สำนักงานพัฒนาเทคโนโลยีอวกาศและภูมิสารสนเทศ (องค์การมหาชน)
Geo-Informatics and Space Technology Development Agency (Public Organization)
WWW.GISTDA.OR.TH

United Nations/Philippines Workshop on the Applications of Global Navigation Satellite Systems

Development of space weather forecast system in Thailand

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Outline

1. Background and Motivations
   - Policy and regulator framework for space activities Research and Development
   - Scientific and technical research and development
2. Research and Development
   - Domestic cooperation
   - International activities and cooperation
3. TEC results in the period of High solar activity
4. Conclusions
5. Future plan and Activity

A. Policy and regulator framework for space activities

Guideline	Summary
A. Policy and regulatory framework for space activities	
A.1	Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities
A.2	Consider a number of element when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities
A.3	Supervise national space activities
A.4	Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites
A.5	Enhance the practice of registering space objects

A. Policy and regulator framework for space activities

A.1

- Space Affairs Act BE (the Draft Act), developed based on LTS, is on process. (Expected approval : 2025)
- The Master Plan has been approved by the Cabinet.

A.5

- All operations require to register the space objects and GISTDA is assigned to be focus point for the registration.

A.5 National Space Act

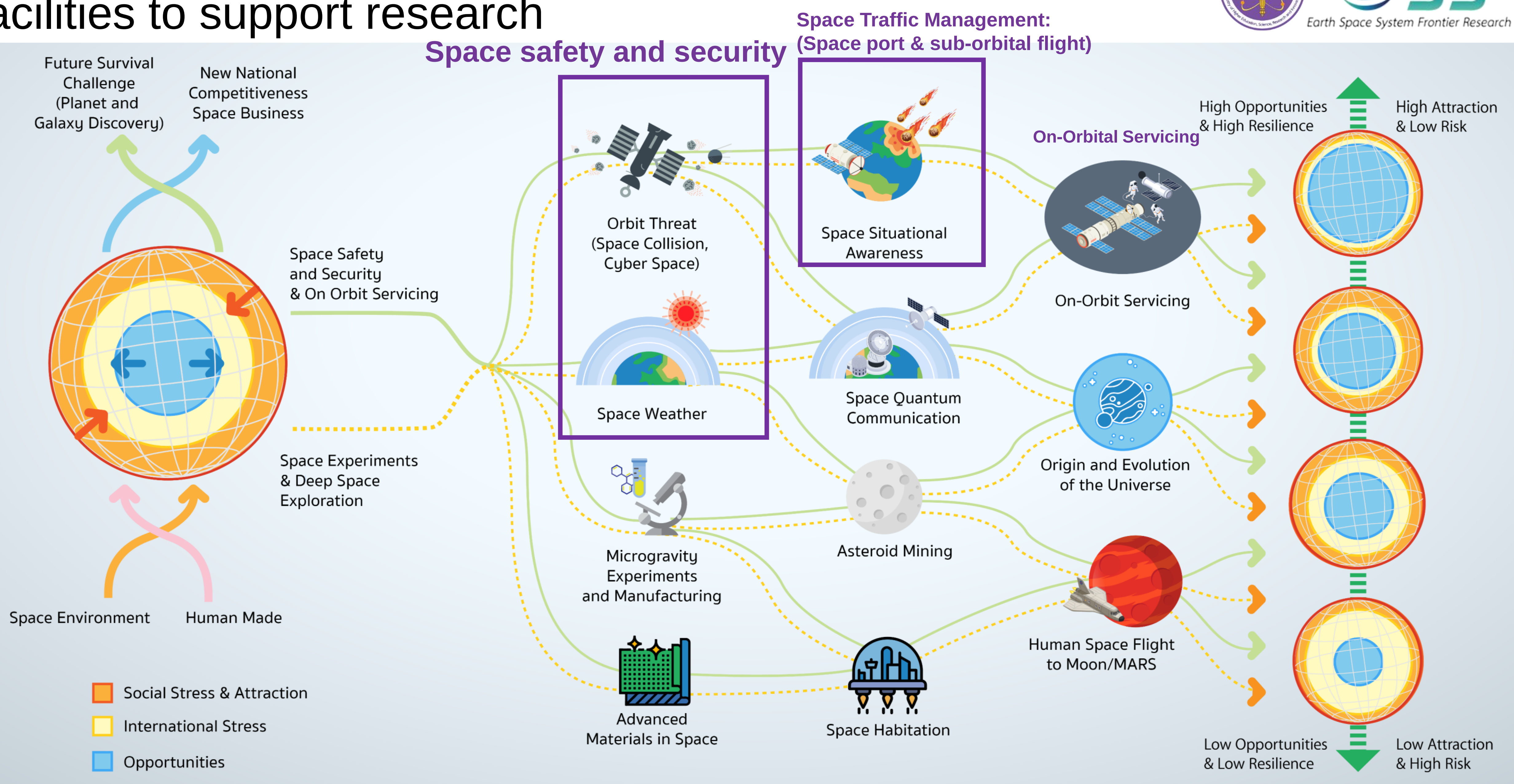
15 Years of National Space Master Plan (2023-2037)

Note : Long-term sustainability of outer space activities (LTS) and IADC space debris guideline are considered in National Space Act and SSA&STM policy.

D. Scientific and technical research and development

D. Scientific and technical research and development	
D.1	Promote and support research on the development of ways to support sustainable exploration and use of outer space
D.2	Investigate and consider new measure to manage the space debris population in the long term

D.1: Define the milestone in National roadmap and facilities to support research

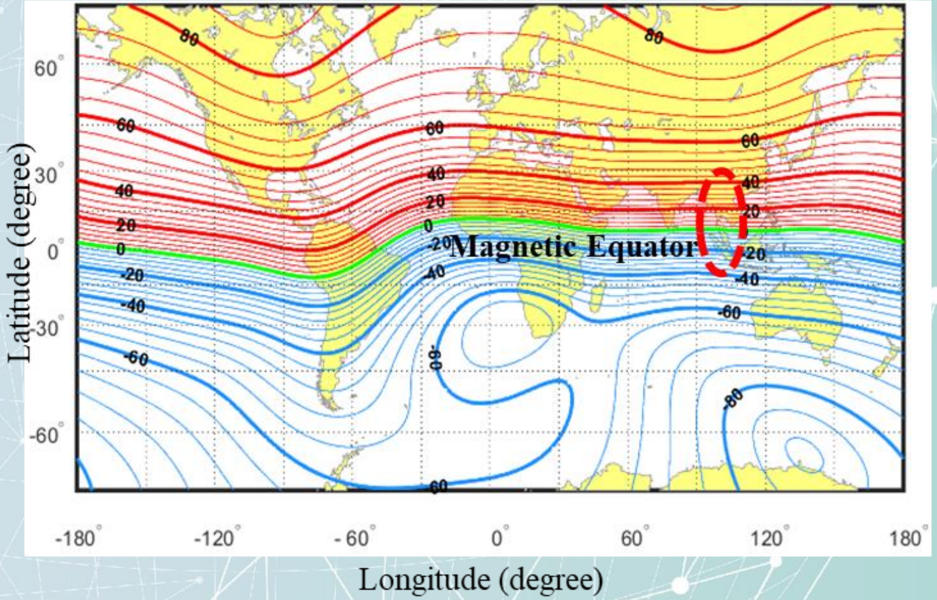


2. Research and Development

Domestic cooperation

Thai Space Physics & Space Weather Consortium

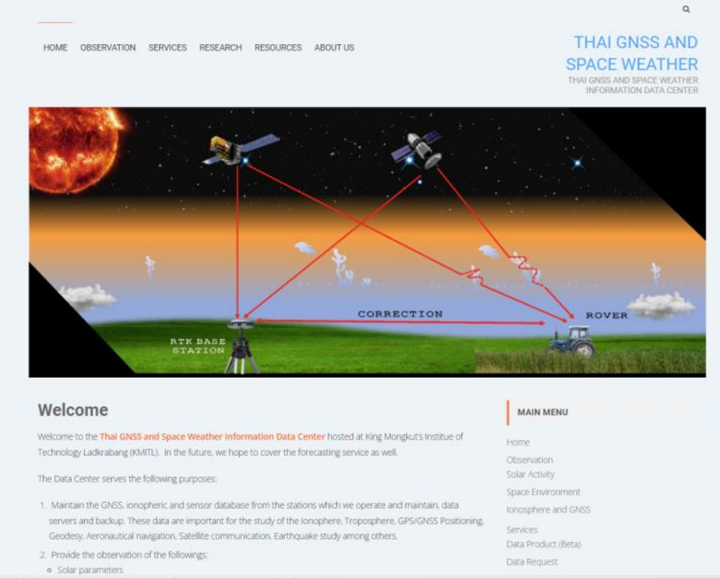
Earth's magnetic field



- **Thailand** is in low-latitude regions [-15,+15 deg] or **Equatorial regions.**
- Suitable for monitoring the atmosphere, **especially Ionosphere**

