

Introduction of space weather Research and Operation in Asia-Oceania

Mamoru Ishii

Director, Space Environment Laboratory, NICT, Japan

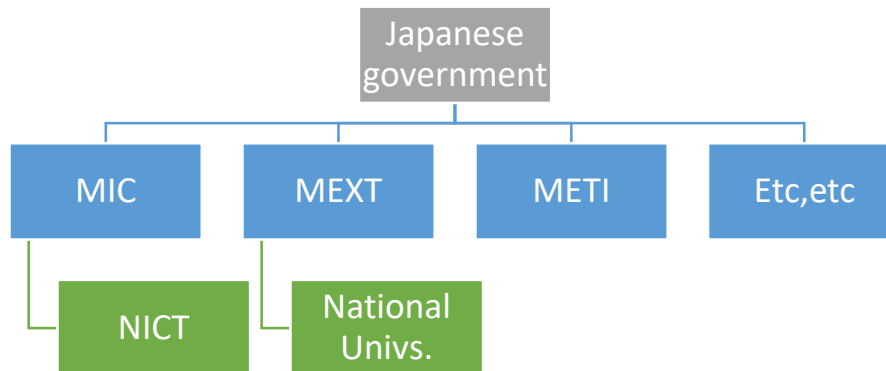
Secretary, Asia-Oceania Space Weather Alliance (AOSWA)

Deputy-Director, International Space Environment Services
(ISES)

NICT

(National Institute of Information and Communications Technology)

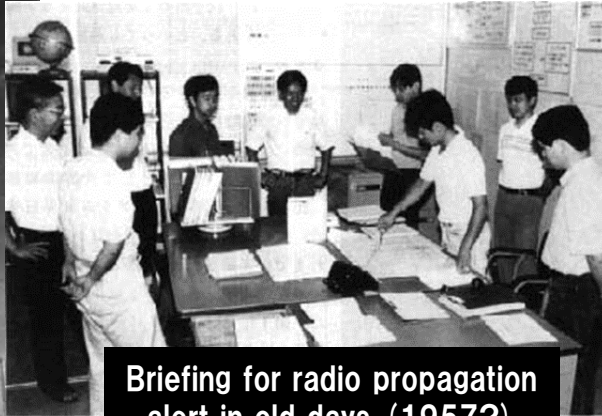
- The “ONLY National Institute” of Information and Communications technology in Japan
- Staff: permanent scientists: 300, temporal scientists: 400, administrative: 200 (approximately).
- Headquarter: Koganei, Tokyo
- Main Branches: Keihanna, Kobe, Kashima, Okinawa
- Observatories: Wakkanai, Hiraiso, Yamagawa, Okinawa



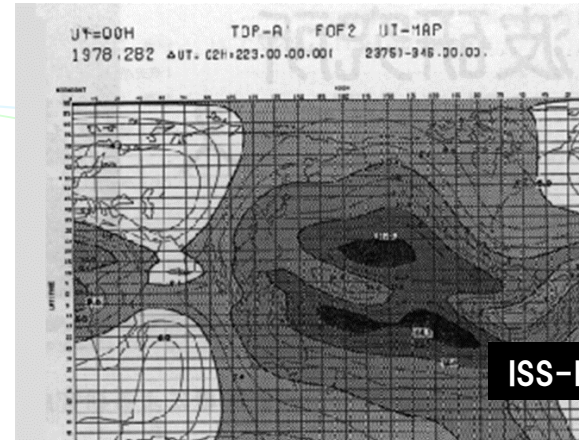
NICT Space Weather Services



Solar radio spectrum antenna
(70-500MHz)



Briefing for radio propagation
alert in old days (1957?)



foF2 global map during Aug-Sep. 1978

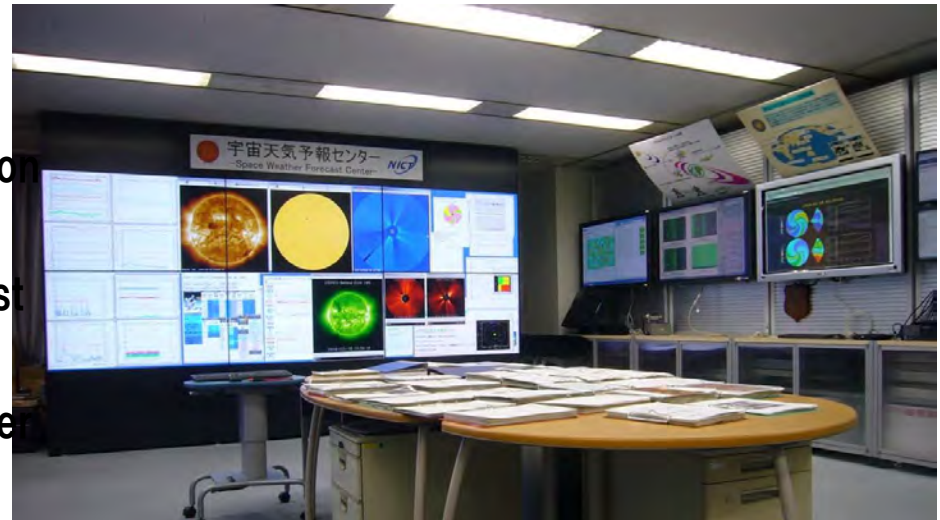


ISS-b "Ume-2" satellite

Since 1952, NICT have operationally measured solar radio spectrum, and started operational alert service for radio propagation since 1957.

In 1978, NICT provided foF2 global map first in the world using satellite observation.

Now, NICT has been providing Space Weather forecast information including weekend, and plan to operate 24/7 since 2019.



The present NICT Space Weather Center

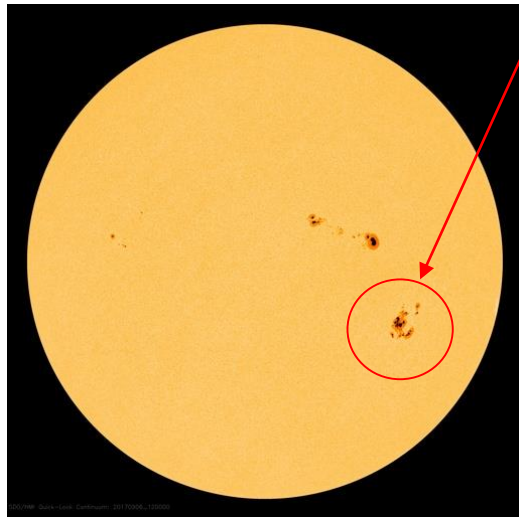
The Solar Flare on Sep. 6, 2017

4

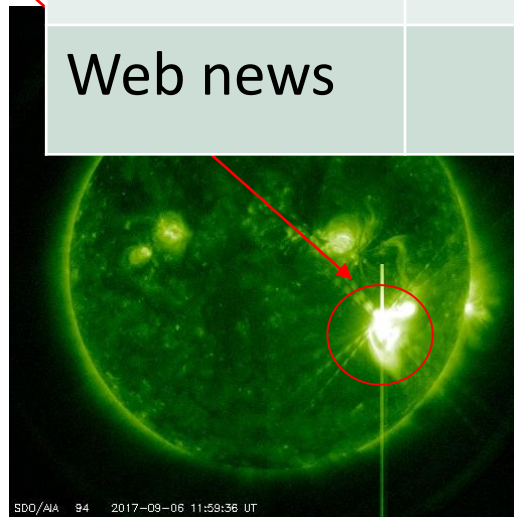
Detail of the event

- ◆ 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 would be forecasted to arrive
- ◆ The impact on GNSS, HF-cor grid from geomagnetic and ion observed.

