Montréal, 7 to 18 July 2014

Agenda Item 2: Improving the safety and efficiency of international air navigation through enhanced meteorological service provision

2.2: Enhanced integrated meteorological information to support strategic, pre-tactical and tactical operational decision-making from 2018 (including ASBU Module B1-AMET)

JAPANESE ACTIVITIES FOR SPACE WEATHER FORECAST

(Presented by Japan)

SUMMARY

This paper gives a summary of the space weather information provided by National Institute of Information and Communications Technology (NICT), Japan for safe and secure use of telecommunications, broadcast, satellite positioning and international air aviation. NICT has been operating space weather forecast since 1988, and doing research and development for improving the precision of the forecast. Action by the meeting is in paragraph 7.

1. INTRODUCTION

1.1 National Institute of Information and Communications Technology (hereafter NICT) is one of the independent administrative agencies under the Ministry of internal affairs and communications of Government of Japan. It provides space weather services operationally within the framework of the International Space Environmental Services (ISES).

1.2 NICT has contributed to space weather research for nearly a century. Work on space weather research began in 1915 at the Hiraiso branch (currently known as Hiraiso Solar Observatory). Ionospheric research for stable radio telecommunications started before World War II and radio wave propagation forecasting service began in the 1940s. Routine ionospheric observation has been conducted in Japan and Antarctica since 1957, which is the International Geophysical Year (IGY). NICT has been operating a space weather forecasting service as one of the ISES Space Weather Information Centers since 1989.

1.3 NICT is a member of the International Space Environmental Service (ISES), which collaborates with the World Meteorological Organization (WMO). Also, NICT staff members have been a part of the Inter-programme Coordination Team on Space Weather (ICTSW) of the WMO since the team’s establishment in 2010 and have contributed to the launch of global space weather forecasting activities as part of the activities of the WMO Space Programme. In addition, NICT played a leading role in establishing the Asia–Oceania Space Weather Alliance (AOSWA) in 2010 to promote space weather research and international cooperation among associated organizations.

(12 pages)
1.4 Japan locates in low geomagnetic latitude and a kind of ionospheric disturbance named “plasma bubble” affects the precision of GNSS in the region. As GNSS including GPS is essential for electric aviation nowadays, it is important to monitor and forecast the plasma bubble for safe and secure aviation. NICT has a network for ionosphere observation “SEALION” (South-East Asia Low-latitude Ionospheric Observation Network) for monitoring, researching and developing the forecast system of plasma bubble.

2. DAILY SPACE WEATHER FORECASTING SERVICE

2.1 Under the international cooperation on observation and simulation, duty forecasters review recent conditions of the Sun’s disk, solar winds, high-energy particles, geomagnetic fields, and the ionosphere and discuss the near-future forecast for solar flares, geomagnetic activities, proton events, high-energy electrons in the radiation belt, and radio-wave propagation in the forecasters’ daily meeting. The forecast information is provided daily via email, websites (http://swc.nict.go.jp/contents/index_e.php), and fax. The number of website hits is approximately 160,000 per month and the number of subscribers of our email information is nearly 10,000, which includes international broadcasters, airlines, telecommunication and satellite tracking companies, Japanese central and local government offices, universities, research organizations, and radio hams. NICT will contribute data exchange as one of the DCPCs under the WIS framework to provide space weather products.

3. OPERATION OF GROUND OBSERVATIONS FOR SPACE WEATHER

3.1 Real time observation of space weather condition is essential for the forecast. NICT operates ground based observation network for providing space weather forecast, and for improving the precision of the forecast.

3.2 For the purpose of supplementing its space weather forecasting activities, NICT has been undertaking ionospheric observations in Japan and Antarctica since the IGY at five stations located in Wakkanai, Kokubunji, Yamagawa, Okinawa, and Syowa Station as of 2013. NICT is one of ground stations of the RTSWnet (Real-Time Solar Wind network) since 1997 and has been operating satellite tracking of two satellites, ACE and STEREO, which retrieve information on real-time solar winds and images on the basis of international cooperation. NICT will contribute data reception from DSCOVR, which will be launched in 2015. About the solar observation NICT has a long history to measure the solar radio wave at Hiraiso observatory since 1952. In 2014 NICT built a new solar radio telescope in Yamagawa observatory and starts the observation (Fig. 1).

