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Activities of the Japanese Space Weather Forecast Center at Communications Research Laboratory

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Space weather / ISES/SEP / CME / Aurora

The International Space Environment Service (ISES) is an international organization for space weather forecasts and belongs to the International Union of Radio Science (URSI). There are eleven ISES forecast centers in the world, and Communications Research Laboratory (CRL) runs the Japanese one. We make forecasts on the space environment and deliver them over the phones and through the Internet. Our forecasts could be useful for human activities in space. Currently solar activity is near maximum phase of the solar cycle 23. We report the several large disturbances of space environment occurred in 2001, during which low-latitude auroras were observed several times in Japan.

INTRODUCTION

Predictions of the space environment (e.g., occurrence of solar flares, solar energetic particle events, and geomagnetic storms) are carried out everyday by forecast centers of the International Space Environment Services (ISES). The ISES is a permanent service of the Federations of Astronomical and Geophysical Data Analysis Services (FAGS), under the International Union of Radio Science (URSI) in association with the International Astronomical Union (IAU) and the International Union of Geodesy and Geophysics (IUGG). The ISES used to be known as the International URSI-gram and World Days Services (IUWDS) until 1996. There are eleven operating forecast centers of the ISES all over the world, located in Australia (Sydney), Belgium (Brussels), Canada (Ottawa), China (Beijing), Czech Republic (Prague), India (New Delhi), Japan (Tokyo), Poland (Warsaw), Russia (Moscow), Sweden (Lund), and the USA (Boulder) as shown in Figure 1. Host institutions responsible for the ISES forecast centers are summarized in Table 1. The center in the USA plays the special role of hub for exchanging data and forecasts among the ISES forecast centers. In Japan, Communications Research Laboratory (CRL) operates the Japanese forecast center of the ISES. This paper reports on the activities of Japanese space weather forecast center and several large space environment disturbances occurred in 2001.

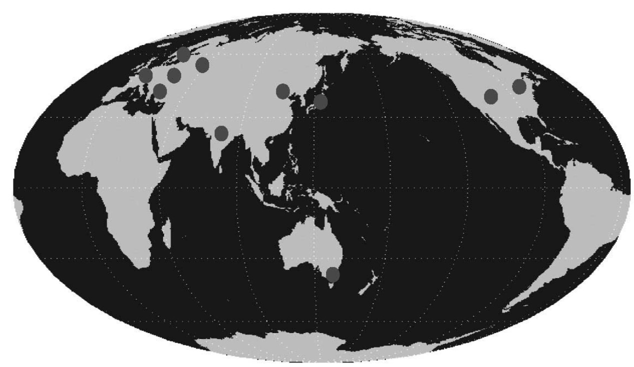

Fig. 1. Location of the ISES forecast centers.

EFFECTS OF SPACE ENVIRONMENT ON OUR DAILY LIFE

Our civilization increasingly depends on technology that is affected by conditions of the space environment[1–2] (see Figure 2). Satellites are heavily used for communication, entertainment broadcasts, metrological observations, navigation, and more. As examples, world news is now delivered through communication satellites in real-time, meteorological satellites provide information on typhoons, navigation systems relay on the global positioning system that use satellites. Satellites failures are frequently associated with severe disturbances of the space environment (e.g.,

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Table 1. Location of the ISES forecast centers and their host institutions.

Location of forecast centers	Host institutions	URL address
Beijing (China)	Beijing Astronomical Observatory	http://rwcc.bao.ac.cn/
Boulder (USA)	NOAA/Space Environment Center	http://www.sec.noaa.gov/index.html
Brussels (Belgium)	Royal Observatory of Belgium	http://sidc.oma.be/index.php3
Lund (Sweden)	Lund Space Weather Center	http://www.irfl.lu.se/HeliosHome/forecastservice.html
Moscow (Russia)	Hydro-meteorological Service	
New Delhi (India)	National Physical Laboratory	
Ottawa (Canada)	Geological Survey	http://www.geomag.nrcan.gc.ca/geomag/e_ottrwc.html
Prague (Czech Republic)	Institute of Atmospheric Physics	http://rwcprague.ufa.cas.cz/
Sydney (Australia)	Ionosphere Prediction Services (IPS)	http://www.ips.gov.au/
Tokyo (Japan)	Communications Research Lab.	http://hirweb.crl.go.jp/index.html
Warsaw (Poland)	Space Research Center	http://www.cbk.waw.pl/rwc/rwc.html

