# A Kinetic Model to Study the Dynamics of Electrons over Short Scales

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## 1. Introduction

A brief review of ionospheric and magnetospheric field-aligned currents, using different satellites like FAST or Ørsted, show that the better the spatial resolution the higher the downward current densities (figure 1).

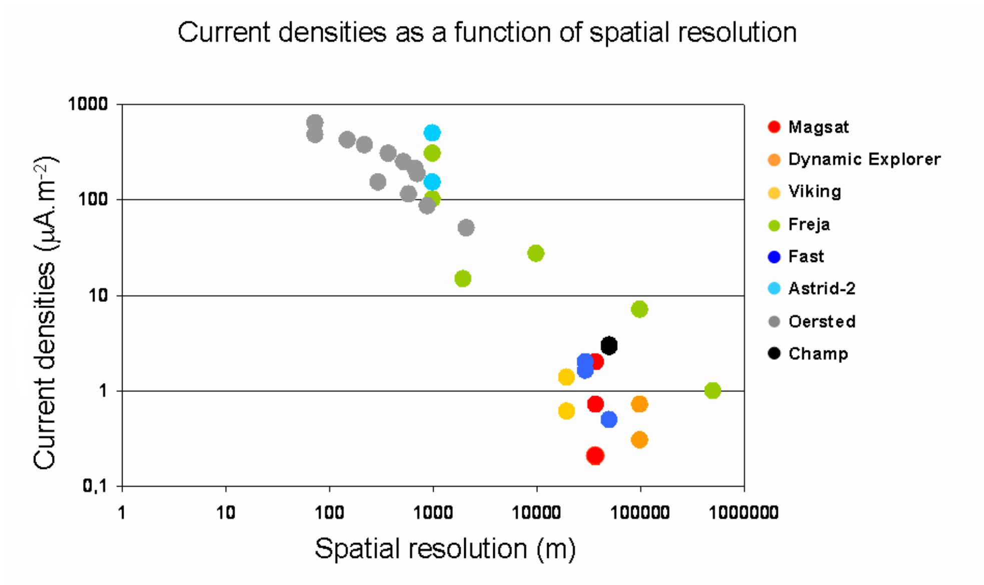


Figure 1: The current densities as a function of the spatial resolution of the satellites. Different colours correspond to different satellites.

Nowadays, downward current densities of several $mA.m^{-2}$ are commonly observed [1-3]. Moreover, different observations such as the optical detection of auroral subarcs a few tens of meters wide indicate that the violent and highly localized electrodynamics can occur at times in the auroral ionosphere. Several scientists [4-6] explain thanks to a fluid model that the increase of the electron density (due to the aurora) implies sharp horizontal gradients in the electron density. This creates a sharp horizontal gradient in the Pedersen conductivity. These gradients cause very intense field-aligned current densities in the edges of the auroral arc. These currents are localized in space and imply the presence of a large parallel electric field. We develop a kinetic model (KInetic Model of Ionospheric Electrons) in order to study the possible kinetic effects of this very intense and field-aligned electric field.

## 2. KInetic Model of Ionospheric Electrons (KIMIE) [7, 8]

This model is important because very few kinetic studies have been led in the ionosphere, and furthermore, in the auroral zone. The dynamics of the electrons which carry these large current densities are studied. We consider the issue of electrons moving through an ionospheric gas of positive ions and neutrals under the influence of a parallel electric field. The kinetic model of collisions includes electrons/electrons, electrons/ions and electrons/neutrals collisions. We use a Fokker-Planck approach to describe binary collisions between charged particles with a long-range interaction:

$$\Delta \boldsymbol{v}_e = \frac{\boldsymbol{F}_{ext}}{m}\Delta t + \frac{\langle \Delta \boldsymbol{v}_{e\parallel} \rangle_b}{\Delta t}\Delta t + \boldsymbol{Q} \tag{1}$$

Where $\frac{\langle \Delta \boldsymbol{v}_{e\parallel} \rangle_b}{\Delta t}$ is a friction coefficient, $\boldsymbol{F}_{\mathbf{ext}}$ is the electric force, m is the electron mass and $\boldsymbol{Q}=\begin{vmatrix} Q_1 \\ Q_2 \\ Q_3 \end{vmatrix}$ is a random velocity vector that correspond to the variation of the velocity in the three directions due to diffusion.
The Monte-Carlo method is implemented for electrons/neutrals collisions. A dynamic electric field is applied. The electrons move in the z direction, parallel to the electric field. As the divergence free of the current density must be conserved, we introduce a feedback on the electric field. The outputs of the model are the electron distribution functions at different altitudes and different time.

