

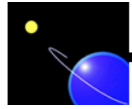
Demonstration of operational real-time space weather prototypes for aviation radiation and magnetospheric sub-storms

AIAA-2011-1059

January 5, 2011

W. Kent Tobiska

Space Environment Technologies



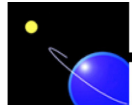
Thanks to team members

Magnetosphere Alert and Prediction System (MAPS)

- ***Space Environment Technologies:*** W. Kent Tobiska, Dave Bouwer, Bill Burke, Pat Hagan, Rian Shelley, Dusan Odstrcil, Delores Knipp
- ***USGS:*** Jeffrey Love, Jennifer Gannon
- ***ISTI:*** Paul Friberg
- ***Carmel Research Center:*** Devrie Intriligator
- ***Space Environment Corporation:*** Bob Schunk. Vince Eccles
- ***Air Force Space Command:*** Bruce Bowman
- ***CCMC:*** Michael Hesse, Masha Kuznetsova

Radiation Alert and Prediction System (RAPS)

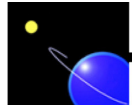
- ***Space Environment Technologies:*** W. Kent Tobiska, Dave Bouwer
- ***NASA Langley Research Center:*** Chris Mertens
- ***Dartmouth College:*** Brian Kress
- ***NCAR/HAO:*** Stan Solomon, Michael Wiltberger
- ***NOAA SWPC:*** Joe Kunches
- ***NIOSH:*** Barbara Grajewsky
- ***Prairie View A&M University:*** Brad Gersey
- ***Boeing:*** Bill Atwell



Space weather systems' status

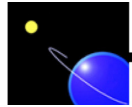
New systems transitioning into operations

- **MAPS** – Magnetosphere Alert and Prediction System (Operational Real-time and Forecast Dst)
 - **Validation process:** USGS, SEC, CCMC, & DMSP comparisons with Kyoto Dst for definitive and quick-look data (2009–2010)
 - **TRL status:** 7 (Q4 2010), 8 (Q3 2011), 9 (Q4 2011)
 - **Users:** LEO satellite operators who require operational geomagnetic Dst index for atmosphere density specification and forecast
- **RAPS** – Radiation Alert and Prediction System (Aviation radiation)
 - **Validation process:** ARMAS project flights of TEPC instrument for comparison with NAIRAS system results (March-September 2011)
 - **TRL status:** 7 (Q4 2010), 8 (Q2 2011), 9 (Q1 2012)
 - **Users:** commercial and military aviation crew and frequent fliers



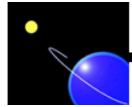
MAPS: Magnetosphere Alert and Prediction System (Operational Real-time and Forecast Dst)

- **Concept:** provide a real-time ring current disturbance storm time index (Dst) characterizing the magnetosphere's perturbation by the solar wind that can be used by operational systems for neutral thermospheric densities, that is calibrated with the Kyoto definitive Dst, and that has a 72-hour forecast.
- **Implementation status:** Phase I SBIR study complete with overall system definition; internal team website running with 4 Dst data sets (Kyoto, USGS, RDst, CCMC) in real-time at TRL 8; Phase II on contract in March 2010.
- **Tasks in 2011:** USGS Dst, SEC RDst TRL 9 capability; system level redundancy with multiple operational Dst data streams; ensemble modeling Dst forecast to 72 hours using ENLIL solar wind; and a functioning distributed network.
- **Users:** AFSPC and LEO satellite operators who require operational geomagnetic Dst index for atmosphere density specification and forecast; the JB2008 model system will be a primary user of Dst.

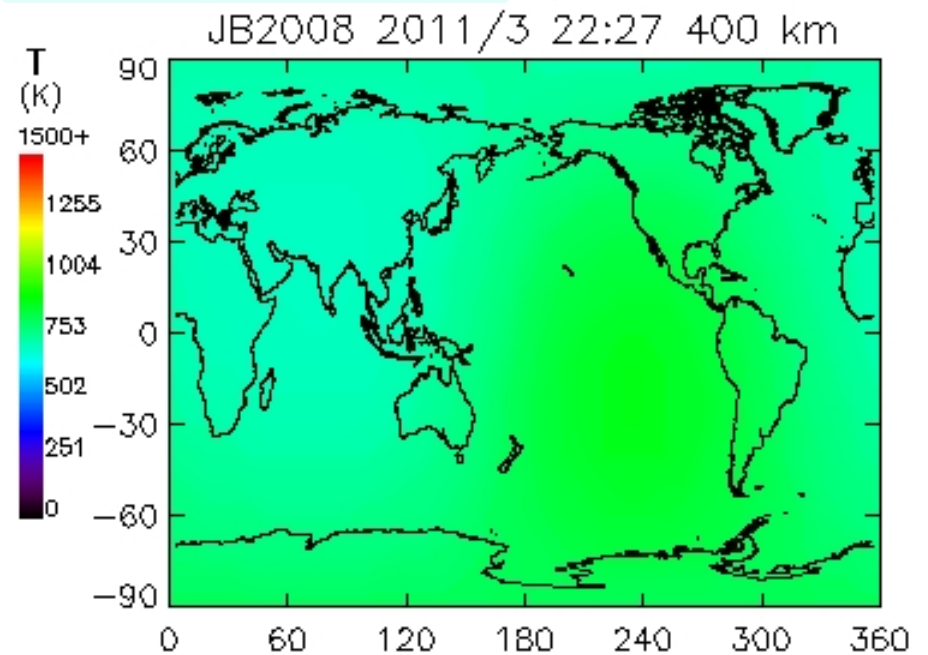
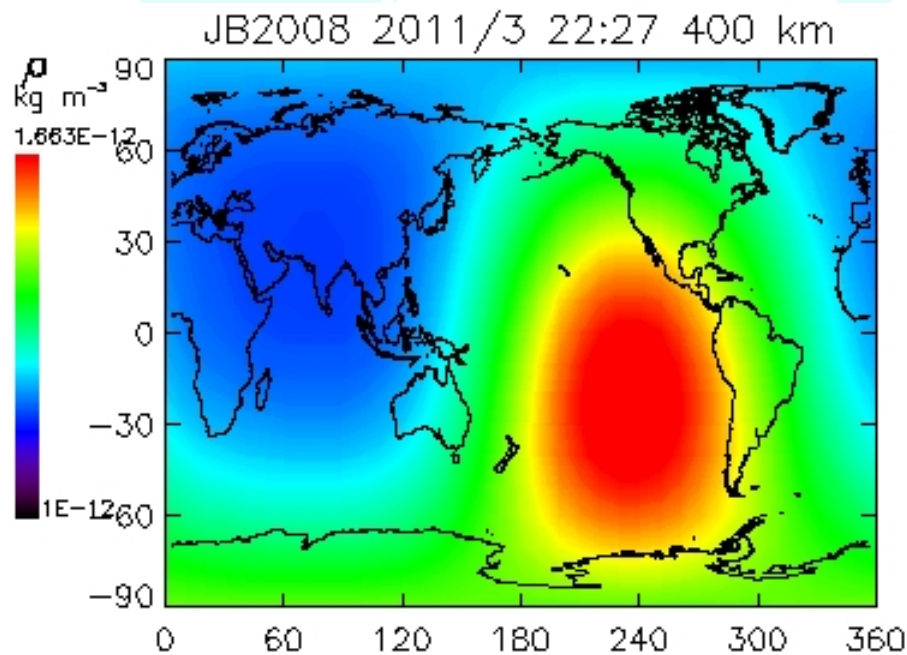


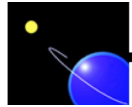
Motivation: JB2008 improves LEO satellite orbit determination For LEO satellite users

- **Legacy capabilities (2010) (global historical):**
 - neutral mass density accuracy based on empirical JB2008 with S10, M10, Y10, F10 solar indices and ap, **Dst geomagnetic indices**
 - 137-day forecast daily densities, updated hourly, latency 1 hour
 - global 3D density visualization is available
- **Coming capabilities (2011) (global):**
 - improved global 3D density visualization and forecast data access for given orbits
 - **Improved Dst redundancy and forecast using USGS Dst**
 - Improved 0-7 day solar forecast



JB2008 densities and temperatures





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Space Weather Division

MAPS and RAPS

JB2008 website

<http://sol.spacenvironment.net/~JB2008/>

JB2008 Home

<http://sol.spacenvironment.net/~JB2008/>

MAPS ops MAPS RAPS ops NAIRAS CAPS ops CAPS terra1 s2kops USTAR GAIM SWC Wells Fargo DEN

JB2008

The Jacchia-Bowman 2008 Empirical Thermospheric Density Model

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Dear Colleague,

Welcome to the JB2008 empirical thermospheric density model website. Please provide your [name and email address](#) if you desire to be notified about updates to the JB2008 model, and the availability of forecasts.

[\[click here to register for updates\]](#) *

Please note that cookies must be enabled in your Browsers Preferences to register. Your local installation may have firewall implementations that prevent cookies or Java servlet protocols, in which case you should email spacenvironment@spacenvironment.net with "JB2008" in the subject line to receive updates.

