Recent Updates and Results From the NAIRAS Aircraft Radiation Exposure Model

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Boulder, Colorado
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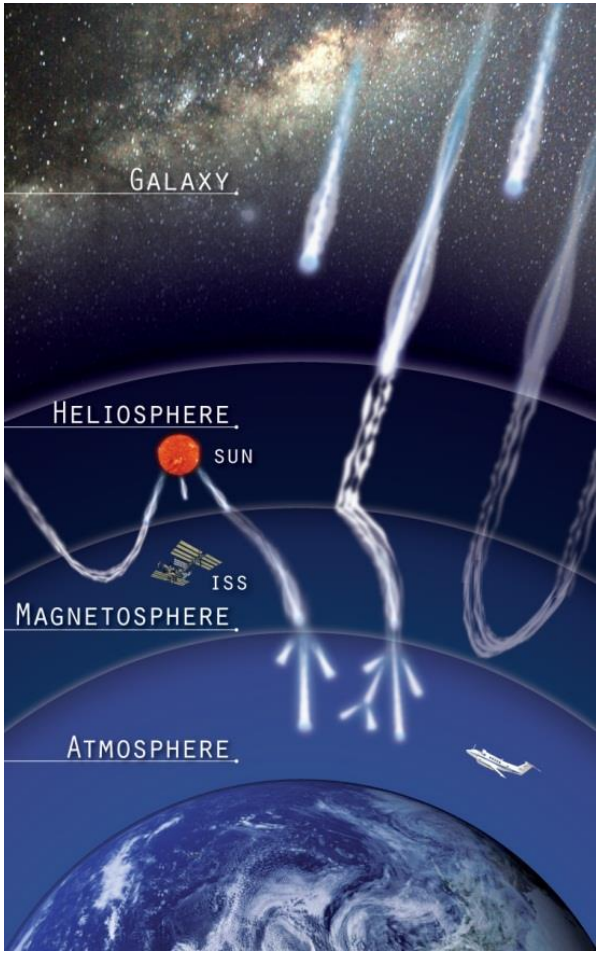
NAIRAS Model

- **Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS):**
  - **Real-time physics-based, global model**
  - **Real-time inclusion of GCR and SEP radiation**
  - **Real-time solar-magnetospheric effects on radiation**
  - **Real-time meteorological data used**



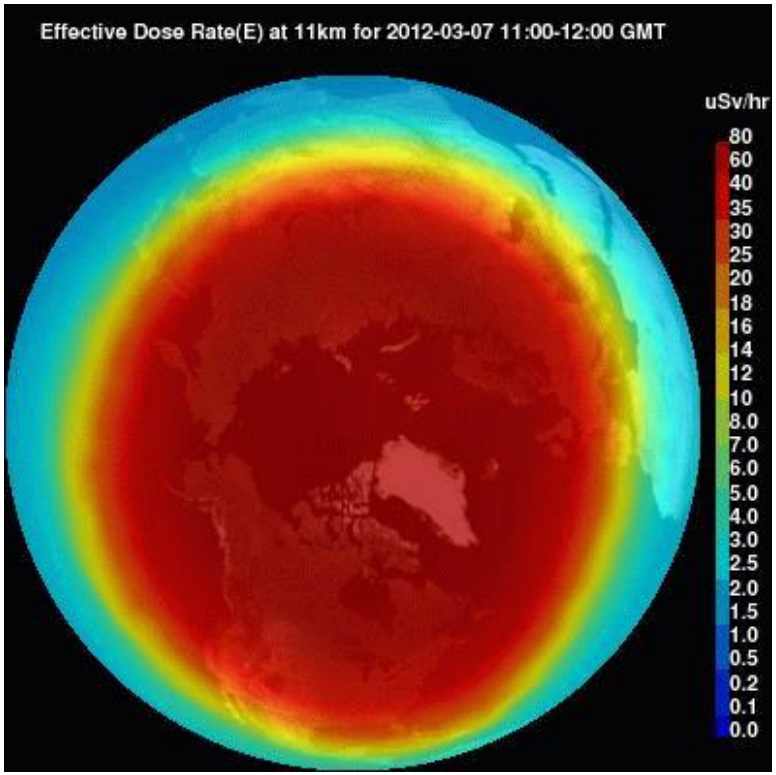
NAIRAS Team

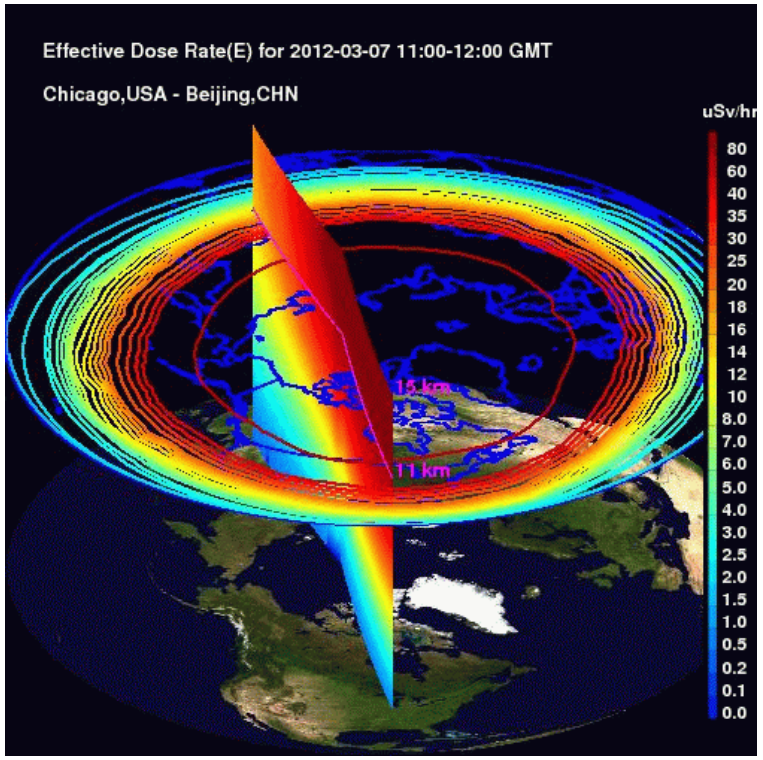
- Chris Mertens (PI), NASA Langley Research Center, Hampton, VA
  - Cosmic ray transport; integration of NAIRAS models and data; V&V
- Kent Tobiska, Space Environment Technologies, Inc, Pacific Palisades, CA
  - Distributed data nerve center and conduit for input data – models – output data
- Brian Kress, Dartmouth College, Hanover, NH
  - Real-time magnetospheric transport / geomagnetic shielding model
- Mike Wiltberger and Stan Solomon, NCAR/HAO, Boulder, CO
  - Benchmark MHD magnetospheric magnetic fields
- Joe Kunches, NOAA/Space Environment Center, Boulder, CO
  - Guidance on research-to-operations; interaction with commercial aviation industry
- Barbara Grajewski, CDC/NIOSH, Cincinnati, OH
  - Aircraft radiation measurement data for V&V; epidemiological studies
- Steve Blattnig, NASA Langley Research Center, Hampton, VA
  - Cosmic ray nuclear interactions; transport physics
- Xiaojing Xu, SSAI, Hampton, VA
  - Scientific programming and data visualization tools
- Ryan Norman (Post-Doc), NASA Langley Research Center, Hampton, VA
  - Cosmic ray nuclear interactions; transport physics

