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TIME-WEIGHTED ACCUMULATIONS ap(τ) AND Kp(τ)

by

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SUMMARY

The planetary geomagnetic indices Kp and ap are widely used in space geophysics. They provide an estimate of maximum magnetic perturbation within a 3-hour period. Many geophysical properties are clearly related to the indices, through energy transfer from a common disturbance source, but direct correlation is often lacking because of poor matching between the frequency of sampling and the physical response functions. The index $ap(\tau)$ is a simple accumulation of the linear ap calculated with an attenuation factor τ included to take account of natural temporal relaxation. The case for $ap(\tau)$ and the related $Kp(\tau)$ is made using applications to the variability of the plasma environment in the ionosphere and inner magnetosphere. These examples of improved correlation suggest that time-weighted integration might profitably be applied to other indices.

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Time-Weighted Accumulations $ap(\tau)$ and $Kp(\tau)$

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The planetary geomagnetic indices Kp and ap are widely used in space geophysics. They provide an estimate of maximum magnetic perturbation within a 3-hour period. Many geophysical properties are clearly related to the indices, through energy transfer from a common disturbance source, but direct correlation is often lacking because of poor matching between the frequency of sampling and the physical response functions. The index $ap(\tau)$ is a simple accumulation of the linear ap calculated with an attenuation factor τ included to take account of natural temporal relaxation. The case for $ap(\tau)$ and the related $Kp(\tau)$ is made using applications to the variability of the plasma environment in the ionosphere and inner magnetosphere. These examples of improved correlation suggest that time-weighted integration might profitably be applied to other indices.

1. INTRODUCTION

Geomagnetic indices are indispensable to much of space geophysics, but they do have severe inherent limitations which are sometimes ignored. In advancing a new treatment, it is important to appreciate the underlying constraints which will be carried through. *Rostoker* [1972] concludes that "indices are of great use in statistical studies of solar-terrestrial interactions, where qualitative correlations between different parameters are being sought" but "it is not advisable to use indices in a study of individual events, particularly where one wishes to rule out the possibility of substorm activity." He also notes that "in general, indices are only capable of defining the lower limit of geomagnetic activity at any given time."

The 3-hour ap index is a linear scaling of Kp which is derived from a statistical composite of the variations at a selected group of subauroral zone stations [*Bartels and Veldkamp*, 1949]. The basic input data are the differences between absolute maximum and absolute minimum for the three components of the magnetic flux density, measured in nanoteslas, in each 3-hour interval [*Rostoker*, 1972]. The computation, involving local K and Ks values and observatory codings appropriate to season and local time, is complex [*Mayaud*, 1980] but the consequence is that ap can be numerically related to the magnitude of the disturbance at a "standard" midlatitude station. The scale of ap is 0 to 400 (that of Kp is 0o to 9o), and each unit is approximately equivalent to a flux density change of 2 nT. There are numerous problems with detailed scaling of magnetograms, but a potential limitation of ap and Kp is introduced by the restricted and nonuniform distribution of observatories around the Earth with respect to longitude, local time, and geomagnetic latitude within the chosen band between 47° and 63° [*Michel*, 1964].

The merit of the ap index lies in its widespread availability and the continuity which now spans more than 50 years. There now exist a great many empirical relationships between ap (Kp) and other geophysical parameters; this considerably extends the usefulness of the index. Other indices (e.g., *Dst, AU, AL, AE, ε*) and direct particle and field measurements are available and may be more appropriate for particular studies. A number of new indices have been proposed, but it is a matter of some controversy whether they are needed or whether they could supersede established ones [*Mayaud*, 1980].

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The index $ap(\tau)$ is a time series accumulation of ap with exponential smoothing. It is an attempt to produce an index which reflects an integration of geomagnetic activity over a number of 3-hour intervals, giving more weight to the recent past and relatively less to measurements from earlier times. It has been used, with some success, to overcome certain inadequacies in the common indices by the introduction of the integrating and smoothing properties coupled with a matched persistence factor. The classification of data as "quiet" or "disturbed" must be arbitrary, but it has been variously based upon index values, sums, or averages for selected periods prior to the events of interest. *Wrenn et al.* [1987] introduced $ap(\tau)$ to control the binning of f_oF_2 values, first to establish valid quiet time references and then to extract main phase storm patterns from their data. Here it is described in detail with additional examples to demonstrate that it can also be matched to studies of the inner magnetosphere and related plasma effects.

