

Managing Space Weather Risks in Space Systems Operations

IMPROVING SPACE OPERATIONS WORKSHOP

SOSTC 2015

May 6, 2015

W. Kent Tobiska

Space Environment Technologies

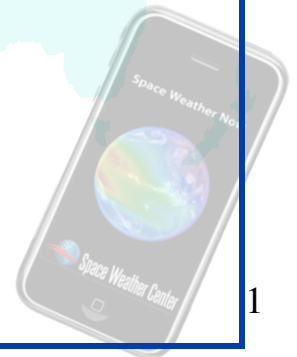
Utah State University Space Weather Center

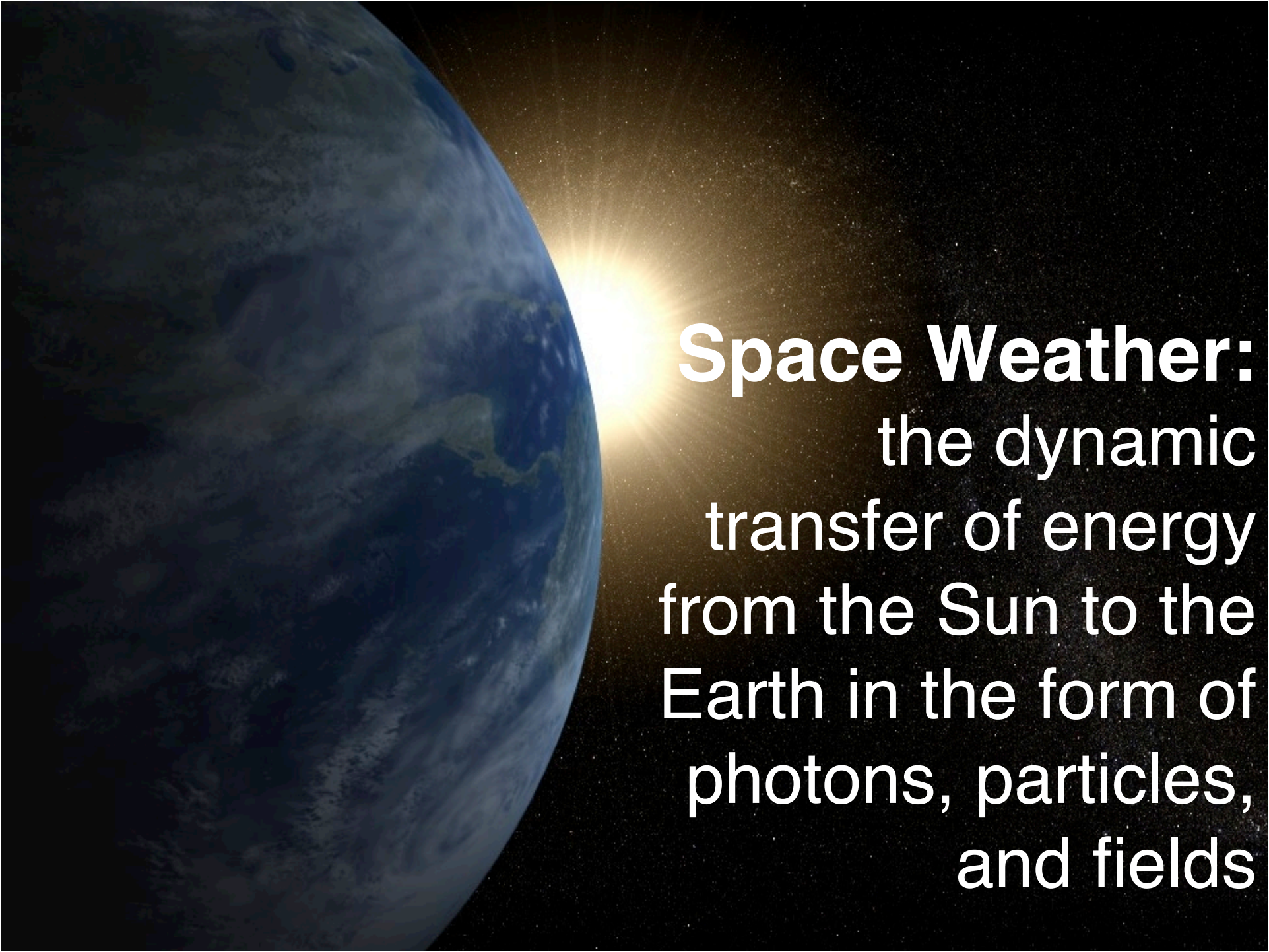
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<http://spaceweather.usu.edu>