Outline

- NAIRAS Products
- NAIRAS Status &Update
  - Model Updates
  - Comparison with Radiation Measurements
  - Climatology of Dosimetric Quantities
- Extreme Space Weather Event: 1859 Carrington Event
- Radiation Measurement Projects
  - Automated Radiation for Aviation Safety (ARMAS)
  - Radiation Dosimetry Experiment (RaD-X)

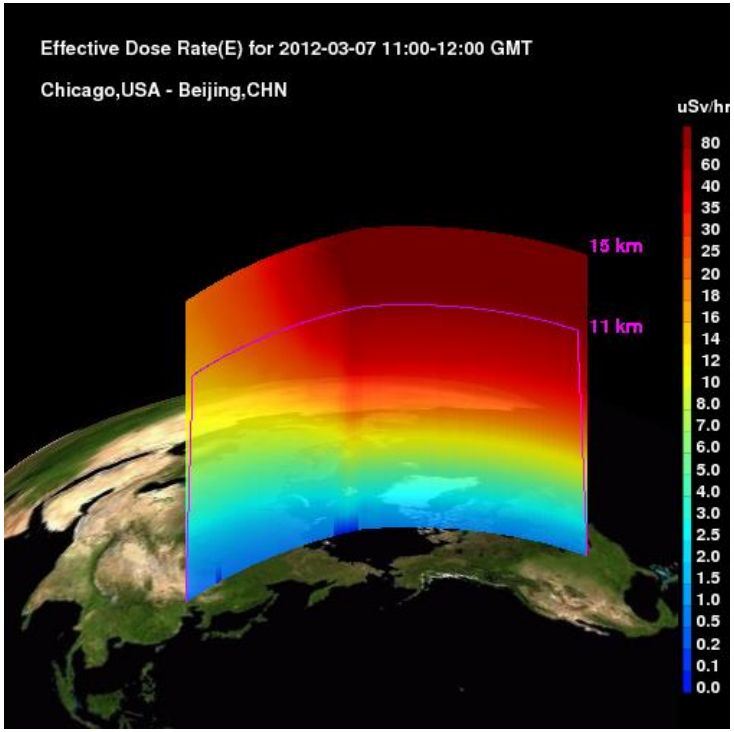
NAIRAS Graphical Products
March 2012 Solar Storm Event





Public Web site: http://sol.spacenvironment.net/~nairas/ (or google NAIRAS)

NAIRAS Graphical Products
March 2012 Solar Storm Event



iPhone app
Search "SpaceWx"

Public Web site: http://sol.spacenvironment.net/~nairas/ (or google NAIRAS)

NAIRAS Model Predictions During March 2012 Solar Storm Events

Effective Dose Rate[1](E) for 2012-03-07 11:00-12:00 GMT

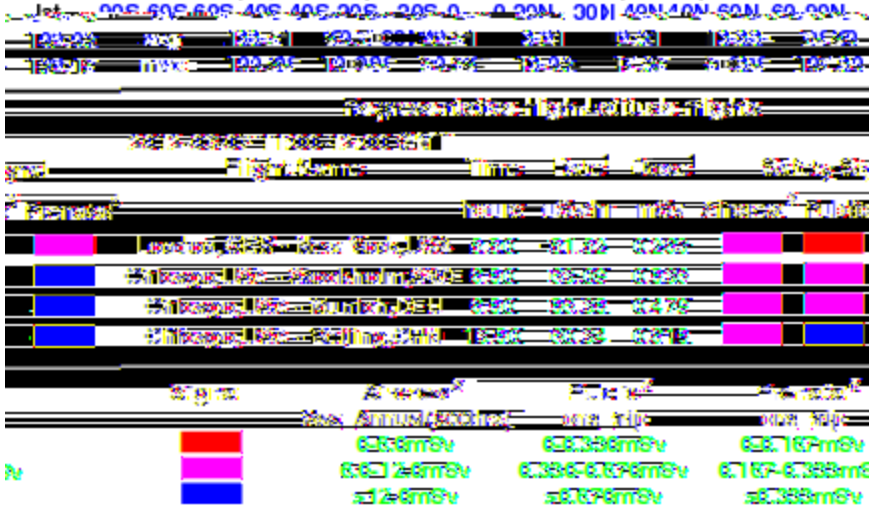
5km (16,000 feet) Radiative Dose Rate (uSv/hr)

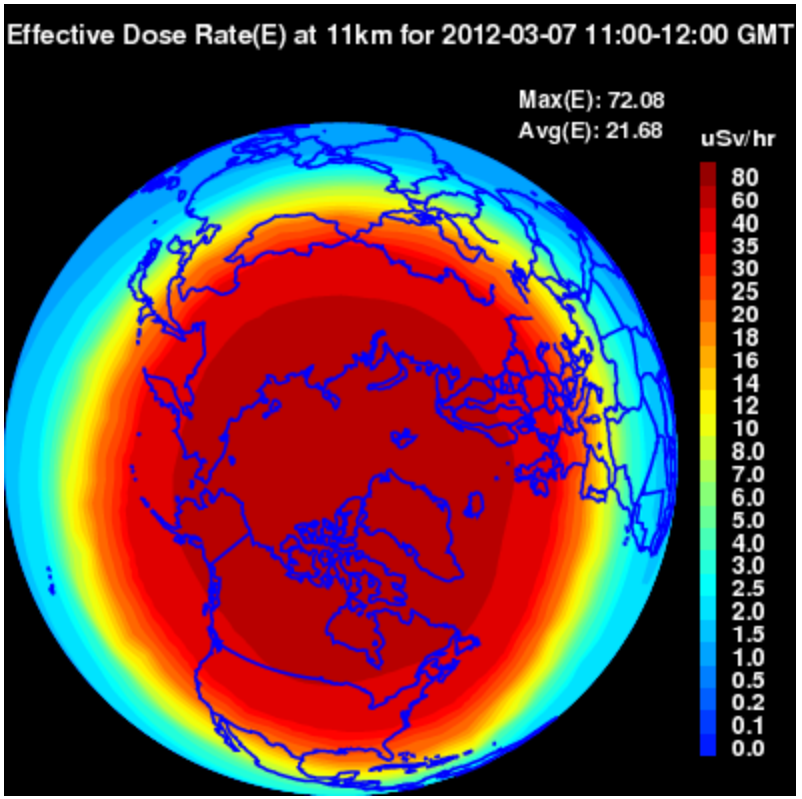
lat	90S-60S	60S-40S	40S-20S	20S-0	0-20N	20N-40N	40N-60N	60-90N
avg	12.01	8.51	3.77	1.06	0.88	2.58	8.21	11.74
max	13.67	12.35	8.81	3.03	3.64	8.71	12.45	13.61

