Aurora and Airglow Observations with an All-Sky Imager on Shirase to Fill the Observation Gap over the Southern Ocean

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We report the project of all-sky imaging observation for aurora and airglow on the icebreaker Shirase, and give the result of development and installation, and the current status of operation. Compared with ground-based all-sky imaging network in the northern hemisphere like THEMIS-GBO and MIRACLE, the coverage of all-sky imagers in the southern hemisphere is sparse, and auroral oval mostly exists in the Southern Ocean surrounding Antarctica. It is known that the auroral oval and sub-auroral regions are interesting to understand the transportation of atmospheric gravity waves (AGWs) between lower- and upper atmospheres. We plan to carry out all-sky imaging observation in the Southern Ocean installing a high-sensitive monochromatic all-sky imager on Shirase to fill the observation gap of aurora and airglow in the southern hemisphere. We also aim to make coordinated observations between Shirase and ground-based observatories, such as Syowa and other Antarctic stations. We proposed this project to NIPR, and it has been approved as Kokai-Riyo research in FY2019 (JARE 61), and also adopted as Hoga (challenging exploratory) research of the phase IX Japanese Antarctic Research Project in FY2020-21 (JARE 62-63). Concerning the observation of JARE61 in FY2019, we focus on establishing technical performances of all-sky imager, gimbal and operation system. On the other hand, we will perform scientific observation for the period of JARE 62-62 by measuring multiple wavelength (630 nm and N2 1PG) with two-camera system.

The monochromatic all-sky imager (ASI) consists of bandpass filter (custom-made by Andover, central wavelength: 630 nm, bandwidth: 4.4 nm), fisheye lens (Fujinon FE185C086HA1, field of view: 185°x185°, focal length: 2.7 mm, F-number: 1.8), 1-inch cooled CMOS camera (ZWO ASI-183MM pro, and 3-axis attitude stabilized gimbal (DJI Ronin-S). The camera is operated with a Linux PC (LIVA-Q2). The all-sky imager mounted on the gimbal was installed in the water proof box on the 06 deck of Shirase. Sensors for temperature, humidity, air pressure, geomagnetic field and acceleration were also installed in the box to monitor the housekeeping data. PC, data storage, GPS receiver, power supplies were installed in the observation room of Shirase. To stabilize the temperature in the box on the deck, we put the heater in the box, the air cooler in the observation room, and connected between the box and air cooler using insulation ducts.

The installation of observation system was carried out on September 3 this year, and continuous measurement has been already started. We operate the observation system only in nighttime to take aurora and airglow images. The observation system works automatically until the return of Shirase in next spring. We developed the intelligent operation system which calculates nighttime period every day, and determines start and end times using the location of Shirase obtained by a GPS receiver. All-sky image at 630 nm is taken every 20 sec (exposure time of 19 sec) with a resolution of 3600 x 3600 pixels and 12-bit ADC. Full-pixel digital data are stored in the RAID HDD in the observation room, and will be used to analyze after the return of Shirase in next spring. To check the status of observation system in almost real time, the quick look images and housekeeping data are emailed from Shirase to our institute every day. In compliance of international law, the camera system does not work in the EEZ region.

We carried out the sensitivity calibration of ASI using the integration sphere in NIPR on July 26 and 27 this year. As a result, we confirmed that ASI has enough sensitivity for faint emissions of 630 nm aurora and airglow, for example, we have S/N greater than 100 for the intensity range from 400 R to 200 kR by selecting an appropriate exposure (integration) time from 10 s to 120 s. We also confirmed that ASI has a capability to observe faint 630 nm airglow emission at mid-latitudes by test observion at the Zao observatory of Tohoku University (geographic latitude N38°06’ and longitude E140°32’) on June 13 and 14 this year. All-sky images at 630 nm were taken with a 2-min exposure time. After 02 JST on June 14, we identified wavy structure of 630 nm airglow emission. The wavelength and intensity variation of wavy structure were ~300 km and 40 R assuming the emission altitude of 250 km, and it traveled from north-east to south-west directions, suggesting that the variation was caused by middle-scale ionospheric disturbances (MSTID). The similar structure was also seen in GNNS TEC data and 630 nm all-sky imaging data at Shigaraki during this period.