# REAL TIME MONITORING OF GLOBAL MAGNETIC ACTIVITY: THE $AP_{EST}$ INDEX

**Ellen Clarke**

*British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA, UK,*
*Email: E.Clarke@bgs.ac.uk*

## ABSTRACT

Definitive *Kp*/*ap* (3-hourly) and *Ap* (daily) values provided by GeoForschungsZentrum, Potsdam, are currently made available twice per month. A time delay is inevitable because of the need for a high quality homogeneous data set. In operational Space Weather programs, small discrepancies in the data are often less important than their timely availability. An automated algorithm has been developed by the British Geological Survey (BGS) to derive real-time estimates of the *ap* and *Ap* indices, called $ap_{est}$ and $Ap_{est}$ respectively. The derivation process is described and an evaluation of the performance of the algorithm is carried out by comparing the estimated indices to the final definitive values. A linear correlation of 0.98 is found between the definitive *Ap* and the values of $Ap_{est}$ available at 02:45UT the following day. Daily $Ap_{est}$ and 3-hourly $ap_{est}$ are available on-line at www.geomag.bgs.ac.uk/gifs/apindex. The estimates are continuously updated as additional observatory data become available.

## 1. INTRODUCTION

Global geomagnetic activity indices play an important role in Space Weather projects. Derived from data recorded at a network of mid-latitude magnetic observatories, the 3-hourly planetary index (*ap*) and the daily planetary index (*Ap*) were designed to measure the irregular disturbances of the magnetosphere caused by the interaction with the solar wind. Originally devised by Bartels [1], these indices are now very well established and extensively used in many areas of research. They are provided by the GeoForschungsZentrum (GFZ), Potsdam, Germany, on behalf of the International Service of Geomagnetic Indices (ISGI) of the International Association of Geomagnetism and Aeronomy (IAGA).

The data are available twice per month as soon after the 15$^{th}$ and the last day of the month as possible. This time delay is inevitable because of the need for a high quality homogeneous data set and for most scientific research is adequate. However the process is not sufficiently responsive to the needs of the Space Weather community, in particular in an operational sense, where small discrepancies in the data are less important than their timely availability. The British Geological Survey (BGS) has developed an automated algorithm to derive estimated values of *ap* and *Ap* and provide these on-line in near real-time.

## 2. REAL TIME ESTIMATED $ap_{est}$ and $AP_{est}$

The estimated indices have been designed to match that of the definitive values as closely as possible. In order to do this, estimated *K* indices are derived for as many of the official *Kp* magnetic observatories as possible. The map in Fig 1 shows the locations of observatories used.


**Fig. 1 Map of the global distribution of mid-latitude magnetic observatories used in the definitive production of *Ap* (blue dots) and the BGS $Ap_{est}$ (red circles).**

The data are collected from the various locations making use of INTERMAGNET data whenever possible. If definitive local 3-hourly *K*-indices are available from any of the observatories, these are collected. Otherwise estimates of the *K*-indices are made for each observatory. The derivation of these depends on the type of data available. Normally hourly or 3-hourly ranges are used. The *K* values (real and/or estimated) are then converted to standardised indices, *Ks*. These are then used to calculate $Kp_{est}$, $ap_{est}$ and $Ap_{est}$. This method closely follows that for the production of the definitive indices. The more observatories from the network that can be included and the better the *K* estimates from these are, then the better the final $ap_{est}$ and $Ap_{est}$ will be.

## 3. ESTIMATED *K* Indices

Using data from 1997 to 2000, a logarithmic regression curve was derived for each 3-hour period for each observatory to give the *K* value from the maximum horizontal range. An example is shown in Fig 2, which is the curve derived for the 3-hour period from 1800 to 2100 UT at Eskdalemuir observatory.

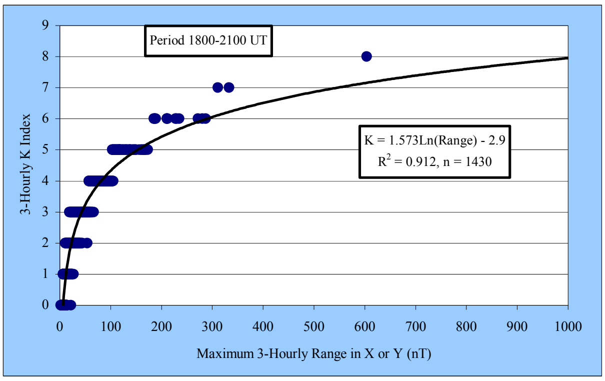


**Fig. 2 Observed *K* values plotted against the maximum horizontal 3-hourly range for the period 1800 to 2100 UT at Eskdalemuir observatory during 1997 to 2000.**

