

# Modification of the natural plasma line during HF heating at Tromsø

A. Senior and M. J. Kosch

Department of Communication Systems, Lancaster University, U. K.  
(e-mail: [a.senior@lancaster.ac.uk](mailto:a.senior@lancaster.ac.uk))

## Abstract

The F-region "cutoff" of the natural (photoelectron-enhanced) plasmaline was observed with the EISCAT UHF radar during O-mode HF heating with the EISCAT HF facility near Tromsø, Norway. The F-region critical frequency was slightly above the HF pump frequency of 4.544 MHz during the daytime in January 2006. Large electron temperature enhancements (~2000 K) were observed. The natural plasma line cutoff frequency was observed to increase by ~200 kHz coincident with the increases in electron temperature, but the cutoff spectrum also became weaker and less well-defined while the pump wave was switched on. The shift of the cutoff appears to be consistent with the shift in Langmuir frequency estimated from the electron density and temperature derived from the analysis of the UHF ion line spectrum. This suggests that the large temperature enhancements observed by the UHF radar during heating can be correctly interpreted in terms of a Maxwellian plasma and non-Maxwellian effects due to electrons accelerated by plasma turbulence play only a minor role. The weakening and spreading of the plasma line during heating is probably due to the formation of density irregularities in the plasma.

## 1. The Natural Plasma Lines

The natural plasma lines are the part of the incoherent scatter spectrum due to backscatter from Langmuir waves. In a Maxwellian plasma, the natural level of these waves is very low, but can be enhanced to a detectable level by the presence of suprathermal electrons. In the ionosphere, photoelectrons provide such a suprathermal population.

The radar observes up- and down-shifted plasma lines corresponding to Langmuir waves propagating towards and away from the radar. From the dispersion relation and Bragg backscatter criterion, the offset frequency is given by:

$$f^2 = f_p^2 + \frac{12k_B T_e}{\lambda_{\text{radar}}^2 m_e} = \frac{N_e e^2}{4\pi^2 \epsilon_0 m_e} + \frac{12k_B T_e}{\lambda_{\text{radar}}^2 m_e}$$

## 2. Experiment

A series of experiments were carried out at EISCAT Tromsø during 18-20 January 2006. The HF facility was operated mainly on 4.544 MHz radiating O-mode in the field-aligned direction (12° south of vertical) with a ERP of ~100 MW. The pump wave was cycled 2 minutes on, 2 minutes off during the time interval 11-13 UT (~12-14 LT).

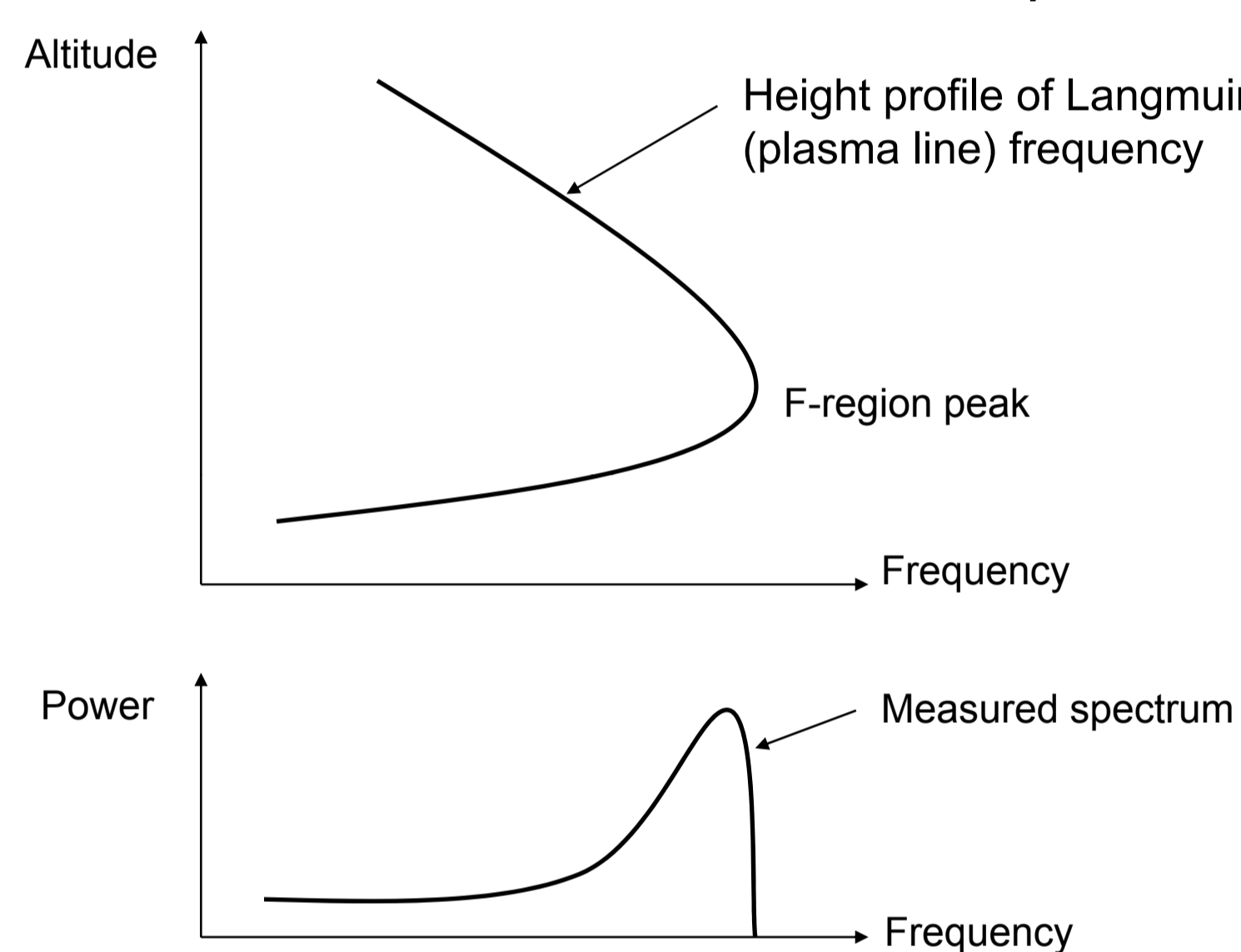
The UHF (930 MHz) incoherent scatter radar viewed the pumped ionosphere along the field-aligned direction. The radar ran a modified version of the standard *tau2pl* modulation, transmitting a 16-bit alternating code with 36 μs bauds with one ion line and three downshifted plasma line channels. The plasma line channels sampled the F-region peak with 1.6 MHz bandwidths centred on -4, -5.3 and -6.6 MHz.

