National Institute of Information and Communications Technology

Japan's Space Weather Plans

Mamoru Ishii

National Institute of Information and Communications Technology

International Space Environment Service Regional Warning Center Japan

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

Solar Terr. Phys.

SWx the social needs

Sun

IPS

Magnetosphere/Ionosphere

influence

Social hazard/needs

Coronal Hall

High speed solar wind

Plasma cloud

CME/CIR

X-ray

Soalr flare

Increase of high energy particle

Disturbance of magnetosphere

Increase radiatoin

Increase of high energy particle

Disturbance ionosphere

Ionization of lower ionophsere

Increase of electron density

Increase of ionospheric current

Expanding upper atmosphere

Ground conductivity distribution

Satellite anomary

Human radiation

Disability of GNSS

Change the satellite orbit

GIC

Hazard to satellite operation

Hazard to human activity in space

d to aviation

Hazard to telecom, broadcast

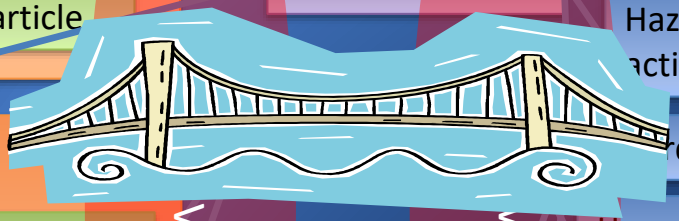
Hazard to positioning

society

Hazard to power line

Valley

Valley

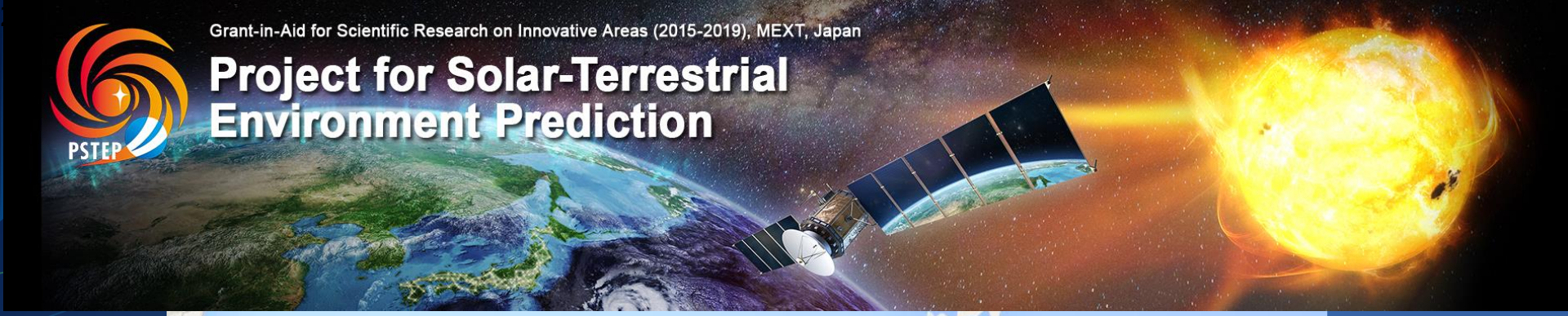


Academic institutes

Study of unknown process

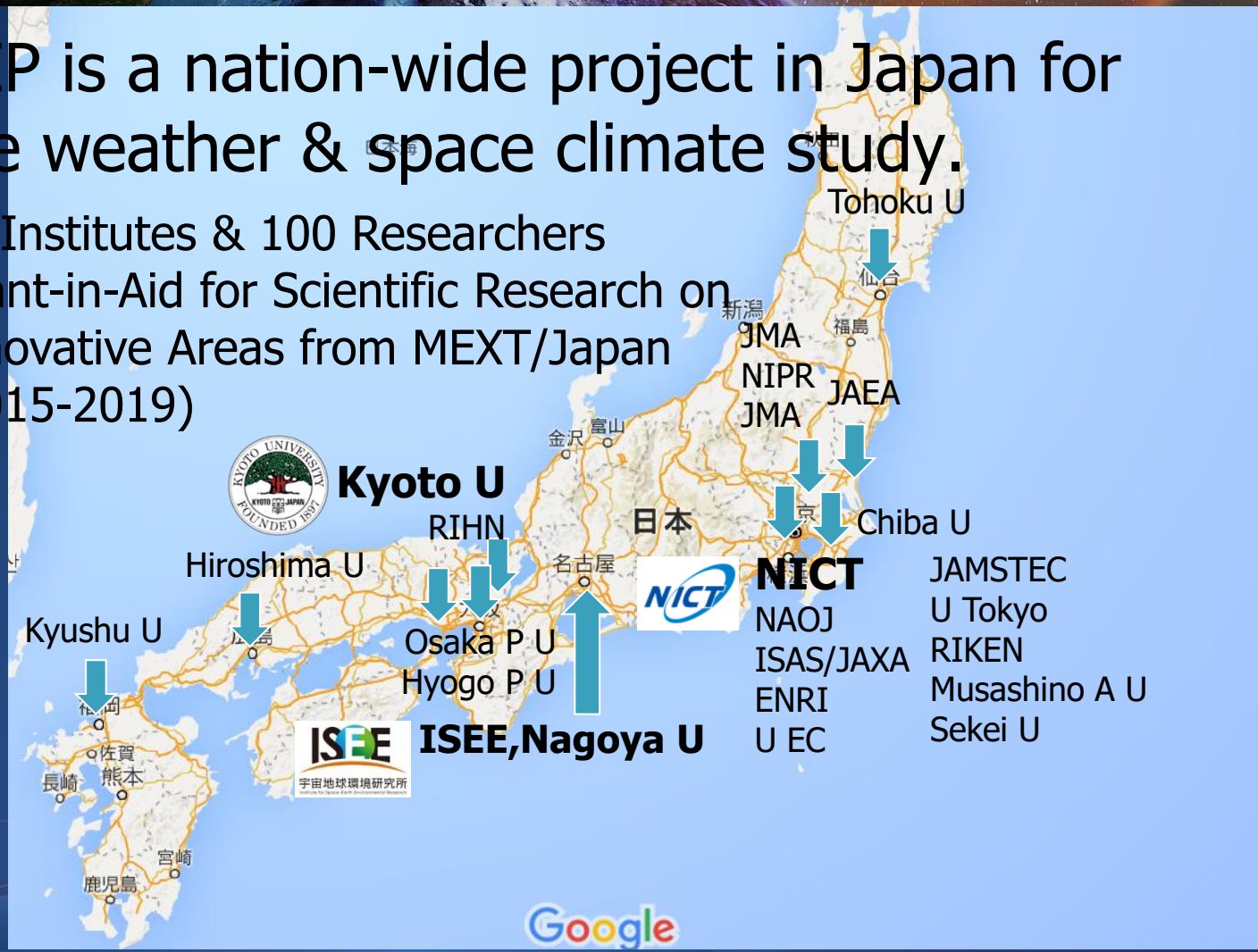
SWx becomes Indispensable information for their task

NICT



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)

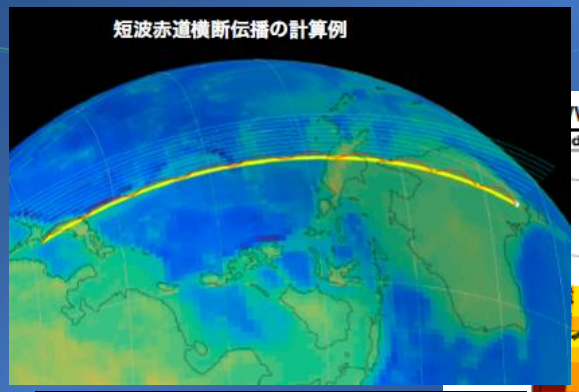


Developing Radio Propagation model

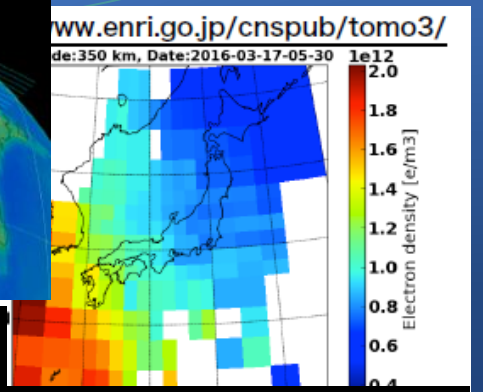
Radio propagation model is necessary to notice the usability of HF, VHF and GNSS at a particular point. We develop a new 3D radio propagation model “HF-START”

- 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 planed 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.

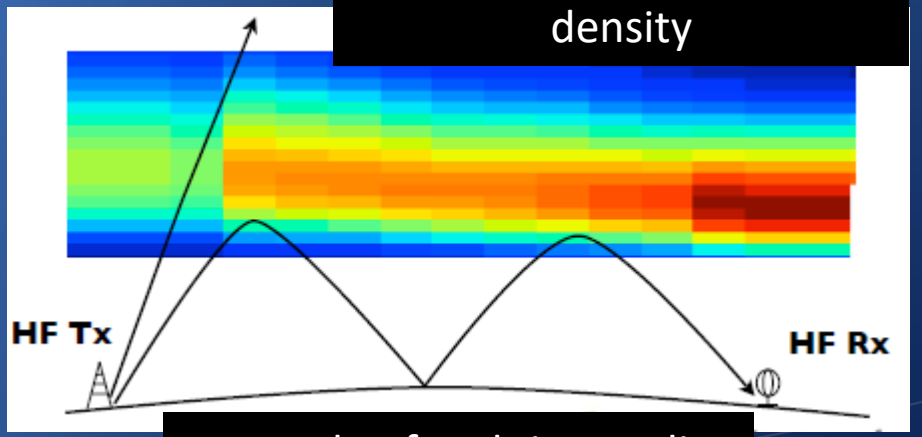
Web service will open soon!



