Contribution of proton and electron precipitation to the observed electron concentration in October-November 2003 and September 2005

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Introduction

Solar energetic particle precipitation affects the neutral composition of the upper stratosphere, mesosphere and lower thermosphere in the polar regions. Ionization caused by precipitating protons and electrons leads to changes in a variety of hydrogen and nitrogen species which can decrease the ozone concentrations. The particle precipitation induced ozone changes in the middle atmosphere may then modulate regional ground-level climate on solar cycle time scales.

When modelling the mesospheric effects of solar proton events (SPE) it is typically assumed that the ionization by electrons is negligible below the mesopause. However electron precipitaiton can significantly increase ionization caused by protons. Around the mesopause the transition to increasing auroral electron input leads to electron dominance at the upper altitudes. Understanding this transition is an important issue to the odd nitrogen production and descent, because a bulk production above the mesopause is less likely to have and impact on stratospheric ozone.

Here we use EISCAT incoherent scatter radar measurements of two SPEs to study the contribution of proton and electron precipitation to the observed electron density in the meso-sphere-lower thermosphere region. The observations are compared with the Sodankylä Ion and Neutral Chemistry model (SIC) predictions from three different runs designed to separate the effects of protons and electrons. The proton ionization rates are calculated by two different methods, a simple energy deposition calculation and the Atmospheric Ionization Model Osnabrück (AIMOS), the latter providing also the electron ionization rates.

Data & model setup

Tab 1. Selected characteristics of the data and the events.

Event	Case 1 October–November 2003	Case 2 September 2005
Start day	26 Oct	8 Sep
pfu maximum	29 500 (28 Oct)	1880 (11 Sep)
A_p maximum	203.9 (29 Oct)	100.8 (11 Sep)
Solar F10.7 maximum	275.4 (30 Oct)	117.6 (11 Sep)
Solar X-ray maximum	X17 (28 Oct)	X17 (7 Sep)
EISCAT radar	VHF 224 MHz	UHF 928 MHz
EISCAT dates	28 Oct–2 Nov	6–9 Sep
EISCAT temporal resolution	0.4 s	90 s
EISCAT experiment	arc_dlayer	tau2pl
EISCAT altitudes	60–130 km	50–700 km
EISCAT calibration	ionosonde	IS plasma line

Tab 2. Particle ionization rates used inSIC.

Run	Protons	Electrons
SIC1	None	None
SIC2	CSDA ($E > 1$ MeV)	None
SIC3	CSDA ($E > 1$ MeV)	AIMOS ($E > 154$ eV)
SIC4	AIMOS ($E > 154$ eV)	AIMOS ($E > 154$ eV)

