国立研究開発法人
情報通信研究機構

Recent NICT's activities for space weather research and operation

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National Institute of Information and Communications Technology, Japan

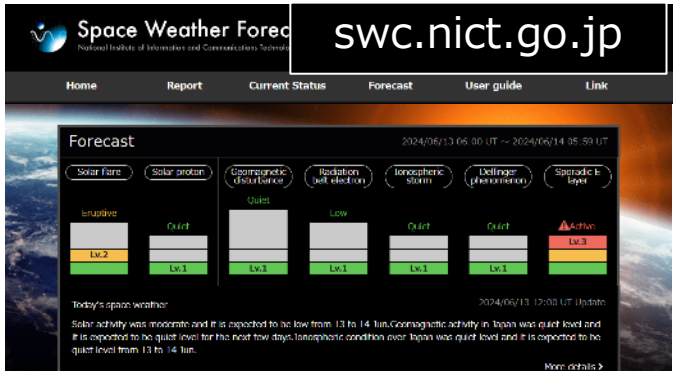
Current NICT Space Weather Operation


Ionosonde (VIPIR2)

Hokkaido

NICT HQ (Tokyo)

Space Weather Forecast Center



Backup center (Kobe)

Tokyo

Hyogo

Solar Wind data receiving Antenna (ACE/DSCOVR)

Kagoshima


Yamagawa solar radio observatory

Okinawa

Services

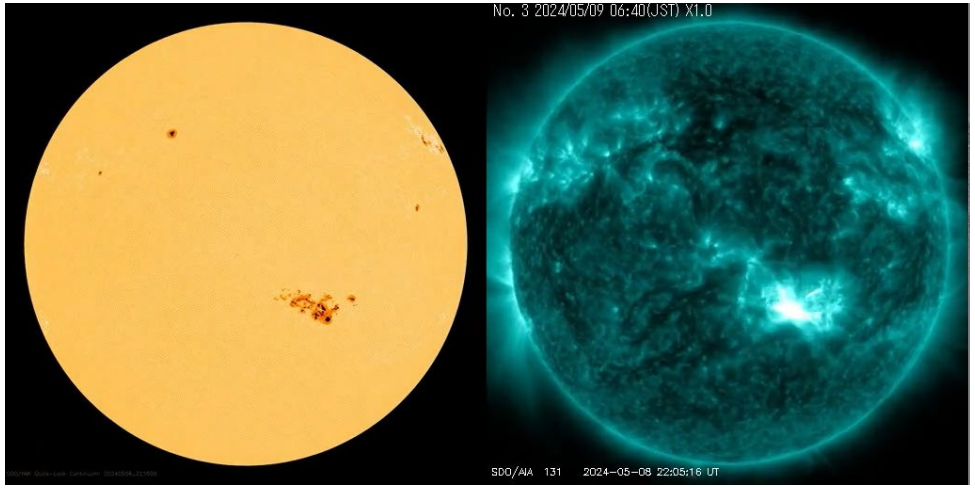
- **Domestic users:** satellite operator, aviation office and companies, power supplier, HF telecommunicator/broadcaster, GNSS service provider/user, resource survey, Univ. and research institutes, amateur HF operators, etc.
- **E-mail subscribers:**7000, **Web access:** 70,000/month, SNS (Facebook, X)

Recent activities

- ICAO service in (since Nov. 7, 2019)
- 24/7 operation (since Dec. 1, 2019)

Operational Space Weather Forecast: May 2024 storm

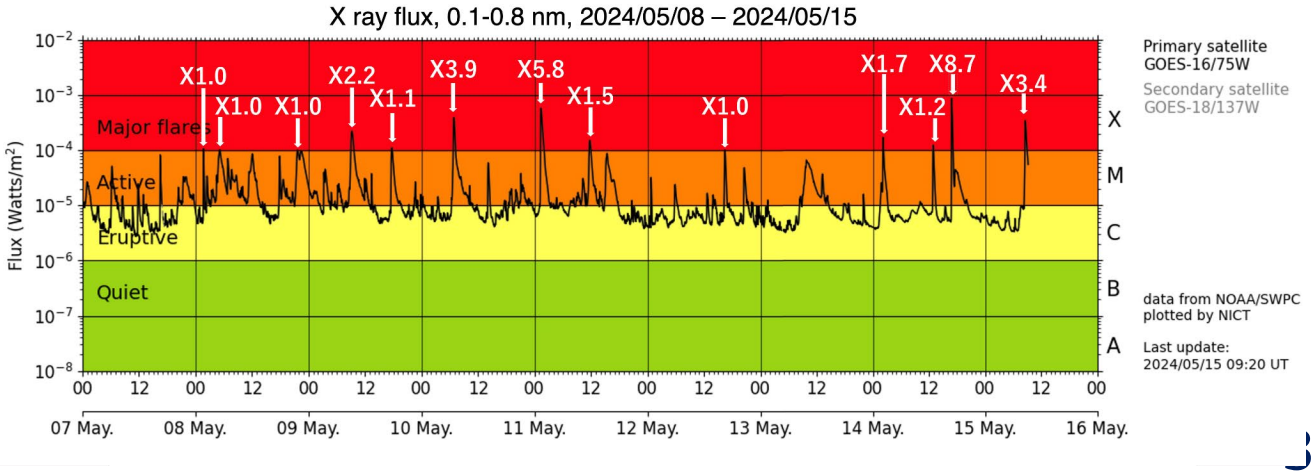
- From May 8 to 15, 2024, multiple X-class solar flares were observed. This included seven X-class flares occurring within 72 hours, a first in recorded history since 1975.
- NICT issued an announcement warning that the space environment around Earth could be significantly disturbed for several days due to the arrival of a coronal mass ejection (CME). This event had the potential to cause satellite malfunctions, GNSS positioning errors, and HF communication disruptions.
- Forecast information was posted on the NICT website, a press conference was held, and the information was disseminated to relevant organizations.