3D radio propagation simulator



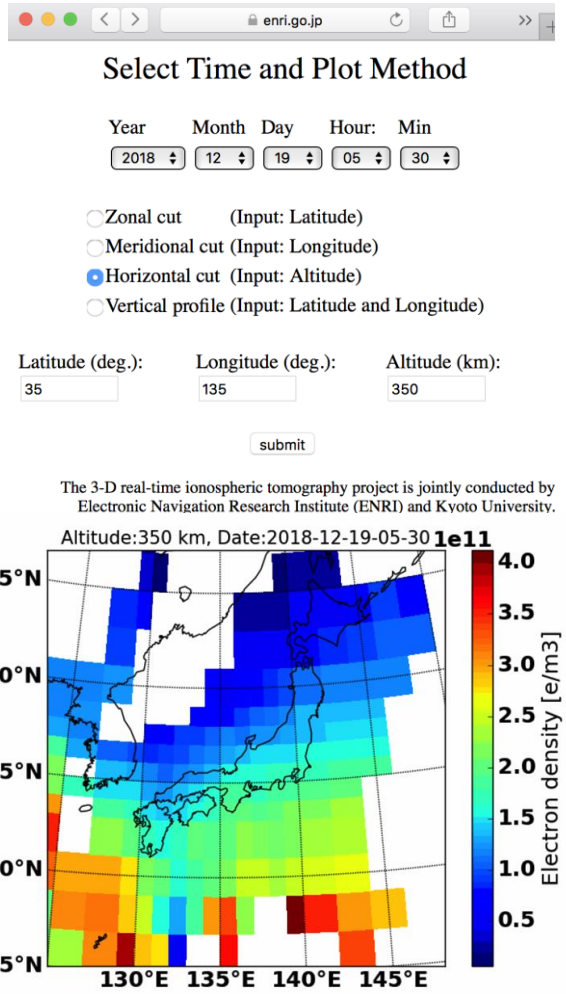
3D distribution of ionospheric electron density



Example of real time radio propagation model

Near real-time HF-START service

Japanese GNSS Tomography



Basic domestic option

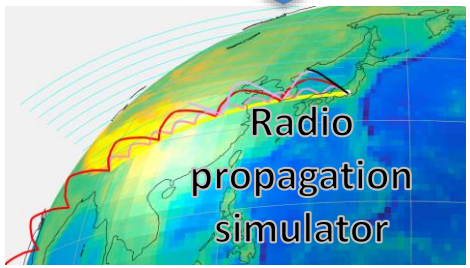
Input from user

Tx | Rx | Date | Time | Frequency

↓

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

↓



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Output for user

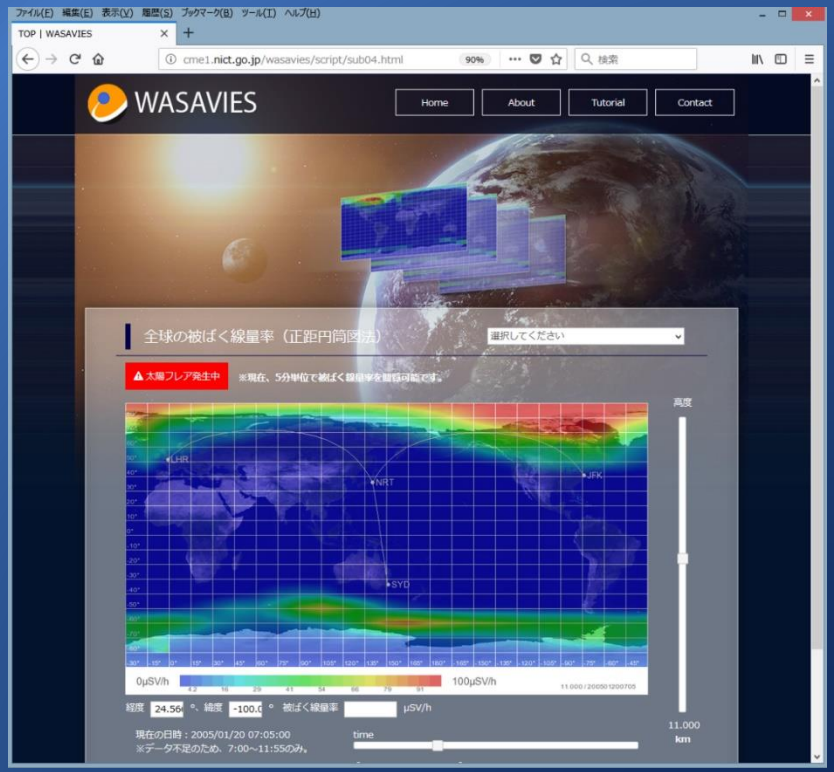
MUF-LUF map for specified propagation link

Specified frequency is usable or should be avoided.