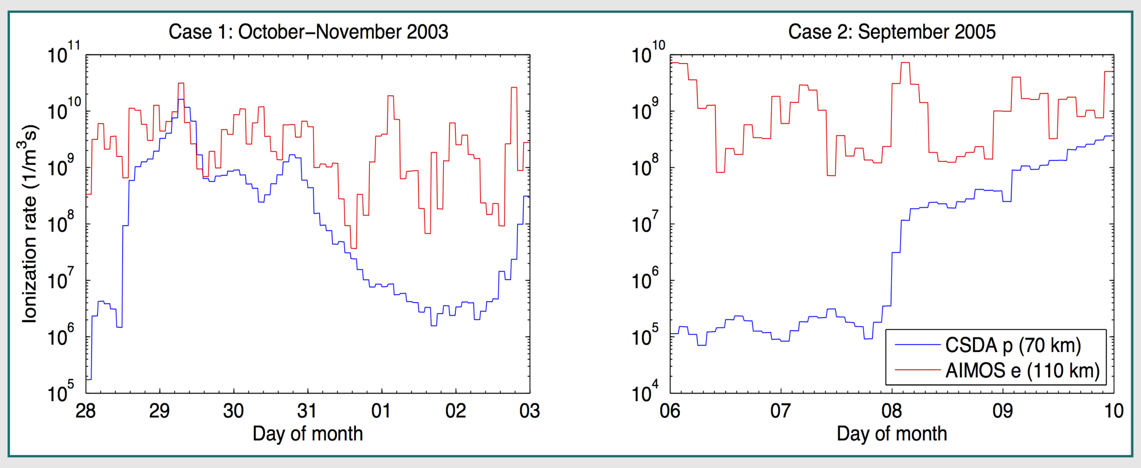

Fig 1. Calculated ionization rates due to protons and electrons at 70 and 110 km.

October-November 2003

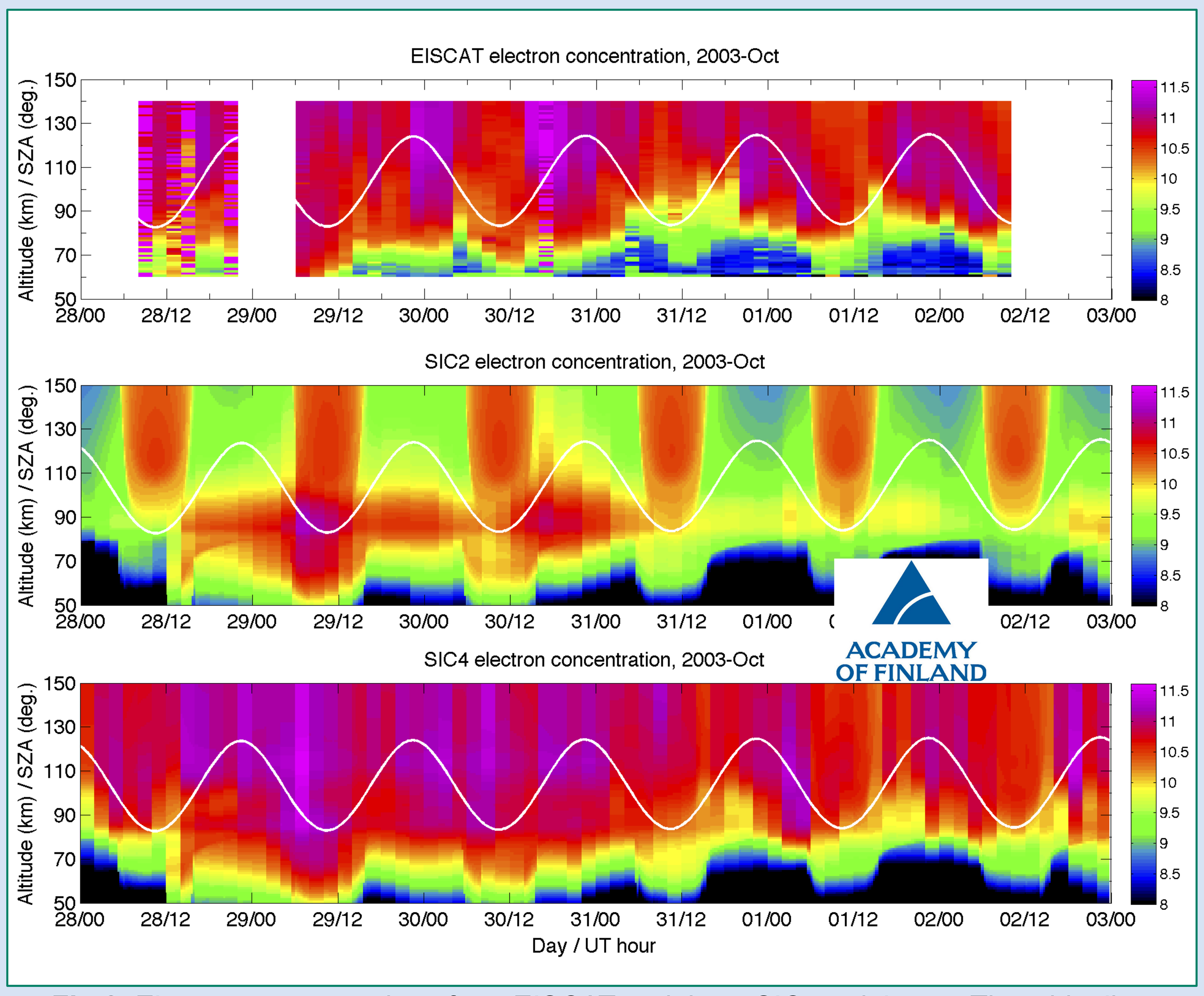

Fig 2. Electron concentrations from EISCAT and three SIC model runs. The white lines shows the diurnal cycle of the solar zenith angle at the EISCAT Tromsø location.

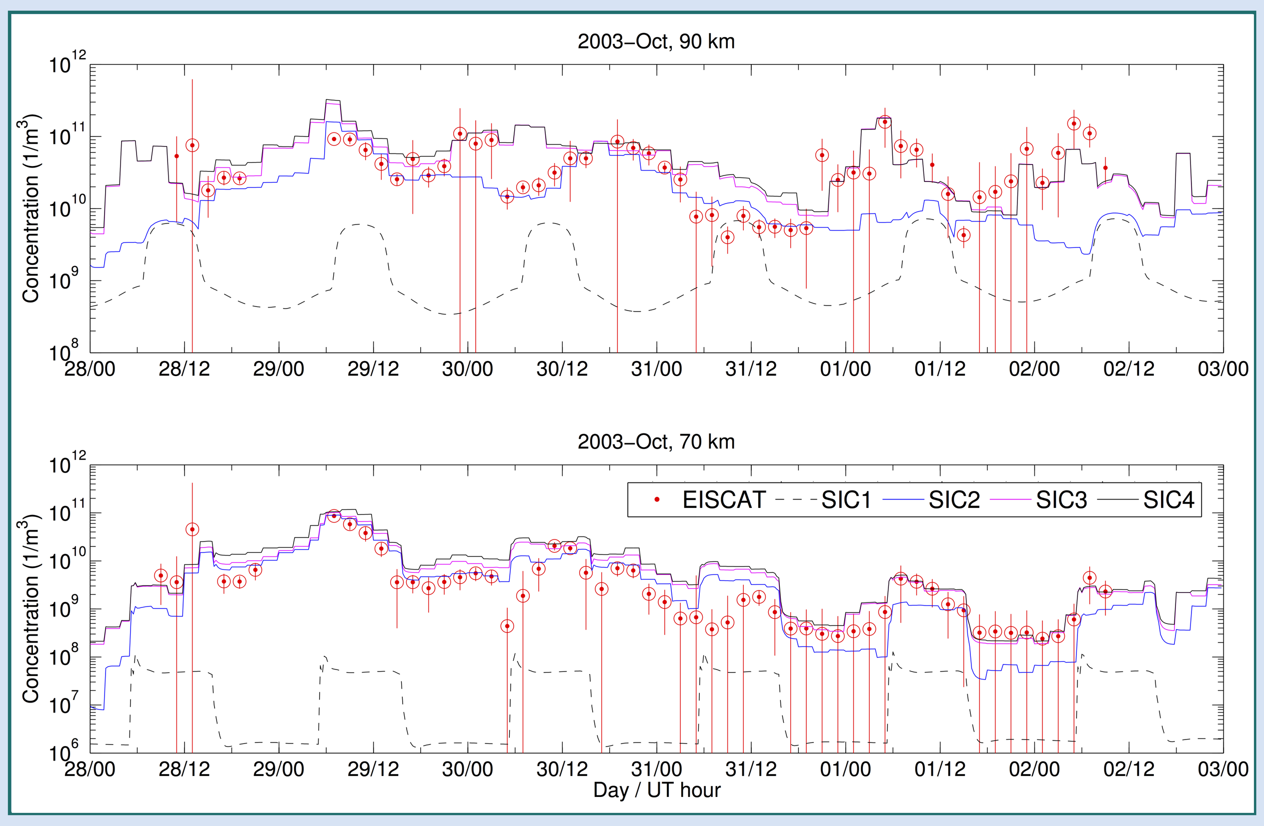

Fig 4. Electron concentrations from EISCAT and three SIC model runs at 90 km altitude.