<http://spacewx.com>

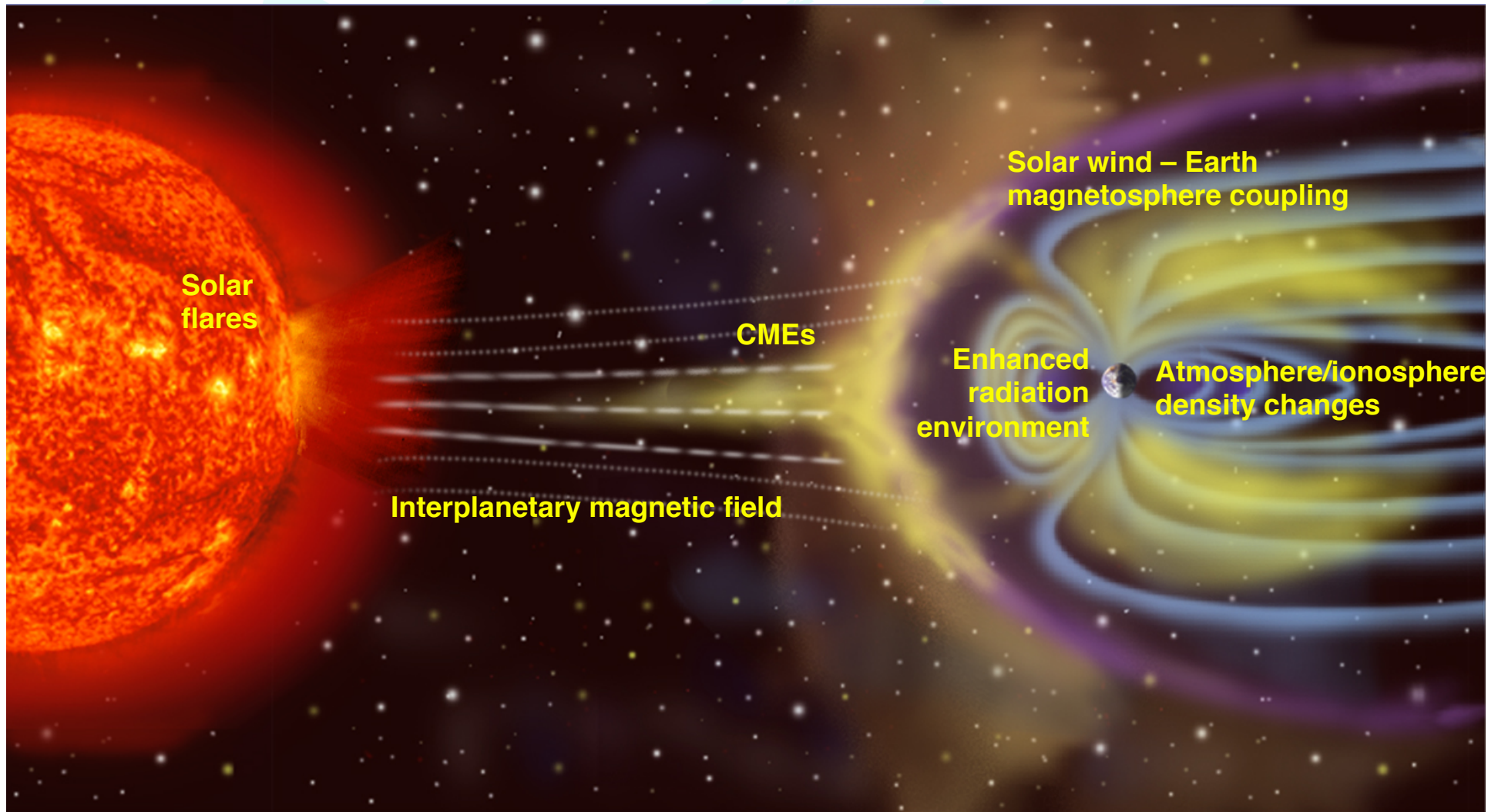
SpaceWeather app



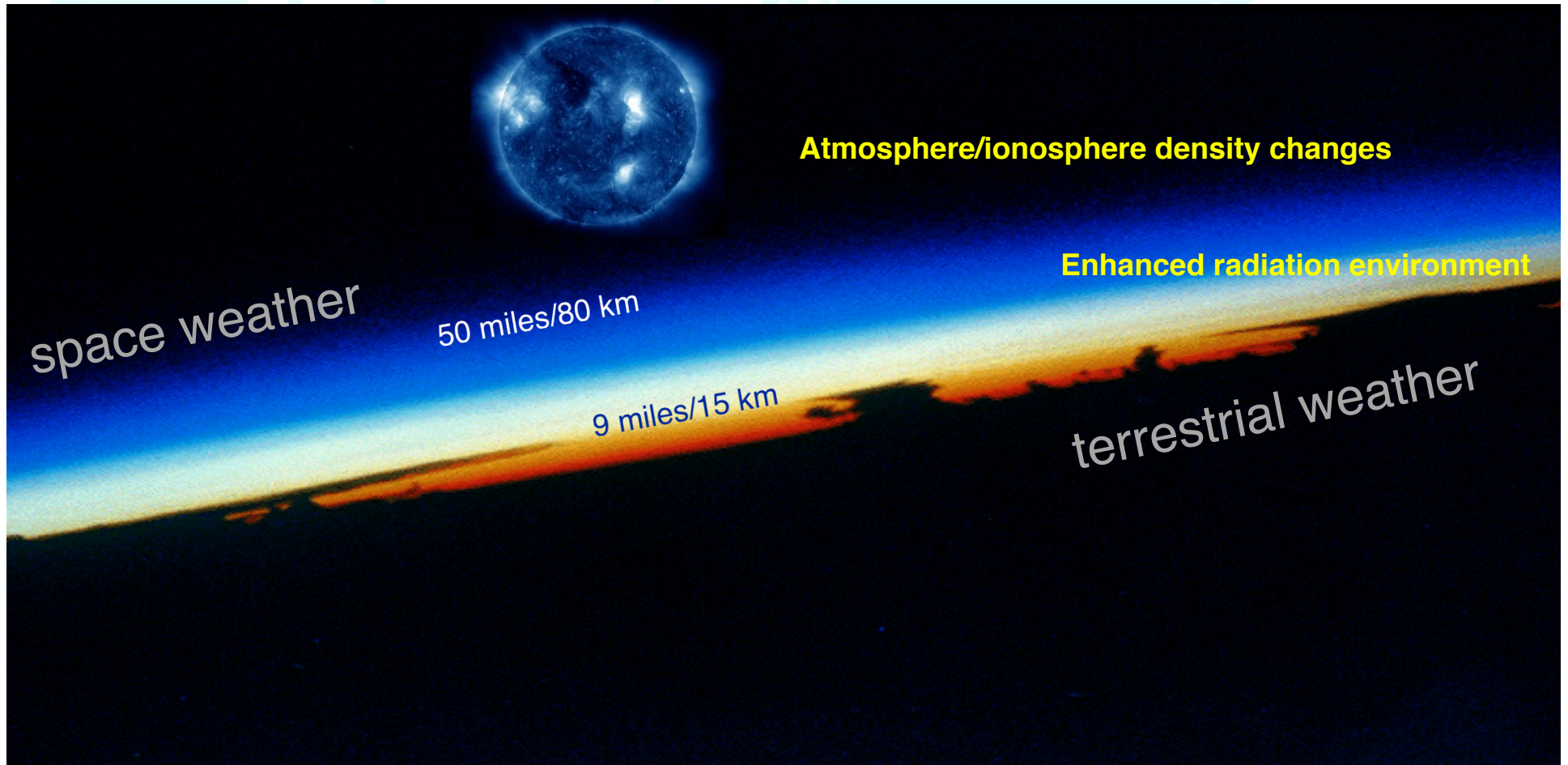


Space Weather:
the dynamic
transfer of energy
from the Sun to the
Earth in the form of
photons, particles,
and fields

The space environment contains both the long-term “climatology” and the short-term “weather”



The short-term space weather arrives at Earth in minutes to days



Technologies affected by Space Weather

- **Communication** – D-region absorption; HF loss; HF/UHF/L-band radio signal scintillation
- **Aviation** – HF communication loss; radiation above 26,000 ft.; GPS position error for WAAS
- **Satellite operations** – LEO orbit error from drag; GEO spacecraft charging; SEUs and latchup
- **Navigation** – GPS position and timing error
- **Energy production** – drill-bit misalignment from magnetometer error in oil/gas drilling
- **Power grid** – transformer loss from GIC surges



Space weather activity has moved beyond understanding (2000) into tailored data risk management (2015)

3 operational technology areas affected by space weather

1. Ground-to-space radio communication disruption

- HF radio communication (defense, emergency response, shipping)
- Scintillation outages for L-band, UHF, HF (satcom, radar, comm)

2. Aviation to LEO radiation exposure

- GCR background dose (career health)
- SEP event dose (fleet operations and aircrew/passenger safety)

3. Satellite conjunction hazard

- Thermospheric density specification and forecast for LEO sats



Radio communication disruption management

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The Lesson of Hurricane Katrina

Katrina

+

Solar Flare

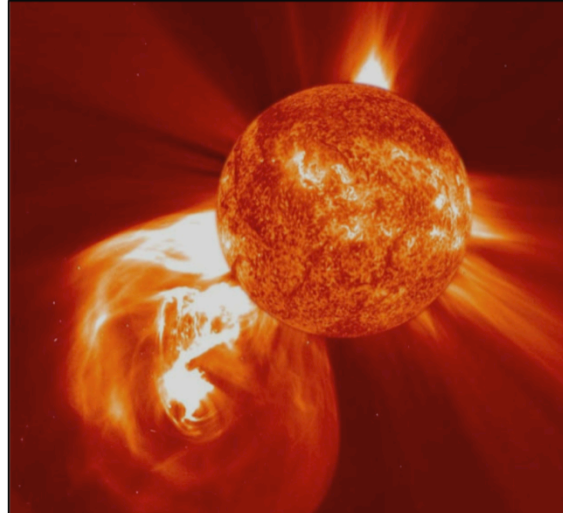
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Hazard



Aug. 29, 2005

Katrina strikes NOLA



Sept. 7, 2005

4th largest flare in history



Sept. 7, 2005

Loss of ship-to-helicopter communications

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Great East Japan Earthquake March 11, 2011

Massive destruction



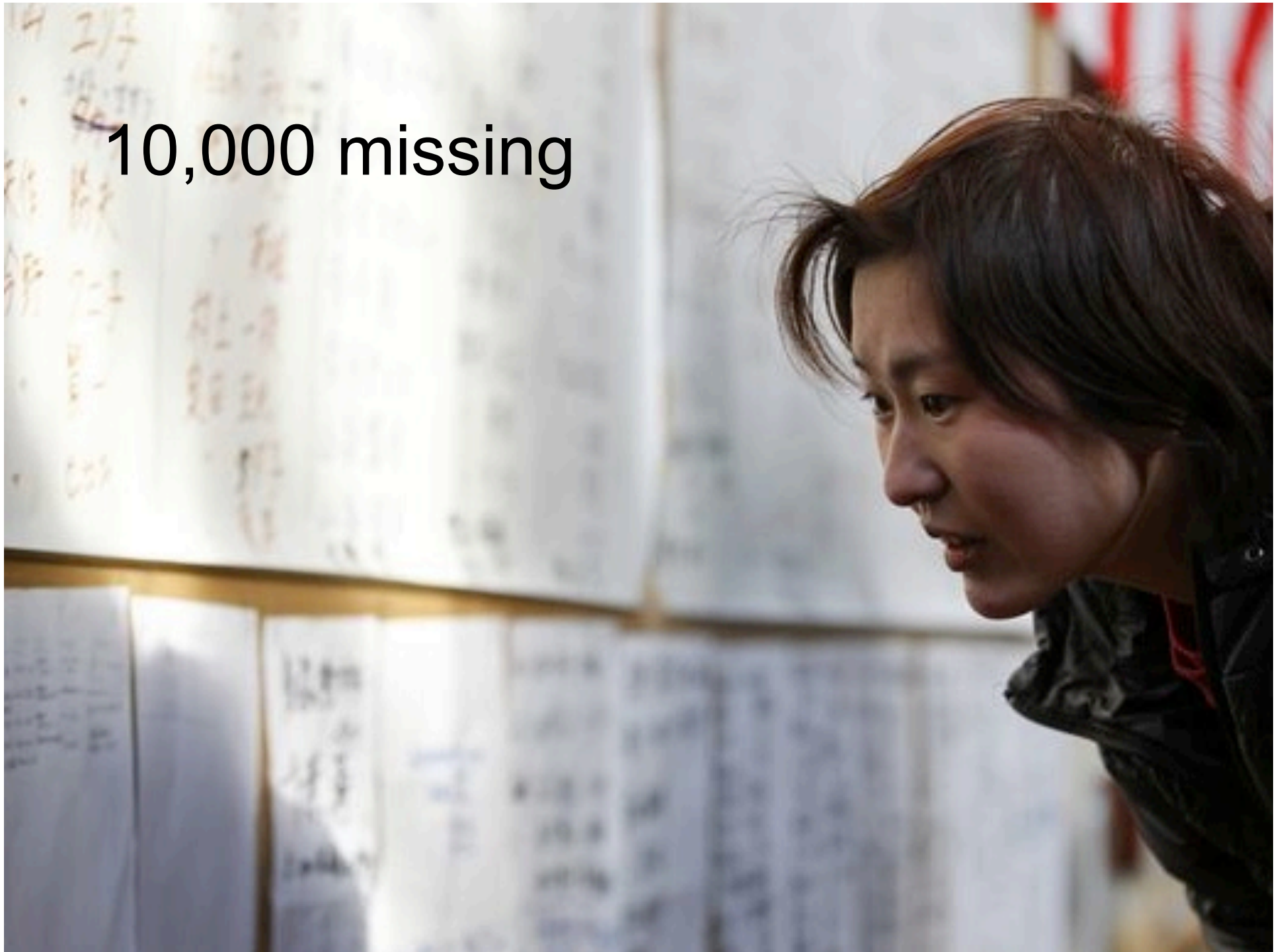


Demolished infrastructure

\$300 billion in damages



10,000 missing





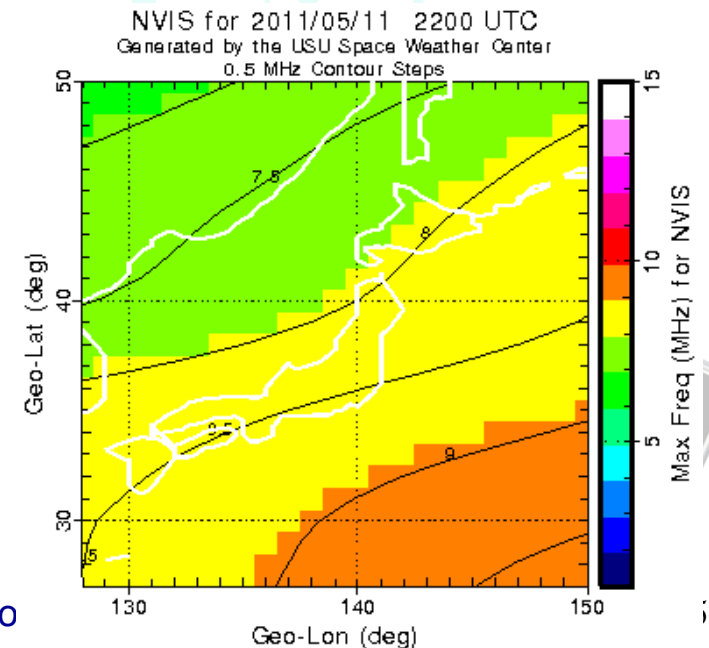
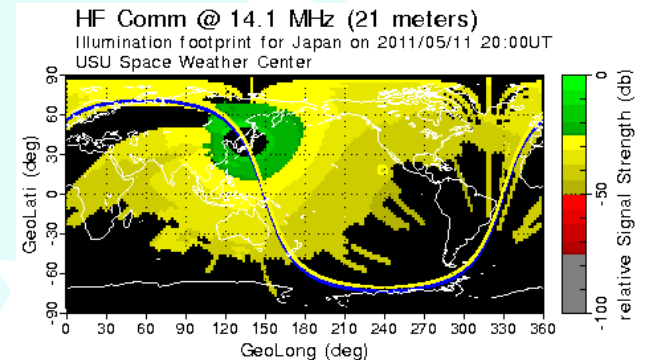
14,000 dead

Unusable
cell phone
tower



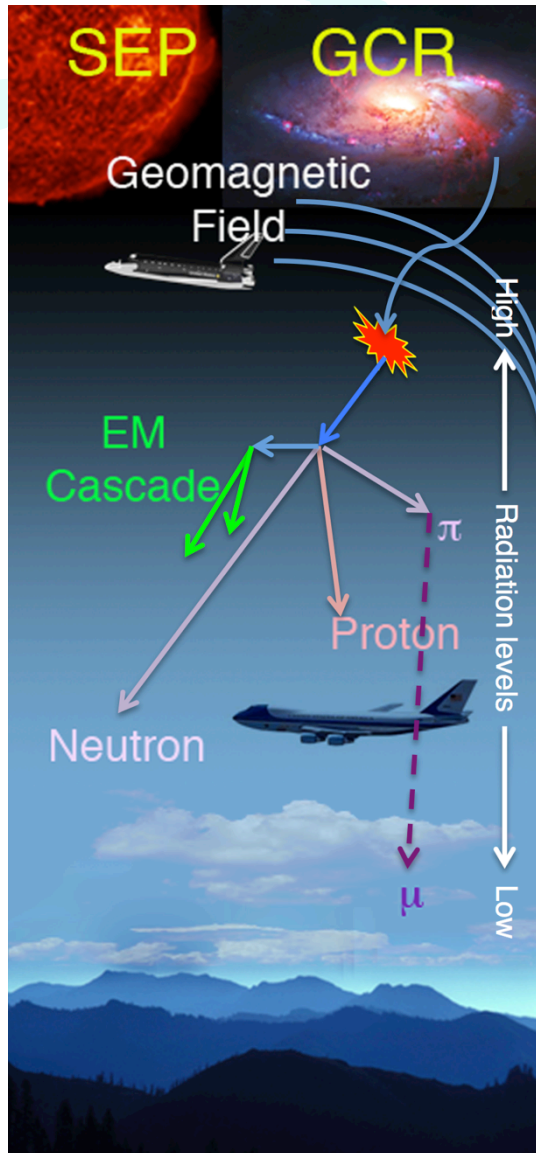
HF communication aid was provided for Japanese disaster response

- Frequencies to transmit over nearby mountains.
- 3-hour forecast of frequencies.
- Recommendation of available frequencies to global operators.
- Available HF frequencies for Emergency Responders

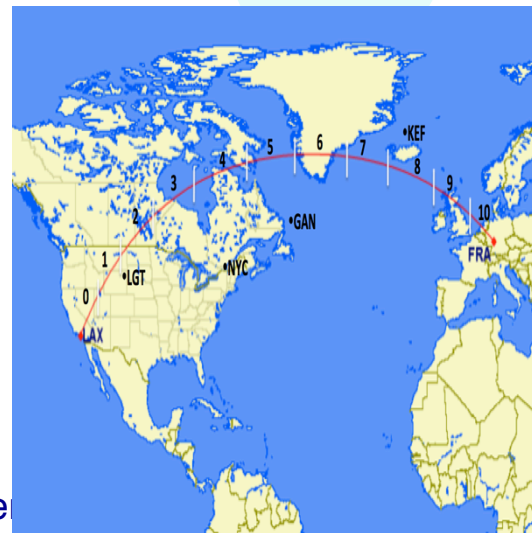
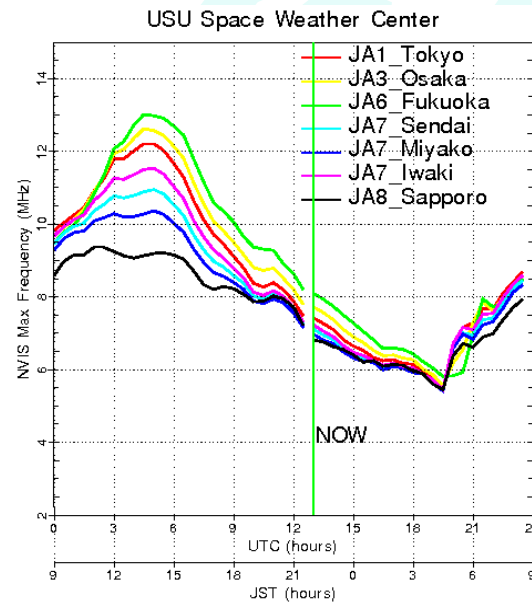


Space Weather effects on aviation

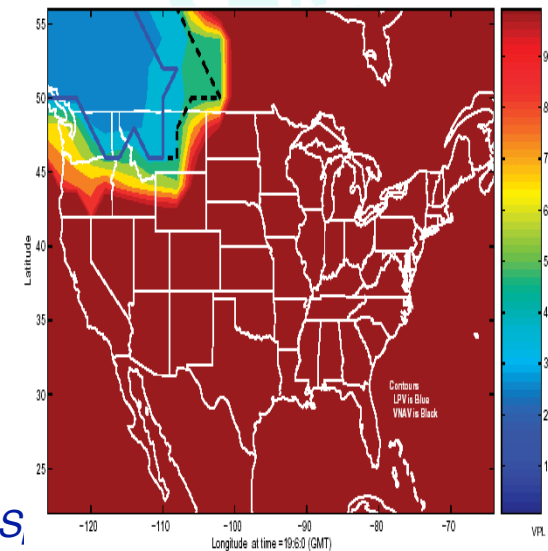
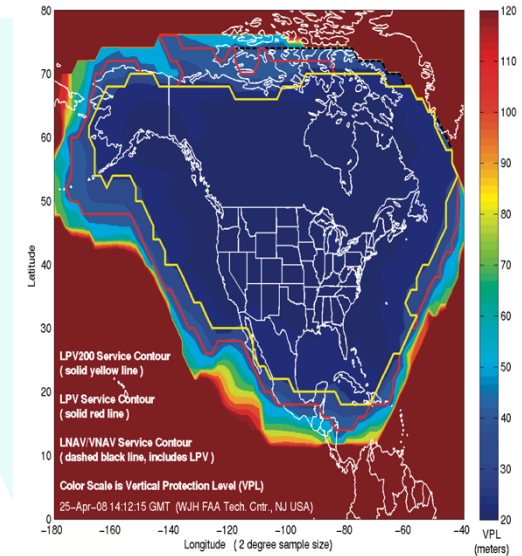
Radiation exposure



