New Space Weather Products for HF Radio, GPS Navigation and Aviation

Space Weather Center

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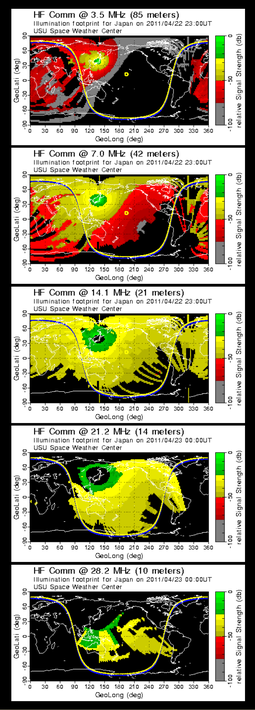
Abstract: The Space Weather Center (SWC) at Utah State University is committed to developing and providing real-time, operational products for customers that will help mitigate adverse space weather effects on radio communication and navigation systems. New space weather products for HF radio and GPS navigation users are demonstrated via real-time and forecast applications on web browsers and iPhone/iPad apps. Our team shows the wealth of new information available, including global and Japanese regional HF radio communication frequencies. In response to the Japanese earthquake and tsunami disaster recovery, SWC now has 3 hour forecast capabilities for HF communication. Improvements to GPS uncertainty characterization in real-time are demonstrated, especially capabilities that can improve use of signals affected by scintillation. In addition to the SpaceWx iPhone and iPad app linking together the four major space environment domains (sun, solar wind, magnetosphere, atmosphere) it now includes new information relevant to dose rate radiation exposures to commercial air flight crews and frequent flyers.

High Frequency Communication

Project Lead: David Hansen

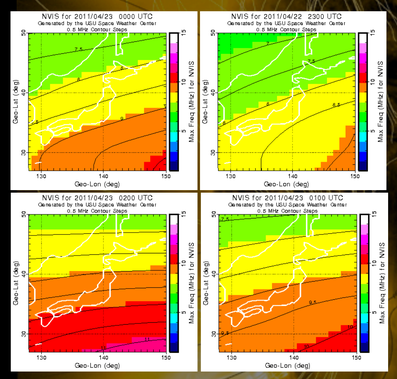
The SWC has a number of products available on the web at spaceweather.usu.edu. Among these products are a set of resources that may be utilized by high frequency (HF) radio users for monitoring space weather effects on HF communications. Radio users are able to determine real-time signal strength for transmitting and receiving at various frequencies and from various locations worldwide. In response to the recent earthquake and tsunami in Japan, a new web-page has been developed for HF emergency communications in the Japanese region. This page incorporates a new 3-hour forecast capability that projects the anticipated HF availability into the near future. The SWC web-page also provides a tool that allows users to enter a flight plan and locate air traffic control stations with the strongest HF signals for that particular path.

Japan Emergency Response HF Communication



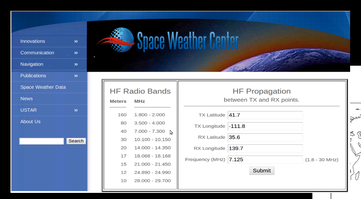
HF Regional Signal Strength
https://spaceweather.usu.edu/htm/japan-emergency-response

- Obtain real-time signal strength for the Japan region.
- View the strength of various HF frequencies.



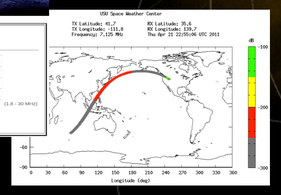
Near Vertical Incidence Skywave (NVIS)
https://spaceweather.usu.edu/htm/japan-emergency-response

- Obtain current conditions as well as the 3-hour forecast.
- Find the maximum usable frequency for NVIS propagation.
- NVIS is a method of radio communication most useful in mountainous areas where line-of-sight propagation at VHF or UHF frequencies is ineffective or when the communication distance is beyond ground wave (more than 50 miles, 80 km) and less than sky-wave (300 to 1500 miles, 500 to 2500 km).



