Recent Updates and Results From the NAIRAS Aircraft Radiation Exposure Model

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Space Weather Workshop
Boulder, Colorado
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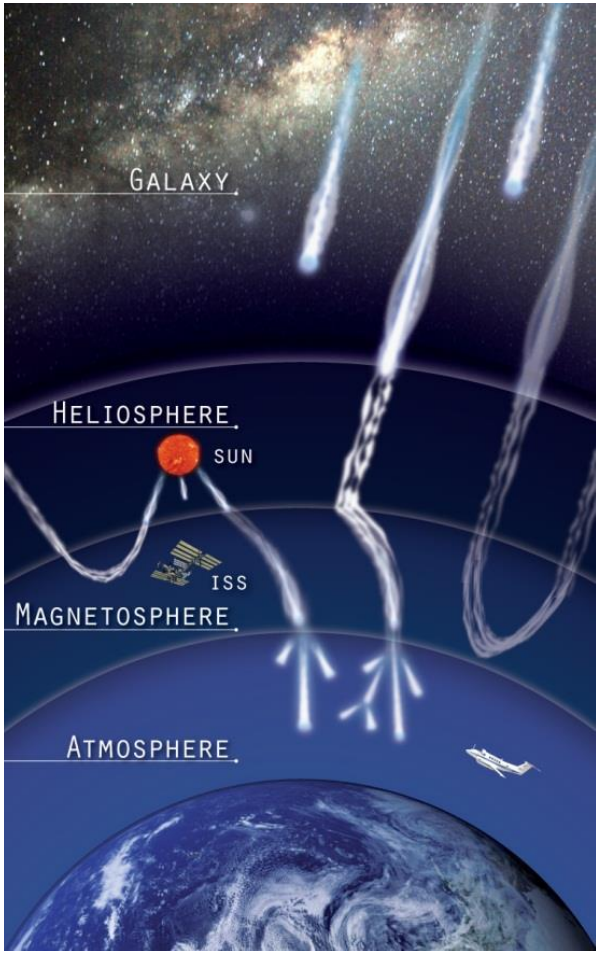
NAIRAS Model

- **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



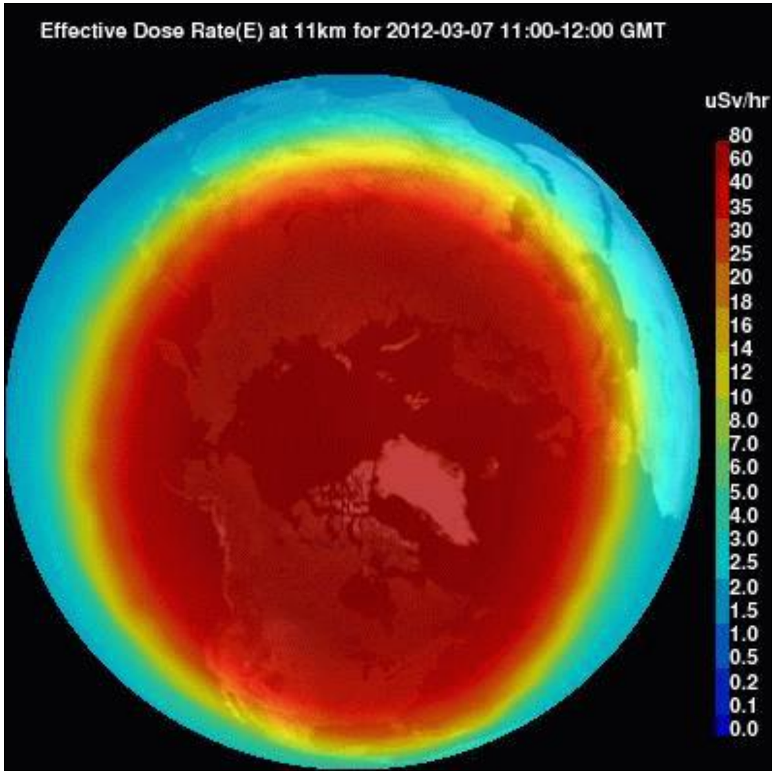
NAIRAS Team

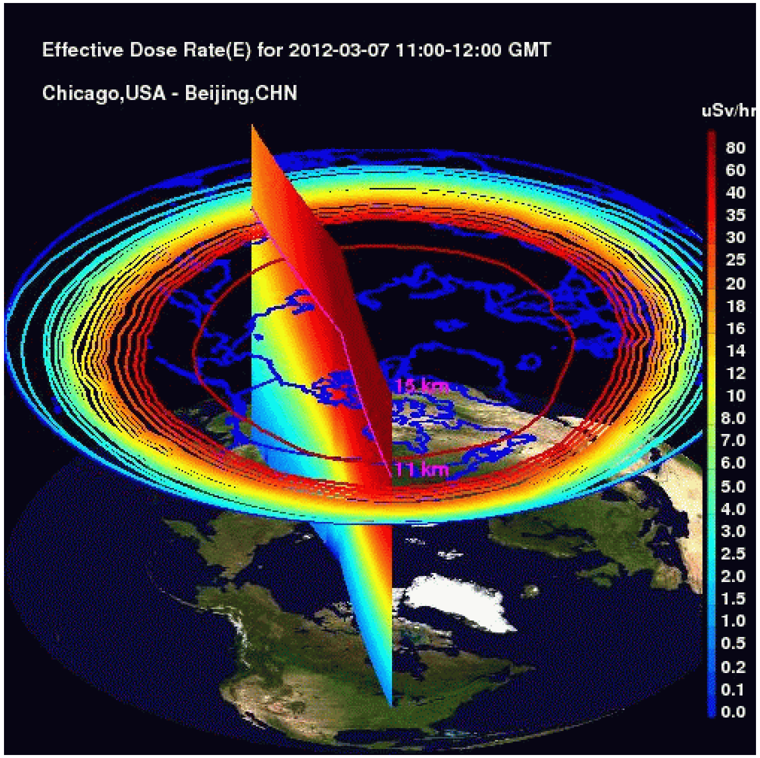
- Chris Mertens (PI), NASA Langley Research Center, Hampton, VA
  - Cosmic ray transport; integration of NAIRAS models and data; V&V
- Kent Tobiska, Space Environment Technologies, Inc, Pacific Palisades, CA
  - Distributed data nerve center and conduit for input data – models – output data
- Brian Kress, 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)