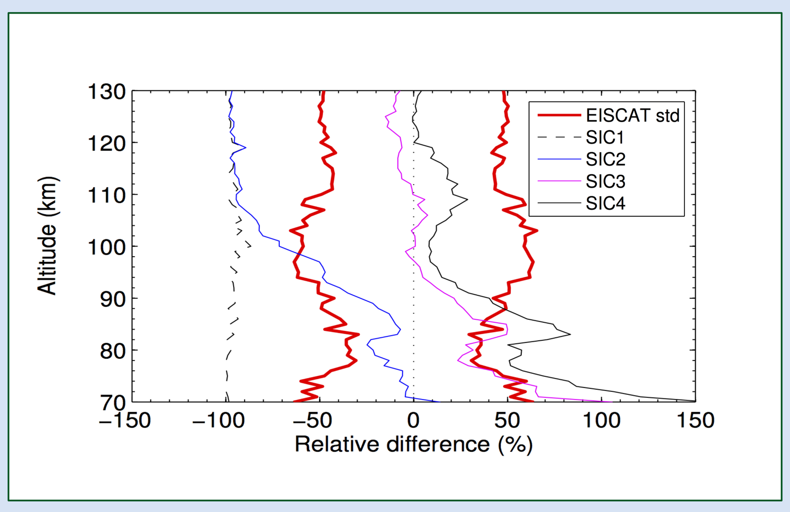

Fig 6. Relative difference of the four SIC runs to the median EISCAT electron concentration.

