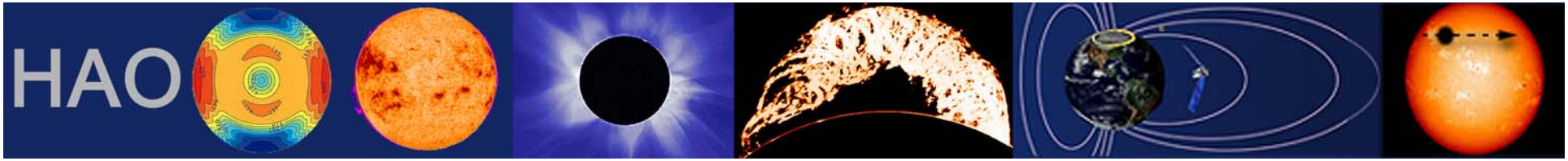


Sources of Energetic Particles and Their Impact on the Upper Atmosphere

Gang Lu and Ray Roble
High Altitude Observatory, NCAR

Dave Evans
Space Weather Prediction Center, NOAA

Charles Jackman
NASA Goddard Space Flinght Center

Xiaohua Fang
LASP, University of Colorado

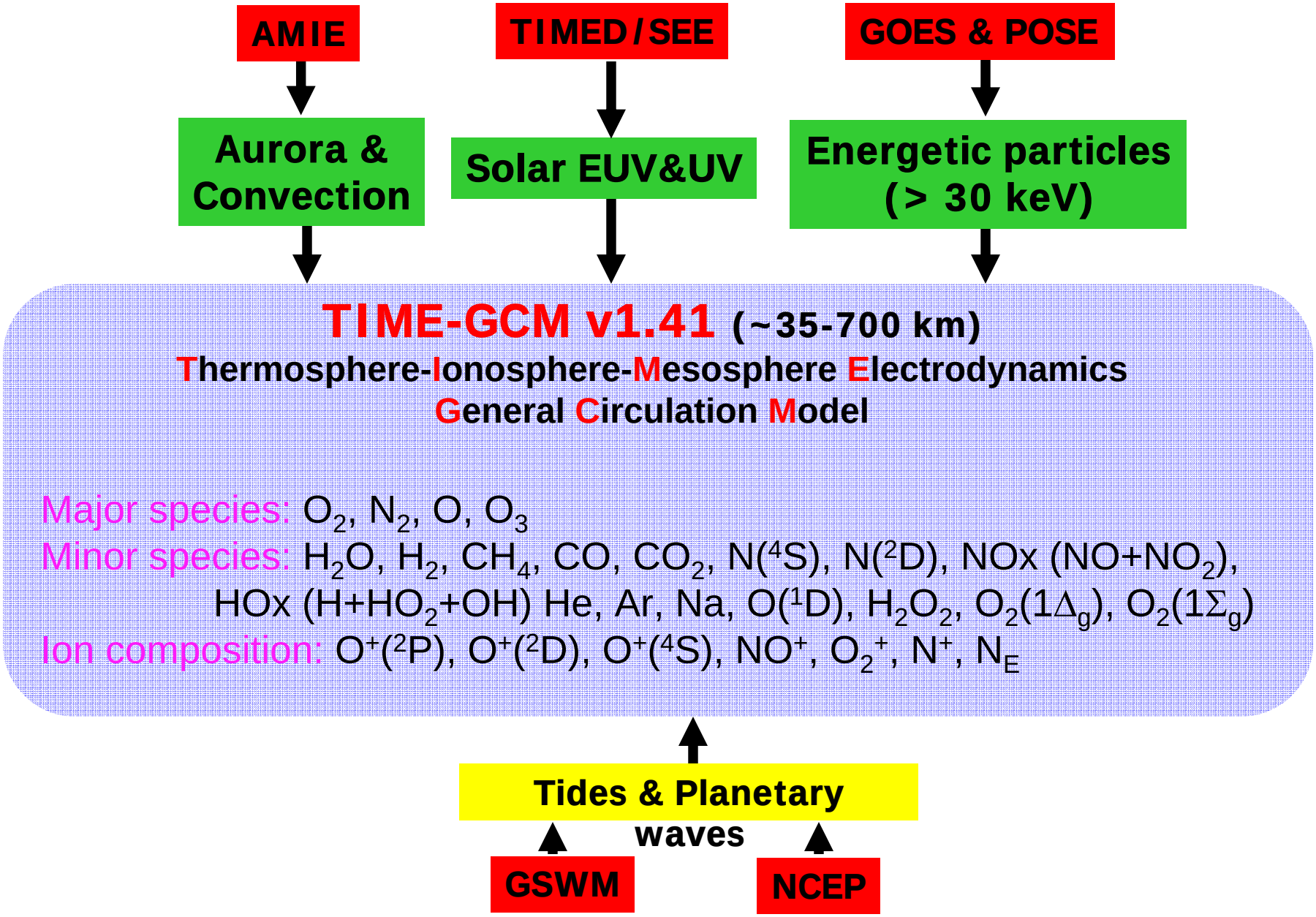
Acknowledgments: Art Richmond, Hanli Liu, and Ben Foster

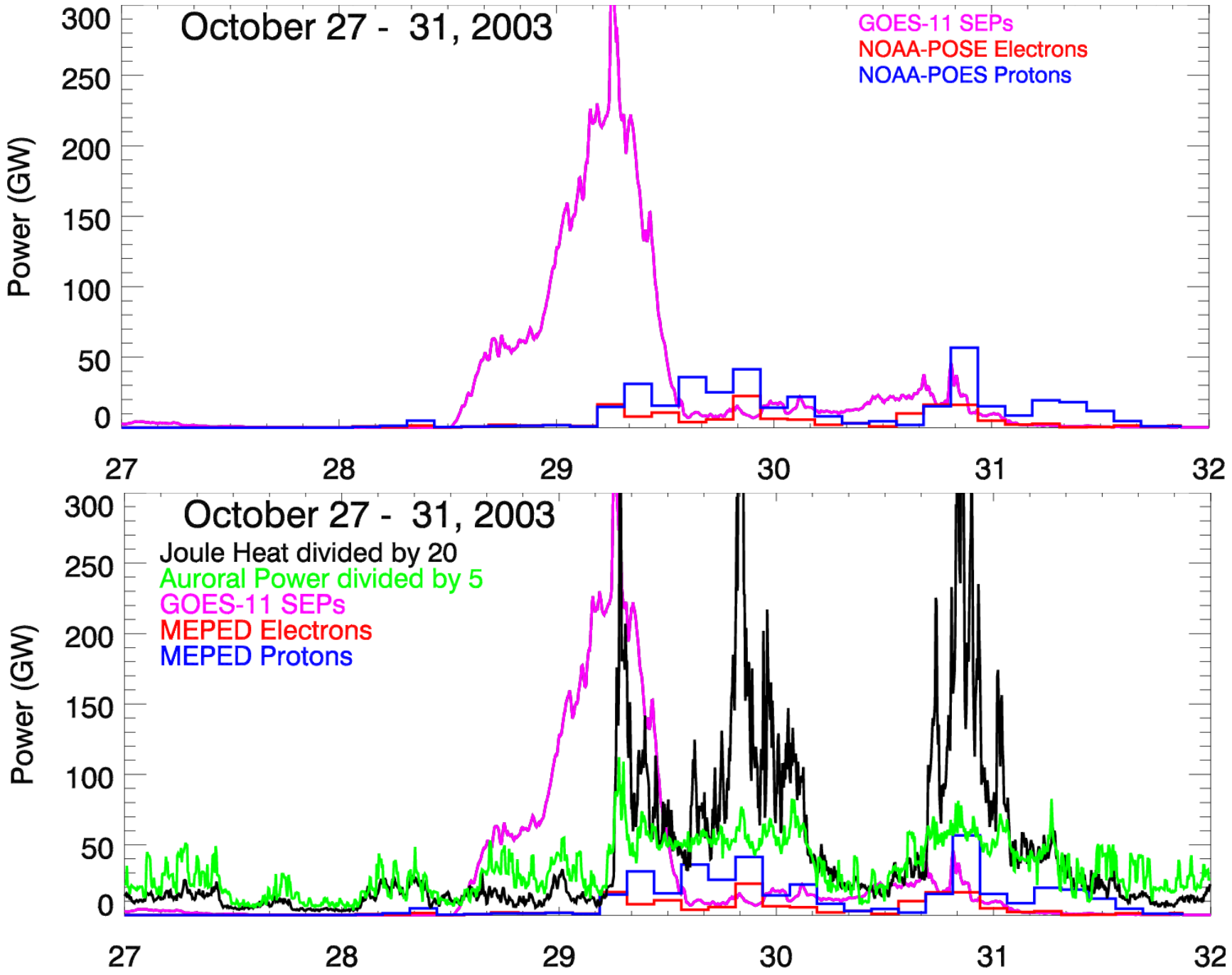
NCAR

HEPPA Workshop, October 6-8, 2009, Boulder, Colorado

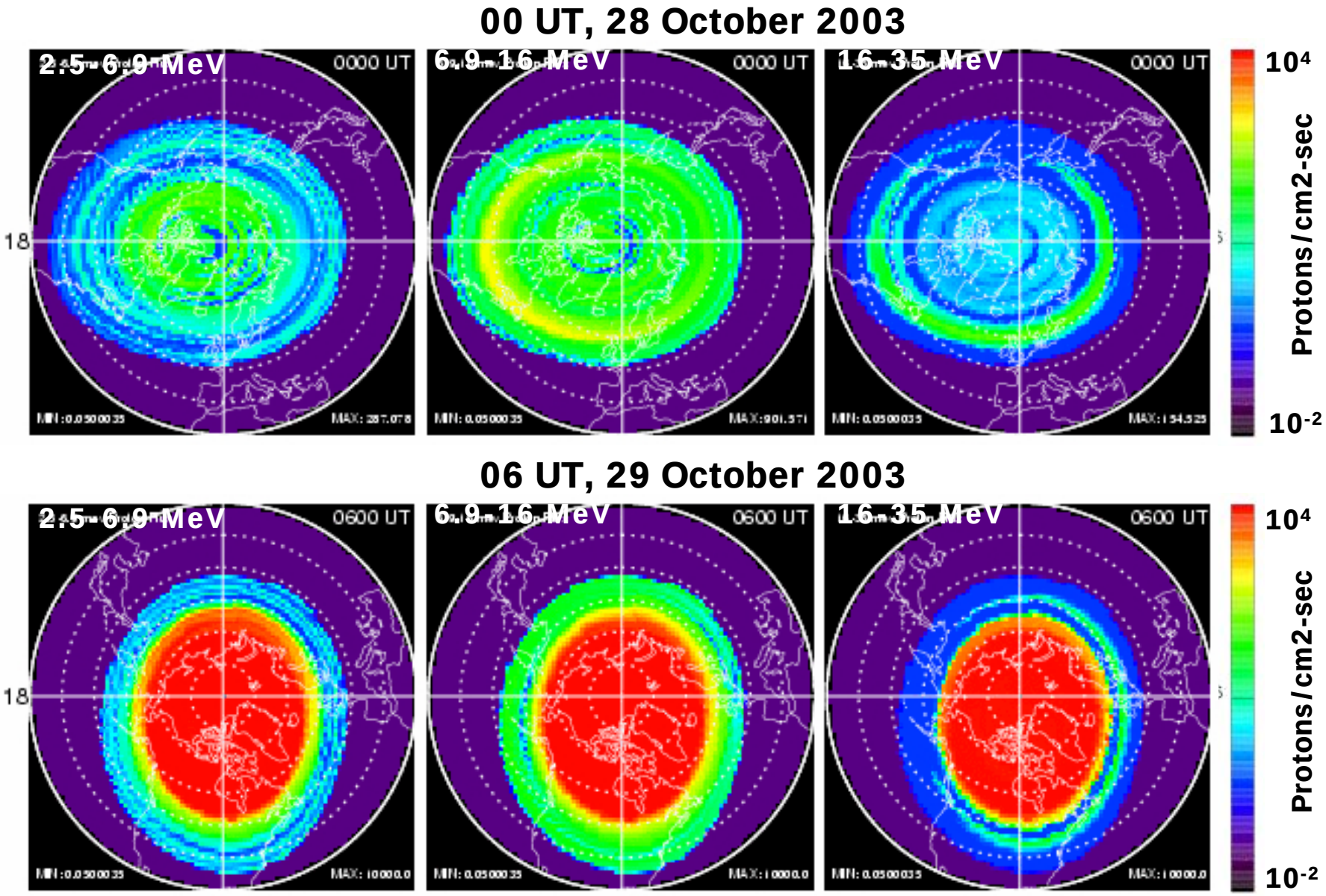
Outline

- Brief Overview of the TIME-GCM
- Sources, Distributions, and Impact of Energetic Particles
- Investigation of the Spring 2004 "Anomaly"
- Summary


AMIE
TIMED/SEE
GOES & POSE
Aurora & Convection
Solar EUV&UV
Energetic particles (> 30 keV)
TIME-GCM v1.41 (~35-700 km)
Thermosphere-Ionosphere-Mesosphere Electrodynamics General Circulation Model
Major species: O_2, N_2, O, O_3
Minor species: H_2O, H_2, CH_4, CO, CO_2, $N(^4S)$, $N(^2D)$, NOx (NO+NO_2), HOx (H+HO_2+OH) He, Ar, Na, $O(^1D)$, H_2O_2, $O_2(1\Delta_g)$, $O_2(1\Sigma_g)$
Ion composition: $O^+(^2P)$, $O^+(^2D)$, $O^+(^4S)$, NO^+, O_2^+, N^+, N_E
Tides & Planetary waves
GSWM
NCEP

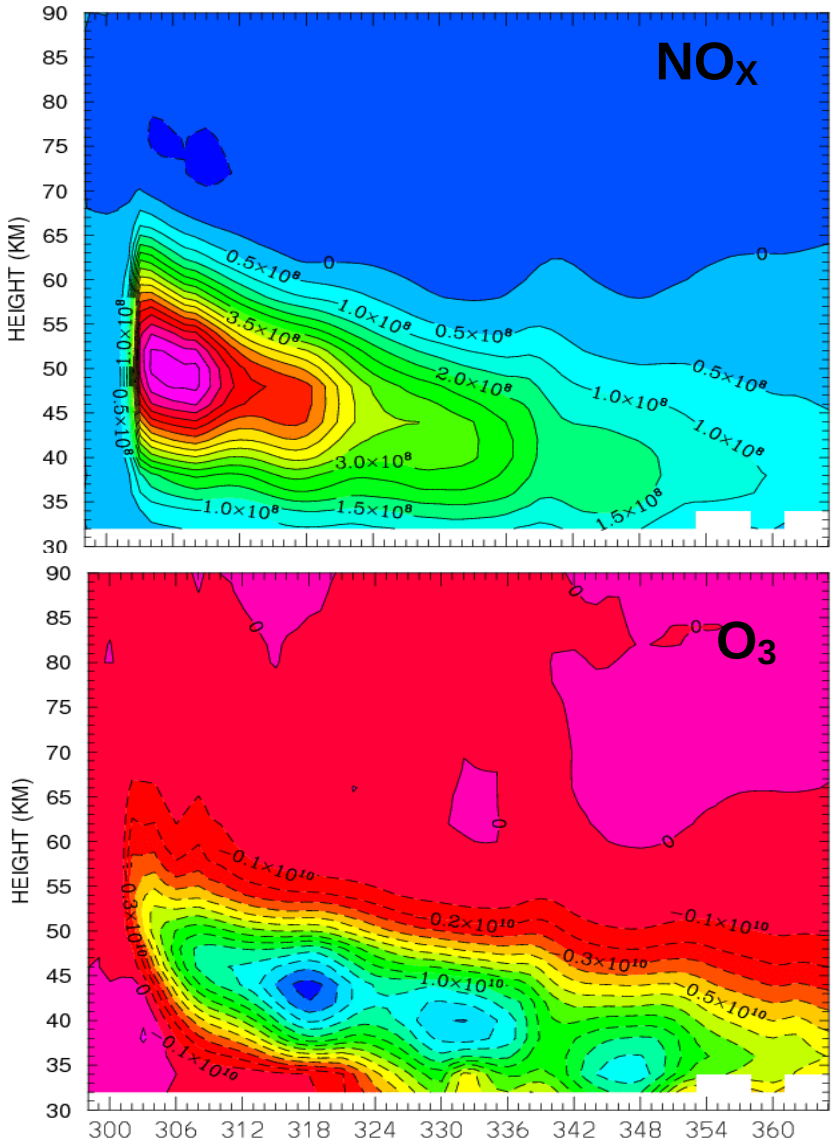

October 27 - 31, 2003
GOES-11 SEPs
NOAA-POSE Electrons
NOAA-POES Protons
Power (GW)
300
250
200
150
100
50
0
27
28
29
30
31
32
October 27 - 31, 2003
Joule Heat divided by 20
Auroral Power divided by 5
GOES-11 SEPs
MEPED Electrons
MEPED Protons
Power (GW)
300
250
200
150
100
50
0
27
28
29
30
31
32

