Regional Warning Center Report – SEPC (China)

1. Recent accomplishments

1.1. Extension of space weather operational system

We have a mature, complex IT structure supported 24/7 with dozens of space weather data and forecast products. With the development of internet technology, our system capacity extends from intranet to internet, since the space weather services increase evolves from large IT frameworks encompassing all potential scientific/user needs, to highly compact appliances addressing specific user needs. Specifically, we have developed the first space-weather App in China, and a web-based space weather analysis and graphics software.

The space-weather App for iOS and Android has features showing the primary space weather information from both international data providers and local observations (Figure 1). It also provides alerts, model forecasts, minute-by-minute updating observational data and news for scientists and engineers.

Figure 1 The interfaces of the space-weather App

The web-based space weather analysis and graphics software is customer-configurable and adaptable for use as a powerful decision-making tool and graphics tool (Figure 2). It provides abundant on-line data resources with charts, movies, reports, and statistics forms. It provides chat room services to promote collaboration between users.

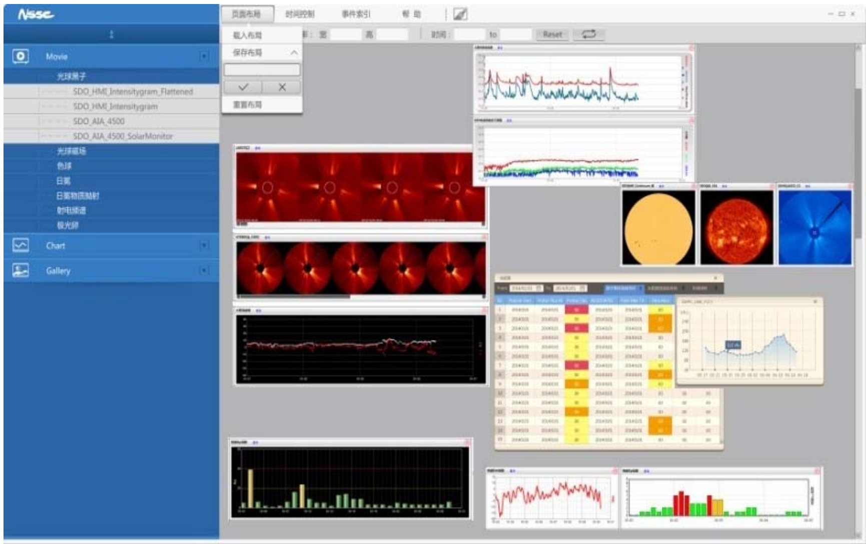

Figure 2　The web-based space weather analysis and graphics software

1.2. New data

We developed ionospheric observations based on Chinese Beidou (COMPASS) signals. The space segment of COMPASS consists of 5 GEO satellites and 30 Non-GEO satellites. The whole constellation will be completed by 2020.The current constellation includes 5 GEO satellites and 9 Non-GEO satellites. For ionospheric observations, the GEO and IGSO satellites have an advantage in satellite's lock time, over GPS. The lock time of a GEO satellite is about 24 hours, and an IGSO satellite can be locked for 18 hours (Figure 3).

