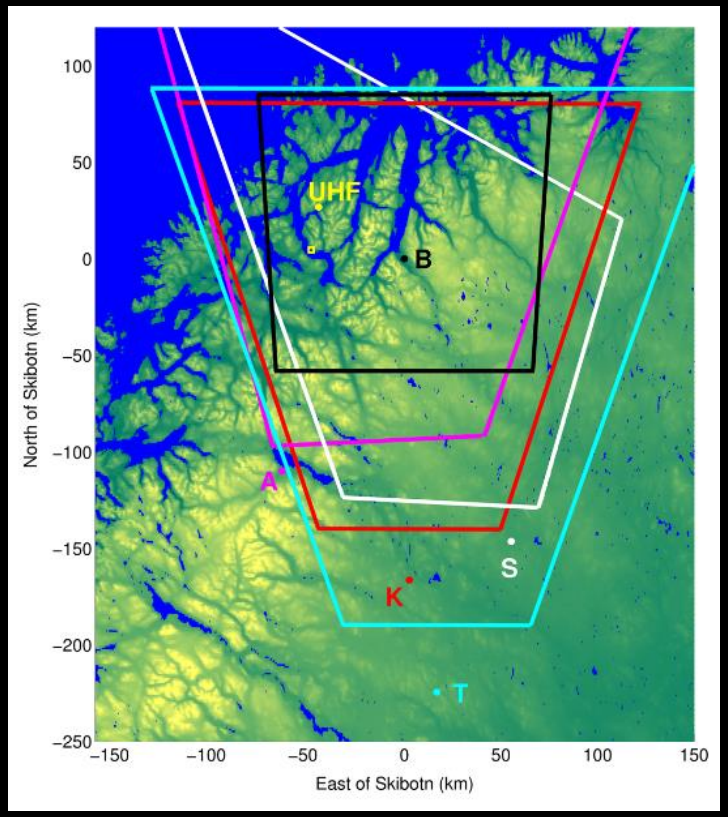
Tomographic inversion of previous campaigns
Status and Goals

