Thermal Plasma Measurements: Laboratory Experiment and In Situ Ionospheric Data

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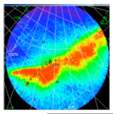


UiO Camera, Ny-Alesund

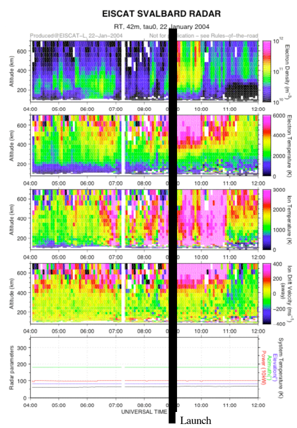
SERSIO

Svalbard EISCAT Rocket Study of Ion Outflows

MISSION: Investigate ion outflows (increased ion velocity above 500km in conjunction with enhanced electron or ion temperatures) in dayside cusp/cleft region with in situ particle and wave instrumentation while simultaneously observing event with incoherent scatter radar.

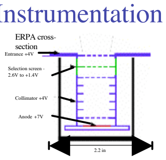
Unusually broad altitude coverage of thermal particle population

ESR

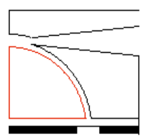


42m field-aligned radar located in Longyearbyen used to detect outward ion flow

Particle Instrumentation



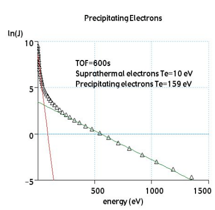
Retarding Potential Analyzer designed to measure ionospheric thermal electrons. Range 0-3 eV.

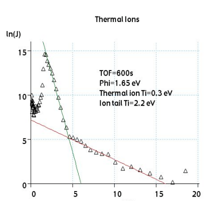


Hemispherical electrostatic analyzers designed to measure ionospheric thermal ions (Range 0.1-20 eV) and precipitating electrons (5-16000 eV)

Interpreting Data

Given the ACS failure, we have limited directional information. Efforts have been concentrated on energy information and temperature extraction.

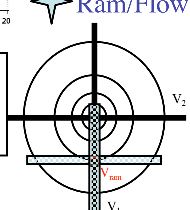




Temperatures of the suprathermal and precipitating populations are obtained from the hemispherical electron detector data.

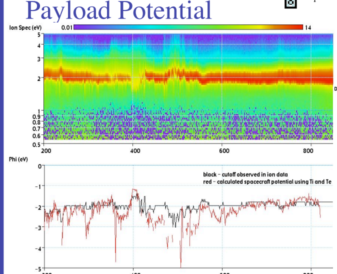
Ram/Flow Effects

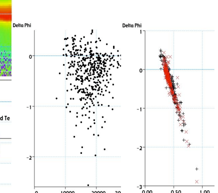
In addition to ion core temperatures, the thermal ion data can also be used to extract payload potential. **The effects of payload ram must be included for temperature accuracy.**



Note the difference in distance between the energy contours if the collimating detector aperture is parallel or perpendicular to the ram direction. The worst case is the perpendicular aperture, giving an ion temperature that is too high.

Payload Potential





- Spacecraft potential was calculated using T_e and T_i from the thermal particle data.
- Difference between calculated and observed ϕ_c is T_e not density dependent.
- Thus we need to include effects of plasma flow in our calculation of ϕ_{sc}.

$$eV = -kT_e \ln \frac{\sqrt{\frac{kT_e}{2\pi m_e}}}{\sqrt{\frac{kT_i}{2\pi m_i} + \frac{v^2}{16}} + \frac{i_{ph}}{4ne} - \frac{I}{4\pi r^2 ne}}$$

Fahleson, 1967

Abstract

Hemispherical electrostatic analyzers are a common choice for particle instrumentation suites in satellite and sounding rocket programs. We use an extension of this design to measure the thermal particle population in the ionosphere down to about 0.1eV. This paper will present our efforts to interpret the thermal data in the presence of a potential sheath around a sounding rocket payload. The dayside cusp/cleft auroral data used is that from the SERSIO (Svalbard EISCAT Rocket Study of Ion Outflows) rocket, which was launched January 22, 2004 at 8:57UT from Ny-Alesund, Svalbard, Norway. The performance of our thermal ion detectors will be presented as well as our recent work with density extraction and temperature measurements. Comparison of our data with EISCAT observations compels us to further investigate our detector response. Fabrication has begun on a calibration/testing facility that will quantify our thermal ion analyzer performance. A microwave source will be used to create a low energy neutral plasma (tenths of an eV range). The design and proposed energy/sheath testing will be outlined. This work will further influence SERSIO data analysis and thermal particle detection - a key element to understanding bulk processes in the ionosphere.