Sun spot No.



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



Media

Number

TV

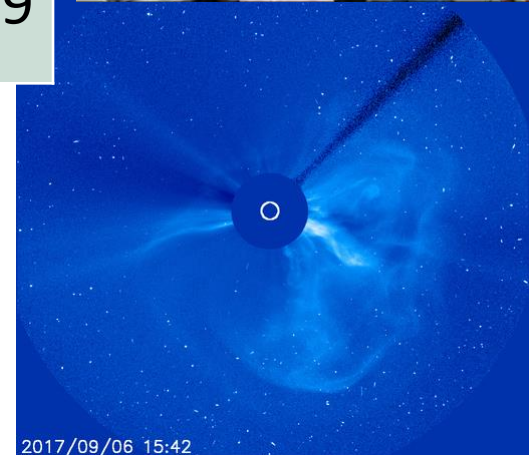
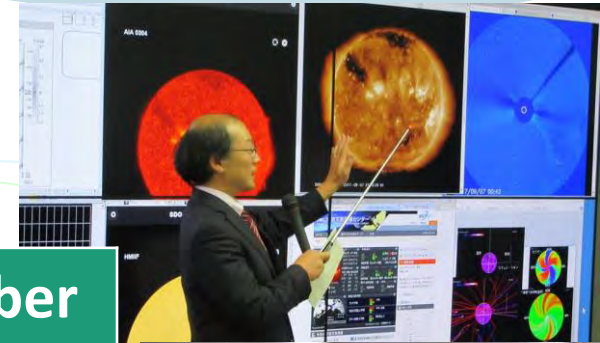
60

Newspaper

271

Web news

779



Colonal gas observed by SOHO satellite

After the Event on Sep. 6, 2017



- Cabinet Office starts the discussion on space weather as a part of SSA in Aerospace Basic Strategy plan
- NICT prepared a robust system of Space Weather services. NICT headquarter locates in Koganei, Tokyo. It has been preparing a back up Center for space weather services at Future ICT Center, Kobe city.
- **The Japanese Radio Law was amended for including space weather as categories of Spectrum User Fee Budget.**
- **NICT started 24/7 human operation for Space Weather services since Dec. 2019.**

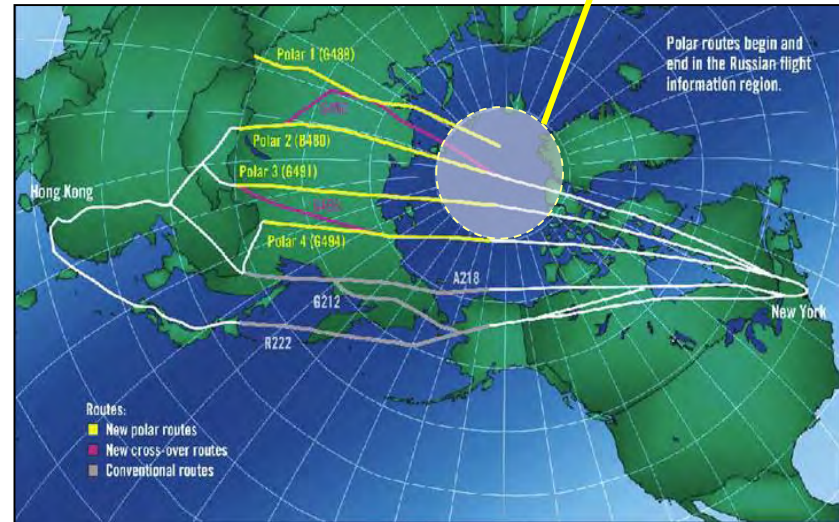
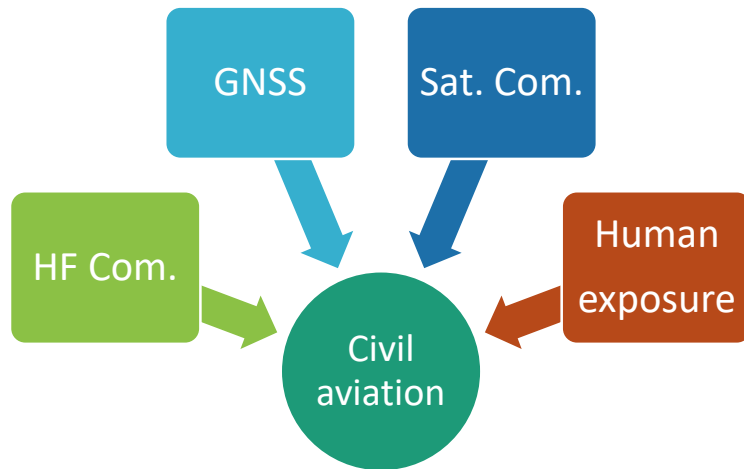
NICT Koganei Campus



ICAO/WG-MISD (MET Information and Service Development)

