Diurnal and seasonal variability of D-region electron densities at 69° N

R. Latteck[1], W. Singer[1], M. Friedrich[2], M. Wakabayashi[3]

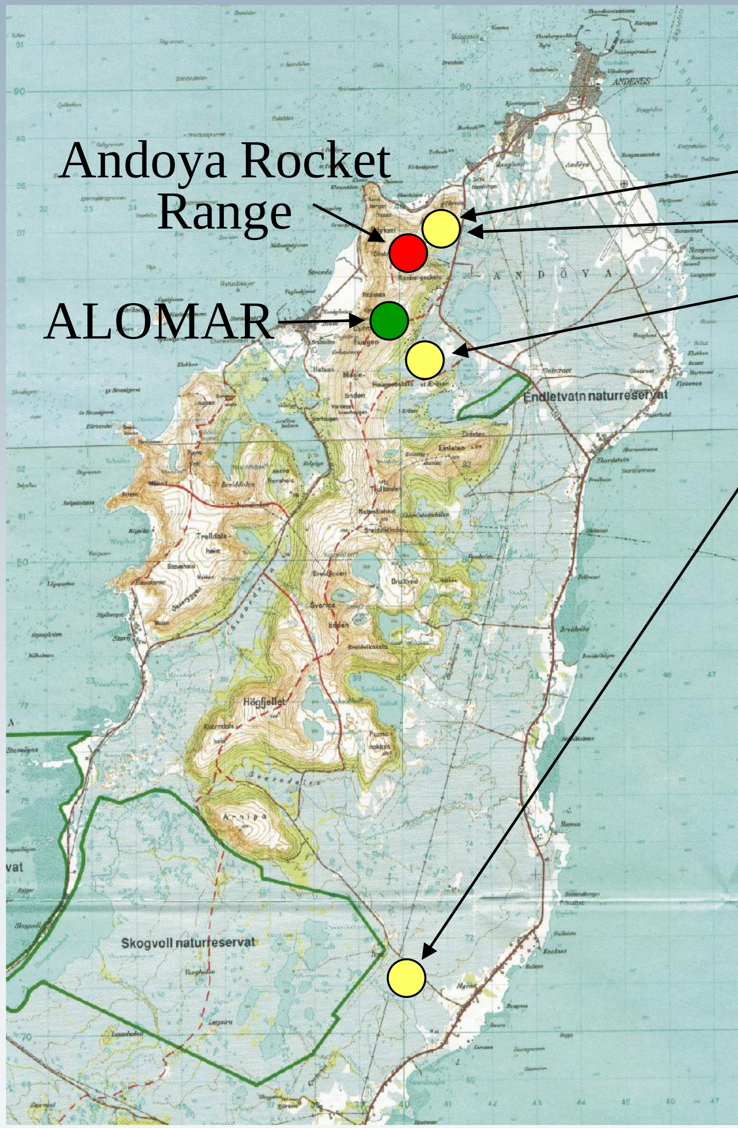
[1] Leibniz Institute of Atmospheric Physics, Kühlungsborn, Germany
[2] Technical University of Graz, Graz, Austria
[3] Niihama National College of Technology, Niihama-shi, Ehime, Japan

Outline

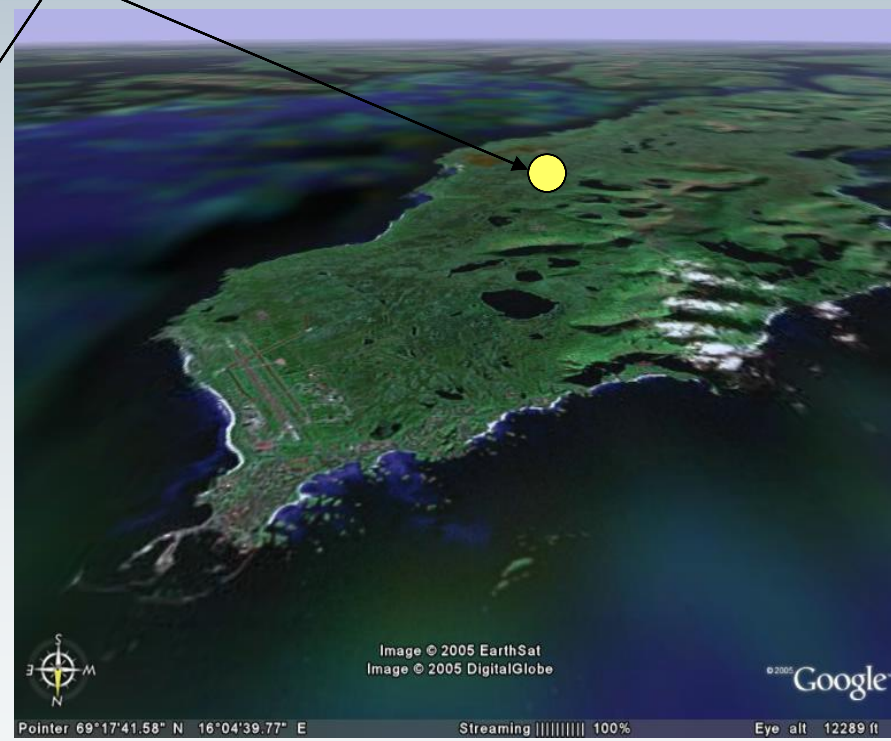
1. Electron density estimation at 3 MHz
   - Instrumentation
   - Differential absorption/phase measurements
2. Comparison of insitu and ground-based observations
3. Diurnal and seasonal variation of electron density at 69°N
4. Electron densities during
   - solar proton events
   - Polar Mesosphere Summer Echoes (PMSE)
5. Summary and outlook

1. Electron density estimation at 3 MHz

Radar experiments, Lidar observations, and rocket soundings on Andøya island

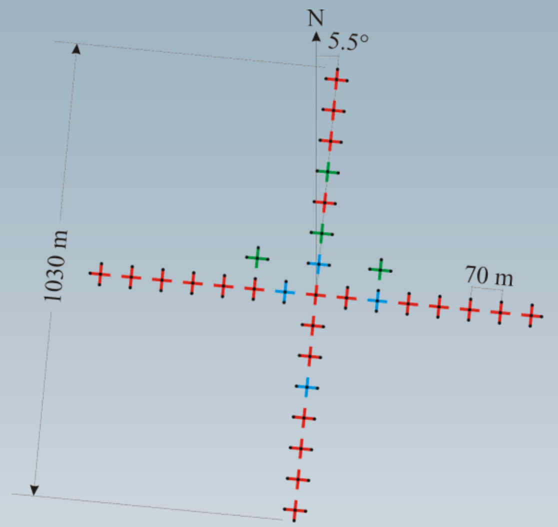


- ALWIN VHF radar (53.5 MHz)
- SKiYMET meteor radar (32.5 MHz)
- ALOMAR MF radar (1.98 MHz)
- **Saura MF radar (3.17 MHz)**



1. Electron density estimation at 3 MHz

The 3-MHz Doppler radar at Saura on Andøya island (69°N)



- narrow beam transmitting/receiving antenna
  - Mills Cross
  - 29 crossed dipoles
  - arm length of 1030m
  - HPFW = 6.6°
- each dipole is fed by a 2-kW transceiver unit with individual phase control
- total peak power of 116 kW
- ➢ high flexibility in beam forming and pointing
- left/right circular polarisation, changing of polarisation from pulse to pulse
- best range resolution of 1 km

1. Electron density estimation at 3 MHz
Differential absorption/phase measurements

- Electron densities from differential absorption (DAE) & differential phase (DPE) measurements using QL- approximation of generalised refractive index (Sen and Wyller)

- Amplitude ratio of backscattered signals of ordinary (O) and extra-ordinary (X) mode is related to the ratio of reflection coefficients *R* and the differential absorption

$$\frac{A_x}{A_o} = \frac{R_x}{R_o} \exp\left\{ -2 \int_0^h (k_x - k_o) dh \right\}$$

- DAE: electron number density *N(h)* is obtained from amplitude ratios at adjacent heights
- DPE: electron density *N(h)* is obtained from phase differences at adjacent heights

DAE: $$N(h) = \frac{\Delta(\ln R_X / R_O) - \Delta(\ln A_X / A_O)}{2(\chi_X - \chi_O)\Delta h}$$

DPE: $$N(h) = \frac{\Delta(\phi_{RX} - \phi_{RO}) - \Delta(\phi_X - \phi_O)}{2(\mu_X - \mu_O)\Delta h}$$

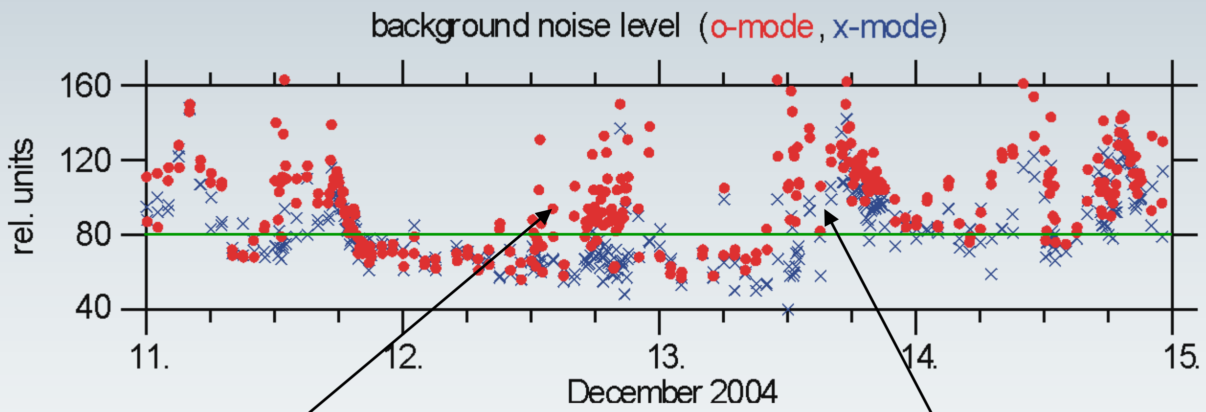
- A collision frequency is required
- pressure *p(h)* from model atmosphere (e.g. CIRA) or from pressure climatology after insitu falling sphere measurements at Andenes

$$\nu_m(h) = K \cdot p(h) \quad with \;\; K = 6.4 \cdot 10^{-5} m^2 s^{-2} N^{-1}$$

1. Electron density estimation at 3 MHz

Standard scheduling of Saura MF radar measurements

- DAE and DPE measurements are combined with Doppler wind measurements
  - Experiment sequence:
    180 s electron density + 360 s Doppler wind (turbulence)
  - time resolution 9 (3) min
- Electron densities are given if the results of differential absorption and differential phase experiment are in agreement within a factor of **2**.
- Continuous observations since June 2004 (first May - August 2003)



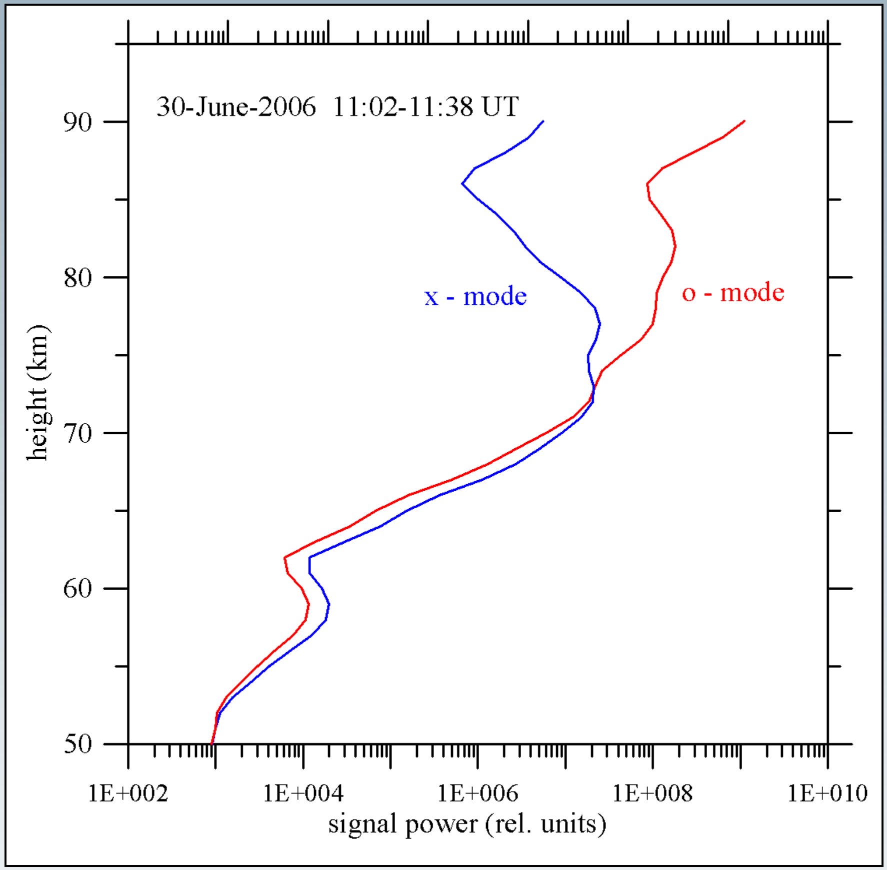
Background noise taken from altitudes 41-44 km

Enhanced background noise level due to external interference influences height coverage. (long distance HF propagation during polar night)

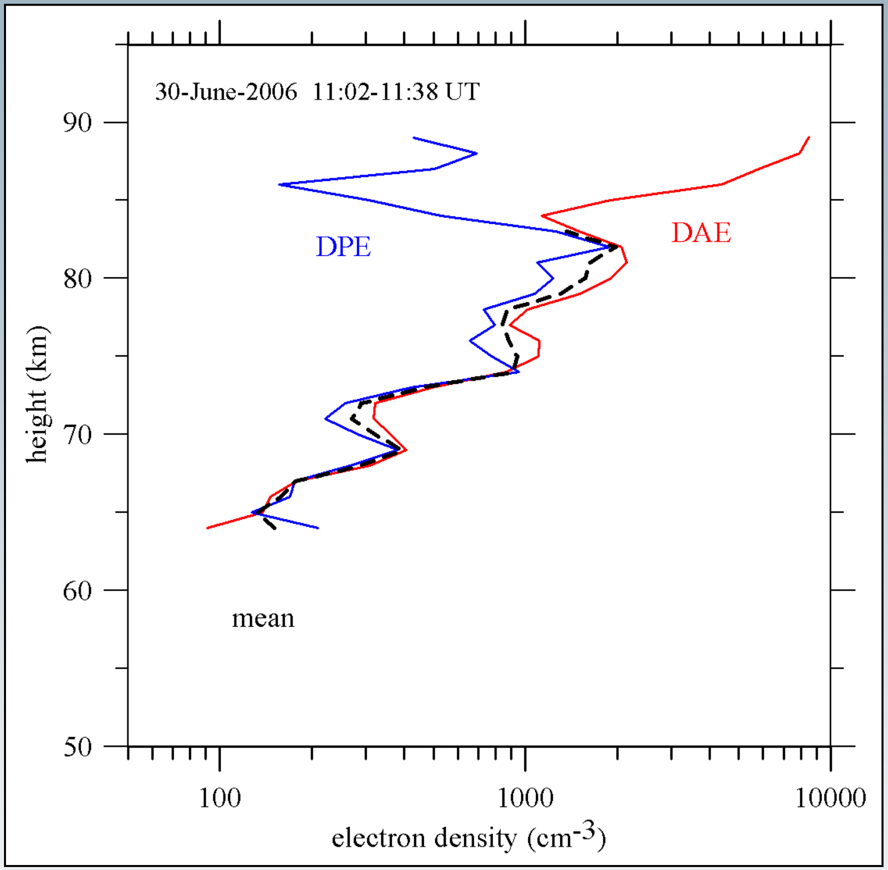
O-mode enhancement only long distance propagation

O-mode & X-mode enhancement nearby transmitter

1. Electron density estimation at 3 MHz
by differential absorption (DAE)/phase (DPE) measurements



Echo power of O- and X-mode



Electron densities from DAE and DPE experiments

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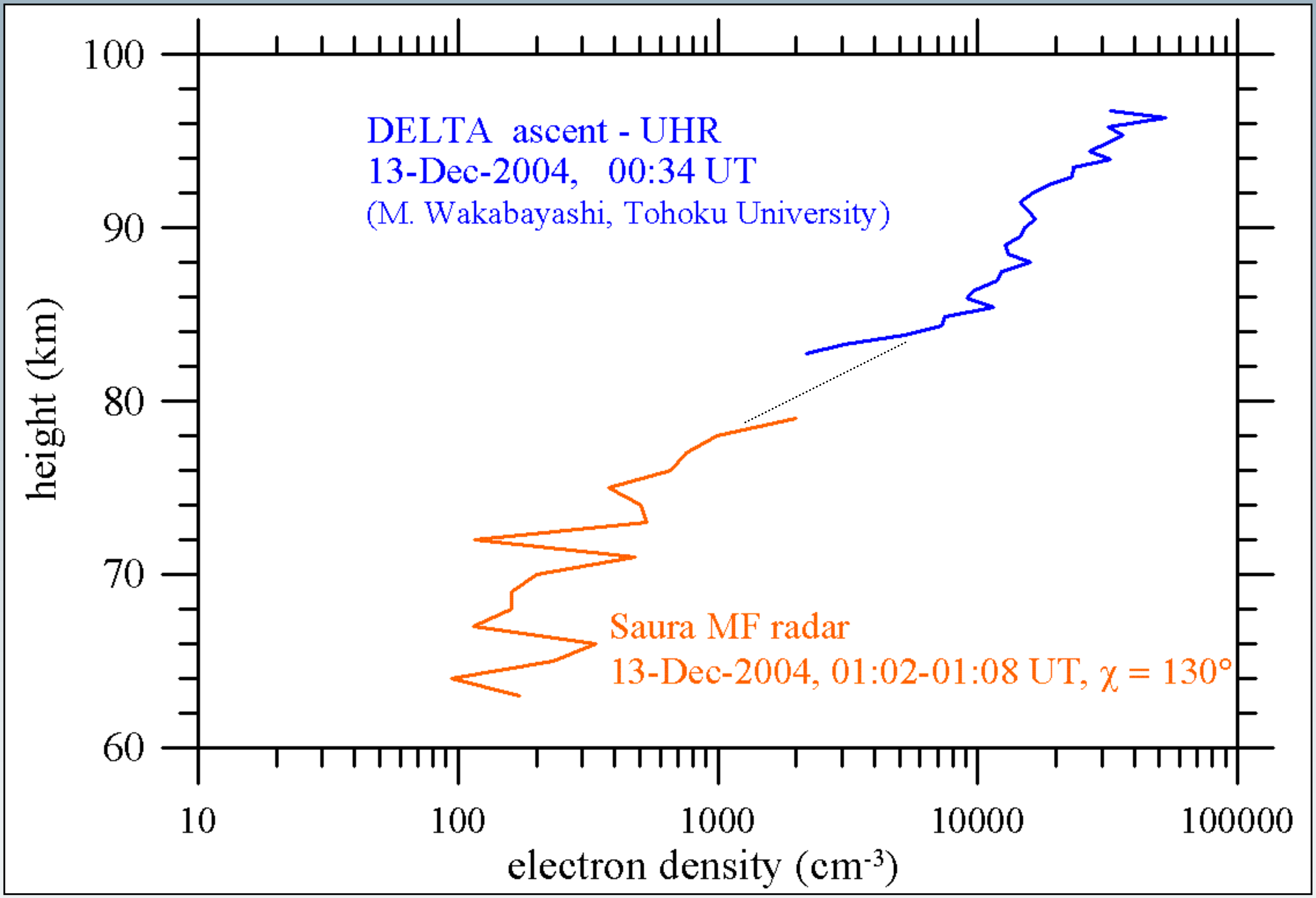
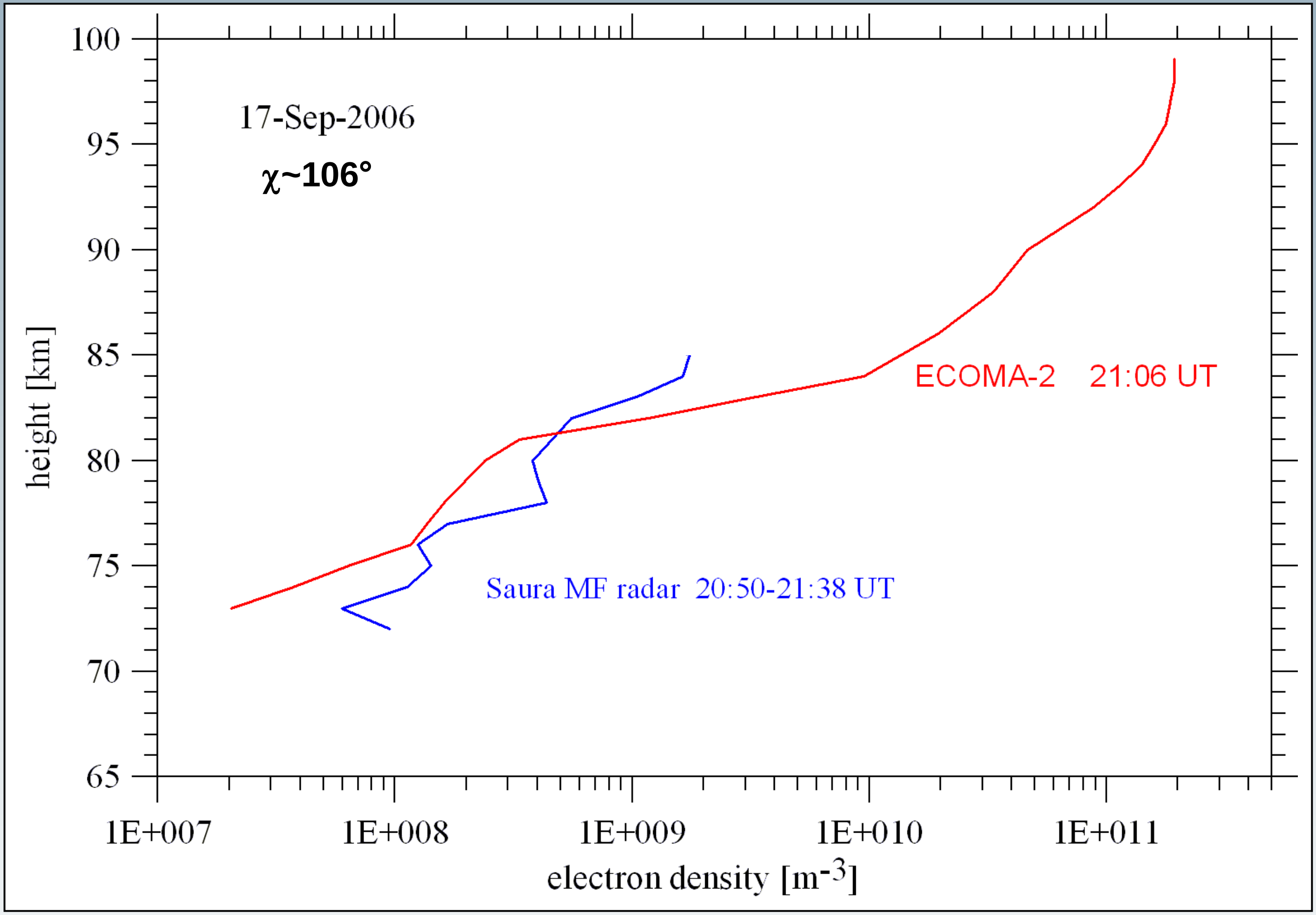
2. **Comparison of insitu and ground-based observations**
3. Diurnal and seasonal variation of electron density at 69°N
4. Electron densities during solar proton events
5. Summary and outlook

2. Comparison of insitu and ground-based observations



Electron density profiles from radar observations and rocket-borne measurements of the Upper Hybrid Resonance (UHR) frequency at Andenes during the Japanese DELTA campaign 2004

2. Comparison of insitu and ground-based observations



Electron densities after rocket-borne radiowave propagation measurements and MF radar observations during the ECOMA campaign in September 2006

