Response of the upper mesosphere on solar proton events after radar observations at high, middle and low latitudes

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Outline

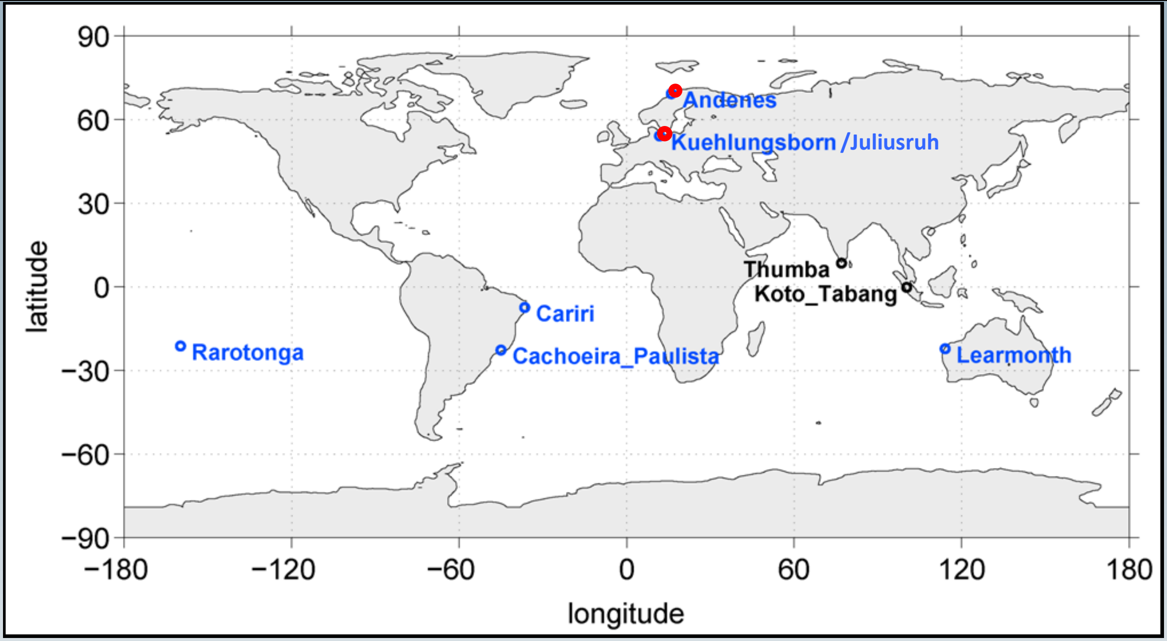
- Mesospheric winds, temperatures, and electron densities from radar observations
  - SKiYMET meteor radars
  - MF radars
- Mesospheric winds, turbulence, temperature and electron density during solar proton events
  - October 2003,
  - January 2005
- Summary

Mesospheric winds, Temperatures, and Electron densities from observations obtained by

METEOR RADARS
MF RADARS

3-MHz Doppler radars and SKiYMET meteor radars (since 1999/2000)

Meteor radars with identical hardware, meteor detection and data analysis



Station	Latitude	Longitude	Radar	Parameter
Andenes	69.3°N	16.0°E	MF 3.17 MHz	u, v, turb, N_e
Andenes	69.3°N	16.0°E	meteor	T, u, v
Juliusruh	54.6°N	13.4°E	MF 3.17 MHz	u, v
Juliusruh	54.6°N	13.4°E	meteor	T, u, v
Kühlungsborn	54.1°N	11.8°N	meteor	T, u, v
Koto Tabang	0.2°S	110.3°E	meteor	T, u, v
Learmonth	22.2°S	114.1°E	meteor	T, u, v
Cachoeira Paulista	22.7°S	315.0°E	meteor	T, u, v

SKiYMET Meteor Radar
all sky interferometer meteor radar

<u>Basics</u>

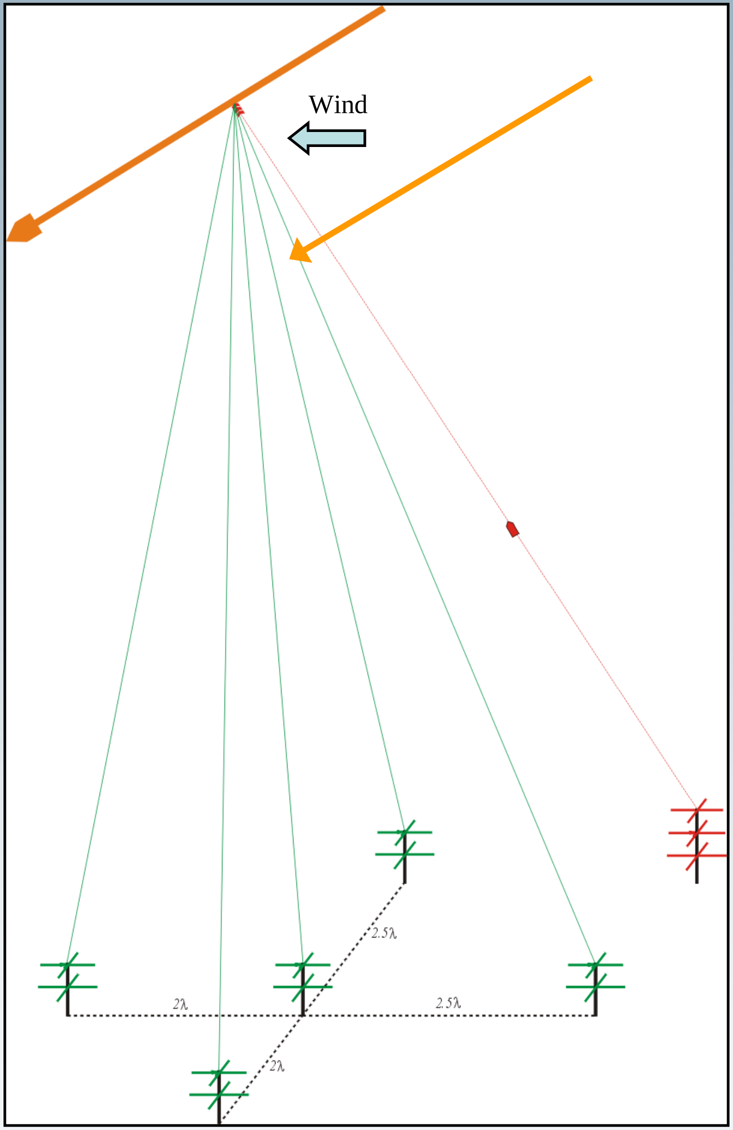
- meteor detection: radar beam ⊥ meteor trail
- Underdense meteors:
  plasma frequency of the trail < radar frequency

<u>Parameters</u>

• Frequency	32.55 MHz
• Peak power	12 kW
• Pulse width	13 µs
• Pulse rep. Frequency	2144 Hz
• Range resolution	2 km
• Angular resolution 2°	
• Height range	80 – 100 km
• Radio magnitude	+8.6

