



Current State of Space Weather Operation in Taiwan

I-Te Lee^{1,2}, Pei-Yun Chiu^{1,2}, Jyun-Ying Huang¹, Hsu-Hui Ho¹, Tzu-Wei Fang³, Mark Chia-Ping Cheng¹

1. Central Weather Bureau, Taiwan; 2. National Central University, Taiwan; 3. Space Weather Prediction Center, NOAA, USA

Based on the geolocation of Taiwan, higher plasma density during the day time period overhead are recorded associated with the equatorial ionization anomaly, and to easier observe plasma bubbles/irregularities in the evening to midnight period. These phenomena related ionospheric space weather significantly influence high-frequency and satellite communication as well as navigation and positioning services. Therefore, the Central Weather Bureau has established the Space Weather Operational Office (SWOO) since 2015 to play the role of providing space weather information and forecasts locally. With the assistance of the Taiwan Space Agency and scientific research teams, routine operations have become more stable and reliable. We provides real-time observations of solar images, regional GNSS-TEC, ionosonde and geomagnetic disturbance as well as the global ionospheric electron density structure, scintillation index, in-situ ion composition and temperature and radio frequency interference index by using FORMOSAT-7/COSMIC-2 measurements. Meanwhile, a data assimilated ionosphere and thermosphere coupled model is operated since 2018 to provide a 6-hour forecast of ionosphere and thermosphere hourly.

SWx Observations, Products, and Services

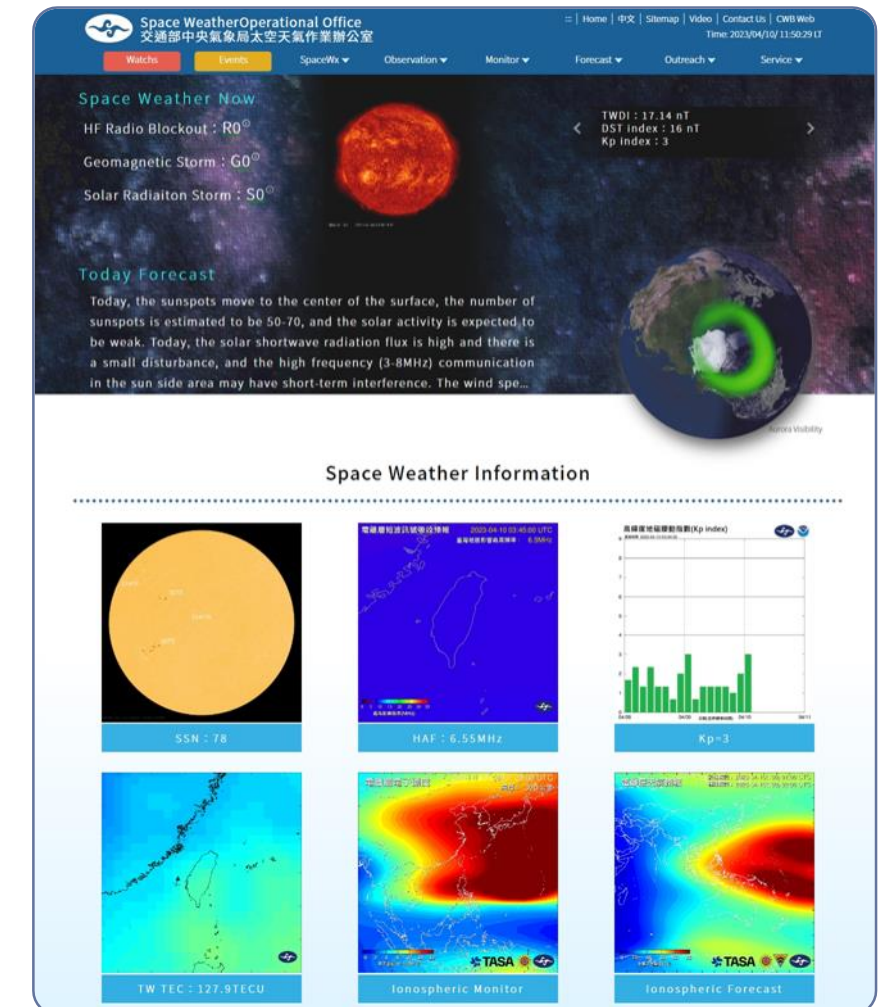
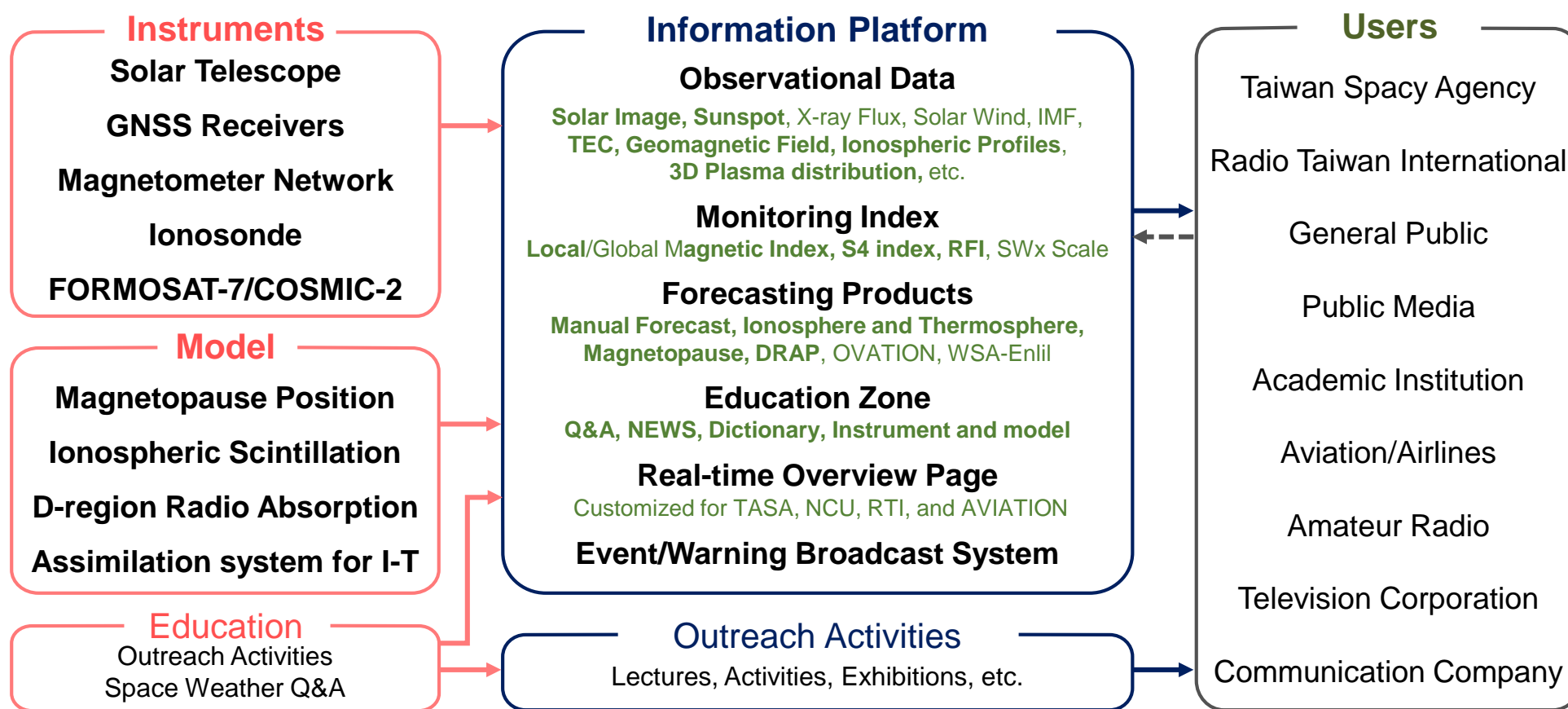


