APPLICATION OF DUAL-FREQUENCY EISCAT MEASUREMENTS TO DETERMINE ION-NEUTRAL COLLISION FREQUENCIES WITH THE DIFFERENCE SPECTRUM METHOD

21ST INTERNATIONAL EISCAT SYMPOSIUM, TROMSØ, NORWAY

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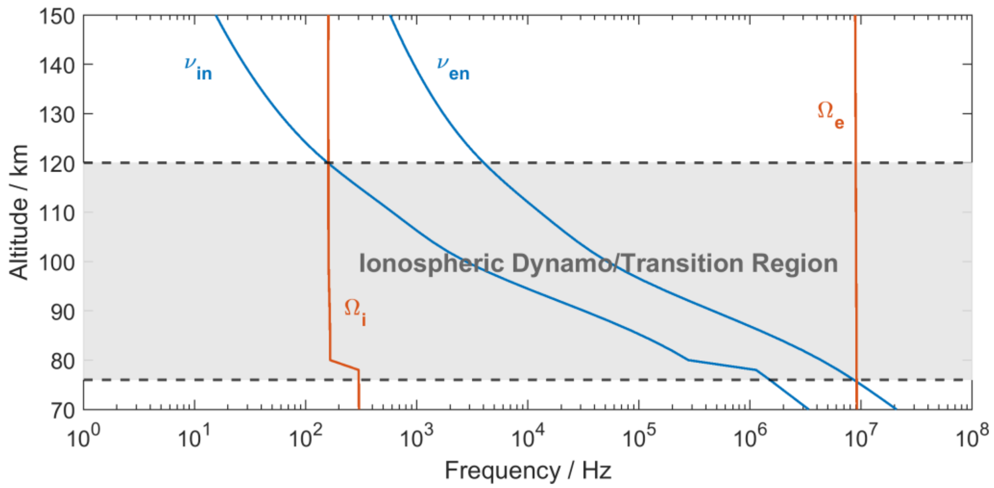
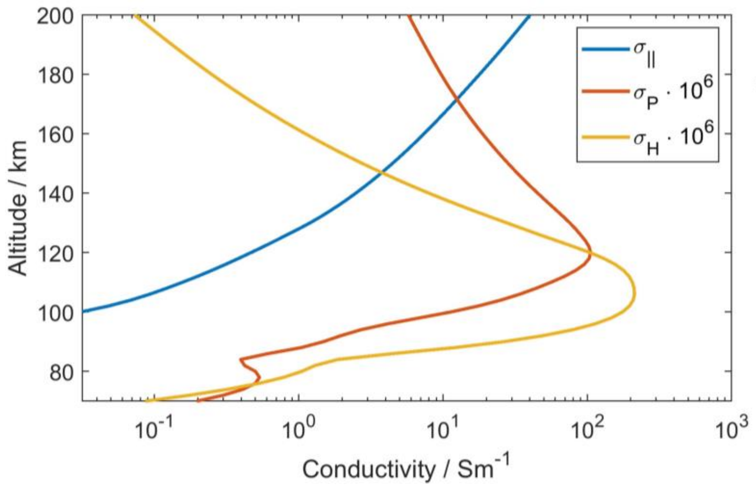
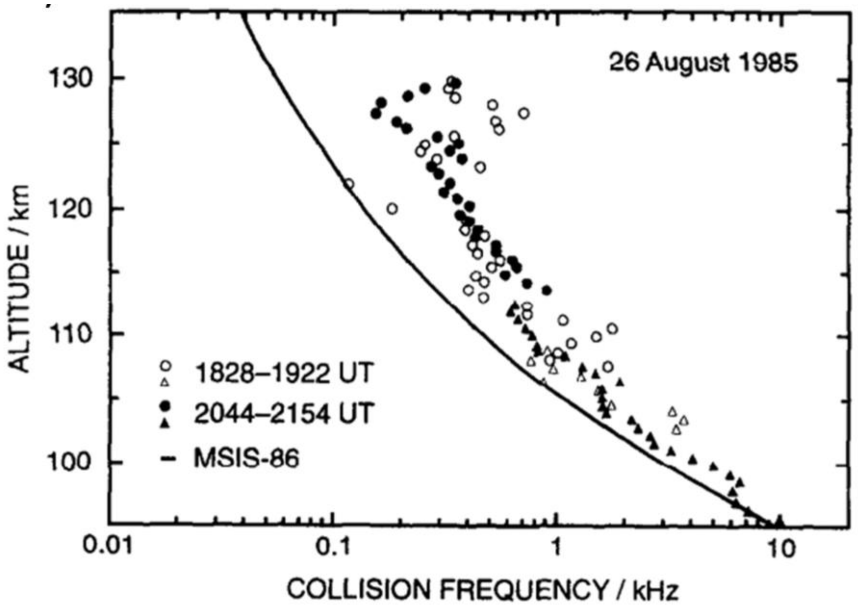
DLR

