NAIRAS Annual Report 2009

Overview

The Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model is a prototype operational model currently under development at NASA Langley Research Center. The NAIRAS model provides global, real-time, data-driven predictions of atmospheric ionizing radiation exposure for archiving and assessing the biologically harmful radiation levels at commercial airline altitudes. The sources of ionizing radiation are galactic cosmic rays (GCR) and solar energetic particle events (SEP) which can accompany disturbances on the Sun's surface. The composition and energy spectra of atmospheric ionizing radiation originate from and are subject to variability in space weather phenomena. As such, the NAIRAS model provides a space weather decision support tool related to radiation impacts on crew and passengers of long-range aircraft, an area of national priority for NASA's Applied Science Program.

The NAIRAS model will enhance the performance of the decision support tools provided by the NOAA Space Weather Prediction Center (SWPC), since this decision support system does not currently monitor or estimate the ionizing radiation present in the atmosphere at commercial airline altitudes. The end-user communities that will benefit from the NAIRAS model are the commercial airline industry (airline corporation and aircrew professional association), the FAA, the National Institute of Occupational Safety and Health (NIOSH), and NOAA/SWPC. Results from the NAIRAS model will provide tools for its end-user organizations to develop policy and operational procedures for mitigating biologically harmful radiation exposure and provide an aircrew career planning tool – especially during SEP events. NAIRAS results will also aid in the formulation of recommended aircrew annual and career radiation exposure limits, and will enhance epidemiological studies conducted to better understand the biological effects of atmospheric ionizing radiation on passengers and crew.

The key NAIRAS data products are global distributions of vertical profiles of radiation exposure rates, computed from the Earth's surface to approximately 100 km in real-time. NAIRAS output will be made available at NOAA's National Weather Service, Aviation Digital Data Service (ADDS). NOAA/ADDS is a decision support system whereby NAIRAS results can provide a tool for commercial airlines and aircrew to monitor current and accumulated radiation exposure. NAIRAS output will also be available from our public website (http://sol.spacenvironemt.net/~nairas). The long-term goal is to transition the prototype NAIRAS model into an operational system that will be adopted by NOAA/SWPC.

The NAIRAS team has completed year two of the three year prototype operational development effort. The anticipated completion of the prototype model is mid-year 2011. Below are highlights and completed milestones from 2009 and early 2010. More information can be found at http://sol.spacenvironemt.net/~nairas/index.html.

Highlights

Summary

The major highlights of the second year of NAIRAS prototype development are:

- Calculation of full-body radiation dose (i.e., effective dose)
- Integration of a galactic cosmic ray (GCR) model into NAIRAS with coupling to the real-time neutron monitor count measurements
- Good agreement with aircraft TEPC measurement during the Halloween 2003 storm
- Real-time prototype operational NAIRAS demonstration presented at the NOAA Space Weather Conference
- Publication of two journal articles in Space Weather

nairas news

System Development

The development of the critical input data stream formats and I/O interface modules between the input datasets and the distributed network server database is complete. Input datasets for historical storm periods were prepared for NAIRAS verification and validation studies. A real-time prototype operational NAIRAS global GCR radiation exposure prediction has been demonstrated.

The previous dosimetric quantity computed by the NAIRAS model was the dose equivalent rate at the tissue boundary without transport through the body. This approximation overestimates the radiation exposure, and the overestimation is significant for SEP events. All ICRP radiation exposure limits are given in terms of effective dose, which is representative of the average full-body exposure. The NAIRAS model has been updated to compute effective dose rates.

A real-time GCR model was developed and integrated into NAIRAS. The Badhwar and O'Neill GCR model was adapted to real-time predictions by cross correlating the Climax-based solar modulation potential with four real-time, high-latitude, ground-based neutron monitor count rate measurements. The GCR model specifies the GCR spectral flux incident on Earth's atmosphere for transport through the atmosphere. This effort provided a student research opportunity through the NASA Langley Aerospace Research Summer Scholars (LARSS) program.

Considerable effort was made in increasing the computational efficiency and assessing the accuracy of the CISM-Dartmouth geomagnetic cutoff rigidity model. The model is suitable for a real-time nowcast and integration into the NAIRAS distributed network operational architecture.