2. DERIVATION OF 3-HOURLY $ap(\tau)$ AND $Kp(\tau)$

Values of ap have been tabulated for all years since 1932 and are now available on computer input media. Any integration is limited by the 3-hour resolution and cannot, therefore, be usefully applied to events with time scales of less than several hours. A 3-hour attenuation multiplier τ is introduced ($0 \le \tau < 1$), and $ap(\tau)$ defined by a geometric progression to be

$$ap(\tau) = (1 - \tau)[ap + (\tau)ap_{-1} + (\tau^2)ap_{-2} + \cdots]$$

where ap_{-1}, ap_{-2} are ap values for -3 hours, -6 hours, etc.

The factor $(1 - \tau)$ normalizes the summation because

$$1 + \tau + \tau^2 + \tau^3 + \cdots = (1 - \tau)^{-1}$$

The repeated summing of infinite series can be avoided by setting up a recursion loop and simply stepping sequentially through the table of ap values, applying the multipler as

$$ap(\tau) = [1 - \tau]\, ap + [\tau] ap_{-1}(\tau)$$

An initial value of $ap_{-1}(\tau)$ is required. If this is unavailable, then a dummy number (say, 6) may be input, in which case the output for the first few days should be disregarded.

For every value of τ, $ap(\tau)$ falls within the same range of values as ap, 0 to 400. Note that $ap(0)$ equals the single unsmoothed 3-hour value of ap.

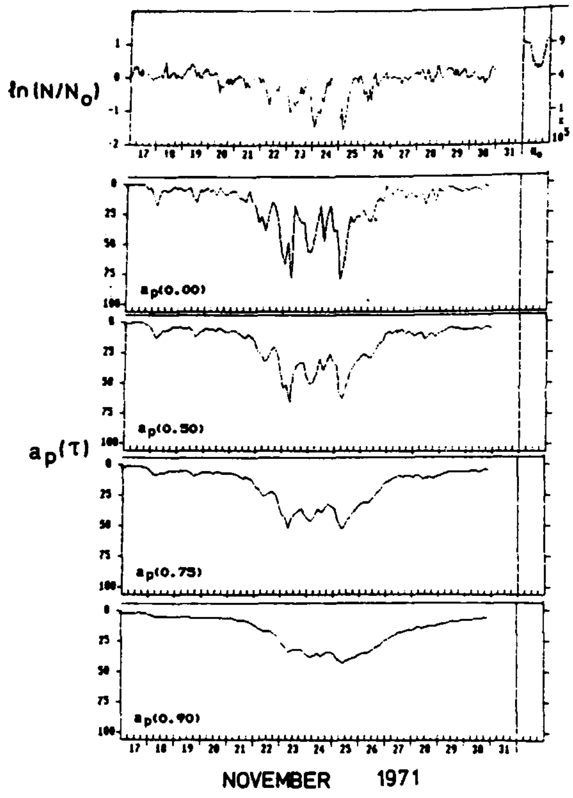

Fig. 1. Variations of f_oF_2 and $ap(\tau)$ for November 17–30, 1971. The top panel shows ln N/N_0 for Argentine Islands. Electron concentration N is computed from hourly f_oF_2 values, and N_0 (inset) is interpolated from the monthly medians, for November (curve) and December (points); units are cm^{-3}. Other panels show $ap(\tau)$ for τ = 0.0, 0.5, 0.75, and 0.9.

In order to demonstrate the form of $ap(\tau)$, Figure 1 plots four profiles for the second half of November 1971 using values of τ = 0.0, 0.5, 0.75, and 0.9. The effect of increasing τ is clear, as the short-term variations are smoothed out in the integrating operation. The curves are inverted to ease the comparison with the changes in F region electron density presented in the same figure and discussed in the next section.

The choice of multiplier τ is fundamental to the procedure and depends upon the characteristic response-recovery time of the effect being investigated. This is best illustrated by taking a delta function in ap and comparing the subsequent decay of $ap(\tau)$ for different values of τ. Figure 2 presents such a plot for a 10-day period using τ = 0.99, 0.975, 0.95, 0.90, 0.75, and 0.50. The times required for a $1/e$ decay are 12.4 days, 4.9 days, 2.4 days, 1.2 days, 10.4 hours, and 4.3 hours, respectively. It is useful to define persistence as $3/(1-\tau)$ hours as an approximate measure of these times (see Table 1).

