REGRESSION TECHNIQUE FOR DETERMINING ELECTRON AND ION TEMPERATURES ACCORDING TO IRKUTSK ISR DATA

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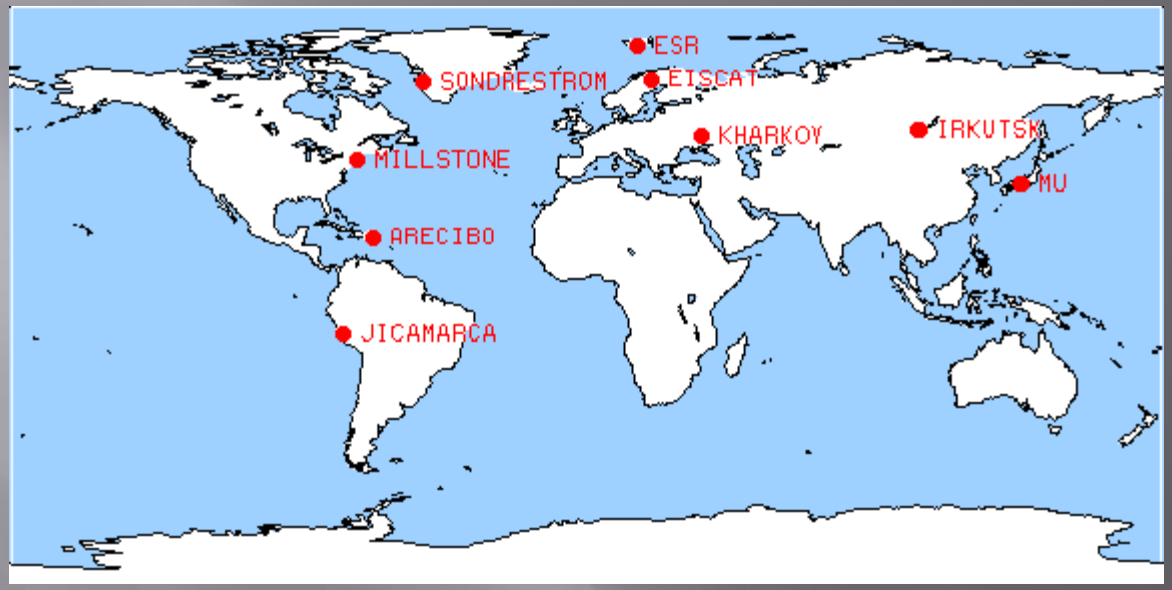
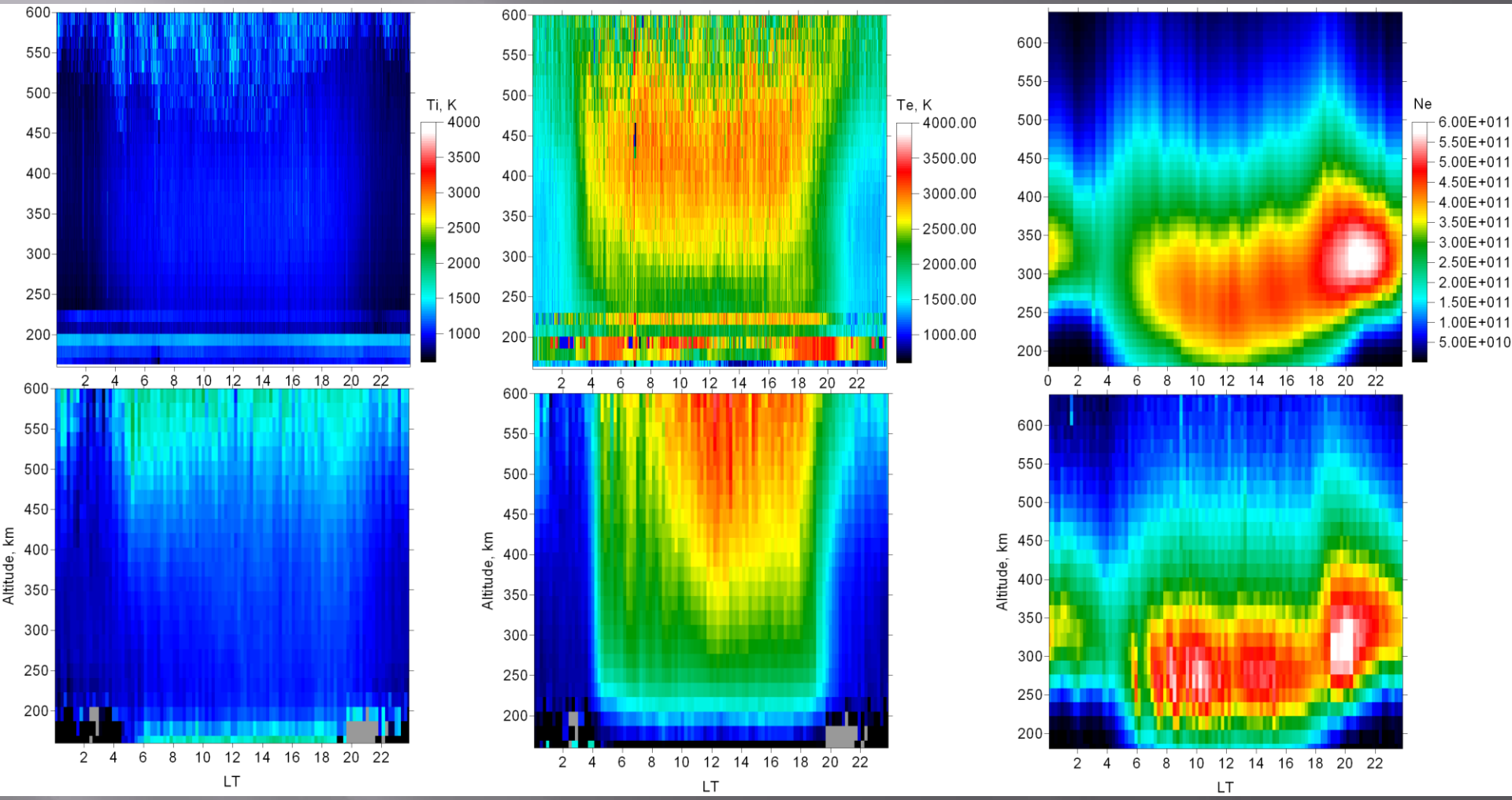