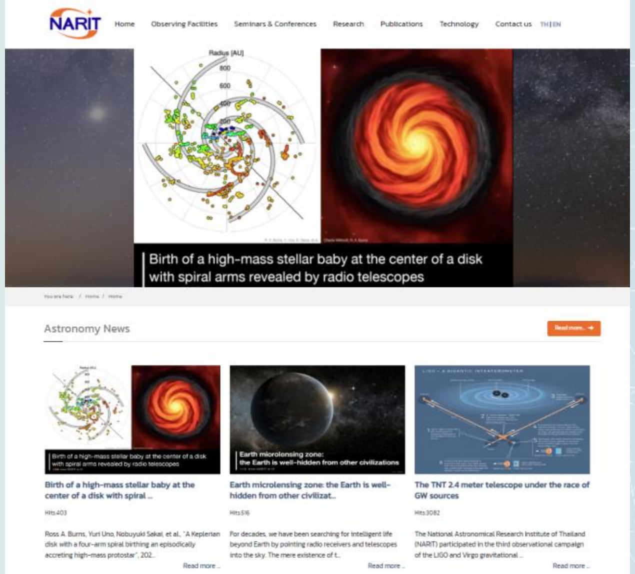
2. Research and Development

Domestic cooperation



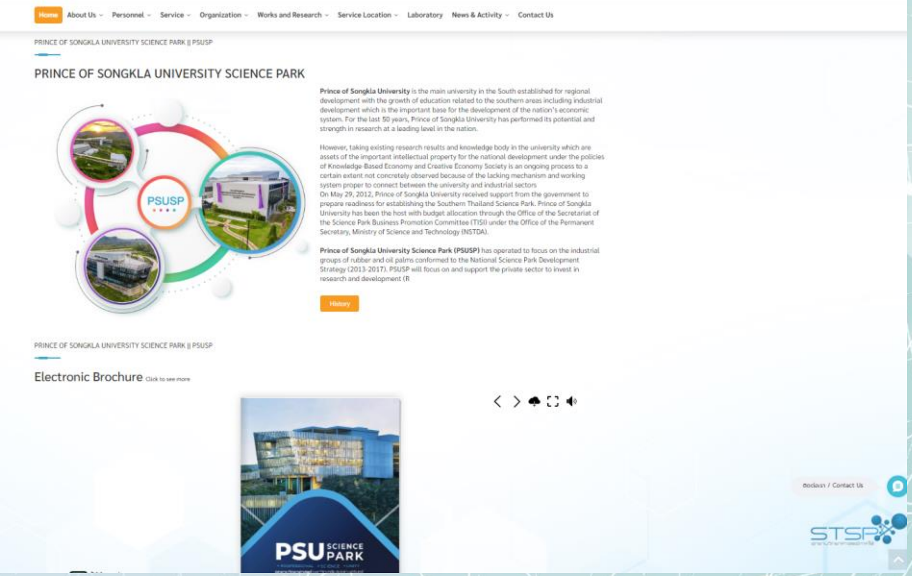
KMITL

Center of Excellence in GNSS and Space Weather, KMITL



NARIT

National Astronomical Research Institute of Thailand



PRINCE OF SONGKLA UNIVERSITY SCIENCE PARK

International activities and cooperation

Starting of Space Weather project

Memorandum of Understanding (MOU) on Space Weather (SW) technology between GISTDA and NICT

Dr. Anond Snidvongs Na Ayutthaya and
Dr. TOKUDA Hideyuki

MOU signing ceremony on 29 November 2019

- In June 2019, GISTDA approached NICT for the first time about developing a space weather forecast service.
- The collaboration between GISTDA and NICT was concluded, and the MOU was signed in November 2019.

International activities and cooperation

- **UN COPUOS cooperation**

Share statement of space weather activities in Thailand

- **NICT cooperation**

- **Asia-Oceania Space Weather Alliance (AOSWA)**

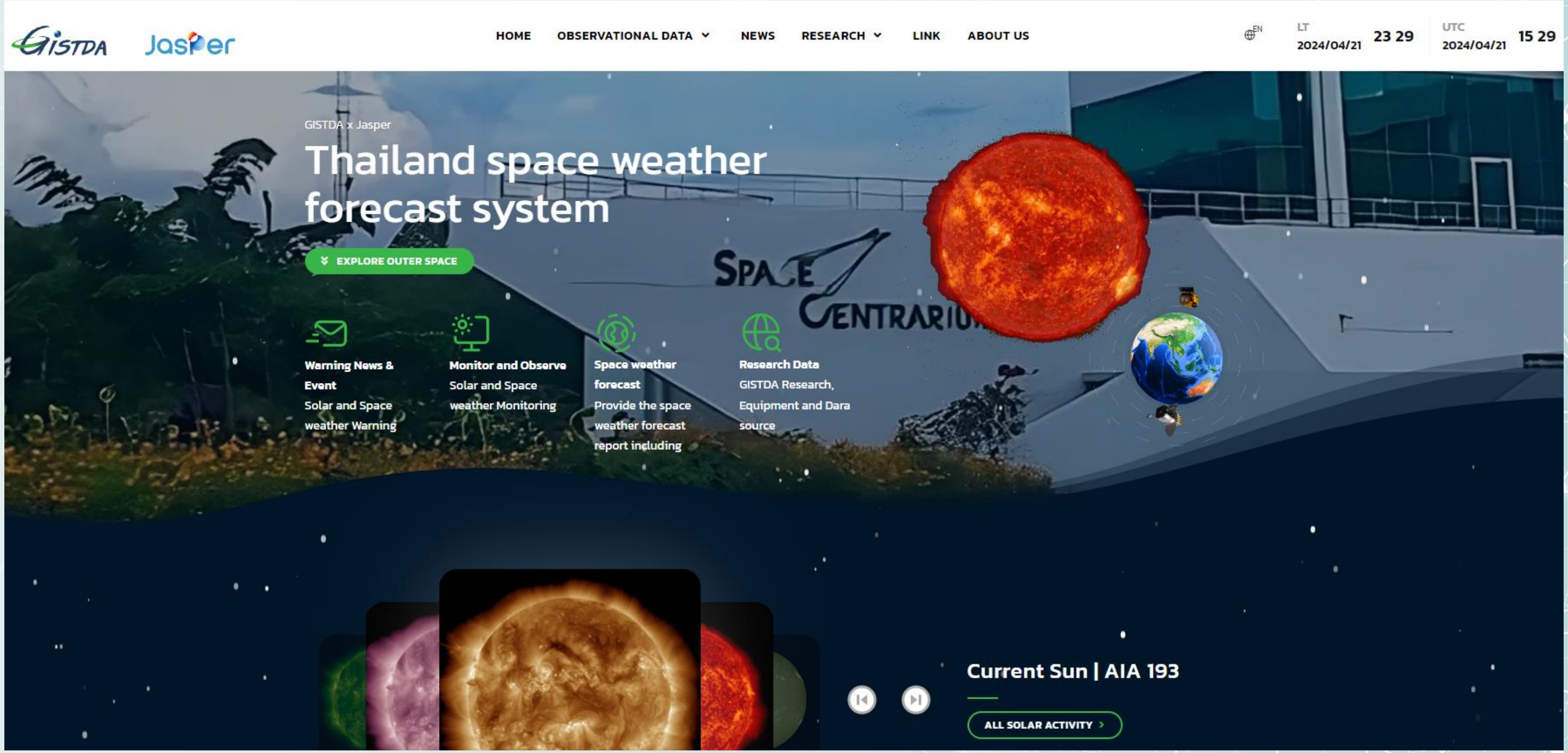
- **International Space Weather Initiative (ISWI)**