$Kp(\tau)$ can be determined from $ap(\tau)$ using the standard conversion table with appropriate bisectors. $Kp(\tau)$ does permit a direct comparison of accumulated values with those used previously in many applications. Ap is a daily average of ap, being a simple mean of the eight 3-hourly ap values. J. H. Allen (personal communication, 1985) recognized a problem of using Ap to characterise magnetic storms which start well into the UT day and introduced Ap^* as the largest value computed from successive eight-point running means of ap. The author

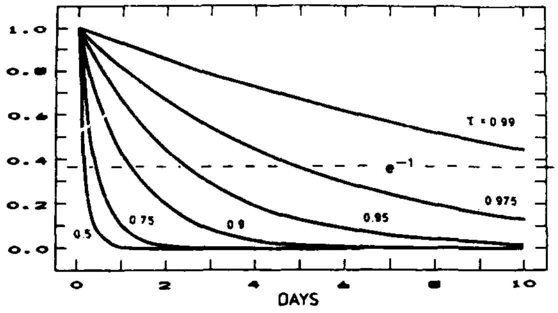

Fig. 2. Decay of $ap(\tau)$ for τ = 0.5, 0.75, 0.9, 0.95, 0.975, and 0.99. The contribution of any single value of ap reduces with time.

knows of no other attempt to systematically generate a retrogressively weighted sampling of geophysical indices, but there have, of course, been numerous searches for lagged relationships.

Although the scale of $ap(\tau)$ is the same as that o' ap, the distribution of values is changed by the smoothing, extremes being eliminated. This is shown by an examination of extremely disturbed times. The most active period in recent years occurred in February 1986, when ap registered as follows:

Feb. 7	Feb. 8	Feb. 9
15	132	300
22	132	179
18	154	56
67	111	39
67	207	48
179	179	94
111	400	56
179	300	27

Determination of $ap(\tau)$ leads to the following maxima:

$ap(0.50) = 297$ $[Kp(0.50) = 9-]$

$ap(0.75) = 252$ $[Kp(0.75) = 8+]$

$ap(0.90) = 167$ $[Kp(0.90) = 8-]$

$ap(0.95) = 108$ $[Kp(0.95) = 7-]$

These figures can be compared with those for the previous superactive period in August 1972, when the maxima were

$ap(0.50) = 240$ $[Kp(0.50) = 8+]$

$ap(0.75) = 204$ $[Kp(0.75) = 8o]$

$ap(0.90) = 143$ $[Kp(0.90) = 7+]$

$ap(0.95) = 100$ $[Kp(0.95) = 6+]$

TABLE 1. Frequency Distribution of $ap(\tau)$, 1974–1984

τ	Persistence, hours	$ap(\tau)$ Peak	10%	25%	75%	90%
0	3	9	2.8	4.9	17.5	33.3
0.5	6	5.5	3.8	5.8	19.7	32.8
0.75	12	6.0	4.4	6.7	19.9	31.8
0.9	30	7.5	5.6	8.0	20.5	29.7
0.95	60	10.0	6.8	9.2	19.7	27.8
0.975	120	11.5	8.1	10.4	19.4	25.9
0.99	300	13.5	9.9	11.4	19.0	23.4

Bartels [1963] discussed the variations of *Kp* and *ap* over three solar cycles and defined frequency distributions for selected epochs. With $ap(\tau)$, the frequency distribution is a function of τ, and this has been examined for one unexceptional solar cycle, 1974 to 1984 (32,144 intervals). The following divisions were set: very quiet, 0–10%; quiet, 10–25%; disturbed, 75–90%; and very disturbed, 90–100%. Half the distribution, 25–75%, could then be classed as normal or moderately disturbed. Employing a step width of 0.5, the frequencies were plotted for the selected values of τ. Table 1 lists the interpolated values of $ap(\tau)$, corresponding to the frequency peak and the prescribed percentile boundaries, for the same set of τ values as was used in Figure 2.

