Japan’s Space Weather Plans

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Agenda

Update of Japanese SWx R&O
  - PSTEP, Hazardous Map, contents
  - 24/7 operation, ICAO Global Center

Next step
  - Ground Base obs.
  - Operational Satellite
  - Post PSTEP: planetary space weather
Update of Japanese SWx R&O
Relation of Needs-Seeds in Space Weather


Sun
- Coronal Hall
- CME/CIR
- Solar flare

IPS
- High speed solar wind
- Plasma cloud
- X-ray

Magnetosphere/Ionosphere
- Disturbance of magnetosphere
  - Increase radiation
  - Increase of high energy particle
- Disturbance ionosphere
  - Ionization of lower ionosphere
  - Increase of electron density
  - Increase of high energy particle
  - Expanding upper atmosphere
- Ground conductivity distribution

Disturbance of magnetosphere

SWx the social needs

- Satellite anomaly
- Human radiation
- Disability of GNSS
- Change the satellite orbit
- GIC

Social hazard/needs
- Hazard to satellite operation
- Hazard to human activity in space
- Hazard to aviation
- Hazard to telecom, broadcast
- Hazard to positioning
- Hazard to power line

Society
- SWx becomes Indispensable information for their task

Academic institutes
- Study of unknown process
PSTEP is a nation-wide project in Japan for space weather & space climate study.

- 20 Institutes & 100 Researchers
Radio propagation model is necessary to notice the usability of HF, VHF and GNSS at a particular point. We develop a new 3D radio propagation model “HF-START”

- The fundamental structure of radio propagation parameter for HF has completed. Validations of the model comparing with observational results are to be executed.
- The model for GNSS is planned to be build cooperated with CNES, France.
- Real time radio propagation model is to be possible by connecting the 3D tomography technique build by Kyoto Univ.

Web service will open soon!
Near real-time HF-START service

Japanese GNSS Tomography

Input from user

- Tx
- Rx
- Date
- Time
- Frequency

Search for interpolated tomography data (Near real-time capability)

Output for user

- MUF-LUF map for specified propagation link
- Specified frequency is usable or should be avoided.

Purpose of Estimation system of human exposure

• Initial purpose
  – Is to establish the system for providing the present radiation level in the airplane when the large proton event is occurred to happen to the GLE events.

• Final goal
  – Is to develop the system to provide the forecast of temporal variation of human radiation in the airplane with several hours from the event occurred.
  – And to develop the system to estimate the nowcast and forecast of human radiation in ISS

https://wasavies.nict.go.jp/about_e.html
An example of WASAVIES global map

SEP dose rate at 12 km at the peak of GLE69

- 色づけはD-indexに従う (例 赤: severe, D > 80 μSv/h)
- 高度や時間はユーザーが選択可能
An example of exposure along route with WASAVIES

SEP dose rate on the flight route between NRT & JFK at the peak of GLE69

9 routes are available
(NRT-JFK x 3, NRT-LHR x 3, NRT-SYD, SYD-JNB, SYD-SCL)
Survey of SWx impact on Japanese economy

- SWx information users need quantitative estimation of SWx impact on their systems, e.g., power plant, aviation system, radio communication, satellite operation for preparedness. However, any clear information has not been shown ever, especially in Japanese region.
- In this survey, we had two steps; (1) we estimate the worst (most severe) case of SWx phenomena considering with the relation between the scale and the occurrence frequency, and (2) we estimate what happen in Japan in the worst case.
- Especially for aviation and electric power grid, we estimate economic impact with support from social scientists.
3. Structure of Hazardous Map

Preface
1. Space Weather Phenomena
   1.1. What is space weather?
   1.2. Space environment and Space weather phenomena
   1.3. Space weather forecast and action
   1.4. Estimation of space weather impact

2. Social impact of space weather event

3. Impact on power grid

4. Impact on satellite operation

5. Impact on aviation

6. Impact on radio communication/broadcast

7. Impact on satellite positioning

8. Impact on human activity in space

9. Impact on human activity on ground

10. Unsolved issue

11. reference
1.4 Estimation of max. size of space weather event

Discuss occurrence frequency and size in each field and prepare definition table of max. size

![Occurrence frequency of solar flare vs. energy](image1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>often〜several times a year</th>
<th>Once a year</th>
<th>Once in decade</th>
<th>Once in 100 years</th>
<th>Once in 1000 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOES peak flux (1〜8A)</td>
<td>M1 ~ X1</td>
<td>X7.6</td>
<td>X12</td>
<td>X44</td>
<td>X101</td>
</tr>
<tr>
<td>energy(erg)</td>
<td>2.7x10^{28} 〜 2.0x10^{30}</td>
<td>1.0 x10^{31}</td>
<td>1.0 x10^{32}</td>
<td>1.0 x10^{33}</td>
<td>1.0 x10^{34}</td>
</tr>
</tbody>
</table>

- When discussing rare case like once in 1000 years, we should discuss if the value is plausible or not, and should not estimate with simple extrapolation.

