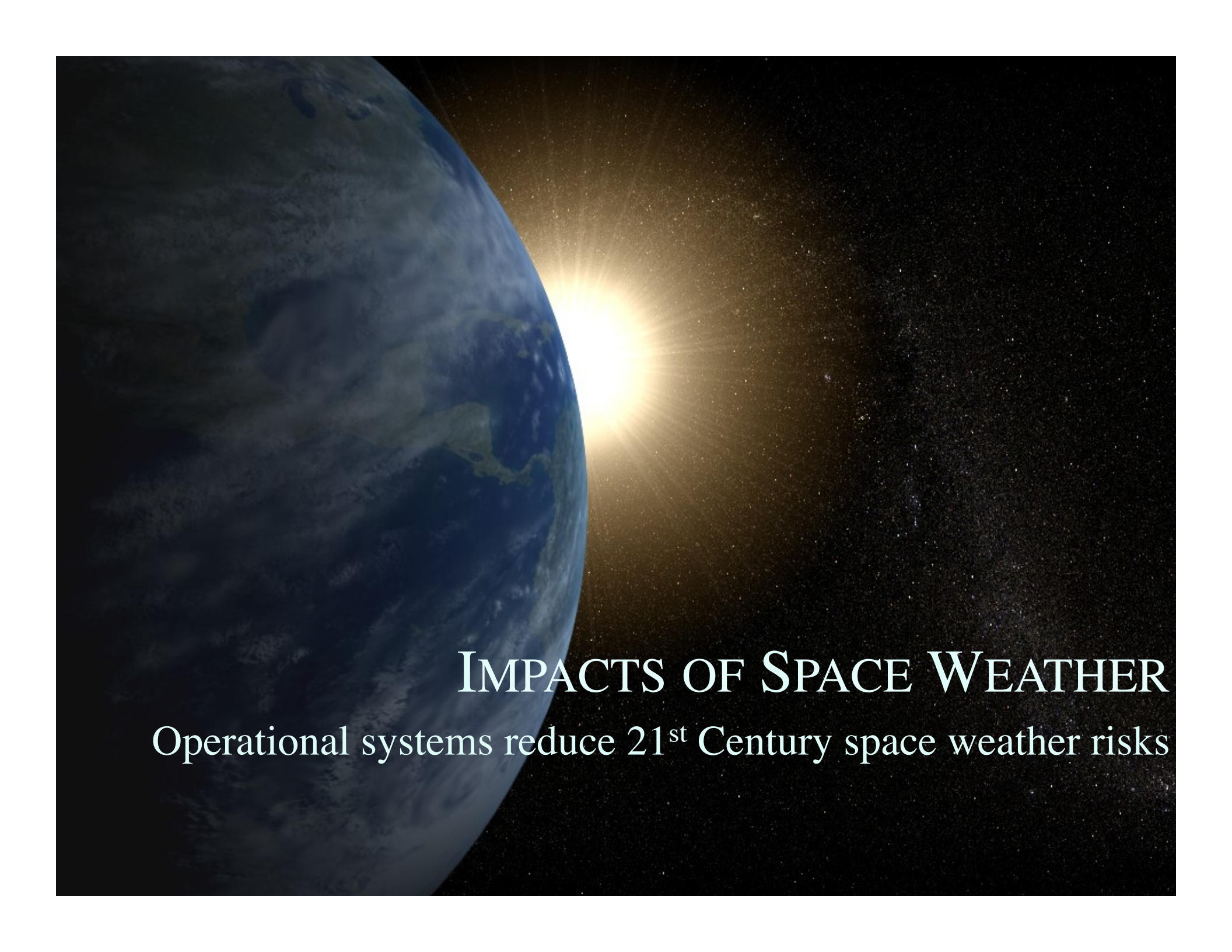
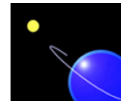


A composite image showing the Earth's horizon on the left, with a bright sun rising over it, creating a lens flare effect. The background is a dark, star-filled space.

IMPACTS OF SPACE WEATHER

Operational systems reduce 21st Century space weather risks



Impacts of Space Weather Operational Systems Reduce 21st Century Space Weather Risks

July 19, 2013

Heliophysics Summer School

W. Kent Tobiska

Director, USU Space Weather Center

President, Space Environment Technologies

Adjunct Faculty, USC and USU

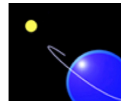
W. Kent Tobiska

<http://spaceweather.usu.edu>

<http://spacewx.com>

SpaceWx app





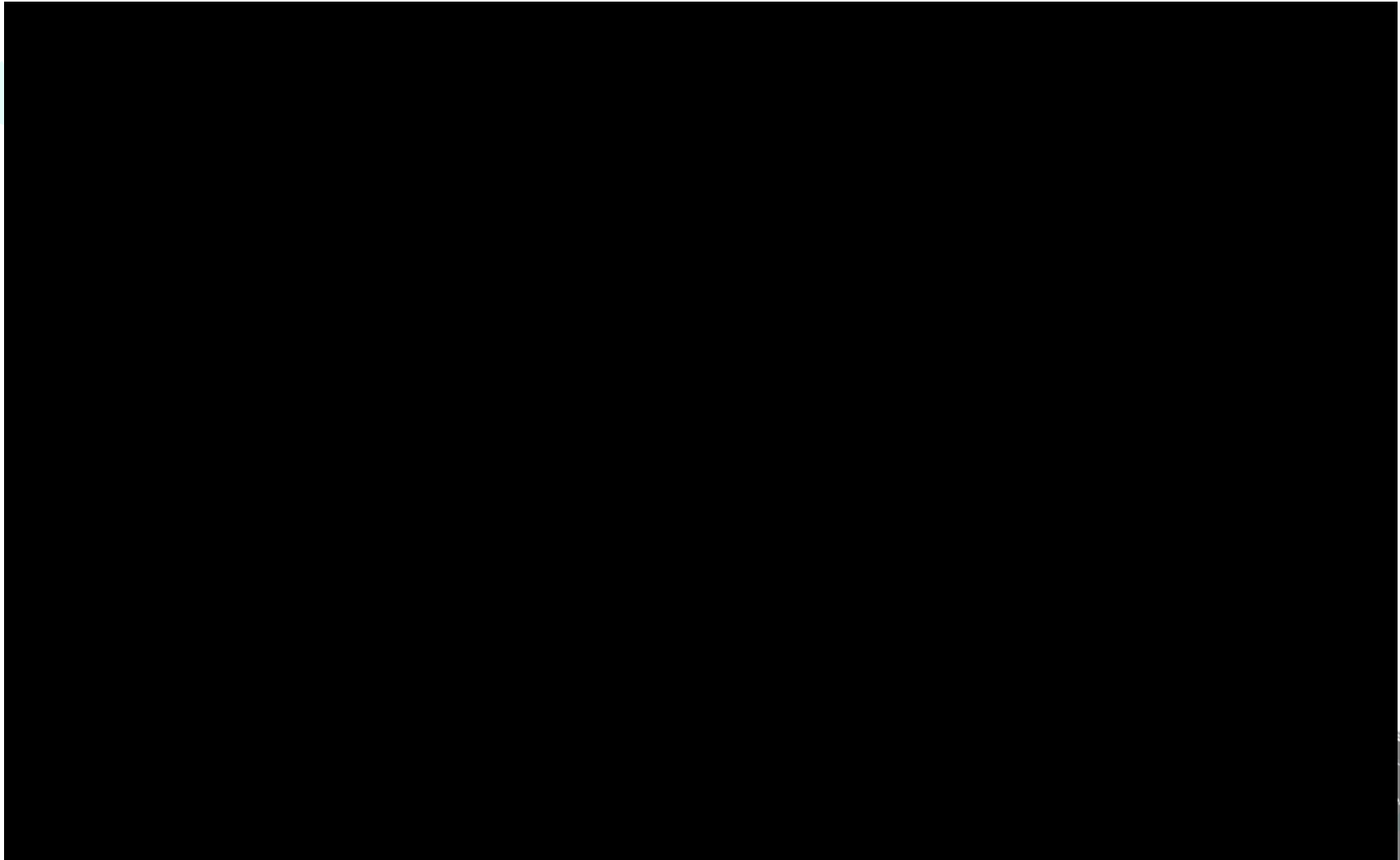
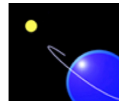
What is Space Weather?



Definition of Space Weather

- The Earth's near space environment and our technology are affected by space weather.
- Space weather is the dynamical transfer of energy from the Sun to the Earth in the form of solar photons, charged particles, and fields that vary on multiple time and spatial scales.
- This variability occurs primarily through direct photo-absorption processes in the terrestrial upper atmosphere and, secondarily, through solar wind/magnetosphere coupling with the terrestrial ionosphere.





Credit: SOHO

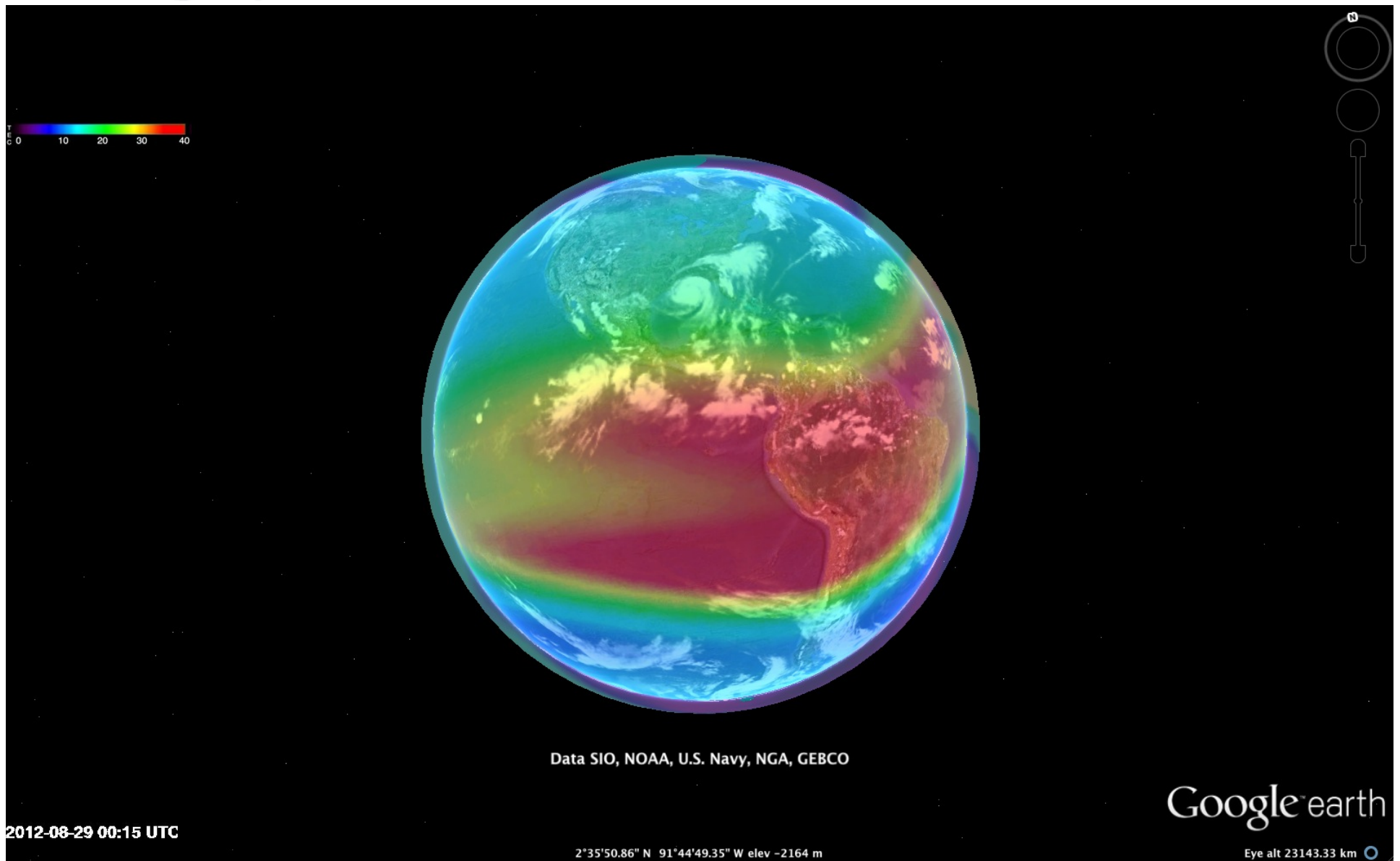
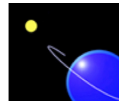
W. Kent Tobiska

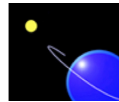
<http://spaceweather.usu.edu>

<http://spacewx.com>

SpaceWx app

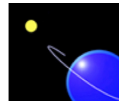






Astro_Soichi



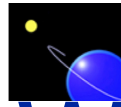


Vandenberg launch



Accessing Space Weather on-the-go: apps for iPhone, iPad, and Android





Early SpWx moments

- ◆ **1859:** Carrington identifies massive solar event that affects human technology
- ◆ **1882:** A conducting region in Earth's upper atmosphere was speculated by Kelvin and Stewart in connection with daily magnetic variations
- ◆ **1901:** Marconi's performed his wireless radio experiment from Cornwall to Newfoundland
- ◆ **1902:** Kennelly and Heaviside independently postulated that the radio waves were reflected from an ionized layer (E region) to explain the communication
- ◆ **1912:** Eccles provided rudimentary theory
- ◆ **1926:** Watson-Watt coined term 'ionosphere'



Historical SpWx moments

- ◆ **1936:** Saha theorized excess irradiances (EUV and Xrays) were needed above the solar blackbody spectrum to give the observed ionization levels
- ◆ **1946:** first NRL upper atmosphere rocket with captured German V-2 detected excess solar EUV irradiances above blackbody spectrum
- ◆ **1950s:** One-dimensional atmosphere models were developed by Chapman, Bates, and Nicolet
- ◆ **1965:** USAF **OV1-1** satellite observed electron density, magnetic fields, proton concentration
- ◆ **1970s:**
 - Schunk (USU) developed first ionospheric, coupled 3-ion, model
 - Schunk, Raitt, and Sojka (USU) produced the first Lagrangian ionosphere model describing auroral phenomena with particles and electric fields



Operational SpWx moments

- ◆ **1980s:** Roble (NCAR) achieves 3D modeling of the thermosphere and ionosphere
- ◆ **1990s:**
 - Schunk and Sojka (SEC) developed mid- and high-latitude ionosphere descriptions for the USAF PRISM model
 - Schunk and Sojka develop the Ionospheric Forecast Model (IFM)
 - First GAIM data assimilative ionospheric models using physics-based core models were developed through the ONR MURI program (USU and JPL/USC were two competing teams)
- ◆ **2000:** Tobiska (SET) provides 1st operational real-time and forecast solar irradiances at NOAA
- ◆ **2002:** US AFSPC HASDM system (NORAD catalog with <10% error) declared operational using SET code
- ◆ **2005:** AFRL and NRL validate USU GAIM as the “gold standard” for operational use by AFWA



Innovative SpWx moments

- ◆ **2006:** US AFWA implements USU GAIM operationally
- ◆ **2007:** Fry (EXPI) provides first solar wind data to AFWA
- ◆ **2008:** US AFSPC and SET release JB2008 thermospheric density model
 - most significant advance for satellite orbit accuracy in 40 years
- ◆ **2008:** SET and SEC release first real-time and forecast Communication Alert and Prediction System (CAPS) operational ionosphere via Google Earth KMZ files
- ◆ **2009:** USU SWC and SET release 1st smartphone app with real-time space weather (*SpaceWx*)
 - 19 participating institutions and 150 real-time data streams available for iPhone, iPad, iPod, and Android devices
- ◆ **2010:** USU SWC turns on first commercial GAIM operational ionosphere system



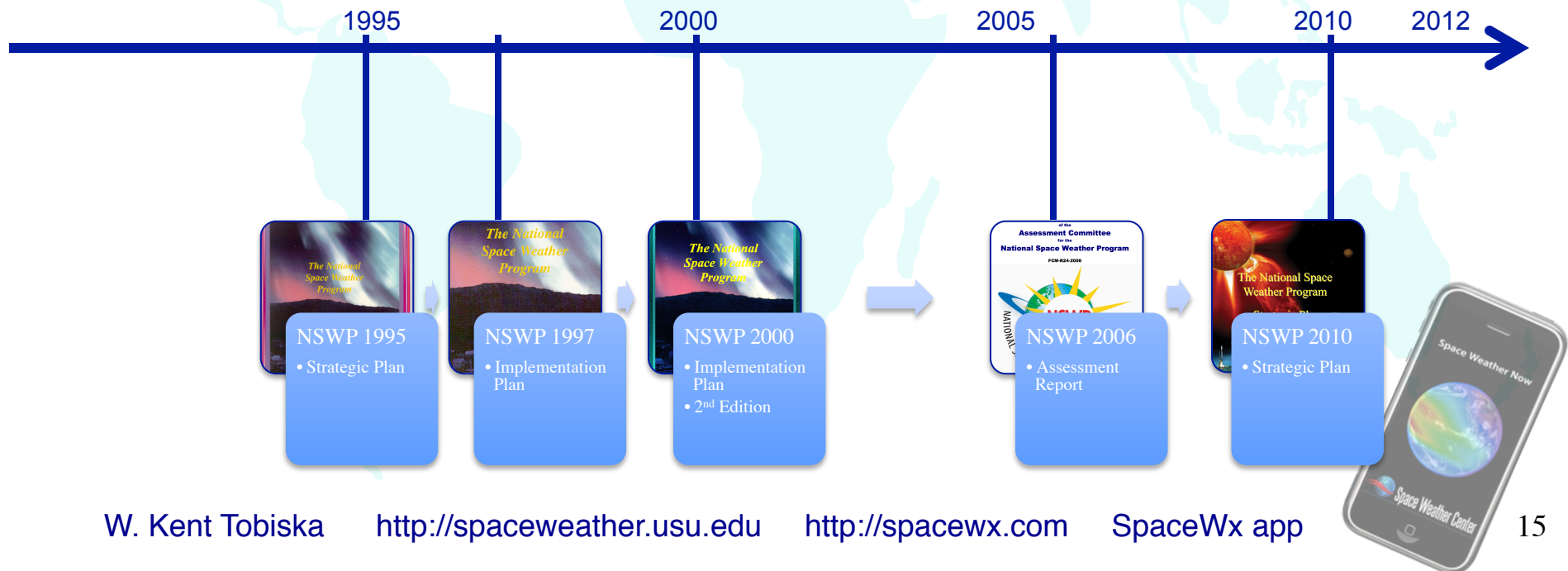
Commercial SpWx moments

- ◆ **2011:** Mertens (NASA LaRC) and SET release 1st real-time global aviation radiation environment with NAIRAS
- ◆ **2011:** USU SWC achieves accuracy in global real-time and forecast HF ray-tracing & GPS 2-meter accuracy
- ◆ **2012:** SET demonstrates first operational Dst forecasts up to 3 days with 1 hour granularity using Anemomilos algorithm for USAF Space Command
- ◆ **2012:** Crowley (ASTRA) achieves first commercial data streams for Alaska scintillation with CASES
- ◆ **2013:** HASDM upgrade with SET solar, Dst forecasts to 72 hours becomes operational; SWC as backup site
- ◆ **2013:** SET demonstrates first real-time downlink of aviation radiation dose and dose-rate, integrated into NAIRAS, and redistributed to world via *SpaceWx* app