## 3. Plasma line measurement technique

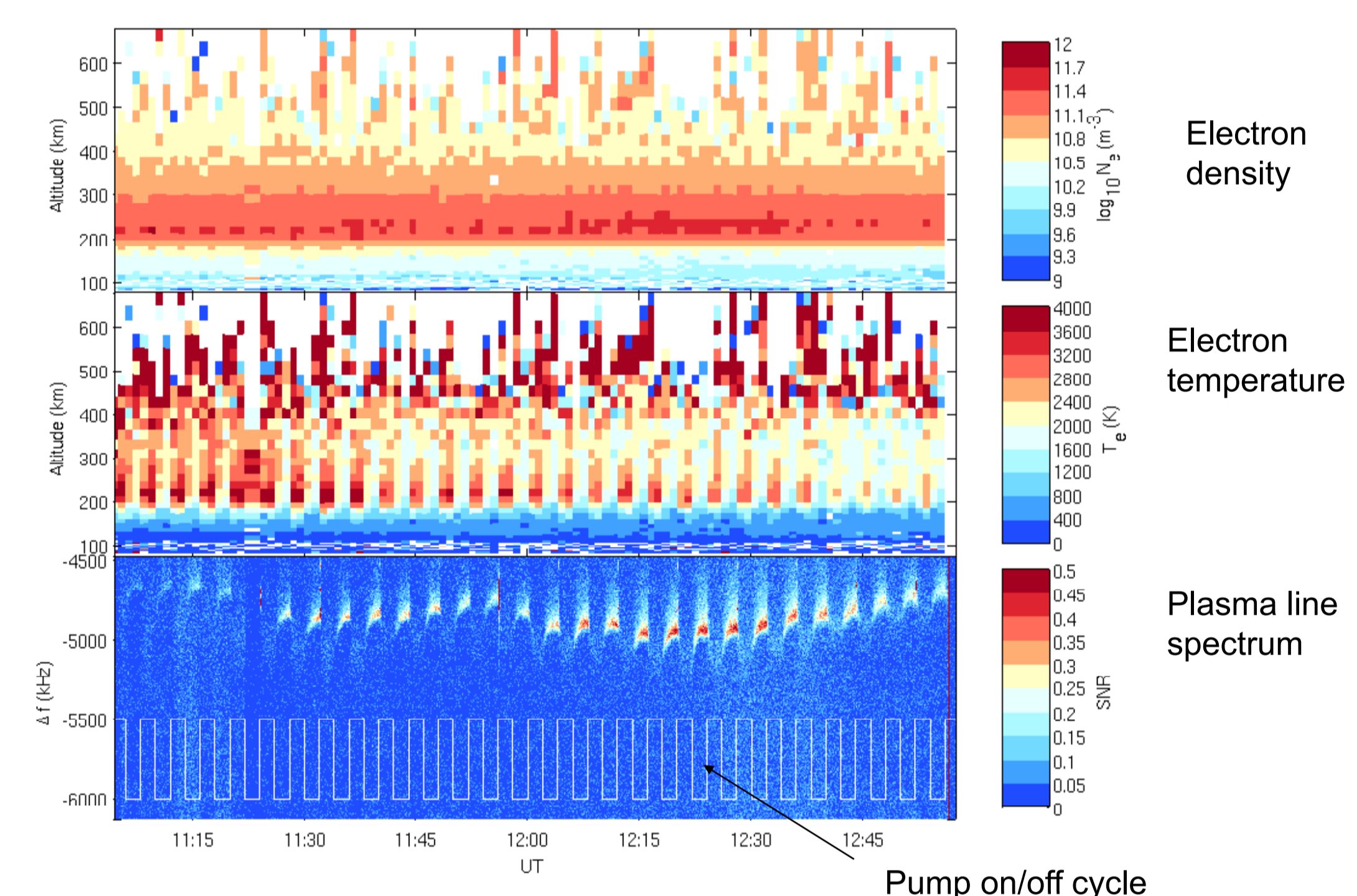
The plasma lines were measured using the *spectral plasma line* technique [1]. The vector of received signal samples is Fourier-transformed to yield a spectrum which contains contributions from all altitudes illuminated by the pulse. The power is highest from regions where the Langmuir frequency varies slowly with height. In our case, this means the F-region peak.

Since we transmit alternating codes, but do no decoding, the modulation spectrum is convolved with the signal spectrum broadening a line spectrum to a width of ~30 kHz.