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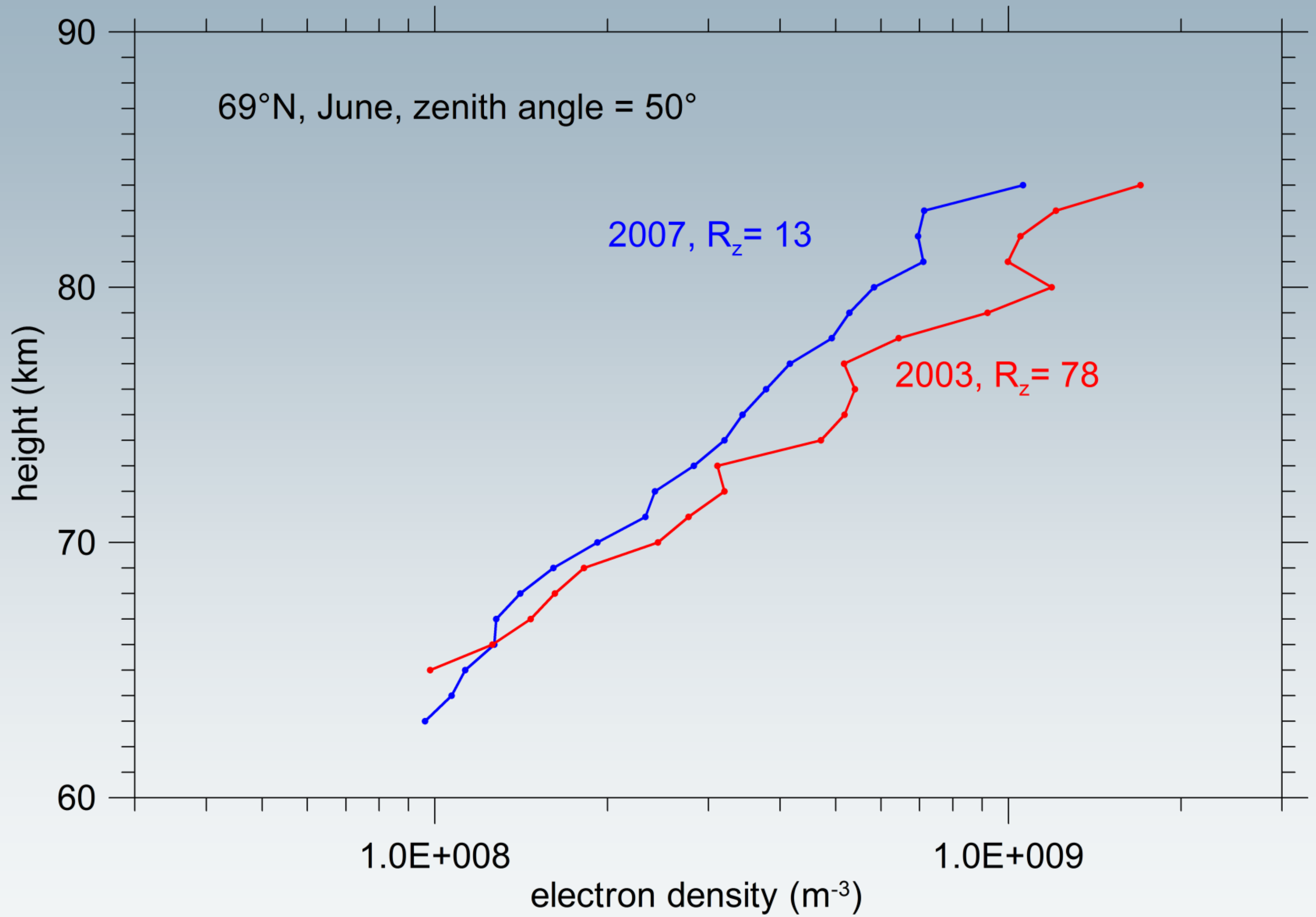
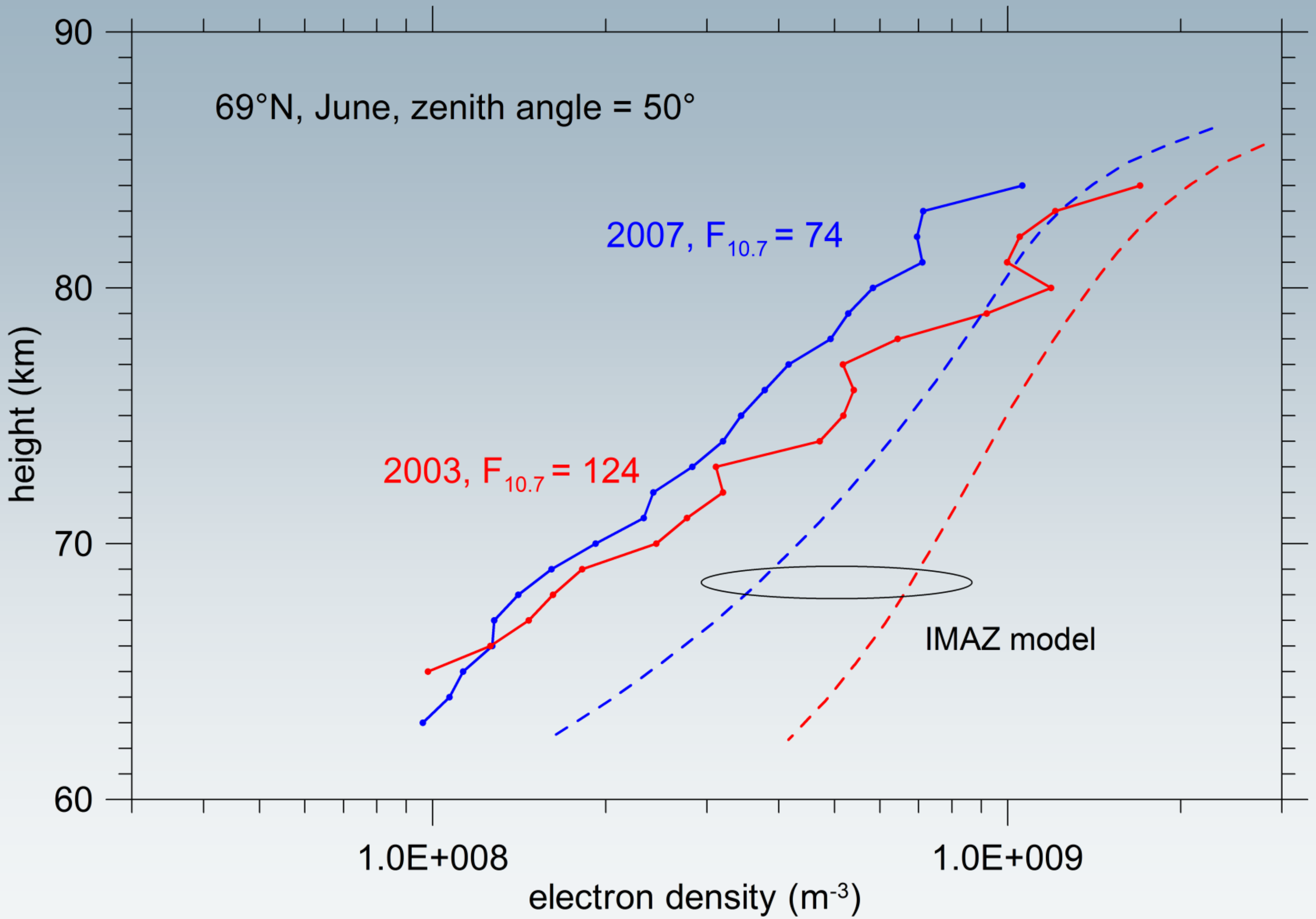
3. Diurnal and seasonal variation of electron number density

dependency on solar activity

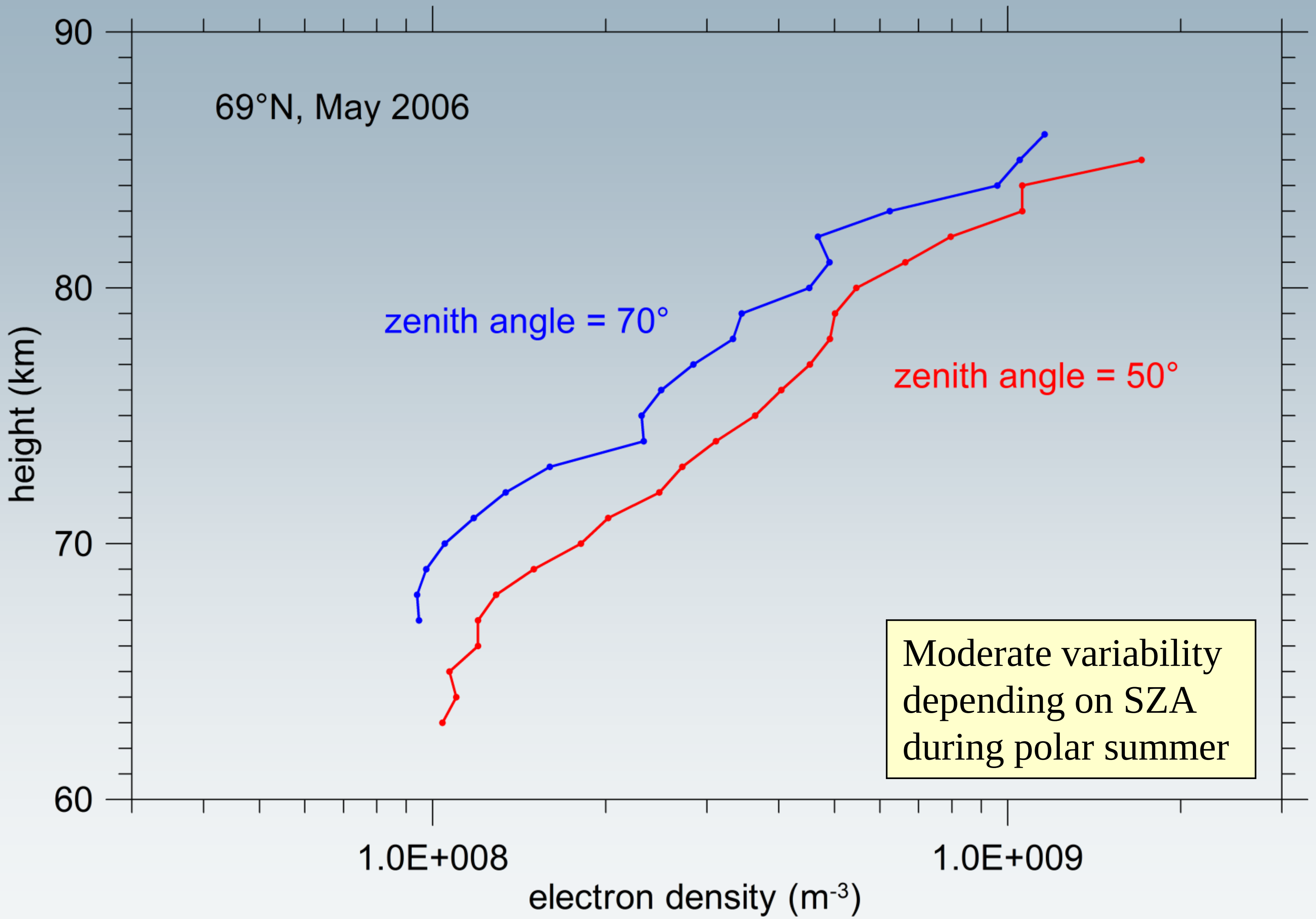


3. Diurnal and seasonal variation of electron number density
dependency on solar activity, comparison with IMAZ



3. Diurnal and seasonal variation of electron number density

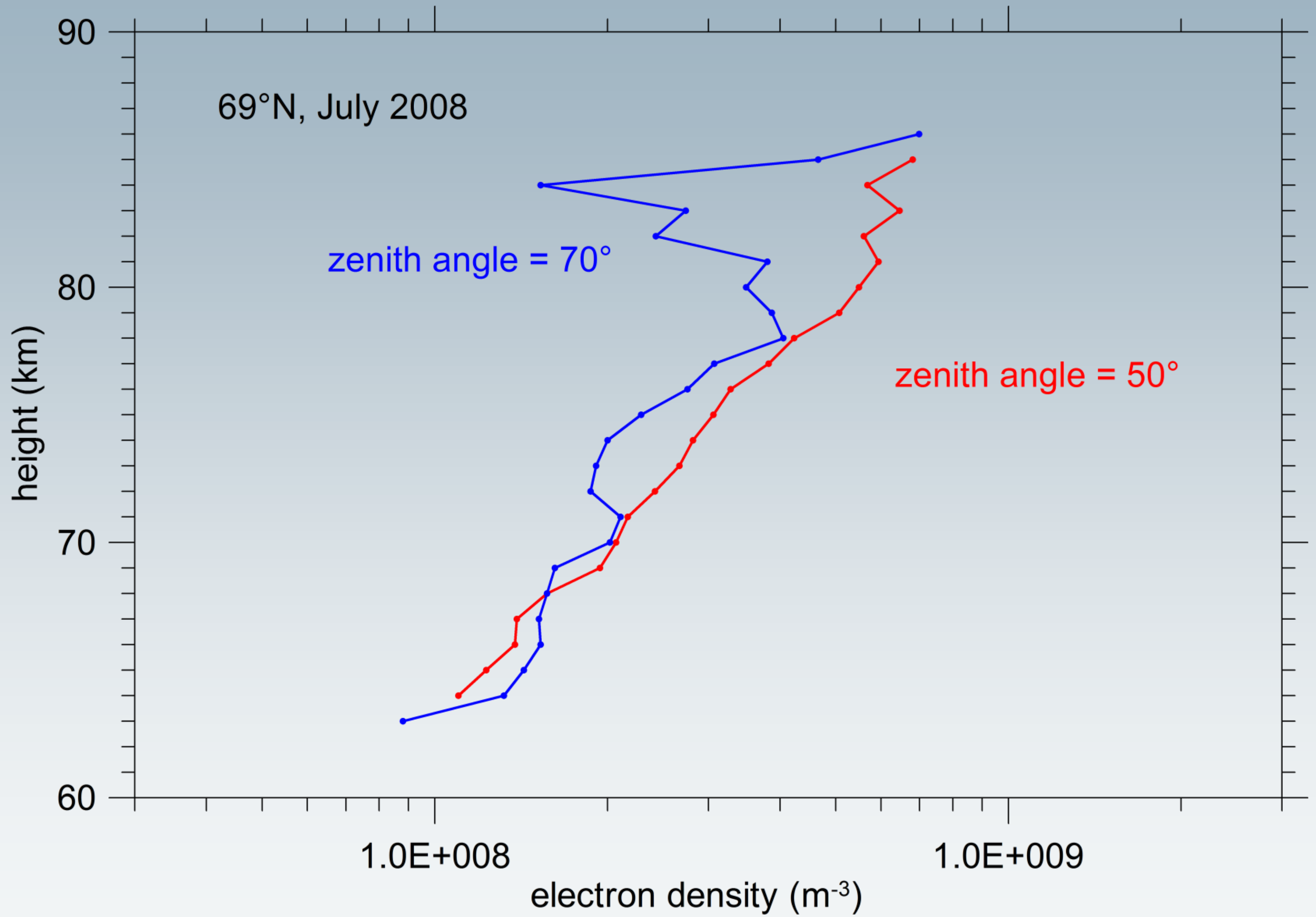
dependency on solar zenith angle



Moderate variability depending on SZA during polar summer

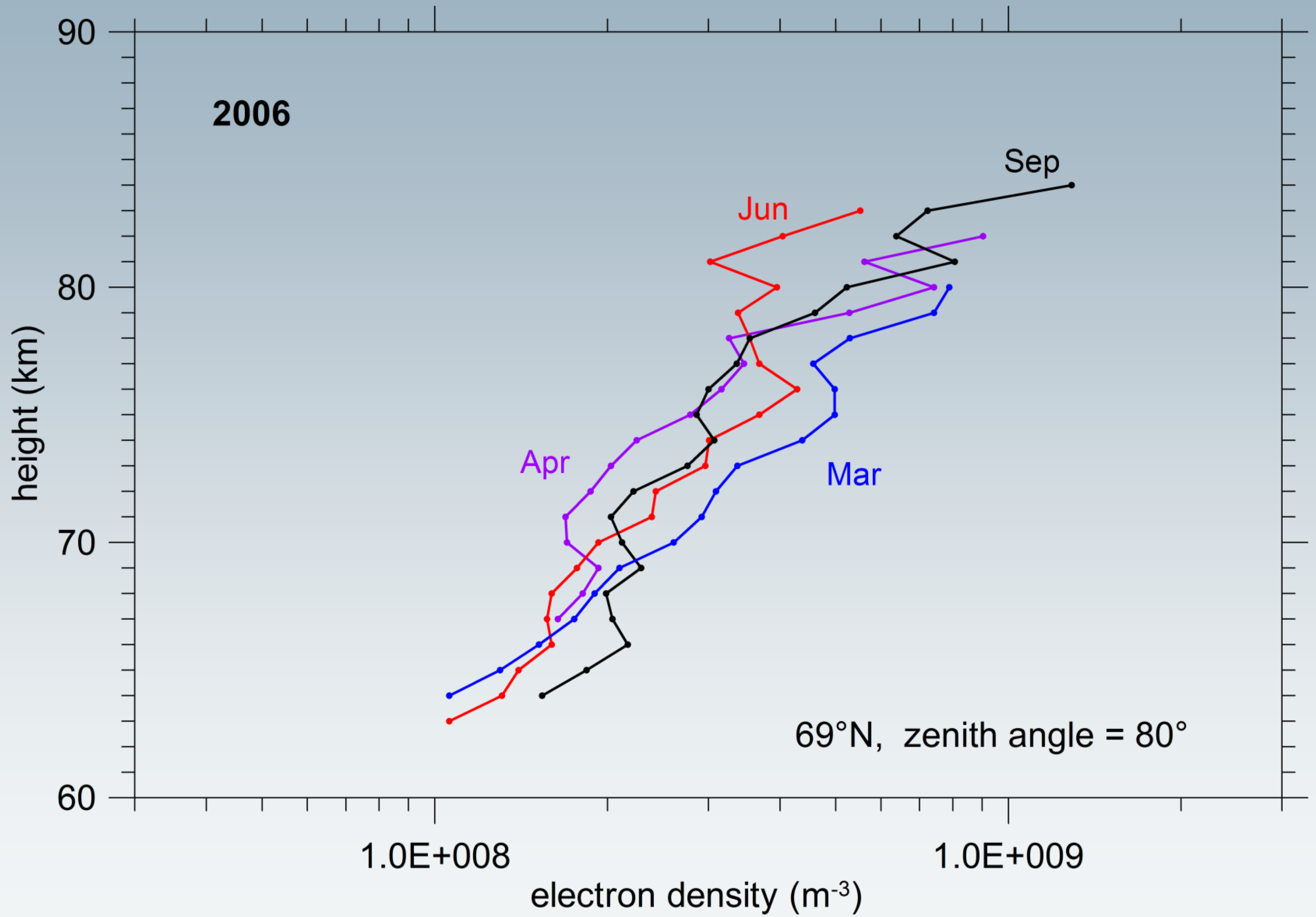
3. Diurnal and seasonal variation of electron number density