U.S. space weather enterprise

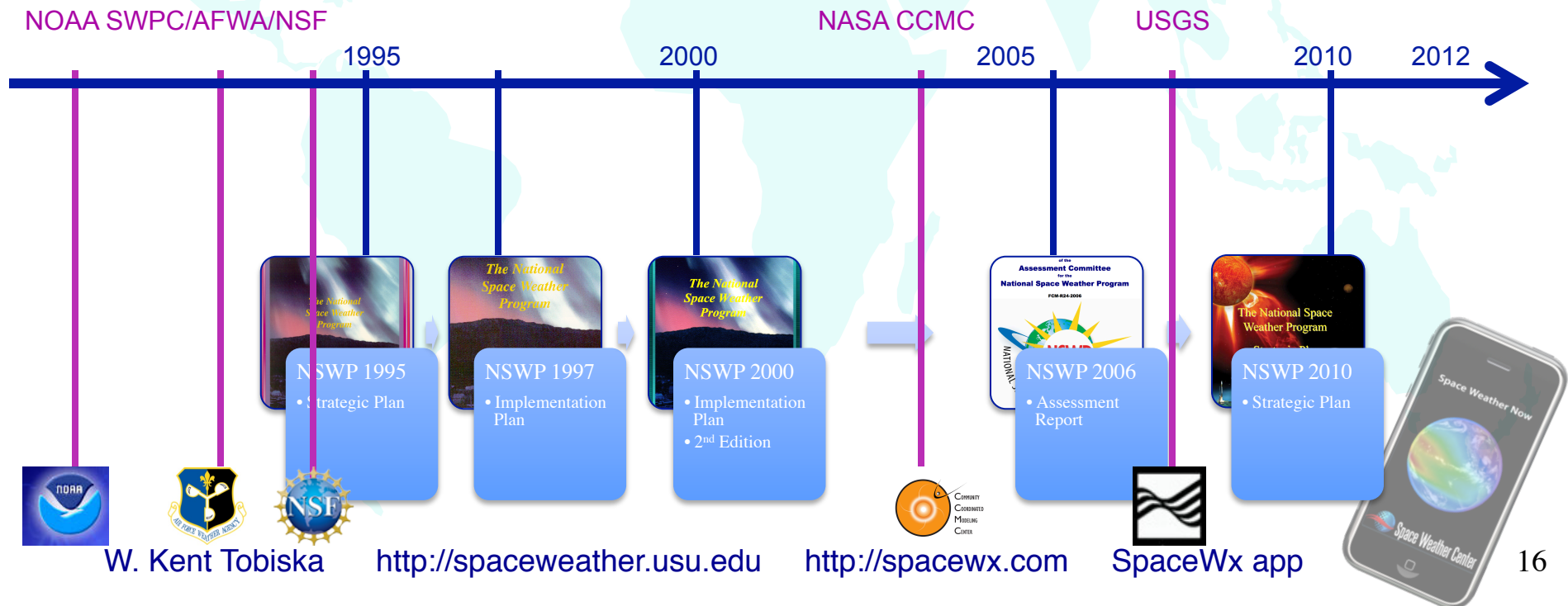
National Space Weather Program (1995,1997,2000,2006,2010)



U.S. space weather enterprise

National Space Weather Program (1995,1997,2000,2006,2010)

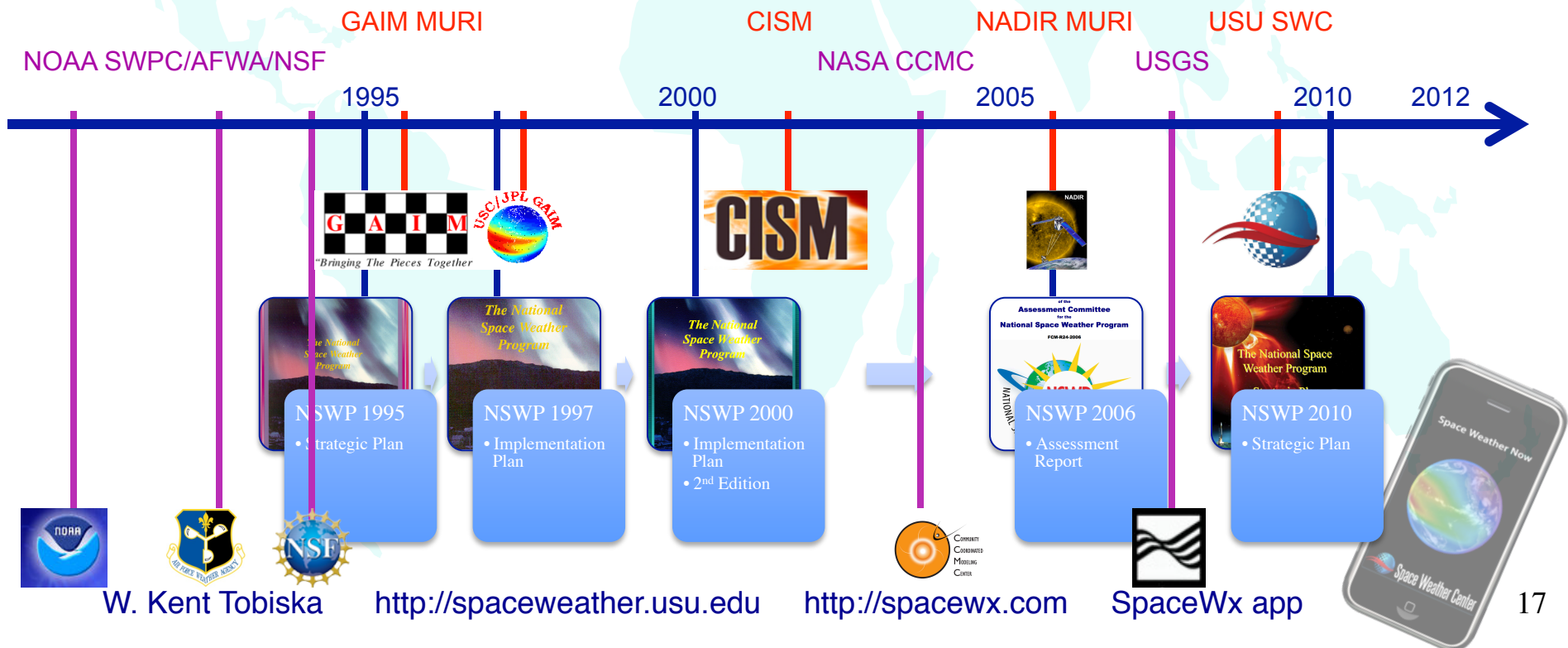
- Agencies** (NOAA SWPC, AFWA, NASA CCMC, USGS, NSF)



U.S. space weather enterprise

National Space Weather Program (1995,1997,2000,2006,2010)

- **Agencies** (NOAA SWPC, AFWA, NASA CCMC, USGS, NSF)
- **Academia** (GAIM MURI, CISM, NADIR MURI, USU SWC)



U.S. space weather enterprise

National Space Weather Program (1995,1997,2000,2006,2010)

- **Agencies** (NOAA SWPC, AFWA, NASA CCMC, USGS, NSF)
- **Academia** (GAIM MURI, CISM, NADIR MURI, USU SWC)
- **Industry** (AER, CPI, SEC, CRC, SSI, EXPI, SET, ASTRA, PSI, Q-up)

AER/CPI/SEC/CRC

SSI EXPI

SET

ASTRA

PSI

ACSWA

Q-up

GAIM MURI

CISM

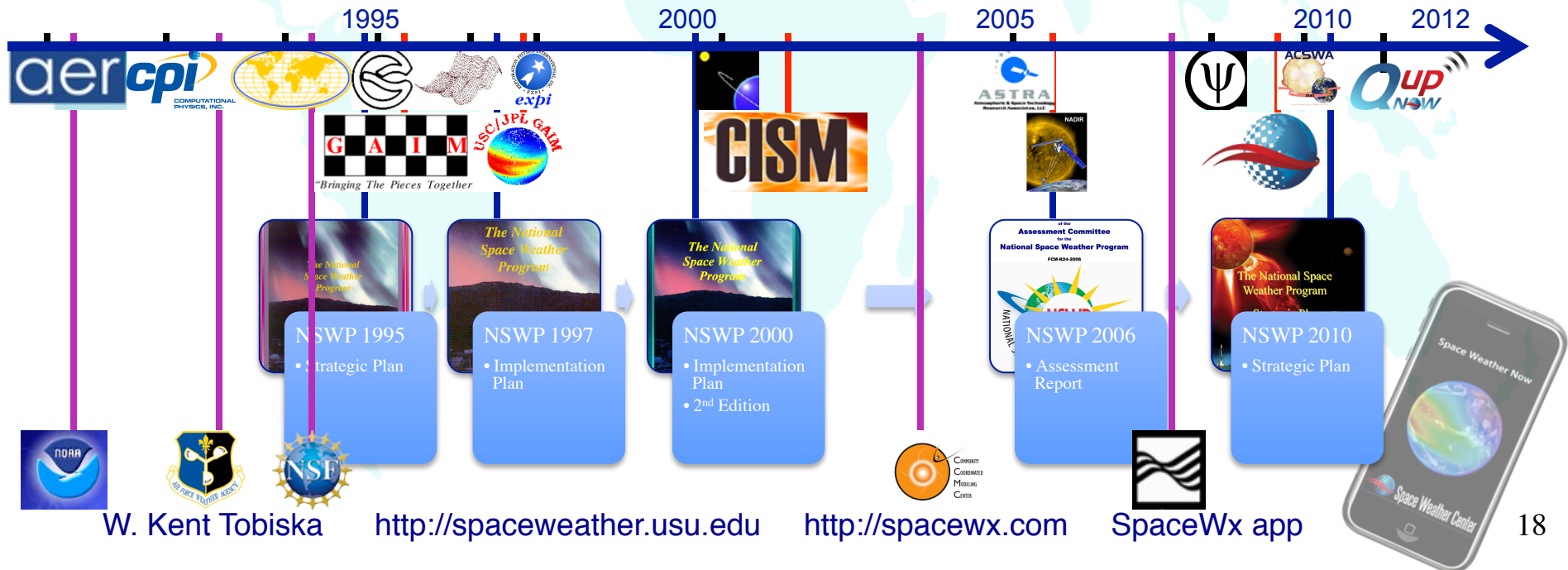
NADIR MURI

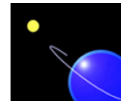
USU SWC

NOAA SWPC/AFWA/NSF

NASA CCMC

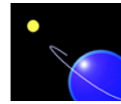
USGS





Impacts of Space Weather





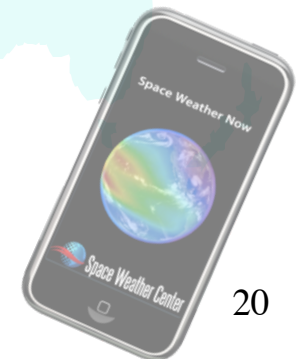
Great disasters move us to improve the human condition

Katrina Hurricane in Gulf of Mexico

August 29, 2005

Great East Japan Earthquake

March 11, 2011



Hurricane Katrina

Katrina

+

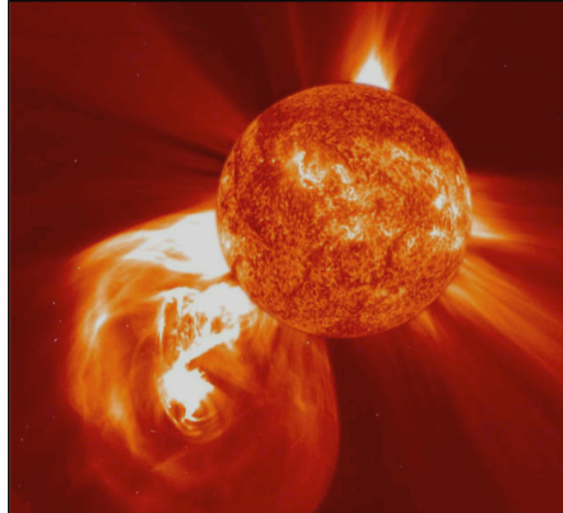
Solar Flare

=

Hazard



Aug. 29, 2005



Sept. 7, 2005
(4th largest flare
in history)



Loss of ship-to-
helicopter
communications



Great East Japan Earthquake

Massive destruction





Demolished infrastructure

\$300 billion in damages



10,000 missing





14,000 dead

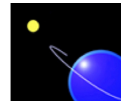
Unusable
cell phone
tower



Technologies affected by Space Weather

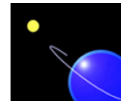
- **Aviation** – HF communication loss; radiation above 30,000 ft.; GPS position error
- **Navigation** – GPS position and timing error
- **Communication** – D-region absorption; HF loss; HF/UHF/L-band radio signal scintillation
- **Satellite operations** – LEO orbit error from drag; GEO spacecraft charging; SEUs and latchup
- **Energy production** – drill-bit misalignment from magnetometer error in oil/gas drilling
- **Power grid** – transformer loss from GIC surges



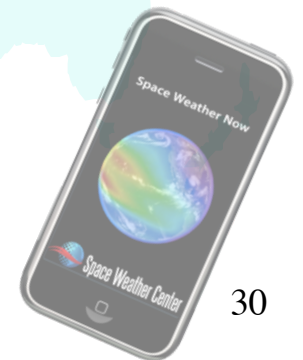


Methods of Space Weather Mitigation





Space Environment Standards – ISO TC20/SC14 WG4





Space Environment Domains

existing document (work to be initiated)	
Cosmic Rays	N
Solar photons	
Solar particles	(1
Solar fields	
Internal field	
Magnetosphere	
Radiation Belts	er
Plasmasphere	
Ionosphere	1
Neutral atmosphere	1 (at
Micrometeoroids	
Debris	
W. Kent Tobiska	http://s
General: 15856(a), 1670	

Space Environment Technologies – Home Page

spacewx.com

Contacts

Bonjour

SpaceWx Alert System

LAPS hasdm1a

LAPS hasdm1b

ASWA: Action... Advisories

SpaceWx Alert System

iCloud – Find My iPhone

SPACE ENVIRONMENT TECHNOLOGIES

Space Research

Space Operations

Space Standards

Home

SpWx Now

Innovations

Products

Users

Partners

Support

About SET

Contact Us

News from Space Environment Technologies

Solutions

Solar Variability

Geomagnetic Effects

GEO Charging

LEO Orbits and Reentry

Communication Outages

Aviation Radiation

Space Sciences

Space Operations

Space Systems

Space Environment Technologies awarded by William Shatner's Moving America Forward

SET President W. Kent Tobiska was presented the Entrepreneur Award by Rear Adm. Kevin F. Delaney (Ret.) on June 27, 2012 during a television broadcast of William Shatner's Moving America Forward.

New Index for Real-Time and Forecast Geomagnetic Disturbances

SET is developing a new real-time and forecast Dst geomagnetic index using the USGS magnetometer network under a newly awarded AFRL contract.

New System Will Specify Radiation Hazard to Air Crews

SET is building a new system to specify damaging radiation exposure to pilots, crew, and passengers on commercial flights. [\(NASA Press Release\)](#)

50% Improvement in 1-sigma LEO Orbit Determination Uncertainty

JB2008 provides improved accuracy for LEO orbit determination precision, debris and collision avoidance maneuvers, and reentry planning during active solar conditions. Real-time and forecast data are available, contact us at spacenvironment@spacenvironment.net for additional information.

The new Solar Irradiance Platform

SIP v2.37 provides current epoch and forecast JB2006 and JB2008 solar and geomagnetic indices.

Real-time Charging and Discharging for GEO Communication Satellites

The new Geosynchronous Alert and Prediction System (GAPS) monitors space weather charging and deep dielectric discharge probability hazards at GEO orbit from the past 48-hours to future 72-hours.

Current Communication Outages

The Communication Alert and Prediction System (CAPS) and Earth Space 4D (ES4D) provides HF, UHF & L-band applications for aviation, first responders, amateur radio, and satellite users. [\(NASA press release\)](#)

Featured Products

SpaceWx iPhone App

Book:

Understanding Space Weather

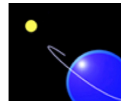
Resources

Standards

Publications

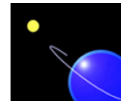
Education

Definitions and Descriptions



Space Weather Operations





Operational systems for space situational awareness require the mitigation of space weather effects



Space weather definition and risk

◆ The short-term variable impact of the Sun's

- Photons, solar wind particles, and interplanetary magnetic field upon the Earth's environment
- Can adversely affect technological systems
- Effects come from
 - ▶ solar coronal mass ejections
 - ▶ solar and galactic energetic particles
 - ▶ solar flares and irradiances
- and they affect Earth's
 - ▶ magnetospheric particles and fields
 - ▶ geomagnetic and electrodynamical conditions
 - ▶ radiation belts
 - ▶ ionosphere
 - ▶ neutral thermosphere

Photon

Part/Fields



Space Weather Impact on Operations

◆ Earth-Orbiting (EO)

Photon

Part/Fields

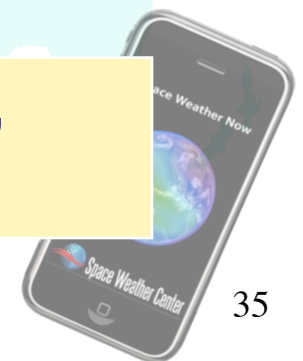
- Atmospheric drag affects location knowledge
- Attitude perturbations affect pointing precision and gas supply

◆ Deep Space (DS)

- Attitude perturbations affect pointing precision and gas supply

◆ End-of-Life (EL)

- Atmospheric drag affects end-of-life timing,
- Missile reentry location



Space Weather Impact on Operations

◆ Mission Planning (MP)

Photon

Part/Fields

- Atmospheric drag affects location knowledge
- Attitude perturbations affect pointing precision and gas supply

◆ Telemetry Transmission (TT)

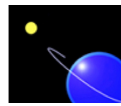
- Ionospheric scintillation can impact radio link

◆ Command and Control (CC)

- Atmospheric drag error, ionospheric variability (scintillation and GPS location error), memory upsets from charged particle impacts

◆ Analysis Capability (AC)





		SPACE SYSTEMS USER ACTIVITIES						
		EO	DS	EL	MP	TT	CC	AC
SPACE WEATHER ACTIVITY	I_s							
	I_{EUV}							
	T_{heat}							
	T_{wind}							
	I_{ono}							
	Q_J							
	Q_P							
	E							
	B							
	S_{wind}							

W. Kent Tobiska

Photon

Part/Fields

<http://spaceweather.noaa.gov>

Available

Improve

Space Weather Center

37

W. Kent Tobiska

Photon

ack

Part/Fields

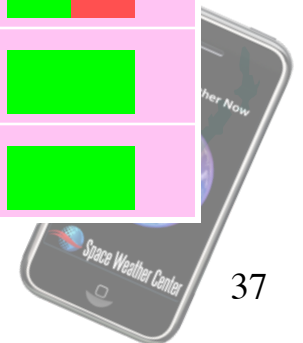
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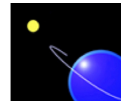
<http://spacew>

Available

Space

Improv
e





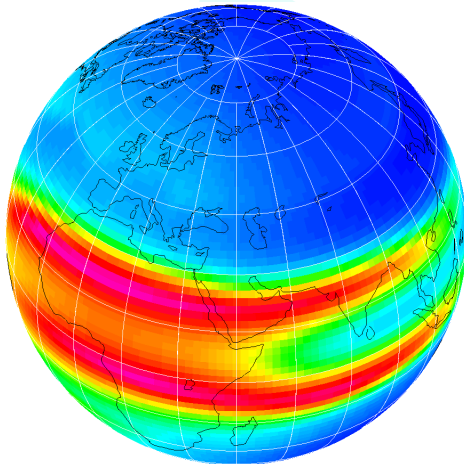
Space Weather Operations – Ionosphere



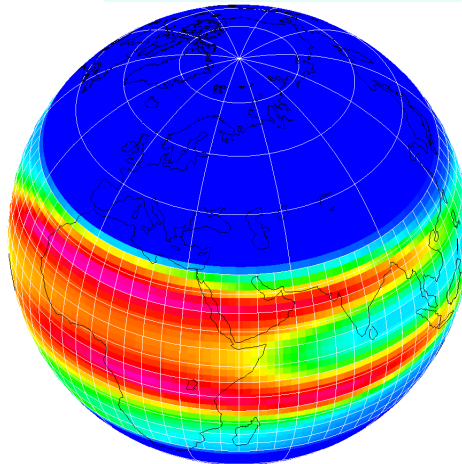
GAIM Basic Approach for Ionosphere

We use a physics-based ionosphere or ionosphere-plasmasphere model as a basis for assimilating a diverse set of real-time (or near real-time) measurements. GAIM provides both specifications and forecasts on a global, regional, or local grid.

