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High-resolution incoherent scatter plasma parameter fits and ion composition fits using Bayesian filtering

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High range and time resolution plasma parameter fits and the unknown F_1 region ion composition profile are long standing problems in incoherent scatter radar data analysis. With the EISCAT incoherent scatter radars, four-parameter fits of electron density N_e, electron temperature T_e, ion temperature T_i and line-of-sight plasma bulk velocity V_i are routinely accomplished with 60 s time resolution and a range resolution varying from 2 km in the E region to tens of kilometres in the F region.

Better resolutions can be reached in favourable conditions, but observations of auroral electron precipitation would require range resolution better than 2 km [1] and time resolution of a few seconds [2], which cannot be reached with sufficient statistical accuracy. The so-called raw electron density N_r, which is a scaled backscattered power, is typically used in high resolution auroral observations. The raw density N_r is equal to the actual density N_e if $T_e = T_i$, but it is an underestimate when $T_e > T_i$, which often occurs when electron precipitation heats the electron gas.

The standard four-parameter fits assume ion composition from the International Reference Ionosphere, which often predicts unrealistically high molecular (NO^+ and O_2^+) ion concentrations in the F_1 region around 200 km altitude. The incorrect ion composition leads to overestimation of T_i and T_e in the four-parameter fits, because the incoherent scatter spectrum is, roughly speaking, sensitive to the ratio T_i/m_i, where m_i is the mean ion mass.

We have recently developed a technique that combines Bayesian filtering and correlation priors to introduce prior information about plasma parameter variations in time and altitude. The Bayesian Filtering Module (BAFIM) [3] is an extension to the standard EISCAT data analysis tool, GUISDAP [4]. BAFIM allows us to control temporal and spatial gradients in each plasma parameter separately, thus enabling effectively different resolution to be used for each parameter. With BAFIM we can fit also T_e and T_i in high resolution electron density observations and thus avoid the bias in N_r when $T_e > T_i$), and we can fit the F_1 region ion compositions and thus avoid the bias in T_i and T_e in the four-parameter fits.

References

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