RETRIEVAL OF RADON COLUMN DENSITIES AND URANIUM CONCENTRATIONS FROM AN ANALYSIS OF MARS ODYSSEY GAMMA RAY SPECTRA.

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Introduction:

The detection of atmospheric trace gases, the characterization of their spatial and temporal variations, and the localization of their sources have become key objectives of the Martian exploration program. In particular, the 2016 *Trace Gas Orbiter* mission (TGO) will be specifically dePvoted to these goals. Radon-222, a radioactive gas produced in the subsurface by the decay of uranium-238, which is eventually released to the atmosphere where it is transported as a passive tracer, has been identified as an interesting radionuclide to investigate the transport of gaseous species, both in the soil and in the atmosphere, and to study the water and dust cycles [1-6]. Its study is therefore relevant to the preparation of the TGO mission, but also to the analysis of the *Mars Odyssey* hydrogen data [4,6]. It has also some geochemical importance, since the retrieval of its atmospheric distribution is necessary to correctly map uranium-238 in the near subsurface [2], which is one of the targets of the *Mars Odyssey* Gamma Ray Spectrometer (GRS) [7].

A comparison between GRS preliminary data and results from a radon transport model has shown that the presence of radon in the atmosphere can explain, at least to first order, the main spatial features of the apparent U/Th ratio observed by *Mars Odyssey* GRS [3]. It confirmed the fact that the exhalation of radon from the subsurface is not negligible on Mars, which was first evidenced by the detection of unsupported polonium-210 on atmospheric dust by *Opportunity* APXS [2].

However, one of the difficulties that must be overcome when analyzing these gamma ray data stems from the fact that both radon in the atmosphere and radon in the soil will ultimately produce the gamma emitters bismuth-214 and lead-214 (the short-lived decay products of radon which are measured by the GRS), and it is not straightforward to separate the two contributions to the total signal measured from orbit (the surface and the atmospheric ones) [3]. The methods used to correct for the atmospheric radon contribution during airborne uranium exploration campaigns on Earth cannot be carried out with *Mars Odyssey* spacecraft. Usually, upward oriented detectors measure the atmospheric radon concentration which is subsequently subtracted, or the aircraft flies over a lake to perform the same correction. The first solution is obviously ruled out with a satellite. The second option is not possible either because the GRS already uses data acquired above the polar caps to estimate the total background signal of its germanium detector. However, several solutions remain, which were summarized in [3,6].

Here, we will investigate a method based on the energy dependence of the ^{214}Bi and ^{214}Pb signals, which is different in essence from our original approach (comparison between a predictive model and the U/Th ratio). This method is made possible by the careful extraction of several of ^{214}Bi and ^{214}Pb gamma ray lines carried out by the GRS team.

Method:

Four gamma ray lines from ^{214}Bi (at 609, 769, 1765 and 2204 keV) and two from ^{214}Pb (at 294 and 351 keV) have been extracted so far by the GRS team, and a few more lines are probably yet to come. Analyzing these different lines provides an efficient way to investigate the vertical distribution of the radioisotope being measured. Indeed, gamma photons with low energy will be attenuated more strongly than high energy photons, but this difference will depend on the medium they travel through (subsurface or atmosphere). Let us first assume that the uranium distribution within the soil is uniform with depth and that the radon profile in the atmosphere is as predicted by atmospheric models. Let us also assume that the vertical profiles of ^{214}Bi and ^{214}Pb closely match the ^{222}Rn profile (this is true to first order and far from the surface where dry deposition of radon progeny induces disequilibrium with radon). We are then left with two unknowns: the uranium concentration in the soil and the radon atmospheric column density. If the soil and atmospheric attenuation factors are calculated, the measurement of ^{214}Bi (or ^{214}Pb) at two energies provides the two equations needed to determine these two unknowns. Theoretically, measuring additional lines provides redundant equations that can help test the validity of the above assumptions and refine the vertical distribution of the radioisotopes. However, poor statistics will probably limit the feasibility of such an approach and restrict it to a two-layer model, as described above. Instead, the six lines will be used to obtain a better fit of the energy dependence of the ^{214}Bi (or ^{214}Pb) signal. In a later stage, diurnal variations of these lines will add another constraint to our assumptions by providing some independent information regarding the radon atmospheric profile and column density.

At high latitudes, the energy dependence of the ^{214}Bi signal also contains some information on the uppermost structure of the permafrost.

Expected results:

As analysis is currently under way, the method used and the first results of this approach will be presented at the meeting. Expected results are maps of ^{222}Rn atmospheric column densities and estimates of ^{238}U concentrations in the subsurface. This retrieval of ^{238}U in the regolith will enable us to estimate directly the radon source term in our subsurface production and transport model, freeing ourselves from our original assumption of a constant and uniform U/Th ratio over the surface of Mars. This will improve our estimates of the spatial variations of radon exhalation rate on one hand, and yield the distribution of the real U/Th ratio – of interest for geochemists – on the other hand.

References:

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