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Tomographic Techniques Applied to Space-based Ionosphere Measurements

Bruce A. Fritz*(1)
(1) U.S. Naval Research Laboratory, Wash., DC, 20375, e-mail: bruce.fritz@nrl.navy.mil

Remote sensing instruments are important tools that can be used to determine many key parameters in Earth's ionosphere, from plasma density to energy flux. Space-based remote sensors are particularly useful for characterizing regions of the ionosphere where ground-based instruments cannot easily be placed, like over the ocean, or where space-based in situ instruments cannot easily reach, like the lower ionosphere. Tomography is a powerful method frequently used to maximize the utility of remote-sensing measurements. This tutorial will first outline the basic principles of tomography, including a very brief description of the theory and mathematical formulation. The tutorial will then provide examples of how various tomographic techniques are applied to space-based ionosphere measurements as a method for illustrating the power of the technique. Several instrument types will be discussed, including global navigation satellite system (GNSS) receivers and optical imagers. The relative strengths of each instrument type will be discussed, but one limitation of any remote sensing instrument is that they only provide one-dimensional information along the line of sight. A one-dimensional result is typically sufficient for hard targets, like the Earth's surface, but characterizing a distributed target like the ionosphere can becomes more complicated as the measurement is integrated along a line of sight that may span hundreds or even thousands of kilometers. Tomography helps maximize the output of remote sensing instruments by combining a set of multiple one-dimensional measurements from different viewpoints to produce a two-dimensional image of the source region. Examples will show how the derived two-dimensional images are then used to infer key parameters in Earth's ionosphere.