Valiadtion of CMIP solar forcing input using EISCAT incoherent scatter radar, Rockets and Arase satellite measurements

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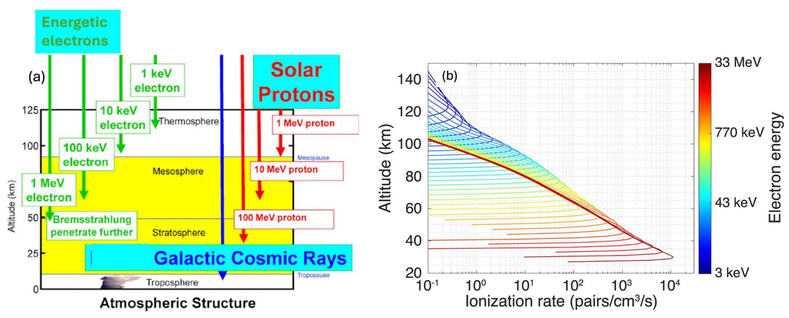
Introduction

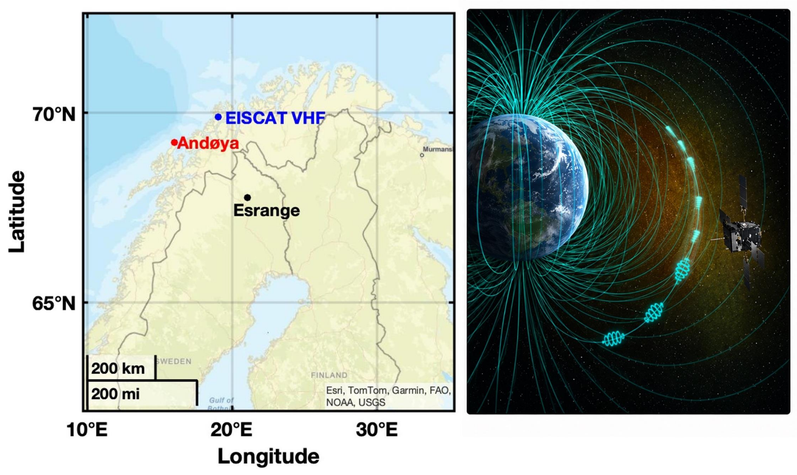
In polar latitudes, energetic electron precipitation (EEP; energies ~10s of keV to a few MeV) has a significant impact on the neutral composition and chemistry of the atmosphere in the mesosphere–lower thermosphere (~60–120 km) region. However, EEP is not accurately represented in solar forcing inputs used by Coupled Model Intercomparison Project (CMIP) climate models. This study presents a validation of EEP forcing in climate models using ground truth measurements of EEP.



Schematic representation of (a) energetic particle precipitation and the (b) Ionization rate profile by monoenergetic beams of precipitating electrons

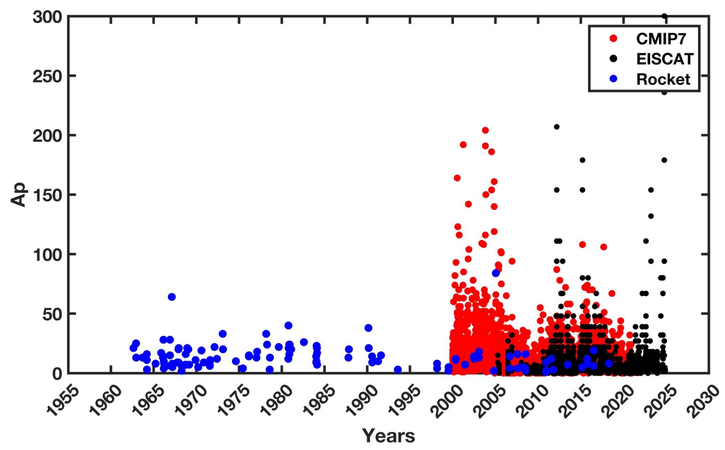
Data

- Rocket electron density (Ne) profile measurements from Andøya and Esrange between 1956 to 2018 (total 135 profiles).
- EISCAT VHF Ne profiles from manda vertical measurements between 2004 - 2020
- Whole Atmosphere Community Climate Model (WACCM) Ne profiles estimated using CMIP7 solar forcing input.
- Arase electron flux data within the 0-10° pitch angle bin (encompassing both precipitating and trapped electron populations) from MEPe, HEPL instruments with energies ranging from a few keV to ~1 MeV.



