Multi-instrument Ionospheric Tomography in Scandinavia with Bayesian Statistical Inversion and Correlation Priors

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We present a novel algorithm for ionospheric tomography and the latest results obtained with it.

Ionospheric tomography is mathematically a sparse limited-angle tomography problem and therefore severely ill-posed. This means that to obtain reasonable reconstructions the problem needs a strong regularisation. In ionospheric tomography the regularisation is often implemented with a limited set of base functions, Tikhonov regularisation, initial profiles for iterative methods, or with a different combinations of these schemes. These methods have been shown to produce satisfactory reconstructions, but the role of the regularisation and how much the chosen method actually constraints the possible outcomes is not always clear. Our tomography scheme is implemented in the Bayesian statistical framework (Markkanen et al. *Ann. Geophys.,* vol. 13, pp. 1277-1287, 1995). In Bayesian inference the regularisation is given as an a priori distribution. The a priori distribution contains the information about the unknown parameters before the measurements. The second step is to build a likelihood function for the unknown parameters, given the observed measurements. By combining the likelihood with the prior density function, we obtain the a posteriori distribution, from where we can obtain the estimate with the highest probability, based on the information in our disposal. Here we give the a priori distribution with the novel correlation priors (Roininen et al. *Inverse Probl. Imag.*, vol. 5, issue 2, pp. 611-647, 2011). Essentially the correlation priors are Gaussian Markov random fields, wherein we can state the physical assumptions of the ionosphere in an interpretable manner. With this implementation we get a very thorough understanding of what is the role of the regularising a priori distribution. On addition to that, the statistical framework also gives a very natural way to combine different ionospheric measurements. Therefore we can use measurements from Low Earth Orbit (LEO) and Global Positioning System (GPS) satellites as well as ground based measurements in the same model.

Starting from 2011, as a part of TomoScand project, Finnish Meteorological Institute has been installing a new receiver network for LEO beacon satellites. At the moment, together with the receiver network of Sodankylä Geophysical Observatory, we collect data from 11 receivers stations. The northern most receiver located in Svalbard and southern most in Estonia. We also collect data from 86 GPS receiver stations provided by Finnish company Geotrim. We present the latest results with the new network and algorithm in a 2-dimensional case, however, the goal in the near future is to extend the model to a 3-dimensional case to cover over Scandinavia.