MOMA meeting

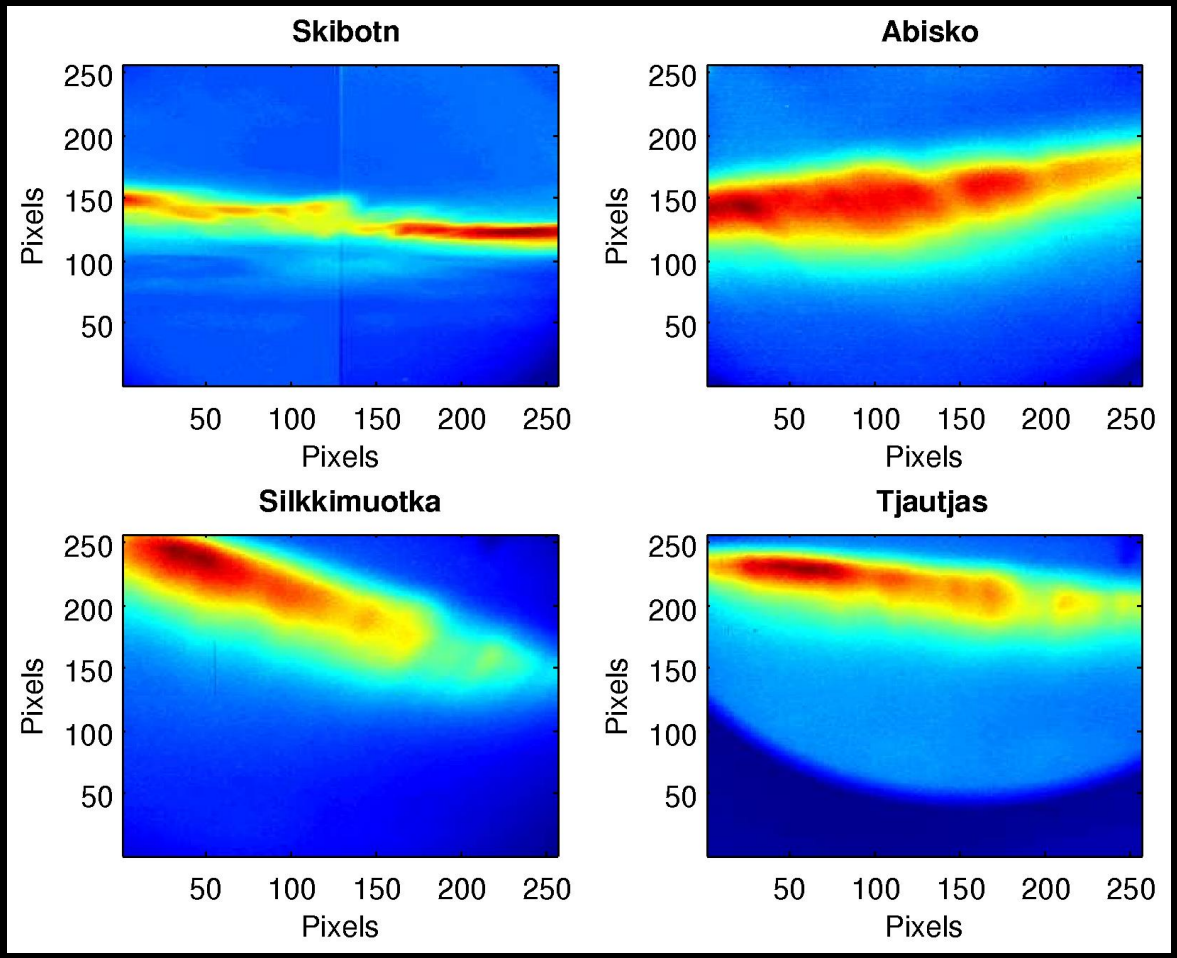
Brussels, November 2019

Aurora Optical Observations



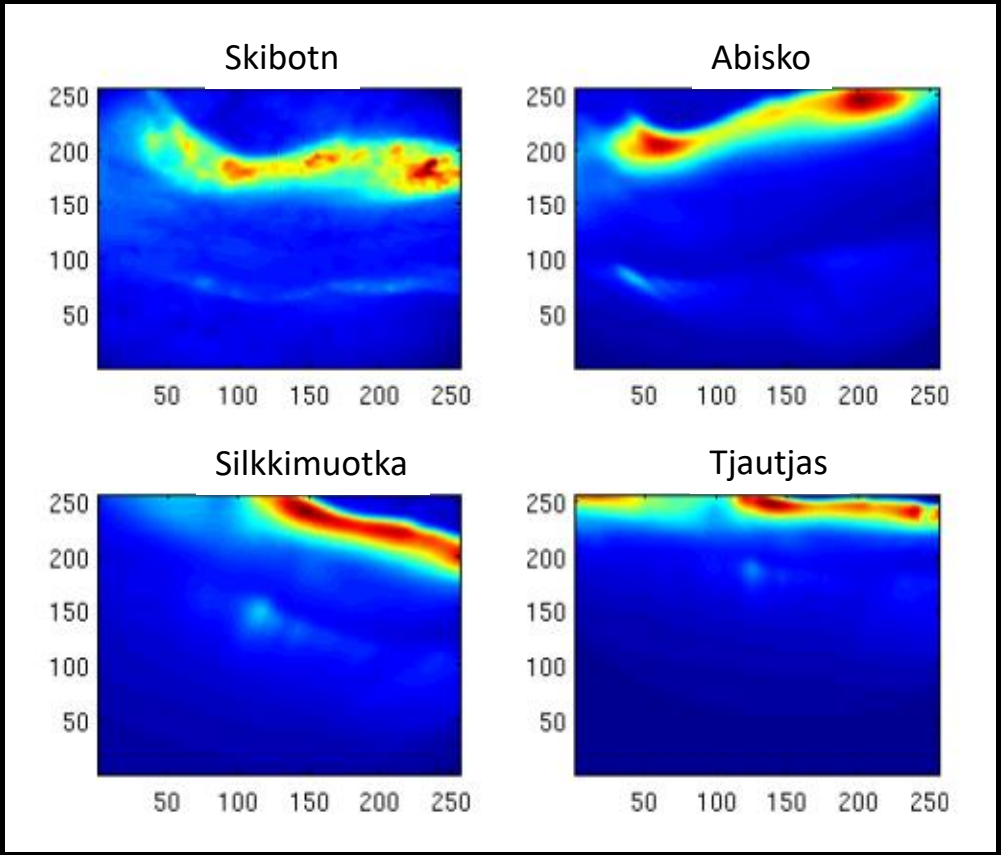
- ✓ ALIS: network of 5 optical stations (Skibotn, Abisko, Silkkimuotka, Kiruna, Tjautjas). High-res CCD cameras observing the same volume of sky above 80 km altitude.
- ✓ Images of auroral arcs obtained using narrow interference filters at 427.8 (blue), 630.0 (red), 557.7 (green) and 844.6 nm (NIR). FOV of each camera ~ 50-70°
- ✓ Simultaneous images from different stations are properly calibrated
- ✓ Results from Simon Wedlund et al. 2013

Aurora Optical Observations



March 5th, 18:41:25 UT, 5577 Å

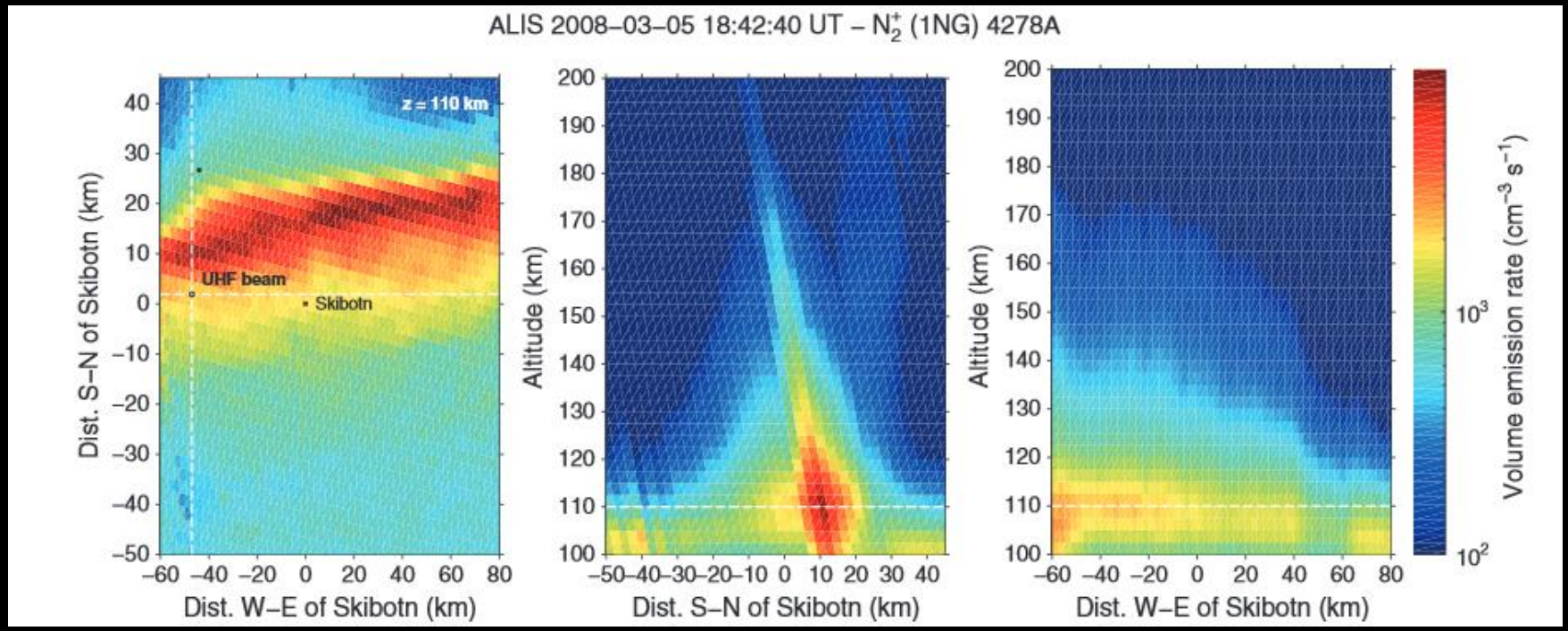
Aurora Optical Observations



March 7th, 20:32:05 UT, 5577 Å

- ✓ Using a 3D reconstruction (tomography technique), we will have access to the ALIS Volume Emission Rates (VER)
- ✓ The 2-D intensity of each pixel in an image for a station s can be seen as a line integral across the 3-D distribution of the auroral intensity source.
- ✓ Multiplicative Algebric Reconstruction Technique (MART) as inversion method (Simon Wedlund et al. 2013)

Volume Emission Rates for the blue line



- ✓ Interest of the blue band of N2+ at 427.8 nm
- ✓ Only excited by electron impact and thus nearly linearly related to the incoming electron precipitation flux.