Irkutsk Incoherent Scatter Radar

Millstone Hill Incoherent Scatter Radar



Averaged altitude-time profiles of Ti (at the left), Te (at the center) and Ne (at the right) for July 2013 according to data of Irkutsk ISR (at the top) and Millstone Hill ISR (at the bottom)

Incoherent scattering spectra

$$S(\omega) = \frac{2\sqrt{\pi}}{ka}\left\{\frac{Ae + Ai}{|\varepsilon|^2}\right\}$$

$$Ae = \exp(-x_e^2)\left[\left(1+\alpha^2\frac{Te}{Ti}Rw(x_i)\right)^2 + \left(\alpha^2\frac{Te}{Ti}Iw(x_i)\right)^2\right];$$

$$Ai = \sqrt{\frac{m_i Te}{m_e Ti}}\exp(-x_e^2)\left[(\alpha^2 Rw(x_e))^2 + (\alpha^2 Iw(x_e))^2\right];$$

$$|\varepsilon|^2 = \left\{\left[1+\alpha^2\left(Rw(x_e)+\frac{Te}{Ti}Rw(x_i)\right)\right]^2 + \left[\alpha^2 Iw(x_e)+\alpha^2\frac{Te}{Ti}Iw(x_i)\right]^2\right\}$$

$$x_e = \omega / ka;$$

$$x_i = \omega / kb;$$

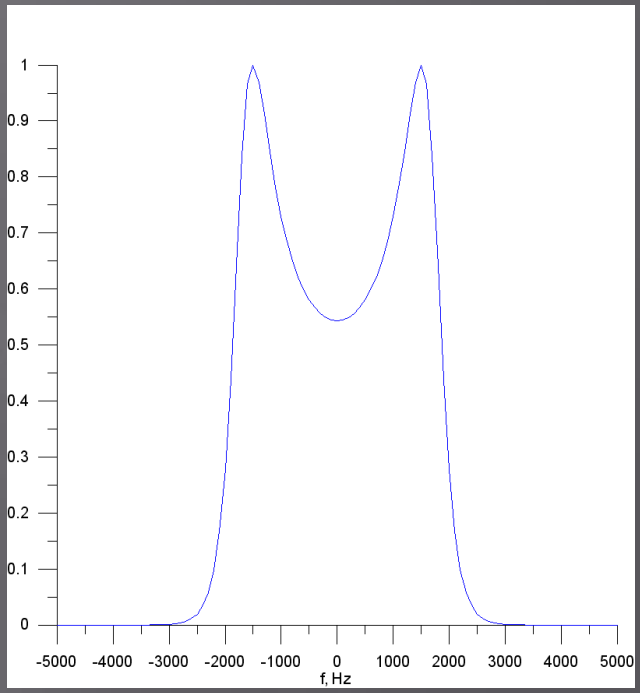
$$\alpha = 1/k\lambda_D;$$

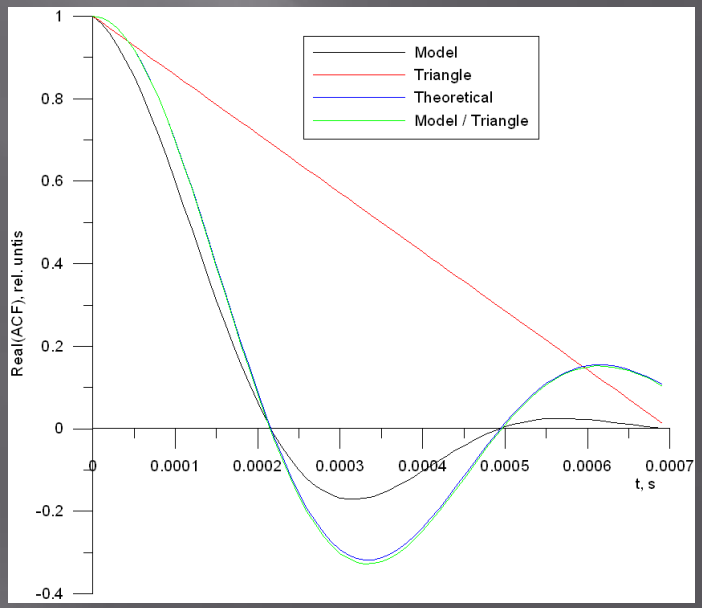
$$a = \sqrt{2KTe/m_e};$$

$$b = \sqrt{2KTi/m_i};$$

$$Rw(x) = 1 - 2x\exp(-x^2)\int_0^x \exp(p^2)dp;$$

$$Iw(x) = \sqrt{\pi}\,x\exp(-x^2);$$

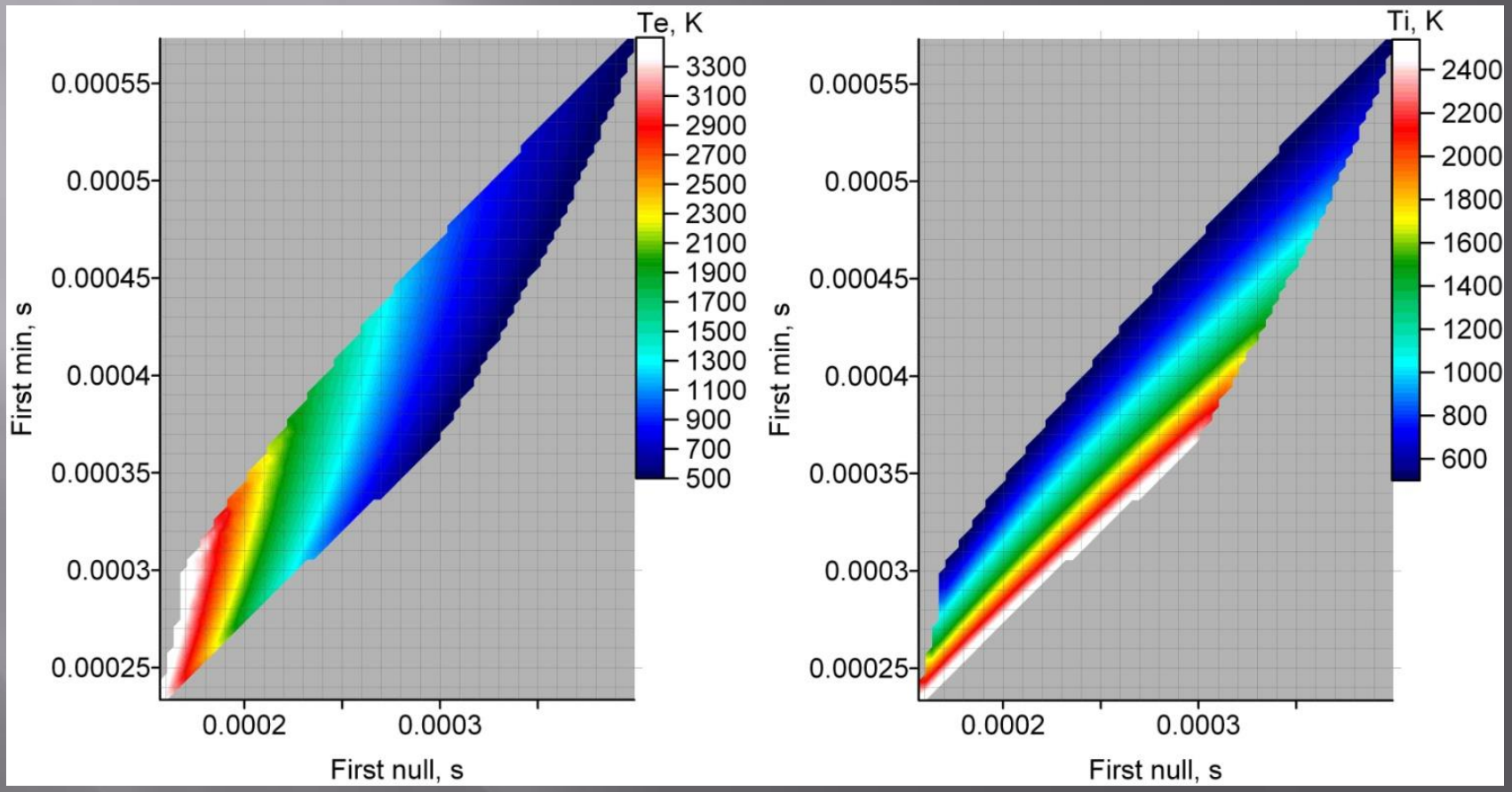




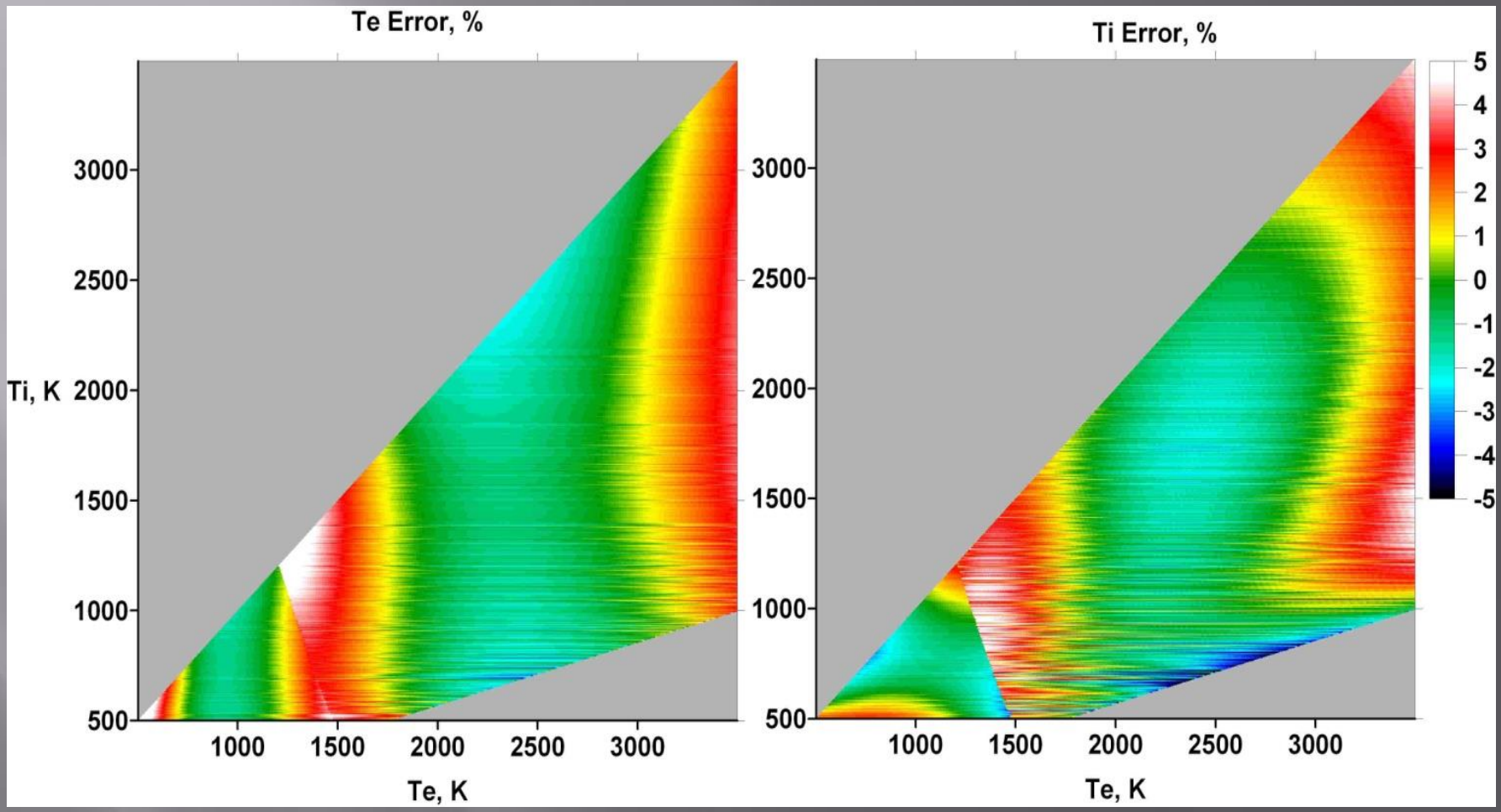
Nonlinear regression

$$f(\beta, x) = f(\beta_0, x) + \mathbf{X_0}(\beta - \beta_0)$$

$$\beta_{j+1} = \beta_j + (\mathbf{X}_0^{\mathrm{T}} \cdot \mathbf{X}_0)^{-1} \cdot \mathbf{X}_0^{\mathrm{T}} \cdot \mathbf{e}$$



