An alternative estimation of the RF-enhanced plasma temperature during SPEAR artificial heating experiments

H. Vickers and L. Baddeley, University Centre in Svalbard (UNIS)

1. SPEAR (Space Plasma Exploration by Active Radar)

- High-power, high frequency radar located on Svalbard at 78.154˚N, 16.055˚E
- Consists of 48 x 4kW solid state transmitters which feed 4 x 6 array of crossed dipole antennas
- Capable of transmitting in the range 4.45 - 5.82MHz. Typical Effective Radiated Power (ERP) = 16MW

Fig.1. The SPEAR facility on Svalbard

2. Artificial Heating

- Strong plasma turbulence from interaction of SPEAR 'heater' wave with ionospheric plasma
- Parametric Decay Instability (PDI) & Oscillating Two-Stream Instability (OTSI) or purely growing mode (PGM) excited just below ordinary ('O') mode wave reflection height
- PDI enhances ion-acoustic signatures detected by incoherent scatter radars, PGM appears as zero-frequency peak in spectrum
- 'Anomalous' (collisionless) absorption of EM wave at upper hybrid resonance height =strong plasma heating & development of Thermal Parametric Instability (TPI), growth of field-aligned irregularities (FAI
- FAI at high latitudes can be detected using HF backscatter radars - act as Bragg scatterers

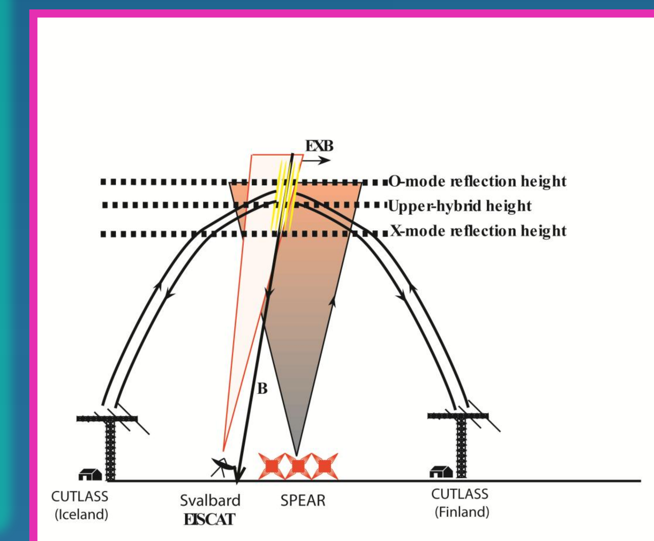

Fig.2. Schematic of reflection and resonance heights in relation to EISCAT and CUTLASS

