SuperMAG: The Global Ground Magnetometer Initiative

Jesper W Gjerloev
Professor, Dept. of Physics and Technology, University of Bergen, Norway.

This paper was prepared for presentation during the 12th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, August 15-18, 2011.

Abstract

For decades ground based magnetometers have proven to be the workhorse of magnetosphere-ionosphere physics and their importance is indisputable. The data set provided by the ground magnetometer community is truly unique since it provide continuous and nearly global measurement of a fundamental parameter - the ground level magnetic field perturbations.

The SuperMAG initiative (Gjerloev, 2009) provide a fully operational solution to these complications. This is a worldwide collaboration of organizations and national agencies that currently operate more than 300 ground based magnetometers. SuperMAG provides easy access to validated ground magnetic field perturbations in the same coordinate system, identical time resolution and with a common baseline removal approach. The purpose of SuperMAG it to help scientists, teachers, students and the general public have easy access to measurements of the Earth's magnetic field. In addition to a presentation of the initiative itself we discuss results from published studies enabled by SuperMAG.

Introduction

SuperMAG is a worldwide collaboration of organizations and national agencies that currently operate ~300 ground-based magnetometers. 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 resample's the data to 1-minute temporal resolution and converts all units into nano teslas (nT). Artifacts and errors are removed or corrected by automated as well as manual correction routines. Data are then rotated into a local geomagnetic coordinate system, and finally the baseline is determined and subtracted by an automated technique. 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. Before SuperMAG, global or even local studies required painstaking and labor-intensive data handling, which effectively limited or even prevented research projects. 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 the researcher is offered a unique opportunity to easily obtain data and publication quality plots that allow them to address the global spatiotemporal behavior of the global ionospheric electric current system and its coupling to the magnetosphere.

Method

SuperMAG currently includes data from 1997-2010 and is funded by National Science Foundation (NSF) and NASA. In addition to the ground magnetometer data is includes solar wind observations (from the ACE mission) and global auroral imaging (from the Image mission, Polar and DE to be added in near future).

The SuperMAG system is designed to easily scale both as new ground stations are added to the network and when additional data products are developed. SuperMAG is founded on four cornerstones and we provide here a brief introduction to these.

First cornerstone (Memorandum of Understanding): The MoU's are written per request of the individual collaborator as they join the SuperMAG family. Many of these are a first ever.

Second cornerstone (Data Repository): The data repository currently consists of ~2,0 million files (~1,5Tb). Despite the massive amount of data the storage structure was designed to be simple yet flexible enough to be able to ingest data from new collaborators regardless of their data formats. Data are stored locally at the SuperMAG server since many of the collaborators do not provide online access.

Third cornerstone (Data Handling Package): The data handling package consist of tens of thousands of lines of code. It has been finalized and was used to process the 14 years of data currently available on the website.

Fourth cornerstone (Website): The website (http://supermag.jhuapl.edu) is fully operational. The system is comprised of a series of shell scripts that process data as it is ingested into the system. The scripts call a variety of utilities that create additional data products from the raw data and archive them on disk. The web site acts as the principal tool for working with SuperMAG data. Registered users can use the user interface to interactively generate both web based and publication quality PDF plots. As an added and much needed benefit, the registration system incorporates a logging system that allows the usage statistics of individual users to be tracked, providing principal investigators with the feedback needed to justify future funding from their respective supporting agencies. The

service has ~250 registered users (as of April 2011) and provide ~20,000 plots per month with a constant increase in all measures of usage.

SuperMAG is intended to be driven by the needs of the users, aiming first at the requirements of the typical user and we have later expanded by responding to many user requests. As such, several of the plotting options are the result of user request.

Examples

SuperMAG is intended to enable science and thus include supportive observations/datasets such as solar wind observations and auroral images. While the reasoning behind the solar wind data may be obvious the latter may need some additional explanation. Figure 1 shows two polar plots of the ground perturbation vectors, the left with just the set of perturbation magnetic field vectors, and the right with a Polar Visible Imging System (VIS) Earth Camera image of the ultraviolet aurora superposed. Combining these two datasets, as first suggested by Frank et al. [1981] and later quantified by Fujii et al. [1994] and Gjerloev and Hoffman [2000], reveals that ground perturbations are related to the overhead emissions rather than any fixed coordinate system. Combining these different datasets provides a powerful tool for scientists to help unlock the secrets of the dynamic large-scale auroral disturbances.

Results

Ground magnetometers have three observational strengths that make their application in monitoring and understanding the M-I current system particularly useful: 1) Continuous uninterrupted monitoring; 2) Nearly global coverage; 3) Decades of observations. Many studies of have been published but often they have been limited in scope and usually they involve case studies. The main reason for this shortcoming is the inherent problems in obtaining as well as working with the data. SuperMAG provides easy access to a solid observational basis that enable researchers to address fundamental questions regarding the global ionospheric current system.

Currently there are at least 20 papers that are based on observations included in the SuperMAG initiative. We here mention three recent studies.
1) A study of the behavior of the auroral electrojet indices following abrupt southward turnings of the IMF Bz (Gjerloev et al., 2010).
2) An Evaluation of SuperMAG Based AE(100) and the Traditional AE(12) as Substorm Onset Indicators, (Newell and Gjerloev, 2011)
3) Conjugacy and non-conjugacy of the auroral electrojet system (Gjerloev et al., 2011).