Solar image observed by satellite SDO (NASA) on May 9, 2024
(left: visible light, right: ultraviolet light)

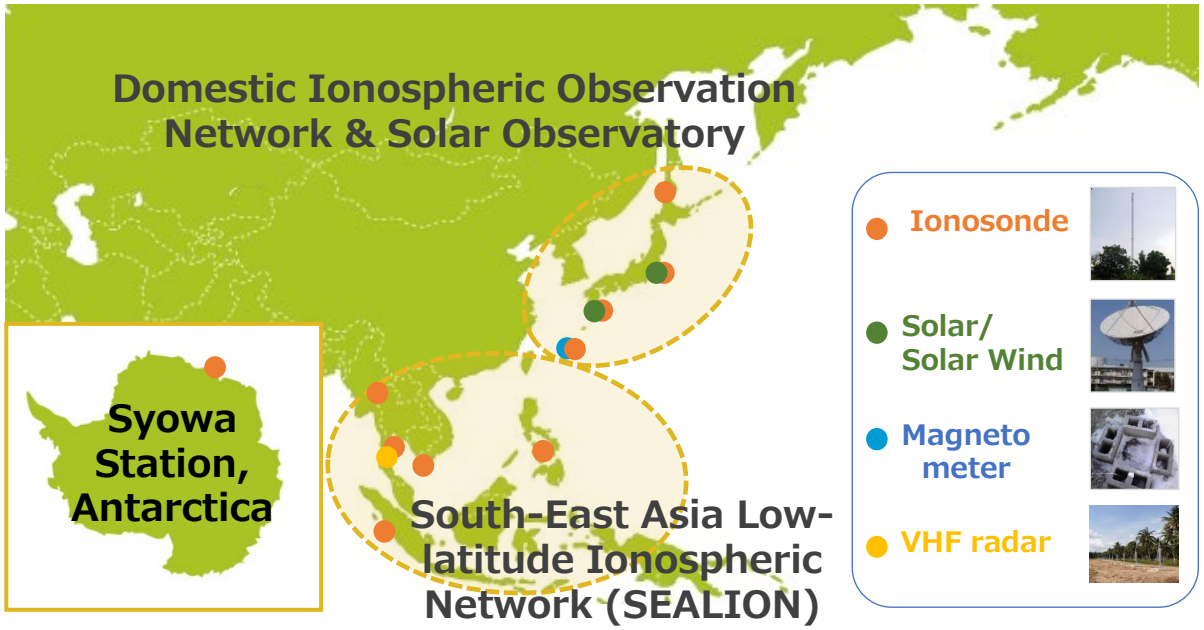
NICT's announcement on the web and press conference on May 10.

Solar X-ray intensity observed by GOES satellite (NOAA)



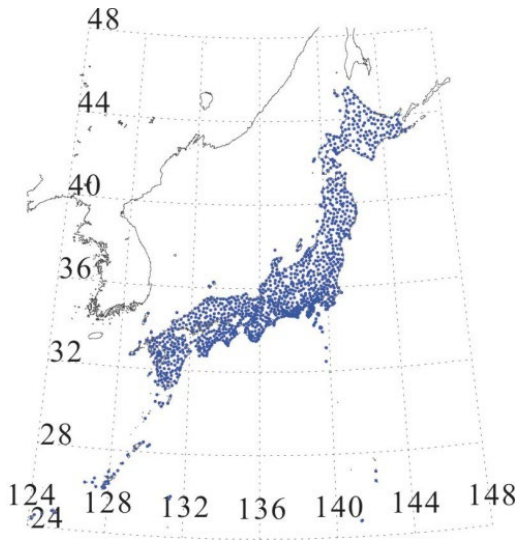
Observation Network

Space Weather Observation Network



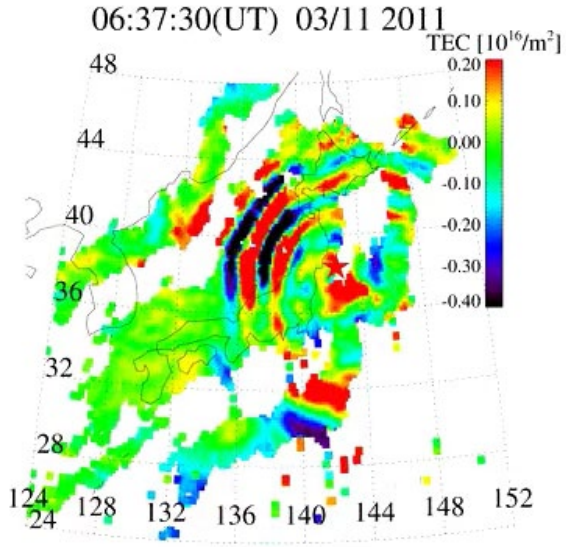
- We have developed ground-based observation technologies and networks to monitor space weather phenomena through international collaboration.

GEONET GNSS Receivers operated by GSI, Japan



GEONET consisting of more than 1,200 GPS stations.