Thank you,

Space Environment Technologies

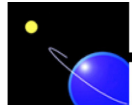
[Current Server Status](#)

Last Website Update 15 Nov 2009

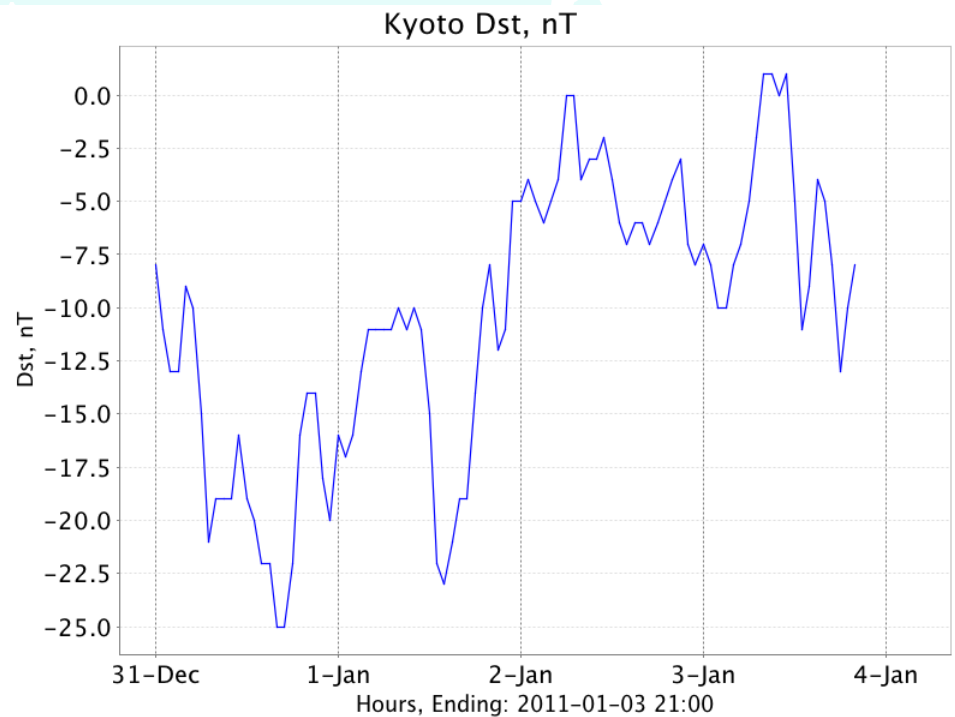
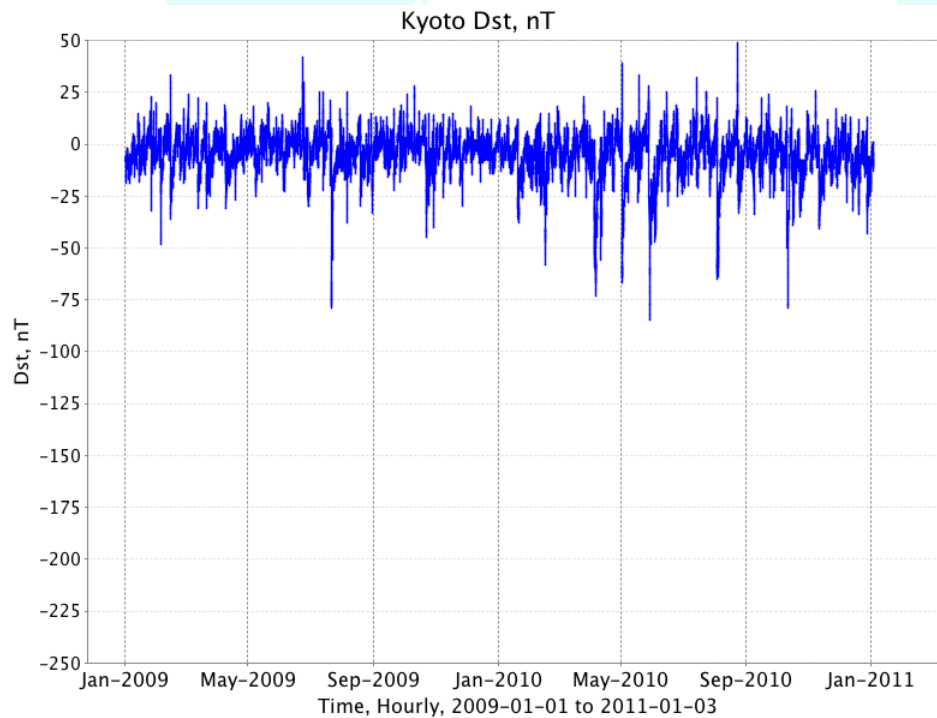
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<http://SpaceWx.com>

Tobiska

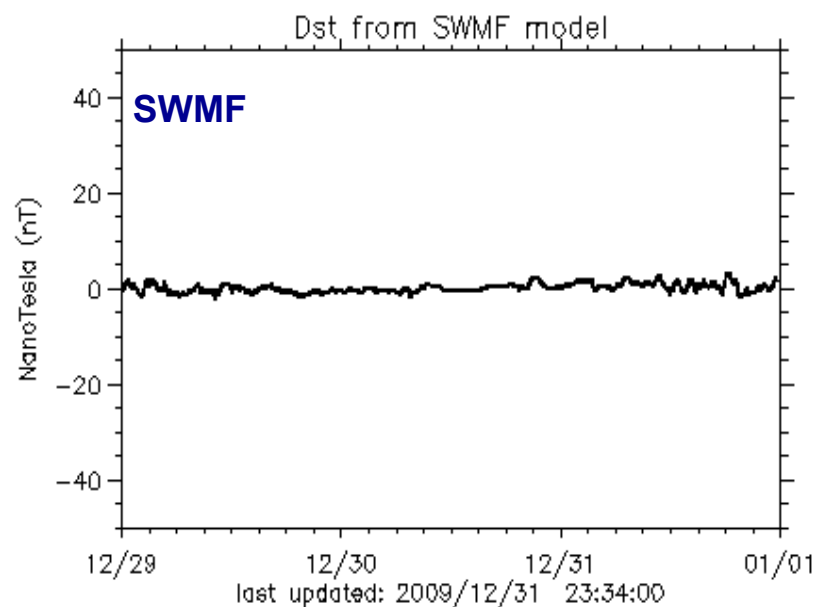
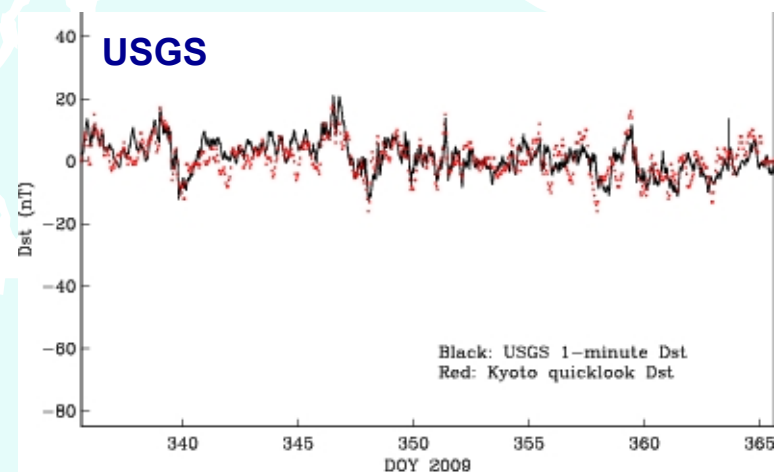
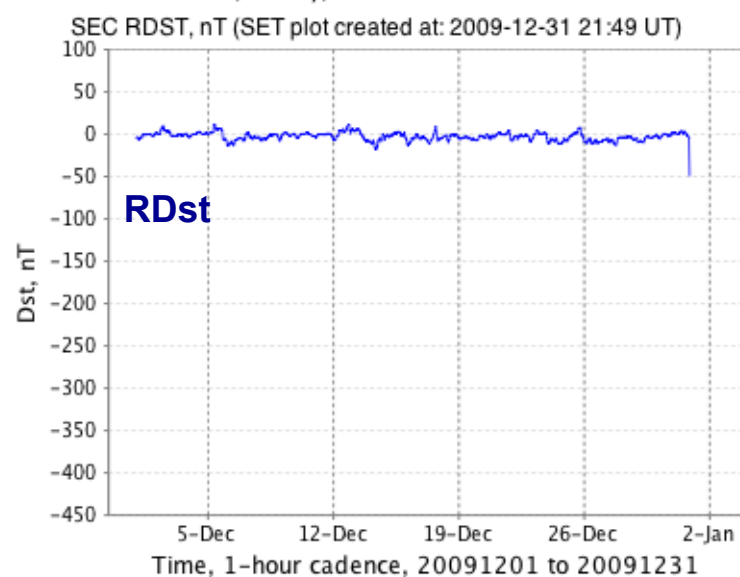
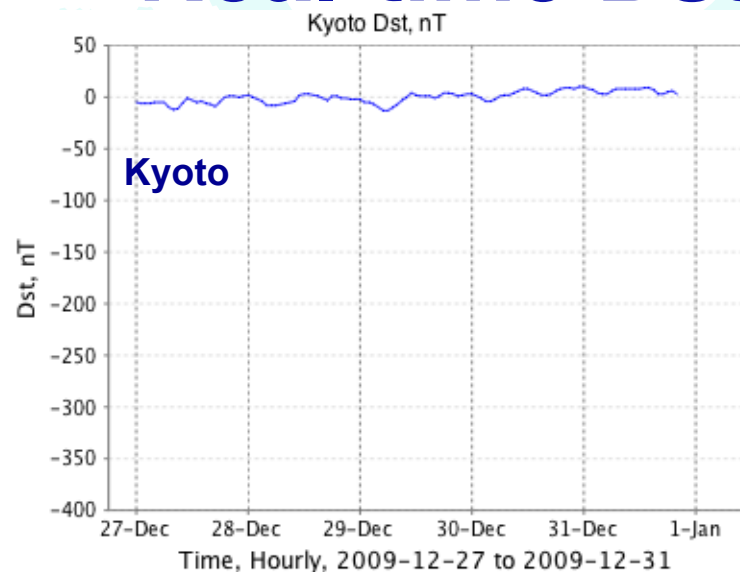


