



Title	The capacity-building and science-enabling activities of the IUGONET for the solar-terrestrial research community
Author(s)	Yatagai, Akiyo; Sato, Yuka; Shinbori, Atsuki; Abe, Shuji; Ueno, Satoru
Citation	Earth, Planets and Space (2015), 67
Issue Date	2015-01-08
URL	http://hdl.handle.net/2433/212460
Right	© 2015 Yatagai et al.; licensee Springer. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited.
Туре	Journal Article
Textversion	publisher

TECHNICAL REPORT

Open Access

The capacity-building and science-enabling activities of the IUGONET for the solar-terrestrial research community

Akiyo Yatagai^{1*}, Yuka Sato², Atsuki Shinbori³, Shuji Abe⁴, Satoru UeNo⁵ and IUGONET project team

Abstract

Background: This paper presents an overview of the capacity-building activities and science-enabling services of the Inter-university Upper atmosphere Global Observation NETwork (IUGONET) project. This Japanese program, which started in 2009, is building a metadata database (MDDB) of ground-based observations and is developing an analysis software to handle the data linked to the MDDB system for use by the solar-terrestrial physics community. Because the institutional members of the IUGONET are mainly universities in Japan, we explore tools that can contribute to advanced education as well as promote research activities.

Findings: In this paper, we describe the utilities of the IUGONET for education, including our capacity-building activities in developing countries. We have regularly facilitated training seminars for Japanese students on the use of our tools (IUGONET MDDB and the software), and we have held capacity-building seminars for young scientists in developing countries. In addition to the MDDB, we have prepared various 'gateway' tools for users who are unfamiliar with 'keywords' to search for data. One of these is a geographical display tool that uses Google Earth (KML file), which is included as supplemental material to this paper. The usefulness of the IUGONET has been proven over its first 5 years of operation by the increasing number of its users, which has led to the production of approximately 500 scientific papers, including 42 thesis papers.

Conclusions: The IUGONET community collaborates with the Scientific Committee on Solar-Terrestrial Physics program, not only in its scientific activities, but also in the establishment of E-infrastructure and capacity building.

Keywords: Ground-based observation; Solar-terrestrial physics (STP); Database; Metadata; Interdisciplinary studies; Capacity building; E-infrastructure

Findings

Background of data activities of the STP community

The series of the Climate And Weather of the Sun-Earth System (CAWSES) projects of the Scientific Community on Solar-Terrestrial Physics (SCOSTEP) required considerable standardization efforts to unify the variety of ground-based and satellite-derived observational data obtained across disciplines and countries (CAWSES Office 2014; Davila and Tsuda 2014). The solar-terrestrial physics (STP) research community handles diverse data resources that span the globe, reach altitudes over 100 km into the heliosphere, and extend over many decades in

¹Solar-Terrestrial Environment Laboratory, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan

Full list of author information is available at the end of the article



duration. To complicate matters further, the sophistication of ground-based and spaceborne observatories for remote and *in situ* sensing of the STP domain results in the archives of these data resources being distributed among various organizations throughout the world. This has culminated in the long-standing challenges associated with centralized STP data exchange and distribution. It is the responsibility of the CAWSES program to preserve observational data that are spread across individual institutions and to help students and early career scientists from different backgrounds to obtain data relevant to their research.

The International Council of Scientific Unions (ICSU)/ World Data Center (WDC) for STP was established in 1957 to manage data collected during the International

© 2015 Yatagai et al.; licensee Springer. This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly credited.

^{*} Correspondence: akiyoyatagai@stelab.nagoya-u.ac.jp

Geophysical Year (IGY, 1957 to 1958) to avoid catastrophic damage to all the observed geophysical data. This system has evolved over the approximately 60 years of its operation for the STP community, especially in Japan. The Space Physics Interactive Data Resource (NOAA National Geophysical Data Center 2014) of the former WDC for Solar-Terrestrial Physics, Boulder, in the National Geophysical Data Center (NGDC)/National Ocean and Atmosphere Administration (NOAA), is the pioneer database for archiving STP observational data. Satellite mission data from the upper atmosphere and heliosphere have been archived at the National Space Science Data Center (NSSDC) of the National Aeronautics and Space Administration (NASA) (Grayzeck 2014) since 1966. These include the Virtual Magnetospheric Observatory (VMO), Virtual Heliospheric Observatory (VHO), and Virtual Solar Observatory (VSO), which constitute satellite data archives for each field and are NASA projects that are grouped under the abbreviated name 'VxO.'

Solar data have been archived mainly at the VSO (Gurman 2014), and this system, which includes a data exchange function, has become a community tool for solar scientists.

In terms of the analysis system, the Coordinated Data Analysis (Workshop) Web system of NASA (McGuire 2014) enables researchers to handle key parameters and statistics of STP as well as observed data prepared by the VxO. In the United States, for ground-based observations, the incoherent scatter radar community has started the Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR) program database, and the CEDAR Madrigal database (Rideout 2014) is currently collecting international upper atmospheric observational data and/or metadata obtained in South America, Europe, China, and the United States, in addition to providing analysis software.

Necessity for the IUGONET metadata system

Long-term ground-based, i.e., stable, observational data are of considerable importance because the upper atmosphere is strongly affected by solar activity. The STP research community of Japan does not have any central institutions for data exchange and distribution, as mentioned above. Thus, the observational data from solar telescopes, various radars, optical instruments, and magnetometers are held mainly by the relevant institutions. This means that it is difficult for early career scientists from different backgrounds to obtain data for their research work. Hence, in 2009, the leading institutions of the National Institute of Polar Research, Tohoku University, Nagoya University, Kyoto University, and Kyushu University started the Inter-university Upper atmosphere Global Observation NETwork (IUGONET) project for managing ground-based observations of the upper atmosphere and the Sun.

The primary objective of the IUGONET project was to build a metadata database (MDDB) for ground-based observations of the upper atmosphere, which could be searched by a dedicated analysis software for relevant observed data (Hayashi et al. 2013). However, we deal with data pertaining to both the Sun as well as the upper atmosphere.

The IUGONET was quickly able to fulfill its original purpose of developing an MDDB and analysis software (Yatagai et al. 2014). Currently, the IUGONET is expanding to provide additional tools for related geoscience fields and the international CAWSES society, including developing countries, not just the member institutions and domestic Japanese STP community. The general activities of the IUGONET and developed products have been described elsewhere (Tanaka et al. 2013; Yatagai et al. 2014), including this volume (Abe et al. 2014).