EISCAT Svalbard and CUTLASS Radar Observations

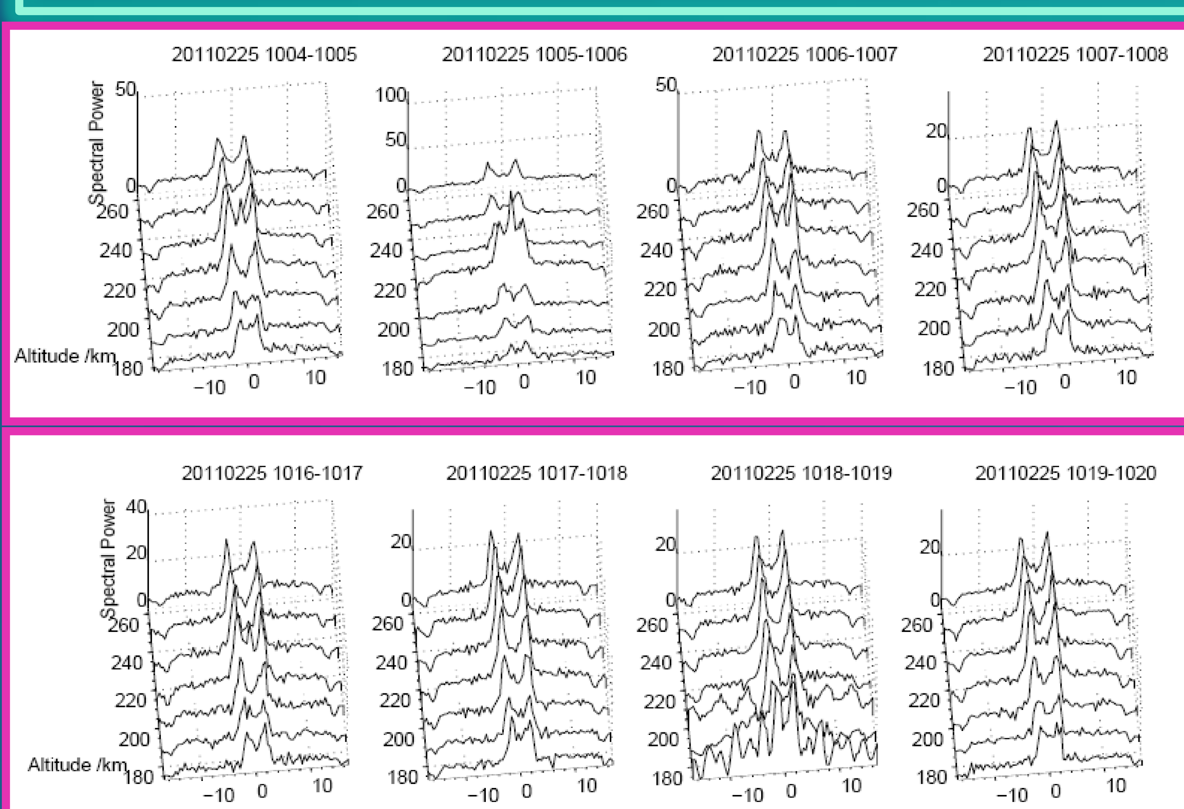

Fig.3(a). – upper left row of panels. Ion line spectra between 170-270km, 1004 to 1008UT at 1-minute intervals (SPEAR O-mode)

Fig.3(b). – lower left row of panels. Ion line spectra between 170-270km, 1016 to 1020UT at 1-minute intervals (SPEAR O-mode)

3. SPEAR experiment, 25th February 2011

- Tx frequency = 5.2MHz; 4-minutes 'O', 4-min. 'X' ,4-min. 'off' from 1004 – 1052UT
- Beam directed along geomagnetic field
- EISCAT Svalbard Radar employed to diagnose SPEAR effects
- CUTLASS (Cooperative UK Twin-Located Sounding System) HF radar observations of SPEAR artificial backscatter at Finland/Iceland

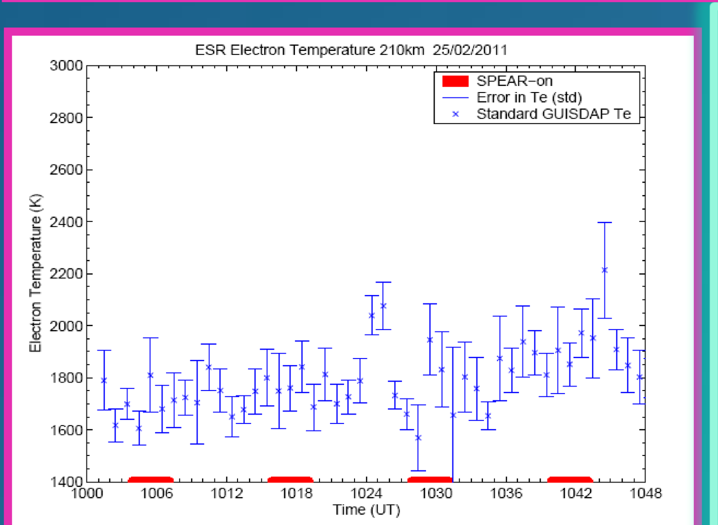

Fig.4. ESR electron temperature at 210km for 25 February, 1000-1048UT

- Enhanced ion lines & PGM at 210km throughout O-mode heating (Fig.3(a)) from 1004-1008UT. Only in spectrum for first minute of O-mode, 1016-1020UT
- No obvious enhancement in electron temperatures, with respect to SPEAR-off levels at this altitude (Fig.4)
- SPEAR-induced artificial backscatter observed on both channel A and B with CUTLASS Finland and Iceland radars (Fig.5)
- Strongest backscatter for 1016-1020UT but substantially weaker for 1004-1008, 1028-1032UT, almost non-existent 1040-1044UT SPEAR-on
- Presence of artificial backscatter suggests plasma is being heated through EM wave absorption at UHR height

