A Method to estimate the Physical Properties of Magnetospheric Generators from Observations of Quiet Discrete Auroral Arcs

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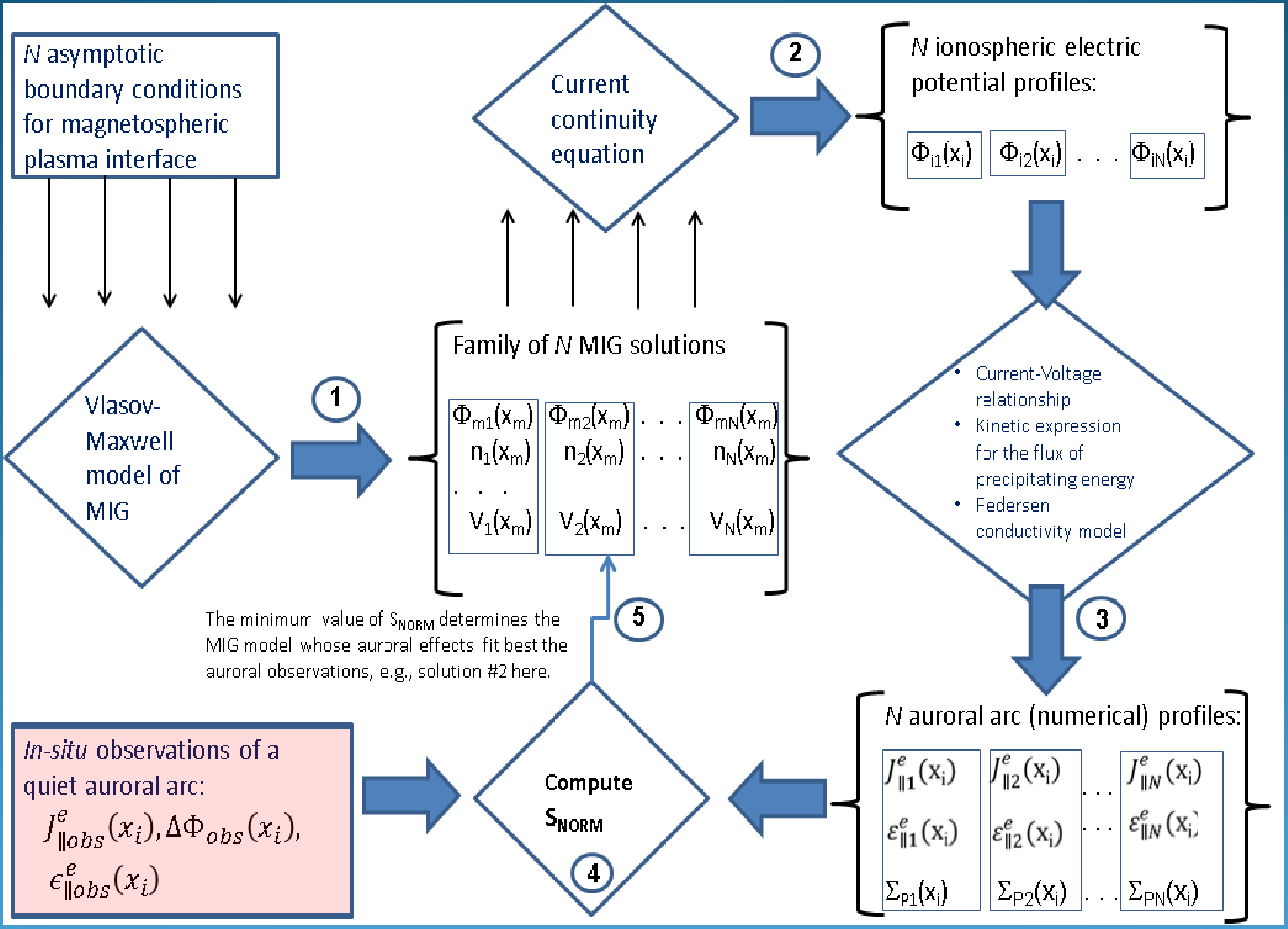
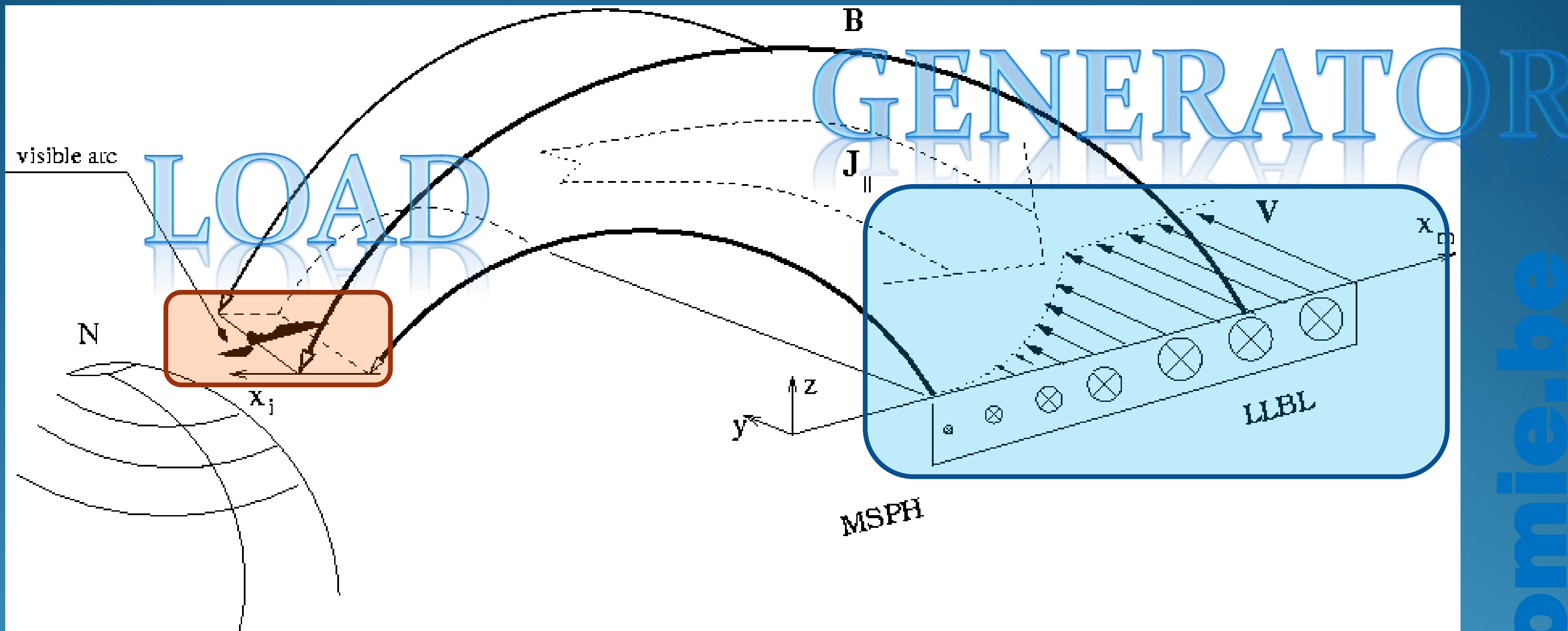
METHODOLOGY