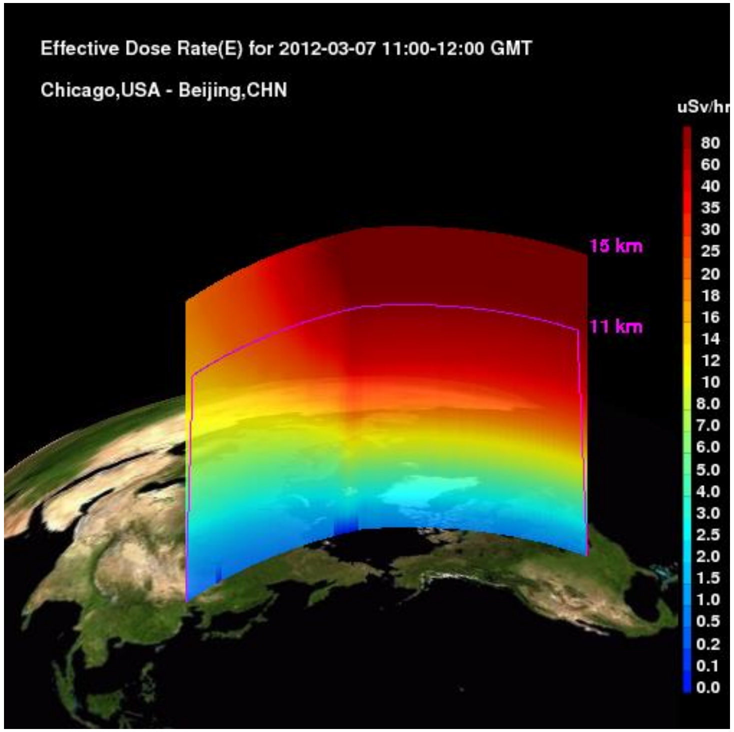
NAIRAS Graphical Products
March 2012 Solar Storm Event





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)

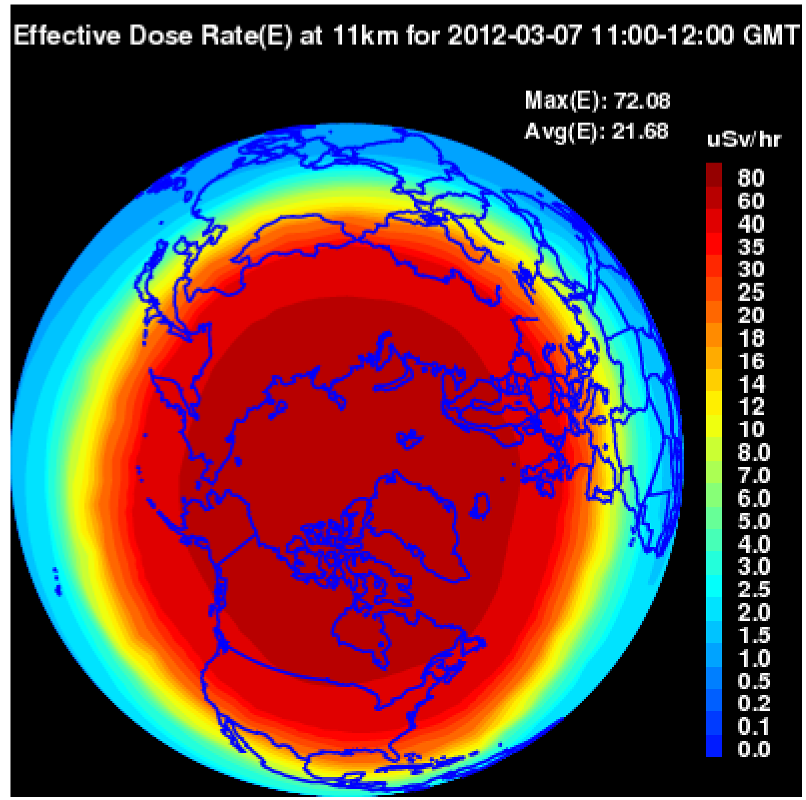
lat	90S-60S	60S-40S	40S-20S	20S-0	0-20N	20N-40N	40N-60N	60-90N
avg	133.91	84.70	22.91	3.21	2.51	13.33	76.84	142.45
max	144.86	140.66	94.98	13.45	17.59	90.36	147.34	152.19

Representative High-Latitude Flights

2012-03-07 11:00-12:00 GMT

Flight Name	Time hours	Rate[1] uSv/hr	Dose[1] mSv	Safety Signal Aircrew[2]	Safety Signal Public[3]	Safety Signal Prenatal[4]
London,GBR - New York,USA	5.50	51.52	0.283	yellow	green	yellow
Chicago,USA - Stockholm,SWE	8.50	63.09	0.536	yellow	yellow	red
Chicago,USA - Munich,DEU	8.50	56.35	0.479	yellow	yellow	red
Chicago,USA - Beijing,CHN	13.50	60.34	0.815	yellow	red	red

Signal	Aircrew[5] Max_Annual(800hrs)	Public[6] one_trip	Prenatal[6] one_trip
green	0-6.0mSv	0-0.330mSv	0-0.167mSv
yellow	6.0-12.0mSv	0.330-0.670mSv	0.167-0.333mSv
red	>12.0mSv	>0.670mSv	>0.333mSv



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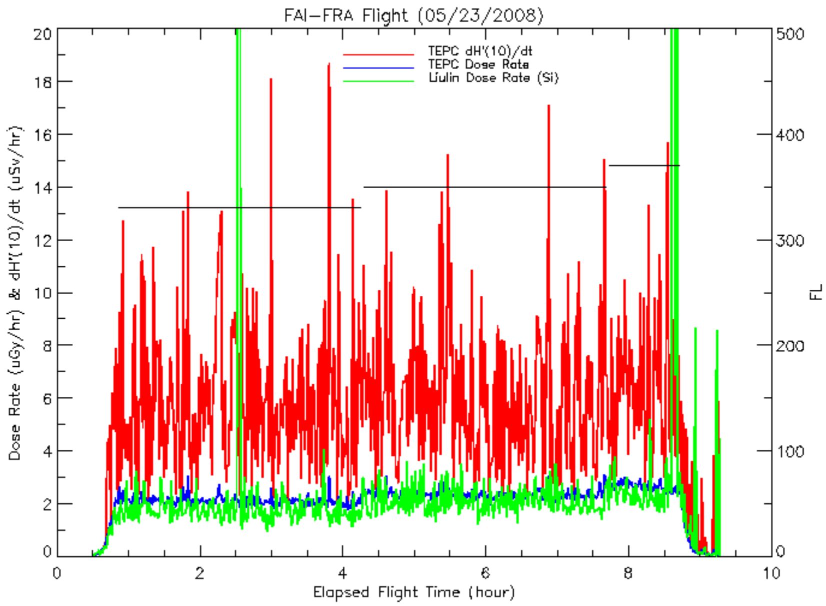
NAIRAS Updates