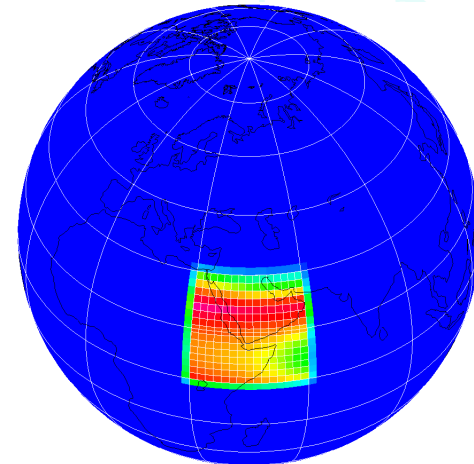
Global



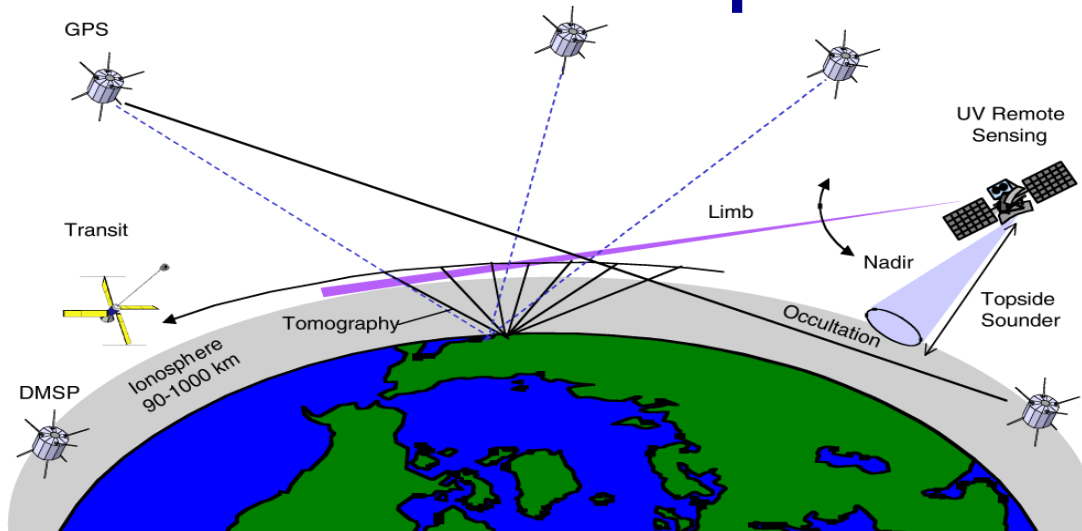
Regional



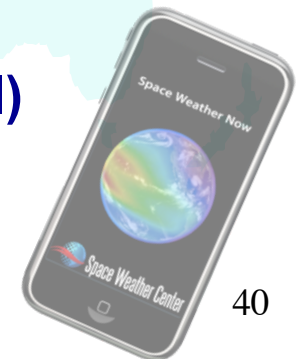
Local



2006: GAIM Assimilates Multiple Data Sources

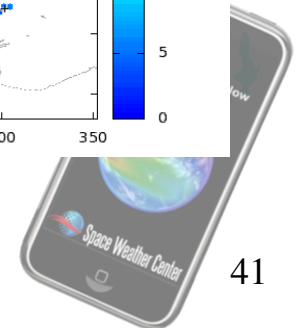
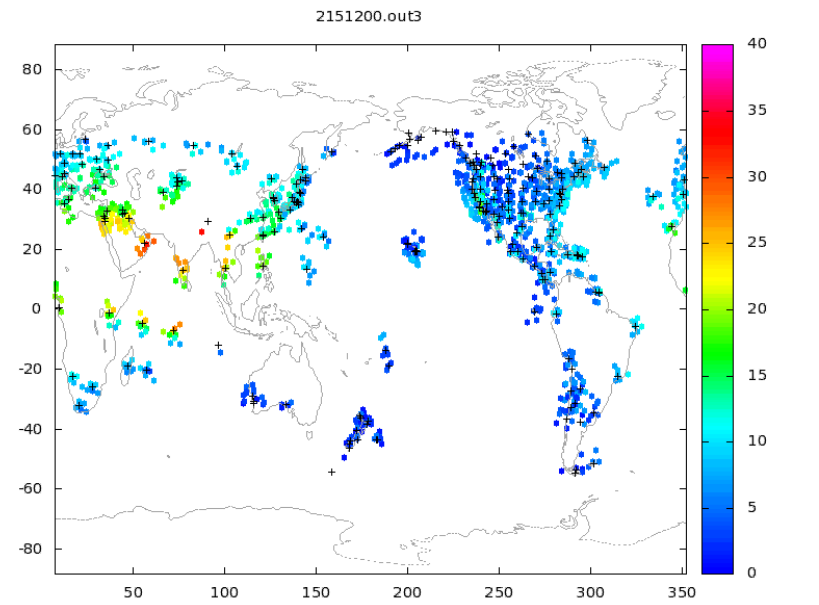
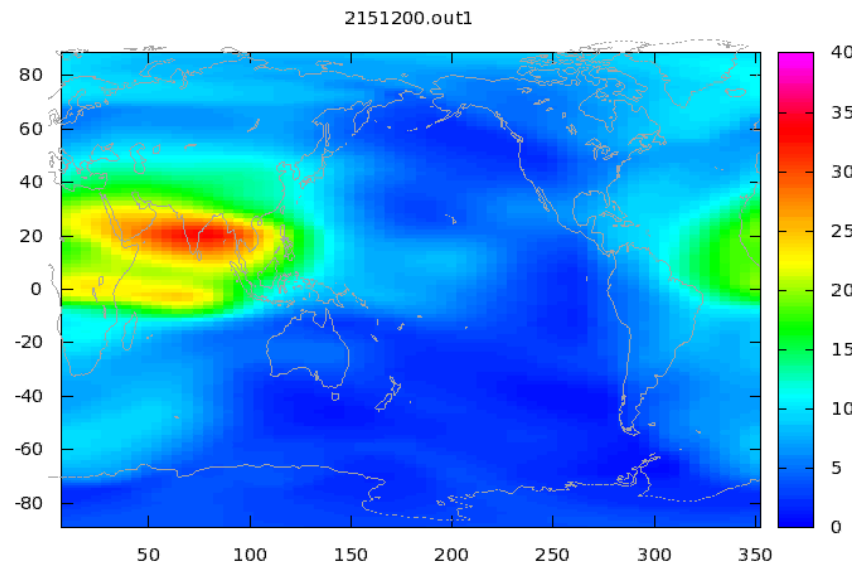


- Data Assimilated Exactly as They Are Measured
 - Bottomside N_e Profiles from Digisondes (80)
 - Slant TEC from more than 1000 Ground GPS Receivers
 - N_e Along Satellite Tracks (4 DMSP satellites)
 - Integrated UV Emissions (LORAAS, SSULI, SSUSI)
 - Occultation Data (CHAMP, IOX, SAC-C, COSMIC)



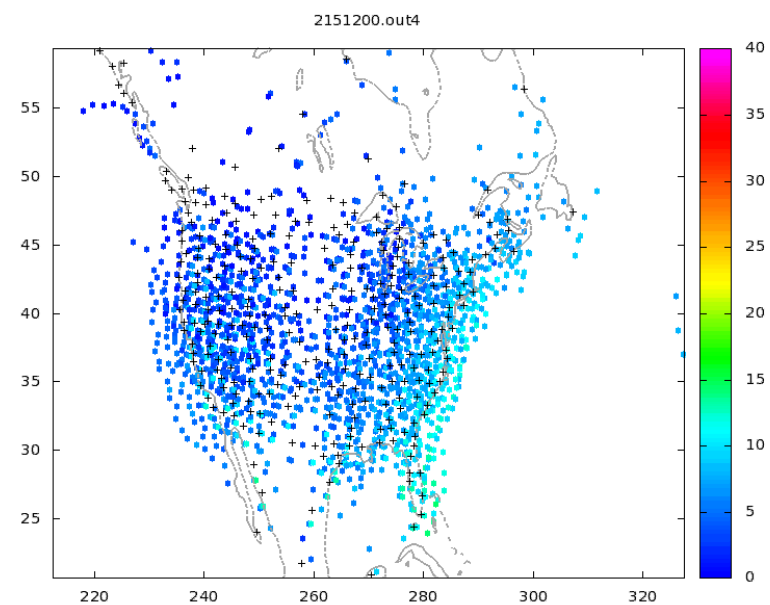
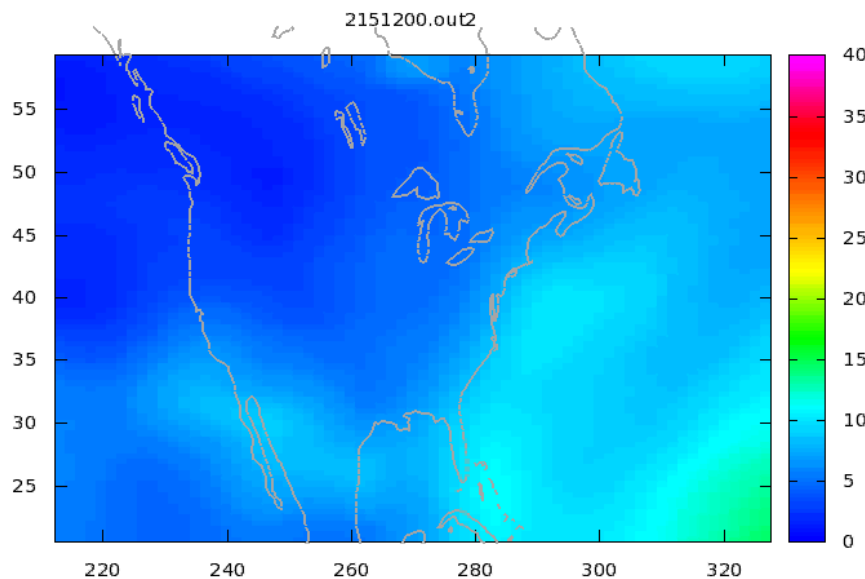
GAIM-GM global Run

- ▶ 357 global TEC stations (IGS network) used in real-time at USU Space Weather Center
- ▶ 10,000 measurements assimilated every 15-min

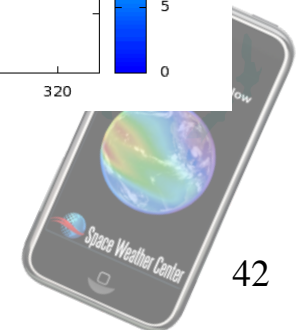


GAIM-GM regional (High Resolution) Run:

- ▶ 424 USTEC stations (CORS network) used in real-time at USU Space Weather Center
- ▶ 10,000 measurements assimilated every 15-min

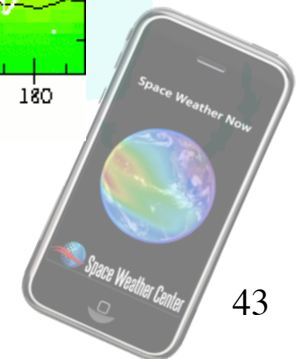
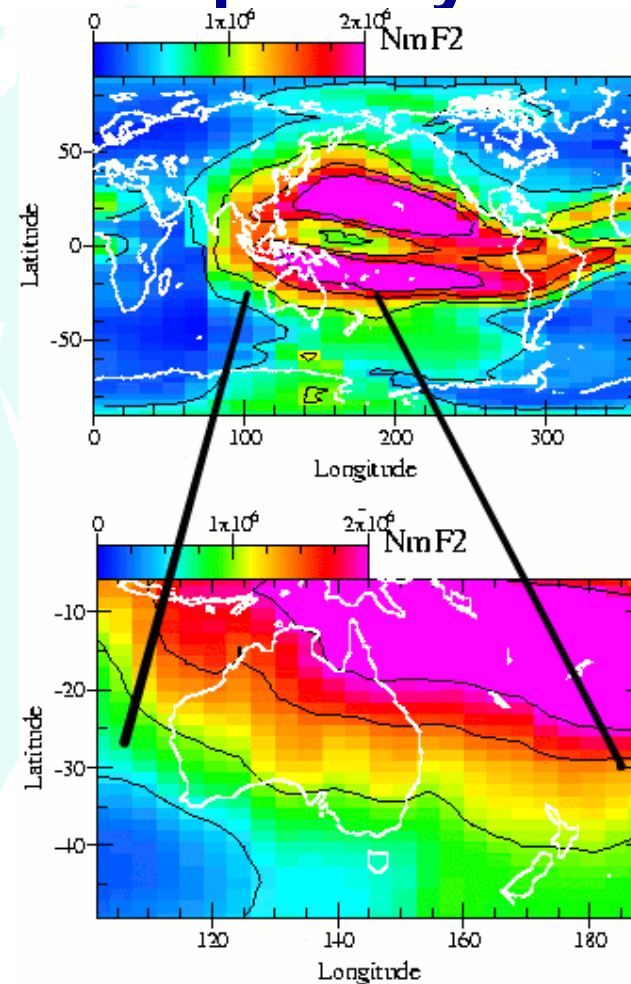


"Bringing The Pieces Together"



GAIM-GM Nested Grid Capability

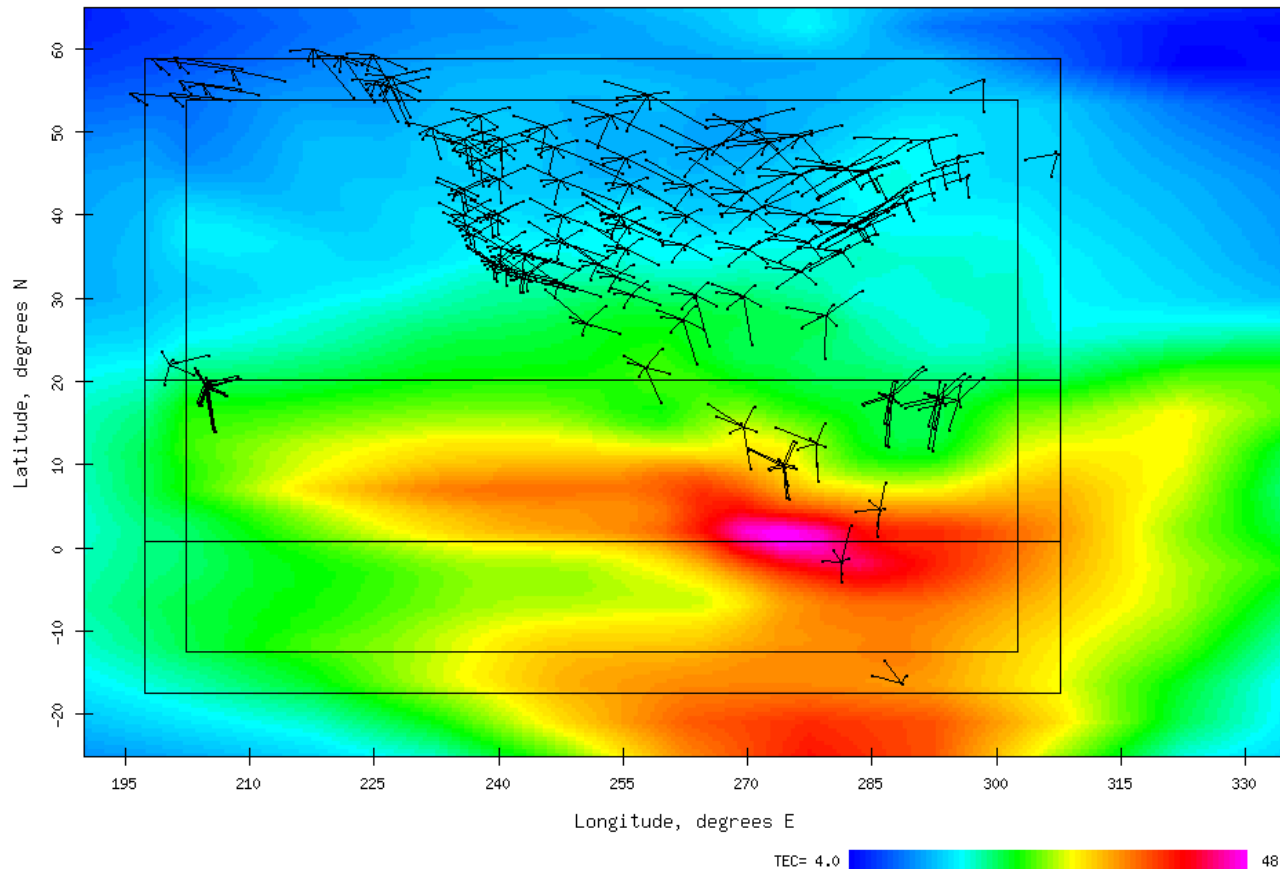
- **Improved Spatial Resolution**
 - 1° Latitude (variable)
 - 3.75° Longitude (variable)
- **Usefulness Depends on Data**
- **Capability Since 2004 in GAIM-GM Operational Model**
- **In 2004 Run - 11 ionosondes, 15 GPS in Nested Grid Region**
- **Captures Edge of Anomaly**



GAIM Requirements for Corrections

- To calculate corrections for GPS in North America, two overlapping higher-resolution regional grids are included
- Grid coverage is shown below, with an example of the resultant GAIM ionosphere showing ingested data sites

Merged VTEC gmF53 2010/283 2000 UT



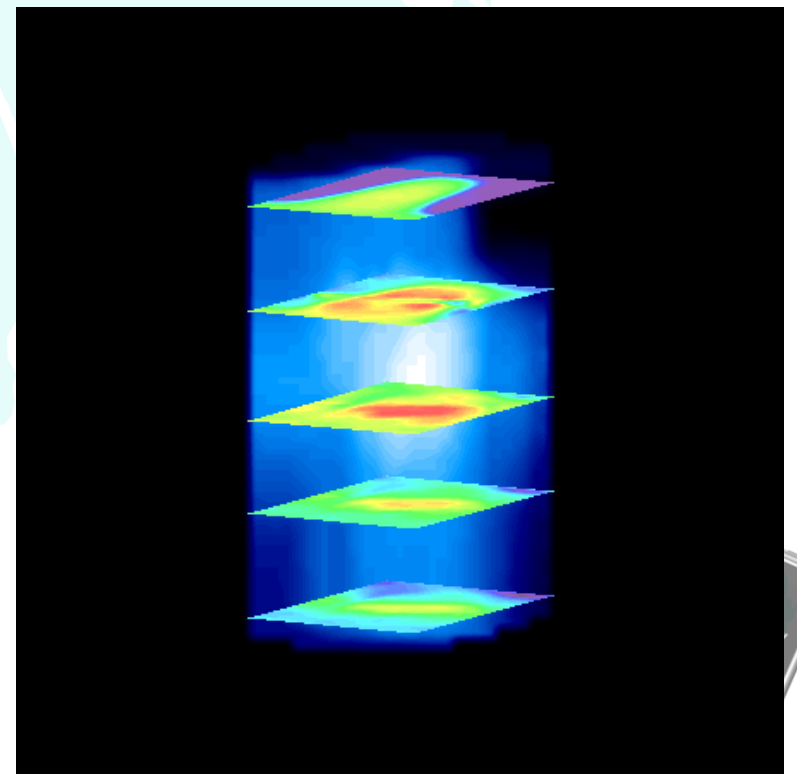
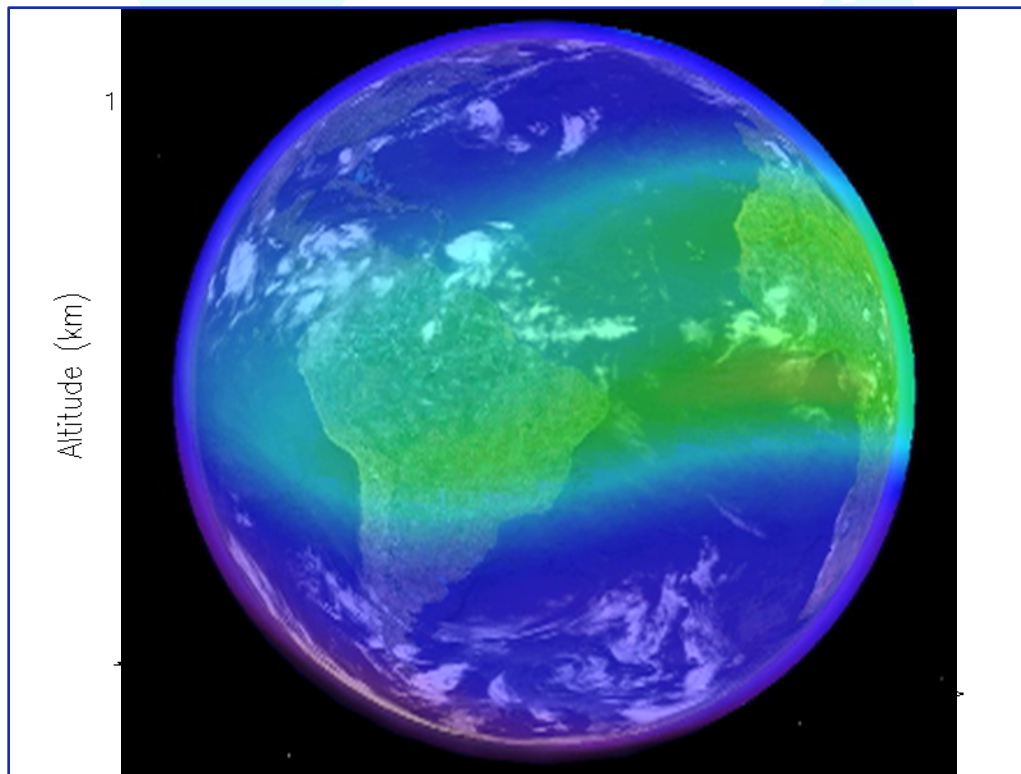
W. Ker

