Space Weather Center

SPACE ENVIRONMENT TECHNOLOGIES
Space Weather Division

Managing Space Weather Risks in Space Systems Operations

IMPROVING SPACE OPERATIONS WORKSHOP

SOSTC 2015

May 6, 2015

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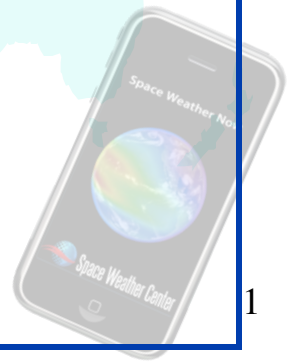
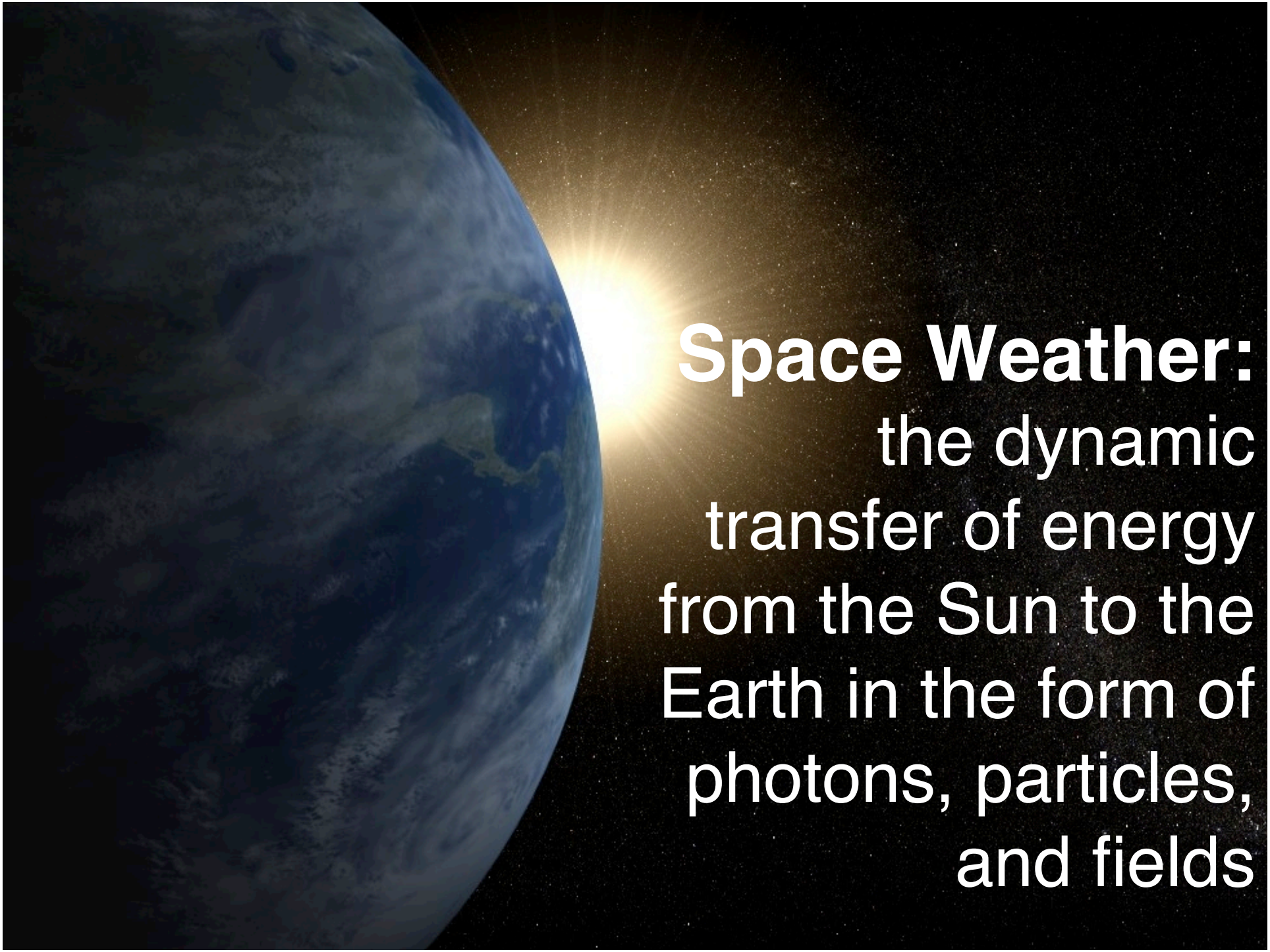
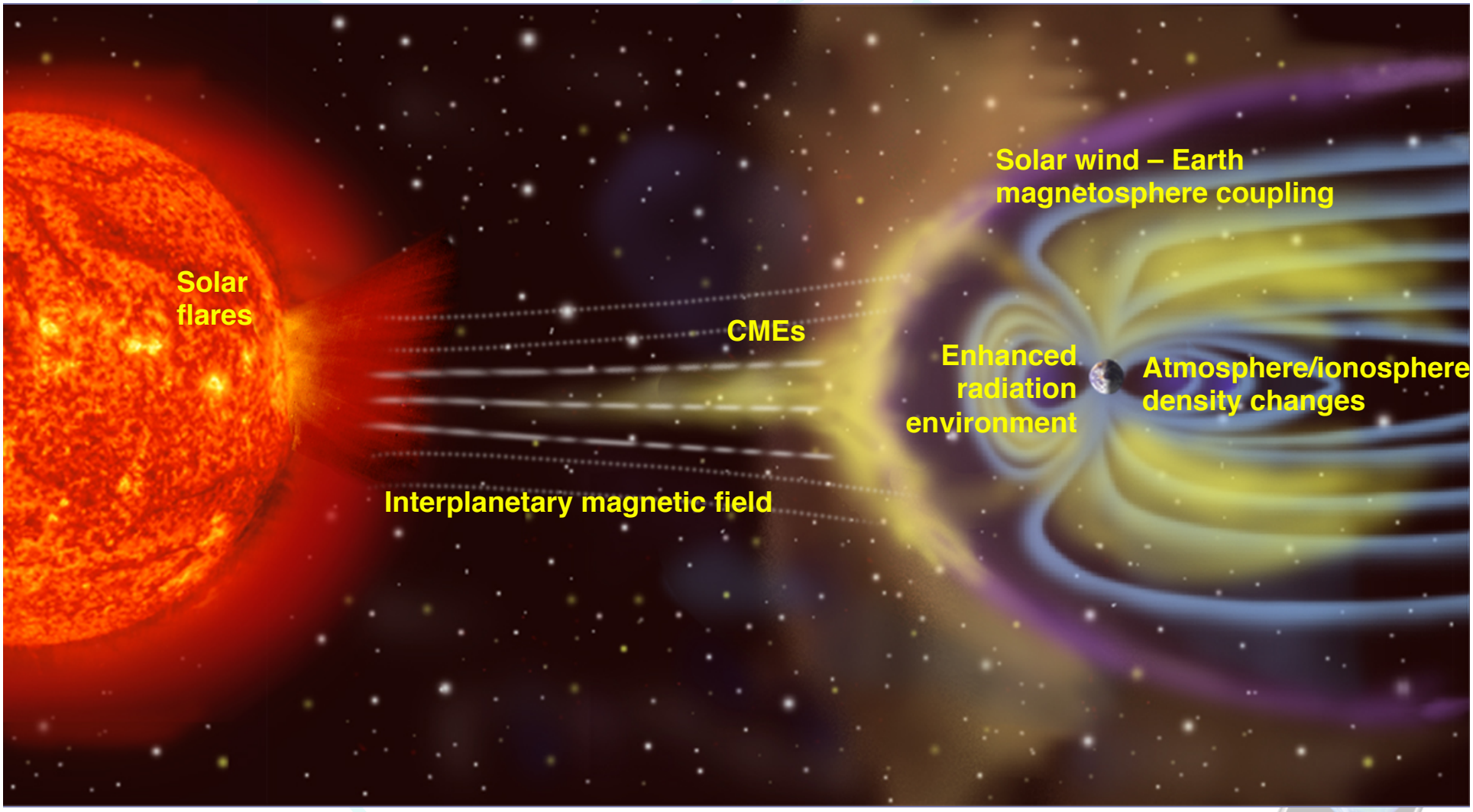


