N76 14533

# Proposed Geomagnetic Control of Semiannual Waves in the Mesospheric Zonal Wind

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The polar semiannual oscillation in zonal wind can explain midwinter weakening of the polar vortex and the relatively short stratospheric and mesospheric summer easterlies. The phase of the wind oscillation is equinoctial, as is the phase of the semiannual component in magnetic storm activity. For a given altitude, the contours of amplitude of the semiannual wind oscillation have less variability in geomagnetic than in geographic coordinates. It is suggested that the polar wind oscillations are caused by the semiannual maxima in magnetic storm activity, which lead to electron dissociation of $O_2$ into O, in turn increasing ozone more rapidly than the dissociation of $N_2$ destroys ozone, and thereby inducing a semiannual variation in the thermal and wind fields. This implies that geomagnetic processes may cause or affect the development of sudden warmings. As the tropical semiannual wind oscillation is symmetric about the geomagnetic Equator, the same processes may also influence the location of the tropical wind wave.

Two new distinct polar centers of the semiannual oscillation of the mesospheric zonal wind have recently been identified (Belmont et al., 1974; Groves, 1972). The well-known tropical center is centered near the geographic Equator at about 45 km, while a northern center is near 60° N at about 65 km and a southern center is near 70° S at 60 km. Original attempts to explain the tropical oscillation attributed it to the semiannual variation of insolation at the Equator due to changes of the solar zenith angle (Webb, 1966). This mechanism, however, would inherently demand equatorial symmetry that, in figure 1, is not found to exist (Belmont and Dartt, 1973). Furthermore, energy and momentum considerations have shown that some other process is forcing this oscillation. Meyer's (1970) study of the dynamics of the tropical semiannual oscillation show that an eddy momentum flux by tidal motions could furnish the necessary energy. However, because of the rapid variations of tidal phase with altitude, he concludes that other mechanisms also probably contribute in driving the tropical wave.

## POLAR CENTER

The newly described polar center of the semiannual oscillation is of great interest for several reasons. It can help explain the long-observed weakening of the intense, winter polar westerlies as seen on time sections (Belmont and Dartt, 1970). This decrease in winter westerlies was attributed by Webb (1966) to the intrusion of the summer hemisphere easterlies into the winter hemisphere; that is, to the semiannual wave in the tropics, although no direct influence could be measured. The existence of the separate polar semiannual oscillation, however, can now directly explain this phenomenon as can be seen in figure 2. This wave is also probably related to the winter polar sudden warmings.

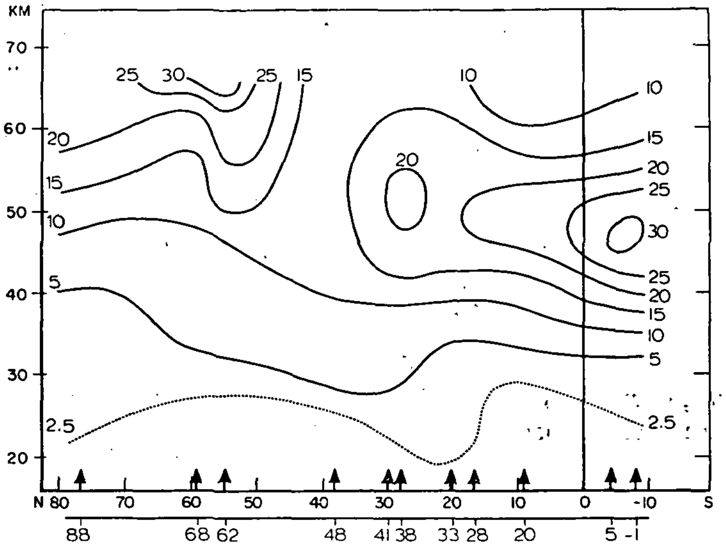


FIGURE 1.—Amplitude of the semiannual wave in zonal wind (meters per second) for stations near 80° W. Arrows indicate rocket stations. Bottom scale is geomagnetic latitude.