11km (35,000 feet) Radiative Dose Rate (uSv/hr)

lat	90S-60S	60S-40S	40S-20S	20S-0	0-20N	20N-40N	40N-60N	60-90N
avg	63.79	43.36	15.16	2.69	2.14	9.45	41.37	66.03
max	69.41	66.18	47.22	10.15	13.08	45.58	67.98	72.08

15km (49,000 feet) Radiative Dose Rate (uSv/hr)





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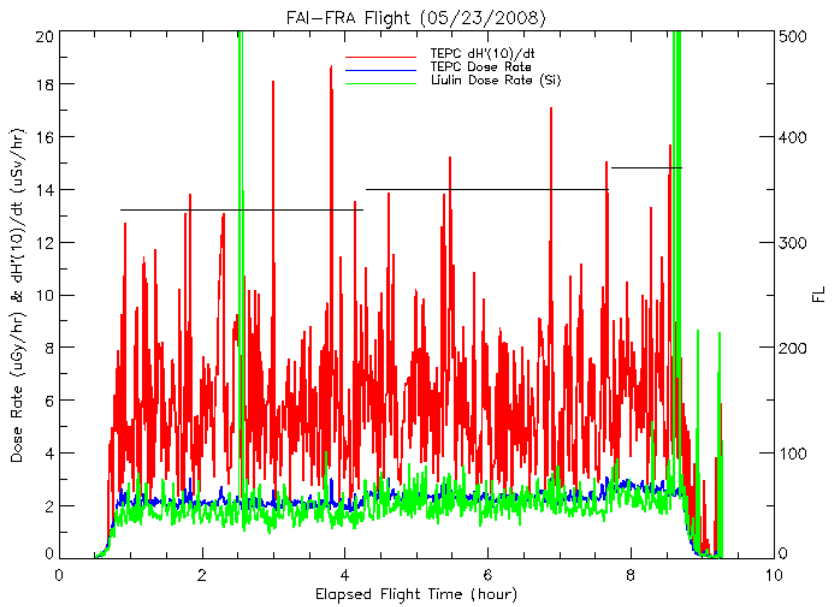
NAIRAS Updates

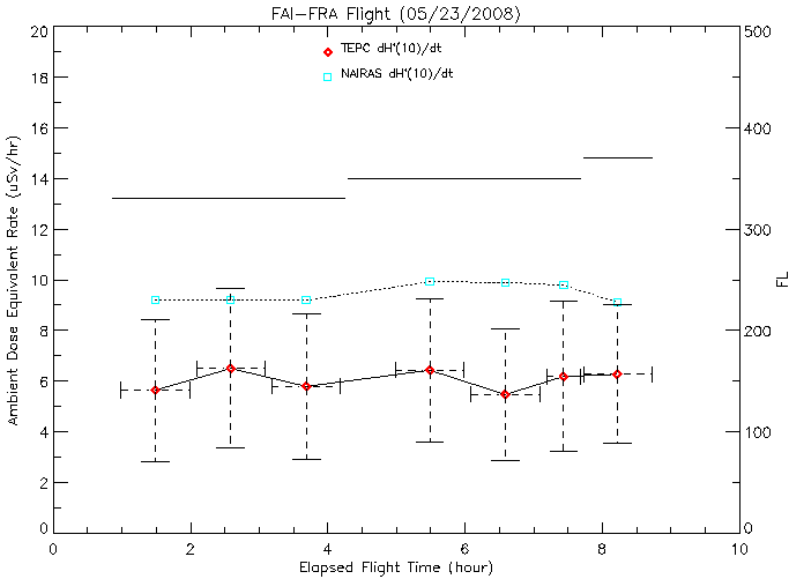
- **Research Model Updates**
  - **Update heliospheric GCR transport to Badhwar and O'Neill 2010 (BON10) model.**
  - **Calculate absorbed dose in silicon**
  - **Annual-average dosimetric quantities from 1960-2010**
  - **Microelectronic effects: SEU rate proxy: >10 MeV neutron flux**
- **Real-Time Version: Coming Soon**
  - **BON10 Model**
- **Real-Time Version: Near Future**
  - **Improved pion-electromagnetic (π/EM) cascade model**
  - **>10 MeV neutron flux**