The IUGONET project team has provided exhibitions at various meetings and committed considerable investments of time, manpower, and funds to enhance the capacity-building aspects of the data service for students of all levels, as well as established scientists unfamiliar with the IUGONET. Figure 1 shows the activities and general flow of the data in the IUGONET.

This paper will discuss the capacity-building and scienceenabling activities of the IUGONET because these have been important topics for the CAWSES-II program. We will first briefly describe the data resources and then outline our educational and capacity-building activities for developing countries. This will be followed by a statistical analysis of the science-enabling capability of the IUGONET, together with a discussion of the overarching objectives for future developments.

Diversity of the IUGONET data resources

The IUGONET MDDB is built as a metadata repository based on the Space Physical Archive Search and Extract (SPASE, King et al. 2010) model, which is widely used in the international STP community, such as NASA's VxOs. While the primary focus of the VxO projects is on satellite data, the IUGONET has made a systematic effort to acquire data resources from assorted groundbased instrumentation, including the digitization of analog data stored on paper and magnetic tapes. Thus, the IUGONET has become a unique repository of ground-based STP data at more than 860 observatories worldwide (Figure 2).

IUGONET data search and various gateways

The IUGONET metadata (MD) are written in XML format, and the style (or format) is defined for individual keywords (Observatory, Instrument, Person, Dataset,



and Granule to reach each specific data file), in accordance with the SPASE ontology. Because these MD are formatted uniformly, conversion to another format (including KML) is relatively simple.

Figure 3 shows an example of how the Observatory MD function with Google Earth to display the information

on the observation, for example, in the region including Kyoto and Nagoya, Japan. Many instruments at Shigaraki Observatory are displayed by browsing (not shown). For instance, if the Optical Mesosphere Thermosphere Imager (OMTI; an all-sky imager at Shigaraki) is chosen, the MD of the instrument appear on screen (Figure 3b). By





(See figure on previous page.)

Figure 3 Observatories and instruments registered in IUGONET MDDB as viewed through Google Earth around Kyoto and Nagoya, Japan. (a) Observatories. Yellow indicates observatories operated by Kyoto University, and orange indicates those operated by Nagoya University. (b) Display of the metadata of the all-sky camera of OMTI at Shigaraki, offered by clicking 'Instrument' metadata viewed through Google Earth. (c) Result of search MDDB followed by clicking IUGONET Metadata (description) in (b). (d) Result of clicking 'Related URL' shown in (b).

clicking the associated web address, the user can obtain descriptions of the MD (Figure 3c) and related URLs, e.g., OMTI's webpage (Figure 3d).

From these tables and the KML file, users can easily recognize the types of data installed in the IUGONET MDDB and find appropriate keywords, for example, 'SuperDARN', 'OMTI', and 'all-sky camera'. The geographical tool mentioned above received much attention from scientists attending inter-disciplinary meetings and workshops (described later). We include this KML file, used for displaying the observatory and instrument MD, as supplementary material for this paper (see Additional files 1 and 2).

A team comprising ten PhD-level researchers is affiliated with the IUGONET development team. They work to create the MD by extracting relevant information from scientific papers and technical documents and by interviewing the relevant data holders. Thus, all the IUGONET resources are linked to meta-information such as 'Description' and 'Keyword' text files, and new users can be navigated quickly to the wealth of data resources using the IUGONET tools. As illustrated earlier (Figure 3), the MD are valuable for explaining the data to newcomers and for various outreach/capacity-building activities.

We prepared a list of the registered MD (IUGONET 2014a) using a function of Google Spreadsheet, as shown in Figure 4. This provides users with knowledge of both types of data: those registered already in the MDDB and those in preparation for release. In addition, it is useful for newcomers as it offers them a selection of suggested keywords to be entered. This is because some keywords are linked to the search results of each deterministic portion of meta-information; therefore, this sheet is instructive in explaining our MDDB.

As shown in Figure 4, if an all-sky monochromatic image dataset is chosen (Figure 4a, red square), the MD of that dataset appear on the screen (Figure 4b), which provides users with a description of the data. If granule MD is registered (e.g., SuperDARN, Figure 4c), one can reach the original data without restriction. If the datahandling software, iUgonet Data Analysis Software (UDAS, described in the following) is available, this is written as 'Load routine for UDAS is available' in the column. By clicking the 'Note' shown on the screen (Load routine for UDAS is available), the user can go to the list of the 'load procedure' of UDAS (Figure 4d).

Development and use of the UDAS software

A suite of custom software was developed to support downloading, plotting, and analysis of data registered in the IUGONET database (IUGONET 2014b). The IUGONET does not regulate individual data formats employed by its member institutes. Instead, in collaboration with the Exploration of Energization and Radiation in Geospace Science Center (Miyoshi et al. 2012), we have developed the UDAS software to handle various types of formatted data using the same platform (Tanaka et al. 2013).

As a part of the IUGONET activities, an institutional educational program (Bachelor and Master's course level) participates in the development of an analysis package in the UDAS. For example, various types of statistical tests of significance have been incorporated into the UDAS (Hamaguchi 2013). The UDAS is useful not only for researchers in terms of handling data (downloading, producing graphs, analyzing), but also for participating in its development of the IUGONET system.

Domestic training seminars and overseas capacity building

The IUGONET has facilitated a series of domestic training seminars for the STP community's early career scientists, as well as more experienced researchers who want to handle data by means of a graphical user interface, on how best to use the UDAS (and MDDB). In addition to regular annual or biannual training seminars, IUGONET developers are conducting small training seminars at several universities.

As shown in Figure 2, IUGONET institutions have been performing ground-based observations for a long time and they have established many observatories throughout the world. To promote the use of our MDDB and the UDAS, we conducted training seminars in Indonesia and Austria in 2012, during which developers had the opportunity to visit the observatories, or during summer schools held in diverse locations, including some in developing countries. We held such seminars at the 208th Symposium on Sustainable Humanosphere Science School 2012 in Indonesia, UN data analysis symposium 2012 at Graz, Austria, and International Space Weather Initiative MAGnetic Data Acquisition System (MAGDAS) School 2012 (Figure 5). In addition to these face-to-face meetings, we held two online seminars in 2013 using