- 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

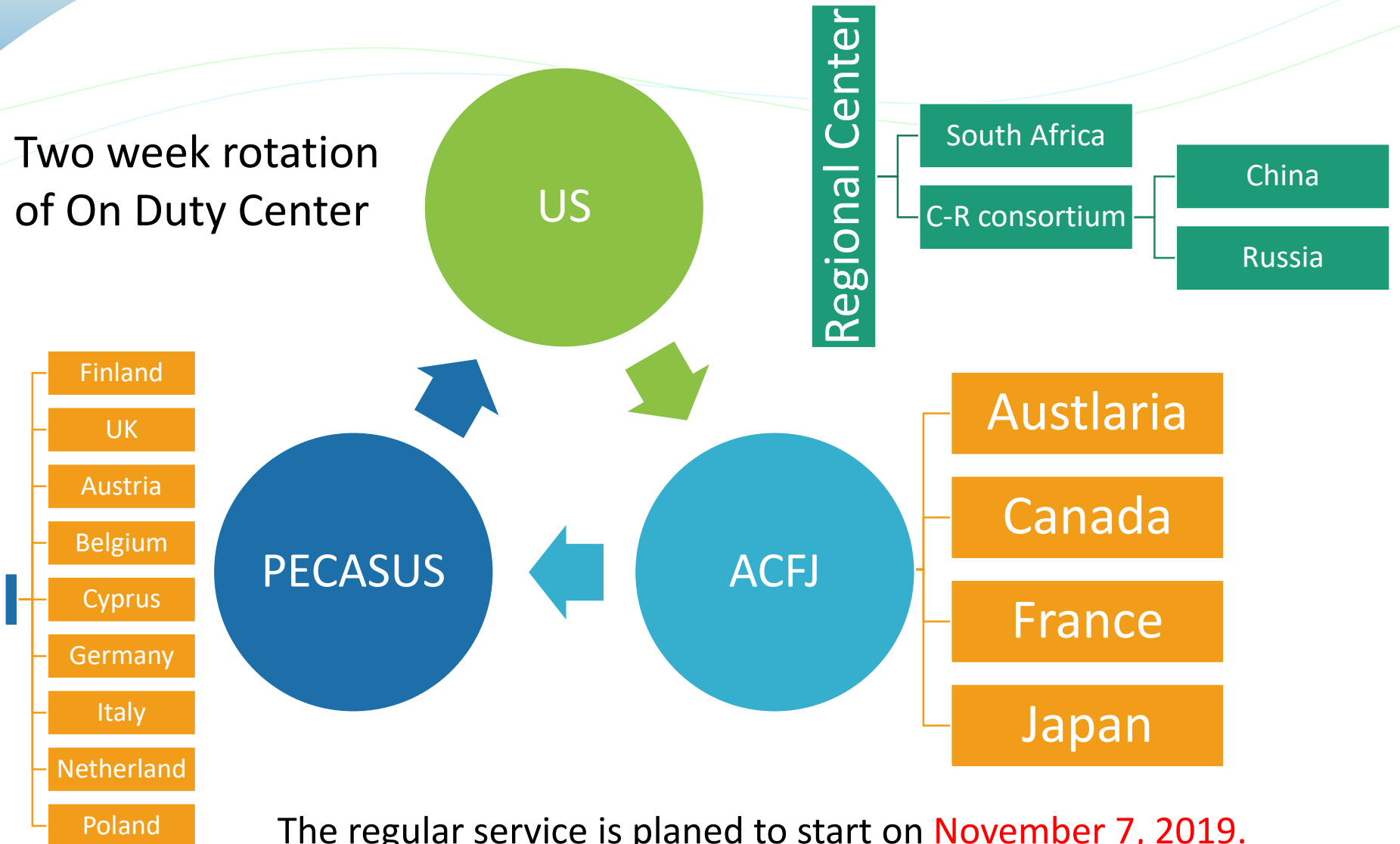


In 2018, The following three entities have assigned as ICAO Space Weather Global Center

- US
- ACFJ (Australia, Canada, France(leader), Japan)
- European Consortium(PECASUS: Austria, Belgium, Cyprus, Finland (leader), Germany, Italy, Netherland, Poland, UK)

ICAO Space Weather Services structure

Two week rotation
of On Duty Center



The regular service is planed to start on November 7, 2019.

AOSWA

Asia-Oceania Space Weather Alliance

Asia-Oceania Space Weather Alliance (AOSWA)

- The Asia-Oceania Space Weather Alliance (AOSWA) established on 2010 for information exchange among Space Weather organizations in Asia and Oceania.
- Members: 27 organizations from 13 countries
- AOSWA workshop is held every one and a half years. The last one was hosted by LAPAN in Bandung, Indonesia in September, 2018.
- Next meeting is scheduled on Aug. 10-13 2020 in Malaysia hosted by UKM.
- Electric newspaper “AOSWA link” is circulated



AOSWA-5 @ Bandung in Sep. 19-21, 2018 hosted by LAPAN, Indonesia

Establishment of VHF radar in Chumphon, Thailand on Jan. 2020



NICT cooperation with Asian Countries

MoU with GISTDA@NICT Otemachi Office,
Nov. 29, 2019



ASEAN IVO symposium@KMITL Chumphon
Campus, Jan. 17, 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.





Space Weather Capability

Space Weather
Operational Office

Central Weather Bureau

中央氣象局

Astronomical Station

天文站

Taiwan Analysis Center for COSMIC

臺灣資料分析中心

Space Weather Operational Office

太空天氣作業辦公室

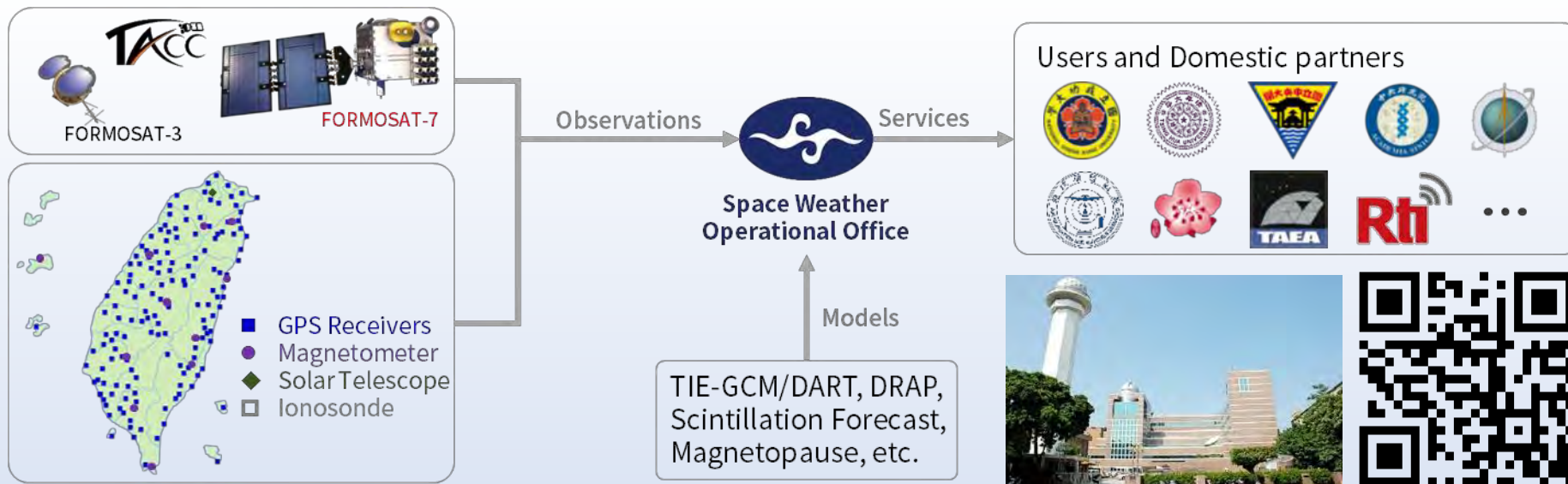


👤 Official agency for weather forecast and service in Taiwan as well as sunspot observatory since 1947.

👤 CWB collaborated with the National Space Organization to process radio occultation data from FORMOSAT-3 & 7.

👤 It started to deliver space weather products and information since 2016.