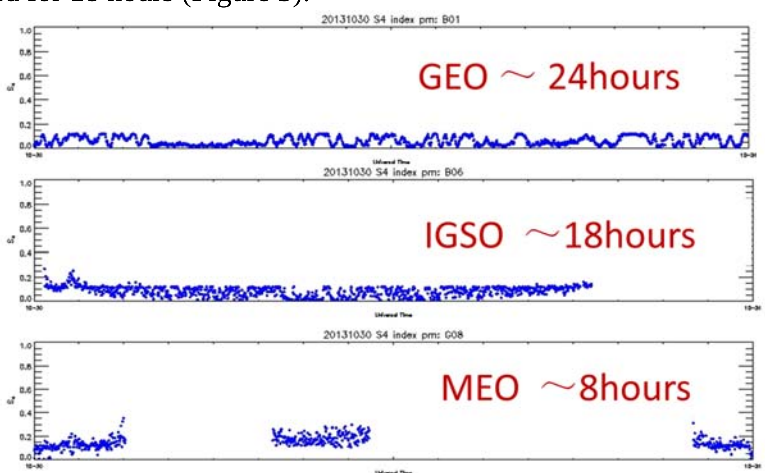

Figure 3 The lock times for COMPASS satellites

We set up GPS plus COMPASS receivers in Beijing and Nanning. The number of locked satellites increased significantly when receiving GPS and COMPASS at the same time. Figure 4 shows the scintillation observation in Beijing on Nov5, 2013, utilizing both the GPS and COMPASS satellites. There is no scintillation in Beijing and the background noise of COMPASS observation is lower than that of GPS. Figure 5 shows the TEC observation from one COMPASS GEO satellite. Continuous

24-hour line from one satellite can be obtained and this is very useful for TEC estimation.

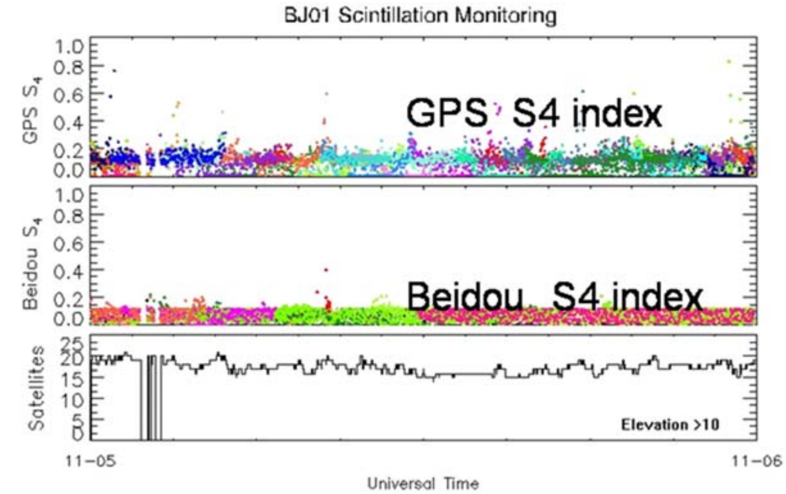

Figure 4 The scintillation observation in Beijing on November 5, 2013 by both the GPS and the COMPASS satellites

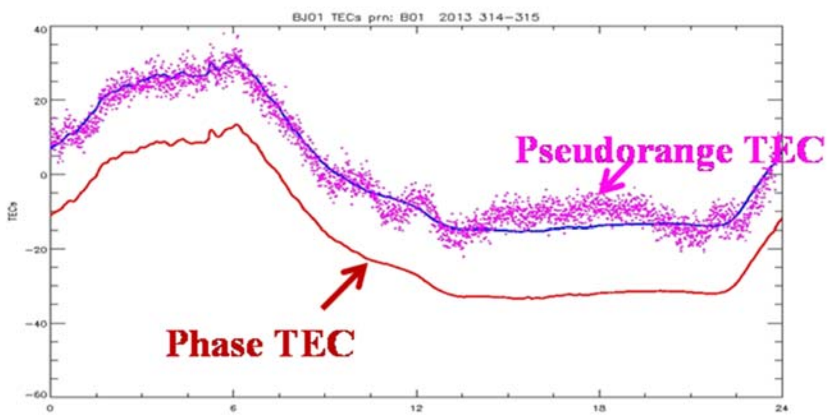

Figure 5 The TEC observations from one COMPASS GEO satellite

1.3. New models

Recently two models, Kp nowcast model and AU/AL/AE forecast model, have been developed and transitioned for operational use in SEPC.

The Kp nowcast model was developed based on the geomagnetic field observation at the Beijing Ming Tomb (BMT) station. Based on the single BMT station, the BMT nowcast Kp has a linear correlation coefficient of 0.89 with the official WDC Kyoto Kp. In the future, the nowcast method of Kp will be optimized by using multi-station data in China. Figure 6 shows an example of the Nowcast Kp. The upper three panels show the monitoring of the geomagnetic field at BMT station. The lower two panels show the comparison of the BMT nowcast Kp and the official WDC Kyoto Kp.