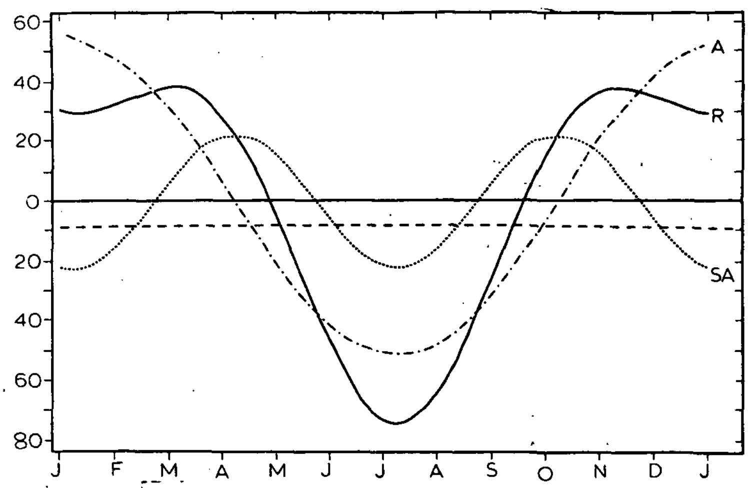


FIGURE 2.—Yearly wind cycle $R$ resulting from addition of annual $A$ and semiannual $SA$ waves at 60 km at Primrose Lake (55° N). (Ordinate is in units of meters per second; Belmont et al., 1974.)

The polar semiannual oscillation can also explain the relatively short duration of the stratospheric summer easterlies, as can be seen in figure 2 where the annual $A$ and semiannual $SA$ are superposed on the long term mean to produce a resultant $R$ yearly cycle. Amplitude and phases used in the figure are for 55 °N at 60 km, from Belmont et al. (1974). This short summer effect varies with location and altitude, being a function of the relative amplitude and phase lag between annual and semiannual waves.

## POSSIBLE MECHANISMS

It is interesting that the phases of both the tropical and polar semiannual oscillations are equinoctial (Belmont and Dartt, 1973). While they are separated by more than a scale height in altitude, they could very well be influenced by the same mechanism because of their similarity of phase. No explanation has yet been offered for the polar wave. Its location, in the auroral zone, and its altitude, just below auroral heights, are intriguing, however, and a possible relation should be examined. The semiannual component in magnetic storm activity also has equinoctial phase (Chapman and Bartels, 1940) and has recently been explained by Russell and McPherron (1973) as arising from the interaction between the magnetosphere and the interplanetary magnetic field. A coupling between the geomagnetic field and atmospheric circulation has long been accepted. The dynamo theory relating geomagnetic fluctuations to winds in the ionosphere was hypothesized long before direct observations were available and is still accepted in modified forms (Fejer, 1965). Also, Flohn (1952) demonstrated a striking similarity between the mean flow at 200 mb and the horizontal intensity of the geomagnetic field and between the mean position of the Inter-Tropical Convergence Zone and the geomagnetic equator. Because of the extremely large energy involved, he concluded that the similarity was due to atmospheric influence upon the geomagnetic field although there is no apparent explanation for this. Therefore, in the ionosphere and the troposphere, for both short-period changes and the long-term mean, the atmosphere appears to influence the geomagnetic field. That the reverse applies to the mesosphere and stratosphere is suggested next.

In figure 3 the amplitude of the semiannual wave at 50 km is plotted in geomagnetic Mercator coordinates; figure 4 shows the same data in geographic Mercator coordinates. Note that the north-south variations of the contours are smaller in geomagnetic, rather than geographic, coordinates. Figures 5 and 6 present the same data in geomagnetic and geographic polar coordinates, respectively. Once again, note the greater symmetry of the contours in geomagnetic coordinates. This suggests that the semiannual oscillation is coupled with the geomagnetic, rather than geographic, coordinate system. Rocket stations depicted by dots on figures 3 to 6 and the corresponding amplitude of the semiannual wave at 50 km are listed in tables 1 and 2.