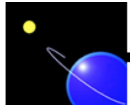
Dst Validation: Use Kyoto definitive and quick-look Dst





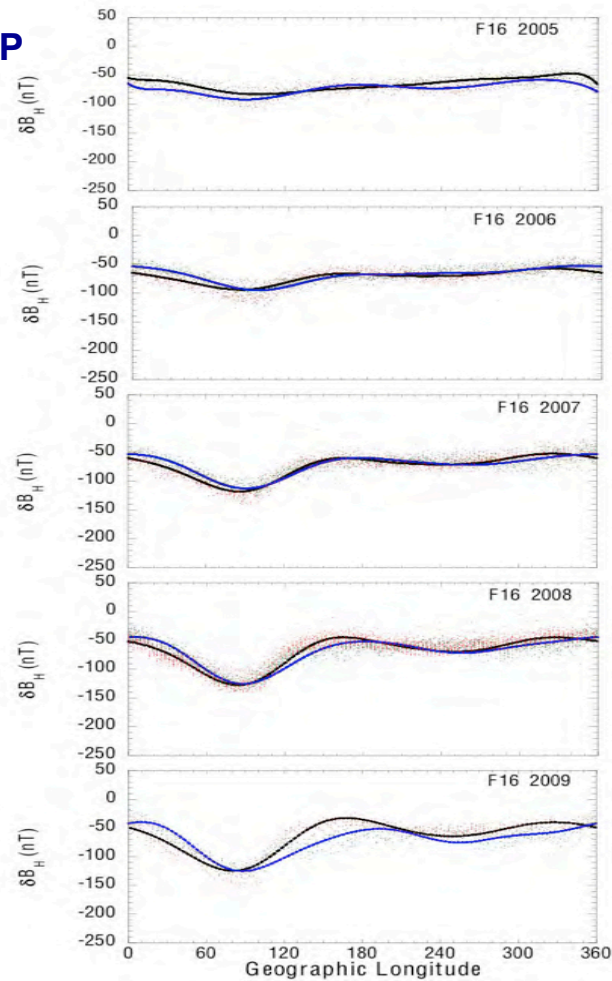
Real-time Dst redundancy – 1





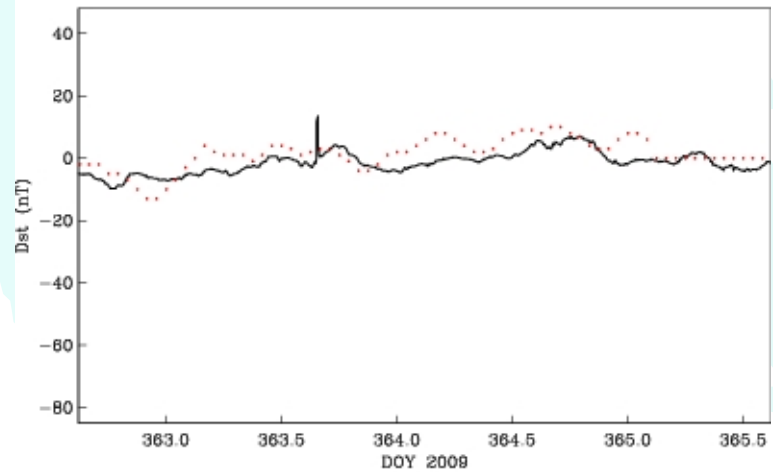
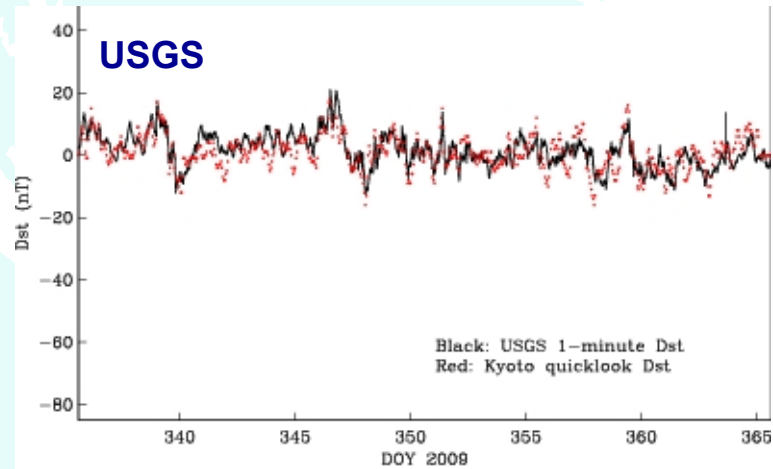
Real-time Dst redundancy – 2

DMSP



<http://SpaceWx.com>

USGS



Thu Dec 31 22:56:48 2009
US Geological Survey

Tobiska

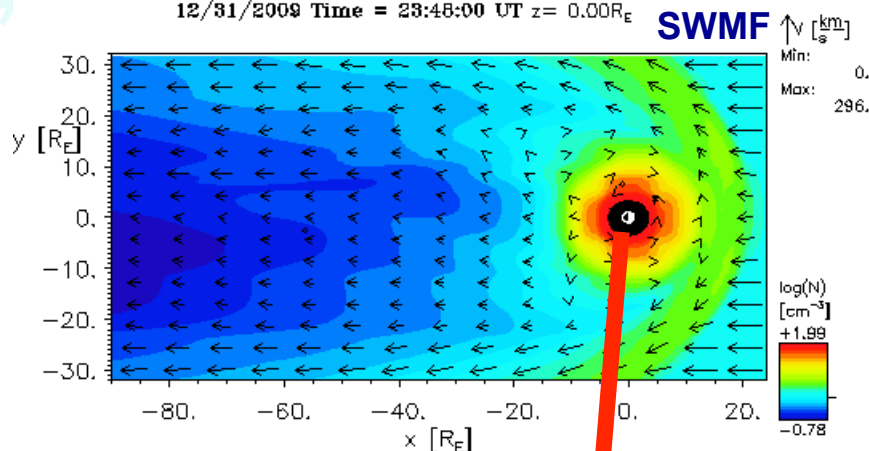


MAPS will provide forecast of Dst

Magnetosphere perturbed by solar wind

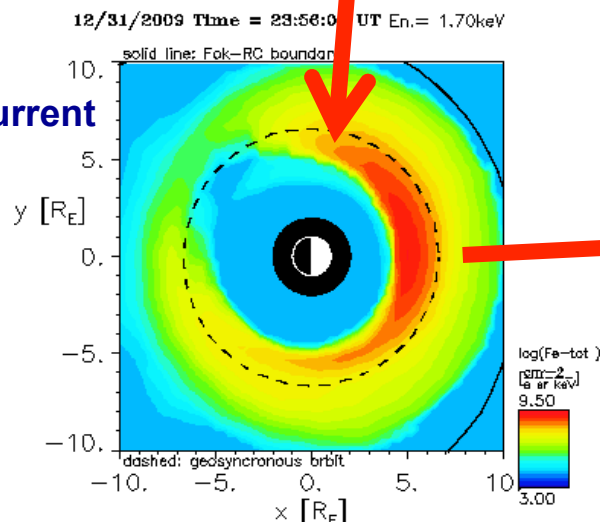
12/31/2009 Time = 23:48:00 UT $z = 0.00R_E$