The 75% disturbed threshold remains remarkably stable ($Kp = 3+$) but the frequency distribution does change with increasing persistence, and this must be taken into account when comparing results from analyses which use different values of τ.

Monthly listings of *Kp* are distributed routinely by the Institut für Geophysik, Göttingen, Federal Republic of Germany, and are readily available from World Data Centres. The derivation of $ap(\tau)$ is very simply accomplished in a computer code or within an instruction sequence on a programmable calculator.

3. F REGION STORMS

The spur for the development of $ap(\tau)$ came from a study of ionospheric storms and depletions in the electron concentration at the peak of the *F* layer, i.e., negative storm effects. From ionosonde data, it is found that the critical frequency f_oF_2, measured at mid-latitude stations, can decrease considerably with respect to undisturbed values for several days at times of geomagnetic activity [*Rishbeth*, 1975]. This is illustrated by the top panel of Figure 1, where hourly values of f_oF_2 are converted to electron concentrations *N* and plotted as $\ln(N/N_0)$, where N_0 is an undisturbed value derived from the appropriate monthly medians. The data from Argentine Islands (54°S geomagnetic) refer to November 1971. The diurnal median profiles of N_0 for November and December are included in the inset. The depletions, strongest during the morning hours, are effectively confined to the period of the 20th to 26th when the high geomagnetic disturbance is reflected by *ap*. This qualitative correlation has been demonstrated in numerous studies of ionospheric storms. Treading carefully through many similar "events," it is clear that high values of *ap* do coincide with F_2 storm effects, but the latter do not persist unless the disturbance continues, i.e., unless *ap* remains high. The extent of the storm effect also depends more on the average value of *ap* through the event rather than the maximum which might be limited to a single 3-hour interval. Significant storm effects are observed when *ap* stays at a moderate value for several days without a sudden commencement or a high peak. The diurnal variations were clear and their envelope depended upon latitutde and season as well as activity, but these effects could not be investigated without a suitable "activity index"; *ap* and *Dst* proved unsatisfactory.

The logic of trying to integrate *ap* is obvious even though any single value reflects the peak deviation in a 3-hour period. The physical processes producing the storm effects are not understood, but some modification of the circulation of global thermospheric winds is thought to be responsible [*Volland*, 1983; *Sojka and Schunk*, 1984]. This relates directly to the atmospheric energy input which could be associated with a suitable integration or accumulation of *ap*. Any effect of an energy input will last for a limited time, and this natural relaxation can be built into the accumulation.

Plots using the formats of Figure 1 were produced for five stations for 8 years. The negative storm effects are complex, but consistent patterns have been identified by sifting the data with respect to $ap(\tau)$. Again it must be stressed that a one to one correlation on single events is beyond the scope of the indices. Initially, $\tau = 0.9$ was chosen because this well matches the common recovery response of *Dst*, but it became clear from the whole survey that the *F* region generally recovers faster than this and the appropriate value of τ is closer to 0.75. The curves displayed in Figure 1 do support this conclusion, but it may be difficult to see without producing overlays.

The power of the new index is demonstrated by treating the 8 years of Argentine Islands data, selecting summer months (November–January), and binning all the computed $\ln(N/N_0)$ values in terms of hour and $ap(0.75)$ ranges 0–7, 7–20, 20–32, and 32–400. Figure 3 presents the results and establishes clear diurnal depletion patterns for disturbed (20–32) and very disturbed (>32) conditions. It is interesting that the monthly median reference values are associated with "moderate" disturbance (7–20) so that quiet and very quiet intervals (0–7) generate apparent positive effects. This is a neat demonstration of the inadequacy of monthly medians as a quiet time reference.

4. PLASMA ENVIRONMENT AT 6.6 R_E: SPACECRAFT ANOMALIES

Plasma boundaries observed at geosynchronous orbit (6.6 R_E) are clearly subject to geomagnetic control. Cold plasma, populating the plasmasphere, is convected away in disturbed periods; the refilling then takes several days. Protons and electrons, with characteristic energies of less than 1 eV, are generally observed in the postnoon–evening sector but are frequently found at other local times. Refilling of the flux tubes takes many days, but *Wrenn et al.* [1984] have supported the notion of filling from the center; this would suggest an equatorial persistence more like 30 hours.