3



44

2008: CAPS 3D [e] real-time densities' visualization HF ray-trace applications (legacy capability)

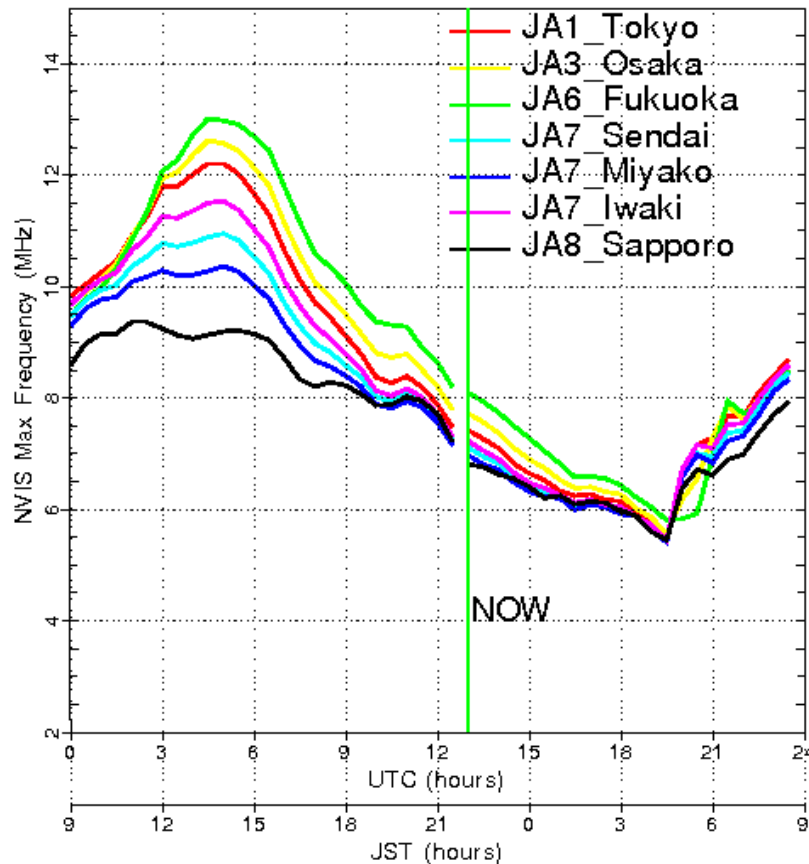


2011: NVIS for Japan

◆ SWC HF communications for Japan emergencies

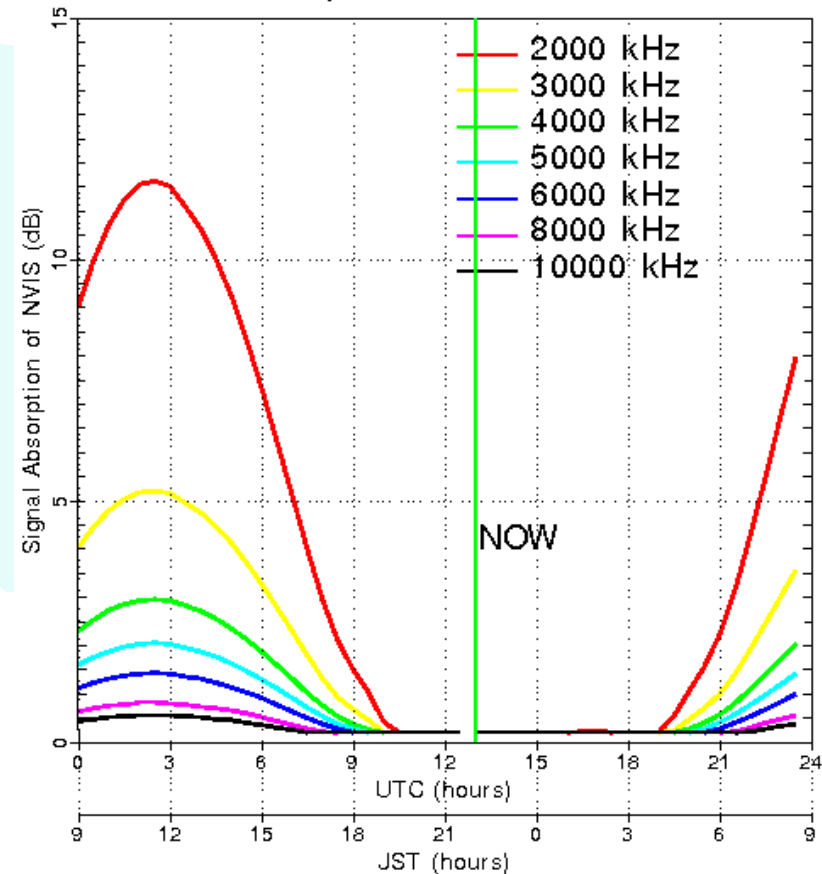
Maximum Frequency (MHz) for
Near Vertical Incidence Skywave

USU Space Weather Center



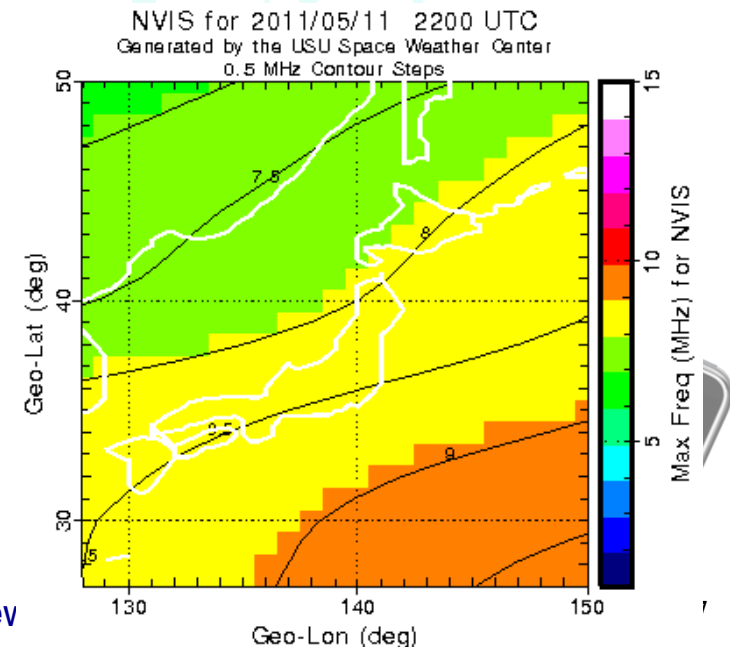
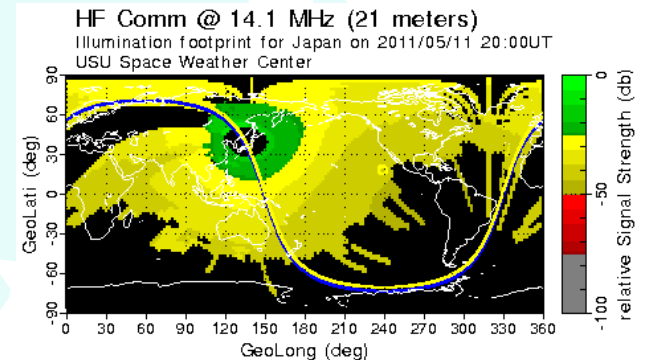
Signal Strength Absorption of
NVIS HF Communication

USU Space Weather Center

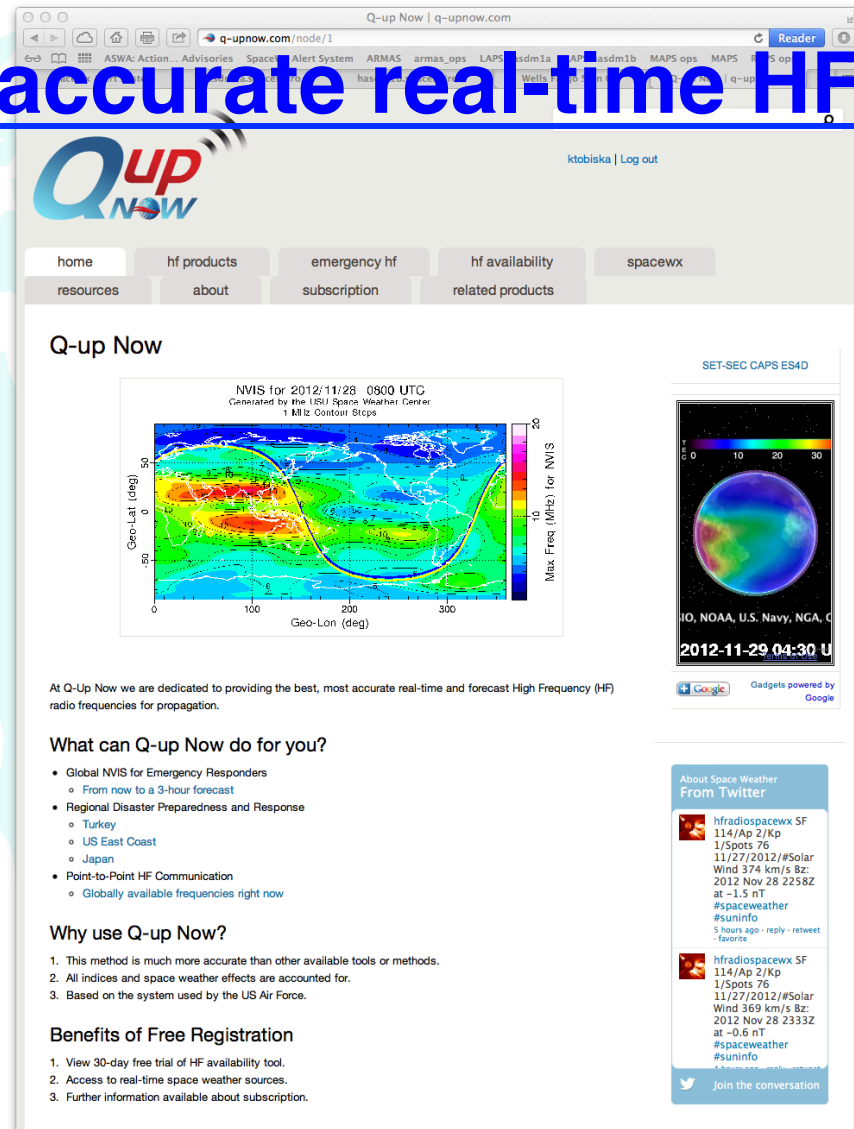


HF product – communications aid: disaster preparedness

- High Frequency (HF) availability to transmit over nearby mountains
- 3-hour forecast of frequencies
- Recommendation of available frequencies to global operators
- Available HF frequencies for Emergency Responders



Corporate & Hams: accurate real-time HF

Q-up Now | q-upnow.com

ktobiska | Log out

home hf products emergency hf hf availability spacewx
resources about subscription related products

Q-up Now

SET-SEC CAPS ES4D

NVIS for 2012/11/28 0800 UTC
Generated by the US Space Weather Center
1 Mhz Contour Steps

Geo-Lat (deg) 50 0 -50
Geo-Lon (deg) 0 100 200 300
Max Freq (MHz) for NVIS 8 6 4 2

At Q-up Now we are dedicated to providing the best, most accurate real-time and forecast High Frequency (HF) radio frequencies for propagation.

What can Q-up Now do for you?

- Global NVIS for Emergency Responders
 - From now to a 3-hour forecast
- Regional Disaster Preparedness and Response
 - Turkey
 - US East Coast
 - Japan
- Point-to-Point HF Communication
 - Globally available frequencies right now

Why use Q-up Now?

- This method is much more accurate than other available tools or methods.
- All indices and space weather effects are accounted for.
- Based on the system used by the US Air Force.

Benefits of Free Registration

- View 30-day free trial of HF availability tool.
- Access to real-time space weather sources.
- Further information available about subscription.

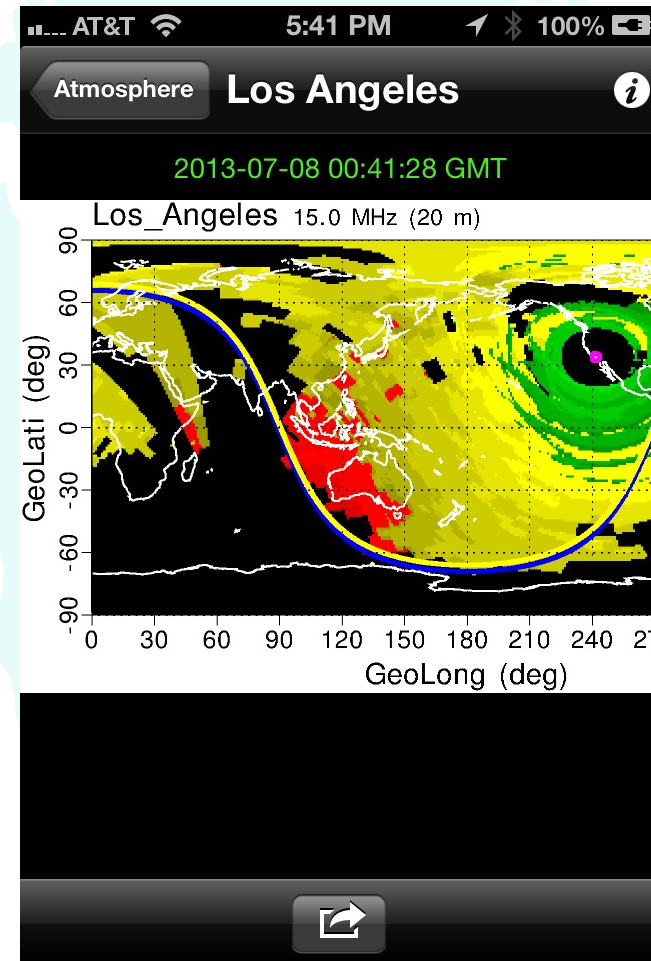
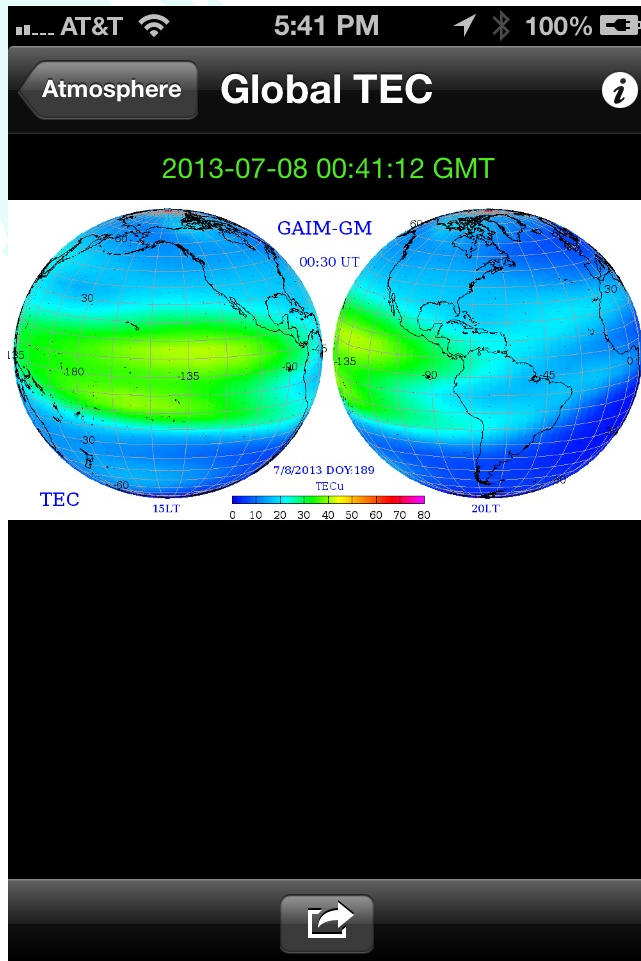
About Space Weather From Twitter

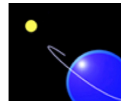
hfradiospacewx SF
11/4/Ap 2/Kp
1/Spots 76
11/27/2012/#Solar
Wind 374 km/s Bz:
2012 Nov 28 2258Z
at -1.5 nT
#spaceweather
#suninfo
5 hours ago · reply · retweet
favorite

hfradiospacewx SF
11/4/Ap 2/Kp
1/Spots 76
11/27/2012/#Solar
Wind 369 km/s Bz:
2012 Nov 28 2333Z
at -0.6 nT
#spaceweather
#suninfo
A minute ago · reply · retweet
favorite

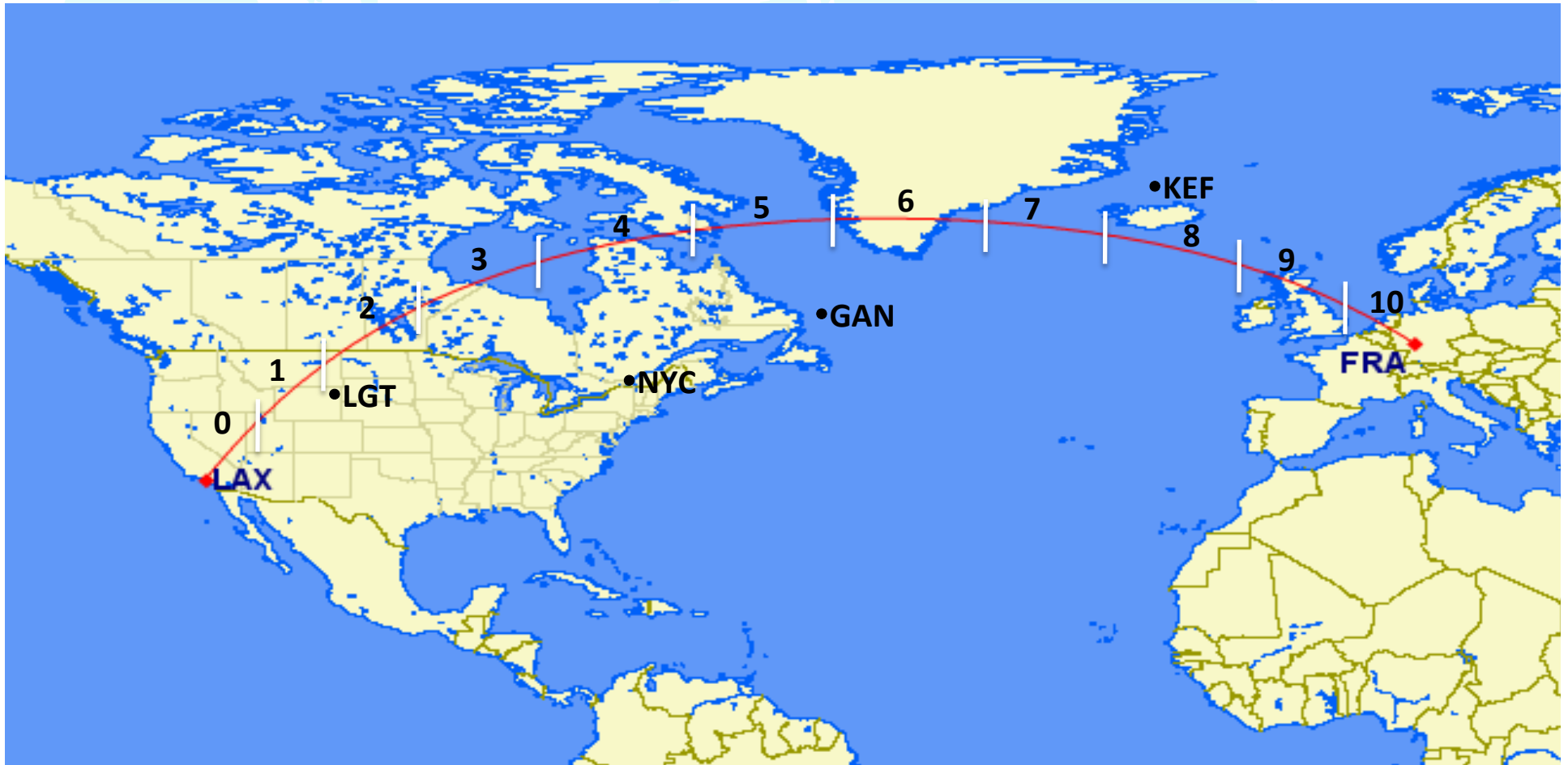
Join the conversation

Global ionosphere and HF solutions via app





2012: Air traffic control



Aviation: Air traffic control

Flight Plan Communications

Real-time flight plan communications has
been tested by 3 major airlines

4 strong station-frequencies

01/20/2012 01:00UTC	NEW_YORK_A_05598	NEW_YORK_E_06628	GANDER_D_04675	GANDER_A_05598
01/20/2012 02:00UTC	NEW_YORK_A_05598	NEW_YORK_A_03000	NEW_YORK_E_06628	NEW_YORK_A_13306
01/20/2012 03:00UTC	NEW_YORK_A_03000	NEW_YORK_A_05598	NEW_YORK_A_08906	GANDER_D_04675
01/20/2012 04:00UTC	NEW_YORK_A_03000	GANDER_F_03476	NEW_YORK_A_05598	GANDER_A_03016
01/20/2012 05:00UTC	NEW_YORK_A_03000	GANDER_A_03016	GANDER_F_03476	GANDER_D_04675
01/20/2012 06:00UTC	GANDER_A_05598	ICELAND_D_04675	GANDER_A_03016	GANDER_F_03476
01/20/2012 07:00UTC	ICELAND_B_02899	SHANWICK_F_03476	SHANWICK_A_03016	SHANWICK_D_04675
01/20/2012 08:00UTC	ICELAND_B_02899	ICELAND_D_04675	SHANWICK_A_03016	SHANWICK_F_03476
01/20/2012 09:00UTC	SHANWICK_F_03476	SHANWICK_D_04675	SHANWICK_A_03016	ICELAND_D_04675
01/20/2012 10:00UTC	SHANWICK_A_05598	SHANWICK_F_06622	SHANWICK_A_08906	SANTA_MARIA_A_13306

Time of Calculation: 01/20/2012 21:00UTC

2012	1	20	1	0	-118.20	34.00	-88.	-88.	-90.	-90.
2012	1	20	2	0	-111.00	41.50	-86.	-87.	-88.	-88.
2012	1	20	3	0	-100.00	46.80	-82.	-83.	-84.	-85.
2012	1	20	4	0	-86.00	51.10	-79.	-83.	-83.	-84.
2012	1	20	5	0	-72.40	55.10	-78.	-79.	-79.	-81.
2012	1	20	6	0	-47.70	61.10	-79.	-79.	-80.	-80.
2012	1	20	7	0	-21.80	64.00	-74.	-78.	-79.	-80.
2012	1	20	8	0	-6.90	62.00	-75.	-79.	-79.	-79.
2012	1	20	9	0	-0.60	51.30	-75.	-75.	-78.	-84.
2012	1	20	10	0	12.50	41.70	-81.	-84.	-87.	-91.