![Accumulative occurrence of solar flare with energy](image2)
## 2 Social Impact with Space Weather Event

### Space Weather Impact Matrix (Tentative)

<table>
<thead>
<tr>
<th>Field</th>
<th>Space Weather Phenomena</th>
<th>Hazardous</th>
<th>Often–Several Times in a Year</th>
<th>1/1 Year</th>
<th>1/10 Years</th>
<th>1/100 Years</th>
<th>1/1000 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power Grid</strong></td>
<td><strong>GIC</strong></td>
<td>Shutdown of electricity</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Partial blackout</td>
</tr>
<tr>
<td>Satellite Operation</td>
<td><strong>High Energy Electrons</strong></td>
<td>spacecraft (internal charge)</td>
<td>No</td>
<td>No</td>
<td>disability</td>
<td>disability</td>
<td>lost</td>
</tr>
<tr>
<td></td>
<td><strong>High Energy Protons and Heavy Ions</strong></td>
<td>spacecraft (single event upset)</td>
<td>No</td>
<td>No</td>
<td>disability</td>
<td>disability</td>
<td>lost</td>
</tr>
<tr>
<td></td>
<td><strong>Atmospheric Heating</strong></td>
<td>spacecraft (solar panel)</td>
<td>No</td>
<td>No</td>
<td>light</td>
<td>shorten lifetime</td>
<td>shorten lifetime</td>
</tr>
<tr>
<td></td>
<td><strong>High Energy Electrons</strong></td>
<td>spacecraft (mag. Torca, surface charge)</td>
<td>No</td>
<td>No</td>
<td>light</td>
<td>Disability</td>
<td>lost</td>
</tr>
<tr>
<td>Ionospheric Scintillation</td>
<td><strong>Satellite Operation</strong></td>
<td>Sat. comm.</td>
<td>No</td>
<td>No</td>
<td>telecom disability (short)</td>
<td>telecom disability (long time)</td>
<td>telecom disability (very long)</td>
</tr>
<tr>
<td><strong>Aviation</strong></td>
<td><strong>Micro Wave from the Sun</strong></td>
<td>Radar utility</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>En route</td>
<td>Close</td>
</tr>
<tr>
<td></td>
<td><strong>Radio Black Out</strong></td>
<td>HF utility</td>
<td>No</td>
<td>No</td>
<td>light</td>
<td>Very long time</td>
<td>Very long time</td>
</tr>
<tr>
<td></td>
<td><strong>PCA</strong></td>
<td>HF utility</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>En route</td>
<td>En route</td>
</tr>
<tr>
<td></td>
<td><strong>High Energy Particles (Proton, Heavy Ion)</strong></td>
<td>avionics (single event upset)</td>
<td>No</td>
<td>No</td>
<td>Partial disability</td>
<td>disability</td>
<td>disability</td>
</tr>
<tr>
<td></td>
<td><strong>Human Exposure</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>light</td>
<td>En route</td>
<td>Close</td>
</tr>
<tr>
<td></td>
<td><strong>Plasma Bubble</strong></td>
<td>HF utility</td>
<td>No</td>
<td>No</td>
<td>light</td>
<td>Very long time</td>
<td>Very long time</td>
</tr>
<tr>
<td></td>
<td><strong>Positive Storm</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>System change</td>
<td>System change</td>
<td>System change</td>
</tr>
<tr>
<td></td>
<td><strong>Comms/Communication/Broadcast</strong></td>
<td><strong>Radio Black Out</strong></td>
<td>HF utility</td>
<td>Telecom disability (short)</td>
<td>Telecom disability (short time)</td>
<td>Telecom disability (long time)</td>
<td>Telecom disability (very long)</td>
</tr>
<tr>
<td></td>
<td><strong>Sporadic E</strong></td>
<td>VHF utility</td>
<td>Telecom disability</td>
<td>telecom disability</td>
<td>telecom disability</td>
<td>telecom disability</td>
<td>telecom disability</td>
</tr>
<tr>
<td></td>
<td><strong>Satellite Positioning</strong></td>
<td>Satellite positioning</td>
<td>No</td>
<td>No</td>
<td>Decline of precision (±xm)</td>
<td>Decline of precision (±xm)</td>
<td>Decline of precision (±xm)</td>
</tr>
<tr>
<td></td>
<td><strong>Human in Space</strong></td>
<td>High energy particles (proton and heavy ion)</td>
<td>Human exposure in space</td>
<td>No</td>
<td>No</td>
<td>evacuation</td>
<td>return</td>
</tr>
<tr>
<td></td>
<td><strong>Human on the Ground</strong></td>
<td>High energy particles (proton and heavy ion)</td>
<td>Human exposure on the ground</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td><strong>GIC</strong></td>
<td>Signal misoperation</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
3 social impact of space weather in power grid

3.2.1 GIC size which can take impact on Japanese power grid

Japanese power grid can survive in Hallowing-class event but unknow for larger.