GEOS 2 measured cold plasma concentration at geostationary orbit between August 1978 and July 1980. The marked

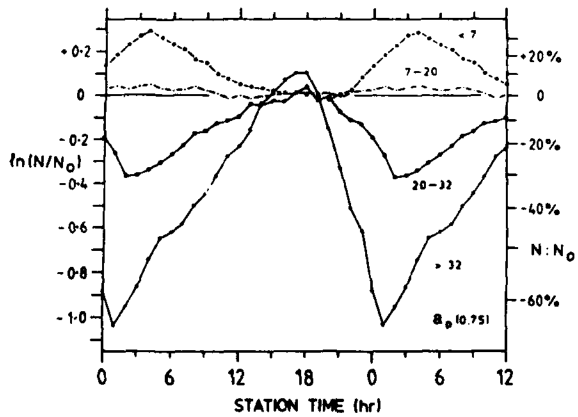

Fig. 3. Diurnal patterns of main phase storm effects. Hourly mean values of ln (N/N_0) from Argentine Islands (summer, 1971–1978) are plotted within selected ranges of $ap(0.75)$. The average numbers of samples per point were as follows: $ap(0.75)$ = 32–400, 50; $ap(0.75)$ = 20–32, 103; $ap(0.75)$ = 7–20, 349; $ap(0.75)$ = 0–7, 203.

day to day variability is clearly related to geomagnetic activity, but neither *ap* nor *Ap* has proved suitable for empirical modeling. However, averaging the data with respect to $ap(\tau)$, does give meaningful results. Figure 4 uses $\tau = 0.9$ to split the data into (from top to bottom) very disturbed, disturbed, normal, quiet, and very quiet and plots average concentration (in cm^{-3}) profiles as a function of local time. The proton data are maximum values detected within hourly intervals. The curves neatly describe the broad features of the equatorial plasmasphere: it extends beyond 6.6 R_E at all local times after a period of sustained quiet [*Sojka and Wrenn*, 1985] and normally exhibits a bulge near 1800 LT, but concentrations peak at earlier local times during active spells. It has been possible to demonstrate the worth of using $\tau = 0.9$ rather than $\tau = 0$ for fitting the data, but the set is too small to yield a statistically significant "best value".

Geosynchronous spacecraft frequently suffer from surface charging effects; the abundance of cold plasma is important because it prevents hazardous charging, but in the past, it has been consistently omitted from environment characterisations [*Garrett et al.*, 1981]. Hot plasma sheet electrons are usually confined to the nightside, but fluxes increase in both intensity and duration as geomagnetic activity rises; spacecraft charging effects and operational anomalies then become more frequent. This phenomenon provides a significance test for $ap(\tau)$ with a value of τ close to 1.

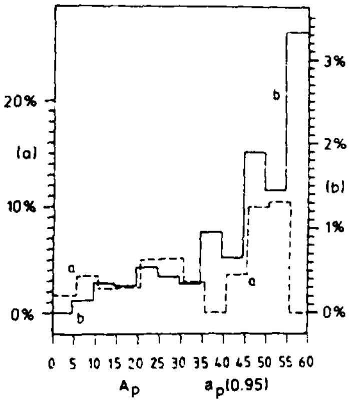

Fig. 5. Meteosat 2 anomaly analysis using *Ap* and *ap*(0.95). Forty-seven radiometer scan anomalies occurred between September 1981 and September 1985. Their distribution with respect to geomagnetic activity is shown (*a*) as a percentage of days in each *Ap* range (1491 days) and (*b*) as a percentage of intervals in each 3-hourly *ap*(0.95) range (11,928 intervals). The vertical scales are equivalent when the sampling factor of 8 is taken into account.

