Visible and near-infrared airglow structures in the mesosphere and the lower thermosphere observed by space-borne instruments

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Visible and near-infrared airglow structures in the mesosphere and the lower thermosphere were investigated using the space-borne instruments in this study.

Prior researches about airglow observations, mechanism of the airglow emissions are described in Chapter 1. Airglow is the emission of the light from atoms and molecules in the upper atmosphere. Entire structure of the airglow emission has not been detected since the field-of-view (FOV) of the instruments were not wide enough, although atmospheric gravity waves (AGWs) in the mesosphere and the lower thermosphere have been studied via observations of nighttime airglow by the ground-based imagers, rockets and satellites. The outline of the ISS-IMAP (International Space Station - Ionosphere, Mesosphere, upper Atmosphere and Plasmasphere mapping) mission and the examples of the observations are introduced in this chapter.

In Chapter 2, development and calibration of Visible and near infrared spectral imager (VISI) of the ISS-IMAP mission are described. VISI was developed for the nadir imaging observation of the airglow emission from the International Space Station with wide FOV. The spectrographic images with 300 - 600 km width were obtained from two FOVs in the forward and the backward directions to the ISS orbit. Observational targets of VISI were the airglow emissions from oxygen molecules (O_2), hydroxyl radical (OH) around the altitude of 95 km and the emission from atomic oxygen (O) around the altitude of 250 km. These airglow emissions were observed in 762-nm, 730-nm and 630-nm wavelength, respectively. Calibrations and alignments of the imager were carried out before its launch. Noises caused from the electrical interference in the images was subtracted by using the observational data after launch. Variance of sensitivity among each pixel which was caused by the difference of slit width was reduced by taking average of the observational data. The relationship between the intensity and the wavelength was re-examined after launch by using the observational data.

Analysis of the concentric structure in the airglow emission observed by VISI is described in Chapter 3. Concentric structure in the O_2 airglow emission was found in the 762-nm wavelength observation over North America on 1 June, 2013. This is the first observation that the entire structure of the concentric airglow in the mesosphere and lower thermosphere (MLT) region was captured from the space. Spatial scale of this concentric structure was determined to be 1,200 km from the center to the edge. Propagation velocity of the waves in the concentric structure was derived as 125 $\pm$ 62 m/s from the center to the edge of the structure. This velocity was derived from the difference of the wave fronts positions between the images taken by two FOVs of VISI. Duration time of the structure was estimated from the spatial scale and propagation velocity which were obtained by VISI in the space. The observational result taken by VISI was compared with the concentric structure observed in GPS-TEC and the observation of the tropospheric clouds. The source of the AGWs which made this concentric structure was identified as the convective clouds in the troposphere in this case.

The statistical analysis of the airglow observations in the Earth's limb direction by the Multi-spectral Auroral Camera (MAC) on the Reimei (INDEX) satellite are described in Chapter 4. Latitudinal and seasonal variations of the O and the OH airglow intensity were derived from the limb direction observations by Reimei/MAC from March 2008 to January 2011. The peaks of intensity of these emissions were found in the region around 30°N from the statistical study of three years data. It was speculated that variation of the intensity and the position of the peak were affected by the atmospheric tides from the difference between the observational result and the calculation using models. Relationship between the activity of AGWs in the MLT region and the lower atmosphere were studied precisely by using the observational data of the nighttime airglow emissions in the nadir direction and the Earth's limb direction.

Calibrations of ISS-IMAP/VISI, the analysis of the concentric airglow structure observed by ISS-IMAP/VISI, and the result of the statistical study of the airglow observations by the Reimei/MAC are summarized as the conclusions in Chapter 5. Coupling between the lower atmosphere and the MLT region were revealed from the comparison with the observations of the troposphere.