Regression errors



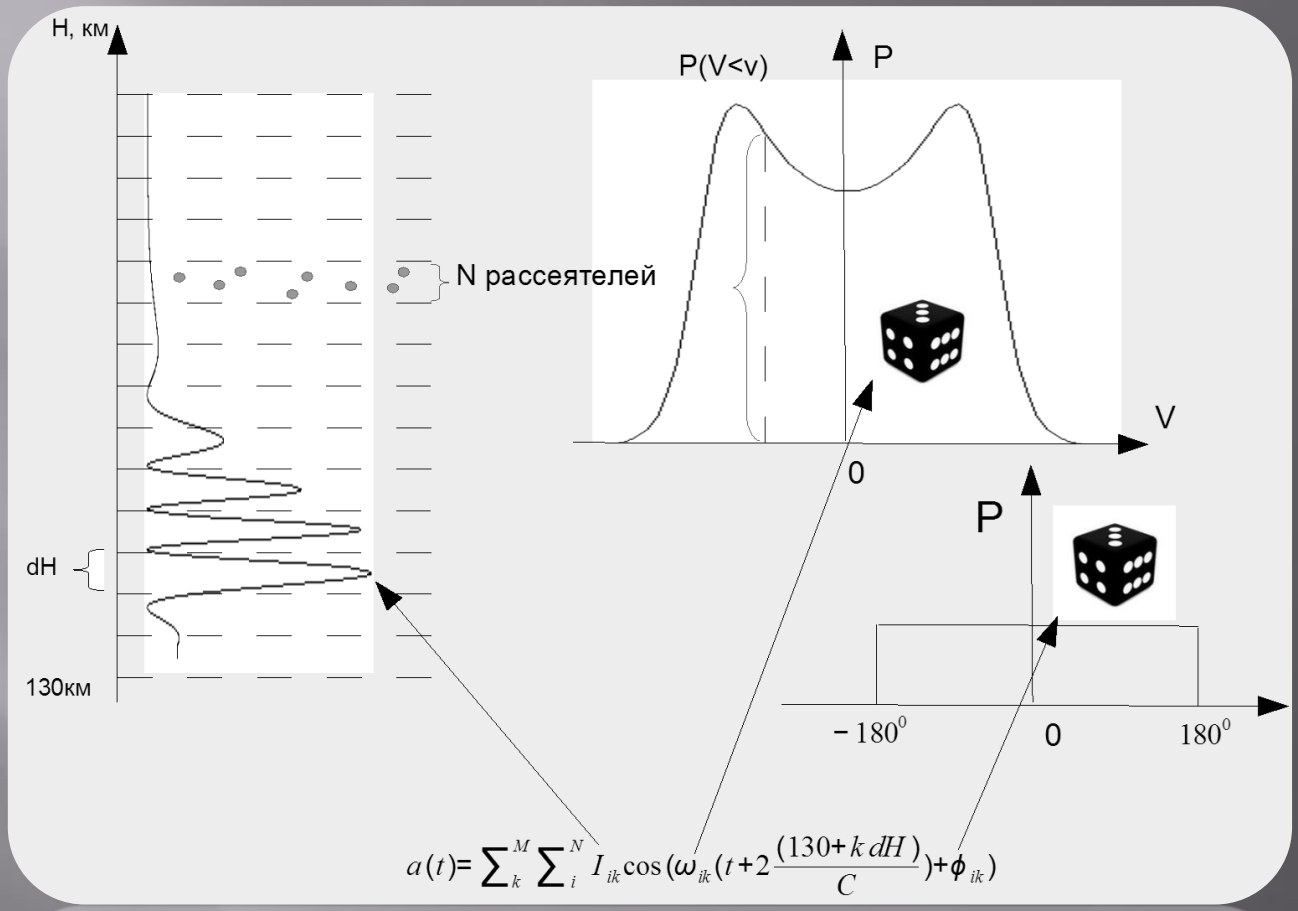
Regression coefficients for high electron temperatures

beta_e	beta_i	Coefs at
4582	3736	**1**
9.636	-36.292	**t_{min}**
-0.023016	0.079569	**$t_{min} \cdot t_{min}$**
-32.074	38.728	**t_0**
0.049541	-0.154483	**$t_0 \cdot t_{min}$**
-0.003808	**0.070897**	**$t_0 \cdot t_0$**