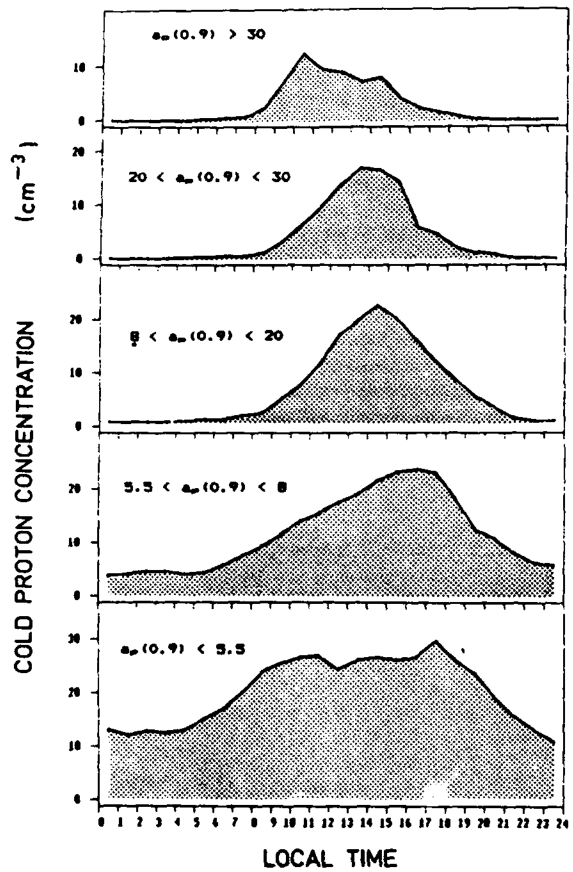

Fig. 4. Cold plasma concentration at 6.6 R_E. Average daily profiles, determined from GEOS-2 measurements between August 1978 and July 1980 are shown for five ranges of *ap*(0.9) from very quiet (< 5.5) to very disturbed (> 30).

Between September 1981 and September 1985, Meteosat 2 suffered 47 radiometer scan anomalies which interrupted the continuous Earth imaging function. Were these anomalies related to geomagnetic conditions? The rather uniform distribution in local time precludes any direct triggering by plasma sheet electron fluxes, but more indirect mechanisms cannot be ruled out. Figure 5 shows the result of an analysis undertaken with respect to the daily *Ap* index. The 1491 days were binned with width 5, and for each bin, the fraction of days exhibiting an anomaly was calculated. Figure 5*a* suggests a bias towards the larger *Ap* values but it is not very convincing. *Johnstone et al.* [1985] concluded that the "anomalies tend to occur after an extended period (> 4 days) of more than average magnetic activity." Repeating the analysis using *ap*(0.95) for the 11,928 3-hour intervals gives Figure 5*b*, which provides clear evidence that the number of anomalies does depend upon the level of activity appertaining to the previous 60 hours, although there is no serious attempt to determine the persistence here.

5. Discussion

The objective of this brief paper is simply to introduce the concept of $ap(\tau)$ and to demonstrate its potential as an aid in working with the common planetary indices. A detailed analysis of its application with F region storms is given by *Wrenn et al.* [1987]. The examples from geosynchronous orbit were selected because the response times appeared to be much longer than 1 day. In such cases, *Ap* or $\sum Kp$ could be adequate if the tie to the UT day is removed b[illegible] $ap(\tau)$ permits an optimization with the selection of τ, and it allows for the retention of diurnal variations in the analyses.

When applying a time dependent filter to data, it is essential to consider whether the product is distorted: characteristic frequencies of the filter should not intrude. Here the *ap* input data are square pulses, sequential averaging merely serves to attenutate the basic 3-hour filter. The normalized series is a discrete first-order one of a simple Markoff type; it has been used widely in autocorrelation and autoprojective analysis [*Kendall*, 1973, p. 118].

The Fourier transform of this RC filter can be defined as

$$G^*(f) = \frac{i(1 - e^{2\pi i f T})}{2\pi f(1 - \tau e^{2\pi i f T})}$$

where T = 3 hours in this case.

As τ increases from 0 to 1 the transform changes smoothly from T sinc $(\pi f T)$ to $1/2\pi f$. Given the nature of *ap*, frequencies greater than $1/T$ are only of academic interest. Within the range of application, say $0.01/T$ to $1/T$, the shape of the spectral window is changed as τ increases, but no "side lobes" are introduced. The important natural triggering frequency here is $0.125/T$ (i.e., 24-hour period).