-- For Another Run --

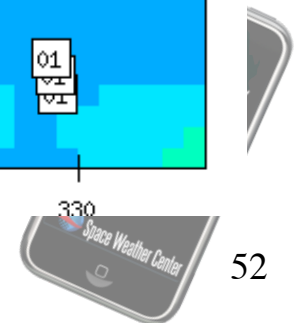
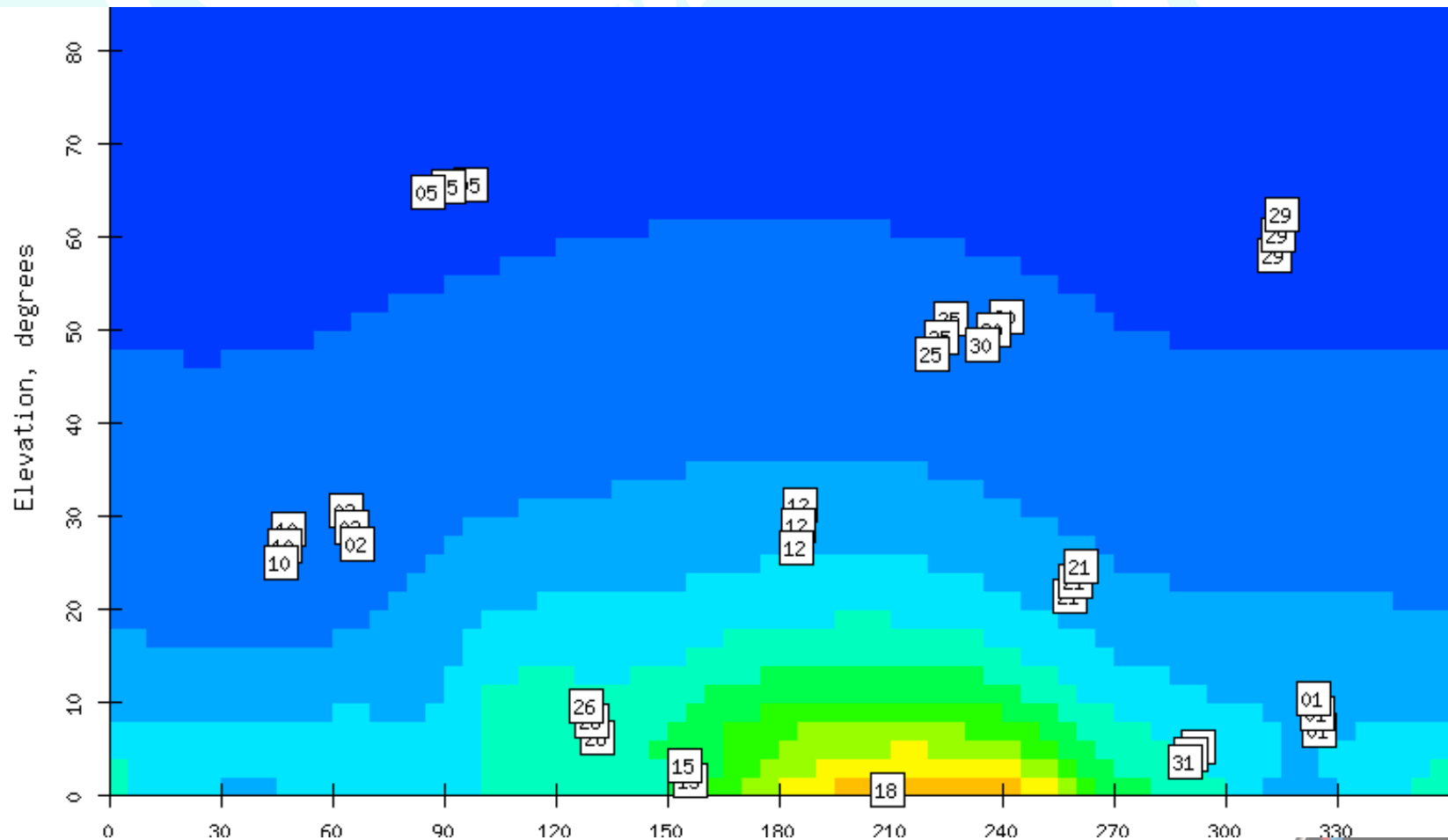


Enter Flight Plan

#Latitude,Longitude,Date (MM/DD/YYYY),Time (24:00)
 34.0,-118.2,01/20/2012,01:00
 41.5,-111.0,01/20/2012,02:00
 46.8,-100.0,01/20/2012,03:00
 51.1,-86.0,01/20/2012,04:00
 55.1,-72.4,01/20/2012,05:00
 61.1,-47.7,01/20/2012,06:00
 64.0,-21.8,01/20/2012,07:00
 62.0,-6.9,01/20/2012,08:00
 51.3,-0.6,01/20/2012,09:00
 41.7,12.5,01/20/2012,10:00

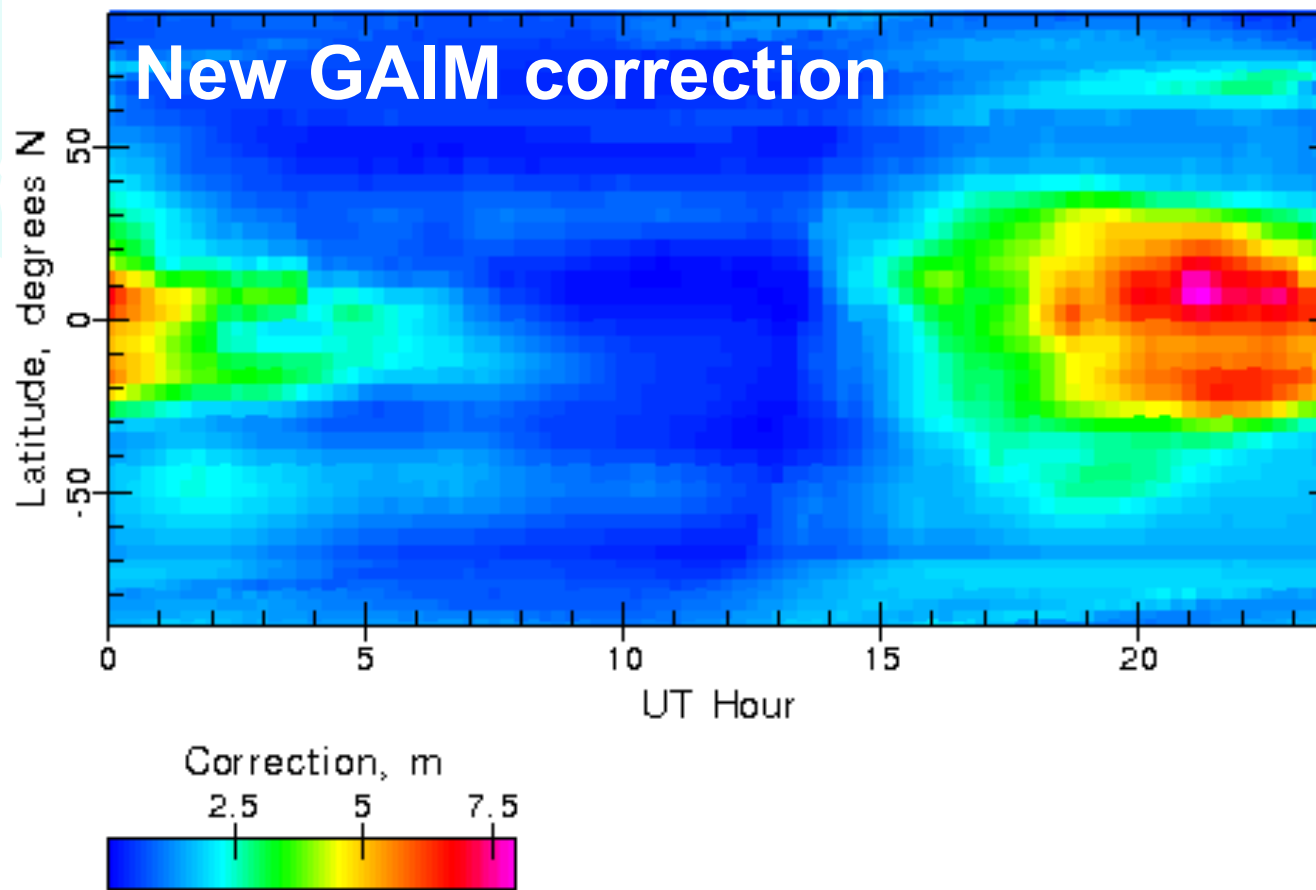
Submit

GPS product – navigation aid: GAIM ionosphere in real-time



SpotOn GPS location: Correction maps

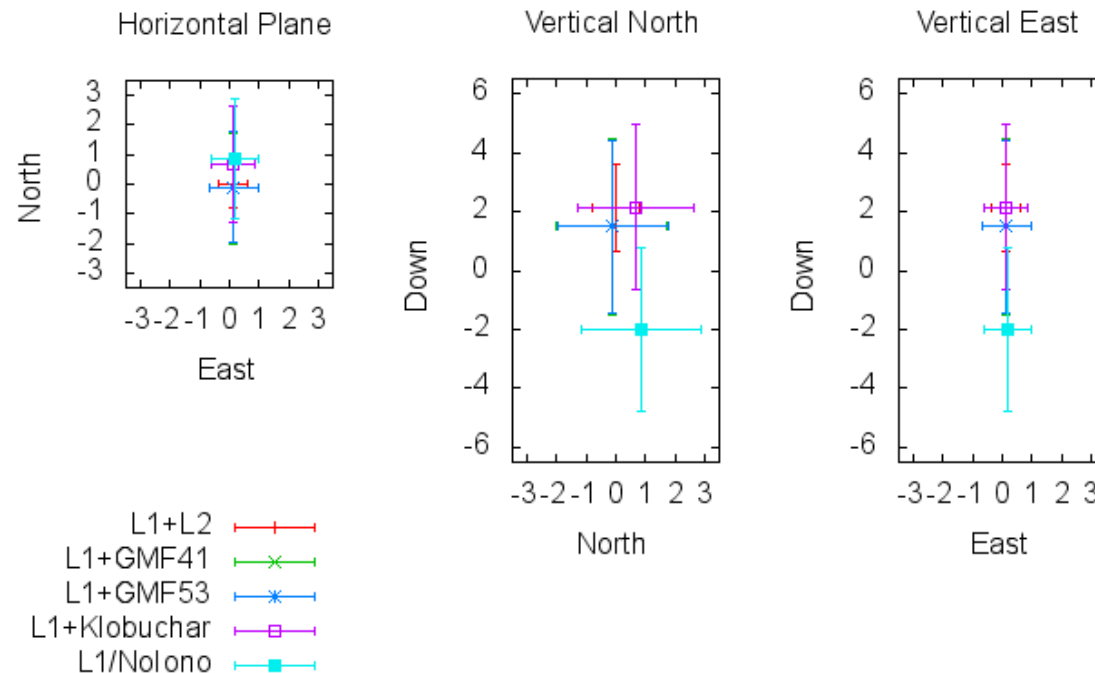
GAIM Corr 2010/284 248.0E Lon



GAIM Correction Example

- Fixes for moderately disturbed day were calculated with Colorado Springs GPS data, 30 second resolution
- Single frequency corrections and dual frequency estimates are compared; the nominal site position is at the origin

AMC2 2010/284



W. Kent Tobis

app



54

SpotOn GPS location: Smart phone 2-m accuracy



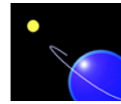
Native iPhone position

January 10, 2012

- 2-meter accuracy demonstrated
- Standing at the center of the hotel drive flower bed (4 meters diameter) in Nashville TN Opryland
- Two red pushpins in SpotOnNow were at app "cold start" and green pushpin is after 45 seconds



SpotOn corrected position



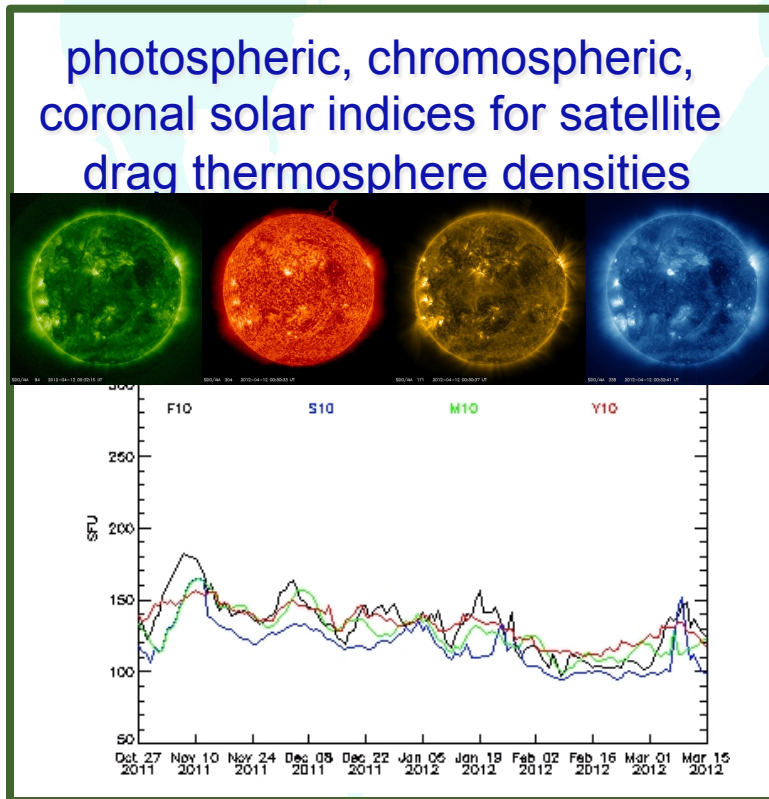
Space Weather Operations – Thermosphere



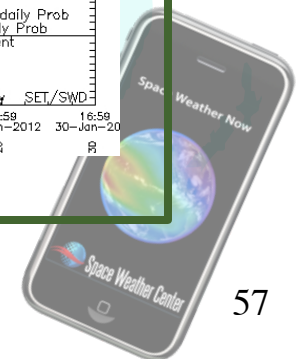
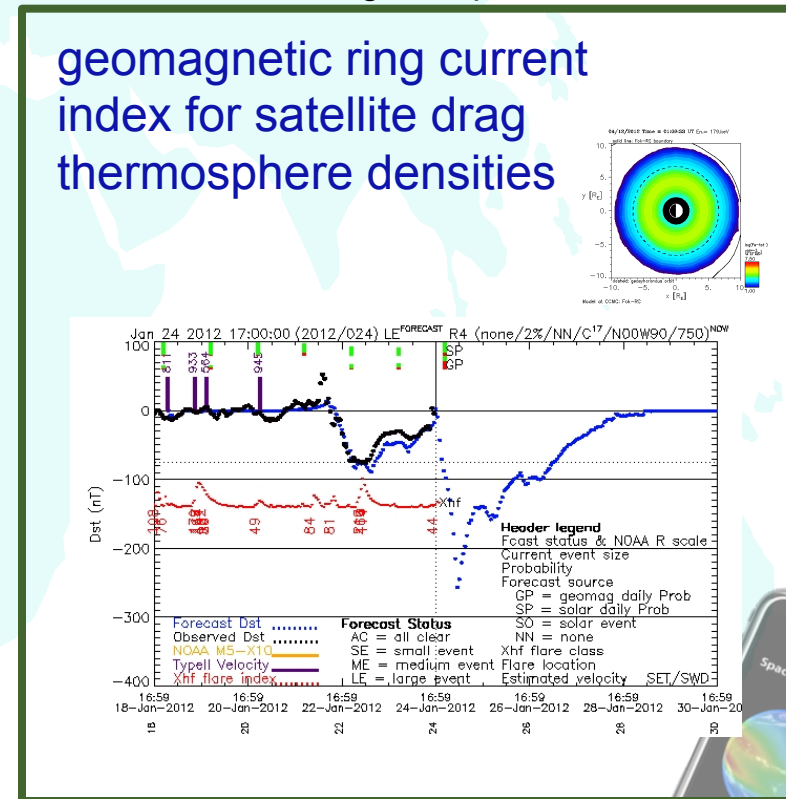
JB2008 Thermosphere Overview – Drivers



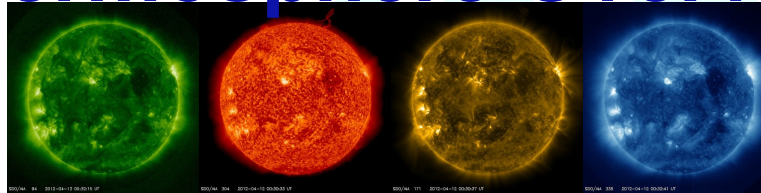
Solar irradiances



Solar wind/magnetosphere



JB2008 Thermosphere Overview – Drivers



Index or proxy	Observing facility	Instrument	Observation time frame	Measurement cadence	Measurement latency	Operational availability
F _{10.7}	Penticton ground observatory	Radio telescope, (S2K)	1947-2013	3 times/day	Up to 24 hours	yes (d)
S _{10.7}	GOES, SDO, TIMED, SOHO	EUVS, EVE, SEE, SEM	1996-2013	15-second	Up to 24 hours	(a)
M _{10.7}	NOAA-16,17,18, SORCE, MetOp	SBUV, SOLSTICE, GOME2	1991-2013	2 times/day	Up to 24 hours	yes (c)
Y _{10.7}	GOES, SDO, TIMED, UARS, SORCE	XRS, EVE, SEE, SOLSTICE (2)	1991-2013	1-minute, 16 times/day	Up to 10 minutes, up to 48 hours	(b)

(a) SOHO/SEM is a NASA research instrument but provides daily irradiances on an operational cadence; GOES 13 EUVS B channel makes measurements in the same bandpass as SOHO SEM.