Existence domain (in red) of the "Cold-hot" interface

Modeling the global auroral circuit



- planar TD surface at the interface between plasmas with different macroscopic properties *(Sestero, 1966; Lemaire & Burlaga, 1976; Roth et al., 1996; Echim & Lemaire, 2005)*
- magnetospheric generators with convergent E-field: *Chiu and Cornwall, 1978; Lyons 1980, 1981*
- Models of auroral generators based on sharp interfaces: *Galperin et al, 1992; Roth et al. 1993; Lennartson , 2006; Johannsson et al., 2006; Echim, Roth, De Keyser, 2007,2008*

- **latitudinal dependence of electrodynamic parameters: $j_{||}$, ε_{em}, E, Σ_P**
- **uniform ionospheric densities and temperatures: e^-,H^+,O^+,He^+**
- **empirical model for Pedersen conductance**
- **B parallel to z-axis; E = (E_x,0,E_z); J = (J_x,0,J_z)**

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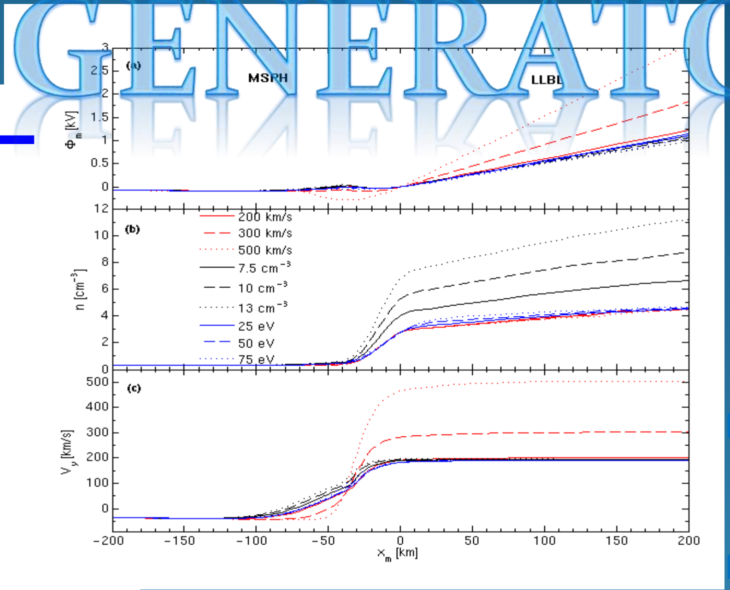
Quasi-stationary magnetosphere-ionosphere coupling:

Numerical implementation of the model

Numerical model

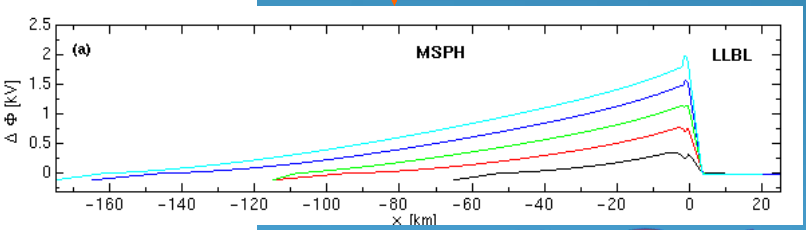
Input parameters: $\Phi_m(x_m)$, $N_m, T_m, \Delta V_m$



Current-voltage relationship, $j_{||}(V_{||})$

$$j_{||}(x_i) = -\frac{\partial}{\partial x_i} I_p = \frac{\partial}{\partial x_i}\left(\Sigma_p \frac{\partial \phi_i}{\partial x_i}\right)$$