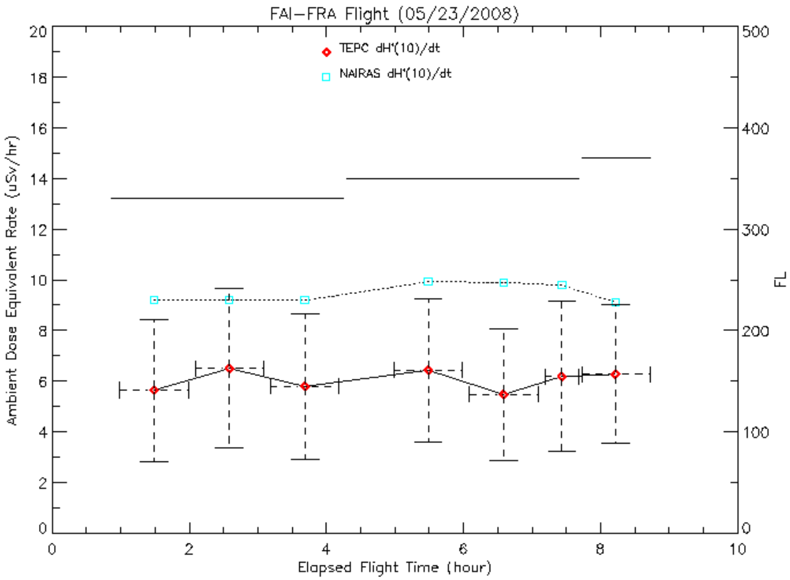
- Research Model Updates
  - Update heliospheric GCR transport to Badhwar and O'Neill 2010 (BON10) model.
  - Calculate absorbed dose in silicon
  - Annual-average dosimetric quantities from 1960-2010
  - Microelectronic effects: SEU rate proxy: >10 MeV neutron flux
- Real-Time Version: Coming Soon
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