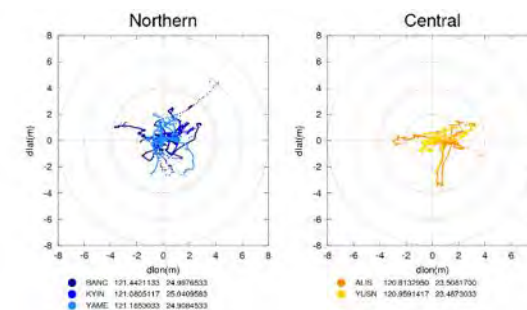
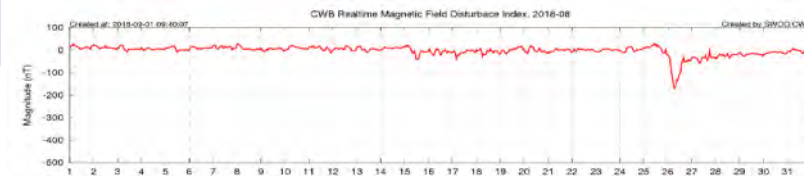
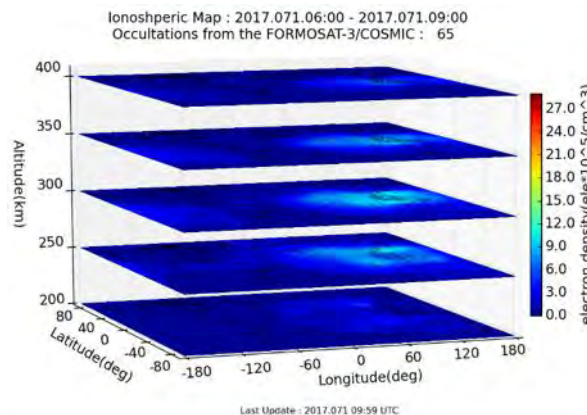
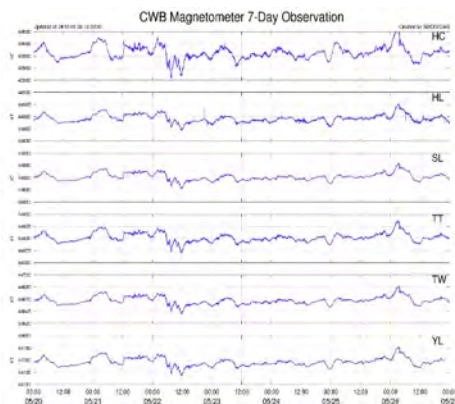
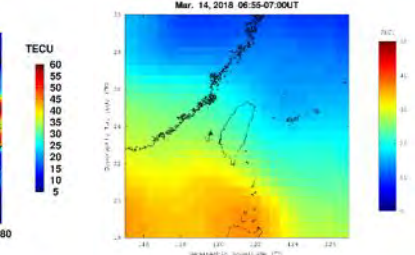
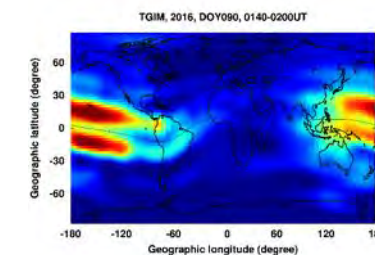
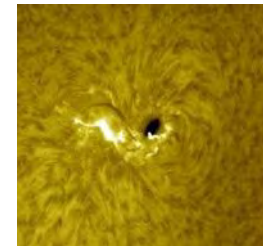
Space Weather Operational Work Flow





Real-time Observation and Monitoring

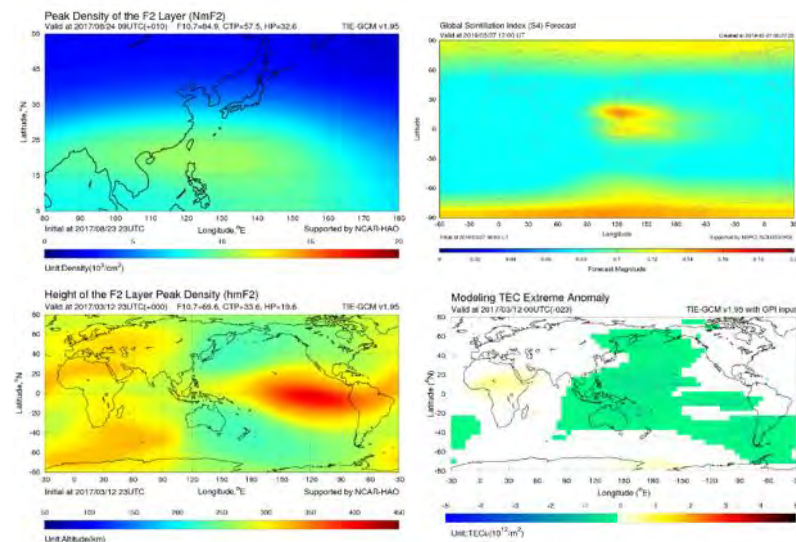
- ✓ Ground solar surface and sunspot observation
- ✓ Real-time global/regional TEC map.
- ✓ Real-time Taiwan magnetometer observation and geomagnetic disturbance index.
- ✓ Real-time Taiwan ground GNSS precise point positioning error monitoring
- ✓ Near real-time global 3D ionospheric electron density structures and specified parameters.



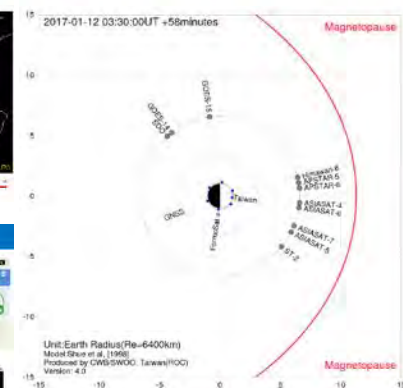
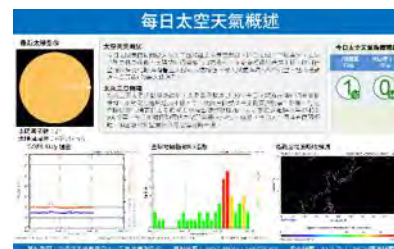
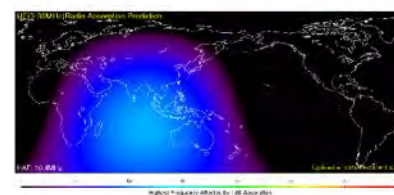


Forecast Model

- ✓ Magnetopause Position Forecast
- ✓ Ionospheric Scintillation Forecast
- ✓ D-region Radio Absorption Estimation
- ✓ Thermosphere-ionosphere Coupled Model
- ✓ Ensemble Data assimilation system for ionospheric space weather.



