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High-Latitude Ionospheric Winds Related to Solar-Interplanetary Conditions

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Treated jointly, two recent results imply that the distribution of winds in the polar ionosphere should change as a function of the direction of the interplanetary magnetic field. From the motions of chemically released ion and neutral clouds, it is apparent that neutral winds in the high-latitude ionosphere are driven principally by ion drag forces. OGO 6 electric field measurements have demonstrated that there are definite relationships between the time/latitude distribution of ionospheric plasma convection and interplanetary magnetic field parameters, and also that the distribution is most sensitive to the azimuthal angle of the interplanetary field. Thus, although direct neutral wind to interplanetary magnetic field comparisons are not available, logic clearly implies a close relationship. The lower altitude meterological effects of these externally driven ionospheric winds are not known; however, observations of infrasonic waves following sudden ionization enhancements indicate the existence of momentum transfer.

The intent of this short contribution is to note results from recent Goddard Space Flight Center measurements that permit one to deduce that there must be a relationship between the solar wind sector structure and the spatial distribution of energy and momentum inputs to the high-latitude ionosphere. It is also appropriate to note that ion drag effects can apparently be detected at Earth's surface in the form of infrasonic waves.

Above 110 km at magnetic latitudes greater than 60°, it has become apparent that the integrated effects of ion drag, caused by the convective electric field, dominate both the heat input and the momentum flux. By "integrated effects" one means not only space/time integration over the convecting region but also the inclusion of all energy dissipation mechanisms that depend directly on the existence of the convection electric field

$$\mathbf{E} = -\mathbf{v} \times \mathbf{B}$$

where $\mathbf{v}$ is the plasma velocity and $\mathbf{B}$ is the magnetic field. For example, joule heating that arises from ionospheric current flow transverse to $\mathbf{v}$, tending to short out the field $\mathbf{E}$, is an ion drag effect. Accurate numbers for the total energy dissipation and momentum flux cannot be given because of the high degree of variability of the ion drag, both in time and in spatial distribution. Between quiet and moderately disturbed times, the integrated $\mathbf{E}$ (that is, the potential drop) commonly varies by a factor of 5 (Heppner, 1973). The coupling of ion and neutral motion determined by the plasma density and its altitude distribution is, however, a much greater variable. Density factors of 100 between sunlit and dark regions and between regions with and without auroral particle precipitation are quite common. Representative numbers for the local columnar energy dissipation most commonly fall within the range 1 to 100 ergs/cm^2 · s. Typically, numbers in the literature tend to be conservative as a consequence of considering relatively stable model conditions. Papers such as those of Walbridge (1967), Cole (1971), and Fedder and Banks (1972) should be consulted. Their numbers for the energy dissipation, and the range 1 to 100 ergs/cm^2 · s given previously, can be compared

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with other energy inputs discussed in this symposium. In doing this it is important to also keep in mind that unlike the localization of auroral particles or the restriction of EUV absorption to the sunlit ionosphere, ion drag exists over the entirety of the polar regions.

Confidence that a relationship exists between solar wind sector structure and the spatial distribution of inputs to the high-latitude ionosphere is based on observations that demonstrate that the spatial distribution of **E** is related to the sector structure and neutral wind observations that demonstrate that mass motions of the high-latitude thermosphere are primarily a response to collisions with the convecting plasma (that is, ion drag).

Observations relating the spatial distribution of **E** to the sector structure are based on OGO 6 electric field measurements (Heppner 1972, 1973). These clearly showed that the distribution of antisolar convection over the north polar cap shifts toward the evening (dusk) or morning (dawn) hours, depending on whether the interplanetary magnetic field is directed toward the west of the Sun ($270^\circ<\Phi<360^\circ$) or away and to the east of the Sun ($90^\circ<\Phi<180^\circ$), respectively. They further showed that this relationship is reversed in the south polar region. Figure 1 is drawn for northern high latitudes; for southern high latitudes the sector headings would be interchanged. The reader should consult the journal publications for examples and discussions of the great variety of deviations from the figure 1 idealizations, and also how these shifts in the **E** pattern provide a physical explanation for the Svalgaard-Mansurov findings relating sector structure to polar magnetic variations.