mont Inco	INET Community	Analysis 1	oft. Meta	data DB	_	_	10 0+8 f	💓 🛨	Unix. MAGUS	Service Filler							
										Solar	Terrestrial E	nvironment	Laboratory, Nago	a Univers	ity		
			CONT						Dataset	Parameter	Data type	Instrument	Observatory	MD status	MD status	Note	_
The progre tach instit Registered Metadata i	ess of registration to I ute or university provi I metadata is indicated n preparation is indica	UCONET Met des each she I by pink colo itedy by sky-	adata Databas et. To see dit or, and the lin blue color.	Metadat se is shown i trerent sheet ik goes to the	a Data n the follo s, please o e search re	wing list. click the tal	b at the top of the l UGONET Metadata	list. Databese.	SuperDARN Hokkado HF rada Interplanetary Scietillation measurement	backscatter power, Doppler velocity, spectral with, etc. Solar wind velocity, activitibition level Annual solar wind speed map	Namerical Data Namerical Date Display Data	Holdkaido HF radar LPP sacio teloscope	SuperDARN Holdvalco HF radar site Hug, Kiso, Sugadane, and Toyokawa Fuji, Kiso, Rugadaine, and Toyokawa Toris, Russia Zhiganak, Russia Yakudok, Nussau Yakudok, Nussau	registered registered registered	registered under proposition registered	Lead routine for UDA evallable	Sin
ogress of a theka Univ AQUSolarOb	NIPR SIEL, Nagoya Univ	HERI, Kyole	Uner. WDC for 0	Geomag, Kyolo U	mv Korasa	n & Hida Obs,	Kyele Univ CSWSE, I	Kyusha Unv					Island, Beijing, China; Lunping, Muntinlupa; Portianak; Wanimaali;				
	Space and Upper At	mospheric Se	lences Group	National Ins	stute of Po	lar Researc	ch						Learmonth; Katarning; Katarning;				
Dataset	Parameter All-sky menochromatic image (557 7, 630 0, 427 0 nm) All-sky menochromatic image (427 0, 557 7 nm)	Data type Display data Display data	Instrument all-sky monochromatic imager (ASI) Electron Aureral Imager (EAI)	Observatory	Dataset MD status index preparation egistered EA(1) egistered EA(2)	Granule MD status under preparation under preparation under	Note		210 Magnetic Mercian (2100M) magnetismater chain	1 Hz magnetic held	Numerical Data	Fluggte magnetamete	Chchurdah, Russia, Zyryanka, Russia, Magadan, Russia, Paratunka, Russia, Moshidi, Japan, Nikubetsu, Japan, Chughan, Japan, Kagoshima, Japan, Cachirna, Japan,	reg stered	registered	Lead routine for UDA realiable	Sis
oral servation at	All-sky monochromatic image (435.0, 400.5 nm) All-sky auroral morie Meridian scarned auroral	Display data Display data (video signals)	Proton Auroral Imager (PAI) all-sky TV camira (A1V) multi-color		egistered PA(1) inder sreporation	under preparation under preparation			•								
wa Station	emission (427.0, 485.2, 497.4, 557.7, 630.0, 777.4, 844.6 nm)	Numerical data	meridian scanning photometer (3PM)		inder preparation	under preparation			d)	nd routines for I	UDAS						
wa Station	emission (427.0, 405.2, 487.4, 557.7, 630.0, 777.4, 844.6 nm) All-sky autoral monochromatic image	Numerical data	maridian scanning photometer (SPM) conjugate auroral imager (CAI)		inder preparation inder preparation	under preparation under preparation			d)	nd routines for I	UDAS	Observal	tions data		nstitutes	Photos/M	ovies/D
va Station	emission (427.0, 465.2, 497.4, 557.7, 630.0, 777.4, 844.6 mm) Aß-sky auroral monochromatic image Aß-sky auroral image	Numerical data Display data Ursplay data (Jpg)	metrifian ecenning phatometer (SPM) conjegate auroral imager (CAN) color sigstal SUR camera (CDC)		inder oreparation inder oreparation orgistered	under preparation under preparation under preparation			C) List of low UDAS load	nd routines for l routines	UDAS Solar ir	Observat nages obta teler	tions data lined by the SMAR scope	Kwas Kwas	institutes an & Hida C (yoto Univ.	Photos/M	ovies/D
sa Station	emission (427 6, 405.2, 487 4, 5517, 630.0, 777.4, 844.6 mm) All-sky auroral monochromatic image All-sky auroral image	Numerical data Display data Usplay data (pg)	metidian scanning phat smeller (SPM) conjugate auroral imager (CA) color digital SLR camera (CDC)		inder inder inder ingestened	under preparation under preparation under preparation			d) List of low UDAS load rug.load.sm	nd routines for I routines sart rt	Solar ir	Observat nages obta teler Iolar HF rad	tions data lined by the SMAR' scope dio spectrum	F Kwas R To	institutes an & Hida C Cyoto Univ. ohoku Univ.	Dbs, Photos/M	ovies/D D / D D / D
va Station	emission (427 0, 465 2, 427 4, 557 7, 500 0, 777 4, 844 6 mm) Alf-sky auroal monochromatic image Alf-sky auroal image raire occasions when your 1	Numerical data Display data Unplay data (Ing) Rowser does no	metidan boarning photometer (SRM) conjugate auroral imager (CAI) suroral	ve list correctly.	inder inder inder ingistered We apologisz	under preparation under preparation under preparation æ for your inc	convenience.		C) List of loa UDAS load Iug.load.sm Iug.load.ipr	ad routines for I routines hart tt _tohokuu	JDAS Solar ir Supriter's/	Observat nages obta teler iolar HF rad solar wide HF	tions data lined by the SMAR' scope dio spectrum band spectral data band	F Kwas R To tin To	Institutes an & Hida C (yoto Univ. ohoku Univ. ohoku Univ.	Photos/M Obs, @ /1 . @ /1	ovies/D D / D D / D D / L)
a Station ere may be	emission (427.0.465.2 437.4.557.4.500.777.4, 844.6 mm) A&Asity: acrost monochromatic amage A&Asity: acrost amage A&Asity: acrost amage rare occasions when your b	Numerical data Display data Unplay data (09) rowser does no	metidian totarning photometer (SPM) conjugate auroral imager (CA) color digital SUR camera (CDC) t display the above	ve list correctly.	inder sreperation inder sreperation ogistered We apologiz	under preparation under preparation under preparation	onvenience.		CL) List of low UDAS load ug_load_sm ug_load_ipr ug_load_hr ug_load_aw	nd routines for l routines aart tt _tohokuu rs_rish	JDAS Solar ir Jupiter's/ Surface autor	Observal nages obta teler iolar HF rad solar wide HF meterolog matic weat	tions data ined by the SMAR' scope dio spectrum band spectral dat band y data taken by th her station (AWS)	F Kwas R To Lin To RISE	institutes an & Hida C Cyoto Univ. ohoku Univ. ohoku Univ. 4. Kyoto Uni	Photos/M 105, B /I . B /I . D /I . D /I . D /I . D /I	ovies/D D / D D / D D / U D / U
re may be	emission (427.0, 465.2, 467.4, 557.7, 450.7,77.4, 844.6 mm) AS-sky avoid monochromatic amage AS-sky avoid image AS-sky avoid image	Numerical data Display data Usplay data (093) Rowser does no	matiSan bCathing phatoweler (SRM) conjugate autoral imager (CAI) color ciptal SLR camera (CDC) t display the abov	ve list correctly.	inder oreparation inder oreparation ogistered We apologiz	under preparation under preparation wfor your inc	unvenience.		CL) List of load UDAS load ug_load_sn ug_load_inf, ug_load_aw ug_load_aw	ad routines for 1 routines aart t tobokuu rs_rish r_rish	JDAS Solar in Supiter's/ Surface autor	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weat Boundary	tions data lined by the SMAR scope Jio spectrum band spectral dat band y data taken by th her station (AWS) layer radar	F Kwas II To I III To RISI RISI	institutes an & Hida C Cyoto Univ. ohoku Univ. ohoku Univ. 1. Kyoto Uni 1. Kyoto Uni	Photos/M Dbs, 6 / / . 7 / 10 / /	ovies/C D / D D / D D / D D / D D / D D / D
