

The geomagnetic indices: derivation, meaning, and availability

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1. INTRODUCTION

Geomagnetic indices constitute data series aiming at describing at a planetary scale the magnetic activity or some of its components. The data series are homogeneous since 1868 for *aa*, 1932 for *Kp*, 1957 for *Dst* and 1959 for *am*. For a complete description of geomagnetic indices, the reader can refer to the AGU monograph prepared by Mayaud [*Derivation, meaning and use of geomagnetic indices, Geophysical Monograph 22*, 1980] which is still a basic reference for this, or to more recent papers such as Rangarajan [*in Geomagnetism*, vol. 3, 1989] and Berthelier [*STPW-4 proceedings*, 3, 3, 1993] for general reviews, Menvielle and Berthelier [*Reviews Geophys.*, 29, 415, 1991] about *K*-derived indices (*aa*, *am*, *Kp* and *Kp*-related: *ap*, *Cp*, *C9*), and Sugiura and Kamei [*IAGA Bulletin 40*, 1991] for the derivation of *Dst*. *IAGA Bulletin 32* series also contain short but precise definitions of geomagnetic indices and remarkable events acknowledged by the International Association of Geomagnetism and Aeronomy (I.A.G.A.).

As a result of their unique temporal and spatial coverage, these remarkable data series allow for instance statistical studies over long time periods (more than 125 years in the cases of *aa* and *ssc*) of the solar wind - magnetosphere coupling. It is then possible to characterise the physical processes driving the coupling, and its dependence on solar wind parameters [Legrand and Simon, *Annales Geophysicae*, 7, 565, 1989; Simon and Legrand, *Annales Geophysicae*, 7, 579, 1989; La Sayette and Berthelier, *J. Geophys. Res.*, 101, 10 653, 1996]. Because they provide a continuous monitoring of the magnetic signatures of processes taking place in the ionosphere and magnetosphere, geomagnetic indices are basic data in the development of 'Space weather' research [see e.g., *STPW Proceedings*].

The International Service of Geomagnetic Indices (I.S.G.I.) is in charge of the elaboration and dissemination of geomagnetic indices with data provided by geomagnetic observatories.

2. DATA ACQUISITION AND PROCESSING

2.1 Definitive, provisional, quick look, and estimated values

In the past, data were made available by the observatories as hard copy magnetograms or data sheets. Because many months was necessary to get all the definitive data, provisional values were computed in order to circulate the indices within reasonable delays. They are still computed and circulated. Produced using the data circulated by the observatories within a delay of a few weeks, they aim at providing estimates of the definitive values of the indices. The provisional data series have similar statistical properties as the definitive ones.

The possibility of dissemination of data through electronic network opened a new era. The I.S.G.I. Publication Office (for *K*-derived planetary indices) and the WDC-C2 for Geomagnetism (for *Dst* and *AE* indices) started routinely preparing and circulating quick-look values of geomagnetic indices within delays of the order of a few days. As it is the case for the provisional values, the quick look values aim at providing estimates of the definitive values, and the quick look data series have similar statistical properties as the definitive ones. The confidence interval on each individual estimate is however significantly larger for the quick look values than for the provisional ones.

Institutes which are not part of I.S.G.I. may however easily derive and circulate preliminary values of geomagnetic indices, for instance in response to strong requests to have preliminary values of geomagnetic indices available on line within very short delays. This would be confusing, and would result in a dramatic loss of quality of geomagnetic indices. During its VIII Scientific Assembly (Uppsala, 1997),

the International Association of Geomagnetism and Aeronomy adopted a resolution which recommend geomagnetic indices designed to provide quasi-real time estimates of existing I.A.G.A. indices to be named by adding *est* to the name of the index (e.g. *Kpest* for *Kp* estimates).

2.2 Derivation schemes of IAGA geomagnetic indices

The derivation processes of IAGA geomagnetic indices are summarised in Table 1, and the map of the used observatory networks is given in Figure 1. Let us briefly describe the differences between the data acquisition and processing used for deriving quick look, provisional, and definitive values of geomagnetic indices.

Figure 1.

Geomagnetic world map on which are indicated the positions of stations belonging to the different networks used in deriving geomagnetic indices: ▲ for AE, ● for Dst, + for Kp, ○ for am, and ⊕ for stations belonging to both Kp and am networks. A solid line indicates the position of the dip equator. The average extension of the auroral zone is sketched by the shaded area, that of the subauroral region by the shaded area [from Berthelier, STPW-4 Proceedings, 3, 3, 1993]

2.2.1 AE index

The *AE* index is now being made available in three steps. The index in the first of these three steps is a near real-time *AE* index, or a quick-look *AE* index, which is made available on line (at the WDC-C2 WWW homepage) with a 12 hours delay. The index is derived on an ‘available data’ basis, and is updated on a daily basis as the missing data are filled. Therefore the derivation of the quick-look *AE* index is an ‘evolving’ process, and a due caution is required in using this index, which is primarily meant for uses for diagnostic purposes and not for scientific analyses. The quick-look *AE* index is plotted on WWW in colour to indicate the number of observatories that are contributing data to each minute. The maximum number of observatories that can contribute data for the quick-look *AE* is 8 at the present time. It is worth noting that no quality check is made on the data used for the quick-look *AE* index. The *AE* index in the second step is a provisional *AE* index derived (and published in a Prompt Report) often responding to demands by various projects. The *AE* index derived by the third step is the final *AE* index in the form familiar to the scientific community.

