a non-adiabatic dissipative interaction between solar wind ions and lunar magnetic anomalies below Kaguya.

**Micro Scale Interaction:** The generation of the backscattered solar wind protons at the lunar surface is an example of the micro scale interaction between the solar wind and the Moon. In order to understand the reflection/scattering characteristics at the lunar surface, the relation between the incidence angle of the solar wind and the output angle of the scattered protons are investigated in detail. The results show that the protons are mostly scattered back inside a scattering cone with \pm 40deg. whose center axis is opposite to the incidence vector of the solar wind. It is also found that the energy decrease of the scattered solar wind is most significant along the axis of the scattering cone. Simultaneously with the backscattered protons, there also exist specularly reflected protons when the incidence angle is nearly tangential to the lunar surface. Recently, a global map of the scattered protons was made using Kaguya MAP-PACE-IMA data. Since the global backscattering proton map is easily contaminated by large ion flux reflected by magnetic anomalies, it was made by masking the major magnetic anomalies based on the magnetic field measurement made by LMAG (Lunar MAGnetometer) on Kaguya. It was found that the intense scattered proton flux was observed especially in the sea region of the Moon. The observed scattered ion intensity may reflect the roughness of the
lunar surface. If so, measurement of the scattered proton will be a new method to remotely assess the surface characteristics of the non-magnetized airless bodies.

References: