Lao Space Weather Learning Center (LSWLC) at National University of Laos

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Background :

Severity of space weather (SW) climatology can impact various communication systems such as HF/VHF radio waves systems, satellite-based positioning systems, etc. These advanced technologies of radio waves communications are more necessary and important for human and country's sustainable development. For example, the failure of communication systems can be caused by irregularities of the ionosphere and the severe space environments resulting huge loss of economy, development, stability, and human life (H. Sato et al., 2019; O.F. Jonah et al., 2020; M. Ishii et al., 2024).

Targets:

LSWLC focuses on three main objectives as follows

(1) To enhance awareness and prevention of space impacts to society and industry

(2) To develop observational center of Space Weather in Laos

(3) To open space research gate in Laos

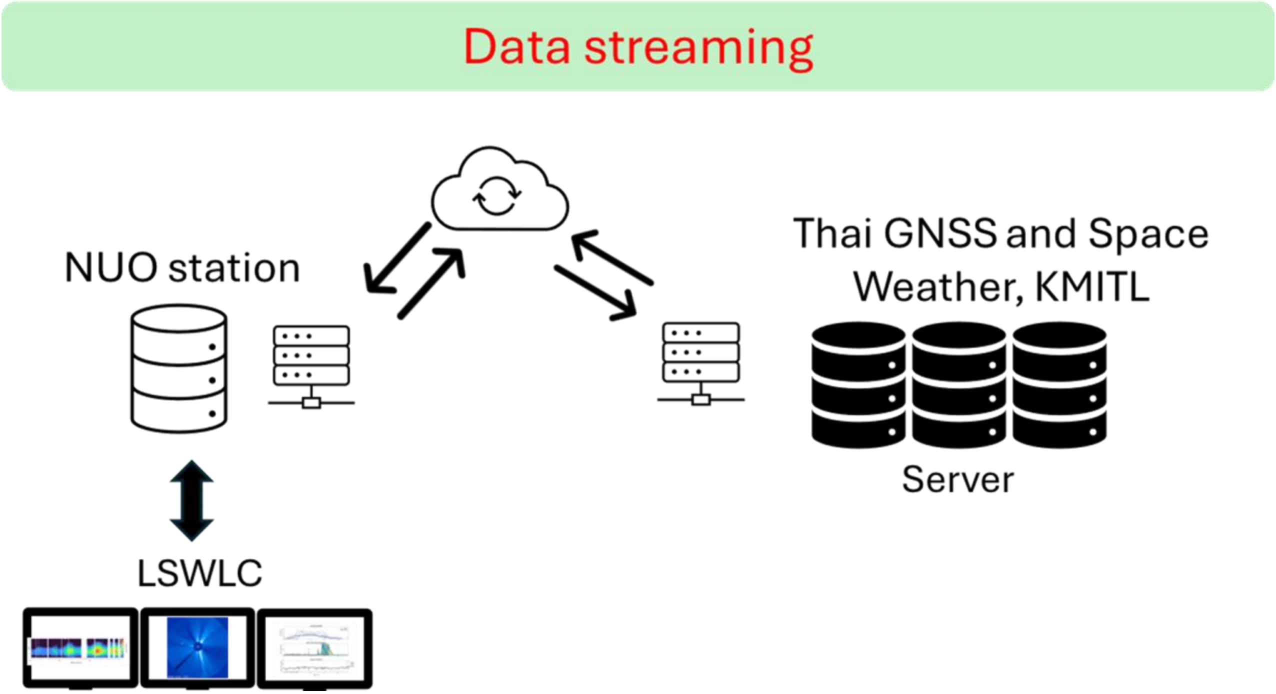
Proposed Method: Lao Space Weather Learning Center

Data sharing network

- Data connection to0 global networks
- Synchronization of data products from global data centers
- Data streaming via NTRIP protocol
- Available RINEX 2.0 and 3.0 data

Ionospheric monitoring and modeling

- Ionospheric plasma densities and irregularities
  - Vertical Total Electron Content (VTEC)
  - Rate of TEC change index (ROTI)
- Deep Learning to model the VTEC
  - Deep Neural Networks
  - Long-Short Term Memory



Proposed Method: STEC, ROTI, and VTEC

TEC along the ionospheric slant path

$$STEC = \int_S N_e ds$$

N_e : Electron density (electrons/m^2)

