URSI GASS 2021, Rome, Italy, 28 August - 4 September 2021

ISR Estimation of Ambipolar Electric Fields and Topside Gradients

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Recent research in magnetosphere-ionosphere coupling has highlighted the importance of ion outflow from the topside ionosphere. Ambipolar electric fields play a major role in controlling the topside profiles and modulating the source of outflow. Evaluating the ambipolar electric field requires the derivative of electron pressure. Incoherent scatter radar (ISR) is the only experimental technique that can measure instantaneous altitude profiles of both electron density and electron temperature. Nonetheless, evaluating derivatives of these plasma parameters can be difficult with traditional methods of ISR analysis. The standard fitted parameters distributed by most ISRs are the result of first averaging lag-product arrays (LPA) into range gates and then fitting the resulting gated autocorrelation functions one range gate at a time. This procedure destroys some information about the derivatives and results in discontinuous profiles in the topside that cannot be differentiated easily. Details of the correlations between range gates caused by the pulse length are also lost.

This work demonstrates a superior way to estimate ambipolar electric fields from ISRs and a way to quantify the uncertainties of those estimates. We perform a full-profile analysis (FPA) that fits for continuous and differentiable profiles of plasma parameters that are consistent with the measured LPA. This analysis incorporates the two-dimensional range-lag ambiguity function and does not require assumptions about the uniformity of parameters in range. Modest regularization of the solution is required to suppress spurious oscillations in the solution. FPA has been demonstrated before with the Millstone Hill ISR [1] and the Jicamarca ISR [2]. In this work we present first examples of FPA applied to the Resolute Bay Incoherent Scatter Radar (RISR-N), as well as examples of how to propagate the complete covariance matrix of the LPA through to the fitted parameters. Furthermore, we demonstrate how to propagate the covariance matrix of the FPA fitted parameters through to the variance of any function of the plasma parameters or their derivatives. This technique can be used for estimates with uncertainties of a variety of parameters that require derivatives of plasma parameters, including ambipolar electric fields, ion pressure gradients, ion heat fluxes, and electron heat fluxes. We will show examples of this analysis applied to polar cap observations from RISR-N and discuss the ability of RISR-N to precisely characterize the forces driving polar cap ion upflow.

References

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