2D TEC map

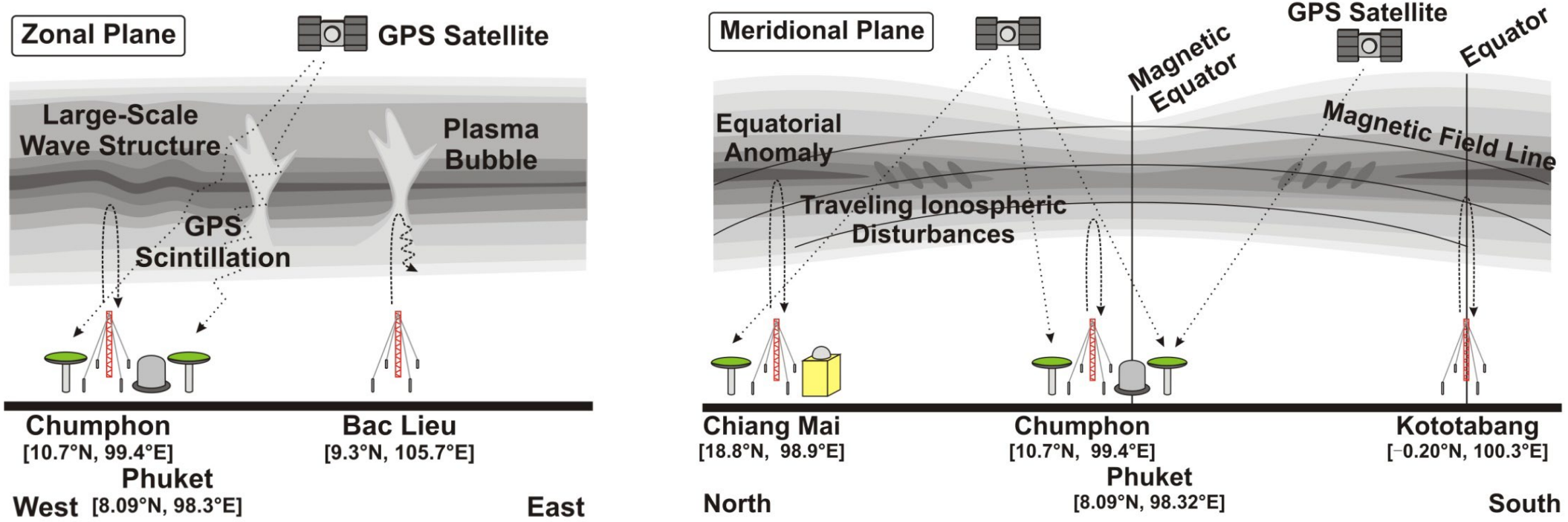


TEC variation map at Tohoku earthquake [Tsugawa et al., EPS, 2011]. The red star represents the epicenter.

- We developed two-dimensional maps of total electron content (TEC) using dense GNSS receiver networks in Japan and in the world.

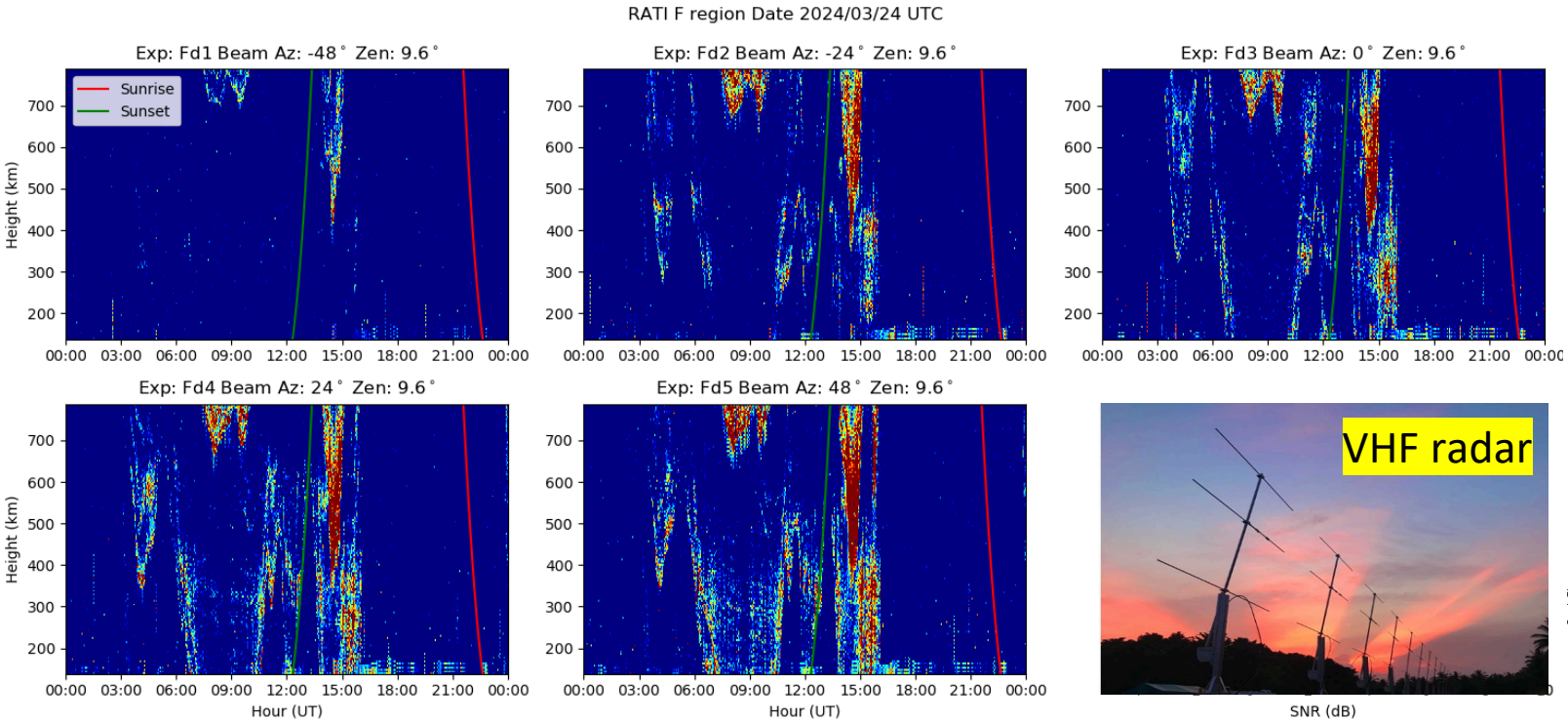
Observation Network: SEALION

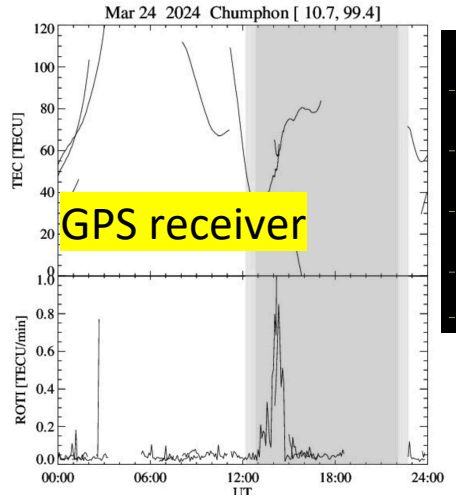
SEALION: SouthEast Asia Low-latitude IOnospheric Network