dependency on solar zenith angle



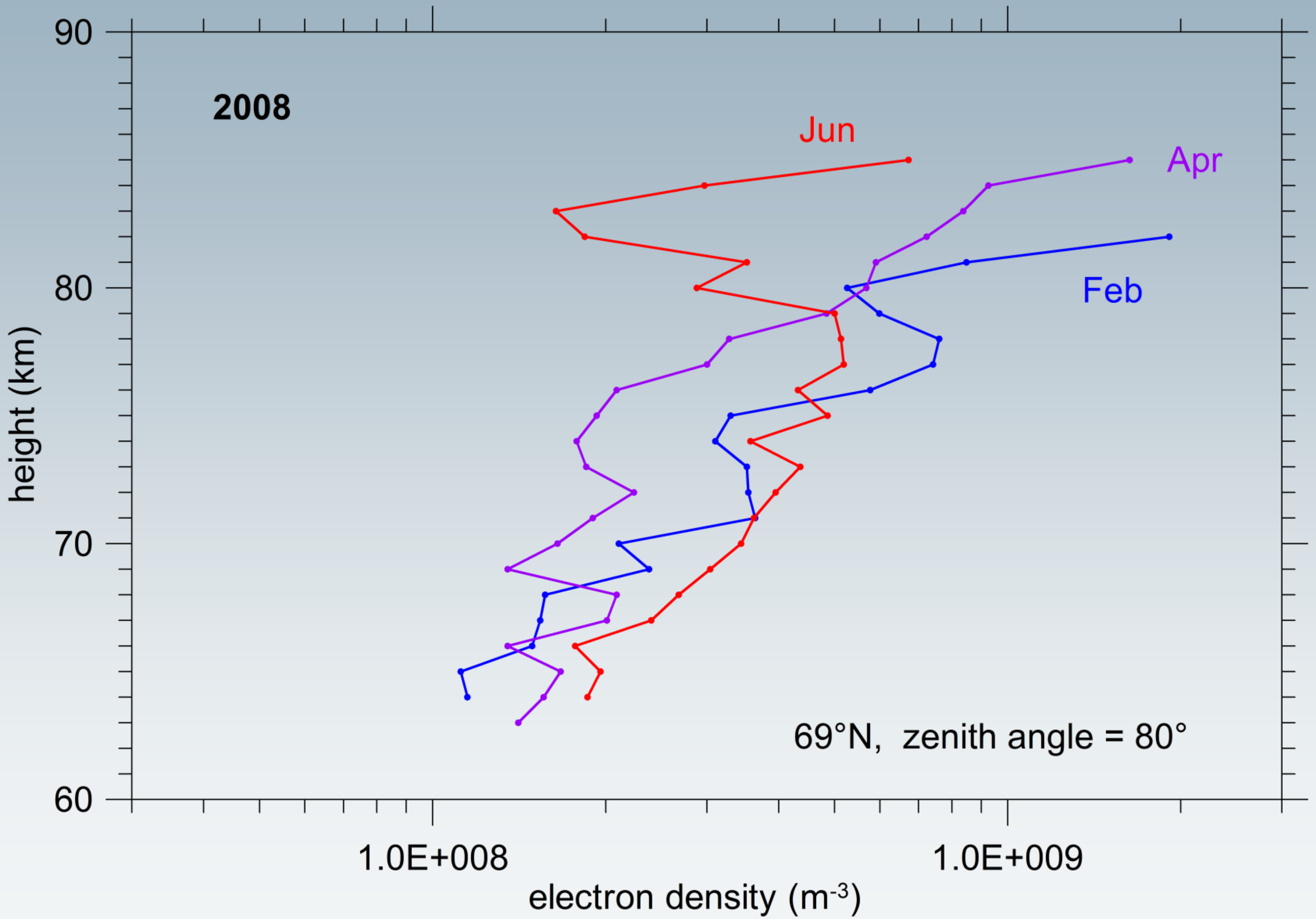
3. Diurnal and seasonal variation of electron number density

seasonal variability at 69°N in 2006



3. Diurnal and seasonal variation of electron number density

seasonal variability at 69°N in 2008



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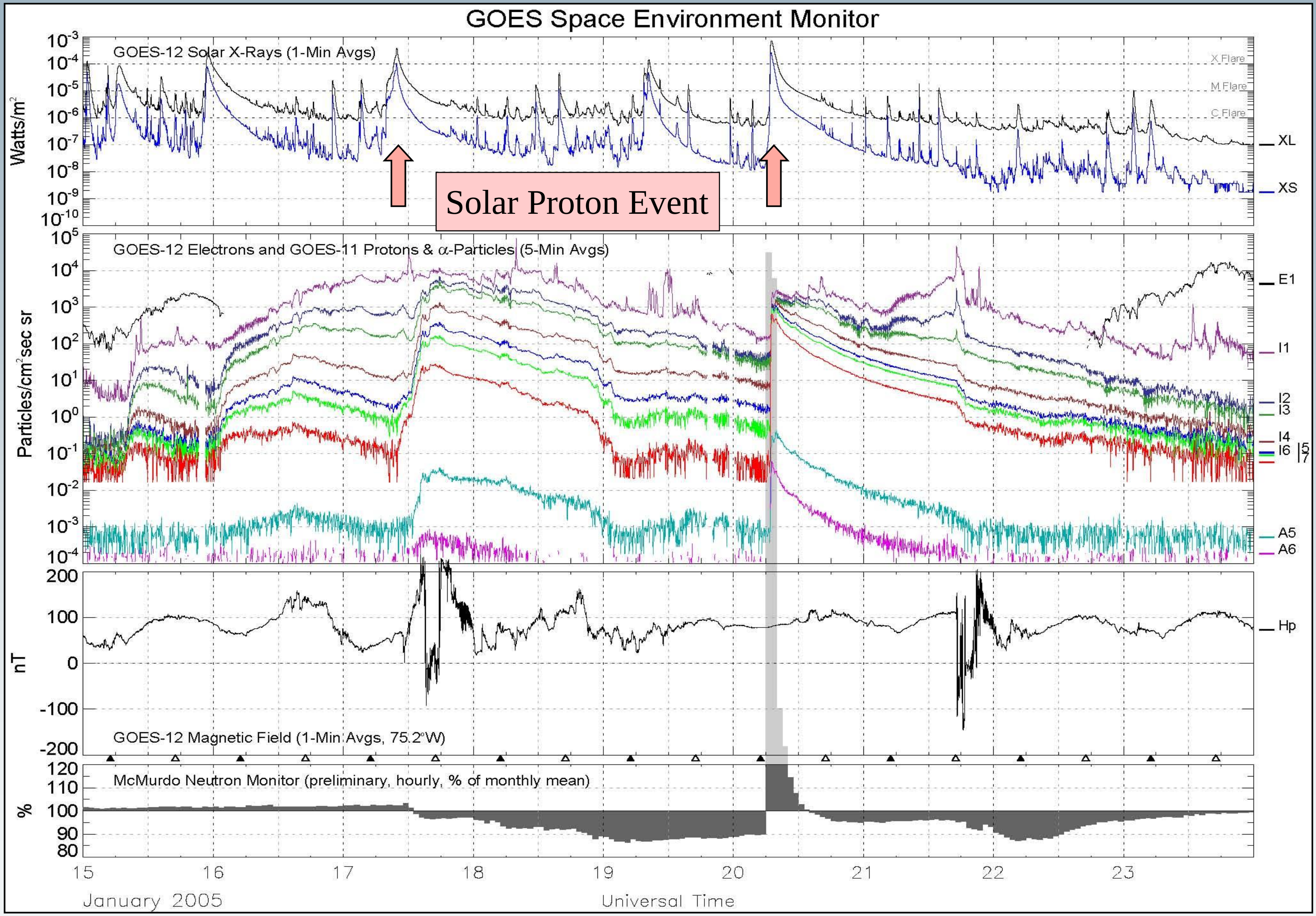
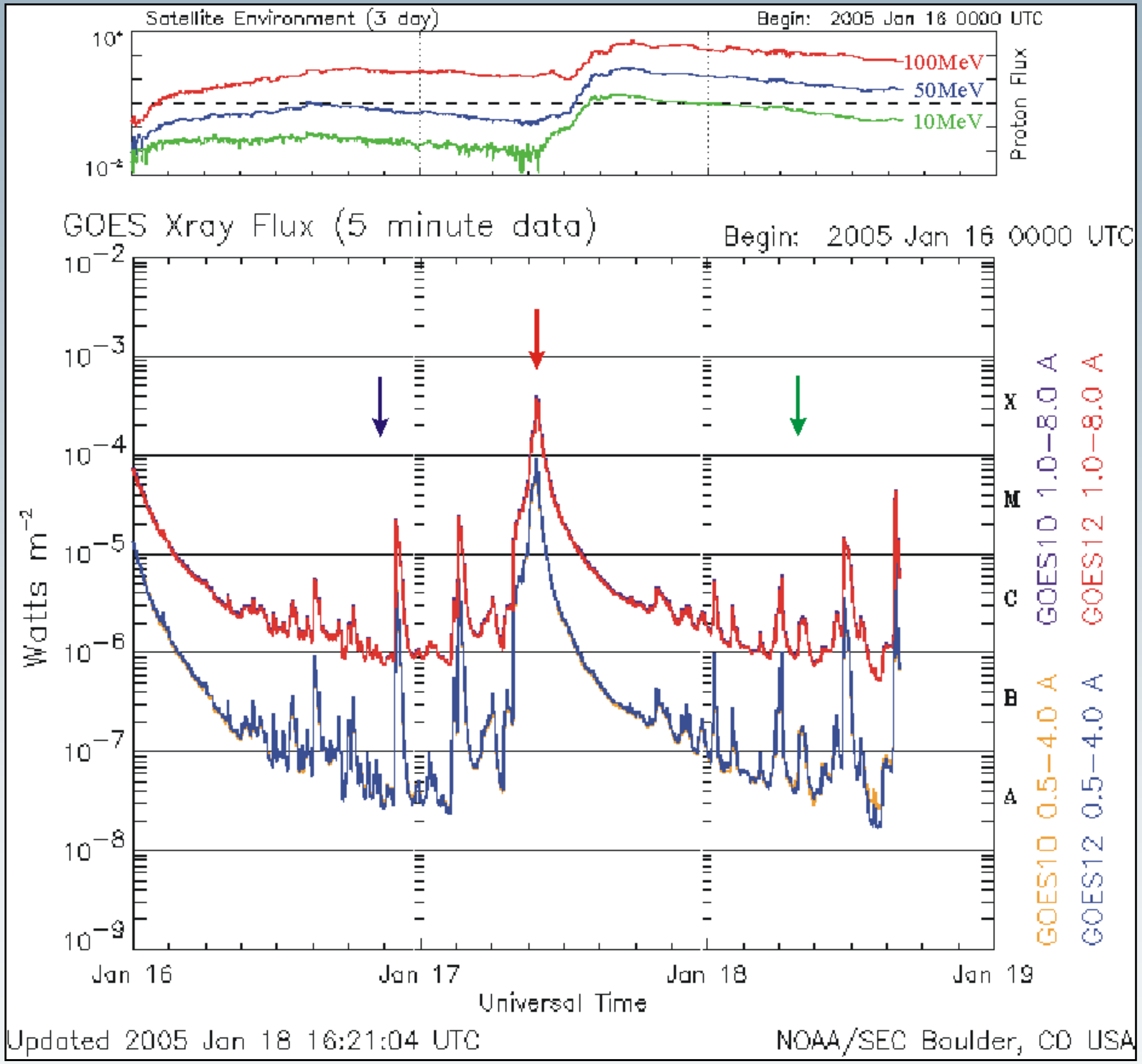
4.1 Electron densities during solar proton events (SPE)