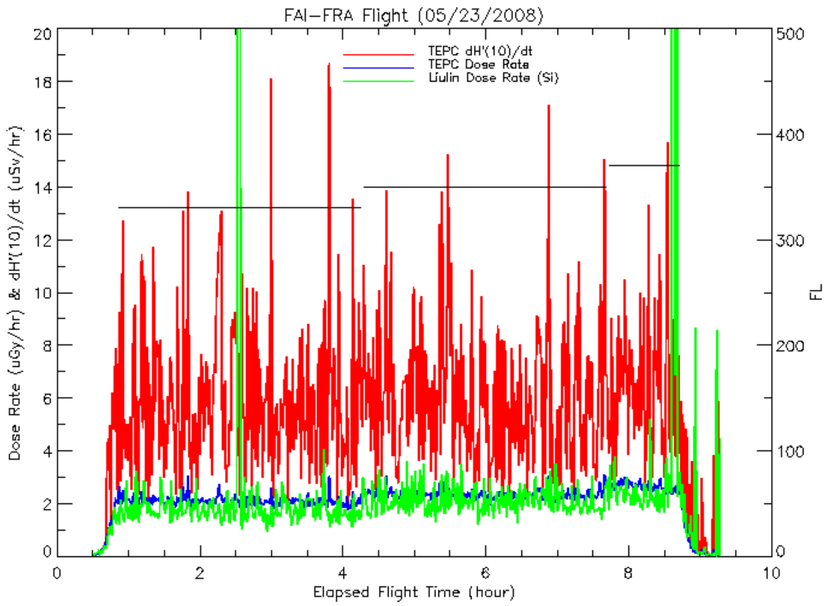


TEPC data courtesy of Matthias Meier

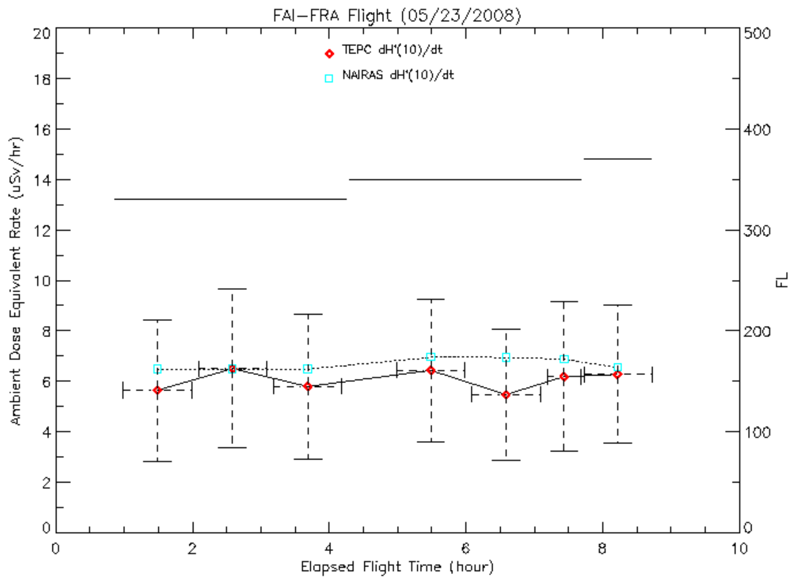
BON04 Model



NAIRAS/DLR-TEPC Comparisons High-Latitude Flight

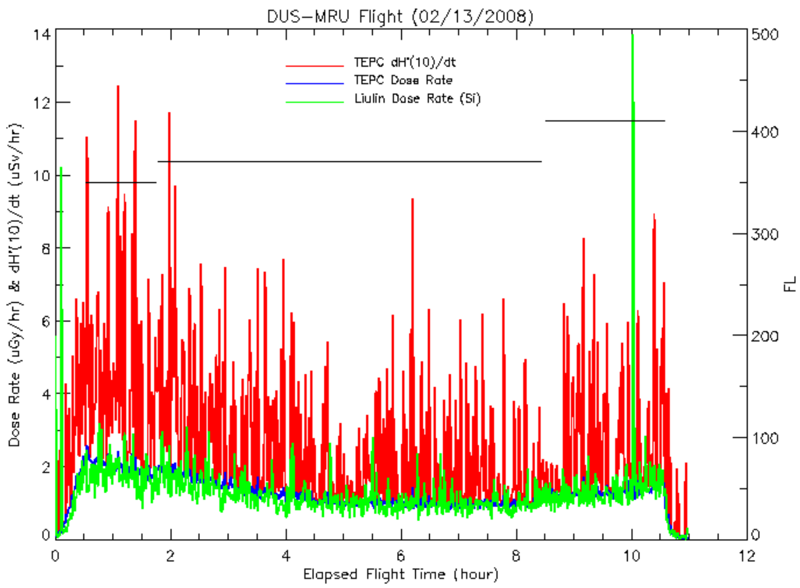


BON10 Model

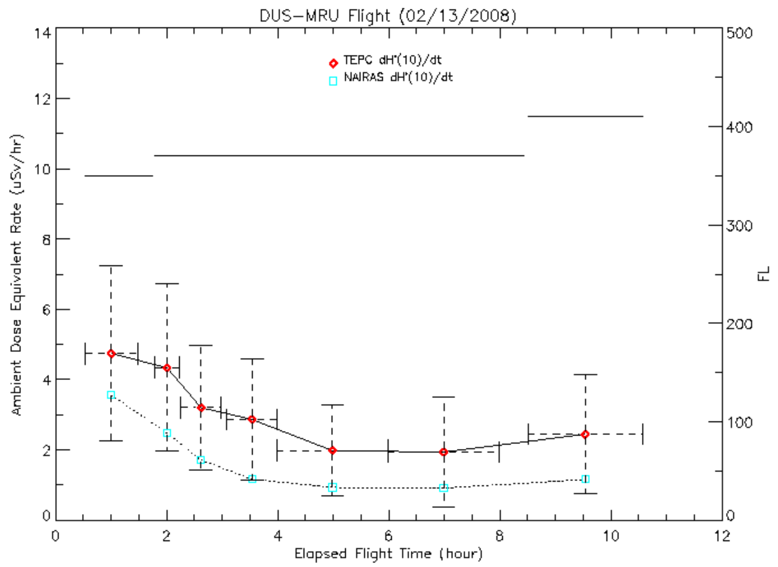


TEPC data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-TEPC Comparisons Low-Latitude Flight

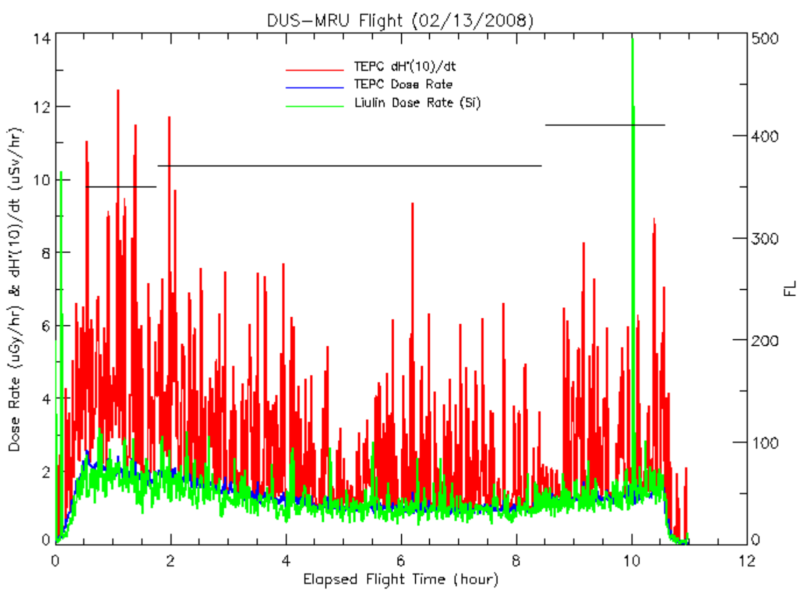


BON10 Model

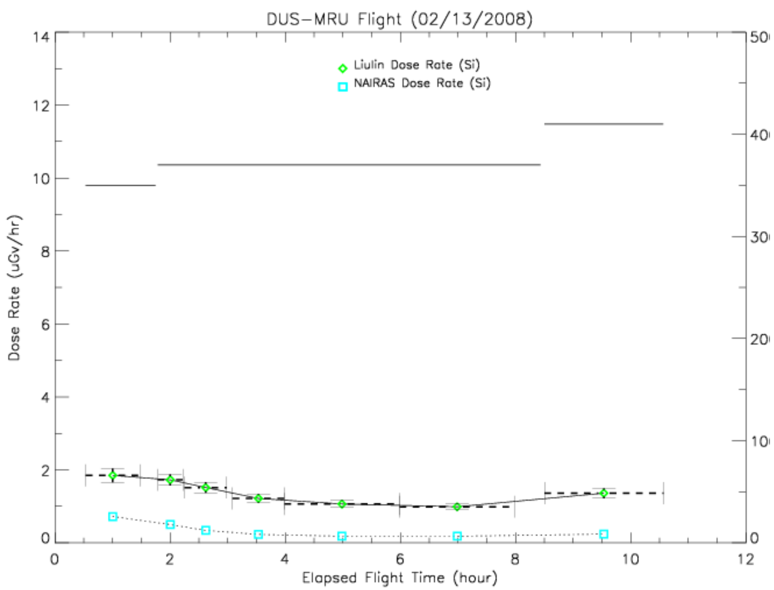


TEPC data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-Liulin Comparisons Low-Latitude Flight