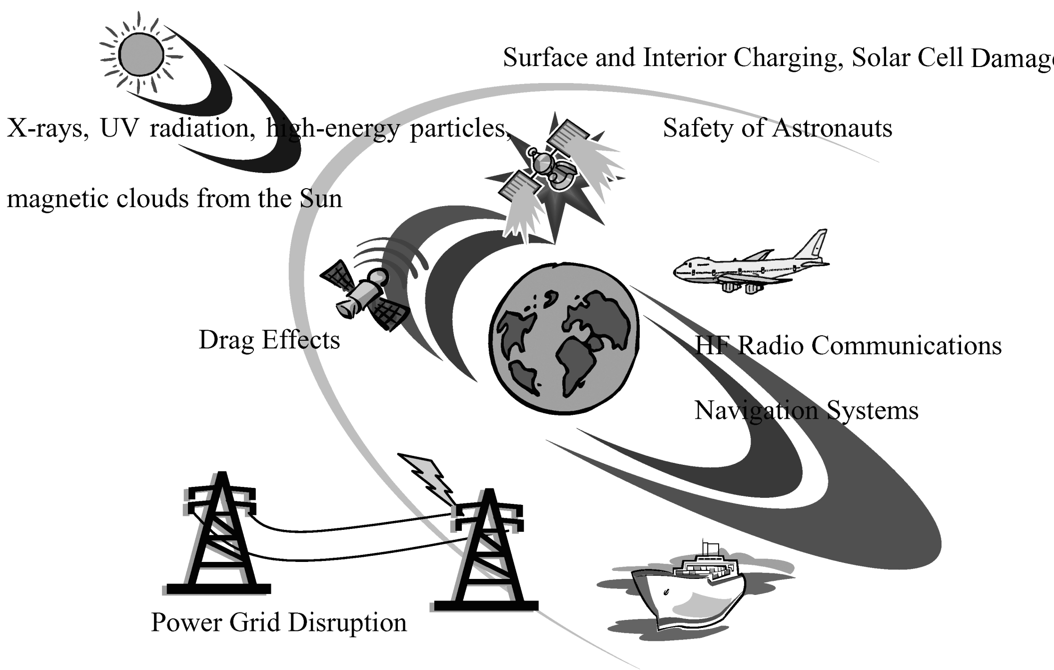

Fig. 2. Effects of space weather.

increases of energetic particles or electrons, or strong geomagnetic storms). An enormous bombardment by solar energetic particles degrades the solar batteries of satellites and shortens their lifetime. Errors of positioning increase when there are strong disturbances in the ionosphere. Transpacific flights still depend on HF (high frequency) communication system, which experience short wave fadeout (SWF) degradation caused by large solar flares. The induced current of strong geomagnetic storms damages power grids, and blackouts occur in the worst case. One example is from Canada in March 1989, when the transformers of power grids burned out because of a large geomagnetic storm, causing widespread blackouts.

ACTIVITIES OF JAPANESE FORECAST CENTER

Japanese forecasts of the space environment were initially started to support HF radio communications in 1945. Data exchange among centers in the world began in 1957 for the International Geophysical Year (1957–1958). Radio Research Laboratory (currently Communications Research Laboratory, CRL) joined this data exchange as a regional warning center. CRL started the "Space Weather Project" in 1989 because of the increase of human activities in space.

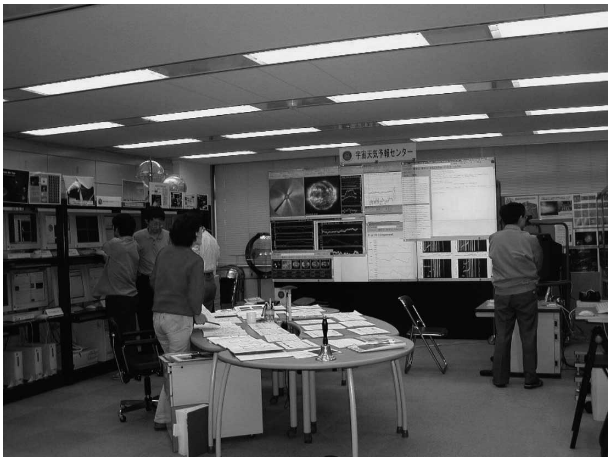

Fig. 3. The space weather center of CRL in Tokyo, Japan.