S : Distance along the slant path)

Rate change of TEC

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

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

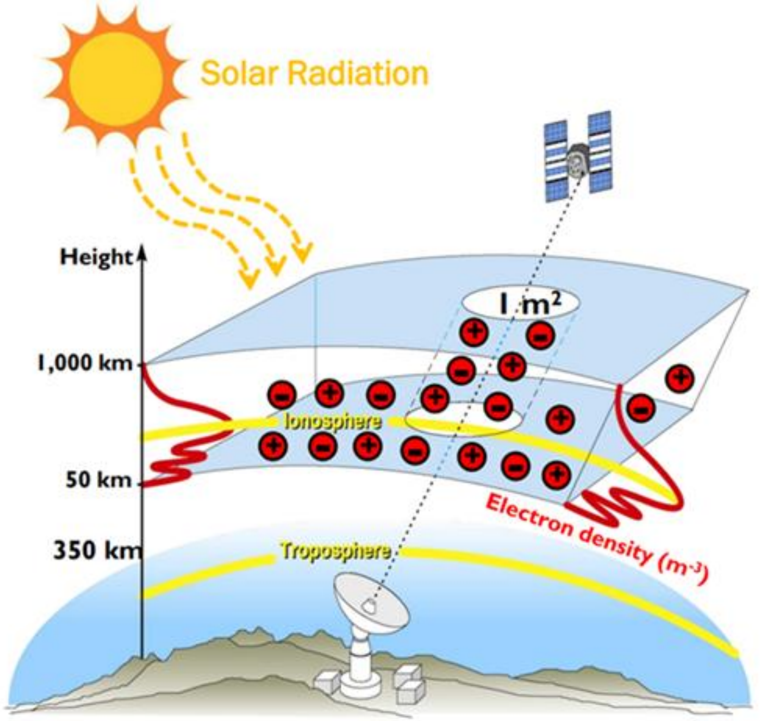
i: index of time

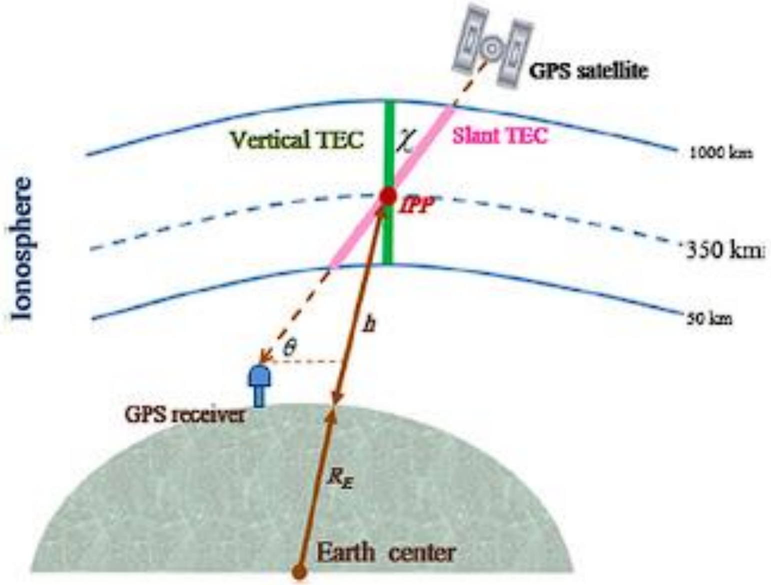
N: Window time (minute)

STEC to VTEC conversion (J.A. Klobuchar, 1987)

$$VTEC = STEC \times cos\chi$$

χ - Zenith angle (degree)

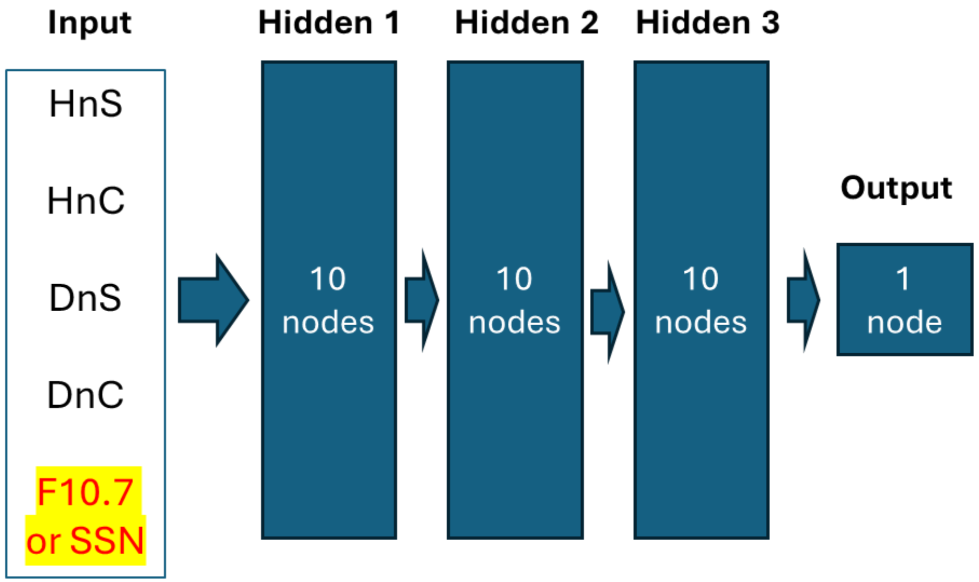




(A. Silwal et al., 2020)

Proposed Method: VTEC DNN model

Model structure with daily F10.7 or SNN



Data sources of F10.7 and SSN:
https://omniweb.gsfc.nasa.gov/form/dx1.html

VTEC DNN Model's details

Input: $X = [HnS, HnC, DnS, DnC, SSN/F10.7]$

Output: $Y = [TEC]$

Model: $\tilde{Y}(X,[W,b]) = f^{1}_{i,j\in[5,10]}\left(f^{2}_{i,j\in[10,10]}\left(f^{3}_{i,j\in[10,10]}\left(f^{4}_{i,j\in[10,1]}(X,[W^{i,j},b^{j}])\right)\right)\right)$

Model learning: $L(\tilde{Y},Y) = 0.5(\tilde{Y}-Y)^2$

$$W^{i,j} = W^{i,j,*} - \alpha \frac{\partial L(\tilde{Y},Y)}{\partial W^{i,j}}$$

