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サブストームオンセット直後に見られるオーロラ形態とオンセット位置からの距離依存性に関する研究

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A study of the auroral morphology seen immediately after substorm onset and its dependence on distance from the onset location

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Temporal and spatial evolution of auroras associated with substorms has been widely investigated on various spatiotemporal scales by many researchers. In a typical pattern, equatorward-shifted auroras at the substorm growth phase abruptly increase the intensity at the substorm onset with expanding rapidly poleward. After this substorm expansion phase, diffuse auroras including pulsating auroras are developed in the whole sky. In case where a ground-based all-sky camera is operated close to the substorm onset location near midnight, the camera may capture a series of these changes in auroral morphology. On the other hand, in case where a ground-based all-sky camera is operated off dawn side from the substorm onset location, auroras with a gentle horizontal gradient in brightness may occur only in a portion of the field of view, coinciding with auroral brightness increases, but more unclear horizontal structure different from that near the onset location. We need further studies on the auroral morphological evolution around the substorm onset, considering relative distance to the onset location. A valuable method to retrieve this issue in an experimental manner should be a statistical analysis of auroral images taken from multiple ground-based optical cameras for many substorm events estimating the relative distance between the onset location and the camera field of view. This study examined the relative distance in latitude and longitude using auroral images taken immediately after substorm onsets.

The analysis was performed using auroral images taken with eight all-sky cameras operated in northern Scandinavia and Alaska in winter 2016-2022 and SuperMAG substorm lists and magnetic field data. Assuming an emission altitude of 100 km, the latitudinal coverage by all cameras installed in Northern Scandinavia and Alaska are 59.3 to 77.7 degrees and 56.

6 to 72.7 degrees, respectively. The optical filters mounted on cameras were RG665, which passes light at wavelengths longer that approximately 665 nm, and BG3, which cuts light at wavelengths between 500 and 700 nm. Both filters are suitable for measuring prompt auroral emission. For this analysis, onset times and locations were taken from a substorm list issued by SuperMAG. Of the substorm onset events listed up for the period covered by this analysis (in total, 1949), 34 events were selected under following four criteria.

1. Substorm onsets after 22 magnetic local time (MLT) at clear night with intervals of at least 2 hours and 30 minutes from the preceding and following onsets, respectively.
2. Minimum value of the SML index reaches -400 nT or lower within one hour after the substorm onset.
3. A single minimum value of SML index for one hour after the substorm onset.
4. Less than one hour difference between substorm onset longitude and longitude of a station to meet the SML minimum.

Results of this analysis suggested that diffuse auroras were found in more wide range of the relative longitude from the onset location than discrete auroras. In addition, discrete auroras tended to be identified more frequently at higher latitudes, while diffuse auroras showed the opposite trend. Analysis of the relative distances in latitude and longitude to the substorm onset location showed that both type of auroras was distributed in a wider latitudinal range at the east side of the onset location. Furthermore, diffuse auroras tended to invade the higher latitudes with displacing eastward from the onset location. Considering the latitudinal standard deviation of the substorm onset position, discrete auroras tended to occur at latitudes closer to the onset location.