

# THE CONTRIBUTION OF A GEOPHYSICAL DATA SERVICE: THE INTERNATIONAL SERVICE OF GEOMAGNETIC INDICES

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## ABSTRACT

*Geomagnetic indices are basic data in Solar-Terrestrial physics and in operational Space Weather activities. The International Service of Geomagnetic Indices (ISGI) is in charge of the derivation and dissemination of the geomagnetic indices that are acknowledged by the International Association of Geomagnetism and Aeronomy (IAGA, an IUGG association). Institutes that are not part of ISGI started early in the Internet age to circulate on-line preliminary values of geomagnetic indices. In the absence of quality stamping, this resulted in a very confusing situation. The ISGI label was found to be the simplest and the safest way to insure quality stamping of circulated geomagnetic indices.*

**Keywords:** Geomagnetic indices, On-line dissemination, Real-time, ISGI

## 1 INTRODUCTION

Geomagnetic activity corresponds to that part of the transient variations of the geomagnetic field observed at the surface of the Earth, which bears the magnetic signature of currents flowing in the ionized environment of the Earth, the dynamics of which is driven by the solar wind. Since the beginning of systematic geomagnetic field observations more than one hundred years ago, efforts to characterize geomagnetic activity led to the definition of a few geomagnetic indices that are widely used by the scientific community and officially recognized by the International Association of Geomagnetism and Aeronomy (IAGA). These quantities are hereafter referred to as IAGA geomagnetic indices.

Since the dynamics of currents flowing in the ionized environment of the Earth are driven by the solar wind, geomagnetic indices are basic data in Solar-Terrestrial physics, and there is accordingly a need for long homogeneous data series. It is worth being noted that, although geomagnetic indices are thus widely used in magnetospheric physics, as, e.g., indicators of the magnetosphere-ionosphere system activity or input parameters in the models, ignorance of their real physical meaning often leads to using them as black boxes. The International Service of Geomagnetic Indices (ISGI) has the mission to make reference values for the IAGA geomagnetic indices available to the scientific community and to maintain archives of these data series.

Magnetospheric activity may otherwise cause disturbance - which can be severe - in the functioning and behaviour of satellites and space systems: geomagnetic indices are also basic data for operational Space Weather activities, and this requires the shortest possible dissemination delay. Early in the Internet age, many institutions that are not part of ISGI started to derive and disseminate online preliminary values (also called quick-look values) of IAGA geomagnetic indices, without any control by IAGA bodies on the quality of their products. This resulted in a very confusing situation and could have resulted in a dramatic loss of user confidence in the quality of geomagnetic indices made available through the Internet.

ISGI had then to face up to two challenges:

- establish a policy for on-line dissemination of indices;
- ensure a quasi real time on-line dissemination of reliable quick-look values of IAGA geomagnetic indices.

ISGI decided to routinely make available on-line preliminary values for almost all IAGA geomagnetic indices. ISGI also drove discussions in the frame of IAGA. They resulted in an IAGA resolution urging the producers of estimated indices to make clear by a specific label that they are not official IAGA indices. The ISGI label thus appeared to be the simplest and the safest way to ensure the quality stamping of circulated geomagnetic indices, and the ISGI Collaborating Institutes therefore decided to quote their ISGI membership in all their publications and databases. This ISGI contribution is used to illustrate the role that a WDS service could play as a provider of reference values for given quantities and to highlight the need for such reference data services.

