V. MAGNETOSPHERIC PREDICTIONS
A. SOLAR WIND AND MAGNETOSPHERE INTERACTIONS


We now have the ability to characterize the state of the magnetosphere quantitatively and to predict this state from a knowledge of interplanetary conditions. We recommend therefore that the conditions of the solar wind and interplanetary medium be continuously monitored, in addition to monitoring the state of the magnetosphere. We further recommend continued study of the relationship of interplanetary conditions to the response of the magnetosphere, continued study of the geomagnetic tail, tests of Pc 3,4 magnetic pulsations as diagnostics of the solar wind and tests of kilometric radiation as a remote monitor of the auroral electrojet. Finally we urge the continued construction of geomagnetic indices and the development of new indices where there is a proven advantage to these new indices.

1. INTRODUCTION

Within the overall Solar Terrestrial system, the interface between the solar wind and the magnetosphere is crucial since it is this interface which determines how much of the solar plasma and field energy is transferred to the earth's environment. This coupling not only varies in time, responding to major solar disturbances, but also to small changes in solar wind conditions and interplanetary field directions. We do not yet fully understand this coupling, though we have some intriguing clues, and yet it is upon this coupling that we base part of our ability to make solar terrestrial predictions. Due to the rapidly evolving nature of this science on the one hand, and the considerable unknowns and complexity on the other, further intensive study of the Solar Terrestrial system is necessary if we are to increase our ability to understand the response of the earth to the sun.

If we are to predict the response of the magnetosphere to some disturbance in the solar wind, we must first have some accurate knowledge of what that disturbance will be. The longest warning one could expect would be from solar observations, but at present our ability to predict the properties of the solar wind at one astronomical unit from observations of the sun are far from adequate for the purpose except for the largest disturbances. We hope that future studies will improve this situation and we urge that these be carried out.

Interplanetary scintillation measurements of radio sources near the sun also promise to provide some warning, but these also have limitations. They provide measurements of the solar wind velocity and turbulence but not magnetic field strength and direction. Furthermore, the radio sources necessary for such studies are not distributed uniformly in the sky. On the other hand, computer modeling studies show that measurements or inferences of solar wind velocity density and magnetic field can be extrapolated over large radial
distances. Thus, if measurements of the solar wind close to the sun were available, they could be useful for long lead-time forecasts. At present we must use solar wind and interplanetary field measurements made close to the earth for accurate predictions of magnetospheric response. As we discuss below, it is important for predictions that we better understand the distance over which solar wind conditions can be extrapolated.

If measurements outside the magnetosphere are unavailable, observations of the present state of the magnetosphere can be useful in predictions since the magnetosphere can store energy before releasing it into the ionosphere. Also geomagnetic pulsations are thought to provide diagnostic information both on the present state of the magnetosphere and to a limited extent on external conditions.

If we have an adequate measure of the solar wind conditions, we can attempt to predict magnetospheric response. This area is still under active investigation but enough is known to provide some practical information. In the past, in the absence of solar wind data, many forecasters used geomagnetic indices to predict the reaction of the ionosphere, for example, to disturbances of the magnetosphere. It now seems possible to bypass the indices for this particular purpose. However, before doing so we should examine the relationship between these indices and the solar wind parameters that control them. We do this in the third section of the report.

Finally we list a number of recommendations. Forecasting magnetospheric conditions promises to become increasingly important in the years to come as technology advances. Thus, it becomes increasingly important to monitor the conditions that affect the magnetospheric environment and to pursue studies which will provide a better understanding of this environment and an improvement in our ability to predict its state.

2. MEASUREMENTS AND INFERENCES OF SOLAR WIND CONDITIONS

For accurate predictions we need accurate measurements of the ambient solar wind conditions. However, even in the absence of measurements, we may still deduce some information on these conditions by examining the state of the magnetosphere itself. In this section of the report we discuss the requirements for in-situ observations and the information available from indirect techniques.