Representative, share, awareness, facilities about space weather

Space Weather Operation Room at GISTDA

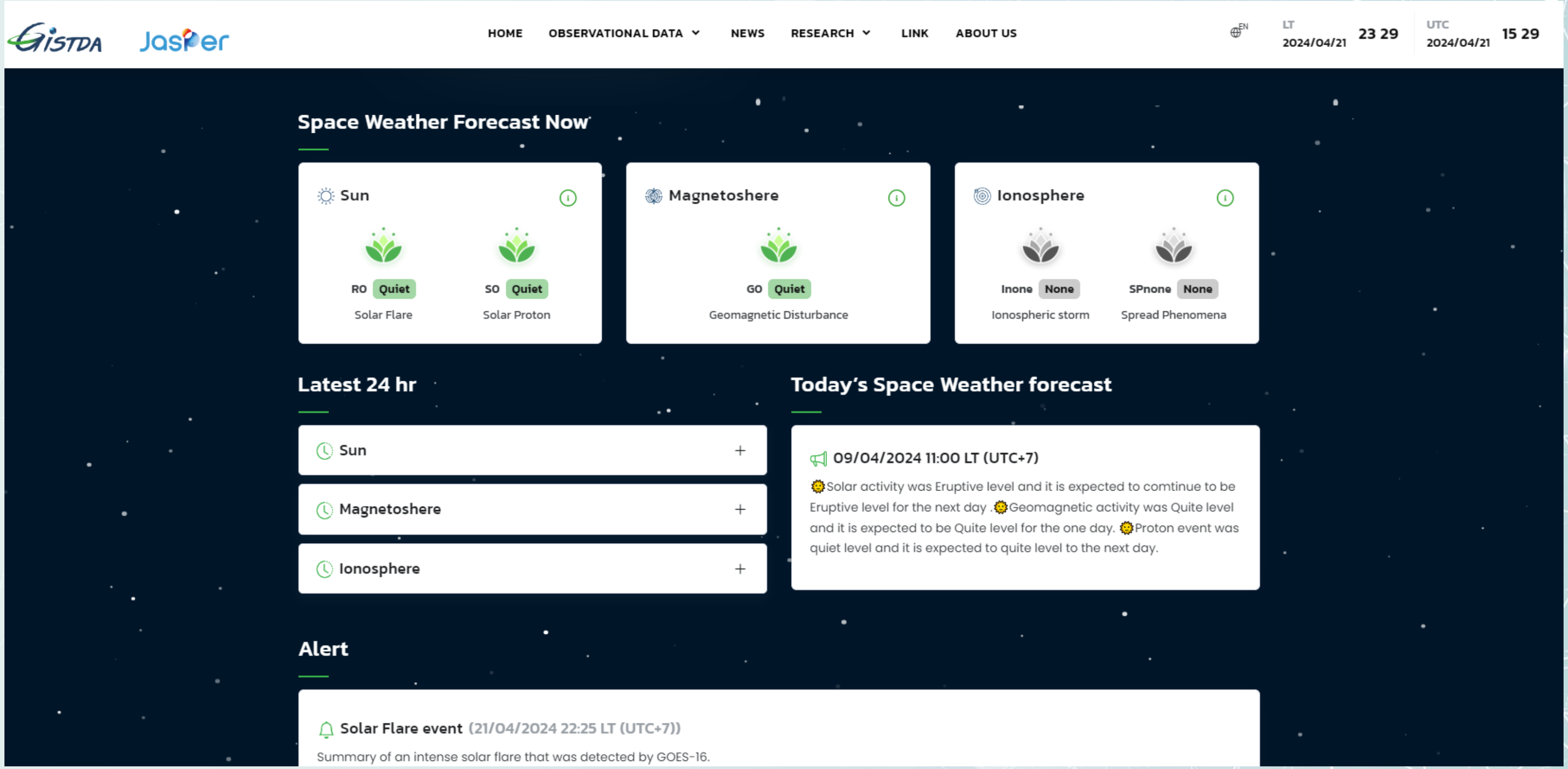
Jasper

Space weather prototype system (website, UI and Database)



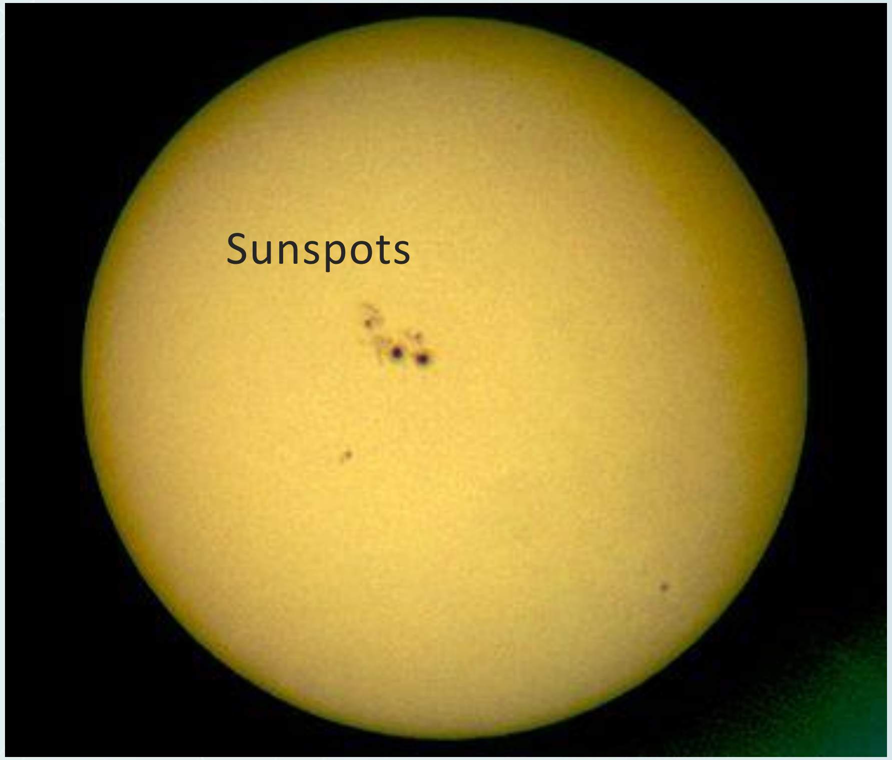
**Deployment is in progress

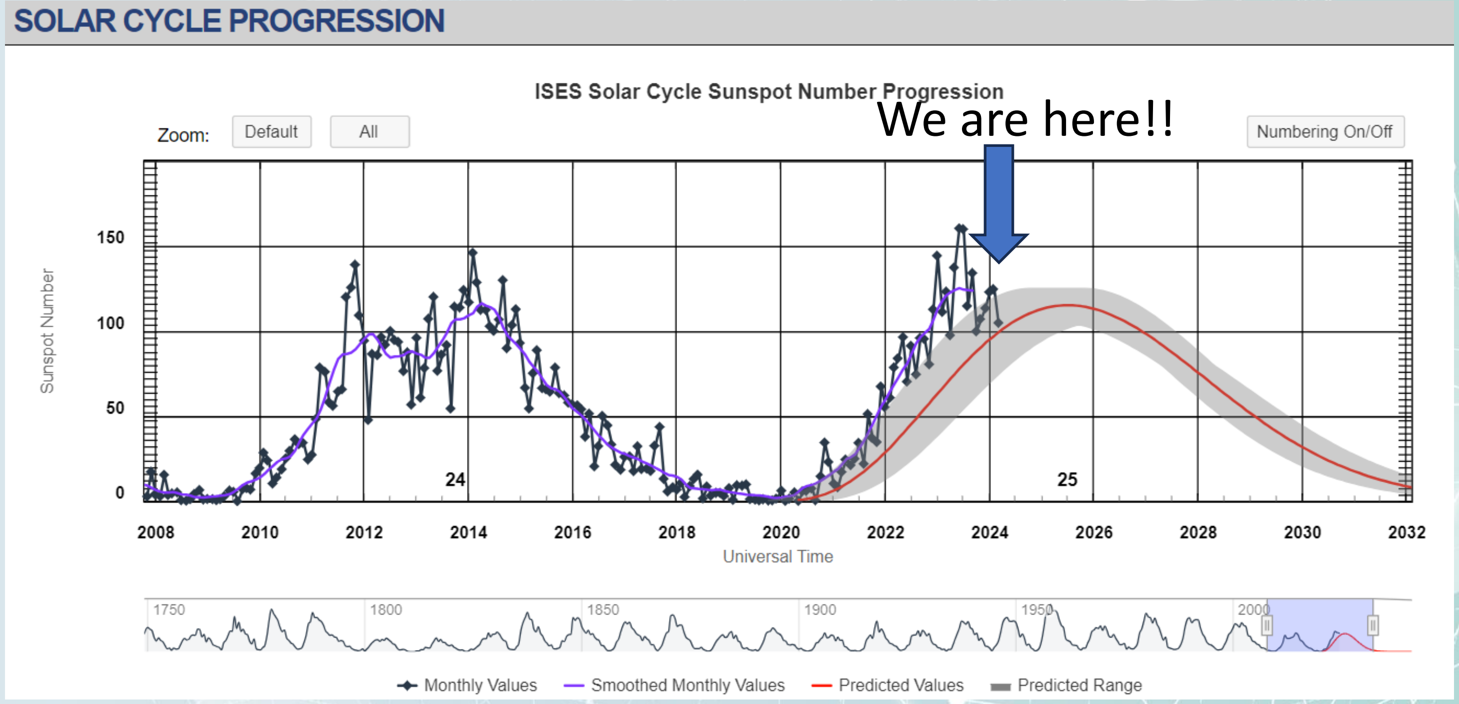
Space weather prototype system (website, UI and Database)