Tomography: https://www.enri.go.jp/cnspub/tomo3/plotting.html

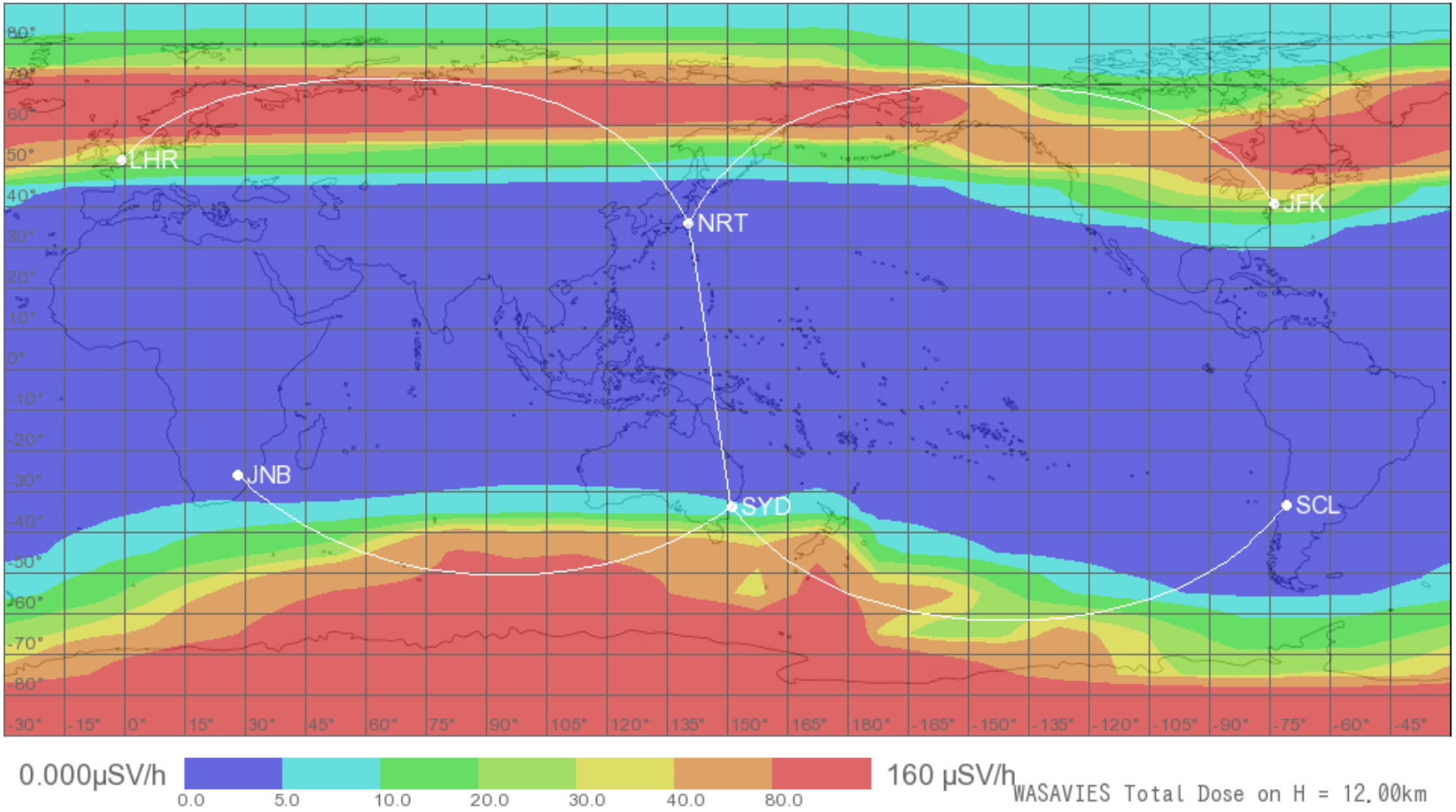
Purpose of Estimation system of human exposure

