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Letter to the Editor

Comment on: On the Sources of the 12-Month Wave in the *an* and *as* Geomagnetic Activity Indices

by P.N. Mayaud
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In an interesting paper Mayaud (1979) discusses possible sources of the annual wave in hemispheric activity indices (*Kn*, *Ks* or *an*, *as*) and comments the results of Damaske (1978b) obtained with the harmonic analysis method. Mayaud claims that his own analysis is the more comprehensive one and that the source model he suggests provides a better fit to the observed activity variations. It seems to us that his arguing against the concept of a modified modulation is based on a number of misunderstandings and misinterpretations and that also his merely qualitative judging deserves some critical remarks, although we can mention only a few details here.

1. Mayaud (1979) objects against the use of 27-day means and the restriction to the annual wave in the paper by Damaske (1978b), emphasizing that his own analysis is more comprehensive because his Fig. 1 displays also the daily variation, within groups of only 6 days. He should remember that it was the declared purpose of Damaske's paper to investigate merely the annual wave in both hemispheres and its behaviour within the eight hemispheric longitude sectors from which *Kn*, *Ks* (or *an*, *as*) are derived. Computing an annual wave from consecutive daily or even hourly values would not yield the slightest increase of accuracy besides much more computation labour. The advantage of 27-day means has been described elsewhere (Meyer 1973). The relation between diurnal and semidiurnal UT waves (including their annual amplitude modulation) and the annual and semiannual waves of geomagnetic activity, as well as their unified deduction from the modified modulation function $\sin^2(\beta+\beta_0)$, has been set forth extensively in previous papers (Damaske 1976, 1977).

2. Mayaud (1979) obviously uses the term 'modulation' in a way different to its common meaning in physics. It is a clear misinterpretation when he states that the modified modulation function $\sin^2(\beta+\beta_0)$ was introduced by Damaske (1977) 'in order to interpret the systematic amplitude modulation (with opposite sign in both hemispheres) of the 24-hour UT wave'. There does not exist such an amplitude modulation with opposite sign or phase. Instead, there exists a systematic *shift* (with opposite sign or direction) in the amplitude modulation curves for the diurnal UT wave in both hemispheres (see Damaske 1976, Figs. 25 and 26; or Damaske 1977, Figs. 13 and 14). Moreover, it is definitely wrong when Mayaud states that it is the 'asymmetry in the amplitude of the daily variation from one solstice to the other in each hemisphere .. what Damaske calls the amplitude modulation of (!) the diurnal UT wave' With this understanding a wave *without* such amplitude asymmetry between the two solstices as, e.g., the top curve in Mayaud's Fig. 2, would not undergo any amplitude modulation at all. Suffice it to say that we are using the term 'modulation' in its generally accepted sense.

3. We cannot follow Mayaud when he assumes that any change of the diurnal wave amplitude modulation would necessarily affect the annual variation of activity, e.g., bringing about a 12-month wave if such a change is confined to a certain season. A primary change of the daily variation would affect the annual variation only if also the average daily activity has changed. One can easily figure a diurnal wave with quite arbitrary amplitude modulation but no annual variation (of daily values) at all. It seems that Mayaud mixes the annual amplitude modulation of the diurnal UT wave with the annual variation of geomagnetic activity itself. Both have to be clearly distinguished. It is just the modified modulation function $\sin^2(\beta+\beta_0)$ that relates the diurnal with the annual activity variation in a definite and confirmed form.

4. Mayaud (1979) judges on the validity of the modified modulation function suggested by Damaske (1976, 1977) by a merely qualitative comparison of the figures he presents, Fig. 1 showing observational data and Fig. 2 illustrating different functions $\sin^2(\beta+\beta_0)$ by a polygonal approximation, although not for the empirical value of β_0. Nevertheless, he admits that one of the two specific features of hemispheric activity modulation, i.e., his feature (b), is similar in both figures. In fact also feature (a) can clearly be recognized in the lower curve of Fig. 2, as far as the existence of a significant daily variation at the equinoxes is concerned.