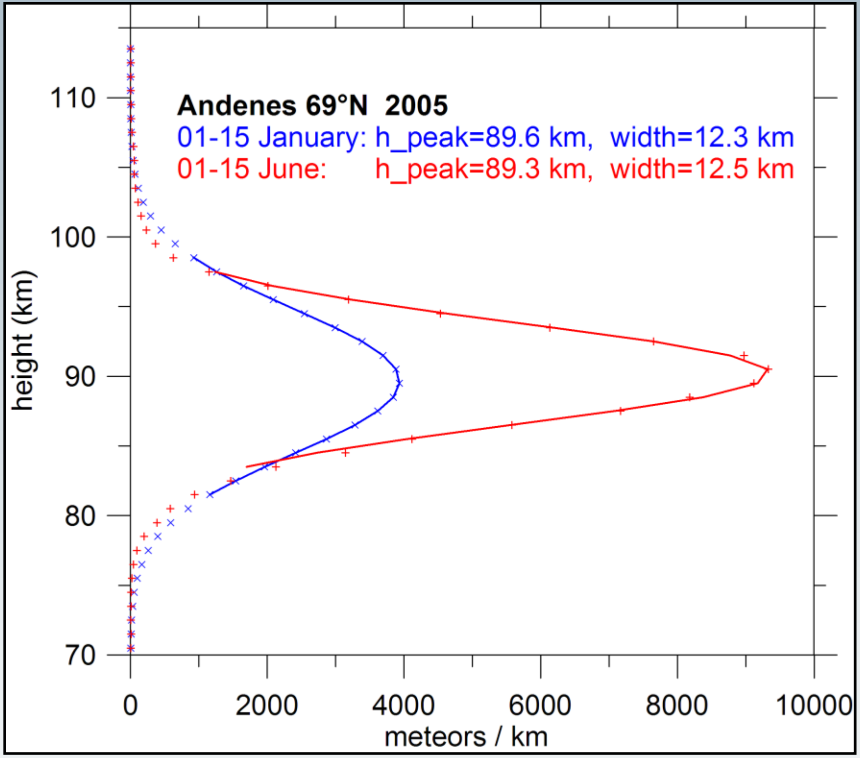
- Transmitting antenna
  3-element crossed Yagi antenna
- Receiving antenna
  5-channel interferometer of 2-element Yagi antennas

➢ omni-directional sensitivity

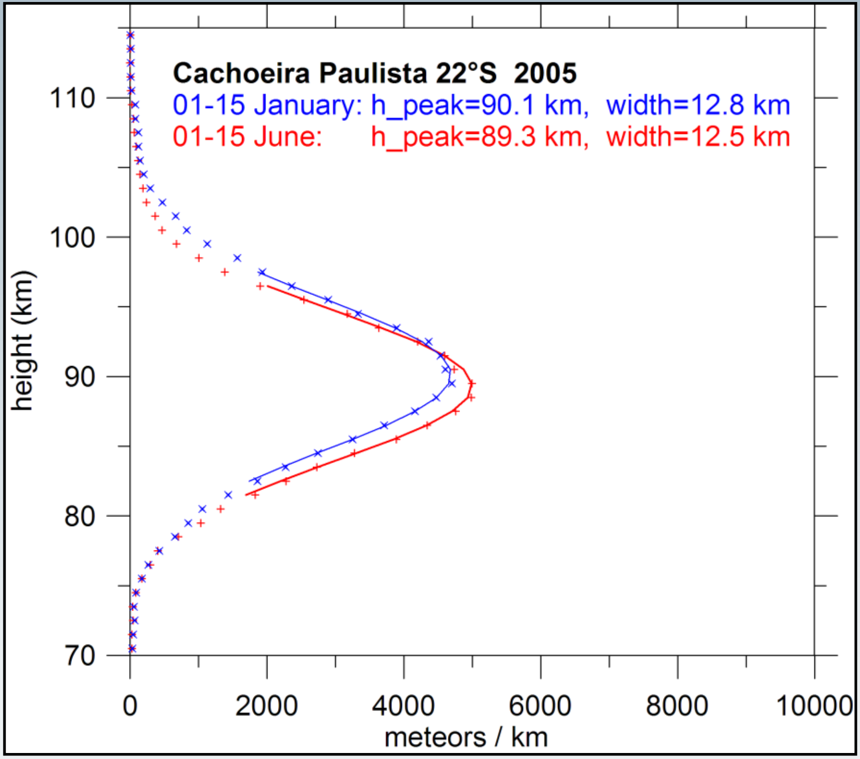


Mean height distribution of meteors
at high and low latitudes in winter and summer

32.55 MHz

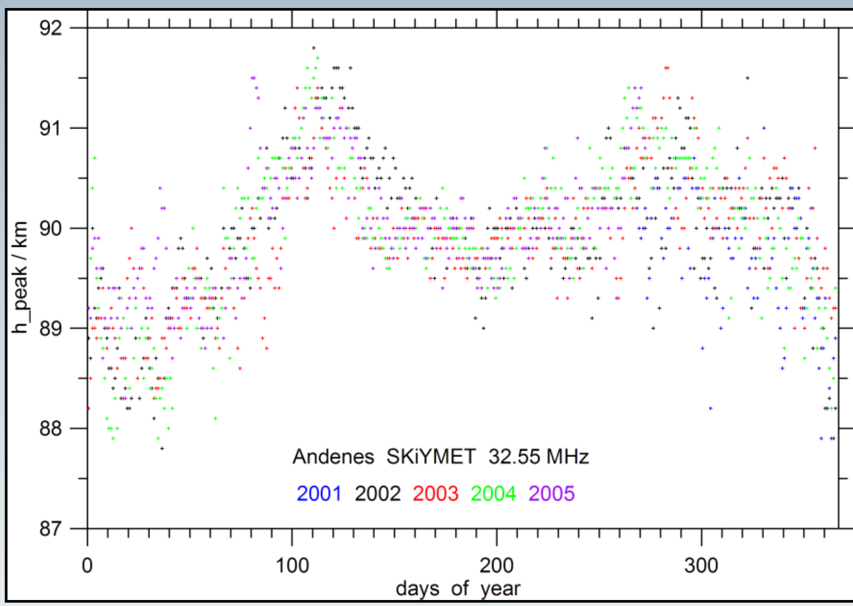


35.24 MHz

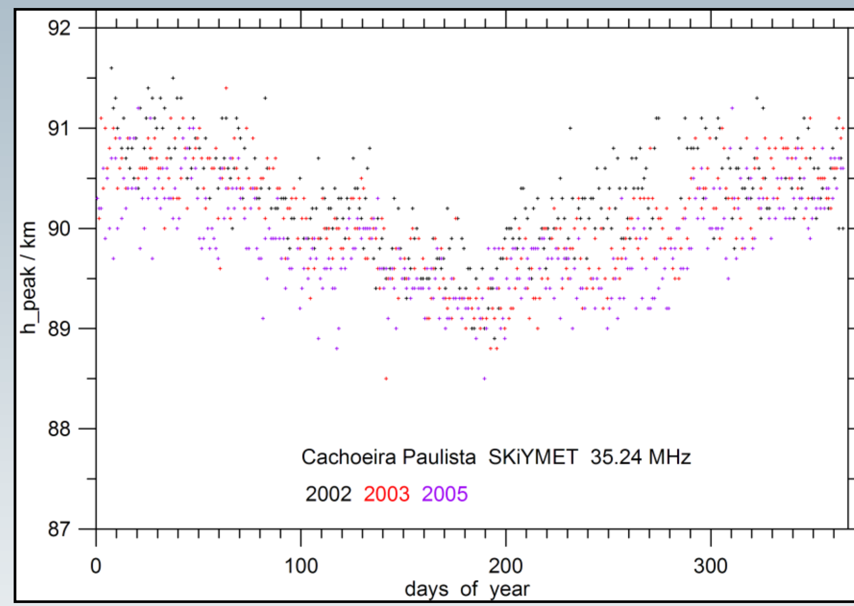


Seasonal variation of the peak height of the meteor layer

69°N



22°S



- ~3 km annual height variation,
- maxima around equinoxes

- ~2 km annual height variation
- maximum in December-January

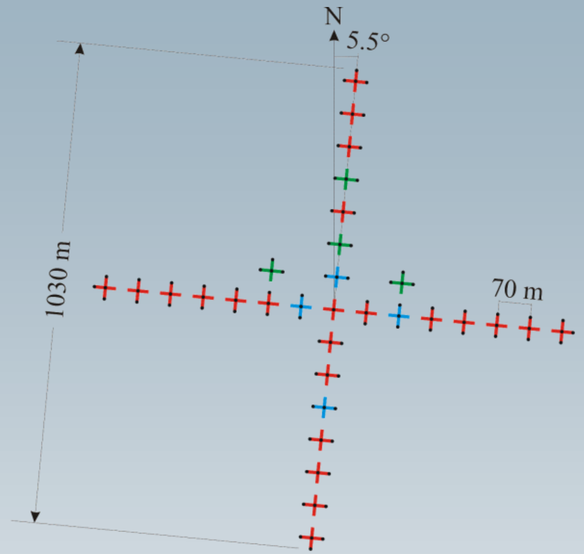
Data analysis

- **Mean winds and tides**
  - (24-h, 12-h, 8-h periods)
  - from harmonic fits of 4-d / 10-d / 60-d composite days
  - height coverage: 80 - 100 km