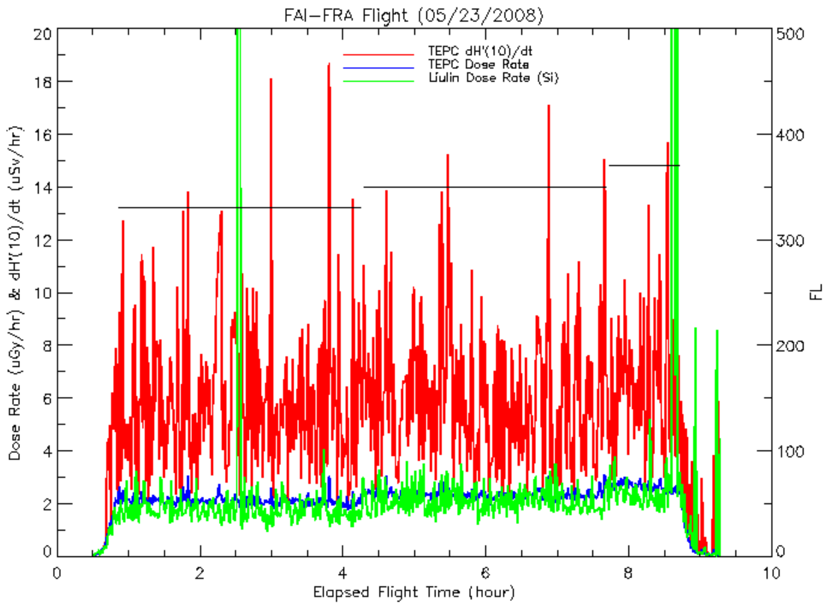


BON10 Model

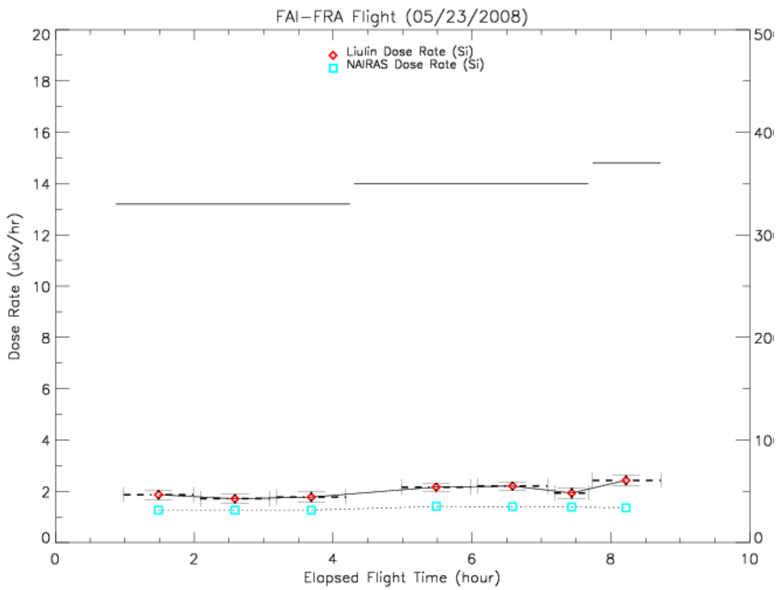


Liulin data courtesy of Matthias Meier (DLR)

NAIRAS/DLR-Liulin Comparisons High-Latitude Flight

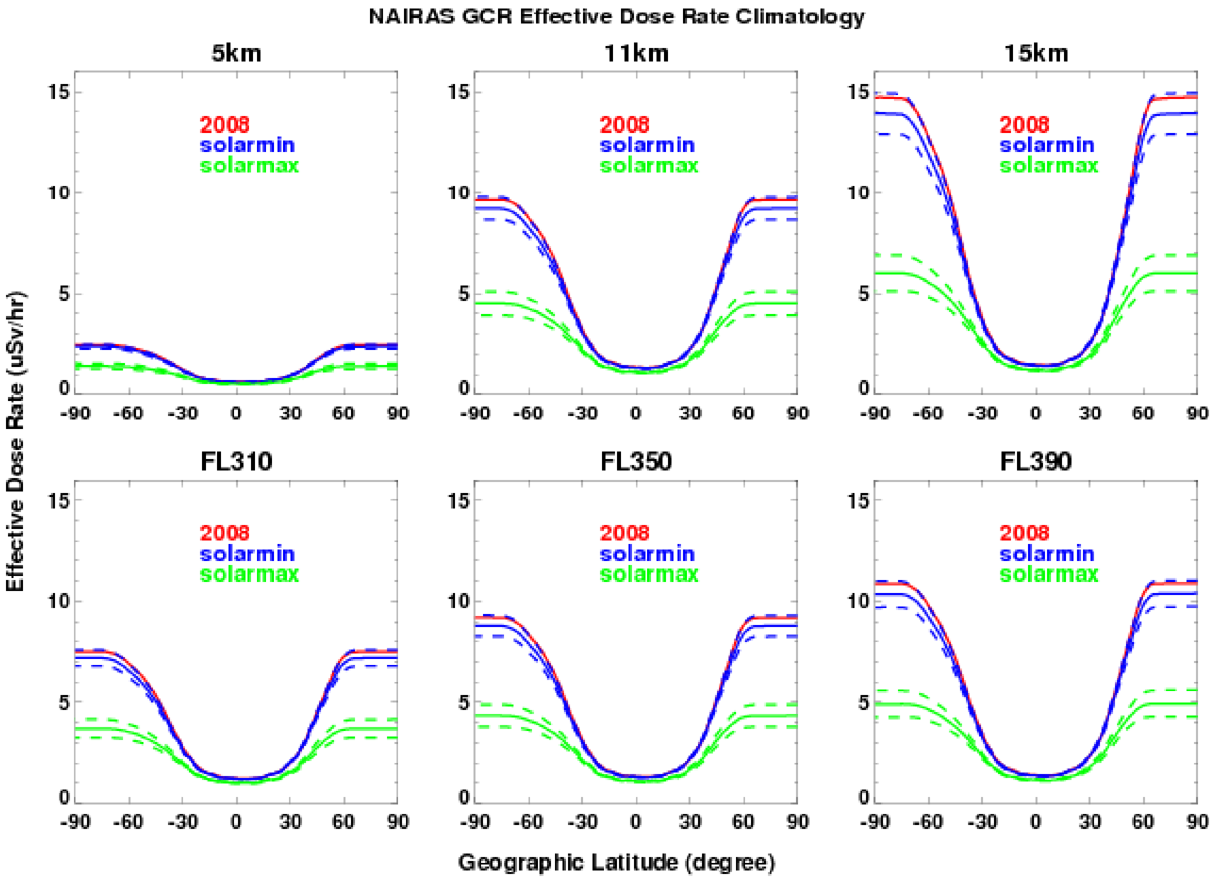


BON10 Model



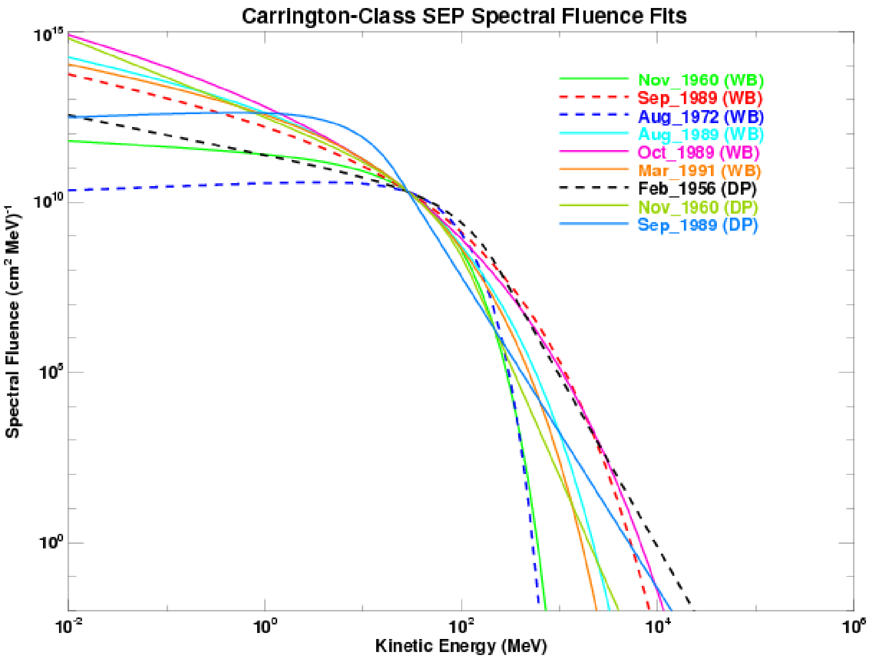
Liulin data courtesy of Matthias Meier (DLR)