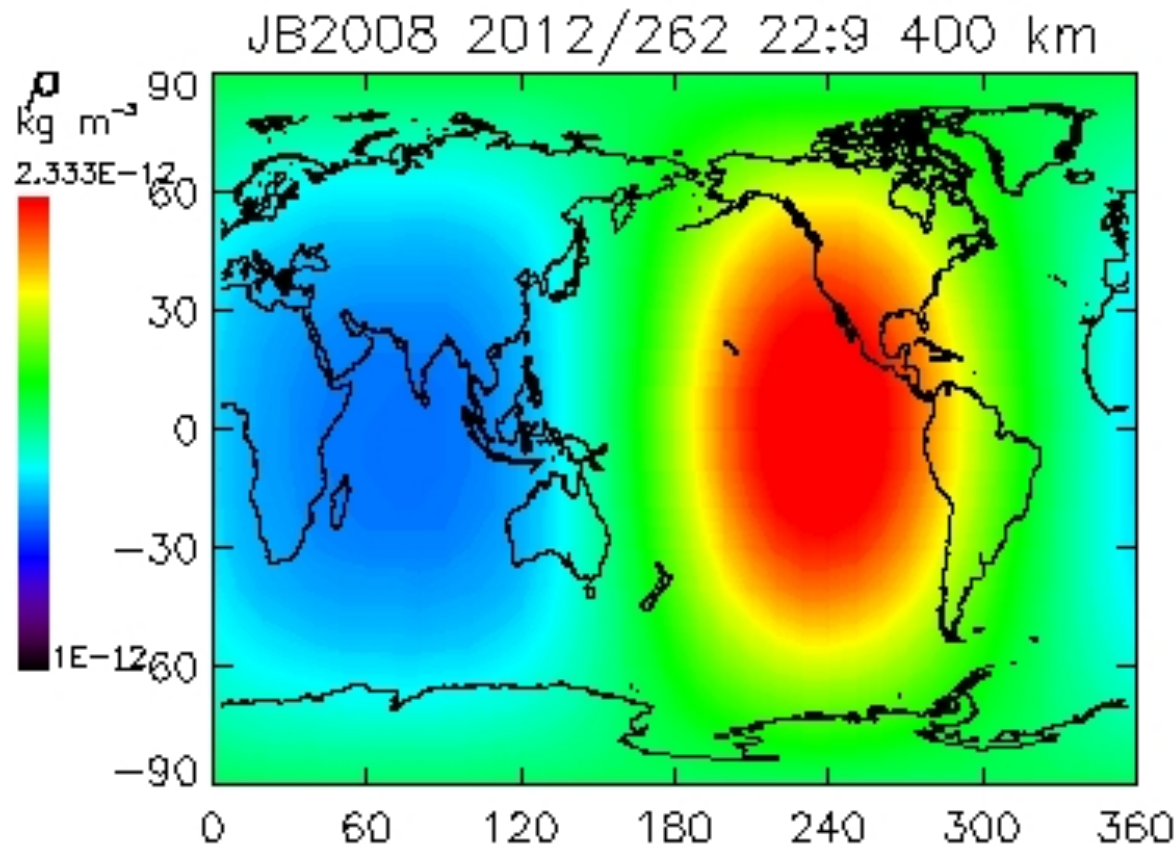
(b) GOES XRS is a NOAA operational instrument whereas TIMED/SEE and SORCE/SOLSTICE are NASA research instruments providing daily irradiances on an operational measurement cadence.

(c) UARS/SOLSTICE stopped in 2005; SORCE/SOLSTICE intends to provide data for several years.

(d) S2K provides E10 modeled surrogate for F10.



JB2008 Thermosphere Overview – Output

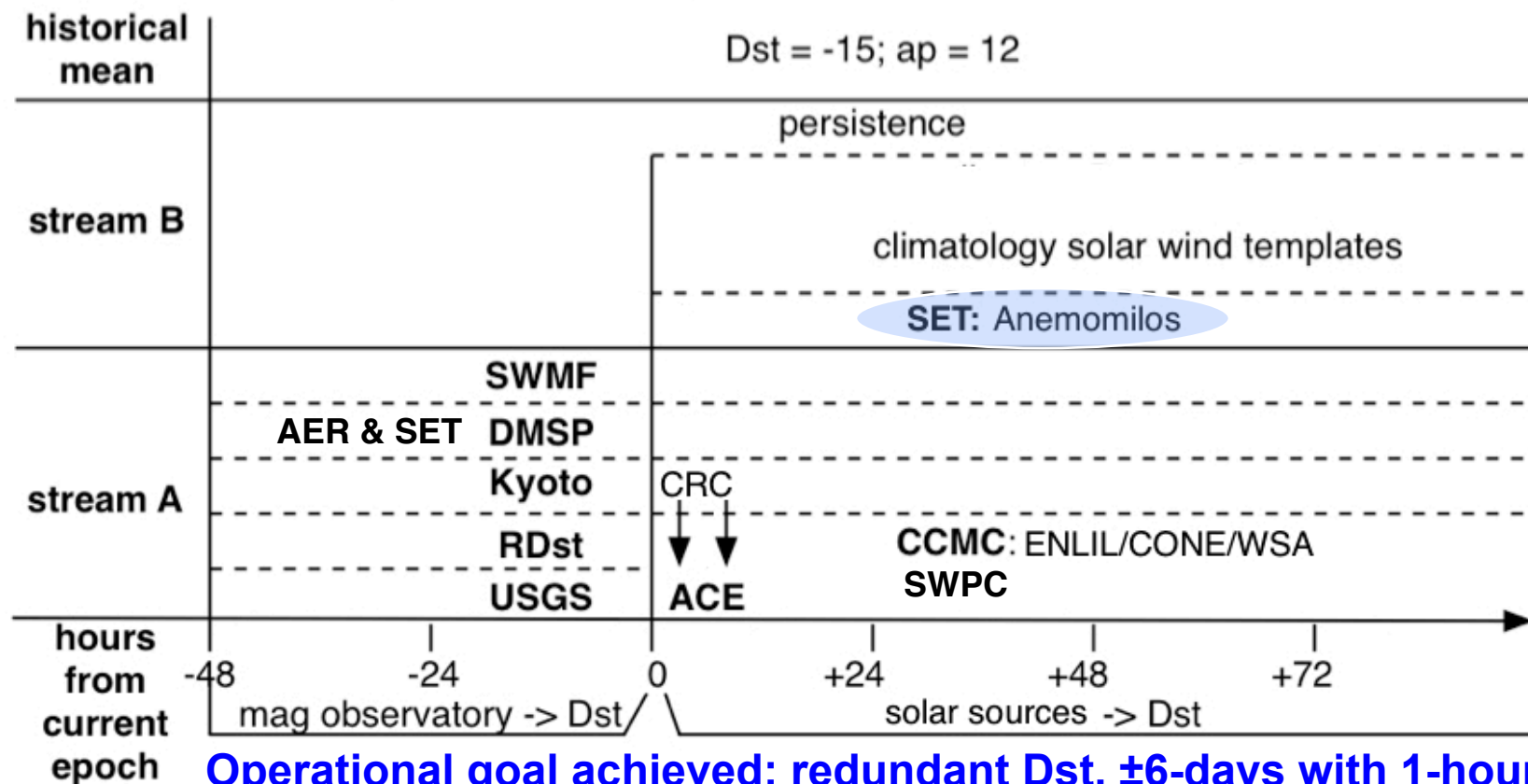


Example of JB2008 operational densities

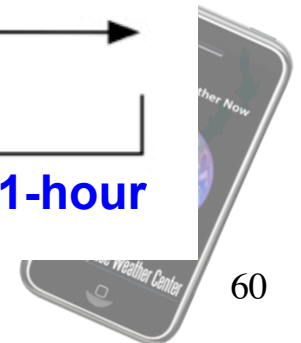


Operational Dst requirement: -48 to +72 hours with 3-hour granularity, 3-hour latency

Hierarchy of definitive, real-time, and forecast Dst redundancy



Operational goal achieved: redundant Dst, ± 6 -days with 1-hour granularity and 1-hour latency



Anemomilos Detail

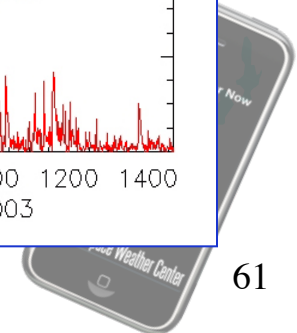
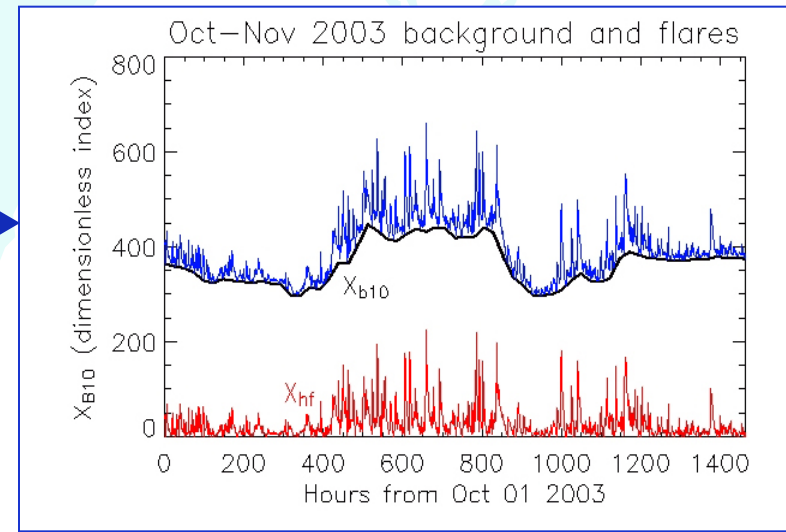
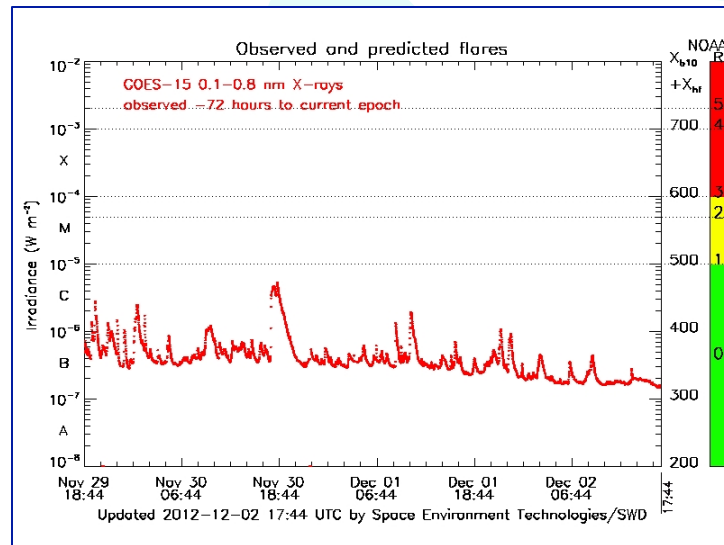
Magnitude

Raw data

- GOES XRS
0.1-0.8nm: remove background, get Xhf

Quantity of ejecta

- Xhf flare index
directly provides flare magnitudes



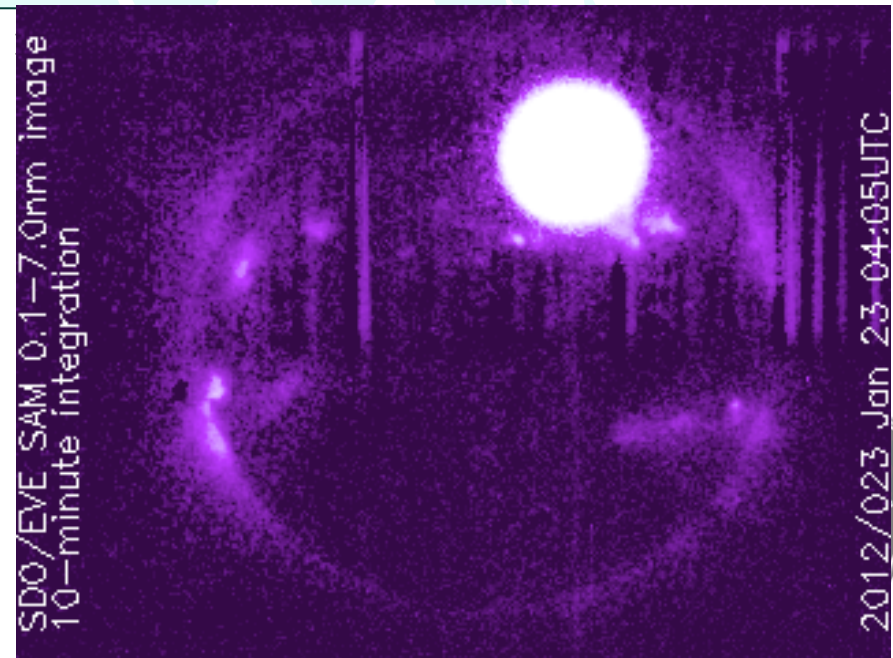
Anemomilos Detail Location

Location of ejecta

- Use flare brightness peak location centroid from **SDO/EVE/SAM**

#YYYYMMDDHHMM	DOY	Julian_Day	Pk_loc
#-----	---	-----	-----
201208111640	224	2456151.19444	S19E17
201208111645	224	2456151.19791	S20E17
201208111650	224	2456151.20139	S21E17
201208111655	224	2456151.20485	S21E17
201208111700	224	2456151.20833	S21E17
201208111705	224	2456151.21179	S21E17
201208111710	224	2456151.21528	S21E17
201208111715	224	2456151.21875	S21E17
201208111720	224	2456151.22221	S21E17
201208111725	224	2456151.22569	S21E17
201208111730	224	2456151.22916	S21E17
201208111735	224	2456151.23264	S22E17

SDO/EVE SAM 0.1-7.0nm image
10-minute integration



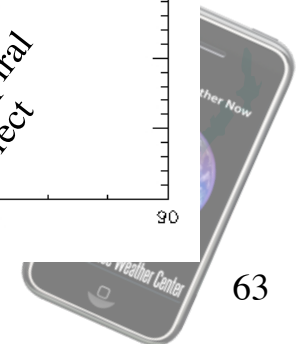
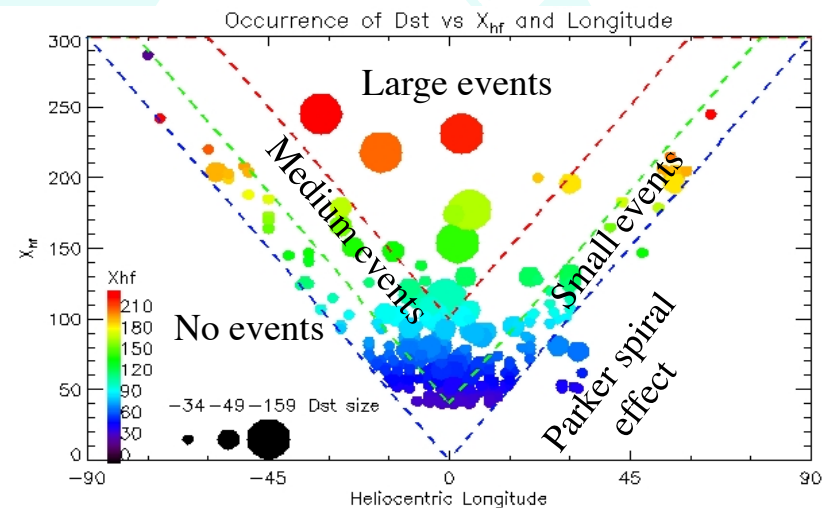
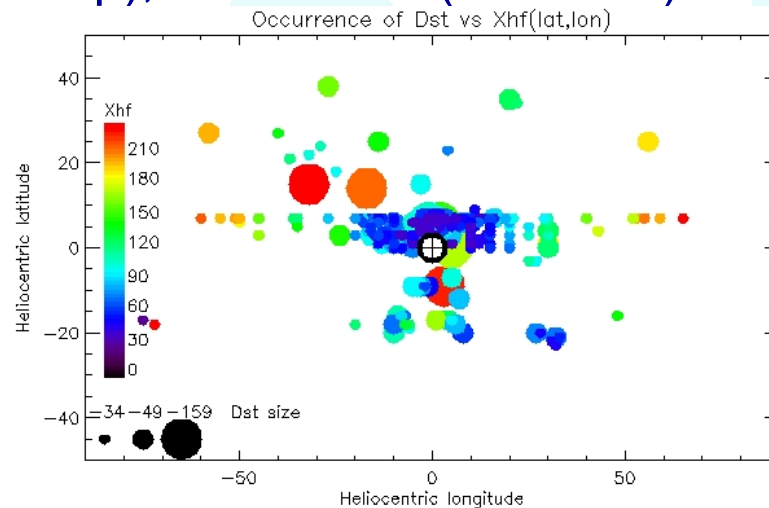
Anemomilos Detail

Geo-effectiveness of location

Occurrence of Dst vs Xhf in solar latitude & longitude (25 months)

- 2001 (Jan-Jul), 2005 (Mar-Sep), 2011-2012 (Dec-Nov)

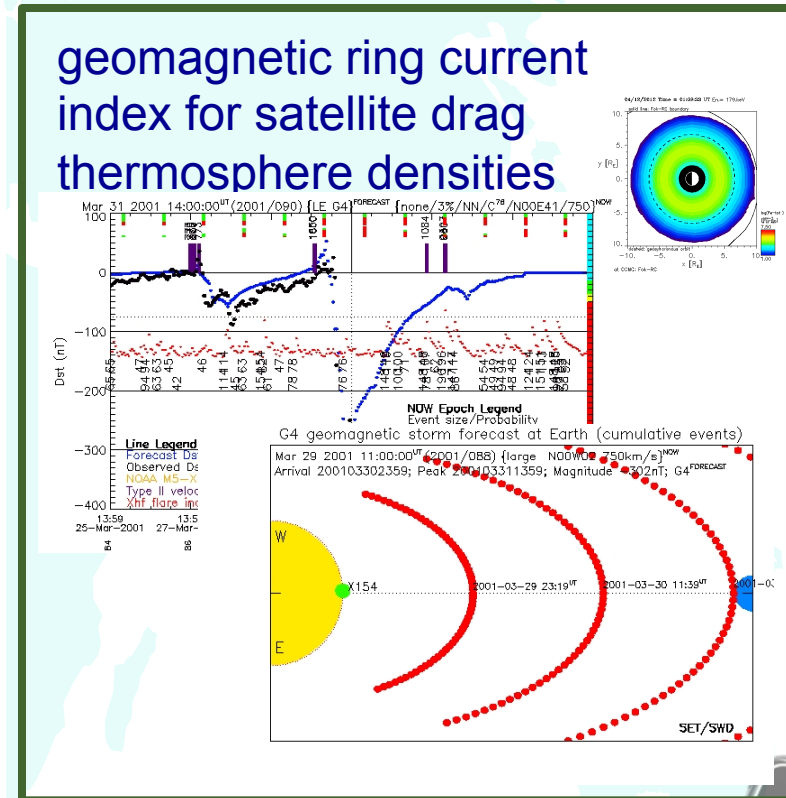
Resulting Dst event size can be sorted by Xhf size and flare longitude/latitude

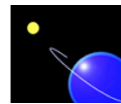


Anemomilos details

Anemomilos

- Greek word for “windmill”
- 6-day forecast of hourly Dst with 1-hour latency
- data-driven deterministic algorithm using 3 solar observables to identify geoeffective events