The neutral wind observations are based on high-latitude chemical releases from rockets. Since 1967, five launching sites between 65° and 81° have been used, and 100 barium ion and barium and strontium oxide neutral clouds have been released at altitudes between 180 and 310 km from 27 rockets. Seven of these rockets also released trimethyl aluminum/triethyl aluminum neutral trails extending from 180 km down to 80 km. Observations of the simultaneous motions of ion and neutral clouds provide a powerful tool

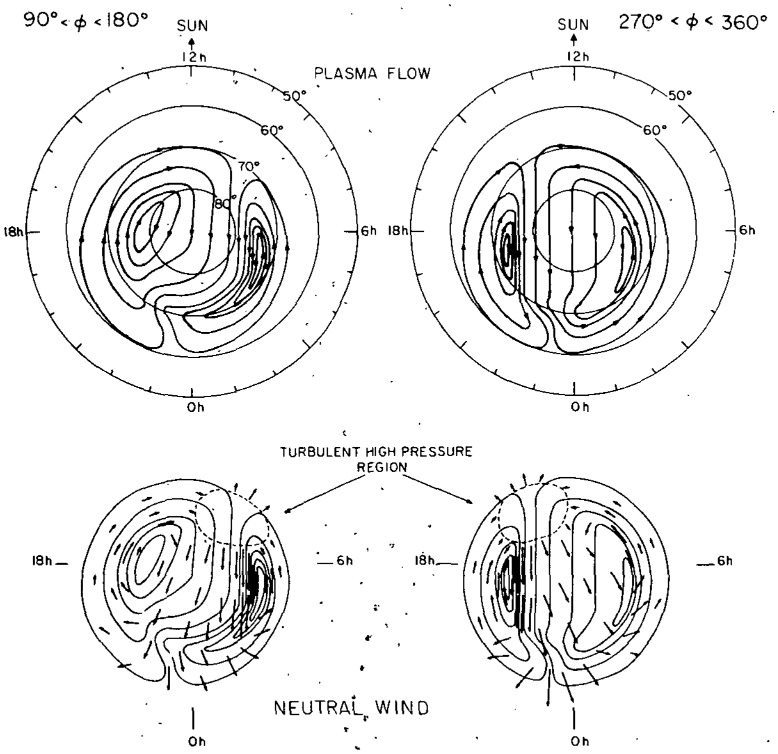

FIGURE 1.—(*Top*) Idealized polar patterns of the convective plasma flow for "away" and "toward" sectors of the interplanetary magnetic field. Streamlines, the direction of **v**, are lines of constant electric potential; thus the spacing between lines is inversely proportional to the magnitude of *E* or *v*. Coordinates are magnetic local time and invariant latitude. (*Bottom*) Idealized vector representation of neutral winds above 180 km relative to the plasma flow patterns.

for evaluating ion drag. An analysis of the first 15 flights appears in Meriwether et al. (1973). This analysis and subsequent data show that most of the observed motions above 180 km fit very well with motions expected from ion drag forces. Apparent discrepancies, in the form of neutral wind vectors not alined with the ion flow, appear consistently in the postmidnight auroral belt, but these can be attributed to the inertia of the wind system. In effect, the neutral flow across the polar cap has too much inertia to suddenly change direction. There are other important details that cannot be discussed here. In a gross way, they have influenced the idealized wind pictures shown at the bottom of figure 1.

The figure 1 neutral wind idealizations are based on observations where possible and on expectations in time/latitude regions where observations have not been conducted. For this crude modeling, it is assumed that there is a narrow band of auroral ionization within the sunward convection and that the ionosphere is sunlit to the dayside of the 18^h to 6^h meridian. Thus, ion/neutral coupling is relatively negligible over the dark portion of the antisolar convection. In addition to the general tendency for the neutral motion to follow the ion motion, an important point to note is that a turbulent, high-pressure region is created on the day side. (See fig. 1.) The existence of this region is a prediction, not an observation. The convergence of sunward, east-west flows is the primary cause of the high pressure, and nonuniformity of these flows with variable inertia will produce a turbulent behavior. A further point is that these regions are also regions where the electric field measurements suggest very strong turbulence (not represented in the fig. 1 idealizations). Through ion drag the plasma turbulence will also produce a wind turbulence, but feedback effects are also operative and it becomes impossible to determine whether the electric field or the neutral wind turbulence is primary. The important point for the present is that the flow away from this high pressure tends to add to the antisolar wind from ion drag; thus it adds to the sector-dependent asymmetry.