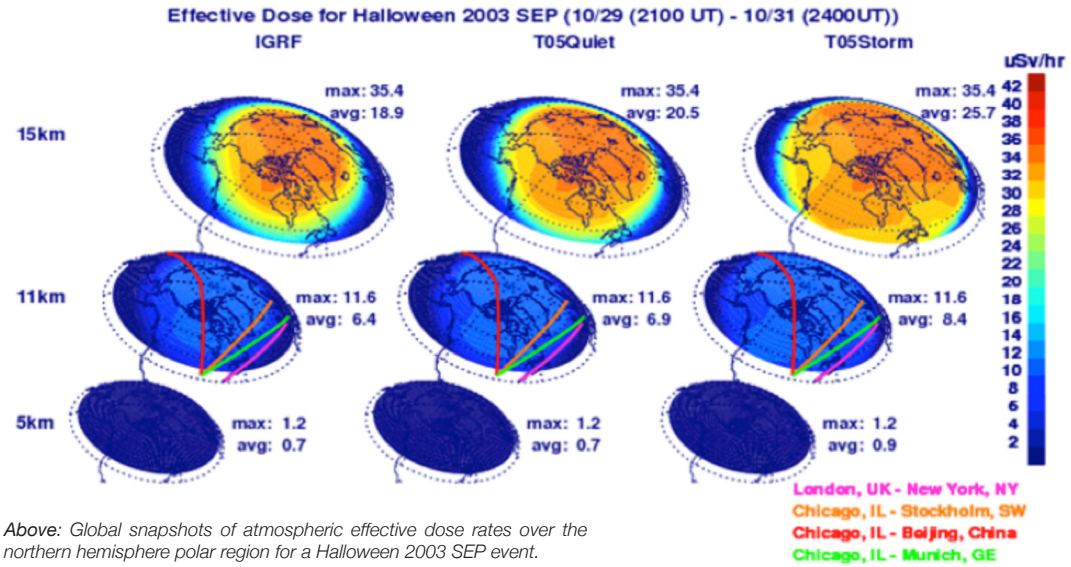
Halloween 2003 Storm Analysis

The team has continued to analysis the Halloween 2003 SEP events. This storm period is ideal for benchmarking the NAIRAS model because of the variety of simultaneous space weather phenomena. The Halloween 2003 storm period is characterized by a series of SEP events, interplanetary shocks, ground-level enhancements (GLEs), anisotropic SEP distributions, Forbush decreases, and the largest geomagnetic storms of solar cycle 23. We have fixed a number of programming errors in the SEP ion spectral flux fitting algorithm and the projection of the incident SEP flux onto the Earth's radial direction. With these code modifications, combined with the change in output dosimetric quantity to effective dose rate, the SEP radiation exposure predictions are now significantly less. The results are within the range of flight path Tissue Equivalent Proportional Counter (TEPC) measurements made during other storms periods along similar flight paths.

The image below shows global snapshots of atmospheric effective dose rates over the northern hemisphere polar region for a Halloween 2003 SEP event. The effective dose rates are shown at three altitudes and for three different magnetic field models used in the cutoff rigidity simulations. Geomagnetic effects have a profound influence of SEP radiation exposure, especially along the north Atlantic corridor region, and their neglect can underestimate the predicted radiation exposure by over a factor of two.

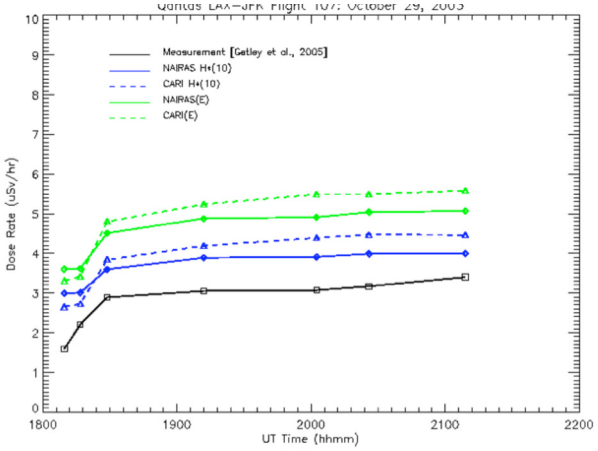
The NAIRAS team published two companion papers in AGU's Space Weather journal on the analysis of the Halloween 2003 storm events. In addition to the papers, animations of the global geomagnetic cutoff rigidity and effective dose rates throughout the Halloween 2003 storm period are available at the NAIRAS web site (http://sol.spacenvironment.net/~nairas/index.html).

Quantitative comparisons were made during the Halloween 2003 storm period between NAIRAS GCR exposure rates and aircraft TEPC measurements. Getley et al. [2005] reported the TEPC measurements taken on Qantas Flight 107 from Los Angeles, California to New York, New York on October 29, 2003. The latitudes of the Qantas flight trajectory were too low to observe significant SEP radiation exposure. However, the GCR exposure was suppressed by a Forbush decrease. The image below shows the comparisons between NAIRAS and the TEPC measurements along the Qantas flight trajectory. This figure shows comparisons of effective dose rate (denote E) and ambient dose equivalent rate



Above: Global snapshots of atmospheric effective dose rates over the northern hemisphere polar region for a Halloween 2003 SEP event.