SWMF



Model at CCMC: BATSRUS

Ring current



Model at CCMC: Fok-RC

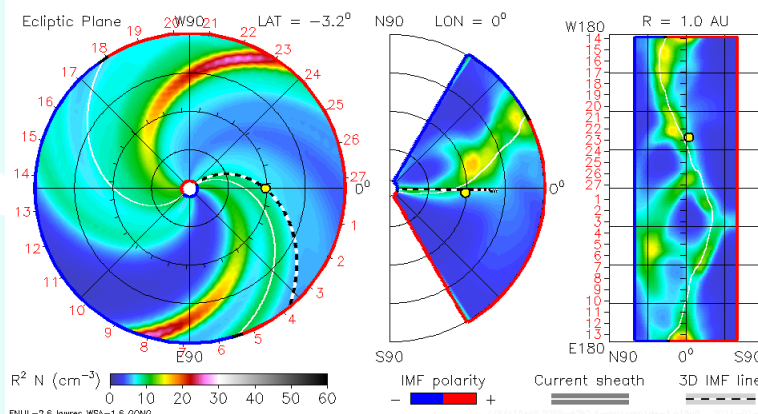
<http://SpaceWx.com>

2011-01-03 23:29:46

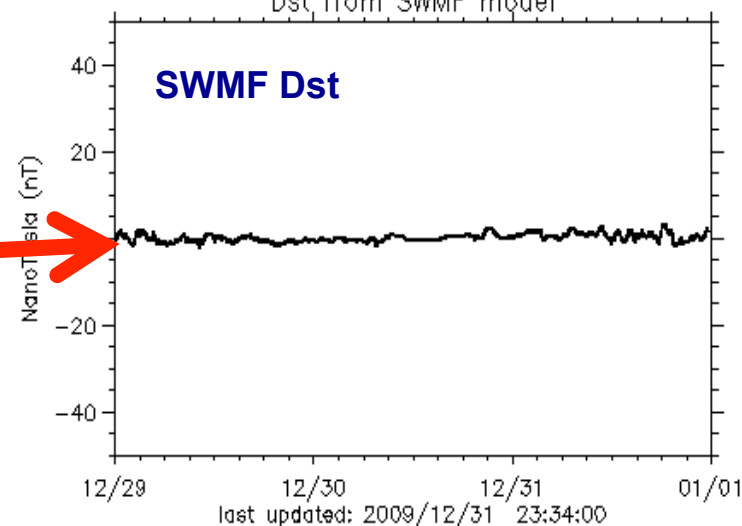
Earth

ENLIL

2010-12-12 +22.73 days

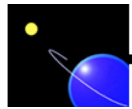


Dst from SWMF model



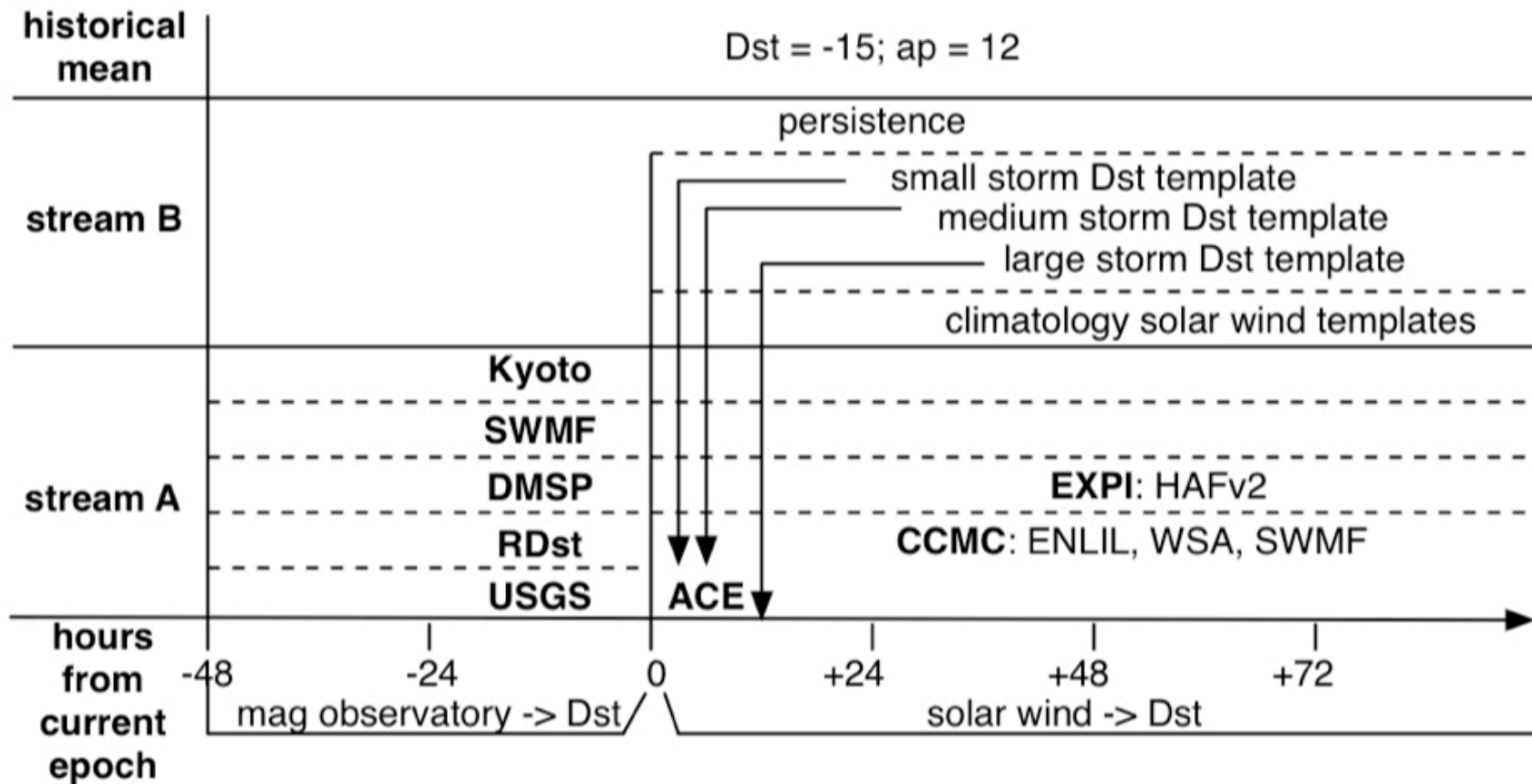
last updated: 2009/12/31 23:34:00

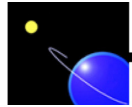
Tobiska



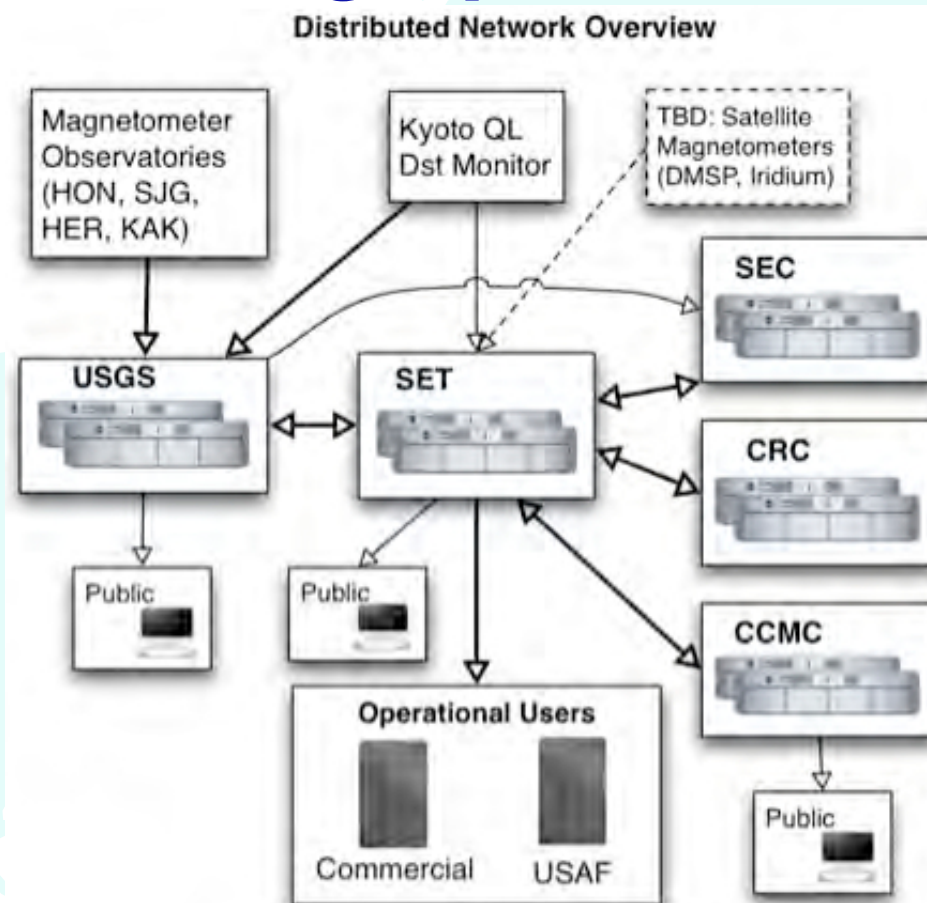
MAPS hierarchy for operational Dst

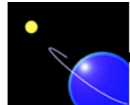
Hierarchy of definitive, real-time, and forecast Dst redundancy





MAPS uses a distributed network for producing operational Dst





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Space Weather Division

MAPS and RAPS

MAPS website

<http://sol.spacenvironment.net/~maps/>

Magnetospheric Alert and Prediction System

<http://sol.spacenvironment.net/~maps/> Google

MAPS ops MAPS NAIRAS RAPS ops CAPS ops CAPS USTAR GAIM terra1 s2kops SWC SWC OPS SWC HF SpaceWx ap...velopment Intersog Wells Fargo EXOSTAR DEN QB online

Space Environment Technologies

MAPS
Magnetospheric Alert and Prediction System

[\[Data\]](#) [\[Docs\]](#) [\[Contacts\]](#) [\[maps_ops\]](#) [\[spacewx.com\]](#) January 4, 2011

Site Map

[Publications](#)
[Data](#)

MAPS

MAPS is the Magnetospheric Alert and Prediction System, an automated system delivering realtime Dst and Dst-related data products to the space weather community. They are being developed by Space Environment Technologies, U.S. Geological Survey, Space Environment Corporation, Carmel Research Center, Instrumental Software Technologies Inc., and the Community Coordinated Modeling Center under an Air Force Research Laboratory SBIR contract.