NAIRAS/DLR-TEPC Comparisons High-Latitude Flight

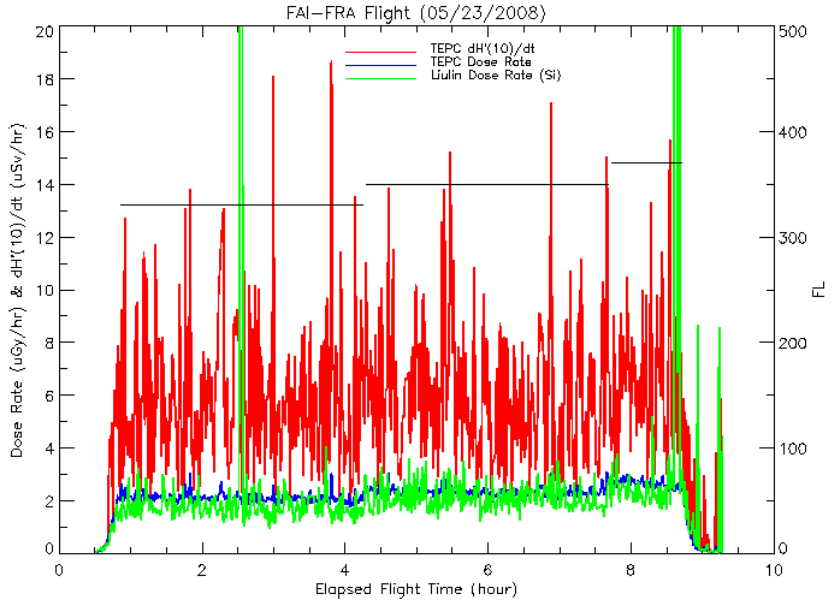


TEPC data courtesy of Matthias Meier

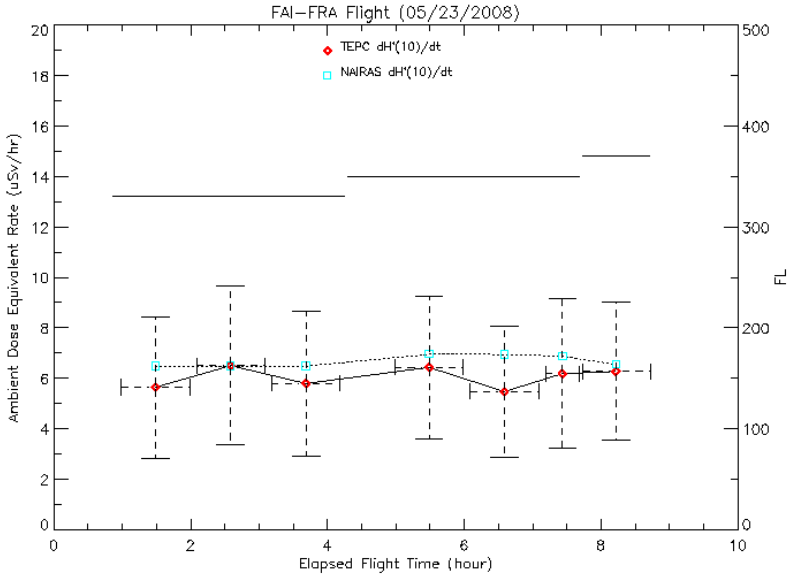
BON04 Model



NAIRAS/DLR-TEPC Comparisons High-Latitude Flight

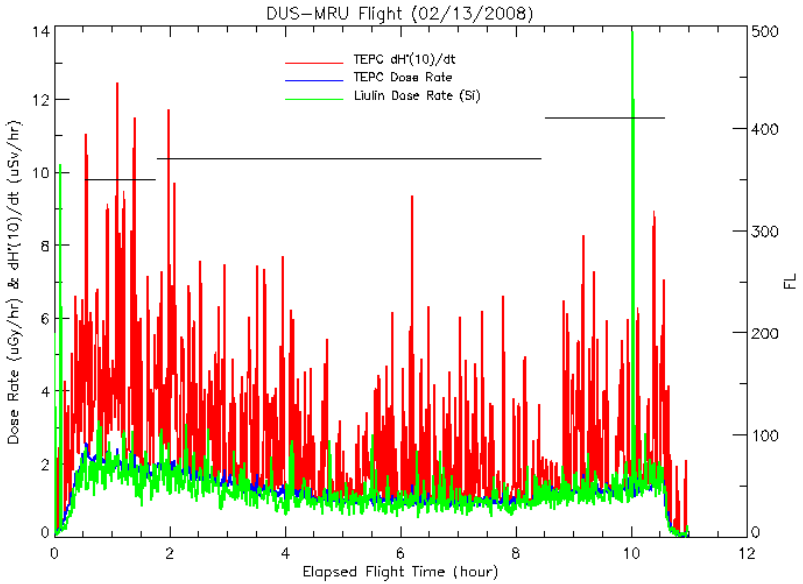


BON10 Model

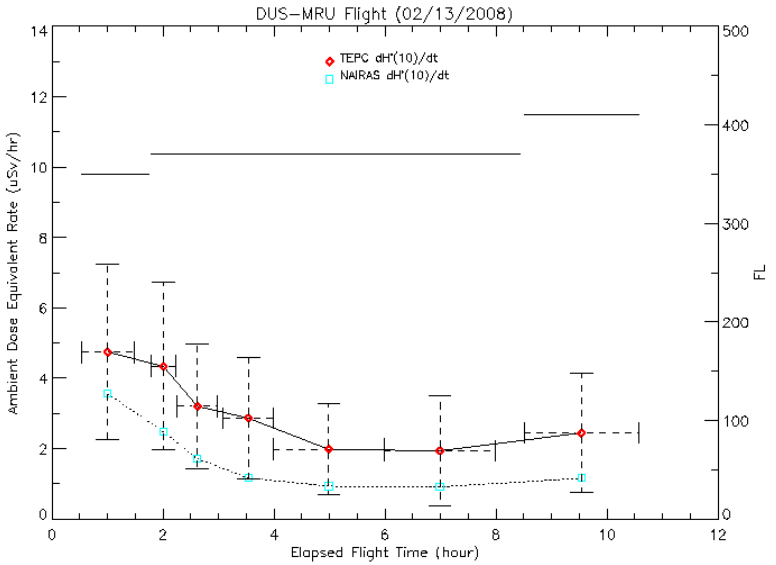


TEPC data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-TEPC Comparisons Low-Latitude Flight

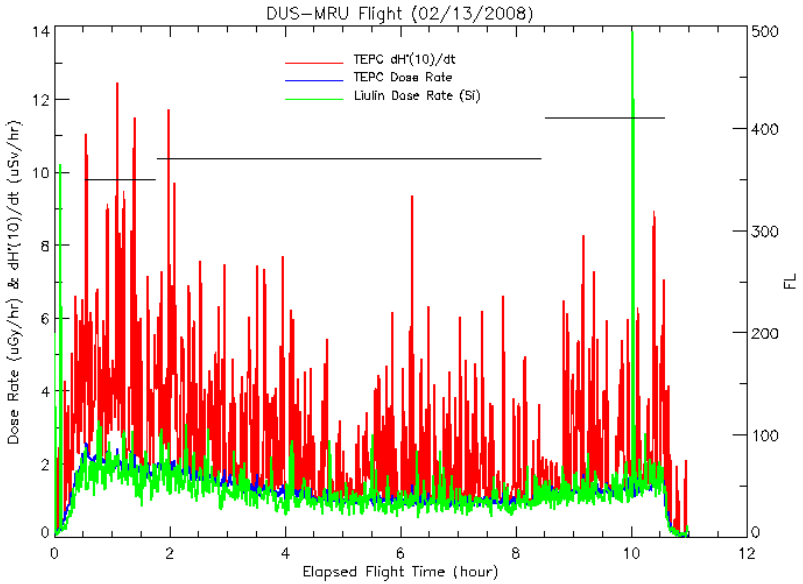


BON10 Model

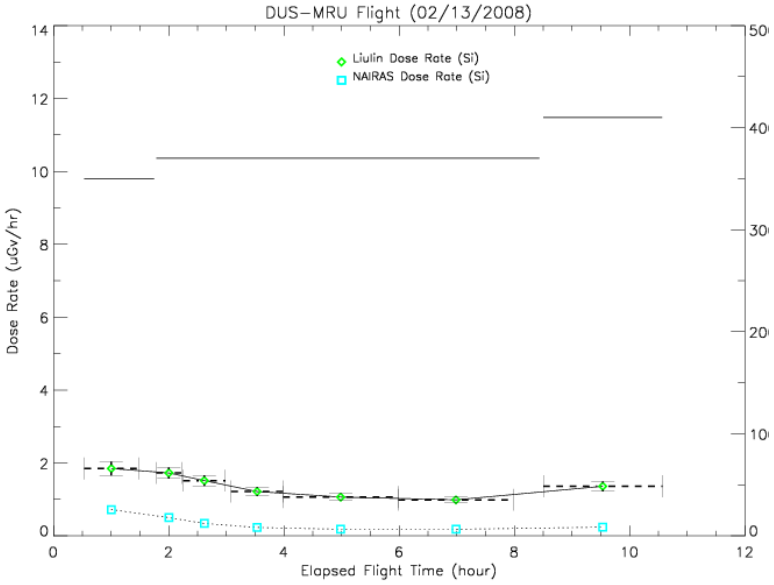


TEPC data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-Liulin Comparisons Low-Latitude Flight