The role of the ion-neutral collision frequency





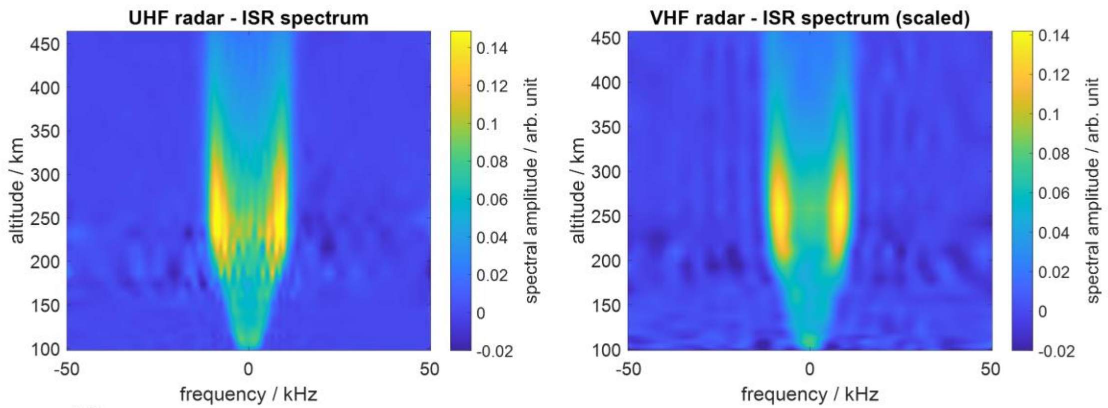


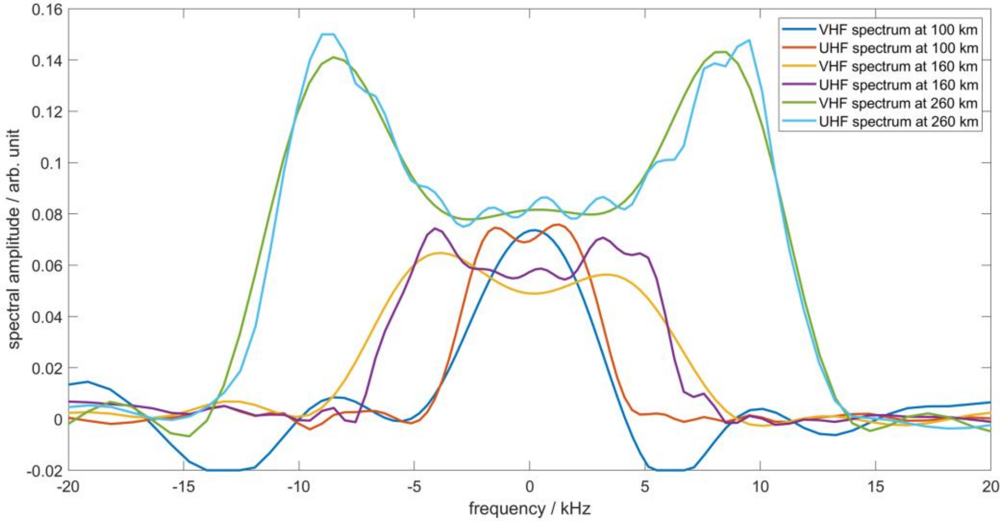
[Nygrén, *Adv. Space Res.*, **18**, 79-82, (1996).]

- ion-neutral collision frequency ν_{in} determines the transition from a collisional to a collision-less ionosphere
  ➔ determines maxima of ionospheric conductivities σ_P and σ_H
- ν_{in} impacts the ISR spectrum due to the ion adiabatic coefficient γ_i
  ➔ $\gamma_i T_i$ term is ambiguous, assumptions **($T_i = T_e$)** required
- ν_{in} determines the drag force between ion and neutral particles
  ➔ vertical ion momentum equation can be applied **($U_z = 0$, $E \gtrsim 20$ mV/m)**
- previous measurements indicated **considerable differences between climatology (MSIS) and measurement ν_{in} profiles** (Nygrén, 1996; Oyama *et al.*, 2012)

The difference spectrum method

[Grassmann, *J. Atmos. Terr. Phys.*, **55**, 573-576, (1993).]





[Günzkofer *et al.*, *Atm. Meas. Tech.*, **16**, 5897-5907, (2023).]

Measured difference function:

$$D(\omega_{UHF}+\delta\omega) = S(\omega_{UHF}+\delta\omega) - \beta\cdot\tilde{S}(\omega_{UHF}+\delta\omega)$$

β determined for $D(\omega_{UHF}+\delta\omega) = 0$ (F region)