Mayaud's final objection mainly bears upon the envelopes of the curves in Figs. 1 and 2, which is certainly insufficient if not misleading. The modified modulation function has been derived from the quasi-logarithmic *Kn*, *Ks* and thus should not be compared with the linear *an*, *as* in all aspects. This does not simply concern the angle β_0. It applies to the whole formulation of activity modulation which is more complex for *an*, *as*, e.g., involving a dependency of all modulation amplitudes on the general level of activity (Damaske 1978a). Above all one has to make allowance

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for the fact that the scale for the square-sine functions in Fig. 2 is limited at its upper end, whereas the scale for *an* and *as* in Fig. 1 is still continuous and unlimited (contrary to that for *Kn*, *Ks* which would also be finite). Hence, any comparison of the upper envelope in Fig. 2, especially near the upper end of the scale, with the one in Fig. 1 is irrelevant.

Likewise Mayaud's statement that the solar longitude distance between the days of vanishing diurnal UT wave in the theoretical curve would not fit the observation, cannot be accepted. A quantitative evaluation of the correct curves derived from the exact formula and the results for the diurnal constituent in *Kn* and *Ks*, as well as in *an* and *as*, clearly shows that both are in good accordance with only minor deviations (cf. Damaske 1976, Figs. 25, 26, and 30, 31; Damaske 1977, Figs. 13, 14 and 17, 18; Damaske 1978a, Fig. 15).

5. Estimating the additional hemispheric effects by directly comparing the observational results in Fig. 1 with the modulation curve $\sin^2\beta$ for planetary activity (upper curve in Fig. 2) is certainly insufficient because the arbitrary scale in Fig. 2 involves the possibility of either exaggerating or suppressing the effect for a certain season, depending on the fitting of the relative amplitude scale. An unbiassed estimate of the specific hemispheric effects requires primarily a comparison with the *average* of both curves in Fig. 1, i.e., with the corresponding curve for *am*. If Mayaud had done this, he might have recognized that an additional diurnal UT wave, with nearly constant amplitude and phase, exists not only during local summer but indeed throughout the year. Since the phase of the *planetary* wave in summer and winter is opposite, its amplitude appears to have increased (in local winter) or decreased (in local summer) as an effect of this additional hemispheric wave, in full accordance with the results of harmonic analysis. Thus it seems that Mayaud is giving separate explanations of only certain features which he sees (and of *how* he sees them), thereby disregarding other features which he does not recognize by his merely qualitative judging.

6. Finally, it is unsatisfactory if Mayaud judges the relative validity of the modified modulation function by a qualitative comparison between the observational results in Fig. 1 and the modified square-sine functions in Fig. 2 (yet, strictly speaking, in an irrelevant way as has been shown above), without presenting and discussing a corresponding synthetic modulation curve for his own source model. In fact, his main source constituent, i.e., the one he relates with the *DP2* fluctuations (the other one does not significantly affect the annual wave in *hemispheric* data) would lead to an alteration congruent to the two envelopes of the upper curve in Fig. 2 'without any change in the range of the UT daily variation due to $\sin^2\beta$'. For a 12-month wave of this type culminating in local summer the upper envelope then would display a 'belly' during that season, instead of the 'trough' actually noticed in Fig. 1. In addition, this conception would match neither of the two specifically hemispheric features (a) and (b) in Mayaud's paper. It is hard to believe that all these systematic discrepancies respecting the daily variation should be explained just as 'irregularities' due to a longitude dependence of the source effect in connection with the non-homogeneous net of stations. If this were true, it would indeed severely question the utility of the hemispheric activity indices which Mayaud himself has introduced.

Summing up we may infer that Mayaud's conclusions are all together untenable. It will be shown in a forthcoming paper that the source model he suggests, though being tentatively acceptable as a working hypothesis, does not contribute significantly to the actually observed hemispheric annual wave.

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