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Towards a refined regional geological model for predicting geoneutrinos flux at Sudbury Neutrino Observatory (SNO+)

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The SNO+ detector is the redeployment of the illustrious Sudbury Neutrino Observatory (SNO) at SNOLAB in Ontario (Canada). After the substitution of heavy water (D_2O) with liquid scintillator (CH_2) inside the inner vessel, in 2014 the 1 kton detector will come on-line and together with KamLAND in Japan and Borexino in Italy will accumulate geoneutrino events. Geoneutrinos are electron antineutrinos originating from beta decays of natural radioactive nuclides in the Earth interior. A fraction of them, generated from ^{214}Bi and ^{234}Pa of ^{238}U decay chain and from ^{228}Ac and ^{212}Bi of ^{232}Th decay chain, are above the threshold for inverse beta reaction on free protons and can be detected by SNO+. Geoneutrinos are a real time probe of Earth interior, because the flux at the terrestrial surface depends on the amount and distributions of U and Th in the Earth's reservoirs. To extract global information such as terrestrial radiogenic heat power or to test compositional models of the Bulk Silicate Earth (BSE), the regional contribution to the geoneutrino signal has to be controlled by study of regional geology.

We present the 3-D refined geological model of the main reservoirs of U and Th in the regional crust extended for approximately 2×10^5 km^2 around SNOLAB, including estimates of the volumes and masses of Upper, Middle and Lower crust, together with their uncertainties. According to the existing global reference model (Huang et al., 2013), this portion of the crust contributes for 43% of the total expected signal at SNO+. The remaining contributions come from the far field crust (34%), from continental lithospheric mantle (5%) and from the mantle (18%). Since SNO+ will accumulate statistically significant amounts of geoneutrino data in the coming years, the calculated signal that is predicted to be derived from the lithosphere can be subtracted from the experimentally determined total geoneutrino signal to estimate the mantle contribution.

The main crustal reservoirs are modeled by identifying three main surfaces: the Moho discontinuity, the top of the Lower Crust and the top of the Middle Crust. About 400 depth-controlling data points obtained from deep crustal refraction surveys and from teleseismic receivers are the inputs for the spatial interpolation performed with the Ordinary Kriging estimator. This method takes into account the spatial continuity of the depths and it provides the uncertainties of the crustal volumes. The Upper Crust is further modeled in detail combining information from vertical crustal cross sections and Geological Map of North America at 1:5,000,000 scale. Seven sub-reservoirs with distinctive characteristics lithologies, metamorphism, tectonic events and chemical composition are identified. The density and the abundances of U and Th in the seven sub-reservoirs are evaluated from the published litho-geochemical databases, including analyses of representative outcrop samples. The Middle and Lower Crust densities and radioactivity contents are evaluated from seismic constraints.

The numerical 3D model consists of about 9×10^8 cells of 1 km $\times$ 1 km $\times$ 0.1 km dimensions. For each of them geophysical information, such as latitude, longitude, depth and reservoir type, are combined with estimates of the U and Th abundances to predict the geoneutrino signal at SNO+ originated from the regional crust. The total geoneutrino signal at SNO+ is about 12% less than that calculated using the global reference model (Huang et al., 2013).

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