- Daily **mean temperatures** from meteor decay times
  - temperature gradient method (meteors ≥ 1000 per day)
  - temperatures refer to the peak altitude of the meteor layer (~90 km, average over the layer width of ~12 km)

Estimation of wind, turbulence and electron density at 3 MHz

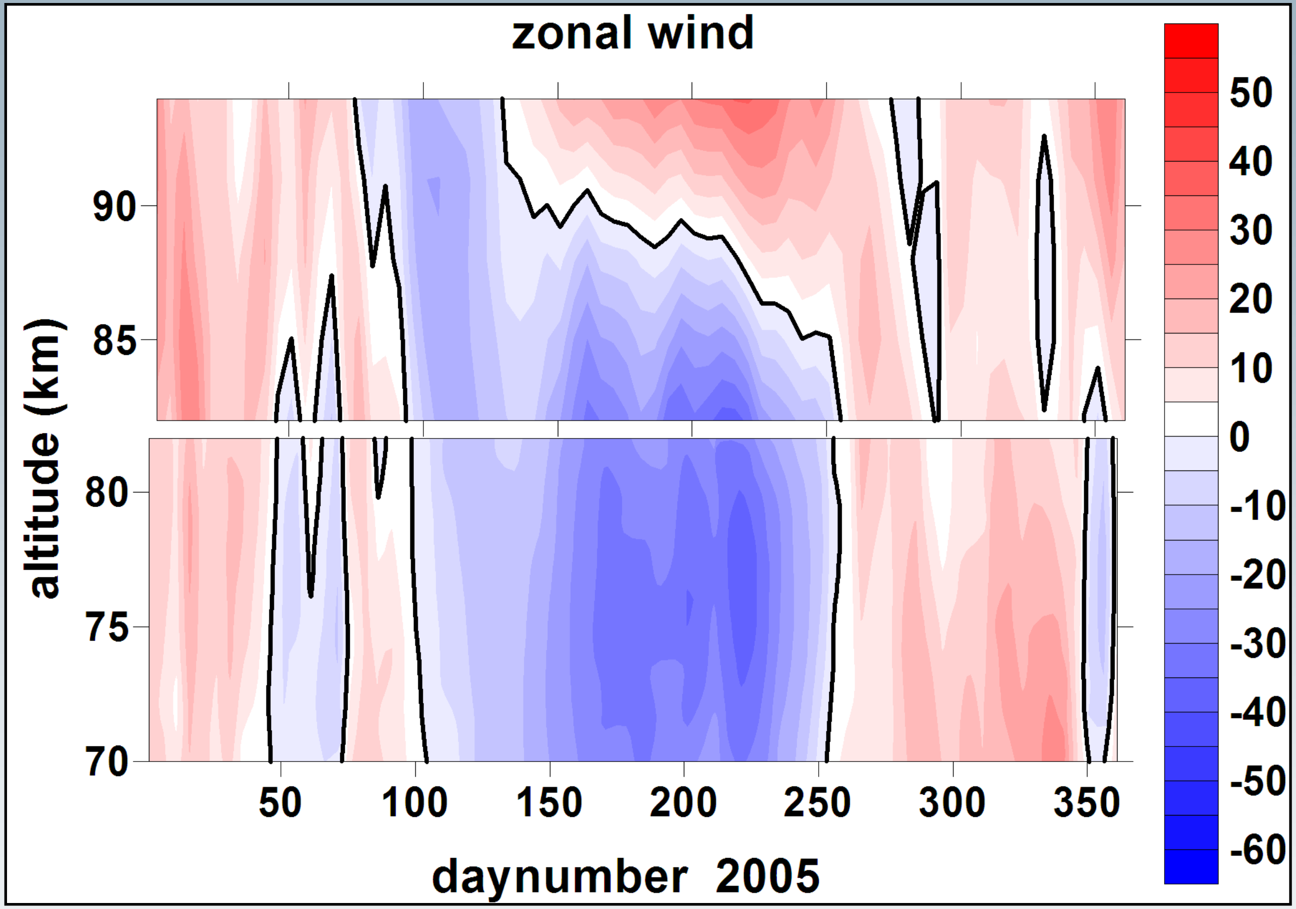
The 3-MHz Doppler radar at Saura on Andøya island (69°N)



- narrow beam transmitting/ receiving antenna
  - Mills Cross
  - 29 crossed dipoles
  - arm length of 1030m
  - HPFW = 6.6°
- ➢ high flexibility in beam forming and pointing

- total peak power of 116 kW
- left/right circular polarisation, changing of polarisation from pulse to pulse
- height range: 55 – 90 km
- best range resolution of 1 km

Mean zonal winds above Andenes after observations by meteor radar (82-98km) and MF radar (70-82km)