Output: $\Phi_i(x_i)$, $V_{||}(x_i) = \Phi_i - \Phi_m$

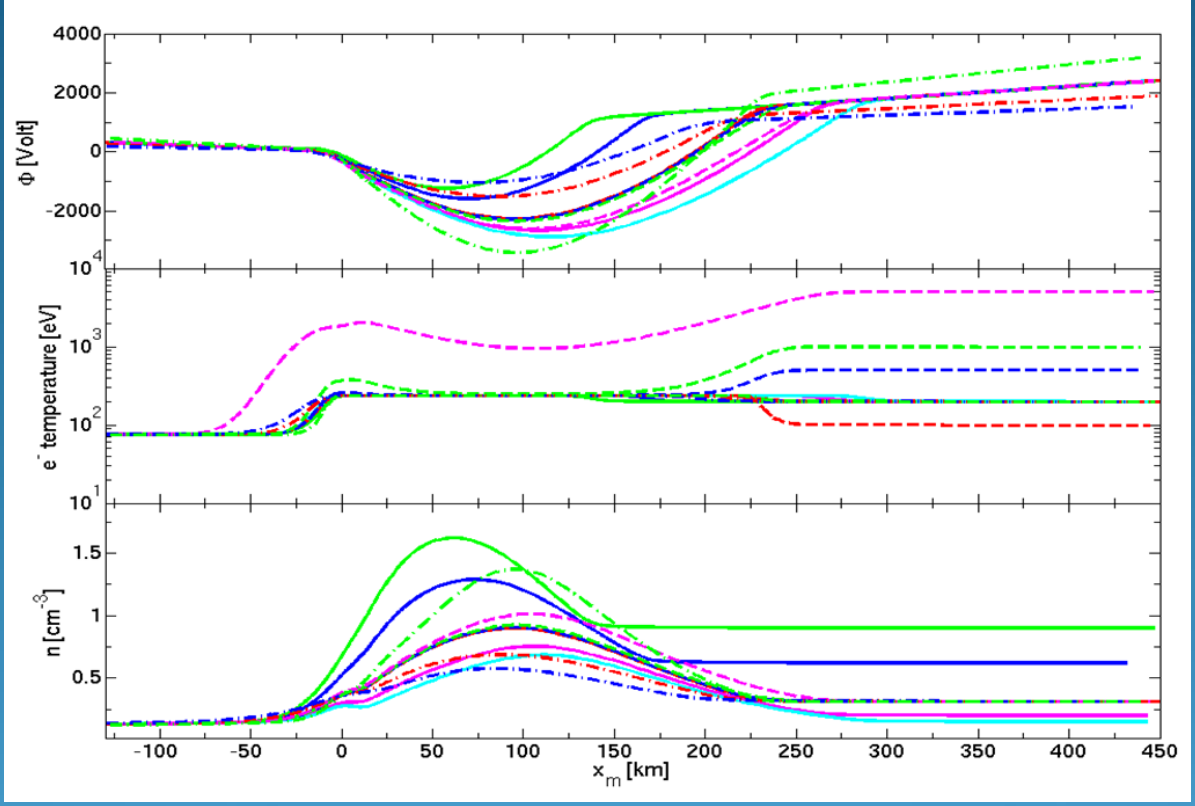


Two-point boundary condition: $V_{||}(+/-x_{iL}) = 0$

Input parameters: N_i, T_i, Σ_p model, $\Delta x_i = 2x_{iL}$

METHODOLOGY

The magnetospheric interface generator (MIG)



STEP 1 : Compute an ensemble of MIG solutions for a set of boundary conditions

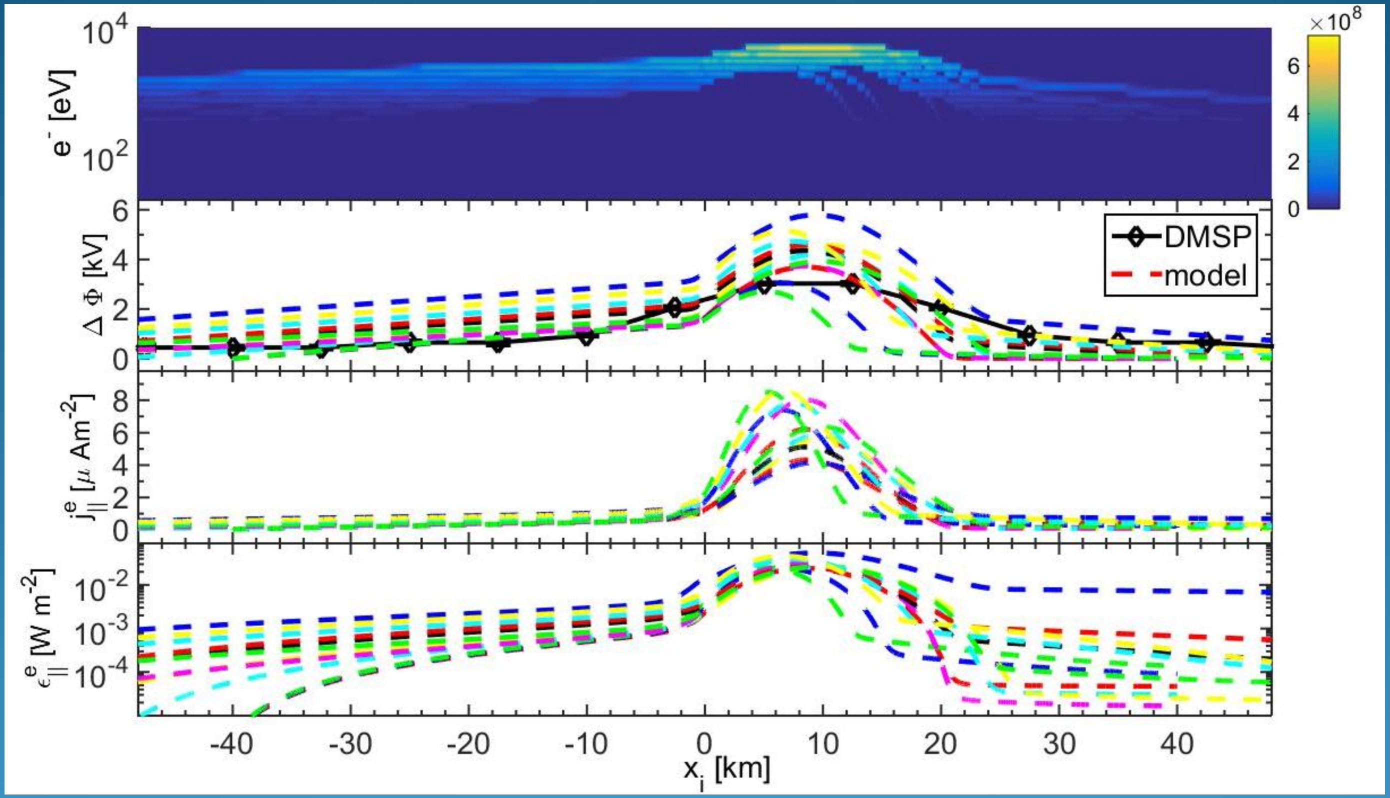
The magnetospheric interface generator (MIG)

The set of input parameters for the Vlasov equilibrium solution is quite large and includes:

- T_{e1}, T_{p1}, T_{e2}, T_{p1}, $T_{e\_trapped}$, $T_{p\_trapped}$, $T_{O\_trapped}$ – the temperatures of left, right and trapped populations;
- n_{e1}, n_{p1}, n_{e2}, n_{p1}, $n_{e\_trapped}$, $n_{p\_trapped}$, $n_{O\_trapped}$ – the densities of left, right and trapped populations;
- $\boldsymbol{V}_{e1}$, $\boldsymbol{V}_{p1}$, $\boldsymbol{V}_{e2}$, $\boldsymbol{V}_{p1}$, $\boldsymbol{V}_{e\_trapped}$, $\boldsymbol{V}_{p\_trapped}$, $\boldsymbol{V}_{O\_trapped}$ – the bulk velocities of left, right and trapped populations;
- $\boldsymbol{B}_0$ – the magnetic field in the center of the transition;
- The velocity distribution function parameters assumed for all species considered in the model Roth et al., 1996);
- $\Phi_1=\Phi(x_1)$ and $\delta\Phi=\Phi(x_1)-\Phi(x_2)$ – the value of the electric potential at the left side and the potential difference across the interface.

