

INTER-UNIVERSITY UPPER ATMOSPHERE GLOBAL OBSERVATION NETWORK (IUGONET)

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ABSTRACT

An overview of the Inter-university Upper atmosphere Global Observation NETWORK (IUGONET) project is presented with a brief description of the products to be developed. This is a Japanese inter-university research program to build the metadata database for ground-based observations of the upper atmosphere. The project also develops the software to analyze the observational data provided by various universities/institutes. These products will be of great help to researchers in efficiently finding, obtaining, and utilizing various data dispersed across the universities/institutes. This is expected to contribute significantly to the promotion of interdisciplinary research, leading to more a comprehensive understanding of the upper atmosphere.

Keywords: Metadata, Database, Analysis software, Ground-based observation, Upper atmosphere, Solar terrestrial physics, Earth and planetary sciences

1 INTRODUCTION

The Earth's upper atmosphere is considered to be a compound system consisting of the mesosphere, thermosphere, ionosphere, plasmasphere, and magnetosphere. Although the different atmospheric layers are often referred to as independent regions, they are closely coupled by exchange of material, momentum, and energy through complicated physical processes. While various internal physical processes exist, the upper atmosphere is strongly influenced by external factors, for example, energy input from the Sun through ultraviolet radiation, solar wind, etc. and momentum injection from the stratosphere and troposphere through propagating atmospheric waves. What we observe in the upper atmosphere is, therefore, the result of mixing such complicated processes.

To investigate the mechanisms of long-term variations of the upper atmosphere, multidisciplinary research is required with combinations of various types of ground-based observations, such as temperature, neutral wind, aurora, geomagnetic field, solar ultraviolet radiation, etc., made at different locations and altitudes. The data or

databases of such observations generally have been maintained and made available to the community by each research organization/group that conducts the observations. Although these data or databases have been well used within certain research communities closely related to the observational activity, they are often difficult to be used by researchers in other research areas due to lack of information on the data. It is also the case that data acquired by some campaign observations have been used by only a very few researchers who were involved in the campaigns, and the availability of the data has not been well known by other researchers.

A six-year research project, Inter-university Upper atmosphere Global Observation NETWORK (IUGONET, <http://www.iugonet.org/>), was begun in 2009 to overcome such problems in data use by the National Institute of Polar Research (Space and Upper Atmospheric Science Group), Nagoya University (Solar-Terrestrial Environment Laboratory), Kyoto University (Research Institute for Sustainable Humanosphere, Data Analysis Center for Geomagnetism and Space Magnetism, Kwasan and Hida Observatories), Kyushu University (Space Environment Research Center), and Tohoku University (Planetary Plasma and Atmospheric Research Center). These universities and research institutes (hereinafter, IUGONET institutes) have been leading ground-based observations of the upper atmosphere and the Sun in Japan. Figure 1 shows where and how the IUGONET institutes have been obtaining their data. The data come from observations made at various locations and altitude layers by using various instruments, such as a magnetometer, airglow imager, radio telescope, solar telescope, atmospheric radar and lidar, etc. They archive a huge amount of and various kinds of observational data, including long-term data obtained over the decades. The IUGONET institutes have formulated a cooperative framework to build a database system for the metadata of those observational data. The metadata describe properties of the data, such as observation location and period, type of instrument, data format, and contact information. By sharing such information about the data through the metadata database, the IUGONET project intends to facilitate distribution of the observational data among researchers of various disciplines.

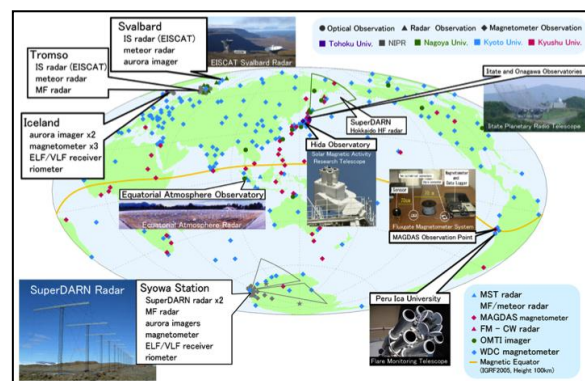


Figure 1. World map showing major observation sites from which the IUGONET institutes have been collecting data

The IUGONET project also develops data analysis software for those various observational data. It is usually difficult for researchers to use data in an area outside of their expertise, especially due to differences of data archiving formats. There have been many kinds of data archiving formats used in the long history of ground-based observations. This might raise another difficulty in promoting the use of data and multidisciplinary research. To standardize data archiving formats, however, would require too much work. Instead, the IUGONET project plans to provide researchers with an integrated data analysis software package so that the users can readily handle various data without having to deal with their different archiving formats.