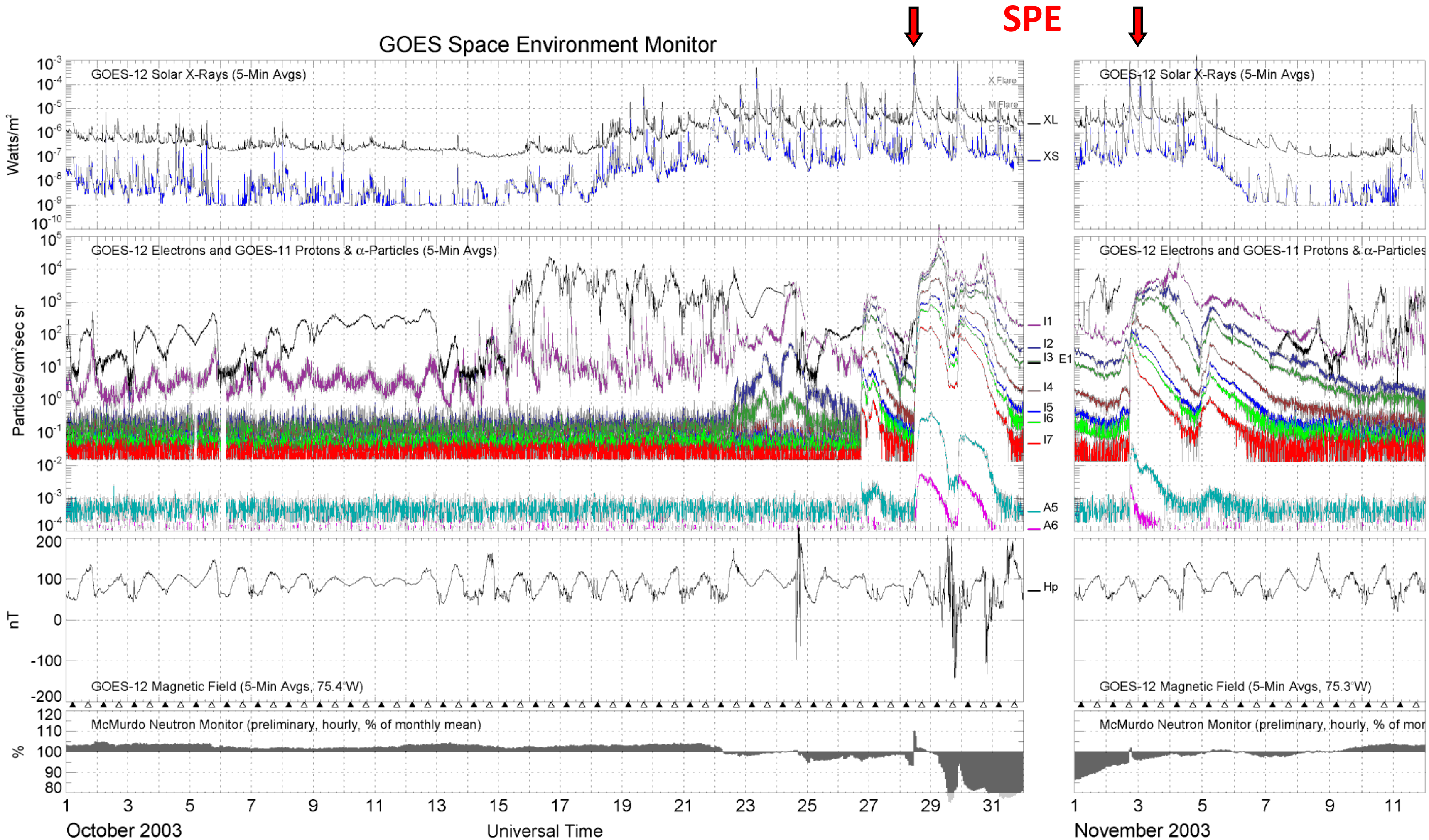


The combination of co-located meteor winds and MF radar winds (e.g. Andenes, Juliusruh) extends the height range down to ~70 km

