

# SUPERMAG: THE GLOBAL GROUND BASED MAGNETOMETER INITIATIVE

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## 1. Executive Summary

For decades ground based magnetometers have proven to be the workhorse of the magnetosphere-ionosphere (M-I) physics community and their importance is indisputable. The SuperMAG initiative (Gjerloev, 2009) is a collaboration between virtually all the worlds magnetometers thereby providing a powerful tool for continuous and global monitoring of the ionospheric and magnetospheric currents. In this paper we urge the Decadal Report Committee to acknowledge the strength of this data set and the need for global collaborations such as SuperMAG since they:

- a) provide a cost effective way to maximize the utilization of this comprehensive data set;
- b) enable studies of the structure and dynamics of the global ionospheric and magnetospheric current systems;
- c) can support current and future missions (e.g. the upcoming RBSP mission).

While investigations based on single stations and/or chains have led to great discoveries the next logical step is to combine all stations into a truly global network allowing us to further advance our understanding of the M-I system.

## 2. What is SuperMAG

SuperMAG is a worldwide collaboration of organizations and national agencies (Table 1) that currently operate more than 300 ground-based magnetometers. It provides easy access to validated measurements of magnetic field perturbations in the same coordinate system, with identical time resolution and a common baseline removal approach. Studies of the variations caused by electric currents flowing in the ionosphere and magnetosphere require a subtraction of the dominant and slowly varying Earth main field. Hence, both absolute and variometer data (data with unknown baselines) are included in SuperMAG.

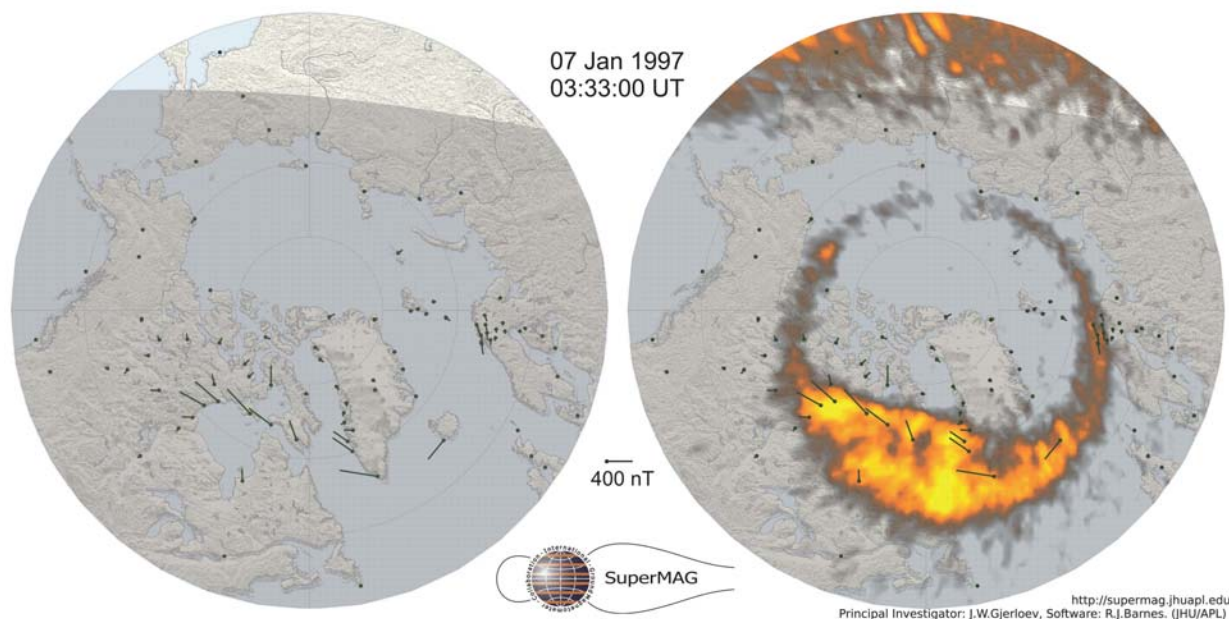
SuperMAG utilizes vector measurements of the magnetic field, which represent a variety of file formats, temporal resolutions, units, and coordinate systems and are provided with or without baseline subtracted. SuperMAG resamples the raw data to 1-minute temporal resolution and converts all units into nanoteslas (nT). Artifacts and errors are removed by automated as well as manual correction routines. Data are then rotated into a local geomagnetic coordinate system and finally the baseline is subtracted by an automated technique.