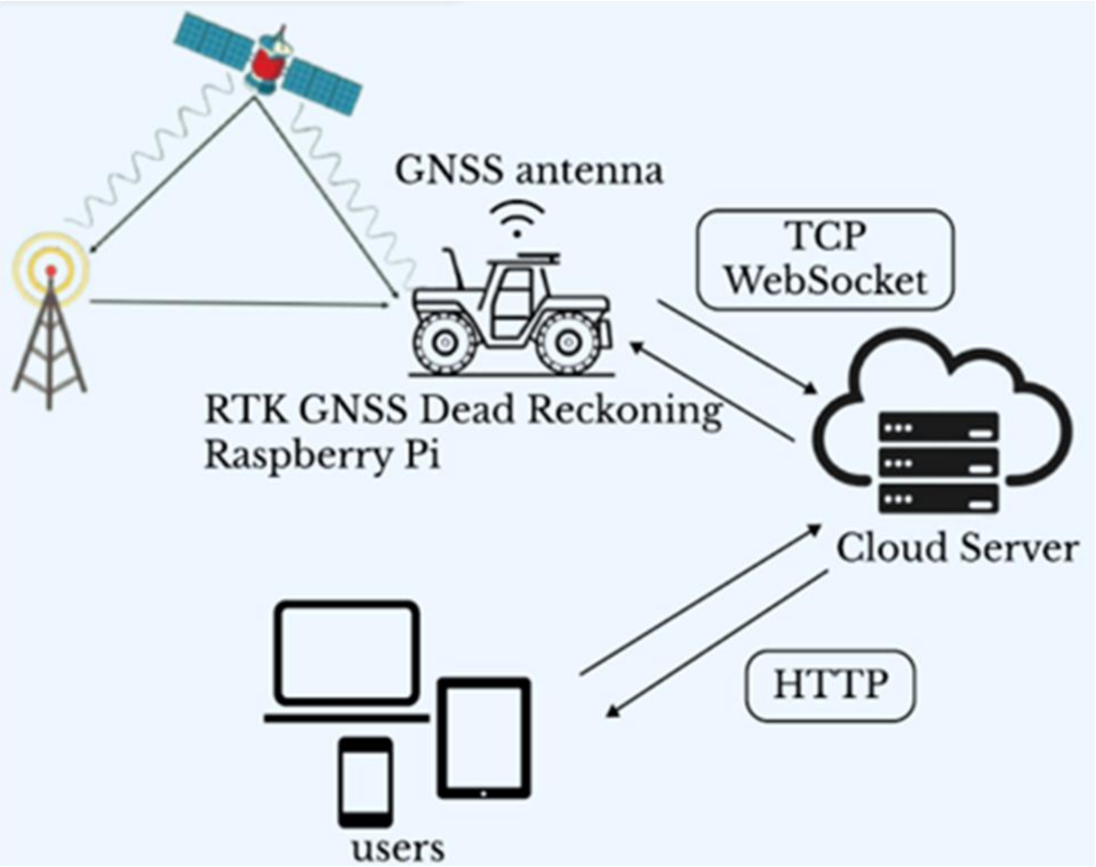
Gradient moving steps

Note: ADAM moment's parameters are not shown here for simplicity

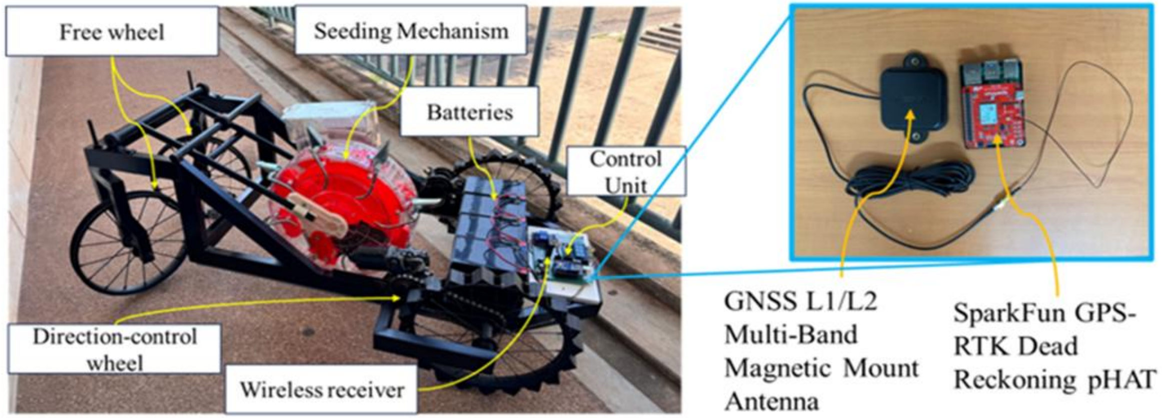
- Model's optimization and initialization are based on Adaptive Moment Estimation - Adam (D.P. Kingma et al., 2017) and Xavier Glorot's initialization (X. Clorote et al., 2010)