In the USA, the National Space Weather Program[3] started in 1995, and ESA started a similar program[4] in 1998. The Japanese space weather forecast center started operating in Tokyo in 2001. Figure 3 shows a meeting of forecasters at the space weather center to make forecasts; such meetings are held almost daily.

The Japanese forecast center collects data on solar activities, solar wind conditions, geomagnetic activities, aurora activities, and ionosphere conditions using its own facilities in near real-time. The sun is monitored by ground-based optical and radio telescopes. Solar wind data observed by the ACE spacecraft and aurora images taken by the IMAGE satellite are directly received at CRL. Geomagnetic activities are monitored via CRL's geomagnetic observation network in the western pacific region. CRL operates HF radar facilities in Alaska as a part of an international radar network in the northern arctic region, and has aurora monitoring cameras on the northern island of Japan (Hokkaido). Conditions of the ionosphere above Japan are monitored by CRL's ionosphere observation network.

The Japanese center issues forecasts of the space environment everyday and delivers them over the phone and through the Web. When a large disturbance of the space environment (e.g., a M-class long duration flare, an X-class flare, a proton event with energy greater than 10 MeV and flux greater than 10 proton flux unit (pfu), or a strong geomagnetic storm with magnitude more than 100 nT) happens, a special report is delivered to several tens of professional users (e.g., power companies, satellite operators, and insurance companies) by fax. These reports are also delivered by e-mail and through the Web. Approximately seven hundreds of users are received our reports and there are approximately fifty thousand accesses per a month to our Web site.

SPACE ENVIRONMENT DISTURBANCES AROUND THE MAXIMUM PHASE OF SOLAR CYCLE 23

Solar activity is modulated on an 11-year cycle; we are around the maximum phase of solar cycle 23 now. Here, we report several large space environment disturbances in 2001. Aurora was observed associated with geomagnetic disturbances on 31 March, on 22 October, and on 24 November in Hokkaido. Table 2 shows a list of historically large solar

Table 2. List of large peak flux events of solar energetic protons with energy of more than 10 MeV and with peak flux more than 5,000 pfu since 1967.

Rank	Date and time (UT) of peak flux	Peak flux (pfu)
1	1972-Aug-04	86,000
2	1991-Mar-24 03:25	43,000
3	1989-Oct-20 16:00	40,000
4	2001-Nov-06 02:15	31,700
5	2000-Jul–15 12:30	24,000
6	2001-Nov-24 05:55	18,900
7	2000-Nov-09 16:00	13,300
8	2001-Sep-25 21:00	12,900
9	1994-Feb-21 09:00	10,000
10	1989-Aug-13 07:10	9,200
11	1989-Dec-01 13:40	7,300

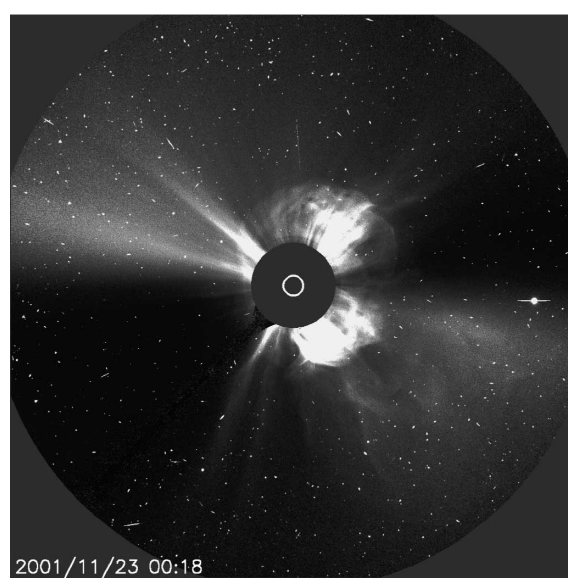

Fig. 4. A halo CME observed by the SOHO/LASCO on 23 November 2001 (courtesy of SOHO/LASCO consortium).

