

Description of Additional Supplementary Files

File Name: **Supplementary Movie 1**

Description: A movie of the bright auroral vortices recorded on 21 March 2025 at the Poker Flat Research Range, Fairbanks, AK. The camera is a Sony A7S all-sky imager (ASI) with an RGB CMOS sensor. The image is oriented with south at the top and east to the right and covers an area of ~600 km in diameter at 110 km altitude. For more information about the camera and images, see Zhou and Hampton (2025).

File Name: **Supplementary Movie 2**

Description: A movie of black auroral vortices recorded on 22 March 2025 at the Poker Flat Research Range, Fairbanks, AK. The camera is a Sony A7S all-sky imager (ASI) with an RGB CMOS sensor. The image is oriented with south at the top and east to the right and covers an area of ~600 km in diameter at 110 km altitude. For more information about the camera and images, see Zhou and Hampton (2025).

File Name: **Supplementary Info**

Description: the technique and method of the auroral electron average energy and energy flux calculations.