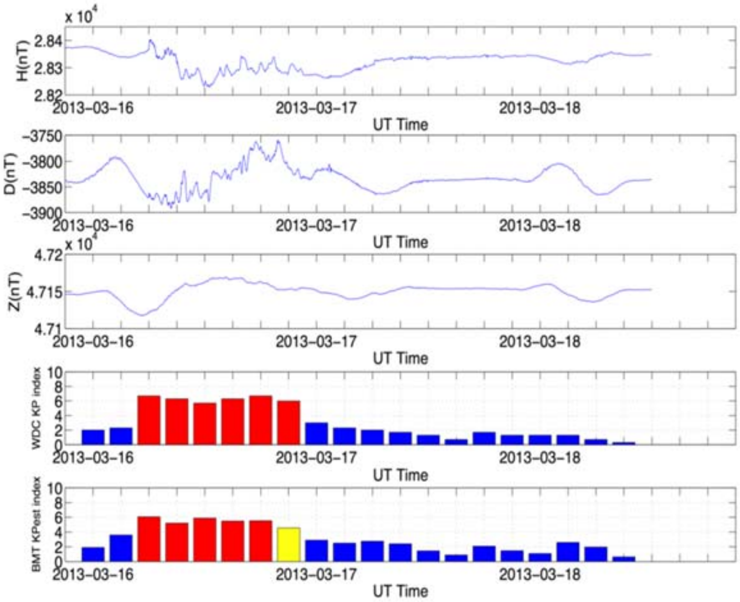

Figure 6 The nowcast Kp based on the BMT geomagnetic field monitoring

We also have developed models to predict AU, AL, and AE indices. Using the ACE solar wind data and F10.7 as input, the AU, AL, and AE indices are predicted about 1 hour in advance, depending on the propagation time from the L1 point to the sub-solar magnetopause thus the solar wind speed. Figure 7 shows a prediction example compared with the observed indices. The predicted results are plotted in red, while the observed ones are plotted in black. Table 1 shows the overall verification performance of the models for years 1995-2001. The models predict the longer time variations very well. The linear correlation coefficient is above 0.9 for 2 hour averages.

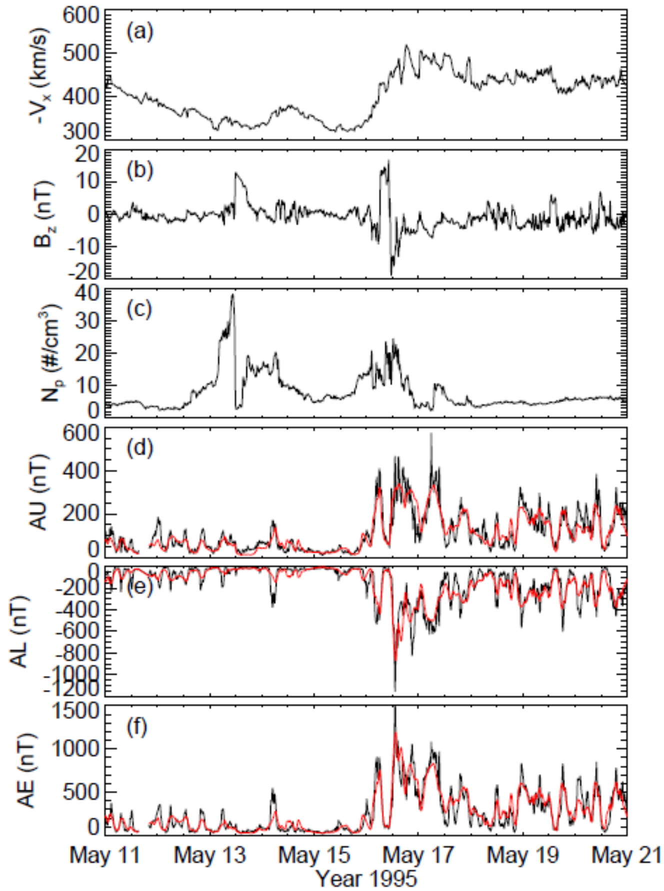

Figure 7 Relevant solar wind parameters and a comparison between the 10 min averaged measured (black) and the predicted AU, AL, and AE indices (red) for days 11-21 May 1995.