**Deployment is in progress

Solar cycle

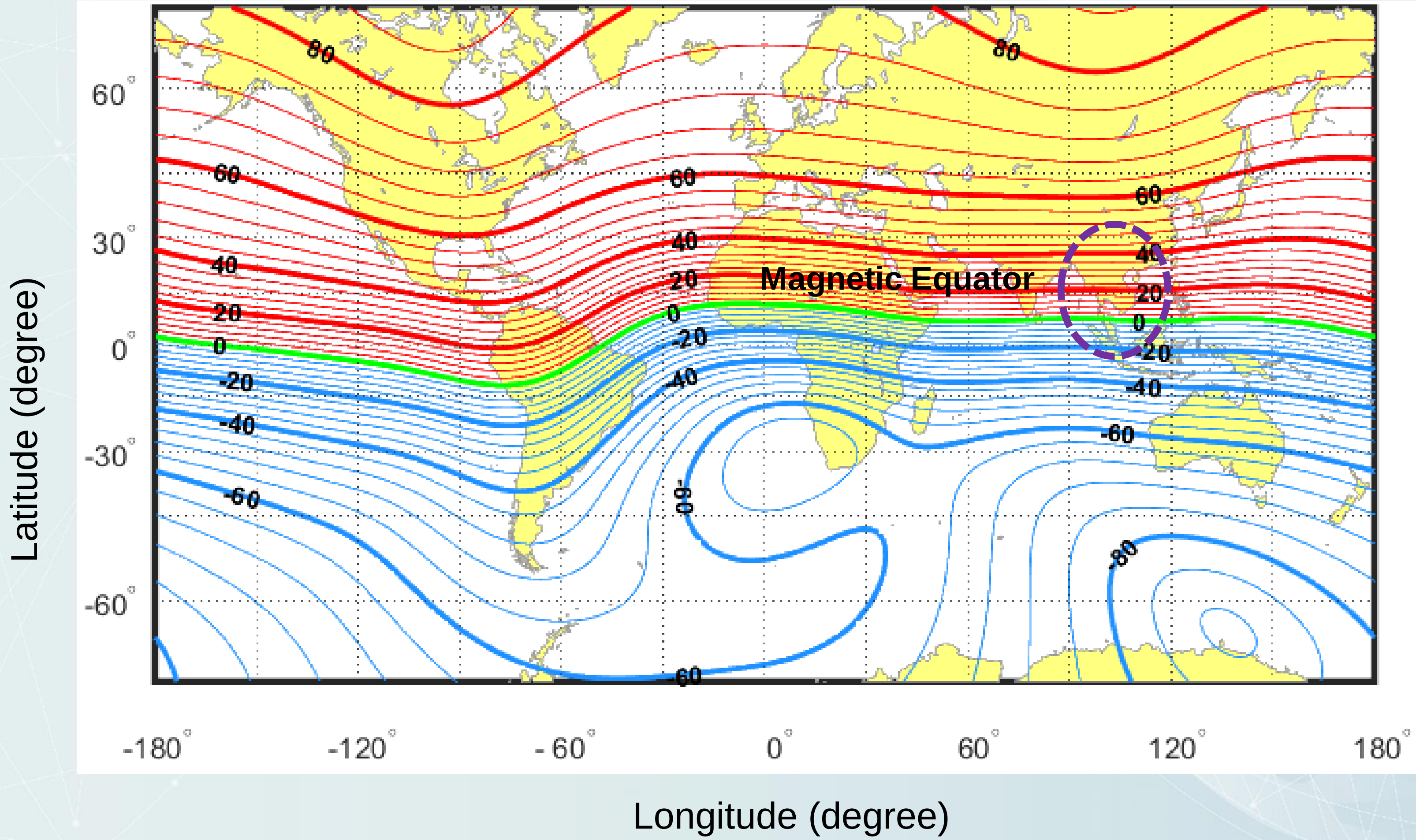




[https://www.swpc.noaa.gov/products/solar-cycle-progression]

The solar cycle period is approximately 11 years. Since 2023, solar activity has been very intense. The highest solar activity is expected in 2025, during the 25th cycle

Earth’s magnetic field

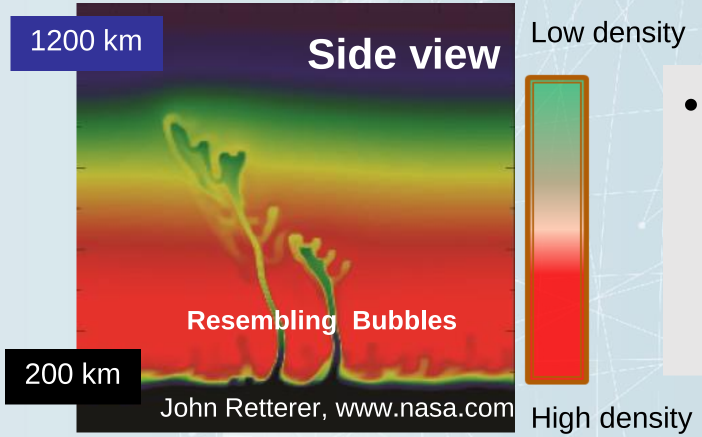


- Thailand is in low-latitude regions [-15,+15 deg] or Equatorial regions.
- Suitable for monitoring the atmosphere, **especially Ionosphere**
- **Thailand located near the magnetic equator, then free electron over the area are variation [1].**

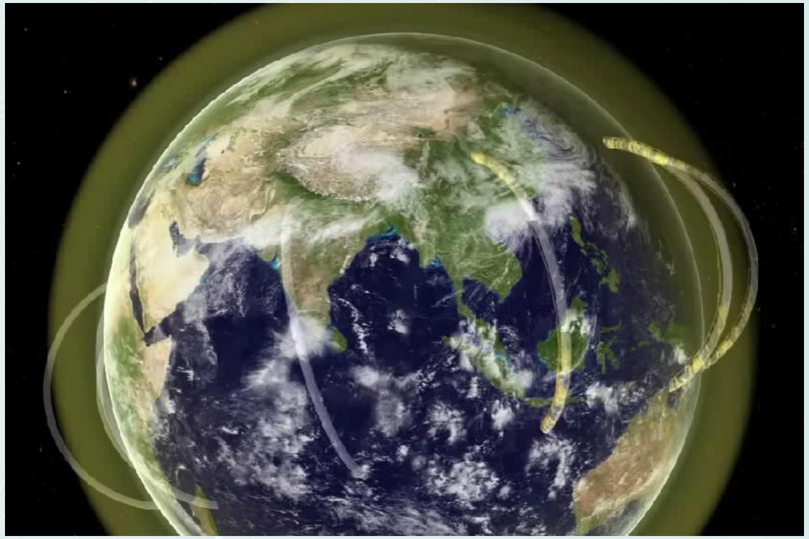
[1] Maruyama, T., Kawamura, M., Saito, S., Nozaki, K., Kato, H., Hemmakorn, N., ... & Duyen, C. H. (2007, July). Low latitude ionosphere-thermosphere dynamics studies with inosonde chain in Southeast Asia. In Annales Geophysicae (Vol. 25, No. 7, pp. 1569-1577).

Equatorial Plasma Bubble Phenomena (EPB)

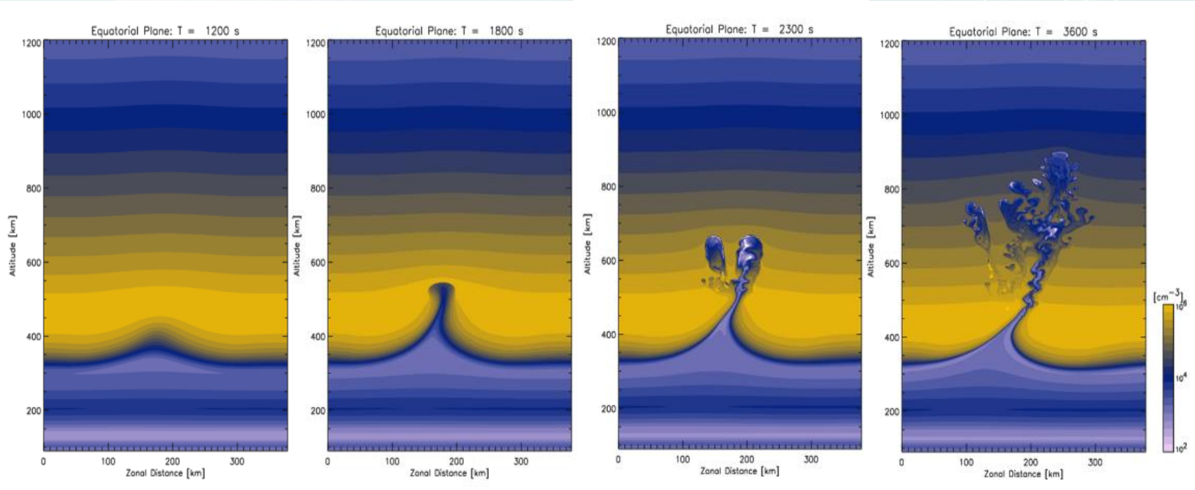
- **The EPBs due to non-uniform electron density areas** and they grow along the magnetic field line. Multiple EPBs are observed quite common.