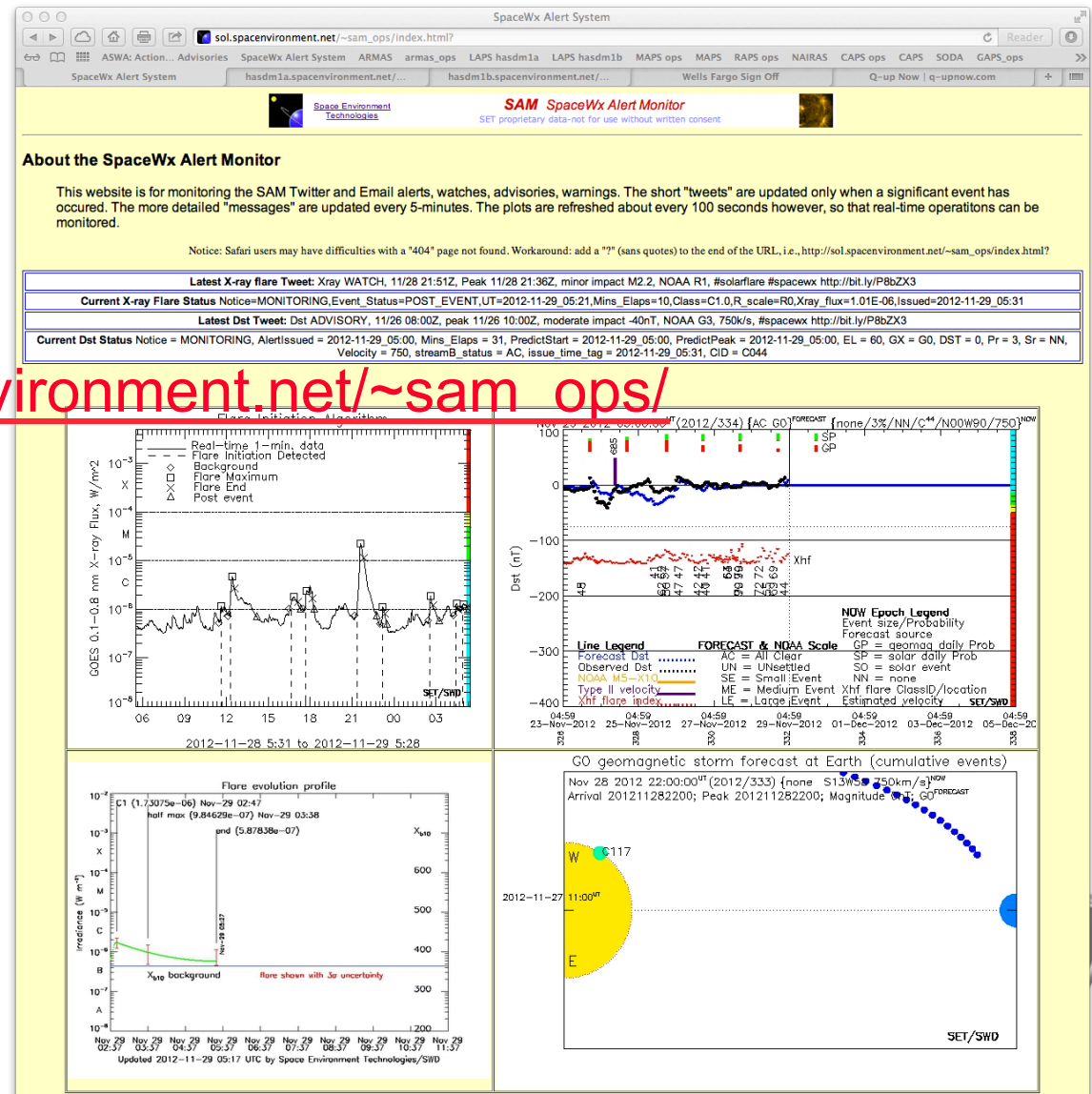
Anemomilos operational forecasts

- Website:**

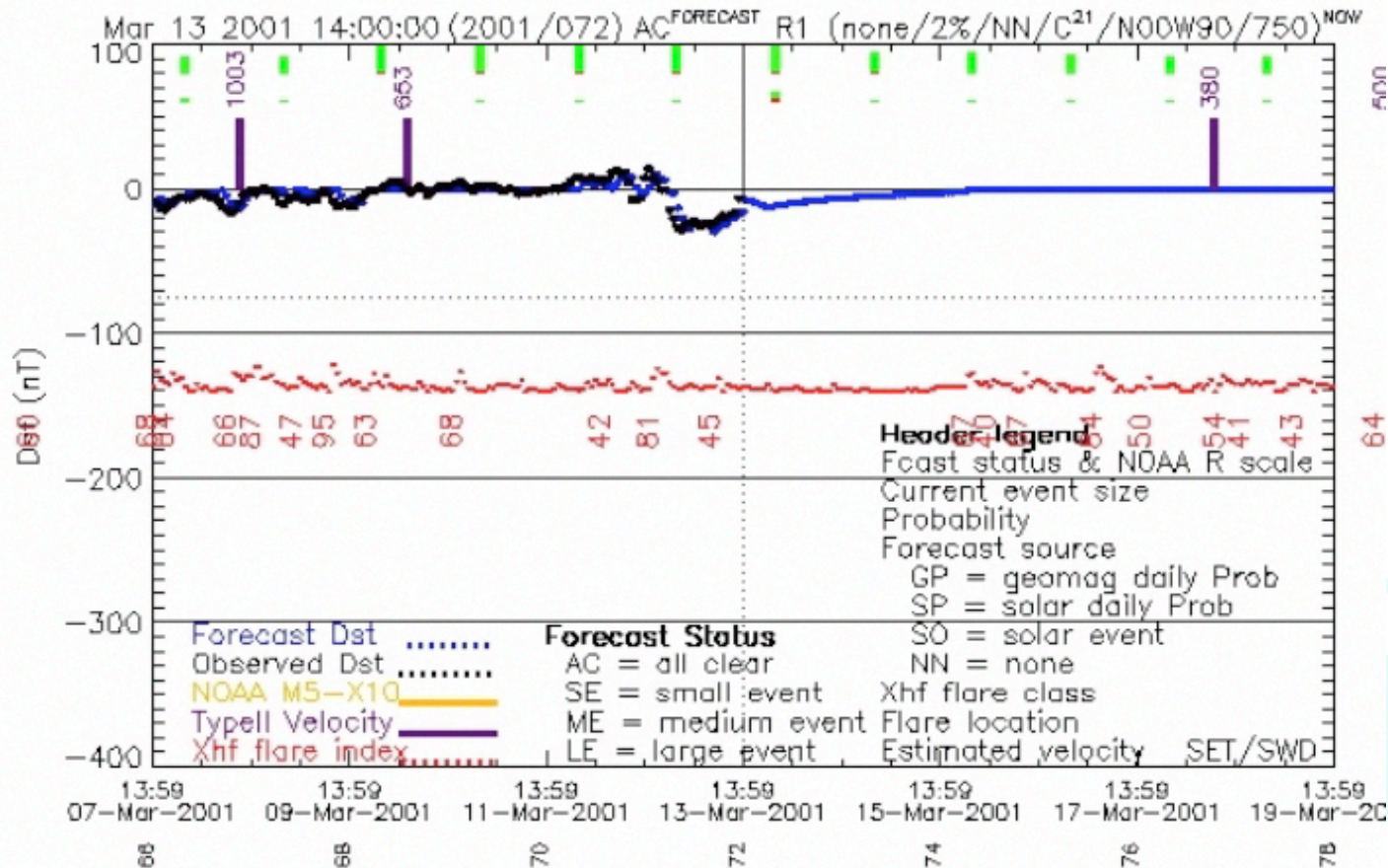
http://sol.spacenvironment.net/~sam_ops/

- Automated Tweets:**
@spacenvironment
reports solar flare
and geomagnetic
storm occurrences

follow **#solarflares**
and **#spacewx**

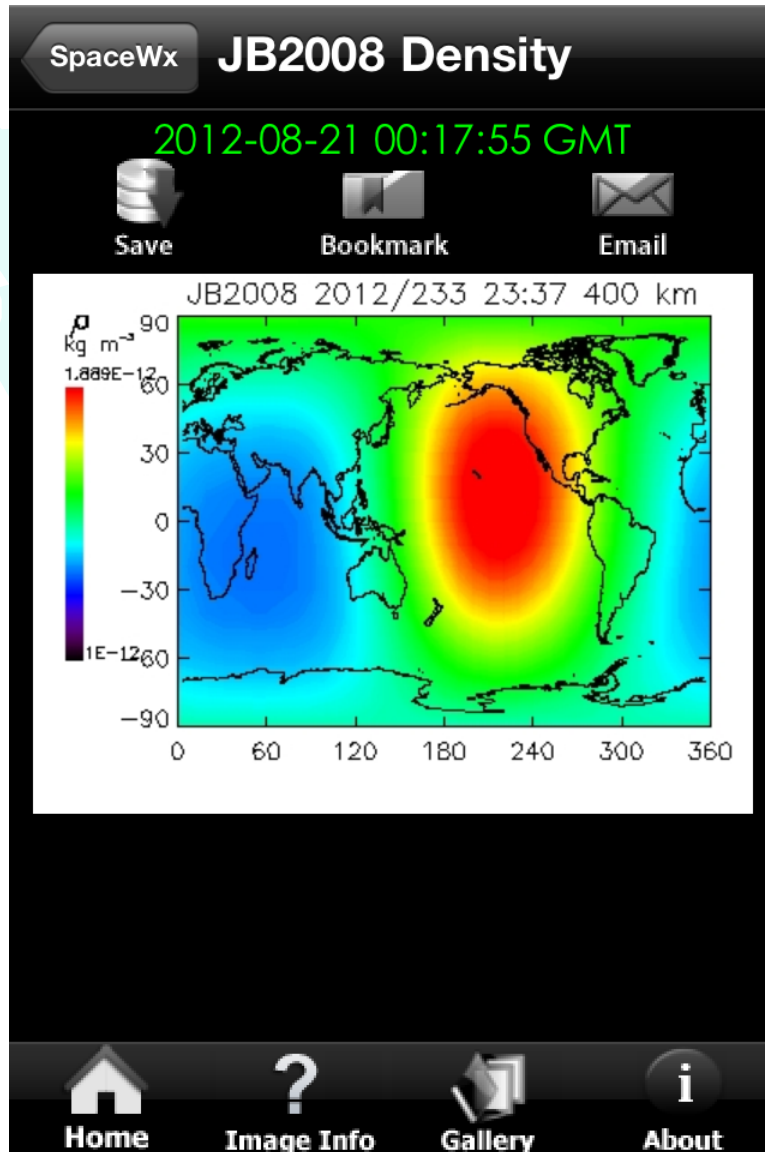


Anemomilos Example



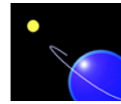
http://youtu.be/snxgoQ_s0o0





Upper Atmospheric Densities in real-time from JB2008 on SpaceWx app



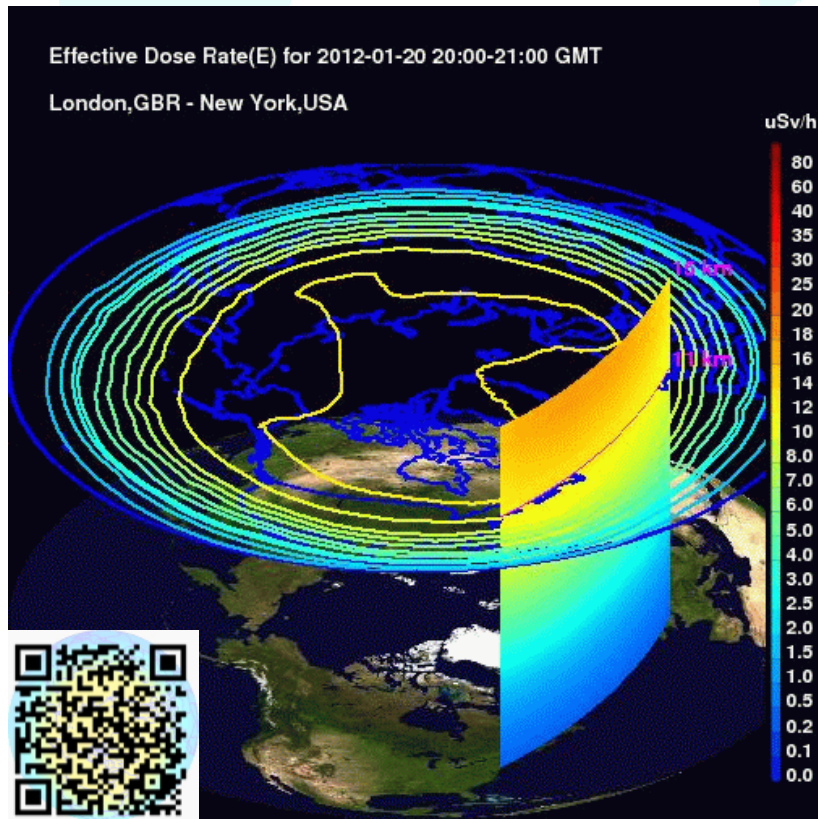


Space Weather Operations – Troposphere



Real-time aviation radiation characterization

NAIRAS

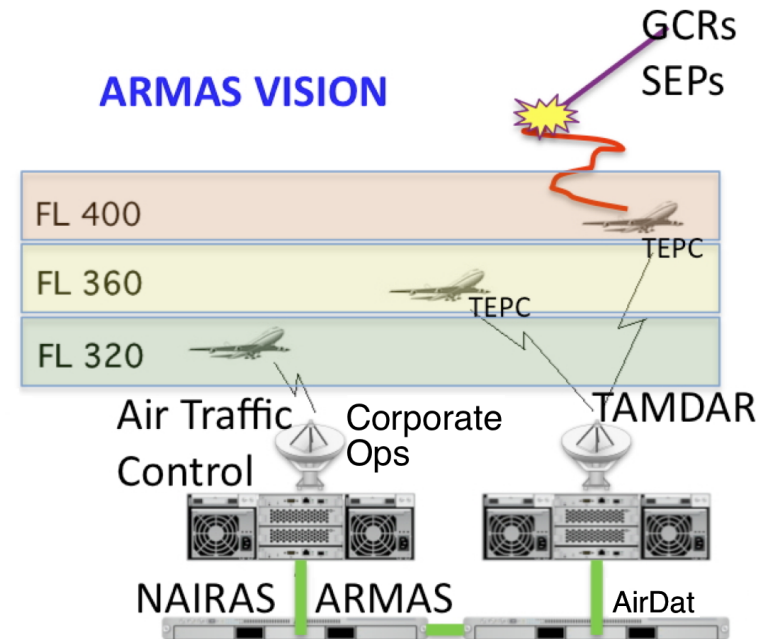


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<http://spaceweather.usu.edu>

ARMAS

ARMAS VISION



<http://spacewx.com>

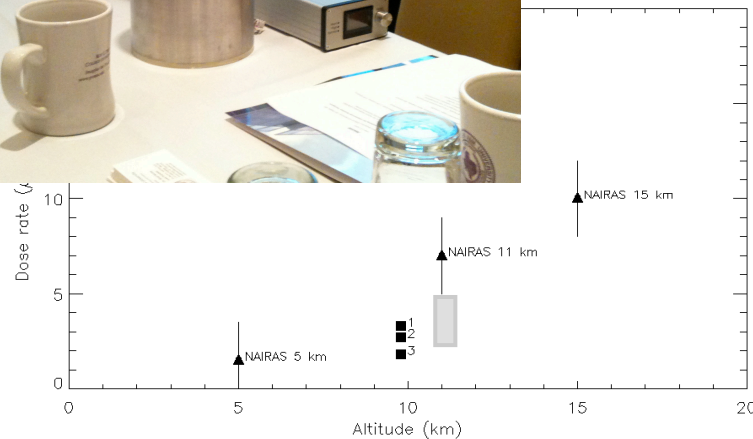
SpaceWx app



ARMAS instrumentation

ARMAS Phase I

- TEPC - 7 flights

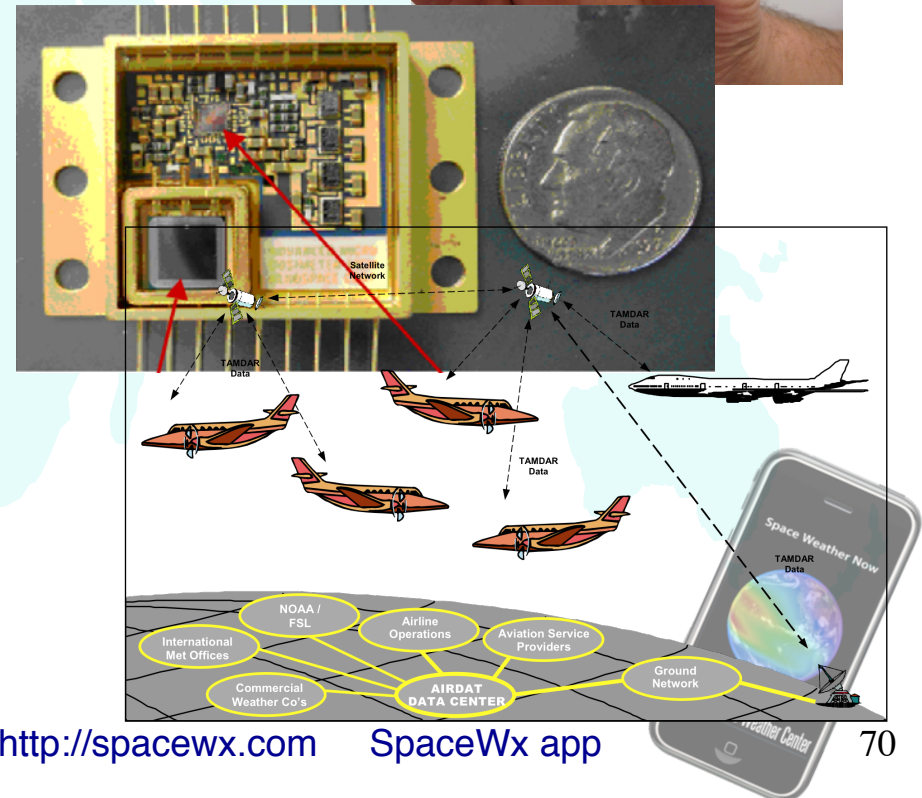
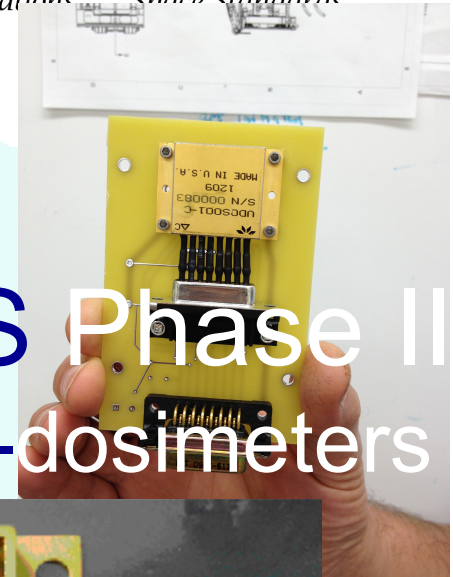


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<http://spaceweather.usu.edu>