Inversion of N2+ (1NG) Emissions

- ✓ Volume Emission Rate is proportional to the energy deposition rate (Janhunen, 2001)

VER = , B Φ, with the precipitation flux Φ and the matrix B which contains all the physics of the degradation of the electrons in the Earth's ionosphere as expressed through the forward model (Rees, 1989)

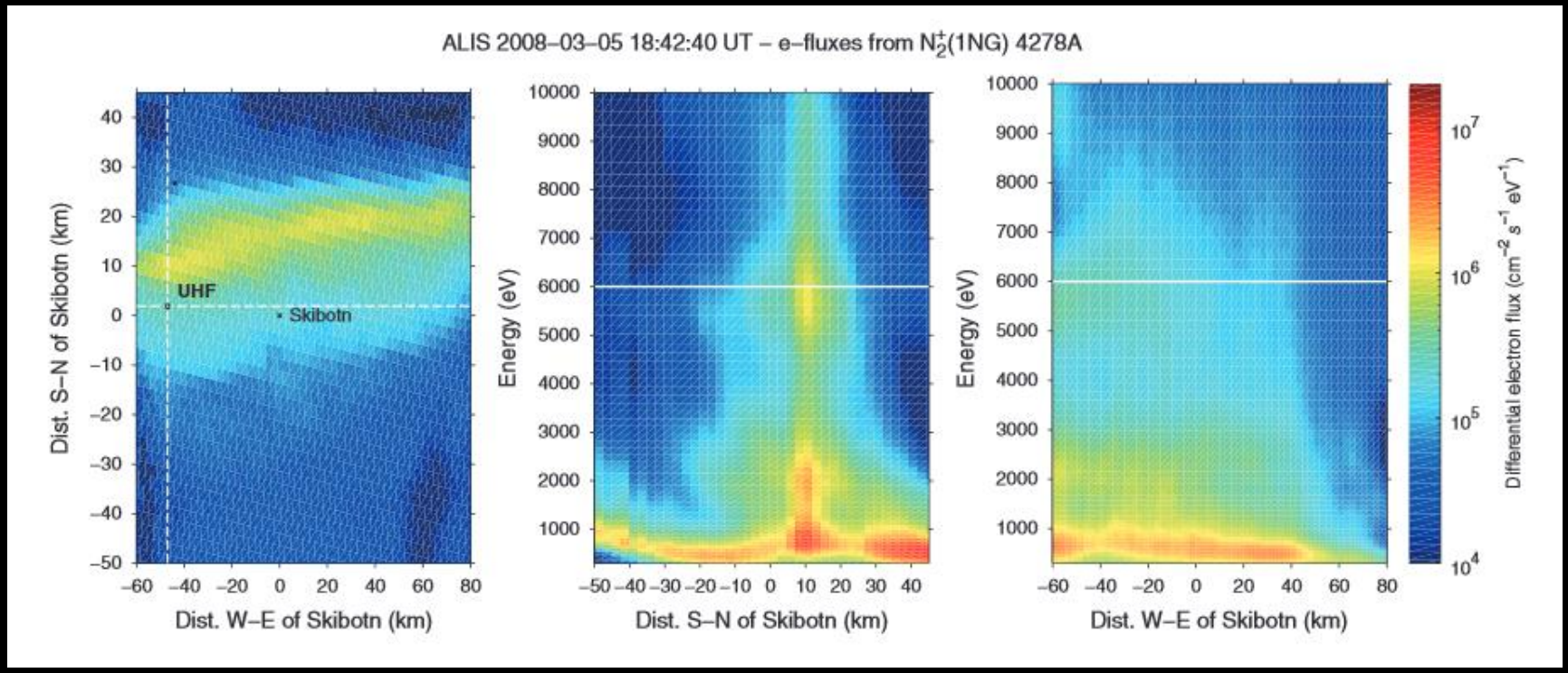
$$B_{ij} = B(z_i, E_j)\,\Delta E_j = \frac{\zeta(z_i)\,\Lambda\left(\frac{s(z_i)}{R(E_j)}\right)\rho(z_i)\,E_j\,(1-\mathcal{A}(E))\,\Delta E_j}{R(E_j)}$$

Λ = energy dissipation function (from Sergienko et al 1993)
ρ = atmospheric mass density model (MSISE-00)
$R(E_j)$ = electron range in air (from Barrett & Hays 1976)

- ✓ Z, the excitation efficiency , has an altitude dependence (Partamies et al., 2004) such as

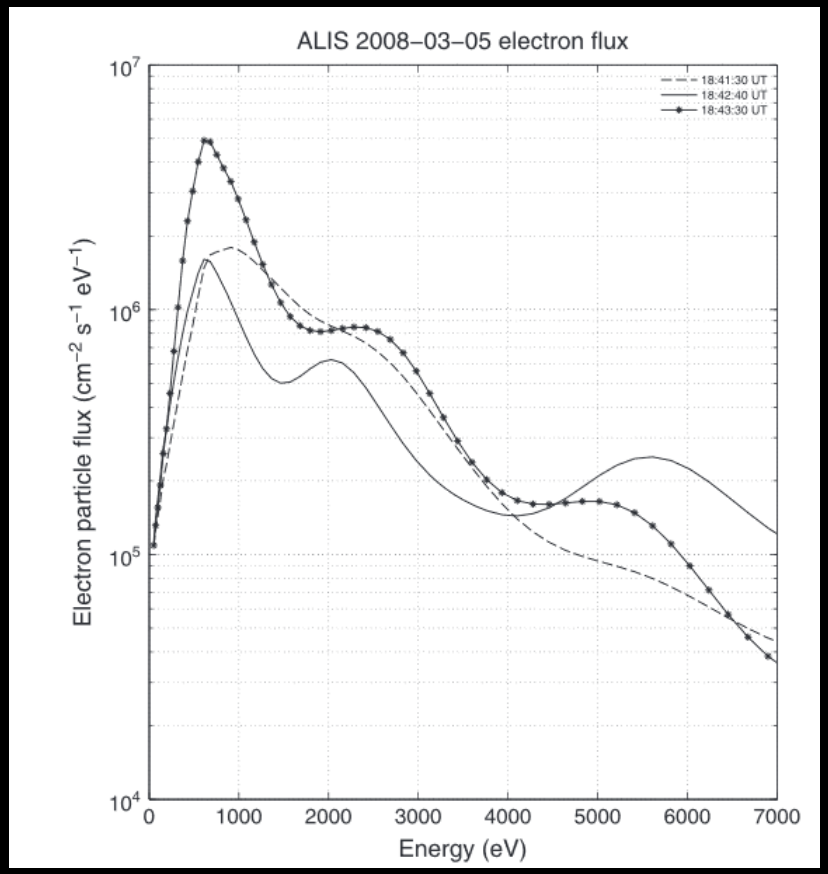
$$\zeta(z) = \frac{n_{N_2}(z)}{n_{N_2}(z) + 0.7\,n_{O_2}(z) + 0.4\,n_O(z)} \cdot 0.628.$$