HF communication outages



WAAS navigation error



Aviation radiation environment specification

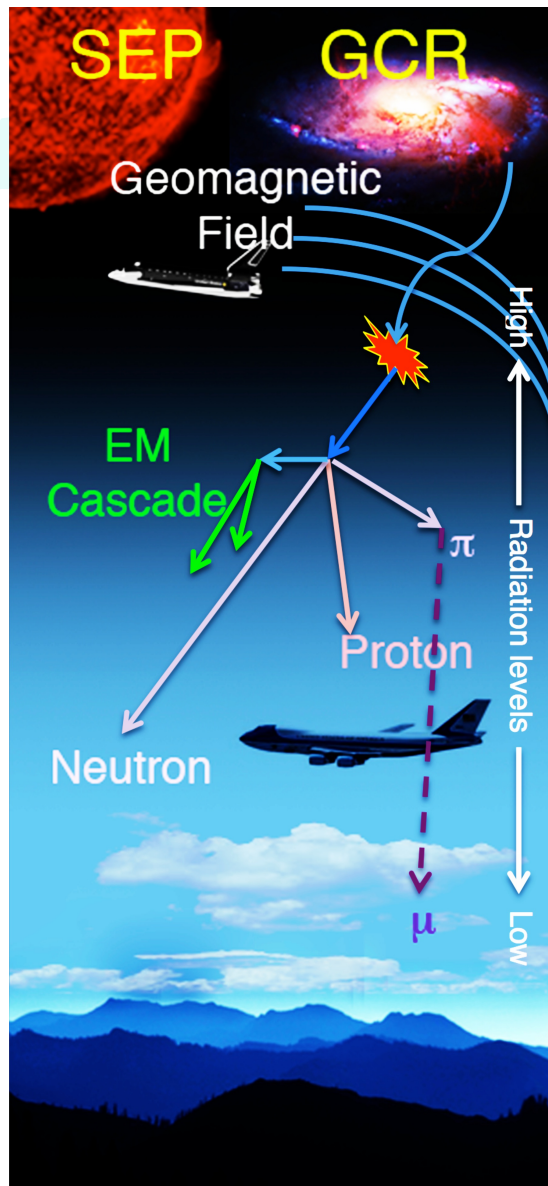
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SpaceWeather app

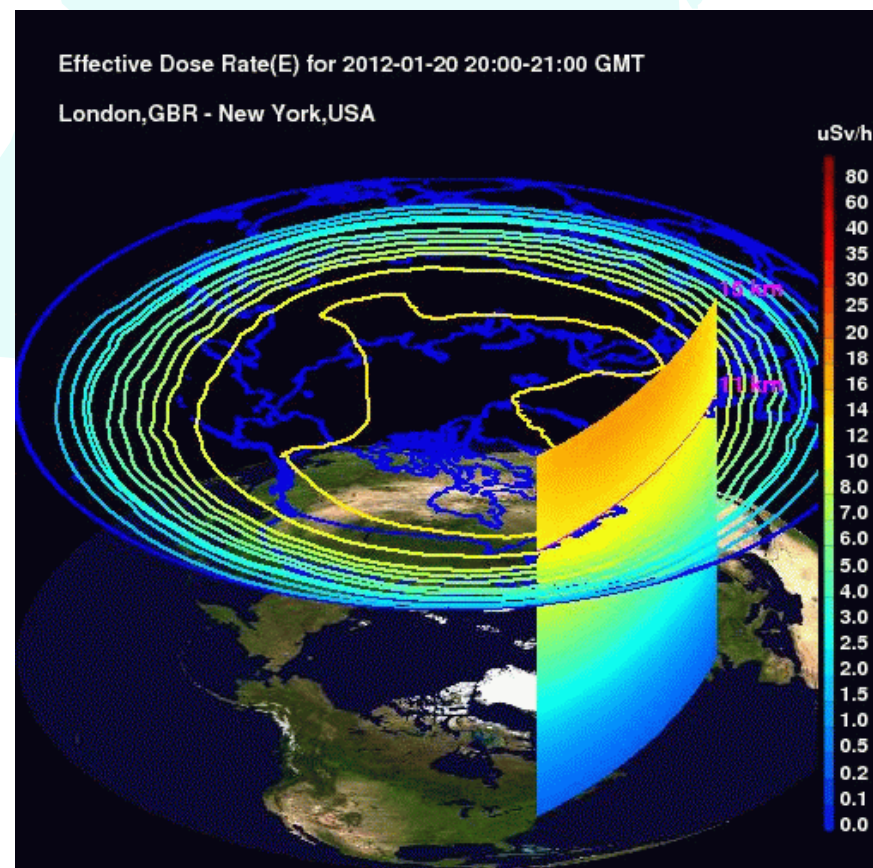




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Real-time global aviation radiation climatology NAIRAS