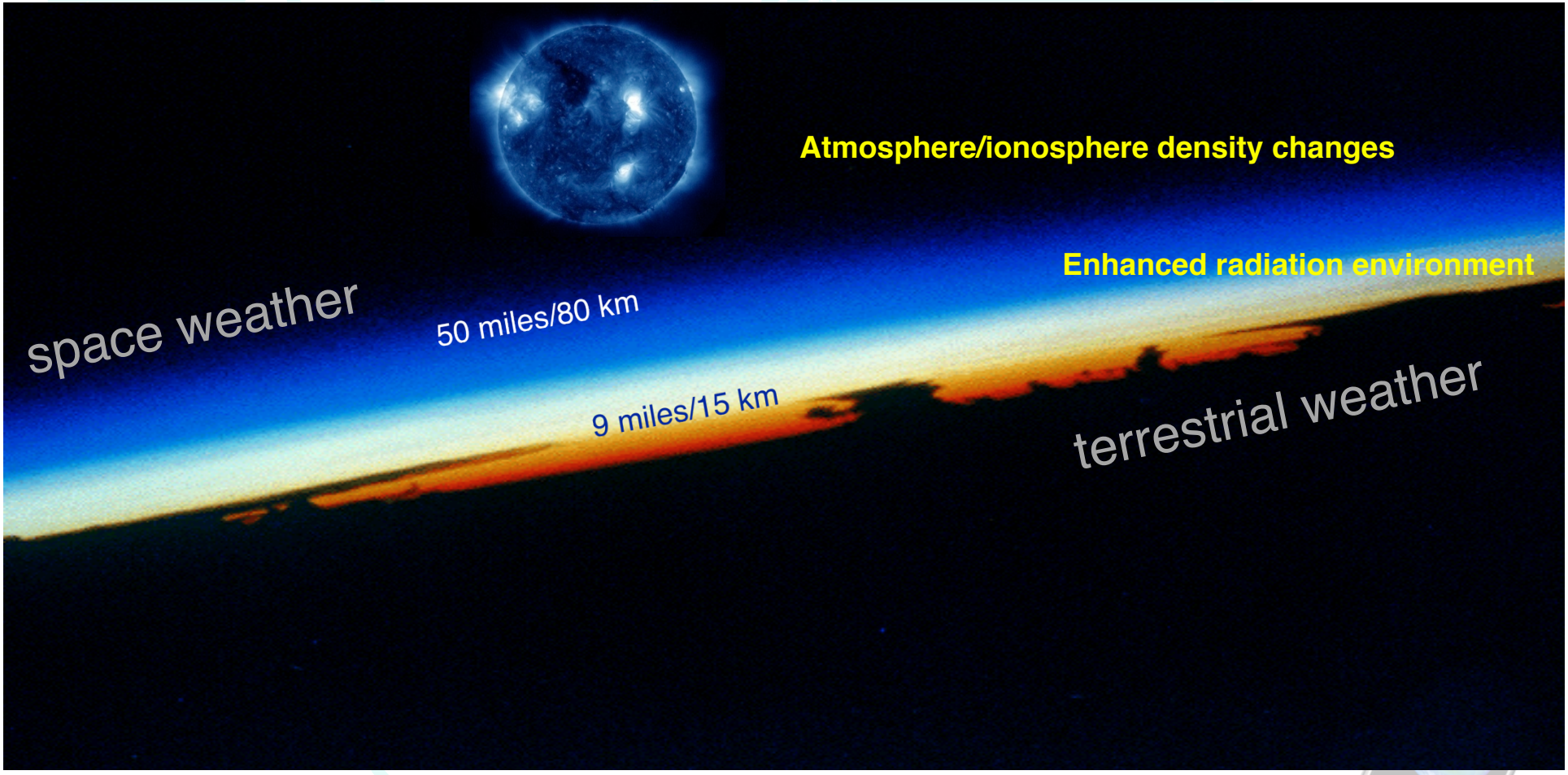

Space Weather:
the dynamic transfer of energy from the Sun to the Earth in the form of photons, particles, and fields

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



Credit: Steele Hill/NASA

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

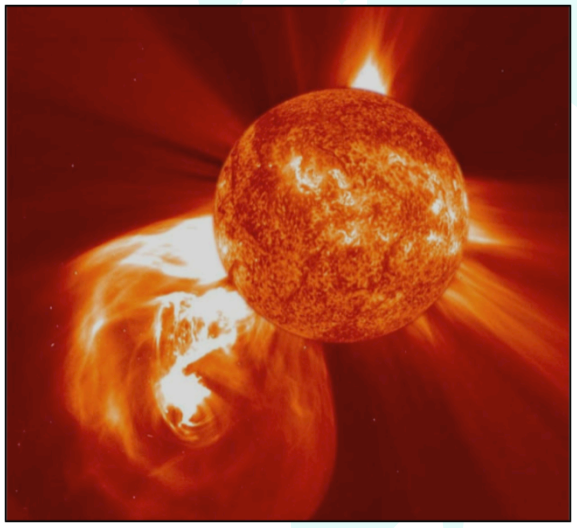
1. **Ground-to-space radio communication disruption**
   - HF radio communication (defense, emergency response, shipping)
   - Scintillation outages for L-band, UHF, HF (satcom, radar, comm)
2. **Aviation to LEO radiation exposure**
   - GCR background dose (career health)
   - SEP event dose (fleet operations and aircrew/passenger safety)
3. **Satellite conjunction hazard**
   - Thermospheric density specification and forecast for LEO sats