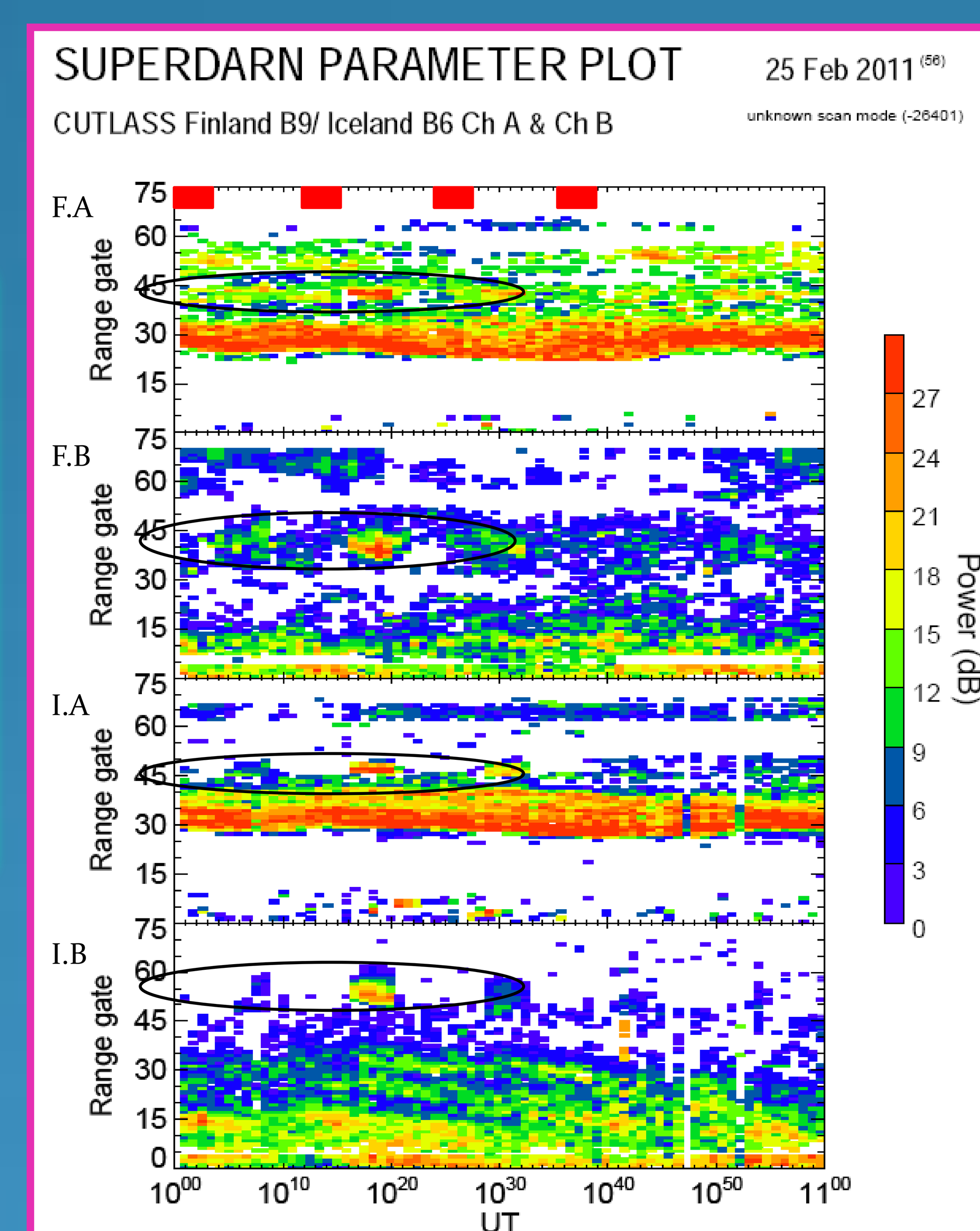

Fig.5. RTI plot of backscatter power measured by CUTLASS Finland (beam 9, channel A, B) and Iceland (beam 6, channel A, B) respectively

- Usually PGM disappears when FAI develop (e.g. Fig.3(b), 1016-1020UT, CUTLASS backscatter)
- PDI & PGM 'quenched' by TPI, less heater wave energy penetrates through to O-mode reflection
- Is lack of temperature enhancement in ESR measurements explained by persistence of PGM in spectra, or simply due to the lower ERP of SPEAR?