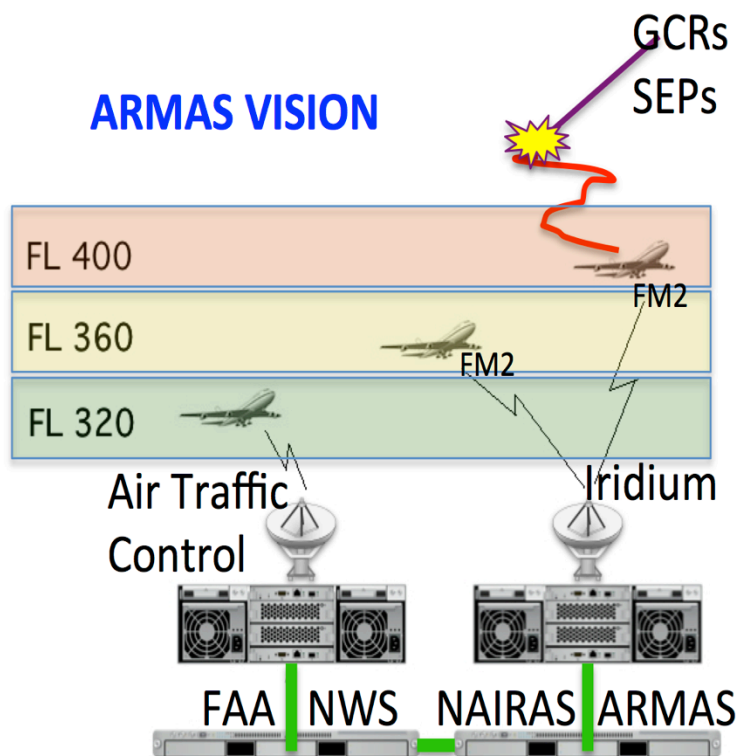


<http://spacewx.com>

SpaceWeather app

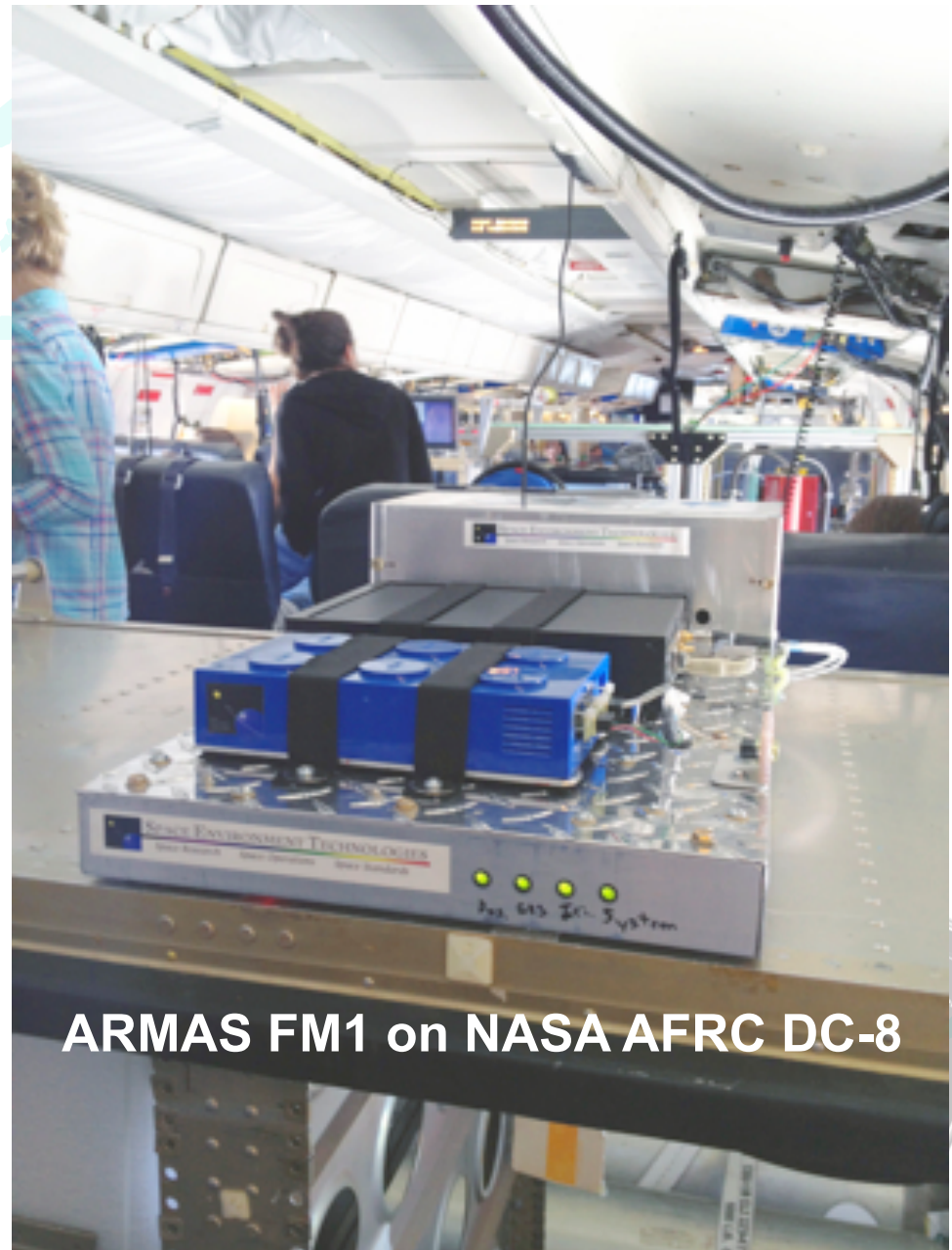


Strategy for real-time local aviation radiation measurements



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<http://spaceweather.usu.edu>



Real-time Automated Radiation Measurements for Aerospace Safety (ARMAS) website

The screenshot shows the ARMAS website in a web browser. The browser's address bar displays `sol.spaceenvironment.net/~ARMAS/index.html`. The website header includes the ARMAS logo and the title "Automated Radiation Measurements for Aviation Safety". A navigation menu lists links: Home, Overview, NAIRAS, Gallery, Movies, Instruments, Data, and Documents. The main content area features a section titled "ARMAS" with a detailed description of the project's goals and methods. Below this, an "Accomplishments" section lists seven key achievements. A "Current Dose Rates" section includes a 3D plot showing dose rate data over time and altitude, with a color-coded legend at the bottom.

ARMAS
Automated Radiation Measurements for Aviation Safety

[About ARMAS](#) [Partners](#) [Gallery](#) [Current Dose Rates](#) [News](#)

ARMAS

The Automated Radiation Measurements for Aviation Safety (ARMAS) project uses an innovative approach with a low-cost dosimeter sensor to enhance Earth science research and improve aviation safety. The ARMAS team will deploy and obtain data from dosimeters to be flown on commercial aircraft. These data will be retrieved in real-time, downlinked to the ground, and used in the validated Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) modeled radiation environment. The result will be improved accuracy of radiation dose and dose rates along flight tracks. In doing so, the ARMAS project has made a significant contribution toward improving U.S. and international aviation safety by laying the groundwork for an automated, reliable operational system that can monitor the natural galactic and solar radiation environment at commercial aviation flight levels.

Accomplishments

The accumulated radiation doses from the flight tests were produced by an operational-grade integrated system that:

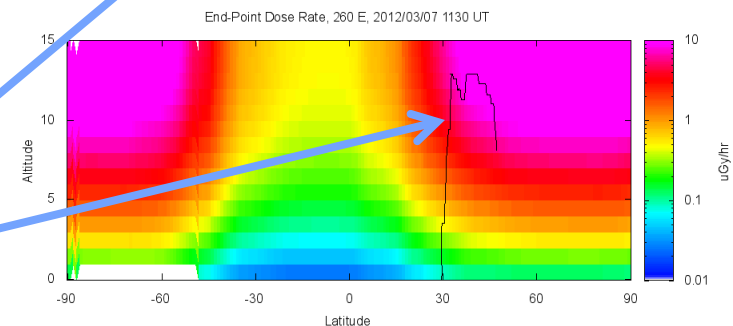
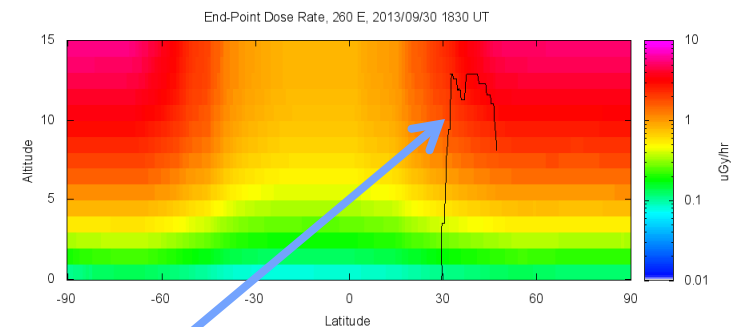
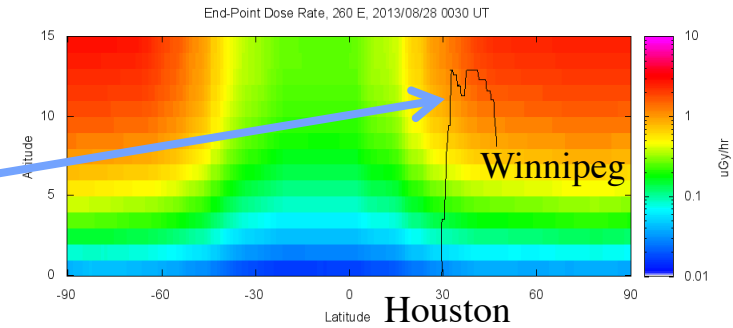
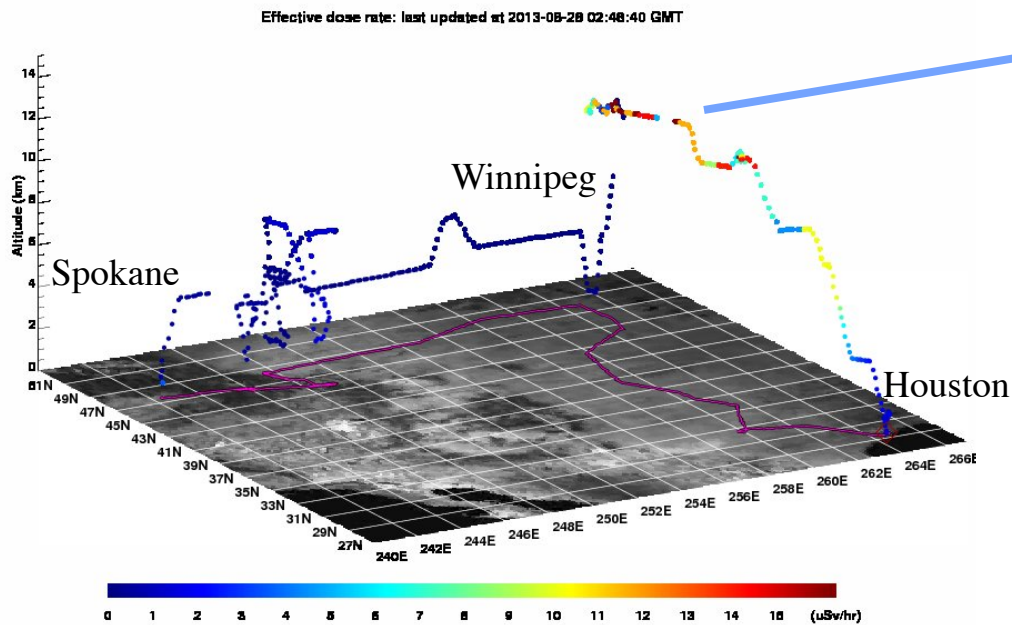
1. Acquires dose rate and GPS data on board.
2. Forms Iridium data packets that are sent in real-time.
3. Captures the real-time aircraft and NAIRAS most recent run data on servers at SET.
4. Pre-processes the data for differences from NAIRAS climatology at USU SWC.
5. Stores those results in an operational database.
6. Provides those results to NASA LaRC for generating accumulated dose rates over flight paths.
7. Delivery of dose rate jpegs to web sites and smart phones with ~15 minutes latency from original measurement.