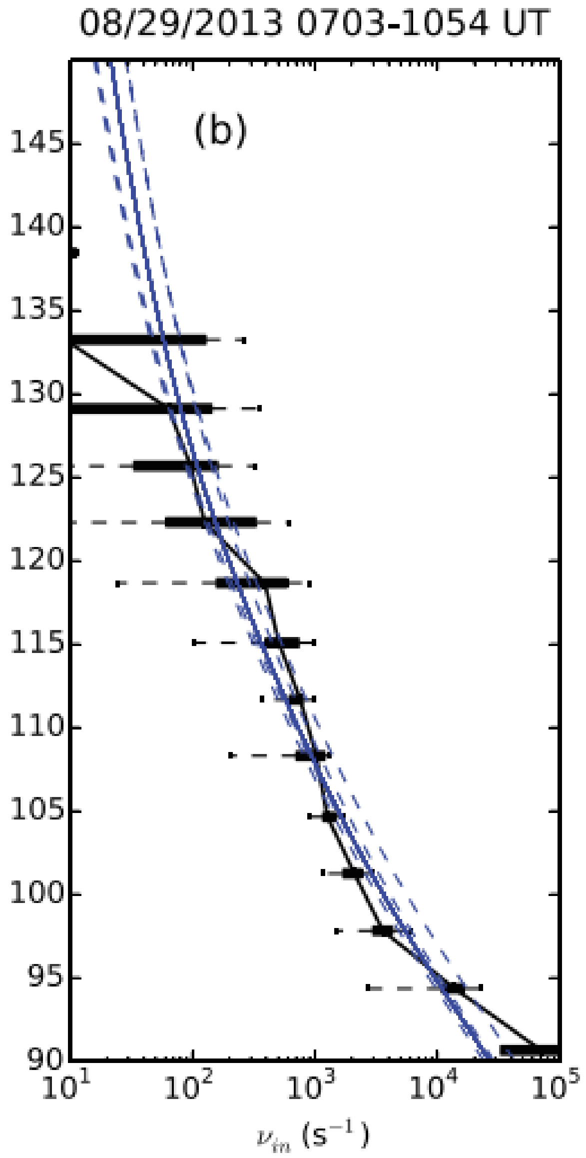
scaled VHF spectrum: $\zeta = \frac{\omega_{UHF}}{\omega_{VHF}} = 4.15$

$$\tilde{S}(\omega_{UHF}+\delta\omega) = \begin{cases} \zeta^2\cdot S(\omega_{VHF}+\delta\omega) \\ s(\omega_{UHF}+\delta\omega, \boldsymbol{\zeta^2}\cdot\boldsymbol{N_e}, T_e, T_i, \boldsymbol{\zeta}\cdot\boldsymbol{\nu_{in}}, v_i) \end{cases}$$

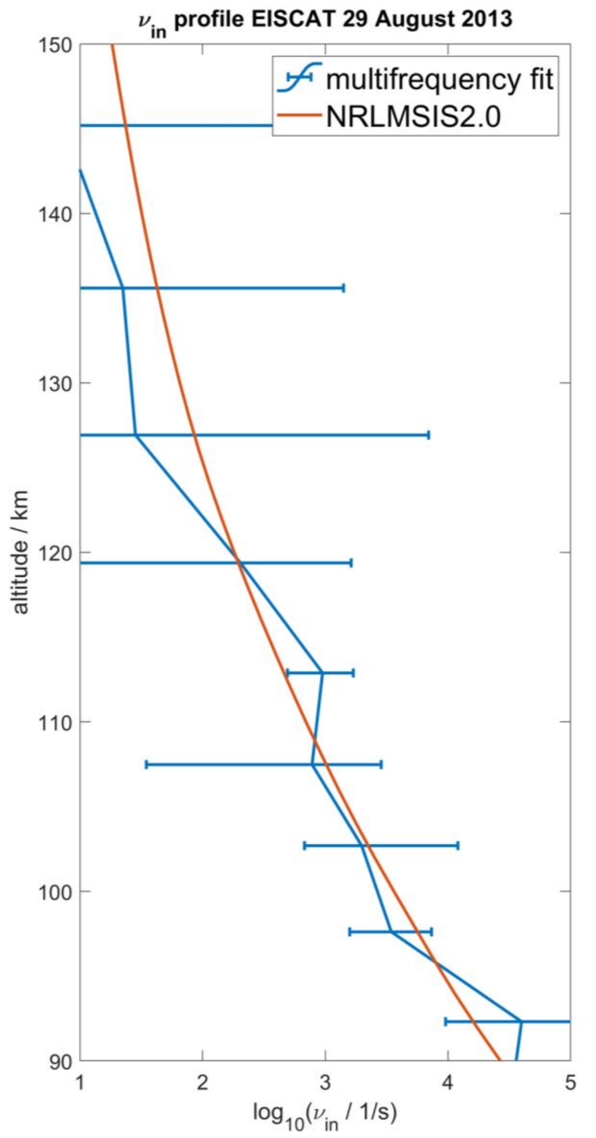
Theoretical difference function:

$$d(\omega_{UHF}+\delta\omega, N_e, T_e, T_i, \nu_{in}, v_i) = s(\omega_{UHF}+\delta\omega, N_e, T_e, T_i, \nu_{in}, v_i) - \beta\cdot s(\omega_{UHF}+\delta\omega, \boldsymbol{\zeta^2}\cdot\boldsymbol{N_e}, T_e, T_i, \boldsymbol{\zeta}\cdot\boldsymbol{\nu_{in}}, v_i)$$

Comparison to Nicolls et al., 2014



[Nicolls *et al.*, *Geophys. Res. Lett.*, **41**, 8147-8154, (2014).]



[Günzkofer *et al.*, *Atm. Meas. Tech.*, **16**, 5897-5907, (2023).]