2.1 In-Situ Solar Wind Conditions at 1 AU

In order to predict the response of the magnetosphere at any particular time, we must know the conditions in the solar wind external to the magnetopause. In particular, it has been shown that geomagnetic activity is principally controlled by the solar wind velocity and the interplanetary magnetic field strength and direction (Burton et al., 1975; Murayama, 1979; Maezawa, 1979). Other parameters such as density may play some role but are generally thought to be less important. With the exception of the occurrence of shock waves, the velocity and magnetic field strength are slowly changing parameters.
Figure 1. Comparison of interplanetary magnetic flux measured by two near-earth satellites. The correlation coefficient is 0.70. The spacecrafts were always separated by less than 100 earth radii (Holzer and Slavin, 1979).

when compared with the magnetic field direction. Thus, while the strength of the interplanetary field and the solar wind velocity may be very important parameters in controlling geomagnetic activity, it is the changes in field direction which are correlated with geomagnetic 'events' in the magnetosphere. Furthermore, since the field of the solar wind changes direction often, its correlation length or region of uniformity is relatively small, requiring that the measurements of solar wind conditions that lead to small or moderate geomagnetic activity be made relatively close to the earth.

Ideally we would like to monitor the element of solar wind plasma that is going to intercept the earth. If we do not and if the planes of discontinuity are not normal to the solar wind velocity, the discontinuities will reach the earth with variable time delays depending on the location of the satellite with respect to the sun-earth line and the orientation of the discontinuity plane. Such variable delays have been deduced for earth-orbiting satellites (Perreault and Kamide, 1978; Pytte, 1978) and the correlation coefficients between spacecraft separated by as little as 80 Re was found to be low by (Chang and Nishida, 1973). Finally as shown in Figure 1 Holzer and Slavin (1979) have made comparisons between time integrated values of \( V_{SW} B_s \), as might be used in forecasting, observed at HEOS 1 and Explorer 35. This comparison shows a good average agreement but a surprisingly low correlation coefficient of 0.7. We feel that it is important to develop a clearer understanding of how the solar wind plasma and field conditions change along and perpendicular to the solar wind flow. The above studies also indicate that it is important to consider carefully the placement of satellites for solar wind monitoring. We leave the question of the functional form of the dependence of geomagnetic activity to a later section of the report.
The interaction region which is thought to be important for geomagnetic activity is generally believed to be the forward hemisphere of the magnetosphere. To probe directly the magnetosheath plasma in this region would require many satellites in circular √12 earth radii (Re) circular orbits to ensure that one was always near the interaction region. Clearly this is impractical. A more practical approach would be an √30 Re circular orbit like IMP's 7 and 8. However, this would require at least 2 satellites in earth orbit. Another proposal is to monitor at the forward libration point 235 Re along the earth-sun line. However, for communication purposes a satellite cannot be placed exactly here. It must orbit around the libration point. ISEE-3 does this but with an 100 Re semi-major axis; tighter orbits are possible. A further possibility is a lunar 'synchronous' orbit which maintains apogee in the solar wind using close encounters with the moon.

At present the ISEE-3 spacecraft is observing the solar wind in a large, √100 Re semi-major axis, ellipse centered on the forward libration point. Comparisons of the data obtained on this spacecraft with that obtained closer to the earth on ISEE 1 and 2 should be undertaken as soon as the requisite data become available to address this problem. It is expected that a high correlation coefficient will result for the largest and long enduring events, but, based on the studies mentioned above, that small events will correlate poorly.

2.2 Measurements Within the Magnetosphere

The earth's magnetotail maps into the polar cap. Thus, changes in the magnetotail are reflected in changes in the polar cap. Changes in the size of the auroral oval can be monitored by spacecraft TV cameras, radar measurements, satellite particle detectors, and ground based magnetometers. Ground based instrumentation suffer the problem of being point, or at best line, measurements and thus must be treated with some caution, taking into account the shape of the auroral oval. In all these measurements it is easier to distinguish the equatorward border of the auroral oval than the poleward border. However, even an approximation to the size of the polar cap should prove useful.