re may be	entistion (427 6, 485.2 437 4, 557.4 (500.2777.4, 644 6 mm) Alikaky auroid monochranatic image Alikaky auroid image raive occasions when your 1 increal image, taken	Numerical data Display data Unglay data (092) nowser does no by the Elec	matiSan Scarning phatoweler (SRM) conjugate auroral imager (CAI) scarning (CDC) t display the above ctron_Auroor	ve list correctly.	inder sreparation inder sreparation ogistered We apologisz	under preparation under preparation ar for your inc	onvenierox.	arctica,	C) List of low UDAS load ug_load_sm ug_load_int ug_load_int ug_load_int ug_load_int ug_load_int	ad routines for 1 routines nart t t,tohokuu rs.rish	JUDAS Solar ir Surface autor L-bar	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weat Boundary nd lower tr	tions data ined by the SMAR scope dio spectrum band spectral dat. band y data taken by th her station (AWS) layer radar oposphere radar	F Kwas F To Lin To RISI RISI RISI	Institutes an & Hida C Qoto Univ. ohoku Univ. ohoku Univ. 4, Kyoto Uni 1, Kyoto Uni 4, Kyoto Uni	Photos/M Dbs, 6 /1 . 6 /1 . 6 /1 . 6 /1 . 6 /1 . 7 . 7 . 7 . 7 . 7 . 7 . 7 . 7	ovies/E D / D D / D D / D D / D D / D D / D
re may be sky au playDec	ensistin (27, 452, 774), Bat 5 million (27, 450, 774), Mat 5 milli	Numerical data Display data Unplay data (020) wowser does no by the Ele	matidan scatning phatometer (SPM) conjugate autoral imager (CAI) color rigial SUR camera (COC) t display the above sctron Auron	w list correctly.	inder reparation inder separation ogsitered We apologiz	under preparation under preparation ar for your inc	onvenerce.	arctica.	CL) List of low UDAS load ug_load_sm ug_load_ipr ug_load_m ug_load_m ug_load_tri ug_load_tri ug_load_tri ug_load_tri	nd routines for 1 routines hart t t,tohokuu sis_rish r;sh r	JDAS Solar in Solar in Supter's/ Surface autor L-ban Equ	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weat Boundary nd lower tr iatorial ate	tions data ined by the SMAR scope lio spectrum band spectral data band y data taken by th her station (ANS) layer radar oposishere radar	e RISI RISI RISI RISI RISI	Institutes an & Hida C Syoto Univ. Jhoku Univ. Jhoku Univ. H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni	Photos/M bbs, @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1 . @ / 1	ovies/E D / D D / D D / D D / D D / D D / D D / D
station re may be <u>sky at</u> olayDat ctron at	ension (27, 452, 150, 1774, 517, 557, 150, 1774, 546, 597, 150, 1774, 546, 597, 150, 1774, 546, 174, 174, 174, 174, 174, 174, 174, 174	Numerical data Display data Unsplay data (99) by the Elec for O() in the	maristan setarring phatsmeter (BMU) conjugite auroal mage (CA) SUR camma (COC) (COC) t display the abor cotion optial SUR camma (COC)	ve list connectiye al Imager taken by the	nder reparation inder separation ogstered We apologiz	under preparation under preparation er for your inc) at Syow h a fish-eyy	unvenence.	arctica,	C) List of load UDAS load ug.load.sm ug.load.sm ug.load.m ug.load.m	ad routines for I routines wart tt tohokuu si_rish rish r si a	JDAS Solar in Solar in Surface autor L-bar Equ	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weatt Boundary nd lower tr iatorial ate MU	tions data ined by the SMAR scope lio spectrum band spectral data band y data taken by th her station (AWS) layer radar oposphere radar radar	e RISI RISI RISI RISI RISI RISI	Institutes an & Hida C Syoto Univ. Jhoku Univ. Jhoku Univ. H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni H. Kyoto Uni	Photos/M bbs, 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1 . 6 / 1	ovies/1 D / D D / D
s Bation re may be sky at playDat ctron at s. The is rt Date	empion (27, 452, 414, 557, 508, 7774, Mark and Mark a	Thumerical data Display data Unplay data (02) monser does no by the Ele for O() in the only during th	maridan searing distinction ghat meter (gRM) conquite (gRM) conquite constant (CC) con	ve list correctly.	inder reperation inder reparation egistered We apologiz 1 (EAI-1 EAI-1 with end of Feb	under preparation under preparation er for your inc) at Syoy h a fish-eye ruary to th	onvenence.	arctica, tation, Antarc	CL) List of low UDAS load ug_load_sm ug_load_sm ug_load_ak ug_load_st ug_load_m ug_load_m	noutines for I routines wart t t,tohokuu r,rish r,rish r s eteor,rish	JDAS Solar in Solar in Surface autor L-bai Equ	Observat nages obta teler iolar HF rad solar wide HF meterolog matic weatt Boundary nd lower tr iatorial atr MU Meteo	tions data lined by the SMAR scope Jio spectrum band spectral data band y data taxen by th her station (AWS) layer radar layer radar oopsphere radar radar rr radar	r Kwas Tr Tr Tr RISI RISI RISI RISI RISI RISI RISI	Institutes an & Hida C cyoto Univ. Jhoku Univ. Jhoku Univ. H, Kyoto Uni H, Kyoto Uni H, Kyoto Uni H, Kyoto Uni H, Kyoto Uni H, Kyoto Uni	Photos/M Dbs, Ø / I Ø / I Ø / I W. Ø / I	ovies/f
s Blation re may be sky at playDat ctron at a. The is st Date ative SI n://prat	emision (27, 452, 474, 557, 508, 7774, 466, emision (27, 508, 7774, 466, emision (27, 508, 7774, 466, emision (27, 508, 7774, 486, emision (27, 508, 7774, 478, emision (27, 2774, 2774, 479, 2774, 2774, 2774, 2774, 479, 2774, 2774, 2774, 2774, 479, 2774, 2774, 2774, 2774, 479, 2774, 2774, 2774, 2774, 2774, 479, 2774, 2774, 2774, 2774, 2774, 2774, 2774, 479, 27744, 2774, 2774, 2774, 2774, 2774, 27744, 277	Thumerical data Display data Unplay data (pg) worker does no by the Ele for O() in the ofly during th 2P110).	maristan scarming photomore averal image (CA) color diptal SUR camoo (CC) t display the above color diptal SUR camoo (CC)	w list correctly.	inder reperation inder reparation egistered We apologiz 1 (EAI-1 EAI-1 with end of Feb	under preparation under preparation meter preparation at Syrony h a fish-ey ruary to th	onvenence.	arctica, Lation, Antarc	C) List of low UDAS load ug_load_sm ug_load_sm ug_load_ft ug_load_ft ug_load_ft ug_load_ft ug_load_ea ug_load_ea ug_load_mu	nd routines for I routines aart t. .obokuu s.rish r.rish r rish r eteor.rish Lirish	UDAS Solar ir Solar ir Jupiter's/ Surface autor L-bar Equ	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weat Boundary Boundary matic weat Boundary Meteo MF r	tions data lined by the SMAR' scope Jio spectrum band spectral data band by data taken by th her station (AWS) layer radar nosphere radar radar radar radar ratar	r Kwas I Ti Risi Risi Risi Risi Risi Risi Risi R	Institutes an & Hida C (yoto Univ. Jhoku Univ. Jhoku Univ. 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni	Photos/M 2005, 2011 2015, 2015, 2011 2015, 20	ovies/f