Table 1 AU/AL/AE model verification result for years 1995-2001

Index	**PE**	**LC**	**PE**	**LC**	**PE**	**LC**
	10-min		13-point-avrg(2-hr)		25-point-avrg (4-hr)	
AU	0.72	0.85	0.81	0.90	0.85	0.92
AL	0.72	0.85	0.84	0.92	0.88	0.94
AE	0.79	0.89	0.87	0.94	0.91	0.95

2. Highest priority product goals

2.1. TEC regional maps

Using observational data from 300+ GPS stations in China, we are now working to construct a TEC regional map through assimilation method of Kalman filter by the IRI model. The map will cover the area of 70^{o}E-140^{o}E, 15^{o}N-55^{o}N, with resolution of 1^o *1^o *5 min. Figure 8 shows the original observational data and preliminary constructed TEC map over China.

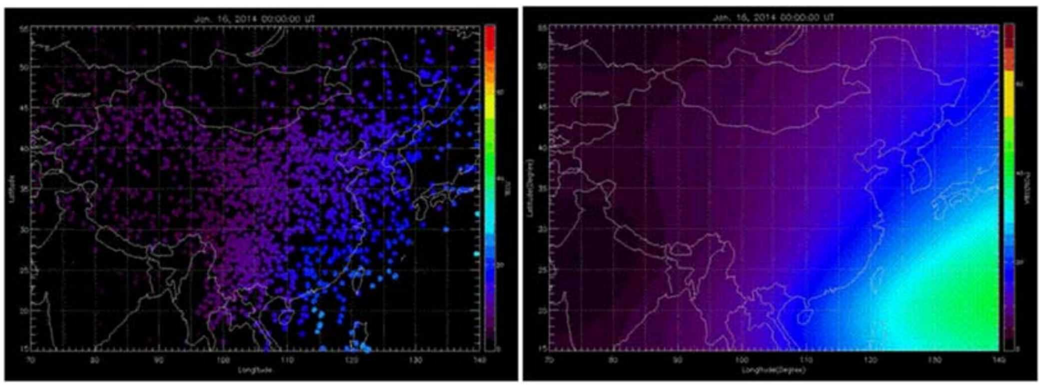

Figure 8 The monitoring data of 300+ GPS stations in China (left) and the constructed TEC regional map using the assimilation method

2.2. Regional ionospheric disturbance index

We are trying to establish a regional ionospheric disturbance index reflecting the ionospheric disturbance in a certain region. Currently we have constructed a primary index called RIDI (equation 1). And we have compared it with several indices that have been used to describe TEC disturbances in mid-latitude regions of China. Figure 9 shows the correlation analysis between the indices and the TEC disturbances. We can see RIDI can represent the disturbance better than the other indices.

$$RIDI1 = \frac{1}{M}\sum_{j}^{M}\frac{\sum_{i}^{N}(TEC_{i,j} - TEC_{i,j}^{ref})^3 \cos\varphi_i \,/(TEC_{i,j}^{ref}\,|TEC_{i,j} - TEC_{i,j}^{ref}\,|)}{N\sum_{i}^{N}\cos\varphi_i} \tag{1}$$