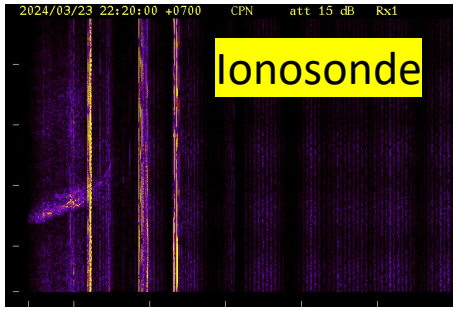


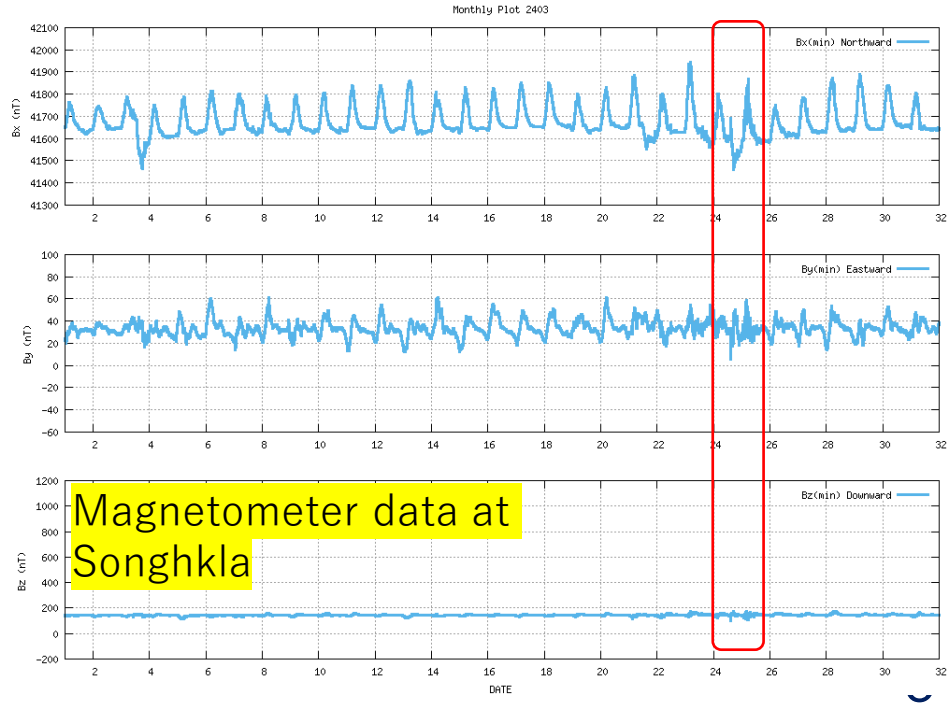
- **Main target**: Generation and propagation mechanism of equatorial plasma bubble (EPB)
- **Key parameters of EPB generation**: Uplifting ionospheric height (→ large growth rate), North-south asymmetry of ionospheric structure (→ small growth rate), large-scale wave structure (seeding), etc.

Observation: Equatorial Plasma Bubble









- Case event on 24 March 2024
- FAIs associated with EPB was observed between 13-16 UTC
- ROTI data showed a high fluctuation
- Spread-F events were observed by the ionosnde

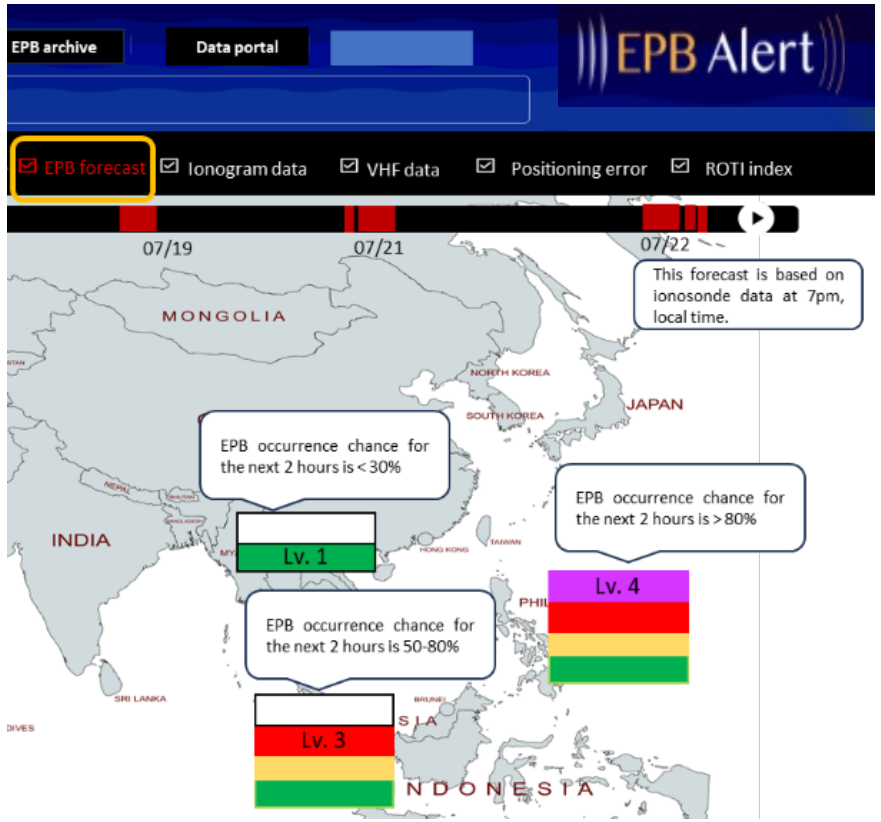
Characteristics, occurrence, mechanisms are well studied (e.g., Li et al., 2024, Adhya et al., 2023, Sun et al., 2023, etc)

