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Radiation environment at candidate landing sites on Mars: effects of Solar activity and of albedo neutrons for different mineralogical content

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Abstract

The study of the radiation environment at the surface of Mars is relevant for the degradation of instruments on rovers, for the hazard to future manned missions, and at a more fundamental level to understand the possible impact on biosignature conservation. Here we present a computational study (via the Monte Carlo Geant4 toolkit) of the radiation environment, effective doses and ambient equivalent doses at the surface of the planet for two potential landing sites, Oxia planum and Mawrth Vallis, assuming different Solar activity conditions and slightly different mineral composition (given by clay and silicate minerals). The results show how the impinging radiation varies with time and how the different hydrological and soil compositional characteristics influences the doses on a hypothetical stay on Mars of 30 days.

1. Introduction

The radiation environment at Mars is constituted by both Galactic Cosmic Rays (GCRs), thought to be accelerated by Type II supernovae and Solar Energetic Particles (SEPs) accelerated by intense flares and coronal mass ejections. radiation. The GCR spectrum is composed of 85% protons, 14% alpha (helium nuclei), and a small fraction of heavy ions (fully ionized atomic nuclei) and electrons. At solar maximum, complex interplanetary magnetic fields interact with incoming GCRs and remove lower energy particles from the incident radiation. As a consequence the GCR component in the inner environment of Mars has a higher average energy but a lower fluence at solar maximum than in the case of solar minimum. SEP are mostly composed of protons and electrons and about 10% He and <1% heavier elements, but although they produce high dose rates on the Martian surface, they penetrate only around 10 cm into the subsurface [1].

Two candidate landing sites for the ExoMARS2020 rover are Oxia planum, located at 18.2°N, 343.3°E, and Mawrth Vallis, located at 22.3°N, 343.5°E. In the first, band positions and shapes are best matched by smectite clays (Fe-Mg-rich saponite) or smectite/mica (e.g. vermiculite) with signatures of Fe2+ smectites found in the eastern part of the lower clay unit, as well as localized Al-phyllosilicate outcrops and an extensive hydrated silica stratum. The second is a wide layered phyllosilicate bearing unit with a widespread presence of a ferrous (Fe2+) phase at the transition between the Fe3+/Mg-smectite and the upper Al/Si-rich unit. Phyllosilicates (see Fig. 1) witness the presence of past water and are also fundamental minerals for water insertion and preservation and catalysis of organic molecules. Silicate minerals such as pyroxenes [(Ca, Fe, Mg)Si_2O_6] are also among the most common minerals in both the upper crust and surface of Mars. In particular, Fe2+ phase are of interest as they might be linked to respiration of Fe3+ reducing microbial communities. This raises an interest in such regions not only for the search for extant life, but also as location to be studied for possible injections of new microbes in future missions. The hazard posed by the radiation environment at such locations is thus of high interest.

1.1 Computational details

In this work, we have used MEREM (Mars Energetic Radiation Environment Model), which allows to simulate the source radiation spectra and which contains Planetocosmics, a Geant4 tool for the transport of particles, used for generating the full cascade in the atmosphere and the interaction with the soil. Only GCRs have been considered in this work, at Solar minimum and Solar maximum in cycle 23. No magnetic field has been considered in this study. The simulated system is composed by the atmosphere, the surface and the subsurface. The European Mars Climate Database has been used in order to specify required atmospheric profile parameters. The surface topography is based on data recorded by the Mars Orbiter, Laser Altimeter/MOLA instrument. The regolith composition is either automatically determined as a function of location using a default basalt/andesitic-basalt composition augmented by information regarding the surface iron concentration and hydrogen concentration (assumed to define prevailing levels of iron (III) oxide and water respectively) taken from Mars Odyssey Gamma-Ray Spectrometer/GRS data, or can be changed by the user under reasonable assumptions.

2. Results

The spectral analysis of the total downward flux, due to primary and secondary downward particles, and the total upward flux due to the albedo component (interaction of primary and secondary with soil) is presented and shows the importance of low energy neutrons in the vicinity of the surface. Doses by H, He, Li, Fe as primary GCRs sources are considered**.** The results show that the effective and ambient dose equivalent have a relatively strong dependence on the assumed Fe content in simulated clay compositions and Ca content in silicates, which in turn influence the production of albedo neutrons, and an expected relatively strong variation under different conditions of Solar activity. Diurnal variation effects of solar longitude and local time on the Martian atmosphere have minor effects. The results well match with the doses reported by previous studies but underestimate the ambient dose equivalent detected by the RAD instrument of the Curiosity rover (Table 1).

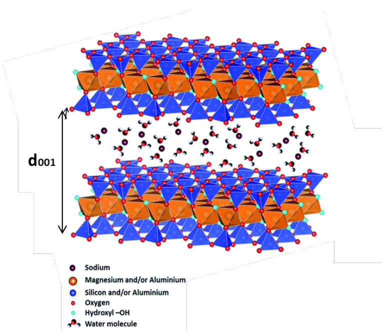

Figure 1: Crystalline structure of Montmorillonite, a typical widespread phyllosilicate. Water can easily enter the interlayer spacing

Table 1: Ambient dose equivalent from this study compared to Ref. [2] and to RAD measurements [3] (µSv per day), under quiet solar conditions

This study (Oxia planum)	Ref. [2] (Viking site)	RAD [3]
343.2	350.0	640.0

3. Summary and Conclusions

The work is inserted in a recent international effort to simulate, via accurate Monte Carlo calculations, the radiation environment at Mars. The results show a variability that should be taken into account, especially for future manned missions which will likely go beyond a 30 day-stay. Future work will focus on the evaluation of radiation doses inside potential hubs protected by different shielding types.

Acknowledgements

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