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Observational constraints on a global circulation model of radon in the Martian atmosphere

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Radon-222 has been proposed as a geophysical tool to study the gaseous surface/atmosphere exchanges on Mars, as well as to localize remaining outgassing vents and pore water reservoirs, owing to the strong dependence of the emanation factor upon soil water content in the 1-10 wt% range (Sabroux *et al.*, 2003; Meslin *et al*., 2007). Recent measurements by the Alpha Particle X-ray Spectrometer onboard *Opportunity*, one of the two Mars Exploration Rovers, have provided direct evidence for polonium-210 – a long-lived decay product of radon-222 – on Martian dust, which enabled us to retrieve an estimate of the global average radon flux, 50 to 100 atoms.m^{-2}.s^{-1}, amounting to about 1% of the Earth continental flux (Meslin *et al*., 2006).

We have implemented a coupled subsurface and atmospheric transport model of radon in a Martian General Circulation Model (LMDZ-Mars, Forget *et al*., 1999). The source term is inferred from the ^{232}Th map measured by the Gamma Ray Spectrometer (GRS) onboard *Mars Odyssey* orbiter (Boynton *et al*., 2004), assuming a constant ^{238}U/^{232}Th ratio, and from any realistic assumption on the pore water distribution (be it adsorbed water or pore ice). The hydrogen maps derived by *Mars Odyssey* gamma or neutron spectrometers can be used as a baseline for these assumptions (Feldman *et al*., 2002; Boynton *et al*., 2002). The subsurface transport model is purely diffusive and is coupled to a thermal model in order to take into account adsorption of radon atoms to the solid matrix. The adsorption coefficient and its temperature dependence have been obtained experimentally with a Martian soil simulant (JSC Mars-1) by gas

chromatography.

The model leads to 3D fields of radon in the Martian atmosphere that can be used to predict the atmospheric contribution to the total bismuth-214 signal observed by *Mars Odyssey* GRS. The knowledge of radon in the whole atmospheric column is indeed necessary to retrieve the actual ^{238}U/^{232}Th ratio from this signal, ^{238}U being routinely mapped through ^{214}Bi gamma rays (Boynton *et al.*, 2004; Evans *et al.*, 2006), as it is for airborne uranium exploration on Earth. Conversely, if the ^{238}U/^{232}Th ratio can be shown or assumed to be constant throughout most of the Martian surface, or if its actual variations are small compared to the observed ones, then the apparent ^{238}U/^{232}Th ratio can be used to constrain the radon atmospheric concentration, and thus radon flux. Moreover, this method will make it possible to search for radon anomalies, which could be the signature of non-diffusive outgassing possibly correlated with methane exhalation.

A lander-based detector measuring radon exhalation rate at the surface of Mars would then allow a comparison between in situ and orbital data, and help constraining the transport model and its input parameters.

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