Figure 2 shows the response of the lower border of the auroral oval to an increasingly southward Bz (Kamide and Winningham, 1977). Burch (1972, 1973) has examined the motion of the polar cusp on the dayside in a similar way. These studies suggest that a measure of the size of the polar cap would be a very useful index of the state of the magnetosphere. However, it may not solely vary in response to the solar wind but also due to internal magnetospheric affects such as auroral activation and changes in the ring current (Siscoe, 1979).

In addition to measuring the size of the polar cap, it is useful to measure plasma flows across the polar cap. Increased stress on the magnetosphere causes flows across the polar cap from noon to midnight. These flows in turn cause currents. These plasma flows can be monitored by low altitude satellites measuring electric fields, by high altitude balloons equipped to measure electric fields and with ground based radars. Low altitude polar orbiting spacecraft spend about 20% of their orbit in the polar cap and could provide
Figure 2. Location of the equatorward boundary of the diffuse electron precipitation at different local times in the dark sector for three $B_z$ values of IMF (Kamide and Winningham, 1977).

A measure of the potential drop across one or the other polar cap about every 50 minutes. Balloons can provide continuous point measurements, but have lifetimes of the order of one day. Scientific radars presently in place, monitor at best only the edges of the polar cap. Magnetometers can measure the resultant currents, but the current systems are complicated and a function of local time. Thus a longitudinal and meridional high latitude network is necessary for 24 hour-a-day coverage.

In the outer magnetosphere increased stress leads to changes in the magnetic field (McPherron et al., 1973). When a substorm occurs, this stress is relaxed and the field configuration returns to a dipolar configuration. This presubstorm phase has been called the growth phase (McPherron, 1970). A very sensitive location in the magnetosphere for measuring these field configuration changes is at synchronous orbit. This can be done with magnetic field measurements or energetic electron measurements. Prior to a substorm, 97% of the time, energetic electrons assume a cigar-shaped distribution about the field direction (Baker et al., 1978, 1979). Thus, energetic particle measurements at synchronous orbit can be used to forcast the injection of fresh energetic particles.

2.3 Geomagnetic Pulsations

The predictive value of geomagnetic pulsations for space science studies or for practical applications is presently undetermined or undeveloped. Pulsations are thought to be able to provide diagnostics of conditions in the distant magnetosphere and the solar wind. Thus, their occurrence rates, periods and amplitudes have been correlated with a wide variety of magnetospheric and solar wind parameters such as the distance to the magnetopause (Vero, 1975), the location of the plasmapause (Orr, 1975), the density in the plasma trough (Orr, 1979), the location of the polar cusp (Bolskakova et al., 1975); the strength of the interplanetary magnetic field (Gul'el'mi, 1974); and its direction (Troitskaya et al., 1971), and the solar wind velocity (Singer et al., 1977). In fact, it is the sensitivity of geomagnetic pulsations to a wide variety of different parameters in the solar wind and magnetosphere, that impairs their present predictive ability, while still offering hope of future profitable applications.
Figure 3. Average interplanetary magnetic field strength versus period of magnetic pulsations seen at a mid-latitude observatory (Troitskaya et al., 1972).

One prevailing model of the generation of these waves proposes that any perturbation at the magnetopause under suitable conditions becomes amplified into a surface wave, via the Kelvin-Helmholtz instability. The waves then couple into the magnetosphere and resonate as standing waves along field lines (Southwood, 1968). A second model suggests that the waves originate as part of the quasi-parallel structure of the shock (Greenstadt, 1972). Quasi-parallel shock associated waves are always present somewhere. When the interplanetary magnetic field is nearly aligned with the velocity of the solar wind, the unstable region moves closer to noon. The waves are convected into the subsolar magnetosheath and blown against the magnetopause. The motion of the magnetopause in response to these waves couples the energy into the magnetosphere and the wave energy builds up wherever the frequency of the disturbance equals a resonant frequency of the field line. Neither model precludes the validity of the other and indeed there is every reason to believe they both apply simultaneously (Wolfe et al., 1978; Greenstadt et al., 1979). Thus, pulsations may offer an opportunity to characterize at least some properties of the solar wind, magnetosheath and magnetopause when direct measurements are unavailable.