Because the maximum of the semiannual wind oscillation coincides with that of the geomagnetic

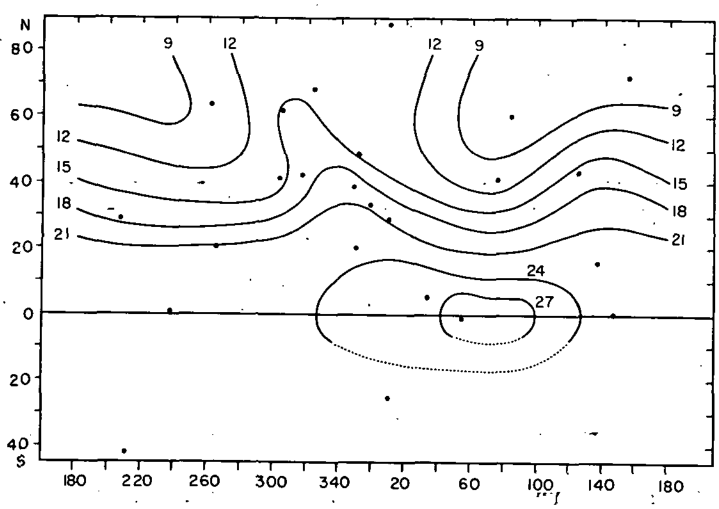


FIGURE 3.—Amplitude (in meters per second) of the semiannual wave at 50 km. Geomagnetic Mercator coordinates are used. The amplitudes of the stations shown by dots are given in tables 1 and 2.

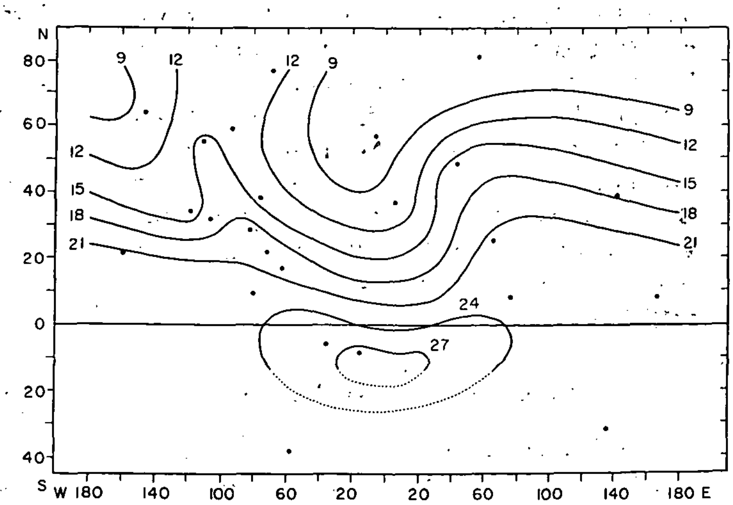


FIGURE 4.—Same as figure 3 in geographic Mercator coordinates.

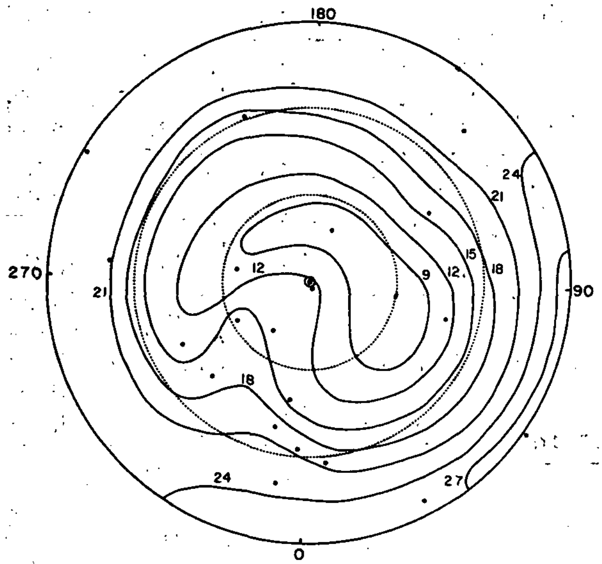


FIGURE 5.—Same as figure 3 in geomagnetic polar coordinates. The dotted lines are 30° and 60° latitudes.