- Generally, the ***electron density inside the bubble is lower than the outside area***, it caused by the instability at the bottom-side of the ionosphere after sunset.



3-D Plasma tubes drifting overhead simulated by Cleo Loi et.al., Curtin University, Australia [2].



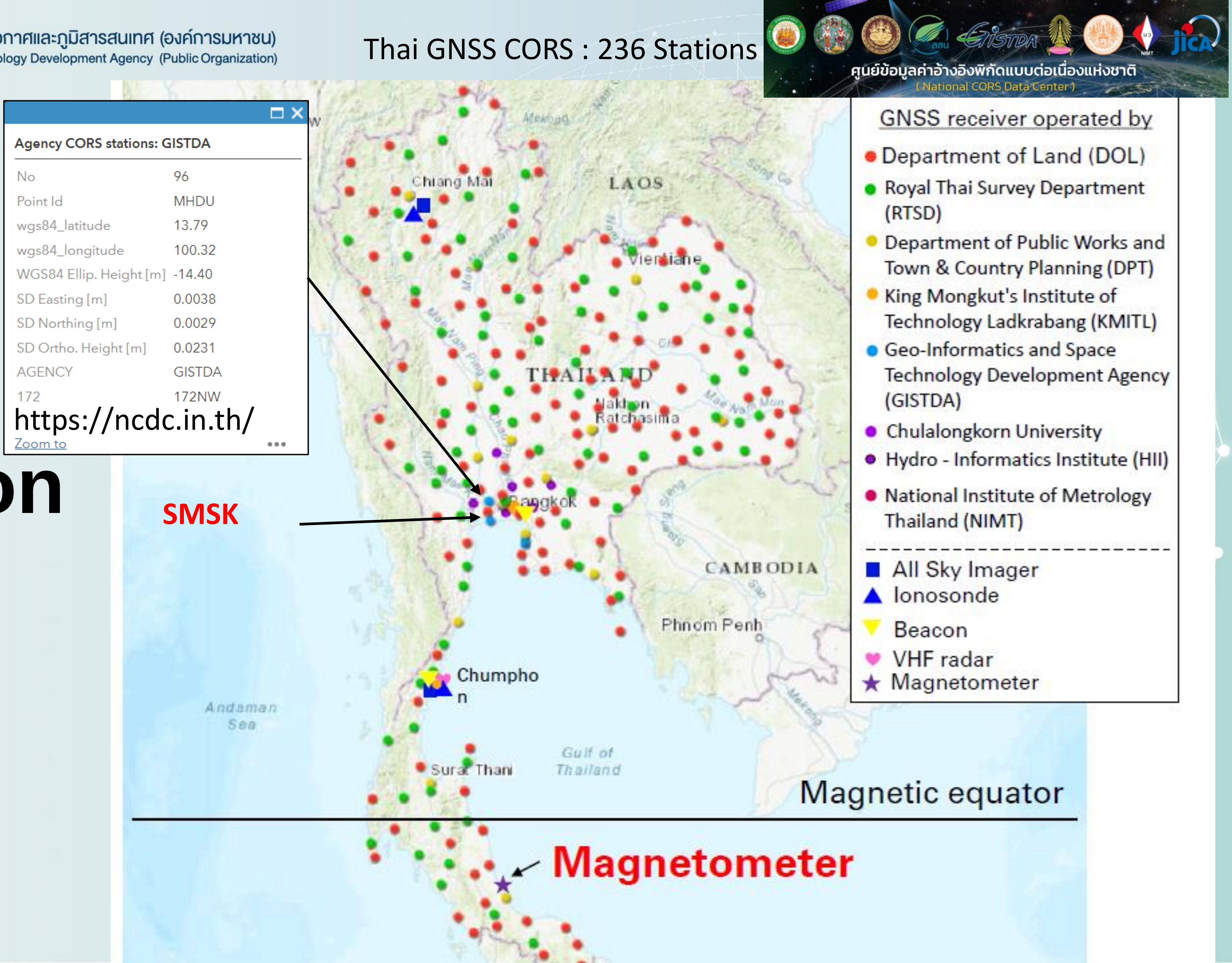
Simulated by T. Yokoyama et. al., 2014

[2] https://www.youtube.com/watch?v=ymZEOihlIdU

Thai GNSS CORS : 236 Stations

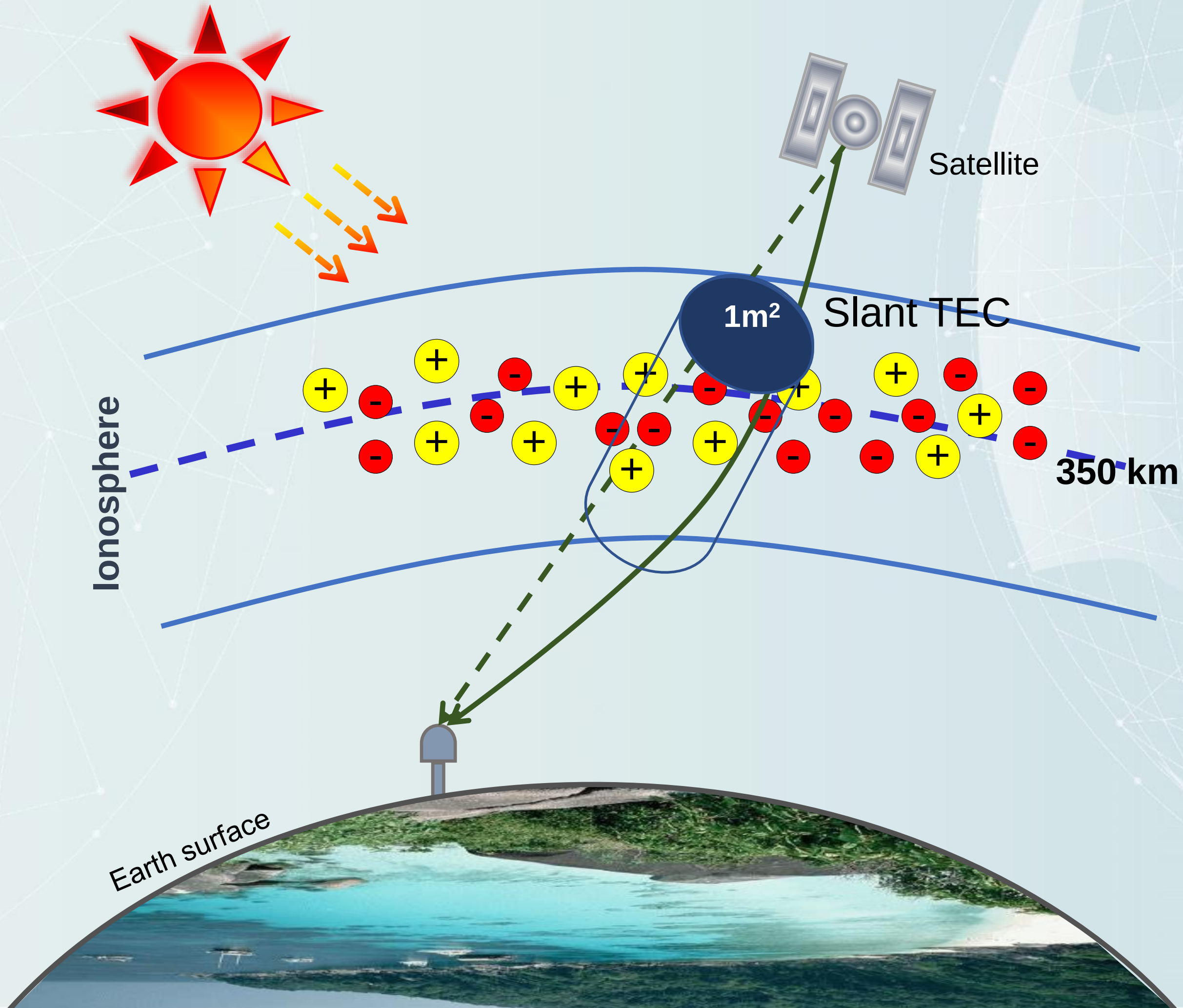
Thailand Space Observation facility

MHDU



Slant Total Electron Content (STEC)

STEC is the total number of electron density in slant path between the satellite and the receiver, expressed in TECU (1 TECU = 10^{16} electrons/m^2)



Slant Total Electron Content

$$STEC = \int_s N_e ds \quad \text{(TECU)}$$

- N_e : Electron density (electrons/m^3)
- S : Distance along the propagation path