Inversion of N2+ (1NG) Emissions



- ✓ MART technique to invert the precipitating flux from the blue volume emission rate.
- ✓ 2-D electron precipitation flux maps over ALIS at 18:42:40 UT
  - ✓ Energy projection at 6 keV (110 km altitude) in the latitude/longitude plane
  - ✓ Latitudinal projection of fluxes versus energy in the plane passing through the UHF EISCAT radar.
  - ✓ Longitudinal projection of fluxes versus energy in the plane passing through the EISCAT radar.

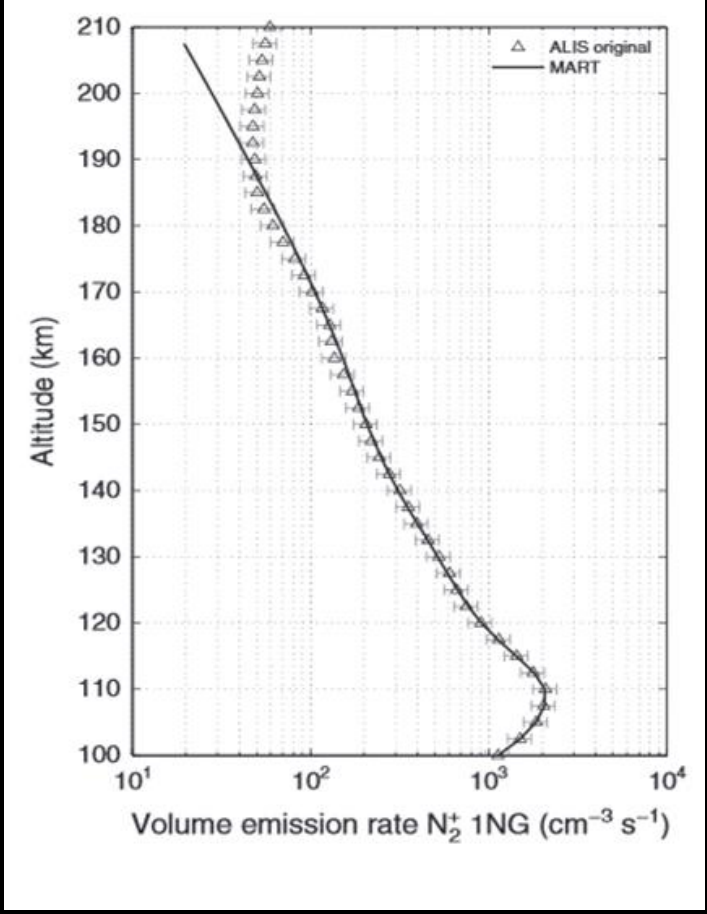
Inversion of N2+ (1NG) Emissions

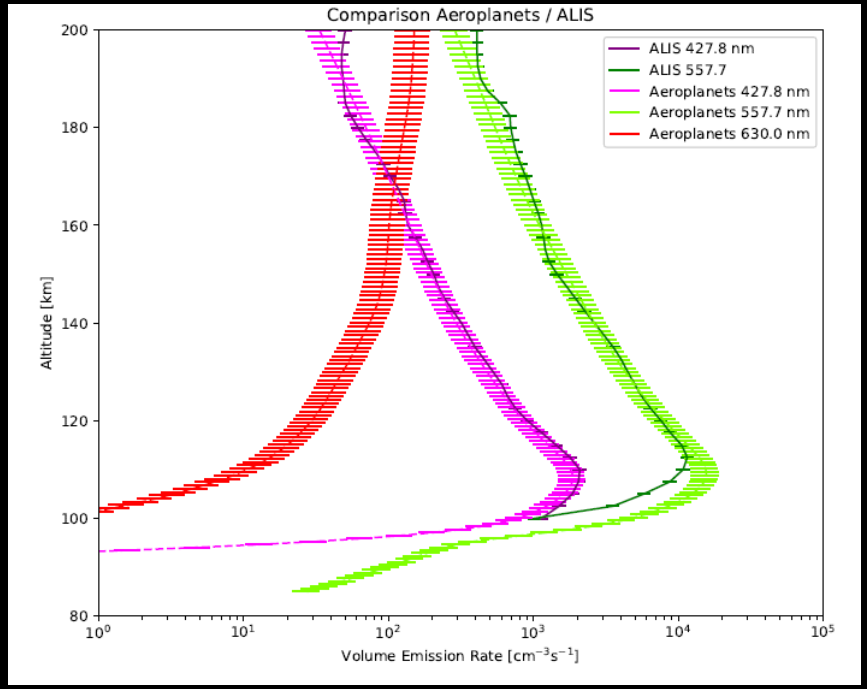


- ✓ The inversion method can be applied to the entire time sequence of N_2^+ (1NG) images at 427,8 nm
- ✓ Electron particle fluxes at three different stages of the auroral arc, at 18:41:30 UT (onset), 18:43:40 UT (middle), and 18:43:30 UT (end) at the EISCAT UHF location.