Solar Energetic Protons Observed by NOAA-POES



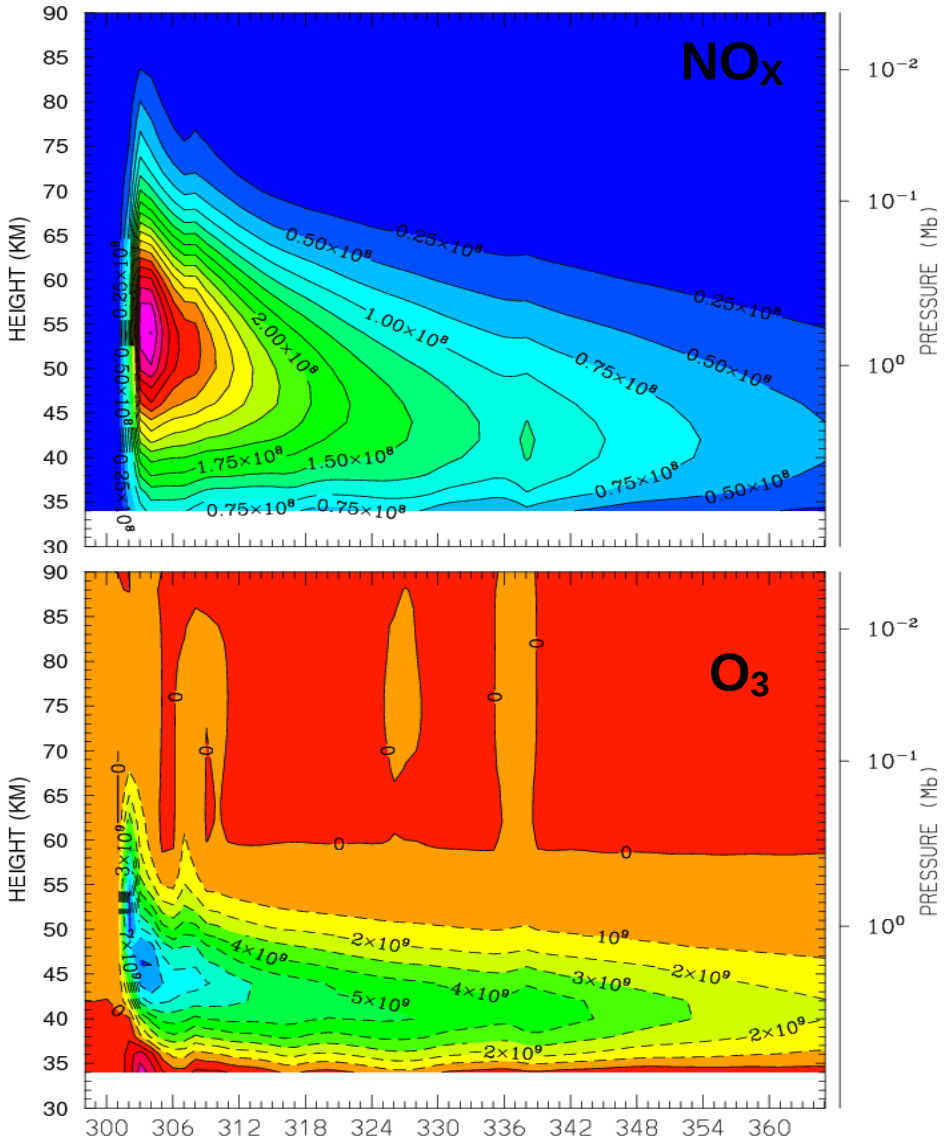
Changes of NO_X ($NO+NO_2$) and Ozone due to SEPs

Northern Polar Cap



October 27 – December 31, 2003

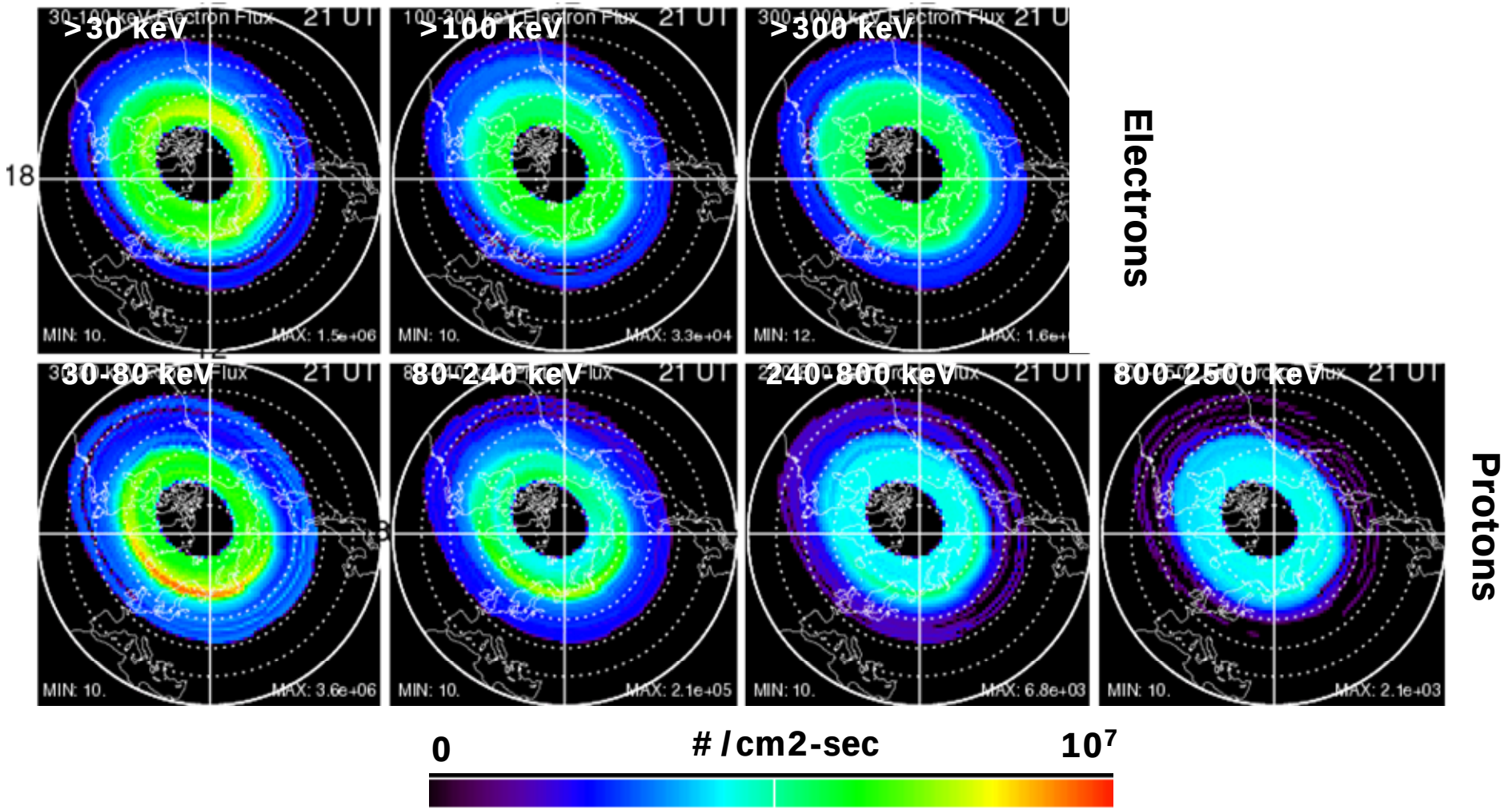
Southern Polar Cap



October 27 – December 31, 2003

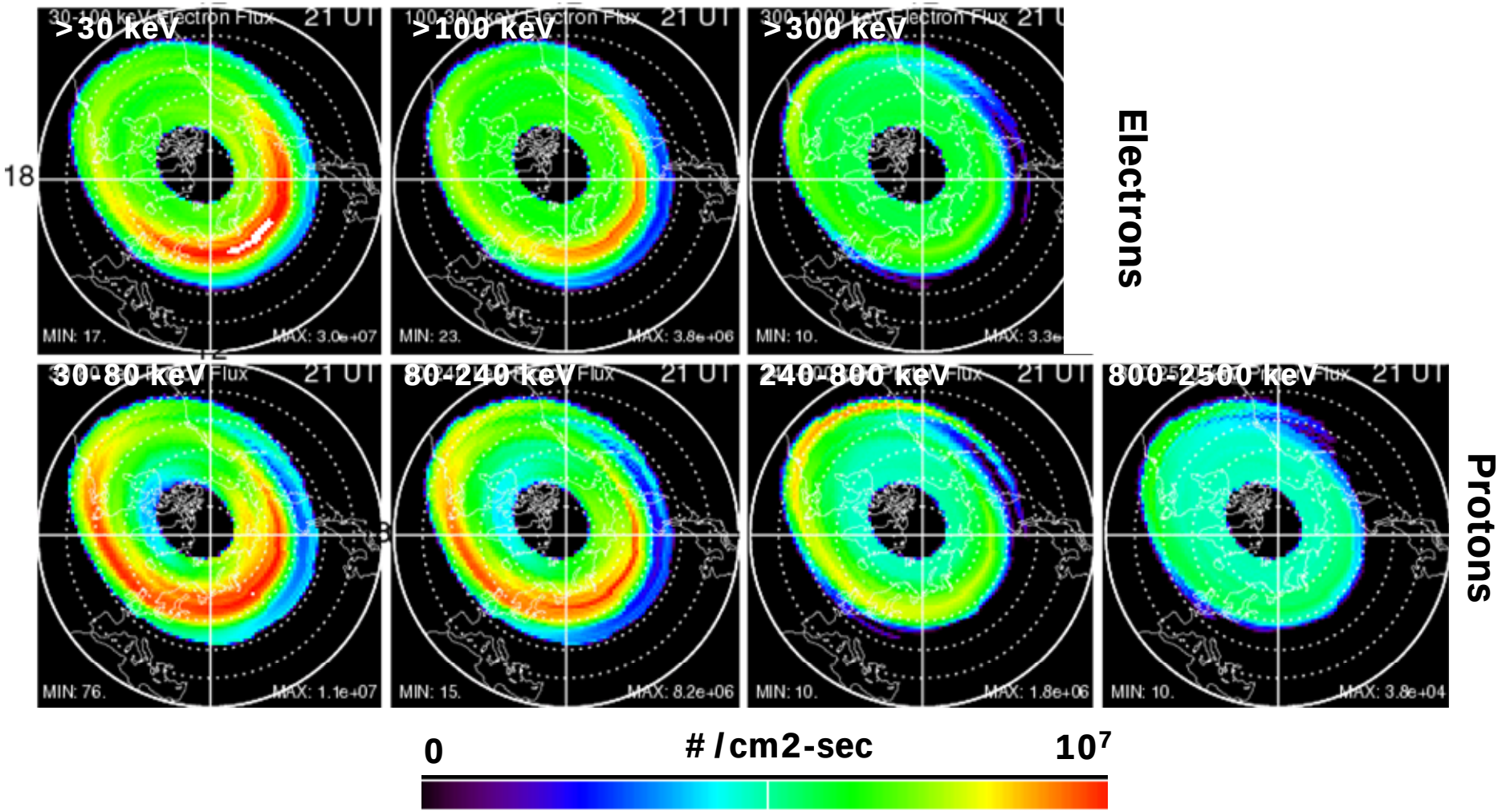
Energetic Particles Observed by POES/MEPED