<u>STEP 1 </u>: Compute an ensemble of MIG solutions for a set of boundary conditions

METHODOLOGY The auroral arc



<u>STEP 2</u> : Computed an ensemble of auroral arcs generated by the MIG at STEP 1

Minimization procedure

STEP 3 : Evaluate of the accuracy of each solution, in the least squares sense

GENERATOR

$$S_{NORM} = \sum_{(\Pi)} S_{NORM}^{(\Pi)}$$

$$S_{NORM}^{(\Pi)} = \sum_{i=1}^{N} \frac{\sqrt{\left| \left(\Pi_i^{\,model} \right)^2 - \left(\Pi_i^{\,obs} \right)^2 \right|}}{\left| \Pi_i^{\,obs} \right|}$$

Example:

$$S_{NORM}^{(\Delta\Phi)} = \sum_{i=1}^{N} \frac{\sqrt{\left| \left(\Delta\Phi_i^{\,model} \right)^2 - \left(\Delta\Phi_i^{\,DMSP} \right)^2 \right|}}{\left| \Delta\Phi_i^{\,DMSP} \right|}$$

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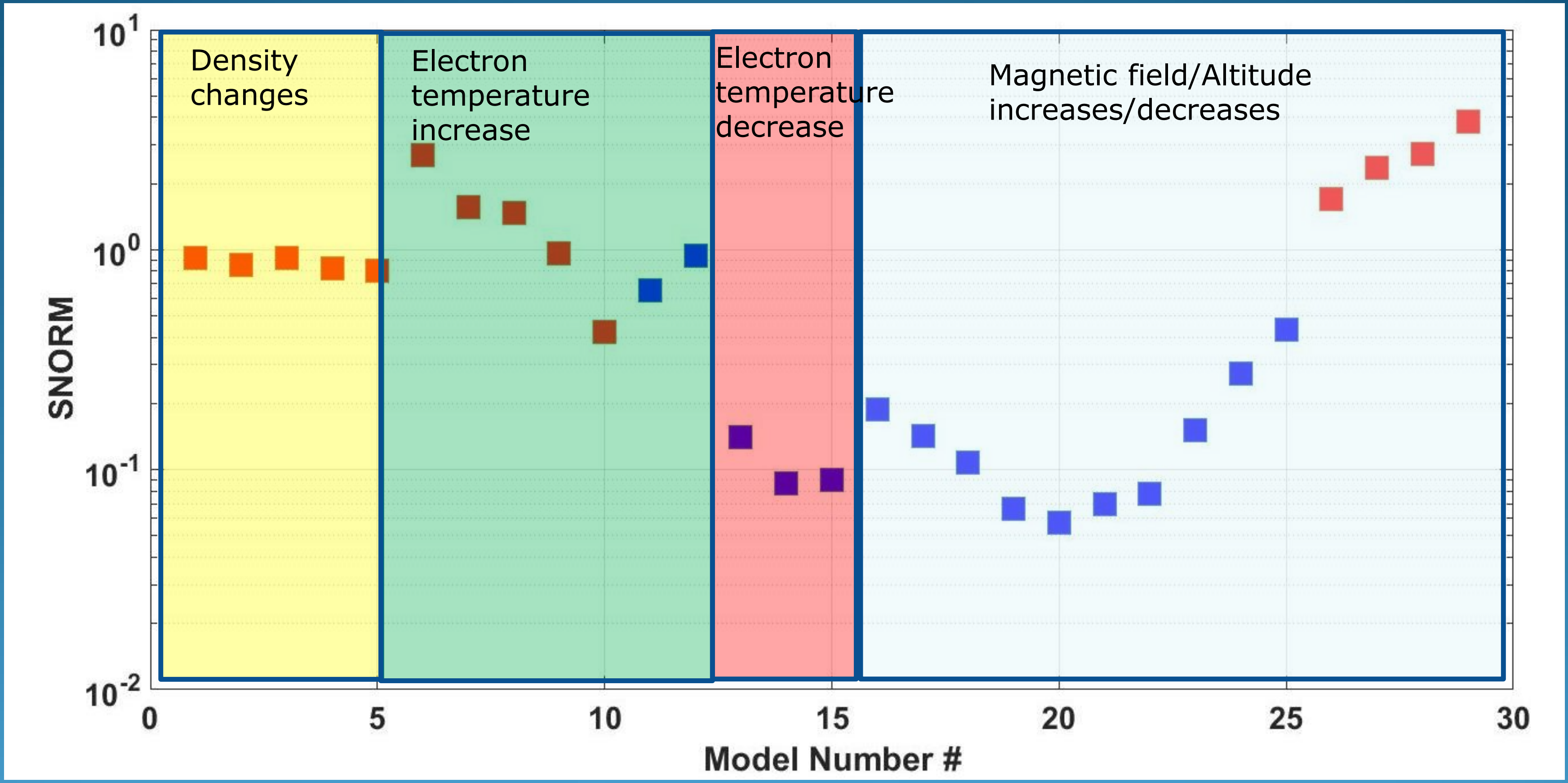
New set of magnetospheric generator

	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19
N_{e2} [cm^{-3}]	0.31	0.62	0.9	0.2	0.15	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
T_{e2} [eV]	200	200	200	200	200	100	500	1000	5000	6000	7000	8000	4000	3000	2000	5000	5000	5000	4000
B [nT]	480	480	480	480	480	480	480	480	480	480	480	480	480	480	480	460	440	420	420

30 instances of MIG typical for the LLBL – lobe interface generated by variations of (1) the LLBL density, (2) the LLBL electron temperature, (3) the magnetic field (proxy for the altitude)