(denoted H*(10)), which is a measurement-based proxy for the effective dose rate. Also shown in the figure are the dosimetric quantities computed from the FAA/CARI6 model.



Above: Comparisons between NAIRAS and the TEPC measurements along the Qantas flight trajectory.

Conference and Workshop Presentations

Mertens, C. J., et al., Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) Project, Joint Interagency Weather Research Meeting, March 22-24, 2010.

Mertens, C. J., et al., NAIRAS model predictions of aircraft radiation exposure during the Halloween 2003 storms, NASA Exploration Technology Development Program (ETDP) Workshop, Hampton, Virginia, March 2-3, 2010.

Wiltberger, M., C. J. Mertens, B. T. Kress, and S. C. Solomon, Results from the NAIRAS model for the Halloween storm, 90th American Meteorological Society Annual Meeting, Space Weather Symposium, Atlanta, Georgia, January 17-21, 2010.

Kress, B. T., Modeling geomagnetic shielding of solar energetic particles and cosmic rays, Fall AGU, San Francisco, California, December 14-18, 2009.

Mertens, C. J., et al., Prototype development of an operational global aircraft radiation exposure nowcast, Fall AGU, San Francisco, California, December 14-18, 2009.

Mertens, C. J., Models of atmospheric response to low- and high-energy particle precipitation, seminar at George Mason University, Fairfax, Virginia, October 28, 2009.

Mertens, C. J., M. Wiltberger, B. T. Kress, and S. C. Solomon, NAIRAS model predictions of aircraft radiation exposure during the Halloween 2003 storms, 2nd International High Energy Particle Precipitation in the Atmosphere (HEPPA) 2009 Workshop, Boulder, Colorado, October 6-8, 2009.

Mertens, C. J., Development of the Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model, brief to the FAA Air Traffic Organization, FAA Office of Commercial Space Flight and FAA Technical Center, Washington, DC, September 10, 2009.

Mertens, C. J., W. K. Tobiska, D. Bouwer, B. T. Kress, M. Wiltberger, S. C. Solomon, and J. J. Murray, Development of the Nowcast of Atmospheric Ionizing Radiation for Aviation Safety (NAIRAS) model, 1st AIAA Atmospheric and Space Environments Conference, AIAA San Antonio, Texas, June 22-25, 2009.

Kress, B. T., C. J. Mertens, and M. Wiltberger, Solar energetic particle cutoff variations during the 26-31 October 2003 geomagnetic storm, Space Weather Conference, Boulder, Colorado, April 28 – May 1, 2009.

Mertens, C. J., B. T. Kress, M. Wiltberger, S. C. Solomon, and S. Blattnig, NAIRAS prediction of aircraft radiation exposure during a high-energy solar energetic particle event in October 2003, Space Weather Conference, Boulder, Colorado, April 28 – May 1, 2009.

Journal Articles

Kress, B. T., C. J. Mertens, and M. Wiltberger, Solar energetic particle cutoff variations during the 28-31 October 2003 geomagnetic storm, Space Weather, in press, 2010.

Mertens, C. J., B. T. Kress, M. Wiltberger, S. Blattnig, T. S. Slaba, S. C. Solomon, and M. Engel, Geomagnetic influence on aircraft radiation exposure during a solar energetic particle event in October 2003, Space Weather, 8, S03006, doi:10.1029/2009SW000487, 2010.

Tobiska, W. K., Operational space weather entering a new era, Space Weather, 7, S10003, doi:10.1029/2009SW000510, 2009.

Mertens, C. J., W. K. Tobiska, D. Bouwer, B. T. Kress, M. Wiltberger, S. C. Solomon, and J. J. Murray, Development of the Nowcast of Atmosphereic Ionizing Radiation for Aviation Safety (NAIRAS) model, AIAA 2009-3633-978, 2009.

Team

Christopher J. Mertens (Principal Investigator)
NASA Langley Research Center, Hampton, Virginia

W. Kent Tobiska (Co-Investigator)
Space Environment Technologies, Inc., Pacific Palisades, California

Brian T. Kress (Co-Investigator)
Dartmouth College, Hanover, New Hampshire

Michael J. Wiltberger (Co-Investigator)
National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado

Stanley C. Solomon (Co-Investigator)
National Center for Atmospheric Research, High Altitude Observatory, Boulder, Colorado

Joseph Kunches (Collaborator)
NOAA Space Weather Prediction Center, Boulder, Colorado

Barbara Grajewski (Collaborator)
National Institute of Occupational Safety and Health, Cincinnati, Ohio

John J. Murray (Collaborator)
NASA Langley Research Center, Hampton, Virginia

Steve R. Blattnig (Collaborator)
NASA Langley Research Center, Hampton, Virginia

Xiaojing Xu (Collaborator)
SSAI, Inc., Hampton, Virginia