21 UT, 28 October 2003

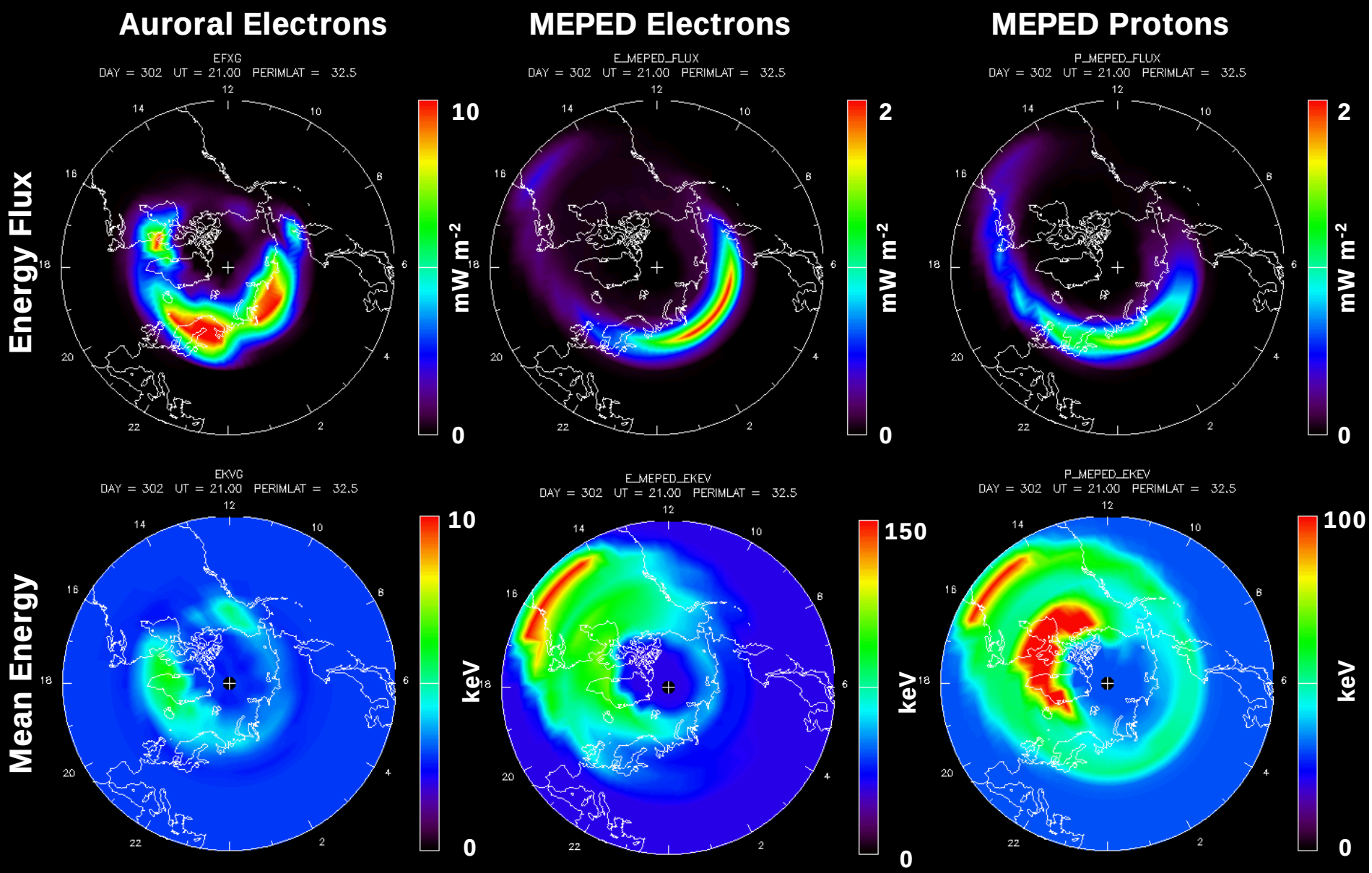


Energetic Particles Observed by POES/MEPED

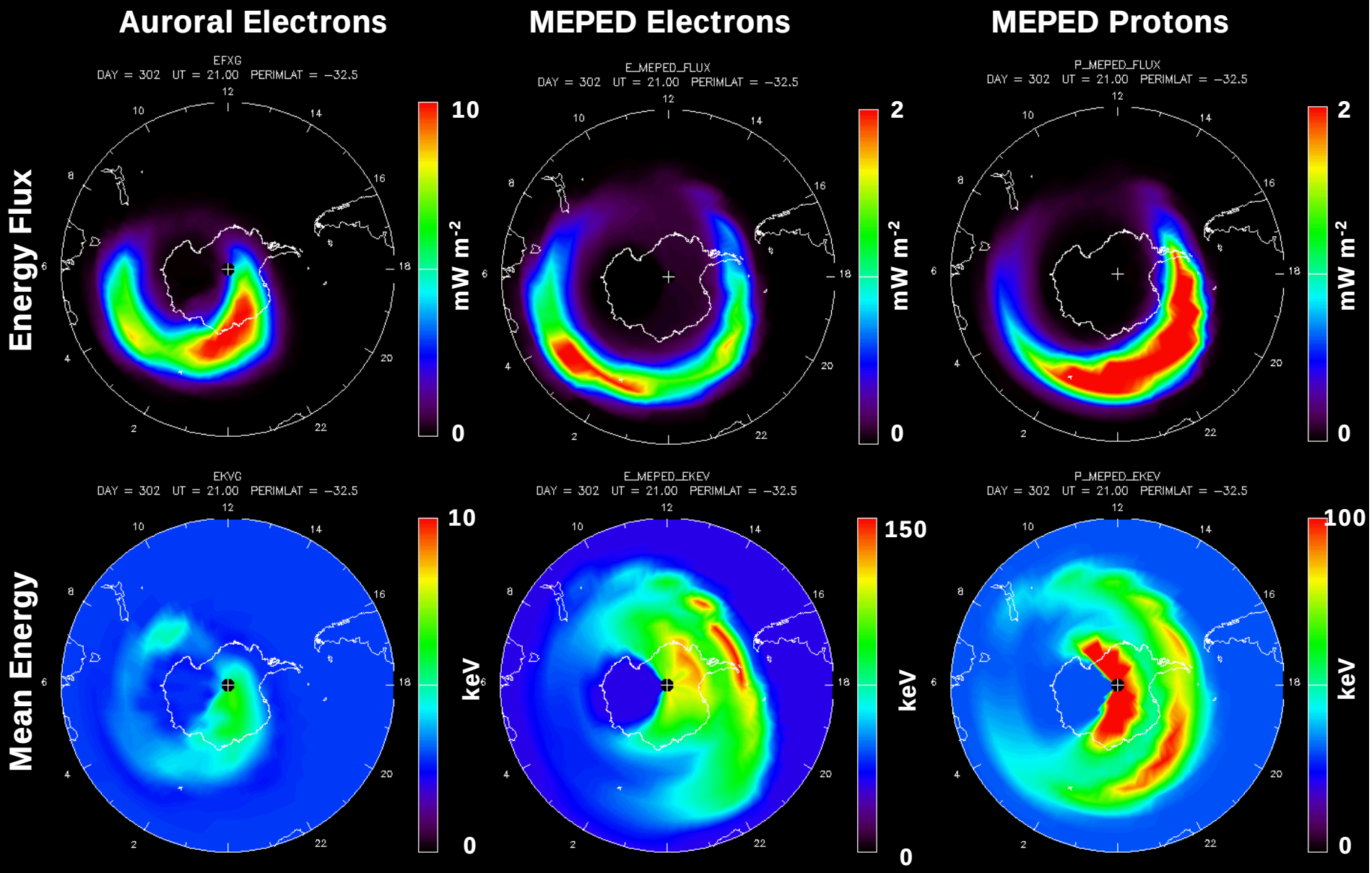
21 UT, 29 October 2003



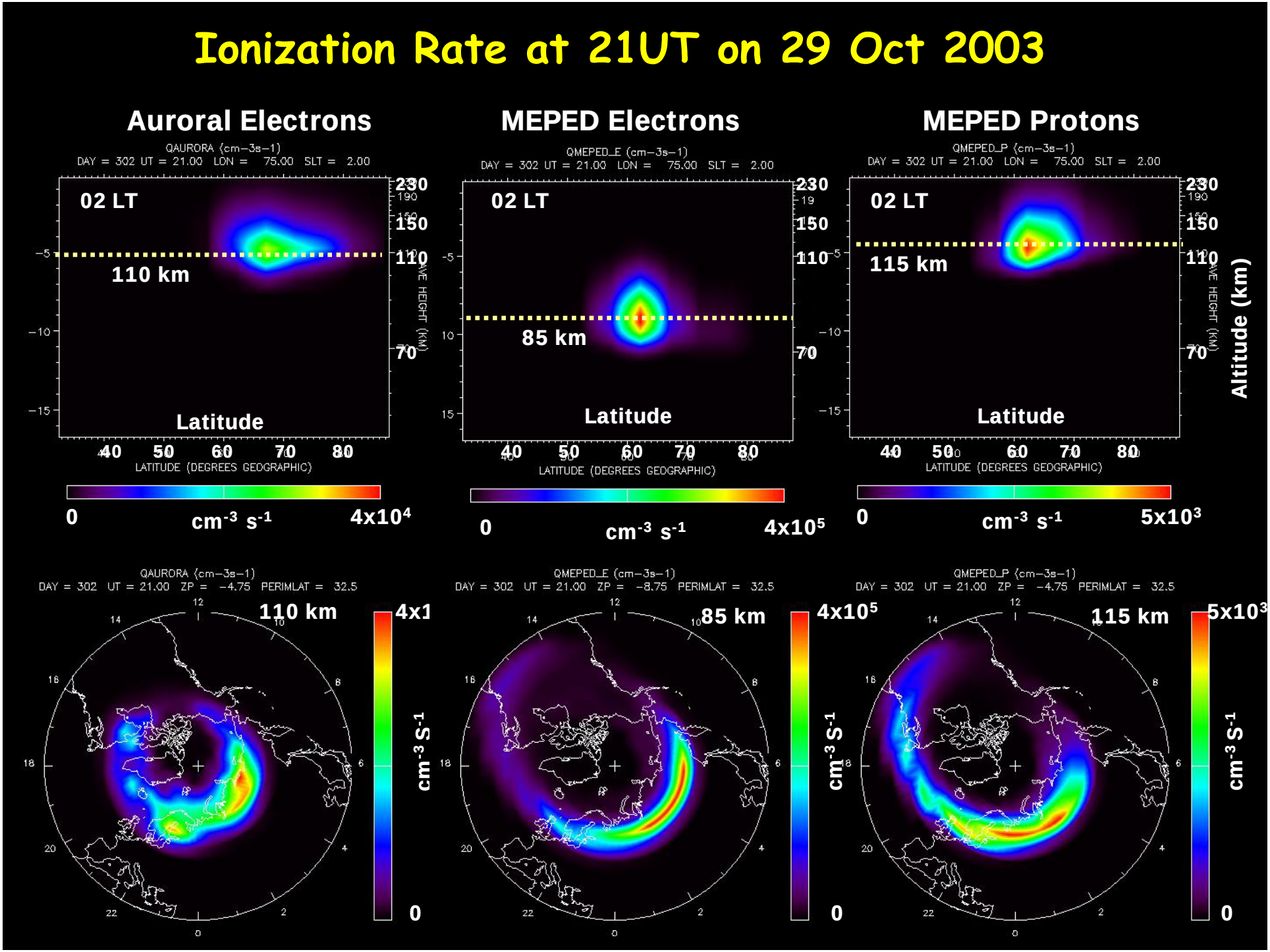
Distributions at 21UT on 29 Oct. 2003 - North



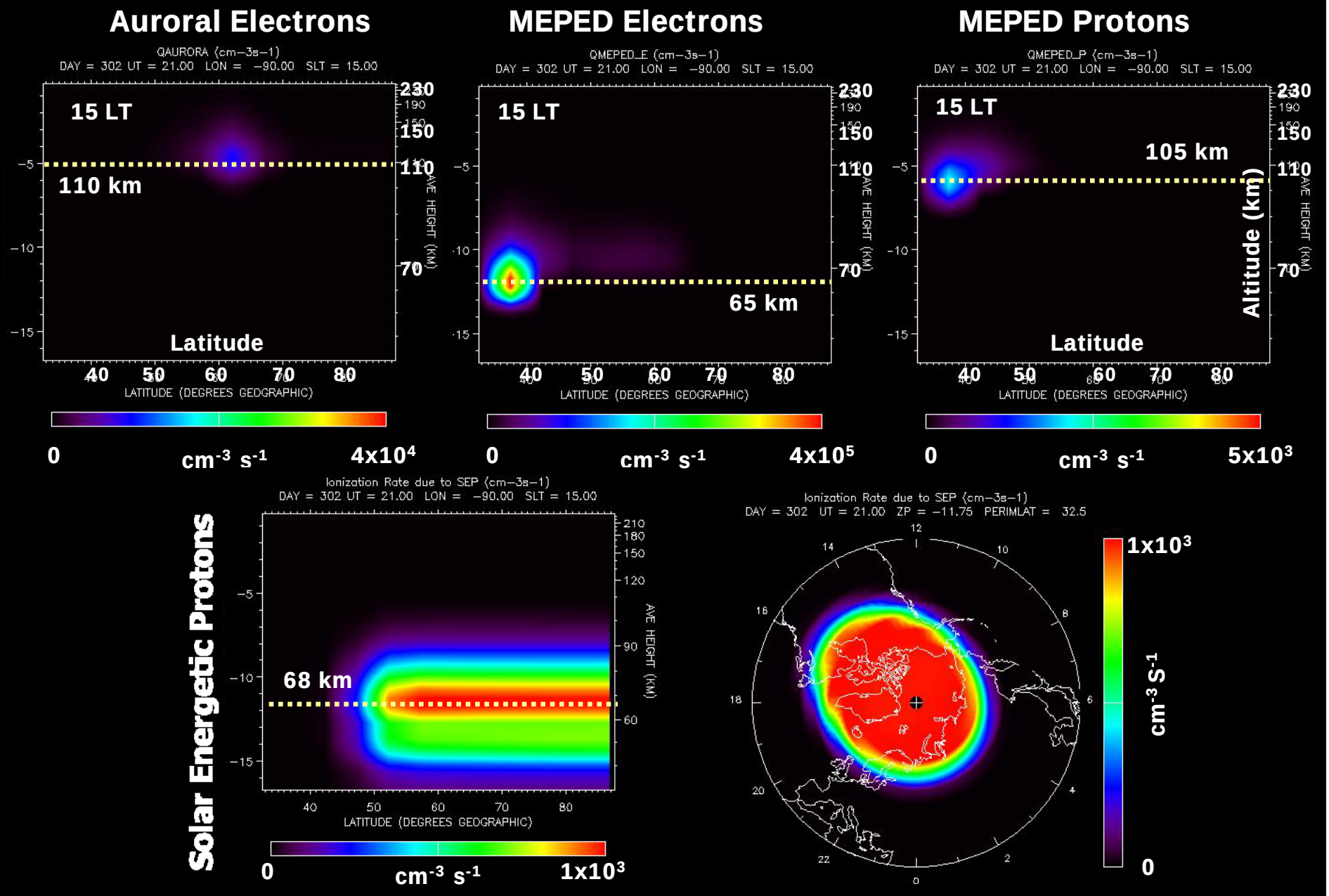
Distributions at 21UT on 29 Oct. 2003 - South



Ionization Rate at 21UT on 29 Oct 2003

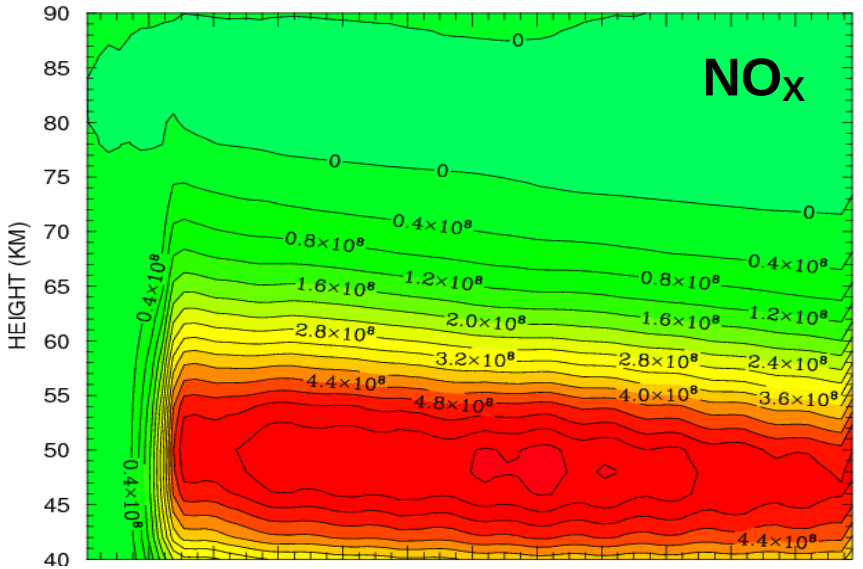


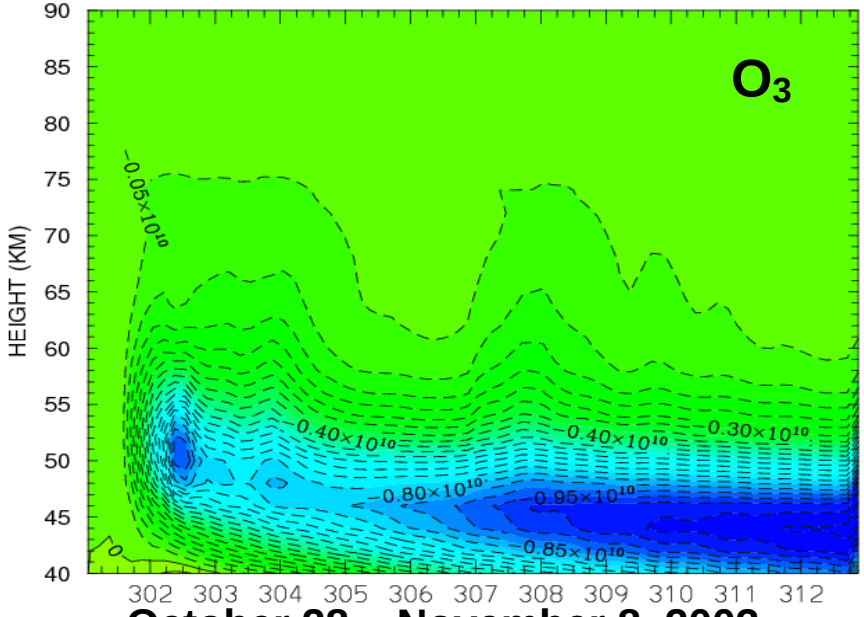
Ionization Rate at 21UT on 29 Oct 2003



Relative Effects on the Upper Atmosphere

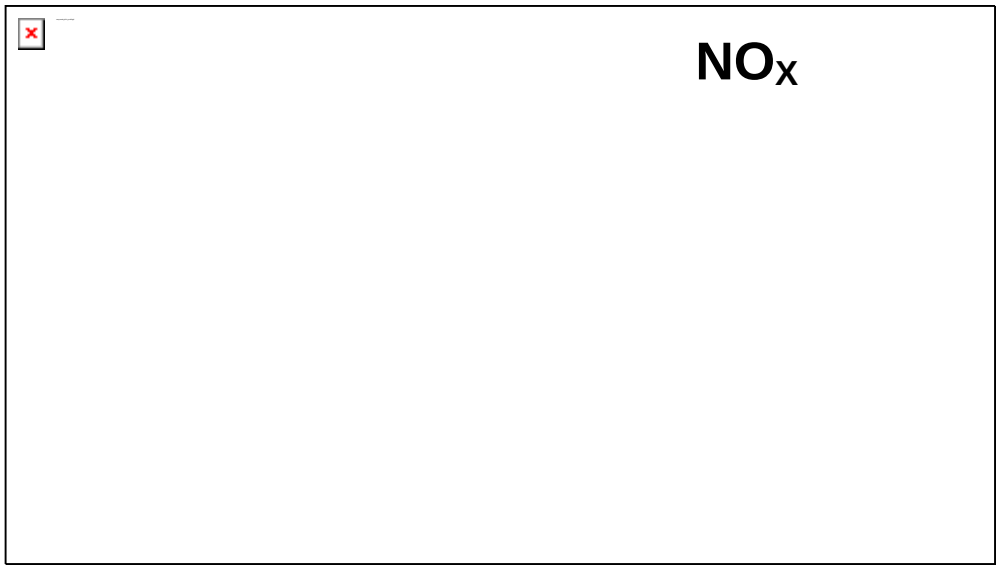
SEP Effects

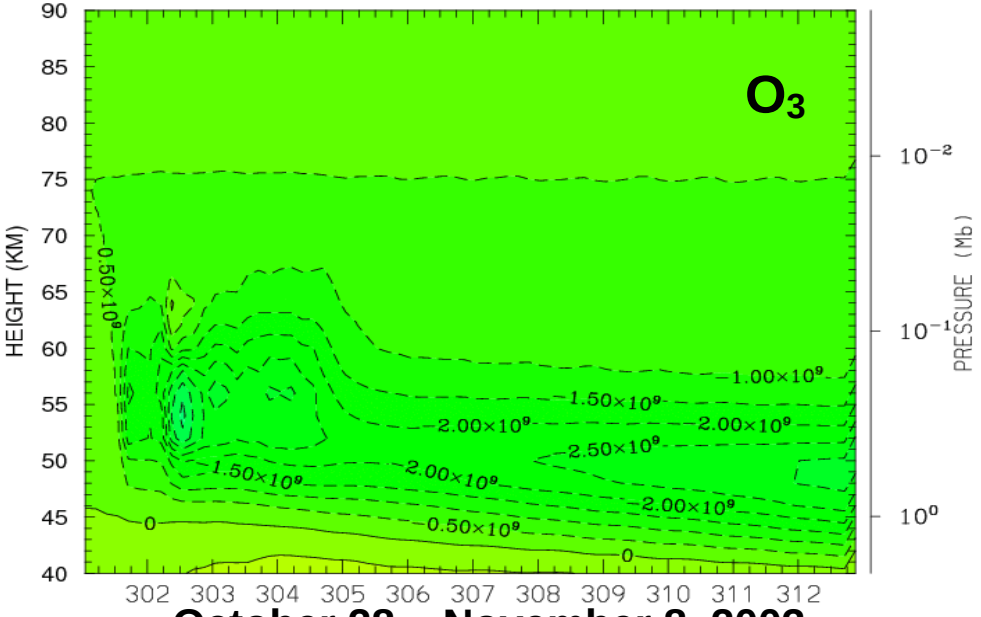




October 28 – November 8, 2003

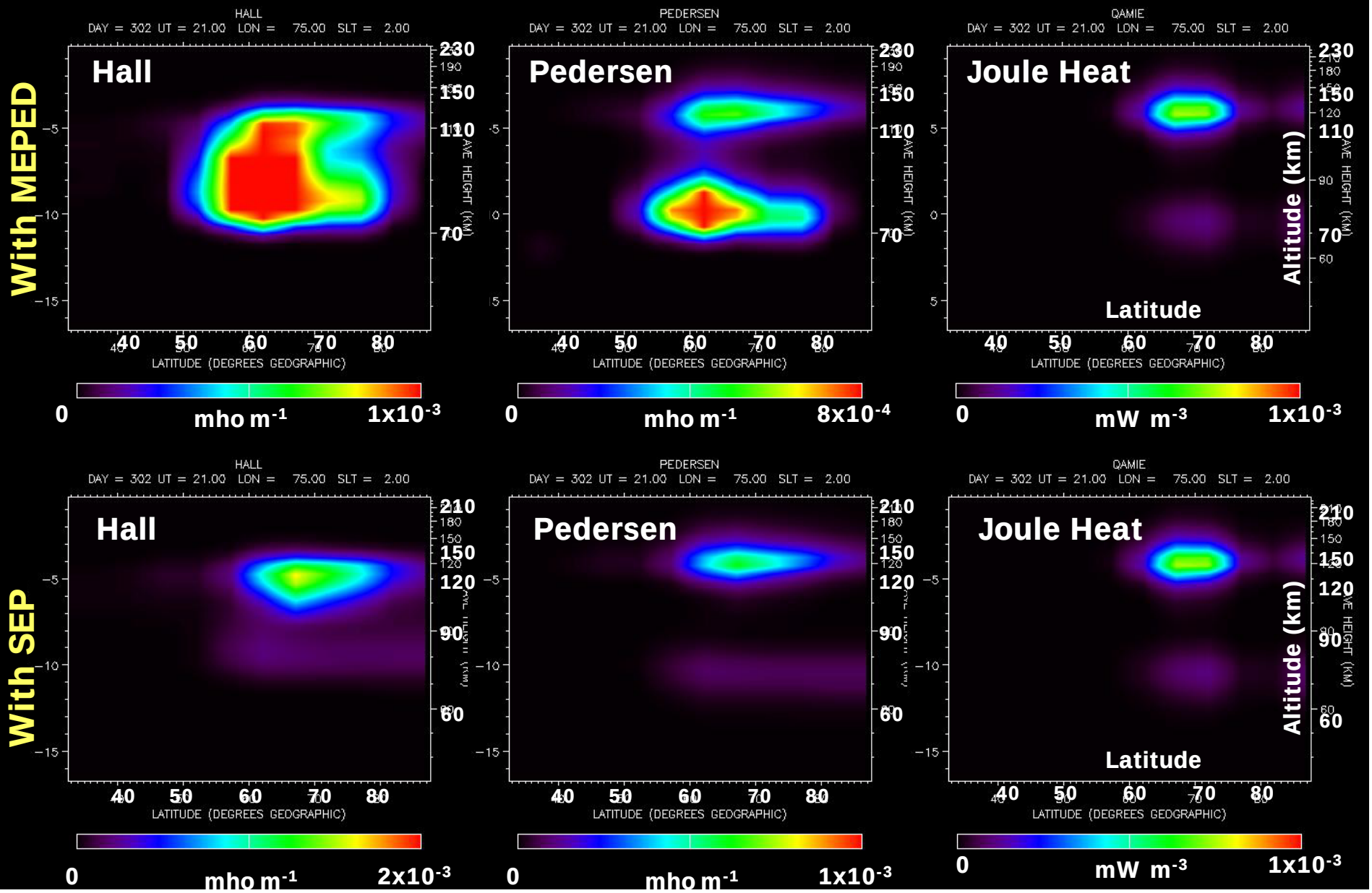
Energetic Electron Effects



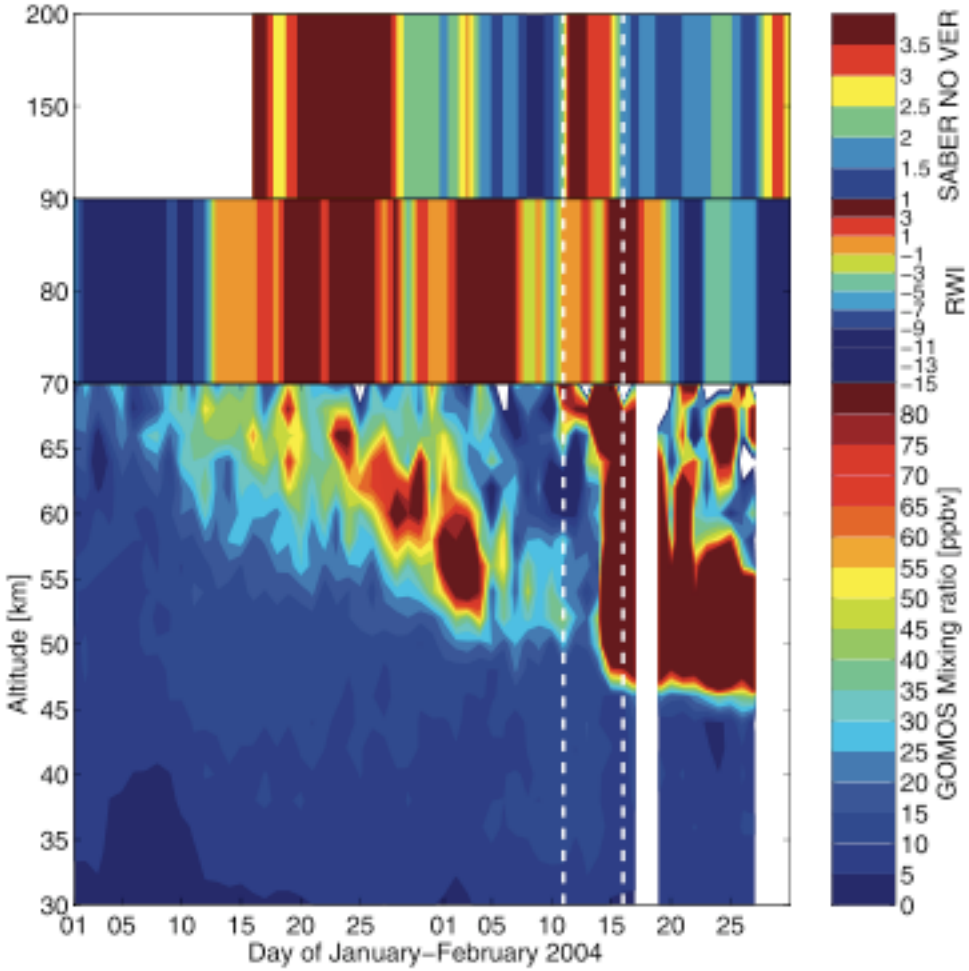


October 28 – November 8, 2003

Relative Effects on the Ionosphere at 02 LT, 21UT on 29 Oct 2003



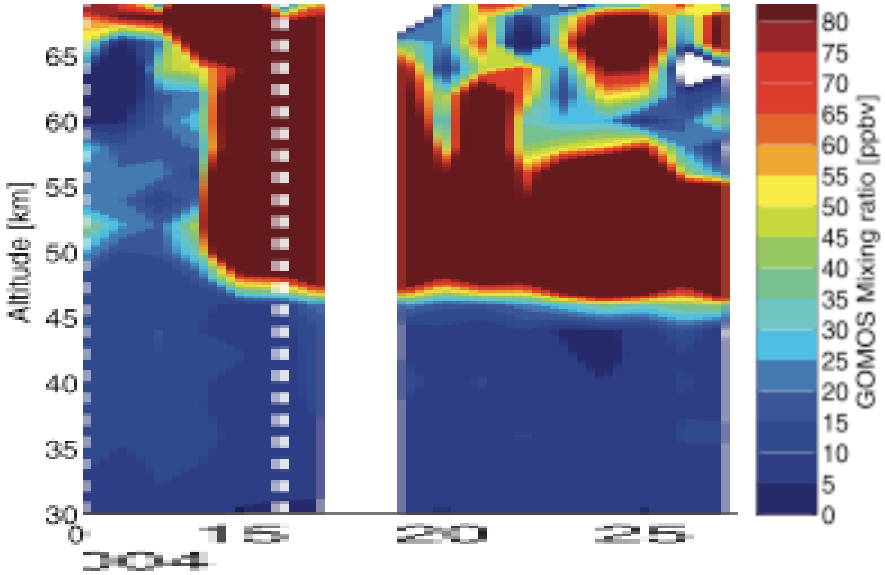
GOMOS NO_2 production by relativistic electrons



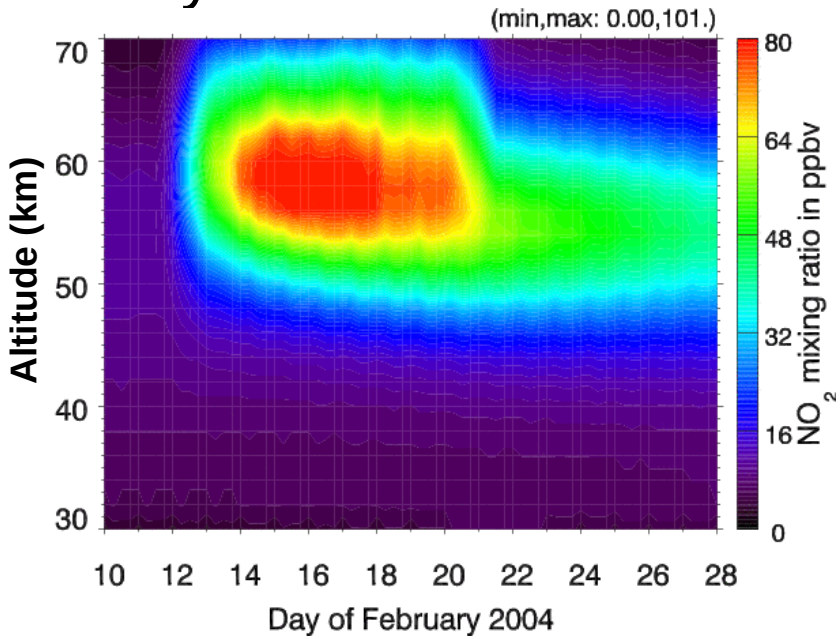
[Clilverd et al., 2008]

Comparison of GOMOS & TIME-GCM NO_2 Produced by Energetic Electrons

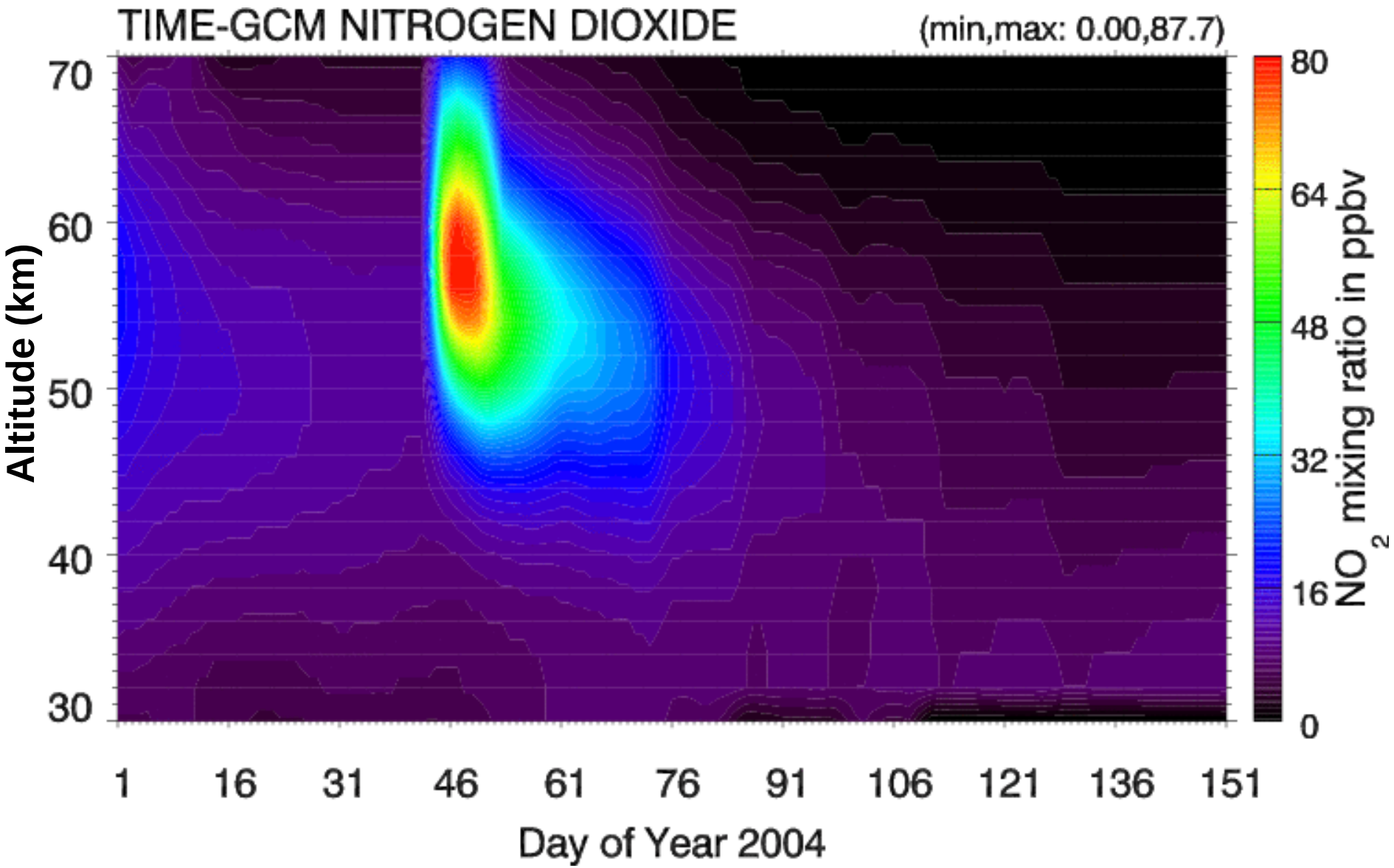
GOMOS NO_2 production by relativistic electrons