When the range is less than the normal lower bound for *K*=4 the *K* value is derived from the range using the observed statistical relationship. For *K*=4 to 9 the normal lower bound for the range for each index value is used. This not only avoids the clear misfit shown in the plot when *K*>5, but mimics the normal derivation process of ignoring the Sq diurnal variation when the geomagnetic field is active. When a definitive value of *K* is unavailable, the accuracy of the *K* estimation method is the limiting factor. It has been found that the logarithmic regression relationship is better in some 3-hour periods than in others. Errors can therefore be minimised in the final $ap_{est}$ values by using as varied a longitudinal range as possible. This of course is limited by the fact that the network of observatories for the definitive index is not an even global distribution.

## 4. ALGORITHM PERFORMANCE

A review of how well the 3-hourly $ap_{est}$ correspond to the definitive *ap* has been carried out. All data from 1997 to 2000 have been compared for each 3-hour period. The result from the regression analysis for each is shown in Fig 3.

The plots show that in all UT periods the $ap_{est}$ values are well correlated with definitive *ap*. Some correlations are slightly poorer than others, which is related to the longitudinal coverage of observatories used not exactly matching that of those used for derivation of definitive *ap* and to the longitudinal dependence of the $K_{est}$ calculations discussed in section 3.

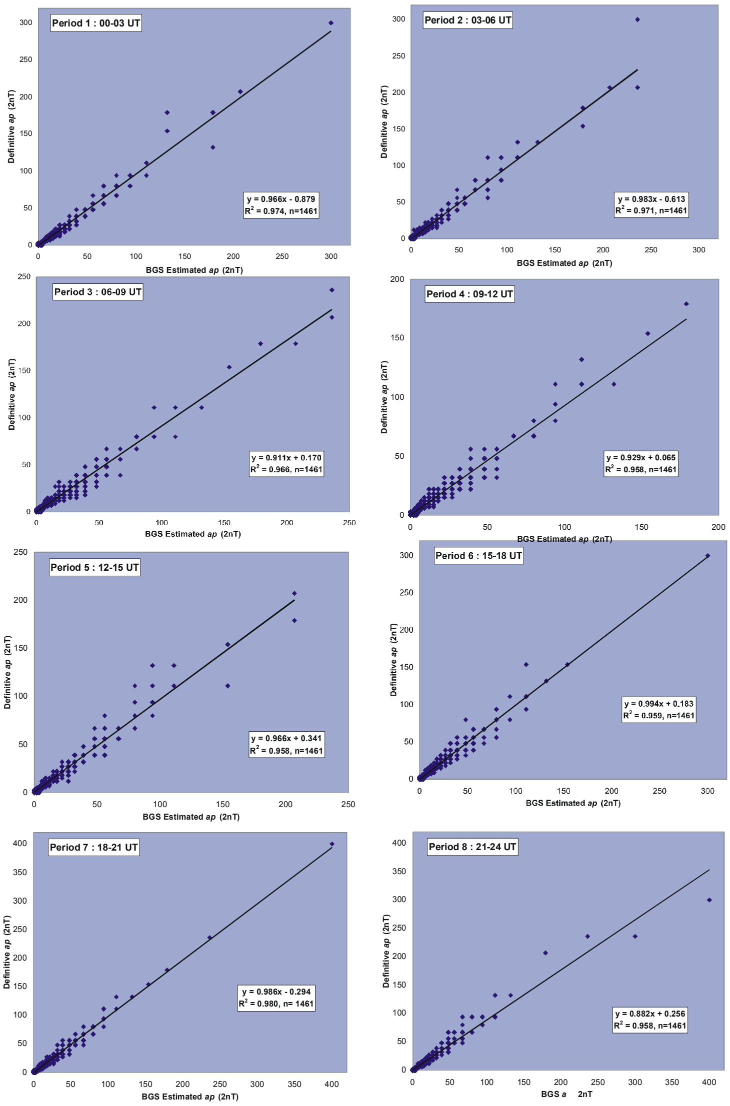


**Fig. 3 Correlation between 3-hourly $ap_{est}$ and *ap* in each UT period.**

Similar estimated planetary indices (3-hourly *Kp* and daily *Ap*) are available in near real time from the Space Environment Center (SEC). These estimates are derived using data from magnetic observatories in North America [2]. An analysis has been carried out on the accuracy of the two estimates by comparing each against the definitive *Ap* for the period 1997 to 2000. In the regression analysis shown in Fig 4 only values of *Ap* ≥ 40 are shown. The SEC *Ap* used in this analysis are the values that were made available by 02:45 UT. The BGS estimates have been derived retrospectively using data that are most likely to have been available at this same time. These results are therefore not conclusive. The SEC values were true real-time and any real-time data retrieval/processing problems that may have occurred are not included in the derivation of the BGS values.