## 3. Why SuperMAG

Before SuperMAG, global or even local studies required painstaking and labor-intensive data-handling, which effectively limited research. Analysts faced several inherent complications: confusing or even unknown coordinate systems, a multitude of data artifacts and errors, unknown baselines, and even difficulties obtaining data. These problems have resulted in a serious underutilization of data from magnetometers. With the introduction of SuperMAG, researchers, teachers, students and the public are provided with a practical and time effective means to study magnetic data (Figure 1).

| Chains / Agencies / Organizations |              |
|-----------------------------------|--------------|
| Intermagnet                       | Penguin      |
| Greenland                         | Izmiran      |
| Carisma                           | Kyoto WDC    |
| Image                             | Autumn       |
| SAMBA                             | ICESTAR      |
| SAMNET                            | Athabasca U. |
| MEASURE                           | BAS          |
| MACCS                             | RapidMAG     |
| 210 Chain                         | GIMA         |
| AARI                              | USGS         |
| DTU Space                         | DMI          |

**Table 1.** Current members of the constantly expanding SuperMAG family.



**Figure 1.** Ground based magnetometers provides global and continuous monitoring of the currents flowing in the ionosphere and magnetosphere. Powerful user-friendly data products are now available.

Beyond the research community, SuperMAG targets the general public—in particular teachers and students. This puts additional requirements on the site because these groups cannot be assumed to have extensive knowledge of either the dataset or the underlying physics. Consequently, the SuperMAG's Web Site is based on an intuitive interface with easily accessible tools and products.

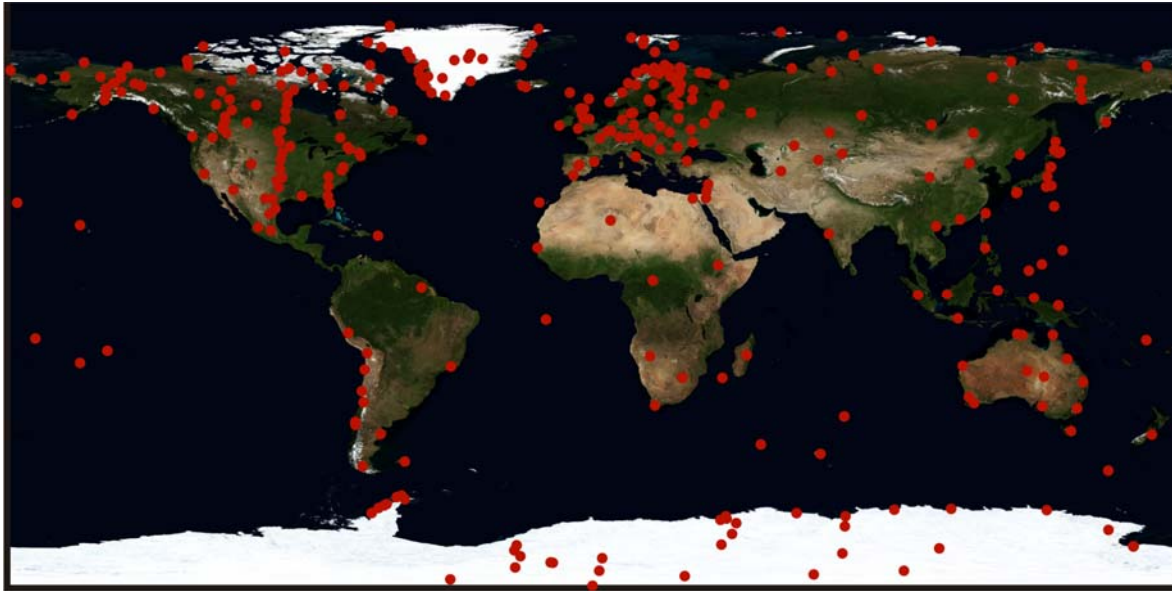
The recent eGY provided an argument for the philosophy on which SuperMAG is based. The eGY declaration stated “*providing ready and open access to the vast and growing collections of cross-disciplinary digital information is the key to understanding and responding to complex Earth system phenomena that influence human survival*” (Baker et al., 2008). Although, humankind is likely to survive without magnetic field data, the philosophy behind the SuperMAG initiative certainly is in line with eGY's focus on data availability, access, and utilization.