Fig. Website of the Space Weather Operational Office

Regional Ionospheric Irregularity Monitoring

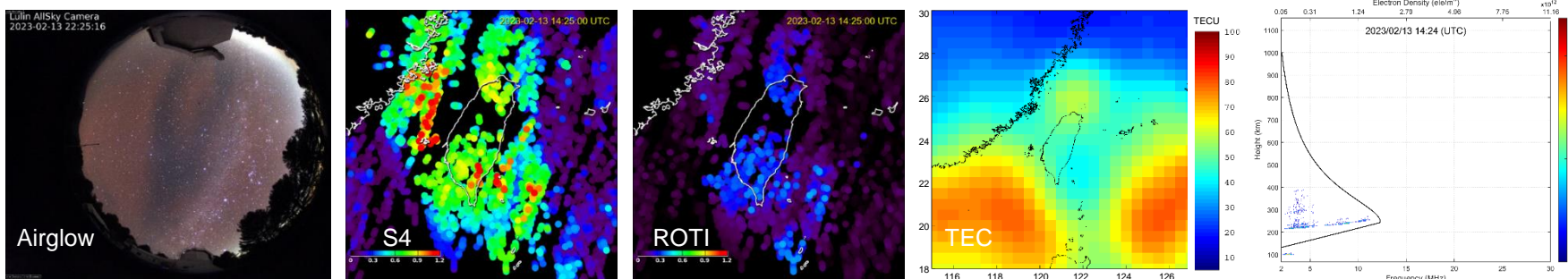
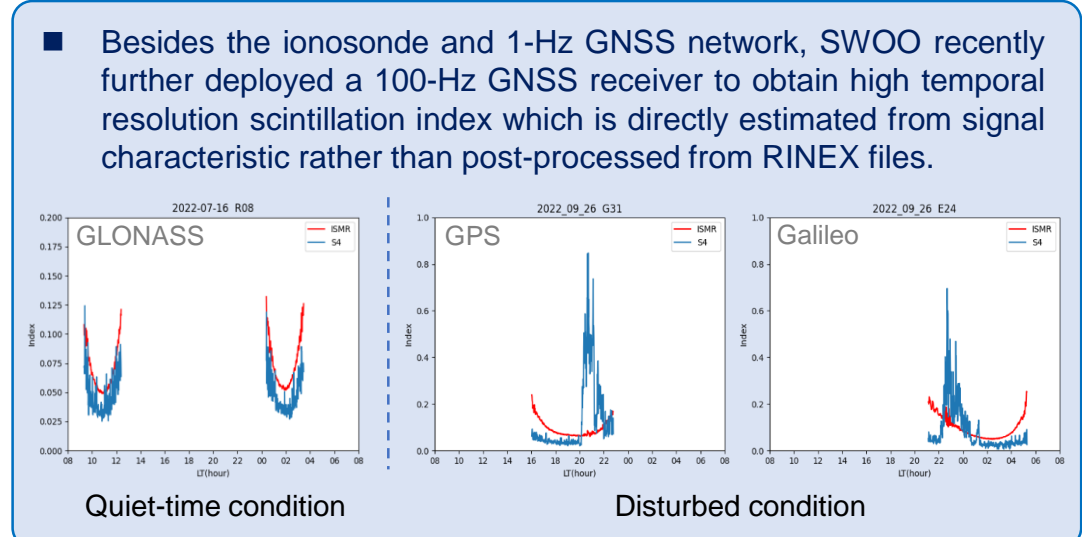


Fig. From left to right are the images of the all-sky camera at NCU Lulin Observatory, GNSS L2-band S4 index, rate of TEC index (ROTI), regional TEC map, and ionogram with true high analysis, respectively, at around 14:25 UT on February 13, 2023. The airglow recorded by the all-sky camera reveals a clear ionospheric plasma bubble, and the ground GNSS network also measures corresponding changes simultaneously. Meanwhile, the ionogram displays Es layer and spread-F at this moment.



Besides the ionosonde and 1-Hz GNSS network, SWOO recently further deployed a 100-Hz GNSS receiver to obtain high temporal resolution scintillation index which is directly estimated from signal characteristic rather than post-processed from RINEX files.

Ionosphere and Thermosphere Forecasting with Assimilated Model

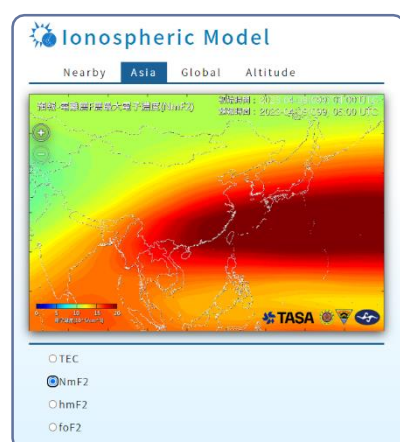
- System:**
 - Ensemble Kalman Filter with 48 members
 - Spatial resolution: $5^\circ \times 5^\circ \times 0.5\text{plev}$
 - Temporal resolution: 60min.

- Input parameters:**
 - Solar 10.7cm flux (F10.7)
 - 3-Hour Kp index

- Assimilated Observations:**
 - FORMOSAT-7 RO ionospheric profiles
 - Global GNSS TEC value

- Output:**
 - Ionosphere and thermosphere parameters.
 - PNG images for 3 spatial ranges and 4 variables.
 - Parameters are outputted with NetCDF file format.

Executed and Updated hourly and forecast for next 6 hours.



Validation with Ionosondes:

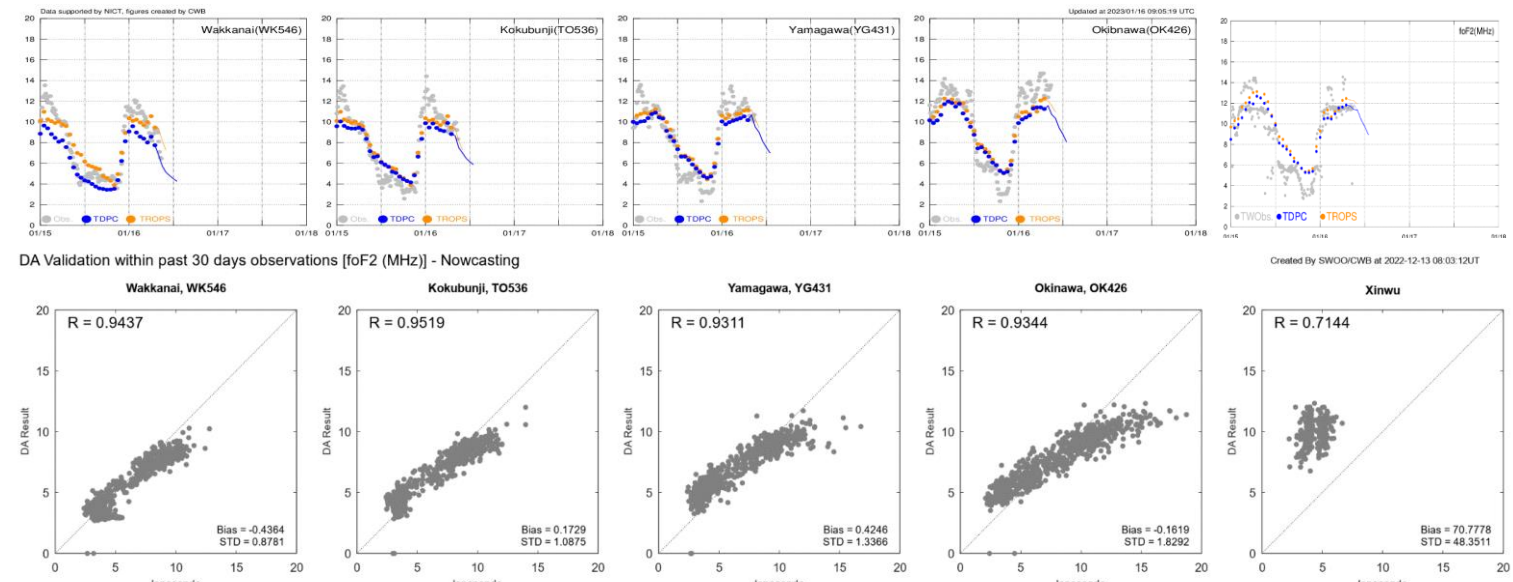


Fig. Upper panel illustrates time series plots of five selected ionosonde foF2, corresponding assimilated results and forecasts. The gray dots are auto-scaled ionosonde foF2, the blue and orange dots indicate that assimilated RO data are processed by TDPC and TROPS, respectively. Lower panel shows the scatter plots and correlation coefficients. The extreme lower correlation between assimilated results and Xinwu stations is due to the antenna of ionosonde not performing well at higher frequency.

Comparison with WAM-IPE:

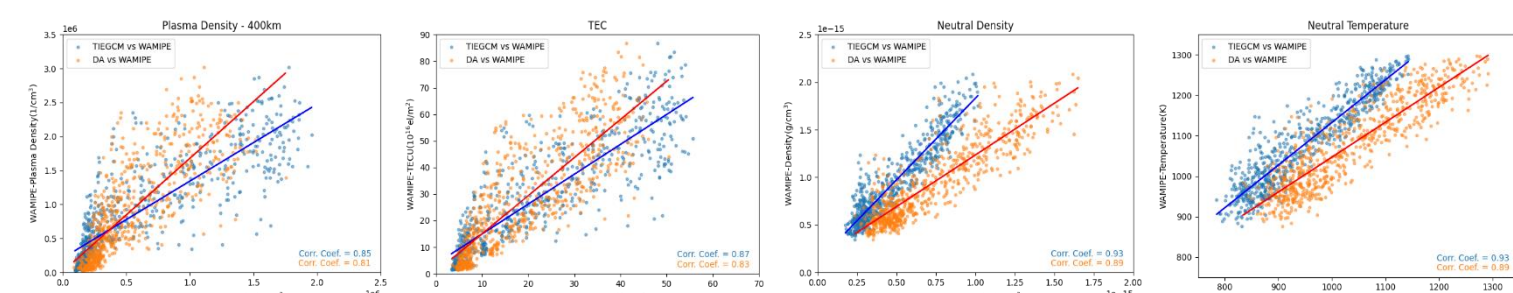


Fig. Since there is no suitable observation that could serve as reference to evaluate the performance of the thermospheric parameters. Therefore, the NOAA/SWPC WAM-IPE outputs are taken into account to conduct a brief comparison with control run (no observation assimilated) and operational output for plasma density at 400 km, TEC, neutral density, and neutral temperature.

The Space Weather Operational Office (SWOO) of the Central Weather Bureau in Taiwan is responsible for providing space environment information, forecasts, and services.

At present, there are 55 domestic and international space weather products of 28 categories that can be provided. In addition, daily overview and forecasts are manually released. A special watch is issued according to the condition. When severe space weather occurs, an event report is automatically generated and notified on the website.

Welcome to check out the SWOO website (swoo.cwb.gov.tw) for more information, products, and data. We are looking for possible international collaborations.