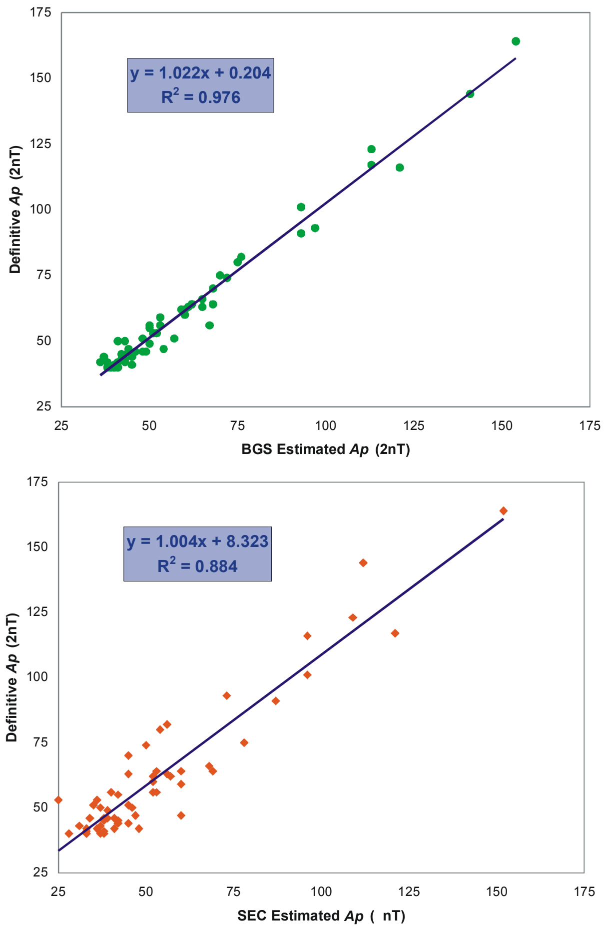


**Fig. 4 Correlations between: BGS $Ap_{est}$ and definitive *Ap* (top); and SEC *Ap* and definitive *Ap* (bottom); for all days with Ap ≥ 40nT in 1997 to 2000.**

Fig 4 shows that $Ap_{est}$ correlates very well ($R^2$ = 0.98) with the definitive values. To confirm this result further analysis is required after the algorithm has been in real time operation for longer and sufficient operational data are available. SEC estimated values also compare well with definitive *Ap*, although the correlation (0.88) is less significant.

A further comparison of these data has been carried out by calculating the residual values between the estimated and definitive *Ap* for all days in 1997 to 2000. These are plotted in Fig 5.

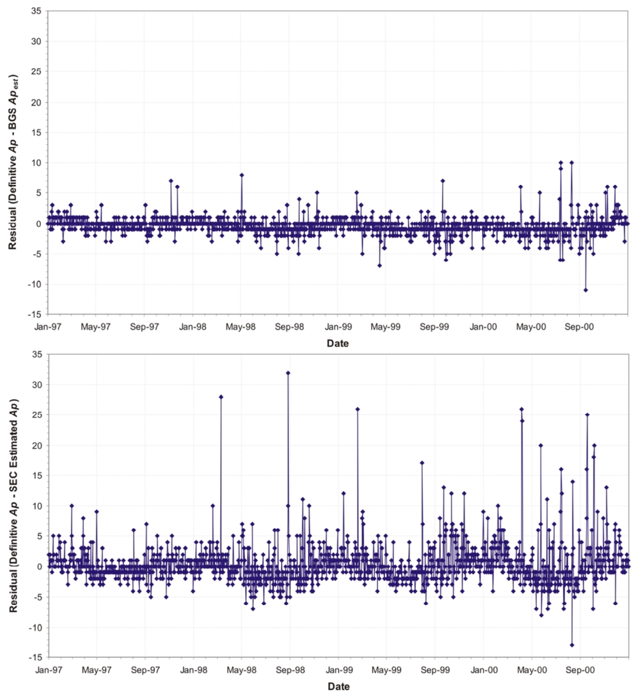


**Fig. 5 Residuals between: BGS $Ap_{est}$ and definitive *Ap* (top); and SEC *Ap* and definitive *Ap* (bottom) for all days in 1997 to 2000**

These provide further evidence of a good agreement between all of the estimated and definitive values. The BGS residuals (top) show no clear bias and are rarely greater than ±5 nT. The SEC residuals are noticeably larger in general, with a bias towards positive values, indicating a tendency to underestimate *Ap*. The SEC residuals also exhibit an annual variation, which is related to the limited longitudinal distribution of the magnetic observatories used. A similar, but much smaller variation is also noticeable in the BGS residuals. This suggests that further improvements are possible.