- 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

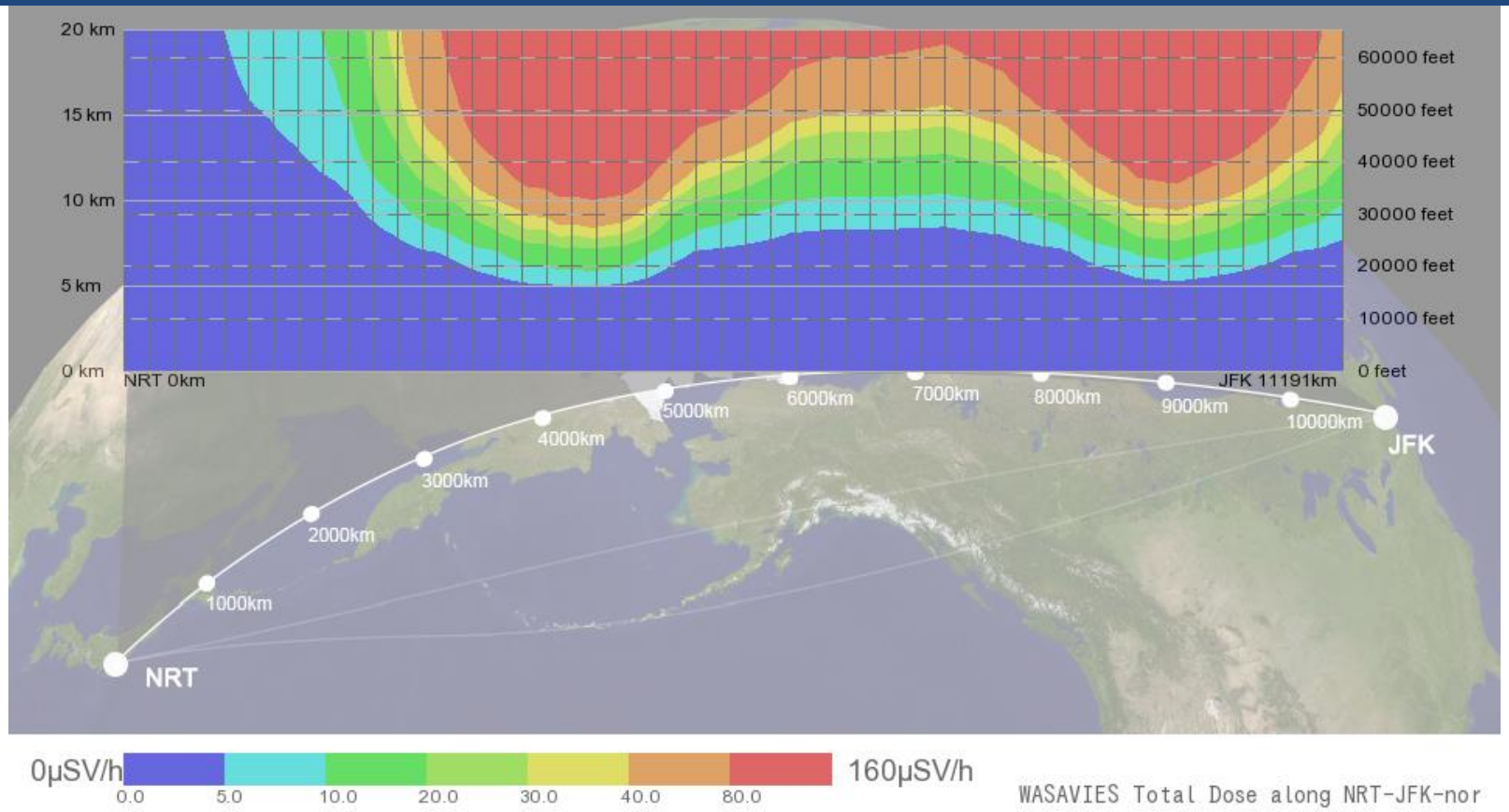
An example of WASAVIES global map



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

Qualitive exmplanation

estimation

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

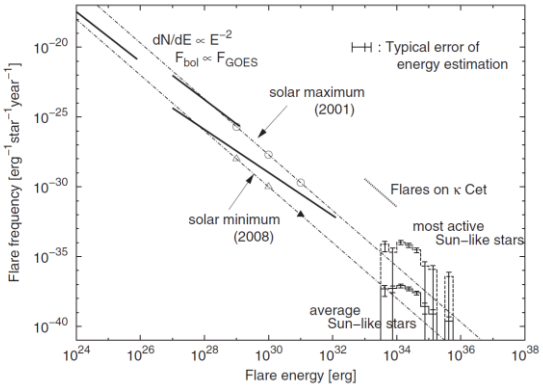
11 reference

Social impact in each field

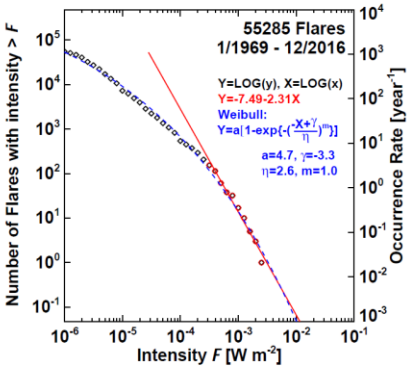
- Introduction
- Past example
- Discussion with users
- Possible maximum event in Japan
- Possible impact
- Impact matrix
- Future plan

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



Accumlative occurrence of solar flare with energy

(ex.) definition of solar flare size (tentative)

Parameter	often～ several times a year	Once a year	Once in decade	Once in 100 years	Once in 1000 years
GOES peak flux (1 – 8A)	M1 ～ X1	X7.6	X12	X44	X101
energy(erg)	2.7×10^{28} ～ 2.0×10^{30}	1.0×10^{31}	1.0×10^{32}	1.0×10^{33}	1.0×10^{34}

- 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.

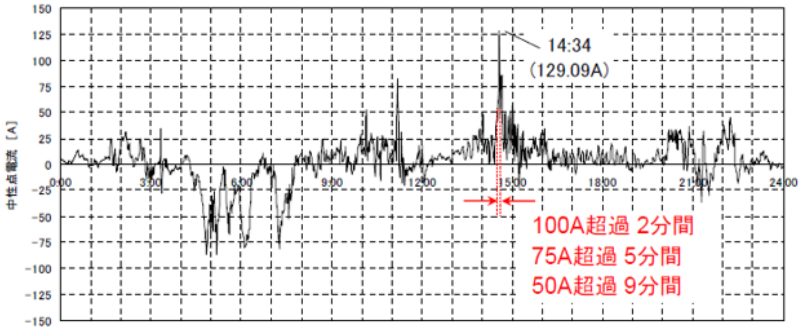
2 social impact with space weather event