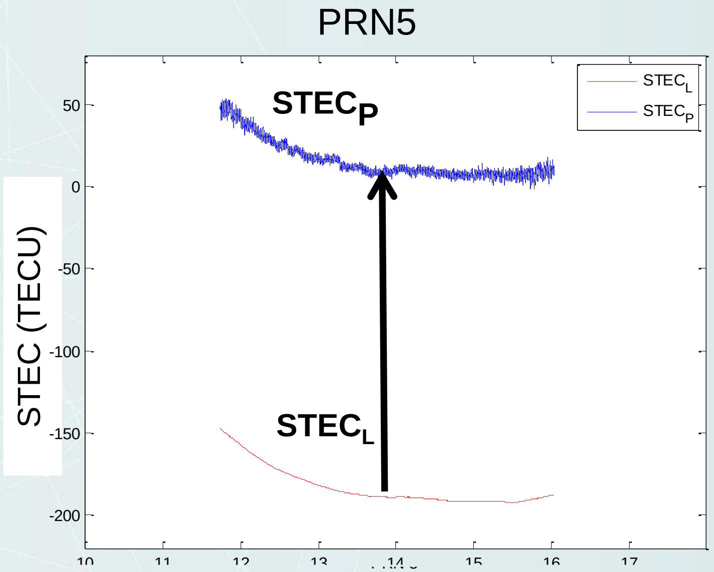
Ionospheric delay

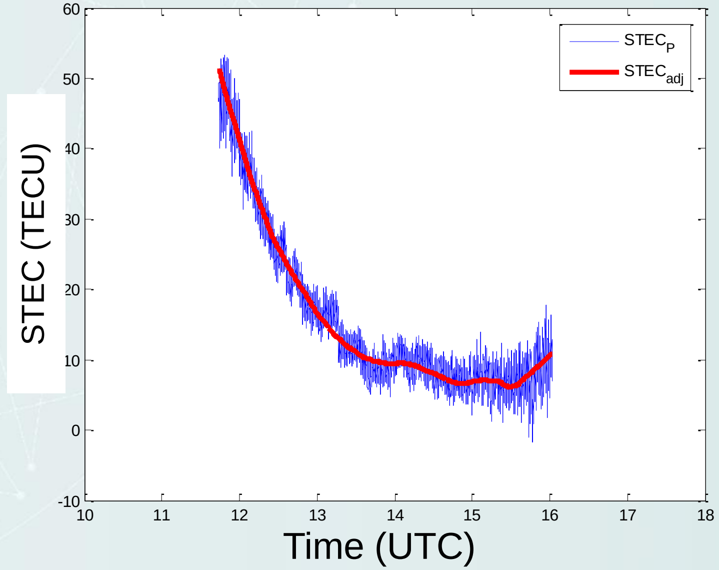
$$I = \frac{40.3 \times STEC}{f^2} \text{ (m)}$$

- I = Ionospheric delay (m)
- STEC = Slant Total electron content (TECU)
- f = Frequency (Hz.)

*L1 = 1575.42 MHz, L2 = 1227.60 MHz, L5 =1176.45 MHz

STEC obtained from GNSS signals (RINEX files)





- For dual-frequency GNSS receiver, the Slant TEC can be derived by both pseudorange and carrier phase linear combinations.

$$STEC_p = K(P_2 - P_1)$$

$$STEC_L = K(L_1 - L_2)$$

- $STEC_P$ = STEC pseudorange measurement (TECU)
- $STEC_L$ = STEC carrier phase measurement (TECU)
- P_1 = Pseudorange using C/A code on L1
- P_2 = Pseudorange using P-Code on L2
- L_1 = Pseudorange using Phase measurements on L1
- L_2 = Pseudorange using Phase measurements on L2
- K = 9.5196 for TEC expressed in TECU

$$STEC_{L\_adj} = STEC_L + (\overline{STEC_P - STEC_L})_{arc}$$

- $(\overline{STEC_P - STEC_L})$ = Mean between different STEC

$$STEC = STEC_{L\_adj} + b_r + b_s$$

- STEC = Adjusted STEC
- $STEC_{L\_adj}$ = Adjusted $STEC_L$
- b_r = The receiver bias
- b_s = The satellite bias

•The **$STEC_p$** is generally **noisier** than $STEC_L$. However, the **$STEC_L$** has a **phase ambiguity** that can lead to negative level.

Rate of TEC change index (ROTI)

The ROTI is used for ionospheric irregularities detection at one station for one day, defined by Standard deviation of rate of TEC change with 5-minute windows. In this work, we determined 0.5 TECU/min as the threshold.

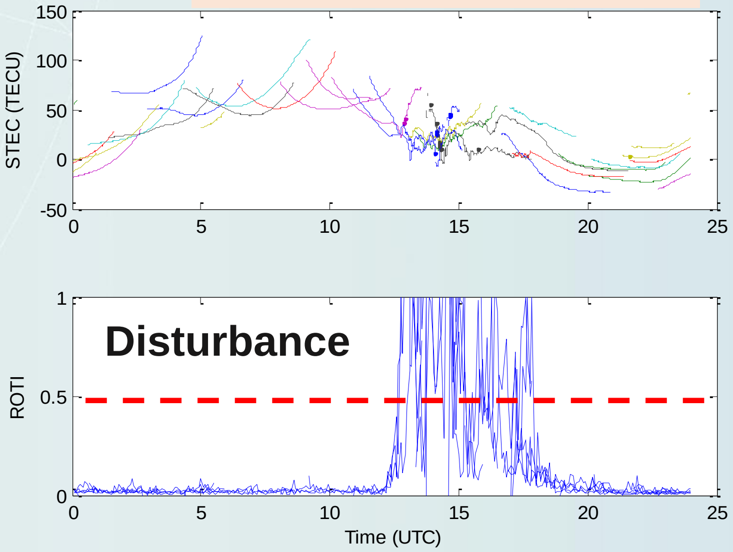
$$ROT(i) = STEC(i+1) - STEC(i)$$

$$ROTI = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(ROT(i) - \overline{ROT}\right)^2}$$

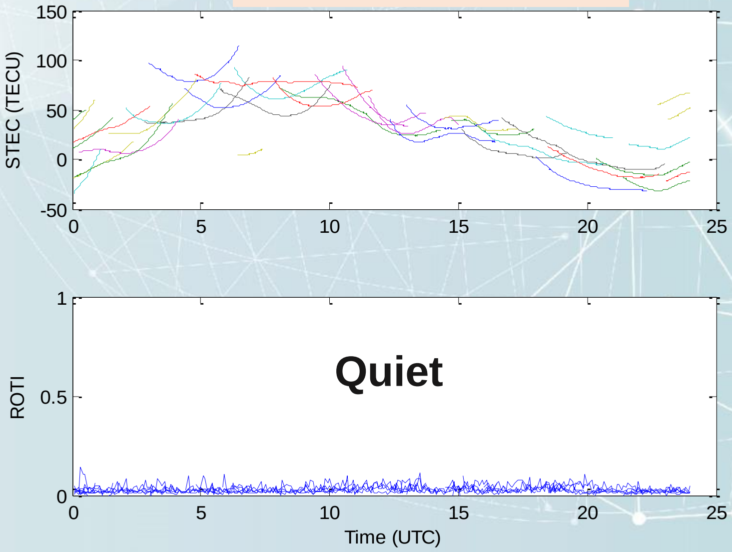
- i = Index of time
- N = Window size (minutes)