Radio communication disruption management

The Lesson of Hurricane Katrina

Katrina + Solar Flare = Hazard

Aug. 29, 2005
Katrina strikes NOLA



Sept. 7, 2005
4th largest flare in history

Sept. 7, 2005
Loss of ship-to-helicopter communications

Great East Japan Earthquake
March 11, 2011

Demolished infrastructure

$300 billion in damages

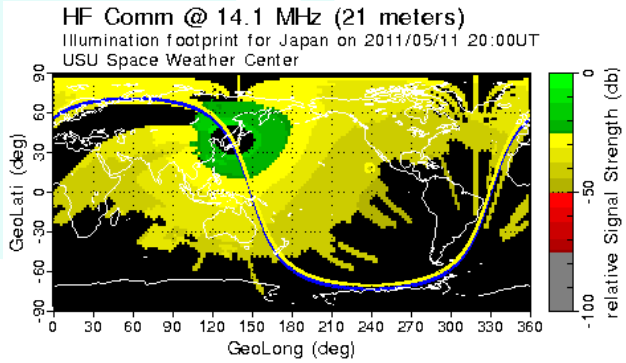

10,000 missing

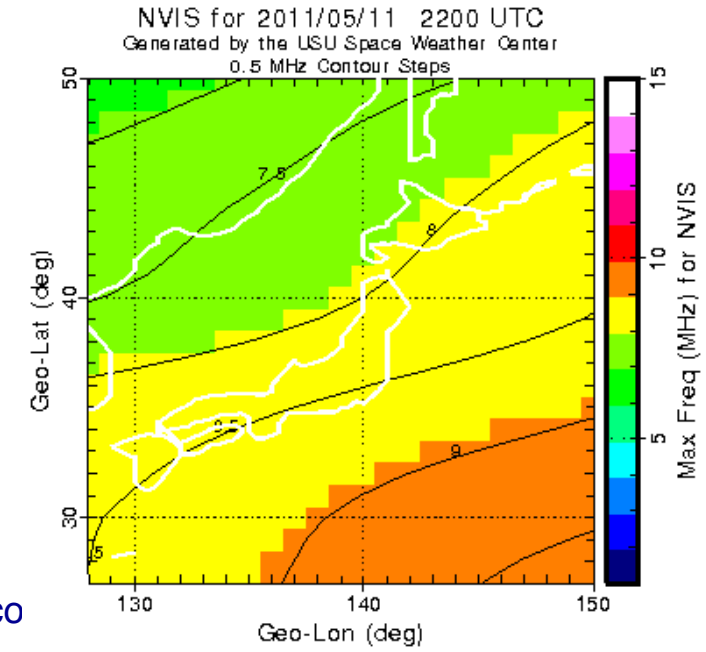

14,000 dead


Unusable
cell phone
tower

HF communication aid was provided for Japanese disaster response

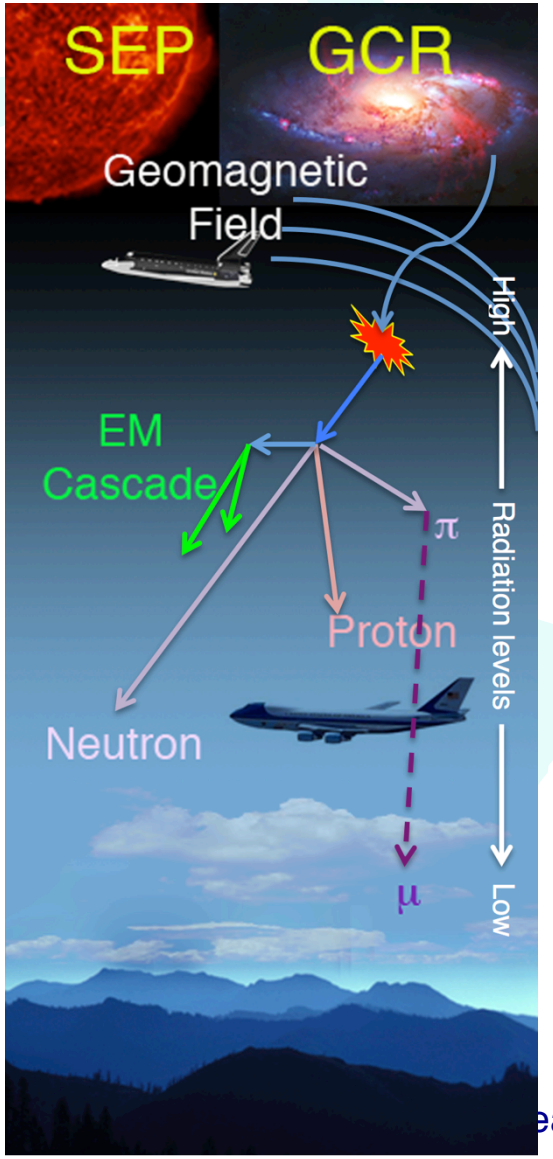
- Frequencies to transmit over nearby mountains.
- 3-hour forecast of frequencies.
- Recommendation of available frequencies to global operators.
- Available HF frequencies for Emergency Responders



