Diffusion controlled underground gamma radiation variation

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Natural gamma radiation measurements have been performed since ten years ago within the seismic tunnel of the Conrad Observatory. These measurements aim on the identification of radon variation patterns linked to environmental and geodynamic effects. The tunnel is not ventilated and well sealed against the environment. Although environmental conditions within the tunnel are very stable, strong seasonal patterns of gamma variations are present corresponding well to variations of the temperature difference between outside and in the tunnel. In order to explain this relationship, a physical model is introduced consisting of two building blocks: a production and a diffusion term. It is shown that such a temperature dependent diffusion process can explain the observed features very well.

Temporal variation patterns of radon gas are of paramount interest basically for two reasons: Firstly, the radioactive gas radon is well known for its health risks, particularly lung cancer. Secondly, radon in a geological environment can provide insights into transport processes and routes, and thus its variations contain information on fault systems and other deformation processes. ^{222}Rn is a radioactive inert gas formed as part of the ^{238}U decay series. The combination of its noble gas character and its radioactive decay make it a unique ultra-trace component for tracking temporally varying natural processes. Measurements are commonly performed using gamma crystal scintillators as they reach the highest sensitivity, although they only provide an indirect measure of the decay products of ^{222}Rn.

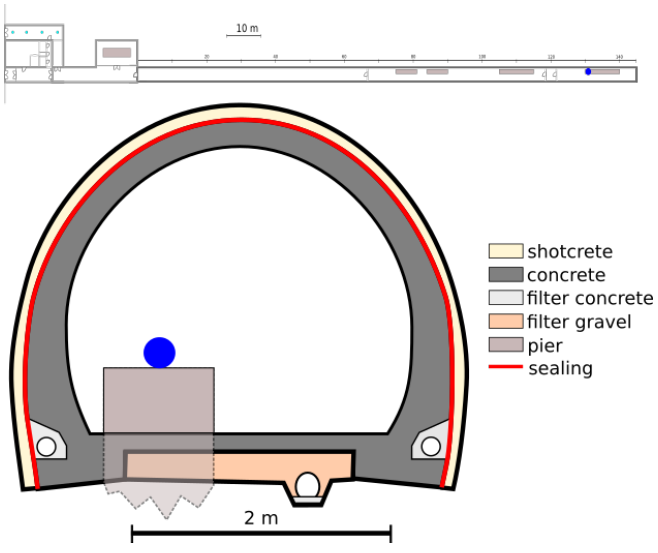

Figure 1: The gamma probe (blue circle) is installed on a pier at the far end of the seismic tunnel and fully exposed to air.

In all previous studies large temporal variations of radioactive count rates are reported, related to ^{222}Rn variation, and seasonal variations are observed. Furthermore, in basically all cases a significant correlation between variational patterns and outside temperature variation has been observed. Concentration related diffusion, however, has never been considered as a dominant transport process so far. A long-term single channel analyzer (SCA) monitoring of gamma variation within the seismological tunnel of the Conrad Observatory shows the already well known seasonal signals and a clear correlation with temperature differences to the outside temperature (Fig. 2). In order to clarify the coupling mechanism we introduced a simple physical model which basically consists of two terms: a production term describing the formation of new radiogenic isotopes and a diffusion term, describing concentration related diffusion, whose effectivity is modulated by temperature differences. This model almost perfectly allows to reconstruct observed gamma variations in a non-ventilated underground structure. Subtracting such environmental signal is essential for interpreting and identifying other dynamic signals within the radon time series.

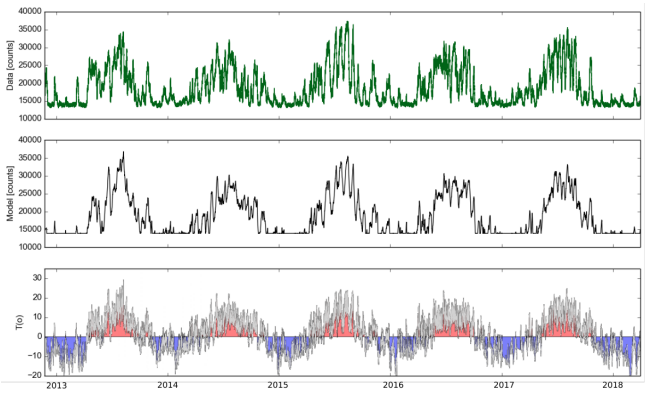

Figure 2: 5 year time series showing variations in count rate with seasonal variations (top), outside temperature variations (bottom, the tunnel temperature remains constant at 6.8°C throughout the time interval) and the diffusion forward model which is based on the temperature difference between outside and inside condition (middle).

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