Proposed Method: RTK positioning system used for the seeding robot

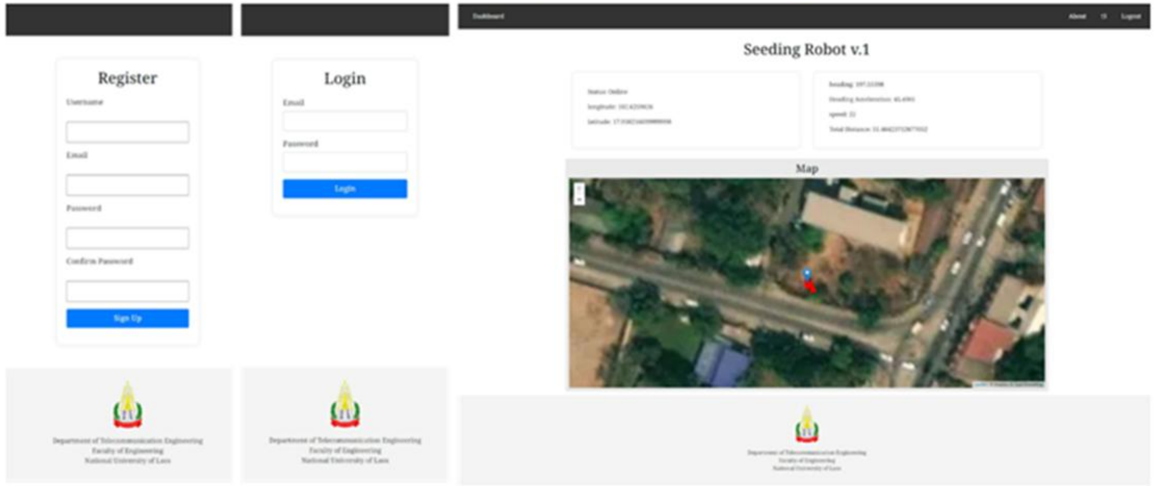
Structure of RTK positioning system



Seeding robot with RTK positioning module



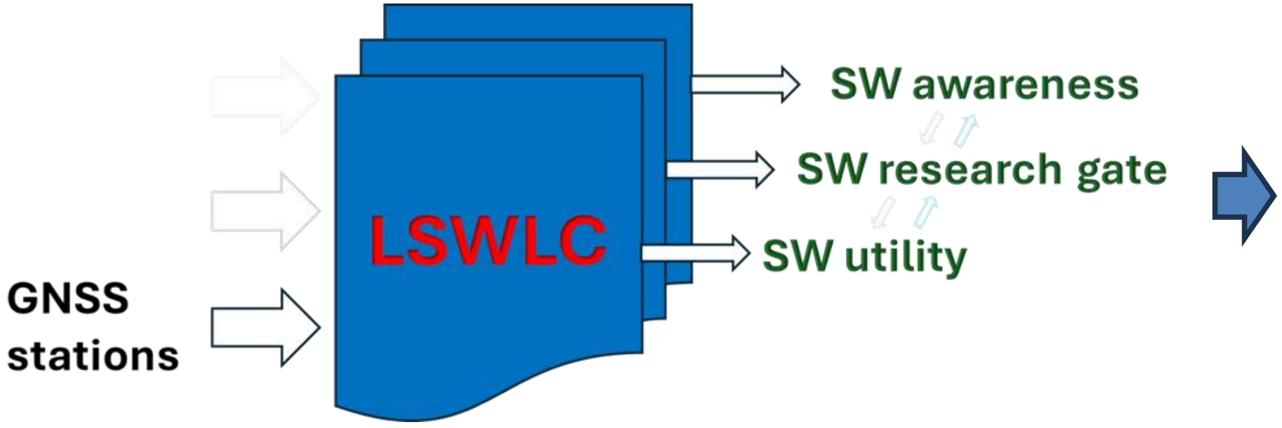
User interface for RTK positioning and monitoring



Impact:

Contributions of the proposed methods

1. Utilization of the space weather information data
2. Conditional warning systems via ionospheric parameters for preventive purpose
3. Public users can access awareness of the ionospheric environments
4. Data sharing and network collaborations with national and international organizations
5. Research gates to national and international network