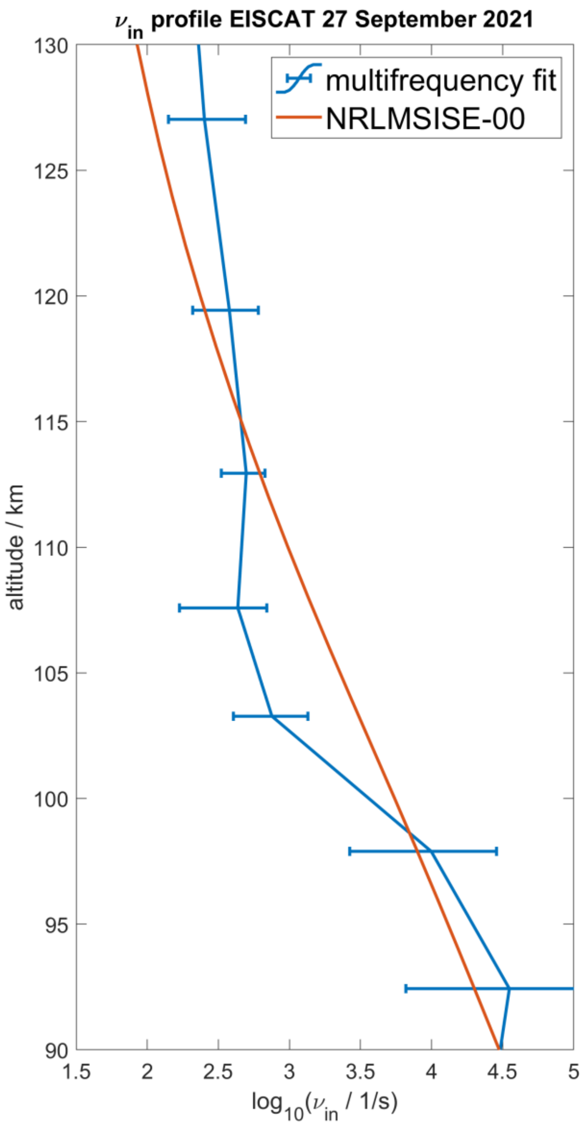
Nicolls *et al.*, 2014:

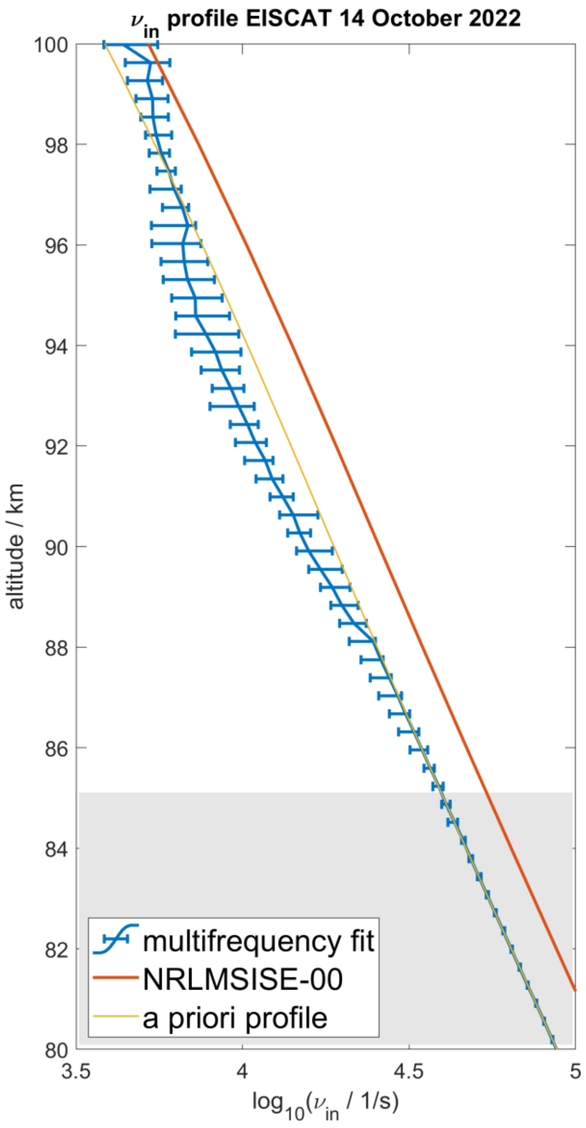
- dual-frequency EISCAT campaign from 29 August 2013 analyzed following Grassmann, 1993b
- simultaneous fit of both spectra with combined error function applied
  ➔ not possible with GUISDAP

Difference spectrum method:

- separate single-frequency analysis
  ➔ analysis possible with GUISDAP
- obtained median profile strongly resembles Nicolls *et al.*, 2014
  ➔ interquartile errorbars are considerably increased

Analyzed dual-frequency campaigns





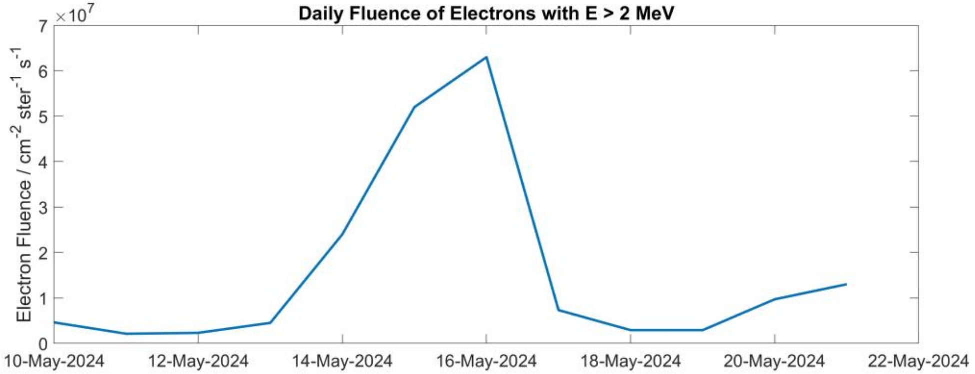
[Günzkofer *et al.*, *Atm. Meas. Tech.*, **16**, 5897-5907, (2023).]

DLR EISCAT dual-frequency campaigns:

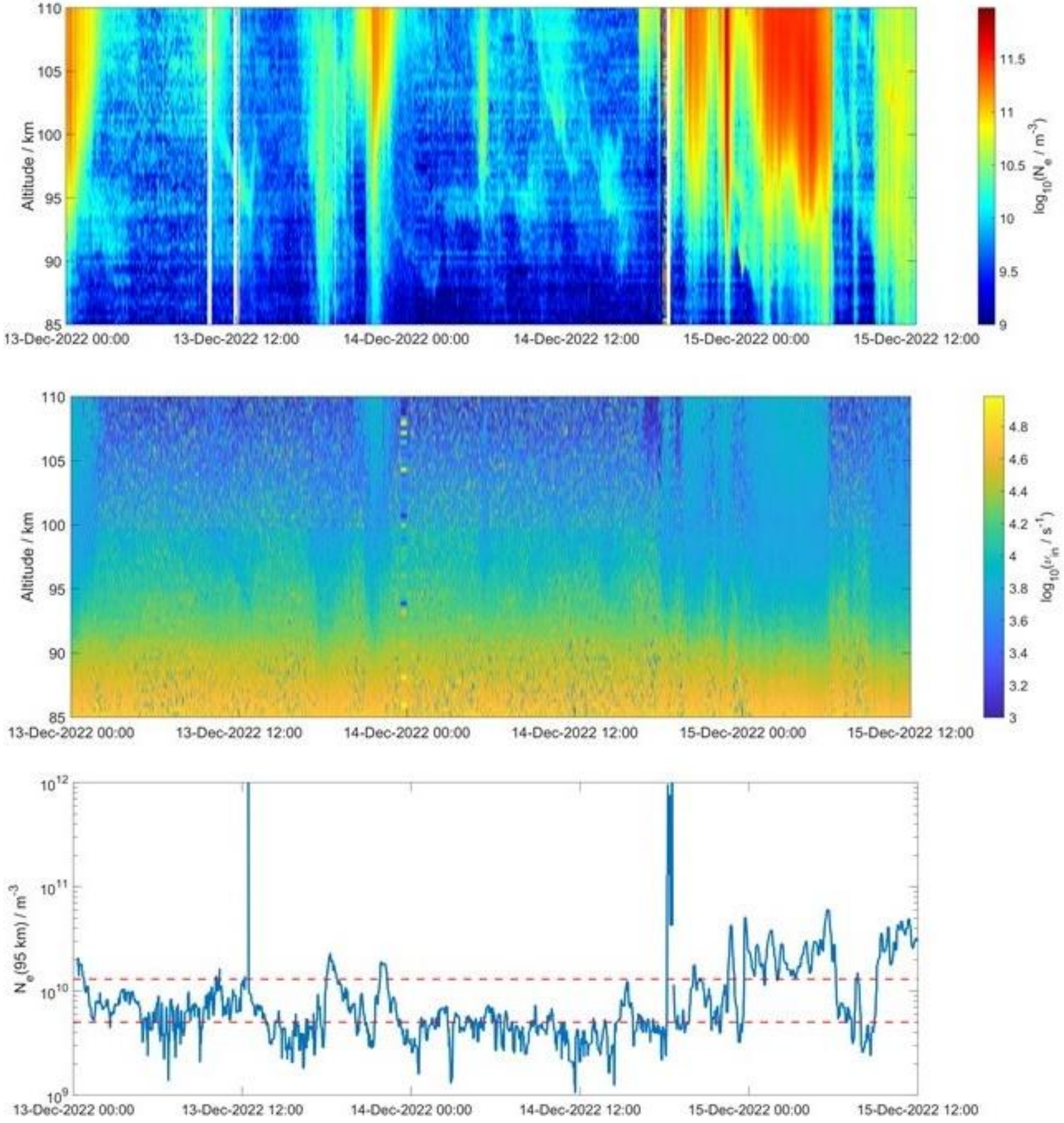
- 27 September 2021
  beata, el 45°, az 180°
- 14 October 2022
  manda zenith (CP 6)

Other EISCAT dual-frequency campaigns:

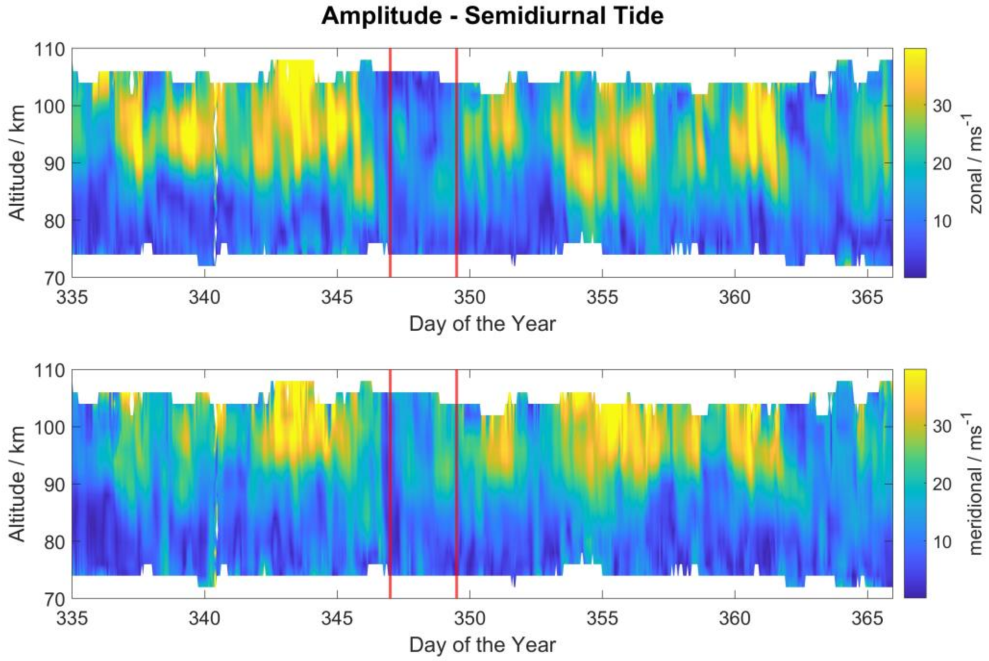
- Geminids 13-15 December 2022 (Sweden)
  manda zenith (CP 6)
- SEP Event 16 May 2024 (UK)
  manda zenith (CP 6)



Impact of particle precipitation – Geminids campaign 2022



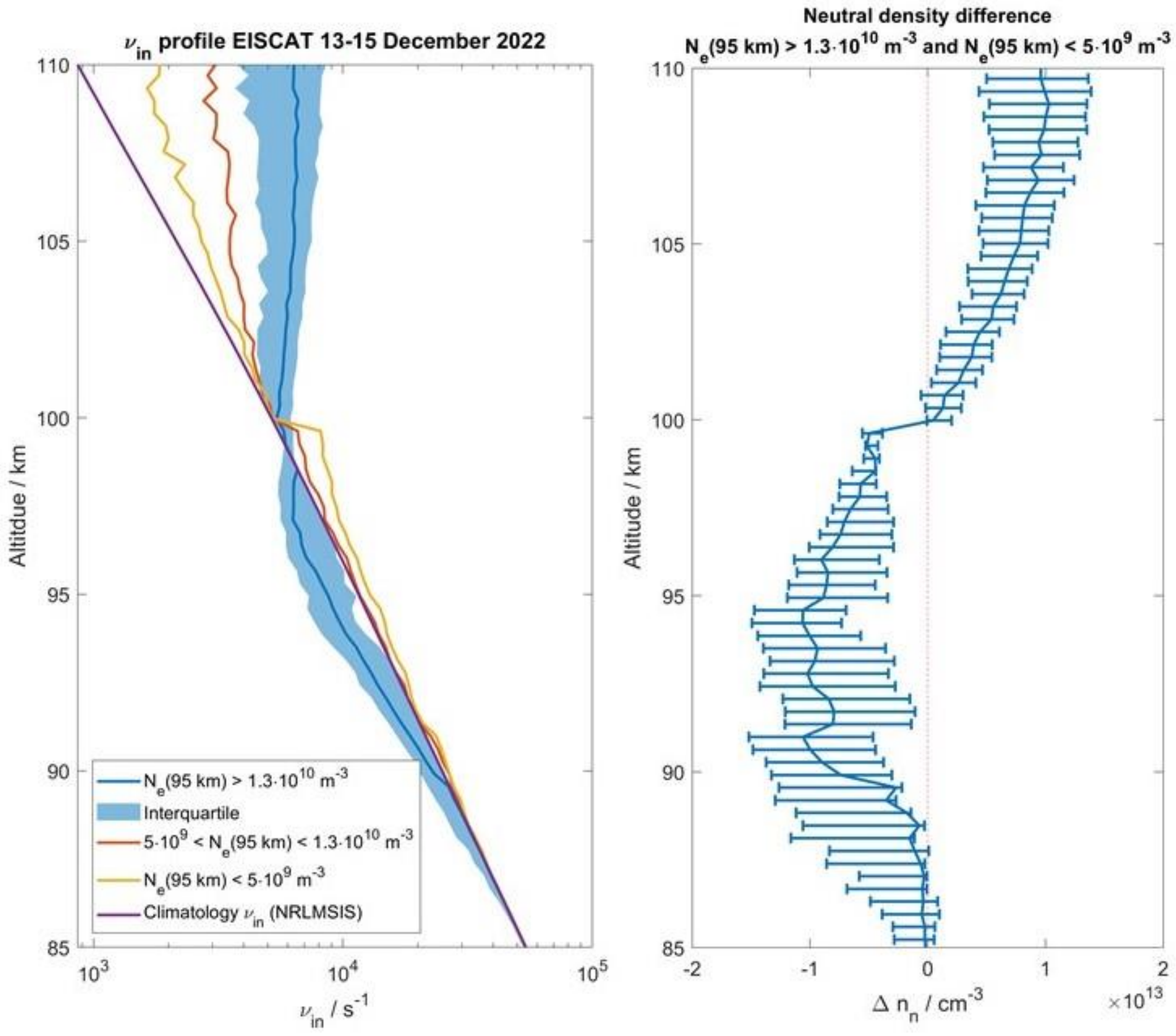
[Günzkofer *et al.*, in preparation]