An overview of the IUGONET project is described first in this article, followed by a brief introduction to the products to be developed in the project.

2 ORGANIZATION AND TIMELINE OF THE IUGONET PROJECT

The project organization chart is shown in Figure 2. The IUGONET project first set up a cooperative framework, called a virtual information center for upper atmospheric science, by introducing a remote conference system, electronic mailing list, wiki, etc. to share and exchange any information, opinions, and ideas regarding the project's activities among the IUGONET institutes. Each IUGONET institute newly employed one or two researchers and/or technical assistants dedicated to the project who organized a core development team. The development team members frequently meet virtually online and discuss many topics of the project in the virtual information center even though they are located at some distance from each other.

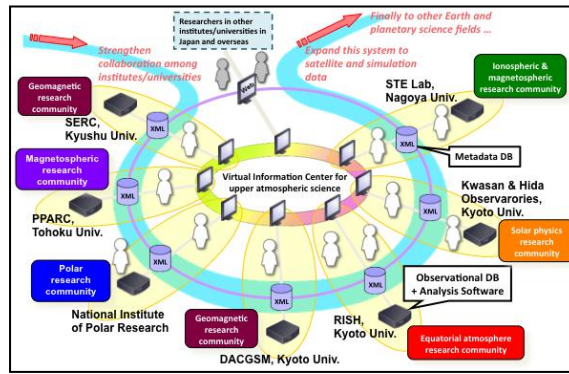


Figure 2. Schematic view of the virtual information center of the IUGONET project

On the basis of the discussions and group work in the virtual information center, the IUGONET development team creates metadata of various kinds of observational data archived at their institutes. A metadata repository is prepared at each institute, as shown with containers labeled “XML”, and connected to the other repositories through the Internet so that all the metadata can be shared. In addition, analysis software to handle these observational data is being developed. Meanwhile, researchers at the IUGONET institutes gather in the virtual information center and discuss new collaborative works using their multidisciplinary data with the developed products. Note that these products mentioned above are made available not only to researchers within the IUGONET project but also to anyone who is interested in the observational data.

Although the IUGONET project focuses on ground-based observational data of the upper atmosphere, the project plans to realize the exchange of metadata or interoperability among similar e-infrastructures for the satellite-borne and computer simulation data of the upper atmosphere. It also aims at further development of its products for future collaborations with a wide variety of disciplines in the Earth and planetary sciences.

Figure 3 shows the project timeline. The main development items of the IUGONET project are designing the common metadata format to describe the ground-based observational data, building the metadata database system to archive the metadata, and producing the analysis software to help users handle those observational data. After the setup of the virtual information center in FY2009, the project began with designing the IUGONET common metadata format and the specification of the metadata database system and data analysis software. According to the specification, these products were developed in the second fiscal year. In the project plan, IUGONET products were made available to the public in the third fiscal year. In the latter half of the project period, the generation and archiving of metadata and the development of data analysis software still continue, but more difficult data to be treated, for example, old data that are poorly documented, undatabased, undigitized, uncomputerized, etc. will be targeted.

ITEMS	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	REMARKS
Virtual Information Center	Installation & stable operation	Install system		Update system			Construct the integrated research environment (video and/or web conference system, etc.)
	Extension to other disciplines						Wrap up the project and discuss further extension of the system to other disciplines
Metadata DB system	Development	Make prototype	Develop regular system	Release product to public			Design and build the IUGONET metadata DB system on the basis of DSpace
	Stable operation			Update computers			Conduct regular operation of the metadata DB and customize it as needed
Metadata	Design of metadata format	Release ver.1 format	Prepare documents	Update format as needed			Formulate the IUGONET common metadata format and keep updating it if necessary
	Creation of metadata		Open metadata into metadata DB	target relatively old, undatabased items			Create metadata in the designated format and register them in the metadata DB system
Analysis Software	Survey & Specification of analysis software	Specification	Prepare documents				Design an integrated analysis software to download, visualize, and analyze data provided from the IUGONET institutions
	Programming		Release product to public	target relatively old, undatabased items			Develop the IUGONET analysis software by using TDAS (a set of DB, subroutines)
Others	Rearrangement of observational DBs		Rearrange DBs corresponding to metadata & software development				Rearrange existing observational DBs and newly compile DBs of undatabased items
	Scientific researches			Conduct scientific researches with the IUGONET products			Do interdisciplinary researches using various data from the IUGONET institutions
	Management of project website	Build project homepage					Provide project information to the public through the website