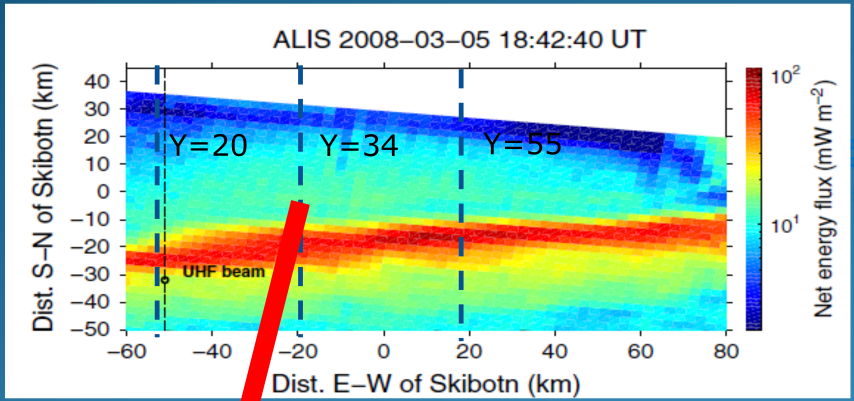
METHODOLOGY

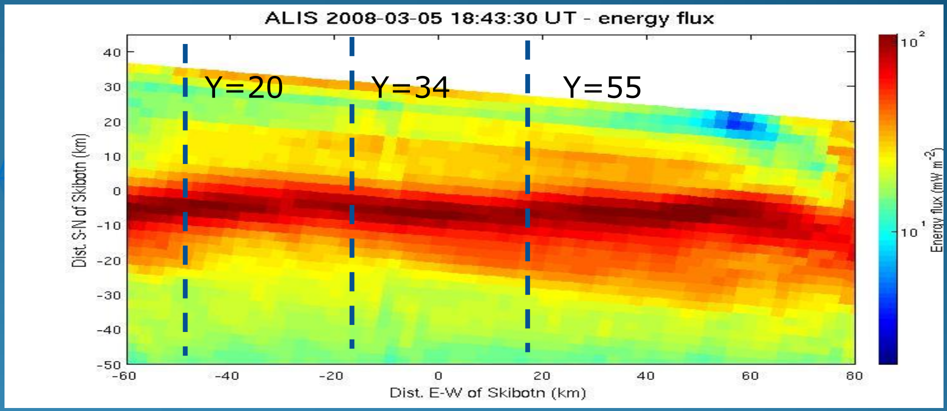
SNORM evaluated for one auroral observable ($\Delta\Phi$ from DMSP)



Solutions computed for S_{NORM} from the 29 generator models. The red symbols illustrate the results of a first scan of the parameter space; the blue symbols correspond to a refined estimation. Different colors emphasize different trends explored in the parameter space

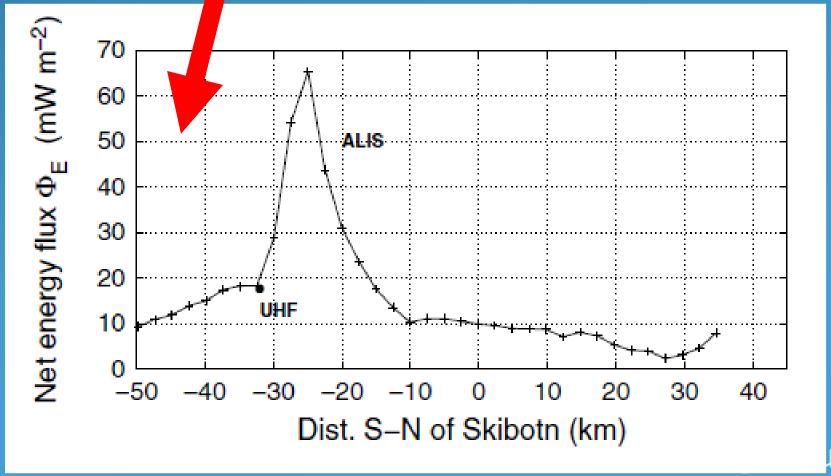
Estimation of generator properties from ALIS observations



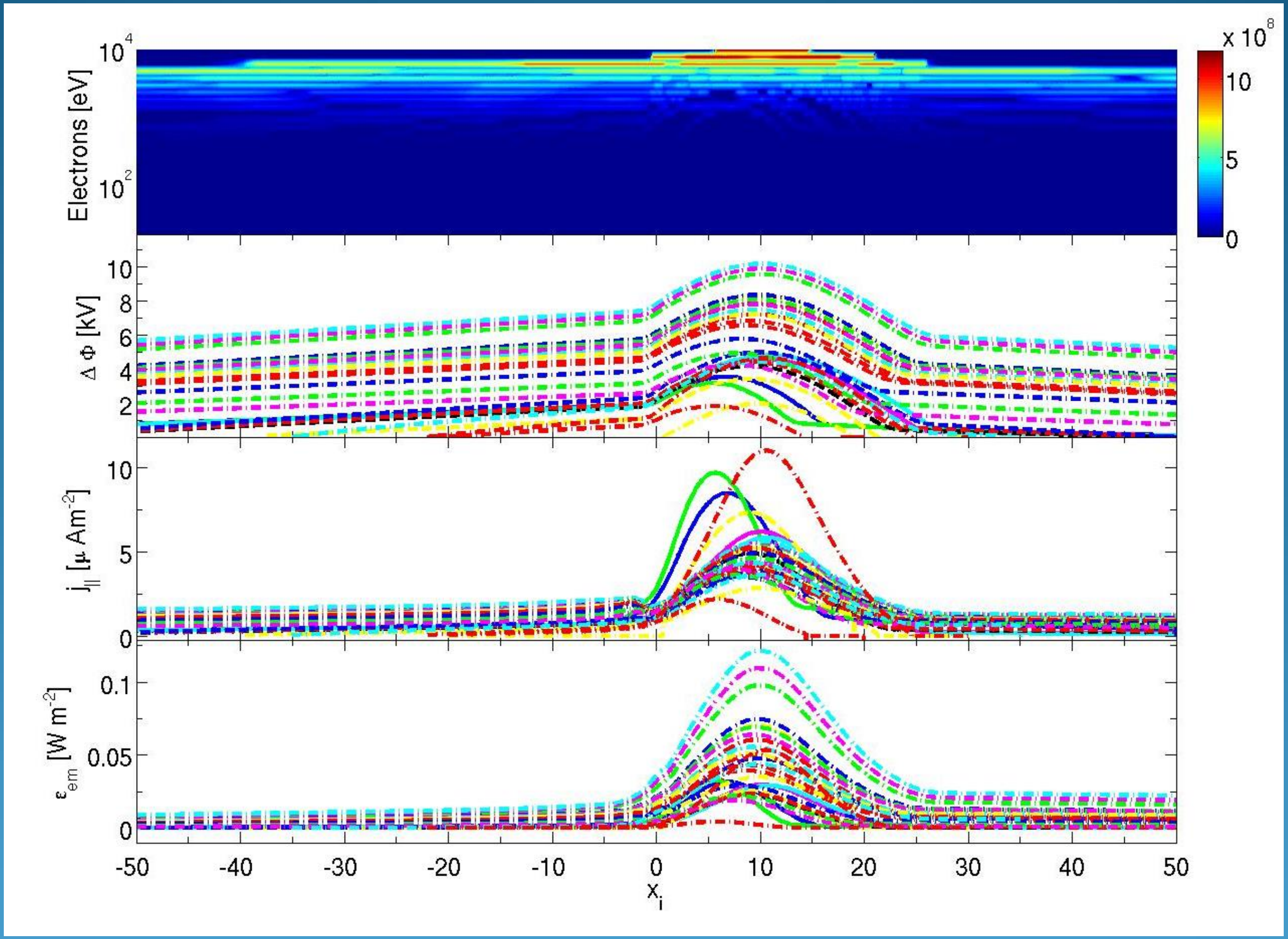


2-D map of the integrated net energy flux (in mW/m^2) at 18:42:40 UT on 05/03/2008 derived from reconstructed fluxes of precipitating electrons at 260 km