increased x-ray radiation and high energetic protons on 17 and 20 Jan. 2005



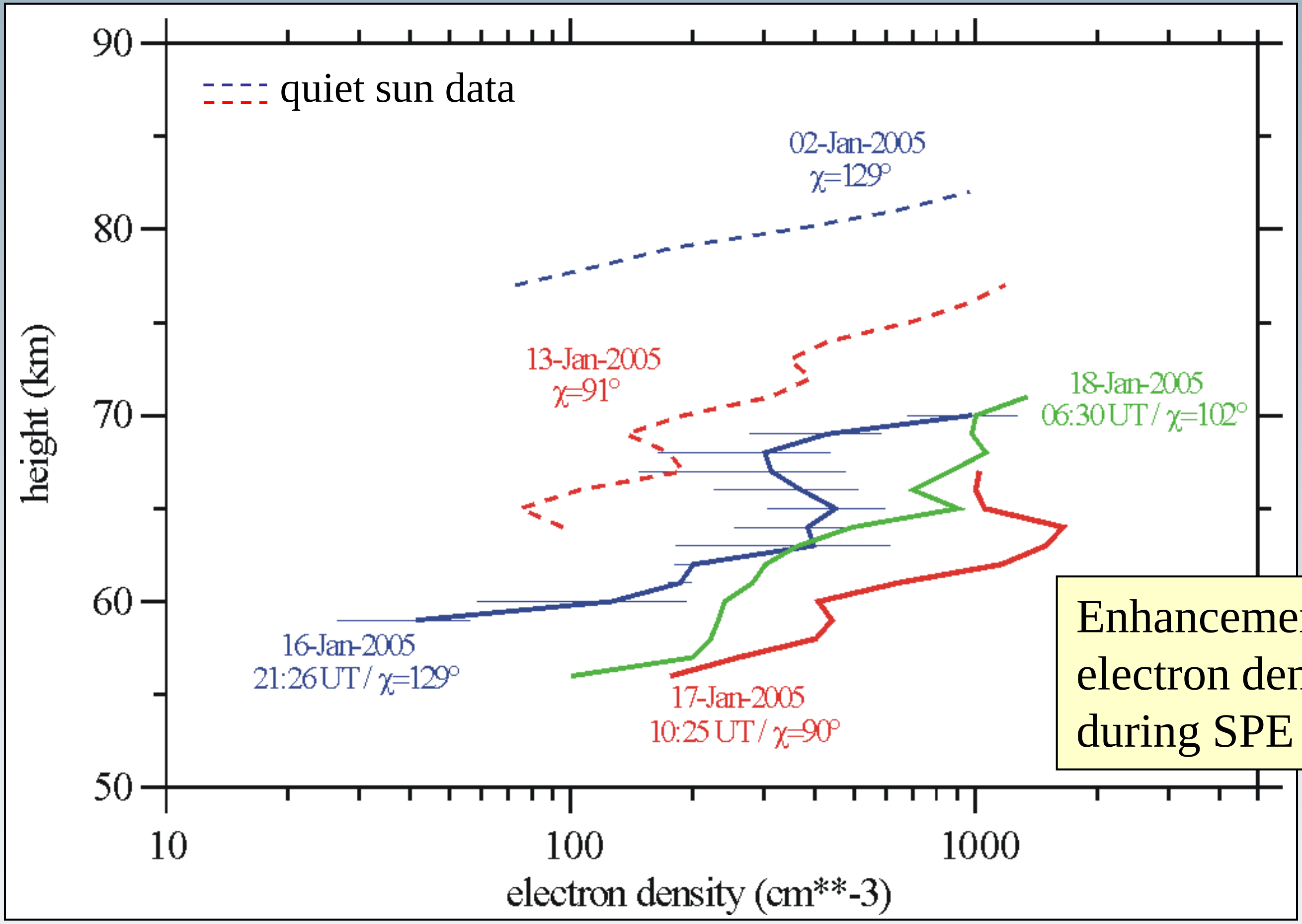
4.1 Solar proton fluxes and x-ray fluxes on January 17, 2005

before, at the peak, and after the solar activity event



4.1 Electron densities during SPE on January 17, 2005

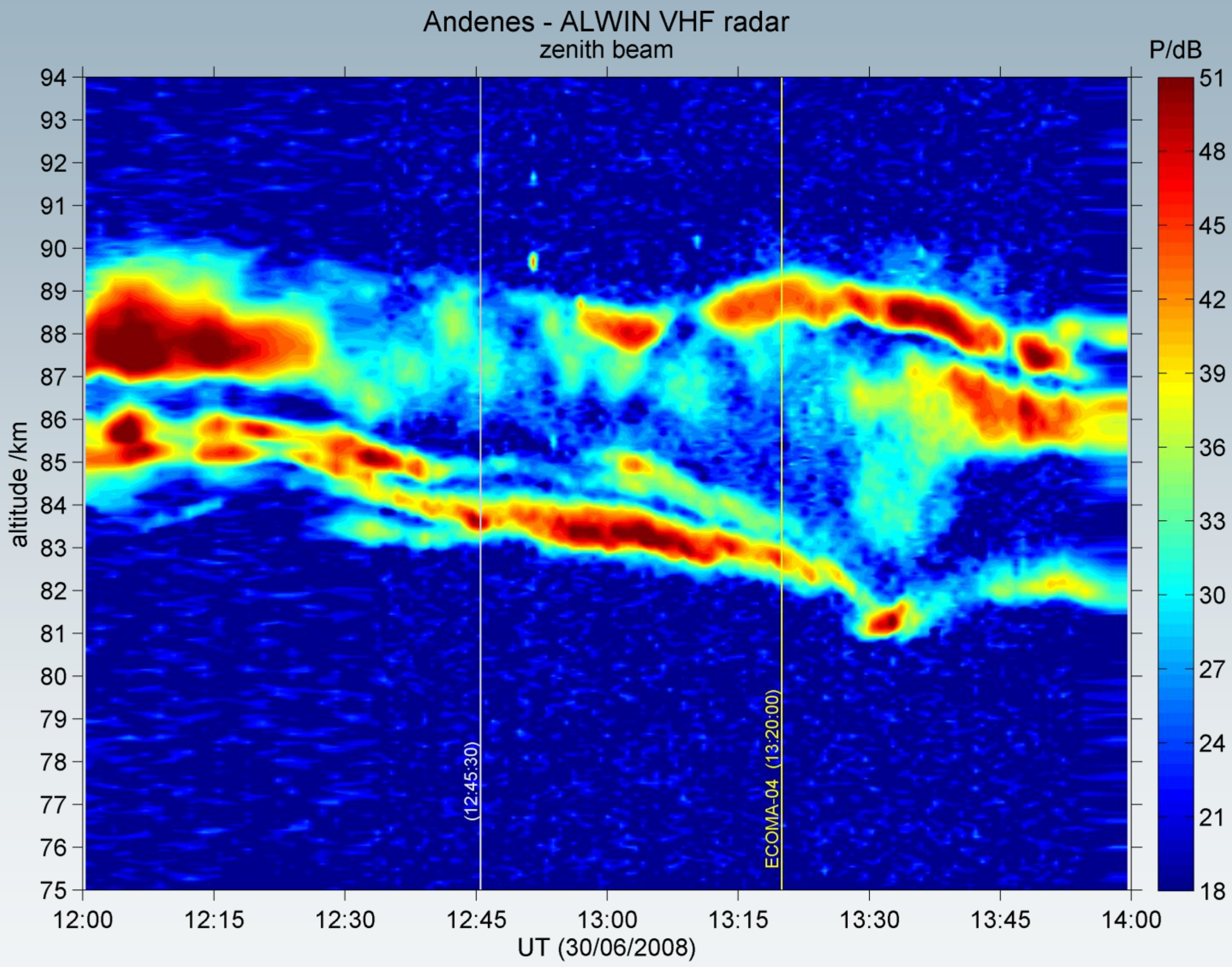
before, at the peak, and after the solar radiation storm