Future expansions of the MAPS site may include other magnetosphere-thermosphere-ionosphere energy inputs and drivers.

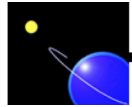
Objectives

Neutral atmosphere heating, whether from solar EUV, geomagnetic storms, or atmosphere dynamics (winds, waves, turbulence, eddies) is the main cause of density variations in the thermosphere between 100 and 1500 km altitude. For LEO satellites, these density changes can cause significant in-track errors within a single orbit. Because the Dst is an indicator of space weather disturbances by the solar wind upon the coupled magnetosphere-ionosphere-thermosphere system, there is a strong interest for having an operational index based on ground magnetometers located near the equator and/or from LEO satellites such as DMSP or potentially Iridium. This site provides access to Dst and Dst-products. Please also see links below.

- Related links:
 - [USGS](#)
 - [SEC](#)
 - [CRC](#)
 - [ISTI](#)
 - [CCMC](#)
 - [Kyoto](#)
 - [SET](#)

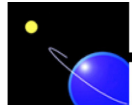
<http://SpaceWx.com>

Tobiska



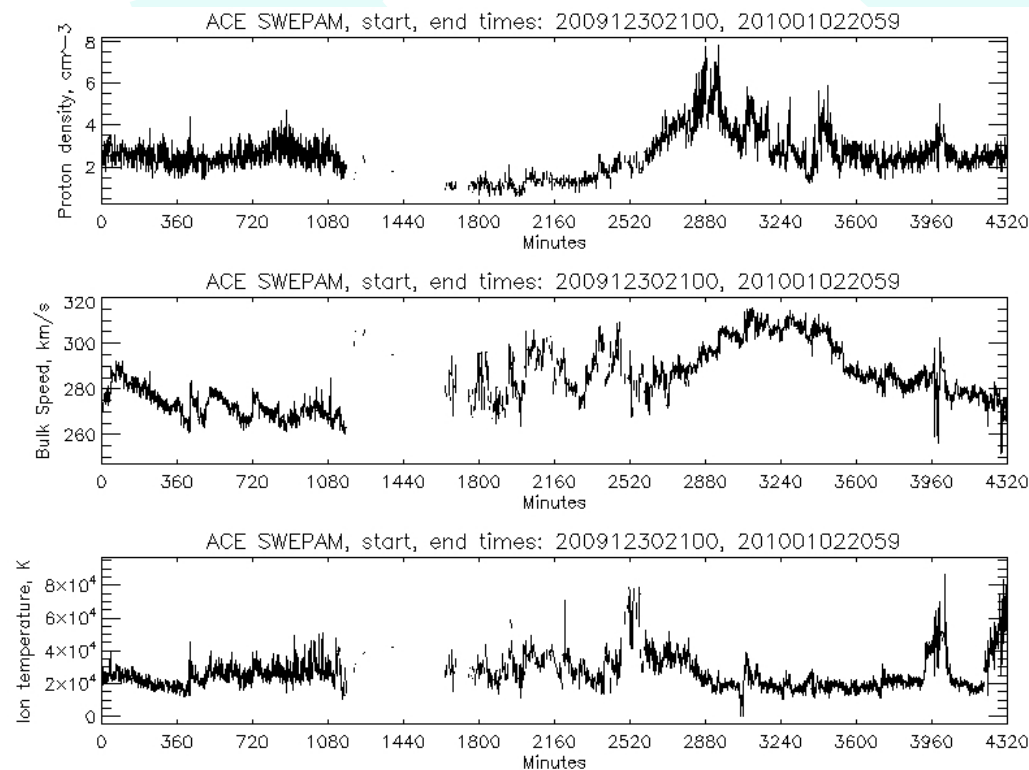
RAPS: Radiation Alert and Prediction System (Aviation radiation)

- **Concept:** need for nowcast prediction of air-crew radiation exposure from both background galactic cosmic rays (GCR) and from solar energetic particle (SEP) events that may result from solar storms; NAIRAS is being developed to provide global, data-driven, real-time radiation exposure predictions of biologically harmful radiation at commercial airline altitudes; dose and total dose will be provided at aviation altitudes in real-time.
- **Implementation status:** operational framework for distributed network has been developed at TRL 7; real-time data streams are being monitored and test case data has been collected.
- **Tasks in 2011:** link models in operational run testing with data streams, validate/verify, then move to TRL 8 prototype system demonstration.
- **Users:** commercial and military aviation crew and frequent fliers.

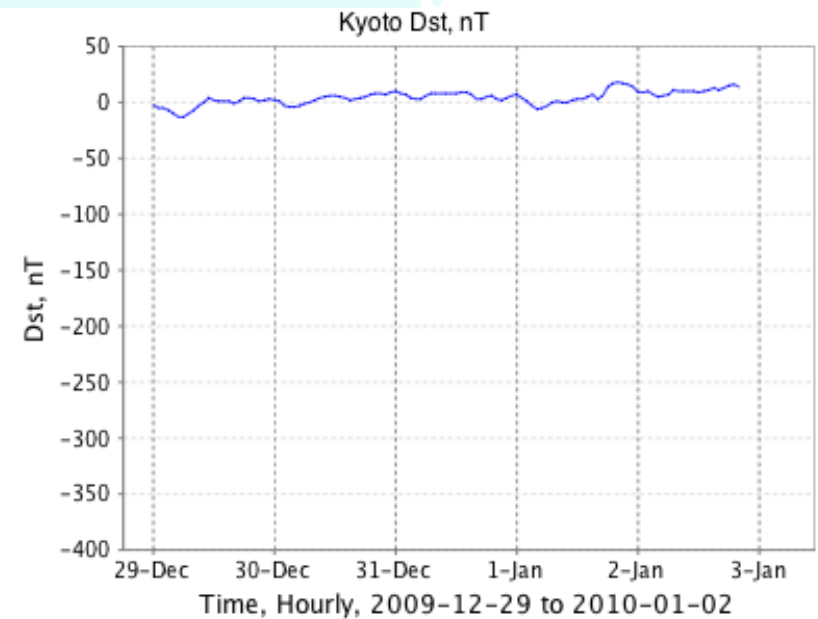


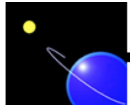
RAPS data streams – 1

ACE solar wind data



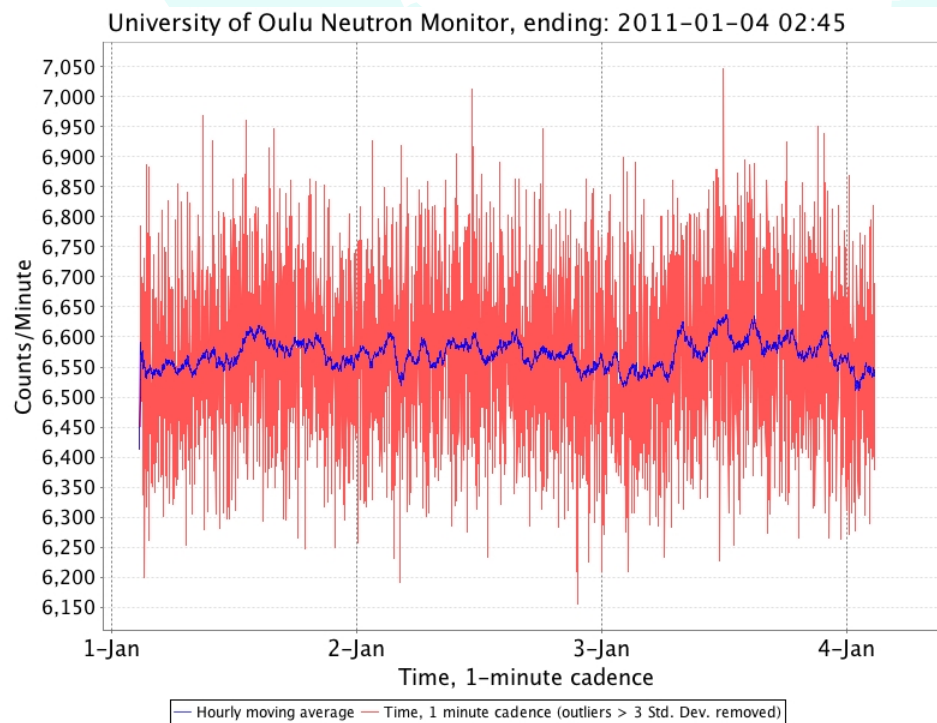
Kyoto Dst (USGS Dst in 2011)