The temperature increase in transformer is about 110 deg with DC 100 A, which is negligible (experiment by TEPCO, Toshiba, Hitachi and Melco).

“Japanese power grid system is completely difference from that in Hydro–Quebec, so we believe we have no similar disabilities with malfunction of safety relay system” report by METI, 2014.

It could be possible that the voltage decrease with iron core satulating by widely spread GIC.

→ It is necessary to discuss the endurance in each transform.
3.2.2 Estimation of possible maximum GIC size in Japan

- Estimate the maximum GIC from maximum magnetic storm discussed in section 1.4
- Discuss local variation of GIC
Update in Operational SWx services in NICT

- ICAO SWx center service in (Nov. 7, 2019)
- 24/7 operational SWx service starts (Dec. 1, 2019)
- Backup center for SWx was built in NICT Kobe Laboratory
- Renewal the NICT SWx Web site
- Legend datasets of SWx were digitize and opened in public
Next Step
Draft Plan of next mid-term of Research in NICT SWx (2021–2025)

Examples of the needs for SWx Service in 2021–2025:

- Space sightseeing and concerning for health
- Spread use of Precise Satellite Positioning and concerning the effect of ionospheric disturbances
- Cycle 25 and concerning the social impact of extreme space weather

Priorities in next term:

1. Numerical forecast
2. Data assimilation
3. Satellite observation
4. Ground observation
5. AI

Contents for easy understanding for Users:

- Input operational observation on the ground and satellites
- Numerical simulation + data assimilation
- Improve the precision of forecast with AI

Users

Improvement of forecast precision
Ionospheric Observation network
Establishment of VHF radar in Chumphon, Thailand on Jan. 2020
“ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO)” is a global alliance of ICT R&D institutes and universities in the ASEAN region and Japan. The mission of ASEAN IVO is to seek and identify strategic ICT research areas in the ASEAN region, and promote collaborative projects in them.

In this project, some new scientists from Laos and Myanmar join us and began to research ionosphere.
**NICT Draft plan in next mid-term research period (2021–2025)**

1. **Development of Satellite Space Environment Sensor**

   - This is the first trial to develop operational SWx sensors in Japan
   - Input the knowledge of scientific satellites to operation cooperating with JAXA and universities
   - There are big differences between scientific and operational policy and scheme; we need to change our mind
   - Start to discuss conceptual design

   **Space Environment Sensors now discussing**
   - **Ion and electron detector, magnetometer**
     - For monitoring solar high energy particles and radiation belt
   - **Satellite charging monitor**
     - For monitoring actual satellite charge and estimate the relation between charge and space environment
   - **Ionospheric imager**
     - For monitoring global distribution of plasma bubbles from the satellites

   We need Your strong support
Research for Space Radiation Environment in Geospace, Moon and Heliosphere ~ a post-PSTEP research project for space weather ~

FY2015-2019: PSTEP: Japanese Nation-Wide Space Wx Research led by Prof. Kusano

Combinations of Basic Research & Operation
- Space Weather Forecast
- Solar Storms (Solar Atmosphere/Solar Wind)
- Geomagnetism
  (Radiation Belts, Ionosphere, GIC)
- Solar Cycle and Climate

2020-: New requirement for Space Wx Research

Human Active Area expands outside the Earth’s magnetosphere
- Human Activities at Moon: Lunar Gateway Project, etc.
- Human Activities at Mars including Interplanetary Space: Mars exploration

Space Radiations (SEP, GCR, Trapped Particle) are the most serious hazards in these area.

Courtesy of Prof. Miyoshi (Nagoya Univ.)
New research group for focusing this topic will be launched in Japan, which contributes to understanding of physics about space radiation in various area and the heliosphere/planetary space weather.

Courtesy of Prof. Miyoshi (Nagoya Univ.)
Summary

• In past five years, we had a fruitful project “PSTEP” and succeeded to communicate with SWx information users and provide several useful contents.
• We prepared “SWx hazardous map” as a guideline of SWx information users. (We should translate the document to English ASAP!)
• In next five years, our direction will change a little “outer” than before, which means to try establishment of operational SWx satellite and planetary SWx.
• It is important to keep/extend ground-based observation in Southeast Asia. We would like to have the action with close relation with these countries.