Validation

- ✓ Good agreement with the forward model and the MART inversion (5%)





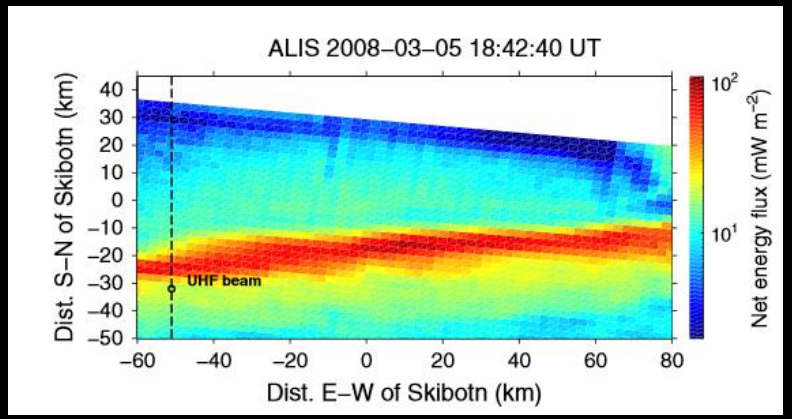
- ✓ Good agreement with Aeroplanets (Gronoff et al.)

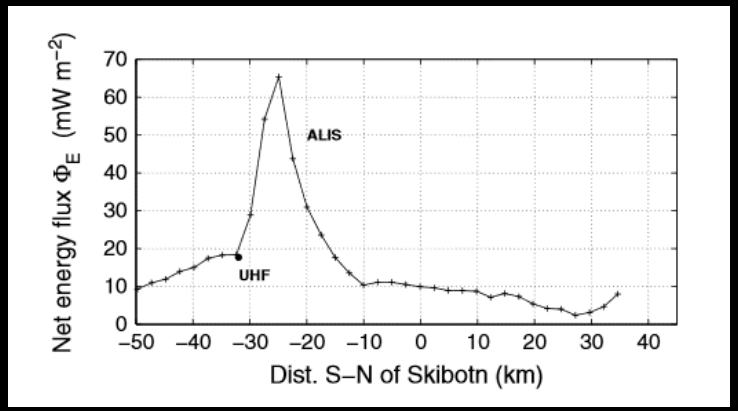
2-D Energy Flux Maps

- ✓ The net energy flux, $$\Phi_E = \int_0^\infty E\,\phi(E)\,\mathrm{d}E.$$

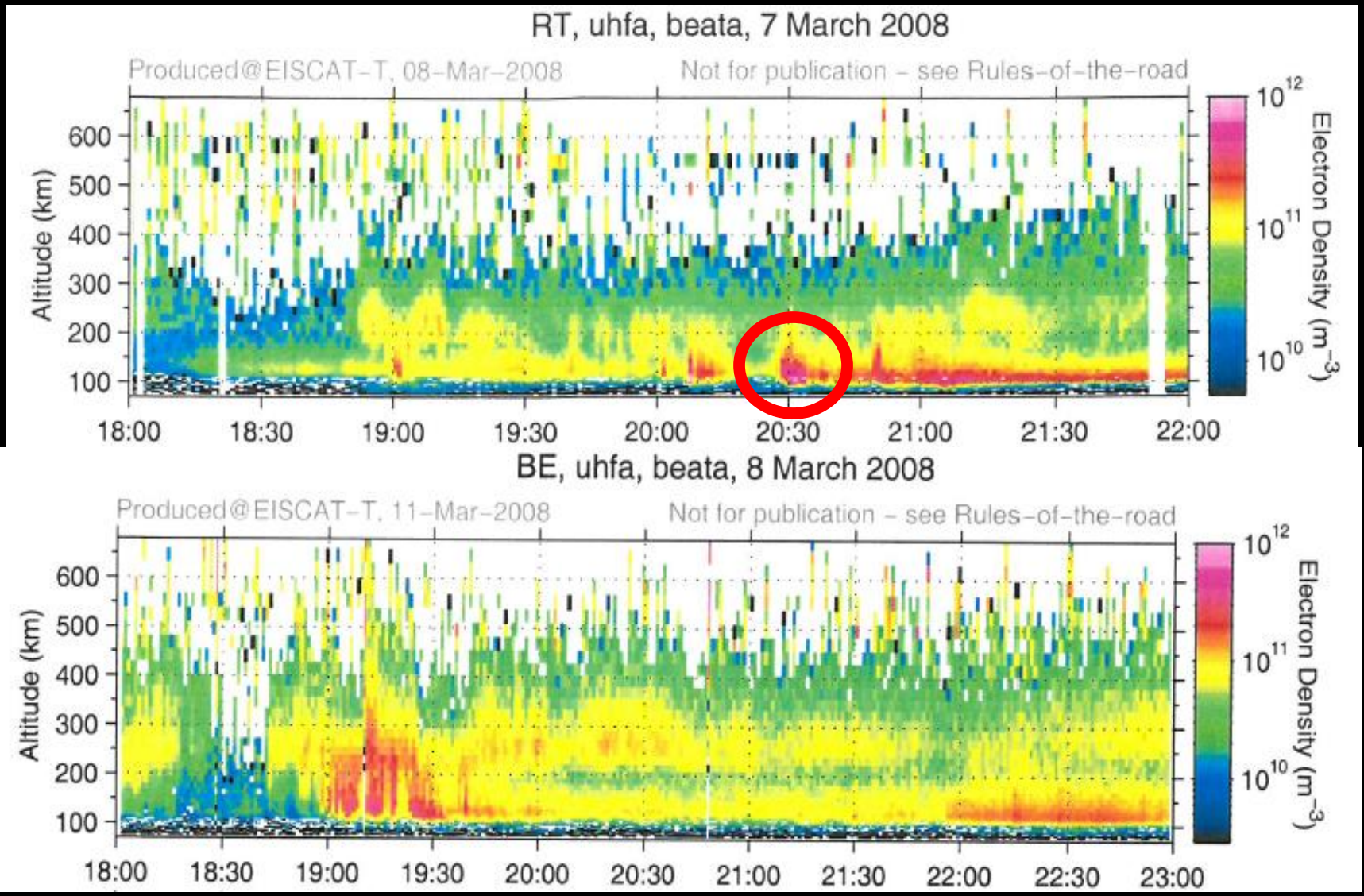
- ✓ Crucial parameter of magnetosphere-ionosphere coupling models (see Echim et al., 2007). N

- ✓ Net energy flux at 18:42:40 UT derived from EISCAT equal to 17.7 mW m^{-2} while for the ALIS-derived net energy flux along the same field line:18.4 mW m^{-2}, (difference of less than 4%)