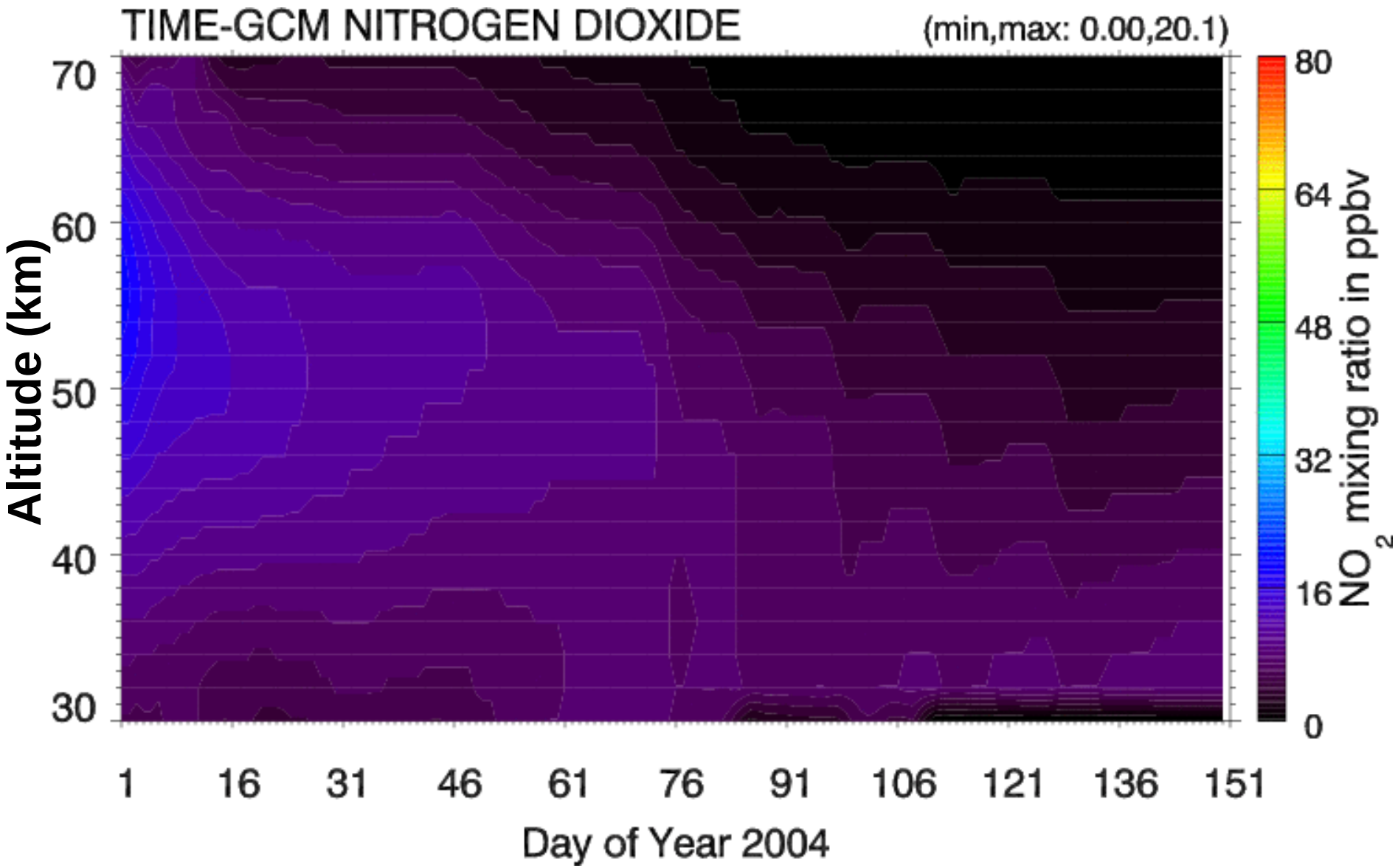
TIME-GCM NO_2 production by MEPED electrons



TIME-GCM NO_2 with MEPED electrons



TIME-GCM NO_2 without MEPED electrons

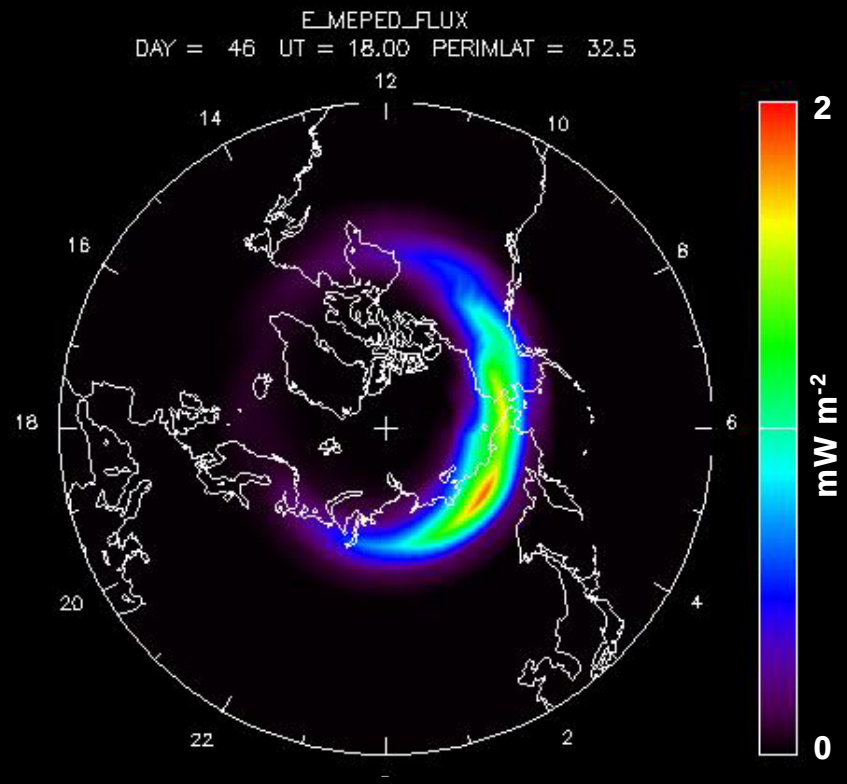


Summary

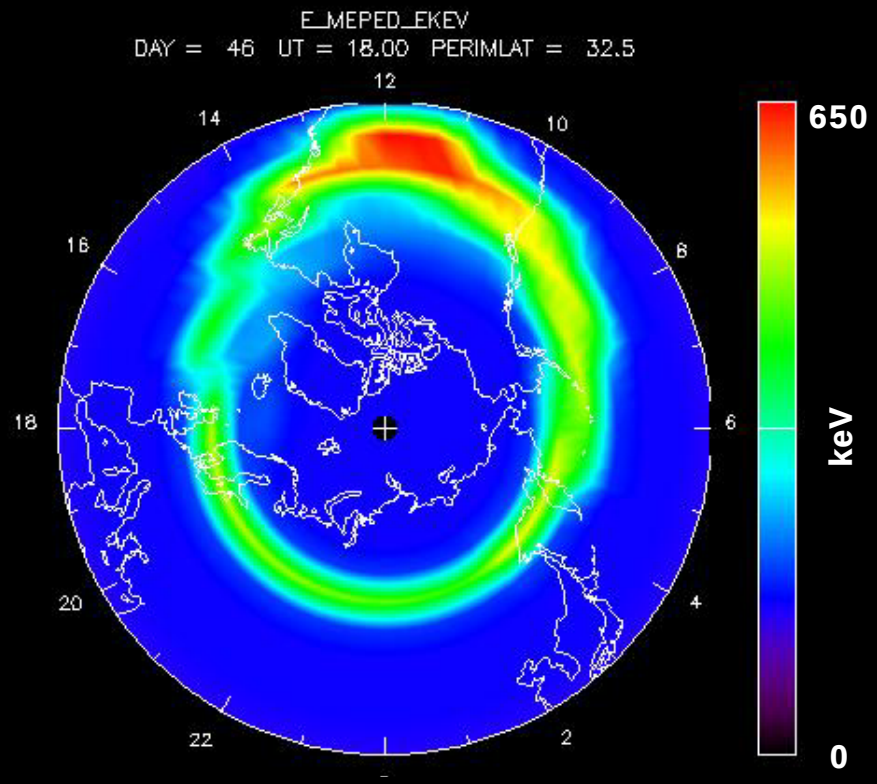
- Energetic particles of various solar and magnetospheric sources have drastically different characteristics, and an accurate specification of EPP is of critical importance to upper atmospheric modeling
- Since the Altitude where energetic particles dissipate depends strongly on the characteristic energy, energetic particles of different origins can have different effects on the upper atmosphere
- Using realistic specification of energetic particle inputs, the TIME-GCM is able to replicate qualitatively the observed Spring 2004 "Anomaly" associated with the ring current energetic electrons

Distributions at 18UT on Feb. 15, 2004

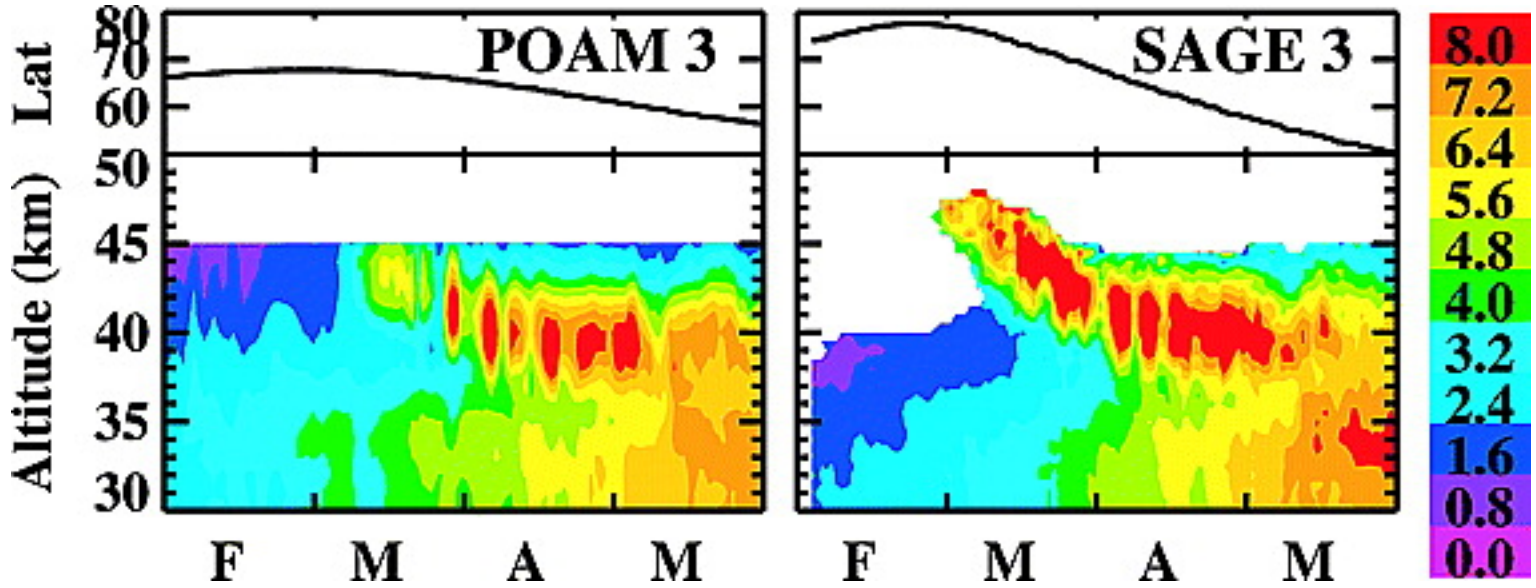
Electrons Energy Flux



Electrons Mean Energy



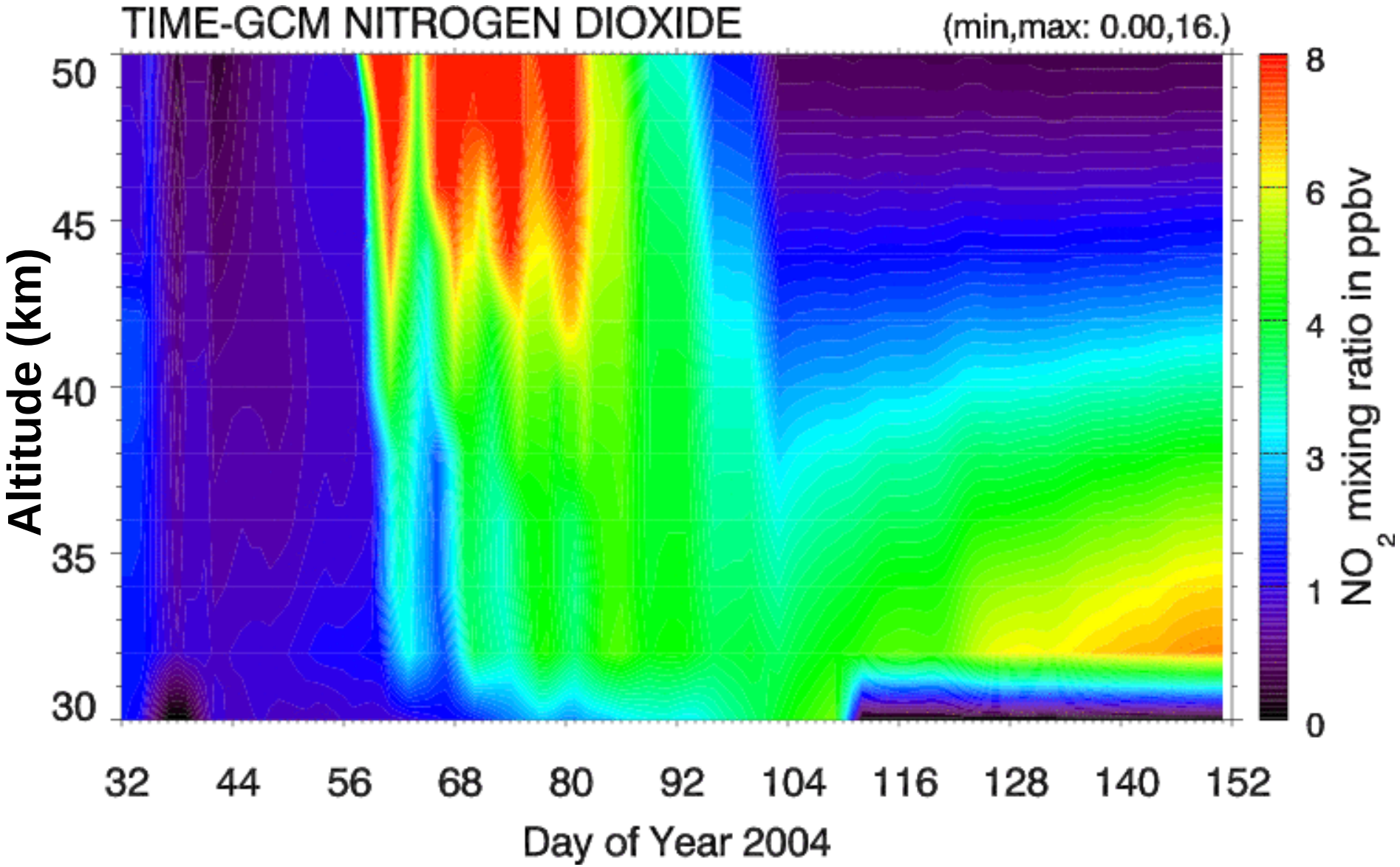
Observed NO_2 mixing ratio (in ppbv)