Figure 3 shows one of the clearest relationships, that of pulsation period versus interplanetary magnetic field strength (Troitskaya et al., 1972). This average correlation was strong enough to convince the observers at Borok Geophysical Observatory to calculate an index of interplanetary field strength. The validity of this index was later tested independently (Russell and Fleming, 1976). The results of this test are shown in Figure 4. The interplanetary field strength correlates well with the index but there is significant overlap between the distribution of field values for each level of the index. Thus although the average correlation is high, the accuracy of the index as a predictor of individual hourly field values is low.
Figure 4. Histograms of the occurrence of interplanetary field strengths for each level of the Borok B index (Russell and Fleming, 1976).

The advantage of pulsation measurements is that they are relatively inexpensive to make. They can be obtained from a modest midlatitude world-wide network with perhaps as few as eight stations. However, this advantage must be weighed against the present low accuracy of the resulting inferences. It is possible that future studies, especially those of waves in space, may lead to a better understanding of the sources of magnetic pulsations, and their properties. In particular, a better knowledge of the conditions under which hydromagnetic waves are generated at the magnetopause and how they propagate through the magnetosphere would be useful. Perhaps studies of wave polarization might assist in distinguishing pulsations with differing sources. Then perhaps the diagnostic capability of magnetic pulsations can be improved. Thus we recommend the continued investigation of the relationships between interplanetary parameters and pulsation amplitudes and periods but cannot define the use of pulsations in magnetospheric forecasts at this time.

3. RESPONSE OF THE MAGNETOSPHERE TO SOLAR WIND CONDITIONS

We shall assume that we have a measure of the solar wind velocity and density and interplanetary magnetic field magnitude and direction close to the location of the earth. As mentioned above, in order to make a confident prediction of the geomagnetic response to these conditions, we must be sure that the scale length for variations in the critical parameters are longer than the impact "parameters" of the element of the solar wind being probed. We currently do not have an adequate measure of these lengths, but satisfactory predictions have been made from data obtained within about 50 Re of the earth in the past.

The earth's magnetosphere responds to changes in dynamic pressure of the solar wind, by changing its size. If the magnetosphere is in a stressed state, compressions may lead to a substorm. Rapid changes cause sudden impulses in ground records and are classified as a form of geomagnetic activity. However, these compressions, per se, are not usually associated with the cur-
Figure 5. Equatorward motion of the polar cusp after a southward turning of the interplanetary magnetic field (Burch, 1972).

Recent systems and energy deposition arising during storms and substorms. If the interplanetary field is southward at the time of an interplanetary shock passage or turns southward sometime later, then the IMF is likely to be strong due to compression by the shock, and significant geomagnetic activity in the form of a geomagnetic storm will result (Burton et al., 1975).

Pressure changes alone are not the only cause of variations in the magnetopause location. Southward turning of the IMF also causes the magnetopause to move inward (Aubry et al., 1970). Figure 5 shows this effect in the motion of the polar cusp (Burch, 1972). However, in this process the magnetosphere does not change size so much as it does shape. The dayside magnetosphere loses magnetic flux which enters the polar cap and hence resides in the magnetotail. The convection across the polar cap causes field aligned current systems to arise which close in the polar cap. Asymmetries may arise in the flow across the polar cap, or equivalently the electric field and the currents, depending on the sign and magnitude of the interplanetary eastwest component of the interplanetary magnetic field (Heppner, 1972).