re may be sky at sky at playDac stre st pi/pbb	emission (27, 452, 452, 454, 457, 458, 174, 557, 458, 1774, 567, 459, 1768, 1774, 564, 597, 1980, 1774, 564, 597, 598, 1794, motocionate mage motocionate mage motocionate mage rare occasions when your 1 rare occasions (19, 19, 19, 19, 19, 19, 19, 19, 19, 19,	Famerical data Display data Unsplay data Unsplay data (pp) by the Elec for OI in the only during the PTIO a/aurora/Sys actiony/INPR	marifian secaring phatmater phatmater parameter averal inager (CA) oblic right (SK) canno (CA) oblic right (SK) ca	ve list correctly- al imager taken by the on from the o	inder reperation ander repetation ogsteved We apologiz <u>1 (EAI-1</u> EAI-1 with end of Feb	under preparation under preparation mer preparation a for your inc) at Syow h a fish-ey ruary to th	unvenence. va Station, Anta re lens at Syowa St e midde of October	arctica. Lation, Antarc	C) List of load up,load_sm up,load_sm up,load_sm up,load_m up,load_m up,load_m up,load_m up,load_m up,load_m up,load_m	ad routines for I routines wart tt tohokusu r_rish r_rish r_rish teor_rish teor_rish c_rish	JUDAS Solar in Solar s Jupiter's/ Jupiter's/ C-ban L-ban Equ Solar Solar in Solar in	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weatt Boundary nd lower tr satorial atm MU Meteo MF i Wind pro	tions data ined by the SMAR scope Elio spectrum band spectral data band y data taxen by th her station (Abre radar radar radar filer radar	r Kwas h Tr in Tr RISI RISI RISI RISI RISI RISI RISI RIS	Institutes an & Hida C Gyoto Univ. Jhoku Univ. 4. Kyoto Uni 4. Kyoto Uni	Photos/M Øbs, Ø, // Ø, // Ø, // W, Ø, //	ovies/I D / D D / D / D / D
re may be sky at playDet ctron a a. The is rt Date attive SI pri/polations	ension (27, 452, 1993), 444, 557, 508, 7774, 466 and Mashy arout map motoconnec map Alsky arout image I are occasions when your 1 inter occasions when your 1 inter occasions when your 1 arout image, 152-7 mm arout image	Famerical data Display data Unplay data (093) by the Elector for O() in the only during the 2 PT100 in the calaurora/Sovy bository/NEPS	Indiana takaneg Lanneg	ve list correctly- tal Imagor taken by the on from the o	inder reperation inder reperation ogistered We apologiz 1 (EAI-1 EAI-1 with and of Feb	under preparation under preparation under preparation a for your inc) at Syow h a fish-ey ruary to th	wa Station, Anta	arctica. Iation, Antarc -).	d) List of load UDAS load ug.load_sm ug.load_sm ug.load_sm ug.load_am ug.load_am ug.load_am ug.load_am ug.load_am ug.load_am	ad routines for I routines aart t. t. t. t. t. t. t. t. t. t. t. t. t.	UDAS Solar in Solar s Jupiters/ Surface autor L-bar Equ Equ Equ	Observat nages obta teler iolar HF rac solar wide HF meterolog matic weat Boundary nd lower tr natorial ath MU Meteo MF i Wind pro i data take Shig	tions data lined by the SMAR scope Elio spectrum band spectral dat band y data taken by y data taken by statistic taken	r Kwas Ti Ti Ti Risi Risi Risi Risi Risi Risi	Institutes an & Hida C (yoto Univ. Jhoku Univ. Jhoku Univ. 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 1, Kyoto Uni	Photos/M bbs 0/1 iiii 0/1 iiiiii 0/1 ivi 0/1	ovies/[) / D) / D
re may be 	empion (27, 452, 44, 557, 508, 7774, and even metodomatic mage At sky arout image rare occasions when your 1 rare occasions when your 1	Fumerical data Display data Useplay data (eq2) by the Ele for O() in the of O() is the of O() in the of O() is the of O() in the of O() is the	realisan tearing consistent averal insper (CA) (CA) (CA) (CA) (CA) (CA) (CA) (CA)	ve lat correctly. al Imager taken by the con from the o PB al Imager	inder inspiration inder exploration explored We apologiz 1 (EAI-1 EAI-1 with end of Feb	under preparation under preparation a for your inc) at Syow th a fish-eye ruary to th	va Station, Anta re lens at Syowa St e midde of October va Station, Anta	arctica.	CL) List of low UDAS load ug_load_sm ug_load_sm ug_load_m ug_load_m ug_load_at ug_load_at ug_load_m ug_load_m ug_load_m	ad routines for I routines mart tt t,tohokuu s_rish r_rish r_rish tetor_rish Lish Lish aosonde_rish diosorde_rish	UDAS Solar in Solar s Jupiter's/ Autor L-baa Equi Equi Equi Equi	Observat nages obta teler olar HF rac solar wide HF meterolog matic weat Boundary nd lower tr iatorial atr MU Meteo MF i Wind pro data taken Shilg Radioso	tions data lined by the SMAR scope Jilo spectrum band spectral data band band spectral data band y data taken by th her station (AWS) layer radar opsoshere radar radar rradar rradar rradar filer radar h by the ionosond araaki me data	r Kuvas in Tro RISI RISI RISI RISI RISI RISI RISI RIS	Institutes an & Hida C Syoto Univ. Jhoku Univ. Jhoku Univ. 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 4, Kyoto Uni 1, Kyoto Uni 1, Kyoto Uni 1, Kyoto Uni 1, Kyoto Uni	Photos/M bbs, 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / / 0, / /	ovies/D 2 / D 2 / D 2 / U 2 / U 2 / U 2 / U 2 / D 2 / D
re may be sky Bi playDac ctron a sky Bi playDac ctron a the EAI the	empion (27, 632, 44, 637, 1020, 1774, and even monochronacc mage All sky auroid image rare occasions when your I rare occasions when you	Plumencal data Display data Using y data Using y data Day the Elec for O() in the only during the PTIO) anarora/Systematic and Systematic by the Elec by the Elec for to Chatter and Systematic at Systema Side of Octobe 8	Insufficient Sector 1 Sector 1 Se	ve list conectly. al imager taken by the on from the r PB al imager. 2012, SS.7.7 tota. The inst	ndar reperiod on adar repeated replaced We apologized We apologized Use apologized Heal-1 with replaced Heal-1 wit	under preparation under preparation under preparation a for your inc) at Syoy h a fish-ey ruary to th) at Syoy after Mar. 1 operated o	va Station, Anta va Station, Anta va Station, Anta va Station, Anta s 2012) in the JPEG niy during the write	arctica. Lation, Antarc 	d) List of low UDAS load ug.load.str ug.load.str ug.load.str ug.load.str ug.load.str ug.load.str ug.load.str ug.load.str ug.load.str	ad routines for I routines aart t. t.t. t.t. t.t. t.t. t.t.sh t.rish t.rish t.t. t.rish t.t. t.t. t.t. t.t. t.t. t.t. t.t. t.	JDAS Solar in Solar in Surface Surface L-ban Equi	Observat nages obta telet solar HF ras solar wide HF meterolog natic weat Boundary d lower tr atorial atorial atorial atorial MG pro data take Shig Radioso	tions data inned by the SMAR scope Jio spectrum band spectral data band y data taken by th her station (AWS) layer radar opsoshere radar radar rradar rradar rradar rradar nt p the ionosondi grafati me data WRN radar	I I Kwas I Kwas I III Tr RISSI	Institutes an & Hida C systol Univ. shoku Univ. shoku Univ. 4. Kyoto Uni 4. Kyoto Uni 1. Kyoto Uni	Photos/M 00 /1	ovies/0 3 / 0 3 / 0