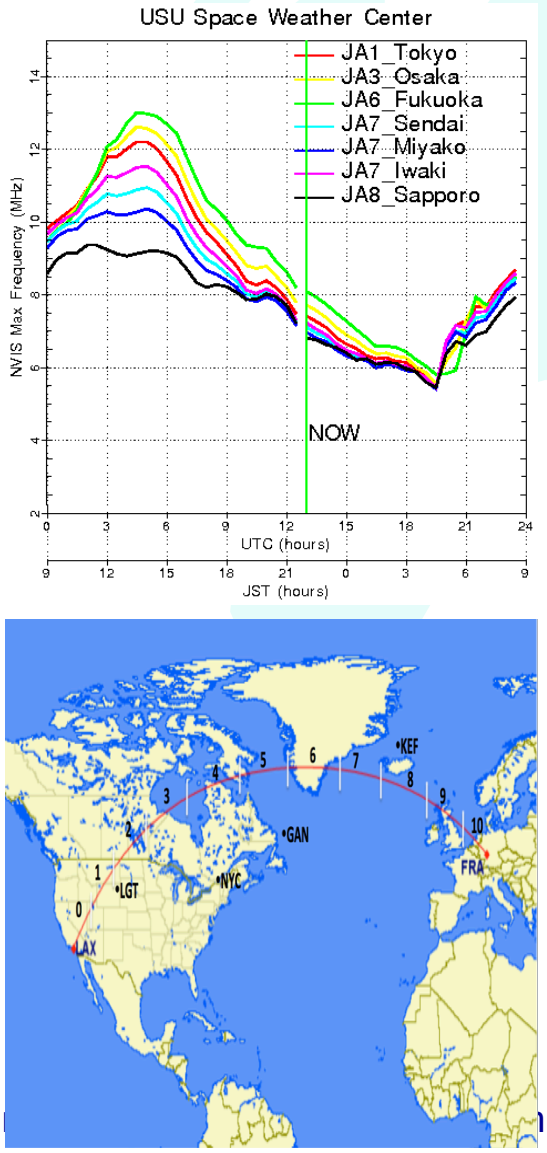


Space Weather effects on aviation

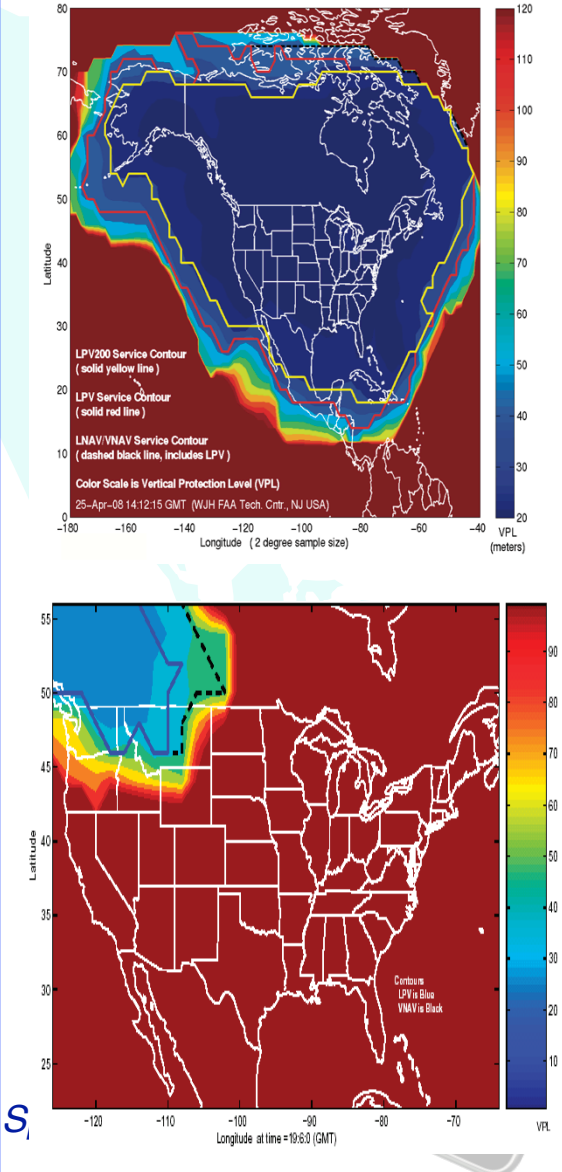
Radiation exposure



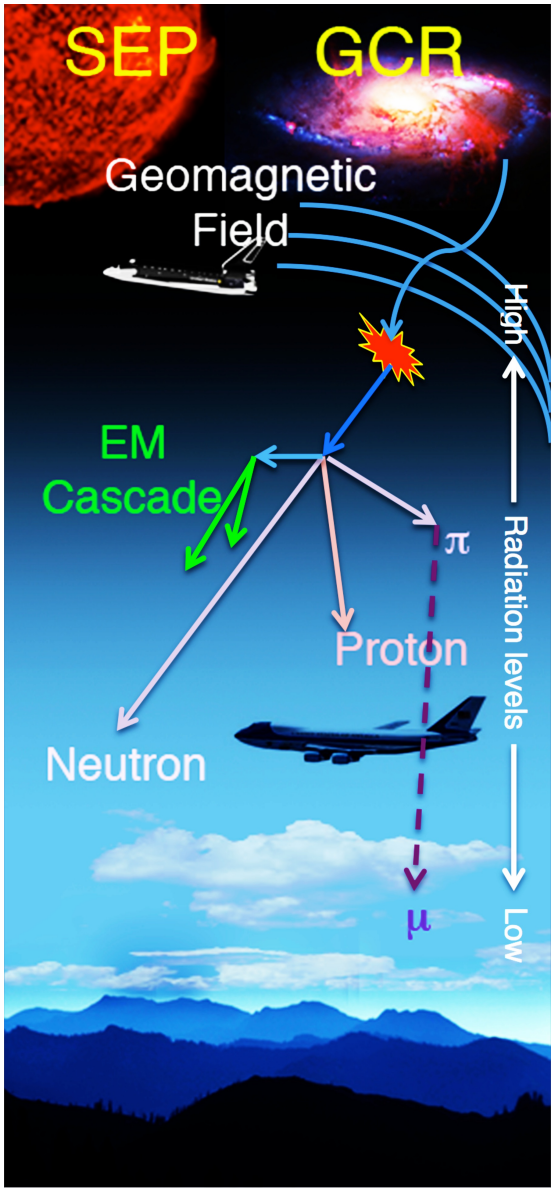
HF communication outages



WAAS navigation error

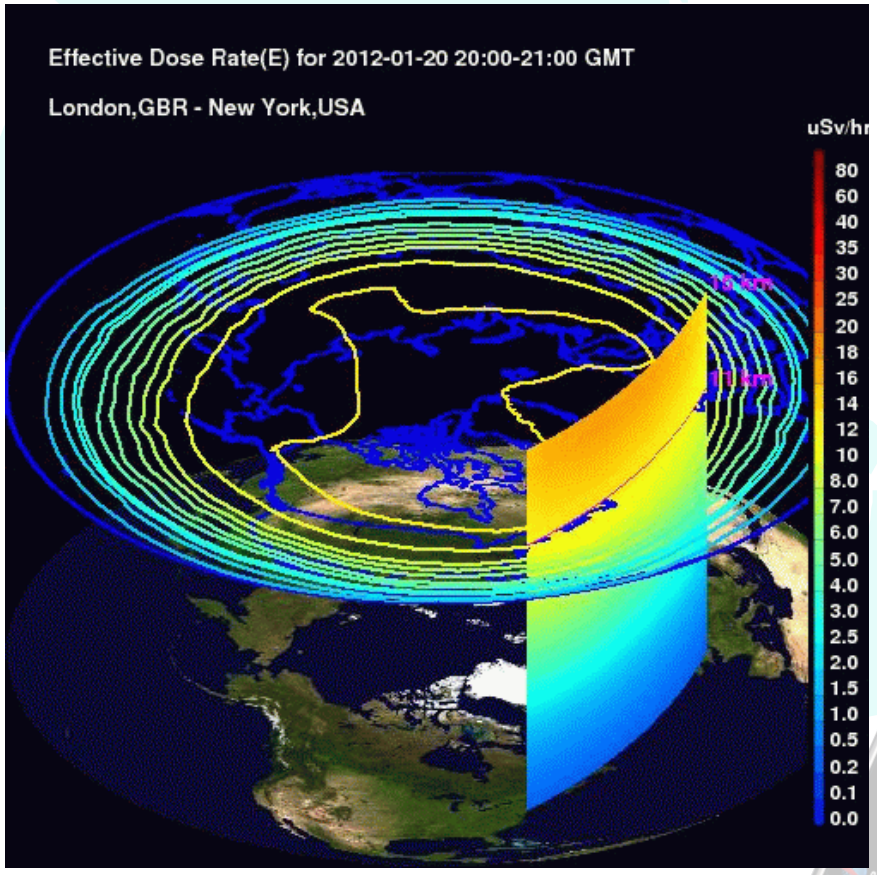


Aviation radiation environment specification

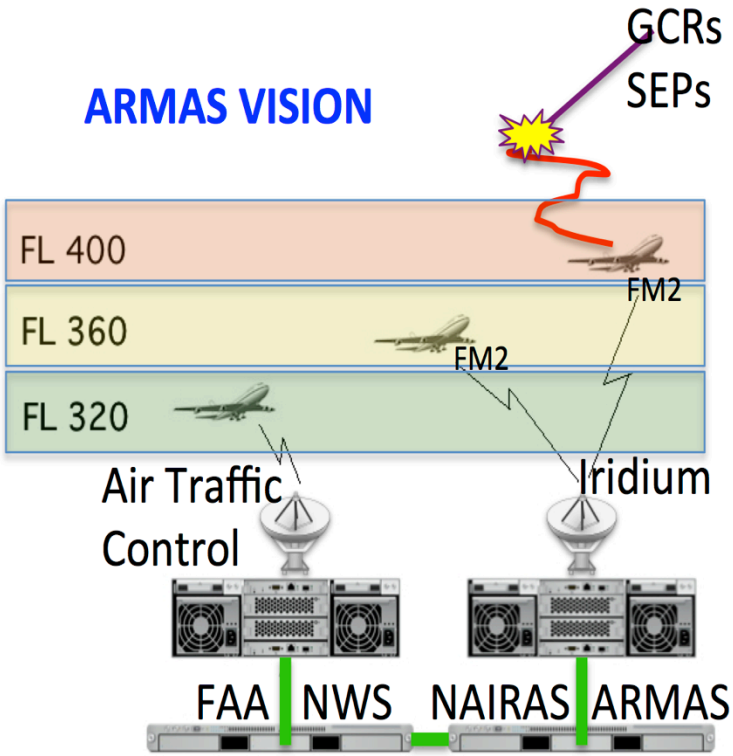


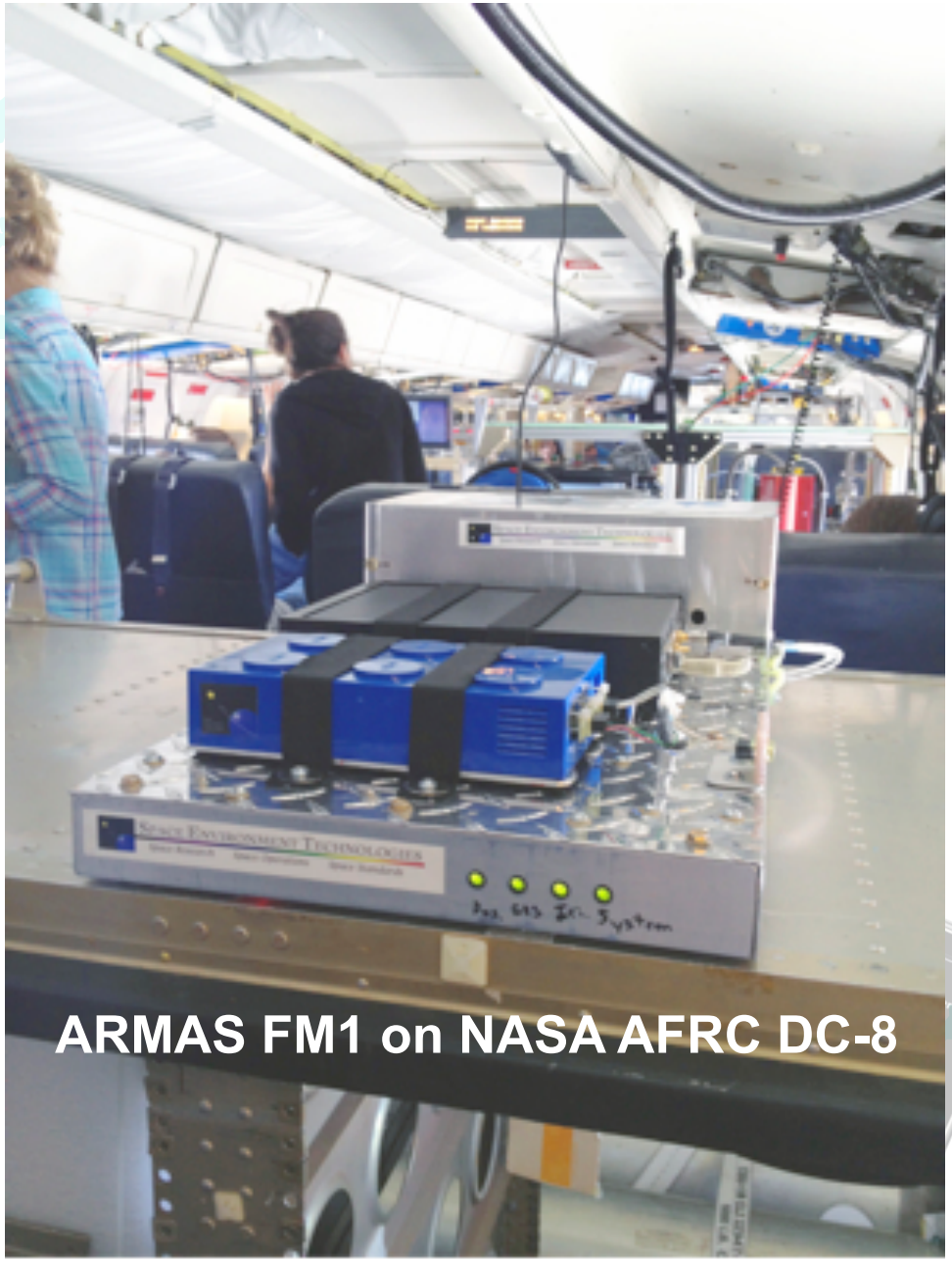
Real-time global aviation radiation climatology