At lower latitudes the electric field is also found to be controlled by the IMF. Horwitz et al. (1978) using the Chatanika radar found that convection in the F-layer from $\lambda = 63^\circ$ to $68^\circ$ was proportional to the $B_z$ component of the IMF. At the highest latitudes this response was simultaneous with the IMF change but at the lowest an $\approx 30$ minute delay was observed. Blanc (1978) has studied the field penetration to even lower latitudes with the Saint-Santin radar ($\lambda = 47^\circ$). Quiet time east-west drift velocities of increased from 10 m/s to $\approx 100$ m/sec within 30 min after $B_z$ turned southward. Estimates of the convected flux returned to the dayside correlate quite well with the applied potential or mergible flux in the solar wind as shown in Figure 6 (Holzer and Slavin, 1979). These measurements are consistent with the studies of injection into the partial ring current (Clauer and McPherron, 1979) and the ring current (Burton et al., 1975) who showed that injection was proportional to the southward $B_z$ and the solar wind velocity.
Figure 6. Comparison of the estimated returned magnetic flux as a function of the applied flux (Holzer and Slavin, 1979).

Since flux eroded from the dayside magnetosphere must pass across the polar cap to get to the night time magnetosphere, we would expect that the polar cap currents, which respond to the stresses imposed on the ionosphere by the flowing plasma at high altitudes, would be quite responsive to the interplanetary magnetic and/or electric field. Not only is there flow across the polar cap, but there are also changes in size of the polar cap as the imbalances develop between dayside and nightside reconnection. No attempt has been made to predict the size of the polar cap and test this prediction against auroral photos. However, an equivalent study of predicting the flux in the tail and comparing with the observed field strength has been performed successfully (Slavin and Holzer, 1979) as illustrated in Figure 7.

Figure 7. Predicted flux in the geomagnetic tail compared with the observed flux density using measured upstream solar wind conditions (Slavin and Holzer, 1979).
The polar cap equivalent current system is basically a double cell system called $S_p$ (Nagata and Kokubun, 1962). By comparing this current system with the IMF one finds that the polar cap current has an IMF dependent and an IMF independent part. The IMF dependent part is expected to have east-west asymmetries controlled by the $B_y$ component of the interplanetary magnetic field. Convection should also be away from the sun unless the IMF is northward under which conditions merging could occur tailward of the cusp and cause sunward convection (Russell, 1972). Such effects have been observed (Friis-Christensen and Wilhjelm, 1975; Maezawa, 1976; Mishin, 1979). An attempt to predict such behavior in terms of a simple merging model in which merging takes place on the dayside only at places in which the magnetosheath and magnetospheric are antiparallel has been made by Crooker (1979). This model has been compared to the observations by Friis-Christensen (1979) and found to be in very good agreement.

4. PREDICTIVE TECHNIQUES FOR GEOMAGNETIC INDICES

Geomagnetic indices are numbers which are designed to quantify the state of geomagnetic activity at a particular time. A description of the most commonly used indices is given as an appendix. There are high latitude indices such as $K_p$, $A_p$, $a_a$, $a_m$, etc. which respond to auroral activity and distant magnetospheric currents and there is the low latitude $Dst$ index which responds principally to the strength of the ring current or equivalently the energy stored in the radiation belts. If we can predict the magnitude of these indices then we feel we have at least an empirical understanding of the energy input to the magnetosphere. Furthermore, forecasts of the indices would permit users to plan programs or actions which take into account the expected level of geomagnetic activity.

![Figure 8. Normalized AL index as a function of the southward magnetic field. Negative values denote periods when interplanetary field was southward; positive values when it was northward (Murayama, 1979).](image-url)
Figure 9. Injection rate into the ring current as a function of the solar wind dawn-dusk electric field, $V_B^2$ (Burton et al., 1975).