September 2005

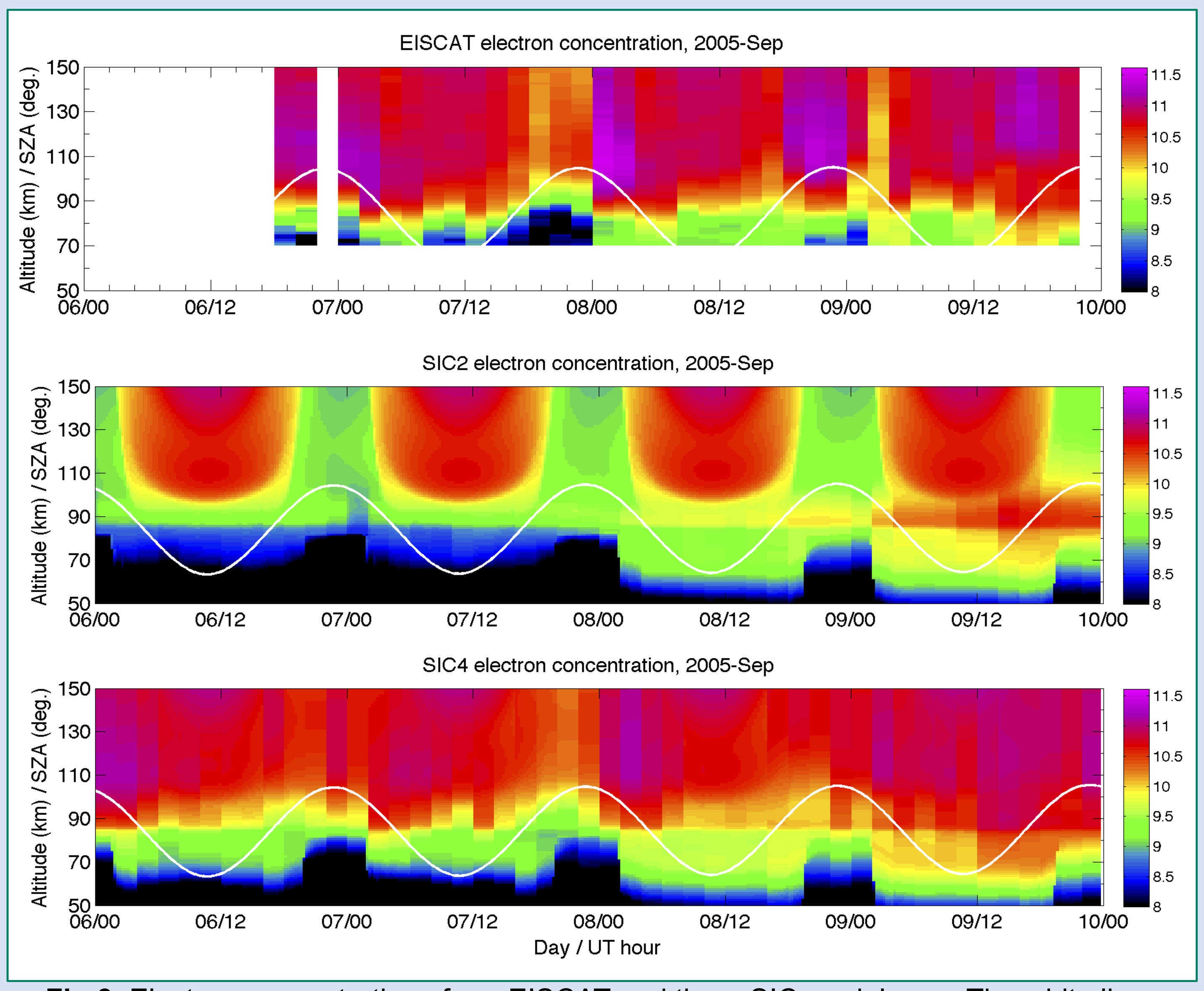

Fig 3. Electron concentrations from EISCAT and three SIC model runs. The white lines shows the diurnal cycle of the solar zenith angle at the EISCAT Tromsø location.

