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Mechanical origin of ionospheric neutral-wind-dynamo currents

V. M. Vasyliunas
Max-Planck-Institut f. Sonnensystemforschung, Katlenburg-Lindau, Germany (vasyliunas@mps.mpg.de, 49 89 66598319)

The neutral-wind dynamo problem is to describe electromagnetic fields and electric currents in the ionosphere that result from motions of the neutral atmosphere. The conventionally used equations that interrelate neutral-wind velocity, plasma bulk flow, electric field, and electric current are time-independent stress balance conditions, required to maintain a quasi-steady-state equilibrium; to describe how the equilibrium is established and on what time scales, more general time-dependent equations must be invoked. It is commonly assumed that the neutral wind creates an electric current directly, by imparting (through collisions) different bulk velocity to ions and to electrons (to first approximation, by affecting ions only). Solving the time-dependent equations shows, however, that this directly driven current lasts only a very short time (of order inverse plasma frequency), after which the electrons have been accelerated by a transient electric field to nearly the same bulk flow speed as the ions. On longer time scales, the neutral wind just accelerates the plasma as a whole until (after a time of order ion-neutral collision time, and in the absence of opposing stresses) the plasma is flowing with the neutral wind. Currents arise if the plasma flow is such as to deform the magnetic field into a non-curl-free configuration. The ionospheric current of the neutral-wind dynamo is thus created ultimately by an imbalance between the frictional force of plasma-neutral collisions, exerted by the neutral wind in the dynamo region, and the mechanical stresses exerted at other locations along the magnetic field line. To illustrate this concept, several examples of electric current and plasma flow, produced by simple neutral wind patterns at different altitudes, will be described.