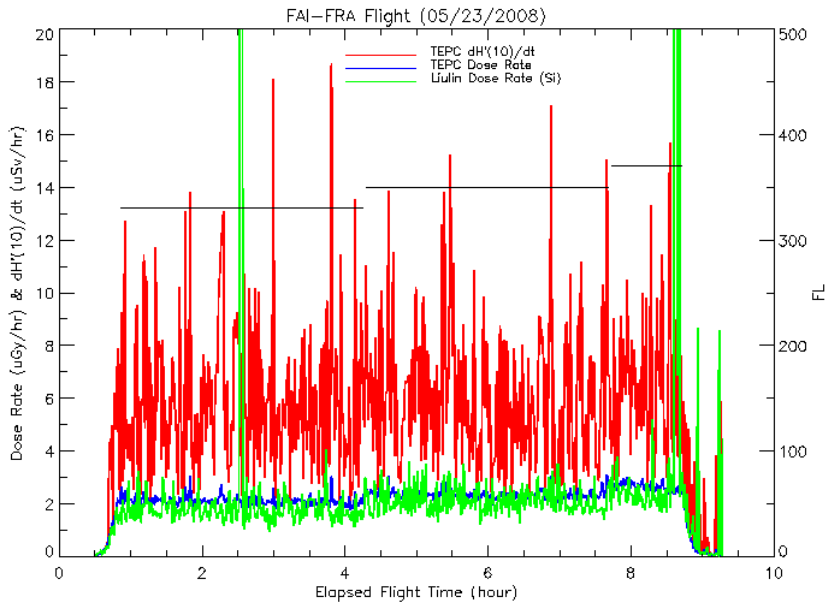


BON10 Model

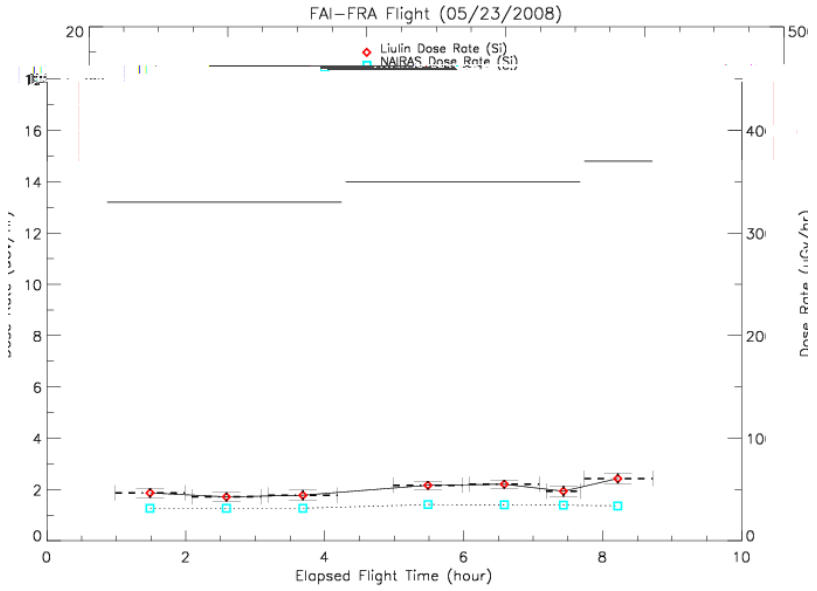


Liulin data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-Liulin Comparisons High-Latitude Flight