Space weather impact matrix（tentative）

Field	Space weather phenomena	hazardous	Occurrence and impact				
			Often-several times in a year	1/1 year	1/10 years	1/100 years	1/1000 years
Power grid	GIC	Shutdown of electricity	No	No	No	Partial blackout	Wide area blackout
Satellite operation	High energy electrons	spacecraft(internal charge)	No	No	disability	disability	lost
	High energy protons and heavy ions	spacecraft(single event upset)	No	No	disability	disability	lost
		spacecraft(solar panel)	No	No	light	shorten lifetime	shorten lifetime
	Atmospheric heating	Trajectory	No	No	light	shorten lifetime	shorten lifetime
	High energy electrons	spacecraft (mag. Torca, surface charge)	No	No	light	Disability	lost
	Ionospheric scintillation	Sat. comm.	No	No	telecom disability (short)	telecom disability (long time)	telecom disability (very long)
Aviation	Micro wave from the sun	Radar utility	No	No	No	En route	Close
	Radio black out	HF utility	No	No	light	long time	Very long time
	PCA	HF utility	No	No	No	En route	En route
	High energy particles (proton, heavy ion)	avionics(single event upset)	No	No	Partial disability	disability	disability
		Human exposure	No	No	No	En route	Close
	Plasma bubble	HF utility	No	No	light	long time	Very long time
	Positive storm Plasma bubble Ionospheric scintillation	Satellite positioning	No	No	System change	System change	System change
communication/broadcast	Radio black out PCA	HF utility	Telecom disability (short time)	Telecom disability (short time)	Telecom disability (long time)	Telecom disability (very long)	Telecom disability (very long)
	Negative storm	HF utility	Light	telecom disability	telecom disability	telecom disability	telecom disability
	Sporadic E	VHF utility	Telecom disability	telecom disability	telecom disability	telecom disability	telecom disability
Satellite positioning	Positive storm Plasma bubble Ionospheric scintillation	Satellite positioning	No	Decline of precision (±xm)	Decline of precision (±xm)	Decline of precision (±xm)	Decline of precision (±xm)
Human in space	High energy particles (proton and heavy ion)	Human exposure in space	No	No	evacuation	return	reurn
Human on the ground	High energy particles (proton and heavy ion)	Human exposure on the ground	No	No	No	No	No
		Single event on the ground	No	No	No	電子機器の不具合	電子機器の不具合
	GIC	Signal misoperation	No	No	No	交通障害、事故	交通障害、事故

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.



Japanese GIC observation on Oct. 31, 2003

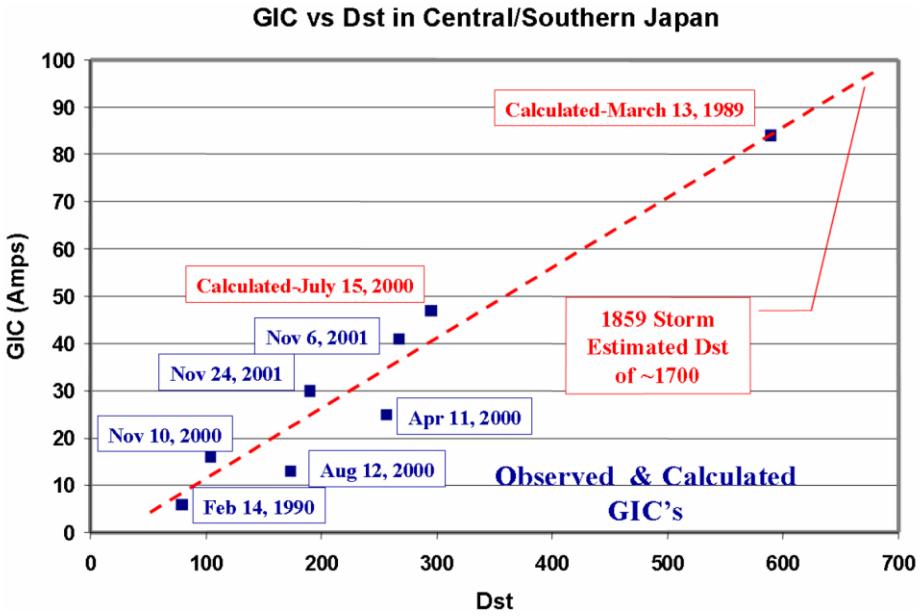
The temperature increase in transformer is about 110 deg with DC 100 A, which is negligible (experiment by TEPCO, Toshiba, Hitachi and Melco)

"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



–relation between Dst–index and GIC observed in Chubu–electronic company (Kappenman, 2004)

- 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

ICAO service in（Nov. 7, 2019）


12月2日（月曜日） 夕刊 読売新聞 3版

「太陽フレア」24時間予測

磁気の乱れで生活に支障も

Newspaper article for announce 24/7 operation of SWx services

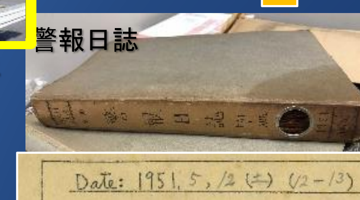
NICT Kobe Laboratory

NICT HQ

Backup center in NICT Kobe Laboratory

④−1

警報日誌



Degitize legend data from paper to web

Next Step

Draft Plan of next mid-term of Research in NICT SWx (2021-2025)