2-D map of the integrated net energy flux (in mW/m^2) at 18:43:30 UT on 05/03/2008 derived from reconstructed fluxes of precipitating electrons at 260 km

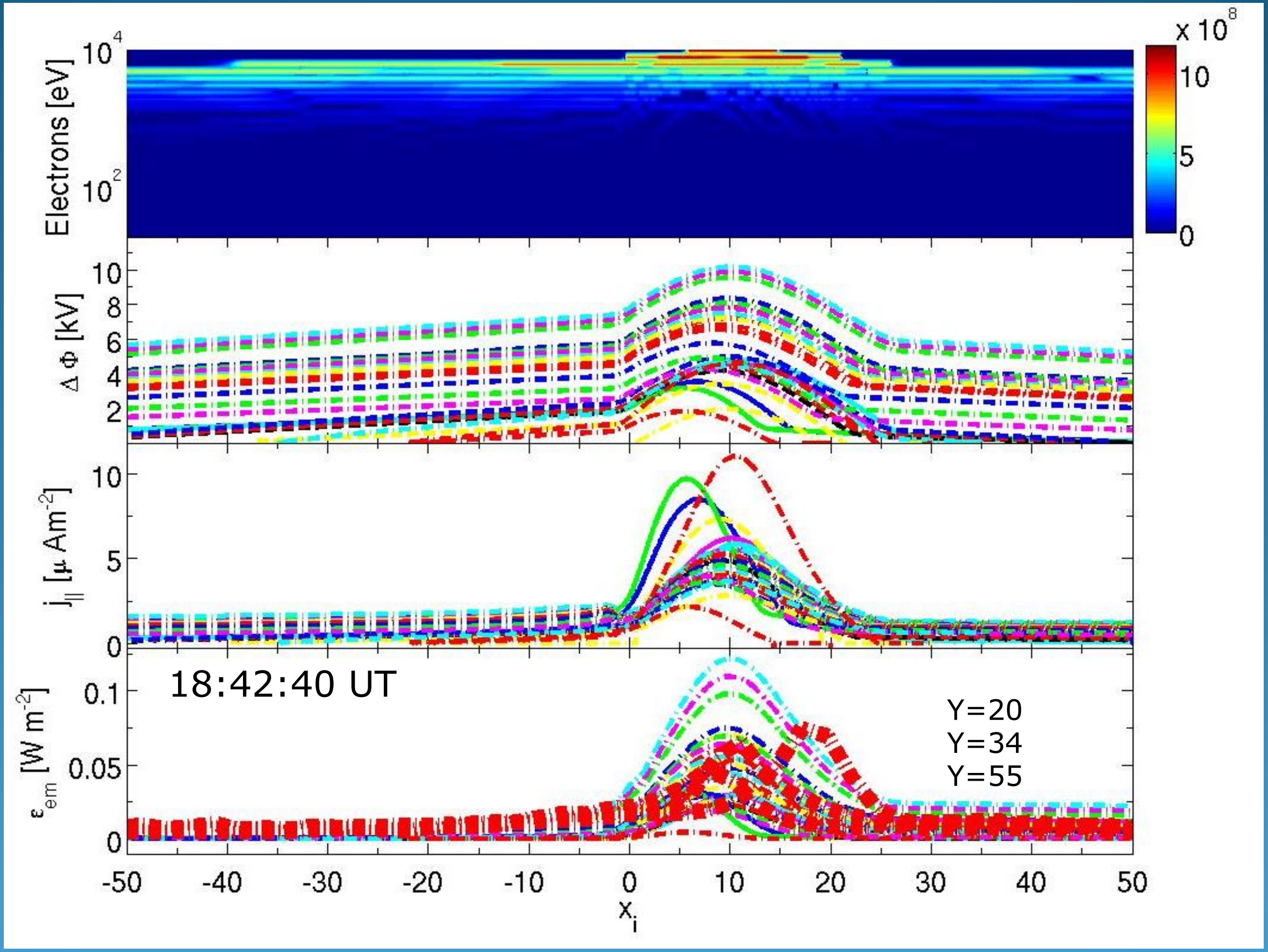


Estimation of generator properties from ALIS observations



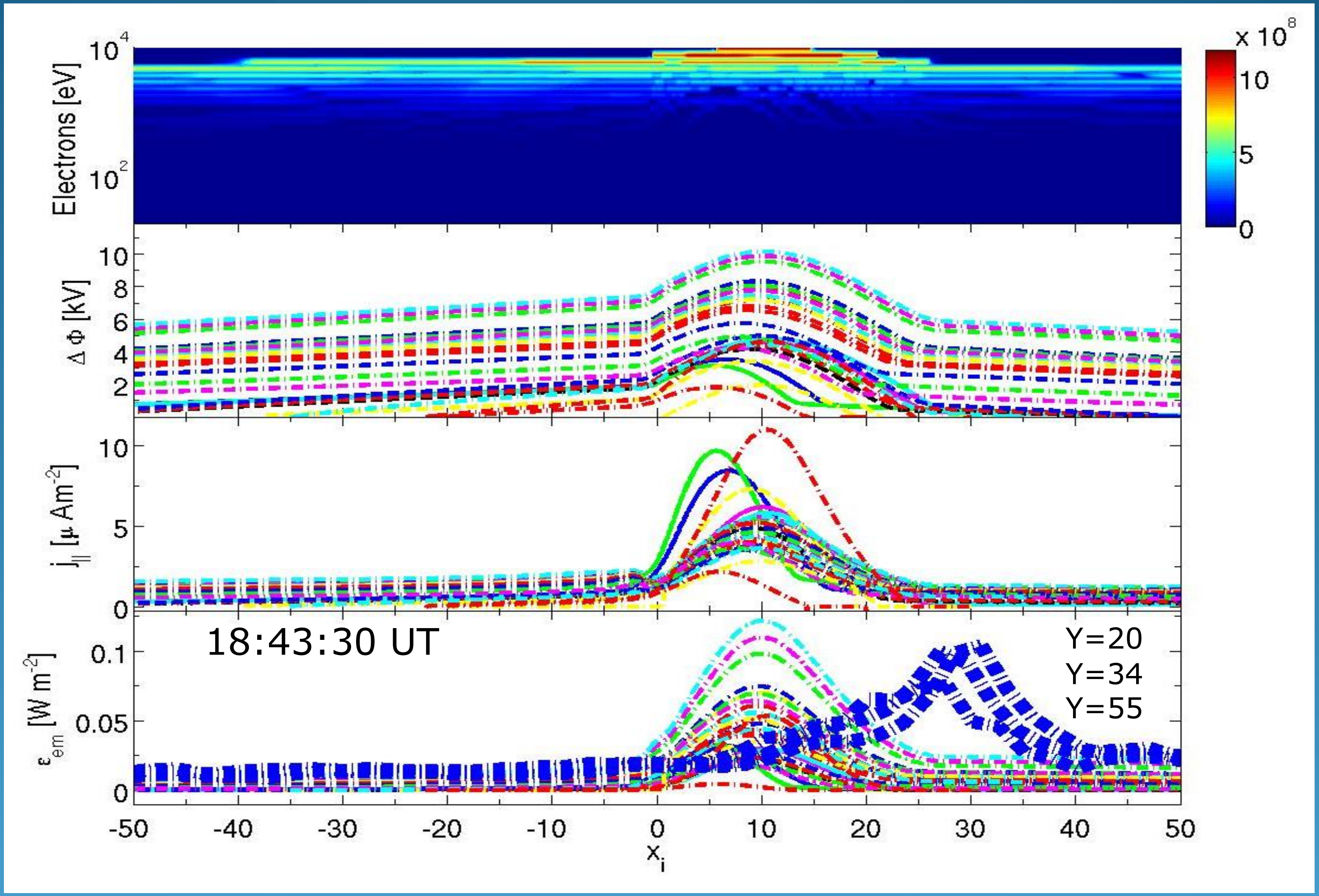
Set of 29 arc solutions. Panels show: energy spectrum of precipitating electrons injected at generator altitude, accelerating potential, field-aligned current density, flux of precipitating energy