Mesospheric winds, turbulence and temperature during solar proton events in

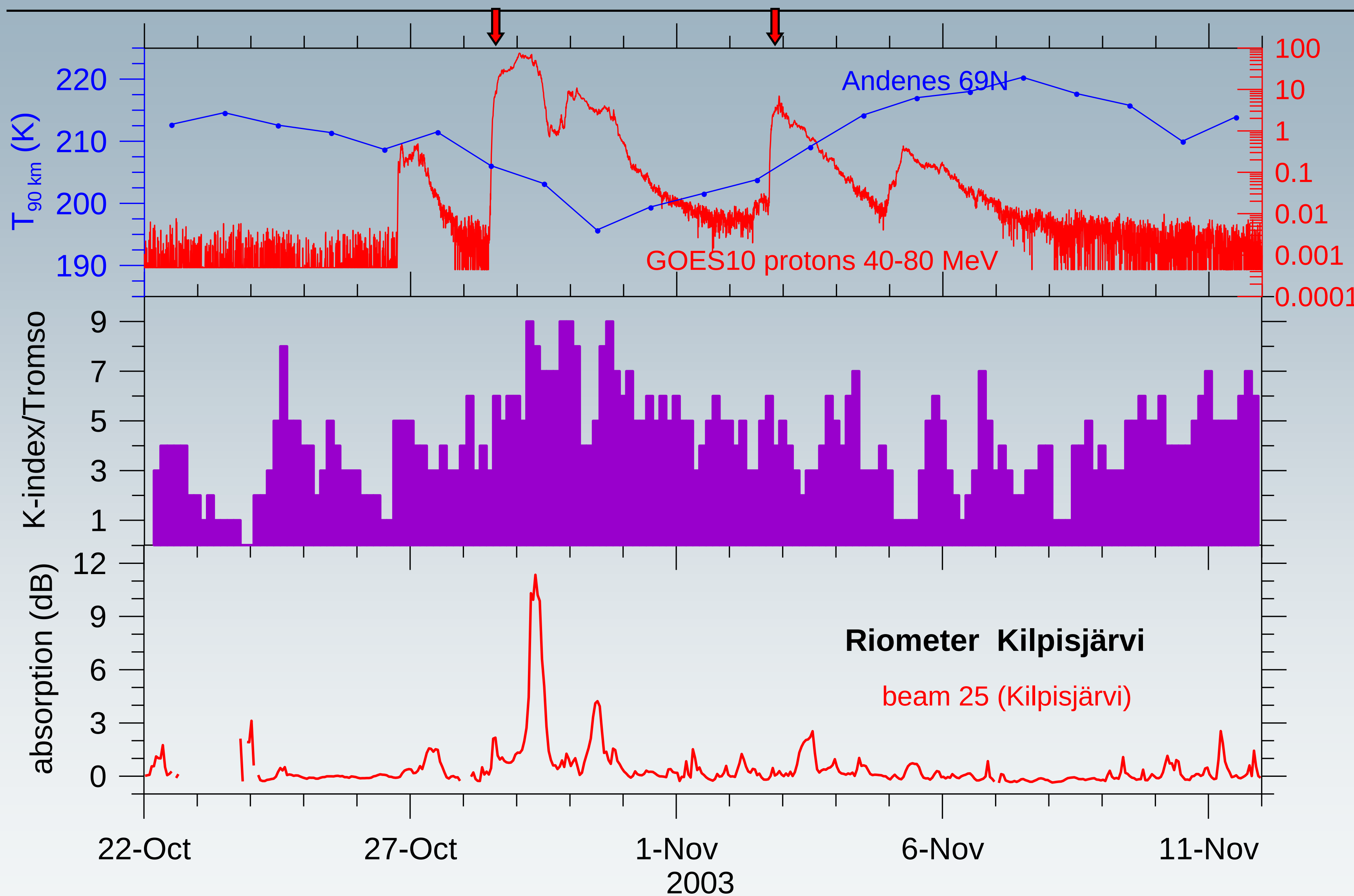
OCTOBER 2003

Solar proton events in October/November 2003

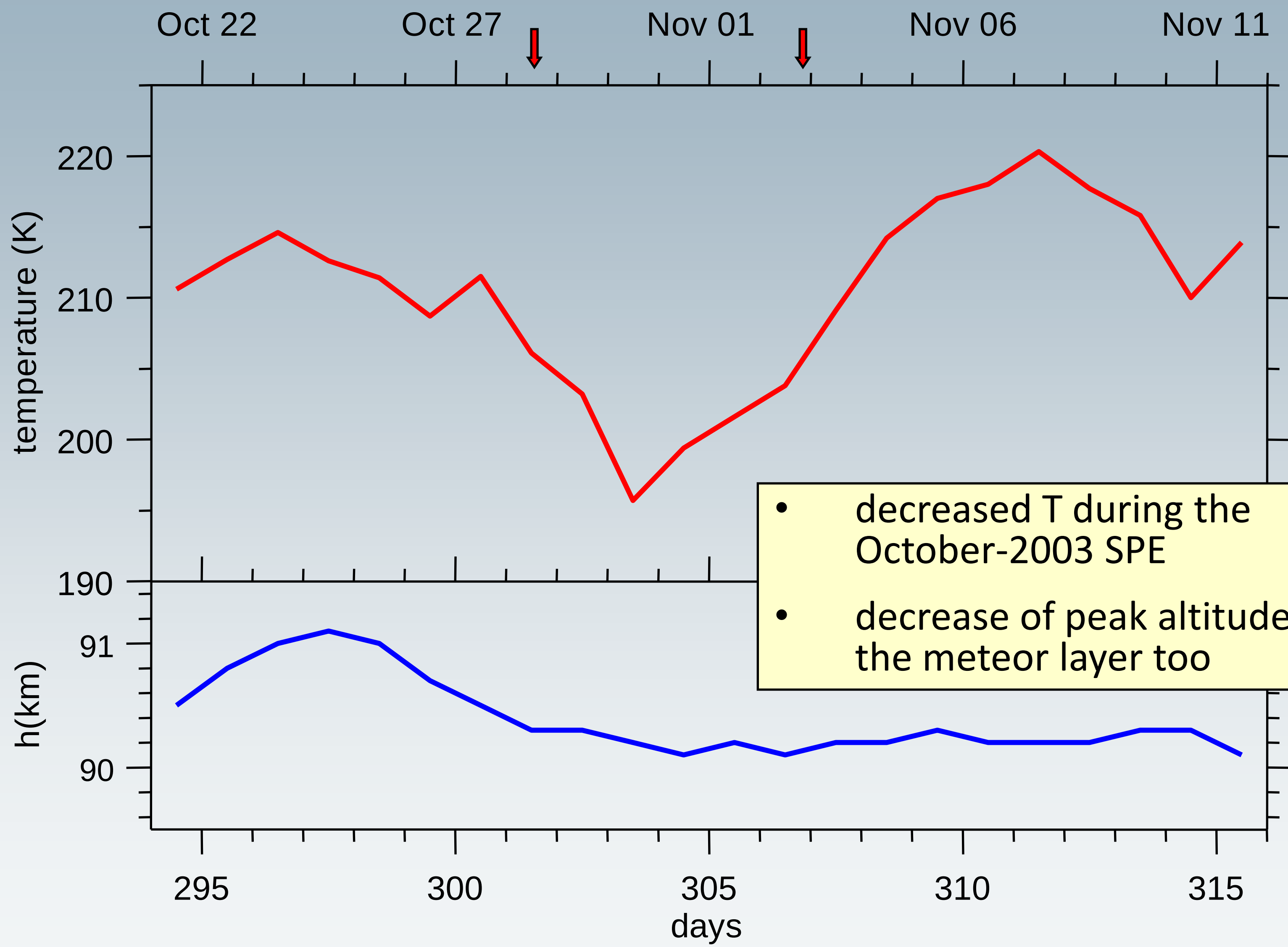


X-ray fluxes and energetic particle fluxes: E1 electrons > 2 MeV, I1 protons > 1 MeV: trapped outer zone particles; I2…I7 protons > 5…100 MeV: originated from the sun

High energetic solar proton fluxes, neutral temperatures, geomagnetic K-index, and ionization at ~69°N in October/November 2003



Neutral temperatures from meteor decay times



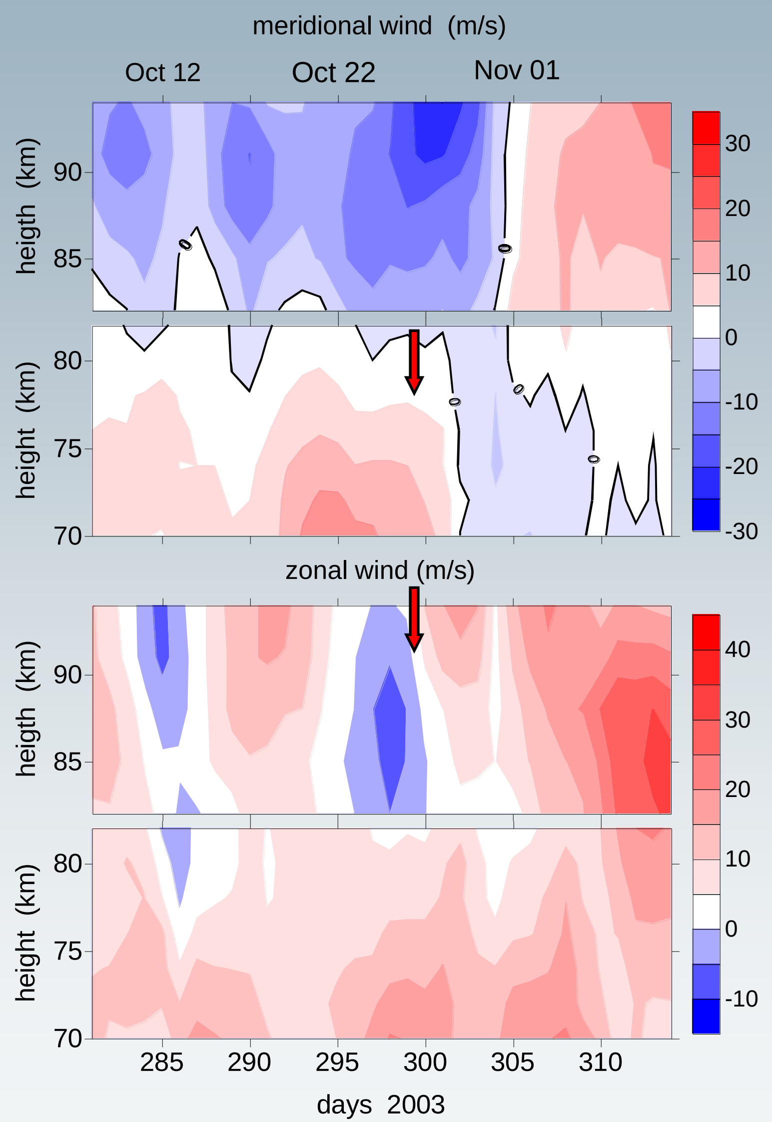
- decreased T during the October-2003 SPE
- decrease of peak altitude of the meteor layer too

Peak altitudes of the meteor layer and temperatures during SPE and non-SPE

		SPE			non-SPE			SPE - non_SPE	
		date	h_peak	T	date	h_peak	T	Δh	ΔT
2000	54N	14-16 July	88,94	165,3	24-25 July	89,00	171,5	-0,06	-6,2
2001	69N	5-6 Nov	90,95	203,6	14-15 Nov	91,55	205,4	-0,60	-1,8
2003	69N	28-29 Oct	91,34	195,7	20-21 Oct	91,72	203,9	-0,38	-8,2
2003	69N	3-7 Nov	91,14	215,6	15-18 Nov	91,74	219,4	-0,60	-3,8
2005	69N	17-18 Jan	89,02	194,1	9-10 Jan	89,38	200,9	-0,36	-6,8
2006	54N	7-9 Dec	87,73	193,9	1-3 Dec	88,38	197,7	-0,65	-3,8

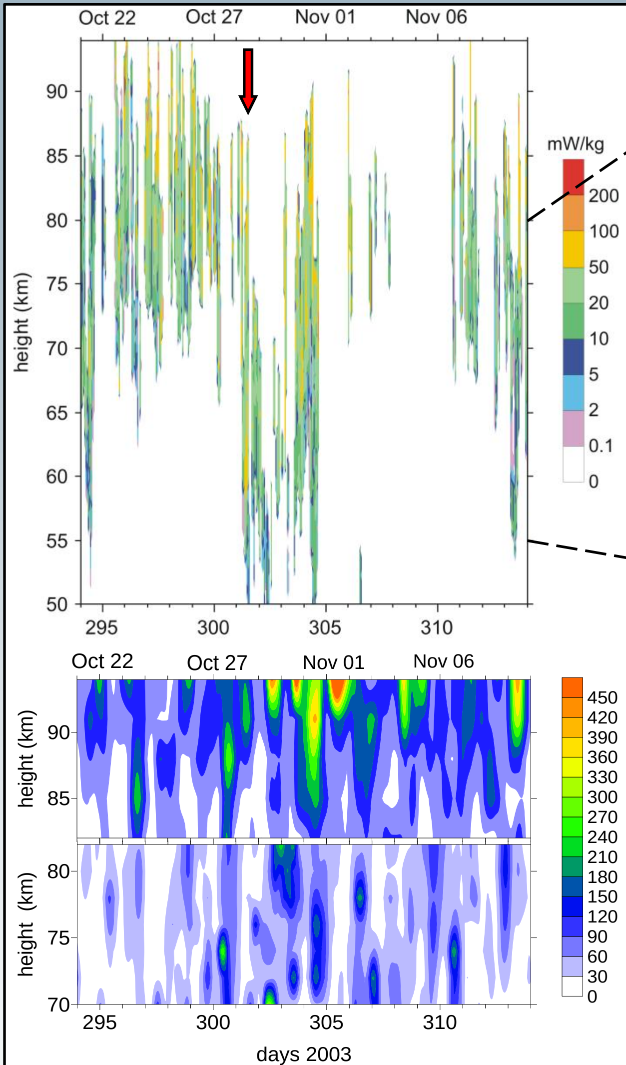
SPE: lowering of peak altitude by ~0.4 km, decrease of temperature by ~ 5K

