



International Civil Aviation Organization

**THE FIFTH MEETING OF ASIA/PACIFIC METEOROLOGICAL
HAZARDS TASK FORCE (MET/H TF/5)**

Seoul, the Republic of Korea, 18 – 20 March 2015

Agenda Item 7: Any other business

SPACE WEATHER ACTIVITIES FOR AVIATION IN KOREA

(Presented by Republic of Korea)

SUMMARY

This paper presents the current status and future plan of the space weather activities in support of the air navigation in Korea.

1. INTRODUCTION

1.1 In Korea, two governmental organizations have developed and delivered the space weather services: The National Meteorological Satellite Center (NMSC) and the Korean Space Weather Center of the national Radio Research Agency (KSWC/RRA). In this paper we will explain the space weather activities in support of the air navigation of two governmental agencies cooperating to improve the space weather services in Korea.

1.2 NMSC was established in 2009 by the Korea Meteorological Administration (KMA). In 2012, NMSC started the domestic space weather services, forecast and warning services, which are categorized into following three: (1) the meteorological satellite operation, (2) aviation in polar route, and (3) ionospheric weather.

1.3 As preparation for the space weather forecast services, NMSC has developed various space weather prediction models for X-ray flare, solar energetic particles, geomagnetic disturbances based on Dst and Kp indices. A cosmic radiation prediction model and polar cap prediction model also have been developed since 2013 and the NMSC will verify these newly developed models' outputs in 2015 and start the official operation from 2016 for the public. All these efforts in the basic research and application are for the space weather public services and air navigation service.

1.4 NMSC and NOAA Space Weather Prediction Center (SWPC) have collaborated based on the KMA-NOAA MOU. NMSC and the Korea Astronomy and Space science Institute (KASI) have also collaborated in developing the cosmic radiation prediction model and the polar cap prediction model. Based on domestic and international collaborations, NMSC has established the basis for the space weather services in support of air navigation

1.5 NMSC is the Data Collection or Production Center (DCPC) of the WMO Information System (WIS). NMSC also takes part in the Inter-Programme Coordination Team on Space Weather (ICTSW) of WMO to support the international space weather activities. ICTSW considers WIS as the data exchange system of the international space weather services. Although NMSC DCPC is functioning just for the meteorological satellite data, it has a plan to evolve as the international facility for space weather data service in the near future.

1.6 KSWC/RRA, which is affiliated with the Ministry of Science, ICT and Future Planning (MSIP) is responsible for delivering space weather service products to the domestic customers. KSWC/RRA has provided space weather services to the public since 1966. The KSWC/RRA has three ground observation sites in Jeju, Icheon, and Gangnung, and operates various ground based observation systems, composed of 20 observation facilities of 10 categories, for space weather operation.

1.7 KSWC/RRA is a member of International Space Environment Service (ISES), has operated as a Regional Warning Center (RWC) for the Korean region since 2011. KSWC/RRA is also a member of WMO ICTSW and has provided useful information into the development of the ICAO Space Weather Concept of Operations (CONOPS), draft standards and recommended practices for Space Weather for inclusion in Annex 3.

1.8 Space weather was included in the national risk assessment process in 2013, and the official manual of space weather risk management was adopted by the Korean government. This manual describes the roles and responsibilities of related ministries and agencies such as Ministry of Land, Infrastructure and Transport (MOLIT), which has rights to supervise airline companies. According to this manual, KSWC/RRA was entitled to the primary action agency of emergency measure against severe space weather condition including aviation sector.

1.9 KSWC/RRA has provided space weather information, products and services via website (www.spaceweather.go.kr/en), and all contents are opened to the public. The 3-day forecast, which is main product of KSWC/RRA, are delivered via E-mail, website, and mobile-App(Android, iOS). Besides, the subscription-based alerts and warnings are delivered in real time via SMS, E-mail, fax and website.