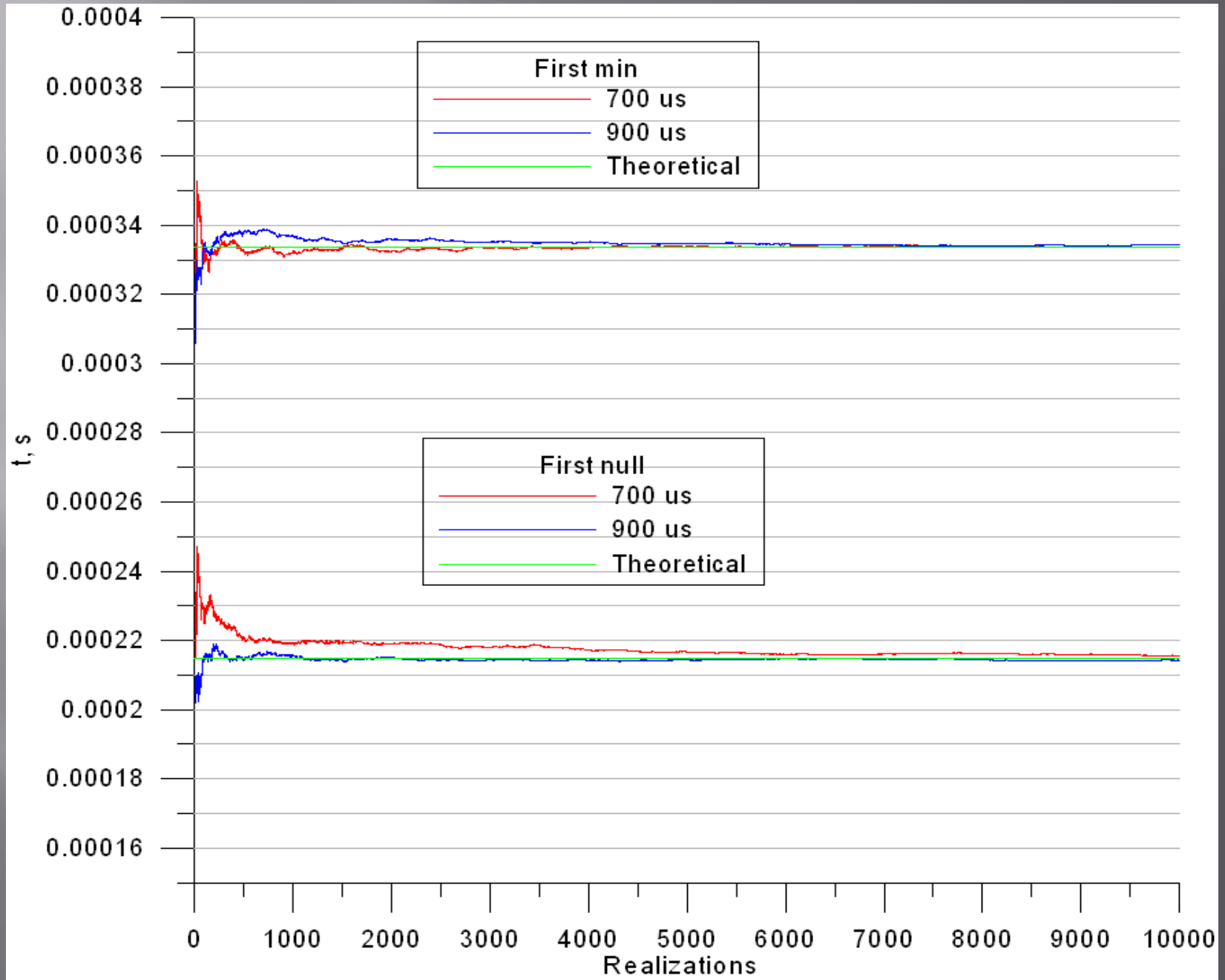
Regression coefficients for low electron temperatures

beta_e	beta_i	Coefs at
11411	23370	**1**
0	80462	**A_{min}**
0	80978	**$A_{min} \cdot A_{min}$**
34.877	93.854	**t_{min}**
0	813.79	**$t_{min} \cdot A_{min}$**
-0.066109	1.487199	**$t_{min} \cdot t_{min}$**
-121.505	-280.611	**t_0**
0	-1573.1	**$t_0 \cdot A_{min}$**
0.089095	-5.012901	**$t_0 \cdot t_{min}$**
0.130828	**4.252756**	**$t_0 \cdot t_0$**