Estimation of generator properties from ALIS observations



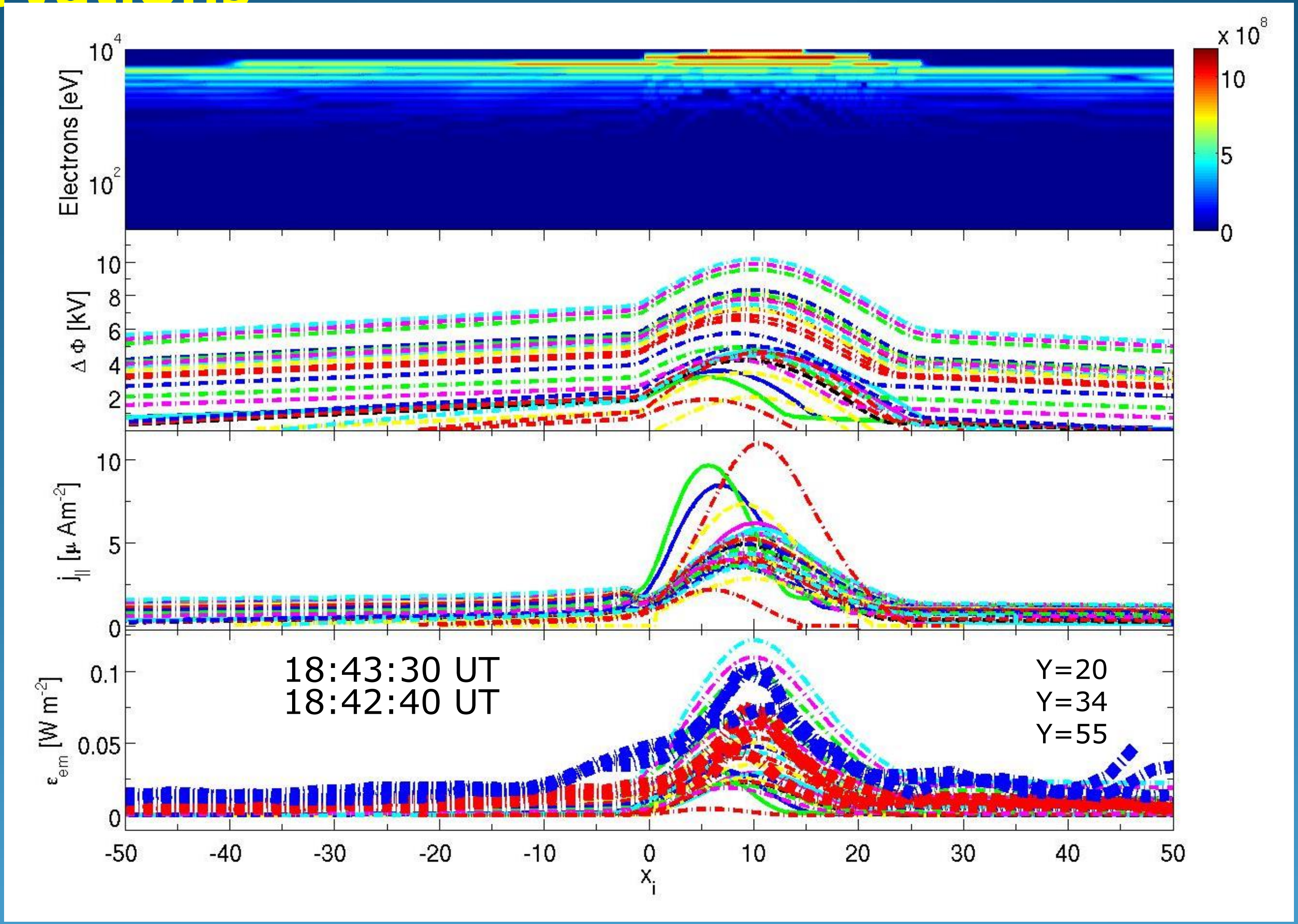
Set of 29 arc solutions. Panels show: energy spectrum of precipitating electrons injected at generator altitude, accelerating potential, field-aligned current density, flux of precipitating energy. Three profiles of ε_{em} from ALIS observations at 18:42:40 UT are superimposed in bold red.