Location of ground-based measurements over northern Scandinavia (left) and an illustration of Arase satellite in the inner magnetosphere (right)

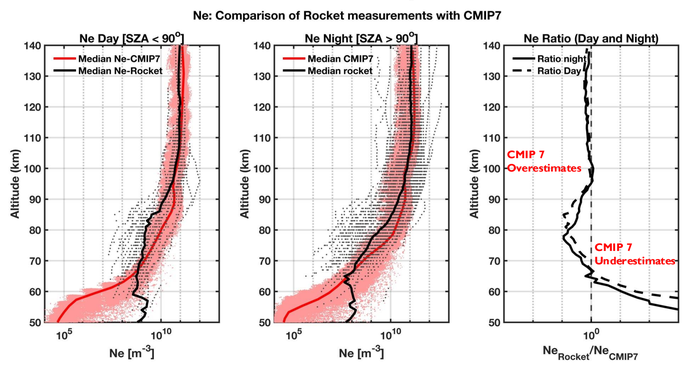
Data distribution



Ap distribution of the electron density profiles obtained from ground-based measurements (Rocket and EISCAT) and WACCM model with CMIP 7 forcing

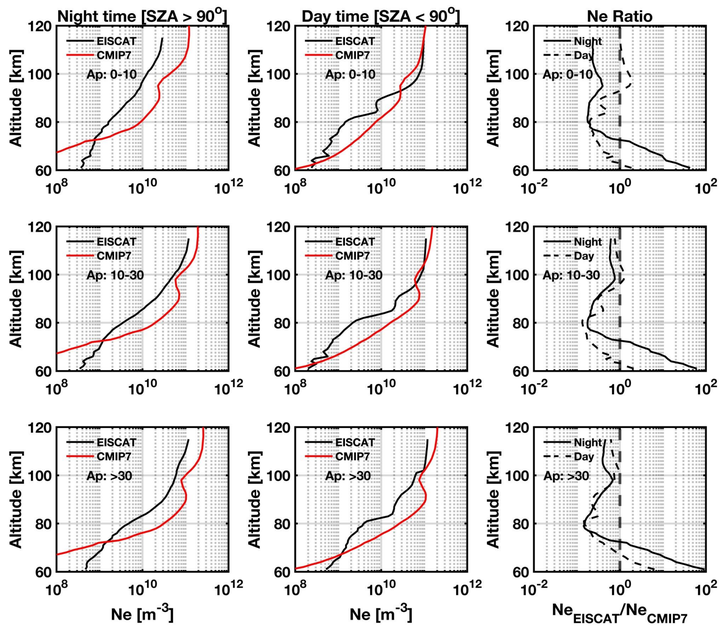
Result I: Validation of CMIP7 forcing using Rocket and EISCAT measurements

1. Rocket Vs CMIP 7 comparison



Comparison of Rocket Ne with WACCM-CMIP7 Ne, for day night solar zenith angles. The ratio of Ne rocket to model shows the altitudes where CMIP7 is under or over estimating the solar forcing.

2. EISCAT Vs CMIP 7 comparison

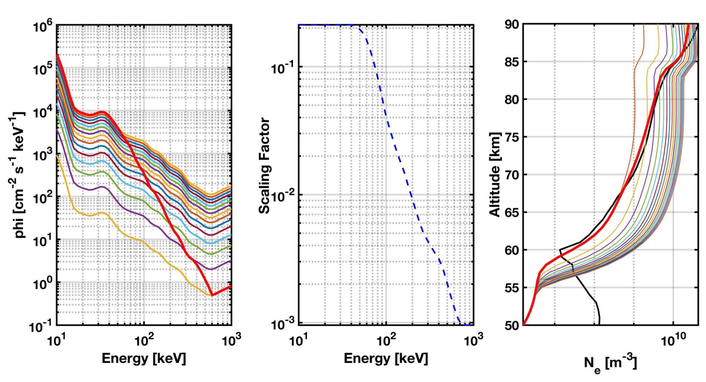


Comparison of EISCAT Ne with WACCM-CMIP7 Ne, for day night solar zenith angles and different Ap bins along with ratios. The ratio of Ne EISCAT to model shows the altitudes where CMIP7 is under or over estimating the solar forcing