- 1-day forecast : www.spaceweather.go.kr/notification/forecast/3hours
- 3-day forecast : www.spaceweather.go.kr/notification/forecast/daily
- 27-day forecast : www.spaceweather.go.kr/notification/forecast/weekly

KSWC (Republic of Korea)

updated 02:00 UTC

	Radio Blackouts (R)		Solar Radiation Storms (S)	Geomagnetic Storms (Mid-Latitude) (G)	
	R1-R2	R3 or greater	S1 or greater	G1	G2 or greater
2.24 (D-Day)	1 %	1 %	1 %	20 %	1 %
2.25 (D+1)	1 %	1 %	1 %	10 %	1 %
2.26 (D+2)	1 %	1 %	1 %	10 %	1 %

2015/02/17 2015/02/18 2015/02/19 2015/02/20 2015/02/21 2015/02/22 2015/02/23 2015/02/24

< 3-day forecast (www.spaceweather.go.kr/enotification/forecast/daily)>

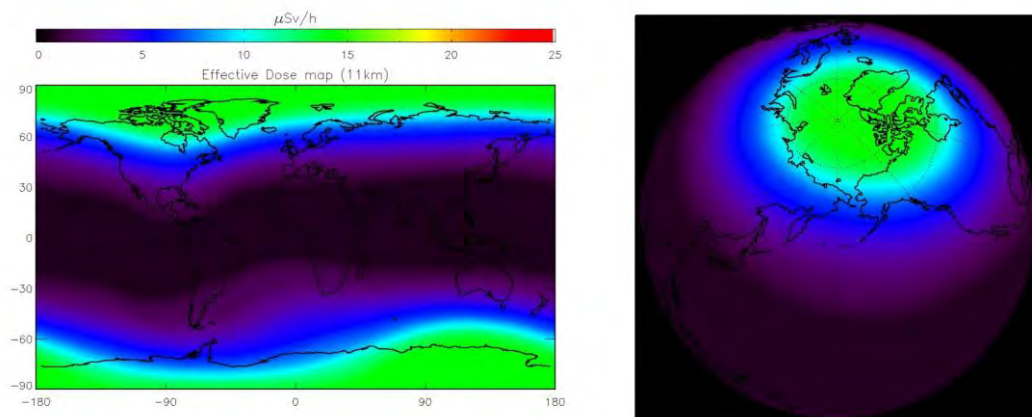
1.10 In this paper, the current status and plan of space weather guidance for air navigation in Korea are reported, especially focusing on two specific topics: (1) Space Radiation and (2) Radio Communication.

2. The Guidance for Space Radiation in Polar Airway

2.1 NMSC has developed the space radiation prediction model with KASI since 2013. NMSC has chosen two track approaches: (1) develop a new physical model composed of very sophisticated particle transport and atmospheric model and (2) develop the heliocentric potential (HCP) prediction model used as a critical input parameter of the CARI-6/6M program.

2.2 A new model was developed by using GEANT4¹ and NRLMSIS00² models. The inputs of this model are the energy spectrum from the Galactic Cosmic Ray (GCR) and Solar Energetic Particle (SEP) and outputs are the particle fluence, equivalent dose and effective dose. The real-time operation of this newly developed model will be after 2016, as required enough verification periods.

2.3 NMSC applies the HCP prediction method for the CARI-6/6M operation from 2015. This enables the real-time operations of the daily prediction of effective dose rate. This will help for dispatchers to decide to use polar route or not.

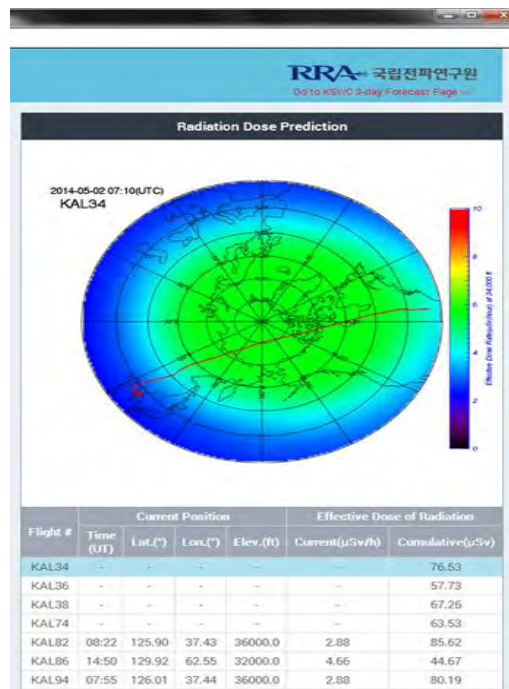


< Global map of effective dose rate at 11 km altitude by CARI-6M using HCP prediction model developed by NMSC >