Mean meridional/zonal winds after meteor/MF radar observations between 10-Oct and 10-Nov

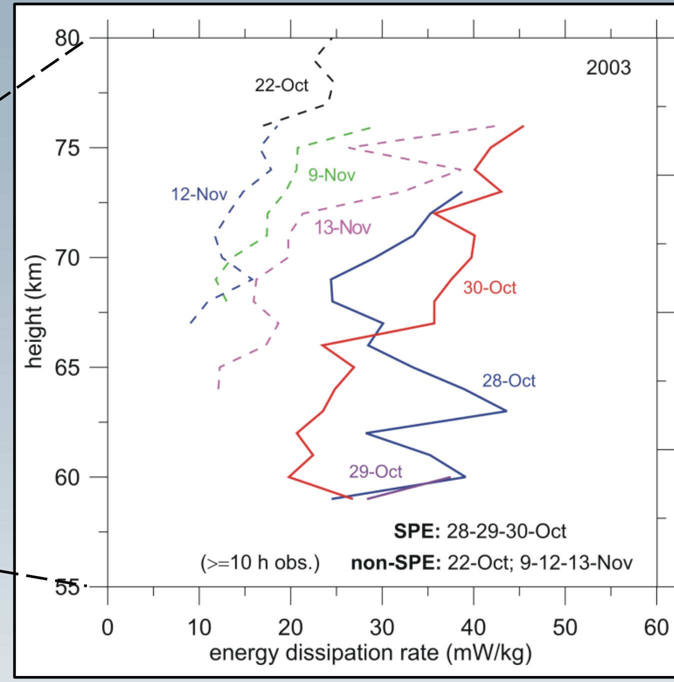


- reversal of meridional winds around SPE
- reduced zonal winds above ~80 km
- (also observed with model simulations by Krivolutsky et al., JASR, 2000
- increased zonal winds below ~80 km during SPE

Turbulent energy dissipation rates and variances of horizontal wind disturbances



Variances of horizontal winds (m**2/s**2) for periods 3 - 9 h from Meteor- and MF radar observations at Andenes.



Mean daily energy dissipation rates are enhanced by a factor of two during the solar proton event

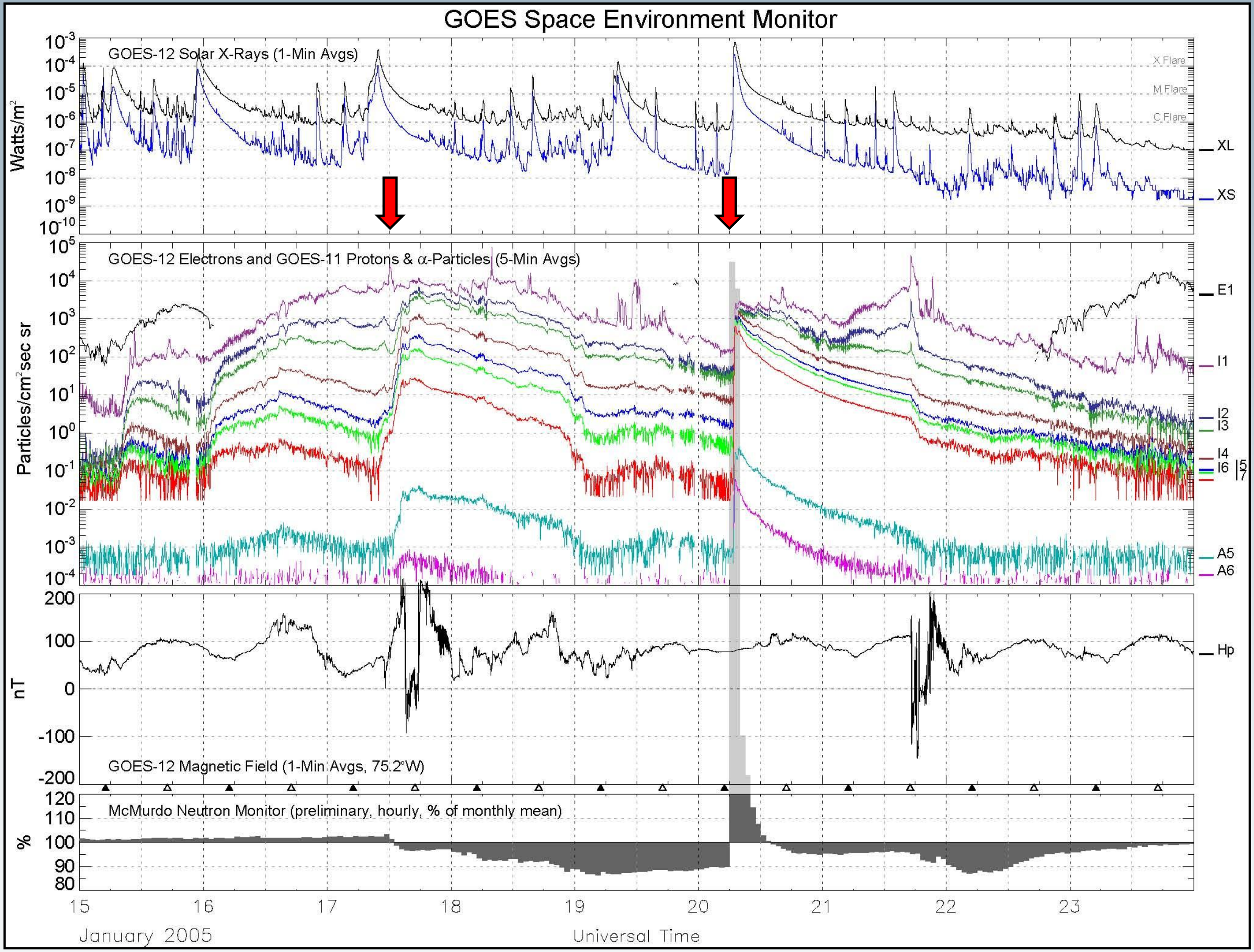
- SPE: 28, 29, 30 Oct
- Non-SPE: 22 Oct.; 9, 12, 13 Nov.

➢ changes of the background wind down to 55 km

Variation of D-region electron density with solar activity / solar proton events in