Application Tools (under development)

Equatorial Plasma Bubble (EPB) Alert

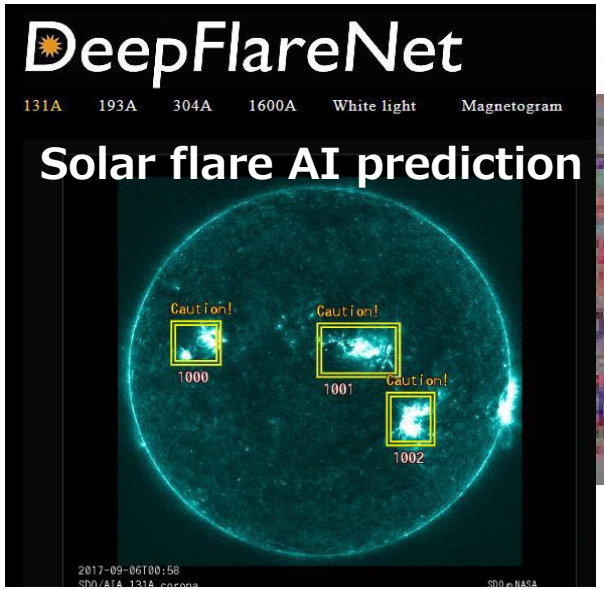
EPB Real-time mode

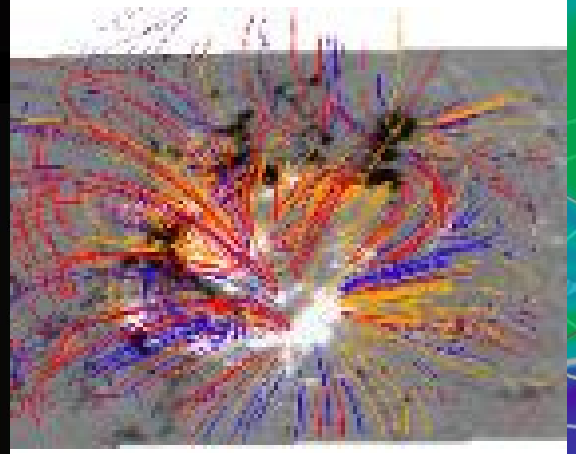
EPB forecast mode



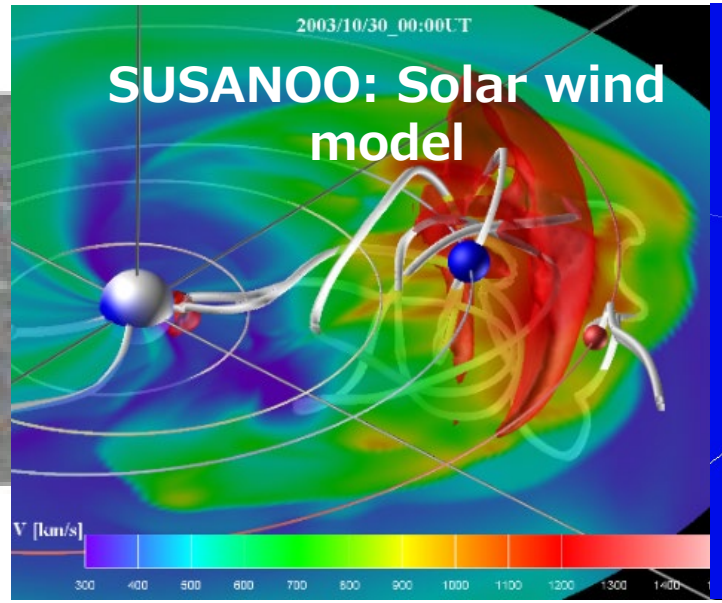
- Real-time EPB occurrence information obtained by auto-detection of EPB signatures from the observations.
- Forecast information of EPB occurrence derived by integrating the observation and model analysis.
- Future Plan: Data Portal for data sharing between various projects (SEALION, ASEAN-IVO, etc)