Figure 3. Development timeline of the IUGONET project

Furthermore, it is necessary to rearrange the existing observational databases in parallel with the progress of the development of the main products. This has been continuously addressed at each IUGONET institute from the second fiscal year. The IUGONET development team members will join collaborative research activities that use various kinds of observational data to examine and improve their products especially in the latter half of the

project. Such research activities by the development team itself will be a strong driver for steady updates of the project products by fixing problems and adding new functions.

3 IUGONET COMMON METADATA FORMAT

A variety of metadata formats or data models are used to describe data of the Earth and planetary sciences, for example, ISO19115/19139, GCMD DIF, FGDC CSDGM, IPY Metadata Profile, ISTP metadata standard, and so on. The IUGONET development team first investigated these existing formats and finally adopted the Space Physics Archive Search and Extract (SPASE) metadata model (King, Thieman, & Roberts, 2010; Thieman, Roberts, King, Harvey, Perry, & Richards, 2010) to describe the upper atmospheric data obtained by ground-based observations. This model is widely used as the common metadata format by the Virtual Magnetospheric Observatory (VMO) and other virtual observatories for solar-terrestrial physics (King, Merka, Walker, Joy, & Narock, 2010). Archiving metadata in the SPASE format would promote metadata exchange among such data management organizations all over the world. It is particularly worth noting that the metadata format keeps being maintained and improved by the open debates in the SPASE consortium that researchers in solar-terrestrial physics from many countries actively join. This is one of the important reasons why the IUGONET has decided to use SPASE as the base of their metadata format.

In addition, to extend the metadata descriptions in SPASE and apply them to ground-based observational data regarding the upper atmosphere, we have made changes by adding small modifications to the SPASE format: (1) more text to explain the non-digital archival data, (2) text to represent coordinate systems for solar image data, and (3) elements to describe the spatial coverage of each observation. Note that the above modifications (1) and (2) were discussed in the consortium and already have been incorporated into the SPASE metadata model version 2.2.0. The XML schema of the IUGONET common metadata format is available at the project website (<http://www.iugonet.org/data/schema/>).

In the IUGONET common metadata format, not only observational data but also any resources regarding observations, such as instruments, observation sites, researchers, and so on, have their own metadata, all of which are archived in its metadata database. They include metadata referring to each data file (called "Granule"), which enable us to perform a search for data files as well as data sets. See Hori, Kagitani, Tanaka, Hayashi, UeNo, Yoshida, et al. (2012) and King et al. (2010) for the details of the metadata format. More than one million metadata describing various observational data had been archived with the above format and made available for search through the metadata database by late 2011.

4 METADATA DATABASE SYSTEM

The IUGONET development team adopted DSpace as the platform of its metadata database system. DSpace is an open source software that manages digital contents and their metadata in the Dublin Core format that is widely used by many academic organizations as their digital repository. The software contains fundamental functions for registering, retrieving, providing, and harvesting digital data written in various formats. It was confirmed that the system on DSpace could manage metadata written even in the IUGONET common metadata format with some customizations. DSpace was, therefore, expected to fit the project timeline because the IUGONET development team had to establish a stable metadata database system in a short development period.

The IUGONET metadata database system must be continuously maintained even after termination of the six-year project. This means that its operation and maintenance should go smoothly even with anyone who is not one of the original development team members. Since DSpace is in widespread use throughout the world today, any information concerning operation and maintenance of DSpace-based systems can be easily obtained through various media, especially from the Internet. In fact, most of the IUGONET institutes are managing their academic digital repositories on DSpace. This is another important reason why DSpace was chosen as the basis of the IUGONET metadata database system.

The IUGONET metadata database is currently under development and has been opened for beta testing on the Internet at <http://search.iugonet.org/iugonet/>. At this site, users can input any free word, time period, and/or spatial location to find observational data they are interested in. The web service provides them with the URL to access the data if they are available online. Otherwise, at least, information about contact person to whom to ask about details of the data should be given. The description of the metadata database system can be found in Koyama, Kouno, Hori, Abe, Yoshida, Hayashi, et al. (2012).