Check our website for more Information



http://swoo.cwb.gov.tw/V1/index_Eng.htm

Korean Space Weather Center

KSWC's Mission

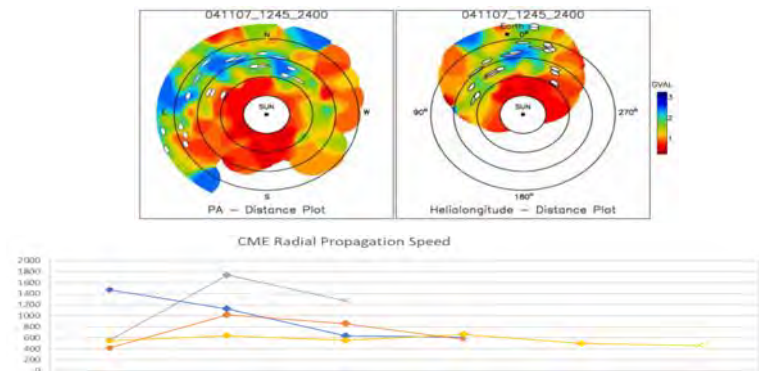
- **Research** on the technology for receiving space radio waves
- **Observation** of solar spots, geomagnetism and ionosphere
- **Analysis** of the received data, the results of observation

Main Task

- **Space weather forecast and alert services**
 - Monitor and analyze solar activities 24 hours a day
 - Provide forecast and alert services to civil area
- **Strengthen space weather cooperation network**
 - Cooperate domestically to mitigate the space weather risk
 - Build international cooperation network with NICT and NOAA(SWPC) to develop more accurate prediction models and improve services



✓ Solar Flare prediction model by Deep learning



International Cooperation - KSWC



<Discussion with NASA JASD>



<SWx conference in Korea>



<Forecaster training with SUPARCO>



<The 4th AOSWA conference in Korea>

<https://spaceweather.rra.go.kr/?lang=en>

E-mail : dyne1225@korea.kr (Jangsuk Choi)

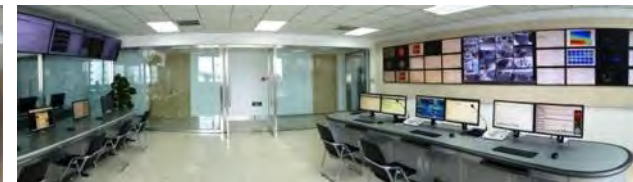
National Space Science Center, Chinese Academy of Sciences (NSSC/CAS)

Main laboratories related to Space Weather

There are two key laboratories related to space weather researches and services at NSSC/CAS: (1) **State Key Laboratory of Space Weather**: the first state key laboratory in space physics in China. Mainly devoted to the investigation of the fundamental space weather processes. (2) **Key Laboratory of Science and Technology on Environmental Space Situation Awareness, CAS (ESSA)**: Mainly devoted to operational space weather observation, modeling, and services. (<http://www.nssc.ac.cn>)

Space Environment Prediction Center (SEPC), NSSC/CAS

The Space Environment Prediction Center (SEPC) in NSSC was established in 1992, which became the first professional organization and official source for providing space weather services in China. It runs under the ESSA key laboratory, while also scientifically supported by the State Key Laboratory of Space Weather in observation and modeling. SEPC is responsible for space weather services for China Manned Space missions, Lunar Exploration missions, and China Space Science Satellites (<http://eng.sepc.ac.cn>).



Space Weather Observations

Ground Based Networks

SEMnet of CAS



Meridian Project

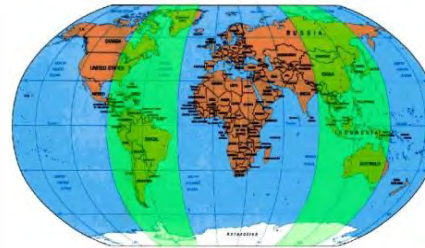


(1) The Space Environment Monitoring Network (SEMnet) of CAS: composed of 17 observatories equipped with a total of 40 ground-based instruments. These key instruments are responsible for providing data in near real time for the purpose of space weather monitoring and forecasting.

(2) The Meridian Project: consists a chain of 15 observatories located roughly along 120°E and 30°N lines, mainly used for basic and applied research and modeling.

Future Missions

International Space Weather Meridian Circle Program (IMCP)



Connect 120°E and 60°W meridian lines forming chains of ground based observatories to enhance the ability of monitoring space environment worldwide.

SMILE Mission



Payloads onboard SMILE:

SXI: X-ray Imaging of the magnetosphere

UVI: UV imaging of the aurora

LIA: Plasma

MAG: Magnetic field

The Solar wind Magnetosphere Ionosphere Link Explorer (SMILE) is a Chinese Academy of Sciences (CAS) and European Space Agency (ESA) collaborative science mission designed to study the interaction between the solar wind and the Earth's magnetosphere.

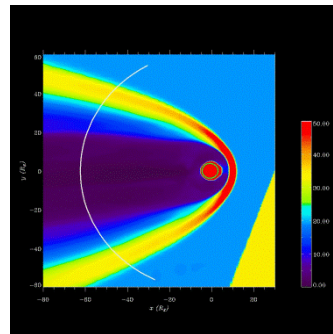
Space Weather Services

Space Weather Models

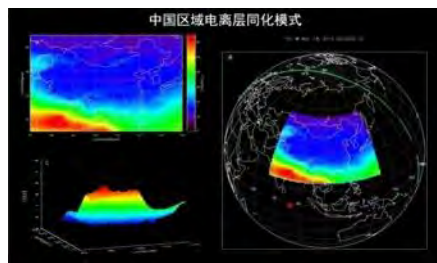
Operational models have been developed covering solar and interplanetary, magnetosphere, ionosphere thermosphere, and solar and geomagnetic indices (F10.7, Ap, Kp, Dst, AE, etc.).



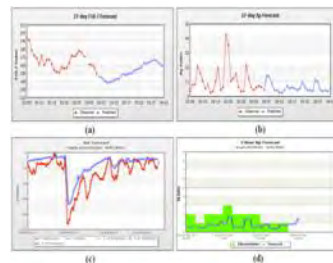
CME Propagation



Magnetosphere



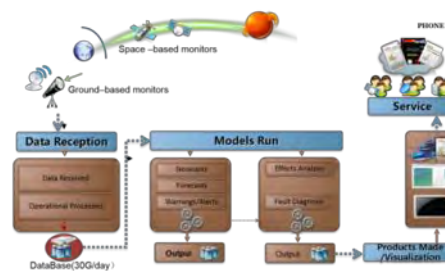
Ionosphere



Indices

Space Weather Services

SEPC of NSSC/CAS develops technology systems to provide both general services to the public and customized services to special users. General services are provided via website, text messages, mobile apps, and China's social networking tools: Weibo and Wechat. Customized users include China's manned space missions, lunar exploration, and China space science satellites.