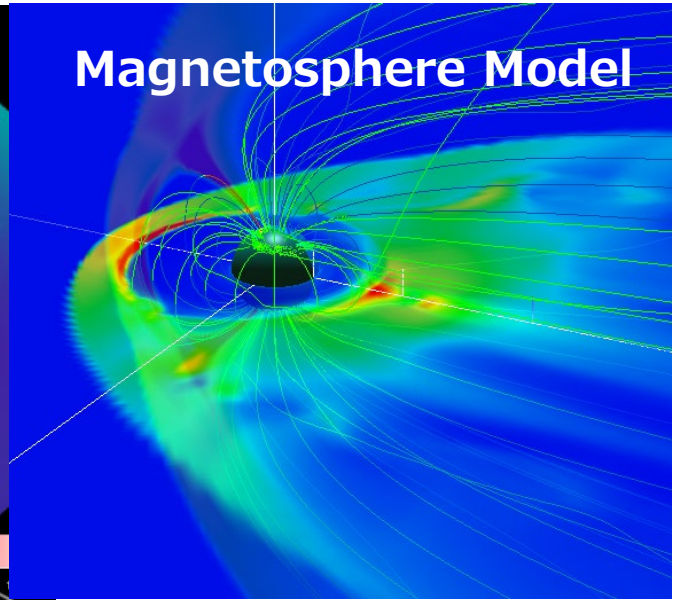
Forecast Models



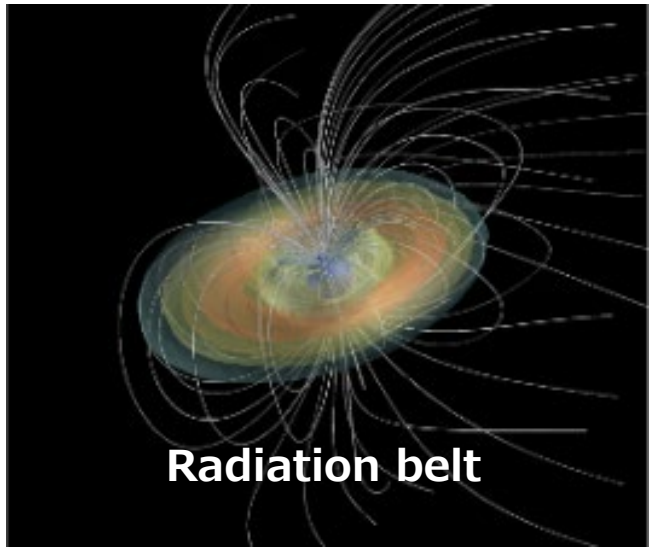


Physics-based flare model

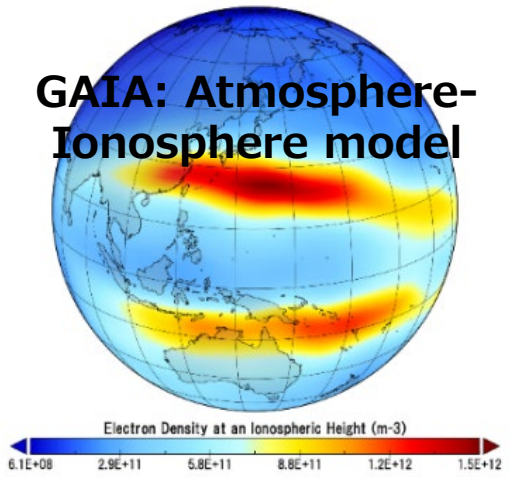




- We have developed forecast models of space weather phenomena, such as solar flare, solar wind, magnetosphere, radiation belt, ionosphere, using numerical simulation, data assimilation, and AI technologies.

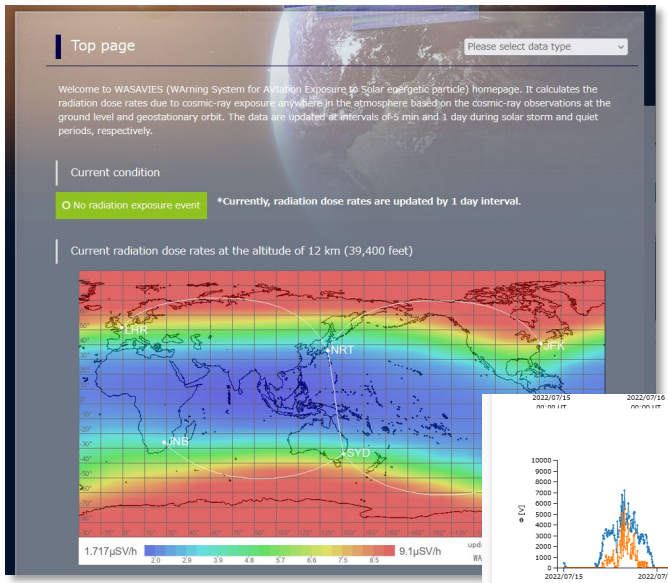


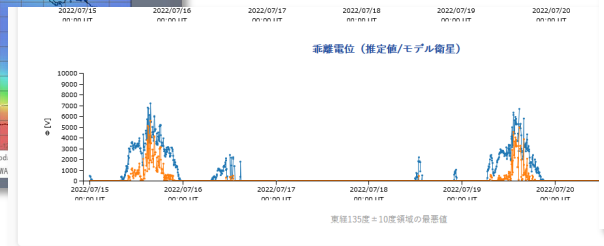
GAIA model



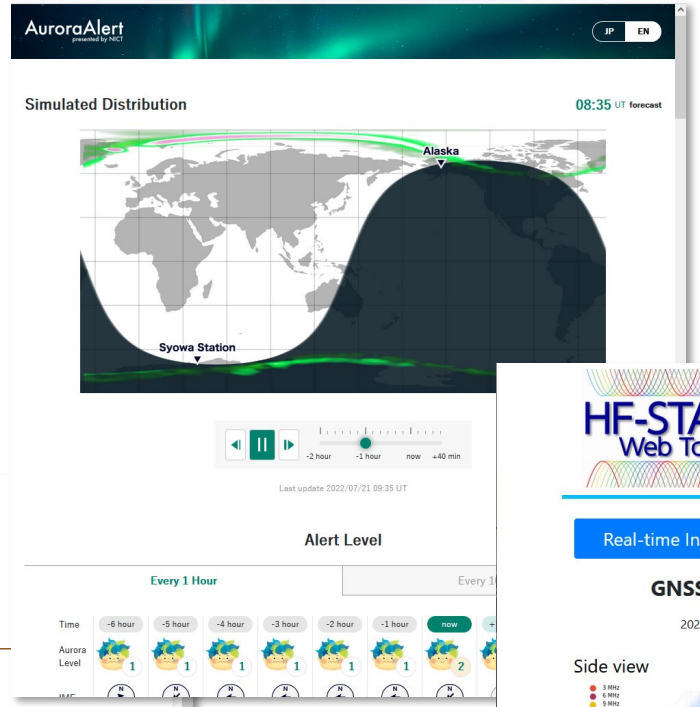
Application Tools

Aviation dose assessment (WASAVIES)