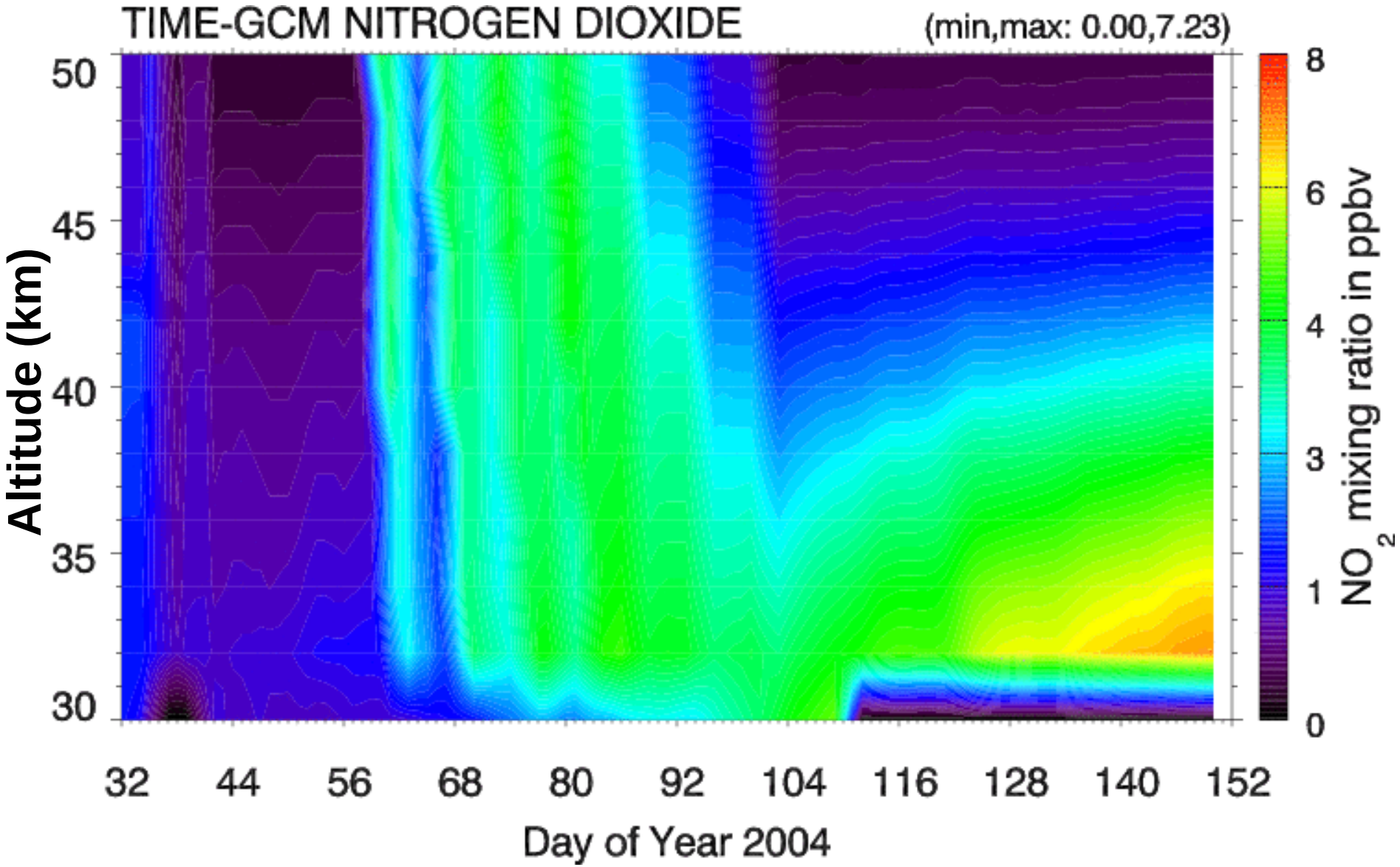
February 1 – May 31, 2004

[Randall et al., 2005]

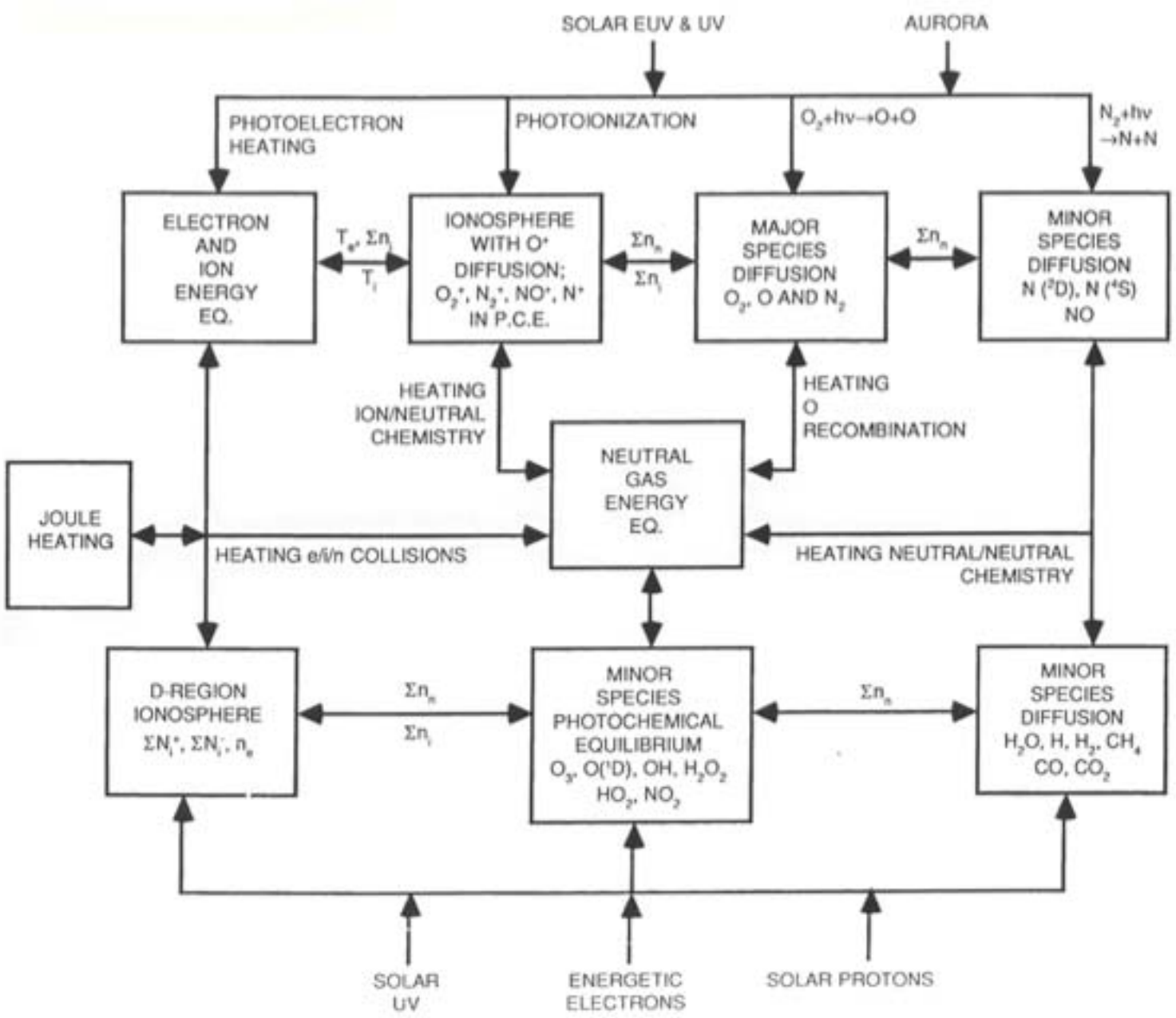
NO_2 production with SEP+MEPED electrons