Current Dose Rates (also see [Movies](#))

Effective dose rate: last updated at 2013-09-18 22:07:40 GMT



ARMAS FM1 (2013-2014) – flight 18 example



- **Top:** ARMAS flight 18 (August 28, 2013)
- **Middle:** S2 event (September 30, 2013)
- **Bottom:** S3 event (March 7, 2012)

ARMAS 2015 FM2 Deployments

- Korea Space Weather Center has purchased two FM2s as part of ARMAS Phase IIE commercialization
- Deployed to NOAA G IV and NSF G V in Feb-Mar 2015
- Data will be available to community beginning mid-2015



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<http://spacewx.com>

SpaceWeather app





ARMAS 2015 FM3 Deployment

- NASA Armstrong Flight Research Center has acquired one FM3 as part of ARMAS Phase III commercialization
- Second anticipated unit to NASA AFRC Global Hawk in late 2015
- Deployment to ER-2 in May 2015
- Data will be available to community beginning mid-2015



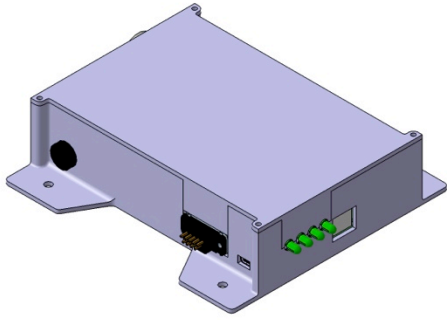
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ARMAS FM4

Deployments

- Stratospheric balloon flights starting in 2015 under MOU between World View and SET
- Data will be extended to ~35 km as a World View pathfinder payload

Credit: World View

ARMAS 2015 FM5 on business jets



ARMAS-Lite FM5

- Flight Module 5 (FM5) configuration has μ Dos
- altitude range up to 16 km on business jets
- μ Dos data reported in global context
- distributed network with global situational awareness
- SEP event flight exposure mitigation
- personal dose exposure collection and reporting



Satellite conjunction avoidance

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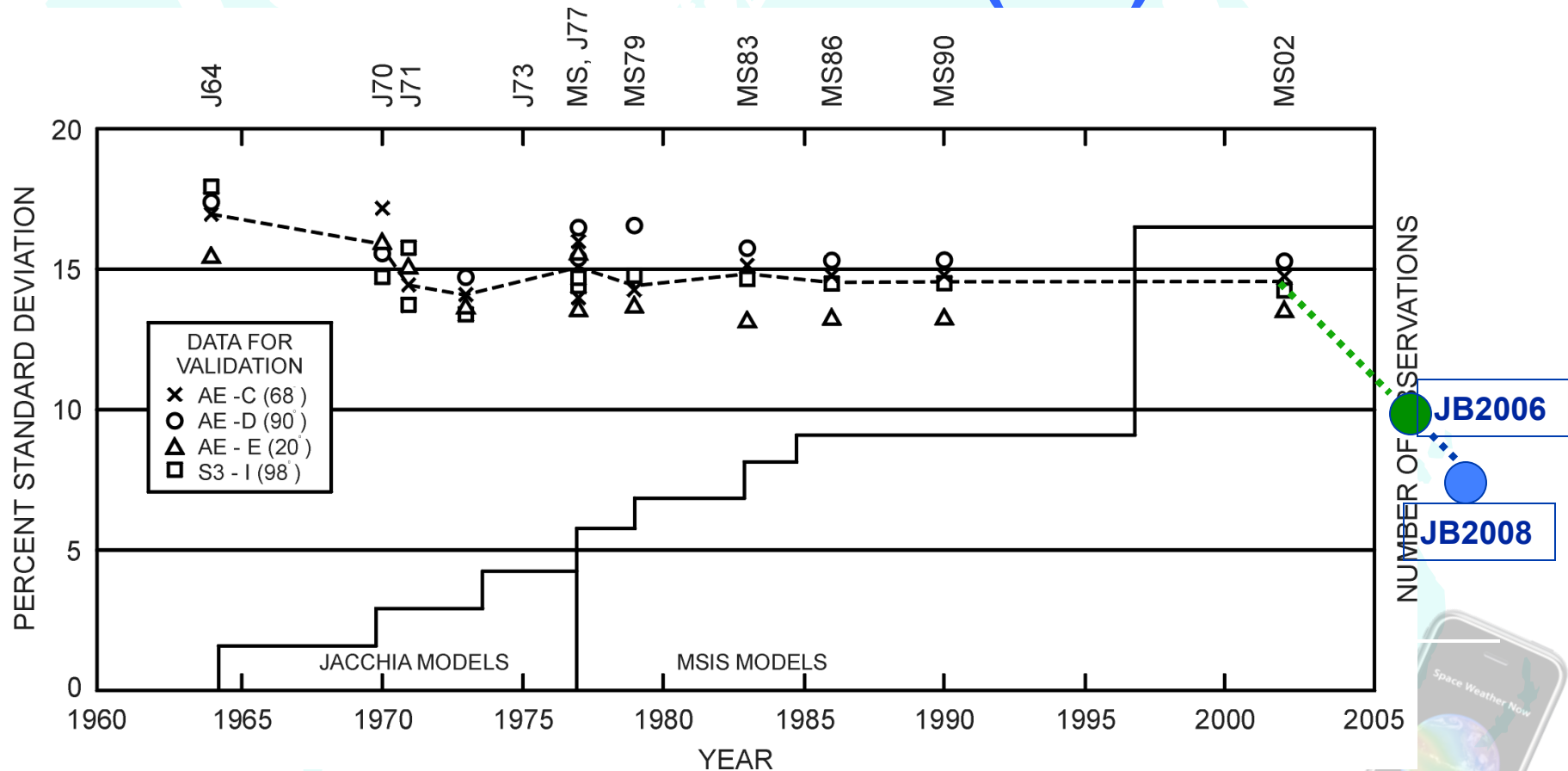
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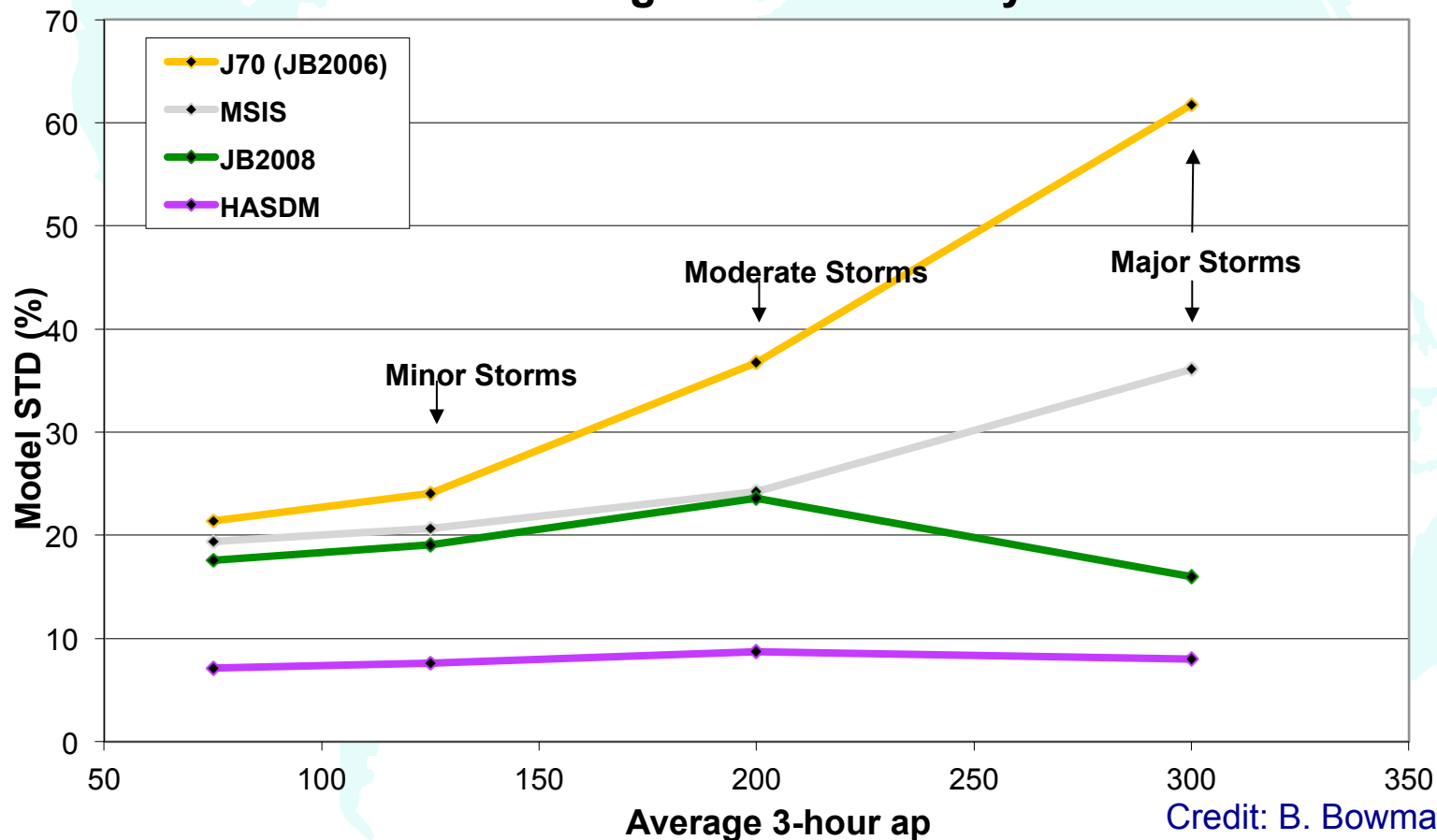