Point to Point Signal Strength
http://spaceweather.usu.edu/htm/mode01-data

- Select any transmission location.
- Select any receiving location.
- Select any HF radio frequency.
- Get real-time signal strength results between 2 locations.



Air Traffic Control (ATC) Station Finder
http://sw05.spaceweather.usu.edu/mode2/

- Enter multiple coordinates of flight plan.
- Identify the ATC station with the best signal.
- Identify the best frequency.

Enter your Flight Plan:

35N150E 35N160E 33N180E 28N170W

Submit

Air Traffic Control Station with Best Signal

Location	UTC	ATC	km	kHz	dB*
35N150E : (LAT:35 LON:150)					
	2011-04-22 22:00:00	NYC	10375	17946	-140
	2011-04-22 22:00:00	NYC	10375	13310	-170
35N160E : (LAT:35 LON:160)					
	2011-04-22 22:00:00	ORD	8935	17946	-142
	2011-04-22 22:00:00	ORD	8935	13310	-185
33N180E : (LAT:33 LON:180)					
	2011-04-22 22:00:00	SLC	5900	17946	-126
	2011-04-22 22:00:00	NYC	8765	17946	-149
28N170W : (LAT:28 LON:190)					
	2011-04-22 22:00:00	SFO	4475	17946	-130
	2011-04-22 22:00:00	ANC	3910	13310	-132

* dB Transmission Color Key: Green=Good : Yellow=Not So Good : Red=Poor : Gray=Bad

GPS Navigation

Project Lead: Jennifer Meehan

Real-time continental U.S. regional GAIM ionosphere data started on November 18, 2009. SWC began operations of the region continental U. S. (CONUS) GAIM Gauss-Markov ionosphere system to produce a high resolution definition of ionosphere parameters. The CONUS Gauss-Markov GAIM system runs operationally on SWC servers. The real-time ionosphere data of total electron content (TEC) and time-dependent electron density profiles are generated every 15 minutes using the CORS U.S. GPS network of approximately 400 stations with multiple slant TEC measurements taken at each station. There are approximately 10,000 slant TEC measurements ingested every 15 minutes in the GAIM system. Real-time data is assimilated into the Ionosphere Forecast Model (IFM), a background physics-based ionosphere.

- GPS receivers in typical mobile appliances are single-frequency with no WAAS capability
- Smartphone GPS receivers may use augmented/assisted GPS (A-GPS) "hints" provided by the cell phone network to improve performance
- Test cases show the GAIM corrections yield better results than the traditional Klobuchar correction, and may be comparable to dual-frequency corrections in some cases

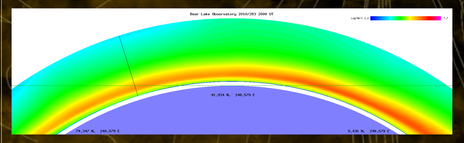
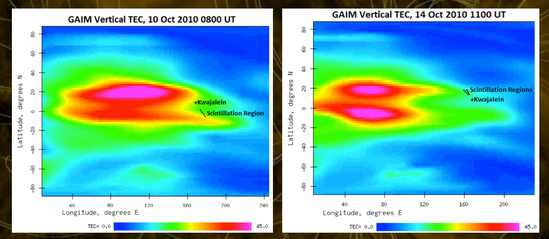


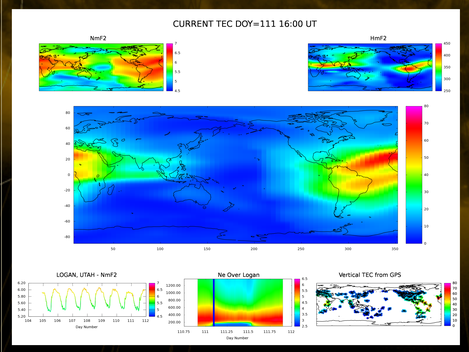
Figure above shows slant path interpolation used to calculate TEC and correction factors through the GAIM grids

Figure above shows the algorithm developed to interpolate electron density between regional and global grids



- GPS signal scintillations typically occur near structures associated with equatorial bubbles in the local evening. These figures show GPS signal paths intersecting the F region along gradients on the evening edges of the equatorial anomaly. These signals showed moderate scintillations at the Kwajalein receiver and match ground-based observations of decreased GPS (mainly L2) signal quality.
- GAIM may be used in conjunction with ground-based observations to identify areas in the evening sector where scintillations are likely to occur due to potentially unstable electron density gradients.