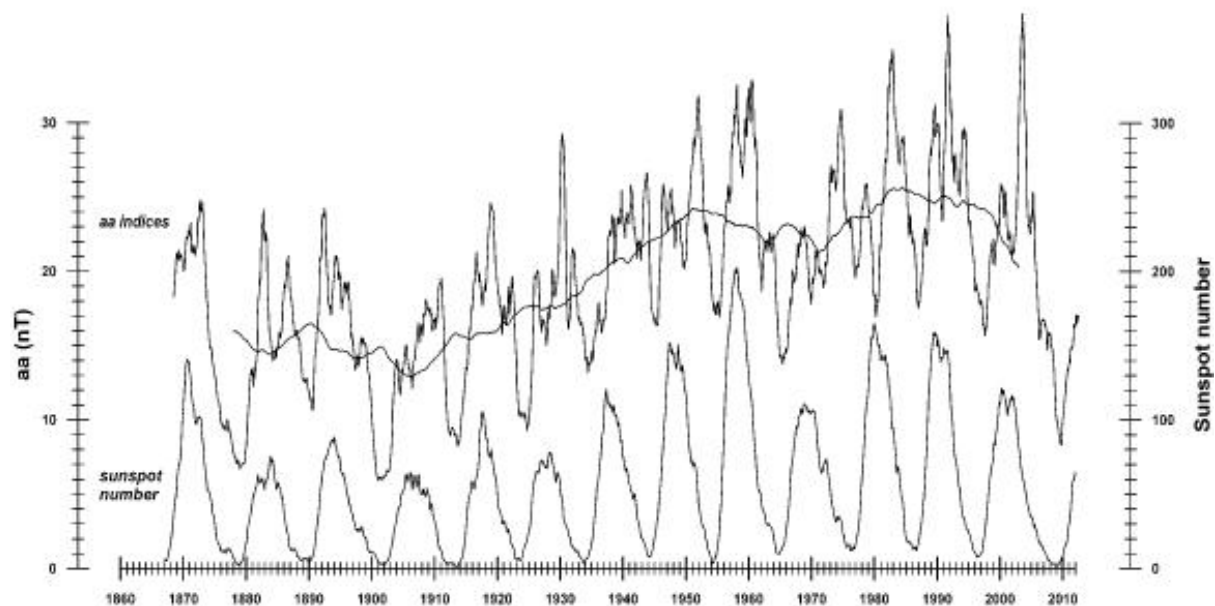
## 2 GEOMAGNETIC INDICES

The Sun emits a variable supersonic plasma flow: the solar wind. The Sun's magnetic field is driven by the solar wind in the interplanetary medium, giving rise to the interplanetary magnetic field. In the vicinity of the Earth, the solar wind is thermalized and flows around the obstacle that constitutes the Earth's magnetic field. This results in compression of the force lines of the geomagnetic field on the day side and stretching of these lines into a long tail on the night side, which gives rise to the magnetospheric cavity.

The solar wind is the energy source of the magnetosphere. The solar wind characteristics directly influence the shape and size of the magnetosphere, the amount of energy that is transferred into the magnetosphere, and how this energy is dissipated. The rapid and wide variations of the solar wind characteristics result in a very dynamic behaviour of the magnetosphere. The transient variations of the geomagnetic field are a signature of the plasma convection inside the magnetosphere and thus of the magnetospheric status that can be observed at the surface of the Earth. The great complexity and the large dynamics of magnetospheric plasma convection result in complex magnetic signatures at the Earth's surface.

The first systematic geomagnetic field observations date from the middle of nineteenth century, and they are currently made at more than two hundred magnetic observatories distributed on five continents. Summarizing quantities that aim to characterize the magnetic activity have recently been introduced to describe in a simple although relevant way the transient magnetic variations at the Earth's surface and their changes with time.

Geomagnetic indices that aim to characterize the magnetic activity at a global scale, the ionospheric auroral electrojets in the auroral zones, and the behaviour of the magnetospheric ring currents as well as the lists of *storm sudden commencements* and of *solar flare effects* are currently recognized as IAGA geomagnetic indices. The longest homogeneous data series are more than 140 years long (they began in 1868), and most geomagnetic indices data series are more than 50 years long. The reader is referred to, e.g., Menvielle and Berthelier (1991), Menvielle et al. (2011), and to the ISGI Internet homepage (<http://isgi.cetp.ipsl.fr>) for a complete description of geomagnetic activity indices.



**Figure 1.** Long-term variations of aa indices (12-month and 20-year running averages; scale on the left) and of sunspot numbers (12-month running averages; scale on the right) from 1868 until 2012. The aa index monitors geomagnetic activity at a planetary level, and the sunspot number monitors the solar activity.

Figure 1 shows the evolution of planetary geomagnetic activity as described by the aa planetary geomagnetic index together with that of the solar activity as described by the Sunspot number. The 11-year solar cycle is clearly depicted by the sunspot number data series. It also modulates the geomagnetic activity although in a more complex way. The geomagnetic activity is at a minimum during the periods of minimum solar activity. Then it increases during the ascending phase of the solar cycle and reaches a maximum during the years where the sunspot number is at a maximum. A secondary maximum of geomagnetic activity is observed during the descending phase of the solar cycle: this secondary maximum corresponds to solar activity related to the onset of the following cycle

(see, e.g., Legrand & Simon, 1991 and references therein). The variations of the 20-years running average of geomagnetic activity show that long-term variations are superimposed on those related to the solar cycle: the average level of activity remained quite low between 1868 and about 1925 while it has been quite high since the beginning of the 1950s. The low activity level observed in 2009-2010 during the last solar minimum may indicate that this high activity period is coming to its end.

Geomagnetic activity indices bear more than 140 years of information on the evolution during the solar wind's (see, e.g., Rouillard et al., 2007) coupling with the magnetosphere and on the state of the ionized environment of the Earth (see, e.g., Ouattara et al., 2009). Geomagnetic indices have many other applications. For instance, they are unique tools for the separation of magnetic variations according to whether their source is located in the ionized environment of the Earth or inside the planet (see, e.g., Thomson & Lesur, 2007)

Although geomagnetic indices of magnetic activity are fundamental data in solar-terrestrial physics and space weather, they are most often used as "black boxes". This situation, which results from the very complex morphology of geomagnetic activity, implies the existence of an organization, the International Service of Geomagnetic Indices (ISGI), with the mission to calculate, to make available to the scientific community, and to maintain archives of reference values for the IAGA geomagnetic indices and to take advantage of its expertise in this area to serve the scientific community

### 3 THE INTERNATIONAL SERVICE OF GEOMAGNETIC INDICES

#### 3.1 History and current organization

Founded in 1906 as the Central Bureau of Terrestrial Magnetism for the calculation of the "*International Magnetic Character*", it was hosted by the *Koninklijk Nederlands Instituut Meteorologisch* (De Bilt, The Netherlands) until 1987. At that date, it was transferred to France, where it was hosted by the *Institut de Physique du Globe de Paris* until 1990, then by the *Centre d'études des Environnements Terrestre et Planétaires (CETP, Saint Maur)* until the date (2009) when *CETP* was replaced by *LATMOS (Laboratoire Atmosphères, Milieux, Observations Spatiales, Guyancourt, France)*. ISGI headquarters are currently hosted by *LATMOS*.