3.3 As a research project mainly studying the dynamics and characteristics of plasma bubble and geospace disturbances related to radiation belt dynamics, we have network observations of ionosphere in the Southeast Asia, and ground-based magnetometer network in Siberian region and HF radar in Alaska under the cooperation with universities and academic institutes. In the present status (May 2014) we have ionospheric observation with ionosonde at Chaing Mai, Chumphon (Thailand), Bac Lieu (Vietnam), Cebu (Philippine), and Kototabang (Indonesia). Other than that the GPS receivers, scintillation monitors and magnetometer are operated. The location of SEALION makes us possible to have magnetic conjugate observation which is ideal for researching plasma bubble, and already published some fruitful results as scientific papers. Geomagnetic observatories are located in Paratunka, Stecolny, Pebek, Tixie Bay, Dixon, Amderna (Russia), and King Salmon (USA). HF radar is also operated at King Salmon. Magnetometer network and HF radar observation enables us to study geomagnetic pulsations related to supply and loss of radiation belt particles.
3.4 NICT has also monitored ionospheric variations using two-dimensional maps of total electron content (TEC) derived from the Japanese dense GNSS network, GEONET. GEONET consists of more than 1,200 GPS receivers and is operated by Geospatial Information Authority of Japan (GSI). Currently, NICT routinely provides quasi-realtime two-dimensional maps of absolute TEC, detrended TEC with 60, 30, 15-minute window, rate of TEC change index (ROTI), and loss-of-lock on GNSS signal over Japan (http://seg-web.nict.go.jp/GPS/QR_GEONET/index_e.html; Fig.2). These maps with spatial resolution of 0.15° in longitude, 0.15° in latitude are useful to reveal spatial structures and temporal evolutions of wave-like ionospheric phenomena such as plasma bubbles and travelling ionospheric disturbances (TID) which can degrade single-frequency GNSS positioning and differential GNSS positioning. To expand the ionospheric observation area, NICT has collected all the available GNSS receiver data in the world (more than 6,000 GNSS stations as of 2014) and made regional and global high-resolution TEC maps. NICT has developed a new standardized TEC data format, GNSS-TEC exchange (GTEX) format, to promote international sharing and exchange of TEC data especially in the Asia-Oceania region. Data sharing based on the GTEX format has been discussed in AOSWA, the Ionospheric Studies Task Force (ISTF) of ICAO APAC, and ITU-R SG3 since 2012.

4. DEVELOPMENT OF MODEL AND SIMULATION CODE FOR SPACE WEATHER FORECAST

4.1 NICT has been developing the model and simulation code of ionosphere and magnetosphere for improving the precision of space weather forecast. As some processes in space weather are still unknown, it is very difficult to build any numerical simulation code. On the other hand, we are required to provide space weather forecast for some application, e.g., aviation, NICT are servicing some information with empirical models under developing numerical models.
4.2 We have been developing several empirical models of space weather forecast, to satisfy
the requirements of current users. Empirical modelling can provide practical information in near real time.
Operational forecasting models for the Dst index, which is an index of geomagnetic storm activity, using
neural network techniques have been developed [Watanabe et al., 2003]. Recently, NICT has developed a
prediction model for relativistic electron flux at GEO using Kalman filter based on multivariate
autoregressive model [Sakaguchi et al., 2013]. In the operational relativistic electron flux model, solar
wind velocity, magnitude of north-south component of interplanetary magnetic field (IMF Bz), relativistic
electron flux is used for the prediction. Current status and prediction of relativistic electron flux at GEO
are provided from the following web page (http://seg-web.nict.go.jp/radi/).

4.3 To realize objective and advanced space weather forecast for operational use in the near
future, development of numerical simulation code for space weather is also important. We have been
developing two types of simulation code. A magnetospheric global MHD simulation code has been
developed for understanding physical processes of space weather [Tanaka, 1995]. Realtime simulation
system of magnetosphere using the 3-D MHD code was developed for the first time and had operated from
2004 to 2012 [Den et al., 2006] and next generation real-time simulation system is now developing. NICT
has also developed a 3-D MHD simulation model of the solar surface–solar wind system. Based on
comparisons with observations, it is confirmed that the MHD model successfully reproduces many features
of both the fine solar coronal structure and the global solar wind structure [Nakamizo et al., 2009].