[Günzkofer *et al.*, in preparation]

- original idea: investigate impact of atmospheric tides, **but**: significantly low tidal amplitudes during campaign
- strong particle precipitation detected
- electron density at 95 km altitude $N_e(95\ \mathrm{km})$ is applied as proxy for particle precipitation

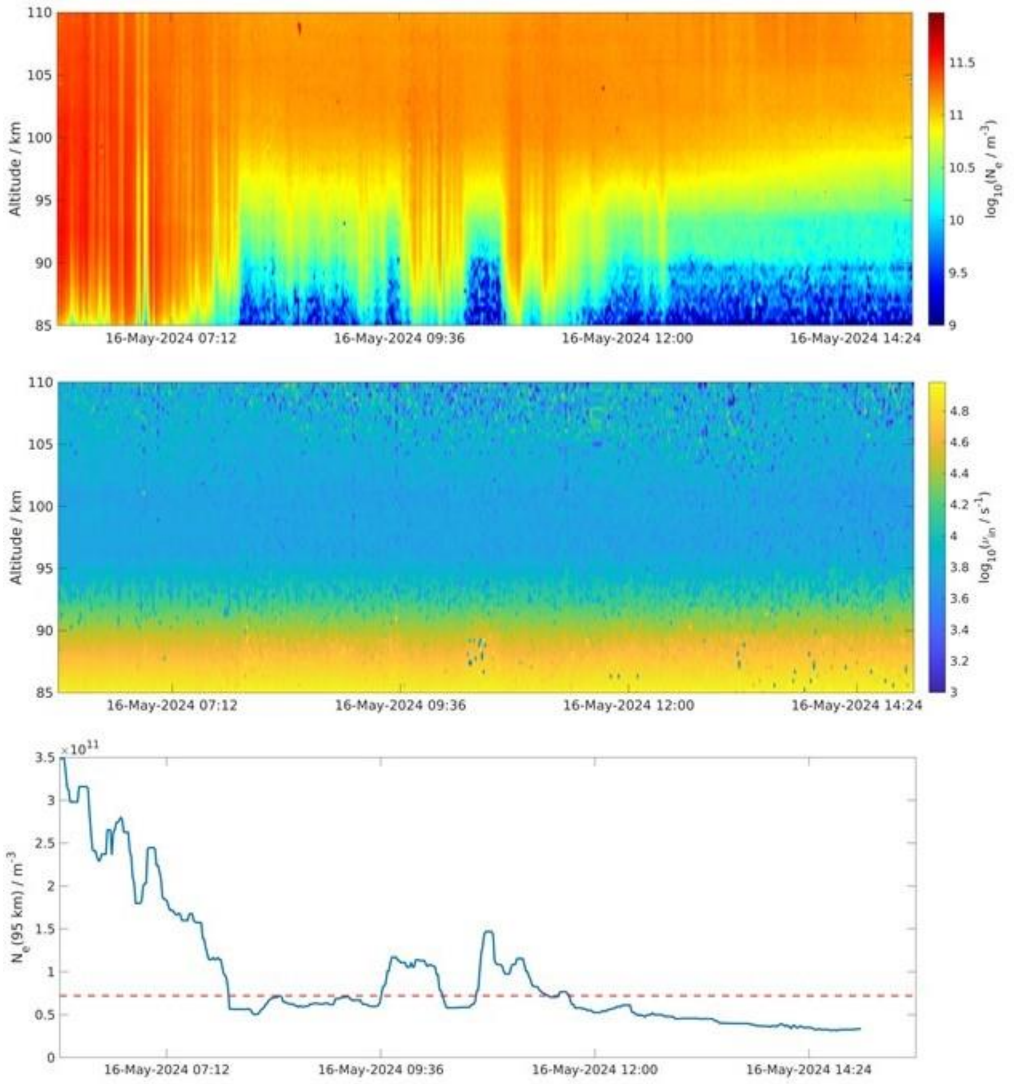
Impact of particle precipitation – neutral upwelling



[Günzkofer *et al.*, in preparation]