The AE index is the sum of the AU index and the AL index. Since statistical studies show these two indices appear to respond differently to the solar wind, we will treat them separately. As shown in Figure 8 for AL these indices appear to be linearly proportional to the southward field with little or no response for northward fields (Murayama, 1979; Maezawa, 1979) and not to $B^2V \sin^4 (\theta/2)$ hypothesized by Perreault (1976) and Akasofu (1978). This half-wave rectifier model has also been shown to be useful to predict Dst (Burton et al., 1975) as illustrated by Figure 9 and flux transport within the magnetosphere (Holzer and Slavin, 1978). The AL also is proportional to $V^2$ as shown in Figure 10 (Murayama, 1979; Maezawa, 1979a). A similar result was found for Ap (Garrett et al., 1974; Crooker et al., 1977). The AU index is related to $V$ rather than $V^2$ (Maezawa, 1979a). Both AU and AL seem to depend to some extent on the variance of the interplanetary field and the solar wind density (Garrett, 1974; Maezawa, 1979b). This effect is particularly important during periods of northward interplanetary magnetic field (Maezawa, 1979b). One surprising result of the study of AL is that it "saturates" at about 500 gammas and is no longer linearly proportional to $B_sV^2$ (Maezawa, 1979a). This could be due to the station distribution not being optimum during very disturbed conditions.

The Dst index can be predicted from the solar wind electric field allowing for the decay of energy from the ring current (Burton et al., 1975). In this model the half-wave rectifier model for the interaction was shown to be most appropriate and a linear dependence on $V$ was assumed. Whether $V^2$ would improve the model was not tested.
Figure 10. Dependence of various geomagnetic indices on the solar wind velocity (Maezawa, 1979).

As mentioned above Ap has been shown to be dependent on $B_0V^2$. This has been confirmed for $a_m$ by Maezawa (1979a) (see figure 10) and for $aa$ by Feynman and Crooker (1978). The dependence of the midlatitude indices on density (Maezawa, 1979a) and on the variance of the interplanetary magnetic field (Garrett et al., 1974) is weak; however, it is more marked than that of the high latitude indices.

5. RECOMMENDATIONS

Although historically geomagnetic indices have been incorporated in many models predicting magnetospheric and ionospheric conditions, we now have the ability to characterize the state of the magnetosphere by more basic parameters. It is with this goal in mind that we recommend below the monitoring of a basic set of magnetospheric and interplanetary parameters that should significantly improve our forecasts. In some areas further study is recommended. This further study includes the investigation of possible future diagnostic techniques and basic research so that we understand the underlying physical mechanisms behind our present imperfect empirical knowledge. Finally, we recommend the continual computation, new computation, and in some cases, tests of several solar and geophysical indices which will improve our predictive capabilities.
5.1 Spacecraft Measurements

a. Continuous in-situ measurements of the solar wind velocity number density and interplanetary magnetic field direction are required for near term geomagnetic forecasts. These measurements should be available in real time and should be taken as close to the earth-sun line as possible and preferably at a fixed distance from the earth such as at the forward libration point.

b. Since the magnetosphere responds to short time scale features (≈1/2 hour) in the interplanetary field and since these features may have short coherence lengths in the solar wind we further recommend magnetic field measurements on a series of spacecraft in 20-40 Re geocentric orbit. These measurements will improve the accuracy of forecast of small to moderate disturbances, and should be available to forecasters in real time.

c. Since geomagnetic effects are first felt in the polar cap it is recommended that low altitude polar satellites be used to monitor the size of the polar cap, the width of the auroral oval, and the potential drop across the polar cap using measurements of particle fluxes, electric currents, and electric fields.

d. Historically auroral monitoring from the ground has provided retrospective information on the stage of substorm development. Spacecraft now can image an entire auroral oval from high apogee earth orbit. We recommend that such imaging systems be pursued and provide real time data to enable forecasts to follow the development of substorms.

e. Three dimensional pitch-angle measurements of E > 30 kev electrons at synchronous orbit have shown their usefulness in predicting substorm occurrence. It is recommended that these data be made available in real time forecasters.

f. Present monitoring of the magnetic field at synchronous orbit by the SMS and GOES spacecraft has been impaired by the close proximity of the sensors to the spacecraft. We recommend that these sensors be so situated on future spacecraft that the full potential of these sensors for prediction purposes be realized.