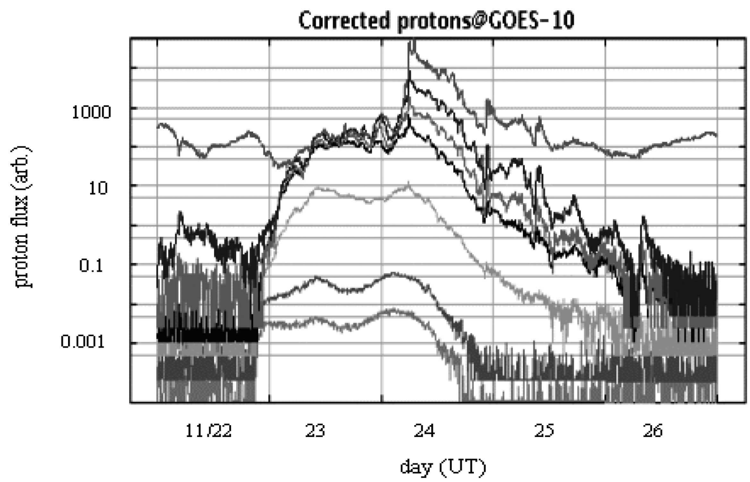

Fig. 5. Proton fluxes observed by the GOES satellite.

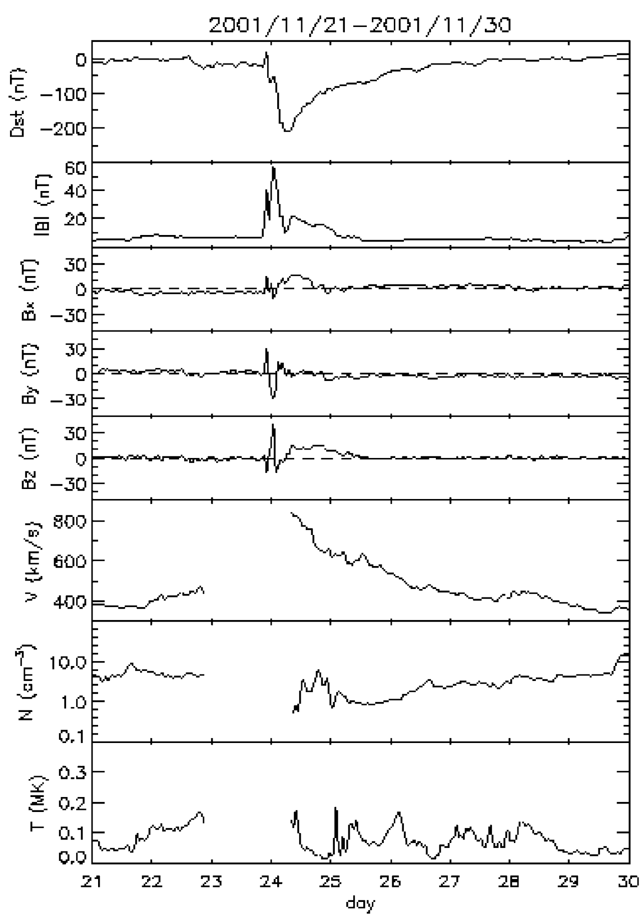

Fig. 6. Dst index and solar wind parameters observed by the ACE spacecraft.

energetic particle (SEP) events having a peak flux more than 5,000 pfu. This list was produced based on the lists of Shea and Smart[5] and Watari, Kunitake, and Watanabe[6]. Three large SEP events occurred in 2001 according to this table. Figure 4 shows a halo coronal mass ejection (CME), which is a solar coronal disturbance towards the earth, observed at 0018 UT on 23 November by the Large Angle and Spectrometric Coronagraph (LASCO) on board the Solar and Heliospheric Observatory (SOHO) spacecraft. This CME was associated with M9.9/2N flare (S15W34) at 2233 UT on 22 November. The 6th SEP event in Table 2 began at 2320 UT on 22 November and reached a peak value of 18,900 pfu at 0555 UT on 24 November associated with a shock passage of the CME (see Figure 5). A strong geomagnetic storm occurred due to this CME passage on 24 November and a red tinged aurora accompanying this event was observed in the middle part of Japan. Figure 6 shows Dst index, which expresses geomagnetic activity, and solar wind parameters observed by the ACE spacecraft. Plasma observation of solar wind was affected by the strong SEP event on 23 as shown in Figure 6.

SUMMARY

Space weather forecasts are important to reduce the damage caused by severe environmental disturbances in space. The recent progress of information technology enables the collection of observational data in near real-time, but the resulting forecasts still depend on an individual forecaster's skill. Numerical forecasts based on models are important for improving the accuracy of forecasts, so present research is focusing on this area now.

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eration between ESA and NASA.

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