Virtual observatories provide access to a wide variety of data acquired in the solar wind, in the magnetosphere, and on the ground. However, one of the fundamental assumptions of virtual observatories is that data and data description are available online. Most often this is not the case for ground based magnetometer data and as a consequence SuperMAG operates as a data repository obtaining the raw data from collaborators and performing all required data handling prior to the inclusion on the web-service.

#### 4. Science Motivation

Ground magnetometers have three observational strengths that make their application in monitoring and understanding the M-I system particularly useful:

- a) Continuous uninterrupted monitoring;
- b) Nearly global coverage (see Figure 2);
- c) Decades of observations.



*Figure 2. The worlds ground based magnetometer community provides continuous and global monitoring.*

For more than a century ground magnetometers have been the work-horse of M-I research. Popular indices such as Kp, AE and Dst are all derived from ground based magnetometer measurements and within the last two decades the use of ground magnetometer observations from sites worldwide has found application in estimating global scale electrodynamics by means of assimilation techniques (e.g. Richmond and Kamide 1988; Lu et al., 1996). Magnetometers have played a central role in a long list of published studies for example: the structure and behavior of the auroral electrojets system (e.g. DP2 current system, Nishida, 1971; Gjerloev et al., 2010; substorm growth phase, McPherron, 1970; two-component electrojets system, Kamide and Kokubun, 1996); traveling convection vortices (Lanzerotti et al., 1986; Friis-Christensen et al., 1988; Glassmeier et al., 1989); characteristic response time of the magnetosphere-ionosphere system to relatively discontinuous changes in the IMF (e.g. Murr and Hughes, 2001); and long-term behavior of the current systems (e.g. Kihn and Ridley, 2006; Ridley and Kihn, 2004). The list of discoveries and other scientific advances for which ground based magnetometer data played a key role is very extensive. In fact the above short list of publications and topics is by no means intended to be complete but simply to illustrate the historic success of magnetometers and the fact they continue to serve as an indispensable measurement.

We have no intention of providing an all-inclusive list of research topics and discoveries enabled by ground based magnetometer data but the Decadal Report Committee may find the following list helpful:

- “What are the differences and similarities of the ionospheric currents in the conjugate hemispheres and what is the cause of non-conjugate events?”
- “What is the spatiotemporal behavior of the auroral electrojets system during magnetic storms?”
- “What are the solar cycle variations of the ionospheric current system and its coupling to the magnetosphere?”
- “What is the role of the terminator in the magnetosphere-ionosphere current system?”
- “What storm-time dynamics do physics based models predict well and what do they miss?”
- “What is the spatiotemporal behavior of the equatorial electrojets?”

## 5. Summary

In this brief paper we urge the Decadal Report Committee to acknowledge the need for infrastructure initiatives such as SuperMAG. Ground based magnetometers have been the workhorse of M-I research for decades and combining all stations into a global continuous monitoring system was the logical next step. SuperMAG is truly an excellent example of the saying that “*the whole is greater than the sum of all parts*”. Investigations based on single stations and/or chains have led to great discoveries but further advancing our understanding of the M-I system dynamics and structure hinges on global collaborations.

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