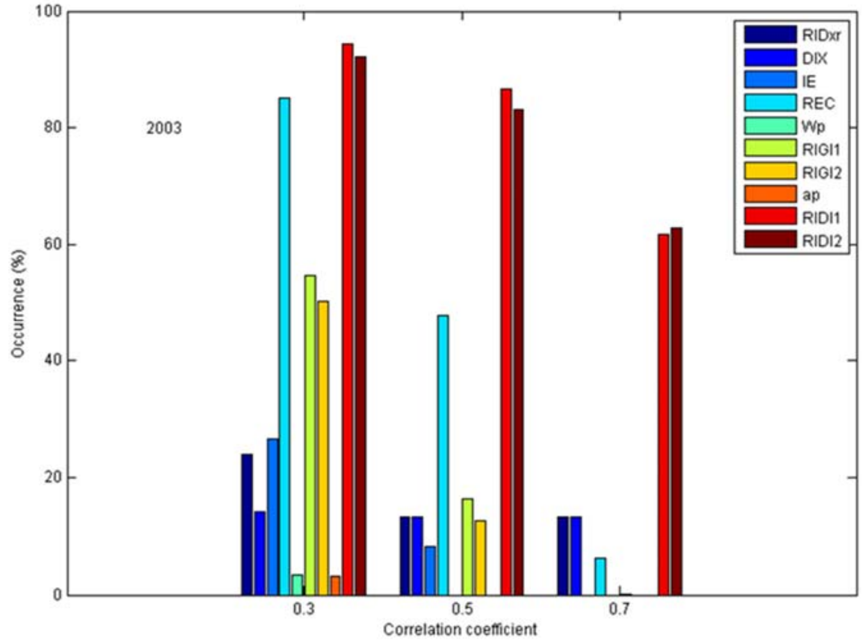

Figure 9 The correlation between indices and DTEC shows that the RIDI index is more appropriate than the others.

3. Highest priority data needs

4. Recent information on user impacts

Two severe solar proton events occurred in 2012. One occurred in January, the other occurred in March. During these events, seven satellites at high risk were shut down to avoid the effects of the events based on our warnings.

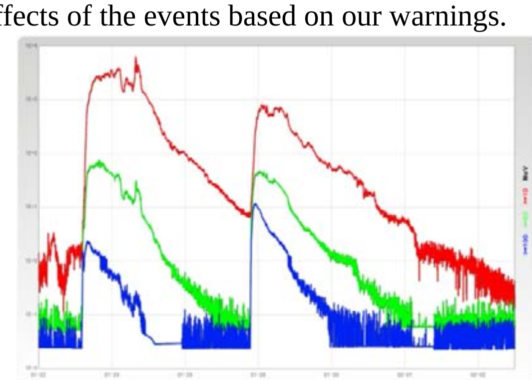

Figure 10 Severe proton events in 2012

5. Forecast verification summary

Three classes of forecast have been chosen to be verified: events warnings, solar and geomagnetic field indices and probabilistic forecasts. There are many verification methods. Different types of forecasts should be verified using different methods. Even the same type of forecasts may have different verification methods due to their characteristics.

By investigating the commonly used verification methods and the products of space weather forecasts in SEPC, we have determined some selected verification methods for each classe of forecasts specifically (not shown here).

Table 2 lists the verification results for the 3-day F10.7 forecast for year 2013. Figure 11 shows the verifications result for solar proton event forecast from March 1998 to Dec 2013.

Table 2 verification results for the 3-day F10.7 forecast for year 2013

LeadTime	**Day1**	**Day2**	**Day3**
Mean(f)	122.7	122.5	122.2
Mean(o)	122.8	122.9	123.0
Median(f)	115.0	120.0	120.0
Median(o)	118.0	118.0	118.0
StdDev(f)	20.0	20.0	20.0
StdDev(o)	20.0	20.0	21.0
ME	-0.1	-0.4	-0.8
MAE	4.1	6.4	8.5
MRE	0.0	0.0	-0.0020
RMSE	5.3	8.4	11.0
MAPE	0.033	0.051	0.068
CC	0.966	0.915	0.852
MAESS	0.775	0.649	0.533
MSESS	0.951	0.878	0.786