4. Analysis – Spectrum 'correction' and some initial results

- Recently developed method [Vickers et al., 2010] to remove PGM from EISCAT spectra during heating experiments at Tromsø. Spectrum modified by subtracting Gaussian
- GUISDAP (standard EISCAT data analysis software) fits to the modified spectra
- Gaussian which produces the smallest fit residual is taken as the 'corrected' spectrum
- Fig. 6 shows example where spectrum corrected, data integrated 1004-1005UT, 25th February. Measured spectrum T_e =1605K (left panel), Gaussian peak subtracted (centre) to produce lowest fit residual, final 'corrected' spectrum, analysis T_e =1690K (right panel) → Temperature correction of 85K

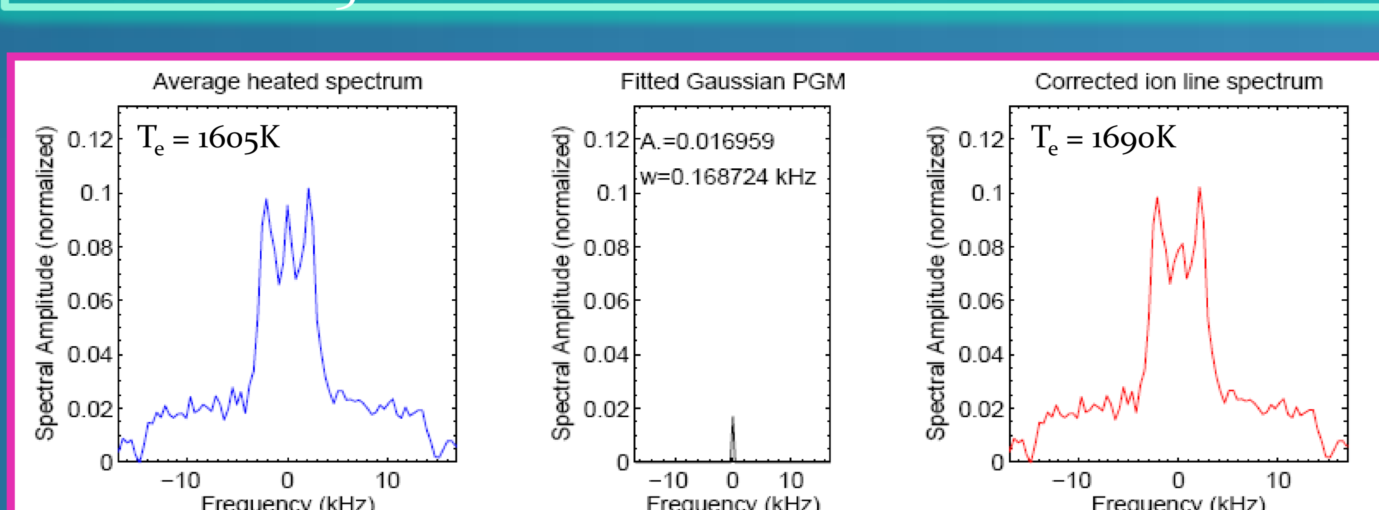

Fig.6. (left) Example of the corrected ion line spectrum after suitable removal of Gaussian peak (1004-1005UT 25 February at 210km)