Examples of the needs for SWx Service in2021-2025)

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

- Numerical forecast
- Data assimilation
- AI
- Satellite observation
- Ground observation

Sun solar wind

magnet osphere

ionosph ere

Operation

Users

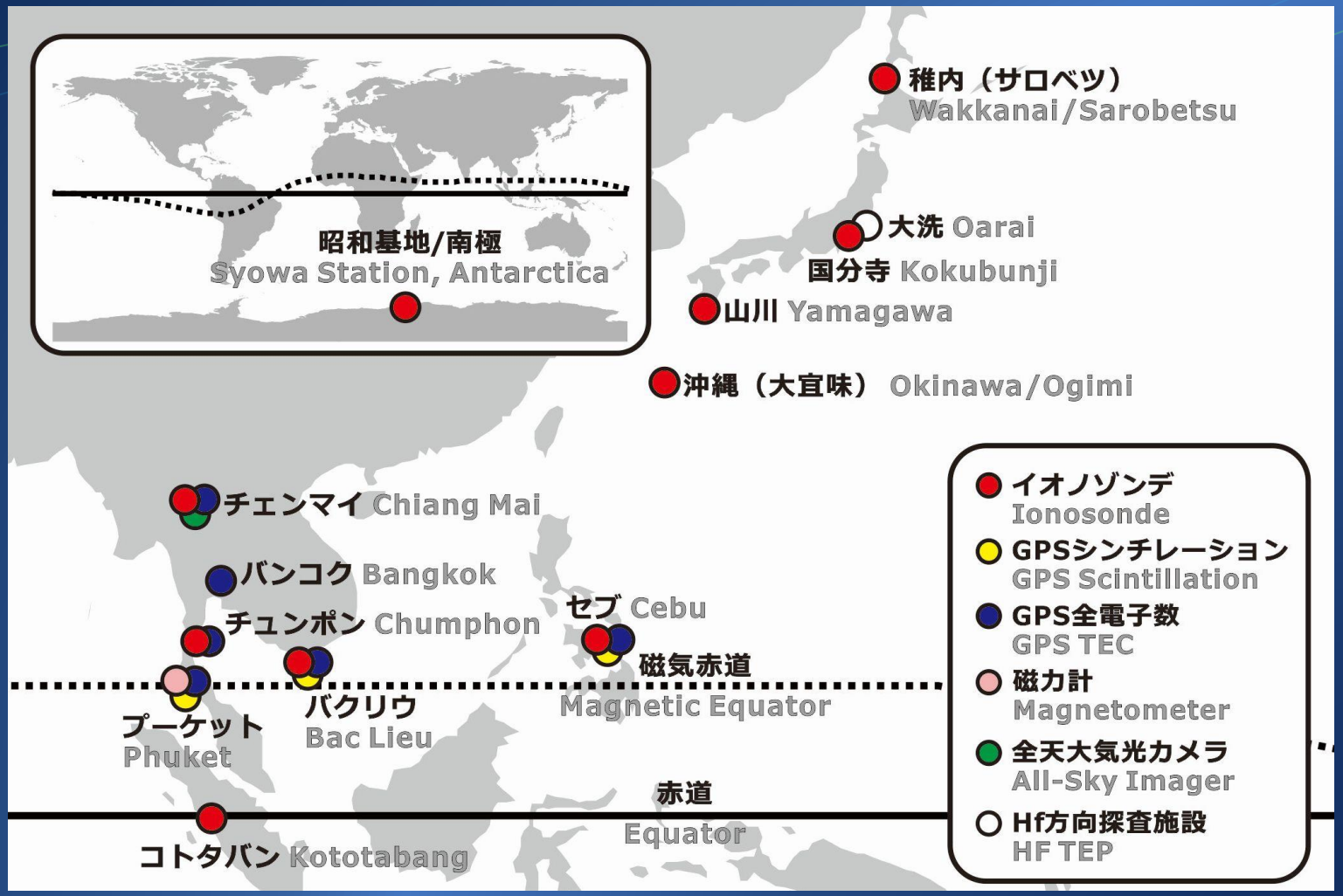
- WASAVIES
- Radio prop. simulator
- Hazardous map

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

Improvement of forecast precision

Ionospheric Observation network



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

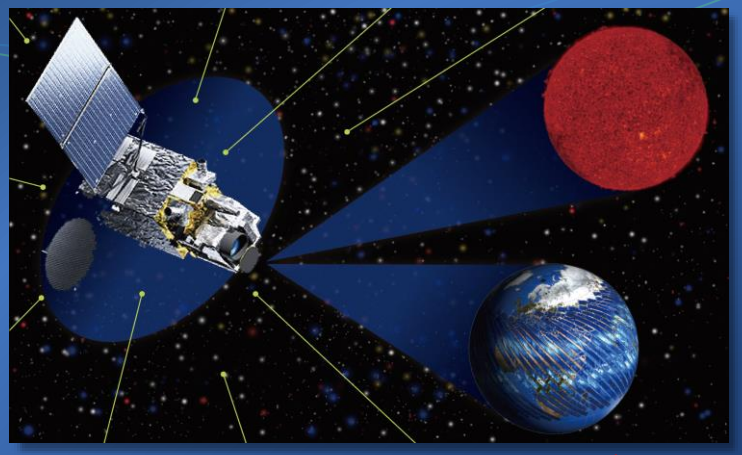
"ICT Virtual Organization of ASEAN Institutes and NICT (ASEAN IVO)" is a global alliance of ICT R&D institutes and universities in the ASEAN region and Japan. The mission of ASEAN IVO is to seek and identify strategic ICT research areas in the ASEAN region, and promote collaborative projects in them.

