Suppression of the ionospheric feedback instability by ion flow velocity shear in the E-layer

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The ionospheric feedback instability (IFI) is often invoked as an explanation of small transverse spatial scale structures in the ionosphere. It is considered to occur in the presence of a strong convection electric field, which polarizes density perturbations in the E-layer ionosphere, causing them to emit Alfven waves. The emitted waves reflect at the upper boundary of the ionospheric Alfven resonator (IAR) and further disturb the lower ionosphere. This leads to an unstable situation for reflected waves that return to the E-layer in time to encounter neighbor density perturbations carried by the E-layer transverse plasma flow.

The classical theory of the feedback instability represents the E-layer plasma as a flat-sheet boundary with electrical properties defined by a height-integrated conductivity. This procedure carries with it the assumption that the E-layer plasma flows at a speed independent of altitude. Although the E-layer covers an altitude between roughly 100-150 km, the density of neutrals in this range varies by several orders of magnitude. Thus, there is a strong variation of the transverse ion mobility with altitude within the E-layer that implies a significant vertical shear in the transverse ion flow. This vertical ion flow shear is not accounted for when a height-integrated conductivity boundary is assumed.

Numerical simulations of the feedback instability are presented for an ionosphere represented by a height-integrated conductivity and for the more realistic case where ion dynamics within the E-layer is resolved. The parameters of the ionosphere and thermosphere used in the simulations are obtained from the IRI and MSIS models. While the instability appears in simulations with a height-integrated conductivity, it does not develop when the E-layer is resolved. In the latter case, it is found that plasma flow shear quickly distorts initially field-aligned density structures and results in a rapid decrease of the height-integrated conductivity. The effect is equivalent to introducing a strong diffusion that suppresses the instability.

To prove that the disappearance of the instability when vertical shear in the transverse ion flow is accounted for is not due to the numerical scheme, a simulation with artificial ionospheric parameters is carried out. The situation considered is an E-layer that is resolved but where the ion mobility does not change with altitude. This configuration of the ionosphere parameters results in the IFI, as expected. The conclusion is that shear of the transverse ion flow caused by vertical variation of ion-neutral collisions within the E-layer is a strong mechanism stabilizing the ionospheric feedback instability under a wide range of conditions [Sydorenko and Rankin, 2017, *Geophys. Res. Lett.*, 44, 6534–6542].