NAIRAS

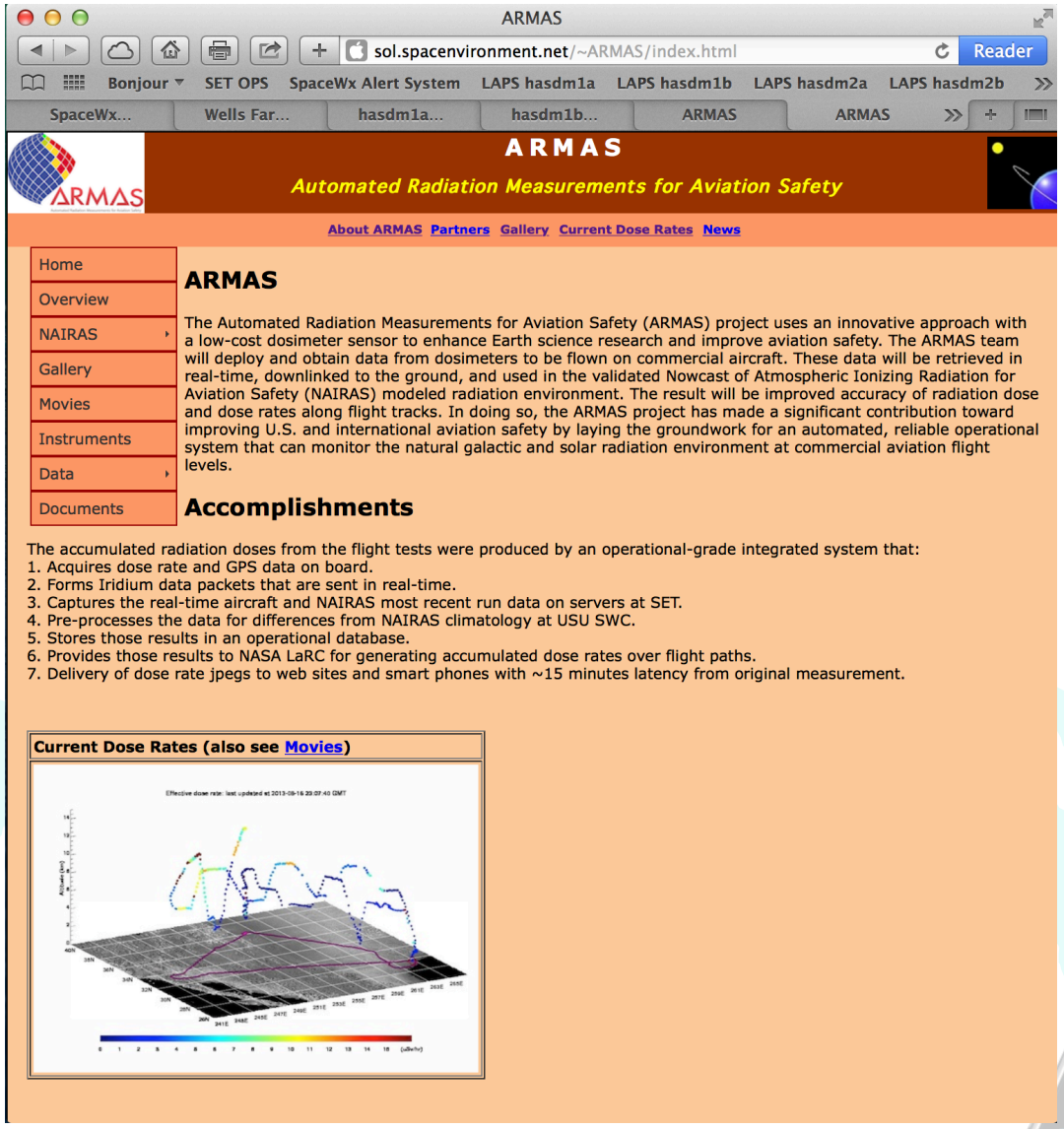


Strategy for real-time local aviation radiation measurements

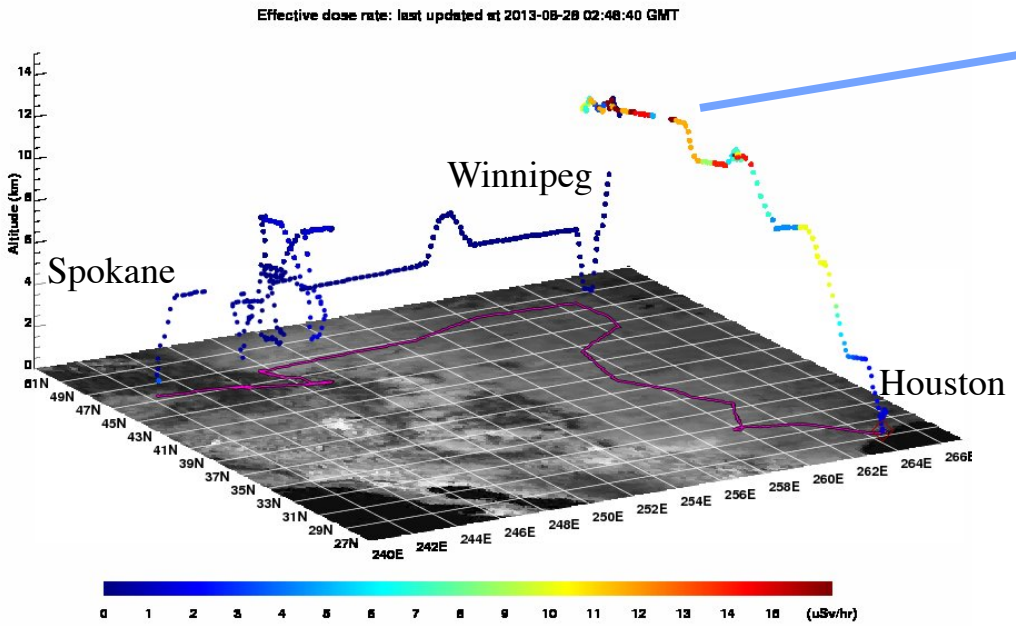


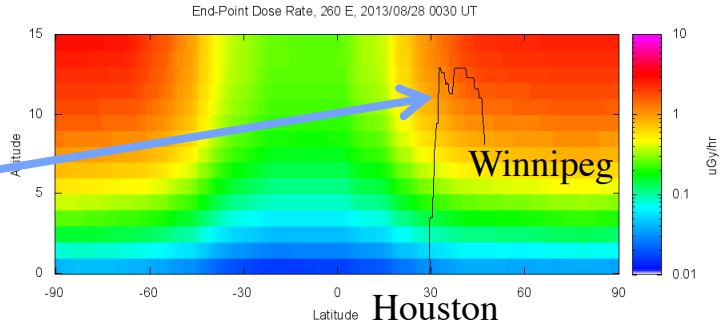


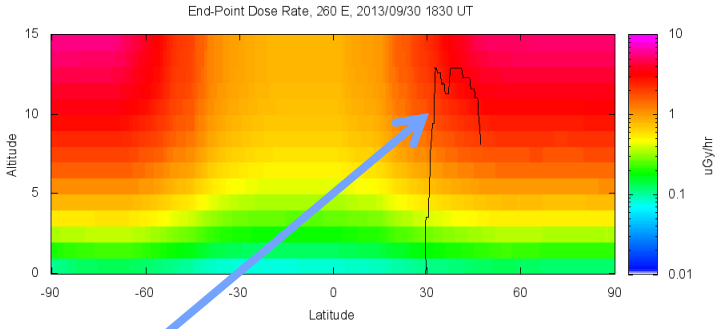
Real-time Automated Radiation Measurements for Aerospace Safety (ARMAS) website

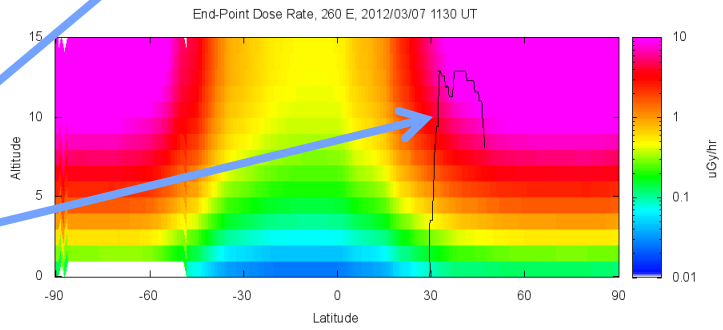


ARMAS FM1 (2013-2014) – flight 18 example





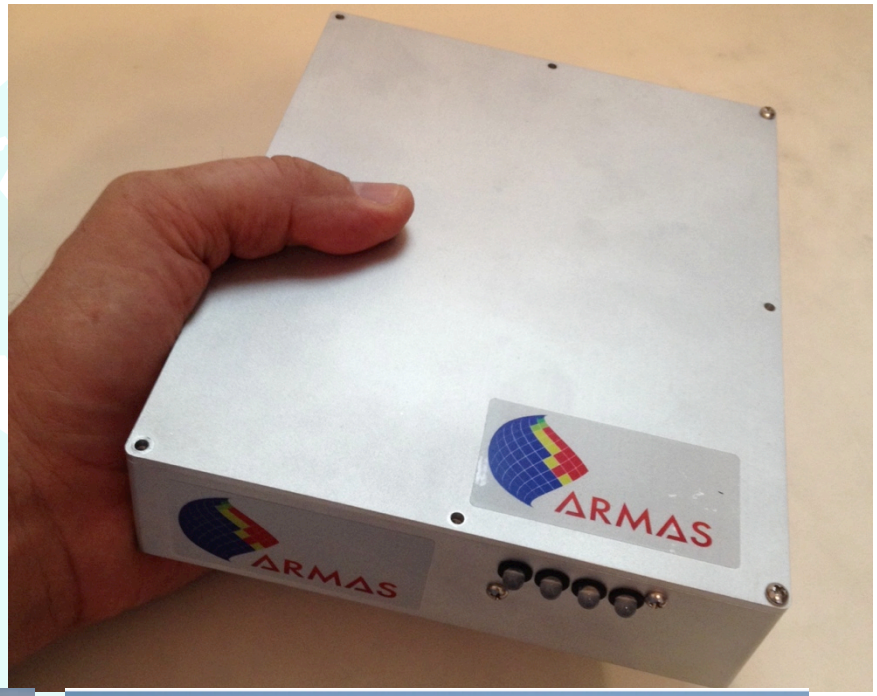




- **Top:** ARMAS flight 18 (August 28, 2013)
- **Middle:** S2 event (September 30, 2013)
- **Bottom:** S3 event (March 7, 2012)