Historical Density Model Errors at 350 km (1- σ)



Orbit Average Density Error for Geomagnetic Storms

Orbit Averaged Model Density Errors



Credit: B. Bowman

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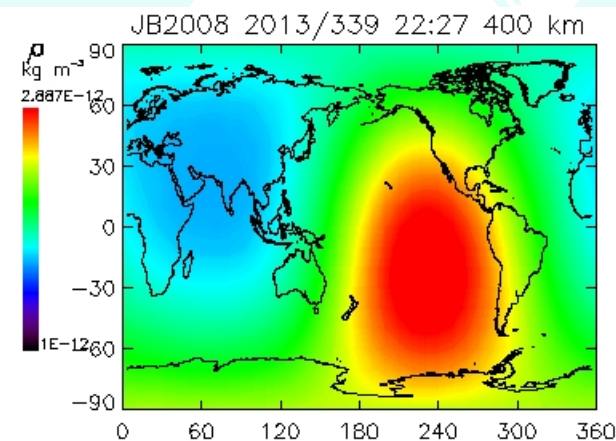
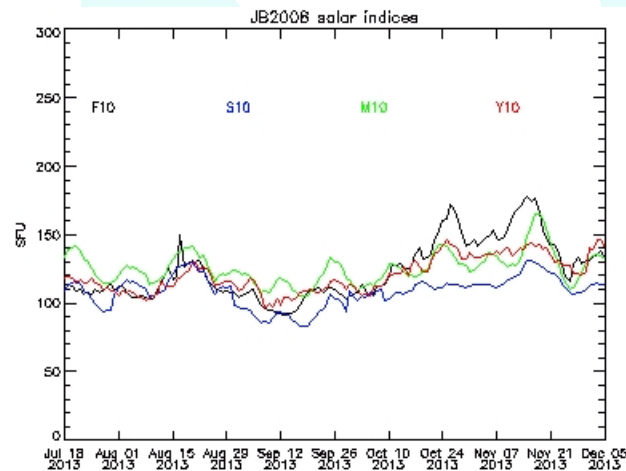
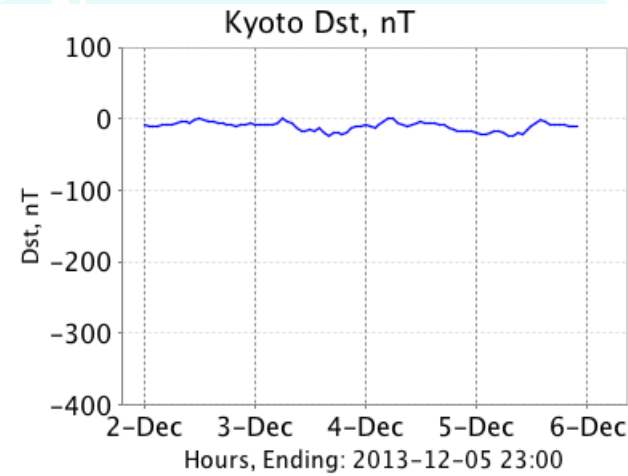
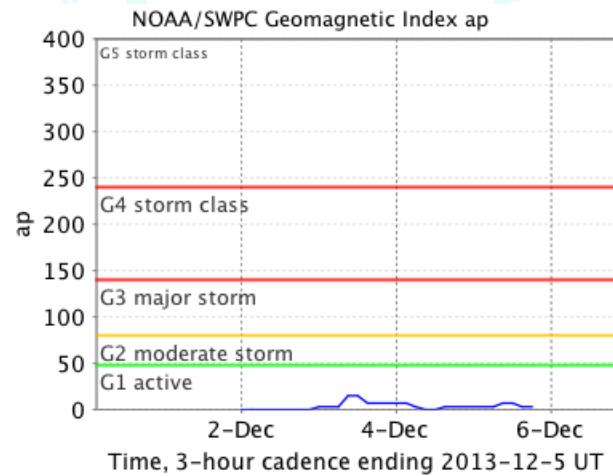
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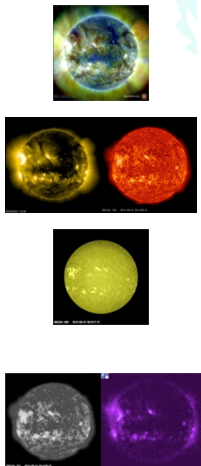


JB2008 Indices



JB2008 Thermosphere – Solar irradiance drivers

Daily operational indices selected



Index or proxy	Observing facility	Instrument	Observation time frame	Measurement cadence	Measurement latency	Operational availability
F _{10.7}	Penticton ground observatory	Radio telescope	1947-2013	3 times/day	Up to 24 hours	yes
S _{10.7}	SOHO, GOES	SEM, EUVS	1996-2013	15 seconds	Up to 24 hours	(a)
M _{10.7}	NOAA-16, 17, 18, SORCE, ERS-2	SBUV, SOLSTICE, GOME	1991-2013	2 times/day	Up to 24 hours	yes (c)
Y _{10.7}	GOES-12, UARS, SORCE, TIMED	XRS, SOLSTICE (2), SEE	1991-2013	1 minute, 16 times/day	Up to 10 minutes, up to 48 hours	(b)

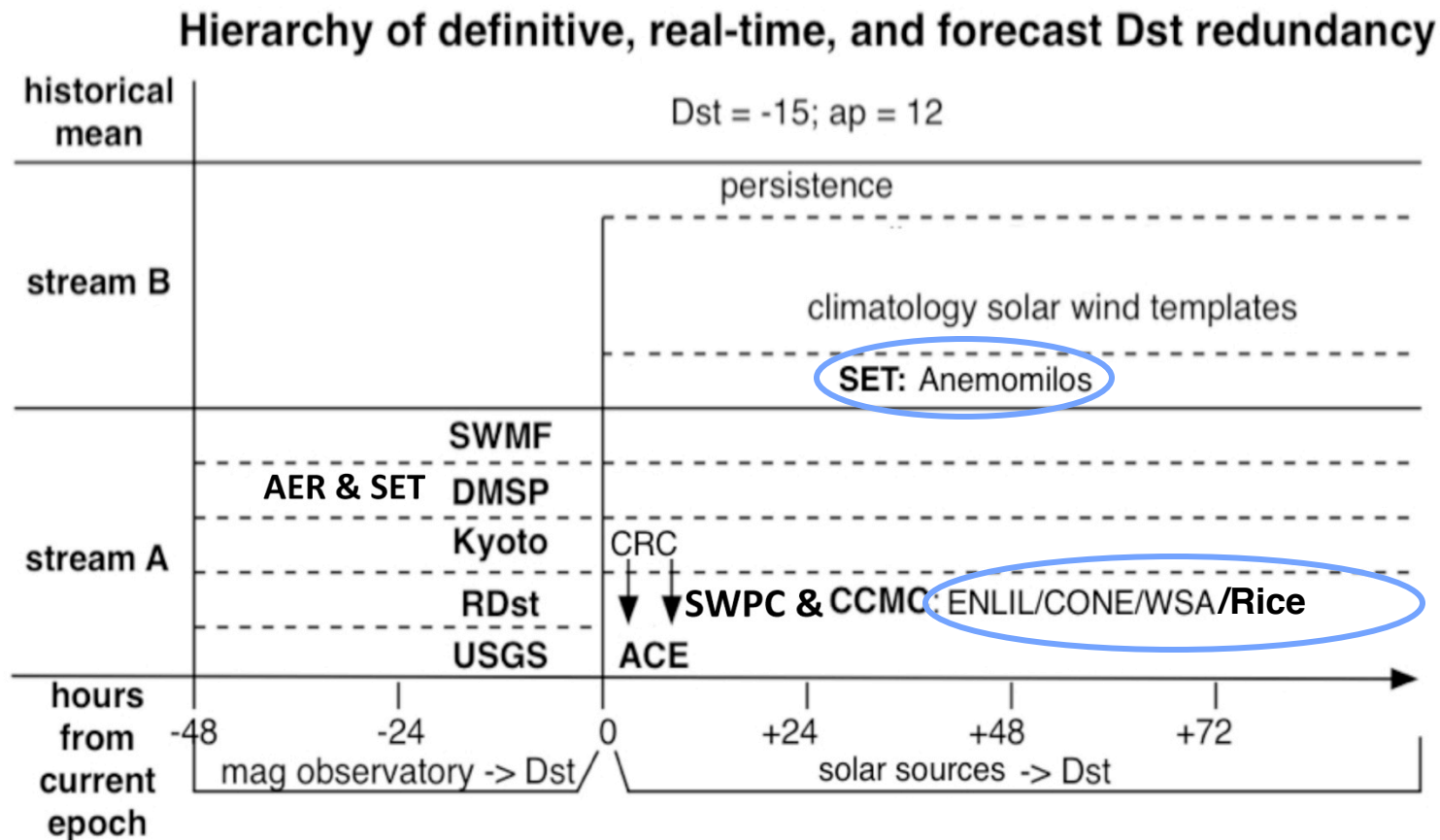
(a) SOHO/SEM is a NASA research instrument but provides daily irradiances on an operational cadence; GOES 13 EUVS B channel makes measurements in the same bandpass as SOHO SEM.