The figure 1 wind pictures are representative for altitudes greater than 180 km. In the lower ionosphere the winds become more complex as the time lag for the neutral masses to respond to changes in ion drag increases (that is, the neutral mass motion is more sluggish). The ratio of ion to neutral mass densities and the duration of a unidirectional ion drag force determines how closely the local low-altitude winds resemble the higher altitude winds. However, on the scale of the entire polar region, there will be a dawn/dusk asymmetry in the momentum transferred to the neutral gas, depending on the sector of the interplanetary magnetic field.

We do not claim to know if or how the momentum transferred to the neutral gas at ionospheric levels influences the lower atmosphere. However, it does appear that effects can be detected in the form of infrasonic waves that Wilson (1972) has observed in Alaska for many years. Figure 2 is Wilson's illustration of the frequency of occurrence of waves seen by microbarographs at three latitudes. The lines, emanating at 20° intervals from each site, point at the direction from which the waves arrive, and their lengths are proportional to the number of occurrences from that direction. If these lines are flipped 180° so that they point in the direction

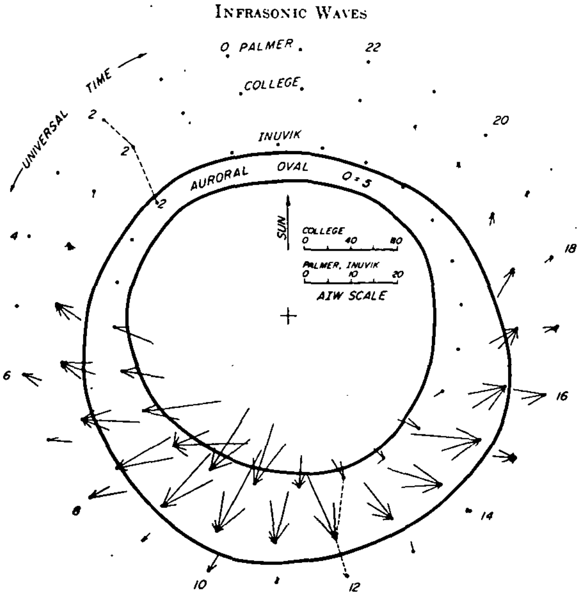

FIGURE 2.—Wilson's (1972) illustration of the frequency of occurrence of auroral infrasonic waves. Vectors point toward the directions from which the waves came. (Q is a geomagnetic index; AIW = auroral infrasonic wave.)

of propagation, their mean pattern in the night hours closely resembles the neutral wind vectors in figure 1. As discussed by Wilson (1972), a complete causative picture to explain these winds involves a number of complex considerations. Our view is that there are at least two essential conditions: (1) a high velocity, antisolar wind blowing into the midnight auroral belt from the polar cap and (2) a sudden increase in the auroral ionization such that the antisolar wind hits a new wall of dense plasma.

If an infrasonic shock is produced by the above conditions, it raises a more general question; that is, whether a similar momentum transfer is taking place all the time but is not identifiable relative to the noise background when the auroral ionization is changing less abruptly. Although this appears plausible, a more comprehensive understanding of the generation mechanism is required. Infrasonic waves appear, however, to be the only directly observed atmospheric effect of ionospheric electrodynamics.

REFERENCES

Cole, K. D., 1971, "Electrodynamic Heating and Movement of the Thermosphere," *Planetary Space Sci.*, **19**, pp. 59–75.

Fedder, J. A., and P. M. Banks, 1972, "Convection Electric Fields and Polar Thermospheric Winds," *J. Geophys. Res.*, **77**, pp. 2328–2340.

Heppner, J. P., 1972, "Polar Cap Electric Field Distributions Related to the Interplanetary Magnetic Field Direction," *J. Geophys. Res.*, **77**, pp. 4877–4887.

Heppner, J. P., 1973, "High Latitude Electric Fields and the Modulations Related to Interplanetary Magnetic Field Parameters," *Radio Sci.*, **8**, pp. 933–948.

Meriwether, J. W., J. P. Heppner, J. D. Stolarik, and E. M. Wescott, 1973, "Neutral Winds Above 200 km at High Latitudes," *J. Geophys. Res.*, **78**, pp. 6643–6661.

Walbridge, E., 1967, "The Limiting of Magnetospheric Convection by Dissipation in the Ionosphere," *J. Geophys. Res.*, **72**, pp. 5213–5230.

Wilson, C. R., 1972, "Auroral Infrasonic Wave-Generation Mechanism," *J. Geophys. Res.*, **77**, pp. 1820–1843.