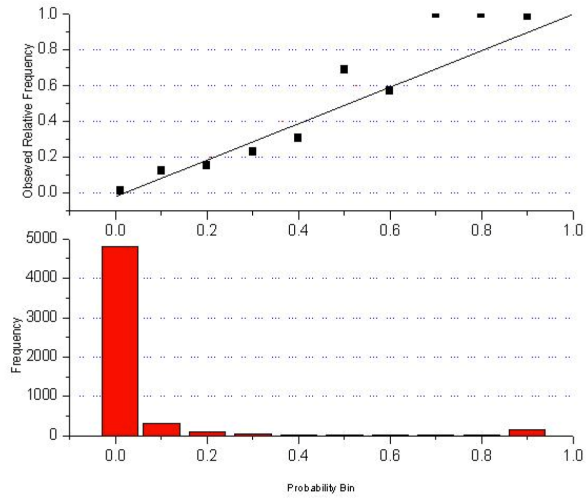

Figure 11 Verification result for solar proton event forecast from March 1998 to Dec 2013. The top panel plots the observed relative frequency of 10 MeV Proton Events against their corresponding forecasts, grouped in 10% (0.1) bins. The diagonal line represents perfect correspondence. Points falling below the diagonal indicate a tendency of the forecasts within that bin to over-predict the occurrence of Proton Events while points above the diagonal indicate under-prediction. The number of forecasts in each bin is plotted in the bottom panel histogram.

Regional Warning Center Coordination

The updated ISES website provides a convenient way to enable and enhance the coordination between regional warning centers. In my opinion, we can benefit from the coordination on two aspects, the routinely “latest forecasts” and “extreme events”.

1. Comments on “Latest Forecasts”

The ISES website has a function of showing “Latest Forecasts” from different regional warning centers. Though not all the RWCs are included currently, I suppose it is not a problem to involve all RWCs in the near future. Sharing the latest forecasts from different RWCs is helpful for forecasters to compare the results and make final decisions. But obviously, the products and displaying formats are quite different for all these RWCs. It is a bit difficult to browse forecast results from other RWCs and then use them as references.

My recommendation for “Latest Forecasts” is that we can discuss and determine some common and essential products (such as F10.7, Ap and more), and then summarize the latest forecast results from all RWCs and list them in a more neat way (maybe a table is fine enough). By doing so, forecasters can easily check and compare the forecast results from all the RWCs.

If it is doable, what needs to be done is to determine what products should be selected, and define the meaning of the products for standardization (such as: are probabilities of each RWC of the same meaning?). Another problem is that each RWC updates forecasts at different UT times and we need to work on this.

Besides, a summarized table (for common and essential products) described above is insufficient because each RWC has their own preferential products. I recommend that a portal (maybe similar to the WMO space weather portal) that lists all the products from RWCs of ISES (or summarized in a more detailed table than for the common products), which can direct the visitor to the product pages of the related provider, might be developed.

2. Comments on Extreme Events

As we discussed before, extreme events are serious enough to urge us into working together. However, by now, we’re just in agreement that the extreme events have critical impacts on space assets, but the “Extreme Events” haven’t been defined specifically. I suggest the specific definition of the “Extreme Events” could be discussed first. We can discuss the actual scales of the extreme event, so that all of us are in the same page when they occur.

And I suppose all RWCs are on call as soon as one extreme event occurs. The extent of the effects depends on our immediate response and precise forecasts. Thus, how we can react when it occurs, to ensure our collaborations could help, to improve the accuracy and promptness of our forecasts, should draw our attentions and maybe turn into one of our topics here.

Additionally, what we aim to achieve through our discussions about extreme event is significant, as well. On one hand, it can be a way to provide useful references for all RWCs involved. The discussion can help improve the ability of forecasters to evaluate the effects of the event, which means it could be useful for our forecast. On the other hand, our discussion can be a consensus-forming process. The final results from our discussion could be published on the web site as formal forecasts of ISES. However, the problem is whether it is needed to reach a consensus about the forecast results through our discussion, thus, what the purpose of the consensus is.

For the convenience of the discussion, I recommend that there should exist a timely and effective way for our communications. According to our experience, the chat room service on the web-based platform may meet the requirements. A chat group will allow us to exchange information and opinions anytime and anywhere.

Besides, I recommend that, on the ISES website, there exists a platform for all RWCs to publish their forecasting results about the extreme events, to enable and facilitate the discussion for the consensus.