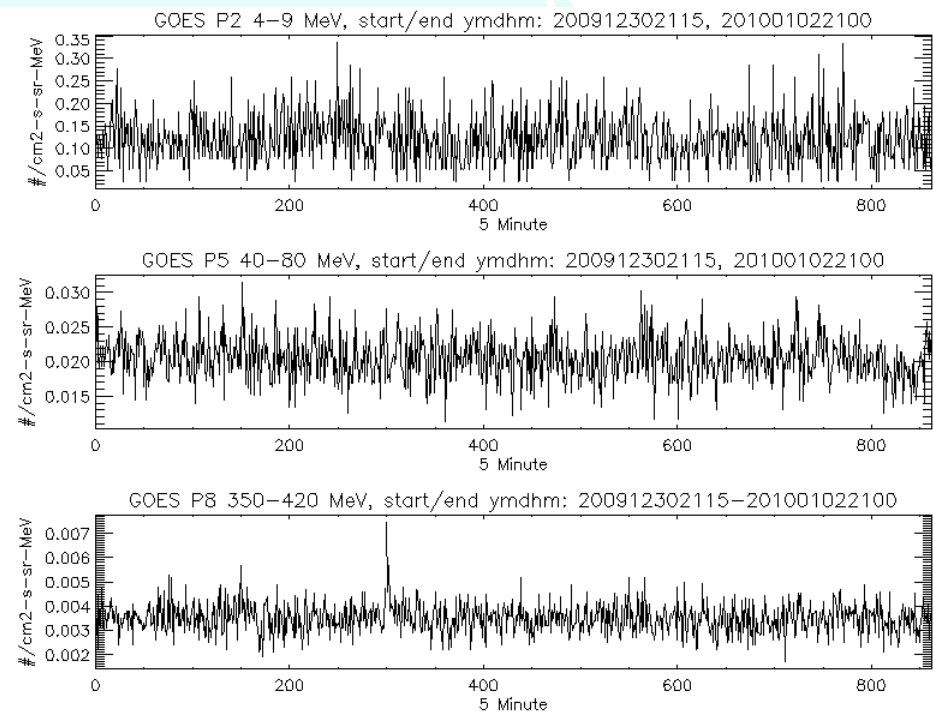


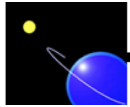
RAPS data streams – 2

Neutron monitor data



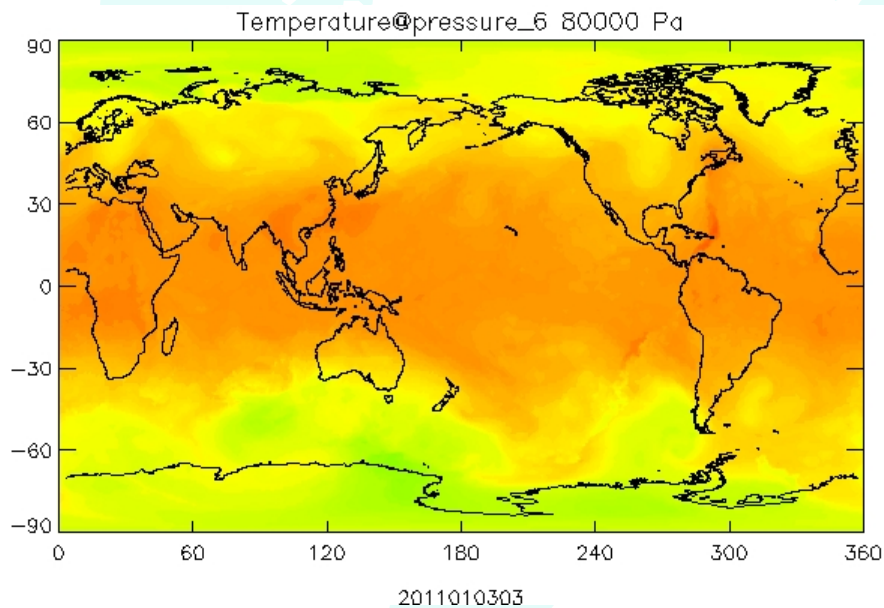
GOES particles





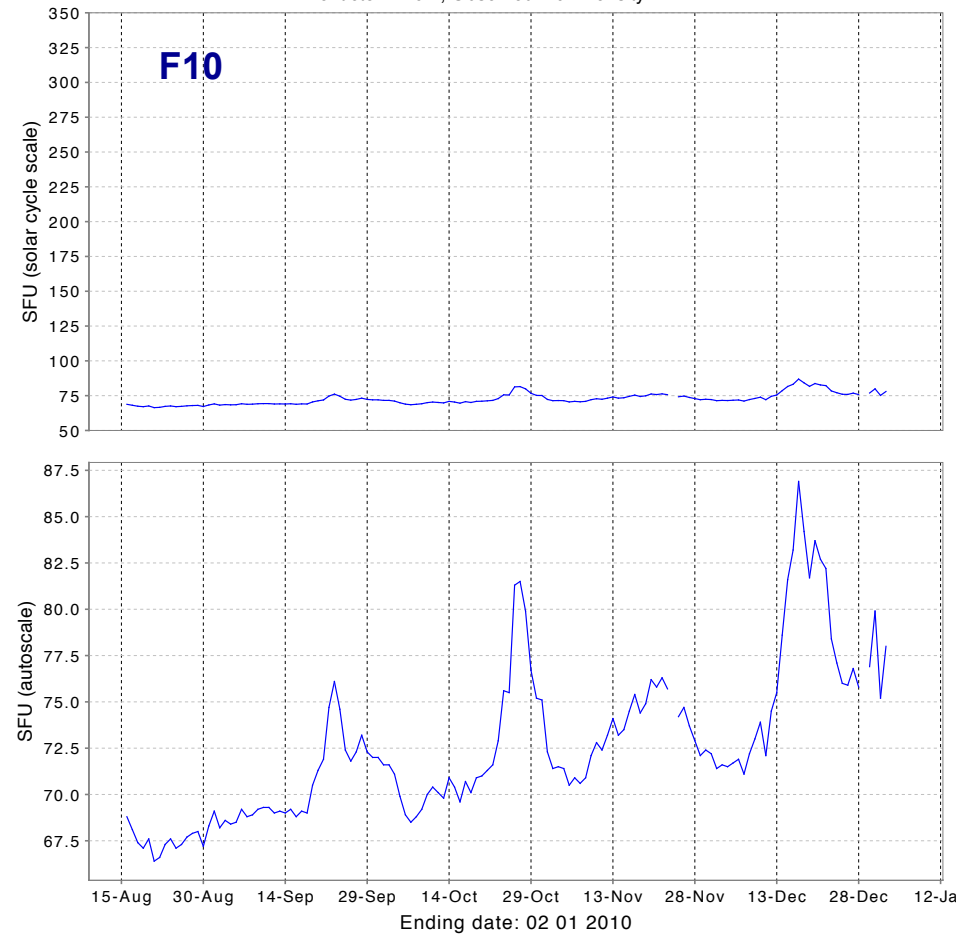
RAPS data streams – 3

NCEP air temperature data



<http://SpaceWx.com>

Penticton F10.7, Observed Flux Density



Tobiska



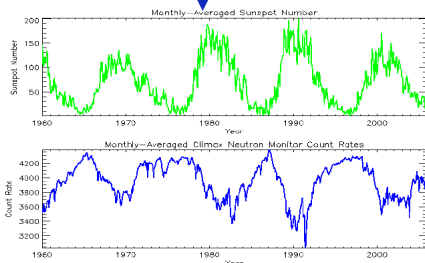
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Space Weather Division

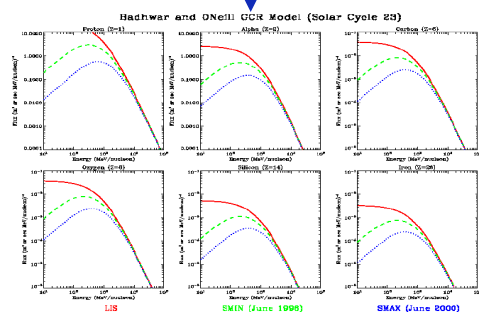
MAPS and RAPS

Real-time Neutron Monitor Data
(e.g., Oulu, IZMIRAN, & LOMNICKY)

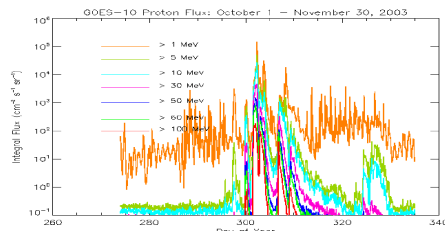
Fit to Climax NMC



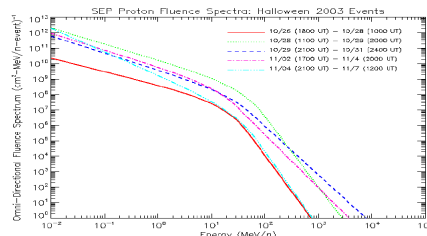
Badhwar+O'Neill GCR Model



NOAA GOES Data

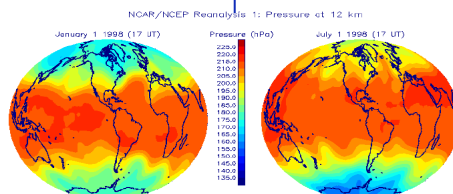


Spectral Fitting



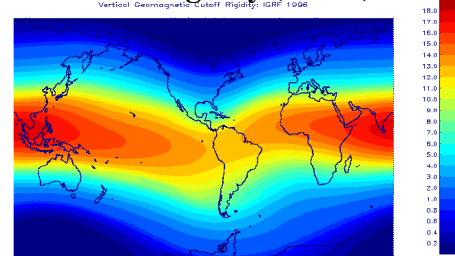
HZETRN + Dosimetry

Atmospheric Density



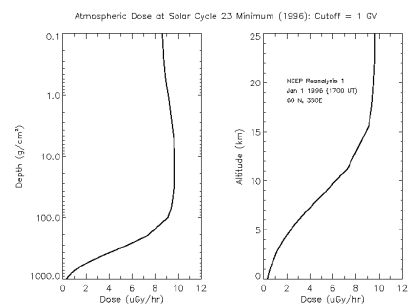
NCEP/GFS

Cutoff Rigidity (IGRF)