USU-GAIM Gauss-Markov Kalman Filter Model



- The Gauss-Markov Kalman filter is based on a physics-based model of the ionosphere and a Kalman filter data assimilation algorithm. The USU-GM is a global model that can support regional, higher-definition assimilation windows within the model specification. The regional higher-definition window is used in areas where there is a large amount of data.
- The current version of the model is GAIM-GM2.9.0, which allows for numerous data types to be assimilated. The data type in the newest version of the model are GPS slant TEC from ground based receivers, occultation TEC measurements, DISS ionosonde measurements, DMSP SSIES in situ electron densities, DMSP F16 SSUSI UV measurement, DMSP F18 SSULI UV measurements and a user supplied High-Latitude Boundary.

Space Weather App

Project Lead: Layne Pedersen

The SWC just released the SpaceWx app, version 1.7, available for the iPhone, iPod Touch and soon available for the iPad. The SpaceWx app makes it possible to view real-time space weather data, from the Sun to the Earth, on a handheld device with Wi-Fi or cell phone signal. The SpaceWx app extracts and compiles data in near real-time combining the four major space environment domains: Sun, Solar Wind, Magnetosphere, and Atmosphere. These include solar images, X-rays, and solar wind conditions as observed from the GOES, SOHO, STEREO, ACE, and SDO satellites, ionospheres's global and regional TEC and HF radio propagation as well as forecasted F10.7 and X-ray flare probabilities up to 6 months in the future. Version 1.7 includes a new product from the NAIRAS (Nowcast Atmospheric Ionizing Radiation System) and has been added under the Atmosphere/SET RAD selections with images showing radiation exposure rates for high-latitude flights.

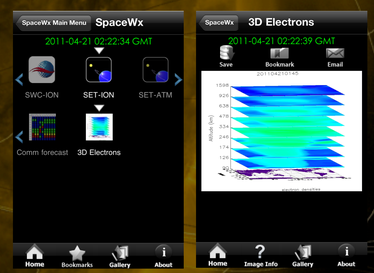
This App can be useful for broadly understanding space weather effects in: HF radio communications, GPS accuracy, power grids and aviation. These systems are affected by space weather disturbances that are visualized by this app.

iPhone and iPod Touch

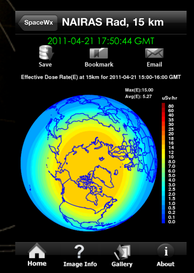
With a tap on the Main Menu screen you have selection for:

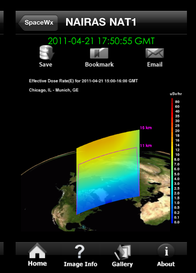
- The 4 space environment domains
- global or regional total electron content
- solar and geomagnetic current status plots
- rotate with zoom on images

In addition, by using the web browser ability, the SpaceWx app can be used to access our GAIM products and other space weather products provided by our partners already designed for the iPhone/PDA screen



Data selection is made by first selecting a category within a domain, choosing instrumentation, and a data set.





Version 1.7 now includes information relevant to dose rate radiation exposures to commercial air flight crews and frequent flyers.

iPad

- In additional to all the features for the iPhone, a version optimized for the iPad accompanies version 1.7.
- Visually, the iPad offers easy to use, high resolution graphics with excellent displays of real-time space weather data .

HF Communication Prime Developers: Vince Eccles, Don Rice, Eric Hunsaker, David Hansen and Jared Fulgham; GPS Prime Developers: Don Rice, Larry Gardner, Jennifer Meehan, Herb Carlson, Layne Pedersen and Lie Zhu; Space Weather App Prime Developers: Layne Pedersen, Dave Bouwer and Jared Fulgham. Background image credit: NASA SDO