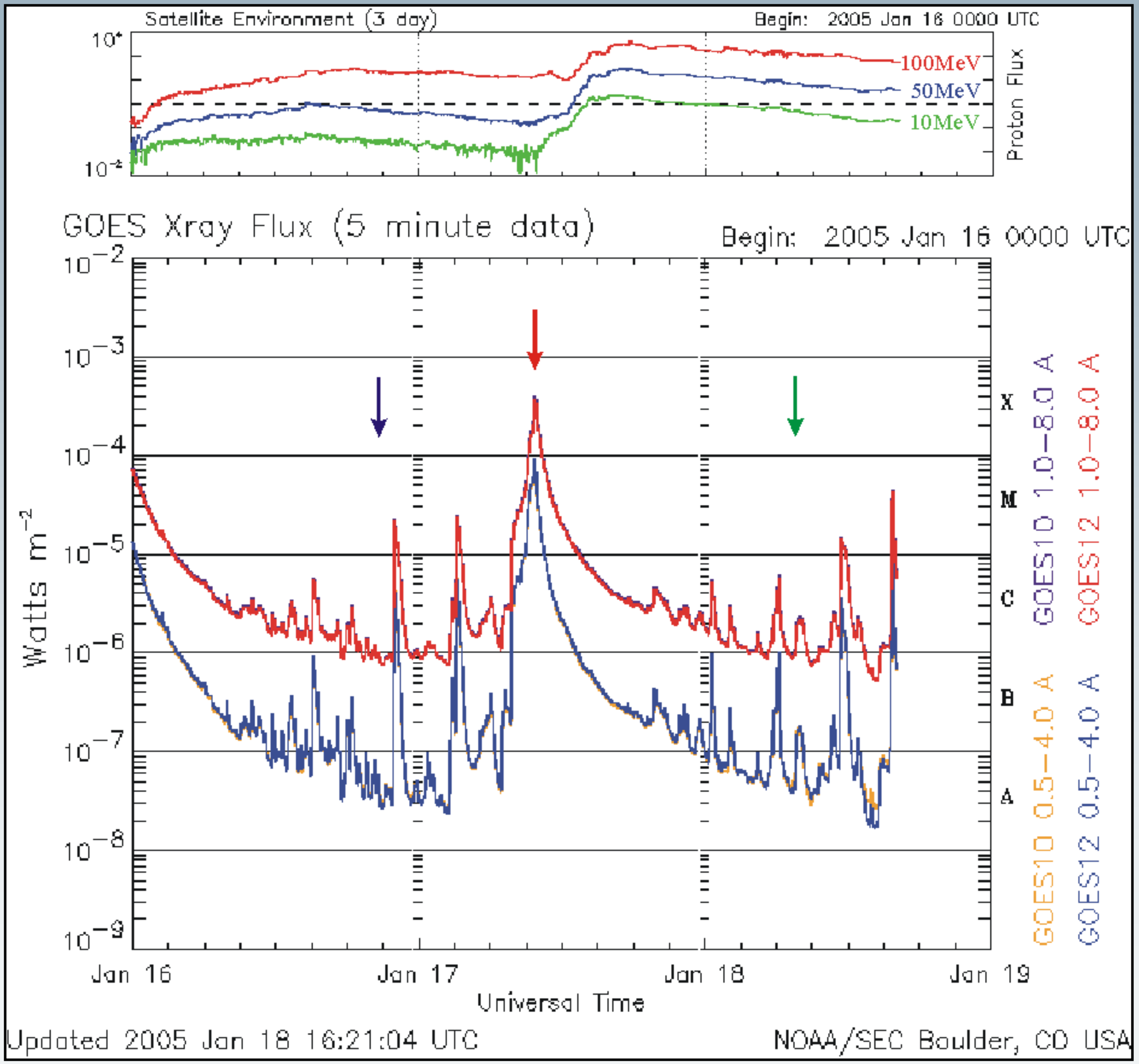
JANUARY 2005

Solar proton events in January 2005



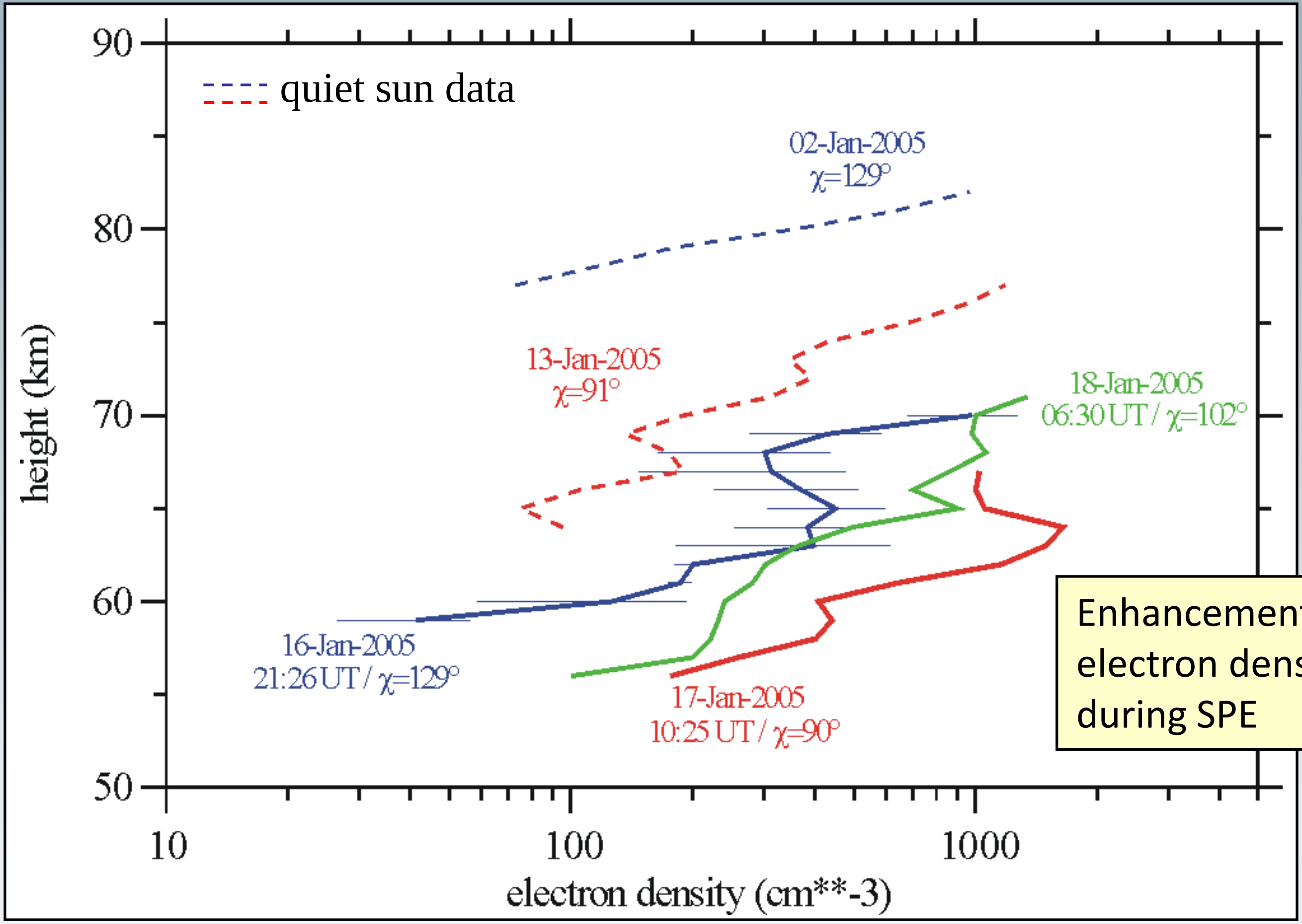
Solar proton fluxes and x-ray fluxes on January 17, 2005