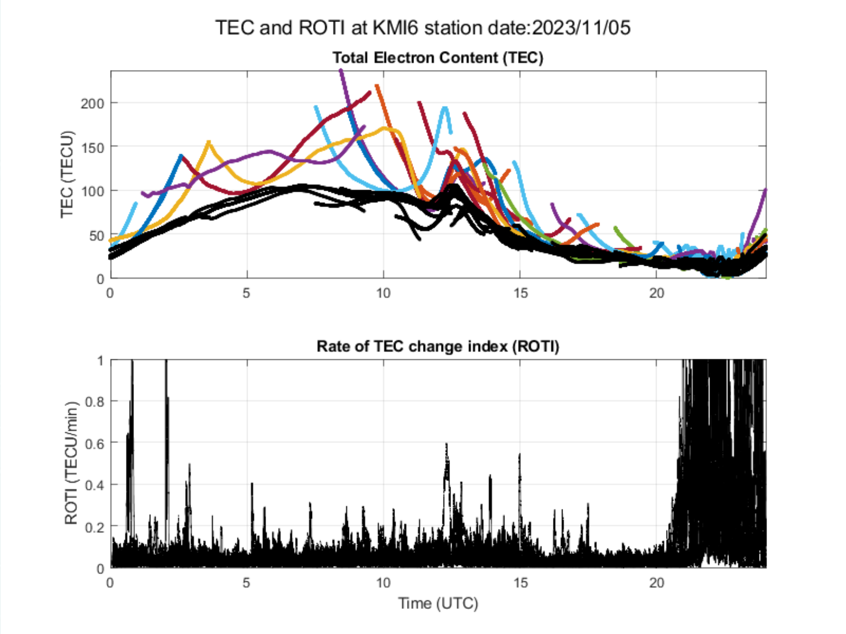
STEC and ROTI at KMITL station

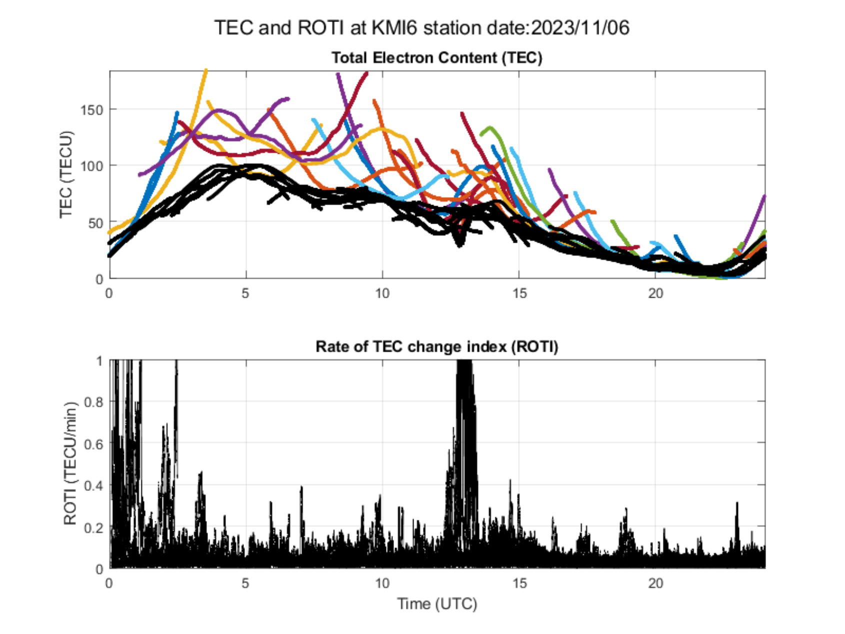
25th September 2015

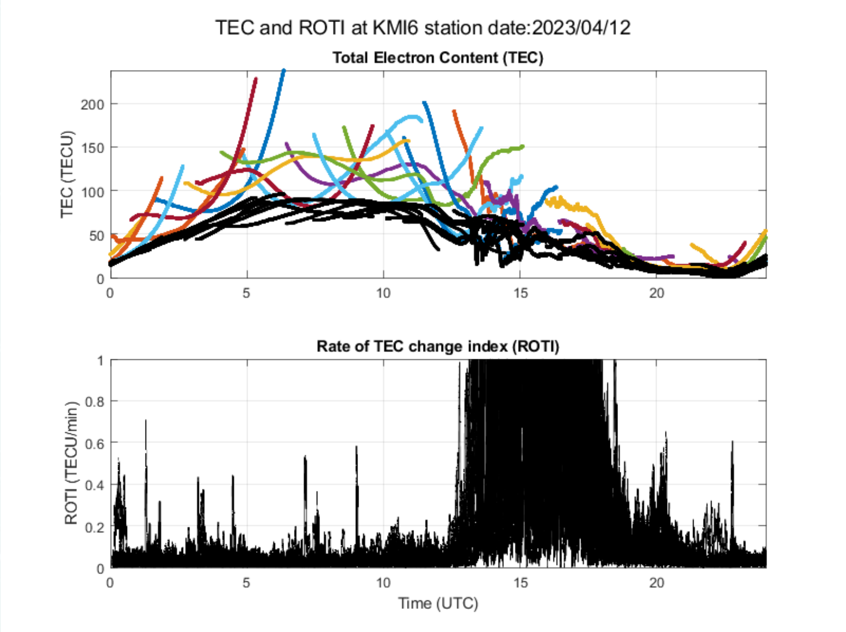


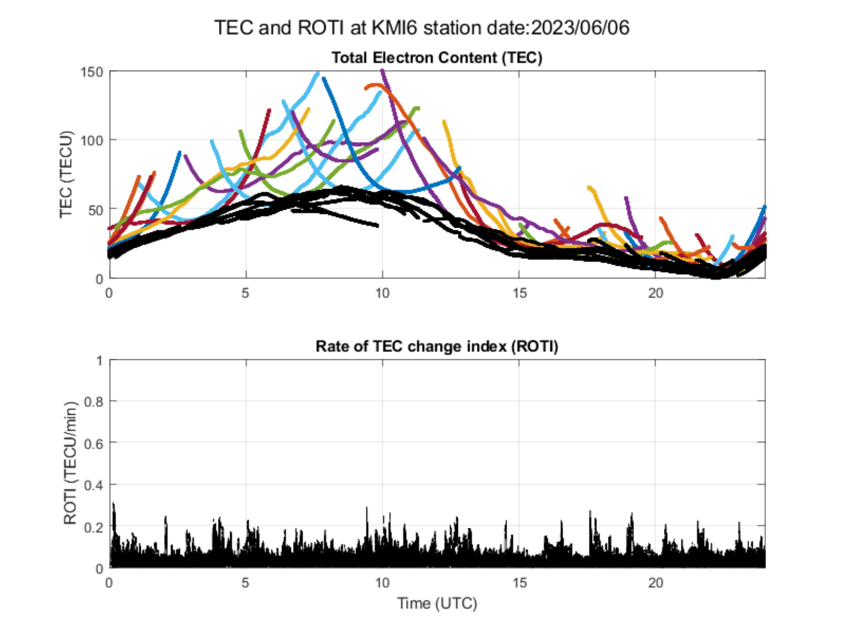
4th August 2015





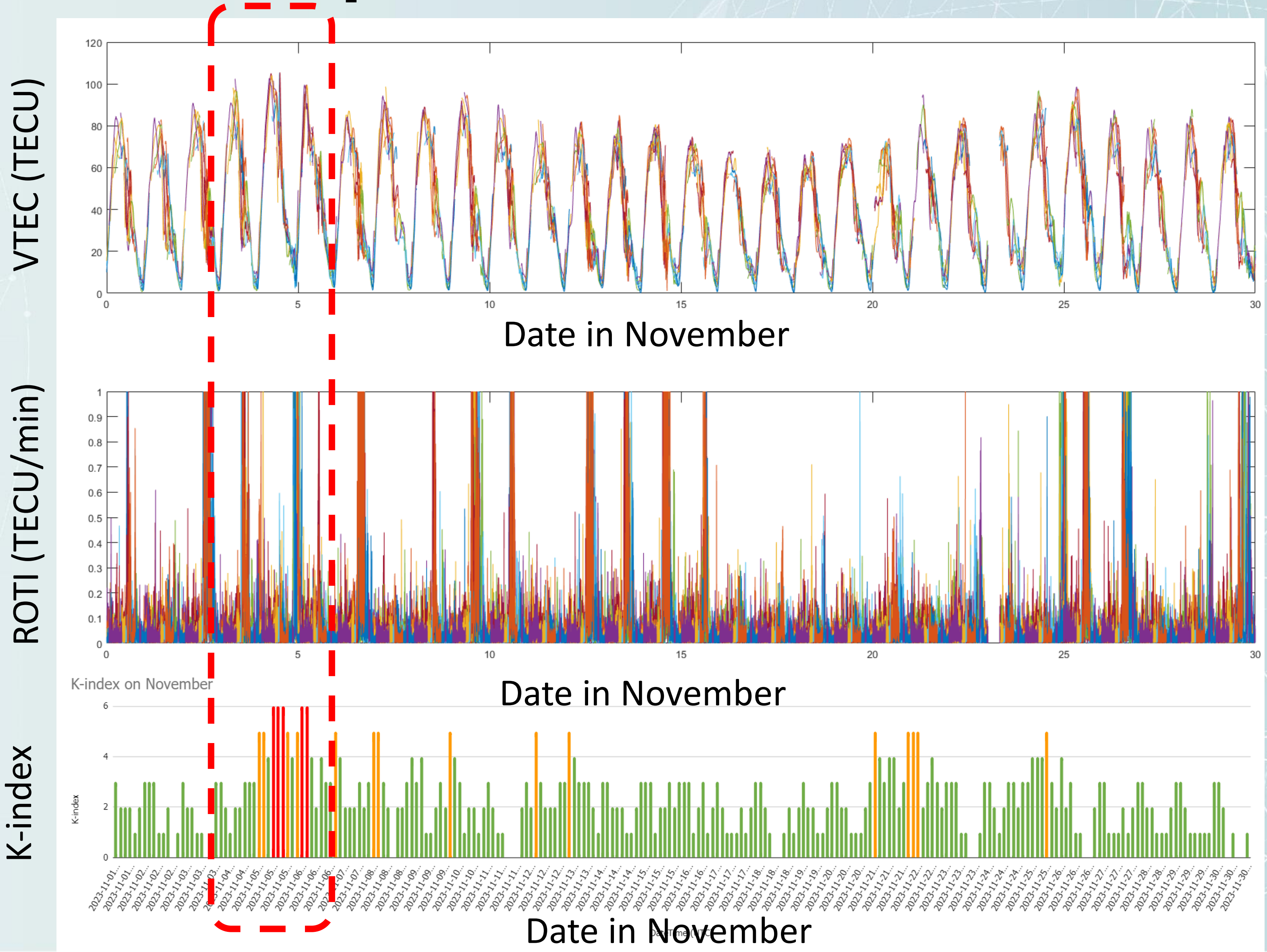




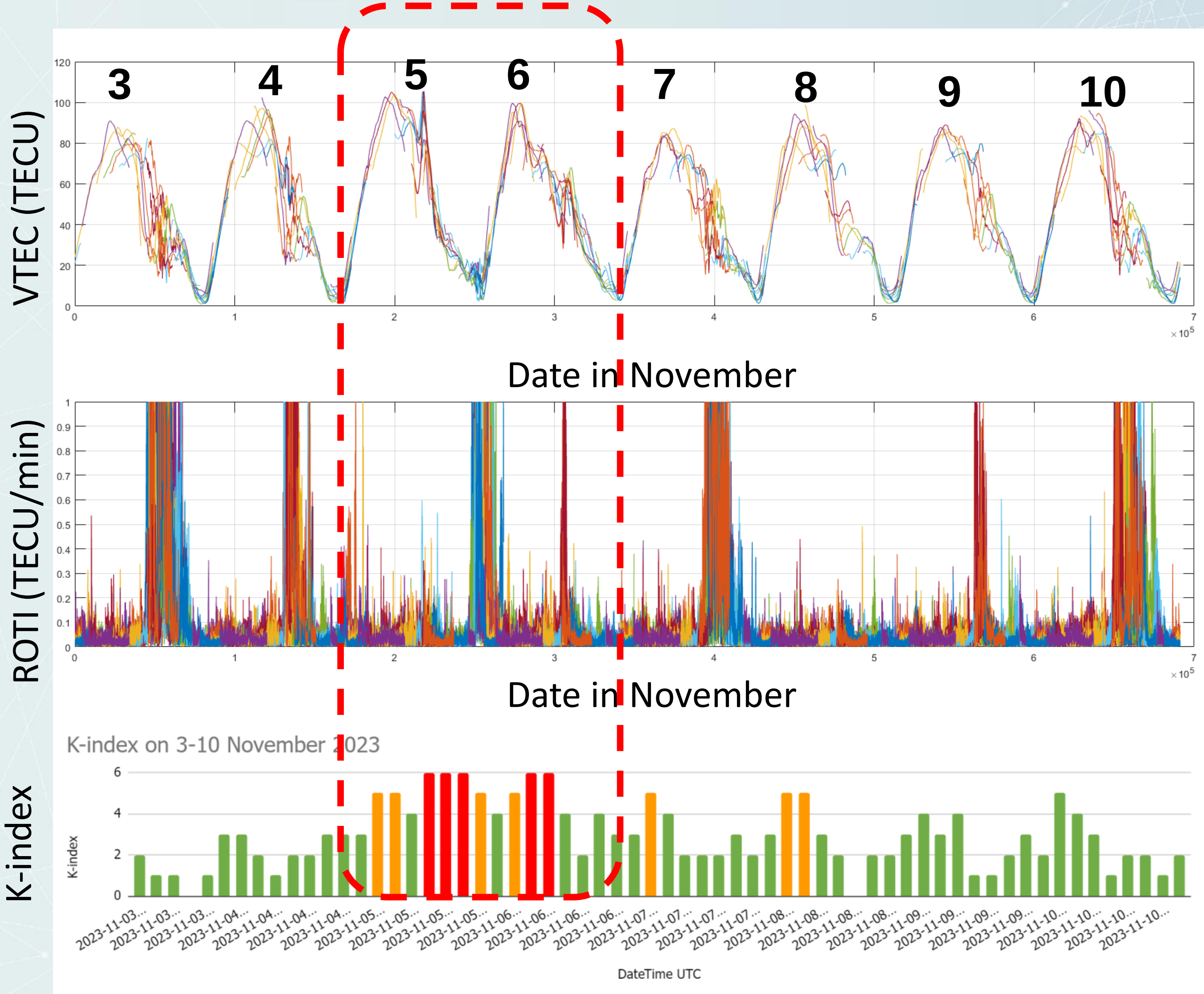


Example results of TEC and ROTI in 2023

VTEC and ROTI plot VS K-index in November 2023



VTEC and ROTI plot VS K-index from 3-10 November 2023

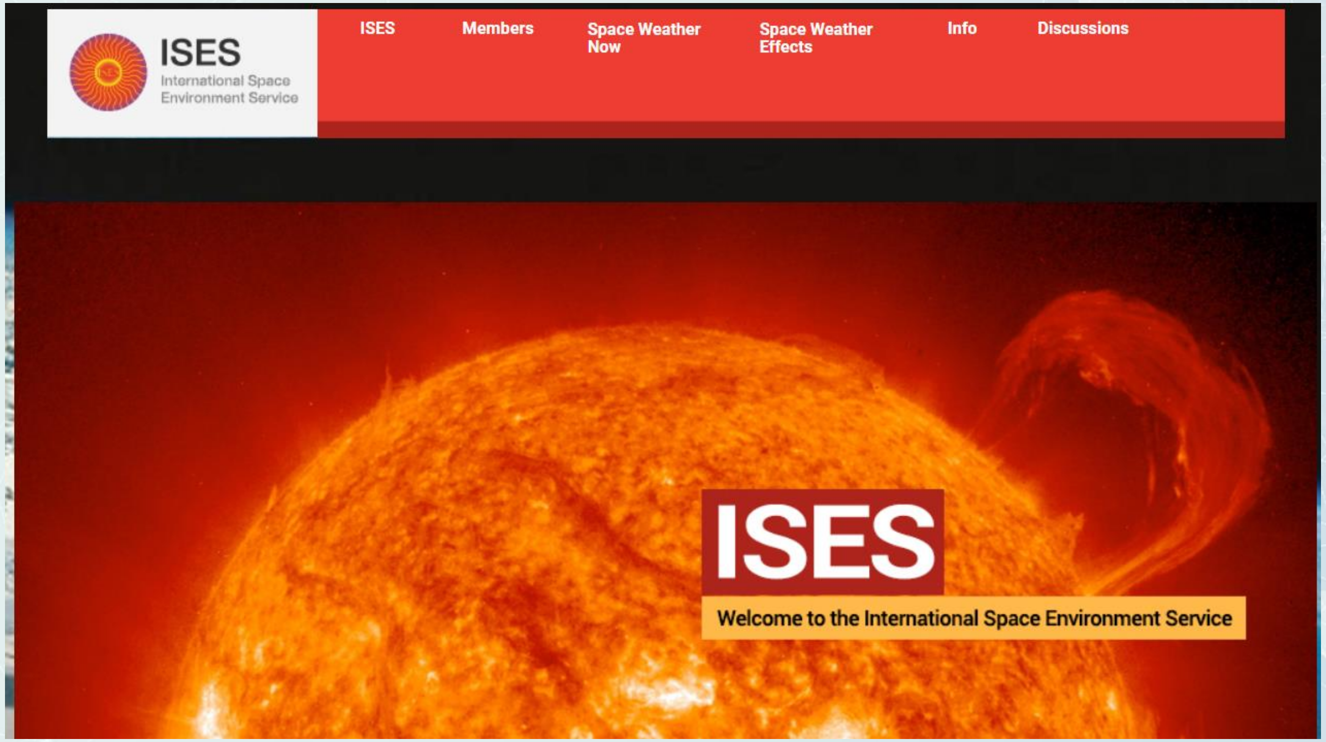


Conclusions

1. Thailand not only recognizes the significance of these guidelines but also actively embraces international cooperation, seeking opportunities to exchange best practices with the global community in order to ensure the enduring and responsible utilization of outer space.
2. Thailand’s welcome for international collaborations across all aspects to preserve of the outer space environment for the benefit of future generations.
3. During periods of high solar activity, frequent geomagnetic storms occur, leading to higher Total Electron Content (TEC) values and more severe ionospheric irregularity.

Future Plan

- To be part of ISES member for sharing the data and to deliver operational space weather services over Thailand region.



At present, there are twenty-two Members distributed around the globe. These centers are located in China (Beijing) , USA (Boulder), Russia (Moscow), India (New Delhi), Canada (Ottawa), Czech Republic (Prague), Japan (Tokyo), Australia (Sydney), Sweden (Lund), Belgium (Brussels), Poland (Warsaw), South Africa (Hermanus), South Korea (Jeju), Brazil (São José dos Campos), Austria (Treffen) and UK (Exeter). The European Space Agency (Noordwijk) is a collaborative expert center providing a venue for data and product exchange for activities in Europe.

GISTDA Host AOSWA2024

https://aoswa2024.gistda.or.th/

Acknowledgement

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Thank you for your kind attention

Q/A

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