Institute of Polar Research. The pink (light blue)-colored cell means registered (under preparation). (b) Search results followed by clicking the red square in (a). (c) Example of the Solar-Terrestrial Environment Laboratory. Details are the same as in (a). (d) Available load procedure list (part) followed by clicking the red square in (c).

Internet conferencing systems, where many young scientists joined from Indonesia.

Science-enabling service of the IUGONET

As described above, about ten developers (researchers) are working exclusively for the IUGONET to build the MDDB/UDAS. In addition to the publication of technical



papers on the development of the system, scientific papers using the IUGONET tools are included in the 'outcomes' of the project. Figure 6 summarizes the annual number of publications in the past 5 years; more than 90 papers have been issued annually. This includes IUGONET members' lead papers on observations that are registered in the IUGONET system (red, in Figure 6), and more than 60% of papers are published with ex-IUGONET researchers named as the lead author (green, in Figure 6). Additionally, papers on the IUGONET development activities (MDDB and software) have been issued (blue, in Figure 6), and a further 42 thesis papers (Bachelor, Master's and Doctoral) have been submitted up to March 2014.

In addition to the abovementioned capacity-building international activities, the IUGONET has initiated international cooperation with a similar European database project, the Near-Earth Space Data Infrastructure for e-Science (ESPAS) (The ESPAS Consortium 2014), to construct an interoperable database. Together with the European and the US SPASE communities, we have



organized several sessions at international meetings, and because of both these international activities, the number of users of the IUGONET products is increasing.

Table 1 shows the countries that access the MDDB and the number of participants included in our mailing list according to their countries. In the 2 years since the release of the MDDB, about 80% of users have been from Japan, and the second and third highest users appear to be our cooperators associated with the SPASE and ESPAS communities. Among the other countries, our capacity-building activities in India, Indonesia, and Austria appear to have contributed to their greater access of our MDDB.

With regard to the mailing list that we started to compile in 2013, 85% of participants are from within Japan. However, the numbers of participants from India and Indonesia, where we have undertaken capacity-building activities, including domestic education to foreign students/PDs, are relatively high. Although the numbers are small, we do have participants from all continents and regions except Oceania (Asia, North/South America, Europe, Africa, and the Middle East).