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

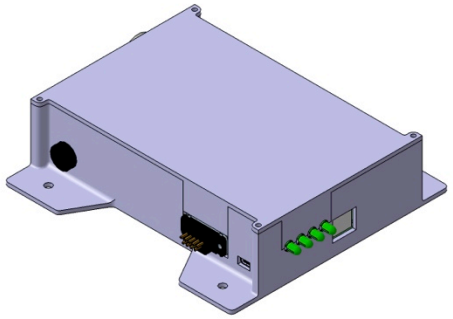



NSF G V


NOAA G IV

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



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

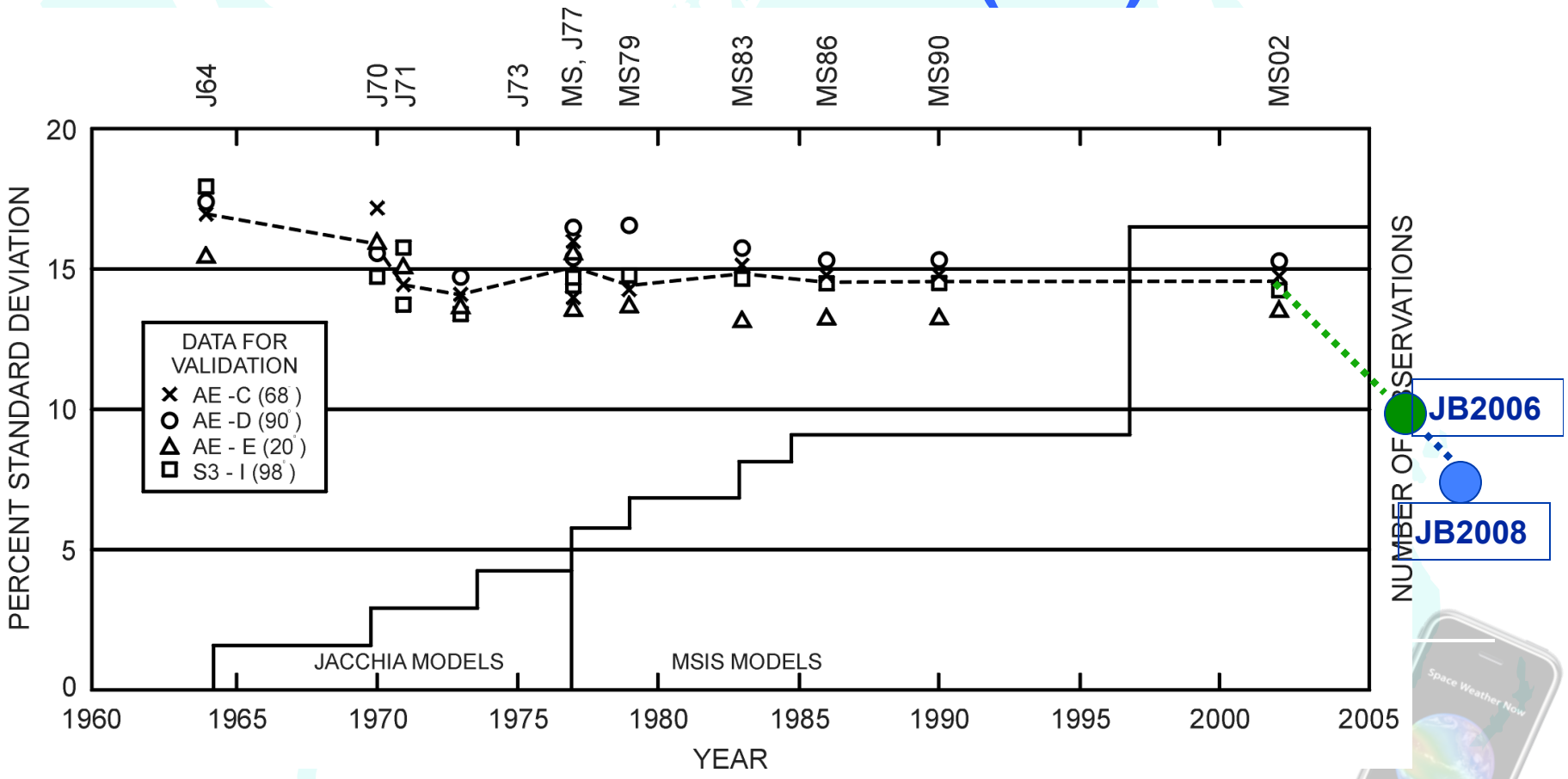
ARMAS 2015 FM5 on business jets

ARMAS-Lite FM5

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

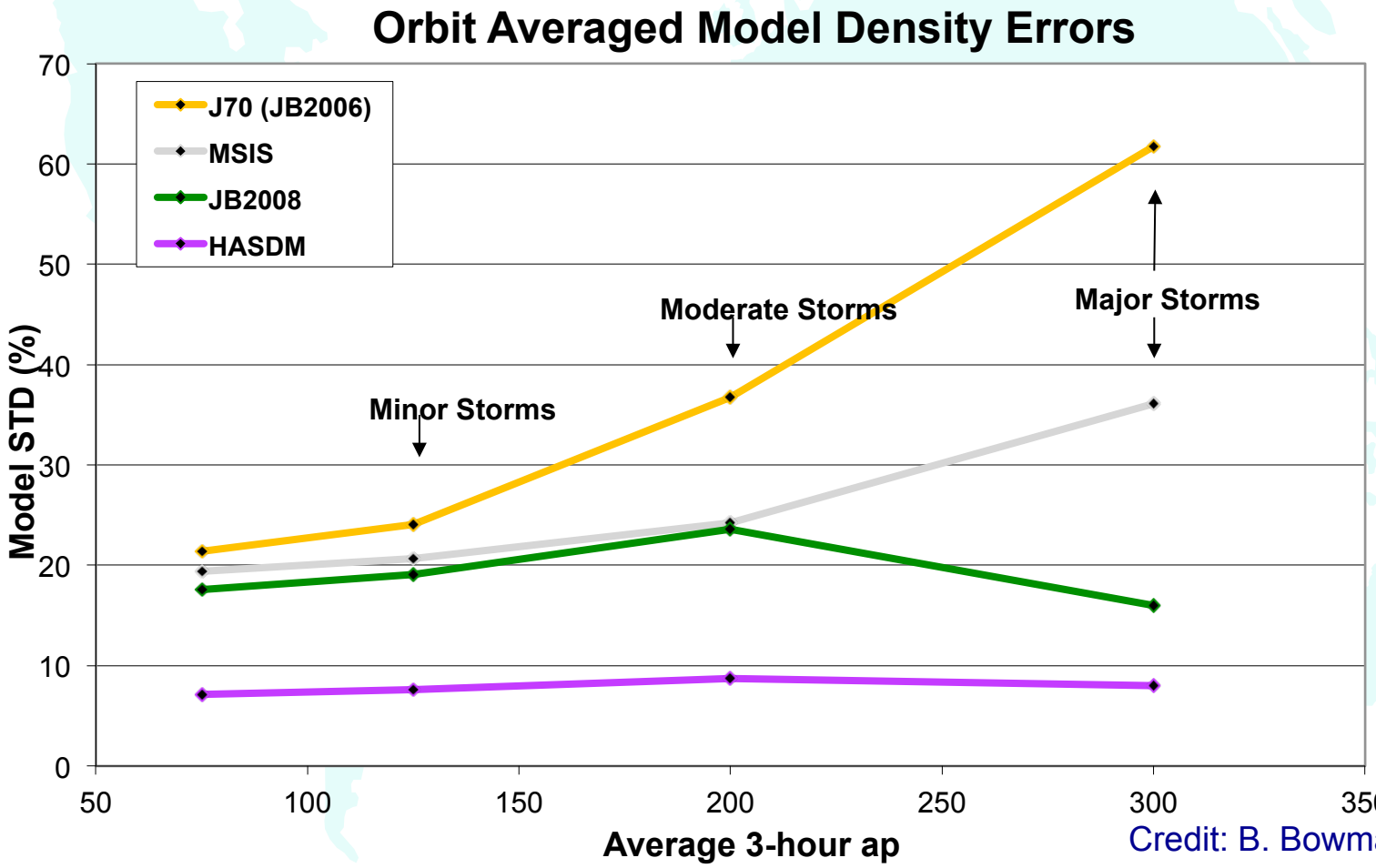
Satellite conjunction avoidance

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



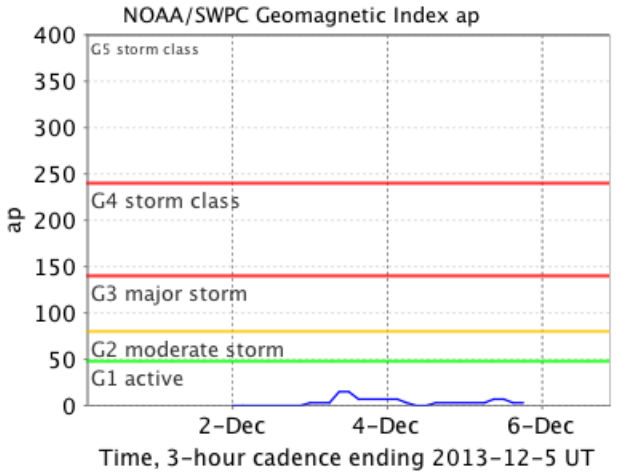
Credit: F. Marcos

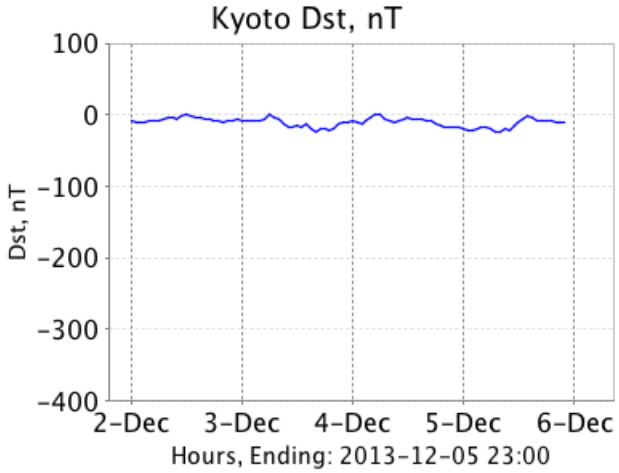
Orbit Average Density Error for Geomagnetic Storms

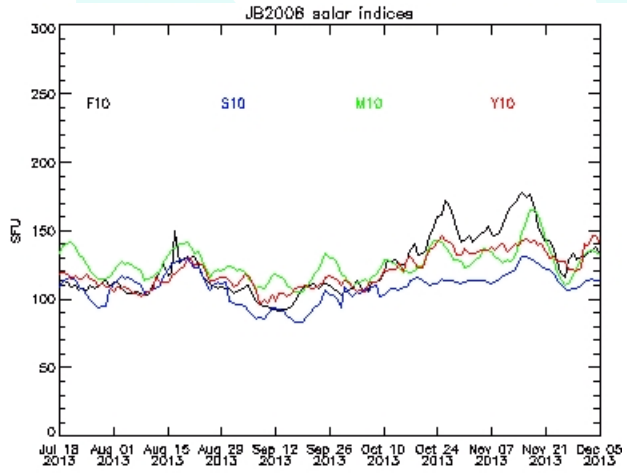


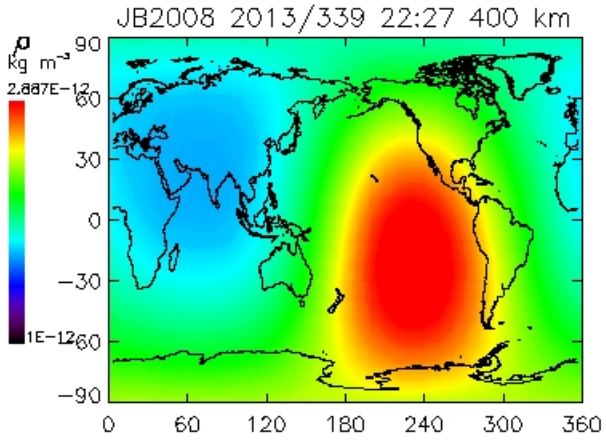
Credit: B. Bowman