5 DATA ANALYSIS SOFTWARE - UDAS

The code of the analysis software for the various observational data provided by various universities/institutes, IUGONET Data Analysis Software (UDAS), is written in the Interactive Data Language (IDL). This is because IDL is a programming language widely used in research on the upper atmosphere and solar physics, and therefore many IDL routines produced so far to deal with this observational data can be utilized. UDAS has been developed on the basis of the THEMIS Data Analysis Software suite (TDAS). It is an IDL library developed to analyze data obtained in the Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission (Angelopoulos, 2008). The TDAS library contains several useful functions that download, visualize, and analyze data. It is easy to draw multiple plots of various one- or two-dimensional time series data in a single frame with the TDAS routines. This feature is really suitable for the IUGONET project because it aims at promoting interdisciplinary research by comparing various kinds of observational data. TDAS is also equipped with the Graphical User Interface (GUI) so that even users who are not familiar with IDL are able to readily make quick plots and perform simple analyses. TDAS was adopted as the data analysis software of the Japanese Energization and Radiation in Geospace (ERG) mission (Miyoshi, Seki, Shiokawa, Ono, Kasaba, Kumamoto, et al., 2010), too. Therefore, UDAS has been developed in collaboration with the ERG Science Center.

Tanaka, Shinbori, Kagitani, Hori, Abe, Koyama, et al. (2012) mention further details about UDAS. The software is distributed to the public as a patch for the latest version of TDAS. As of the time of writing, a preliminary version of UDAS (version 1.00.b4) is available for download from the IUGONET website at <http://www.iugonet.org/en/software.html>.

6 SUMMARY AND FUTURE SUBJECTS

The IUGONET project is developing a metadata database system for ground-based observational data of the upper atmosphere and an integrated analysis software to download, visualize, and analyze the data in order to facilitate their distribution and use. The six-year project is currently in its third year, and the initial version of the metadata database and data analysis software (UDAS) will soon be released. The metadata already registered will become available to the public through the metadata database, and new metadata will be continuously archived even after the release of the products. These IUGONET products will be of great help to researchers in efficiently locating, obtaining, and utilizing the observational data dispersed across various universities/institutes. It is expected that these products will contribute significantly to the promotion of interdisciplinary research, which will lead to a more comprehensive understanding of the upper atmosphere, especially the mechanism of its long-term variations.

The project is not confined to managing the observational data and their metadata from the IUGONET institutes. Instead, it welcomes cooperation with any other universities and research institutes that are interested in IUGONET activities. It is important to promptly set up a new framework to incorporate these data in order to expand the project.

As mentioned in Section 2, scientific research using IUGONET products is one of the major activities in the latter half of the project. While this aims at self-evaluation of the project products for continuous improvement, the project members actively demonstrate to researchers how to use the IUGONET products in actual scientific studies. Such promotional activities working in parallel with the upgrade of the developed products will become more important in order to incorporate them as essential e-infrastructure in the research communities.

Another future subject for the project is to establish collaborative relations with similar scientific projects that engage in developing e-infrastructure for scientific data. Because the SPASE metadata format is widely accepted in virtual observatories for solar-terrestrial physics, as mentioned in Section 3, interoperable access among their metadata services and/or exchange of metadata themselves will be expected. This will provide users of the IUGONET metadata database system with opportunities for using much more science data. It is also important that the IUGONET metadata are utilized by various software and web-based services. There are many such science tools available around the IUGONET, for example, Solar Terrestrial data Analysis and Reference System (STARS) (Murata, Yahara, & Toyota, 2001) - a Windows software to search, get, and analyze observational data by using metadata; Conjugation Event Finder (CEF) (Miyashita, Shinohara, Fujimoto, Hasegawa, Hosokawa, Takada, et al., 2011) - a web-based service to browse various quick plots available on the Web over the world; and DATA-showcase system for Geospace In Kml (Dagik) (Saito & Yoshida, 2009) - a visualizing software based on Google Earth that intends to work as a showcase for various data. The IUGONET project would like to collaborate with these projects to build a system to effectively provide them with

IUGONET metadata. This would provide the IUGONET data to more potential users who have never used IUGONET products. These future challenges will lead to new types of interdisciplinary study on the Earth and planetary sciences.

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