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



Electron densities during SPE on January 17, 2005

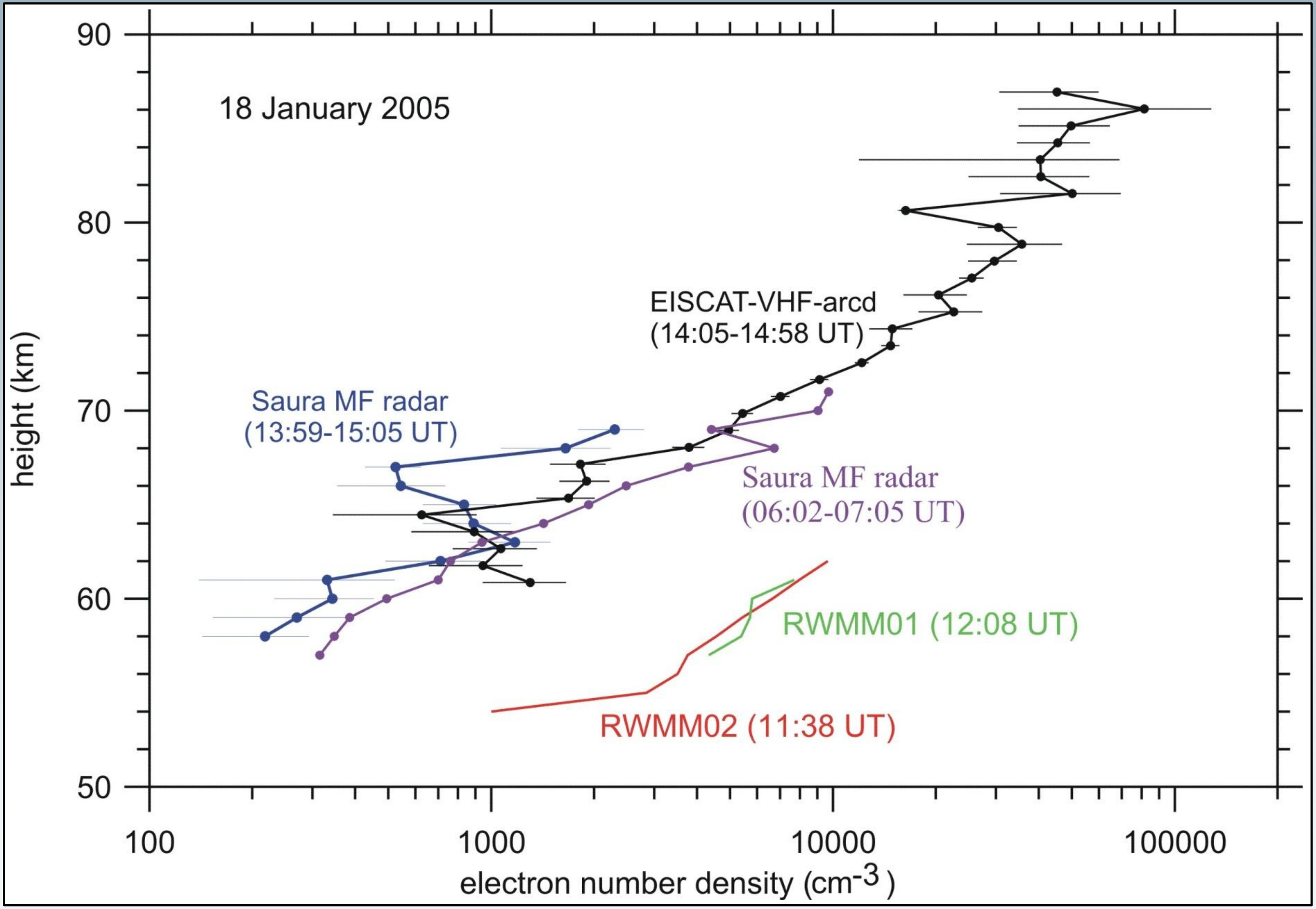
before, at the peak, and after the solar radiation storm



Enhancement of electron density during SPE

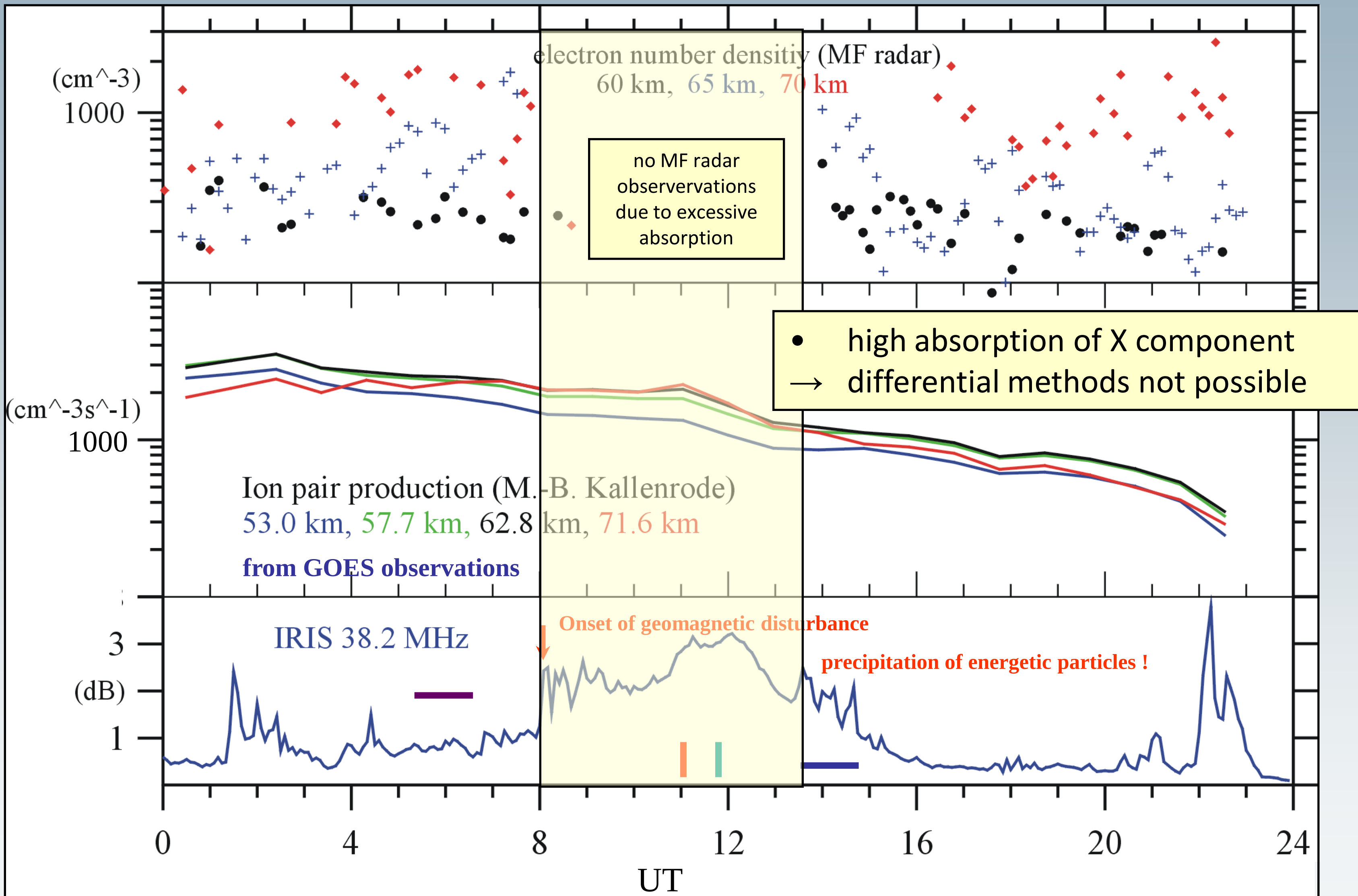
enhanced electron densities on January 18 due to enhanced proton fluxes

Electron densities by radar and insitu radio wave propagation measurements before, during, and after a geomagnetic storm on 18 January 2005



Electron densities during solar proton events (SPE)

enhanced solar and geomagnetic activity on 18 January 2005



Summary

- Neutral temperatures at ~90 km were modified during strong SPEs especially at high and middle latitudes
  - Oktober 2003 and January 2005
    - relative decrease by about 2 -10 K, lowering of the meteor peak height
    - absolute values are uncertain by about +/- ~5-10 K (T-gradient)
- Background wind / turbulence were changed between 85 and 55 km during strong SPE
  - changes in zonal wind and temperature
- SPEs are accompanied mostly with a severe geomagnetic disturbance
  - causing additional precipitation of energetic particles
  - electron densities are enhanced by one order of magnitude (or more) below 85 km during strong SPE down to altitudes of 55 km