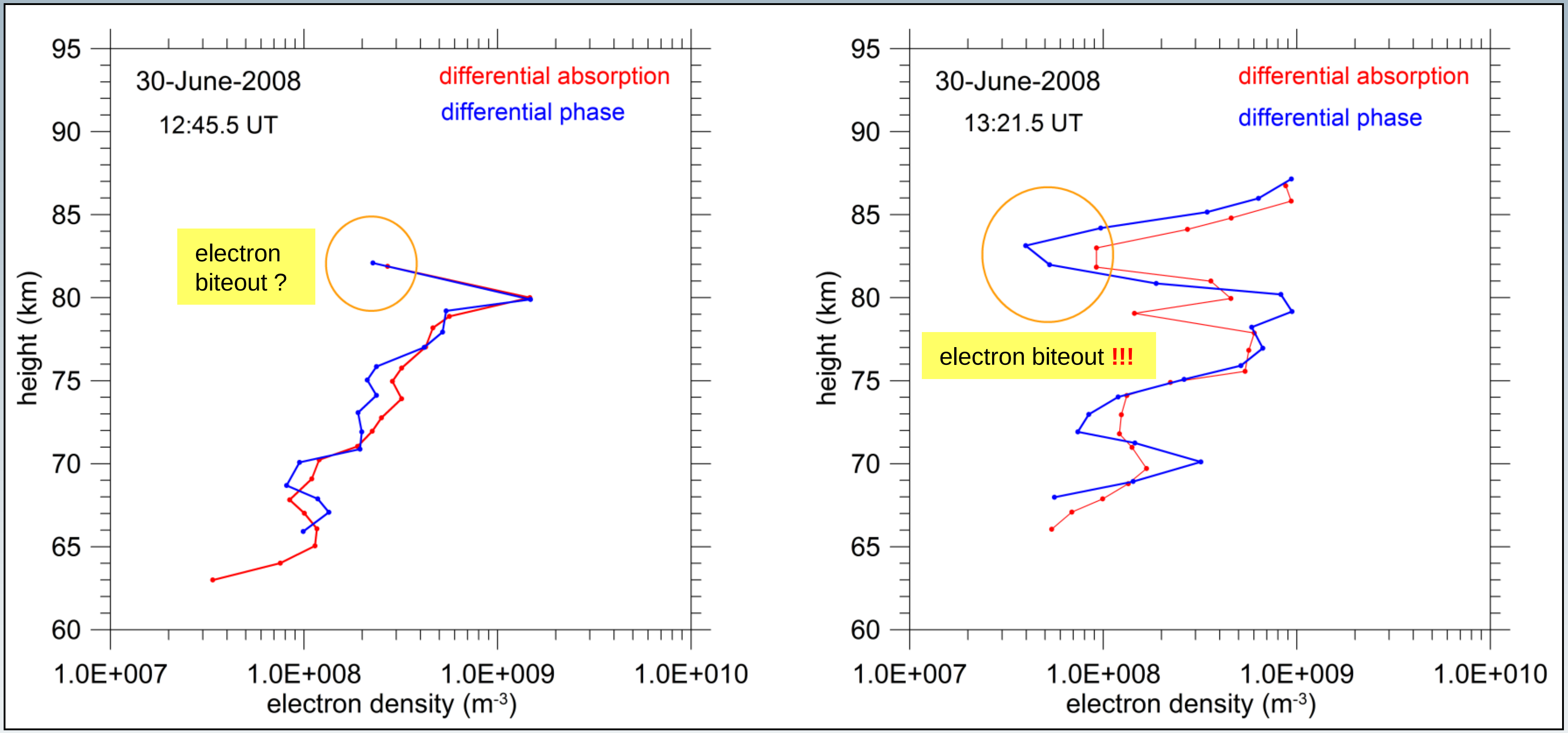
Enhancement of electron density during SPE

enhanced electron densities on January 18 due to enhanced proton fluxes

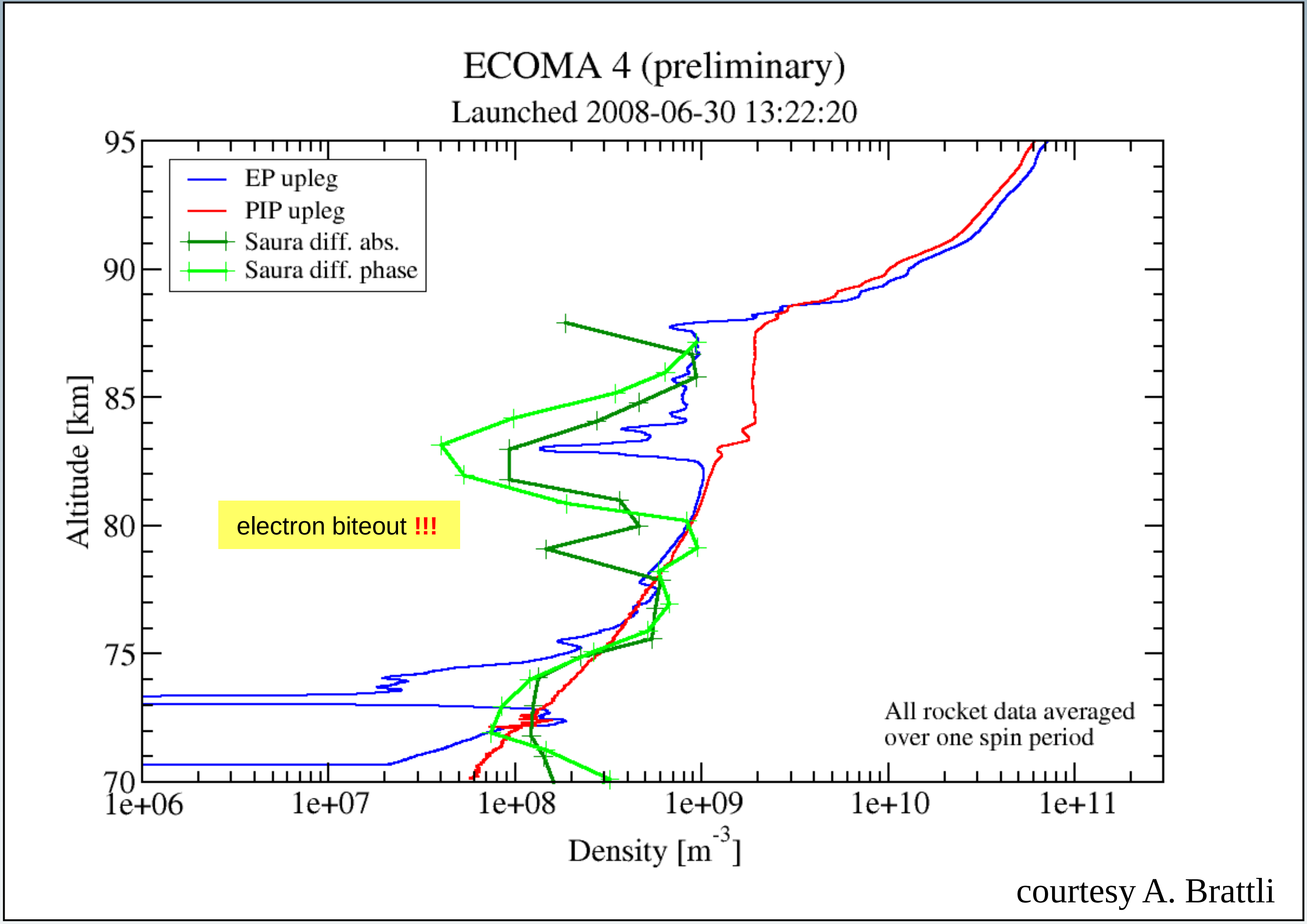
4.2 Electron densities during Polar Mesosphere Summer Echoes
above Andenes on 30 June 2008



4.2 Electron densities during Polar Mesosphere Summer Echoes
above Andenes on 30 June 2008



4.2 Electron densities during Polar Mesosphere Summer Echoes
above Andenes on 30 June 2008



Ground-based electron densities agree with insitu plasma measurements

5. Summary and Outlook

- The Saura MF radar provides electron number densities in the order of $x \bullet 10^7 \dots x \bullet 10^9 \ m^{-3}$ at altitudes between 55 km to 90 km at daytime and nighttime with a time resolution of 9 minutes.
- Electron number densities were obtained down to an altitude of 55 km during periods of strong enhanced solar/geomagnetic activity –
  - $x \bullet 10^9 \ m^{-3}$ at 60 … 65 km.
- The derived electron number density profiles are in general agreement with results from insitu radio wave propagation experiments

In preparation:

- Measurements of D-region electron densities at 54°N, but limited to daytime (high external interference)