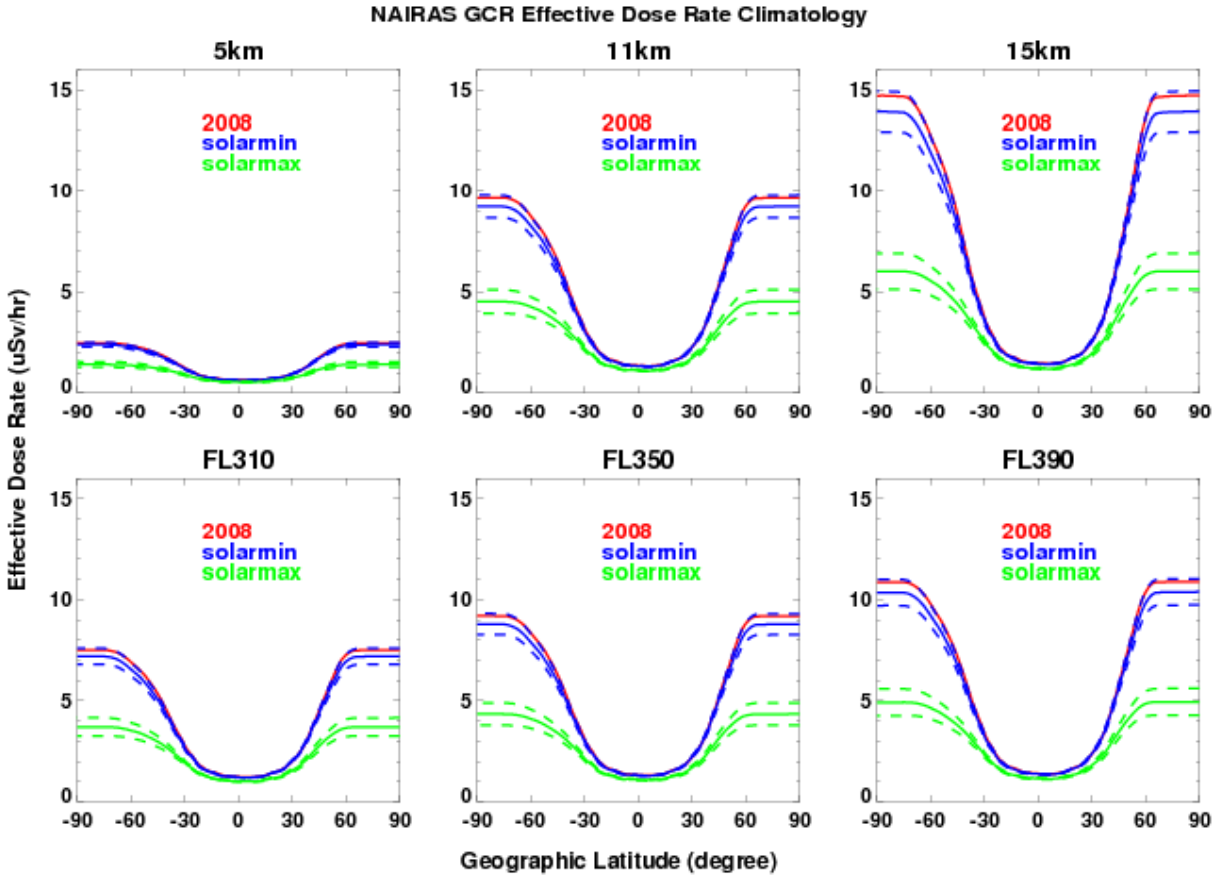


BON10 Model



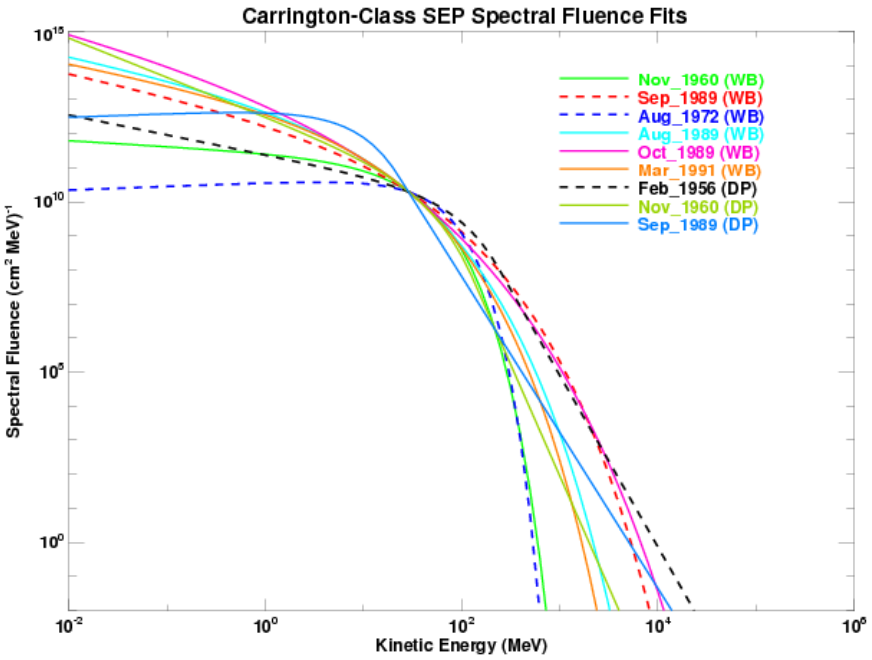
Liulin data courtesy of Matthias Meier (DLR)

NAIRAS Climatology of Dose Rates

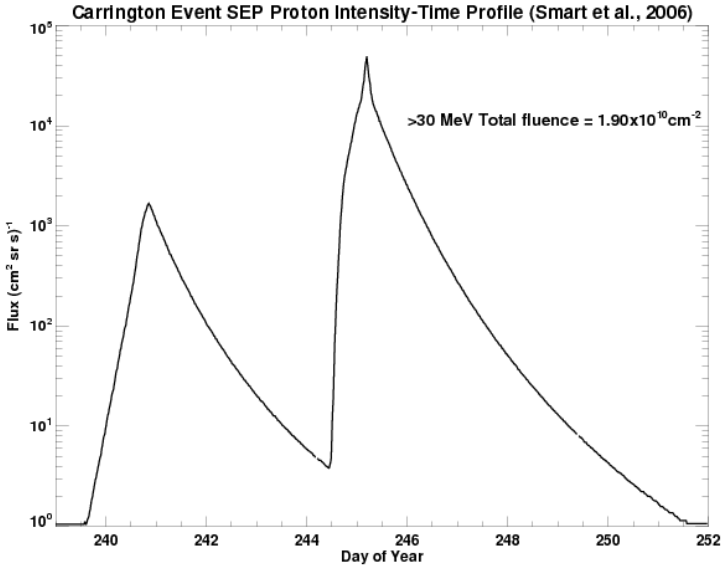


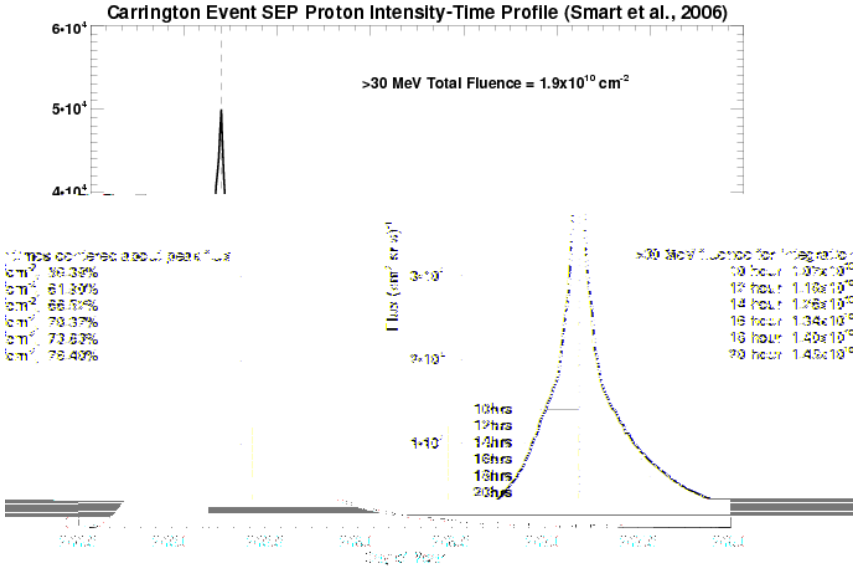
Carrington Event

- **SEP Spectral Fluence [Smart et al., 2006; Townsend et al., 2006, 2011]**
  - **Assume a spectral shape (see figure)**
  - **Normalize spectral shape to >30 MeV proton fluence determined by impulsive NOy deposition in polar ice cores [McCracken et al., 2001]**