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



We need Your strong support

Space Environment Sensors now discussing

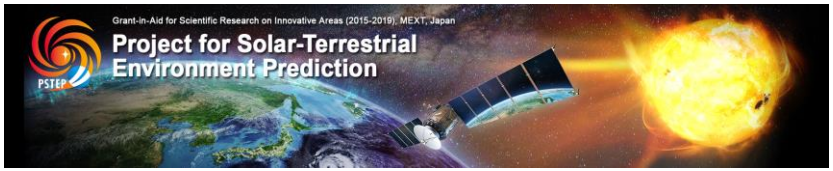
- **Ion and electron detector, magnetometer**
  - **For monitoring solar high energy particles and radiation belt**
- **Satellite charging monitor**
  - **For monitoring actual satellite charge and estimate the relation between charge and space environment**
- **Ionospheric imager**
  - **For monitoring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

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

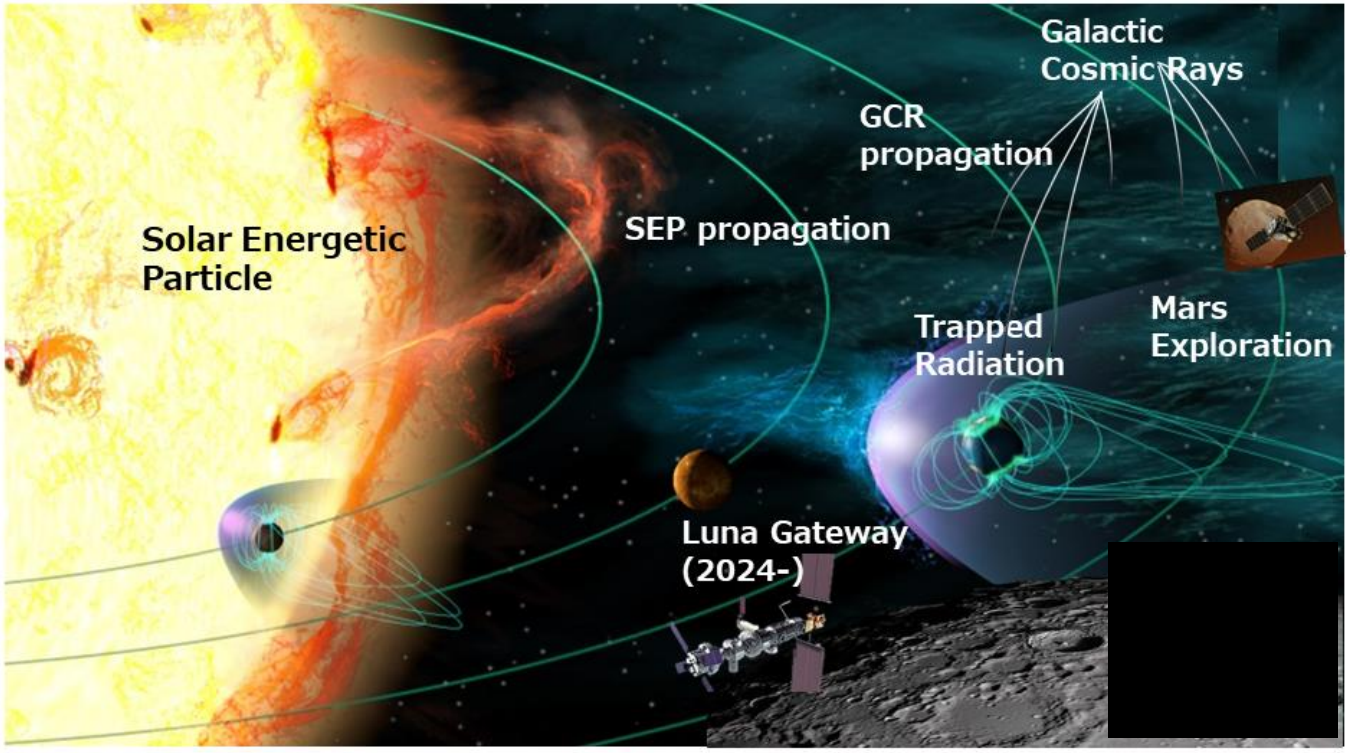
- Human Activities at Moon : Lunar Gateway Project, etc.
- Human Activities at Mars including Interplanetary Space: Mars exploration

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

Courtesy of Prof. Miyoshi (Nagoya Univ.)

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

Major Three Radiation Sources for Human Activity: SEP/GCR/Trapped Radiations



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.