NAIRAS Climatology of Dose Rates

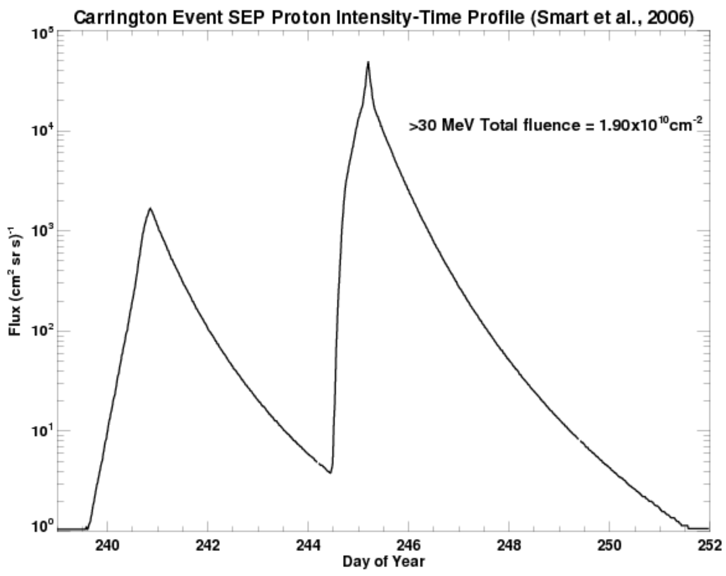


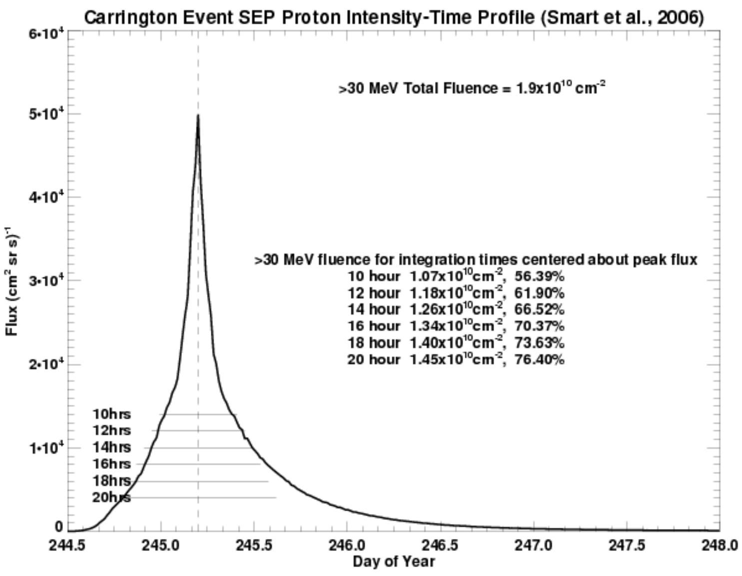
Carrington Event

- **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]