4.4 Plasma bubble is known to affect satellite positioning, and it is still difficult to forecast
the occurrence numerically. NICT is now developing a empirical model of the occurrence of plasma
bubble using neural net. In the present status we provide the TEC distribution on the vicinity of Japan
every one hour and we can show the forecast 24 hour in advance (Fig.3).
4.5 With respect to ionospheric and thermospheric disturbances, modelling effects from the lower atmosphere is necessary. Therefore, NICT is developing an Earth’s whole atmosphere model from the troposphere to the ionosphere, called GAIA (The Ground-to-Topside Model of Atmosphere and Ionosphere for Aeronomy; Fig.4) [Jin et al., 2011]. The GAIA model solves the ionosphere thermosphere interaction self-consistently, including the electrodynamics. The simulation reproduces and confirms the vertical coupling processes proposed so far with respect to the formation of the averaged longitudinal structure of equatorial ionospheric anomalies. Although these numerical simulations are still far from practical use, these approaches are very important for future advanced numerical space weather forecast.

5. WORLD DATA CENTER FOR IONOSPHERE AND SPACE WEATHER

5.1 NICT functions as a World Data Center for the ionosphere and space weather in the framework of the International Council for Science (ICSU). This involves compilation and maintenance of data archives of ionospheric observations, including NICT’s own ionospheric observational data collected since the IGY, as well as internationally exchanged observational data. NICT is also actively working on data rescue activities to ensure that old film datasets can be preserved and used digitally. As a part of its data
center functions, NICT is planning to start generating and providing metadata catalogues in accordance with internationally agreed standards, including that of the WMO Information system (WIS).

6. COMMUNICATIONS WITH USERS

6.1 NICT has been facilitating a “Space weather users’ forum” for the purpose of communicating with users and finding out about their needs regarding space weather information. NICT has been running a project that interviews customers in order to find out how they use space weather information and get their feedback and requests for better operation.

7. ACTION BY THE MEETING

7.1 The meeting is invited to note the information contained in this paper.
# APPENDIX

## NICT SPACE WEATHER PRODUCTS FOR AVIATION

<table>
<thead>
<tr>
<th>Items</th>
<th>Products</th>
<th>Description</th>
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| 1     | Summary of previous 24 hours | a) The solar activity of last 24 hours, latest space weather condition and solar eruptive events  
b) The evolution of geomagnetic field, the geomagnetic storm and its process  
c) The space radiation environment condition, the disturbance and its source  
d) The ionosphere process and its latest condition |
| 2     | Summary of previous 7 days | a) The solar activity of last 7 days,  
b) The evolution of geomagnetic field, the geomagnetic storm and its process  
c) The space radiation environment condition, the disturbance and its source  
d) The ionosphere process and its latest condition |
| 3     | Short term forecast of the probability of solar flare | Forecasting the probability of solar flare in the coming 24, 48 and 72 hours |
| 4     | Short term forecast of the probability of solar proton event | Forecasting the probability of solar proton event in the coming 24, 48 and 72 hours |
| 5     | Short term forecast of the probability of geomagnetic storm | Forecasting the probability of geomagnetic storm in the coming 24, 48 and 72 hours |
| 6     | Short term forecast of the space radiation environment condition | Forecasting the electron flux in radiation belt in the coming 24 hours |
| 7     | Short term forecast of Dst | Forecasting Dst in the coming 24 hours |
| 8     | Forecast of the ionospheric condition | Issue the ionospheric condition in the coming 7 days. |
| 9     | Ionosphere TEC nowcast | The latest condition of TEC map over Japan |
| 10    | Presto for severe space weather event | Warning of severe space weather condition |
Figure A1. Front page of NICT Space Weather Information Center

CME associated with M8.7/2B flare observed by SOHO/LASCO-C3 (ESA&NASA)

Intense solar energetic particle (proton) event occurred on 23 January 2012 and reached its peak flux 6,310 PFU at 15:30 UT on 24. This event was associated with M8.7/2B flare (N28W21) at 03:30 UT on 23. Sudden Impulse (SI) by the CME by this flare was observed at 15:30 UT on 24. Another X1.7/2B flare (N28W21) occurred at 17:37 UT on 27. The solar energetic particle (proton) flux by this flare reached its peak 796 PFU at 02:05 UT on 28. 

http://swc.nict.go.jp/detacenter/daily_latestnews.php
Figure A2. Web product of Radiation Belt Electron Flux Forecast
Figure A3. Web page to notice the region under the influence of Delinger phenomena
Figure A4. Web page to show the ionospheric condition with simple icons
References


— END —