

OBSERVATION OF TRANSIENT OPTICAL EMISSIONS IN THE MIDDLE AND UPPER ATMOSPHERE USING ARRAY

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ABSTRACT

Array photometer, one of the ISUAL instruments for sprite observation, was designed to detect the vertical motion of sprites emission in two wavelength ranges. Photomultiplier tubes used have 16 anodes aligned in vertical direction. In order to cover the wide field of view horizontally without any degradation of the vertical resolution, two cylindrical lenses with different focal lengths are used in each photometer, which realize the FOV of 22° in horizontal and 3.6° in vertical directions. AP consists of two photometers with different color filters, which enable us to estimate the electron energy distribution inducing the sprites, elves or jets.

INTRODUCTION

Lightning-induced optical emissions named sprites, jets and elves in the middle and upper atmosphere have been extensively investigated using data obtained on the ground or from aircraft and space shuttles since the first discovery of sprites in 1989. Sprites are now recognized as worldwide phenomena, which have been identified in various regions in the earth in North and South America, Africa, Oceania, the Mediterranean, Europe and Asia [1]-[13]. Though there are some experiments by aircraft and space shuttle, most observations have been carried out in quite limited regions and season, namely, in North and South America in the summer season. To investigate chemical effects on Earth's atmosphere associated with those optical phenomena and the role of the discharges in the higher altitude on global electrical circuit, we have to know the occurrence frequency of the phenomena in each region. However, optical observations from the ground are seriously affected by clouds and aerosols so that quantitative estimation of occurrence is extremely difficult. To overcome this disadvantage in optical measurement, we plan to make use of an equipment installed at spacecraft, ROCSAT-2 satellite which will be launched in 2003 by Taiwan. Array photometer (AP), one of the ISUAL instruments of ROCSAT-2 [14], was designed to detect the vertical motion of sprites emission in two wavelength ranges.

TARGETS AND DESIGN OF PHOTOMETER

It has been reported that the vertical motion of sprite emission is closely related to the characteristics of spatial structures in sprites [15][16]. It is found that columniform sprites is often accompanied by sprite halo which propagates downward from an altitude of ~90 km at the initial phase of optical emission within several ms from the onset of causative cloud-ground discharge (CG) while the carrot-like sprites move upward from middle of the sprite head (~70 km) in the first stage. To examine the vertical motion of sprites, the spatial resolution of ~15 km and the temporal resolution of ~100 microsecond are required. Further, the carrot-like sprites are categorized into two types: one peaks in emission within 20 ms from the onset of causative CG and the other peak 20 ms after the CG. The data acquisition of AP for one event continues up to 200 ms after the causative CG. In order to identify the columniform sprites and two types of carrot-like sprites, data sampling of AP shall be carried at 20 kHz for each channel until 20 ms after the CG onset and at 2 kHz up to the end of recording. The low pass filter (LPF) with a cut-off frequency of 10 kHz (1kHz) is used for 20 kHz (2 kHz) sampling. It is also well known that the elves show an apparent downward propagation due to the geometrical condition [17], which enables us to distinguish elves from the scattered CG flashes, which show no time difference of peaks at any elevation. The sampling rate of 20 kHz with a 10 kHz LPF is sufficient to measure the apparent vertical motion of elves. Photomultiplier tubes (PMT) which have 16 anodes aligned in one direction (HAMAMATSU : U5900-01-L16) are adopted as sensors of AP. Total anode area of the PMT is approximately a square with sides 16 mm long. Therefore, if a regular lens is adopted as an objective lens, the FOV should be a square. In order to cover the wide field of view in horizontal direction without any degradation of the vertical resolution, two cylindrical lenses with different focal lengths are used in each photometer, which realize the FOV of 22° in horizontal and 3.6° in vertical directions. The FOV of each anode is 22° by 0.23° , corresponding to ~14 km in height at a range of 3500 km. AP consists of two photometers with different color filters. One has sensitivity in the wavelength range of 330-470 nm and another in the range of 510-800 nm. Electron energy distribution inducing the sprites, elves or jets can be estimated from their ratio [18]-[20]. Data recordings of AP for the sprite burst mode is triggered by spectro-photometer (SP) of ISUAL instruments. AP selects pre-triggering or immediate triggering mode according to the channel of the spectrophotometer used for making triggering signal. In case that one of the visible wavelength channel is chosen, the triggering signal will be issued at onset of a CG flash while the ultra-violet channel can detect only sprite emissions. Observations of blue jets are also conducted by AP at a sampling rate of 200 Hz with a 100 Hz LPF. The sensitivities of photometers could be adjusted by varying the high voltage input to PMTs so that it can measure the optical emissions with large dynamic range, covering faint airglow to intense filaments of sprite head.

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