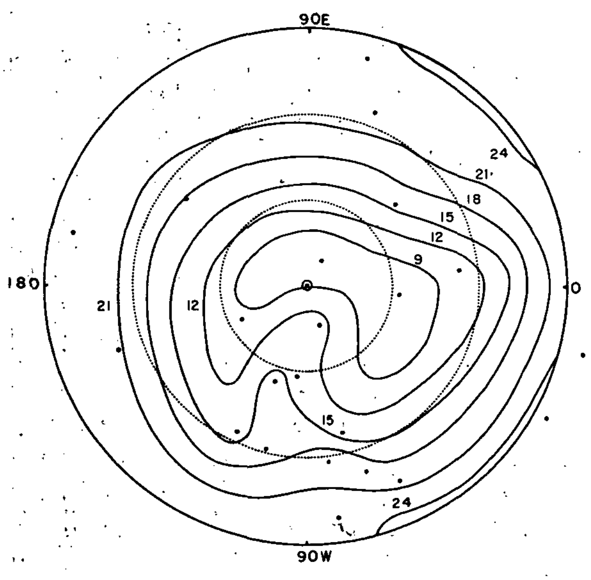


FIGURE 6.—Same as figure 3 in geographic polar coordinates. The dotted lines are 30° and 60° latitudes.

coordinate system, and as the phases of the semiannual wind and magnetic variations are the same, and because the magnetic storm semiannual variation is due to extraterrestrial causes (Russell and McPherron, 1973), and thus not to the atmosphere, the coincidences require an explanation. Direct magnetic field control of the circulation at mesospheric altitudes can be rejected from energy considerations; however, the magnetic field might still indirectly influence the mesospheric circulation.

Large-scale circulation features, such as the semiannual wind oscillation, must be the result of large-scale temperature gradients. Joule dissipation heating of the lower thermosphere is a major heat source at high altitudes (Ching and Chiu, 1973; Hays et al., 1973) and could be the source that drove the meridional circulation postulated by Mayr and Volland (1971) from their analysis of the meridional component in meteor wind data. Joule dissipation, however, is generally important above 100 km, while the heat source driving the semiannual wind oscillation must be near 75 km. An empirical description of an observed heat source is shown in Groves (1972) as a polar maximum near 75 km in the semiannual temperature oscillation.

A coupling of the magnetosphere and thermosphere with the mesosphere could occur, however, through influence upon the radiation field as follows: The semiannual component in the occurrence of magnetic storms leads to semiannual auroral activity. Through particle precipitation associated with this activity, energy is dissipated in the lower thermosphere down to the mesopause. But, more importantly, the particle precipitation may lead, at these levels, to production of O through electron impact dissociation of $O_2$, which in turn increases ozone through three-body recombination (Maeda, 1968; Maeda and Aiken, 1968). This process, though, is somewhat compensated by production of N through electron impact dissociation of $N_2$, which in turn increases NO, which increases destruction of ozone (Strobel et al., 1970). However, the influence of NO upon $O_3$ is small above 70 km (Hunt, 1973). This leads to a semiannual control of ozone, and through its absorption of UV, to a semiannual oscillation in the temperature and wind fields. Although enough measurements have been made to preliminarily identify an annual variation in ozone at these levels (Evans and Llewellyn, 1972), observational verification of a semiannual component in ozone is not yet available. We leave theoretical verification of this theory to atmospheric chemists and radiation physicists who are aware of the latest estimates of reaction rates and the many inter-

TABLE 1.—*Stations Near 80° W*

| Station | Latitude | Longitude | Geomagnetic coordinates | Amplitude,[a] m/s |
|---|---|---|---|---|
| Thule | 76° 33′ N | 68° 49′ W | 88° N 10° | 12.1 |
| Churchill | 58° 44′ N | 93° 49′ W | 68° N 324° | 12.4 |
| Primrose Lake | 54° 45′ N | 110° 03′ W | 62° N 305° | 15.3 |
| Wallops | 37° 50′ N | 75° 29′ W | 48° N 351° | 13.9 |
| Cape Kennedy | 28° 27′ N | 80° 32′ W | 38° N 347° | 20.3 |
| Grand Turk | 21° 26′ N | 71° 09′ W | 33° N 357° | 16.9 |
| Antigua | 17° 09′ N | 61° 47′ W | 28° N 10° | 20.7 |
| Fort Sherman | 9° 20′ N | 79° 59′ W | 20° N 350° | 22.1 |
| Natal | 5° 45′ S | 35° 10′ W | 5° N 34° | 26.6 |
| Ascension Island | 7° 59′ S | 14° 25′ W | 1° S 55° | 28.5 |