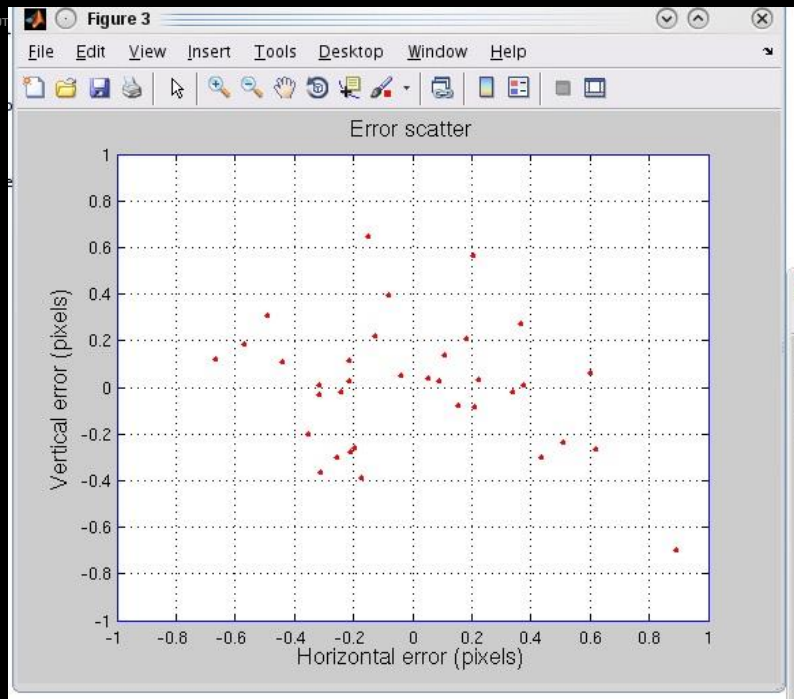


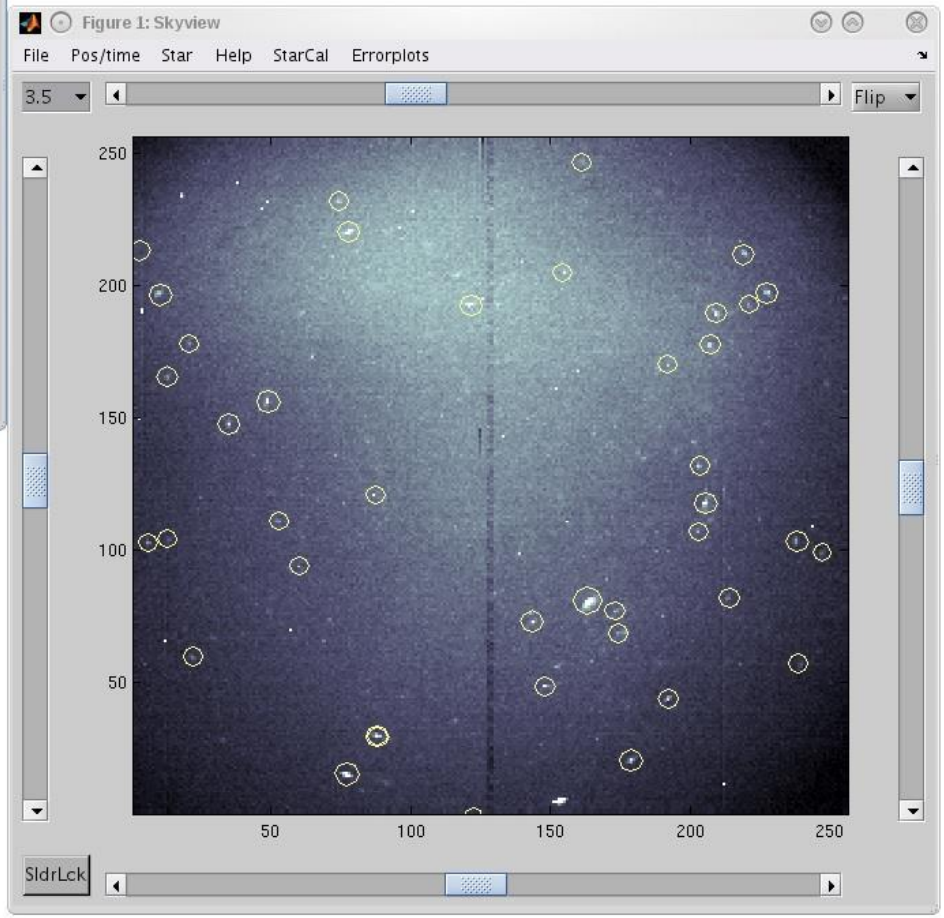


Additional data set

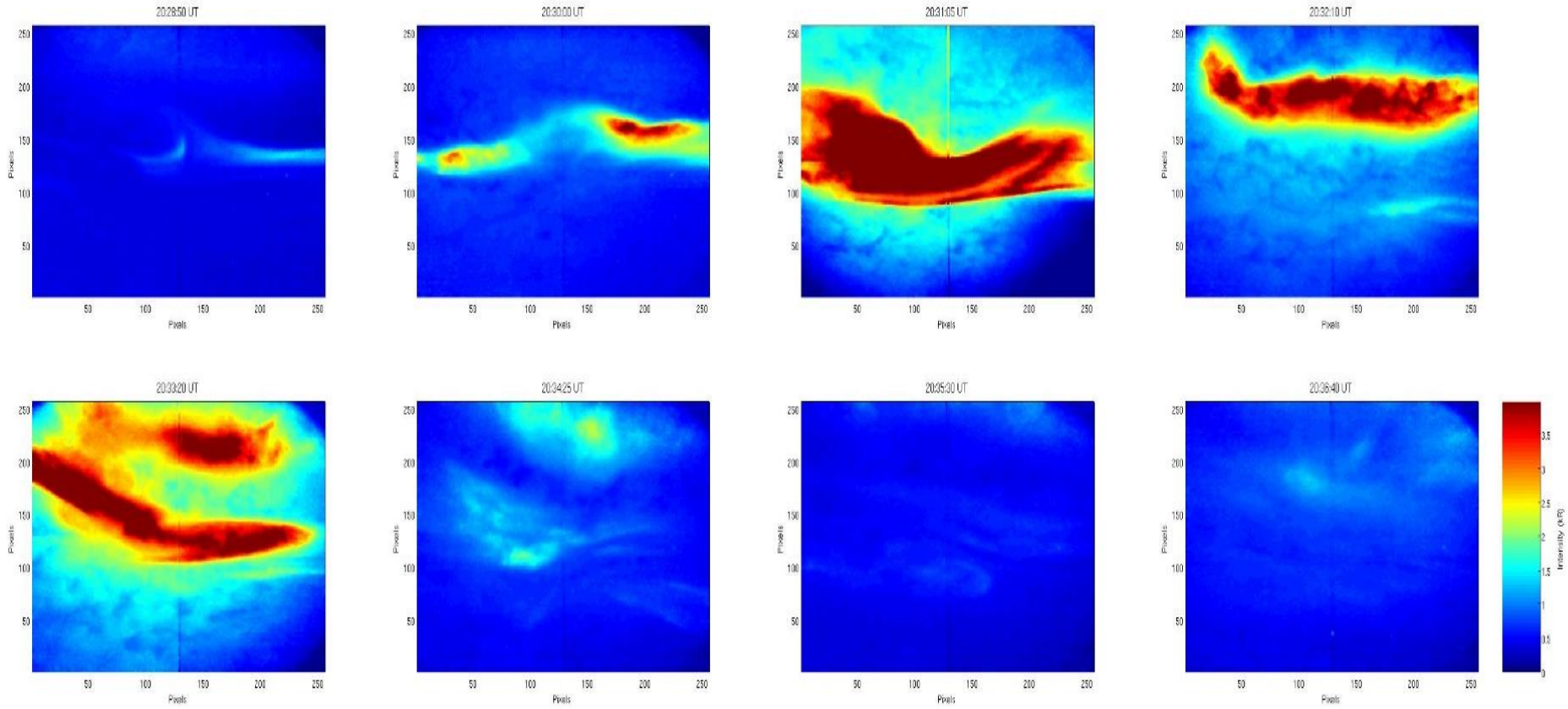


Star Calibration



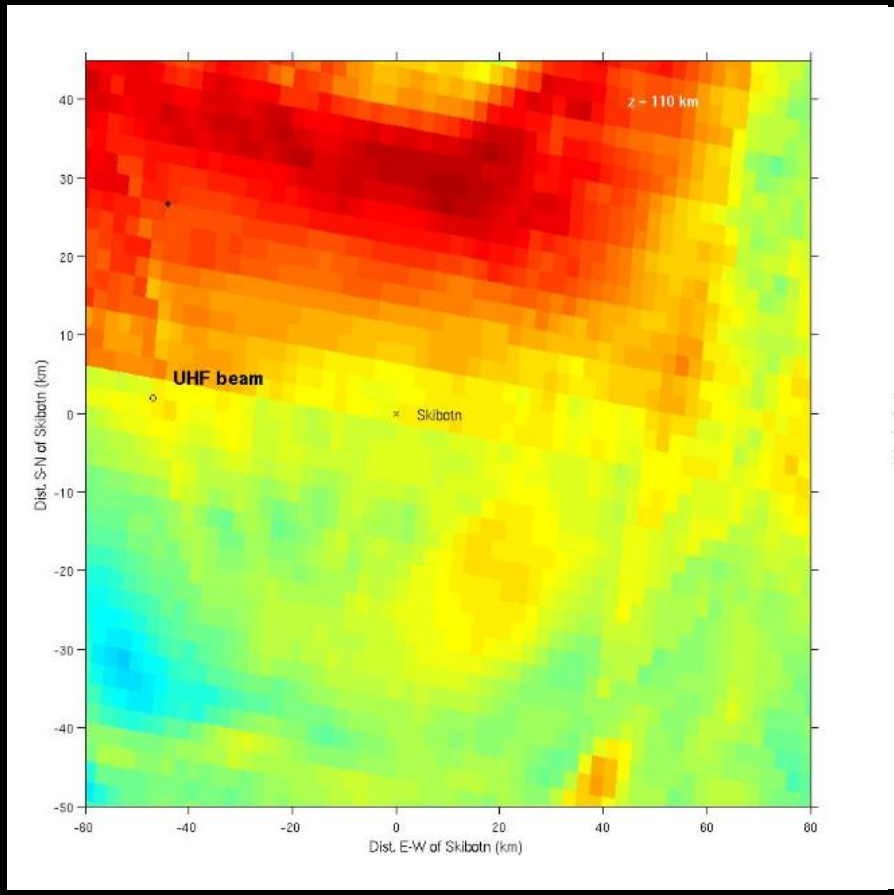


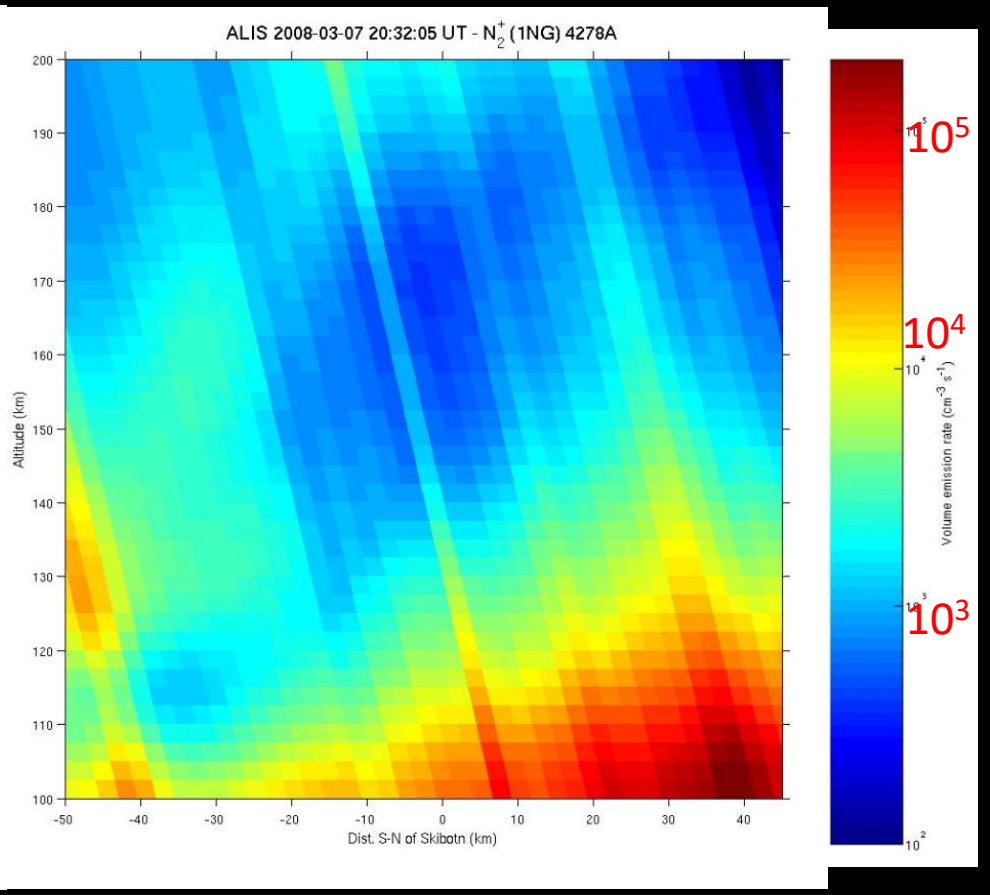
Aurora Optical Observations



Time sequence from 20:28:50 to 20:36:40 for Skibotn at 427.8 nm