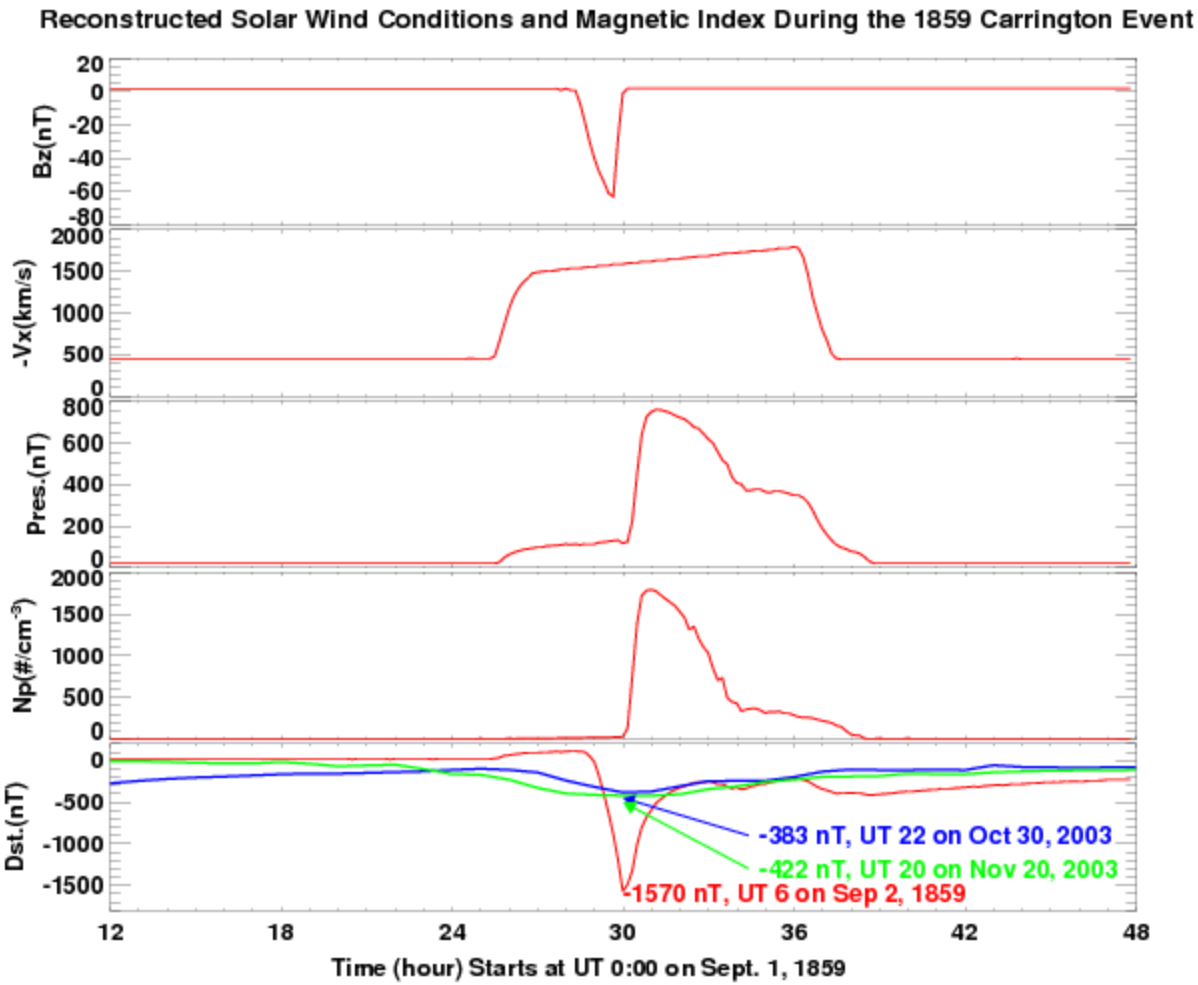
Carrington Event





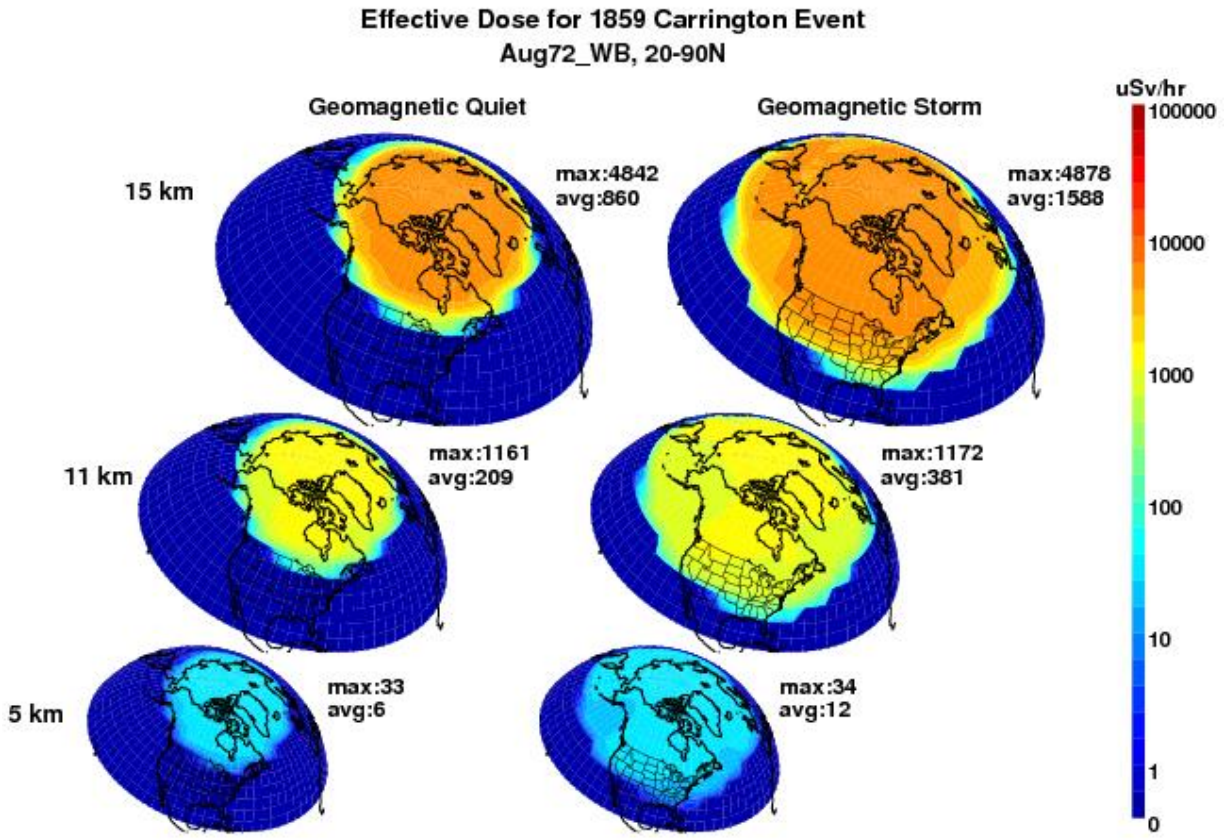
SEP Spectral Fluence Rate: Combine Smart et al. [2006] SEP proton intensity-time profile with Townsend et al. [2006, 2011] SEP fit parameters ($\Phi_0/20$)

Carrington Event

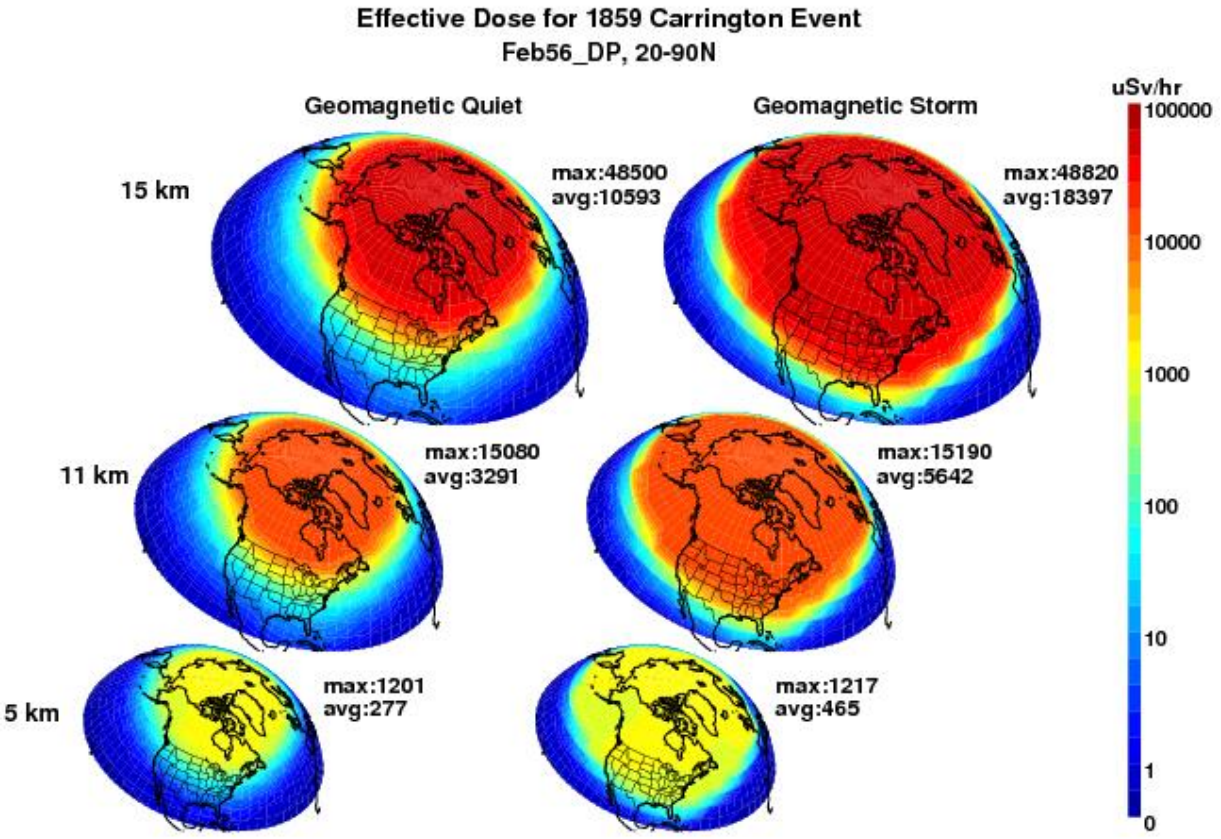


Temerin and Li [2002] & Li et al.[2006]