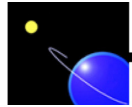
Magnetospheric Magnetic Field
(e.g., T05)
Effects on
Cutoff Rigidity

NASA/ACE Solar Wind and IMF Data

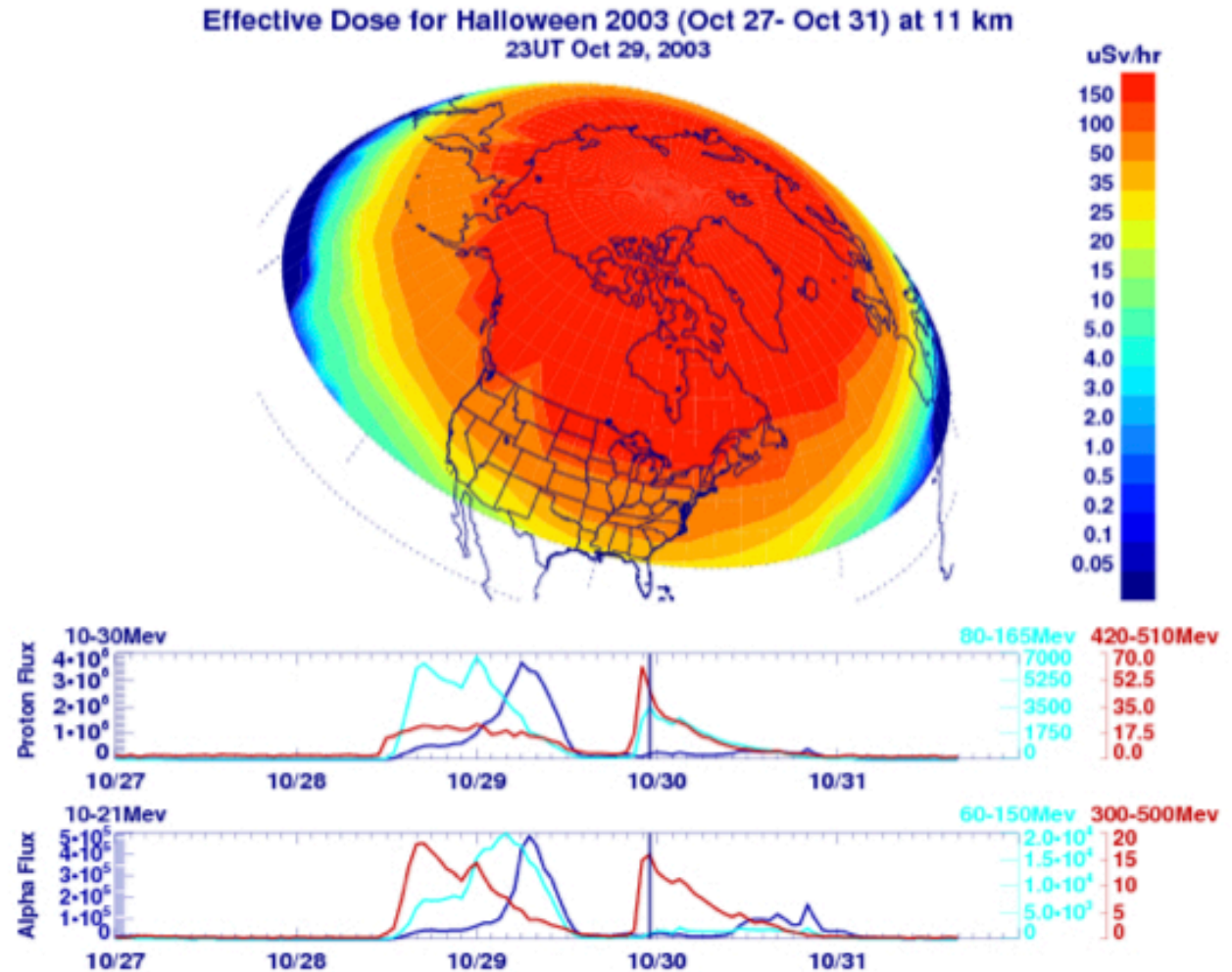


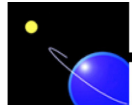
Atmospheric Dose and Dose Equivalent

<http://Space>

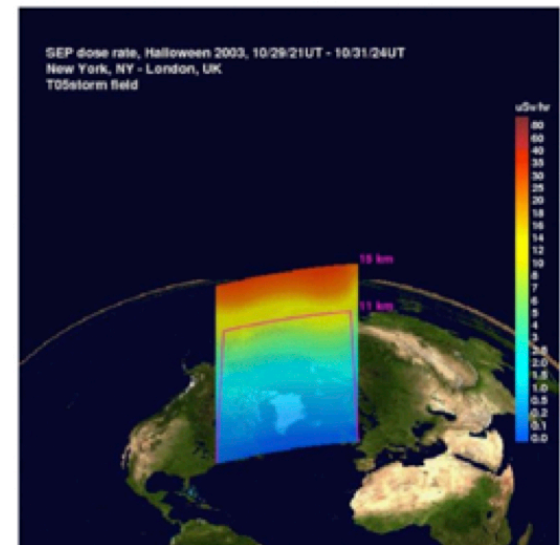
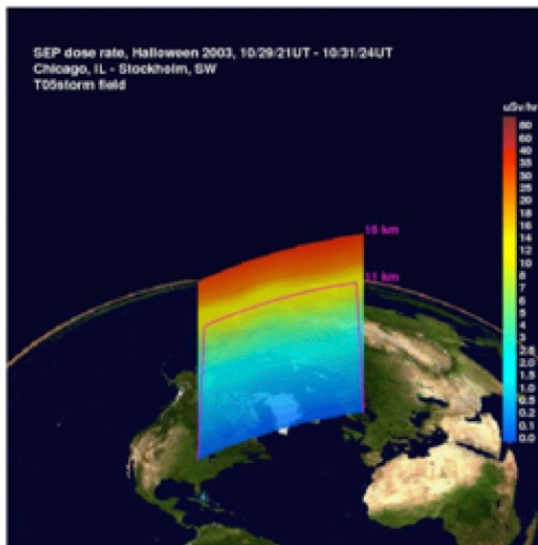
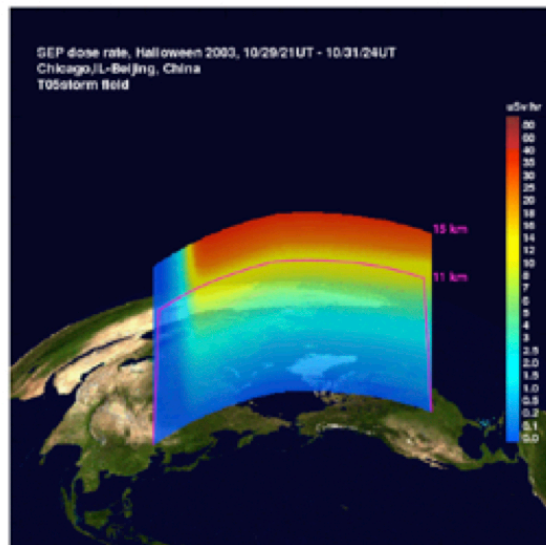
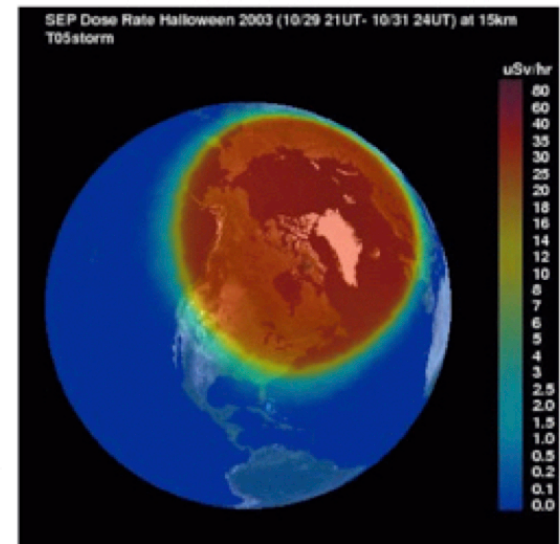
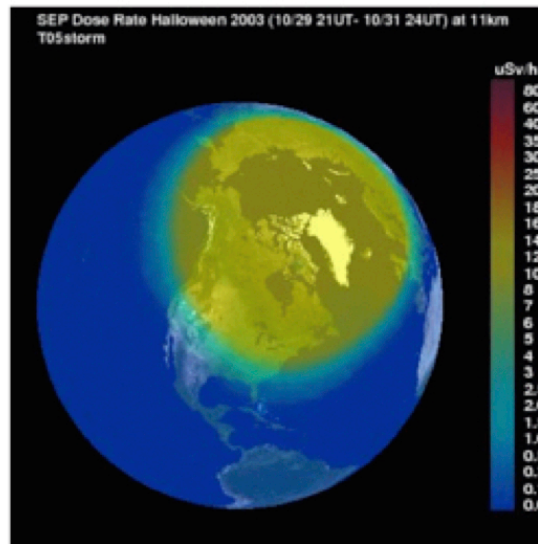
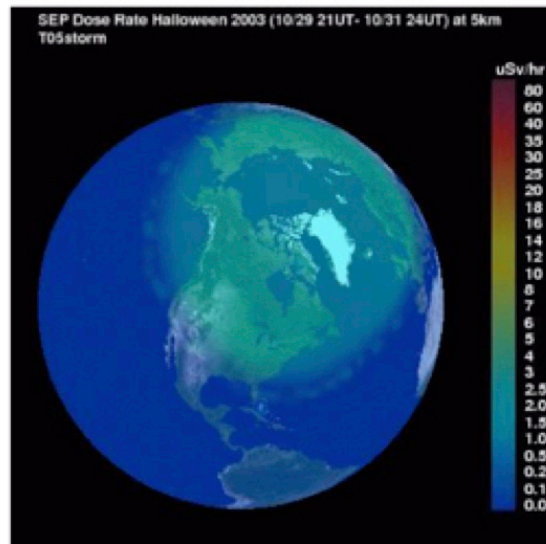