2.4 Space weather event such as solar radiation storms (S) can affect the aircraft operation safety by increasing radiation exposure to passengers and crews. It is well known that radiation increases with altitude, latitude and flying time. The KSWC/RRA has developed radiation dose calculation system which can give the accumulated route dose by cooperating with domestic airline companies. Flight crews can get information of their total radiation dose by connecting this system.

¹ GEANT4 (Geometry ANd Tracking) : A Particle Transport Model

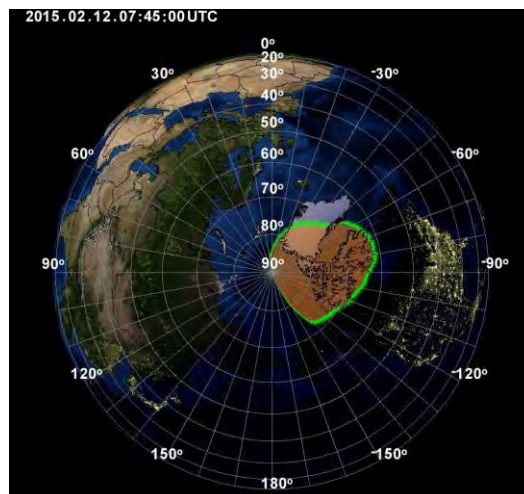
² NRL(US Naval Research Laboratory)MSIS(Mass Spectrometer and Incoherent Scatter Radar)-00(Year of Release) : A real-time atmospheric model



<Radiation dose calculation system (www.spaceweather.go.kr/models/polar)>

3. The Guidance for the Radio Communication

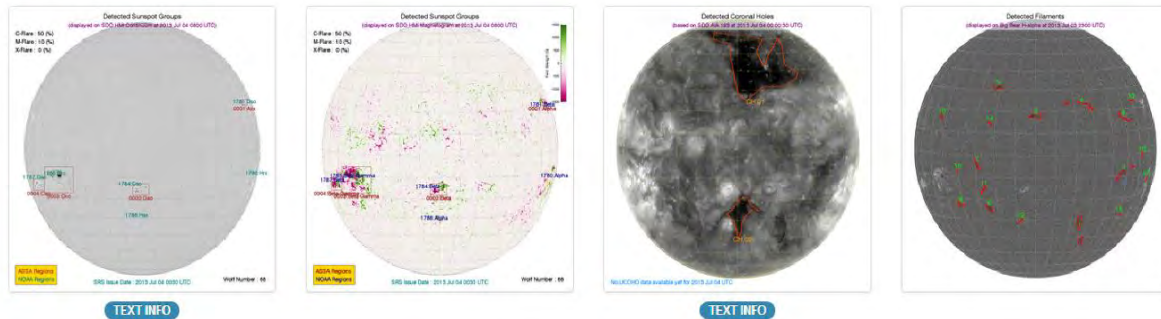
3.1 NMSC is now preparing the official operations of the prediction of Polar Cap Area where HF communication of aircrafts can be significantly disturbed. The polar cap area calculation is based on Ovation Prime model developed by NOAA SWPC, National Geophysical Data Center (NGDC) and Johns Hopkins University/Applied Physics Laboratory (JHU/APL). We apply the specific criteria for estimation of outer boundary of the predicted polar cap area based on recent research results.