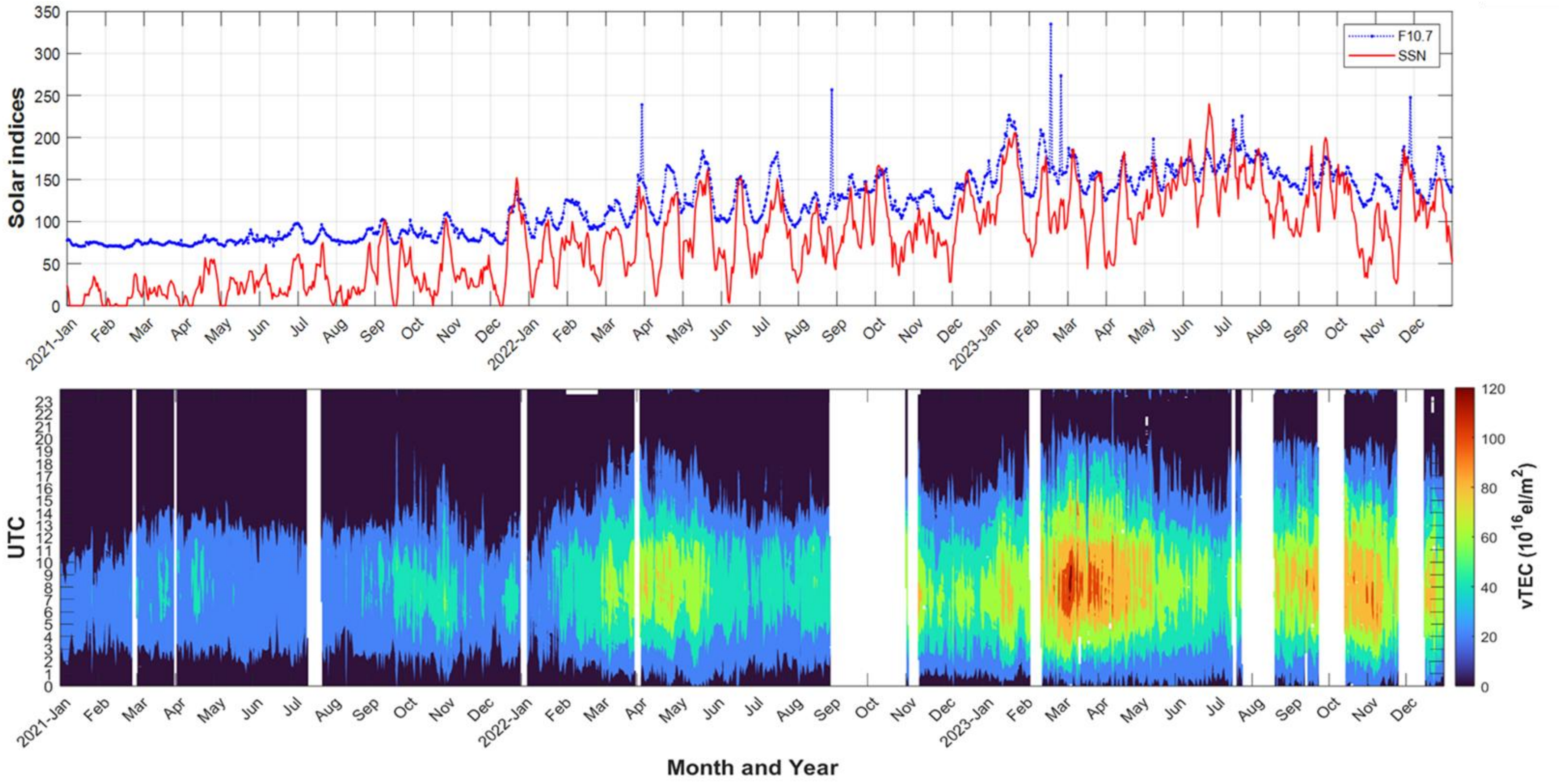


- Public users
- Organizations
- Research networks

Output/Outcome:

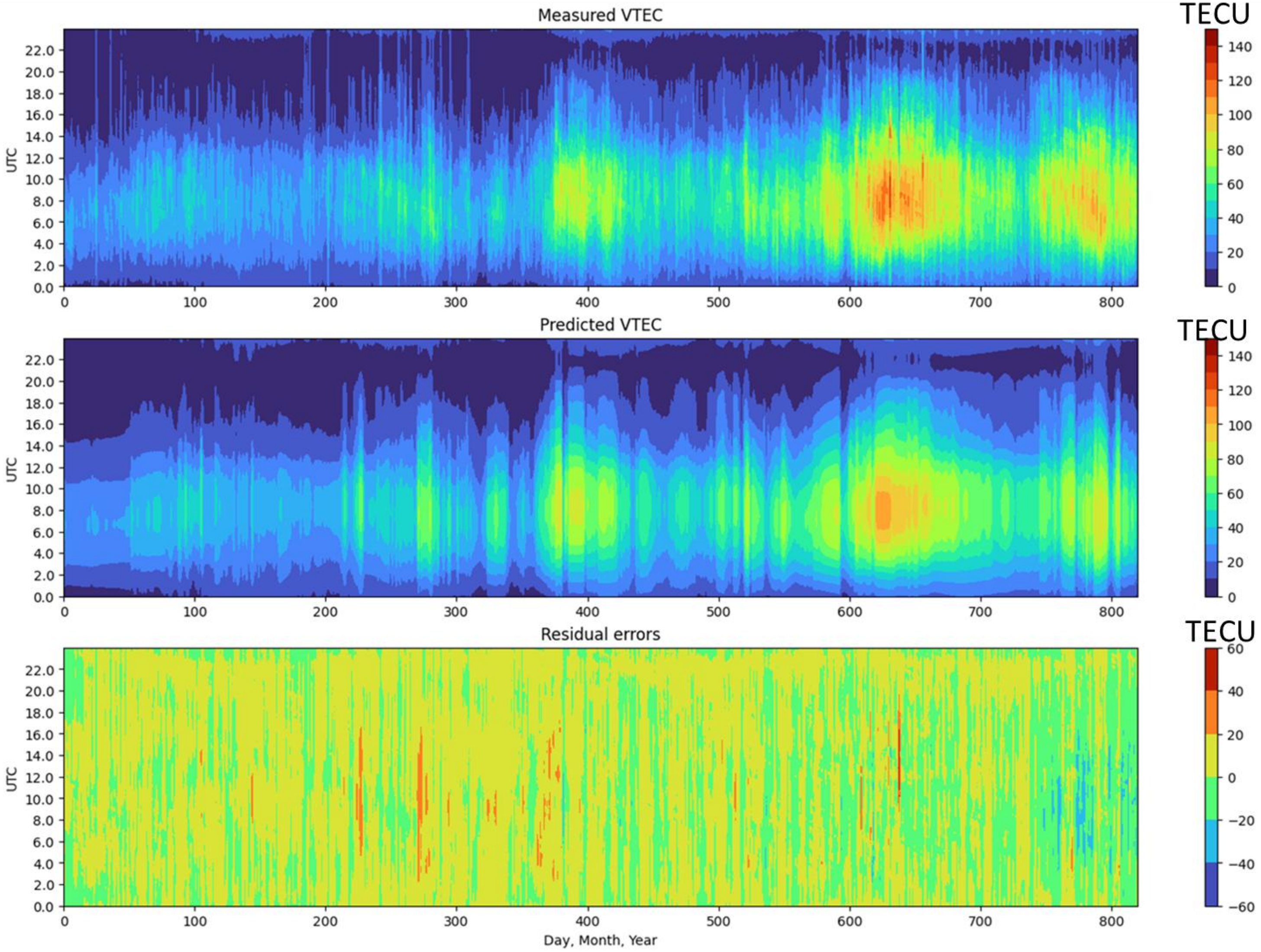
- Space weather monitoring and learning centers
- Upper atmospheric information and awareness to educational sectors, public, and organizations
- Data and seminar/training services
- Space weather information data center
- Space research gate and warning systems

Preliminary results: Observations of the VTEC at NUO station



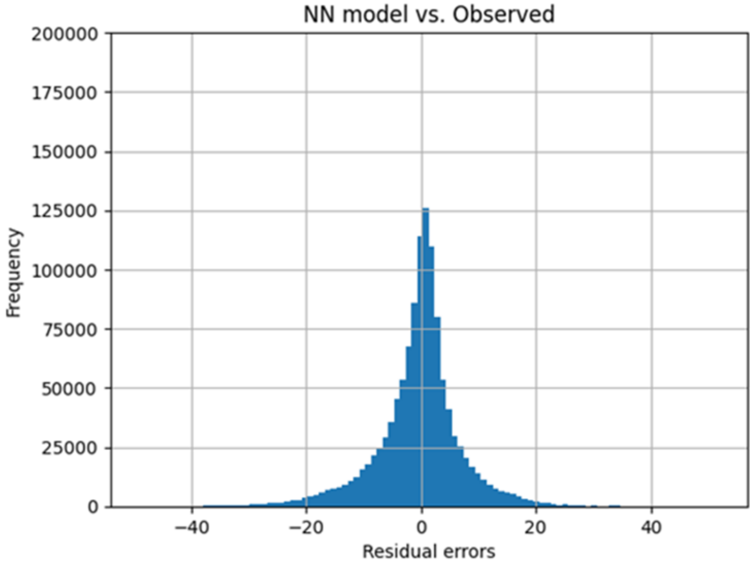
- VTEC (~ 4 – 120 TECU) are increased with increased solar activity
- Period of high VTEC on function of time responds to solar levels.
- VTEC in equinoctial months is regularly higher than solstice months