Carrington Event



Carrington Event

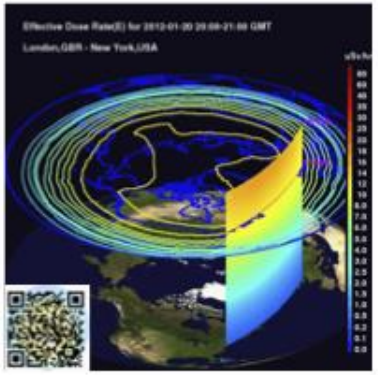


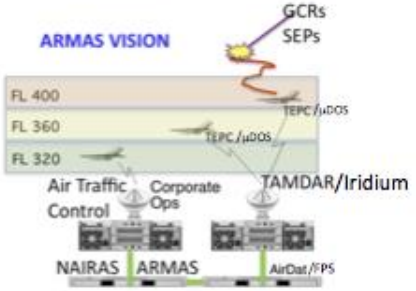
Automated Radiation for Aviation Safety (ARMAS) Project

- Project led by Space Environment Technologies (Tobiska)
- Deploy and obtain real-time dosimeter data at commercial airline altitudes
- Ingest real-time dosimeter measurements into the NAIRAS model to improve accuracy of radiation dose predictions along flight track
- Distribute ingested/improved data to the web and to apps
- Improve aviation safety by laying ground work for automated, reliable predictions of the cosmic ray radiation environment at commercial airline altitudes

Vision and Progress

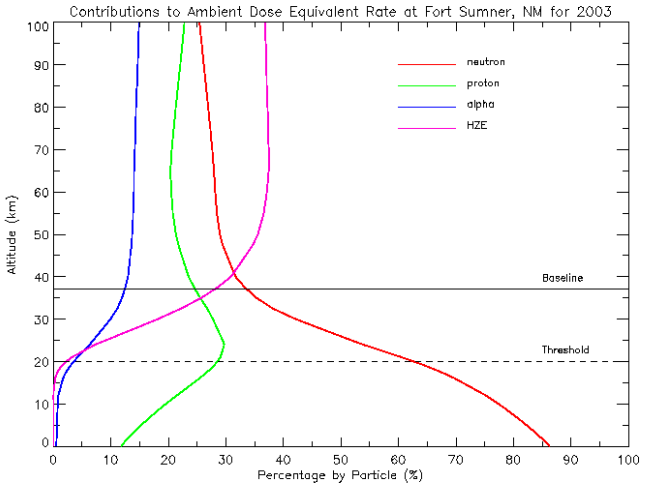
- ARMAS will utilize airborne micro dosimeters, calibrated to TEPC, to make dose and dose rate measurements in real-time, transmit the data to the ground for data ingestion into NAIRAS, and then distribute the updated information via *SpaceWx* app

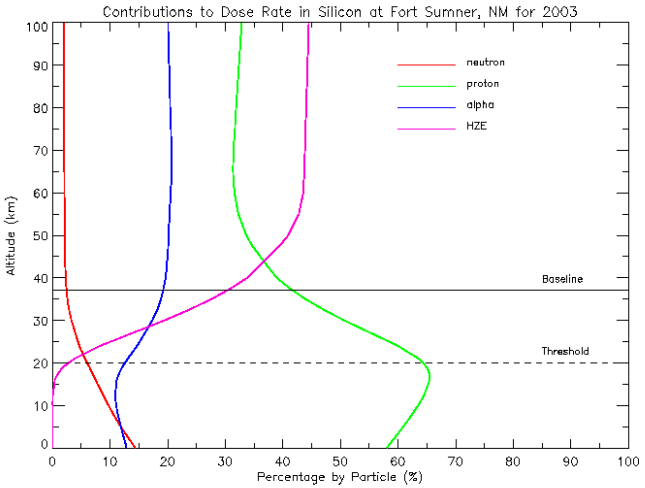




Radiation Dosimetry Experiment
RaD-X

- **Science Goal #1:**
  - **Improve understanding of cosmic ray transport processes and atmospheric interactions**
- **Science Objectives (SO):**
  - **SO1: Dosimeter measurements at high altitude above Pfotzer maximum and compare to NAIRAS**
  - **SO2: Characterize temporal variations in dosimetric quantities above Pfotzer max**
- **Threshold Design:**
  - **Define: 4-hrs science data @ 20 km**
  - **Detectors: TEPC, TID**
  - **Accomplish: SO1**
- **Baseline Design**
  - **Define: 24-hrs science data @ 36.5 km**
  - **Detectors: TEPC, TID, Liulin, RaySure**
  - **Accomplish SO2, SO1+**

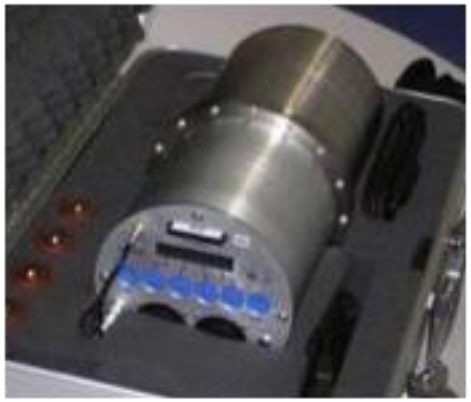




Radiation Dosimetry Experiment RaD-X

- Science Goal #2:
  - Improve understanding of the relationship between silicon-based radiation measurements and radiobiological response
- Science Objectives (SO):
  - SO3: Characterize the extent to which silicon-based dosimeters can emulate radiobiological response
  - SO4: Develop an empirical relationship between microdosimeter measurements and absorbed dose in silicon
- Threshold Design:
  - Define: 4-hrs science data @ 20 km
  - Detectors: TEPC, TID
  - Accomplish: SO4
- Baseline Design:
  - Define: 24-hrs science data @ 36.5 km
  - Detectors: TEPC, TID, Liulin, RaySure
  - Accomplish: SO3, SO4+

TEPC



TID

Conclusions

- Improved NAIRAS accuracy with BON10 heliospheric GCR transport model
- Expanded NAIRAS products
  - Absorbed dose in silicon
  - SEU proxy
- Promising measurement campaigns to support NAIRAS V&V and improve model reliability to advance aviation safety