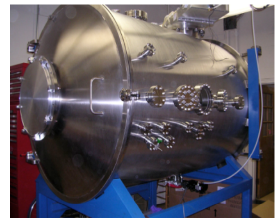
Conclusions

- SERSIO sees structured regions of high T_i (1.5 eV) which we interpret as the beginning of SCIFER-like BBELF TIA events
- Quantification of in situ measurements of the thermal particle population requires careful measurement of flows and potentials around spacecraft.
- As part of this continuing effort, we are developing a thermal plasma source and calibration facility.

ELEPHANT

Experimental Low Energy Plasma for Hemispherical Analyzer Nominal Testing

Laboratory Experiment



Thermal particle calibration facility currently under construction.

Designed to utilize a microwave plasma source for charging and float studies.

Microwave Plasma Source Bowles, Duncan, Walker, Amatucci, Antoniades, 1996	
Electrons	**Nitrogen Ions**
$E_e \sim 0.5$ eV	$E_i \sim 0.05$ eV
$V_{the} \sim 3E5$ m/s	$V_{thi} \sim 450$ m/s
$\omega_{ce} \sim 1E7$ Hz	$\omega_{ci} \sim 370$ Hz
$\rho_e \sim 0.03$ m	$\rho_i \sim 1.2$ m
Plasma Density 10^4-10^6 1/cc B = Earth Field $\lambda_D \sim 0.5$ cm - 5 cm	

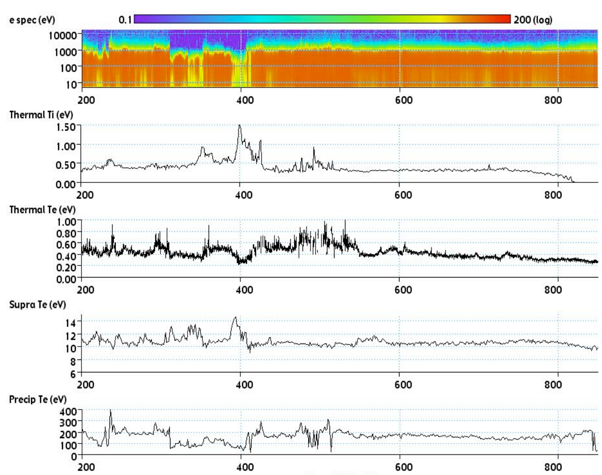
Application

- Chamber Dimensions dxl - 1.2x1.5 m (24-30 λ_D)
- Base Pressure ~10E-8 Torr
- Operational Pressure ~10E-5 Torr
- Neutral $\lambda_{mfp} \sim 10$m, $\nu_{in} \sim 45$ Hz
- Ions unmagnetized
- Electrons magnetized

Areas of Investigation

- Quantify thermal particle detector response and identify lowest detectable energy
- Investigate sheath formation variables such as neutral density and particle energy
- Study the shape and structure of the potential in the boundary regions between plasma and detectors with and without forced bias.
- How does this inform the SERSIO thermal particle data analysis?

In Situ Data and All Sky Camera



TOF=410s

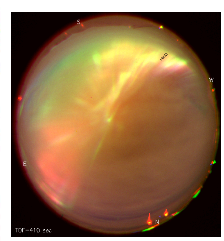


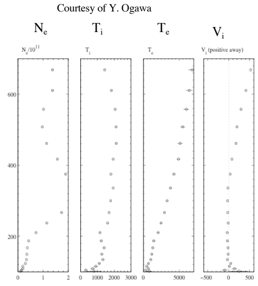
Image courtesy of Huigen Yang and Zejun Hu, Polar Research Institute of China

- Data indicate ~50km columns of high T_i at high altitude ~700km
- High T_i events are not T_e dependent.
- Largest T_i event associated with hole in the electron precipitation
- High T_i events coincident with wave enhancements seen by Cornell
- Background ~2eV ion tail seen throughout the flight
- Lower altitude signature of BBELF conics seen in SCIFER mission

In Situ Data and EISCAT Radar Data

ESR Line Profiles

Courtesy of Y. Ogawa



In Situ Data