Result II: Arase - EISCAT conjunction study to estimate EEP flux

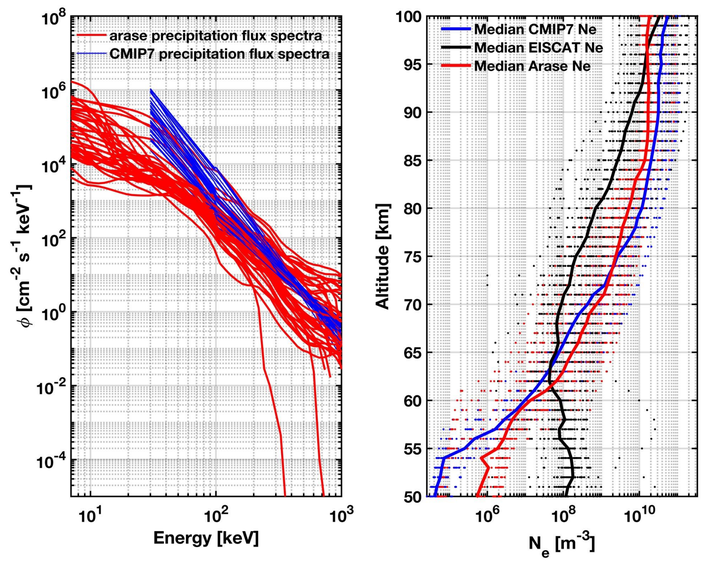
1. EEP estimates from Arase measurements

- The Aarse flux spectrum in the 0°-10° pitch angle bin is scaled by applying a range of loss cone scaling factors to get hypothetical loss cone flux spectra (left panel).
- Arase scaled spectra are converted to corresponding Ne profiles (right panel) by using the forward model, as (i) Arase flux to ionization rates (Q) using Fang et. al [2010], parameterization, and (ii) Q to Ne profiles using a Sodankylä Ion and Neutral chemistry (SIC) model.
- An energy dependent scaling factor (middle panel) is then derived by minimizing the difference between the modelled and EISCAT (black) Ne profiles (shown in right panel).
- The estimated energy dependent scaling factor when applied to Arase measurements give EEP flux spectrum (red line, left panel) that produces Ne (red line right panel) which match best to EISCAT measurements (black line right panel).
- An average energy dependent scaling factor is derived for EISCAT location using all Arase-EISCAT conjunction data.



Arase EEP spectrum (red line, left panel) estimated after applying the energy dependent scaling factor (middle panel) which gives Ne profile (red line, right panel) that match best to EISCAT Ne (black line , right panel)

2. Validation of CMIP7 forcing using Arase satellite measurements



Comparison of Arase derived (left) EEP flux spectra and (right) electron density profiles with CMIP7 results. EISCAT Ne measurements during Arase-EISCAT conjunction intervals are shown on the right.

Conclusions

- Electron density measurements over northern Scandinavia obtained from **Rocket and EISCAT** shows that the current **CMIP7 model overestimates** the **solar forcing inputs in the altitudes 65 - 100 km.**
- Arase EEP results are work in progress. These preliminary findings demonstrate close quantitative agreement with the CMIP7 input spectra.
- These results suggest that Arase derived precipitation spectra can be used to investigate global EEP characteristics in similar L shells.

References

Fang, X., C. E. Randall, D. Lummerzheim,W. Wang, G. Lu, S. C. Solomon, and R. A. Frahm (2010), Parameterization of monoenergetic electron impact ionization, GRL., 37, L22106, doi:10.1029/2010GL045406

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