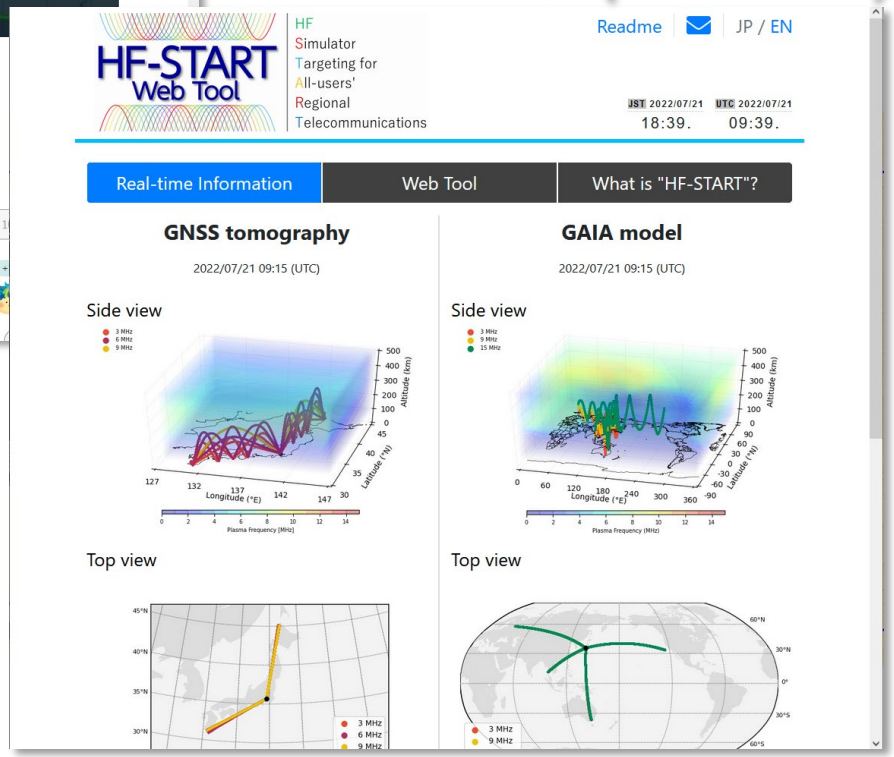




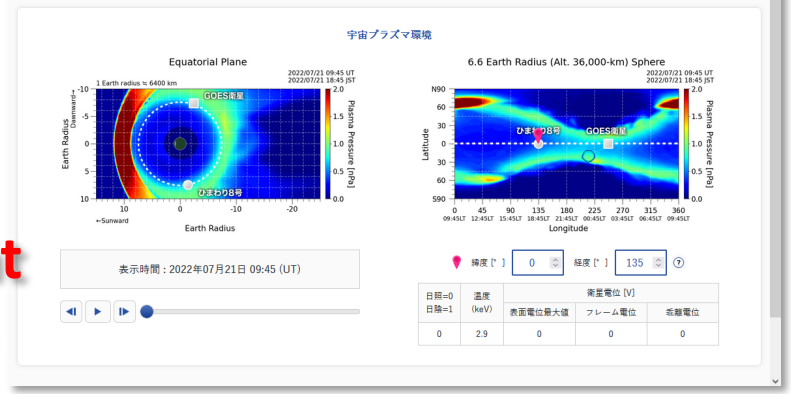
Aurora Alert



HF propagation simulator (HF-START)



Satellite surface charging assessment (SECURES)

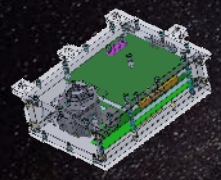


Recent progress 1:
High energy particle sensors aboard Himawari 10

- **Develop engineering models of high energy particle sensors aboard Himawari 10 (Japanese meteorological satellite)**

RMS-p target:
Energetic protons
(10 MeV to 1 GeV)

- Single event effects (SEEs)
- Total ionizing dose (TID)
- Astronauts/Air crew exposure
- Polar cap absorption (PCA)



RMS-e target:
Energetic electrons
(50 keV to 5 MeV)

- Spacecraft charging and electrostatic discharge (ESD)
- Total ionizing dose (TID)

RMS/Himawari10

Radiation Monitors for Space weather
measure radiation belt electrons
solar and galactic protons

Conceptual design 2020~	EM development 2021~	PFM development 2024~	PFT 2027~	Launch	Operation 2029~

Recent progress 2: Development of NICT Warning Operation System for New Warning Criteria

- **NICT has developed a warning operation system based on new criteria that account for risks and potential damage to social infrastructure.**

Target field

HF Communications and Broadcasting, Space System Operations, Aviation Human Exposure

