Satellite-to-satellite radio occultation for the exploration of planetary atmospheres

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In order to understand the climate system of planets, it is necessary to reveal the three-dimensional circulation of energy and atmospheric compounds. Methods of observing planetary atmospheres that have made significant achievements to date can be broadly classified into direct measurements by landers and optical remote sensing by orbiters and ground telescopes. Although the former can accurately measure various physical quantities, it cannot capture physical and/or chemical processes involving large spatial changes. The latter enables global observations; however, the vertical resolution is typically limited to a scale height (several kilometers), and thus layered structures characteristic of planetary atmospheres cannot be well resolved. Moreover, the pressure field, which is critical for understanding atmospheric dynamics, cannot be measured. Because of these limitations, for example, the three-dimensional structures of water and dust transport on Mars have not yet been identified, and the three-dimensional structure of the angular momentum transport in Venus’s atmosphere that sustains the high-speed atmospheric circulation has not yet been identified.

We consider satellite-to-satellite radio occultation can make a breakthrough in the sciences of planetary atmospheres. In conventional radio occultation observations, the planetary atmosphere is observed by using radio waves transmitted from the spacecraft and received at a ground station when the spacecraft is hidden behind the planet as seen from the ground station. This method can measure the temperature, the pressure and absorbing materials at high vertical resolutions of several hundred meters; however, it has a disadvantage that it cannot capture the spatial structure because the observation points are limited by the positional relationship among the spacecraft, the planet and the earth. Based on this recognition, we are studying the possibility of radio occultation observation between a mother spacecraft and small satellites from the viewpoint of both science and engineering. By this method, the altitude distributions of physical quantities can be acquired with high vertical resolution globally at dozens of observation points every day. Such a method has already been used for the earth’s atmosphere.

Satellite-to-satellite radio occultation, when applied to Mars, would enable to (1) derive the three-dimensional wind structure from the temperature and pressure distributions using data assimilation, (2) understand the atmosphere-crustal water exchange and water transport using three-dimensional data of water vapor and atmospheric dynamics including the boundary layer, and (3) expand the observation points, which have been limited to the morning and evening regions in the conventional radio occultation, to all local time to understand the diurnal cycle. Such measurements also serve as basic information for the analysis of observational data taken by other methods in the same period. For Venus, satellite-to-satellite occultation can retrieve three-dimensional atmospheric motions in broad altitude

regions including inside and below the sulfuric acid cloud that is difficult to observe optically. It will also reveal the three-dimensional circulation of sulfuric acid, which is the cloud forming material, leading to the understanding of climate control by cloud processes. In addition to the observations of the neutral atmospheres, three-dimensional tomography of the ionospheres by electron density measurements is also possible. In this presentation we will discuss scientific values of the measurements and introduce preliminary results of engineering studies.

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