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Estimation of ionospheric electric fields using modelling of metastable auroral emissions

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A method of modelling small scale aurora in the magnetic zenith using radar and optical observations has been developed and is used to examine the background ionospheric electric field during the afterglow of an auroral event. Optical observations were obtained using the Auroral Structure and Kinetics (ASK) instrument whilst radar observations were obtained using the EISCAT UHF radar, located in Ramfjorden, Norway. ASK is a platform of 3 co-aligned EMCCD cameras, each equipped with a narrow passband filter centred on auroral emissions at 562.0 nm, 732.0 nm and 777.4 nm. ASK is capable of making high spatial, 20 m at 100 km, and temporal, up to 32 frames per second, resolution measurements of the aurora and was co-located with the radar for these observations. Both instruments were observing in the magnetic zenith. The radar measurements are used to estimate the energy spectra of the precipitating elections. The energy spectra are used as input to an ion-chemistry model to model the production profiles of atmospheric species which contribute to the aurora. A look-up table characterising each production profile in terms of an energy and flux estimate, obtained from the ASK observations, is produced. The look-up table allows the production profiles to be extrapolated outside the radar field of view to cover the ASK field of view.

For prompt emissions, such as the 562.0 nm and 777.4 nm emissions, the lifetime of the excited state is so short that the emission rate is the production rate. The 732.0 nm emission, which selects emissions from the $O^+(^2P)$ ion, does not emit promptly and has an altitude dependent lifetime of up to 5 seconds. In the presence of an electric field, the ion will drift from the location it was produced. The continuity equation for $O^+(^2P)$ ions is used to calculate the emission rate of $O^+(^2P)$ ions, taking into account quenching and drift. Modelled images of the aurora are produced by projecting the emission rates to an image plane on the ground. Comparing the observed 732.0 nm emission to the modelled $O^+(^2P)$ emission allows the drift velocity which gives the closest match to be found. The electric field is then calculated using the $\mathbf{E} \times \mathbf{B}$ drift. Further development of this model will allow the investigation of the electrodynamics of auroral arcs whilst auroral precipitation is occurring.