Discussion

As described above, registration of the MD is performed by postdoctoral fellows and other members of the STP community. This provides both the users of the MDDB and the postdoctoral fellows with greater understanding of the data and of their systems of observation. In

Table 1 Countries	that are	associated	with	IUGONET
activities				

Access to MDDB (top ten countries)	Mailing list	
Japan (approximately 80%)	Japan	126
USª	India ^b	8
Germany ^a	Indonesia ^b	5
Ukraine	Taiwan	3
Austria ^b	US ^a	3
India ^b	Australia	2
Indonesia ^b	China	2
Russia	Finland	2
France	Nigeria	2
China	Brazil	1
(Others)	Egypt	1
	Germany ^a	1
	Iraq	1
	Korea	1
	Malaysia	1
	Thailand	1

(Left) Top ten countries accessing the IUGONET MDDB. (Right) Nationalities of the participants in the IUGONET mailing list (as of 15 July 2014). ^aCountries cooperating in promoting research. ^bCountries that have received training seminars.

addition, the international outreach/capacity-building lecture activities provide good experience for both the students and the facilitator of the training seminar.

Although the UDAS is a powerful tool for acquiring, displaying, and analyzing data, the main software components differ considerably from those used by the science community at large. Therefore, the interoperability of such tools should be improved by using other suitable software, for example, that being used by the meteorological community.

The capacity-building activities of the IUGONET have been linked to the activities of several institutions, e.g., the MAGDAS School and the RISH/Kyoto University's Equatorial Atmosphere Radar site. These institutional capacity-building activities are performed independently under the CAWSES-II program (Ueno et al. 2013). However, we hope that in the future, the IUGONET will take a role in networking these capacity-building activities.

The IUGONET facilitates exchange of data information (MD) on the Internet. Because we carefully selected the international 'standard' of the format of the MD and general design of the analysis software, our tool can be linked easily with other research activities, e.g., satellite missions in the upper atmosphere and other databases such as the Solar-Terrestrial Data Analysis and Reference System (Murata et al. 2002; Kunitake et al. 2013). We believe that our long-term database will play an important role for the international scientific community. In particular, we have

contributed to the building of a database that enables users to search effectively and access the global database obtained through international cooperative projects such as the IGY and CAWSES. However, promoting the use of the IUGONET's tools will not succeed without international and open data exchange. We hope that the SCOSTEP and WDS will promote such exchange. It would be helpful for us if the SCOSTEP sets a general regulation regarding the opening of data, as do other international science communities, e.g., meteorology and hydrology, such as setting the maximum moratorium period to 1 or 2 years for data obtained by international scientific projects.

Conclusions

- The IUGONET is a Japanese project that aims to construct an online system to provide an MD database and analysis tool for upper atmospheric research. These have been released on our website (IUGONET 2014b).
- The usefulness of the IUGONET has been proven by the increasing number of domestic and international accesses to its website by researchers from a variety of disciplines. International collaborations between the IUGONET and other data networks, such as ESPAS and SPASE, are continuing to secure interoperability.
- The IUGONET is an excellent tool for educating students and young scientists in developing countries because of its well-documented database and instructive analysis tools.
- The IUGONET community has been contributing to SCOSTEP programs, and it will collaborate with SCOSTEP's new program, the 'Variability of the Sun and Its Terrestrial Impact', not only in its scientific activities, but also in the establishment of E-infrastructure and capacity building.
- We welcome any kind of cooperation, including increasing the interoperability and MD exchange among the database development groups.

Availability and requirements

Project name: Inter-university Upper atmosphere Global Observation NETwork (IUGONET) project Project home page: http://www.iugonet.org/en/ Operating system(s): Windows, Mac OS, Linux Programming language: IDL (for full use of UDAS/ SPEDAS including command line tools) Other requirements: SPEDAS (for use of UDAS)

Other requirements: SPEDAS (for use of UDAS) **License:** IDL license (for full use of UDAS)

Any restrictions to use by non-academics: Any IUGONET products are freely available from the home page with the exception of IDL license for full use of UDAS.

Additional files

Additional file 1: IUGONET_Observatory.KMZ. A KMZ file for Google Earth to show the locations of IUGONET observatories and each link to the metadata database.

Additional file 2: IUGONET_Instrument.KMZ. A KMZ file for Google Earth to show the location and parameters of IUGONET instruments and each link to the metadata database.

Abbreviations

CAWSES: Climate And Weather of the Sun-Earth System; CEDAR: Coupling, Energetics, and Dynamics of Atmospheric Regions; ESPAS: A European project titled the near-earth space data infrastructure for e-science; ICSU: International Council of Scientific Unions; IGY: International Geophysical Year: IUGONET: Inter-university Upper atmosphere Global Observation NETwork; KML: formerly Keyhole Markup Language; MAGDAS: MAGnetic Data Acquisition System; MD: metadata; MDDB: metadata database; NASA: National Aeronautics and Space Administration; NGDC: National Geophysical Data Center; NOAA: National Ocean and Atmosphere Administration: NSSDC: National Space Science Data Center: OMTI: Optical Mesosphere Thermosphere Imagers; SCOSTEP: Scientific Committee on Solar-Terrestrial Physics; SPASE: Space Physical Archive Search and Extract; STP: solar-terrestrial physics; SuperDARN: Super Dual Aurora Radar Network; UDAS: iUgonet Data Analysis Software; VarSITI: Variability of the Sun and Its Terrestrial Impact: VHO: Virtual Heliospheric Observatory: VMO: Virtual Magnetospheric Observatory; VSO: Virtual Solar Observatory; VxO: a Virtual Observatory; WDC: World Data Center; WDS: World Data System.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

The named authors contributed directly to the capacity-building activity of the IUGONET, and they are responsible for the documentation used in this paper. All authors read and approved the manuscript.

Authors' information

Except for the named authors, the IUGONET project team members as of 31 March 2014 are as follows (in alphabetical order within each institution): Masato Kagitani, Yasumasa Kasaba, Yuto Katoh, Atsushi Kumamoto, Hiroaki Misawa, Takahiro Obara, Takeshi Sakanoi, Naoki Terada, Fuminori Tsuchiya, Manabu Yagi (Tohoku University), Akira Kadokura, Hiroshi Miyaoka, Takuji Nakamura, Yasunobu Ogawa, Masaki Okada, Natsuo Sato, Yoshimasa Tanaka, Yoshihiro Tomikawa (National Institute of Polar Research), Ryoichi Fujii, Yoshizumi Miyoshi, Tatsuki Ogino, Yuichi Otsuka, Kazuo Shiokawa, Norio Umemura (Nagoya University), Jun-ichi Furumoto, Hiroyuki Hashiguchi, Toshihiko Iyemori, Naoki Kaneda, Yukinobu Koyama, Masahito Nosé, Kazunari Shibata, Masahiko Takeda, Hiroaki Toh, Toshitaka Tsuda, Masanori Yabuki, Mamoru Yamamoto (Kyoto University), Daisuke Ikeda, Kiyohumi Yumoto, and Akimasa Yoshikawa (Kyushu University).