ISGI is a kind of network that brings together the activities of the four institutions – called ISGI Collaborating Institutes – that are responsible for calculating and disseminating IAGA Geomagnetic Indices: the *LATMOS*, the *Data Analysis Center for Geomagnetism and Space Magnetism* (Kyoto, Japan), the *GeoForschungZentrum Potsdam* (GFZ, Potsdam, Germany), and the *Observatori de l'Ebre* (Roquetes, Spain). ISGI is under the supervision of the Union of Geodesy and Geophysics (IUGG). ISGI activities are supervised by a scientific board appointed by the IAGA Executive Committee. The Council meets each second year during the General and Scientific IAGA Assemblies.

ISGI used to be a service of FAGS (Federation of Astronomical and Geophysical Data Services); it was accepted for membership in the World Data System (WDS) in August 2011.

#### 3.2 Current ISGI activities

The primary responsibility of ISGI is the calculation, distribution, and archiving of reference values for IAGA geomagnetic indices. As already mentioned, each ISGI Collaborating Institute is responsible for calculating, disseminating, and archiving one or several IAGA Geomagnetic Indices. ISGI headquarters are, as such, responsible for:

- maintaining and updating the Internet ISGI homepage. This site is designed as a portal to all sites of collaborating institutes. Together with the these sites, it provides reference values of IAGA geomagnetic indices;
- promoting the participation of ISGI to networks. This aims to facilitate user access to all necessary data in the physics of solar-terrestrial relations;
- publishing and distributing a Monthly Bulletin that disseminates provisional values of IAGA geomagnetic indices.

ISGI expertise is widely recognized by academic (Solar Terrestrial Physics) and operational (Space Weather) communities. ISGI has thus a role of expertise and advice regarding the characterization of geomagnetic activity by mean of indices. In the frame of IAGA, ISGI is responsible, through the IAGA ad-hoc committee on geomagnetic indices currently chaired by the ISGI Director, for making proposals for all matters relating to geomagnetic indices: dissemination policy, definition, and endorsement of new indices.

### 3.3 A noteworthy ISGI contribution

During the last decades, Internet and computer developments resulted in a revolution in data handling, and – as a consequence of Internet facilities – users strongly required having preliminary values of geomagnetic indices available on line with delays as short as possible.

Early in the Internet age, many institutions that are not part of ISGI started to derive and disseminate online preliminary values of IAGA geomagnetic indices, using derivation schemes different from those endorsed by IAGA. In addition, the used derivation schemes were generally not clearly published, and they varied from one institution to another. It was thus common to find differing estimated preliminary values for a given IAGA geomagnetic index during a given time interval. Such a situation was very confusing for the users since there was no longer clear quality stamping. From the user's point of view, the crucial question became: how to be sure of the quality of the geomagnetic indices that I find on Internet? This could have resulted in a dramatic loss of confidence of users in the quality of geomagnetic indices made available through Internet. Such a loss of confidence would have in turn challenged the possibility to continue the production of high quality long term data series. This made clear the necessity for a policy for on-line dissemination of indices and for quasi real time on-line dissemination of reliable preliminary values of IAGA geomagnetic indices.

ISGI Collaborating Institutes then decided to routinely make available on-line state of the art preliminary values (a few hours to two days delay for all IAGA geomagnetic indices since 1996 for most of them; a 30 min delay since 2004 for the aa index). In parallel, ISGI led discussions within IAGA. IAGA resolved that the reference values of geomagnetic indices are those produced by the ISGI Collaborating Institutes and that they must be posted first at the ISGI and ISGI Collaborating Institutes homepages. IAGA also made a resolution urging the “producers of the estimated indices to clearly label them with ”est” at the end of each index name to distinguish them from the official IAGA indices” (Resolution 5, IAGA News 38 1998, p. 42). This policy succeeded both in fitting with this new environment and in preserving the historical heritage, namely the high quality, homogeneous long term data series. This policy is still in force.

## 4 CONCLUSION

The evolution in the geomagnetic indices activity dissemination during this transition period makes clear the need:

- (i) **for reference(s) scientific organization(s) – IAGA in the present case – in charge of the definition of the policy dissemination of the “added value products” (geomagnetic indices in the present case) and of the labelling of the reference places, and**
- (ii) **for reference places where users are sure to find reliable “added value products” – ISGI and ISGI Collaborating Institutes in the present case.**

Finally, it is important to note that success in defining a new policy for on-line dissemination of IAGA geomagnetic indices was made possible by the deep involvement of the producers in related research activities: their understanding of user needs helped them to propose effective solutions tailored to these needs.

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