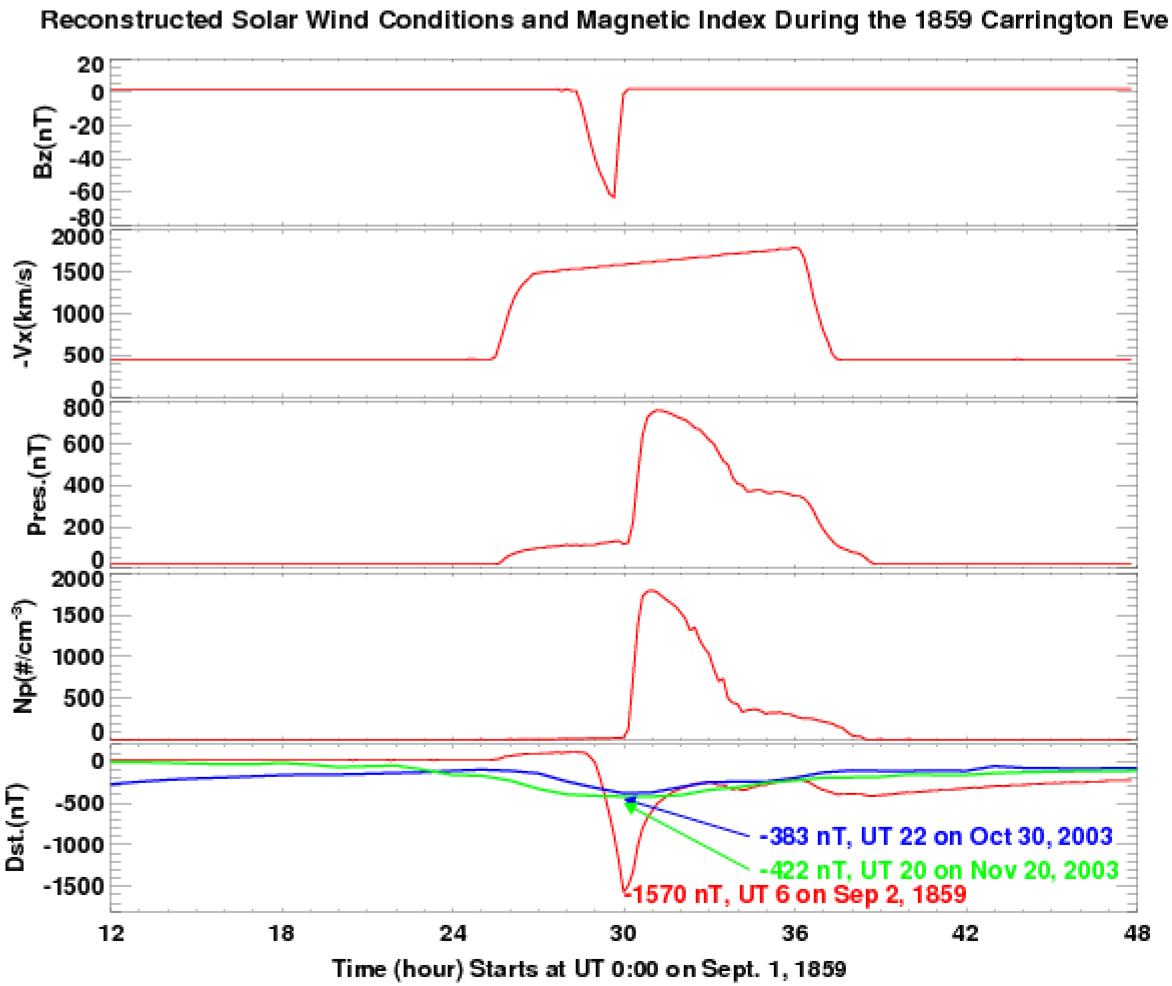
Carrington Event





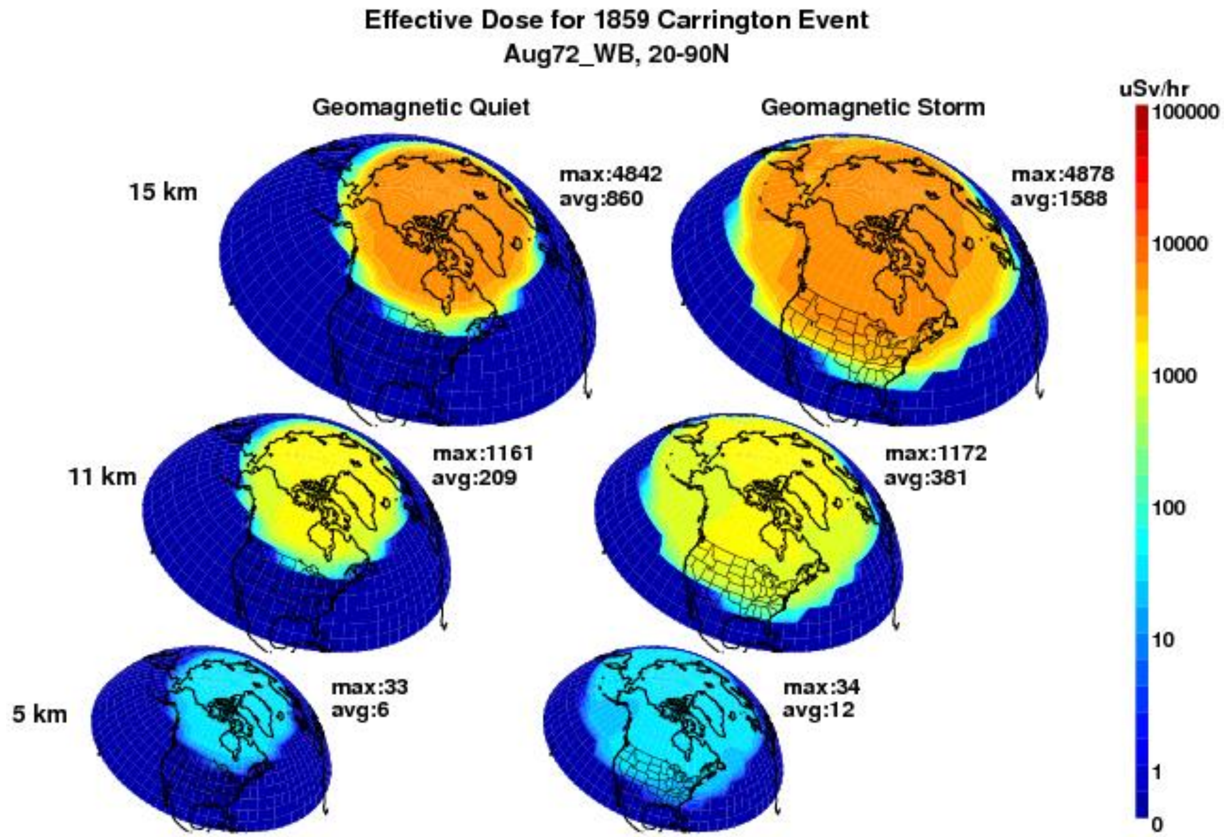
<u>SEP Spectral Fluence Rate</u>: Combine Smart et al. [2006] SEP proton intensity-time profile with Townsend et al. [2006, 2011] SEP fit parameters ($\Phi_0/20$)