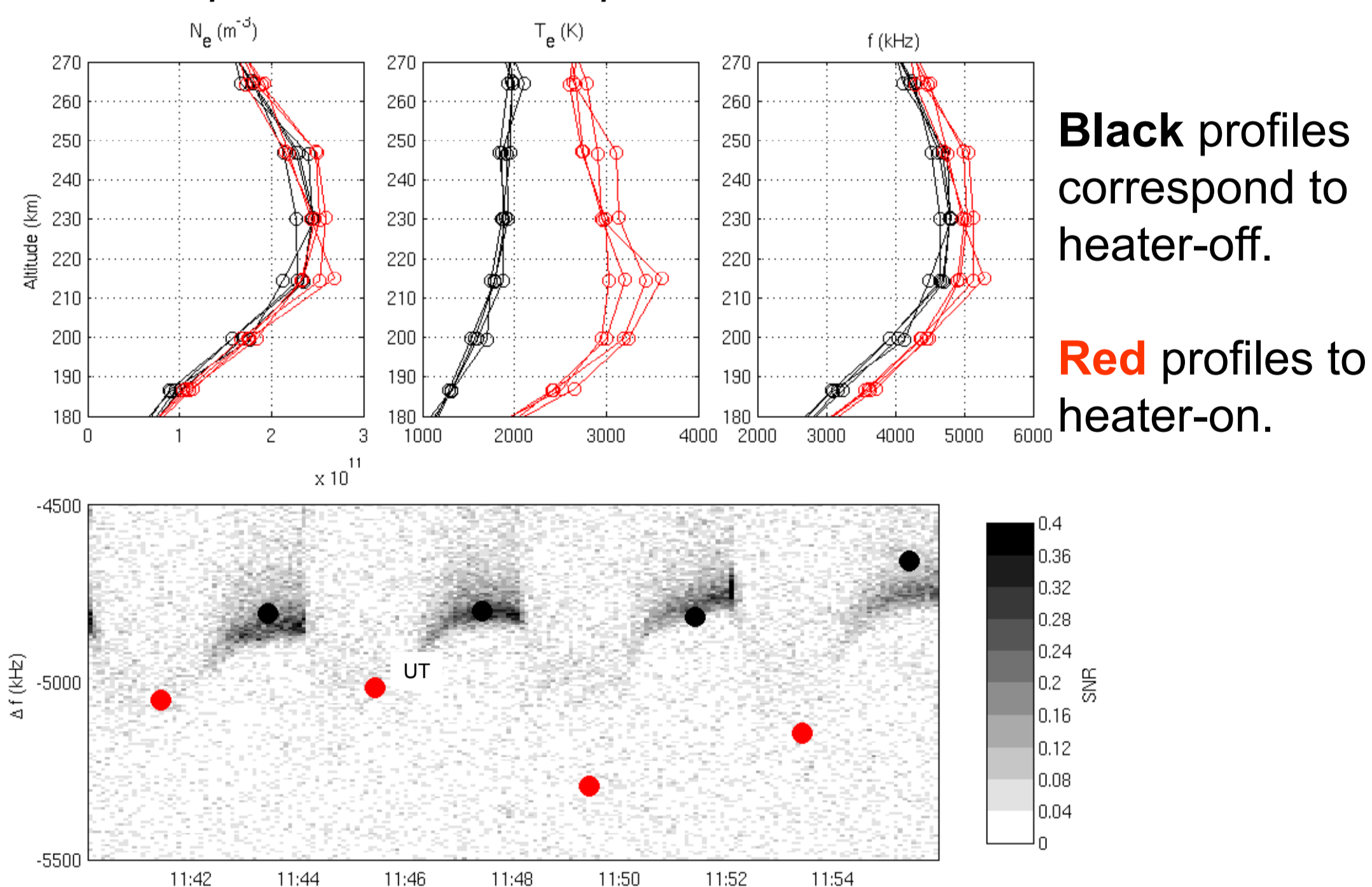
## 4. Plasma line measurement technique continued...