JB2008 Indices



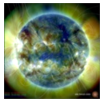


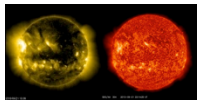


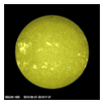


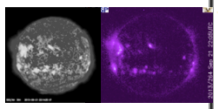
JB2008 Thermosphere – Solar irradiance drivers

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 tel-escope	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, SOL-STICE, GOME	1991-2013	2 times/day	Up to 24 hours	yes (c)
$Y_{10.7}$	GOES-12, UARS, SORCE, TIMED	XRS, SOL-STICE (2), SEE	1991-2013	1 minute, 16 times/day	Up to 10 min-utes, up to 48 hours	(b)

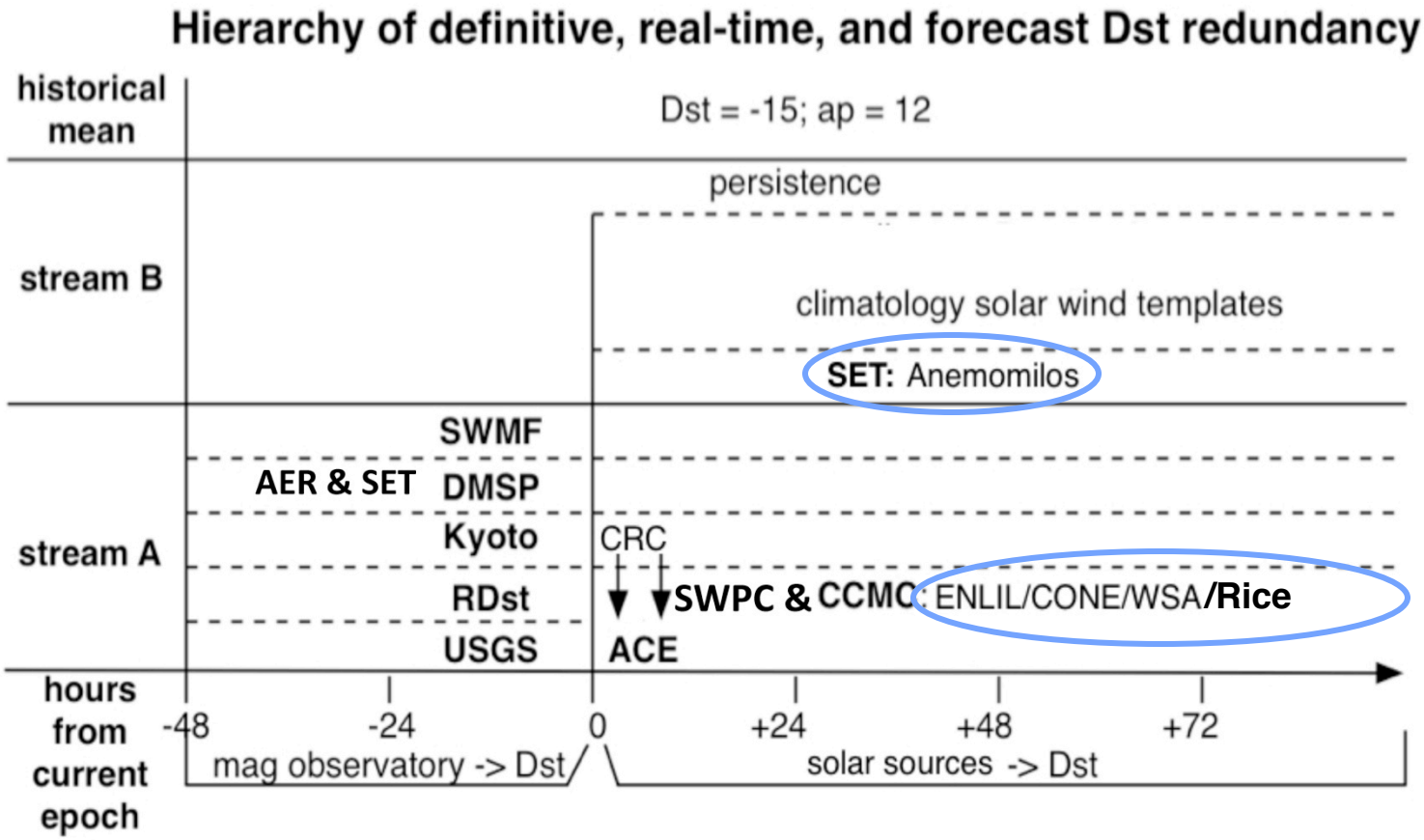
(a) SOHO/SEM is a NASA research instrument but provides daily irradiances on an operational cadence; GOES 13 EUVS B channel makes measurements in the same bandpass as SOHO SEM.