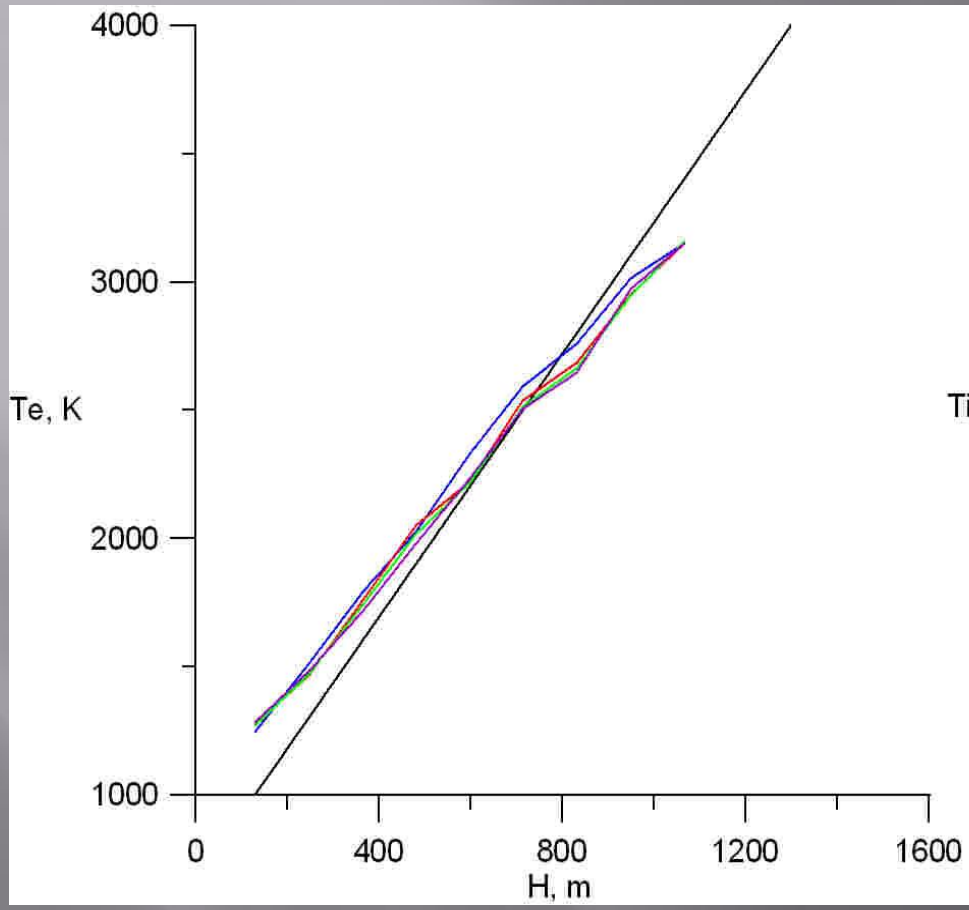
Model for incoherent scatter signal

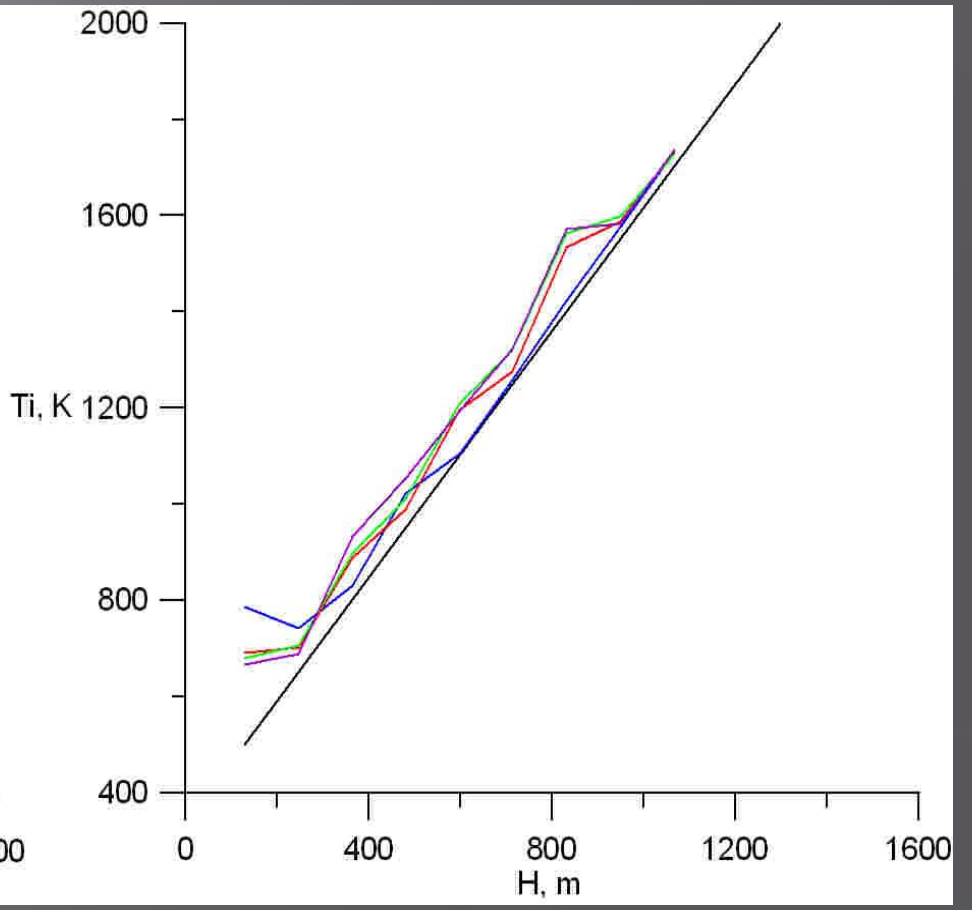


Required accumulation time for stability of ACF parameters