g. Interplanetary scintillation measurements have not reached their full predictive potential because of the limited number of stations in operation around the world. New stations suitably placed would improve this situation.

h. As an aid in assessing the utility of coronal hole monitoring as a predictor of solar wind streams we urge the continuance of optical monitoring of the sun at 10830 Å at least until full disk X-ray images from space become available.
5.2 Ground-Based Measurements

a. Currently, ground-based measurements (e.g. magnetic, etc.) also play a very important role in providing synoptic data which can be used for predictive purposes. We recommend that the quality and quantity of key ground-based measurements continue to be maintained, and improved if possible. (See recommendation (d) on Indices).

b. We recommend that new and better ways of collecting, using and distributing this data continue to be evolved.

c. The scientific results from new research facilities, such as the IMS North American Magnetometer Network, should be examined to see if they give clues to new indices or parameters which might eventually provide more effective predictions.

5.3 Future Studies

a. Present research has shown that geomagnetic activity depends on the solar wind velocity density and the interplanetary magnetic field. We recommend continued study of this dependence to quantify the functional dependence of the various magnetospheric processes on these parameters.

b. In view of the crucial role the geomagnetic tail plays in geomagnetic activity we urge the continued study of the tail and its responses to solar wind parameters.

c. Pc 3, 4 magnetic pulsations are highly correlated with interplanetary conditions but are not yet understood well enough to be used for diagnostic purposes. We recommend continued study of these pulsations to assess their diagnostic capability.

d. Kilometric radiation appears to be a sensitive indicator of the strength of auroral current systems. We urge that the diagnostic capability of kilometric radiation be assessed as its observation might provide a useful remote monitor of the auroral electrojet.

5.4 Indices

a. In view of the long history of the use of the Zurich sunspot number in geomagnetic studies we urge its continuance. The great strength of this data is that it forms a commensurate series.

b. The Comprehensive Flare Index has been shown to enhance significantly our ability to forecast geomagnetic activity. We recommend that it be routinely calculated in real time for all major flares.
c. The indices $a_p$, $a_m$ are apparently redundant. The relationships between them should be studied by the appropriate international body and one of them phased out. The better index should continue to be produced in a timely manner. A two station type aa index is simple to produce and may be useful in predictive applications.

d. The auroral electrojet indices AE, AU, and AL have shown great usefulness in retrospective studies of geomagnetic activity, but the delay in their preparation is unacceptably great, and the number and location of the stations limits their utility. We recommend that countries beneath the auroral oval insure continued monitoring of magnetic variations at auroral latitudes, install new sites where necessary for optimum station spacing, install digital recording and transfer data to the WDC's as rapidly as possible. Further we urge increased efforts to produce these indices on a more timely basis. Potential index applications for predictive uses might be met by prompt preliminary AE indices from a reduced network.

e. Data presently exist from several sources from which an index of polar size and auroral zone width might be obtained retrospectively. We urge that such indices be created and tested as indicators of the state of the magnetosphere and predictors of future conditions. These data should also be provided in real time to forecasters.

f. Data presently exist from which the hourly summations of southward magnetic field might be obtained. We recommend that such an index be prepared and issued in a form similar to the NSSDC Interplanetary Magnetic Field Data Book. We further recommend that data books containing the interplanetary magnetic field in solar magnetospheric coordinate and the solar wind number density and velocity be brought up to date and continue to be produced.

g. The ability to predict geomagnetic disturbances based on the 27-day recurrence of solar wind streams varies strongly across the solar cycle and from cycle to cycle. As an aid to planning a daily recurrence index should be developed and made available in real time.

h. Development of indices giving a global measure of the level of daytime pulsation activity in the Pc 3, 4 period range would serve both to advance the investigation of magnetospheric waves and to establish a quantitative basis for testing and improving the predictive capacity of pulsation observations. We recommend that such efforts be undertaken.

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