Research and Operation of Space Weather forecast in Japan

Mamoru Ishii, Dr. Sci.
Space Environment Lab.
National Institute of Information and Communications Technology (NICT)
宇宙天気現象の発生と障害
A large scale solar flare (X9.3) was observed on 20:53JST Sep. 6, 2017, which has been 11 years since similar size event occurred.

Coronal gas ejected simultaneously with the flare and would be forecasted to arrive to the Earth.

The impact on GNSS, HF-communication and power grid from geomagnetic and ionospheric storm were observed.

<table>
<thead>
<tr>
<th>Media</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV</td>
<td>60</td>
</tr>
<tr>
<td>Newspaper</td>
<td>271</td>
</tr>
<tr>
<td>Web news</td>
<td>779</td>
</tr>
</tbody>
</table>

Solar images observed by SDO satellite (Left: visible, Right: UV)

Colonal gas observed by SOHO satellite
The Biggest Solar Storm on Record:
Carrington event (Sep 1859) → Telegraph systems failed

In July 2012, Carrington-level solar flare occurred on the other side of Sun.

If Carrington-like event occurs now?

<table>
<thead>
<tr>
<th>Regions</th>
<th>Best</th>
<th>Worst</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA, Canada</td>
<td>128,808</td>
<td>163,866</td>
</tr>
<tr>
<td>Scandinavia, UK</td>
<td>28,903</td>
<td>37,210</td>
</tr>
<tr>
<td>German, France, Italy, Switzerland, Austria</td>
<td>73,934</td>
<td>95,185</td>
</tr>
<tr>
<td>Europe</td>
<td>102,837</td>
<td>132,395</td>
</tr>
<tr>
<td>Japan</td>
<td>41,746</td>
<td>53,745</td>
</tr>
<tr>
<td>Australia</td>
<td>7,617</td>
<td>9,806</td>
</tr>
</tbody>
</table>

Unit: million dollars

Reference: SWISS Re, Space Weather Workshop 2014, April 8-11, 2014, Boulder US.

Economic loss will be equivalent to the 2011 Tohoku earthquake in each of north America and Europe
(The economic loss of 2011 Tohoku Earthquake: 100,000-250,000(mil.$) )
In case of US

US government discussed SWx as one of the Threat in “US Strategic National Risk Assessment”

<table>
<thead>
<tr>
<th>Threat/Hazard Group</th>
<th>Threat/Hazard Type</th>
<th>National-level Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural</strong></td>
<td>Animal Disease Outbreak</td>
<td>An unintentional introduction of the foot-and-mouth disease virus into the domestic livestock population in a U.S. state</td>
</tr>
<tr>
<td></td>
<td>Earthquake</td>
<td>An earthquake occurs within the U.S. resulting in direct economic losses greater than $100 Million</td>
</tr>
<tr>
<td></td>
<td>Flood</td>
<td>A flood occurs within the U.S. resulting in direct economic losses greater than $100 Million</td>
</tr>
<tr>
<td></td>
<td>Human Pandemic Outbreak</td>
<td>A severe outbreak of pandemic influenza with a 25% gross clinical attack rate spreads across the U.S. populace</td>
</tr>
<tr>
<td></td>
<td>Hurricane</td>
<td>A tropical storm or hurricane impacts the U.S. resulting in direct economic losses of greater than $100 Million</td>
</tr>
<tr>
<td></td>
<td><strong>Space Weather</strong></td>
<td>The sun emits bursts of electromagnetic radiation and energetic particles causing utility outages and damage to infrastructure</td>
</tr>
<tr>
<td></td>
<td>Tsunami</td>
<td>A tsunami with a wave of approximately 50 feet impacts the Pacific Coast of the U.S.</td>
</tr>
<tr>
<td></td>
<td>Volcanic Eruption</td>
<td>A volcano in the Pacific Northwest erupts impacting the surrounding areas with lava flows and ash and areas east with smoke and ash</td>
</tr>
<tr>
<td></td>
<td>Wildfire</td>
<td>A wildfire occurs within the U.S. resulting in direct economic losses greater than $100 Million</td>
</tr>
</tbody>
</table>

Space Weather Operations, Research, and Mitigation (SWORM) was established on Nov. 2014 and discussed on the followings

- National Space Weather Strategy
- Space Weather Action Plan

White house published them on Oct. 2015

Executive order for acceleration of mitigation on space weather disaster on Oct. 2016

Senate accepted additional budget for space weather action on May, 2017

International cooperative framework “Space Weather as a Global Challenge” is conducted on every year since 2016. Now the next symposium will be held on July 24, 2018, hosted by Japanese Embassy in US.
Report of social impact of SWx in governments/insurance companies
Annex 3 of ICAO is determined the mandatory information of meteorology for aviation.
- ICAO discusses to add SWx information in Annex 3 NOW.
- It is expected to use SWx as one of mandatory information for aviation on 2020s.

HF Com. Is only way for telecommunication.