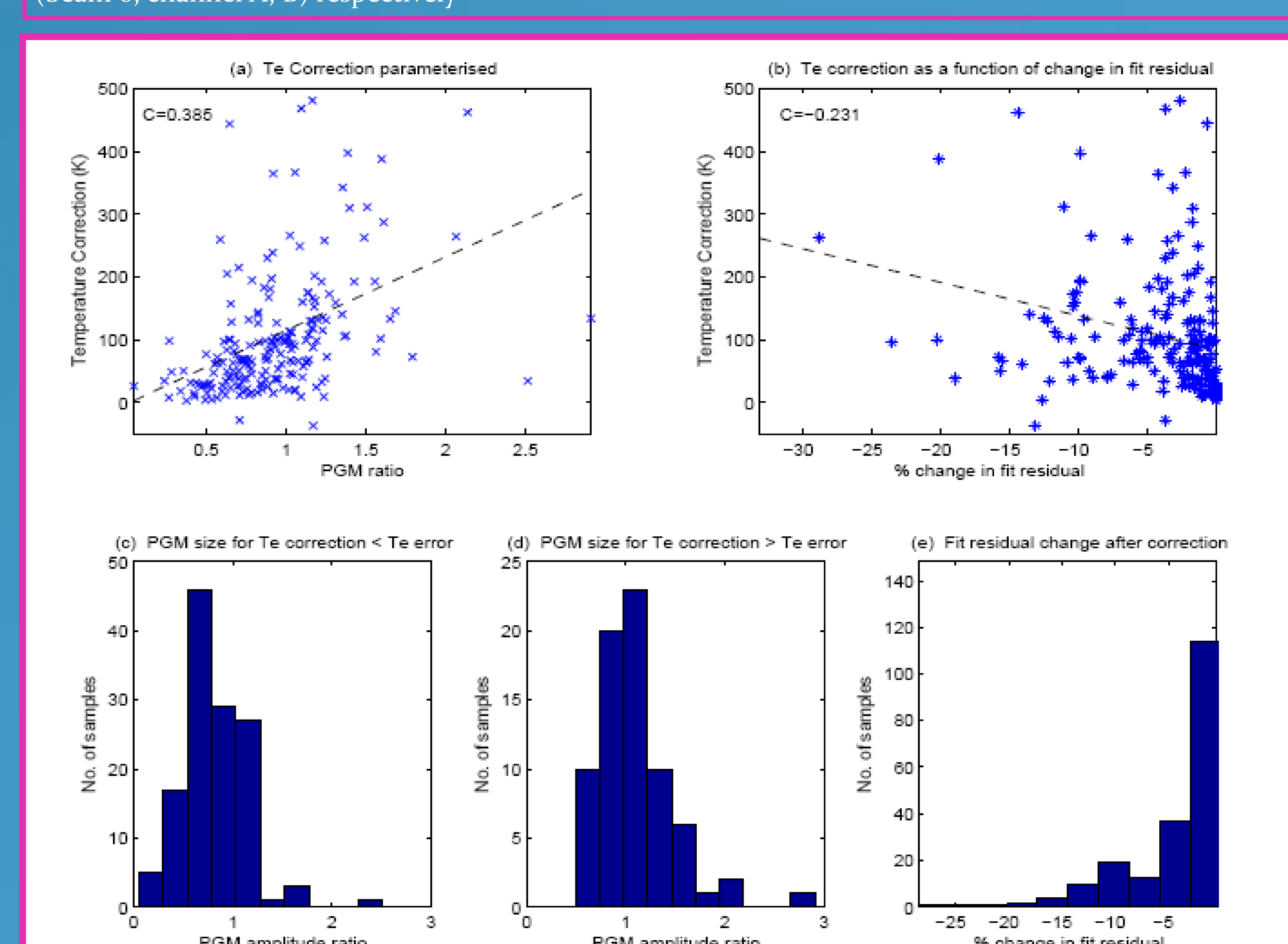

Fig.7 (right) (a) Scatter plot of the T_e correction vs. PGM amplitude ratio (b) T_e correction vs. % change in fit residual (c) Histogram of corrected spectra with T_e correction < T_e error (d) T_e correction > T_e error and (e) histogram of the fit residual change

- Carried out larger-scale study by applying method to ESR spectra by PGM from ~70 SPEAR-on intervals from 2004-2005 experiments
- How significant is the effect on T_e when analysing PGM-contaminated spectrum?

- Weak positive correlation between T_e correction and amplitude of PGM (relative to mean ion line amplitude) and between T_e correction and reduction in fit residual
- Majority of samples showed only small increase (<100K) in T_e after spectrum corrected: 64% where T_e increase < T_e error/uncertainty
- Results indicate method does not improve T_e estimates significantly. Most likely that SPEAR-induced T_e enhancement is small with respect to the uncertainty in GUISDAP estimates, and may not be easily observable in EISCAT data

References: Vickers, H., T. Robinson and I. W. McCrea (2010), A method for improving plasma temperature estimates from incoherent scatter analysis during artificial ionospheric modification experiments, *J. Geophys. Res.*, 115, A11316,