IRENE: AE9/AP9/SPM Radiation Environment Model

Known Issues and Limitations

Version 1.50.001

The IRENE (International Radiation Environment Near Earth): (AE9/AP9/SPM) model was developed by the Air Force Research Laboratory in partnership with MIT Lincoln Laboratory, Aerospace Corporation, Atmospheric and Environmental Research, Incorporated, Los Alamos National Laboratory and Boston College Institute for Scientific Research.

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The IRENE (AE9/AP9/SPM) model and related information can be obtained from AFRL's Virtual Distributed Laboratory (VDL) website: https://www.vdl.afrl.af.mil/programs/ae9ap9

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Listed below are the known issues and limitations of the IRENE (AE9/AP9/SPM) model. Some of these are due to sparse or no satellite sensor data available in specific energy, spatial, and/or temporal regimes, hence our request for new data sets to help fill existing gaps and/or augment the data sets currently incorporated into the model. Other limitations are due to the dependencies upon external models, which have their own limitations.
The IRENE model package continues to be improved and enhanced. The development team is attempting to reduce or eliminate these limitations and minimizing the effect of the various issues when possible.

- The model currently contains no solar cycle dependence, in particular with regard to LEO region proton variations. This will be addressed in a future version.

- Uncertainties in the LEO region protons for energies <20 MeV are large, due to variability in the satellite sensor data, and sparse data coverage.

- There are significant uncertainties in particle flux gradients for altitudes in the LEO region (i.e. <800km), affecting both AE9 and AP9 models.

- The error bars for the inner zone electrons are poorly constrained at all energies. The Van Allen Probes sensors have detected no electrons with energies >1.5 MeV; past measurements of such are ambiguous. It is unknown if this current environment state is temporary or the nominal condition.

- In future releases, we expect the AP9 fluxes in the inner zone, especially those above 400 MeV, will be further reduced through improvements in the processing of the Van Allen Probe RPS data set.

- In specific regions and under certain conditions, the AP9 fluxes calculated along a path may appear 'choppy', due to a rare issue with the normally smooth transition between the low and high altitude grids of the model; details are available upon request. These infrequent occurrences of choppy fluxes will tend to average out when accumulated over time.

- SPM error bars are lower than actual uncertainties, particularly for O+ and electrons; The O+ and He+ models are based on a single data set (Polar CAMMICE/MICS), and thus contain no measure of uncertainty based on disagreements between data sets.

- The SPM model contains no dependence upon Magnetic Local Time (MLT). This will be addressed in a future version.

- *Untrapped* particles, such as solar protons, are *not* included in the AE9/AP9/SPM model flux calculations. This will be addressed in future versions.

- The AE9/AP9/SPM model uses the IGRF magnetic field model for the main geomagnetic field. Due to the limitations of the IGRF model table of coefficients, the magnetic field results are fixed for all dates after 01 Jan 2020. Continuing development of the AE9/AP9/SPM model may include the ability to calculate valid and realistic results beyond that date.

- The neural network databases for Phi and Hmin cover the history of IGRF from 1965 to 2015 (and extrapolated to 2020), with errors of approximately 1% RMS. These neural networks are retrained when the IGRF coefficients are updated at 5 years intervals. The Phi and Hmin results from the new and old neural networks may differ by the 1% training error, even when evaluated at dates for which the IGRF coefficients have not changed. While this error is well within the uncertainty in the full calculation of the Phi and Hmin values using the IRBEM library, it can lead to larger differences, up to 5-15% RMS when used to compute individual fluxes. Therefore, one should not expect to exactly reproduce AE9/AP9/SPM model runs before/after an IGRF update.

- The dose calculations are relatively slow, even when using the multi-threaded capabilities. The processing performance will be improved in future versions through the use of kernels and adjustments to the parallelized task scheduling.

- The multi-threaded execution of the CmdLineAe9Ap9 or API-based programs is unsupported on *32-bit* Windows platforms, due to the deprecated support for this platform by the current version of the Intel MPI Library.

Contact Information

Please send any questions, comments and/or bug reports to: ae9ap9@vdl.afrl.af.mil

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