Carrington Event

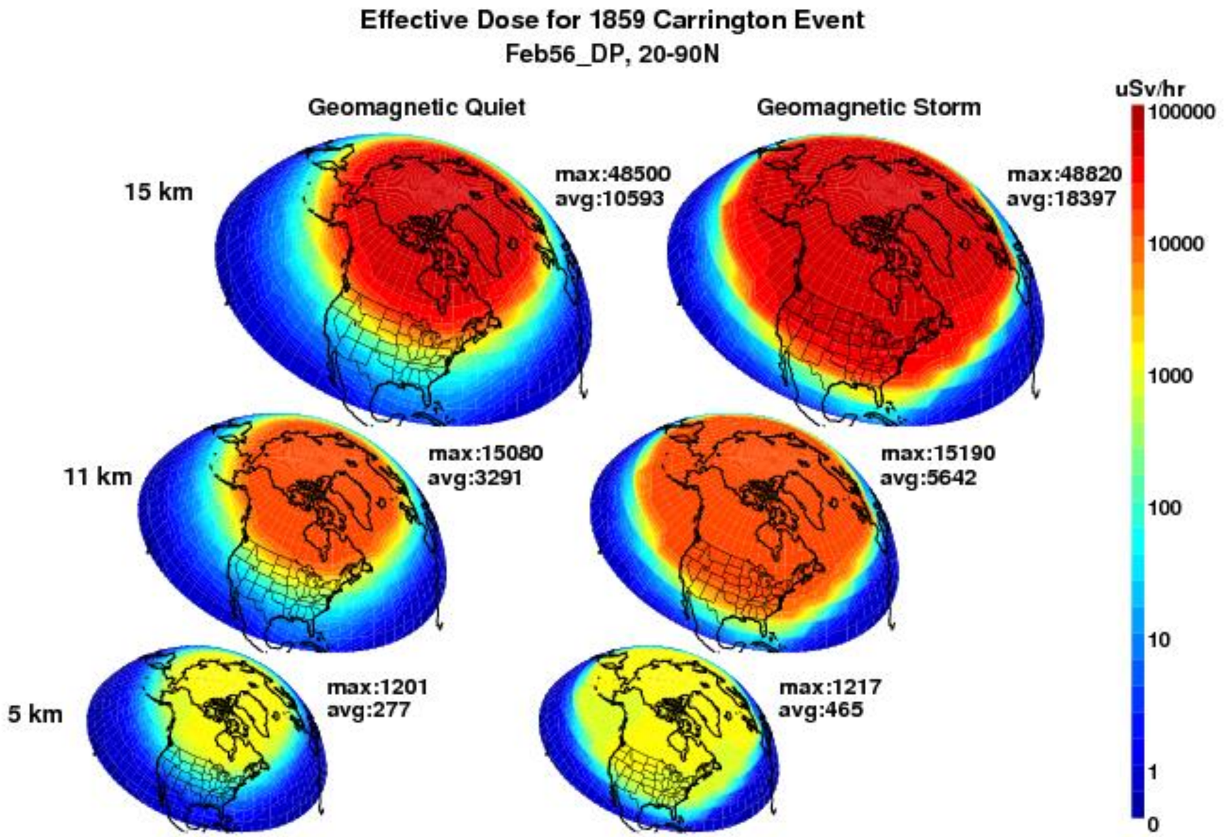


Temerin and Li [2002] & Li et al.[2006]

Carrington Event

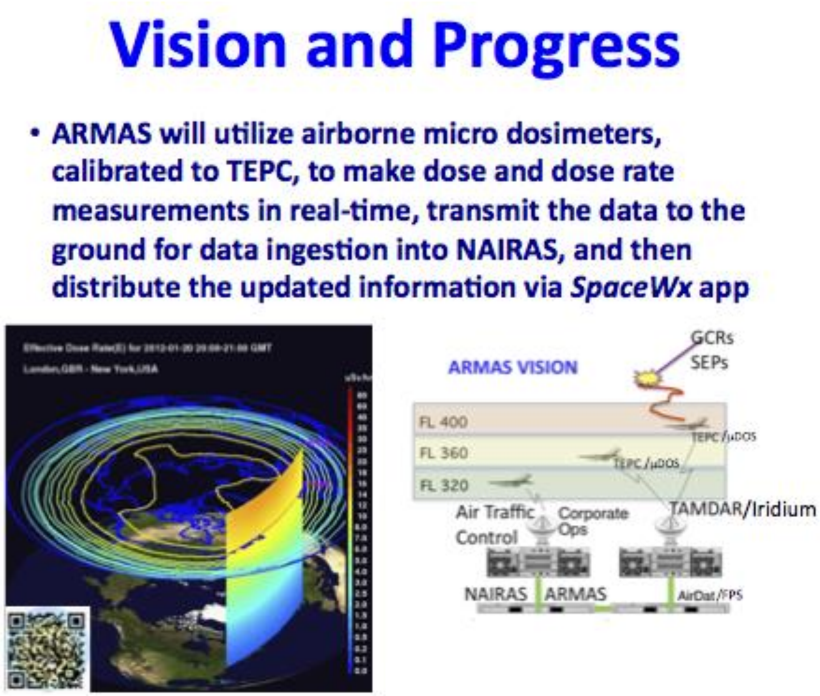


Carrington Event



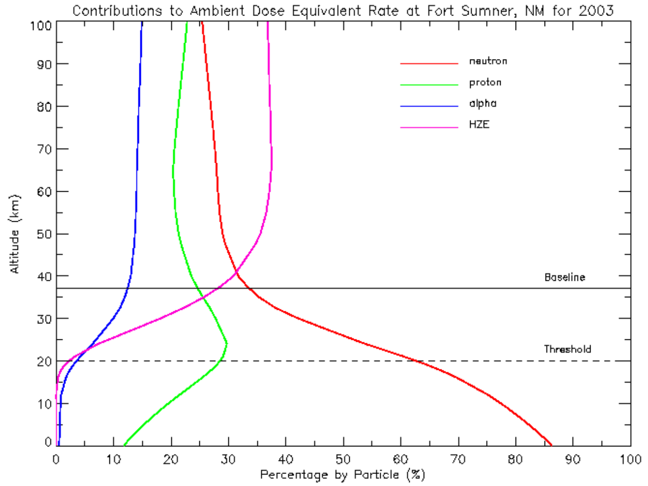
Automated Radiation for Aviation Safety (ARMAS) Project

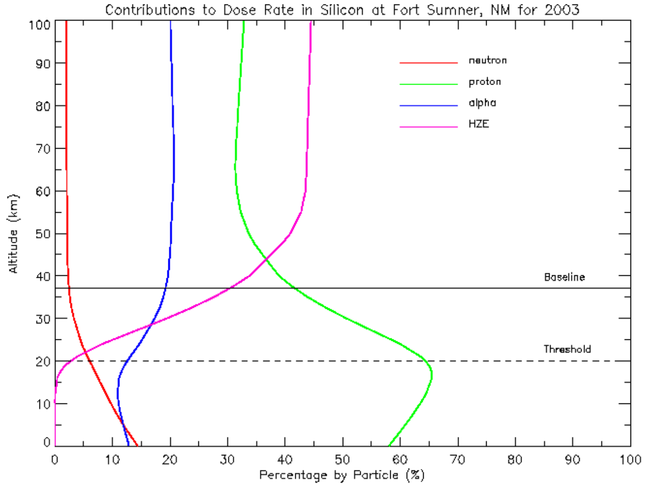
- **Project led by Space Environment Technologies (Tobiska)**
- **Deploy and obtain real-time dosimeter data at commercial airline altitudes**
- **Ingest real-time dosimeter measurements into the NAIRAS model to improve accuracy of radiation dose predictions along flight track**
- **Distribute ingested/improved 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**



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+

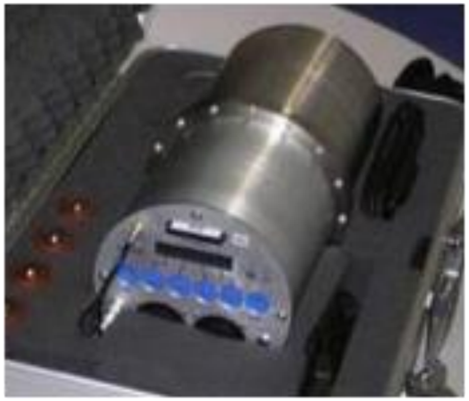




Radiation Dosimetry Experiment RaD-X

- 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