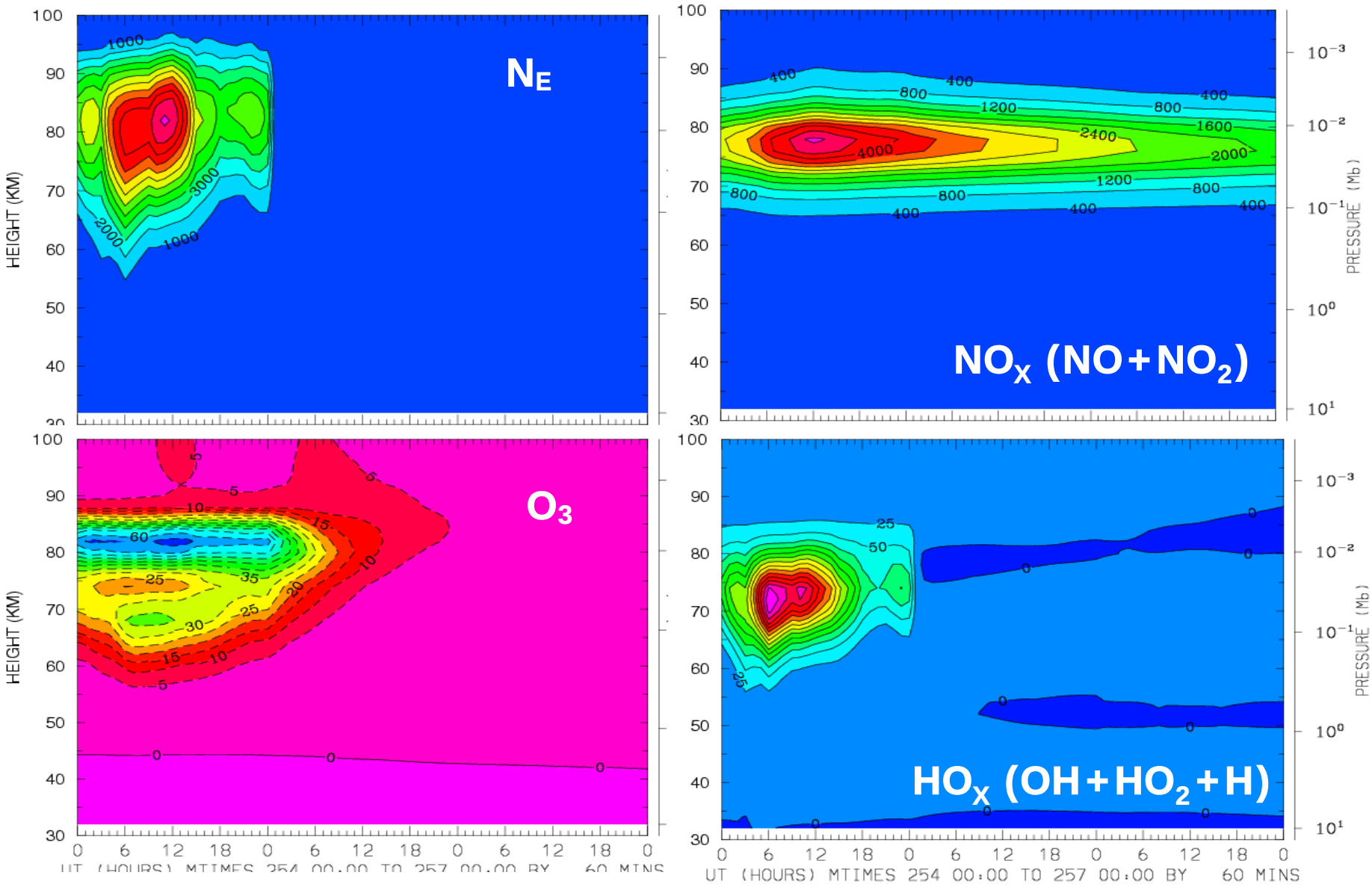
NO_2 without MEPED electrons



Chemical and Dynamical Processes in the TIME-GCM

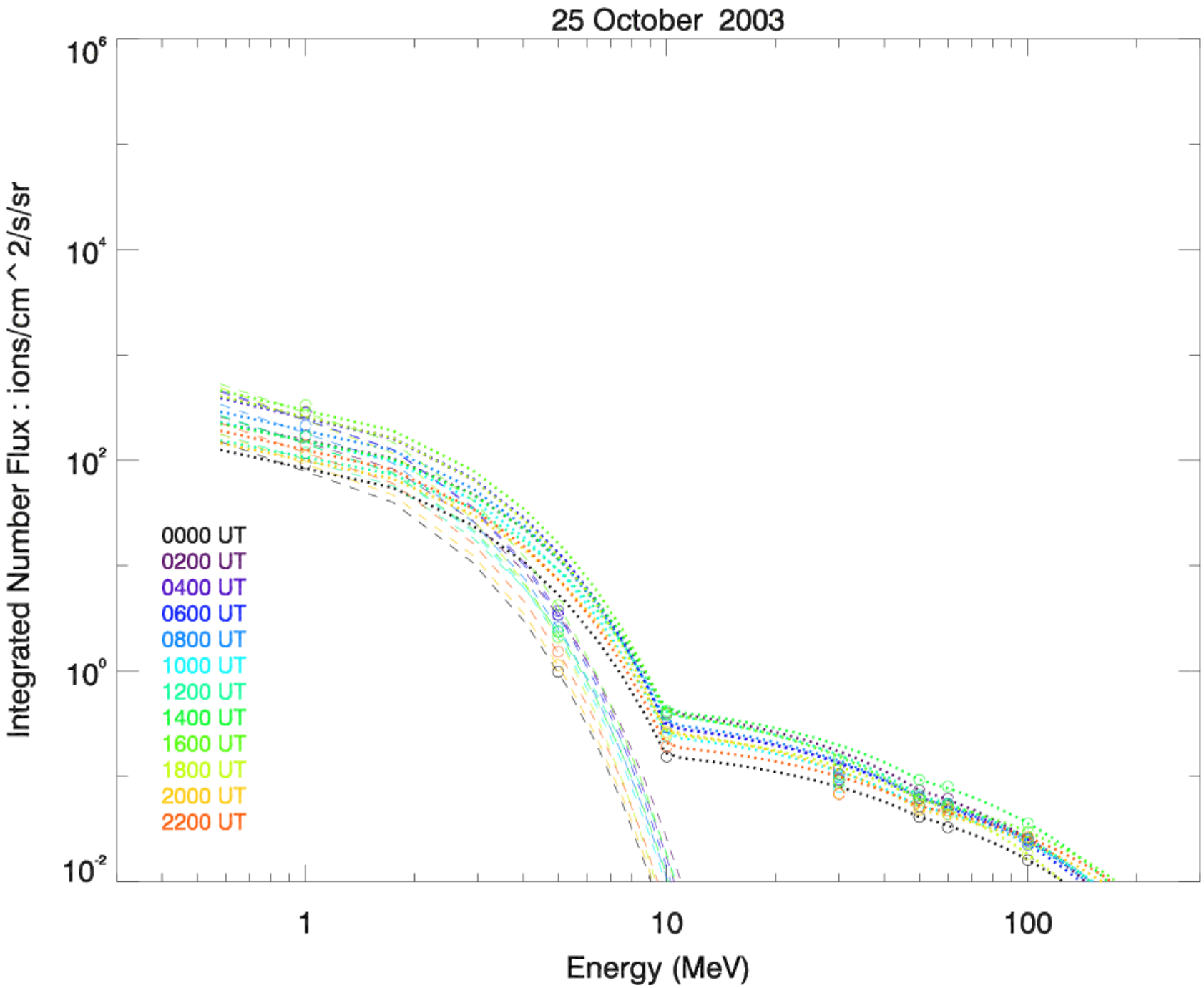


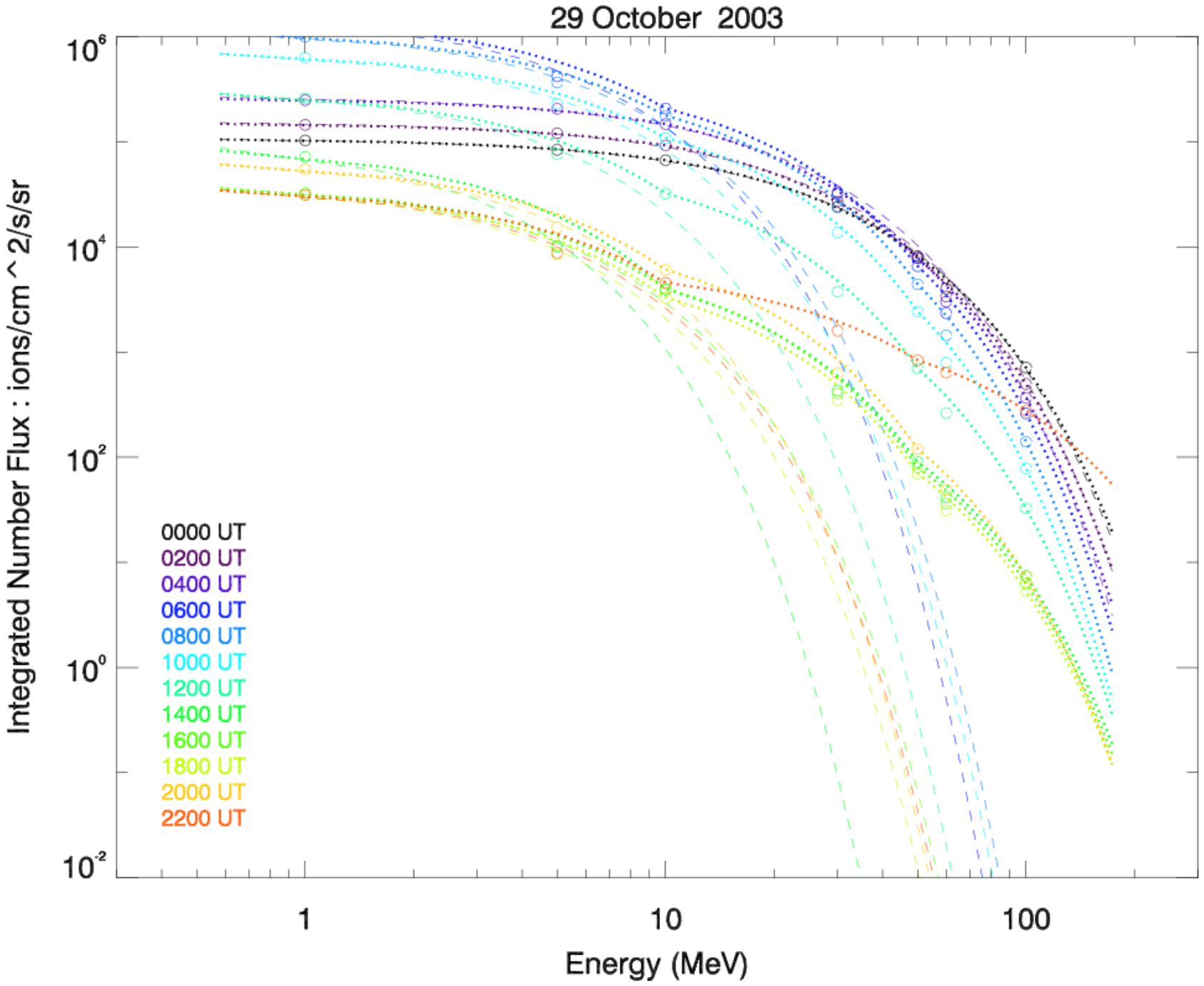
Percent Changes due to Energetic Electrons

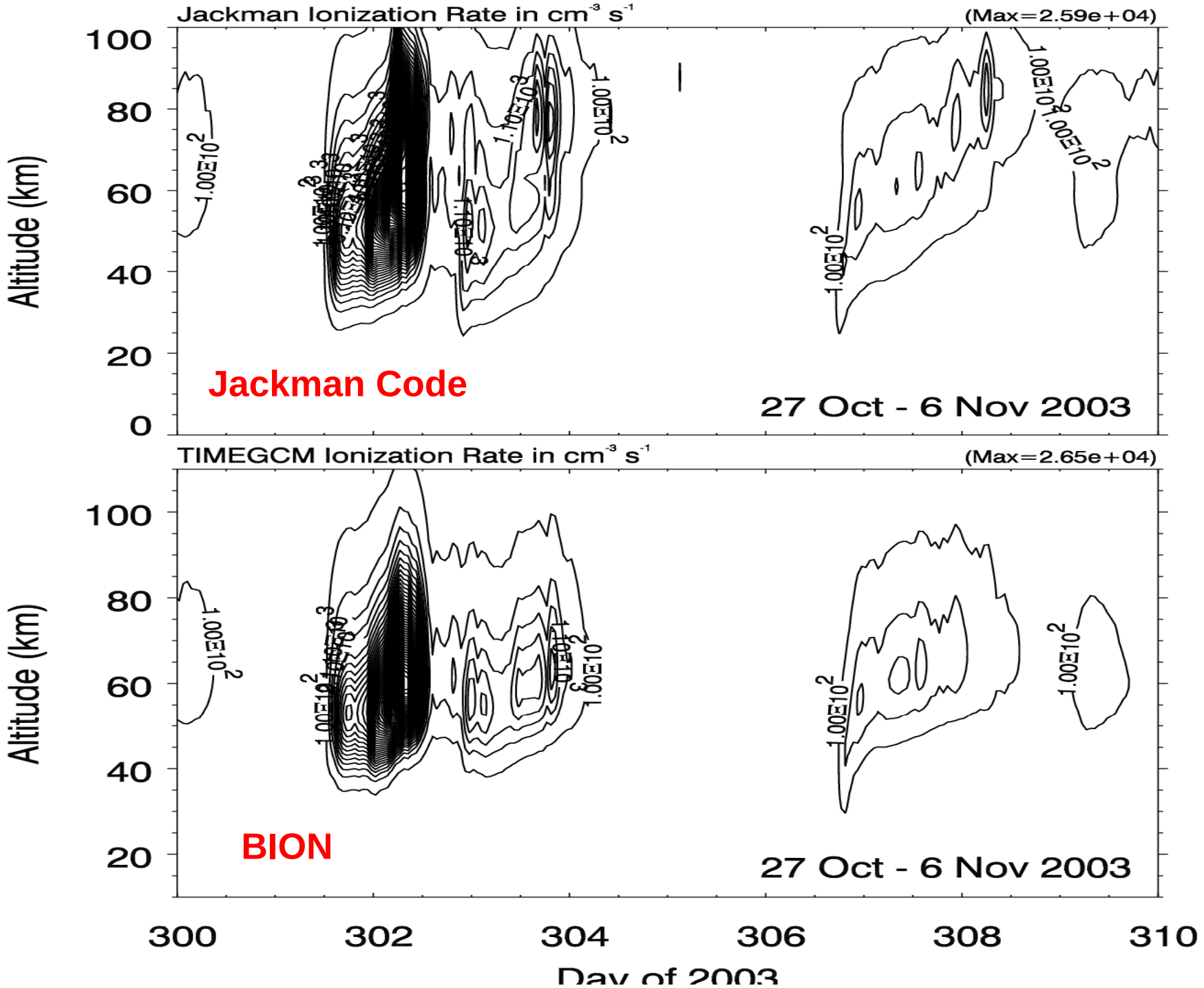


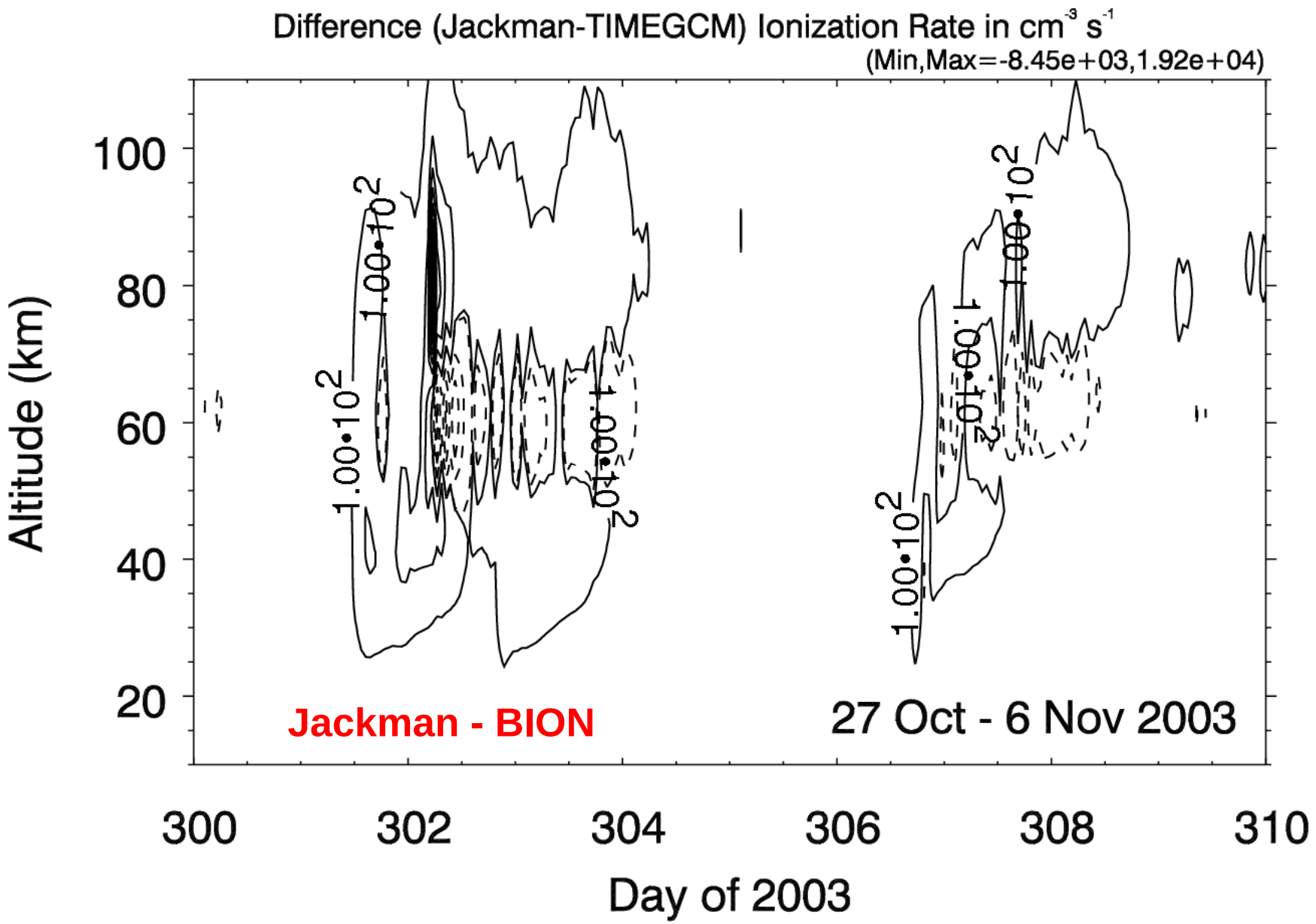
September 11-13, 2005

September 11-13, 2005


25 October 2003
Integrated Number Flux : ions/cm ^ 2/s/sr
10^6
10^4
10^2
10^0
10^{-2}
1
10
100
Energy (MeV)
0000 UT
0200 UT
0400 UT
0600 UT
0800 UT
1000 UT
1200 UT
1400 UT
1600 UT
1800 UT
2000 UT
2200 UT

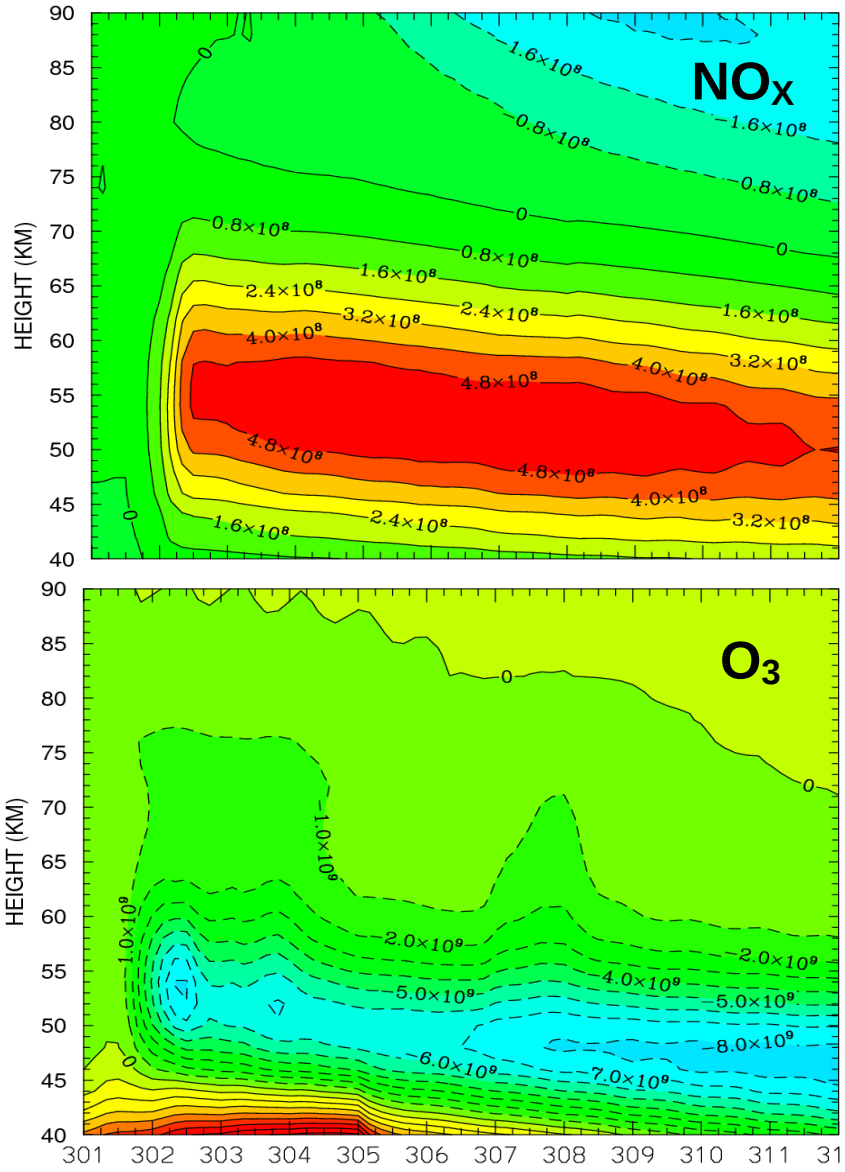

29 October 2003
Integrated Number Flux : ions/cm ^ 2/s/sr
Energy (MeV)
10^6
10^4
10^2
10^0
10^-2
1
10
100
0000 UT
0200 UT
0400 UT
0600 UT
0800 UT
1000 UT
1200 UT
1400 UT
1600 UT
1800 UT
2000 UT
2200 UT


Jackman Ionization Rate in cm-3 s-1
(Max=2.59e+04)
Jackman Code
27 Oct - 6 Nov 2003
TIMEGCM Ionization Rate in cm-3 s-1
(Max=2.65e+04)
BION
27 Oct - 6 Nov 2003
Altitude (km)
Day of 2003
100
80
60
40
20
0
300
302
304
306
308
310