- GNSS
- Human exposure
- Civil aviation
<table>
<thead>
<tr>
<th>Start date</th>
<th>End date</th>
<th>Description</th>
<th>Responsibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2017</td>
<td>Jun 2017</td>
<td>Issue state letter requesting interest in providing the space weather information service</td>
<td>ICAO</td>
</tr>
<tr>
<td>Jun 2017</td>
<td>Sep 2017</td>
<td>Respond to State letter indicating ability to meet criteria for space weather information providers, including funding for site assessment visit and audit</td>
<td>Candidate provider states</td>
</tr>
<tr>
<td>Sep 2017</td>
<td>Oct 2017</td>
<td>Request WMO assistance to evaluate candidate provider states through site assessment visits and audits</td>
<td>ICAO</td>
</tr>
<tr>
<td>Oct 2017</td>
<td>Feb 2018</td>
<td>Conduct site assessment visits and audits of candidate Provider States for space weather information capability</td>
<td>WMO</td>
</tr>
<tr>
<td>Mar 2018</td>
<td>Apr 2018</td>
<td>Complete report to ICAO on candidate Provider States for space weather information capability</td>
<td>WMO</td>
</tr>
<tr>
<td>May 2018</td>
<td>Jun 2018</td>
<td>Review METP recommendations and provide proposals for designation of providers of space weather information for Council consideration.</td>
<td>ICAO</td>
</tr>
<tr>
<td>Jun 2018</td>
<td>Jul 2018</td>
<td>Designate provider(s) of space weather information capability.</td>
<td>ICAO</td>
</tr>
<tr>
<td>Jul 2018</td>
<td>Nov 2018</td>
<td>Commence production and dissemination of space weather information.</td>
<td>Space weather provider(s)</td>
</tr>
</tbody>
</table>
Domestic users: satellite operator, aviation office and companies, power plant companies, HF telecommunicators / broadcasters, resource survey, Univ. and research institutes, amateur radio operators

Forecasting Parameters
• Flare forecast
• Magnetic field forecast
• High-energy particle forecast
• HF propagation forecast

Web access: 160,000/month
No. of e-mail address: 8,000
And also on Facebook, twitter
Research activities in NICT for improving the precision of SWx forecast

Advantages of NICT SWx forecast research:

- Observing network over the western Pacific region: one of the largest in this area
- Simulation techniques: GAIA model is unique in the world
- Development of empirical models with AI: some of them are already used in the operation
2D TEC obs. with High Res. in Japan

Distribution of GPS receivers on GEONET (1,240 points)

TEC variation map at Tohoku earthquake [Tsugawa et al., EPS, 2011]. The red star represents the epicenter.

- We developed an operational TEC observation system with high temporal and spatial resolution (30 sec, 0.15 by 0.15 deg) using 1,240 points of GPS network “GEONET”
Plasma Bubbles

↓ Yokoyama et al. (2015)
It will be possible to forecast the probability of flare occurrence in each active region.
“Taylor made space Weather” is the project to develop a magnetosphere model including satellite shape and material. The present status of the model named “SECURES” is as follows.

- As a real time monitoring of radiation belt, we opened a database of HIMAWARI. Now calibration with comparing the result with other satellite (GOES).
- JAXA is developing numerical satellite model of DRTS.
- NICT is developing a model for estimating high energy particle distribution along the geostationally orbit.
The Asia-Oceania Space Weather Alliance (AOSWA) established on 2010 for information exchange among SWx organizations in Asia and Oceania.

- Members: 27 organizations from 13 countries
- AOSWA workshop is held every one and half years. The last one is hosted by RRA at Jeju, Korea on October, 2016.
- Next workshop will be held on Sep. 19-21 in Bandung, Indonesia hosted by LAPAN.
- Electric newspaper “AOSWA link” is circulated
UNISPACE+50

- UNISPACE+50 marks the fiftieth anniversary of the first UNISPACE conference and takes stock of the contributions to global space governance of the previous three UNISPACE conferences.
- The Committee on the Peaceful Uses of Outer Space (COPUOS) at its fifty-eighth session in June 2015 endorsed a plan of work (A/AC.105/L.297) for UNISPACE+50 to be undertaken by the Office for Outer Space Affairs, the Committee, and the subsidiary bodies of the Committee.
- In order to guide preparatory work for UNISPACE+50, in June 2016 COPUS identified and agreed on seven thematic priorities, as well as their objectives and mechanisms (/71/20)
- Thematic Priorities
  1. Global partnership in space exploration and innovation
  2. Legal regime of outer space and global space governance: current and future perspectives
  3. Enhanced information exchange on space objects and events
  4. International framework for space weather services
  5. Strengthened space cooperation for global health
  6. International cooperation towards low-emission and resilient societies
  7. Capacity-building for the twenty-first century
Summary and Conclusions

- It is eagerly required to estimate the quantitative social impact of SWx.
- Some national governments (e.g., US, UK, Korea), international organizations (e.g., ICAO), and private companies (e.g., Lloyd) reported documents related to SWx disaster and mitigation.
- NICT has been operating space weather forecast since 1988 and improving the precision of the forecast using cutting-edge technology.
- The framework of space weather services has been assigned in the thematic priorities of UNISPACE+50. This framework should be required also in the operation of ICAO space weather centers.
- Many of Asian countries are aware of the importance to measure space weather and are interested in working for space weather service. A decade ago the ground-based observatories had clustered on developed countries. Now we are on the phase to spread the points all around the world.
- We need to discuss the necessary tasks and strategy how we drive the stream, for example, presentation to the decision-maker of the budget, education for glow up the next generation researchers/operators, framework of data sharing etc.