IonoNest: a Bayesian approach to modeling the ionosphere

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The Earth's atmosphere alters the signal that we receive from distant astronomical objects by the absorption or scattering of radio waves by free electrons in the ionosphere. The number density of free electrons in the ionosphere is affected by factors such as the solar wind and direct radiation from the Sun; it varies spatially and temporally, causing changes in the amount of absorption that occurs, hence altering the received signal and detrimentally affecting astronomical radio observations and radio communications.

A riometer (Relative Ionospheric Opacity Meter) is a device used to measure the incident cosmic noise level at the Earth's surface and thus to record indirectly the ionospheric opacity by comparing this cosmic noise to that obtained on a "quiet" day. Here we present new riometry data from the Kilpisjärvi Atmospheric Imaging Receiver Array (KAIRA), which is located in northern Finland, and can be used as a multi-frequency riometer. We also present a new tool for finding the shape of the electron density height profile of the ionosphere based on these multi-frequency (17 MHz – 55 MHz) absorption measurements. This tool, IonoNest, uses the nested sampling method to explore the parameter space describing a given ionospheric model and to determine a best-fitting solution, as well as returning the Bayesian evidence for individual models, allowing quantitative model selection based on the KAIRA data.

We present results from both initial tests on simulated data using a variety of input models, ranging from simple Gaussian profiles to more complex distributions. These models are then used to fit absorption data obtained with KAIRA during observations in October 2013, allowing comparisons to be made with simultaneous observations of the ionosphere by the EISCAT UHF and VHF radars located in Tromsø.