<Pole ward boundary of the Polar Cap by Ovation Prime model>

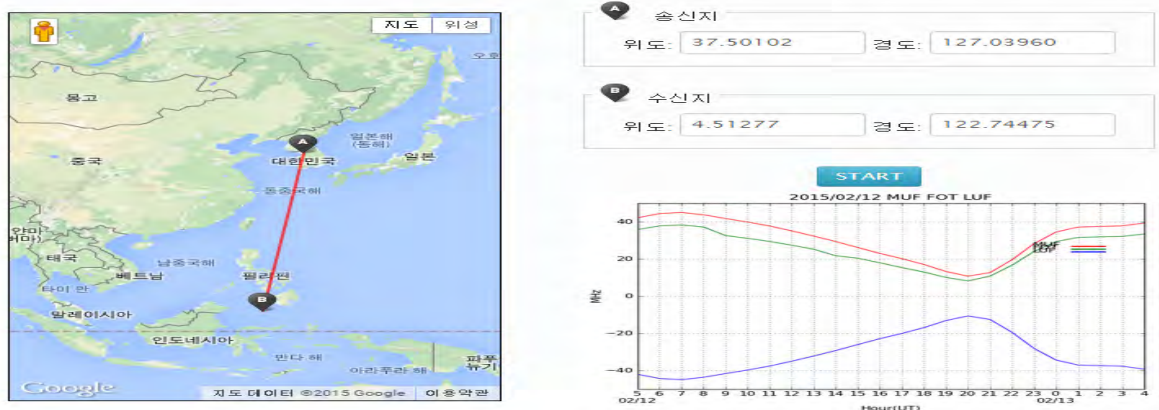
3.2 It is essential that solar flare prediction to mitigate the risks of space weather in air navigation. The KSWC/RRA developed a software system of the Automatic Solar Synoptic Analyzer (ASSA) that is capable of identifying of key solar phenomena such as sunspot groups, coronal holes and filament channels in real time. It automatically provides sunspot classification and solar flare probability with 1-hour cadence.

Latest Results



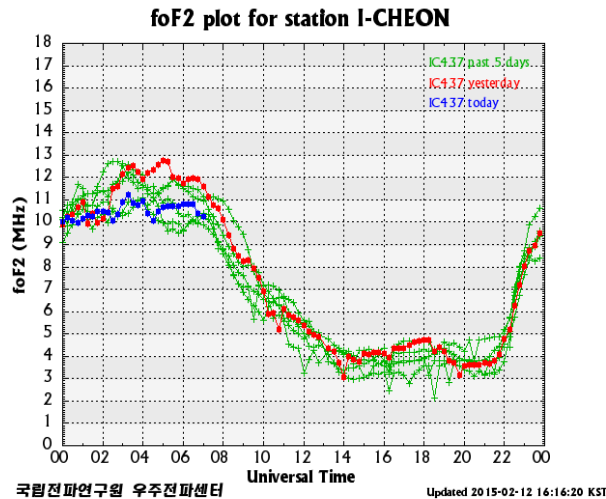
<Automatic Solar Synoptic Analyzer (www.spaceweather.go.kr/models/assa)>

3.3 The KSWC/RRA also developed a regional ionospheric model which provides real-time usable HF frequency information to aviation user group. The model has been provided to the East Asia countries including Korea, Japan, China and also Southeast Asia countries since 2014. Technically, this model is composed of the ITU REC-533 radio propagation model, International Reference Ionosphere model (IRI-2012) and data assimilation techniques, which can ingest the real-time data of international ionosonde network. Using the model, aviation users can find the maximum usable frequency (MUF), lowest usable frequency (LUF), and frequency of optimum transmission (FOT) along their flight route for the next 24-hour.