(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



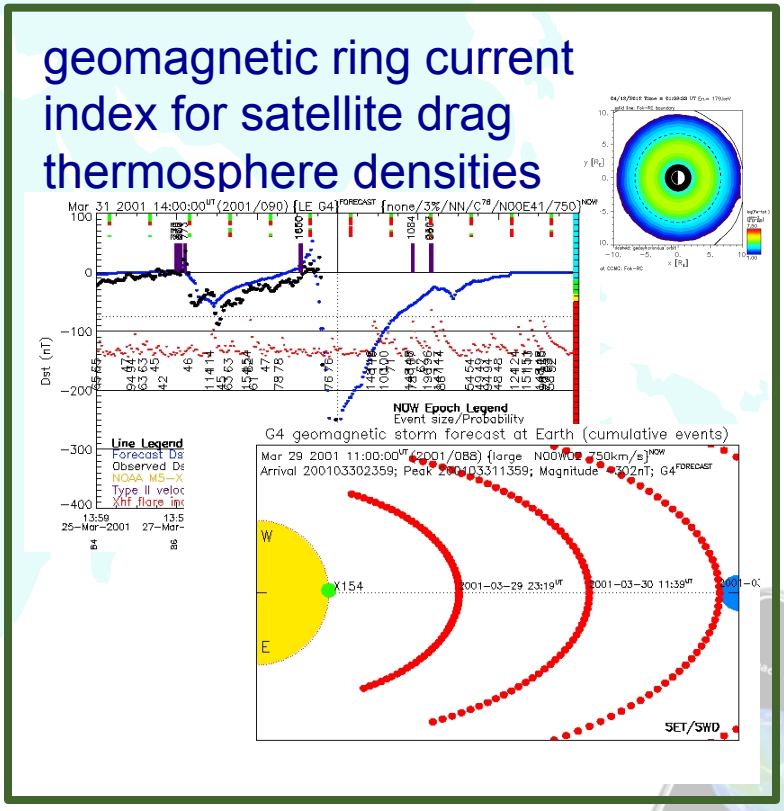
Operational Dst requirement: -48 to +72 hours with 3-hour granularity, 3-hour latency

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

Solar wind/magnetosphere

SET's *Anemomilos*

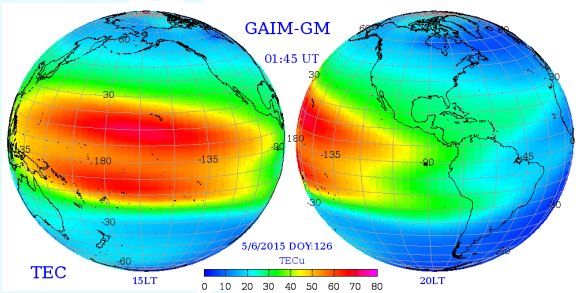
- Greek word for "windmill"
- 6-day forecast of hourly Dst with 1-hour latency
- data-driven deterministic algorithm using 3 solar observables to identify geoeffective events

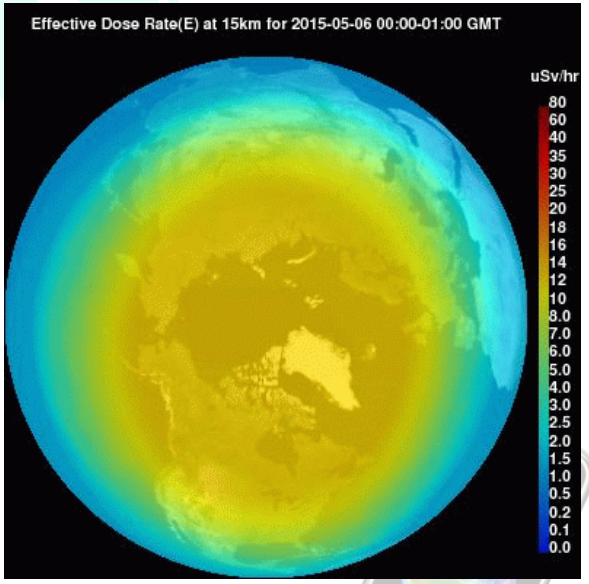


Space Weather Community Operations Workshop (SpWxCOW) lessons

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

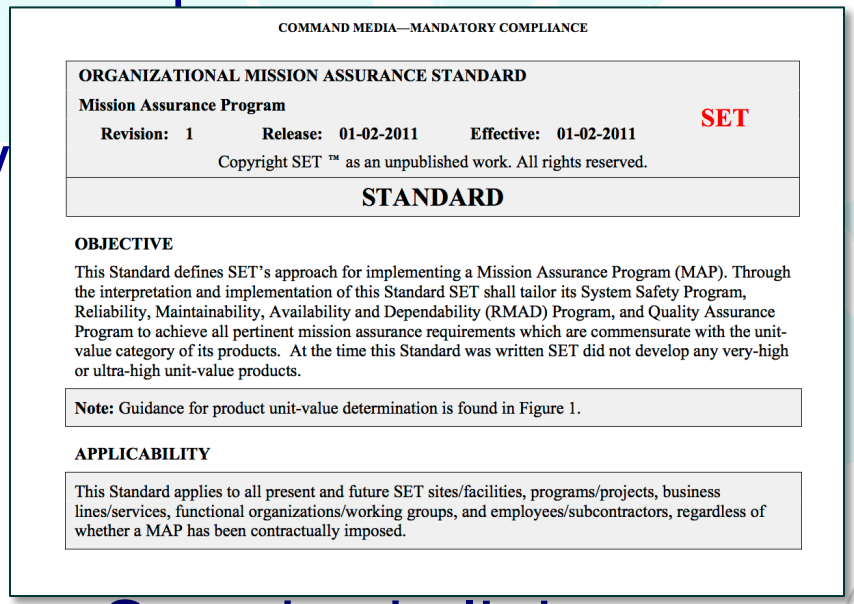
Workshop deliverables

- ✓ ***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

SET

Revision: 1 **Release: 01-02-2011** **Effective: 01-02-2011**

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 Mall

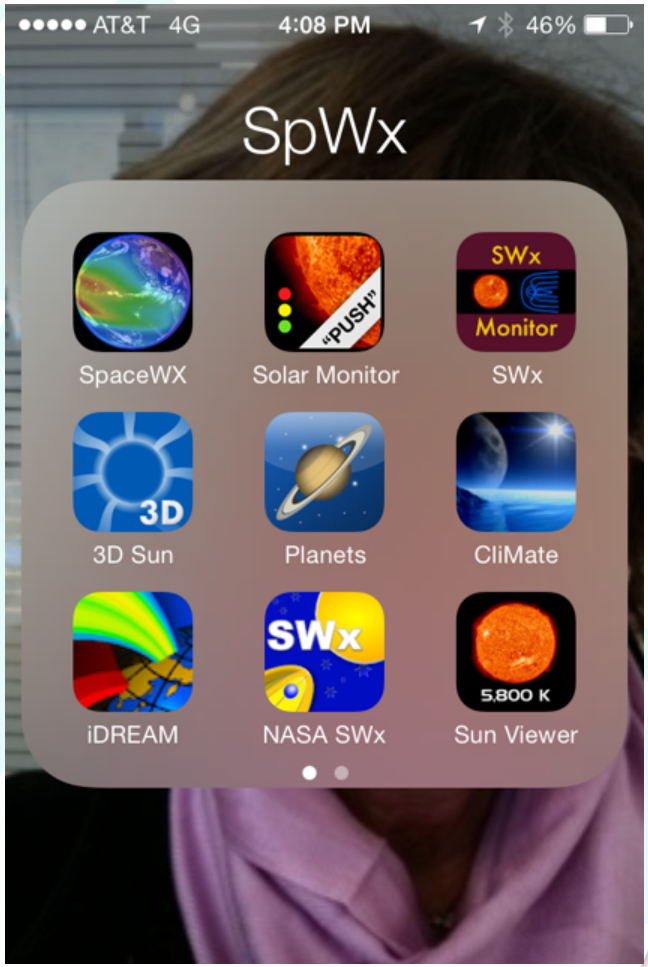
- ✓ Twitter automated feeds:
  - ✓ SEC (@spacenv) and SET (@spacenvironment) implemented Twitter feeds in 2012
  - ✓ Hashtags in use are #spaceweather, #spwx, @spacewx, #sunspot, #sun, #aurora, #cme, #solarflare
  - ○ Examine hashonomy.com/hashtag/spaceweather
  - ○ Recommended list: issuing organization, 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