3. Results

We can calculate the moments of these distributions. We observe that the electron distribution functions are non maxwellian (Figure 2):

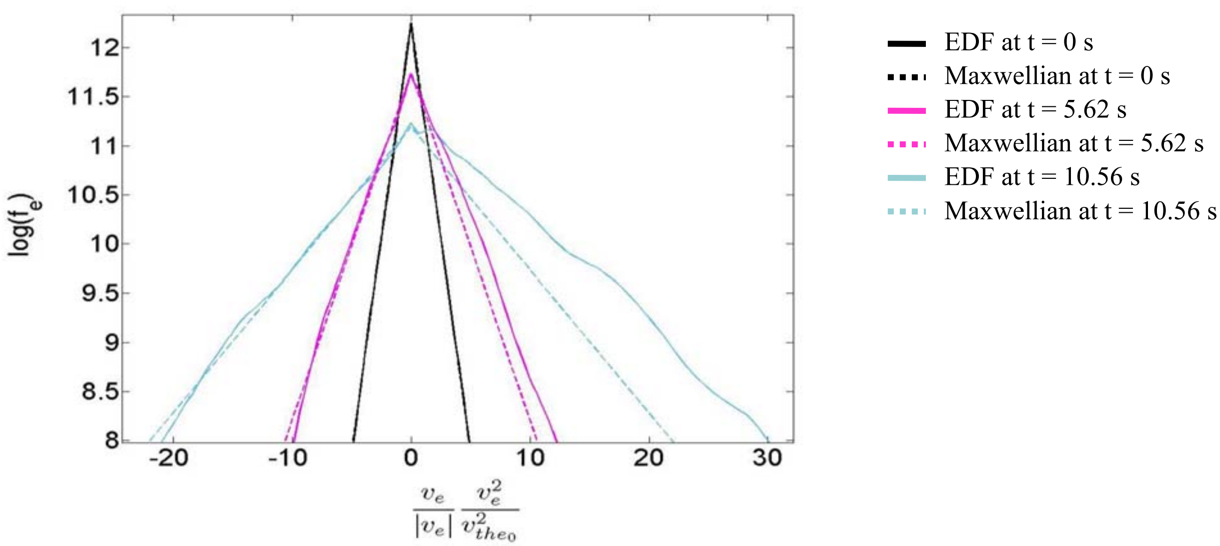


Figure 2: The logarithm of the electronic velocities distribution functions as a function of the squared velocities in plain. The dotted lines represent the corresponding Maxwellians. Different colours correspond to different time.

We can show that suprathermal electrons are created and they carry the current. They represent around 10% of the total electron density. The electrical conductivity can also be calculated. The comparison between classical and the modelled conductivity shows that the modelled one is always larger (figure 3). The suprathermal electrons undergo less collision and consequently tend to increase the electric conductivity.

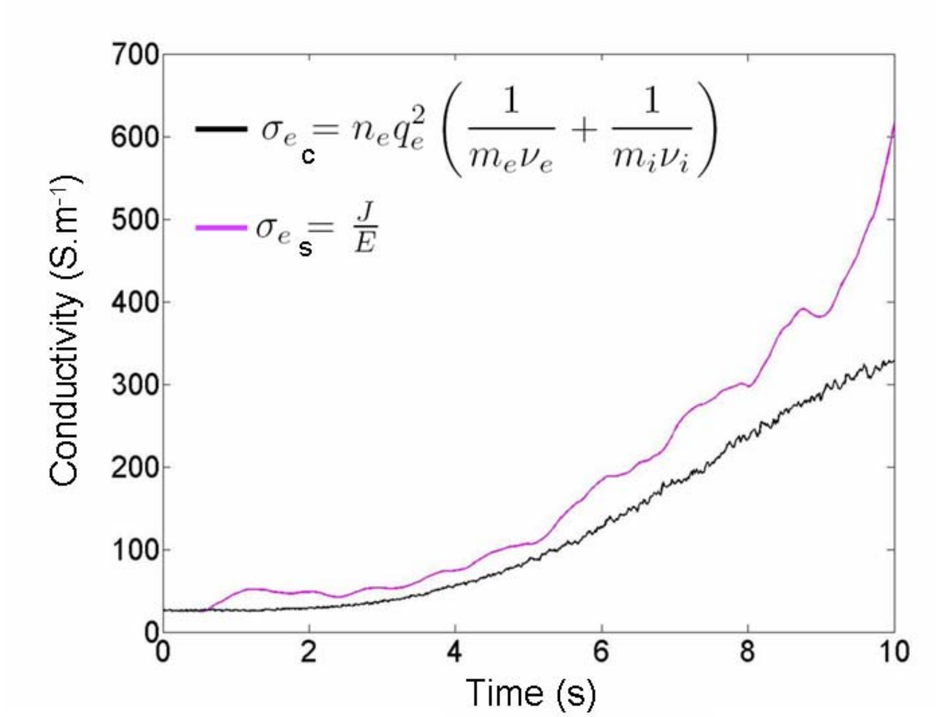


Figure 3: The electrical conductivity as a function of time: the black line (resp. pink) correspond to the classical (resp. modelled) conductivity

It is shown that a significant distortion of the electron distribution functions due to suprathermal electrons occurs. In other words, the electron distribution functions are non-Maxwellian. The suprathermal electrons carry the current density and they can represent up to 10% of the total density. These electrons undergo fewer collisions and so the electric conductivity increases. Our results suggest that the conclusions of the fluid models could be significantly altered by kinetic effects.


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