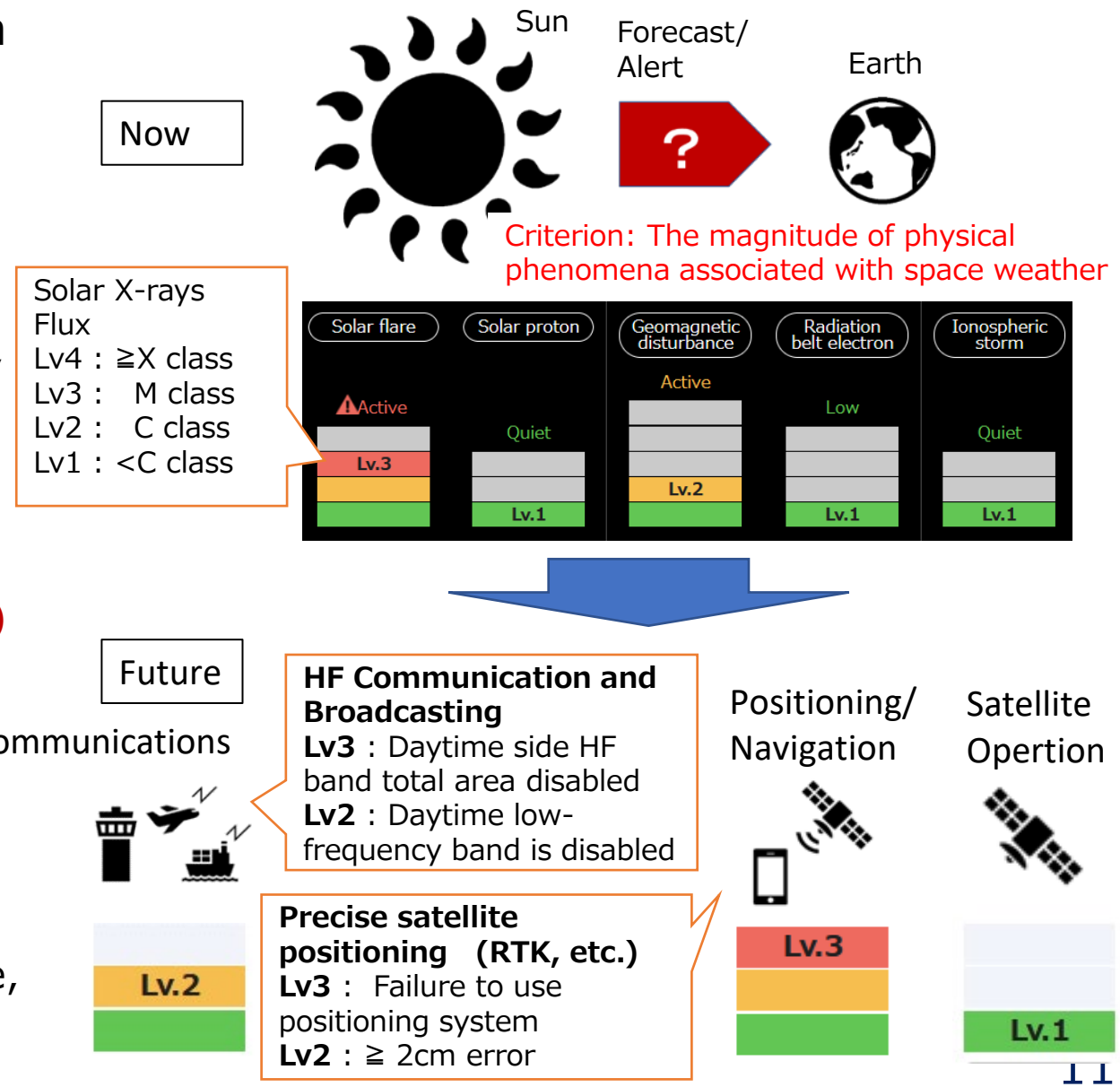
→ The criteria in these fields were established by the "Study Group on the advancement of space weather forecasting" in 2022. Additional criteria will be incorporated into the operation system as they are determined.

Contents and timing of warnings

- **Three levels: Normal, Yellow (caution), Red (warning) in each field**
- **E-mail notifications are automatically sent in Yellow and Red conditions.**
- **For solar flares at the red level, NICT will manually issue an additional report.**

Schedule

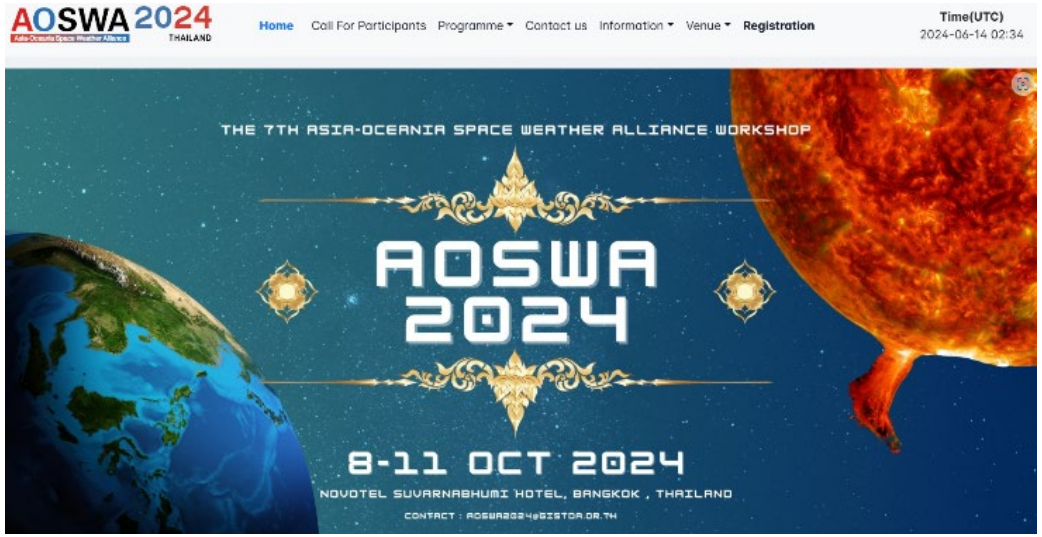
- Development of the e-mail distribution system is complete, and distribution tests are currently underway.
- Distribution to the general public is scheduled for FY2024.



Recent progress 3: Contribution to International Framework

Asia-Oceania Space Weather Alliance (AOSWA)

- The Asia-Oceania Space Weather Alliance (AOSWA) was established in 2010 conducted by NICT to facilitate information exchange among space weather forecasting organizations in the Asia-Oceania region.
- The first workshop was held in Chiang Mai, Thailand in February 2012, followed by workshops in China (November 2013), Japan (March 2015), Korea (October 2016), Indonesia (September 2018), and Malaysia (October 2023) almost every two years.
- **The 7th AOSWA Workshop was held in Bangkok, Thailand on October 8-11, 2024, with more than 90 presentations from 19 countries.**



AOSWA-7 @ Bangkok, Thailand in 8-11 Oct. 2024 hosted by GISTDA

Summary

- NICT is responsible for operational space weather forecasting in Japan, and provide nowcast and forecast information.
- We have been developing the Equatorial Plasma Bubble (EPB) Alert system using observation data of SEALION and ASEAN-IVO project
- We have also developed engineering models for high energy particle sensors aboard Himawari-10 (Japanese meteorological satellite). The development of the engineering model (EM) is nearly complete, and the development of the proto-flight model (PFM) will begin in 2024.
- Additionally, we have developed a warning operation system with new criteria that consider the risks to social infrastructure, based on the June 2022 report from the "Study Group on the Advancement of Space Weather Forecasting.“
- Our contributions extend to international activities such as ISES, WMO, COSPAR, ITU, ICAO and AOSWA.