ARMAS Phase II

- 2 micro-dosimeters



<http://spacewx.com>

SpaceWx app

ARMAS flight demonstration

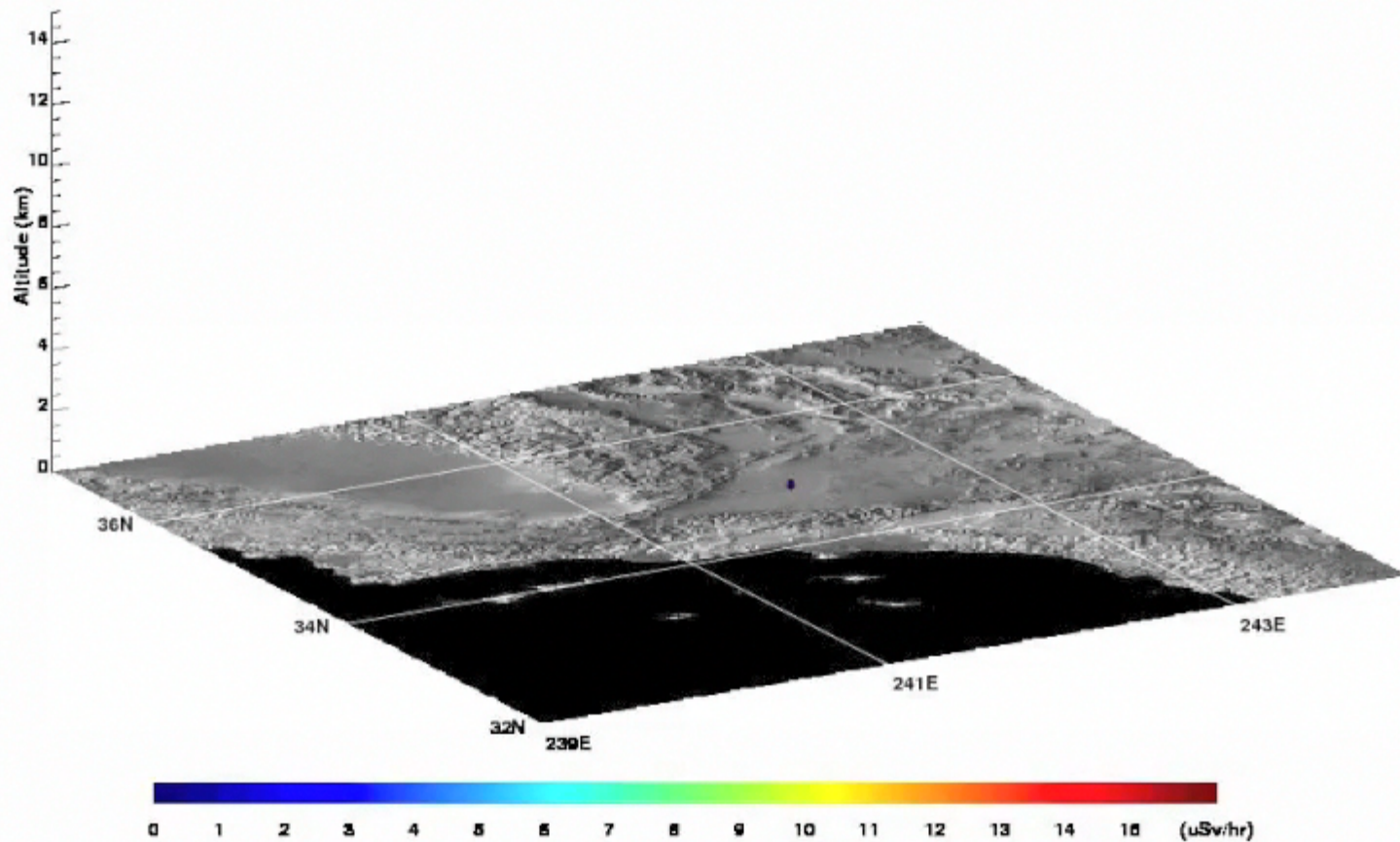
June 17-19 & 27-28, 2013

- ARMAS 1st flights
- demonstrated real-time downlink of dose rate from commercial aircraft altitudes
- Iridium link to ground
- integration into NAIRAS
- distribution to users
- 15-minutes latency

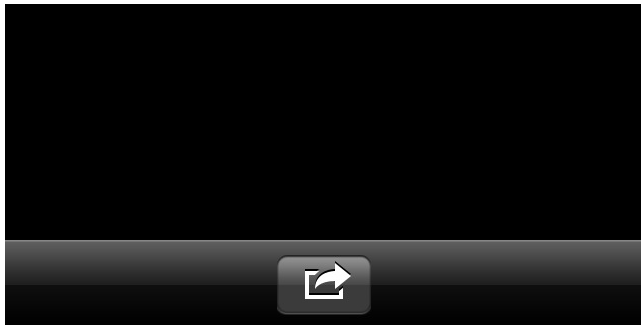
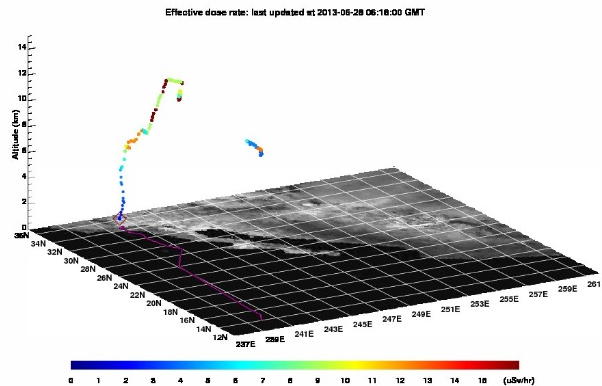
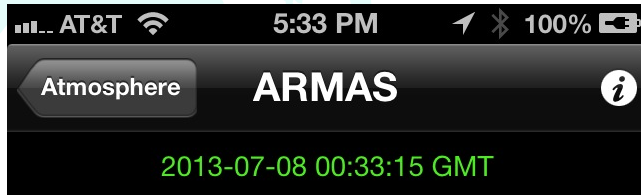


ARMAS flight 6 results

Effective dose rate: last updated at 2013-06-27 22:04:40 GMT



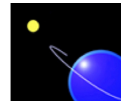
ARMAS flight 6 example



June 27-28, 2013

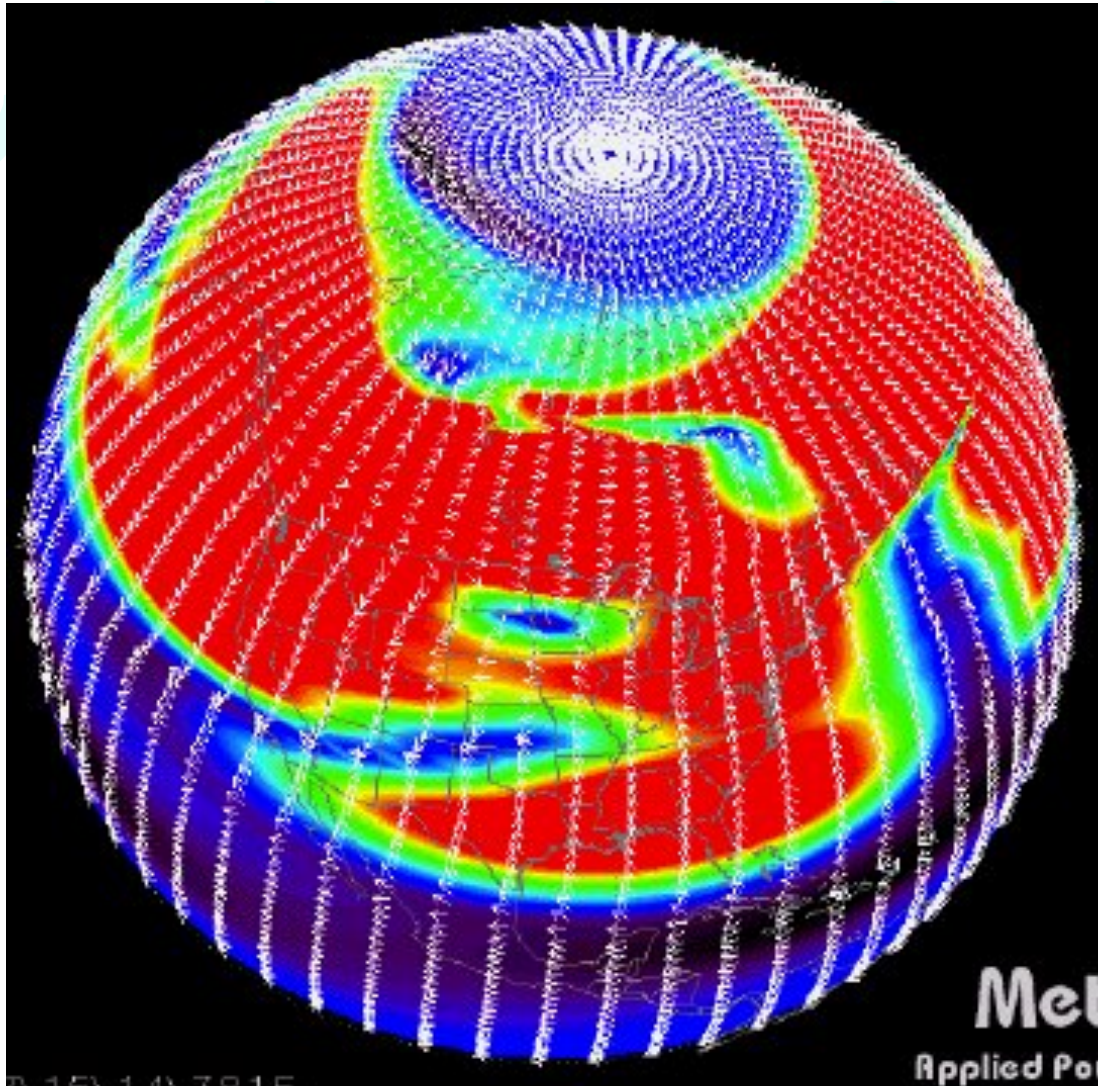
- ARMAS 6th flight
- real-time downlink of dose rate from 42,000 ft.
- Iridium link over Pacific
- integrated into NAIRAS
- distribution to users real-time via *SpaceWx* app





Space Weather Operations – Ground





July 15, 2000: Auroral Currents and GICs

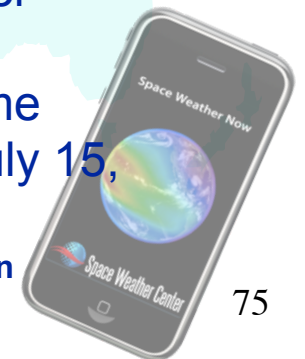
Plot of ground-level
magnetic field
disturbances at time
14:38:15 UT on July 15,
2000

Credit: J. Kappenman
SpaceWx app

W. Kent Tobiska

<http://spaceweather.usu.edu>

<http://spacewx.com>



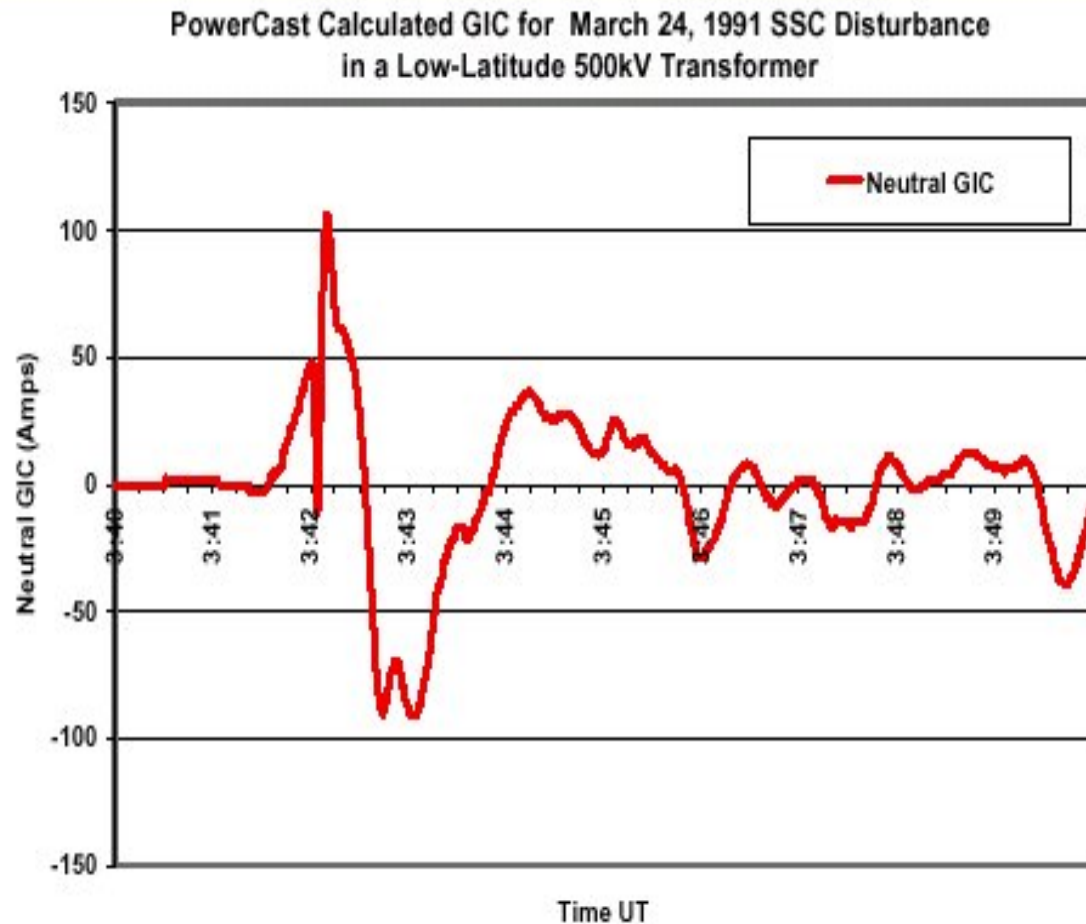
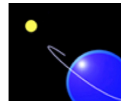


Figure 2 – PowerCast™ Models of a power grid can calculate GIC flows in every transformer for actual and hypothetical storm scenarios. This is an example from a large SSC in March 1991.

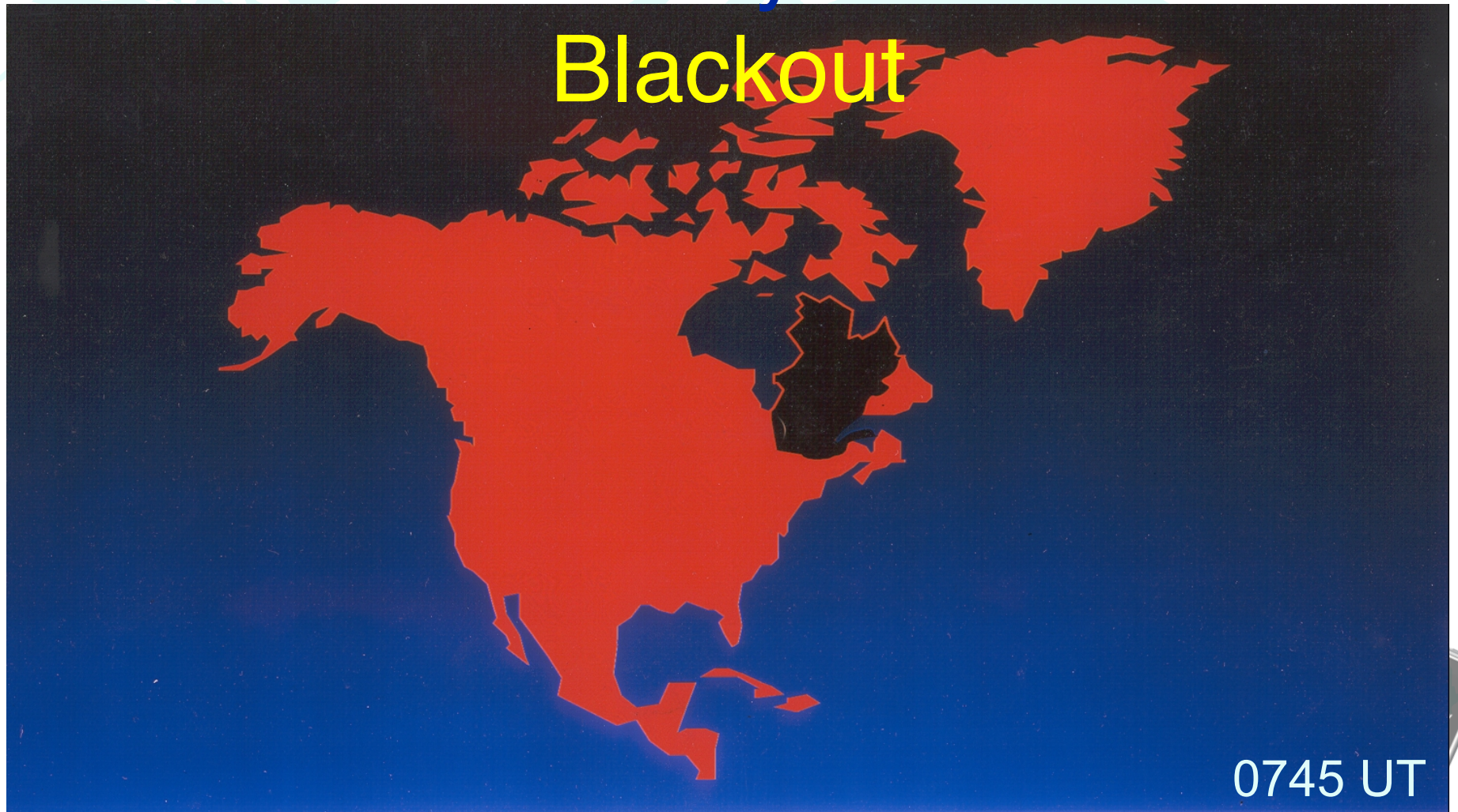
March 1991: Ground- Induced Currents





March 1989: Hydro Quebec

Blackout

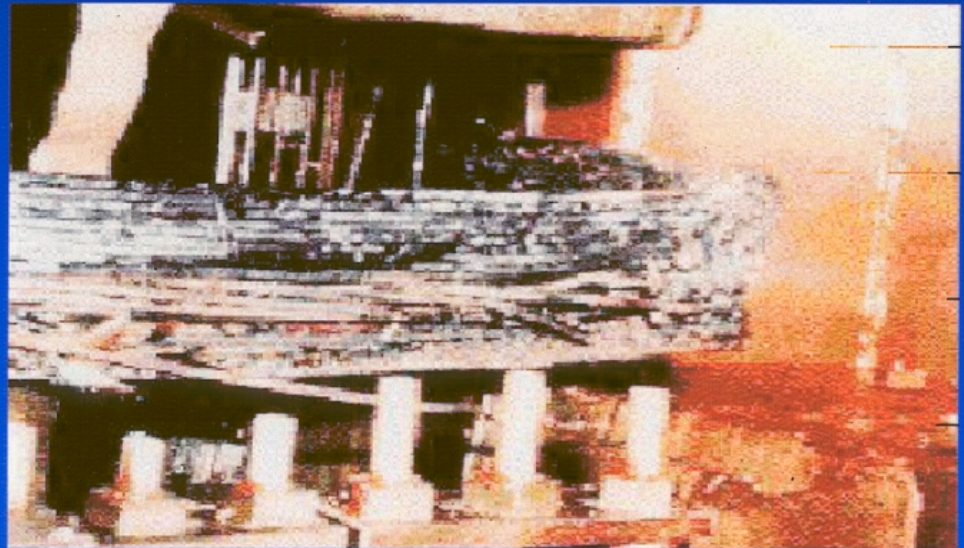


March 1989: Transformer Failure



PJM Public Service Step Up Transformer

Severe internal damage caused by
geomagnetic storm, 13 March 1989



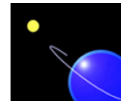
Space environment affects on ground systems Twitter alerts



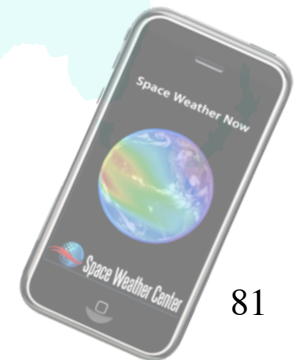
Professional and public access

- SpaceWx smartphone app
 - Released in Fall 2009 as the 1st space weather app
 - iPhone, iPad, iPod, Android versions now exist
 - 10 version releases (v2.0)
 - 150+ real-time data sets of space weather across 4 major environment domains
 - Alerts and event movies
 - 19 separate institutions provide data for app
 - Used in 52 countries with 10,000+ downloads





Today's Challenges of Space Weather



The Next Decade for SpWx Challenges

- **Current state: institutional provincialism**
 - The space weather enterprise of agencies, academia, and industry is divided by institutional “provincialism”
 - Each organization seeks to maximize only its own benefit in the space weather domain
 - Few examples of enterprise collaboration
- **Yet, major challenges: hazards/disasters**
 - Yearly: U.S. \$50B in destroyed property
 - 2010: global \$124B losses with 297,000 lives lost and 217 million people affected



The Next Decade for SpWx Challenges

- **We now know**

- Hazards to our technology clearly exist from space weather, for example
 - Communication outages
 - Navigation position uncertainties
- If unmitigated, space weather hazards create additional stress during emergencies that compounds disasters
- An example occurred during the Gulf Coast Hurricane Katrina recovery from August 29 into early September, 2005



Strengthening the Space Weather Enterprise

Q – How do government policies, funding, and requirements either degrade or strengthen the global competitiveness of the U.S. space enterprise and its capacity to sustain the nation's security?

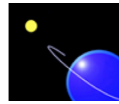
A1 – Degrades security – “Go it alone” approach

- Sequester and persistent funding issues exist to limit capability
- “Not made here” mindset limits an ability to compete globally

A2 – Sustains security – data and model innovation –

- Use all assets of the national space weather enterprise (government agency, academia, industry), e.g., operational satellites as well as research satellites
- Purchase commercial data and services for rapid near term advances – spurs competitive innovation
- Fund academic research base for long term strength





Commercial Space Weather is an emerging solution in this decade ...

YouTube link
at [http://
spacewx.com](http://spacewx.com)