## 5. Overview of results: 2006-01-20

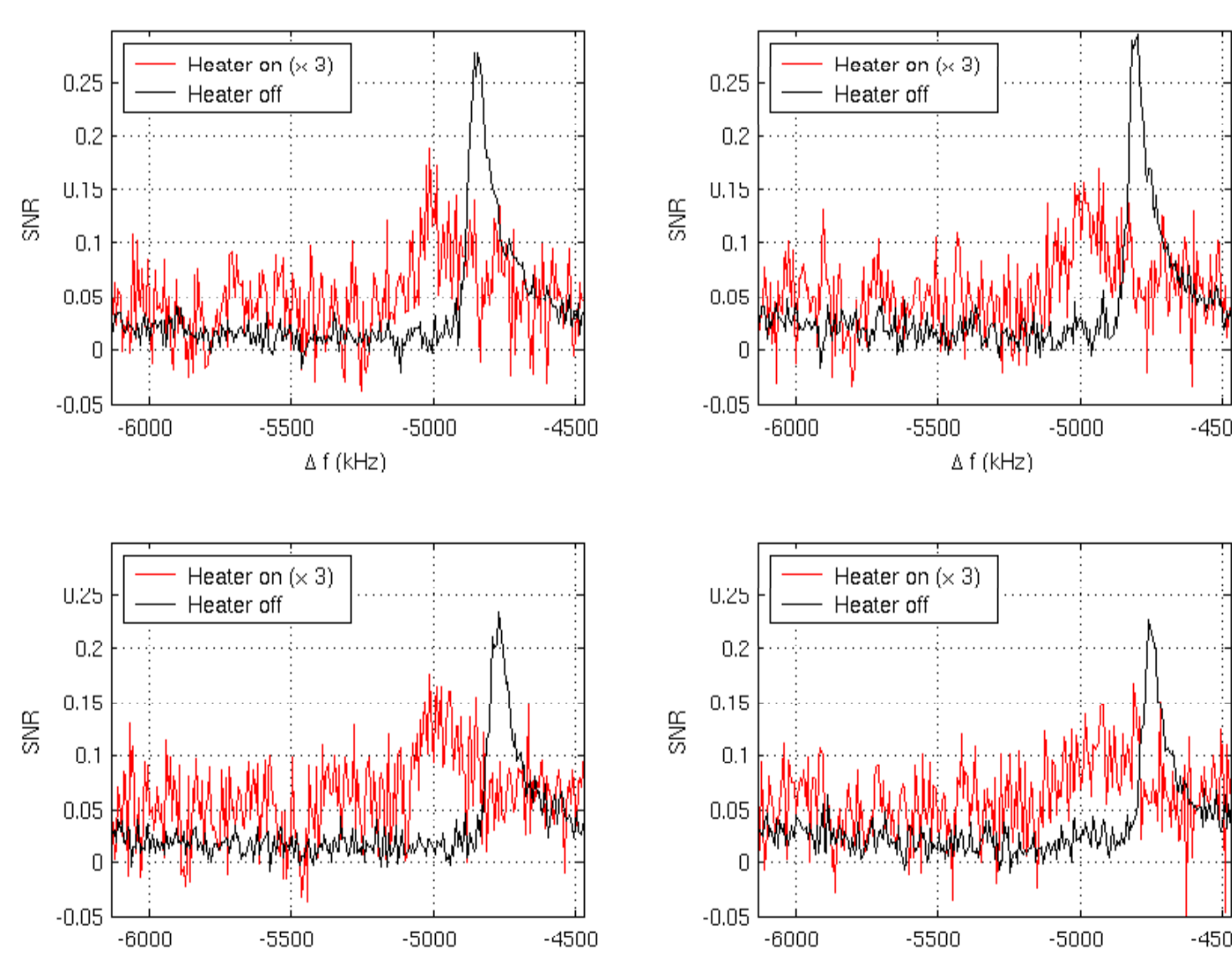


## 6. Comparison of ion and plasma line results



The peak Langmuir frequency from the ion line analysis is compared to the plasma line spectrogram.