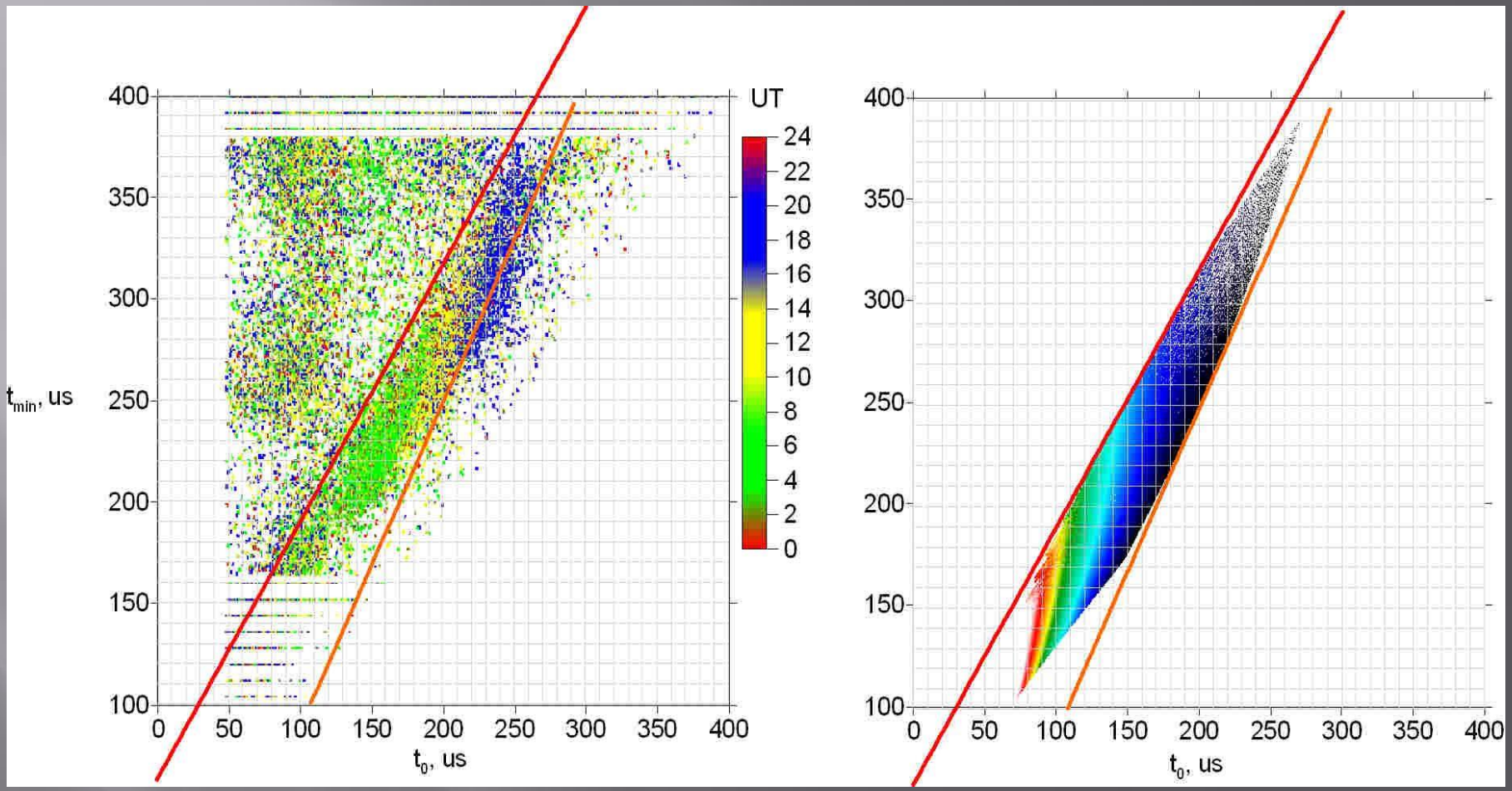


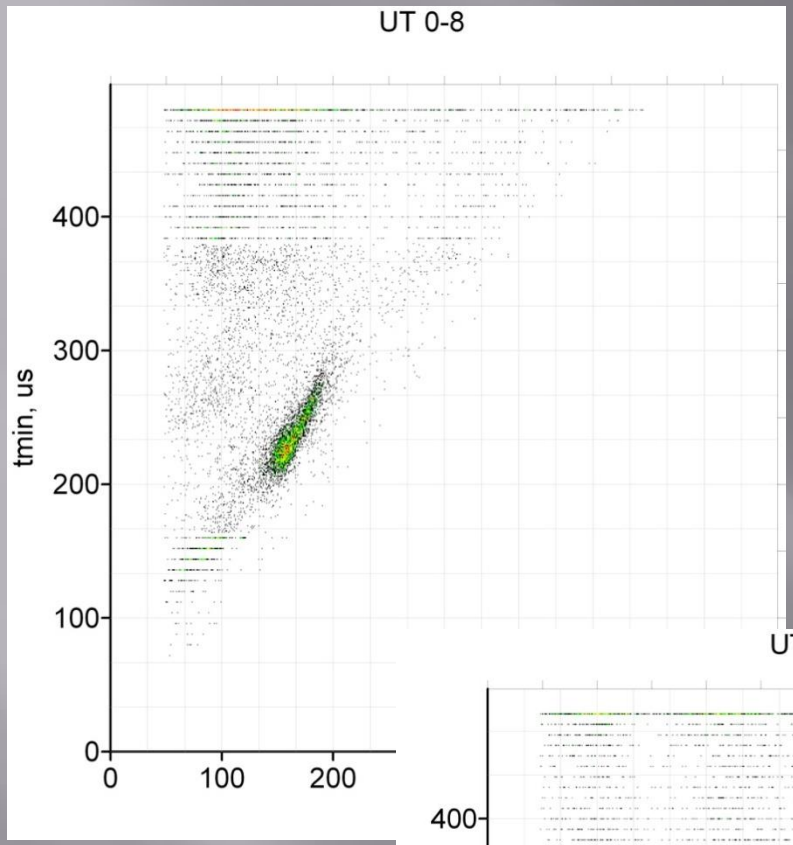
Restored temperature profiles using the regression technique on simulated signal