Difference (Jackman-TIMEGCM) Ionization Rate in cm-3 s-1
(Min,Max=-8.45e+03,1.92e+04)
Altitude (km)
100
80
60
40
20
1.00•10^2
1.00•10^2
1.00•10^2
1.00•10^2
1.00•10^2
1.00•10^2
Jackman - BION
27 Oct - 6 Nov 2003
300
302
304
306
308
310
Day of 2003

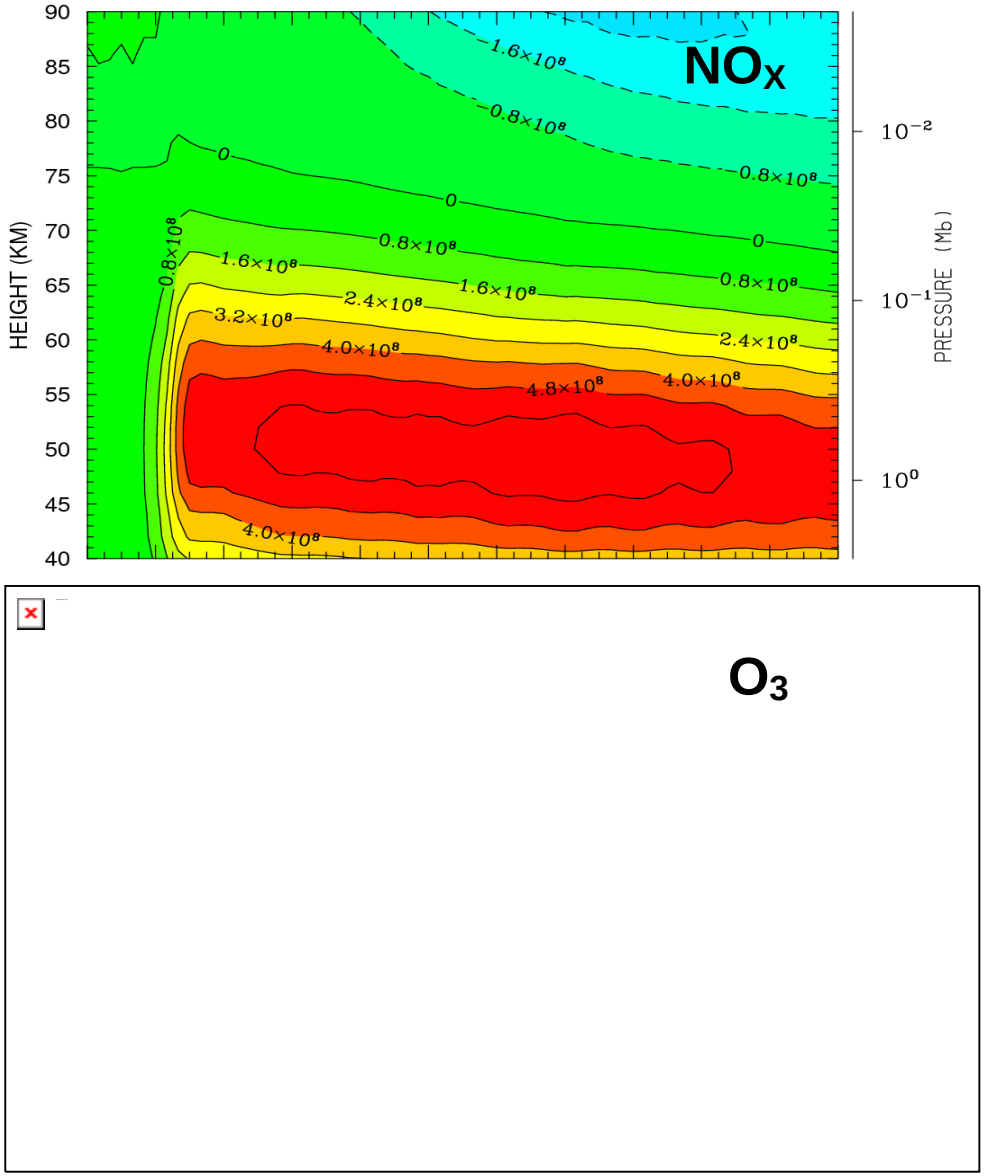
Effects from Different Ionization Codes

BION



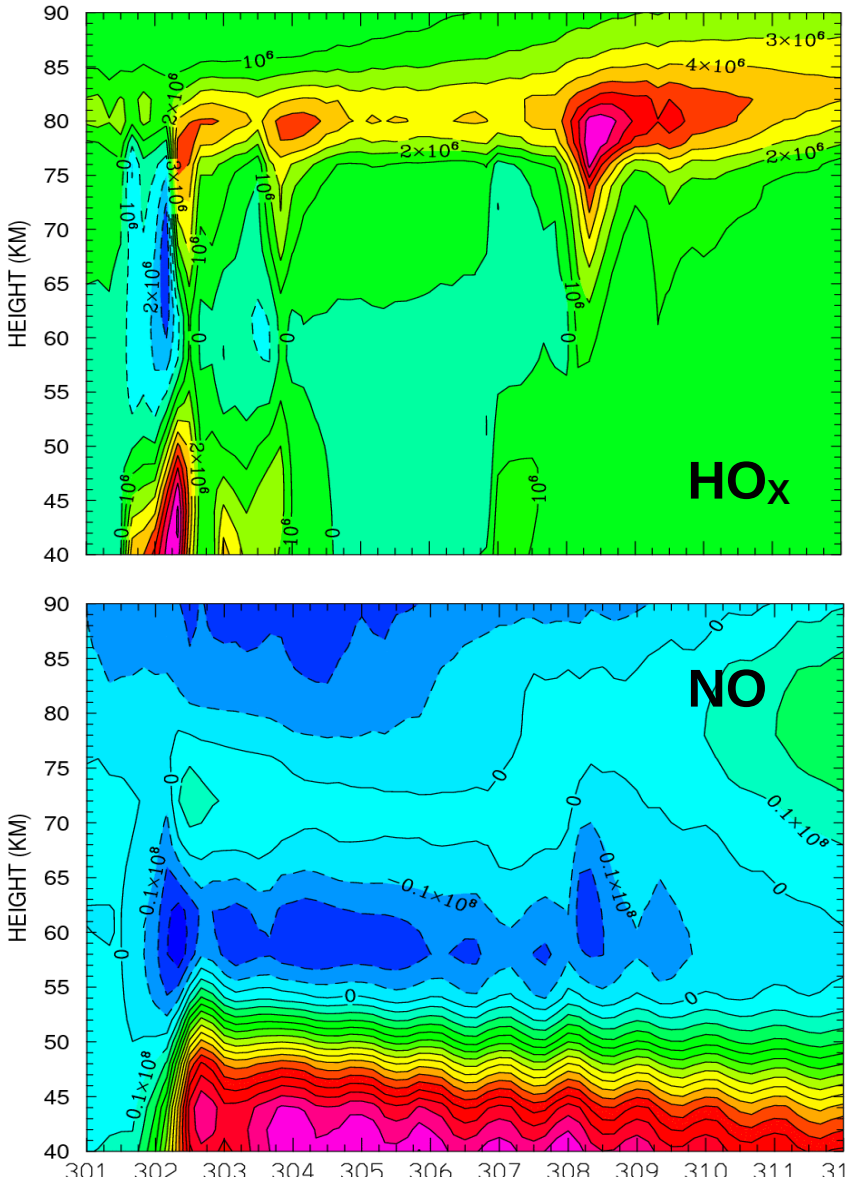
October 27 – November 8, 2003

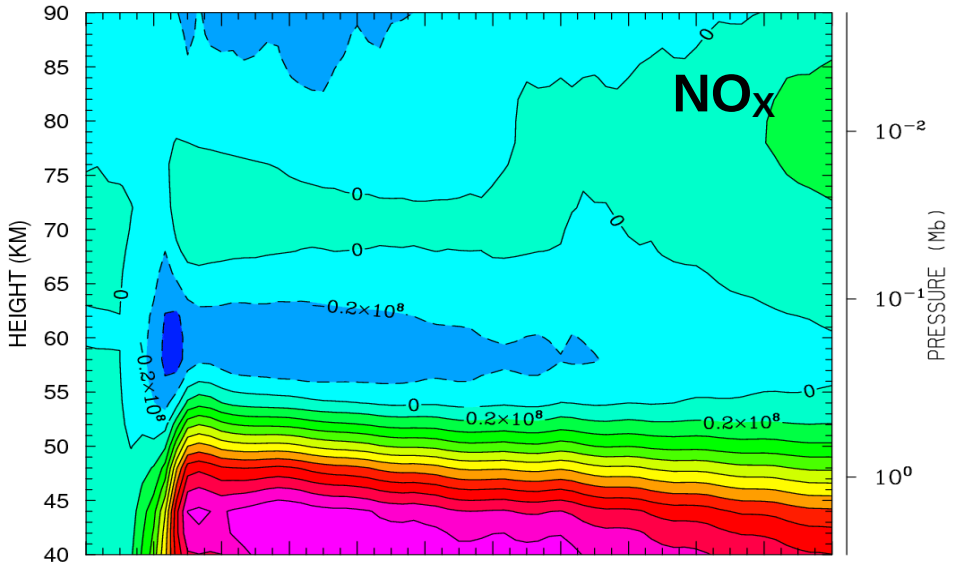
Jackman Code

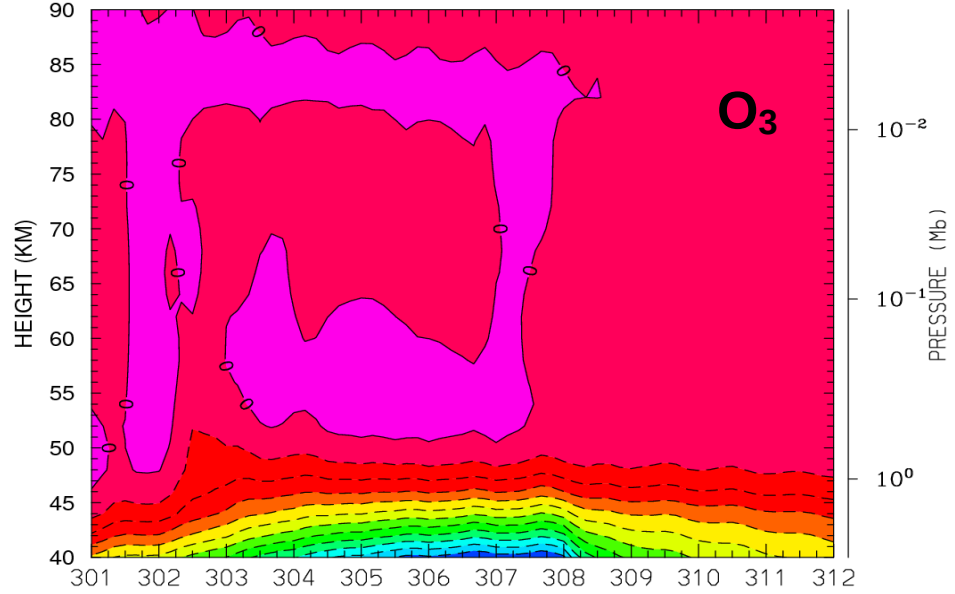


October 27 – November 8, 2003

Difference Plots from (Jackman - BION)



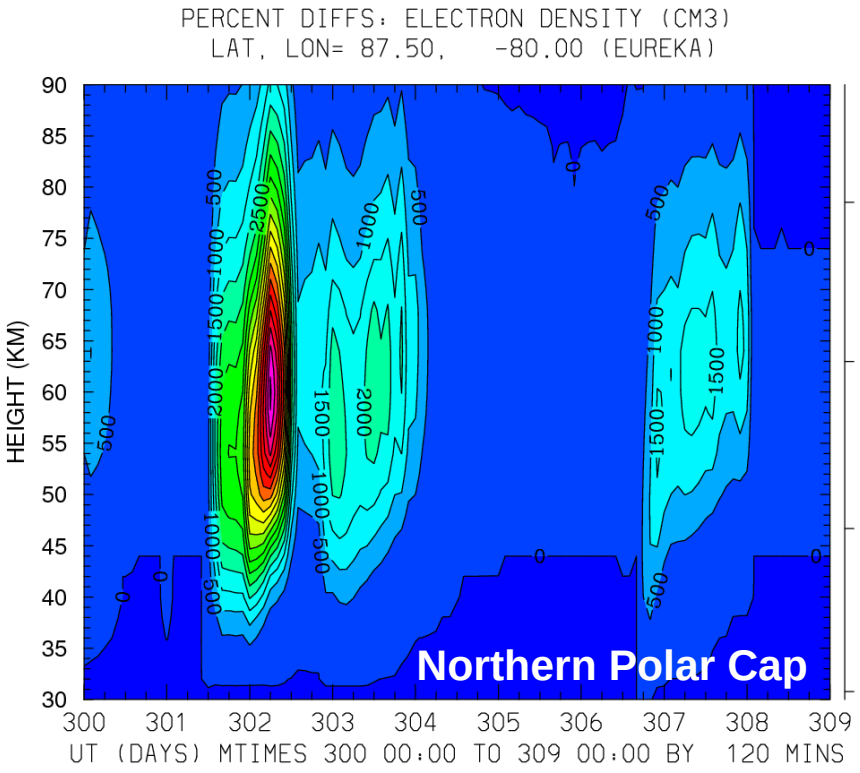




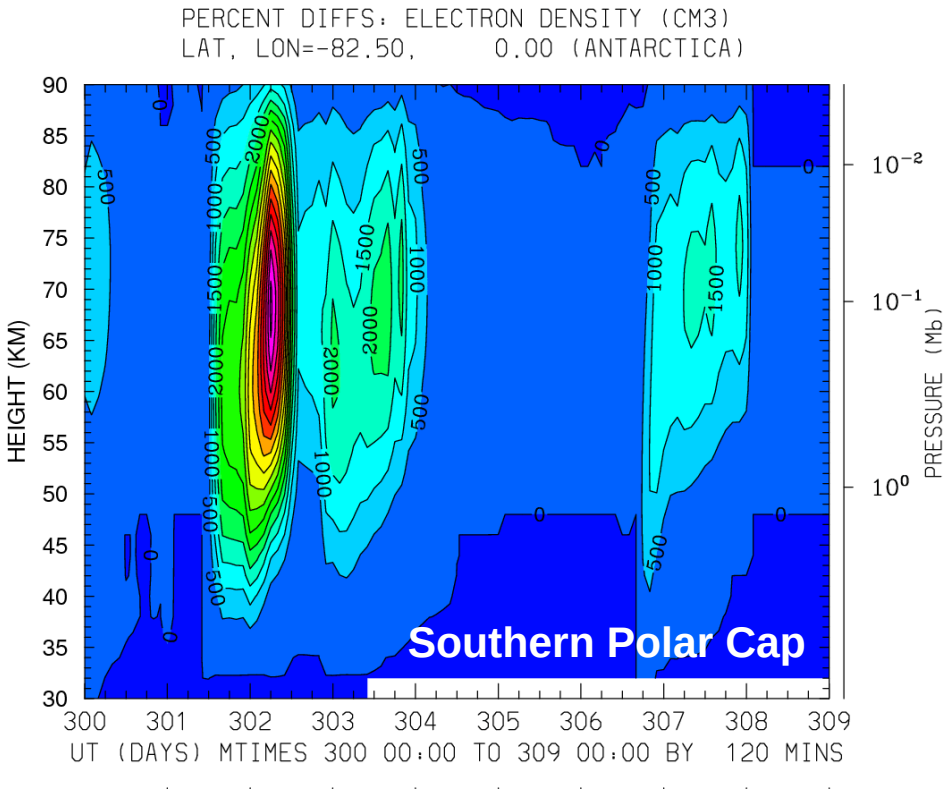
October 27 – November 8, 2003

October 27 – November 8, 2003

% Change of Electron Density due to SEP



October 27 – November 4, 2003



October 27 – November 4, 2003