ASAP Space Weather Initiative

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Impact of Space Weather on Aviation

- Flight crews and passengers are subject to ionizing radiation produced by background galactic cosmic rays (GCR) and solar particle events (SPE).
- Ionizing radiation produces chemically active radicals in biological tissues that can lead to severe illness and cancer.
  - Aircrew are among the most highly occupationally exposed groups.
  - Crew exposures to background radiation could lead to 1.3 per thousand incidence rate of severe illness to a developing child during pregnancy.
  - The number of individuals expected to be subject to serious health effects during a SPE is quite high.
  - There are no current regulations within the US governing aircrew exposures.
- Avionics and aircraft materials are sensitive to ionizing radiation.
  - Ionizing radiation changes the state of logic circuits in avionics devices.
  - Logic circuit upsets are inversely proportional to device size – next generation computers and electronics are expected to be greatly more sensitive to disruptions.
  - Aircraft materials may amplify the internal radiation environment.

AIR - Atmospheric Ionizing Radiation

- AIR is the primary source of human exposure to radiations with high linear energy transfer (LET).
- High-LET radiation is effective at producing chemically active radicals in biological tissues that alter the cell function or result in cell death.
- Consequently, there is increased concern for potential health outcomes among passengers and crew in commercial aviation [*Wilson et al.*, 2003].

GCR and SEP

There are two sources of the extraterrestrial radiations:

1. the ever-present, background galactic cosmic rays (GCR), with origins outside the solar system, and
2. transient solar energetic particles (SEP), which are associated with solar storm activity lasting several hours to days with widely varying intensity.

GCR and SEP

- GCR consist of roughly 90% protons and 8% helium nuclei with the remainder being heavier nuclei and electrons [*Gaisser,* 1990]. When these particles penetrate the magnetic fields of the solar system and the Earth and reach the Earth's atmosphere, they collide with air molecules and create cascades of secondary radiations of every kind [*Reitz,* 1993].

- It is now generally understood that SEP events arise from coronal mass injections (CME) from active regions of the solar surface [*Kahler,* 2001; *Wilson et al.,* 2004].

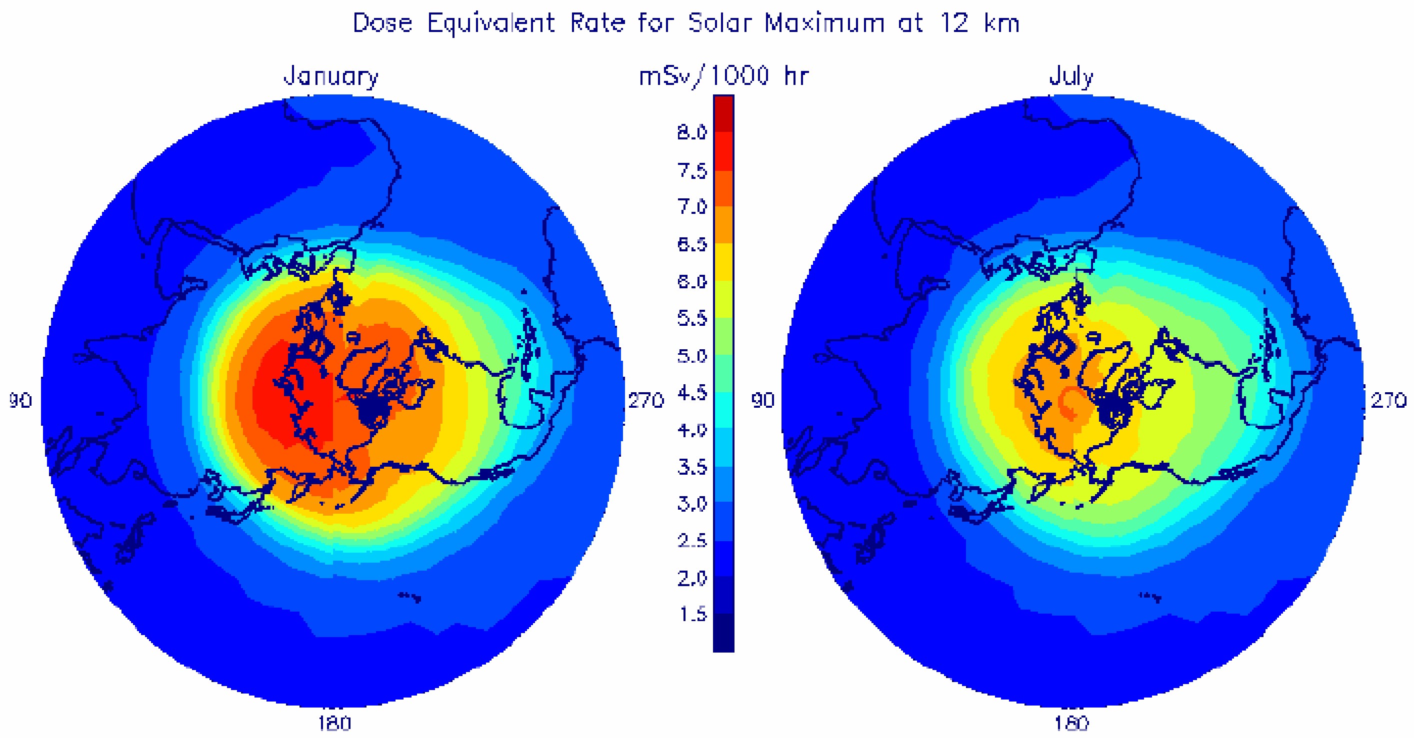
Flight Crew Exposure

- The International Commission on Radiological Protection (ICRP), as well as the EPA and FAA, consider the crews of commercial aircraft as radiation workers [*Wilson et al.,* 2003].
- The FAA estimates annual subsonic aircrew exposures to range from 0.2 to 9.1 mSv* compared to 0.5 mSv exposure of the average nuclear power plant worker.

* Sieverts – SI units of dose equivalent. Medical and other factors are used to convert absorbed dose to Sv.

Average Dosage Rates

Advanced Satellite Aviation-weather Products



Flight Crew Exposure Concerns

- Aircrews may receive exposures above recently recommended allowable limits for even radiation workers if flying their allowable number of flight hours.
- Although as a group the health risks of aircrew are low, *Band* [1990] found increased risks of several types of cancer among Canadian commercial pilots.
- There is further concern for prenatal injury in high altitude flight, as the US National Institute for Occupational Safety and Health continues to study early pregnancy outcomes among commercial flight attendants [*Grajewski et al.,* 1994; *Whelan,* 2002].

Passenger Exposure

- Frequent-flyer business passengers are likely exposed to even higher doses than aircrew, since flight hours are not restricted for airline passengers.
- In addition, if a large SEP occurs during flight, both passengers and crew may greatly exceed allowable limits and potentially serious health outcomes are a strong possibility.

ASAP Space Weather Initiative Objectives

Advanced Satellite Aviation-weather Products

Following the recent LaRC-sponsored workshop, a number of recommendations for future work were put forth [*Wilson et al.,* 2003]. The recommendations relevant to this proposal are:

1. Utilize satellite input data to provide real-time mapping of GCR and SEP radiation levels to provide guidance in exposure avoidance; and
2. Utilize state-of-the-art transport codes and databases to generate input data to the AIR model. The need to combine satellite observations of the space environment variables with HZE (high charge and energy) particle transport codes was further highlighted in a recent Airline Space Weather Workshop [*Friedberg,* 2004]. The objective of this proposal is to address these two recommendations.

Prototype Proposal

We propose to develop a prototype, global, nowcast (real-time) capability for calculating radiation dosimetry parameters at commercial airline altitudes. The work product will consist of a software package comprised of two components:

1. An updated version of the AIR model that incorporates real-time meteorological data of atmospheric density and real-time satellite measurements of incident GCR/SEP properties for nowcasting of ambient atmospheric ionizing radiation dosimetry; and
2. An updated version of a physics-based, state-of-the-art, HZE particle transport code that utilizes real-time satellite measurements of GCR/SEP properties to specify accurate boundary conditions for key dosimetry calculations.

HZE Transport Code

The real-time, HZE transport code serves a number of important functions:

1. Provide benchmark calculations, AIR model validation, and model-measurement comparison capabilities;
2. Provide input data for updated parameterizations of the AIR model as new GCR/SEP-air interaction cross section databases become available [*Wilson et al.,* 1991, 2003]; and
3. Assess the influence of upper atmospheric composition variability on radiation exposure levels at commercial aircraft altitudes.

End Product

- A prototype analysis package for the commercial airline industry to provide global and real-time monitoring of radiation exposure levels.
- The nowcast monitoring will consist of an hourly, global database of radiation dosimetry as a function of geographic location and altitude.
- Flight coordinates (departure/arrival coordinates, cruising altitude, flight time or cruising velocity, etc.) are entered into the software package and the exposure level is calculated from the database.
- The analysis package enables the radiation exposure level of each crewmember to be monitored. Decisions by the airlines can be made to restrict flight hours if annual exposure levels are exceeded.
- In the event of a SEP, flight paths and altitudes can be selected to minimize the exposure levels for both passengers and crew.

Innovations

- The prototype analysis package is the first of its kind to integrate satellite and ground-based measurements with radiation dosimetry algorithms to provide a real-time, global assessment of radiation exposure levels at commercial aircraft altitudes.

- The two- component software package that includes the empirical AIR model and the physics-based HZE transport code provides a flexible tool for benchmarking and validation activities that readily enables the use of past, present, and future measurement data.

- The proposed prototype, global nowcast analysis package provides a major step toward integrating this capability into a fully operational algorithm. Although a limited validation effort is included in this proposal, we believe a broad validation effort is required before migrating to operational status.