Preliminary results: Observations of the VTEC at NUO station

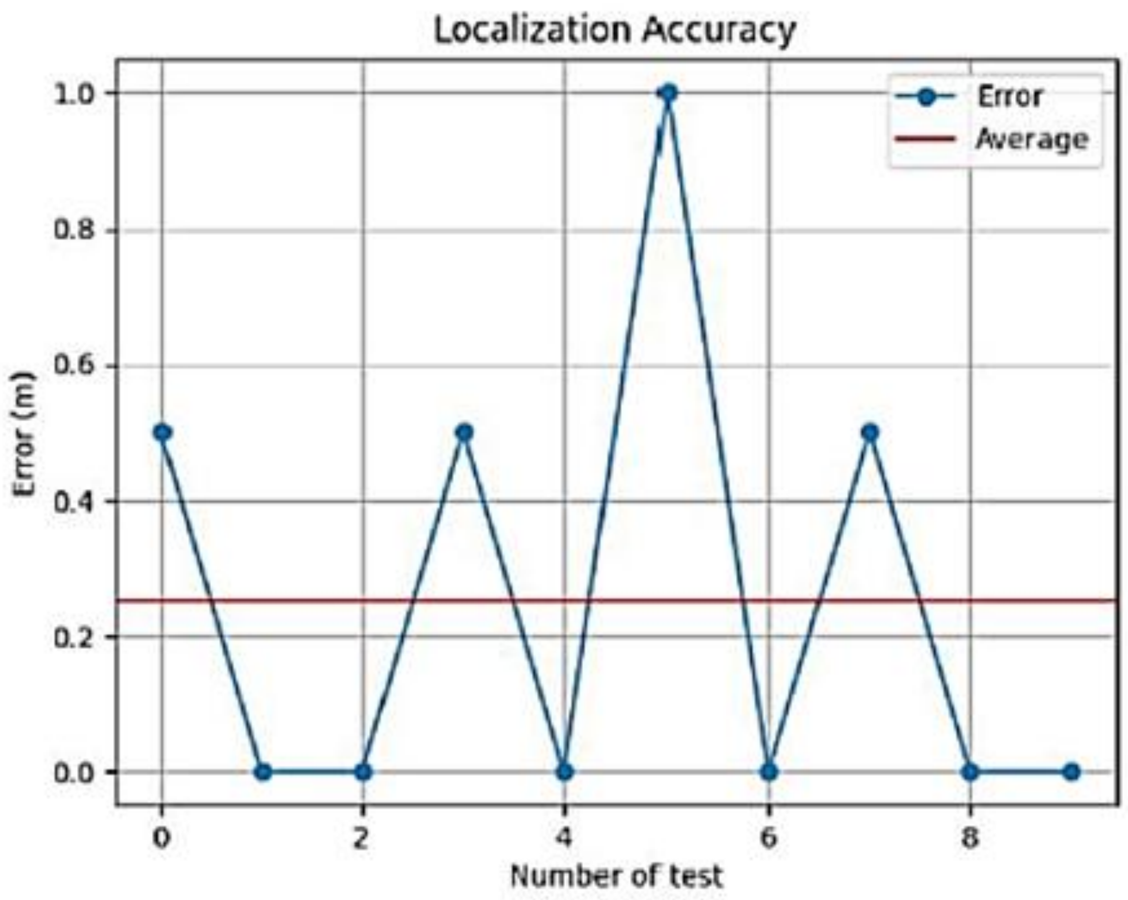


Note: x-axis contains ~ 826 days from 2021 to 2023

- Preliminary result of the VTEC DNN model can capture patterns of the VTEC characteristics
- Deviation between model and observed VTEC is within +/- 40 as shown in histogram



Preliminary results: RTK tested performance for the seeding robot at the NUO station



- The errors are obtained with 90% below 0.6 m of the tests at the university's environment
- The averaged error is about ~ 0.26 m of the tests
- 60% of lowest errors can be obtained around ~0.1 m of the tests

Conclusions

- LSWLC has been started since January 2024 at Department of Electronics and Telecommunication Engineering, National University of Laos

- The NUO station has started sharing and linking the data with the global network such as KMITL, Thailand

- Upper atmospheric information is serviced

- Utility of the GNSS data at the NUO station

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