Technology System



Website and App

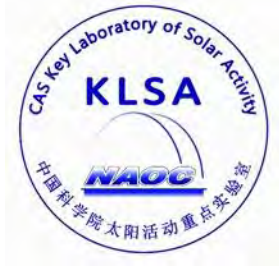


SWx Service for China's manned space missions



CAS Key Laboratory of Solar Activity

National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China



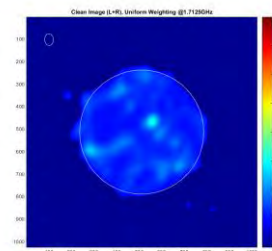
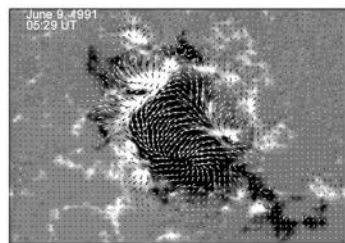
Huairou Observing Station



Mingantu Observing Station



Solar Activity Prediction Center



- Short-term prediction (within 2 or 3 days)
- Medium-term prediction (within 1 or 2 weeks)
- Long-term prediction (in time scale of solar cycle)

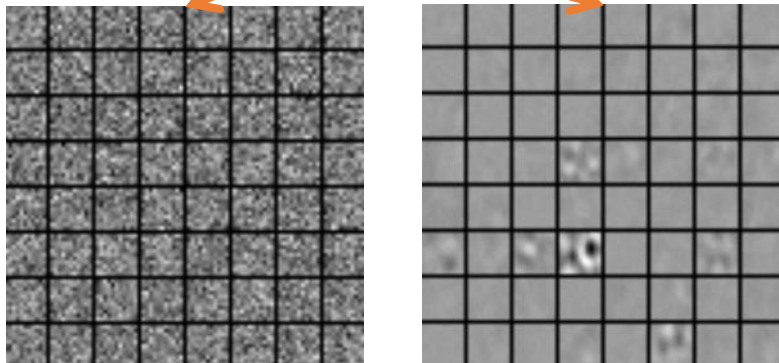
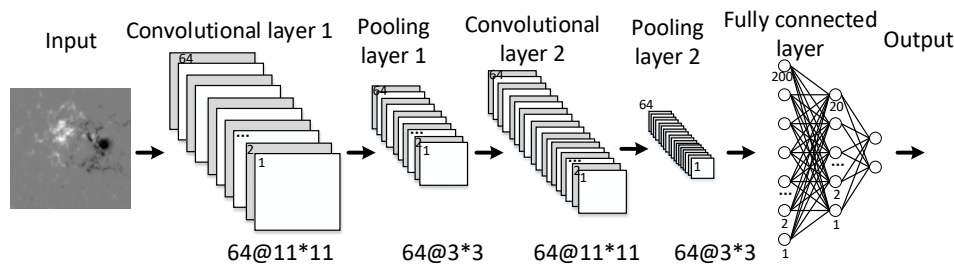
CAS Key Laboratory of Solar Activity

National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China



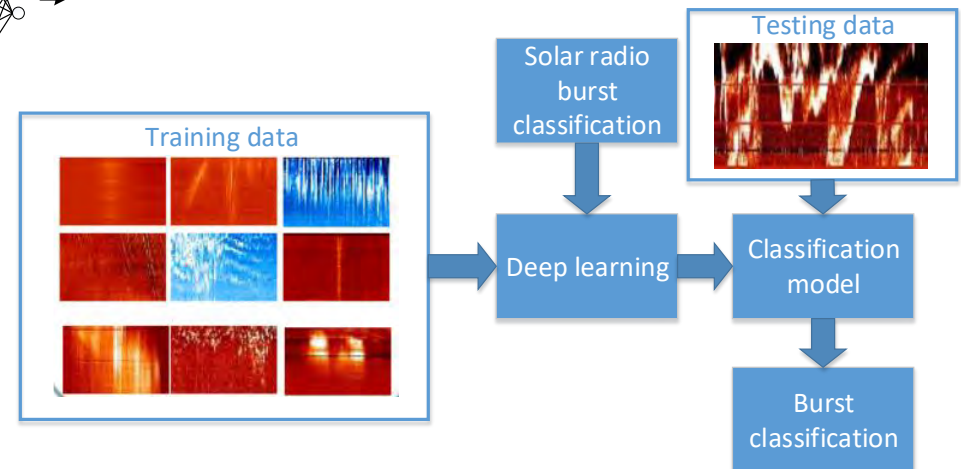
Deep learning based forecasting model and data product

Short-term Solar flare forecasting model



Forecasting patterns can be automatically reached with the training set (Huang et al. (2018), *ApJ*)

Multimodal deep learning for solar radio burst classification



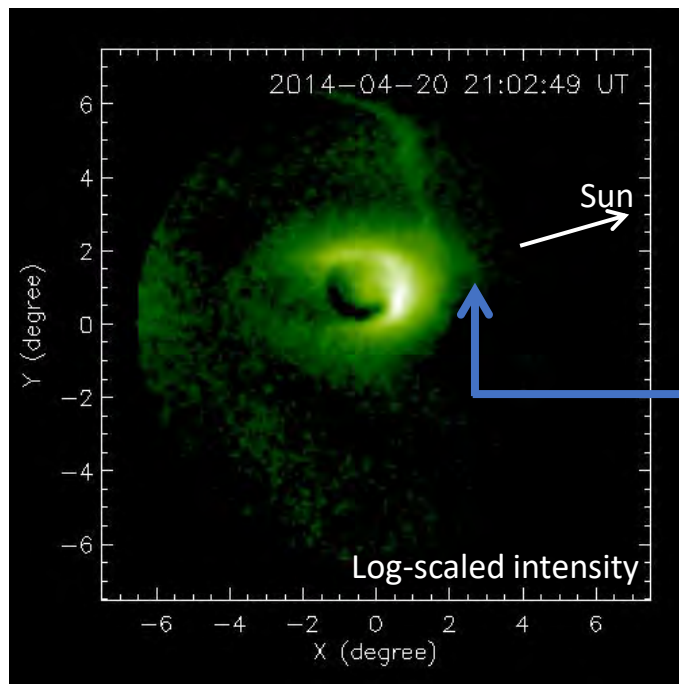
Ma et al. (2017), Pattern Recognition

CAS Key Laboratory of Solar Activity

National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China



Response of the plasmaspheric configuration to substorms



Begin : 2014-04-20 21:02:49 UT
End: 2014-04-22 01:10:07 UT
Cadence: about 10 minutes
Total number of images: 153

**Variation of radial extending distance:
Not a regular torus-shaped structure**

**Reconstructing more realistic
plasmasphere configuration
based on time series EUVC images**

- ✓ FOV: $15^\circ \times 15^\circ$
- ✓ Pixels: 150×150
- ✓ He^+ ions resonantly scattering EUV radiation of sunlight
- ✓ EUV wavelength: 30.4 nm
- ✓ Intensity $\sim \text{He}^+$ column density along LOS

He et al. (2016),
Scientific Reports

Time series images observed by EUVC during 20-22 April 2014

AOSWA

Asia-Oceania Space Weather Alliance

Tack

Vielen Dank

Obrigado

Merci

ありがとうございます

Bedankt

Takk

感謝您

Terima Kasih

谢谢

Grazie

ขอบคุณ

Спасибо

Thank You

Kiitos

Tak

Teşekkür Ederiz

감사합니다

Gracias

Dziękujemy

Σας ευχαριστούμε

Table 3-2. Thresholds for space weather advisory

		Moderate	Severe
GNSS			
	Amplitude Scintillation (S4)(dimensionless)	0.5	0.8
	Phase Scintillation (Sigma-Phi)(radians)	0.4	0.7
	Vertical TEC (TEC Units)	125	175
RADIATION			
	Effective Dose (micro-Sieverts/hour)	30	80
HF			
	Auroral Absorption (Kp)	8	9
	PCA (dB from 30MHz Riometer data)	2	5
	Solar X-rays (0.1 - 0.8 nm)(W-m ⁻²)	1X10 ⁻⁴ (X1)	1X10 ⁻³ (X10)
	Post-Storm Depression (MUF)*	30%	50%