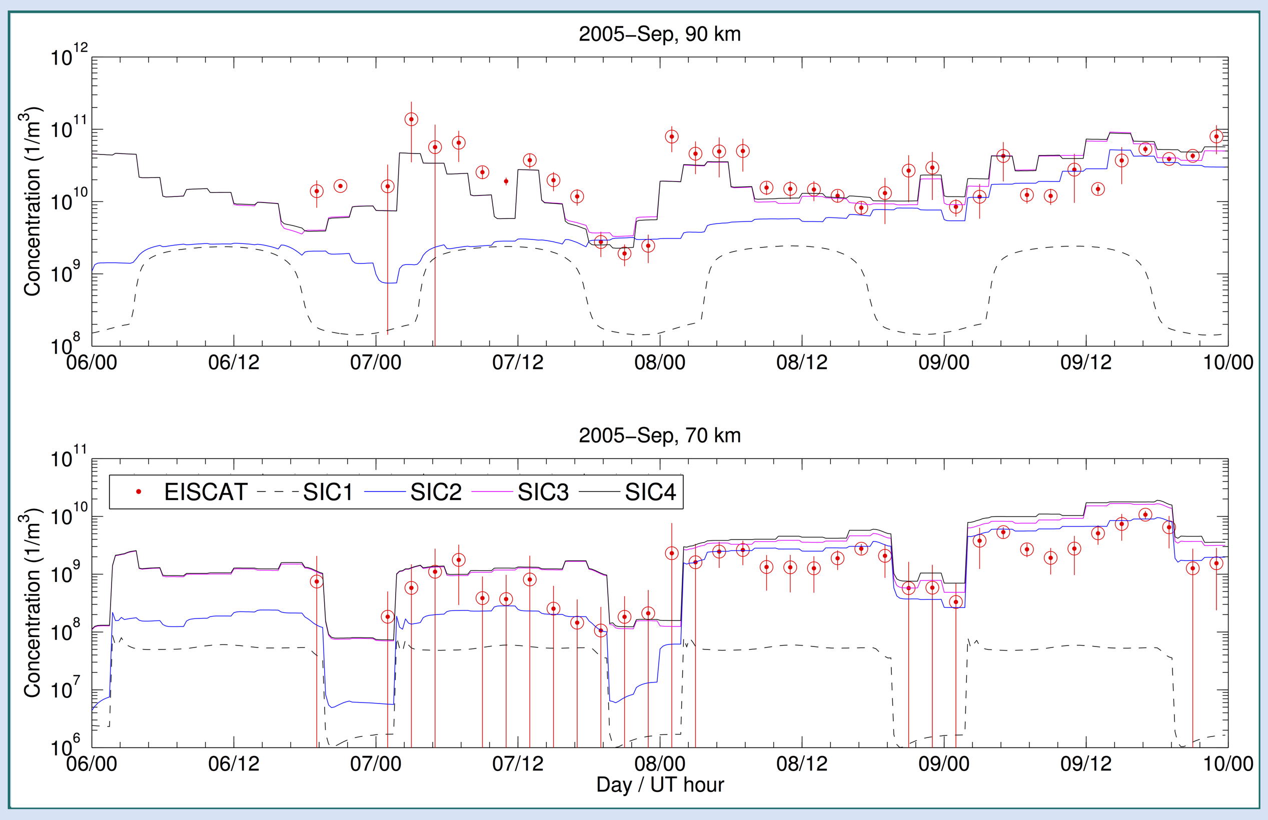

Fig 5. Electron concentrations from EISCAT and three SIC model runs at 90 km altitude.

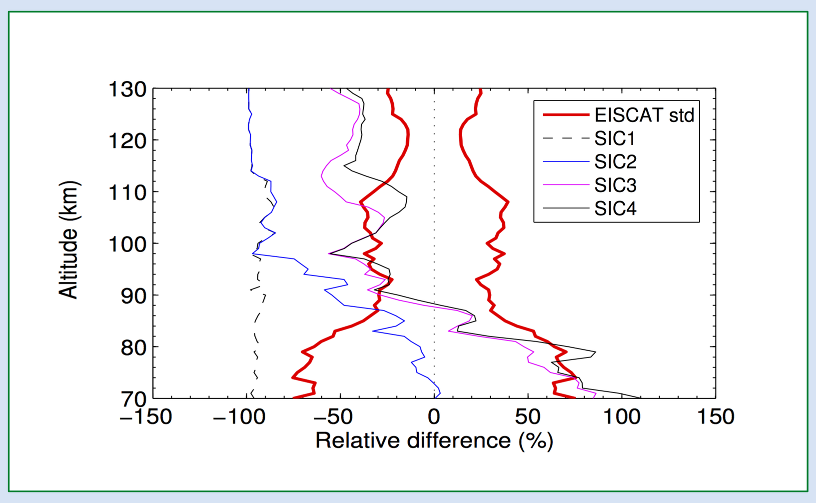

Fig 7. Relative difference of the four SIC runs to the median EISCAT electron concentration.

Conclusions

- Electron concentration of the upper mesosphere/lower thermosphere can be reasonably well modelled using AIMOS ionizationrates except at 70-90 km during strong SPE
- Electron precipitation is an important source of ionization: above 90 km even during strong solar proton forcing and also below mesopause when proton frocing is moderate or weak
- Above 90 km, the SIC-EISCAT difference can vary considerably from event to event
- Below 90 km, the AIMOS electron ionization seems to be overestimated during strong solar proton forcing

Reference

Verronen et al. 2015, Ann. Geophys.

Article

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