Estimation of generator properties from ALIS observations



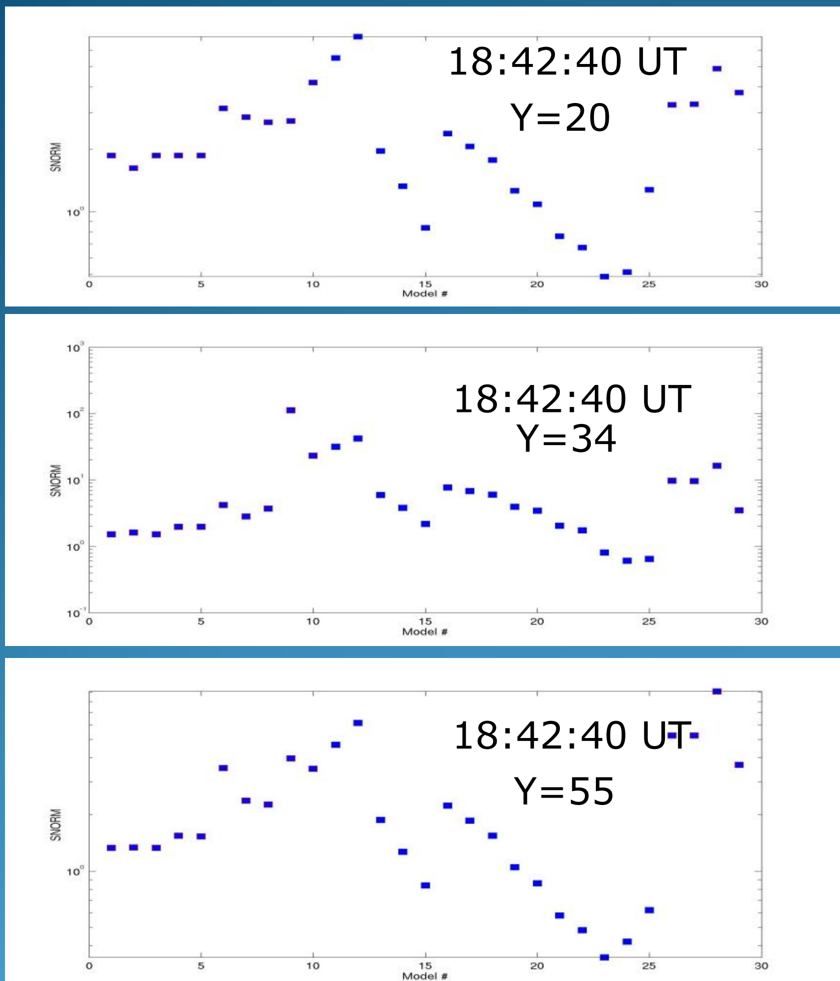
Set of 29 arc solutions. Panels show: energy spectrum of precipitating electrons injected at generator altitude, accelerating potential, field-aligned current density, flux of precipitating energy. Three profiles of ε_{em} from ALIS observations at 18:43:30 UT are superimposed in bold blue.

Estimation of generator properties from ALIS observations

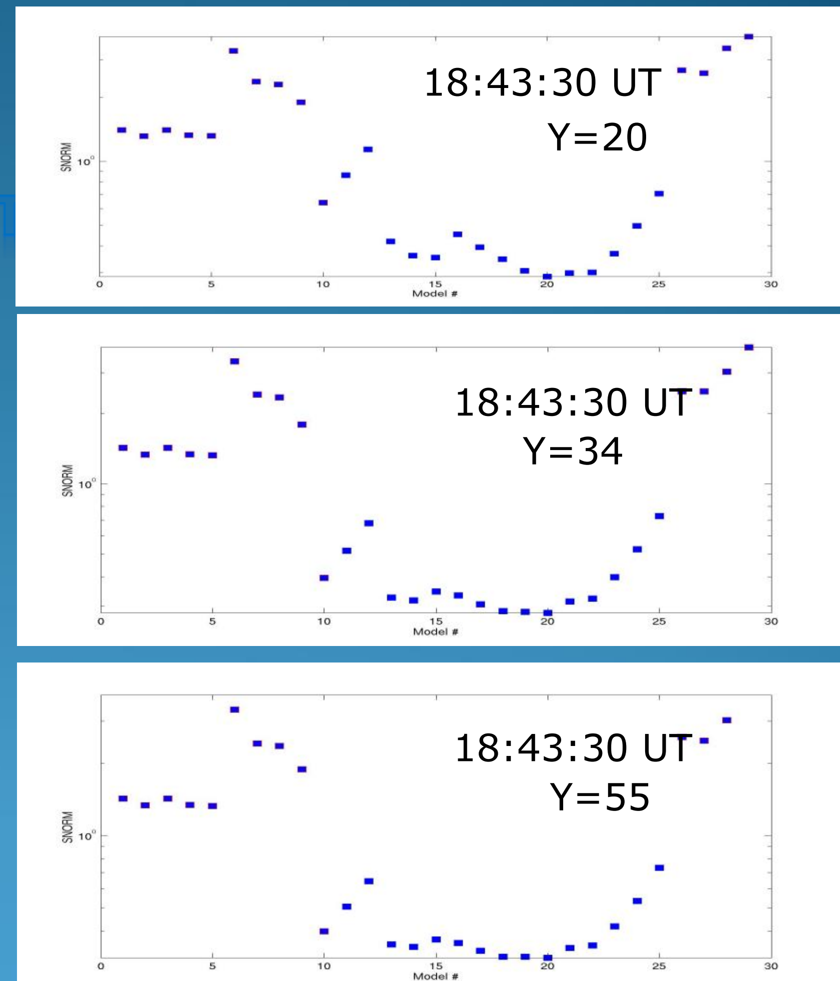


Set of 29 arc solutions. Panels show: energy spectrum of precipitating electrons injected at generator altitude, accelerating potential, field-aligned current density, flux of precipitating energy. Six profiles of ε_{em} from ALIS observations at 18:42:40 UT and 18:43:30 UT are superimposed (and recenter) in bold red and blue.

Estimation of generator properties from ALIS observations



SNORM evaluated for three different sections through the arc observed by ALIS at 18:42:40 UT. Results indicate a slight variation in longitude of generator properties.



SNORM evaluated for three different sections through the arc observed by ALIS at 18:43:30 UT.

Summary, Conclusions

• A magnetosphere-ionosphere coupling model based on a self-consistent description of the generator, a kinetic current-voltage relationship and a description of the ionosphere helps to understand the effects of the magnetospheric variability on the auroral electrodynamics.

• The model shows how velocity shears in the LLBL may drive increased dayside field-aligned current densities.

•The model describes also the coupling between the PSBL and discrete auroral arcs.

• The MI coupling model has the potential to help describing the state of the magnetospheric generator when the electrodynamics of the aurora is known from ground based observations , like, e.g., tomography.