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Investigating the Sources of Auroral Field Aligned Currents: A Comparison Between Data and Global Simulations

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While it is well known that the discrete (inverted-V) aurora is associated with upwards field-aligned currents (FACs), it is less clear how these currents couple to the magnetosphere. At low latitudes on the dawn-side of the magnetosphere upward FACs have the polarity of Region-2 currents, and it is frequently assumed that these currents are driven by plasma thermal pressure gradients. On the dusk-side, by way of contrast, upward FACs have the polarity consistent with Region-1. These currents map further out into the magnetosphere, where plasma flows are stronger. Hence, flow vorticity may be more important for these FACs. Near midnight the picture is even more complex, as the currents no longer show simple Region-1, Region-2 type morphology. In order to provide insight into the sources for field-aligned currents in the auroral ionosphere we have analyzed data from the low altitude Fast Auroral Snapshot Small Explorer (FAST), imaging data from the THEMIS all-sky network, magnetic field-aligned current maps derived using the spherical elementary current system (SECS) method, and in situ data from the THEMIS spacecraft. To place these data in a global context we have performed simulations using the OpenGGCM global magnetohydrodynamic (MHD) model. This model allows us to both map the low altitude observations to the equatorial magnetosphere and also assess the relative importance of pressure gradients versus flow vorticity as a source of the FACs. Based on the sign of $\mathrm{j} \cdot \mathrm{E}$, with $\mathrm{j} \cdot \mathrm{E} > 0$ corresponding to the magnetic field doing work on the plasma, we can assess the role of pressure gradients and flow vorticity. In particular, if $\mathrm{j} \cdot \mathrm{E} < 0$, the plasma does work on the magnetic field, and this is an indicator that flow vorticity is responsible for the field-aligned currents. Nevertheless, even when flow vorticity is present, plasma pressure gradients are also observed, and the pressure gradients may also have a role in diverting the flow that in turn results in flow vorticity. MHD models are inherently dynamic, and do not assume quasi-static or "slow flow" conditions. Based on our comparison of the data with the MHD simulations we conclude that understanding the relative importance of the different sources for field-aligned currents requires the use of global MHD models as a first step in clarifying the complex interplay of plasma flow and pressure as sources of field-aligned currents.