NAIRAS effective dose during Halloween 2003 storm example



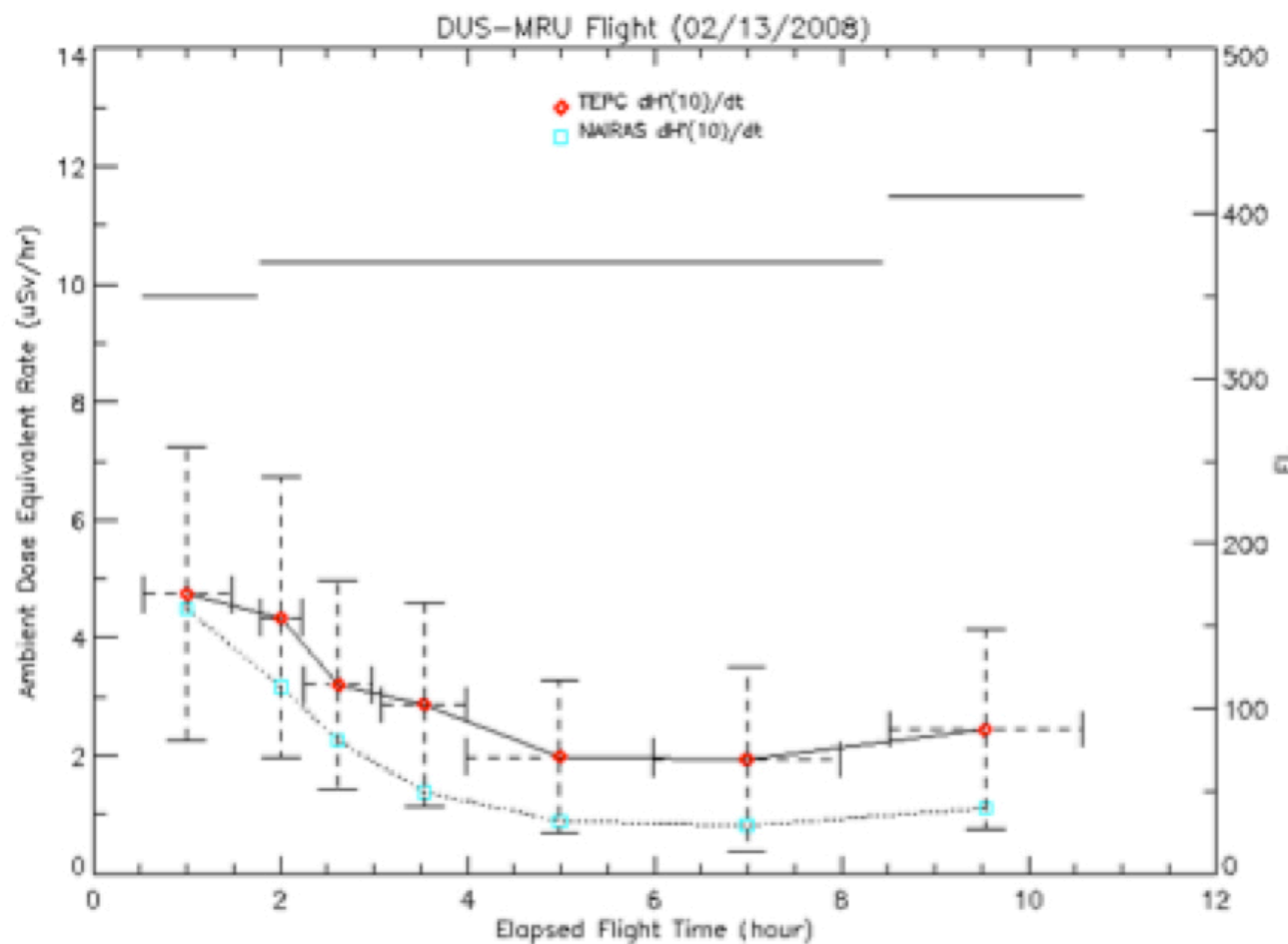


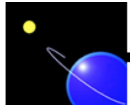
NAIRAS dose during Halloween 2003





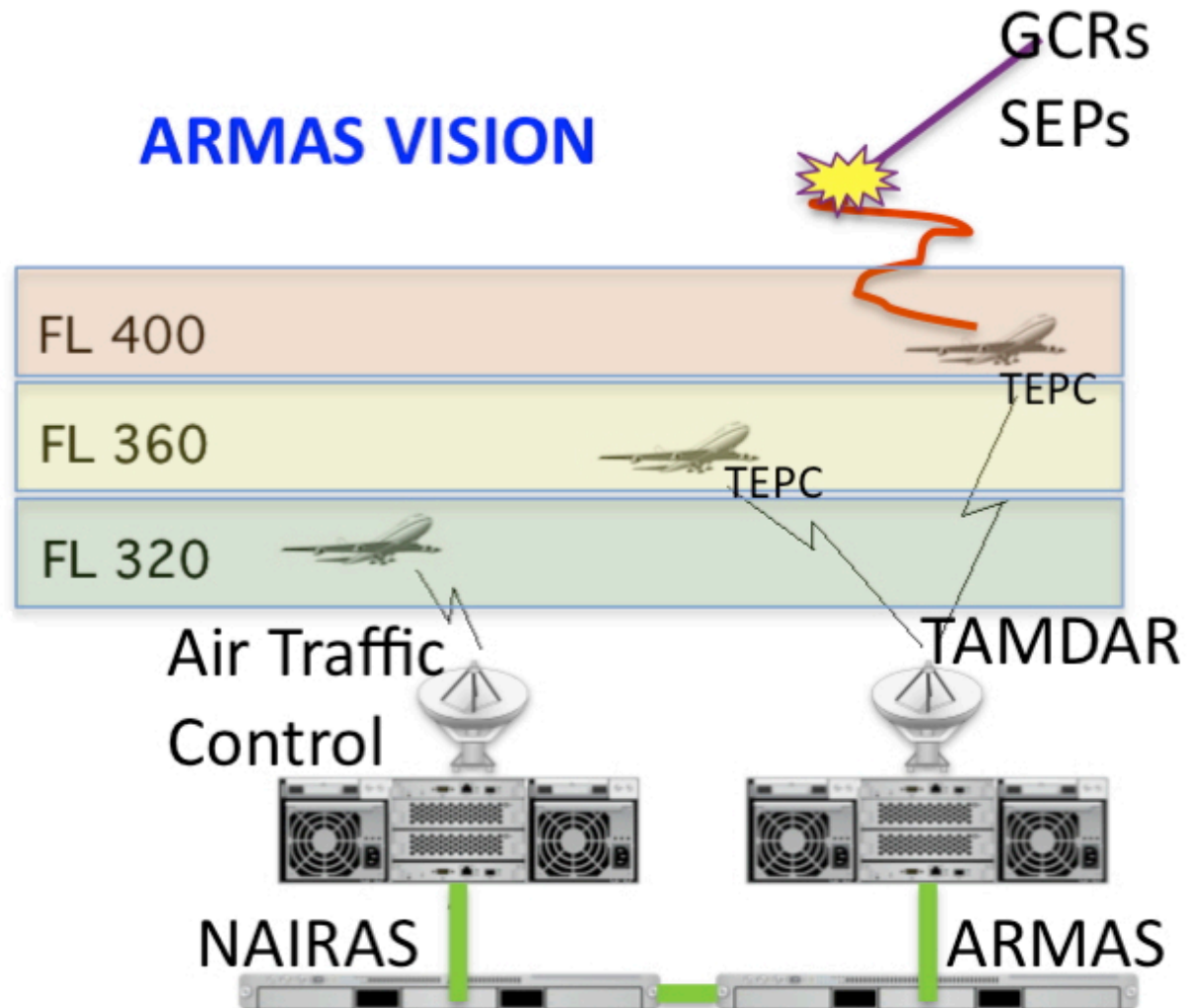
NAIRAS validation with TEPC





ARMAS validation project

ARMAS VISION





RAPS website

<http://sol.spacenvironment.net/~nairas/>

