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Mars Radiation Surface Model

N. Alzate (1), M. Grande (1) and D. Matthiae (2)
(1) Institute of Mathematics, Physics and Computer Science, Aberystwyth, Cymru, United Kingdom (naa19@aber.ac.uk)
(2) Institut fur Luft- und Raumfahrtmedizin (DLR Cologne), Germany

Abstract

Planetary Space Weather Services (PSWS) within the Europlanet H2020 Research Infrastructure have been developed following protocols and standards available in Astrophysical, Solar Physics and Planetary Science Virtual Observatories. Several VO-compliant functionalities have been implemented in various tools. The PSWS extends the concepts of space weather and space situational awareness to other planets in our Solar System and in particular to spacecraft that voyage through it. One of the five toolkits developed as part of these services is a model dedicated to the Mars environment. This model has been developed at Aberystwyth University and the Institut fur Luft- und Raumfahrtmedizin (DLR Cologne) using modeled average conditions available from Planetocosmics. It is available for tracing propagation of solar events through the Solar System and modeling the response of the Mars environment. The results have been synthesized into look-up tables parameterized to variable solar wind conditions at Mars.

1. Introduction

The Planetocosmics application allows the computation of hadronic and electromagnetic interactions of cosmic rays with the Earth, Mars and Mercury environment [1]. It is an application of the Geant4 toolkit for the Monte-Carlo simulation of the passage of particles through matter [2]. The purpose of our work is to produce a PSWS tool for predicting Mars surface space weather conditions. The model consists of the following:

1) prediction of arrivals at the top of the Martian atmosphere for which two models are available, a 1-D MHD code which provides real time archive access to propagated solar wind parameters at Mars, initially developed by Chihiro Tao [3], and the WSA-Enlil, a widely available 2D hydrodynamic code developed at NOAA and available at the Community Coordinated Modelling Centre, which has been used for testing the accuracy of this model in predicting coronal mass ejection (CME) arrival at Venus [4];

2) propagation of energetic particles through the Martian atmosphere. This work has been done for an average atmosphere by DLR. Preliminary Geant4 [2] simulations of Martian atmospheric propagation have also been carried out at Aberystwyth. Tools for Geant4 simulation of atmospheric models are available at Planetocosmics (https://www.spenvis.oma.be/help/models/planetocosmics.html);

3) conversion to dose in silicon. The parameterized DLR radiation surface model calculates the dose rate in silicon on the surface of Mars caused by galactic cosmic radiation (GCR) and their variability due to solar activity. It consists of a combination of the DLR model for the primary GCR intensity [6], the particle transport (Geant4 Monte-Carlo) through the Martian atmosphere including backscatter from the regolith and a particle fluence to dose conversion procedure; and

4) web interface. The results will be mounted into a web interface provided by IRAP. Links to the two heliospheric propagation tools will be provided and an interface to pull up the appropriate atmospheric propagation curves from the derived lookup tables for energetic particles through the atmosphere to a specific location. Data will be available for archive in VESPA format.

2. Methods and Implementation

Planetocosmics (as implemented in SPENVIS) allows someone to calculate the flux of any type of primary and secondary particles at user defined altitudes (SPENVIS allows you to put up to five detectors) or the energy deposited by atmospheric cosmic ray showers in the atmosphere and soil. In addition, Planetocosmics output file contains information about the production of cosmogenic nuclides in the atmosphere.

In the SPENVIS interface to Planetocosmics, run parameters are defined through a series of input pages that the user can access on the main page of the model. The user can choose from a number of input pages and enter their preferred parameters. Once saved, a macro file can be generated. The user can then start a calculation, which will then bring up the results page. The Monte-Carlo simulation-based code can result in long execution times. The runs are therefore limited to five minutes.

The generated (ASCII) output file contains 1D (figure 1) and 2D histograms (figure 2). The former is presented as a 5-column table where each column represents the lower limit, upper limit, mean value, height and error of the histogram bins respectively. The latter, is displayed as a 6-column table where each column corresponds to the x lower limit, x upper limit, y lower limit, y upper limit, height and error of the histogram bins, respectively. The output for particle flux and the energy deposition analysis is shown as 1D histogram while the production of cosmogenic nuclides in the atmosphere is presented as a 2D histogram.

3. Results

Results carried out for a sample of 100 particles reaching a detector on Mars are as follows:

```
////////////////////////////////////////////////
IHistogram1D    /EDEP/ALTITUDE/1
////////////////////////////////////////////////
normalisation_factor :1.000000e+00
Title :    Deposited energy vs altitude [rad*cm2]
Name :  1
Entries :17531
Mean :  2.9765
Rms :    3.6974
Extra Entries :    126
Overflow :   0
Underflow : 126
xaxis_title :  altitude[km]
-2.491400e+00  8.989900e+01   2.976452e+00   3.567897e-06   4.799913e-08
////////////////////////////////////////////////
IHistogram1D    /EDEP/DEPTH/1
////////////////////////////////////////////////
normalisation_factor :1.000000e+00
Title :    Deposited energy vs depth [rad*cm2]
Name :  1
Entries :17531
Mean :  13.369
Rms :    4.1976
Extra Entries :    0
Overflow :   0
Underflow : 0
xaxis_title :  depth[g/cm2]
0.000000e+00   2.100000e+01   1.336882e+01   3.567897e-06   4.799913e-08
////////////////////////////////////////////////
```

Figure 1. Energy deposited by atmospheric cosmic rays. Output from a Plantecosmics run carried out for Mars through SPENVIS.

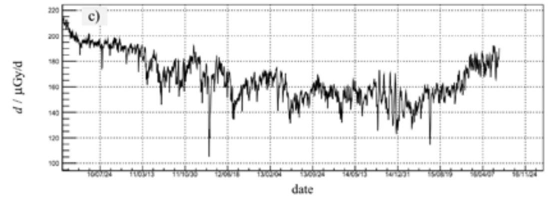

Figure 2. Predicted dose in silicon at the Martian Surface.

4. Summary and Conclusions

Planetary Space Weather Services (PSWS) tools have been developed within the Europlanet H2020 Research Infrastructure, which is strongly linked to the space weather services developed within the ESA's Space Situational Awareness Program (http://swe.ssa.esa.int/heliospheric-weather). The PSWS tools will have an impact on planetary space missions and on the hardness of spacecraft and their components to be evaluated under variety of known conditions, particularly radiation conditions.

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References

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