## 5. CONCLUSIONS AND RECOMMENDATIONS

The benefit of having a wide global coverage of data, when producing a global index has been shown.

An example of the real time display available on-line is shown in Fig 6. This can be found at www.geomag.bgs.ac.uk/gifs/apindex. This page is updated hourly.

These real time values are currently used by BGS staff when forecasting geomagnetic activity levels in the short-term. The noon-noon averaged values are used to give a better representation of global activity levels during local night time in the UK. Forecasting performance is also better tracked by using these data.

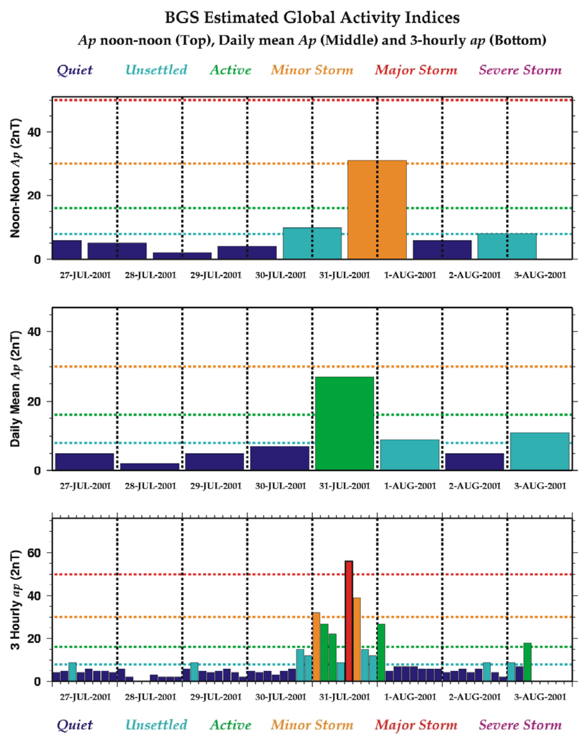


**Fig. 6 BGS $Ap_{est}$ (noon-noon), $Ap_{est}$ and 3-hour $ap_{est}$**

The two most important considerations for $Ap_{est}$ to be of use in Space Weather programs are its timeliness and its accuracy. Currently, 3-hourly $ap_{est}$ and daily $Ap_{est}$ are made available by BGS in real time and are continuously updated. Any improvement on this would mean the values would be predictions, not estimates. Improvements to the accuracy of the estimates could be made by:

(i) changing the method of $K$ derivation to match as far as possible that used at each observatory; and
(ii) including all of the observatories that are used in the definitive $Ap$ calculations.

The requirement for real time indices has increased significantly in recent years resulting in an increase in the number of algorithms for estimating indices and an increase in the number of organisations involved in this work. In the main, algorithms are developed initially for the use of the developers themselves, but demand is such that good estimates are inevitably circulated. This could lead to unnecessary confusion in the future. One solution would be for the organisation responsible for the definitive index production to also take on the responsibility for production and delivery of real time estimates of the same index.

## 6. ACKNOWLEDGEMENTS

BGS would like to thank the following data providers: The Geological Survey of Canada, Natural Resources of Canada; Wingst Observatory, GeoForschungsZentrum, Potsdam; and Canberra Observatory, Australian Geological Survey Organisation. Data from these organisations are used to calculate the estimated indices. In addition, for the supply of information and indices used in the evaluation of the algorithm, BGS also acknowledges the Space Environment Center, Boulder, CO, National Oceanic and Atmospheric Administration, US Dept. of Commerce, and GeoForschungsZentrum, Potsdam, Germany.

This paper is published by permission of the Director, British Geological Survey (NERC).

## 7. REFERENCES

1. Bartels, J., The standardised index, Ks, and the planetary index , Kp, *IATME Bull. 12b*, 97, IUGG Pub. Office, Paris, 1949.

2. Space Environment Center World Wide Web pages, http://www.sec.noaa.gov/rt_plots/kp_3d.html