2018 Space Weather as a Global Challenge

- International cooperative framework “Space Weather as a Global Challenge” is conducted on every year since 2016.
- The 3rd meeting of “Space Weather as a Global Challenge” was held at Japan Embassy on July 24, 2018 hosted by Japan Embassy, NICT, JAXA and DoS.
- 77 people attended from various countries.
- Discussing Theme
 - Japan’s Space Weather Efforts and Outlook
 - Perspectives from around the Globe
 - Toward Improved Space Weather Services and preparedness
 - Perspectives from the Private Sector
- Preparedness for severe space Weather disaster with international collaboration and activation of private sector were mainly discussed.



Relation of Needs-Seeds in Space Weather

Solar Terr. Phys.

SWx the social needs

Sun

IPS

Magnetosphere/Ionosphere

influence

Social

hazard/needs

Coronal Hall

High speed solar wind

CME/CIR

Plasma cloud

Solar flare

X-ray

Increase of high energy particle

Disturbance of magnetosphere

Increase radiation

Increase of high energy particle

Disturbance ionosphere

Ionization of lower ionosphere

Increase of electron density

Increase of ionospheric current

Expanding upper atmosphere

Ground conductivity distribution

Satellite anomaly

Human radiation

Hazard to satellite operation

Hazard to human activity in space

Hazard to aviation

Hazard to telecom, broadcast

Hazard to positioning

Hazard to power line

Disability of GNSS

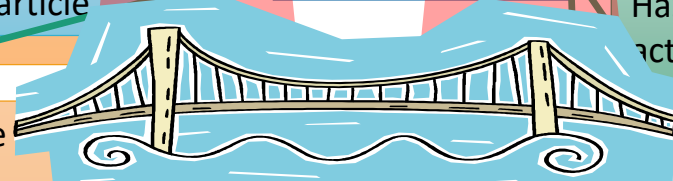
Change the satellite orbit

GIC

Academic institutes



Study of unknown process



SWx becomes Indispensable information for their task

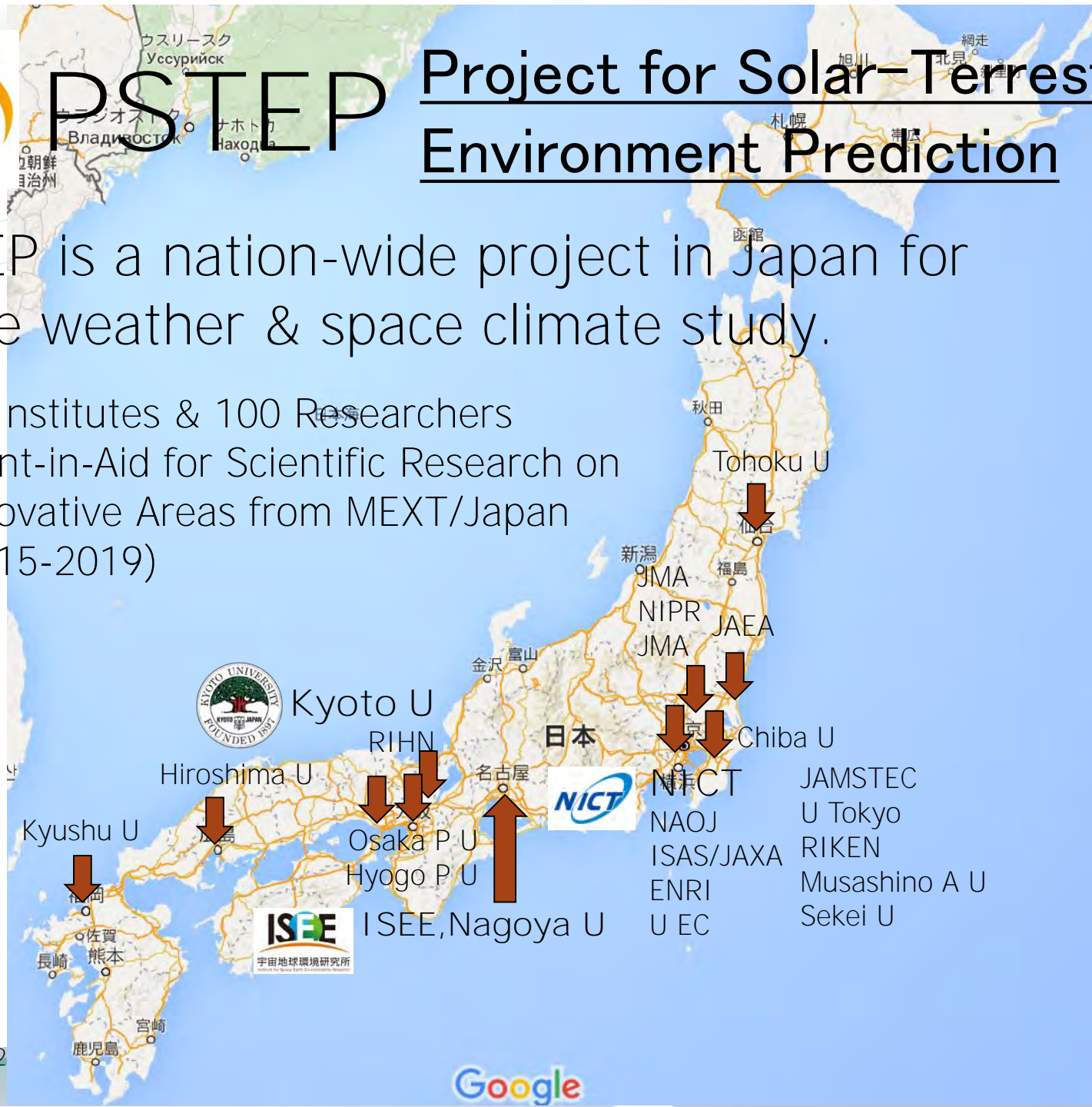


PSTEP

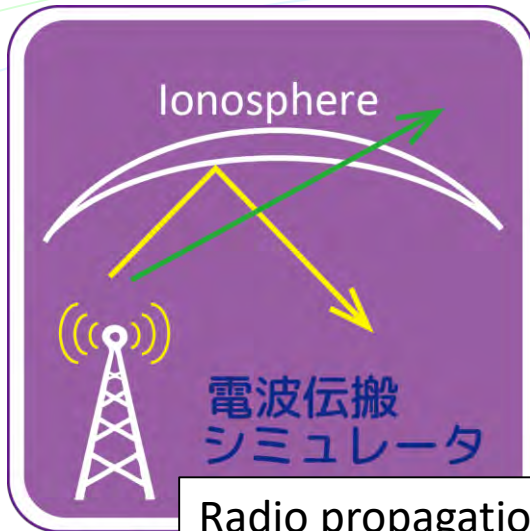
Project for Solar-Terrestrial Environment Prediction

PSTEP is a nation-wide project in Japan for space weather & space climate study.