Indices are an essential ingredient of empirical modeling, but they often fall short of being an effective aid to the understanding of relevant physics. If the frequency of the index is small compared with those characterizing the phenomenon being studied then such an index is clearly inappropriate. Accordingly, the need for 1-min *AE* has been appreciated in the study of substorms. When the frequency of the index is comparable or relatively high, then it is still important to achieve a good match between the sampling of the index and the time constants involved in the process. The type of accumulation described here for *ap* might well be applied to *AE*, *AU*, or *AL* for the investigation of substorm responses in the 1- to 100-min range.

Numerous parameters have been correlated with *ap* or *Kp* using a lag time, but it would now be instructive to include τ as a variable in the regression analyses in attempts to establish appropriate response times; these could provide valuable pointers to the identification of the controlling physical processes. It is possible that the coarseness or nonlinearity in *ap* might preclude a meaningful result, but given a very large data base, the broad-brush statistical treatment is surprisingly powerful.

Relationships between different indices are of special interest. *Dst* monitors the storm time enhancement and subsequent decay of the ring current; the recovery phase typically lasts for 3 days. An attempt to correlate *Dst* and $ap(\tau)$ could throw more light on the real significance of both indices and the relevant processes of particle injection, trapping, and precipitation.

It is hoped that the few examples presented here will convince space scientists that there can be significant merit in employing a simple accumulation procedure to extend the usefulness of the readily available geomagnetic indices: *ap* is a crude index of geomagnetic activity and one must be aware of its limitations; the 3-hour resolution is clearly inadequate for many studies, and better indices may be available. Even so, the introduction of weighted running averages does offer some advantage in the search for correlations with time-varying features of the ionosphere/thermosphere, the plasmasphere, and the inner magnetosphere, and $ap(\tau)$ represents a useful tool in the building of a better understanding of the physics of some complex geospace systems from raw materials supplied by routine monitoring.

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REFERENCES

Bartels, J., Discussion of time-variations of geomagnetic activity, indices *Kp* and *ap*, 1932–1961, *Ann. Geophys.*, *19*, 1–20, 1963.

Bartels, J., and J. Veldkamp, Geomagnetic and solar data, *J. Geophys. Res.*, *54*, 295–299, 1949.

Garrett, H. B., D. C. Schwank, and S. E. DeForest, A statistical analysis of the low-energy geosynchronous plasma environment, II, Ions, *Planet. Space Sci.*, *29*, 1045–1060, 1981.

Johnstone, A. D., G. L. Wrenn, H. E. Huckle, and R. F. Scott, Meteosat F2 spacecraft charging monitors, Final report, Eur. Space Agency contracts 4715/81/F CG and 5911/84/F CG, 269, pp., Mullard Space Sci. Lab., Univ. Coll. London, 1985.

Kendall, M. G., *Time-Series*, 197 pp., Griffin, London, 1973.

Mayaud, P. N., *Derivation, Meaning, and Use of Geomagnetic Indices*, *Geophys. Monogr. Ser.*, vol. 22, 154 pp., AGU, Washington, D. C., 1980.

Michel, F. C., *Kp* as a planetary index, *J. Geophys. Res.*, *69*, 4182–4183, 1964.

Rishbeth, H., *F*-region storms and thermospheric circulation, *J. Atmos. Terr. Phys.*, *37*, 1055–1064, 1975.

Rostoker, G., Geomagnetic indices, *Rev. Geophys.*, *10*, 935–950, 1972.

Sojka, J. J., and R. W. Schunk, A theoretical *F* region study of ion composition and temperature variations in response to magnetospheric storm inputs, *J. Geophys. Res.*, *89*, 2348–2358, 1984.

Sojka, J. J., and G. L. Wrenn, Refilling of geosynchronous flux tubes as observed at the equator by GEOS 2, *J. Geophys. Res.*, *90*, 6379–6385, 1985.

Volland, H., Dynamics of the disturbed ionosphere, *Space Sci. Rev.*, *34*, 327–335, 1983.

Wrenn, G. L., J. J. Sojka, and J. F. E. Johnson, Thermal protons in the morning magnetosphere: Filling and heating near the equatorial plasmapause, *Planet. Space Sci.*, *32*, 351–363, 1984.

Wrenn, G. L., A. S. Rodger, and H. Rishbeth, Geomagnetic storms in the Antarctic *F*-region, I, Diurnal and seasonal patterns for main phase effects, *J. Atmos. Terr. Phys.*, *49*, 901–913, 1987.

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17. Abstract

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