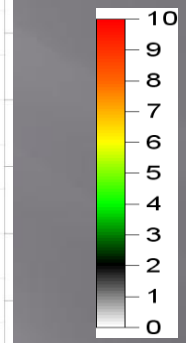


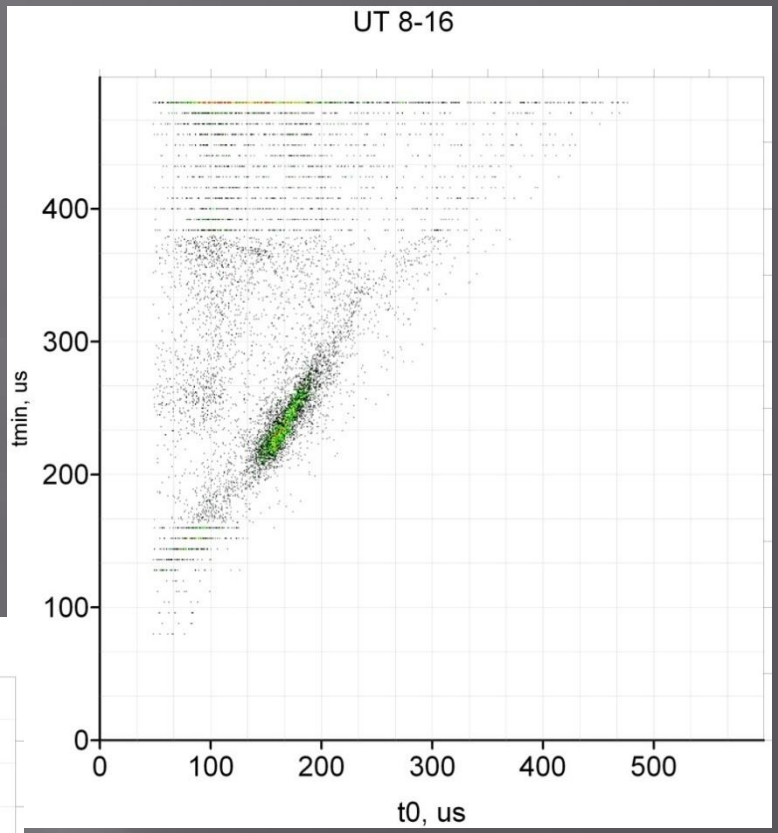


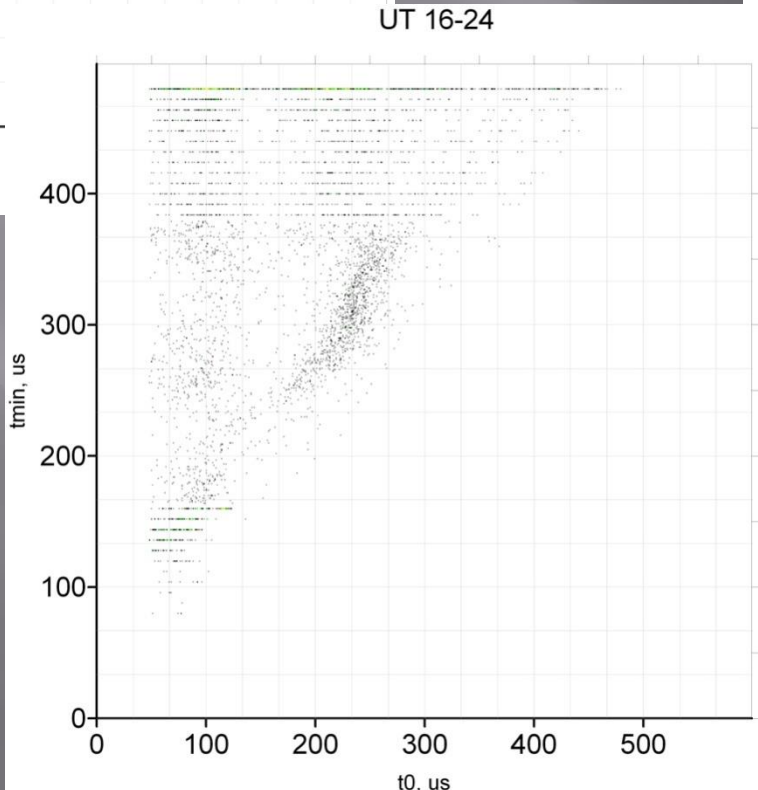
Time distribution of ACF parameters for 8.01.2014 in comparison with definition domain of the regression



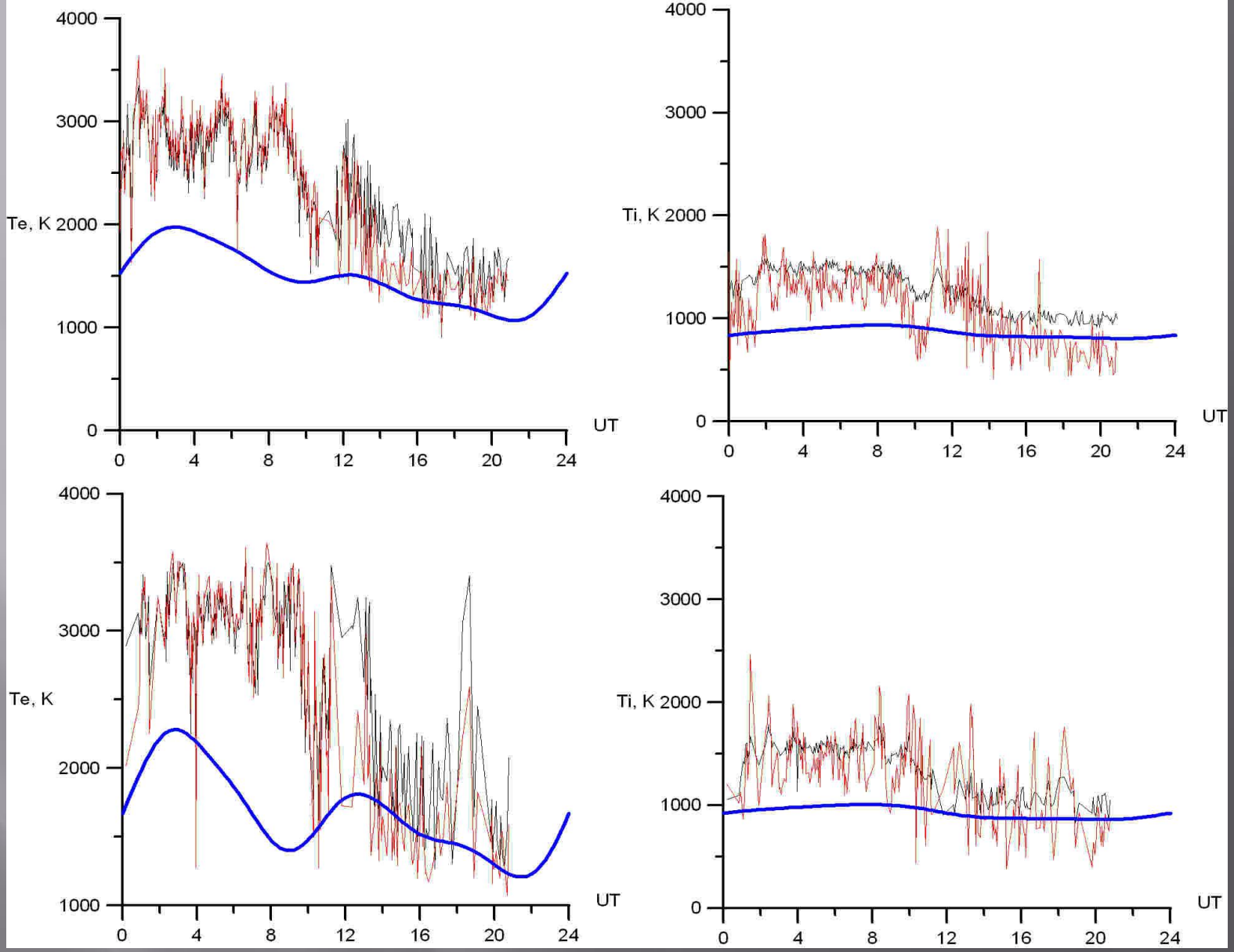








Histograms of ACF parameters distribution for 8.01.2014



Altitude of 350 km

Altitude of 250 km

Time profiles of temperatures according to technique used for Irkutsk ISR data (black line), regression technique (red line) and IRI-2012 (blue line)

CONCLUSIONS

- Inverse problem of determining electron and ion temperatures on parameters of incoherent scattering signal was solved numerically.
- On the basis of this solution, nonlinear regression was carried out using Gauss-Newton algorithm.
- Regression coefficients were verified using signal simulation.
- We seek systematic errors that contribute to the determined temperatures. Then we'll be able to correct the algorithm.
- Possible factors that impact on incoherent scattering signal and should be taking into account to correctly determine electron and ion temperatures:

1. Doppler shift along radar beam
2. Spectra skewness
3. Faraday effect
4. Signal-to-noise ratio

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Воеводин Вл. В.

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