(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. Credit: ISO 14222

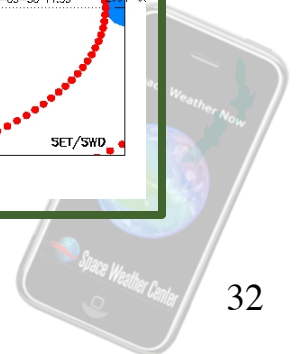


JB2008 Thermosphere – Geomagnetic Storm Drivers



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

geomagnetic ring current
index for satellite drag
thermosphere densities



Space Weather Community Operations Workshop (SpWxCOW) lessons

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<http://spaceweather.usu.edu>

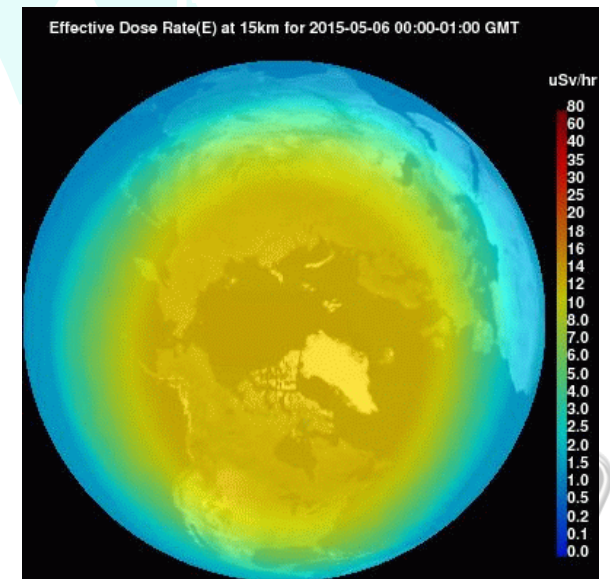
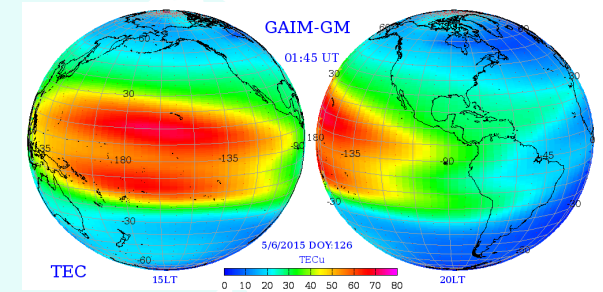
<http://spacewx.com>

SpaceWeather app



Important Space Weather Operational Product Qualities

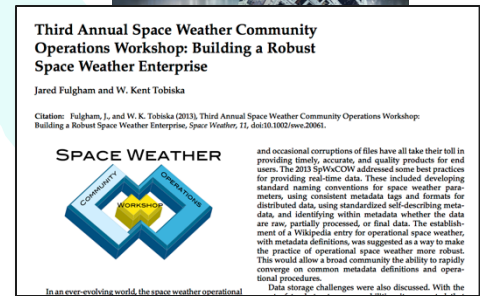
- 1) Simple to understand – visual
- 2) Accurate representation
- 3) Sufficient information for decisions
- 4) Easy access to information
- 5) Low latency and appropriately rapid updates
- 6) Unambiguous guide to action now and in the future



Accomplishments

Workshop deliverables

- ✓ *Space Weather Journal* articles (2011, 2012, 2013)
- ✓ **SpWxCOW report**
- **AIAA Guidelines document** via AIAA ASETC CoS: lessons for reliability, maintainability, accessibility, dependability, quality, and safety in SpWx ops



First Standard Document: SET Corporate Space Weather Mission Assurance Standard

Scope: Focuses on SpWx ops for areas of

- a) Reliability
- b) Maintainability
- c) Accessibility
- d) Dependability
- e) Quality
- f) Safety

COMMAND MEDIA—MANDATORY COMPLIANCE			
ORGANIZATIONAL MISSION ASSURANCE STANDARD			
Mission Assurance Program			
Revision: 1	Release: 01-02-2011	Effective: 01-02-2011	SET
Copyright SET™ as an unpublished work. All rights reserved.			
STANDARD			
OBJECTIVE			
This Standard defines SET's approach for implementing a Mission Assurance Program (MAP). Through the interpretation and implementation of this Standard SET shall tailor its System Safety Program, Reliability, Maintainability, Availability and Dependability (RMAD) Program, and Quality Assurance Program to achieve all pertinent mission assurance requirements which are commensurate with the unit-value category of its products. At the time this Standard was written SET did not develop any very-high or ultra-high unit-value products.			
Note: Guidance for product unit-value determination is found in Figure 1.			
APPLICABILITY			
This Standard applies to all present and future SET sites/facilities, programs/projects, business lines/services, functional organizations/working groups, and employees/subcontractors, regardless of whether a MAP has been contractually imposed.			

<http://spacewx.com> Standards link



Example Next Steps

Space Weather Accessibility

Move to new technologies: Google Earth, Twitter while maintaining legacy systems

- ✓ Twitter automated feeds
- ✓ Wikipedia entry
- ✓ spaceweather.com
- ✓ RSS automated feed
- ✓ KMZ files
- Cloud data sourcing
- Facebook



Example Next Steps

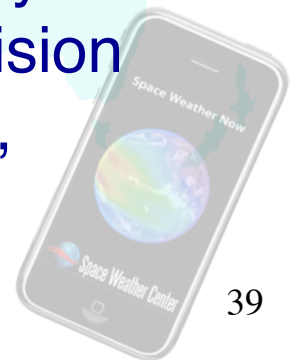
1) Space Weather Cloud Mail

- ✓ Twitter automated feeds:
 - ✓ SEC (@spacenv) and SET (@spacenvironment) implemented Twitter feeds in 2012
 - ✓ Hashtags in use are #spaceweather, #spwx, @spacewx, #sunspot, #sun, #aurora, #cme, #solarflare
- Examine hashonomy.com/hashtag/spaceweather
- Recommended list: issuing organization, time, phenomenon, links, URL
- Put alert threshold high otherwise people drop-off; consider how long since last event
- Utility of feeds? Too much info? Links to URLs?



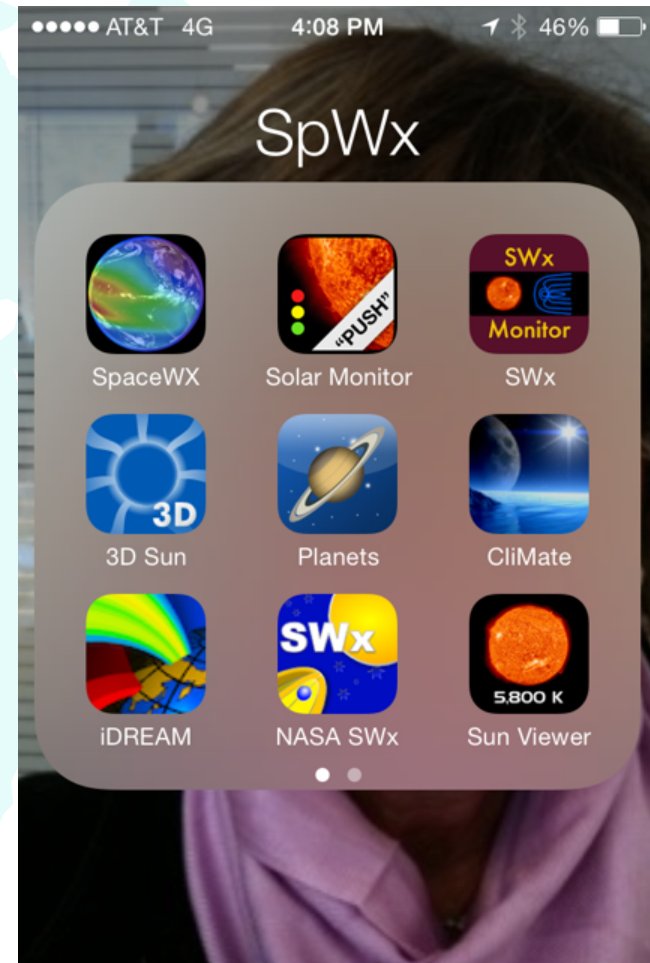
Milestones in Operational Space Weather

- All major agencies now have space weather activities
- American Commercial Space Weather Association (ACSWA) formed in 2010 now has 20 companies
- ***Space Weather Journal*** is a peer review publication (15 years old)
- OSTP now planning space weather risk mitigation across all agencies
- Space weather activity has moved from a purely science activity in 2000 to information and decision tool use by multiple industries in 2015 (sat ops, aviation, power grid, oil/gas)



How to access real- time space weather:

SpaceWeather app
for iPhone, iPad
and *SpaceWx* app
for Android



Credit: USU SWC & SET