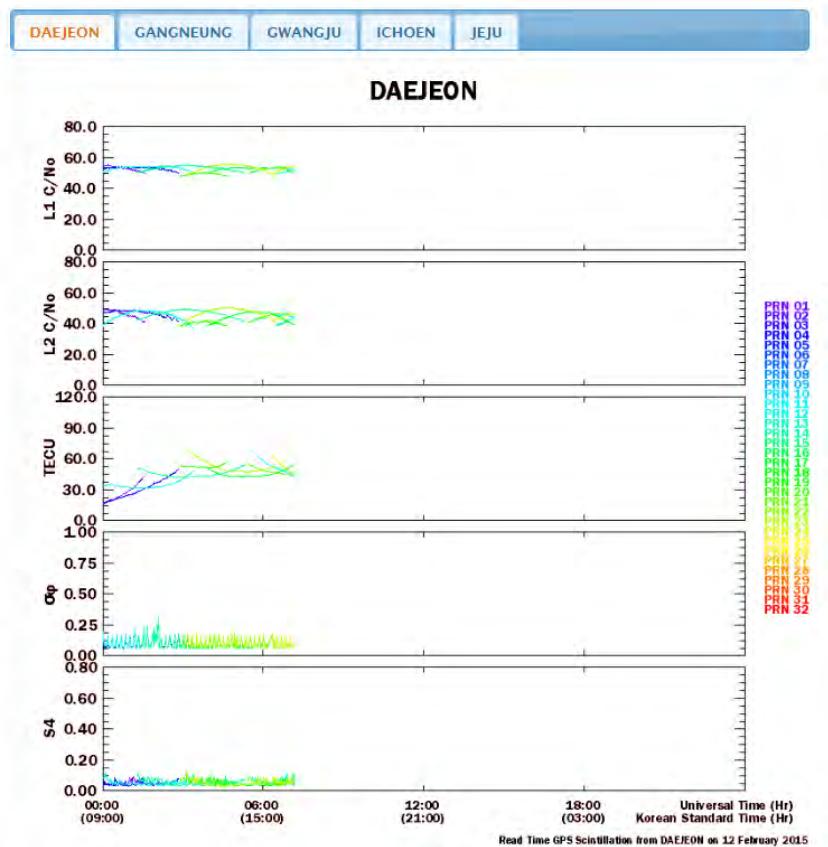
<Usable HF communication (www.spaceweather.go.kr/models/prehf)>

3.4 The ionosphere affects radio signals which are used for communication and air navigation. The KSWC/RRA has monitored the radical variation of ionosphere conditions such as foF2 morphology and plasma irregularity of ionosphere over the Korean Peninsula using ionospheric sounder operated in Icheon and Jeju stations with 15-minutes' time cadence.



<Observation of Ionosphere (www.spaceweather.go.kr/observation/ground/ionosphere)>

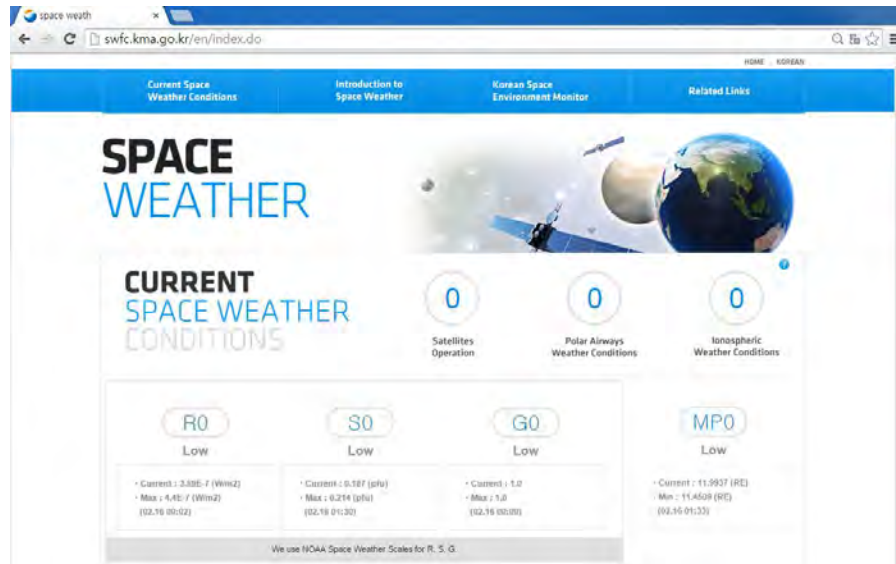
3.5 GPS scintillation varies depending on local time, season, geomagnetic activity, and solar cycle. Severe scintillation condition prevents a GPS receiver from locking on to the signal and affects GPS positioning. The KSWC/RRA has operated five GPS scintillation monitor sites since 2013, which provides information of GPS Carrier to Noise Ratio (CNR), Total Electron Content Unit (TECU), phase of signal and S4 index.