## 7. Plasma line spectrum during heating



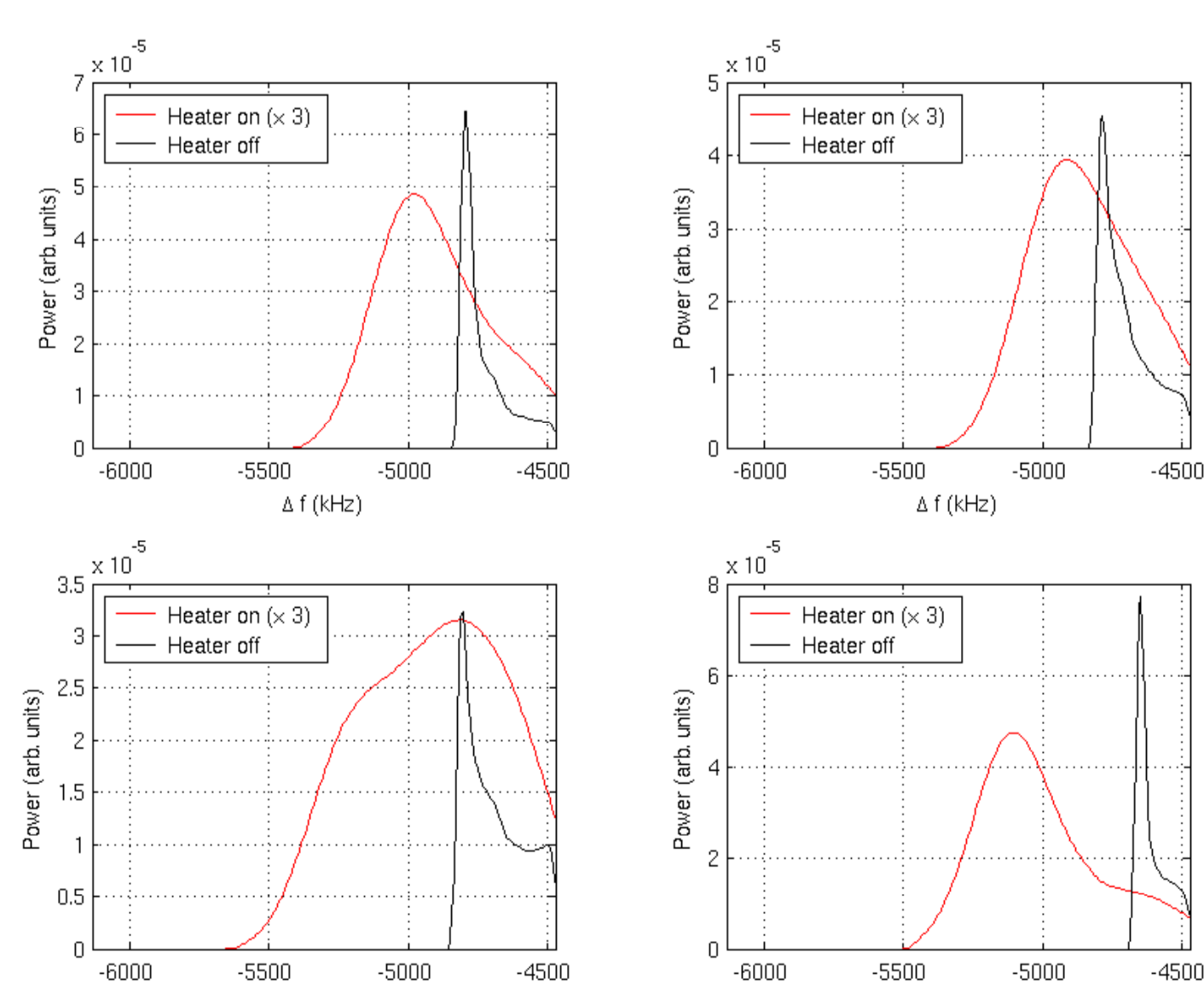
During heating, the plasma line becomes much weaker and the spectrum appears broader.

## 8. Discussion

The natural plasma line is strongly affected by HF heating of the plasma. The shift of the plasma line frequency appears to be consistent with the changes in electron density and temperature inferred from the ion line spectrum. In particular, this suggests that the high electron temperature does represent the Maxwellian part of the distribution and is not strongly affected by the presence of supra-thermal electrons.

Similar frequency shifting and spreading was observed at Arecibo, but the effects were much smaller [2]. The spreading was interpreted in terms of heater-induced density irregularities. We have applied a similar interpretation.

## 9. Discussion continued...



Spectra simulated from the measured density and temperature profiles.

During heating, the spectrum is broadened with a Gaussian distribution with standard deviation 130 kHz. This corresponds to a density fluctuation of about 6%.

## 10. Discussion continued...

A mean 6% depletion in striations was found at Arecibo [3] by in situ measurement and 2% was found at Tromsø by anomalous absorption [4]. In our case, all irregularity scales up to the radar beam diameter (~1 km) will be involved.

Changes in the excitation and damping of Langmuir waves due to electrons accelerated in plasma turbulence created by the pump wave could alter the intensity of the plasma line.

The radar experiment recorded the raw signal samples, enabling further off-line processing to decode the alternating code modulation. This may lead to clearer spectra, especially during heating. If SNR permits, limited height profiles of plasma line spectra could be extracted allowing profiles of irregularity density and growth/decay times to be determined.

## Acknowledgements

We are grateful to Ingemar Hågström and Assar Westman of EISCAT for helpful comments on the design and implementation of the radar experiment. EISCAT is an International Association supported by Finland (SA), France (CNRS), Germany (MPG), Japan (NIPR), Norway (NFR), Sweden (VR) and the United Kingdom (PPARC).

## References

- Showen, R. L., *Radio Sci.*, 14(3), 503-508, 1979.
- Isham, B. and Hagfors, T., *J. Geophys. Res.*, 98(A8), 13605-13625, 1993.
- Kelley, M.C. et al., *J. Geophys. Res.*, 100(A9), 17367-17376, 1995.
- Robinson, T. R., *Phys. Rep.*, 179(2&3), 1989.