2.2.2 Dst index

Similarly, the *Equatorial Dst* index (*Dst*) is now prepared and issued in three steps. In the first step, a near real-time *Dst*, or quick-look *Dst*, is derived using data from any number of observatories of the five designated *Dst* observatories (the four observatories shown in Figure 1 plus Alibag), beginning with a 12-hour delay and updated on a daily basis. As in the case of the quick-look *AE* index, no quality check is made on the data used for the quick-look *Dst* index. Therefore it is recommended that the quick-look *Dst* index is used only for diagnostic purposes; it should not be used for scientific analyses. The second stage product is the provisional *Dst* index which is now being made available on a monthly basis with approximately 2 months delay. Beginning January 1997 the provisional *Dst* index is derived using data from 5 observatories including Alibag. The *Dst* index derived by the third step is the final *Dst* index published annually, normally with several months delay.

Table 1: *Derivation processes of geomagnetic indices [from Berthelier, STPW-4 Proceedings, 3, 3, 1993].*

2.2.3 *K*-derived planetary indices

The *K*-derived planetary indices (*am*, *an*, *as*, *aa*, and *Kp*; see Table 1) were traditionally computed on a monthly basis with *K*-indices hand scaled on analogue magnetograms and provided as hard copies by the observatories. Provisional values were thus circulated with a delay of a few weeks after the end of the month of observation. Definitive values were computed once definitive *K* values made available by all the observatories. Provisional and definitive values are still computed with the *K* values provided by the observatories. Provisional values are circulated on a monthly basis with a few weeks delay for *am*, *an*, and *as*, twice a month with a few weeks delay for *Ap*, and on a weekly basis with a few days delay for *aa*.

Quick look values are computed with provisional *K* values computer derived from digital minute values. A software was then developed at the I.S.G.I. Publication Office. It gets automatically on a daily basis digital minute values from geomagnetic observatories through electronic data transfer procedures, and computes *K* indices using the FMI method [see, for a review, Menvielle et al., *Geophys. J. Int.*, **123**, 866, 1995]. The quick-look values of planetary indices are then computed and circulated once data availability makes it possible. Quick-look values of *K*-derived planetary indices are then made available on the I.S.G.I. www homepage, with a nominal time delay of a few days. As it is the case for *AE* and *Dst* indices, the *am* and *Km* quick-look indices are derived on an 'available data' basis, and a due caution is required in using them.

3. DATA DISSEMINATION:

3.1 On-line services

The I.S.G.I. Publication Office, the World Data Centre C2 for Geomagnetism (Kyoto University, Japan), and the GeoForschungsZentrum Potsdam (Germany) have developed their www homepage:

- The I.S.G.I. www homepage (<http://tango.cetp.ipsl.fr/~isgi/homepag1.htm>) is developed in the frame of the C.E.T.P. homepage, with mirror link with each I.S.G.I. Collaborating Institutes www homepage. It makes possible to have easily access to descriptions of I.A.G.A. indices, and to all the available data;
- The World Data Centre C2 for Geomagnetism www homepage (<http://swdcdb.kugi.kyoto-u.ac.jp/>) makes available the *Dst* and *AE* data series, including the quick look values.
- The GFZ Potsdam www homepage (http://www.gfz-potsdam.de/pb2/pb23/gm/kp_index/) makes available the whole *Kp* series, as well as the derived indices and the quietest and most disturbed days of every month.

3.2 Printed Bulletins

In parallel with the development of the on-line facilities described in the previous section, the I.S.G.I. Publication Office and the I.S.G.I. Collaborating Institutes continue to issue printed bulletins. All the printed bulletins are available on request.

The I.S.G.I. Publication Office circulates a *monthly bulletin* contains the provisional values of planetary magnetic indices (*am*, *aa*, *Kp*, and *Dst*) and the list of the quiet magnetic days of the month. It is normally sent six to eight weeks after the end of the current month. It also publish *the yearly IAGA Bulletin 32 series*, which contain the definitive values of the I.A.G.A. indices.

The Analysis Centre for Geomagnetism and Spacemagnetism, Kyoto University, publishes and distributes the provisional *Dst* index on a monthly basis, the provisional *AE* index in Prompt Reports, and the final *AE* index in Data Books.

The *Kp* and *Kp*-related geomagnetic indices are distributed on tables edited half-monthly. The definitive values of these indices are circulated on monthly tables, together with musical diagrams of *Kp*, semi graphic tables of *C9*, and lists of the quietest and most disturbed days of the month.

The provisional values of geomagnetic indices are also published in the *Solar Geophysical Data* NOAA/NGDC reports, and in *Journal of Geophysical Research* (Editor: H. Coffey).