<GPS scintillation monitor (www.spaceweather.go.kr/observation/ground/sciserial?lang=en)>

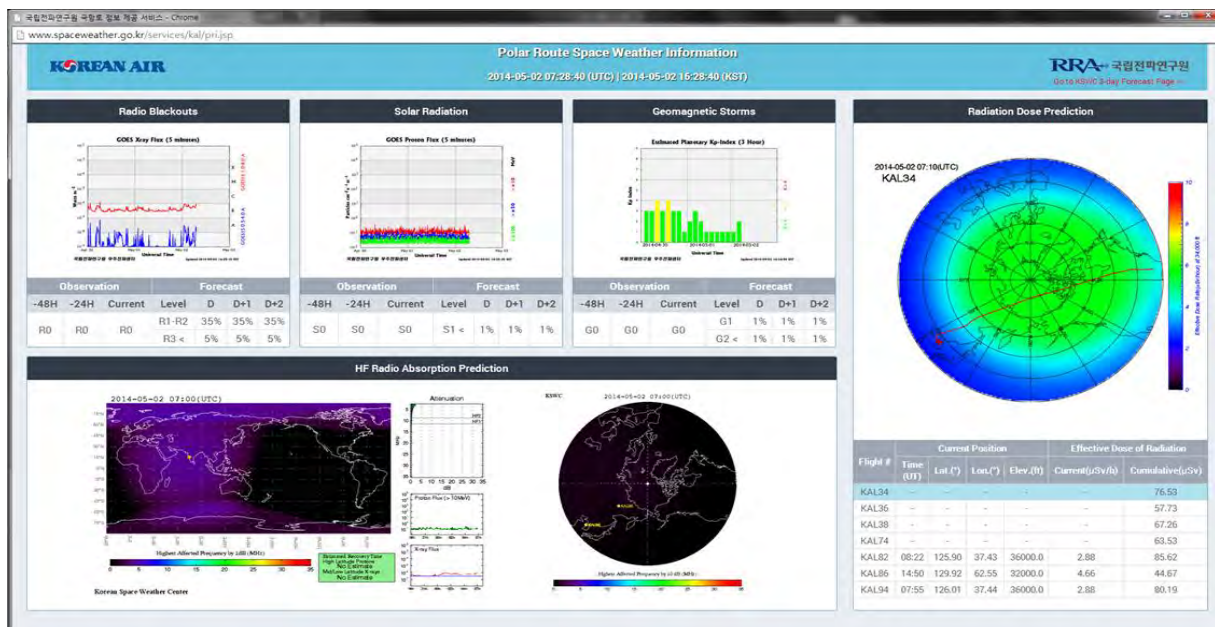
4. SPECIFIC WEBPAGE FOR AVIATION

4.1 NMSC has delivered space weather information and services for Korea through homepage (swfc.kma.go.kr/en/index.do). The space weather services in support of the air navigation are delivered through this homepage.



<Space Weather Homepage of NMSC>

4.2 Space weather contents for the aviation made by KSWC/RRA are provided through a specific webpage (www.spaceweather.go.kr/notification/custom/aviation/institution). It is composed of 3 categories according to NOAA space weather scale (R, S, G), D-Region Absorption Prediction model (D-RAP), Polar Cap Absorption (PCA) and radiation dose prediction model.



<Polar route monitor for aviation safety>

(www.spaceweather.go.kr/notification/custom/aviation/institution)

4.3 NMSC and KSWC/RRA make an effort on data sharing and comparison to improve space weather information and service quality. Through the cooperation, the space weather services for air navigation will advance.

5. ACTION BY THE MEETING

5.1 The meeting is invited to note the information in this paper.