TABLE 2.—*Other Rocket Stations*

| Station | Latitude | Longitude | Geomagnetic coordinates | Amplitude,[a] m/s |
|---|---|---|---|---|
| Heiss Island | 80° 37′ N | 58° 03′ E | 72° N 156° | 7.1 |
| Fort Greely | 64° 00′ N | 145° 44′ W | 64° N 261° | 10.8 |
| West Geirnish | 57° 21′ N | 7° 22′ W | 60° N 84° | 4.8[b] |
| Volgograd | 48° 41′ N | 44° 21′ E | 43° N 125° | 17.1 |
| Ryori | 39° 02′ N | 141° 50′ E | 29° N 207° | 17.4[b] |
| Arenosillo | 37° 06′ N | 6° 44′ E | 41° N 76° | 10.9[b] |
| Point Mugu | 34° 07′ N | 119° 07′ W | 41° N 302° | 14.1 |
| White Sands | 32° 23′ N | 106° 29′ W | 42° N 317° | 16.1 |
| Sonmiani | 25° 12′ N | 66° 45′ E | 16° N 137° | 22.6[b] |
| Barking Sands | 21° 54′ N | 159° 35′ W | 21° N 265° | 21.1 |
| Woomera | 31° 58′ S | 136° 31′ E | 42° S 211° | 9.6 |
| Mar Chiquita | 37° 45′ S | 57° 25′ W | 26° S 10° | 15.4 |
| Kwajalein | 8° 42′ N | 167° 42′ E | 1° N 238° | 22.8 |
| Thumba | 8° 32′ N | 76° 52′ E | 0° 146° | 23.3[b] |

[a] From Belmont et al., 1974.
[b] Stations added since Belmont et al. (1973); sources of amplitude data are World Data Center A, Asheville, N.C., and Pakistan Space and Upper Atmosphere Research Committee (1971).

dependent processes which are now being discussed so actively in the literature. If geomagnetic activity is indeed the cause of the polar semiannual wave, this implies it may thus influence the development of sudden warmings which are disturbances of the thermal field and which progress downward from about 50 km.

The tropical wind oscillation appears located closer to the geomagnetic than the geographic equator (figs. 1, 3, and 4). Also, note that the presently known extreme maximum of the tropical oscillation is centered near the anomalously weak magnetic field in the South Atlantic and Brazil. At tropical latitudes, the most particle precipitation occurs in the region of relatively weakest magnetic field (Reagan and Imhof, 1970; Trivedi et al., 1973). Also, Cole (1971) suggested that near the equator increased electric field activity during terrestrial magnetic storms could lead to energy dissipation, with more energy dissipated in regions of relatively weak magnetic field at a given altitude. Could it be that the semiannual component in magnetic storm activity influences the tropical wind field so as to shift the tropical semiannual wind oscillation toward the geomagnetic equator? This could then help resolve the dynamic modeling problem encountered by Meyer (1970).

## CONCLUSIONS

The polar semiannual wind wave can help explain the decrease in strength of the midwinter stratospheric and mesospheric westerlies and the shorter summer season in the stratosphere.

The phases of both the polar and tropical semiannual wind oscillation are very similar to the phase of the semiannual component in magnetic storm activity and the amplitude, at a given level, of the semiannual wind oscillation appears more symmetric in geomagnetic, rather than geographic, coordinates.

It is suggested that the *polar* semiannual wind centers are caused by the UV heating of mesospheric ozone, which is contributed semiannually by particle precipitation during magnetic storms. The same process may influence the random occurrence of sudden warmings.

The *tropical* semiannual wind center may be influenced enough by similar processes to account for its apparent symmetry in the geomagnetic coordinate system.

These hypotheses are offered in the hope of stimulating investigation of the chemistry and dynamics of the mesosphere with regard to the semiannual variation in magnetic storm activity.

## ACKNOWLEDGMENT

This paper has been supported by contract N00014–72–C–0308 with the Office of Naval Research, Naval Air Systems Command, and the Department of Transportation.

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