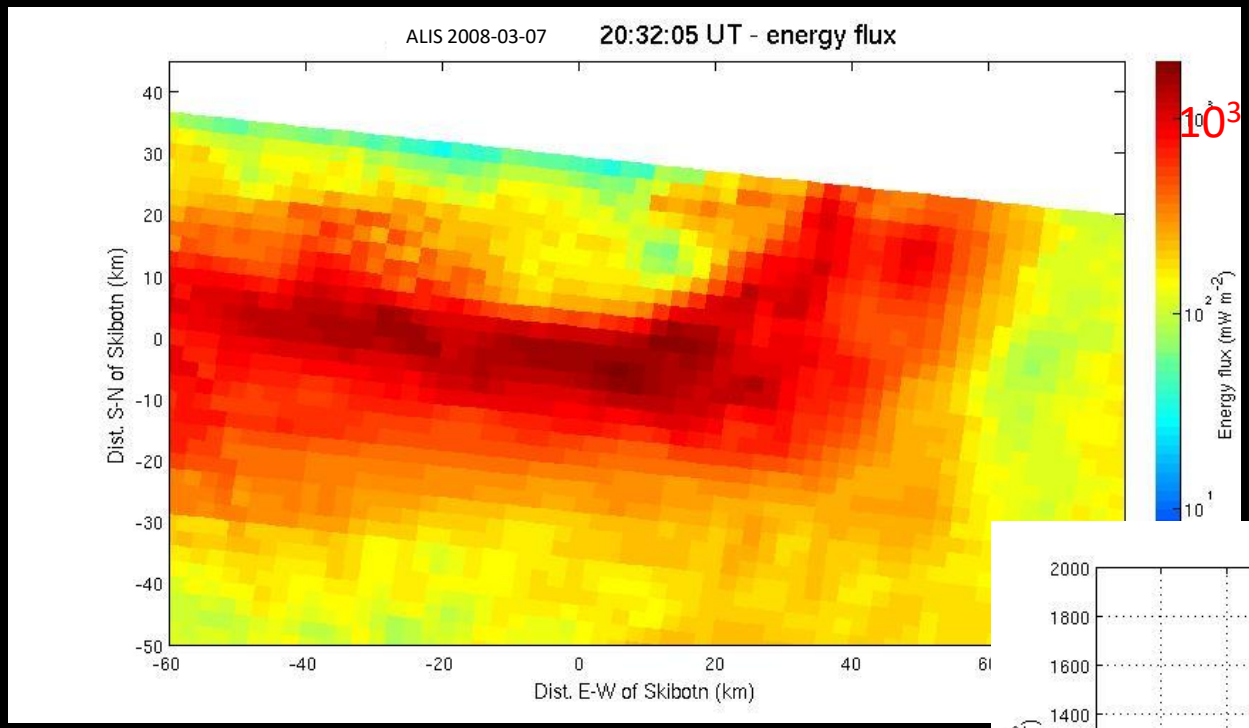
Volume Emission Rates for the blue line

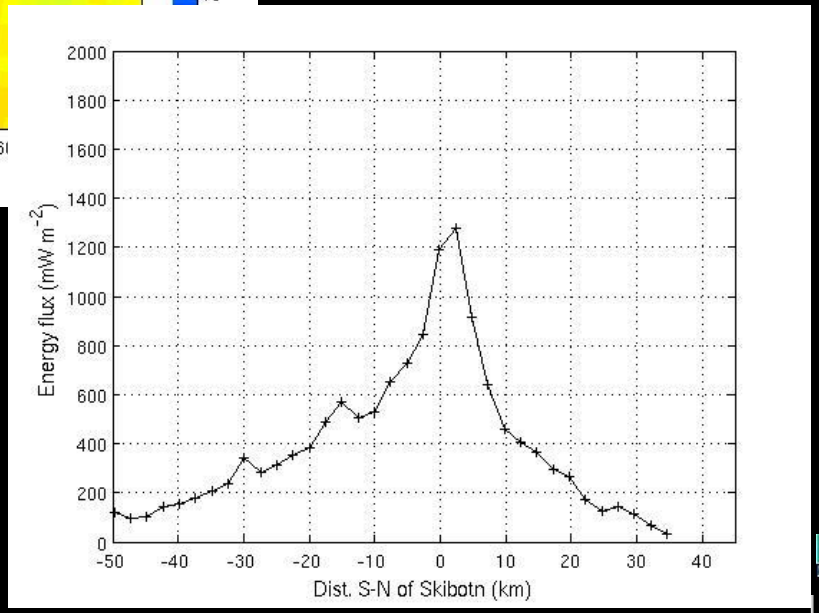




VER 10 times more important than for 05/03/2008

2-D Energy Flux Maps





Energy flux at 260 km~ 10 times more important than 05/03/08

Need to check up (Initial Guess)

Take home message

Multi-station observations of auroral arc at 427.8 nm

→ Tomography-like reconstruction

3-D Volume Emission Rate VER at 427.8 nm

↓ MART inversion

- ✓ 2-D (lat/long) spectra of precipitating electrons
- ✓ Net energy flux

← M-I coupling model (Echim et al. 2007) in order to infer properties of magnetospheric auroral generators.

- ✓ Same methods will be applied for further existing and future datasets (ALIS 4D)