Conclusions

SuperMAG is fully operational and currently it provides easy access to 14 years of ground magnetometer data obtained by ~300 stations. The purpose of SuperMAG is to help scientists, teachers, students and the general public have easy access to measurements of the Earth's magnetic field. The initiative has ~250 registered users, provides roughly 20,000 plots per month and ~20 published papers have utilized the service.

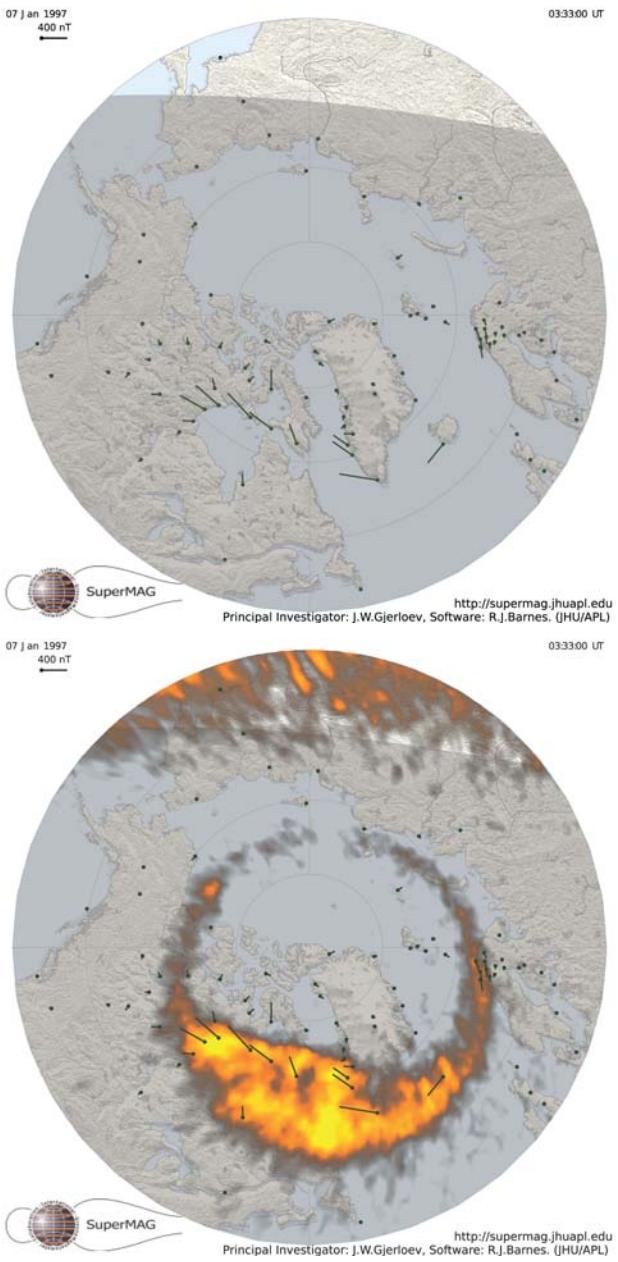

Figure 1. *Top: Ground magnetometers operated by SuperMAG collaborators during the peak of an auroral event known as a classical auroral substorm. The vectors (black lines with starting points at dots) are in units of nanoteslas (nT) and are rotated 90 deg clockwise to indicate the ionospheric equivalent current direction Bottom: With an image from the Polar VIS Earth Camera superposed illustrating the relationship between UV emissions and ground perturbations.*

Acknowledgments

We gratefully acknowledge:

Intermagnet; USGS, Jeffrey J. Love; Danish Meteorological Institute; CARISMA, PI Ian Mann; CANMOS; The S-RAMP Database, PI K. Yumoto and Dr. K. Shiokawa; The SPIDR database; AARI, PI Oleg

Troshichev; The MACCS program, PI M. Engebretson, Geomagnetism Unit of the Geological Survey of Canada; GIMA; MEASURE, UCLA IGPP and Florida Institute of Technology; SAMBA, PI Eftyhia Zesta; 210 Chain, PI K. Yumoto; SAMNET, PI Farideh Honary; The institutes who maintain the IMAGE magnetometer array, PI Eija Tanskanen; PENGUIN; AUTUMN, PI Martin Conners; Greenland magnetometers operated by DTU Space; South Pole and McMurdo Magnetometer, PI's Louis J. Lanzarotti and Alan T. Weatherwax; ICESTAR; RAPIDMAG; PENGUIn; British Artarctic Survey; McMac, PI Dr. Peter Chi; BGS, PI Dr. Susan Macmillan.

References

Gjerloev, J. W., A Global Ground-Based Magnetometer Initiative, EOS, 90, 27, 230-231, 2009.

Gjerloev , J. W., R. A. Hoffman, S. Ohtani, J. Weygand, and R. Barnes, Response of the Auroral Electrojet Indices to Abrupt Southward IMF Turnings, Annales Geophysicae, 28, 1167-1182, 2010.

Newell, P. and J. W. Gjerloev, An Evaluation of SuperMAG Based AE(100) and the Traditional AE(12) as Substorm Onset Indicators, J.Geophys.Res., Submitted, 2011

Gjerloev, J. W., N. Shah, M. Friel, P. Martin, Conjugacy and non-conjugacy of the auroral electrojet system, Annales. Geophysicae, Submitted, 2011.