Acknowledgements

We express deep sadness at the passing of Professor Takayuki Ono in December 2013; he was the one of the five professors who started the IUGONET project. We appreciate the fruitful comments and discussions with Dr. Tohru Araki, Professor Figmeritus of Kyoto University. We also appreciate the very constructive comments of the two anonymous reviewers that helped us in revising and improving the manuscript. AY acknowledges the first executive director of the IUGONET, Dr. Hiroo Hayashi, as the succeeding director for June 2012 to March 2014.

Author details

¹Solar-Terrestrial Environment Laboratory, Nagoya University, Furo-cho, Chikusa-ku, Nagoya 464-8601, Japan. ²National Institute of Polar Research, 10-3 Midori-cho, Tachikawa, Tokyo 190-8518, Japan. ³Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan. ⁴International Center for Space Weather Science and Education, Kyushu University, 6-10-1, Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan. ⁵Kwasan and Hida Observatories, Graduate School of Science, Kyoto University, Kurabashira, Kamitakara-cho, Takayama, Gifu 506-1314, Japan.

Received: 15 November 2014 Accepted: 10 December 2014 Published online: 08 January 2015

References

- Abe S, Umemura N, Koyama Y, Tanaka Y, Yagi M, Yatagai A, Shinbori A, UeNo S, Sato Y, Kaneda N (2014) Progress of the IUGONET system - metadata database for upper atmosphere ground-based observation data. Earth Planets Space 66(11):133, doi:10.1186/1880-5981-66-133
- Davila J, Tsuda T, Climate And Weather of the Sun-Earth System (CAWSES-II), http://www.cawses.org/CAWSES/Home.html. Accessed 7 Oct 2014
- Grayzeck EJ, Welcome to the NSSDC! http://nssdc.gsfc.nasa.gov/. Accessed 7 Oct 2014 Gurman, JB, Virtual Solar Observatory. http://docs.virtualsolar.org/. Accessed 7 Oct 2014
- Hamaguchi R (2013) A study on development of statistical analysis system for variations of atmospheric environment. Graduate School of Informatics, Kyoto University, Master Thesis (in Japanese)
- Hayashi H, Koyama Y, Hori T, Tanaka Y, Abe S, Shinbori A, Kagitani M, Kouno T, Yoshida D, UeNo S, Kaneda N, Yoneda M, Umemura N, Tadokoro H, Motoba T, IUGONET project team (2013) Inter-university Upper Atmosphere Global Observation Network (IUGONET). Data Sci J 12:WDS179–WDS184, doi:10.2481/dsj.WDS-030
- IUGONET (2014a) Progress of registration to IUGONET metadata database, http://www.iugonet.org/en/mdblist.html. Accessed 14 May 2014
- IUGONET (2014b) IUGONET Inter-university Upper atmosphere Global Observation NETwork, http://www.iugonet.org/en/. Accessed 7 May 2014
- King T, Thieman J, Roberts DA (2010) SPASE 2.0: a standard data model for space physics. Earth Sci Inform 3:67–73, doi:10.1007/s12145-010-0053-4
- Kunitake M, Yamamoto K, Watari S, Ukawa K, Kato H, Kimura E, Murayama Y, Murata KT (2013) Solar-Terrestrial data Analysis and Reference System (STARS) – its high potentiality for collaborative research. Data Sci J 12:WDS225–WDS228
- McGuire R, SPDF Coordinated Data Analysis Web (CDAWeb), http://cdaweb.gsfc. nasa.gov/about.html. Accessed 7 Oct 2014
- Miyoshi Y, Ono T, Takashima T, Asamura K, Hirahara M, Kasaba Y, Matsuoka A, Kojima H, Shiokawa K, Seki K, Fujimoto M, Nagatsuma T, Cheng CZ, Kazama Y, Kasahara S, Mitani T, Matsumoto H, Higashio N, Kumamoto A, Yagitani S, Kasahara Y, Ishisaka K, Blomberg L, Fujimoto A, Katoh Y, Ebihara Y, Omura Y, Nose M, Hori T, Miyashita Y et al (2012) The Energization and Radiation in Geospace (ERG) Project. In: Summers D, Mann IR, Baker DN, Schulz M (eds) Dynamics of the Earth's radiation belts and inner magnetosphere, vol 199, Geophys. Monogr. Ser. AGU, Washington, D.C., pp 103–116. doi:10.1029/ 2012BK001304
- Murata T, Okada M, Abe F, Araki T, Matsumoto H (2002) A design and estimation of distributed meta database for Solar-Terrestrial Physics Observation Data, IPSJ Transaction on [database], No. SIG 12 (TOD 16), 115–130 (in Japanese with English abstract).
- NOAA National Geophysical Data Center, SPIDR: SPIDR Home, http://spidr.ngdc. noaa.gov/spidr/. Accessed 7 Oct 2014
- CAWSES Office, CAWSES Home, http://www.bu.edu/cawses/. Accessed 7 Oct 2014 Rideout B., Welcome to the CEDAR Archival Madrigal Database, http://cedar.
- openmadrigal.org/. Accessed 7 Oct 2014
- Tanaka Y-M, Shinbori A, Hori T, Koyama Y, Abe S, Umemura N, Sato Y, Yagi M, UeNo S, Yatagai A, Ogawa Y, Miyoshi Y (2013) Analysis software for upper atmospheric data developed by the IUGONET project and its application to polar science. Adv Polar Sci 24:231–240, doi:10.3724/SPJ.1085.2013.00231
- The ESPAS Consortium, Welcome to the EU FP7 ESPAS Project, http://www. espas-fp7.eu/. Accessed 7 Oct 2014
- UeNo S, Yumoto K, Yoshikawa A, Makita K, Munakata K, Mizuno A, Tsuda T (2013) Report of capacity-building activities of Japan during CAWSES-II period, (abstract/presentation of the CAWSES-II symposium).
- Yatagai A, Tanaka Y, Abe S, Shinbori A, Yagi M, UeNo S, Koyama Y, Umemura N, Nosé M, Hori T, Sato Y, Hashiguchi NO, Kaneda N, IUGONET project team (2014) Interuniversity upper atmosphere global observation network (IUGONET) meta-database and analysis software. Data Sci J 13:DA37–PDA43

Submit your manuscript to a SpringerOpen[®] journal and benefit from:

- Convenient online submission
- ► Rigorous peer review
- Immediate publication on acceptance
- Open access: articles freely available online
- High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at > springeropen.com