- 20 Institutes & 100 Researchers
- Grant-in-Aid for Scientific Research on Innovative Areas from MEXT/Japan (2015-2019)



Product to be created



Radio propagation simulator



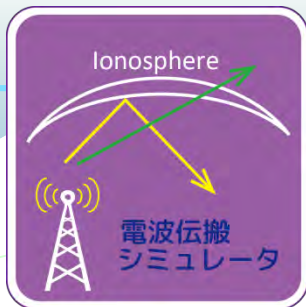
Human radiation estimation system



GIC hazardous warning system



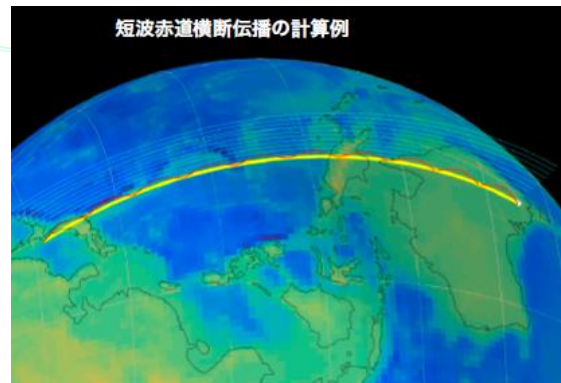
“Taylor-made Space weather” satellite Warning system



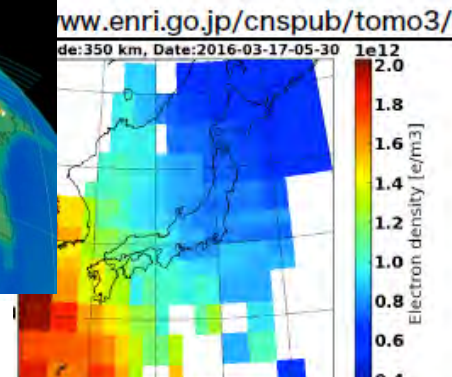
Developing Radio Propagation model

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”

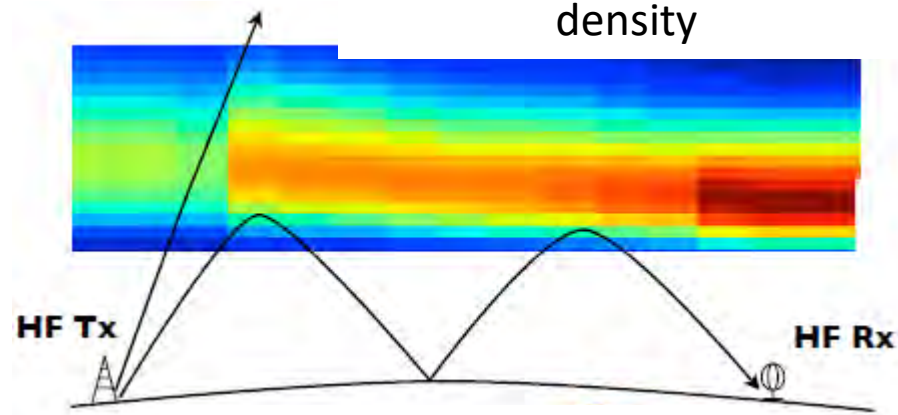
- The fundamental structure of radio propagation parameter for HF has completed. Validations of the model comparing with observational results are to be executed.
- The model for GNSS is planned to be build cooperated with CNES, France.
- Real time radio propagation model is to be possible by connecting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



3D radio propagation simulator



3D distribution of ionospheric electron density

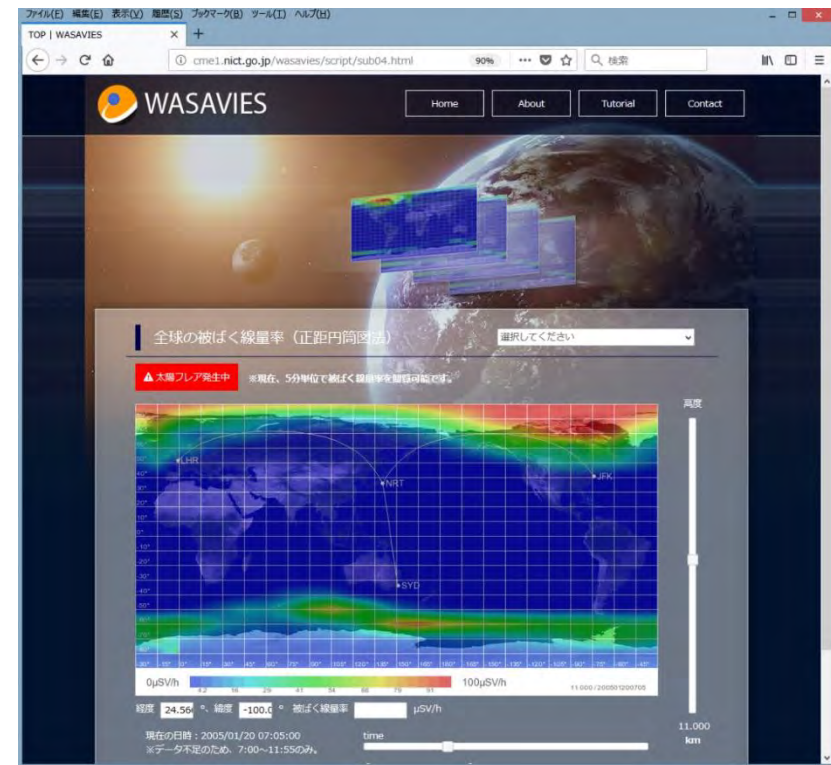


Example of real time radio propagation model



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





Accuracy improved
Up to 80 %

- Warning 24 hr

Probability
≥ M-class
Flares
74%

WARNING

SDO/AIA 131A corona

No.	X	M	C	forecast/comment/etc.
1002	--%	50%	59%	The probability of occurrence of large flares is high.
1001	--%	33%	48%	The probability of occurrence of flares is very low.
1000	--%	23%	37%	The probability of occurrence of flares is very low.

SDO/NASA

2019-01-26T23:58
SDO/AIA 131A corona

No.1002

IV	X	M	C	No.	Probability
IV	X			1002	--%
IV	M			1002	50%
IV	C			1002	59%

No.1001

IV	X	M	C	No.	Probability
IV	X			1001	--%
IV	M			1001	33%
IV	C			1001	48%

No.1000

IV	X	M	C	No.	Probability
IV	X			1000	--%
IV	M			1000	23%
IV	C			1000	37%

※X-class flares are not predicted by DeFN model now.

Space Weather international bodies