- collision frequency profiles binned for:
  1. $N_e(95\ km) < 5 \cdot 10^9\ \mathrm{m}^{-3}$
  2. $5 \cdot 10^9 < N_e(95\ km) < 1.3 \cdot 10^{10}\ \mathrm{m}^{-3}$
  3. $N_e(95\ km) > 1.3 \cdot 10^{10}\ \mathrm{m}^{-3}$
- neutral particle density profile calculated from collision frequency
- difference of neutral particle density profile for high and low particle precipitation calculated
- neutral atmosphere heating at 90 – 100 km altitude with consequent atmospheric upwelling

Impact of particle precipitation – SEP event May 16, 2024



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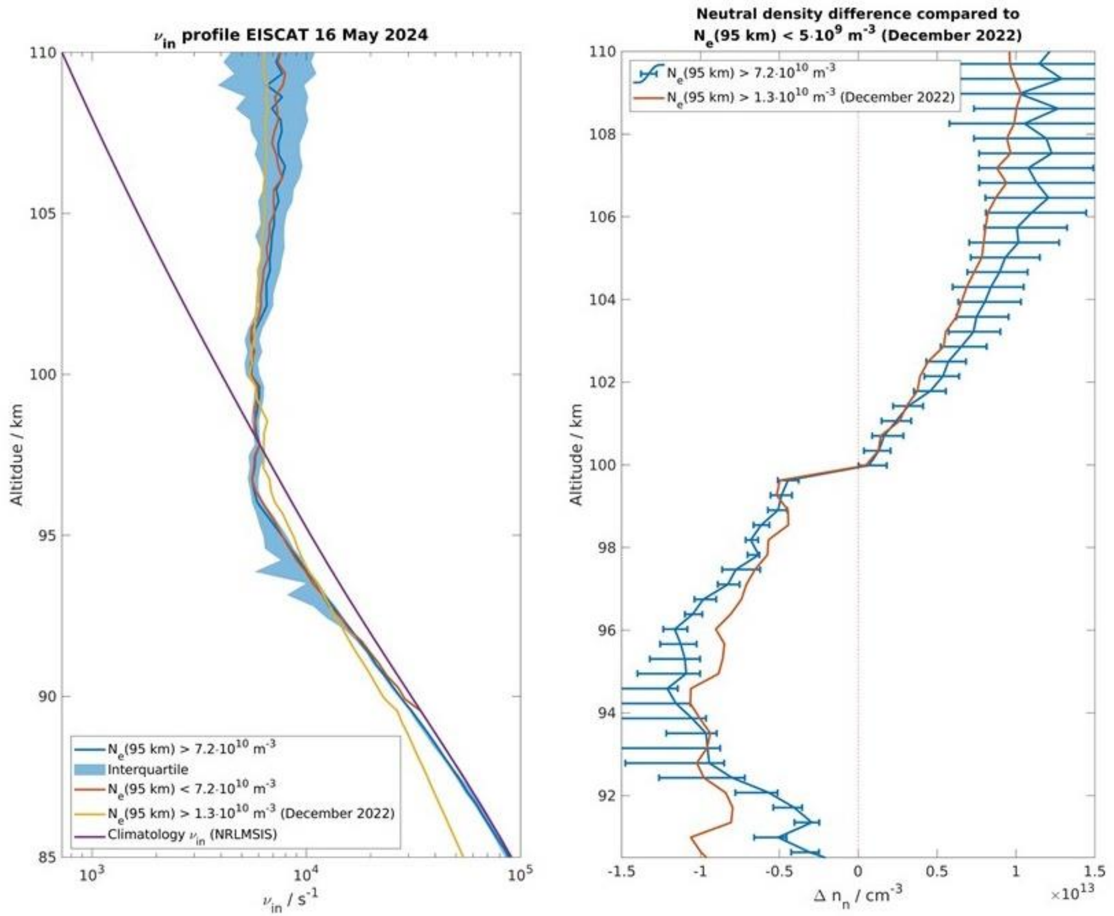

[Günzkofer *et al.*, in preparation]

➔ profiles similar to December 2022 measurement for $N_e(95\ km) > 1.3 \cdot 10^{10}\ \mathrm{m}^{-3}$

➔ neutral uplift becomes more pronounced for stronger particle precipitation

Summary

➔ dual-frequency ISR campaigns allow for ν_{in} measurements without restrictions on the state of the ionosphere

Difference spectrum method

Advantages	Disadvantages
based on standard ISR analysis software (GUISDAP)	increased uncertainties due to two-step analysis (1. single-frequency ISR fit, 2. difference spectrum fit)
easily adaptable for different radar modes	β parameter required to compensate technical differences of the two radars

➔ investigation of the neutral atmosphere in the MLT region possible since $n_n \sim \nu_{in}$

➔ ionospheric conductivities and currents are strongly impacted by the collision frequency which therefore have a direct impact on the space weather

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References:
Günzkofer *et al.*, *Atm. Meas. Tech.*, **16**, 5897-5907, (2023).
Nicolls *et al*., *Geophys. Res. Lett.*, **41**, 8147-8154, (2014).
Oyama et *al.*, *J. Geophys. Res.*, **117**, A05308, (2012).
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